The CMS forward CASTOR calorimeter performance and operation

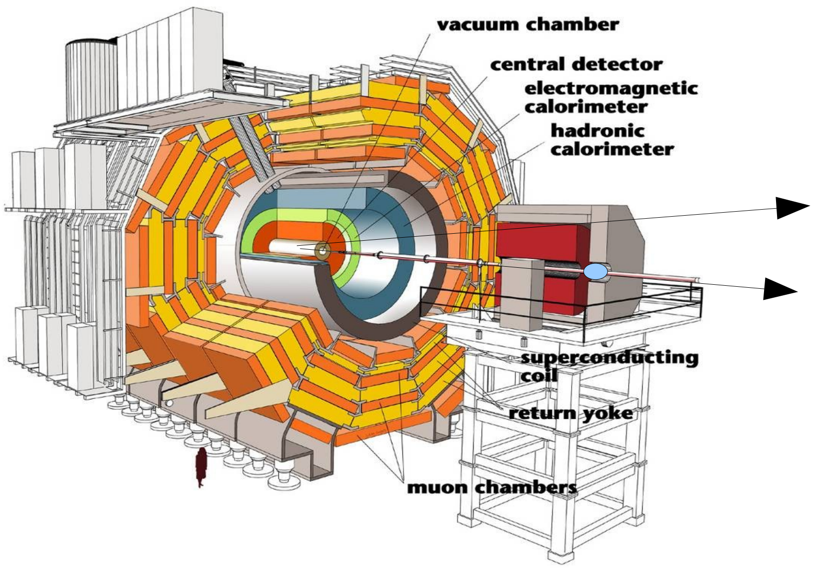
For the CMS-CASTOR Collaboration

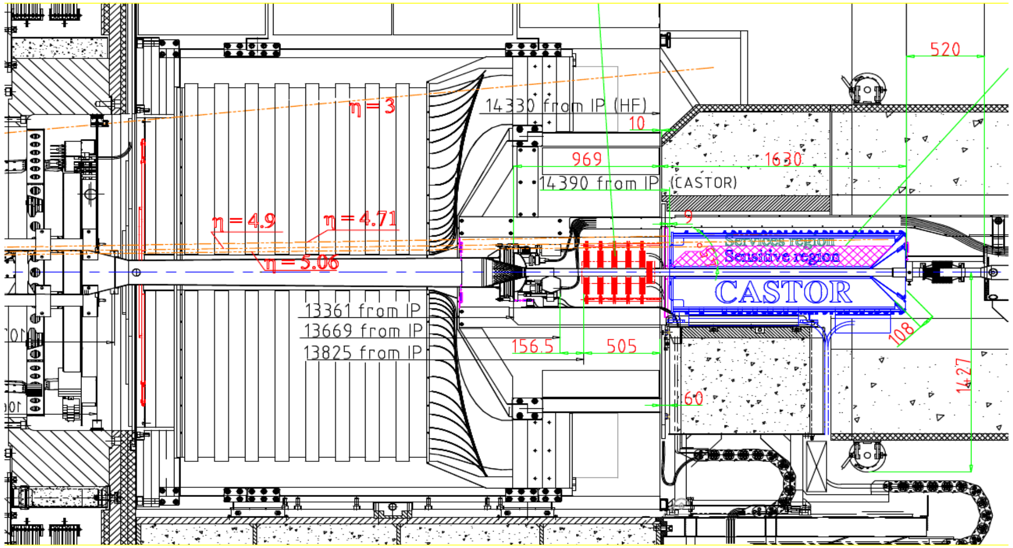
Igor Katkov

PLHC2010: Physics at the LHC 2010,
7-12 Jun 2010, DESY, Hamburg (Germany)

HELMHOLTZ ASSOCIATION

Placement and physics goals

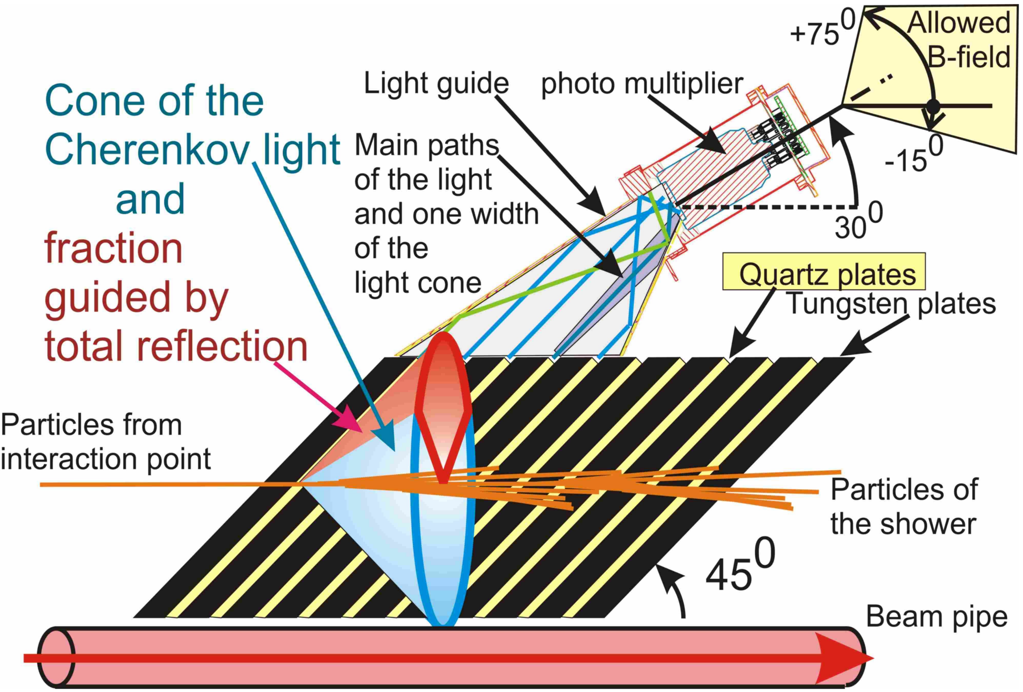


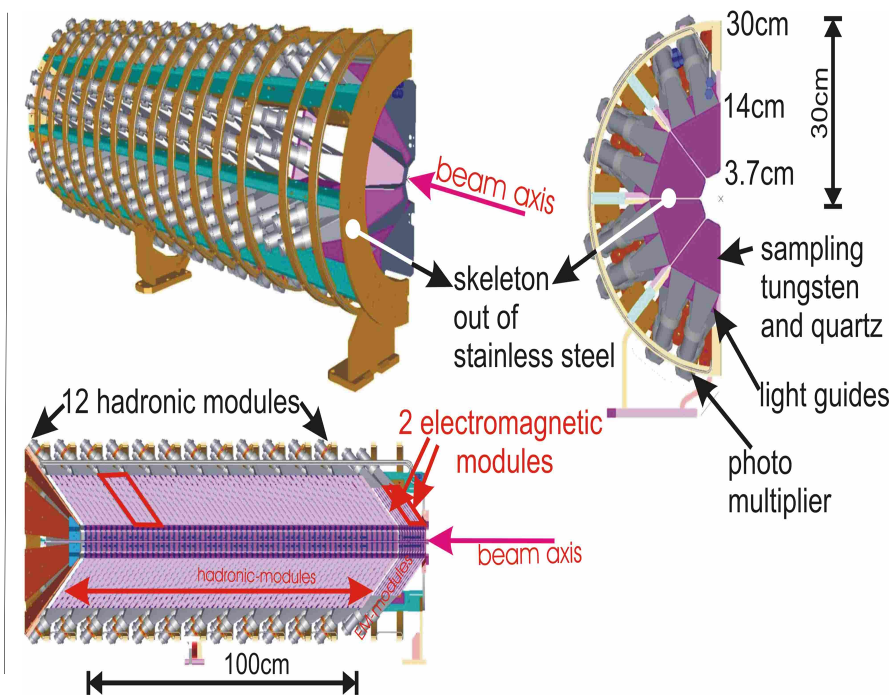


> Forward calorimeter (-6.6 < η < -5.2) for low-x parton dynamics,minimum bias event structure, diffraction, cosmic ray related physics in low-luminosity proton-proton and heavy-ion collisions

> Design challenges: restricted space available, high radiation level (≤ 20 kGy in 2009/10), operation in magnetic field (≤ 0.16 T), pileup

Detector design





> Cherenkov quartz-tungsten sampling calorimeter for CMS@LHC with quartz plates as active medium and tungsten as absorber → compact, radiation hard and fast

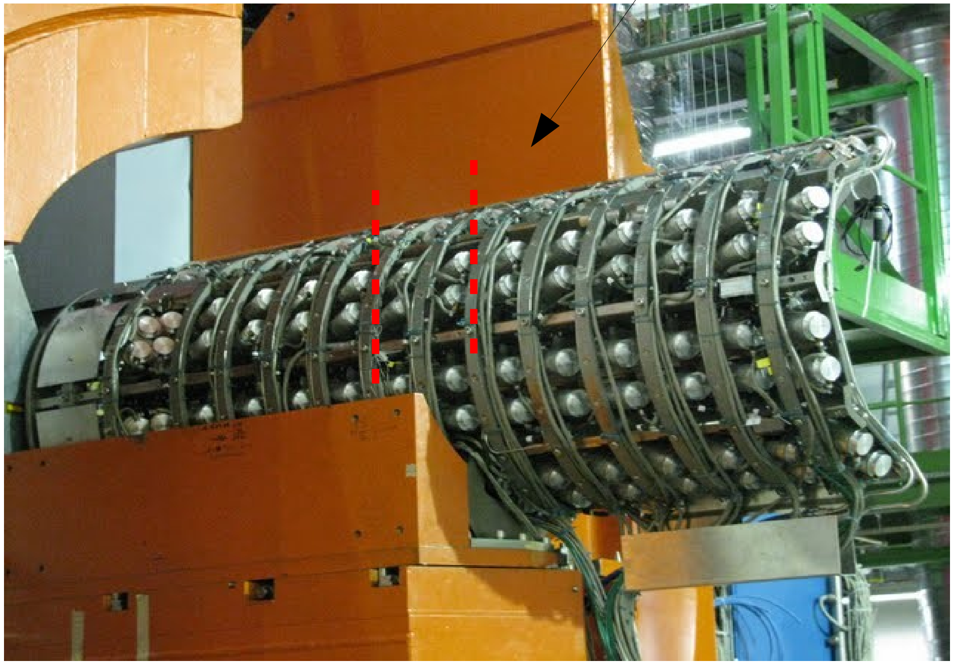
> 16 azimuthal sectors (semi-octants/towers) mechanically organised in two half calorimeters; EM part (2 modules) + HAD part (12 modules);
EM = $0.7\lambda = 20X_0$; HAD = $12 * 0.7 = 9.24\lambda$; overall depth = 10λ

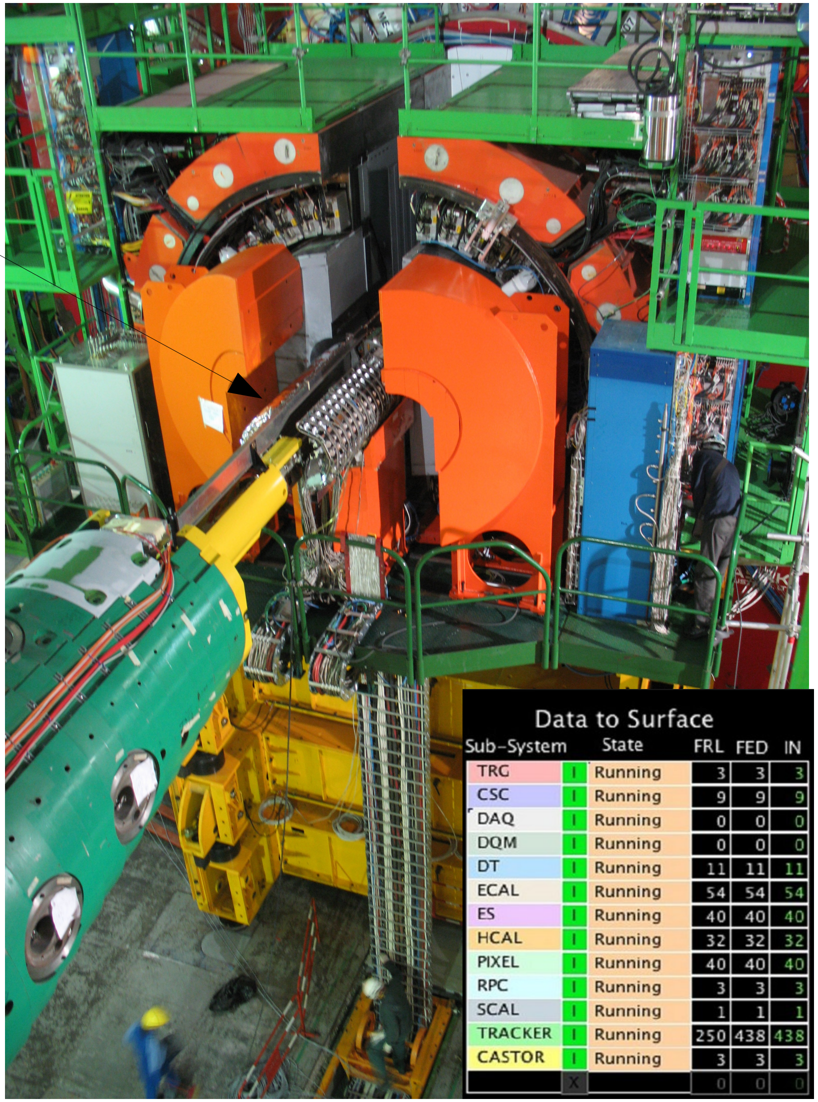
CASTOR calorimeter in CMS cavern: up and running!

> Design polished in beam tests of several prototypes

> CASTOR installed on collar table of HF platform (-Z side) in June 2009

> Fully functional and integrated into CMS operations



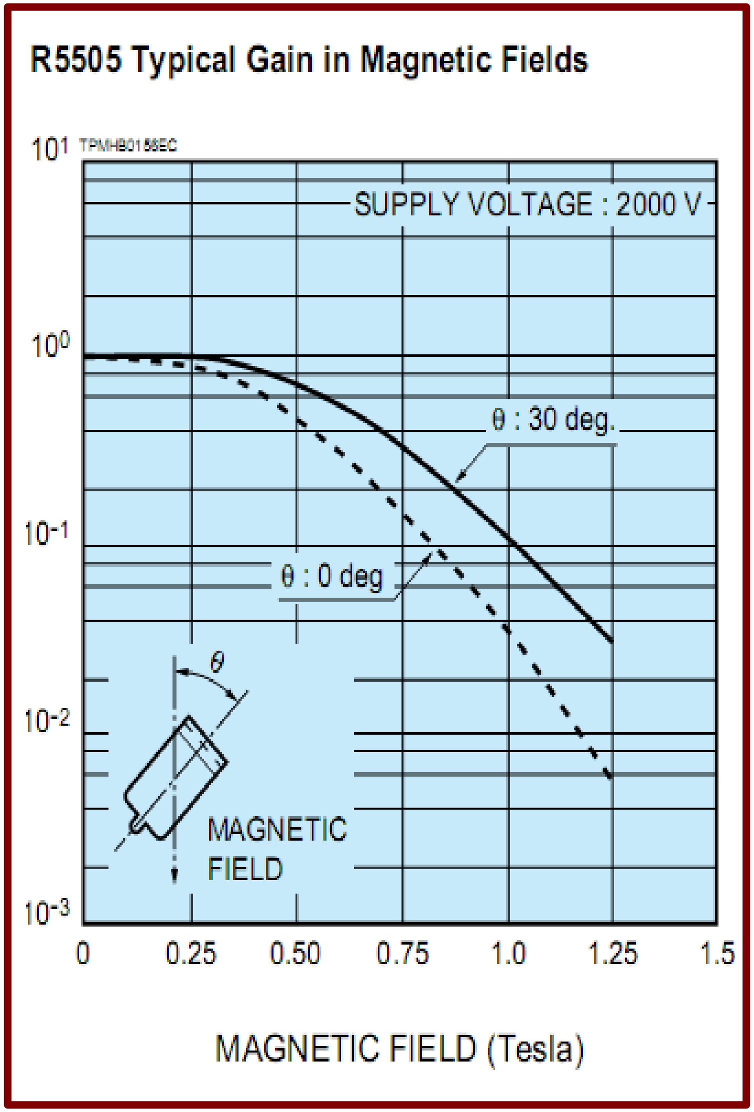


Data to Surface

Sub-System		State	FRL	FED	IN
TRG	I	Running	3	3	3
CSC	I	Running	9	9	9
DAQ	I	Running	0	0	0
DQM	I	Running	0	0	0
DT	I	Running	11	11	11
ECAL	I	Running	54	54	54
ES	I	Running	40	40	40
HCAL	I	Running	32	32	32
PIXEL	I	Running	40	40	40
RPC	I	Running	3	3	3
SCAL	I	Running	1	1	1
TRACKER	I	Running	250	438	438
CASTOR	I	Running	3	3	3
	X		0	0	0

Magnetic field

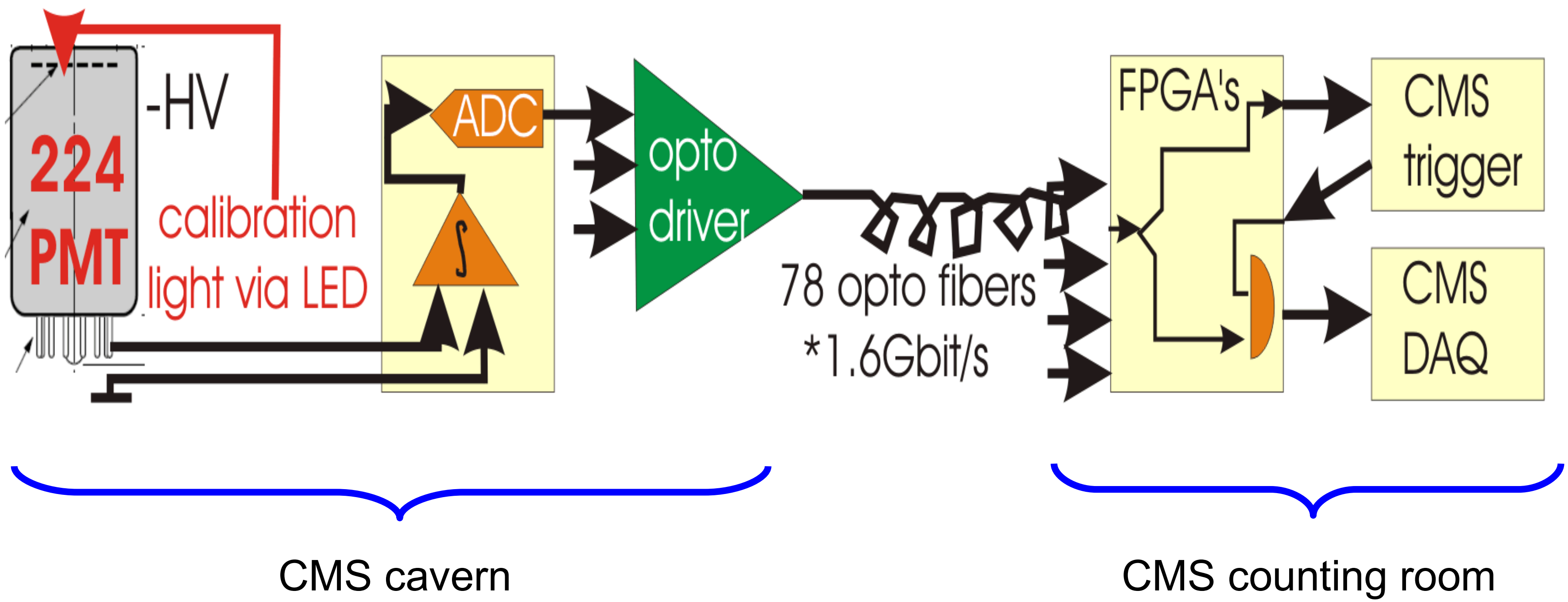
- Parts of CASTOR located in beam pipe shield gaps => high stray magnetic field, field vector direction varies => try to recover:
  - H1 SpaCal fine-mesh PMT’s (tolerate < 0.5 T, should survive radiation corresponding to 800 pb^{-1})
  - Redesign of air-core light guides to account for field direction
  - Close shield gaps
- Operation of modules from 6 (3.5λ) to 9 (5.6λ) hampered; some channels can be recovered



From Hamamatsu data-sheet

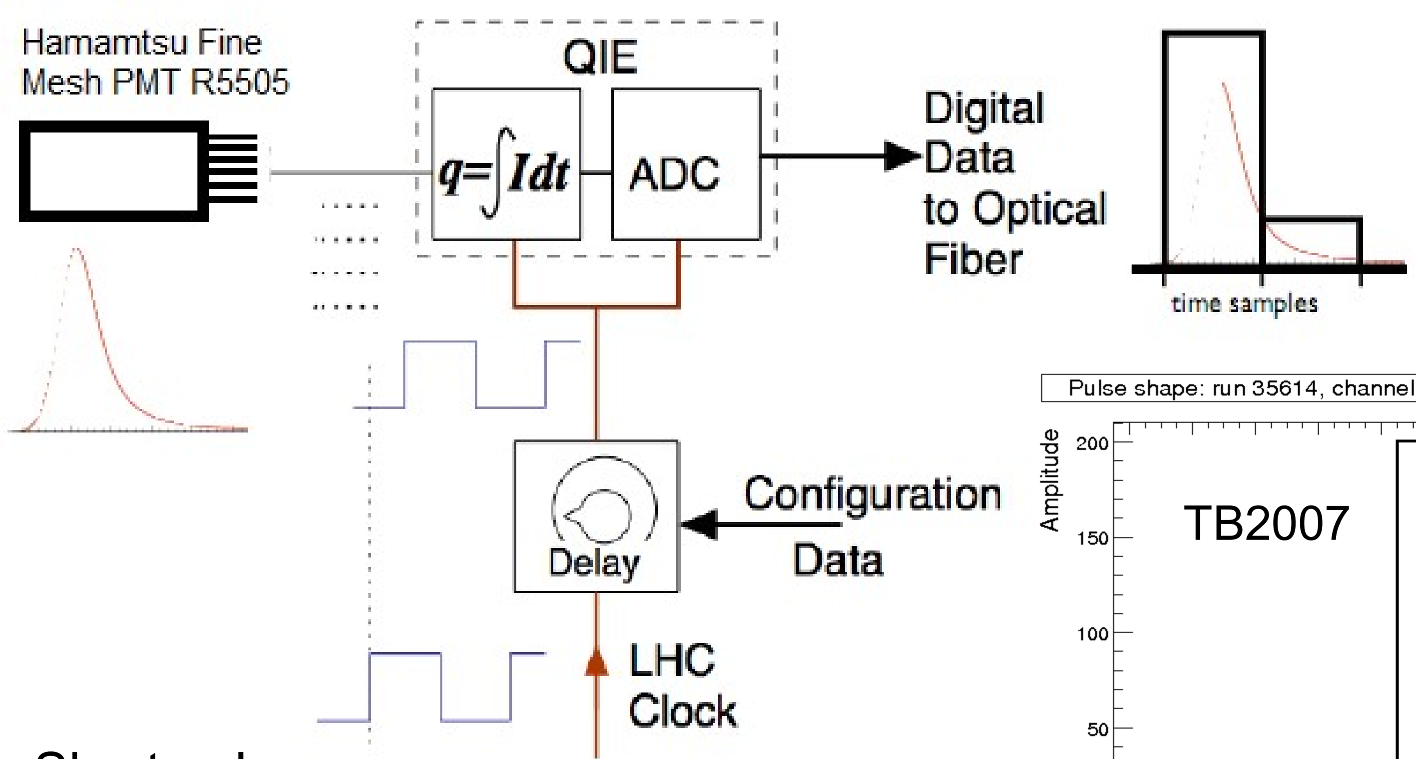
Readout chain

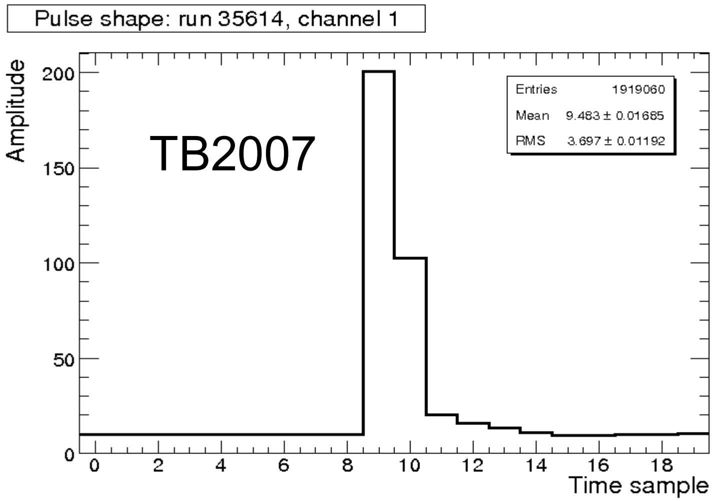
- High occupancy, signal separation for every LHC bunch crossing, wide dynamic range needed (from mip for calibration to beam energies): Conditions are similar to HF calorimeter hence design of CMS hadronic calorimeter readout electronics is used



Front-end electronics

- Front-end electronics based on charge integrating and encoding card providing almost constant relative precision over range of 10000

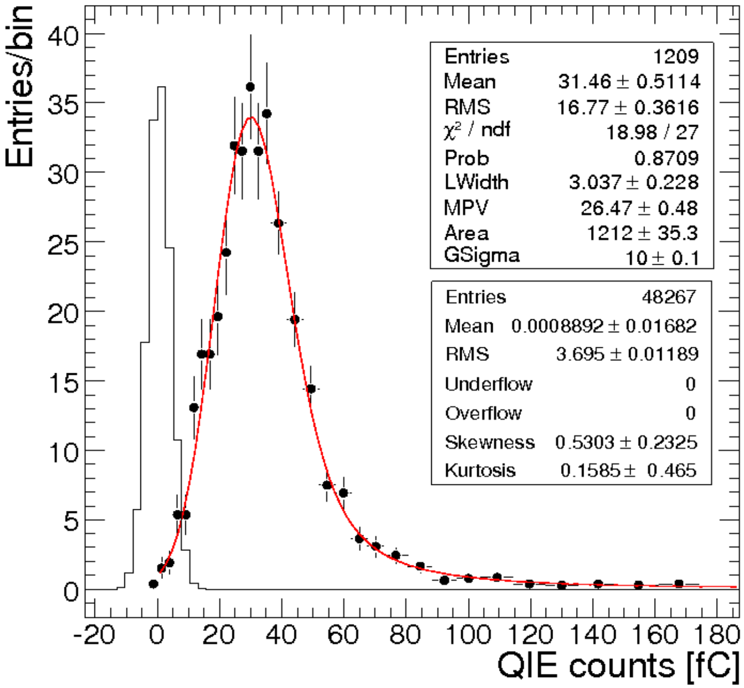




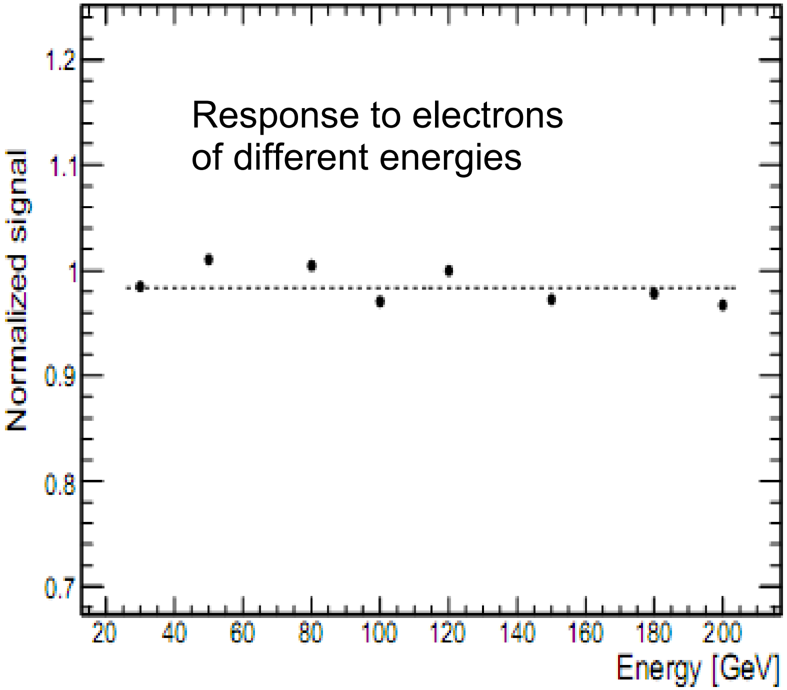
- Short pulse
- Timing adjustment

Results from beam tests

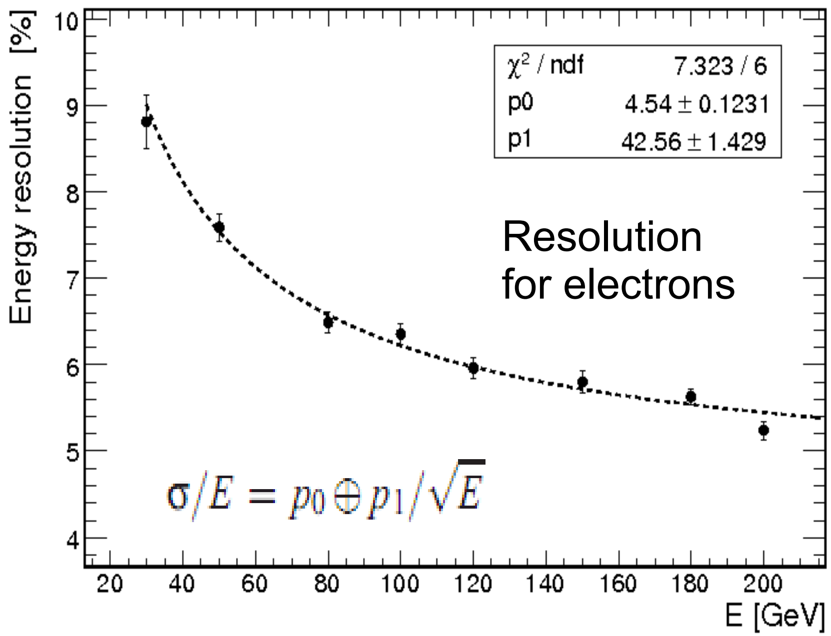
- Test beam 2007 results [DOI: 10.1140/epjc/s10052-010-1316-4]: full-length prototype tested with muons, electons, pions in wide energy range
- Muon signal vs pedestal: noise under control, important for calibration
- Reasonable linearity and resolution for harsh conditions of CMS forward region

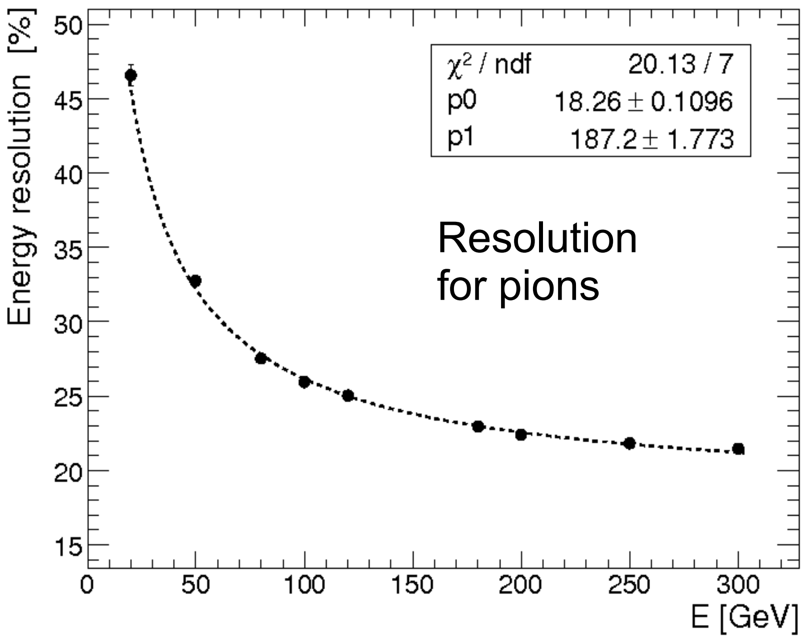


Response to 150 GeV muon beam in one EM channel



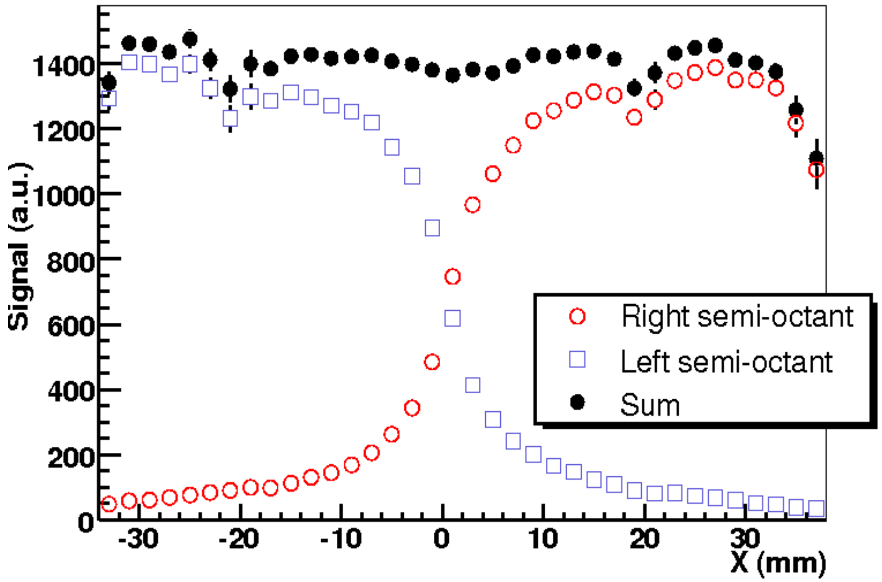
Results from beam tests

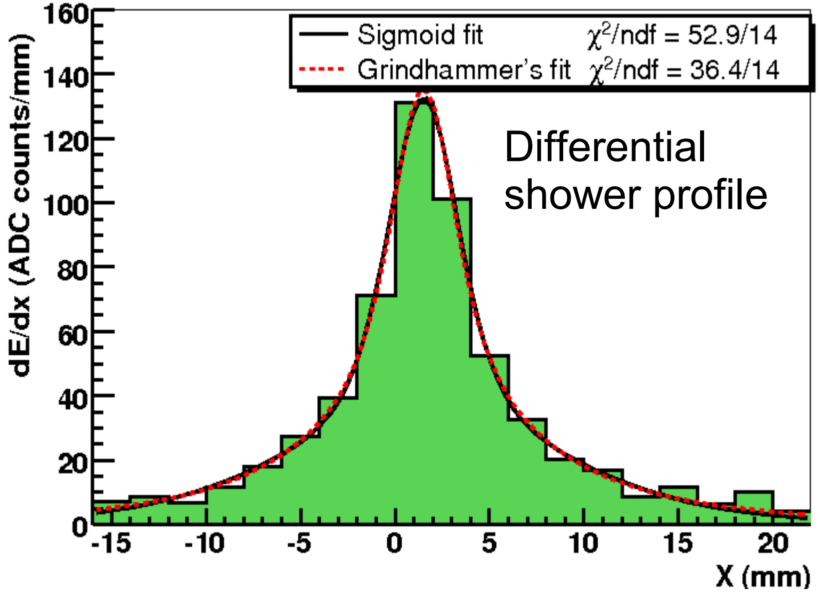


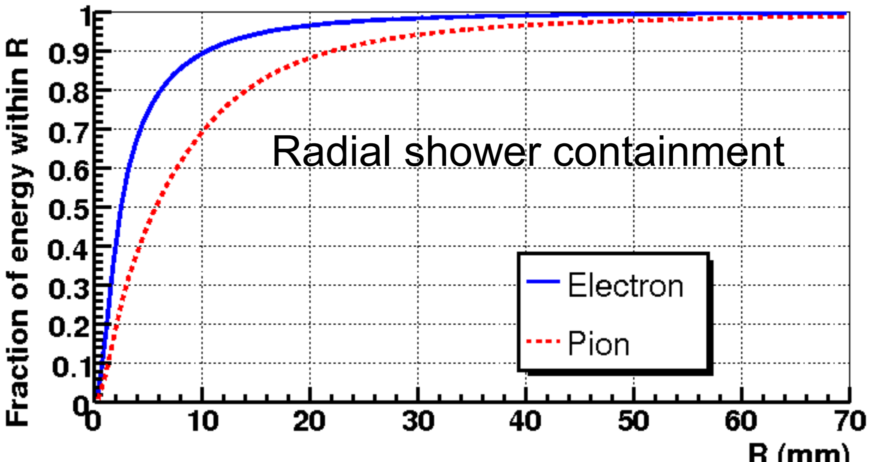


- Test beam 2007 [DOI: 10.1140/epjc/s10052-010-1316-4]
- Results with beam spot cut

Results from beam tests







Test beam 2007

[DOI: 10.1140/epjc/s10052-010-1316-4]

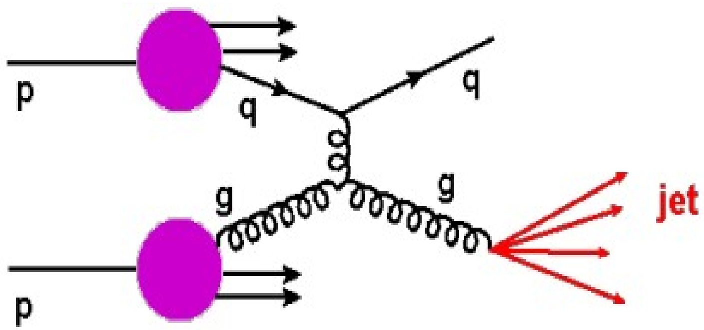
- Horizontal position scan with 80 GeV pion beam: FWHM of differential x-profile ~6 mm indicating compact shower dimensions (shower core calorimeter)

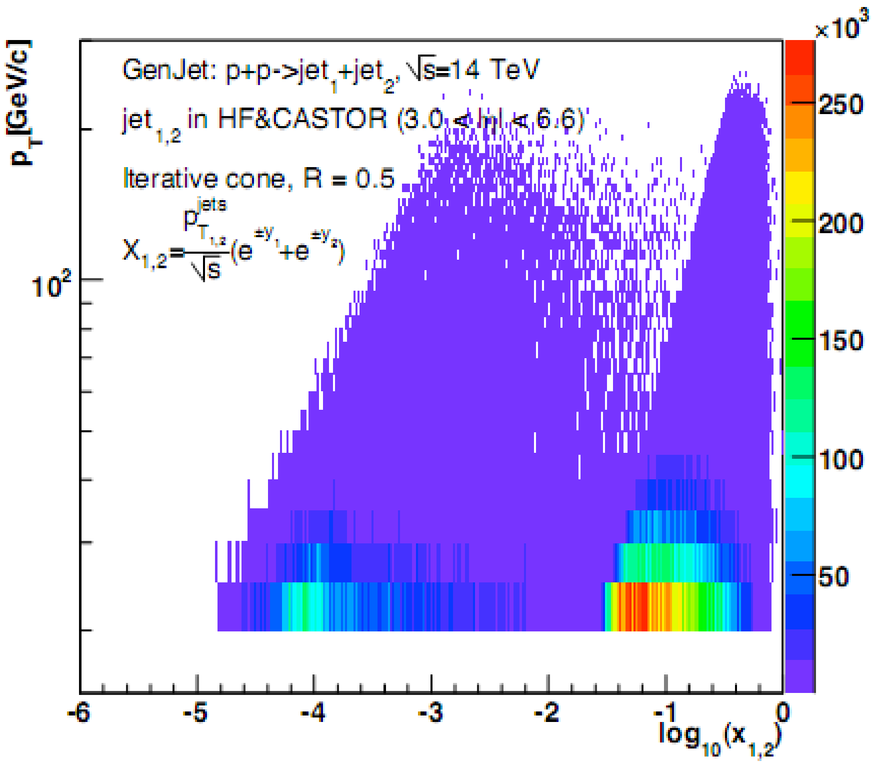
Trigger

- HCAL-based technical trigger architecture (to be implemented soon)
- All at calorimeter sector level:
  - Muon trigger (calibration)
  - E^{tot} above thresholds
  - Rapidity gap
- Basic trigger strategy
  - Use existing (central detector) triggers at low lumi
  - Add CASTOR conditions at high lumi to avoid prescale factors
  - Inclusive forward jets, forward jets plus central jets, diffractive jets/W

Physics with CASTOR calorimeter

- Forward jets allow to probe Bjorken-x as low as 10^{-5}: region sensitive to non-linear QCD effects of parton recombination and saturation



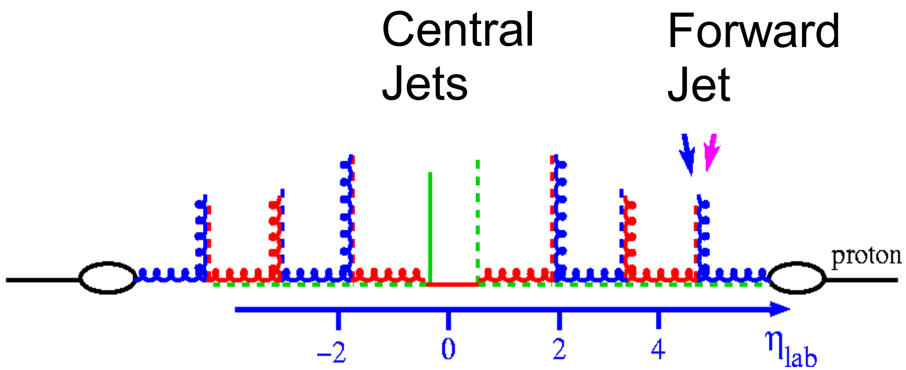


[CMS PAS FWD-08-001]

[CMS and TOTEM Collaborations, CERN/LHCC 2006-039/G-124]

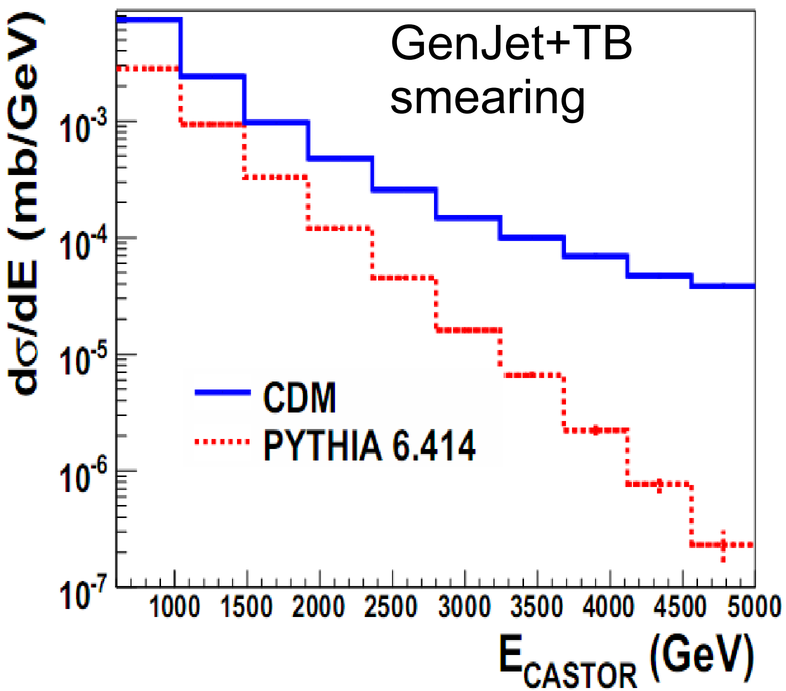
Physics with CASTOR calorimeter

- Centrally produced dijets plus a forward jet in CASTOR: ability to distinguish between DGLAP- and BFKL-like QCD parton dynamics



Feasible with < 1 pb^{-1}

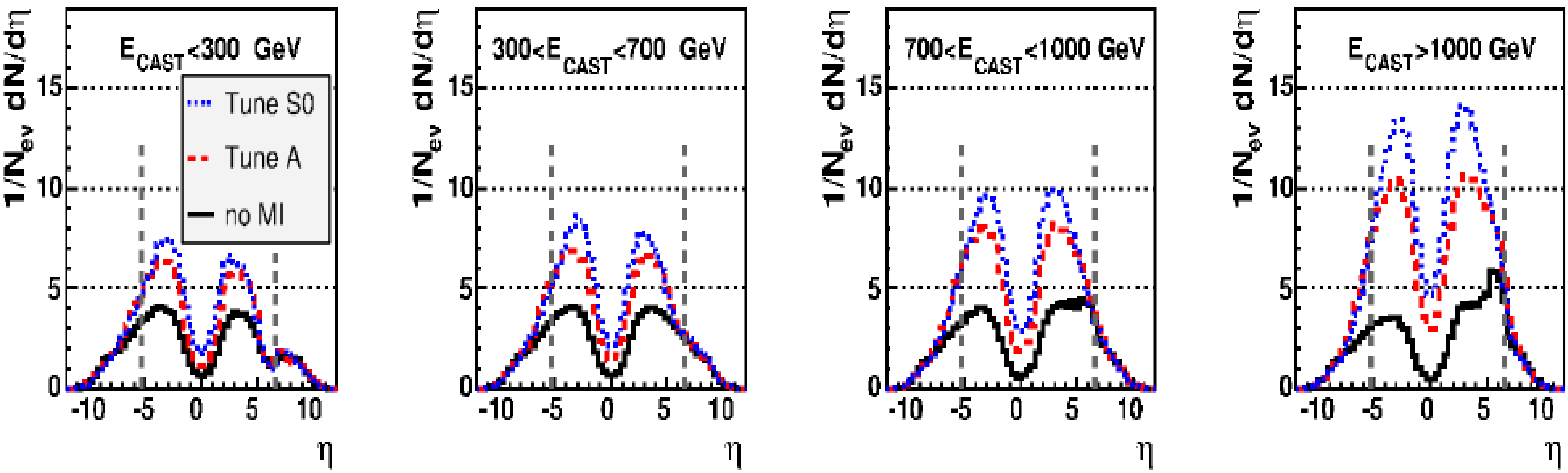
[A. Knutsson in Proceedings of HERA-LHC workshop DESY-PROC-2009-002]



Physics with CASTOR calorimeter

- Forward - central multiplicity correlations: better constraints on underlying event contributions
- Clear long-range correlation observed in case of

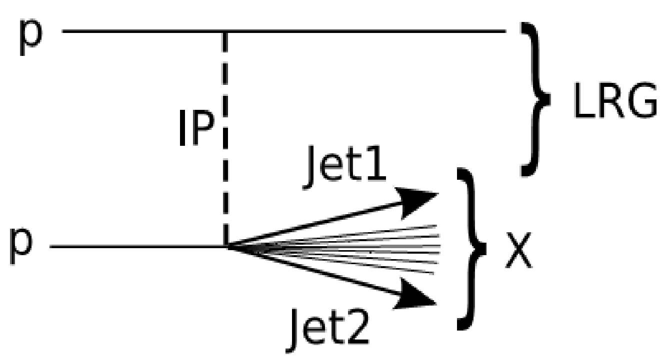
  Multi-Parton-Interactions

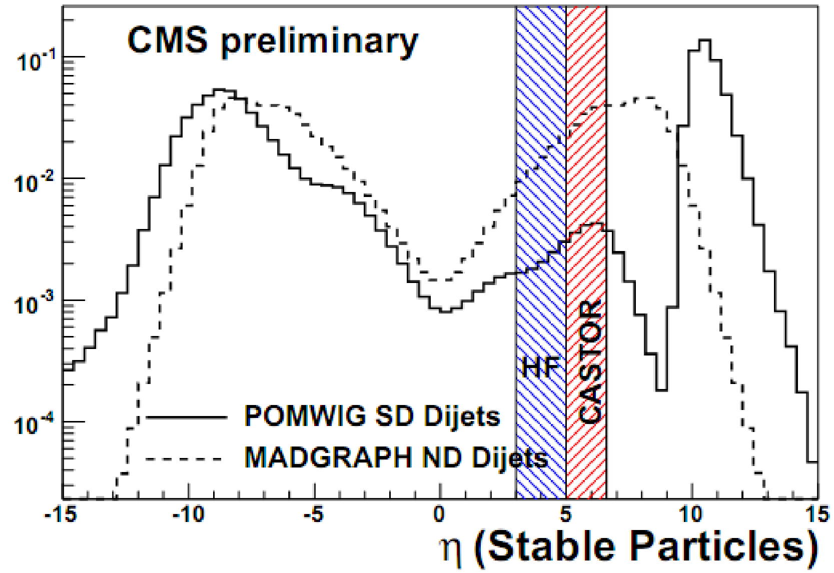


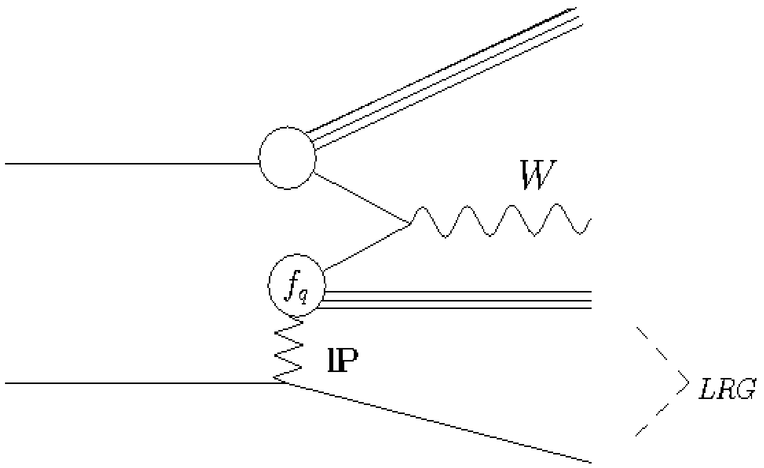
[Z. Rurikova, A. Bunyatyan in Proceedings of HERA-LHC workshop DESY-PROC-2009-002]

Physics with CASTOR calorimeter

- Forward activity veto detector for diffraction: analysis strategies based on selection of large rapidity gaps







Wider η coverage suppresses non-diffractive events where gap is due to fluctuations

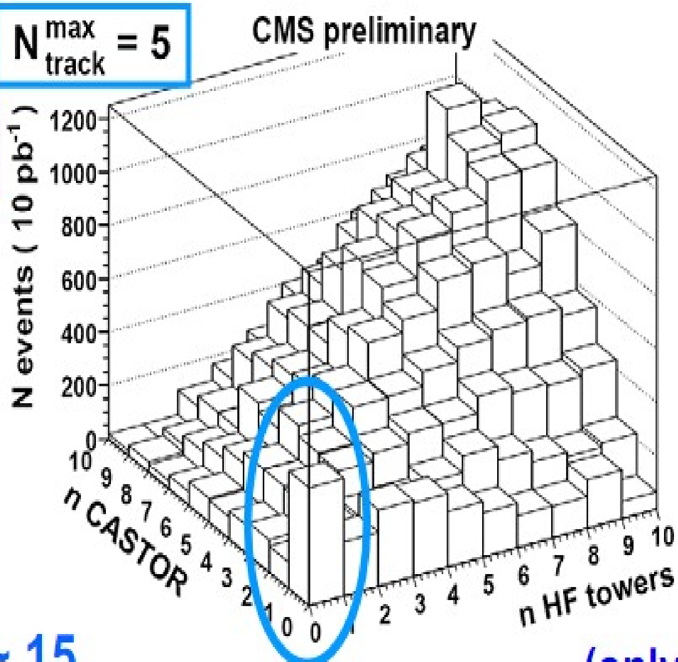
Physics with CASTOR calorimeter

Maria Margherita Obertino

O(300) evts/10 pb^{-1} ← [n(Castor), n (HF)] = [0,0] bin → O(100) evts/100 pb^{-1}

DIJET

$N_{track}^{max} = 5$



S/B ~ 15

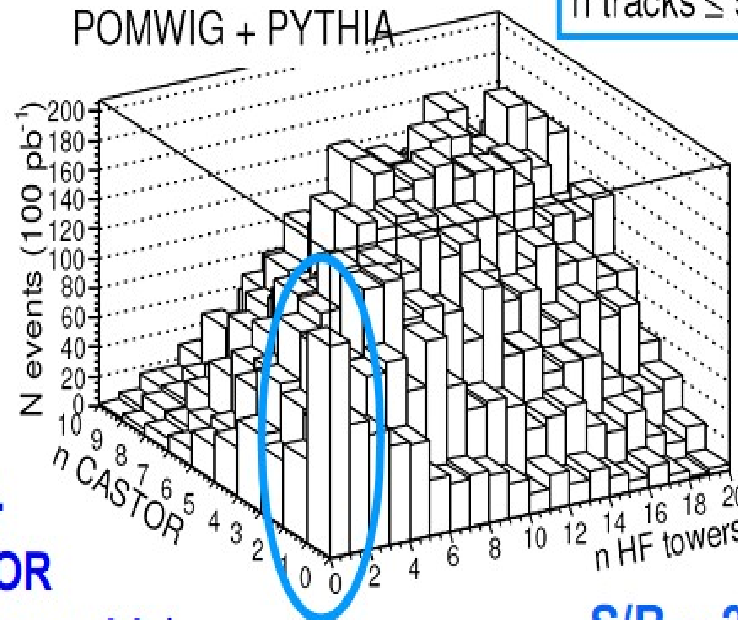
[CMS PAS FWD-08-002]

HF+ CASTOR

(only negative η side)

n tracks ≤ 5

W



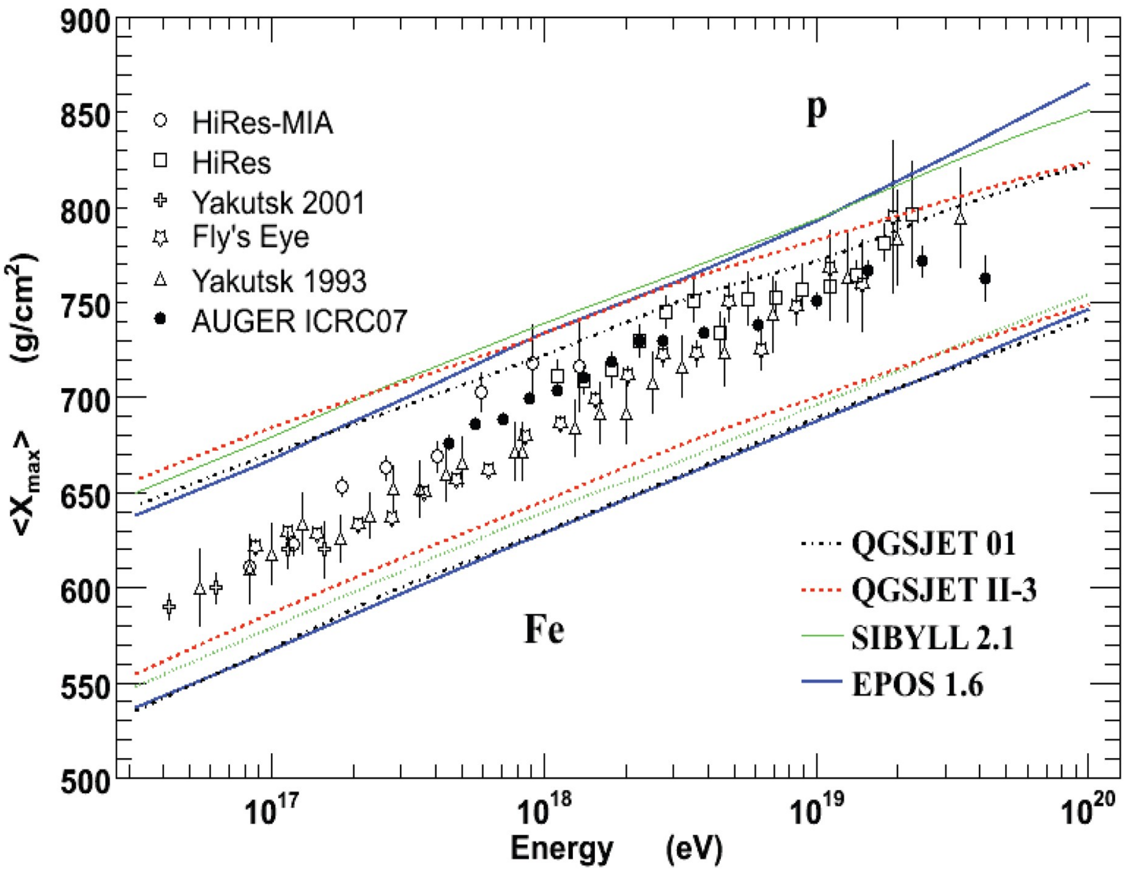
S/B ~ 20

[CMS PAS DIF-07-002]

- If only CASTOR multiplicity used signal would be further enhanced

Physics with CASTOR calorimeter

Shower maximum of extensive air showers



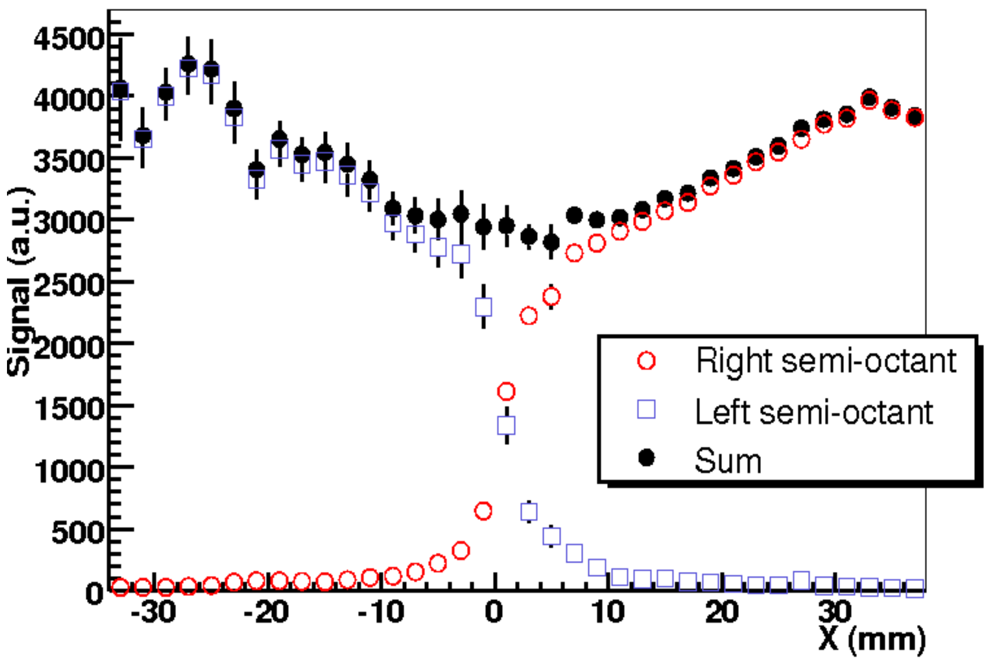
- High energy cosmic rays
- So far only indirect measurements (EAS) at $E^{lab} > 10^{15}$ eV
- Treatment severely dependent on simulations
- In particular, conclusions on chemical composition of most interesting Ultra High Energy Cosmic Rays
- Large uncertainty of hadronic interactions modeling
- Most important for shower development simulation is projectile (pion, proton, nuclei) fragmentation region
- Accelerator data are scarce
- Castor looks at that region → is very valuable for validation of shower simulation codes

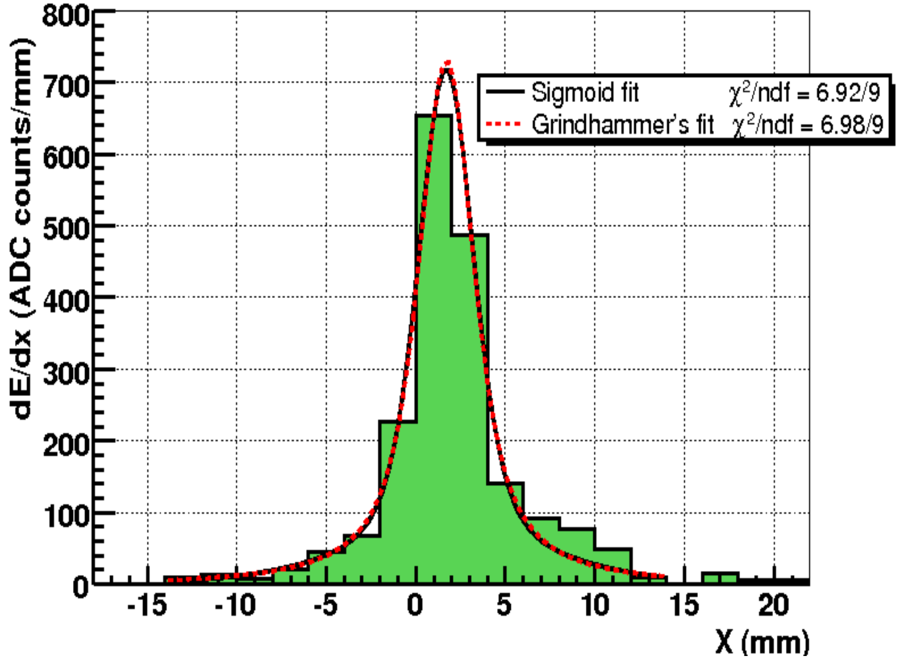
Summary and Outlook

- Cherenkov forward CASTOR calorimeter has been designed, studied in beam tests, installed, commissioned and fully integrated into CMS
- CASTOR calorimeter in CMS enhances physics potential substantially: largest rapidity coverage in a collider experiment; broad range of topics such as tuning of Monte Carlo generators, investigation of fundamental properties of QCD, astrophysics studies, potential discovery of exotica
- Detector took data at centre-of-mass energies 900, 2360 and 7000 GeV; first results on forward energy flow are coming soon: sensitive to underlying event modeling

BACKUP SLIDES

Results from beam tests





- Horizontal position scan with 80 GeV electron besm: FWHM of differential x-profile ~ 4 mm

$$\frac{1}{E}\frac{dE}{dr} = p\frac{2rR_C^2}{(r^2+R_C^2)^2} + (1-p)\frac{2rR_T^2}{(r^2+R_T^2)^2}$$

Grindhammer-Peters