LC HCAL Absorber (SS vs W) and P-Flow Performance (Scintillator vs RPC) Comparisons

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- *Motivation*
- *SS/W Absorbers : Single Pion Results*
- *Analog (Scintillator) vs Digital (RPC) Detector Comparisons*
- *P-Flow Analyses : e+e- -> Z (jets)*
- *Summary*

Motivation for Study

Can the outer radius of the HCAL be reduced?

-> make B-field volume smaller

-> saves cost of magnet coil $\propto BR^2$

Keep 4 λ_I thickness of HCAL

-> use a denser absorber than SS, i.e., W

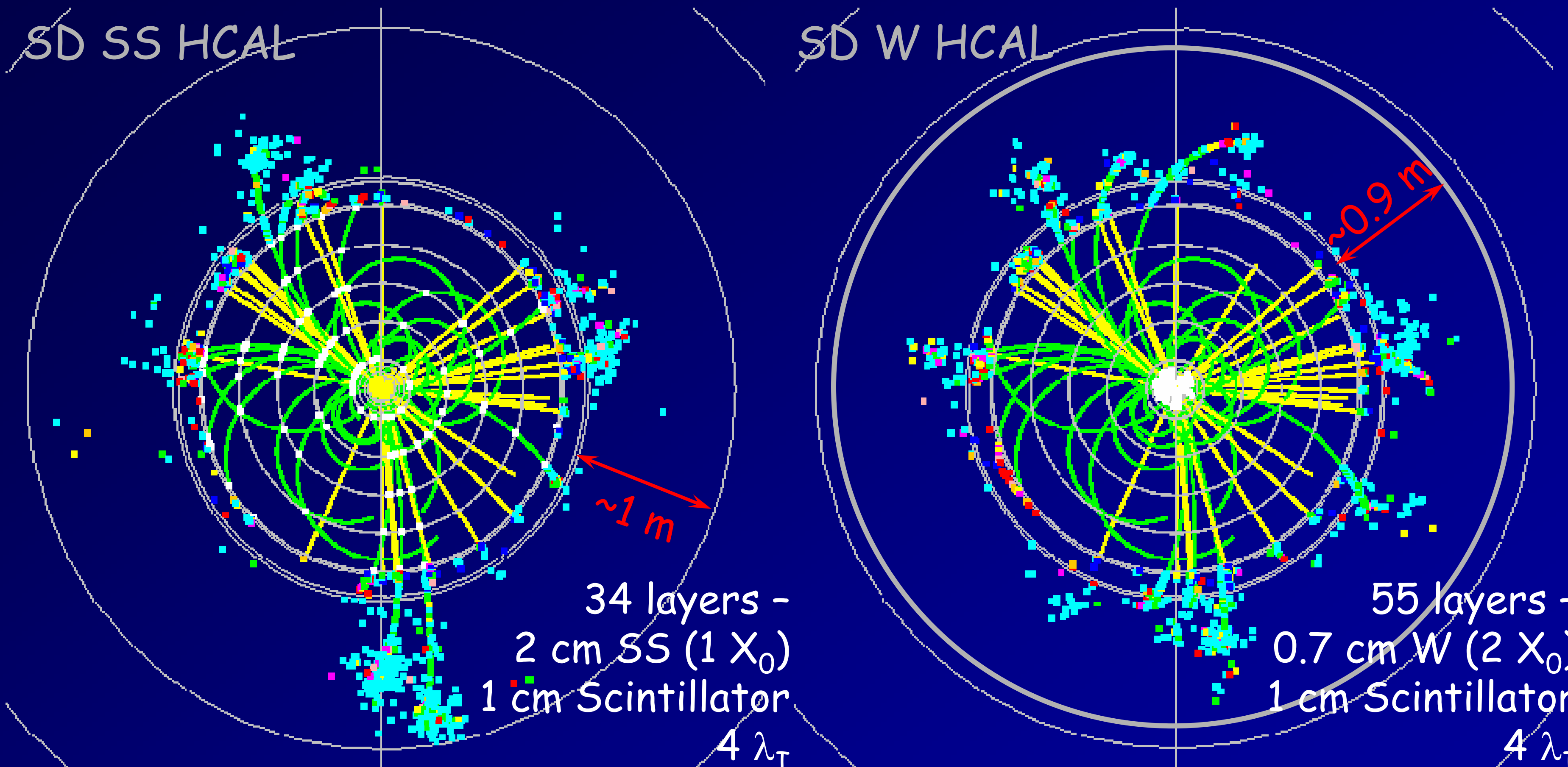
-> why does SD HCAL have 1 X_0 sampling?

-> change to 0.07 λ_I (2 X_0) sampling in HCAL (already proposal to double the sampling in the last 10 ECAL layers to 1.4 X_0)

Effects on PFAs, Calorimeter performance?

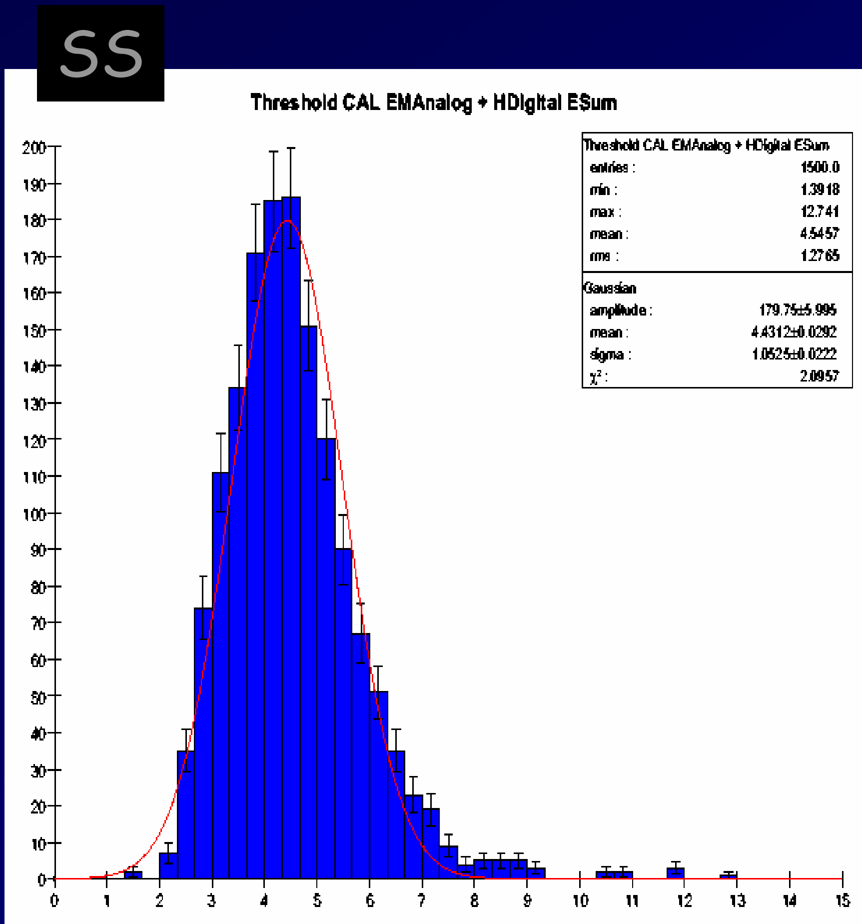
	Present SD (SS/Scin)
0.07 λ_I W -> 0.7 cm/layer	1 X_0 SS -> 2.0 cm/layer
1 cm Scintillator	1 cm Scintillator
4 λ_I requires 55 layers	4 λ_I requires 34 layers
-> 93.5 cm from HCAL IR to OR	-> 102 cm from HCAL IR to OR
.5 cm scintillator	*.5 cm scintillator*
-> 66 cm from HCAL IR to OR	*-> 85 cm from HCAL IR to OR*

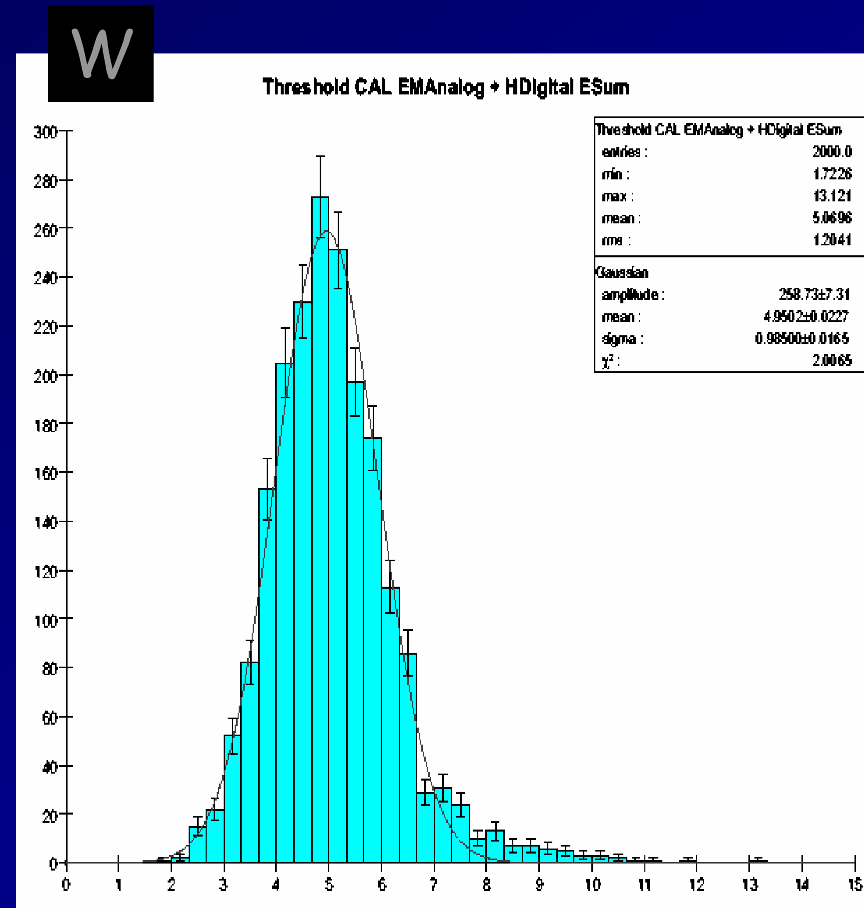
Z jets in SS/W HCAL



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

Single 5 GeV Pion – E measurement with DHCAL



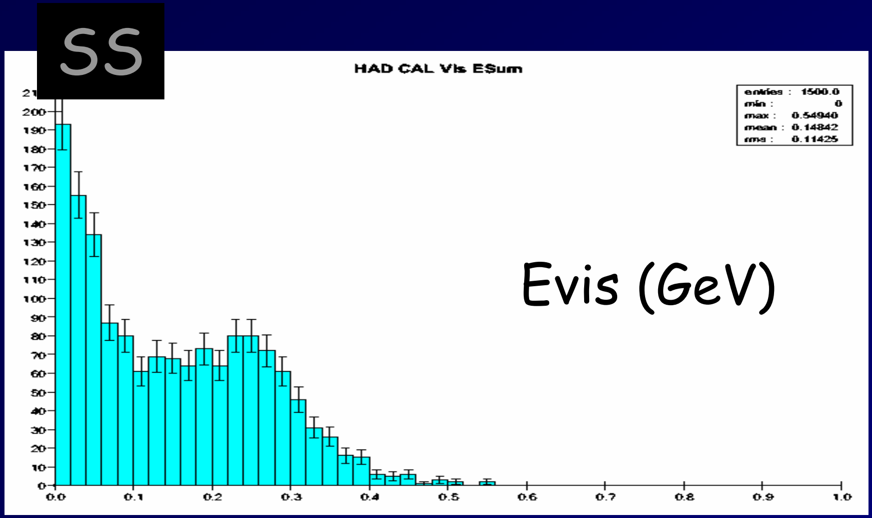


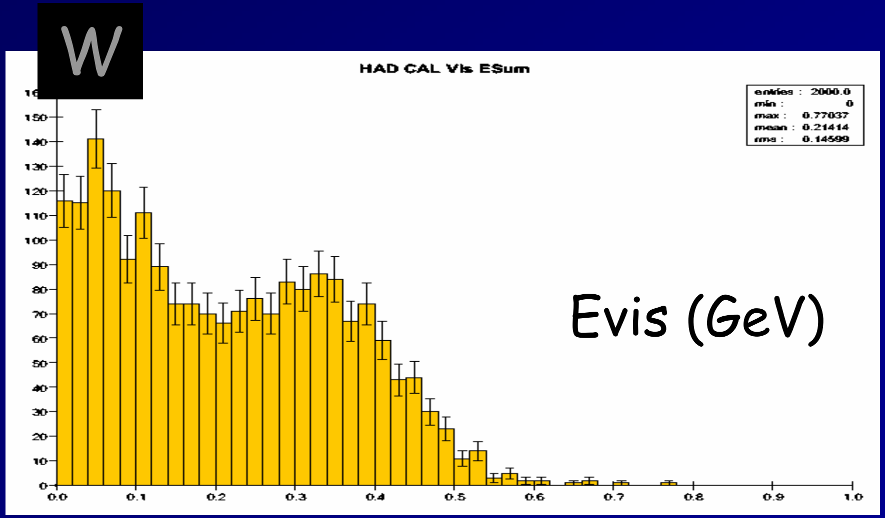
Energy measurement in calorimeter – Analog ECAL, Digital HCAL

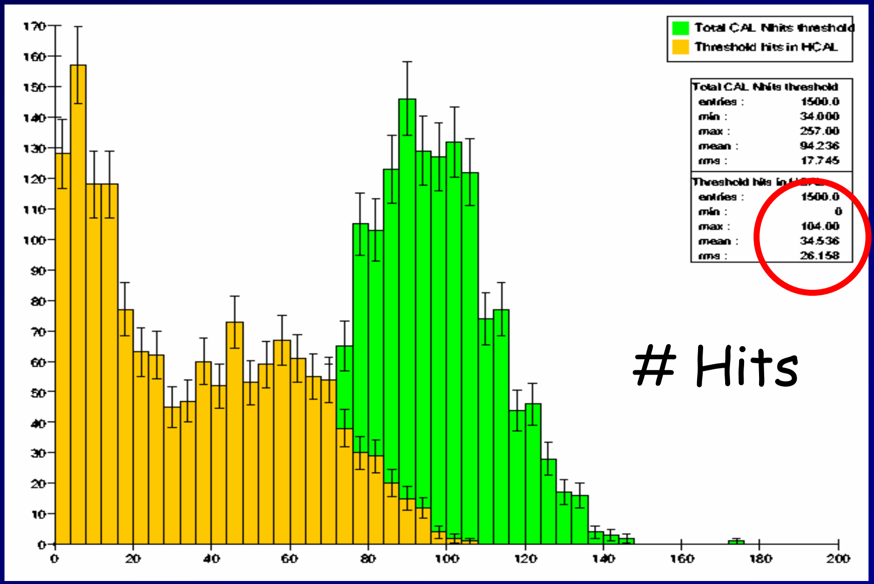
-> σ/mean smaller in W HCAL

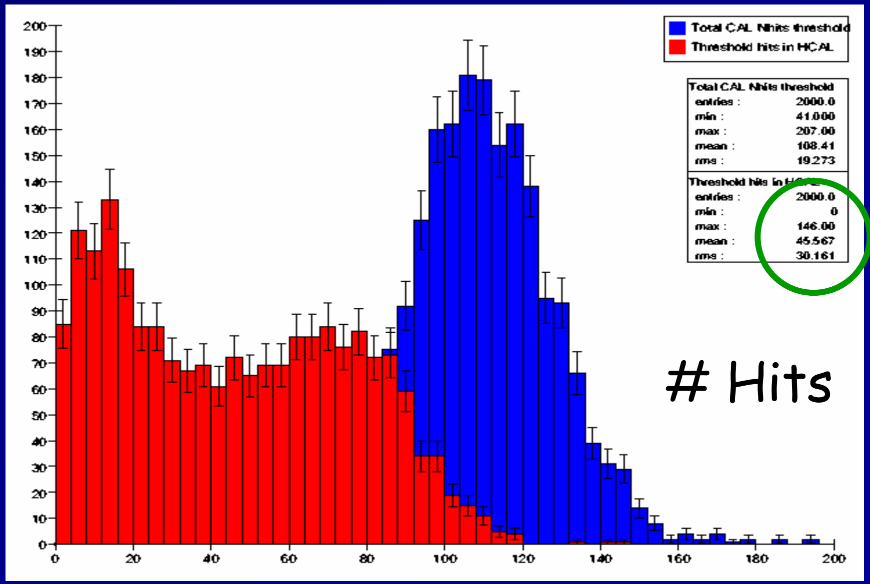
-> same behavior for analog HCAL, but smaller effect . . . Why?

Single 5 GeV Pion – E_{vis} and # hits (1/3 mip thresh)









More Evis, # hits in this W HCAL than in SS

-> ~45% more visible energy

-> ~31% more hits

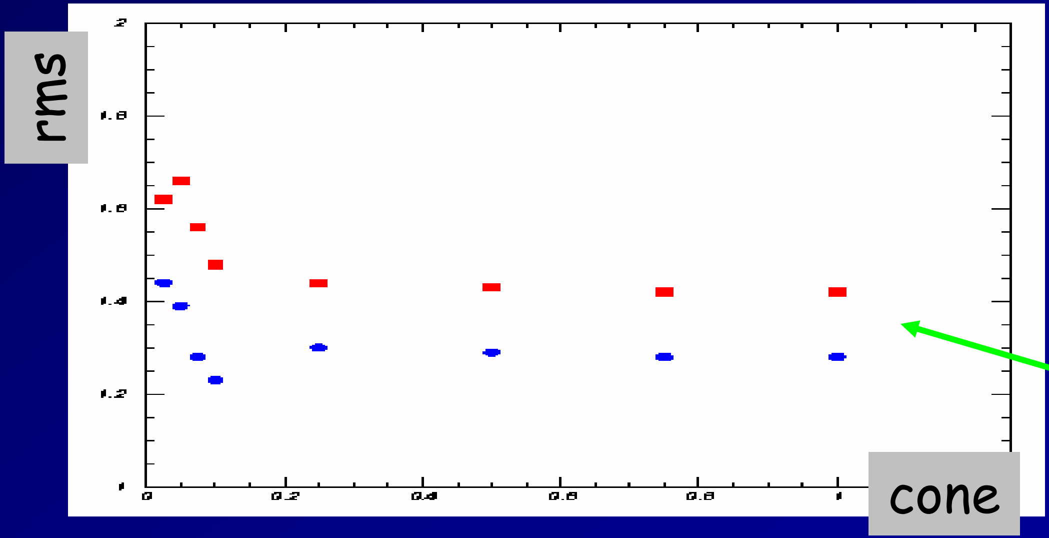
Single 5 GeV Pion – Shower Shape Analysis

SS

cone	mean (GeV)	rms	σ/mean	χ2
.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

cone	mean (GeV)	rms	σ/mean	χ2
.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

Summary of Single Pion Results

Energy versus fixed cone size

-> means very similar for SS/W . . . however, the rms in the W HCAL was ~10% smaller than the SS

CAL Energy Sums

-> for analog energy sum with 1/3 mip threshold in the HCAL, sigma/mean is ~14% smaller in the W HCAL

-> for ECAL analog and HCAL digital - again, the sigma/mean was smaller in the W HCAL

-> for HCAL only when the pions deposited only mips in the ECAL, sigma/mean ~10% smaller in the W HCAL

CAL Number of Hits

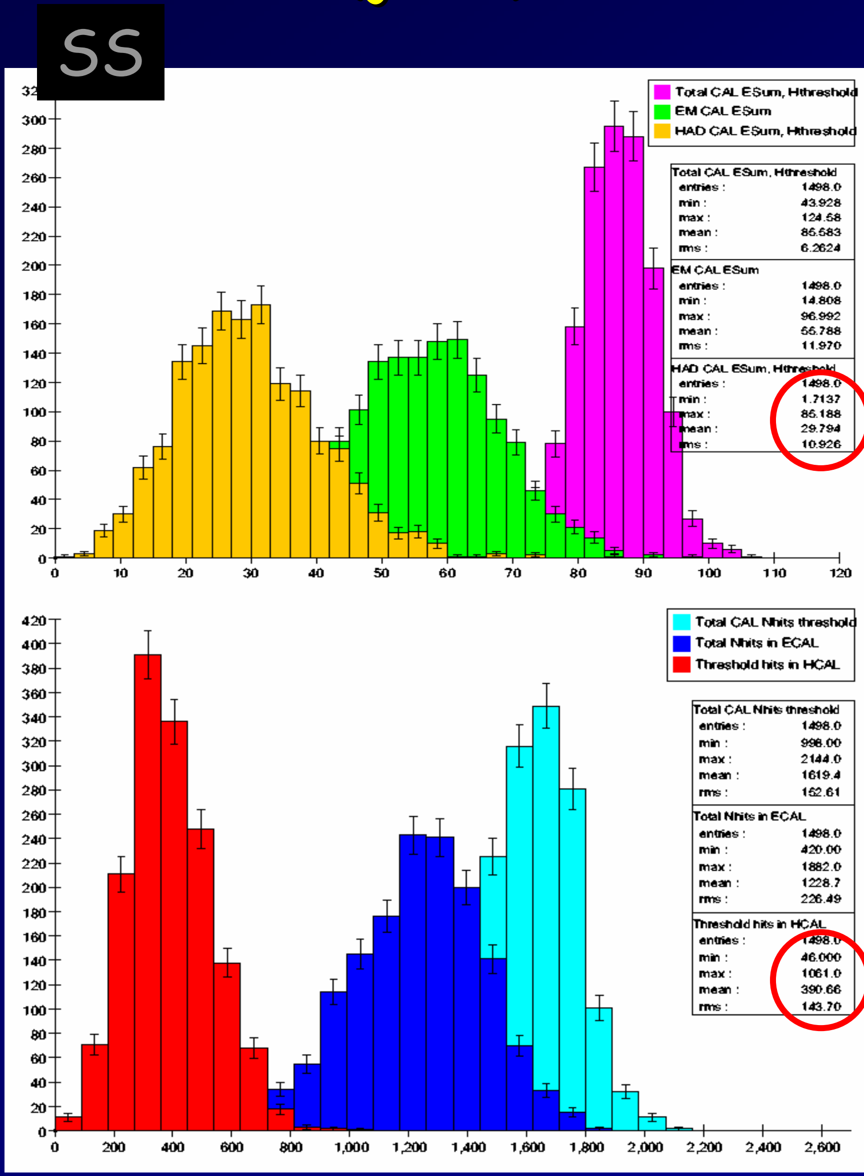
-> total number of hits in the CAL, counting hits in ECAL and HCAL with a 1/3 mip threshold in the HCAL was 108 in W, 94 in SS

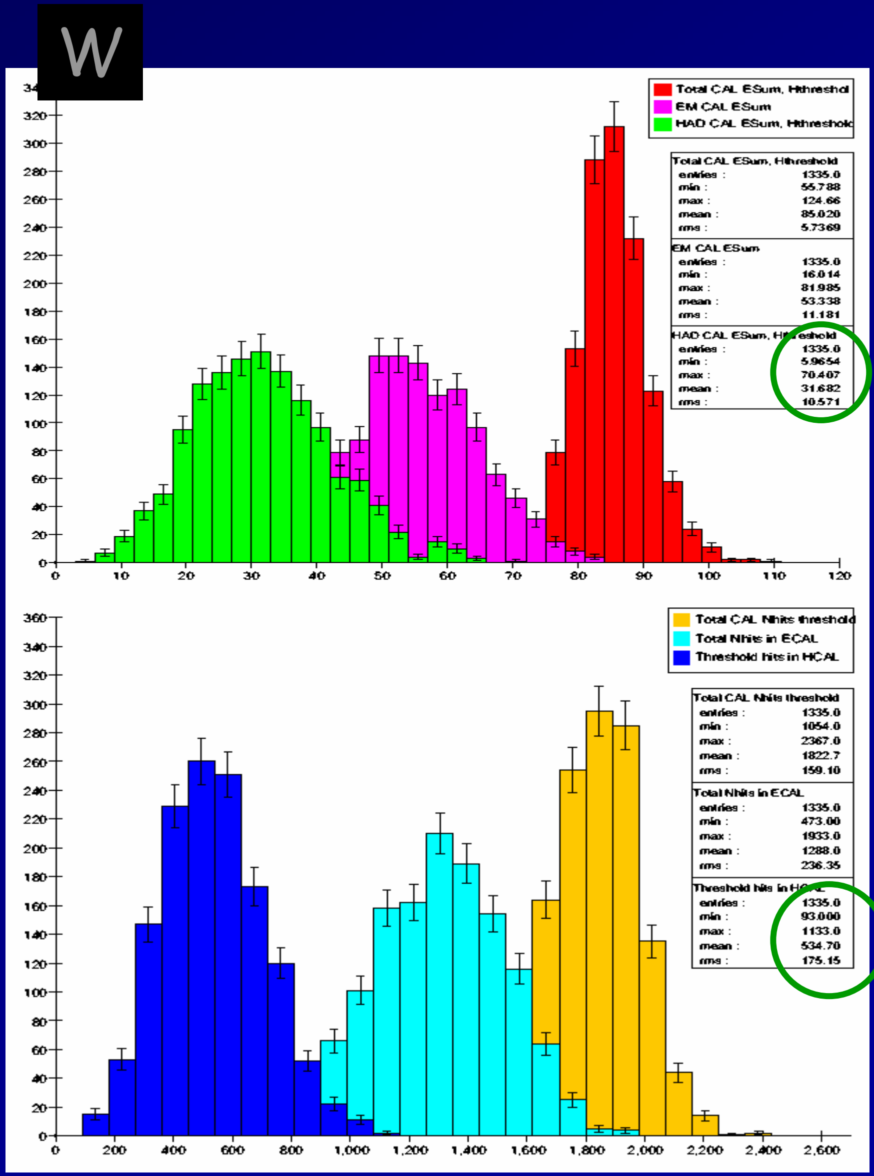
-> in HCAL alone, 46 in W, 35 in SS (30% more in W)

1) More hits and visible energy -> better digital and analog E resolution
2) All of the above in smaller B-field volume -> R^2 cost savings

Now on to PFA performance ->

e+e- -> Z (jets) - ESums, # Hits in Calorimeters

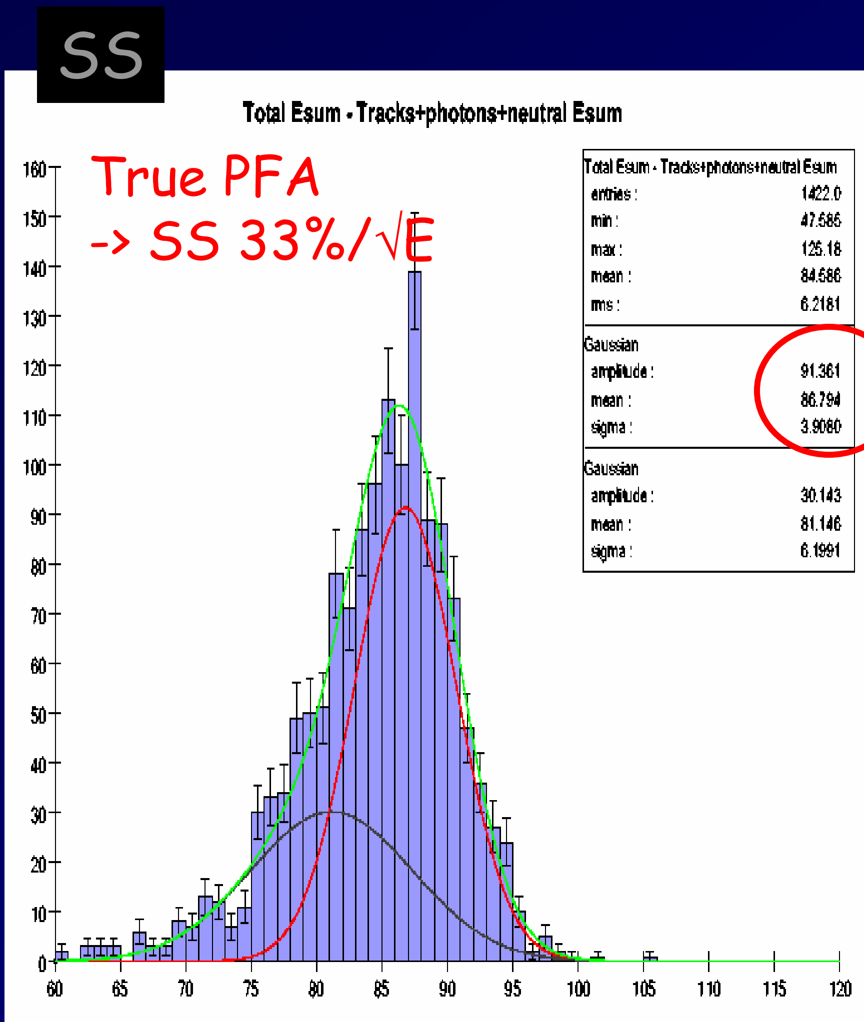


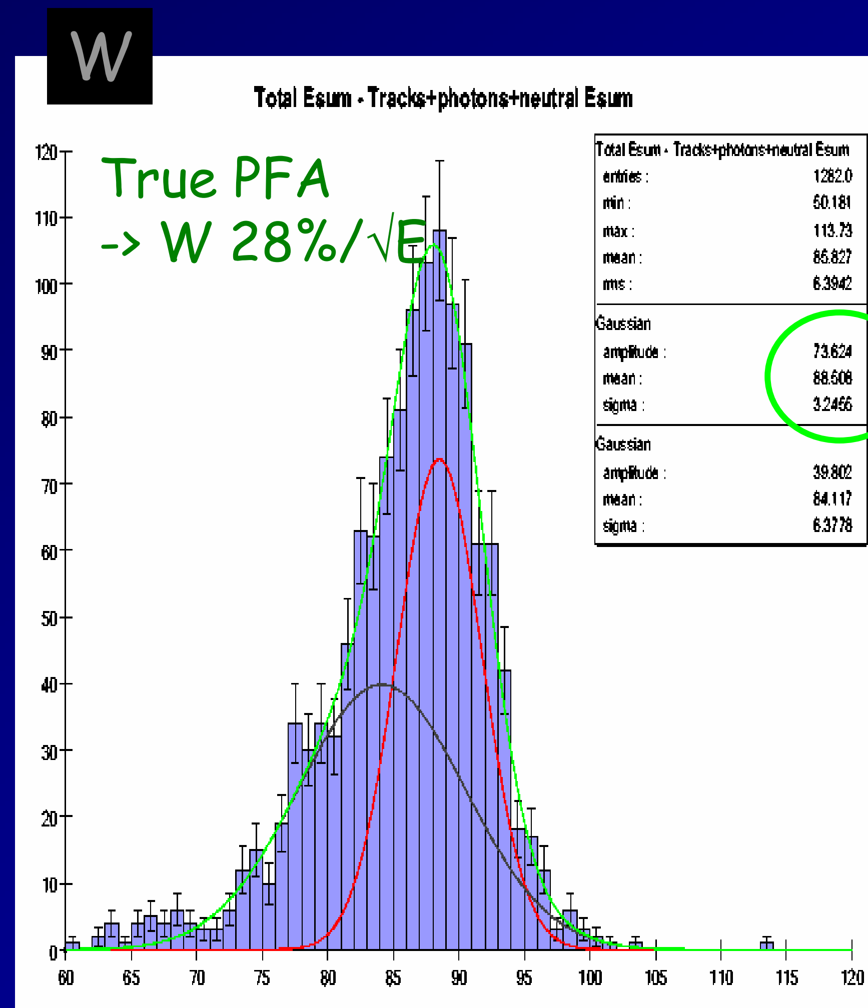


Total CAL ESum rms smaller in W HCAL-> better analog E resolution

More hits in HCAL -> better digital E resolution

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





Better PFA performance with the W HCAL for conical showers . . .

however, simple iterative cone reconstructs smaller fraction of events*

* Improve with neutral clustering?

Summary of PFA Results

HCAL Absorber Material

-> dense absorber is optimal for LC HCAL

-> single particle analog and digital E resolutions improved with W compared to SS (more hits and visible E per volume)

-> better sampling in W HCAL (7% compared to 12% of λ_I per layer)

-> PFA performance not compromised with a shorter, denser HCAL (in fact, improved!)

-> major cost savings if magnetic coil radius can be reduced

-> last 10 layers of ECAL will sample at 1.4 X_0 (0.5 cm W absorber)

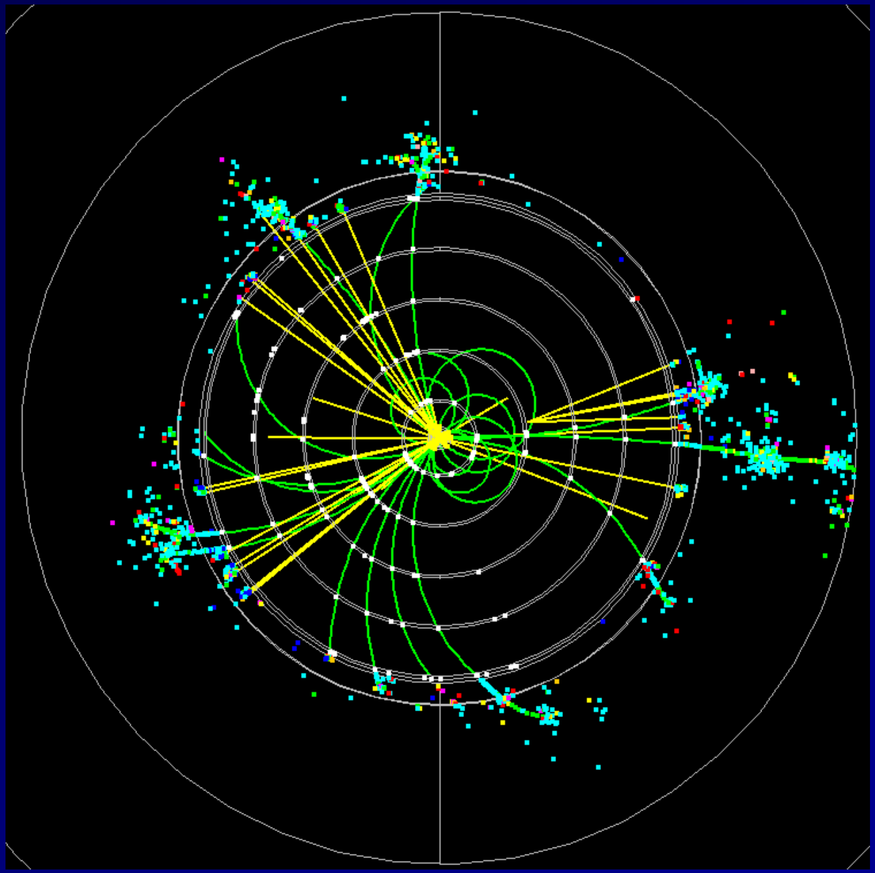
-> using W for absorber with 2 X_0 sampling (more accurately, 0.07 λ_I sampling) improves PFA performance while reducing the coil radius

Now, compare dense W HCAL with analog (scintillator) and digital (RPC) readout modes (same depth - 4 λ_I)

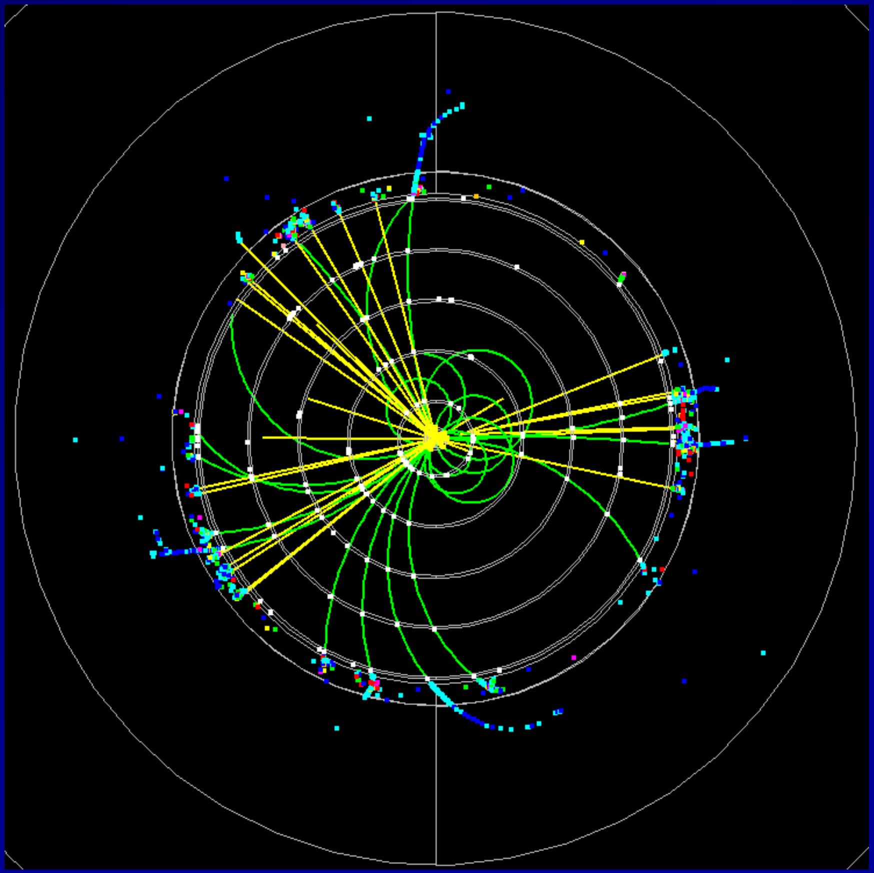
New Detector Models based on SD Design

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

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

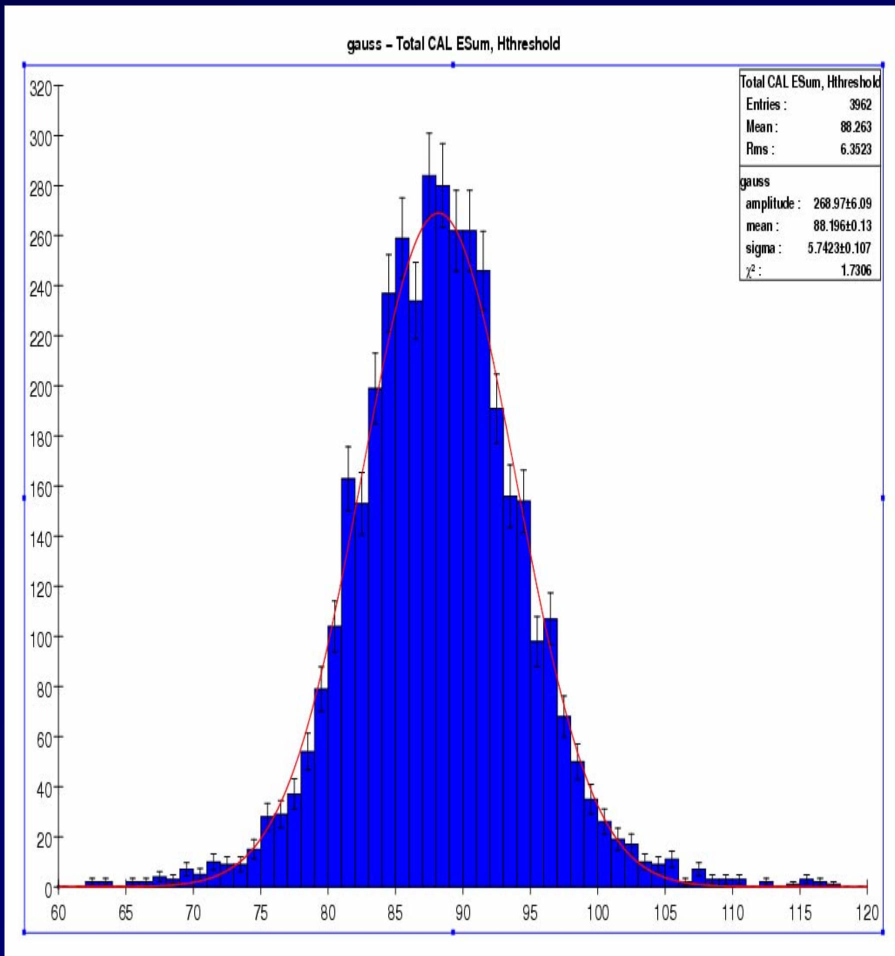


SDFeb05 RPC HCAL
55 layers of 0.7 cm W/0.8 cm RPC
1.2 mm gas gap
Sampling Fraction ~0.0025%!!!

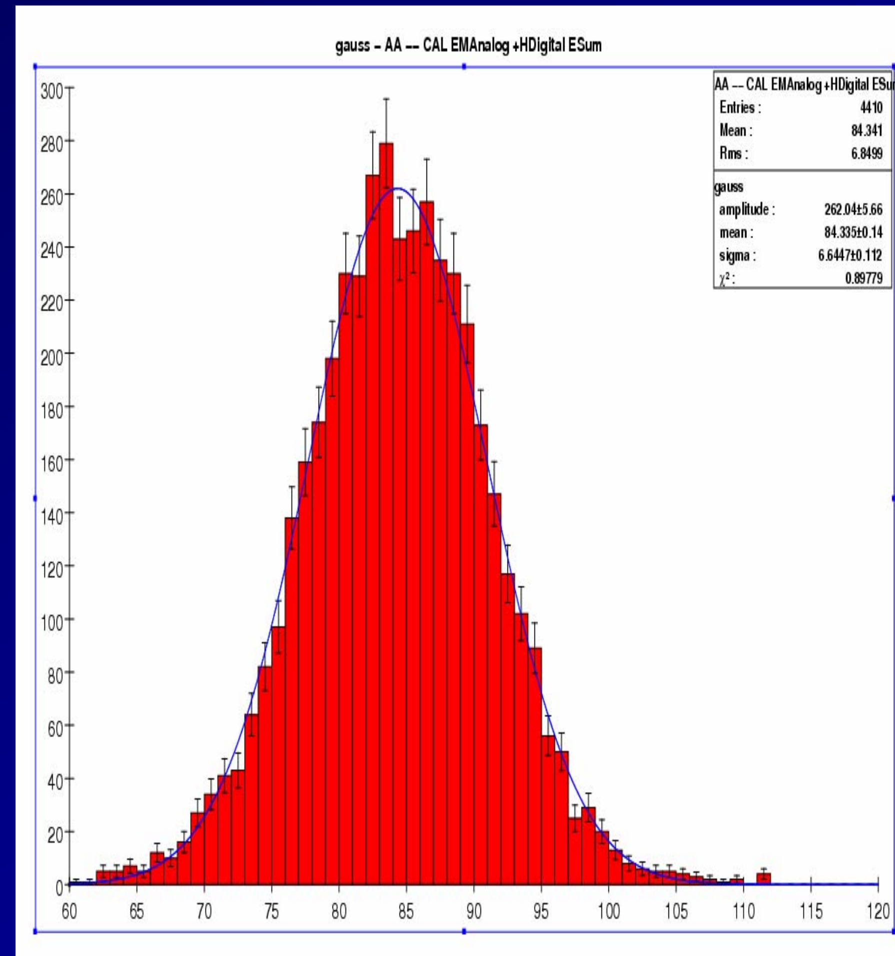


First – Calorimeter Performances

Scin. – Analog Readout



RPC – Digital Readout



Hard to compete with no visible energy?

Not a great start, but lets continue anyway →

Track Extrapolation Particle-flow Algorithm

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1st step *– Track/CAL cell association algorithm*

– substitute for Cal cells (mip + ECAL shower cone + HCAL cone : reconstruct linked mip segments + iterated in E/p hits in cones)

- Analog (scin.) or digital (RPC) techniques in HCAL

2nd step *- Photon Finder algorithm (currently MC photons)*

- use analytic long./trans. energy profiles, ECAL shower max, etc.

3rd step *– Neutral Finder algorithm* (New)

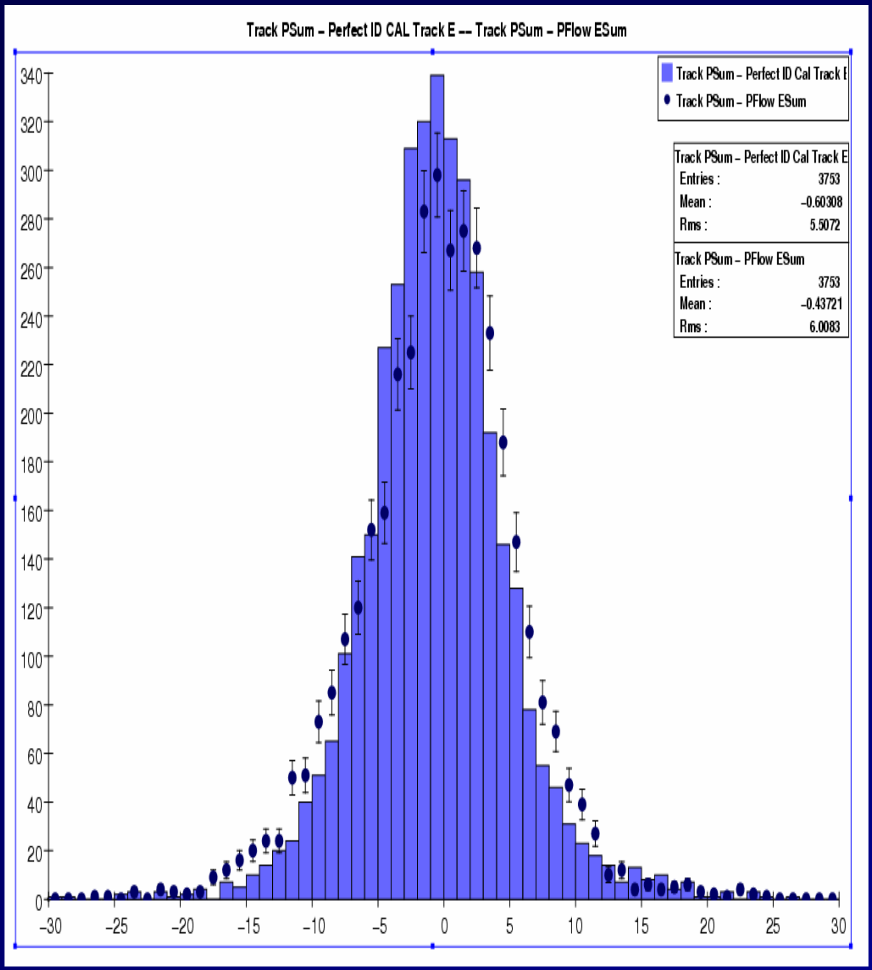
- Cluster remaining CAL cells, make cluster quality cuts (# of cells, energy or density threshold, etc.)

4th step – Jet algorithm (New)

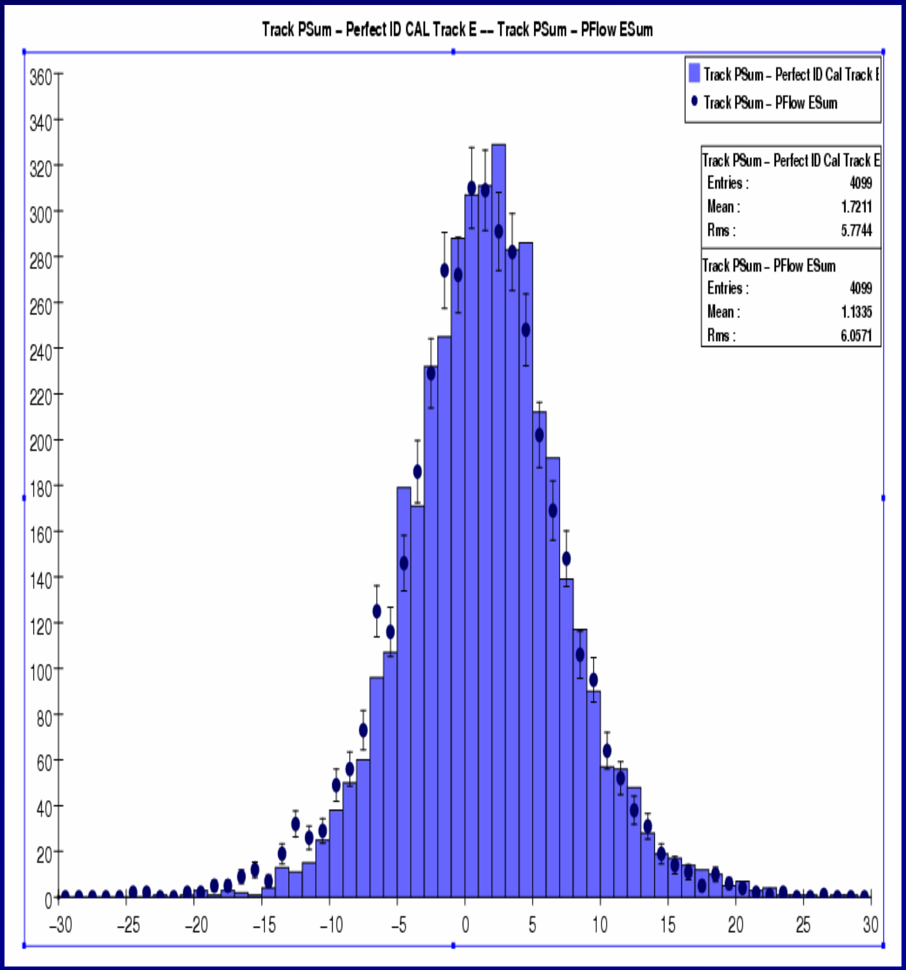
- tracks + photons + neutral clusters used as input to jet algorithm

Track/CAL Cell Association Algorithm

Scin. – Analog Readout



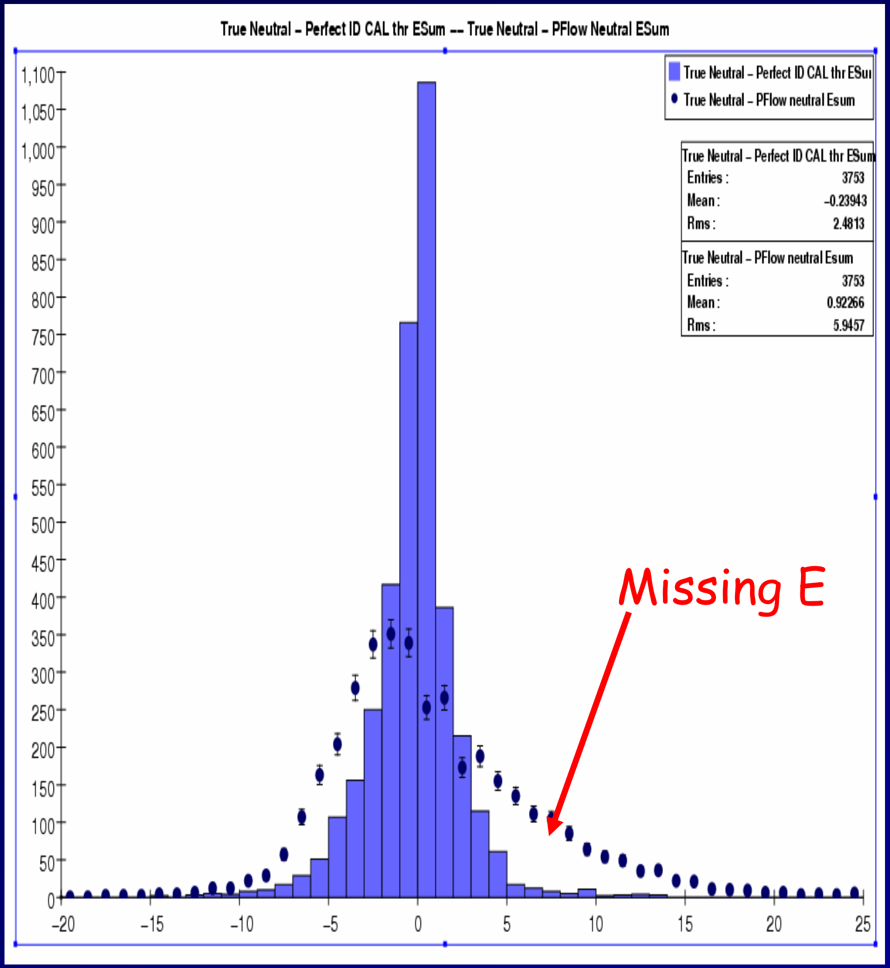
RPC – Digital Readout



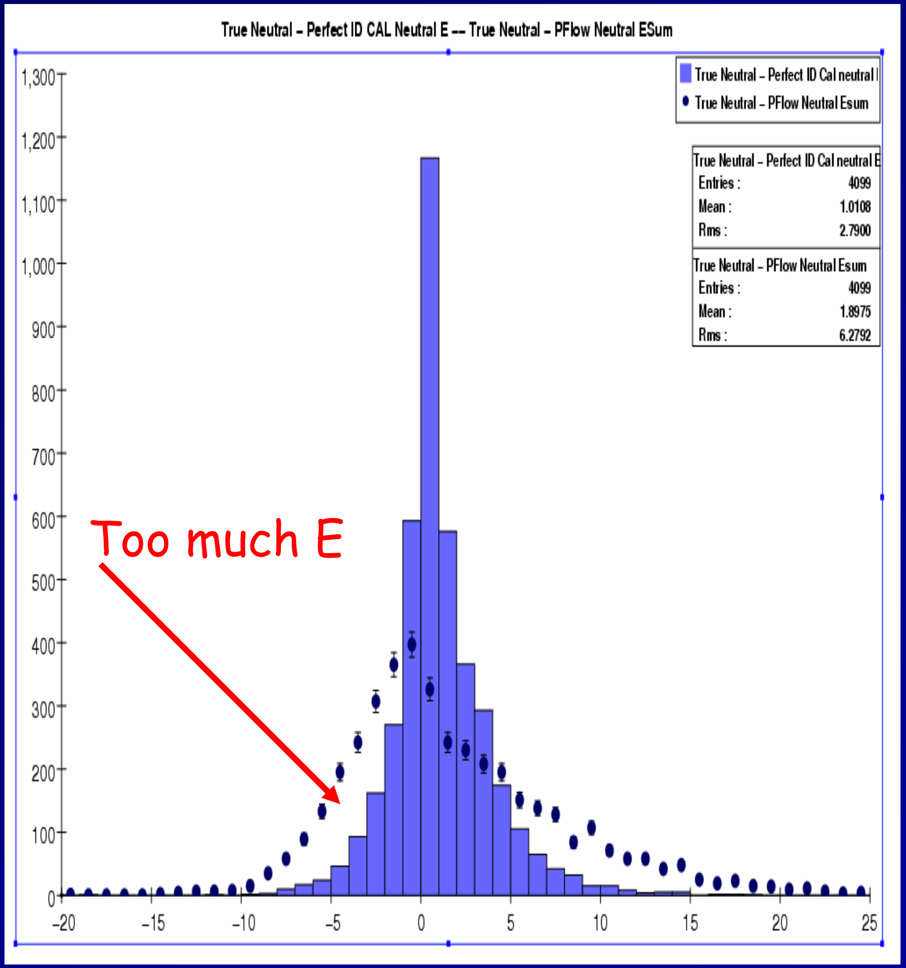
Resolution still slightly better in scintillator, but Track/Cell association algorithm reproduces perfect ID in both cases

Neutral Finding Algorithm

Scin. – Analog Readout



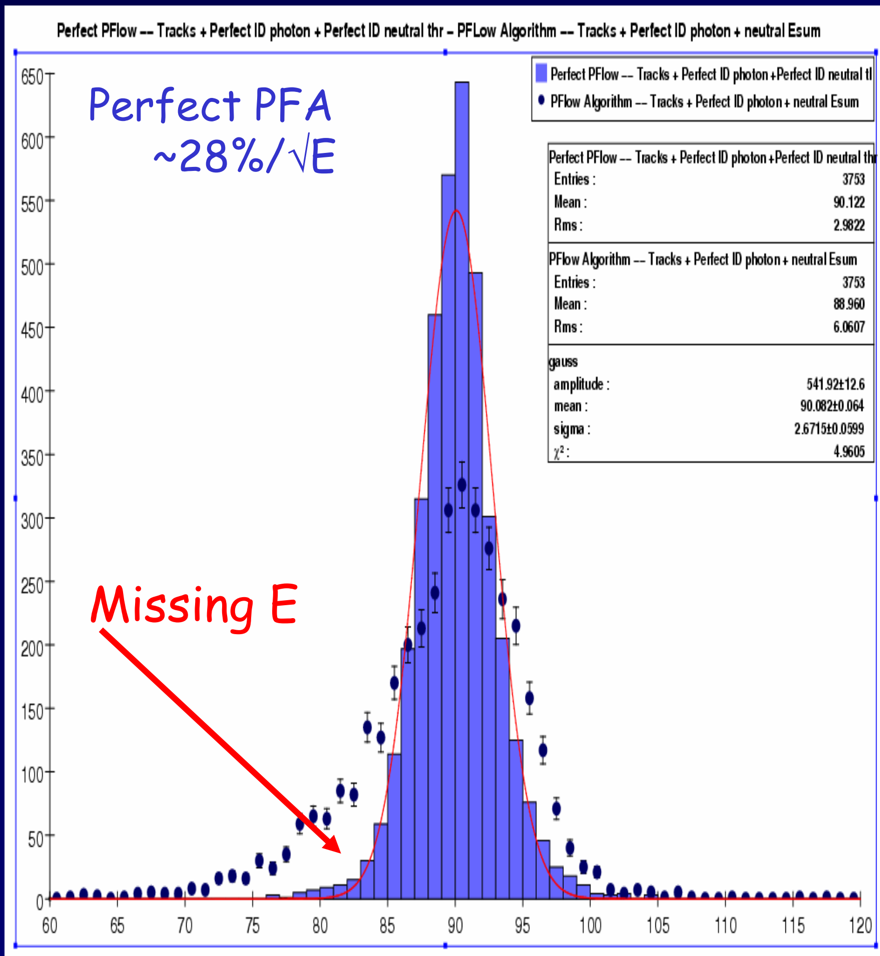
RPC – Digital Readout



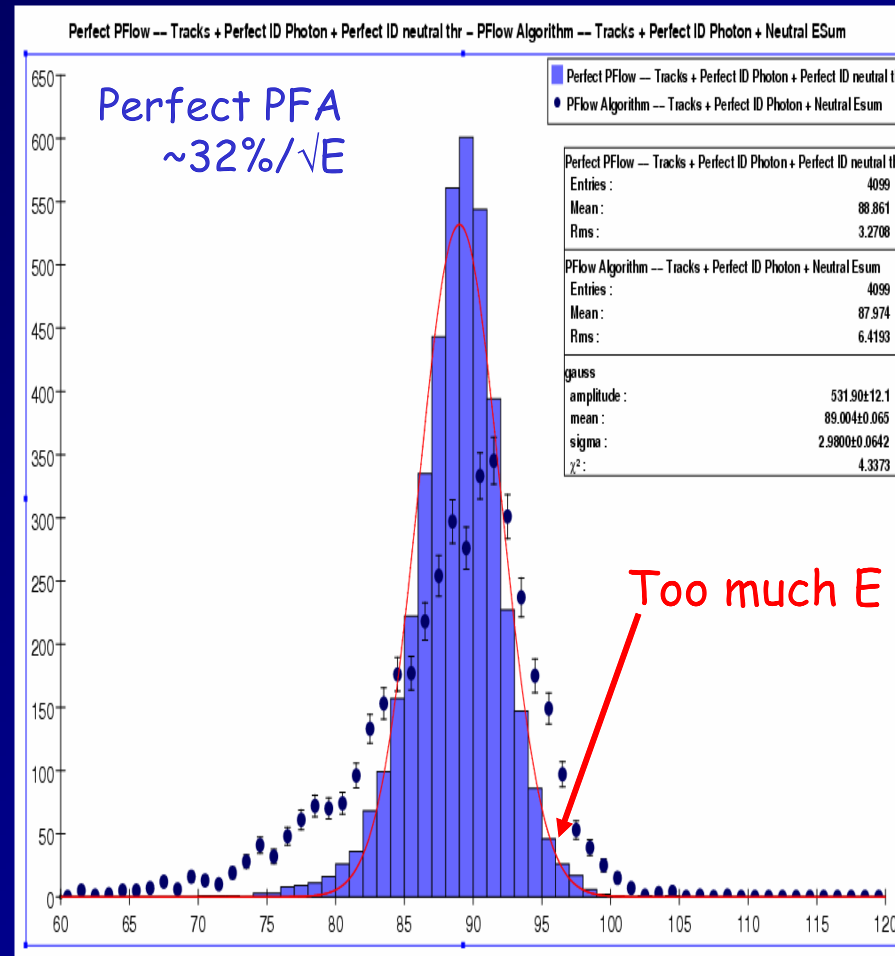
Once again, very similar performance

PFA Results

Scin. – Analog Readout



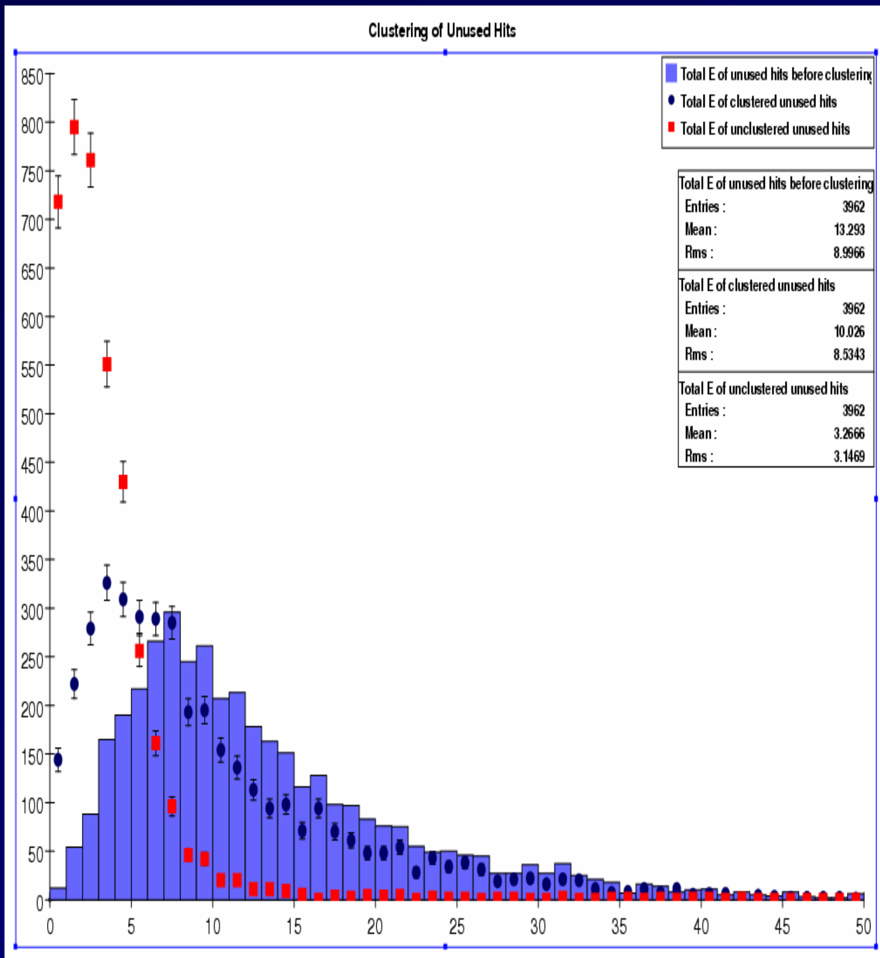
RPC – Digital Readout



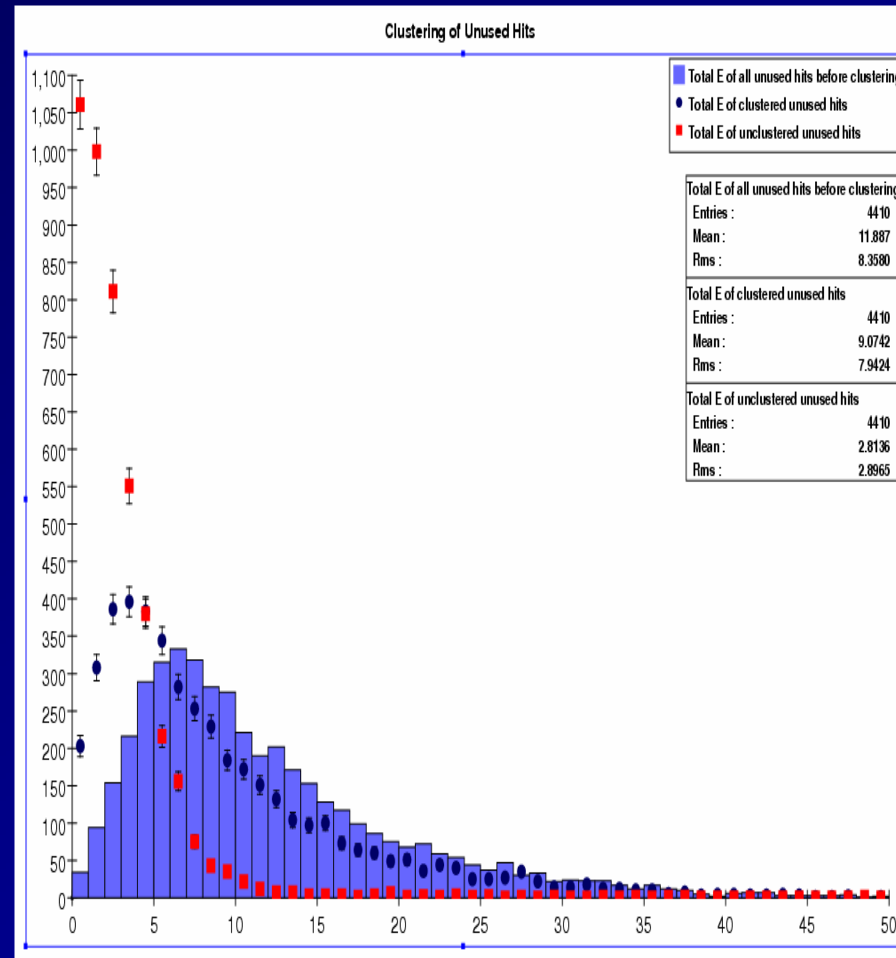
PFA performance is very similar (with same cuts) but reflects underlying CAL resolution – Missing/extra E from neutral Finder Algorithm

Confusion – Leftover Hits!

Scin. – Analog Readout

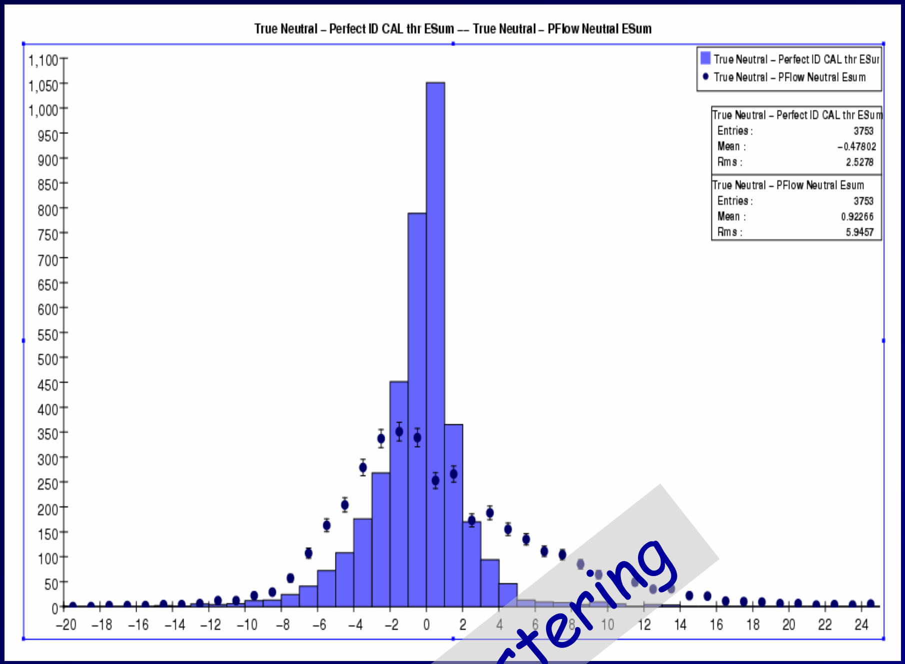


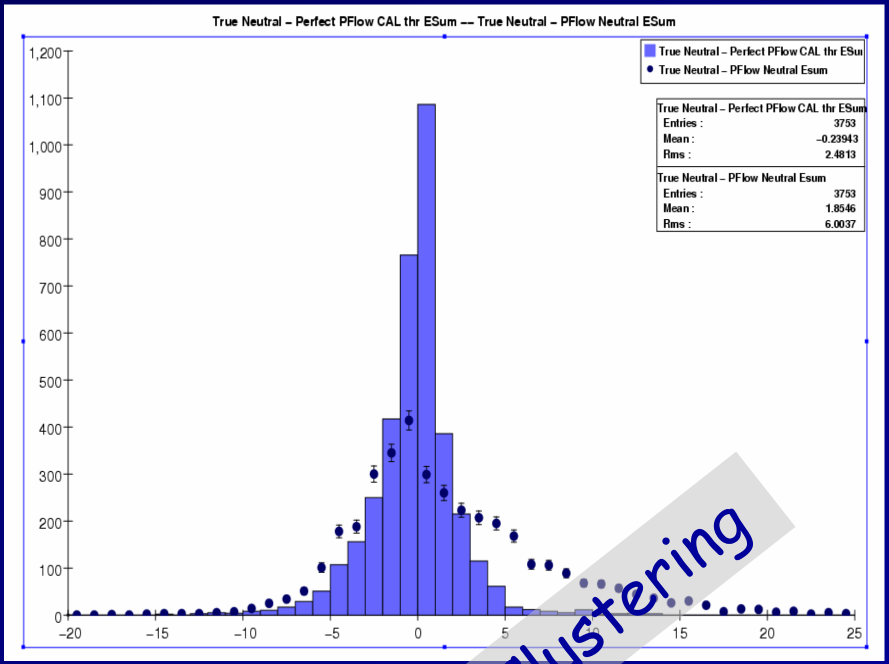
RPC – Digital Readout

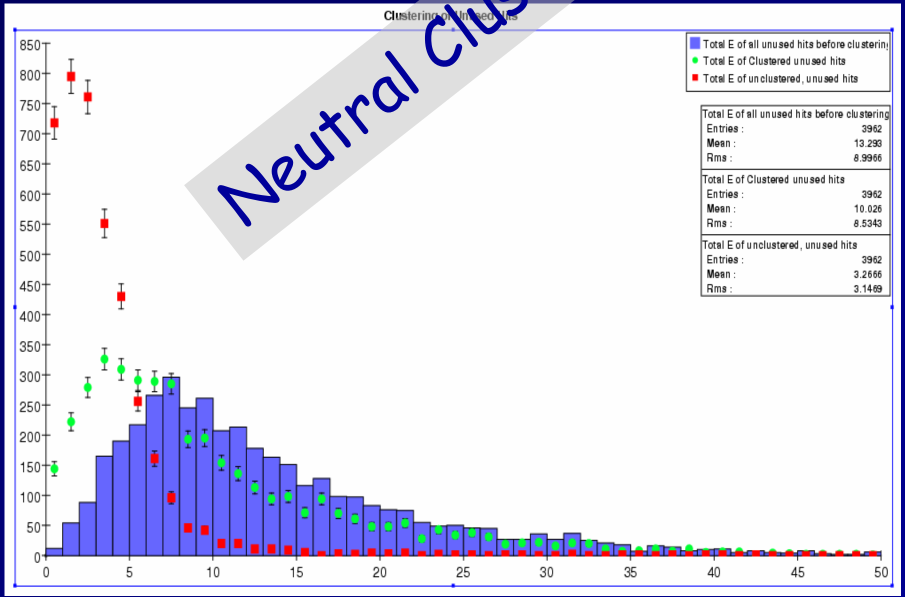


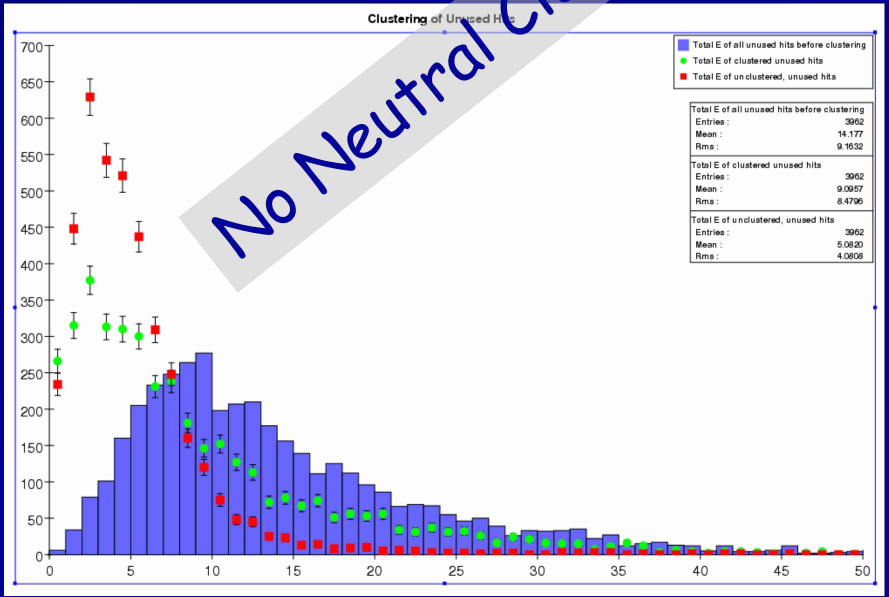
Promising -> better use of hits in RPC?
– good since there aren't that many!

PFA Improvements - Neutral Clustering









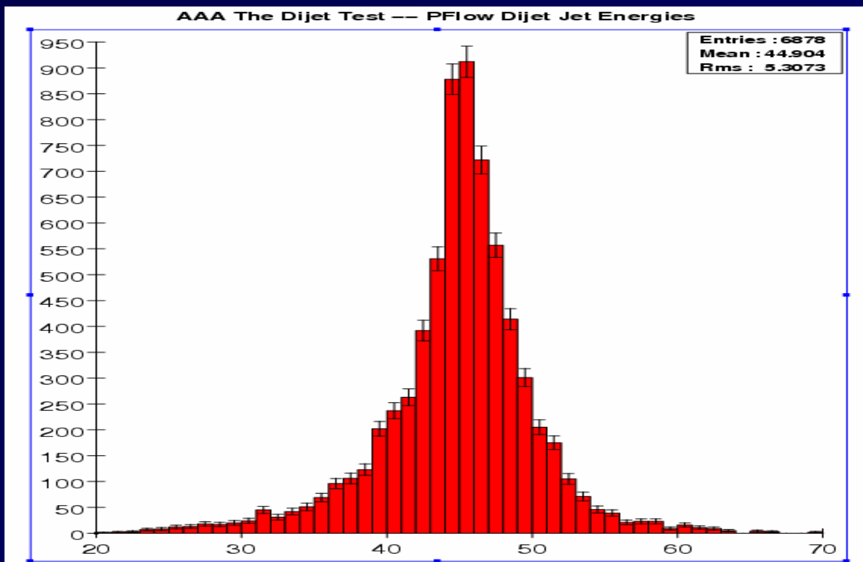
Neutral Clustering

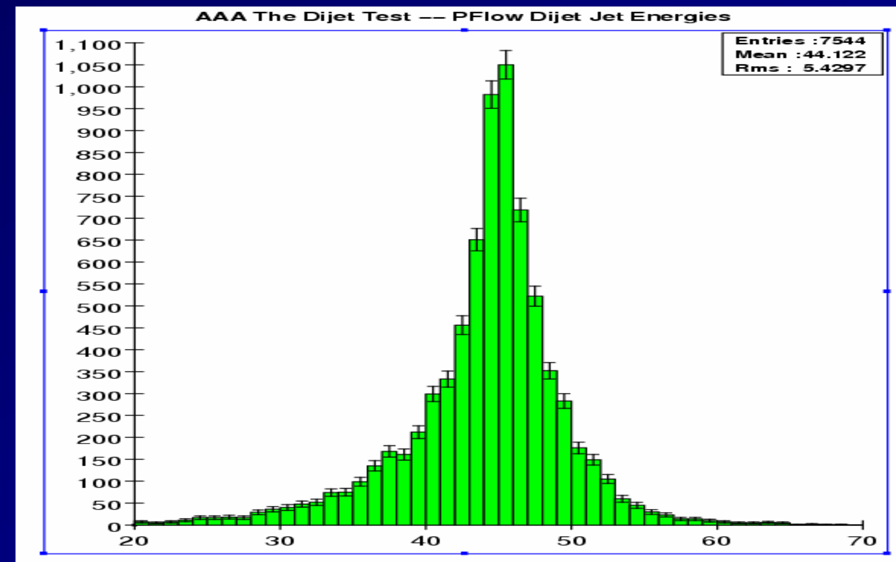
No Neutral Clustering

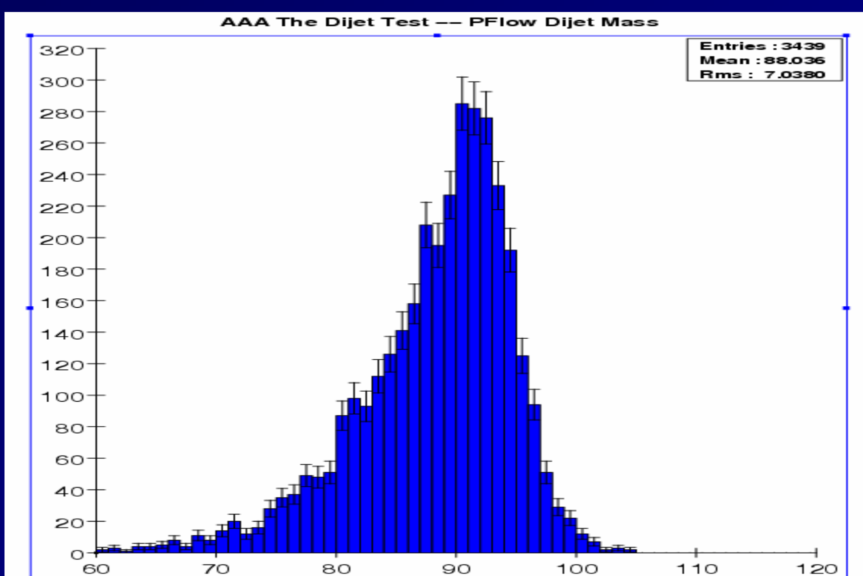
DiJet Mass from PFA

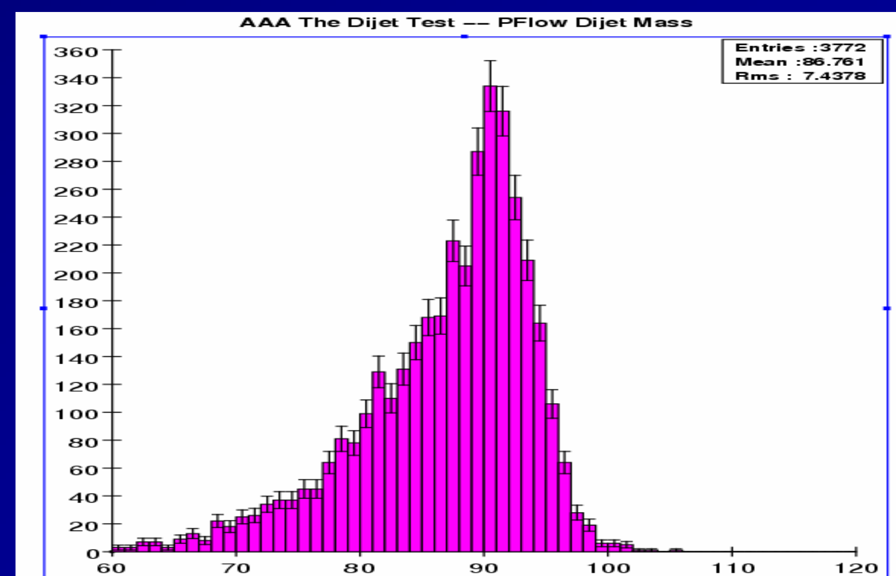
Scin. - Analog Readout

RPC - Digital Readout









Summary

For LC Detector, HCAL should be as dense as possible

-> 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

Comparing W and SS absorbers, hadron showers appear to be smaller (rms of E distribution) in W

-> results in improvement of PFA analysis

Beginning systematic studies of readout modes, absorber types and thickness for HCAL using flexibility of XML detector geometry description – should result in optimization of *both the LC Calorimeter and its associated PFA analysis method.*

W Absorber HCAL for Test Beam

For 95% containment of a 5(10) GeV pion shower :

$R\pi(95\%) = 2(0.5 + 0.03 \ln E)$ in λ_I

$= 1.10\ \lambda_I\ (1.14\ \lambda_I)$ transverse to beam

$L\pi(95\%) = 1.2 + 1.62 \ln E$ in λ_I

$= 3.81\ \lambda_I\ (4.9\ \lambda_I)$ along beam

So, for 0.7 cm W/0.5 cm Scintillator each layer :

Need 22 cm x 22 cm transverse to beam, and

52 (67) layers along the beam HCAL standalone

-> 25K (32K) 1 cm^2 readout channels

41 (56) layers along the beam with ECAL

-> 20K (27K) readout channels

For 2 cm SS/0.5 cm Scintillator each layer :

Need 38 x 38 cm transverse to beam, and

32 (41) layers along the beam HCAL standalone

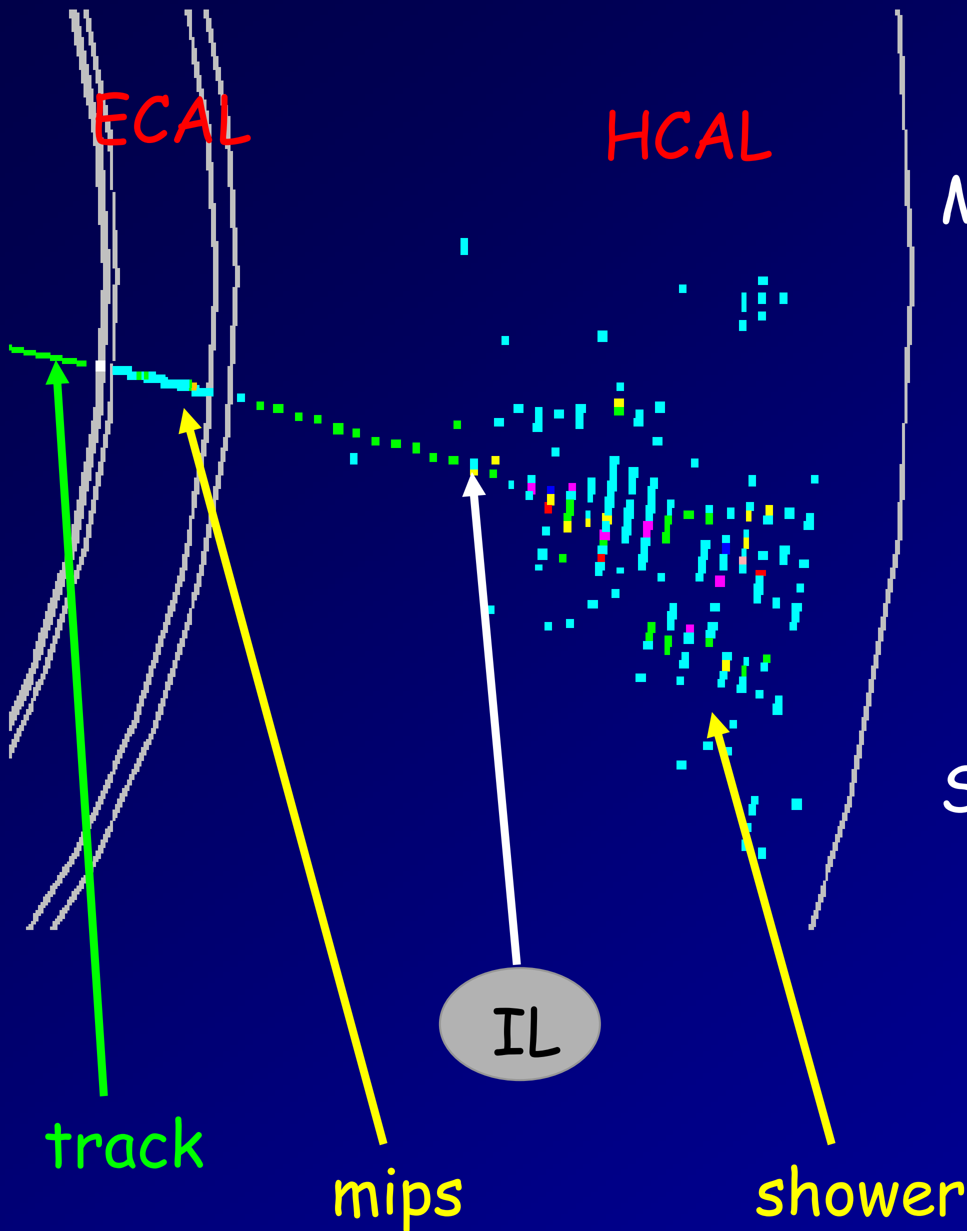
-> 46K (59K) 1 cm^2 readout channels

25 (34) layers along the beam with ECAL

-> 36K (49K) readout channels

X ~2

Shower reconstruction by track extrapolation



Mip reconstruction :

Extrapolate track through CAL layer-by-layer

Search for “Interaction Layer”

-> Clean region for photons (ECAL)

Shower reconstruction :

Define cones for shower in ECAL, HCAL after IL

Optimize, iterating cones in E,HCAL separately (E/p test)