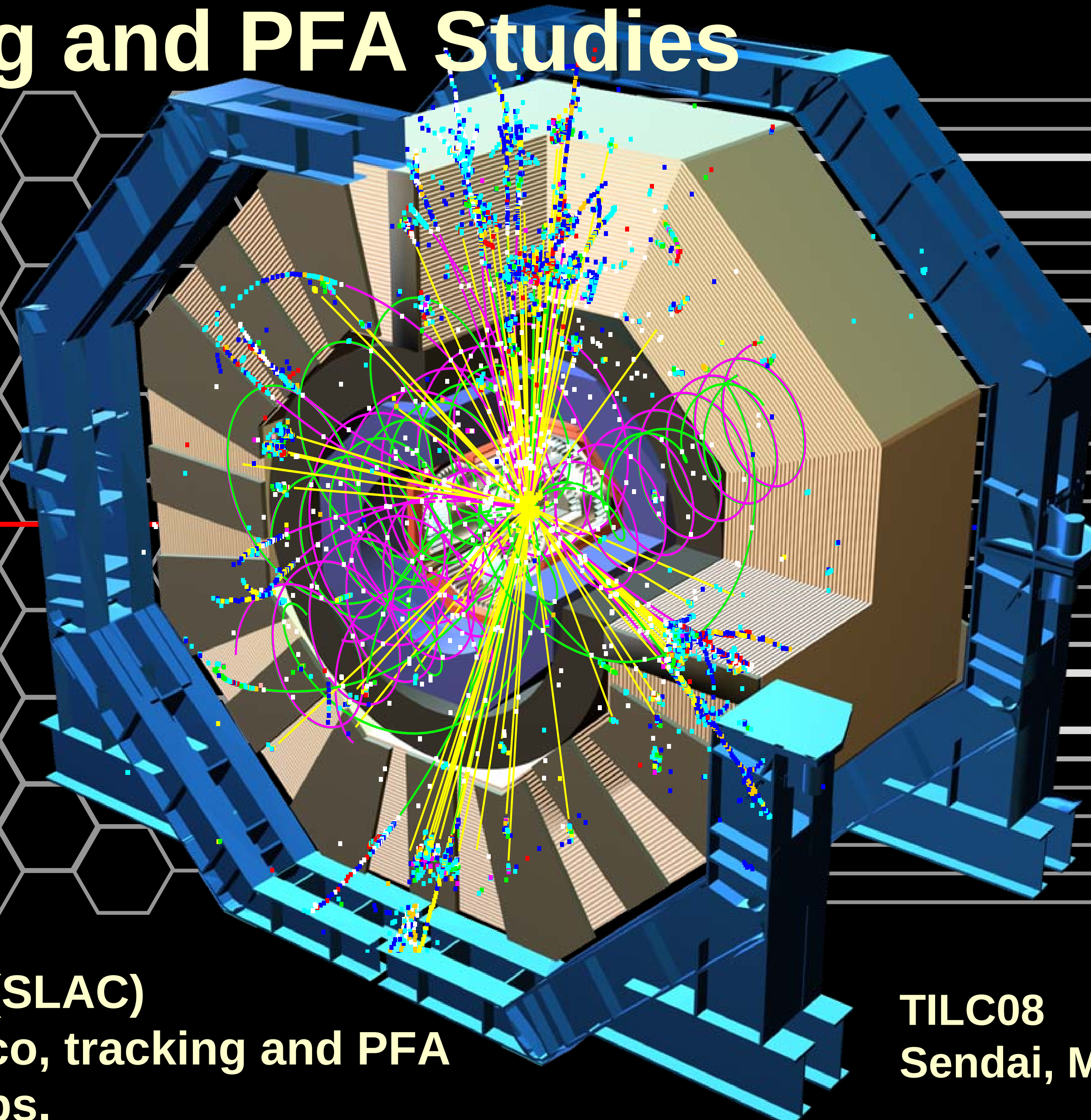
Simulating the Silicon Detector Tracking and PFA Studies



Norman Graf (SLAC)
for the sim/reco, tracking and PFA working groups.

TILC08
Sendai, March 4, 2008

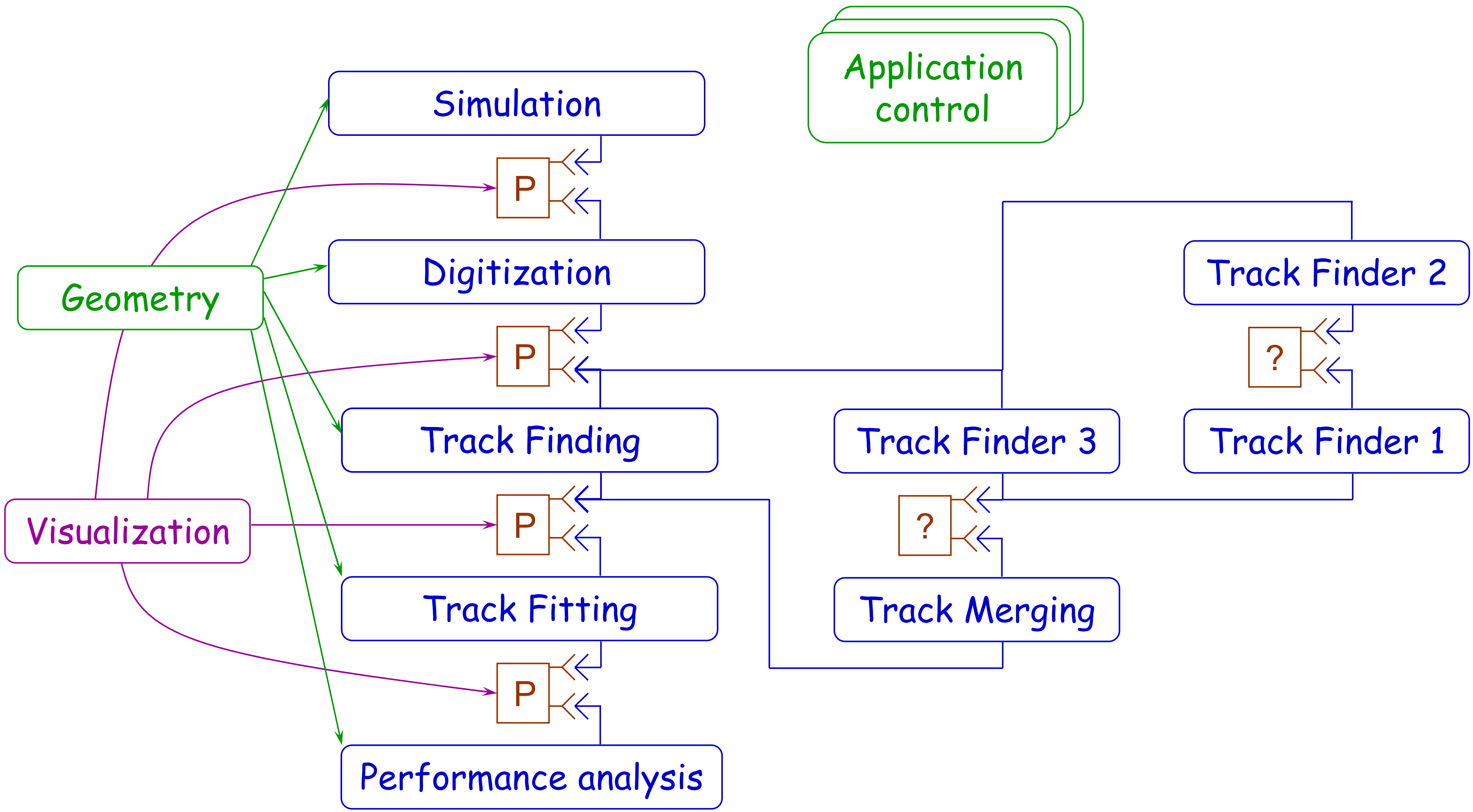
Outline

- The goals
- Tracking infrastructure, status & plans
- Status & plans of PFA implementations
- SiD Detector Optimization using PFA
    - See talk by Marcel Stanitzki later today for PANDORA
- Outlook

The goals

- Study the physics performance of the silicon detector, particularly the benchmark channels
  - See talk by P. Burrows for SiD overview.
- Optimize the detector design quantitatively
- Make informed, rational technology choices
- To do these with confidence, we need:
  - Highly efficient, excellent resolution tracking
  - a robust, high-performance PFA.
    - Rule of thumb: dijet mass resolution ~ 3 to 4 GeV.

Tracking Toolkit

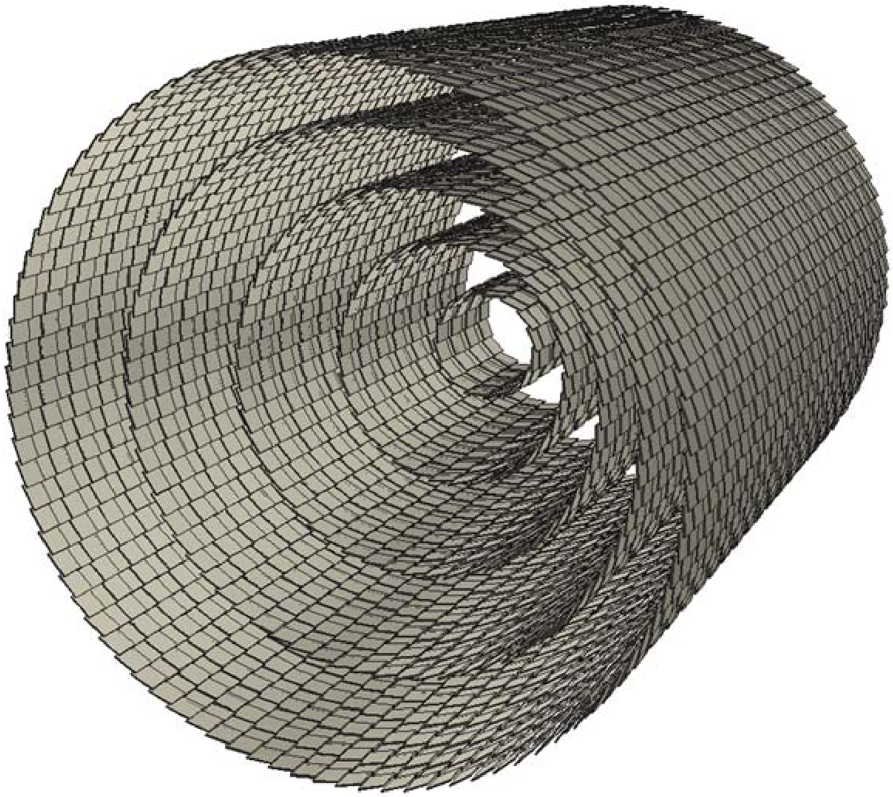


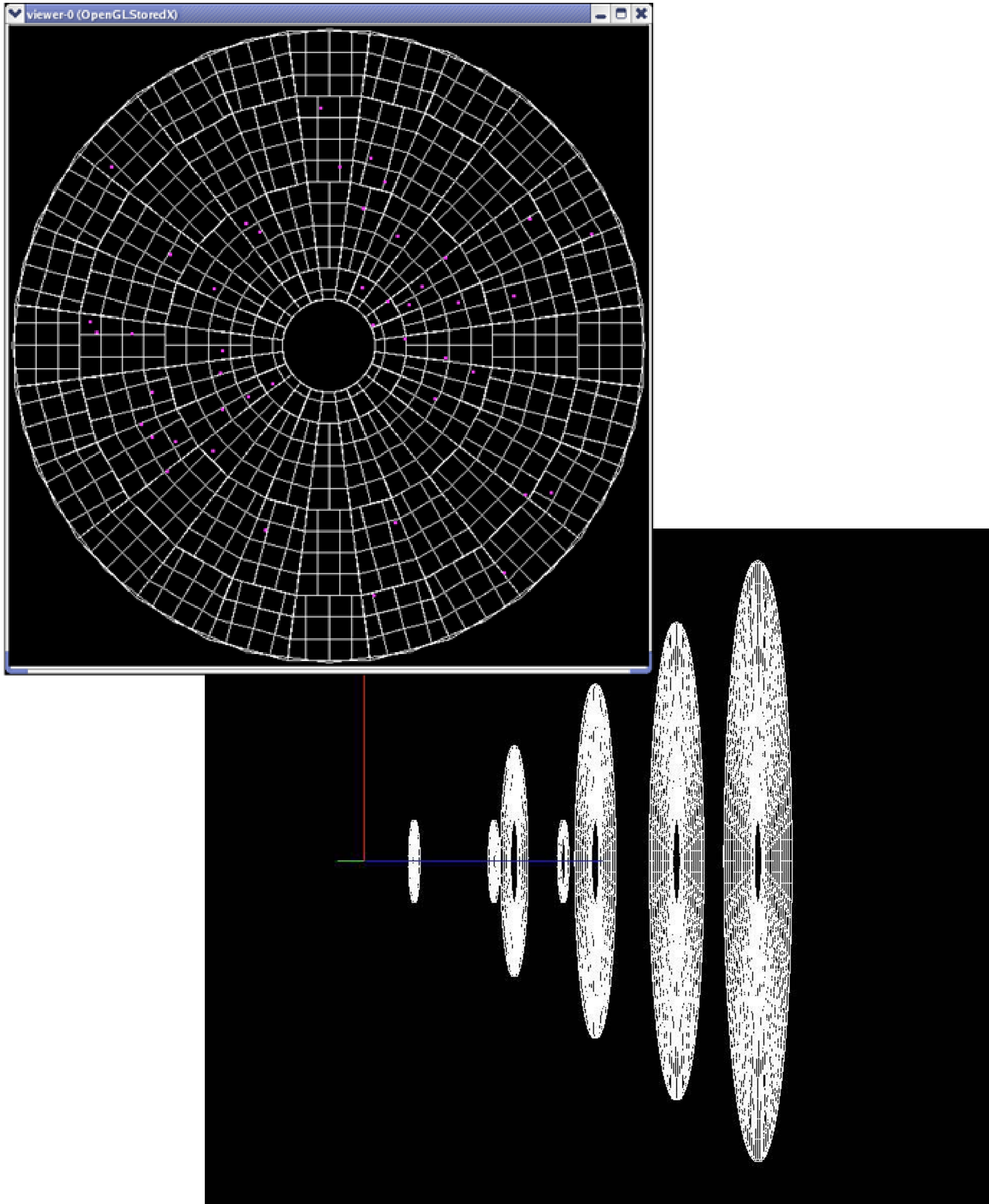
from: D. Onoprienko

Tracking

- Full Simulation and benchmarking of design
  - Full planar geometry description and virtual segmentation
  - Hit generation and digitization SimTrackerHit $\rightarrow$ TrackerHit
  - Pattern recognition code almost complete
    - Number of different approaches
      - outside-in, inside-out, calorimeter assisted, …
  - Full Kalman filter available
  - Need to bring all together into one user-friendly package.
  - See talk by M. Demarteau in tomorrow’s SiD parallel session.

Silicon Tracker Design





List of existing SiD PFAs

- Steve Magill: Track following + E/p clustering
- Lei Xia: Density-based clustering.
- NIU/NICADD group: Directed tree clustering
- Mat Charles: NonTrivialPFA & ReclusterDTree

However, most PFA developers are working part time on – split between other tasks (BaBar, ATLAS, ILC Test Beam,…)

Side note on manpower

- Important not to forget that there are other people working on modules, infrastructure, benchmarking, tools, etc:
  - Ron Cassell (tools, PFA testing)
  - Dima Onoprienko (looking into PFA/tracking interface)
  - Ray Cowan, Lawrence Bronk (testing/benchmarking PFA output)
  - Ray Cowan, Marcel Stanitzky (PandoraPFA)
  - Qingmin Zhang (photon-finding)
  - ... and more besides (apologies!)

Processes for PFA Development

e+e- -> ZZ -> qq + $\nu\nu$ @ 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, $d\theta/\theta$ -> dM/M characterization with jet E

2 jets

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

e+e- -> ZH

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.)

4 jets

e+e- -> tt @ 500 GeV

6 jets

Lower E jets, but 6 – fuller detector

e+e- -> qq @ 500 GeV

-> 1 TeV?

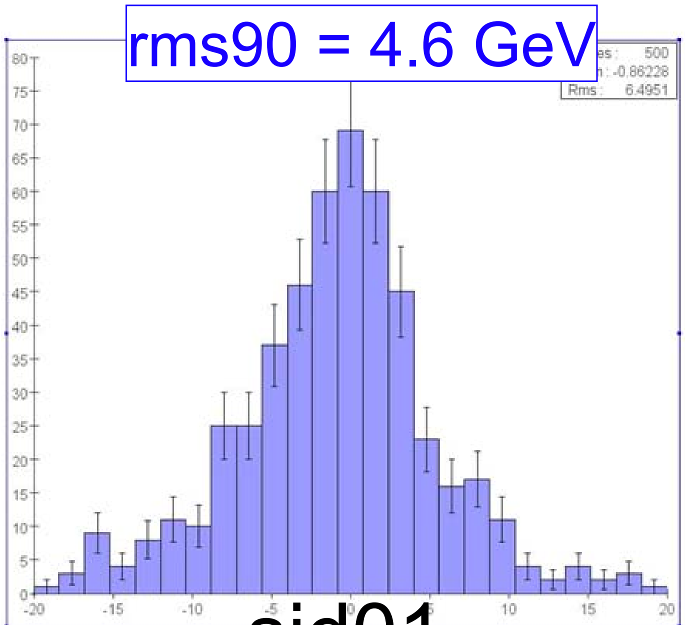
250 GeV jets – challenge for PFA, not physics

Progress (Magill): PFA summary

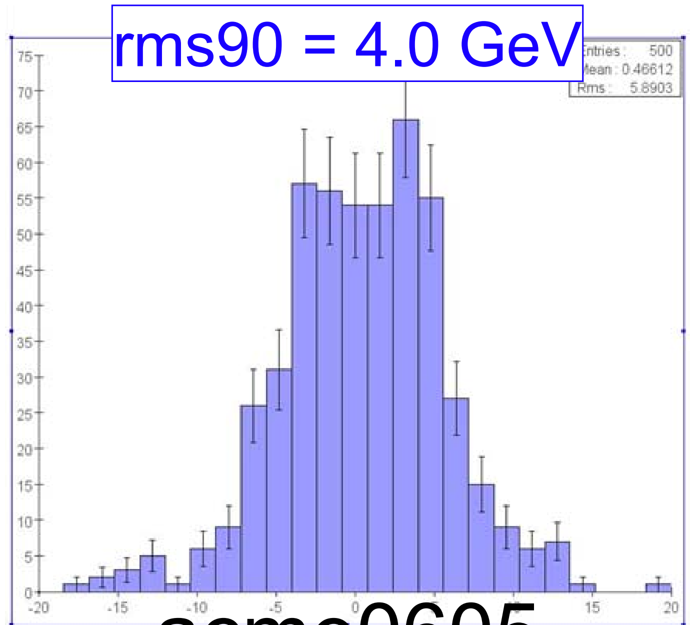
- Current implementation (updated since October):
  - Track-MIP association
  - Track-cluster association (DT clustering, E/p)
  - Photon finding (DT & NN clustering, H-matrix ID)
  - Neutral hadron finding (DT clustering, cluster merges w/ cone algorithm)
- Algorithm parameters tuned only on single-particle events (W/Scint HCAL). Process-independent!

Progress (Magill): Z-pole performance

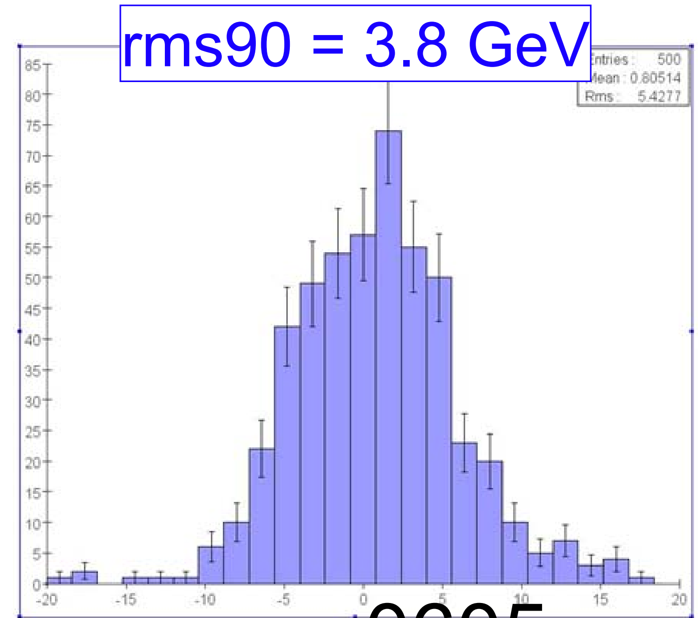
Showing dijet invariant mass for events with |cosθ|<0.9
KT algorithm used to find 2 jets.



sid01
Steel/RPC HCAL
ECAL radius
125cm



acme0605
W/Scint HCAL
ECAL radius
125cm



acme0605
W/Scint HCAL
ECAL radius
175cm

Scint HCAL helps a lot for this algorithm.
- That wasn't the case for perfect PFA... possibly due to E/p checking?

Bigger ECAL radius helps a bit

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

Progress (Iowa): Algorithm development

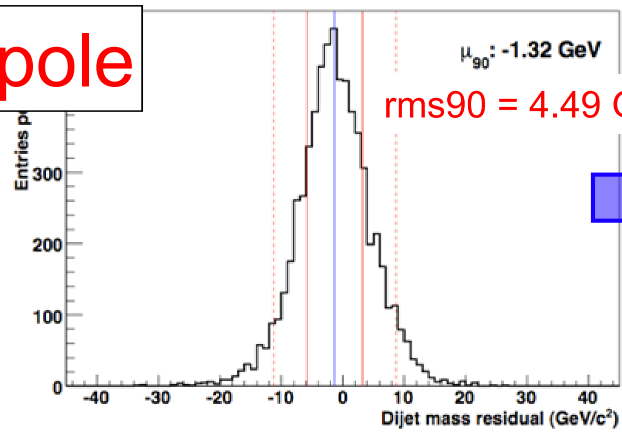
- New(ish) approach: iterative reclustering
- Basic premise presented at FNAL in October:
  - Break hadronic showers into digestible pieces.
  - Use geometrical information to link them...
  - ... taking into account E/p and other nearby showers.
- Now coded up & running. Approach has evolved:
  - Use fuzzy clustering to for unassigned hits (fragments)
  - Use DirectedTree clusterer to define “envelope” clusters
  - Introduce E/p veto if wrong by more than 2.5σ
  - Recoded MIP-finder to do better with shower “tentacles”
  - Aggressive second pass to match clusters to tracks

Progress (Iowa): Performance

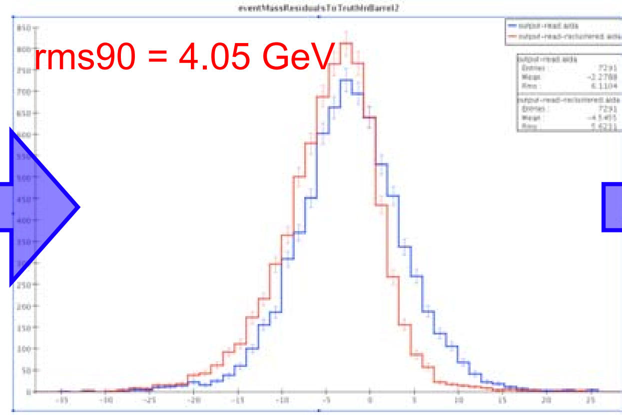
Showing dijet invariant mass for events with |cosθ|<0.8.
Detector design: sid01 (Steel/Scint HCAL)

NonTrivialPFA (previous algorithm)	Reclustering Shown on Nov 28th	Reclustering+DTree Shown on Jan 9th

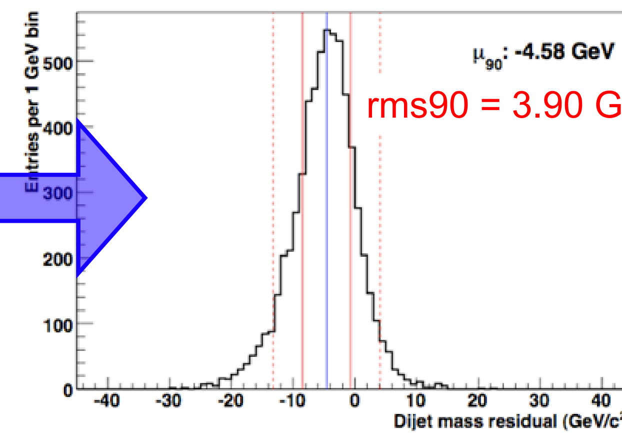
Z-pole



rms90 = 4.49 GeV

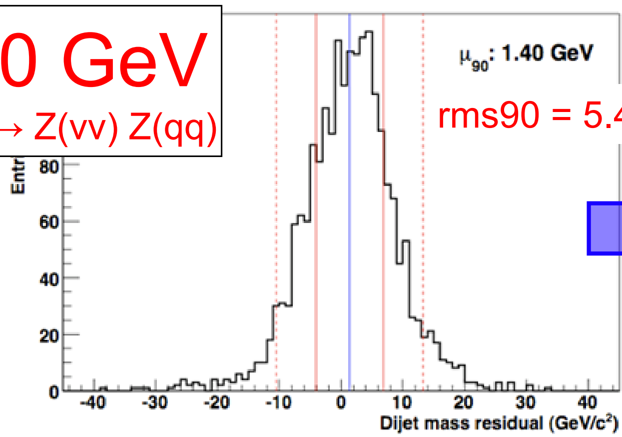


rms90 = 4.05 GeV

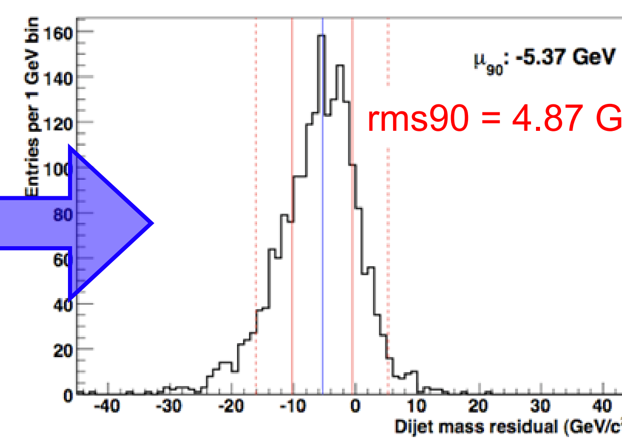


rms90 = 3.90 GeV

500 GeV
$e^+e^- \to Z(\nu\nu)\,Z(qq)$



rms90 = 5.46 GeV



rms90 = 4.87 GeV

Progress (Iowa): Tools & plans

- Some useful tools:
  - Ron Cassell's cluster analysis package (picks out confusion matrix)
  - Cheaters for various pieces
  - Global chi2 based on E/p (not quite trustworthy yet...)
- Plans & known problems:
  - Currently limited to rms90 ~ 4.3 GeV even when cheating on linkage -- need to understand why & break through.
    - Candidate: Some fragments get thrown away => lose neutral energy
    - Candidate: Large clumps that should be broken up/shared but are treated as single lump
    - Candidate: Impurities in photon list
    - Candidate: E/p goes bad for muons & punch-through
  - Over-aggressive assignment of clusters to tracks can force mistakes
  - MIP-finding still not 100% efficient (clear by eye)

Comparisons & benchmarks

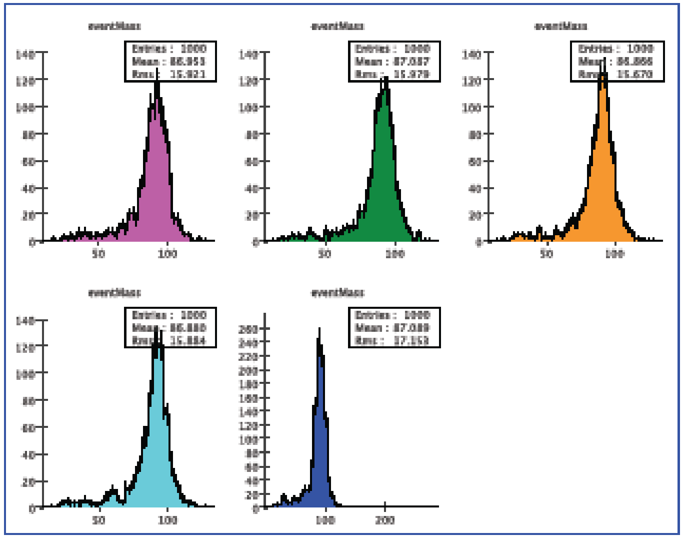
Still not at the point where PFA can unambiguously say which detector design is better.

Z-pole results

rms_{90}	sid01	acme0605
Steve PFA	4.6 GeV	4.0 GeV
NonTrivialPFA	4.5 GeV	4.1 GeV
ReclusterDTree	3.9 GeV	3.9 GeV

... but important to start thinking about this now, doing trial runs, looking for obvious patterns

MIT group (Ray & Lawrence) just got started on survey of design variants with Iowa PFA code.
[Example: # HCAL layers]



Other things on the radar

- Dual-readout (?)
  - Promising idea (for both confusion and σ_{NH} terms)
  - Simulation framework available in slic (Hans Wenzel)
  - Being pursued by Fermilab group.
- Tracking improvements
  - PFA still using either cheated tracks or fastMC smeared tracks, but targets Track interface, so swapping in full tracking when it becomes available will be seamless.

Outlook

- Tracking studies moving towards realistic geometries and digitization. Many pieces in place, bring together soon.
- PFA is critical for SiD (& most generic LC detectors) and, despite recent budget and manpower cuts, remains under active development.
- Making progress on a number of fronts, but no breakthroughs yet.
- Template architecture will make it straightforward to assemble the best parts of each of the implementations.
- SiD meeting at RAL in April is next milestone for major review. Expect to have versions of full tracking and PFA available for detector optimization.
- SiD parallel session tomorrow. Interested parties invited to attend and participate in this detector concept.