SiD Calorimetry Studies with Simulation

Calorimetry R&D Review
LCWS07
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Motives for Simulation Studies

- Understand the physics requirements for jet energy resolution.

- Quantify the benefits of good jet energy resolution.

- **Optimize hcal parameters, prepare for technology choice. Complement PFA studies.**
  - Build up some intuition
  - Sample a larger parameter space

What Jet Energy Resolution do we Need?

Need clean identification of W's, Z's, H's, tops,…

This requires dijet mass resolution ≤ few GeV.

$$M_{12}^2 \approx 2E_1E_2\left(1-\cos\theta_{12}\right)$$

$$\frac{dM_{12}}{M_{12}} \approx \frac{1}{2}\left[\frac{dE_1}{E_1} \oplus \frac{dE_2}{E_2} \oplus \ldots\right]$$

Requiring $\sigma \sim \Gamma_Z$, sets dM/M = 2.5/92 = 2.7 %.

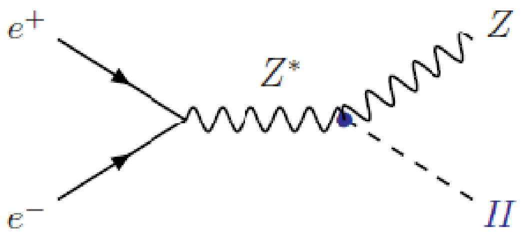
This requires

$dE_{jet}/E_{jet} = \sqrt{2}\,(2.7\%) = 3.8\ \%$, independent of E_{jet}.

This is roughly comparable to the goal often cited,

$dE_{jet}/E_{jet} = 30\%/\sqrt{E(GeV)}$, for $E_{jet} \leq 100$ GeV.

Benefits of Good Resolution



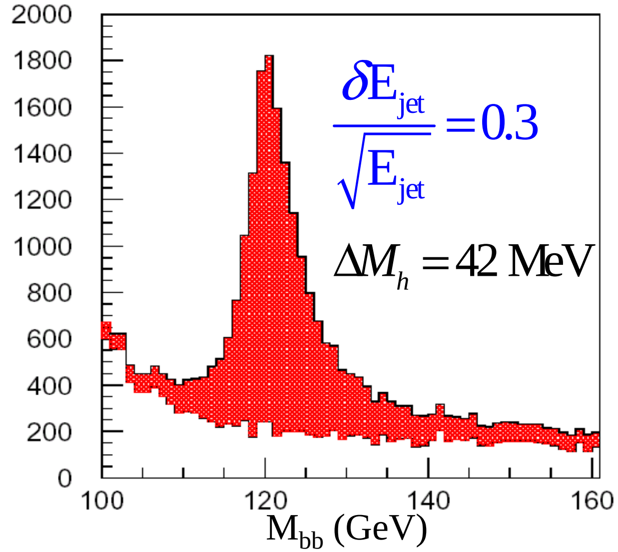
$$e^+e^- \to ZH$$
$$\to qqb\bar{b}$$

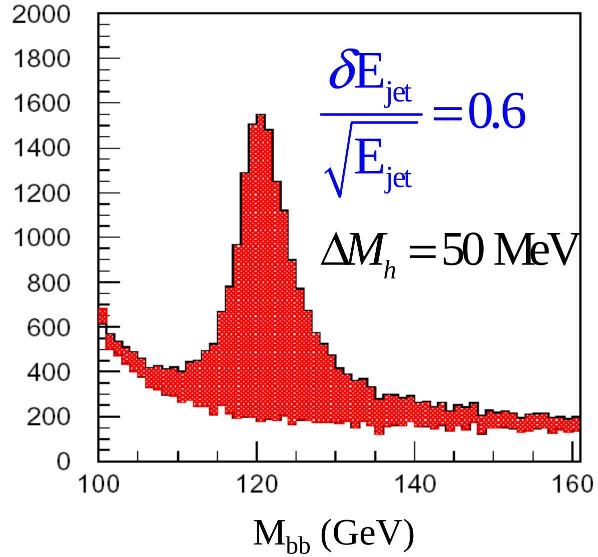
$$\sqrt{s} = 350\ GeV$$
$$L = 500\ fb^{-1}$$

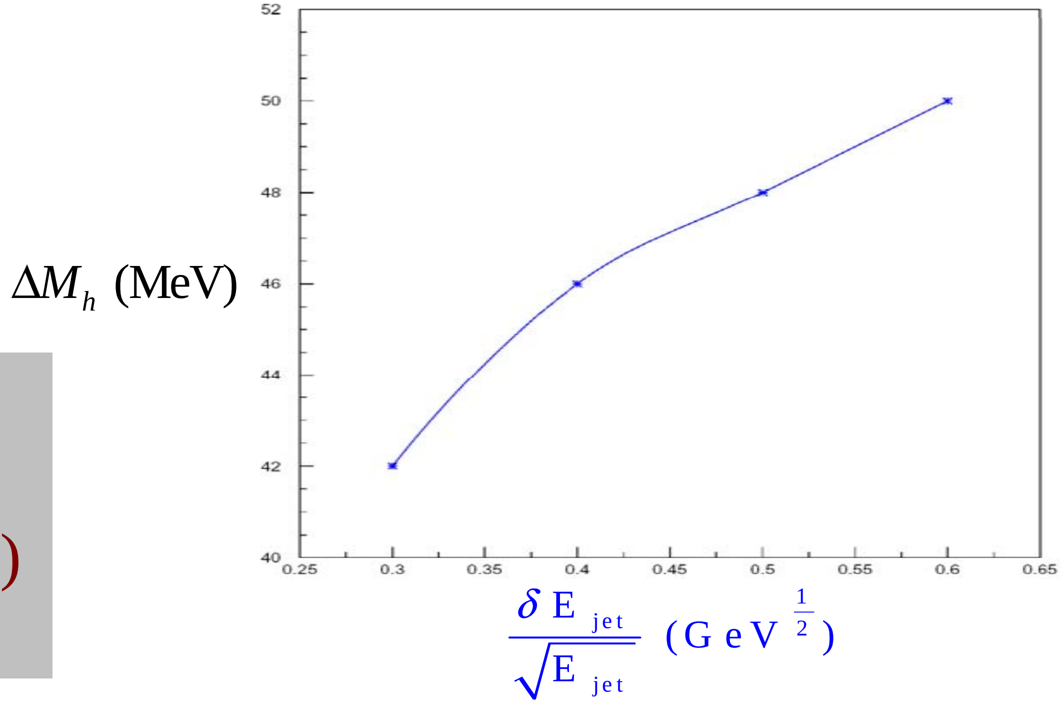
$\Delta E/\sqrt{E} = 60\% \to 30\%$

equiv to $1.4\times$ Lumi

Similar gains for other measurements: BF(H->WW*), σ(HHZ) (T. Barklow)







Simulation Study Overview

Topics Studied

- Single Neutral Hadron Response
- Realistic SiD Ecal/Hcal Response to Neutral Hadrons
- Jet Energy and Dijet Mass Resolution with Perfect PFA
- Hadron Shower Sizes in RPC and Scint Hcals

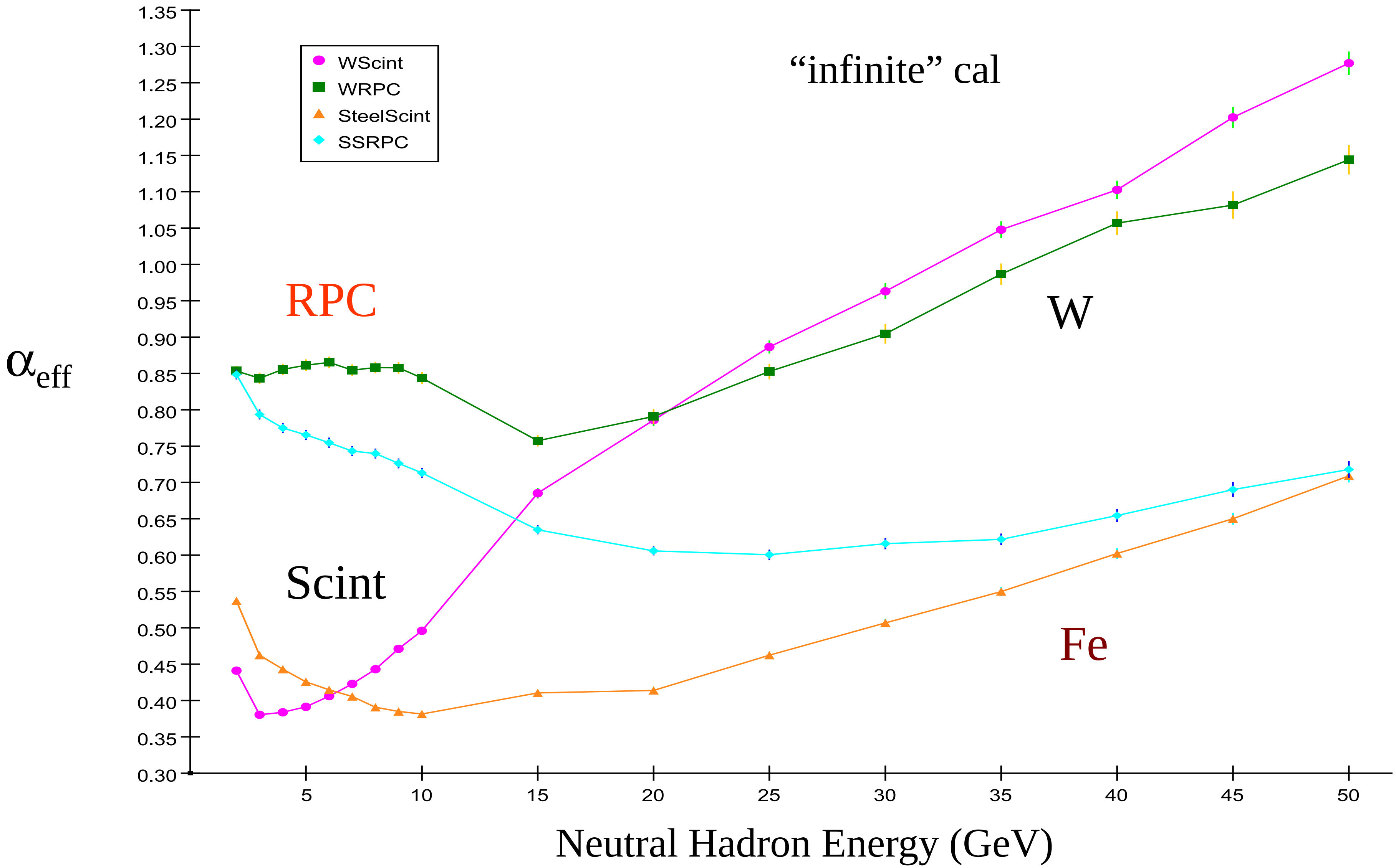
Ground Rules

- SiD in Geant4 with LCphys physics models
- "neutral hadron" = .5 K^0_L + .25 n + .25 nbar
- Detectors: .12 cm thick RPC; .5 cm thick scintillator
- Absorbers: .75 cm W; 2.0 cm Fe; .75 cm detector gap
- Transverse segmentation: 1 x 1 cm^2

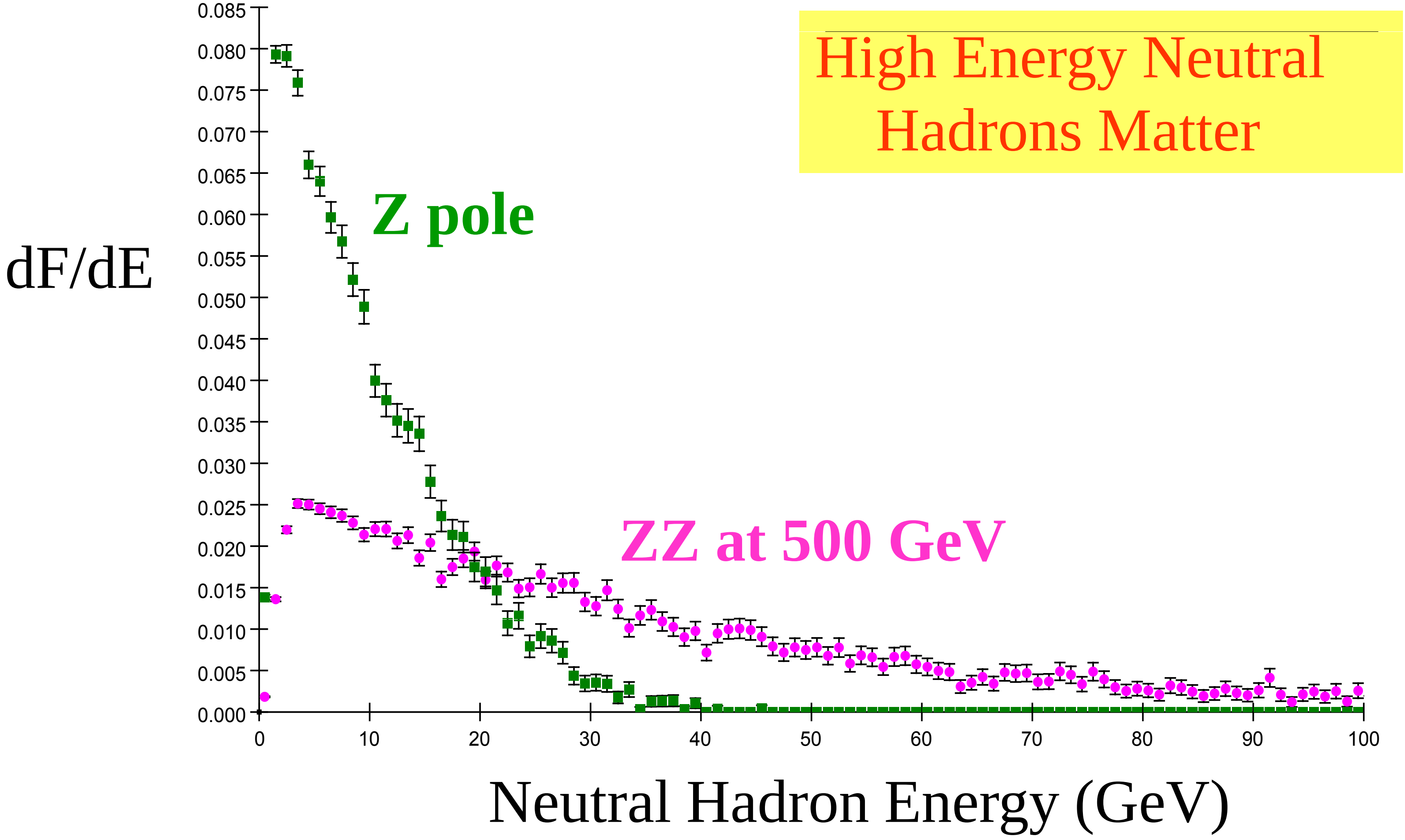
"Resolution Parameter α_{eff}" is given implicitly by

$$\sigma/E = \alpha_{eff}/\sqrt{E}$$

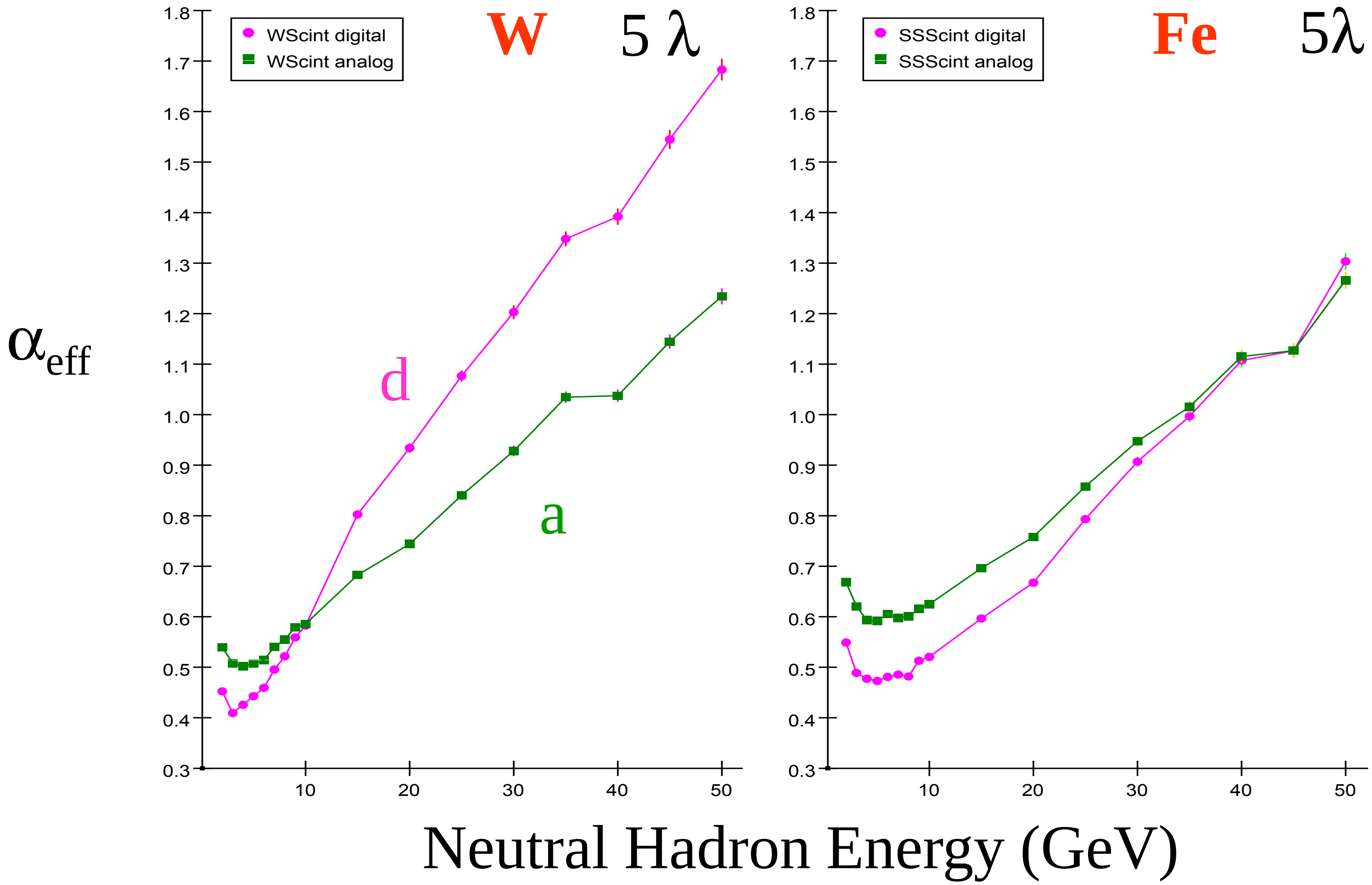
Resolution vs Energy for Single Neutral Hadrons



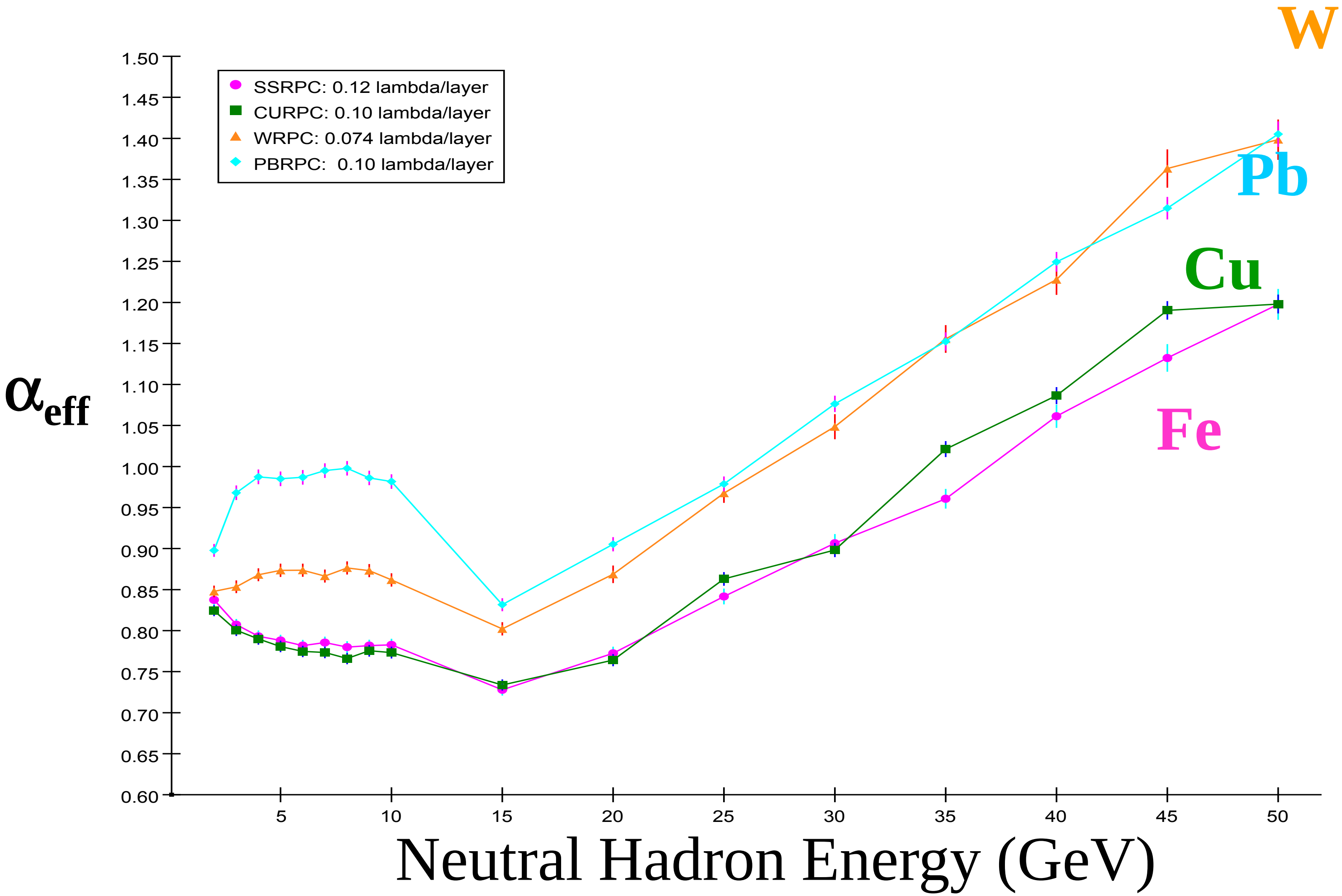
Differential Neutral Energy Fraction
(normalized)



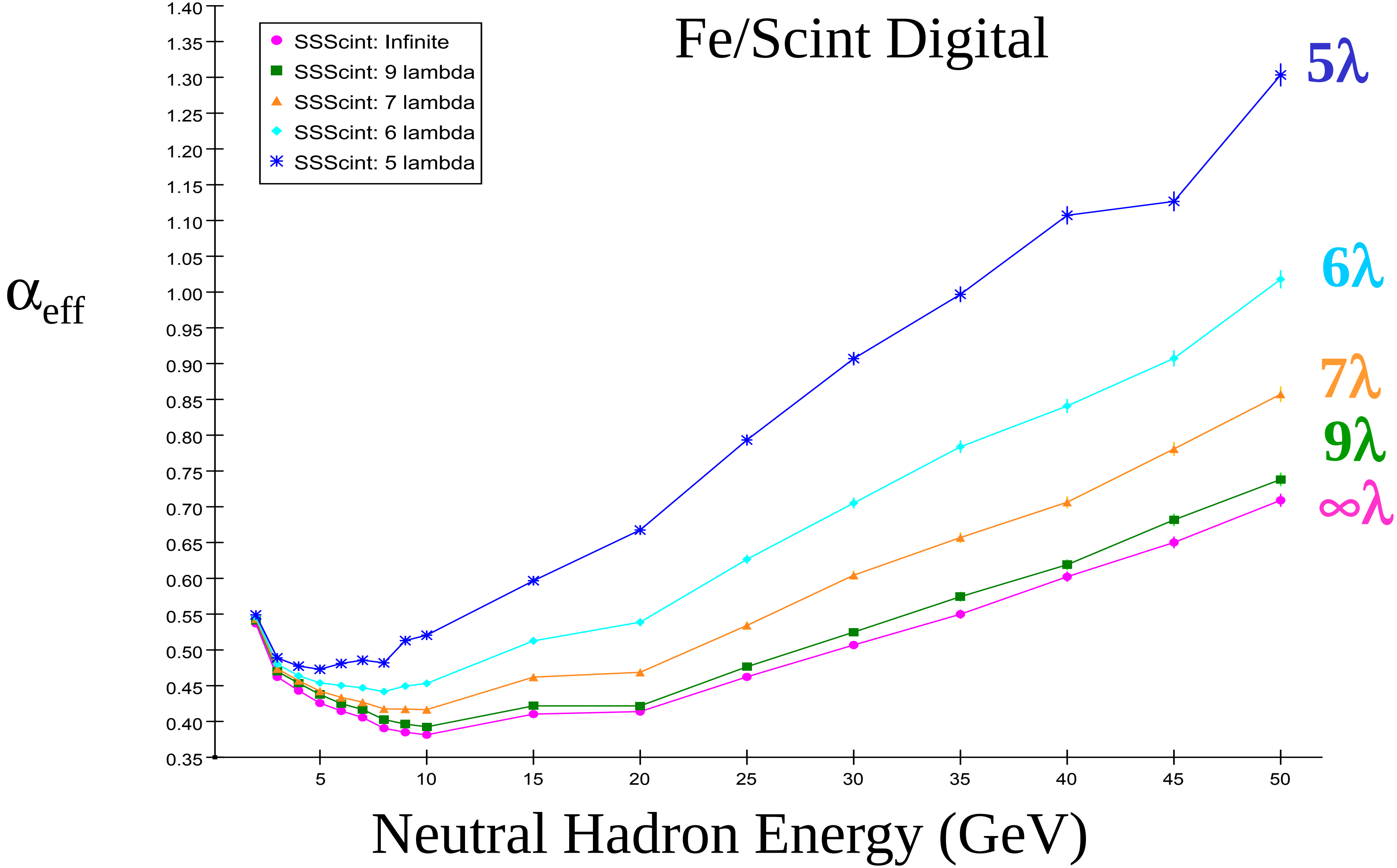
Digital vs Analogue (Scint only)



Resolution and Absorber Material (RPCs; 5λ)



Resolution vs Absorber Depth

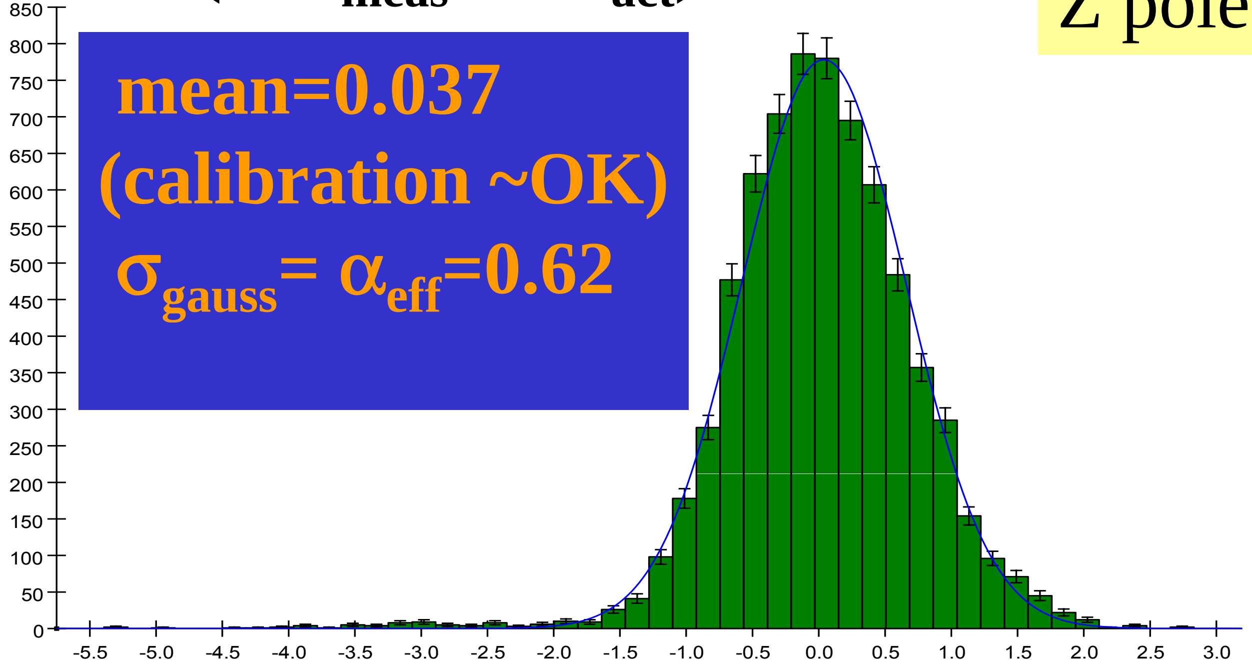


SiD Response to Jets

- **Simulate SiD Cal *with Perfect Pattern Recognition***
  1λ Si/W Ecal + 4λ (Fe/W)/(RPC/Scint) Hcal
  Cross-calibrate Ecal and Hcal Had response
  Hcal Layers: W 0.074 λ; Fe 0.12 λ.

Fe/RPC
Z pole

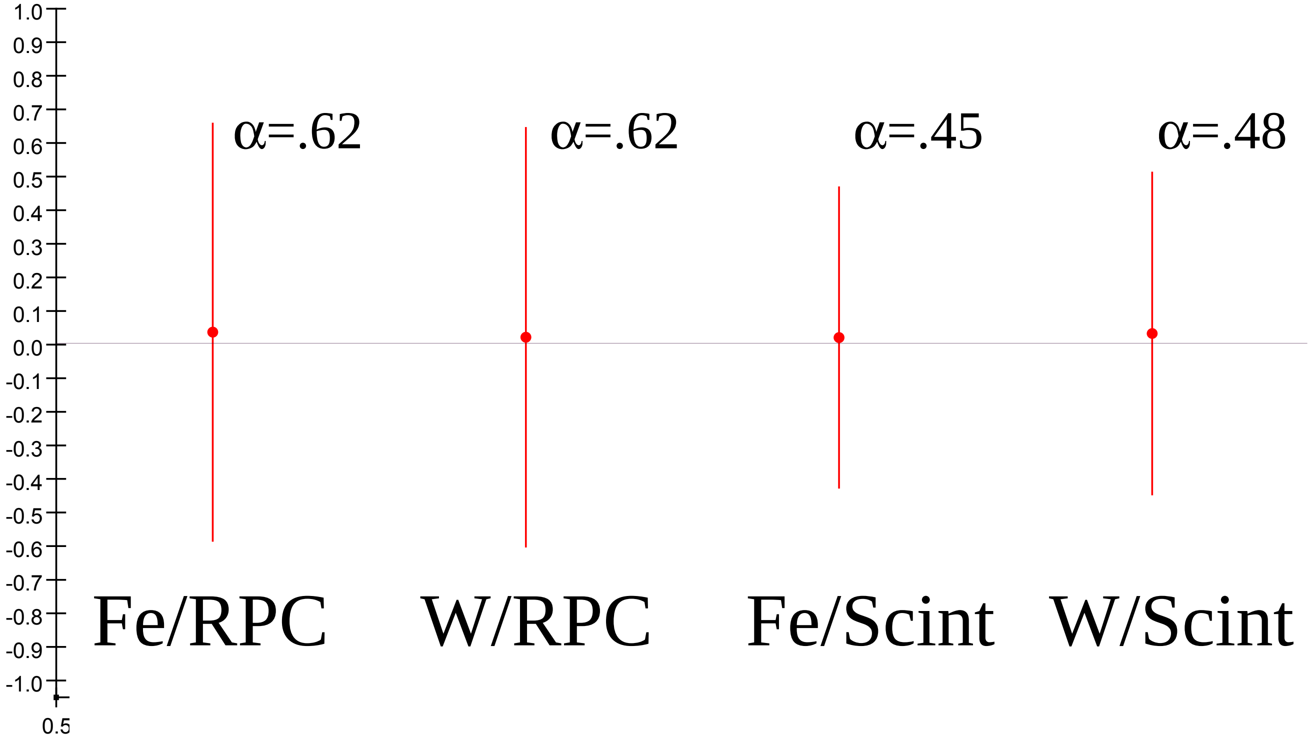
$(\Sigma E^0_{meas} - \Sigma E^0_{act}) / \sqrt{\Sigma E^0}$



$(GeV^{1/2})$

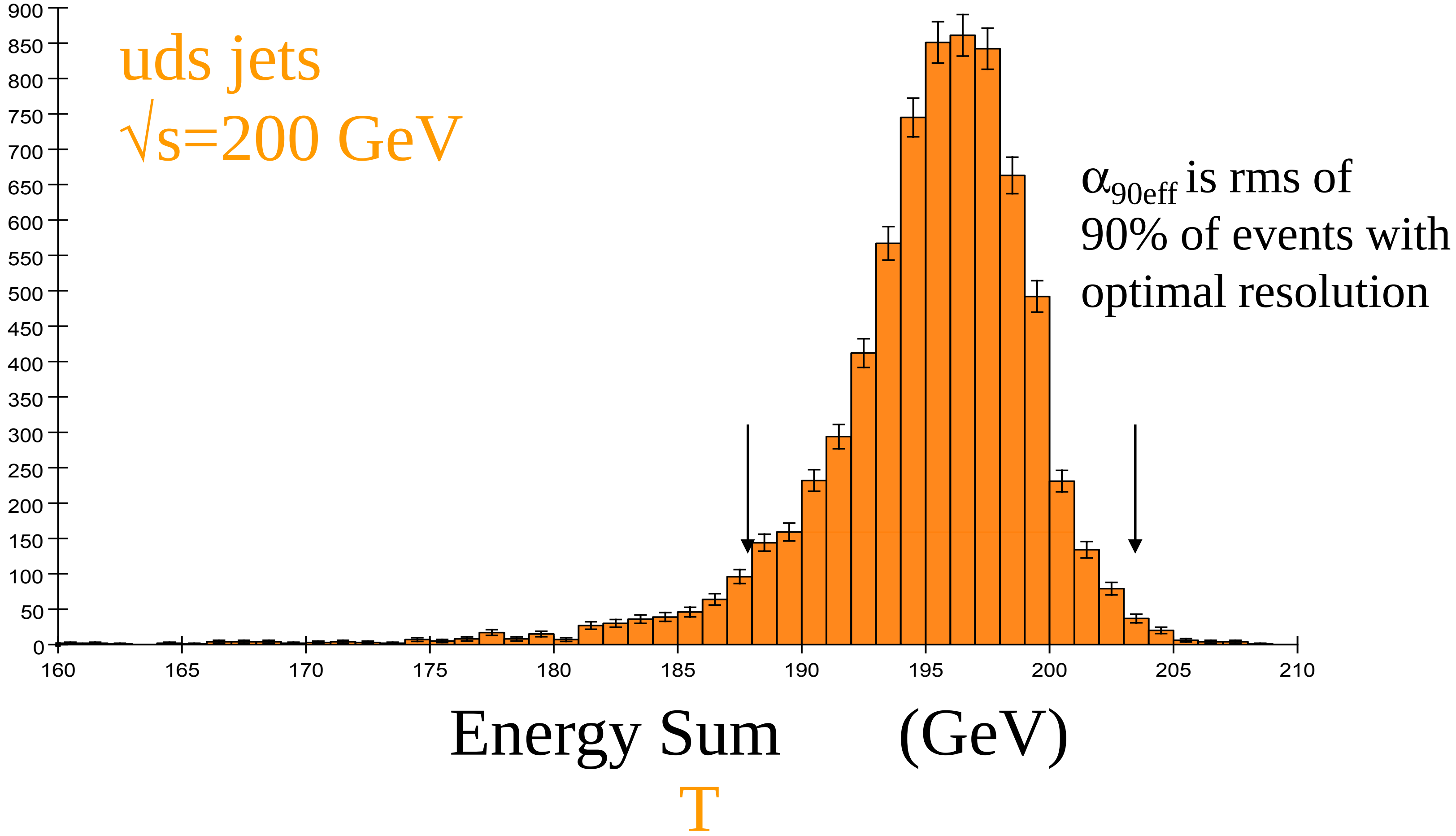
Neutral Energy Resolution at the Z

$$(E^0_{meas} - E^0_{act}) / \sqrt{E}$$

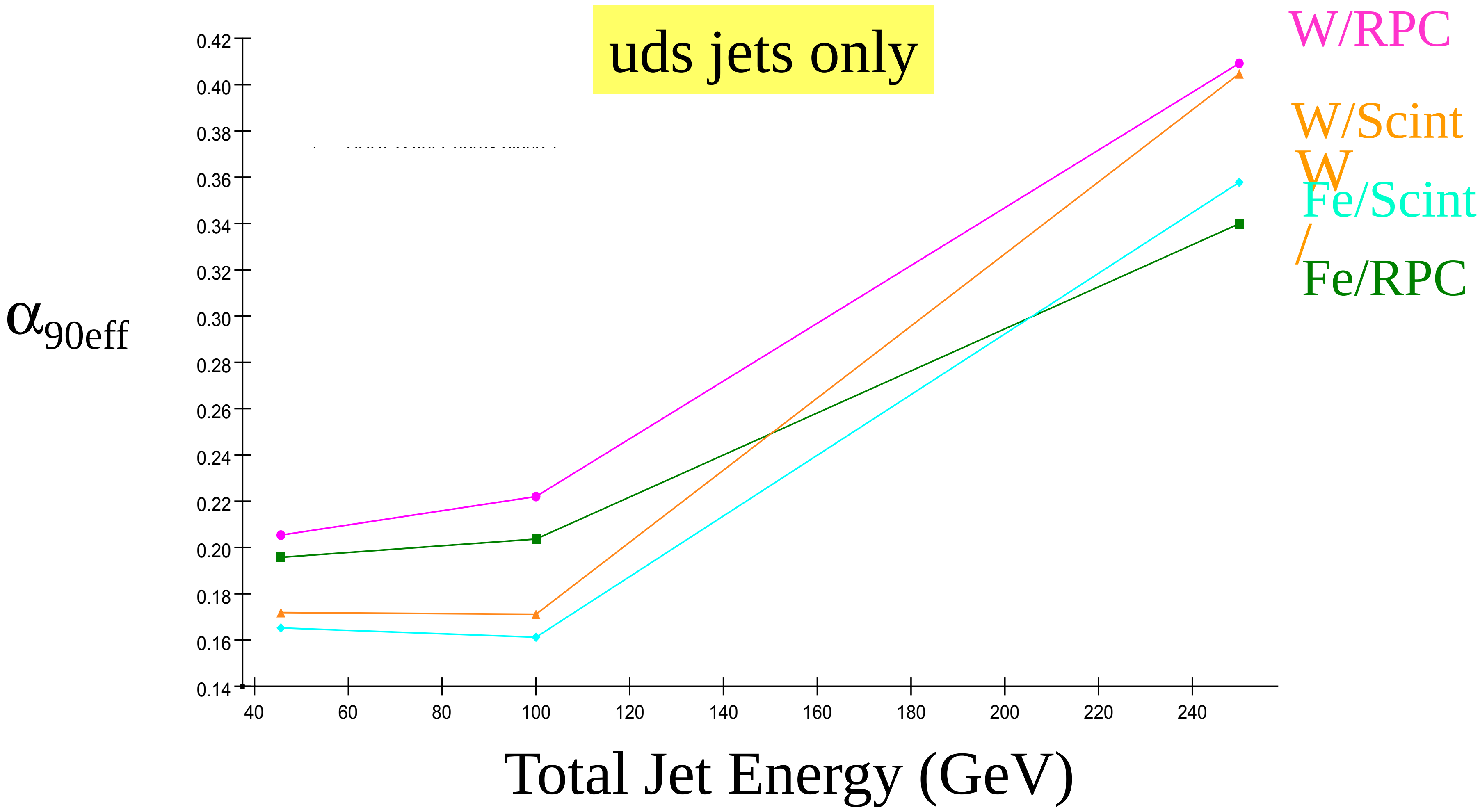


Total Jet Energy
with Perfect Pattern Recognition, i.e. Assign All Cal Energy Correctly

Charged Tracks + Photons + Neutral Hadrons

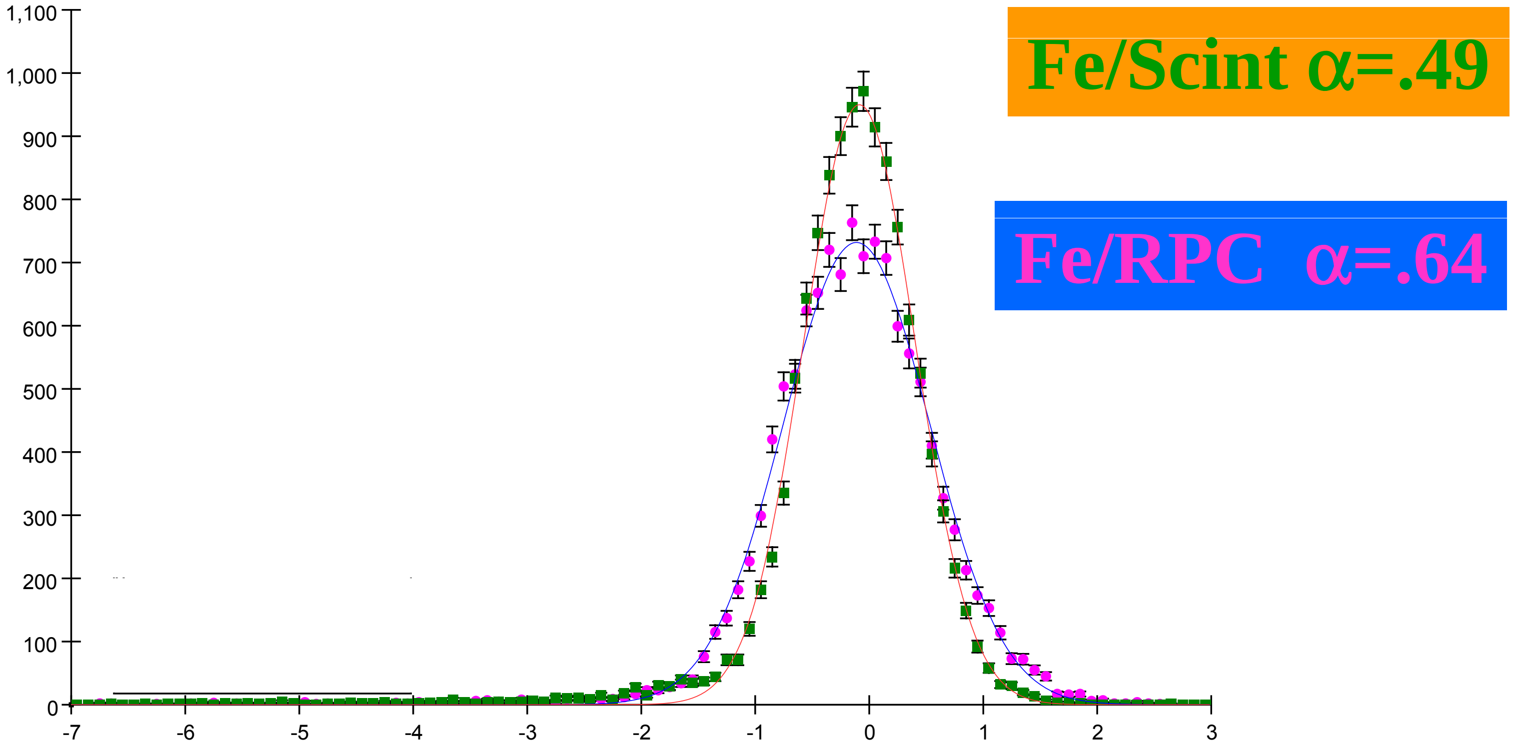


Jet Energy Resolution vs Jet Energy
Perfect Pattern Recognition



Energy Resolution for Neutrals in Jets

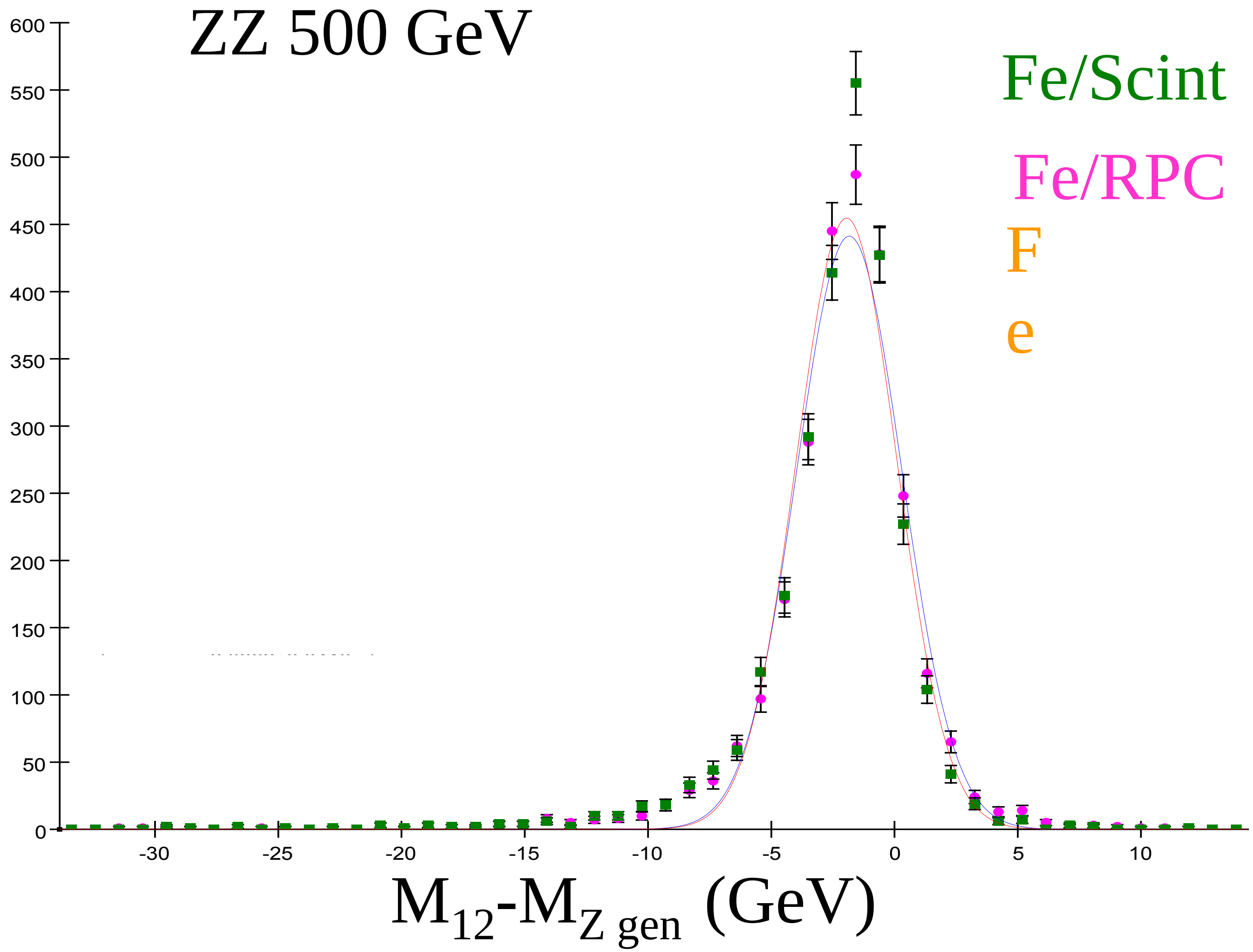
ZZ 500 Gev



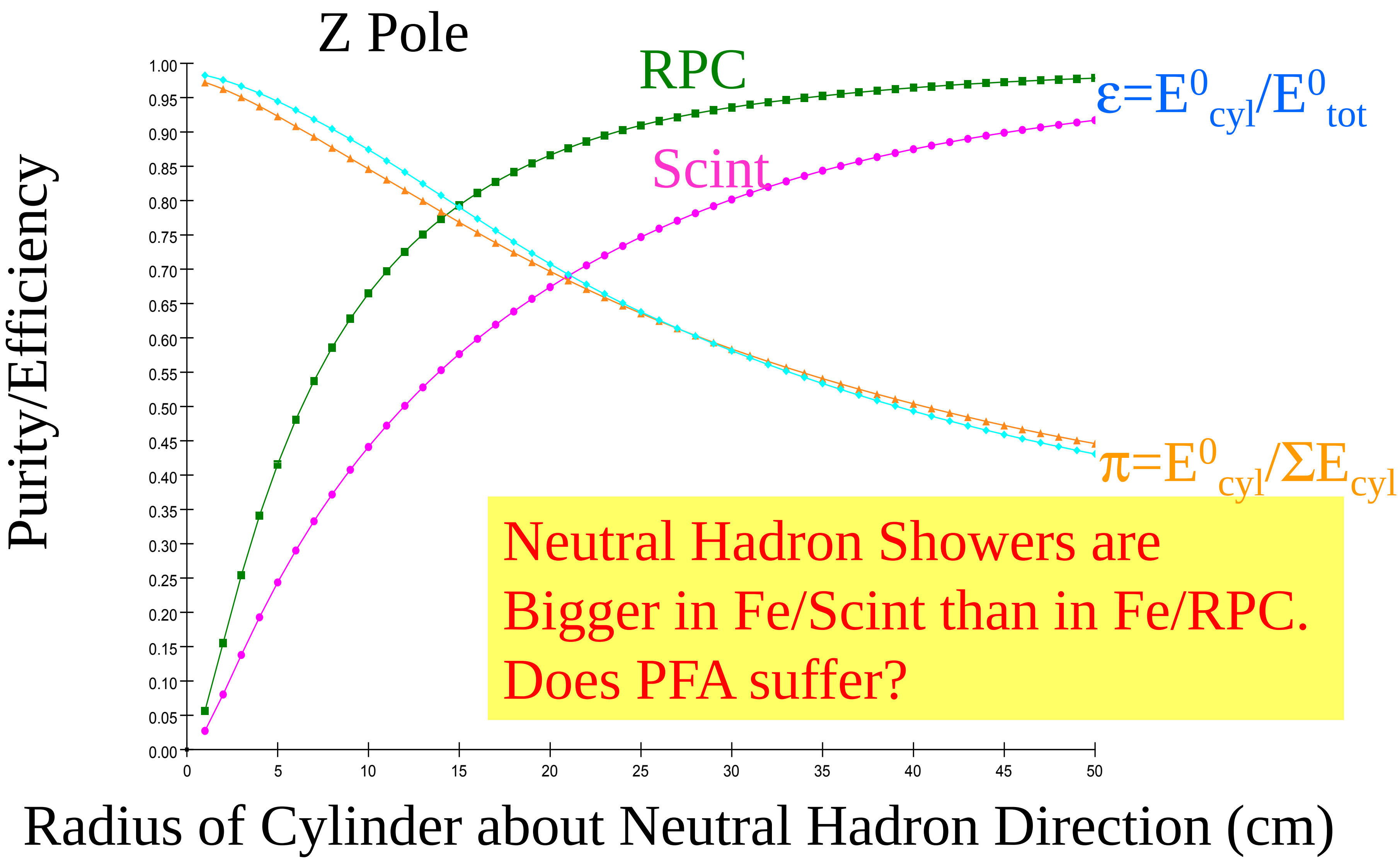
$(E^0_{meas} - E^0_{act})/\sqrt{E}$

Effect on Dijet Mass Resolution…Small

(still assuming perfect pattern reconstruction)



RPC/Scint Hadronic Shower Sizes



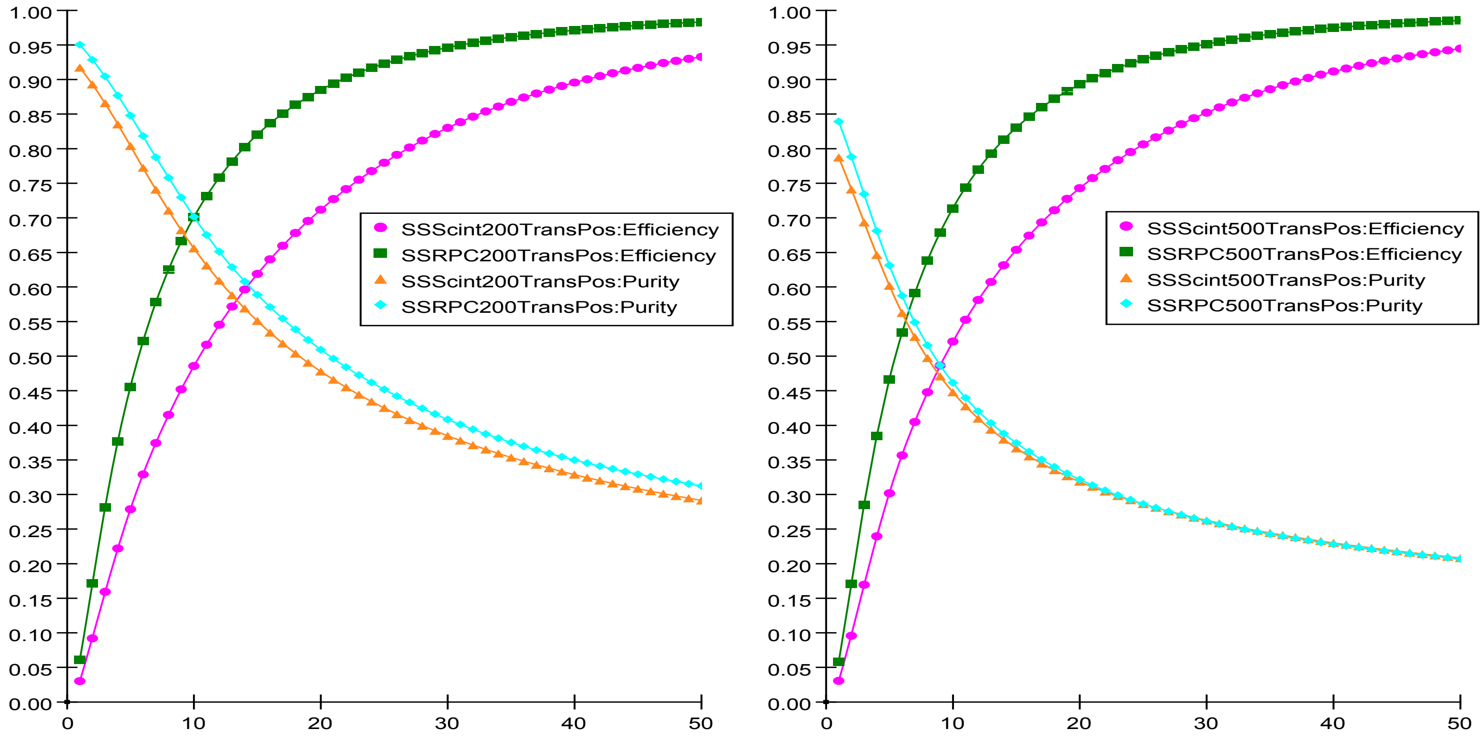
RPC/Scint Differences for PFA

Higher energies

100 GeV uds jets

250 GeV uds jets

Purity/Efficiency



Radius of Cylinder about Neutral Hadron Direction (cm)

Conclusions

Simulation studies are impacting design of SiD Calorimeters

- Fe/Scint Resolution is better than Fe/RPC for single neutral hadrons, and somewhat better for jets.
- Fe or Cu give better resolutions than W or Pb in the hcal.
- $>5\lambda$ total calorimeter thickness desirable.
- Digital readout for Fe/Scint, with 1 cm^2 pixels, better than analogue readout.
- Dijet mass resolution with perfect pattern recognition is comparable for Scint or RPCs.
- Shower sizes, potential confusion, larger in Scint than RPCs.

Sim studies will continue.

- Comparisons and contrasts with PFA studies
- Optimize SiD design