PFA Status and Plans
SiD Workshop April 9, 2007

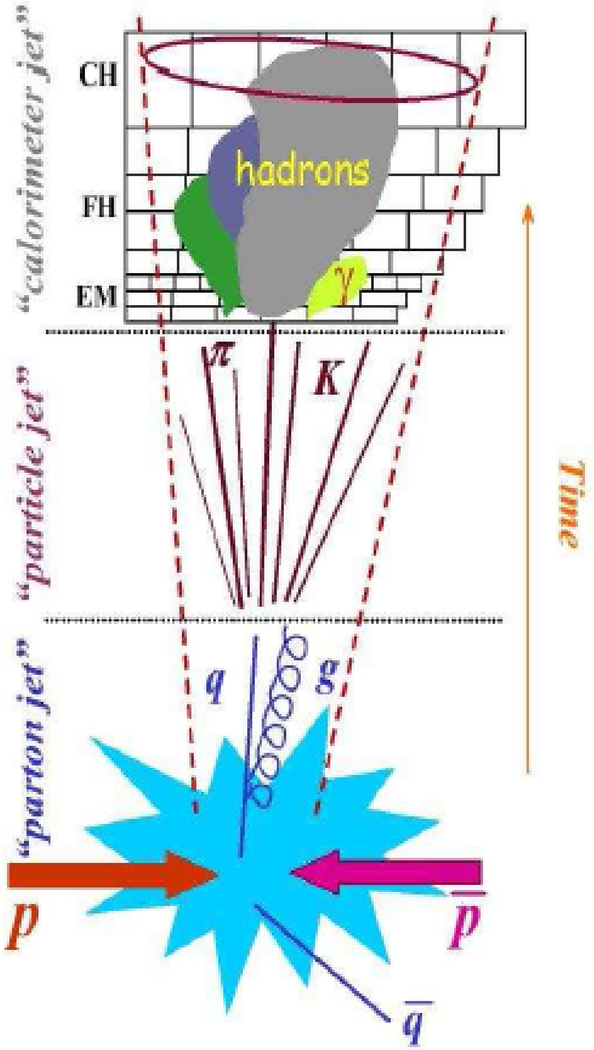
N. Graf, S. Magill

Motivation for PFA Jet Reconstruction

PFA Status – Individual PFA Performance

PFA Plans – Towards DCR and Beyond

Motivation for PFA Jet Reconstruction



- Calorimeter jet
  - Interaction of hadrons with calorimeter.
  - Collection of calorimeter cell energies.
- Particle jet
  - After hadronization and fragmentation.
  - Effect of hadronization is soft $\Rightarrow$ allows comparison between particle and parton jets.
- Parton jet
  - Hard scattering.
  - Additional showers.

From J. Kvita at CALOR06

Cal Jet -> *large correction* -> Particle Jet -> *small correction* -> Parton Jet

Jet Measurements – Fully Compensating Calorimetry

Conventional Calorimetry :

Jet measurement with a compensating calorimeter requires use of detector simulation to make the large correction to the particle level and a MC physics process generator to make the correction to the parton level -> compare to theoretical calculation of a fixed number of partons.

Potential problems :

- "Partial" compensation (i.e., energy dependent) is ~ no compensation.
- Large corrections from calorimeter jet to particle jet are dominated by fluctuations in particle showers in the calorimeter and compounded by overlapping particles.
- Complete reliance on MC since no handle on particle distributions – assumes separate correction from detector to particle and from particle to parton (not generally correct).

Jet Measurements – PFA Reconstruction

PFA Jet Reconstruction :

- Calorimeter Jet ~= Particle Jet
- Eliminates (or at least reduces) correction from detector to particle jet.
- Reduces dependence on MC by providing a handle on the intermediate step (particles) between detector and parton.

Potential problems :

- Requires high granularity -> large number of readout channels in calorimeter.
- Large shower fluctuations challenge ability to correctly associate calorimeter hits with particles.
- Must not be dominated by confusion in particle/shower association algorithms.
- Relies on shower separation in calorimeter -> poor performance for high energy jets?

Goals for PFA Development in SiD Context

Prove PFA concept works for jet reconstruction in the SiD Detector.

Show that significant improvement in measurement of dijet mass is obtained compared to conventional calorimeter-only results.

Understand energy and angular contributions to the dijet mass resolution and the confusion resulting from incorrect shower association.

Ultimately use the PFA to optimize the SiD detector design for the ILC.

Understand limitations in the application of PFAs, e.g., jet energy dependence.

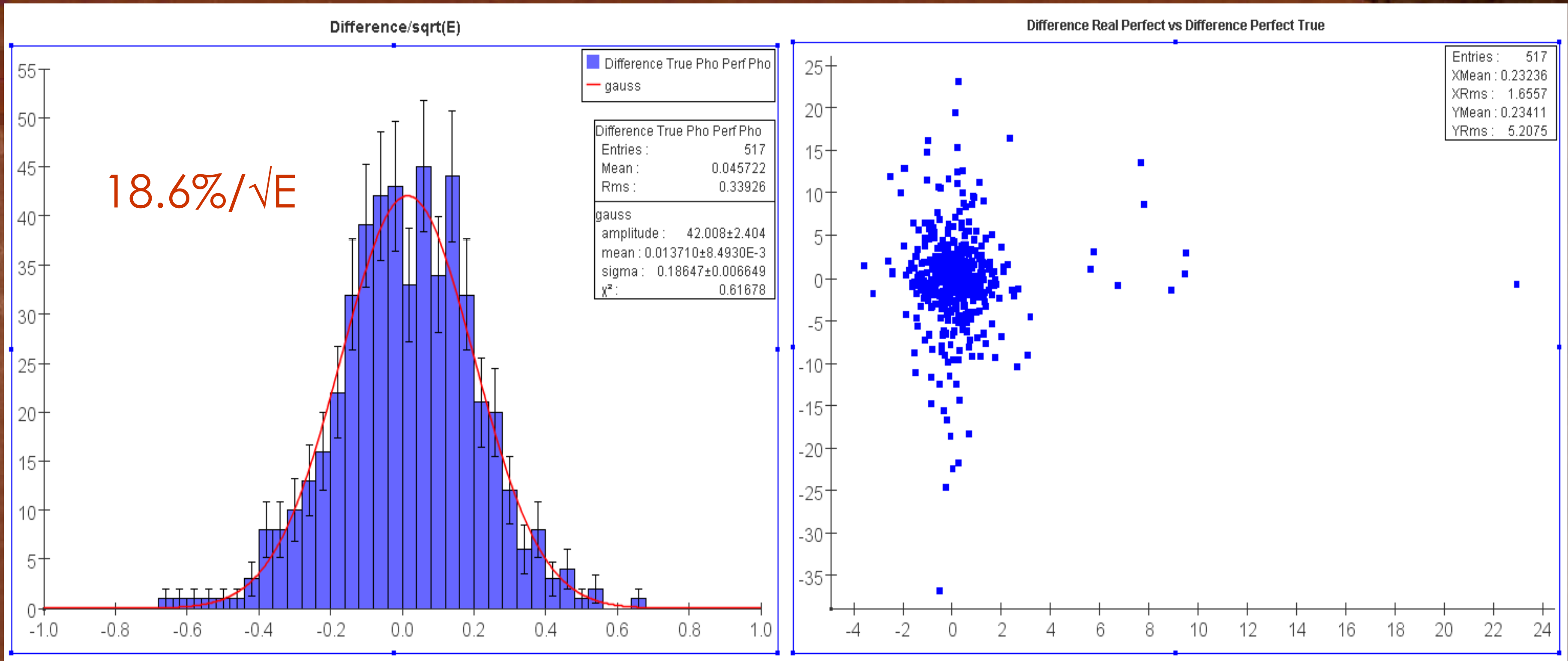
Following slides will illustrate the current status of PFA development for the SiD detector and plans for future effort.

Standard Detector Model Tools

Calorimeter Calibration

- Essential for PFA development, detector model comparison
- Method developed by R. Cassell
- Standard calibrations for at least 4 detector models

EM Calibration



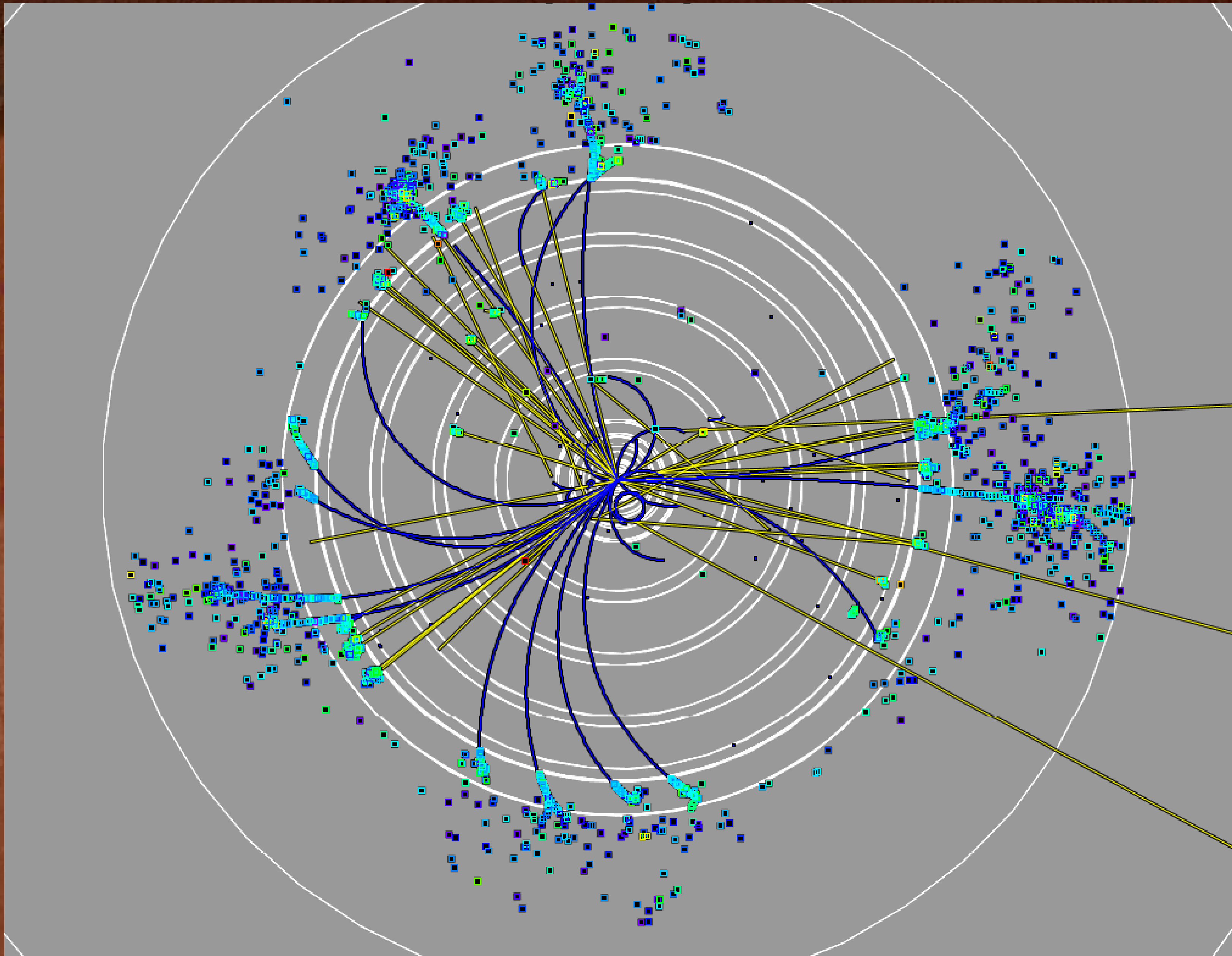
Standard Detector Model Tools

Perfect PFA Definition

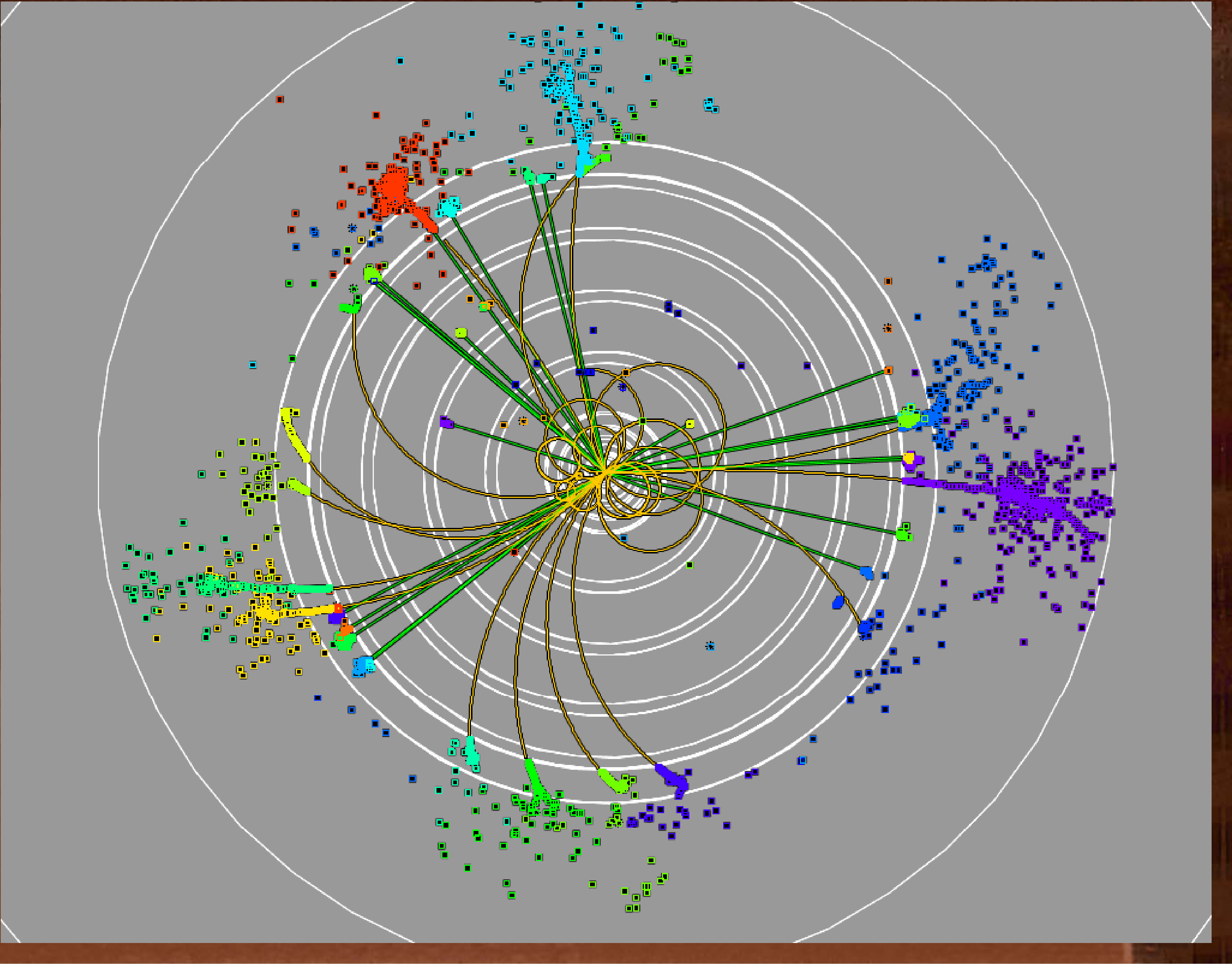
- Essential for PFA development, useful for detector model comparisons
- Based on Generator or Simulated Particles?
- Standard cheated tracks, cheated clusters

```
        // Set up the MC list for perfect PFA
        double rcut = 400.;  //  Bruce said 400 mm at meeting March 13
        double zcut = 400.;
//      CreateFinalStateMCParticleList mcListMakerGen = new CreateFinalStateMCParticleList("Gen");
        CreateFinalStateMCParticleList mcListMakerSim = new CreateFinalStateMCParticleList("Sim");
        mcListMakerSim.setRadiusCut(rcut);
        mcListMakerSim.setZCut(zcut);
//      add(mcListMakerGen);
        add(mcListMakerSim);
//      String mcListGen = "GenFinalStateParticles";
        String mcListSim = "SimFinalStateParticles";
        String mcList = mcListSim; // Can choose the Gen or Sim list here

        String Tname = "RefinedCheatTracks";
        add(new CheatTrackDriver());

        String Cname = "PerfectCheatClusters";
        String[] collections = {"EcalBarrDigiHits","EcalEndcapDigiHits","HcalBarrDigiHits","HcalEndcapDigiHits"};
        add (new CheatClusterDriver(collections,Cname));

        String CRPname = "CheatReconstructedParticles";
        CheatParticleDriver cpd = new CheatParticleDriver(Cname,Tname,mcList);
        //  Inputs Cheated Tracks, Cheated Clusters, and MC particle list to create Cheated Particles
        cpd.setOutputName(CRPname);
        add(cpd);

        // now make (more realistic) cheat tracks, etc with PPR driver
        String outName = "PerfectRecoParticles";
        int minT = 0;
        int minC = 0;
        PPRParticleDriver d = new PPRParticleDriver(CRPname, outName);
        d.setMinTrackerHits(minT);
        d.setMinCalorimeterHits(minC);
        add(d);

        //  this makes perfect tracks from the perfect particles
        PerfectTrackDriver perftrk = new PerfectTrackDriver();
        perftrk.setParticleNames(outName);
        perftrk.setTrackNames("PerfectTracks");
        add(perftrk);
```

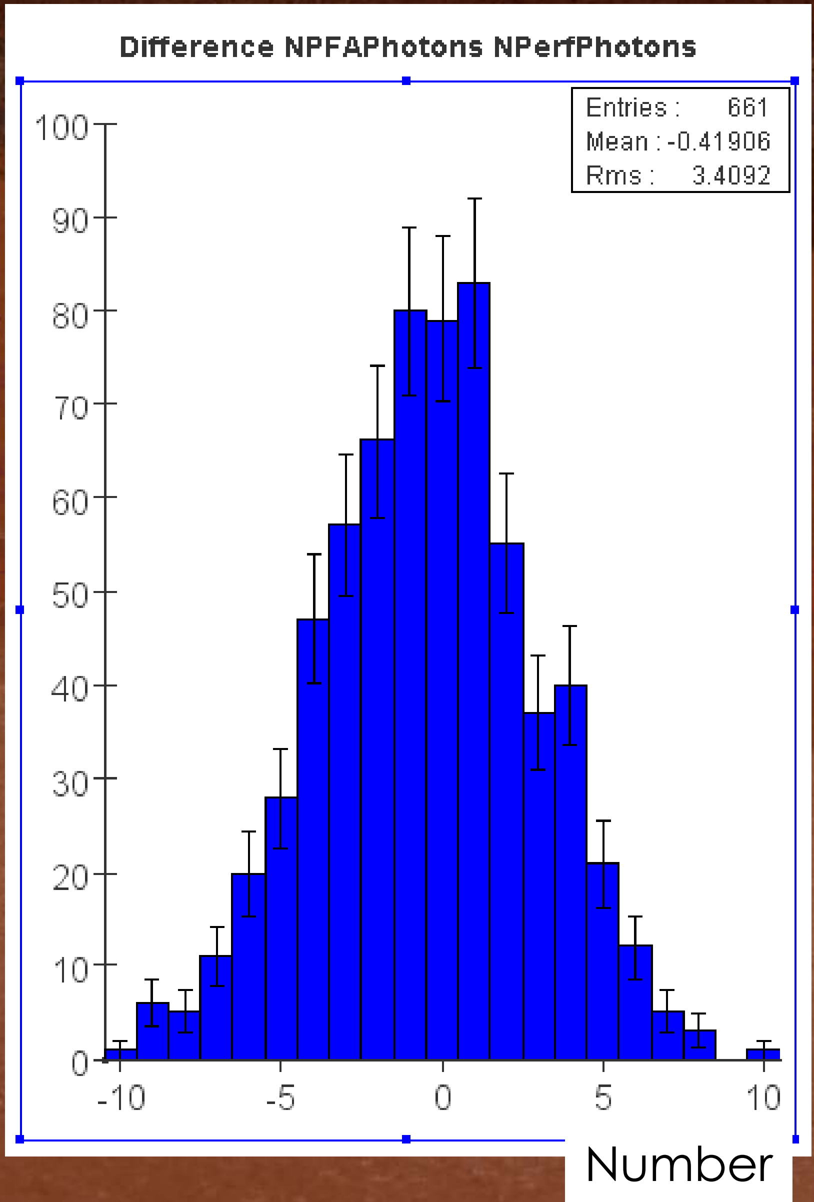
ZPole event, all MC Particles, all DigiSim hits

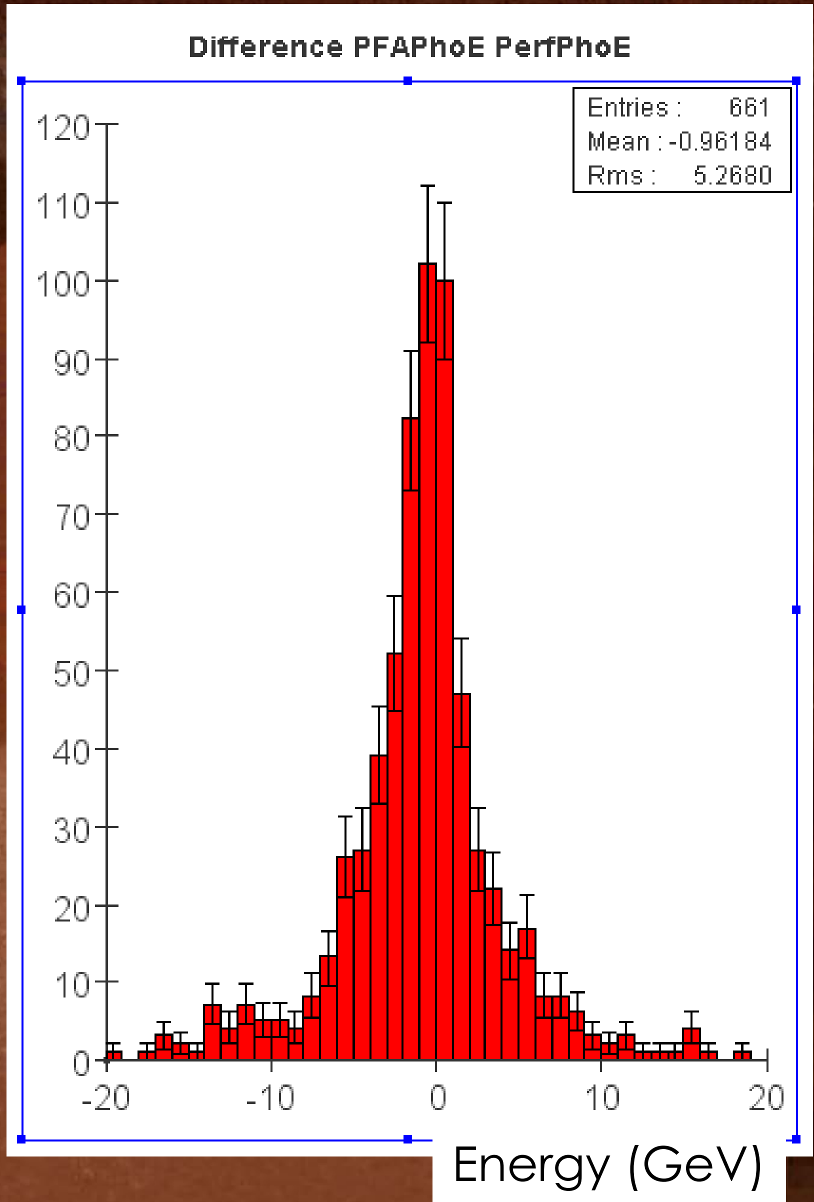


ZPole event, Perfect PFA Particles, Perfect Charged Particle Hits



Photon-Finding with Longitudinal H-Matrix





Photon-Finding Optimization

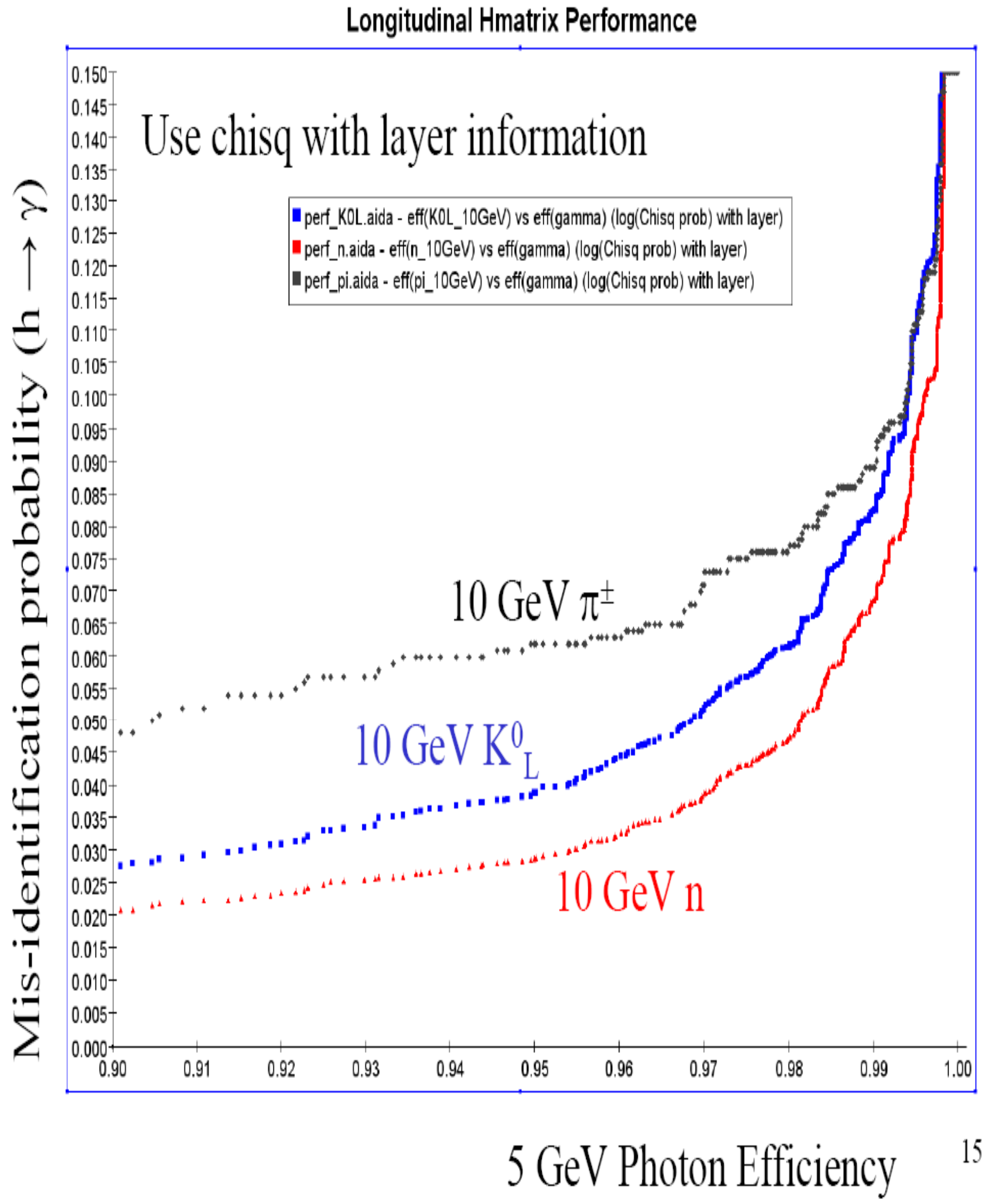
Update on Photon ID using a Longitudinal H-Matrix

Graham W. Wilson
Univ. of Kansas
April 3rd 2007

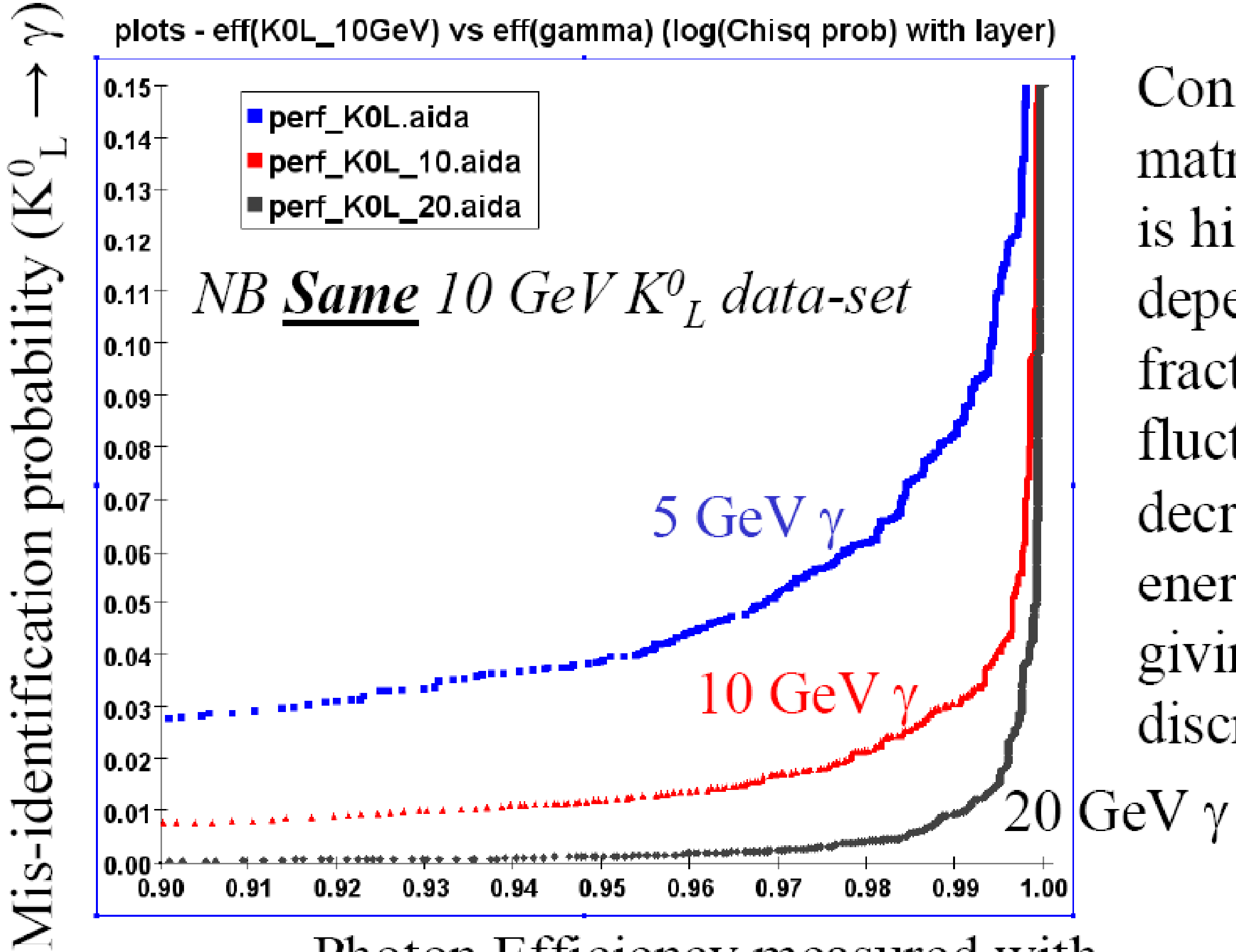
Further H-matrix studies (with Eric Benavidez).

See Sept 19th 2006 for previous report

Full chisq with start layer info



10 GeV K^0_L analyzed with 5 GeV, 10 GeV, 20 GeV photon H-matrices



Photon Efficiency measured with photons of same energy as the H-matrix

Conclusion: H-matrix performance is highly energy dependent. The fractional fluctuations decrease at high energy for photons, giving more discrimination

Progress on PFA at Z-pole

L. Xia

	Barrel events	All events
ALCPG Vancouver workshop (7/2006)	46. %/sqrt(E)	49. %/sqrt(E)
Last SiD workshop (10/2006, SLAC)	38.2 %/sqrt(E)	41.6 %/sqrt(E)
SiD calorimeter meeting (11/2006)	35.9 %/sqrt(E)	39.1 %/sqrt(E)
This workshop (4/2007, Fermilab)	%/sqrt(E)	%/sqrt(E)

- Compare to
  - LDC (PendoraPFA) 30. %/sqrt(E)
  - GLD 29.8 %/sqrt(E)

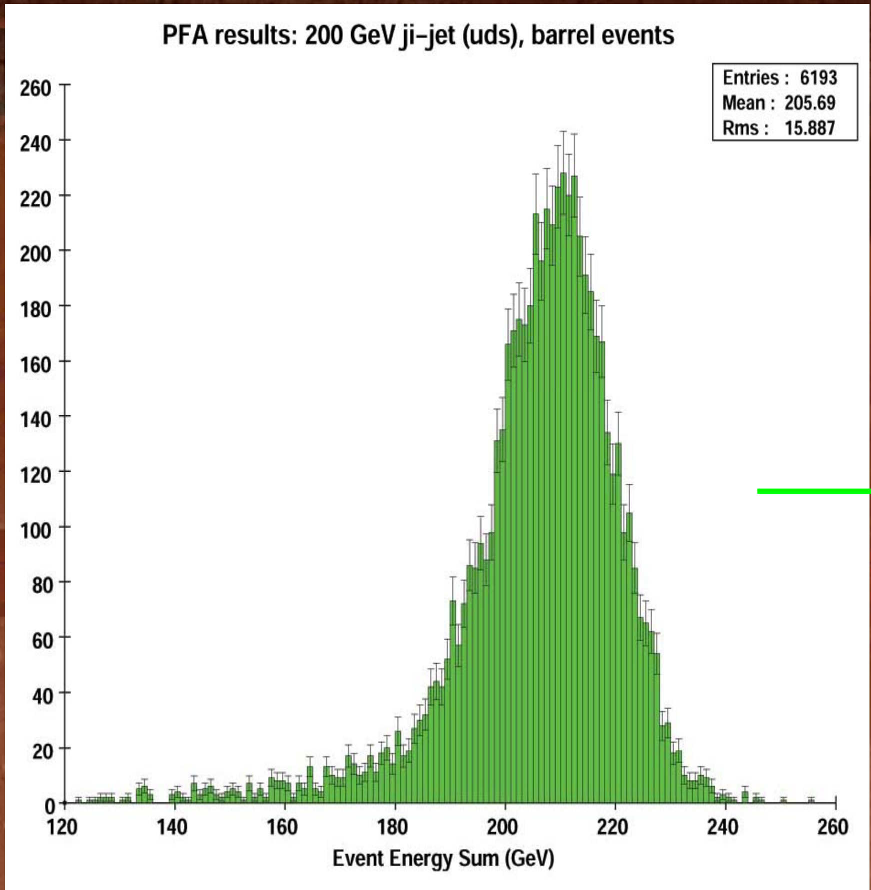
Using Z-pole tuned PFA at higher energies

Barrel events	200 GeV	350-360 GeV	500 GeV
• SiD calorimeter meeting (10/2006)	132. %/sqrt(E)		201. %/sqrt(E)
• Last SiD workshop (10/2006, SLAC)	77. %/sqrt(E)		140. %/sqrt(E)
• SiD calorimeter meeting (11/2006)	66.7 %/sqrt(E)		127. %/sqrt(E)
• This workshop (4/2007, Fermilab)	? %/sqrt(E)		? %/sqrt(E)

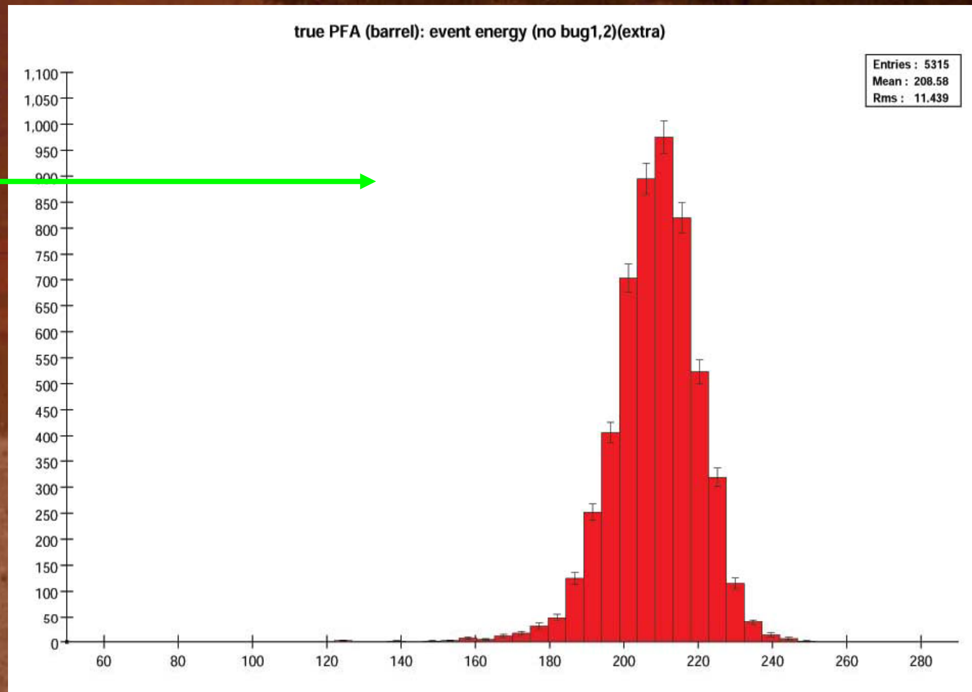
- Compare to
  - LDC (PendoraPFA)

	200 GeV	350-360 GeV	500 GeV
LDC (PendoraPFA)	37. %/sqrt(E)	57. %/sqrt(E)	75. %/sqrt(E)
GLD	~45 %/sqrt(E)	~68 %/sqrt(E)	~85 %/sqrt(E)

Shower leakage: di-jet at 200 GeV



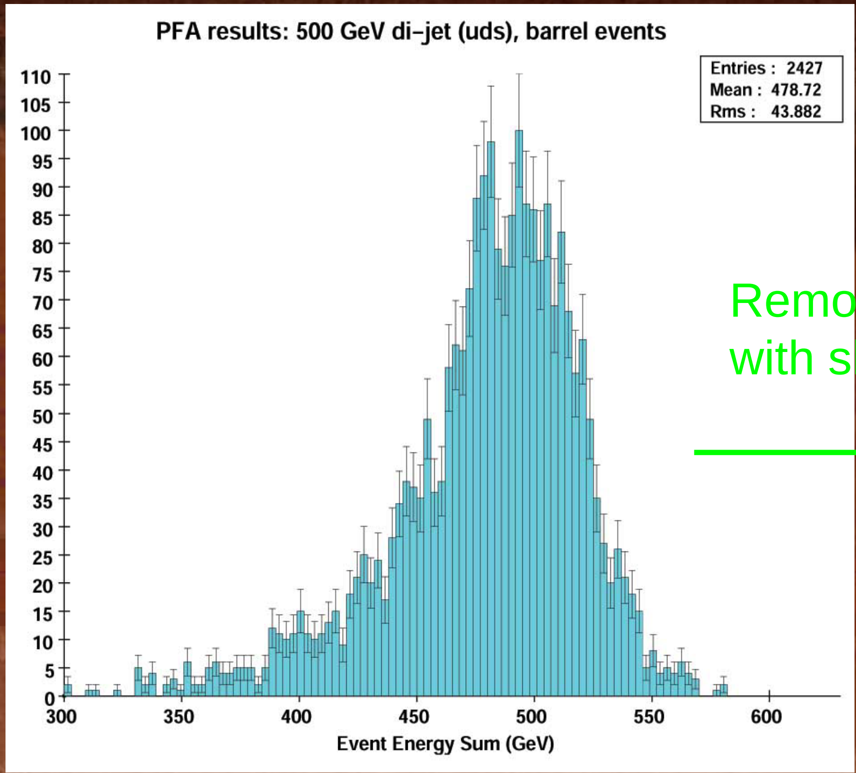
Removing events
with shower leakage



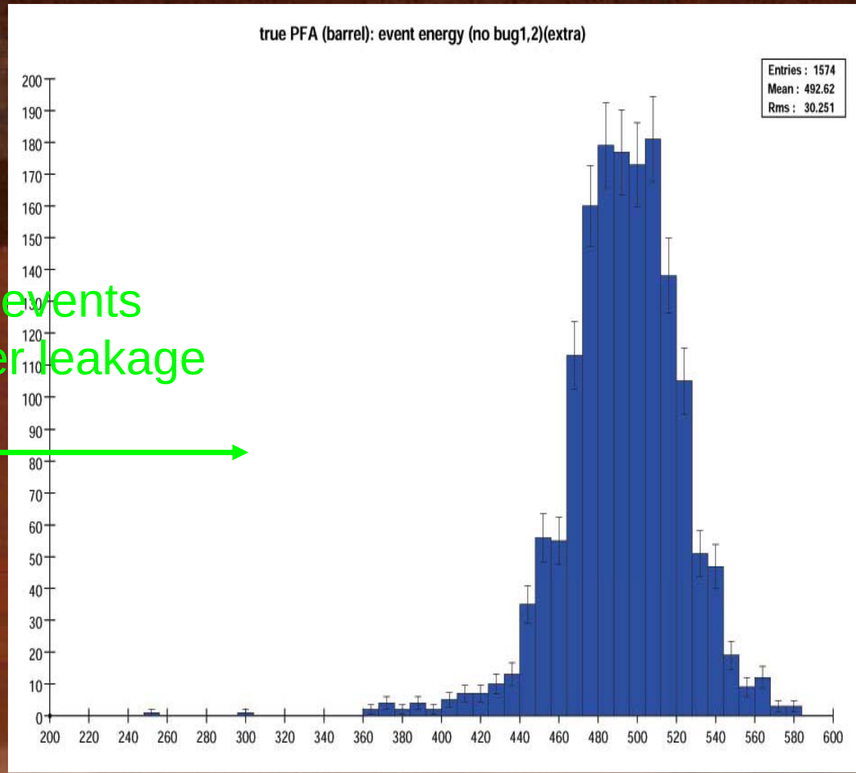
RMS = 15.89 GeV
RMS90 = 9.632 GeV
[66.7%/sqrt(E)]

RMS = 11.44 GeV
RMS90 = 8.45 GeV
[~59%/sqrt(E)]

Shower leakage: di-jet at 500 GeV



Removing events
with shower leakage



RMS = 43.88 GeV
RMS90 = 28.11 GeV
[127.%/sqrt(E)]

RMS = 30.25 GeV
RMS90 = 21.4 GeV
[~97%/sqrt(E)]

- Shower leakage affect PFA performance at high energy
- Events with heavy shower leakage could be identified by hits in the muon detectors
- Use hits in the muon detectors to estimate shower leakage?

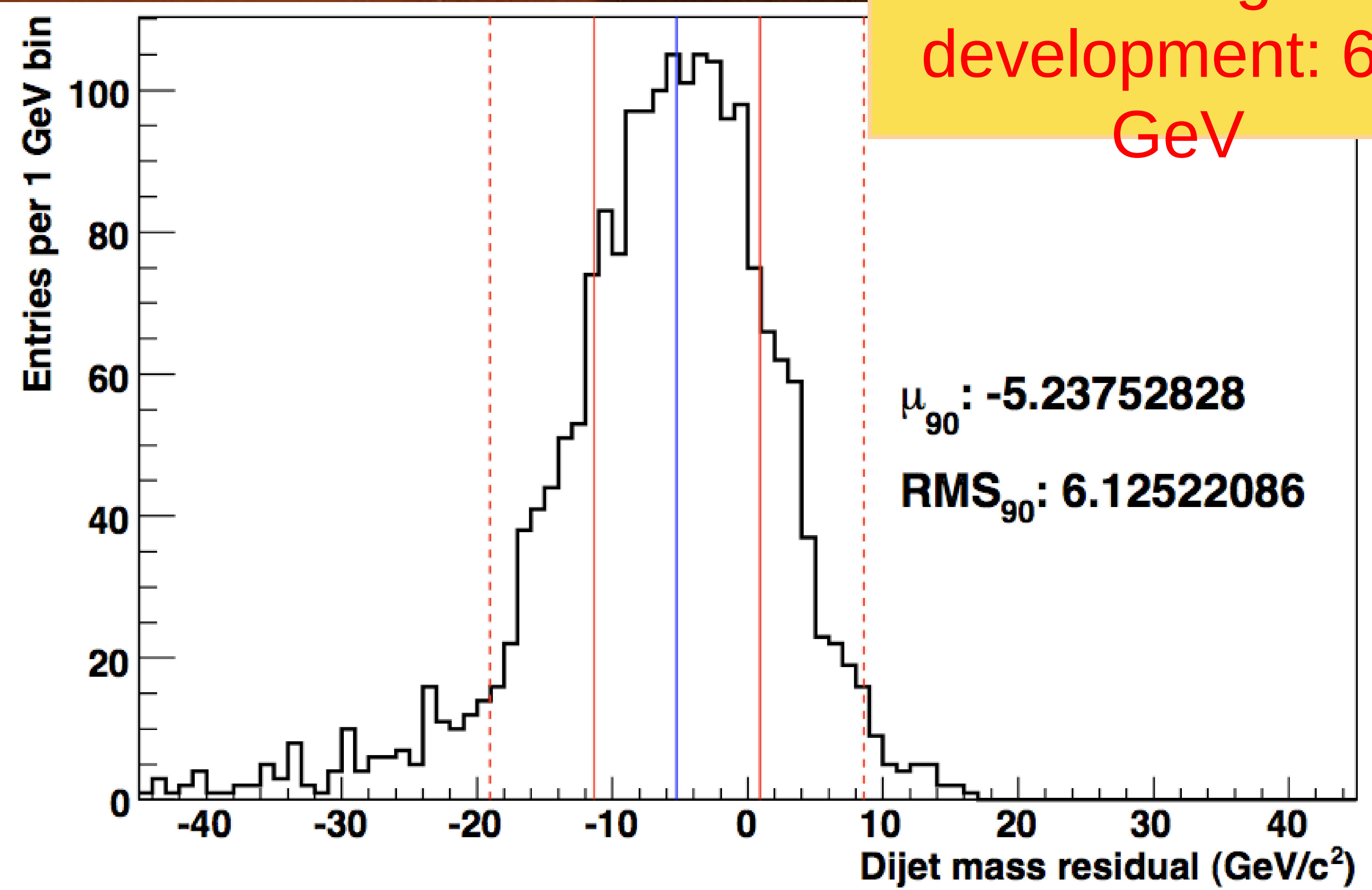
ZZ -> qqνν

acme0605_W_Scintillator

M. Charles

Mass residuals in barrel

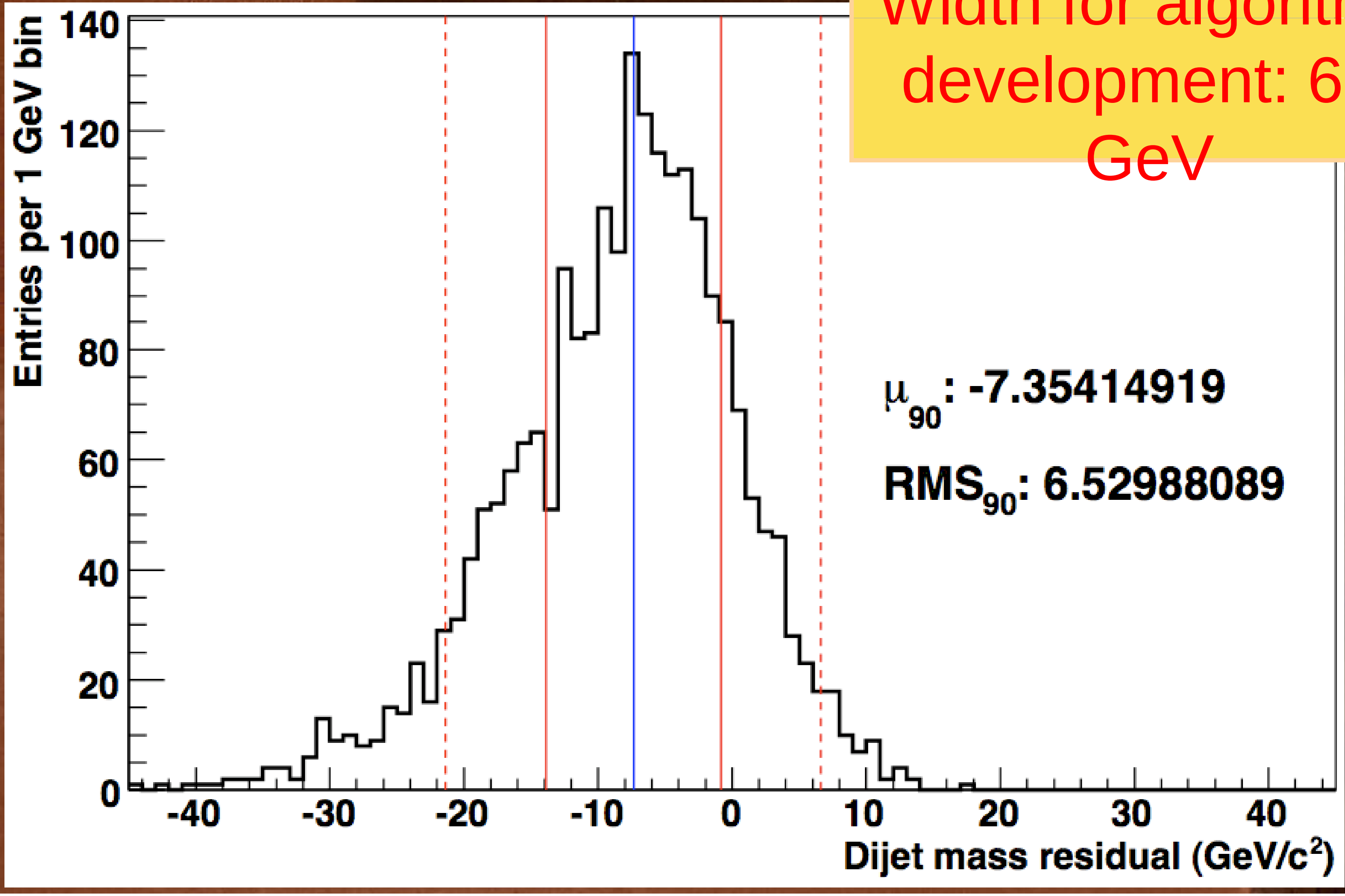
Width for algorithm development: 6.1 GeV



acme0605_steel_scint

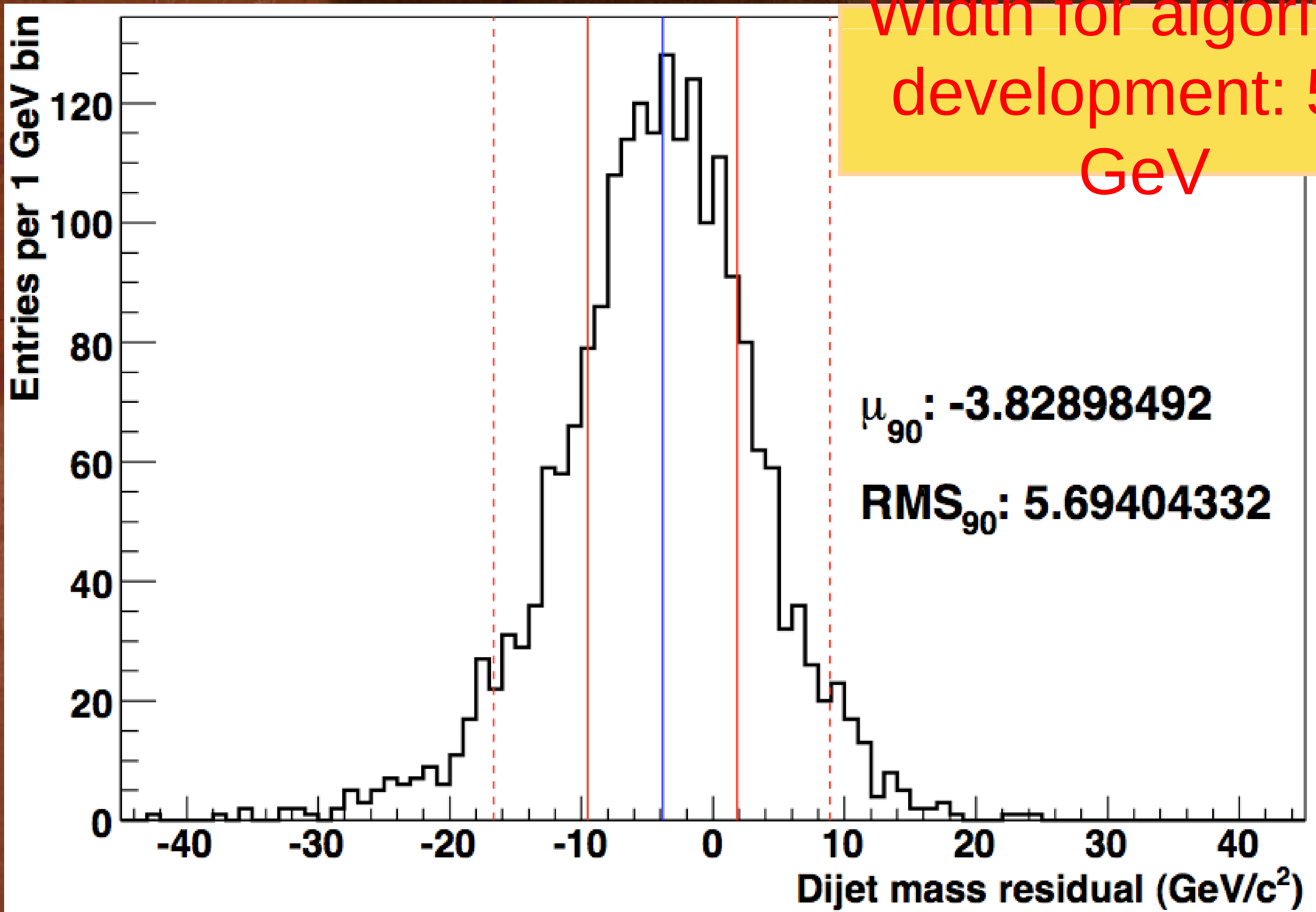
Mass residuals in barrel

Width for algorithm development: 6.5 GeV



acme0605_w_rpc

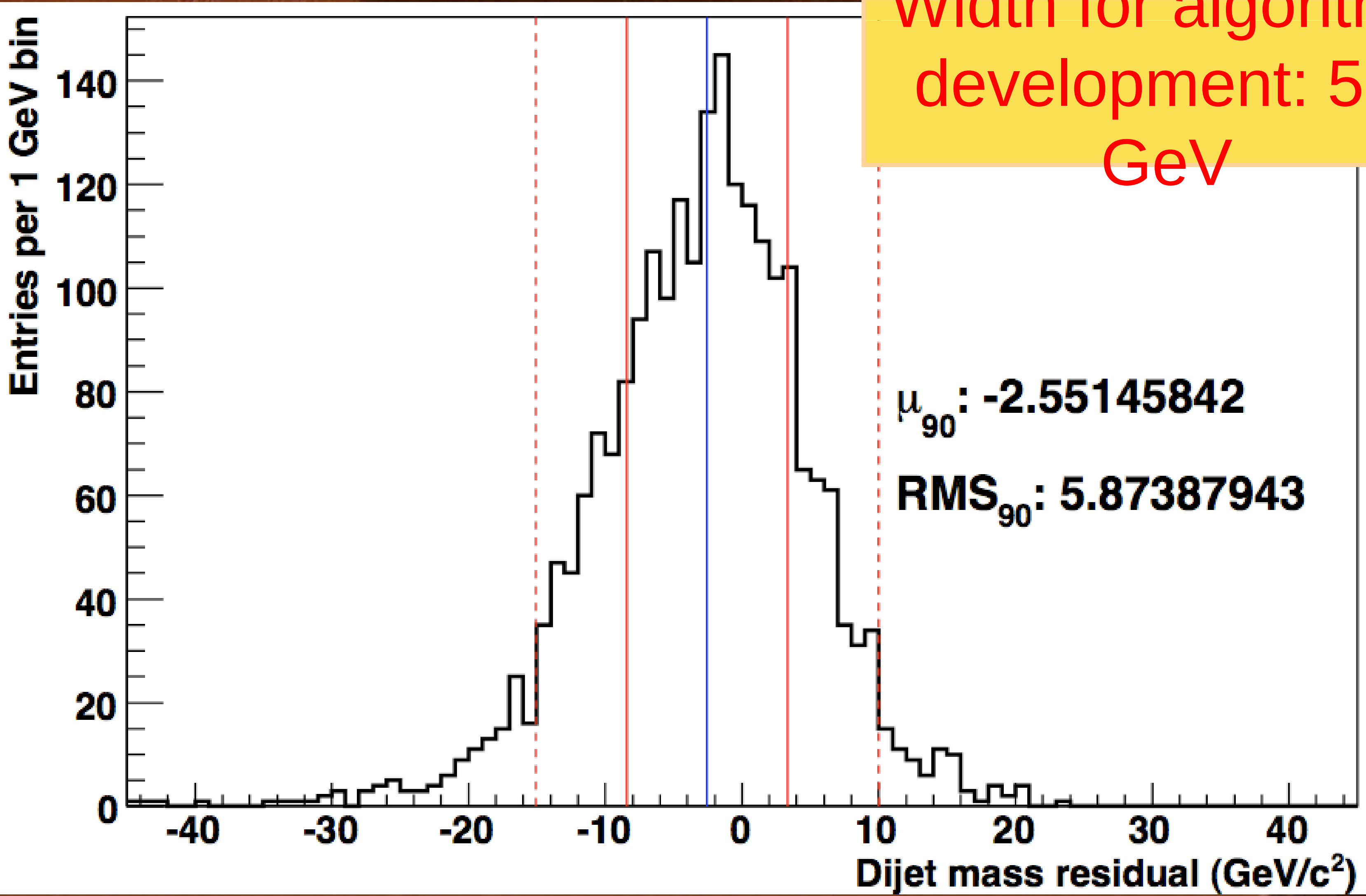
Mass residuals in barrel



Width for algorithm development: 5.7 GeV acme0605_steel_rpc

Mass residuals in barrel

Width for algorithm development: 5.9 GeV

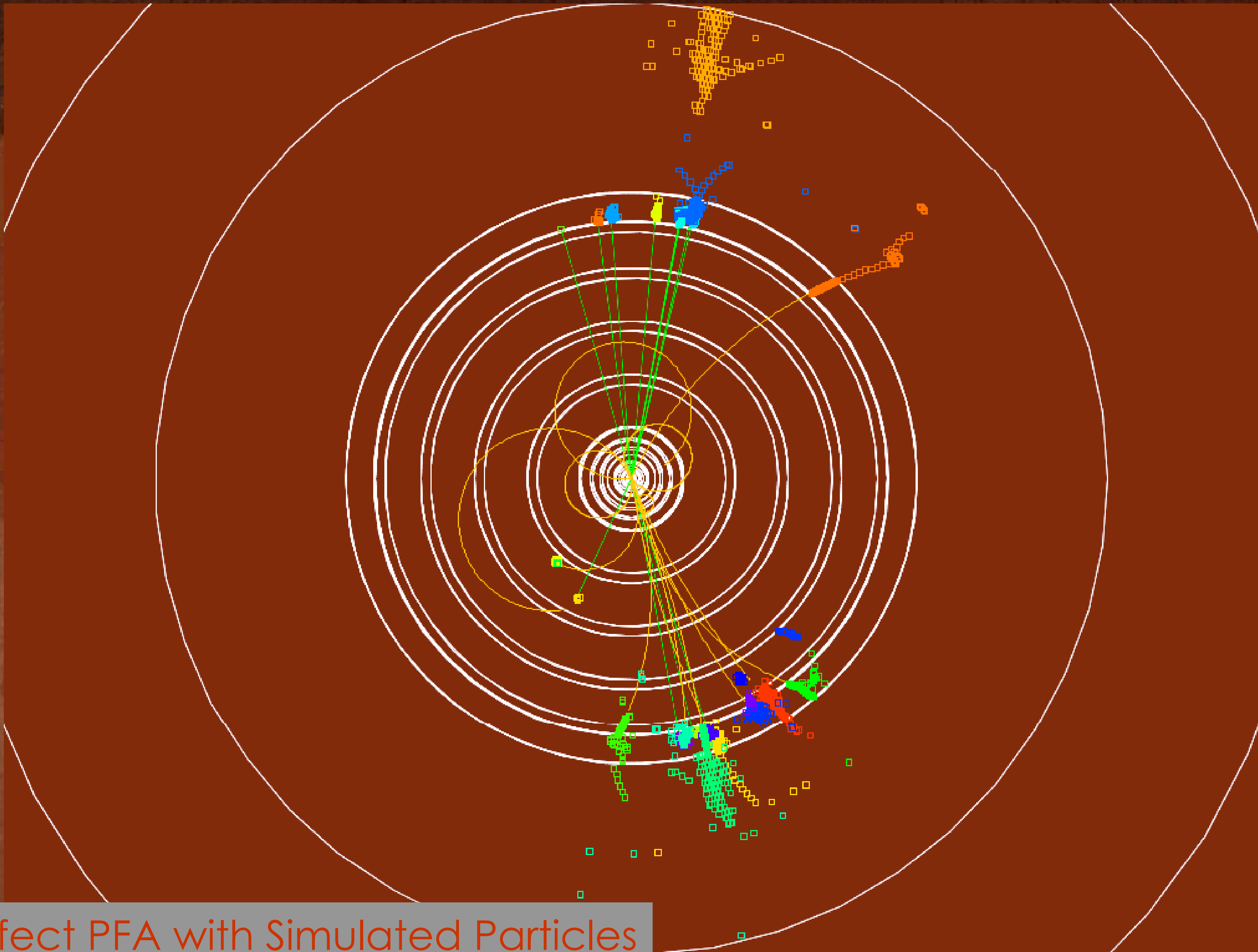


Design	RMS90 of mass (including Γ)	RMS90 of residuals (no Γ)	Bias
acme0605 [w/scint]	6.9 GeV	6.1 GeV	−5.2 GeV
acme0605_steel_scint	7.3 GeV	6.5 GeV	−7.4 GeV
acme0605_w_rpc	6.6 GeV	5.7 GeV	−3.8 GeV
acme0605_steel_rpc	6.8 GeV	5.9 GeV	−2.6 GeV

For this real (i.e. confused) PFA:

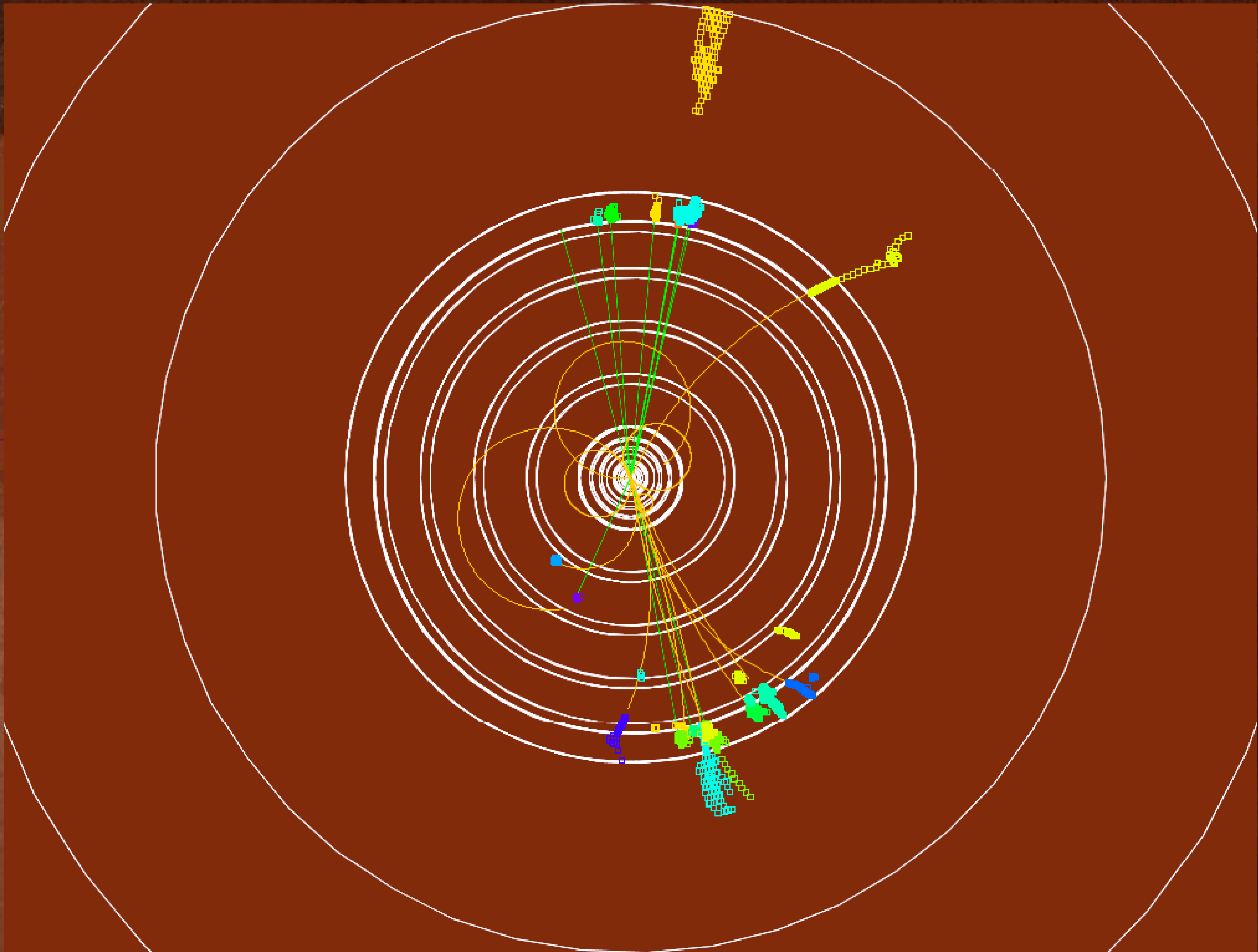
- RPCs give noticeably better resolution and smaller bias than scintillators
- Tungsten gives somewhat better resolution than steel

ZZ event, Perfect ReconstructedParticles, Perfect CAL Clusters

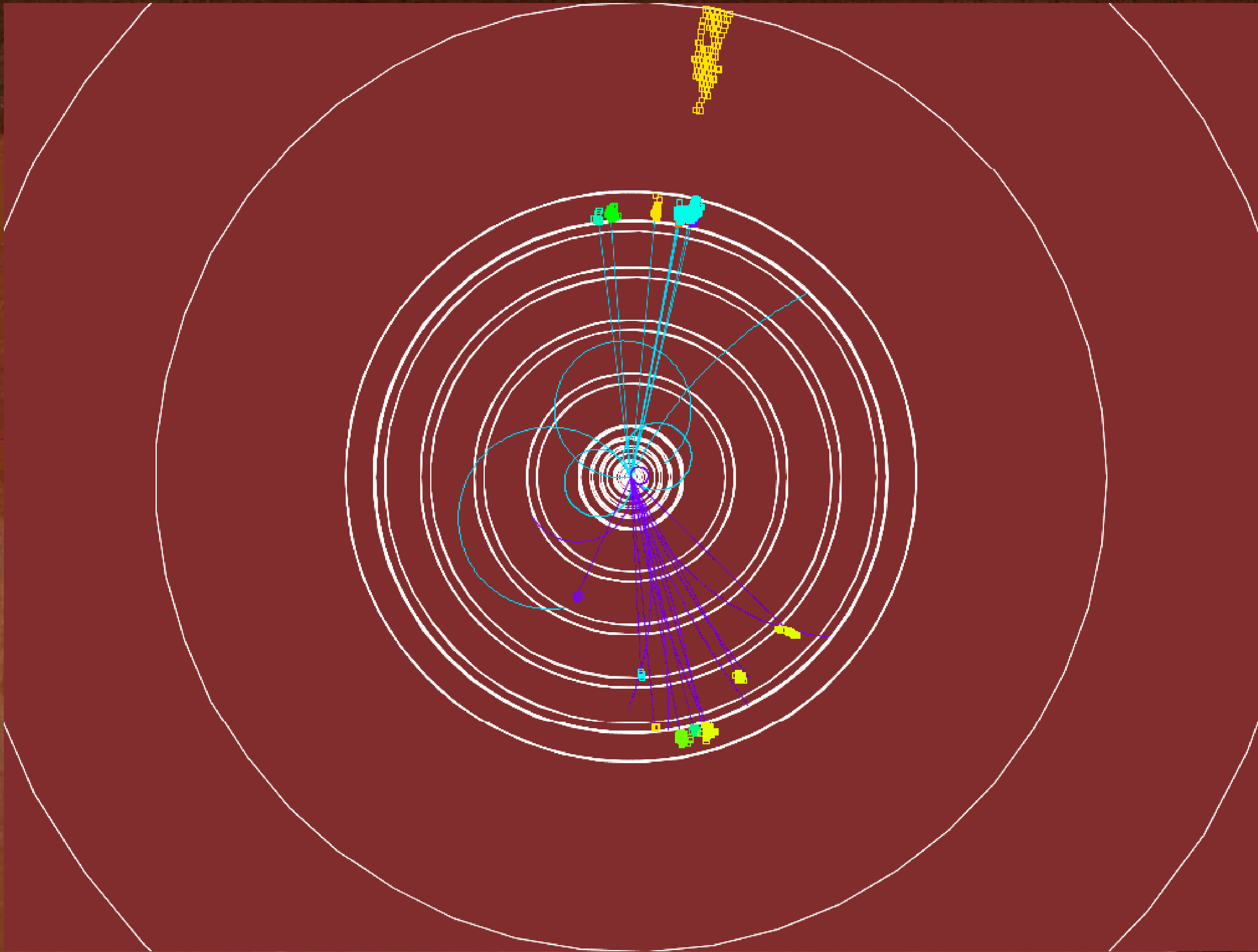


Perfect PFA with Simulated Particles

ZZ event, PFA Results



ZZ event, PFA Jets



Plans for PFA Development

e+e- -> ZZ -> qq + νν @ 500 GeV

- Development of PFAs on ~120 GeV jets – most common ILC jets
- Unambiguous dijet mass allows PFA performance to be evaluated w/o jet combination confusion
- PFA performance at constant mass, different jet E (compare to ZPole)
- dE/E, dθ/θ -> dM/M characterization with jet E

e+e- -> ZH

e+e- -> ZZ -> qqqq @ 500 GeV

- 4 jets - same jet E, but filling more of detector
- Same PFA performance as above?
- Use for detector parameter evaluations (B-field, IR, granularity, etc.)

e+e- -> tt @ 500 GeV

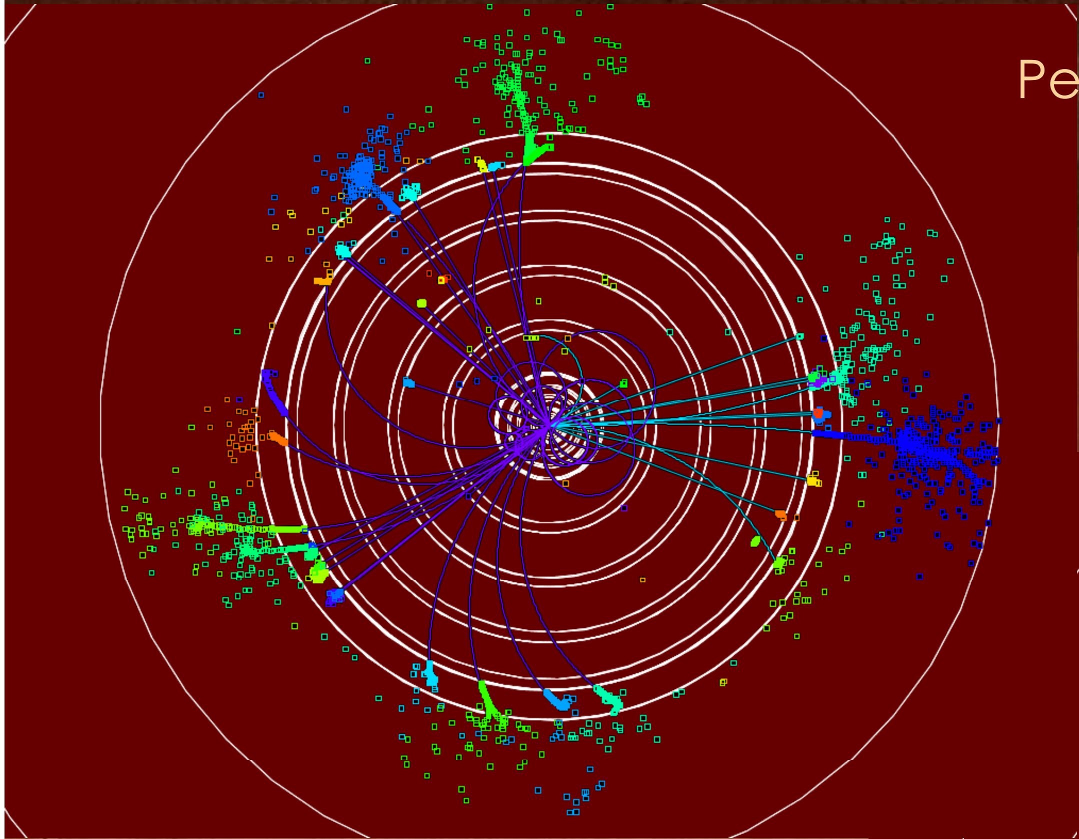
- Lower E jets, but 6 – fuller detector

e+e- -> qq @ 500 GeV

- 250 GeV jets – challenge for PFA, not physics

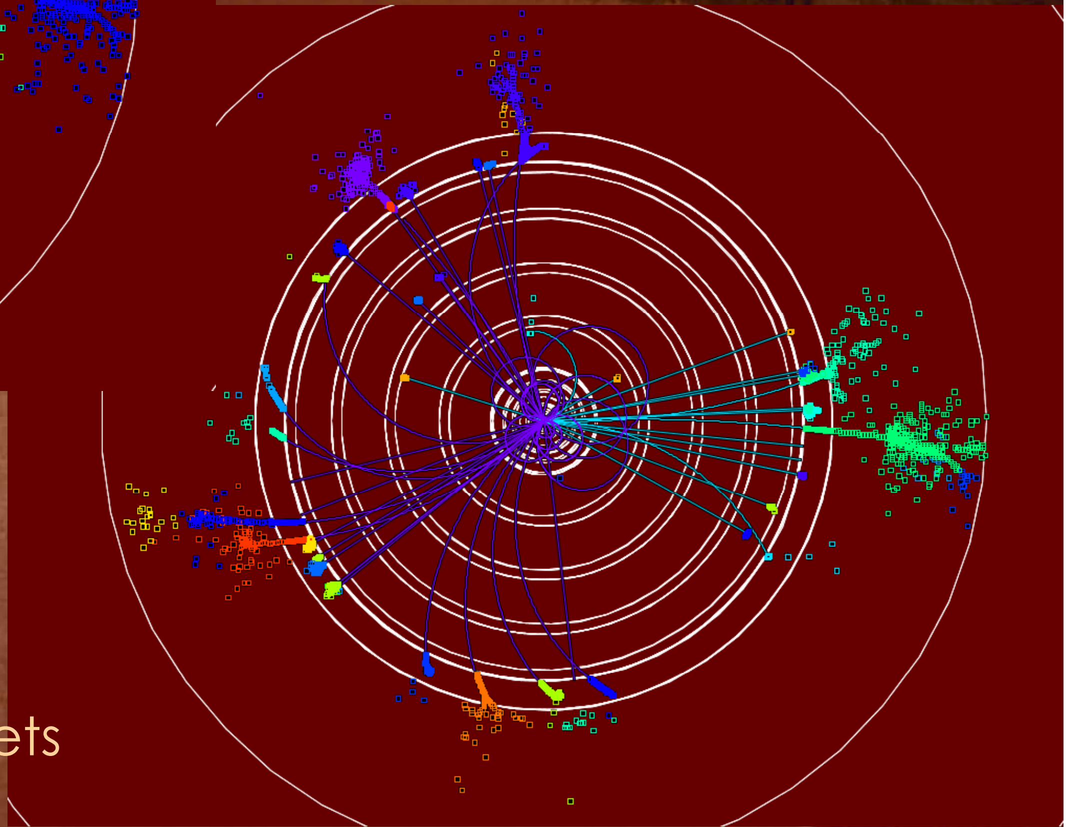
PFA Development – ZPole Jets

Perfect PFA Jets

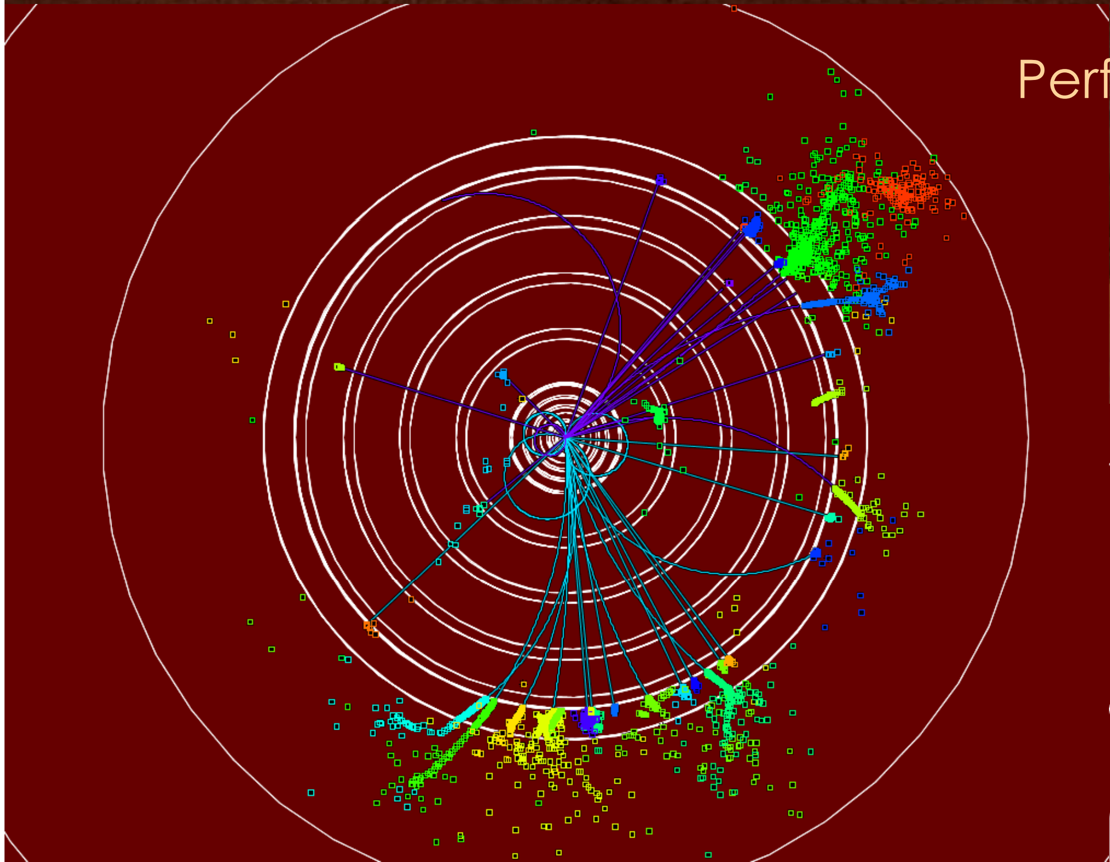


kT jet algorithm in 2 jet mode

PFA Jets

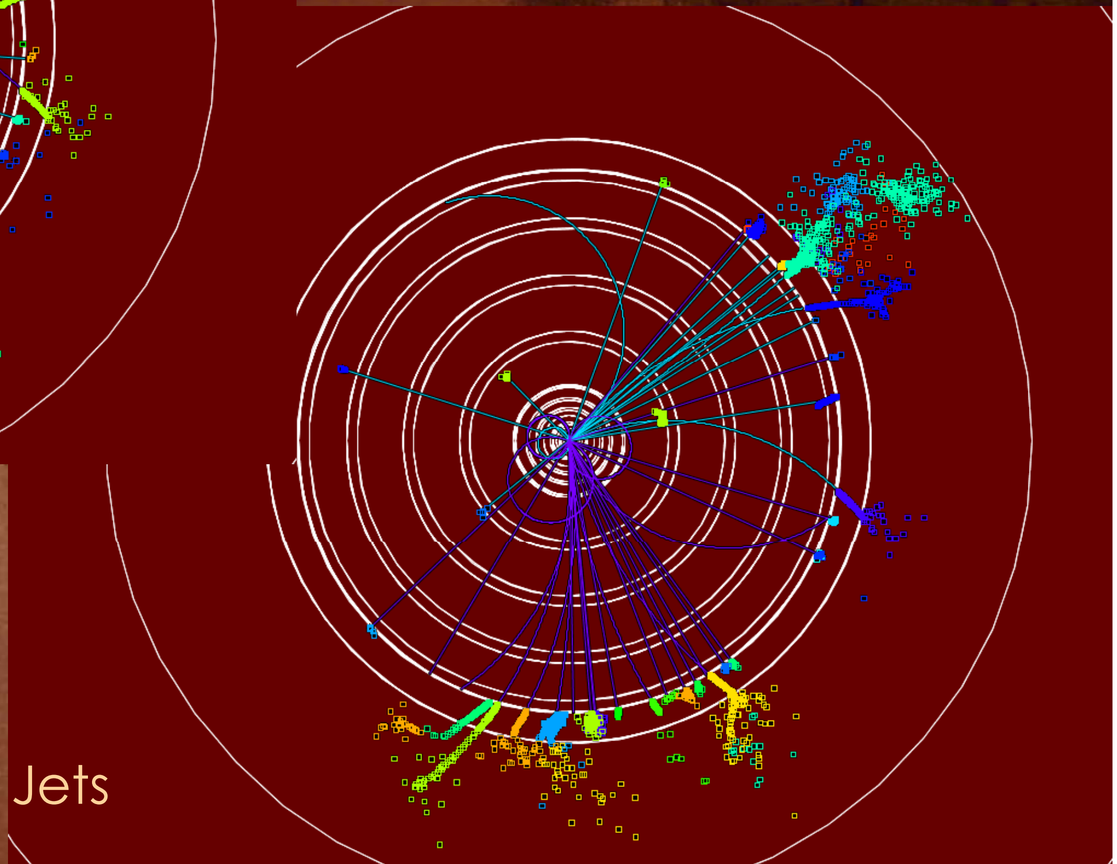


Plans for PFA Development – ZZ -> qqνν Jets



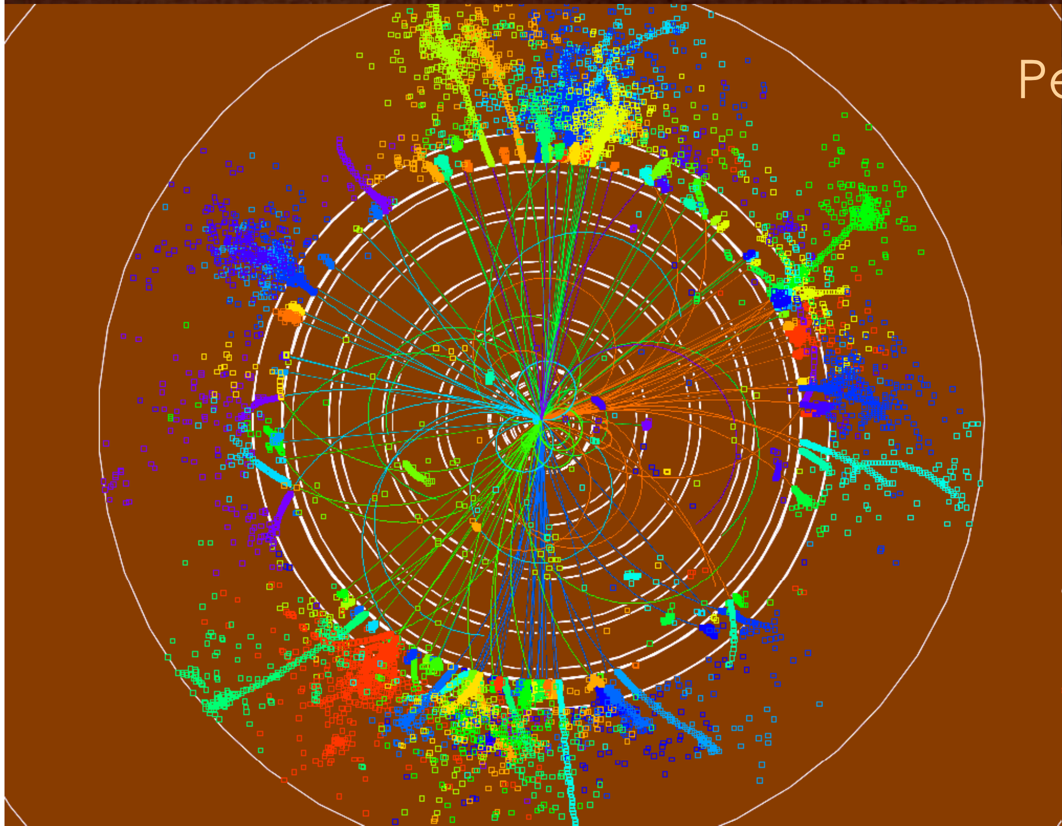
Perfect PFA Jets

kT jet algorithm in 2 jet mode

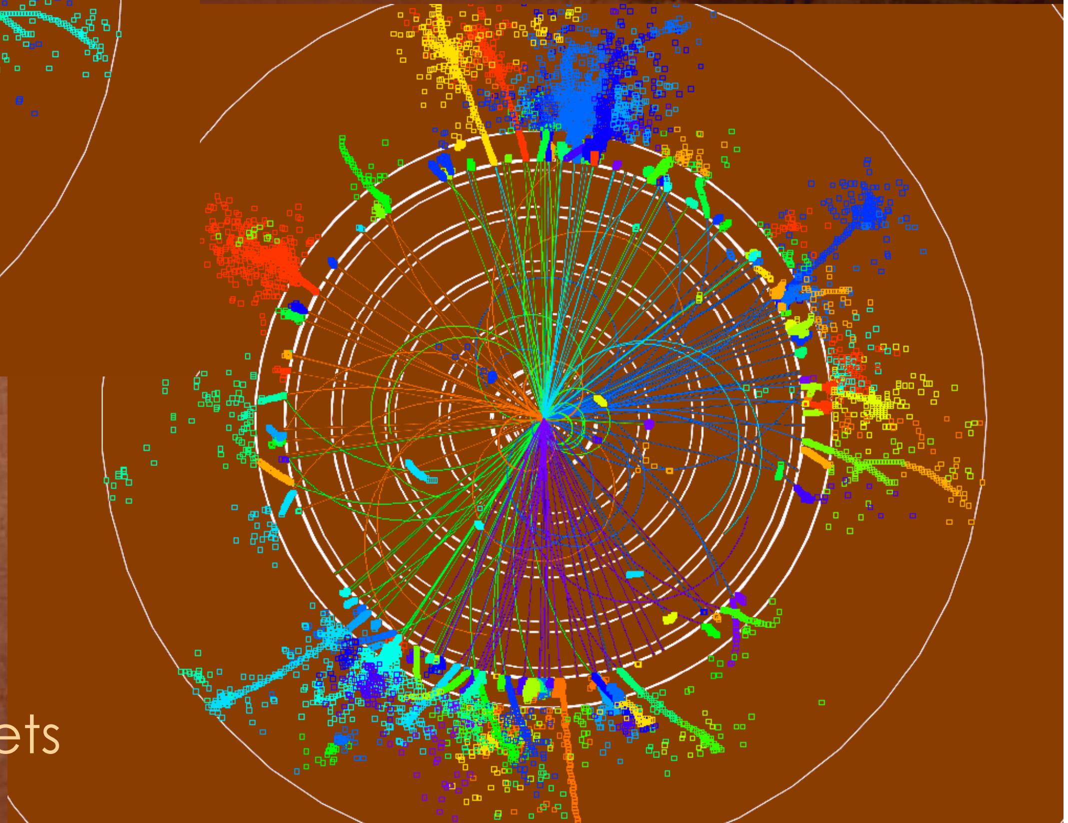


PFA Jets

Plans for PFA Development – tt Jets



Perfect PFA Jets



PFA Jets

6 jets in both events using
ycut = 0.00025 in kT jet algorithm

Plans for PFA Development with SiD Model

By Paris Sim Workshop (May 2-4) :

- Finish standard Perfect PFA definition
- Use Perfect PFA to study contributions to dM/M w/o confusion (dE_j/E_j, $d\theta_{12}/\theta_{12}$)
- Results for PFA on ZZ -> $qq\nu\nu$ @ 500 GeV (Barrel, then whole detector)
- Results for PFA on ZZ -> qqqq @ 500 GeV

By LCWS-DESY :

- PFA performance on ZZ -> $qq\nu\nu$ @ 500 GeV, ZZ -> qqqq @ 500 GeV, tt @ 500 GeV
- E_j dependence of dijet mass (3 points including ZPole, single Z,W?)
- PFA performance on ZH benchmark process?
- With template, study confusion contribution to PFA (E_j dependence? by comparing with ZPole results)
- Add real track reconstruction to PFA?

Plans for PFA Development with SiD Model

After LCWS-DESY :

- Start detector model comparisons using PFA on ZH @ 500 GeV
  - B-field variations
  - ECAL IR variations
  - HCAL technology/parameter variations
  - LDC, GLD comparisons with SiD variants
- Ongoing optimization of PFA algorithms - π^0 reconstruction, cluster fragment pointing analyses, etc.
- Explore limits of PFA performance – very high E (250 GeV jets, physics at 1 TeV CM?, 2 TeV at NLC?

By end 2007 :

- Optimized SiD Detector for ILC @ 500 GeV
- Characterization of PFA performance for SiD model variants
- Physics Benchmark studies with SiD and real PFA analysis
- Towards merger with another concept?

Summary

- Finishing development of tools necessary for PFA development
  - Calibration method for detector models
  - Perfect PFA prescription
- Finished and released PFA Template
  - Cluster algorithm substitution
  - CAL hit/cluster accounting
- PFA development emphasis on DiJets at 500 GeV CM
- Optimization of photon finder
- Closing in on path to PFA/Detector optimization