The ALICE Electromagnetic Calorimeter

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For the ALICE Collaboration

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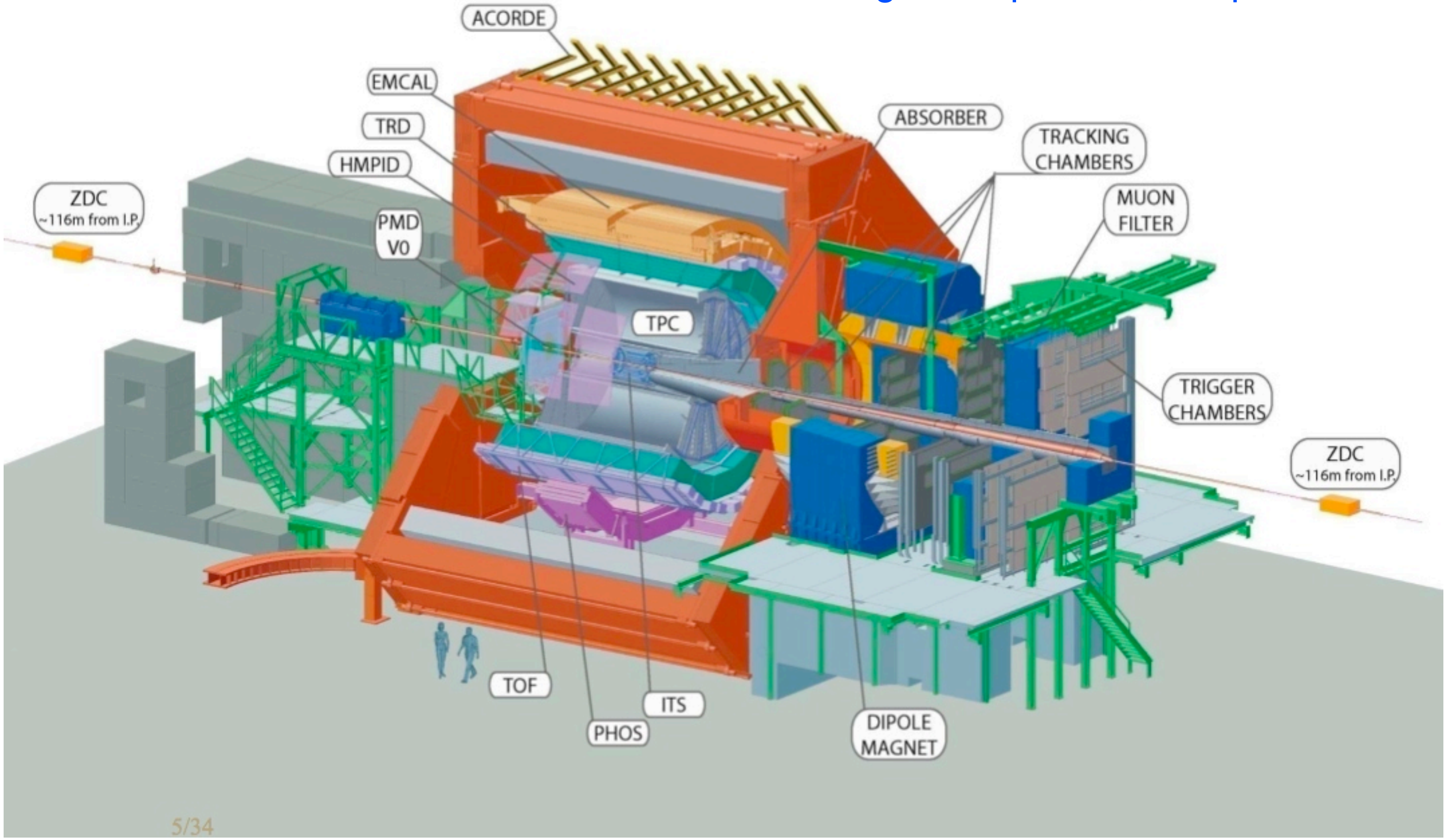
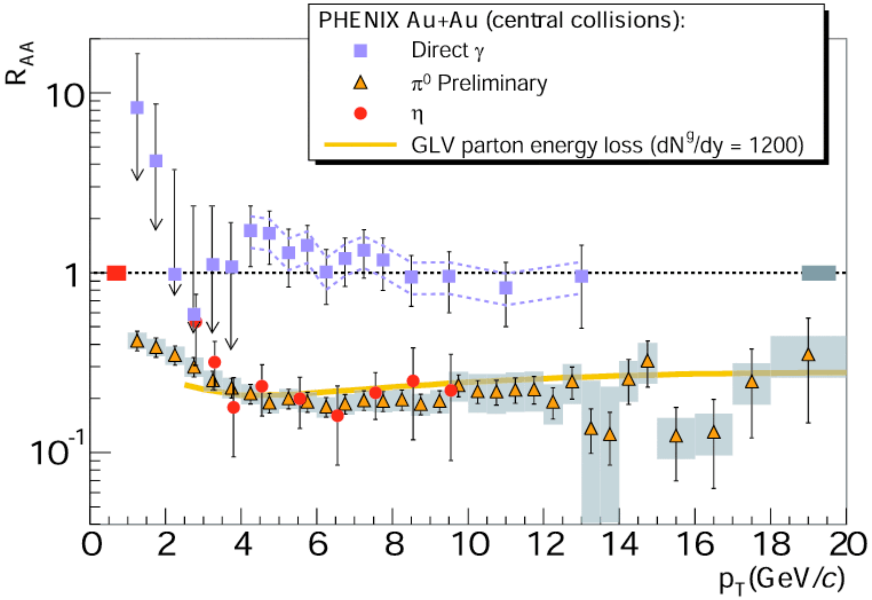
The ALICE Experiment

- Pb+Pb @LHC emphasis
  - High multiplicities, soft particles

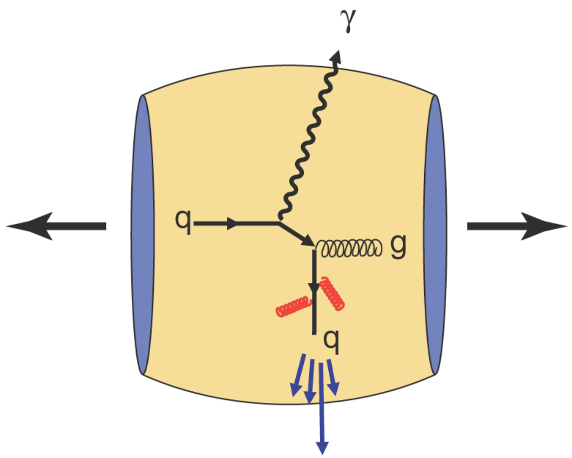


Jets in ALICE

Jet "Quenching" at RHIC

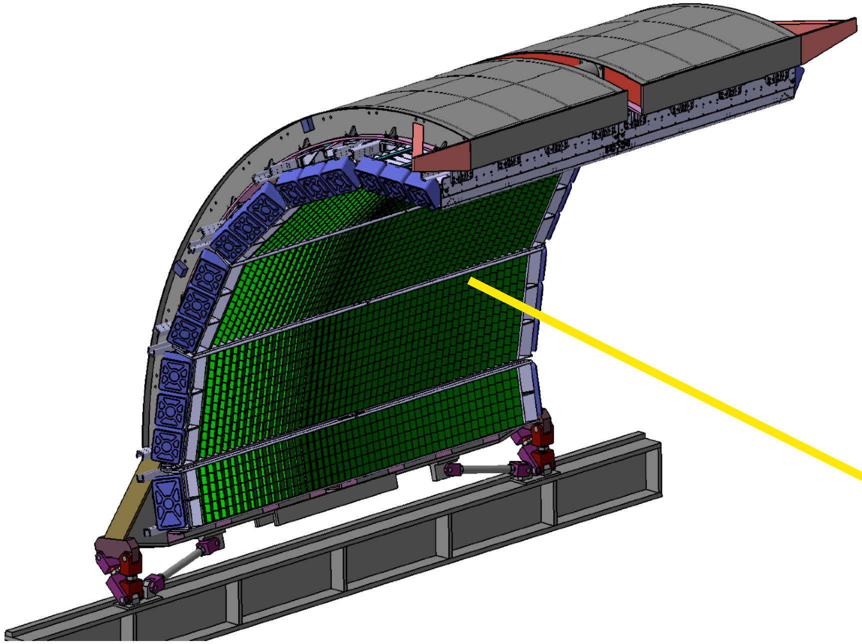


$$R_{AA}(p_t,\eta;b) = \frac{1}{\langle N_{coll}(b)\rangle}\frac{d^2N^{hard}_{AB}/dp_t d\eta}{d^2N^{hard}_{pp}/dp_t d\eta},$$

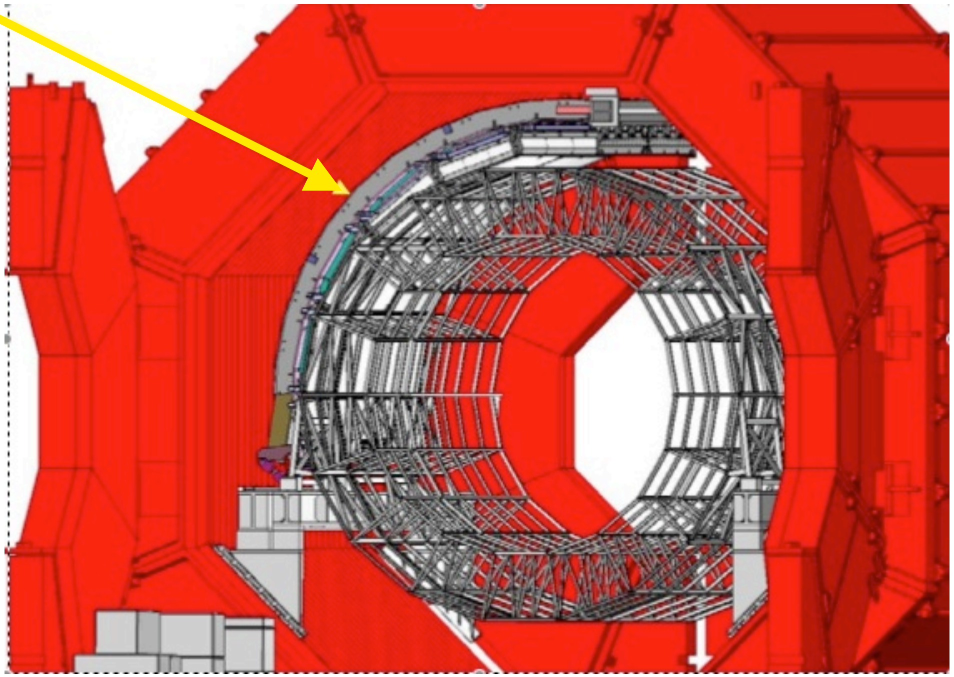


- Hard-scattered partons interact strongly with the medium and lose energy resulting in softer fragmentation
  - Probe of medium
  - Important at LHC due to increased jet cross section
- To study jet fragmentation in detail requires EMCal
  - Measure EM energy to provide total jet energy (or recoil γ)
  - Provide jet (or γ) trigger

The Electromagnetic Calorimeter



- Funding approval: Feb. 2008
  (~ALICE Upgrade: US, Italy, France, CERN, Finland)
  – 7+2/3 US Super-Modules (SM)
  – 3 EU SMs (Italy and France)
  – Construct and Install 2008-2011

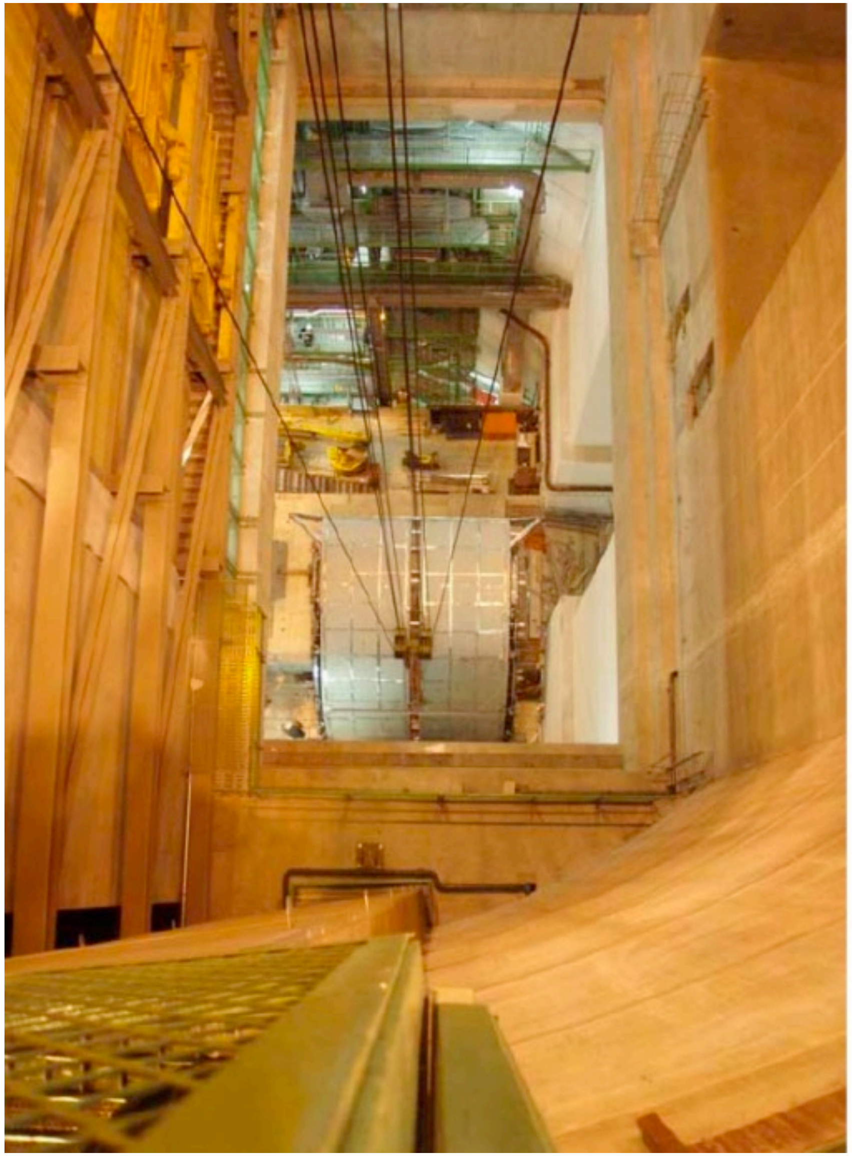


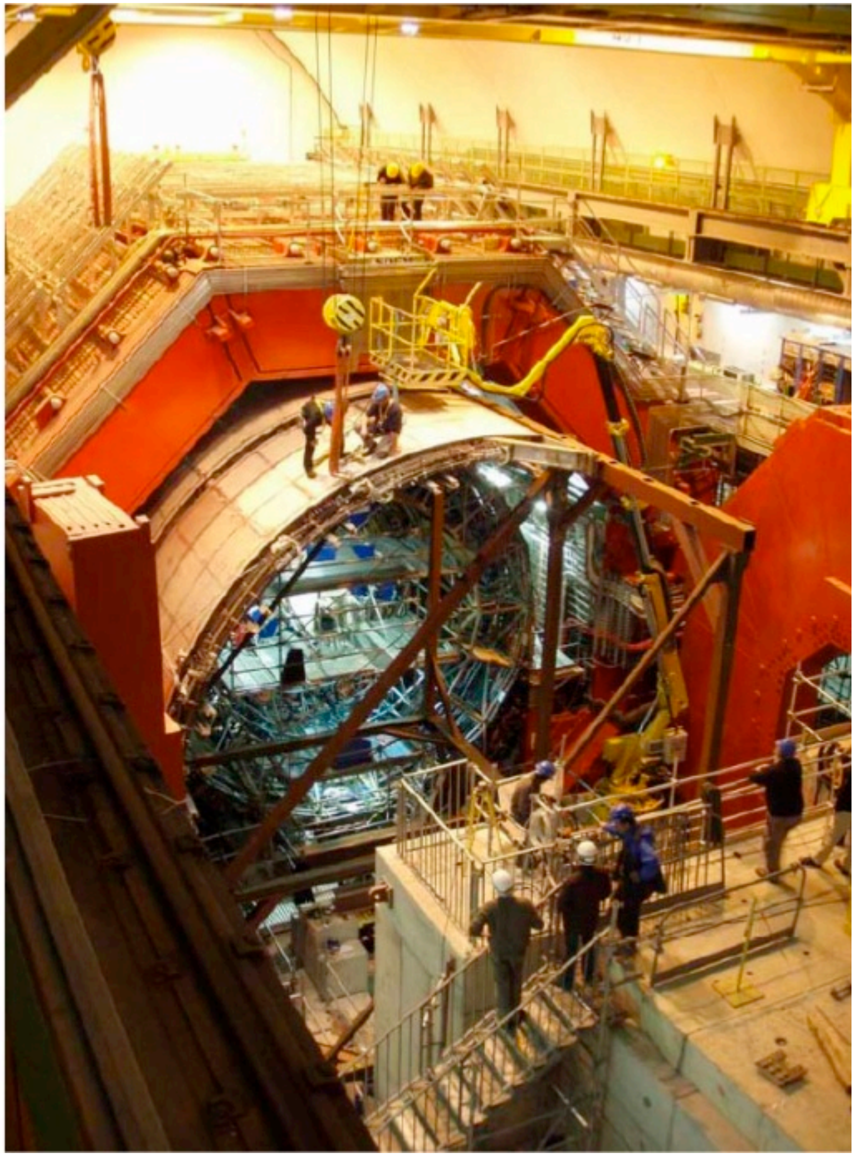
Lead-Scintillator Sampling Calorimeter
$\Delta\eta$ = 1.4, $\Delta\phi$ =107°

Shashlik Geometry, APD Photosensor
12288 Towers

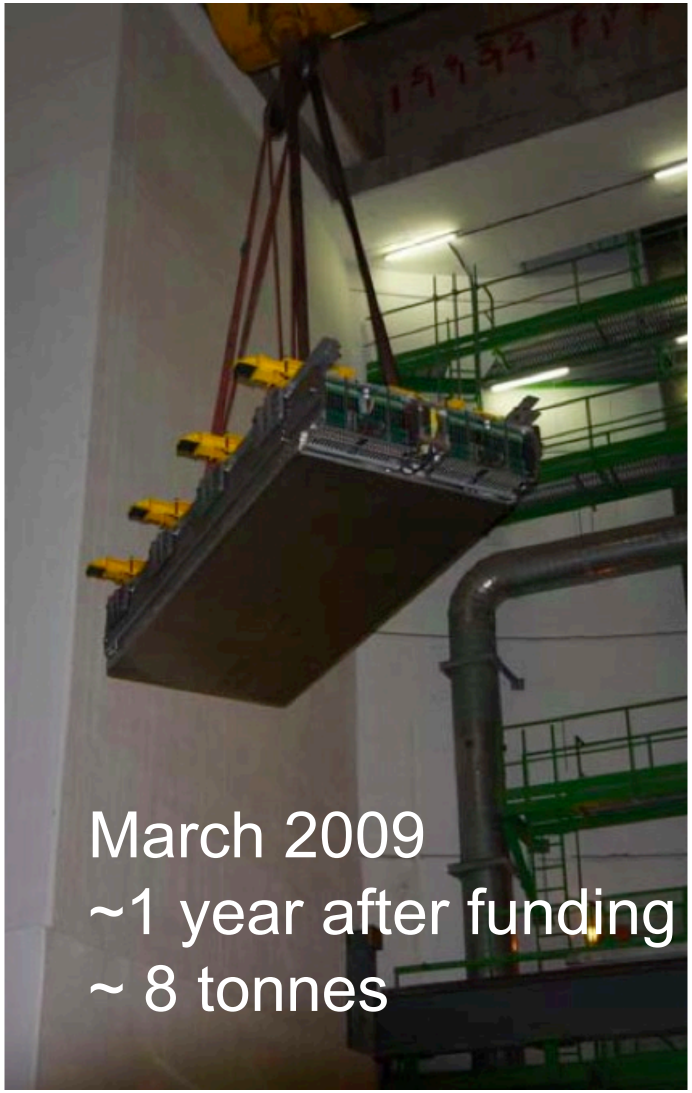
EMCal Support Structure

EMCal Installation in ALICE

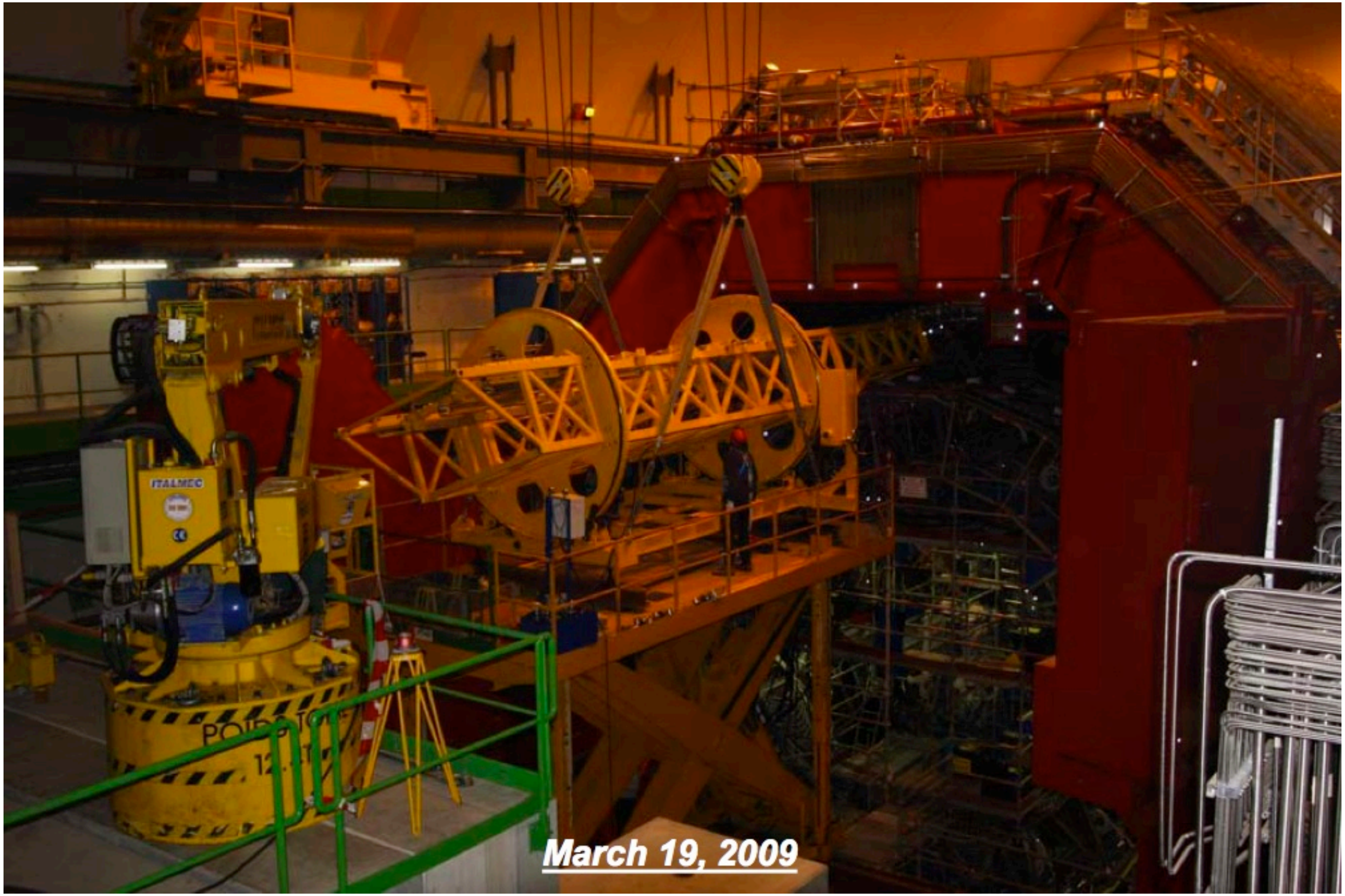




Arrival of First EMCal SM

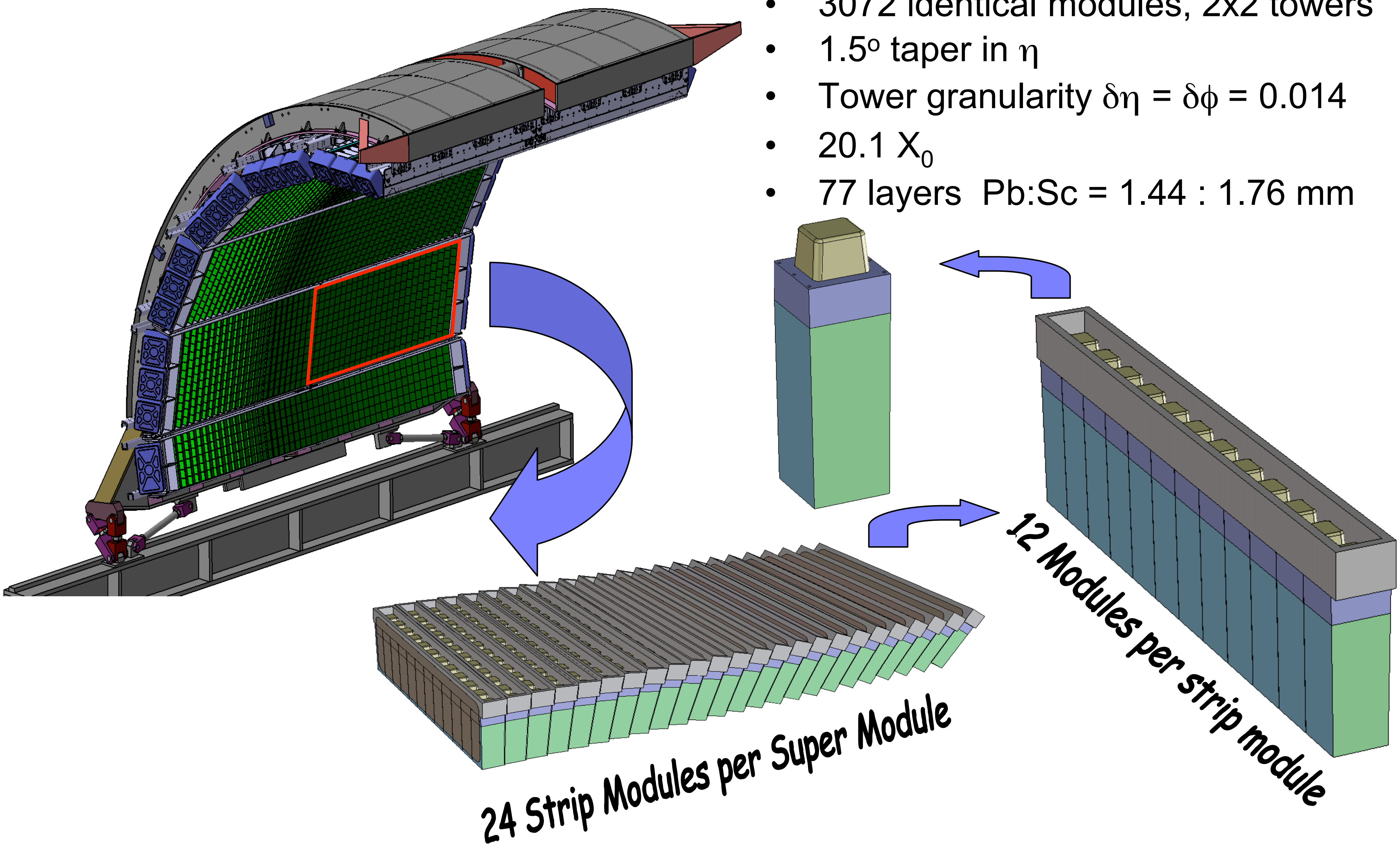


Installation of EMCal (SM #2)

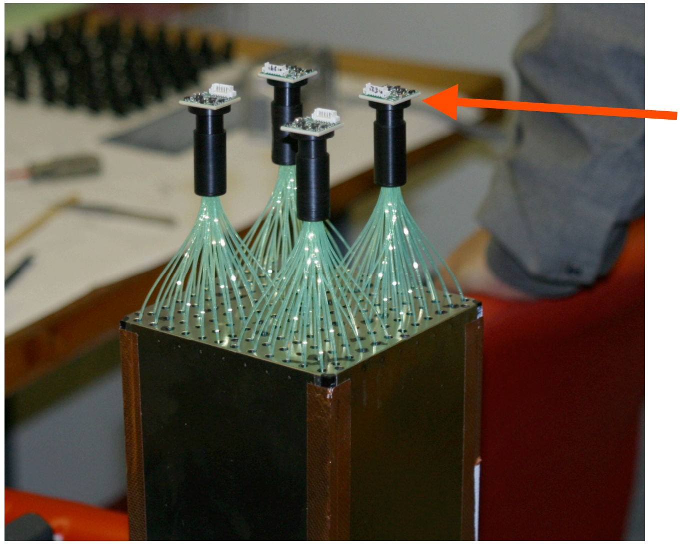


EMCal Assembly

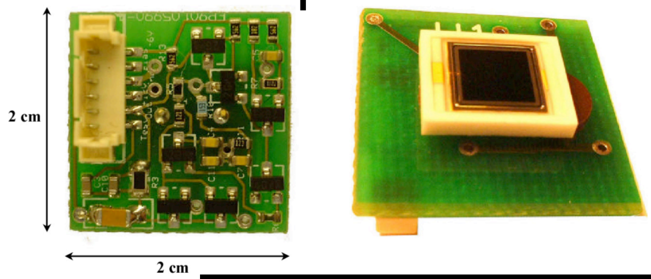
- 3072 identical modules, 2x2 towers
- 1.5^{o} taper in η
- Tower granularity $\delta\eta = \delta\phi = 0.014$
- $20.1\ X_0$
- 77 layers Pb:Sc = 1.44 : 1.76 mm

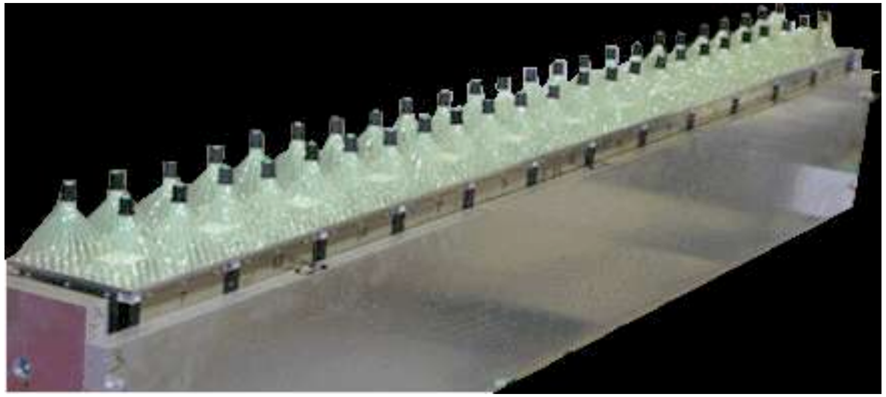


EMCal Readout



Preamplifier+APD



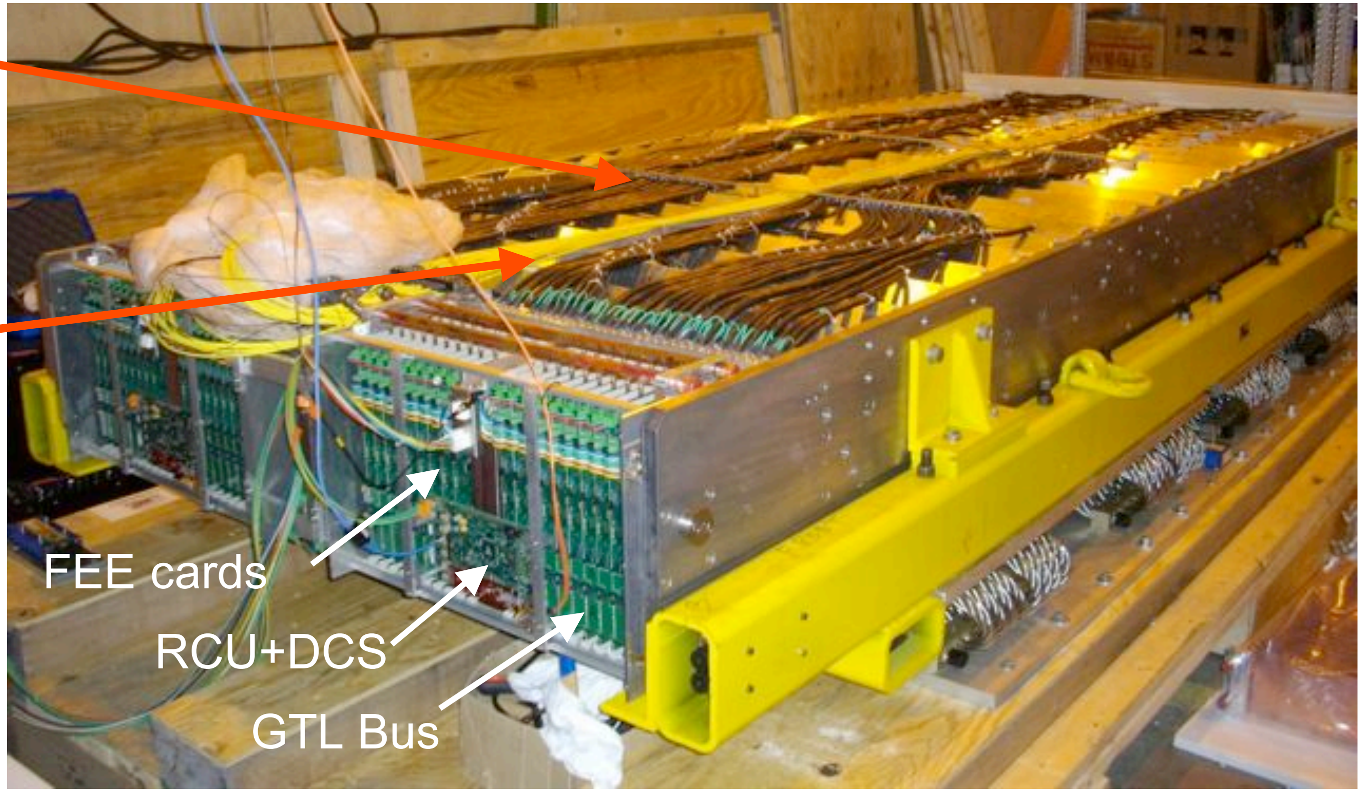


- 4 6x6 cm^2 towers/module
- WLS fiber readout on 1cm grid
- 5x5 mm^2 Hamamatsu S8148 APD
- ~4.5 photo-electrons/MeV at gain M=1
- Operated at nominal M=30
- Fullscale Energy = 250 GeV

EMCal SM Readout Assembly

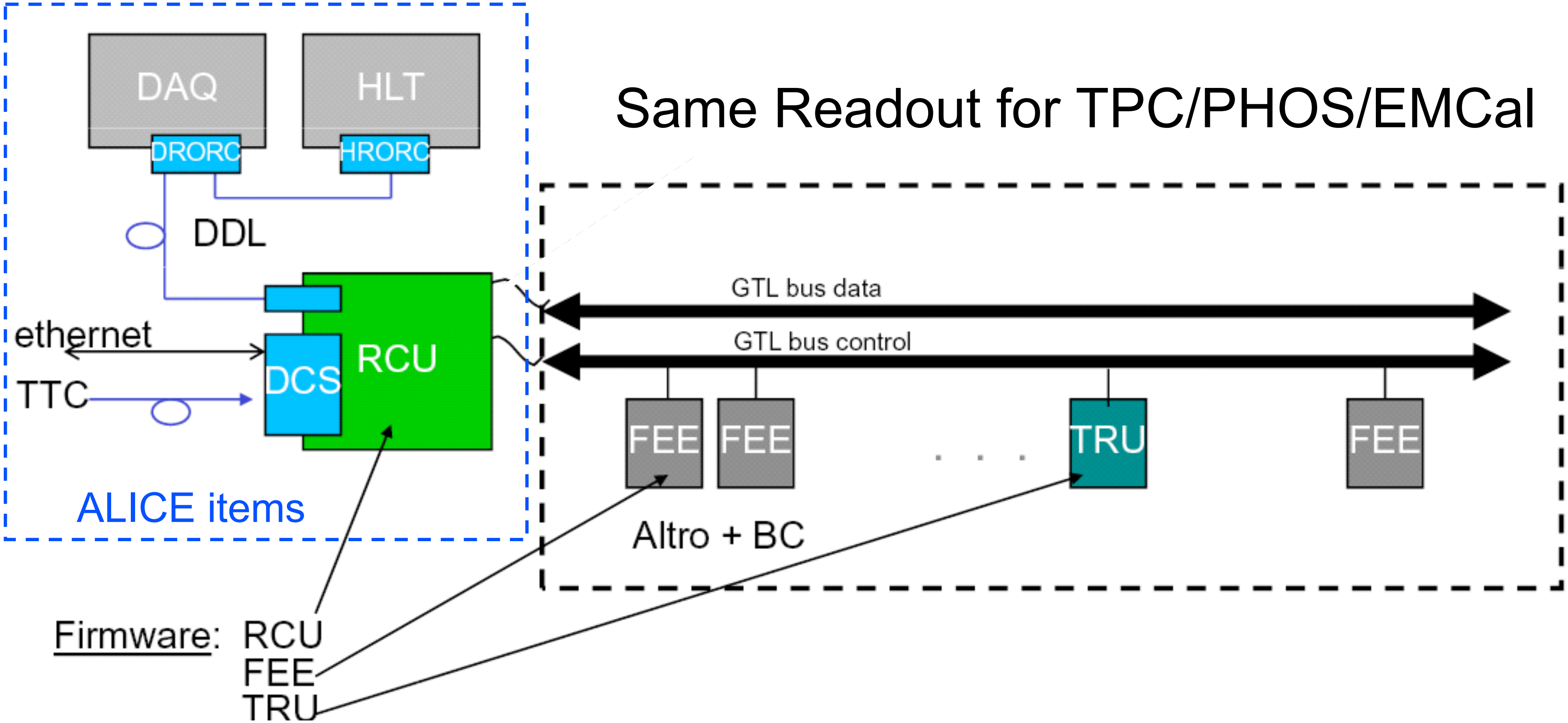
- Signal Cables
  - 4 modules each
    - 16 towers
  - 2 per FEE

LED fibers (monitoring)



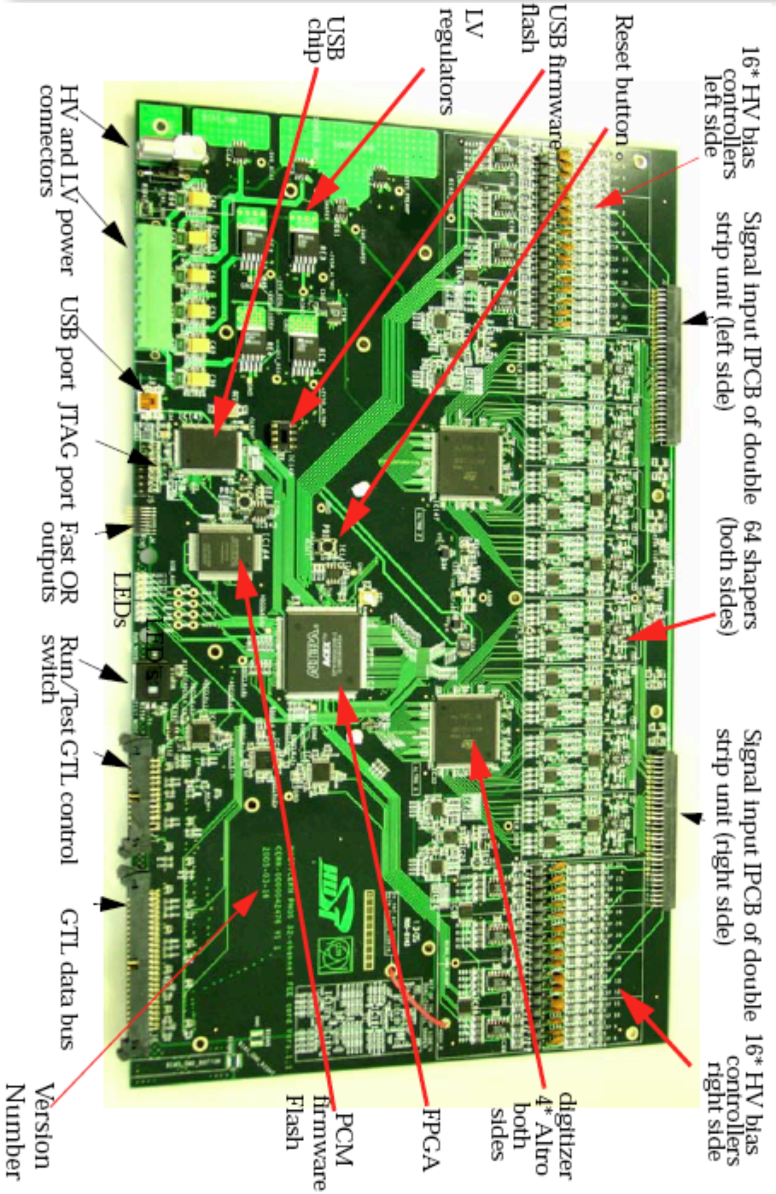
- 2 FEE crates per SM
- 1 Readout+Detector Control Unit (RCU+DCS) per FEE crate
  - Control via ethernet. Readout via fiber optic (ALICE DDL standard)
  - 2 GTL Readout/Control Bus per FEE crate
    - 9 FEE cards + 1 Trigger Region Unit (TRU) card per GTL bus
      - 36 + 1 FEE cards + 3 TRU per SM

EMCal Readout Overview



- 9 FEE + 1 Trigger Region Unit (TRU) setup/readout via GTL bus.
- Readout Control Unit (RCU) controls FEE on up to 2 GTL bus branches.
- Detector Control System (DCS) RCU daughter card for FEE setup (e.g. APD bias)
- Data to DAQ via Detector Data Link on RCU - passed to High Level Trigger.

EMCal FEE



- 32 channels/FEE Card
- Individual APD Bias control (between 210 and 400V)
- Dual shapers (CR-2RC) for each channel for increased dynamic range. E.g. x16 gain difference.
  - EMCal uses 100ns shaping time
- Shaper output flash digitized with ALice Tpc ReadOut (ALTRO) chip: 10-bits, Sampling rate of 10MHz, multi-event buffering.
- 14-bits effective dynamic range
- Trigger capability with Analog sum of fast shaped (100ns) 2x2 adjacent towers (1 module), output to TRU trigger board to perform trigger logic.
- Readout via GTL backplane (same as ALICE TPC), same Readout Control

Designed by: H. Muller, CERN.
See Y.Wang, FEE poster session, Thurs. 16:00

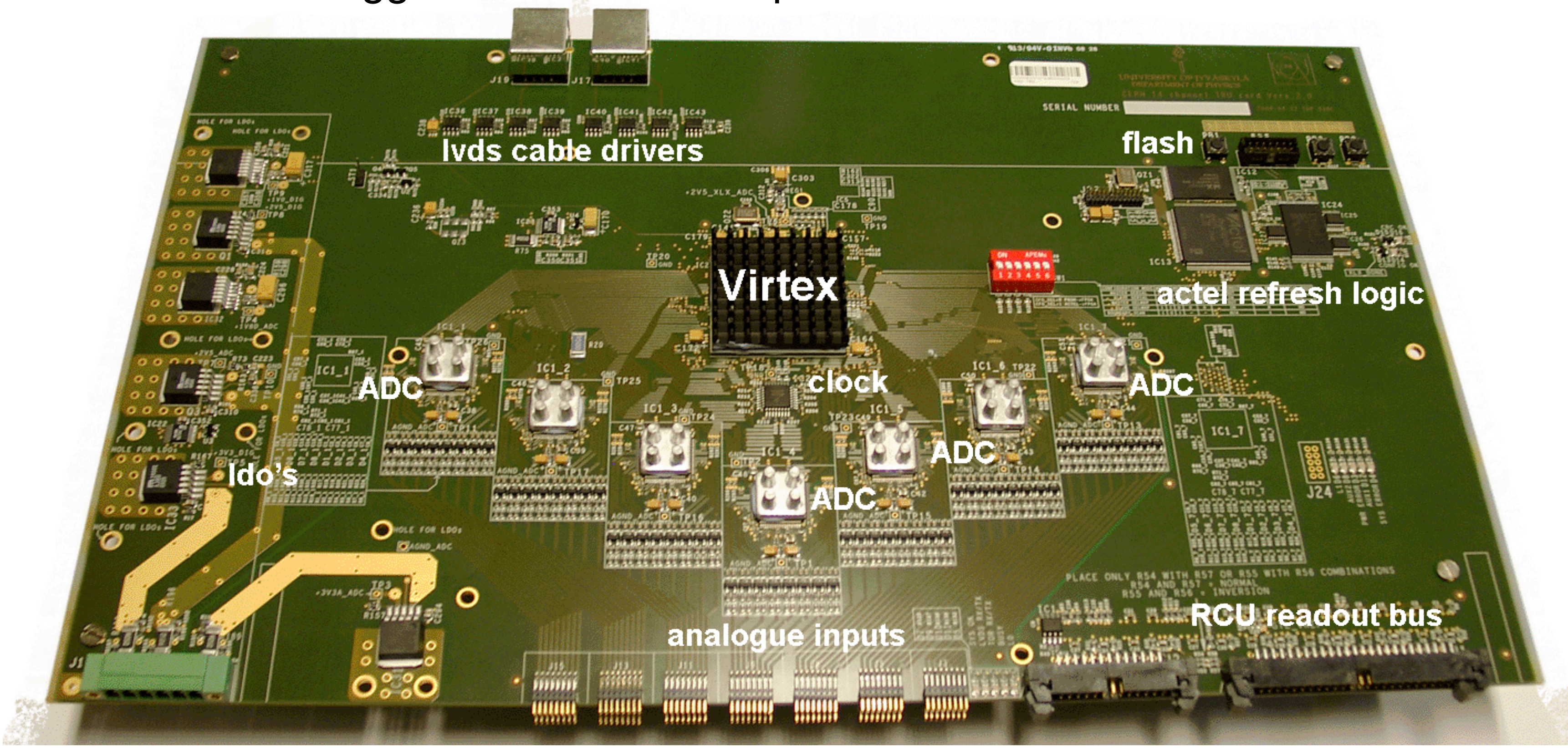
H.Muller, et al., NIM A565 (2006) 768.

EMCal Trigger Overview

- L0 - required at Central Trigger Processor within 800ns
  - Form trigger primatives
    - 2x2 towers analog summed in FEE (FastOR)
    - Output (via cable) to Trigger Region Unit where
      - flash digitized, pedestals subtracted, time-summed (integrated)
  - L0 algorithm (“activity” in EMCal) runs in TRU
    - Overlapping 2x2 FastORs digitally summed
    - Peak detect and Thresholds applied (low energy - EMCal activity)
    - Valid L0 triggers passed to Summary Trigger Unit (STU) to be OR’d
    - Upon accepted L0 from ALICE CTP
      - Pass FastOR time-summed data to STU for L1 algorithms
      - If desired, store trigger primative FastOR FADC samples, via GTL bus
- L1 - input from all TRUs to STU. L1 required at CTP within 5 μs
  - L1 High energy EM shower (γ, π^0, electron)
    - Form overlapping 2x2 FastOR digital sums
      - Multiplicity (centrality) dependent Thresholds applied (V0 detector input)
  - L1 Jet trigger
    - Form overlapping NxN FastOR digital sums (where N is large)
      - Multiplicity (centrality) dependent Thresholds applied (V0 detector input)

EMCal Trigger Region Unit

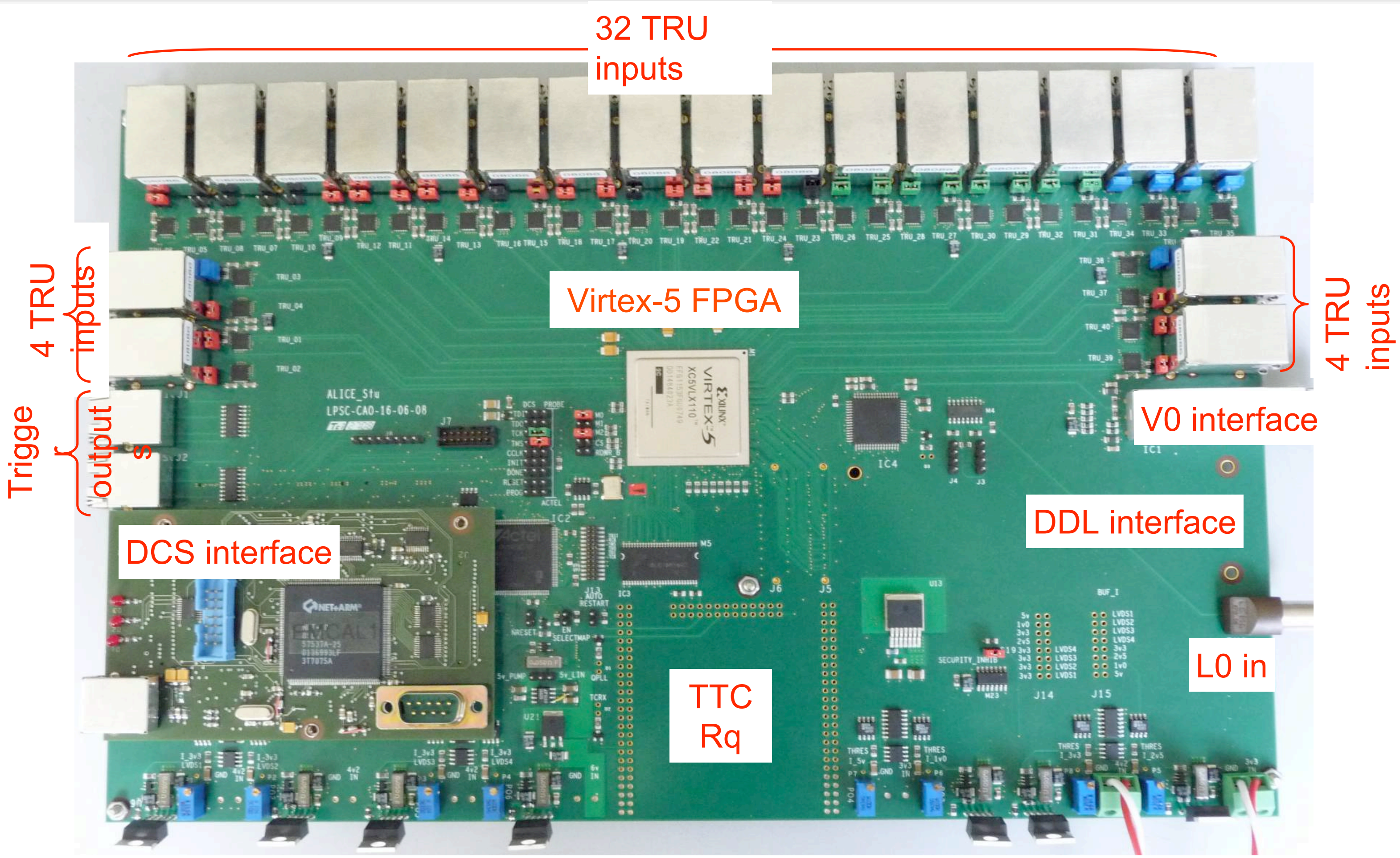
- Output: 4 LVDS lines to STU - L0, 2 serial data, 1 serial clock
- Raw 2x2 trigger FADC data samples can be recorded as FEE data



- Up to 112 2x2 tower (= 1 module) analog sums from FEE digitized (12-bits) at 40MHz
- L0 algorithm: overlapping 4x4 towers with low threshold (VIRTEX-5 FPGA)

Designed by: H. Muller, CERN. See FEE poster session, Thurs. 16:00

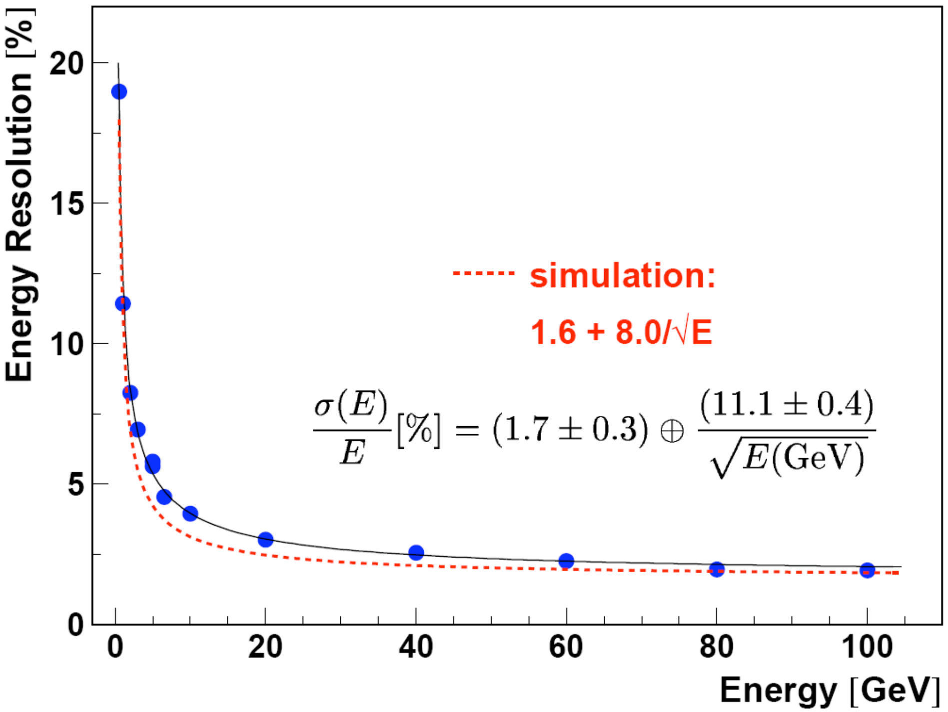
Summary Trigger Unit

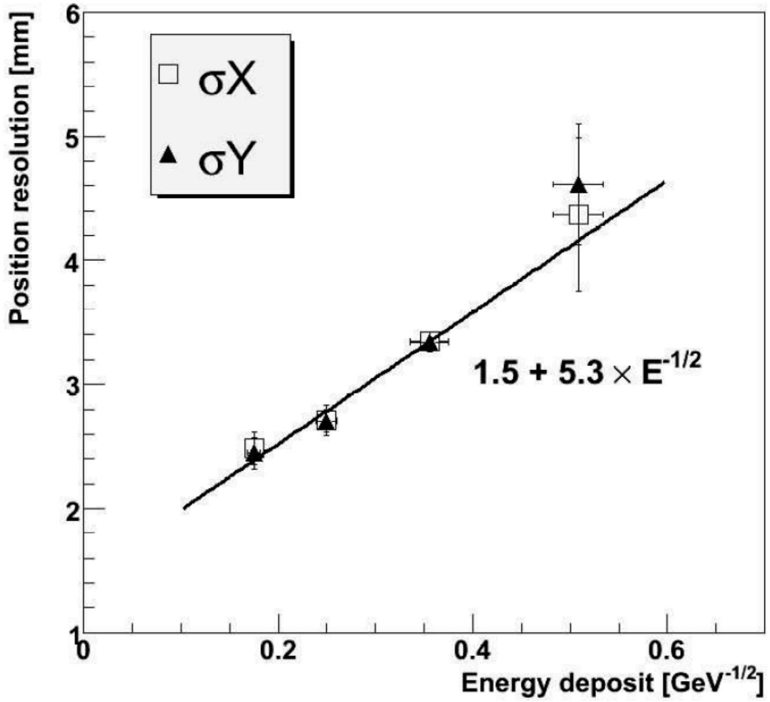


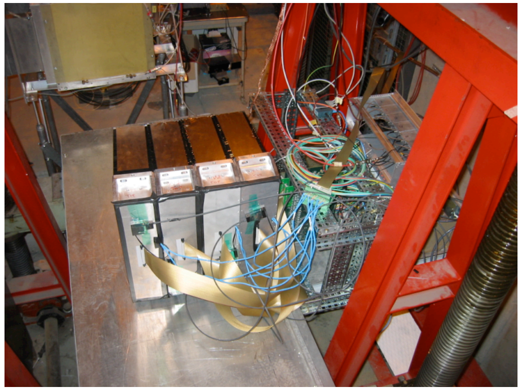
- LHC clock via TTC for LVDS serial data transmission from up to 40 TRUs
  - FastOR data transmitted serially at 2x400 Mbits/s
- L0, L1 Trigger pattern data stored as ALICE DDL data packet

Designed by: O.Bourrion, LPSC, Grenoble

EMCal Beam Test Results

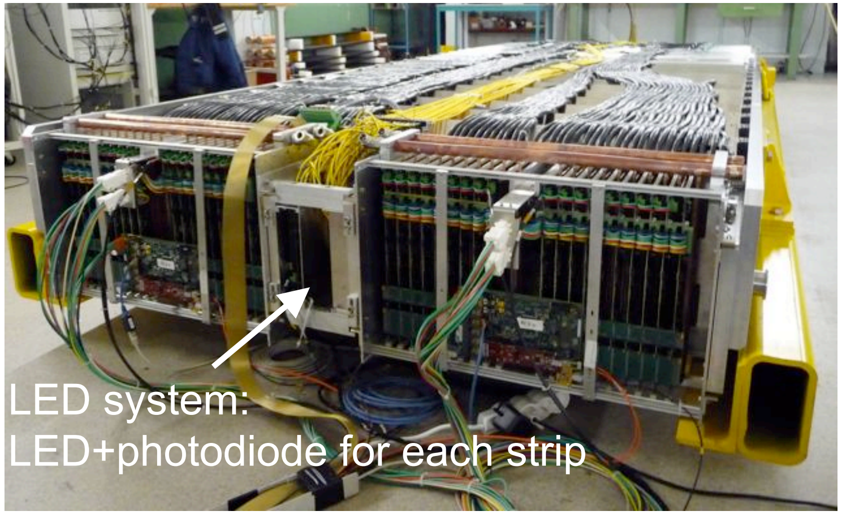


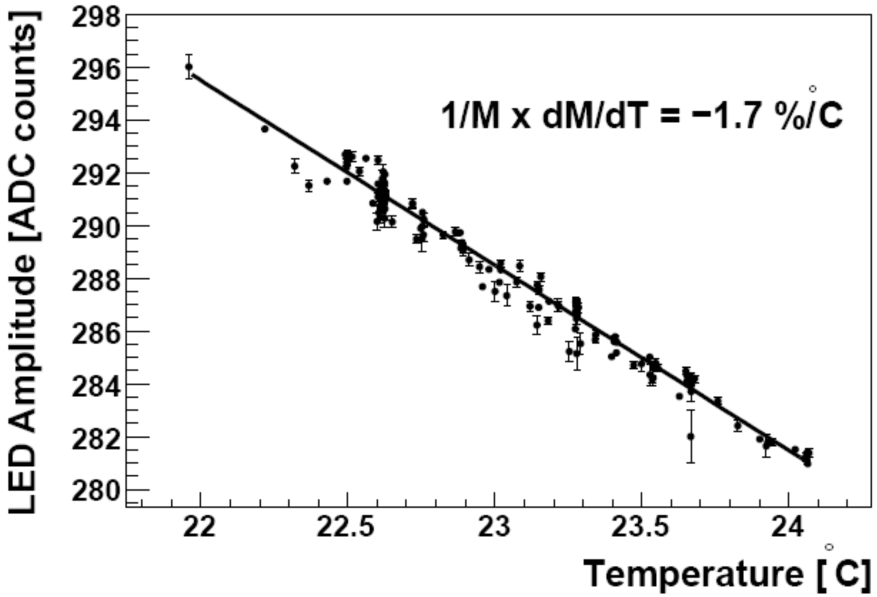




- Beam tests with 4x4 Module array (8x8 towers)
  - First Prototypes tested at FNAL fall 2005
  - Pre-production Modules+FEE tested at CERN PS and SPS 2007
    - Electron, hadron data 0.5 - 100 GeV/c
  - NIM paper in preparation

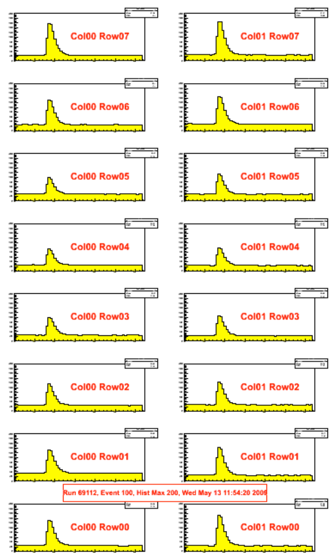
APD Gain Monitoring





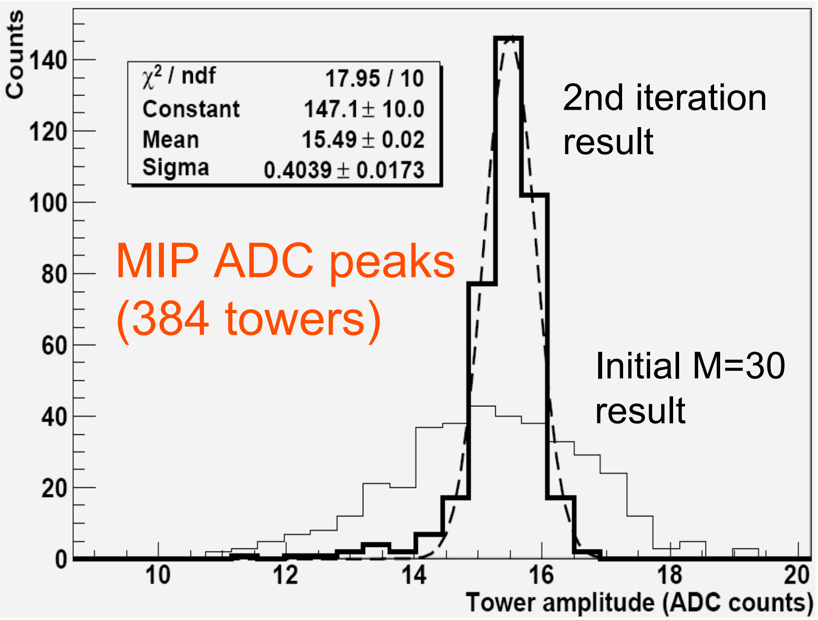
- Measure Temperature field at 8 points on SM
  - Readout via ALICE slow control (ELMB system)
- LED pulser system on SM to track gains
  - One ultra-bright blue LED per strip module
    - Custom LED driver system with 3x8 LED channels
  - Photodiode reference to monitor LED light
  - Photodiodes read out with 1 extra FEE card

LED signals in towers ~ 5 GeV

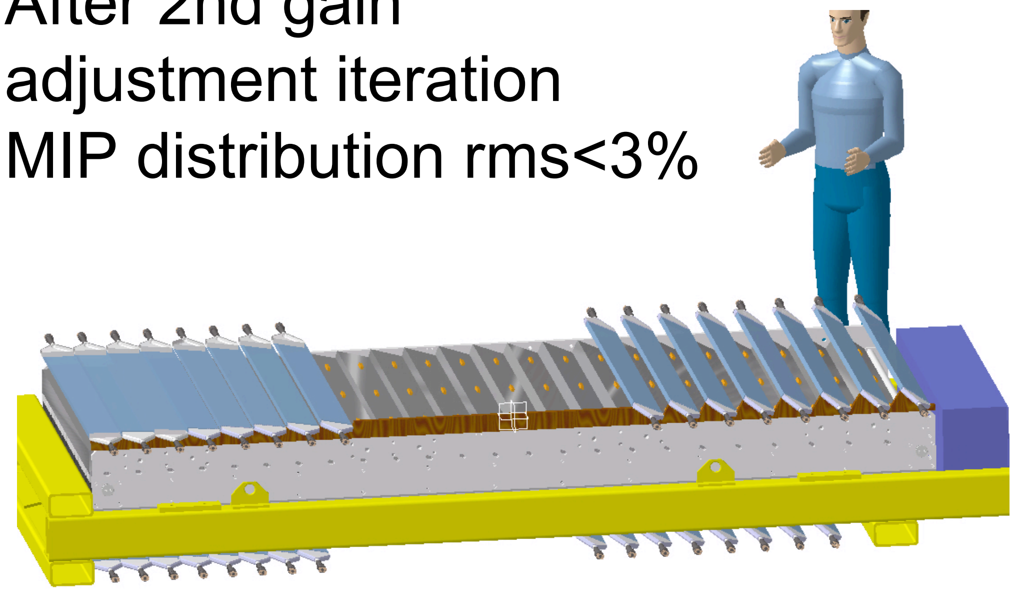


EMCal Cosmics pre-Calibration

- After SM assembly and test completed calibrate SM with cosmics
  - Overnight cosmics runs with scintillator triggers
    - OR of all (Top AND Bottom) scintillator pairs
      - Record scintillator ADC and Time
    - Apply Time difference cut to locate within ~ 1 module
    - Apply EMCal tower isolation cut to locate mip to single tower
- Design goal (trigger): Relative calibration to within better than 10%
- Final calibrations performed *in situ* with π^0 mass (*a la* PHENIX)

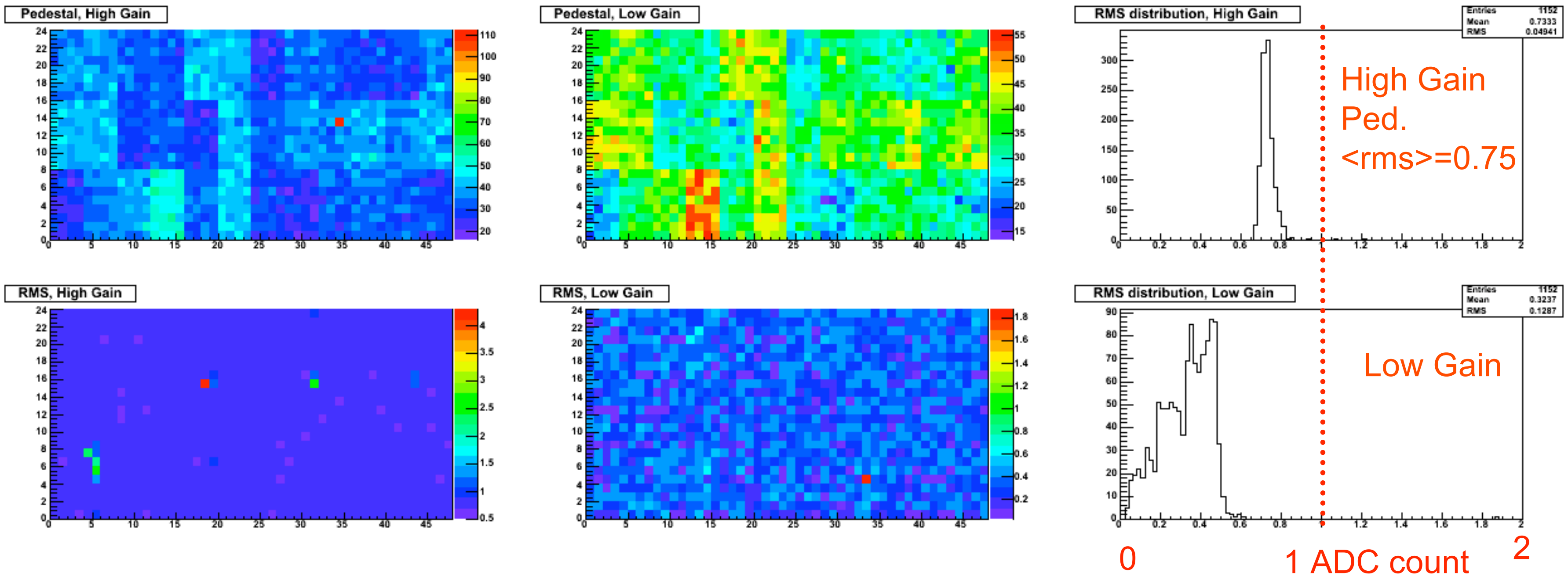


After 2nd gain
adjustment iteration
MIP distribution rms<3%



EMCal in ALICE

- 2 EMCal SMs installed and being commissioned
  - Pedestal and LED data have been taken
    - Same performance as during calibrations
- 2 additional EMCal SMs to be installed July ‘09
- EMCal will be nearly 40% installed for 2009 LHC run



Summary

- EMCal addition to ALICE will enhance jet studies
  - EM component of jets, γ-jet, π^0 measurement, electron identification
  - Provide L0 trigger, L1 γ and jet trigger
- ALICE EMCal will be ~40% installed for first collisions at LHC
  - 2 SMs installed already, 2 more SMs in July
  - Commissioning will be completed during ALICE cosmics run
  - Ready for physics with first collisions