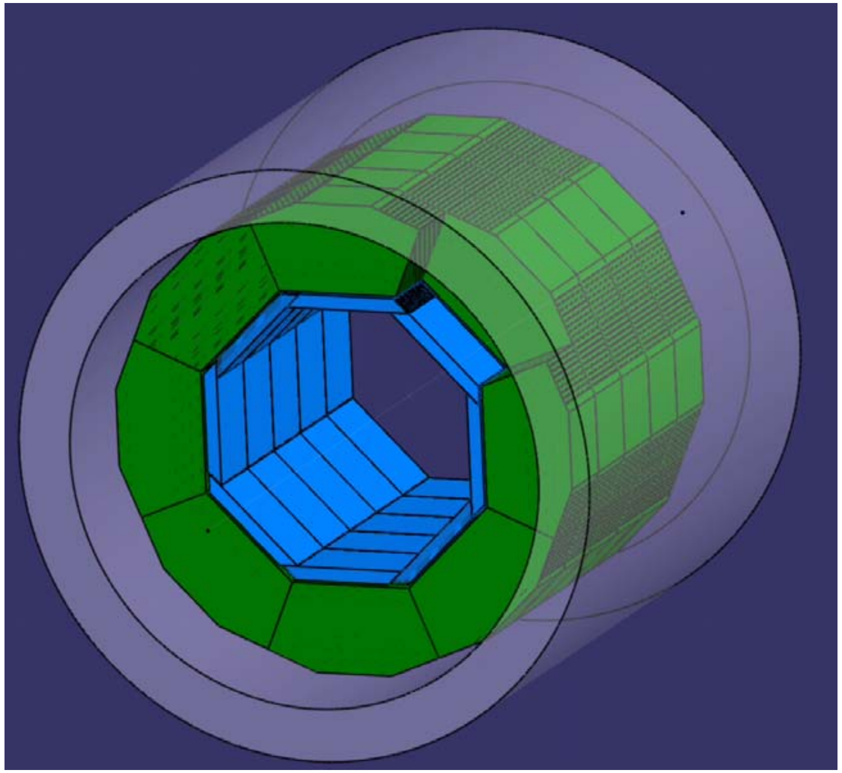
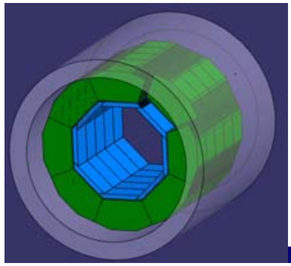


# Hadron Calorimeter

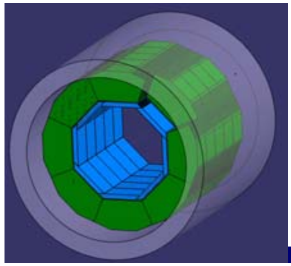
Felix Sefkow

EUDET Annual Meeting
October 20, 2006



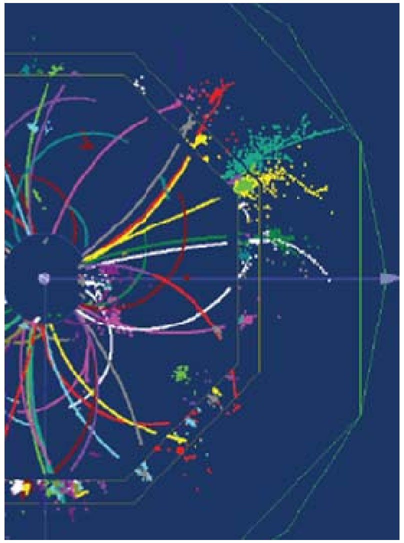
# Outline

- Goals, milestones, roadmap
- Detector structure: experience and R&D
- Calibration system studies

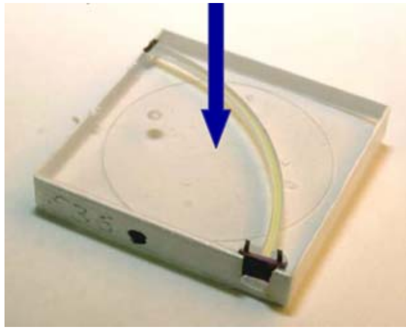


# Kickoff Meeting HCAL Summary

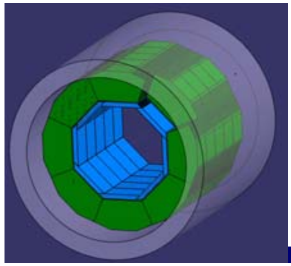
- The goal is to propose a realistic scintillator HCAL for the ILC by the end of the decade
  - Novel concept: PFLOW imaging
  - Novel technologies: embedded SiPMs
  - Realistic = scalable + basis for costing



- The HCAL task – together with FEE and DAQ – will provide a framework for
  - The R&D towards a realistic detector structure
  - Connecting to the dynamic photo-sensor developments



- Feedback from the testbeam effort will be vital for the refinement of concepts in the near term conceptual phase 2006-2007



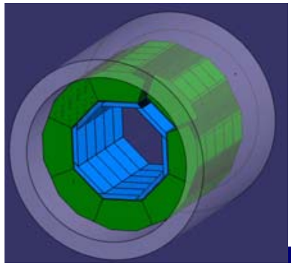
# R&D collaborations

- JRA3 work is embedded in international R&D collaborations
  - Input from previous detector prototypes
  - Input from operational experience at ongoing testbeams
  - Input from generic R&D for future detector components
- Ensure that the provided infrastructure matches the R&D requirements of the community

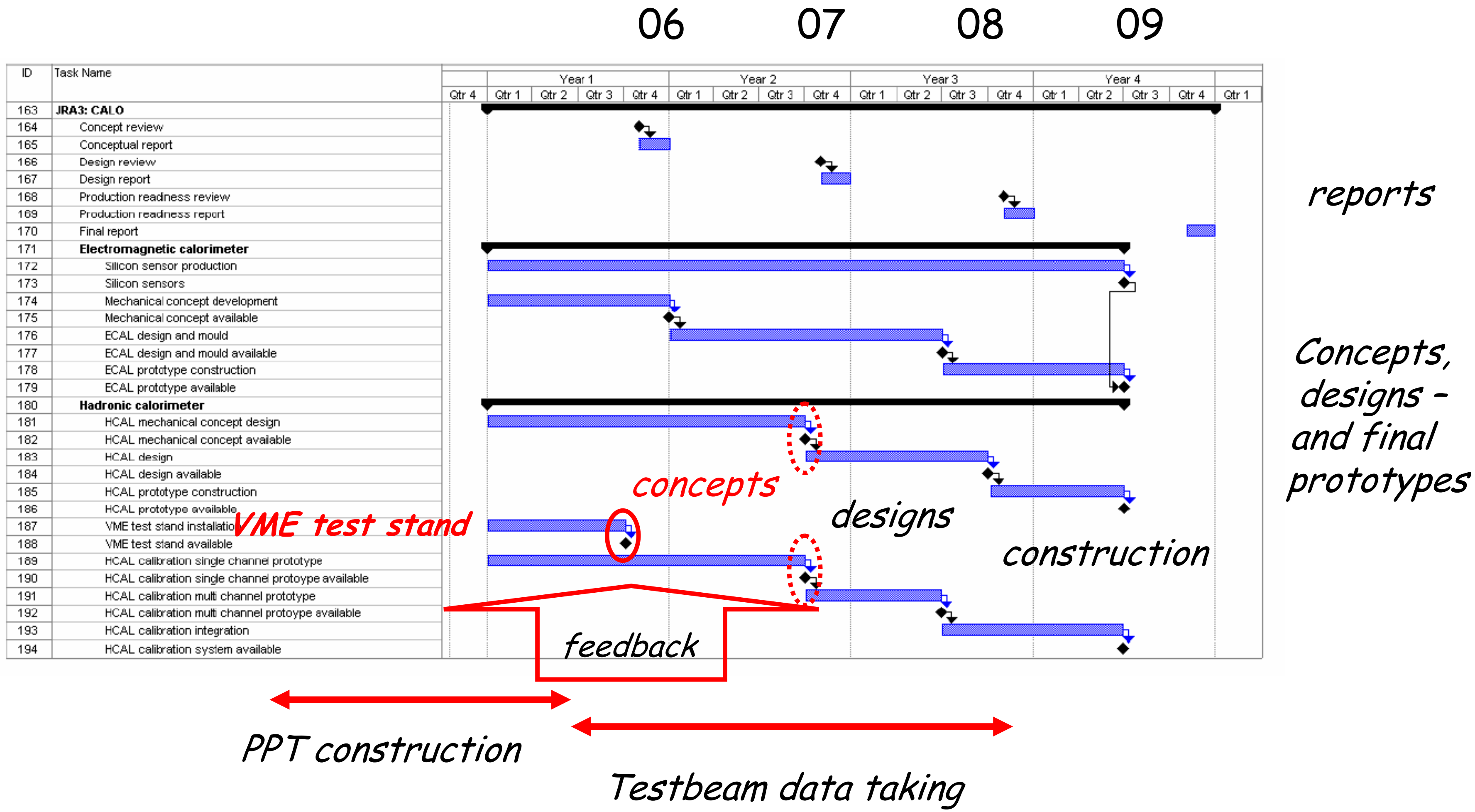
CALICE
Calorimeter for ILC

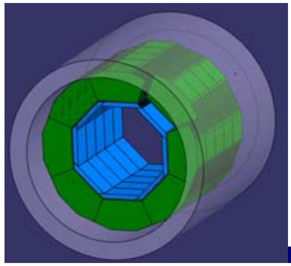
*International collaboration:*
*36 institutes*
*fom Europe, Asia and America*

*+ Japan*



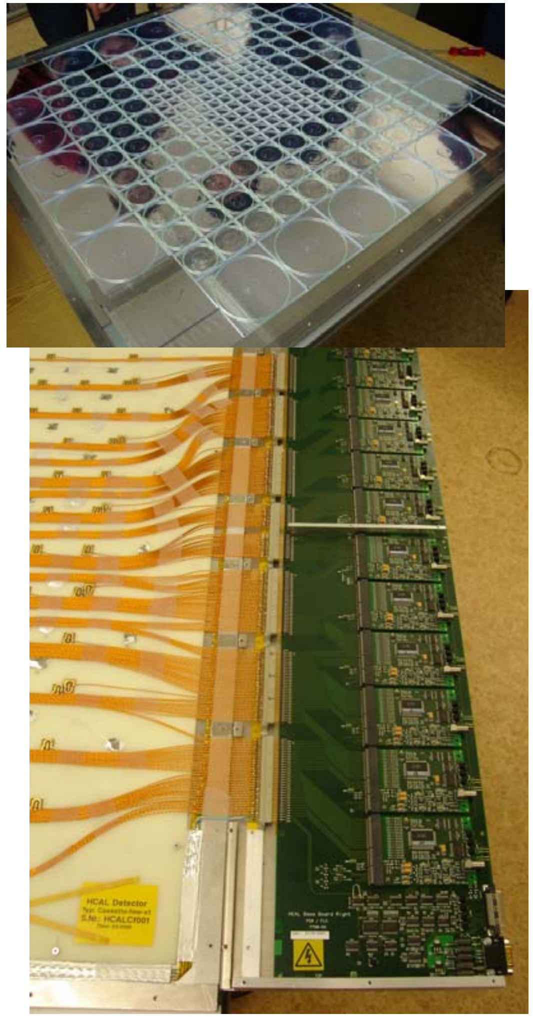
# Milestones and Deliverables





# HCAL testbeam prototype

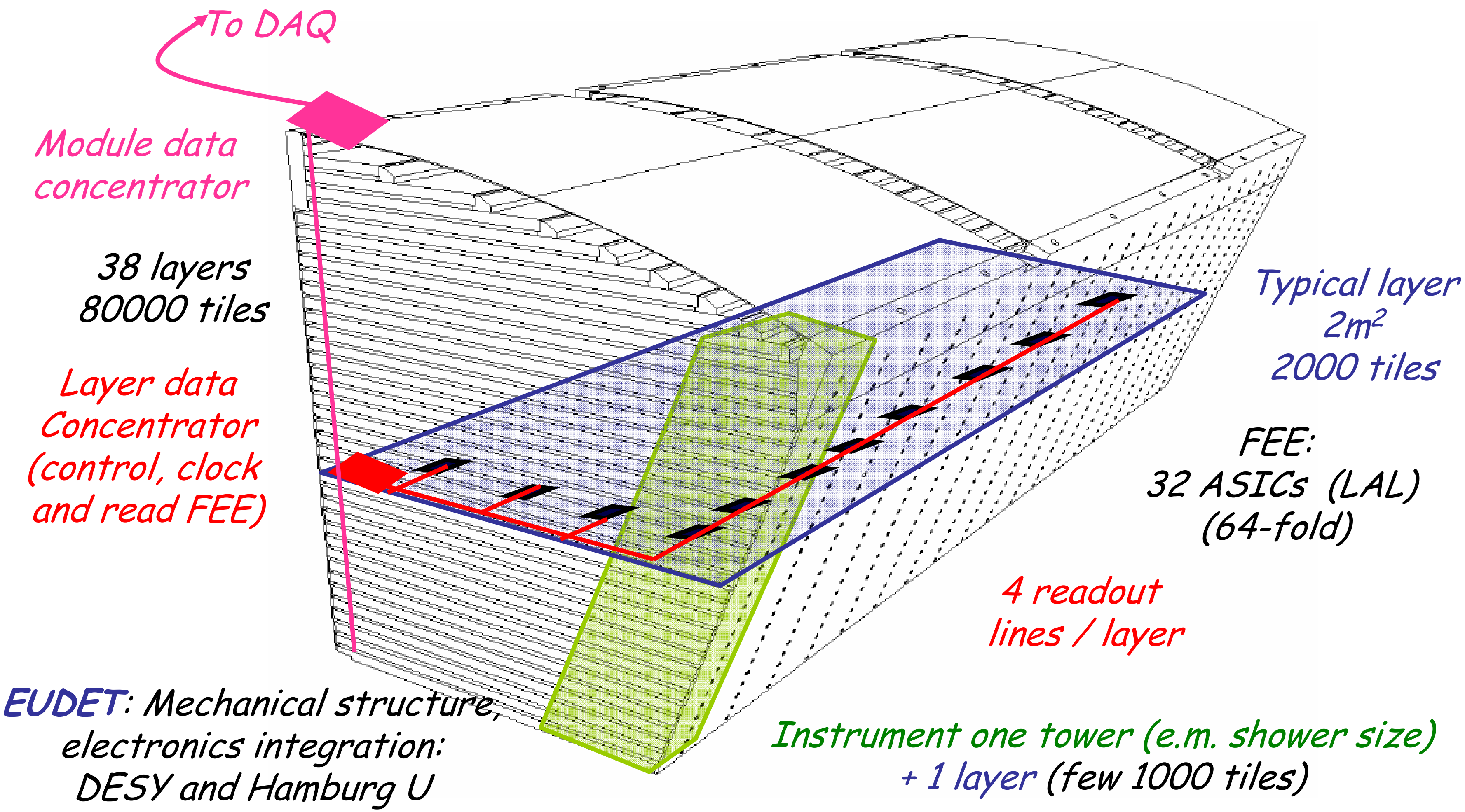
- 1 cubic metre, 8000 tiles with SiPMs
- Electronics based on CALICE ECAL design, common back-end and DAQ
- Versatile LED calibration system

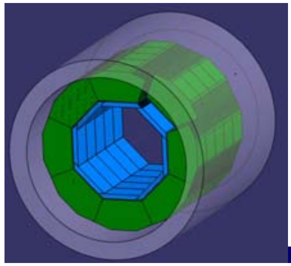


- The design is not scalable to a full detector
  - Front end components not integrated
  - Electronics not optimized to SiPM signal
  - Calibration system too complicated
  - Scintillator layer thickness not minimized
  - Assembly still quite labour-consuming

- A precedence for the electro-mechanical concept of a scintillator calorimeter with integrated photo-sensors does not exist

# HCAL readout architecture





# Scalable prototype roadmap

- Milestones on the horizon
  1. Mechanical concept — 9/2007
  2. Calibration electronics concept — 9/2007

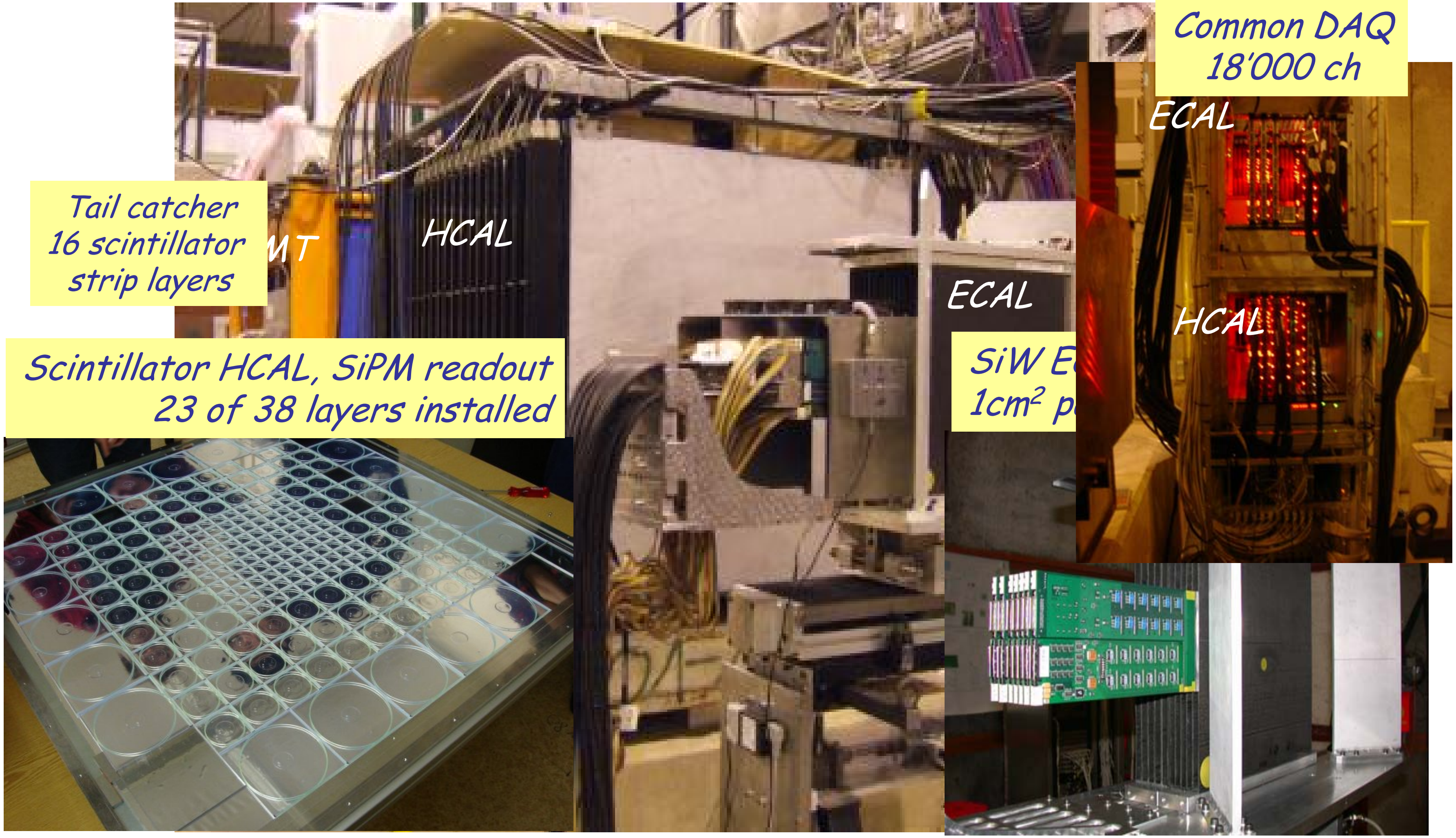
- Input to mechanical concept

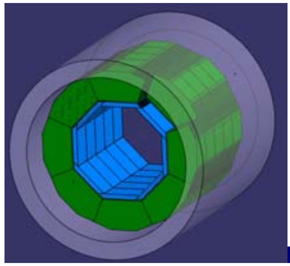
| | | |
|---|---|---|
| – Photo-sensor development | Industry | |
| – Photo-sensor scintillator coupling | us | started |
| – Electronics to photo-sensor coupling | next | |
| – Electronics integration, cooling | then | |
| – Electronics and DAQ architecture | | started |
| – Calibration concept | parallel | |

- Ingredients to overall concept

| | | |
|---|---|---|
| – Testbeam experience | | started |

# CALICE Testbeam at CERN SPS

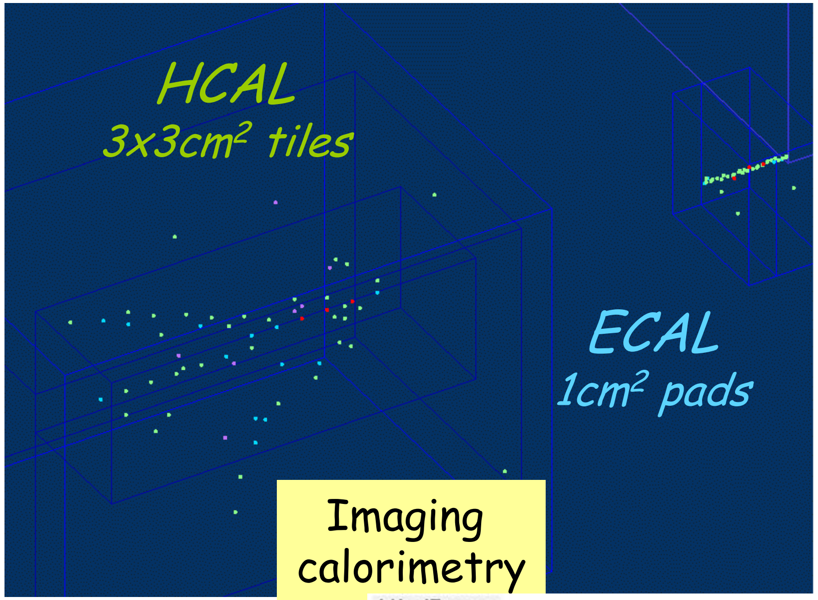




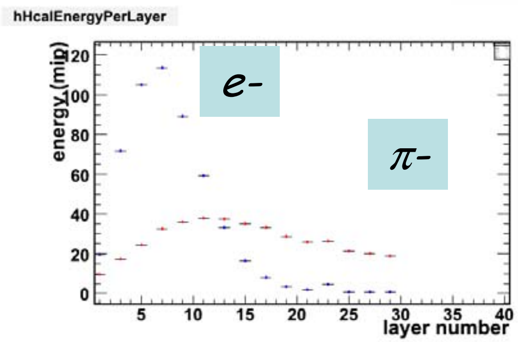
# Data taken

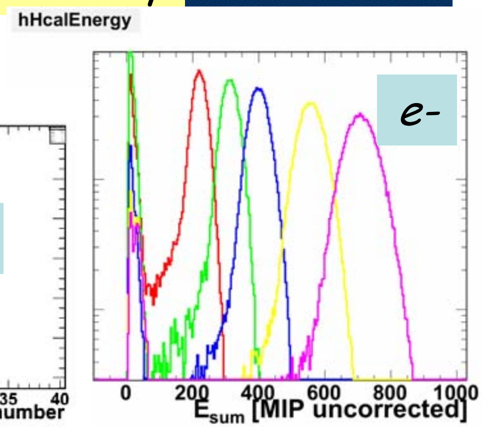
- First period (end July): only two days of beam availability
- Second period (end August): ~30 million events on disk
  - Muons, electrons, hadrons
  - 6-80 GeV
  - Smooth detector operation
- Third period: ongoing this week
  - More active layers
  - Optimized geometry

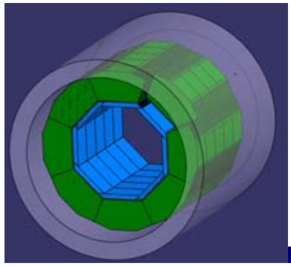
- 2007: will request continuation
  - All detector layers completed
  - Movable stage for angular scans




*First analysis:*





# First lessons

- Detector is robust and stable, impressively efficient running
- Preparation in DESY testbeam was extremely valuable

- Integrated ECAL HCAL TCMT electronics approach proved successful
  - Common DAQ
  - Common online monitoring
  - Common analysis software
  - “no” detector integration effort

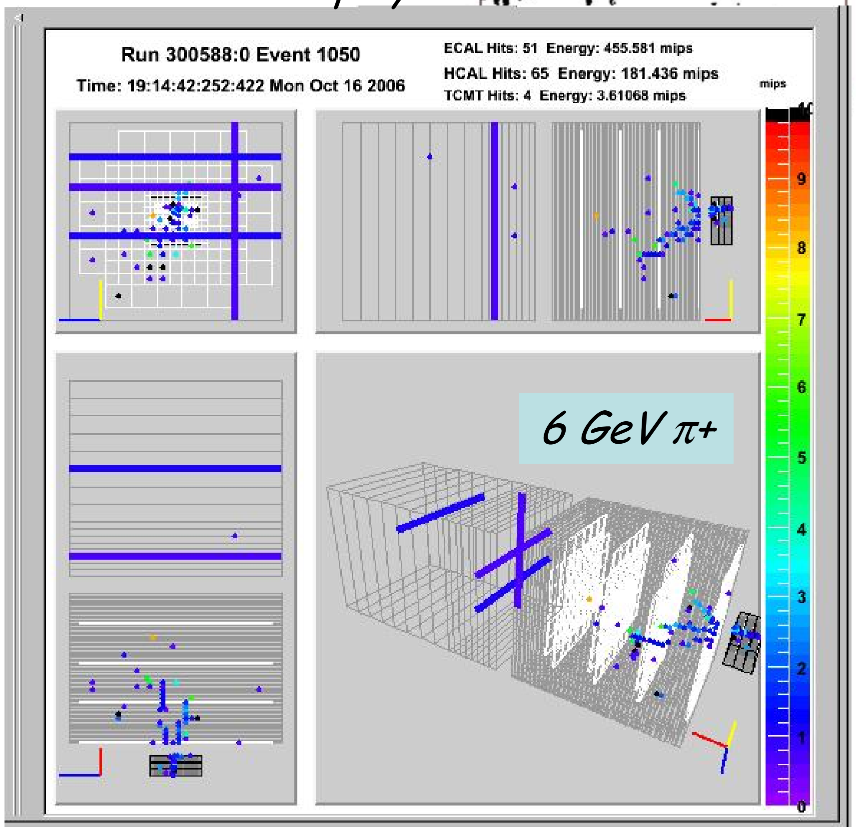
- SiPMs are still a pioneering technology
  - no real mass product yet
  - flexibility and adjustments necessary

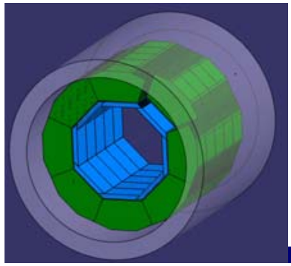
- SiPM noise is ***just*** small enough, requires careful operation

- Coherent noise from FEE in first data, already eliminated

*Front end gain ratio (fast / slow mode)*

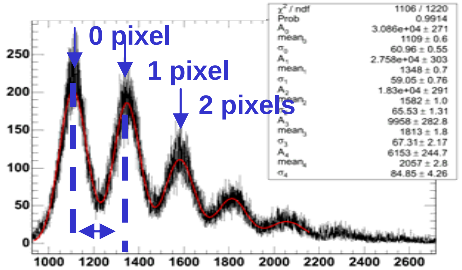

*Online event display*



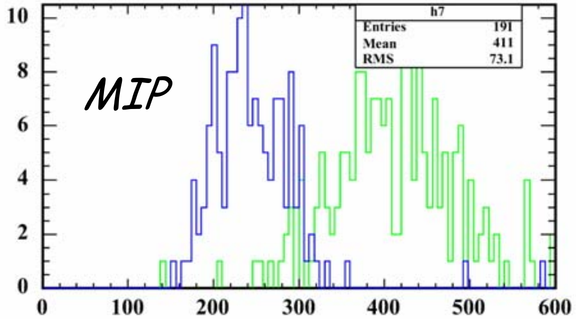


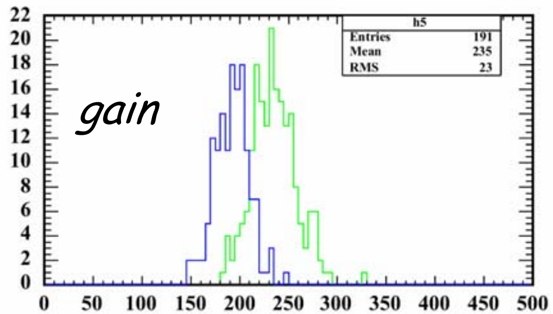
# More lessons

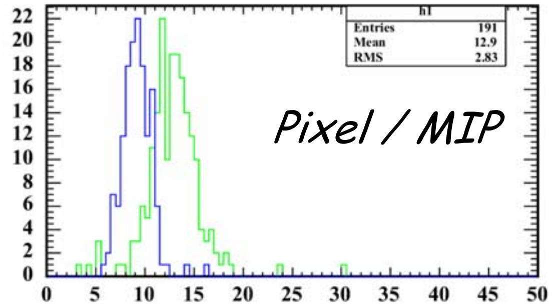
- Redundancy proved vital
  - Observe single photo-electron peaks:
  - “auto-calibration”
  - SiPM equalization, scintillator quality control, detector operation, non-linearity, stability monitoring

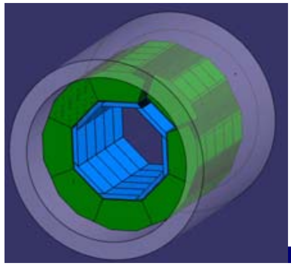



- Temperature variations occurred recently
  - Exercise monitoring and correction concepts
    1. PIN diode monitored LED reference signals
    2. Gain measurements
    3. Temperature monitoring
- Stability of saturation
  - Simplify calibration system?



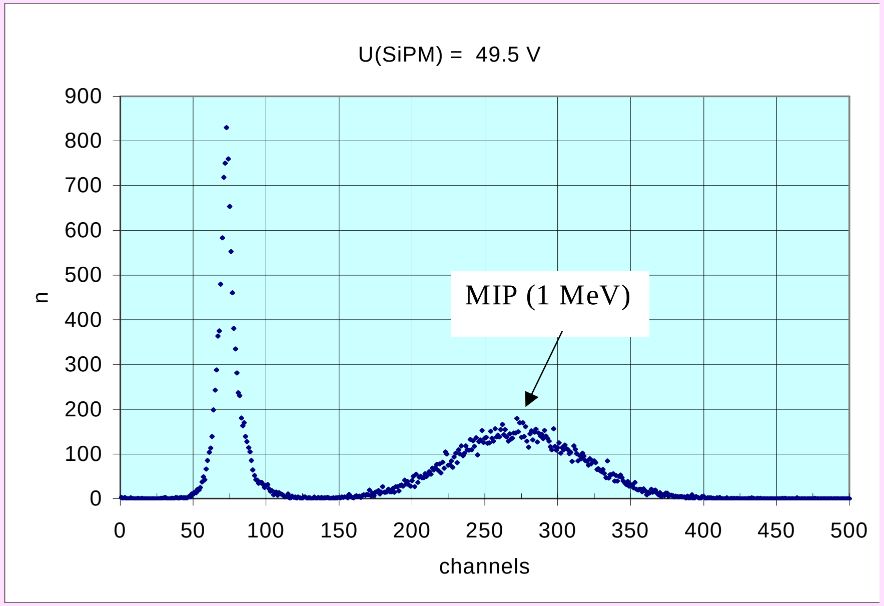





# SiPM development

- Very active field, driven by non-HEP applications
  - Medical imaging (PET), diagnostics, night vision, radiation monitoring
- More players entering:
  - MEPHI/PULSAR, CPTA, JINR, MPI-Munich, Hamamatsu, SensL, Geneva, Trento
- Directions: higher signal – lower noise –lower cost
  - Lower noise and / or inter-pixel Xtalk → lower thresholds
  - Better spectral sensitivity – to blue scintillation light
  - Larger area and / or better geometrical packing factor
- Will allow to
  - Significantly simplify the coupling between SiPM and scintillator
    - Eliminate fibre, ease precision requirements
  - Use thinner scintillator
    - Save coil cost
    - Buy containment
    - Improve electromagn. Performance
    - ➔ maybe keep the fibre…

# 5x5 mm² SiPM room temperature



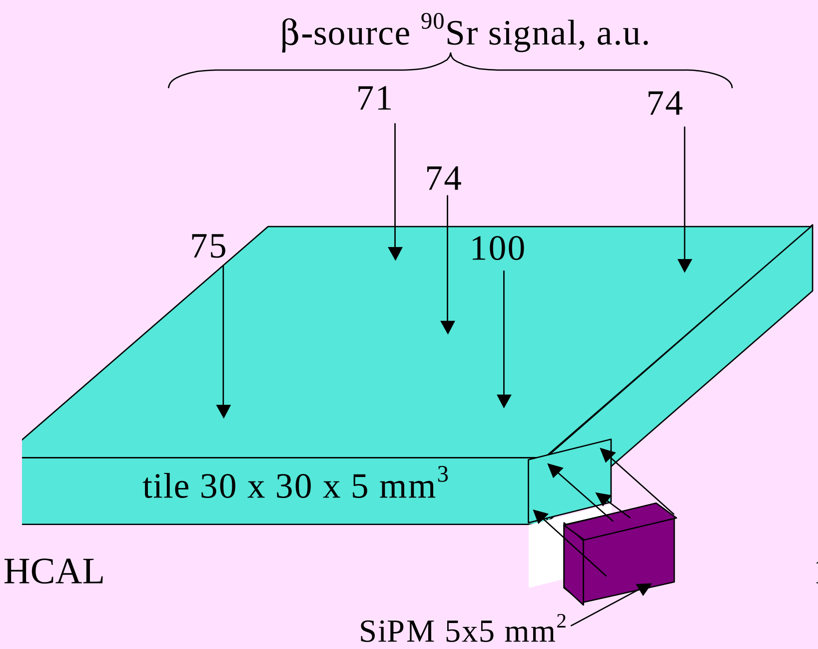

SiPM: sensitive area 5.2x4.9 mm$^2$

Number of pixels 40x40=1600

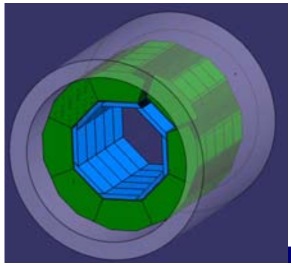
Active pixel area 100x100 μm$^2$

Period 130x120 μm$^2$

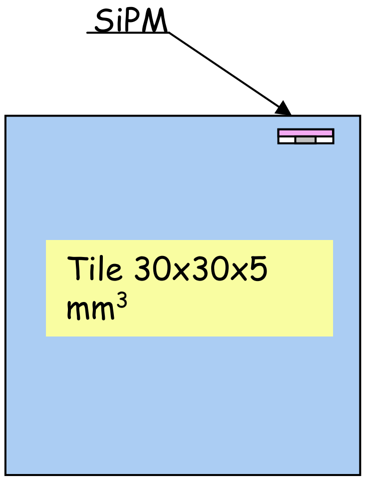
*From MEPHI / PULSAR*



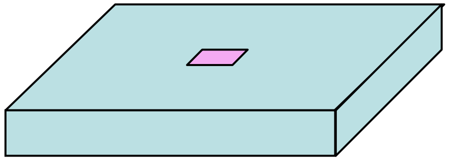

*M.Danilov*



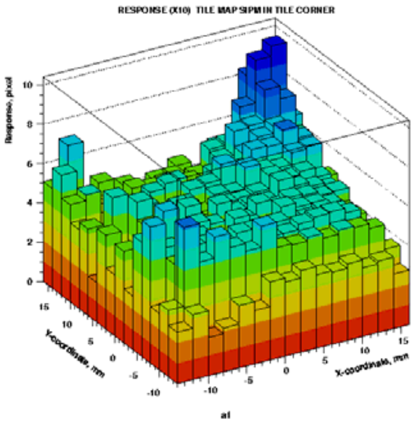
# SiPM scintillator coupling

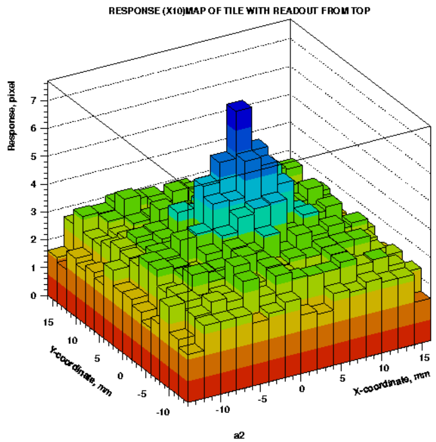



Tile 30x30x5 mm3



- Uniformity to be re-addressed, not as good as with fibre
- Also studied: 3mm thin tiles

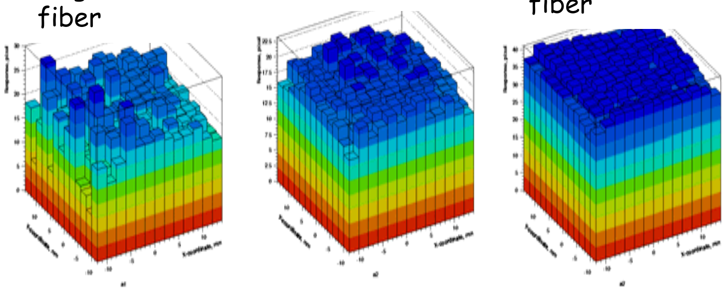


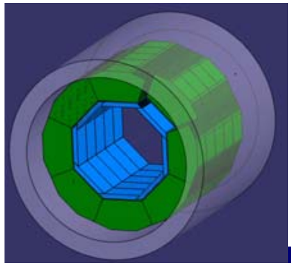

Tile with diagonal fiber

Tile with arch fiber

Standard 5 mm thick tile with arch fiber

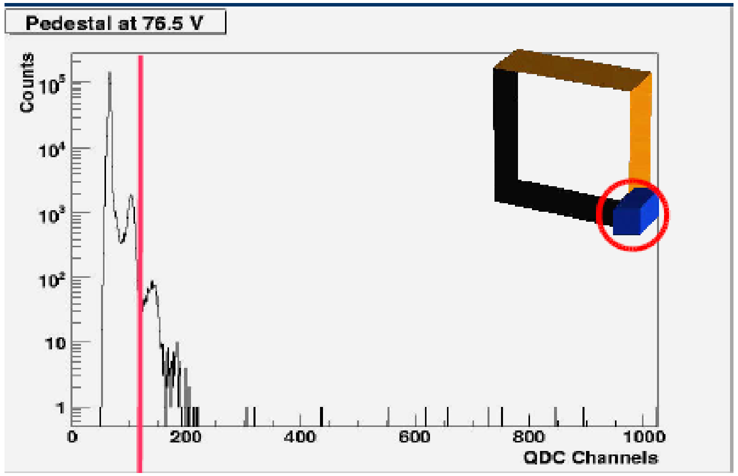


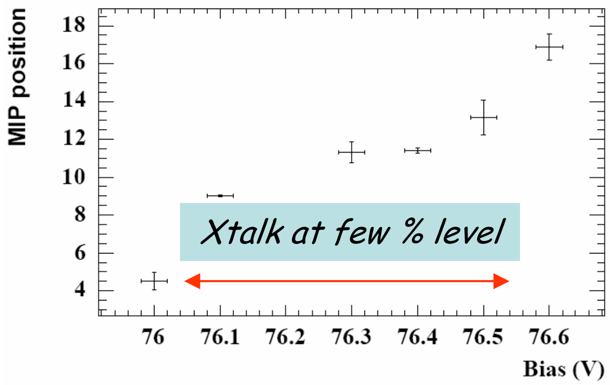
*M.Danilov*

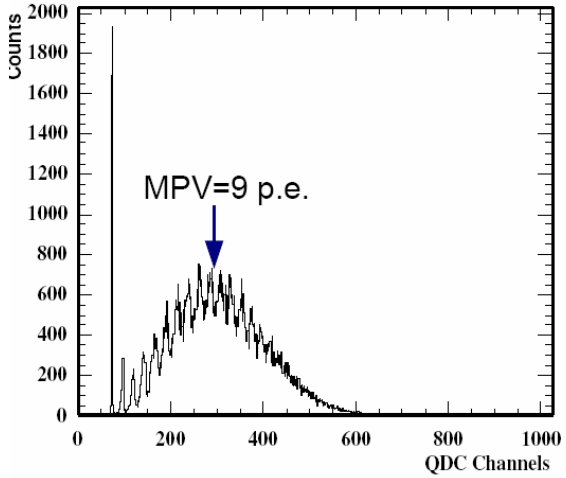


# Blue-sensitive SiPMs

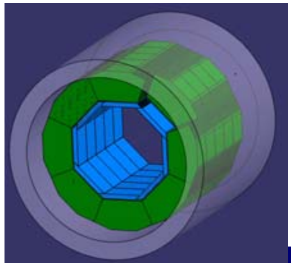
- New devices from Hamamatsu
  - Inverted structure
- 400 pixels on $1mm^2$, moderate crosstalk
- 2-3x more lightyield with green WLS
- 5-6 times more with blue scintillator light
- Simplified coupling
  - **Plan test layer for testbeam**



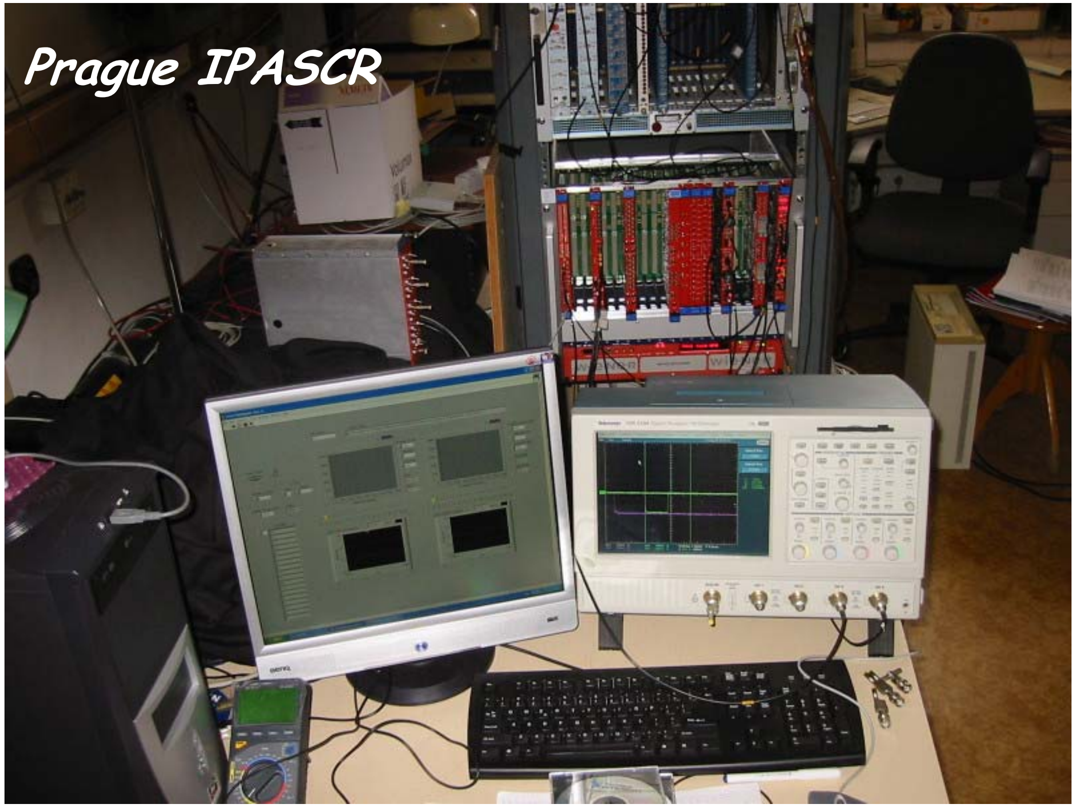




N Dascenzo



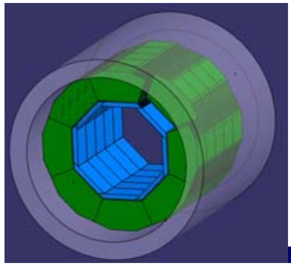
# Calibration system test stand

- VME-based system For tests of optical calibration system electronics
  - Presently working with APD readout
  - Crate, ADCs, discriminators
  - Already used for stability tests of present testbeam equipment
- Also: complement testbeam calibration electronics




*(scope, computer, NIM p/s not on EUDET bill)*

*J.Cvach*



# Progress summary

- EUDET HCAL concept and schedule largely driven by testbeam
  - Test beam started on schedule - real data are rolling in
  - Operational experience rapidly accumulating
  - Engineering resources needed for completion
- Critical R&D issues around new photo-sensors identified and being addressed
- Next: invent a novel readout structure
- Calibration system infrastructure in place:
  - **First milestone met**