SDC-91-00030

SDC
SOLENOIDAL DETECTOR NOTES

RATES IN THE SDC MUON CHAMBERS AND OPTIMAL DESIGN

A. Kulik

Alexei Kulik 28.4.91, SSCL, Dallas SDC-91-00030

Rates in the SDC Muon Chambers and Optimal Design

This is a crude estimation of the rates in muon system. It contains also an attempt to optimize design with respect to muon rates. Attention is paid mostly to the forward direction: 1.6 < ETA < 3.

There are several different sources of charged particles in the muon chambers. One of them is the muons which are hard enough to penetrate the calorimeter. This was estimated by Y.Sakai[1] and me[2]. The two results are similar: 10MHz outside the calorimeter and 500KHz outside the steel toroids (at 10**33 luminosity). Here I present a full GEANT/GHEISHA simulation although with a simplified detector model.

GEANT SIMULATION

Two-jet events were simulated with the ISAJET code, 5 < jet Pt < 50 GeV. The cross section of this process is about 100mb, slightly dependent on ISAJET version.

The simplification of the detector model is as follows: calorimeters are structureless, they are just the bulky pieces of material. The material is a mixture of iron and plastic with a density of 5.5, radiation length 2.65 cm, and nuclear absorbtion length 26.4 cm. May be it is not an optimal proportion, I don't know. The same approach was taken for the chambers and central tracker.

Another simplification deals with the forward calorimeter. My former experiance in EMPACT shows that the backsplash from the forward calorimeter does not matter very much. So the optimization study was made without it. The influence of the forward calorimeter was studied separately and was shown to be not crucial.

Shielding (Absorber) geometry was modified slightly as compared to LoI design: its inner surface has a radius 10 cm more than in the projective design. This is done to make the absorber invisible from the IP and by this means to avoid particles going directly from IP to absorber. This design is similar to one worked out by the muon integration group 91/4/17 (see Fig.1).

In order to get a good idea of the optimal absorber thickness the following software trick was done. Absorber was divided to 7 layers: 4*5 + 3*10 cm thick and rate was watched in each layer separately, as to see how fast it decreases with thickness.

Standard energy cuts for GHEISHA were applied: 10MeV for hadrons and 1MeV for electrones and gammas.

The program running on VAXSTATION 3100-38 takes about 8 mins/event without forward calorimeter and about 40 mins/event with it.

THE MAIN BACKGROUND SOURCE

Let us consider all charged particles coming to the inner absorber surface. Fig.2 a), b) show where do they come from, the axes are Z and radius of a vertex. The conclusion is that 92% of them come from the vacuum pipe wall. Here and throughout of this

paper the vacuum pipe is assumed to be made of Aluminum 1 mm thick. The other 8% come from scattering in the air and decays. Hadronic punchthrough is negligible, which agrees with [1] and contradicts a wide-spread prejudice. Fig.2c) showes the energy of hadrons coming from the primary vertex and hitting the front face of the end-cap calorimeter. Why should there be any significant punchthrough for a 12 Lambda calorimeter?

CONCLUSION # 1: THE VACUUM PIPE DESIGN IS EXTREEMLY IMPORTANT

PROJECTIVE PIPE DESIGN

Why the interactions in the pipe wall are so significant? Obviously this is due to the very small angle: if a particle traverses a 1 mm wall at an angle of 2 mrad (2 cm at 10 m) it sees a half-of-meter of Aluminum and that's a lot. The next step was to change the vacuum pipe shape and to make it more close to projective one. For this design the probability to hit 1 mm thick wall at few meters distance should be small. The pipe shape was taken form [3], no optimisation done for the moment. Fig.2d) is similar to b) but for projective pipe, it showes the pipe shape well. Still the pipe role is a dominant one: 75% of interactions take place in the pipe wall.

For the case of projective pipe design, particles hit the shielding at smaller angles: compare Fig.3 a) and b). This has a very clear geometrical reason: the source is located predominantly at 2.5 m from IP (see Fig. 2d). For this reason shielding should be more effective.

About 90% of charged particles, hitting the shielding are electrones. The energy spectrum of hadrons (together with muons) is shown in Fig.3c). This gives an idea of how good the absorber should be.

Fig.4 gives the comparison of two pipe designs in terms of rate vs. absorber thickness. The gain is an order of magnitude. The words "Muon Level" on Fig.4 show roughly the rate of muons coming through the end-cap calorimeter. So a good design should bring the flux of other charged particles down to this level or less. It should be noted that a 50 cm thick absorber is not enough for conventional pipe design while it is adequate for projective one.

CONCLUSION # 2: PROJECTIVE PIPE IS MUCH BETTER

ABSORBER

A lead absorber was considered till now, but iron is cheaper and better mechanically. What can one expect from iron? Almost the same. In both cases the absorber has more than enough radiation lengths to absorb an electromagnetic component. As to hadrons and muons, these two materials are very similar to each other in nuclear absorption length and dE/dx. Fig.4 showes this comparison. The difference is not very big.

The crazy idea to magnetize an iron absorber was checked also. When entering an absorber which is magnetized in the longitudinal direction, charged particle starts a helix-like motion which increases the path. That is true, but appears to be unimportant for a field of reasonable strength. From Fig.4 one can see some indication that a magnetized absorber is better at its maximum depth but this is not significant statistically: 3 events against 10.

Another exotic possibility, a Tungsten absorber, was studied also. The summary of pipe design/absorber studies is given in Fig.4 and Tables 1,2. Table 1 contained rough data while Table 2 has the rates normalized to the number of events.

CONCLUSION # 3: IRON IS ABOUT AS GOOD FOR ABSORBER AS LEAD.

CONCLUSION # 4: TUNGSTEN ABSORBER CAN BE MADE OF HALF AS THICK AS AN IRON/LEAD ONE.

FORWARD CALORIMETER

In the new SDC drawing of 91/4/17 the forward calorimeter is pushed closer to IP as compared to LoI. I don't know whether is it possible to withstand the double radiation doze or not, but as to the muon chambers this it is OK. FC works as a plug protecting everything behind it. To emphasize this idea I have changed a little its design (see Fig.5). First, I made it 3 meters thick instead of 2 meters. Assuming the material mentioned above this is 12 absorption lengths. Second, this last meter has cone-shaped hole to collimate the products of interaction. I don't know how important are these two changes, it should be checked.

Fig.6 showes the distribution of the entrance point of charged to the shielding along the beam-line. The curve "No Forward Calorimeter" corresponds to the study presented above while the other curve includes FC. Both curves are normalized to one interaction in the IP. The FC position is shown by the arrow. Surely, FC stops everything. The excess of the rate upstream of the FC is due to backsplash, it is not very large, so the pipe shape/absorber study done without it is reasonable.

CONCLUSION # 5: FORWARD CALORIMETER IS A GOOD PLUG.

CONCLUSION # 6: BACKSPLASH FROM THE FC ADDS ABOUT 30% TO THE INTERACTIONS IN THE BEAM PIPE.

GAP

The new drawing has a 1 meter-wide gap between the barrel and endcap toroids for cabling and personal access. This gap doesn't affect chambers rates much. On the sample of 200 events they have: FW4 - 0 hits, FW5 - 0 hits, BW2 - 0 hits.

CONCLUSION # 7: THE GAP IS NOT DANGEROUS FOR THE CHAMBER RATES.

PROPOSAL OF A NEW ABSORBER DESIGN

It follows from above that the most important part of the absorber is the about 3 meter long piece between the endcap calorimeter and the first toroid. This piece may be done of 25 cm thick Tungsten saving space for light absorber against neutrons (see later) or for chambers acceptance. The part which corresponds to the toroid may be easily removed because toroids themselves are good absorbers. The last part (behind FC) is not very important and may be done of 30 cm thick steel. This design is shown in Fig.7. The amount of Tungsten is about 100 tons for each arm.

FUTURE PLANS

Charged particle flux across the absorber at different depths was used as a criterium till now. But not all of these particles hit muon chambers because of various reasons. For example a particle can be absorbed in the steel toroid or go between chambers at large angle. So the actual chambers rates should be lower than just the flux penetrating absorber. I guess these two values are to some extent proportional to each other and the proportionality coefficient should be determined.

Pipe shape optimization should be done taking into account accelerator requirements, mechanical stability, fabrication feasibility, etc...

PROBLEMS

Two problems are obvious now. First is the slow neutrons. The flux of neutrons above the energy threshold of 10 MeV is rather low: about 1 neutron/interaction in two first chambers and much lower in the last chambers. But how many of them are below this threshold? These slow neutrons can convert to protons in a chamber increasing the rates. GHEISHA code does not deal properly with slow neutrons and this is why it becomes really a problem. Another transport code should be used.

The second problem is the trigger. Even in a simplified model without FC this (or similar) code yields about 200-250 events/day which is too slow to get to the actual trigger rate.

REFERENCES

1. Yoshihide Sakai, KEK. "Muon Trigger Rates and Momentum Resolution Calculations".
2. A. Kulik. "Muon Rates in the SDC Forward Muon System". (comes as appendix to present paper)
3. A. Kulik. "Forward Muon Rates and Shielding" EMPACT note 330 (1990).

Def.	cm.
μFW1	32
μFW2	64
μFW3	32
μFW4	52
μFS4	15
μFC1	200
μFW5	80
μFS5	15

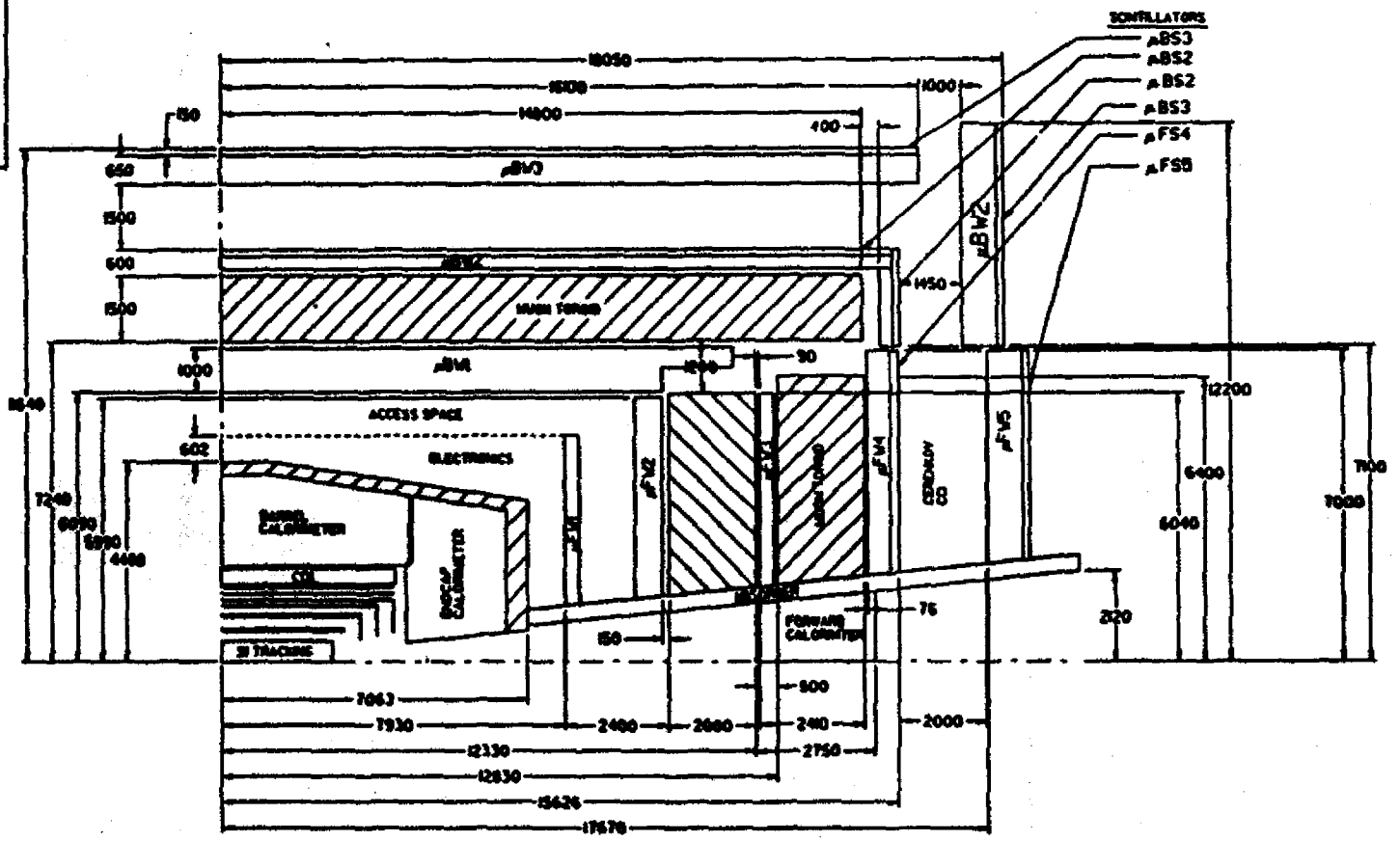


Fig.1

Fig.2. a), b): the origin of chrged particles which hitting the shielding
c): the energy spectrum of hadrons from IP hitting the endcap calorimeter;
d): the same as a) and b) but for projective beam pipe design.

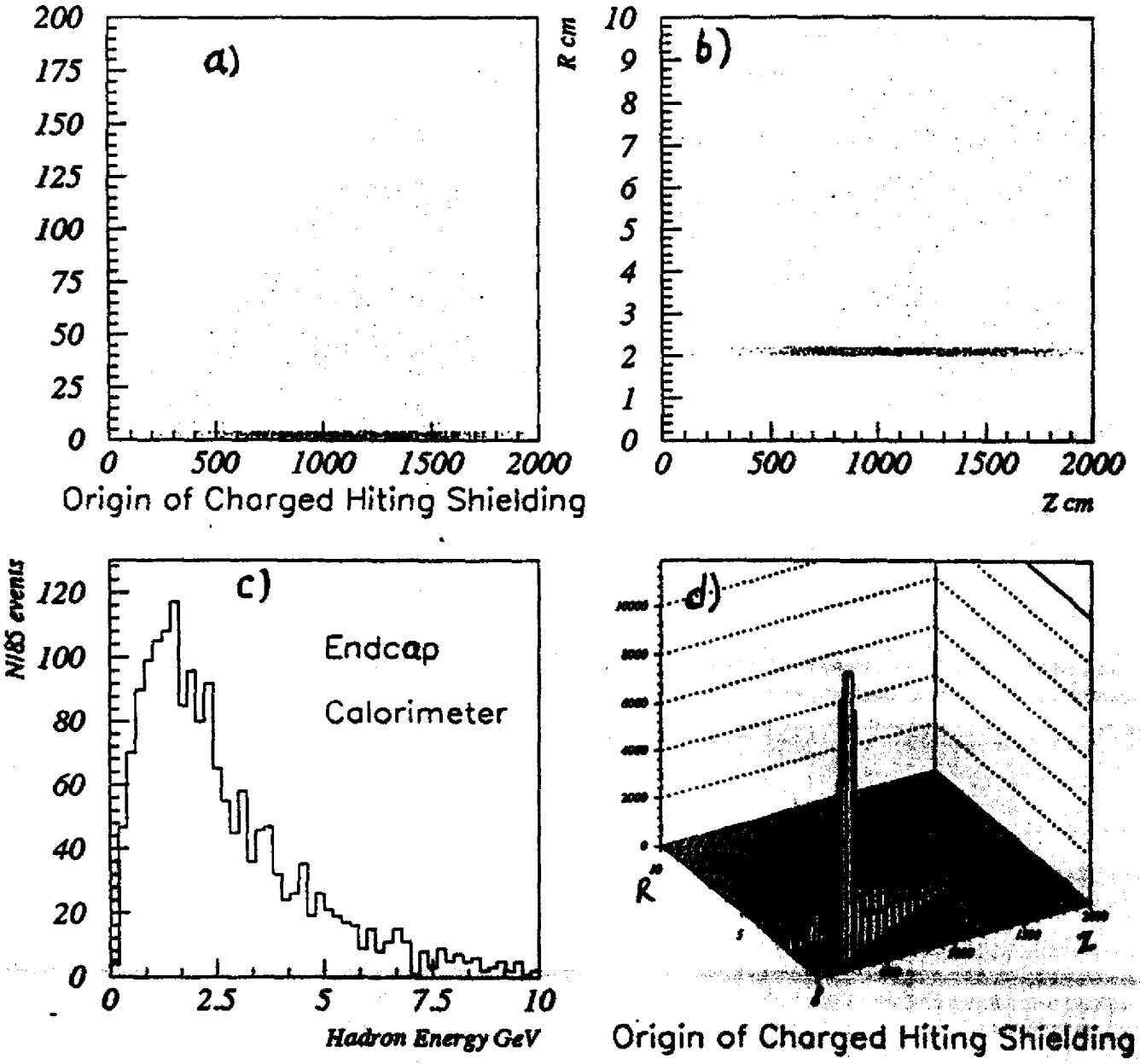
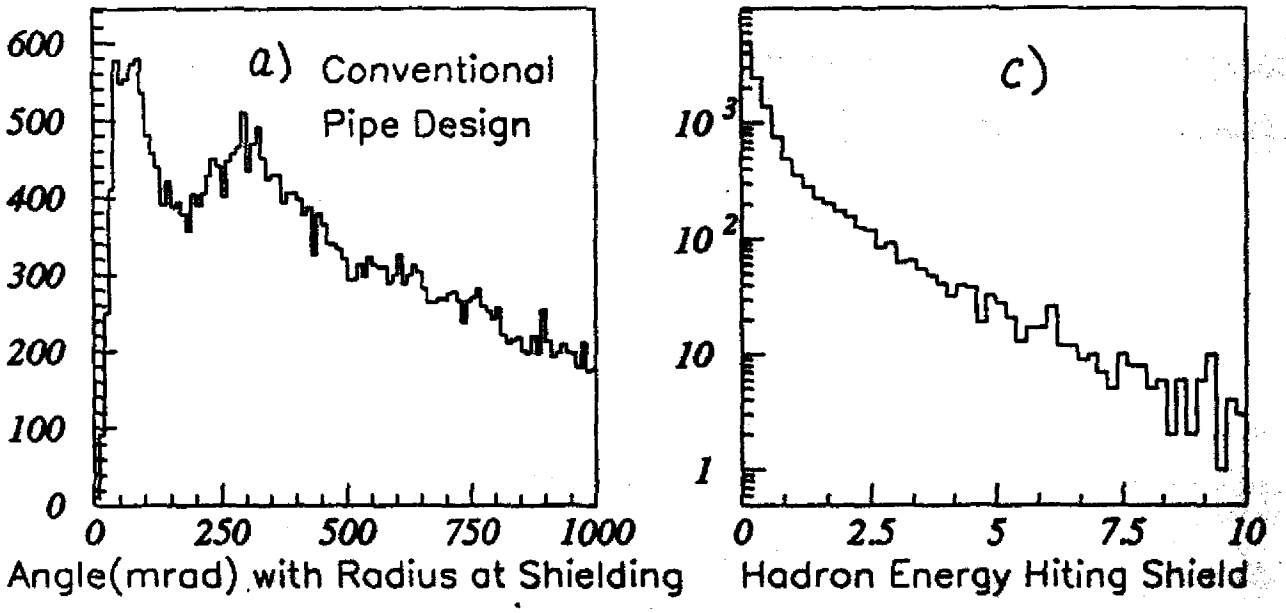


Fig.3. a): the distribution of the angle at which charged particle hits the absorber for the conventional pipe design; b): the same for the projective pipe design; c): energy spectrum of the hadrons and muons hitting the shielding.



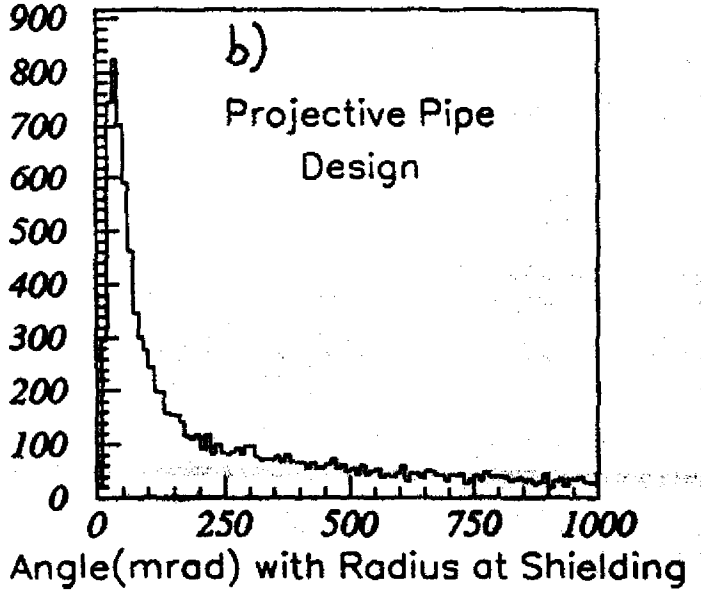


Fig.4. The integrated flux of the charged particles through the absorber vs absorber thickness for various designs. The uppermost curve corresponds to the conventional cylindrical pipe and the lead absorber. All other curves are for the projective pipe design and different absorbers: lead, iron, magnetized iron and tungsten. All curves are normalized to one interaction in the IP. "Muon Level" showes roughly the rate of charged particles (dominantly muons) coming through the endcap calorimeter.

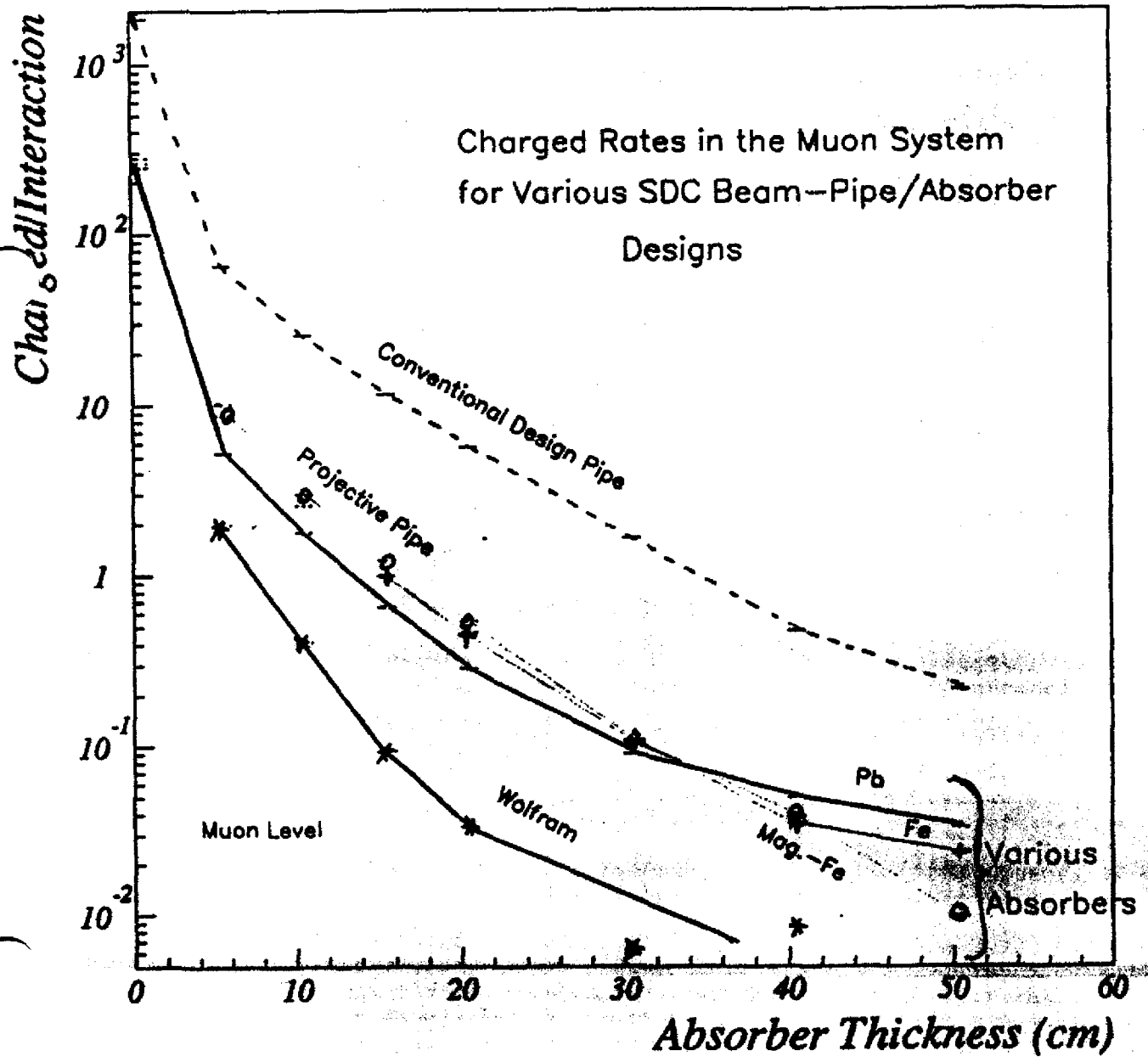


Table 1. The input data for the Fig.4. Nmu is a number of muons which come through the endcap calorimeter.

PIPE/ABSORBER	TUBE/Pb	CONE/Pb	CONE/Fe	CONE/Mag	CONE/W
vents	210.	415.	420.	305.	470.
Nch(0cm)	388485	115290	102641	79344	115794
Nch(5cm)	13680	2176	3683	3140	931
Nch(10cm)	5386	738	1081	918	194
Nch(15cm)	2442	273	419	373	45
Nch(20cm)	1213	120	196	166	16
Nch(30cm)	346	38	46	33	3
Nch(40cm)	101	21	15	12	4
Nch(50cm)	46	14	10	3	2
Nmu	6	7	12	7	12

Table 2. The same as the Table 1 but normalized to the one event.

PIPE/ABSORBER	TUBE/Pb	CONE/Pb	CONE/Fe	CONE/Mag	CONE/W
ents	210	415	420	305	470
Nch(0cm)	1849.929	277.807	244.383	260.144	246.370
Nch(5cm)	65.143	5.243	8.769	10.295	1.981
Nch(10cm)	25.648	1.778	2.574	3.010	0.413
Nch(15cm)	11.629	0.658	0.998	1.223	0.096
Nch(20cm)	5.776	0.289	0.467	0.544	0.034
Nch(30cm)	1.648	0.092	0.110	0.108	0.006
Nch(40cm)	0.481	0.051	0.036	0.039	0.009
Nch(50cm)	0.219	0.034	0.024	0.010	0.004
Nmu	0.029	0.017	0.029	0.023	0.026

Fig.5. The forward calorimeter

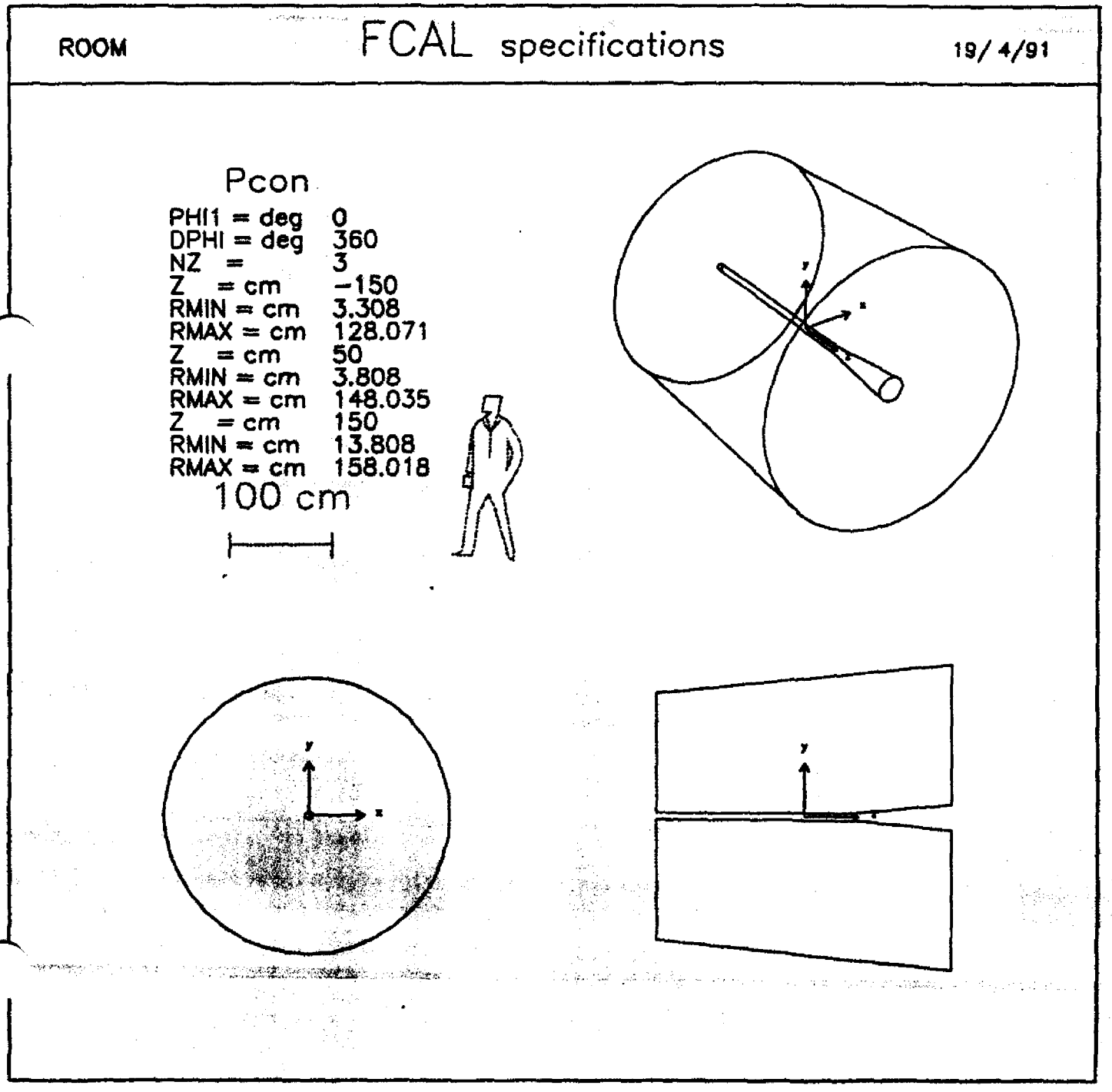
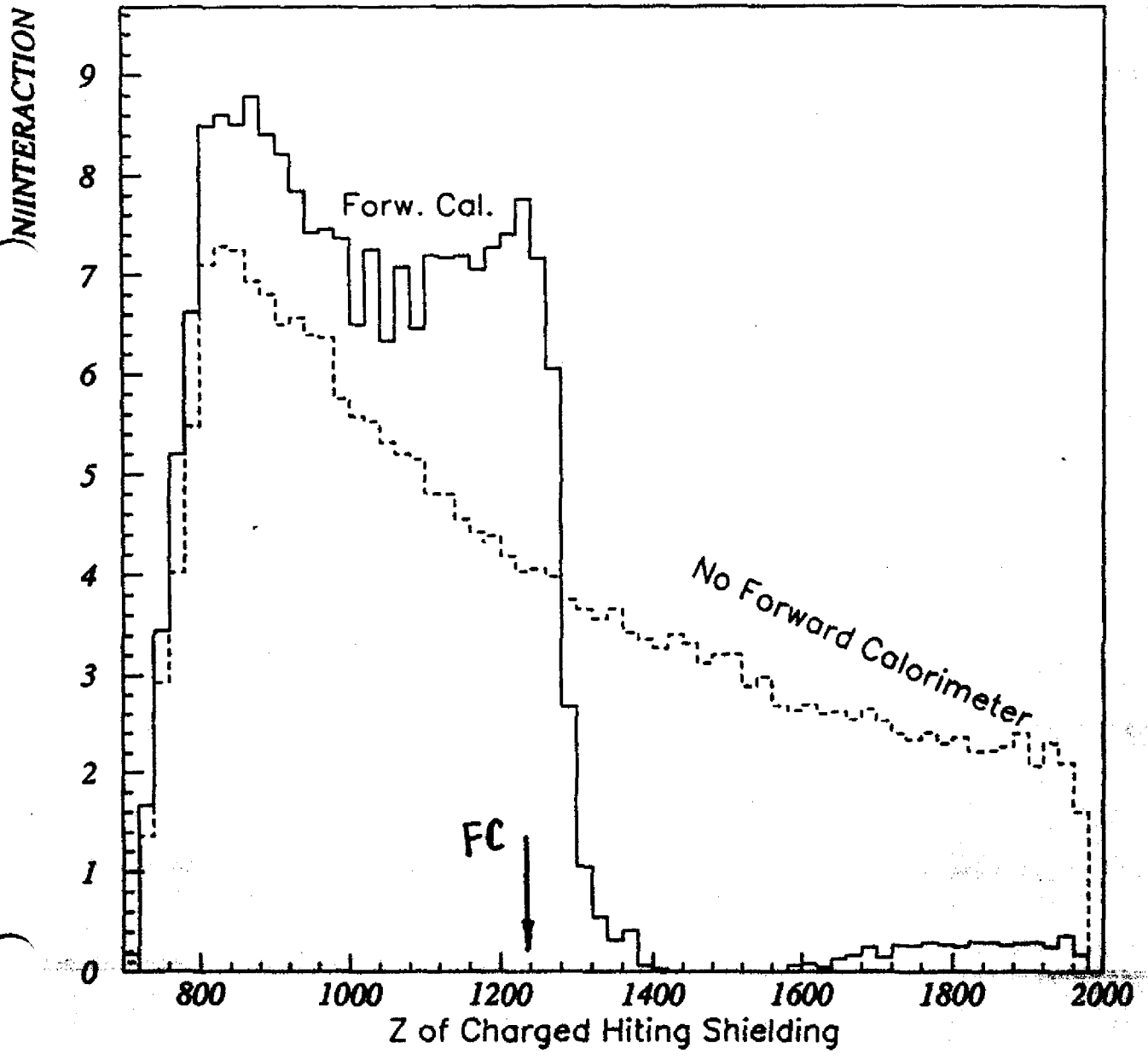
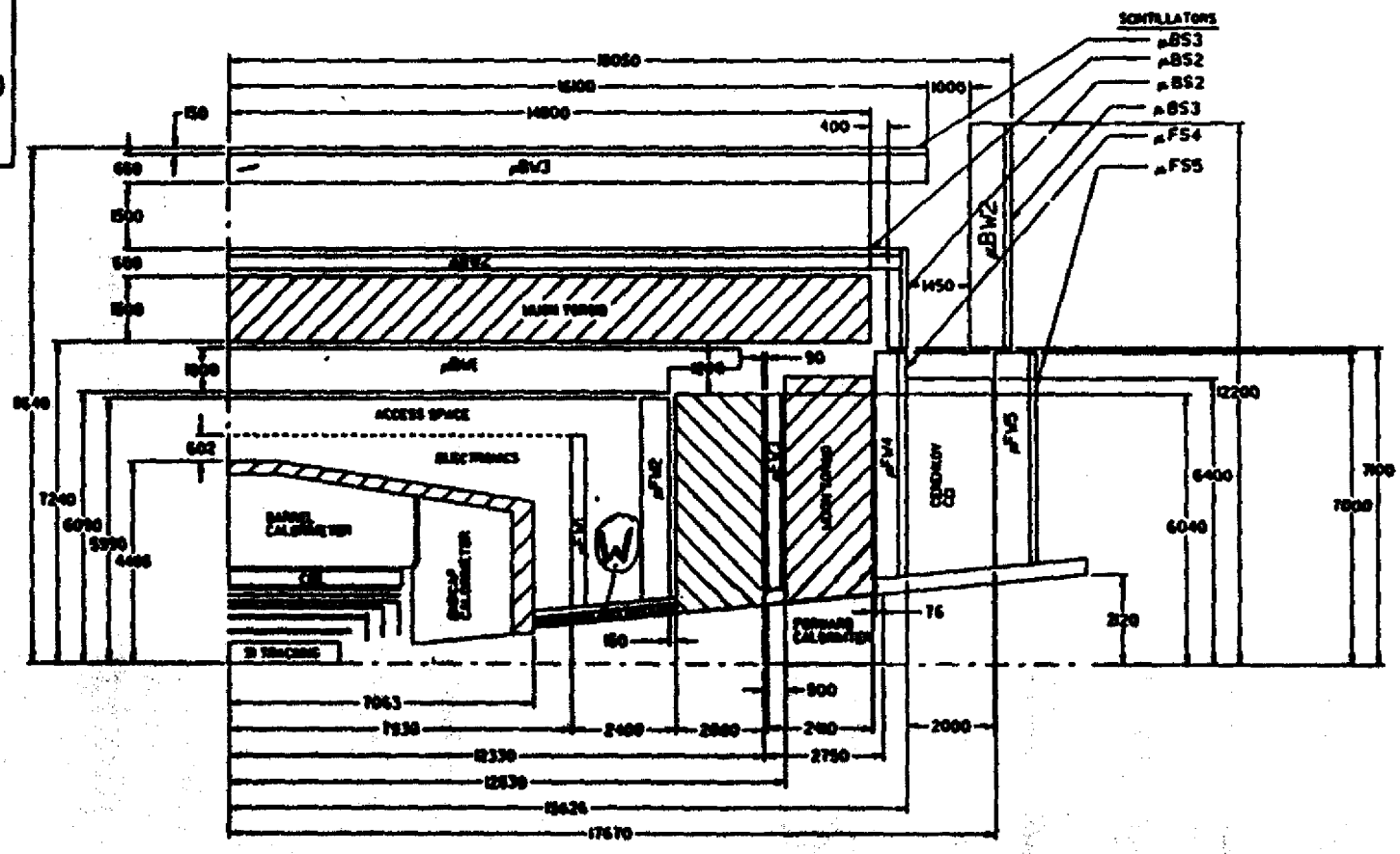


Fig.6. The Z-distribution (along the beam line) of the charged particles flux through the absorber surface. Two curves are obtained with and without the forward calorimeter. The arrow showes the position of the forward calorimeter front face.



Def.	cm.
μFW1	32
μFW2	64
μFW3	32
μFW4	52
μFS4	15
μFC1	200
μFW5	80
μFS5	15



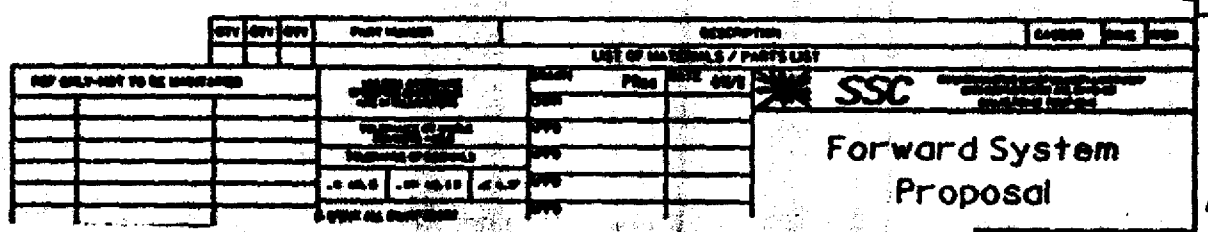


Fig. 1. The proposal of the absorber design. The frontmost part is done of 25 cm thick tungsten, the middle part is removed and the endcap toroids are extended inwards, the rear part is done of 30 cm thick steel.

Alexei Kulik 28.3.91, SSCL, Dallas

Muon Rates in the SDC Forward Muon System (APPENDIX)

This is the first step of evaluating of the rates in the forward muon system. Only muon rates are calculated here, others will be evaluated later. The model used is very similar to that of Yoshihide Sakai. TWOJET events in Pt interval of 5-50 GeV were generated by ISAJET. Pion and Kaon decays to muon and neutrino were simulated. Then stopping power of the filters was taken into account: 2 GeV for the Calorimeter (10 int. len.), 2.25 Gev for Toroid (ETA<1.6, 1.5 m of iron) and 4.5 GeV for Toroid (ETA>1.6, 4 m of iron). A total of 45,000 events were generated which corresponds to a half of millisecond (5*10**-4) at 10**33 luminosity. An area of ETA<3 is considered.

The results are very similar to those of Yoshihide Sakai too.

Pions produced	5.85*10**6	
Pions decayed	2.03*10**5	
Kaons produced	5.63*10**5	
Kaons decayed	3.70*10**4	(Mu-Nu mode only)
Muons produced	2.41*10**5	(from Pi- and K-decays mostly)
Muons survived after Cal.	4836 = 3446(Pi) + 1263(K) + prompt	
Muons survived after Toroid	247 = 190(decay) + prompt	
Above Cherenkov threshold (Nitrogen)	47	
Pt > 10 GeV	2	
Pt > 20 GeV	0	

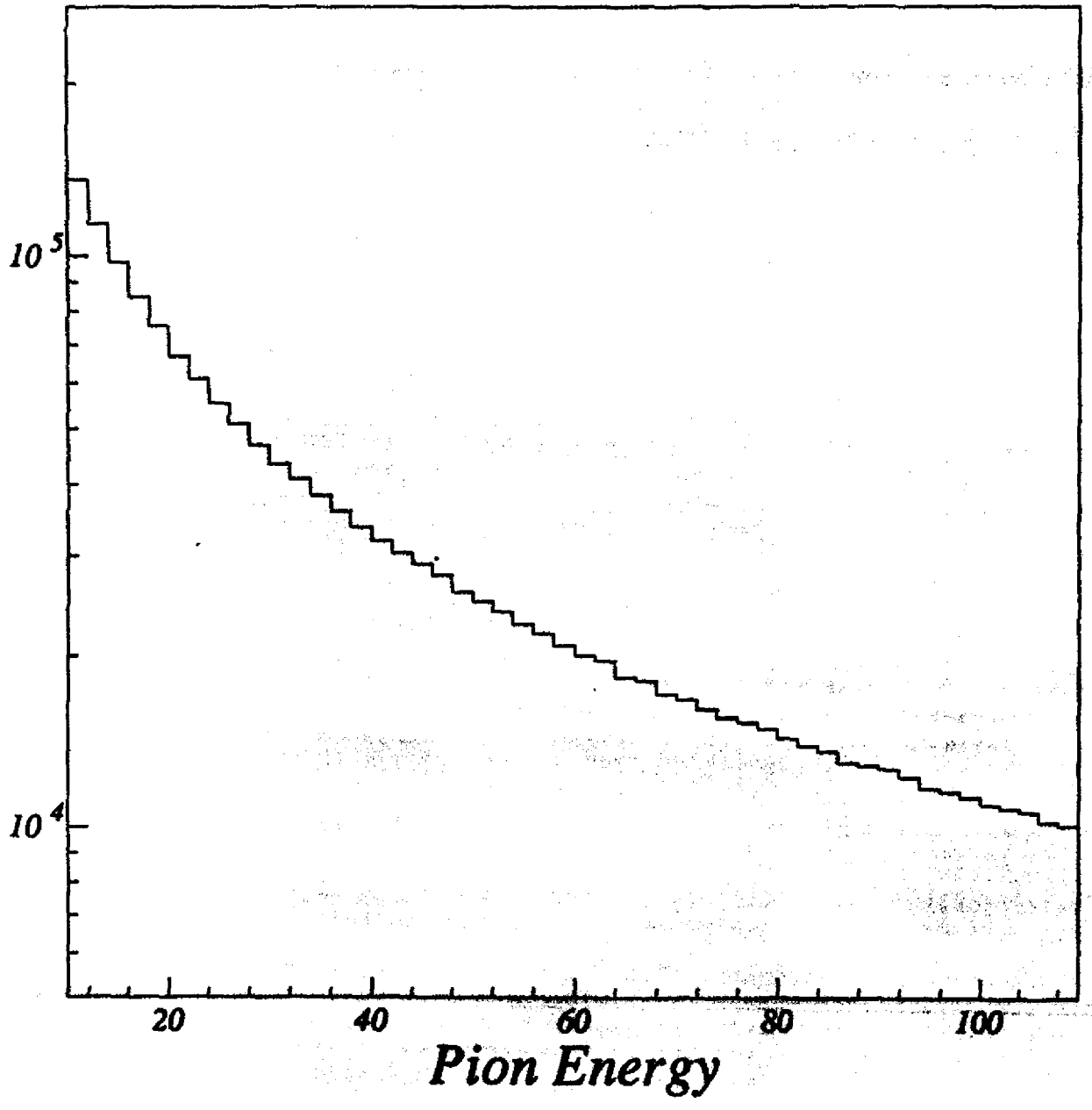
Muon rates are: 10 MHz after Calorimeter and 500 kHz after Toroid. Muon rates are dominated by decay muons.

Fig. 1-5 show that only soft fraction of initial hadron spectra decays and so muon spectrum is soft too. Fig. 6 showes the rapidity distribution of muons. The rate is decreased by many orders of magnitude by the filters (Calorimeter and Toroid). Fig. 7 showes the fraction of decay muons after Calorimeter.

The rates given here are irreducible, so they put the lower limit for the actual rates. The next step which we are going to do (me and Yuri Gornushkin) is to evaluate the non-muon rates which perhaps will be higher. This needs GEANT/GHEISHA calculations in some realistic geometry and optimization of the experimental setup.

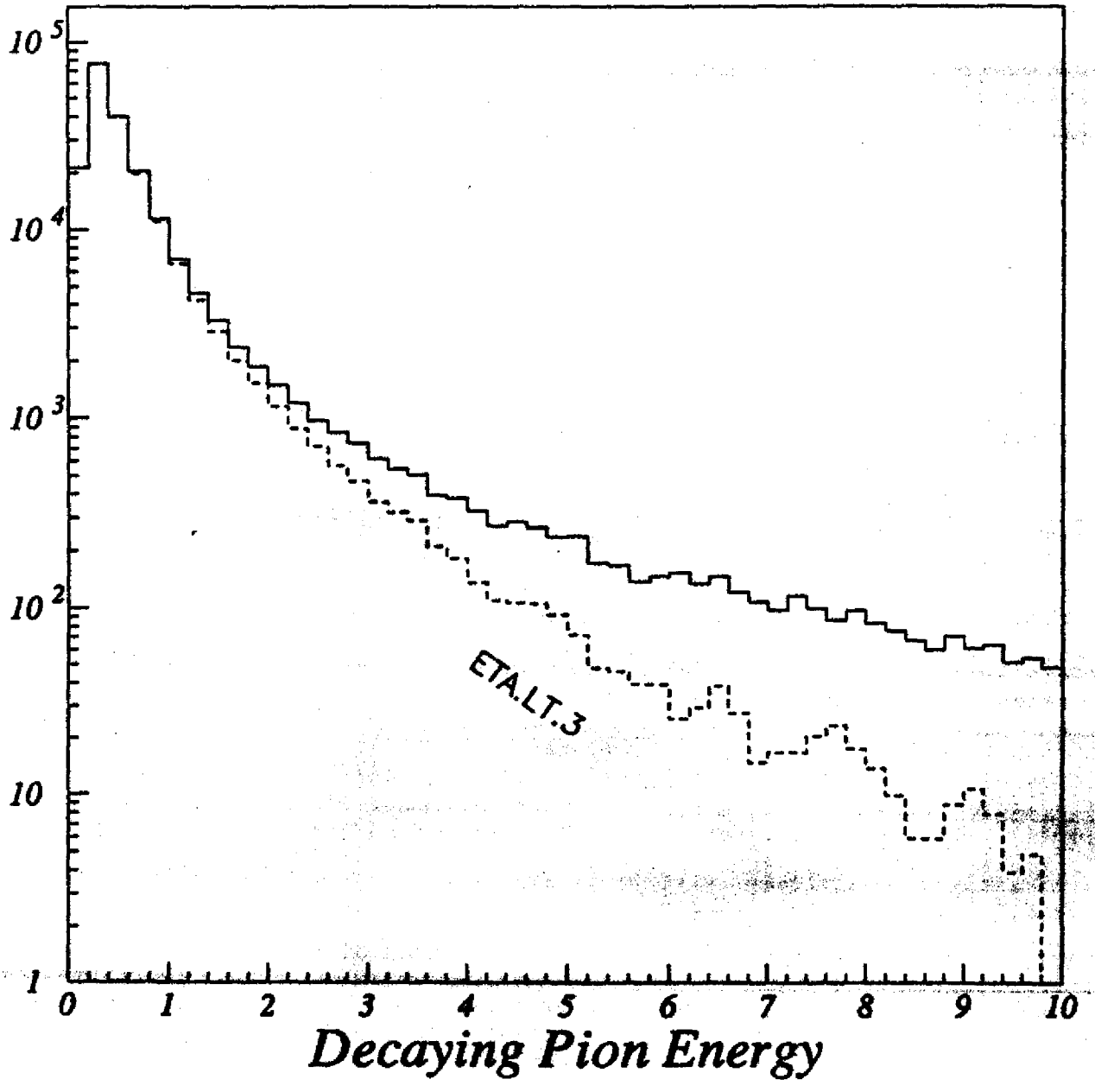
1

28/03/91 16.12



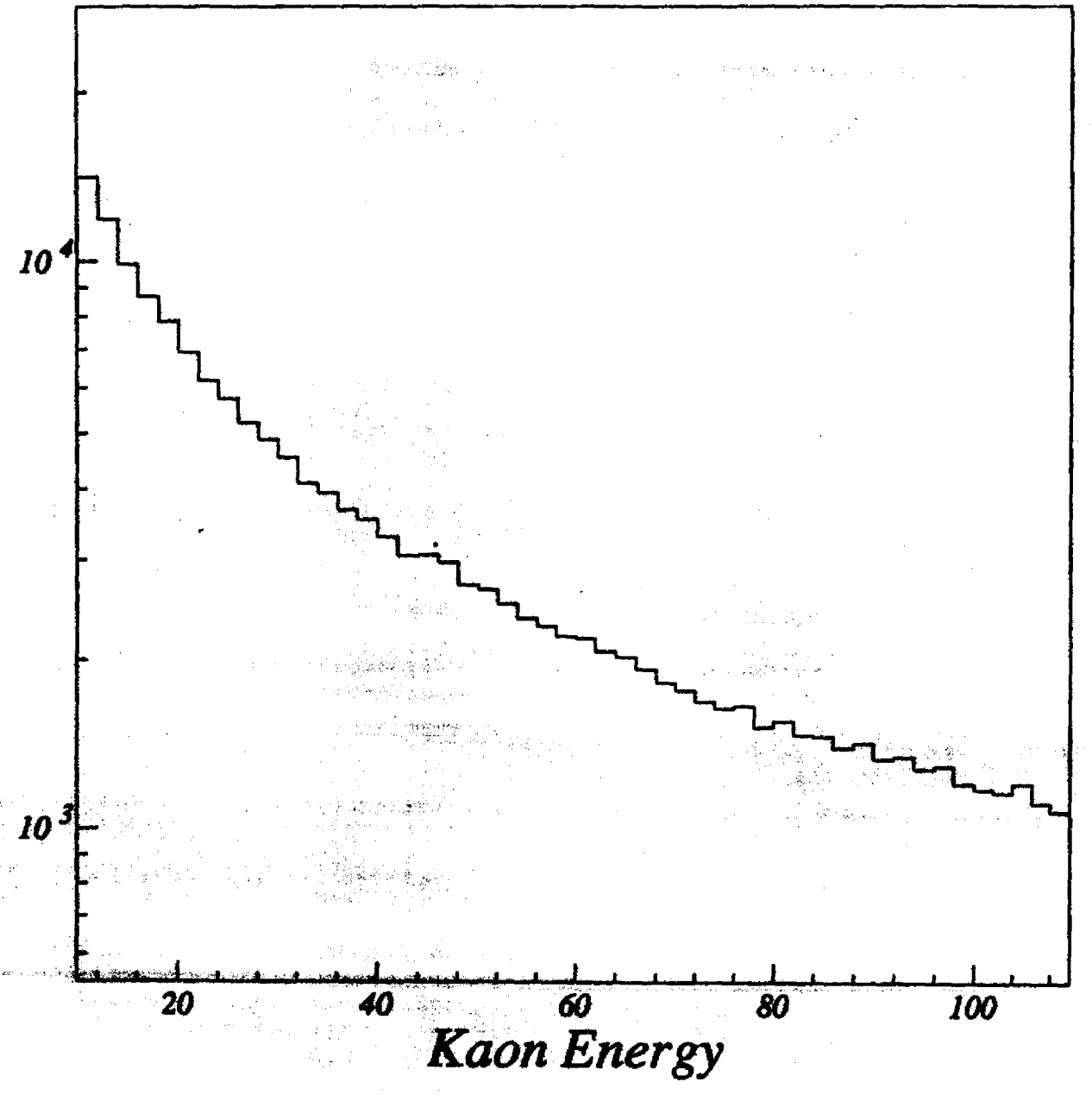
2

28/03/91 16.12



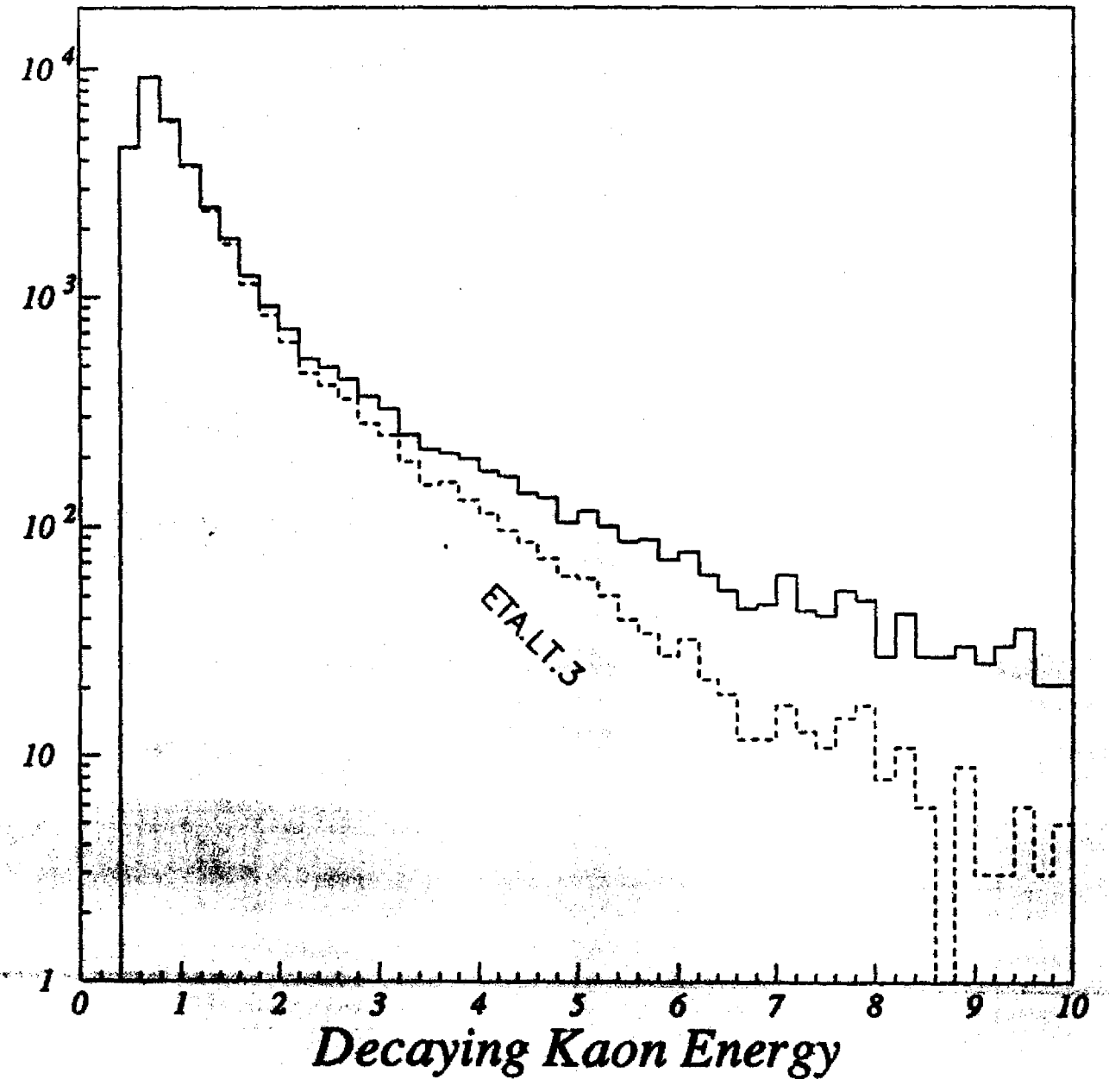
3

28/03/91 16.12



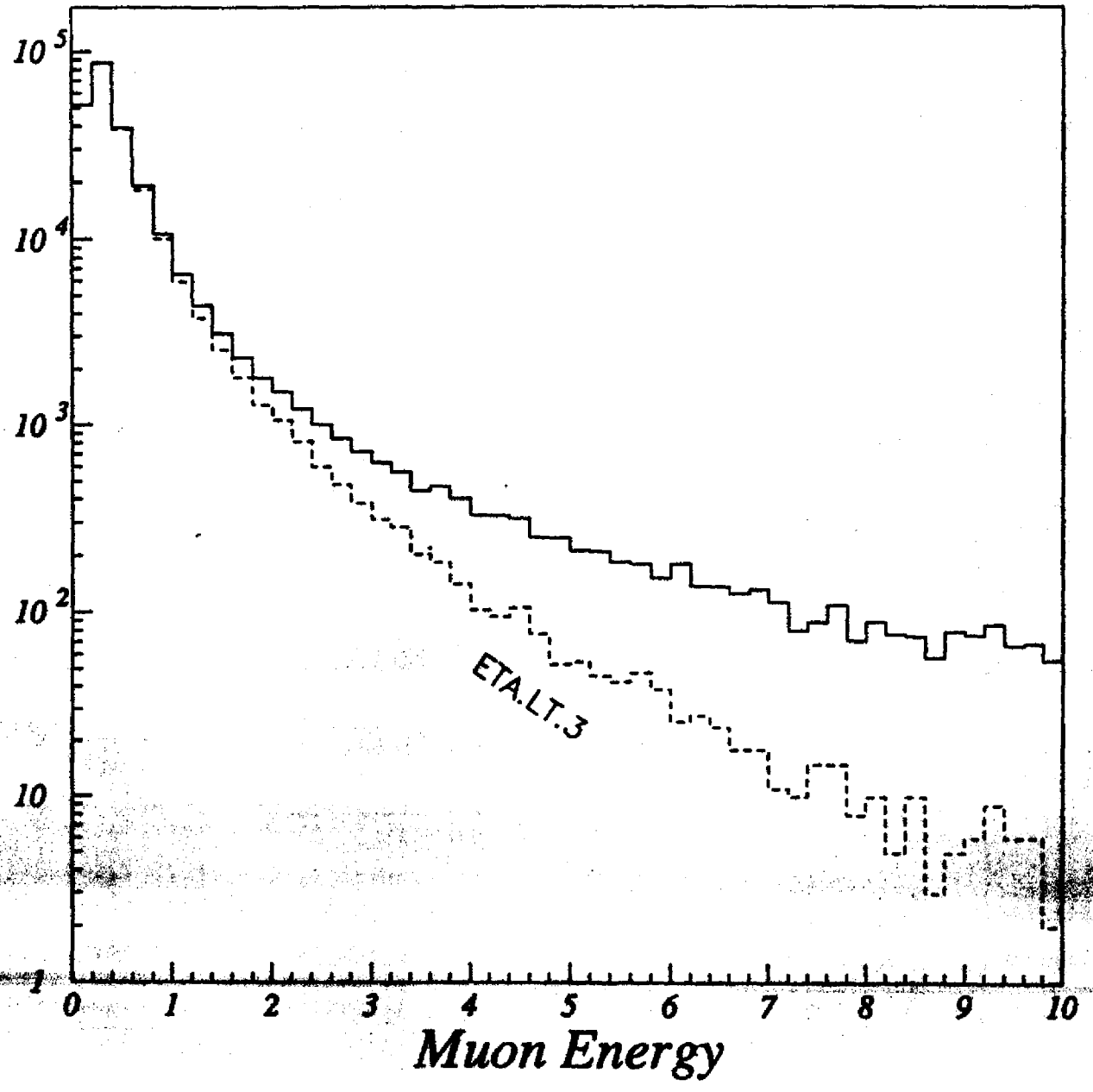
(4)

28/03/91 16.12



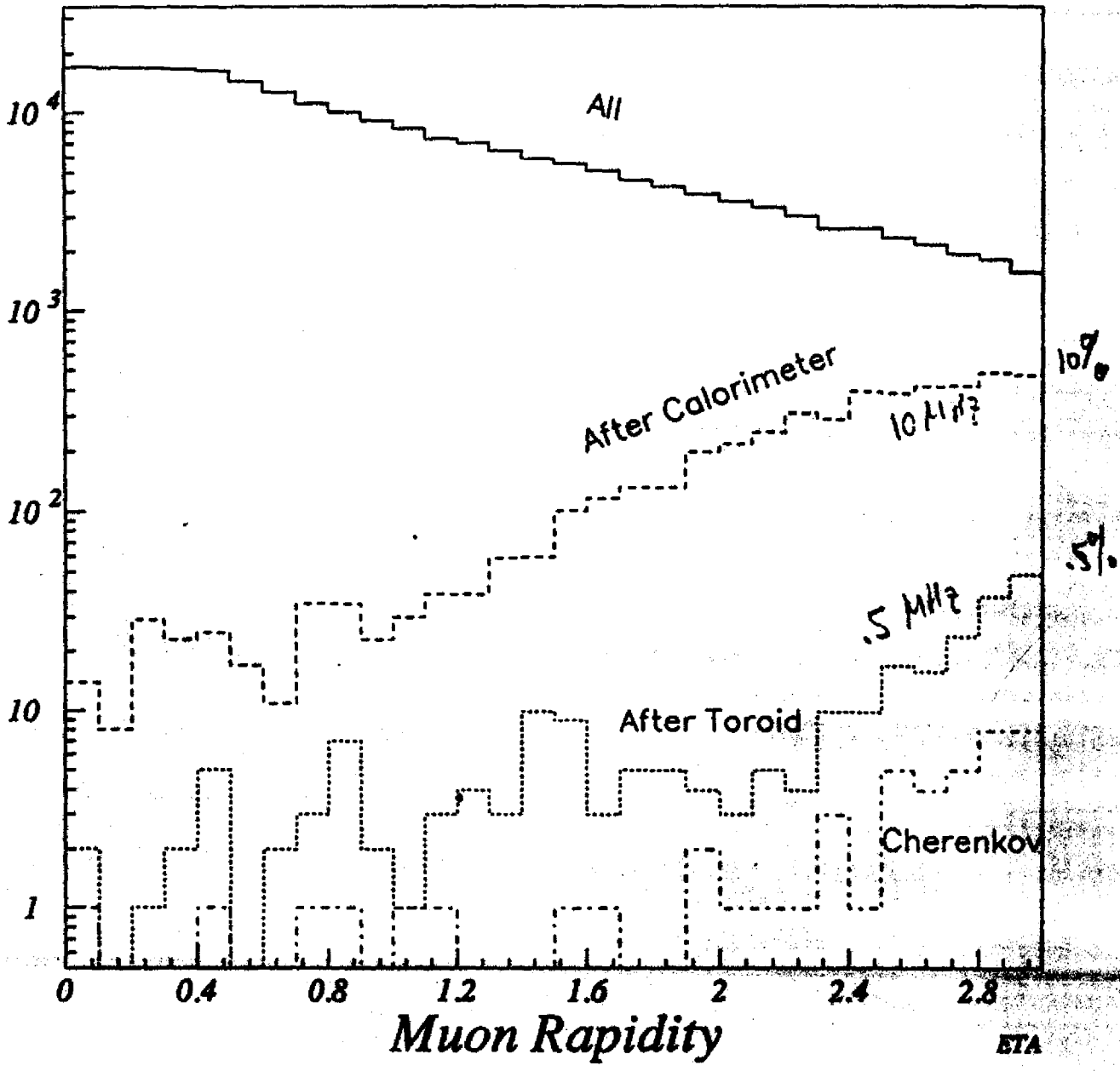
5

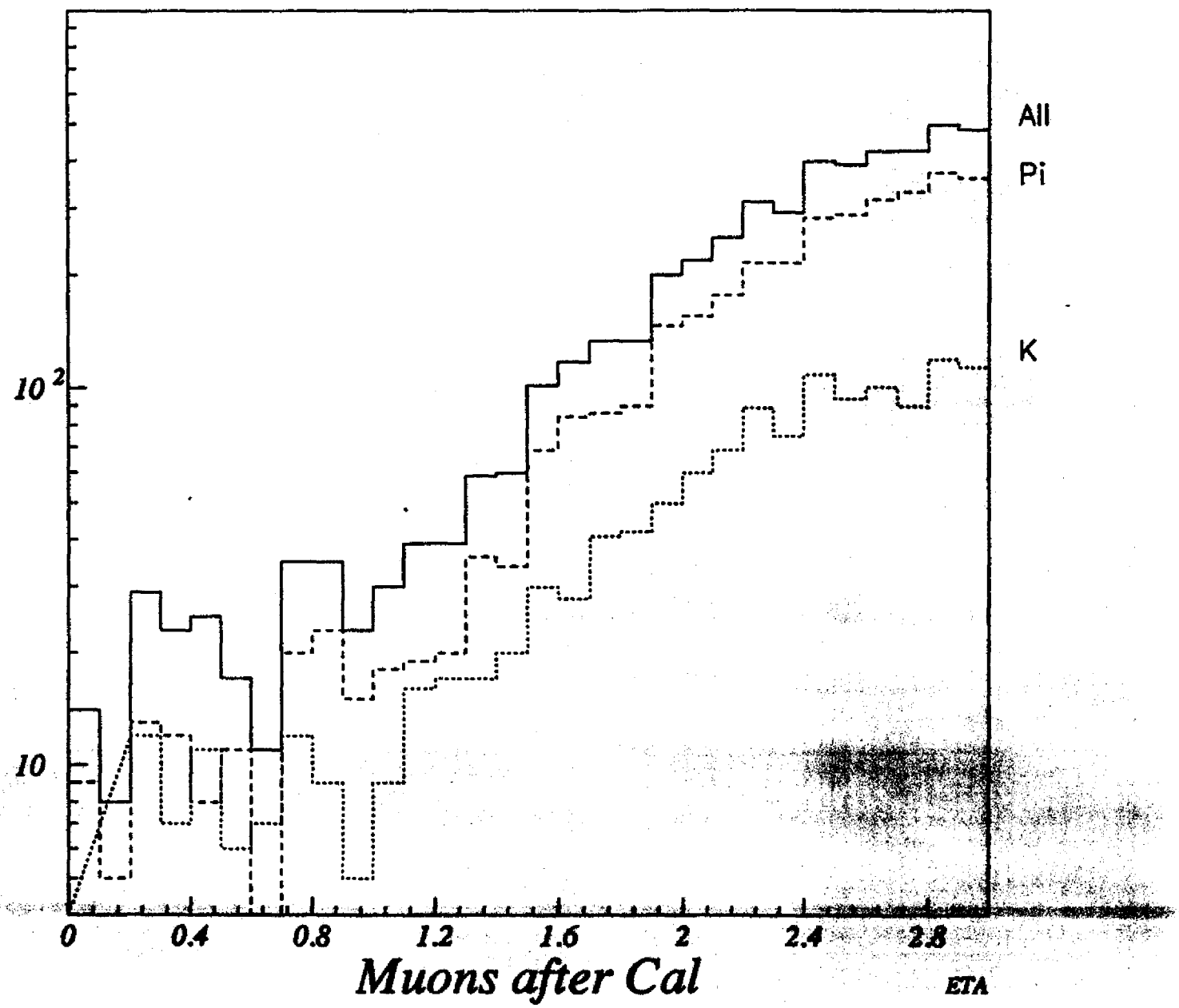
28/03/91 16.12



6

28/03/91 17.56



7

28/03/91 17.31