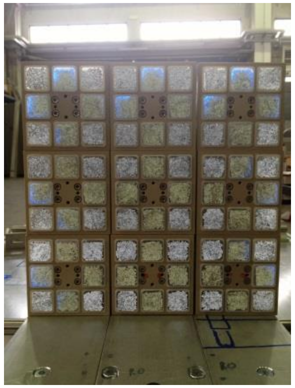
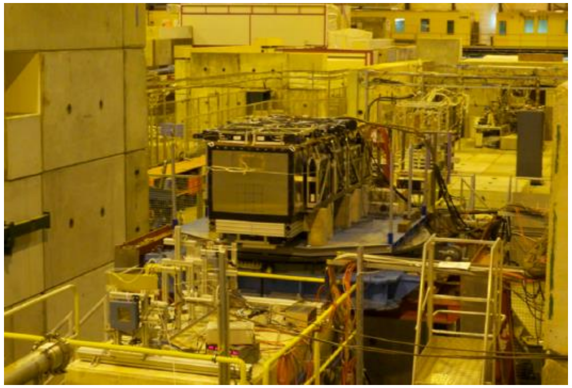
RD52 (DREAM) Status report

Dual-Readout Calorimetry
For High-Quality Energy Measurements





Silvia Franchino* (CERN)
CERN, LHCC meeting, 3/6/2015

**On behalf of the RD52 Collaboration:*
Cagliari, CERN, Cosenza, Lisbon, Pavia, Pisa, Roma,
Iowa State, TTU, Tufts University, Korea University, UCL

RD52 goal

RD52 is a generic detector R&D project,
not linked to any experiment

Goal:

- Investigate and eliminate factors that prevent us from measuring hadrons and jets with similar precision as electrons and photons
- Develop a calorimeter that is up to the challenges of future particle physics experiments

Dual-Readout Calorimetry

Dual REAdout Method (DREAM):

Simultaneous measurement, during shower development, of:

- Scintillation light (dE/dx charged particles)
- Cherenkov light (em part of the shower)

→ Measurement, event by event, of em fraction of hadron showers

→ Reduction of fluctuations in em fraction

Same advantages as for compensating calorimeters (e/h=1), without their limitations (sampling fraction, integration volume, time)

Result:

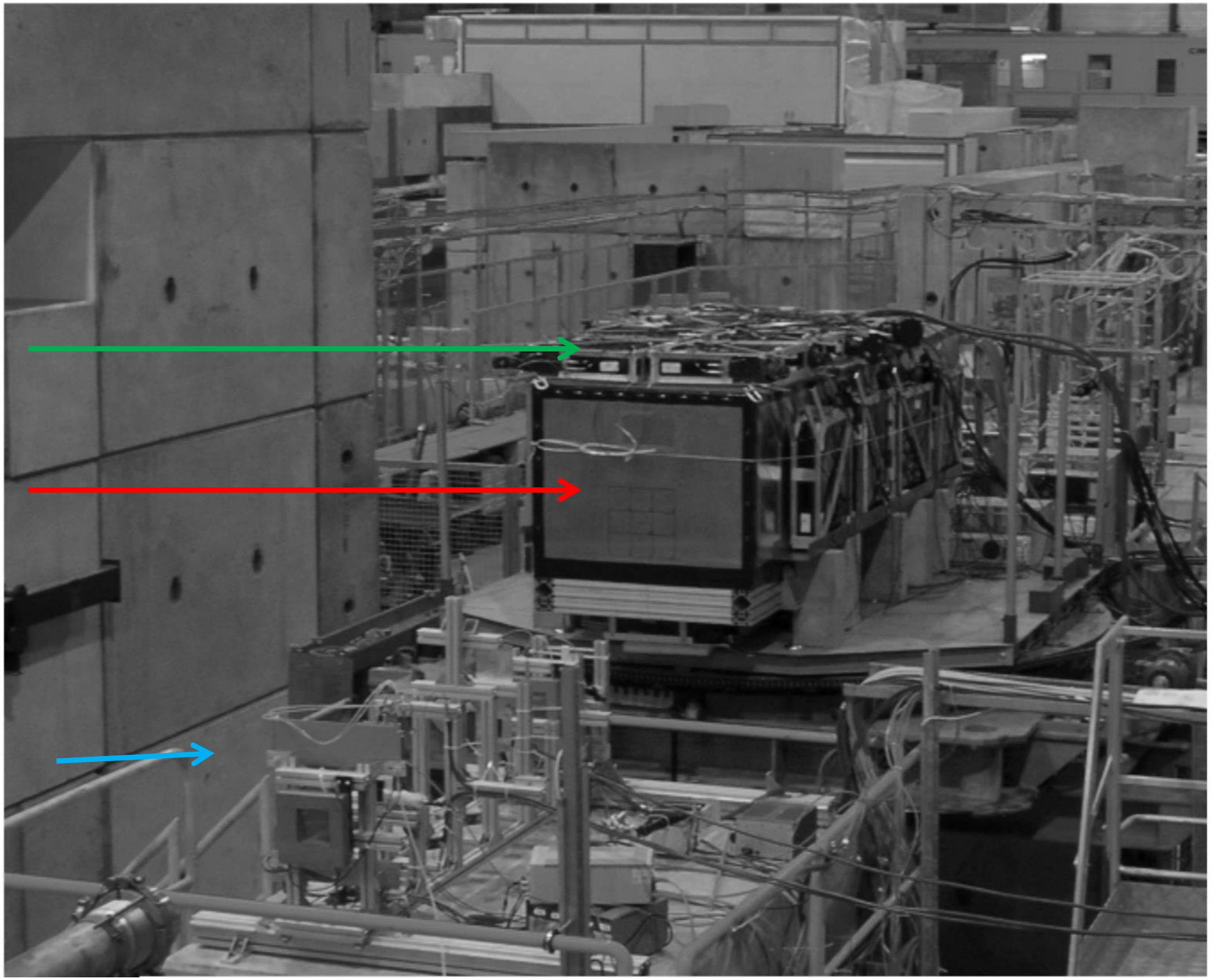
- Correct hadronic energy reconstruction (detector calibrated with electrons)
- Linearity
- Good energy resolution for hadrons and jets
- Gaussian response functions

H8 beam area

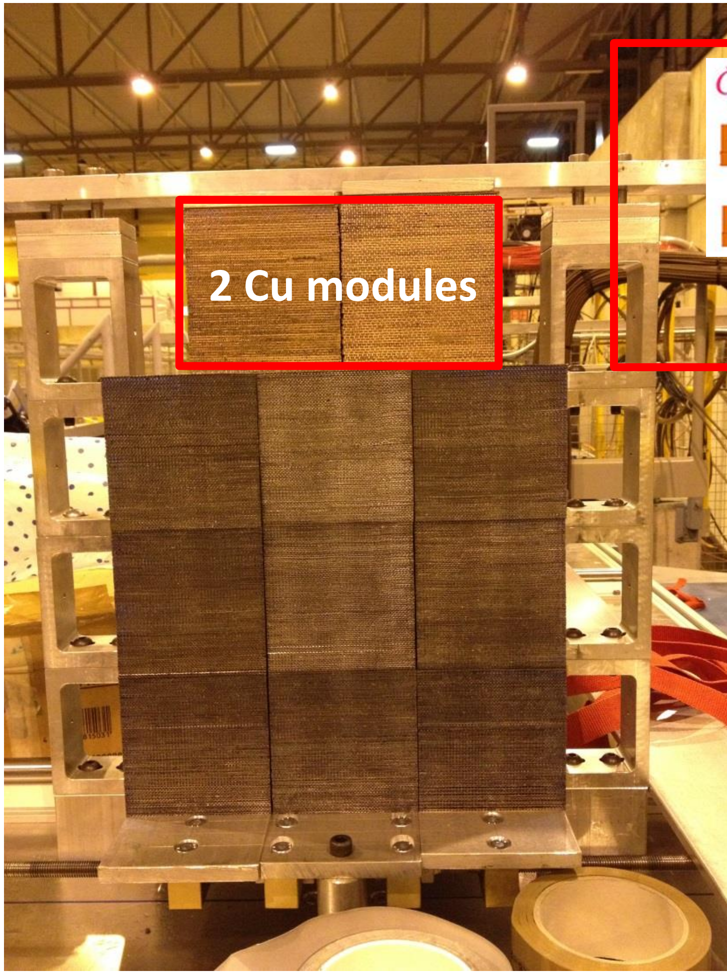
Scintillators to detect leaking showers

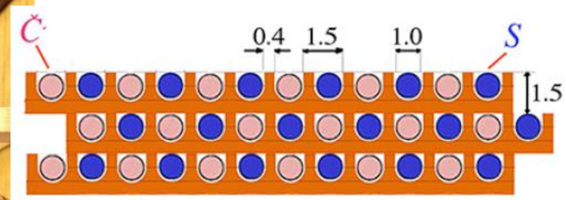
Calorimeter on XYΘ table

Trigger and beam – cleaning detectors



Our calorimeters in H8





Each module:

- 9.3 * 9.3 * 250 cm3 (10 λint)
- Fibers: 1024 S + 1024 C (S: scintillating, C: PMMA)
- 8 PMT

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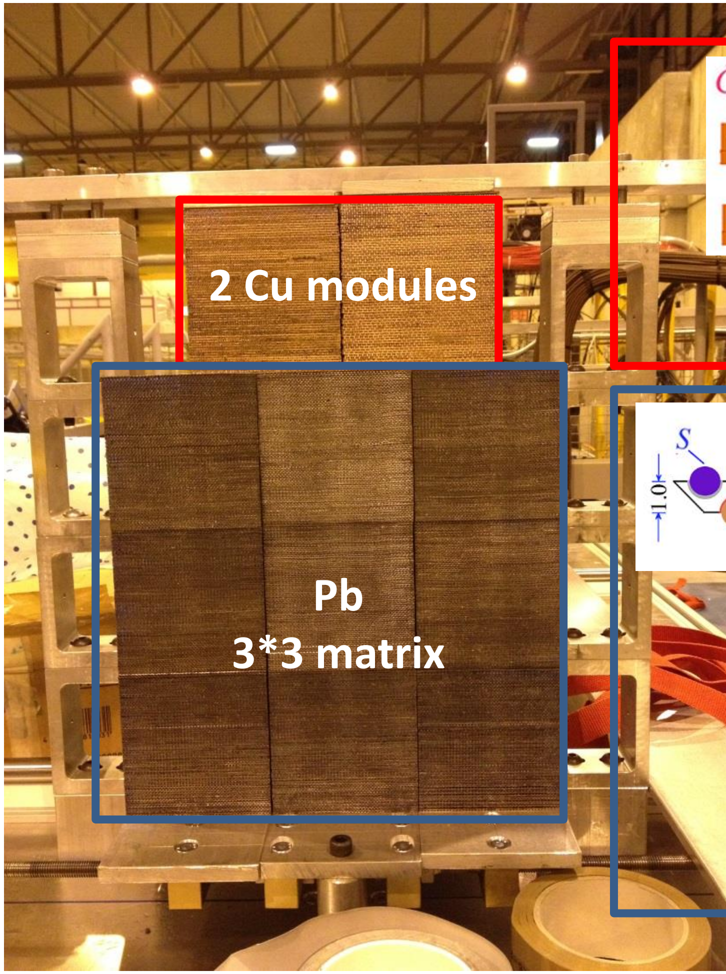

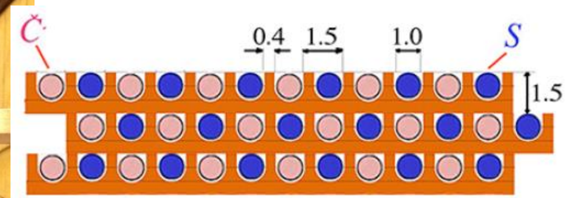

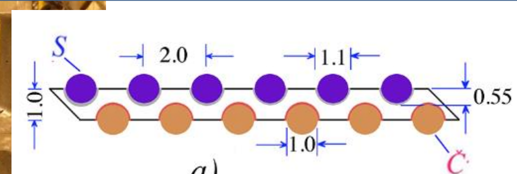

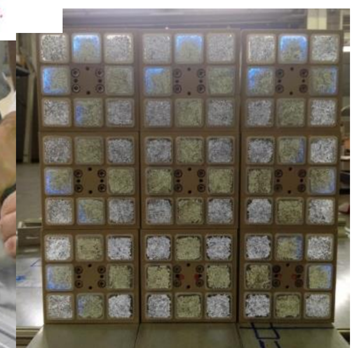

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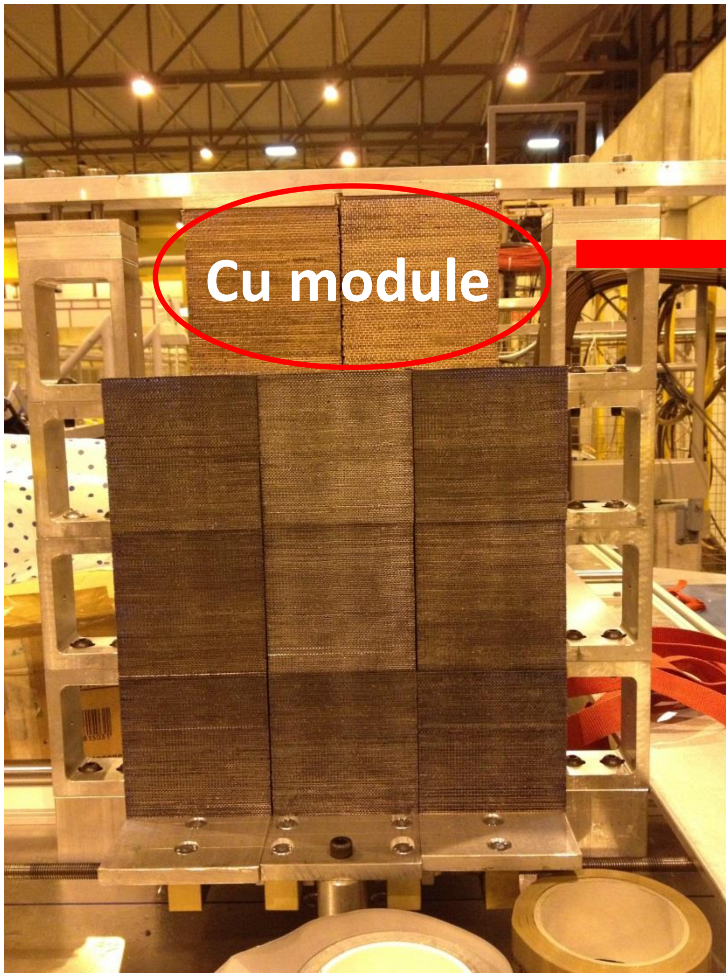
Latest results (1)

6 test beam days in December 2014



1) Small angle electromagnetic performance

Angular scan with 20 GeV e^+

(Thanks to I. Efthymiopoulos, M. Jeckel for rotating table with mrad precision)

The small-angle performance of a dual-readout fiber calorimeter

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L. La Rotonda[k], S. Lee[m], F. Li[j], M. Livan[f],
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TO BE SUBMITTED TO NIM

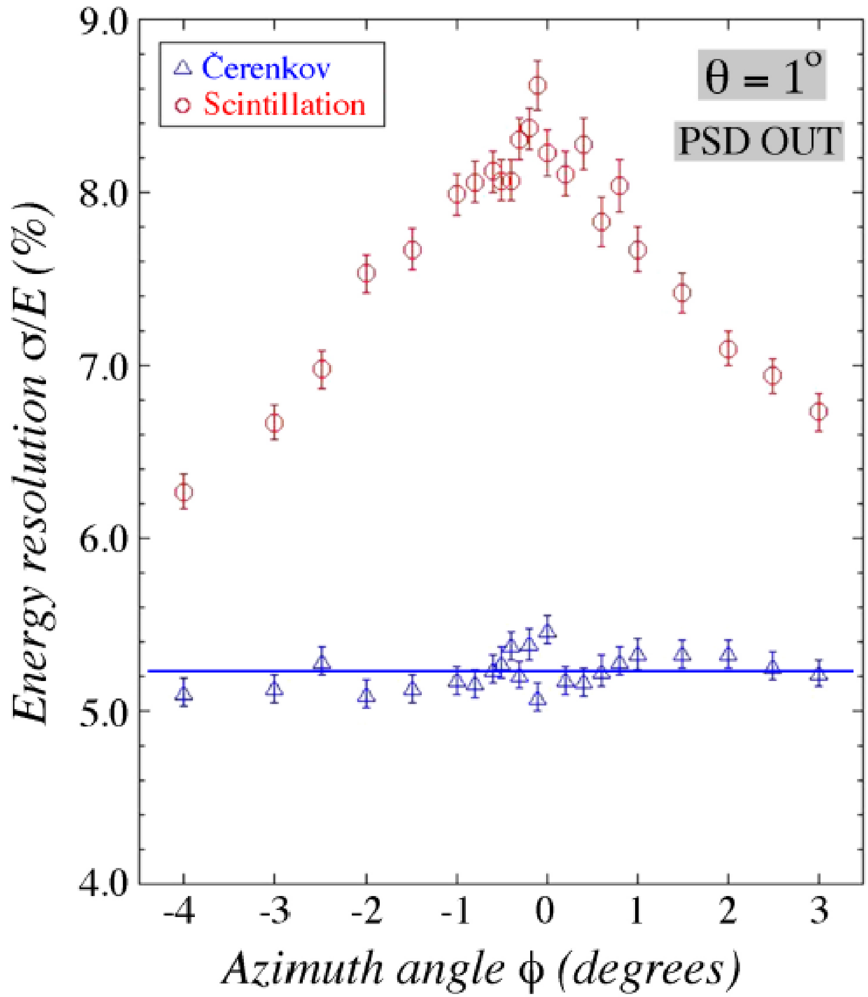
Abstract

The performance of the ... calorimeter is measured for very small angles of incidence between the 20 GeV electron beam particles and the direction of the fibers that form the active elements of this calorimeter. The calorimeter response is observed to be independent of the angle of incidence for both the scintillating and the Čerenkov fibers, whereas significant differences are found between the angular dependence of the energy resolution measured with these two types of fibers. The experimental results are on crucial points at variance with the predictions of GEANT4 Monte Carlo simulations.

PACS: 29.40.Ka, 29.40.Mc, 29.40.Vj

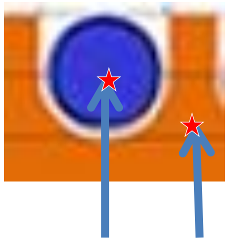
Key words: Dual-readout calorimetry, Čerenkov light, optical fibers

Small-angle em performance



Em showers very narrow at the beginning; Sampling fraction depends on the impact point (fiber or dead material)

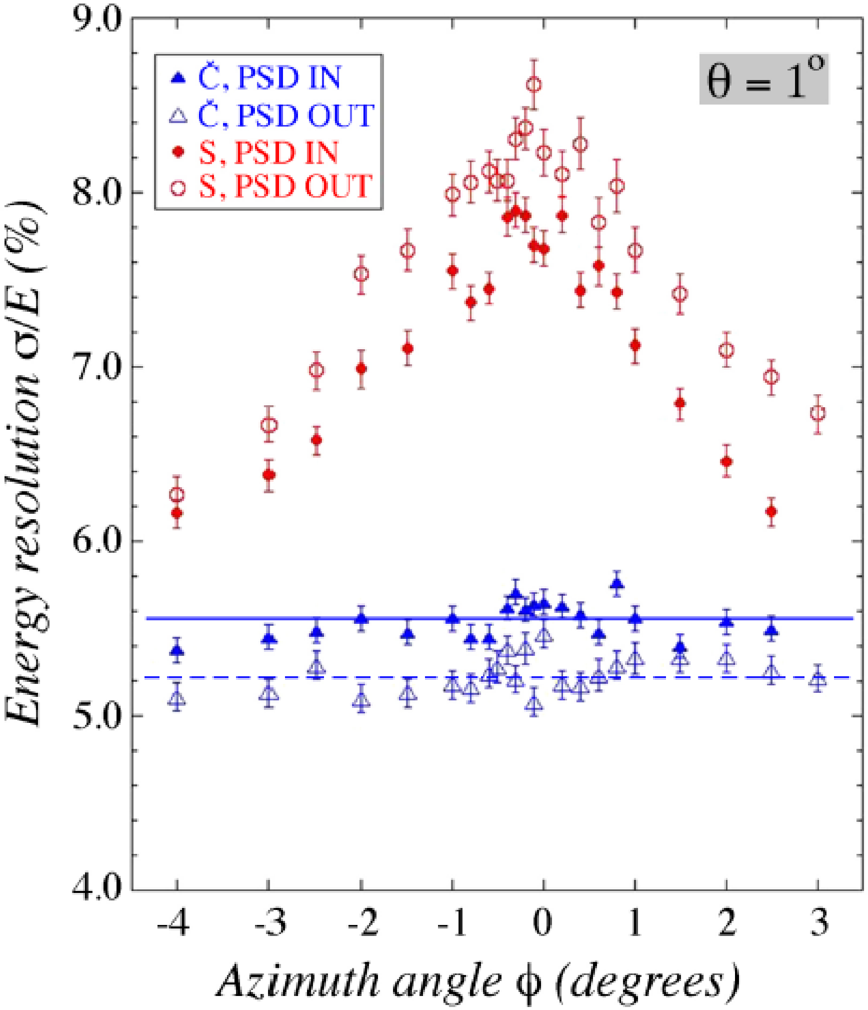
If particles enter at an angle the dependence disappears



Fluctuations on different impact point

Effect NOT seen in Cherenkov signals since early part of the shower do not contribute to the signal (outside numerical aperture C fibers)

Effect of upstream absorber (1X0)



Effect of absorber

S: Widens the shower and thus reduces impact point dependence on the response

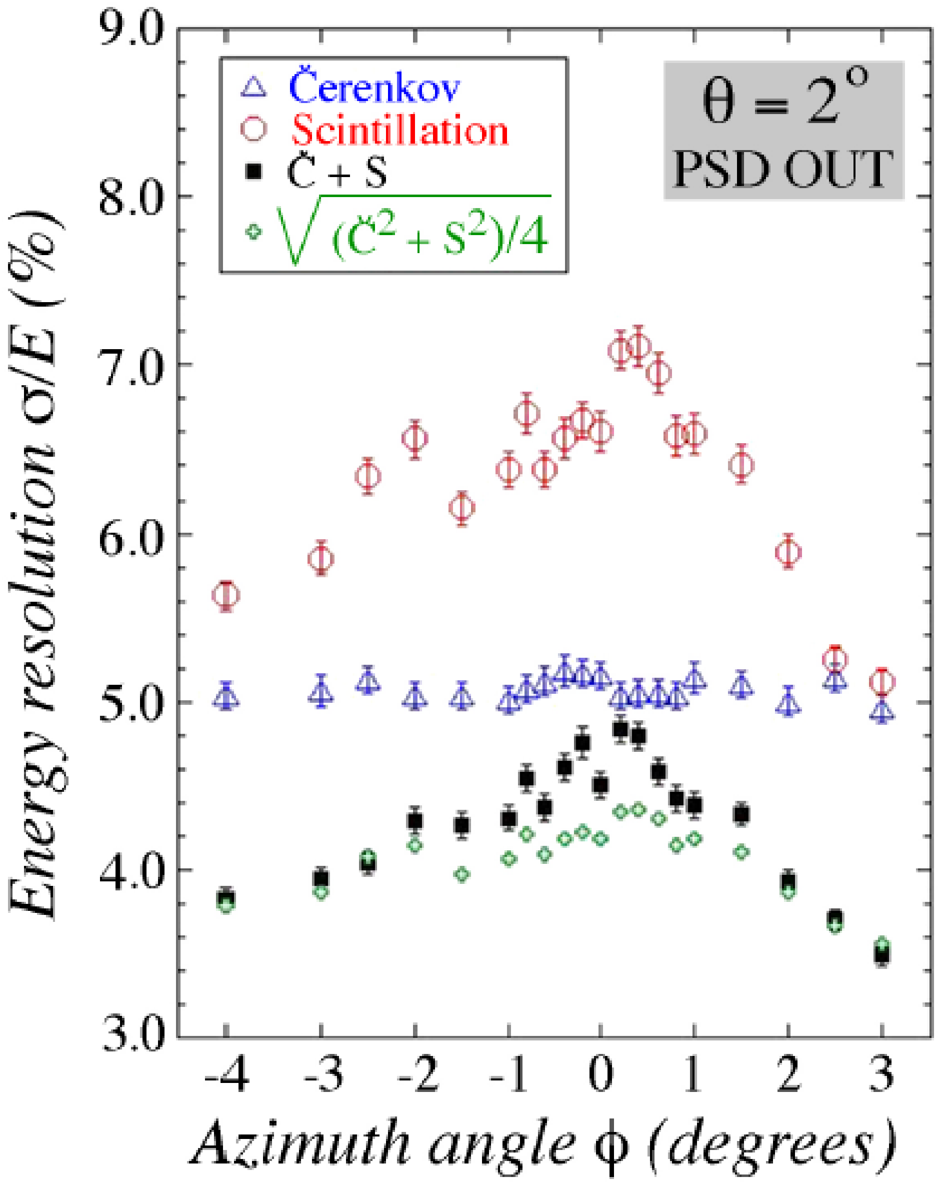
C: fluctuations in energy loss lead to a worse energy resolution

Small-angle em performance

S, C: sample INDEPENDENTLY
the em showers

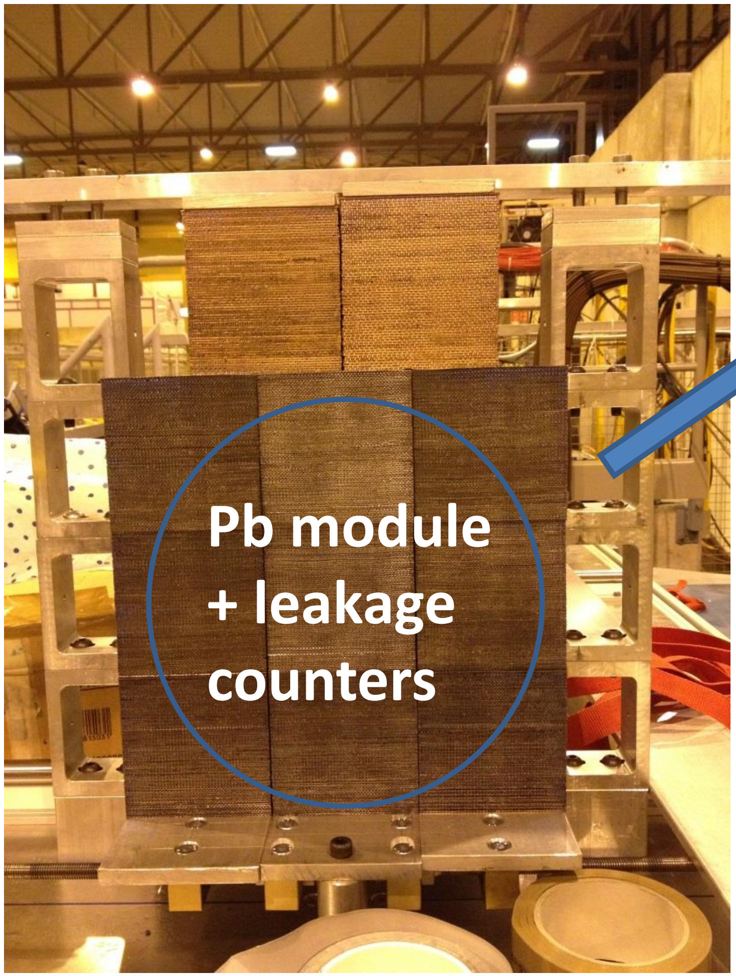
→ We can sum their contributions
→ em energy resolution improves by a factor √2

Good em energy resolution



Latest results (2)

6 test beam days in December 2014



2) Time structure measurements

- 40 GeV mixed beam: e, μ, π
- readout with DRS, 5Gs/s

Depth dependence effect:

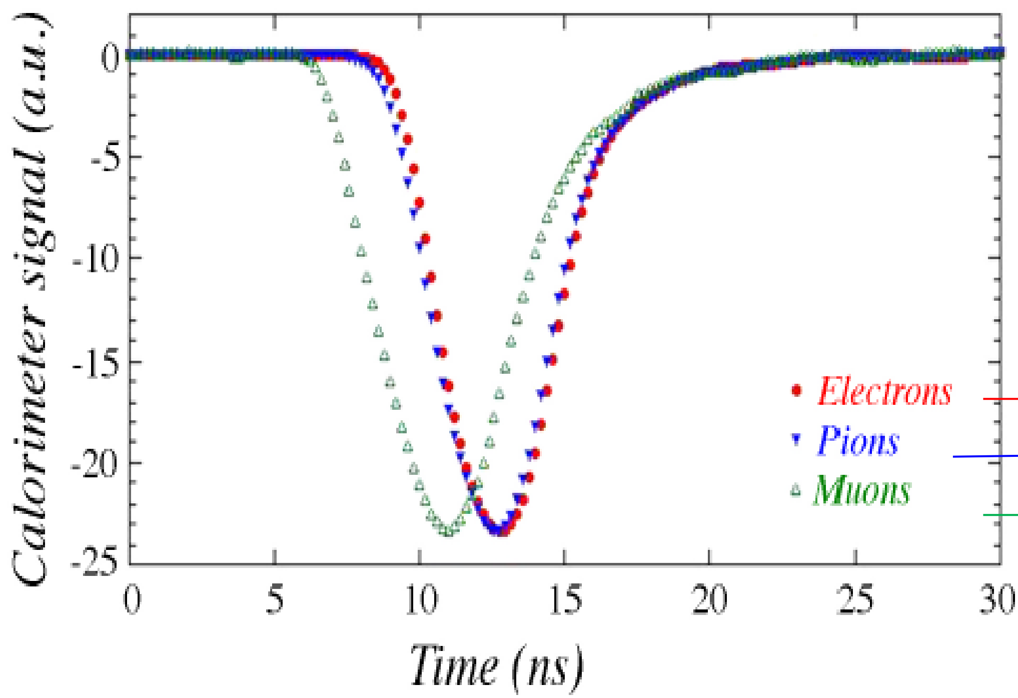
- Light travels at c/n (17 cm/ns) in the fibers;
- Particles that generate light travel at ~ c (30 cm/ns)
- Very slow neutron component

Still work in progress for analysing data..

Time structure (1)

Preliminary

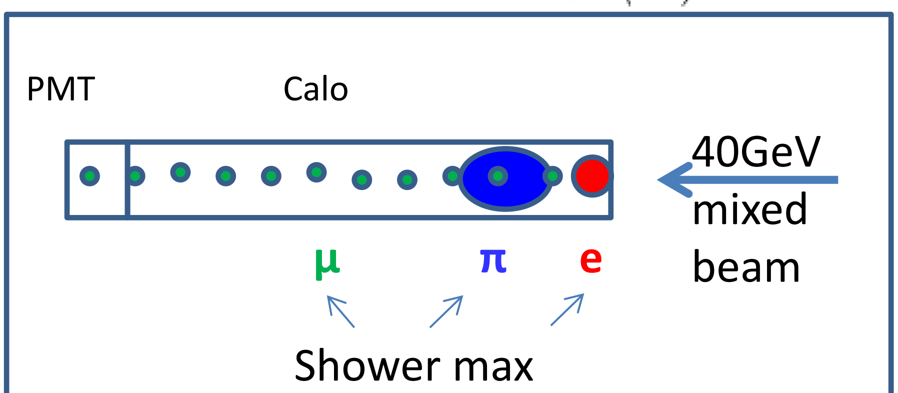
Average Cherenkov signal (40 GeV mixed beam) from tower around the beam axis



Depth shower max ~ 5cm

Depth shower max ~ 25cm

Average depth light production ~125 cm

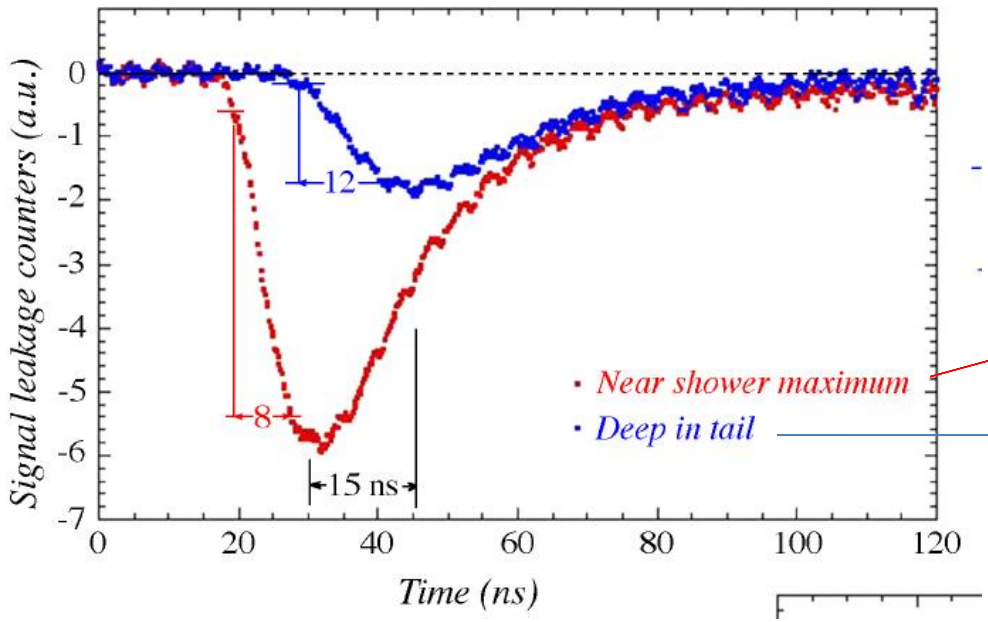


Particle ID possibility
in longitudinally unsegmented detector.

Time structure (2)

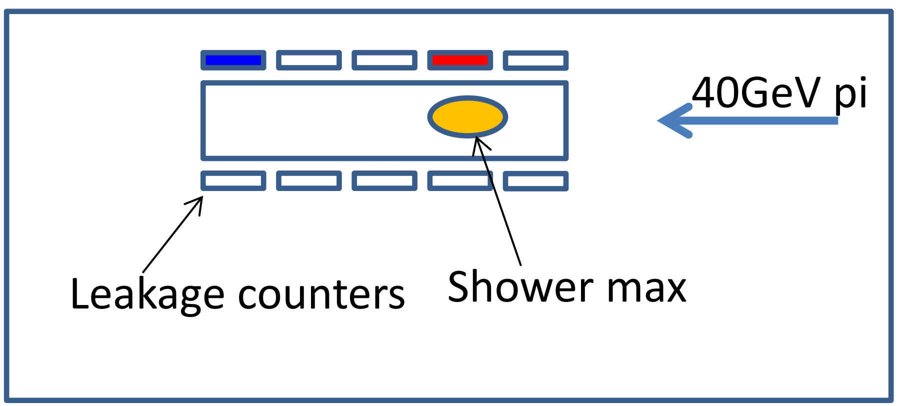
Preliminary

Comparison signal shape leakage counters (average signal)



Prompt charged shower particles escaping the calorimeter

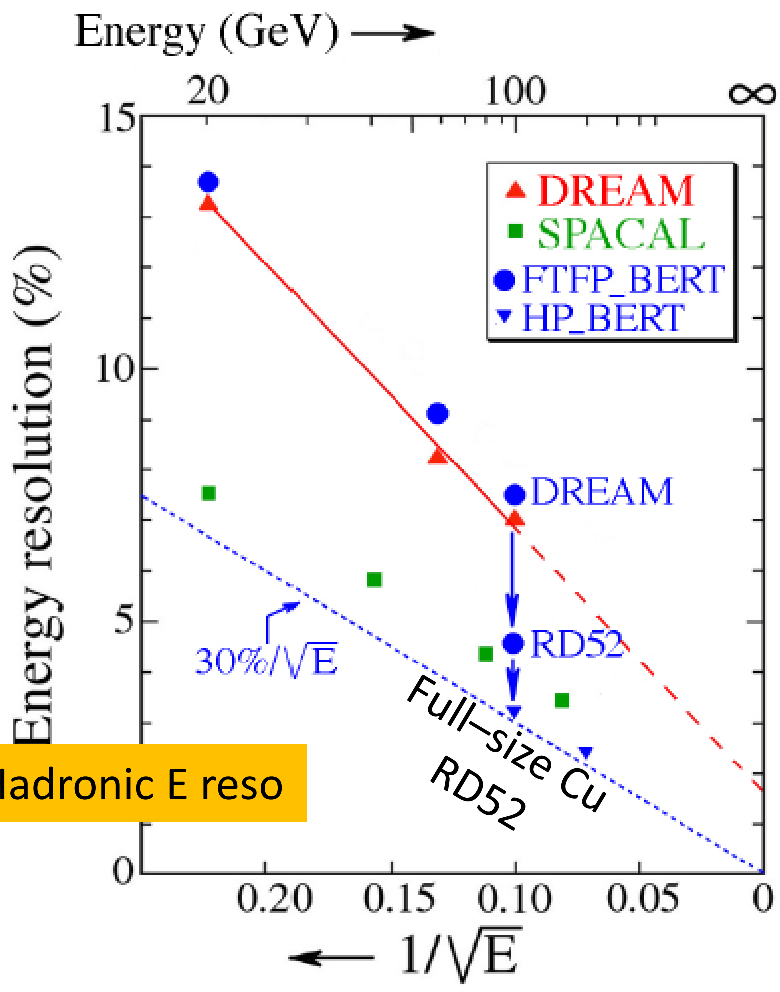
Signal produced by recoiled protons from elastic neutron scattering
time constant 10-20 ns



Sensitivity to the neutrons
→ Possible to improve resolution

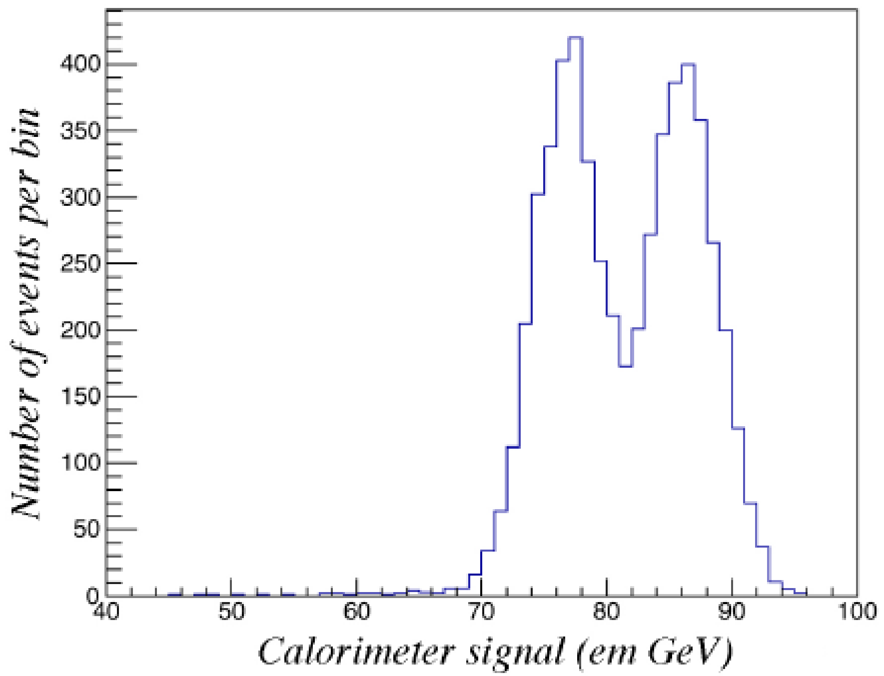
Monte Carlo simulations

Nucl. Instr. Meth. A762 (2014) 100 DREAM method simulated with GEANT4
2015: Repeated some of these simulations with high precision version of had. showers (neutrons followed in details)



Hadronic E reso

W/Z hadronic decay separation, high precision GEANT4 full-size Cu RD52



Goal for future e+e- accelerators

Future plans

2015 plans

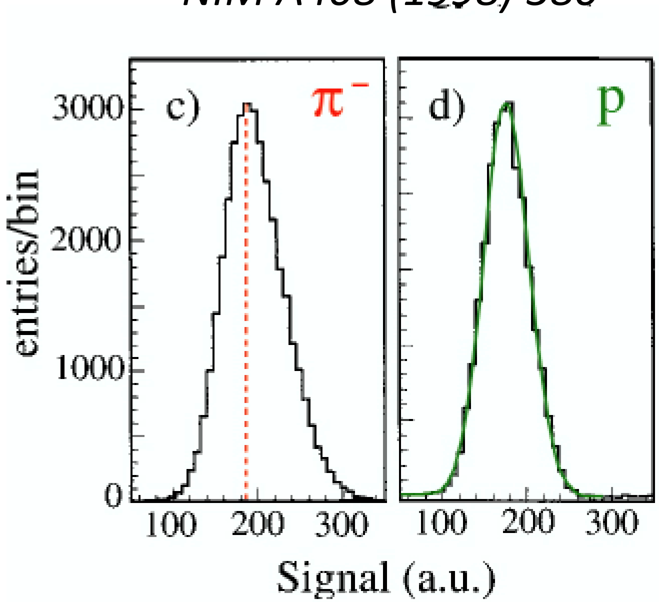
2 weeks of beam time in October 2015;

Planned measurements with Cu module:

Precise time structure measurement with much faster detector (MPC, rise time 0.5 ns, transit time spread 35 ps)

Main goal: Measure differences in time between showers induced by proton / kaon/ pion

NIM A408 (1998) 380



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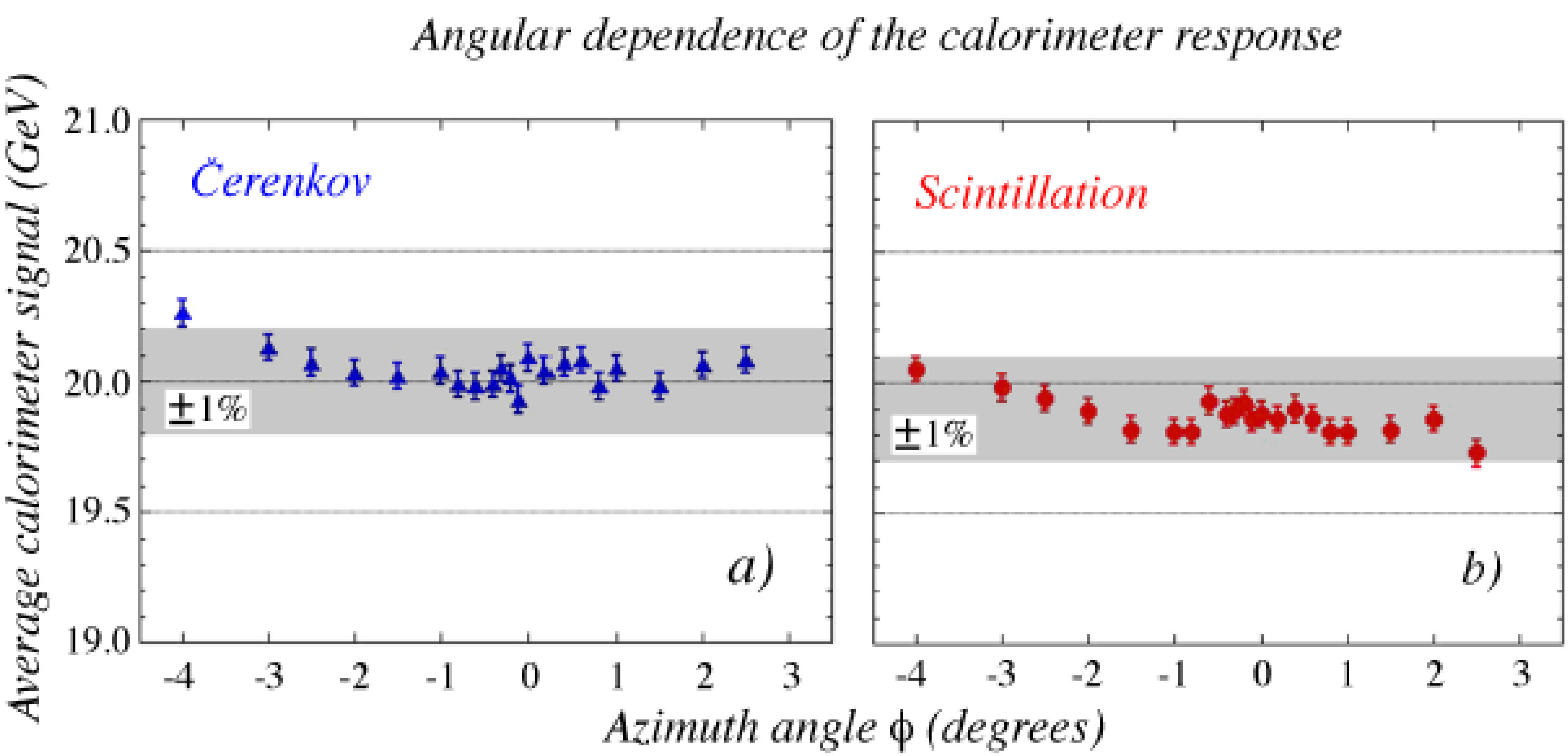
Long term plans

Idea to build a full containment Cu dual readout calorimeter (same structure as the few tested modules). On the way of finding the best technology to machine 1 mm grooves in Cu

Problem: no new funding, few resources

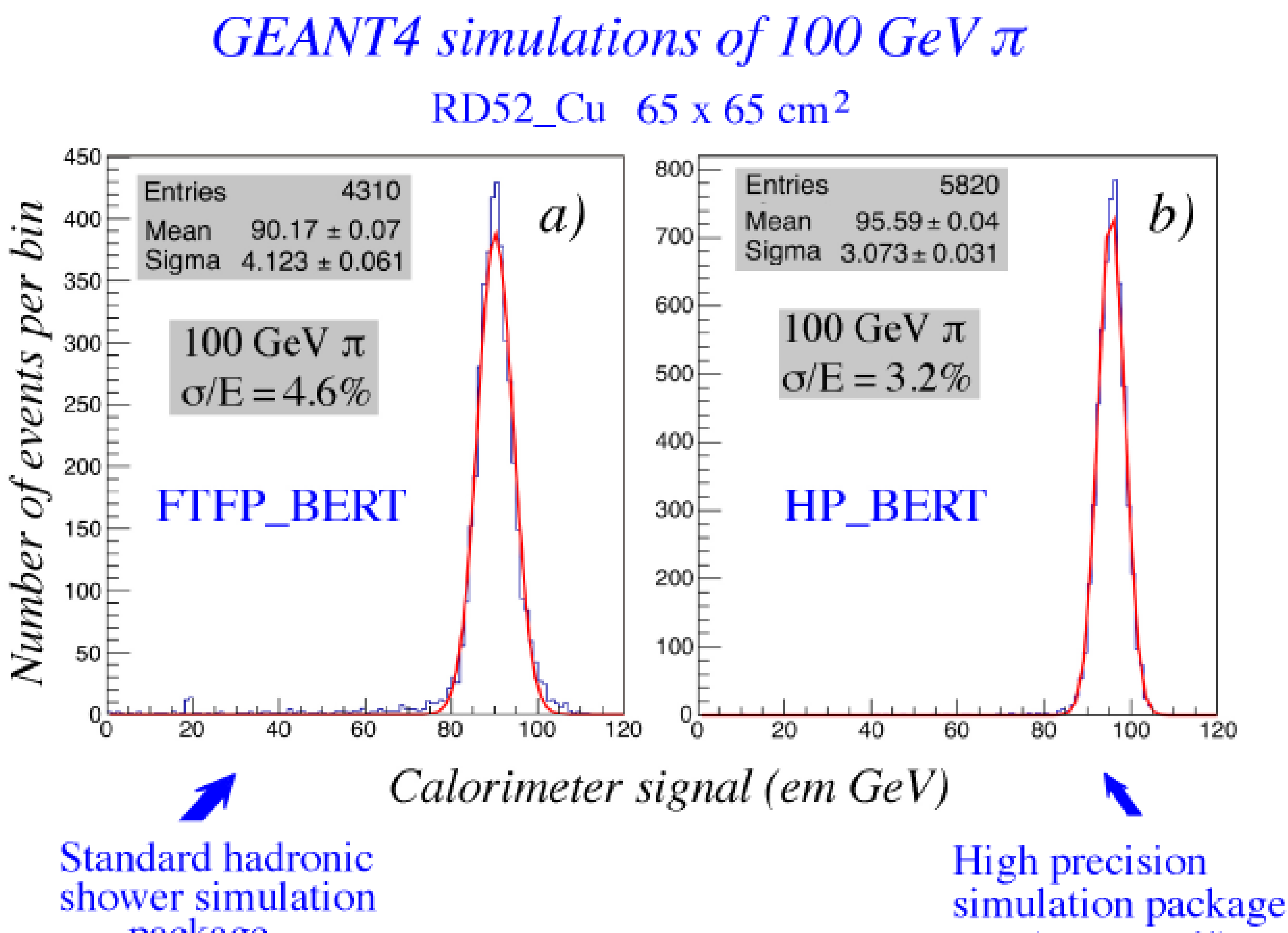
Backup slides



Calorimeter response

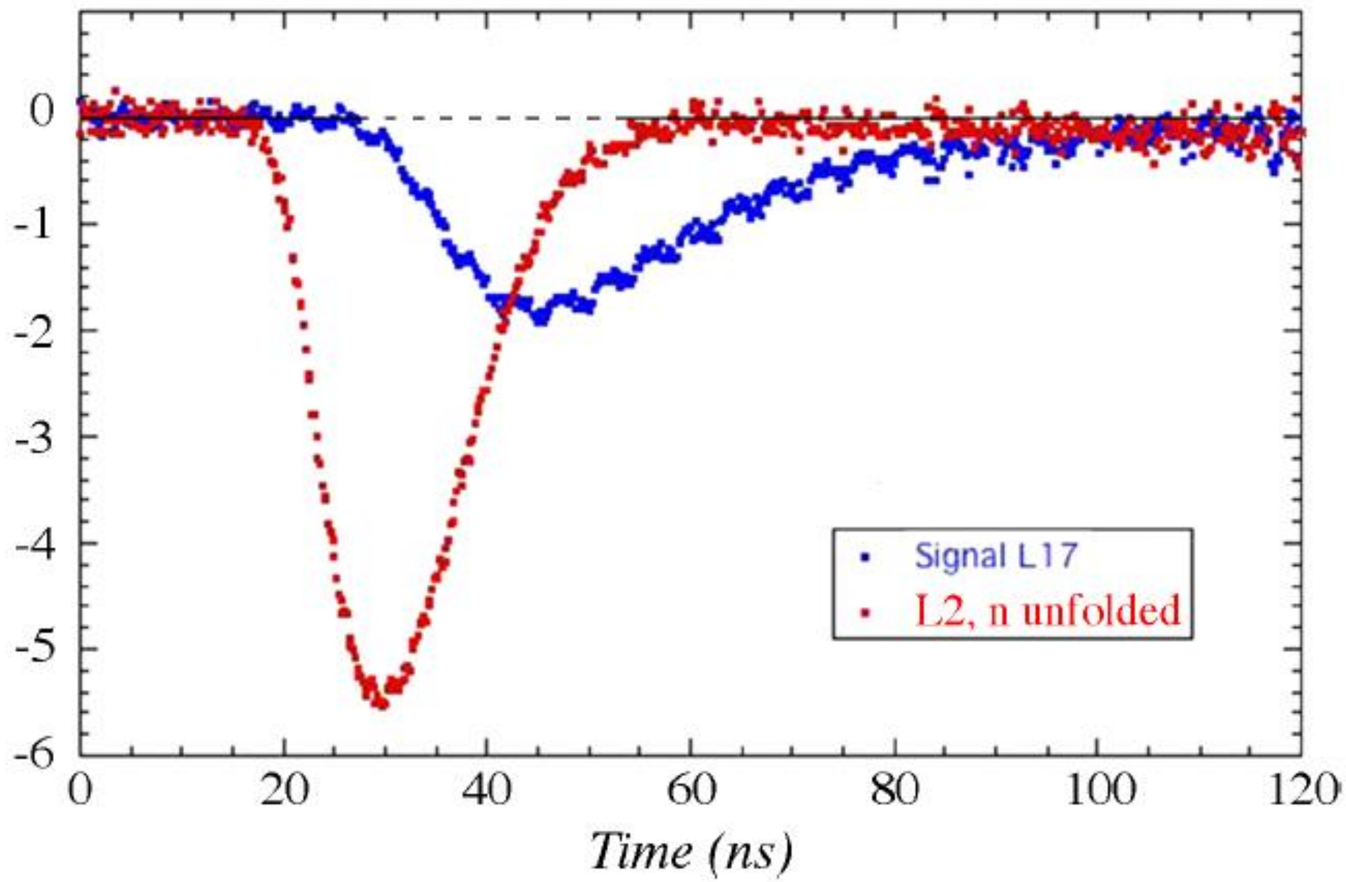
R. Wigmans, SPSC report

- How well is the measured hadronic shower performance described?
- How well does the DREAM method work in GEANT4?
- What improvement is expected for a full size Cu based calorimeter?



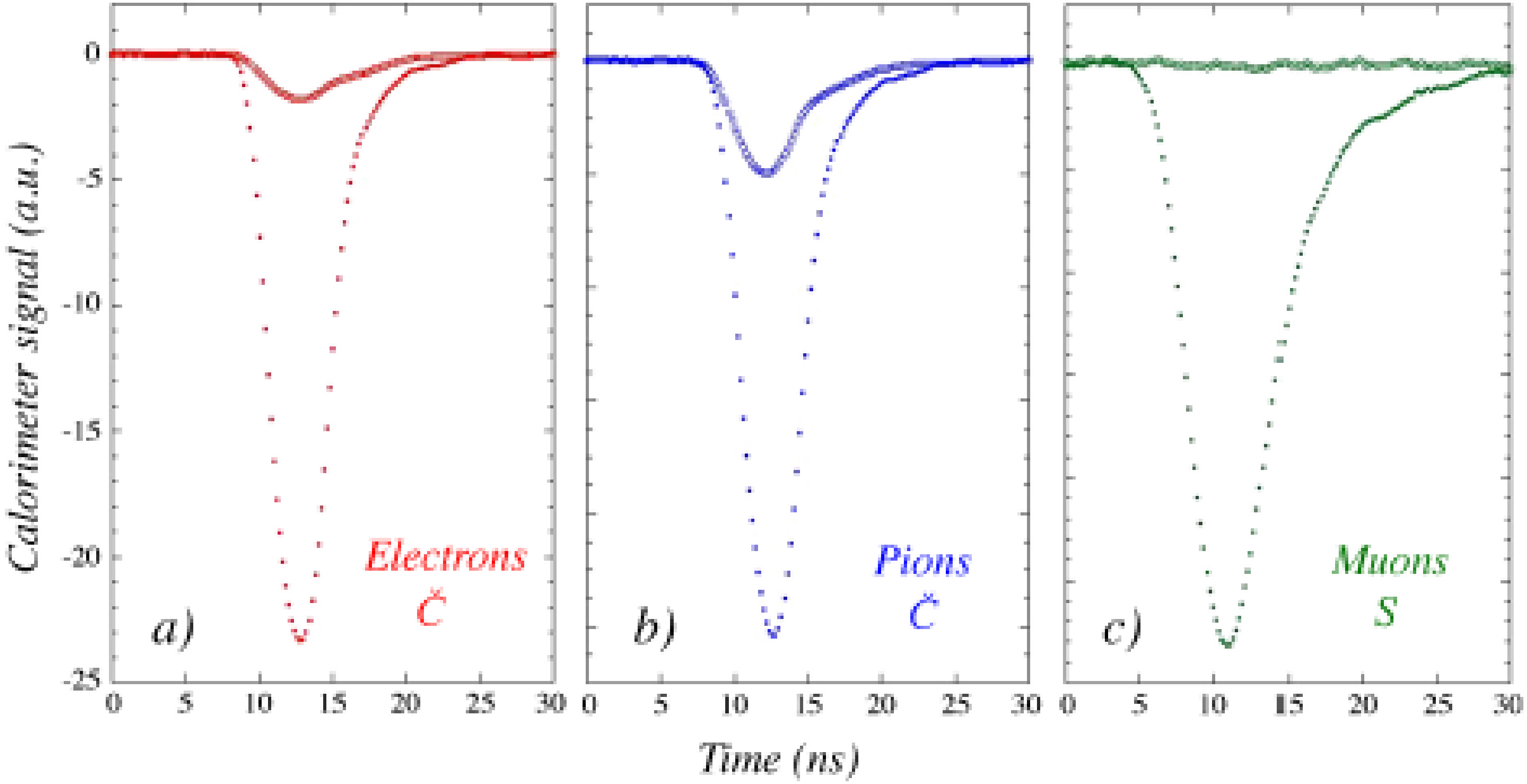
R. Wigmans, SPSC report

Unfolded n contribution



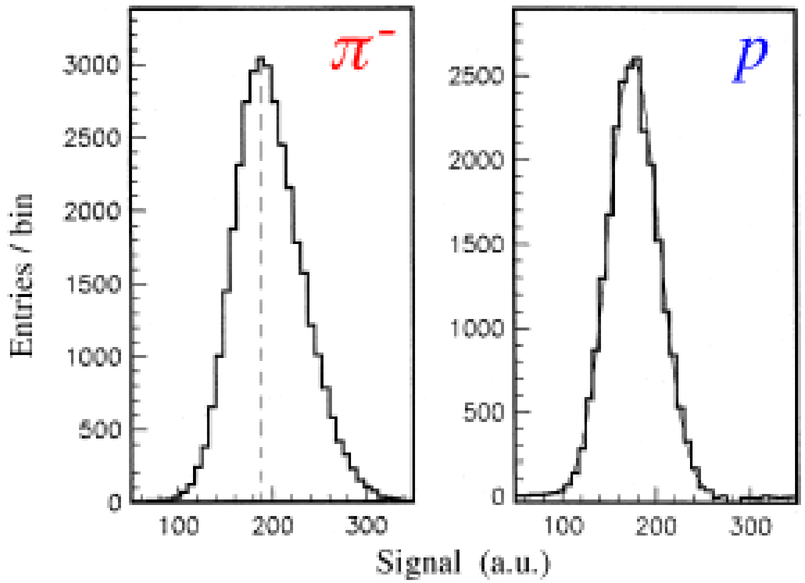
R. Wigmans, SPSC report

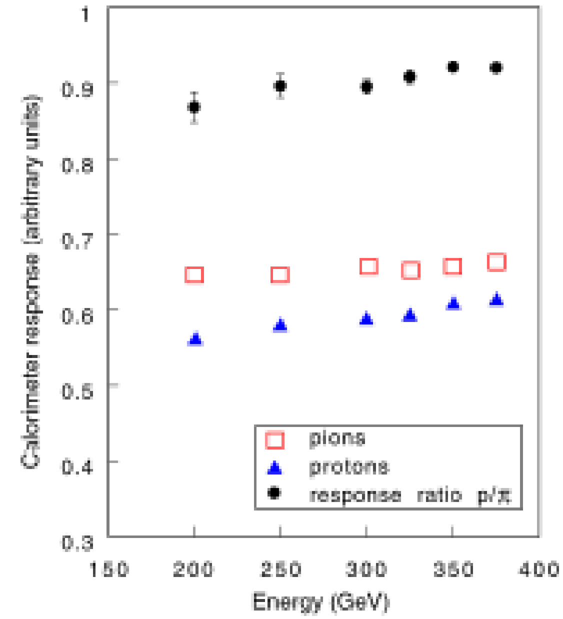
Comparison on-axis / off-axis calorimeter signals
Tower 15 / Tower 21

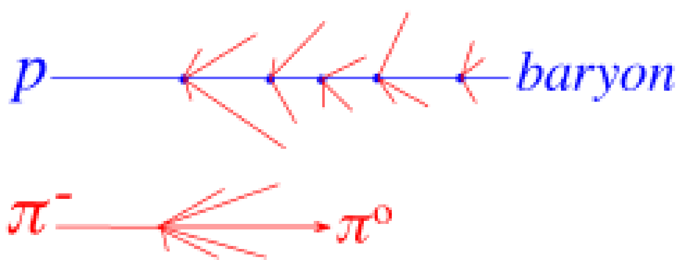


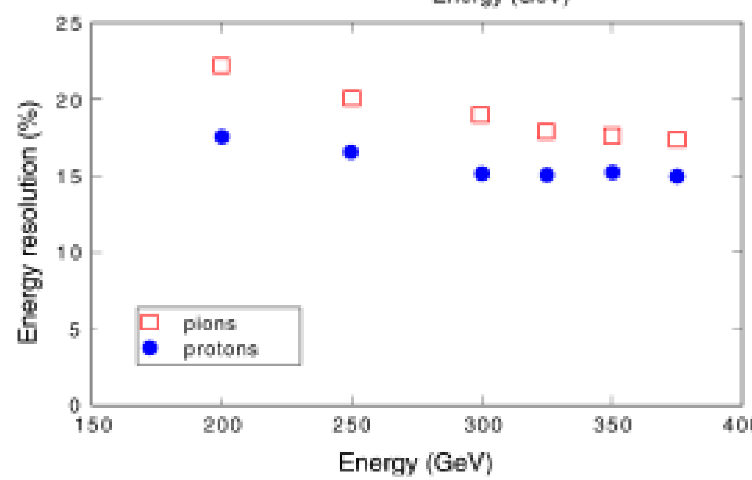
R. Wigmans, SPSC report

Proton / pion differences in calorimeter signals
caused by differences in em shower fraction characteristics









data from NM A408 (1998) 380

em fraction in p showers:
- *smaller*
- *less fluctuations*
- *more symmetric*
- *less concentrated near axis*