Contribution to Hardware and the Reconstruction of MET at ATLAS

Bruce Mellado (UW)

On behalf of Task H-2 (Pan, Mellado)

DoE Review, 08/26/2010

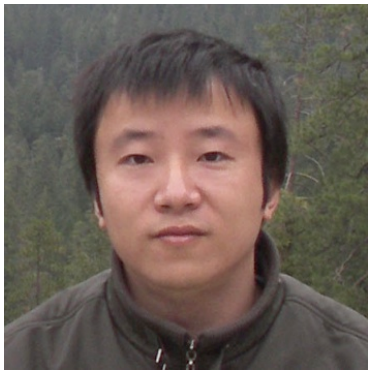
Outline

- Group's Composition
- The Hadronic Tile Calorimeter (TileCal)
- Contribution to the TileCal
  - Maintenance and Operations
  - Upgrade activities
- Interdisciplinary collaboration with UW Engineering
  - Important role of Physics Graduate Students
- Missing E_T (MET) reconstruction for ATLAS
- Positions of responsibility at ATLAS
- Summary of ATLAS documents

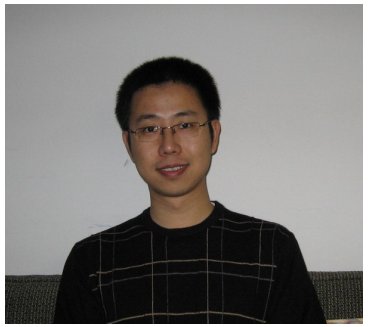
Group's Composition

- Faculty
  - Yibin Pan
  - Bruce Mellado


- Poctdocs
  - Yingchun Zhu
  - Xin Chen

- Graduate Students
  - Amanda Kruse
  - Dalong Geng

- Undergrad Students
  - Jusuk Han (left), Joshua Sanchez (URM fellow) Not funded by DoE

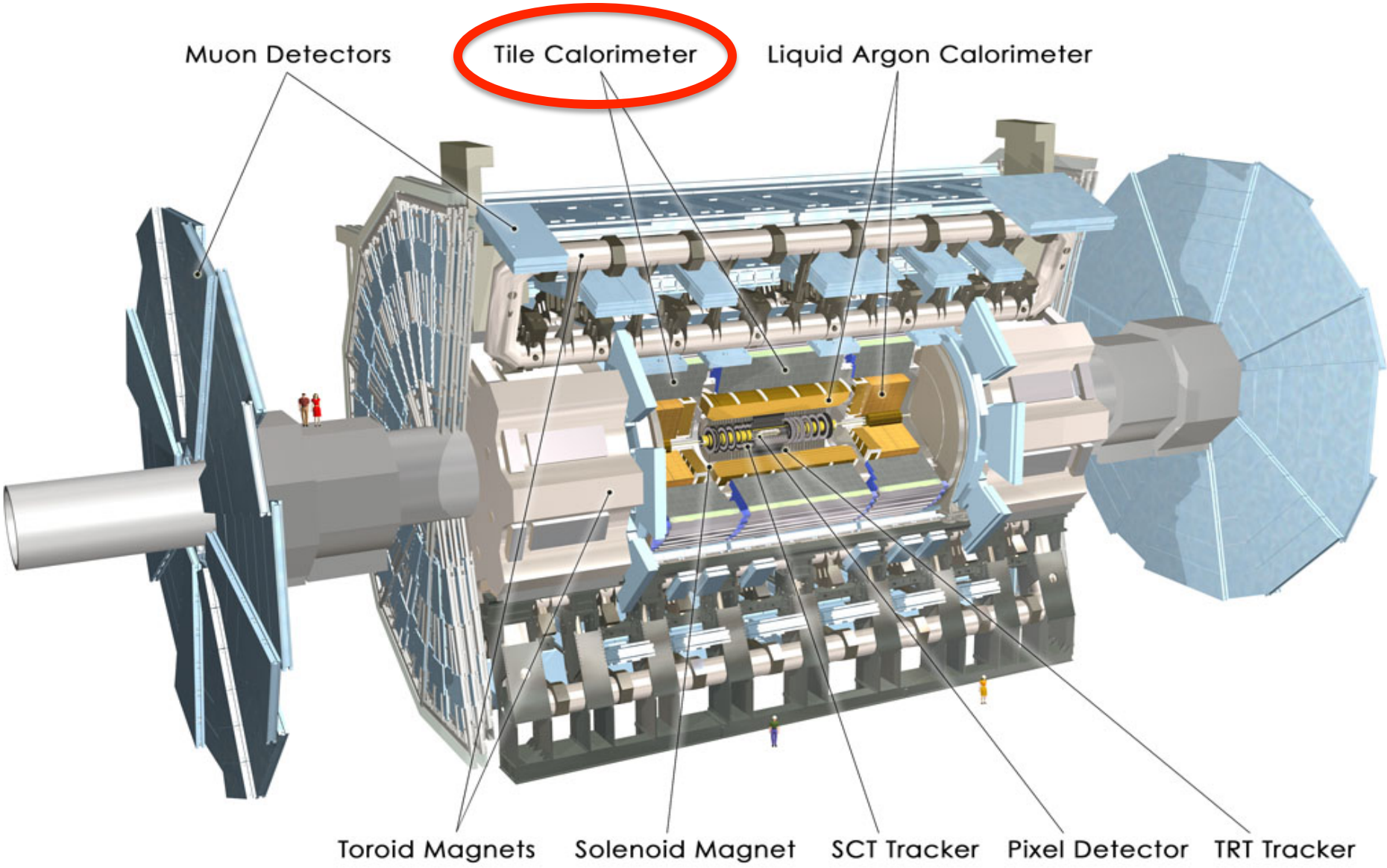
Collaboration with UW Engineering
(Hardware) Not Funded by DoE

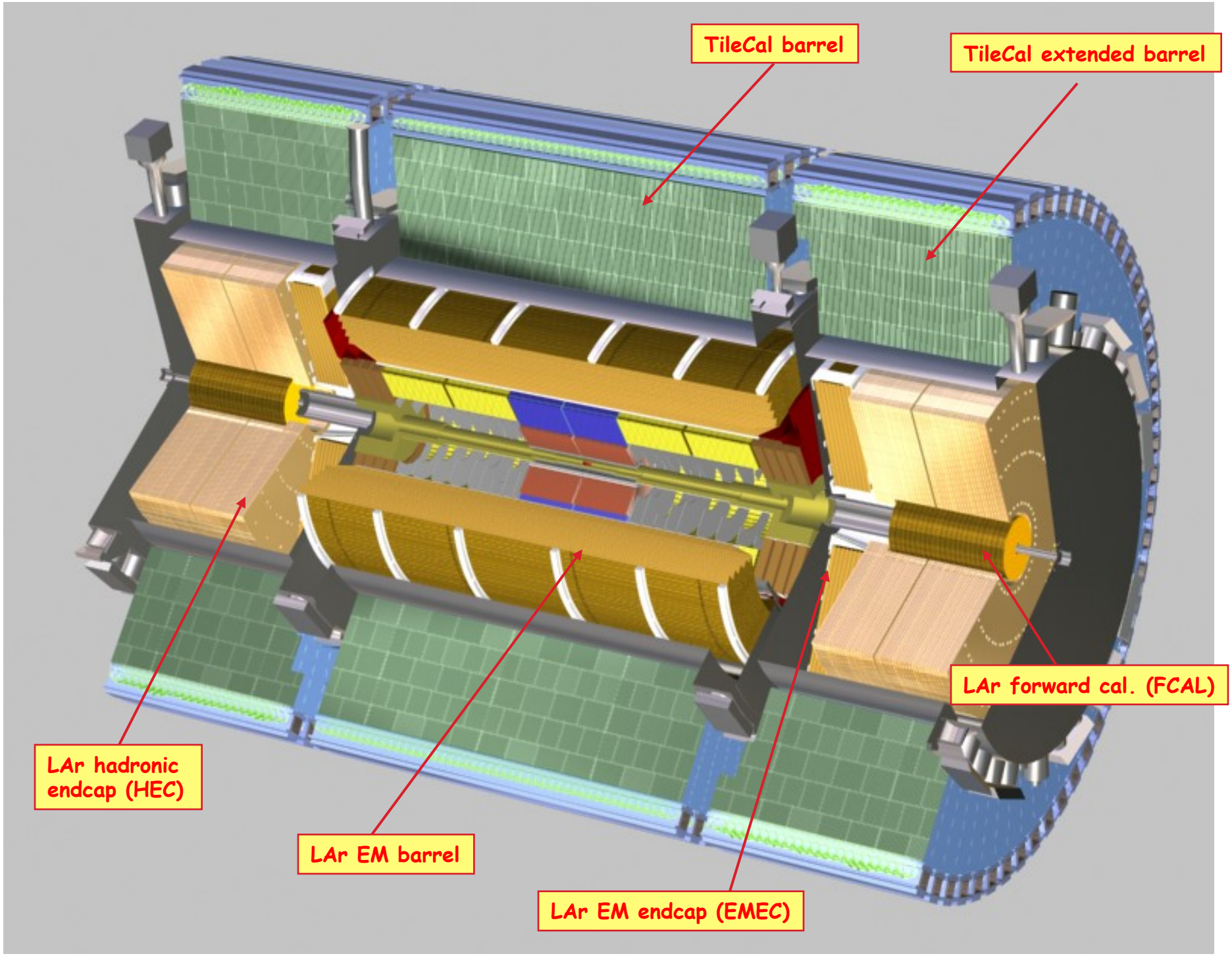
- **Kewal Saluja (Faculty)**
  - Electrical and computing engineering
  - Fault-tolerant computing
  - Error recovery in data transmission

- **Manuela Romero (Assistant Dean, PhD)**

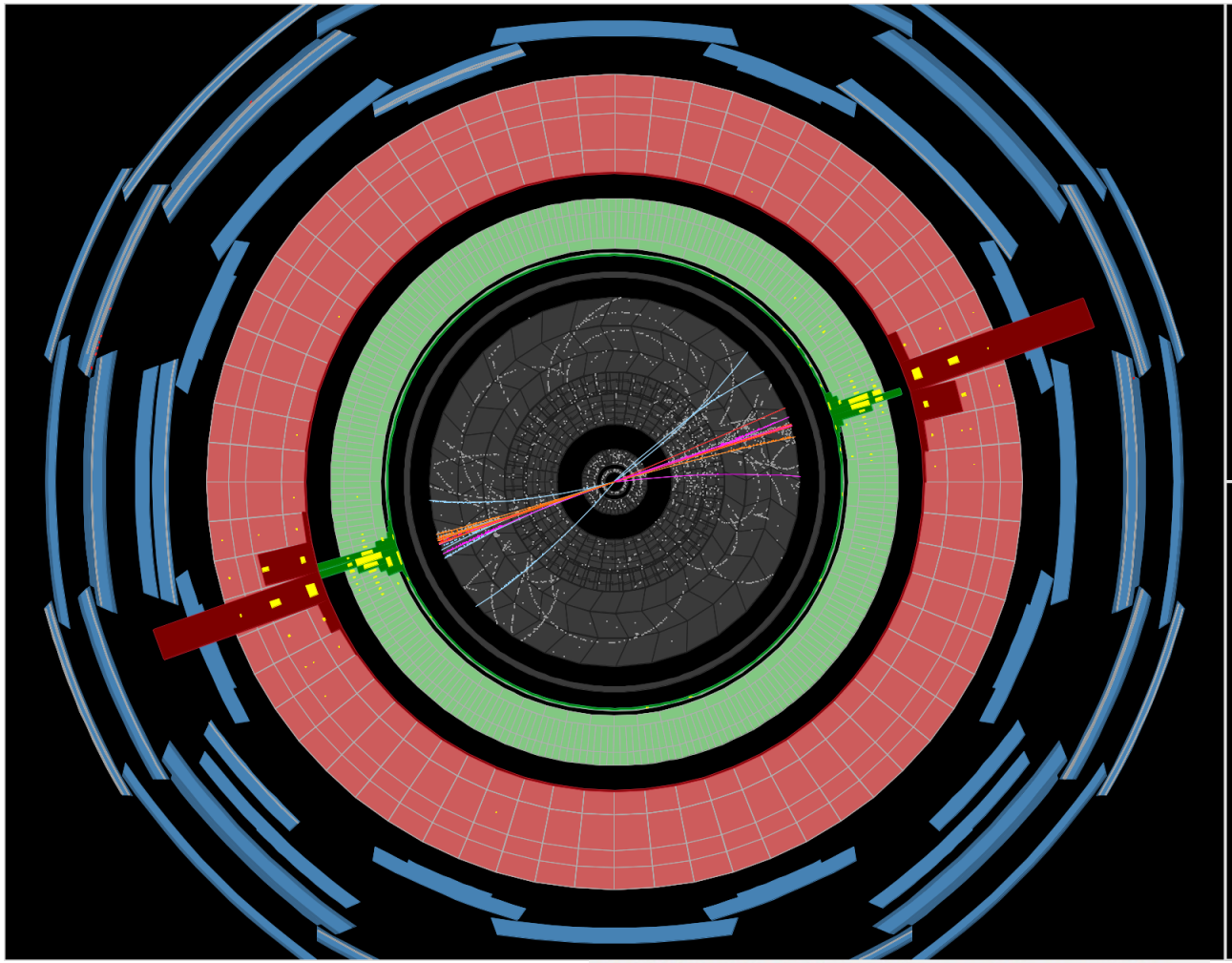
- **Students**
  - Soumya Nair, Ahmed Fikri, Abdullah Al Hajri (Dean's Honor List), Sheikh Haque, Raja Ram Yavdav

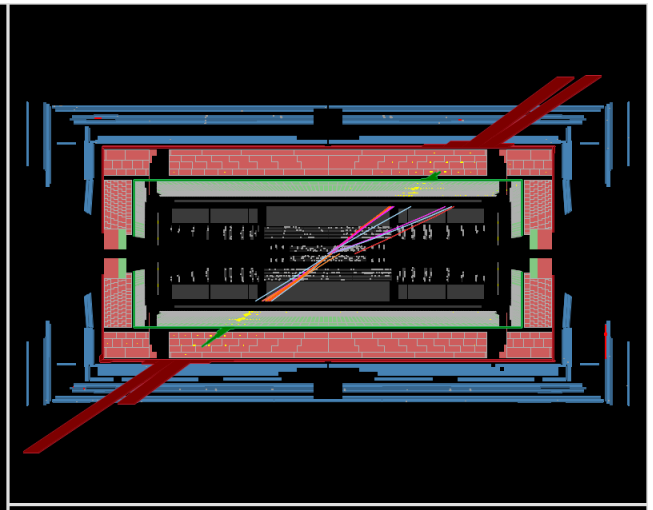
The ATLAS Detector

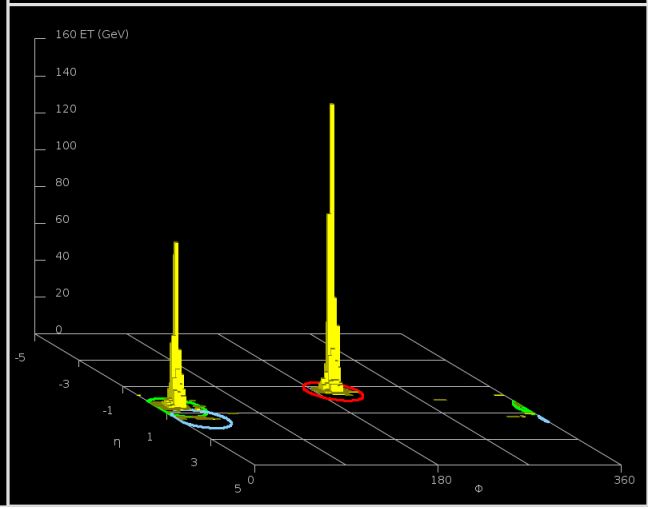



TileCal barrel
TileCal extended barrel
LAr forward cal. (FCAL)
LAr hadronic endcap (HEC)
LAr EM barrel
LAr EM endcap (EMEC)

Event Display run: 160958, event 23181152:
The highest mass central dijet event we have so far: two central high p_T jets and dijet mass ~1.9 TeV. Most of energy deposited in the TileCal





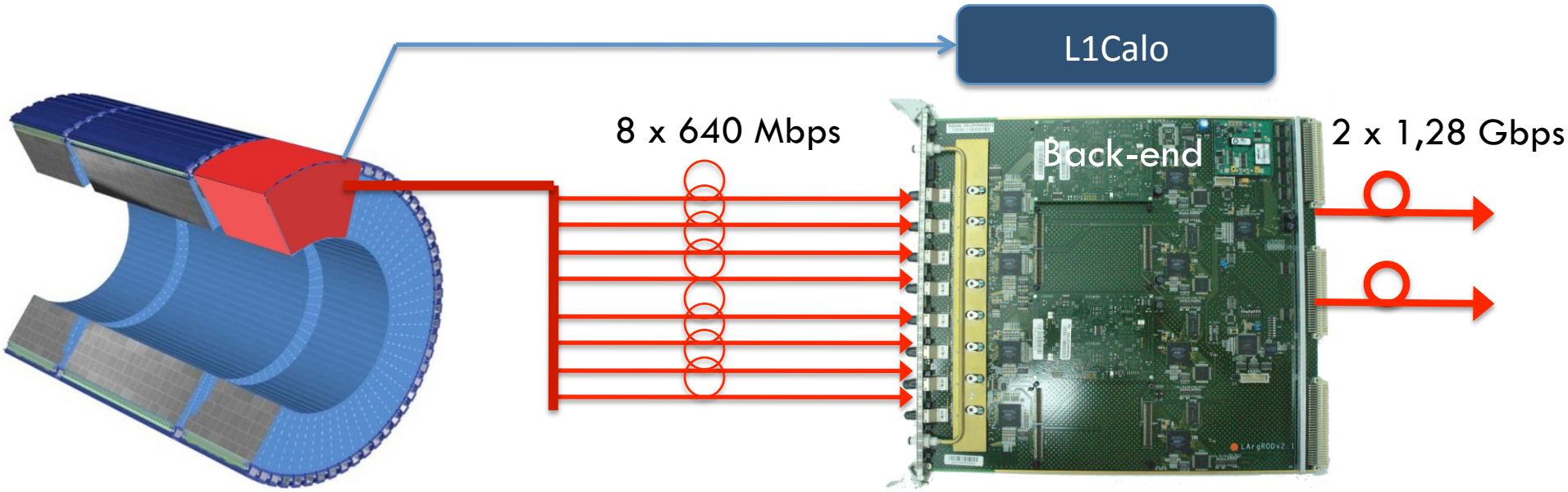


- 1st jet: pT = 890 GeV, y = -0.6, φ = -2.8
- 2nd jet: pT = 760 GeV, y = 0.6, φ = 0.3
- 3rd jet: pT = 30 GeV, y = 1.5, φ = 0.4

Contribution to the TileCal

- On June 24th the TileCal collaboration voted **unanimously** in favor of our entrance
  - http://indico.cern.ch/conferenceDisplay.py?confId=98886
  - Started to contribute to M&O in 2008
- Collaboration mainly with two institutions: **Argonne NL and IFIC (Spain)**
- Maintenance and Operations
  - Interface with the Trigger and DAQ (D.G.,Eng.)
  - Timing reconstruction (X.C., B.M.)
  - Maintenance of Optimal Filtering (Y.Z., Y.P.)
  - Contribution to the upgrade (all)
    - Replacement of Low Voltage PS (with ANL)
    - Read-out electronics (with IFIC)

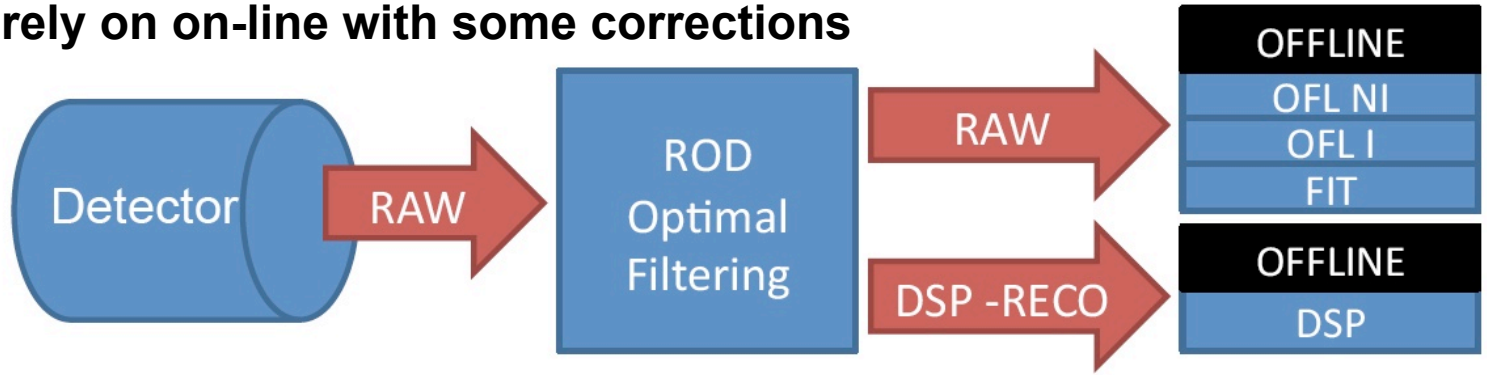
Read-Out: Present system



- **Tile Module: 45 / 36 Channels. Pipeline & Derandomizer at FE.**
- **Analog Read-out for L1Calo : 40 MHz**
- **Read-Out Driver: 8 optical inputs @ 640 Mbps**
- **One TileCal Barrel – 64 Modules – 8 RODs ; Total bandwidth : 40,96 Gbps**
- **Data processing: 2 modules / DSP.**
- **Data compression in ROD:**
  - **Output data bandwidth half of the input → raw data replaced by reco data (E, T ,QF)**

Validation with data of on-line reconstruction of Energy and Time in TileCal (Y.Z., B.M. + IFIC). Continue to do it with increasing luminosity

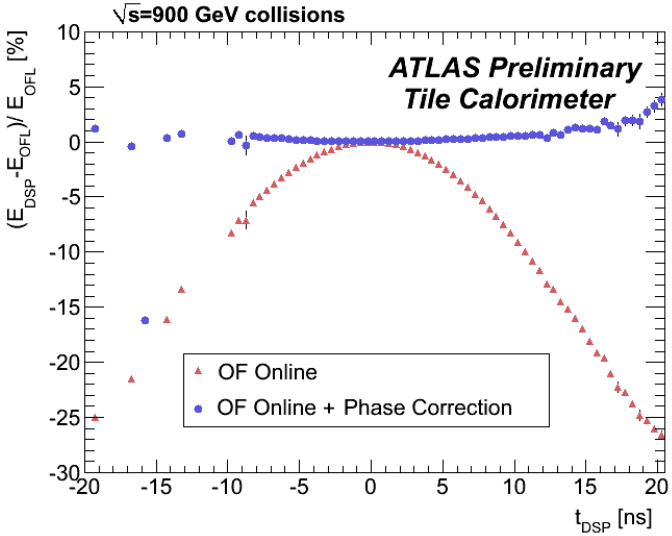
Eventually the sampling information will not be saved and the off-line rec. will rely on on-line with some corrections



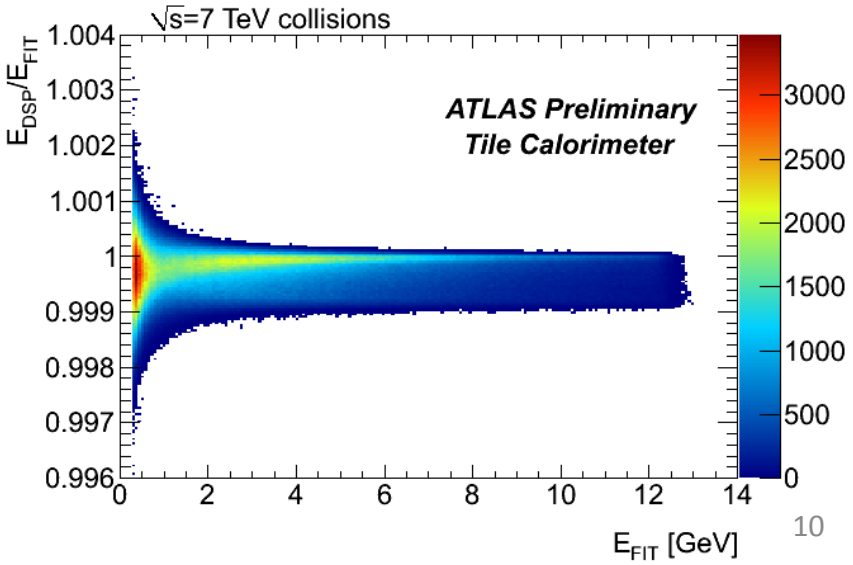
$$A = \sum_{i=0}^{n} a_i S_i$$

$$\tau = \frac{1}{A} \sum_{i=0}^{n} b_i S_i$$

Performance of the ROD/DSP Optimal Filtering (on-line) Non Iterative reconstruction with collision data, before and after phase correction. Differences between on-line and off-line within 1%



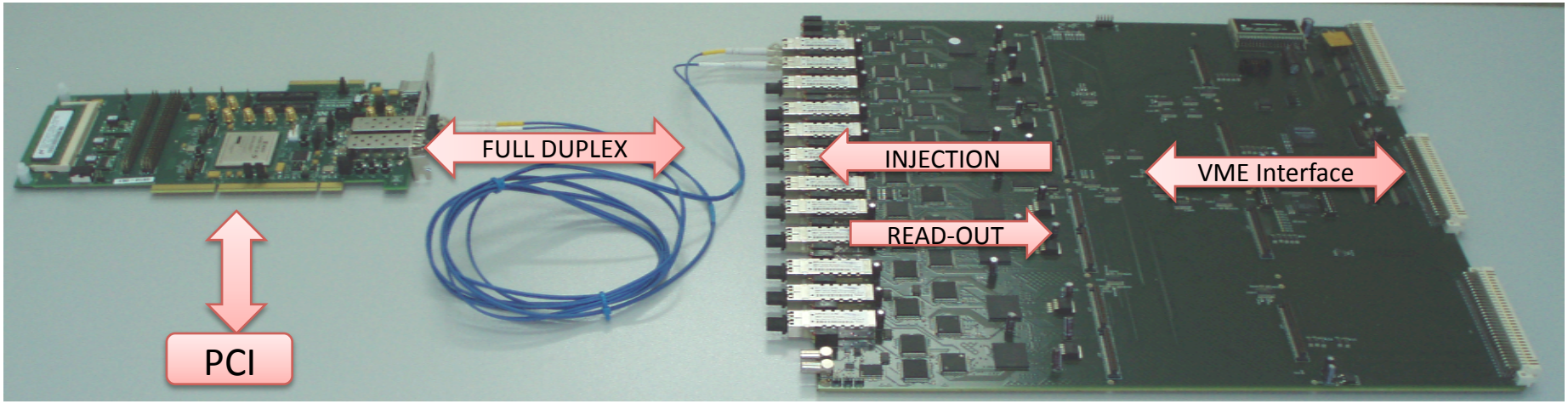
The difference between the amplitude reconstructed between on-line and off-line, for well synchronized pulses, is less now than 0.3%.



Upgrade of Read out: Data processing with FPGA.

- ❑ **Gb transceivers for data reception (10 Tbps).**
- ❑ **FPGA processing**
- ❑ **PCI read-out**

Plan to contribute to the debugging and commissioning of the upgraded read out in collaboration with IFIC

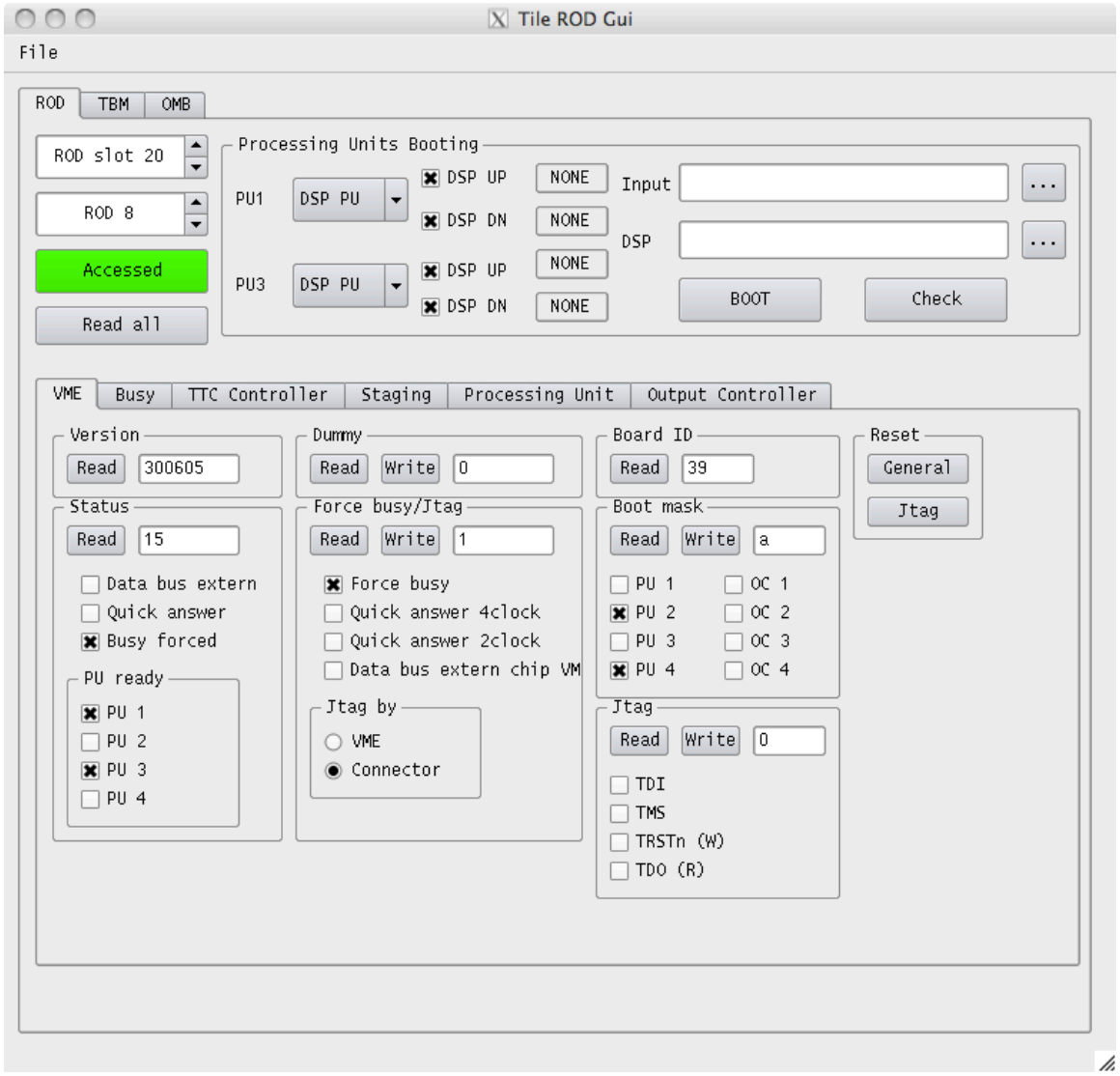


Possible mini-upgrade by 2012 would be to increase the output bandwidth of back-end by increasing number of links, compressing digits, etc…

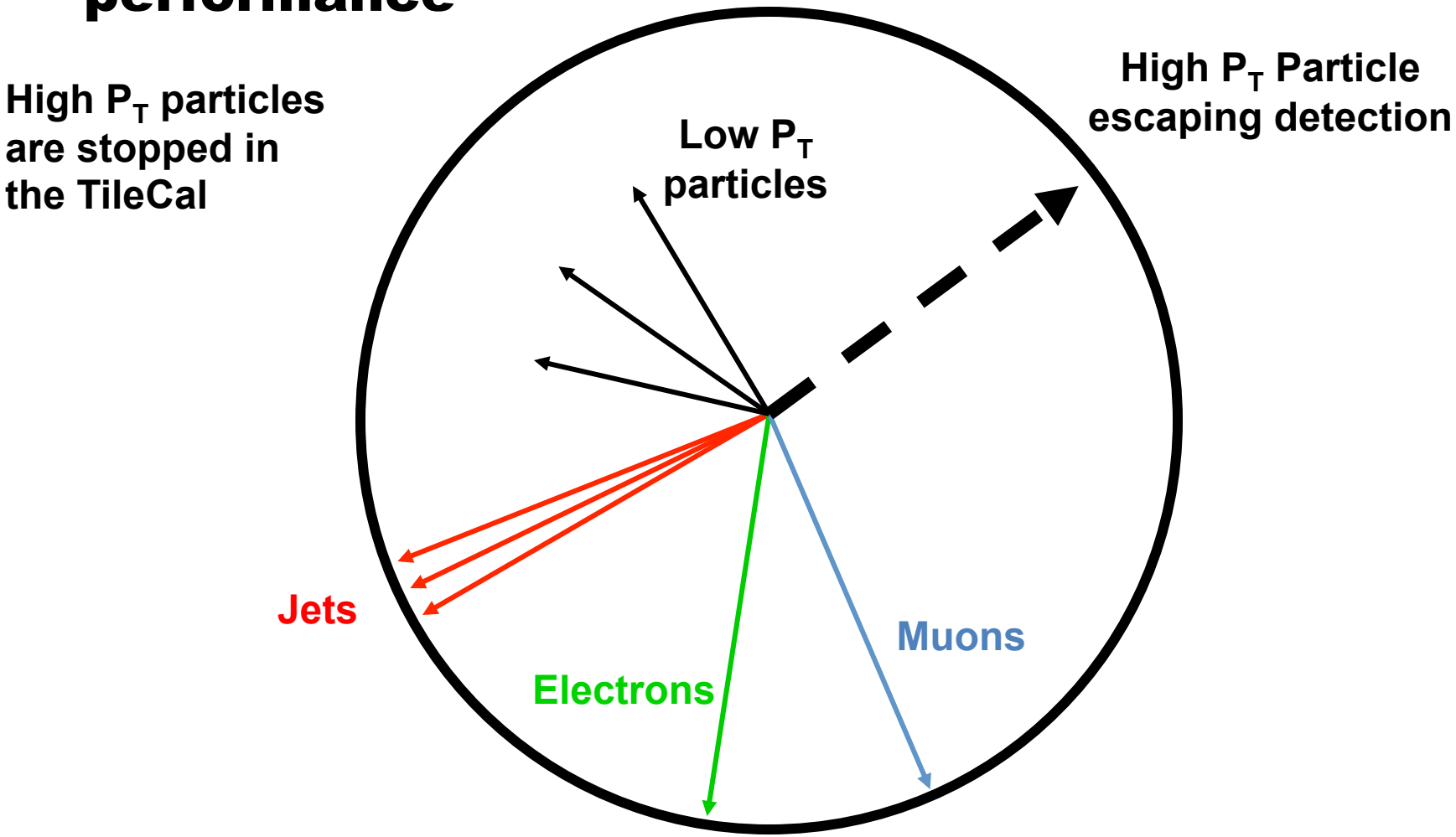
Collaboration with UW Engineering

- We have a collaboration with the Engineering department in UW
- The High-tech environment of the LHC attracts the attention of engineering students
  - Training in the boundary between electronics and computing in the TileCal
    - With support of Argonne NL and IFIC
- Developing in-campus interdisciplinary collaboration. This is very much liked by UW.
  - In contact with Graduate School and the Wisconsin Alumni Association
- Physics Graduate Students play a central role, linking faculty and engineering students

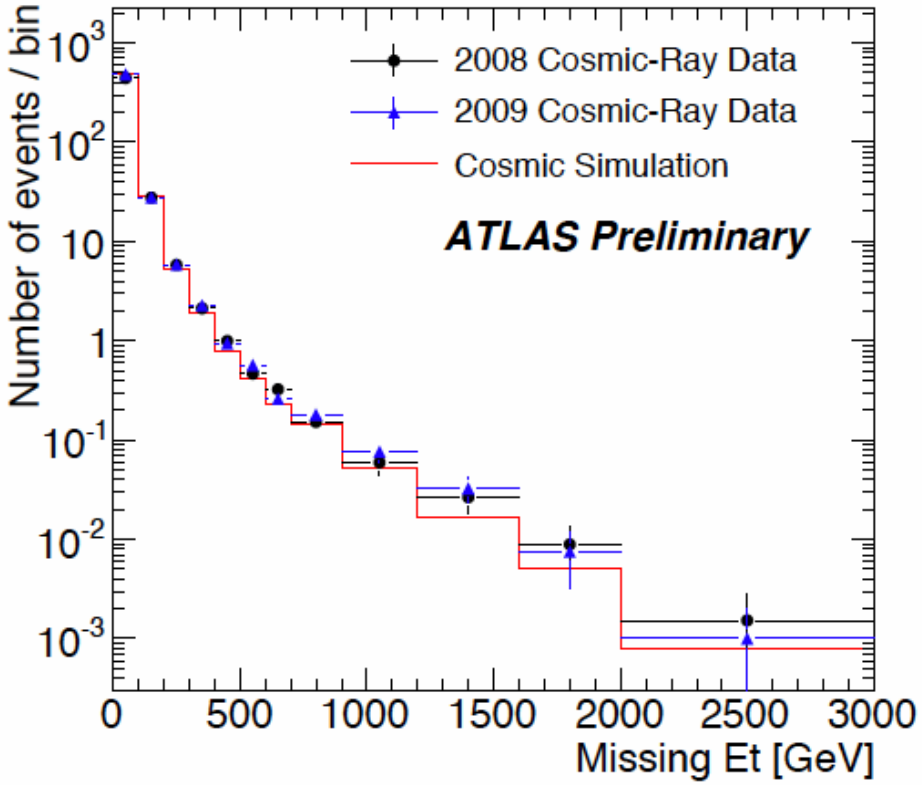
- **One of the contributions from the engineering students. Debugged and improved gui used by TileCal shifters in the ATLAS control room and for satellite shifts!**

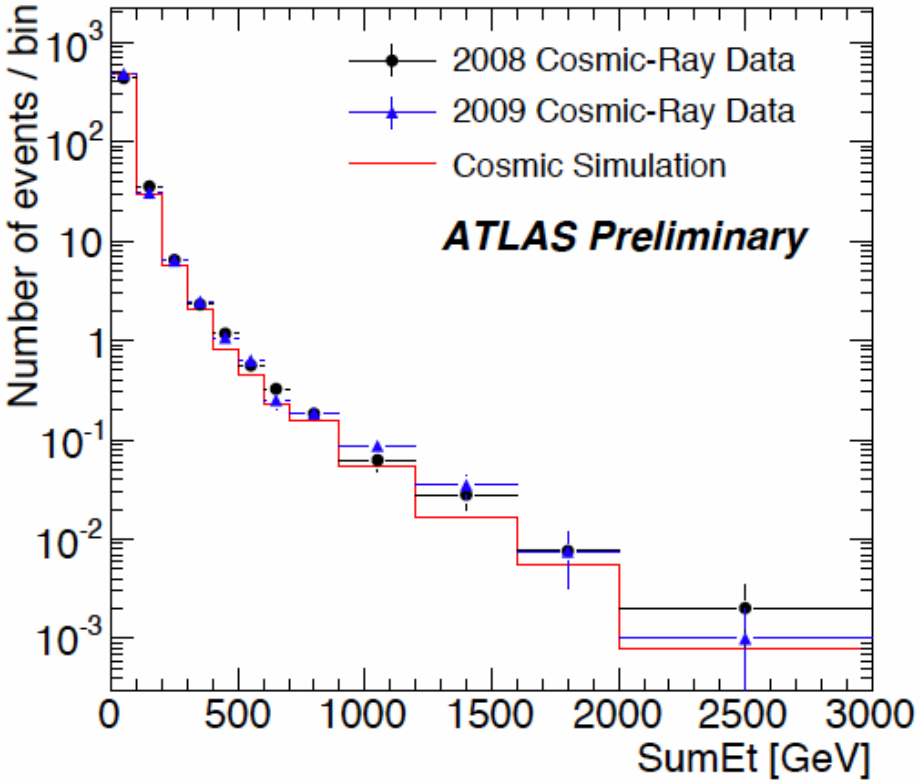


- **The reconstruction of the Missing Transverse Momentum is crucial for the physics program of ATLAS. So is understanding of the TileCal performance**



Before data-taking started our group contributed to the understanding of potential non pp collision sources of fake MET, like calorimeter noise, cosmic muons. Use shower shapes and timing. Developed likelihood-based discriminator against these backgrounds:
https://twiki.cern.ch/twiki/bin/view/Atlas/Approved2009CosmicPlotsJetEtMiss





This includes exhaustive understanding of calorimeter noise

Y.Zhu, B.Mellado

Combined performance studies of the ATLAS detector using cosmic-ray muons

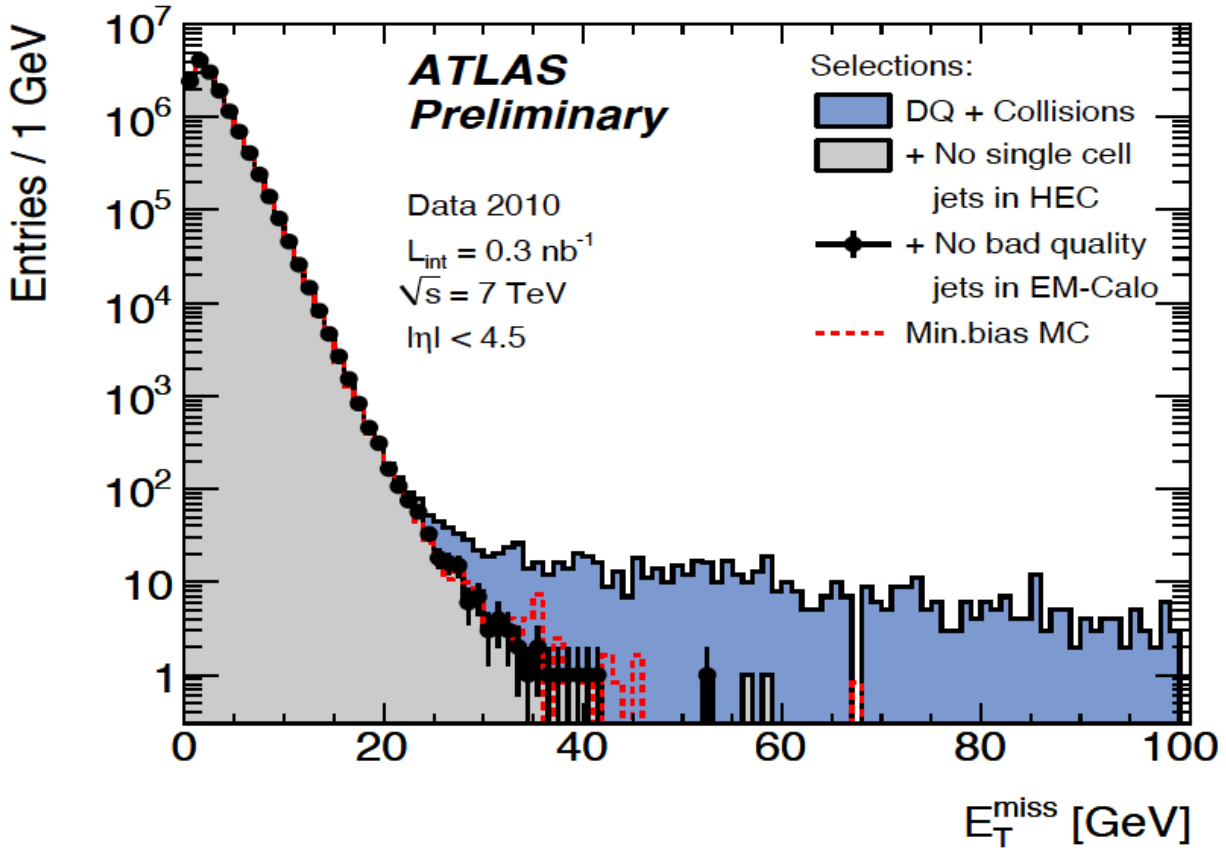
Version: 0.95

To be submitted to: Eur. Phys. J. C

Fake MET in ATLAS

- **We have contributed strongly to define the cleaning criteria used ATLAS-wide to clean the event from fake MET**
  - **Plan to continue to do so as TileCal experts**
  - **Need to reduce fake MET by a factor of 10 or more**

Y.Zhu, B.Mellado



Fake MET in ATLAS

- **B.M. is a convenor of the session "Jet and MET cleaning for 2010/2011 data analysis" as the representative of the TileCal**

http://atlas.pi.infn.it/hcworkshop

Continue working for the next three years in the areas marked on the right (Y.Z., X.C., Y.P., B.M.) as TileCal contacts

1. Good run list criteria
2. Scrutinize the jet and met distributions (from L1Calo and MinBias
3. Source of fake jets and etmiss tails:
    1. Cosmic and beam background rejection
    2. Detector failures (HEC spike, EM coherent noise, ...)
        1. origin,properties,characteritics
        2. rate,evolution
    3. Jet punch through
4. Response in bad calorimeter regions
    1. TileGap3
    2. Corrections from trigger read-out in bad calorimeter regions
    3. non-nominal LAr HV
    4. TileNoiseFilter
5. Tools to kill fake jets and etmiss tails:
    1. Vertex requirement
    2. Data/MC comparison of actual cleaning variables: ,...
    3. Tracks
6. Improvement on calorimeter cell quality
    1. Normalized Q-factor
    2. Tile
7. Improvement on calorimeter timing
8. Cells and clusters cleaning
9. Efficiency measurements of cleaning cuts from data

Leadership at ATLAS

- Y.Pan chaired the session "Detectors and Performance (Calorimetry) at the 4th ATLAS Physics Workshop of the Americas (August 2010)
- Y.Pan to join the TileCal publications committee
- B.Mellado is the convenor of the H->WW group
  - Editor of the two ATLAS public notes in 2010
- B.Mellado to chair MissingET cleaning session at the ATAS-wide Hadronic calibration workshop (September 2010)
  - TileCal contact person
- B.Mellado appointed ATLAS contact person for data-driven extraction methods for H->WW,ZZ searches
- B.Mellado was a member of the Higgs cross-sections task force
- B.Mellado was a member of the US ATLAS Tier3 task force
- B.Mellado is a member of the ATLAS cross-section task force
- B.Mellado is a member of US ATLAS panel "Collaboration involvement in remote analysis"

Summary of ATLAS documents

- Data-driven determinations of W, Z and top background to Supersymmetry searches at the LHC, ATL-PHYS-INT-2008-030
- SUSY searches in the lepton plus inclusive jets plus missing transverse energy final state, ATL-PHYS-INT-2009-031
- Prospects for the exclusion of a SM Higgs decaying to two photons, ATL-PHYS-INT-2010-061
- Searching for Supersymmetry with two same-sign leptons, multi-jets plus missing transverse energy in ATLAS, ATL-PHYS-INT-2009-065
- b-Tag-Independent Search for the Neutral MSSM Higgs Boson in the Dimuon Decay Channel, ATL-PHYS-INT-2009-086
- Discovery Potential and Exclusion Limits for R-Parity Conserving SUSY Signals at $\sqrt{s}$ =10 TeV in ATLAS, ATL-PHYS-INT-2009-114
- Suppression of Fake Missing Transverse Energy from Cosmic Ray Muons in the ATLAS Calorimeter, ATL-PHYS-INT-2010-028
- Higgs Boson Production Cross Sections and Decay Branching Ratios, ATL-PHYS-INT-2010-030

Summary of ATLAS documents

- Prospects for the exclusion of a SM Higgs decaying to two photons, ATL-PHYS-INT-2010-061
- ATLAS sensitivity prospects for the Standard Model Higgs boson in the decay channel $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ at $\sqrt{s}$=10 and 7TeV, ATL-PHYS-INT-2010-062
- Prospects for W/Z+jets early data measurements with the ATLAS detector at the LHC, ATL-COM-PHYS-2010-150
- Prospects for Higgs boson searches using the $H \rightarrow WW \rightarrow \ell\ell \upsilon \upsilon$ decay mode with the ATLAS detector at $\sqrt{s}$=10 TeV, ATL-PHYS-PUB-2010-005
  - ATLAS strategy for Higgs analysis with first data
- ATLAS Sensitivity Prospects for Higgs Boson Production at the LHC Running at 7 TeV, ATL-PHYS-PUB-2010-009
- Initial sensitivity of ATLAS inclusive SUSY search at $\sqrt{s}$ = *10 TeV in* the one-lepton final state by fitting and number counting, ATL-PHYS-INT-2010-077
- ATLAS Standard Model Cross Section recommendations for 7 TeV LHC running (to appear)

ATLAS Notes with Data

- Performance of the missing transverse energy reconstruction in minimum bias events at √s of 900 GeV and 2.36 TeV with the ATLAS detector, ATLAS-CONF-2010-008
- Data-Quality Requirements and Event Cleaning for Jets and Missing Transverse Energy Reconstruction with the ATLAS Detector Proton-Proton Collisions at a Center-of-Mass Energy of √s =7 TeV, ATLAS-CONF-2010-038
- Performance of the missing transverse energy reconstruction in minimum bias collisions at center-of-mass energy of √s =7 TeV with the ATLAS detector, ATLAS-CONF-2010-039
- Observation of W→ℓυ and Z→ℓℓ production in proton-proton collisions, ATLAS-CONF-2010-044
- Measurement of the W→ℓυ production cross-section and observation of Z→ℓℓ production in proton-proton collisions at √s =7 TeV with the ATLAS detector, ATLAS-CONF-2010-051
- Performance of the Missing Transverse Energy Reconstruction and Calibration in Proton-Proton Collisions at a Center-of-Mass Energy of √s =7 TeV with the ATLAS Detector, ATLAS-CONF-2010-057

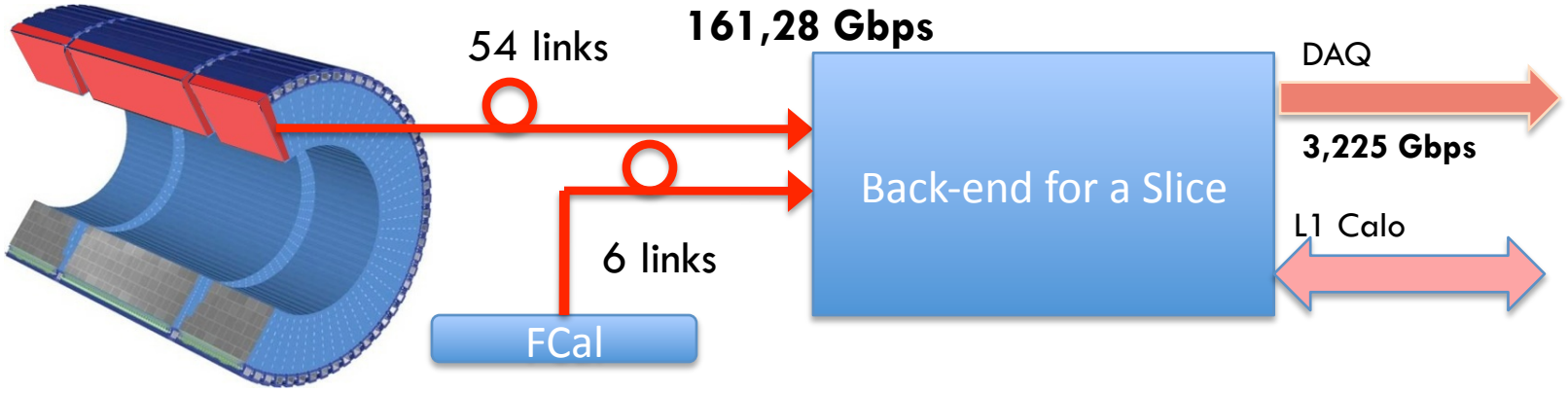
ATLAS Notes with Data

- **Measurement of the Background from W+jets to the H→WW→ℓ υ ℓ υ Search with the ATLAS detector at 7 TeV, ATLAS-COM-CONF-2010-084**
  - **HISTORIC, first Higgs-like note with data!**
- **Tests of the data driven ZZ and Z+jets background estimation methods for the Higgs boson search in the 4-lepton final state, ATL-COM-PHYS-2010-611 (To appear publicly)**
- **Combined performance studies of the ATLAS detector using cosmic-ray muons, To be submitted to: Eur. Phys. J. C**

Additional Slides

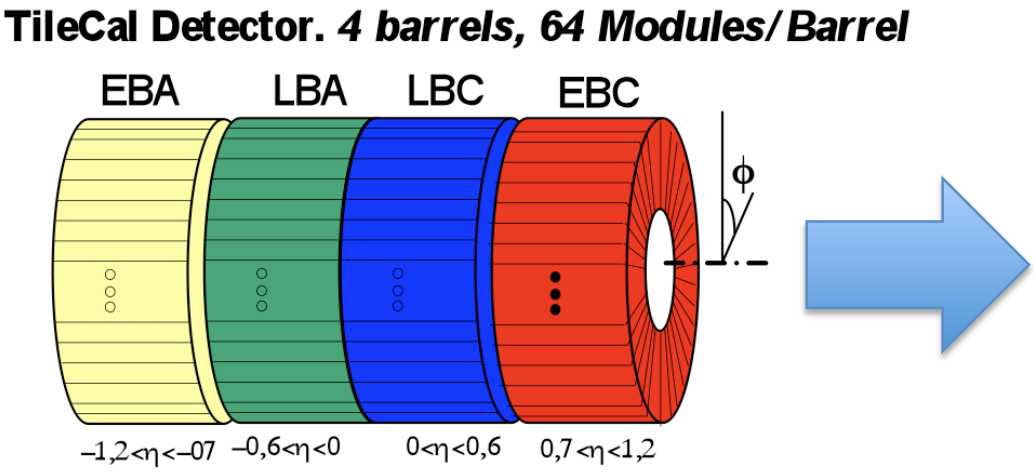
Back-end requirements for Upgrade

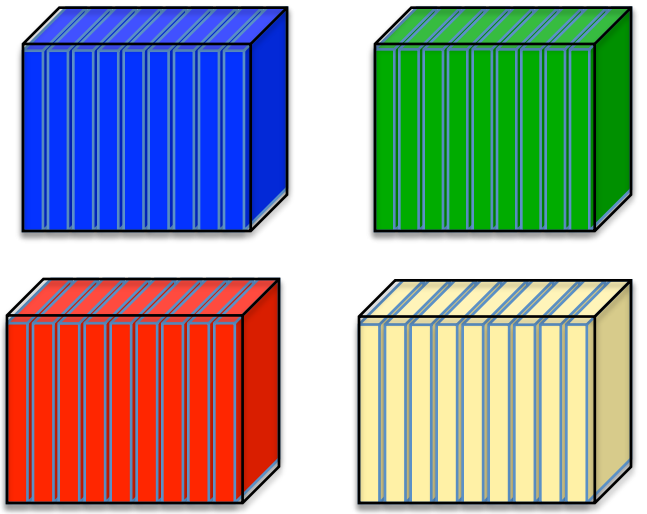
- **Front-end links**
  - **5 SNAP12 connectors = 60 Transceivers (current GBT speed)**
  - **Fcal links for tower computation**
- **MEMORY**
  - **Pipeline memory: (36 + 48 + 48 + 36) * 24 * 256 (6,4us / 25 ns) = 1033Kb**
  - **Derandomizer: 168(ch) x 16(samples) x 24 (bits) x 20 (events) = 1290Kb**
- **PROCESSING**
  - **Embedded processor for control, monitoring, weights handling, interruptions.**
  - **ROD Processing : E , T , QF in parallel : 168 Ch → 168 DSP blocks**
- **L1CALO PP**
  - **ROD_Input - PP links /per slice = 43,120 Gbps (77 cells @ 560 (14bitsx40Mbps))**
  - **PrePro: Energy and Phase computation at BC rate :: 168ch x 5 smp x 2 (E & T) = 1680 DSP blocks**
  - **Output links to L1Calo after Preprocessing**
- **DAQ out**
  - **168 (ch / FPGA) x 16 Samples x 12 bits x 100KHz = 3,225 Gbps**



TTC Partitions :: Crates

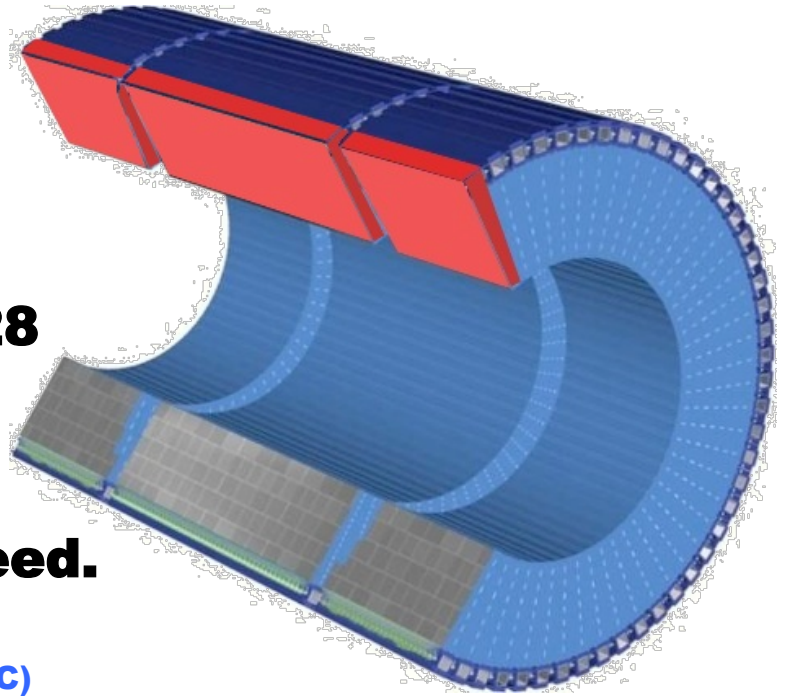
ROD& TTC Partitions : 8 ROD x 4 Crates





- **Complete TileCal Read-Out: 32 RODs (8 x 4 crates)**
- **Divided in four TTC partitions corresponding with four barrels /crates.**
- **ROD processing:**
  - **EB : 288 Ch / ROD** **Unbalanced use of RODs**
  - **LB : 384 Ch / ROD**

Tentative Upgrade of read-out



- TileCal Slice: Allows complete towers computation 168 Ch.
- 12-bits Samples (HG + LG) @ 40 Msps
- Slice: 40 x 24bits x (72 + 96)ch = 161,28 Gbps
- TileCal : 64 x 161,28 Gbps ~**10 Tbps**
- Link structure depends on links speed.
  - GBT :
    - Current 130nm technology : 5 Gbps (Data-DCS-TTC)
    - Max: 3,2 Gbps for data
    - Speed improvement for 90 nm to be decided.
  - 5 SNAP12 connectors (12 links each) to read-out one TileCal Slice
  - Front-End : Rad-hard needed : GBT
  - Back-end implementation in FPGA SER/DES ports.