GEM TN-92-59

GEM Computing/Simulation Meeting - SSCL

January 20 - 21, 1992

Abstract:

The Physics group's menu of physics reactions were presented, along with a list of desired single particle types for which parameterizations were desired for fast physics simulations. The subsystem simulation groups worked out sets of parameters which could be provided to the physics group. The simulation groups also gave status reports, and other issues (coding standards and methods, "GEMLIB", and PDSF upgrade) were discussed.

AGENDA for GEM SIMULATION MEETING -- Jan. 20-21, 1992 at SSCL

The purpose of the meeting is to develop a coordinated simulation effort across the collaboration, in preparation for the July 1992 PAC meeting, the Technical Proposal, and to the extent possible, for the Tucson meeting. There will also be a February meeting at SSCL which will address other issues as well as simulation.

The simulation coordination is to be across the Physics group, detector subsystem designers and trigger groups. One goal is to produce detector subsytem simulations which can be combined for a full simulation, including triggers. These subsystem simulations will also be used to provide parameterizations of performance which can be used to provide quick evaluations of overall performance on physics processes. Further, this system should be centralized and archived so that versions used to produce key results can be recovered and re-run if needed.

The meeting, as an organizational meeting, is expected to be somewhat informal, so times are approximate. Besides discussing physics, subsystem representatives are asked to discuss their approach to computing.

Jan. 20th -- Monday

9:00 a.m.	Agenda revision -- K. McFarlane
9:15 a.m.	Physics requirements -- Lane, Paige
10:30 a.m.	COFFEE
10:45 a.m.	Central tracker -- S. McKee, S. Sen, M. Brooks
12:30 p.m.	LUNCH
1:30 p.m.	Forward Calorimetry -- M. Shupe
2:00 p.m.	LAr calorimetry -- TBA
	BaF2 -- RY Zhu
	Scintillation calorimetry -- Rob Carey
	Muon system --
3:00 p.m.	Muon trigger -- C. Yanagisawa, P. Dingus
	Magnet -- J. Sullivan
	Trigger/DAQ -- Lissauer/Seman

Jan. 21st -- Tuesday

9:00 a.m.	SSCL support
	CERNLIB in 1992 -- L. Roberts
	PDSF upgrade plans -- B. Scipioni
	GEMLIB proposal -- K. McFarlane
	Development of full simulation -- discussion
	Coding standards for subsystems
	File formats for exchange
	Overall coding standards
	PDSF/Unix user environment and utilities
	CAD/GEANT -- J. Womersley
	Agenda for February meeting and schedule of future meetings

Related GEM meetings

Jan 22nd: Forward Calorimeter, Muons simulation, CT simulation
Jan 23rd: Council, CT
Jan 24th: Trigger/DAQ, Central Calor, CT, Muons HW

List of GEM simulation 'groups'

Physics -- K. Lane, F. Paige, B. Zhou
Beam pipe --
Radiation Environment -- D. Lee (LANL)
Central Tracker -- Shawn McKee, Geoff Mills, S. Sen, M. Brooks, J. Musser
Calorimetry -- Jim Brau
LAr calorimetry -- H. Gordon, H. Ma
BaF2 -- H. Newman, RY Zhu
Scintillation calorimetry -- W. Worstell, Rob Carey
Muon System -- R. McNeil, B. Zhou, M. Atiya, T. Wenaus, J. Shank,
Muon trigger -- M. Atiya, Chiaki Yanagisawa (SUNY), P. Dingus (SSCL)
Magnet -- J. Sullivan
Forward Calorimetry -- M. Shupe, G. Forden
Trigger/DAQ -- Marlow, Lissauer/Seman
Level 3 --

Here is a list of GEM directories on PDSF:

admin	gem	lee	paradiso	tracker
akchurin	gemlib	lei	ramana	tully
barish	gmills	lelchuk	ras	turk
bls	gurtu	leltchou	rbd	userfiles
branson	hipple	lissauer	read	vanyashi
brooks	huazhong	lost+found	reidy	wenaus
busenitz	itep	ma	ritchie	wenwen
cca	jcwu	manly	sen	wolin
chen	jjb	marin	share	worstell
dingus	jke	marlow	shi	xjyan
dms	jthomas	mcfarlan	shmakov	yamamoto
ecarlson	kahn	mckee	shotkin	yhchang
ejke	kan	mount	soldate	yost
esimmons	kinnison	musser	sullivan	yuwuyu
ficenec	kirkby	mutrig	sumorok	zhou
fredl	kobrak	nevski	tarle	zhu
furuno	lane	newman	themann	

Summary of meeting

1. Ken Lane presented, on behalf of the Physics group, a menu of interactions designed to test the GEM detector, divided into first and second priorities. The Physics group requests that simulation effort be focussed on developing parameterizations of each subsytem based on detailed (full) simulations of the subsystem. He also presented a list of particles with energy ranges to be simulated. With an approach where each subsystem provides up-to-date parameterizations, it will then be easy for the Physics group to run fast evaluations of the performance on the Physics menu.

Ken distributed several documents (attached): "Physics Simulations for the GEM Technical Proposal", detailing the above program, and "Physics simulations requested by the PAC" and "Comments on the PAC report on GEM Physics."

The simulations groups worked during the meeting to produce a set of parameters which would characterize their detectors; these reponses follow Ken's transparencies.

2. This was followed by status reports from several simulation groups:
   Central tracker -- S. McKee, S. Sen, M. Brooks and G. Mills (see transparencies)
   LAr calor -- H. Ma
      Simulations are being setup and run for the following subsubsytems:
         Prototype
         EM accordion -- projective and non-projective
         Hadron calorimeter -- plates
         Pre-radiator
      The next step is a full LAr simulation
   BaF2 calor -- R.Y. Zhu (see transparencies)
   Scint. Cal. -- Rob Carey -- this group is getting underway
      -- K. Shmakov
      -- Yu. Kamyshkov commented on measuring energy resolution
   Trigger group -- C. Yanagisawa (see transparencies), D. Lissauer (see transparencies)
   Forward Calorimetry -- J. Rutherfoord (see also Shupe below)

3. PDSF -- Brian Scipioni described the PDSF upgrade plans. See attached transparencies.) There are three phases -- Phase I which is the existing PDSF, Phase II in which Increment 1 is added (32 HP9000/720 headless boxes and additional disk space), and Phase III in which another 64 headless boxes would be added. Only Phase II (Increment 1) is definite. The transition to Phase II will take place in several stages (see transparencies):

1. PDSF will be shutdown for two days to reconfigure to half capacity.
2. PDSF will come back up with two SGI machines (fs0 and br0), half the Sun boxes and half the disks (but see below). This configuration will last for two weeks, while the two other SGI's are re-configured as file(data) servers (ds2 and ds3) with 15 Sun boxes from one and 16 HP's from the other.
3. PDSF will again be shutdown for two days to re-configure to using the new system(s). This will involve style changes: Directory structures will be new (e.g /home/ds2/gem/gemlib) and login will be to a specific segment (e.g. rlogin pdsf2 OR rlogin pdsf3). Users are expected to select a preferred segment to keep their files and do their work. The other segments will be available over NFS/FDDI but efficiency dictates being 'close' to one's data. User files will be moved to this new system.
4. For two weeks this new system will be available while the other equipment is built into two matching segments (pdsf0 and pdsf1).
5. Another two-day shutdown to merge all into one connected system.

There was much discussion of the PDSF changeover, with the following recommendations to the support groups and to GEM users:

1. The upgrade should be delayed till the end of the GEM Tucson meeting (March 11th).

2. The disk space available to users should NOT be reduced during step 2 above. New equipment will be available to achieve this.

3. Some of the new HP boxes should be put on the network to allow users to begin the transition to using HP.

4. Users should back up files to tape (using dms). This needs to be looked into to give convenience.

4. CERNLIB in 1992 -- Lee A. Roberts presented his views on the likely evolution of CERNLIB (including GEANT) in 1992. These comments are attached. One important point is that the SSCL order of priority of support of various systems is:

HIghest:

Silicon Graphics (IRIX 4.0.1)
Sun Sparcstation (SunOS 4.1.1 + FORTRAN 1.4)
HP 9000/7xx (HP-UX 8.07)

Next:

DEC Ultrix 4.2 + DEC FORTRAN 3.1
DEC Ultrix 4.2 + FORTRAN for RISC 2.0

GEM support will be targeted at DEC FORTRAN 3.1

LOwest:

IBM RS6000

For more details, see the notes.

5. CAD/GEANT -- John Womersley described efforts at Florida (SCRI) to ease the CAD to GEANT transition and also described useful software available from SCRI. See transparencies.

6. THE GEMLIB proposal, to create a library of useful software on PDSF, was briefly described.

7. News: will be made available on SSCVX1 (>SETUP GEM_NEWS, followed by > GEMNews), pdsf -- newsgroups ssc.pdsf.announce and ssc.pdsf.gem (use rn or xrn).

8. There was discussion of coding standards and code management. The consensus was that something must be used, and that Unix could be the base system. (E. Wolin, K. McFarlane). M. Shupe also sent a set of suggestions (attached).

9. M. Shupe sent information on useful programs he is working on. These will, we hope, be available in GEMLIB. Descriptions are attached.

10. It was decided to use a right-handed coordinate system. If GEM is on the East Campus, *z* would be north, *y* up and *x* towards the center of the machine.

GEM Simulation meeting Jan 20-21

Name	Institution	Email address (preferred)	Internet address	Operating systems		Interest
				Software	Product'n	
Tomasz Skwarnicki	Syracuse Univ.	TOMASZ@SUHEP				
Wojtek Furmanski	Syracuse Univ.	furm@SCCS.syr.edu				
Yuri Kamyshkov	ORNL	KAMYSHKOV@ORPHA				
Elliott Wolin	Yale	wolin@Yalph2	wolin@Yalph2.physics.yale.edu	vms unix	vms unix	
SUMIT SEN	YALE	SEN@YALPH2	SEN@YALPH2.PHYSICS.YALE.EDU	VMS UNIX	VMS UNIX	
Mikhail Leltchouk	Columbia Univ.	LELTCHOUK@NEVIS		VMS UNIX	VMS UNIX	TR, EC, HC FC LA
Sasha Vanyashin	SSCL	VANYASHIN@SSCVX1	VANYASHIN@SSCVX1.SSC.GOV	UNIX		
Jin Chu Wu	SSCL	jcwu@SSCVX1.ssc.gov		UNIX	UNIX	
Melynda Brooks	LANL	BROOKS@LAMPF		UNIX	UNIX	
Rita Benary	Tel-Aviv Univ.	BENARY@TAUNIVM		IBM		
IULIU STUMER	BNL	STUMER@BNLVMXA		~~IBM UNIX~~ UNIX, VMS	IBM, VMS UNIX	
David Lissauer	BNL	LISSAUER@BNLVMXA		"	"	TR/LA.
John Womersley	SCRI / FSU	Womersley@FNAL	Womersley@FSUHEP.PHYSICS.FSU.EDU			
Hong Ma	BNL	BNLCL6::HMA	HMA@BNLCL6.BNL.GOV	unix	unix	LAr
Chiaki Yanagisawa	Stony Brook	SBHEP::CHIAKI CHIAKI@SBHEPNY		VMS UNIX	UNIX	MU and MUTR.

GEM Simulation meeting Jan 20-21

Name	Institution	Email address (preferred)	Internet address	Operating systems: Software	Operating systems: Product'n	Interest
Kostya Shmakov	ORNL	SHMAKOV@ORPHOR				
Robert Carey	BU	CAREY@BUPHYC		VMS UNIX	VMS UNIX	
Ken McFarlane	SSCL	MCFARLAN@SSCVX1	@SSCVX1.SSC.GOV	Unix	Unix	
Ren-yuan Zhu	CALTECH	ZHU@CITHEX	@CITHEI.CITHEP CALTECH.EDU	Unix	Unix	
Fred Olness	SMU	Olness@SSCVX1	SSCVX1.SSC.GOV	VMS Unix	VMS UNIX	
Frank Paige	SSC	PAIGE@SSCVX1	PAIGE@SSCVX1.SSC.GOV	VMS UNIX, ...	VMS, UNIX, ...	FC, TR, L3, ...
Shawn McKee	Univ of MI	MCKEE@MICH	TARLEI.PHYSICS.LSA.UMICH.EDU	VMS	VMS	CT
Peter Dingus	SSCL	DINGUS@SSCVX1	DINGUS@SSCVX1.SSC.GOV	VMS UNIX	"	
Charles Allen	UTexas Austin	allen@uthep2.ph.utexas.edu		Unix	Unix	TR
Kenneth Lane	Boston Univ.	LANE@BUPHYC (Bitnet) LANE@BUPHYC.BU.EDU (internet)	LANE@BUPHYC.BU.EDU	VAX/VMS DECstation/Unix	Unix	Physic
Geoffrey B. Mills	LANL	mills@lanlsscl.lanl.gov		UNIX/HP/Apollo	UNIX	CT/Vert
Hans Cohn	ORNL	COHN@UTKVX	COHN@SSCVX1			
Peter Dingus						
MOHAMMAD MOHAMMADI	Stony Brook	SBHEP!! MOHAMMADI		VMS UNIX	VMS UNIX	
		MOHAMMADI@SBHEPNY				

Ken Lane 1/20/92

GEM PHYSICS SIMULATIONS

- **List of processes to test GEM's capabilities for the BROADEST POSSIBLE RANGE of new physics in the TeV energy region.**

⇒ *List is TOO LONG for detailed, full detector simulations!*

⇒ *Must rely on PARAMETERIZATIONS of full simulations of detector/subsystem response to individual "particle" stimuli.*

- **FIRST PRIORITY:**
  FULL DETECTOR SIMULATIONS
  → List of "particles", η and E_T range, etc.
  → List of subsystem parameters, trigger requirements, etc.
  → Generate stimuli with underlying event —
  e.g., $\overline{q}q \rightarrow \gamma\gamma$, e^+e^-, $\mu^+\mu^-$, $\ell^\pm\nu$, etc.
  → Experimentalists needed for simulations!

  ⇒ **COMPLETE BY JULY PAC MEETING**

- **PHYSICS PROCESSES**
  → *Priority 1 List:* Broadly test GEM capabilities for physics "favorites" (a.k.a "benchmarks").
  → *Priority 2 List:* Test GEM's REACH for new physics possibilities.

FULL DETECTOR SIMULATIONS

TENTATIVE LIST OF "PARTICLE" STIMULI

particle/jet	η_{max}	E_T range	Subsystem
γ	2.5	10 GeV – 1 TeV	CT, ECAL, HCAL, TR
e	2.5	10 GeV – 5 TeV	CT, ECAL, HCAL, TR
μ	2.5	10 GeV – 5 TeV	CT, MUON, HCAL, TR
jet	3.0	50 GeV – 6 TeV	ECAL, HCAL, TR
$b \rightarrow \mu$	2.5	50 – 500 GeV	CT, E/HCAL, MUON
$\tau \rightarrow \nu\,\pi$'s	2.5	50 – 500 GeV	CT, E/HCAL
$\not{E}_T$ (jets, $\ell\nu$)	5.0	50 GeV – 1 TeV	E/HCAL, F/B

WE NEED TO:

- Formulate physics goals for each subsystem and the detector as a whole.
- Coordinate with computation group: tools, disk space, archiving, etc.
- Simulate "particles" with appropriate underlying event *and* backgrounds at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.
- Simulate γ, e, μ at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.
- Develop and refine trigger strategies.
- Study responses as a function of adjustable subsystem parameters.
- Parameterize subsystem responses to "particle" stimuli.
- Integrate subsystem responses into FULL detector parameterizations.
- Set up library of detector parameterizations (protected, with full comments) on PDSF.
- **ASSIGN MANPOWER NOW!**
- **COMPLETE FOR PRESENTATION AT JULY PAC MEETING!**

PHYSICS PROCESSES

- **PRIORITY ONE — TO BE COMPLETED FOR THE TDR**

  → Broadly test GEM capabilities for physics "favorites".

  → Determine and simulate *physics and nonphysics* backgrounds.

  → Refine trigger strategies.

1. $H^0 \to \gamma\gamma$ ($M_H \simeq 100\,\mathrm{GeV}$)
   — tests CT, ECAL, (HCAL), TR.

2. $H^0 \to e^+e^-e^+e^-$ ($M_H \simeq 150 - 400\,\mathrm{GeV}$)
   — tests CT, ECAL, (HCAL), TR.

3. $H^0 \to \mu^+\mu^-\mu^+\mu^-$ ($M_H \simeq 150 - 400\,\mathrm{GeV}$)
   — tests CT, MUON, TR.

4. $H^0 \to \ell^+\ell^-$ jet jet, $\ell^\pm = e^\pm$ or $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — tests CT, ECAL/MUON, HCAL, TR.

5. $H^0 \to \ell^+\ell^-\nu\overline{\nu}$, $\ell^\pm = e^\pm$ or $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — tests CT,
   ECAL/MUON, F/B, TR.

6. Leptoquark pair-production and decay, $\mathcal{G}\mathcal{G} \to \pi_{\overline{L}Q}\pi_{\overline{Q}L} \to b\tau^+\overline{b}\tau^-$
   — tests CT, MUON, HCAL, F/B, TR.

7. Quark substructure in high-p_T and invariant mass jet production (deviation from QCD cross sections at $p_T \gtrsim 4\,\mathrm{TeV}$)
   — tests ECAL, HCAL, TR.

8. Quark/lepton substructure in $\overline{q}q \to \mu^+\mu^-$ at high invariant mass (a deviation from the Drell-Yan cross section at $\mathcal{M} \gtrsim 2\,\mathrm{TeV}$) and ultrahigh luminosity, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Determination of the chiral structure of the contact interactions and the reach in the substructure scale, Λ
   — tests CT, MUON, (ECAL, HCAL), TR.

9. $Z'^0 \to \ell^+\ell^-$, with $\ell^\pm = e^\pm,\ \mu^\pm$. Precision measurements of mass, width (via e^+e^-) and asymmetries (via $\mu^+\mu^-$); determination of the reach in $M_{Z'}$. Detector performance at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}, 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
   — tests CT, ECAL, HCAL, MUON.

10. Gluino pair production via the $\not{E}_T$ and and likesign-dilepton signatures
    — tests F/B, E/HCAL, CT, MUON.

PHYSICS PROCESSES

- **PRIORITY TWO**

  → Determine GEM's reach for potential new physics.

  → Determine and simulate *physics and nonphysics* backgrounds.

  Not all need to be done for TDR, but a plan should be developed for completion in a year or two.

1. $W'^{\pm} \to \ell^{\pm}\nu_{\ell}$. Precision measurements of mass, width and asymmetry; determination of the reach in $M_{W'}$. Detector performance at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

2. Quark/lepton substructure in the processes $\overline{q}q \to \ell^{\pm}\nu_{\ell}$. Determination of the chiral structure of the contact interactions and the reach in the substructure scale, Λ, at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

3. Technicolor signatures in the processes:

(a) Color-singlet $\rho_T^{\pm} \to Z^0 W^{\pm} \to \ell^+\ell^-\ell^{\pm} + \not{E}_T$ and $\ell^+\ell^-$ jet jet.

(b) Color-octet $\rho_T \to$ jet jet.

(c) Color-octet $\rho_T \to \pi_{\overline{Q}Q}\pi_{\overline{Q}Q}$. The $\pi_{\overline{Q}Q}$ will be assumed to decay to $b\bar{b}$, $t\bar{t}$ and $t\bar{b}$. Signals will be studied both with heavy flavor identification and without it (i.e., in multijet modes).

4. Supersymmetry signals in the processes:

(a) $\tilde{\mathcal{G}}\tilde{\mathcal{G}} \to$ multileptons ($N_{\ell} = 3, 4$). These signatures do not rely on F/B calorimetry.

(b) $\tilde{\mathcal{G}}\tilde{\mathcal{G}}$ detection via a complicated multijet signature.

(c) Squark and/or slepton detection.

(d) Representative supersymmetry signals in the case that R-parity is not conserved, so that there is no characteristic $\not{E}_T$ signature.

5. Neutral and charged Higgs-like color-singlet scalars (H'^0) and ($H^\pm$) found in extensions of the standard model, supersymmetry and technicolor.

(a) $H'^0 = h^0$, $\pi_T^0 \to \gamma\gamma$ ($M_{H'^0} < 2M_W$).

(b) $t \to H^+ b$, for $m_t > M_{H^+}$, with $H^+ \to c\bar{s}$ and $\tau^+\nu_\tau$.

(c) Electroweak pair-production of H^+H^-, with $H^+ \to t\bar{b}$ ($M_{H^+} > m_t$).

6. $H^0 \to \ell^+\ell^-\tau^+\tau^-$ at $M_H \simeq 800\,\mathrm{GeV}$.

7. Alternatives to $H^0 \to \gamma\gamma$ need to be developed and studied for the intermediate mass Higgs and similar particles (h^0 and π_T^0). Some possibilities are $\mathcal{G}\mathcal{G} \to H^0 \to \tau^+\tau^-$ and $t\bar{t} \to t\bar{t}H^0$ with $H^0 \to \tau^+\tau^-$ and/or $b\bar{b}$.

8. Strong WW interactions, especially in the $W^\pm W^\pm$ mode.

9. For either technical or financial reasons, certain subsystems or parts of subsystems may have to be postponed. Two examples are F/B calorimetry ($3 < \eta < 5$) and a preradiator (in the case of LAr EM calorimetry). If there are others, they should be identified as soon as possible. We need to determine alternative search modes for physics signals that generally rely on these systems and determine whether GEM can discover the physics in the alternative modes. Some examples were listed above (like-sign dilepton signature for gluinos; alternatives to $H^0 \to \gamma\gamma$). Others will be developed when and if the need arises.

IMMEDIATE TASKS

1. Complete or revise the table of "particle" signals for full detector simulations. Add backgrounds. Develop / refine trigger strategies.

2. Formulate physics goals for each subsystem.

3. Get people to do simulations work and organize them, with a timetable for completing various segments of the work.

4. Start development of simulation packages for each subsystem.

5. WHAT ELSE?

CENTRAL TRACKING PARAMETERIZATION

INPUT: ID - Particle type

X_{in}, Y_{in}, Z_{in} - Vertex

E_{in} - Energy/Momentum (4 vector)

Input vertex must be within beam pipe.

OUTPUT: ID - Unchanged

X_{out}, Y_{out}, Z_{out} - Output point (intersection of particle trajector with outer CT cylinder)

E_{out} - Energy/momentum (4 vector)

L_R - Number of radiation lengths passed through

I - Number of interaction lengths.

XM_{in}, YM_{in}, ZM_{in}, - Measured vertex

Em_{in} - Measured input 4 vector

DXM_{in}, DYM_{in}, DZM_{in} - Error on measured vertex

DEM_{in} - Errors on measured input 4 vector

XM_{out}, YM_{out}, ZM_{out} - Measured output point

EM_{out} - Measured output 4 vector

DXM_{out}, DYM_{out}, DZM_{out} - Errors on measured output point

DEM_{out} - Errors on measured output 4 vector

b - Impact parameter (primary vertex)

Db - Error on impact parameter

Z - Charge (+ or -)

KMC/cl 1/24/92

CALORIMETRY PARAMETERIZATION - H. MA

Inputs: P, ID, vertex

Options: Detector choice (LAr, BaF_2/spag)

Luminosity (for pile-up noise)

Outputs:

a) Simple: E_{total}, E_{em}, $\hat{n}_{em}$, $\hat{n}_{tot}$

b) cell list: (transverse, longitudinal shower profile),

number of towers, list of energy in hit towers

c) Cell Array

energy deposition to a complete array of towers

d) (em shower pointing)

Utility: clustering

jet finding

Simulation required to obtain the parametrization.

1) prototype response

2) noise

3) η (or φ) dependence of resolution due to structural material, etc.

full detector simulation, with simplied detector details

4) e, π, μ

(A utility to return the probability of being EM or hadronic and the corrected energy in either case was suggested.)

KMC/ct 1/24/92

0th ORDER PROPOSAL FOR MUON BLACK BOX

M. Mohammadi, C. Yanagisawa, P. Dingus

Will provide a subroutine that returns for every charged track in an event:

a) smeared 4-vector

b) trigger probability (L1) in μ system.

c) momentum reconstruction probability in the μ system.

d) space point in μ system

– isolated

– in jet

i.e. (* = returns these objects),

Call RMU (V4, IP, Q, VM4*, XM4*, P^*_{trig}, P^*_{recon})

This will be discussed in muon meeting 1/22

KMC/ct 1/24/92

Central Tracking Parameterization

INPUT: ID – Particle type

X_{IN}, Y_{IN}, Z_{IN} – Vertex

E_{IN} – Energy / Momentum (4 VECTOR)

Input vertex must be within beam pipe.

OUTPUT ID – Unchanged

$X_{OUT}, Y_{OUT}, Z_{OUT}$ – Output point (intersection of particle trajectory with out CT cylinder)

E_{OUT} – Energy / Momentum (4 VECTOR)

L_R – Number of radiation lengths passed through

I – Number of interaction lengths.

$XM_{IN}, YM_{IN}, ZM_{IN}$ – Measured vertex

EM_{IN} – Measured input 4 vector

$\Delta XM_{IN}, \Delta YM_{IN}, \Delta ZM_{IN}$ – Errors on measured vertex

ΔEM_{IN} – Errors on measured input 4 vector

$XM_{OUT}, YM_{OUT}, ZM_{OUT}$ – Measured output point

EM_{OUT} – Measured output 4 vector

$\Delta XM_{OUT}, \Delta YM_{OUT}, \Delta ZM_{OUT}$ – Errors on measured output point

ΔEM_{OUT} – Errors on measured output 4 vector

b – Impact parameter (primary vertex)

Δb – Error on impact parameter

Z – Charge (+ or −)

Calorimetry Parameterization — H. Ma

INPUTS: $\vec{P}$, ID, vertex

options: detector choice (LAr, BaF_2/Spag)

Luminosity (for pile-up noise)

Outputs: a) Simple:

E_{total}, E_{em}, $\hat{n}_{em}$, $\hat{n}_{tot}$

b) Cell list: (transverse, longitudinal shower profile)

# of Towers, list of energy in hit towers

c) Cell Array.

energy deposition to a complete array of towers.

d) (em shower pointing)

Utility: clustering

jet finding

Simulation required to obtain the parametrization.

1) prototype response.

2) noise

3) η (or φ) dependence of resolution due to structural material, etc.

full detector simulation, with simplied detector details

4) e, π, μ.

1/21/92

0TH ORDER PROPOSAL FOR MUON BLACK BOX

WILL PROVIDE A SUBROUTINE THAT RETURNS FOR EVERY CHARGED TRACK IN AN EVENT:

a) SMEARED 4-VECTOR

B) TRIGGER PROB. (L1) IN μ SYSTEM

c) MOMENTUM RECONSTRUCTION PROB. IN THE μ SYSTEM

d) Space point

i.e. (* => RETURNS THESE OBJECTS)

CALL RMU(V4, IP, Q, VM4*, P^*_{TRIG}, P^*_{RECON})

THIS WILL BE DISCUSSED IN MUON MEETING 1/22

— isolated

— in jet

M. MOHAMMADI, C. Yanagisawa, P. Dingus

PHYSICS SIMULATIONS FOR THE GEM TECHNICAL PROPOSAL

Kenneth Lane, January 20, 1992

The detector and physics simulations should done in two stages: (1) full detector simulations and (2) physics simulations with parameterized detector responses.

I. Full Detector Simulations

Full simulations of each subsystem, or groups of subsystems, should be carried out to determine responses to the relevant individual "particle" stimuli (with the underlying event included). These simulations should cover the full rapidity range of the subsystem and the expected dynamic range for new physics and their backgrounds. As a *tentative* example, I offer the following table (subsystems are denoted by: TR (trigger/DAQ), CT (central tracker), ECAL (EM calorimeter), HCAL (hadron calorimeter), MUON, and F/B (forward / backward calorimetry)).

particle/jet	η_{max}	E_T range	Subsystem
γ	2.5	10 GeV – 1 TeV	CT, ECAL, HCAL, TR
e	2.5	10 GeV – 5 TeV	CT, ECAL, HCAL, TR
μ	2.5	10 GeV – 5 TeV	CT, MUON, HCAL, TR
jet	3.0	50 GeV – 6 TeV	ECAL, HCAL, TR
$b \to \mu$	2.5	50 – 500 GeV	CT, E/HCAL, MUON
$\tau \to \nu\pi$'s	2.5	50 – 500 GeV	CT, E/HCAL
$\not{E}_T$ (jets, $\ell\nu$)	5.0	50 GeV – 1 TeV	E/HCAL, F/B

One of our tasks right now is to prepare a COMPLETE table along these (or better) lines. Then, we have to do the following:

- Formulate physics goals for each subsystem and the detector as a whole. What are the physics missions of each subsystem? What precision, dynamic range, speed, occupancy, lifetime, etc. are required to carry out these missions? Lane and Paige should submit a list of physics questions to each subsystem to help them define their goals.
- Coordinate with computation group: tools, disk space, archiving, etc. Ken McFarlane et al. will define the questions and propose the answers.
- Simulate "particles" with appropriate underlying event *and* backgrounds at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. e.g., γ, e, μ might be generated as $\bar{q}q \to \gamma\gamma$, e^+e^-, $\mu^+\mu^-$. Backgrounds include jet $\to$"γ", "e", punchthrough and decaying pions $\to$ "μ", etc.

- Simulate signals *and* backgrounds for γ, e, μ at ultrahigh luminosity, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. In my opinion, ultrahigh luminosity is to be used *only* for very high-mass physics involving $E_{\gamma,\ell} \gtrsim 1\,\mathrm{TeV}$. Important considerations here are survivabilty and speed of subsystems, and triggering.
- Develop and refine trigger strategies. Dan Marlow et al. are in charge.
- Study responses as a function of adjustable subsystem parameters — energy, position and angle resolutions; segmentation; depth and length; etc. Interacting subsystems must coordinate simulations — e.g, CT and ECAL; CT, HCAL and MUON.
- Parameterize subsystem responses to "particle" stimuli as functions of energy and rapidity.
- Integrate subsystem responses into FULL detector parameterizations. This requires *uniformity and compatibility* of simulation packages.
- Set up library of detector parameterizations (protected, with full comments) on PDSF.
- **ASSIGN MANPOWER NOW!** These simulations are to be carried out by experimentalists in the respective subsystem groups.
- **COMPLETE FOR PRESENTATION AT JULY PAC MEETING!** We must demonstrate to the PAC that our simulations effort is well-organized and running smoothly. We must respond as much as possible to the concerns expressed in the PAC report.

II. Physics Processes for Simulation

Here I list a set of first and second priority processes to be simulated using the detector parameterizations developed in part I. The priority one list is intended to provide a broad test of GEM's capabilities for "standard" TeV-region physics and to address issues and concerns specific to GEM — high precision ECAL, precise and robust MUON, ultrahigh luminosity running, e/h response, and $\not{E}_T$ capability. As many of these simulations as possible should be completed for the TDR. The priority two list contains suggestions of a broad range of processes designed to test GEM's discovery reach for potential new physics in the TeV-energy region. These need not be completed for the TDR, but an orderly plan for carrying them out over the next $\sim$ two years should be developed soon. For both lists, *physics and nonphysics* backgrounds must be determined and simulated, and trigger strategies proposed and refined. These simulations should be carried out by *experimentalists and theorists* working together.

A. First Priority Processes to Determine GEM Capabilities

1. $H^0 \to \gamma\gamma$ ($M_H \simeq 100\,\mathrm{GeV}$)
   — tests CT, ECAL, (HCAL), TR.

2. $H^0 \to e^+e^-e^+e^-$ ($M_H \simeq 150 - 400\,\mathrm{GeV}$)
   — tests CT, ECAL, (HCAL), TR.

3. $H^0 \to \mu^+\mu^-\mu^+\mu^-$ ($M_H \simeq 150 - 400\,\mathrm{GeV}$)
   — tests CT, MUON, TR.

4. $H^0 \to \ell^+\ell^-$ jet jet, $\ell^\pm = e^\pm$ or $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — tests CT, ECAL/MUON, HCAL, TR.

5. $H^0 \to \ell^+\ell^-\nu\overline{\nu}$, $\ell^\pm = e^\pm$ or $\mu^\pm$ ($M_H = 800\,\mathrm{GeV}$)
   — tests CT, ECAL/MUON, F/B, TR.

6. Leptoquark pair-production and decay, $\mathcal{G}\mathcal{G} \to \pi_{\overline{L}Q}\pi_{\overline{Q}L} \to b\tau^+\overline{b}\tau^-$
   — tests CT, MUON, HCAL, F/B, TR.

7. Quark substructure in high-p_T and invariant mass jet production (deviation from QCD cross sections at $p_T \gtrsim 4\,\mathrm{TeV}$)
   — tests ECAL, HCAL, TR.

8. Quark/lepton substructure in $\overline{q}q \to \mu^+\mu^-$ at high invariant mass (a deviation from the Drell-Yan cross section at $\mathcal{M} \gtrsim 2\,\mathrm{TeV}$) and ultrahigh luminosity, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Determination of the chiral structure of the contact interactions and the reach in the substructure scale, Λ
   — tests CT, MUON, (ECAL, HCAL), TR.

9. $Z'^0 \to \ell^+\ell^-$, with $\ell^\pm = e^\pm, \mu^\pm$. Precision measurements of mass, width (via e^+e^-) and asymmetries (via $\mu^+\mu^-$); determination of the reach in $M_{Z'}$. Detector performance at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
   — tests CT, ECAL, HCAL, MUON.

10. Gluino pair production via the $\not{E}_T$ and and likesign-dilepton signatures
    — tests F/B, E/HCAL, CT, MUON.

B. Second Priority Processes for GEM Discovery Reach

1. $W'^{\pm} \to \ell^{\pm}\nu_\ell$. Precision measurements of mass, width and asymmetry; determination of the reach in $M_{W'}$. Detector performance at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

2. Quark/lepton substructure in the processes $\bar{q}q \to \ell^{\pm}\nu_\ell$. Determination of the chiral structure of the contact interactions and the reach in the substructure scale, Λ, at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

3. Technicolor signatures in the processes:
   (a) Color-singlet $\rho_T^{\pm} \to Z^0 W^{\pm} \to \ell^+\ell^-\ell^{\pm} + \not{E}_T$ and $\ell^+\ell^-$ jet jet.
   (b) Color-octet $\rho_T \to$ jet jet.
   (c) Color-octet $\rho_T \to \pi_{\overline{Q}Q}\pi_{\overline{Q}Q}$. The $\pi_{\overline{Q}Q}$ will be assumed to decay to $b\bar{b}$, $t\bar{t}$ and $t\bar{b}$. Signals will be studied both with heavy flavor identification and without it (i.e., in multijet modes).

4. Supersymmetry signals in the processes:
   (a) $\tilde{\mathcal{G}}\tilde{\mathcal{G}} \to$ multileptons ($N_\ell = 3,4$). These signatures do not rely on F/B calorimetry.
   (b) $\tilde{\mathcal{G}}\tilde{\mathcal{G}}$ detection via a complicated multijet signature.
   (c) Squark and/or slepton detection.
   (d) Representative supersymmetry signals in the case that R-parity is not conserved, so that there is no characteristic $\not{E}_T$ signature.

5. Neutral and charged Higgs-like color-singlet scalars (H'^0) and ($H^{\pm}$) found in extensions of the standard model, supersymmetry and technicolor.
   (a) $H'^0 = h^0, \pi_T^0 \to \gamma\gamma$ ($M_{H'^0} < 2M_W$).
   (b) $t \to H^+ b$, for $m_t > M_{H^+}$, with $H^+ \to c\bar{s}$ and $\tau^+\nu_\tau$.
   (c) Electroweak pair-production of H^+H^-, with $H^+ \to t\bar{b}$ ($M_{H^+} > m_t$).

6. $H^0 \to \ell^+\ell^-\tau^+\tau^-$ at $M_H \simeq 800\,\mathrm{GeV}$.

7. Alternatives to $H^0 \to \gamma\gamma$ need to be developed and studied for the intermediate mass Higgs and similar particles (h^0 and π_T^0). Some possibilities are $\mathcal{G}\mathcal{G} \to H^0 \to \tau^+\tau^-$ and $t\bar{t} \to t\bar{t}H^0$ with $H^0 \to \tau^+\tau^-$ and/or $b\bar{b}$.

8. Strong WW interactions, especially in the $W^{\pm}W^{\pm}$ mode.

9. For either technical or financial reasons, certain subsystems or parts of subsystems may have to be postponed. Two examples are F/B calorimetry ($3 < \eta < 5$) and a preradiator (in the case of LAr EM calorimetry). If there are others, they should be identified as soon as possible. We need to determine alternative search modes

for physics signals that generally rely on these systems and determine whether GEM can discover the physics in the alternative modes. Some examples were listed above (like-sign dilepton signature for gluinos; alternatives to $H^0 \to \gamma\gamma$). Others will be developed when and if the need arises.

III. Organization of the Simulations Effort

A. IMMEDIATE TASKS — To be Completed at the January 20 – 22 Meeting

1. Complete or revise the table of particle/jet signals for full detector simulations.
2. Formulate physics goals for each subsystem.
3. Get people to do simulations work and organize them, with a timetable for completing various segments of the work.
4. Start development of simulation packages for each subsystem.

B. People

1. For the full detector simulations, we need 1 – 2 people from *each* of the subsystem groups to work actively, devoting a large fraction of their time to the simulations. They must know the issues to be addressed for their particular subsystem and the mutual interactions between their subsystem and the others. They must be experienced in the use of the event generators (ISAJET and/or PYTHIA/JETSET) and the particle-interaction simulators (GEANT, CALOR, etc.). These people will be the conduits of information between the physics simulation and subsystem groups. *These people should attend the computing group meeting on January 20 – 22.* At that meeting we will formulate plans for the work and set up a timetable that allows the detector-response parameterizations to be completed in time to be of use by the physics simulations group.
2. We also need a group of people (theorists and experimentalists) to carry out the priority one and two physics simulations designed to determine GEM's capabilities.

C. Plans and Operations

1. We need *now* to develop an orderly plan of precisely what questions need to be answered by the detector *and* physics simulations groups for the technical proposal (and which can be delayed), and to set a timetable for the work.
2. We need to compile a common set of event generating and analysis programs and put them in a library, presumably on PDSF. The programs should be as well documented as possible to facilitate their use. A minor, but persistently nagging, issue is that we need to agree upon certain basic common features (such as m_t,

choice of parton distribution functions, jet-finding algorithm, isolation algorithm, etc.).

3. We need, as soon as possible, a *realistic* range of parameters for each subsystem.

D. Resources

1. It is anticipated that most computations will be done on PDSF. (It would be helpful if PDSF were made more user-friendly, with more versatile and useful .login, editors, etc.) For convenience, however, it should be possible to transport programs to other machines
2. We probably should have full physics group meetings once a month to monitor progress and make course corrections as necessary. Funds must be made available to support travel to SSCL for simulations meetings (Physics and Computer Groups). Somebody will have to talk to Barry, Bill, etc. about this ASAP!

Kenneth Lane, January 19, 10:00

PHYSICS SIMULATIONS REQUESTED BY THE PAC

The PAC report on the GEM LOI explicitly or implicitly asks that several physics simulations be done or repeated under different assumptions. This is a list of the simulations in question. They should be done and results presented at the PAC meeting in July. The PAC also asks that certain detector / subsystem simulations be carried out. A list of these should be prepared and and tasks assigned.

A. $H^0 \to \gamma\gamma$

1. Repeat $H^0 \to \gamma\gamma$ signal and backgrounds for the following resolutions:

$$\frac{\Delta E}{E} = \frac{10\%}{\sqrt{E}} \oplus 1\text{-}2\% \qquad \text{(LAr)}$$
$$\frac{\Delta E}{E} = \frac{1.5\%}{\sqrt{E}} \oplus 1\text{-}2\% \qquad \text{(BaF}_2\text{)}$$

The PAC asks that background from misidentified electrons be considered. It is also important to consider the ability of the tracker to identify the event vertex.

2. $t\bar{t} + H^0 \to \ell\nu\gamma\gamma + X$ signal and backgrounds for "standard" LAr and BaF_2 resolutions as well as the poorer resolutions above. Renyuan Zhu has done most of this already. Determine whether the other associated production process, $W + H^0 \to \ell\nu\gamma\gamma + X$ is competitive with $t\bar{t}H^0$. The role of the tracker should be carefully considered.
3. The PAC noted that $\gamma\gamma$ detection at $\mathcal{L} = 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$ was not studied. We should discuss the difficulties of this for moderate energy photons (implementation of vertex and position couts, isolation cuts).

B. $H^0 \to ZZ^* \to e^+e^-\ell^+\ell^-$

1. Repeat these calculations for the poorer ECAL resolutions above. Determine the efficiency for electron identification in the endcaps.

C. Flavor tagging with inclusive muons.

1. Repeat calculations of heavy top-quark discovery in standard and nonstandard modes by tagging events with one isolated lepton and one inclusive muon from $t \to W^+b \to \ell^+\nu_\ell + \mu^-$ jet.

D. Electron identification and measurement at $\mathcal{L} = 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$,

1. Discuss the possibilities and problems for detecting and measuring moderate energy ($\sim$ few 100 GeV) electrons at $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ from, e.g, and 800 GeV $H^0 \to Z^0 Z^0 \to e^+e^-\ell^+\ell^-$.

2. Give a careful discussion of electron detection and backgrounds for a 4 TeV $Z'^0 \to e^+e^-$ at $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. There are no significant physics backgrounds, so only detector (especially central tracker) considerations are relevant here.

E. Muon identification and measurement at $\mathcal{L} = 10^{33},\ 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

1. The PAC requests further study of the calorimeter thickness and more realistic simulations to determine the muon measurement goals. The role of the tracker in muon identification and measurement and background rejection also must be determined and credible simulations carried out. These are primarily detector simulations issues.

F. 300 GeV Gluino

1. More careful study of the $\not{E}_T$ signature for $\tilde{\mathcal{G}}\tilde{\mathcal{G}}$ production should be carried out. This requires that a credible proposal and design of the F/B calorimetry be developed.

2. More careful study of the likesign-dilepton signature for $\tilde{\mathcal{G}}\tilde{\mathcal{G}}$ should be carried out. Special attention needs to paid to the tracker's ability to determine electron signs up to $E_e \simeq 500\,\mathrm{GeV}$.

Kenneth Lane, January 17, 08:00

COMMENTS ON THE PAC REPORT ON GEM PHYSICS

I have extracted statements from the PAC report on GEM physics and comment on them below. These comments are mine alone and do not necessarily represent the views of others. Generally, I think the PAC's remarks and concerns are on target, and we have much work to do — in detector design *and* simulations. In a few instances, I think the PAC is off the mark. This is true especially of the PAC's remarks about electron identification at ultrahigh luminosity, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. That is my fault for not stressing more clearly and forcefully what $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ is for, namely, *very* high energy electrons and muons — which should be nearly background-free and relatively easy to trigger on and detect.

1. "We have considered the physics capabilities of the GEM experiment assuming the detector parameters as presented in the LoI. In general, it appears that if the performance of the detector can really be established as claimed, then the physics reach of the experiment will be adequate to the tasks."

   This, of course, is the job that the Physics Group must do this year for the TDR. It seems unlikely to me that reasonably full simulations of physics processes (based on parameterizations of full detector simulations of responses to individual particles and jets) will be completed by the time of the July PAC meeting.

2. "In comparison with SDC, the GEM detector has emphasized photons, leptons and robustness at high luminosities."

   I am gratified that our message about GEM's *potential* capabilties for measuring muons and electrons at ultrahigh luminosities has gotten through to the PAC. One thing that did not seem to get through (for which I am at fault for not stressing clearly enough) is that ultrahigh luminosity running is intended *almost entirely* for very high mass physics, with $E_\ell \gtrsim 1\,\mathrm{TeV}$ for $|\eta| \leq 2.5$, as discussed in section 3.6 of the LOI. I shall say more about this below when the issue comes up.

3. "It would be interesting to repeat some of the studies of the calorimeter performance with somewhat more conservative assumptions about the resolution (10%/sqrt(E) for liquid argon and 1-2% for the constant term for either the liquid argon or crystal option)."

   This shows the PAC's skepticism with our claimed ECAL resolutions for the LAr (especially) and BaF_2 options. The PAC is right to be skeptical and we have to determine these resolutions *experimentally* as well as carry out the simulations with the poorer resolutions, as requested.

4. "The GEM LoI also emphasizes the importance of electrons and muons both with respect to precision energy measurement and with respect to running at high luminosity. In the Committee's view, further study of the calorimeter thickness and more realistic simulations are necessary to demonstrate that GEM's muon measurement goals can be met. The GEM muon measurement system has the potential to be more robust at high luminosity than that of SDC, which relies on its inner tracker. It also must be demonstrated that it is possible to trigger on muons at high luminosity, especially in the forward direction where the bending is significantly reduced."

   This needs no comment. The PAC is right.

5. "Excellent muon identification in the vicinity of jets is a potential advantage for heavy flavor tagging. However, the present LoI does not make a strong case as to how this information can be used."

   Precisely this method of heavy flavor tagging was supposed to be used in discussing the discovery of a heavy top quark (section 3.3), just as was done in the L^* LOI. However, due to a breakdown in communication between Frank Paige and the person doing the the top-quark simulations, a different method was used which relied on forcing the t to be produced at high p_T. We tried to cover up for this in the LOI by noting (at the end of the introductory paragraphs to section 3.3) that we could use the L^* method of tagging an isolated lepton and inclusive muon to measure m_t in $t\bar{t}$ production. The cover-up didn't work.

6. "The ability of the GEM detector to identify electrons at high luminosity is much less clear. The inner tracking is potentially more difficult for GEM than for SDC, since the track measurements must be performed at smaller radii. While the occupancy of the silicon detector for GEM is sufficiently small at 10^{34} , pattern recognition has not been demonstrated and it has not been shown how long the silicon will survive."

   The only place in the LOI that *I recall* discussing measuring electrons at 10^{34} cm^{-2} s^{-1} is in the study of a 4 TeV Z'^0 decaying to e^+e^-. After discussions with a number of people, I concluded that this process would have *no* significant backgrounds, that there should be no serious impediment to triggering on such high energy EM clusters, and that their energy should be well-measured. As stated in 3.6, we found that using electron direction information from the central tracker made little difference on our determination of $M_{Z'}$ and $\Gamma_{Z'}$. However, our simulations were at a crude level, assuming that shower-shape information could be used to point back to the correct vertex, and the PAC's concern here must be addressed. This applies to muons as well,

which rely to some extent on the central tracker for p_T-measurement and background reduction. But, again, I emphasize that I envisage employing ultrahigh luminosity only for *very* high energy electrons and muons.

The remaining comments are on the PAC's remarks about specific physics processes:

7. "Intermediate Mass Higgs: H → 2-gamma
One of the strengths of the detector is its excellent photon detection and mass resolution. Thus, the performance of the detector in the search for the Higgs in the 2-gamma mode is considered in some detail in the LoI. Its conclusion is that the Higgs can be observed even at a mass as low as 80 GeV. However, the final result on signal over background depends crucially on the resolution of the calorimeter. While the result is best for a BaF2 calorimeter, the liquid argon option also leads to good results with an assumed 7%/sqrt(E) resolution.
Also, the analysis should be implemented in several ways. For example, the background from mis-identified electrons was not considered, even though it could be significant. In general, a more realistic simulation of the detector should be pursued. Another important omission is the study of the associated production channels, W + H and t tbar H, which lead to a small number of events relatively free of background. The study of these channels in the GEM detector will also be important for a direct comparison with SDC. In fact, SDC can only detect a low mass Higgs through the associated production channels and it would be important for the GEM collaboration to demonstrate its capabilities in these modes. Finally, we comment that the performance of the detector for 2-gamma detection at high luminosities has not been studied. It could be particularly important for the relatively rare associated production events."

(a) As stated above, *both* experimental and simulation work need to be done on the $H^0 \to \gamma\gamma$ mode and presented at the next PAC meeting. This includes background from mis-identified electrons *and* the ability of the tracker to determine the correct vertex (important for photon direction). Zhu is the expert here and I defer to him.

(b) Concerning the associated production channels, $W + H^0$ and $t\bar{t} + H^0$, with $H^0 \to \gamma\gamma$: It is my understanding that, at SSC energies, $W + H^0$ is small compared to $t\bar{t} + H^0$. At the time the LOI Higgs section was written, I also understood from Renyuan Zhu that he had calculated signal *and* background for the $t\bar{t} + H^0$ mode. As I recall, he told me that the signal was about 10 – 20 events per year over a background of 60 – 100 events, *after extensive cuts*. Therefore, I decided not to include this negative

result in the Higgs section of the LOI, principally because of lack of space and the (apparently misguided) belief that anyone else looking at this process would come to the same discouraging conclusion. What I did not understand properly at the time, (and what Renyuan has just clarified for me in a phone conversation) is that this background is over the *entire* mass region 75 – 165 GeV. This makes the signal-to-noise much better *if* the ECAL resolution is sufficiently good. Notwithstanding all this, I doubt that anyone would find a signal of 10 events in one SSC year convincing. For comparison, the ***background-subtracted*** signal in the straight $H^0 \to \gamma\gamma$ mode is typically $\sim$ 200 events. In any case, we should have had someone at the PAC presentation knowledgeable enough to make these points clearly and forcefully. We shall have to do that at the next PAC meeting, giving the PAC the comparison of GEM with SDC that they ask for.

(c) I cannot make sense of the PAC's comment regarding 2-gamma detection at high luminosities, *if* they mean by this $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. As I understand it, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ is not needed for $H^0 \to \gamma\gamma$ and ***probably cannot be used!*** I do not see how the photon vertex and position cuts and the isolation cut will work at $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

8. "Intermediate Mass Higgs: H $\to$ Z Z* $\to$ 4 leptons
The assumed characteristics of the calorimeter lead to good evidence for the signal in this channel, with especially remarkable resolution in the 4-electron channel. However, also in this case, it would be interesting to see the corresponding results with a 10%/sqrt(E) resolution for the liquid argon calorimeter. We also point out that, in general, the overall efficiency for electron identification in the end-cap region has not been demonstrated."

(a) We *did* show results for a sampling calorimeter with $\Delta E/E = 15\%/\sqrt{E}\oplus 1\%$, *assuming* no help from the central tracker. This is Figure 3.2-3(c). The results were dismal. We should repeat the simulations for poorer LAr (and BaF_2) resolutions as indicated earlier.

(b) Studies of the efficiency for electron identification in the end-caps must be presented at the next PAC meeting.

9. "Heavy Higgs
The mass region between 0.2 and 0.6 TeV is the ideal interval for observing the Higgs in the H $\to$ ZZ $\to$ 4-lepton mode. As the mass increases beyond 0.8 TeV, the signal detection becomes more and more difficult. The performances of the GEM and SDC detectors turn out to be quite comparable in this region, except that for high Higgs

masses, GEM could have some advantage due to its robustness at high luminosity. In this connection, we note that the ability to detect electrons at high luminosities has not been studied in the LoI."

(a) As we stated in the LOI, for $M_H > 800\,\mathrm{GeV}$, the Higgs is so broad that other approaches must be taken to discovering its presence.

(b) As we stated, $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ is *not* needed to find the 800 GeV H^0. It can be found by GEM *and* SDC in the modes $H^0 \to \ell^+\ell^-\ell^+\ell^-$, $H^0 \to \ell^+\ell^-$ jet jet, and (if the F/B calorimetry is adequate) $H^0 \to \ell^+\ell^-\nu\bar{\nu}$.

(c) The only ultrahigh luminosity running I would envisage for an 800 GeV H^0 is to search for the mode $H^0 \to \mu^+\mu^-\mu^+\mu^-$. As I have said several times, modes involving e^+e^- could be problematic at $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ for such relatively low-energy electrons. That is why we did not study electrons at $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ *except* for the high-mass (4 TeV) Z'^0.

10. "Other

The PAC was generally satisfied with the GEM detector capabilities to answer the other physics questions posed. However, there are many remaining questions and concerns. Heavy quark decays may be observable and useful in the study of various high mass events, but no convincing case was made for GEM's special abilities to use leptons for heavy flavor tagging. Also, the case presented for the observation of a 300 GeV gluino was not completely convincing and needs further study."

(a) I have already discussed the breakdown that led to our not discussing heavy-quark tagging by isolated leptons *plus inclusive muons*. We must correct this for the next presentation to the PAC.

(b) It is hardly surprising that the case for observing the 300 GeV gluino was not completely convincing to the PAC. No convincing case can be made for the $\not{E}_T$ signature until a credible F/B calorimeter is proposed *and* designed. The search for the gluino via the like-sign dilepton signature can become credible only when all the PAC's concerns about the central tracker are resolved.

$\frac{dn}{d\eta}$ ~ 0 [illegible]

Summit Sem-CT
1/20/92

$\frac{dn}{d\eta\, d\phi}$ ~/ track/event

$\Delta\eta\, \Delta\phi = 0.00071$ per pad

$\therefore$ expected occupancy/event/pad = 0.00071

$\mathcal{L} = 10^{33} \Rightarrow 1.6$ event/crossing
$\mathcal{L} = 10^{34} \Rightarrow 16$ event/crossing
} expect to collect from 2 crossings

$\therefore$ $\mathcal{L} = 10^{33}$ occupancy = 0.23%

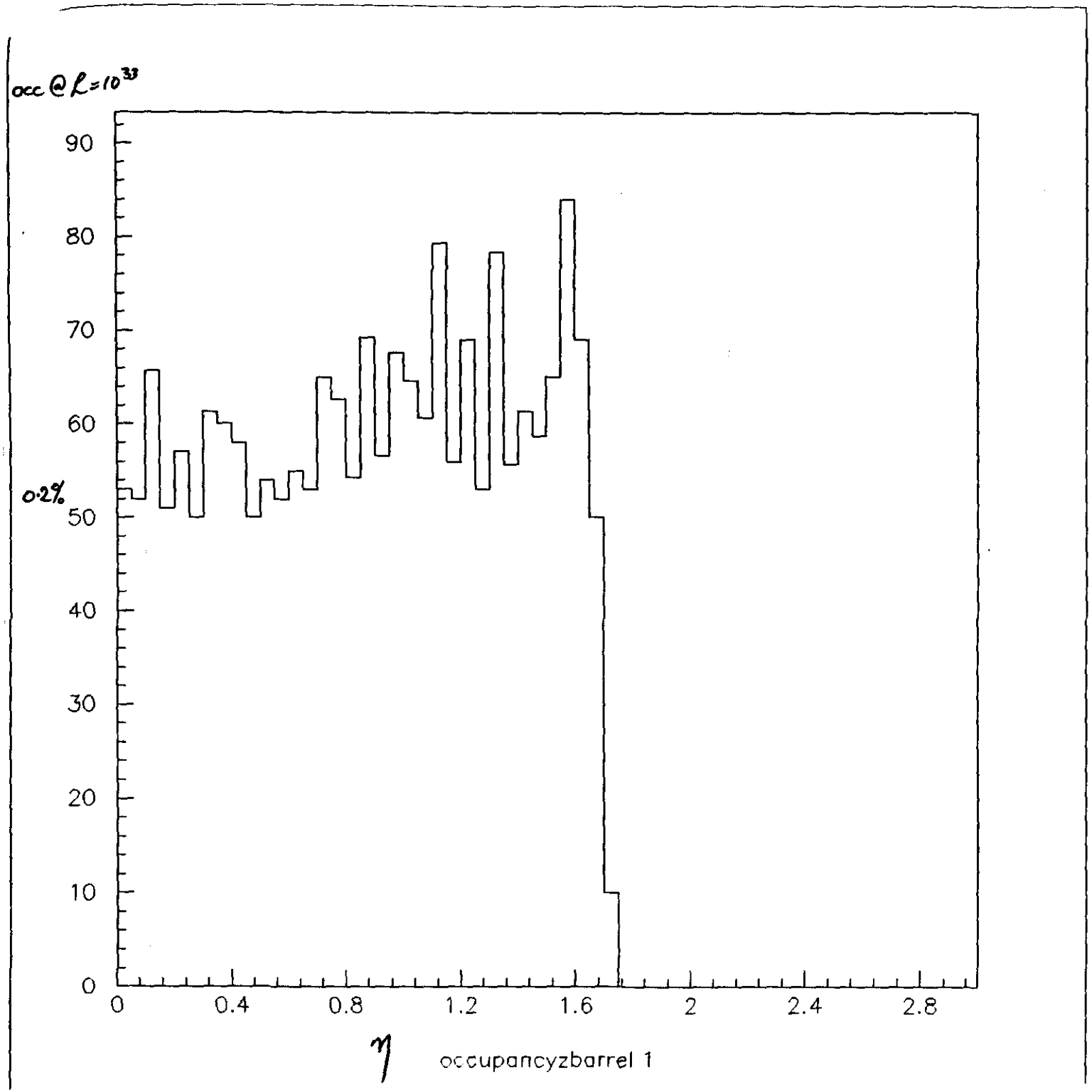
$\mathcal{L} = 10^{34}$ occupancy = 2.3%

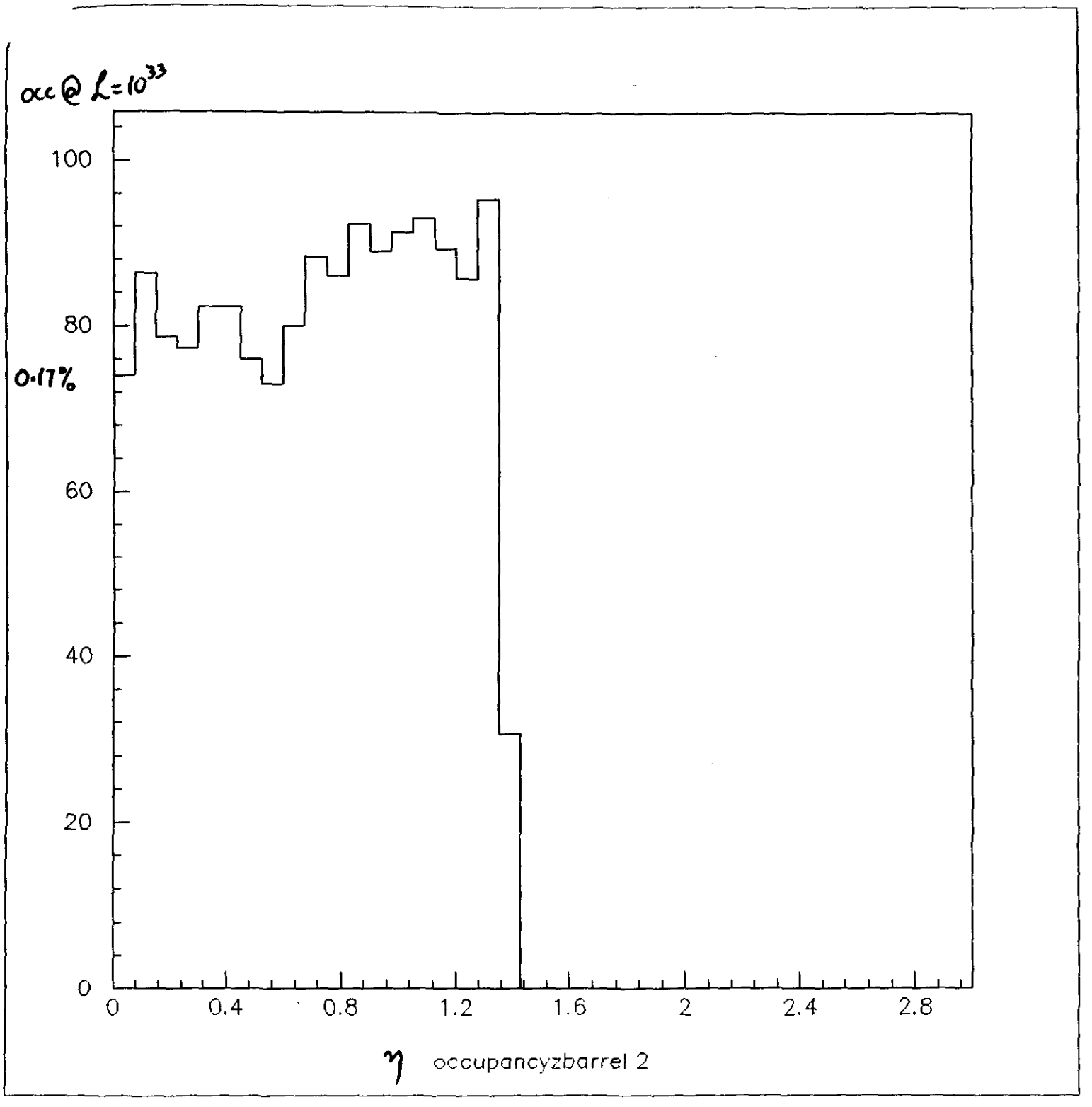
<u>SIMULATION</u> : 3 superlayer design
16 pad chambers/superlayer

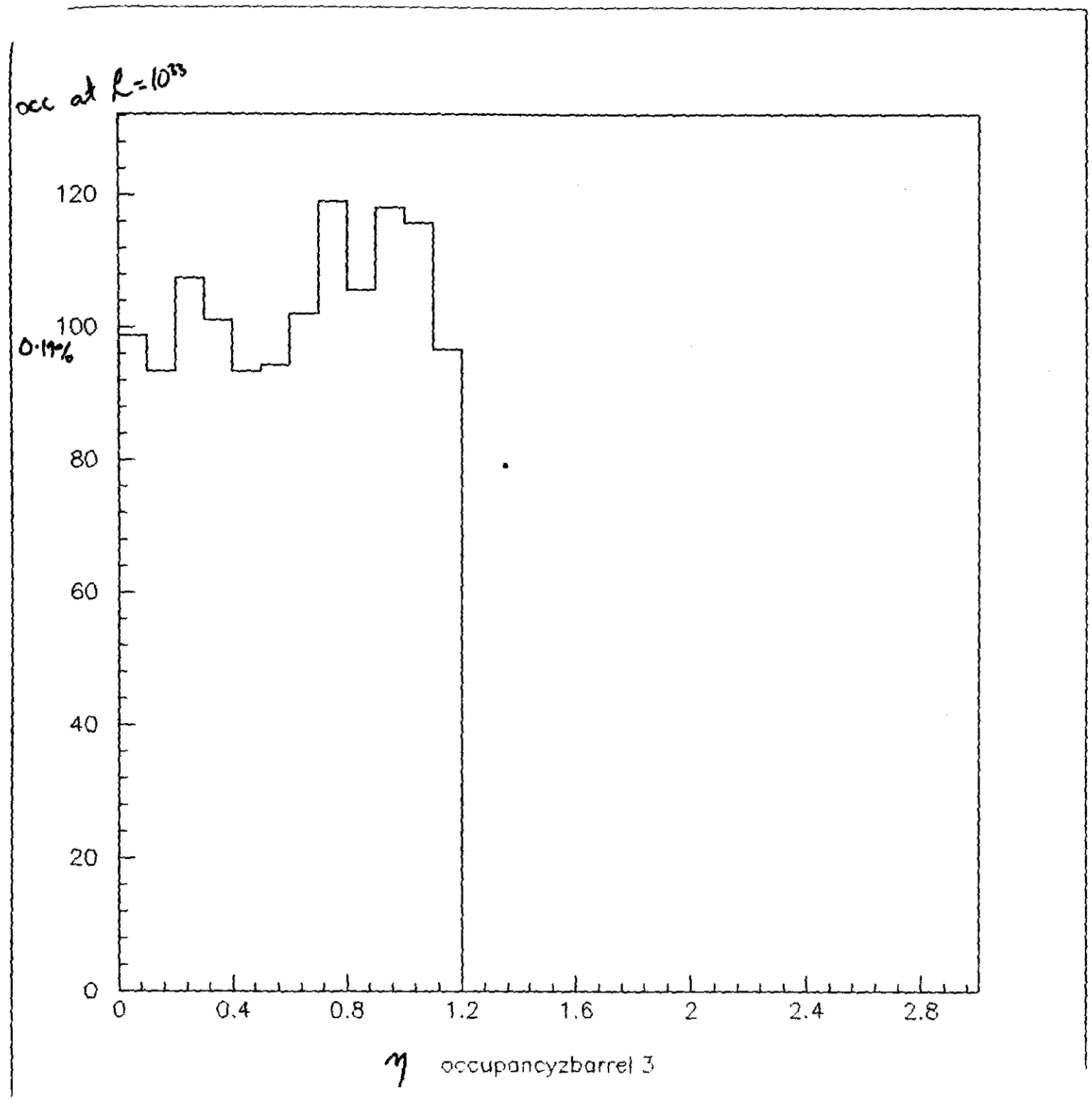
3200 MIN BIAS events.

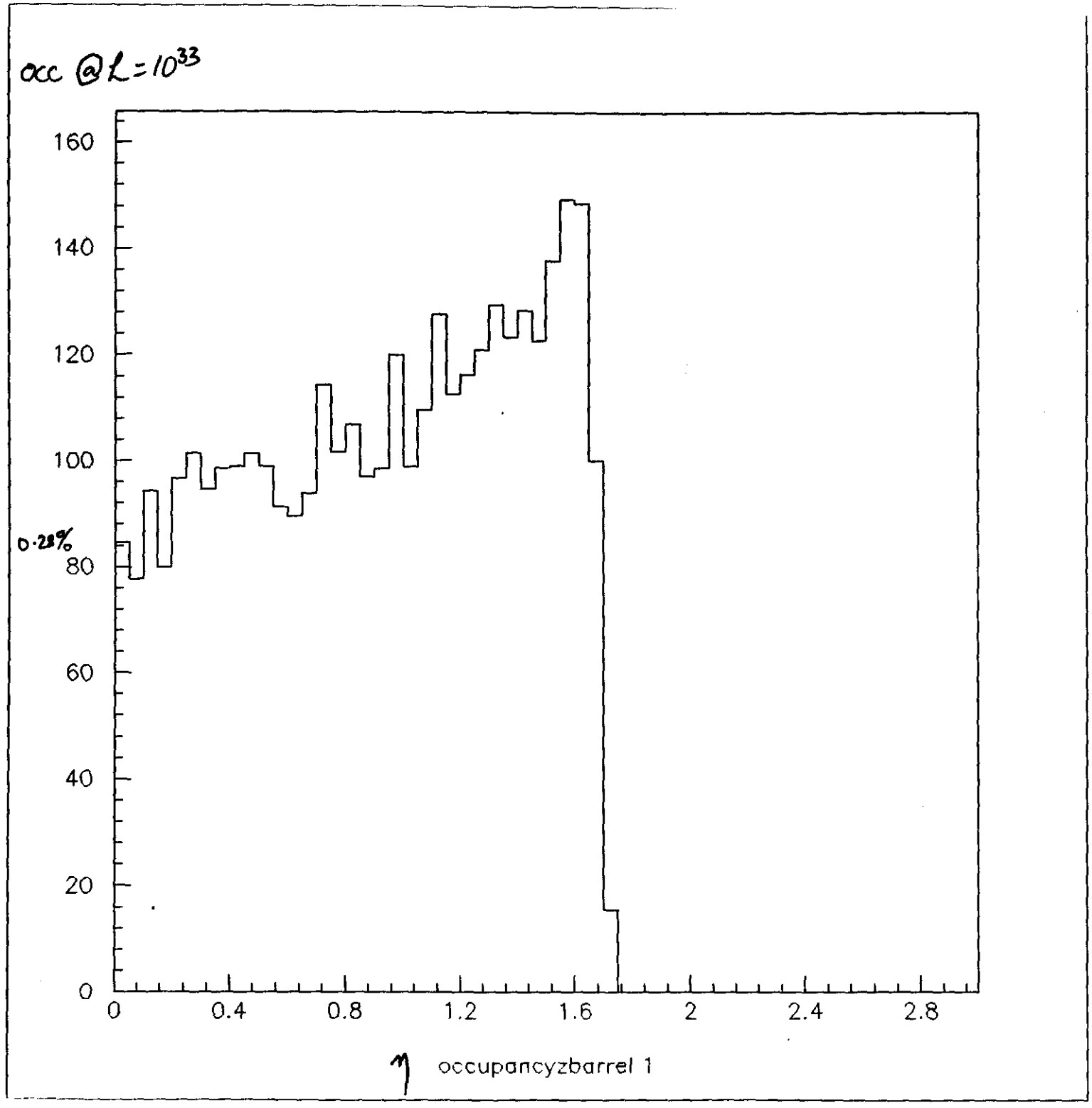
<u>OCCUPANCY</u> <u>@ $\mathcal{L} = 10^{33}$ @ $\eta = 0$</u>

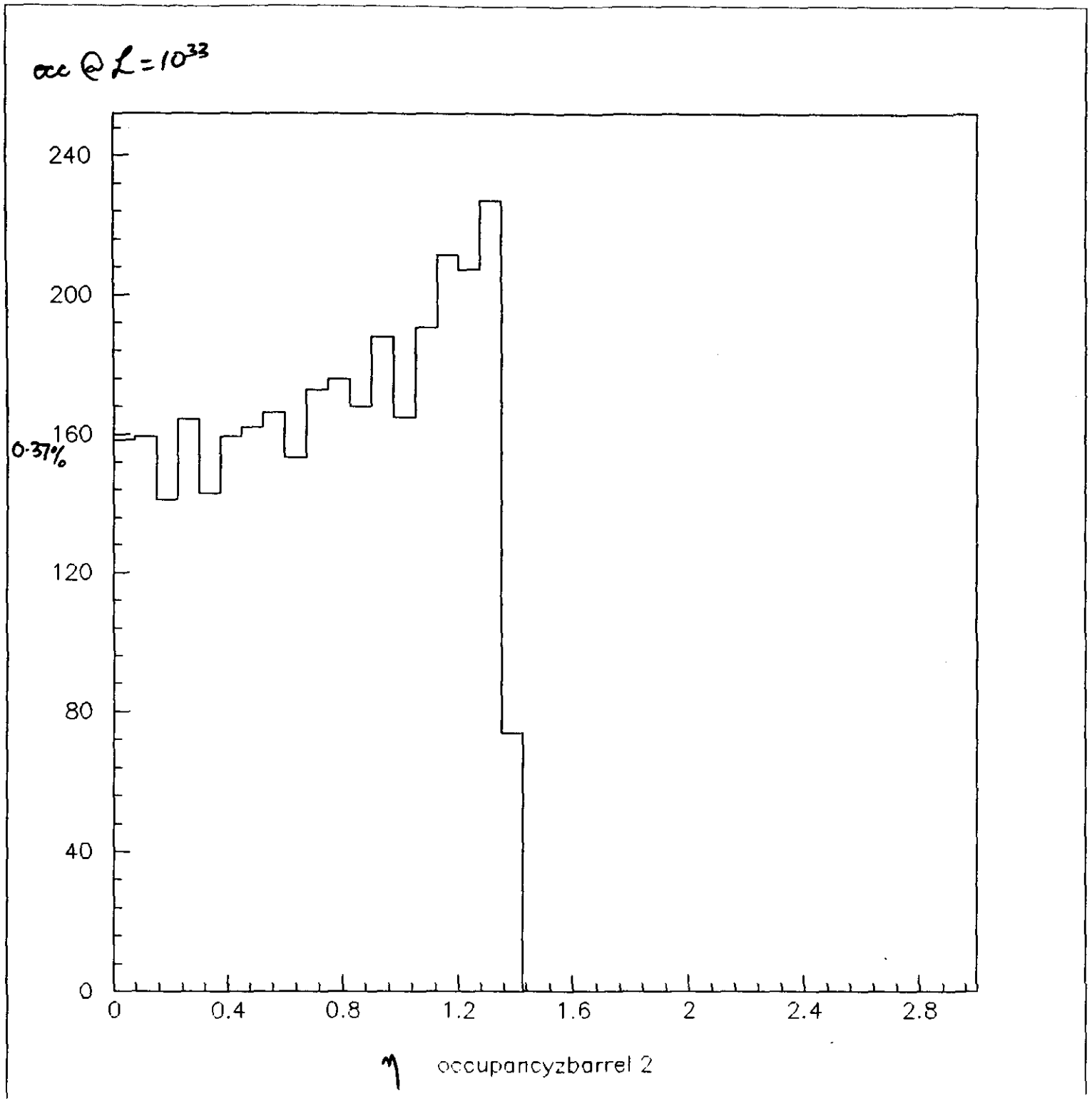
	1st superlayer	2nd superlayer	3rd superlayer
NO SECONDARIES	0.2%	0.17%	0.19%
W/ SECONDARIES	0.28%	0.37%	0.31%

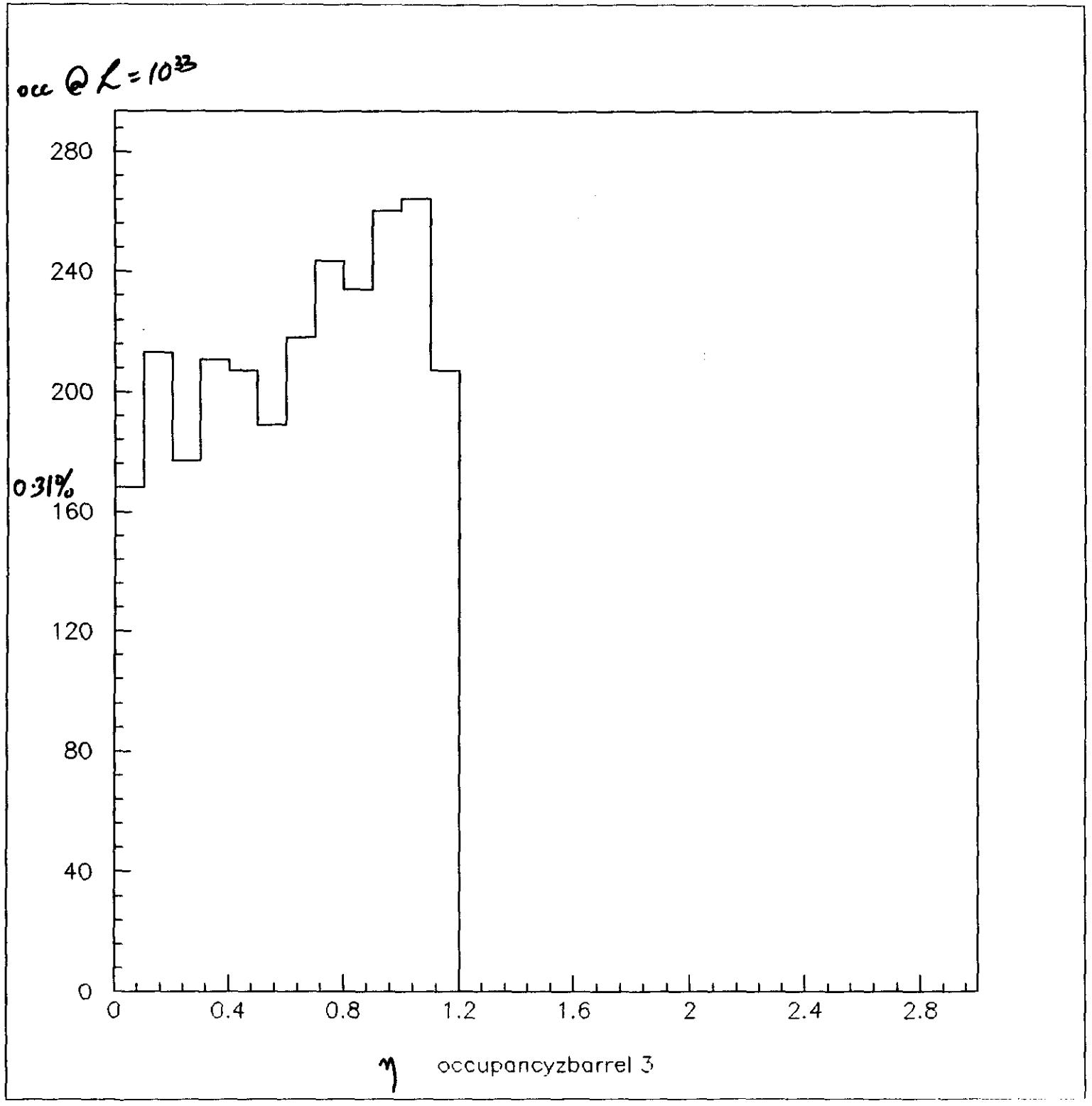

occ @ $\mathcal{L}=10^{33}$
90
80
70
60
0.2%
50
40
30
20
10
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
η
occupancyzbarrel 1

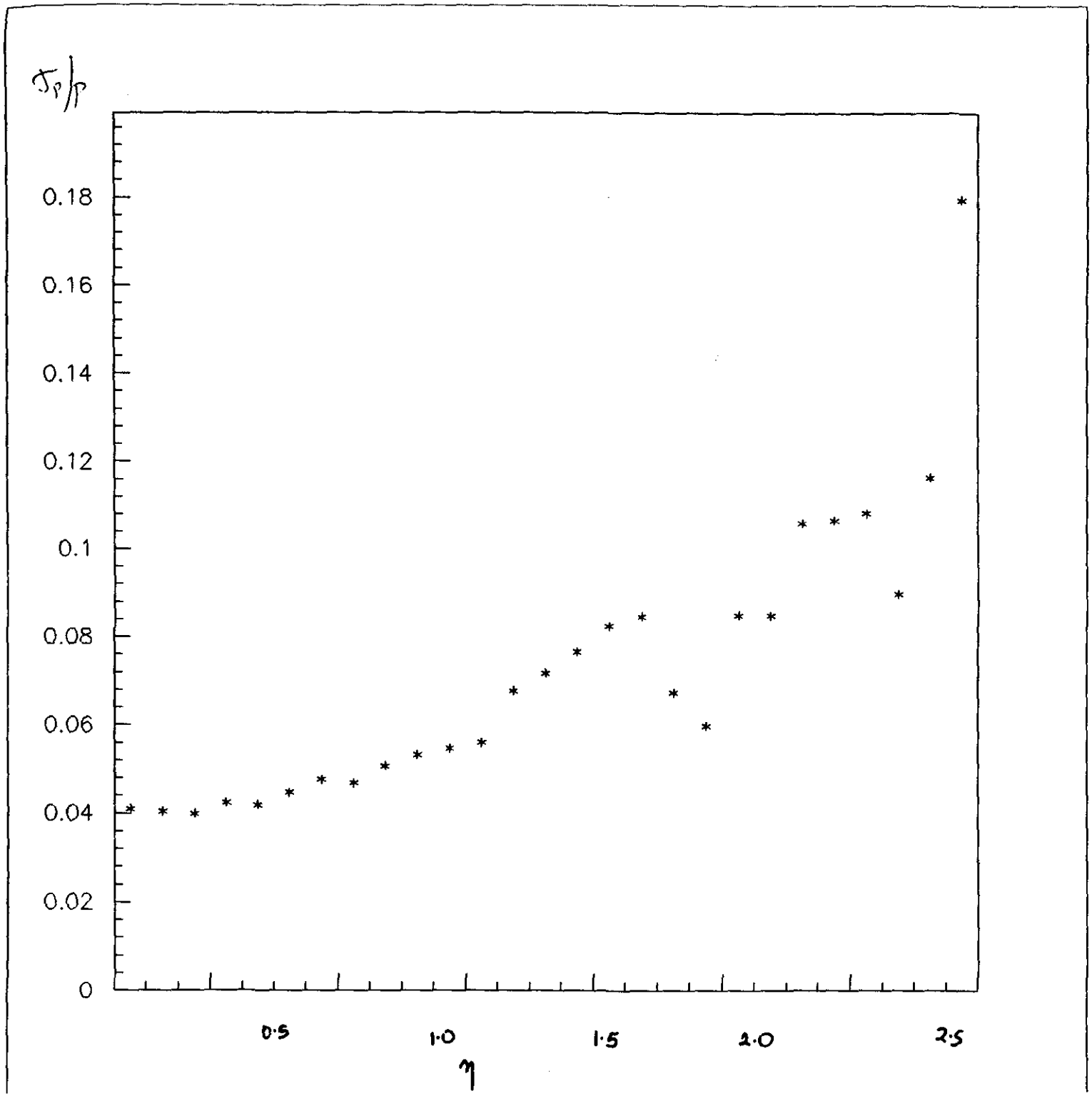

occ @ $\mathcal{L}=10^{33}$
100
80
0.17%
60
40
20
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
η
occupancyzbarrel 2


occ at R=10^33
120
100
0.19%
80
60
40
20
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
η
occupancyzbarrel 3


occ @ $\mathcal{L} = 10^{33}$
160
140
120
100
0.28%
80
60
40
20
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
η
occupancyzbarrel 1

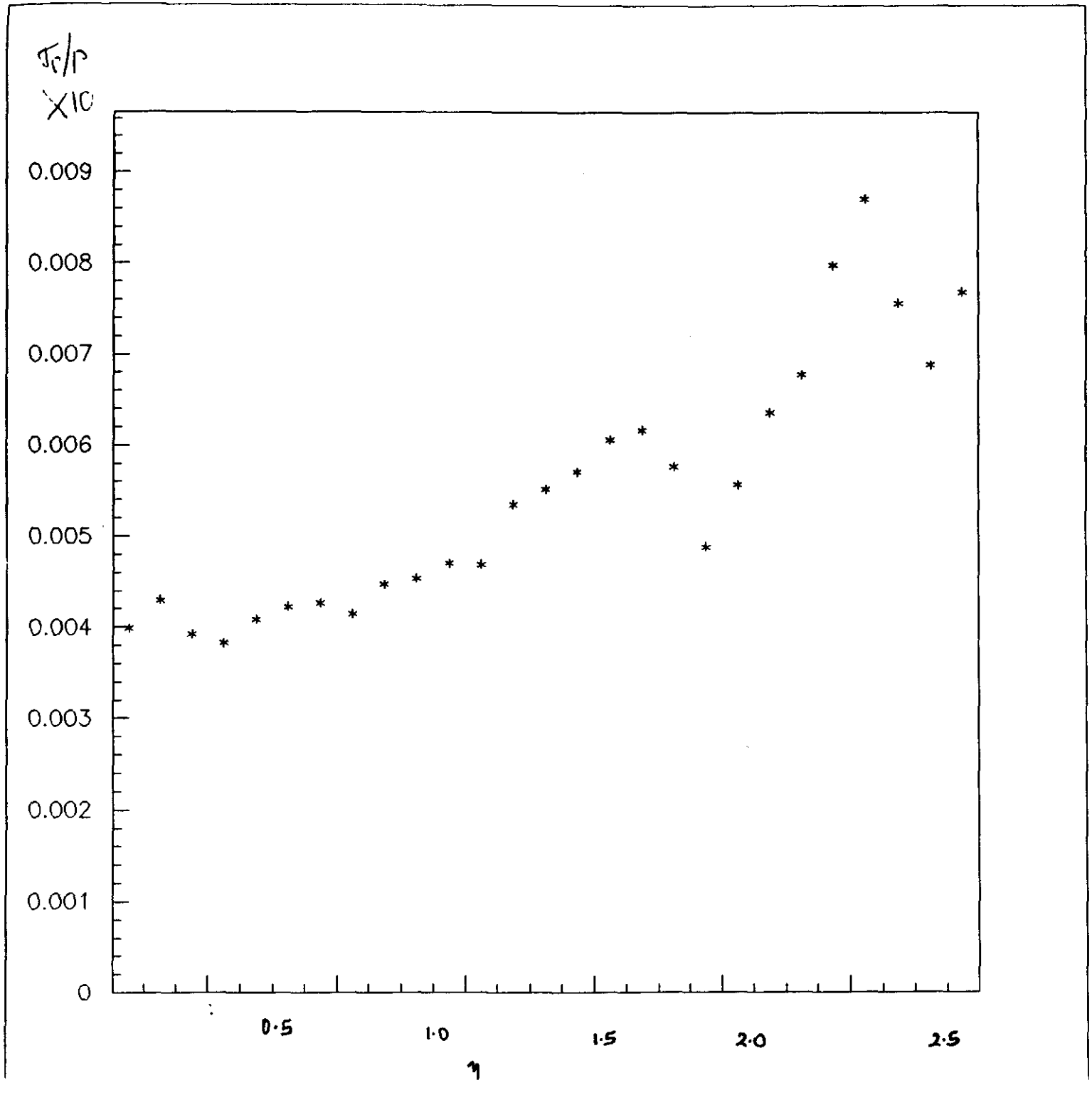

occ @ $\mathcal{L} = 10^{33}$
240
200
160
0.37%
120
80
40
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
η
occupancyzbarrel 2

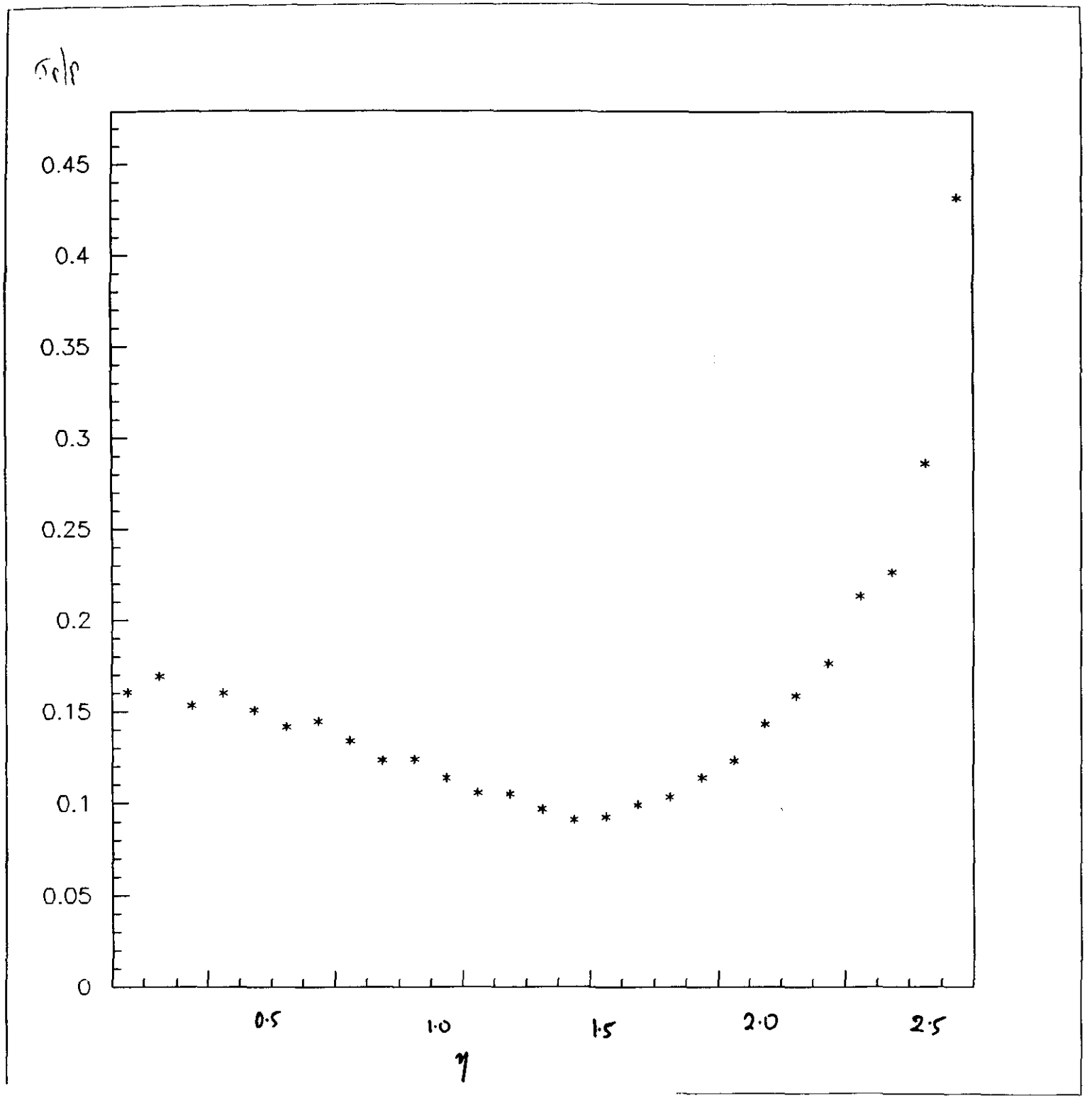

occ @ $\mathcal{L} = 10^{33}$
280
240
200
0.31%
160
120
80
40
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
η
occupancyzbarrel 3



1 GeV

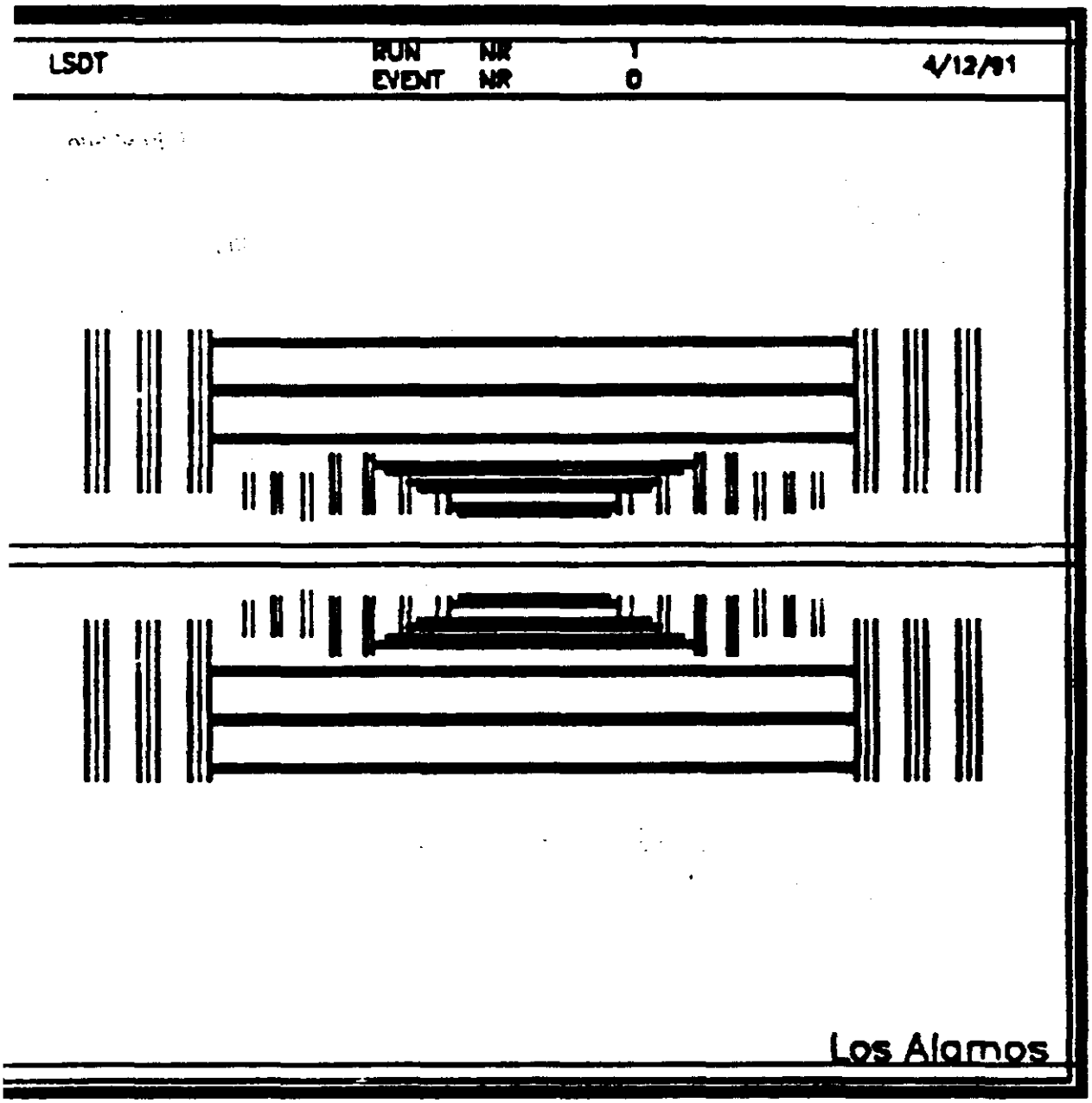
10 GeV


σ_c/ρ
$\times 10$
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0·5
1·0
1·5
2·0
2·5
η



100 GeV

Melynda Brooks (LANL) — Central Tracker
1/20/92



GEANT Simulation Includes:

1) A fairly complete geometry of the silicon tracker, down to the wafer/strip level. The support structure is included just as an overall increase in density.

2) The resolution of the Si that is produced by the code is approximately 10 microns.

3) The pad layers are represented by copper tubes that are 0.6% radiation length thick.

4) The input resolution of the pads is 50 microns in r/phi and 1 mm in z in the barrel region. There is nothing in the code that takes into account charge sharing among pads, occupancy problems, efficiency, etc.

5) All physics processes suchs as multiple scattering, Bremsstraahlung are turned on.

6) A helical fit of tracks is done after pattern recognition to get the momentum of the particles and the impact parameter.

7) Tracking efficiency and charge measurement efficiency plots are available for pattern recognition.

Questions Being/To Be Addressed at Los Alamos

1) How are impact parameter and momentum resolution affected by geometry of tracker, i.e. radii of layers, number of layers and spacing?

2) How is pattern recognition affected by tracker geometry?

3) What is forward tracking region capable of doing in present configuration?

4) What is charge determination efficiency of tracker?

5) What tracking capabilities are necessary to match particles in calorimeter or muon chambers with tracker?

6) Put in dead time and backgrounds from previous events and look at how the pattern recognition is affected.

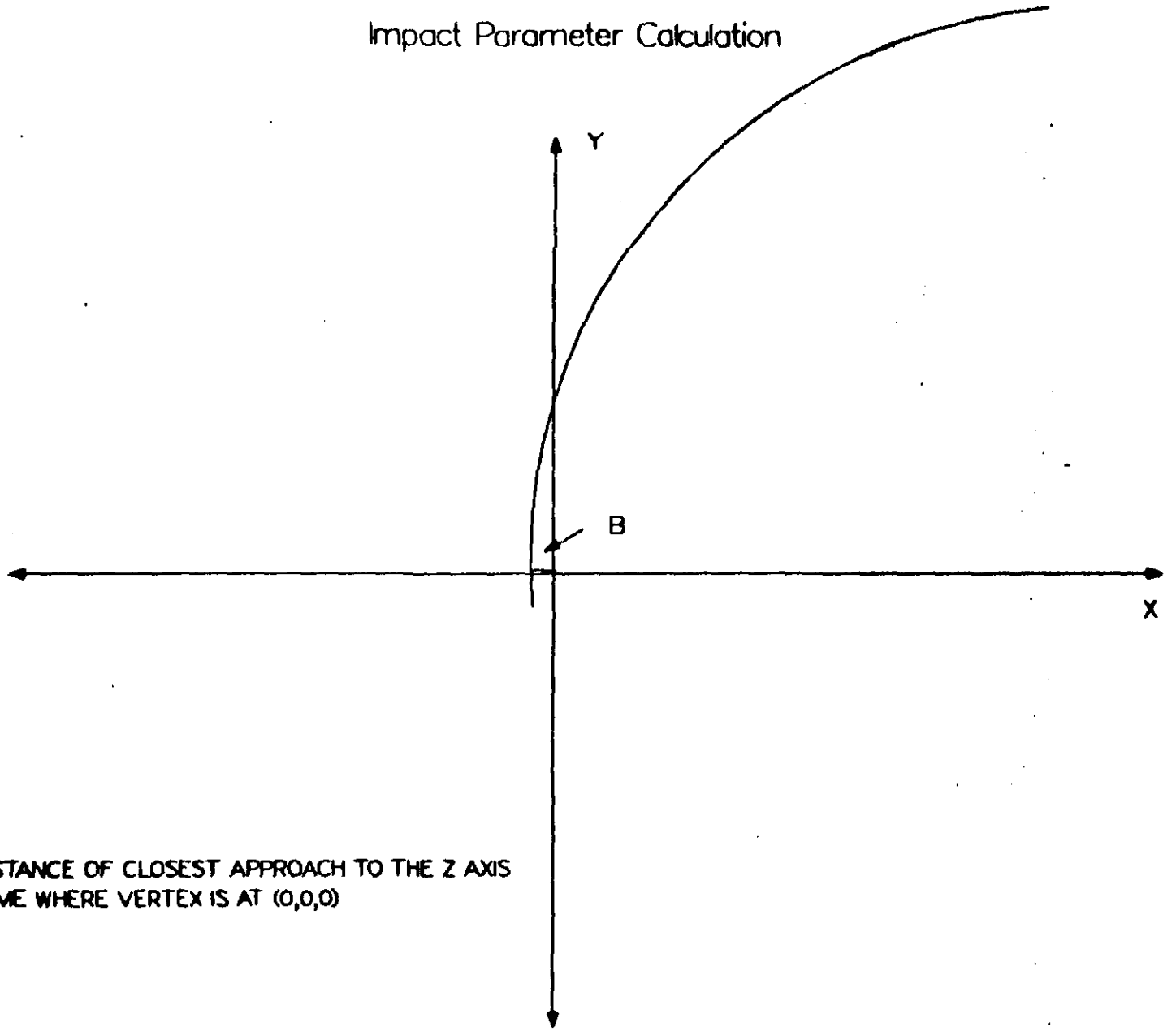
Progress on GEANT

1) Impact parameter and momentum resolutions in barrel region for various geometries have been calculated.

2) Beginning to study pattern recognition in barrel region. Charge and track efficiencies produced.

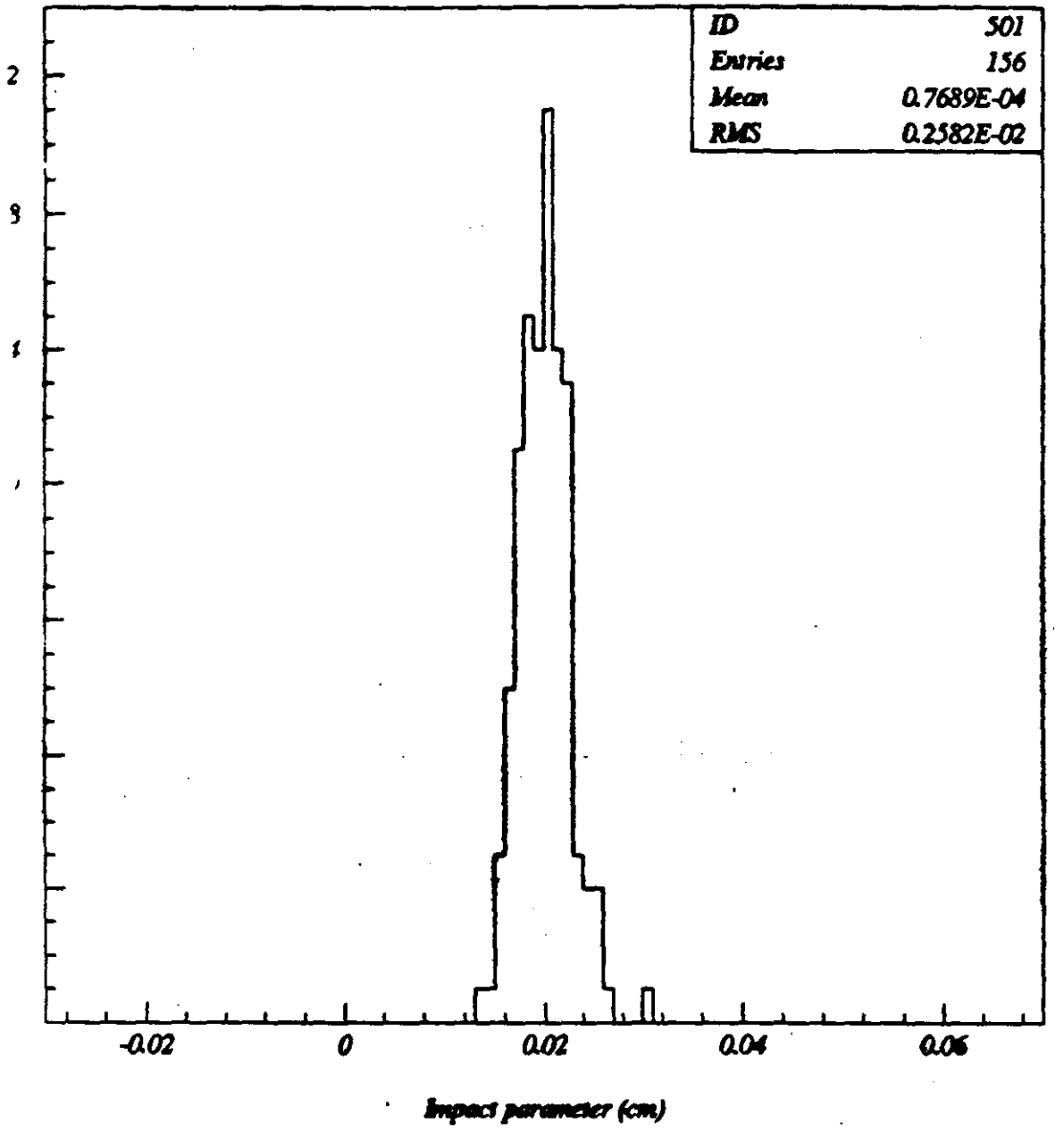
3) Much of forward region is complete but tracking from silicon to pads is not possible yet.

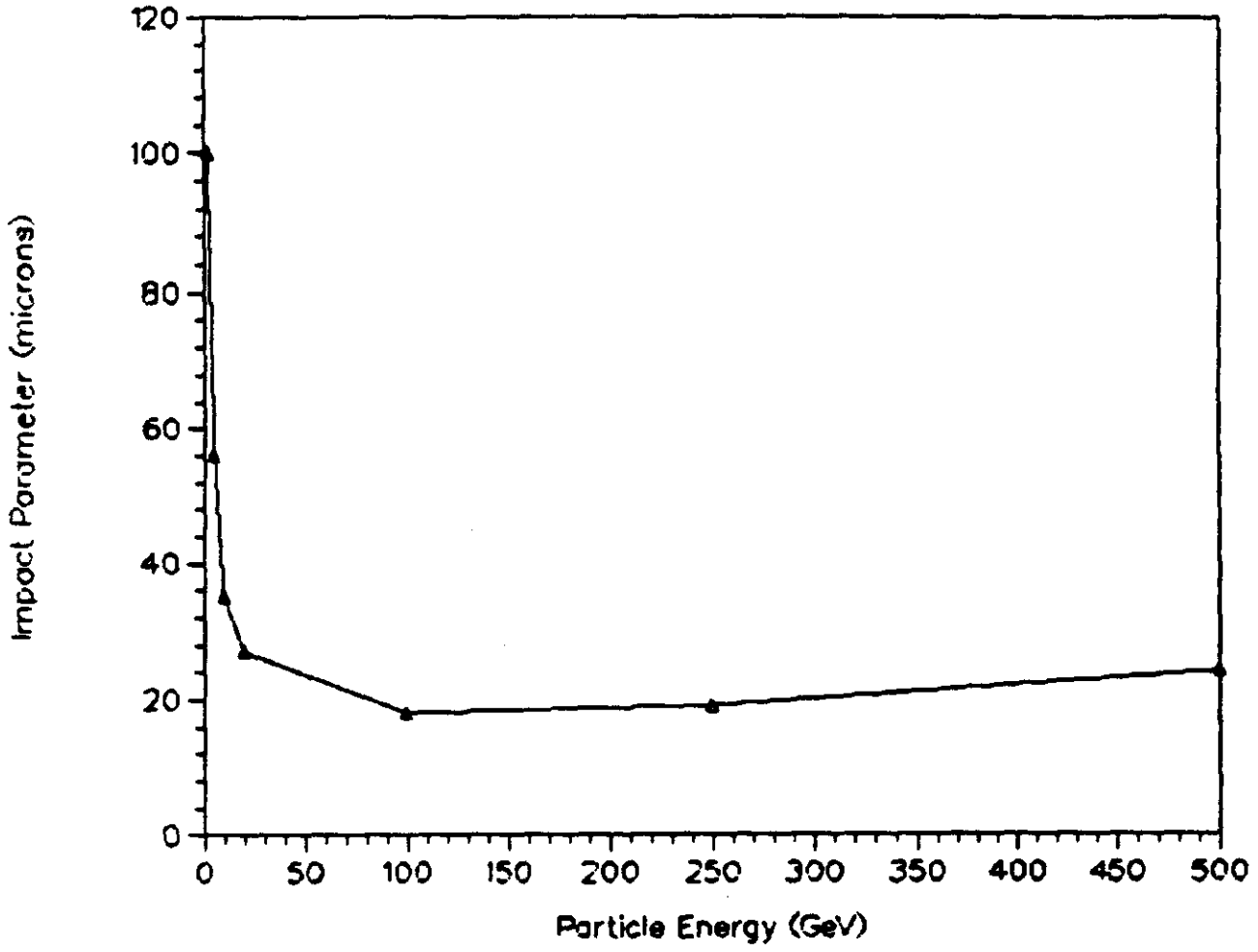
Impact Parameter Calculation

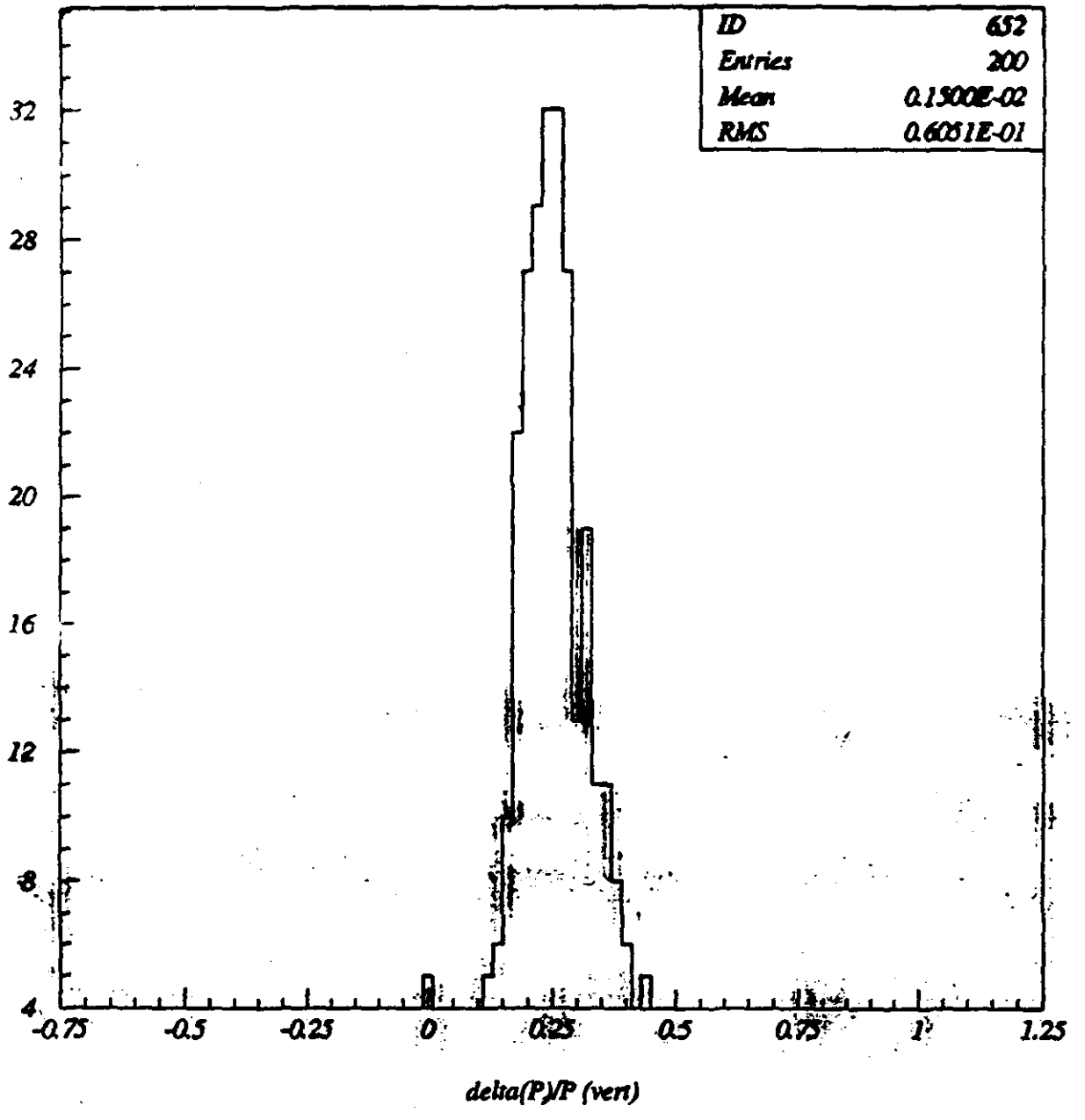


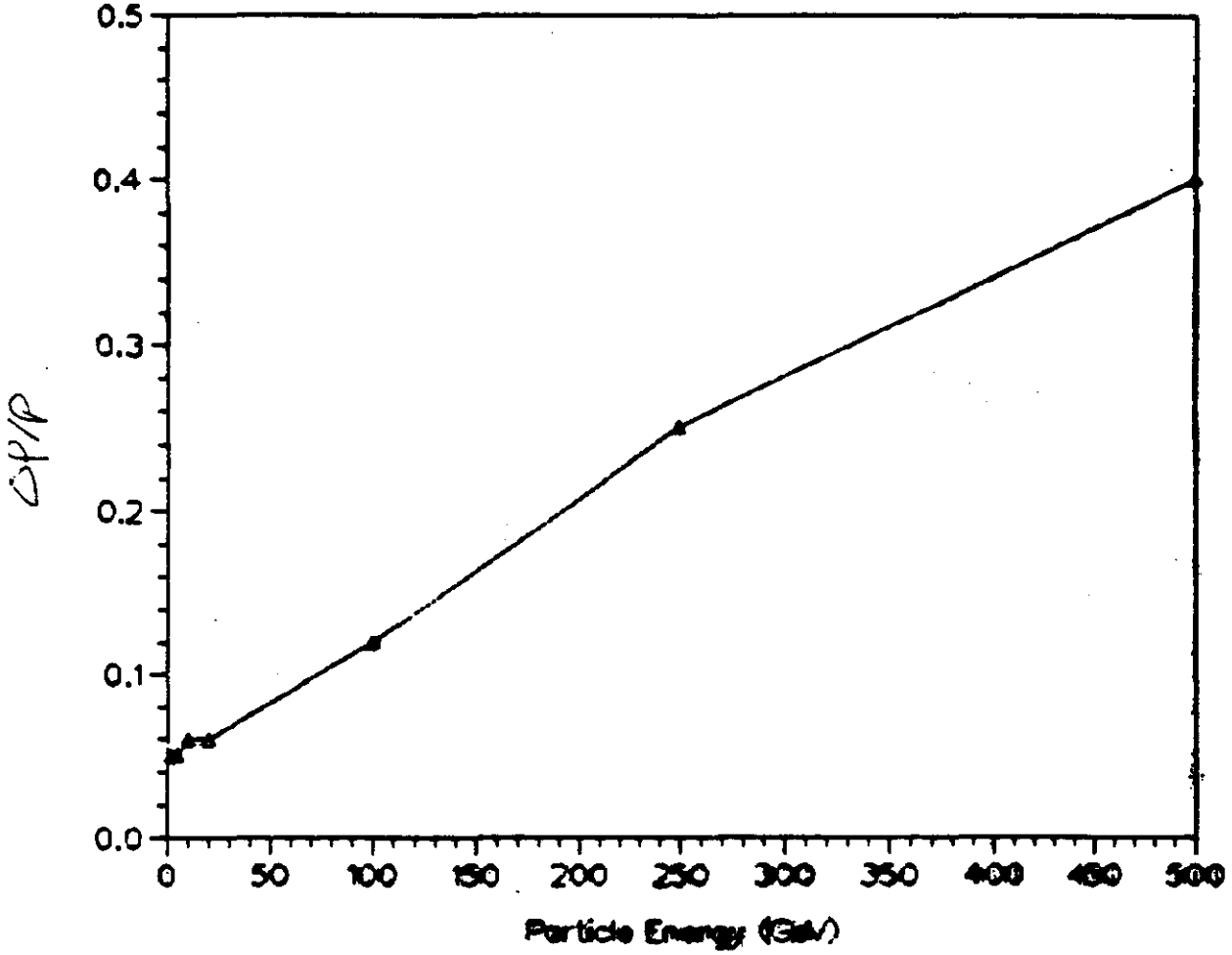
B = DISTANCE OF CLOSEST APPROACH TO THE Z AXIS
IN FRAME WHERE VERTEX IS AT (0,0,0)

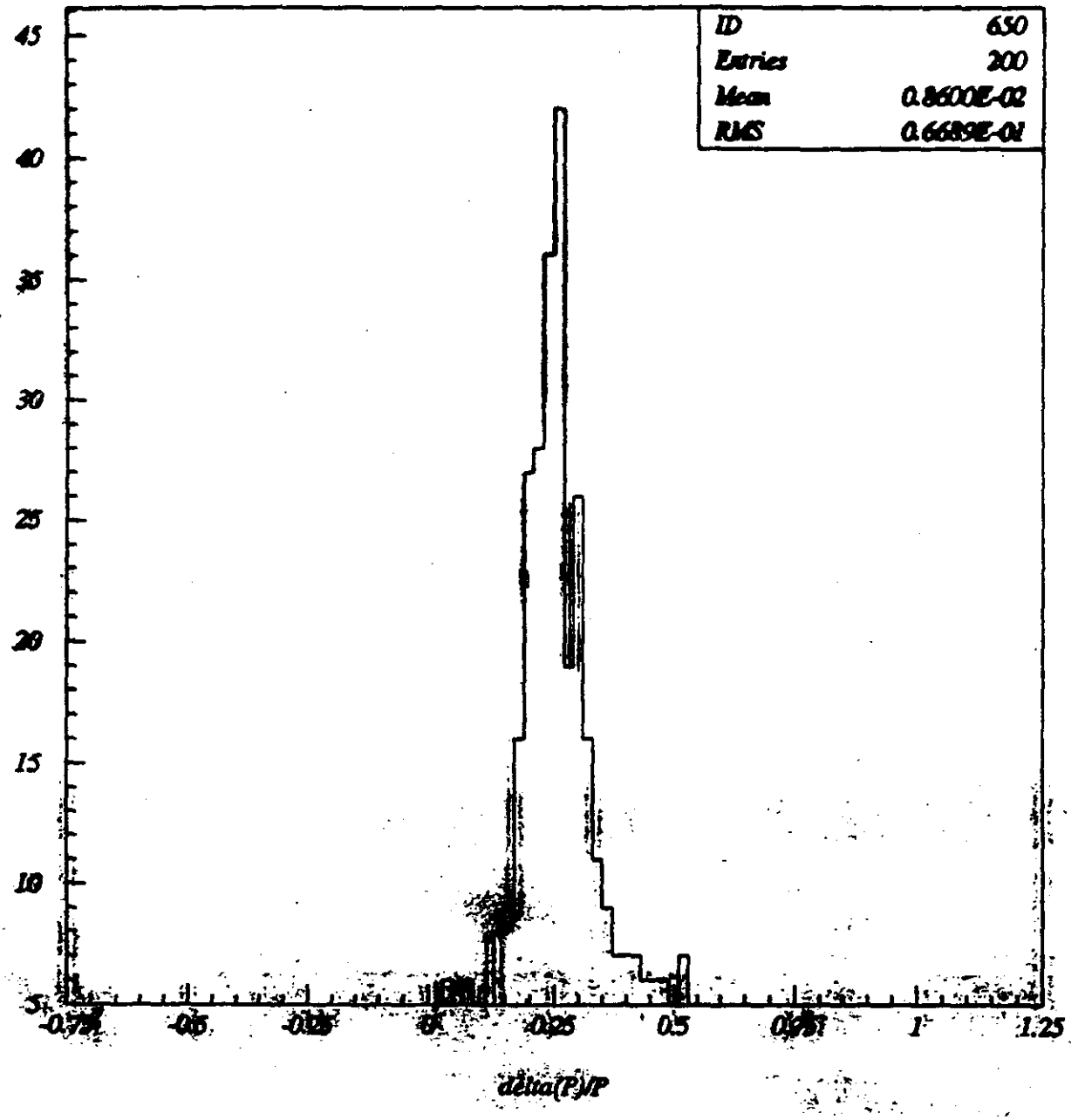
20 GeV Muons
Si: r = 10, 22 cm
Pads: r = 35, 67 cm
5μm vertex




120
100
80
60
40
20
0
Impact Parameter (microns)
0
50
100
150
200
250
300
350
400
450
500
Particle Energy (GeV)


ID 652
Entries 200
Mean 0.1500E-02
RMS 0.6051E-01
32
28
24
20
16
12
8
4
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
1.25
delta(P)/P (vert)


0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
450
500
Particle Energy (GeV)
δP/P


ID 650
Entries 200
Mean 0.8600E-02
RMS 0.6689E-01
45
40
35
30
25
20
15
10
5
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
1.25
delta(P)/P

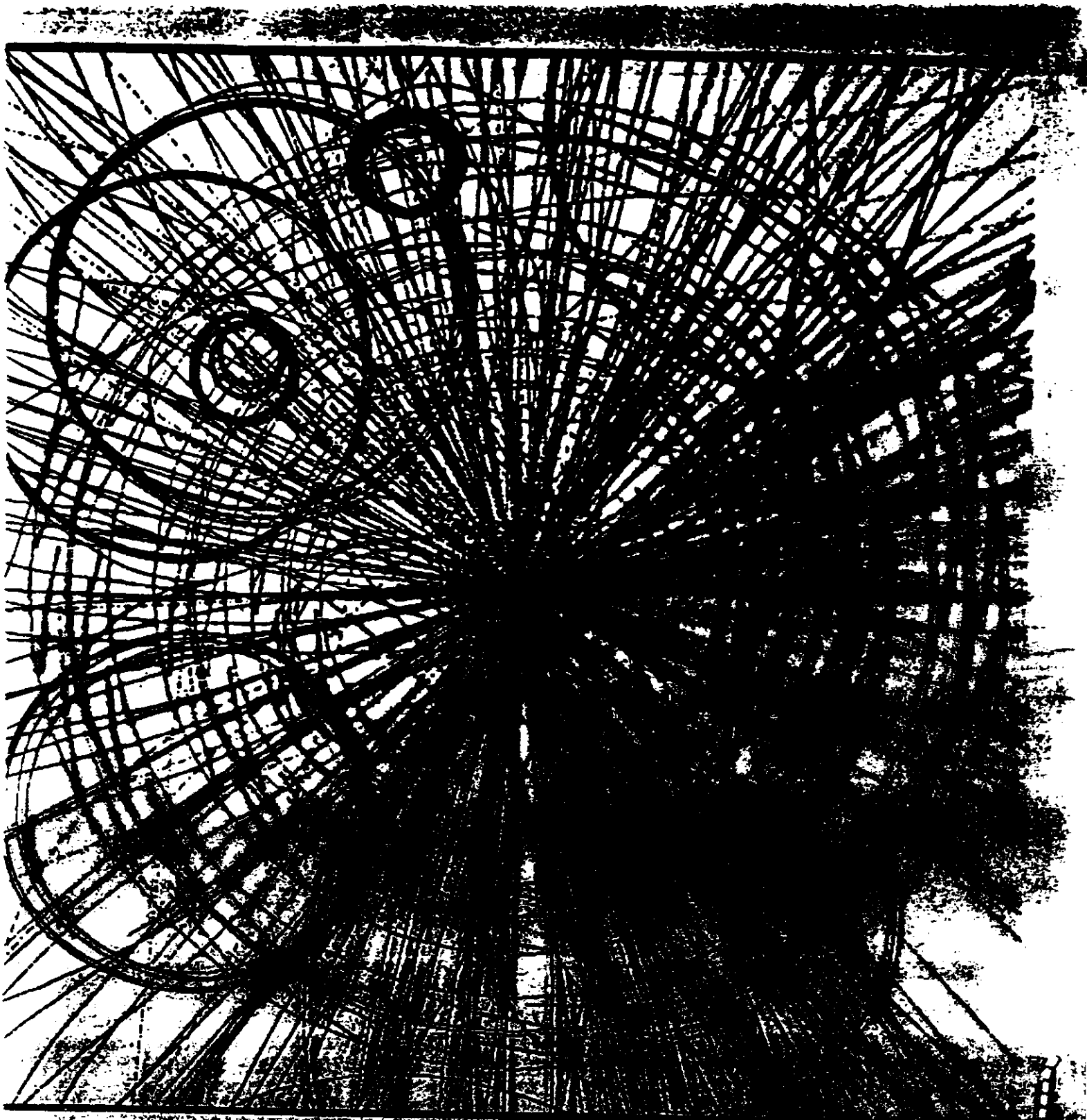
Impact Parameter and Momentum Resolution for Various Geometries

(Single track muons at 20 GeV)

Si layers	Si radii*	Pads layers	Pads radii	Impact param.**	$\Delta p/p$	$\Delta p/p$ w/ vert.
6	13,20,28	0	—	79	0.31	0.12
6	—	3	35,50,65	400	0.20	0.10
6	—	3	25,45,65	100	0.16	0.08
4	13,20	4	64-67	20	0.16	[illegible]
6	13,20,28	4	64-67	[illegible]	[illegible]	[illegible]
6	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]
		1	[illegible]	[illegible]	[illegible]	[illegible]
		1	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]
		1	[illegible]	[illegible]	[illegible]	[illegible]
		3	25,45,[illegible]	28	0.07	0.03

* in cm
** microns

THESE POINTS ARE [illegible] FOR IMPACT PARAMETER RESOLUTION. TOTAL NUMBER OF HITS AND SPATIAL HITS BE DETERMINED BY PATTERN RECOGNITION CAPABILITIES.



Higgs Event with 1.6 minimum bias events overlayed in Silicon detectors

Efficiency Definitions

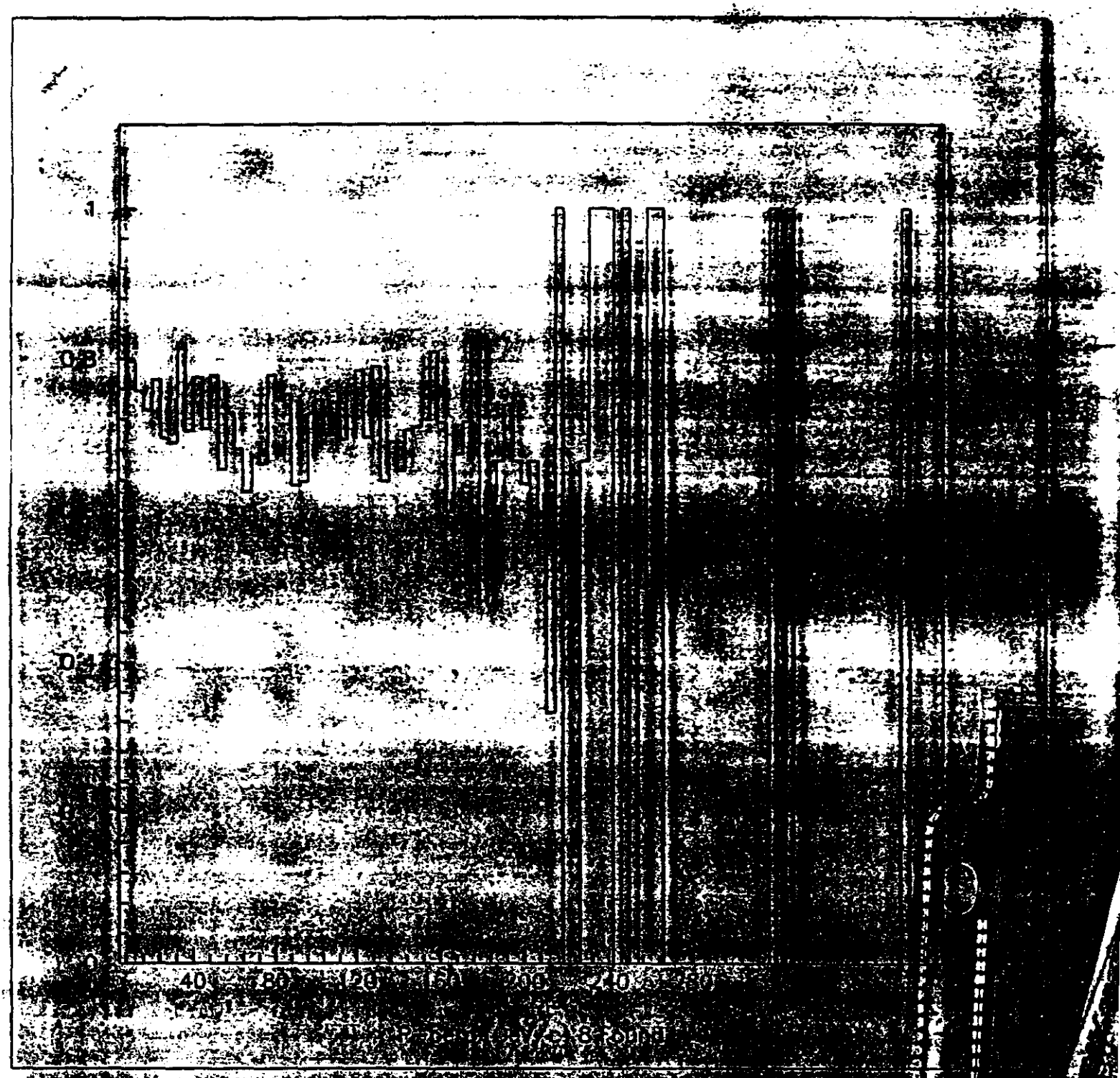
Tracking Efficiency Definition:

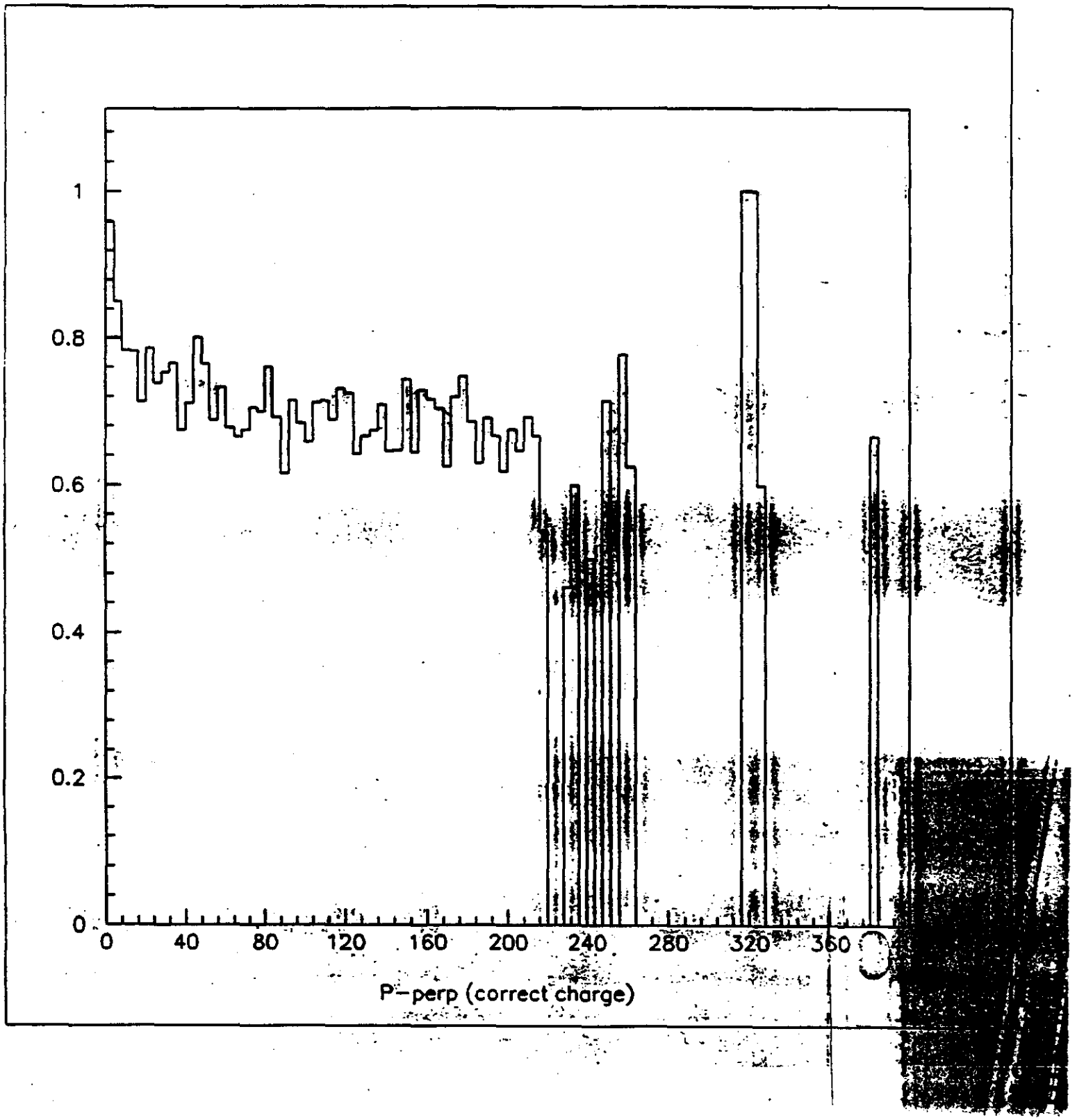
$$E = \frac{\text{\# found tracks with 5 or more correct hits}}{\text{\# tracks that produced 5 or more hits in detectors}}$$

Charge Efficiency:

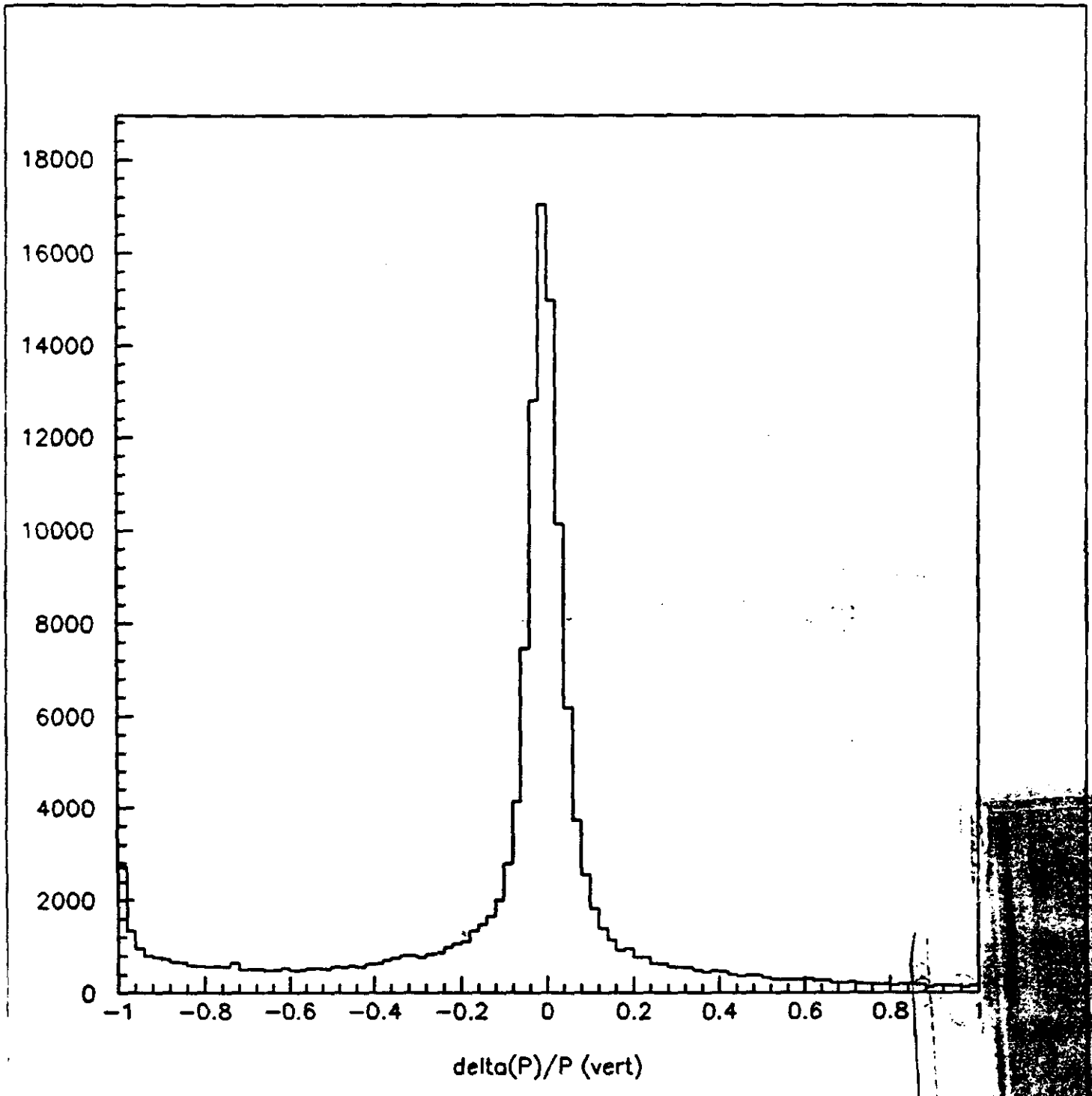
$$E = \frac{\text{\# tracks with measured charge = true charge}}{\text{\# found tracks}}$$

Track [illegible]
minimum bias events w[illegible]
with Higgs.
8 or more out of 14 hits correctly
identified



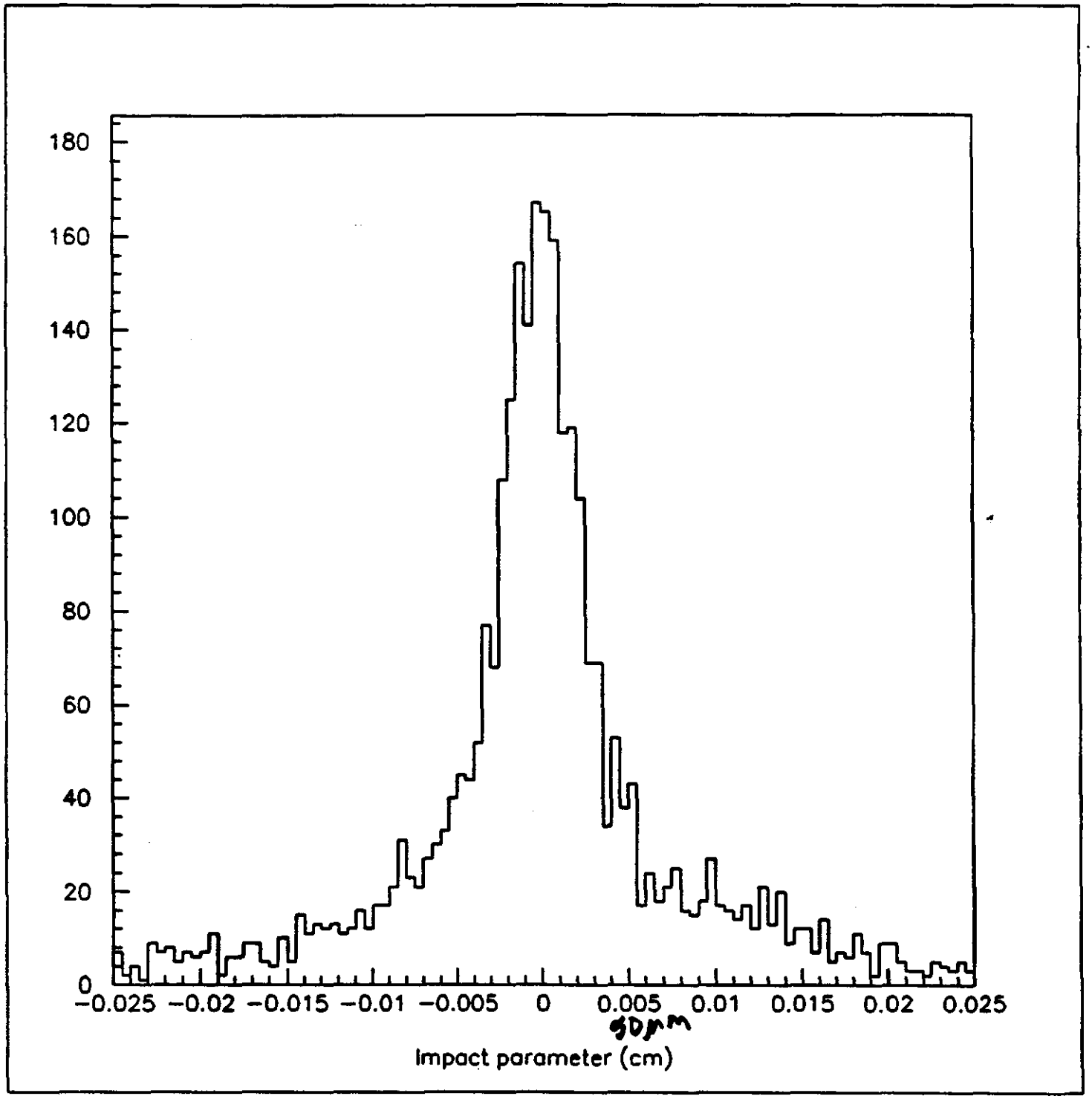

1
0.8
0.6
0.4
0.2
0
0
40
80
120
160
200
240
280
320
360
P−perp (correct charge)

Higgs with 1.6 minimum bias events overlayed. Momentum resolution for all tracks



Higgs events with 16 minimum bias events overlayed
Impact param. resolution for all tracks

Higgs events overlayed with 16 min. bias, Poisson dist.



CENTRAL TRACKING

G. MILLS

(LANL)

@

SSCL 1/20/92

AMPAD 22-141 50 SHEETS 22-142 100 SHEETS 22-144 200 SHEETS

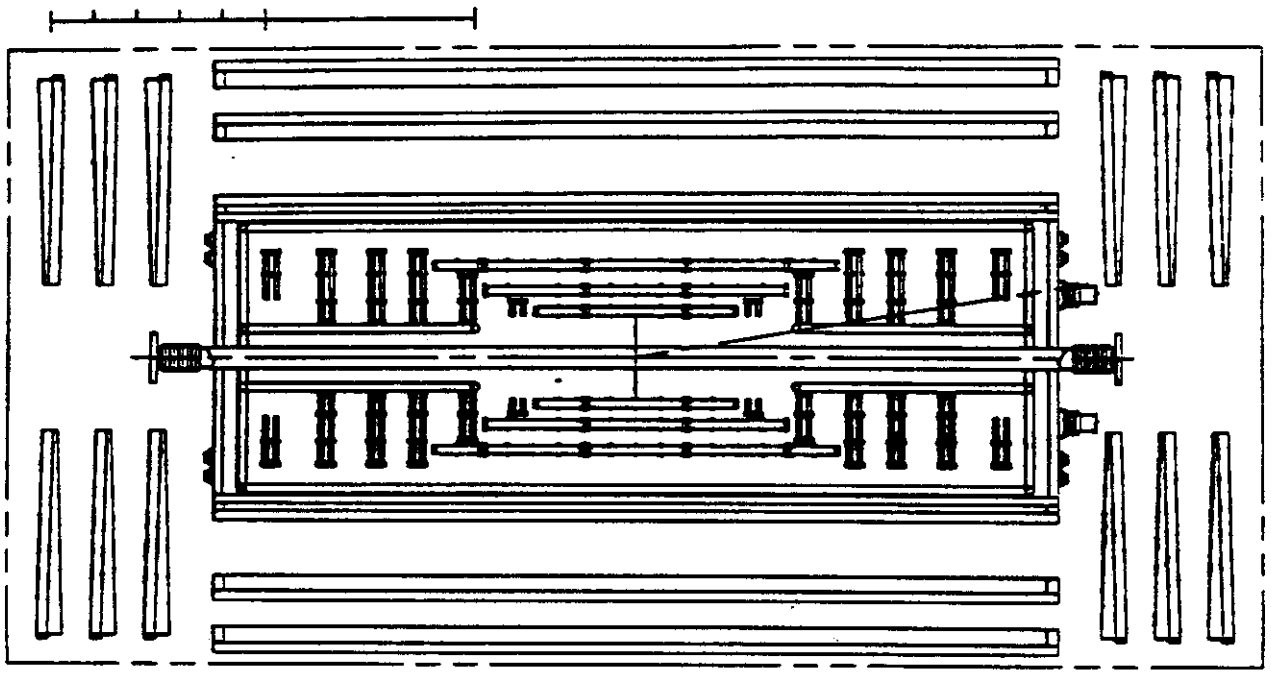
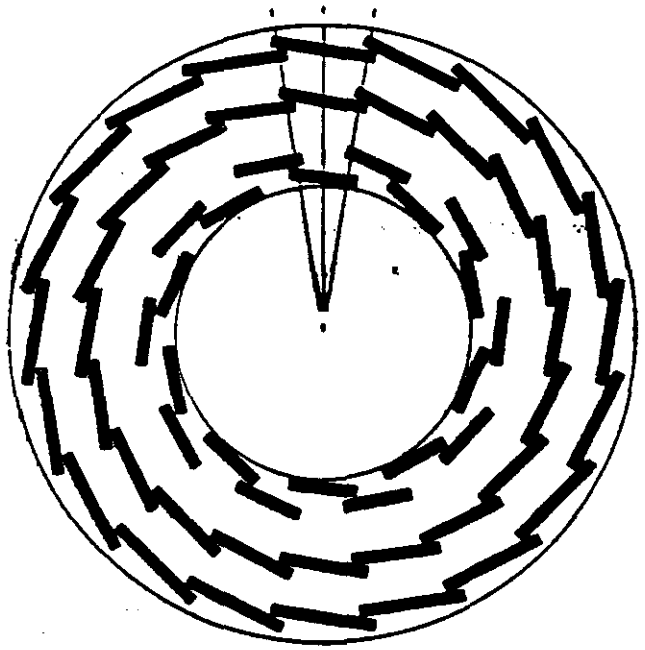


Figure 5. Strawman Central Tracker with Silicon Strip inner tracker and IPC outer tracker. The inner and outer trackers each cover the rapitdity range $-2.5<\eta<2.5$ with three super-layers.

a)



b)

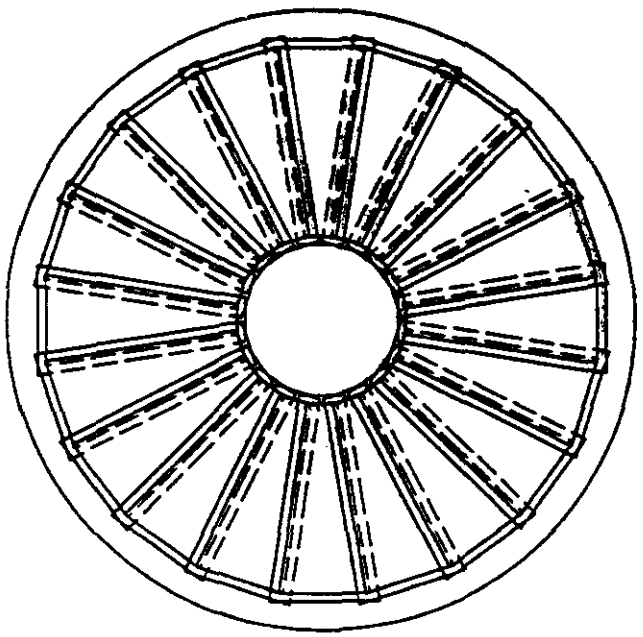
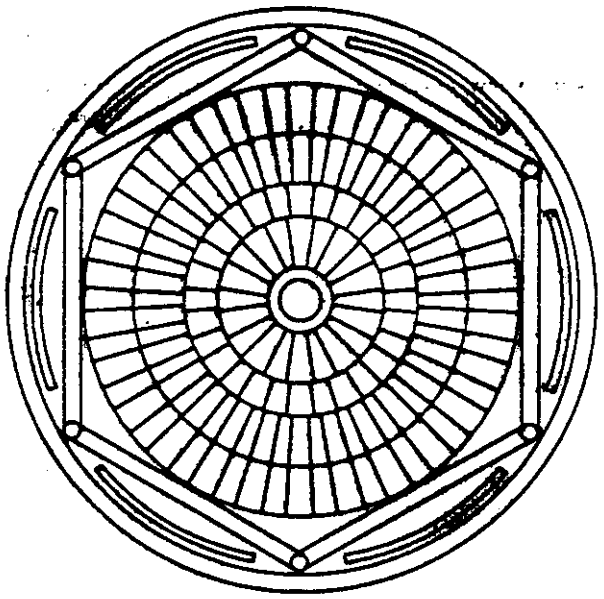


Figure 7. Endviews of the IPC outer tracker. A. Forward region disks B. Central region barrels. Note the staggering of the inner barrel layer due to Lorentz angle considerations.

a)



b)

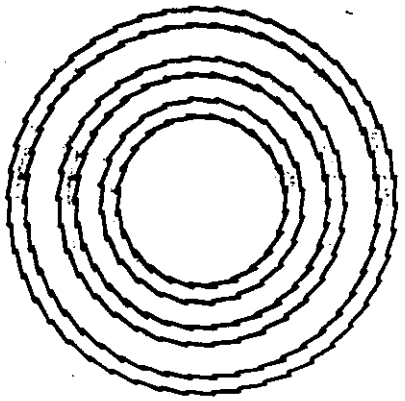


Figure 6. Endviews of the silicon inner tracker. A. Disks in forward region B. Central region barrels

Table 1. SSC operational parameters

Luminosity	10^{33} $cm^{-2}s^{-1}$
Crossing Frequency	62.5 MHz
Minimum Bias Cross Section	90-100 mb
$\frac{dN_{ch}}{d\eta d\phi}$ for Minimum Bias Event	1.2 charged particles
Minimum Bias Events per Crossing	1.6
$\frac{dN_{ch}}{d\eta d\phi}$ for one beam crossing	1.9 charged particles
$\frac{dN_{ch}}{d\eta d\phi}$ for 300GeV Higgs Events	4.1 charged particles

Table 2. Occupancies in the Central Tracker

Silicon	$\Delta\eta\Delta\phi$ cell	Occupancy (%)	Fraction of Time Dead(%)	Space Point Occupancy(%)
$L=10^{33}cm^{-2}s^{-1}$	0.9-8.0x 10^{-4}	0.06-0.22	.6-2.2	.72-2.6
$L=10^{34}cm^{-2}s^{-1}$	"	0.26-2.2	2.6-22.2	3.1-23.2
IPC				
$L=10^{33}cm^{-2}s^{-1}$	.001	1.0	0	26.0
$L=10^{34}cm^{-2}s^{-1}$	"	4.9	0	78.0

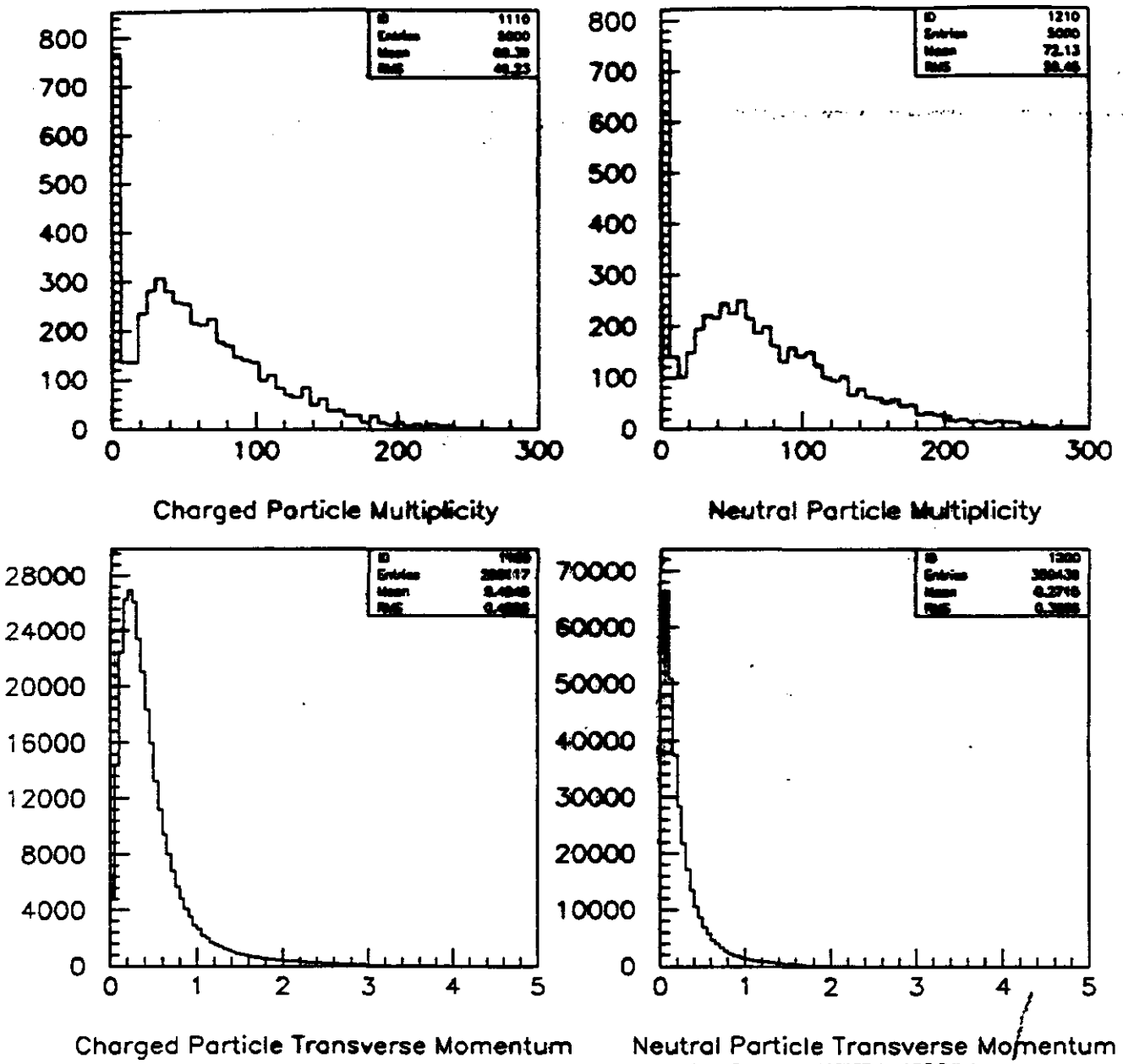


Figure 1. Minimum bias event properties from PYTHIA (5000 beam crossings). Elastic, diffractive, and low P_t have bean included. Charged and neutral particle multiplicities and transverse momentum distributions (neutrinos not included).

IPC Geometry and Occupancy from Primary Tracks:

D(eta)D(phi) for the IPCs	0.001
Number of Crossing Integrated	2
Occupancy	3.2E-06
Total Number of Pads (see Below)	370,635

IPC Pad Size:

Wire Spacing (mm)	2.5
Pad Width	5
Number of Pad Layers per Super Laye	3

IPC Barrel Dimensions:

Barrel Length	2000

Super Layer	R	Pad D(eta)	Pad Length	N Pads in eta	N Pads in Phi	N Pads/Layer
1	370	0.074	27	72	464	100224
2	500	0.1	50	39	628	73476
3	625	0.125	78	25	785	58875
						232575

Total number of Pads in Barrel	232575

IPC EndCap Region:

Inner Radius	200
Outer Radius	700

Super Layer	Z	Inner eta	Outer eta	Eta Divisions	N Pads (x2 Endcaps)
1	1100	2.41	1.23	19	46410
2	1300	2.57	1.38	19	45960
3	1500	2.71	1.51	19	45690
					138060

Total Number of Pads in Endcaps	138060

Notes:
1. all dimensions in mm
2. All pad sizes are calculated by by assuming a fixed width and then adjusting the length to obtain the requisite D(eta)D(phi) element area.

Minimum Bias Events

Luminosity(cm^2/s)	1.0E+33
Bunch Frequency	8.26E+07
Luminosity per bunch(mb)	1.00E-02
Minimum bias cross section (mb)	100
Minimum bias events per crossing	1.6
d^N/d(eta)d(phi) per MB event	1
Number of Bunches Integrated	1
d^N/d(eta)d(phi) per crossing	1.6

Silicon Strip Occupancy

Strip Length(mm)	120
Strip width(mm)	0.05
Stereo Angle(radians)	0.005

SIMASA Tracker Occupancies

Notes :
1. all distances in mm
2. Occupancy refers to the average over all minimum bias like beam crossings. It refers to the average number of tracks in a single strip.
3. Space Point Occupancy refers to the average number of tracks in a band around a strip which is covered by the strips 'stereo partner', i.e., an area about 12 times as largeas a single strip.

Hit Occupancy Calculations for Primary Tracks

Barrel Cylinders:

R	Ladder	Z	D(eta)	D(phi)	D(eta)D(phi)	Occupancy	Space Point Occupancy
100	1	0	1.02	5.0E-04	5.1E-04	8.1E-04	9.8E-03
	2	120	0.59	5.0E-04	3.0E-04	4.7E-04	5.7E-03
160	1	0	0.69	3.1E-04	2.2E-04	3.5E-04	4.2E-03
	2	120	0.50	3.1E-04	1.6E-04	2.5E-04	3.0E-03
	3	240	0.36	3.1E-04	1.1E-04	1.8E-04	2.1E-03
220	1	0	0.52	2.3E-04	1.2E-04	1.9E-04	2.3E-03
	2	120	0.42	2.3E-04	9.6E-05	1.5E-04	1.8E-03
	3	240	0.32	2.3E-04	7.4E-05	1.2E-04	1.4E-03
	4	360	0.25	2.3E-04	5.8E-05	9.2E-05	1.1E-03

Forward Disks:

Z	Type	Inner R	Outer R	D(eta)	D(phi)	D(eta)D(phi)	Occupancy	Space Point Occupancy
290	Inner	100	140	3.1E-01	3.6E-04	1.1E-04	1.8E-04	7.1E-04
400	Inner	100	140	3.2E-01	3.6E-04	1.2E-04	1.8E-04	7.4E-04
400	Outer	140	200	3.3E-01	2.5E-04	8.2E-05	1.3E-04	7.9E-04
520	Inner	100	140	3.3E-01	3.6E-04	1.2E-04	1.9E-04	7.5E-04
520	Outer	140	260	5.8E-01	1.9E-04	1.1E-04	1.8E-04	2.1E-03
620	Inner	100	140	3.3E-01	3.6E-04	1.2E-04	1.9E-04	7.6E-04
620	Outer	140	260	5.9E-01	1.9E-04	1.1E-04	1.8E-04	2.2E-03
740	Inner	100	140	3.3E-01	3.6E-04	1.2E-04	1.9E-04	7.6E-04
740	Outer	140	260	6.0E-01	1.9E-04	1.2E-04	1.8E-04	2.2E-03
870	Inner	140	260	6.0E-01	1.9E-04	1.2E-04	1.9E-04	2.2E-03

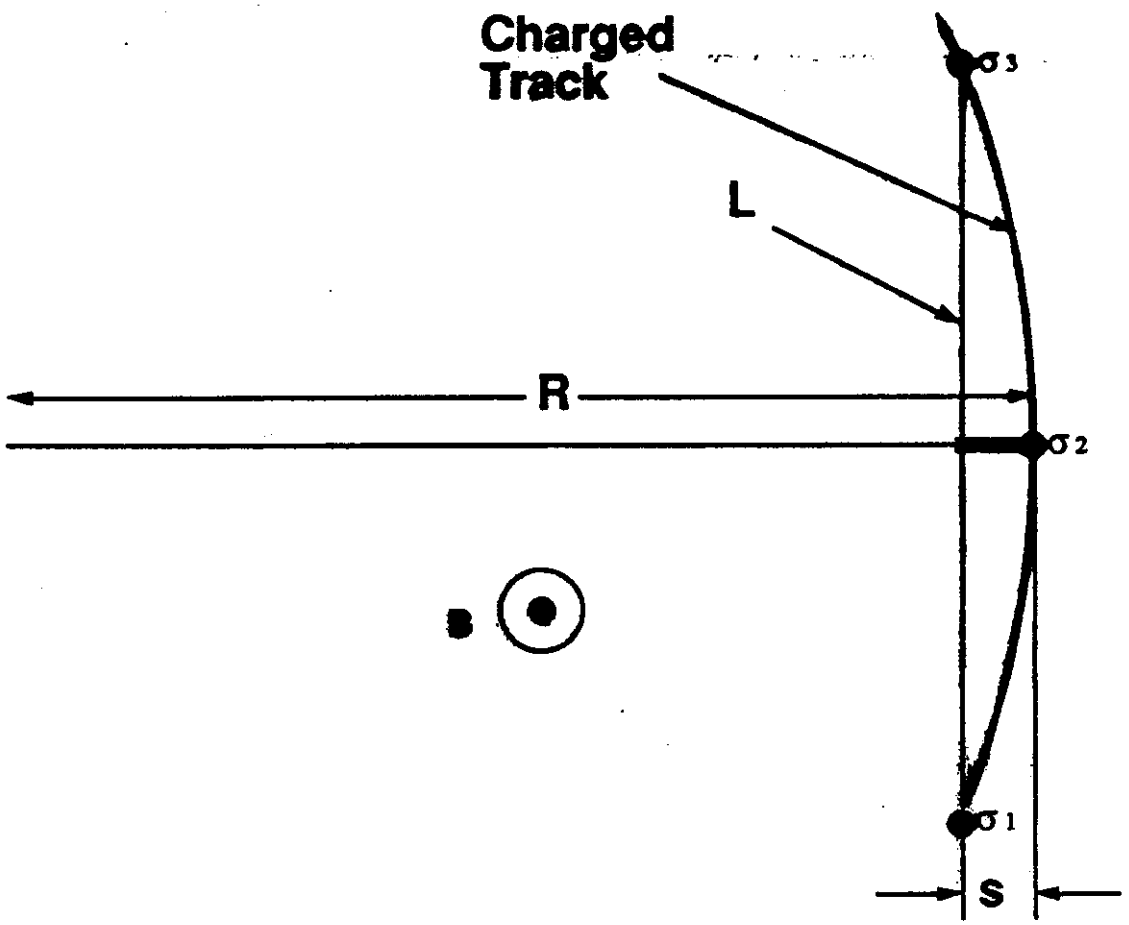
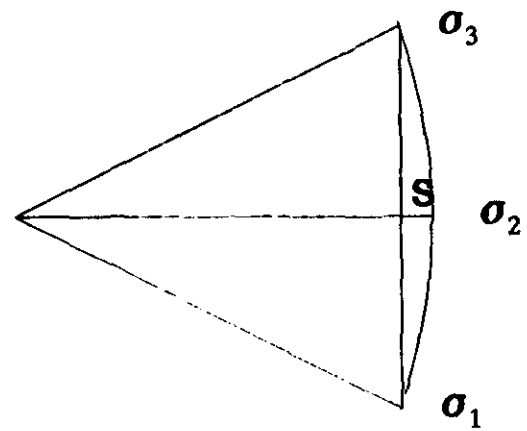


Figure 10. The sagitta, s, of a track segment can be related to the track length, L, and to the radius of curavature, R. R is in turn determined by the magnetic field strength and by the transverse momentum of the particle.

Sagitta Measurement

$$s = .0375\frac{BL^2}{P_t(\mathrm{TeV})} = \begin{cases} \dfrac{12.5\mathrm{um}}{P_t} & \text{with vertex (L=0.65m)} \\ \dfrac{9.0\mathrm{um}}{P_t} & \text{without vertex (L=0.55m)} \end{cases}$$



$$\delta s = \sqrt{\sigma_2^2 + \frac{(\sigma_1^2 + \sigma_3^2)}{4}}$$

$$\frac{dP_t}{P_t^2} = \frac{1}{.0375\ BL^2}\frac{\delta s}{s} = \frac{\sqrt{\sigma_2^2 + \frac{(\sigma_1^2 + \sigma_3^2)}{4}}}{12.5(9)\mu m}$$

$$\frac{dP_t}{P_t^2} = \frac{1}{.0375\ BL^2}\frac{\delta s}{s} = \frac{\sqrt{\sigma_2^2 + \frac{(\sigma_1^2 + \sigma_3^2)}{4}}}{12.5(9)\mu m} = \begin{cases} 1.5\ (\mathrm{TeV})^{-1} & \text{with vertex} \\ 2.1\ (\mathrm{TeV})^{-1} & \text{without vertex} \end{cases},$$

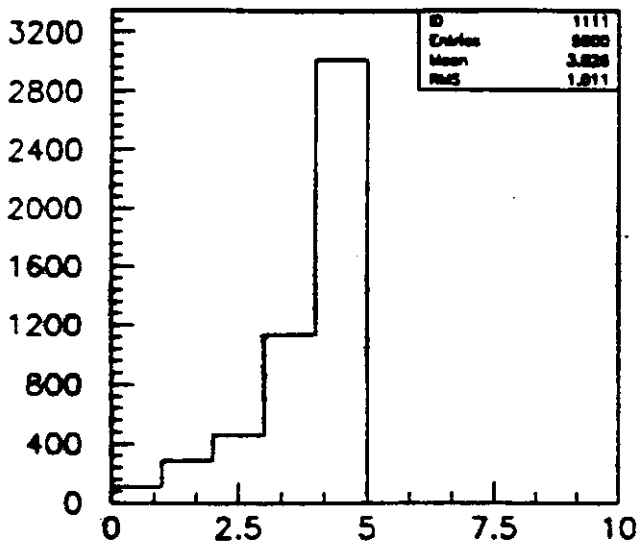
with $\sigma_1 = 10\mu m$, $\sigma_2 = 11\mu m$, $\sigma_3 = 30\mu m$

Table 3. Tracker resolutions

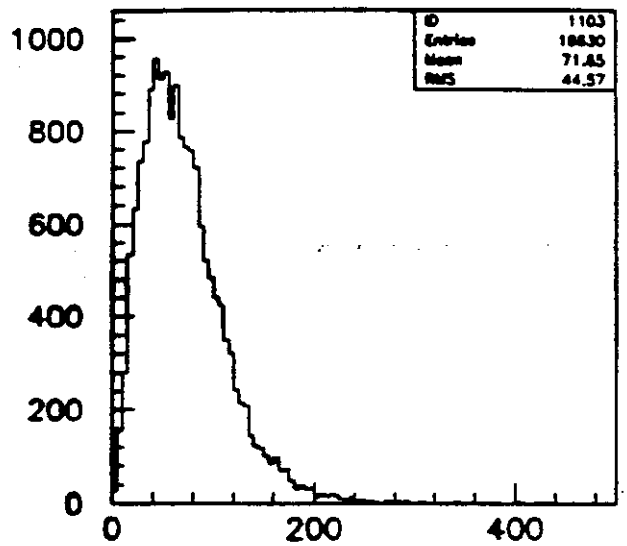
Fit type	$\sigma_1(\mu m)$	$\sigma_2(\mu m)$	$\sigma_3(\mu m)$	$\delta s(\mu m)$	$\sigma_p(GeV^{-1})$
without vertex (L=.55m)	10	11	30	19	2.1×10^{-3}
with vertex (L=.65m)	11	8	30	18	1.5×10^{-3}

Table 4. IPC Performance Paramters when used without the silicon.

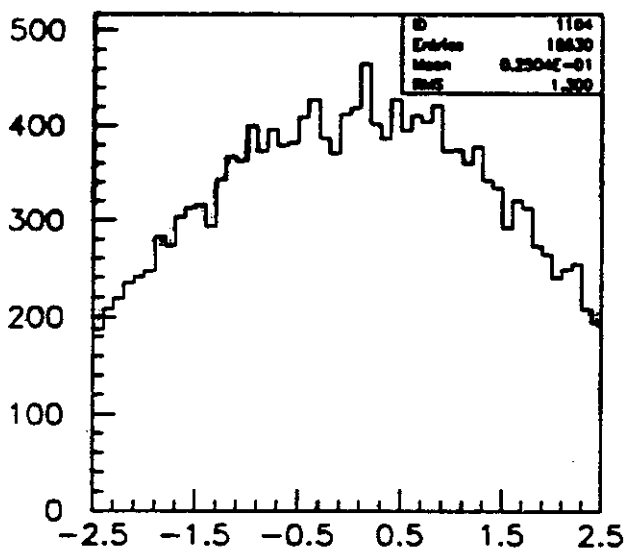
Superlayer point resolution	30μm
Sagitta Error	37μm
Sagitta at 1TeV	3μm
$\sigma_p \left(\frac{dP_t}{P_t} = \sigma_p P_t\right)$	14.0×10^{-3} GeV^{-1}
$\sigma_p \left(\frac{dP_t}{P_t} = \sigma_p P_t\right)$ with beam spot (150μm)	6.5×10^{-3} GeV^{-1}
Impact paramter resolution	$\sqrt{(380\mu m)^2 + \left(\frac{600\mu m}{P_t}\right)^2}$



Higgs Daughter Multiplicity



Higgs Daughter Transverse Momentum



Higgs Daughter Pseudorapidity

Figure 3. Higgs decay product properties from PYTHIA (5000 beam crossings) with M_H = 300GeV, $H_0 \rightarrow Z_0Z_0 \rightarrow$ 4 leptons. The number, the transverse momentum, and the η of the charged leptons found in the interval $-2.5<\eta<2.5$. are plotted above.

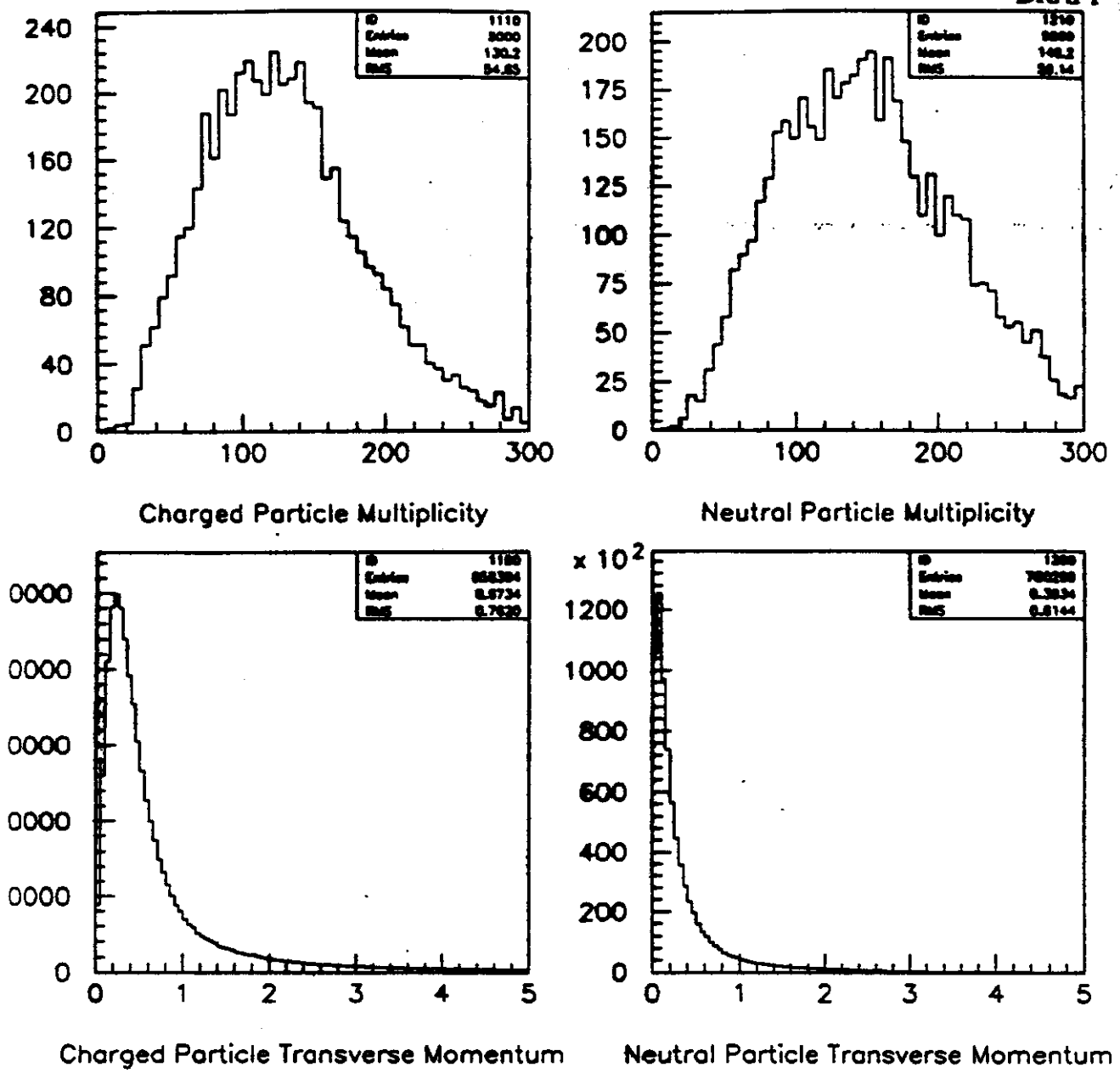
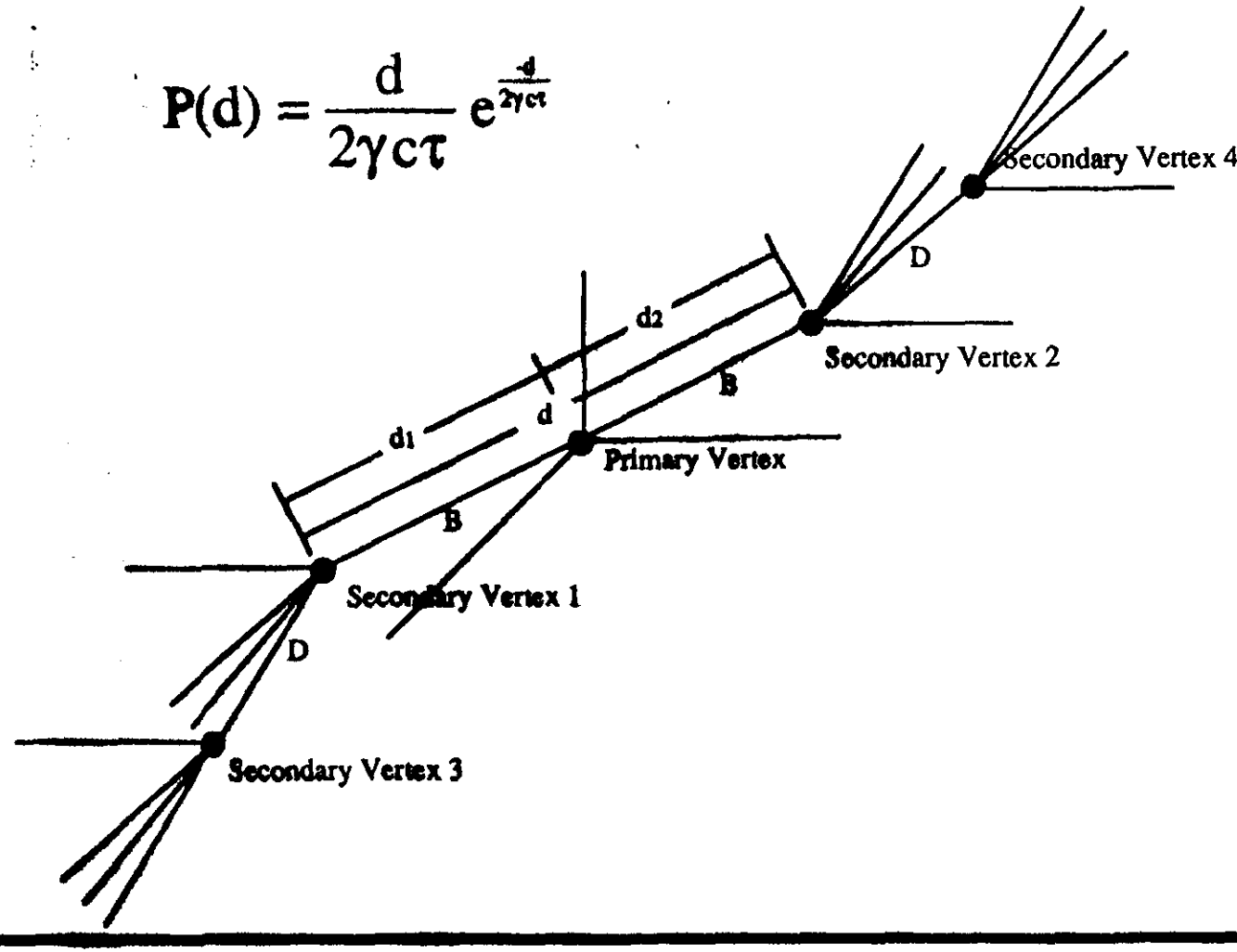


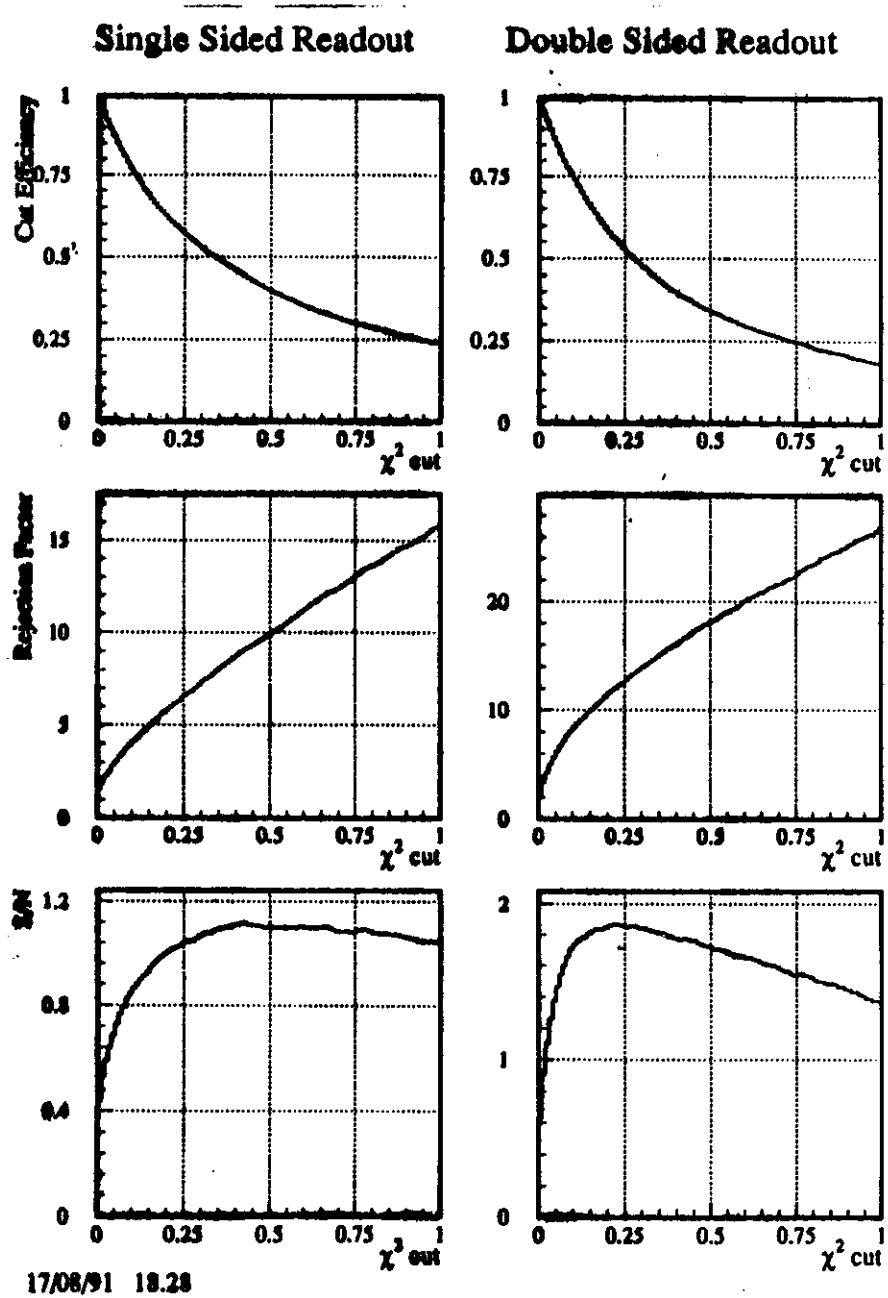
Figure 2. Higgs event properties from PYTHIA (5000 beam crossings). Elastic, diffractive, and low P_t have bean included in addition to the Higgs production with M_H = 300GeV. Charged and neutral particle multiplicities and transverse momentum distributions (neutrinos not included).

b-jet Vertex Tagging

- In general there are 5 vertices:

$$P(d) = \frac{d}{2\gamma c\tau} e^{\frac{-d}{2\gamma c\tau}}$$





b-jet Tagging Study

$$\chi^2 = \sum_{\substack{\text{all tracks} \\ P>2.5\text{GeV}}} \left\{ \frac{d_t^2}{\sigma_t^2} + \frac{d_z^2}{\sigma_z^2} \right\}$$

Backgound: $u\bar{u}$, $d\bar{d}$, $s\bar{s}$, $c\bar{c}$

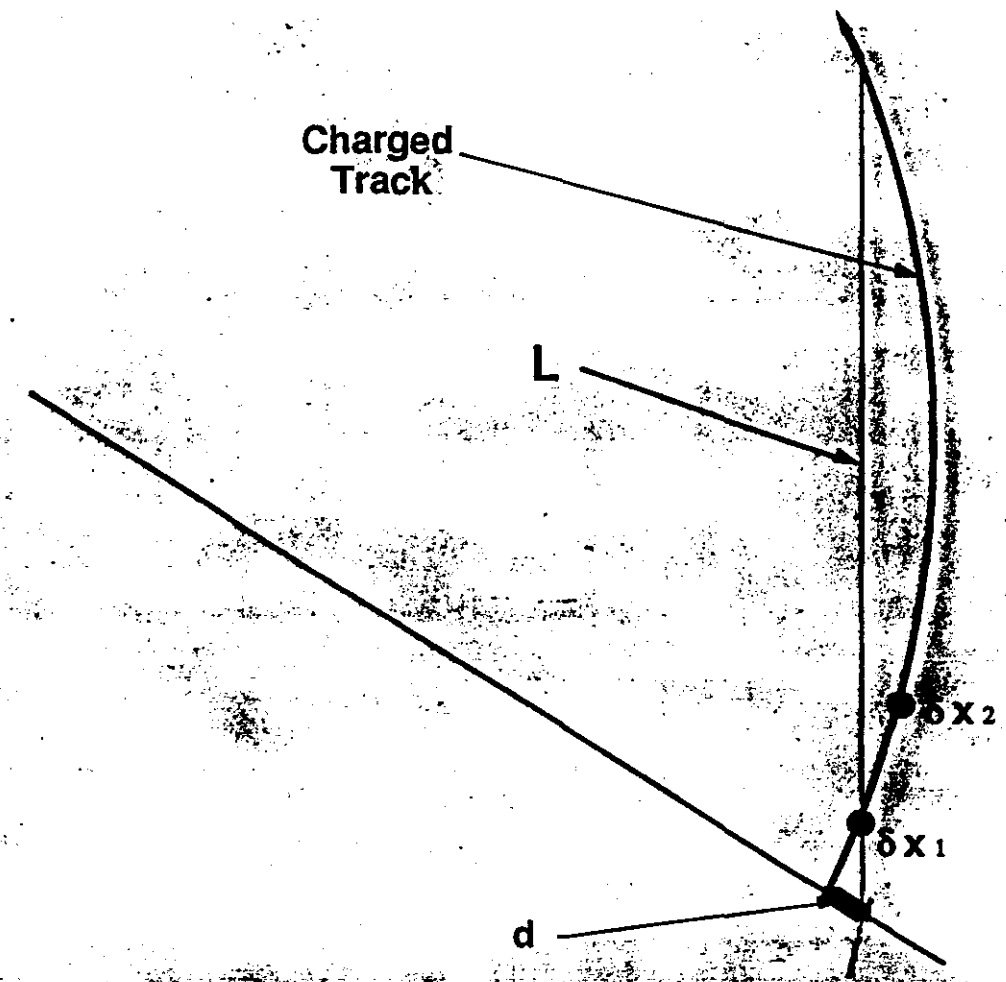
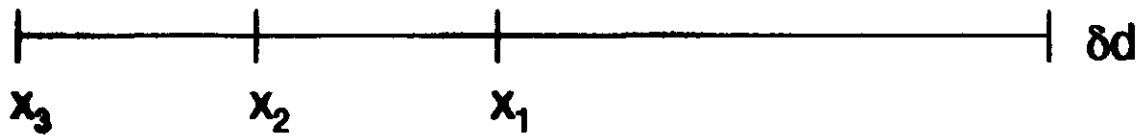


Figure 12. The impact parameter, d, of a track to a projected vertex point. The impact parameter is determined by extrapolating into the vertex region with the inner (x_1) and outer (x_2) points in the silicon tracker. The error in the curvature must also be included in the total impact parameter error.

Impact Parameter Error



- use x_3, x_1 for impact parameter (inner and outer silicon layers)

$$\delta d^2 = (r+1)^2 \delta x_1^2 + r^2 \delta x_3^2 + \left[\frac{4x_1}{L}\left(1+\frac{x_1}{L}\right)\right]^2 \delta s^2$$

where

$$\delta s = 19\mu m, \quad r = \frac{x_1}{x_3 - x_1}, \quad \delta x_3^2 = \left(\delta x_3^{\text{measurement}}\right)^2 + \left(\delta x_3^{\text{multiple scattering}}\right)^2, \text{ and}$$

$$x_3^{\text{multiple scattering}} = \frac{110\mu m}{P_t} \quad (1\%\ X_0 \text{ per layer})$$

- Impact Parameter Error

use $\delta x_{1,3}^{\text{measurement}} = 10\mu m$

$$\sigma_{ip} = \sqrt{(20\mu m)^2 + (17\mu m)^2 + \left(\frac{110\mu m}{P_t}\right)^2}$$

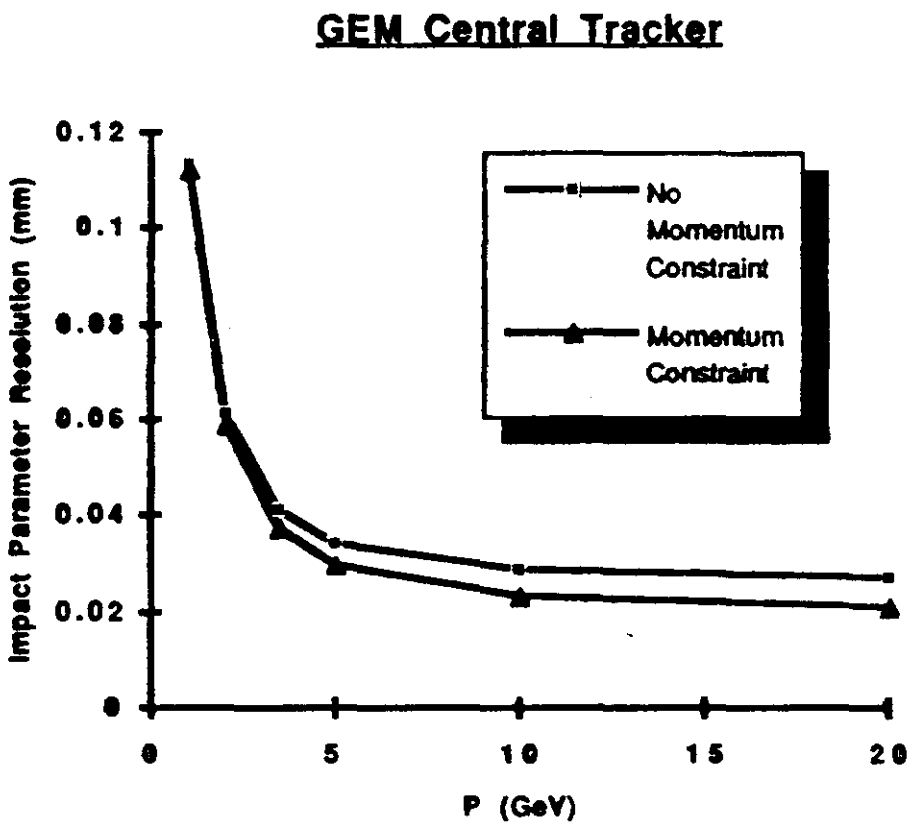


Figure 13. The impact parameter resolution as a function of momentum for a momentum constrained calculation and a momentum unconstrained calculation. The momentum constrained calculation would apply to leptons only where the momentum would be measured i n the calorimeter or muon system.

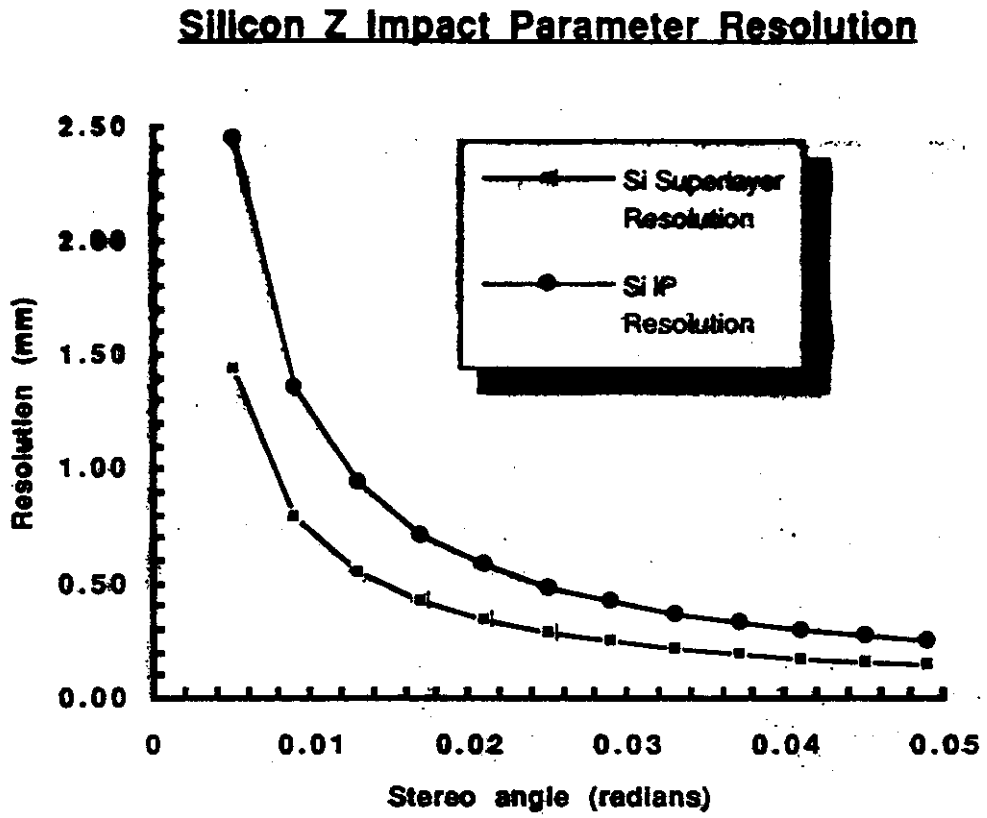


Figure 14. The Z resolution of the silicon as a function of strip stereo angle stereo angle. For an impact parameter resolution better that 1mm one would need a stereo angle of roughly 12 mrad.

---

[1] D Groom et al, 'Radiation in the SSC Interaction Regions', SSC-SR-1033, 18 Feb., 1988

[2] D. Lee, LANL MP-4 , Private Communication

[3] D. Pitzl et al, H. Ziock et al, ...

[4] Kadyk et al, LBL or IEEE I believe...

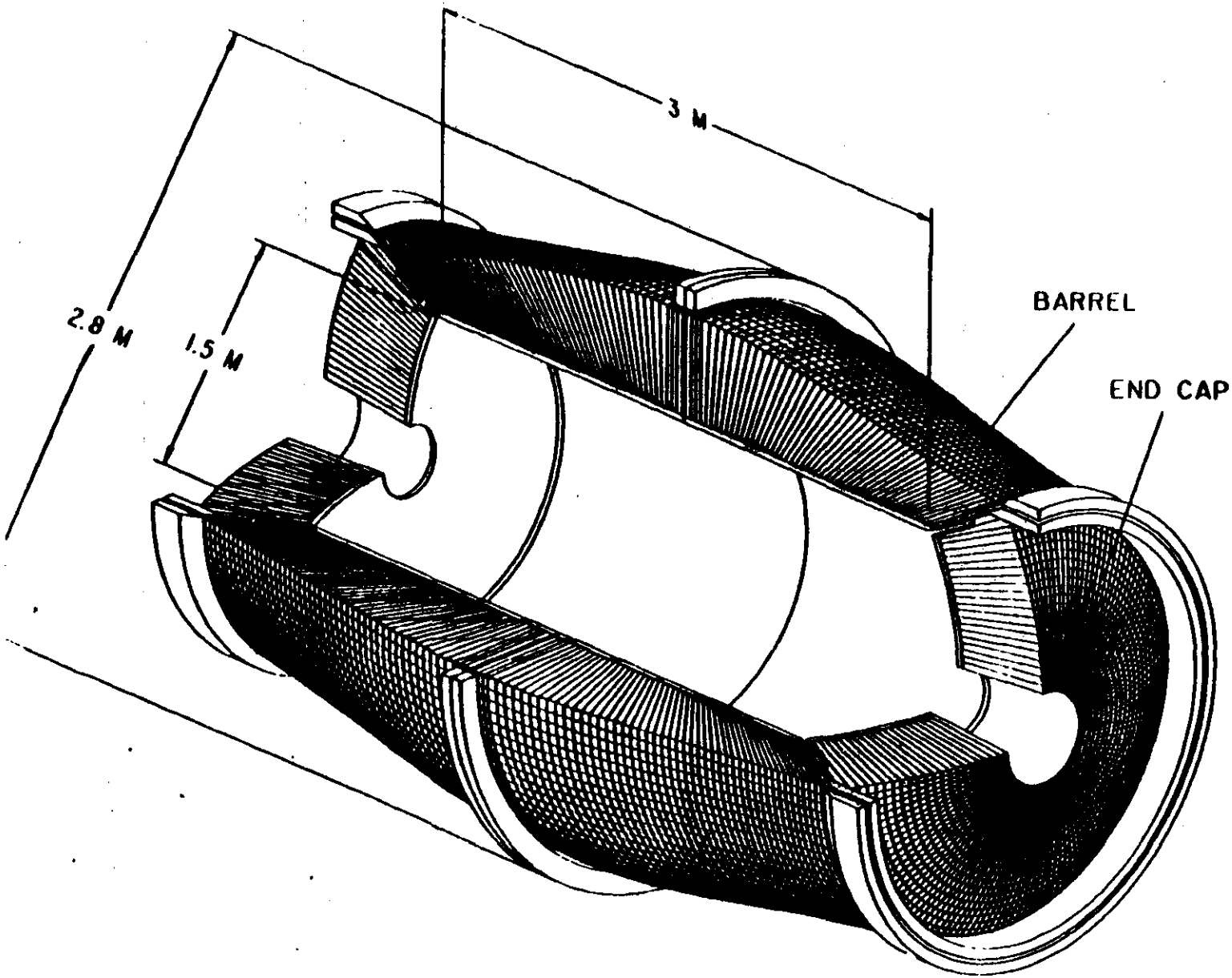
Status of BaF_2 Simulation

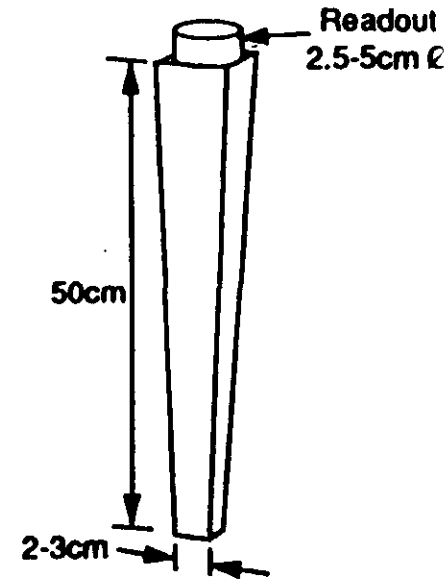
Ren-yuan Zhu
CALTECH

Jan 20, 1992

- Detailed GEANT Simulation Package on PDSF: BaF_2 Matrix (11×11 ....)
  - Predict Energy Resolution;
  - Light Uniformity Effect;
  - Carbon Wall Effect;
  - Preradiator in middle of BaF_2
- Full GEANT Geometry of BaF_2 Calorimeter exists, and used in Trigger Simulation. But, no detailed structure yet...
- Work to be done:
  - Detailed structure of BaF_2 detector;
  - Estimation of material at front of BaF_2;

GEM BaF_2 Calorimeter





Ba F2 EM CALORIMETER

Features of the BaF_2 Calorimeter

Detector	Barrel	Two Endcaps
Rapidity Coverage	$\lvert\eta\rvert \leq 1.32$	$1.32 \leq \lvert\eta\rvert \leq 2.5$
Crystal Front Face (cm^2)	3.1 x 3.1	2.3 x 2.3
Crystal Rear Face (cm^2)	5.1 x 5.1	3.1 x 3.1
Crystal Length (cm)	50	50
Crystal Number	10,880	4,144
Total Crystal Volume (m^3)	8.4	2.2
Total Crystal Weight (t)	41.1	10.7

Total: 15 K Crystals
10.6 m^3 & 52 Tons

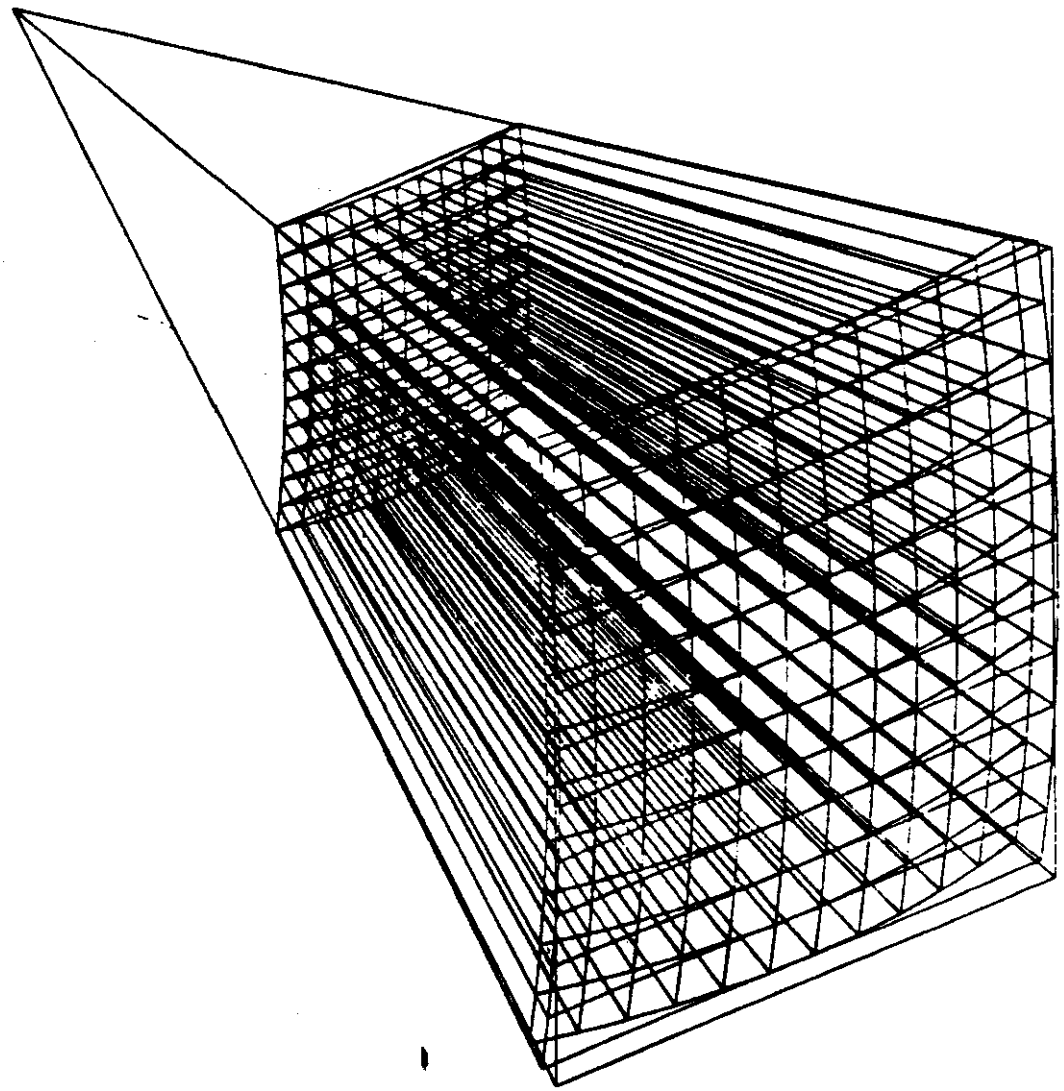
Cost: $80 M

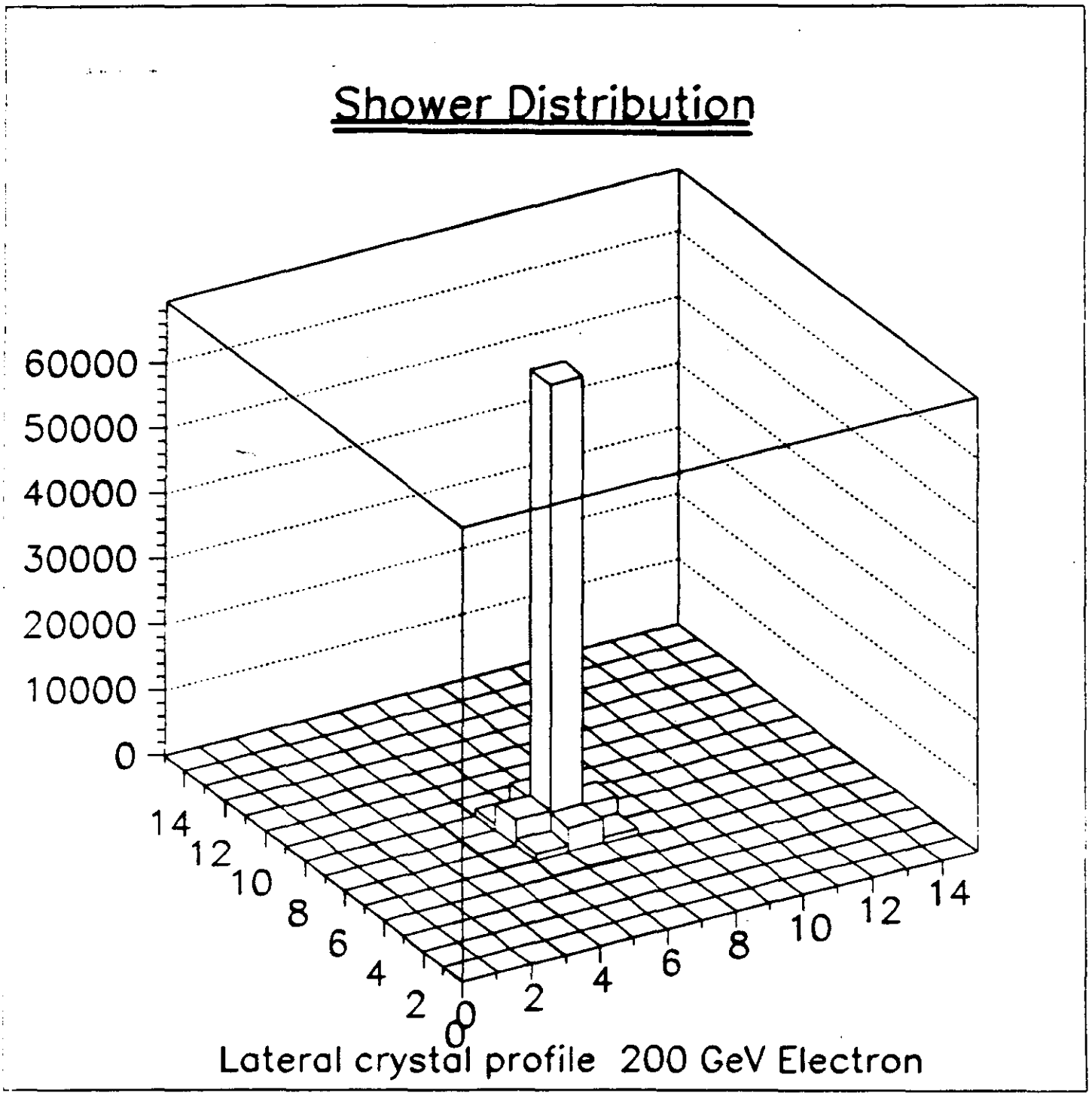
GEANT SIMULATION
Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

- Number of BaF_2 crystals: 11 x 11
- BaF_2 Crystal length: 50 cm
- Front (rear) face of BaF_2 :
  3 cm x 3 cm (5 cm x 5 cm)
- Carbon fiber wall thickness between any two crystal faces: 0.025 cm
- Particle is hitting over the front face of central BaF_2 crystal.
- One centimeter Aluminium placed just before the crystals and two 0.5 cm Aluminium placed between track origin and midway point to crystals (i.e., total 2 cm Al, whose $X_0 = 9$ cm)
- No magnetic field.
- Light yield response (Y) is parametrized with deviation (δ):

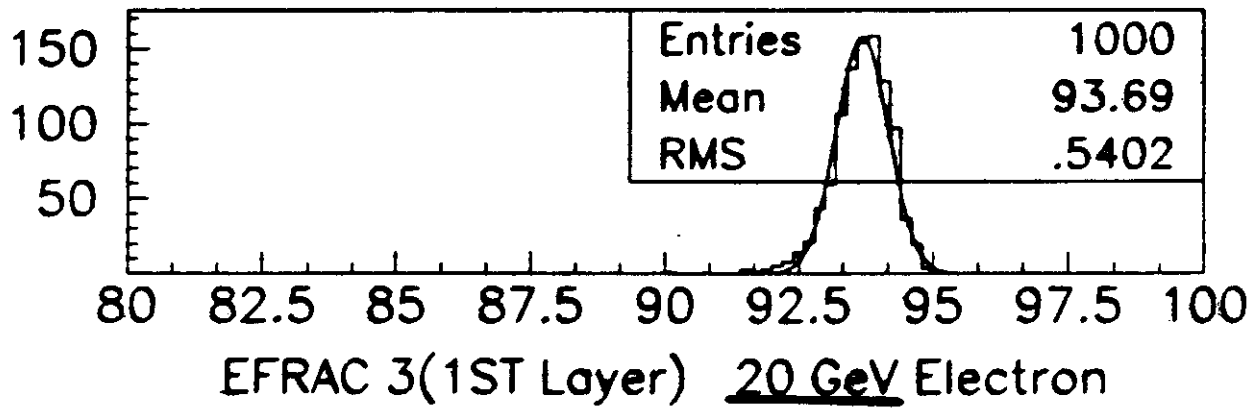
$$Y = Y_{25}[1 + \delta(Z/25 - 1)]$$

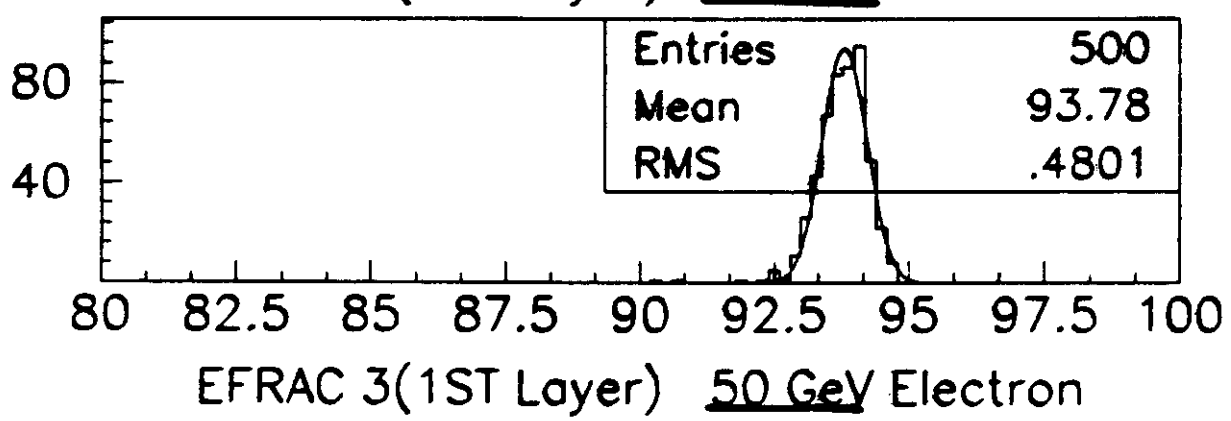
11 × 11 BaF_2 Matrix

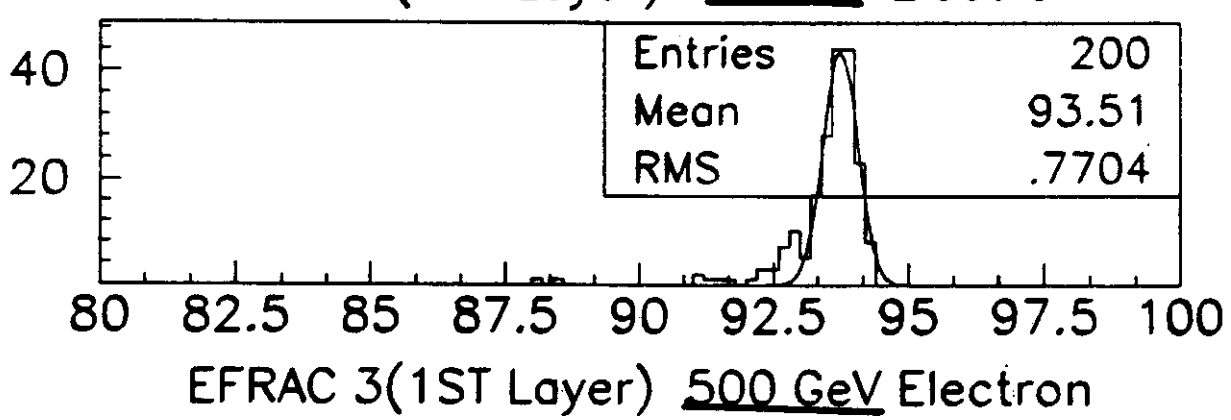



Shower Distribution
60000
50000
40000
30000
20000
10000
0
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Lateral crystal profile 200 GeV Electron

Energy Fraction in 3x3 Crystals







Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

$\delta = 0\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	71.0	72.5	73.5	74.0	74.4	74.9
(σ)	(4.2)	(4.2)	(5.5)	(4.4)	(3.8)	(3.4)
3 x 3	93.5	93.7	93.8	93.7	93.8	93.5
(σ)	(.63)	(.49)	(.41)	(.36)	(.34)	(.32)
5 x 5	97.2	97.3	97.3	97.1	97.0	96.7
(σ)	(.43)	(.32)	(.30)	(.31)	(.30)	(.29)
7 x 7	98.4	98.4	98.3	98.2	98.0	97.6
(σ)	(.35)	(.29)	(.26)	(.47)	(.33)	(.39)

Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

$\delta = 5\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	69.6	71.2	72.5	73.2	73.8	74.5
(σ)	(4.0)	(4.2)	(3.9)	(4.3)	(3.9)	(3.6)
3 x 3	92.0	92.3	92.7	92.9	93.2	93.2
(σ)	(.76)	(.62)	(.53)	(.47)	(.38)	(.31)
5 x 5	95.6	95.9	96.2	96.3	96.5	96.4
(σ)	(.51)	(.43)	(.36)	(.29)	(.27)	(.25)
7 x 7	96.8	97.1	97.3	97.4	97.5	97.4
(σ)	(.41)	(.37)	(.30)	(.20)	(.26)	(.35)

Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

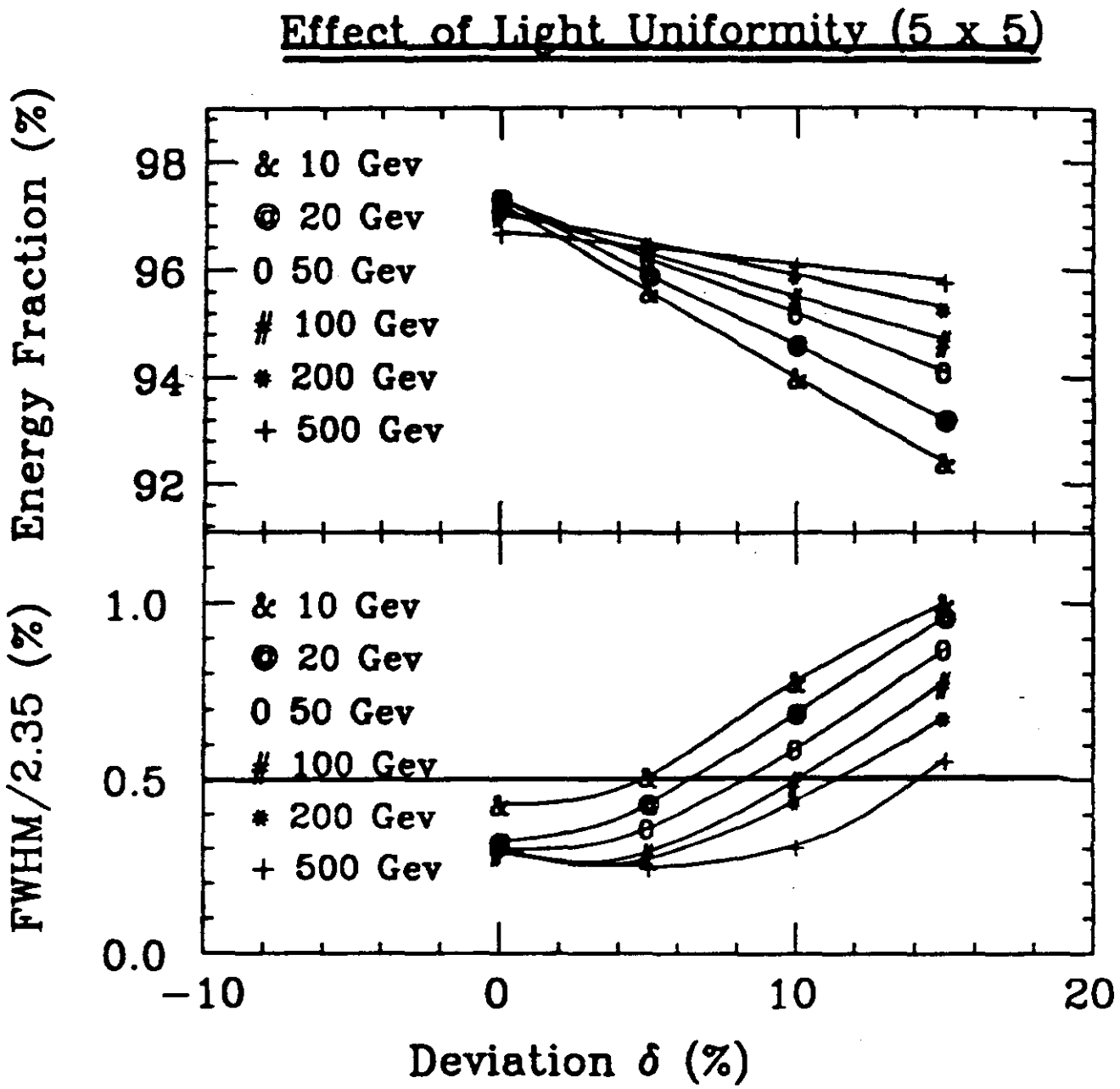
$\delta = 10\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	68.2	70.0	71.6	72.4	73.2	74.1
(σ)	(4.2)	(4.6)	(4.3)	(4.2)	(3.9)	(3.6)
3 x 3	90.4	91.0	91.7	92.1	92.6	92.9
(σ)	(1.0)	(.86)	(.76)	(.66)	(.56)	(.45)
5 x 5	94.0	94.6	95.2	95.5	95.9	96.1
(σ)	(.78)	(.69)	(.59)	(.50)	(.44)	(.31)
7 x 7	95.2	95.7	96.2	96.6	96.9	97.1
(σ)	(.69)	(.62)	(.55)	(.45)	(.39)	(.30)

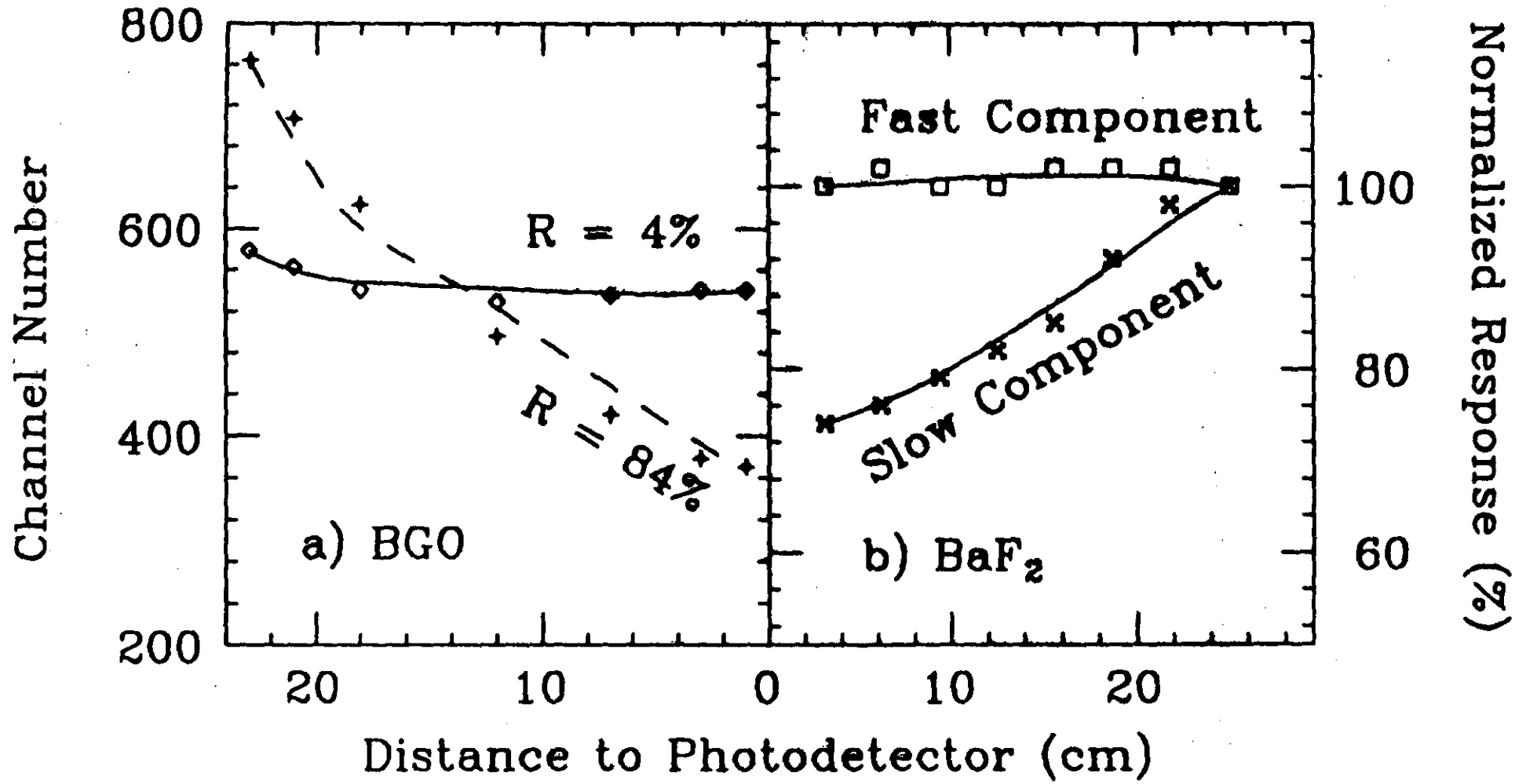
Fraction Energy Deposited in BaF_2 with Deviated Light Uniformity

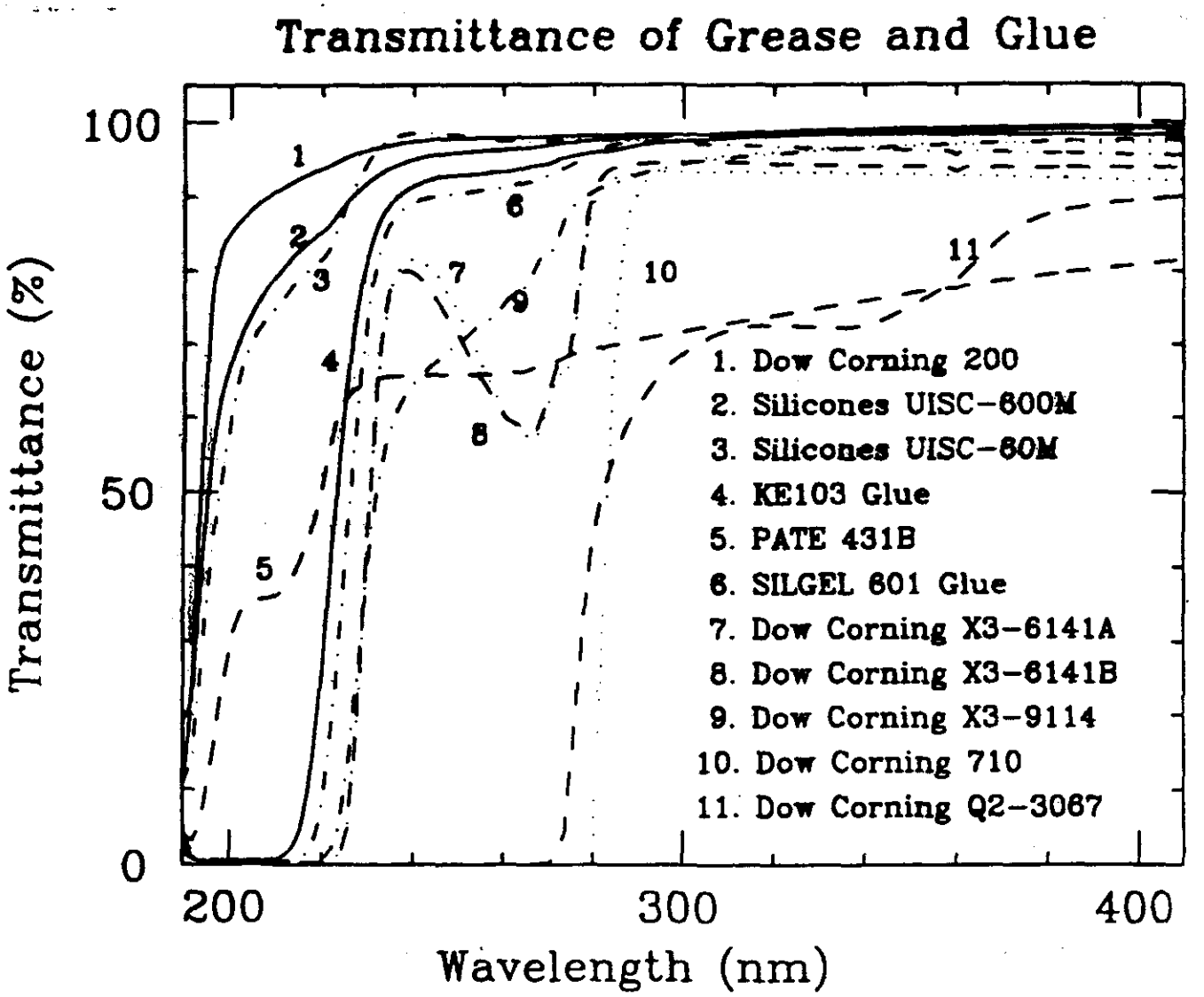
$\delta = 15\%$

E(GeV)	10	20	50	100	200	500
NEVT	1000	1000	500	500	500	200
1 x 1	66.8	68.8	70.6	71.6	72.6	73.7
(σ)	(4.1)	(4.3)	(4.5)	(4.0)	(3.7)	(3.5)
3 x 3	88.8	89.6	90.6	91.3	92.0	92.6
(σ)	(1.2)	(1.1)	(.97)	(.90)	(.81)	(.72)
5 x 5	92.4	93.2	94.1	94.7	95.3	95.8
(σ)	(1.0)	(.96)	(.87)	(.78)	(.68)	(.56)
7 x 7	93.6	94.3	95.2	95.8	96.3	96.8
(σ)	(.96)	(.90)	(.82)	(.73)	(.63)	(.48)


Effect of Light Uniformity (5 x 5)
Energy Fraction (%)
98
96
94
92
& 10 Gev
@ 20 Gev
0 50 Gev
100 Gev
* 200 Gev
+ 500 Gev
FWHM/2.35 (%)
1.0
0.5
0.0
& 10 Gev
@ 20 Gev
0 50 Gev
100 Gev
* 200 Gev
+ 500 Gev
−10
0
10
20
Deviation δ (%)

Light Response Uniformity



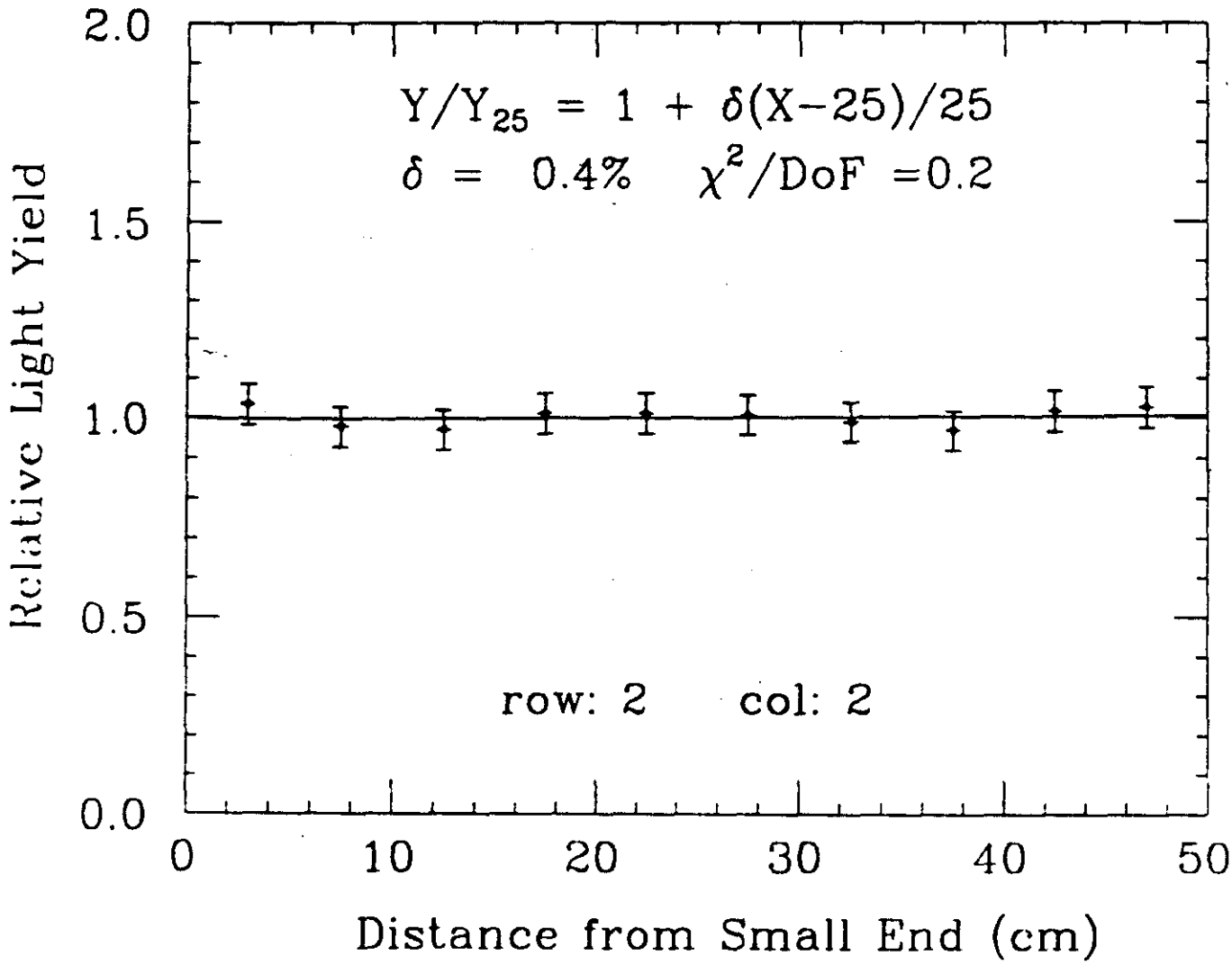


Tickness : 500μ

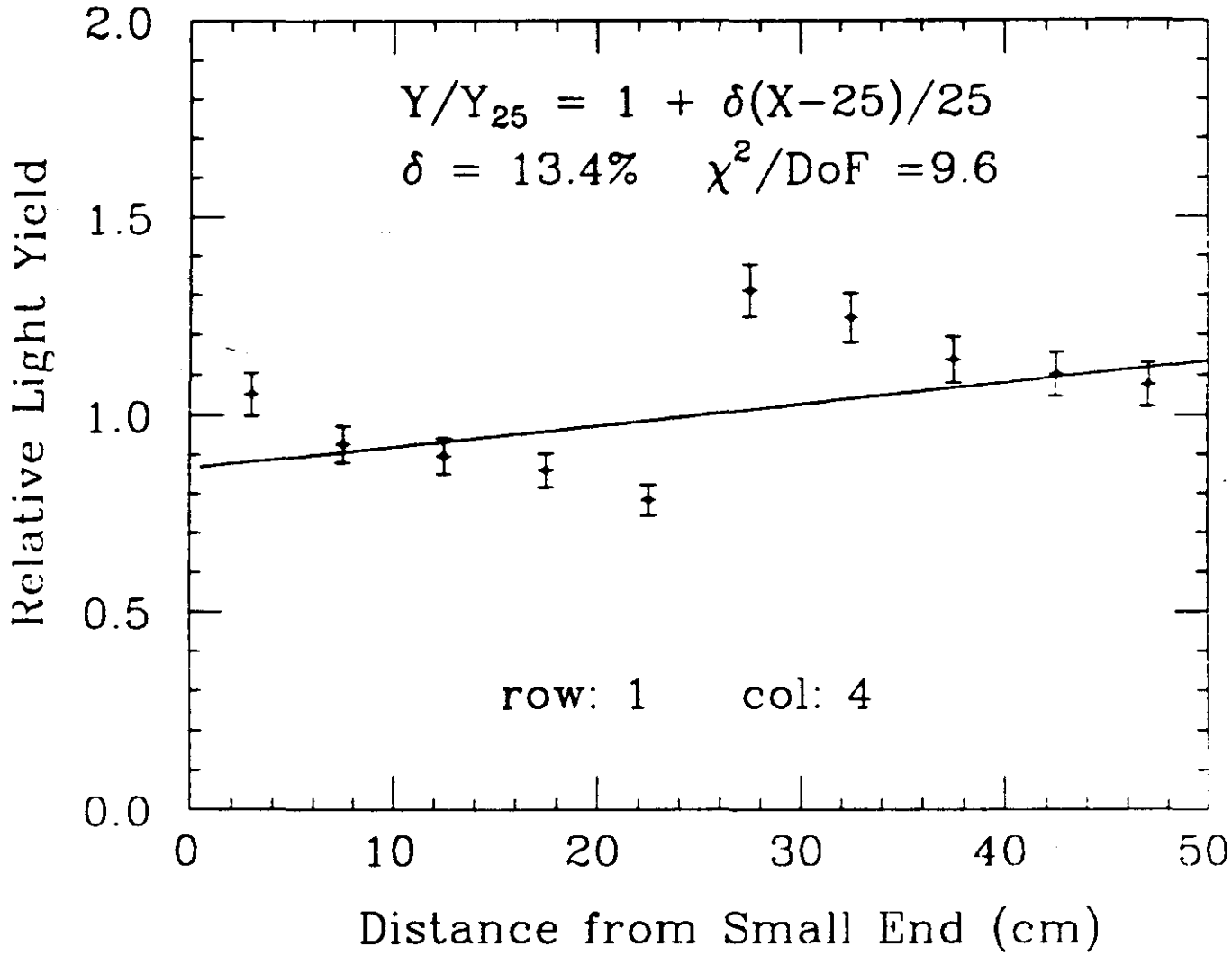
KE103 Glue is very good if few tens μ tick.

BaF_2 Test Matrix Data

from Fermi Lab Test Beam



A broken BaF_2 Glue Joint
Fermi Test Beam Data



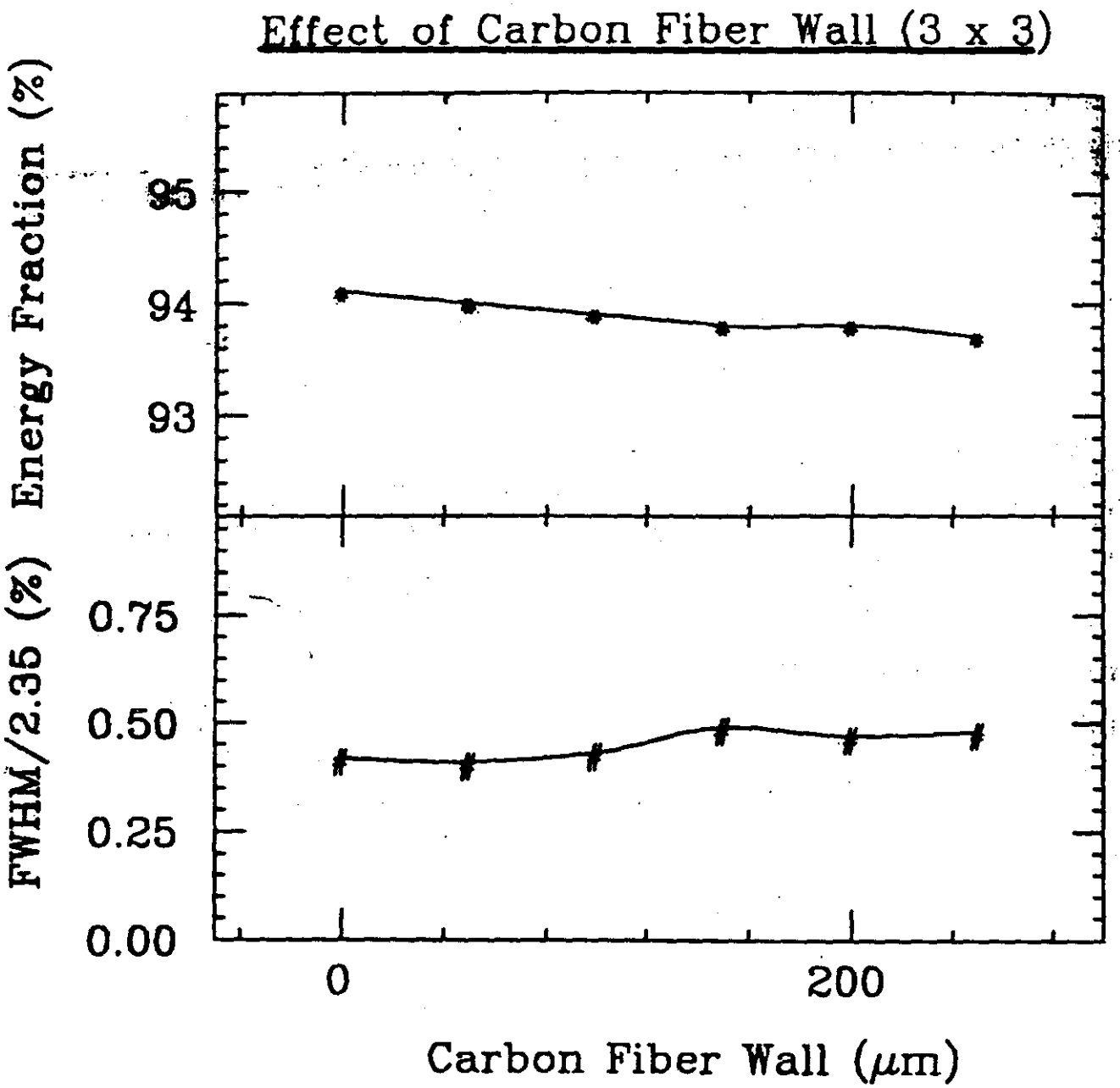
GEANT SIMULATION

Fraction Energy Deposited in BaF_2 as Function of Carbon Fiber Wall

- Charge Particle : 20 GeV Electron
- Carbon fiber wall thickness between any two crystal faces: from 0 to 250μm
- Number of BaF_2 crystals: 11 x 11
- BaF_2 Crystal length: 50 cm
- Front (rear) face of BaF_2 :
  3 cm x 3 cm (5 cm x 5 cm)
- Particle is hitting over the front face of central BaF_2 crystal.
- One centimeter Aluminium placed just before the crystals and two 0.5 cm Aluminium placed between track origin and midway point to crystals (i.e., total 2 cm Al, whose $X_0 = 9$ cm)
- No magnetic field.

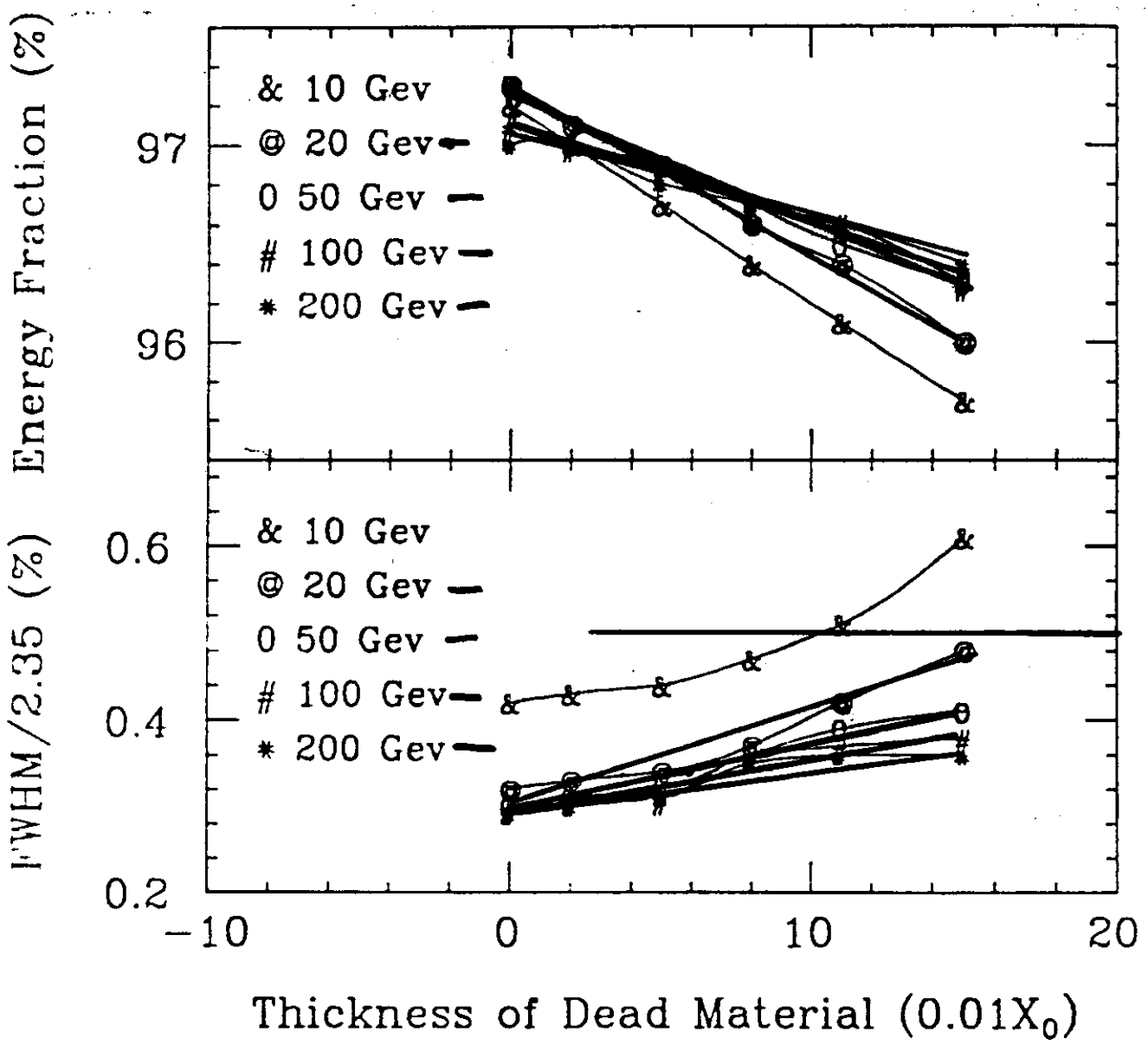
Fraction Energy Deposited in BaF_2 as Function of Carbon Fiber Wall

Carbon(μ)	0	50	100	150	200	250
1 x 1	73.0	73.0	72.8	72.7	72.7	72.9
(σ)	(5.4)	(5.8)	(7.0)	(4.8)	(4.1)	(4.7)
3 x 3	94.1	94.0	93.9	93.8	93.8	93.7
(σ)	(.42)	(.41)	(.43)	(.49)	(.47)	(.48)
5 x 5	97.7	97.6	97.5	97.4	97.4	97.3
(σ)	(.23)	(.28)	(.30)	(.35)	(.30)	(.31)
7 x 7	98.8	98.7	98.7	98.6	98.5	98.4
(σ)	(.20)	(.22)	(.20)	(.28)	(.25)	(.26)
9 x 9	99.2	99.1	99.1	99.0	98.9	98.8
(σ)	(.15)	(.15)	(.18)	(.27)	(.27)	(.24)


Effect of Carbon Fiber Wall (3 x 3)
Energy Fraction (%)
95
94
93
FWHM/2.35 (%)
0.75
0.50
0.25
0.00
0
200
Carbon Fiber Wall (μm)

preradiator

Effect of Dead Material at $5X_0$ (5 x 5)



Energy Resolution (%)

of BaF_2 Calorimeter

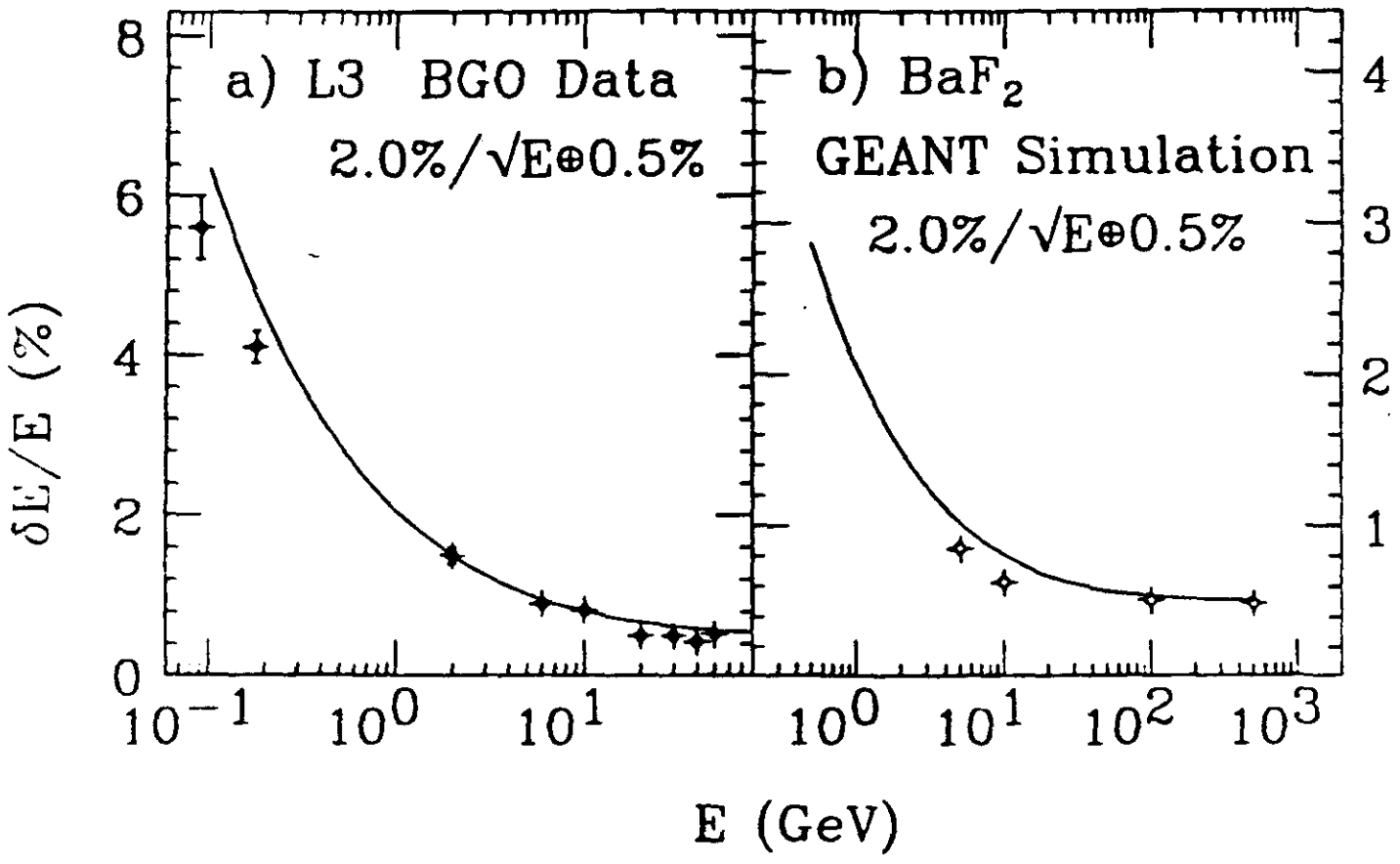
GEANT Simulation

E (GeV)	5	10	100	500
Electrical Noise	0.4	0.20	0.02	0.004
Photoelectrons	0.2	0.1	0.04	0.02
GEANT	0.60	0.43	0.31	0.29
Calibration	0.40	0.40	0.40	0.40
Total	0.85	0.63	0.51	0.49

Energy Resolution (%)

of BaF_2 Calorimeter

GEANT Simulation



π/e Rejection of BaF_2 Calorimeter

- Lateral shower development:

$$\frac{\sum_{3\times3} E_{EM}^{cell}}{\sum_{5\times5} E_{EM}^{cell}} < \mathbf{S_{cut}} \Rightarrow \textbf{ Reject}$$

where S_{cut} = 0.95, 0.96, 0.96 for E_{EM} = 10, 100, and 1000 GeV, respectively;

- Matching the E_{EM} and P_{trk}:

$$|E_{EM} - P_{trk}| > 3\sigma \Rightarrow \textbf{ Reject}$$

where

$$\sigma = \sqrt{\sigma^2_{E_{EM}} + \sigma^2_{P_{trk}}},$$

$$(\sigma_E/E)_{EM} = 1.3\%/\sqrt{E_{EM}} + 0.5\%, \text{ and}$$

$\sigma_{P_{trk}}$ is a function of polar angle (θ):

$$\sigma_{P_{trk}}/P_{trk} = X\% \ sin\theta \ P_{trk} \ (in \ GeV)$$

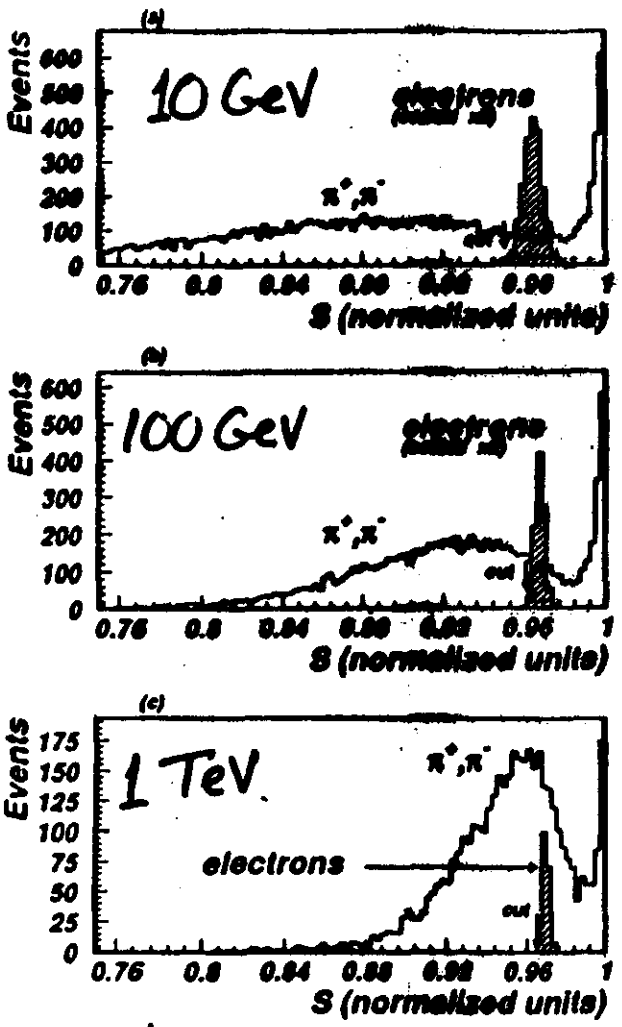
with X = 0.13, 0.22, 0.29, and 0.65 for θ in the range of (26°, 154°), (22°, 26°) or (154°, 158°), (17°, 22°) or (158°, 163°), and < 17° or > 163°, respectively.

- Hadron Calorimeter Veto:

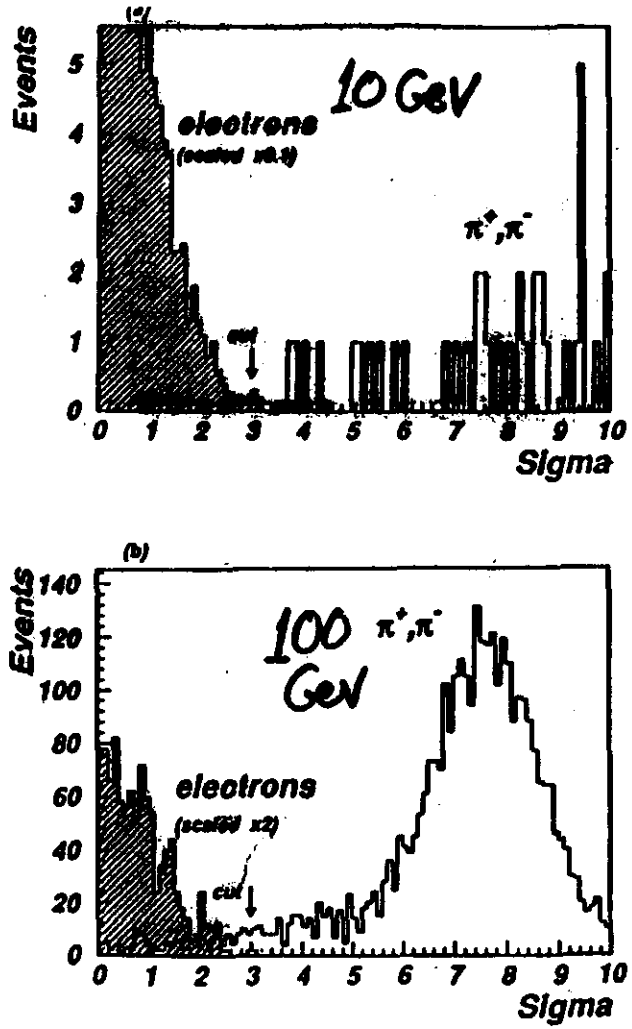
$$E_{HCAL} > E_{EM} \times \mathbf{H_{cut}} \Rightarrow \textbf{ Reject}$$

where H_{cut} = 0.025, 0.025, 0.035 for E_{EM} = 10, 100, and 1000 GeV, respectively.

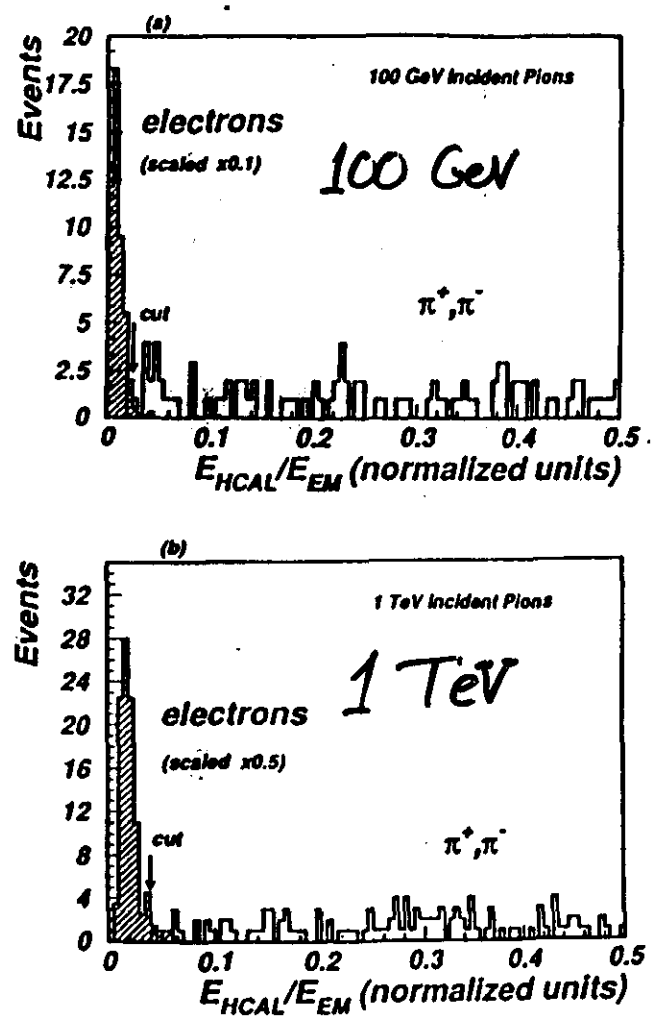
π/e rejection with BaF₂



shower shape



E − p match



HCAL Veto

π/e Rejection of BaF_2 Calorimeter (cont.)

E (GeV)	10	100	1000
After Lateral Shower Cut:			
π acceptance (10^{-2})	32.6±0.4	34.7±0.5	39.4±0.7
e acceptance (%)	99.3	99.5	99.5
After Matching E_{BaF_2} and P_{trk}:			
π acceptance (10^{-3})	<0.1	12.3±0.9	388±7
e acceptance (%)	97.3	99.2	99.5
After HCAL Veto:			
π acceptance (10^{-4})	<1	2.0±1.4	<2.2
e acceptance (%)	97.3	96.4	95.0

$\sim 10^{-4}$ rejection

Electromagnetic Trigger

- Primary Goal:
  - Reduce 60 MHz QCD Background;
  - Keep Interesting Physics: Isolated Electrons and Photons.

- Level 1 trigger rate 35 kHz, requests on 0.2 × 0.2 (5×5 BaF_2) Super Cells:
  - n electromagnetic clusters (EMC) with transverse energy larger than E_n^{Tcut} within the full calorimeter coverage $|\eta| < 3.8$, i.e.

    $$E_T^{cluster} > E_n^{Tcut}, \ and$$

    where $E^n_{T_{cut}}$ equals 50, 15 and 5 GeV for n equals 1, 2 or 3 and >4 respectively;
  - the sum of the transverse energies in the matching hadron calorimeter tower E_T^{tower} is less than 10% of the sum of the transverse energy in the electromagnetic cluster, i.e.

    $$E_T^{tower} < 10\% \ E_T^{cluster}.$$

- Level 2 Trigger rate ~ 100 Hz, selects isolated electromagnetic clusters (IEMC):

  $$E_T^{cluster} > 20 \ GeV, \ and$$

  $$\sum_{R<0.3} E_T - E_T^{cluster} < 10 GeV.$$

Electromagnetic Trigger (cont.)

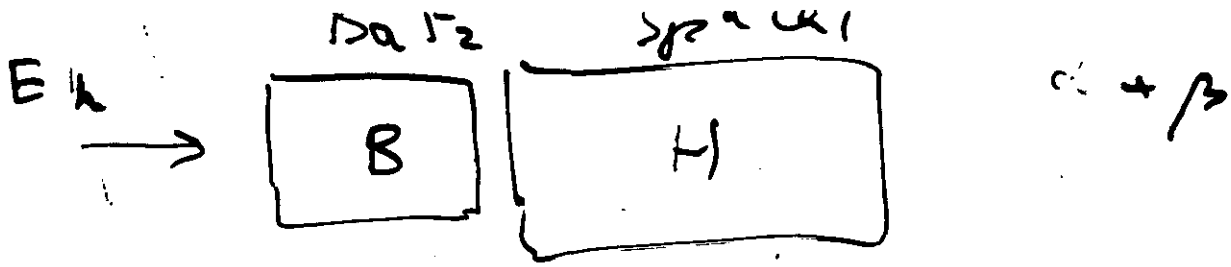
- **Trigger Rate from QCD:**

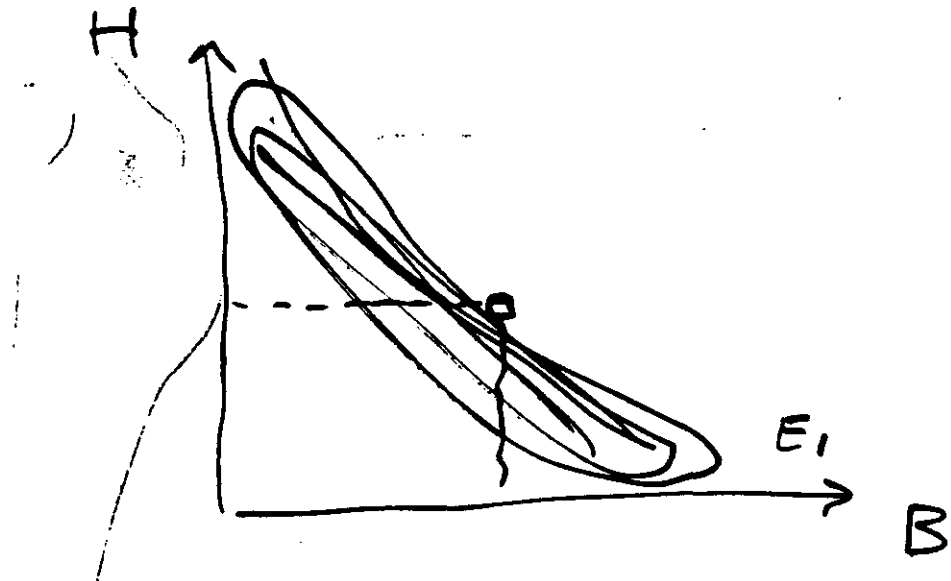
n (EMC)	1	2 or 3	> 4	Total
Level 1 (kHz)	7.1	14.3	17.6	35
Level 2 (Hz)				<135*

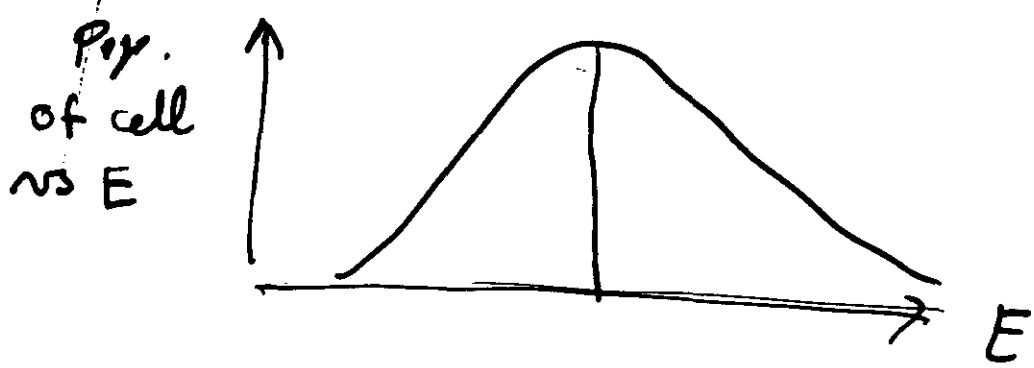
* Limited by statistics in calculation. (100K ~ 13.615 mb)
QCD with P_T > 10GeV

- Acceptance (%) of $H^0 \rightarrow \gamma\gamma$ (80 GeV) or 4 electrons (150 GeV):

N (EMC)	1	2 or 3	> 3	Level 1	Level 2
$H^0 \rightarrow \gamma\gamma$	40	77	9.7	85.0	84.5
$H^0 \rightarrow 4e$	52	49	87	98.4	97.8







Y. Kamyshkov on ideal approach to measuring E resolution in calorimeter.

Activities of Muon Trigger Simulation Group.

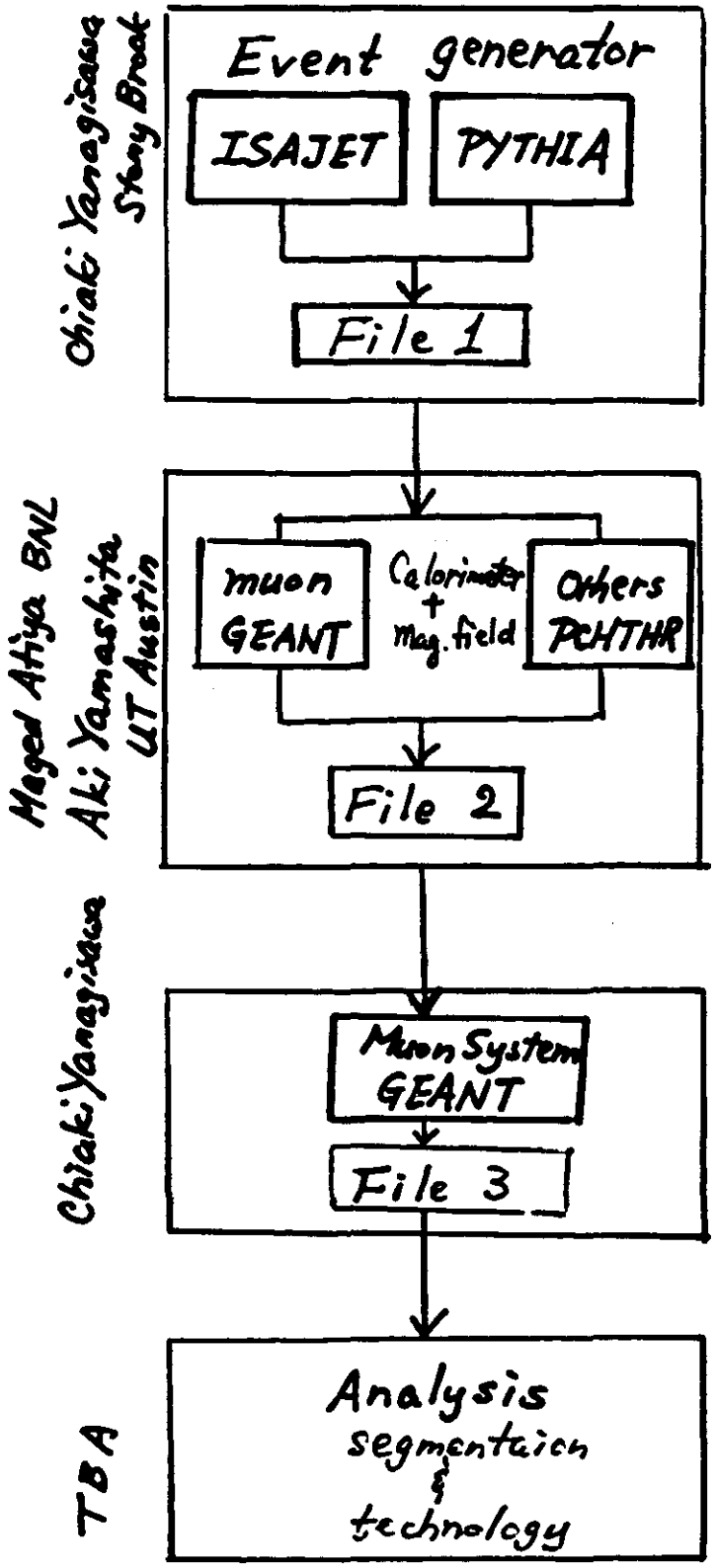
Chiaki Yanagisawa
Stony Brook

- Structure of trigger simulation
- Physics
- PCHTHR
- Standard configuration of the muon system
- Monte Carlo studies

Structure of trigger simulation

at SSCL PDSF

Maged Atiya
Aki Yamashita



◎ Physics

- File 1 format
  - Event#
  - # of particles
  - particle ID (P.D.G Standard)
  - p_x
  - p_y
  - p_z
  - E
  - mass
- Binary or ASCII file?
  - Conversion of binary file?
  - UNIX ↔ VMS ?

◎ PCHTHR (by Roger McNeil LSU

◎ Simple geometry
  No segmentation except planes.

- File 3 format
  - particle ID
  - p_x
  - p_y
  - p_z
  - # of hits
  - R
  - ϕ
  - z
  - ⋮

◎ MC studies

Physics

Signals

- $H \to ZZ^*$ ($m_H = 130, 150, 170, 190$ GeV/c^2)
- $H \to ZZ$ ($m_H = 200, 400, 800$ GeV/c^2)
- $Z' \to \mu\mu$ (4 TeV)
- Strongly interacting W, Z ($W_L^+ W_L^+$ etc.)
- $\tilde{g}\tilde{g} \to \mu^\pm\mu^\pm$
- Inclusive W/Z production including $Zq\bar{q}$
- $t\bar{t}$ ($m_t = 250$ GeV)

.... suggestions?

Backgrounds

- Prompt μ from c, b
- — " — t with $m_t = 140$ and 200 GeV
- Punch thru and decays QCD

PCHTHR (Roger McNeil)

Inputs:

- material thickness in λ
- particle ID
- p

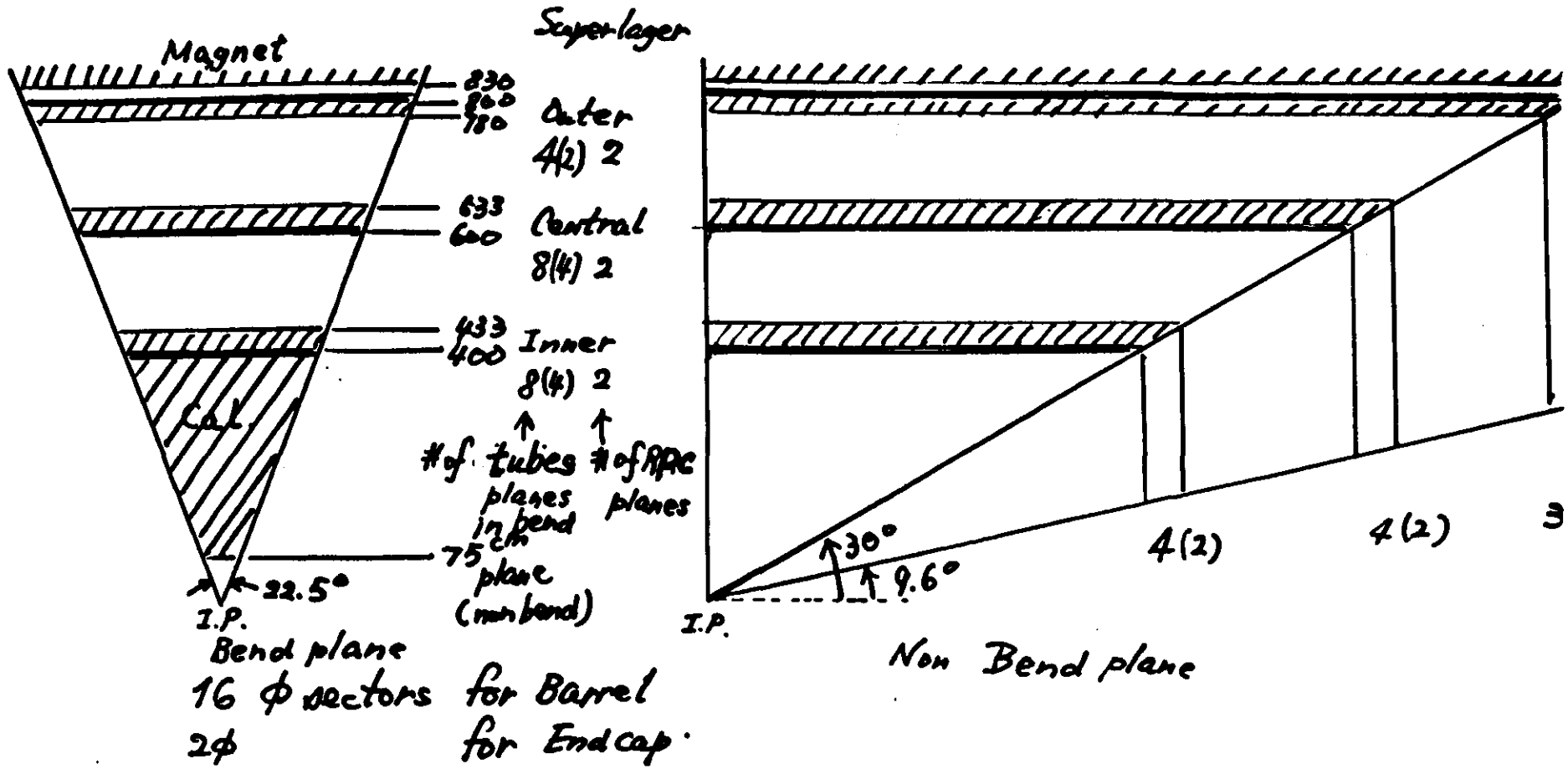
Outputs:

- # of punch thru particles
- p
- particle ID
- weight (prob. of punch thru)

! Validation of GEANT !

{ Mohammad Mohammadi
Roger McNeil

Standard configuration of the muon system



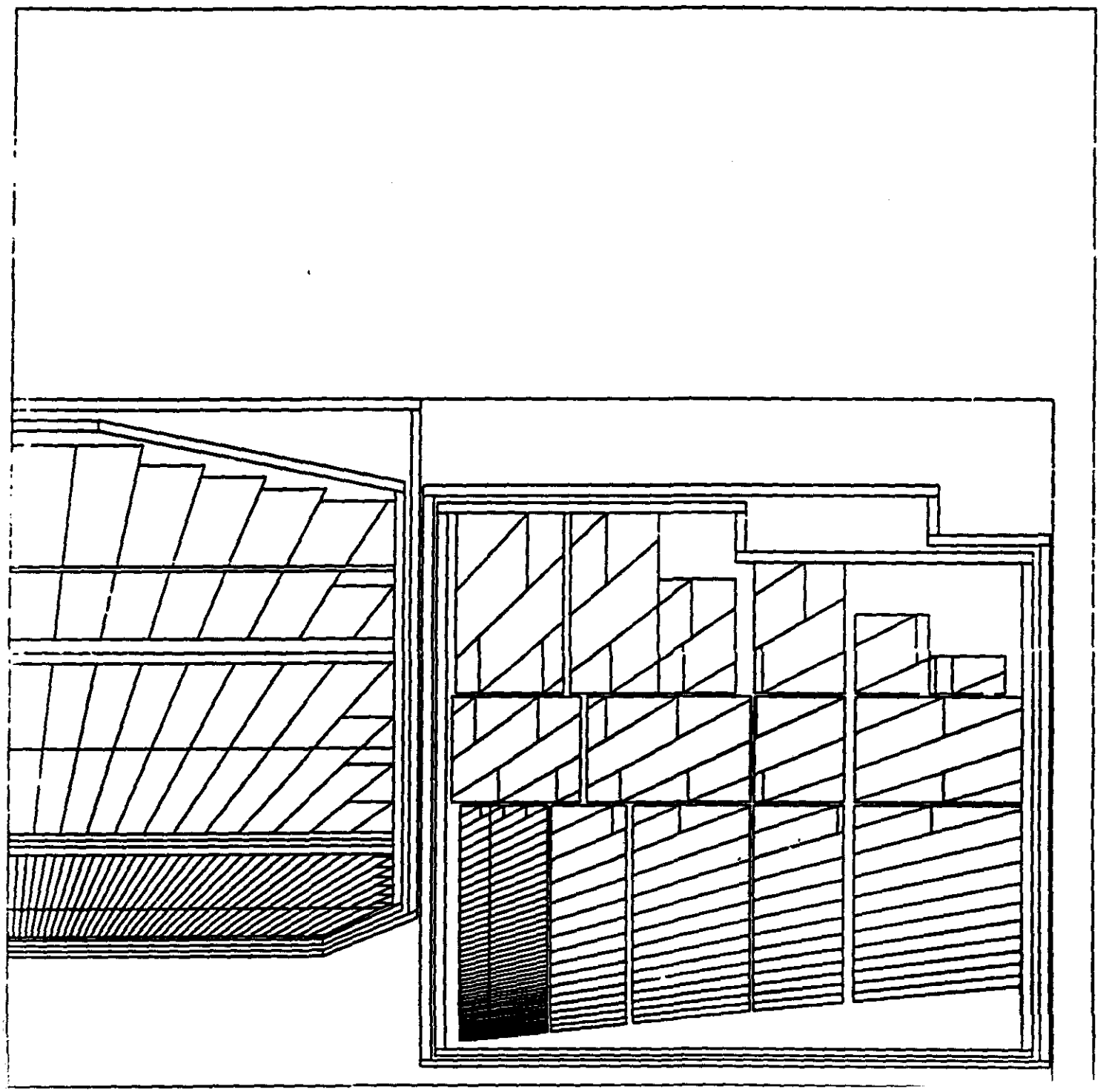
Monte Carlo studies

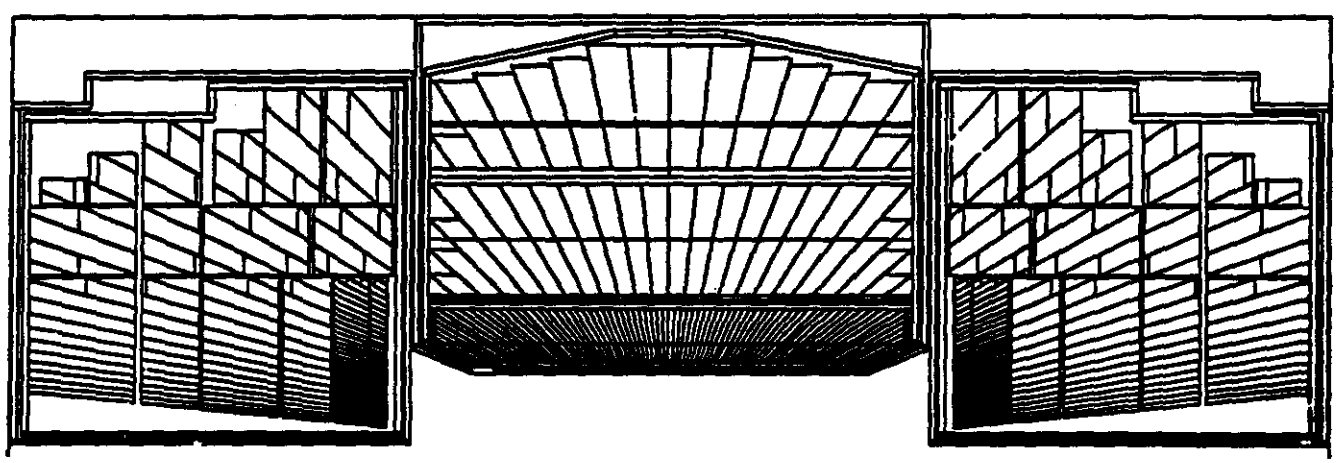
- Trigger efficiency – acceptance, dead area, ...
- Trigger rate at level 1 (decision $\leq 1\mu s$)
- — " — 2 ($2-100\mu s$)
- Fake rate
- Trigger hardware simulation
- ⋮

Trigger

1. Isajet + Det: parametrization (D.M., F.P., ...)
2. Detail Geant Geometry of LA Cal. (M. Seman)
   - I
3. Trigger Strategy - Machine learning tool.
   a) List of trigger primitive.
   b) Isajet + det Simulation
      (Signal + Background)
4. E.G.S. - Detail shower.

Lissauer/BNL





Trigger Primitive:

I: Physics Program:

Channel → $\mathcal{L}$ needed → Trigger Primitive.
(Down Scaling)

Min bias events.
Inclusive Jet cross-section.
Multijet
Single high P_t Photon
$\gamma\gamma$
Drell-Yan : e^+e^-, $\mu^+\mu^-$

Inclusive Z^0.

Inclusive W.

ZZ, WW, ZW, $Z\gamma$ Pair production

top – Inclusive cross section
mass measurment
$H^+ b$
$t\bar{t}$ Condensate.

Higgs → $\gamma\gamma$
$Z^* Z$
ZZ, e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$ ..

1.3 Jet production.

1.3.1 Inclusive Jet production

We assume that Jet triggers cover the η range of +/- 2.5 only at the trigger level. We will be able to tag jets at higher rapidity but at the trigger level we will deal only with this rapidity region.

One would like to measure the Inclusive Jet cross section all the way from 50 Gev/c to the max P_t Luminosity will allow. This can be done with different threshold and down scaling.

In the following table we show the integrated rates for Jets in the trigger fiducial volume . ($\eta =$ +/- 2.5)

Jet Cross section	σ	Events/sec at L=10^{33}	Events/crossing
P_t > 50 Gev/c	100 μb	10^5	$1.6\ 10^{-3}$
P_t > 100 Gev/c	12 μb	$1.2\ 10^4$	$1.92\ 10^{-4}$
P_t > 150 Gev/c	4.5 μb	$4.5\ 10^3$	$7.2\ 10^{-5}$
P_t > 200 GEv/c	2.0 μb	$2.0\ 10^3$	$3.2\ 10^{-5}$
P_t > 250 Gev/c	0.5 μb	$5\ 10^2$	$8\ 10^{-6}$
P_t > 500 GEv/c	μb		
P_t >1000 Gev/c	μb		

The question here is how efficient is the trigger as a function of the cone size of the jet. In General as the jet threshold is higher a smaller cone will do. This is both because the jet size is decreasing as well as due to the fact that we have a threshold in our trigger and can than collect the energy in any cone we like. As one goes to lower energy there is an optimal size due to both thermal and event pile up noise.

****

Trigger:

The trigger sums will be made from the more primitive sums in the e.m and hadronic sections that will be used for e.m triggers. One will use in the case of the liquid argon only the first three hadronic sections.

There are two fundamental questions we need to answer here:

1) Do the Jet sum overlap?

   a) How do we build the jet sums from e.m and veto sums??

2) What should be the optimal size of the Jet sum?

   a) In depth? b) In ϕ and η

1.3.2 Multi Jet Cross section

The min jet energy we will want to measure is still of the order of 50 Gev/c. the main question here is how do we count the number of jets? i.e do we ask for edge counting?

We thus assume that the multi Jet definition is essentially a counting of the number of events passed the single Jet with some edge counting.

Two Jet Cross section	σ	Events/sec at L=10^{33}	Events/crossing
P_t > 50 Gev/c	25. μb	2.5 10^4	4.0 10^{-3}
P_t > 100 Gev/c	3.0 μb	3.0 10^3	4.8 10^{-4}
P_t > 150 Gev/c	1.2 μb	1.2 10^3	1.92 10^{-4}
P_t > 200 GEv/c	0.5 μb	5 10^2	8.0 10^{-5}
P_t > 250 Gev/c	0.125 μb	1.25 10^2	2.0 10^{-5}
P_t > 500 GEv/c	μb		
P_t >1000 Gev/c	μb		

****

Trigger:

The Jet definition in multi-jet events might be difficult especially if we are looking for a good trigger on Z or W decay to two jets. AT high P_t of the parent the separation between the two Jets might be of the order of the Jet size.

****

1.5 Inclusive Z^0 production

One would like to measure the total inclusive cross section as well as the differential cross section as a function of P_t. A reminder of the Z^0 dominant branching ratio are given here.

Z^0 Decay Mode	Fraction in %
e^+, e^-	3.21 +/- 0.07
μ^+, μ^-	3.36 +/- 0.11
τ^+, τ^-	3.33 +/- 0.13
$\nu\nu$	19.2+/- 1.0
$b\bar{b}$	14.6 +/- 1.9
other hadrons	56.3 +/- 2.0

At low P_t there are only two channels that are open to investigations:

$Z \longrightarrow e^+ + e^-$ $\qquad$ $Z \longrightarrow \mu^+ + \mu^-$

Here one would like to go for a trigger that has two leptons with a minimum P_t of 15-20 Gev/c. The lepton can be isolated.

At higher P_t new channels can be identified and one would like to measure Z production also in the following channels:

$Z \longrightarrow q\bar{q}$ and $Z \longrightarrow \tau^+ + \tau^-$

If we assume that the minimum Z P_t of interest here is of the order of 200 Gev/c than we are looking for two jet trigger with min jet threshold of about 50 Gev/c and a total E_t^{total} of 300 Gev.

For the $\tau^+ + \tau^-$ channel we will need single hadron trigger of threshold of 50 gev/c + E_t^{total} > 300 Gev/c. If needed we can probably add some missing E_t requirement.

Z^0	σ	Rate for L=10^{33}	Events/crossing
Inclusive	100 nb		
P_t > 50 Gev/c			
P_t > 100 Gev/c			
P_t > 150 GEv/c			
P_t > 200 Gev/c			

*****

Trigger:

For the Lepton channels: Two leptons with a P_t > 20 Gev.

For the two Jet channel: Do we need to be able to trigger on two jets? or is one Jet + total E_T is enough?

For the τ decay channel do we need to have a "single" hadron trigger??

*****

1.7 Top production

1.7.1 Inclusive Top cross section

Probably the best way to measure the top cross section is to look for events two isolated leptons and two b jets. I.e we are looking for the decay

$t \longrightarrow W\,b \quad ; \quad W \longrightarrow l + \nu$

This decay mode is well understood. And by measuring the inclusive cross section one can get rough measurement of the top mass.

t σ m140 (200) gev.	σ	Rate at L=10^{33}	Events/crossing
Inclusive	160 nb (4nb)		
P_t > 50 GEv/c			
P_t >100 Gev/c			
P_t >150 Gev/c			
P_t >200 Gev/c			

****

Trigger:

For the inclusive top measurement we will look at the leptonic decay modes only. One would like to cover the full P_t range and thus the basic trigger is two leptons with P_t > 20 Gev.

****

1.7.2 Top mass measurement.

The top mass measurements can be done in three ways:

1) From an accurate determination of the top cross section one gets a estimate of the top mass.

2) Looking at the invariant mass of the leptons from the top decay.

t decay	$\bar{t}$ decay.
l_{11} lepton from W decay.	l_{21} lepton from W decay
l_{12} lepton from b decay.	l_{22} lepton from b decay
l_{13} lepton from c decay.	l_{23} lepton from c decay.

Now we have a number of mass combination and decay modes we would like to measure.

M(l_{11}, l_{21}): Inv. mass of the two leading leptons from $t\bar{t}$.

m(l_{11}, l_{12}): Inv. mass of the leading leptons from the same t ($\bar{t}$)decay.

3) M(b-jet, W $\longrightarrow q\bar{q}$) events need to be tagged by the second top decaying to Wb but W$\longrightarrow$ *lepton*ν

1.7.3 t $\longrightarrow H^+$+b

In this channel we are looking for a charged Higgs with a mass less than the top mass. The charged Higgs in this case is below the Top mass and is expected to have a large coupling to lepton ν. The way we distinguish this from the more standard decay of the top to W^+ b is that the H^+ is expected to have much stronger coupling to the τ channel.

****

Trigger:

The idea here than is to check e, μ, τ universality in the W's originating from top decay. This can be done effectively only for high P_t top production.

****

1.7.4 Top decay to SUSY particles.

1.7.5 t $\bar{t}$ Condensate

1.12 Maximal List of Trigger Primitives

(a) em Sum

- size of individual towers: .04X.04
- size of em sums : .12X.12

  The size of the em sum has to be a multiple of the tower size. The smallest one would consider is 3x3 and probably one would not like to go for a size greater than 5x5.
- overlaping sums? no

  The problem with the overlapping sums is that the accordion by design tend to spread the charge over more than one tower. Thus one tends to have a soft threshold over a large area near the edge of the tower.
- Edge counting ? Yes.

(b) Isolation criteria

- Had veto .24x.24 in 1st hadronic

  The Had veto sum is made up of 4 had towers (0.08X0.08) in the 1st floor of the liquid argon cal. (3 λ deep).
- EM veto

  The how we use the em sum information in the veto depends on the detail if we have overlapping sums or not. The general idea is to use the ration of the energy in a large area to the energy we have in the center.
- Jet cone veto

(c) Shower shape veto

- From tower information
- from individual towers

(d) $e^{+/-}$ Trigger

- isolated e.m shower + any track from tracking
- isolated e.m shower + high P_t track

(e) Mass cut on $\gamma\gamma$

- $M(\gamma\gamma)$

(f) Total E.m energy

- min th to go to the sum

- do be have a before and after prot? on indiv sums

(g) Had sums

- Had toawer . 0.08X0.08
- Size of had sum 0.24x0.24
- depth of sum for veto first floor in Liquid Argon 3 λ
- Depth of sun for single particle trigger
  For single particle trigger if we want it we need to add:
  e.m + first three floors in the liquid argon cal.
- edge counting for high p_t single had trigger?

(h) Jet sum

- size of sum R=0.3 in $\eta\phi$ space : 0.48x0.48
- depth of sum 8 λ we do not include the tail catcher in the trigger sum.
- overlaping sums?

(i) E_{Trans}^{Had}

- depth of sums? same as Jet sums.
- How is the sum done?
  do be have a before and after prot? on indiv sums

(j) Missing E_T

- What sums go to make the missing E_T?
- Do we have before and after prot to go into the sum?

(k) μ trigger

- Any track candidate min P_t
- Confirmend track candidate P_t cut?
- isolated μ candidate

Cal.

Individual towers

Sum Type.	$\Delta\eta\Delta\phi$	Number	Level Needed
E.M Tower (f,b)	.04x.04	20,000 x2	Level III
Had Tower 1st floor	.08x.08	5000	Level III
Had 2nd, 3rd floors	.08x.08	5000 x 2	Level III
Had Veto tower	.08x.08	5000	Level III
E.m Trigger Sum	.12x 12 / .2x.2	2000/800	Level I
Had Veto sum	.24x.24	500	Level I
Single Part sum	.24x.24	500	Level I
Jet Sum	.48x.48	125	Level I
E_t^{em}	5.x 2π	1	Level I
E_t^{all}	5.x2π	1	Level I
ΣP_x	10.x2π	1	Level I
ΣP_y	10.x2π	1	Level I
Missing P_t	10.x2π	1	Level I

Trigger Σ.

Using Machine Learning in SSC Trigger Strategy Studies

S. Clearwater
W. Cleland
E. Stern

University of Pittsburgh

Questions, questions, ...

Problems of designing and building SSC detectors generates questions at an exponentially increasing rate

- What size of ⟨⟨*something*⟩⟩ is optimal for separating ⟨⟨x⟩⟩ from ⟨⟨y⟩⟩?
- Is it possible to trigger on ⟨⟨*your favorite reaction*⟩⟩? What is the best way to do it? What hardware is necessary?

DID YOU CONSIDER

Shower spreading
High luminosity
Pileup noise
Thermal noise
Other particles
Other backgrounds

Machine Learning to the rescue?

RL4:

Finds a set of rules (cuts) which separate signal events from background events.

Inputs:

A. Preclassified signal and background events. (MC)

B. Attributes (event characteristics) that RL4 will use in constructing rules.
Total E_t, number of leptons, etc.

C. Performance thresholds
Trigger rate
Signal/Background

D. Rule complexity
(condition 1) AND (condition 2) AND ...

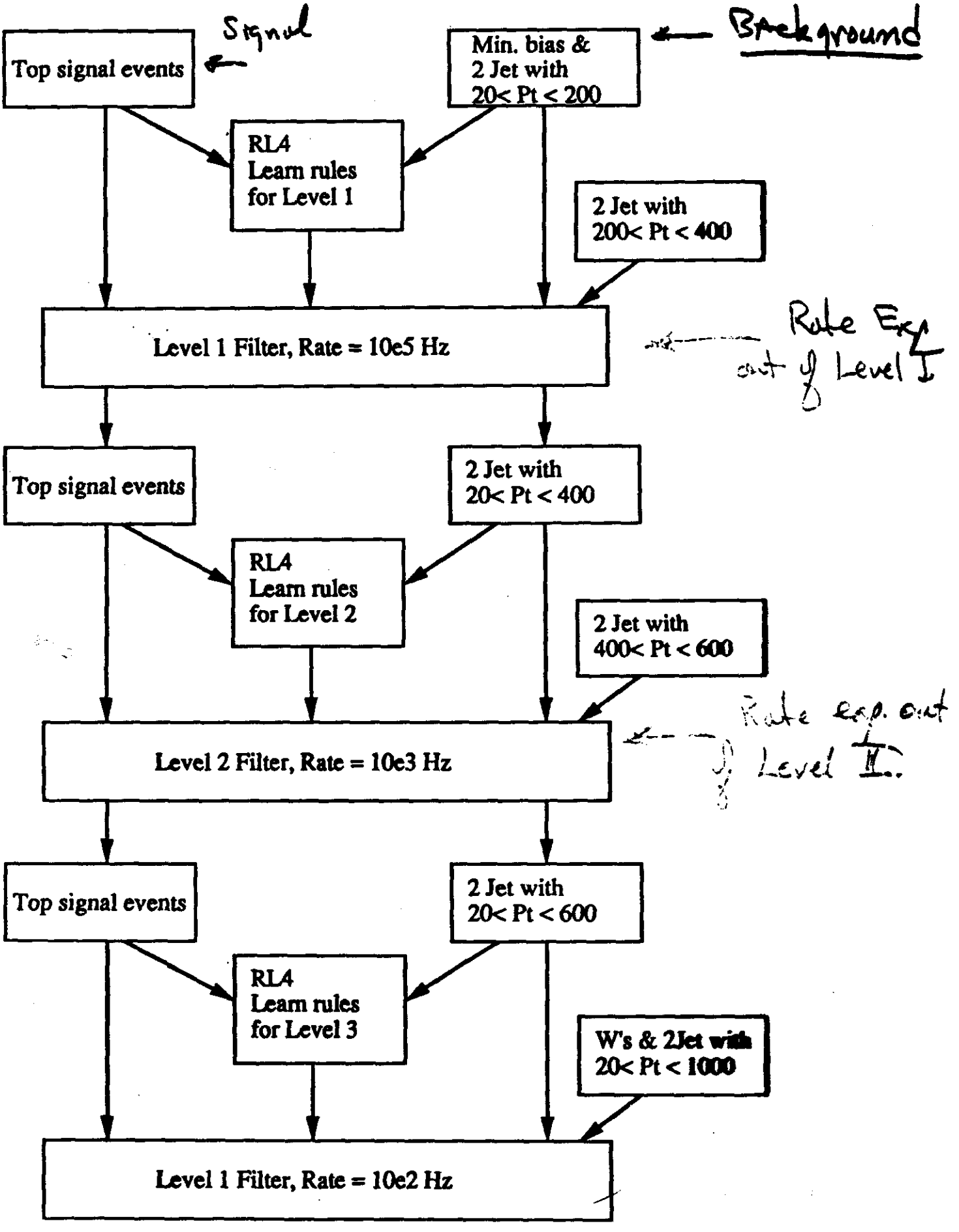
Outputs:

Cuts that meet the performance criteria for separating signal from background.

$$\left(\text{Total } E_t > 650.0^{+17}_{-23}\right)$$

How does it work?

Efficient search of plausible rules (analogous to histogram inspection)


Signal
Background
Top signal events
Min. bias &
2 Jet with
20< Pt < 200
RL4
Learn rules
for Level 1
2 Jet with
200< Pt < 400
Level 1 Filter, Rate = 10e5 Hz
Rate Exp
out of Level I
Top signal events
2 Jet with
20< Pt < 400
RL4
Learn rules
for Level 2
2 Jet with
400< Pt < 600
Level 2 Filter, Rate = 10e3 Hz
Rate exp. out
of Level II.
Top signal events
2 Jet with
20< Pt < 600
RL4
Learn rules
for Level 3
W's & 2Jet with
20< Pt < 1000
Level 1 Filter, Rate = 10e2 Hz

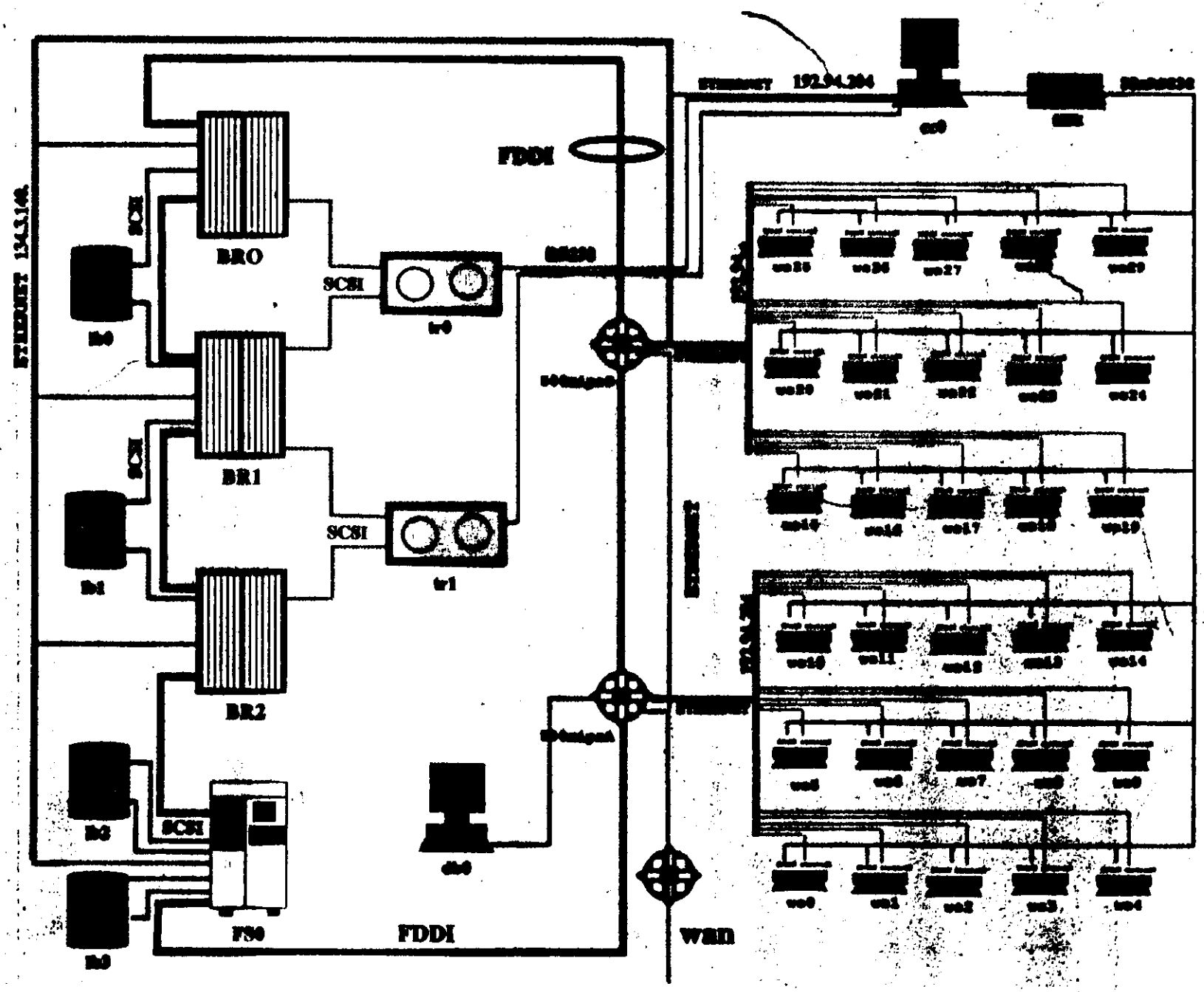
B. Scipioni

PDSF UPGRADE

1/21/92

PHYSICS DETECTOR SIMULATION FACILITY NETWORK

T. SONG 2/14/91



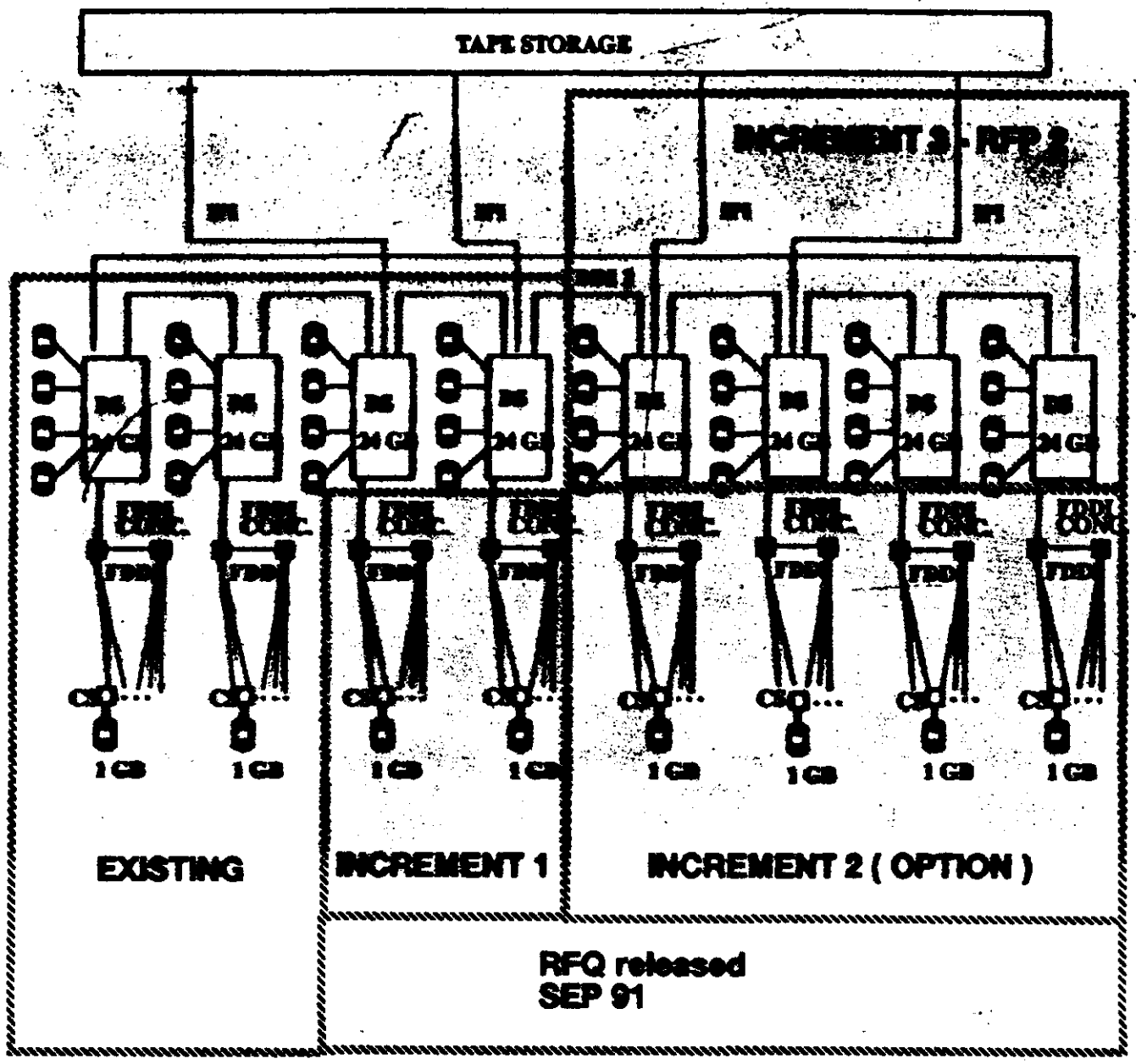


Figure 2.1. Functional diagram (block diagram) of the simulation facility. The diagram indicates the two FDDI networks of data servers (DS) and compute servers (CS). (The diagram is representative and is not intended to show the actual number of data servers or compute servers to be purchased.

PDSF Phase II Architecture

All Data Servers and all Compute Servers [illegible]

One fourth of each corral interactive [illegible]

[illegible] directories always [illegible]

[illegible] directories over Data Servers [illegible]

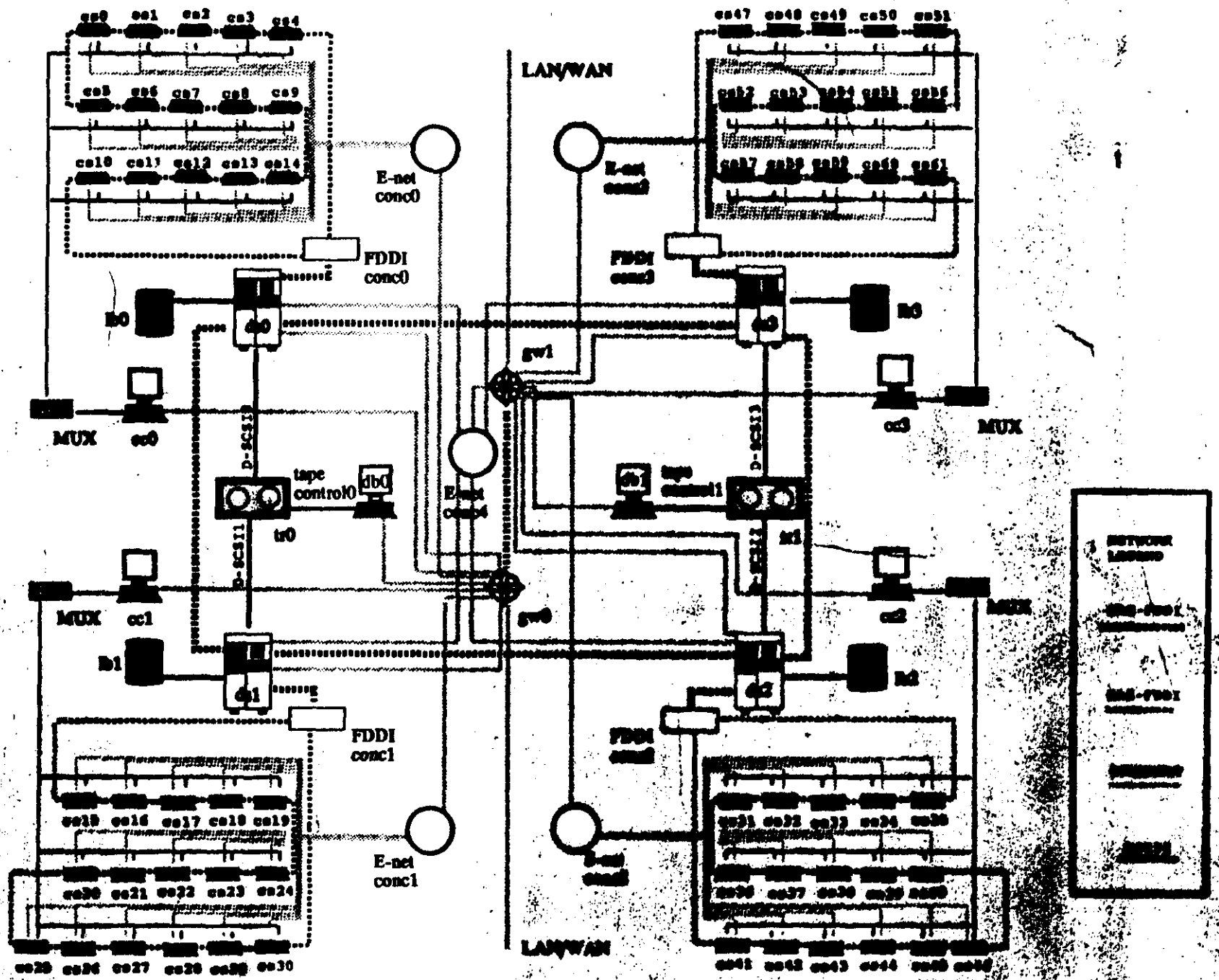
[illegible] raw partitions [illegible]

[illegible] and computes [illegible]

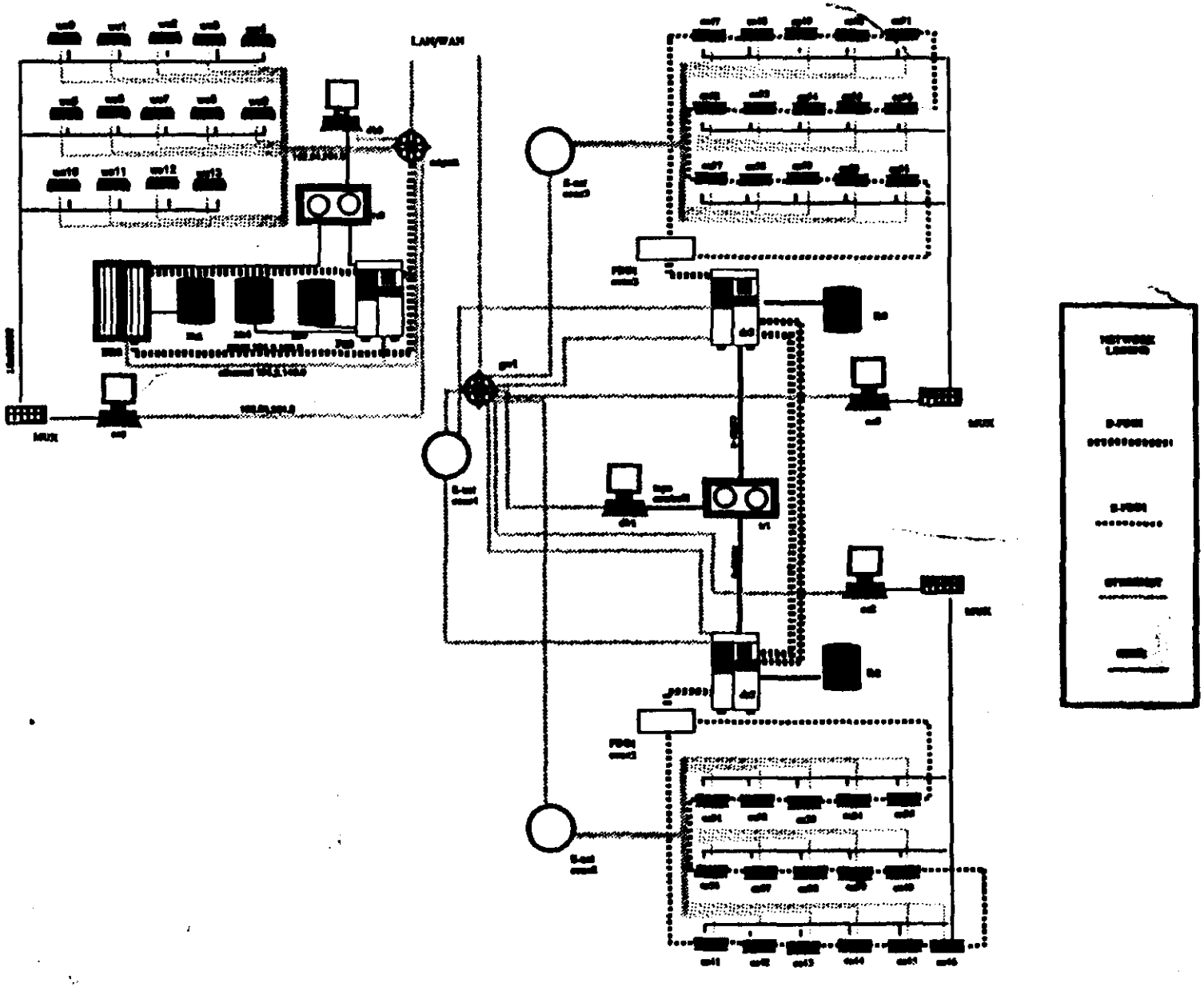
[illegible] same directory [illegible]

[illegible] for 4 WA[illegible]

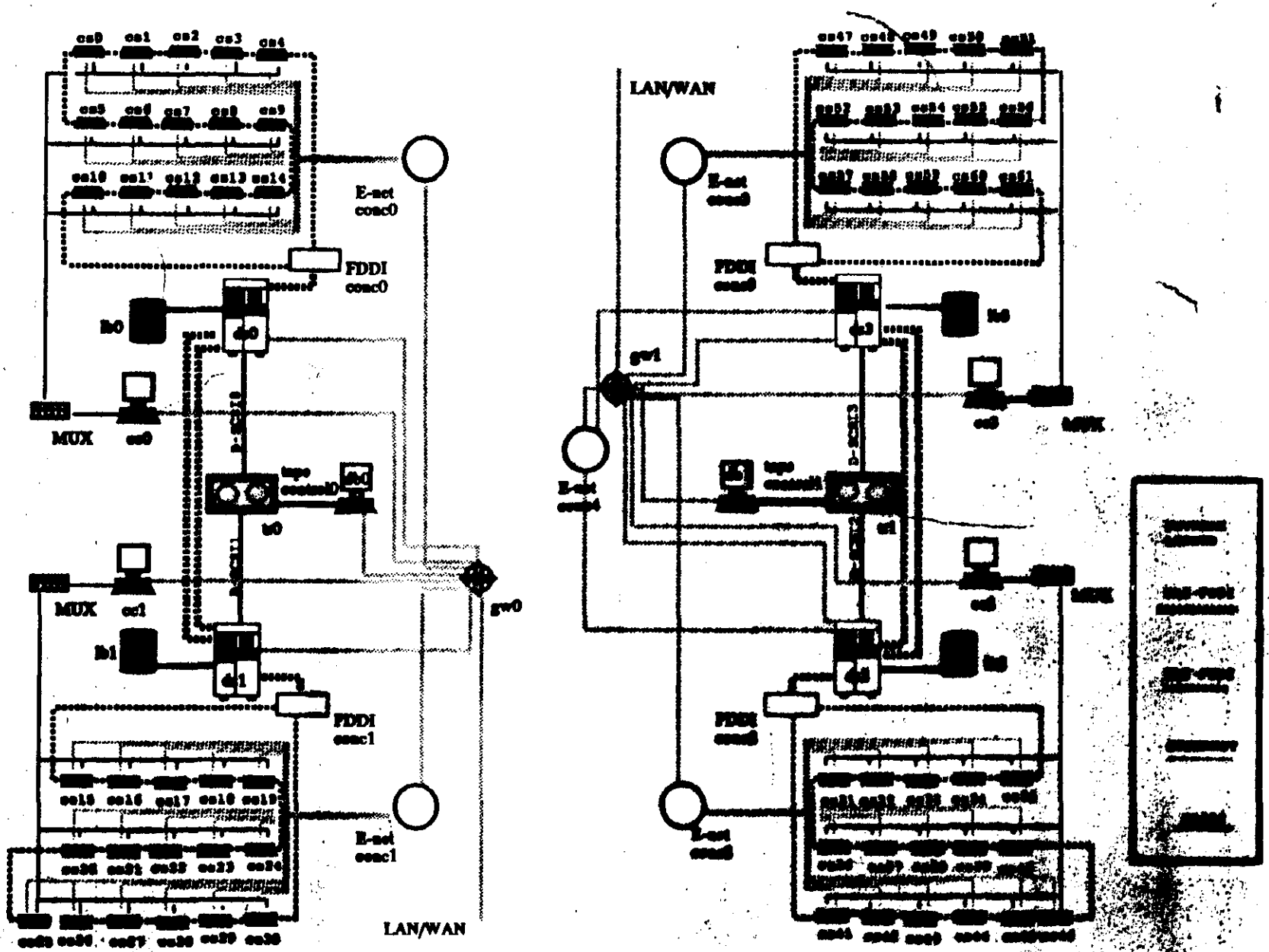
PLANNED PDSF WITHOUT OPTION

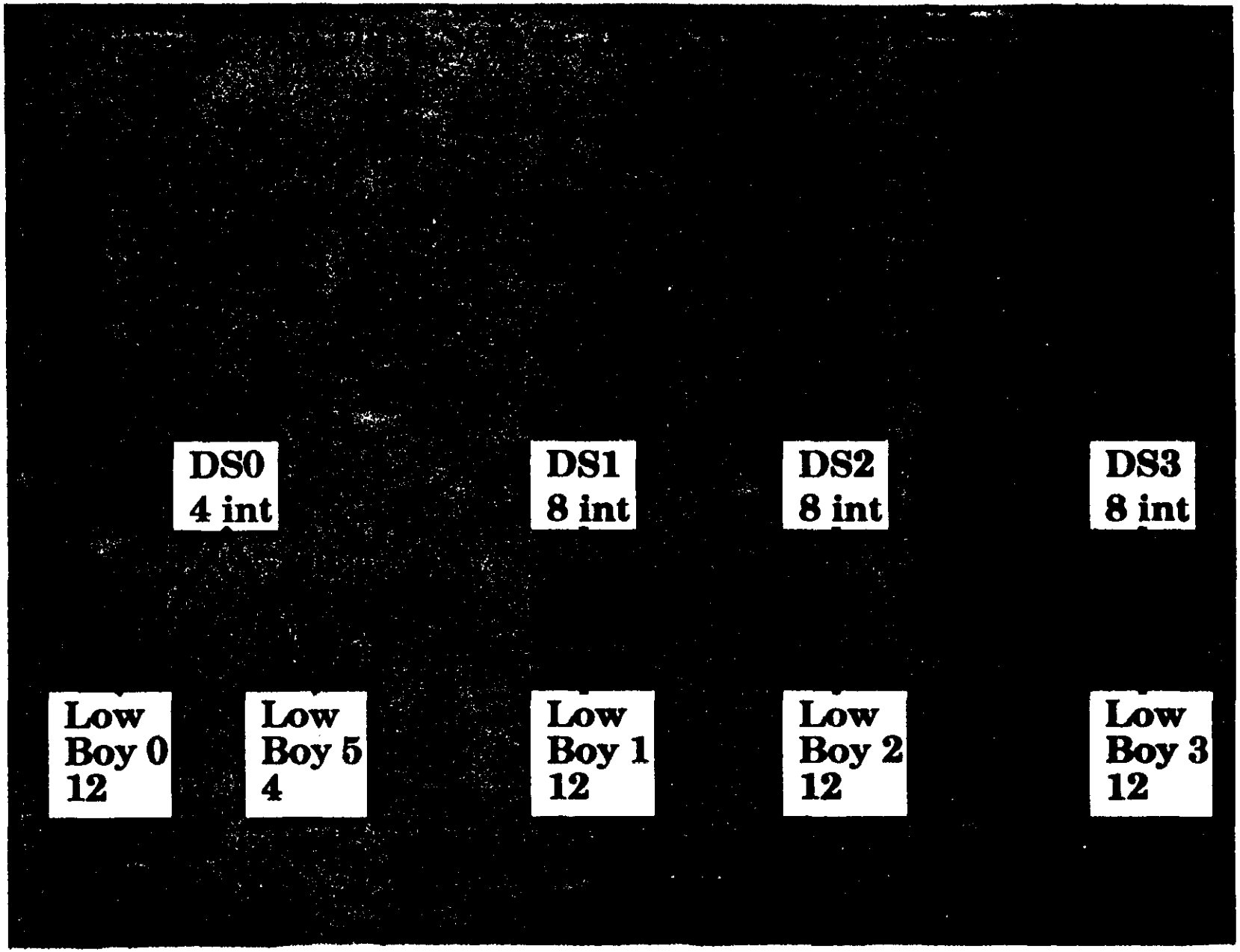


PDSF UNDER RECONFIGURATION (STEP 1)

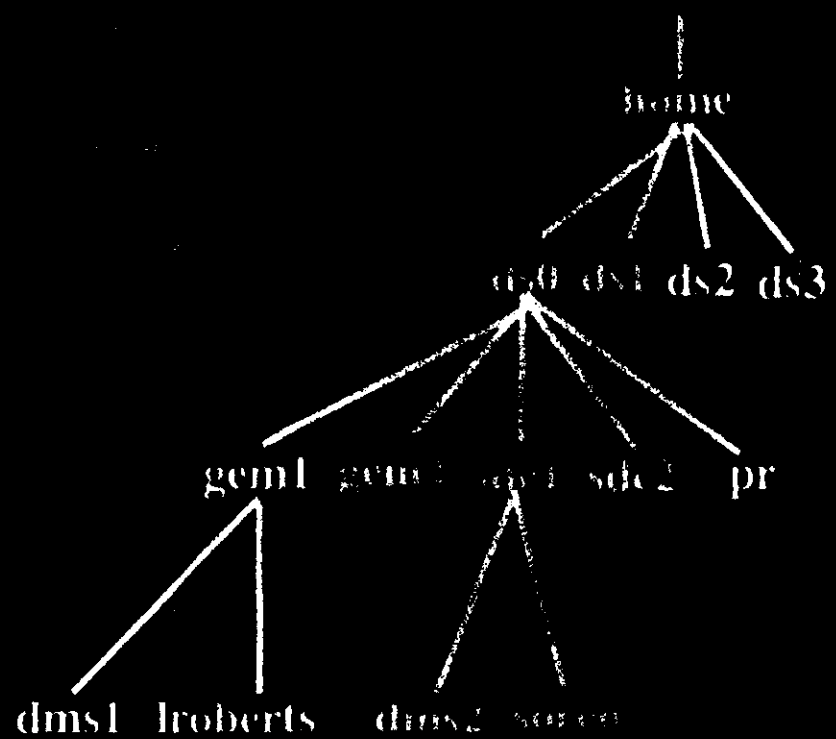


PLANNED PDSF WITHOUT OPTION (STEP 2)

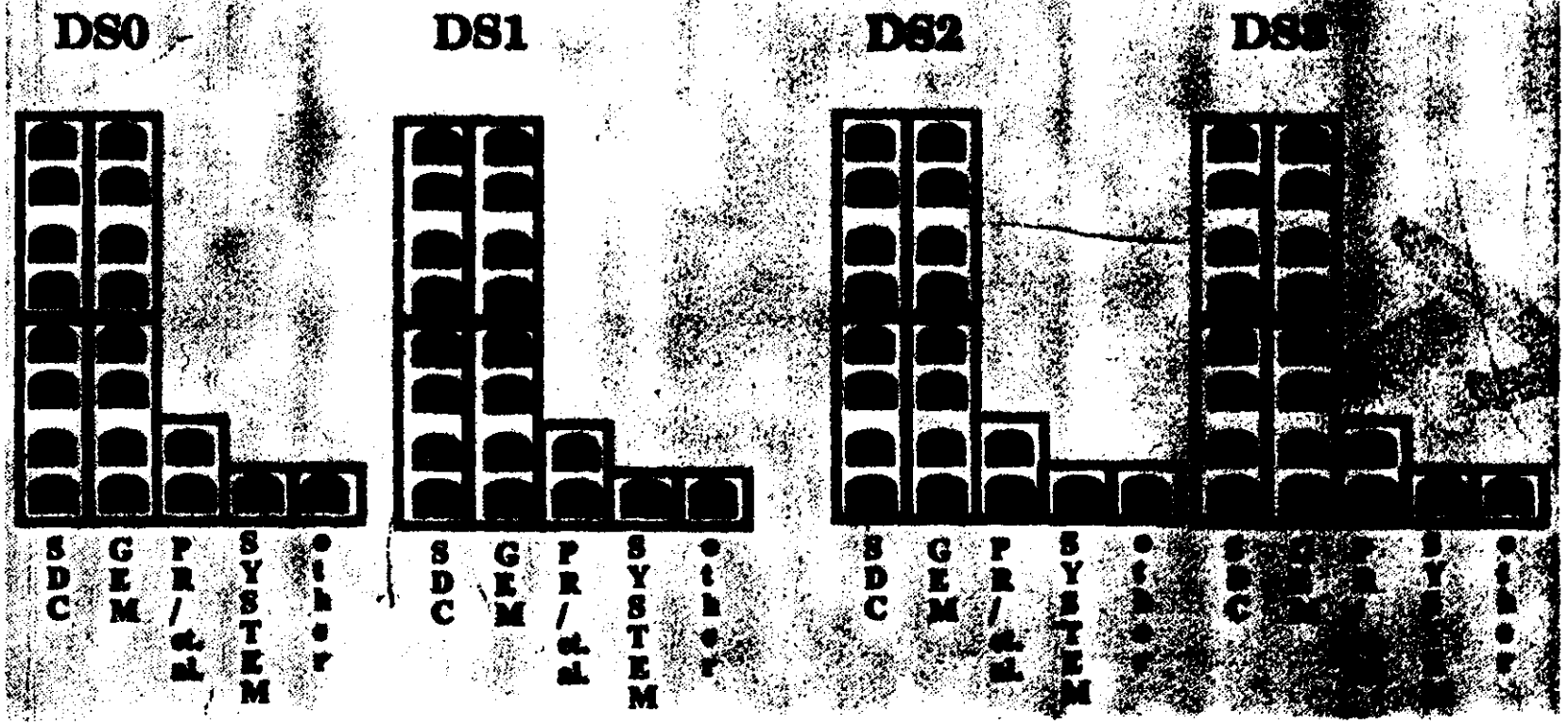



DS0
4 int
DS1
8 int
DS2
8 int
DS3
8 int
Low
Boy 0
12
Low
Boy 5
4
Low
Boy 1
12
Low
Boy 2
12
Low
Boy 3
12

Directory/File System Mapping



User/File System Disk Allocation



CERN Program Library Support

A Jeweler's View

Lee A. Roberts
January 19, 1992

This document is intended as a projection of CERN Program Library support available to GEM collaborators from the SSC Laboratory during the next year. These projections should be viewed as guidelines, not as absolute truths. Support of these libraries appears to be in a state of flux both at CERN and at the SSC Laboratory. Future directions will be influenced by changes at CERN, changes at the SSC Laboratory and the needs of the GEM and SDC collaborations.

Several issues will be addressed in this document. These include the following:

a) Support priority of each machine.

b) Software versions of CERN Program Library, including GEANT.

c) Forecast.

Support Priorities:

GEM collaborators can expect the machines in the Physics Detector Simulation Facility (pdsf) to be fully supported and given the highest priority. These machines include:

Silicon Graphics @ IRIX 4.0.1

Sun SPARCstation @ SunOS 4.1.1 & SunFORTRAN 1.4

HP 9000/7XX @ HP-UX 8.07

The HP 9000/7XX machines comprise the PDSF Upgrade to be installed in the immediate future (March 1992). HP has recently announced HP-UX 8.07; we expect this version will be used on the PDSF. We are presently working with HP-UX 8.05 on a small collection of HP 9000/7XX machines; we anticipate full compatibility.

Support for DEC ULTRIX/RISC machines will probably assume second-highest priority. A number of GEM (and SDC) collaborators have expressed interest in these machines. In addition, the SSCL has general purpose DECsystem 5500 machines (sscux[1-3].ssc.gov) which require CERN Program Library support. Support for such machines includes:

DEC ULTRIX/RISC 4.2 & DEC FORTRAN 3.1

DEC ULTRIX/RISC 4.2 & FORTRAN for RISC 2.0

I expect that GEM support will be targeted toward DEC FORTRAN 3.1.

Support for IBM RS/6000 machines will probably assume, in the absence of substantial demand, third-highest priority among UNIX/RISC machines. Present CERN Program Library support at the SSCL for the IBM RS/6000 is performed on an IBM RS/6000-320E with AIX 3.1.5 & AIX XL FORTRAN 2.2. Upgrade to AIX 3.2 is anticated in the near future.

April	V92A release (estimate)
May	V92A available (estimate)
June	
July	
August	
September	
October	V92B release (estimate)
November	V92B available (estimate)

Release of GEANT 3.15 is imminent. CNL203 and GEANT 3.15 should be available for UNIX machines of interest by the end of January 1992. My hope is that CNL203 and GEANT 3.15 can serve as a stable simulation environment for the first half of 1992. GEANT 3.15 is intended to be compatible with GEANT 3.14; updates to GEANT 3.14 will cease with the release of GEANT 3.15. A new version of GEANT (GEANT 3.16) with a new geometry package is probably one year away and will not be useful for development of the technical proposal.

Dates for the release of V92A and V92B are guesses. I would anticipate a new release of CERN software for GEM usage in late spring or early summer that would serve as the standard through the submission of the technical proposal. Any CERN release in the early fall would probably not be useful for development of the technical proposal due to time constraints.

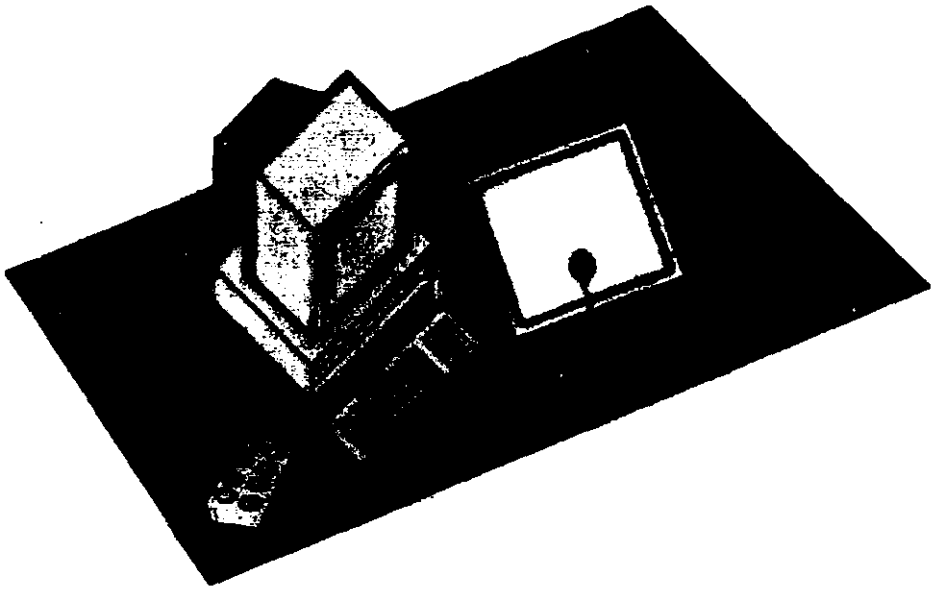
Absorbing CAD System Geometries into GEANT

John Womersley and Saul Youssef

W.L. Dunn, J.D. Simpkins and A.M. Yacout

In the 1990's:

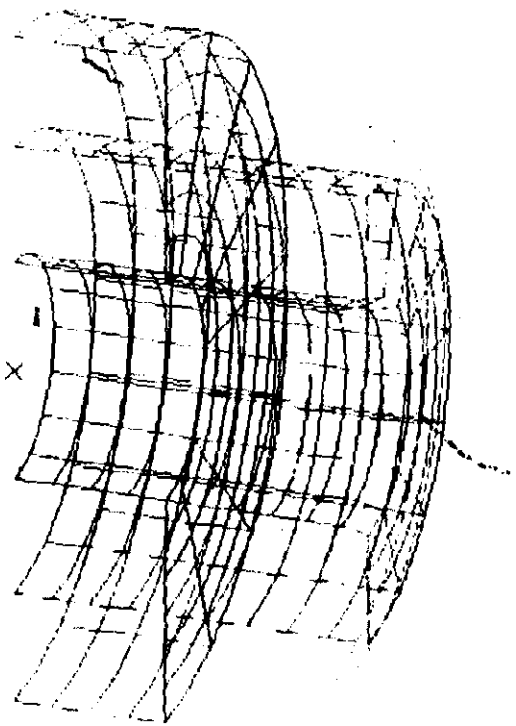
Cheap, readily available CAD/3D modeler systems are becoming commonplace.

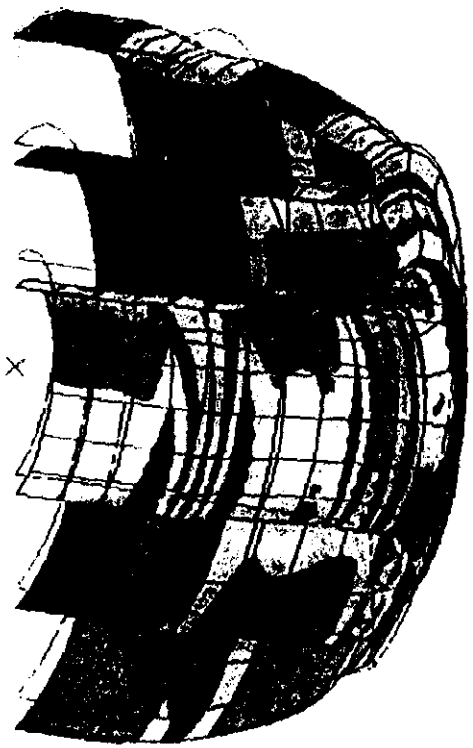


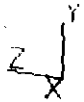
These systems contain many useful engineering tools: structural analysis, thermal, fluid flow etc. A great help in design of detectors --- engineers are already using them.

e.g. EMPACT design studies

LOADCASE:5 ARGON
FRAME OF REF:GLOBAL
STRESS - VON MISES MIN: 1.44E+02 MAX: 1.04E+04
Calculation groups: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10,







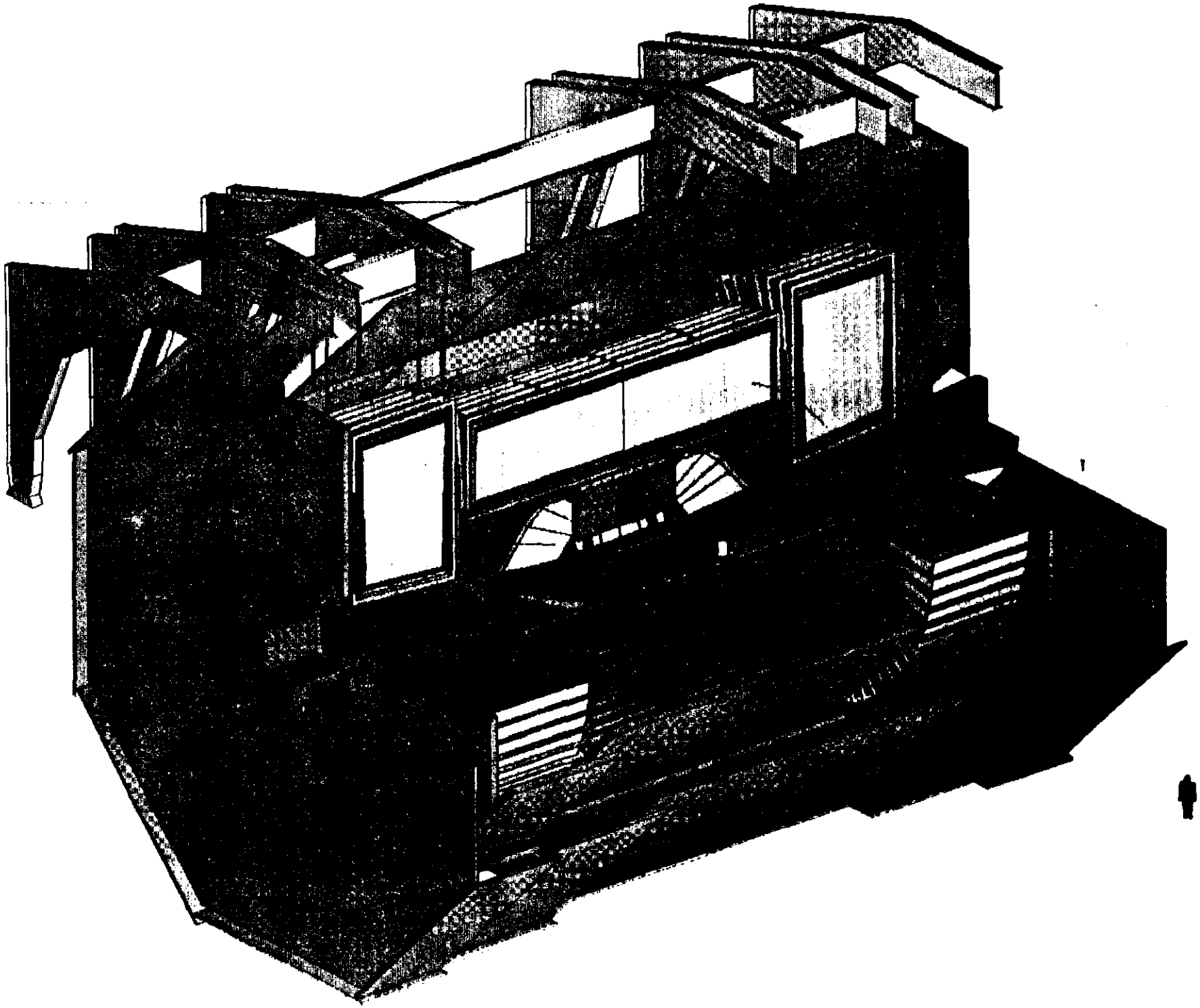
1.60E+03

8.90E+03

LEVELS:6 DELTA: 1.46E+03

To see how far things have progressed...

Contrast this computer-generated 3D view of EMPACT (1990) with a laboriously hand-drawn 3D view of D-Zero (circa 1985):



Integrate CAD and GEANT models

- enables the design to be optimized for physics at the same time as it is optimized structurally - eliminates the design bottleneck
- Provides a user-friendly way of creating GEANT models

Unfortunately . . .

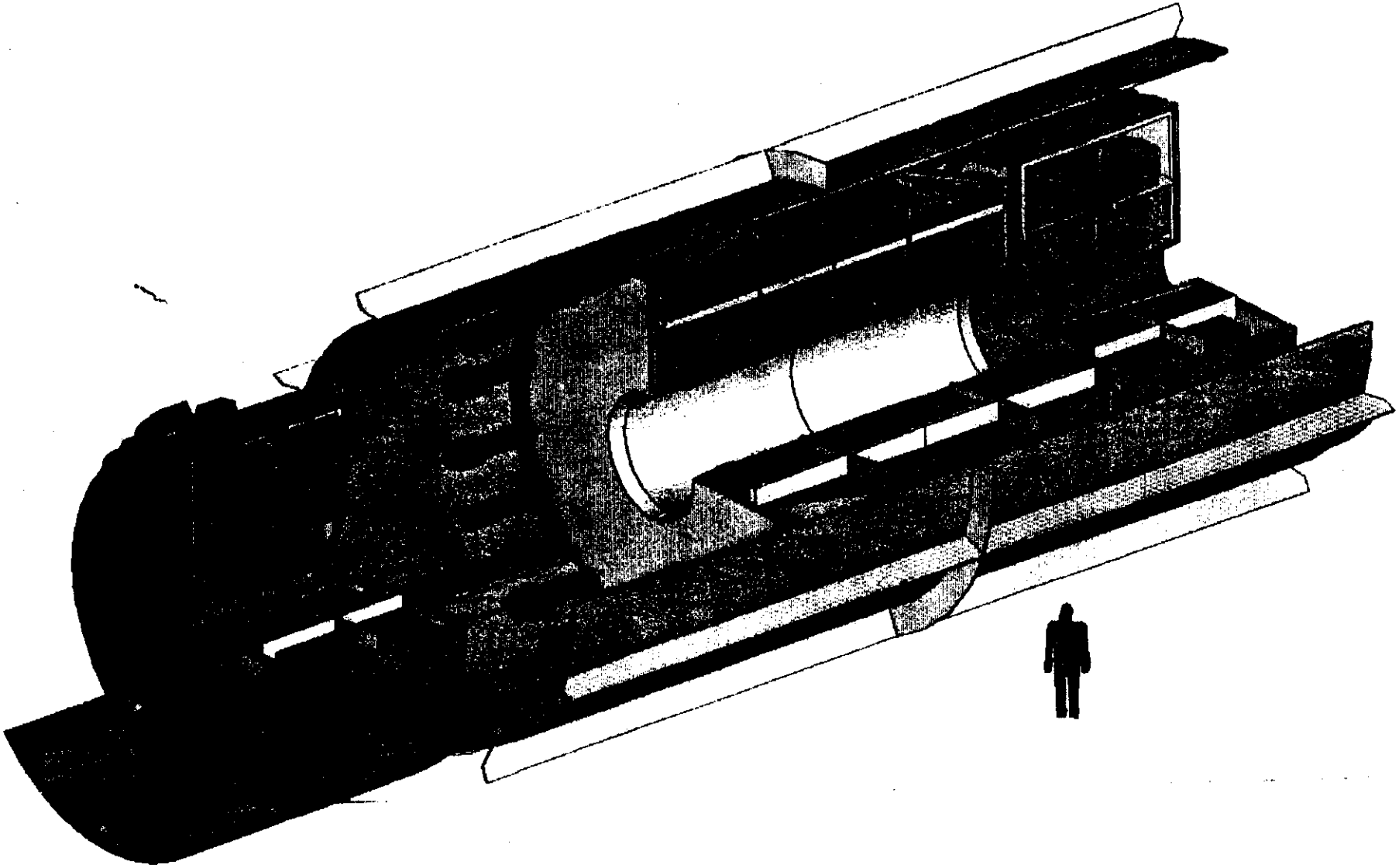
- Computer aided modelling systems come in two broad classes:

  and

- Many varieties of each
- Many vendors
- Most are mutually incompatible
- Most permit non-GEANT shapes (such as volumes of rotation, extrusions along a curve)

Solid Modellers

- Engineering Type Systems
- Interfaces to stress analysis, thermal, fluid flow etc.
- Deal with actual solids built of materials
- (Relatively) expensive
- Example: I-DEAS



CAD Systems

- Drafting systems: primarily concerned with drawing plans and blueprints
- Seldom have materials or solid blocks
- Deal with wire-frames or projections
- (Relatively) cheap
- Examples: AutoCAD, Versacad

File Edit Tools Draw Modify Display Settings Options Help 2:46 PM

Bolt

Layer 0 Snap 0.7000,1.0000

AutoCAD
* * * *
Angle
from XY
Plane
+80
+60
+45
+30
+10
0
-10
-30
-45
-60
-80

LAST
DRAW
EDIT

F1 F2 F3 F4

Regenerating drawing.

Command:

CAD Interchange Formats

- Example:
- Can be output by most systems
- Disadvantage:
  'Lowest Common Denominator'

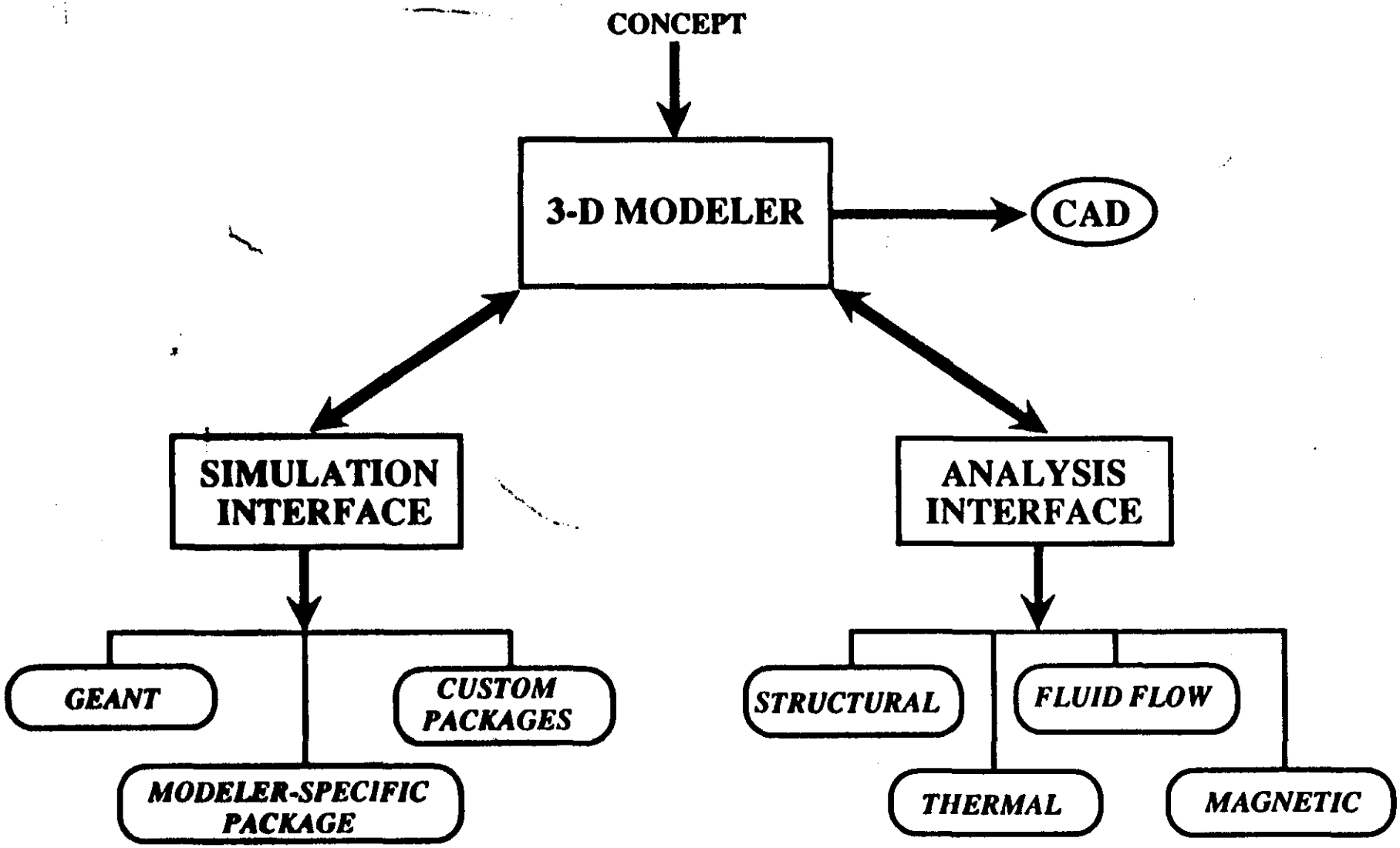
ASCII DXF FILE

```
  0
SECTION
  2
HEADER
  9
$ACADVER
  1
AC2.10
  9
.
.
.
ENTITIES                <-------   Start of geometrical elements
  0
LINE                    <-------   A line
  8
0010010226
 10                     <-------   Header for x coordinate of start poin
39.3700012401550        <-------   Coordinate value
 20
39.3700012401550
 11                     <-------   Header for x coordinate of end point
275.5900086810853                  etc etc.
 21
39.3700012401550
 38                     <-------   Lower z of extrusion (making a plane)
1.0000000000000
 39                     <-------   Upper z of extrusion
2.0000000000000
  0
ENDSEC                  <-------   End of this line
  0
.
.
.
CIRCLE                  <-------   A circle
  8
0010010226
 10                     <-------   Header for x coordinate of centre
127.9525040305039
 20
127.9525040305039
 40                     <-------   Header for radius
78.7400024803101
 38
1.0000000000000
 39
2.0000000000000
  0
ENDSEC                  <-------   End of this circle
  0
EOF                     <-------   End of file marker
```

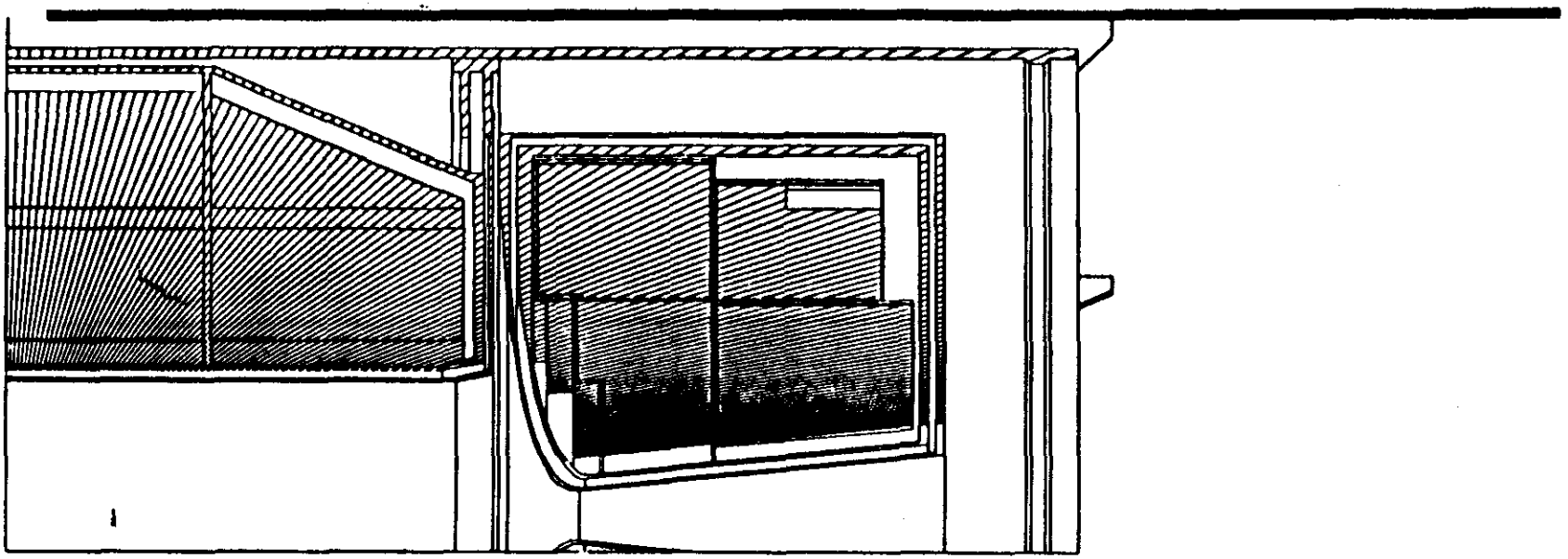
EMPACT ray-tracing software

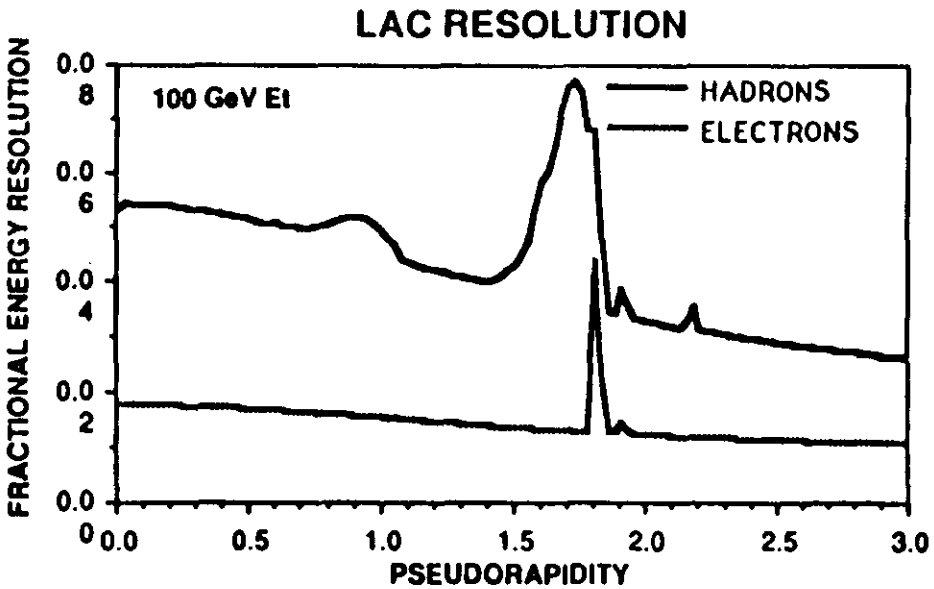
- Based on I-DEAS solid modeller
- Added ray tracing to track particles through the 3D model
- Code for estimating the effect of uninstrumented material and leakage on calorimeter resolution

DESIGN, MODELING, ANALYSIS AND SIMULATION TOOLS



Present Capabilities





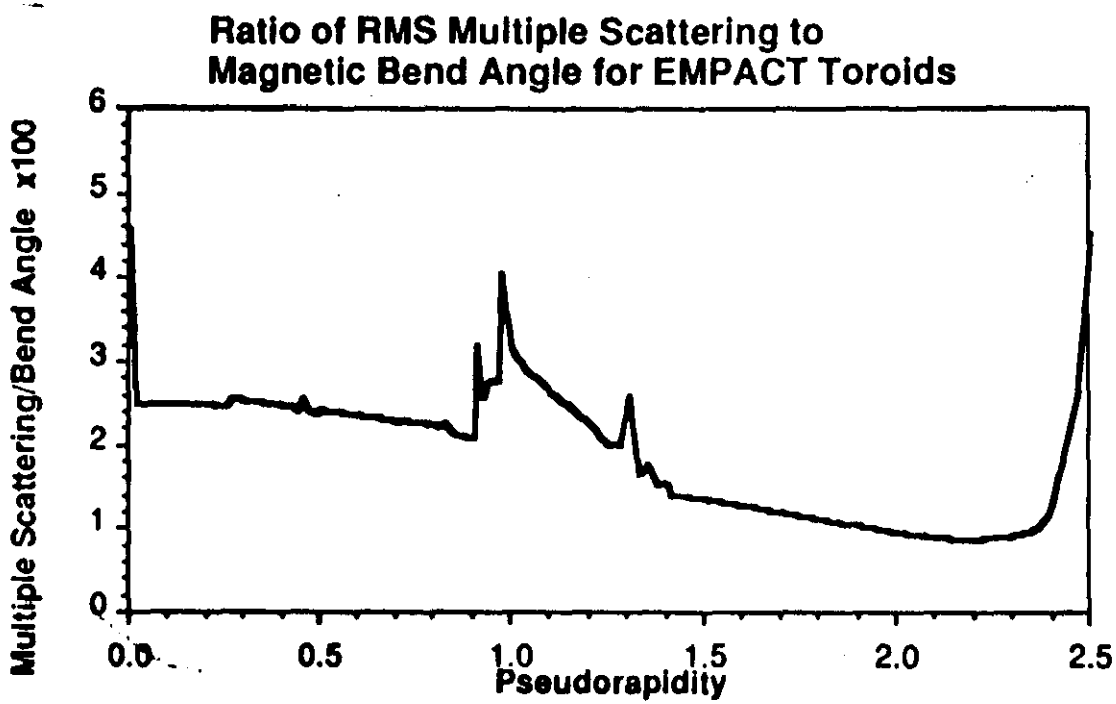
Ray Tracing and Resolution Calculations Done by Tool NO External Processing Required

Sampling Similar to EM Resolution

$\Delta\eta = .02$

Plotting Done on Macintosh

Geometry Calculations Done for Muon Bending Data

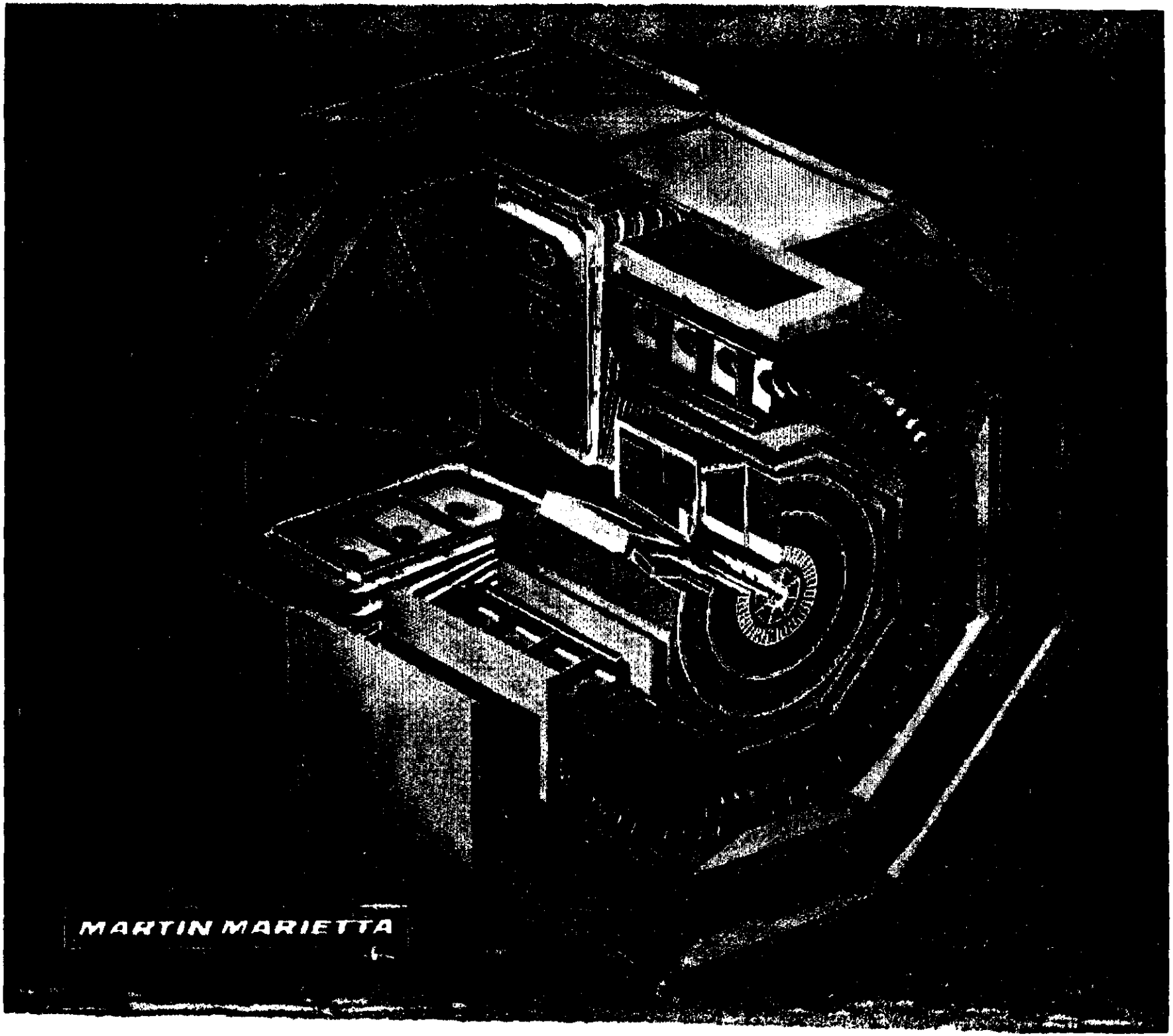


Ray Tracing Provided Locations of Toroid Superconducting Wires

Fine Sampling to Catch Corner Details

$\Delta\eta = .0125$

Geometry Information Imported to Spread Sheet Program for Further Processing


MARTIN MARIETTA

MARTIN MARIETTA

COGENT project

- Development of CAD-to-GEANT interpreter
- Based on shape recognition in DXF file
- Completed first phase 1991,
  second phase unfortunately not funded.

How COGENT Works

- The Graphical User Interface is the environment that provides the communication link between the user and the code

- The Shape Interpreter

  reads DXF files

  performs rule-based volume identification from either 2-D or 3-D CAD descriptions

- The GEANT Input Generator

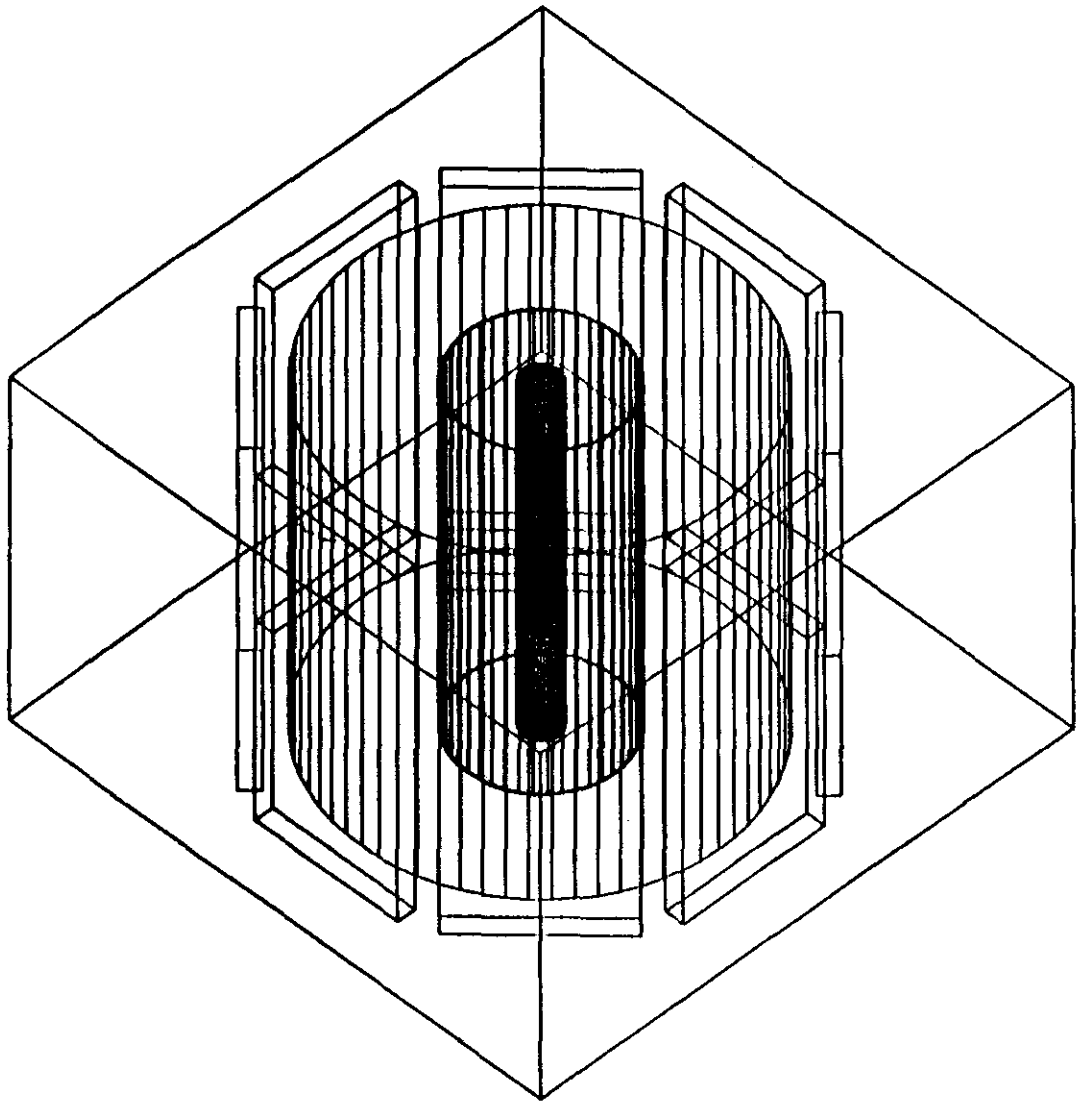
  writes a FORTRAN source file that makes the appropriate calls to the GEANT geometry routines

  incorporates a library of material compositions

Current Capabilities

COGENT Recognizes	GEANT Nomenclature
in 2-D and 3-D representations	
Rectangular parallelepiped	BOX
Parallelepiped	PARA
Solid rod	TUBE
Hollow tube	TUBE
Truncated solid rod	TUBS
Truncated hollow tube	TUBS
Right trapezoidal prism	TRD1
in 2-D only	
Sphere	SPHE

Example – 3-D View

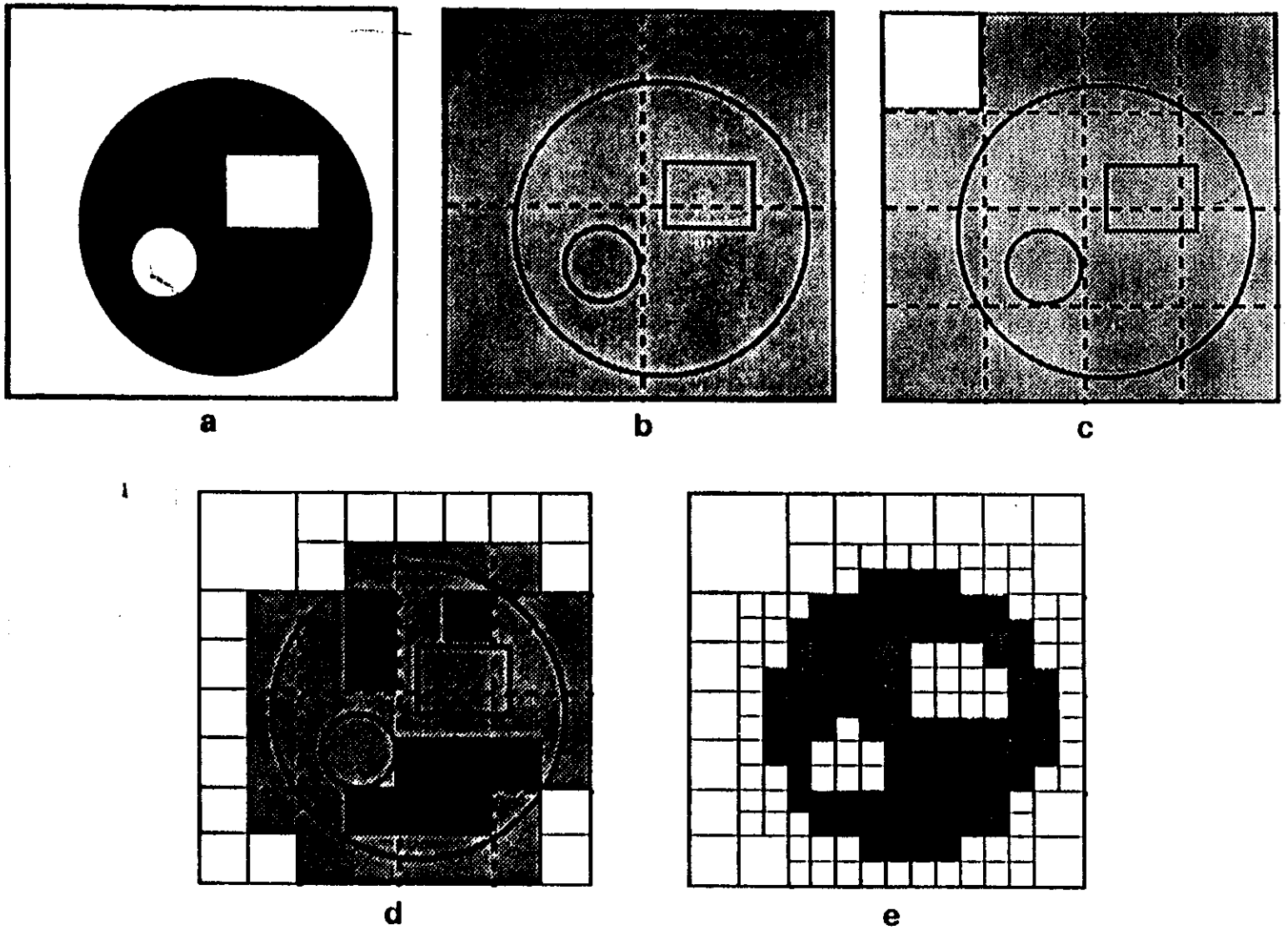


OCTAGON

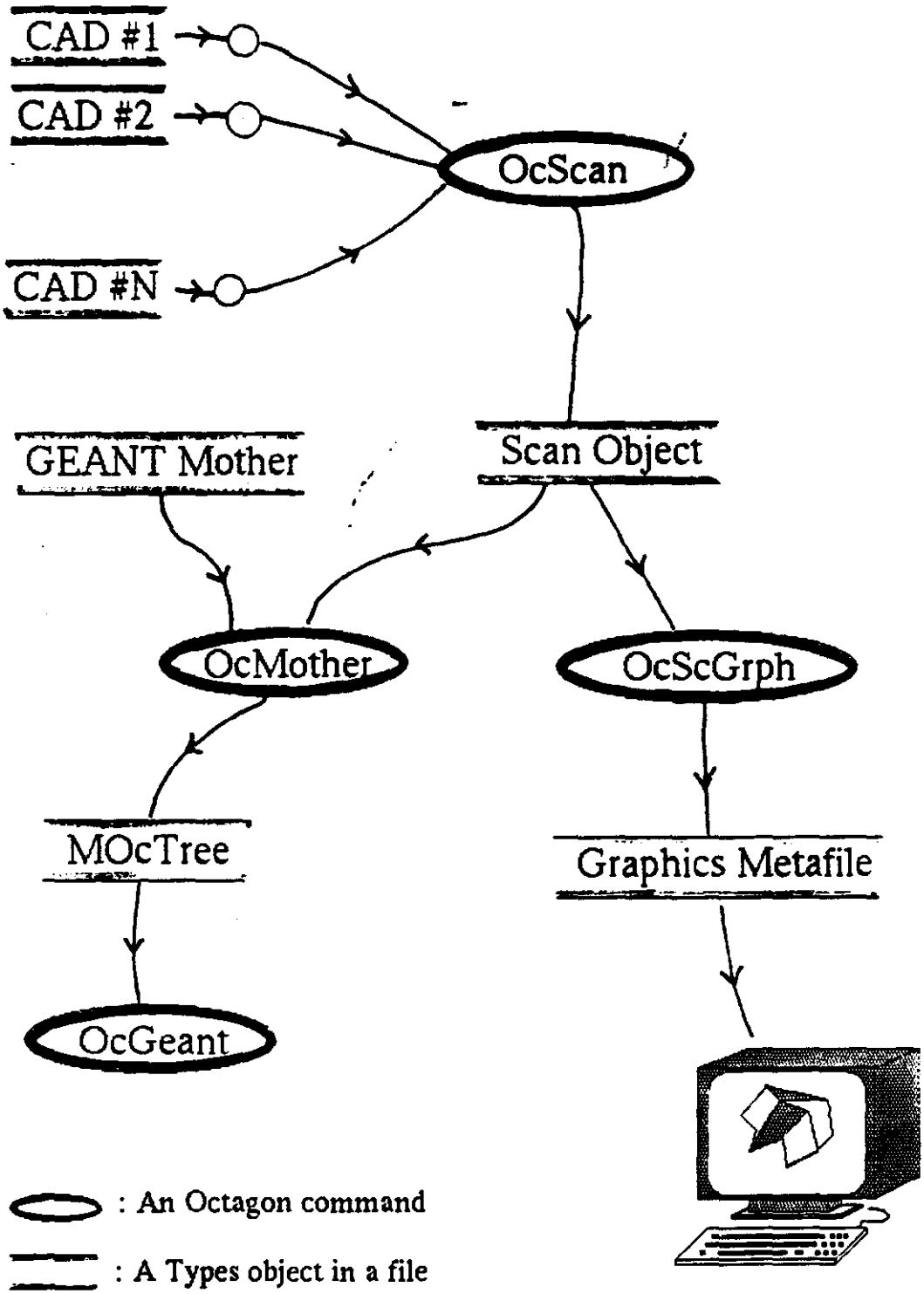
- Based on Octree concept: divide arbitrary volume into small "bricks" and build up GEANT model out of these
- Input is DXF file: other formats foreseen (e.g. I-DEAS solid models)
- Output is GEANT subroutine calls

- OCTAGON is not intended to translate full detector geometries from CAD to GEANT.
- It is designed for odd-shaped parts that are hard to build out of GEANT volumes but easy to sketch in the CAD system.
- These parts can be translated and then positioned into an already created GEANT geometry.

Two-dimensional Analogue of an Octree Analysis

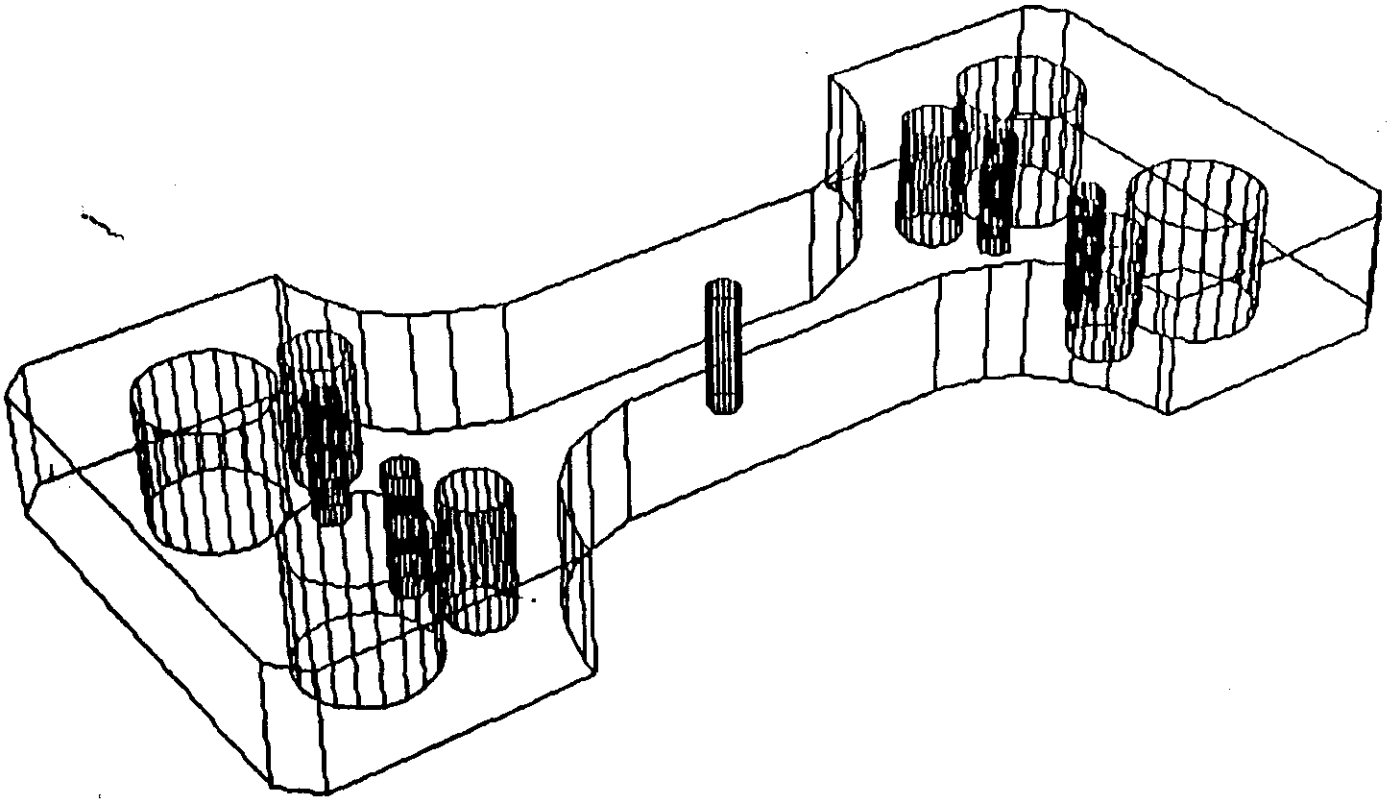


OCTAGON

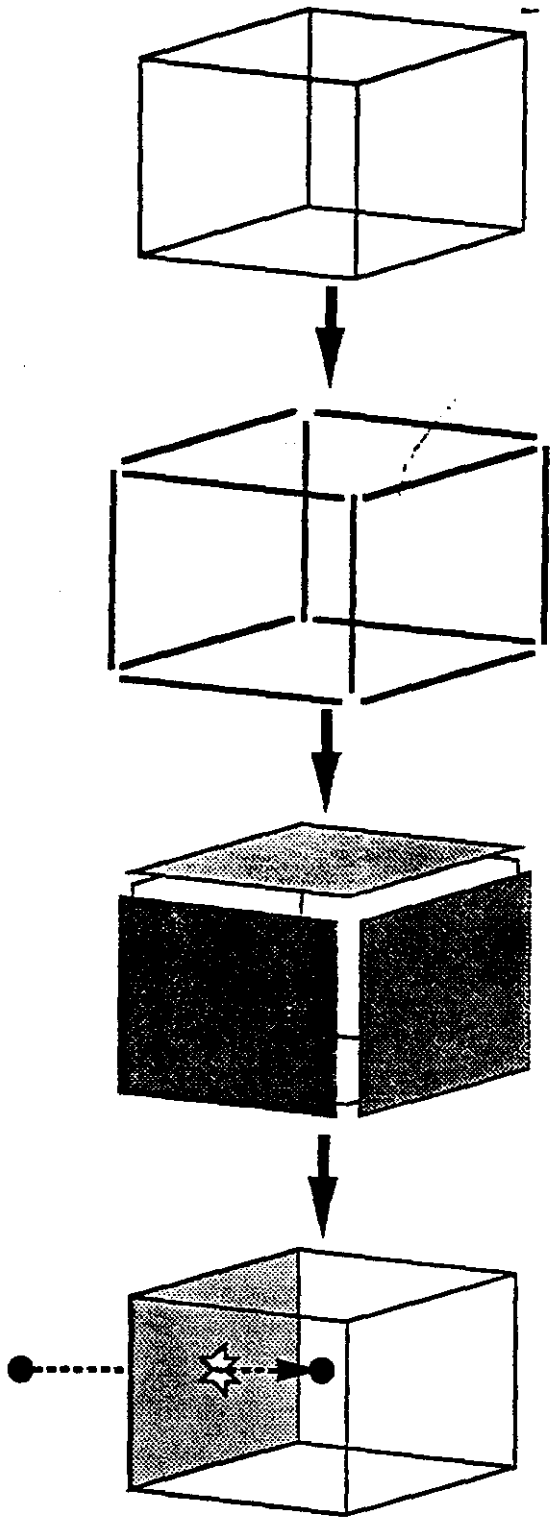

CAD #1
CAD #2
CAD #N
OcScan
Scan Object
GEANT Mother
OcMother
OcScGrph
MOcTree
Graphics Metafile
OcGeant
: An Octagon command
: A Types object in a file

File Camera Rendition Settings

dogbone.vcad



Making solids from wireframes



CAD model

Find line elements

Assemble lines into planes

Scan model and count plane crossings

Odd number of crossings means inside the object

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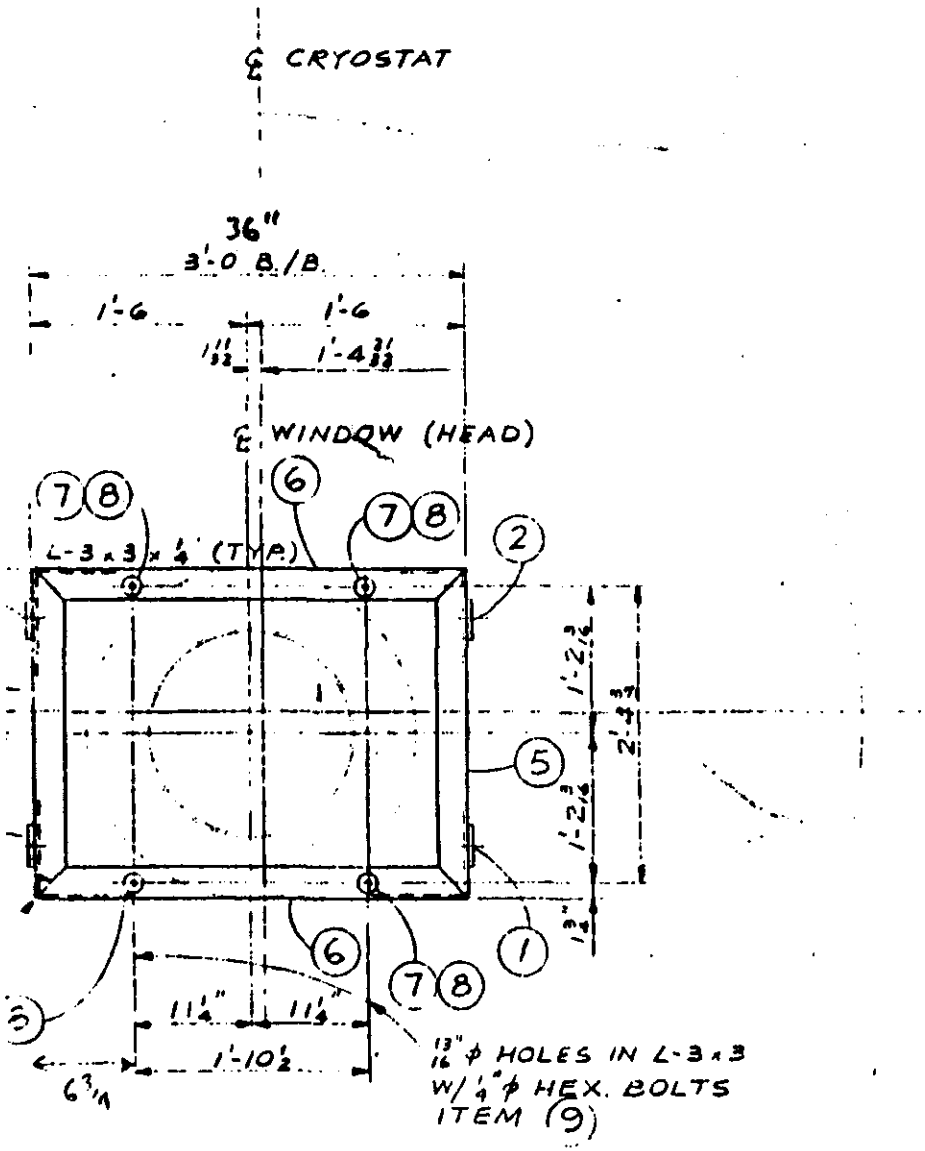
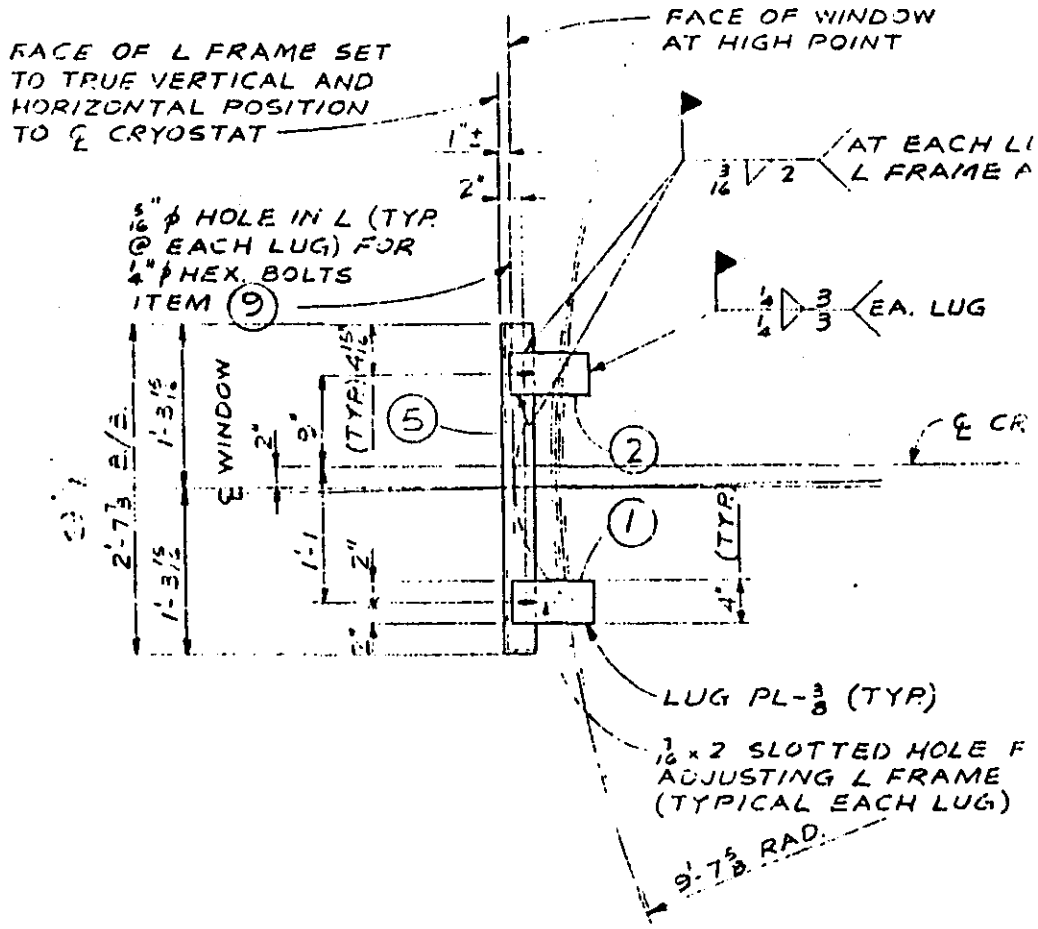
dogbone1.ascii Isosurface





SIDE VIEW

SCALE: 1" = 1'-0

File Edit Group Palettes Settings

Messages

VERSACAD®

Macintosh

EDITION

Version 2.1.1

Copyright © 1988, 1989 Versacad Corp.
All rights reserved.

OK

Credits

Coordinates

in (3. 7/64" , 19.45/64") ∂

File Edit Group Palettes Settings

Messages

invitro

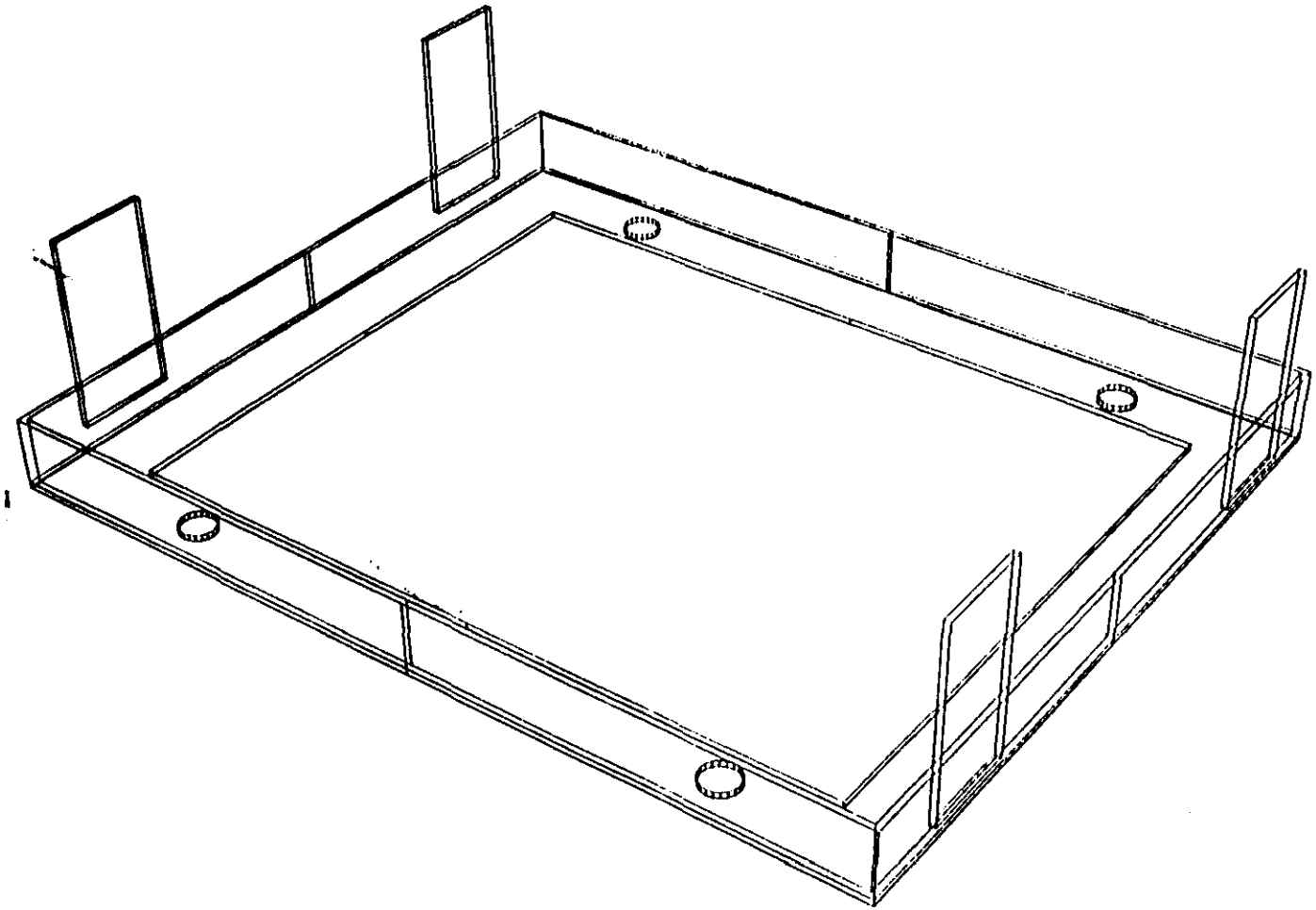
Properties

Level:	1	Density:	1	Z top:	0.2500	☐	Arrow
Pen:	1	Width:	1	Z bottom:	0.0000	☐	Marker
Color:	169	Style:	1	Name:	PWC Frame	☐	Template

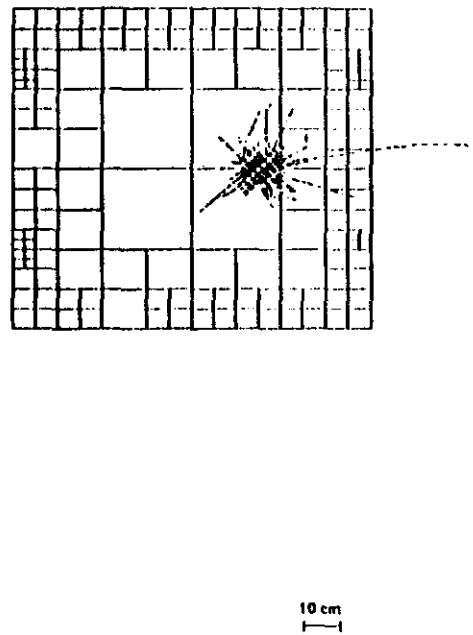
Object Default Revert

Coordinates

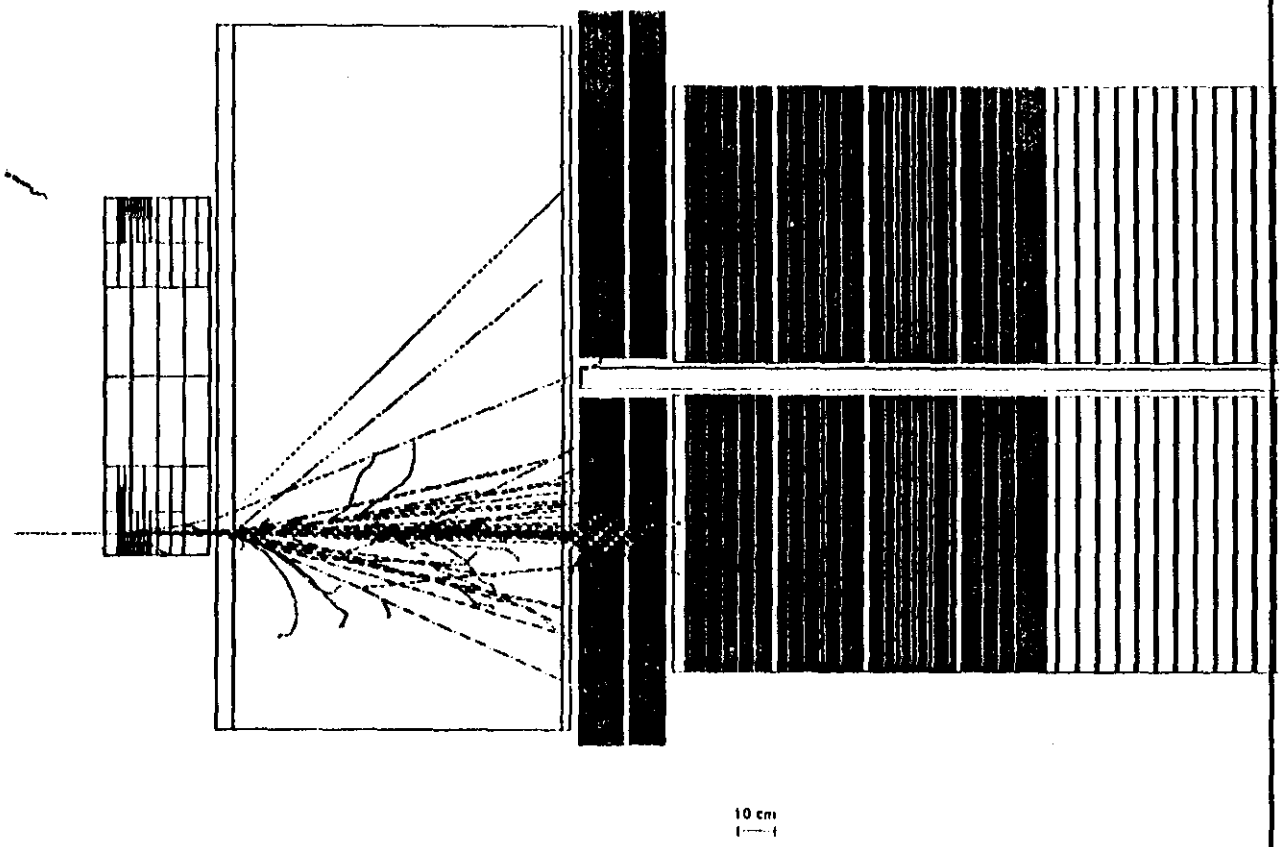
In [35.7236 , 8.1675]



D--Zero Test Beam 1990



D–Zero Test Beam 1990



CERN 'CADD' project

- CERN plans an interface between GEANT 3.16 and CAD using the French SET file exchange standard as a NFF.
- Around 1994 will switch to new ISO standard STEP.
- The main emphasis seems to be on the GEANT → CAD direction and persuading engineers to use GEANT to design detectors: requires development of GUI input for GEANT.

The USA 41293

Future Directions

- OCTAGON will continue to be enhanced.

- COGENT
  A proposal for continued development has been submitted to DOE.

- An interactive GEANT shape editor by customizing AutoCAD.

- <u>A modest proposal:</u>

  What's so special about GEANT?

  We can imagine building a simulation program of our own on top of a CAD system. The graphics and geometry are done already; the physics packages (GHEISHA etc.) are largely modular.

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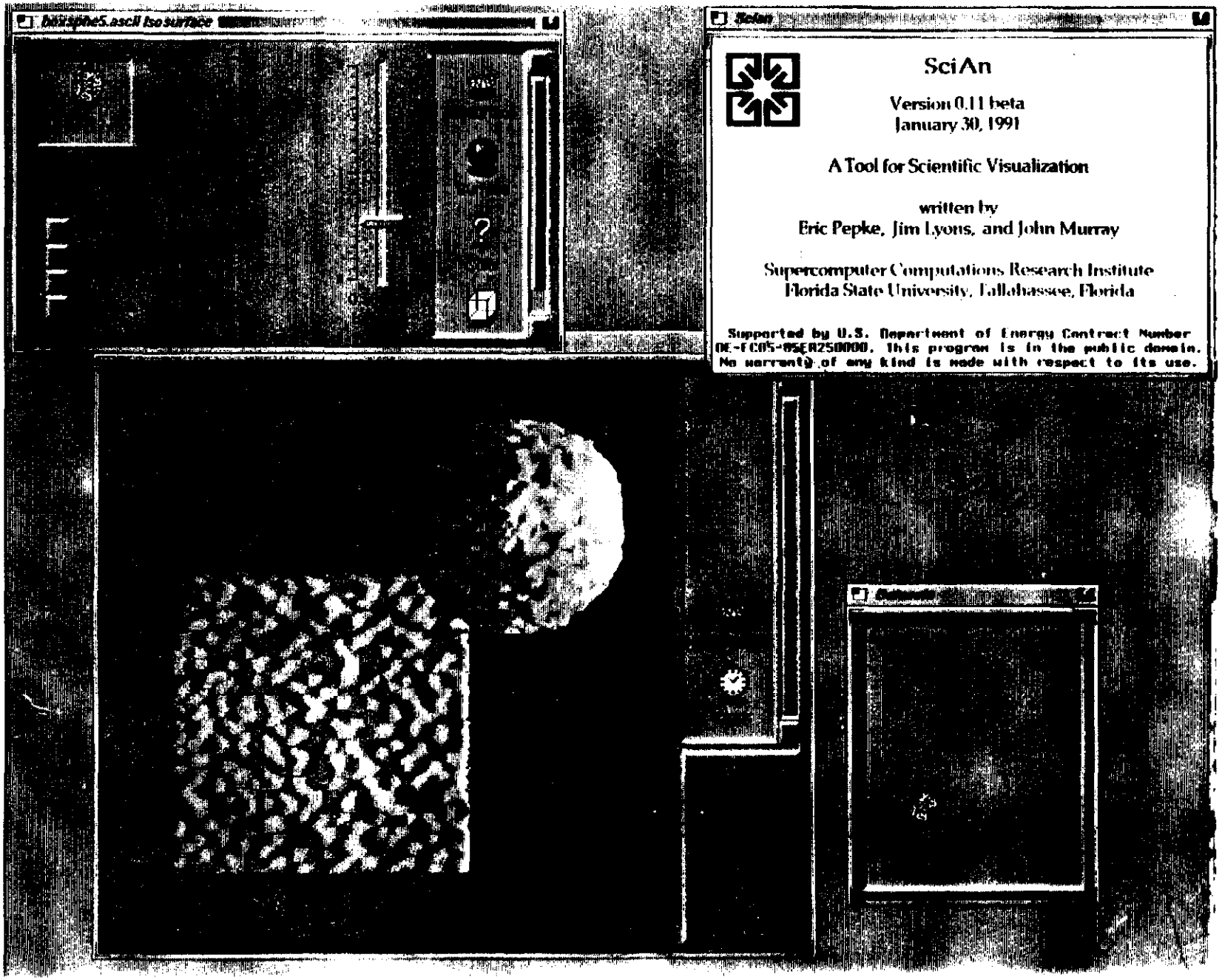

SciAn
Version 0.11 beta
January 30, 1991
A Tool for Scientific Visualization
written by
Eric Pepke, Jim Lyons, and John Murray
Supercomputer Computations Research Institute
Florida State University, Tallahassee, Florida
Supported by U.S. Department of Energy Contract Number
DE-FC05-85ER250000. This program is in the public domain.
No warranty of any kind is made with respect to its use.

GVERIFY
OCTAGON
SCIAN

Mail to Womersley
@ FSUHEP.PHYSICS.FSU.EDU

or Youssef @ SCRI.FSU.EDU

Useful SCRI Software Packages

- **SciAn**
  A package for 3D visualization

- **GVerify**
  A package to find errors in GEANT geometries

- **Types**
  A package for data abstraction in a machine independent way using Fortran

Presentation By:

E. J. Wolin

Thoughts on GEM Software

E.J. Wolin
Yale Univ

- Don't confuse <u>MEANS</u> and <u>ENDS</u>
- flexibility ⇐ simplicity
  → complexity localized or encapsulated
- central code mgmt - ? granularity
  - versions, releases, groups, etc - reservations, time stamps
- Networking -
- code distribution - "pull" vs "push"
- coding standards (!)
- common block distribution (languages?)
- ?? conditional compilation ??
- * Fortran 90 *

Simulations /GEMLIB

CMG (1)

Central Facility — PDSF + SSCUX1 + ?

1/20/92

- Operating Systems
  - Unix, various flavors
  - VAX/VMS
- Code management/distribution
  - Unix
  - (- CMZ
    - CMS/MMS)
- Generators and generator interface
  - HEPEVT
  - KINE
- Data Structures between phases of simulation

  ZEBRA
- File structures

  ZEBRA

  NTUPLES
- Parameterization storage

  ZEBRA?

  'Data base?'

  DØ shower library
- Conventions for coding

GEMLIB

- Packages of subsystem modules in separate (protected) directories for each version
- CERNLIB, GEANT libraries
- Isajet, Pythia versions (not CERNLIB)
- QFL, gflash available
- Interface modules between systems
- CPS support for multi-CPU versions
- Scripts / make (build) files to build combinations by defining a few parameters

'Package' can consist of:

- FORTRAN and documentation files in SCCS files
- CMZ or PATCHY files in protected directories

- Utilities to extract files
- New code on PDSF should use Unix tools (SCCS..)

Issues:

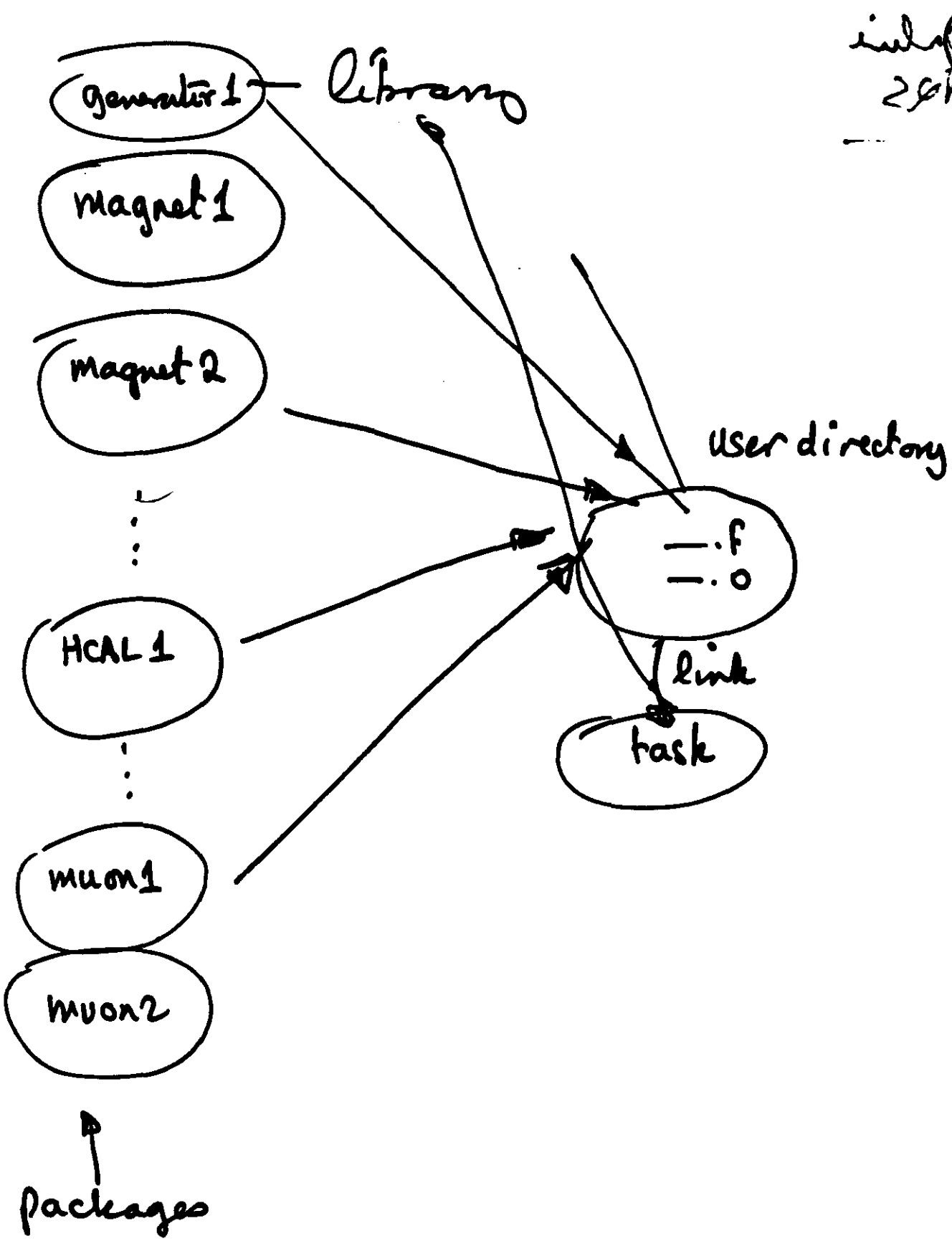
names of modules, variables....

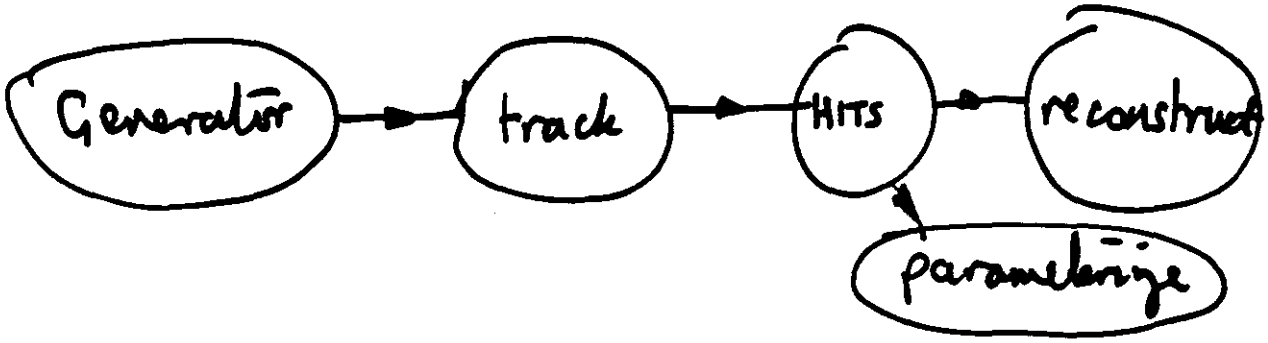
I/O in module

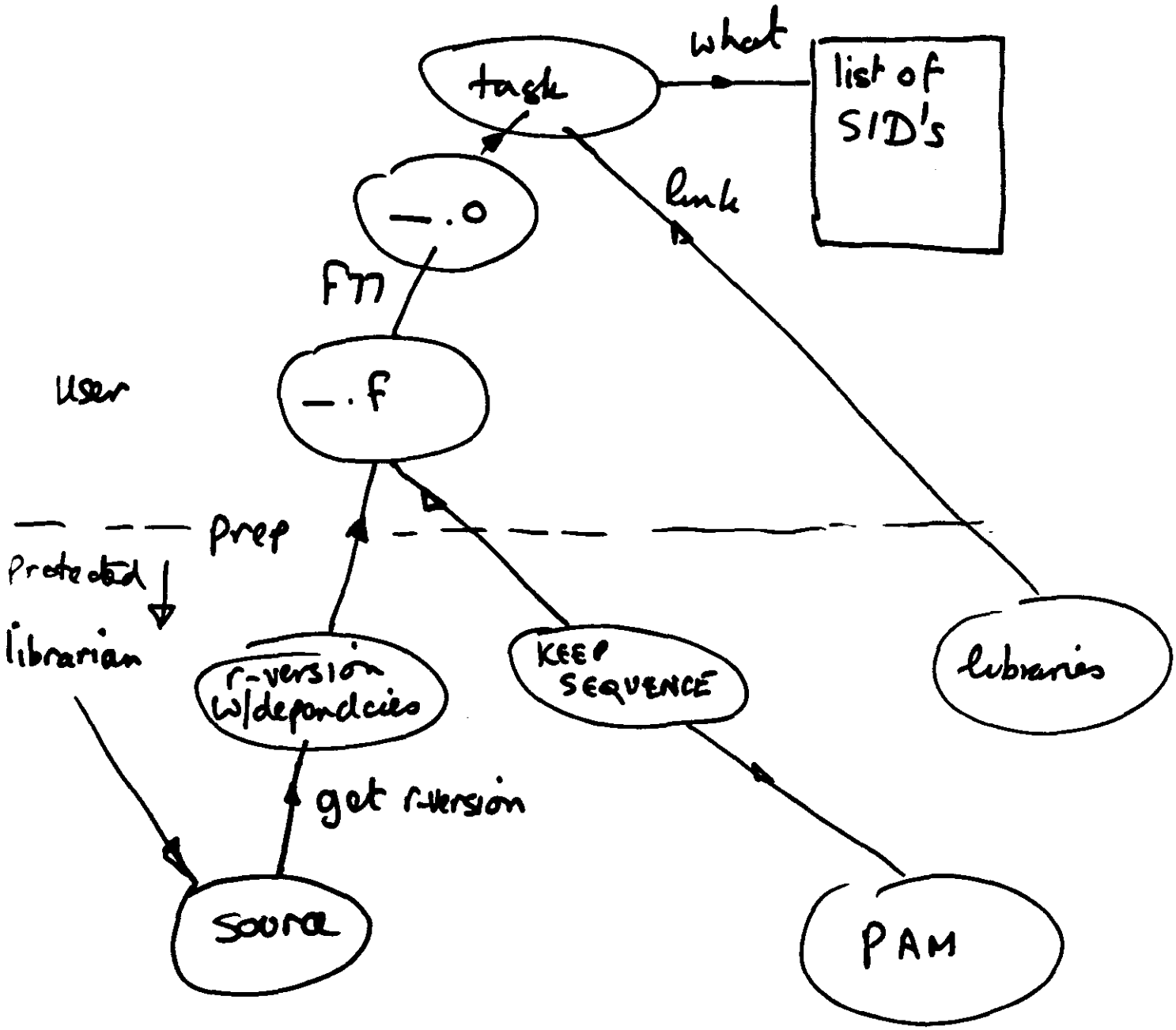
Histogram definitions

Reconstruction association -

forward muons / magnet


generator 1
library
magnet 1
magnet 2
HCAL 1
muon 1
muon 2
packages
user directory
.f
.o
link
task


Generator
track
HITS
reconstruct
parameterize


task
what
list of SID's
link
—.o
FM
—.f
User
prep
Protected
librarian
r-version w/dependencies
KEEP SEQUENCE
libraries
get r-version
source
PAM

GEMLIB software standards
Some tentative recommendations:
0. Unix and PDSF will be the basic opsys and central system.

1. F77 is the basic language, with extensions. particularly IMPLICIT NONE. There should be compatibility with C in naming conventions. Tabs shall not be included in F77 files. Variable names should not be split across lines. Hollerith constants should not contain the string /* (e.g. 4H,/*z not allowed).

2. 31-character names are permitted for external (global) AND internal names. External names include subroutine, function names and common block names. Names shall be significant in all positions. This is consistent with PDSF and F90. There will be a standard GEM header to modules.

3. Names should be mnemonic. 8-10 characters should be used in a standard way.
As a 'straw man' it is suggested that GEANT simulation subroutines, functions, common blocks, variables and volumes begin with two characters as follows:
GM -- overall GEM
CT -- Outer part of Central tracker
SI -- Silicon Vertex detector/tracker
PD -- Pad chambers
EC -- EM calorimeter
HC -- Hadron calorimeter
FC -- FOrward calorimeter
MU -- Muon system
MG -- Magnet system
L1, L2, L3 -- trigger levels
FE -- front-end
BP -- beam pipe
SC -- slow control
SS -- supports (where separate from other subsystems)

Subroutines with specific functions (geometry defn., hits, digitizing, reconstruction..) should include other two-character codes: GE, HT, DG, RC, AN.

Regions may be denoted by BR - barrel/central, CP endcap.

SO a routine that defines the geometry of the ECAL barrel might be:
SUBROUTINE ECGEBR(MOTHER)
where MOTHER is the name of the volume in which it is placed.
The volume name could be 'ECBR'

4. Alternate (F77) program versions (machine dependencies and purposes) are to be handled using the C preprocessor, with limitations. The basic use is for file and line inclusion/exclusion. Changes of constant values should be done with care to ensure that line length is not changed to an improper length. This can be ensured with use of the PARAMETER statement.

5. Packages and routines will be put in subdirectories, using SCCS to ensure appropriate protection and version numbering. Utilities will be provided for convenient access to these files. 'Flat' FORTRAN are perfectly acceptable -- the people providing the routines need make no special effort. Files and version will be stored in appropriately named and protected subdirectories. E.g.

```
          gemsm
            I
      ____________________________
      I              I                I
    v21            v22             README
 files.f        files.f
```

More sophisticated ways of providing versions will evolve. Each 'provider' or donor is expected not to alter versions already provided/shared.

Suggestions are welcome on this interim suggestion.

BRIEF DESCRIPTION OF SOFTWARE PACKAGES IN DEVELOPMENT AT ARIZONA

Michael Shupe
Univ. of Arizona
January 16, 1992

I. HSCRIPT - A standalone histogram package with CERNLIB HBOOK entry points. This package is very small and fast. If disk output is requested (by HRPUT, for example), it produces an ASCII disk file of the histogram descriptions and contents. This file may be read back on any machine without conversion. Routines are provided for reading this ASCII file. Alternately, a program HCONVRT may be run to produce a standard HBOOK file.

Status: In use for more than 6 months to create histograms on SGI machines and read them on Vaxes.

II. SIMPLE_GRAPHICS - A small graphics language, similar to GL and DI-3000 in its graphics primitives, which supports displays on SGI workstations, Vax workstations running DECWindows or UIS, and Tektronix terminals. For hardcopy, there are POSTSCRIPT, Tektronix, and QUIC drivers, both color and black and white. 3D graphics image manipulation is supported on the SGI machines.

Status: Most features working. UIS and QUIC still in development. In use for two months.

III. MENUS - A standalone package to do popup menus on SGI workstations, and Vax workstations running DECWindows or UIS.

Status: In use for two to three months. Usable now. Features being added.

IV. HISTOGRAMS - A workstation and hardcopy histogram plotting package which may be linked with CERNLIB HBOOK or HSCRIPT and which utilizes the SIMPLE_GRAPHICS and MENUS packages above to display histograms. This package has many of the features one uses most frequently in PAW, but is small enough to be run with online applications.

Status: Usable now for histogram viewing and POSTSCRIPT hardcopy. Features being added and debugged.

V. SIMULATOR - A simulation shell using all of the above facilities which presents a menu of physics benchmark processes and allows one to generate events from ISAJET, PYTHIA, or HERWIG. The events are put into the standard /HEPEVT/ common for further analysis within the frame. The current benchmark menu is as follows:

Minimum Bias
QCD with Pt Threshold
Direct Photons
Direct Di-photons
t-tbar to All
t-tbar to 6 Jets
t-tbar to 1 Lept 4 Jets
t-tbar to 2 Lept 2 Jets
W (Wprime) Pairs to All
W (Wprime) Pairs to Lepts
W (Wprime) Pairs to Jets
W (Wprime) Pairs to L/J
Z (Zprime) Pairs to All
Z (Zprime) Pairs to Lepts
Z (Zprime) Pairs to Jets
Z (Zprime) Pairs to L/J
Higgs to All
Higgs to 4 Chrged Leptons
Higgs to 2 Ch Lept 2 Nu
Higgs to 2 Ch Lept 2 Jet
Higgs to 1 Ch Lept 2 Jet
Higgs to Gamma-Gamma
Drell-Yan to WZ
b-bbar production
Particle and Jet Gun

Pt limits may be set, and pileup events generated. Also available, and under development, are various toy detector subsystems, analysis routines, and displays.

Status: The package currently generates most benchmarks from ISAJET and PYTHIA. The HERWIG setups are being debugged. We will be plugging the forward calorimeter simulation routines into this framework to do jet resolution and pileup studies.

SIMPLE_GRAPHICS

The Minimal Graphics Language

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January, 1992
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Complicated graphical displays can be created from a very small set of drawing primitives. SIMPLE_GRAPHICS attempts to reduce this set to a bare minimum. The resulting package is small and fast, and can be learned in a few minutes by anyone who has used another graphics language. SIMPLE_GRAPHICS operates on Tektronix compatible graphics terminals, Vax workstations running DECWindows or VWS (UIS), and Silicon Graphics workstations (GL). Hardcopy drivers exist for Postscript, Tektronix, and QMS (Talaris), with and without color.

Some of the entry points in SIMPLE_GRAPHICS look like GL entry points, and others, like DI-3000. Converting existing routines in either language frequently involves only a few minutes of "global" editing to the new entry points. What this then buys is device independence, public domain software prices (free), and new capabilities (such as hardcopy files on the Silicon Graphics machines).

The routines are contained in a few files:

1. SIMPLE_GRAPHICS.FOR - Common primitives and hardcopy drivers.
2. SIMPLE_FONTS.FOR - Basic (CDF) stroke fonts.
3. FANCY_FONTS.FOR - Extended font set with Greek, script, et.
2. SIMPLE_GRAF_VAX.FOR - Vax versions of some routines.
3. SIMPLE_GRAF_DECW.FOR - Vax DECWindows routines.
4. SIMPLE_GRAF_UIS.FOR - Vax VWS (UIS) routine.
5. SIMPLE_GRAF_SGI.FOR - Silicon Graphics versions of some routines.
6. SIMPLE_GRAF_GL.FOR - GL versions of some routines.
7. GRF_CTRL.INC, GRF_COLRS.INC, GRF_COLRS_DATA.INC - The commons.

Demonstration programs (with link files) are also provided which which exercise all features of the language: DEMO_GRAPHICS.FOR and DEMO_GRAPHICS.LNK.

THE SIMPLE_GRAPHICS LANGUAGE

1. Opening a window and positioning it on the screen (must call):

```
CALL OPEN_WINDOW(IDEVIC,TITLE,XLO,YLO,DX,DY,ICOLOR,IORIE,IERR)

IDEVIC - 0 = Current workstation or terminal (DECW, UIS, SGI, etc)
         1 = Postscript hardcopy
         2 = Tektronix hardcopy
         3 = Tektronix terminal
         4 = QMS hardcopy
 TITLE - Character string for window title
 XLO,YLO,DX,DY - Origin and width of window on screen (range 0.to 1.
 ICOLOR - 0 = Black and white, 1 = Color
 IORIE  - 1 = Landscape , 2 = Portrait
 IERR   - Negative if error encountered during OPEN_WINDOW
```

2. Defining the world coordinates of the window corners (must call):

```
CALL WINDOW_CORNERS(WXLO,WXHI,WYLO,WYHI)
```

3. Selecting a viewport placing these corners within the window (opt):

```
CALL VPORT_D(VXLO,VXHI,VYLO,VYHI)   (range and defaults -1. to 1)
```

4. Drawing primitives:

```
MOVE_D(X,Y,Z),          and RMOVE_D(X,Y,Z)   (for relative)
DRAW_D(X,Y,Z),          and RDRAW_D(X,Y,Z)   (for relative)
RECT_D(X1,Y1,X2,Y2),    and RECTF_D(X1,Y1,X2,Y2)  (filled)
CIRC_D(X,Y,Z,R,NSEG),   and CIRCF_D(X,Y,Z,R,NSEG)  (filled)
PLIN_D(N,ARRAY)  for poly-line of N points in ARRAY(3,N)
POLY_D(N,ARRAY)  for closed polygon, POLF_D for filled
CLEAR_D          Clear the screen to the current color
```

5. Defining attributes:

```
COLOR_D(N)       Set the drawing (or filling) color to N
DEFLIN_D(N,LS)   Define a new linestyle N with bitpattern LS
SETLIN_D(N)      Select linestyle N
LINEWI_D(IW)     Set the line width to IW pixels
```

6. Transformation operations:

```
ROT_D(A,AX)      Rotate by A degrees about axis AX = 'X','Y','Z'
SCALE_D(X,Y,Z)   Magnify the world coordinates by scales X,Y,Z
TRANSL_D(X,Y,Z)  Translate in world coordinates by X,Y,Z
TRESET_D         Reset the matrix for all of the above to unit.
```

(SIMPLE_GRAPHICS language continued)

7. Mouse operations:

```
MOUSE_WAIT(XMOUSE,YMOUSE)  Wait for mouse click and return X,Y
MOUSE_READ(XMOUSE,YMOUSE)  Read mouse X,Y on the fly
SET_MOUSE(IMODE)   IMODE = 1  X,Y in world coords
                         = 2  X,Y in screen coords
                         = 3  X,Y in screen fractions
```

8. Fonts and character strings (drawn at current X,Y,Z):

```
STCHAR(STRING)    Write a stroke font string
STBASE(VX,VY,VZ)  Write along the baseline direction VX,VY,VZ
STPLAN(VX,VY,VZ)  Put the characters in the plane containing VX,VY,VZ
STJUST(IH,IV)     Justify the strings in the horizontal and vertical
                  1 = left or bottom, 2 = center, 3 = right or top
STSIZE(XS,YS)     Set the X and Y character size in world coordinates
STFONT(N)         Select font N (odd fonts italicized):
                  -1 = Hardware raster font
                  0  = Simple stroke font
                  2  = Boldface simple
(Fancy fonts)     4  = Roman
                  6  = Greek
                  8  = Script
                  9  = Old English (C'est vrai!)
                  10 = Math and symbolic
                  100 = Display a font table in current window
```

NOTE: THIS LANGUAGE CONTAINS NO GRAPHICAL OBJECTS. All refreshes must be done by redraw operations. However, on machines with 3D graphics hardware, the following facilities are provided to allow for a number of interactive manipulations of the image on previously drawn images:

```
STORE_D    Start creation of the object at this point
STATIC_D   Starting here, this portion of the image will not
           respond to interactive manipulation
MOBILE_D   Starting here, this portion of the image will respond
           (may be used alternately with STATIC_D)
SPINMEN_D  Call up a menu for doing SPIN, ZOOM, MOVE, ROLL, etc
           on the mobile parts of the image
```

SUGGESTIONS ON CODE MANAGEMENT, CODE COMPATIBILITY, AND DATA FILE STANDARDS FOR GEM

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January 12, 1992

Our operation of Vax VMS and Silicon Graphics Unix clusters at the University of Arizona has lead to a number of procedures yielding programs which run without modification on either machine, and make it unnecessary to convert, "port", or otherwise manage the code. This experience is the basis for a number of the following suggestions. Other suggestions are inspired by experience with D0 code and on some contact with the SDCSHELL package.

I. Code Management by Directory and Copy:

We suggest that the code be maintained without the use of any code management or development tool such as PATCHY or CMS. The subdirectory structure of VMS and Unix machines allows all the flexibility one needs to maintain production, old, and new versions of routines in areas such as [GEMLIB.CALORIM.OFFLINE.PRO] , .OLD], or .NEW] under VMS and /gemlib/calorim/offline/pro, /old, or /new under Unix. By setting up logicals in VMS or links in Unix, one may choose to link with libraries or object files in any sequence and combination of these areas.

Specifically, these areas are filled with *.FOR, *.INC, *.COM, *.LNK, and *.OLB files; or *.f, *.inc, *.inp, *.lnk, and *.a files. As will be outlined below, the source files residing in these areas may be written in "vanilla" FORTRAN, with no loss of flexibility. Porting the code then consists of simply copying the files or entire directories from one machine to the other, or of NFS co-mounting the libraries so that both VMS and Unix machines have access to the same disk.

As in all code management schemes, the whole system relies on the "Czar's" of the various libraries to insure that their versions are operating on internal tests and are synchronized with versions in other libraries. And as in other systems, there would be periodic global shifts of interrelated libraries from NEW to PRO to OLD, where these shifts could only be done after a set of certification tests had been passed.

The problem with existing code management systems is that you don't get something for nothing, and too often we are getting nothing for something. PATCHY is arcane and antiquated. Like most CERNLIB facilities, it must be operated with an open manual. One either stays fluent in its operation, or periodically loses half a day trying to wrestle it into operation. CMS is a whole universe unto itself. When combined with the power of VMS logicals, it frequently

leads to programs whose most current operating versions can only be built on one particular cluster where the code is being developed. Because the number and hierarchy of alpha, beta, and standard release libraries proliferates, one gets frequently trapped by being able to pick up versions of routines from the wrong library.

The way to avoid the confusion of too much flexibility is to have tight communication among the Czars and to maintain no more than a three level structure, with tape archiving of versions which drop out of OLD. Those libraries which need distribution can either be "pushed" D0 style to subscribers, so that clusters not at the SSC lab have images of the SSC GEMLIB, or release notices could be circulated for those users who would rather copy their own libraries. One also has the choice of distributing library files, or just source files with "build" procedures.

II. Writing Vanilla FORTRAN

Our experience to date is solely with Silicon Graphics machines, so we cannot be certain that the following statements apply to SUN and IBM machines. However, we feel that the issue of code porting is serious enough, in terms of the drain on human resources and the time lag in program versions, that the possibility of writing code which can be run without conversion on all machines should be pursued.

1. The bulk of FORTRAN 77 code that we write for the Vax works "as is" on the SGI. This is not a scientific statement, and doesn't span the space of possible traps, but for example, all the IF, ENDIF, DOWHILE, etc, statements one might use to make FORTRAN look more like PASCAL are available.

2. One must be careful on the SGI that array boundaries in common blocks come out in the right phase. For example,

```
      COMMON/MYCOMN/MYBYTE(NB),MYWORD(100)
```

where MYBYTE is CHARACTER*1 for example, is fine if NB is 4,8,12,..., but will foul up the phase of MYWORD for INTEGER*4 addressing otherwise.

3. Some places where VMS allows logicals will not work in Unix. The most common one we encounter is the INCLUDE statement. In D0 VMS code, the construction INCLUDE 'D0$INC:MYINC.INC' is used, where D0$INC might be a logical which could itself span several lines pointing to different areas where .INC files reside. We now use the form INCLUDE 'myinc.inc', and keep the include files local. Under Unix, myinc.inc could be linked externally to a files in a subdirectory if one desired.

4. String argument passing is different under Unix, which does not pass the string length as an argument. This causes one to have to break things up a bit to be compatible. For example:

```
      CALL DOSTRING('This is just'//' a sample of the mess')
```

would need to be broken up into

```
      CHARACTER*N CTEMP
      ...
      CTEMP=' one can get into'//' fooling with strings'
      CALL DOSTRING(CTEMP)
```

5. Byte ordering is different on the SGI. If the Vax is ordered 1234, the SGI is ordered 4321. Normally this would be invisible, but sometimes in unpacking raw data or flag words written on one machine and read by the other, one runs into this. We handle this by having a logical SWPBYT in a controlling common. As part of initialization, one establishes what machine the program is being run on, and what machine the data was written on to determine whether bytes should be swapped or not. In general these swaps occur very infrequently in analysis code.

6. Disk and tape file management routines (OPEN, CLOSE, etc) are not identical in VMS and SGI Unix, but for most applications the same statements can be used on both machines. Once again, the usual exceptions involve files crossing machine boundaries.

III. ZEBRA, and CERNLIB utilities in general.

CERNLIB has the advantage of being an international standard known and used by many people. It has the disadvantage that many of its procedures are large, slow, poorly documented, antiquated, and user-hostile. Among other things, its graphics capabilities are poorly matched to the power of modern 3D graphics workstations. And we suspect that following each release, as much effort is expended on this side of the Atlantic by research groups seeking to get the latest version running as was expended on the other side in creating it.

Currently, ZEBRA appears to be the best way to write and read data tapes in a machine independent fashion, either by employing exchange mode or by using ZFTP to do the conversion. However, it is our opinion that the use of ZEBRA in internal calculations leads to several forms of programming disaster:

1. The access to information in ZEBRA commons does not lead to readable code. A typical line of D0 ZEBRA code looks like:

```
LMUON=LQ(LPMUO-IQ(LPMUO-2)-2)
```

The pointer structures necessary for rapid access to ZEBCOM are very difficult to debug.

2. Programmers who embrace the ZEBRA structure tend to use its facilities to book, fill, clear, and compress temporary banks used for calculations internal to their routines. These facilities have not been cleverly realized, and the time and space penalties for using these features without an expert level awareness of the way they function can make programs large and slow.

3. There is typically an overhead of a couple of dozen words associated with each bank. Sometimes convenience causes programmers to make many banks, as if banks were as available as array elements, and what gets stored internally or written to disk becomes more packing than contents.