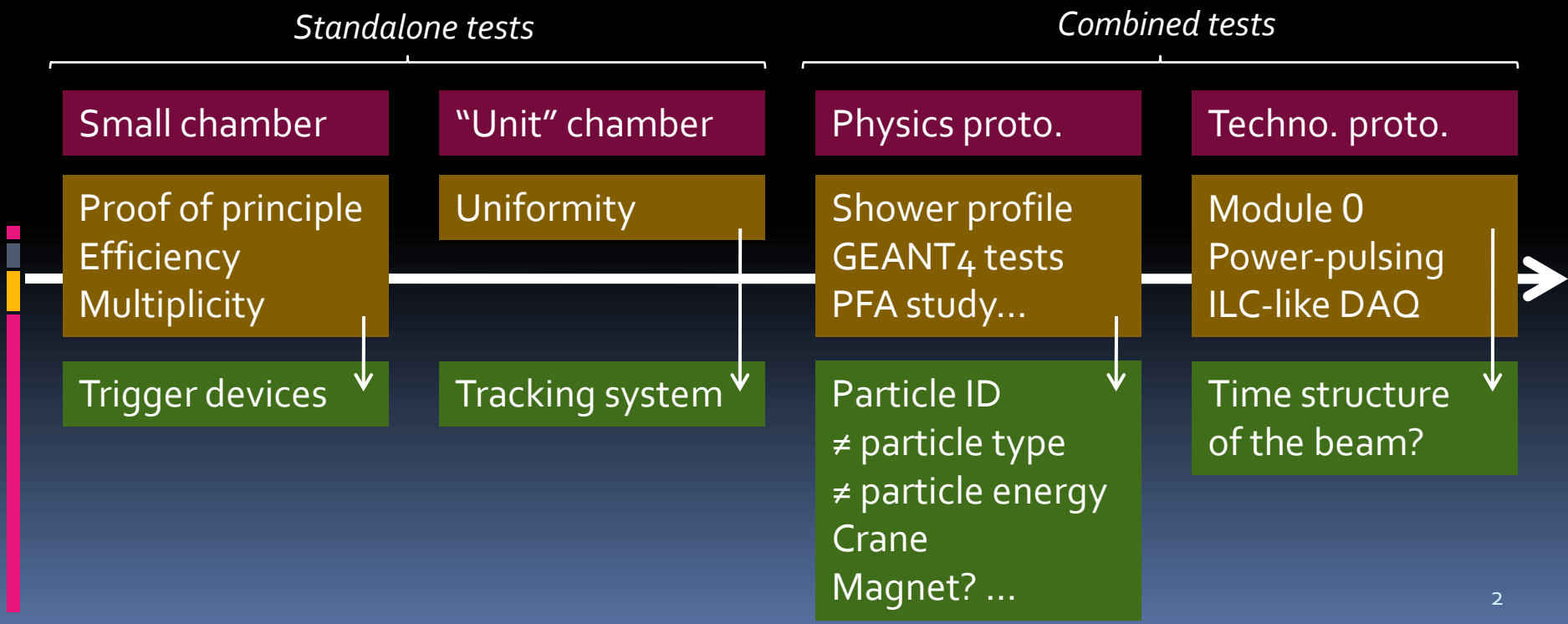
LCTW Orsay Nov. 2009

M. Chefdeville, LAPP, Annecy

CALICE HCAL'S & TCMT TB EXPERIENCES AND PLANS

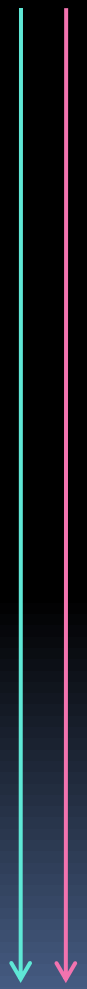
HCAL concepts & Test beams

- Several HCAL concepts
  - AHCAL & TCMT — combined test
  - RPC DHCAL — physics prototype
  - GEM/GRPC/MICROMEGAS DHCAL — "unit" chamber
- Specific TB plans/needs however common story-line



Outline of the talk

- GEM DHCAL
- GRPC sDHCAL
- MICROMEGAS sDHCAL
- RPC DHCAL
- AHCAL & TCMT



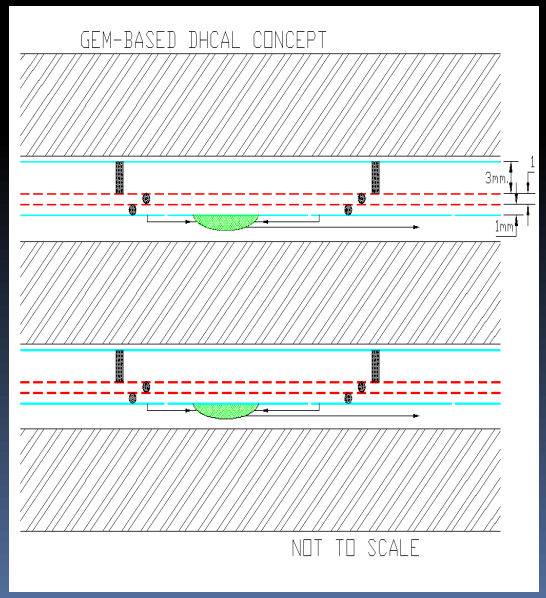
- Available prototypes
- Testbeam status
  Experience & feedback
- Testbeam plans (4) coming years
  Wish list

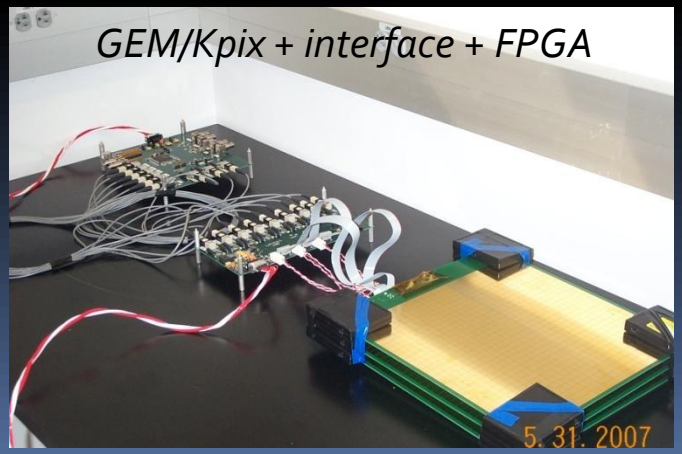
(double)GEM DHCAL status

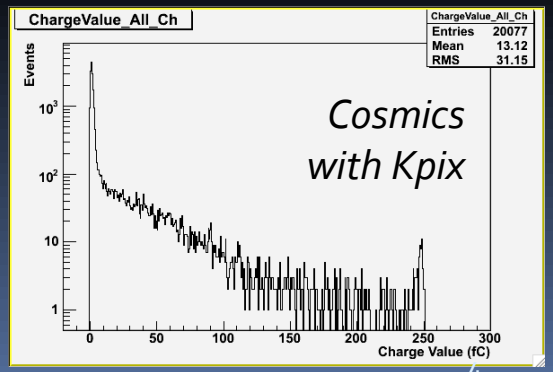
- Gas Electron Multiplier
  - Rate, ageing, stable, 2kV, stackable, high gain, Ar/CO2
- Tested prototype
  - 30x30 cm² with QPA02 electronics
  - Recent bench test with Kpix

- Test beams
  - High flux e- beam chamber survived
  - **8 & 120 GeV protons at FNAL/MTBF response/eff./gains**
  - 20fC MPV, 100% eff. @ 4fC

6.5 mm



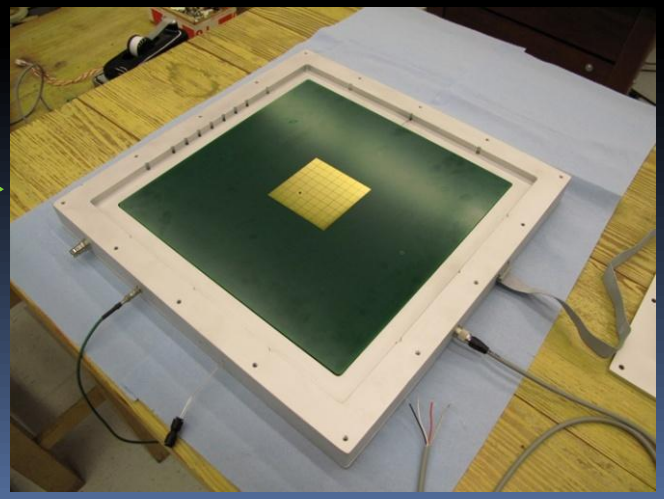




GEM DHCAL plans for end 2009

Prototypes

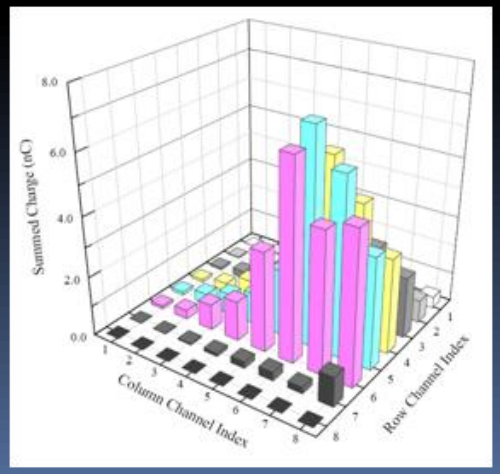
- 30x30 cm² chamber
  - Improved gas flow design
  - 64 pads & Kpix readout
- Unit chamber
  - Single GEM foil: 33x100 cm²
  - Send design to CERN workshop



Test beams

- Characterization
  - Response, efficiency, multiplicity, uniformity …

55Fe charge signal on pads



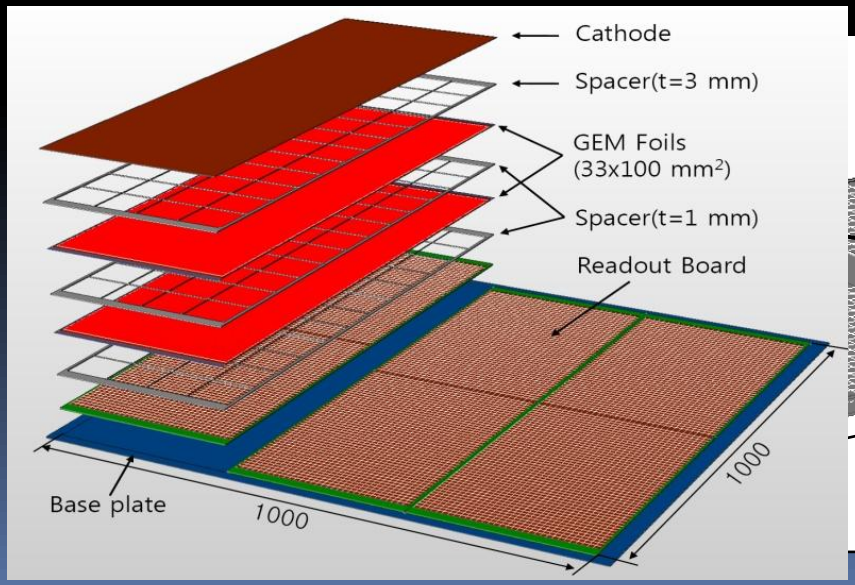
GEM DHCAL plans 2010…

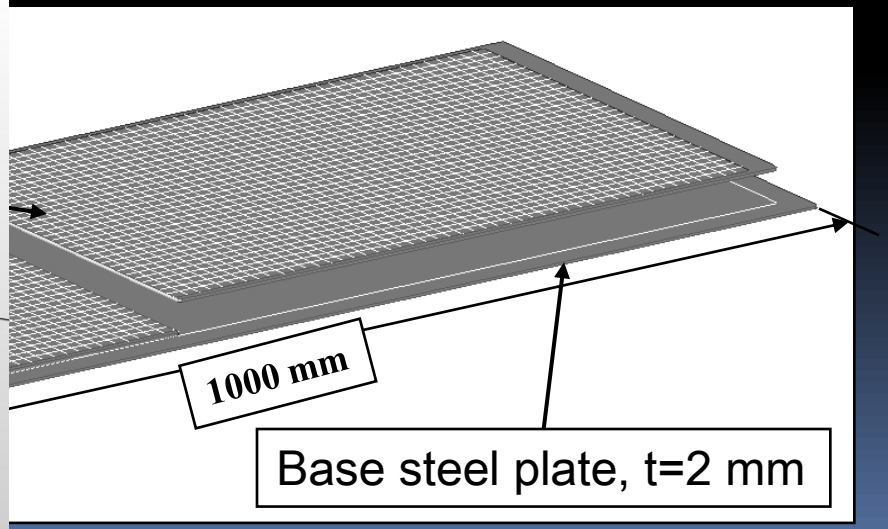
Next steps

- Production/certification 33x100 cm^2 foils
- Characterisation of Kpix chips
- Start using DCAL chips
- Construction of Unit chambers with Kpix & DCAL

Test beam plans

- Mid 2010-late 2011
  - 15 Unit chambers with DCAL
  - 1 with TGEM or RETGEM
- Test in existing CALICE stack (see AHCAL) of 5 DHCAL planes



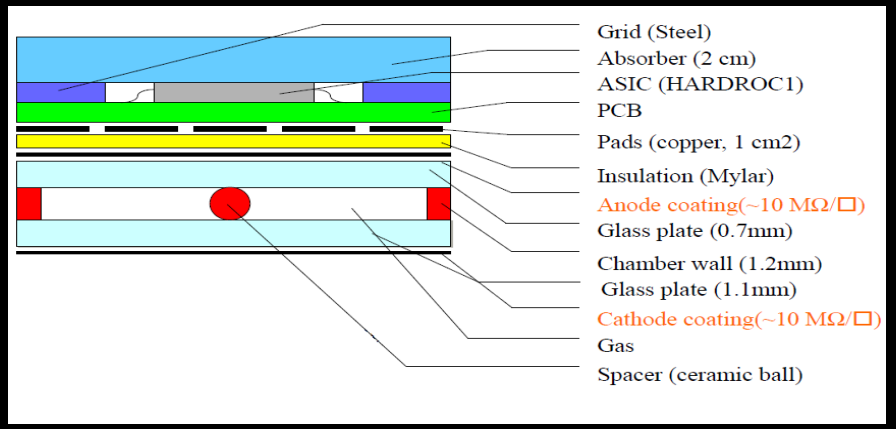


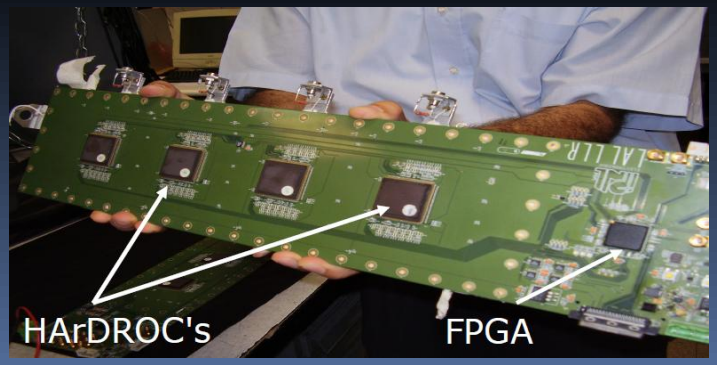
Glass-RPC semi-DHCAL status

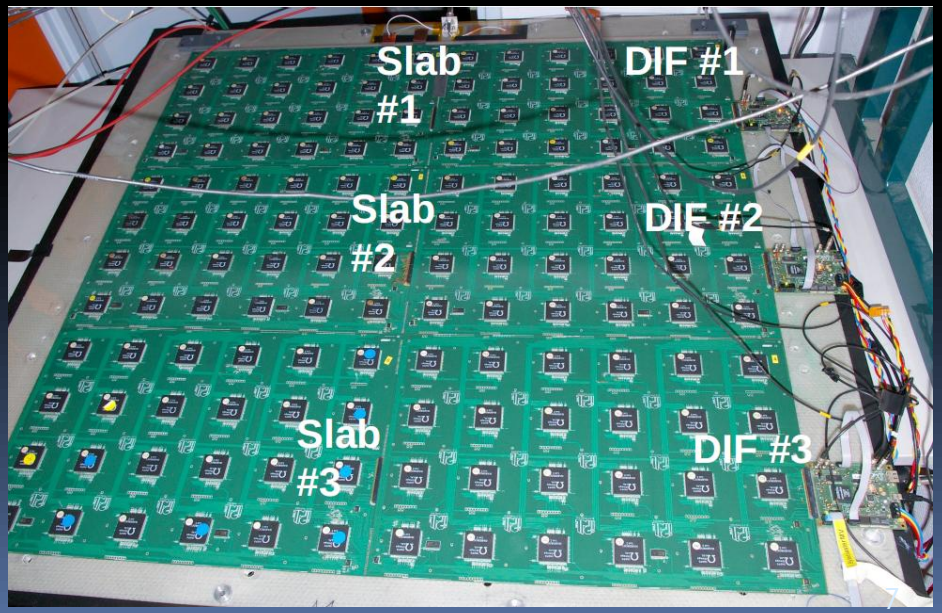
- Resistive Plate Chambers
  - Large signals
    Well-suited for large area
  - Rate effects, 8 kV

- Prototypes
  - 1.2 mm of gas, 1 cm² pads
  - HARDROC readout
    - 64 channels, 2-3 thresholds
  - DIF + Xdaq framework

  - 4 HR boards, 8x32 cm²
  - 1 m² with 6 boards of 24 HR



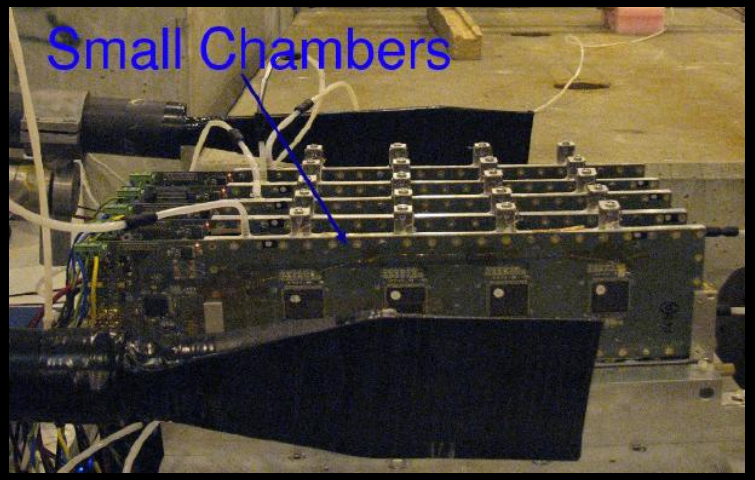




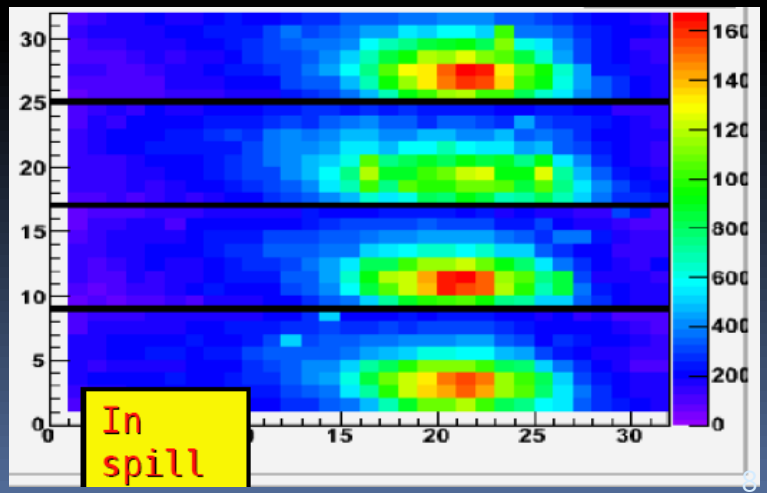
Performed tests in 2009 (I)

2 Test beams at CERN PS & SPS

- Mini-DHCAL with small GRPC
  - Efficiency/multiplicity
  - Hadronic shower study
  - High rate tests with semi-conductive glass (10^{10} Ω.cm)



- 1m2 prototype
  - Readout electronics tests
  - Detector response

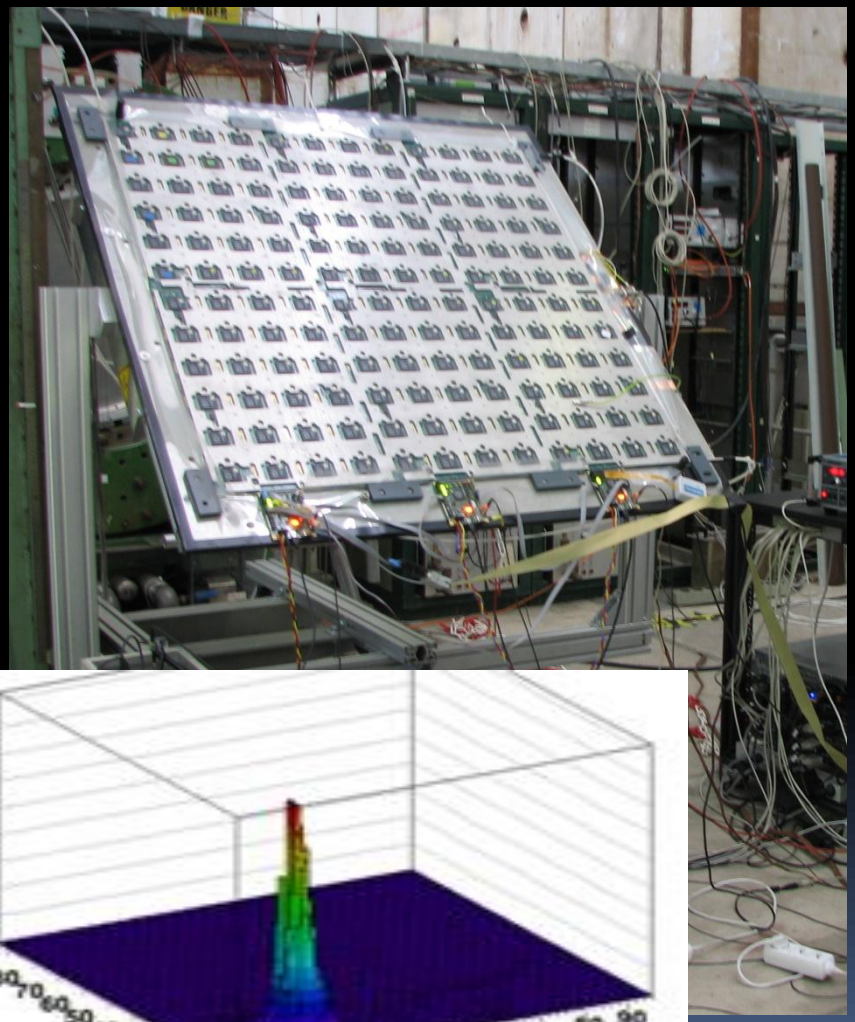


- Beam test setup:
  mainly scintillators

Performed tests in 2009 (II)

2 Test beams at CERN PS & SPS

- Mini-DHCAL with small GRPC
  - Efficiency/multiplicity
  - Hadronic shower study
  - High rate tests with semi-conductive glass (10^{10} Ω.cm)



- $1m^2$ prototype
  - Readout electronics tests
  - Detector response

- Test beam setup:
  mainly scintillators

Program for next year

Electronic boards for 3 prototypes of 1m² mid. 2010

- Test different kinds of resistive coating GRPCs

  Graphite, Statguard, Licron
  - pad multiplicity study

- Test Multi-Gap GRPC developed by CERN-Bologna group
  - Compare with Single-Gap GRPC

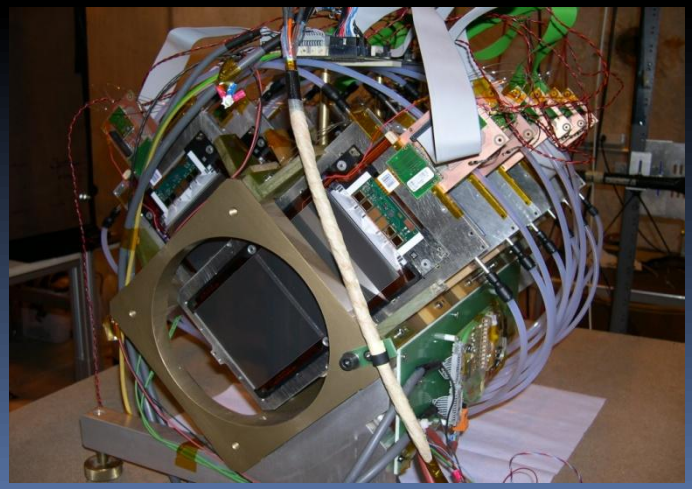
- Study the hadronic shower extension with 0-4 λ_i in front

Local efficiency study

- Use of CMS tracker telescope in collaboration with CMS people
  - Edges, spacers zone,

    inlet/outlet gas,

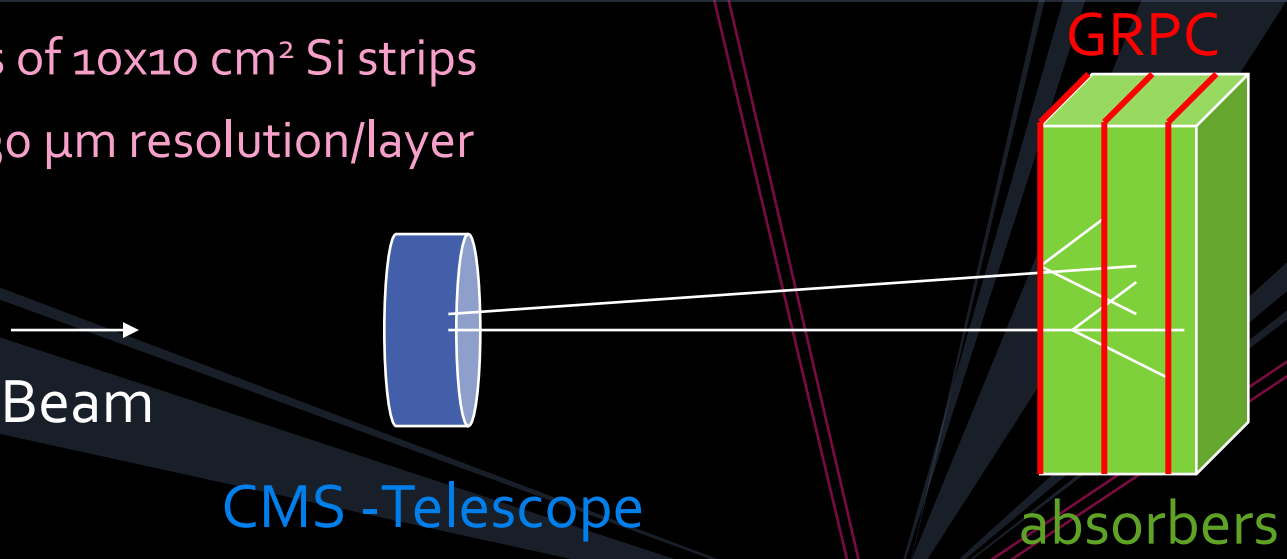
    H.V connections area…



Scheme of the TB with CMS-Telescope

12 layers of 10x10 cm² Si strips

6X+6Y, 30 µm resolution/layer



Simple case of PFA study can be achieved at low cost by combining existing/future calorimeters with existing tracker telescope

More advanced PFA study needs more sophisticated setup. Complete PFA test on "pseudo-jet" remains very difficult.

A combined, modular test is not a new idea but it becomes now necessary to validate concepts and options.

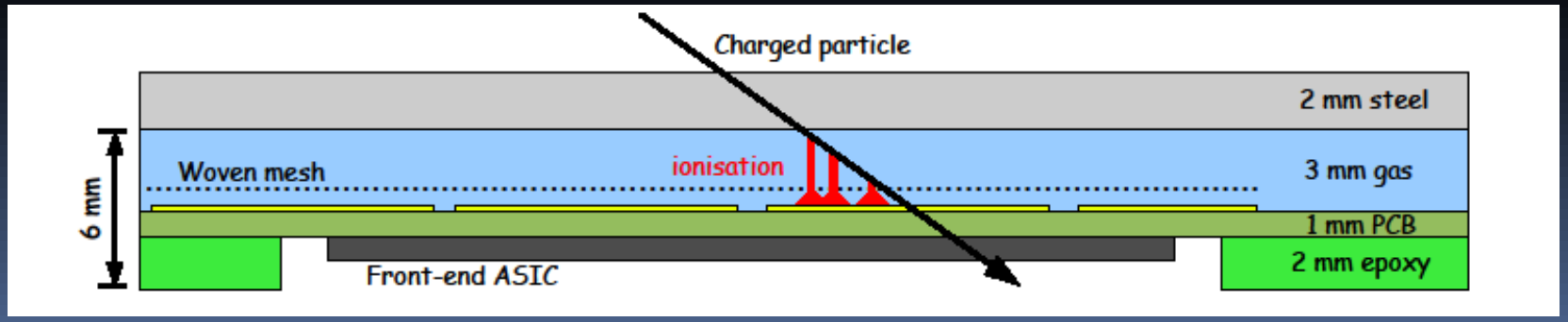
MICROMEGAS (semi-)DHCAL

Micro Mesh Gaseous Structure

- Rate, ageing, spark-proof, fast, robust, standard gas, 500 V, large area (RD51), low pad multiplicity, high gains in prop. mode
- Small avalanche charge w.r.t. RPCs

Prototypes

- 3mm gas, 1cm² pads
- GASSIPLEX readout
  analog electronics "outside"
- Active Sensor Unit
  digital embedded electronics
  - HARDROC or DIRAC ASICs (64 ch.)
  - DIF, USB DAQ with Xdaq or LabView



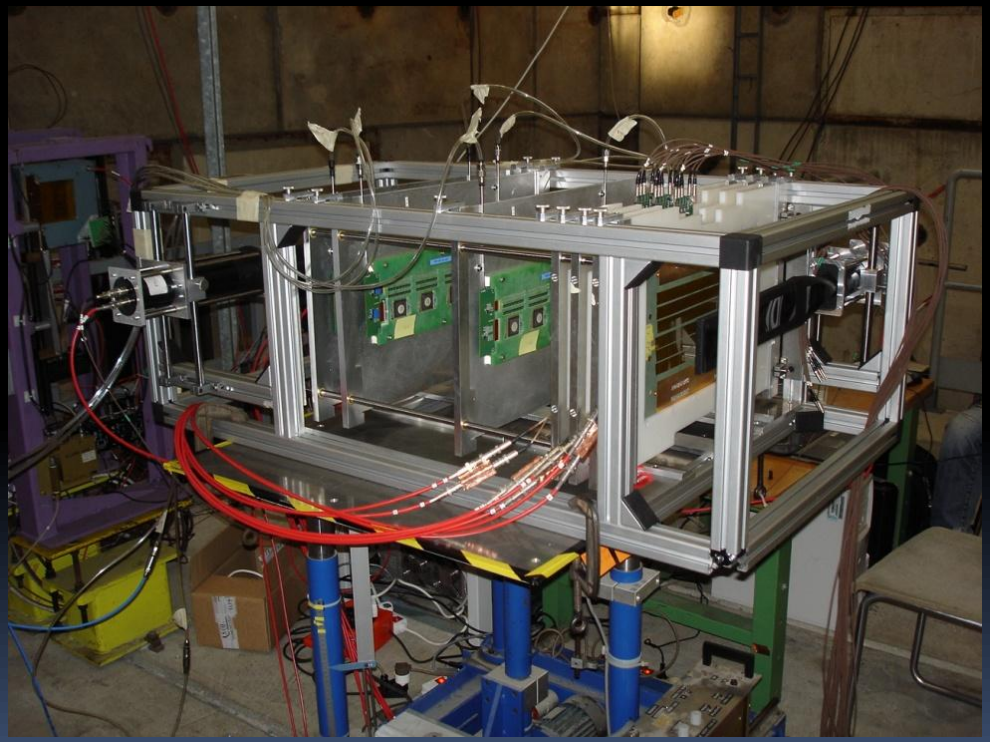
MICROMEGAS DHCAL beam test status

Test beams @ CERN PS & SPS

- **Aug + Nov 2008**
  4 GASSIPLEX chambers
  1 DIRAC

- **May-June 2009**
  4 GASSIPLEX + absorbers
  4 HARDROC (4HR1)

- **Sep + Nov 2009**
  4 DIRAC
  1-4 HARDROC (24 HR2)



MICROMEGAS DHCAL beam test status

Test beams @ CERN PS & SPS

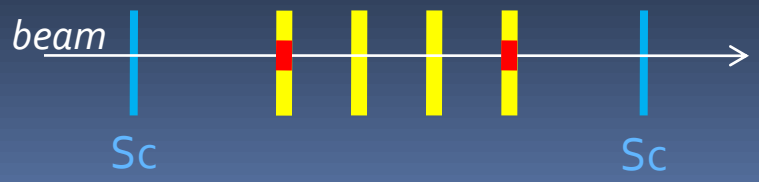
- **Aug + Nov 2008**
  4 GASSIPLEX chambers
  1 DIRAC

- **May-June 2009**
  4 GASSIPLEX + absorbers
  4 HARDROC (4HR1)

- **Sep + Nov 2009**
  4 DIRAC
  1-4 HARDROC (24 HR2)

- In a few days
  - 400.10^3 Pions & Muons @ 200 GeV
  - 250.10^3 Pions with Fe block
  - 200.10^3 Pions @ 7 GeV
- Complete characterisation
  - Efficiency, multiplicity, uniformity, MIP response

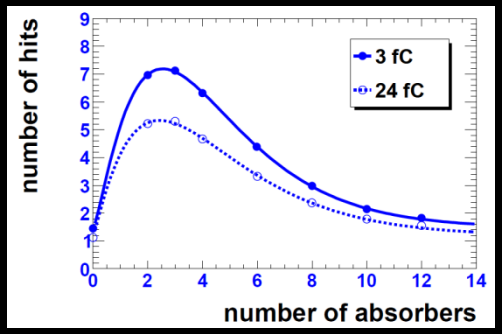
  Accepted for publication in JINST
- Simple test setup with 2 scintillators



MICROMEGAS DHCAL beam test status

Test beams @ CERN PS & SPS

- **Aug + Nov 2008**
  4 GASSIPLEX chambers
  1 DIRAC

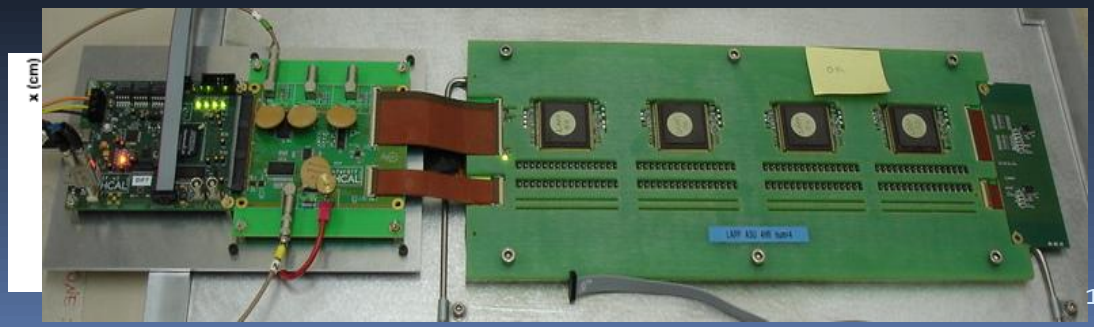


- **May-June 2009**
  4 GASSIPLEX + absorbers
  4 HARDROC (4HR1)

→

- Electron & hadron showers
  - Momentum up to 6 GeV/c
  - Hit & energy profile
  - Chamber behaviour in showers
- Efficiency and multiplicity of HR1

- **Sep + Nov 2009**
  4 DIRAC
  1-4 HARDROC (24 HR2)



MICROMEGAS DHCAL beam test status

Test beams @ CERN PS & SPS

- **Aug + Nov 2008**
  4 GASSIPLEX chambers
  1 DIRAC

- **May-June 2009**
  4 GASSIPLEX + absorbers
  4 HARDROC (4HR1)

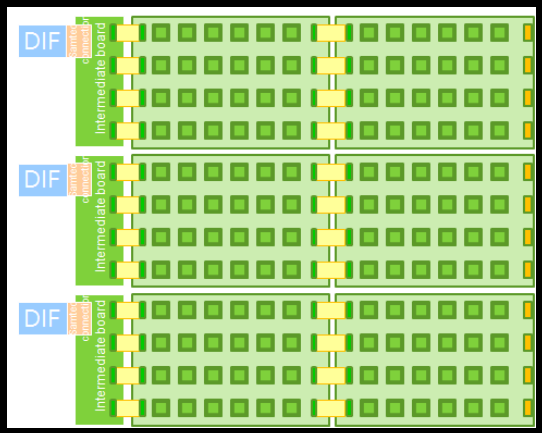
- **Sep + Nov 2009**
  4 DIRAC
  1-4 HARDROC (24 HR2)

- Choice between HR & DIRAC to be made soon
  - Compare efficiency/multiplicity

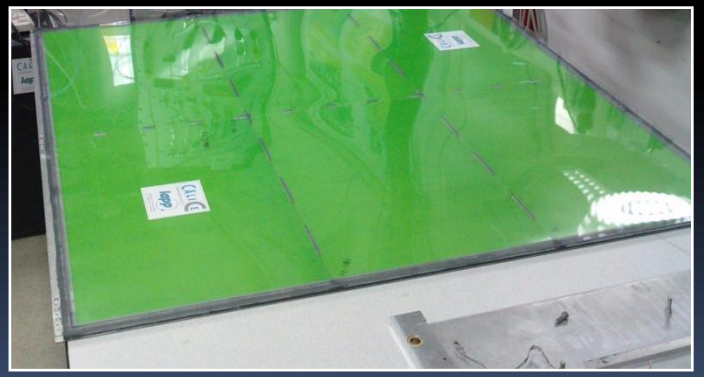
- Already have 4 ASU 24 HR2
  - Test individual ASU in beam or with 55Fe
  - Assembly of 1 m²

Next test beam plans

- Beginning 2010
  - Assembly of 4 ASU 24 HR2 inside 1 m2 (mechanical proto. already validated)
  - Test beam as soon as beam available
    - Rotating supporting structure tilted tracks
    - Precise tracking (σ~1 mm) would be interesting to check response close to dead areas



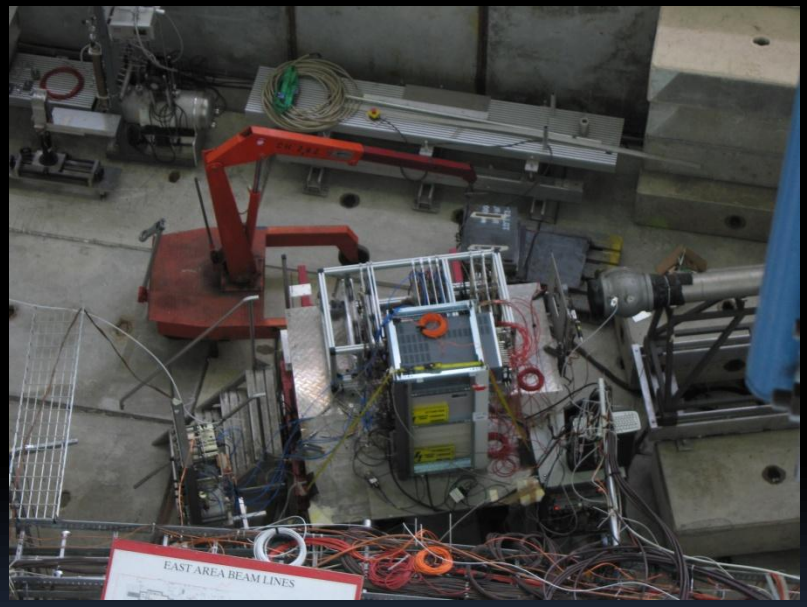
- Production in 2010
  - Q2: electronics & mechanics
  - Q3: Assembly
  - Q4: A few planes (Production profile should fit financial profile)

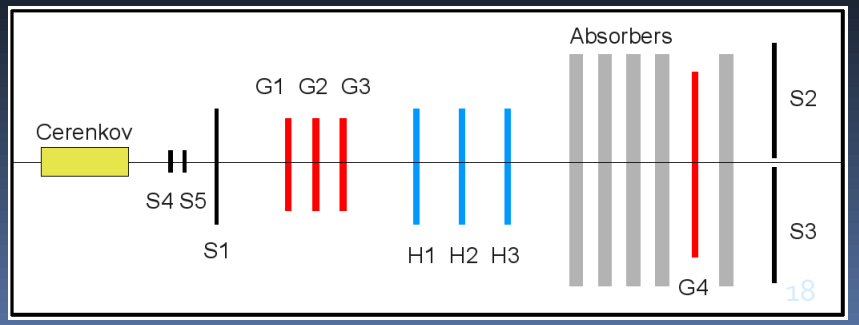


- Future beam test with absorbers 2011-201…
  - Within EU DHCAL 1m^3 SS structure
  - Within W structure (see last slide)

Our experience working at CERN

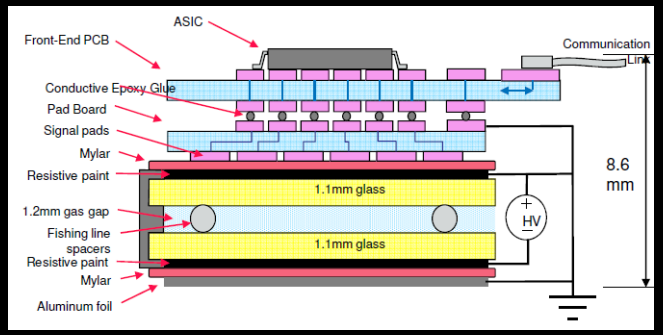
- Goods:
  - LAPP (Annecy) proximity to CERN makes transport easy and fast
  - Fast installation
    20 tons crane, very efficient people
    Using isobutane manageable
  - Appreciated infrastructure
    Tutorial for tuning beam parameters
    Cerenkov & Scint. & MWPCs
    2x2m² XY table (1 ton weight)
    HARP magnet on PS/T9
  - Machine experts do their best to satisfy user needs (number of spill/cycle)
  - Parasitic runs
- Bads: machine unstability





RPC DHCAL

- Sampling calorimeter
  - 2 cm thick steel plates
  - 1.2 mm gas (Fr:iso:SF6), 1 cm² pads
  - DCAL chip (single bit/pad)



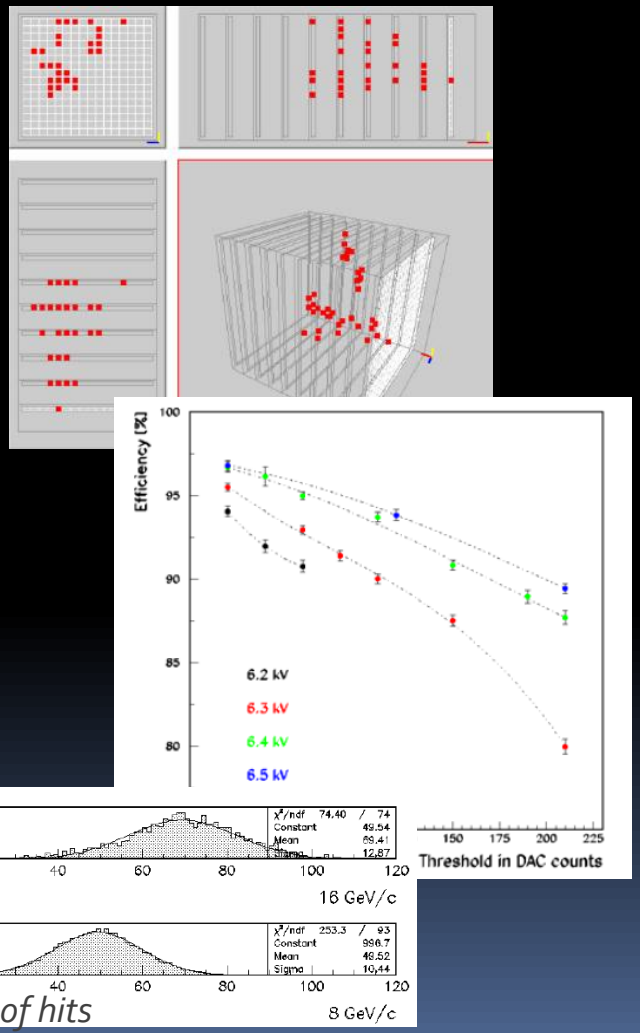
- Small scale HCAL
  - 10 RPCs of 20x20 cm²
  - ~ 2560 channels
  - 1.6 cm Fe + 0.4 m Cu plates
  - Extensive studies published in JINST

- Physics prototype of 1m³
  - 40 planes of 1m² with 3 RPC each
  - ~ 400 000 channels
  - Construction initiated fall 2008

RPC DHCAL beam test status

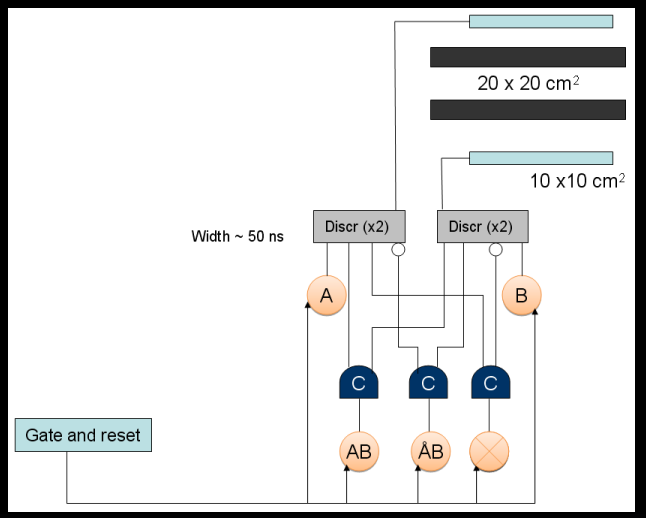
Beam test of small HCAL

- So-called Vertical Slice Test
- Performed @ Fermilab on MT6 line
  - Broadband muons
  - 120 GeV protons
  - 1-16 GeV secondaries (e+,π+)
- Completed measurements
  - Calibration with muons
    - Efficiency, multiplicity
  - Positron showers
  - Rate capability with protons
  - Hadron showers

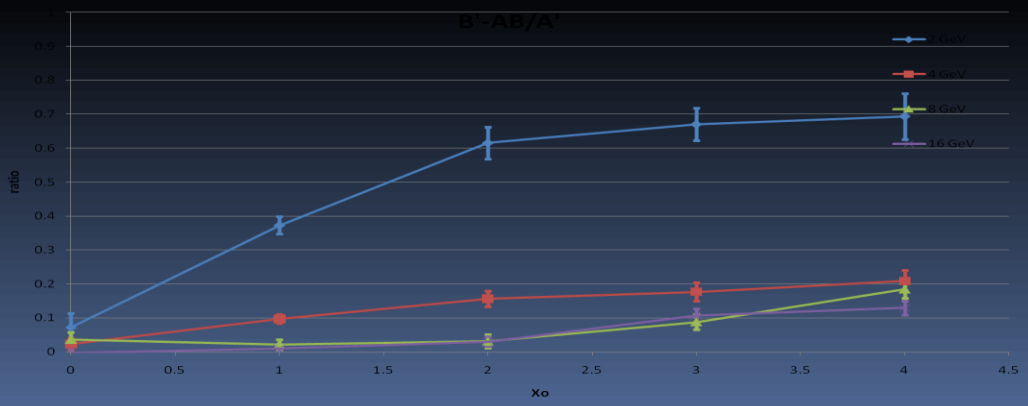


Experiences and challenges with Glass-RPCs

- With rates > 100 Hz/cm² drop of efficiency
  - MTBF successfully reduced rates < 100 Hz/cm²
  - Analysis of positron/pion date show evidence of rate problems, despite low beam intensity
  - → suspicion of sizable flux of (asynchrounous) photons in beam line



- Measurement with a pair of scintillators and absorber plates
  - → confirmation of suspicion at least for the 2 and 4 GeV setting



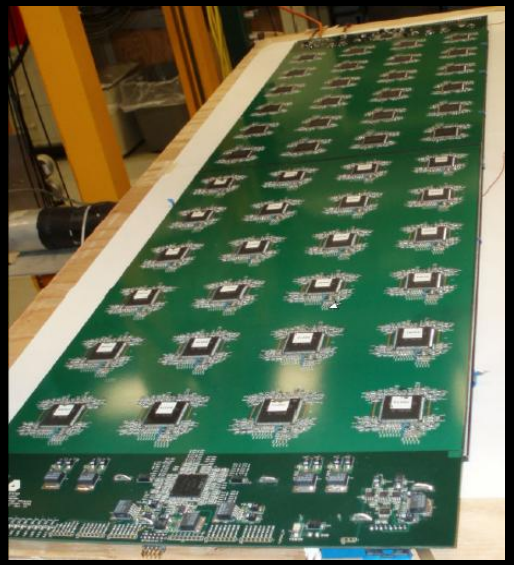
- Plan:

  will return to MTBF on

  Nov 24 and 25 and remeasure

Physics proto. test plans

- Currently constructing the 1m^3 prototype
  - Expect to finish by Spring 2010
  - Re-use CALICE AHCal absorber structure



- Purpose
  - Validate DHCAL concept
  - Gain experience running large RPC system
  - Measure hadronic showers in great detail
    Validate hadronic shower models

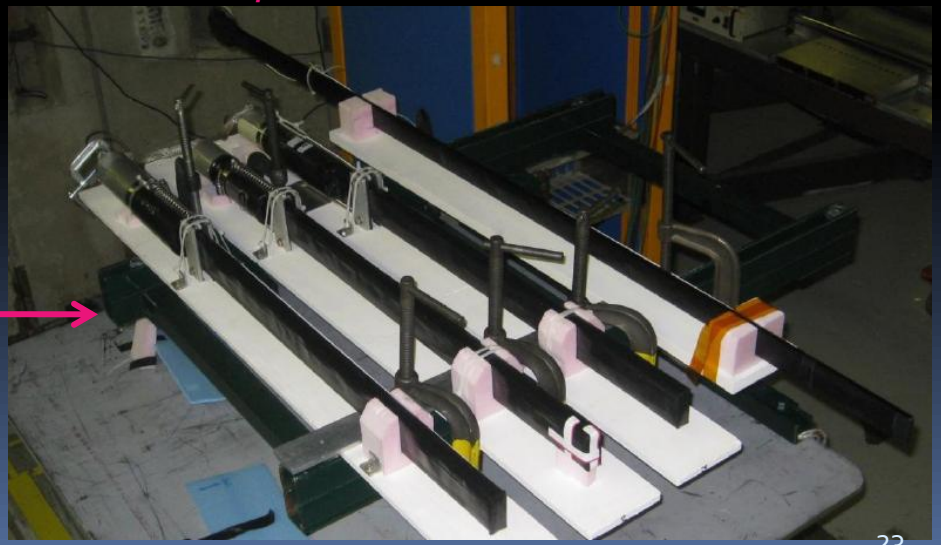
- Beam test plans
  - Feb 2010: layer test planned
  - Spring 2010: stand alone with TCMT
  - Followed by combined test with CALICE ECAL+TCMT
  - Test with muon, electron, pion and proton

Tail Catcher Muon Tracker status

- Mechanical structure
  - "Fine" section: 8 layers of 2 cm SS
  - "Coarse" section: 8 layers of 10 cm SS

- 16 cassettes
  - Extruded Sc. Strips
  - WLS fibers + SiPMs
  - CALICE DAQ

2008 TB setup at MT6

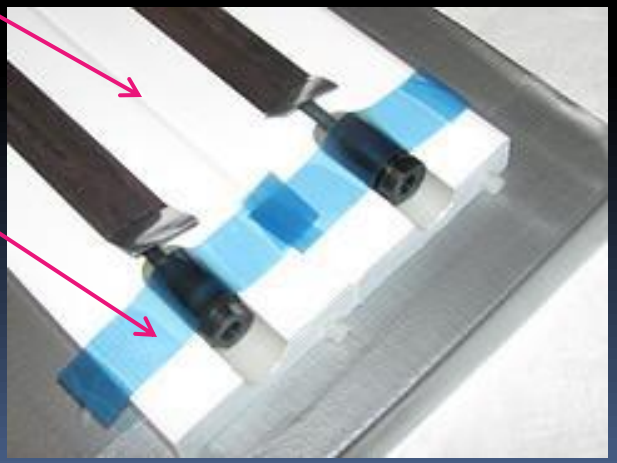


- Test beam
  - Part of CALICE AHCAL TB setup
  - Quick run with a few strips
    efficiency
    attenuation along strips

TCMT future TB plans

- Performed measurements with
  - More channels
  - Much longer strips (284 inches)
  - Double ended readout

- Investigations
  - Losses in the crack between adjacent strips
  - Losses in scint. behind SiPM

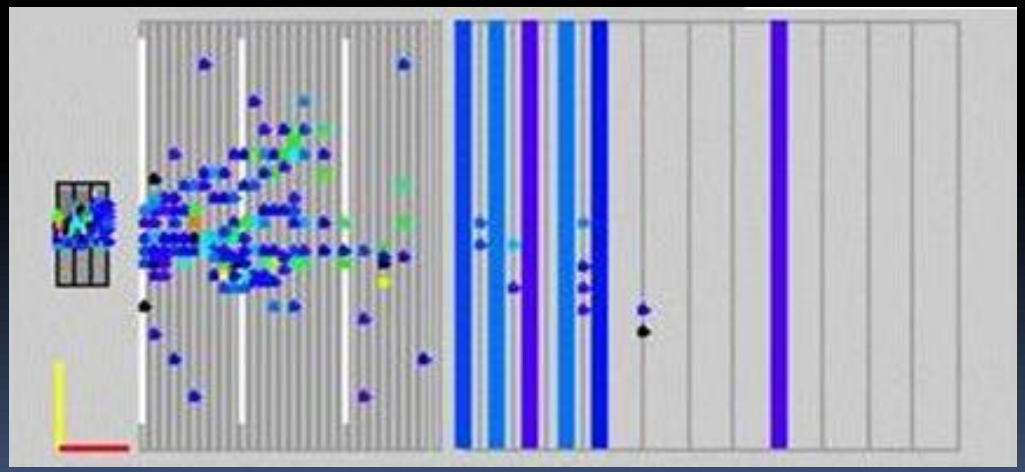


Use of a tracking system

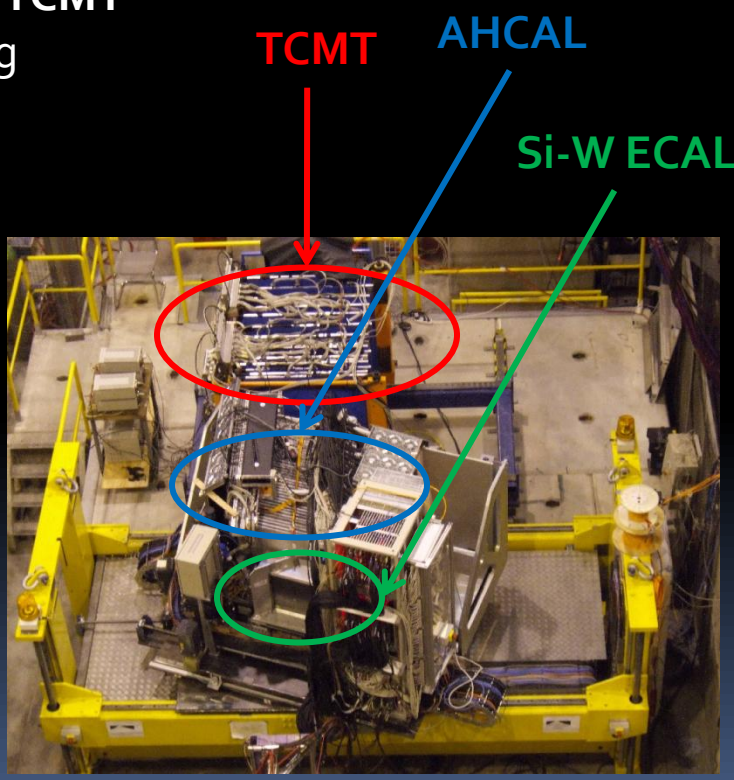
- Heterogeneous system
  Increased number of channels
- Very good position resolution without hurting rate
  Very good two track rejection
  Powerful tool that can be used in future studies
  - e.g. testing of dual readout crystals

Scintillator Analog HCAL

- R&D well advanced: 1m³ physics prototype beam test done
  - Standalone test and **combined test with CALICE ECAL(s) & TCMT**
  - A lof of data collected, analysis on-going
  - First comparison with MC simulation

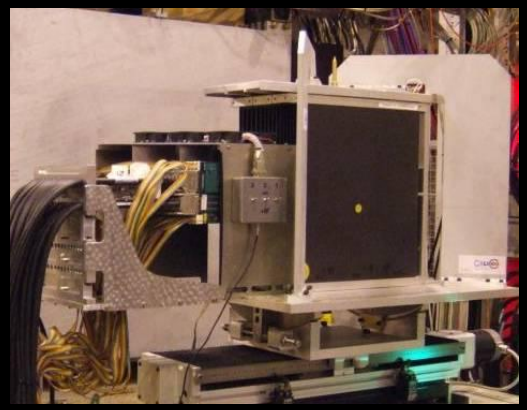


Online event display of 10GeV pion n Si-W ECAL+ AHCAL+TCMT



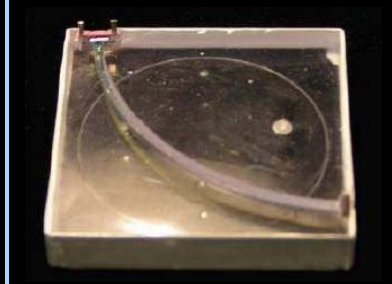
Test beam prototypes

Si-W ECAL



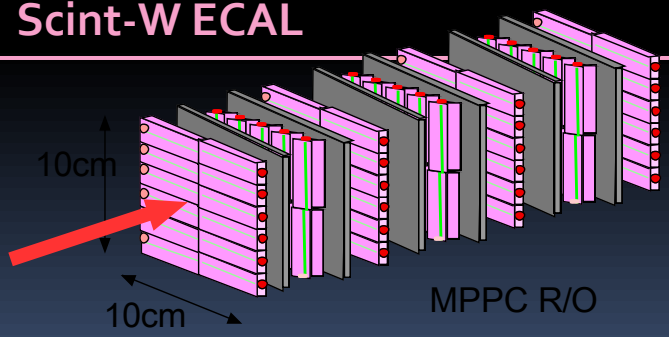
1x1cm² lateral segmentation
1 X_0 longitudinal segmentation
~10000 channels

Sc. tiles – SS HCAL



3x3 cm² with SiPM, 38 layers, 4.5 λ, 8000 channels

Scint-W ECAL



1x4.5cm² lateral segmentation
1 X_0 longitudinal segmentation
~ 600 channels

Scint. Strips-Fe TCMT

16 layers, 5x100cm² strips, ~5 λ
300 channels, SiPM readout

CALICE test beam campaigns

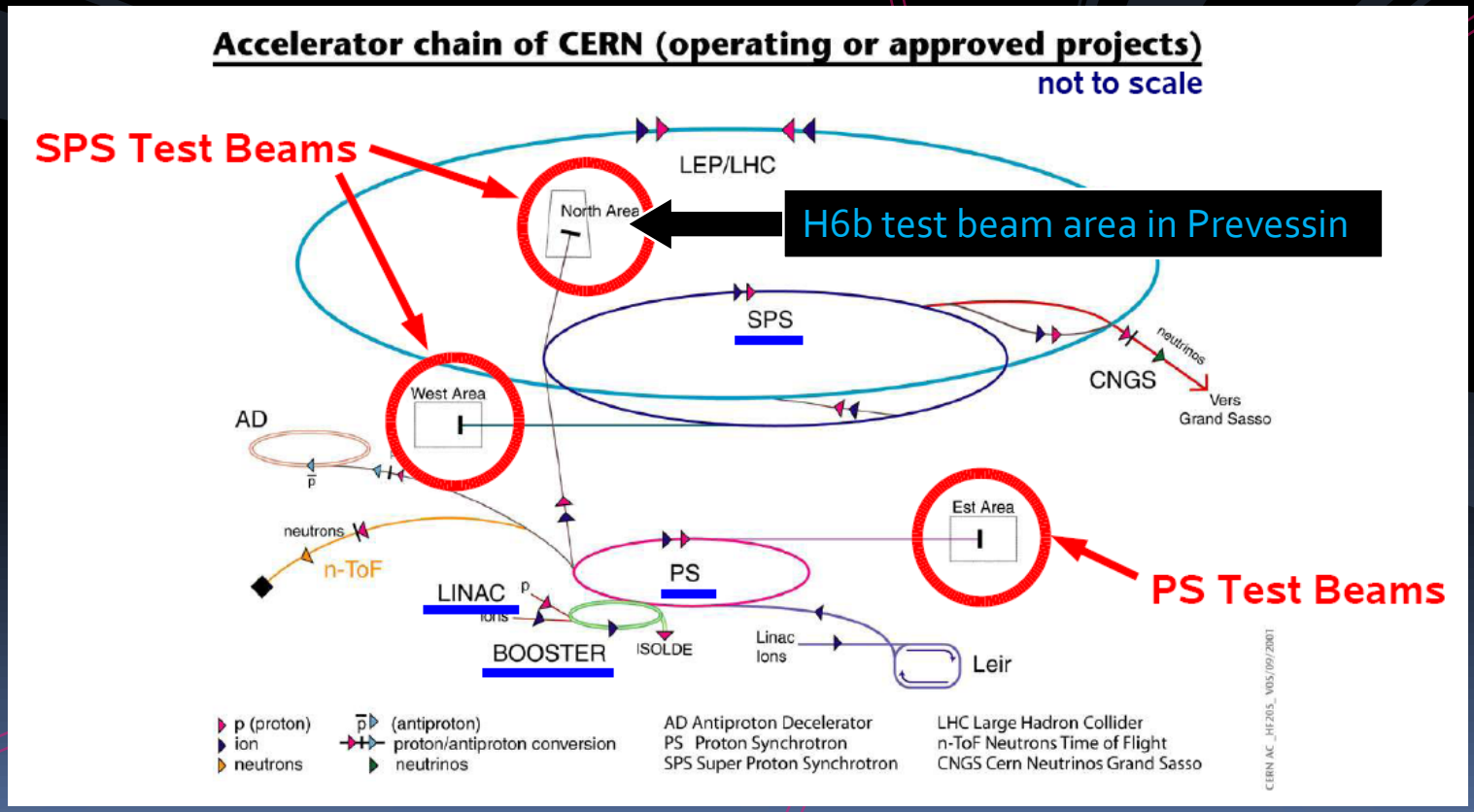
- Major test campaigns @ CERN 2006-07 & FNAL 2008-09 with 2 major detector configurations:
  - Si-W ECAL+ AHCAL + TCMT
    - Aug. & Oct 2006 @ CERN
    - Jul. & Oct. 2007 @ CERN
    - May & July 2008 @ FNAL
  - Scint-W ECAL + AHCAL + TCMT
    - Sep. 2008 & May 2009 @ FNAL

- Goal of the prototype calorimeters:
  - establish the technology
  - collect hadronic showers data with unprecedented granularity to:
    - tune reco. Algorithms
    - validate MC models

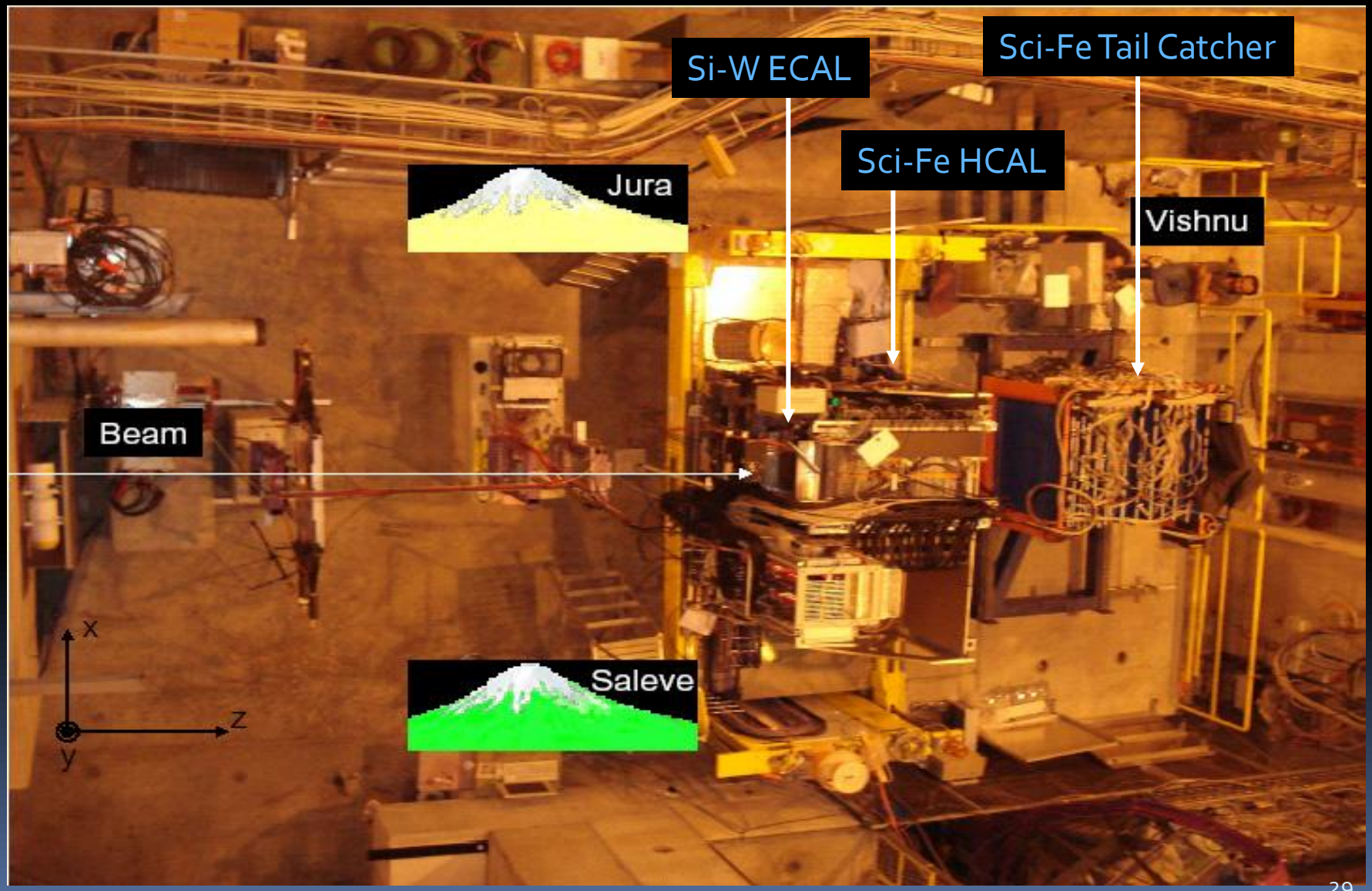
Year ‘06 CALICE moves to CERN

“…end of June ’06 the CALICE collaboration is packing up 3 calorimeter prototypes from DESY (D) and NIU (US). Destination: Geneva.

Expected duration of the mission: 4 months. ”

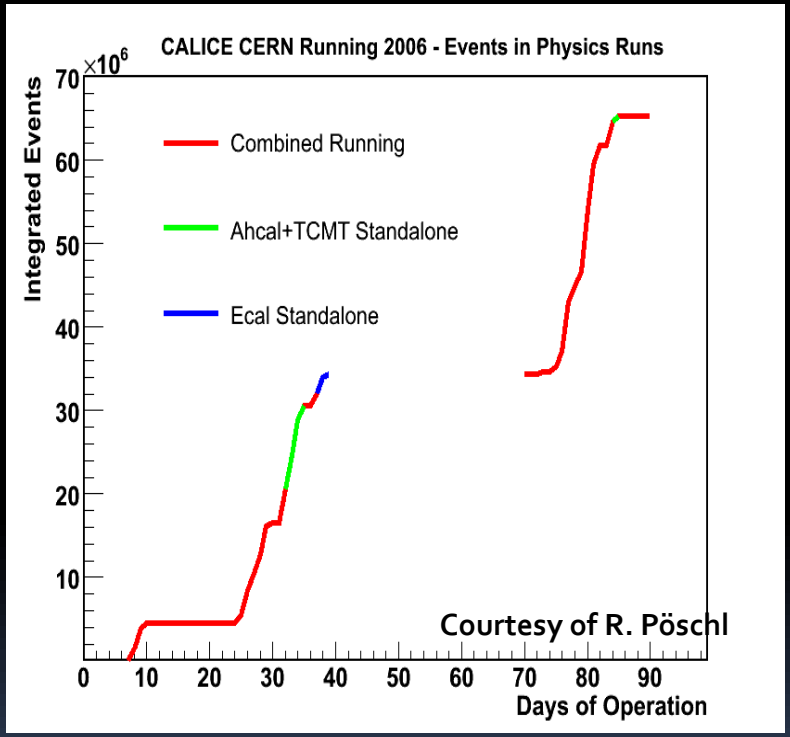


after 2 weeks of installation in H6B

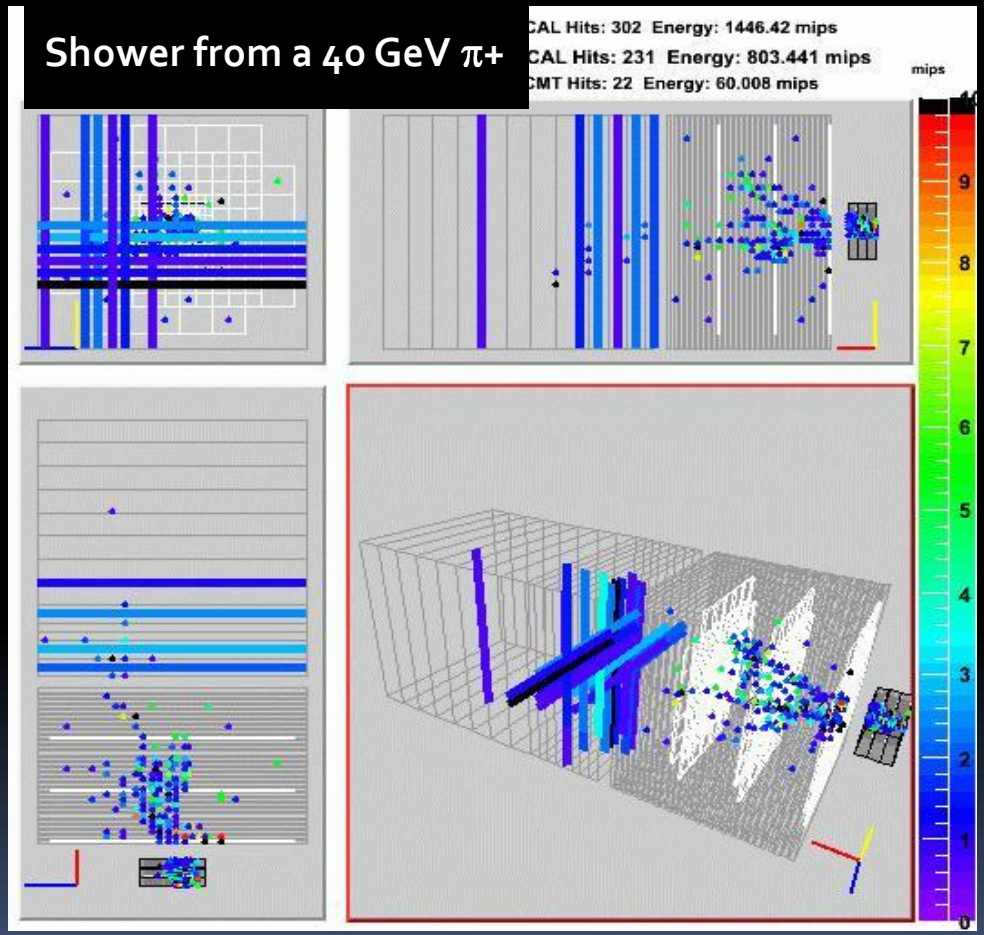


Impressive data rate at CERN

Limited by our DAQ + rate limit due to radiation limit for the detector



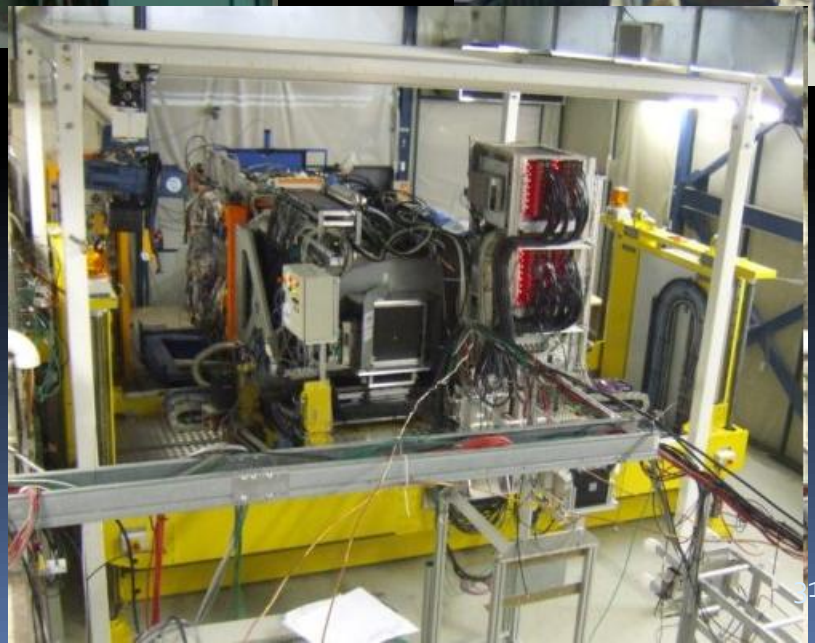
The physics is there ➔
Now starts the fun !!



Year ‘08 installation at FNAL

Flying the CALICE stage into the MTBF-M6 area

the CALICE installation with Si-W ECAL + AHCAL + TCMT

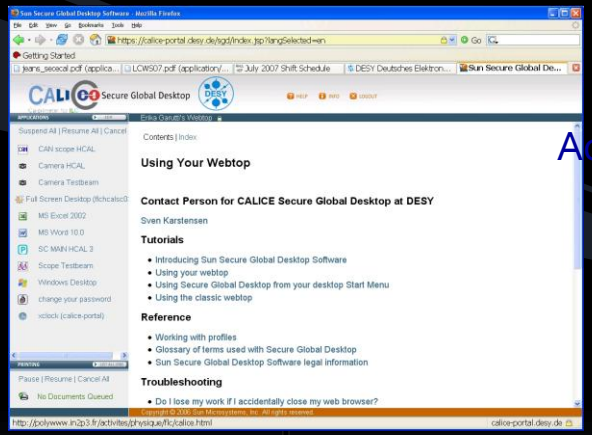


World-wide

Established use of sophisticated system

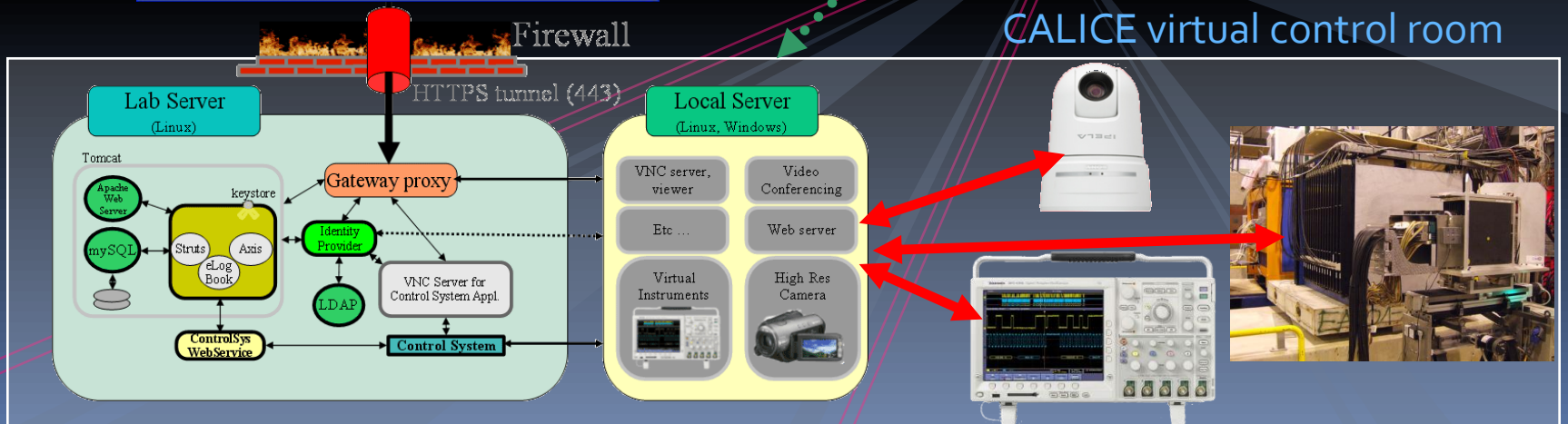
for remote control of detector & online monitor from around the globe

➔ Thank you FNAL for making it possible!



Access via web-port

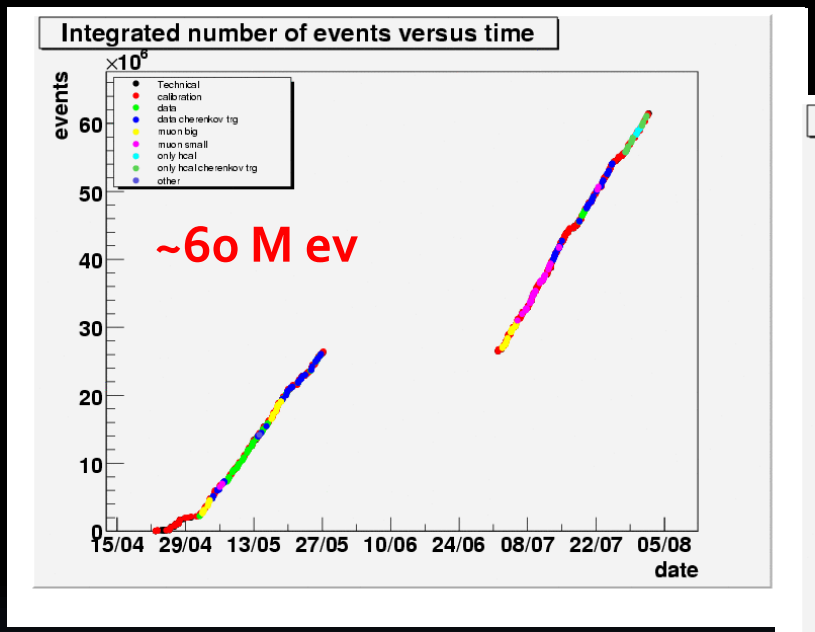
CALICE virtual control room



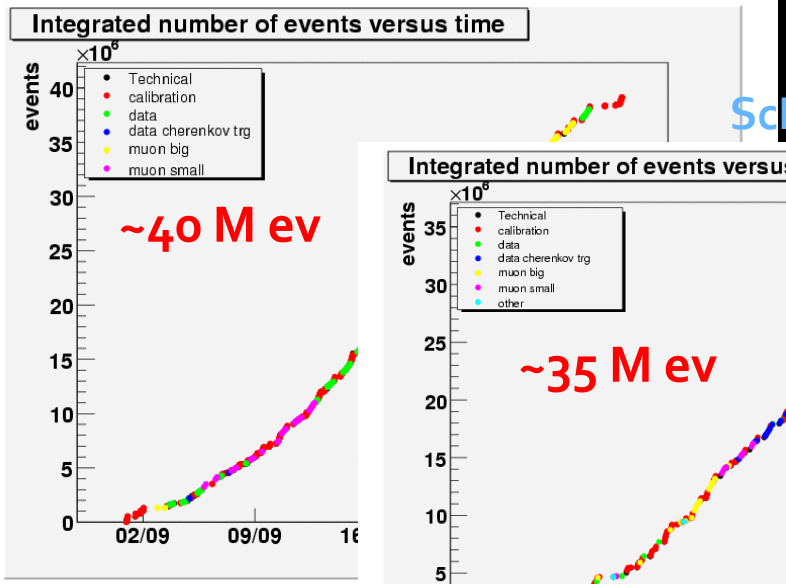
Data taking at FNAL

Limited by beam rate

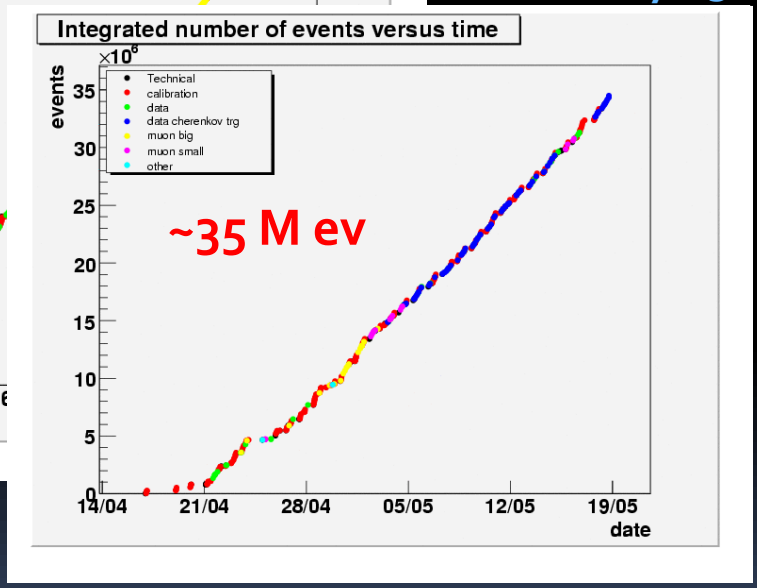
SiECAL – May+ July 08



ScECAL – Sept. 08



ScECAL – May 09



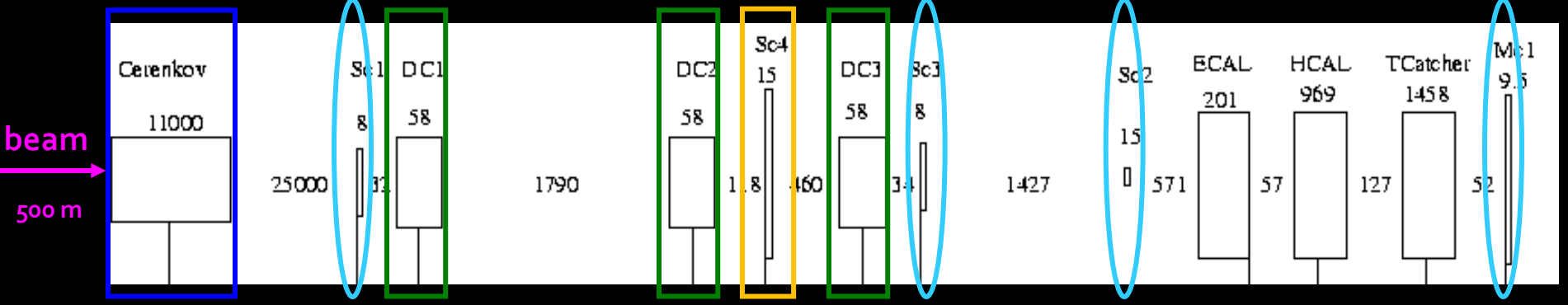
Smooth data taking after initial commissioning phase

~60 M events collected with Si-W ECAL + AHCAL (same as at CERN 07)

~75 M events with Sc-W ECAL + AHCAL (first time tested)

The setup in the beam

…much more than "just" 3 calorimeters



- Steps towards a clean data sample

1. Optimize beam ➔ tune magnets, collimators, secondary trg, abs
   ➔ Beam parameters stored in data stream difficult due to often broken communication
2. Separate e/π ➔ Cherenkov detector (for E_{beam} < 40 GeV)
   ➔ Ideally also separate protons and kaons (not possible on H6)
3. Identify beam impact point on ECAL ➔ 3 x/y pairs of MWPC with double readout
   ➔ CERN chambers used, prove to be not precise enough and very unstable, FNAL offered no tracking system
4. Tag multi-particle events ➔ amplitude r/o of 1cm thick scint. counter (veto)
5. Trigger physics with high efficiency ➔ trigger system
   ➔ Veto and trigger system self-provided could be improved or made permanent

Wish list

More reliable connection to beam parameters data base

Reliable, well documented beam instrumentation:

- High precision tracking system
- Dedicated high speed triggering system with veto walls
- Differential Cerenkov detectors for pi/p/K/e separation over large E range

More documentation on usage of beam instrumentation

- i.e. Cerenkov pressure curves vs energy

More info on muon energy spectrum/multiplicity (requires simulation of beamline)

High hadron rate at low energy:

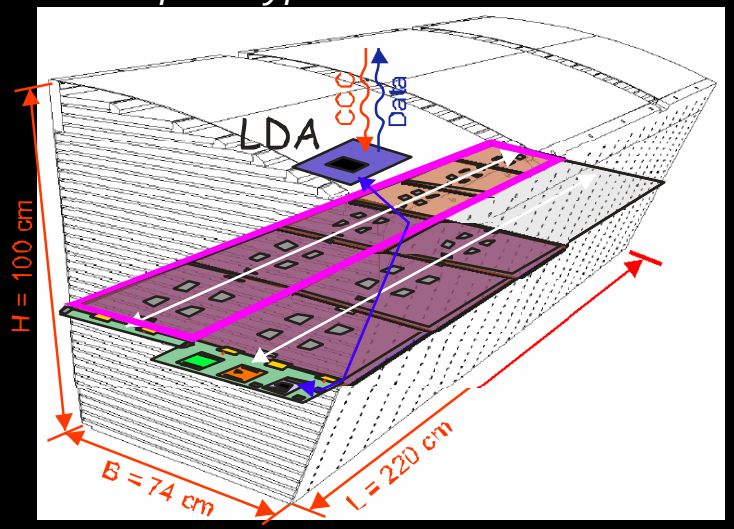
- > 5 Hz @ 1-6 GeV (FNAL achieved rates)
- G4 model of beam line and instrumentation
- High duty cycle
- Large bore magnet

AHCAL EUDET module

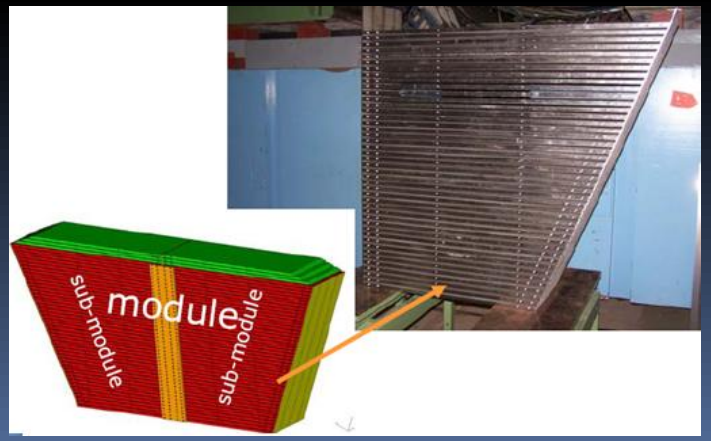
Future technical prototype

- Instrumented with HCAL Base Unit (HBU)
- ILD-like mechanics, realistic to test novel readout techniques

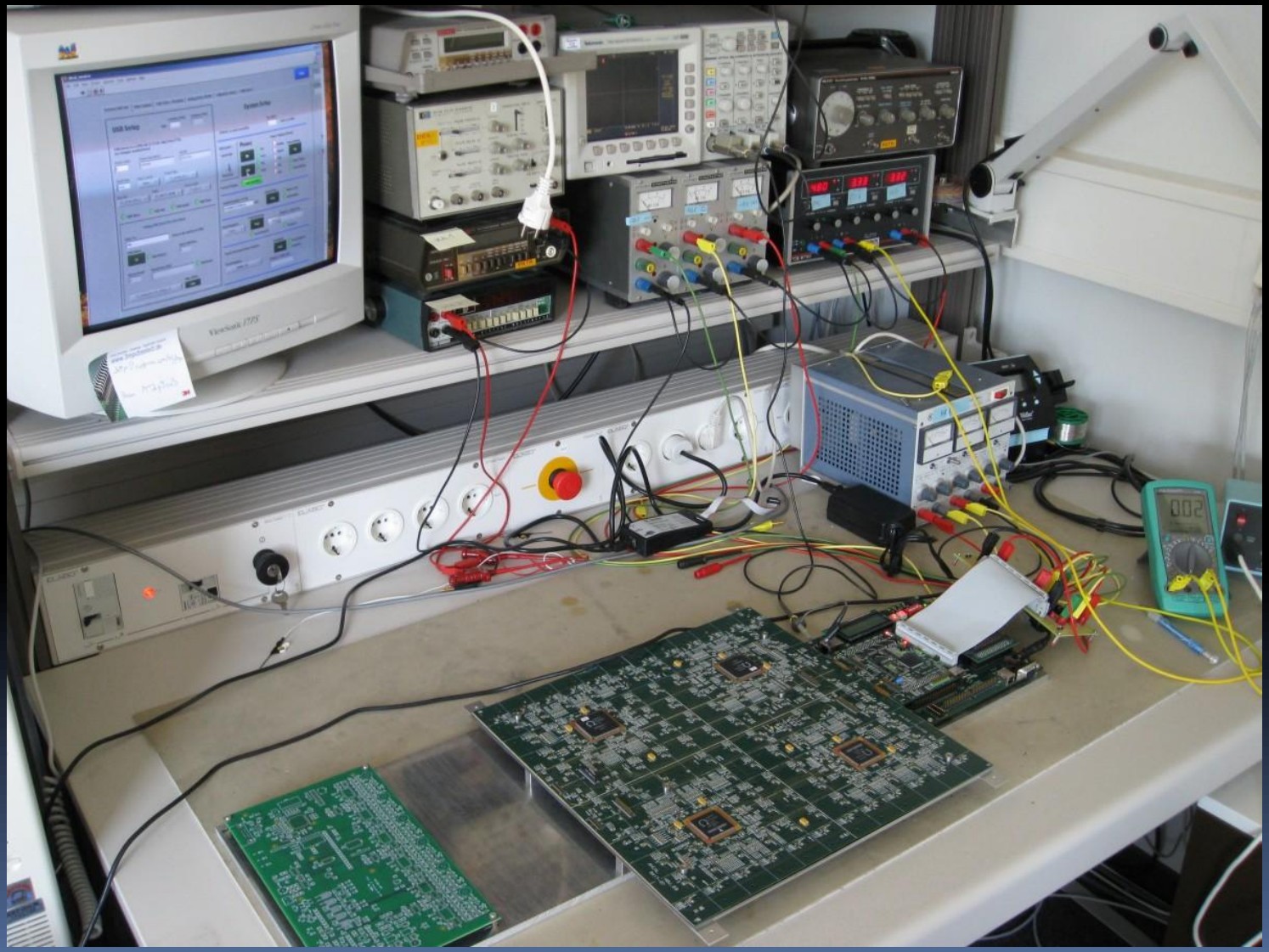
Future prototype architecture



- EUDET deliverables
  - HCAL mechanical structure
  - HCAL calibration system
  - HCAL readout integrated electronics



Prototype system commissioning

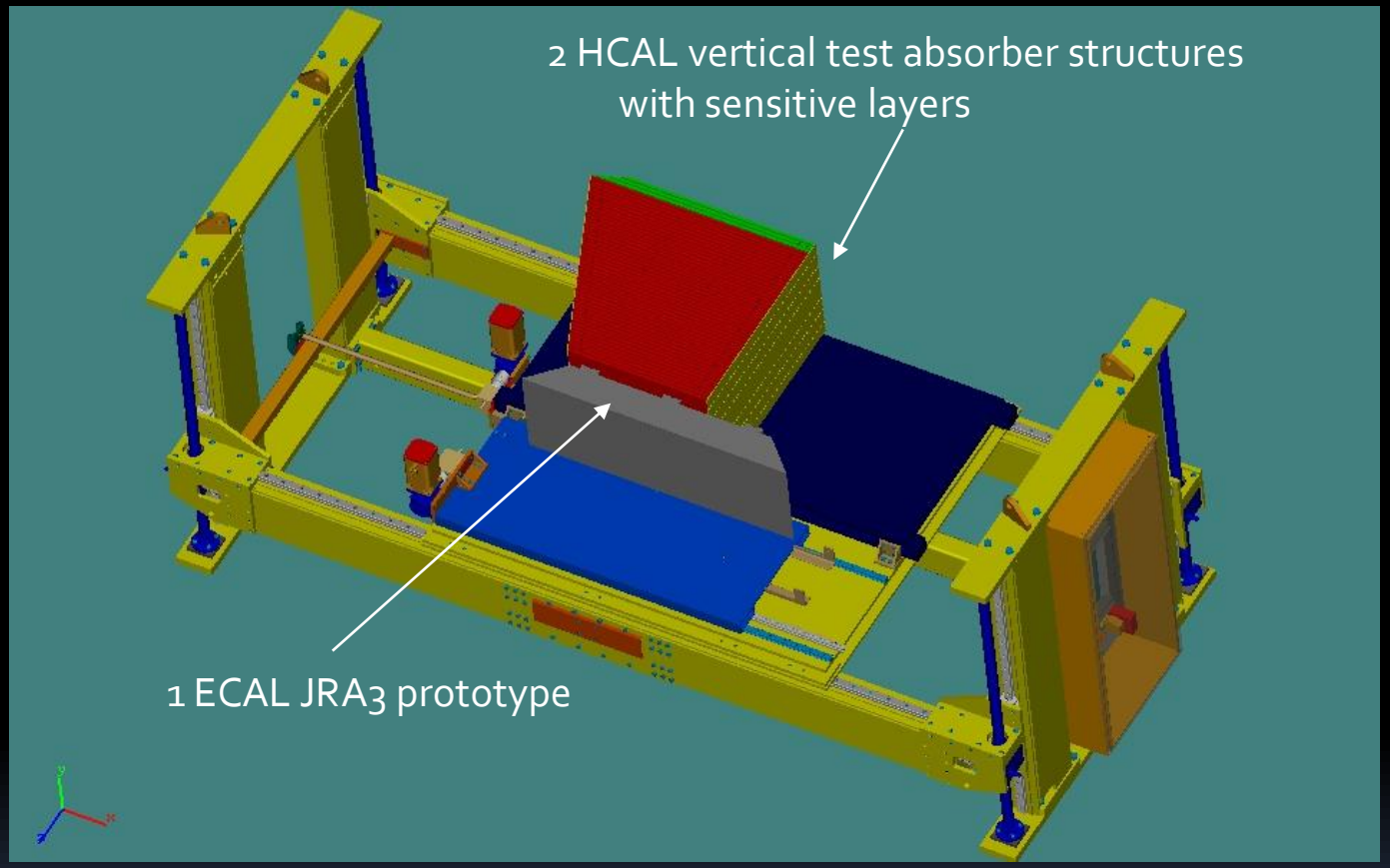


- Full system integration (electronics + mechanics) incorporating tiles and SiPMs from first user is ongoing

- First prototype is being assembled and tested.
  All components delivered:
  - CALIB and POWER modules: available
  - Calibration multi-channel prototype: both options available
  - Mechanical structure: available

- Outlook: AHCAL integration prototype to DESY test beam in 11/09

Future HCAL project



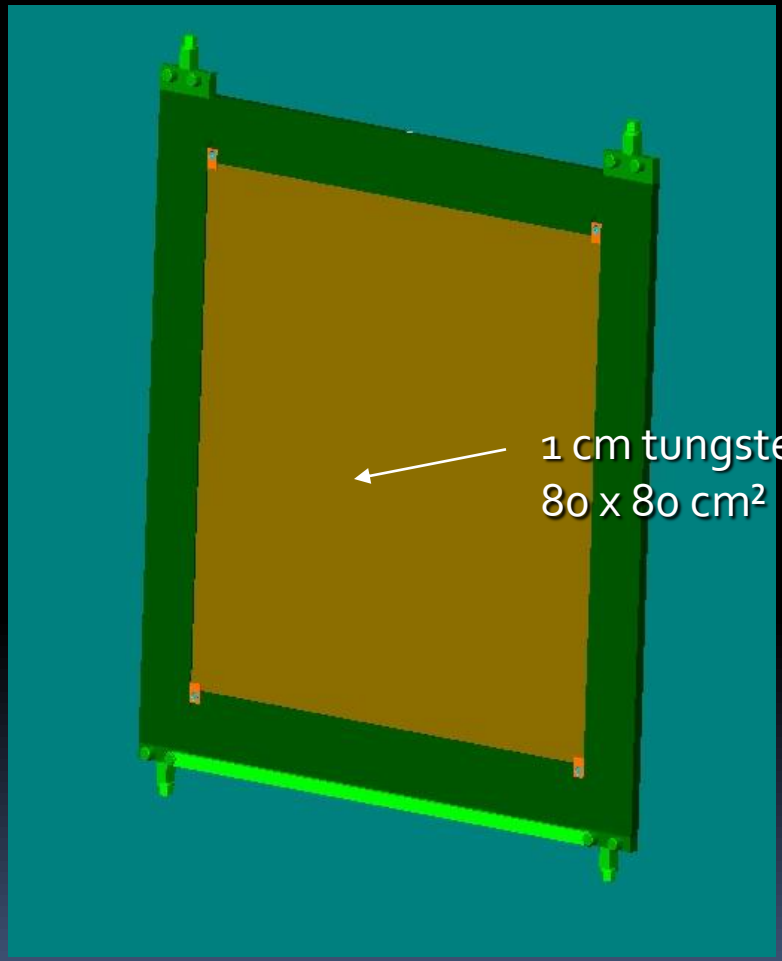
- Mechanical structure assembled together with ECAL for test beam experiment
- Test in magnetic filed also under discussion

Future prototype: 2012…

CERN, DESY, LAPP

- W-based calorimeter with scintillators or MICROMEGAS sensors for CLIC

- Keep detectors but change mechanical structure:
  - Use of 1 m2 detector planes
  - Structure with W 80x80 cm2 and Al frame



Conclusion

- Several HCAL prototypes developed
  - Several TBs in the past
    good progress on the different concepts
  - More TBs to come

- Individual needs for infrastructure are different
  - Should, however, merge in the future
  - Important to share experience and define common requests

Thanks for your attention

Special thanks to Vincent, Erika, Felix, Frank, Jae, Imad & Jose who provided me with some slides