SiD PFA Status and Plans

Andy White, UTA

SiD Phone meeting, Dec 6, 2007

SiD PFA Status and Plans

- Goal(s)

- Organization/meetings

- PFA basics

- Which PFA?

- SiD PFA examples

- Perfect PFA

- Real PFA performance

- Towards the LOI

- Benchmarking and PFAs

-Issues – manpower, convergence, timescale, use of PFAs up to 1 TeV??

Goal for SiD PFA

- Principal focus is the SiD LOI – October 2008

- We will have O(10) benchmark processes defined by the RD…plus some of our own to highlight SiD performance.

- PFA and Benchmarking have been discussing starting to use a “Perfect PFA” for initial benchmark studies (more on this later…).

- Ultimately we want to use a fully developed SiD PFA to
a) optimize the SiD detector design, *and*

b) demonstrate the SiD physics performance

SiD PFA organization/meetings

Currently involved:

Ron Cassell, Dhiman Chakraborty, Mat Charles, Ray Cowan, Norman Graf, Guilherme Lima, Steve Magill, Jose Repond, Marcel Stanitzki, Andy White, Lei Xia, Vishnu Zutshi … but only 3-4 FTEs!

Regular weekly meetings: Wednesday 10.30am – 12pm CDT

-> updates, performance comparisons, cross checks, bug identification and fixing,

PFA - Basics

PFA: an algorithmic problem of making the correct assignments of energy depositions in the calorimeter system:

Component	Detector	Frac. of jet energy	Particle Resolution	Jet Energy Resolution
Charged Particles ($X^{\pm}$)	Tracker	0.6	10^{-4} E_X	neg.
Photons (γ)	ECAL	0.3	$0.11\sqrt{E_\gamma}$	$0.06\sqrt{E_{jet}}$
Neutral Hadrons (h^0)	HCAL	0.1	$0.4\sqrt{E_h}$	$0.13\sqrt{E_{jet}}$

$0.14\sqrt{E_{jet}}$

$$\sigma_{jet}^2 = \sigma_{x^{\pm}}^2 + \sigma_{\gamma}^2 + \sigma_{h^0}^2 + \sigma_{confusion}^2 + \sigma_{threshold}^2 + \ldots$$

Quantitative goal: for jets σ/E ~3-4%

This equivalent to $\sigma \sim 0.3\sqrt{E}$ at the Z-pole

Matt Charles, ALCPG07 - many efforts:

What PFAs are there?

There are many:

In Europe:

- Mark Thomson (PandoraPFA)
- Alexei Raspereza (Wolf)
- Oliver Wendt (TrackBasedPFA)

In Asia:

- Tamaki Yoshioka et al

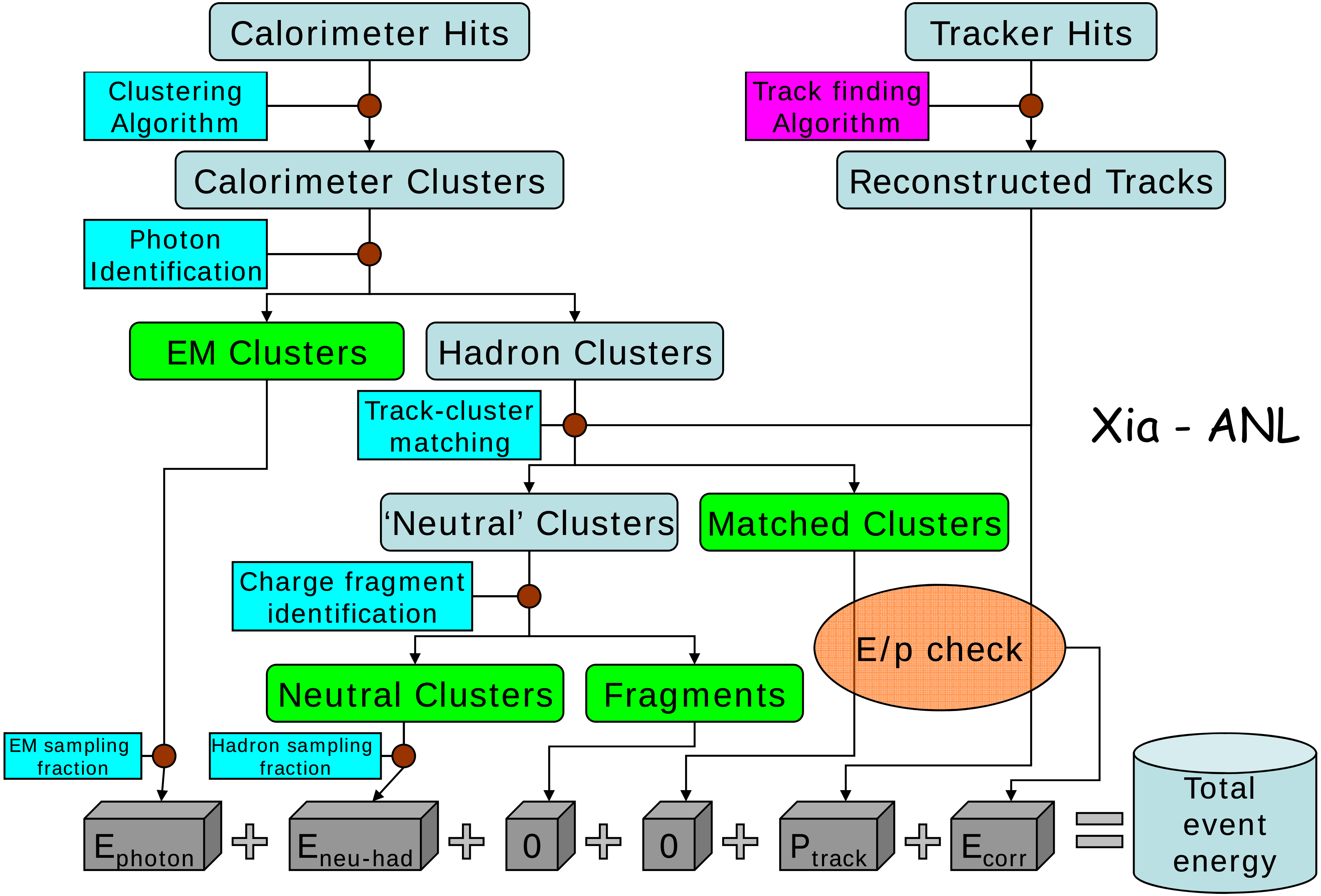
In North America:

- Mat Charles
- Steve Magill
- Lei Xia (Density-based)
- NIU (Directed tree)

... plus more components at various stages of integration:

- Photon finders and identifiers (e.g. H-matrix)
- Muon finders
- π^0 reconstruction
- Calibration
- Tools (e.g. DigiSim, template)
- ...

PFA: an example of a real implementation



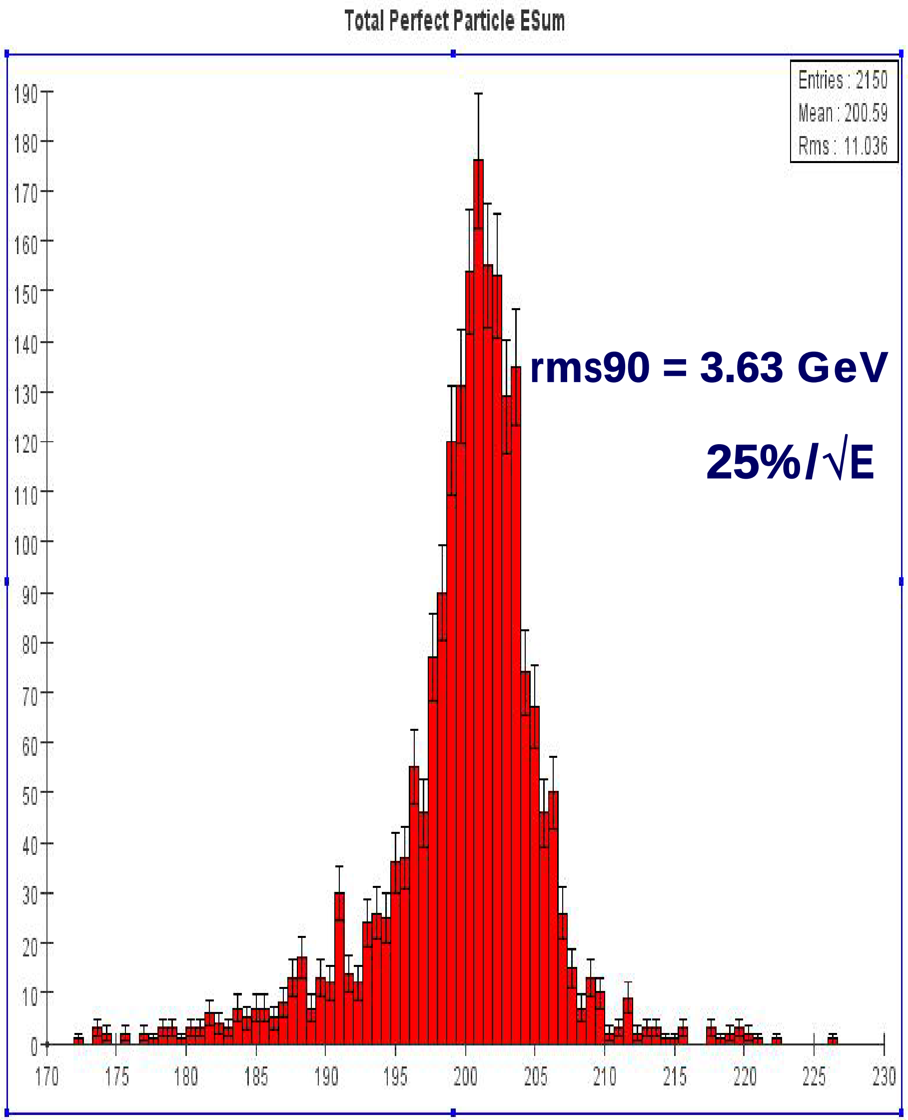
Example: Structured Clustering Algorithm

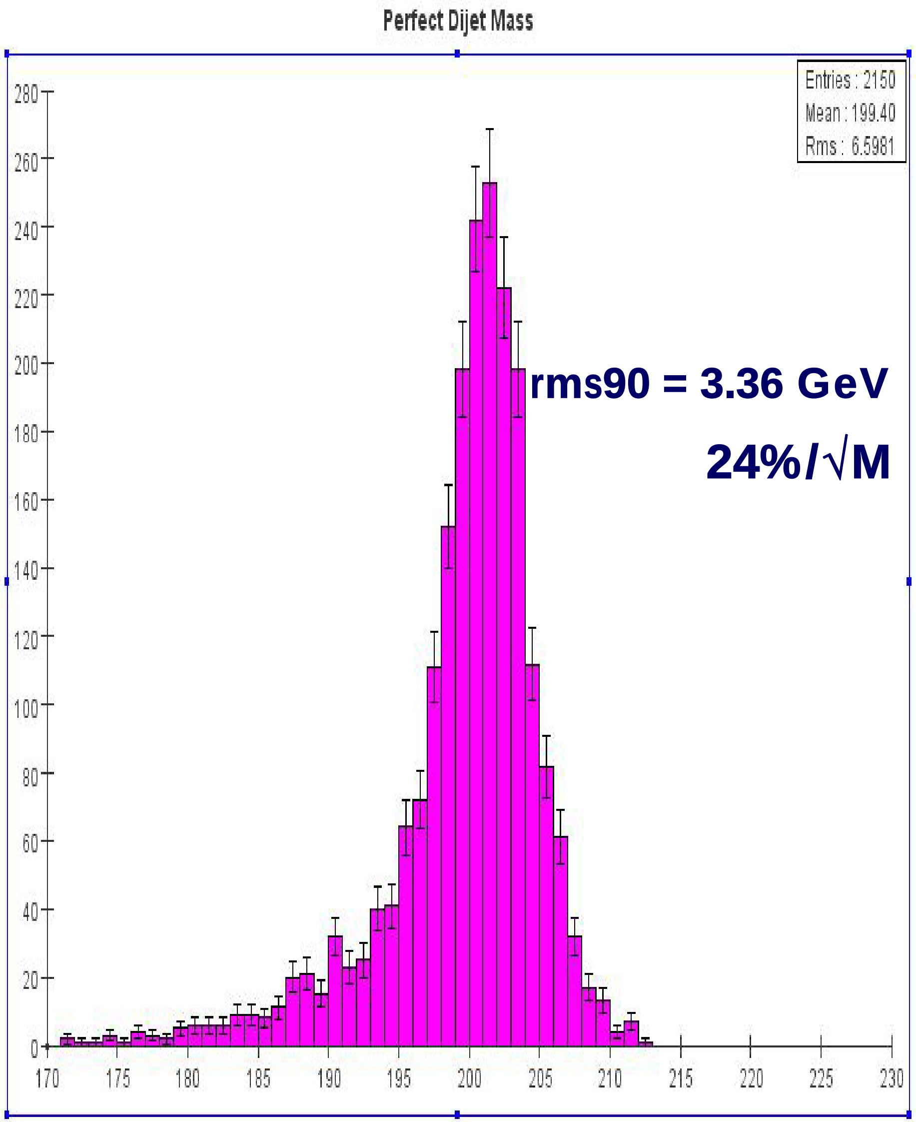
Mat Charles -Iowa

- Step 1: Find photons, remove their hits.
  - Tight clustering
  - Apply shower size, shape, position cuts (very soft photons fail these)
  - Make sure that they aren't connected to a charged track
- Step 2: Identify MIPs/track segments in calorimeters. Identify dense clumps of hits.
  - These are the building blocks for hadronic showers
  - Pretty easy to define & find
- Step 3: Reconstruct skeleton hadronic showers
  - Coarse clustering to find shower components (track segments, clumps) that are nearby
  - Use geometrical information in likelihood selector to see if pairs of components are connected
  - Build topologically connected skeletons
  - If >1 track connected to a skeleton, go back and cut links to separate
  - Muons and electrons implicitly included in this step too
- Step 4: Flesh out showers with nearby hits
  - Proximity-based clustering with 3cm threshold
- Step 5: Identify charged primaries, neutral primaries, soft photons, fragments
  - Extrapolate tracks to clusters to find charged primaries
  - Look at size, pointing, position to discriminate between other cases
  - Merge fragments into nearest primary
  - Use E/p veto on track-cluster matching to reject mistakes (inefficient but mostly unbiased)
  - Use calibration to get mass for neutrals & for charged clusters without a track match (calibrations for EM, hadronic showers provided by Ron Cassell)
- Known issues & planned improvements:
  - Still some cases when multiple tracks get assigned to a single cluster
  - Punch-through (muons and energetic/late-showering hadrons) confuses E/p cut
  - Improve photon reconstruction & ID
  - Improve shower likelihood (more geometry input)
  - Use real tracking when available
  - No real charged PID done at this point

What is the target performance?

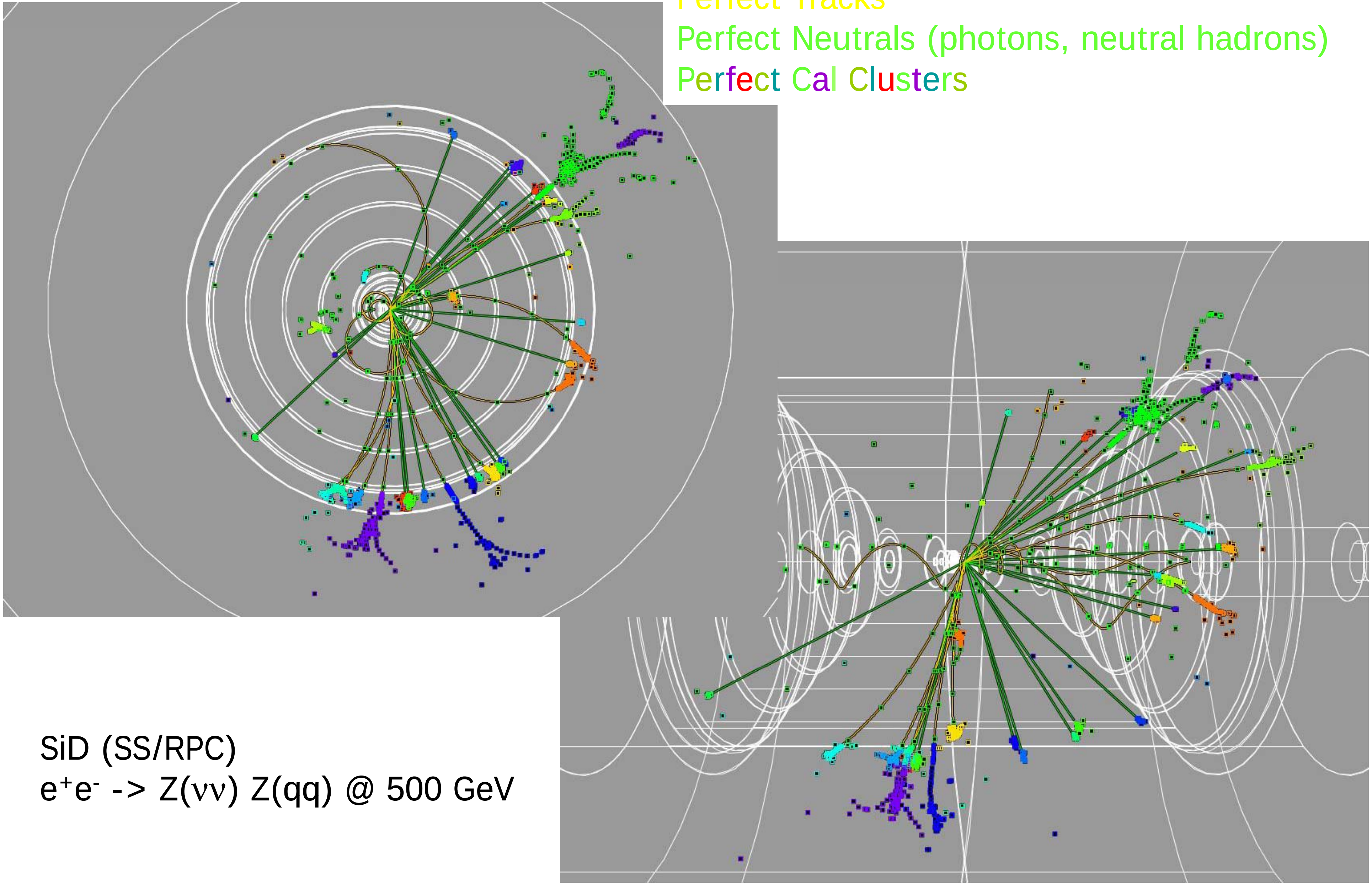
Perfect PFA – SiD01 e^+e^- -> qq @ 200 GeV





Perfect PFA

Perfect Tracks
Perfect Neutrals (photons, neutral hadrons)
Perfect Cal Clusters



SiD (SS/RPC)
e^+e^- -> Z($\nu\nu$) Z(qq) @ 500 GeV

Status of PFA peformance/June 2007

rms_{90}(GeV)	Detector model	Tracker outer R	Cal thickness	Shower model	Dijet 91GeV	Dijet 200GeV	Dijet 360GeV	Dijet 500GeV	ZZ 500GeV[b]
ANL(I)+SLAC	SiD	1.3m	~5 λ	LCPhys	3.2/9.9[a]				
ANL(II)					3.3	9.1		27.6	
Iowa									5.2[c]
NIU					3.9/11.[a]				
PandoraPFA*	LDC	1.7m	~7 λ	LHEP	2.8	4.3	7.9	11.9	___
GLD PFA*	GLD	2.1m	5.7 λ	LCPhys	2.8	6.4	12.9	19.0	___
30%/sqrt(E)	___	___	___	___	2.86	4.24	5.69	6.71	(?)
3%					1.93	4.24	7.64	10.61	(?)
4%					2.57	5.67	10.18	14.14	(?)

* From talks given by Mark Thomson and Tamaki Yoshioka at LCWS'07

a) 2 Gaussian fit, (central Gaussian width/2nd Gaussian width)

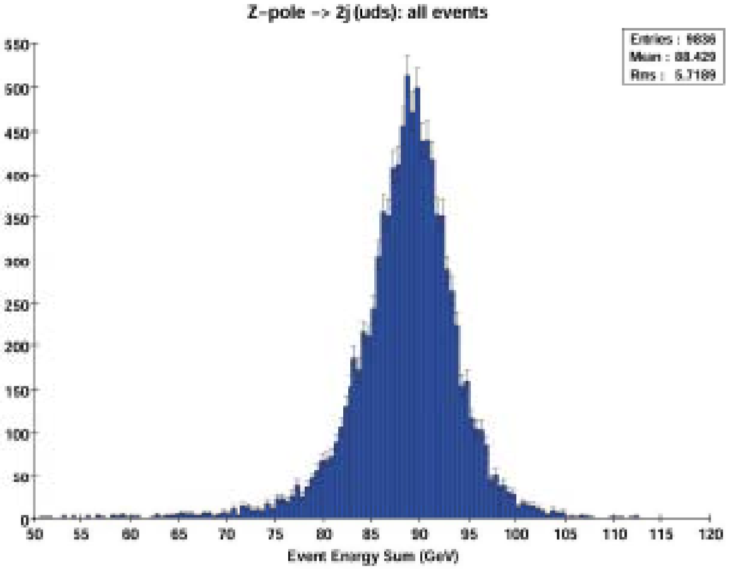
b) $Z_1 \rightarrow$nunubar, $Z_2 \rightarrow$qqbar (uds)

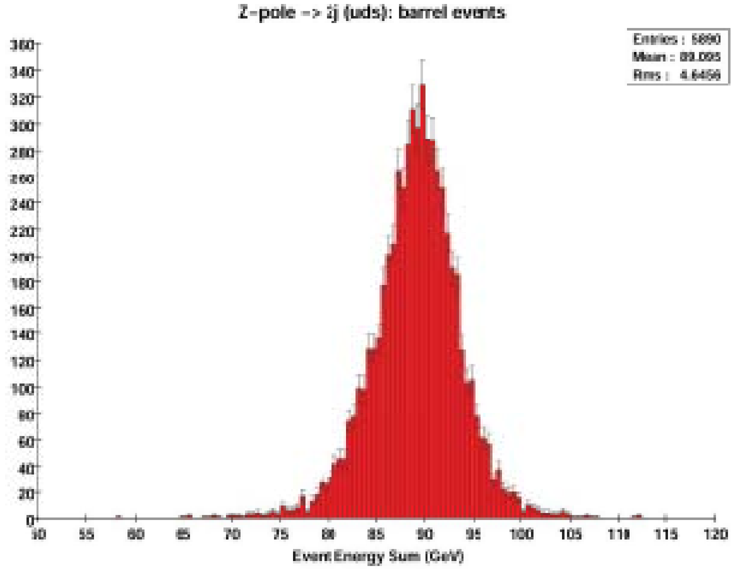
c) Di-jet mass residual [= true mass of Z2 - reconstructed mass of Z2]

Incomplete and not directly comparable!

PFA performance: $e^+e^- \rightarrow$ qqbar(uds) @ 91GeV (ANL)

(rms90: rms of central 90% of events)





All events, no cut

Mean	88.43 GeV
RMS	5.718 GeV
RMS90	3.600 GeV [38.2 %/sqrt(E)]

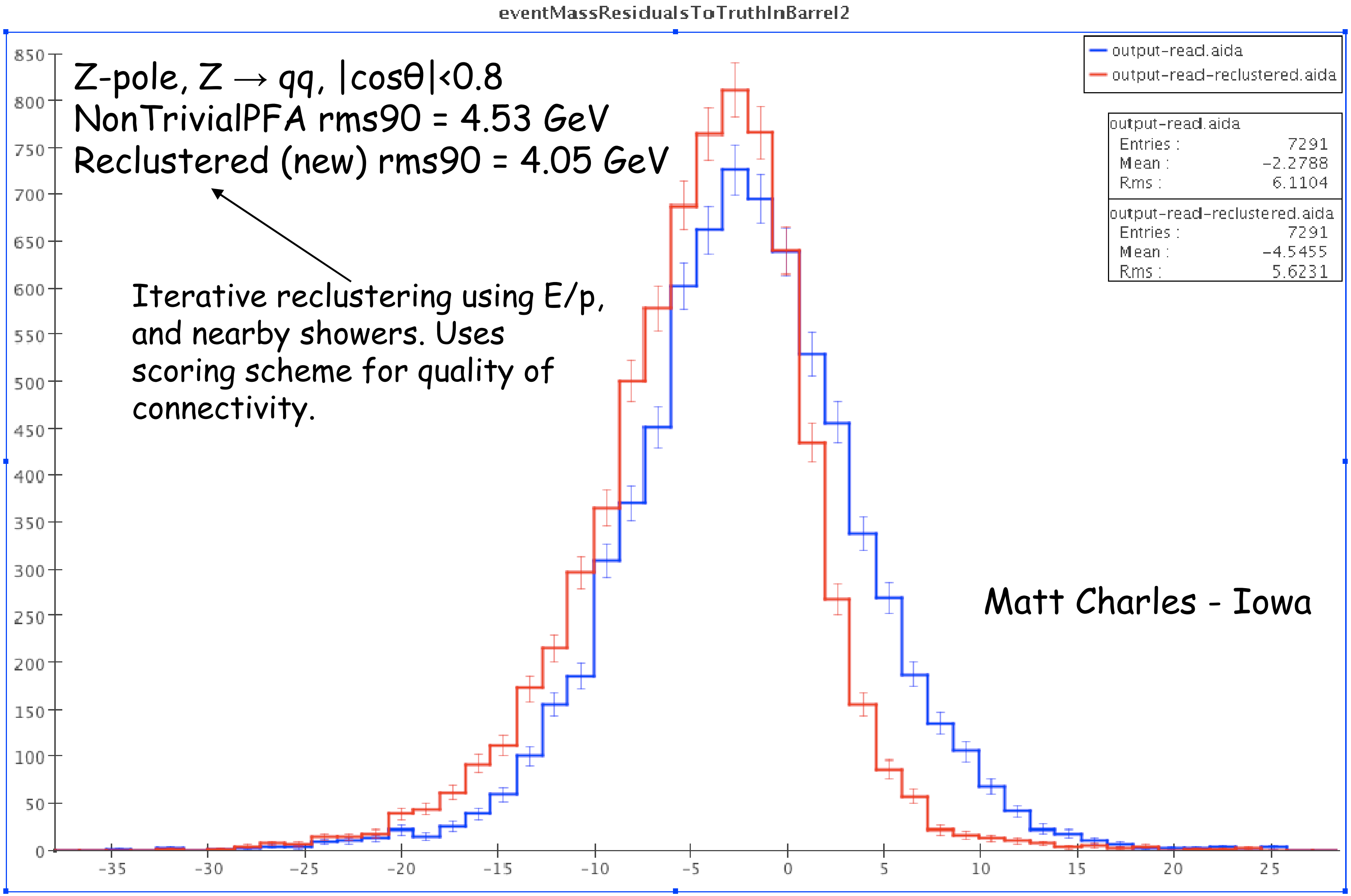
Barrel events (cos(theta[Q]) < 1/sqrt(2))

Mean	89.10 GeV
RMS	4.646 GeV
RMS90	3.283 GeV [34.7 %/sqrt(E)]

Still not quite 30%/sqrt(E) yet, but very close now

Xia - ANL

Example of recent progress on SiD PFA



Alternative approach/cross-check: PANDORA/PFA

Configuration	n/sqrt(E)	Jet energy
LDC00Sc	30.5	45
LDC00Sc 5T	31.2	45
LDC00Sc 30 layer ECAL	32.4	45
LDC00Sc Sid-ish 4T	32.6	45
LDC00Sc Sid-ish 5T	32.0	45
LDC00Sc Sid-ish 6T	33.8	45
LDC00Sc	36.7	100
LDC00Sc Sid-ish 4T	42.7	100
LDC00Sc Sid-ish 5T	41.0	100
LDC00Sc Sid-ish 6T	39.8	100

← $\sigma \sim 3.1$ GeV

Errors ± 0.2-0.3

100 GeV Numbers very preliminary

M. Stanitski (RAL)

Alternative approach/cross-check: PANDORA/PFA

What have I learnt so far ?

- ECAL depth 40->30 layers
  - ~ 2-3 % worse
- Shrinking radius and increasing field to 5 T
  - ~ 2 % worse
- Changing physics lists
  - 2-10 % ?

An *additive* 10% !! Huge effect: under investigation.

M. Stanitski (RAL)

Towards the LOI

- Discussions with SiD Benchmarking Group
- Initially use the SiD Perfect PFA:
    - test the software and LCIO data structure
    - allows the benchmarking to start with something closer to the final PFA tool than e.g. Fast MC
    - hopefully will give SiD 1-2 analysis examples fast to serve as basis for getting more people involved in benchmarking for the LOI.
- Major issue! Can we complete the work on a useable SiD PFA in time for the physics studies for the LOI?

How realistic is it?

- Tracking: The tracking is parameterized as in the FastMC. However, full detector effects (interactions and decays) before the calorimeter are taken into account in deciding which particles are actually tracked.
- Neutrals: No parameterization. Perfect pattern recognition (no confusion term), but actual detector responses used for energy and direction. So most of the nasty nonlinear, non-gaussian effects are included.

SiD PFA Manpower

- Currently 3-4 FTEs
- Recruitment:

SLAC – 1 new person (Simulation/PFA)

SUNY/Stony Brook – search underway

U. Iowa – possibility of new person

NIU – restarting work on Directed Tree

+ re-assignment of existing personnel??

SiD PFA: 500 GeV/1 TeV

- We do not have the "official" benchmark list yet.

- Consensus within SiD -> put emphasis on 500 GeV…

- …however, the calorimeter system we will build will be for 1 TeV running also.

- Possibilities:

    1) Study e.g. rise in confusion 500 GeV -> 1 TeV

    2) PFA-assisted calorimetry (e.g. ALEPH, ZEUS) at 1 TeV?

    3) be sensitive to how the calorimeter system would perform as "traditional" calorimetry.

    4) ??