Performance of the combined zero degree calorimeter for CMS

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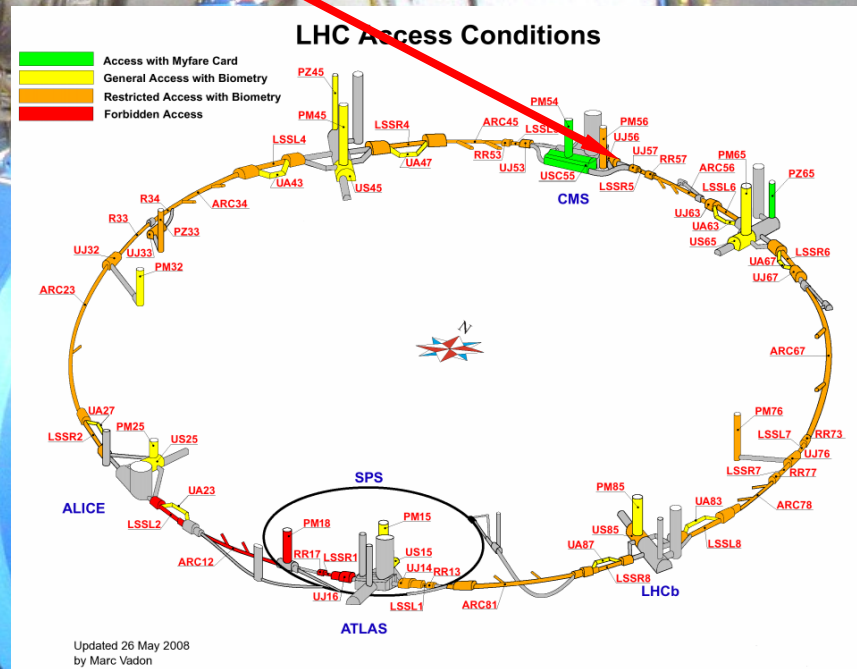
LHC tunnel

Combined Zero Degree Calorimeter (Quartz/Tungsten)



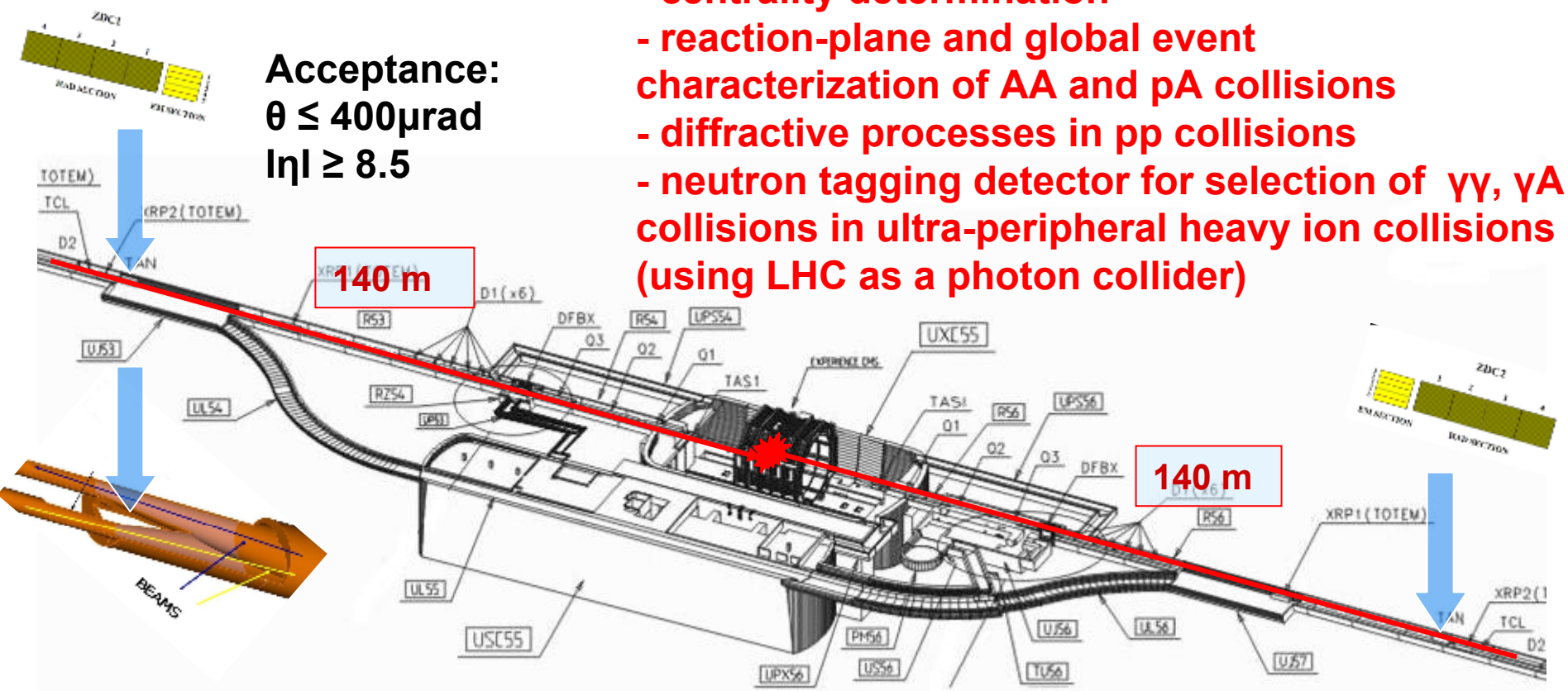
Outline

- Introduction
- Requirements
- Calorimeter design
- Experimental setup
- Read-out electronics
- Response to positrons
- Response to hadrons
- Current status
- Summary

Introduction

- beam tuning and luminosity monitoring tool
- centrality determination
- reaction-plane and global event characterization of AA and pA collisions
- diffractive processes in pp collisions
- neutron tagging detector for selection of γγ, γA collisions in ultra-peripheral heavy ion collisions (using LHC as a photon collider)

Acceptance:
θ ≤ 400μrad
|η| ≥ 8.5

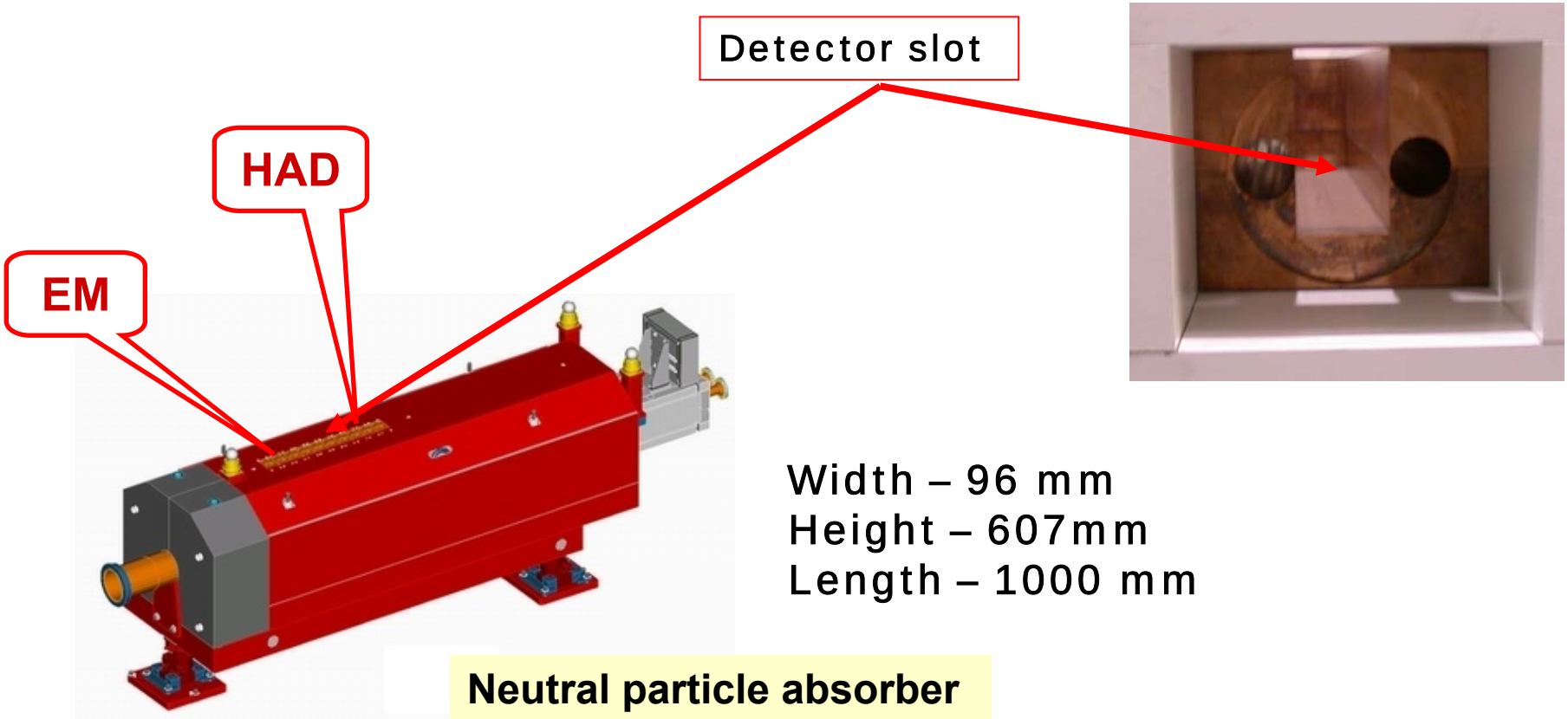


Requirements

1. Calorimeter should allow the reconstruction of the energy of 2.75 TeV spectator neutrons and 50 GeV photons with a resolution of 10 – 15%.
2. Radiation hard.
   During the low - luminosity p-p and design -luminosity Pb-Pb runs, the expected average absorbed radiation doses is about 180 MGy and 300 kGy, respectively, per data - taking year.
3. Calorimeter should utilize the fast detection technology.
   The expected interaction rate for minimum bias events in PbPb collisions is ~8000 event/sec and 25ns crossing time in pp interactions.

Requirements

4. Limited space

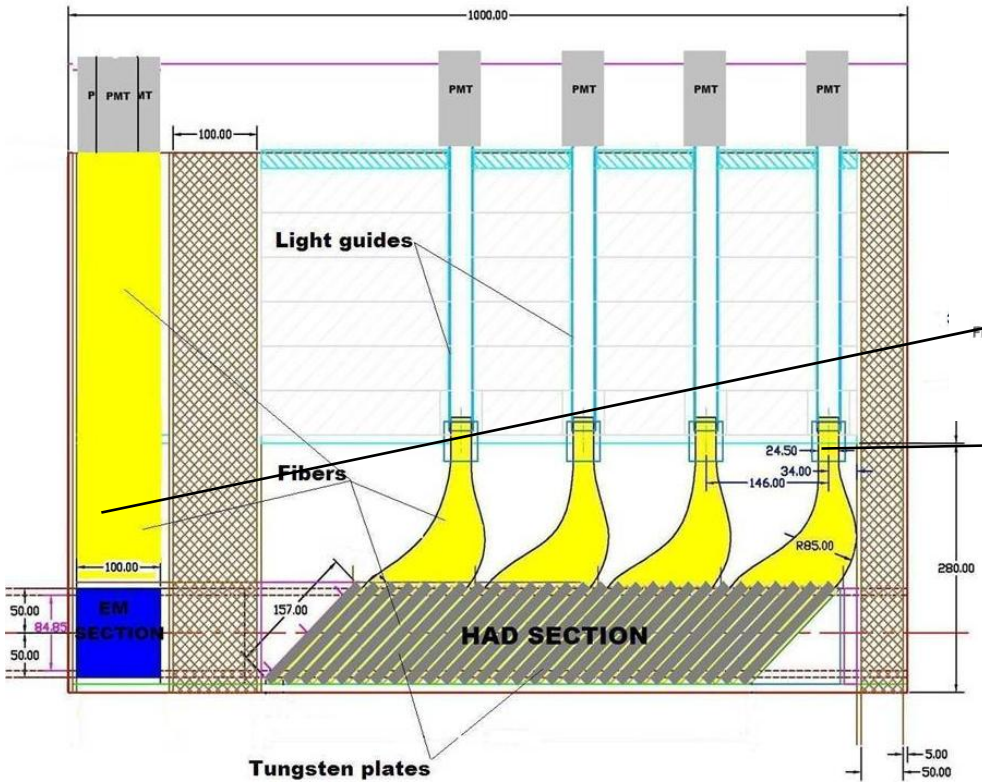


Width – 96 mm
Height – 607mm
Length – 1000 mm

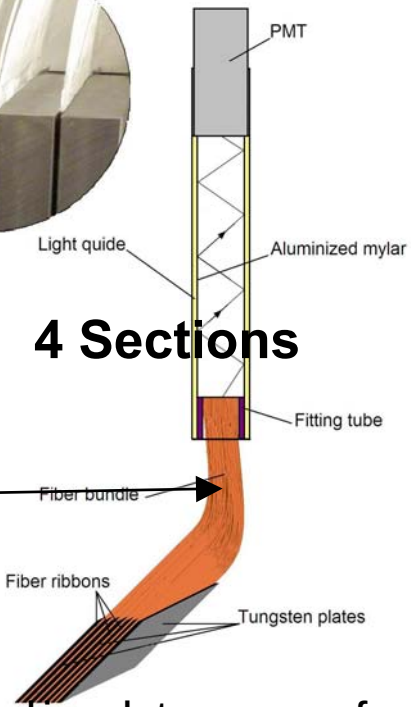
Neutral particle absorber

Calorimeter design

Horizontal tower of
EM section (~16 mm)



Tungsten – 2 mm



Tungsten – 15 mm

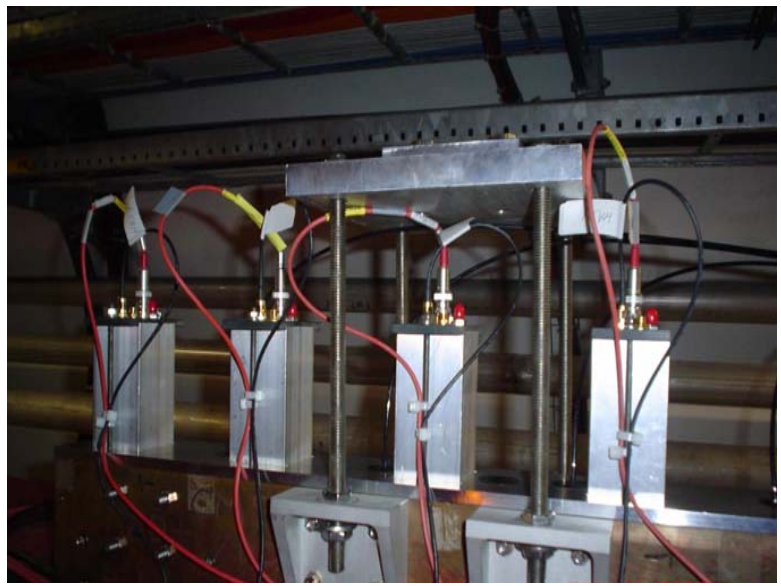
Longitudinal tower of
HAD section (80 mm-
transverse dim.)

Quartz fiber bundles

EM Read-out

HAD Section

EM Section

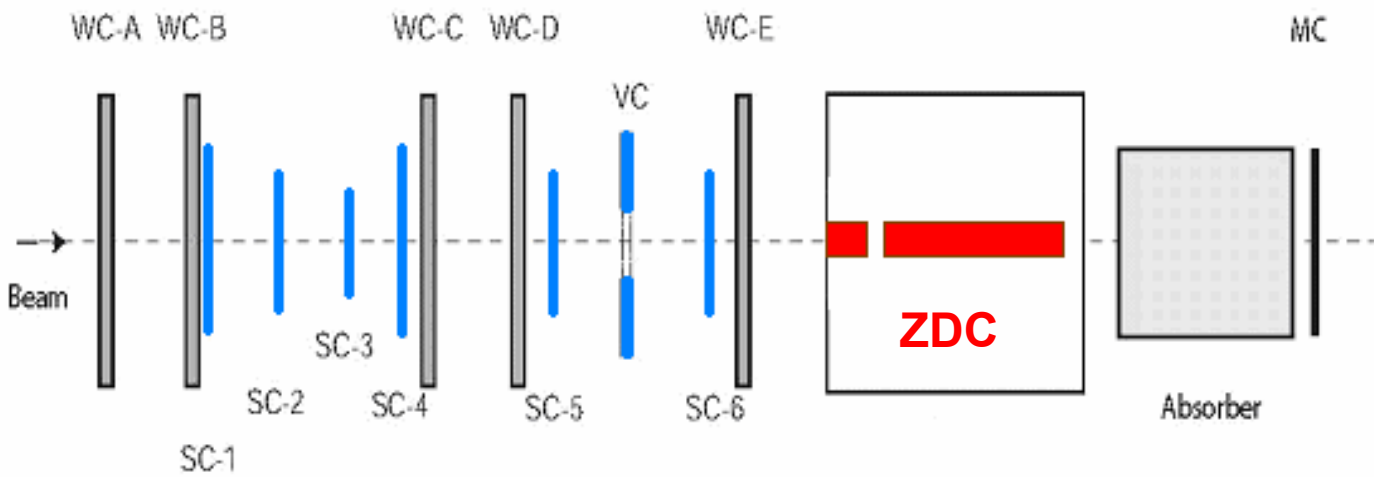


Experimental setup

The main goals of the test beam measurements were to study the performance of the zero degree calorimeter (energy resolution and linearity) and tests of the full electronic chain to be used in CMS.

Downstream from the primary target, a secondary hadron or electron (positron) beam were made with momenta from 10 to 350 GeV/c.

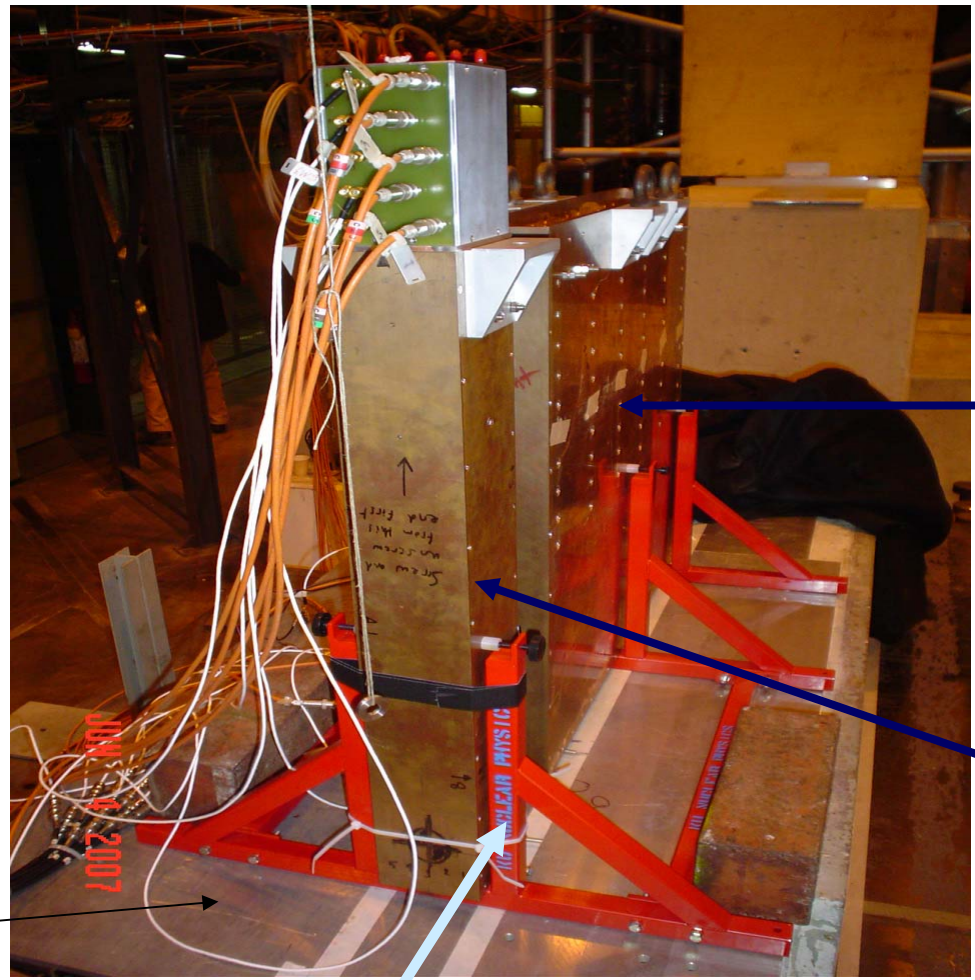
SPS H2 beam at CERN



Gas threshold Cherenkov counter;
WC: multi – wire proportional chambers;
SC: 1 cm thick scintillator counters;

Experimental setup

The calorimeter sat on table that could be moved horizontal and vertical directions under remote control.This made it possible to direct the beam anywhere in the calorimeter front face.

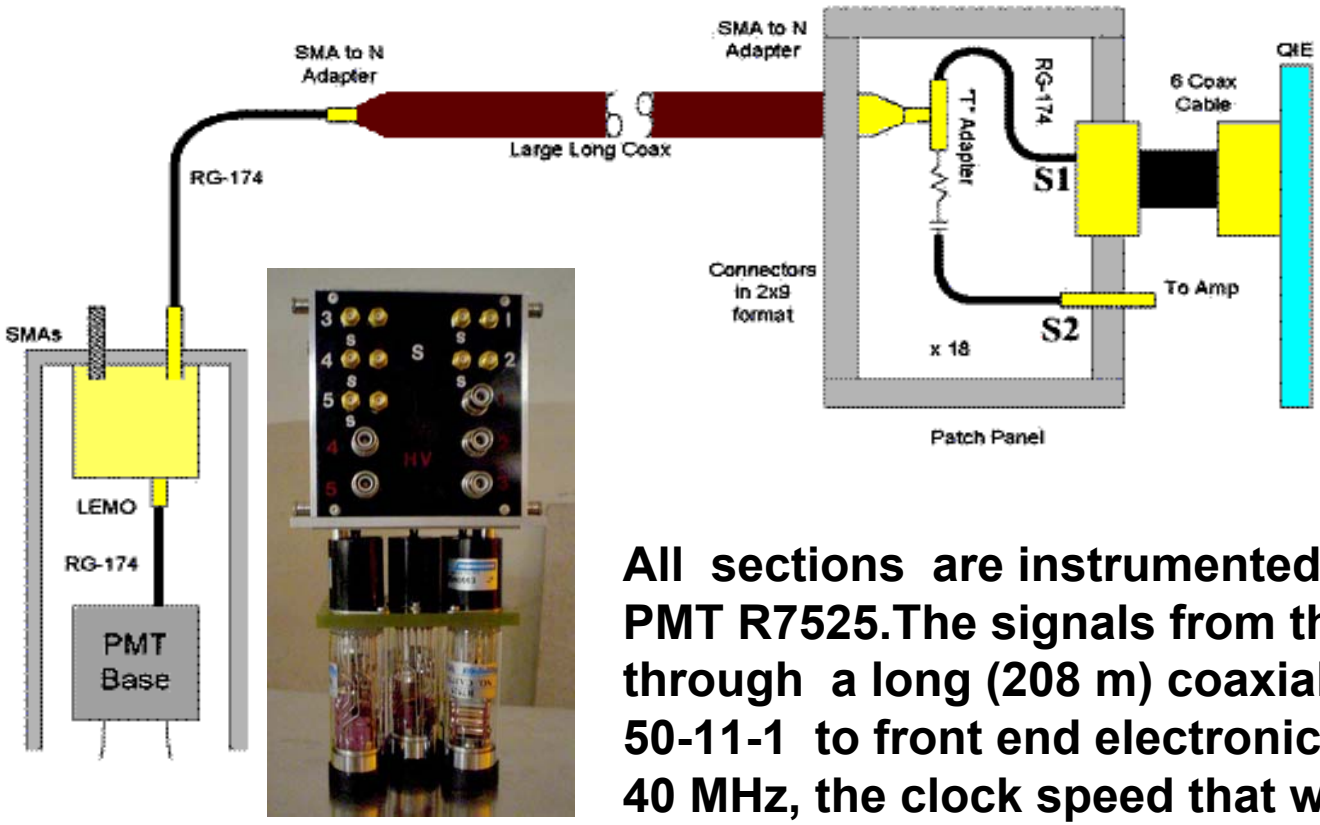


HAD Section (~5.6λ)

EM Section (~1λ)

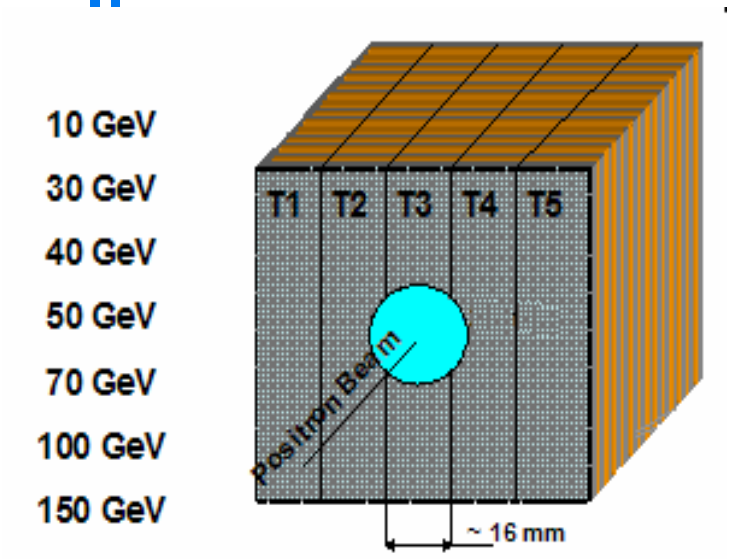
Motion platform

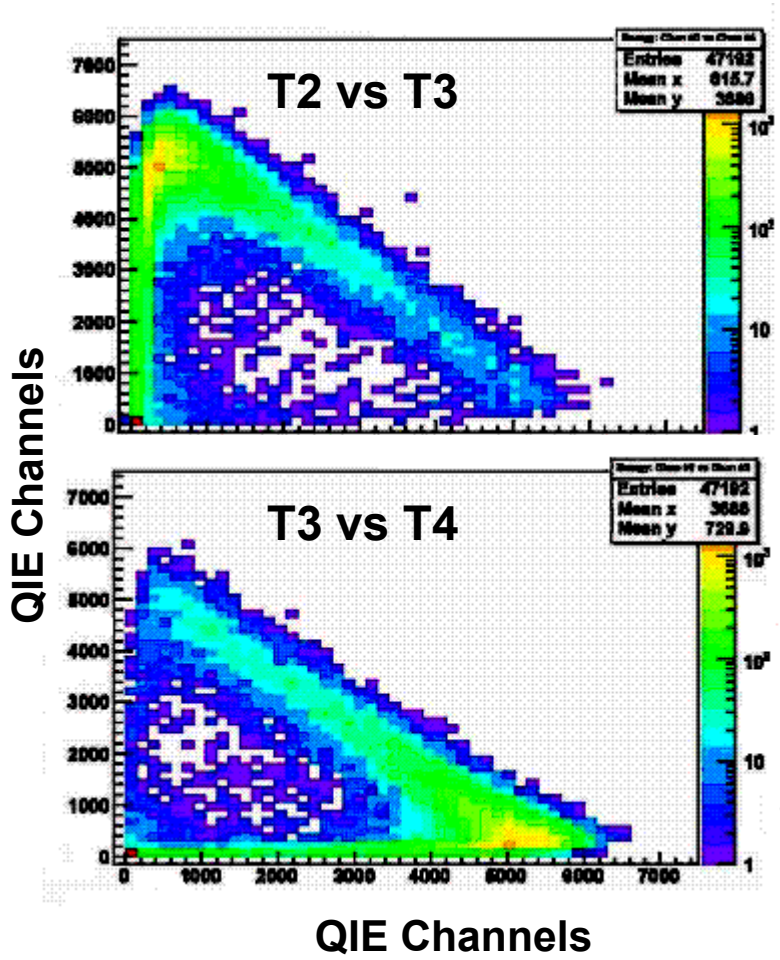
Read-out electronics



All sections are instrumented with the same type of PMT R7525.The signals from the PMTs are transmitted through a long (208 m) coaxial 50 Ohm cables type C-50-11-1 to front end electronics. An electronics ran at 40 MHz, the clock speed that will be used at the LHC.

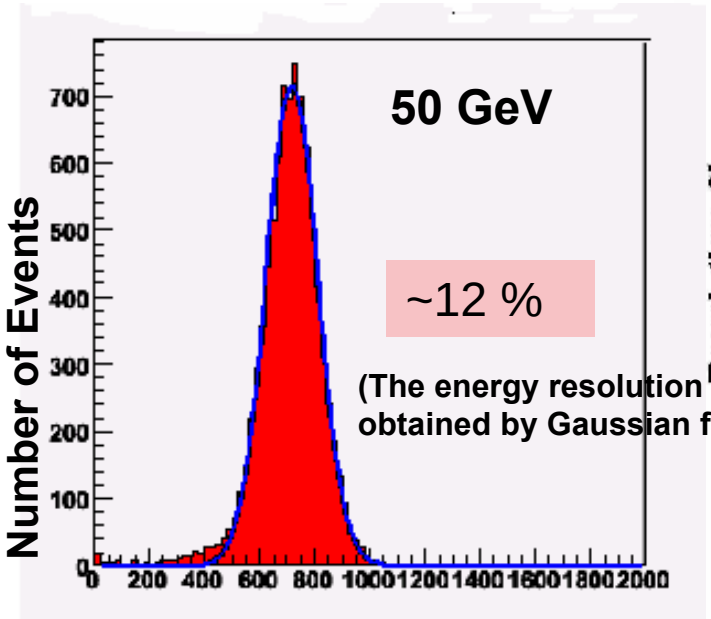
Response to positrons





To equalize each tower the center of each tower was irradiated by 50 GeV positron beam. The peak position obtained from a Gaussian fit of the amplitude distribution for each tower was used to determine the calibration coefficients.

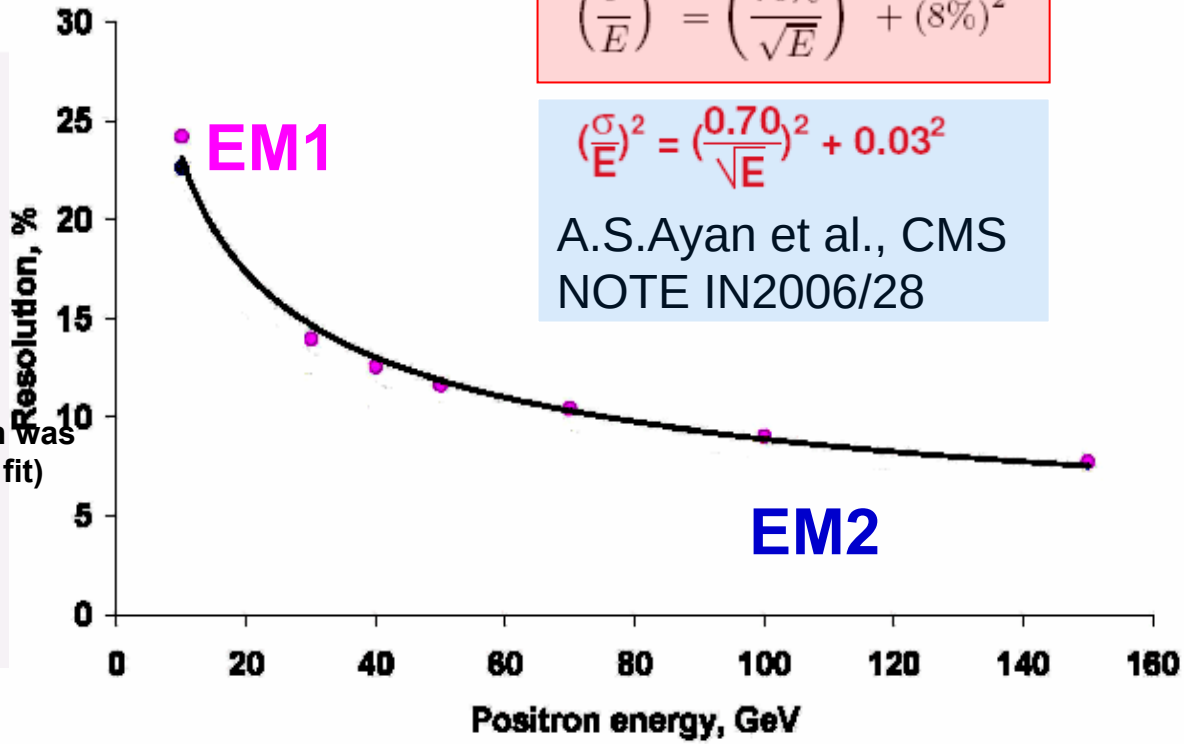
Response to positrons



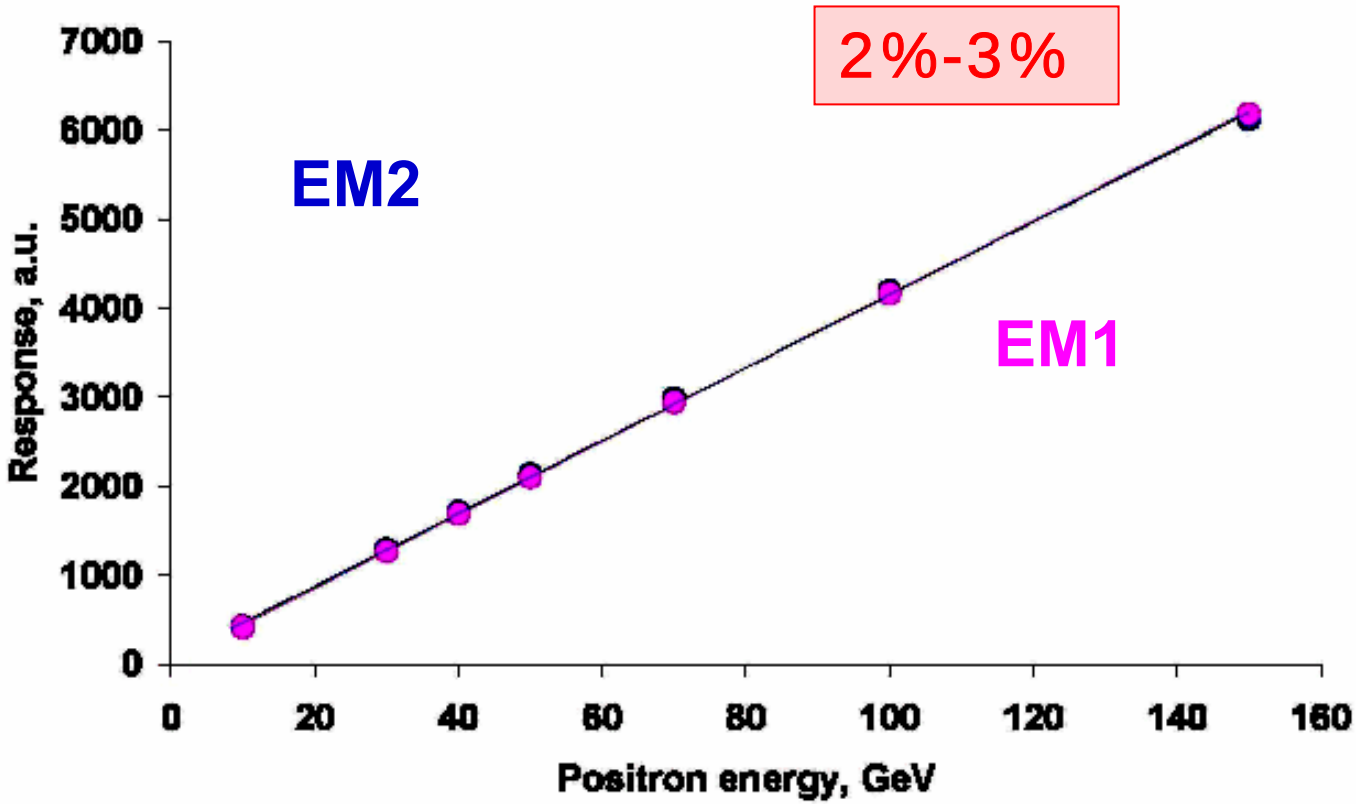
$$\left(\frac{\sigma}{E}\right)^2 = \left(\frac{70\%}{\sqrt{E}}\right)^2 + (8\%)^2$$

$$\left(\frac{\sigma}{E}\right)^2 = \left(\frac{0.70}{\sqrt{E}}\right)^2 + 0.03^2$$

A.S.Ayan et al., CMS NOTE IN2006/28



Response to positrons



Response to hadrons

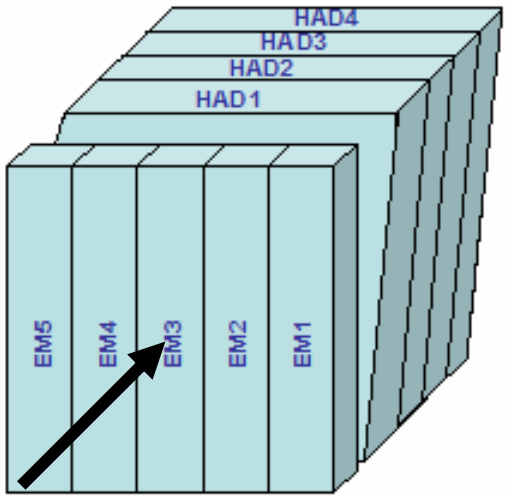
π+

150 GeV

200 GeV

300 GeV

350 GeV



The total energy:

$$E_{TOT} = \alpha E_{EM} + E_{HAD}$$

is defined as the sum of energy in EM section:

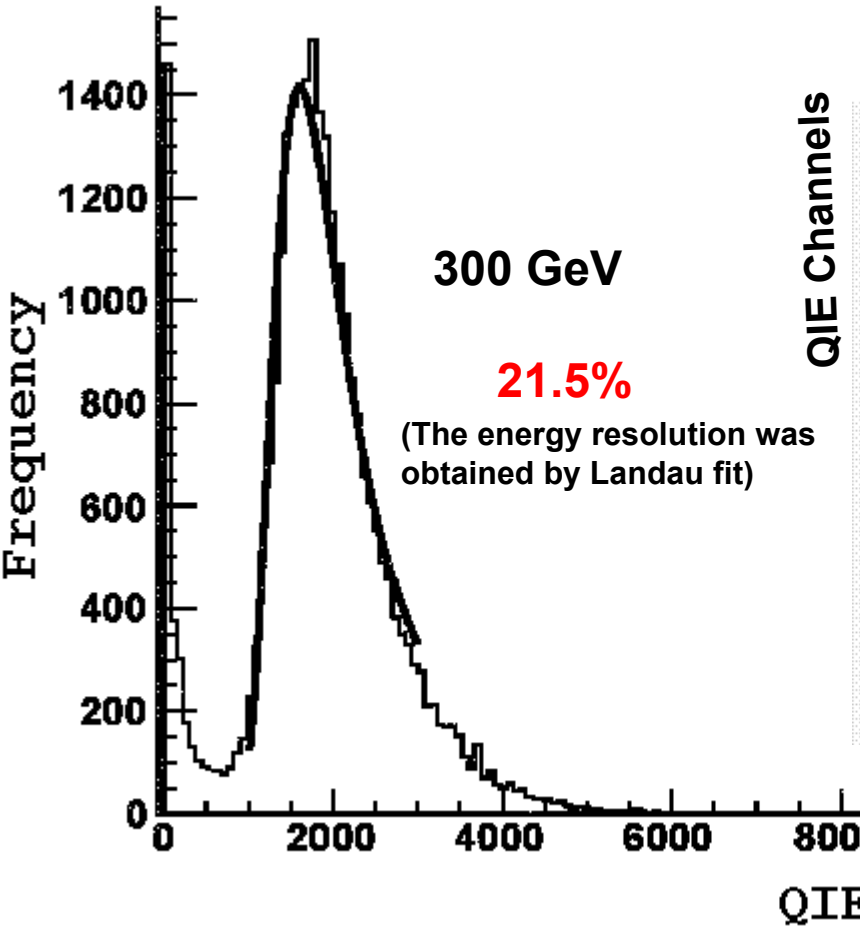
$$E_{EM} = E_{EM1} + E_{EM2} + E_{EM3} + E_{EM4} + E_{EM5}$$

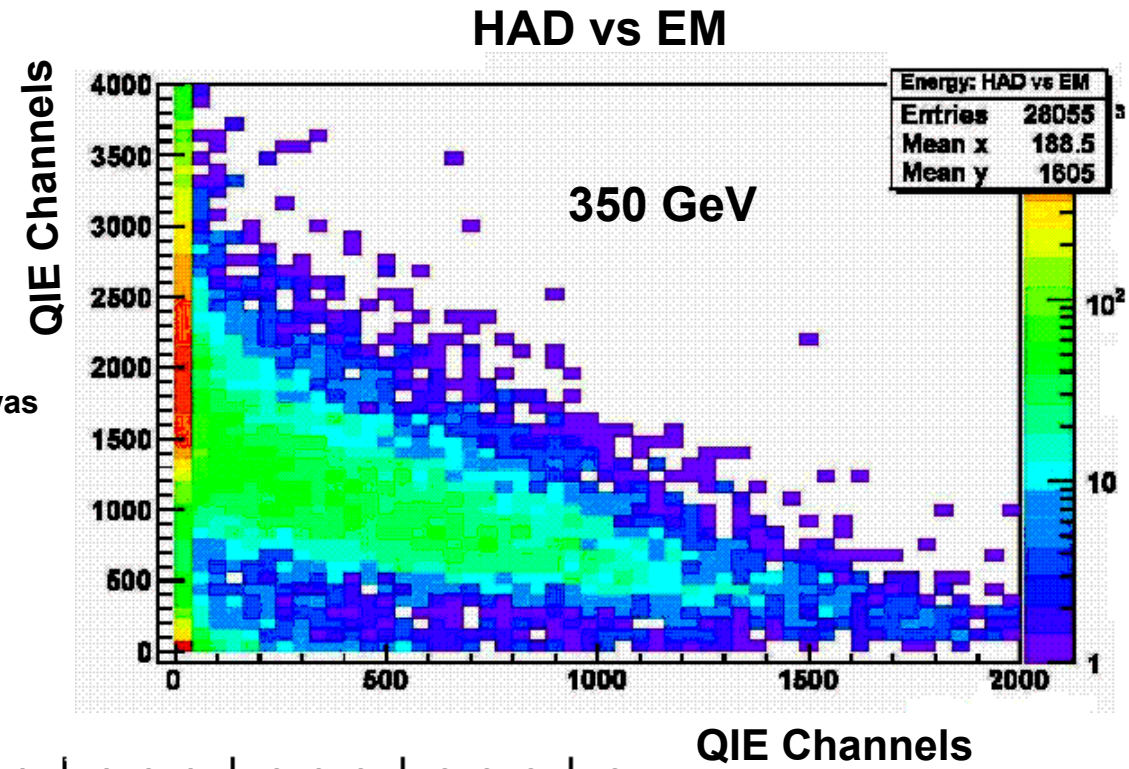
and energy in HAD section:

$$E_{HAD} = E_{HAD1} + E_{HAD2} + E_{HAD3} + E_{HAD4},$$

The total depth of combined system is ~ 7 hadronic interaction lengths (λ)

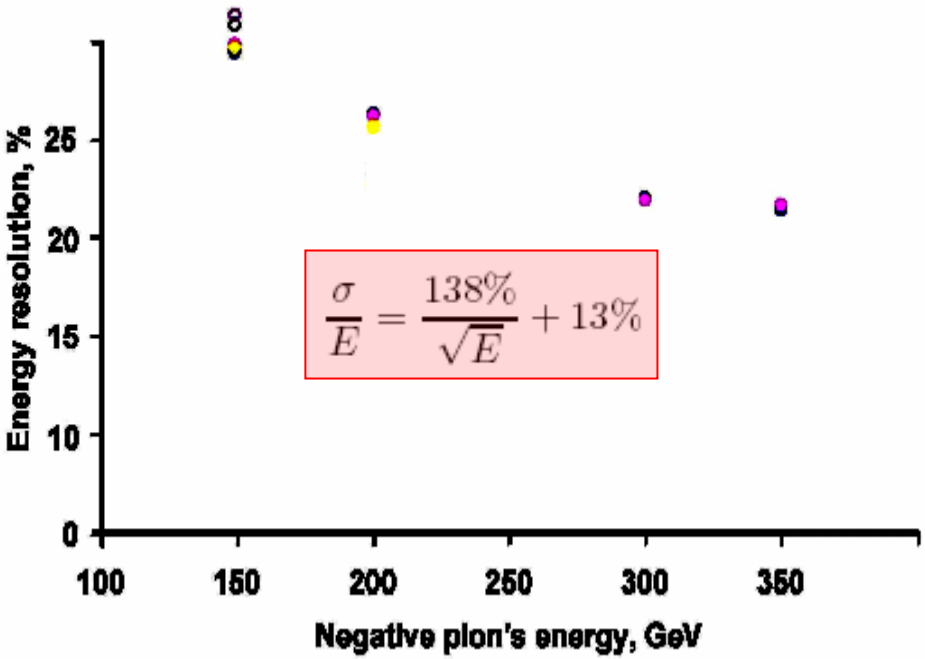
Response to hadrons

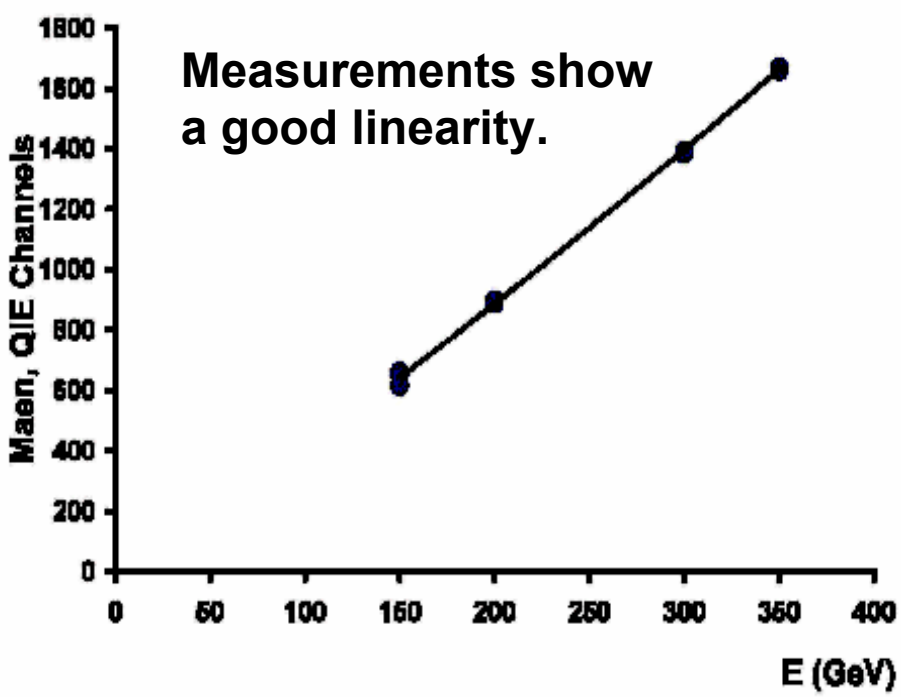




Response to hadrons

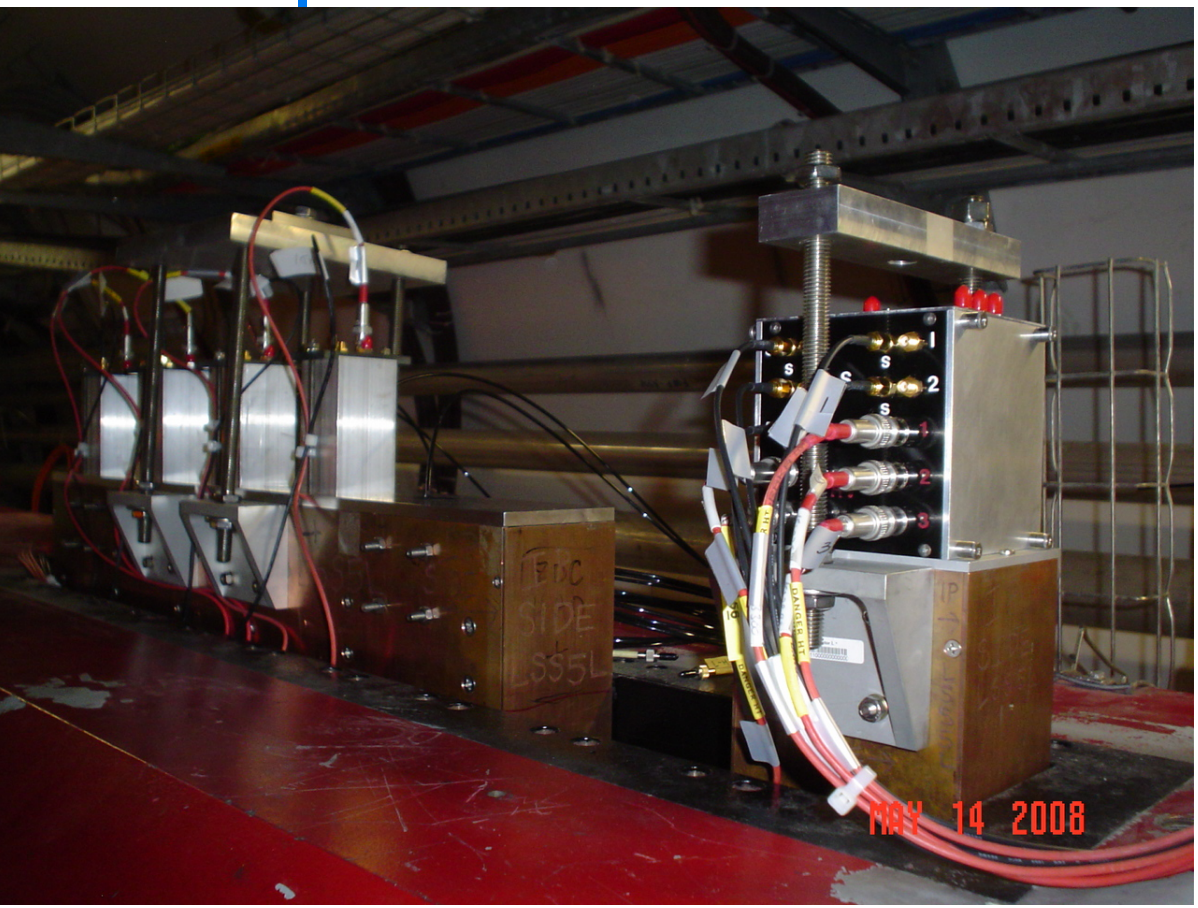
ZDC1 and ZDC2





An extrapolation to energy 2.75 TeV will give the resolution of about 15%
(Geant4 simulation (A.S.Ayan et al., CMS NOTE IN2006/28) - ~12%)

Current status



- Installation and preparation of detectors for operation in machine tunnel
- Commissioning of the detectors and electronics using laser (and LED) system

Summary

- We designed, constructed and tested combined zero degree calorimeter.
- GEANT4 simulations reproduces well the test beam data.
- Calorimeter completely fulfills the technical, geometrical and physics requirements.
- The ZDC has sufficient energy resolution and linearity to meet our physics goals.