

Summary of Calorimetry/Muon Sessions

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Calorimetry Requirements

- Jet energy resolution (σ/E) $\leq 3.5 - 5 \%$ for jet energies $\sim 1 \text{ TeV} - 50 \text{ GeV}$
- Excellent e/ γ ID
- Low noise, fit inside the coil, radiation hard (for forward calorimeters)
- Precision timing ($\sim 1 \text{ ns}$) needed for CLIC
- Conventional \rightarrow Novel

Two major methods

Dual Readout Calorimetry:

Different hardware concepts under beam test

ADRIANO: A Dual-Readout Integrally Active Non-segmented Option



- Cells dimensions: $4 \times 4 \times 180 \text{ cm}^3$
- Absorber and Cerenkov radiator: lead glass or bismuth glass ($\rho > 5.5 \text{ gr/cm}^3$)
- Cerenkov light collection: 10/20 WLS fiber/cell
- Scintillation region: scintillating fibers, dia. 1mm, pitch 4mm (total 100/cell) optically separated from absorber
- Particle ID: 4 WLS fiber/cell (black painted except for foremost 20 cm)
- Readout: front and back SIPM (Scifi only)
- CoG z-measurement: light division applied to SCSF81J fibers (same as CMS HF)
- Small θ_{Cerenkov} : due to WLS running longitudinally to cell axis ($\theta_{\text{Cerenkov}} < \theta_{\text{Small}}$ for slower hadrons).

- Fully modular structure
- 2-D with longitudinal shower CoG via light division techniques

C. Gatto

Imaging/PFA Calorimetry:

Has large scale prototypes with \sim established principles

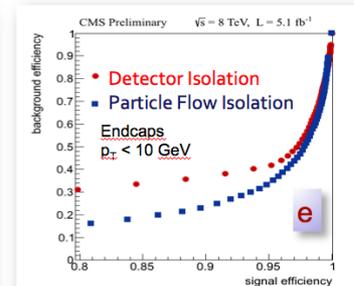
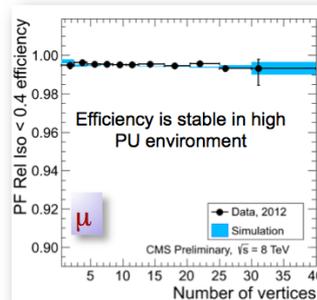
Pileup and Particle Flow

- Particle flow isolation is less sensitive to pileup
 - Propagated into trigger, it reduces tau, jet, MET trigger rates and improves efficiency
- Pile-up contribution:
 - Negligible for charged hadrons (vertexing)
 - Neutrals corrected w/global energy density (ρ)

J. Incandela

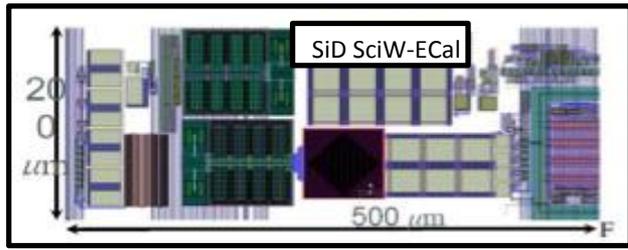
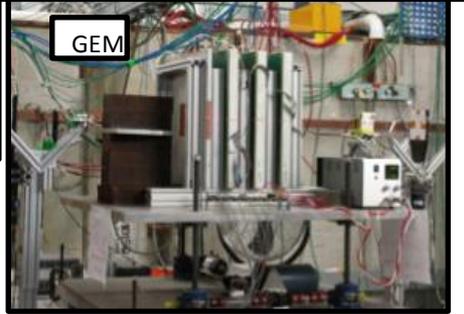
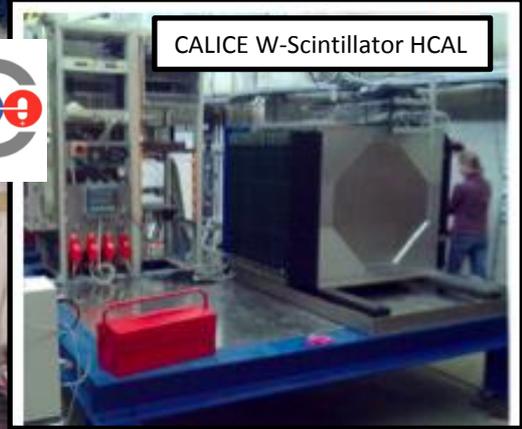
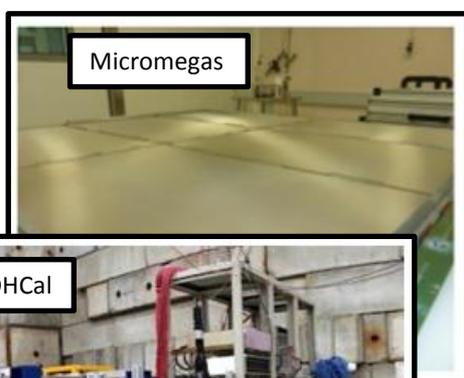
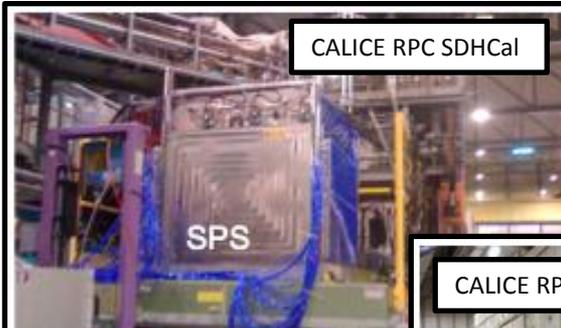
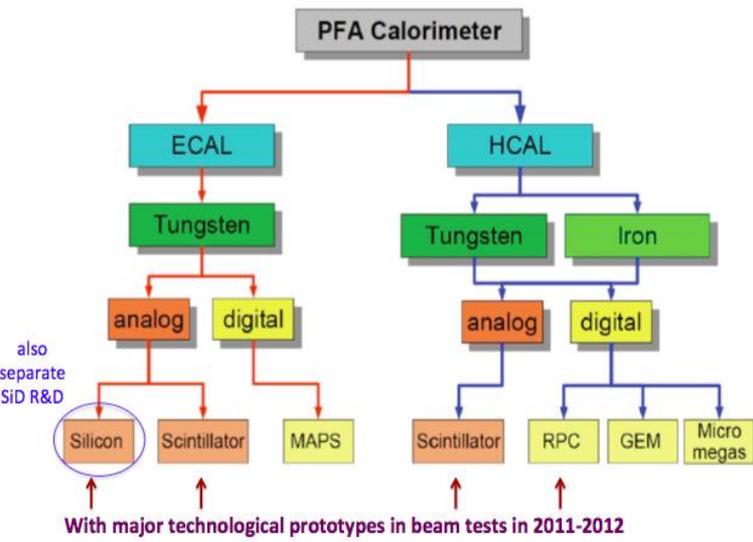


October 24, 2012 LHC Higgs CMS Adriano, Texas J. Incandela LUISSE/GEN



Detector vs Particle Flow

Experiments:



Common Features:

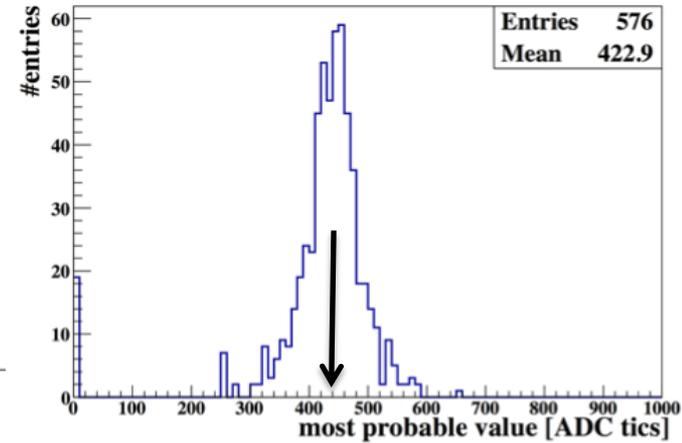
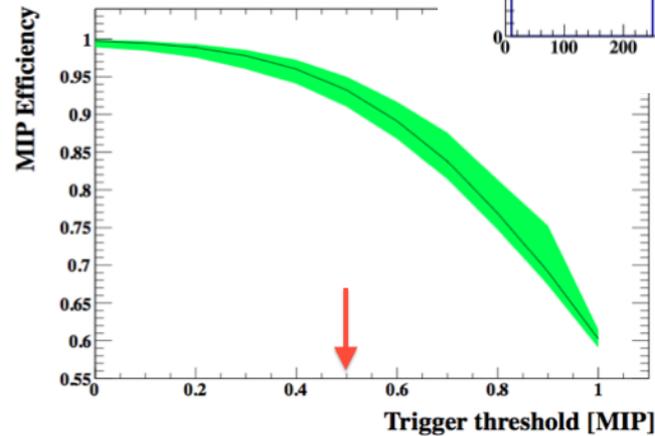
- ✓ Fine granularity
- ✓ Embedded front-end

2nd Generation Prototypes:

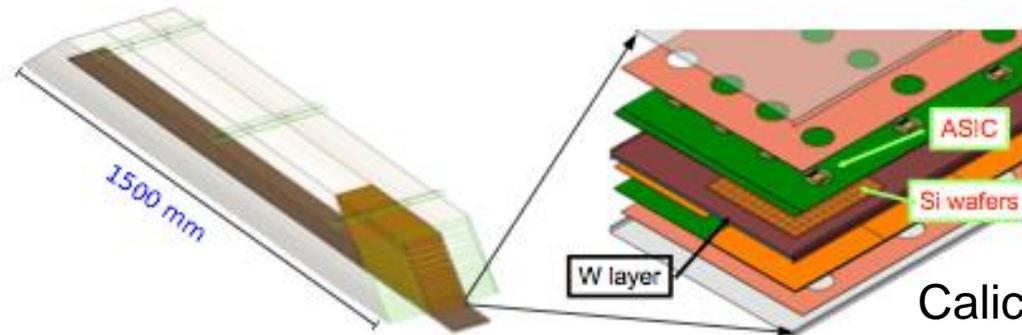
~ Realistic dimensions (partly equipped)
Technological solutions for the final detector



Calice AHCAL

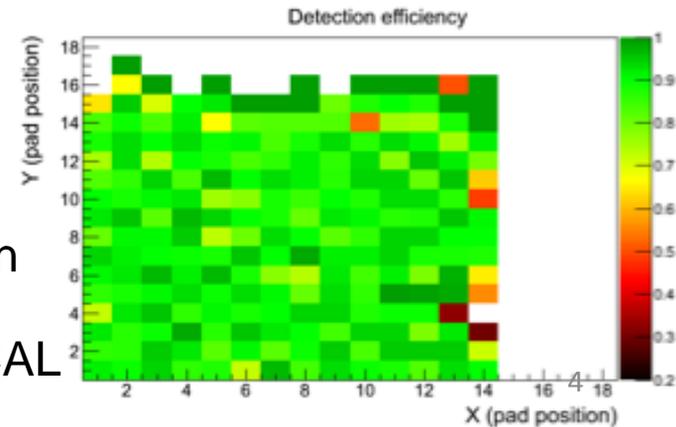


K. Kruger



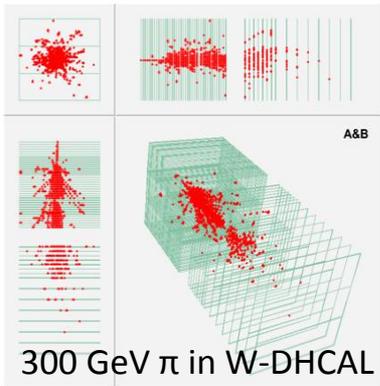
T. Frisson

Calice SiW ECAL

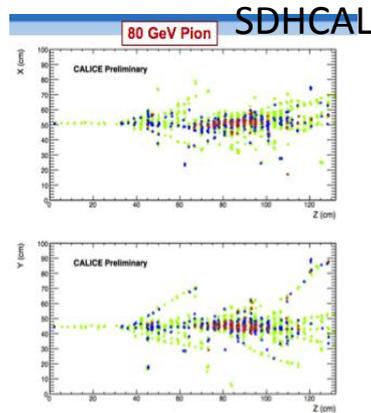


Overall Achievements

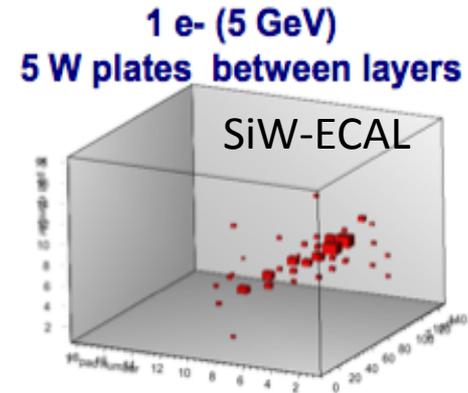
- A lot of data – Successful test beams at FNAL, CERN and DESY; 100Ms of events
- Very beautiful images.



J. Repond



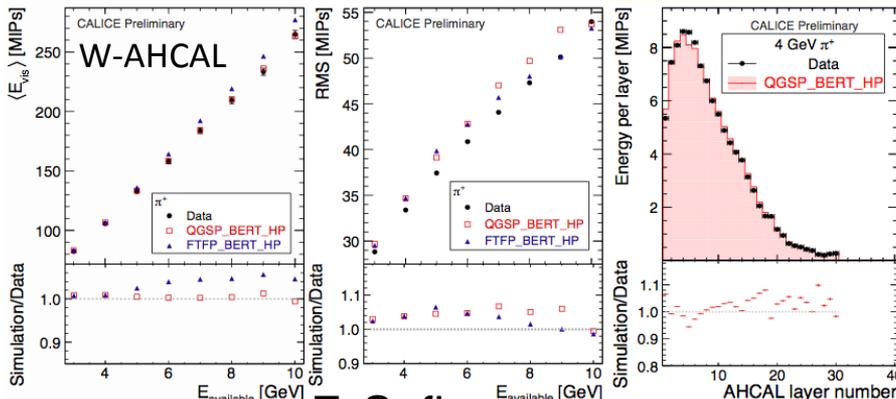
V. Boudry



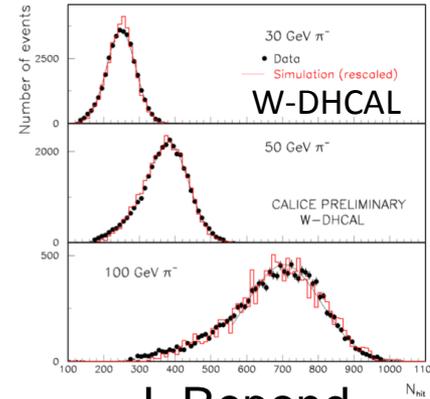
T. Frisson

- Comparison with MC and testing the reliability of detector simulations.

Immediately accessible after/during test beam → Excellent understanding of the calorimeters!

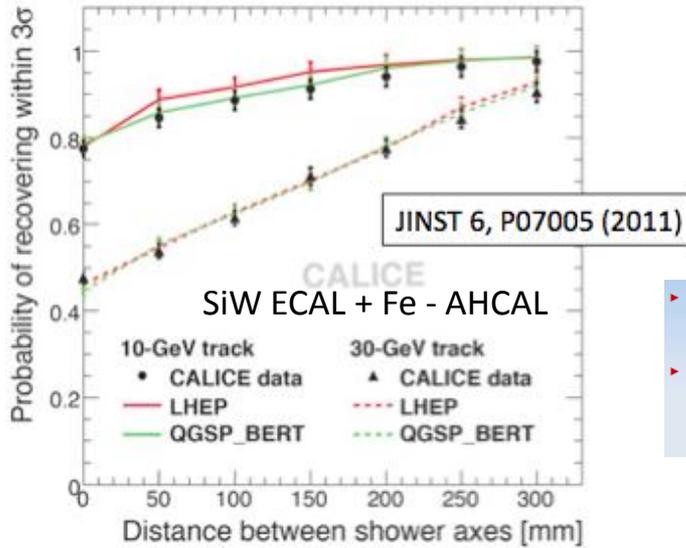


F. Sefkow

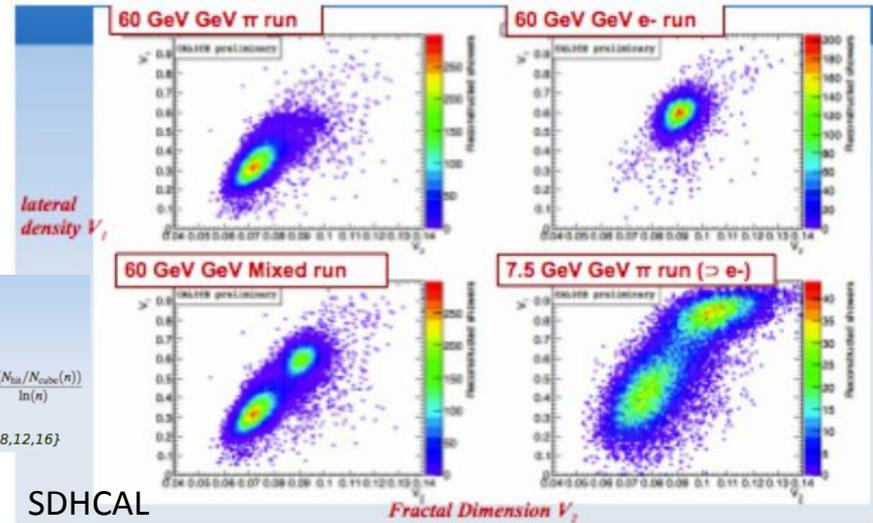


J. Repond

• Particle ID and separation

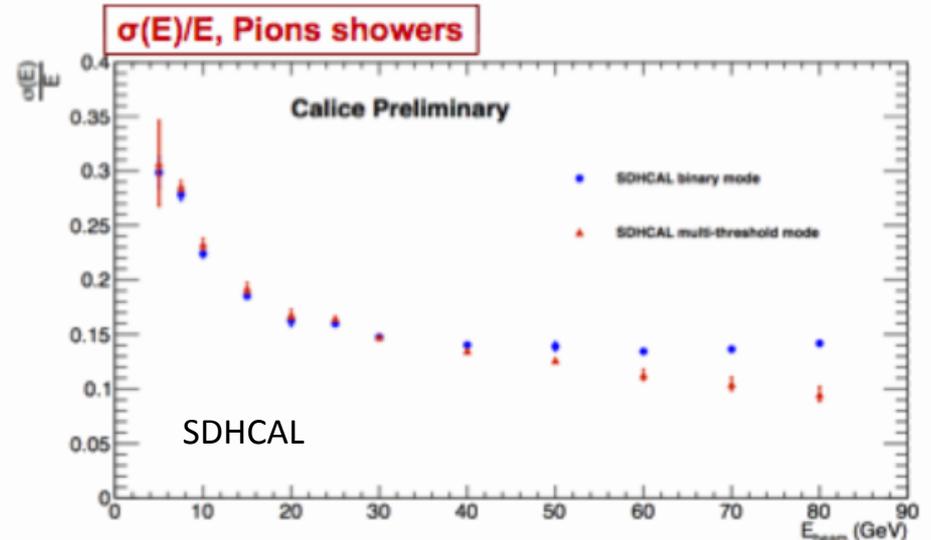
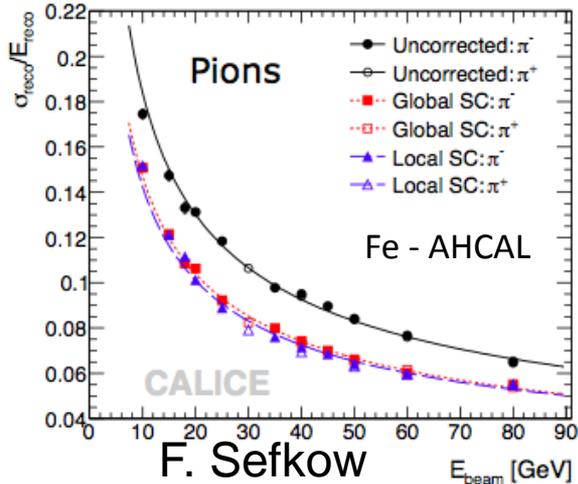


$V_1 = (\sum_{i=1}^n N_{i,1}^{top}) / N_{20}$
 $N_{i,1}^{top} = N_{i,1}$ in 5×5 around barycenter in 1 layer
 $V_2 = FD_{1D} / \ln(N_{20})$
 Fractal dimension: $FD_{1D} = \frac{1}{|I|} \sum_{n \in I} \frac{\ln(N_{i,1} / N_{cube}(n))}{\ln(n)}$
 $N_{cube}(n) =$ number of cube in $I = \{2,3,4,6,8,12,16\}$



• In addition to PFA, software compensation is also possible

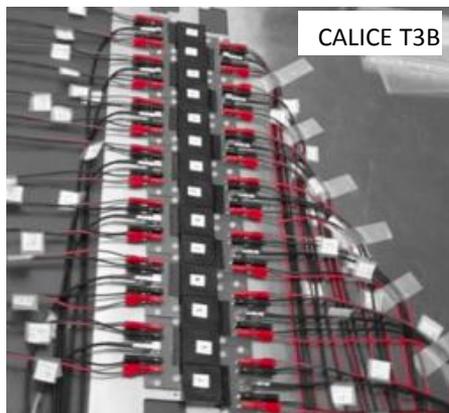
• Utilization of multiple thresholds V. Boudry



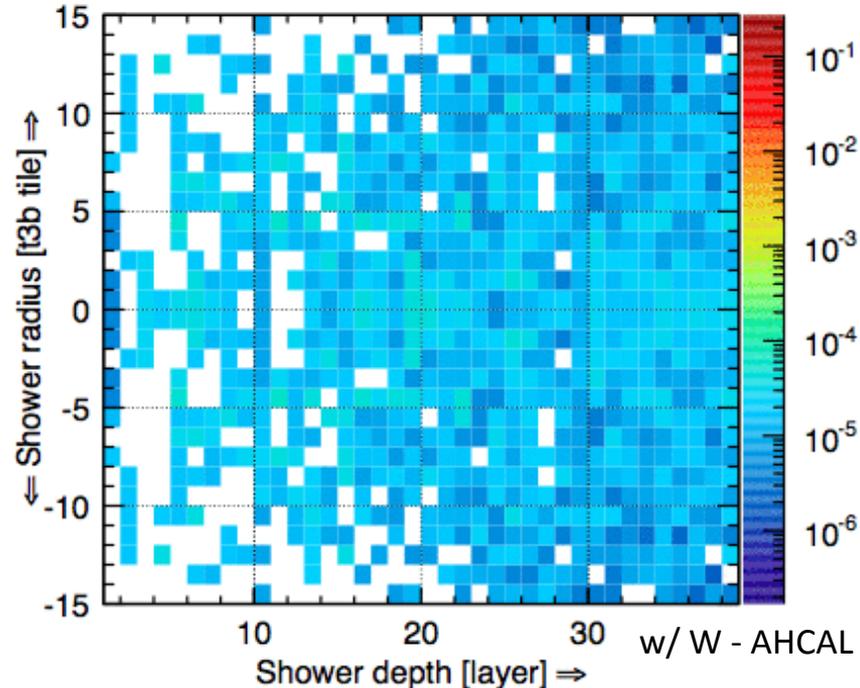
Local compensation: re-weighting based on single cell energy density
 Global compensation: correction factor calculated on event-by-event basis

Precision Timing for CLIC

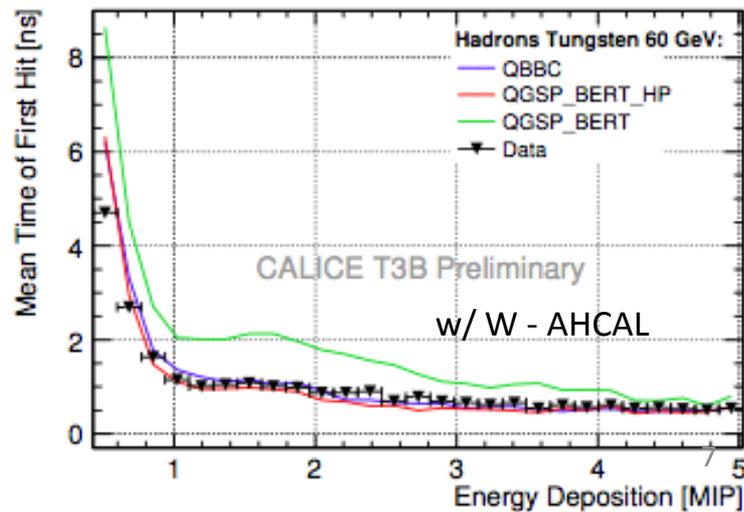
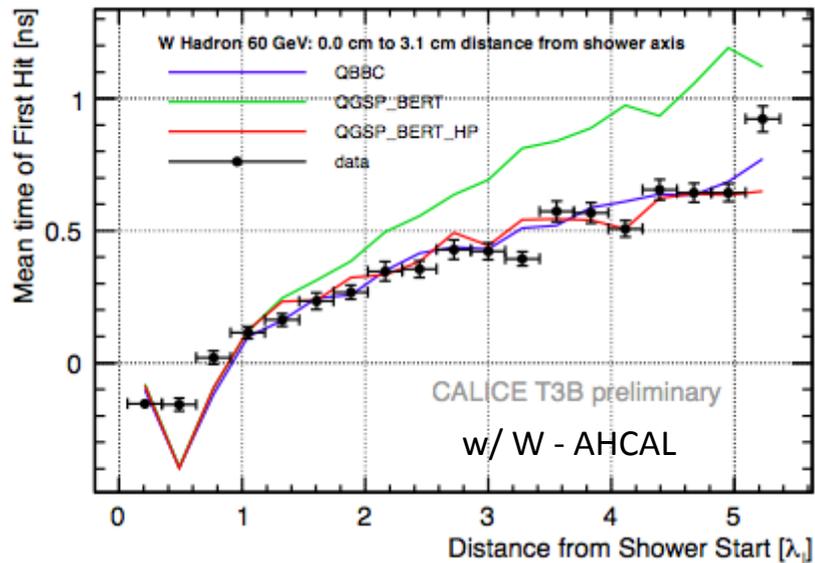
Measure the time structure of the signal within hadron showers



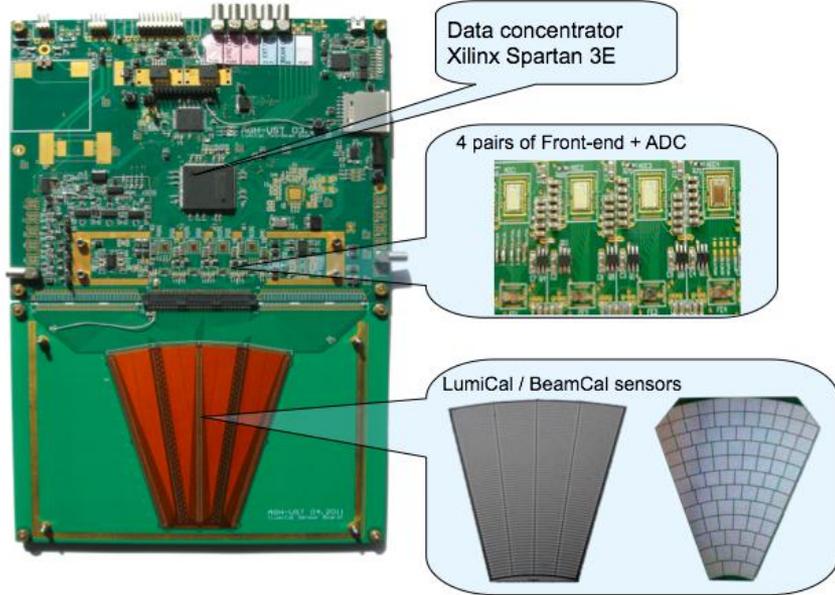
Shower @ 30 to 40 ns



F. Simon



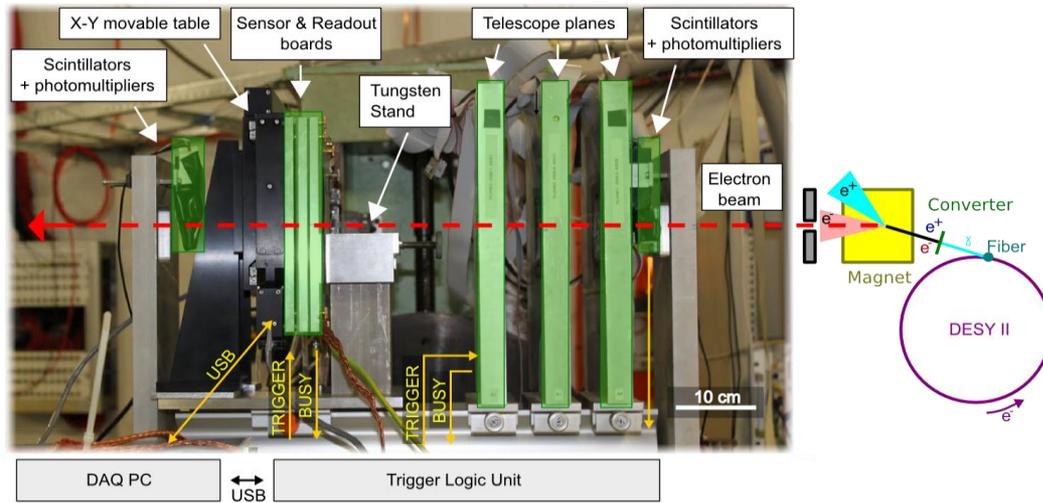
Forward Calorimetry



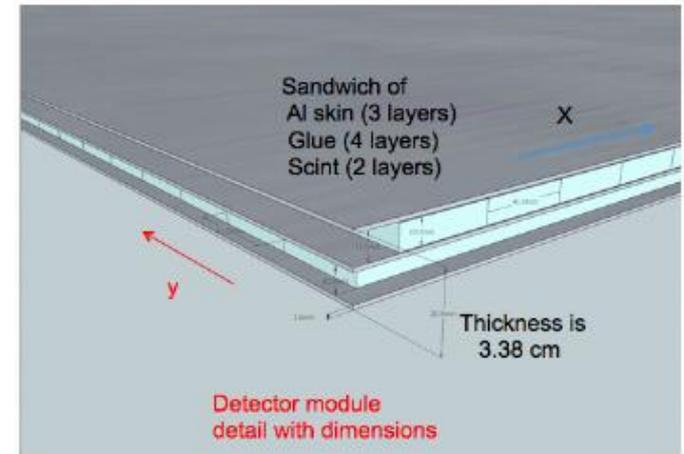
SiD Muon Detector

SiD Muon Detector Baseline Design

- Large planar modules $\sim 5.54\text{m} \times 3.8\text{m} \sim 21\text{m}^2$.
- Si avalanche photo-diodes-pixelated photon det.
- Common electronics: KPiX.



E. Fisk



W. Lohmann

Radiation damage studies underway.

Conclusions and Outlook

- Several projects at different stages of prototyping.
- Full scale beam test series completed for all major technologies.
- First test beam results from 2nd generation prototypes addressing integration issues available.
- Viability of PFAs and imaging calorimetry not questioned anymore.
- No expectation of breakthrough in basic principles and technology in the near future.
- **BUT**, the calorimeters already started to produce unprecedented physics results well before collider detector integration.