"CASTOR"
a novel calorimeter at very forward CMS
Enhancing forward Physics

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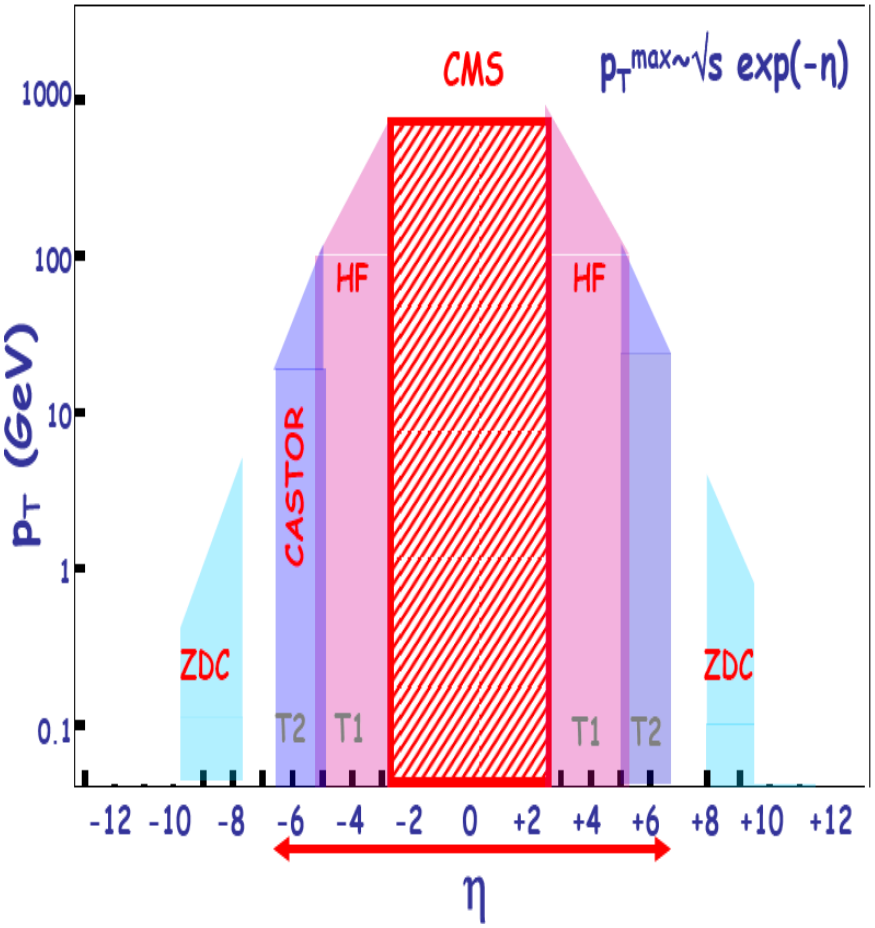
CMS/CASTOR Group

Contents

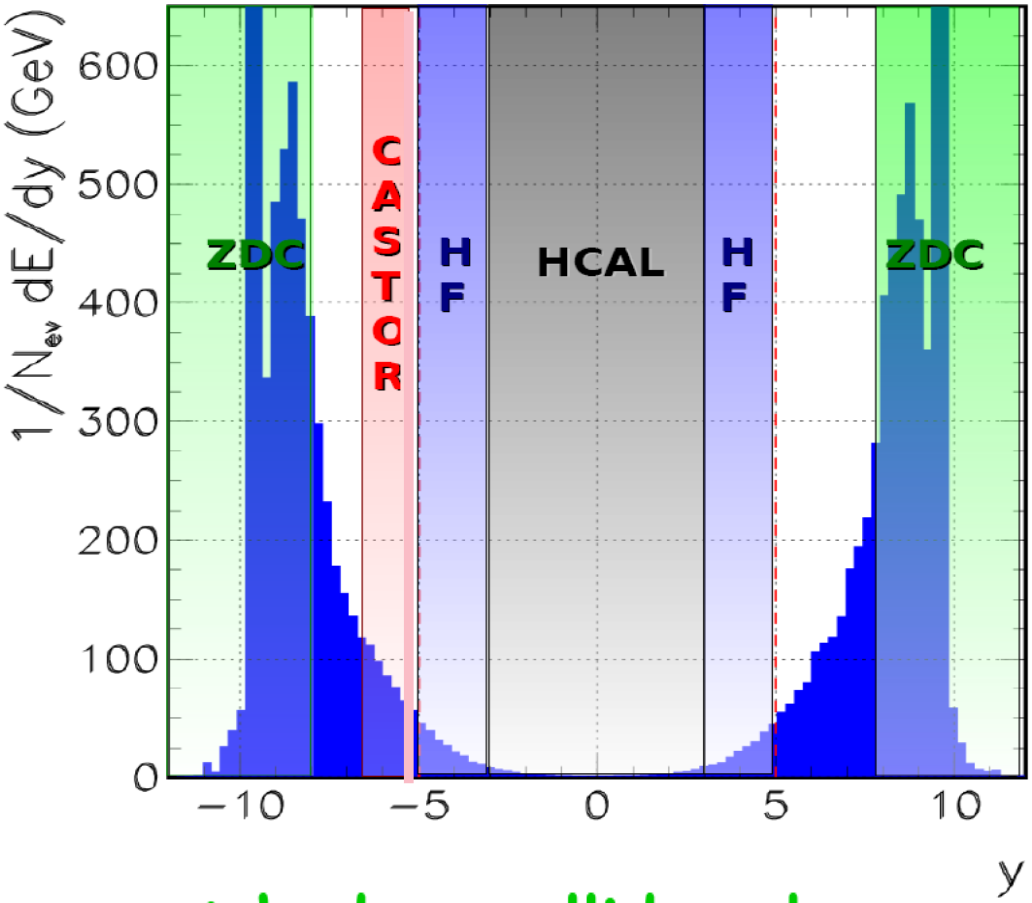
- Enhancing forward Physiscs
- The "CASTOR" Calorimeter
- Beam Test '07 & '08
- ½ Calorimeter installation in CMS beam line
- Full CASTOR construction / installation schedule

CMS Coverage in p_T - η & dE/dy

CMS fwd calorimetry up to $|\eta| \approx 5$ + Castor + ZDC



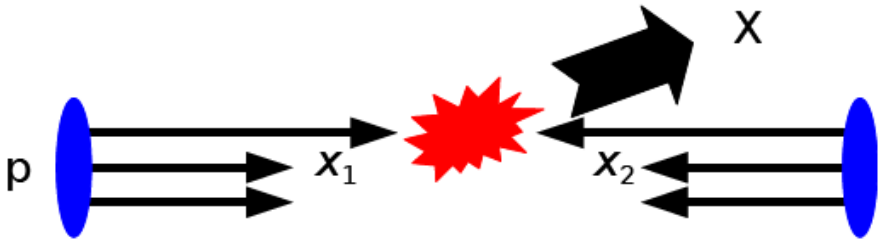
Energy flow at the LHC



Unprecedented coverage at hadron colliders !

Enhancing forward Physics

Forward Hard Parton Scattering

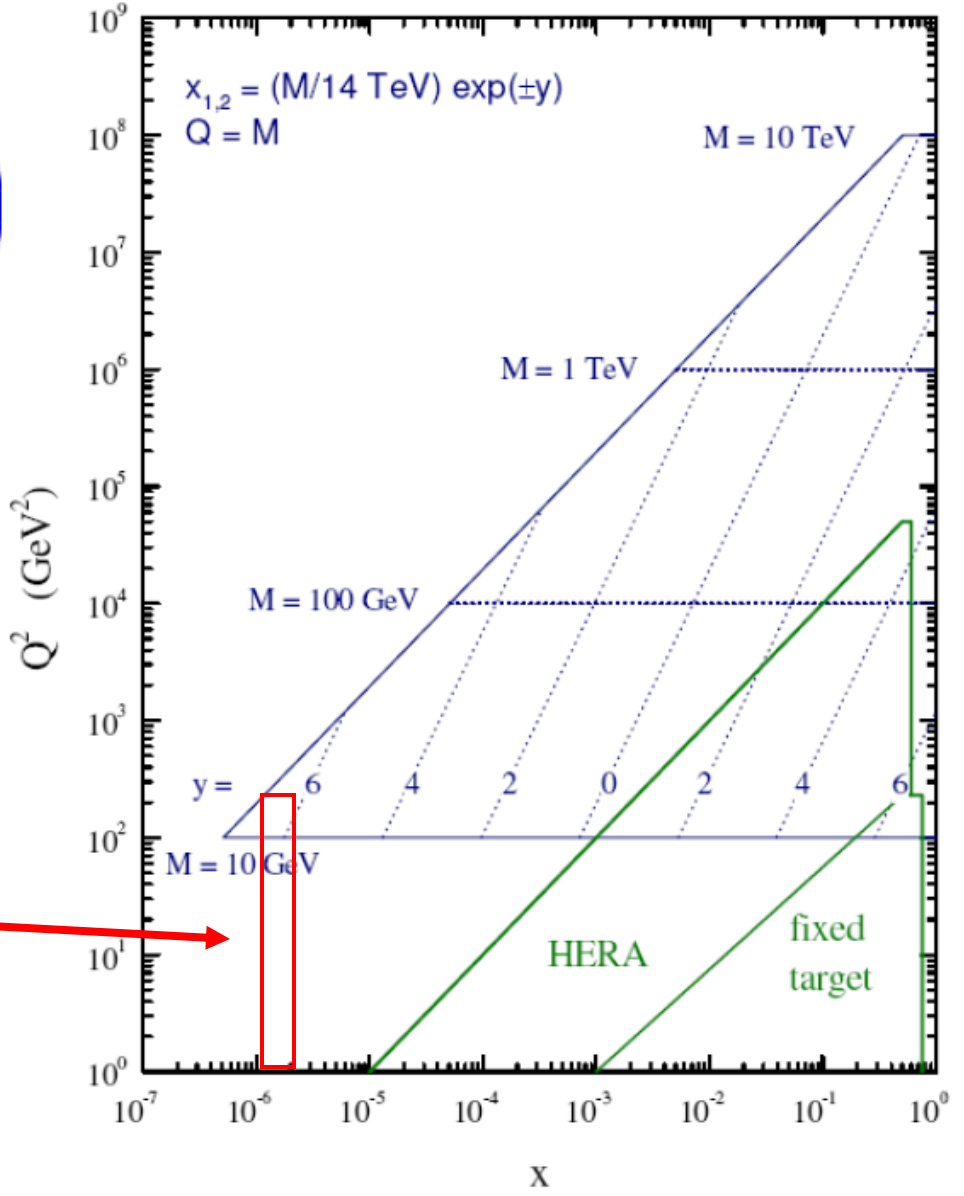


- X can be jets, Drell-Yan pairs, prompt photons, heavy quark pairs, ...
- X goes forward if $x_2 \ll x_1$ → access to low-$x_{Bjorken}$ proton structure:

$$x_{Bj} = \frac{Q}{\sqrt{s}} e^{-\eta}, \qquad Q = p_T, M, \ldots$$

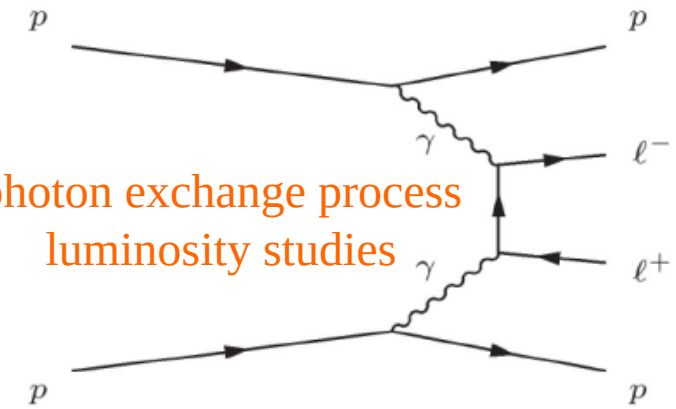
→ at LHC (for $Q \gtrsim 10$ GeV and $\eta = 6$):
$x_{Bjorken} \gtrsim 10^{-6}$

→ $x_{Bjorken}$ decreases approx. by factor 10 for each 2 units in rapidity



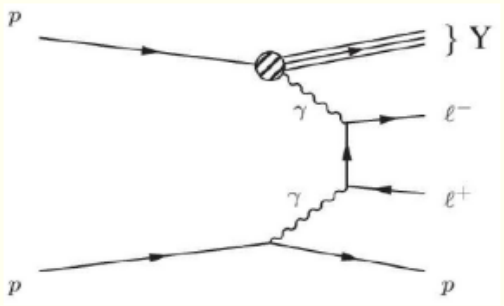
Exclusive Dilepton Production

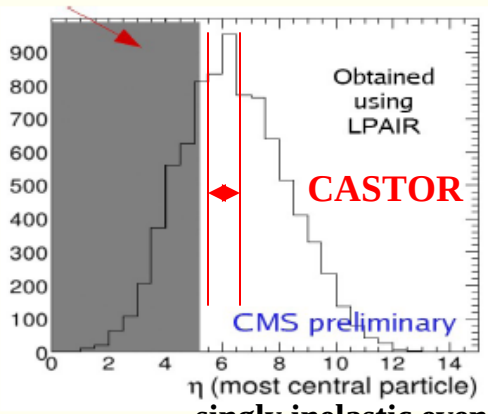
pp → pp l^+l^-



photon exchange process
luminosity studies

Inelastic background





singly inelastic event

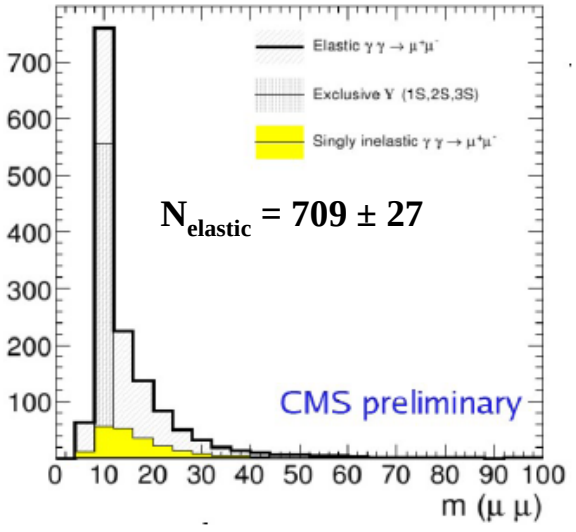
→ can be reduced using CASTOR/ZDC

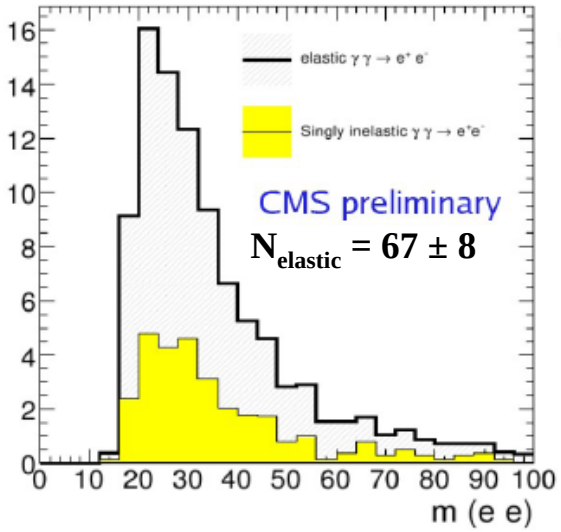
Motivations:

- Nearly pure QED process

  → Absolute lumi monitoring with precision O(5%) for 100 pb^{-1}
- Study of lepton identification
- Calibration of forward proton detectors

Final distributions of the dilepton invariant mass after all selections & Castor and ZDC vetos





Multiple Parton Interactions

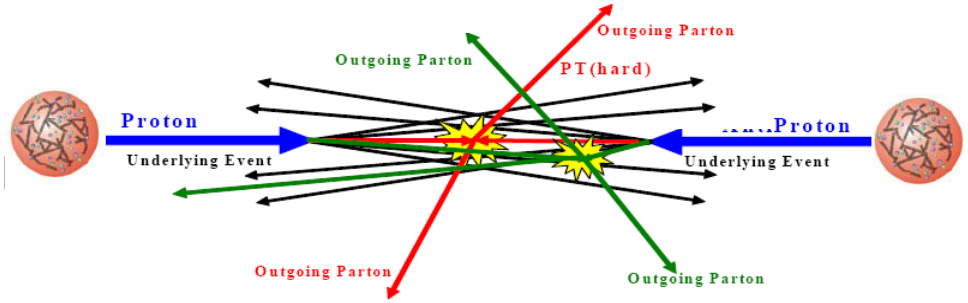
Basic partonic cross section

$$\sigma_{hard}(p^2_{\perp min}) = \int_{p^2_{\perp min}} \frac{d\sigma(p^2_\perp)}{dp^2_\perp}\, dp^2_\perp$$

→ diverges faster than $1/p^4_{\perp min}$ as $p_{\perp min} \to 0$

→ eventually exceeds σ_{tot} (even for $p_{\perp min} > \Lambda_{QCD}$).

Consequence: **Multiple parton interactions per event**



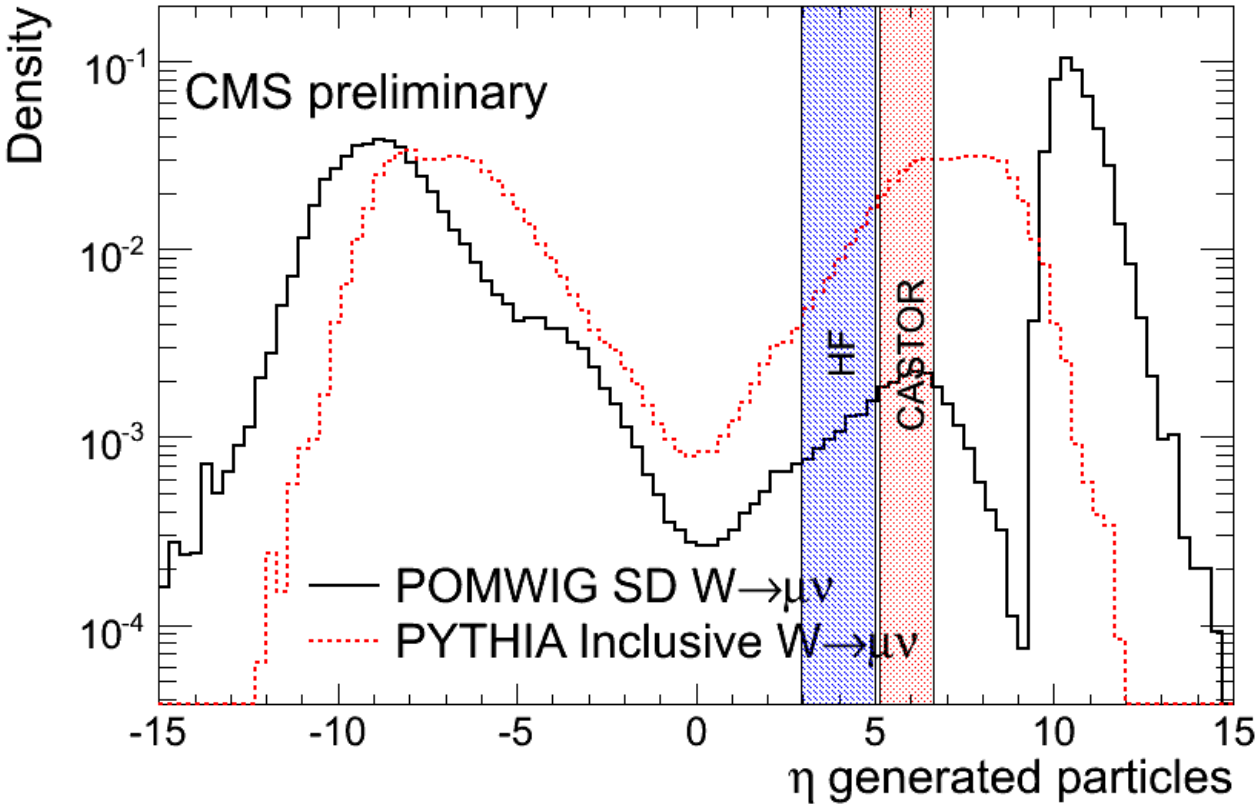
→ higher particle multiplicity (additional energy offset in jet profiles)

→ long distance correlations in rapidity (need to cover forward region!)

→ additional hard interactions may fake a discovery signal !
(e.g. pp → W H X with H → b$\underline{\text{b}}$ vs. pp → W b$\underline{\text{b}}$ X)

Selection of SD events

Single-Diffractive di-jet production: pp → Xp
Generated particles – Energy weighted
(here diffractive sample with gap at positive η)



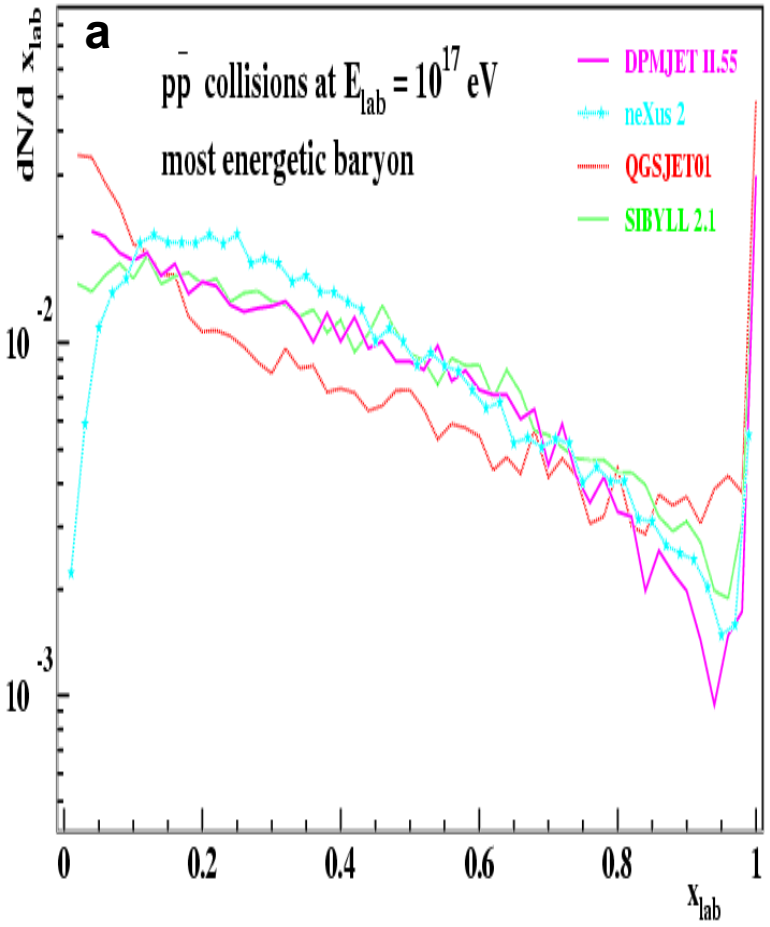
- **Diffractive event candidates selected on the basis of multiplicity distribution in the central tracker, in the HF and/or CASTOR [in the gap side]**
- **"Gap side" defined as that with lower hadronic activity in the forward region**

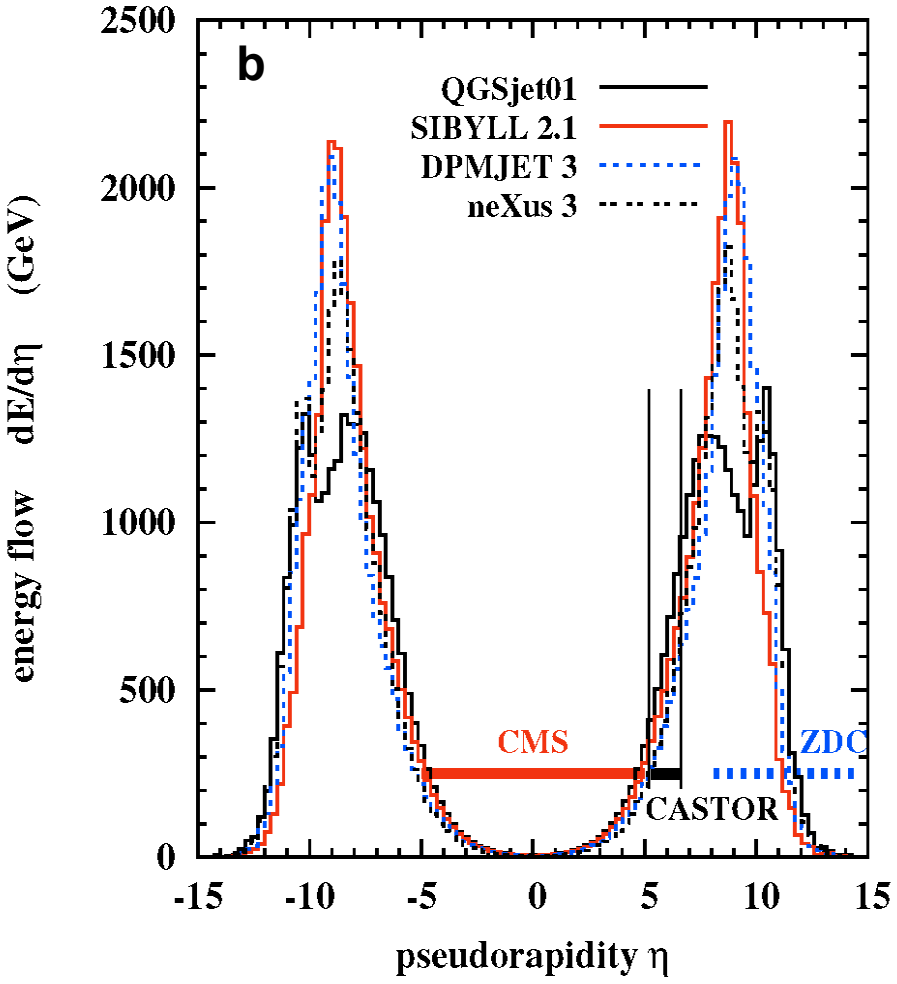
High Energy Cosmic Rays

→ Collisions in air with 100 PeV c.o.m. E corresponds to pp interaction at LHC

→ Models for showers by primary cosmic rays (PeV=10^{15} eV) differ substantially

→ Tune shower models by comparing to measurements with T2, CASTOR, ZDC.

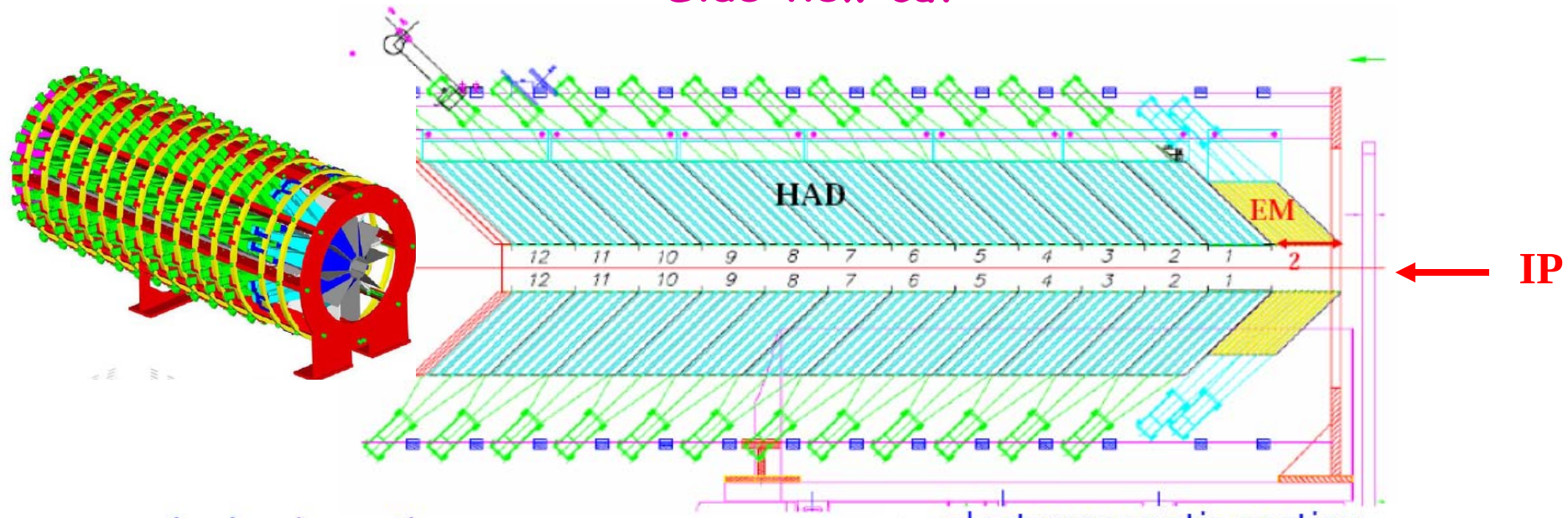




The "CASTOR" Calorimeter

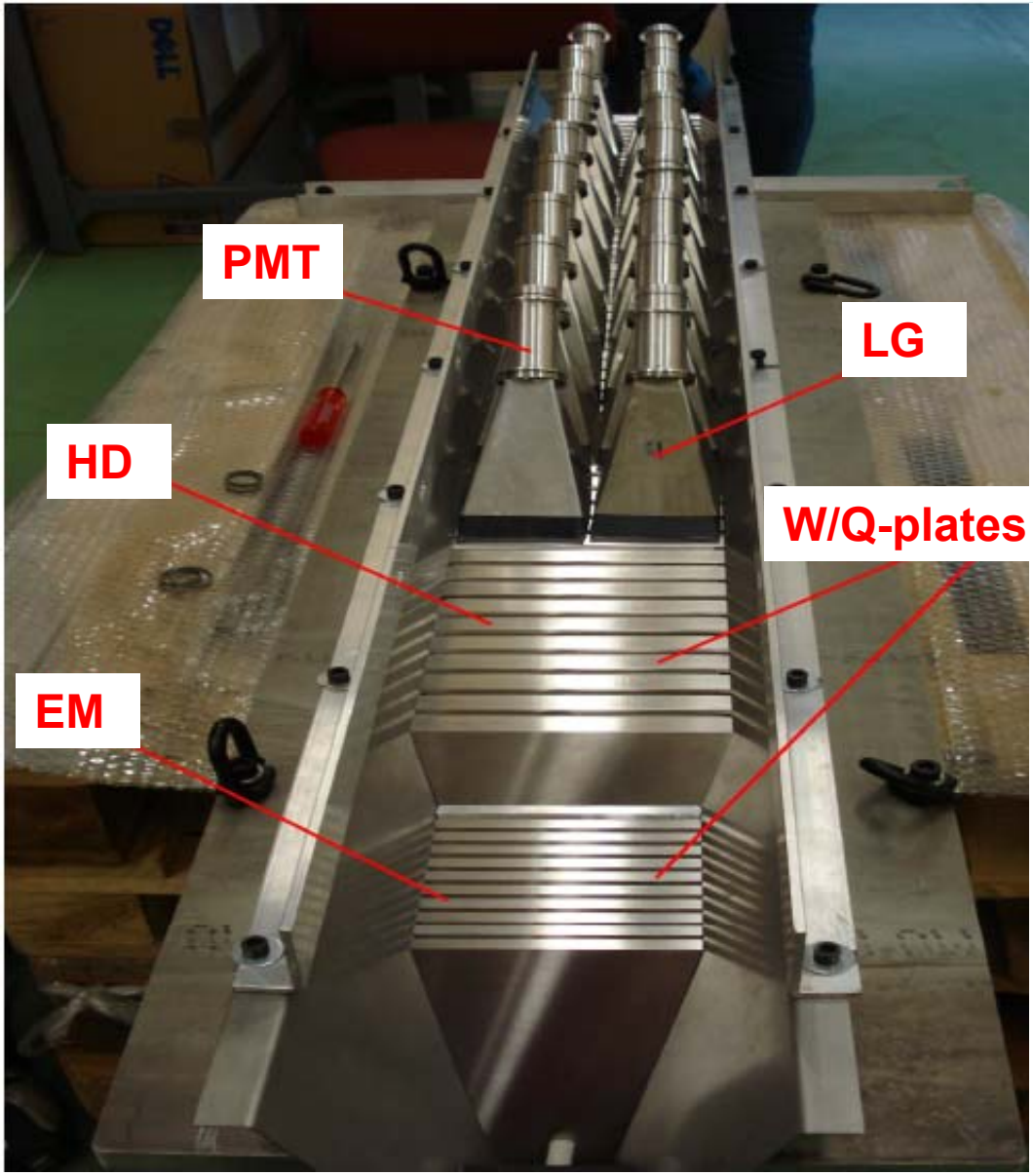
The "CASTOR" Calorimeter design

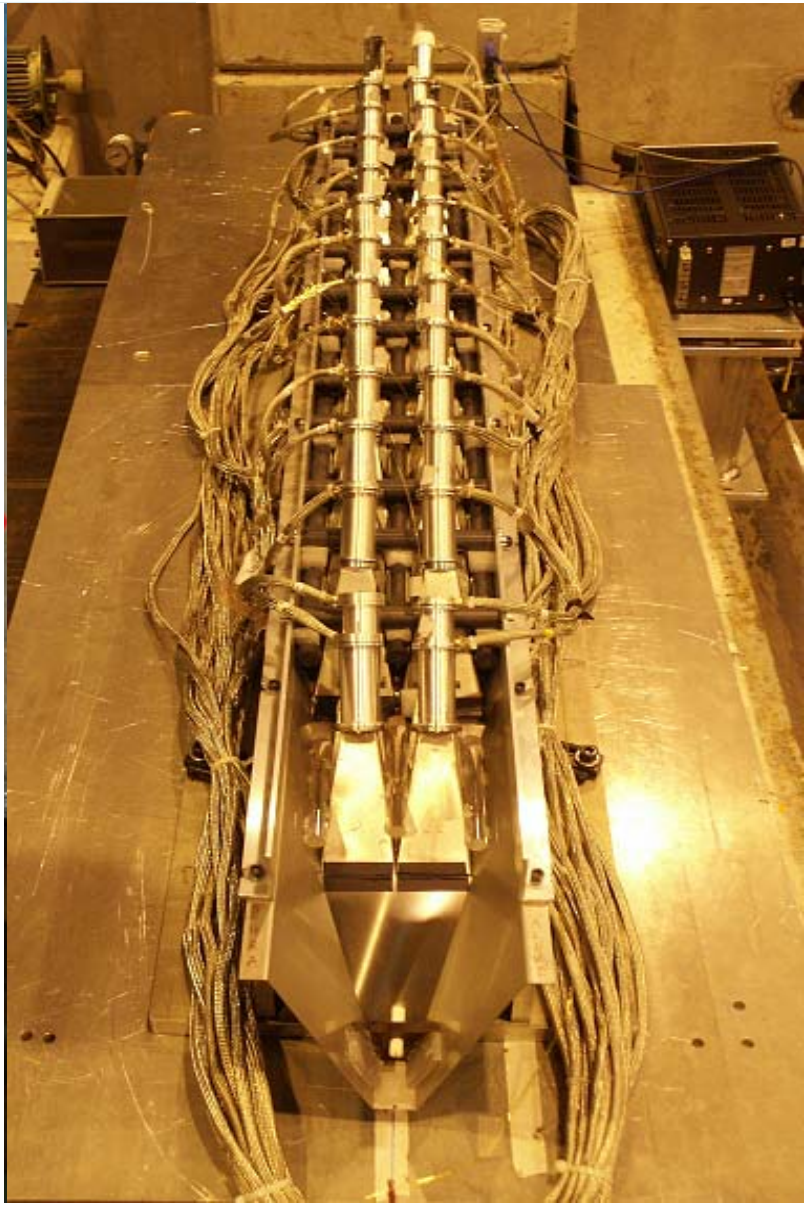
Side view cut



- hadronic section
  - absorber: tungsten plates of 10mm thickness
  - active material: fused silica plates of 4mm thickness
  - 5 tungsten-quartz sandwiches form 1 reading unit
  - total interaction length (2+12 r.u.) 10.3 λ_I
- electromagnetic section
  - absorber: tungsten plates of 5mm thickness
  - active material: fused silica plates of 2mm thickness
  - 5 tungsten-quartz sandwiches form 1 reading unit
  - total radiation length (2 reading units) =20.12 X_0

Full-length octant Prototype BT 2007 & 2008





BT 2007 Results

CMS Note-2008/022.

EPJ manuscript No.
(will be inserted by the editor)

Performance studies of the final prototype for the CASTOR forward calorimeter at the CMS experiment

V. Andreev[1], X. Aslanoglou[2], A. Azman[3], M.N. Bakirci[3], S. Başeğmez[3], W. Beaumont[4], J. Blocki[5], K. Borras[6], A. Campbell[6], S. Çerçi[3], D. d'Enterria[7], M. de Silva[7], I. Dumanoğlu[3], S. Erturk[3], E. Eskut[3], Y. Ershov[8], P. Göttlicher[6], L. Gouskos[9], G. Onengut[3], Y. Gusev[10], H. Jung[6], I. Katkov[6,14], P. Katsas[9,a], L. Khein[6,14], F. Kisoglu[3], A. Knutsson[6], S. Kuleshov[11], A. Kuznetsov[8], M. Lebeau[9], T. McCauley[12], C. Muhl[6], Y. Musienko[12,13], S. Ochesanu[4], M. Oroku[7], K. Ozdemir[3], S. Ozturk[3], A.D. Panagiotou[9], S. Reucroft[12], M. Ripert[4], K. Shileev[13], K. Sogut[3,15], J. Swain[12], V. Tiflov[13], A. Kayis-Topaksu[3], H. Van Haevermaet[4], P. Van Mechelen[4], and E. de Wolf[4]

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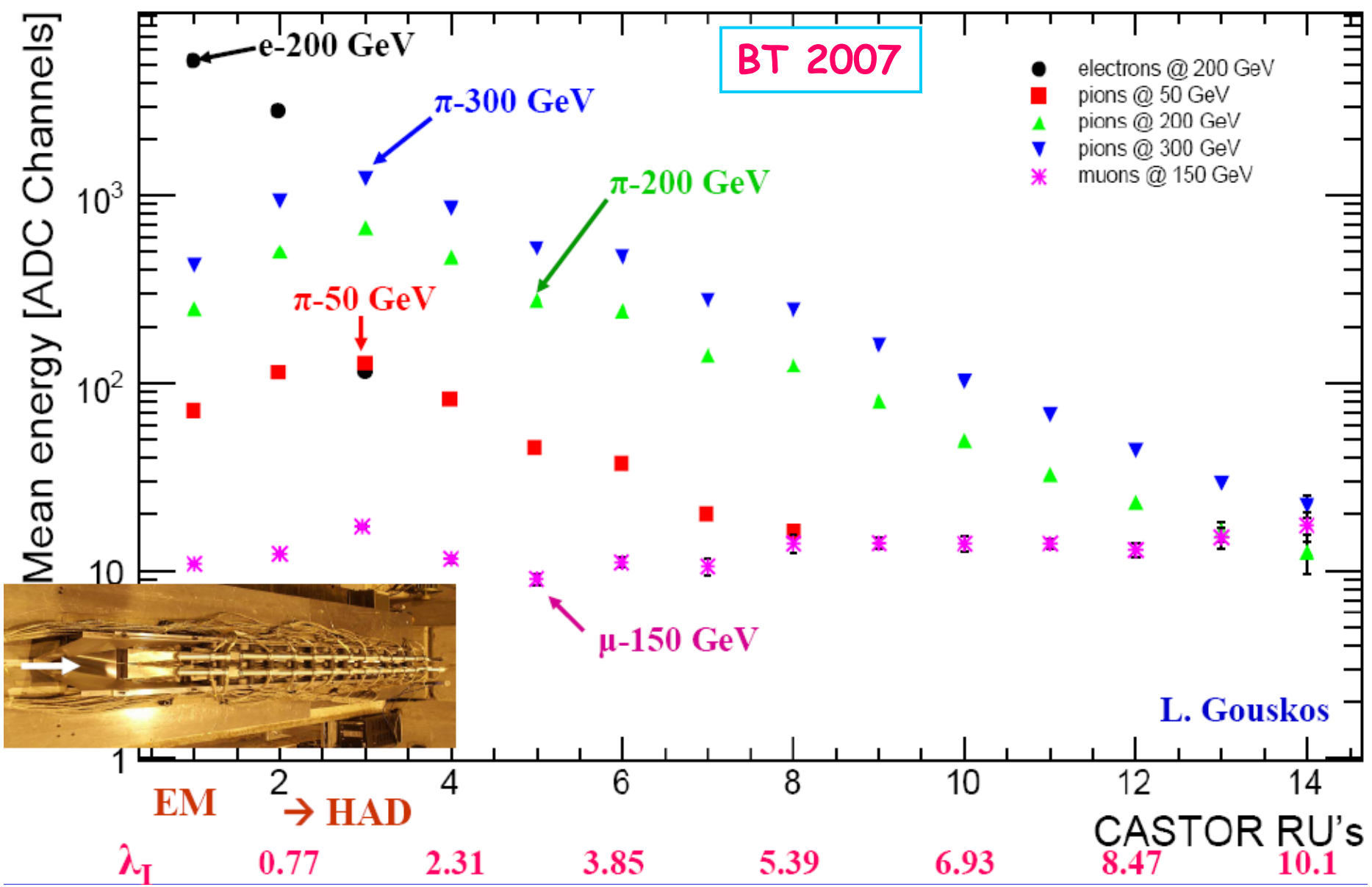
Abstract. We present performance results of the final prototype for the CASTOR quartz-tungsten sampling calorimeter, to be installed in the very forward region of the CMS experiment at the LHC. The energy linearity and resolution, the uniformity, as well as the spatial resolution of the prototype to electromagnetic and hadronic showers are studied with $E = 10$–200 GeV electrons, $E = 20$–350 GeV pions, and $E = 50, 150$ GeV muons in beam tests carried out at CERN/SPS in 2007.

PACS. 29.40.Vj Calorimeters – 29.40.Ka Cherenkov detectors

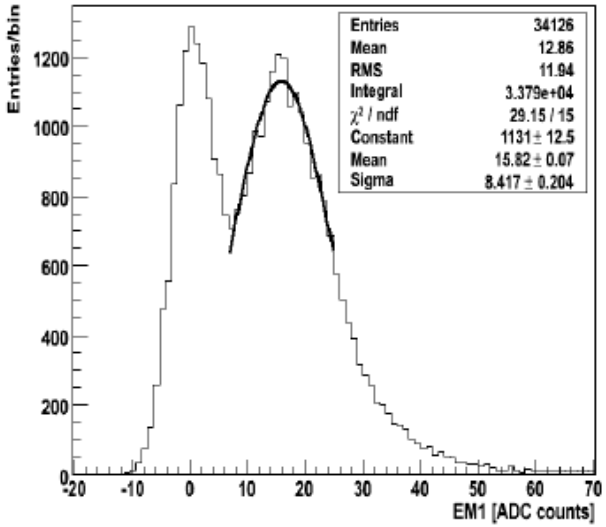
Energy distribution along depth of calorimeter

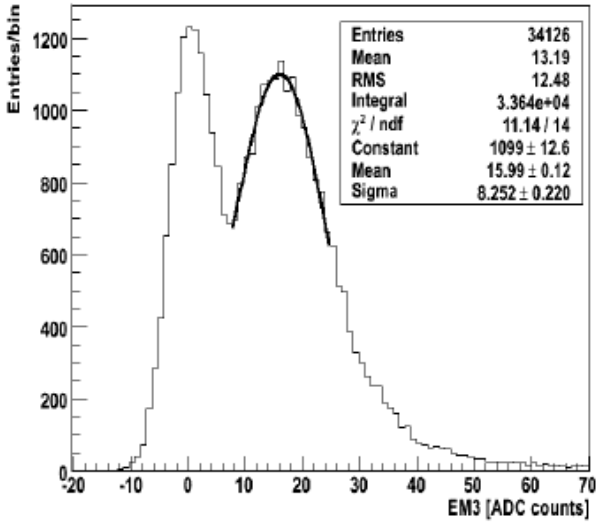


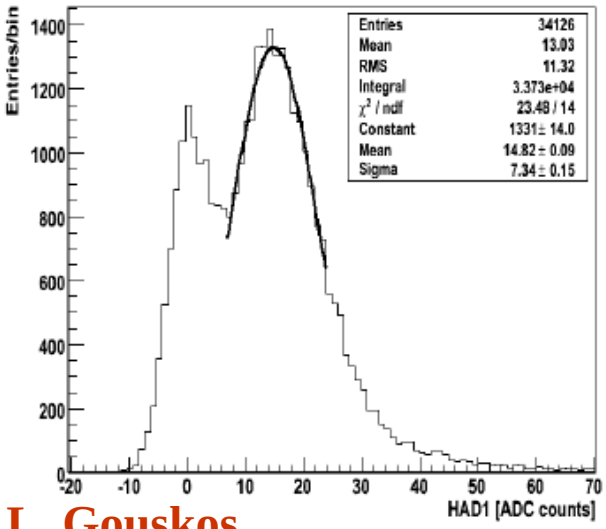
BT 2008 Preliminary Results

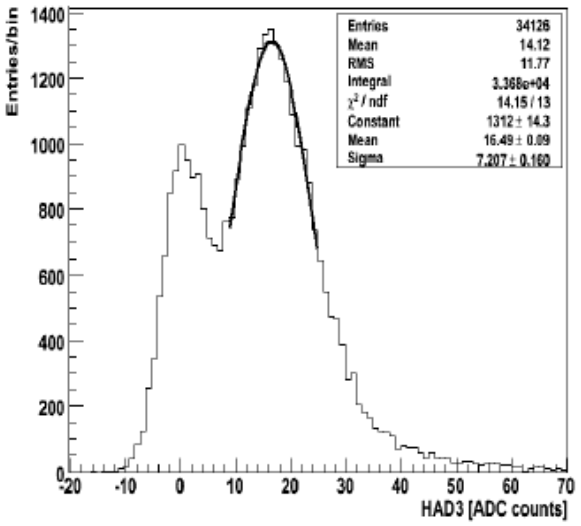
Muons - Electrons

μ^- signals @ 150 GeV

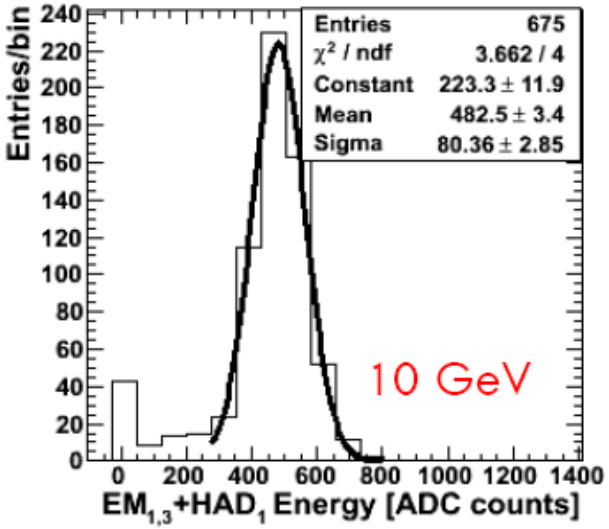


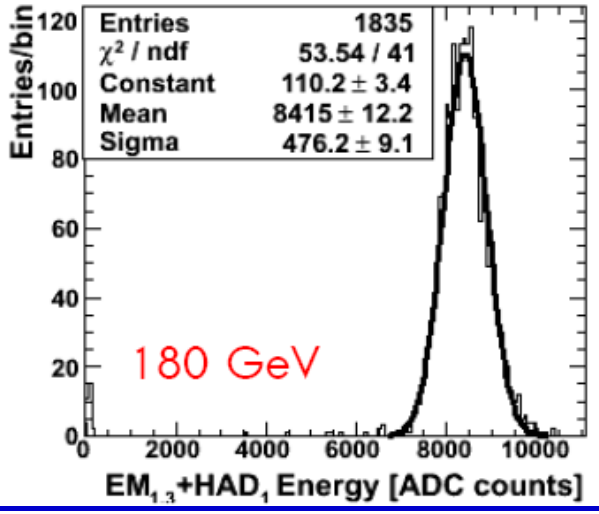






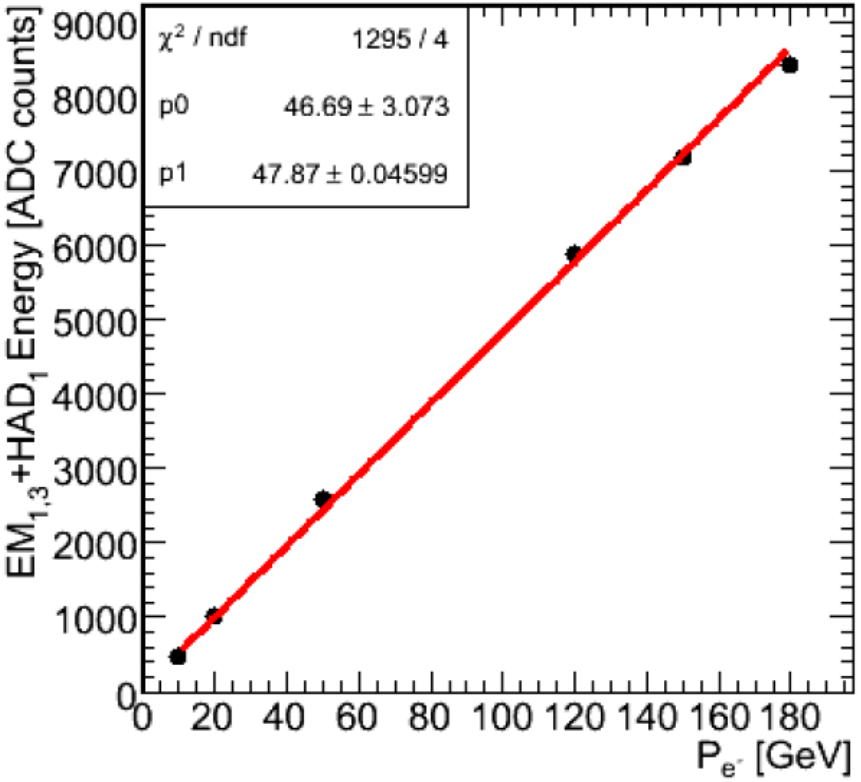
e^- signals

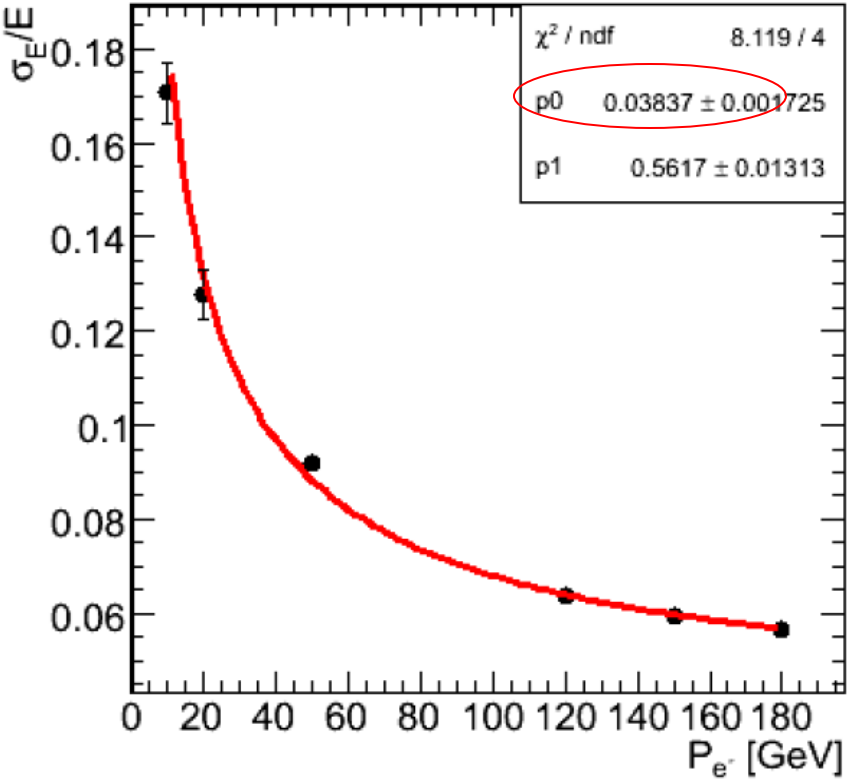


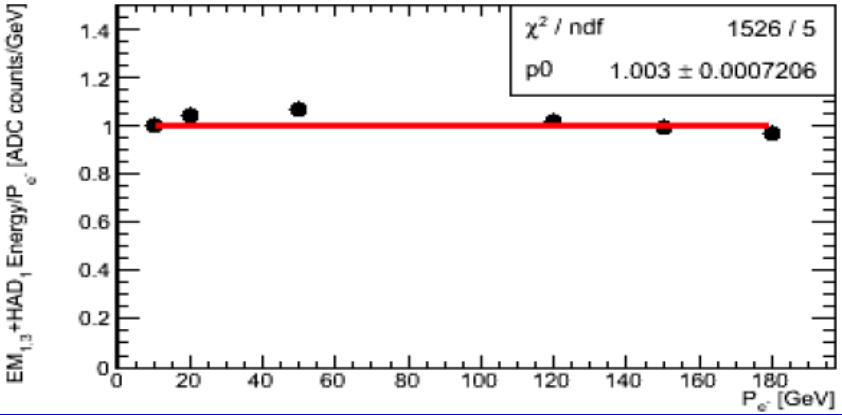


L. Gouskos

Electrons: Linearity & Resolution







Linearity

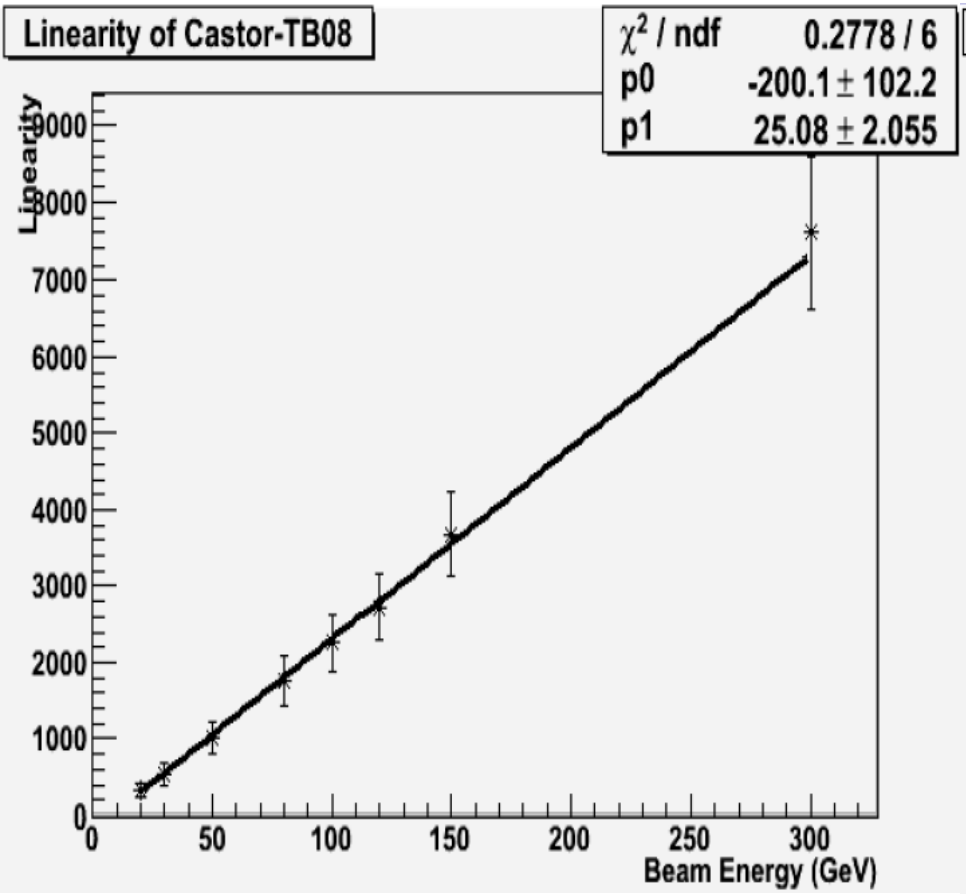
mean response (ADC counts) = p_0 + p_1xE (GeV)

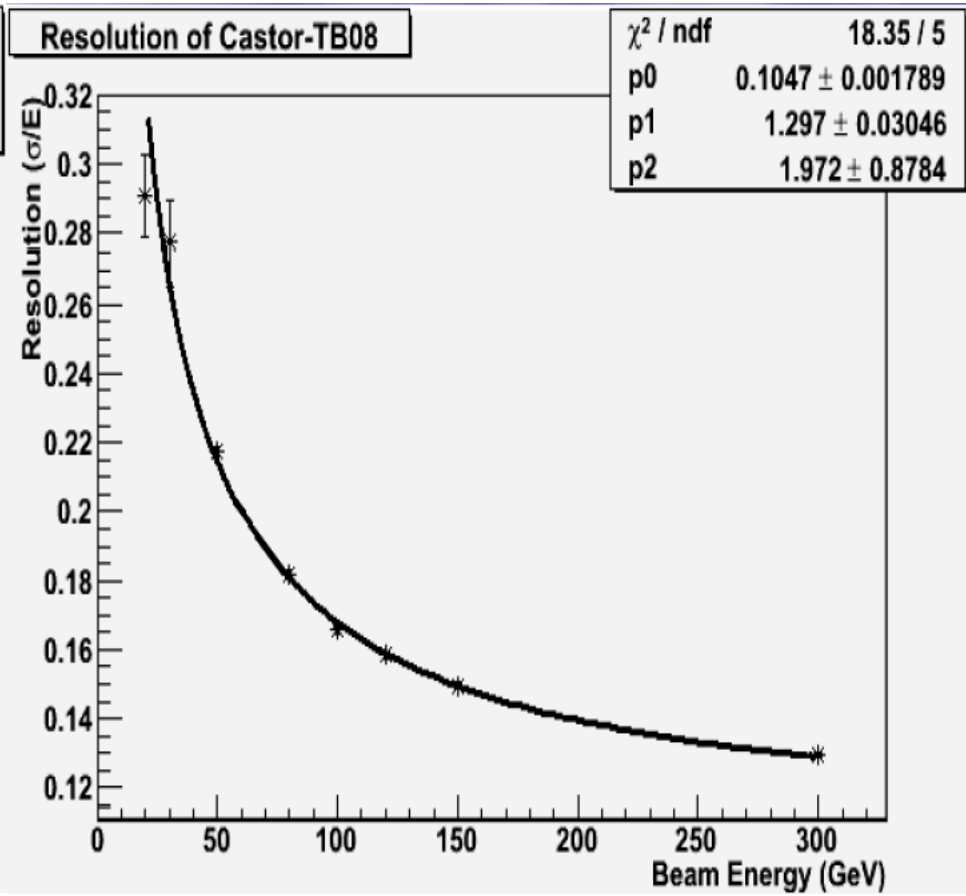
Resolution

$$\sigma/E = \sqrt{\left(p_0^2 + \left(p_1/\sqrt{(E)}\right)^2\right)}$$

L. Gouskos

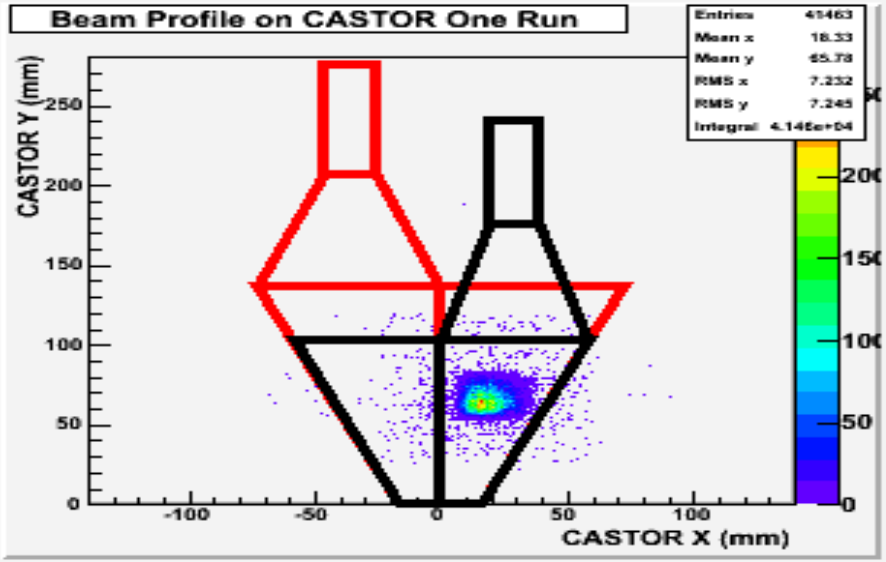
Pions: Linearity & Resolution

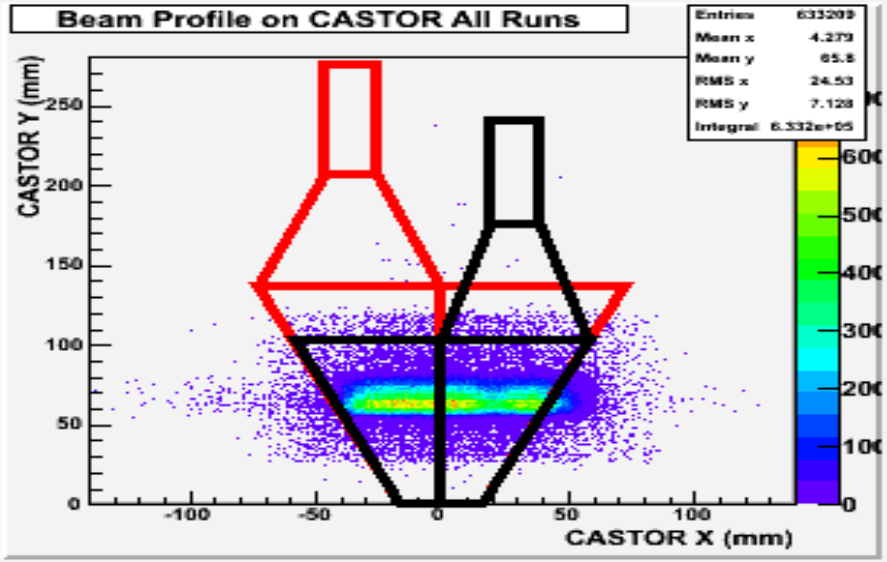


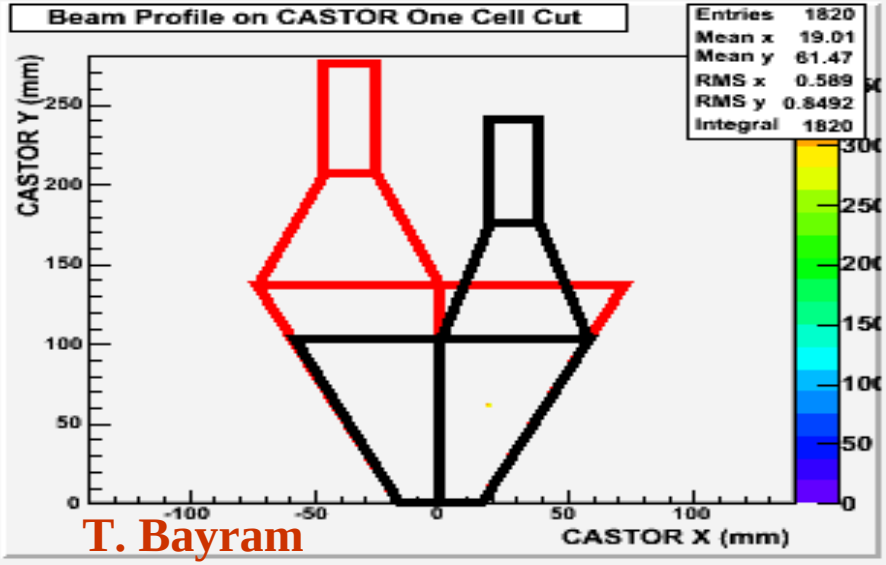


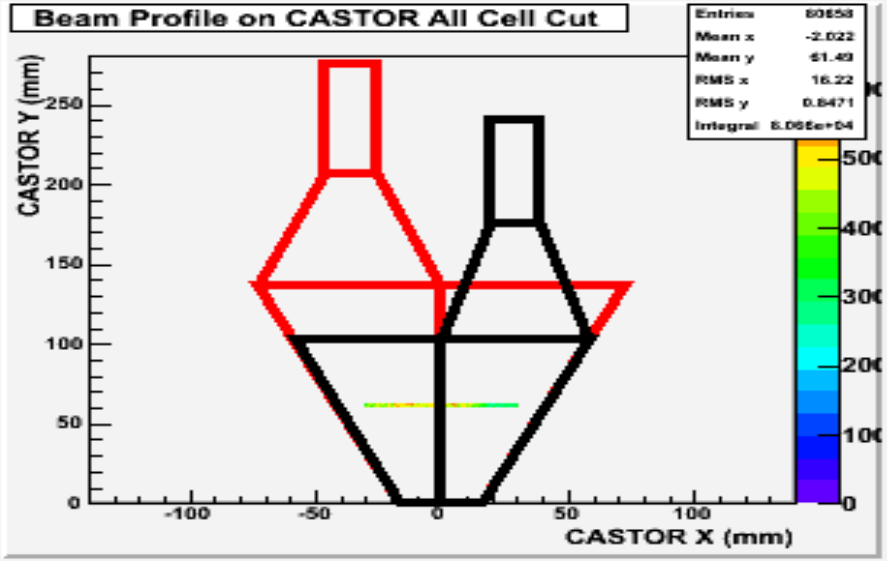
S. Girgis

X-Position Scan





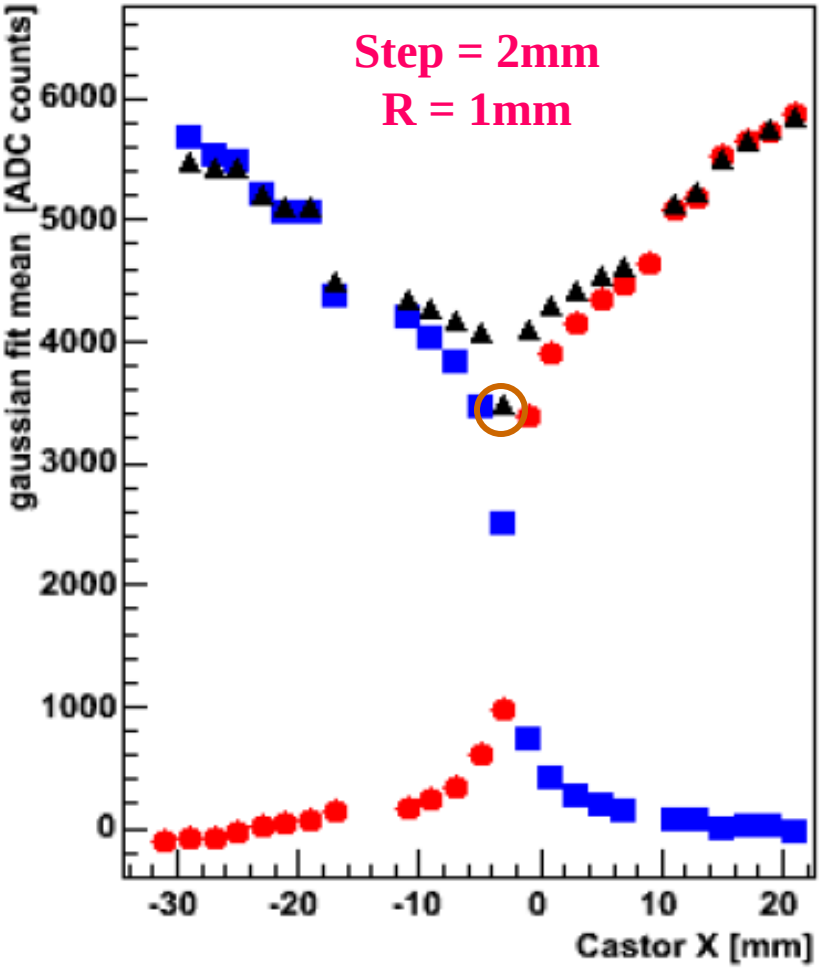


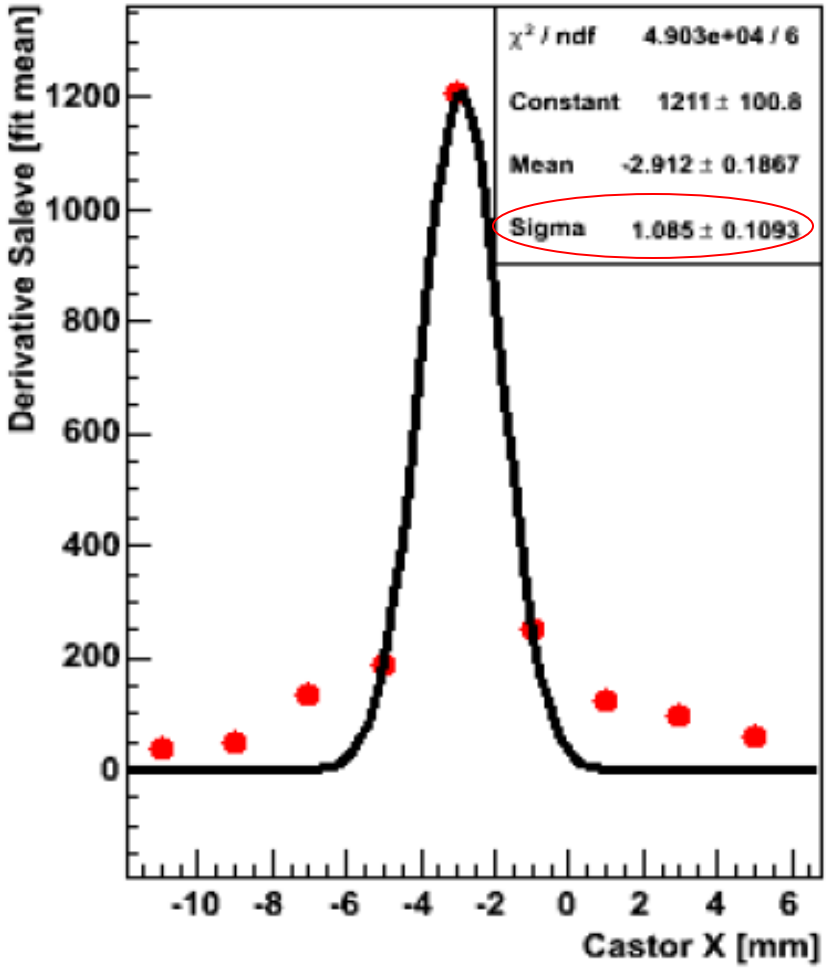


T. Bayram

X-Position Scan – Electrons

- Sigmoid curve from mean values
- Width of EM shower

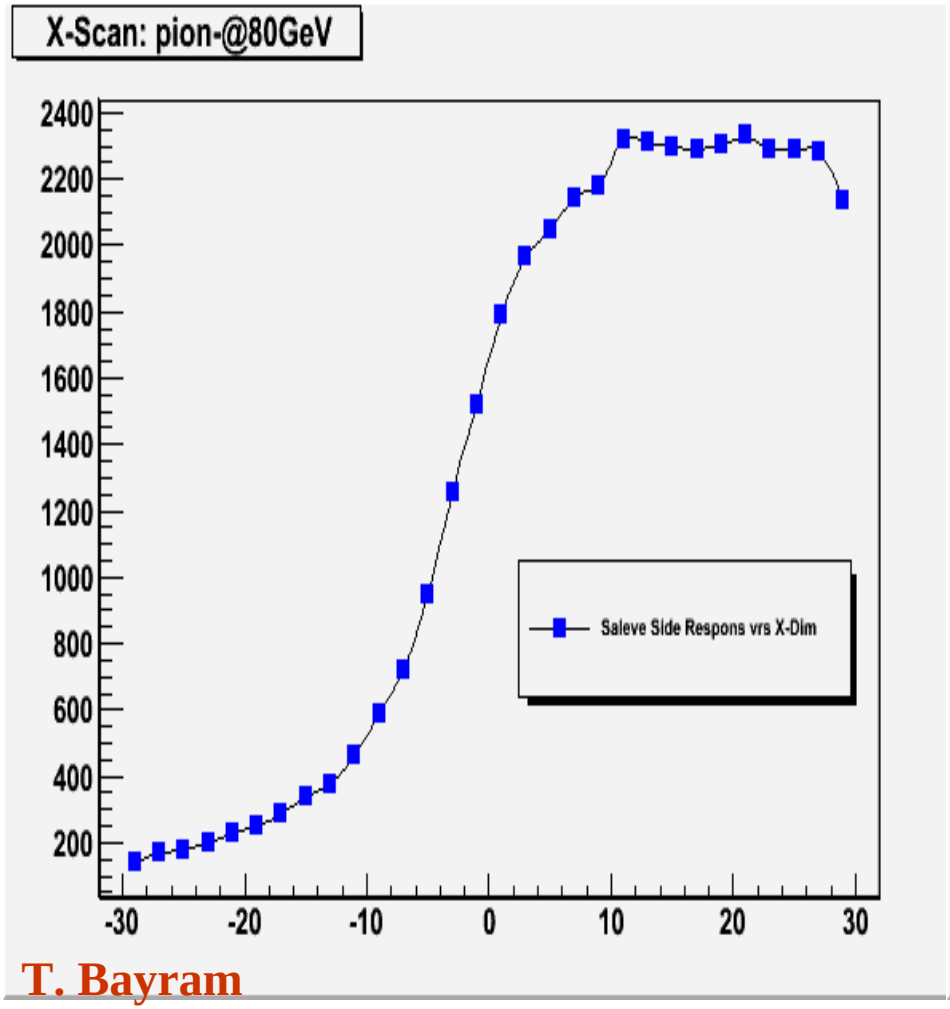


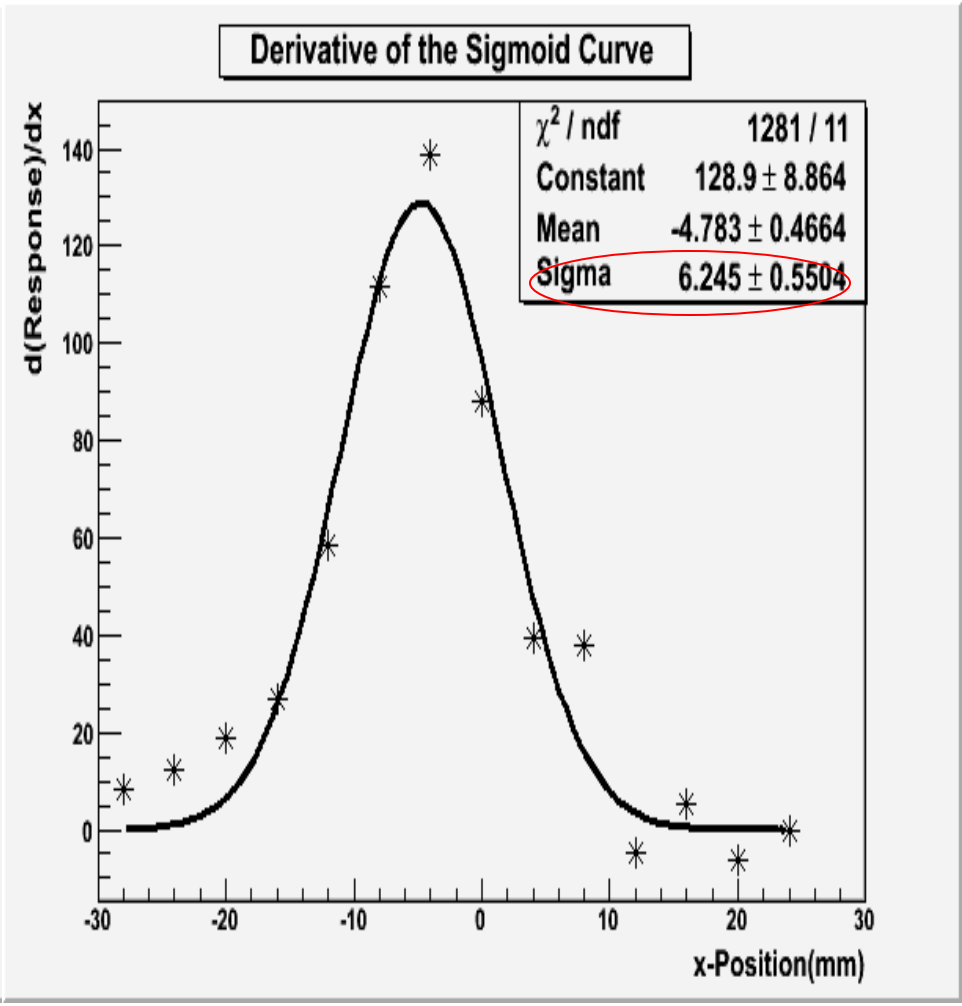


L. Gouskos

X-Position Scan – Pions

- Sigmoid curve from mean values
- Width of hadronic shower



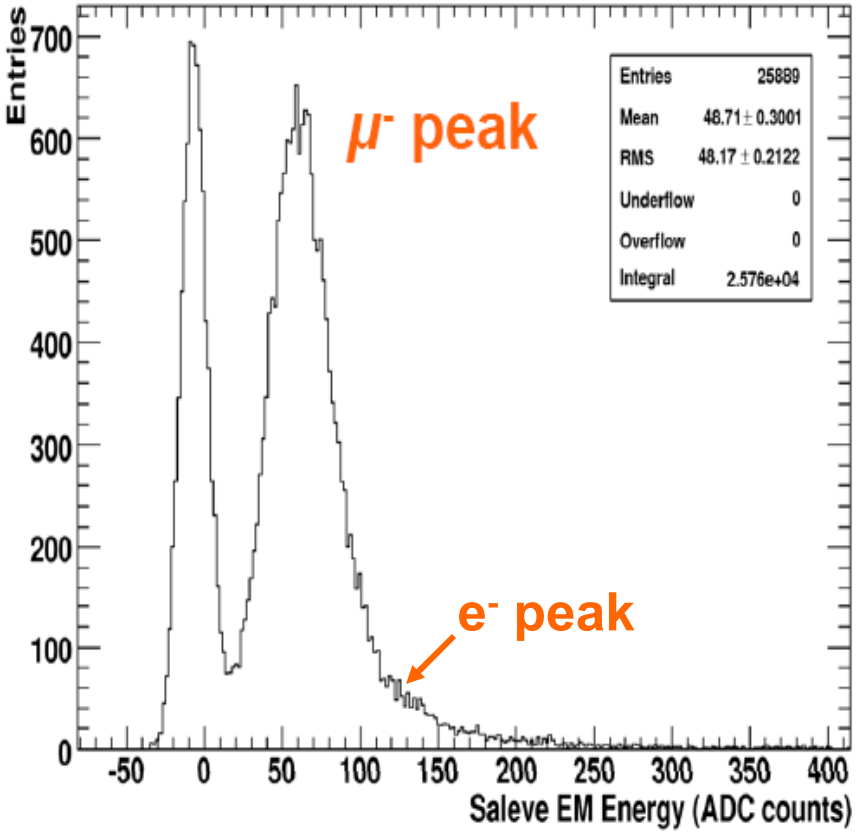


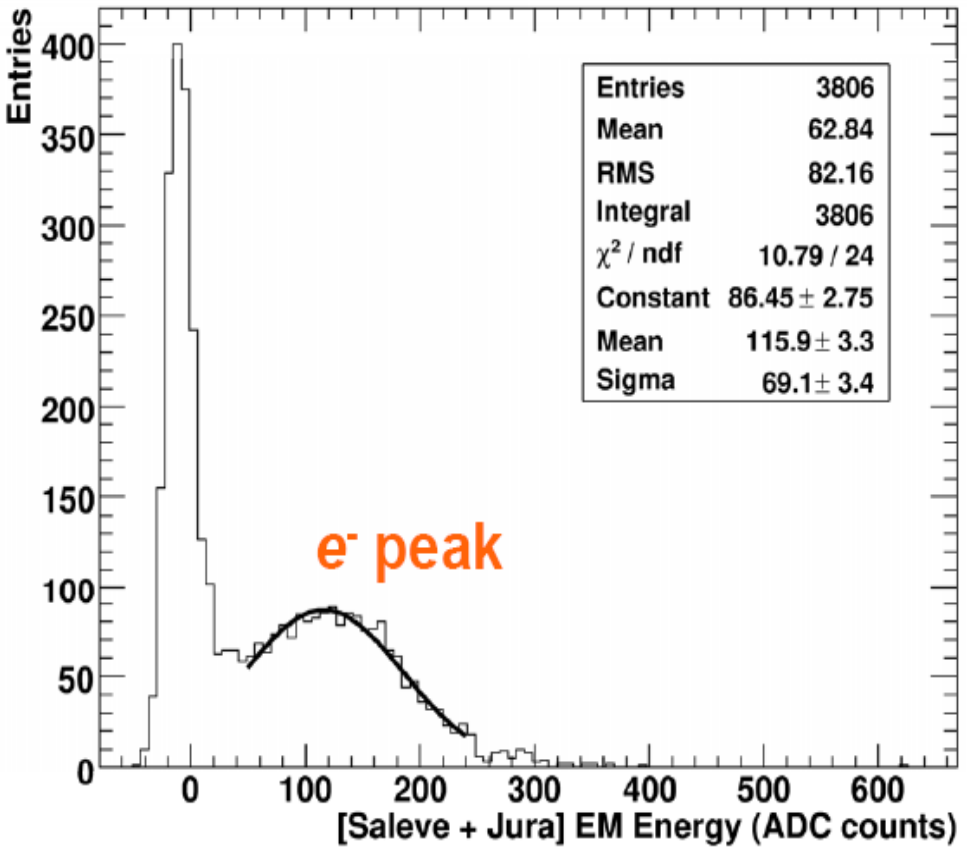
T. Bayram

VLE e^- 3 GeV: Muon Contamination

Run #48319

E=3 GeV

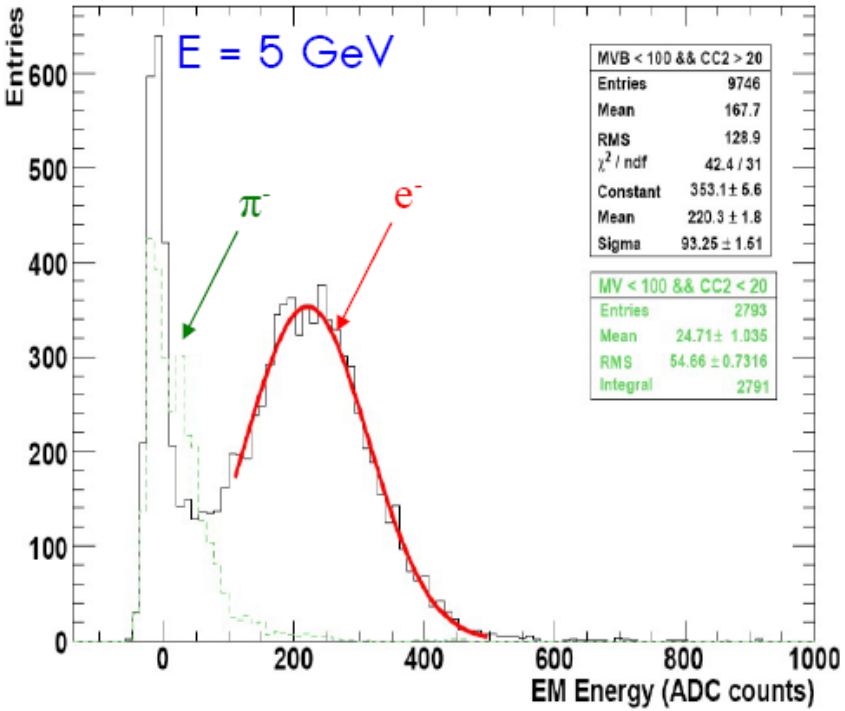


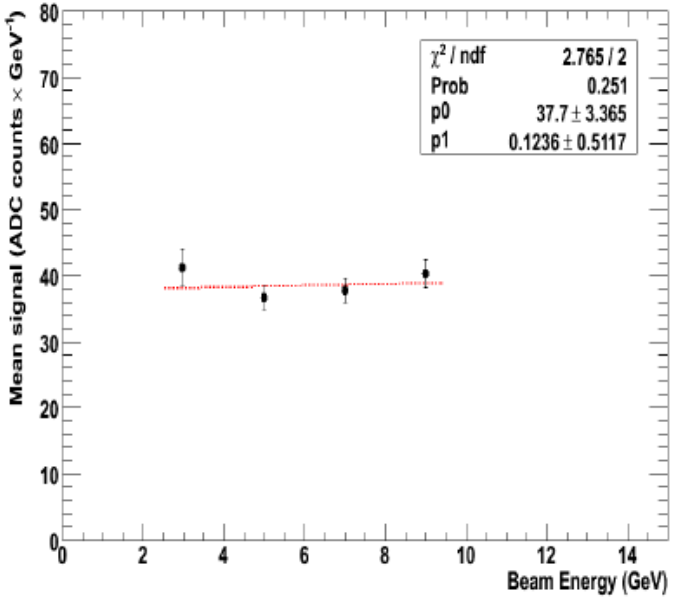


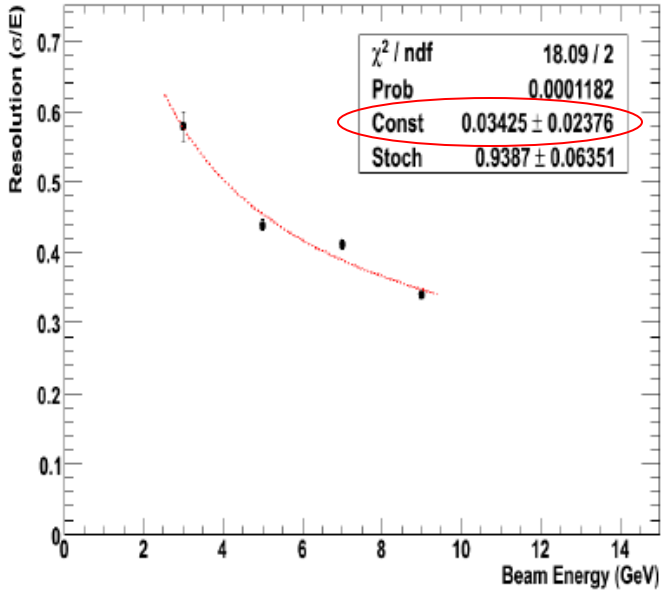
cut applied in Muon Veto (back) counter

P. Katsas

VLE e^-: Linearity & Resolution





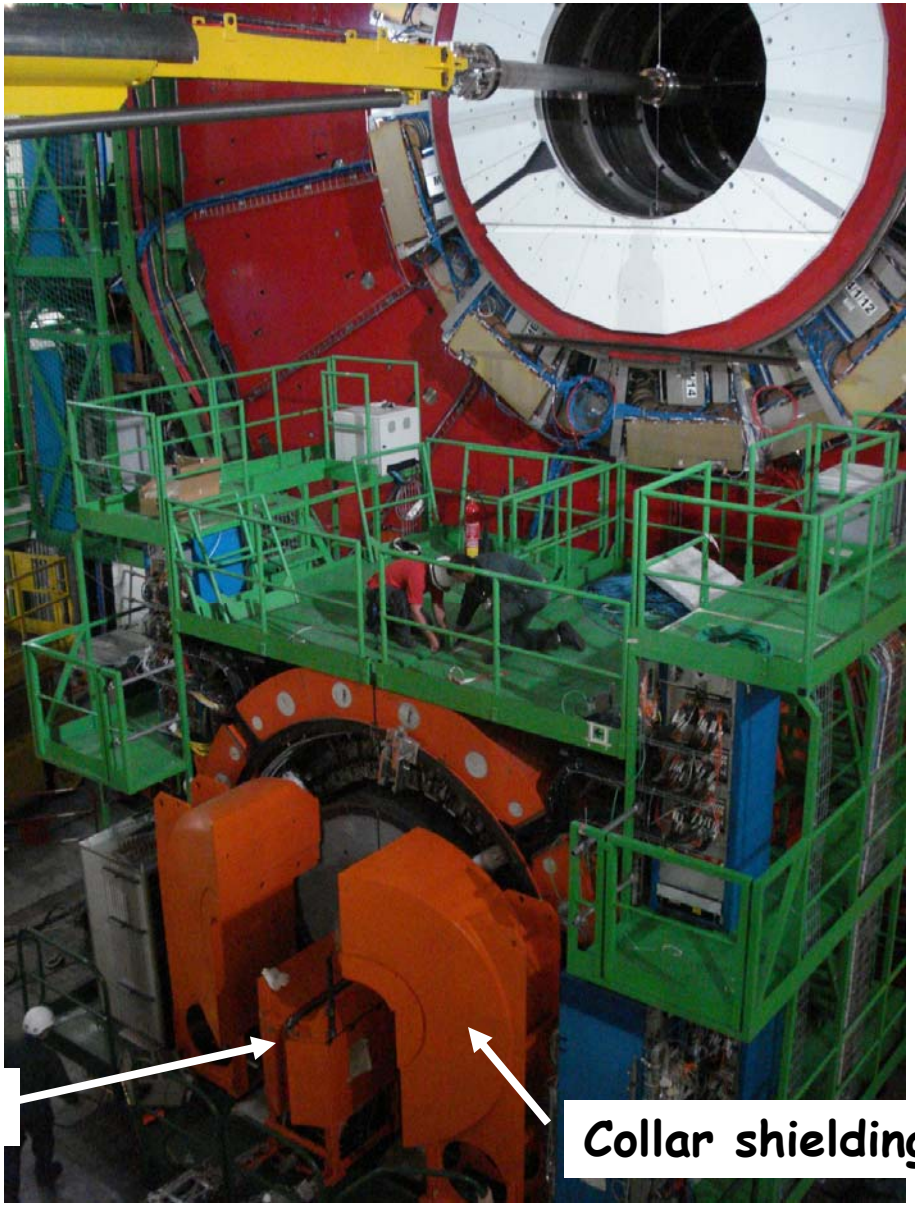


P. Katsas

½ Calorimeter installation in CMS
August 26, 2008

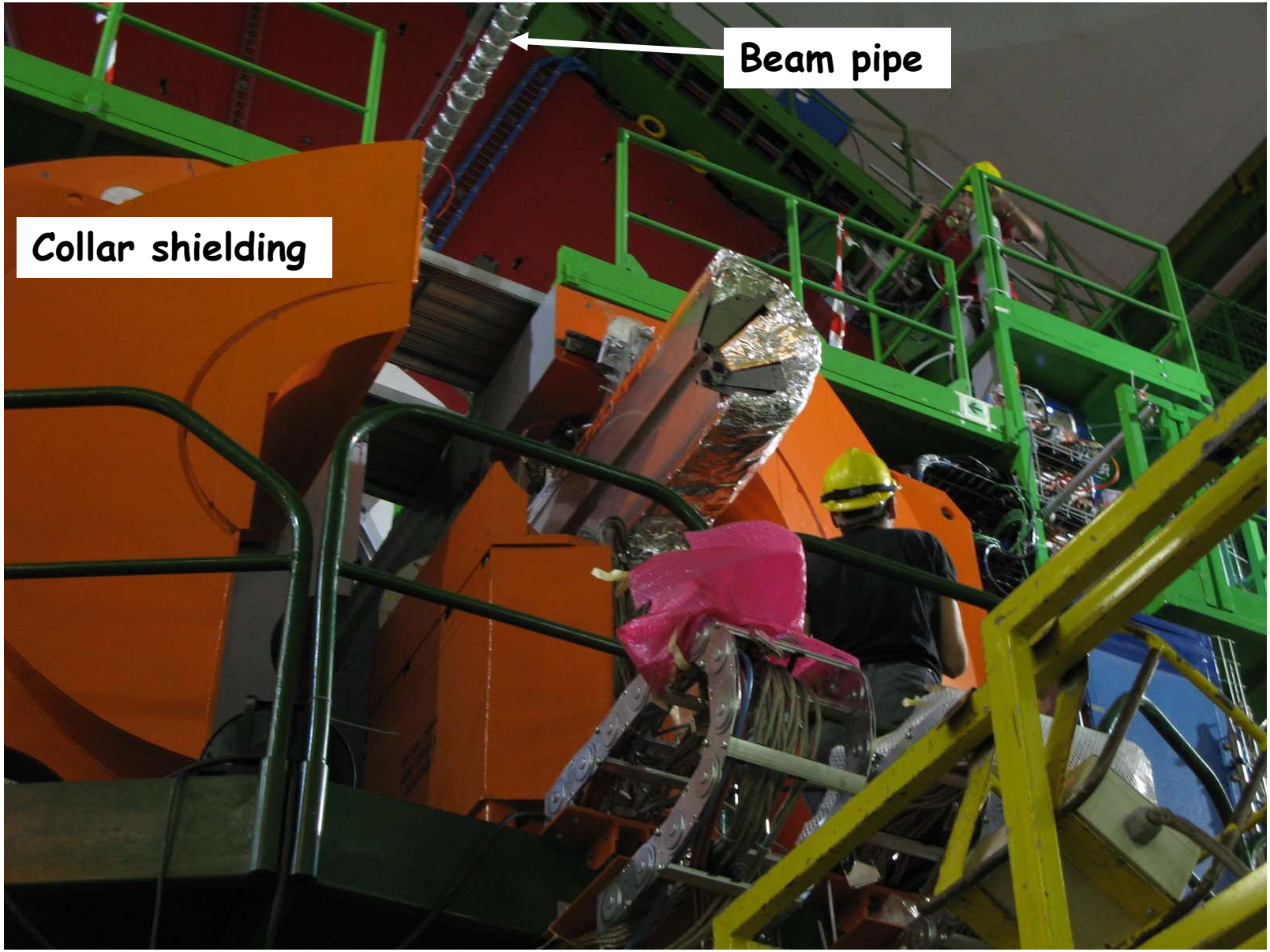
½ Skeleton one octant Instrumented

CASTOR table & Collar shielding

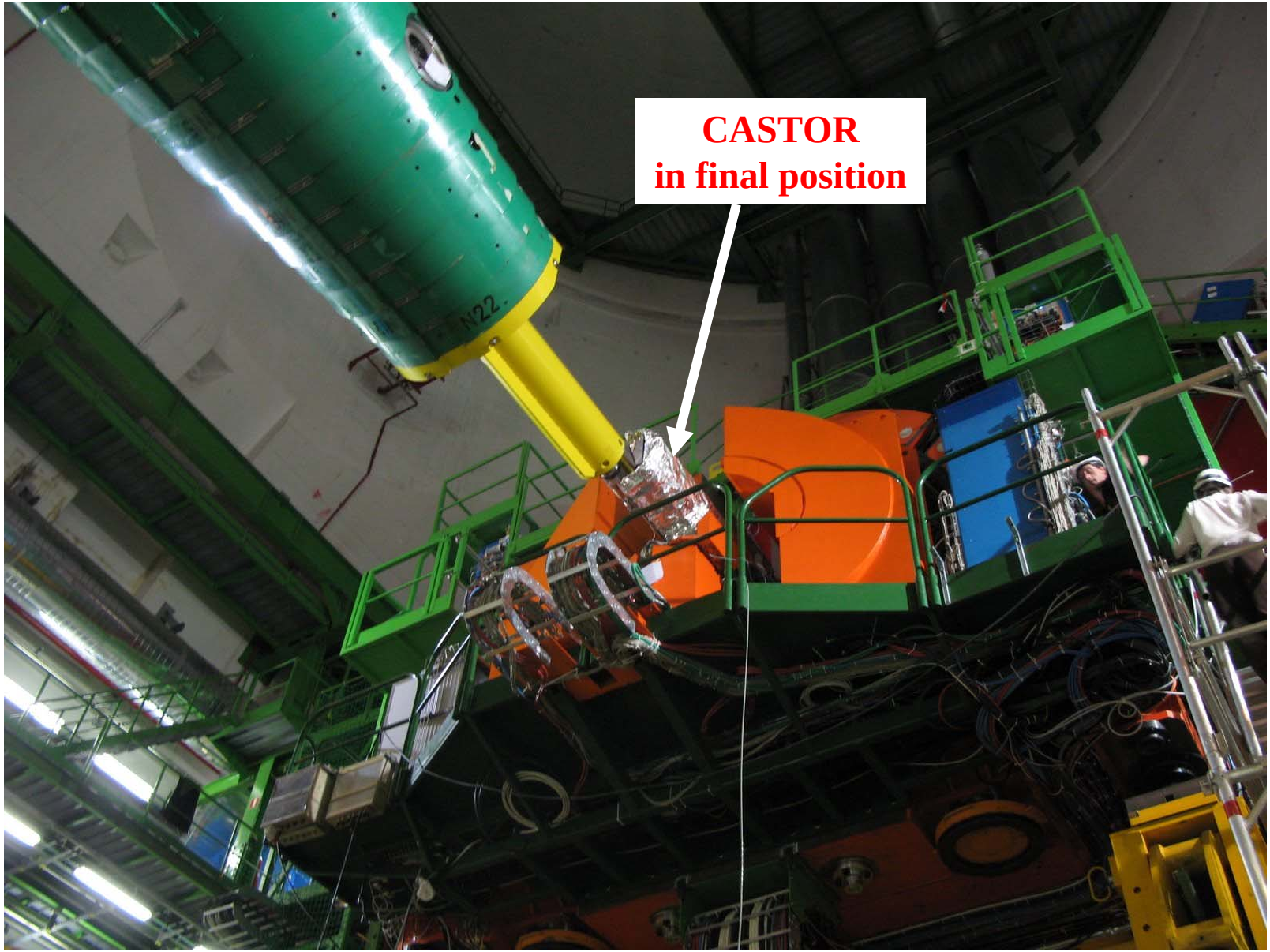


½ CASTOR on table

HF platform raised towards beam pipe



HF platform in final position



Plans for 2008 - 2009

- Take out 1st ($\frac{1}{2}$)- CASTOR, replace DELPHI with radhard Q-plates
- Produce 2nd ($\frac{1}{2}$)- calorimeter skeleton & instrument with radhard Q-plates
- Finalize electronics (esp. trigger)
- Fully instrument & commission CASTOR
- Install full CASTOR calorimeter on (-) z side. Target: March 2009

Collaborating Institutes & Tasks

- **Antwerp:** Trigger, Installation, funding; Electronics coordination
- **Athens:** Design, SW-MC, beam test, analysis, funding; Project management
- **Brazil:** Assembly, analysis
- **CERN:** Beam test, analysis; SW-Physics coordination
- **Cukurova :** PMT testing, assembly, beam test, analysis
- **DESY:** FEA calculations, construction, electronics, DAQ, analysis, funding; Project management
- **JINR:** Design; Technical coordination
- **INR:** Light guides & 2mm Q-plates, funding
- **ITEP:** Laser/LED calibration system
- **MSU:** Electronics, DCS/data base, MC, analysis (within HRJRG with DESY)
- **Northeastern:** Readout devices