# HCAL and PFA at MIT


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SiD PFA Meeting

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# Plans and goals

- Short tem: revisit SiD global parameters
  - Especially those relating to calorimetry
  - Follow up Marcel's "SiDish" study
    - Used in preparing the SiD LOI
    - Many parameters studied
  - Keep in mind physics performance vs. cost as well as jet energy resolution vs. global parameters
- Longer term: contribute to PFA development
  - Provide additional effort on existing SiD PFAs
  - And/or investigate PandoraPFA
    - What would be needed to run a Pandora-like PFA in org.lcsim?
    - Identify the important differences between SiD PFAs and PandoraPFA
- Feedback is welcome
  - What should be the highest priorities?

# Where SiDish studies got us

- Explored a considerable region of detector parameter space
  - B-field (4T, 5T (sid02), 6T)
  - ECAL inner radius (1.0 m, 1.25 m (sid02), 1.5 m)
  - ECAL inner Z (length of SiD) (1.5 m, 1.7 m (sid02), 1.9 m, 2.1 m)
  - HCAL depth (3.5 – 5.5 lambda)
  - HCAL longitudinal segmentation (30 – 60 layers)
  - Documented in Marcel Stanitzki's talk and paper
    - "Detector Optimization for SiD"
    - http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=147&sessionId=23&confId=2628
    - arXiv:0902.3205
- Used qqbar events
  - at 91 and 200 GeV CMS
  - $|\cos(\theta)| < 0.7$
  - Also studied forward endcap region using *u*-jets
- Provided essential input for the LoI

# Resources and running at MIT

- Scripts set up at MIT for easy job submission and book-keeping
- Given stdhep and compact.xml files
  - Run GeomConverter and SLIC
  - Calibrate each detector variant using Ron Cassell's and IowaPFA script
    - Use LCDetectors/detectors/sid02/ calibration files as starting point
    - Sampling fractions
      - Use qqbar at all energies of interest (100 to 1000 GeV)
      - Use QSFCalibrationFromData.java
      - Save AIDA file for inspection
      - Save last set of SF values printed in log files
        - Replace values in ./SamplingFractions/{EM,HAD}{Barrel,Endcap}.properties files
    - Photon and neutral hadron calibration
      - Use ZZnunubaruds events at 500 GeV
      - Use QuickCalibrationFromData.java
      - Save photon and nh values printed in log file
        - Replace values in ./{photon,hadron}Calibration/{photon,nh}Qcal-v2r3p10.properties files
    - PFA calibration
      - Use ZZnunubaruds events at 500 GeV
      - Run Iowa PFA calibration script (likelihood.sh)
      - Produces a binary likelihood.bin file
        - Place this file in the ./structuralPFA/ calibration directory
    - Assume we can use existing sid02 LongitudinalHmatrix.hmx file
      - What sorts of detector variations will require a new version?
        - Major ECAL changes, presumably
  - Run reconstruction/PFA
  - Determine jet energy resolution, other numbers

# Resources at SLAC

- A number of existing detector variants already exist at SLAC
  - Leverage these where appropriate, noting simulation and recon versions
    - Some variants may benefit from re-running simulation and/or recon/PFA with current org.lcsim code
  - Ron's summary file lists many of these: /nfs/slac/g/lcd/mc/prj/users/cassell/Summary.table

**E.g., sid01**

**Produce same numbers for variants under study**

| Detector info | Data | Anal | #evts | Emean90 | Erms90 | jEres% | alpha% | Mmea90 | Mrms90 | dM/M % |
|---|---|---|---|---|---|---|---|---|---|---|
| s_127_S_rpc_dig | qq200 | PPR | 7275 | -0.72 | 2.77 | 1.96 | 19.6 | -0.74 | 2.77 | 1.39 |
| | | DT>2 | 7275 | -2.16 | 3.71 | 2.65 | 26.5 | -2.17 | 3.72 | 1.88 |
| | | DT>5 | 7275 | -2.94 | 3.84 | 2.76 | 27.6 | -2.96 | 3.87 | 1.96 |
| | | MatPFA | 7275 | 195.14 | 6.6 | 4.78 | 47.8 | -4.98 | 6.66 | 3.42 |
| | | FastMC | 7275 | -1.59 | 7.74 | 5.52 | 55.2 | -1.76 | 7.85 | 3.96 |
| | | PPRGen | 7275 | -0.7 | 2.68 | 1.91 | 19.1 | -0.71 | 2.68 | 1.35 |
| | qq500 | PPR | 5506 | -1.63 | 5.81 | 1.65 | 26.0 | -1.67 | 5.83 | 1.17 |
| | | DT>2 | 5506 | -6.52 | 20.25 | 5.8 | 91.8 | -6.52 | 20.43 | 4.14 |
| | | DT>5 | 5506 | -7.3 | 20.36 | 5.84 | 92.4 | -7.33 | 20.57 | 4.17 |
| | | MatPFA | 6582 | 486.76 | 21.18 | 6.15 | 97.3 | -13.36 | 21.39 | 4.4 |
| | | FastMC | 7332 | -8.6 | 26.36 | 7.59 | 119.9 | -9.5 | 27.84 | 5.68 |
| | | PPRGen | 7332 | -1.78 | 5.76 | 1.64 | 25.9 | -1.8 | 5.8 | 1.16 |
| | qq1000 | PPR | 7246 | -11.86 | 18.41 | 2.63 | 58.9 | -12.06 | 18.8 | 1.9 |
| | | DT>2 | 7246 | -19.38 | 51.57 | 7.44 | 166.3 | -19.17 | 52.44 | 5.35 |
| | | DT>5 | 7246 | -20.28 | 51.65 | 7.46 | 166.7 | -20.08 | 52.53 | 5.36 |
| | | FastMC | 7246 | -24.82 | 59.46 | 8.62 | 192.8 | -27.19 | 63.86 | 6.56 |
| | | PPRGen | 7246 | -11.86 | 18.38 | 2.63 | 58.8 | -12.06 | 18.77 | 1.9 |
| | ZZ500 | PPR | 2639 | -0.29 | 3.2 | 1.97 | 21.2 | 0.08 | 2.33 | 2.55 |
| | | DT>2 | 2639 | -2.19 | 6.1 | 3.78 | 40.6 | -0.86 | 2.91 | 3.22 |
| | | DT>5 | 2639 | -2.89 | 6.18 | 3.85 | 41.3 | -1.34 | 2.97 | 3.31 |
| | | MatPFA | 2639 | 223.12 | 28.32 | 17.95 | 192.5 | -1.89 | 4.4 | 4.93 |
| | | FastMC | 2639 | -2.33 | 10.16 | 6.31 | 67.7 | -1.28 | 4.67 | 5.19 |
| | | PPRGen | 2639 | -0.38 | 3.14 | 1.93 | 20.7 | -0.66 | 1.81 | 2.0 |

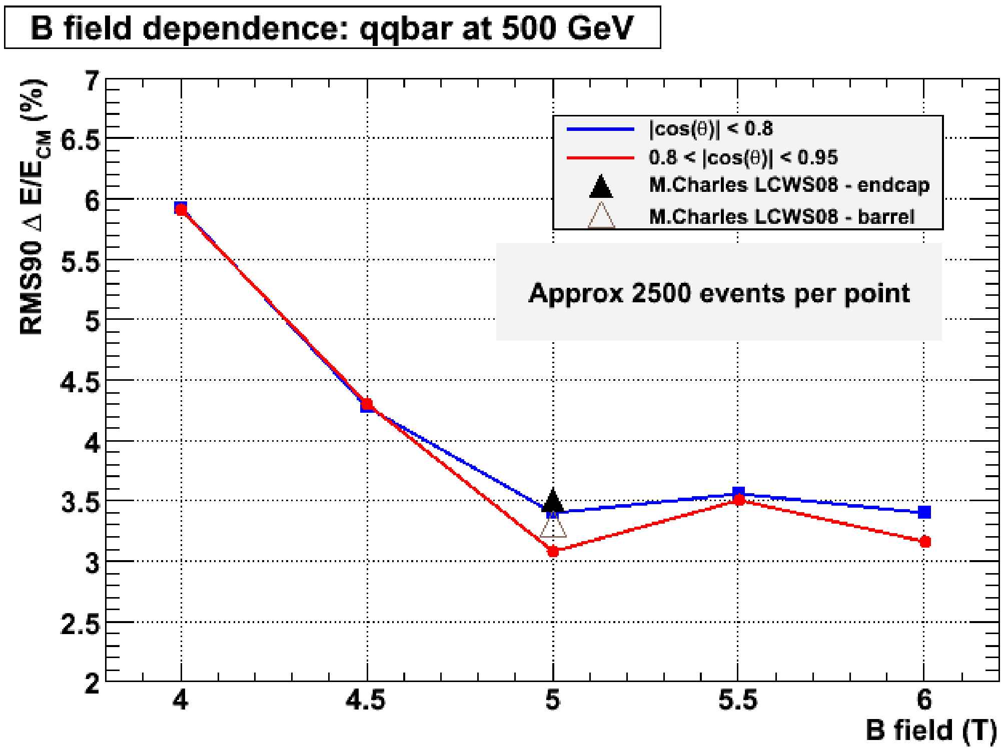
# What we're working on

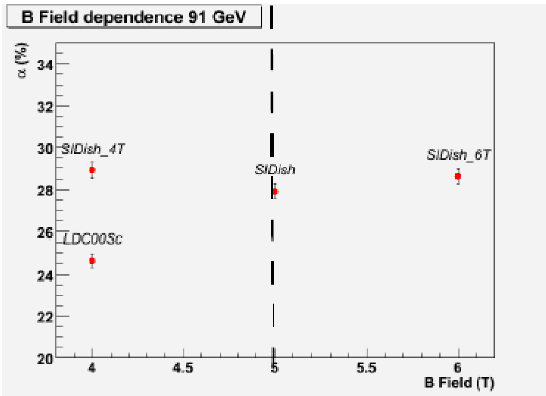
- Revisit HCAL parameter studies in SiD framework
  - Extend to higher energies (500 and 1000 GeV)
  - Determine alpha vs. energy for each variant
  - Check for any differences with SiDish
  - Changes include
    - Simulation: Mokka → SLIC
    - Reconstruction: Marlin → org.lcsim
    - PFA: PandoraPFA → Iowa PFA
    - Tracking: TPC → All silicon
    - Track cheaters → real tracking
    - HCAL readout Scint/analog → RPC/digital
    - HCAL segm. 3x3 cm → 1x1 cm
  - Study single particles too
    - Check linearity and resolution for gammas, n's, KL's
      - Similar to Norm Graf's studies in sid02_scint
        - http://ilcagenda.linearcollider.org/materialDisplay.py?contribId=1&materialId=slides&confId=3378

# Sid02 variants presently under study

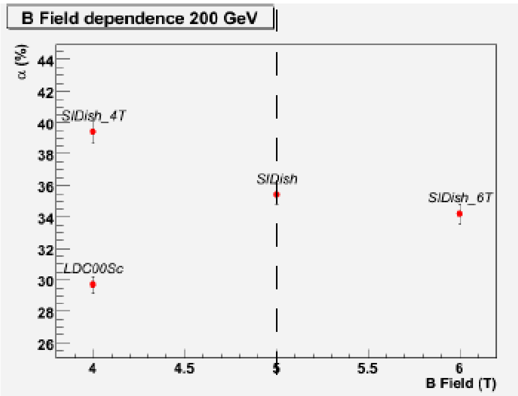
- Length "stretched" by +10%, +20%
  - ECAL inner_z
  - Affects ECAL and systems outside it
    - No changes in tracker
- HCAL depth increased by +10%, +20%
  - 40 layers → 44, 48 layers
    - Same layer structure
- B-field
  - 4, 4.5, 5, 5.5, 6 T
- HCAL cell size
  - 5x5 $mm^2$, 1x1 $cm^2$, 3x3 $cm^2$
- More to come

# B-field variants



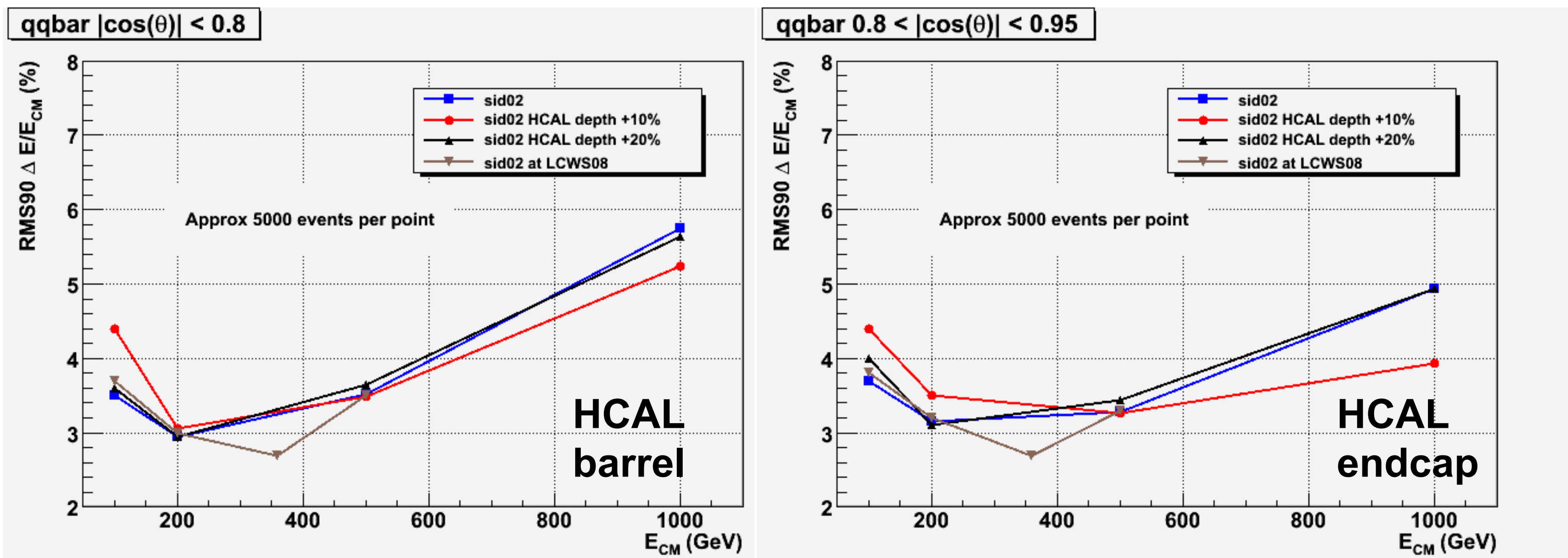

**Marcel's "sidish" B-field study at 91 (above) and 200 GeV (below)**



# HCAL depth variants

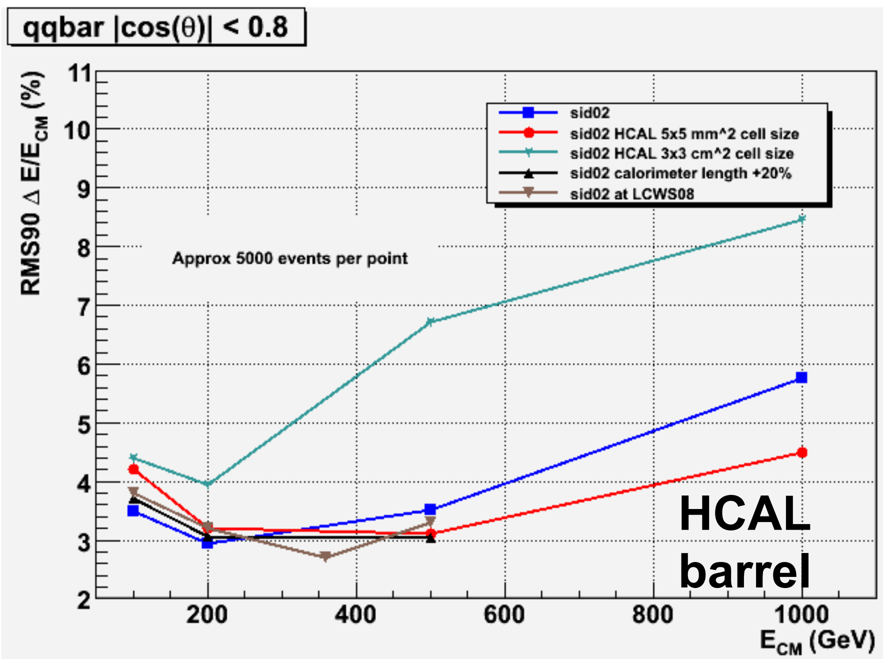
## Studied +10% and +20% in HCAL depth

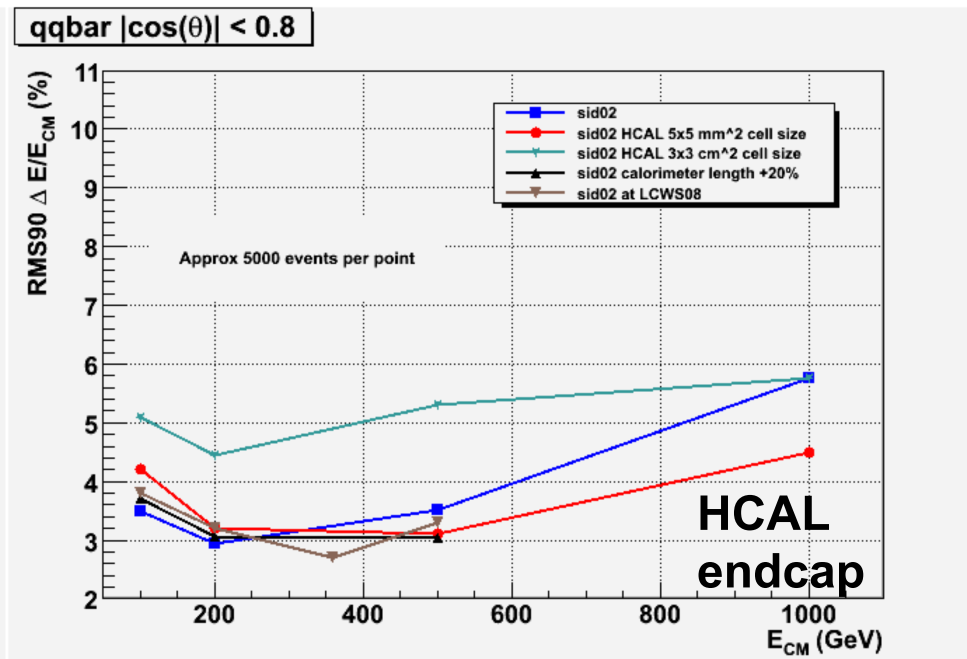
### Retain sid02 cell size and layer structure



# Three more variants

- **Cell size**
  - 5x5 $mm^2$, 3x3 $cm^2$
- **Length increase**
  - ECAL inner_z +20%



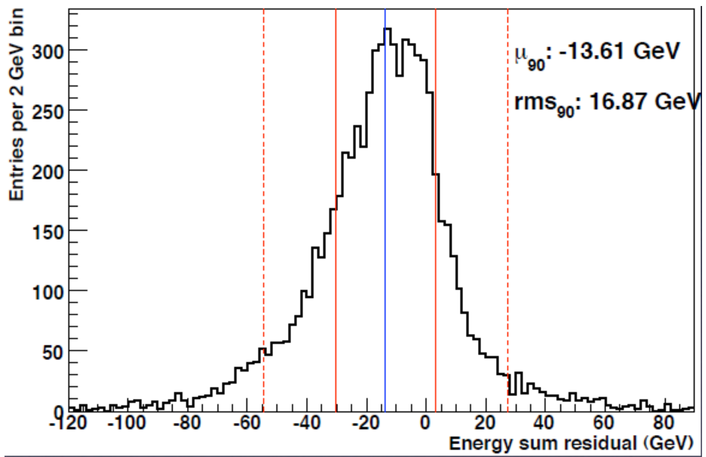
# Energy residuals comparison

**Double-check our simulation & recon**

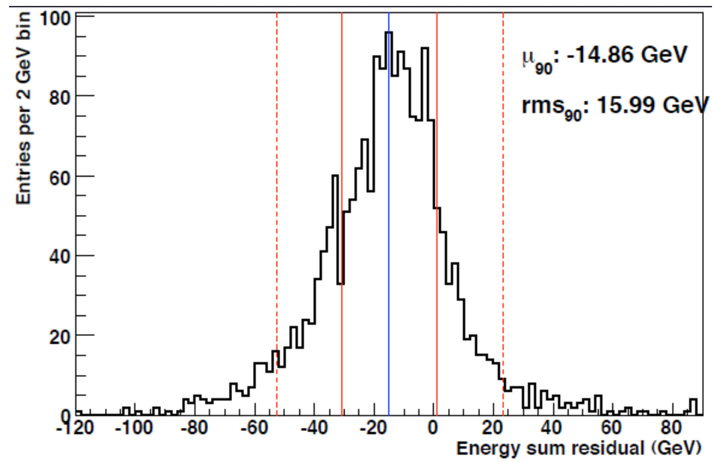
**Compare our sid02 running against "official" sid02 results from LCWS08**

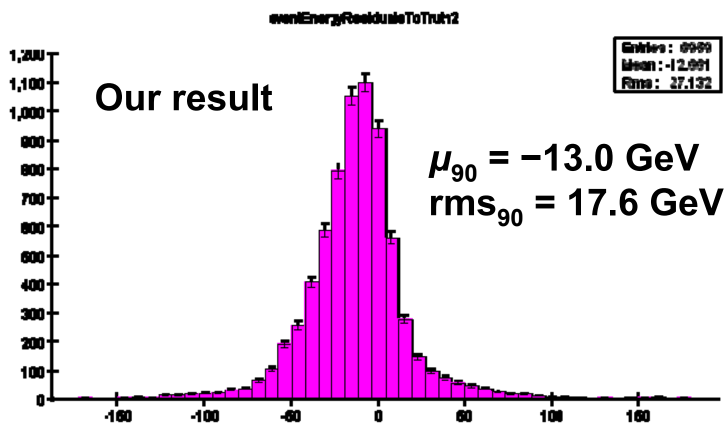
**Energy sum residuals at 500 GeV qqbar**

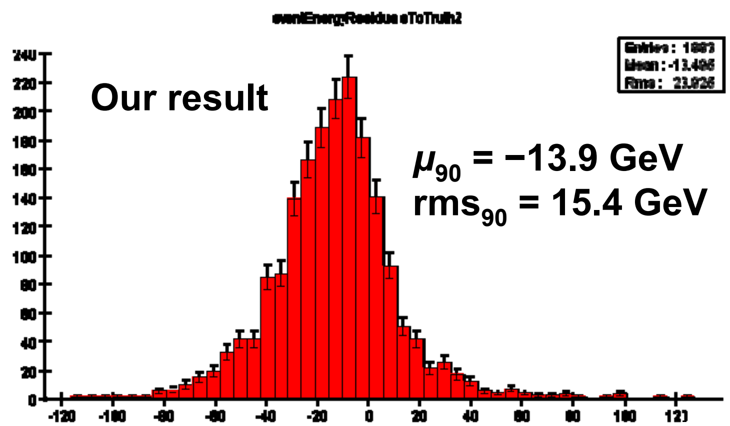
**Barrel region**




**Endcap region**



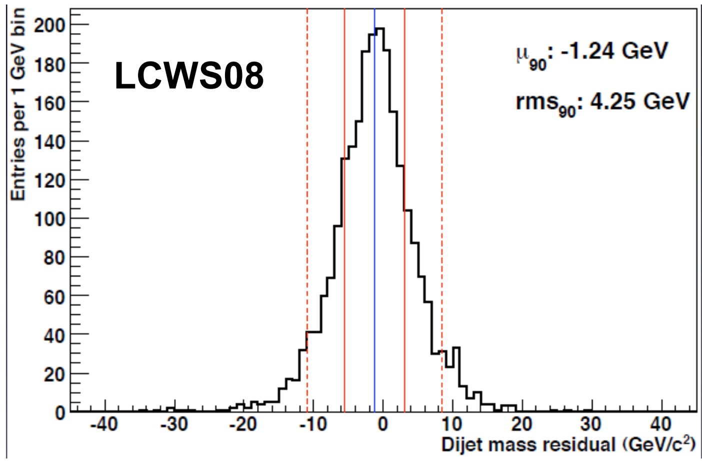



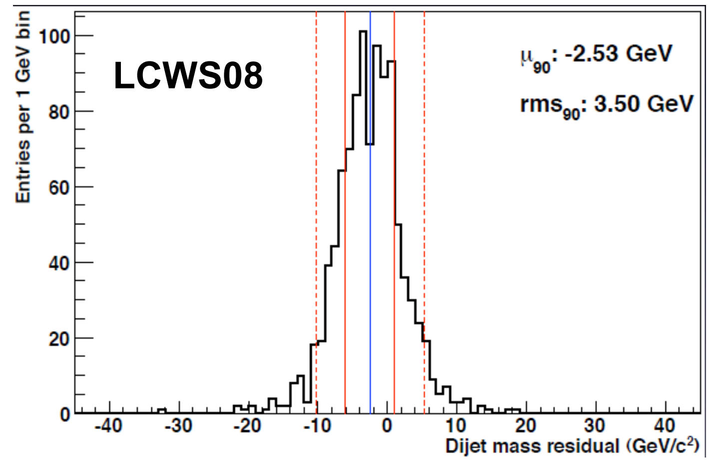
# Mass residuals comparison

**Double-check our simulation & recon**

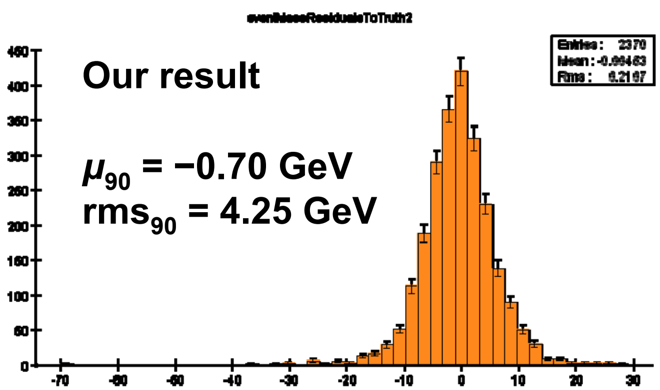
- Compare our sid02 running against "official" sid02 results from LCWS08

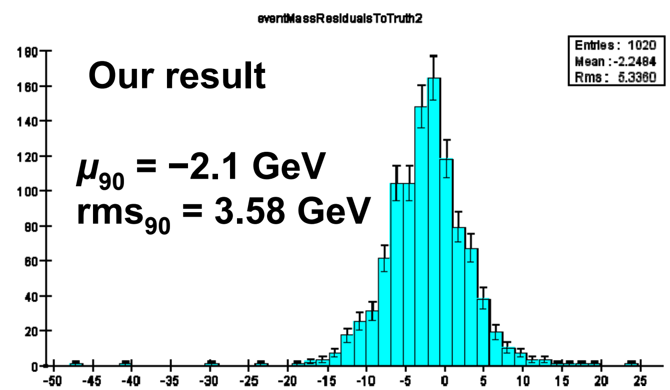
**Barrel region** | **Endcap region**




**Mass residuals at 500 GeV *ZZ* → *uds* + *νν*bar**



# Additional Ideas

- **Remember that the PFA approach is being used outside the context of ILC detectors**
  - Example: CMS
    - Joe Incandela: *"Particle–Flow Event Reconstruction in CMS and Performance for Jets, Taus, and Emiss_T"* http://cms-physics.web.cern.ch/cms-physics/public/PFT-09-001-pas.pdf
- **It may be useful to keep in touch with folks outside the ILC PFA community as well**
  - We wonder if it might make sense at some point to hold a PFA workshop addressing both the ILC and non-ILC PFA community
- **Can other shower characteristics be used to divide showers into categories with different statistical behavior?**
  - What about the effect of leading particles in showers?
  - Can consideration of lateral vs. longitudinal spread provide information?
  - Some studies along this line have been done before
    - Is it useful to do so again?
- **Look at effects of HCAL cross-talk/noise using digisim**
- **Choose two or three variants to use as testbed for PFA development**
  - Get a better idea of how detector and software improvements change energy resolutions