Backward Calorimetry For SuperB

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Introduction

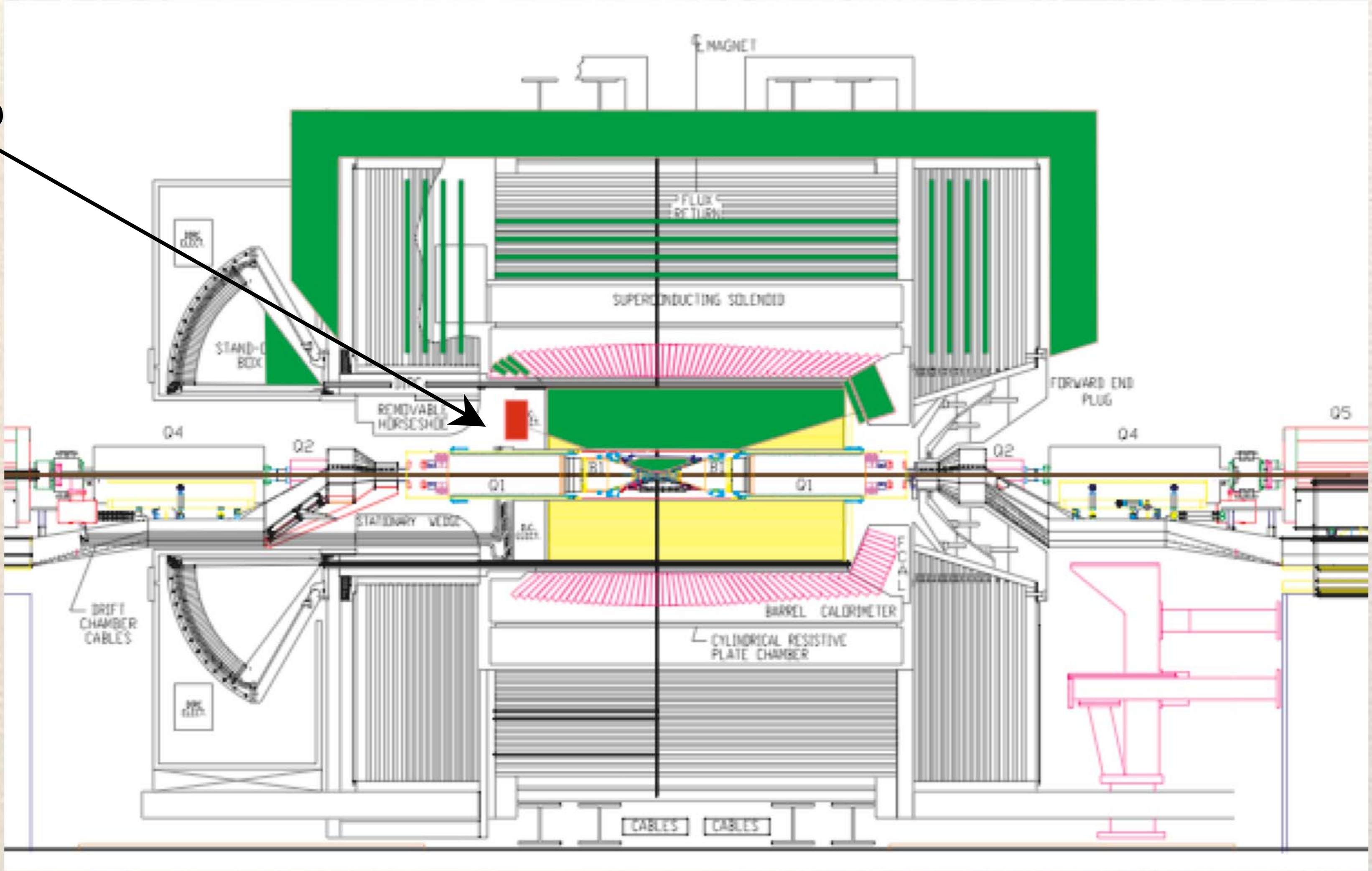
- Since in SuperB the asymmetry of beam energies is reduced to 4 GeV×7 GeV from 3.1 GeV×9 GeV, the rear region of the detector gains more importance than in BABAR

  ➔ need a more hermetic 4π detector than BABAR

- In addition, one important physics goal in SuperB is to exploit the recoil of fully reconstructed B decays
- Analyses like $B \to K^{(*)}\nu\bar{\nu}$ and $B \to X_s \ell\ell$ profit significantly from a hermetic detector, since E_{miss} is improved
- For inclusive $B \to X_s \gamma$ the π^0 veto is improved
- Thus, an endcap calorimeter for the backward region is an important improvement

SuperB: Baseline Design

Rear endcap



Rear Endcap EM Calorimeter

- In the barrel add three CsI(Tl) crystals layers
- Behind DCH I propose to place Pb-scintillator sampling calorimeter
  - 2.8 mm thick Pb plates ➔ 1/2 X_0
  - 3.0 mm thick scintillator tiles
  - Sizes vary from 3.8 cm × 3.8cm → 7.8 cm × 7.8 cm (R_M ~6.0 cm)
  - cylindrical geometry, r_i=0.31 m, r_a=0.75 m Pb: R_M=1.5 cm
    ➔ coverage~ 300mr
  - 24 planes with thickness of $12X_0$
  - scintillator is segmented into tiles, size increasing outwards
    ➔ total: 11,520 channels
  - Scintillator tiles are read out with WLS fibers (Y11) coupled to a SIPM

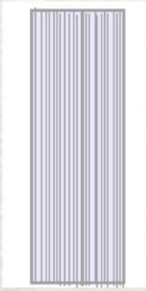
Rear Endcap EM Calorimeter

- Use cylindrical geometry, split calorimeter into 2 halves

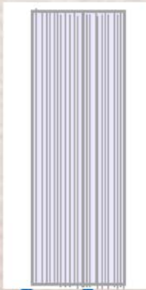
r-φ view

z view

- Pb plates:



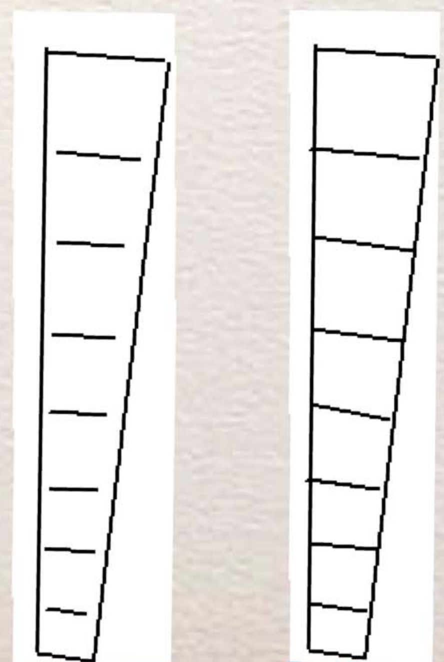
- Scintilator plane:



Rear Endcap EM Calorimeter

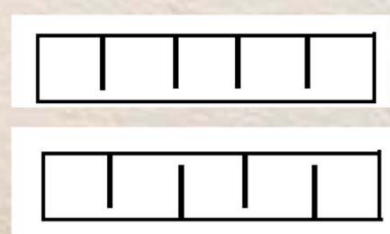
- Use half ring-shaped Pb plates, 2.8 mm thick, 48 identical plates
- Build two halves for easy mounting in IR
- Fabricate scintillator planes from 30 identical wedges per half plane
  ➔ simplifies mechanical construction
  - cut slits to produce tile structure, or grooves
    ➔ get light cross talk between neighboring tiles (probably small, need simulation)
  - Fill slits or groove with white diffuse reflector
  - Covers all sides with white diffuse reflector
  - (in AHCAL we have used matting process)

slits grooves



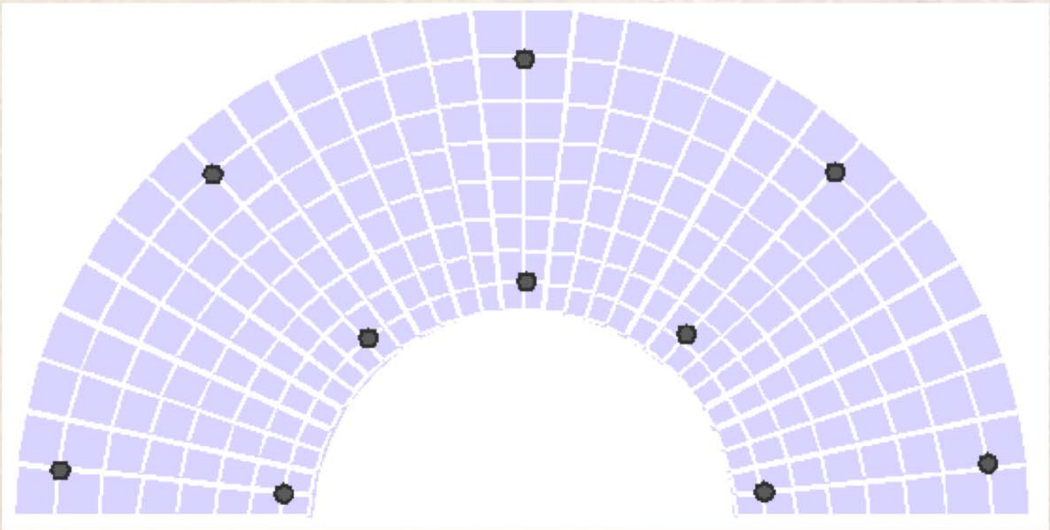
grooves (side view)

or alternating grooves



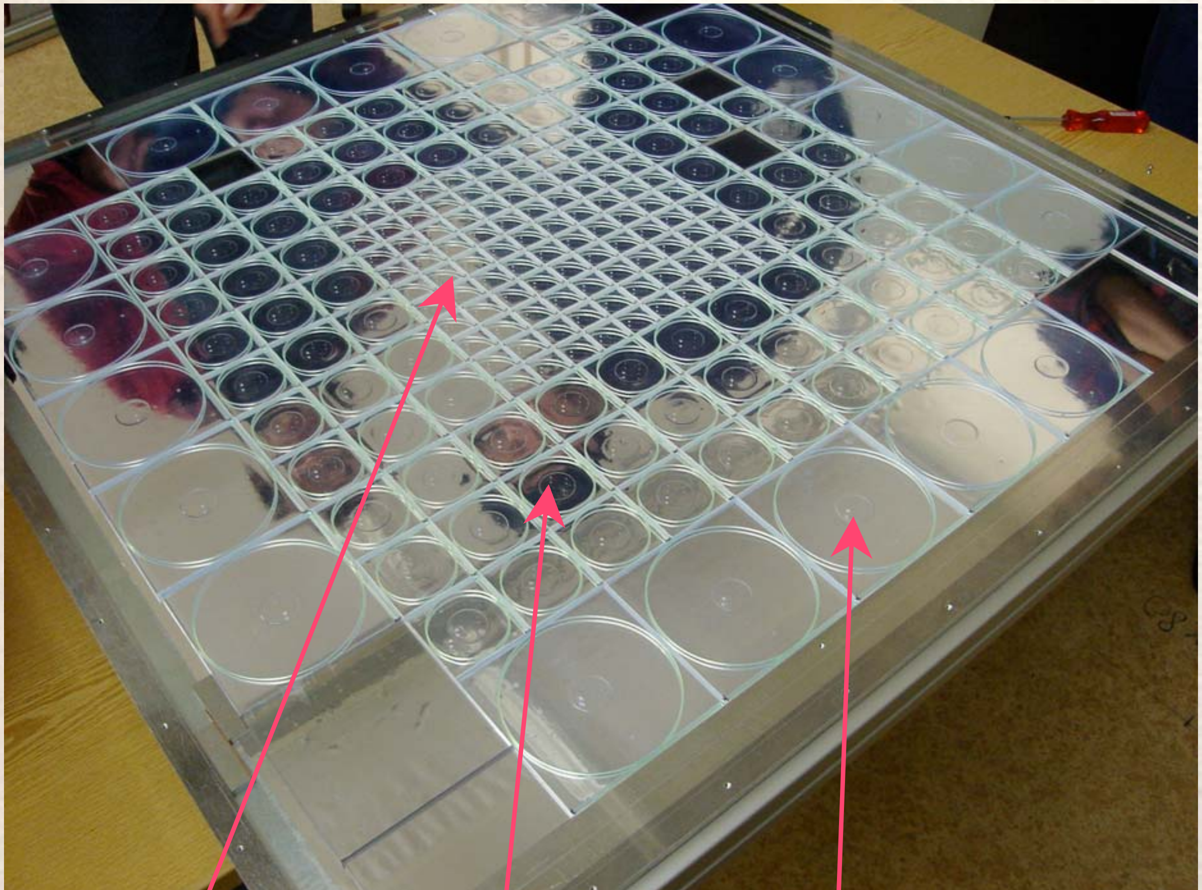
Rear Endcap EM Calorimeter

- Cover top and bottom of scintillator plane with 3M reflector
- Solder SiPM pins to flexible strips (for stress relief) that in turn are soldered to traces on thin board taking out signal to VFE board
- Use a strong back to hold Pb plates and scintillator planes use bolts or fix at outside by bolts



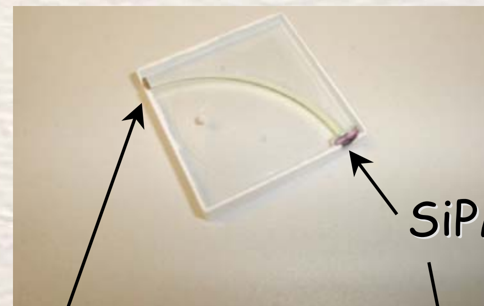
Tile Readout

- Example of a scintillator layer for an analog hadron calorimeter



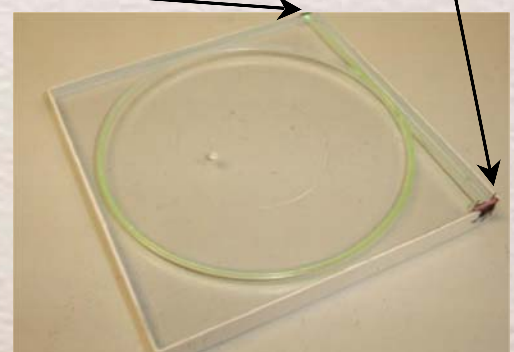
3×3 cm²   6×6 cm²   12×12 cm²

- Propose same types of tile-fiber-SiPM couplings



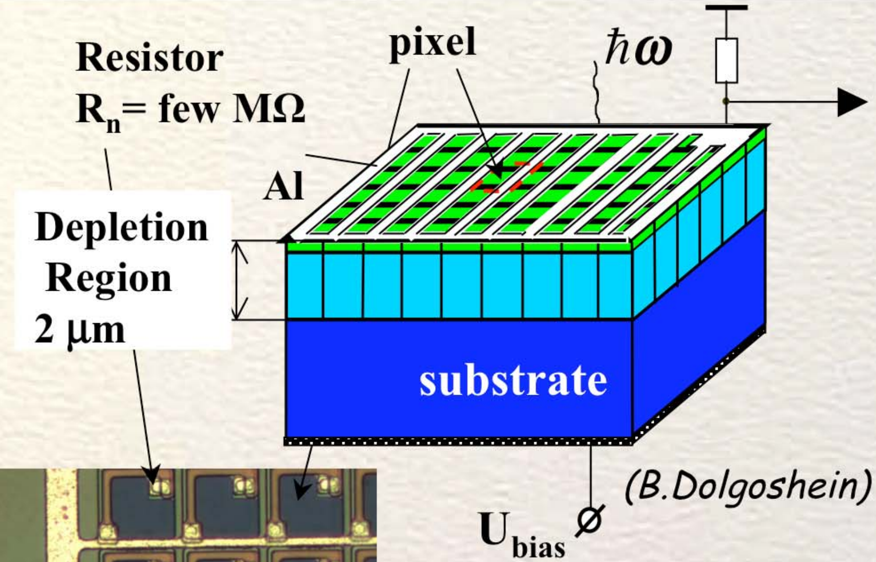
SiPM

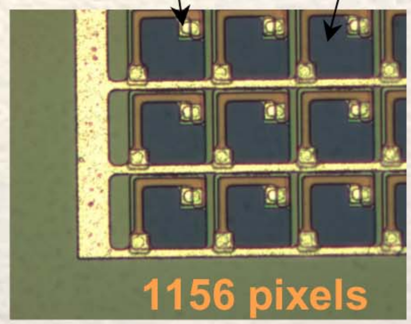
3M reflector

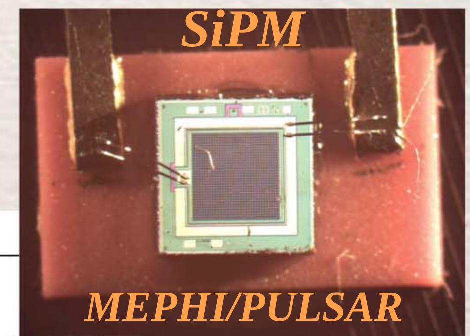


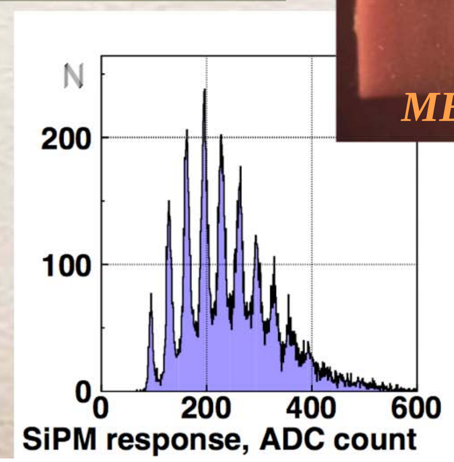
Properties of SiPMs

- Multipixel Geiger Mode APD
  - Gain 10^6
  - Bias U~50 V
  - Active area 1 mm^2
  - 1156 pixels, 20μm × 20μm
  - Efficiency 10-15%
  - Insensitive to B field
  - Each pixel has few MΩ quenching resistor
  - Recovery time < 100 ns
- SiPM detectors are auto-calibrating
- SiPM response is non linear
- Dynamic range is limited by #pixels
- Hamamatsu MPPC have 1600 pixels



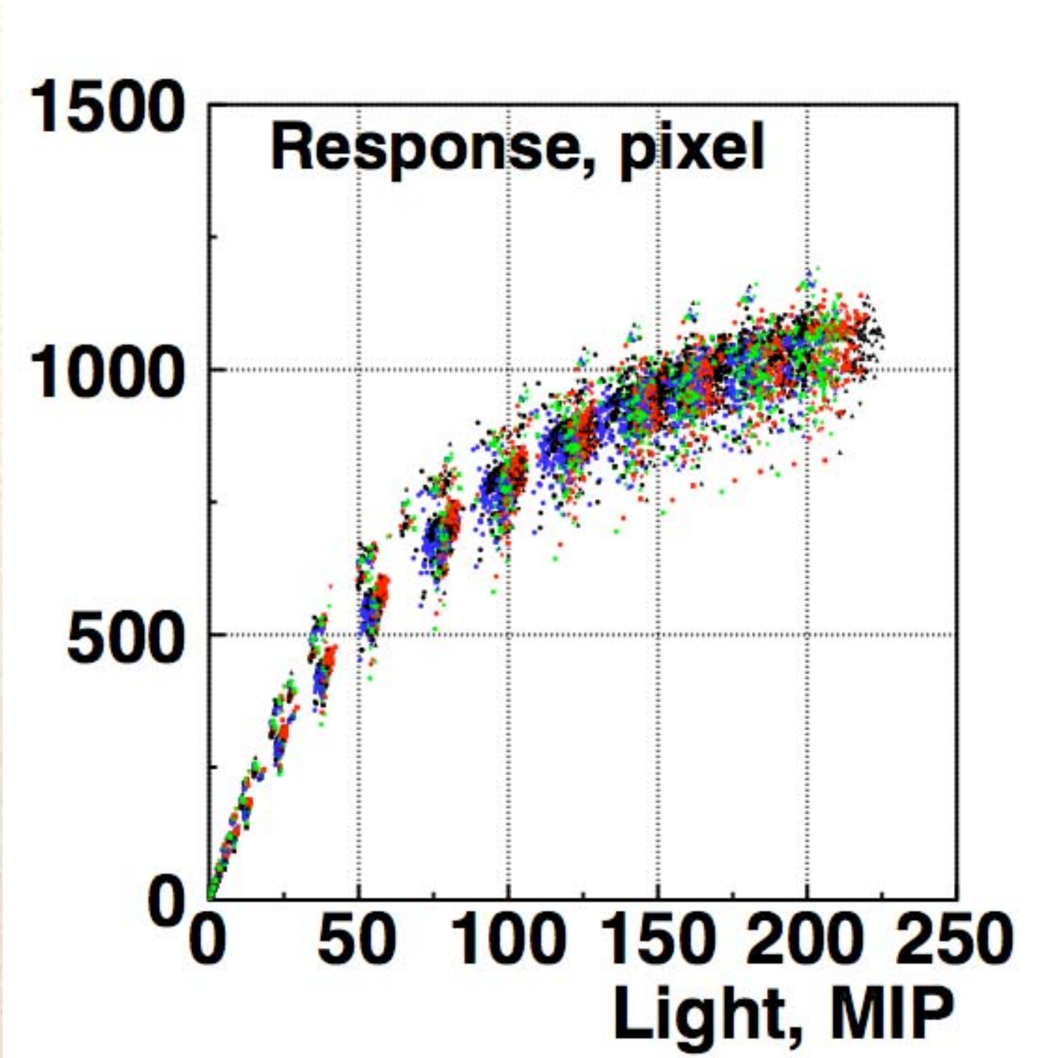






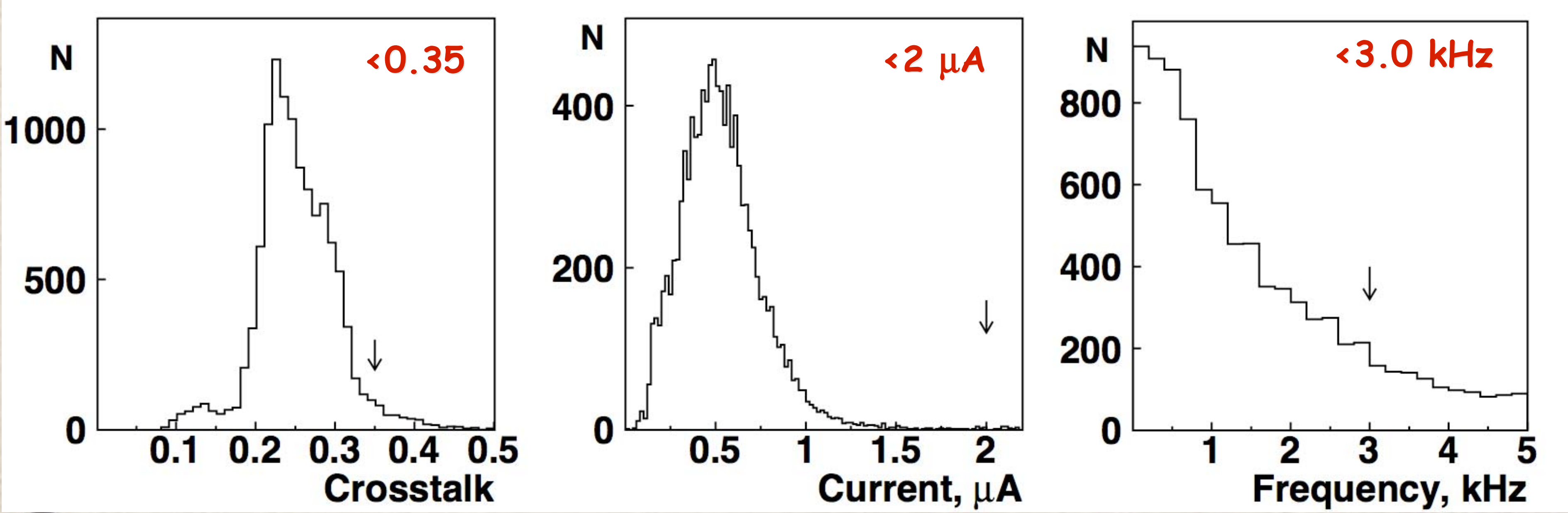
SiPM Response Function

- The SiPM response is non-linear and needs to be measured for each detector
- The shapes are very similar and agree within 15%
- A monitoring system may be necessary to measure the SiPM response function when required



Measured Properties of 10000 SiPMs

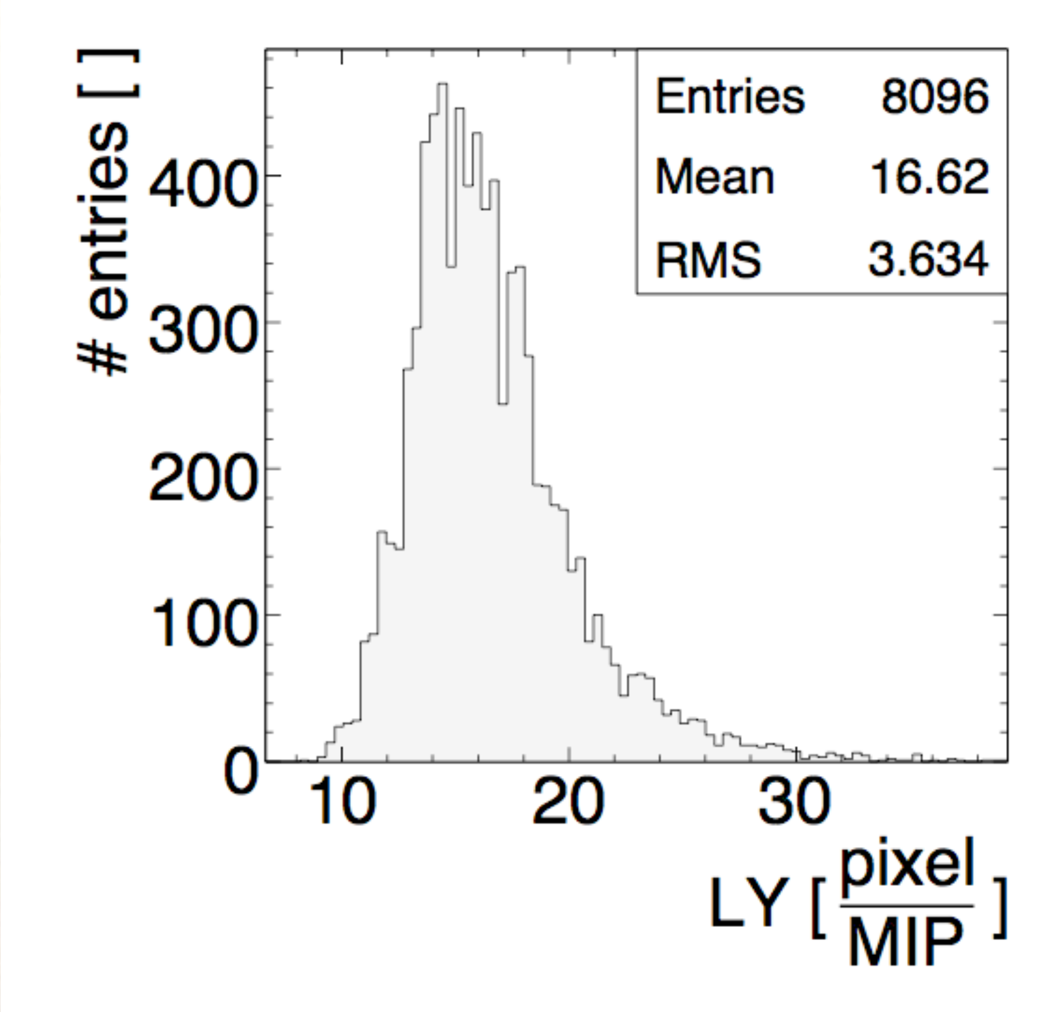
- We have measured various properties of SiPMs on the bench, such as the crosstalk among pixels, dark current and noise
- The arrows indicate our cut-off



Measured Light Yield of MIP

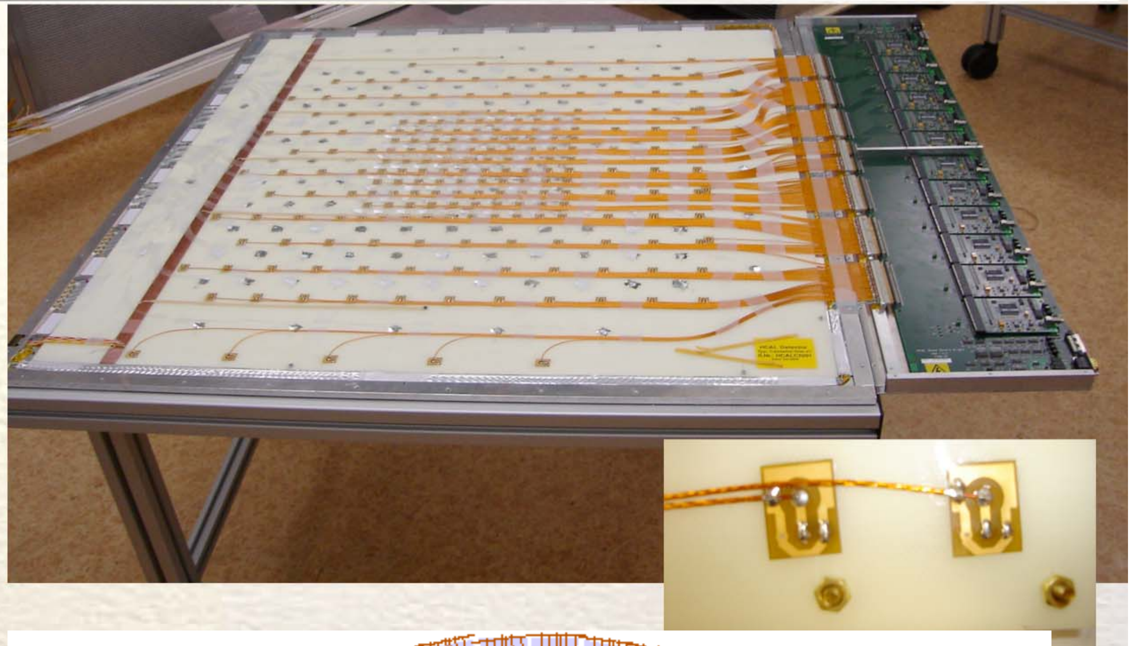
- We have measured the light yield of the tile-fiber-SiPM configuration for the cells installed in the AHCAL prototype plus spares

- The MIP is at 16.6 pixels the spread is 3.6 pixels
  ➔ this gives a dynamic range of 70 MIPs per cell
  (For Hamamatsu MPPCs
  dynamic range is 96 MIPs per cell)

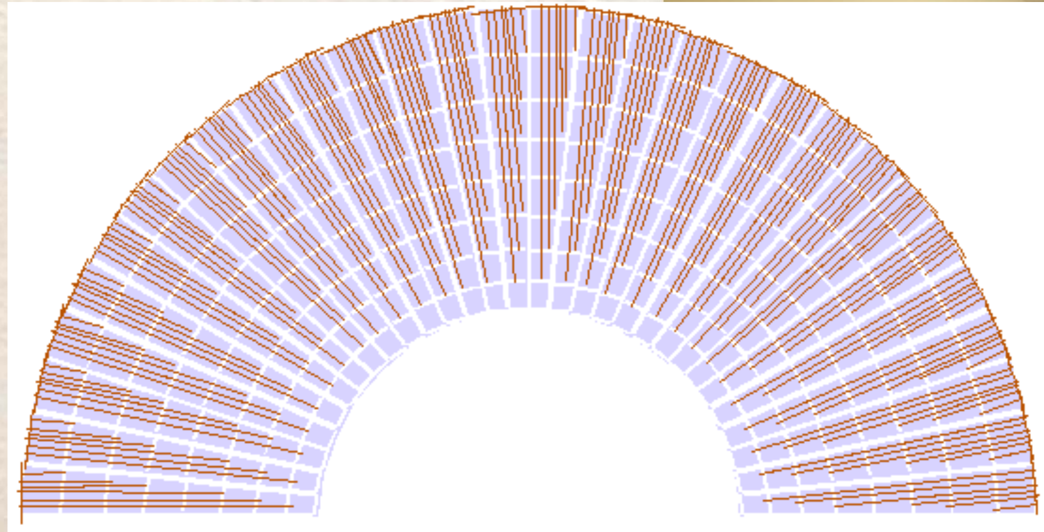


Routing of Fibers and Wires

- In AHCAL we used cables to transport SiPM signals to VFE



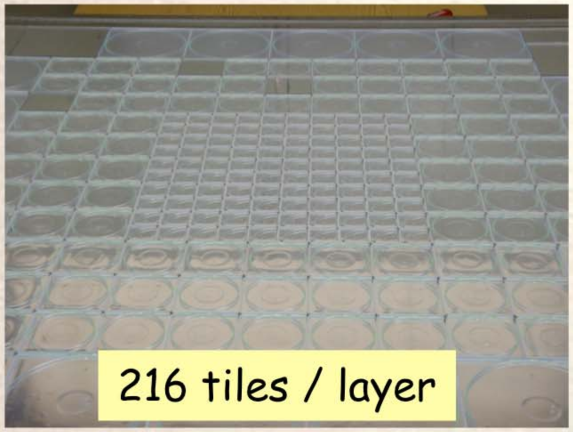
- For next prototype a specially designed board is planned
- For rear endcap I also propose a thin board with 8 traces per sector



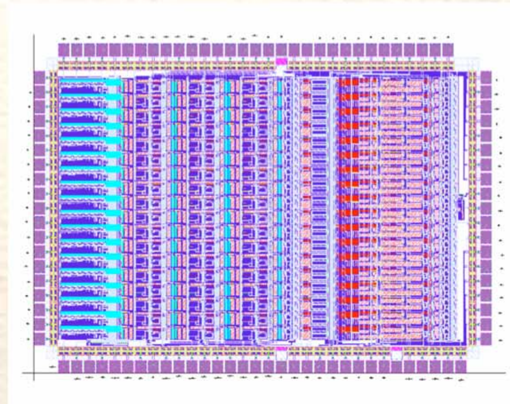
- The SiPM pins need to be attached to a stress relieved pad that is connected to the traces

HCAL Readout Architecture

- The VFE electronics from the AHCAL prototype can be used for the rear endcap

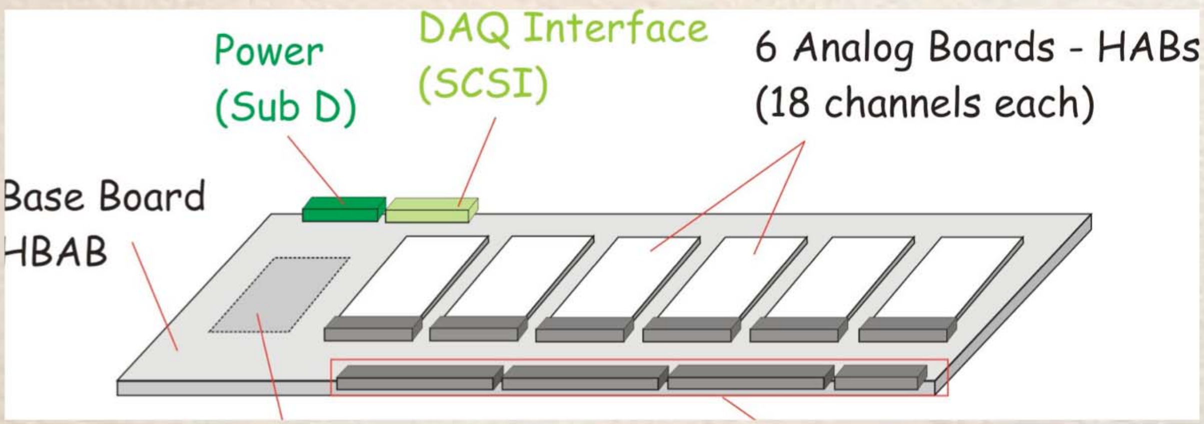


216 tiles / layer

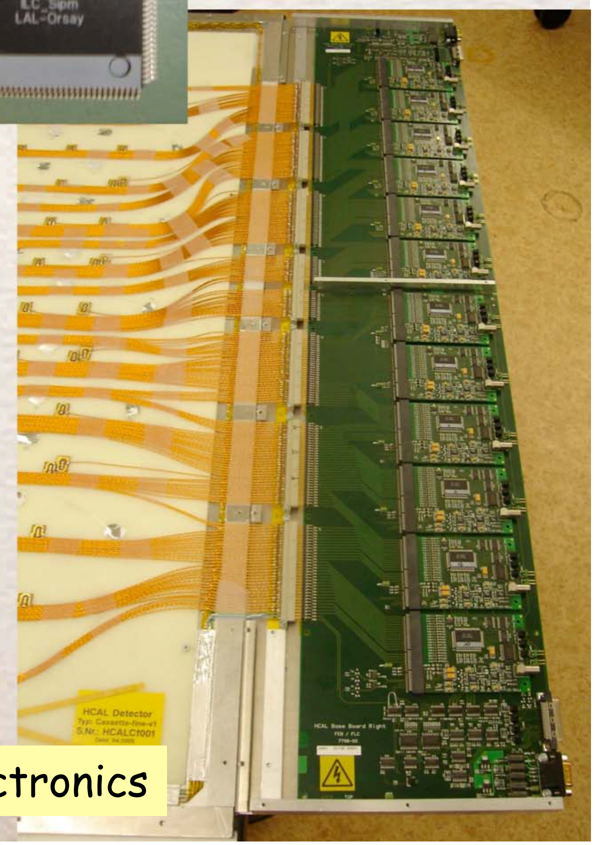


18 analog channels / chip

ILC_SiPM chip



2 base boards (12 piggy backs) / layer



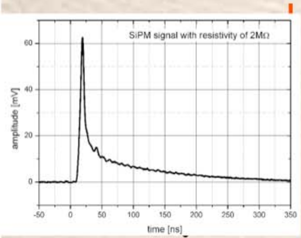
very front-end electronics

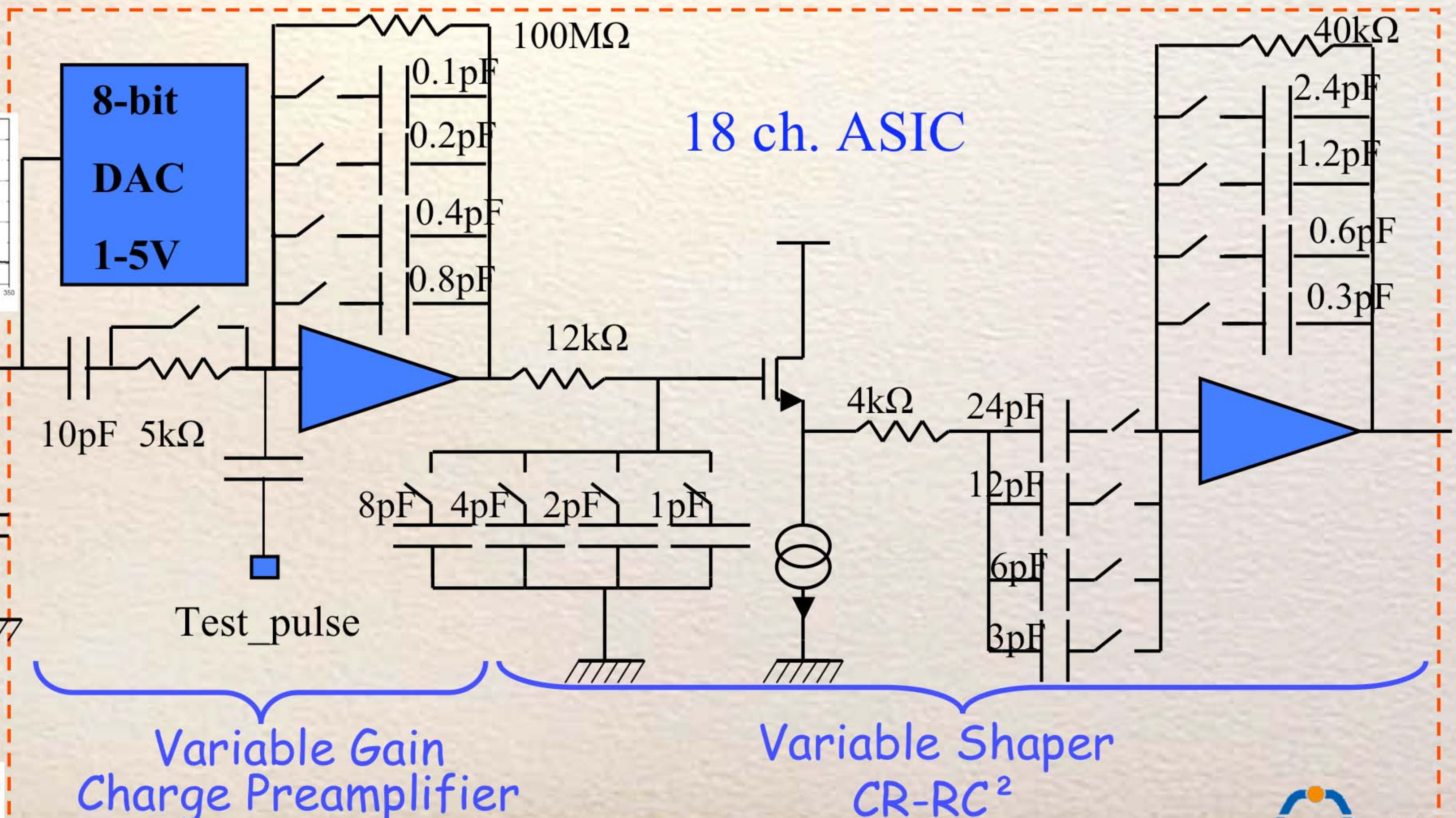
Frontend SiPM Chip

- SiPM bias voltage adjustment (1-5 V)
- Global gain settings and shaping
- Track & hold, multiplexing

- Based on ECAL Si-W ASIC

From L.Raux (LAL)



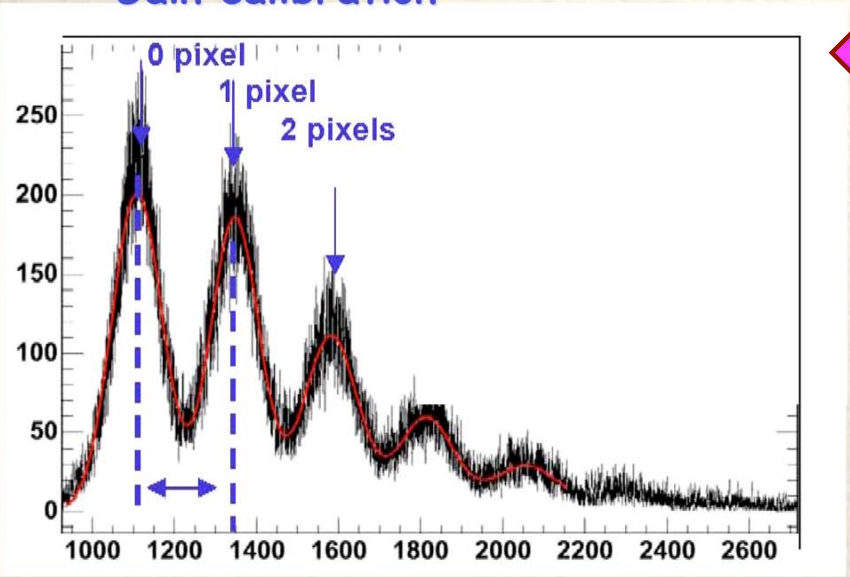


Calibration and Physics Mode Operation

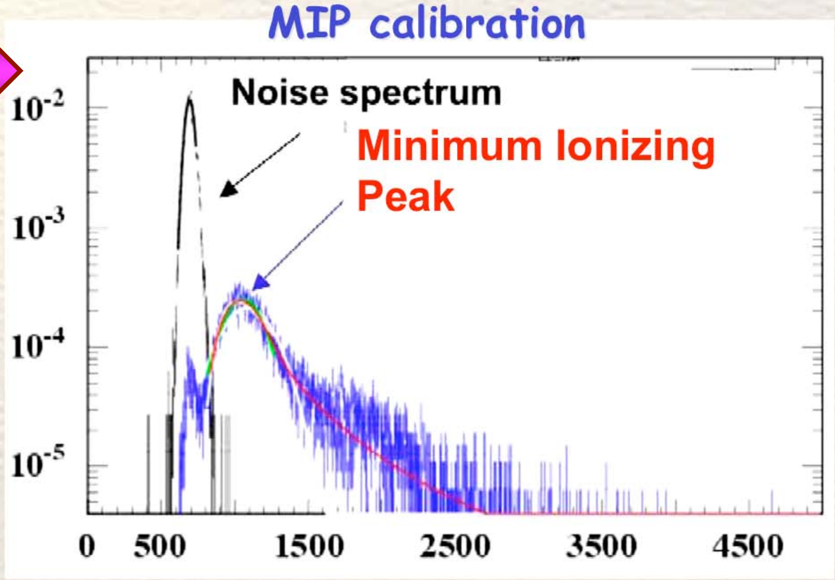
- Use high gain & fast shaping for calibration
- Use low gain & long shaping for beam mode

Intercalibration

Gain calibration



MIP calibration



- MIP set at ~15 pixels
- Get 33.2 MIPs/GeV

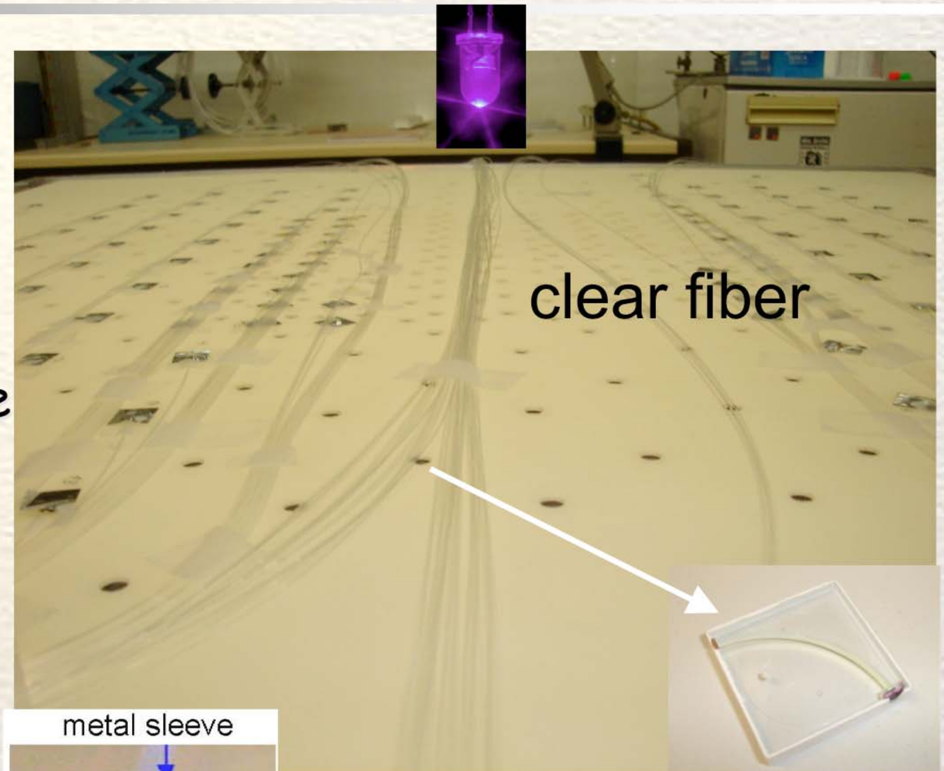
Calibration-Monitoring System

- Monitor stability of tile-fiber-SiPM system between MIP calibrations with fixed LED intensities
- Perform gain calibration
- Measure SiPM response function
- Determine intercalibration constants
- Temperature and voltage dependence of SiPM
  - dG/dT ~ -1.7% / K
  - dG/dV ~ 2.5% / 0.1V
- Temperature and voltage dependence of light yield at fixed light intensity
  - dQ/dT ~ -4.5% / K
  - dQ/dV ~ 7% / 0.1V

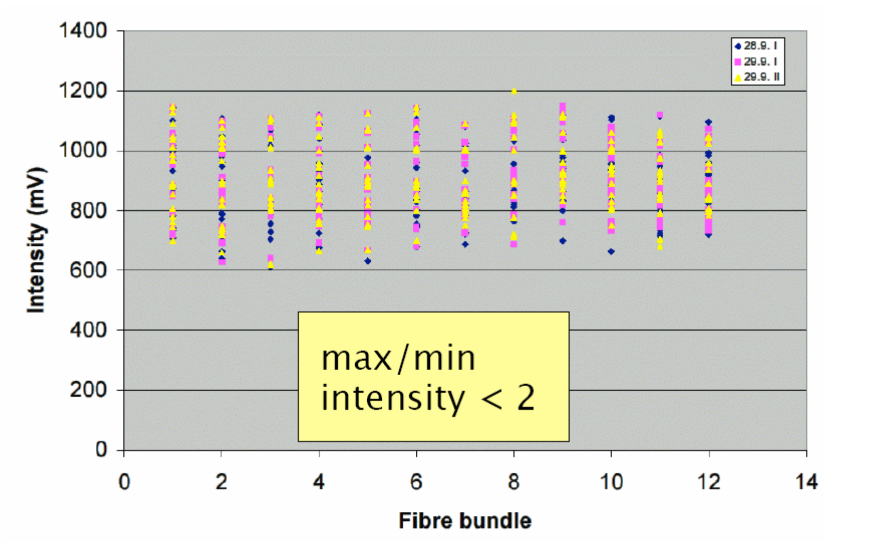
➔ stability of LED system after PIN diode correction <1%

Calibration-Monitoring System

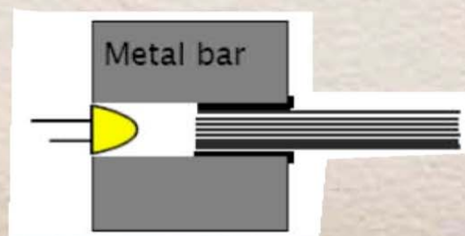
- Use system similar to that of AHCAL
- Provide UV light to each tile via clear fiber
- Monitor each LED with PIN diode
- Record temperature & voltage with slow control system



Light Uniformity in Test Module



bundle of 19 fibers
18 → tiles, 1 → PIN diode

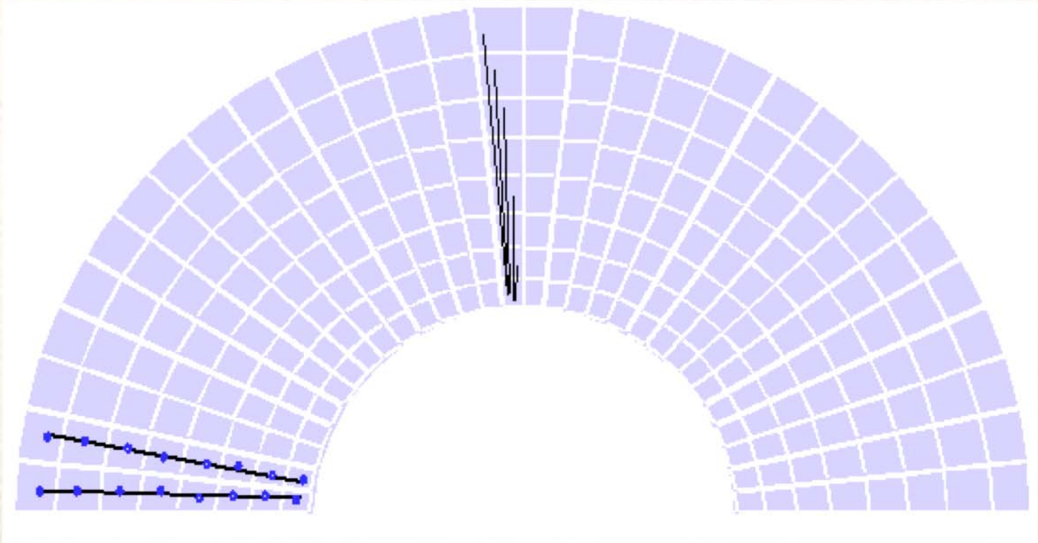


LED fiber coupling

Layout of Monitoring System

- If a single fiber gives enough light for 8 tiles, one could combine 6 fibers two adjacent in 3 planes to one LED

➔ need 240 LED & 240 PINs



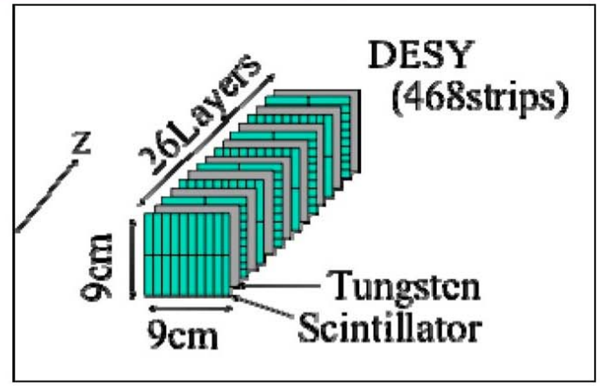
- If we need one fiber per tile combine 16 fibers of 2 adjacent sector to LED

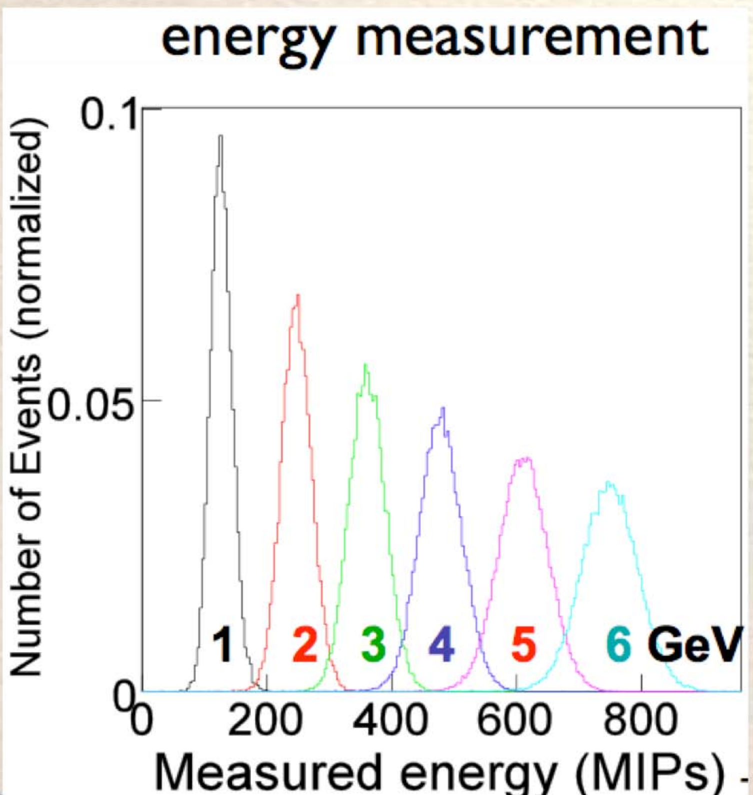
➔ need 720 LED & 720 PINs

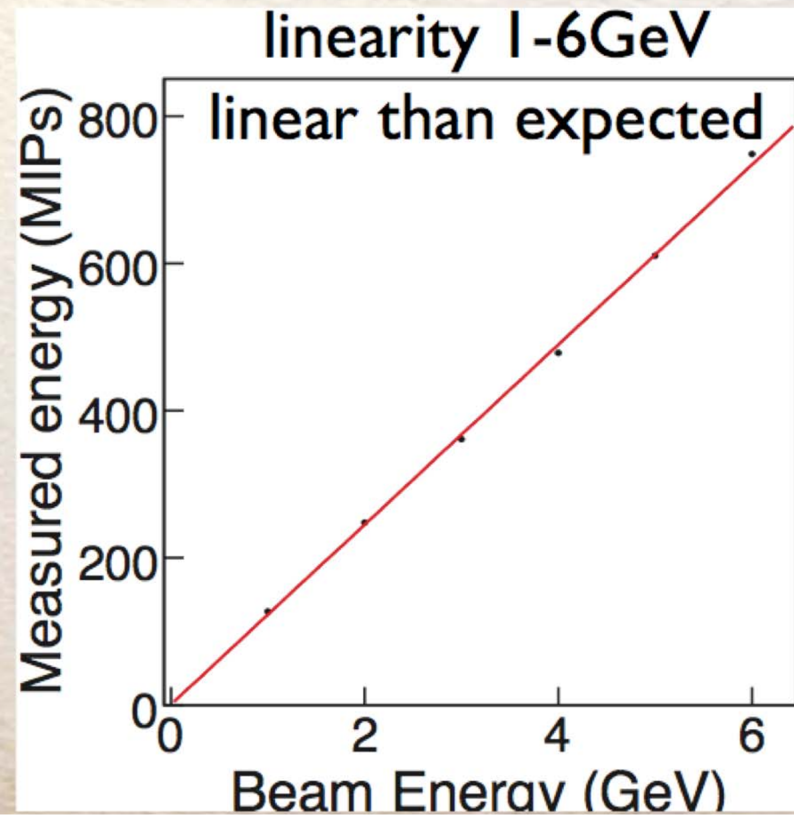
- Work is ongoing at DESY to simplify the monitoring system and to reduce the number of LEDs

Linearity Measurement

- Results from 1cm×4.5cm×0.3mm scintilator 0.35 mmW sandwich structure (Takeshita et al)

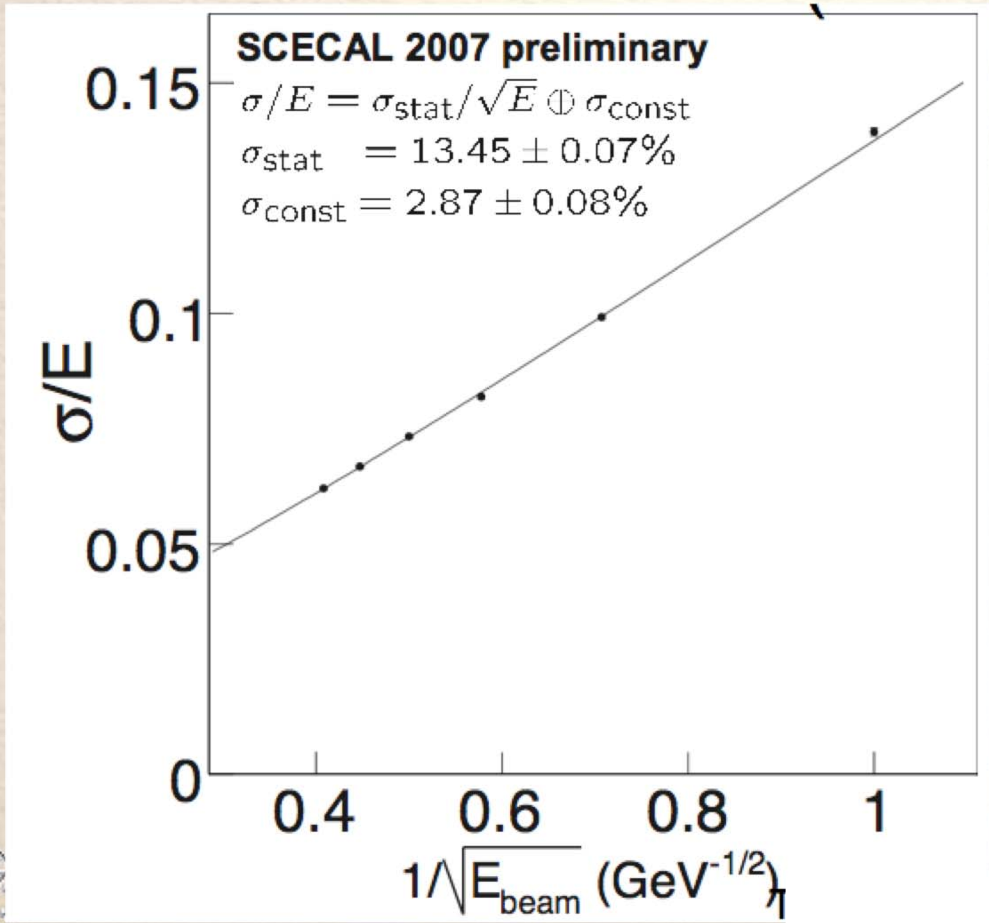


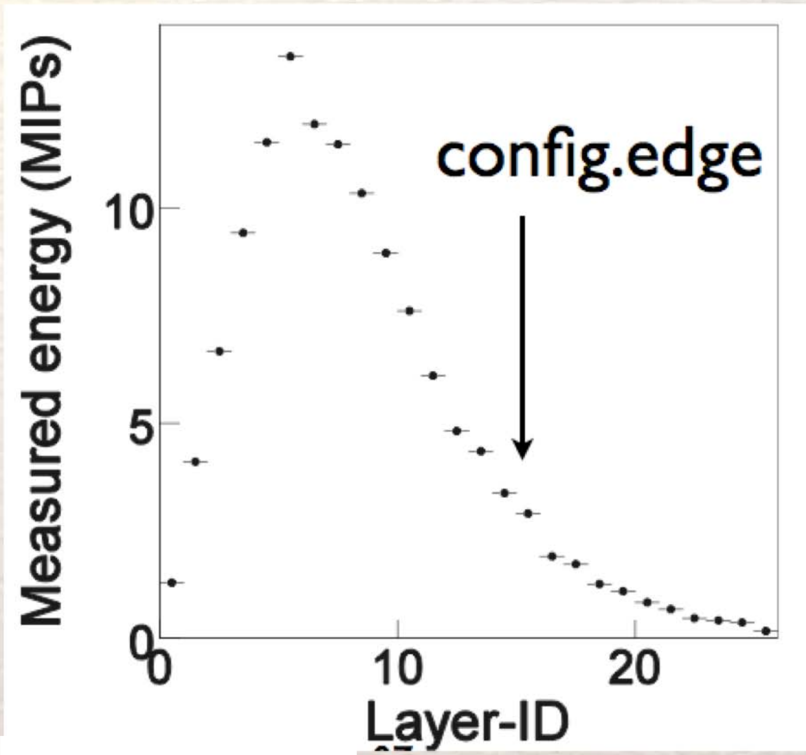




E-Resolution & Longitudinal Shower Shape

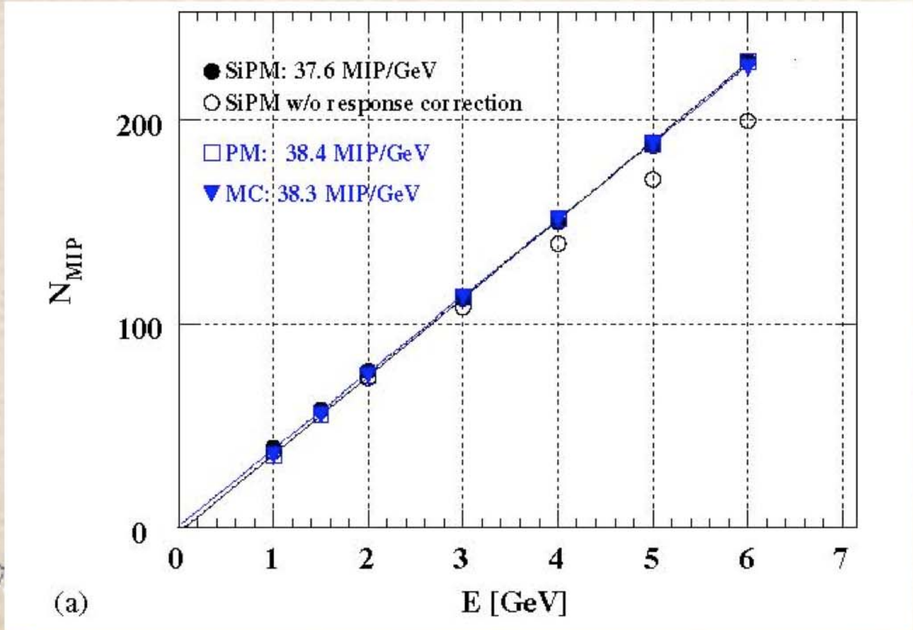
- Energy resolution has a 2.9% constant term & 13.5% stochastic term
  ➔ for a similar configuration with Pb, constant term is zero & stochastic term is 13.1%
  ➔ for 25 4cm×4cm×0.1mm scintillator tile 0.1 mm Pb σ_{stoch}=16%

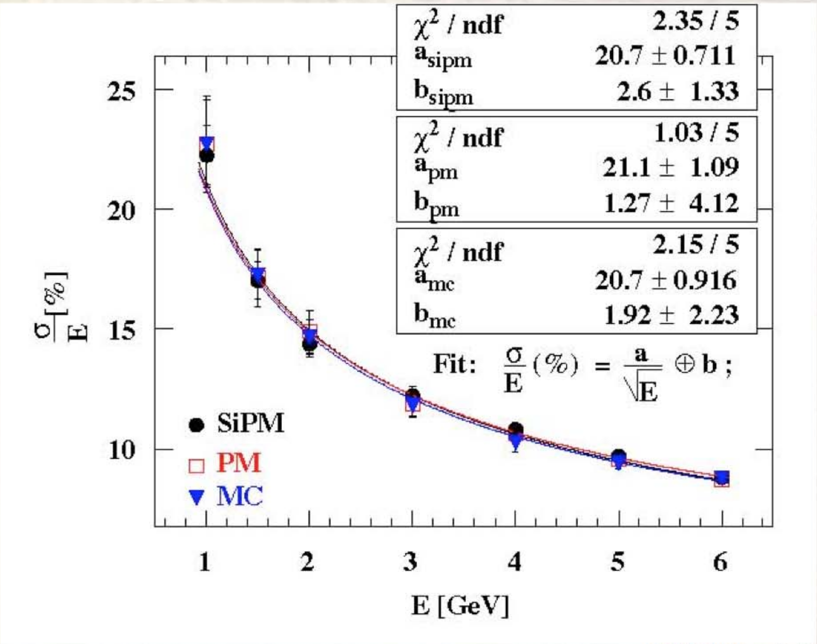




Electron Results from AHCAL Prototype

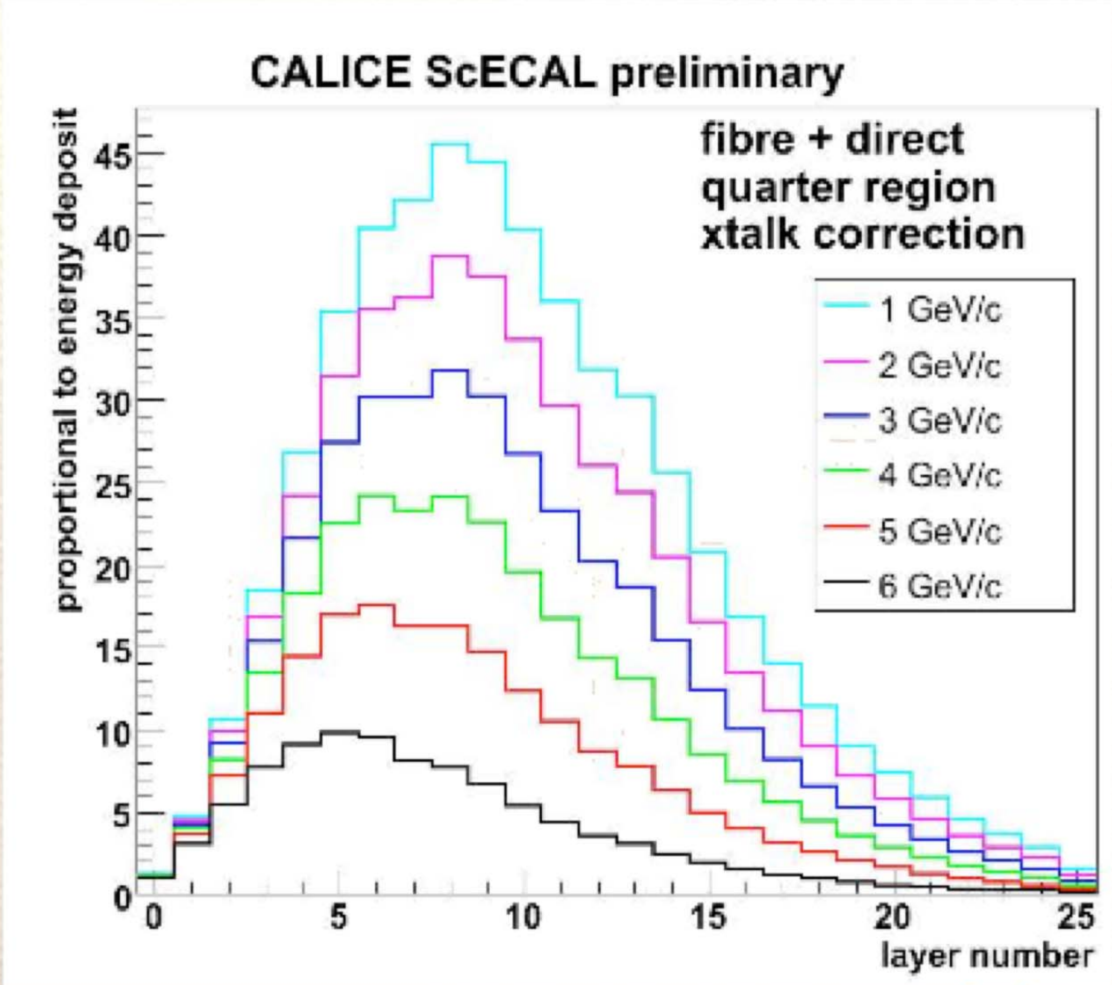
- For 11-layer AHCAL prototype: 2cm Fe plus nine 5cm × 5cm ×0.5 cm scintillator tiles we have measured linearity and energy resolution
- The linearity plot shows that non-linear SiPM response is necessary
- The energy resolution just needs the stochastic term
  - So for the rear endcap calorimeter expect σ_E~14-18%





Longitudinal Shower Distribution

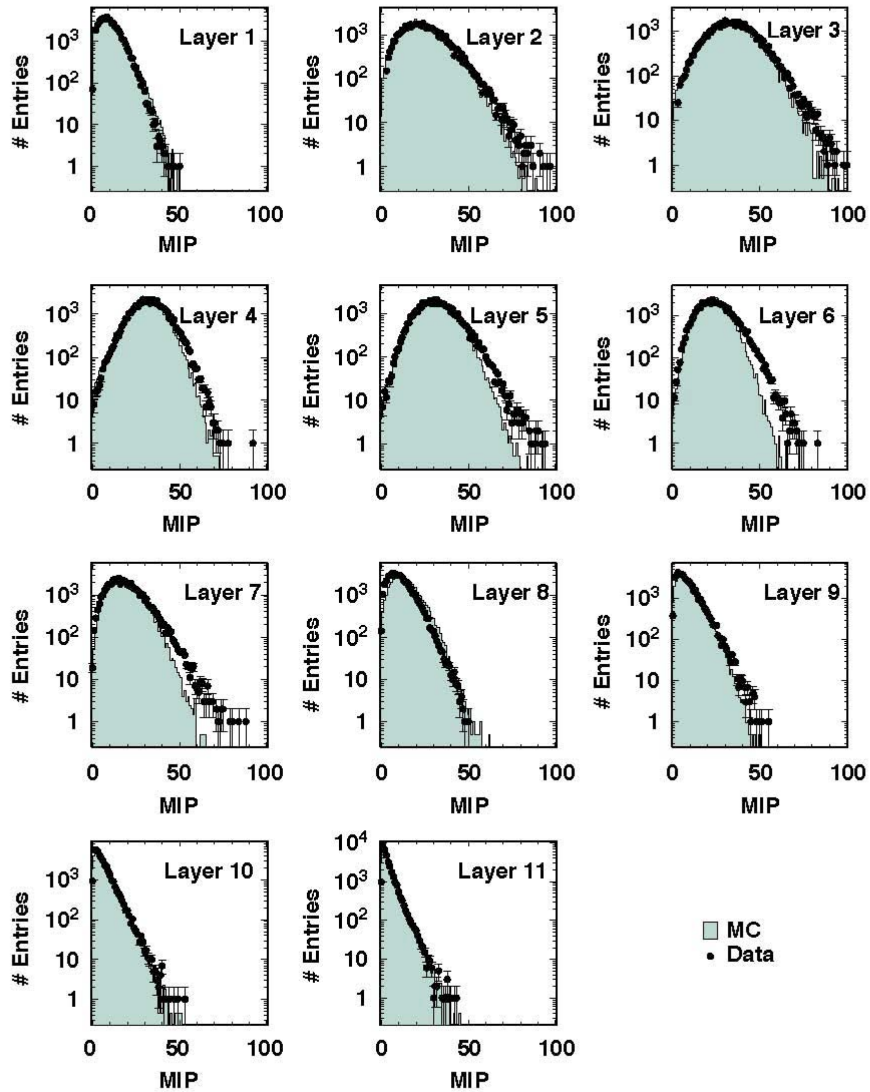
- Longitudinal shower shape for W-scintillator strip ECAL prototype for 1-6 GeV electron showers



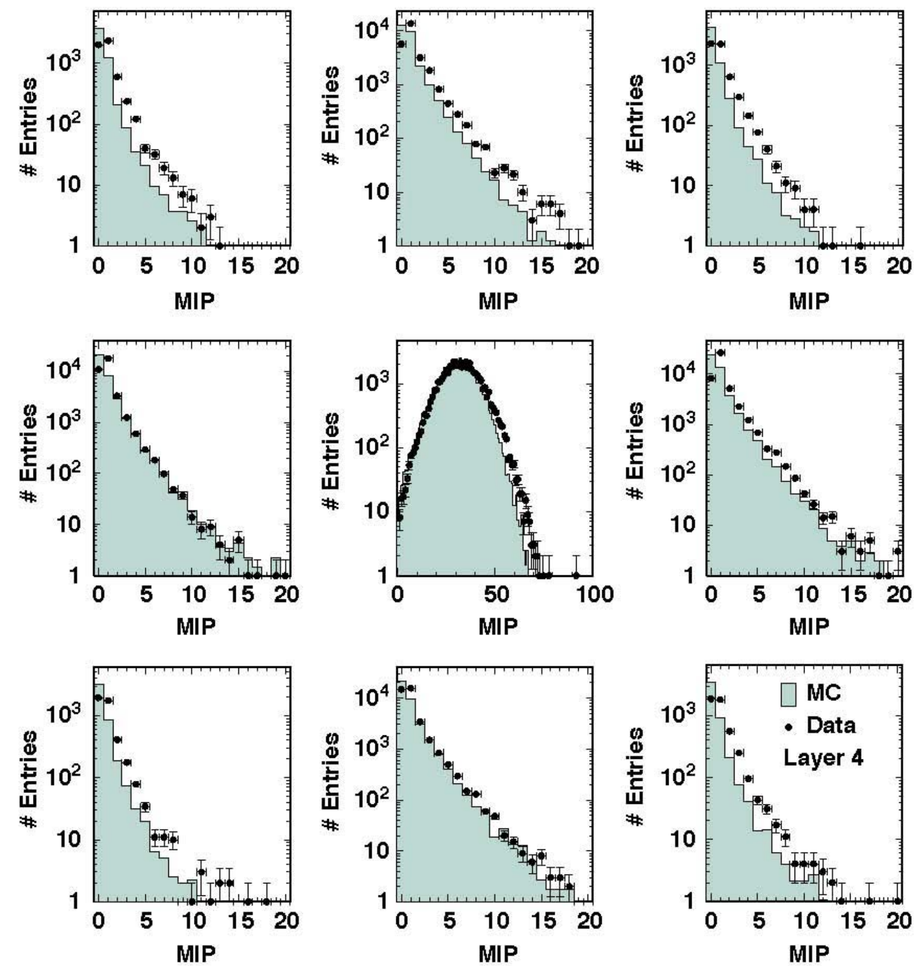
- Issue is if the dynamic range is sufficient for 30MeV to 12 GeV range
- I think it is ok for even for MePhi SiPMs, Hamamatsu MPPC's have a factor of 5 higher dynamic range
- There are also SiPMs from Dubna that have more pixels

AHCAL Shower Shapes for 3 GeV Electrons

- longitudinal shower shape



- transverse shower shape



- AHCAL prototype: 2cm Fe
9 5cm × 5cm ×0.5 cm scintillator

Conclusion

- The experience in Calice with the scintillator-tile AHCAL and the scintillator-strip ECAL prototype provide a useful starting point for the design and construction of a rear endcap calorimeter for SuperB
- These prototypes provide a proof of principle
- Several design components can be taken with small modifications e.g. VFE electronics, calibration/monitoring system
- Design details can be decided upon simulation studies
- However, it is desirable to test the final design in a small prototype