GEM TN-93-435

GEM Muon Performance Meeting - SSCL

June 30, 1993

Abstract;

Agenda, attendees, and presentations of the GEM Muon Performance Meeting held at the SSC Laboratory on June 30, 1993.

June 30, 1993
GEM muon performance meeting

Presentations by:

Session I: Backgrounds.

- Chris Lyndon
- Roger McNiel
- Yuri Fisyak
- Yuri Efremenko

Session II: Reconstruction.

- Yuri Fisyak
- Peter Dingus
- Torre Wenaus

Session III: Acceptance.

- Roger McNeil
- Frank Nimblett
- Torre Wenaus

gem

γeμ

Presentation by:

Chris Lyndon

GEANT simulations of CERN experiment RD5

RD5 GEM group
(LSU, Stony Brook)
and
other RD5 collaborators

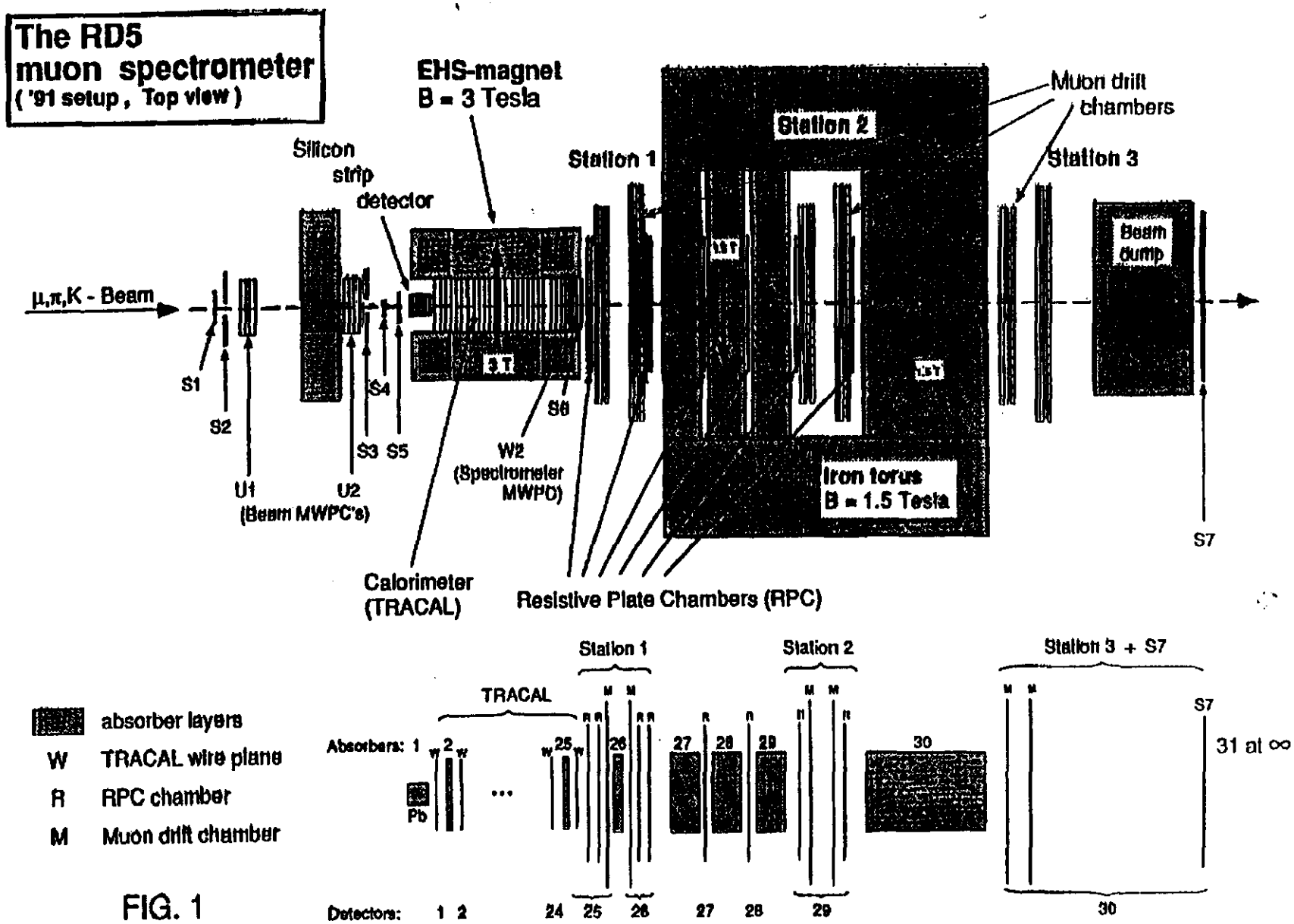
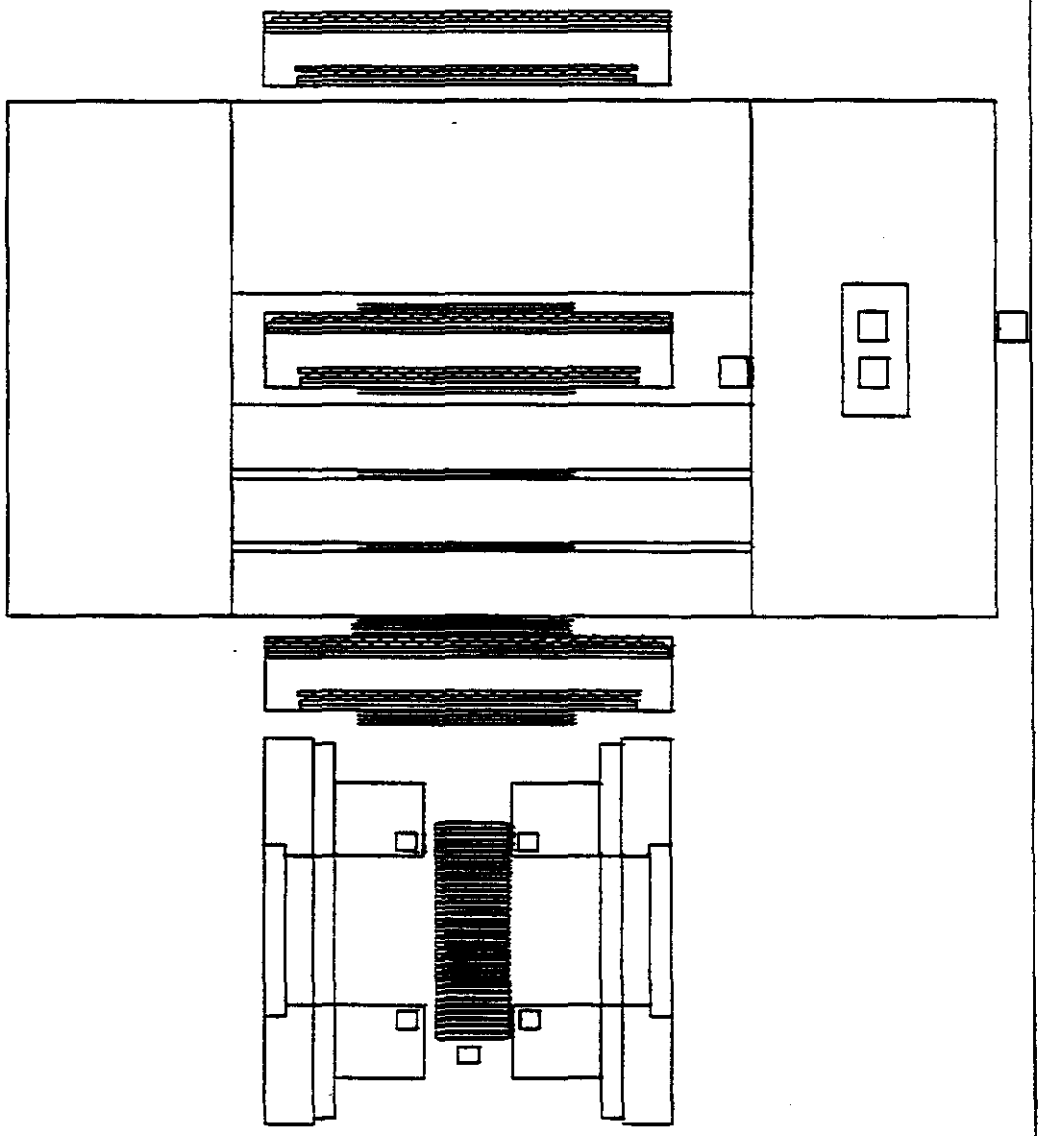
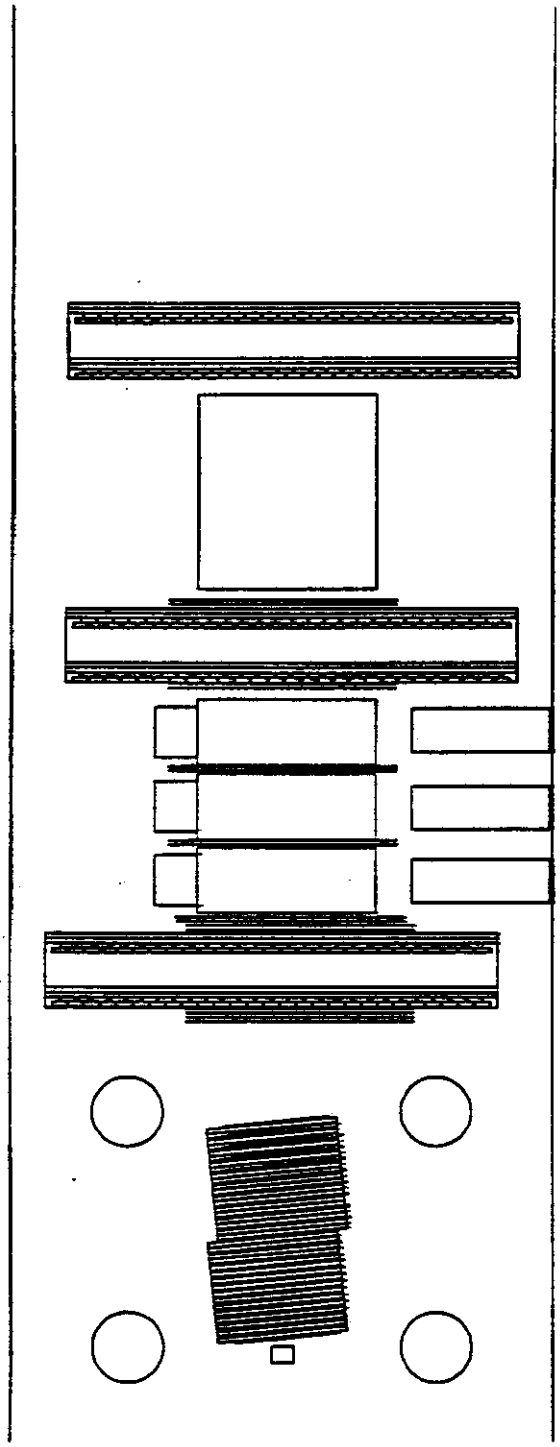

The RD5
muon spectrometer
('91 setup , Top view)
EHS-magnet
B = 3 Tesla
Silicon
strip
detector
Station 1
Station 2
Station 3
Muon drift
chambers
Beam
dump
μ,π,K - Beam
S1
S2
U1
(Beam MWPC's)
U2
S3
S4
S5
S6
W2
(Spectrometer
MWPC)
3 T
1.5 T
1.5 T
Iron torus
B = 1.5 Tesla
S7
Calorimeter
(TRACAL)
Resistive Plate Chambers (RPC)
absorber layers
W TRACAL wire plane
R RPC chamber
M Muon drift chamber
TRACAL
Station 1
Station 2
Station 3 + S7
Absorbers: 1
Pb
Detectors: 1 2 24 25 26 27 28 29 30
31 at ∞

FIG. 1





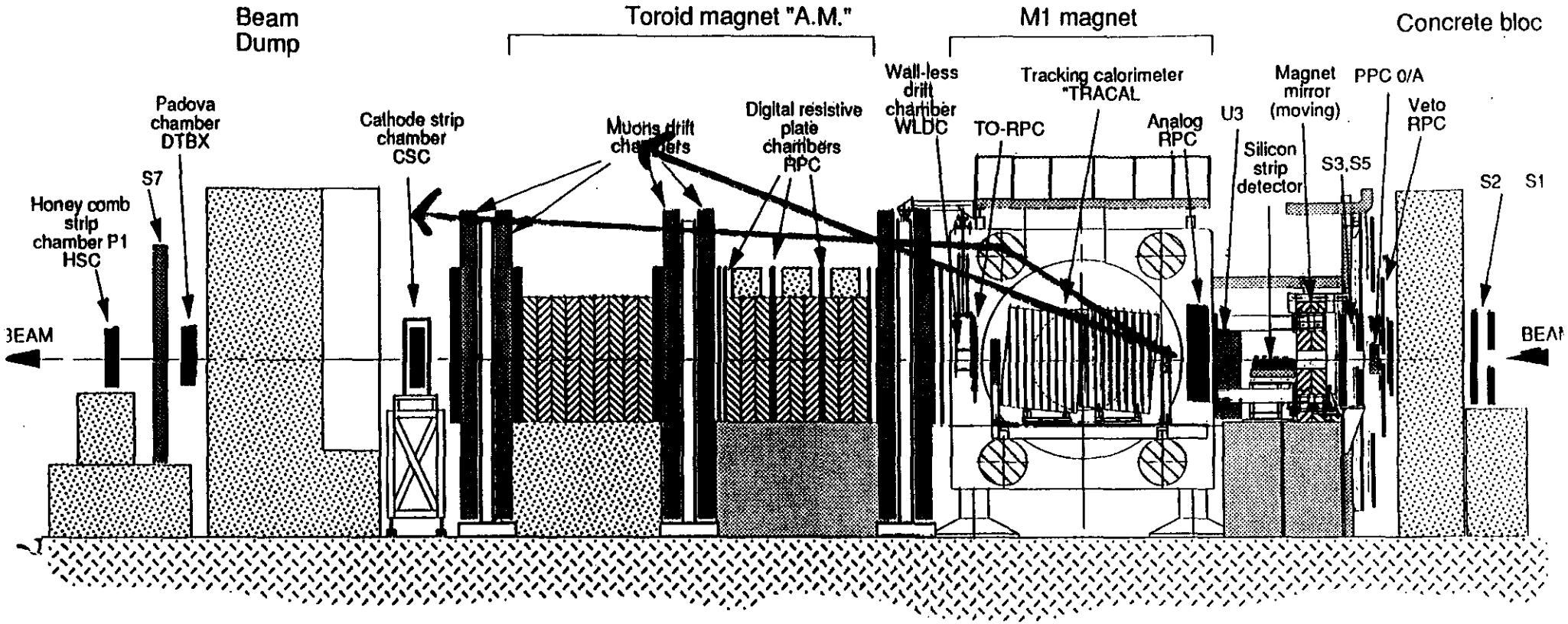
Experiment 91, 92, 93
in 91
30, 40, 50, 75, 100, 200, 300 GeV
π^- and μ^- beams
field only in M2 (1.5 T)
detectors used in punchthrough
study: Tracal, RPC's, UA1 muon chambers

Simulation 91 set up so far
all GEANT processes
GHEISHA for hadronic interactions
1 MeV cutoffs (10 keV in detectors)
same detectors, field in M2
2 methods of analysis
- ntuples from GUSTED
- full analysis from simulated raw data

Data Analysis:

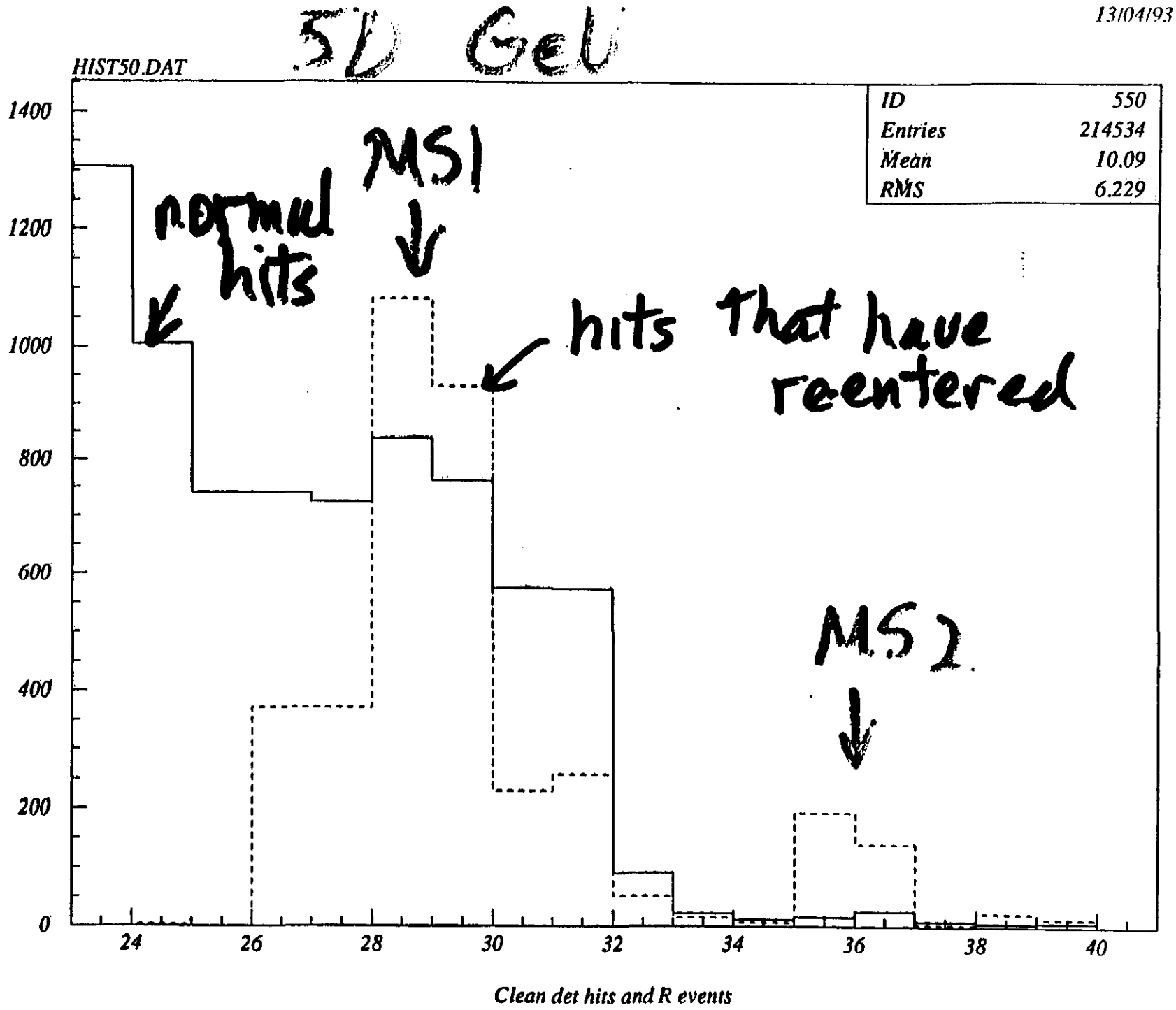
1. subtraction of primary muons using dispersion of Tracal hits
2. superimposed events by visual scanning
3. re-entering events

Simulation events for 1 and 3 treated similarly



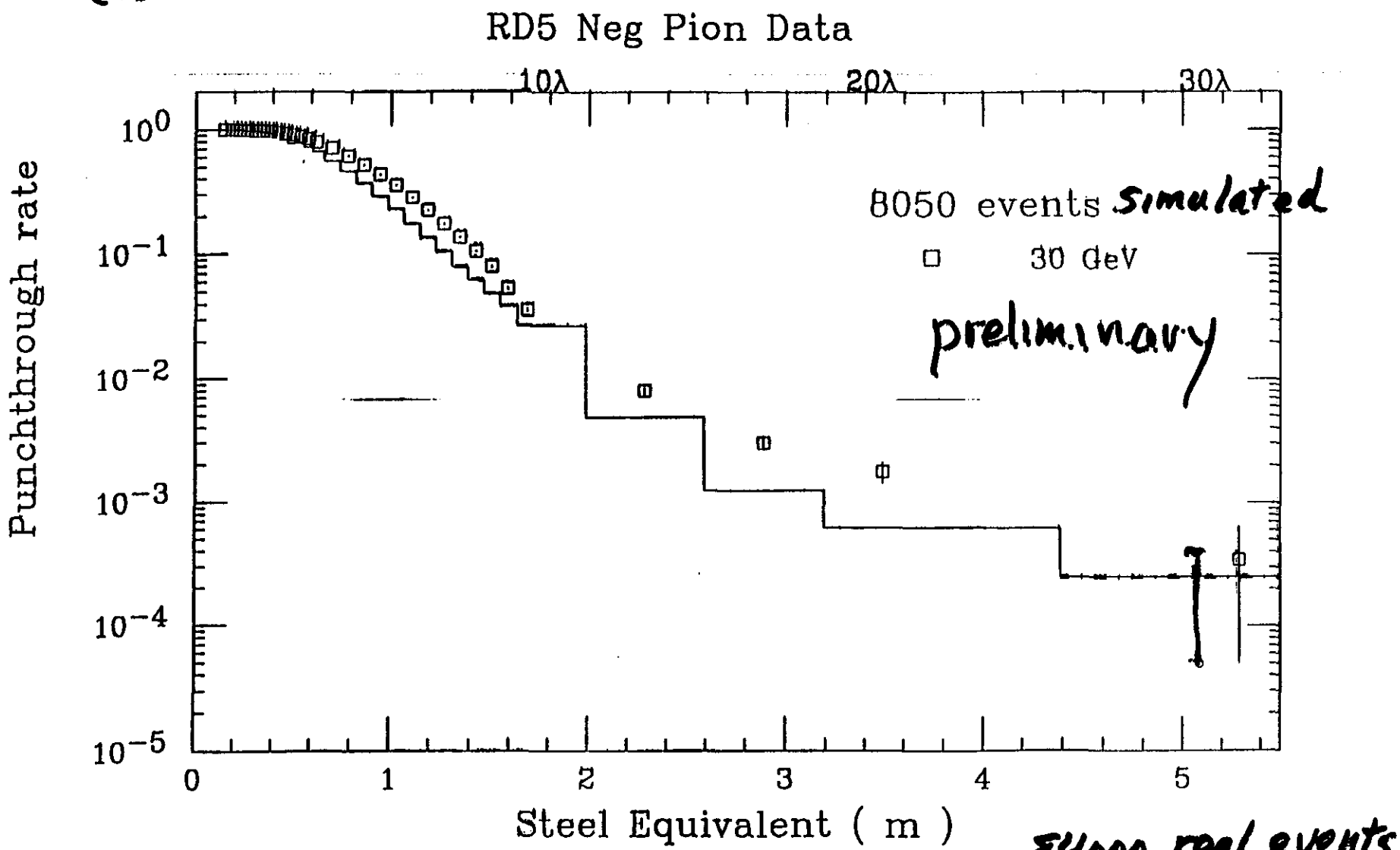
PLAN D'ENSEMBLE EXPERIENCE RD5
Situation 09/92

Dessiné :P. PETIOT
CERN le 28/9/92


50 GeV
13/04/93 15.38
HIST50.DAT
ID 550
Entries 214534
Mean 10.09
RMS 6.229
normal hits
MS1
hits that have reentered
MS2
1400
1200
1000
800
600
400
200
0
24
26
28
30
32
34
36
38
40
Clean det hits and R events

1 MeV cutoffs
(10 keV in detectors)

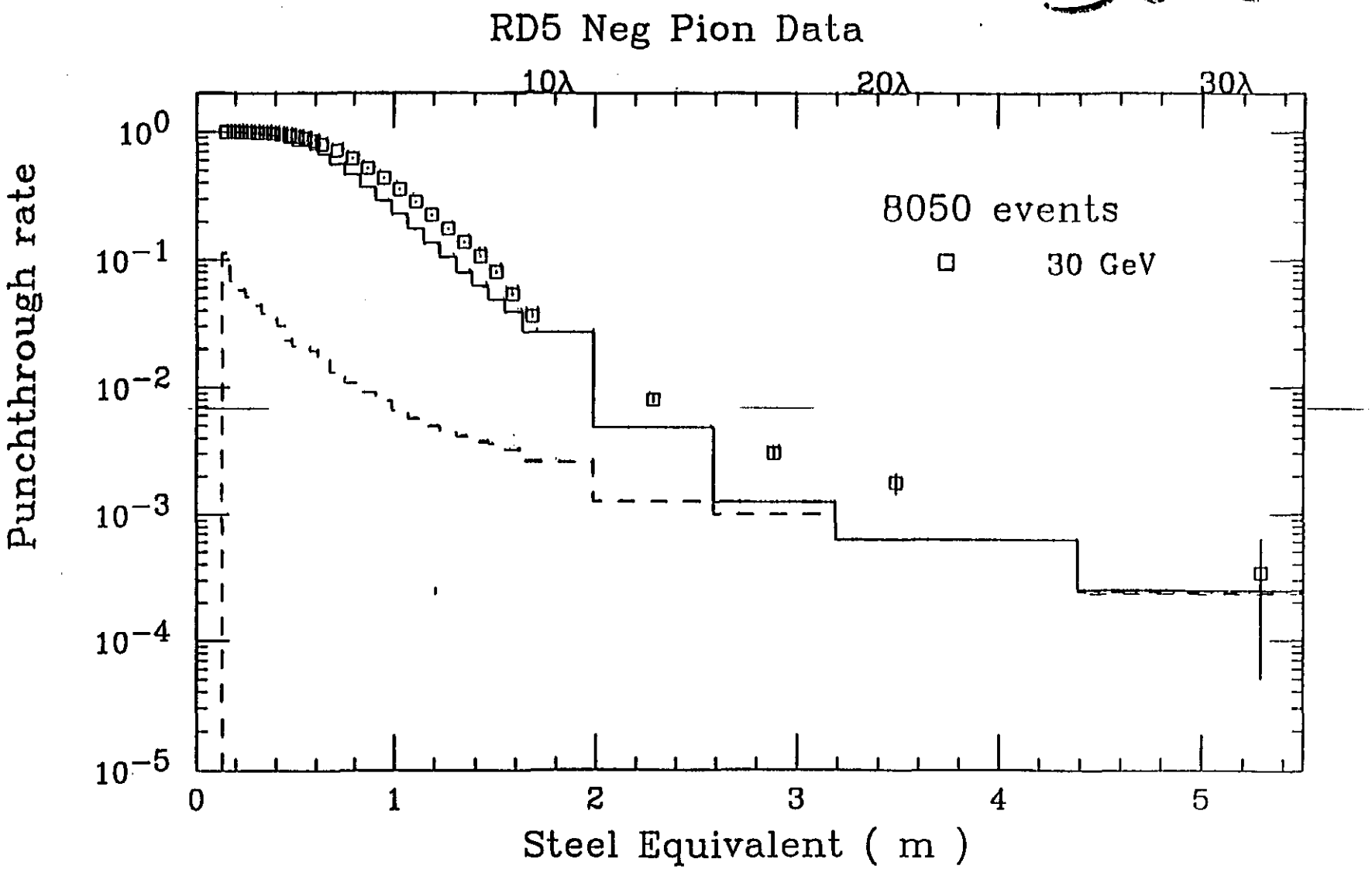
30 GeV π^-



84000 real events

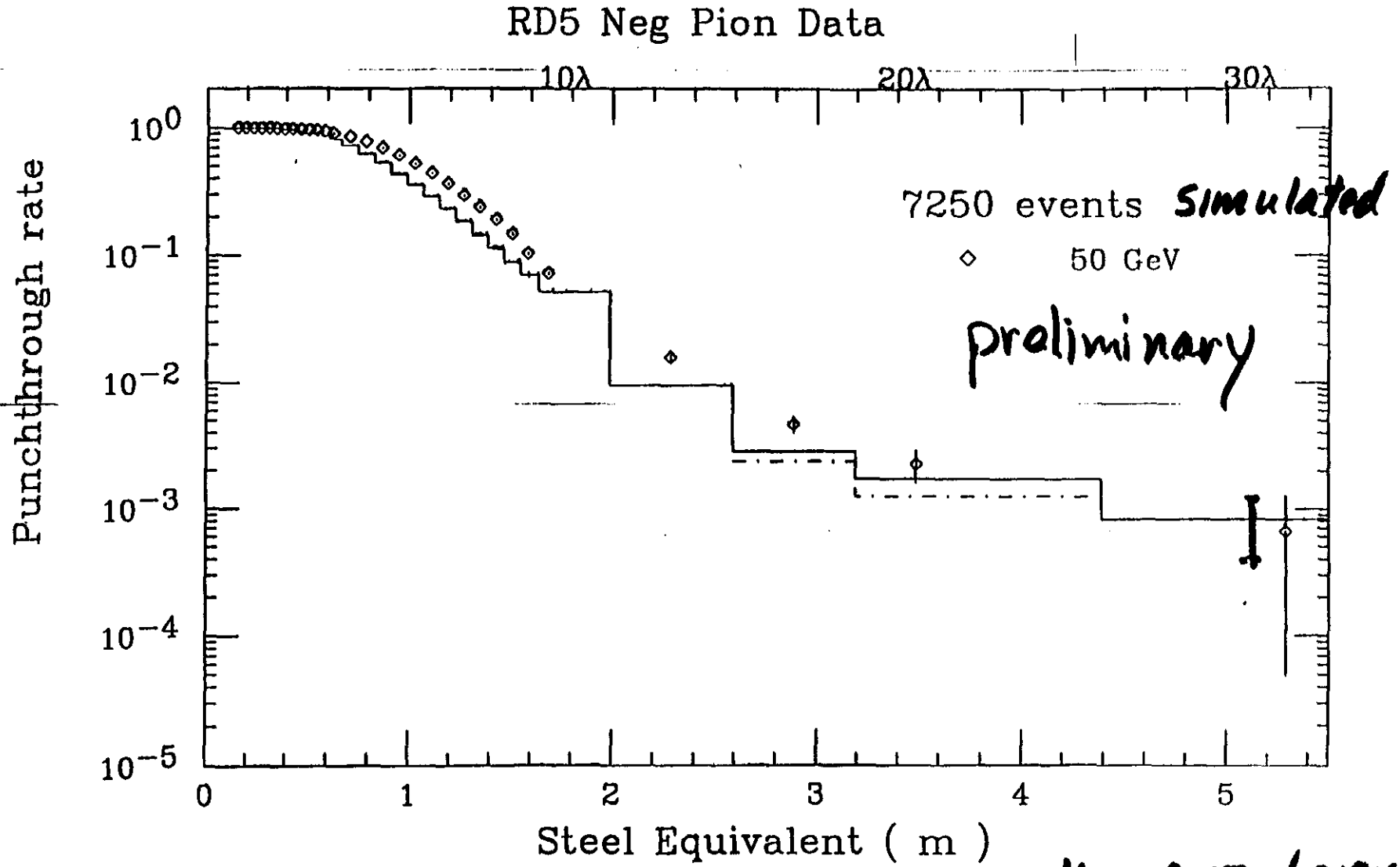
Dashed line is only μ's

30 GeV



1 MeV cutoffs
(10 keV in detectors)

50 GeV π^-



40000 real events

Plans

other energies
different cutoffs
position angular & momentum distributions
effect of acceptance
muon radiation studies

Analyze '92, '93 data
higher quality data

gem

γeμ

Presentation by:

Roger McNeil

R. McNeil
6.29.93

Optimizing the Calorimeter depth

Calorimeter depth requirement established for TDR utilized Conservative approach

Calorimeter depth is maximum imposed by 3 criteria

1. Punchthrough rate < ½ real muon rate

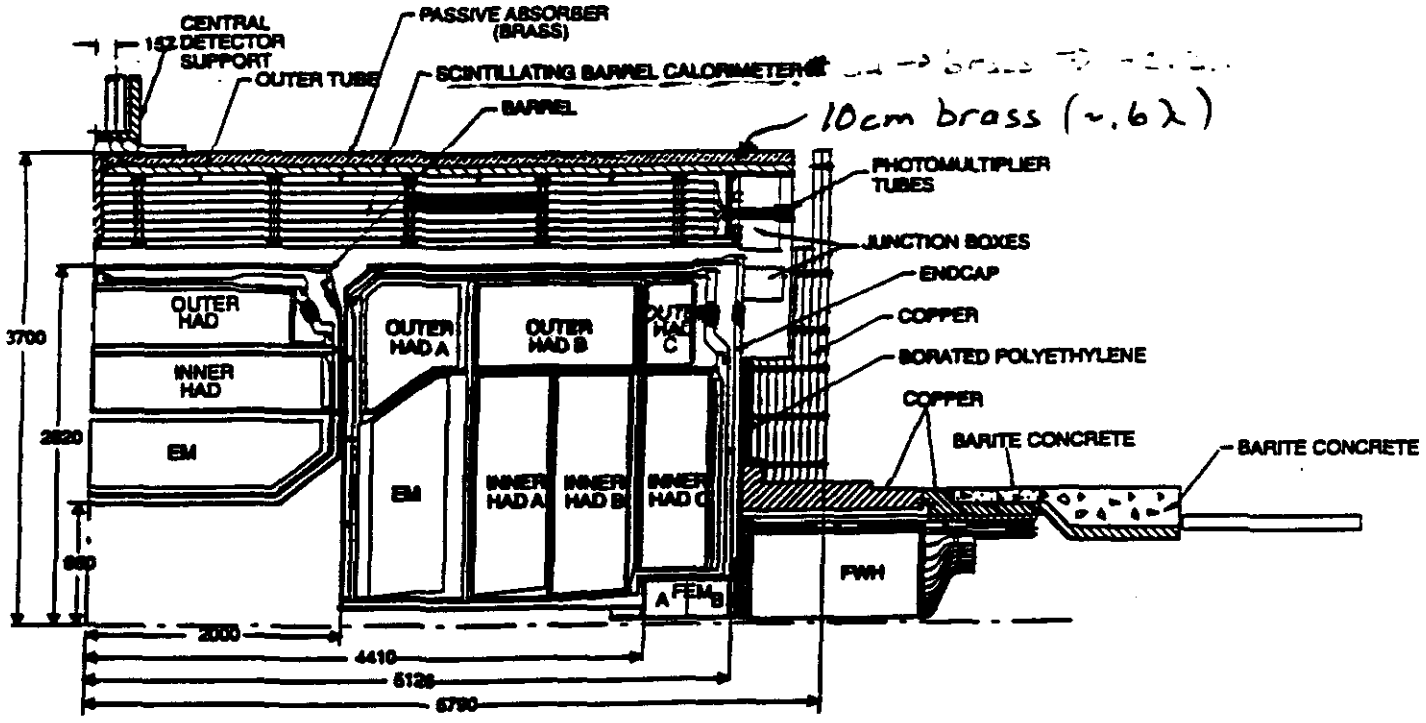
2. Punchthrough rate with $P_T > 10$ GeV/c < ½ real muon rate $P_T < 10$

3. 4-strip CSC occupancy from charged particles @ 10^{34} is < 1% ⇒ reconstruction eff > 97%

Table 4-7. Depth Requirements imposed by criteria 1, 2, and 3.

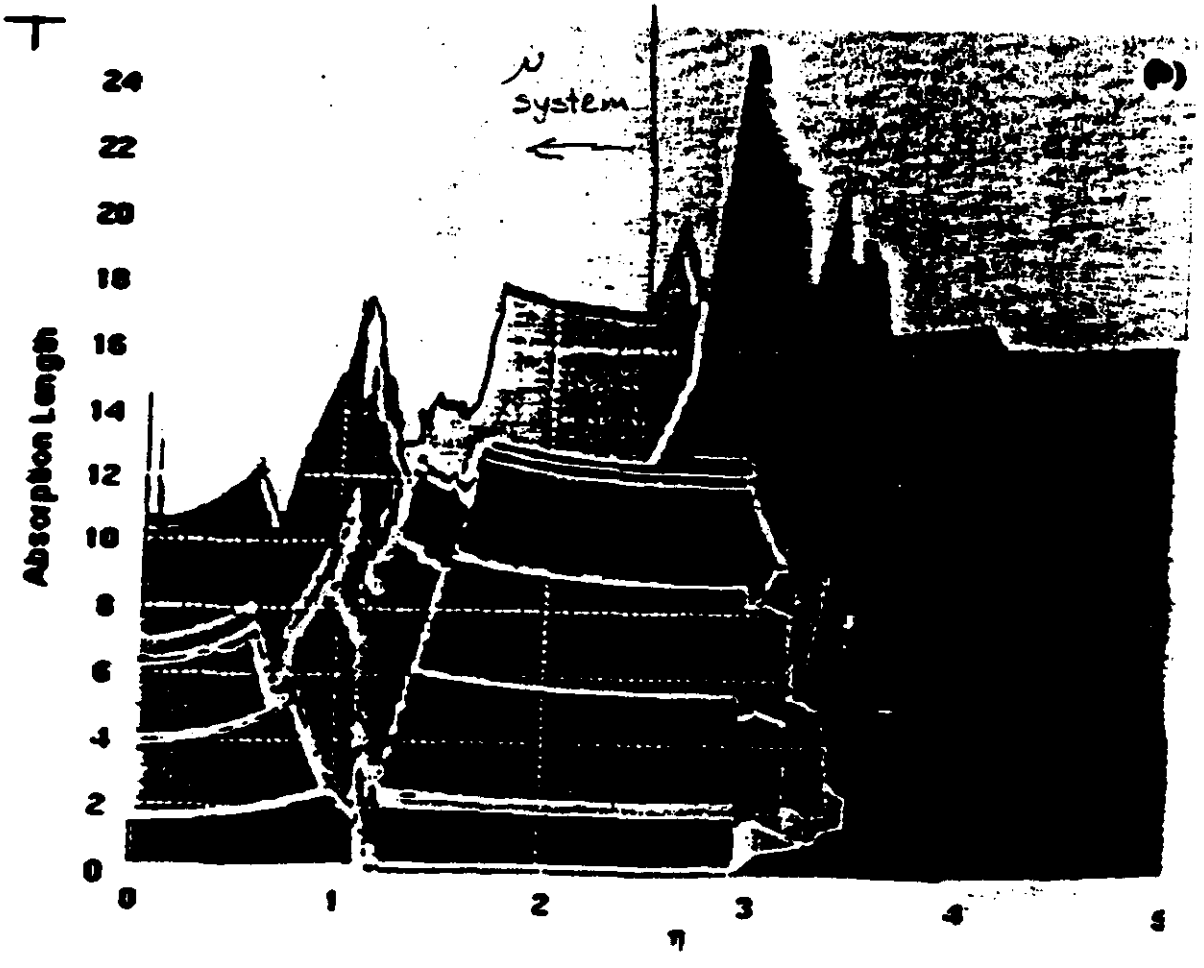
Criteria	Minimum Depth required		
	$0.1 < \lvert\eta\rvert < 1.34$	$1.38 < \lvert\eta\rvert < 1.86$	$1.86 < \lvert\eta\rvert < 2.46$
1	11	11	11
2	10	10	10
3	10 strip from .92 - 1.34 in η	12	16
Overall	11	12	16
GEM TDR Calor. is	≳11 λ	≳14 λ	≳16 λ

What if we are not so conservative?



TDR

G. 5-1. Overall layout of GEM Calorimeter showing the Inner Barrel with LKr, the Outer Scintillating Barrel alorimeter, and the Endcap with LAr.



In the barrel the muon system design parameters are not set by hadron punchthrough. The are set by

- resolution – strip size, number of layers, lever arm, #sectors
- mechanical constraints – #sectors, chamber lengths/widths, ...
- EM backgrounds – strip size, number of layers, z-track resol.

Barrel muon system specification set

In the endcap, Criterion 3 determines calorimeter thickness

Relax the requirements for the barrel: Use <u>only</u> criteria 3

Keep 4-strip occupancy below 1% at $10^{34} s^{-1} cm^{-2}$

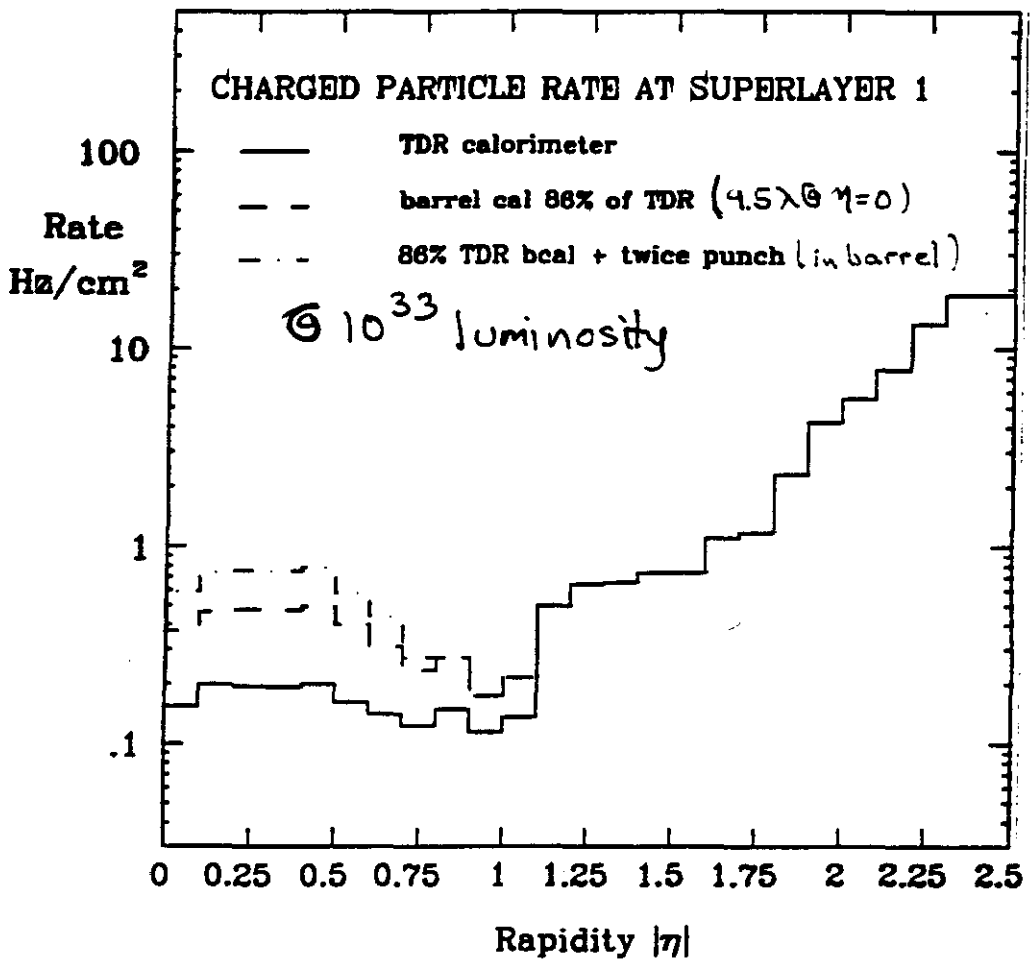
<u>Dangers</u>

- If criteria 1 & 2 not satisfied, then punchthrough rate will dominate the occupancy; rely more on punchthrough simulation ⇒ greater uncertainty

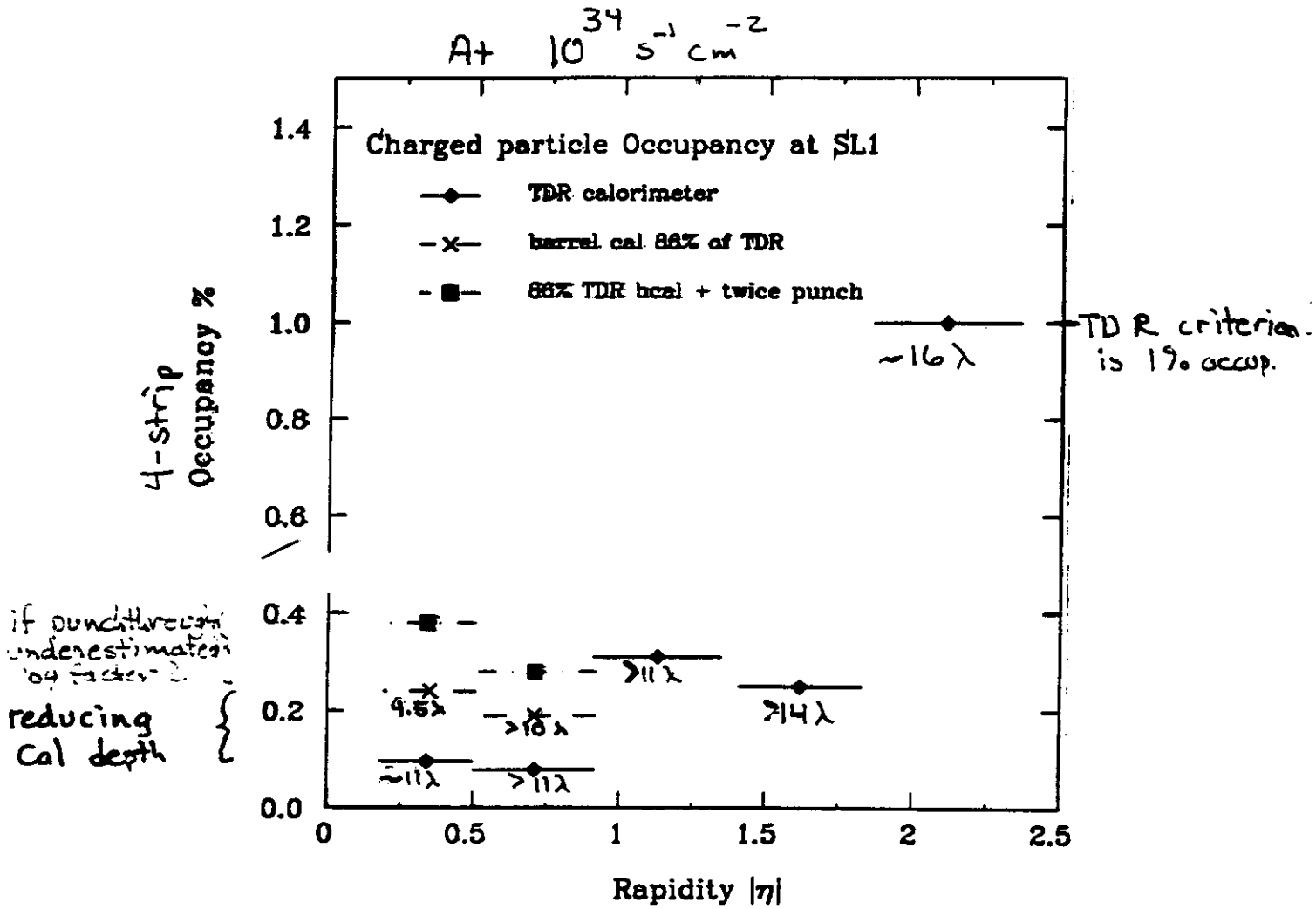
- For thin calorimeters ($\ll 12\lambda$) hadron punchthrough has large hadron/electron component ⇒ higher multiplicity, harder to simulate. (neutrons, δ, etc.) For thick calorimeters ($\gg 12\lambda$), punchthrough is usually a single muon from decay of primary or secondary hadron ⇒ simulations agree better, easier

If Barrel calorimeter depth reduced by 14%
(9.5λ @ 90°)

If punchthrough 9.5λ – 12λ factor 2 higher than Sharin



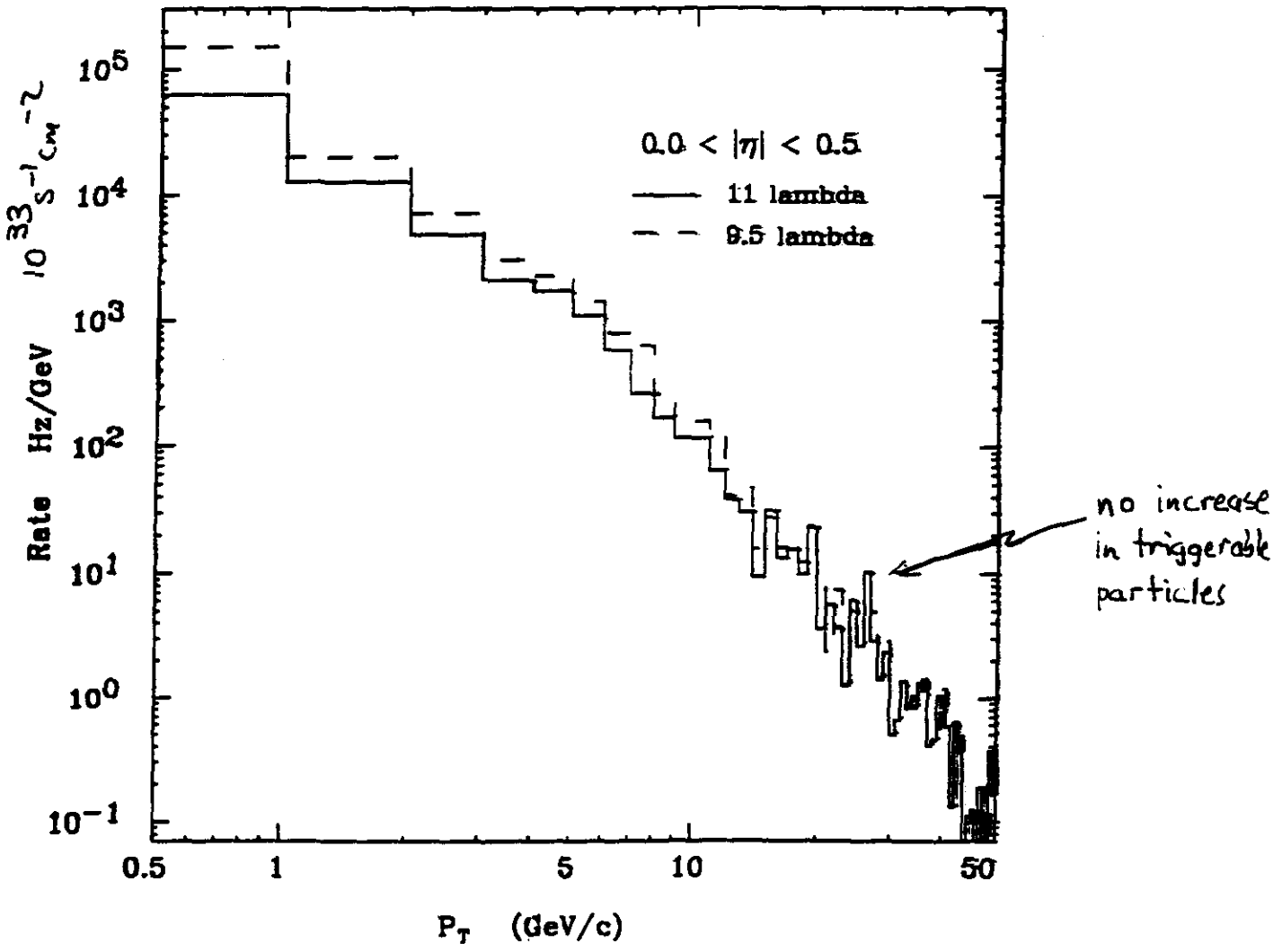
Convert to CSC 4-strip occupancy



Even with factor 2 increase in punchthrough and barrel calorimeter reduced to 9.5 λ at 90° CSC 4-strip occupancy still below 1% at 10^{34} lum.

Transverse momentum spectrum in barrel region (0<η<0.5

Increase in particle rate from reduction of cal depth to 9.5λ comes mainly at low P_T.



Conclusions

By using <u>only</u> criterion 3 in the barrel, the calorimeter depth can be further reduced

- In the range $0<|\eta|<0.5$, 9.5λ will be adequate calorimeter thickness to satisfy criterion 3, where $11-12\lambda$ was used in the GEM Calorimeter TDR design.

- In the range $0.5<|\eta|<1.0$, the calorimeter depth can be reduced further by $\sim 15\%$ and still satisfy criterion 3.

What would we gain?

- more lever arm – better resolution
- higher fraction of high resol. calorimetry – ν Eloss
- less costly calorimeter

Making this thickness reduction puts greater reliance on details of hadron punchthrough simulation. Further validation of codes (RD5) needed.

gem

γeμ

Presentation by:

Yuri Fisyak

Neutron and gamma fluxes (update)

Yuri Fisyak

The reasons to update of the calculated neutron and gamma fluxes are the following:

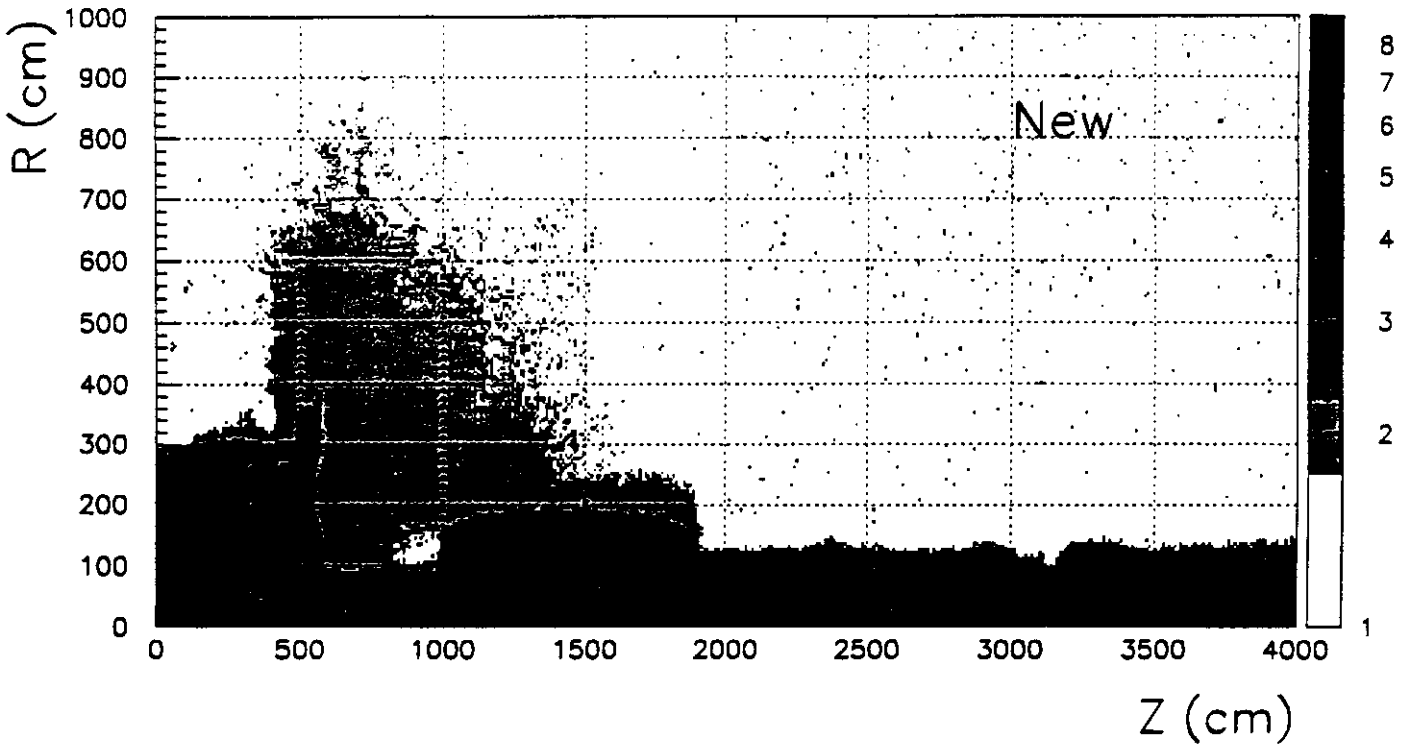
- rather pure statistics (40 DTU events) which had been used for TDR, at least it is needed to check the result stability;
- new version of GCALOR 1.01/03 930610 11.10 with set of bugs has been fixed

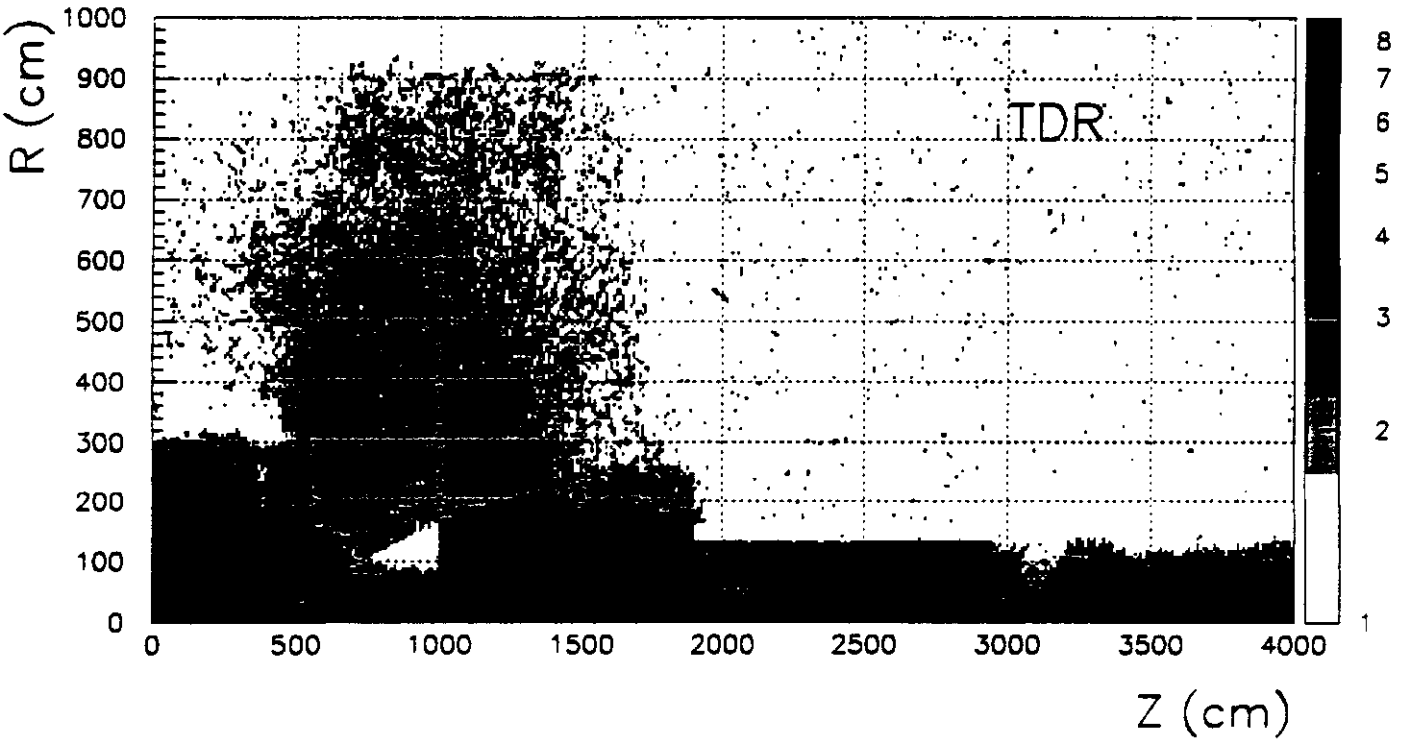
The results presented are based on statistics 238 DTU events. There is a fz-file with hits which will be used to simulate neutron background.

This report contains the following information:

- comparison TDR and "NEW" calculation for neutron and gamma fluxes, their ratio;
- new neutron fluxes in muon chambers;
- neutron and gamma kinetic energy spectra in "volume" and on the "surface";
- minimum bias event hit distributions.

Neutron flux 10^n Hz/cm^2





New

Neutron flux (Hz/cm^2)

R (cm)

3535	4666	4035	3154	3034	3942	4055	3996	3938	3756	2843	2521	2502	1683	4443
4466	4771	4023	3993	3894	3996	3773	3559	3669	2735	2712	2297	2566	2494	2173
4917	5521	4527	4158	3909	3784	4249	4267	4241	3273	2822	2501	3357	3058	2413
4755	4853	5302	4750	3174	3424	3468	4452	4589	3351	1999	2276	3117	2724	2034
5300	5024	4367	4598	4434	3551	4007	3572	4417	2788	3041	2564	2781	2367	2195
6105	5363	4562	4973	3692	3738	3531	3670	4322	3535	3354	2775	2728	2414	2270
5572	6224	4571	5534	3407	3243	3719	4193	4235	3918	3887	2652	2648	2418	1869
6165	5160	5414	5803	3787	3539	4429	4422	4159	3644	3976	2581	2616	2380	1870
6386	5562	5681	4353	3857	4946	4608	4237	3943	4073	3782	3547	3317	2717	2972
6955	6288	6564	6590	5163	5758	5023	4467	5330	4146	3912	3506	4307	4804	5080
7012	5703	6238	5573	5130	5147	5237	5287	5784	5087	5744	7024	10086	9393	9478

Z (cm)

TDR

R (cm)

9250	9844	6812	6662	6561	7215	4915	6357	5642	5601	6758	4132	5260	3602	4474
8879	7756	9050	6747	7750	6371	7434	6032	6165	6351	7610	4672	4240	3616	4499
7523	7259	8941	8687	8753	9186	8822	9246	8664	8712	5636	3971	3136	4076	3682
8376	10228	8477	10202	10749	8799	8433	9461	8243	8647	5800	4011	3295	2948	2741
9034	9417	8936	10561	12349	10094	7955	8901	9830	7738	5702	2497	3509	2847	2573
13905	9718	10734	13191	9924	9250	7309	6250	8461	7665	5587	4439	2880	2939	2696
12294	11176	12486	14238	8195	7702	8714	8882	7455	5731	6255	4259	2974	4830	2486
12688	11200	13922	14700	9721	8748	7959	9683	8246	6859	4756	6238	4312	4495	2963
12687	13392	12564	11707	11996	10094	9981	10633	8425	5197	4614	5414	4713	4171	1529
17822	14796	13196	12570	12127	10849	12812	9655	6476	8778	6555	4649	2393	1878	649
16860	14651	14200	12462	16254	11531	11830	9460	6794	5926	2950	806	819	1314	1451

Z (cm)

Neutron flux (Hz/cm^2) New

R (cm)

2716	3055	2964	3200	3615	3068	3295	3637	3104	2728	2333	2419	2117	1791	1822
3774	3428	3689	3584	3033	3610	3897	3087	2703	2866	2007	2261	2316	2015	2000
4107	3299	3940	3638	3353	3643	3519	3760	2942	2191	2405	2291	2241	2124	2184
4417	3656	3321	3612	4041	3565	2971	3427	2733	2744	2570	1962	2479	2191	2420
4969	3579	3151	3105	3359	3233	3555	3689	3544	3147	2726	1986	2033	2001	2309
4227	3817	3422	3303	4115	3594	4435	3543	2983	2986	2463	2580	2398	1988	1820
3943	3511	3888	3615	3421	3078	3086	3295	3060	3401	2656	2084	1900	2000	1743
4187	3730	3816	4704	4094	3198	2967	3350	3297	3496	2762	2244	2114	2044	2184
3769	4123	3642	4018	4284	3677	3390	3507	4392	3148	3352	2380	1836	2043	1951
4174	3899	3555	3442	3362	3621	3870	3978	3356	3801	3085	2627	2344	1843	2264
3535	4666	4035	3154	3034	3942	4055	3996	3938	3756	2843	2521	2502	1683	4443

200 190 180 170 160 150

600 620 640 660 680 700 720 740

TDR

Z (cm)

R (cm)

3683	4520	5681	4667	3889	4569	5229	5421	5722	3177	3625	3058	2758	3145	2675
4678	4162	4646	5756	4655	4623	5787	4463	4858	2938	3427	2986	2945	3364	2691
5299	5162	6198	5831	4171	4959	4741	4789	3945	3357	3904	3591	3211	3363	3893
4521	5053	5850	5578	5634	3807	4115	4933	5240	4281	3288	3370	3775	3962	4051
6231	5953	6955	5206	5314	3705	3938	5458	4669	6186	4919	3200	3470	3313	3492
5263	5963	5657	5229	5840	5285	7043	5273	5029	5180	5661	3698	3660	3953	3202
6062	6062	7007	6063	6117	6242	6238	5087	6711	5209	5695	2463	2555	3282	4350
6795	7860	6074	6996	6711	5387	5795	6643	6775	3962	4983	2968	2235	2788	3162
8333	6708	7343	8527	5979	6161	5378	5415	7147	7835	4923	2066	3426	3600	2735
7465	6997	8262	7901	8311	7570	4896	5752	6948	6498	6134	2901	3433	4084	3702
9250	9844	6812	6662	6561	7215	4915	6357	5642	5601	6758	4132	5260	3602	4474

200 190 180 170 160 150

600 620 640 660 680 700 720 740

Z (cm)

Neutron flux (Hz/cm^2) New

R (cm)

3319	2958	2689	2889	2794	3356	3640	2644	2825	3074	2648	2100	2020	2092	2395
2895	3068	2419	3151	2616	3298	3375	3197	2816	2752	2652	2248	2064	2078	2355
2794	3191	2788	3326	3123	3375	3079	3561	2902	2676	2504	2172	2303	2066	1808
2830	3407	3089	2680	3404	3308	2910	3249	2951	2535	2272	2386	2162	2256	2144
3296	3478	3632	2604	2518	2649	3043	3361	3099	2780	2469	2107	2166	2477	2464
2889	3121	2832	2948	2605	2764	2897	3382	3292	2872	2884	2588	1908	2080	2730
2998	2617	2592	2643	2787	2415	2879	3411	3548	3491	2669	2915	2005	2357	2502
2795	2767	3044	2675	3717	2379	3256	3401	3556	3154	2510	1775	2176	2270	2087
3600	2951	2983	2687	2960	3361	2847	2900	3355	3207	2520	2143	2133	2253	1945
2968	2682	3178	2884	3400	2870	3466	3040	3714	3026	2523	2288	2435	1822	1661
2716	3055	2964	3200	3615	3068	3295	3637	3104	2728	2333	2419	2117	1791	1822

250 240 230 220 210 200

600 620 640 660 680 700 720 740

TDR

Z (cm)

R (cm)

3858	3155	3117	3726	3974	4783	2954	3245	4153	2863	2950	2440	1736	1993	2170
3885	3356	2899	3314	3480	4276	4249	3316	3280	2399	3030	2133	3365	1847	1117
3302	3151	2589	3376	3810	4125	4270	3501	3279	1739	2763	2073	2773	2244	2570
4099	3388	2468	4005	3796	4595	4750	4106	3314	2669	2871	1958	2136	2844	2439
4463	3314	3621	2901	4825	3962	3888	4047	3702	3259	1748	1464	3112	2821	2138
5196	4065	4740	3709	5593	5581	4306	4569	5222	3425	2499	2499	2526	2640	2361
5043	3939	3894	4666	4062	4331	4816	3994	5343	4151	2839	2639	1472	2912	2309
4418	5641	4519	4147	5048	5979	4872	4425	3260	4219	3614	2273	2214	2605	2423
3659	4756	3993	4114	5433	5798	4310	4119	3934	3954	3522	2501	2944	2353	2809
3659	4737	4691	3864	5150	4753	3882	4816	4054	3023	4050	2570	2637	2483	3333
3683	4520	5681	4667	3889	4569	5229	5421	5722	3177	3625	3058	2758	3145	2675

250 240 230 220 210 200

600 620 640 660 680 700 720 740

Z (cm)

Neutron flux (Hz/cm^2) New

R (cm) \ Z (cm)	600	620	640	660	680	700	720	740							
300	6379	5463	4695	4368	4014	4286	3563	3359	2629	2533	3151	3083	2635	2246	2173
	6383	4966	4681	3828	4318	4342	3384	3098	2514	2335	2847	3017	2263	2248	2280
290	5893	5151	4284	3728	3371	3558	3740	3082	2591	2682	2572	2876	1991	2057	3011
	5178	4782	4261	4338	4220	3468	3029	3409	2279	2765	2806	2514	2389	2402	1850
280	4041	3499	3934	4231	4021	4055	3006	3073	2628	2518	2577	2847	2620	2073	2079
	3793	3671	3377	3562	3728	3798	3508	3357	3096	2802	2787	2560	2498	2409	2440
270	4059	3726	3086	3693	3436	3902	3163	3875	3163	2343	3105	2818	2547	2023	2172
	4570	3513	3319	3341	3845	3556	3037	2715	2645	2601	2485	2648	1956	1883	2211
260	3655	3216	3413	2906	3943	3280	4219	3124	2869	2653	2656	2256	1783	2183	1846
	3339	2869	3331	2830	3201	3252	3692	3039	2803	2920	2871	2221	1794	1840	2195
250	3319	2958	2689	2889	2794	3356	3640	2644	2825	3074	2648	2100	2020	2092	2395

TDR

R (cm) \ Z (cm)	600	620	640	660	680	700	720	740							
300	3451	3321	2336	3485	2828	2550	2587	2529	1588	1500	1683	2367	2464	1920	1725
	3890	3198	2623	2757	2836	2626	3124	2155	2394	1923	1744	2083	1557	2476	1071
290	4513	3303	2875	3096	2154	2801	3151	2232	1924	1913	1314	1347	1293	2032	5080
	2659	2649	3329	3518	2276	2618	3666	2472	1823	1716	1395	1611	1840	2160	1552
280	2783	2486	5443	3476	2765	3409	2530	2057	1879	2124	1817	1162	1942	1673	3590
	4752	2836	2852	4795	3284	4722	3281	2615	2472	1505	1923	1352	1881	1219	1977
270	2356	3262	4031	3615	3122	3468	2991	1569	2798	2016	1714	1882	1893	2086	2194
	3872	3258	4176	4851	3003	3143	2968	2766	2259	1958	1722	2150	1769	1400	1056
260	3728	2761	3198	3583	3601	3243	3240	3216	2786	2347	2958	2381	1717	1390	1340
	3284	4624	3623	3524	4950	3590	3372	3432	2555	3022	1917	1904	1843	1614	1014
250	3858	3155	3117	3726	3974	4783	2954	3245	4153	2863	2950	2440	1736	1993	2170

Neutron flux (Hz/cm^2) New

R (cm)	600–620	620–640	640–660	660–680	680–700	700–720	720–740
740–750	1013	1125	1077	1077	1066	1338	1055
	852	1048	982	825	1055	1171	1128
730–740	1003	1089	1325	899	1075	1041	1133
	946	1048	1200	1012	953	906	1150
720–730	885	1018	1267	1033	1069	962	1218
	1095	947	1055	1029	1118	969	1203
710–720	1108	1060	927	1043	1076	1070	1233
	1142	1009	933	1096	1057	1126	1200
700–710	1042	903	1075	1052	961	1140	1233
	1097	992	1166	1090	1133	1214	1326
690–700	1314	994	1068	1117	1089	1490	1381

R (cm)	680–700	700–720	720–740
740–750	1250	1147	1166
	1129	1298	1123
730–740	1229	1429	1298
	1421	1302	1322
720–730	1302	1345	1165
	1325	1300	1245
710–720	1132	1099	1091
	1245	1136	1105
700–710	1212	1202	1239
	1121	1600	1270
690–700	1184	1078	1017

R (cm)	720–740	740–760	760–780	780–800	800–820	820–840	840–860
740–750	1266	947	1024	995	1288	1212	1008
	1285	940	929	832	1257	1144	960
730–740	1028	1089	940	853	1288	1202	1015
	977	1022	885	958	1239	1105	1098
720–730	940	979	907	914	1212	1136	920
	1166	1094	885	1023	1245	1126	1038
710–720	989	1079	1060	969	1121	1057	961
	1144	960	1098	888	1335	1260	1015
700–710	1257	1008	1015	920	1301	1200	1038
	916	1021	1038	961	1184	1126	1076
690–700	1041	946	918	1076	1078	1017	1041

TDR

Z (cm)

R (cm) — Z (cm)

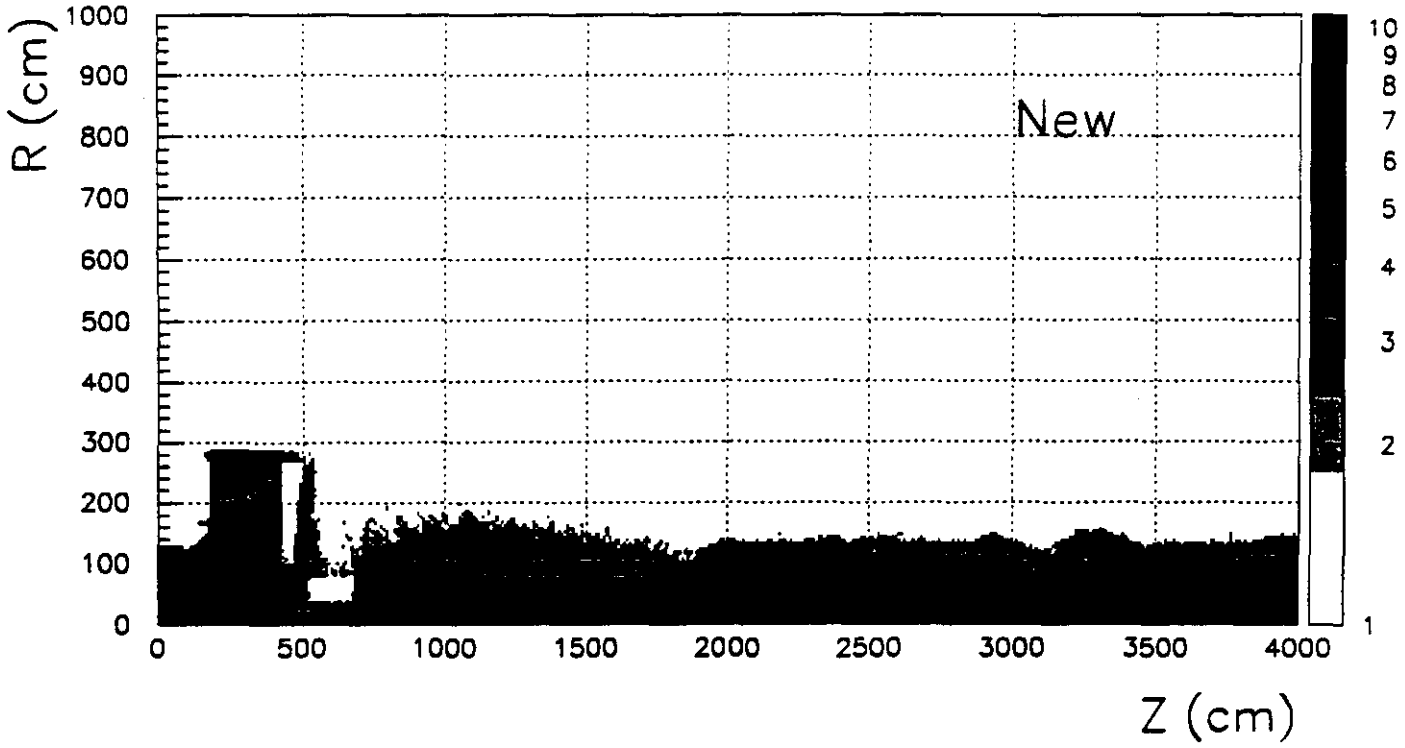
R (cm)	600–620	620–640	640–660	660–680	680–700	700–720	720–740
740–750	721	651	634	668	925	1146	842
	573	834	599	813	555	1070	992
730–740	517	818	602	585	766	1698	753
	416	832	699	558	744	1276	1025
720–730	473	802	682	664	713	1218	764
	611	624	624	844	826	1217	624
710–720	811	733	669	990	701	1365	710
	839	961	1011	975	975	1339	844
700–710	1005	1502	693	743	895	968	772
	1081	887	822	1548	896	1073	708
690–700	1145	810	1050	1327	1240	1086	807

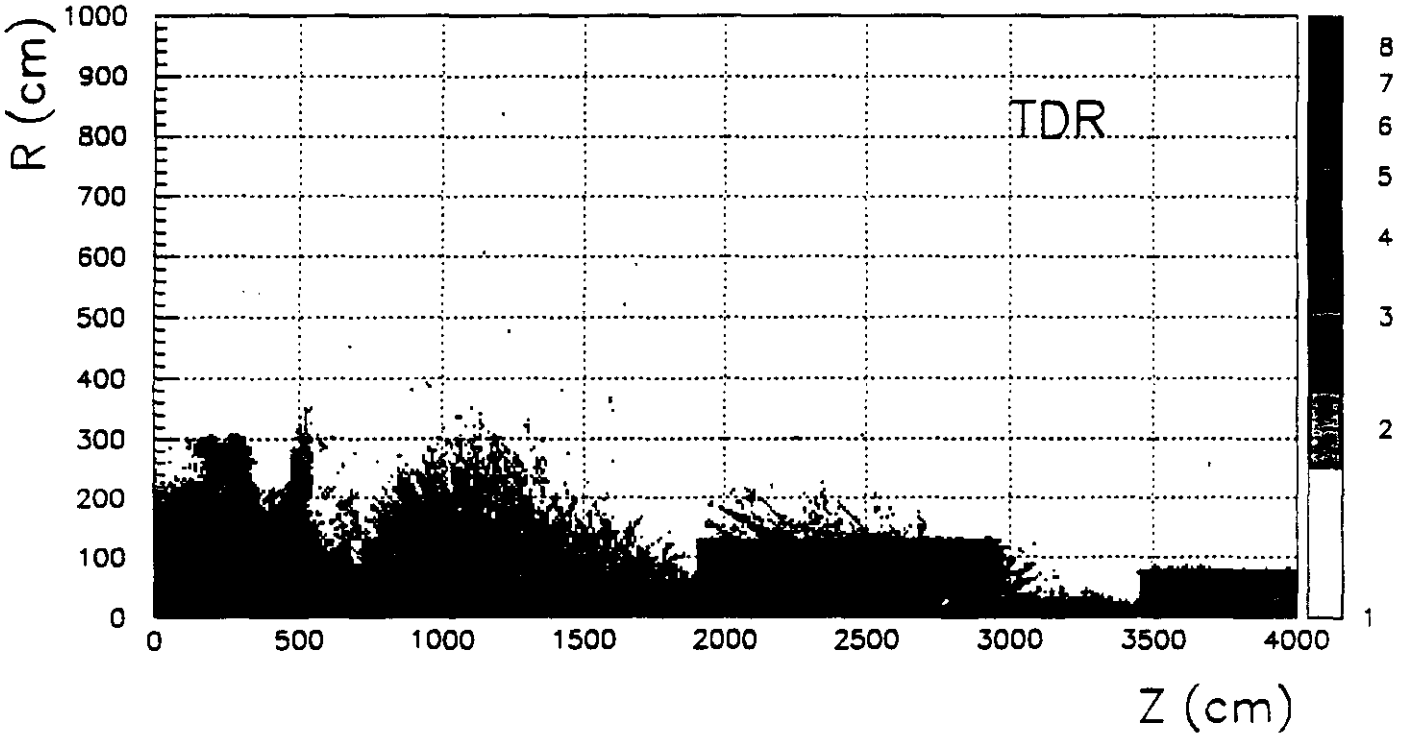
R (cm)	680–700	700–720	720–740
740–750	991	1891	1254
	849	1138	826
730–740	1043	1058	934
	740	905	815
720–730	657	997	1051
	703	667	445
710–720	699	650	749
	523	785	804
700–710	709	1035	1071
	1171	1074	1096
690–700	953	717	1047

R (cm)	720–740	740–760	760–780	780–800	800–820	820–840	840–860
740–750	895	1332	1298	921	2053	1366	1733
	1376	1180	650	1019	887	1186	933
730–740	819	866	1023	645	765	1333	977
	682	1447	1424	865	890	1194	711
720–730	674	1366	1733	896	1030	1084	1450
	904	1186	933	884	1086	1143	869
710–720	969	1333	977	786	873	932	959
	1211	1194	711	610	1120	1047	1086
700–710	1084	1450	720	742	853	1240	1327
	1143	869	767	859	535	1050	810
690–700	932	959	992	866	654	1145	1240

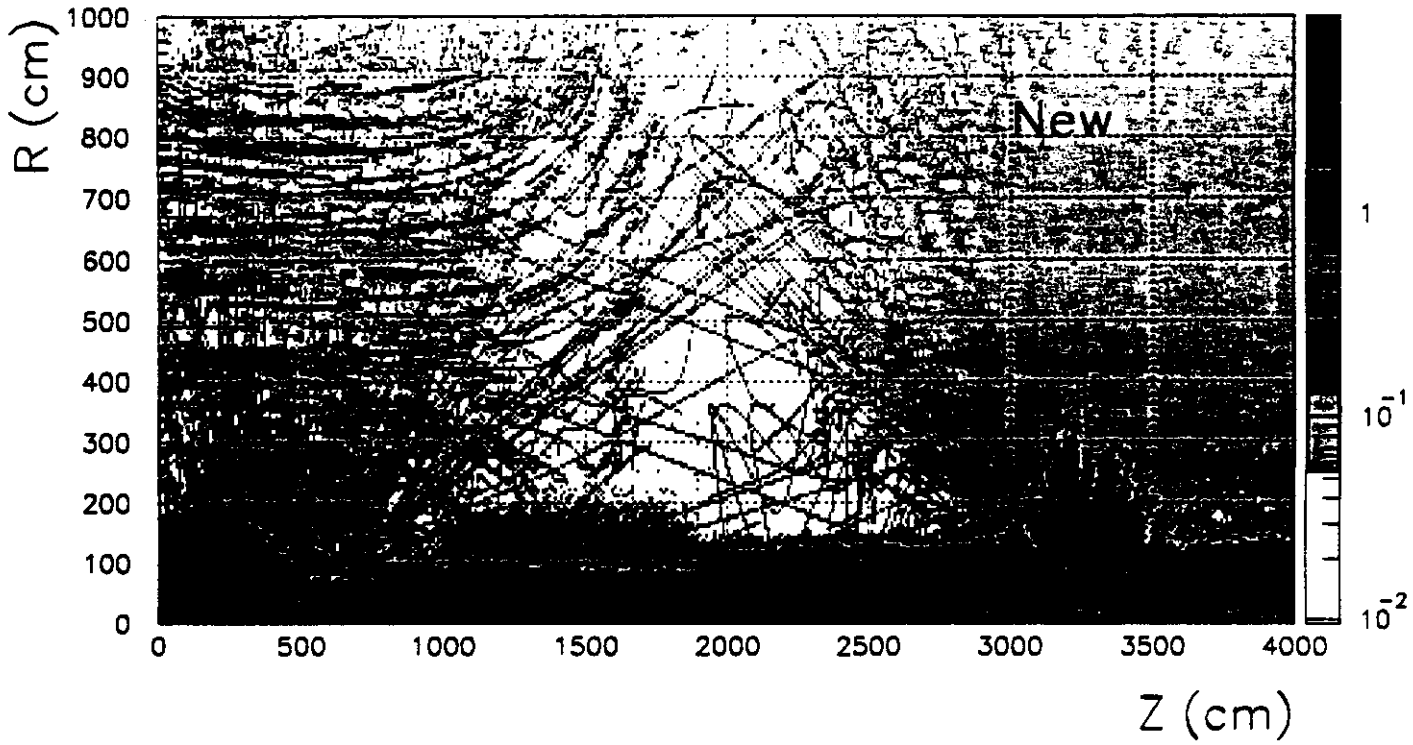
Z (cm)

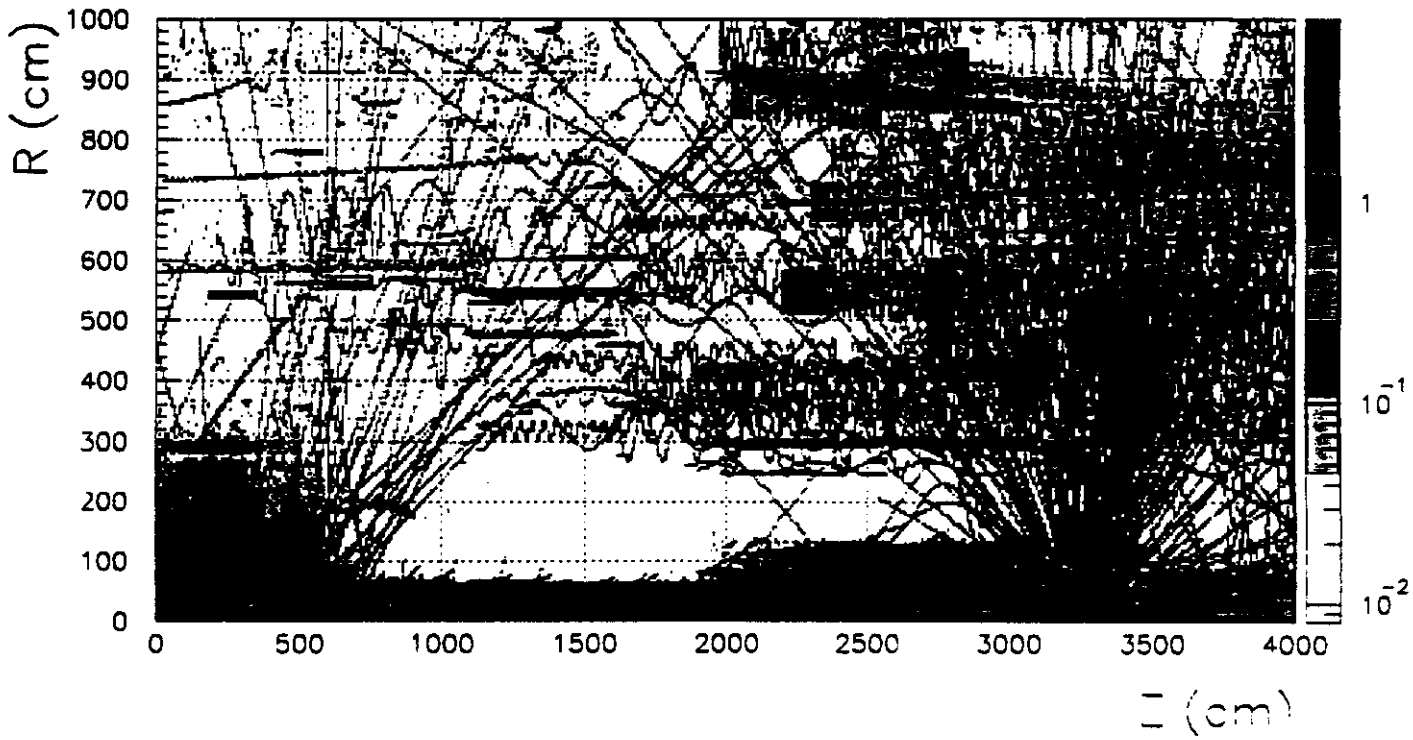
γ flux in 10^n Hz/cm²



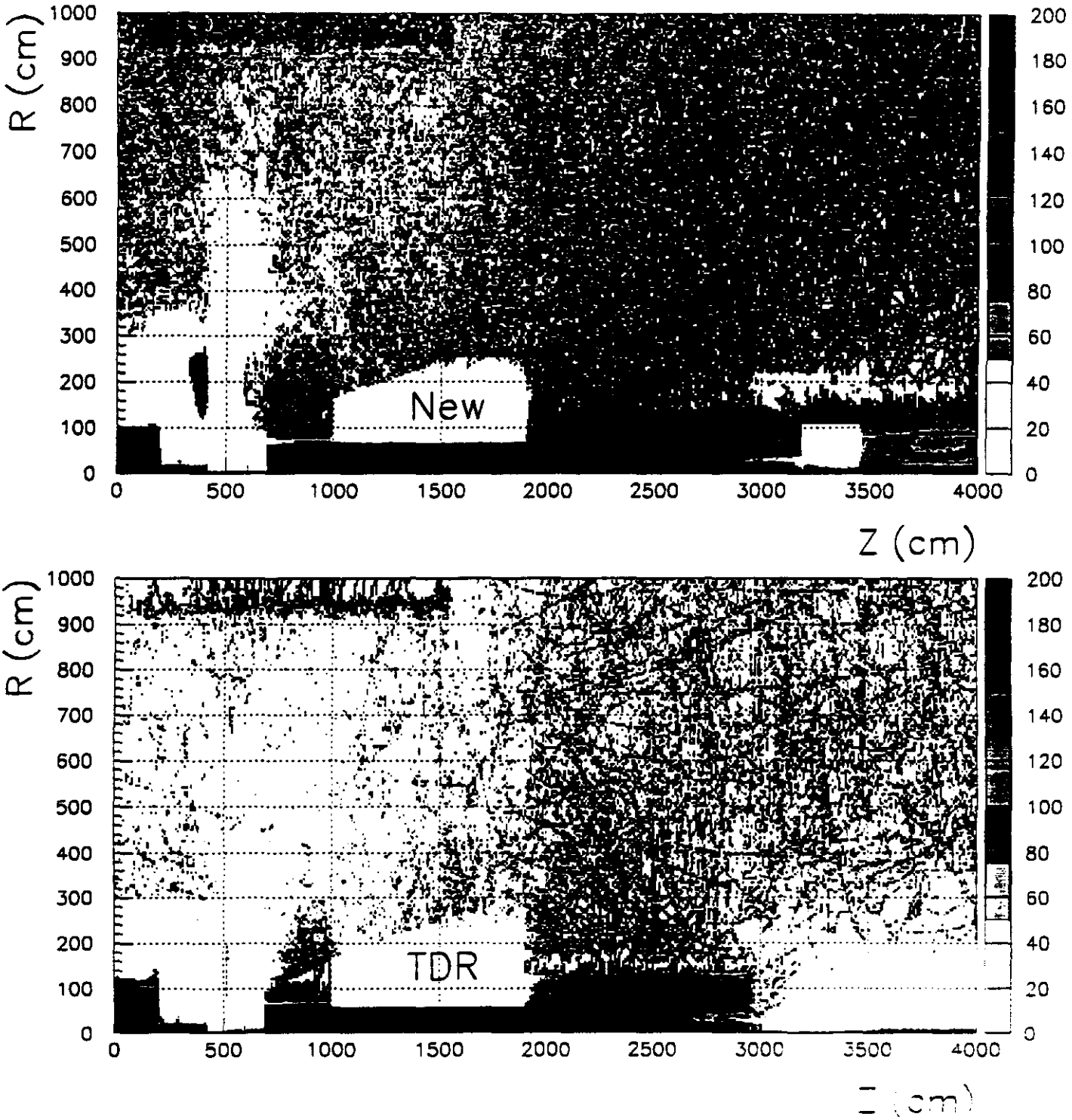


Charged particles (π, K, e, p) flux (Hz/cm^2)

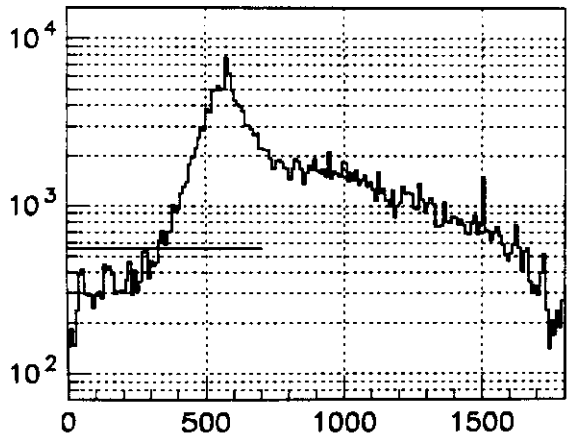




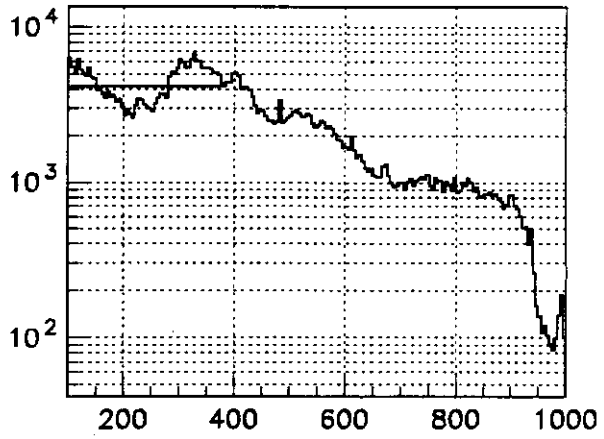
TDR and new calculation of γ/n ratio (%)



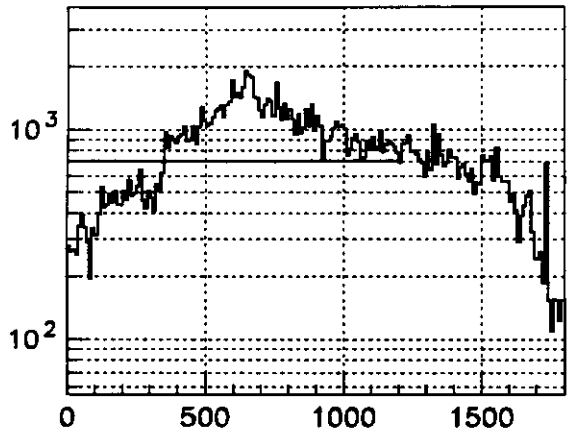
Neutron flux in Muon chambers



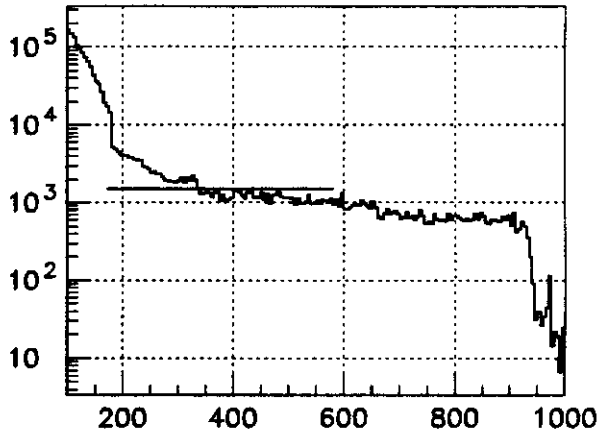
Neutron flux at R=420 cm vs Z



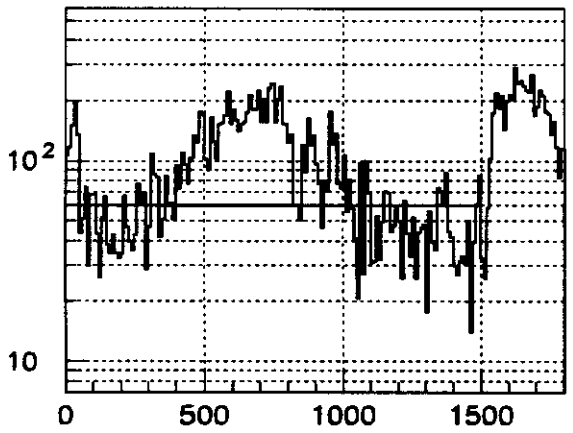
Neutron flux at Z=620 cm vs R



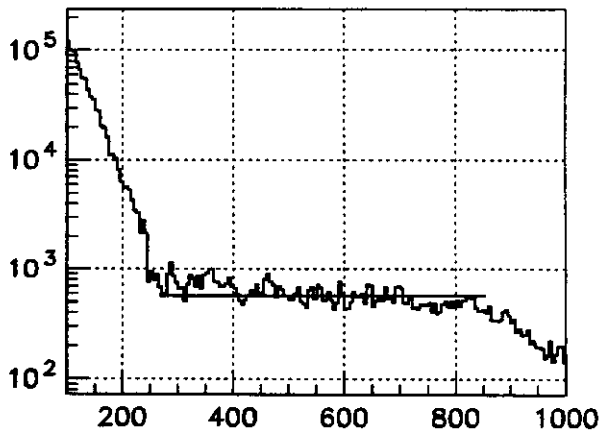
Neutron flux at R=630 cm vs Z



Neutron flux at Z=1110 cm vs R

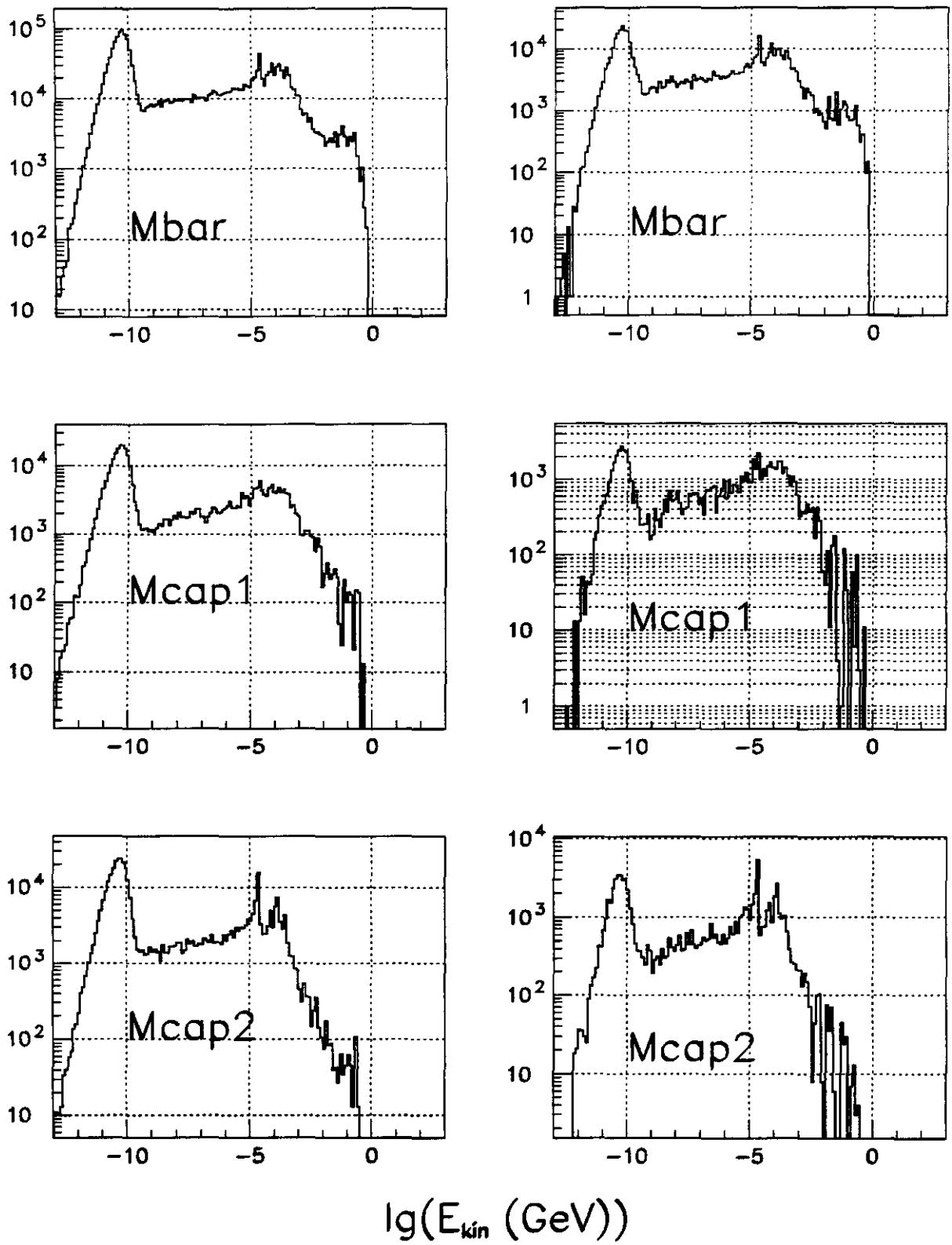


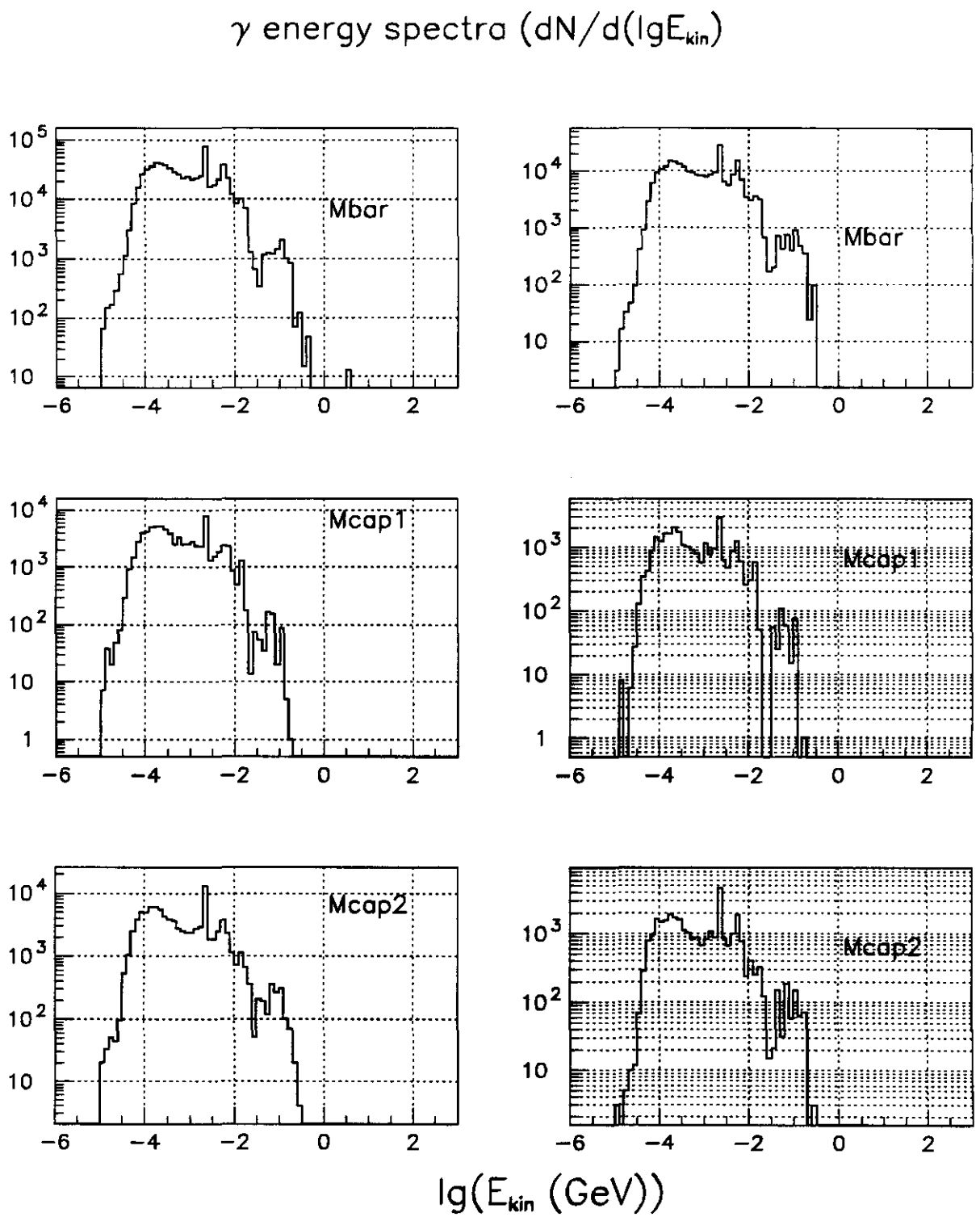
Neutron flux at R=850 cm vs Z



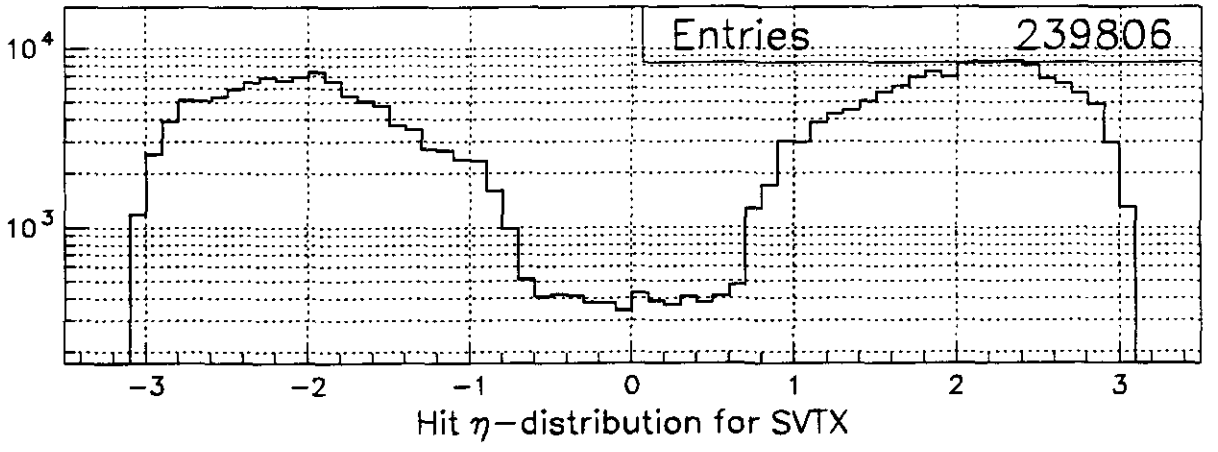
Neutron flux at Z=1600 cm vs R

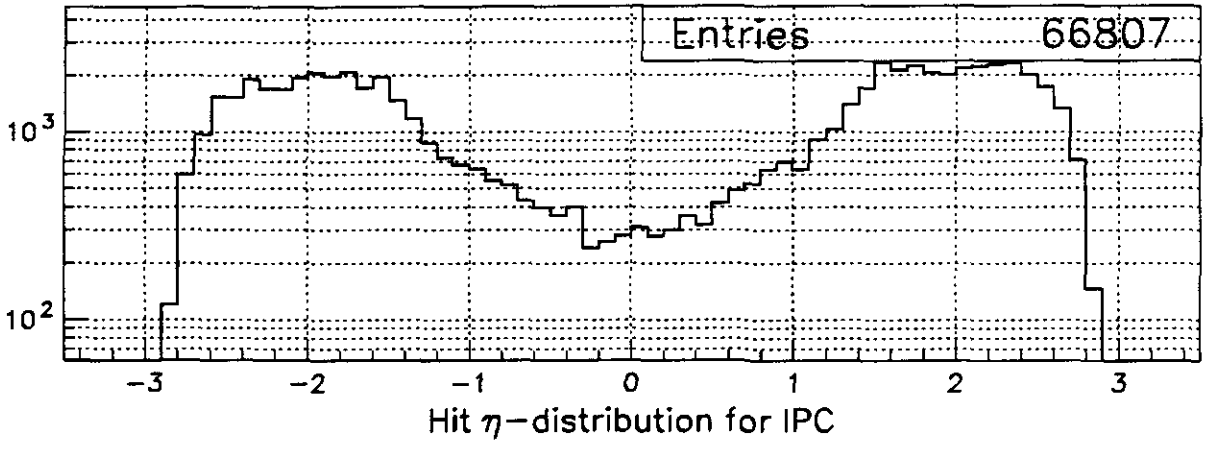
Neutron energy spectra (dN/d(lgE$_{kin}$)

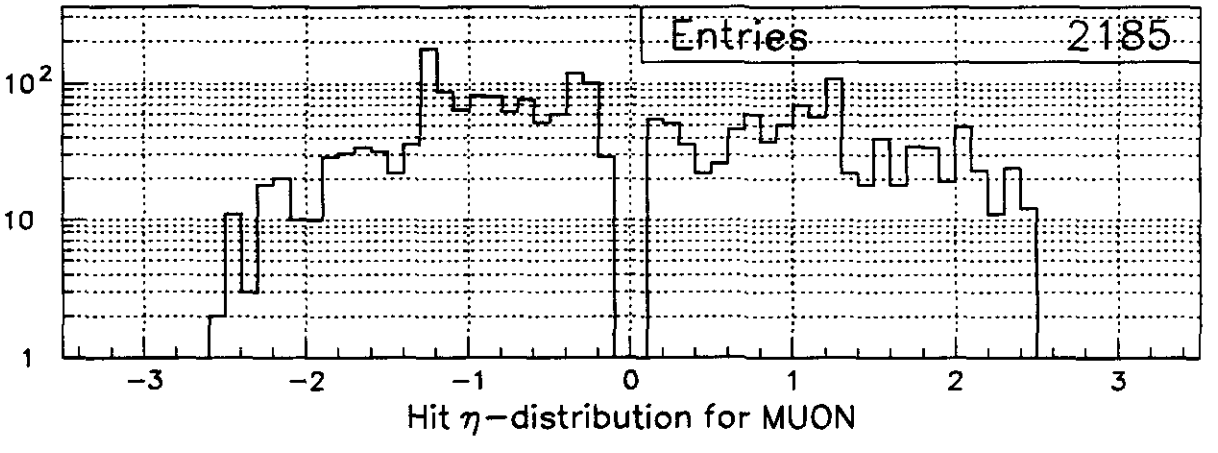



γ energy spectra (dN/d(lgE_kin))
Mbar
Mbar
Mcap1
Mcap1
Mcap2
Mcap2
lg(E_kin (GeV))

Hit per 208 minimum bias (DTU) event vs particle type

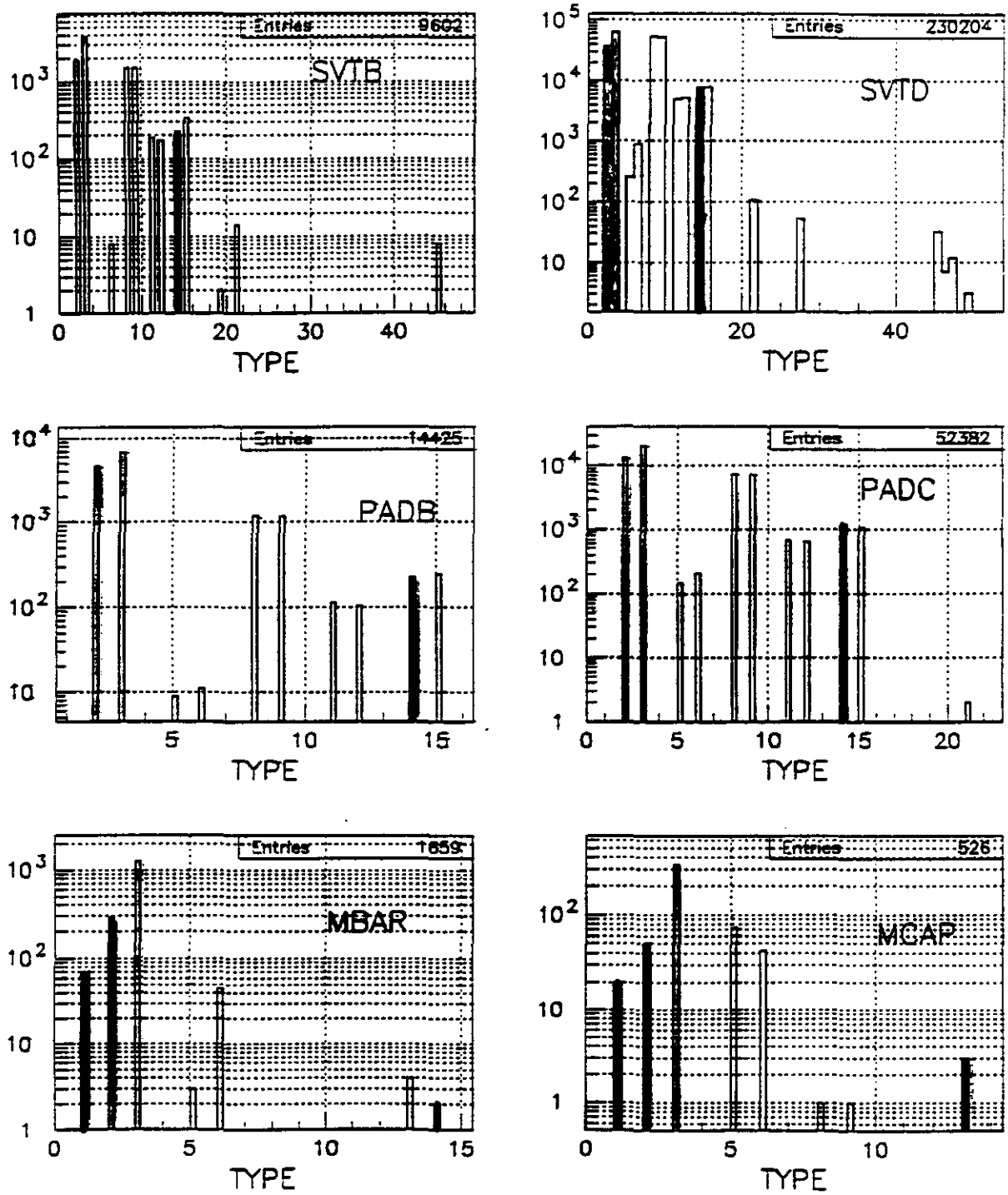






$-\gamma$ $-e^+$ $-e^-$ $-n$

Hit per 208 minimum bias (DTU) event vs particle type



gem

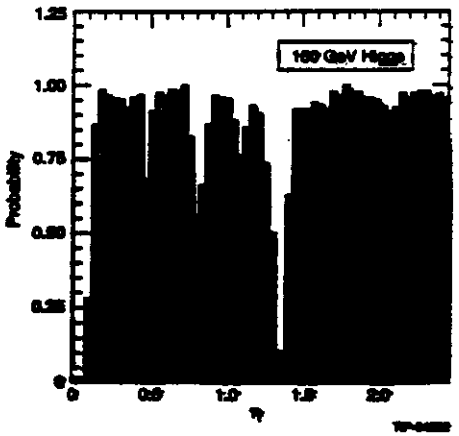
γeμ

Presentation by:

Yuri Efremenko

Higgs in Four muons channel.

The acceptance for a single muon for the rapidity less 2.46 is 84%



The result is decreasing Higgs registration efficiency to 43 %.

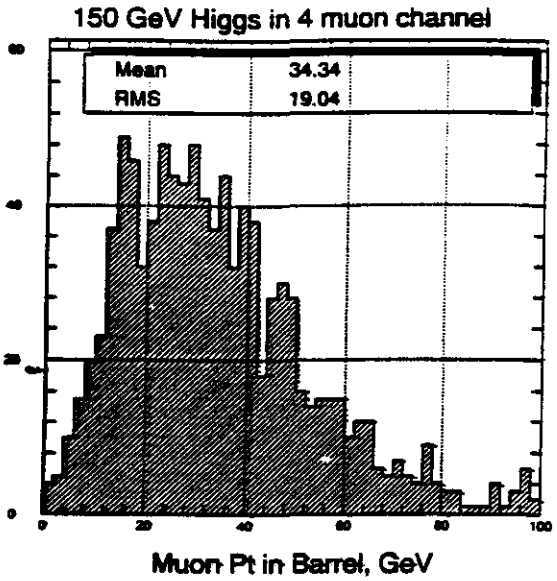
There is two diff. ways.

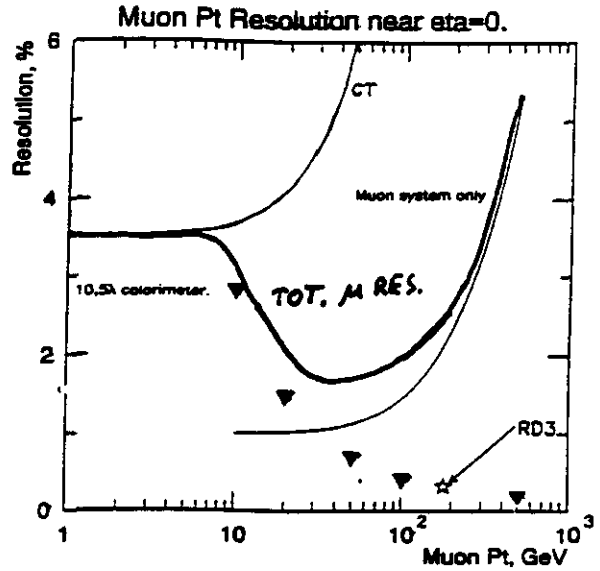
1. Improve muon system.
2. To use information from other detector subsystem, for muon detection.

CT, Calorimeter.

For muons with low Pt we can:

1. Measure Pt in CT.
2. Identification in CAL.





Muon Pt is 10 - 40 GeV.

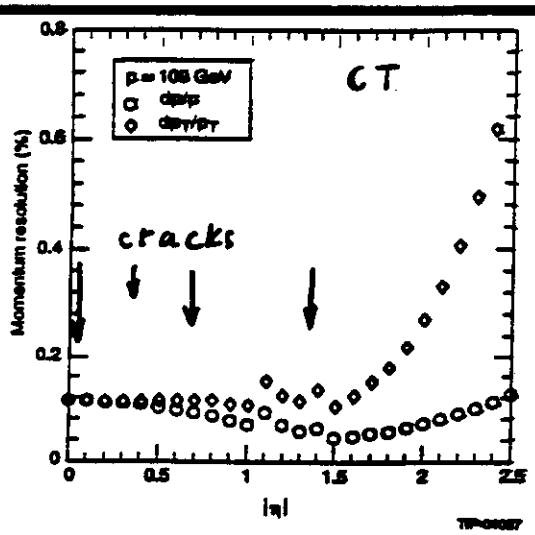
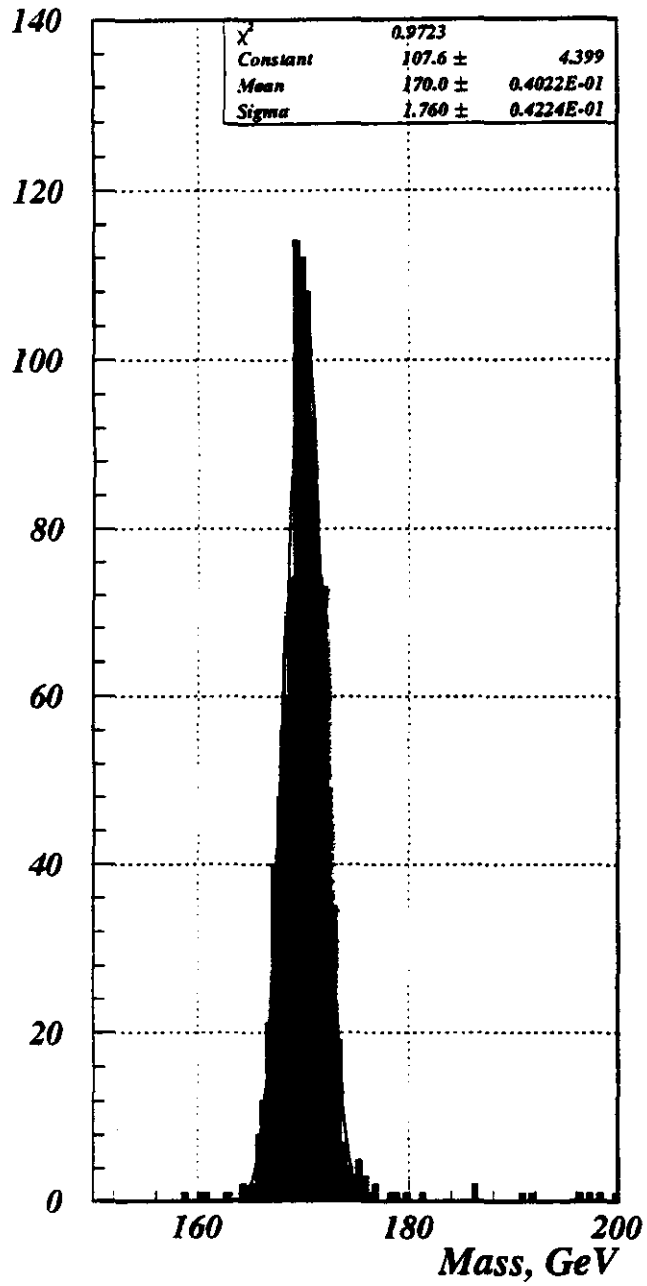


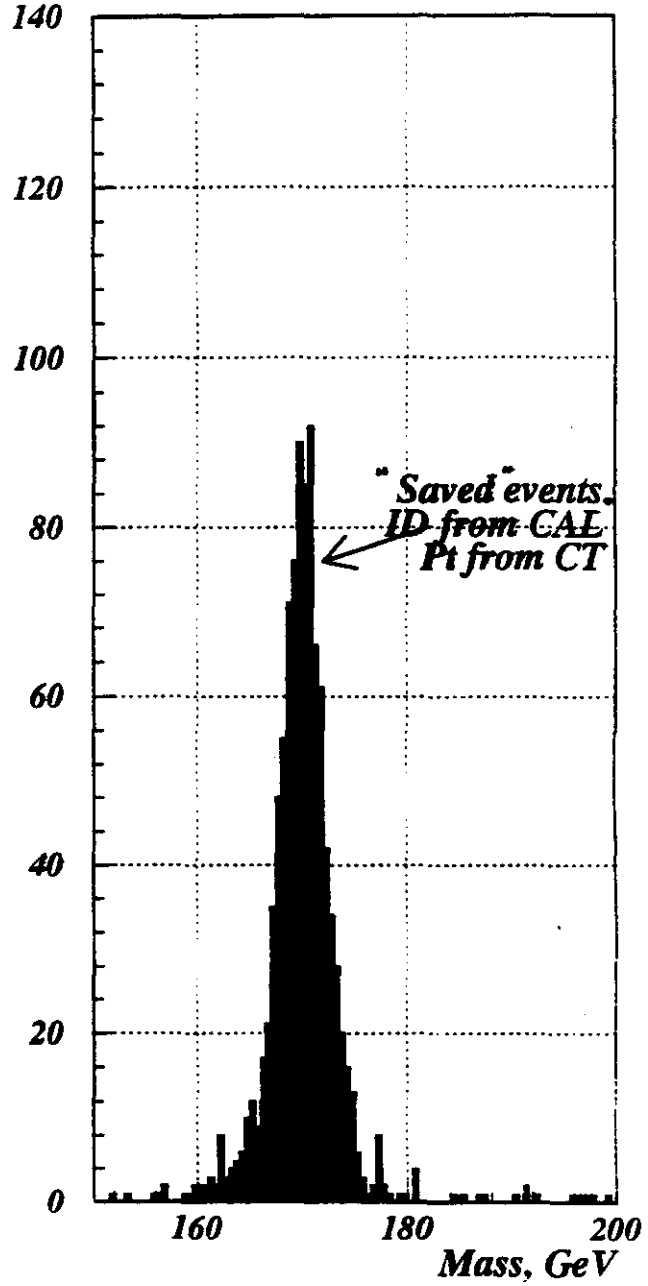
FIG. 6-8. Momentum resolution for 100 GeV/c tracks as a function of pseudorapidity η.

All cracks in the muon system are in the barrel region.

170 GeV Higgs to 4 Muons

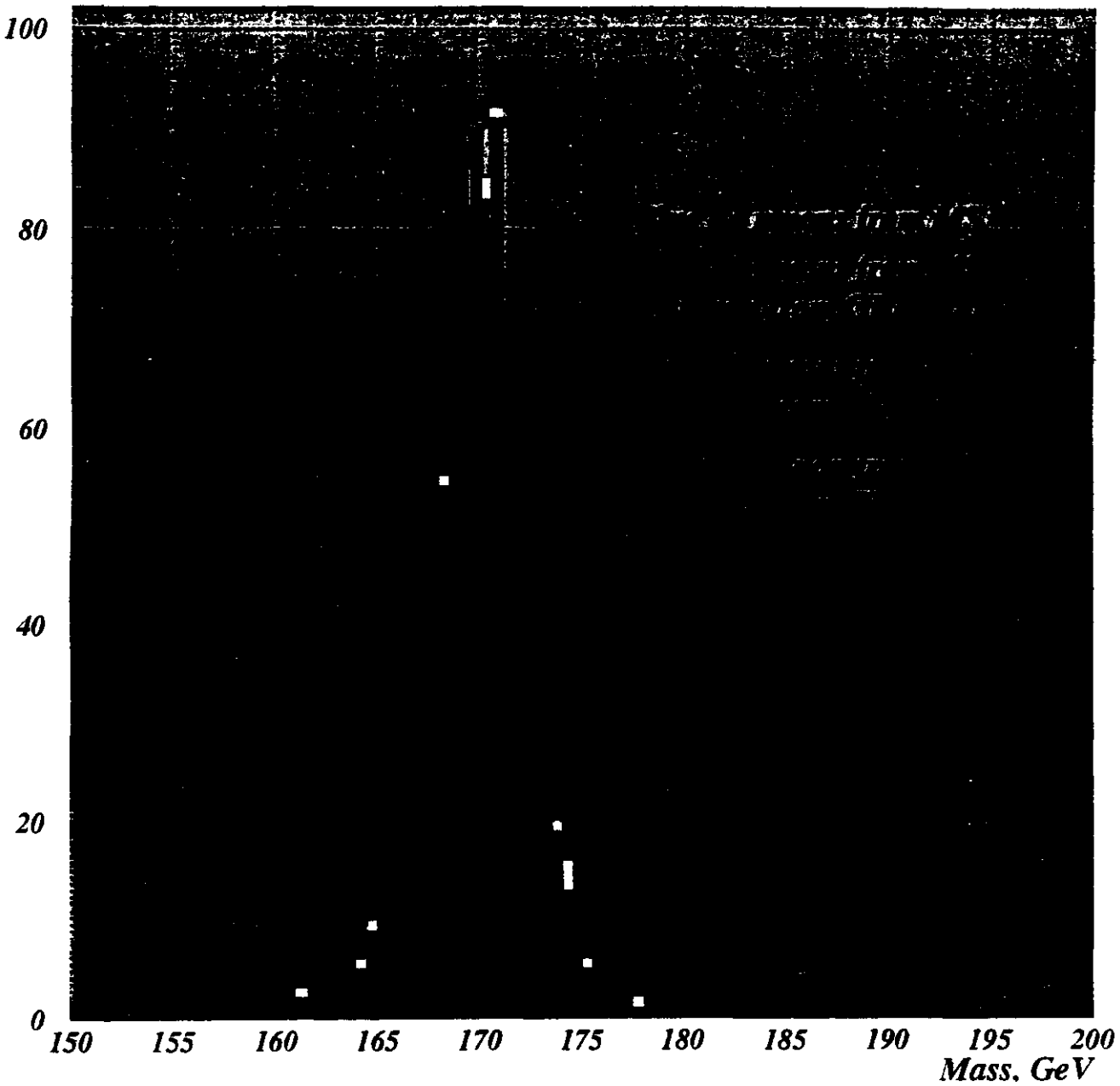


Muon syst. without dead regions.



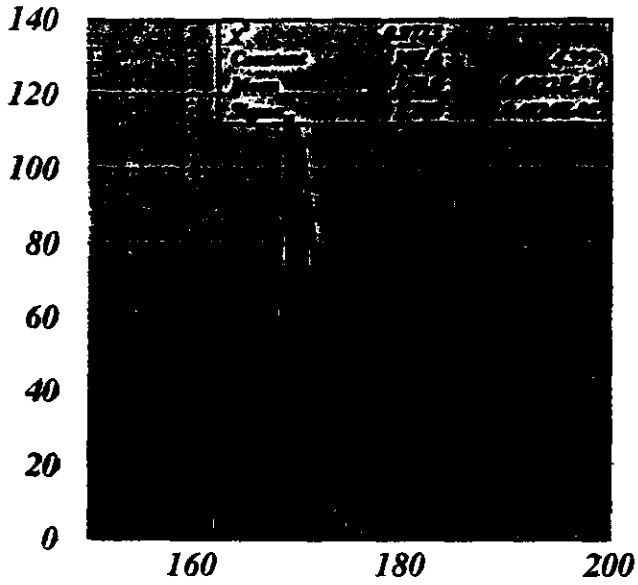
Real Muon syst.

170 GeV Higgs to 4 Muons

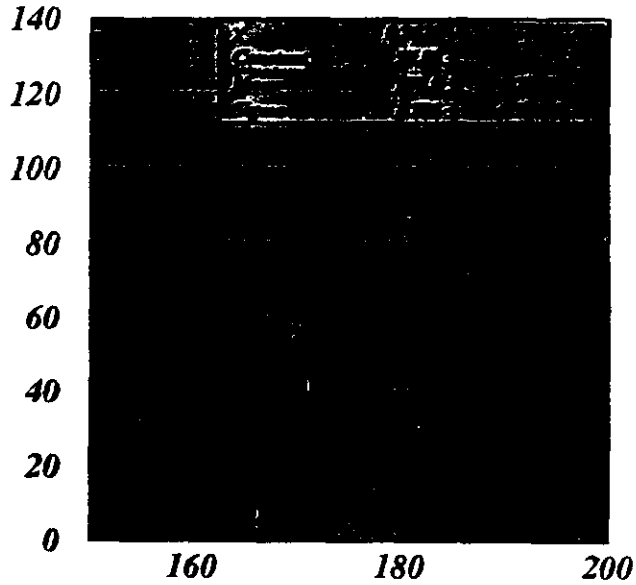


Real M.S.

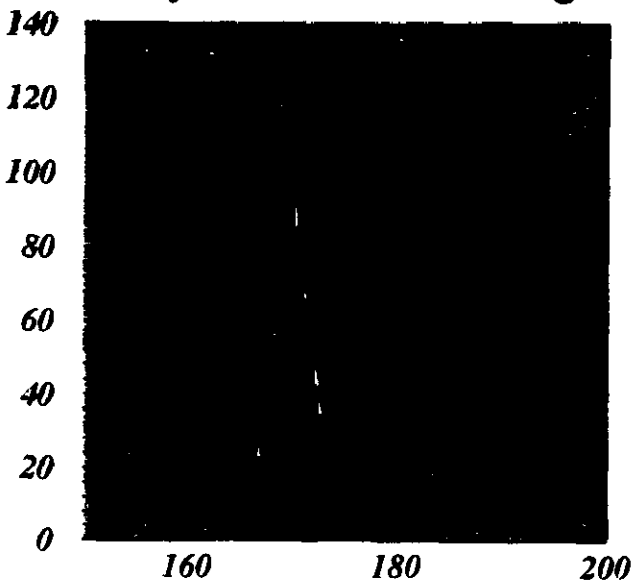
170 GeV Higgs to 4 Muons



Muon syst. without dead regions.



Real Muon syst.



MS + CT + CAI

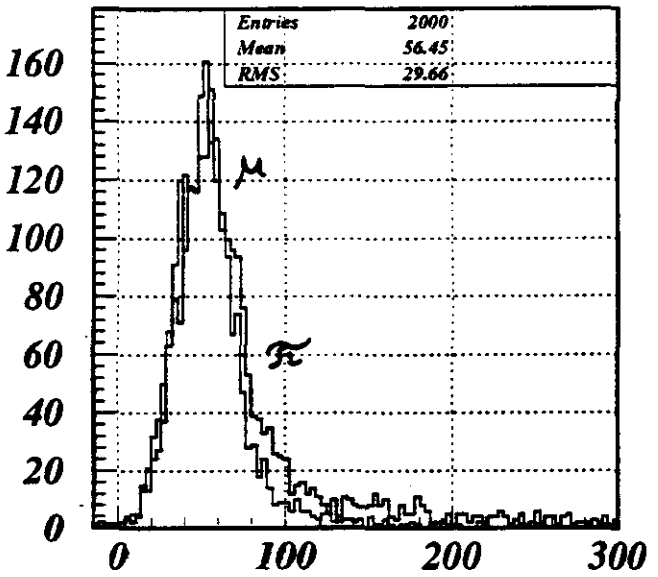
And so:

1. We have to look for 3 muons events.
2. We can use Pt from CT.

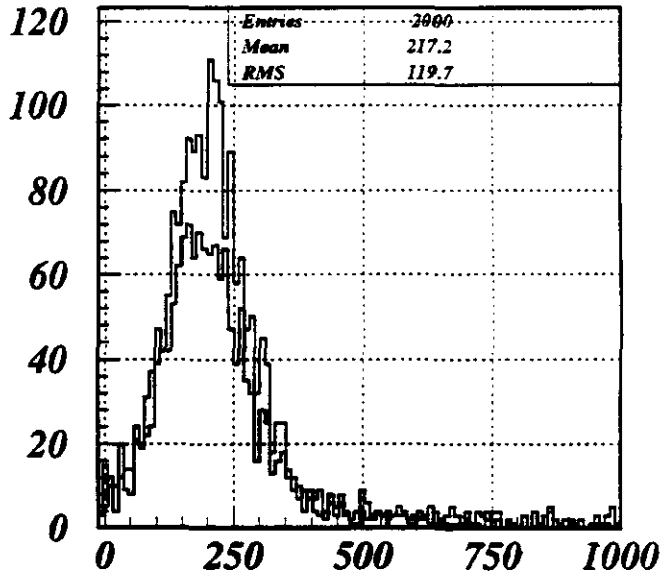
What muon/single hadron rejection we can get from calorimeter?

Preliminary results.

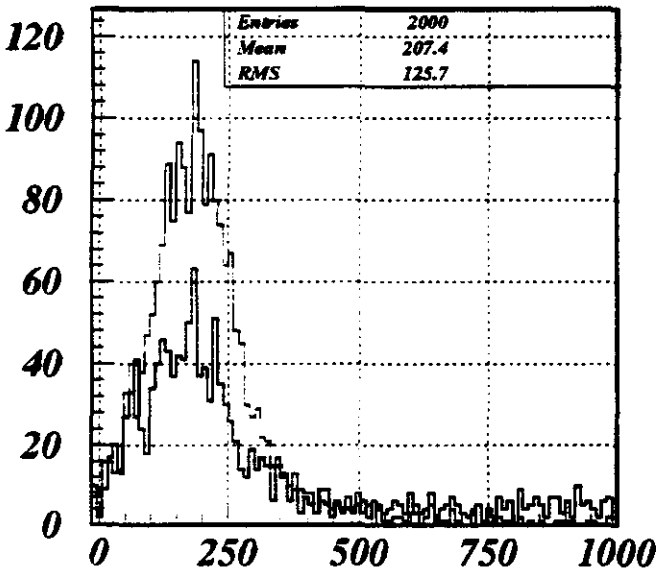
Difference in longitudinal distributions only.



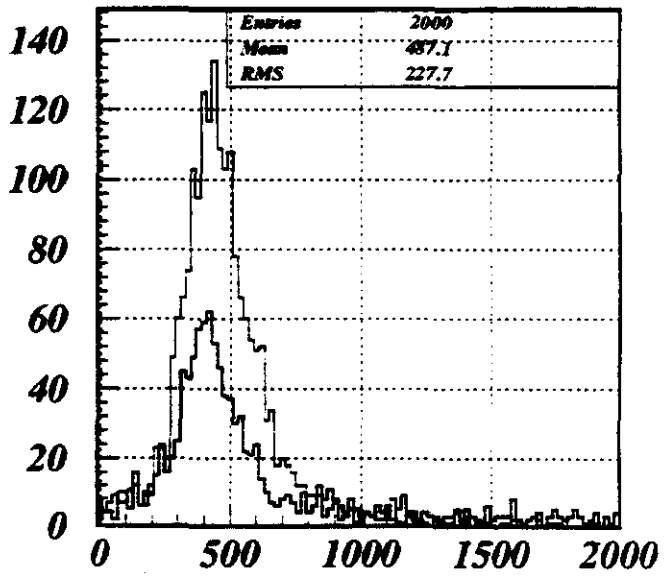
E loss in EM1 section, MeV



E loss in EM2 section, MeV

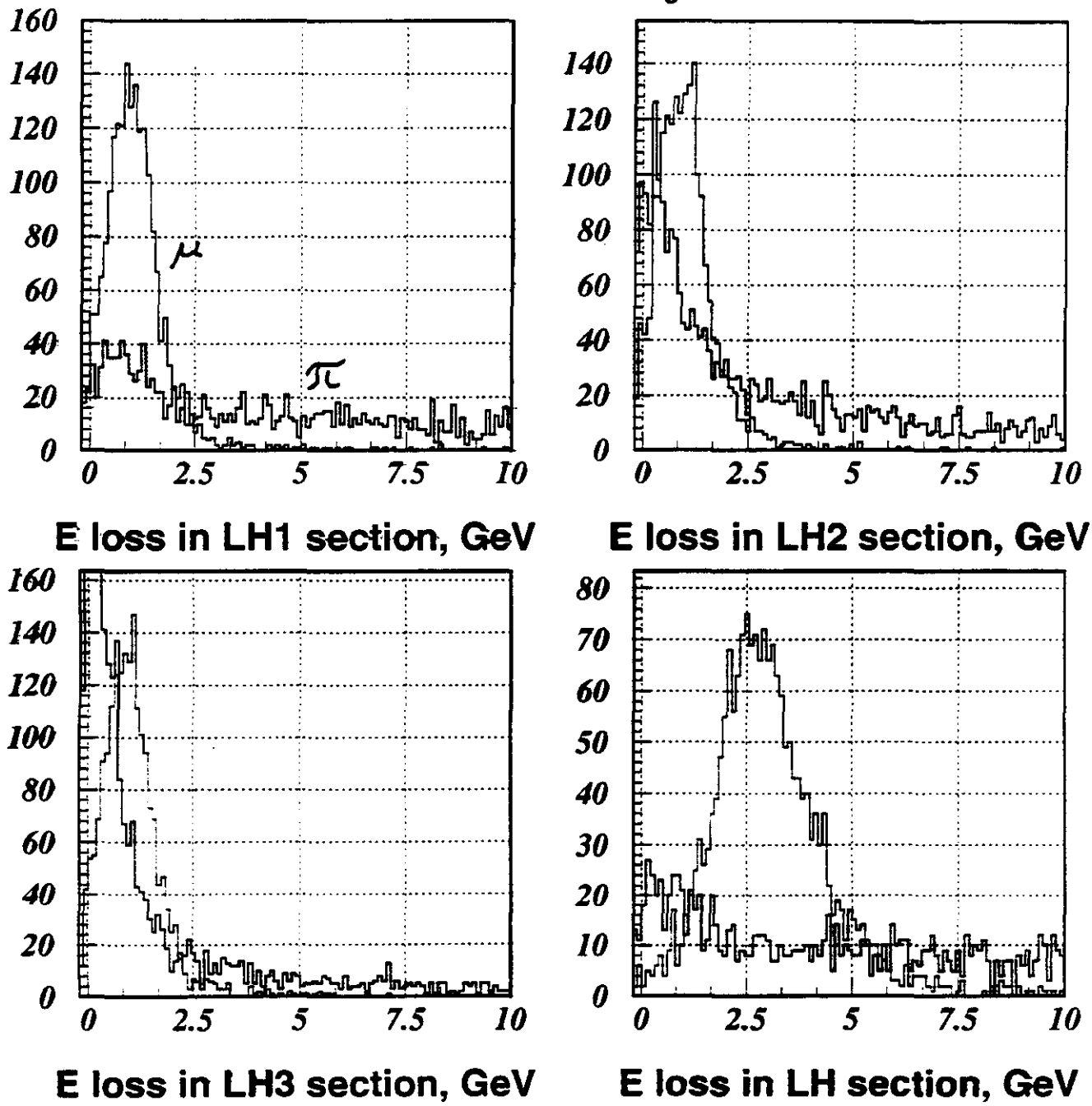


E loss in EM3 section, MeV



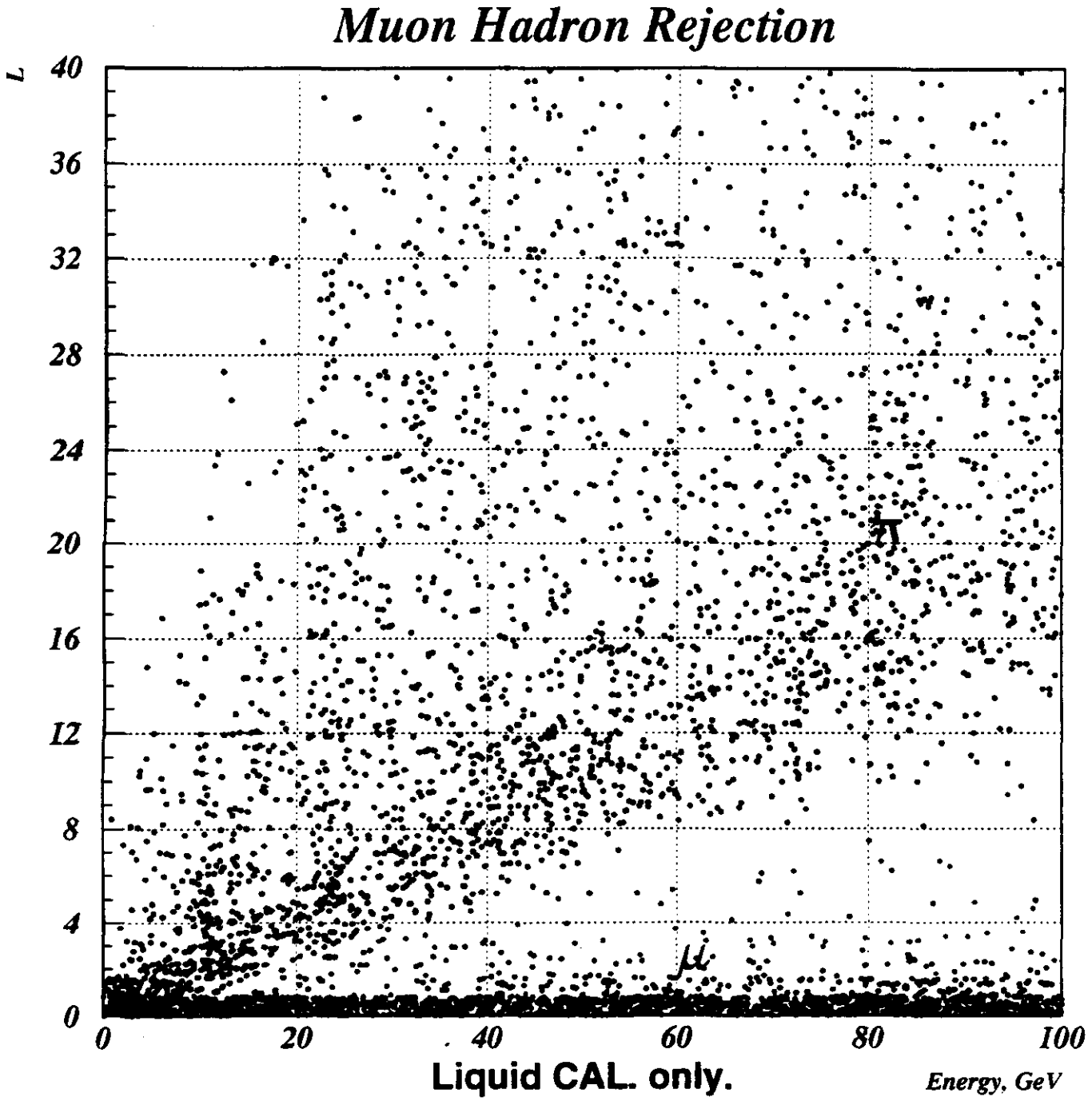
E loss in EM section, MeV

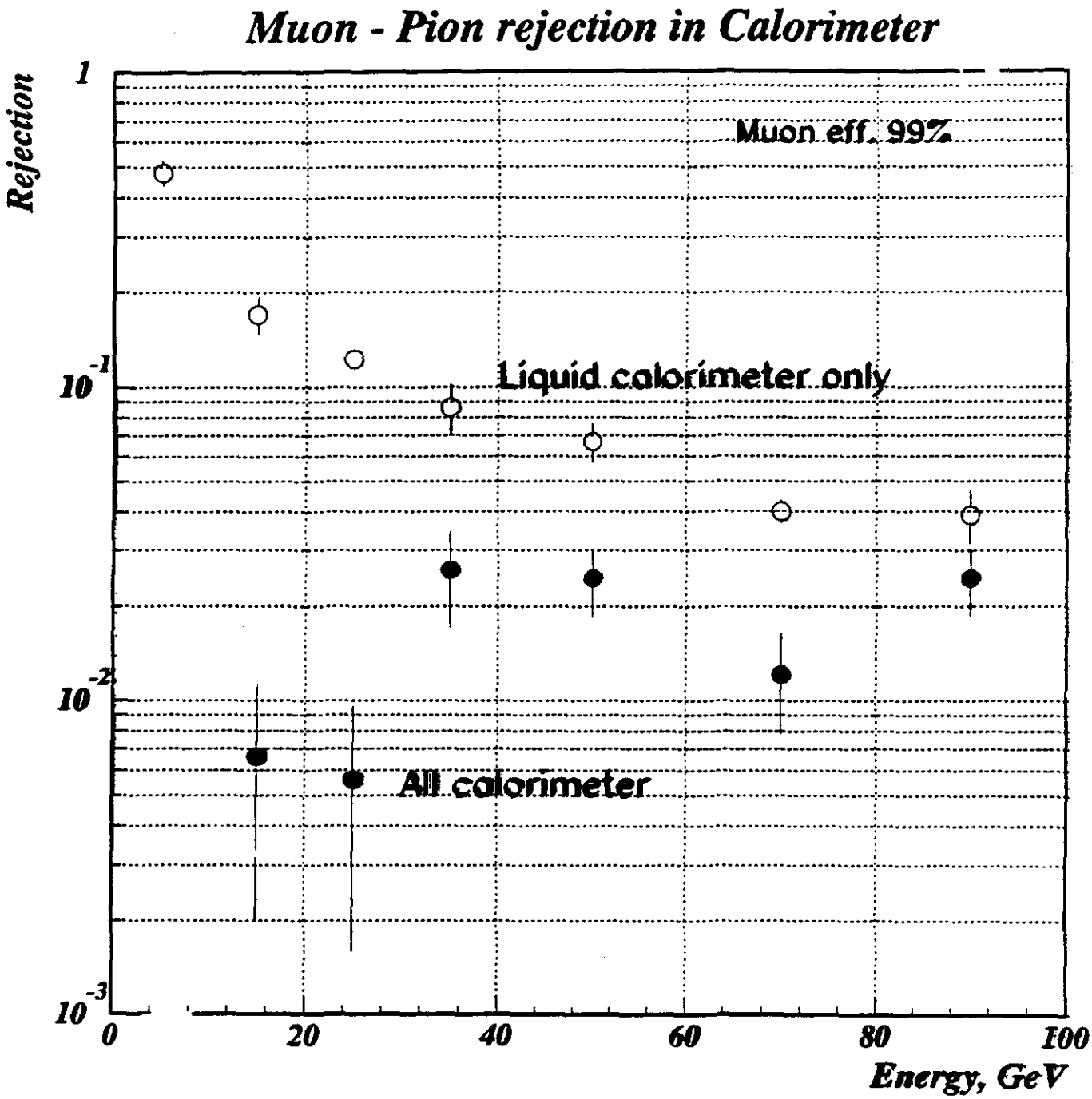
Muon - Pion Rejection

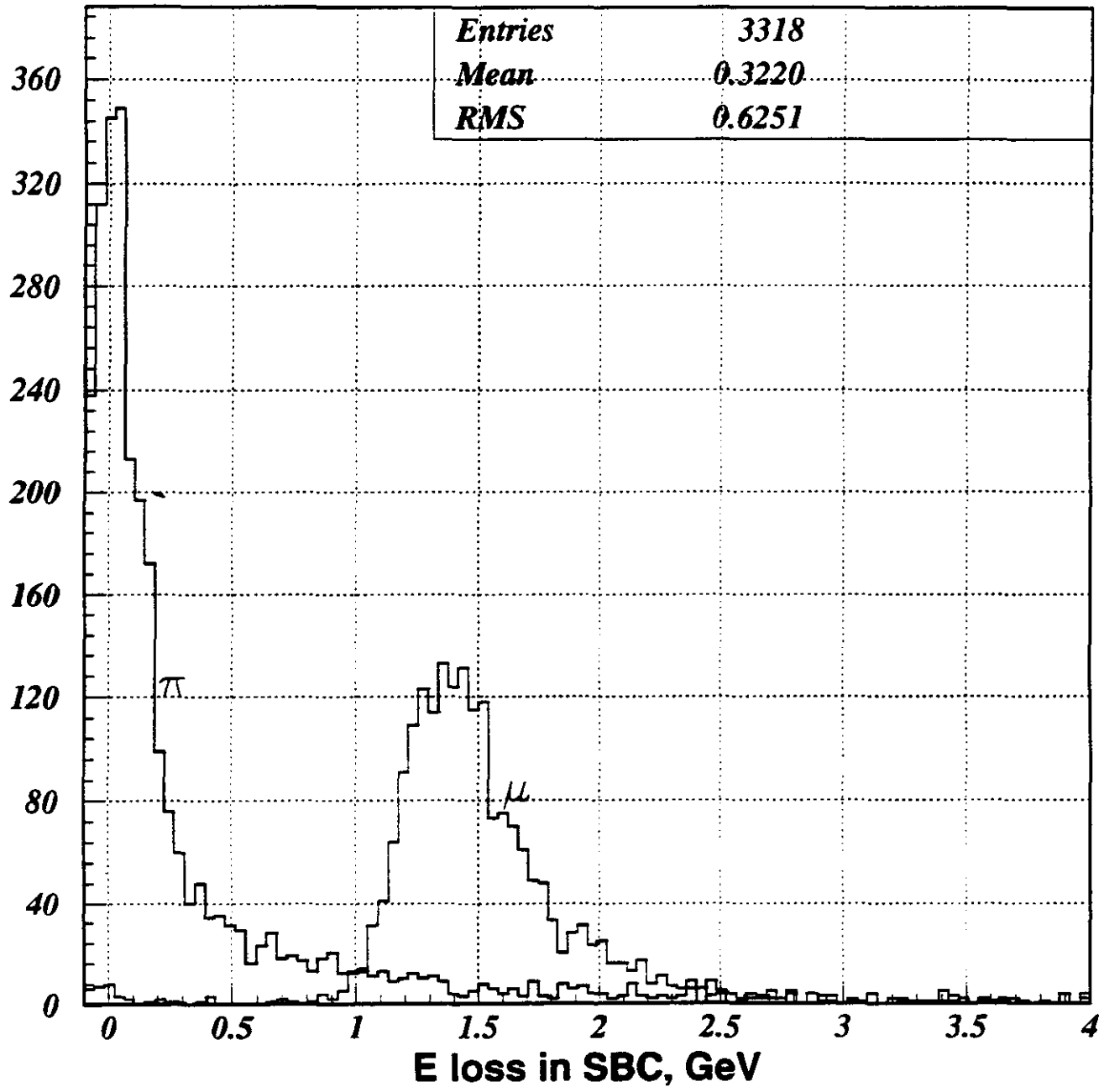


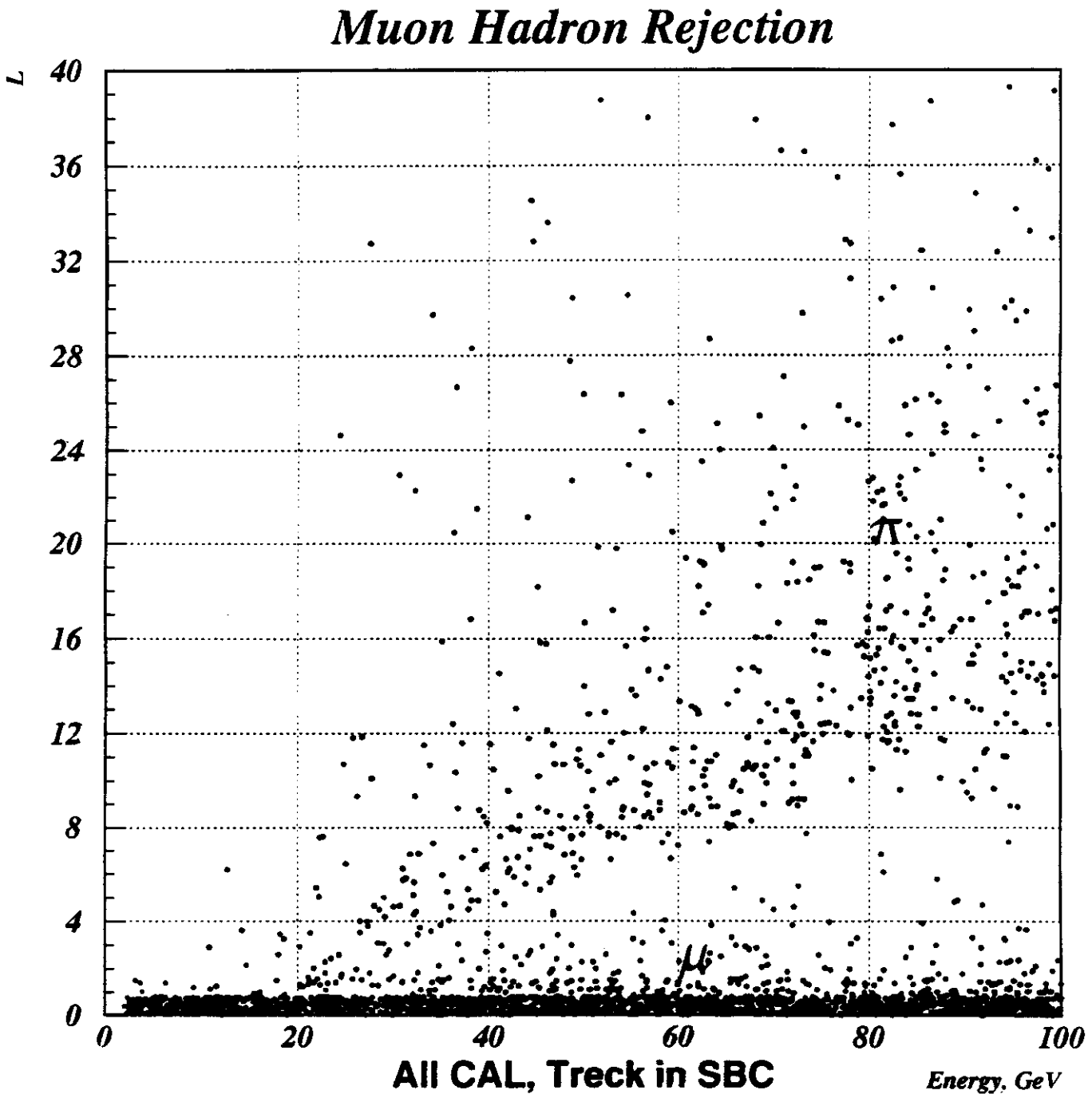
LIKELIHOOD

$$L = \sum_{EM_i, LH_i, SBC}^{N} \left(\frac{\bar{E}_i - E_i^{Meas}}{\delta_i} \right)^2$$


Muon Hadron Rejection
L
40
36
32
28
24
20
16
12
8
4
0
0
20
40
60
80
100
π
μ
Liquid CAL. only.
Energy, GeV


Muon - Pion rejection in Calorimeter
Rejection
1
10^{-1}
10^{-2}
10^{-3}
Muon eff. 99%
Liquid calorimeter only
All calorimeter
0
20
40
60
80
100
Energy, GeV


Entries 3318
Mean 0.3220
RMS 0.6251
360
320
280
240
200
160
120
80
40
0
0
0.5
1
1.5
2
2.5
3
3.5
4
π
μ
E loss in SBC, GeV


Muon Hadron Rejection
L
40
36
32
28
24
20
16
12
8
4
0
0
20
40
60
80
100
π
μ
All CAL, Treck in SBC
Energy, GeV

Conclusion

1. Using CT and CAL is helpful for muon system for detection Higgs to 4 muons channel.

Questions:

Muons/Hadrons rejection:

What do we need?
What can we get?
Longitudinal, and transfers distributions.

gem

γeμ

Presentation by:

Yuri Fisyak

Global fit for muons with Central Tracker

Yuri Fisyak

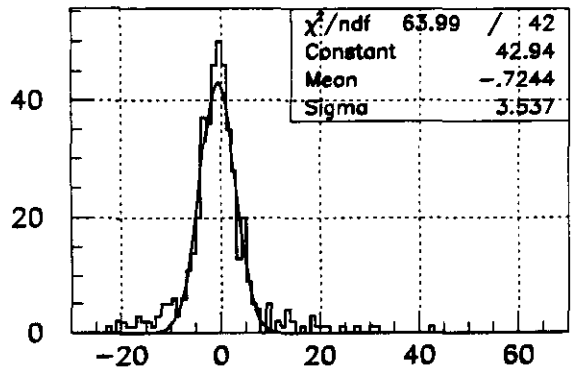
I am trying using SIGEM philosophy which implies to use both for simulation and reconstruction the same GEANT based data base and Kalman filter approach to build program for **global muon** fit with information from Central Tracker.

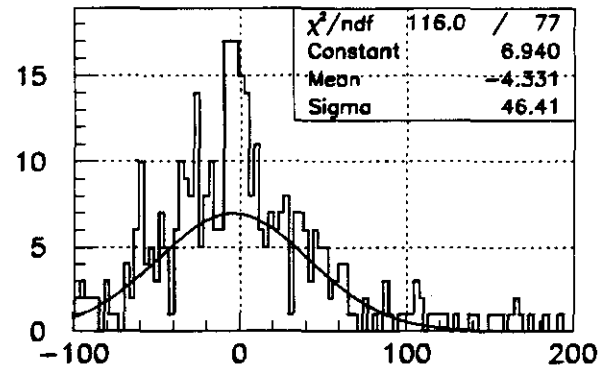
The global fit includes the following steps:

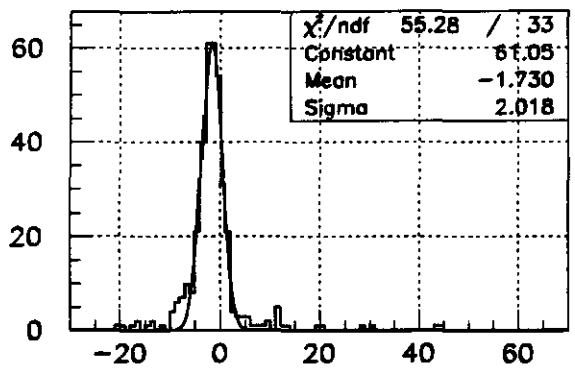
- Cluster finding, matching bending and nonbending coordinate measurements, and reconstruction based on digitized GEANT hits (will be implemented in SIGEM version 2.2);
- Finding of track segments in each superchamber by combing the nearest in ϕ clusters and fit them by straight line in space. The requirement is at least 3 cluster in the track segment;
- Using Kalman filter and smoother combining track segment in track and finding the first approximation for track parameters;
- Using obtained track parameters selection of hits belonging the track and fit them in order to obtain the final parameter estimation from muon system;
- Define the road and pick up hits in Central tracker and afterwards make global fit;

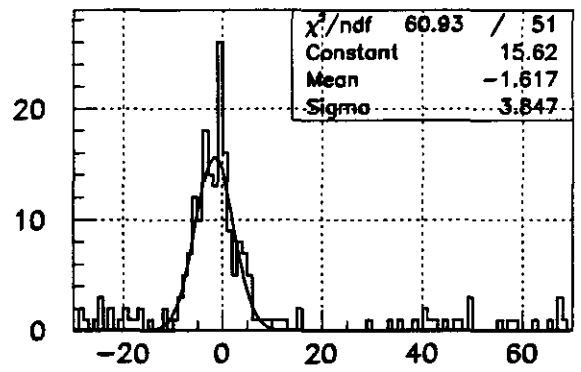
Status: Procedure for barrel does work. In endcap there are problems with fit of the track segments and obtaining the first guess for track parameters.

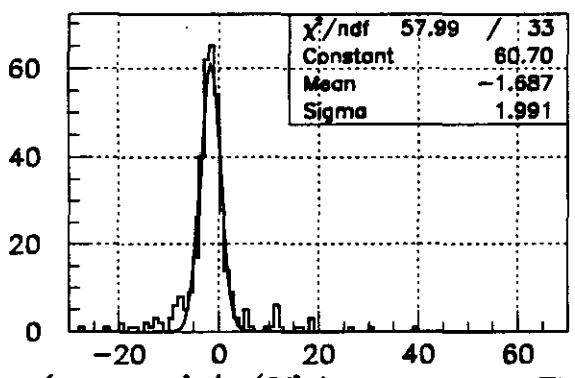
Single muon with p_T = 100 GeV/c

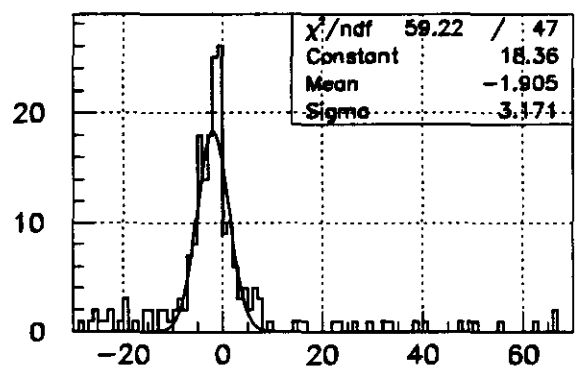




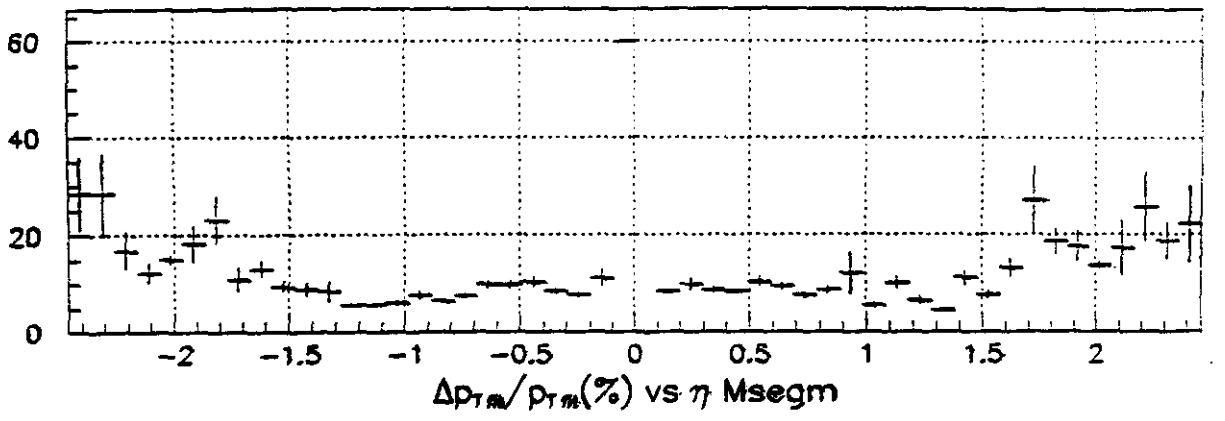


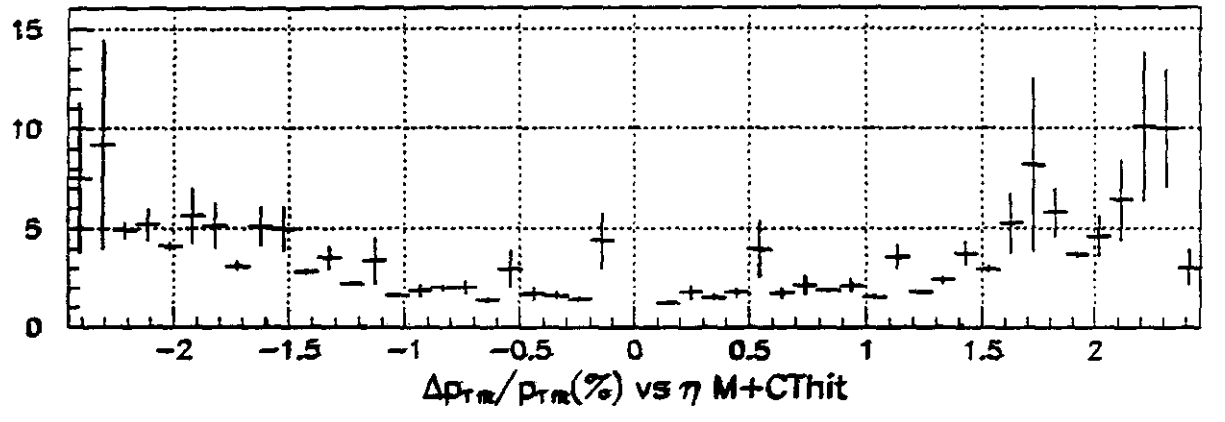


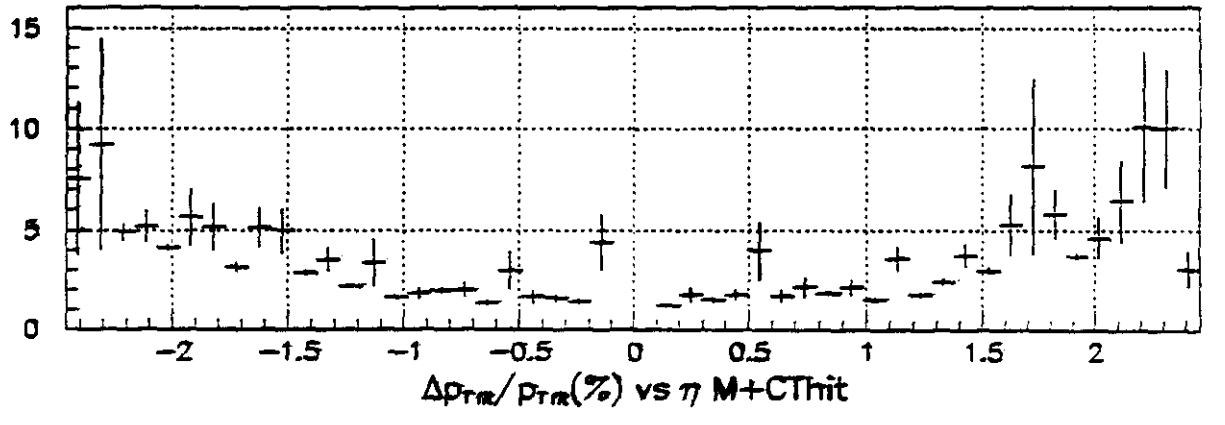




Single muon with p_T = 100 GeV/c







gem

γeμ

Presentation by:

Peter Dingus

Pattern Recognition in the GEM Muon System

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Physics Research Department
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Abstract: A systematic monte carlo study of the ability of the proposed GEM Muon system to find and measure various types of muon tracks in the presence of both correlated and uncorrelated backgrounds is presented. A sample of 16000 isolated muon tracks with transverse momentum, $100Gev \leq P_t \leq 1000Gev$ and 4000 events from $t\bar{t} \Rightarrow b\bar{b} + \mu\mu\nu\nu \Rightarrow X + \mu\mu\nu\nu$ were simulated in the detector using the SIGEM[1] monte carlo, which was used in calculating GEM performance for the GEM TDR. Track reconstruction efficiencies and momentum resolution are calculated with respect to a given set of constraints that include the most basic performance assumptions underlying the architecture and techology choices made for the GEM muon system.

1 Introduction

There are two basic limitations that prevent the GEM muon system from reaching the quantitative limits of track reconstruction efficiency and track measurement resolution that one would naively calculate from just geometric acceptance and chamber resolution and chamber and superlayer alignment errors. The first problem is that of correlated and non-correlated track backgrounds such as punchthrough from the calorimeter, δ rays, γ conversions and random hits from ambient neutrons and γ's comming from neutron-nucleus interactions. The second, which only limits the momentum resolution are the fluctuations in energy loss for relatively low momentum μ's passing through the calorimeter and the multiple scattering of muons in the material of the muon system. We will describe the nature of the correlated background associated with three files of isolated μ's of constant P_t distributed uniformly throughout the detector and then with μ's in b jets coming from $t\bar{t}$ events. Finally we will, in the presence of these various correlated backgrounds, give track finding efficiencies and track reconstruction resolutions.

[1] Y.Fisyak GEM TN-162

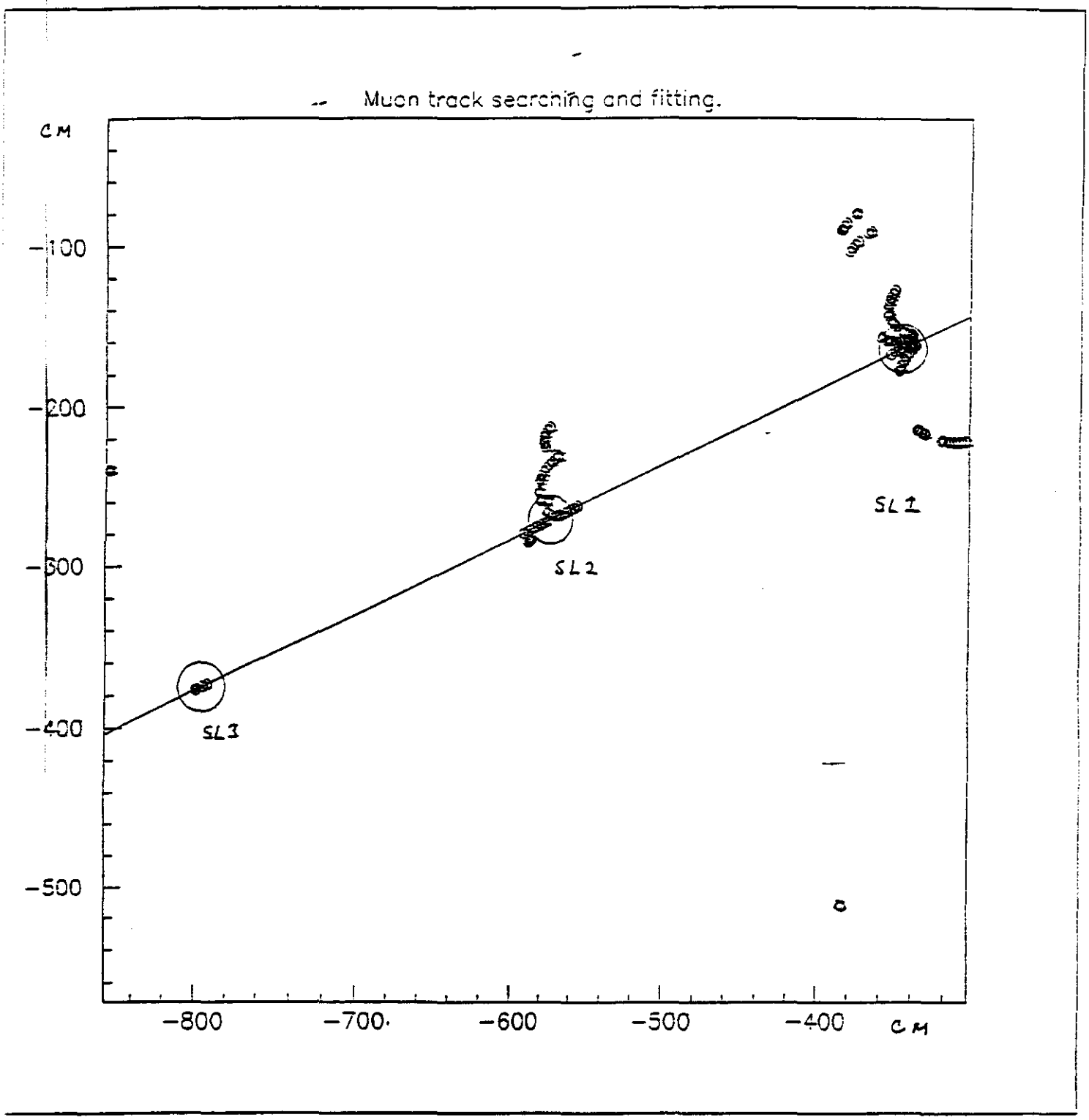

Figure 11 Track found using the cluster search-merge algorithm .

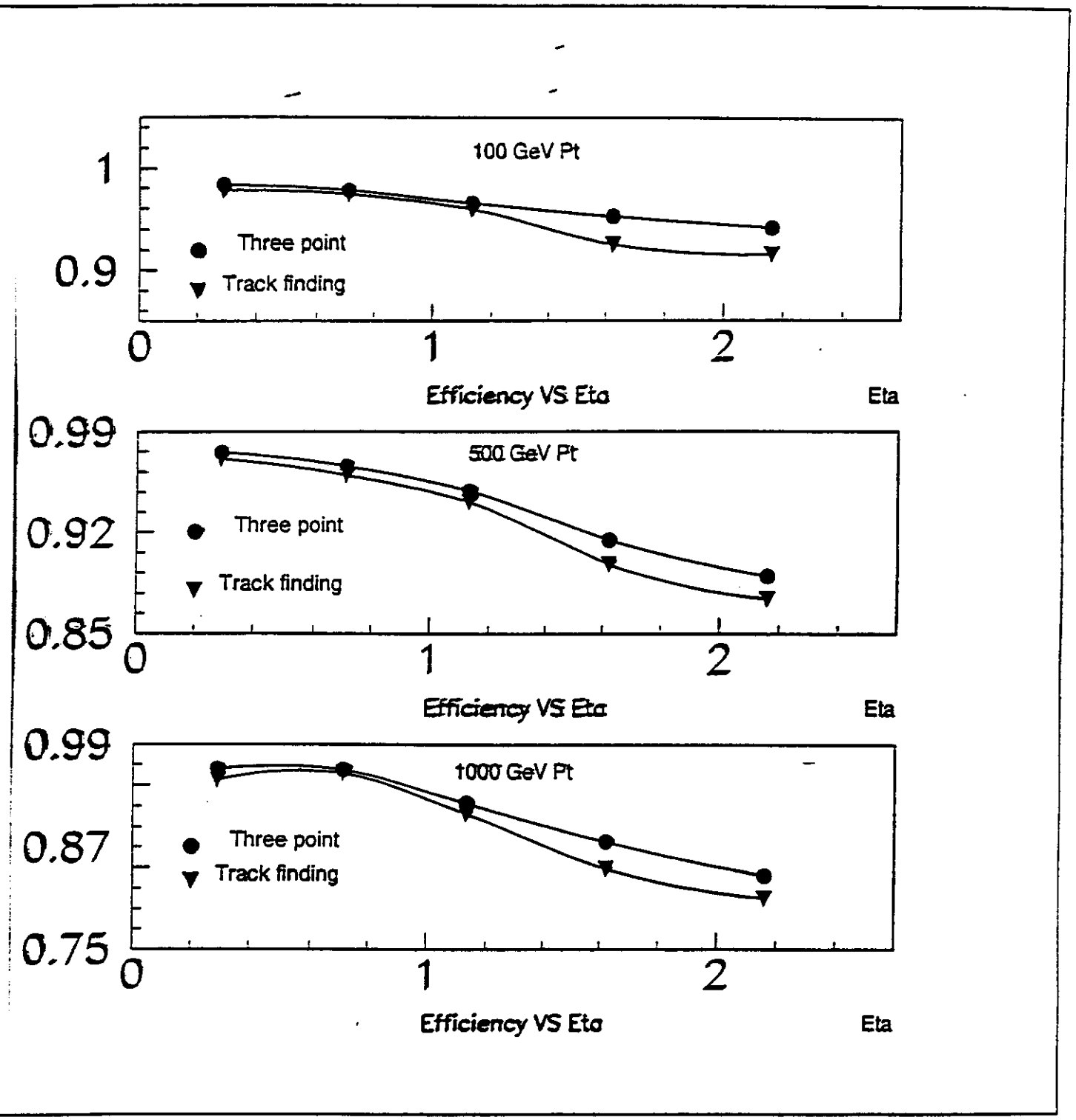

Figure 10) Comparison of the track finding efficiency using the "three good hits" method and the cluster search-merge algorithm discribed in the text. The comparison is made by using a preselected data set where three "good" hits had already been found, thus showing the inefficiency of the cluster-algorithm. The cluster algorithm is shown to be very efficient .

as a condition for merging the tracks. We find an increase in efficiency of about 1% to 3%, the results are tabulated below. Senario 1 refers to (3,3,3), senario 2 refers to (2,2,4), and T.F. refers to track finding algorithm.

100 GeV P_t Isolated muons.			
η	3 good	T.F. (senario 1)	T.F. (senario 1+2)
0.08-0.5	0.9836	0.9779	0.9866
0.5-0.92	0.978	0.974	0.9846
0.92-1.34	0.965	0.959	0.9714
1.38-1.86	0.952	0.925	0.9598
1.86-2.46	0.9412	0.915	0.9594

500 GeV P_t Isolated muons.			
η	3 good	T.F. (senario 1)	T.F. (senario 1+2)
0.08-0.5	0.9757	0.971	0.9807
0.5-0.92	0.966	0.9598	0.9683
0.92-1.34	0.9488	0.941	0.9547
1.38-1.86	0.9148	0.898	0.9415
1.86-2.46	0.89	0.874	0.9215

1000 GeV P_t Isolated muons.			
η	3 good	T.F. (senario 1)	T.F. (senario 1+2)
0.08-0.5	0.9581	0.948	0.9714
0.5-0.92	0.9643	0.956	0.9648
0.92-1.34	0.9212	0.909	0.9488
1.38-1.86	0.8764	0.845	0.8935
1.86-2.46	0.8367	0.81	0.8475

Examples of found clusters and merged tracks are shown in figure 11.

3.1 Muons in b Jets

In order to understand the differences in track reconstruction efficiency in quite and noisy enviroments we prepared a sample of 4000 events of muons coming from b jets. Thes events were generated via Pythia as follows:

$$t\bar{t} \Rightarrow b\bar{b} + X \quad (2)$$
$$\Rightarrow b \rightarrow \mu^- \bar{\nu} + X \quad (3)$$
$$\Rightarrow \bar{b} \rightarrow \mu^+ \nu + X \quad (4)$$

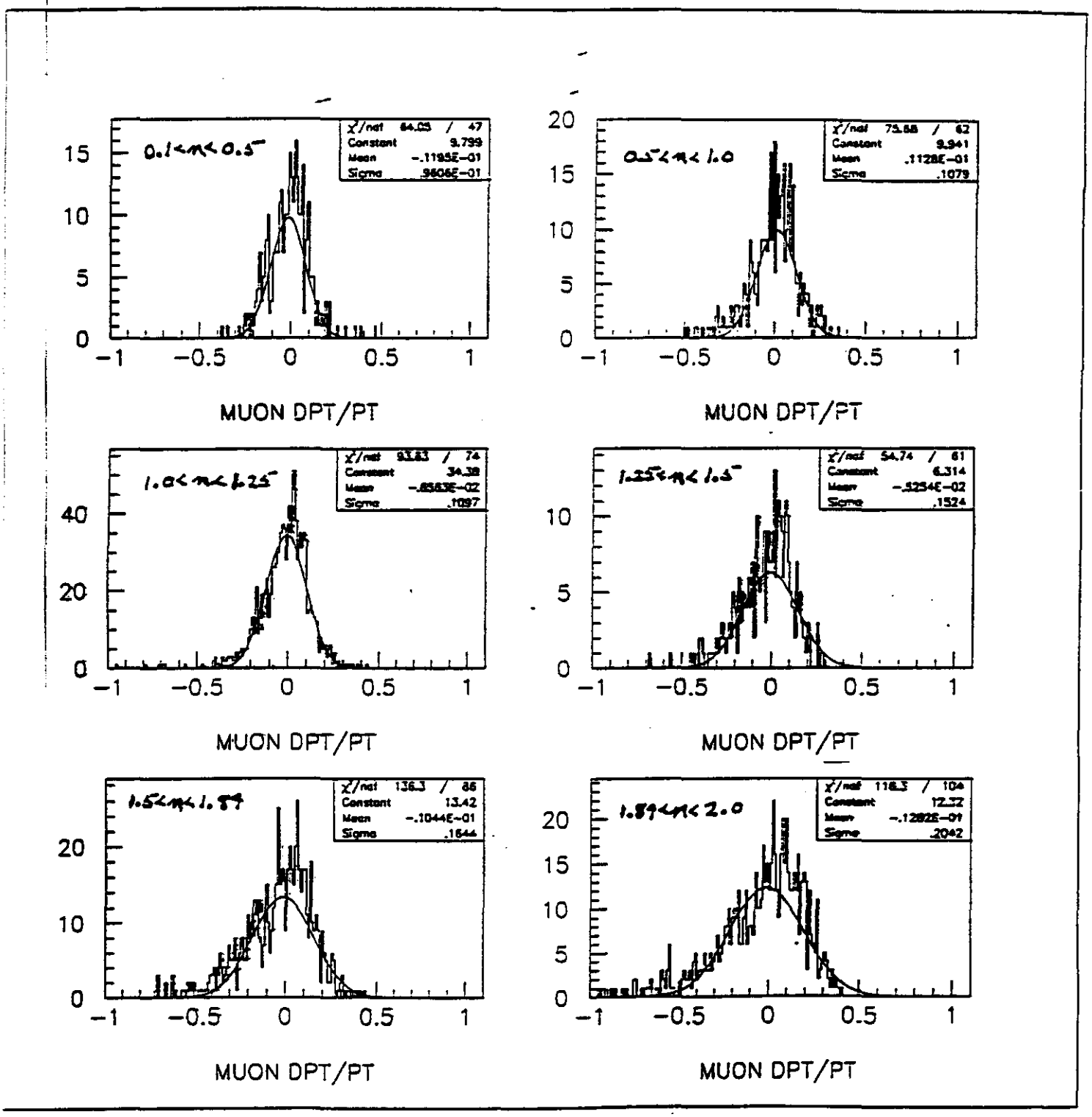

Figure 15a) Resolution distributions as a function of η for the isolated 1 TeV P_t muon sample, including all correlated backgrounds, computed by the Kalman Filter .

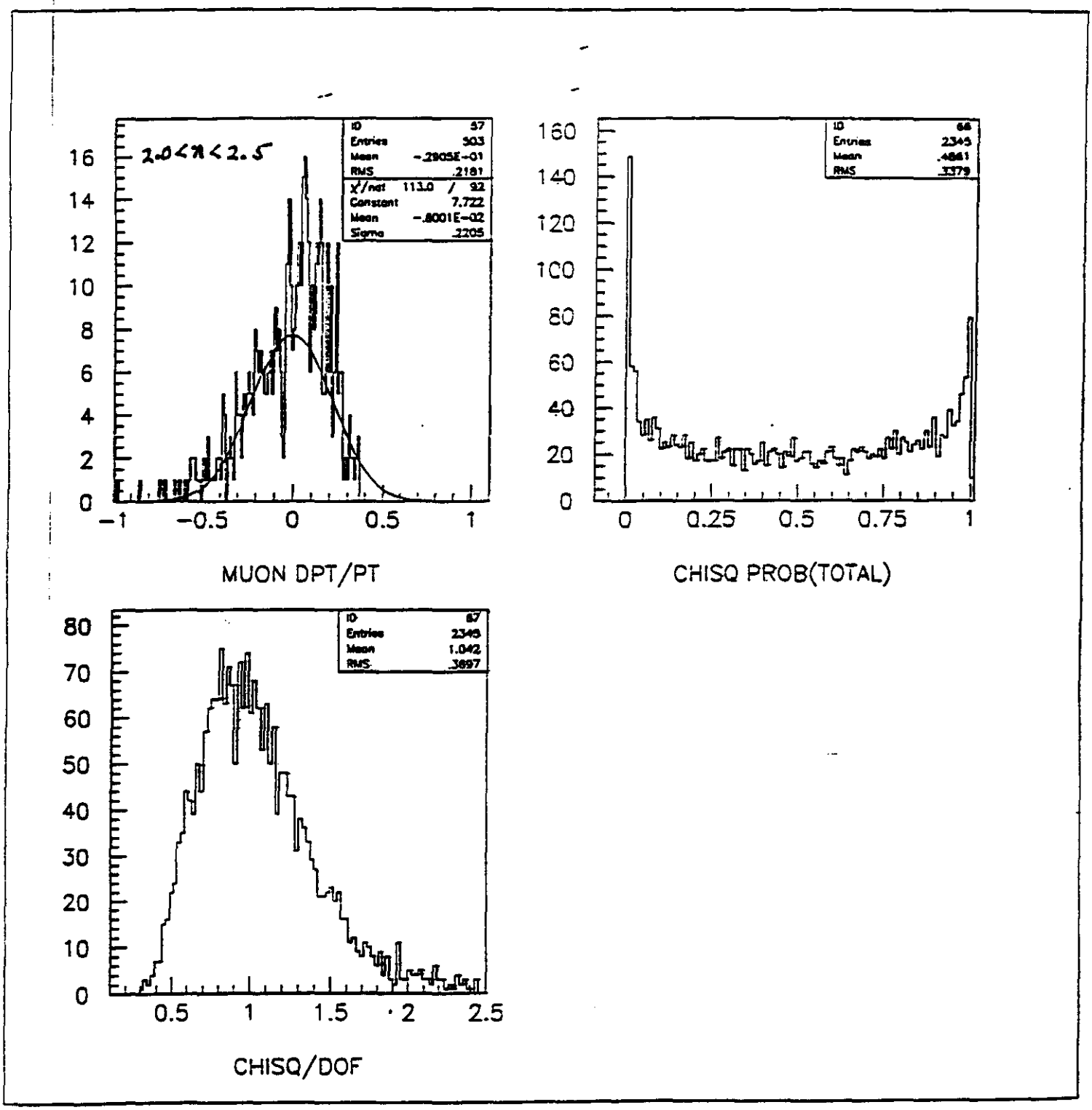

Figure 15b) Distributions of χ^2 probability and $\frac{\chi^2}{DOF}$ resulting from the Kalman Filter track fit for the 1 TeV muon sample with background .

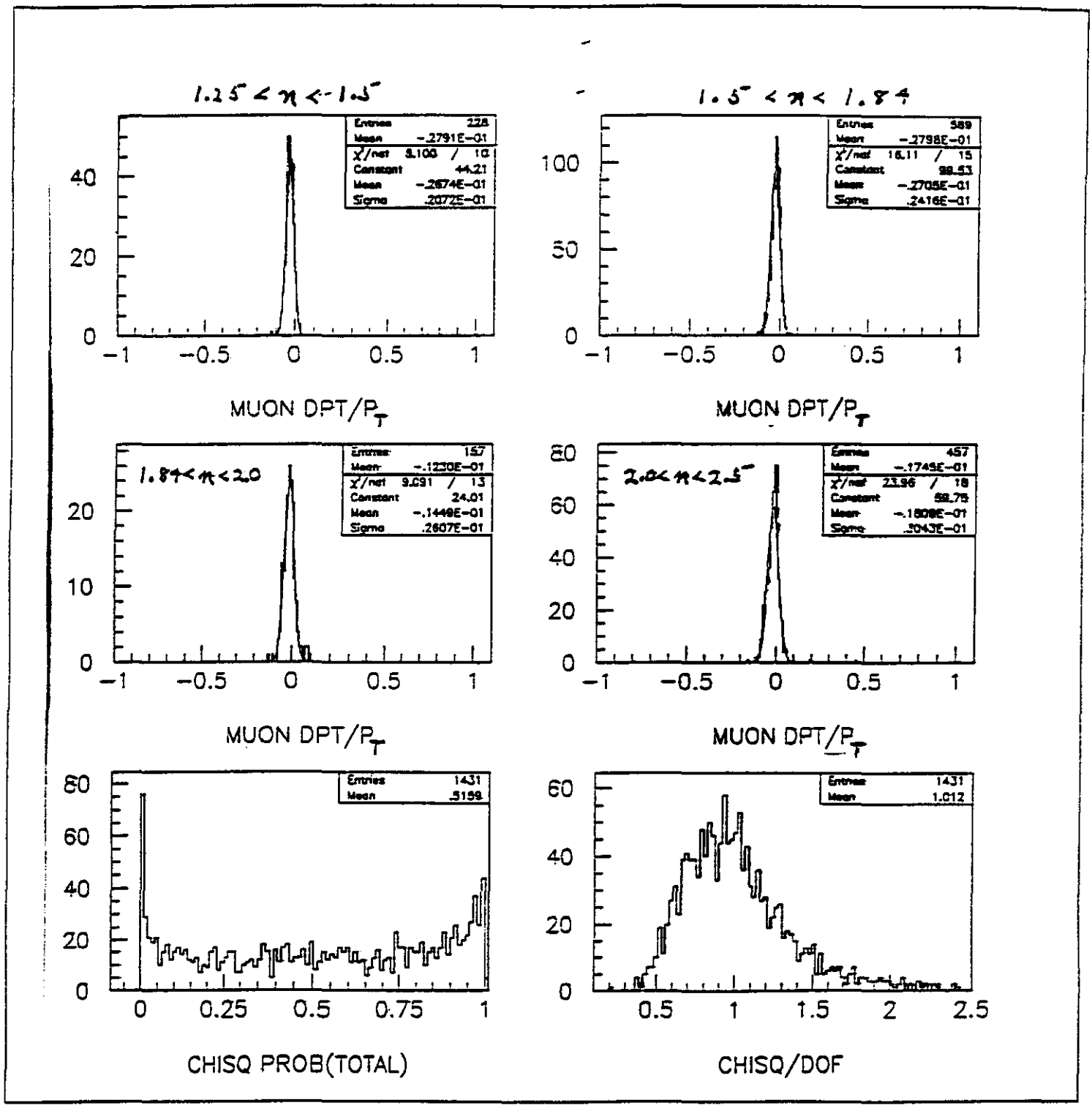

Figure 20) Track resolution distributions and quality of fit for the structure-free 100 GeV P_t sample of muons in the endcap. This sample of muon events scanned the detector in η but not in ϕ in order to access the effect of the staggering of chambers in ϕ and of chamber supports.

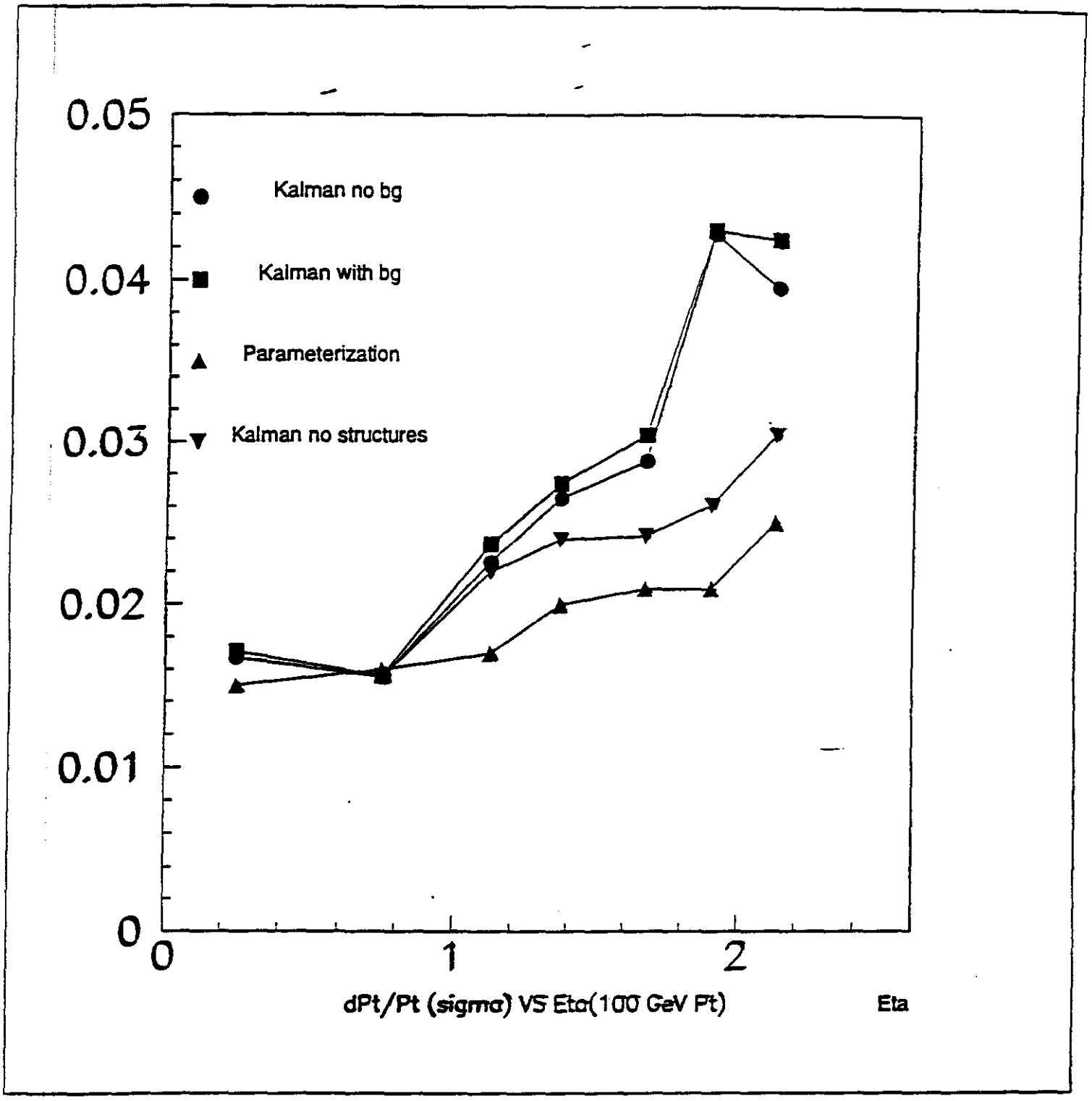

Figure 16) Track resolution plot as a function of η for the 100 GeV P_t muon sample using the Kalman Filter .

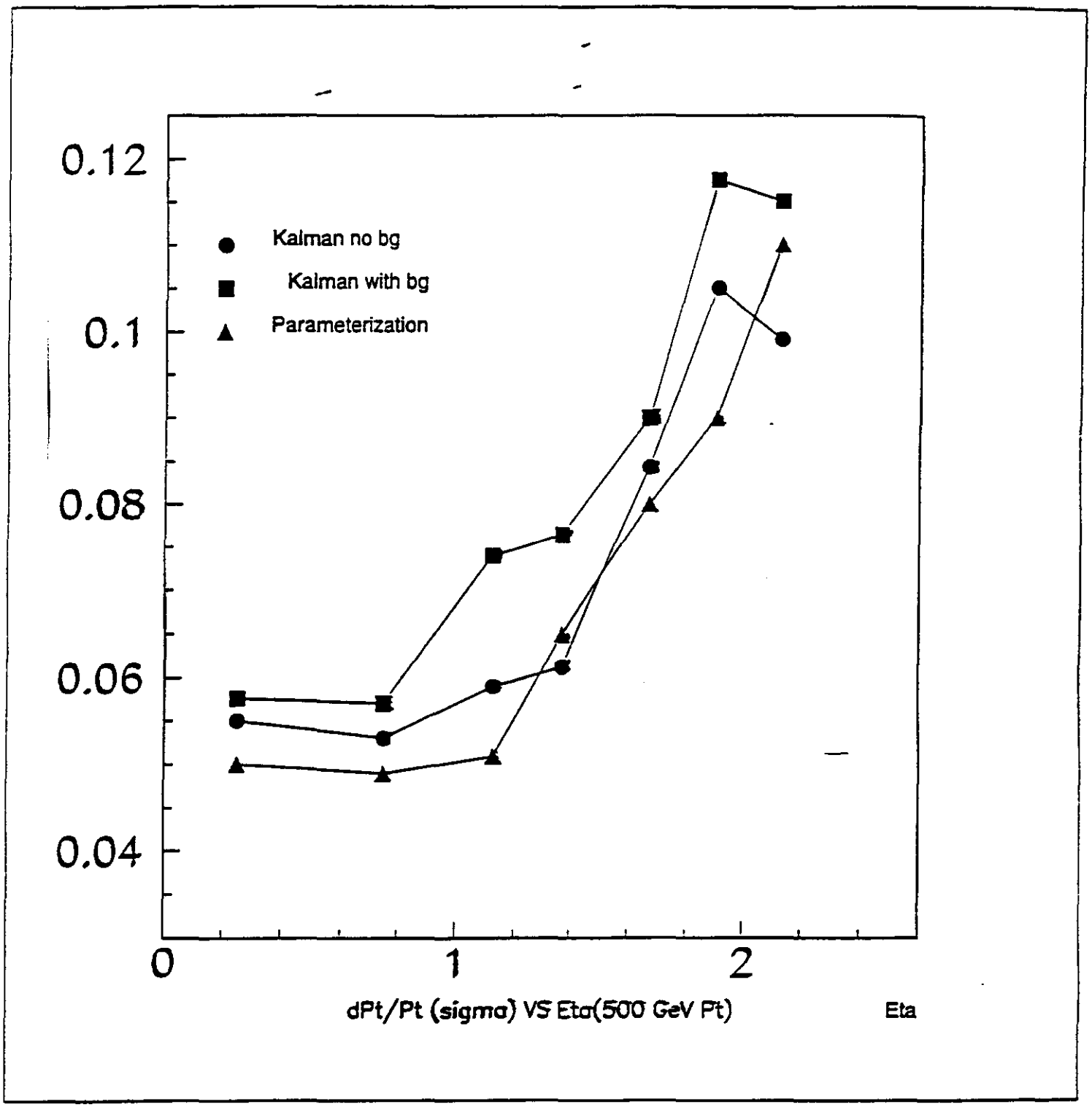

Figure 17) Track resolution plot as a function of η for the 500 GeV P_t muon sample using the Kalman Filter .

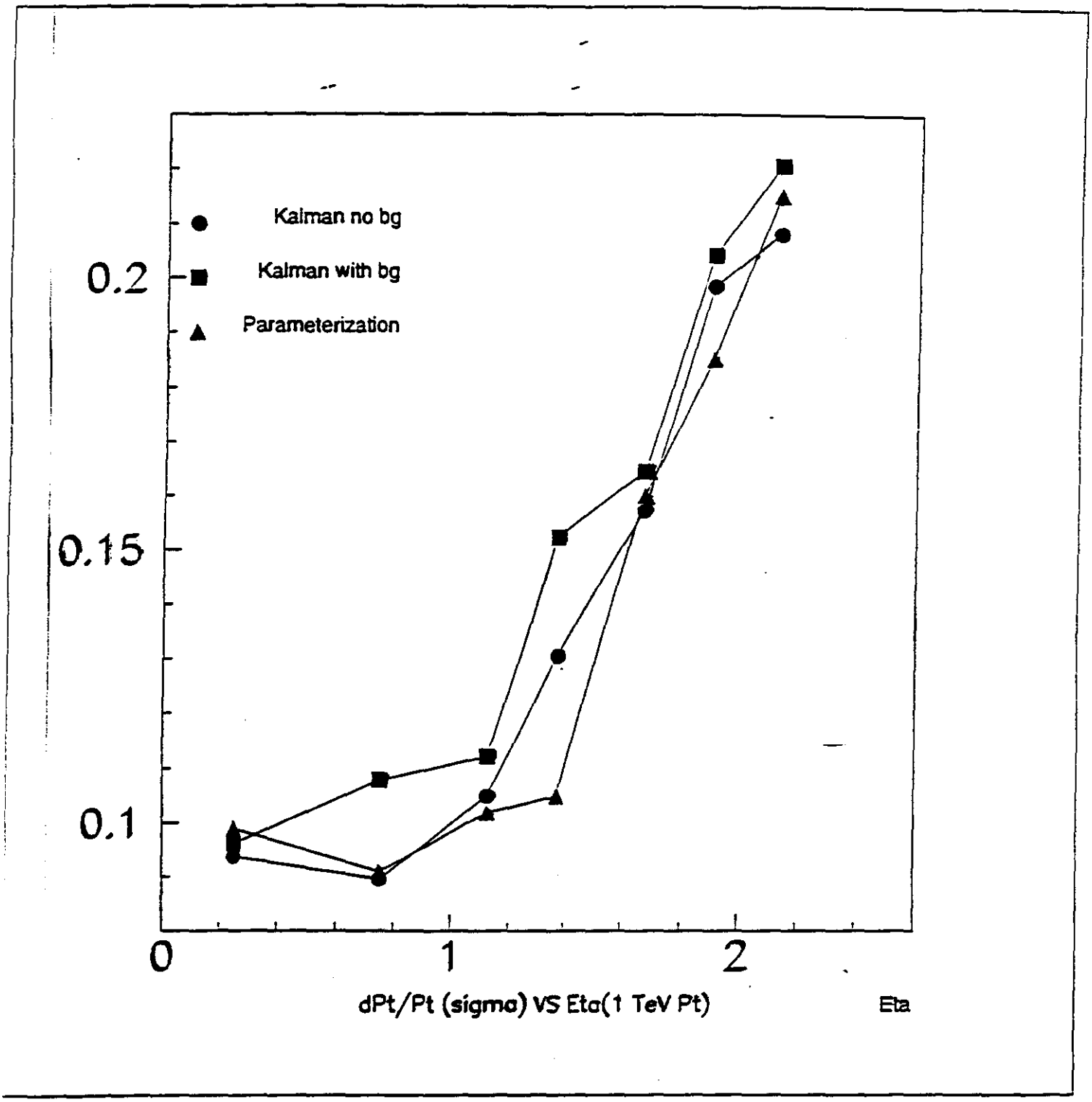

Figure 18) Track resolution plot as a function of η for the 1 TeV P_t muon sample using the Kalman Filter .

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Presentation by:

Torre Wenaus

MUON RECONSTRUCTION STATUS

TOPICS:

MOMENTUM RESOLUTION

MISSING SL'S; SIGEM 2.1;
BACKGD INCLUSION; VTX CONSTRAINT

ACCEPTANCE

SIGEM v2.1 ACCEPTANCE COMPARED
TO PREVIOUS BASELINE;
Z SMEAR; DOUBLET ACCEPTANCE

$Z' \to \mu^+\mu^-$

VERTEX CONSTRAINT

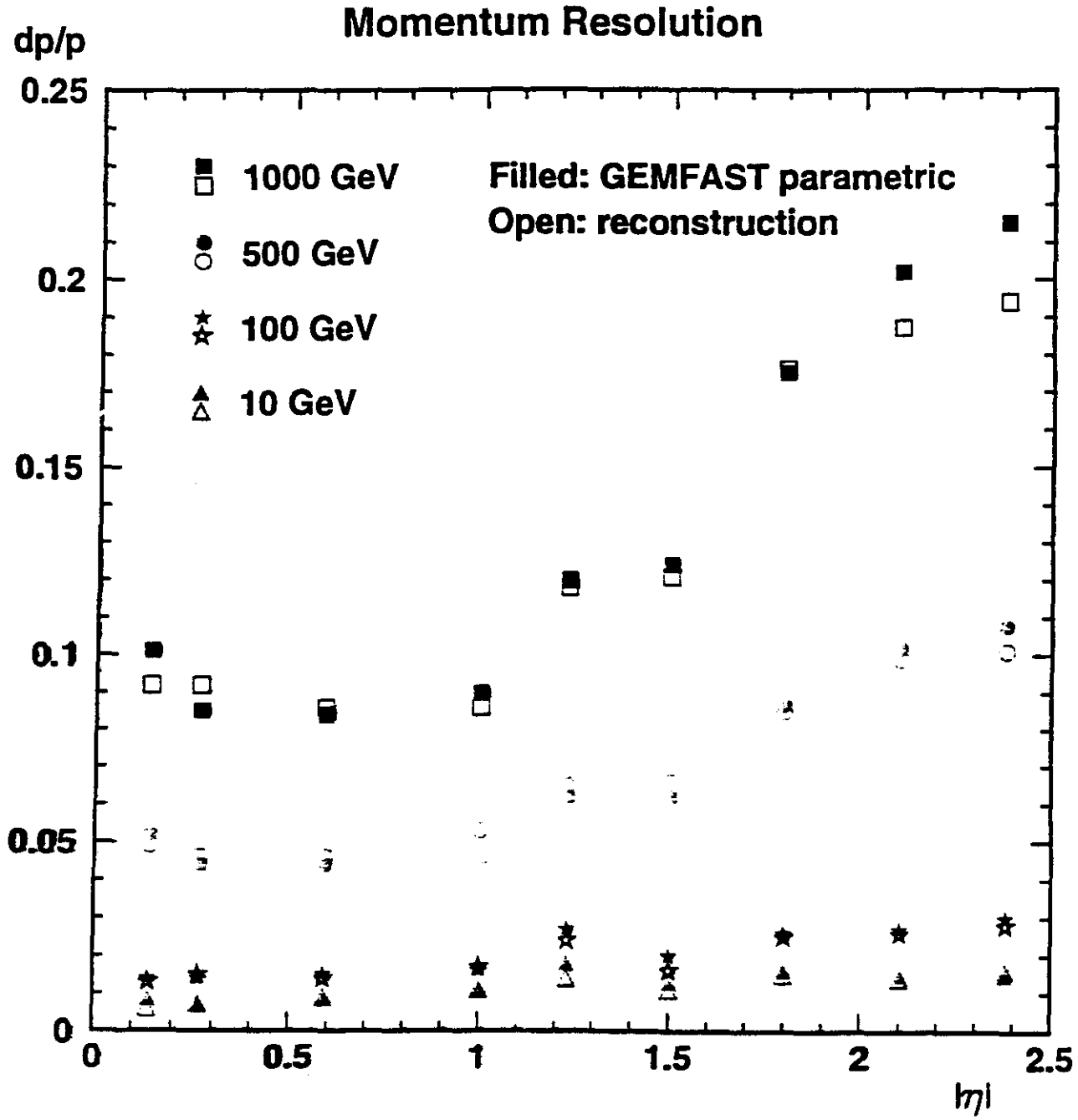
$H \to 4\mu$

CT INCLUSION; COVERAGE IN v2.1;
M_H RESOLUTION IN v1.3 AND v2.1;
VTX CONSTRAINT

MOMENTUM RESOLUTION:

- MISSING SL 1,2,3 (DOUBLET RES)

- SIGE M 2.1 RESOLUTION
  WITH + WITHOUT BACKGD.
- VERTEX CONSTRAINT
  200 μm
  500 μm
  200 μm, NO SL1


Momentum Resolution
dp/p
0.25
0.2
0.15
0.1
0.05
0
1000 GeV
500 GeV
100 GeV
10 GeV
Filled: GEMFAST parametric
Open: reconstruction
0
0.5
1
1.5
2
2.5
|η|

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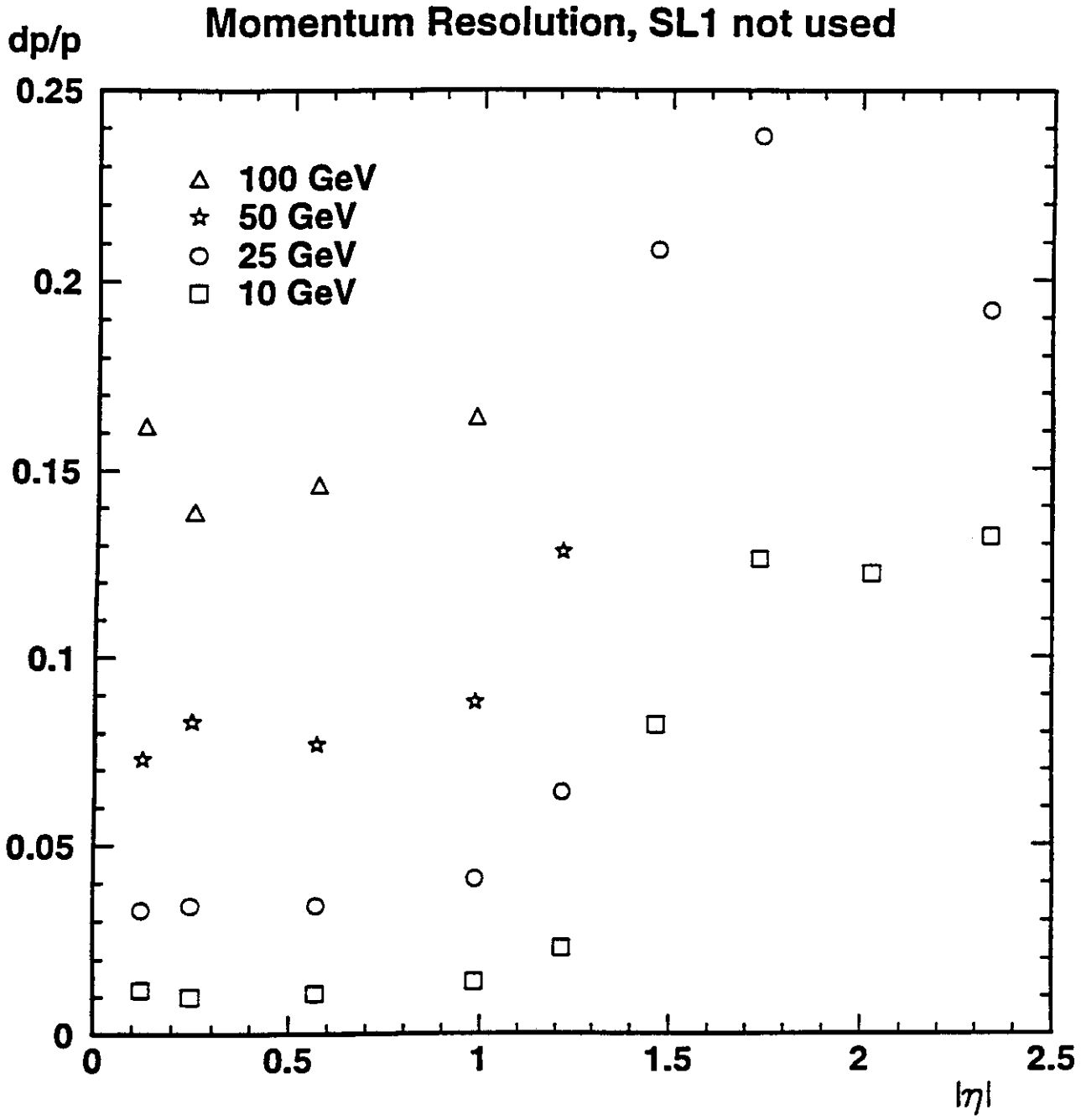
Momentum Resolution, SL1 not used
dp/p
0.25
0.2
0.15
0.1
0.05
0
100 GeV
50 GeV
25 GeV
10 GeV
0
0.5
1
1.5
2
2.5
|η|

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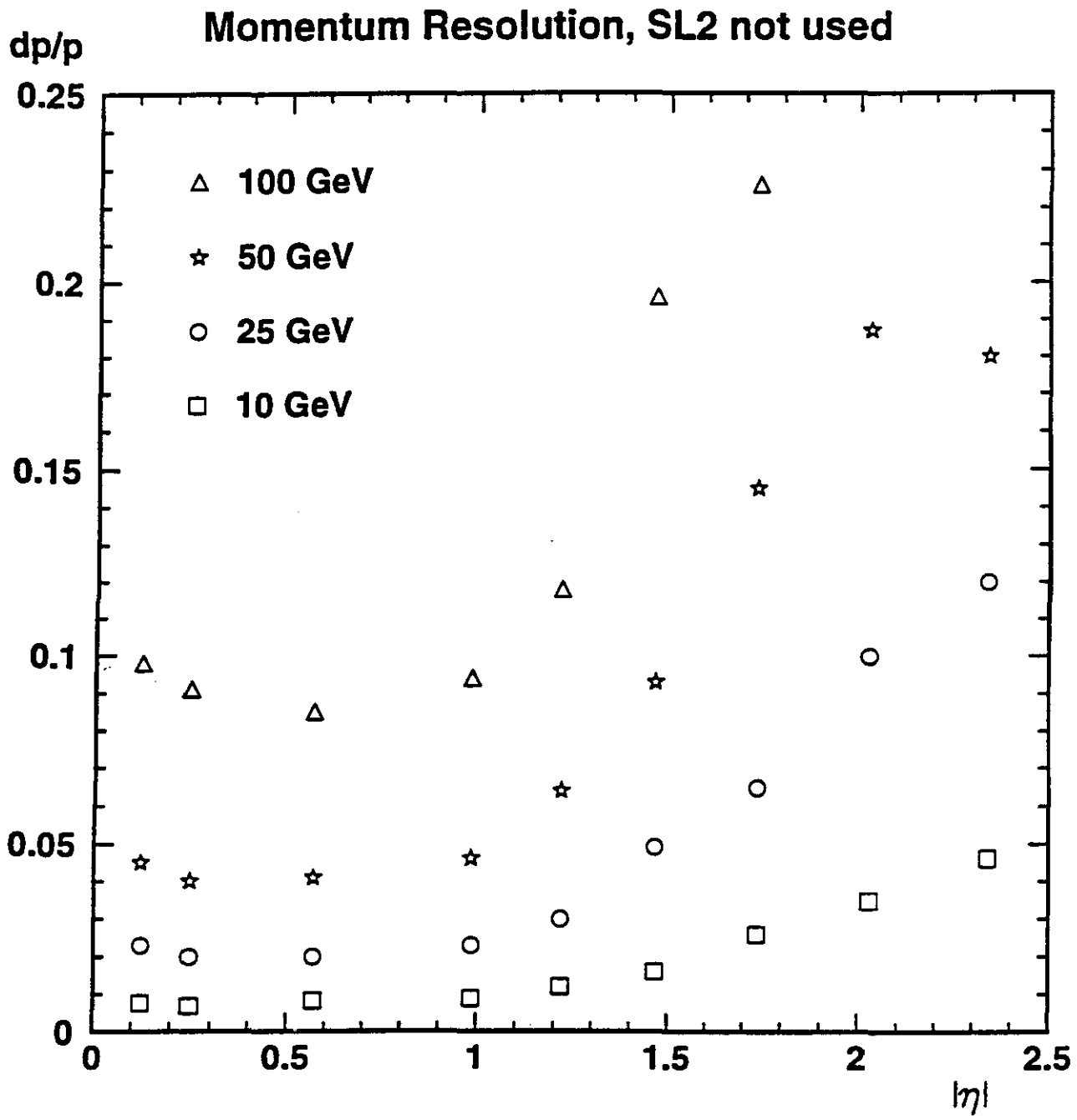
Momentum Resolution, SL2 not used
dp/p
0.25
0.2
0.15
0.1
0.05
0
100 GeV
50 GeV
25 GeV
10 GeV
0
0.5
1
1.5
2
2.5
|η|

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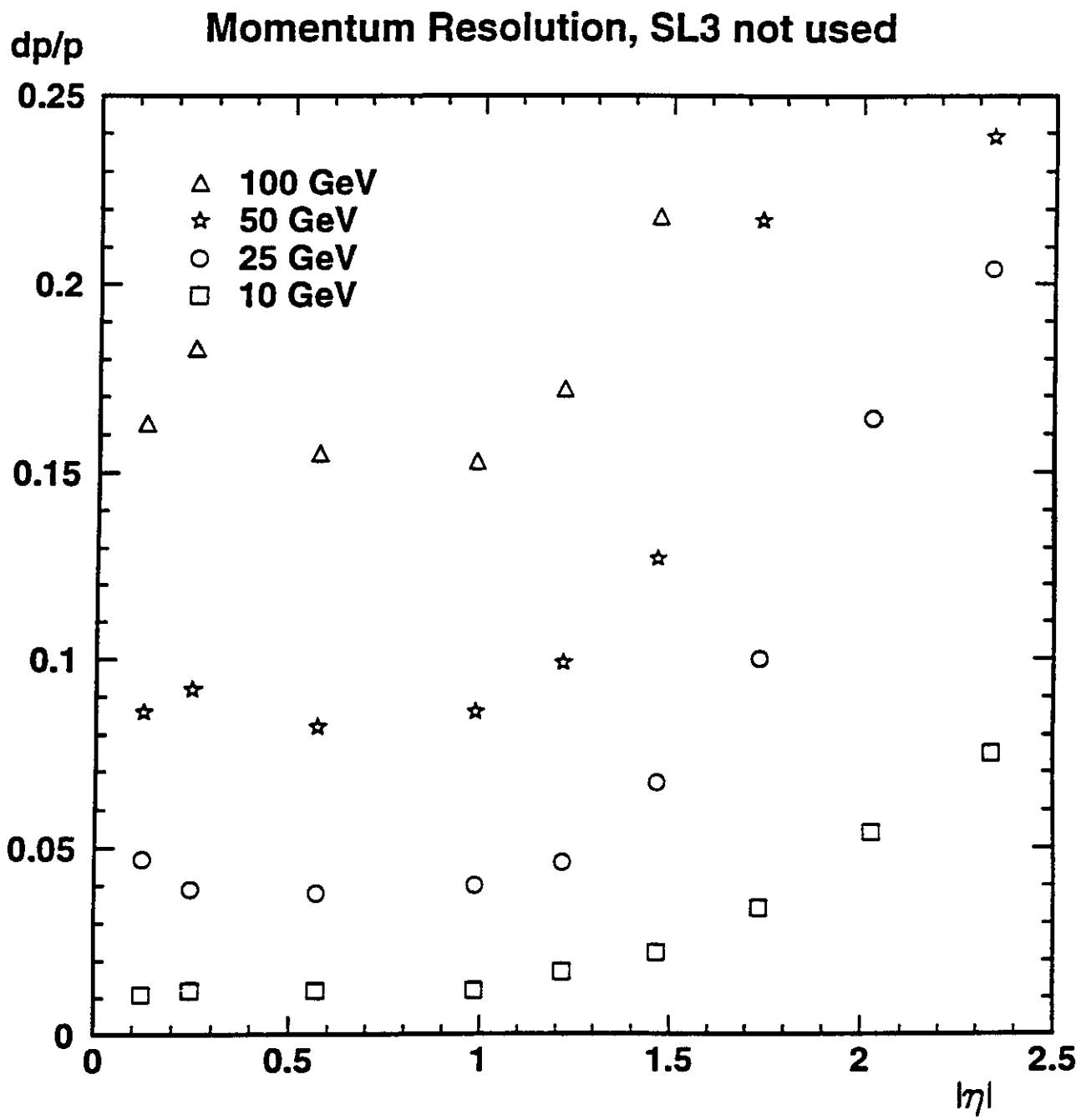
Momentum Resolution, SL3 not used
dp/p
0.25
0.2
0.15
0.1
0.05
0
100 GeV
50 GeV
25 GeV
10 GeV
0
0.5
1
1.5
2
2.5
|η|

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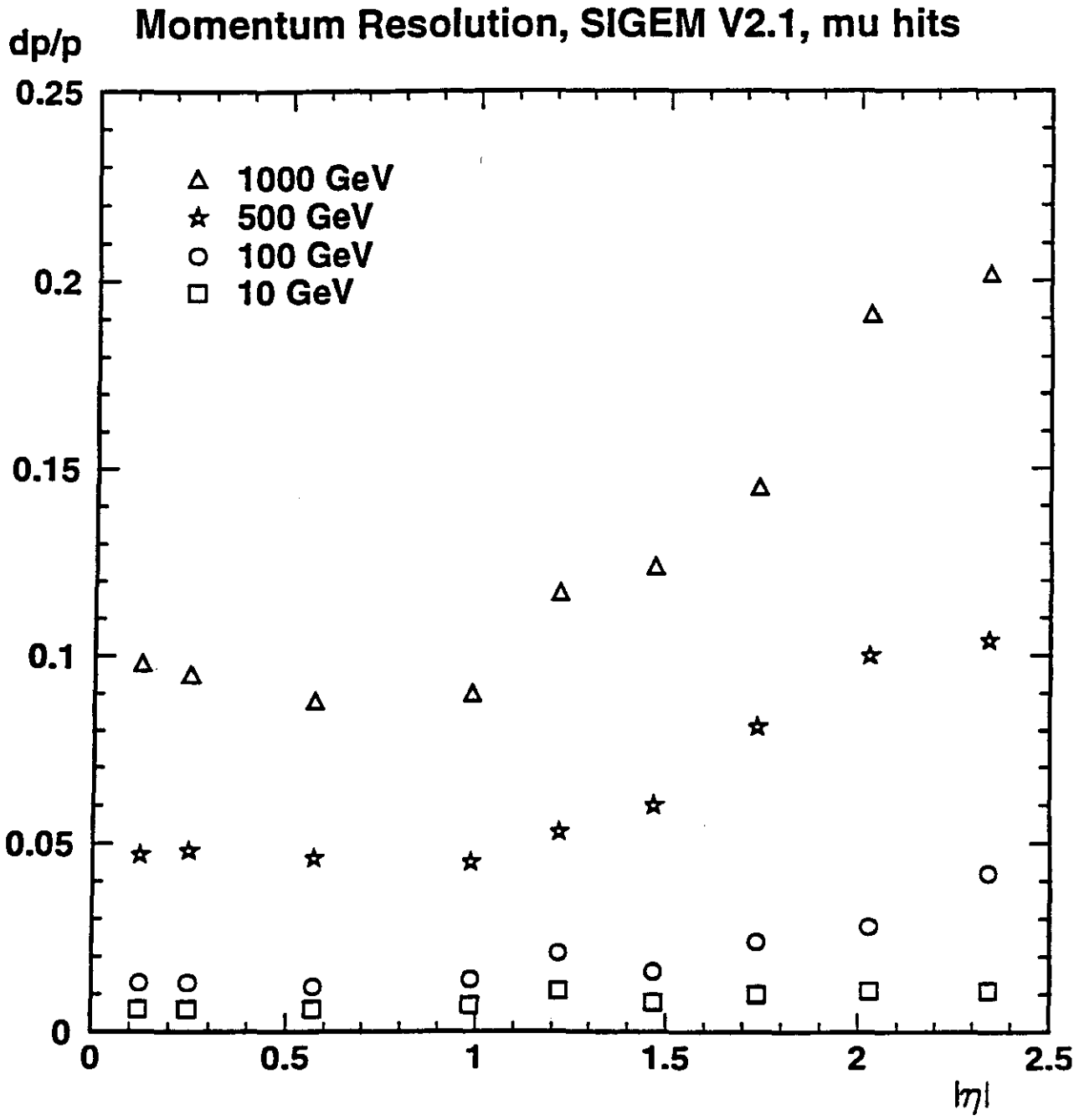
Momentum Resolution, SIGEM V2.1, mu hits
dp/p
0.25
0.2
0.15
0.1
0.05
0
1000 GeV
500 GeV
100 GeV
10 GeV
0
0.5
1
1.5
2
2.5
|η|

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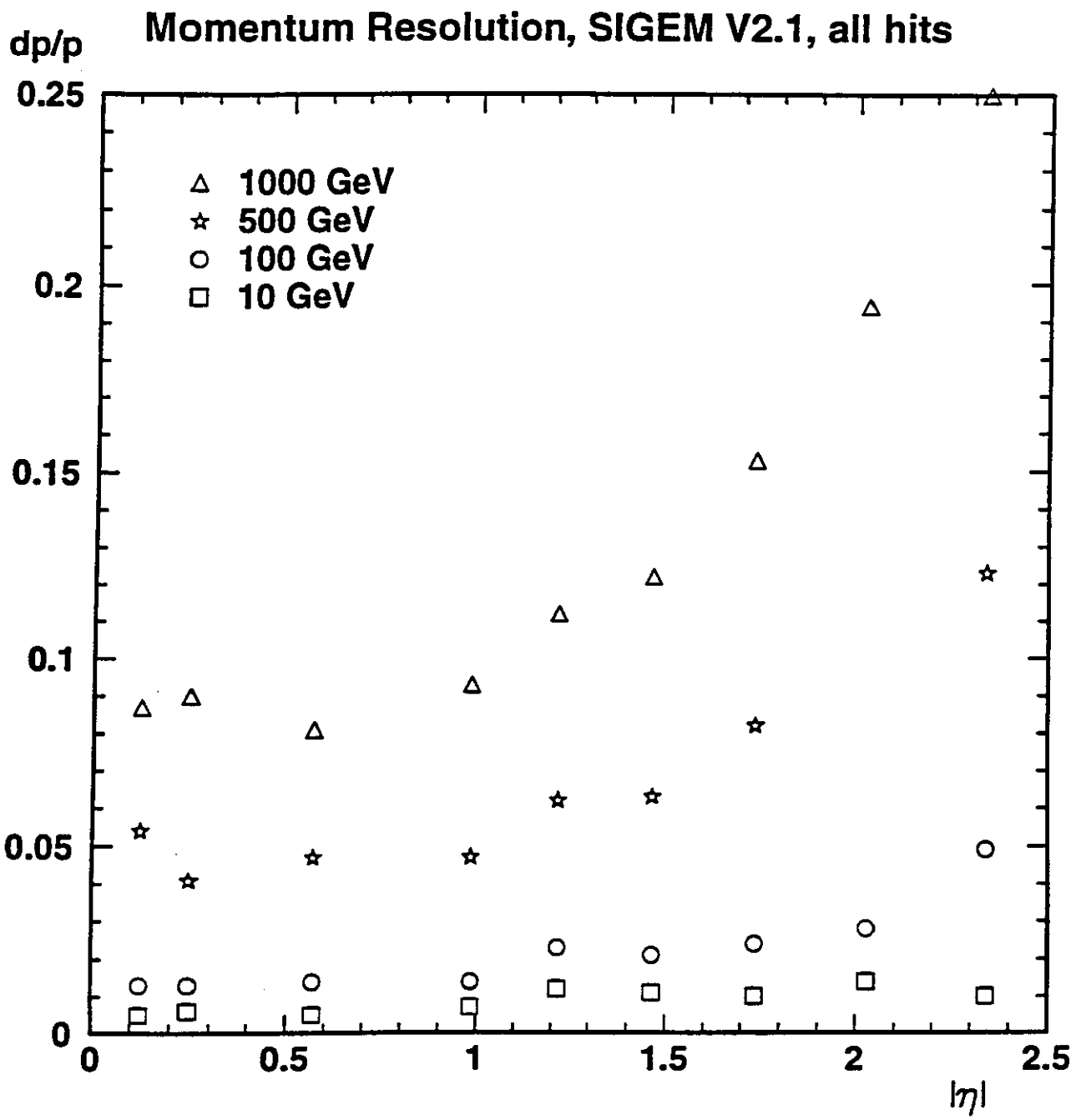
Momentum Resolution, SIGEM V2.1, all hits
dp/p
0.25
0.2
0.15
0.1
0.05
0
1000 GeV
500 GeV
100 GeV
10 GeV
0
0.5
1
1.5
2
2.5
|η|

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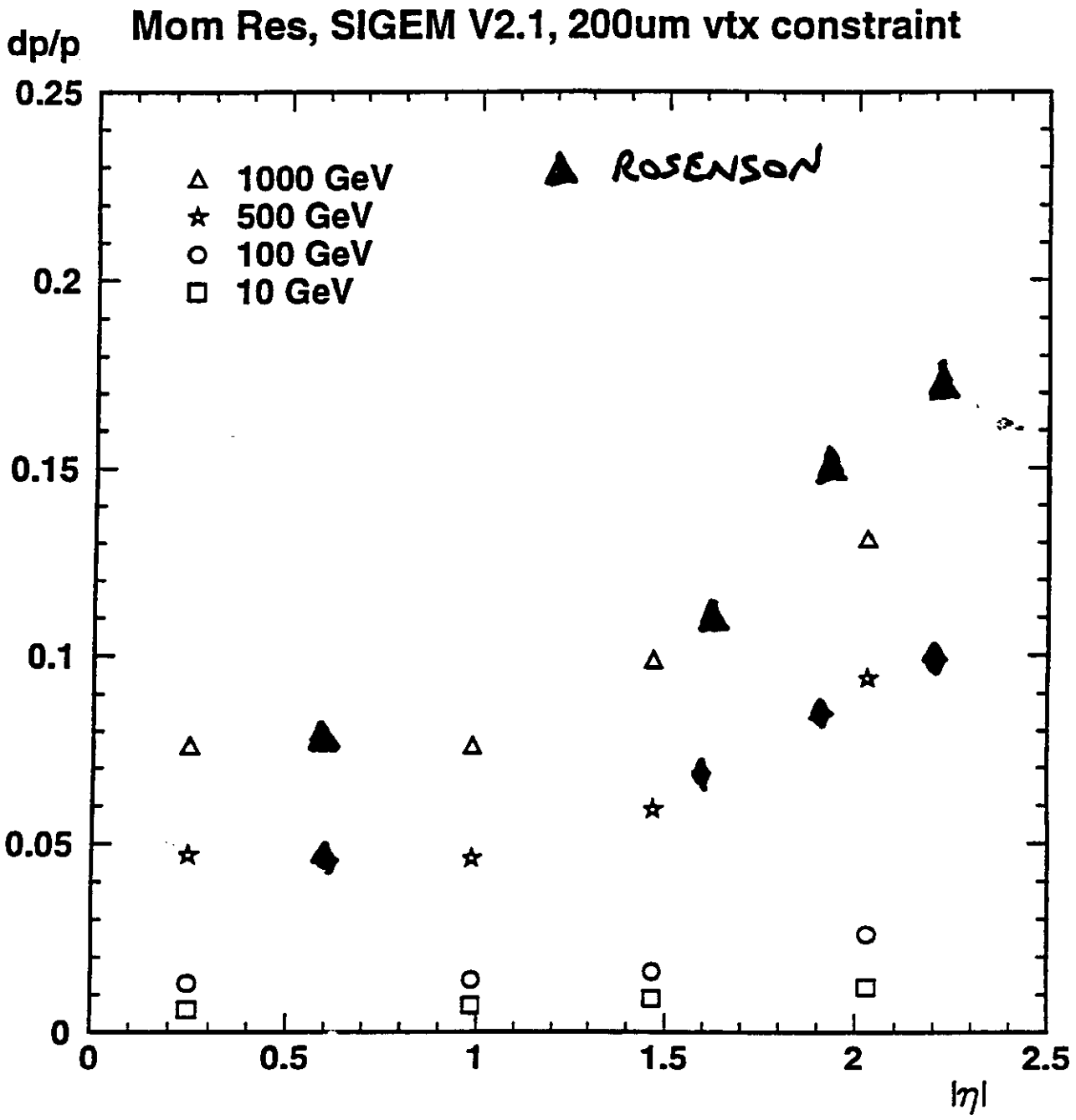
Mom Res, SIGEM V2.1, 200um vtx constraint
dp/p
0.25
0.2
0.15
0.1
0.05
0
1000 GeV
500 GeV
100 GeV
10 GeV
ROSENSON
0
0.5
1
1.5
2
2.5
|η|

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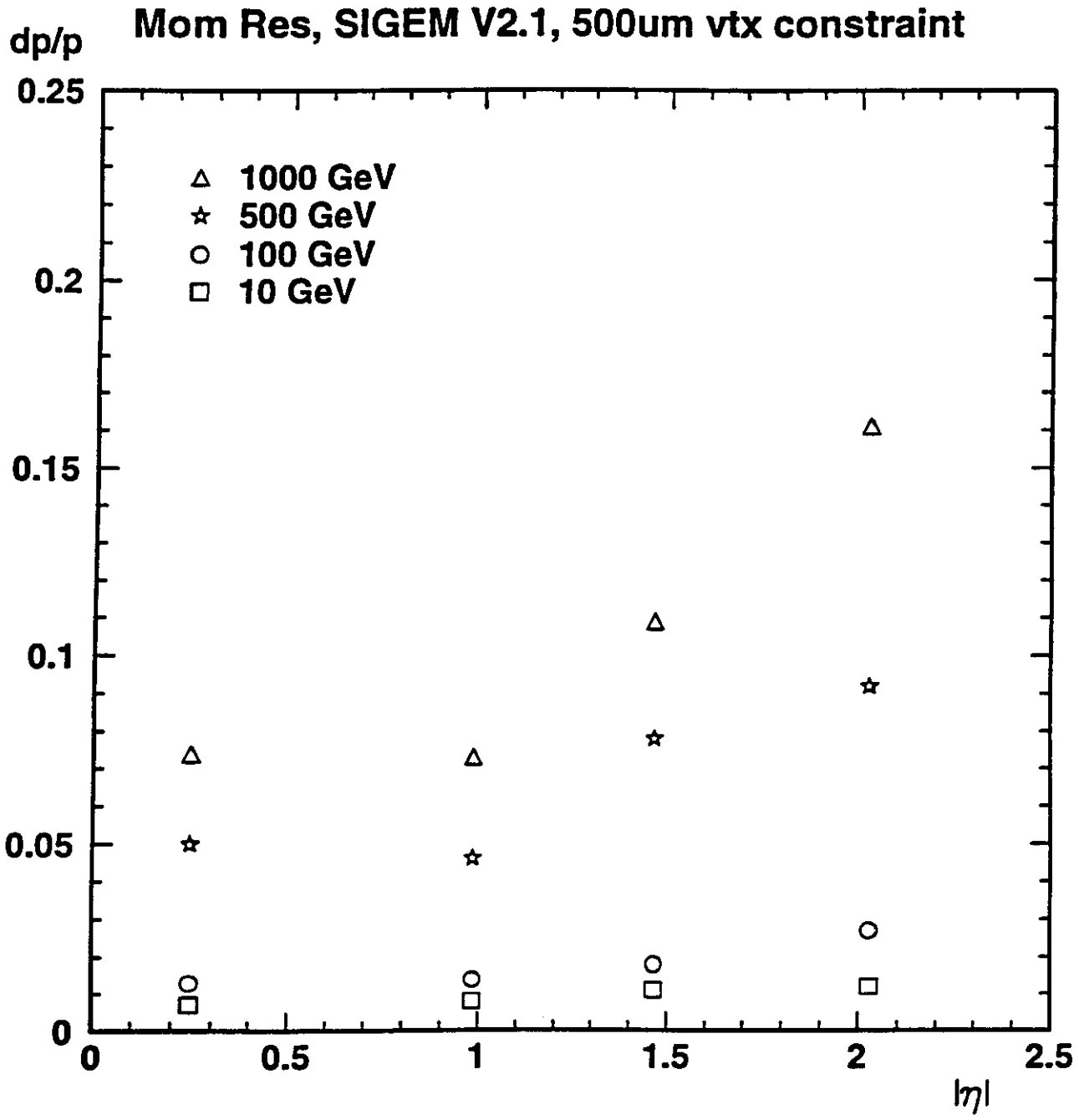
Mom Res, SIGEM V2.1, 500um vtx constraint
dp/p
0.25
0.2
0.15
0.1
0.05
0
1000 GeV
500 GeV
100 GeV
10 GeV
0
0.5
1
1.5
2
2.5
|η|

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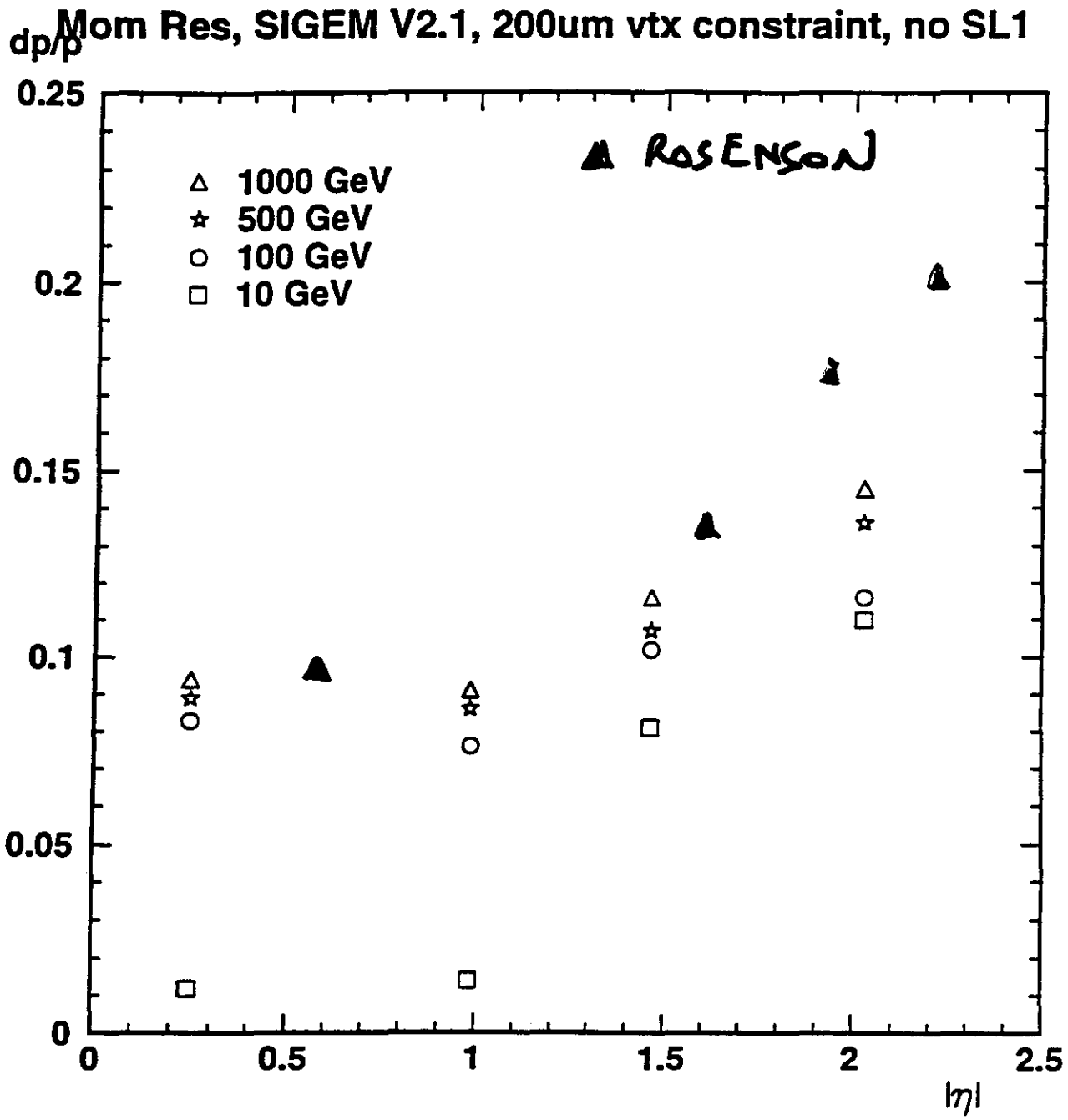
Mom Res, SIGEM V2.1, 200um vtx constraint, no SL1
dp/p
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
|η|
1000 GeV
500 GeV
100 GeV
10 GeV
ROSENSON

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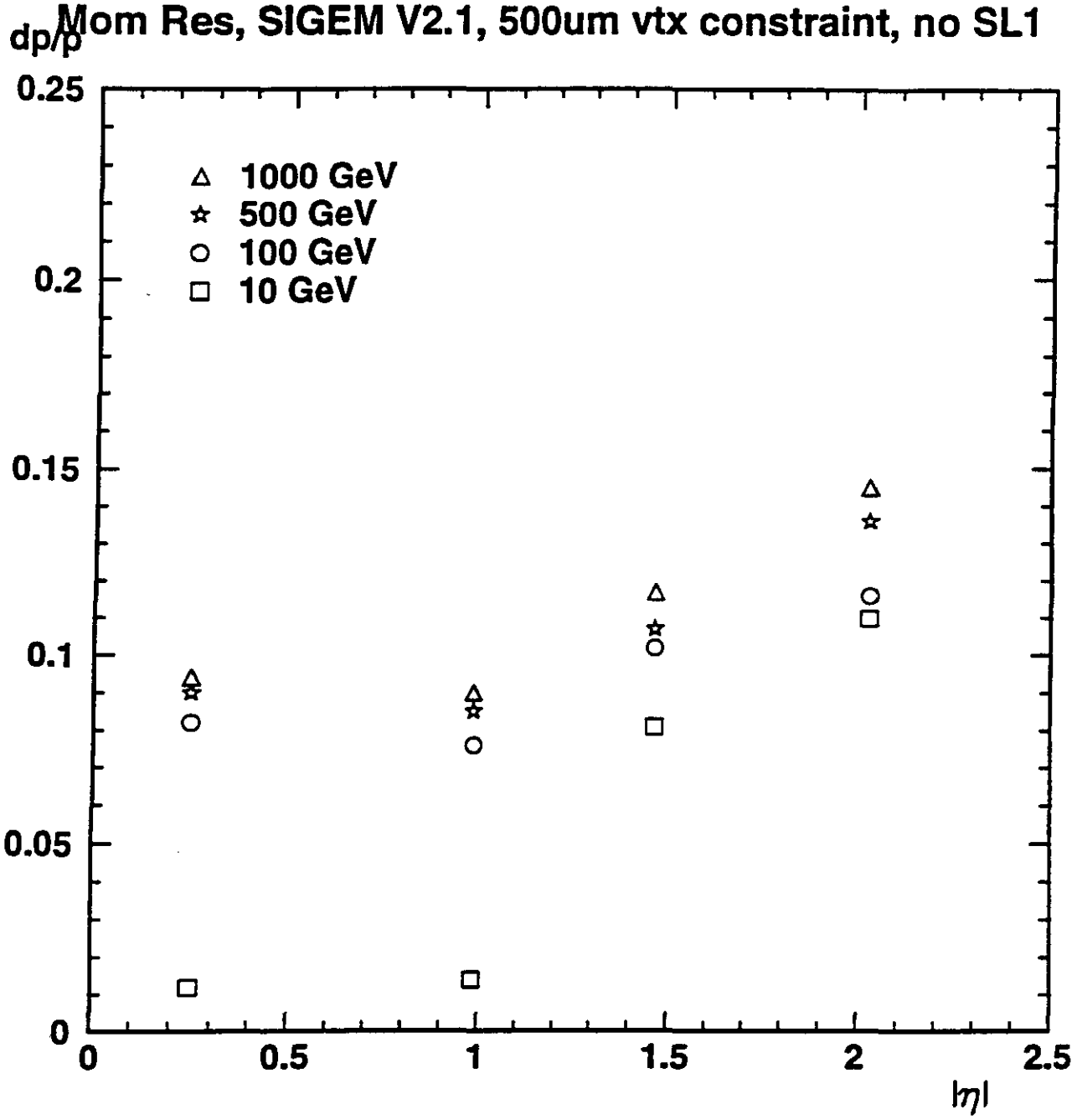
Mom Res, SIGEM V2.1, 500um vtx constraint, no SL1
dp/p
0.25
0.2
0.15
0.1
0.05
0
1000 GeV
500 GeV
100 GeV
10 GeV
0
0.5
1
1.5
2
2.5
|η|

T. Wenaus 6/93

gem

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Presentation by:

Roger McNeil

R McNeil
6/29/93

Pattern Recognition for Physics Benchmarks

SIGEM used to simulate muons in GEM

1. $H^0 \to ZZ \to \mu^+\mu^-\mu^+\mu^-$

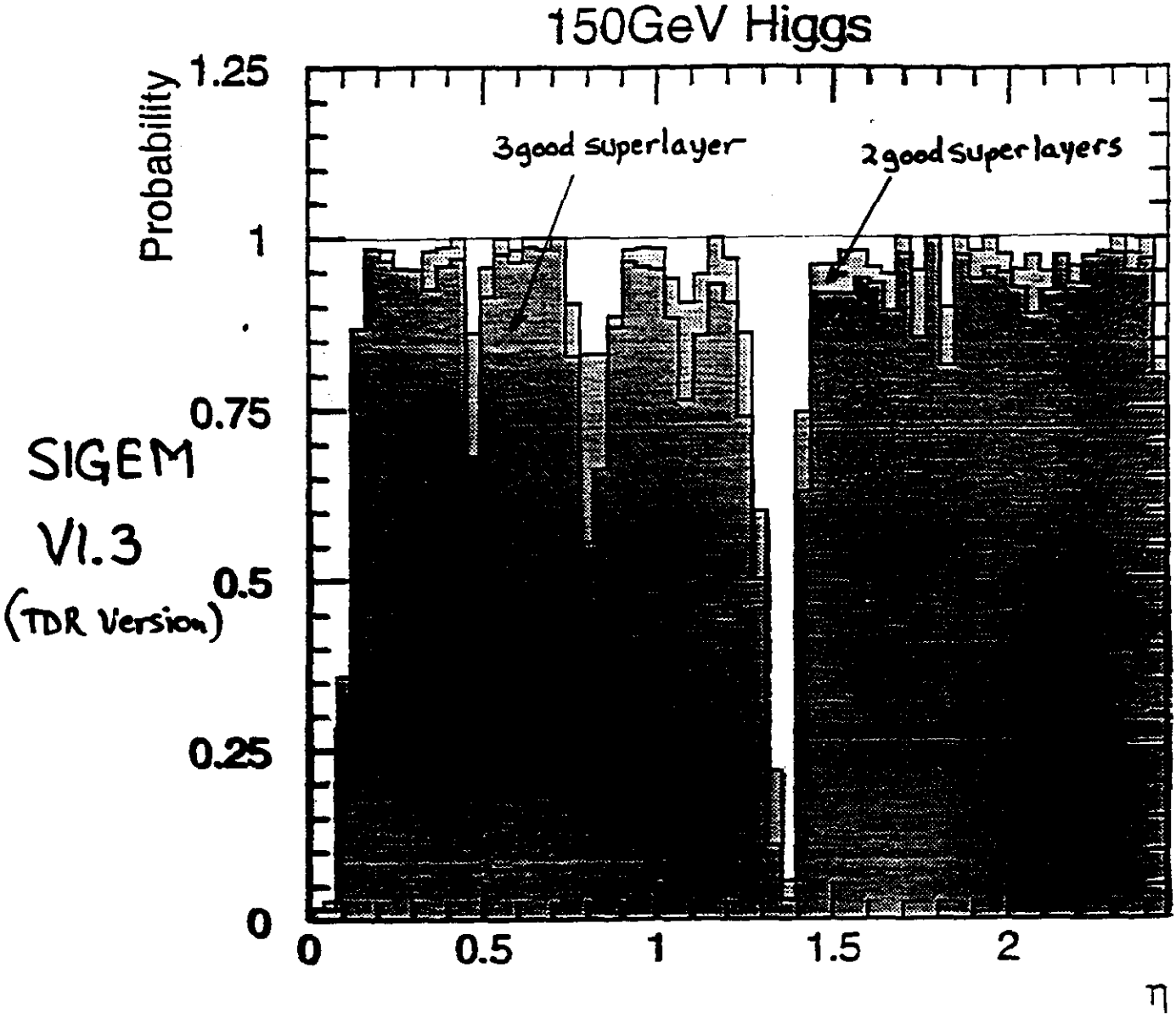
M_H(GeV)	Acceptance 4μ with $\lvert\eta\rvert<2.46$	All 4μ with $\lvert\eta\rvert<2.46$			
		4μ with all 3 superlayers	4μ with at least 2 SL	$\geq 3\mu$ with all 3 superlayers + Tracker/CAL	$\geq 3\mu$ with at least 2 SL + Tracker/Cal
150	54 %	42.6 % TDR 42 % full rec.	54.0 % TDR 56 % full rec.	80 %	87 %
400	64 %	45.0 %	57.9 %	83 %	89 %
800	78 %	47.4 %	59.1 %	82 %	94 %

2. $Z' \to \mu^+\mu^-$ $\quad M_{Z'} = 4$ TeV

Require both μ $\lvert\eta\rvert<2.46$ (87 % acceptance for Z')

2μ with all 3 superlayers	1μ with 3SL + 1μ with at least 2 superlayers	2μ with at least 2 superlayers
59.6 % TDR (good track segments)	71.5 % (TDR) → 62 % in 4π	72.6 % (TDR) → 63 % in 4π
66 % full rec 0.6 % found to be same sign	72 % full rec → [illegible] in 4π	

Pattern recognition performance for muons from Higgs



84% Acceptance per μ for 3 superlayers $|\eta| < 2.46$

97% efficiency for good track segments in 3 superlayers

43% efficiency for Higgs; $|\eta|_{4\mu} < 2.46$; 3 superlayers

87% Acceptance per μ for ≥ 2 superlayers $|\eta| < 2.46$

99% efficiency for good track segments in ≥ 2 superlayers

54% efficiency for Higgs; $|\eta|_{4\mu} < 2.46$; ≥ 2 superlayers

SIGEM V1.3 (TDR Version)

Acceptance gain by filling 30°, 90° crack

TDR Design: 54% eff for $H \to 4\nu$ $|\eta|_{4\nu} < 2.46$
and $\geq 2SL$

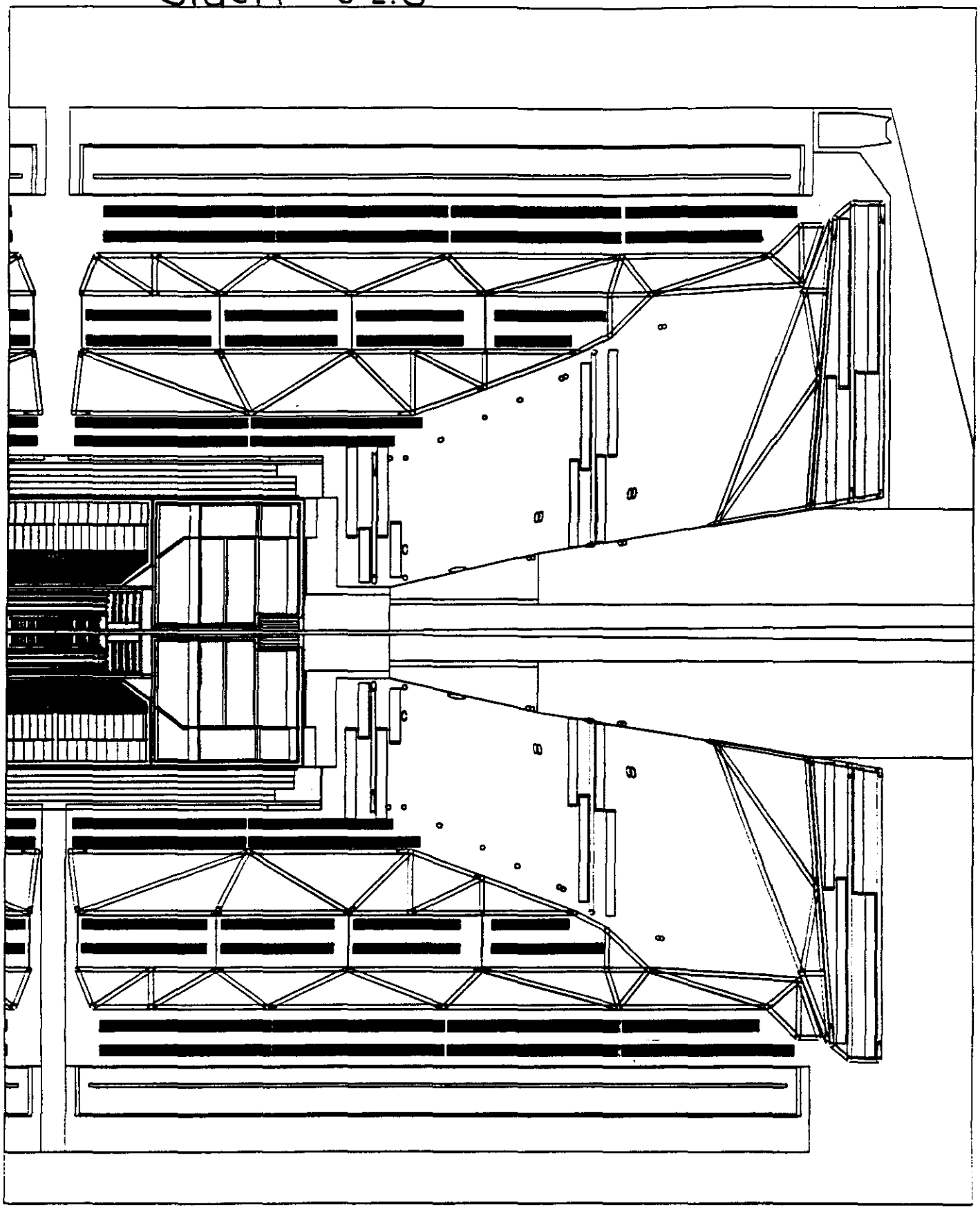
1. Filling 30° crack with 2SL

   54% → 68% eff for $H \to 4\nu$ $|\eta|_{4\nu} < 2.46$
   and $\geq 2SL$

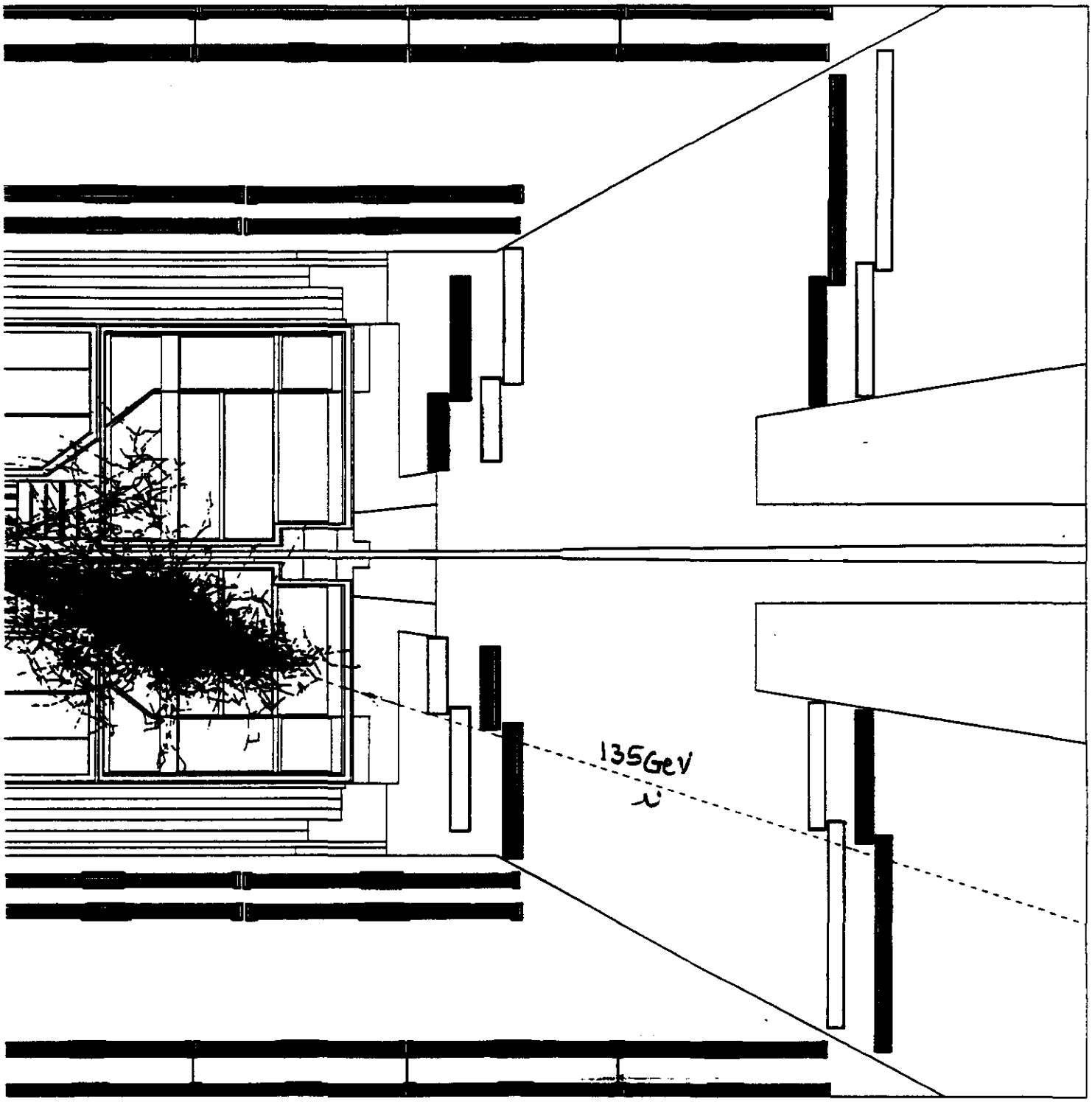
2. Filling 30° crack + ~40% of 90° crack with 2SL

   54% → 77% eff for $H \to 4\nu$ $|\eta|_{4\nu} < 2.41$
   and $\geq 2SL$

SIGEM V2.0



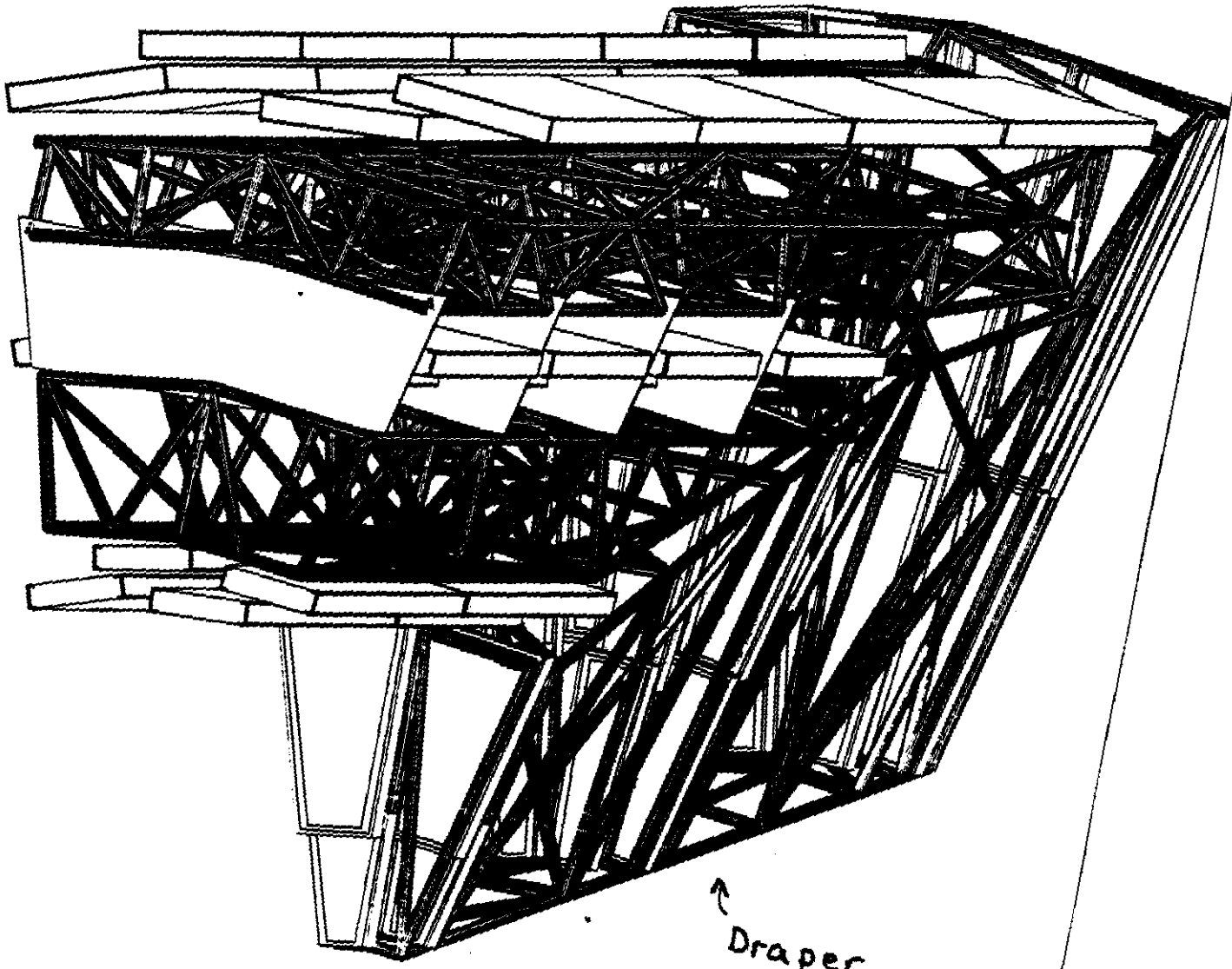
2-jet



145 GeV π^+ in cone with the ν !

V 1.3 SIGEM

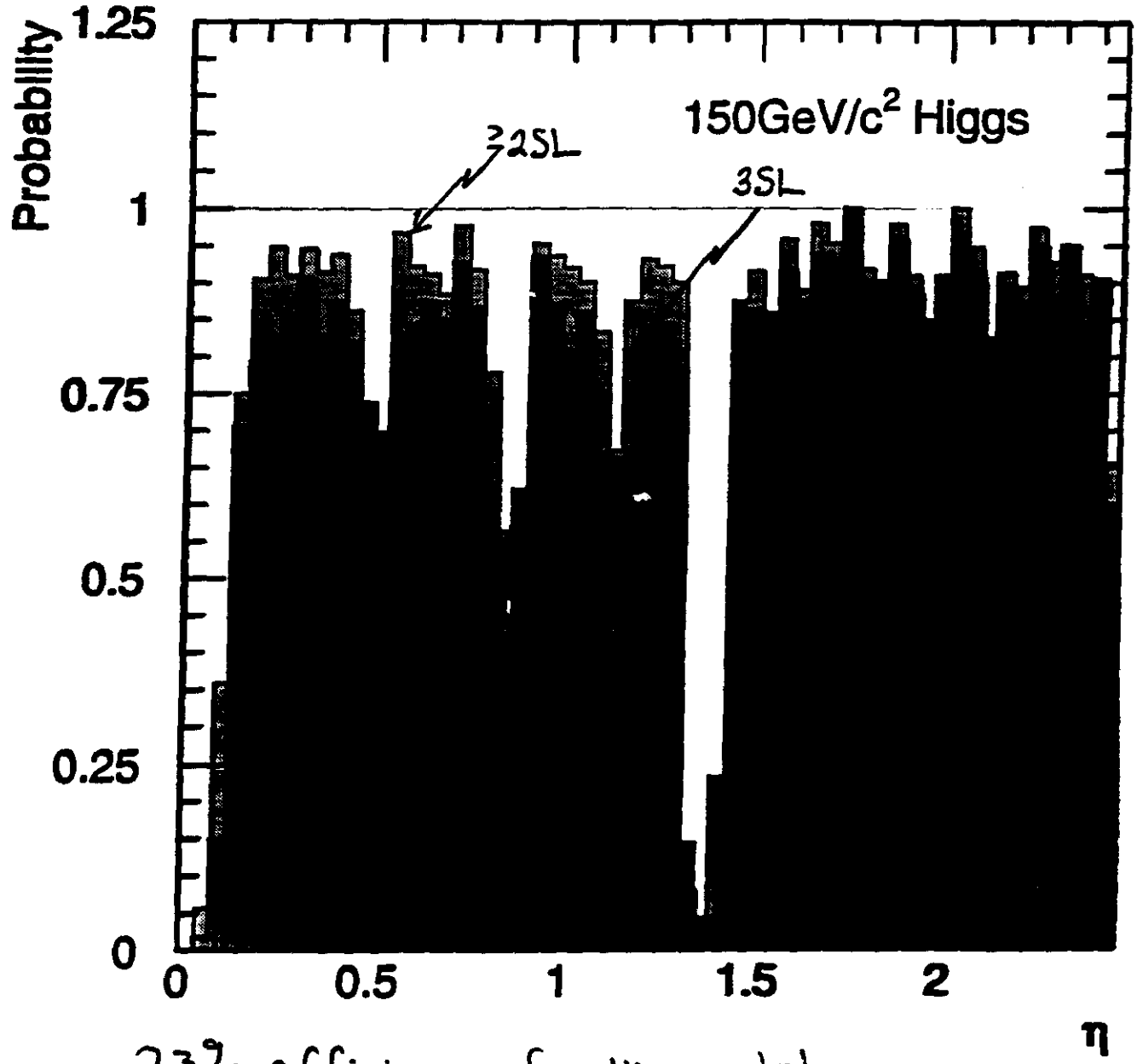
SIGEM V2.0 -



Draper support structure

SIGEM V2.1 (New Version)

Analysis is Preliminary!



23% efficiency for Higgs $|\eta|_{4\mu} < 2.46$; 3 super layers

~70% efficiency per muon average

42% efficiency for Higgs $|\eta|_{4\mu} < 2.46$; ≥2 super layers

150 GeV/c² Higgs with SIGEM V2.1

muons with 2SL

# muons with 3SL	0	1	2	3	4	Totals 3SL
0	0.4%	0.6%	0.4%	0.2%	0	1.6%
1	0	2.2%	3.2%	1.0%	0.6%	7.0%
2	0	0	9.4%	13.5%	3.8%	26.7%
3	0	0	0	27.1%	14.3%	41.4%
4	0	0	0	0	23.3%	23.3%
Totals 2SL	0.4%	2.8%	13.0%	41.8%	42.0%	

Muons which go into 30°, 90° crack $|\eta|_{\mu i} < 2.46$

muons $0 < |\eta| < 0.16$ (90° crack) 2SL

# μ $1.26 < |\eta| < 1.46$ (30° crack)	0	1	2	3
0	64.5%	16.9%	3.2%	0%
1	10.6%	2.6%	0.2%	0
2	1.0%	0.8%	0	0
3	0.2%	0	0	0
	76.3%			

SIGEM V2.1 (new Version)

Acceptance gain by filling 30°, 90° crack

Current Design: 42% eff for $H \to 4\nu$ $|\eta|_{4\nu} < 2.46$ and $\geq 2SL$

1. filling 30° crack with 2SL

   42% → 50% eff for $H \to 4\nu$ $|\eta|_{4\nu} < 2.46$ and $\geq 2SL$

2. filling 30° crack and ~40% of 90° crack with 2SL

   42% → 55% eff for $H \to 4\nu$ $|\eta|_{4\nu} < 2.46$ & $\geq 2SL$

Caution: <u>Results are preliminary</u>

with this in mind:

- We need work to understand why losses occur in regions between cracks
- need to formulate strategies to improve design w.r.t. acceptance.

gem

γeμ

Presentation by:

Torre Wenaus

μ SYSTEM ACCEPTANCE

MARCH BASELINE (IN GEMFAST):

85.4% IN $|\eta| < 2.5$

SIGEM v2.1:

$$\frac{80.4\%}{.97} = 82.9\%$$

.97 ← RECO EFF. CORR'N.

N.B. LOSS IS IN BARREL WHERE $H \to 4\mu$ MUONS ARE PEAKED.

INTRODUCE Z SMEAR $\sigma_z = 6$ cm

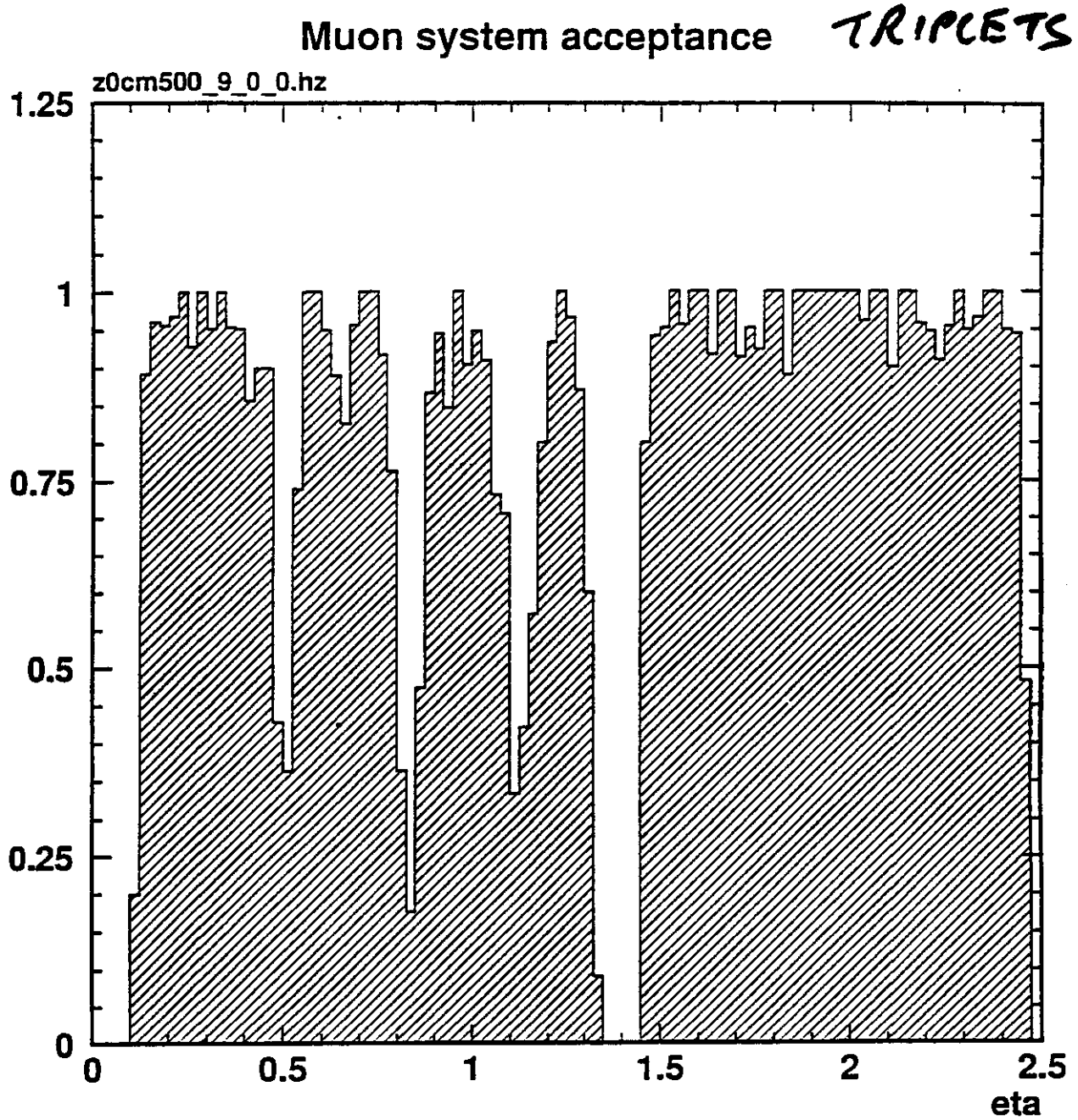
$\sigma_z = 0$: $\frac{1627}{2000}$ EVS $\sigma_z = 6$: $\frac{1615}{2000}$ EVS

NEGLIGIBLE EFFECT.

DOUBLET ACCEPTANCE:

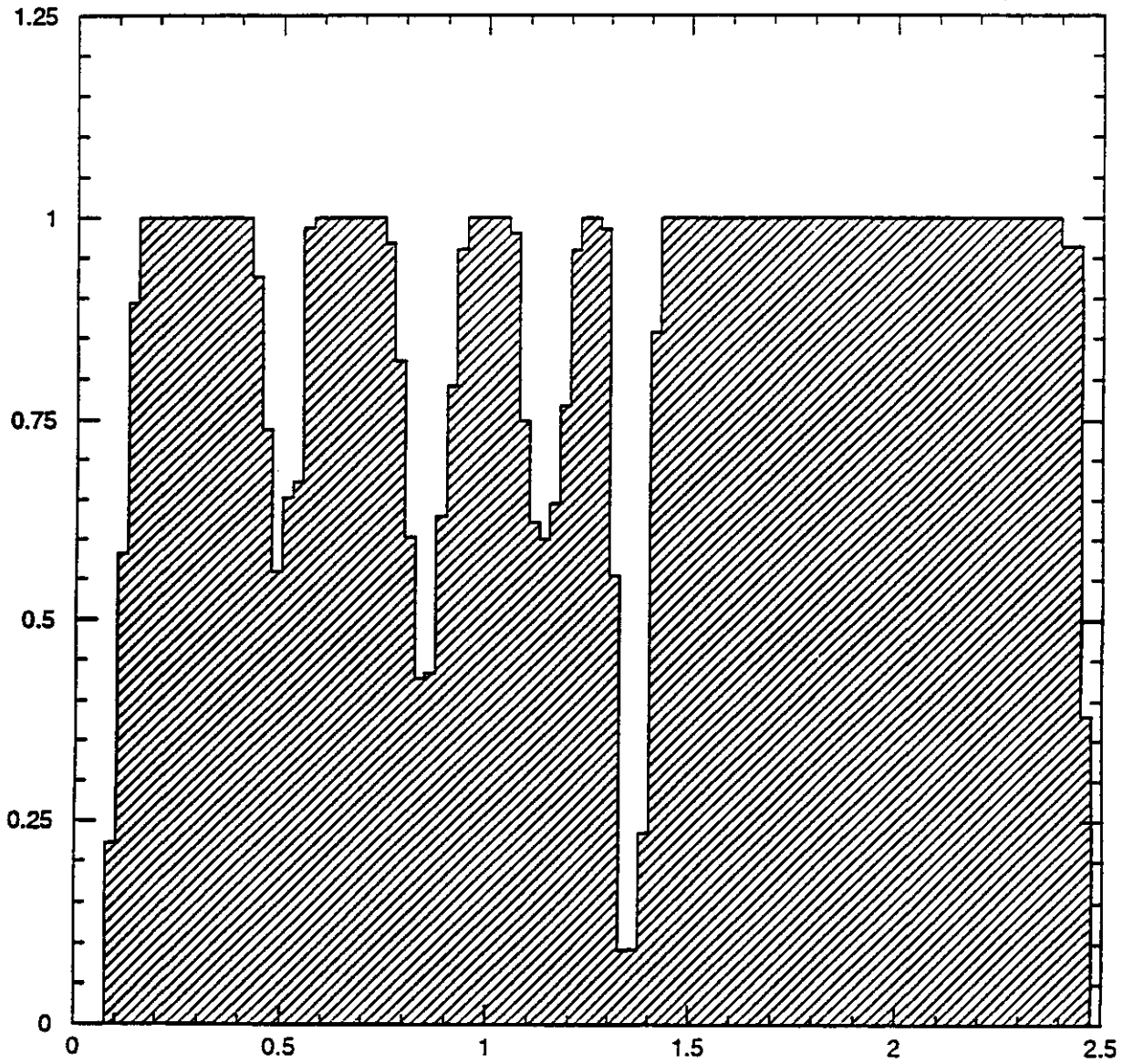
86.3% INCLUDING RECO EFF.

SIGEM v2.1 500 GeV μ's.



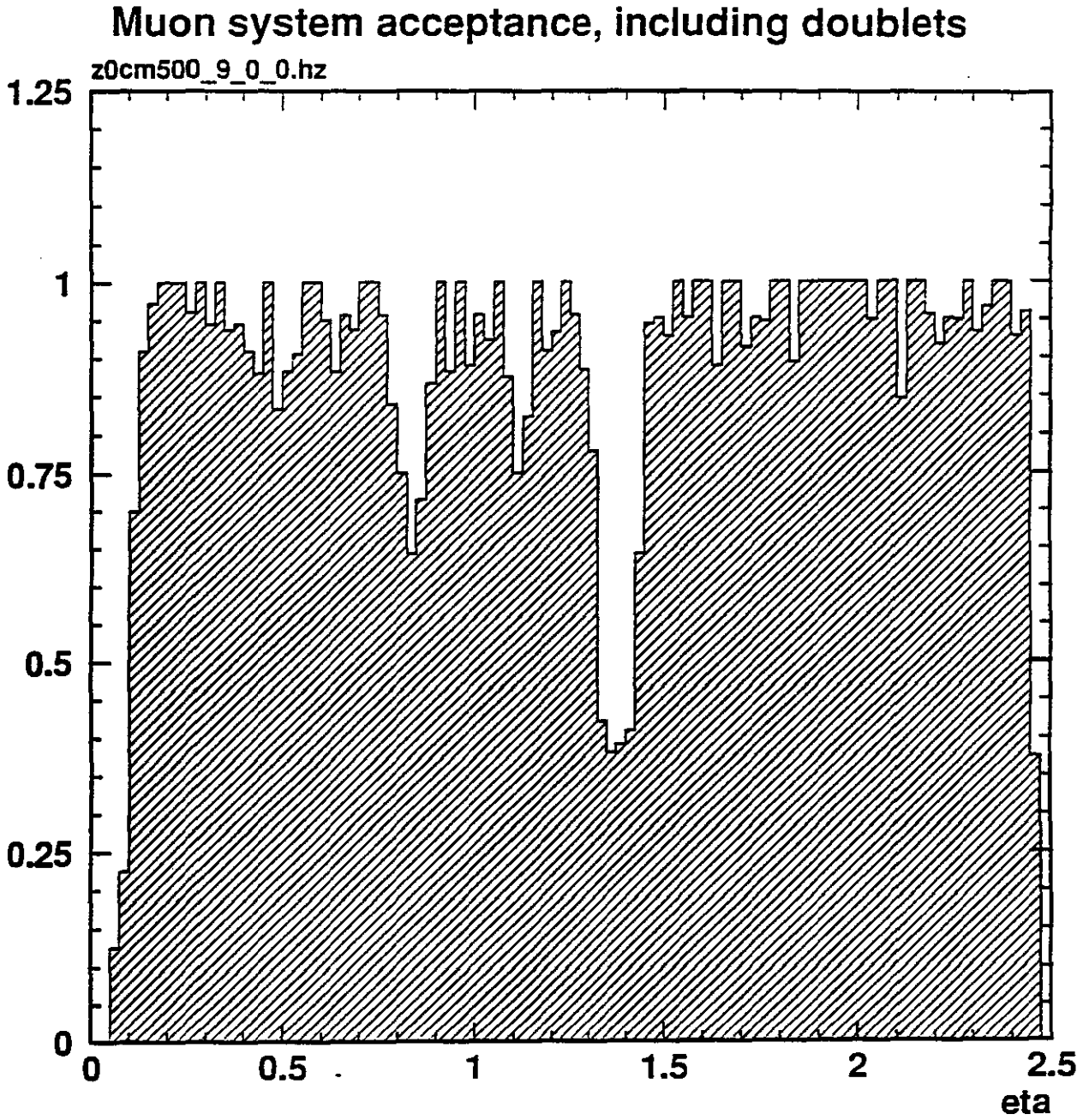
FROM RECONSTRUCTION;
INCLUDES RECO EFF.

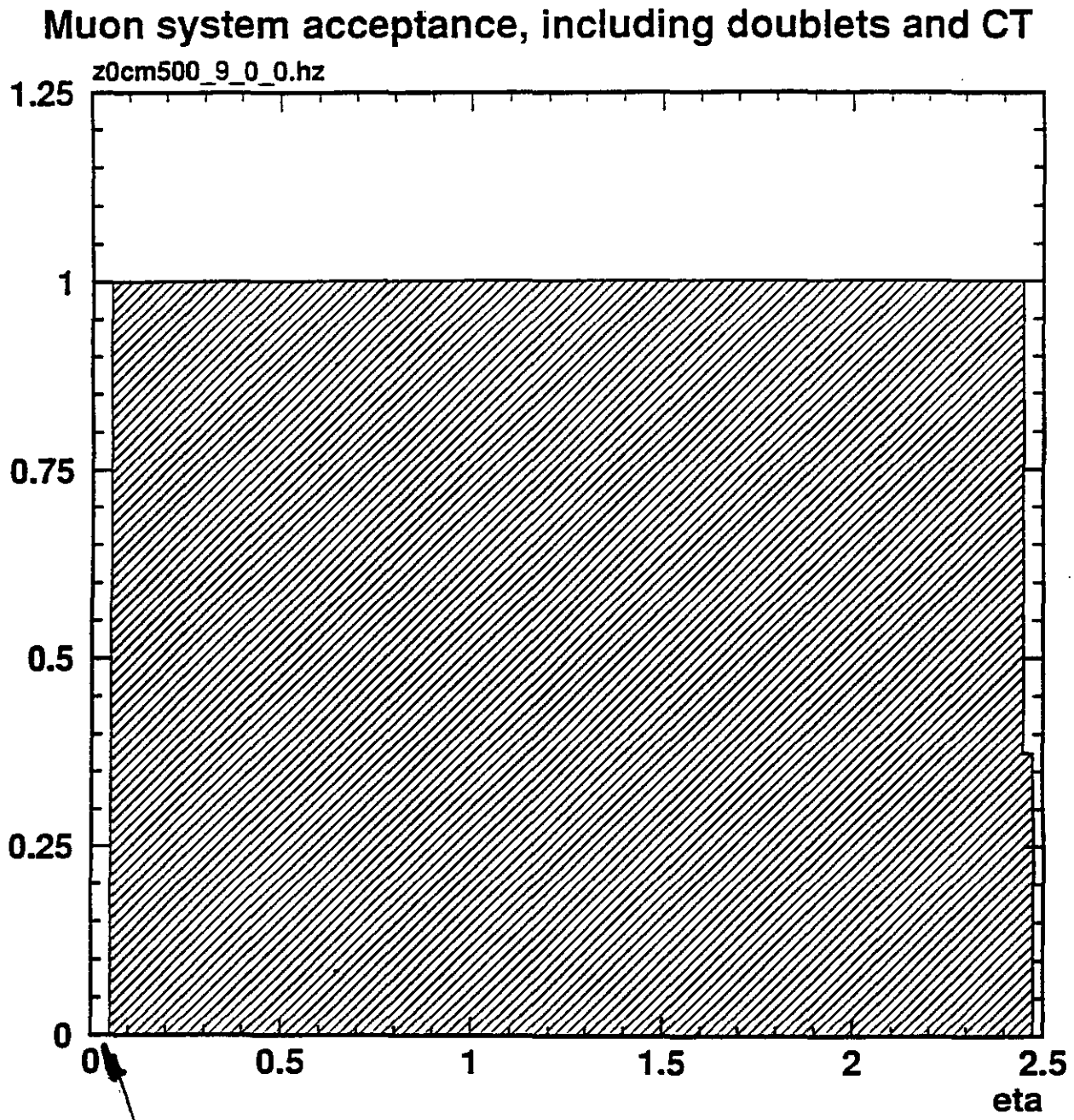
GEMFAST muon acceptance



MARCH BASELINE

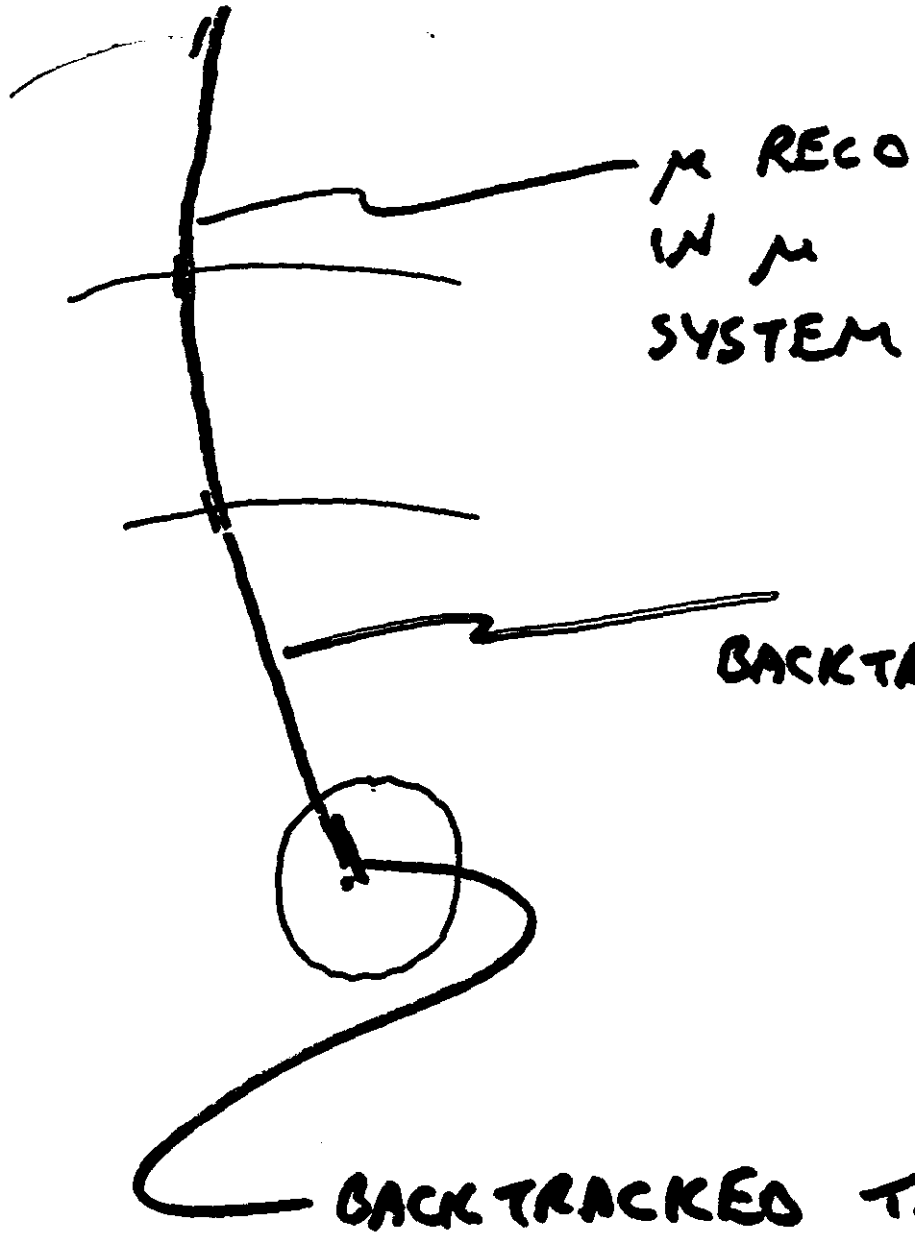
SIGEM v2.1


Muon system acceptance, including doublets
z0cm500_9_0_0.hz
1.25
1
0.75
0.5
0.25
0
0
0.5
1
1.5
2
2.5
eta



ARTIFACT. μ's NOT FIRED INTO CENTRAL GAP.

COMBINING μ SYSTEM + CT
IN HIGGS RECO



→ GEMFAST CT →
CT RECO PROB. ↓
SMEARED $\vec{p}$

$H \to 4\mu$ RECO EFF. in $|\eta| < 2.46$

1000 EVENTS IN 4π.

	TRIPLETS	TRIP+DOUB
TDR	43%	54%
RECO, MARCH BASELINE (SIGEM 1.3)	42%	56%
RECO, SIGEM 2.1	ROGER: 23% 27% (-36% FROM v1.3)	42% 45% (-20% FROM v1.3)

INCLUDE CT:

1 CT TRACK + 3 μ TRACKS.

	TRIP + CT	TRIP+DOUB + CT
RECO SIGEM 1.3	65%	80%
RECO SIGEM 2.1	45%	73%

$H \to 4\mu$ ΔM_H

RECO SIGEM 1.3	σ_{M_H}	TOR GeV
TRIPLETS $\lvert\eta\rvert < 1.8$, NO ELOSS FLUCT	1.17	1.4
" " WITH ELOSS	1.51	1.6
" " " + CT	1.79	
T+D " "	1.72	
" " " + CT	2.04	
" FULL DET "	2.23	
" " " + CT	2.30	

RECO SIGEM 2.1	
TRIP, FULL DET, NO ELOSS	1.41
" " WITH ELOSS	2.04
" " " + CT	2.29
T+D " " + CT	2.69