Operational experience with the very forward calorimeter CASTOR at CMS

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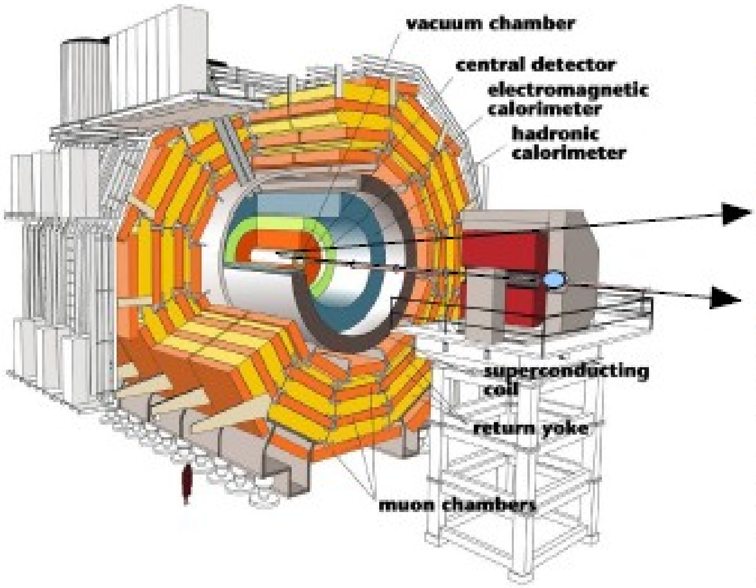
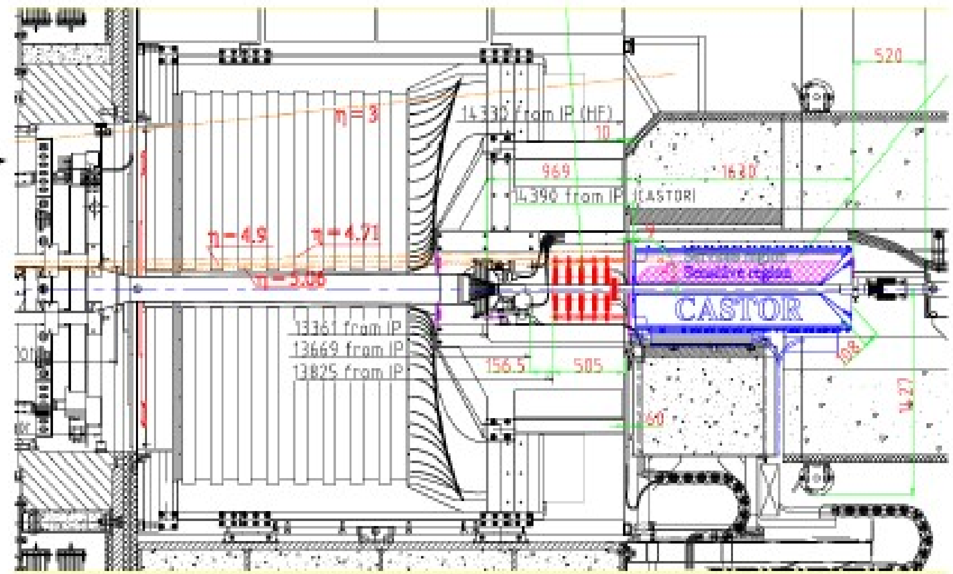
On behalf of the CMS collaboration

Outline

- Physics motivation
- CASTOR calorimeter in CMS
- Results from test beam and Monte Carlo validation
- Very first data collected with CASTOR at LHC
- Conclusions

Placement and Physics Programe





- Underlying Event/ Multi Partonic Interaction
- Parton Shower Evolution
- Diffraction
- Cosmic Ray Physics

low-luminosity proton-proton and heavy-ion collisions

Underlying event and why do you care about it?

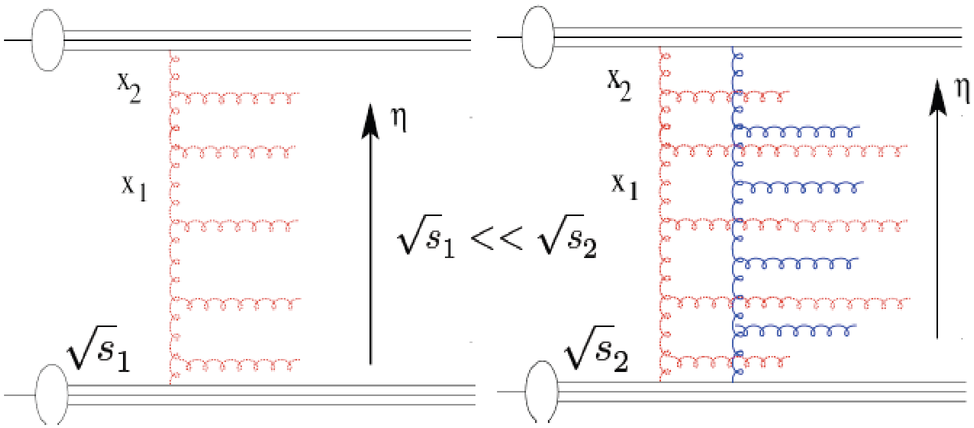
- UE constituents: Everything except first hard interaction

  - Soft beam remant interaction
  - additional (semi)hard constituent scatterings (multi-parton interactions, MPI)
  - Intial and final state radiations . . .

→ hard to calculate because these process are related with soft physics and non-perturbative interactions play a dominant role.

→ need to model them phenomenologically

Small -x region



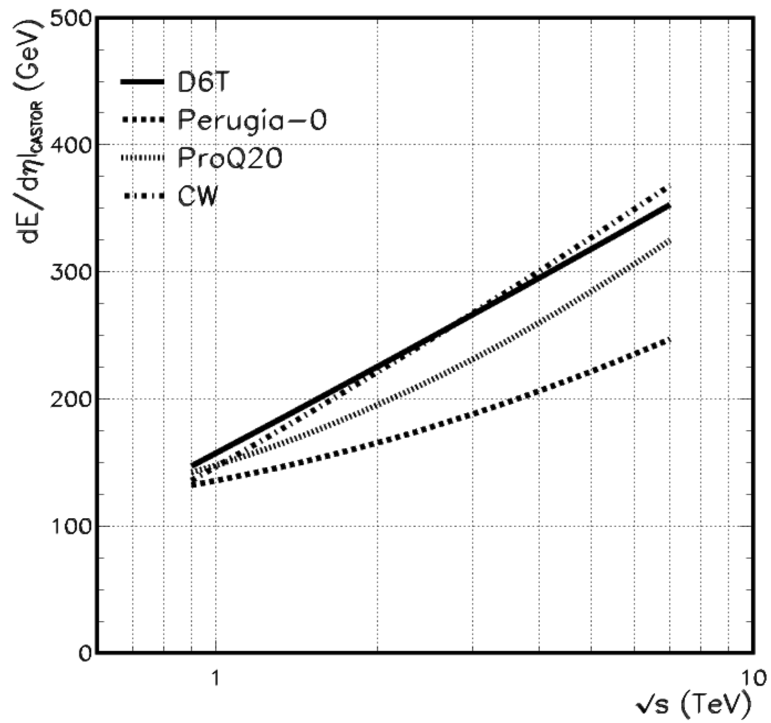
- At high energies low x values become accessible and the density of partons grows with decreasing x, in this dense system of partons, many of them could interact
- Probability for more than one partonic interaction per event increases.

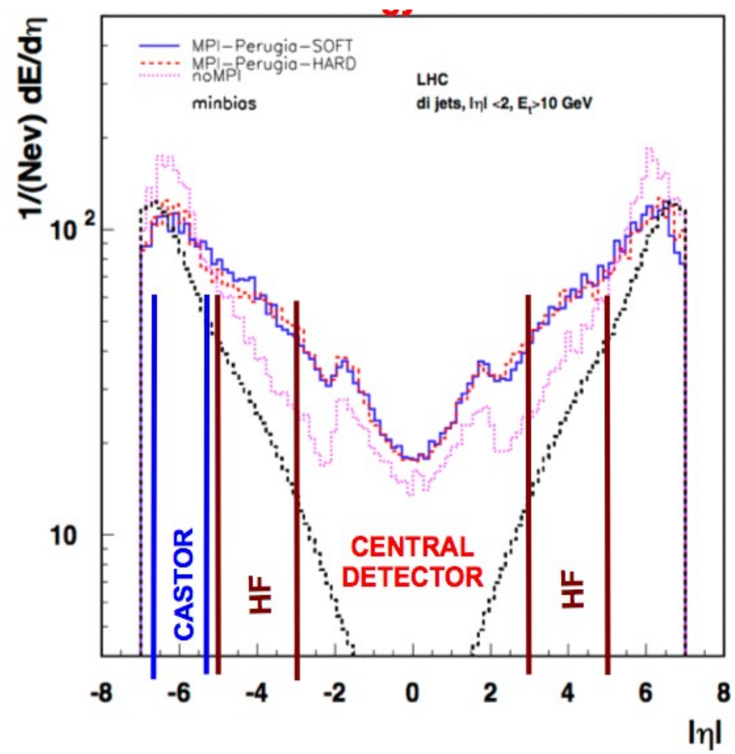
➔ UE has several components, adjusting MC models to mimic the data is challenging.

Underlying event and CASTOR

- MPI affect strongly the energy flow in the forward region and induce correlation in activity between central and forward region
  - energy deposit sensitive to different MPI modeling

[G.Brona talk]

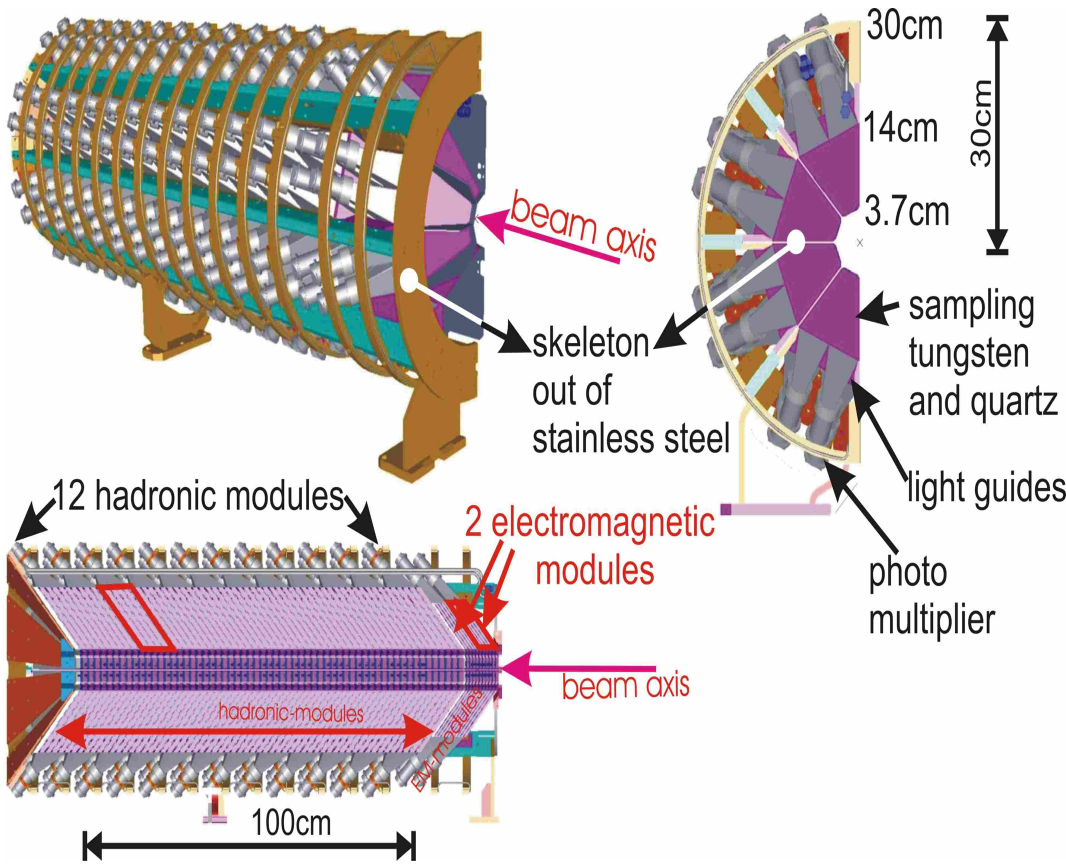




- **CASTOR** can make a relevent measurement and improve the UE modeling at very high eta.

CASTOR calorimeter

- Cerenkov calorimeter situated at 14.39 m (-z) from CMS IP
- extend the coverage of CMS in forward direction to $-6.6 < \eta < -5.2$
- sampling calorimeter with quartz plates as active medium and tungsten as absorber → compact, radiation hard and fast
- electromagnetic and hadronic module
- 16 – azimuthal sectors (φ)
  14 – longitudinal module (z)
  224 readout channels
  no segmentation in η



CASTOR in CMS cavern

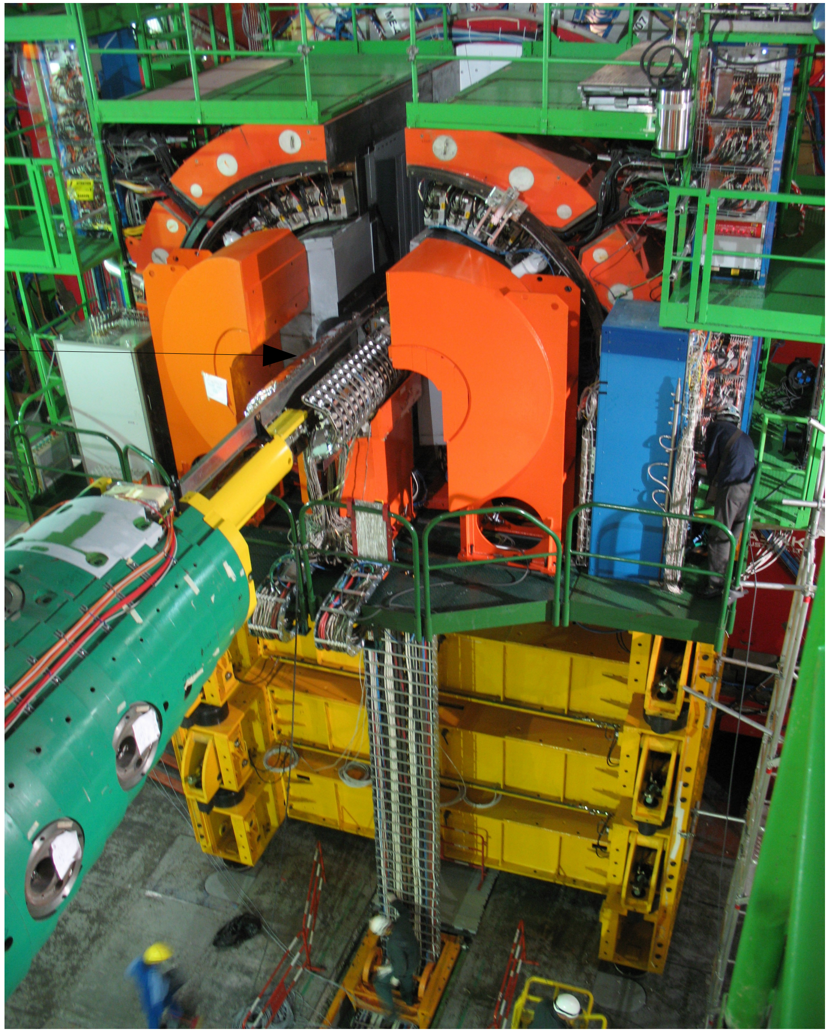
- Fully functional and integrated into CMS operations since **June 2009**

- operation in magnetic field (≤ 0.16 T)
  ► modules from 6 (3.5λ) to 9 (5.6λ)
  loss in the efficiency;
  some channels can be recovered

CMS preliminary

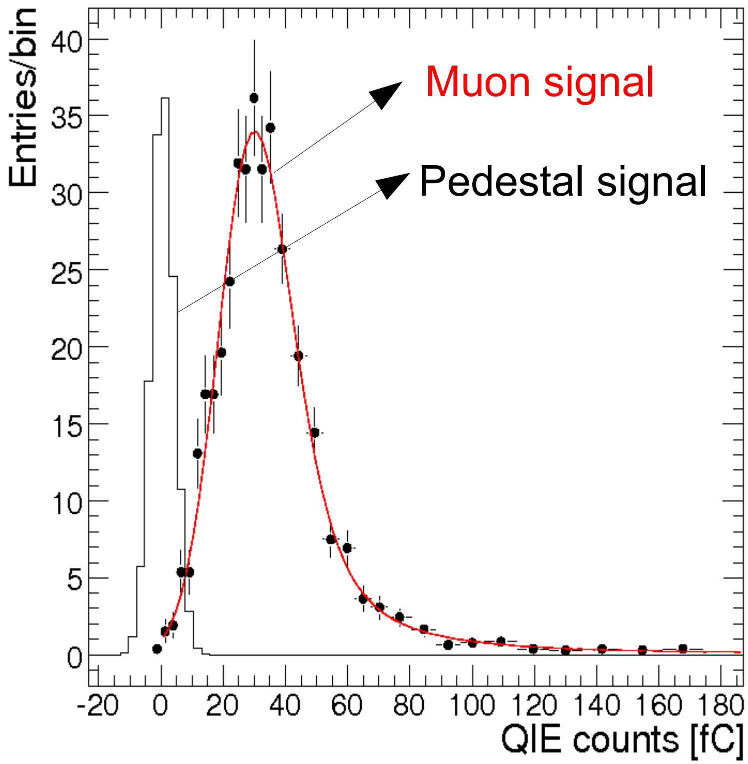
φ	1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	0.96	1.03	1.06	1.10	1.44	0.71	0.03		0.79	0.92	1.00	1.09	1.12	1.06
15	1.06	1.00	1.0	1.11	1.32	1.44	0.02		0.89	1.01	0.98	1.03	1.09	1.10
14	0.93	1.02	1.07	1.06	1.35	0.60	0.04		0.82	0.94	1.13	1.12	1.21	1.3
13	1.01	1.05	1.05	1.15	1.48	0.21	0.03			0.87	1.03	1.13		1.21
12	0.99	1.10	1.12	1.10	1.10	0.17	0.00	0.00	0.67	0.86	1.07	1.05	1.16	1.21
11	0.99	1.00	1.10	1.14	1.31	0.28	0.01	0.02	0.81	0.99	1.06	1.01	1.08	1.10
10	1.10	1.06	0.99	1.06	1.08	0.34	0.01	0.69	0.98	0.98	1.01	0.95	0.99	1.19
9	0.99	1.00	1.03	1.09	1.01	0.33	0.02	0.76	0.83	0.95	0.95	0.98	1.03	0.96
8	1.03	0.85	0.94	1.00	0.91	1.14	0.02	0.77	0.78	0.88	0.95	0.93	1.03	0.95
7	1.01	0.90	1.00	1.01	1.03	0.20	0.01	0.60	0.84	0.78	0.88		0.90	0.95
6		1.14	0.95	0.90	1.23	0.32	0.02	0.02	0.75	0.76	0.89	0.76	0.80	0.94
5		1.00	0.95	0.95	1.2	0.49	0.07	0.01	0.04		0.82	0.68	1.06	1.03
4	0.93	1.01	0.94	1.01	0.90	0.58	0.03	0.00	0.02	0.78	0.85	0.94	0.96	1.06
3	0.98	1.00	0.97	0.94	1.08	0.60	0.03	0.03	0.42	0.78	0.93	0.96	1.08	0.89
2	0.94	0.88	0.98	0.96	1.02	1.48	0.07	0.25	0.79	0.85	0.83	0.96	0.99	1.00
1	1.11	0.95	1.01	1.11	1.06	1.91	0.04	0.72	0.83	0.96	0.92	0.98	0.99	1.06

Minimum bias data: Run 133874 (Nominal B-field) / Run 133239 (No B-field)



Results from beam test

Test beam 2007 [European Physical Journal C: Volume 67, Issue 3 (2010), Page 601]
full-length prototype tested with muons, electons, pions in wide energy range

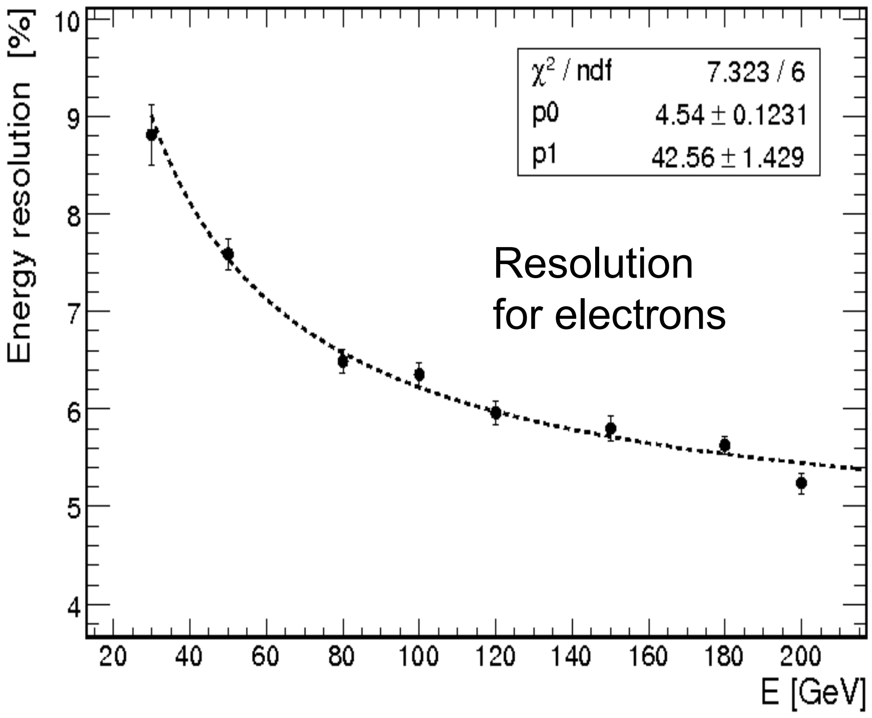


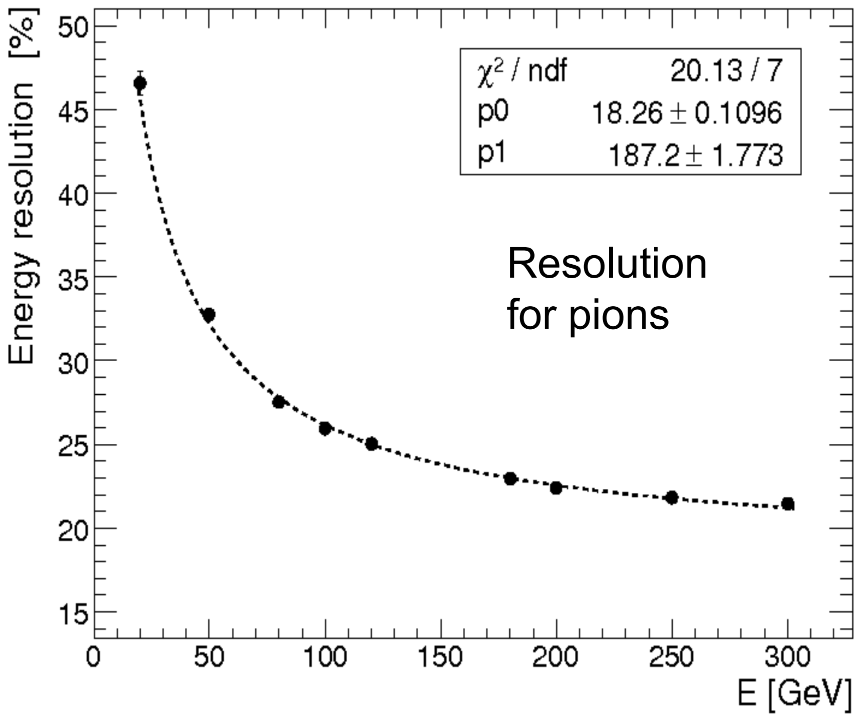
Response to **150 GeV muon** beam
in one EM channel

- clear separation of the muon signal from the pedestal
- Muons studies very important for the intercalibration

CASTOR Energy Resolution

Test beam 2007 [European Physical Journal C: Volume 67, Issue 3 (2010), Page 601]

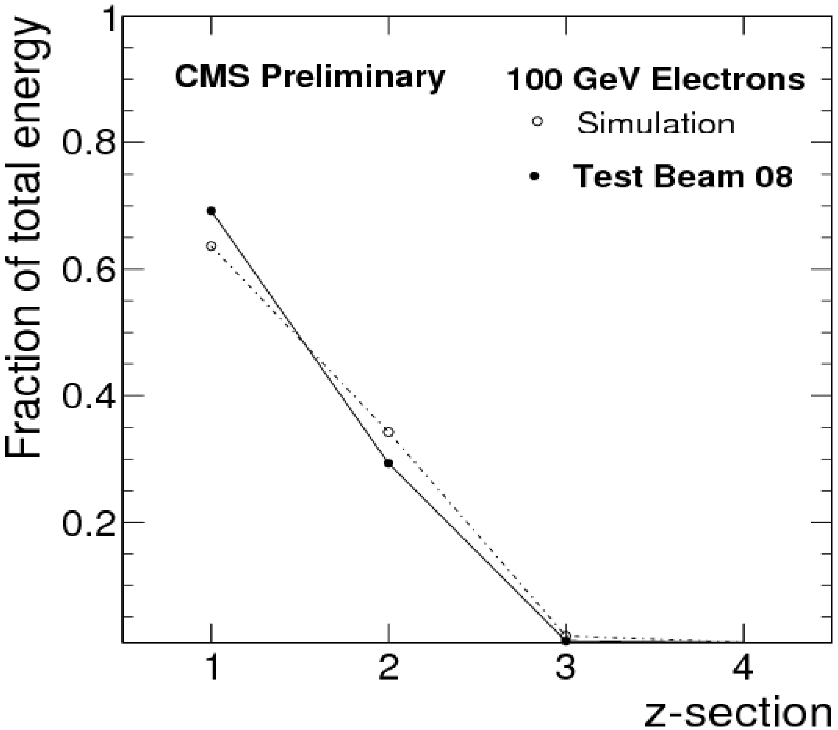


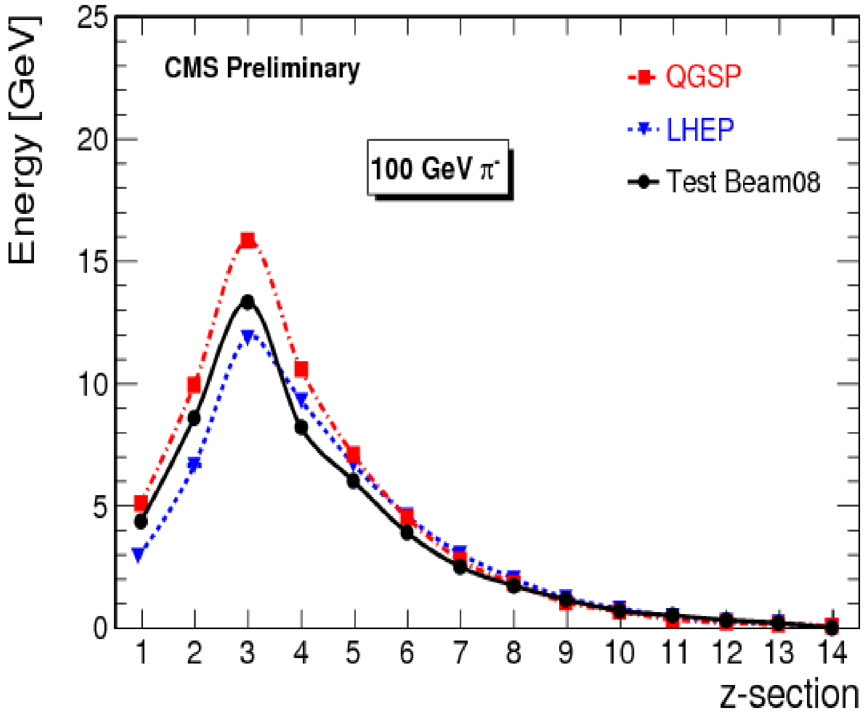


- from 8.8% at 30GeV to 5.3 % at 200GeV
- from 46.5% at 20GeV to 22 % at 300GeV

★ Results obtained with pencil like beam

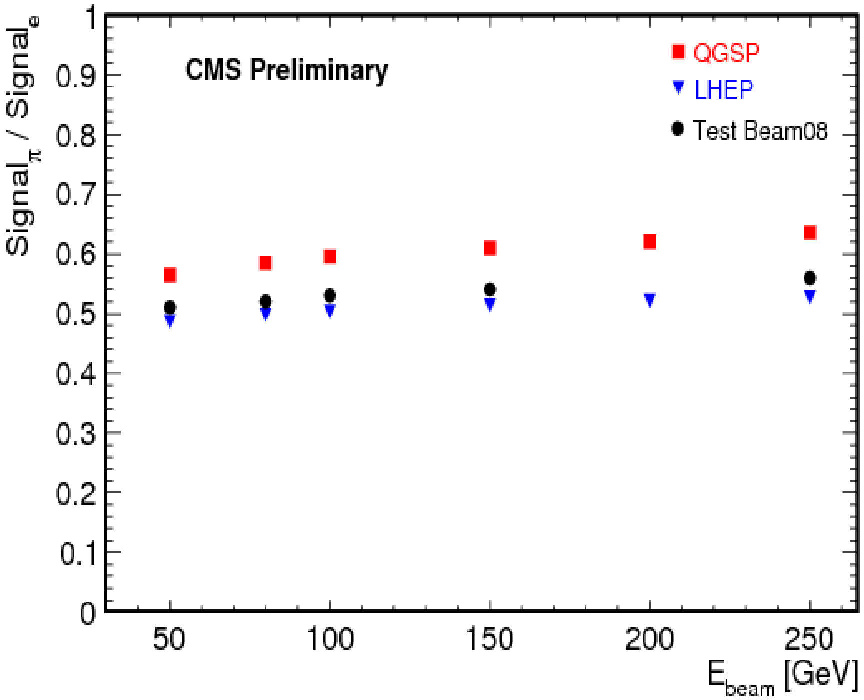
Shower Profile description





- the channel response is equalized using a muon beam.
- the absolute calibration factor is obtained from the response to electrons
- agreement between simulation and beam test data within 10 %.

Non-linearity(Non-compensation) for pions



The comparison shows that the electromagnetic component of hadronic showers (which dominates the Čerenkov signal) is not described in non-compensation by the QGSP shower model.

- the channel response in the test beam is equalized using a muon beam
- the absolute calibration factor in the test beam is obtained from the response to electrons.

Collision Event Selection

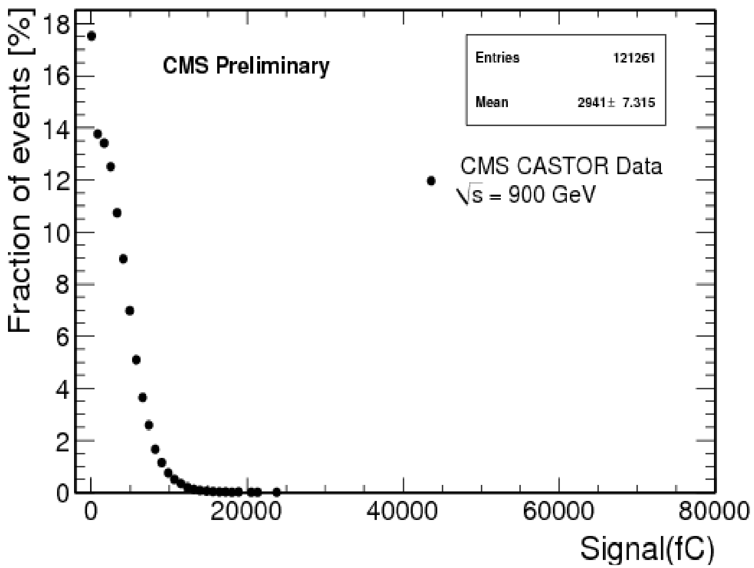
Trigger:

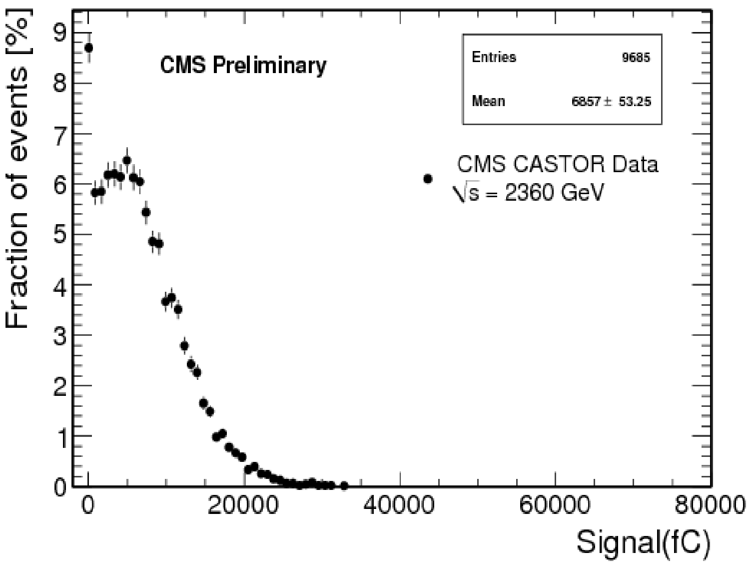
- Filled bunch
  - L1 Tech bit 0
- Beam Halo rejection (BSC):
  - L1 veto Tech bit 36-39
- remove a large fraction of the single and double diffractive events
  - L1 Tech bit 40 or 41 - signal in each Beam Scintillator Counters(BSC) in coincidence with a signal from the Beam Pick up Timing(BPTX)

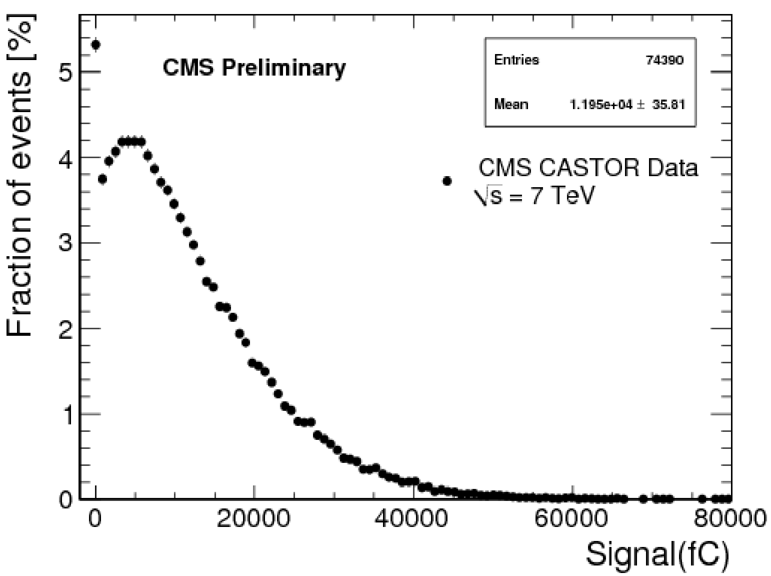
Event selection:

- beam background rejection(anomalus large number of pixel hits)
  - the fraction of the high purity tracks with respect to the total number of tracks is at least 20% for events with more then 10 tracks
- at least 1 collision vertex within 15 cm of IP and impact parameter has been reconstructed with number of tracks > 3.

Minbias Data at 0.9, 2.4 and 7 TeV







The charge (in fC) collected per channel is added after subtraction of the mean pedestal for all channels in *z*-module 1 to 5, without inter-calibration of the channel response.

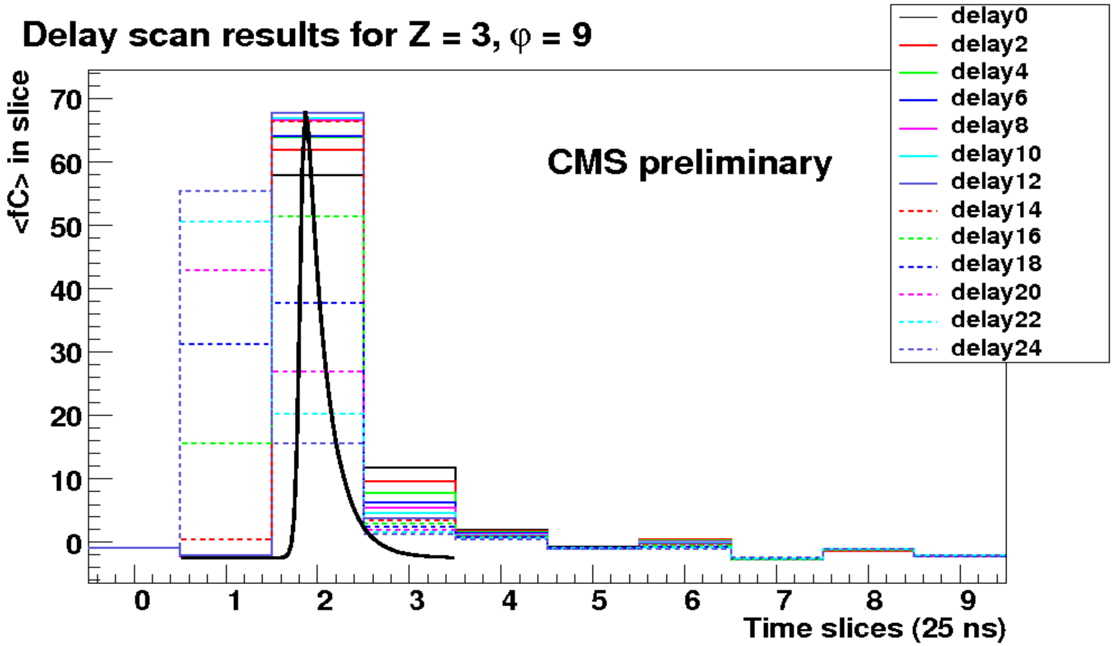
- increase of mean energy flow with centre-of- mass energy
- sensitivity to events with a rapidity gap in CASTOR.

Conclusions

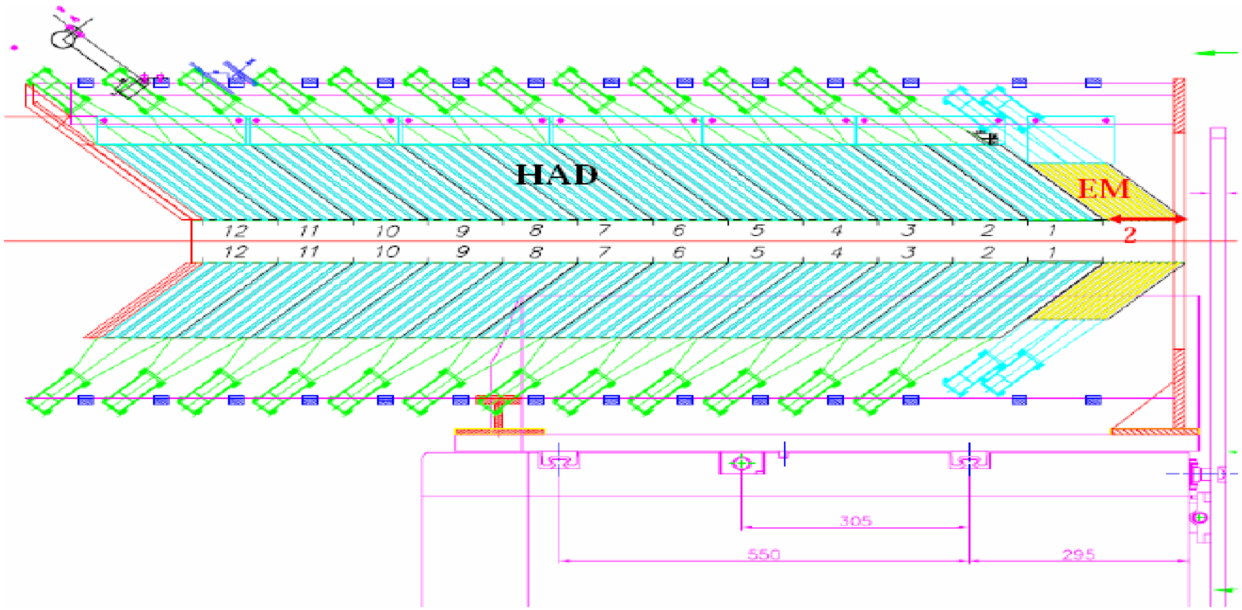
- Cherenkov forward CASTOR calorimeter has been designed, studied in beam tests, installed, commissioned and fully integrated into CMS
- CASTOR detector is operational and taking data
- we presented energy flow in CASTOR for different center of mass energies :0.9, 2.4, 7 TeV
- we observed the increase of mean energy flow with centre-of-mass energy and the sensitivity to events with a rapidity gap in CASTOR.
- CASTOR can make a relevent measurement and improve the UE modeling at very high eta.
- first results on forward energy flow ratio in CASTOR are coming soon

Backup Slides

Pulse Shape


Delay scan results for Z = 3, φ = 9
<fC> in slice
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
Time slices (25 ns)
CMS preliminary
delay0
delay2
delay4
delay6
delay8
delay10
delay12
delay14
delay16
delay18
delay20
delay22
delay24

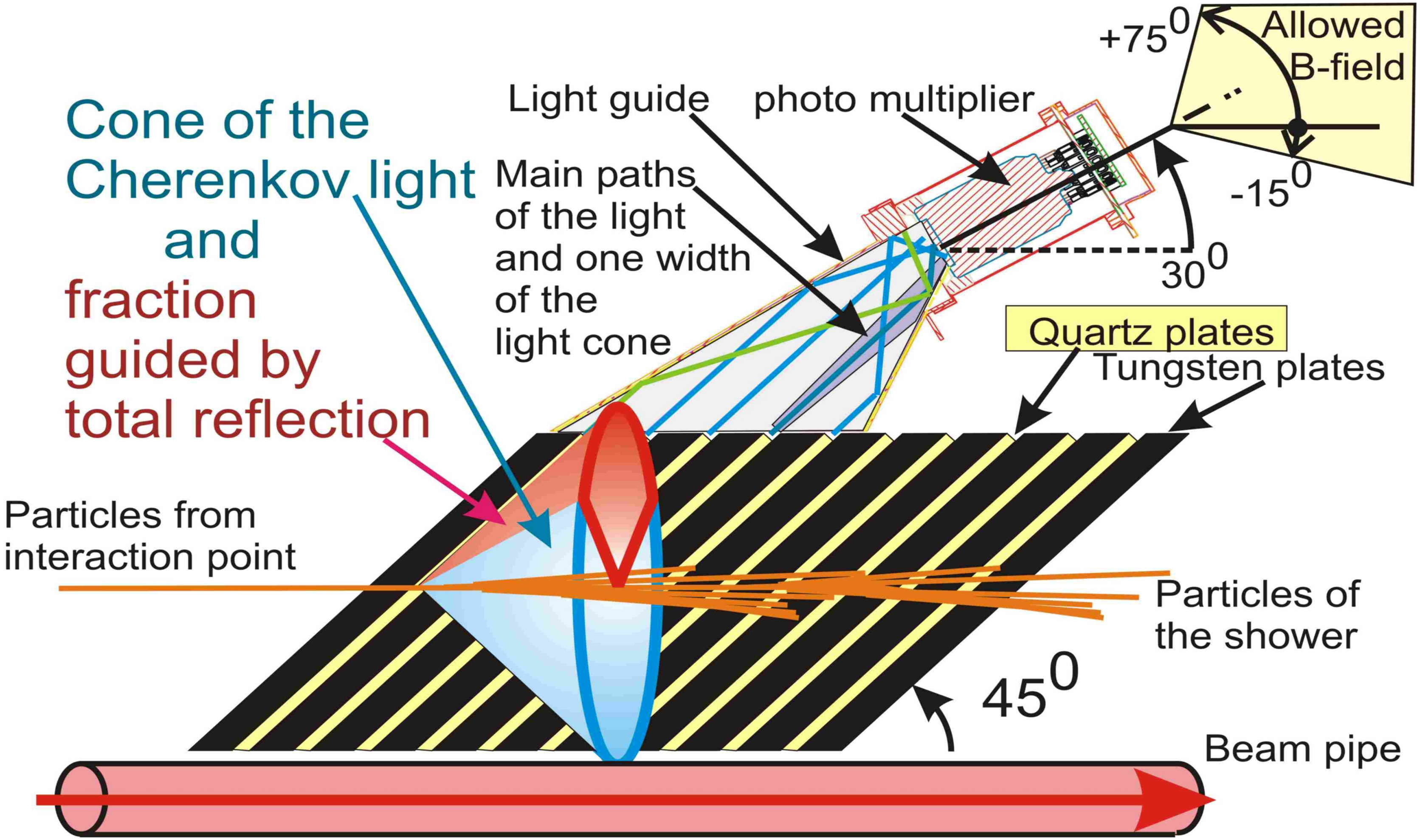
CASTOR readout geometry

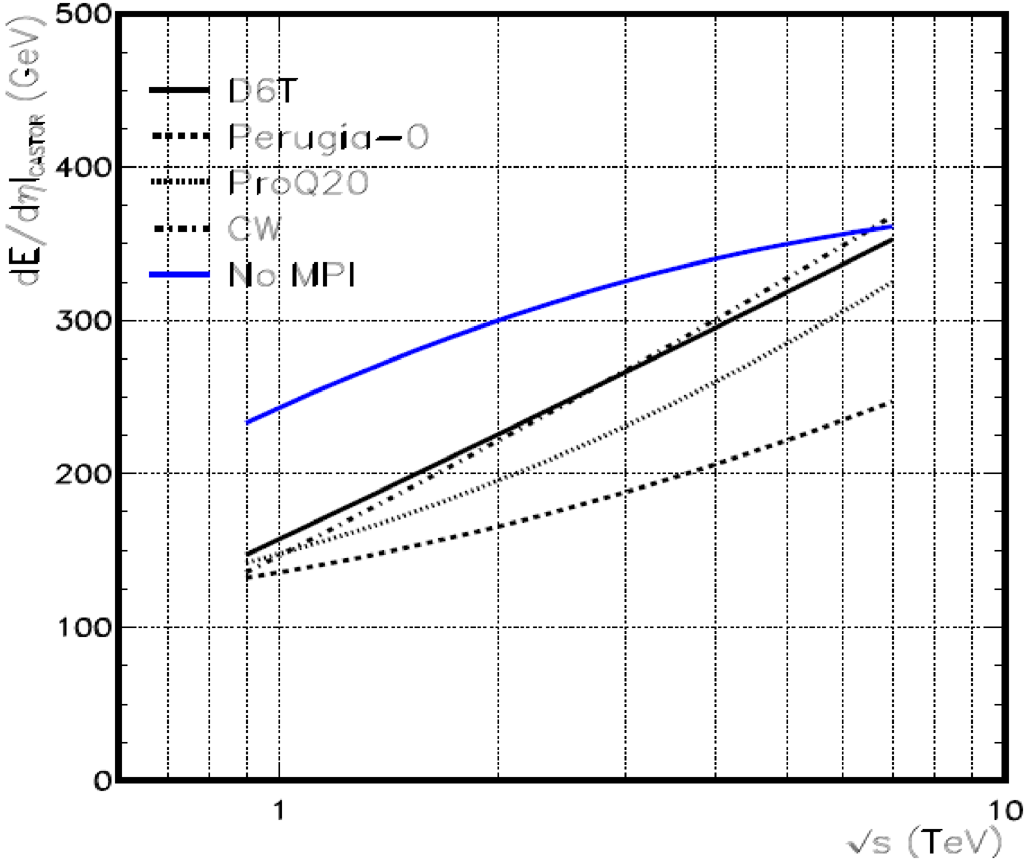


- hadronic section
  - absorber: tungsten plates of 10mm thickness
  - active material: fused silica plates of 4mm thickness
  - 5 tungsten-quartz sandwiches form 1 reading unit
  - total interaction length (2+12 r.u.) 10.3 λ_I

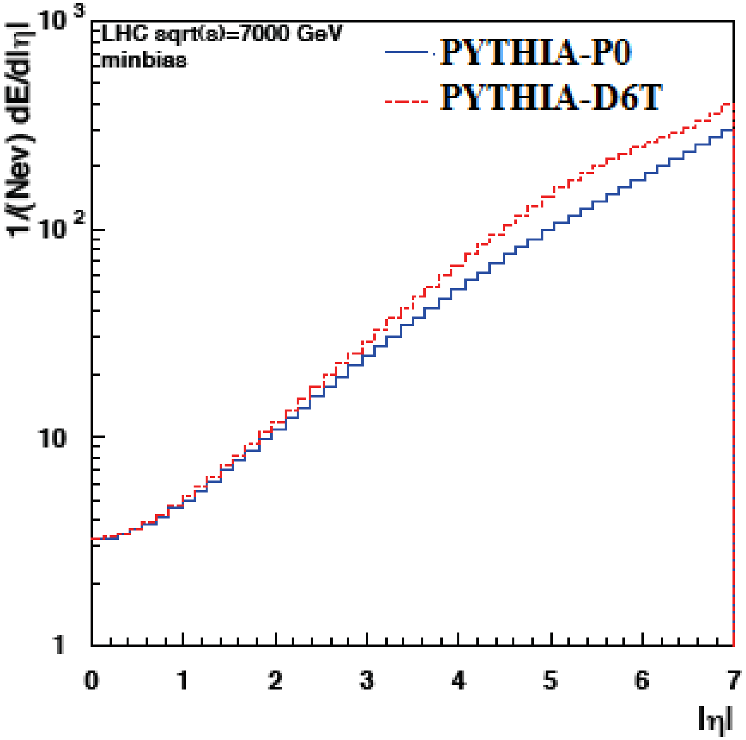
- electromagnetic section
  - absorber: tungsten plates of 5mm thickness
  - active material: fused silica plates of 2mm thickness
  - 5 tungsten-quartz sandwiches form 1 reading unit
  - total radiation length (2 reading units) =20.12 X_0

CASTOR signal generation

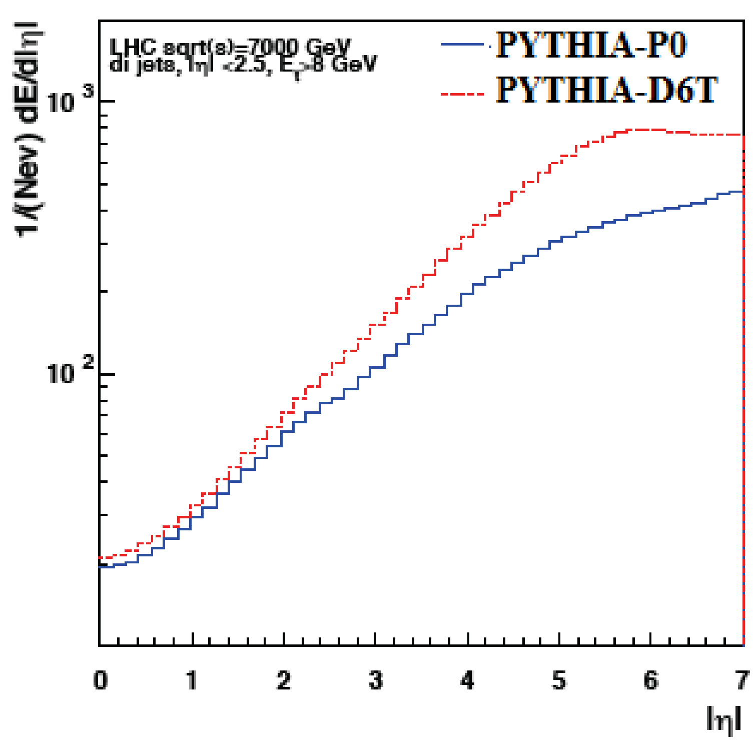




D6T
Perugia−0
ProQ20
CW
No MPI
dE/dη|CASTOR (GeV)
√s (TeV)
0
100
200
300
400
500
1
10



LHC sqrt(s)=7000 GeV
minbias
PYTHIA-P0
PYTHIA-D6T
1/(Nev) dE/d|η|
|η|



LHC sqrt(s)=7000 GeV
di jets, |η| <2.5, E_T>8 GeV
PYTHIA-P0
PYTHIA-D6T
1/(Nev) dE/d|η|
|η|