PFA Development – Definitions and Preparation

0) Generate some events w/G4 in proper format

1) Check Sampling Fractions ECAL, HCAL separately

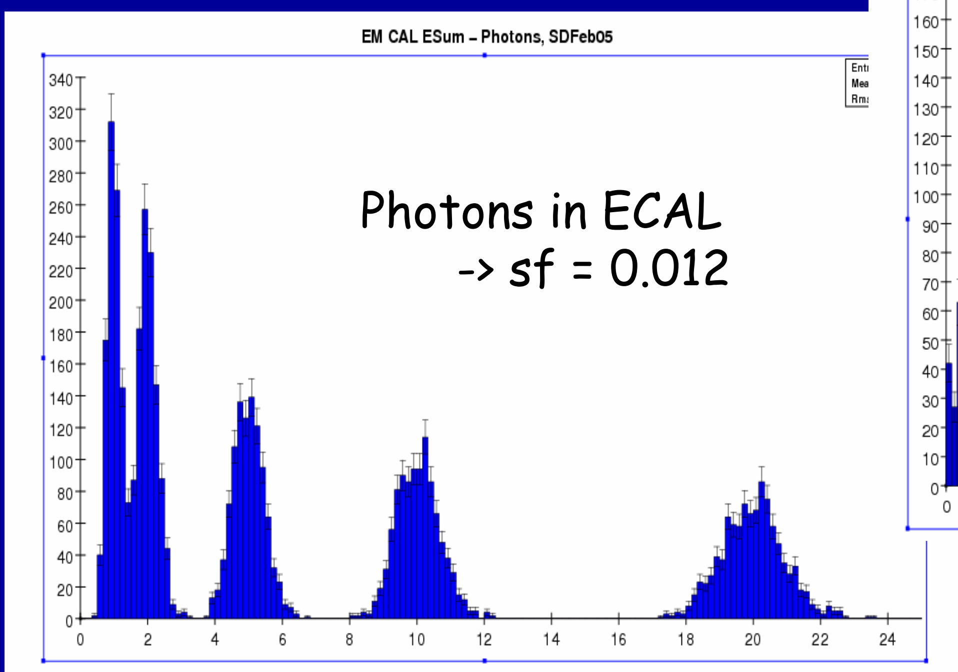
How?

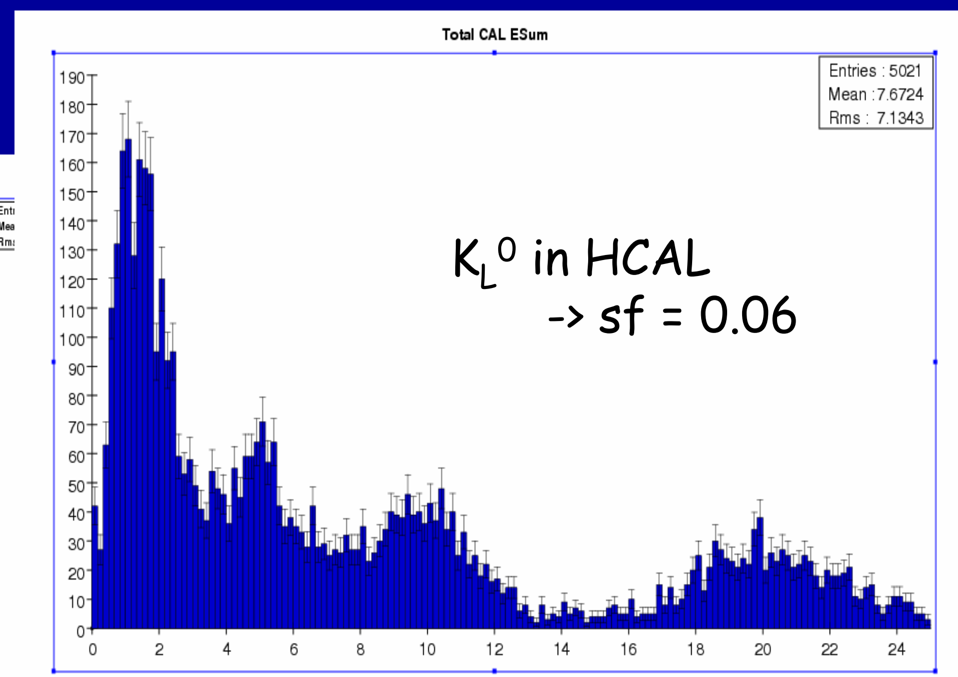
Photons, electrons in ECAL

Neutral hadrons in HCAL (no ECAL int.)

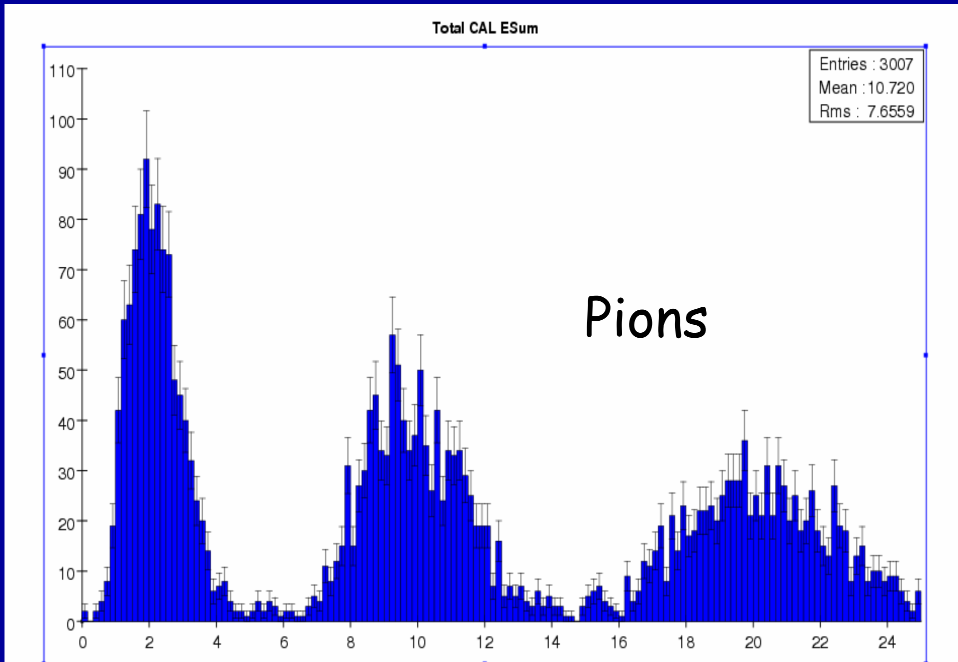
Charged Pions in HCAL (don't forget ECAL mips)

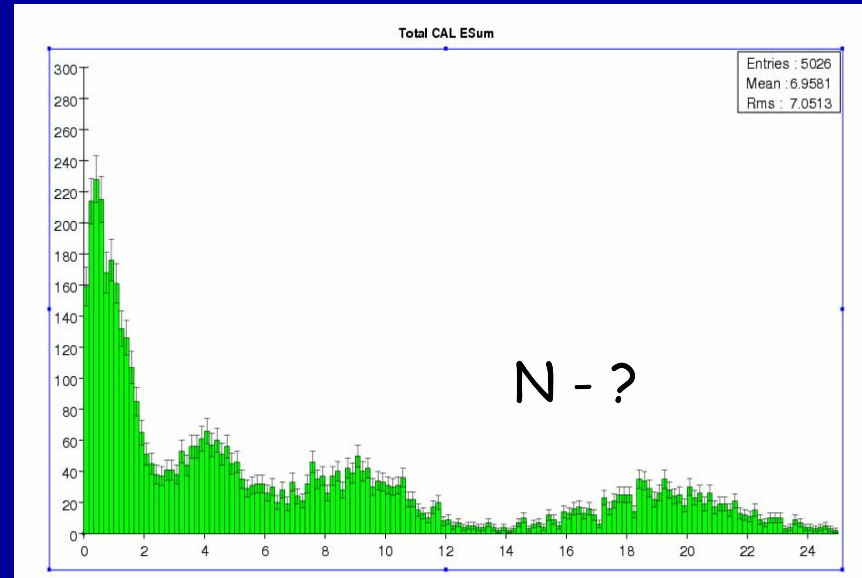
Detector – SDFeb05 Sci HCAL

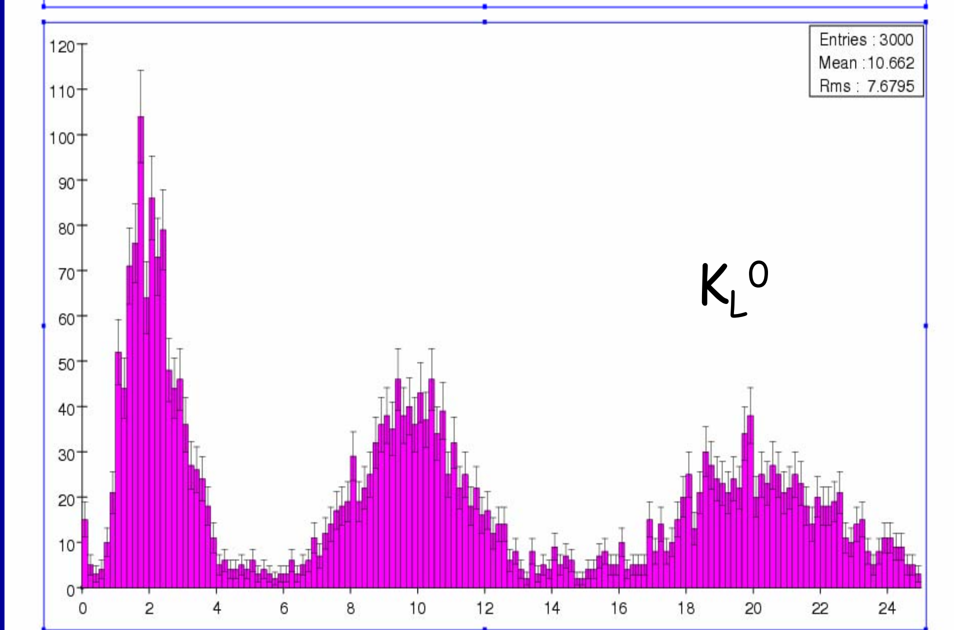


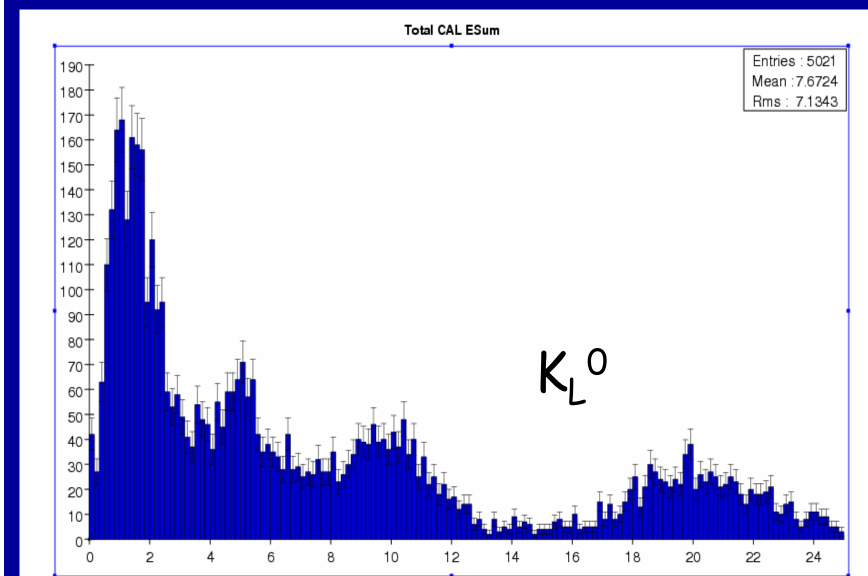


Hadron Comparisons







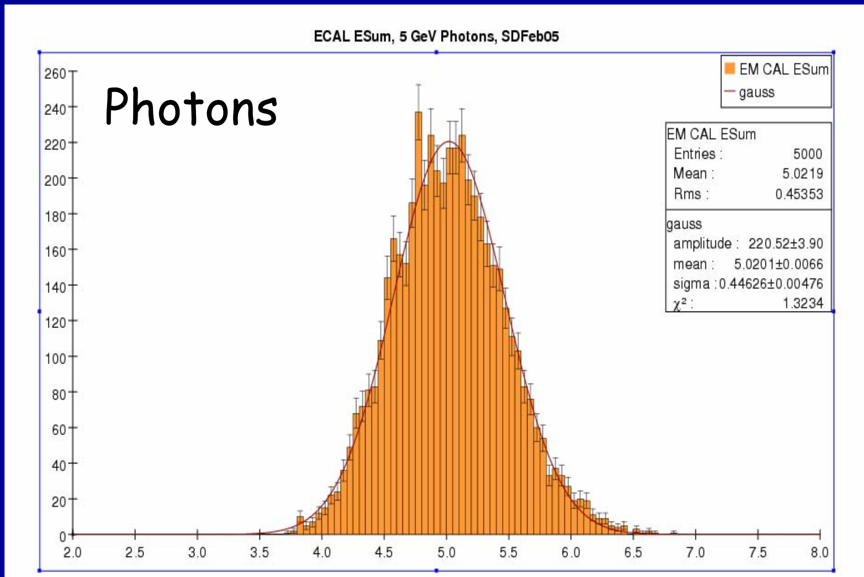


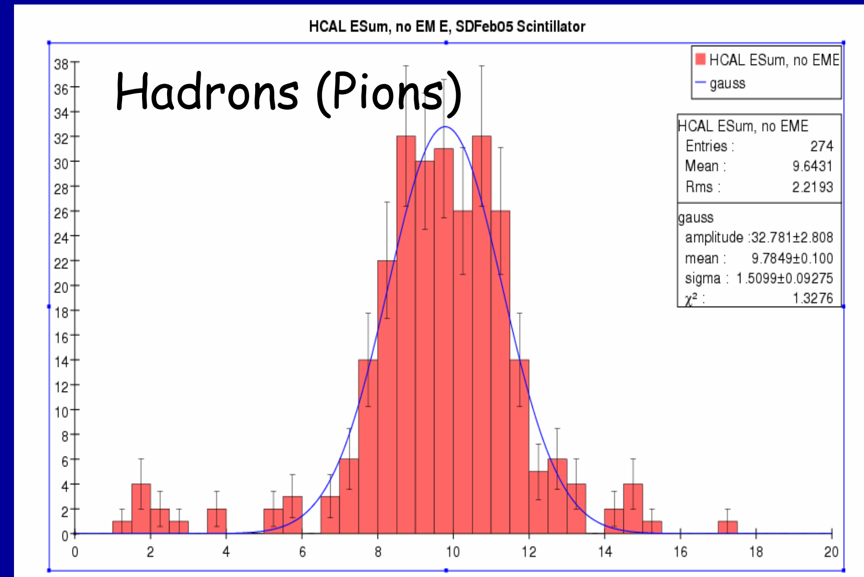
G4 Physics List? – under investigation

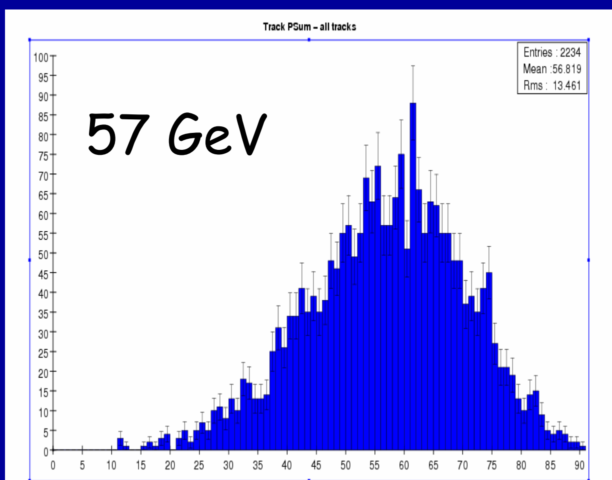
PFA Development – Definitions and Preparation

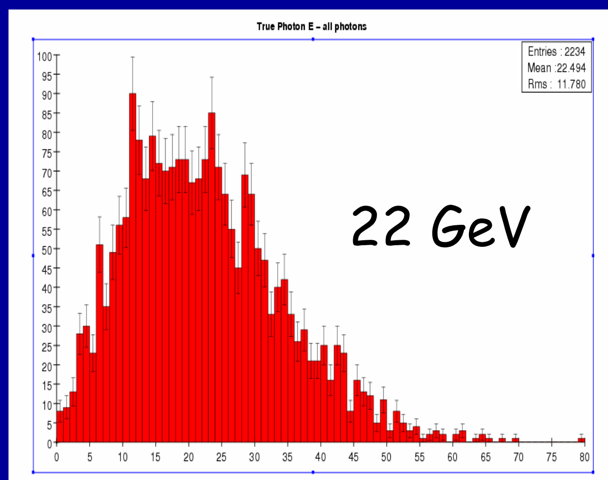
2a) Single Particle Response -> Analytic Perfect PFA
   Expected values for E resolution?
   Why not!? -> G4 problem? Go Back To 0)
2b) Analog/Digital Readout!?
2a) Calibration
   How?
   With/without threshold cut?
   Realistic methods?
2b) Choice of threshold cut
   Necessary?
   Realistic?

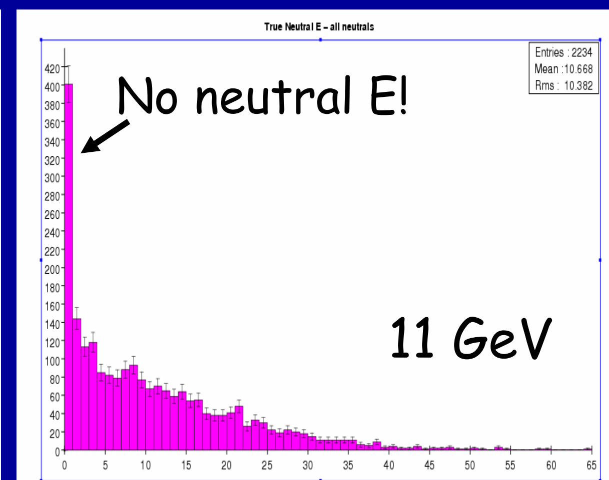
Analytic Perfect PFA - SDFeb05 Detector Model











Photon resolution = $\sqrt{22.5} \times .199 = 0.94$ GeV

Neutral H resolution = $\sqrt{10.7} \times .48 = 1.57$ GeV

-> PPFA = $19\%/\sqrt{E}$

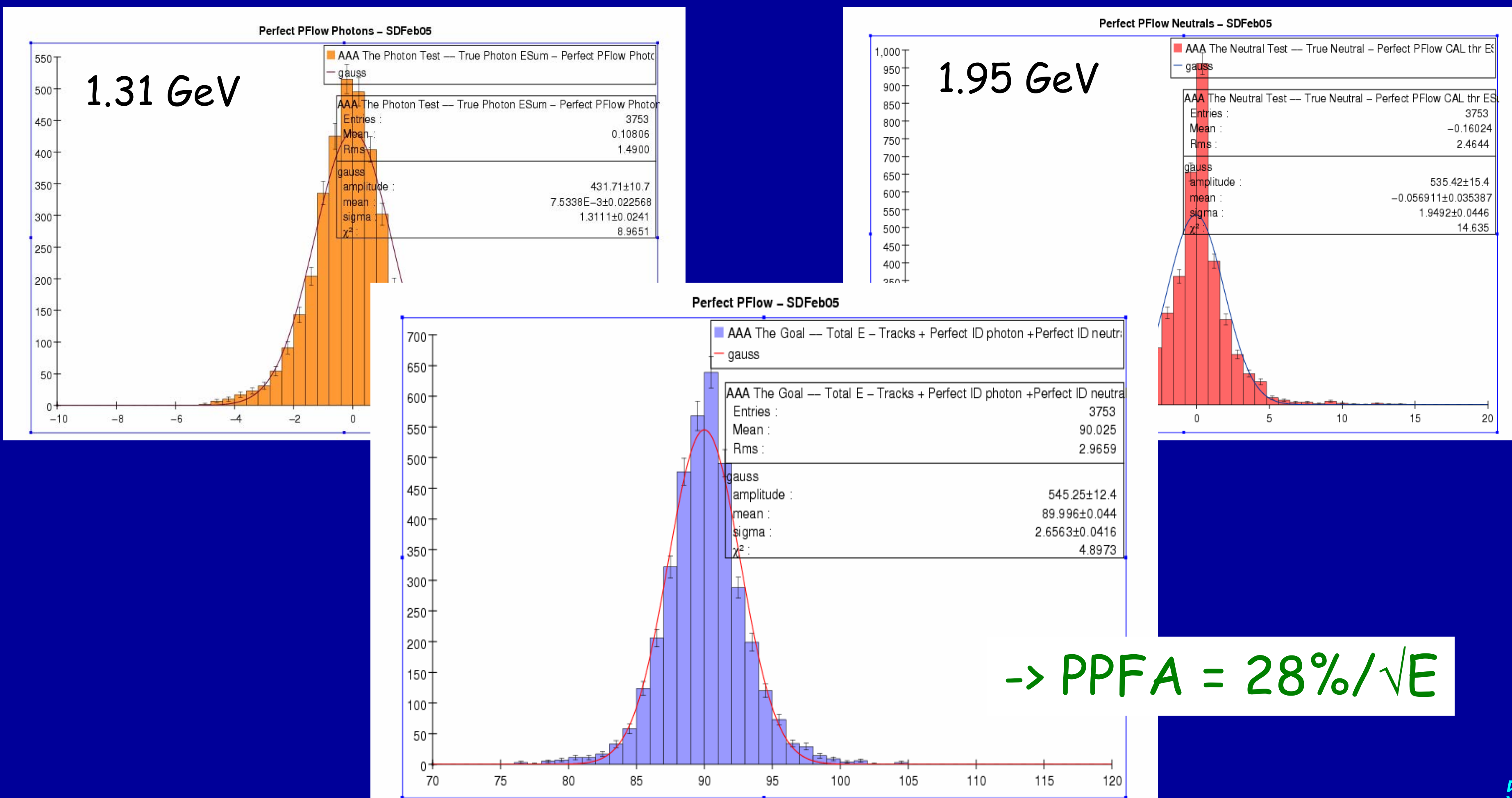
PFA Development – Definitions and Preparation

3) Perfect PFA with Detector Effects

Equal to 2a)?

Better than 30%/√E?

4) Now ready for PFA development



PFA Development – Definitions and Preparation

4) Document and archive all of the above for each Detector Model
   - Web site for archived plots and detector documentation
   - Also needs to include special cuts, etc.

5) Now ready for PFA development
   - Examples of PFA use in detector optimization/evaluation ->

Calorimeter Absorber Optimization – PFA Application

1) PFA optimization - beginning of hadron showers separated (longitudinally) from beginning of EM showers . . .

$$\mathcal{P}(e,\gamma) = 1 - C_{e,\gamma}\, e^{-x/X0}$$

$$C_{e,\gamma} = (1,7/9)$$

$$\mathcal{P}(h) = 1 - C_h\, e^{-l/\lambda I}$$

$$C_h = 1$$

So, in first layers of calorimeter, want $\mathcal{P}(e,\gamma) \gg \mathcal{P}(h)$

-> $x/X_0 \gg l/\lambda_I$

-> λ_I/X_0 should be as large as possible

Dense, Non-magnetic

Material	λ_I (cm)	X_0 (cm)	λ_I/X_0
W	9.59	0.35	27.40
Au	9.74	0.34	28.65
Pt	8.84	0.305	28.98
Pb	17.09	0.56	30.52
U	10.50	0.32	32.81

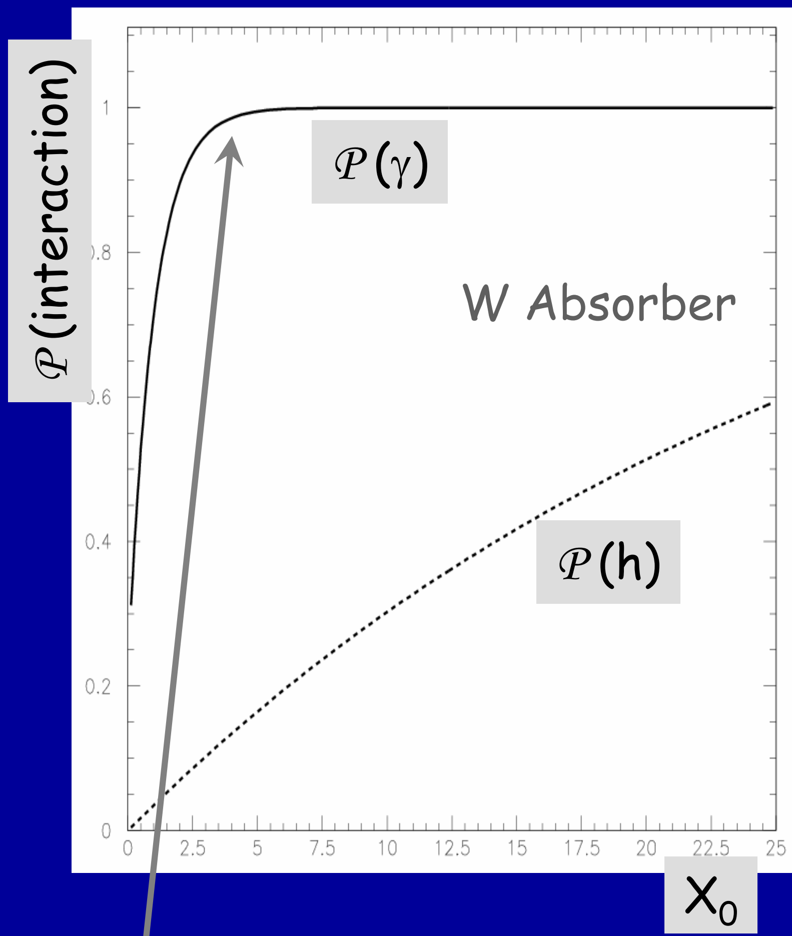
. . . Use these for ECAL

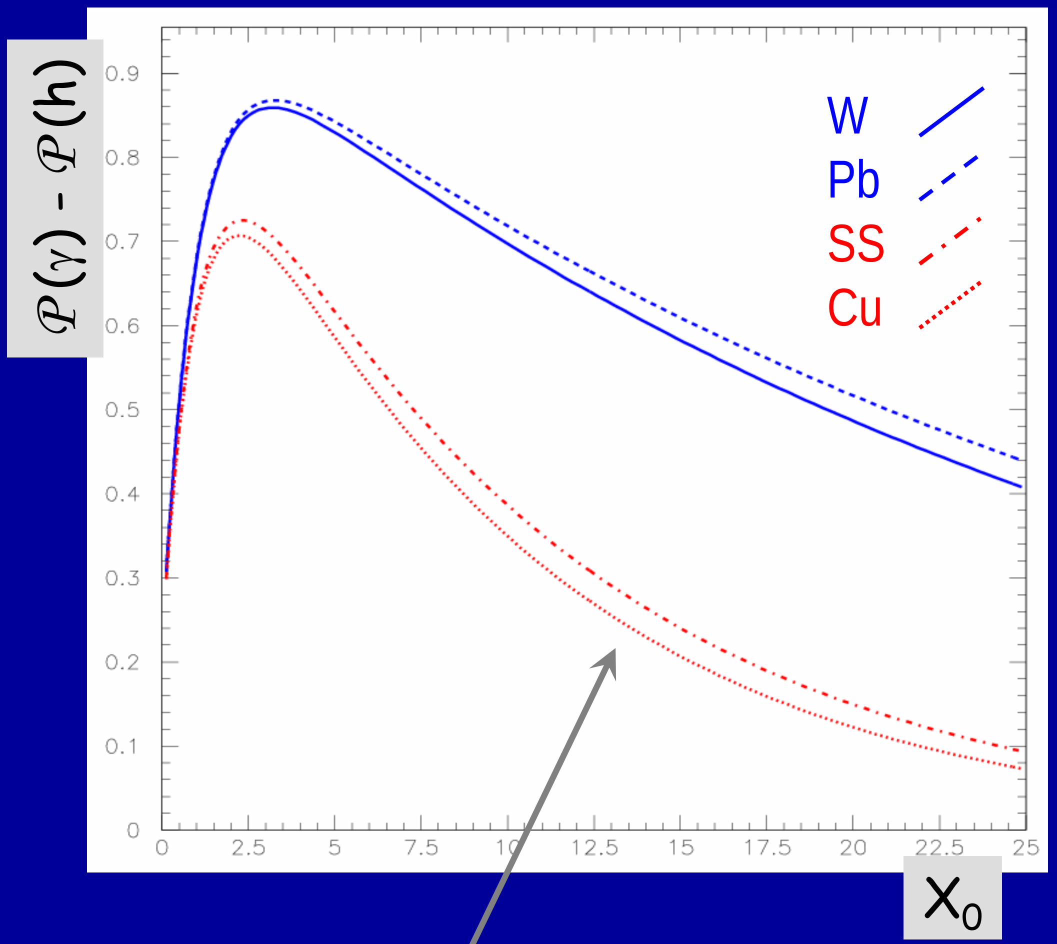
Less Dense, Non-magnetic

Material	λ_I (cm)	X_0 (cm)	λ_I/X_0
Fe (SS)	16.76	1.76	9.52
Cu	15.06	1.43	10.53

* Note ~X2 difference in λ_I for W/Pb – important for HCAL later

Shower Probabilities in ECAL (25 X_0)



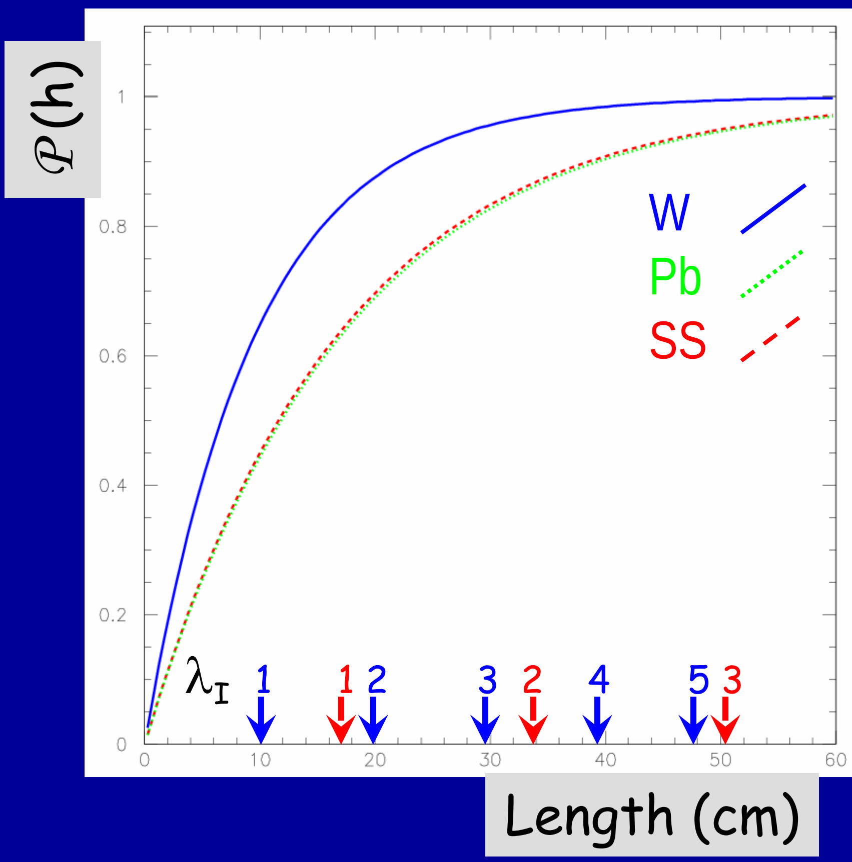


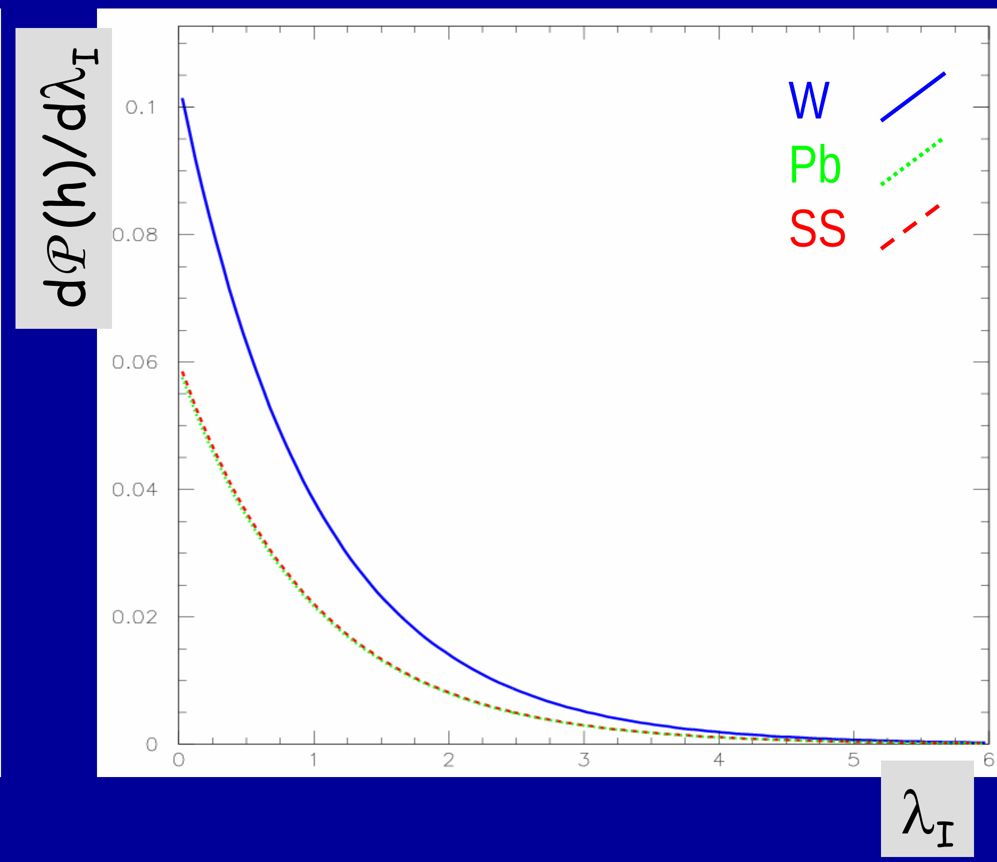
$\mathcal{P}(\gamma)$ reaches ~100% while $\mathcal{P}$(h) still <20%

-> W,Pb probability differences >> SS,Cu

-> better shower separation in dense material

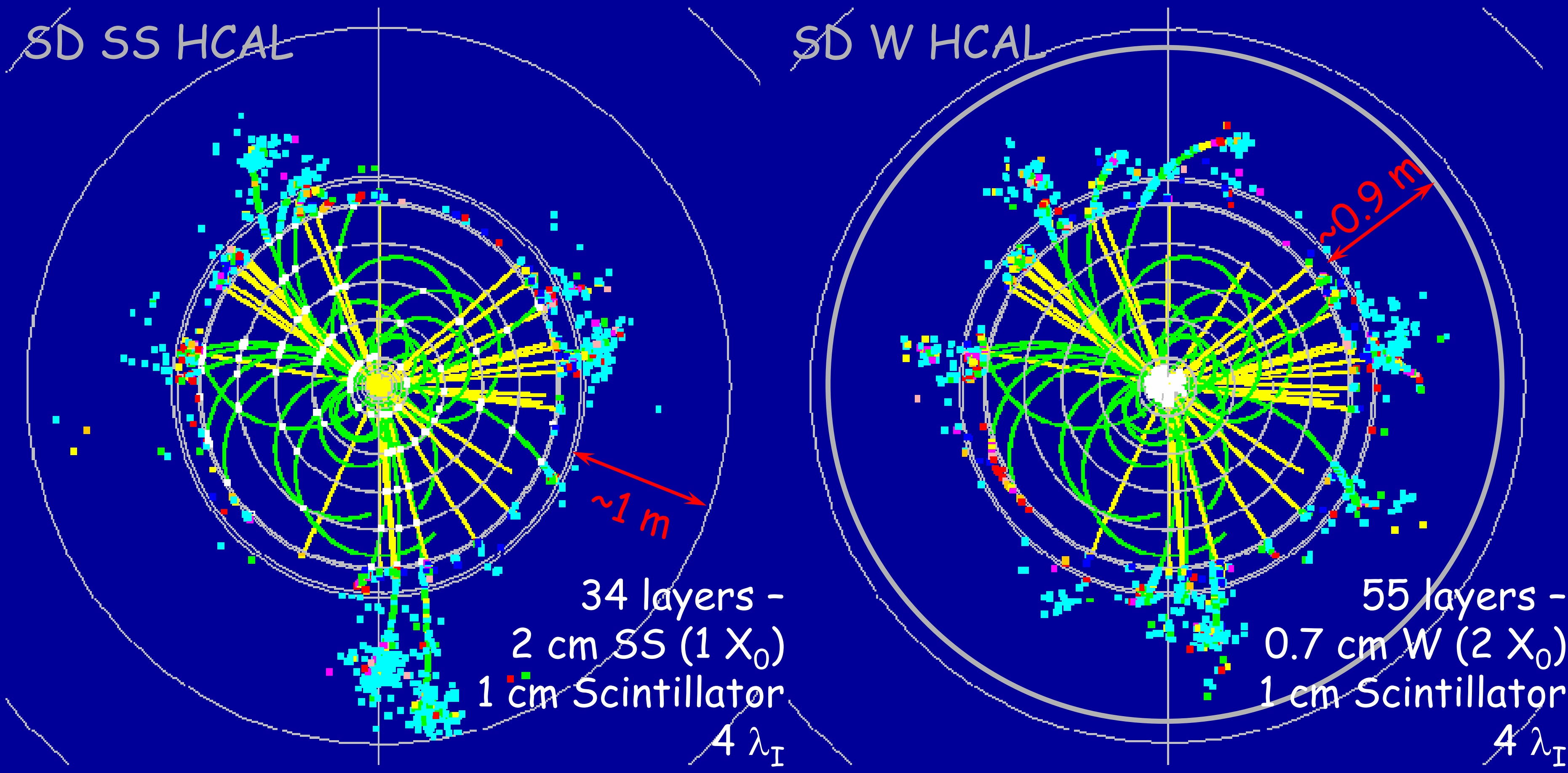
2) Once $\mathcal{P}(e,\gamma)$ -> 1 and γ's are fully contained (end of ECAL), want $\mathcal{P}(h)$ -> 1 as fast as possible . . .





. . . W performs better than SS and Pb for HCAL

Z jets in SS/W HCAL – Absorber Comparison



Same event - different shower shape in W compared to SS?

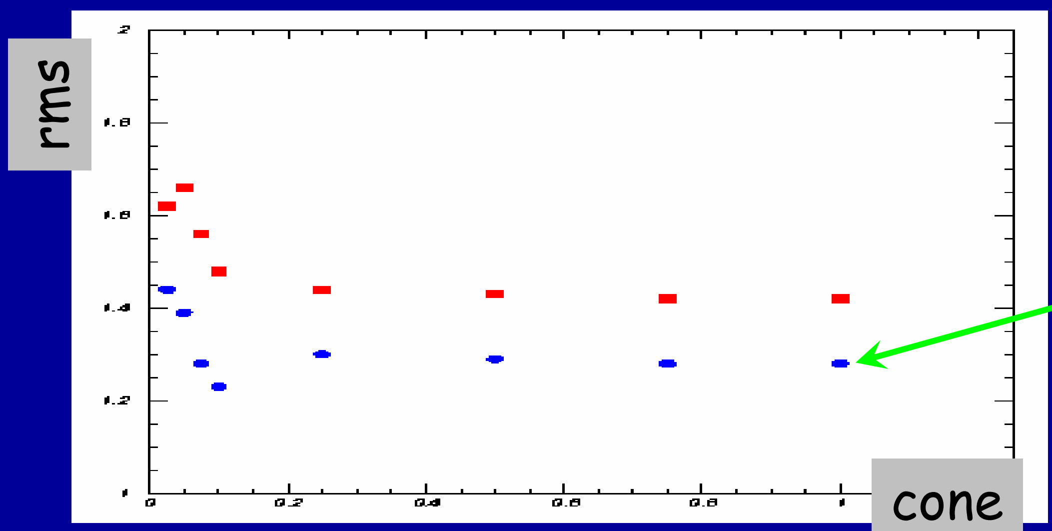
3) And, hadron showers should be as compact as possible . . .

SS — Single 5 GeV π

cone	mean (GeV)	rms	σ/mean	$\chi 2$
.025	2.07	1.62	.79	10.61
.05	2.96	1.66	.51	4.51
.075	3.63	1.56	.38	2.74
.10	4.08	1.48	.31	2.56
.25	4.76	1.44	.25	2.49
.50	4.85	1.43	.25	2.42
.75	4.86	1.42	.25	2.25
1.00	4.87	1.42	.25	2.45

W — Single 5 GeV π

cone	mean (GeV)	rms	σ/mean	$\chi 2$
.025	1.92	1.44	.78	9.36
.05	2.94	1.39	.41	4.29
.075	3.59	1.28	.31	2.42
.10	4.01	1.23	.25	2.35
.25	4.64	1.30	.23	2.70
.50	4.77	1.29	.23	2.50
.75	4.79	1.28	.23	2.41
1.00	4.80	1.28	.23	2.40



Energy in fixed cone size :
- -> means ~same for SS/W
- -> rms ~10% smaller in W

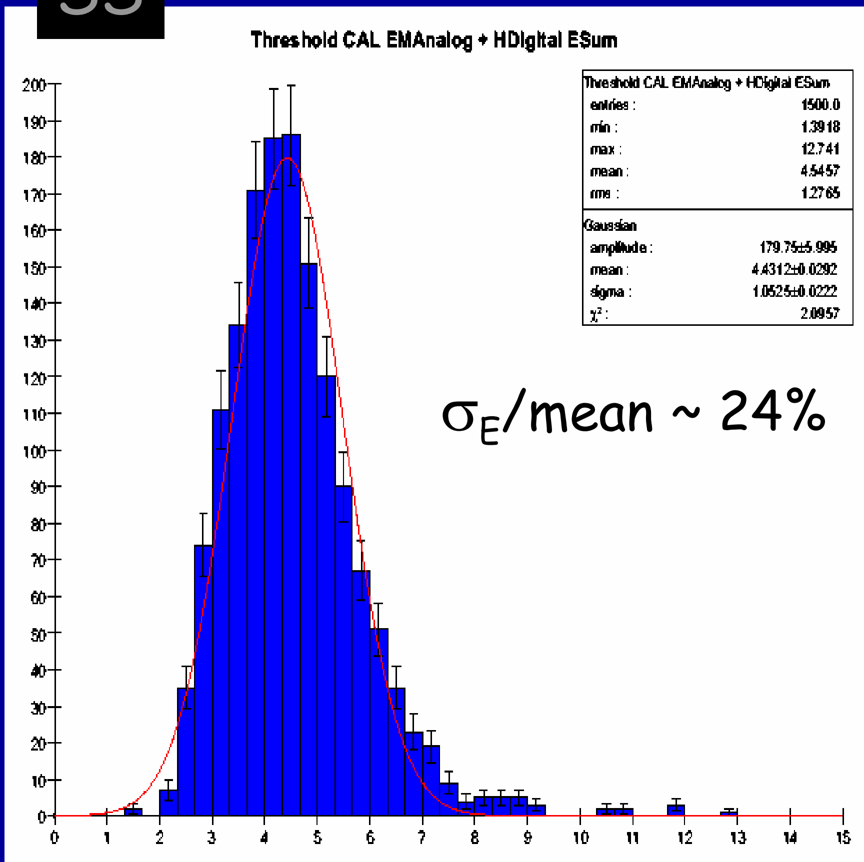
Tighter showers in W

. . . W looks like the best choice for HCAL

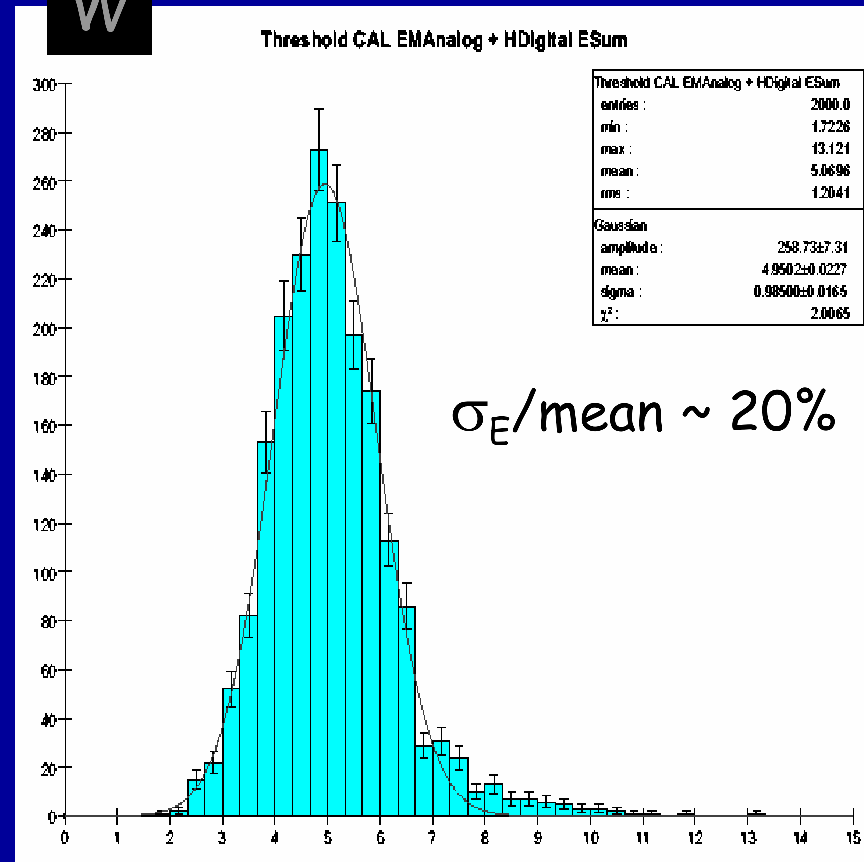
4) Energy resolution comparisons for SS, W . . .

Single 5 GeV Pion

SS



W



Energy measurement in calorimeter – Analog ECAL, Digital HCAL

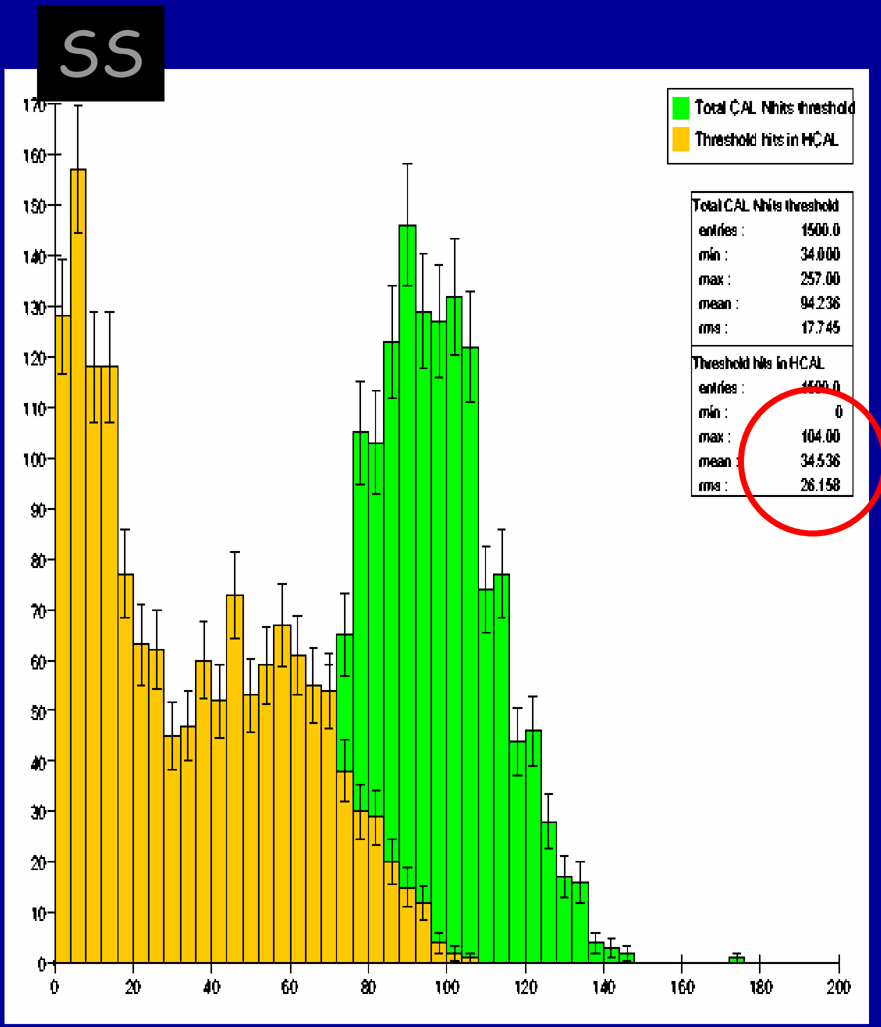
-> σ/mean smaller in W HCAL

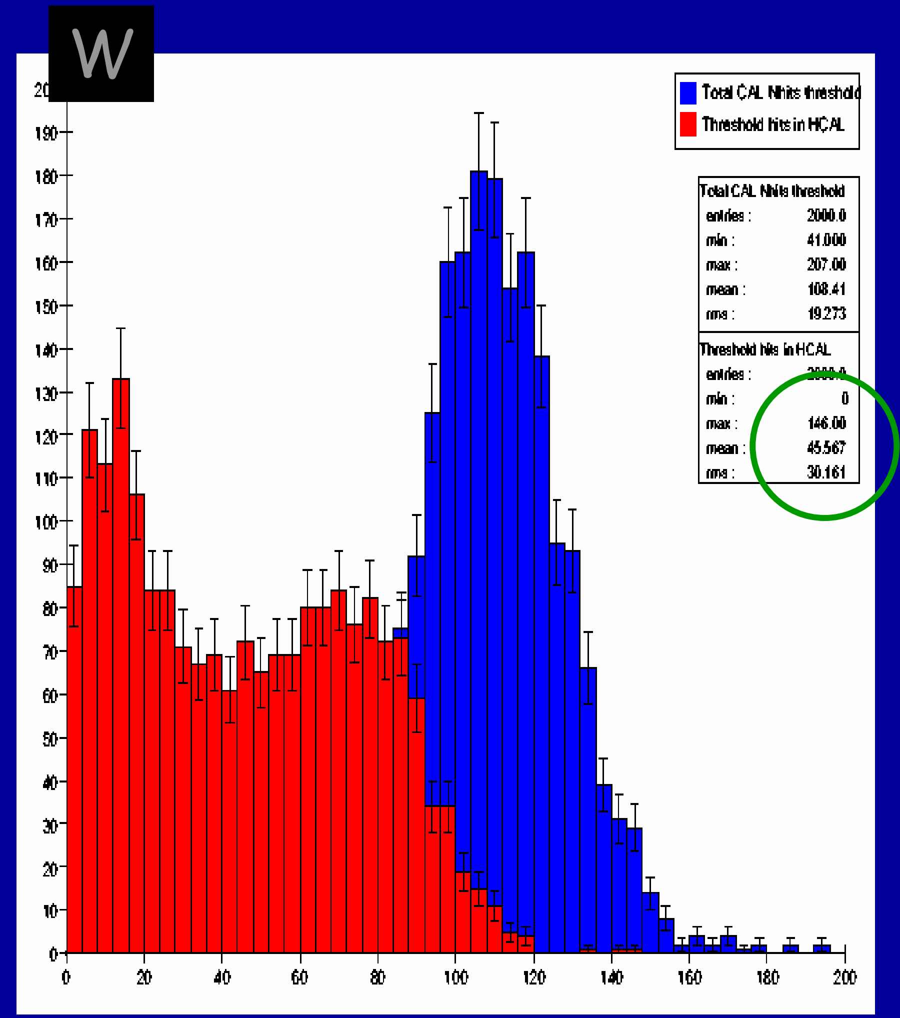
-> same behavior for analog HCAL

W – 2 X_0 sampling

SS – 1 X_0 sampling

Single 5 GeV Pion – Number of hits (1/3 mip thresh)





More hits in W HCAL than in SS

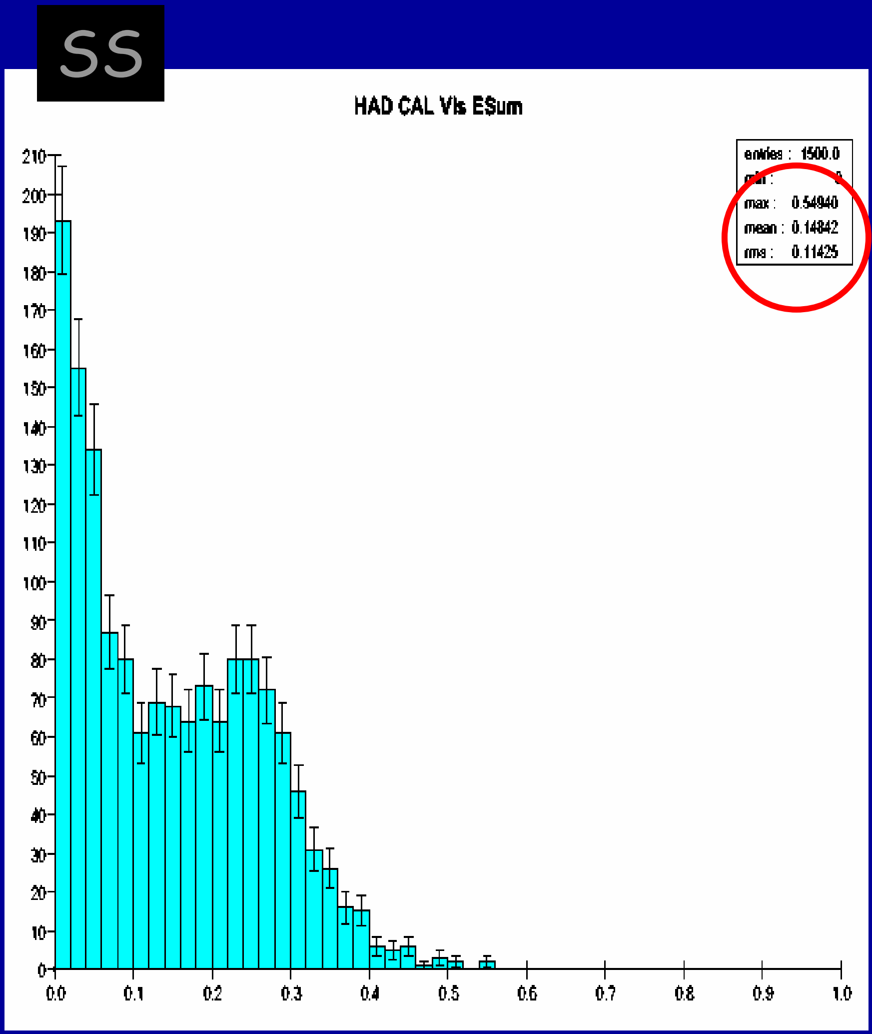
-> 30% more hits in the HCAL for W

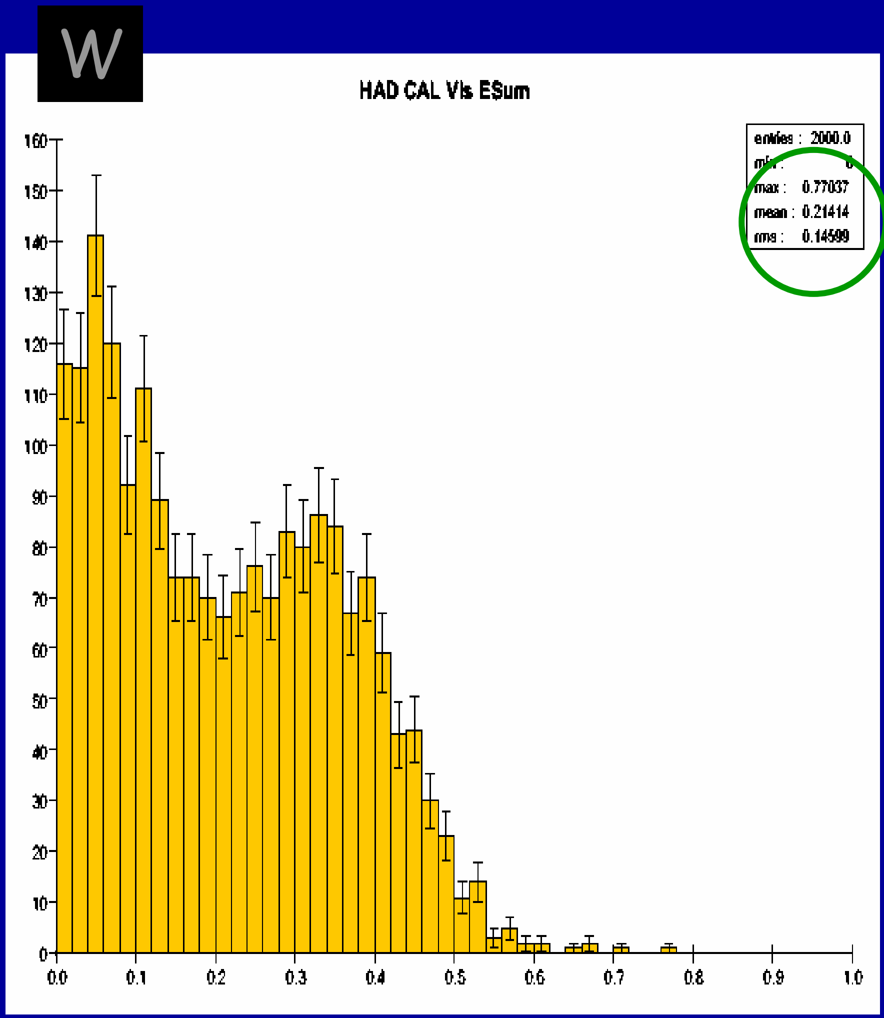
-> <u>better digital resolution for W!</u>

W – 2 X_0 sampling

SS – 1 X_0 sampling

Single 5 GeV Pion – Visible Energy in HCAL





More visible energy in W HCAL

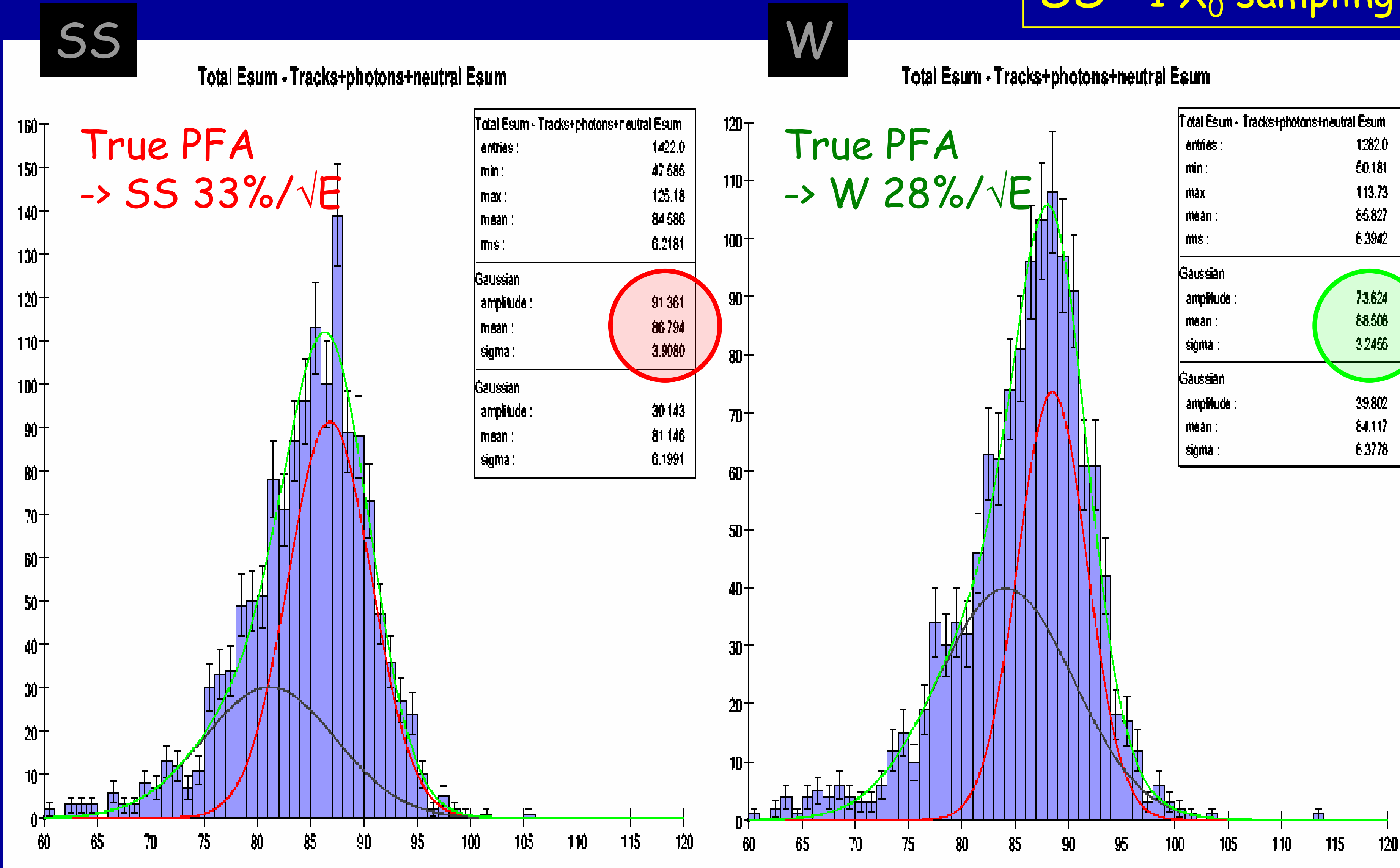
-> <u>better analog resolution in W</u>

W – 2 X_0 sampling

SS – 1 X_0 sampling

e+e- -> Z (jets) – PFA performance Fits

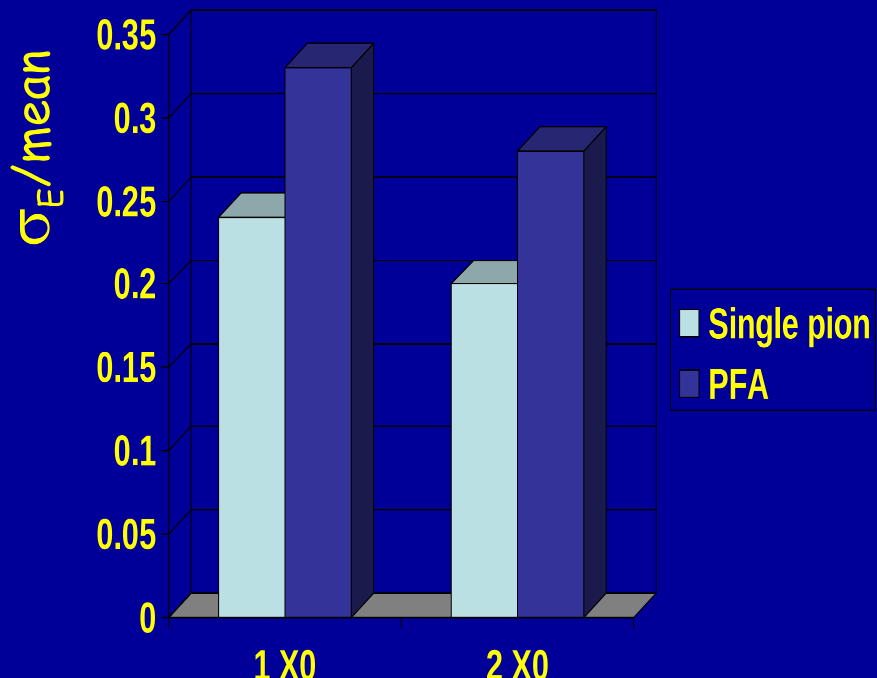
W – 2 X_0 sampling
SS – 1 X_0 sampling



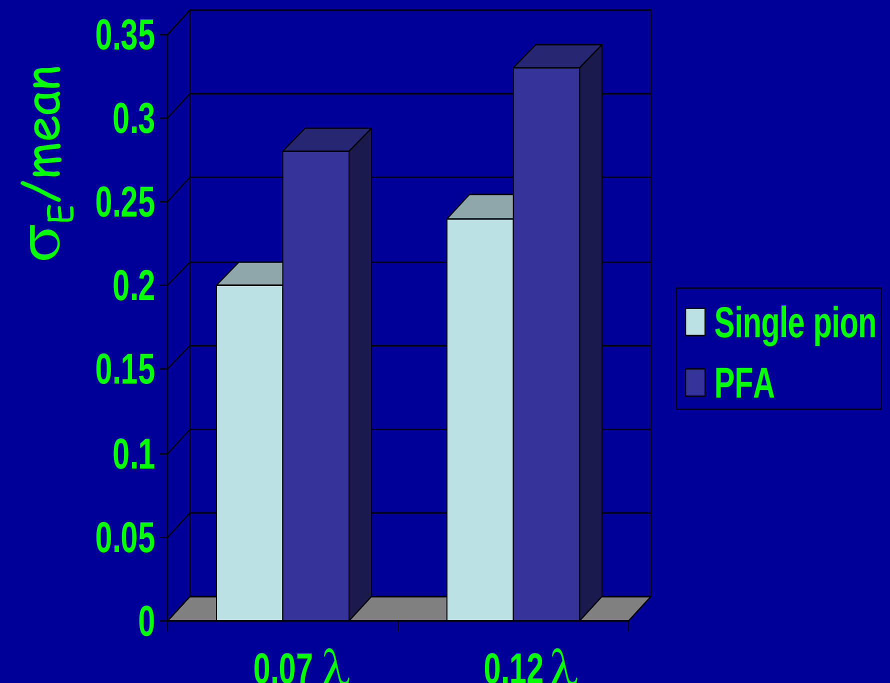
Better PFA performance with the W HCAL for conical showers . . .
however, simple iterative cone reconstructs smaller fraction of events*

W - 2 X_0 sampling
SS - 1 X_0 sampling

Single particle, PFA resolution comparison results . . .



SS W



W SS

σ_E/mean ↓, X_0 ↑ ! Coarser X_0 sampling gives better σ_E!?

σ_E/mean ↓, λ_I ↓ Finer λ_I sampling gives better σ_E

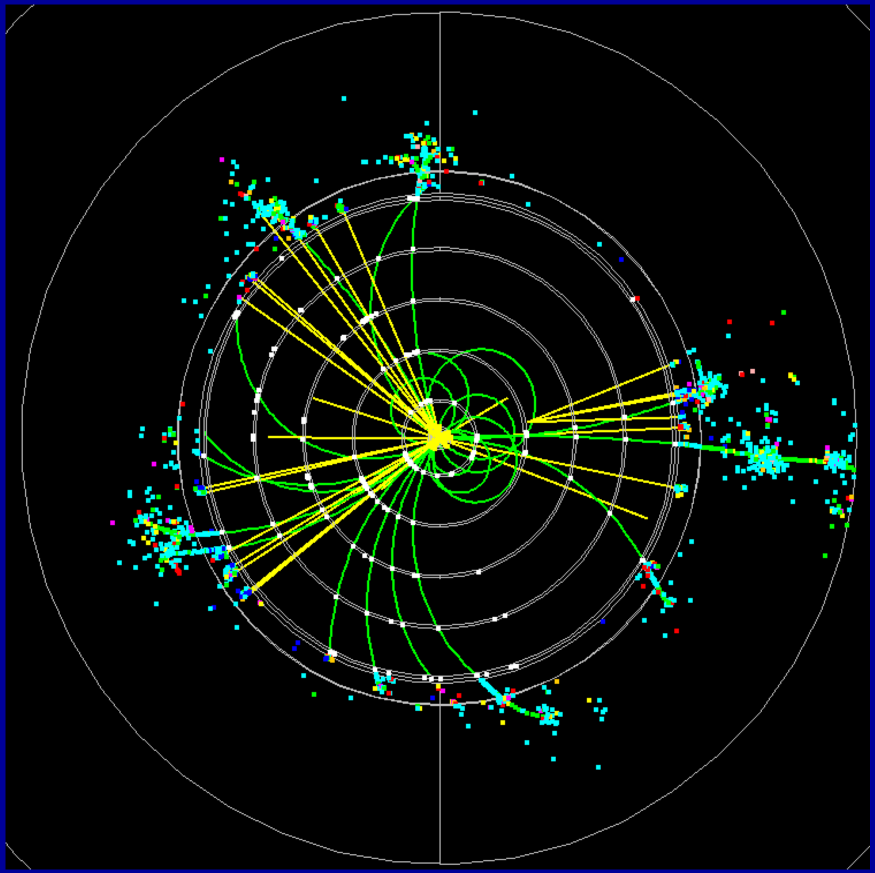
. . . W looks like the best choice for HCAL

-> hadron E resolution depends on λ_I, not X_0

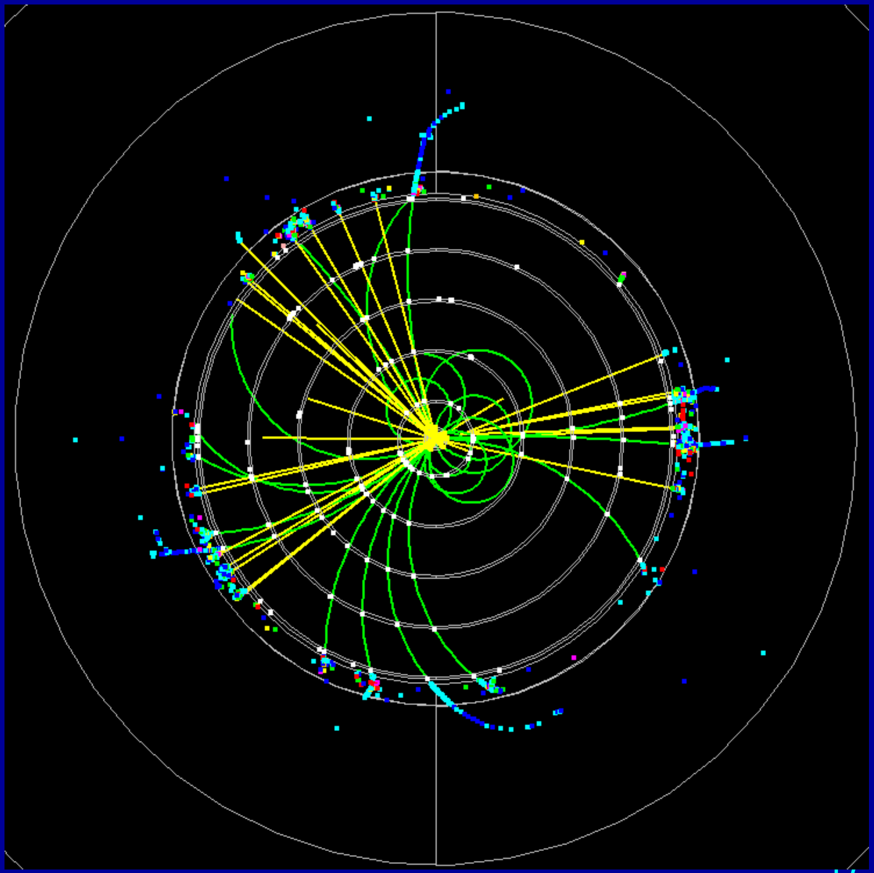
HCAL Readout Optimization – PFA Application

Dense HCALs (W absorber) - 4 λ_I in ~82.5 cm IR -> OR

SDFeb05 SCI HCAL
55 layers of 0.7 cm W/0.8 cm Scin.
Sampling fraction ~6%

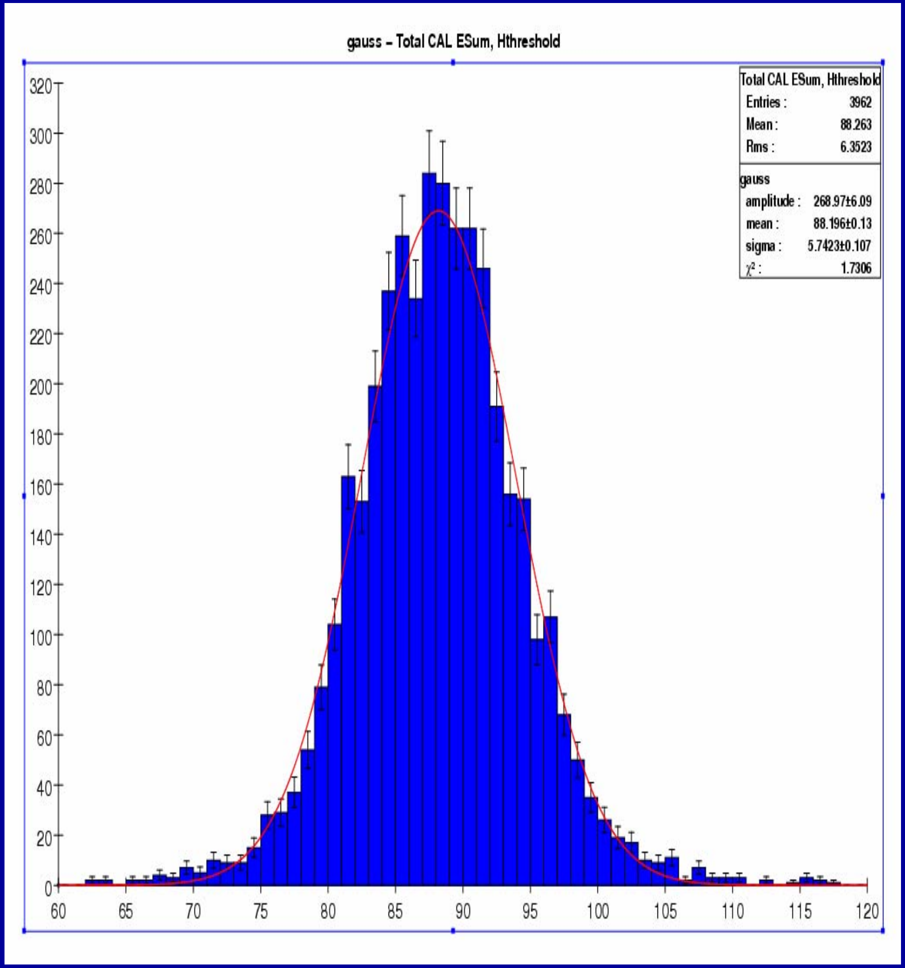


SDFeb05 RPC HCAL
55 layers of 0.7 cm W/0.8 cm RPC
1.2 mm gas gap
Sampling Fraction ~0.0025%!!!

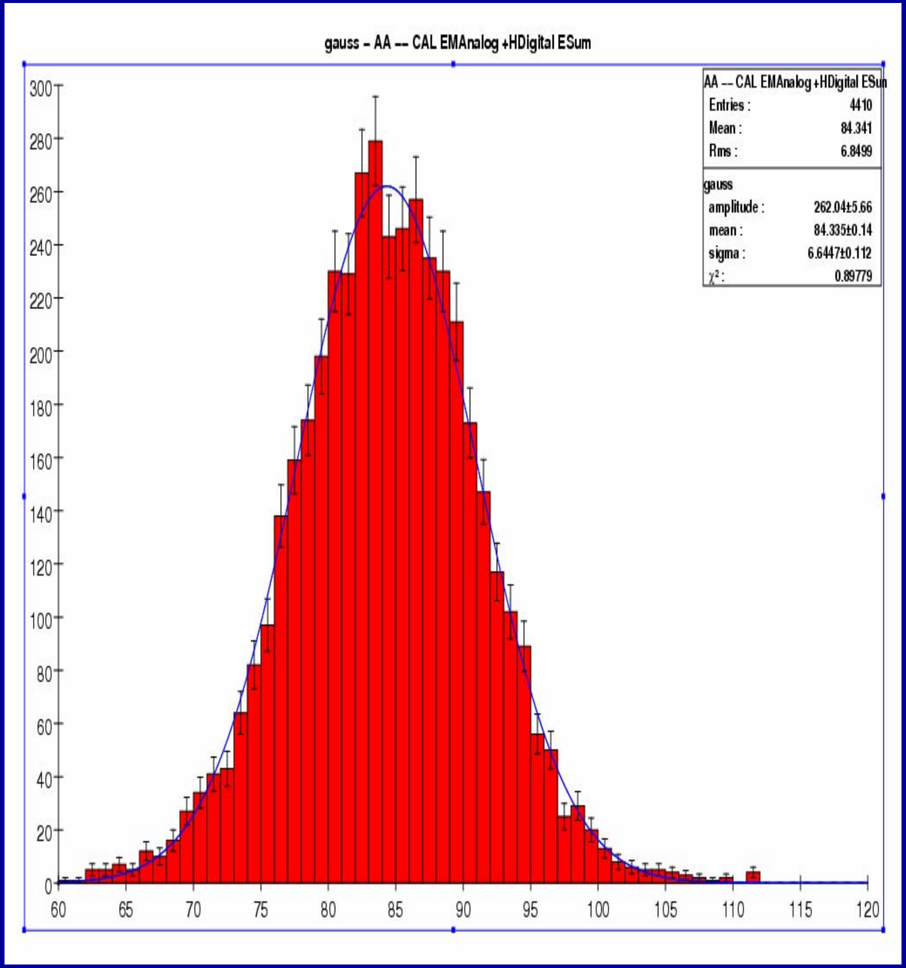


First – Calorimeter Performances

Scin. – Analog Readout



RPC – Digital Readout

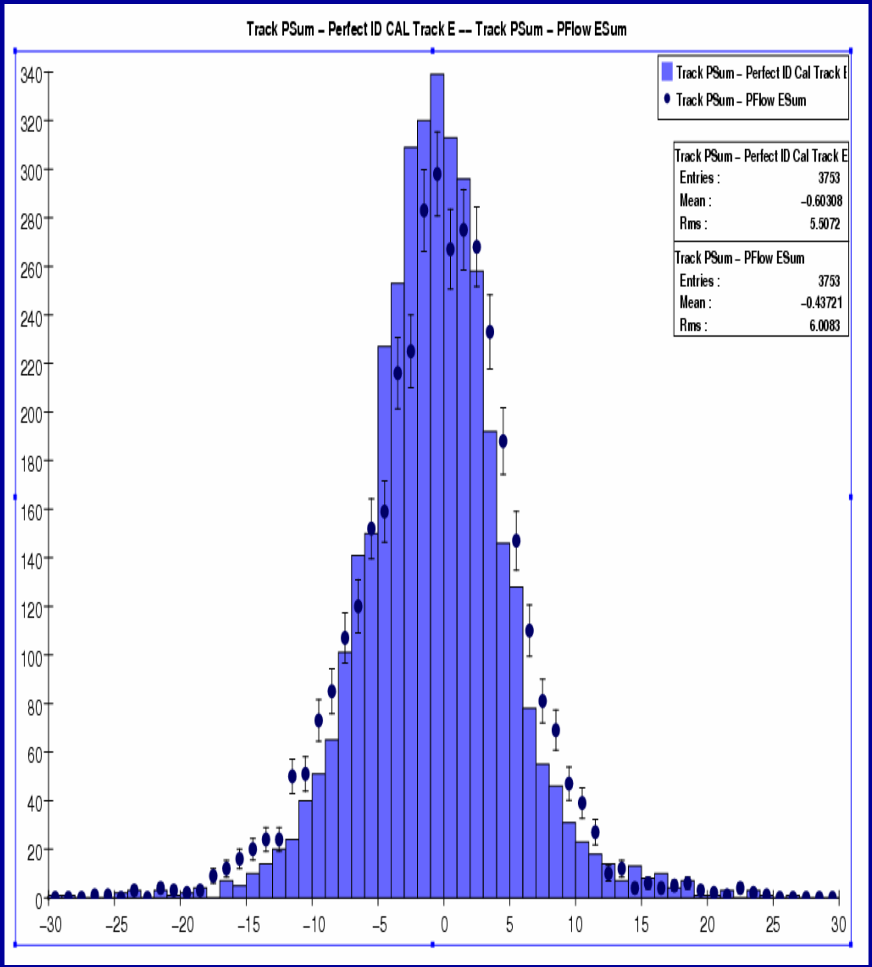


Hard to compete with no visible energy?

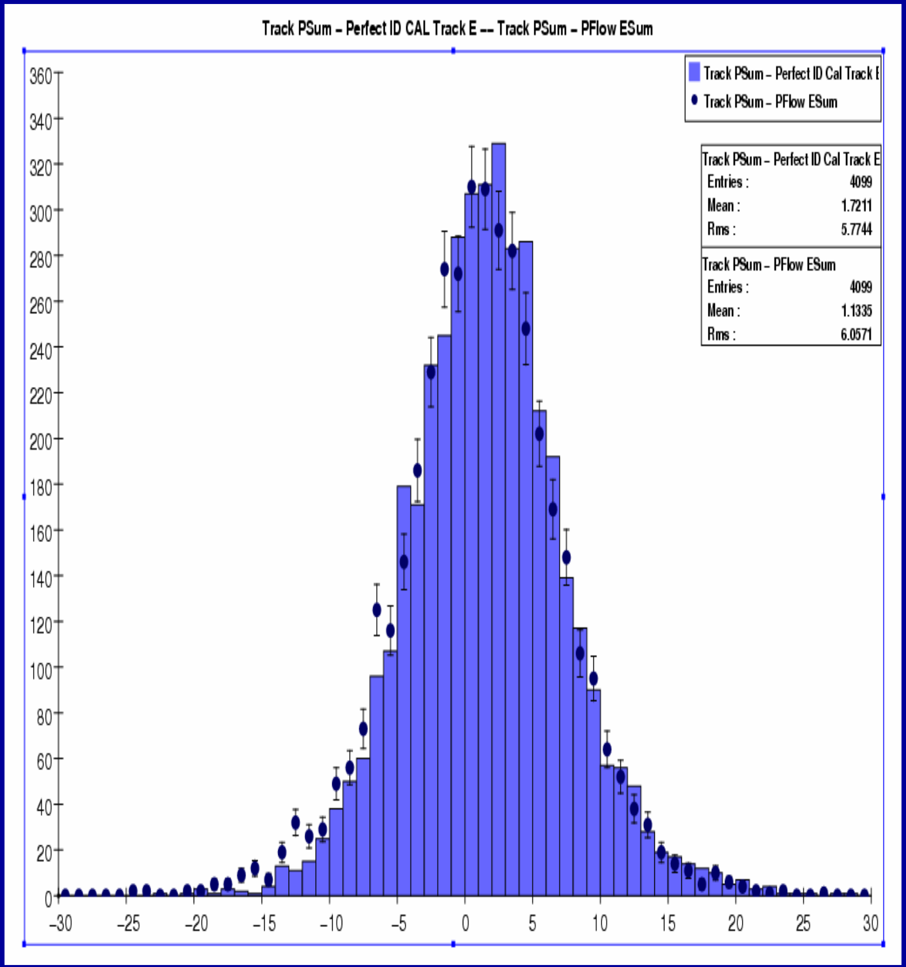
Not a great start, but lets continue anyway →

Track/CAL Cell Association Algorithm

Scin. – Analog Readout



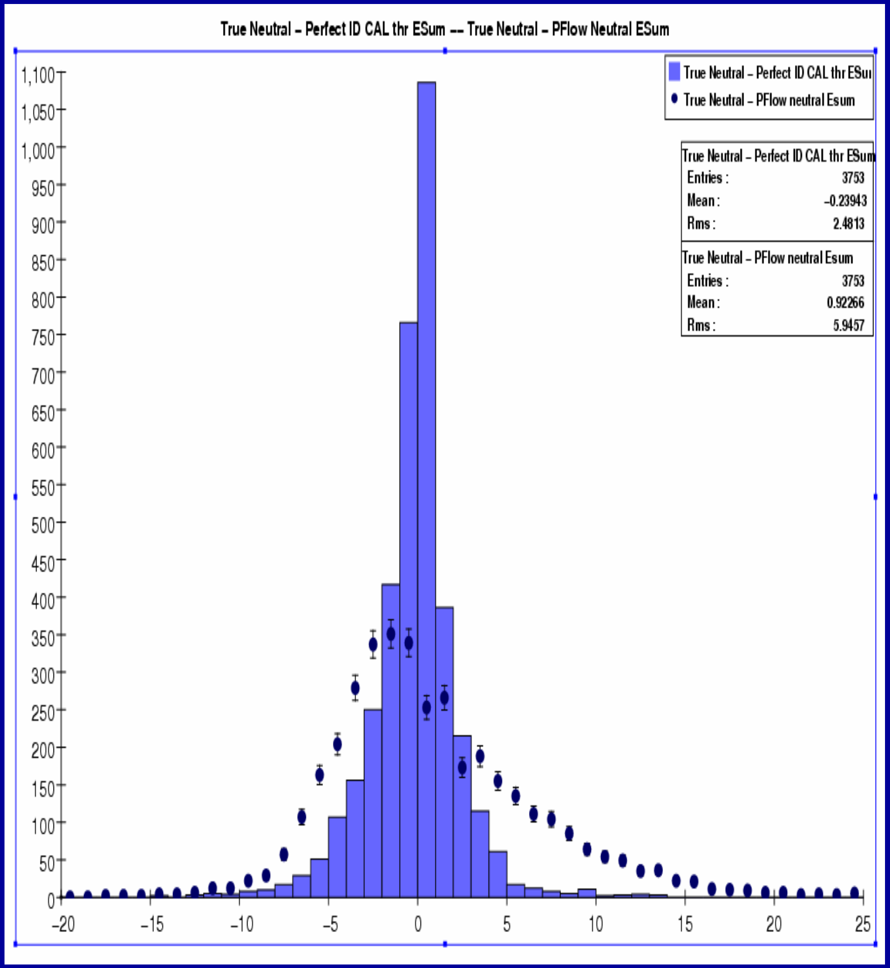
RPC – Digital Readout



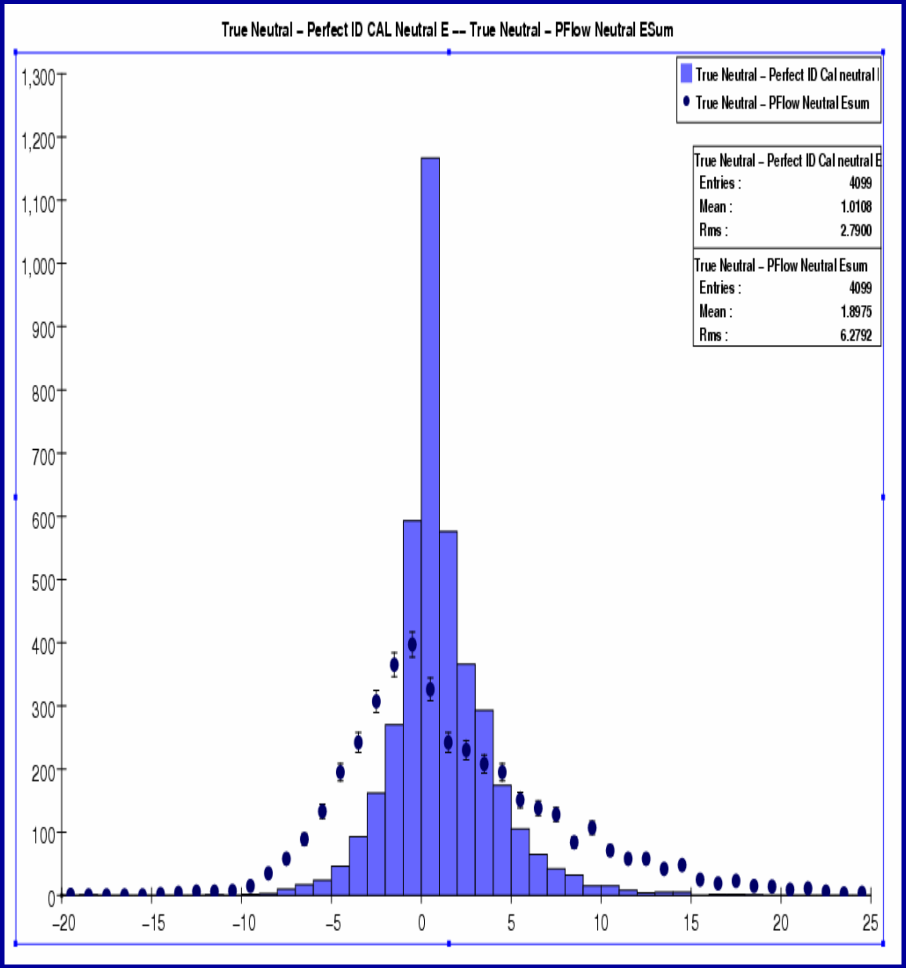
Resolution still better in scintillator, but algorithm reproduces perfect ID in both cases

Neutral Finding Algorithm

Scin. – Analog Readout



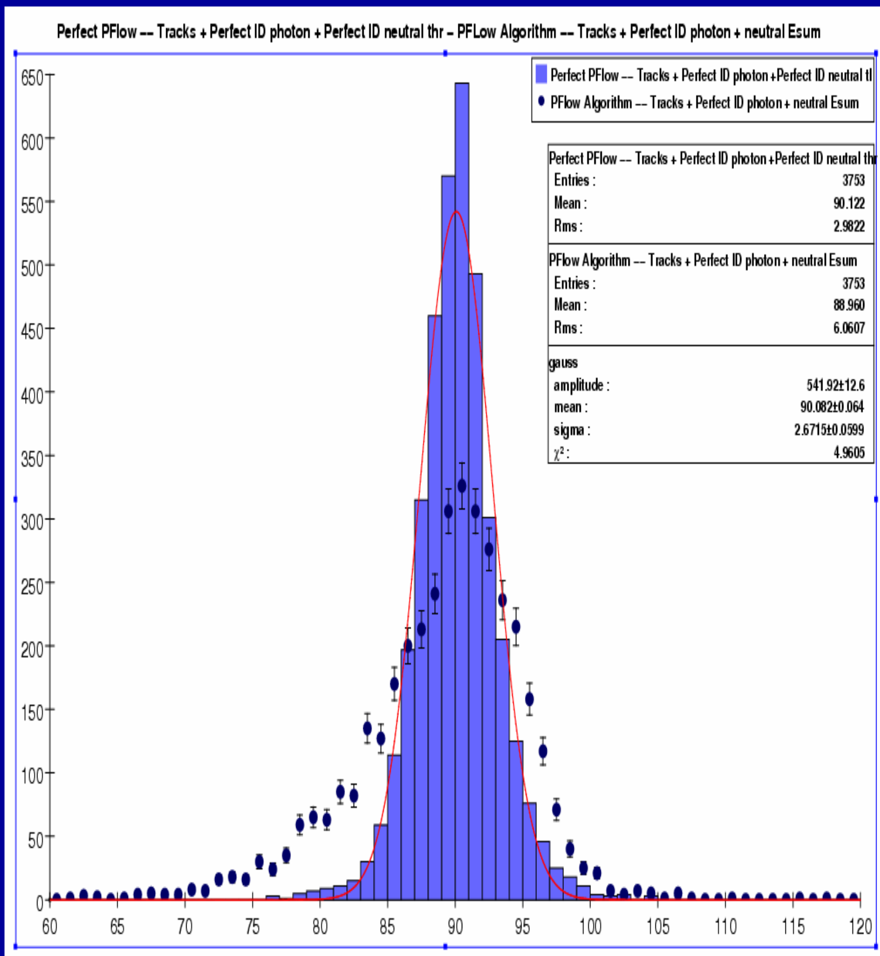
RPC – Digital Readout



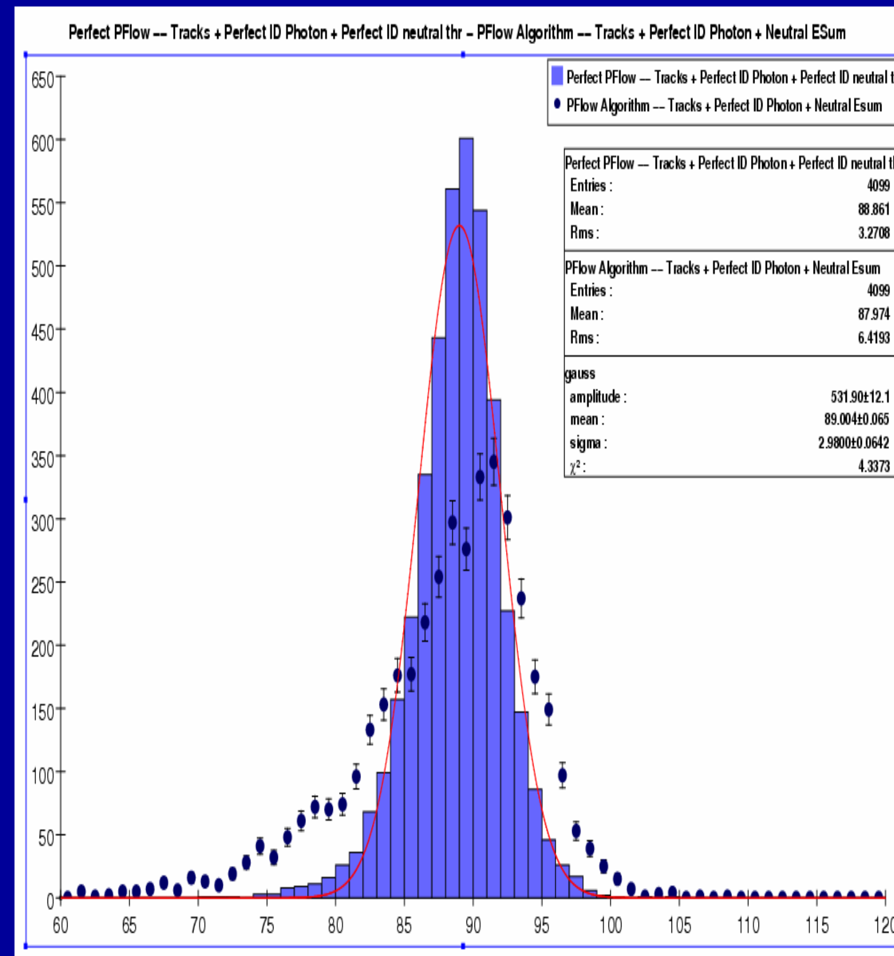
Once again, very similar performance

PFA Results

Scin. - Analog Readout



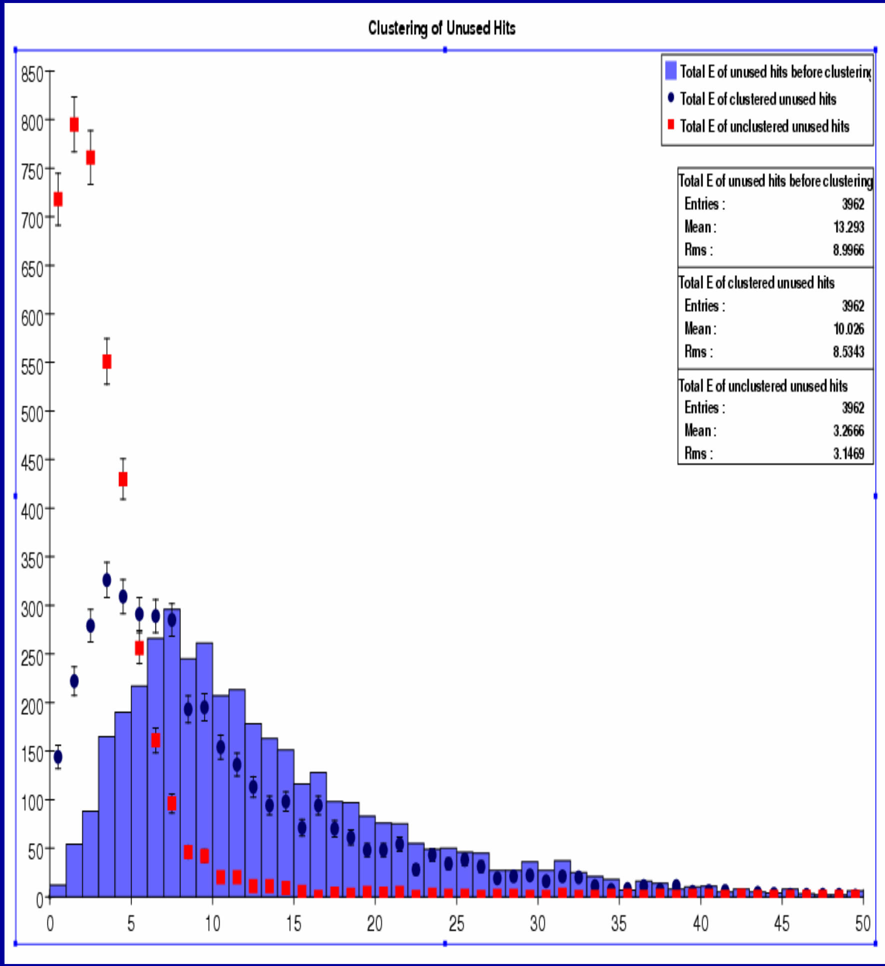
RPC - Digital Readout



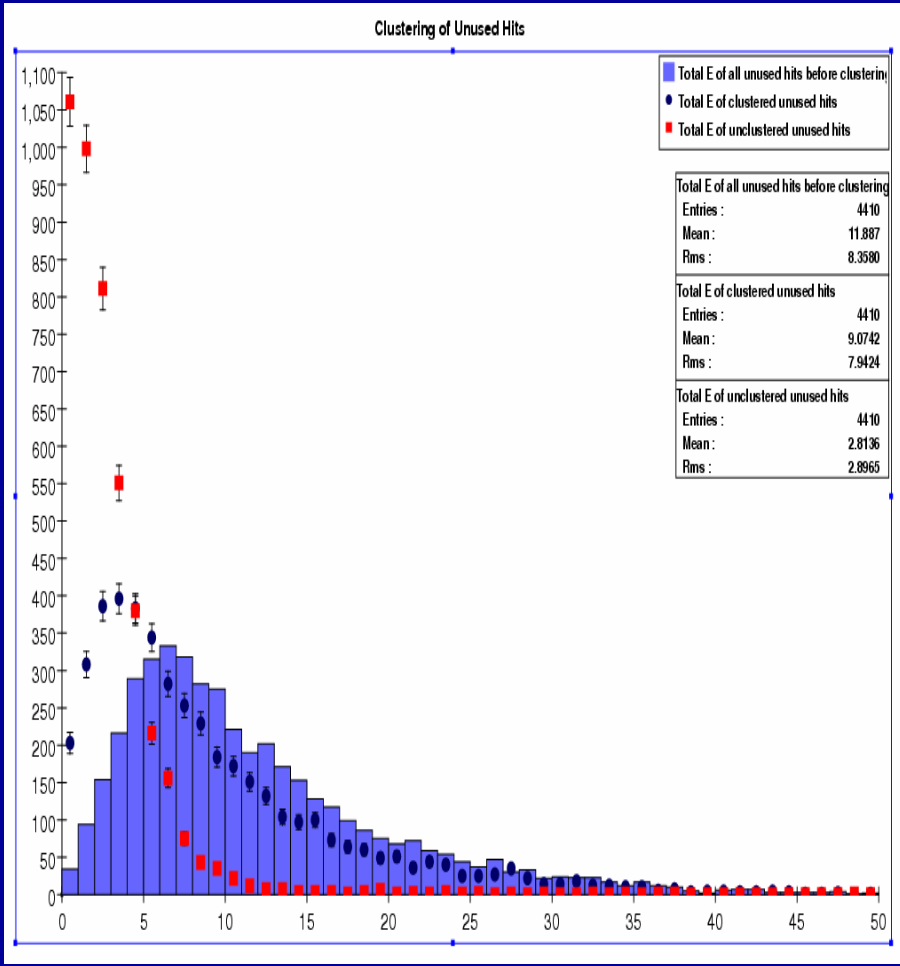
PFA performance is very similar (with same cuts) but reflects underlying CAL resolution

Confusion – Leftover Hits!

Scin. – Analog Readout



RPC – Digital Readout



Better use of hits in RPC? – good since aren't that many

Summary

For LC Detector, HCAL should be as dense as possible

-> hadron showers more compact in W – smaller HCAL volume

-> more λ_I per cm – smaller Solenoid B-field volume

-> more layers for fixed total λ_I HCAL – better resolution since more sampling

-> more hits - better digital resolution

-> more visible E – better analog resolution

PFA (incomplete) used to optimize HCAL absorber

First look at comparison of analog (scintillator) and digital (RPC) readout modes for HCAL

-> very little visible E, number of hits in W/RPC showers – try finer λ_I sampling?

-> compared analog and digital modes with same analysis program

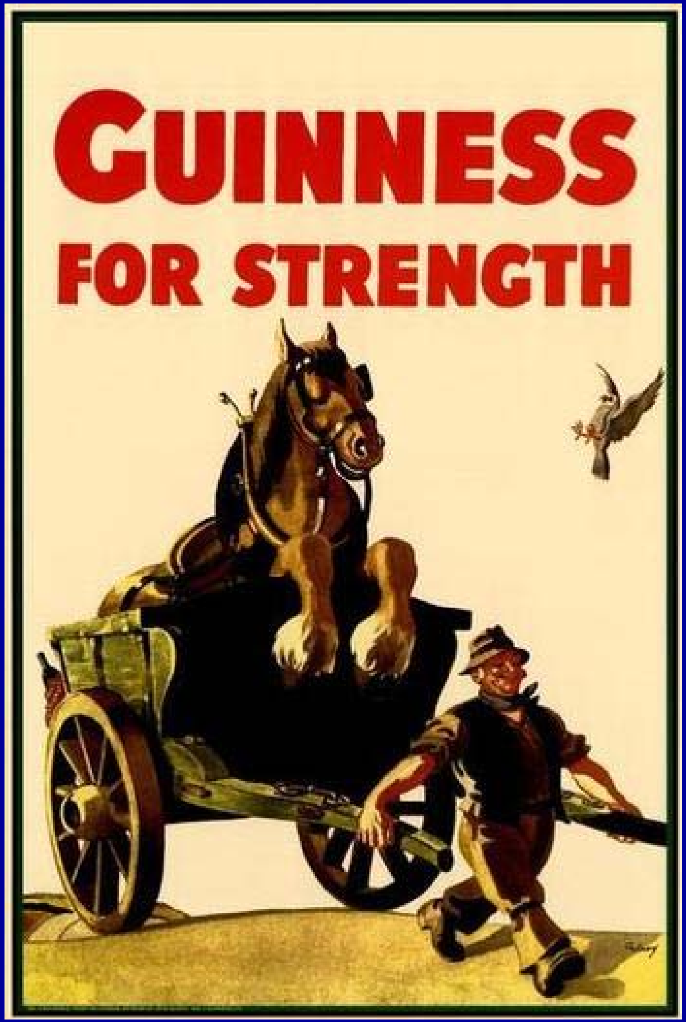
Once again, PFA used to evaluate detector performance

Particle Flow Algorithm – Horse or Cart?

PFA used for :

1) Detector Optimization – absorber type/thickness, longitudinal segmentation and transverse granularity, B-field, tracking volume (radius), etc. -> Detector Model(s)
2) Detector Model evaluation – comparisons, tradeoff evaluations, etc.

-> PFA is the Horse!



Physicists still have to do work!