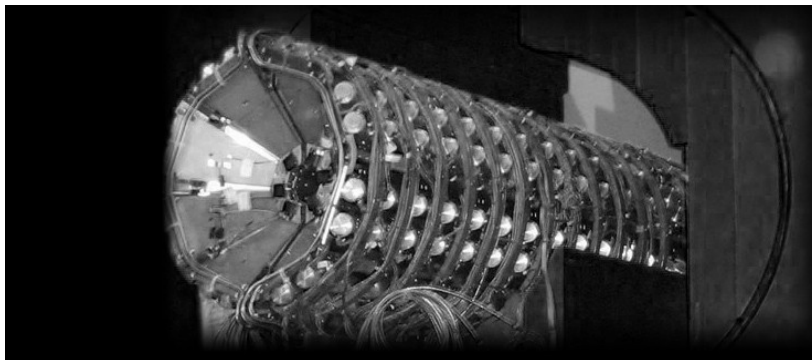


CMS/CASTOR Calorimeter

Plans and Preparation for Run 2

LPCC forward physics WG meeting

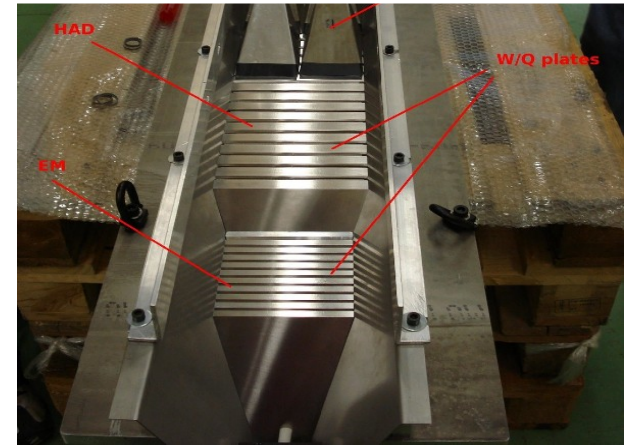
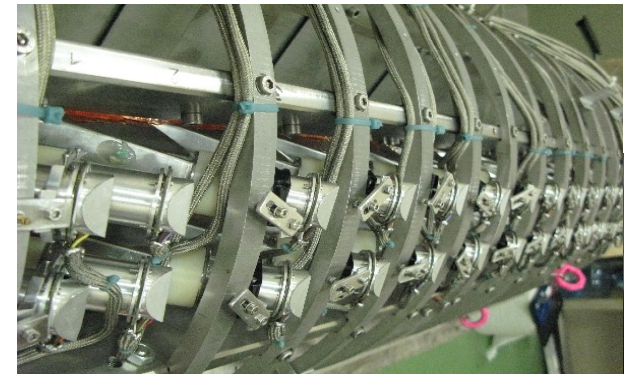
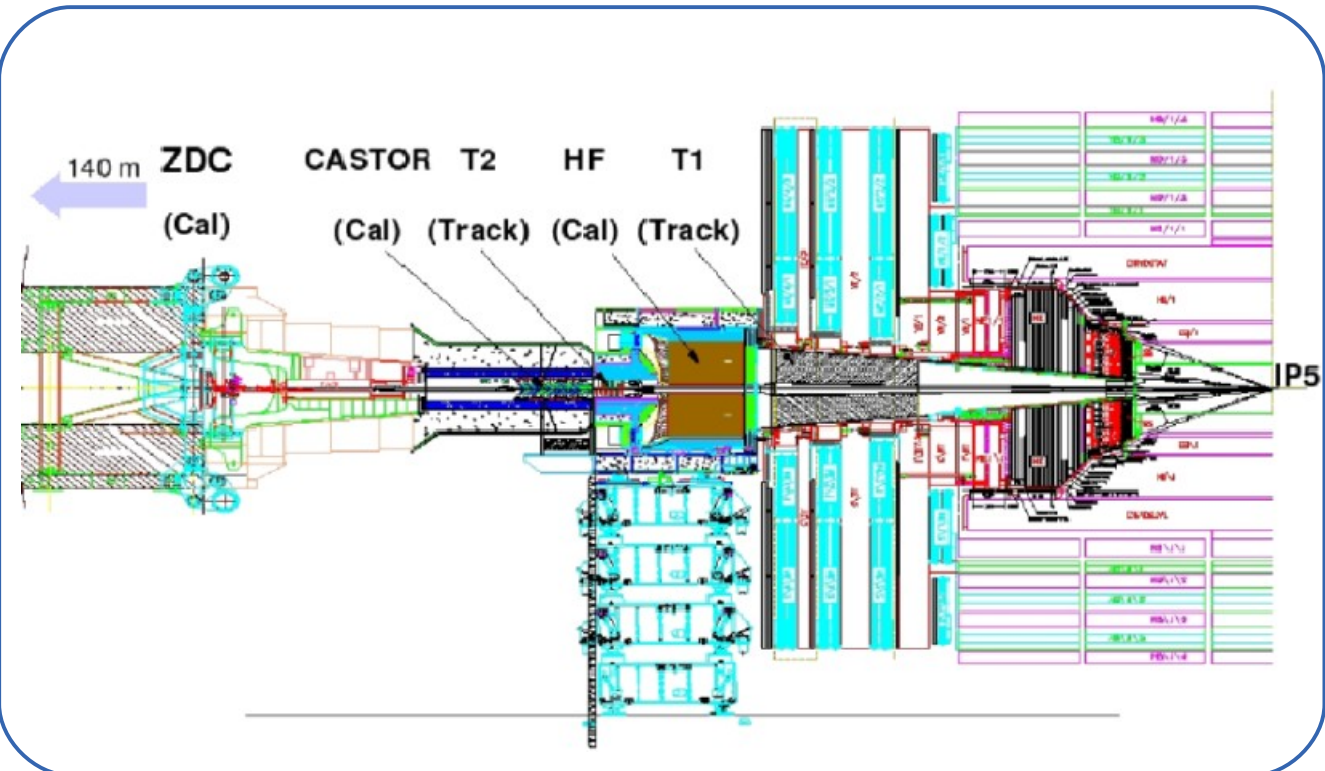
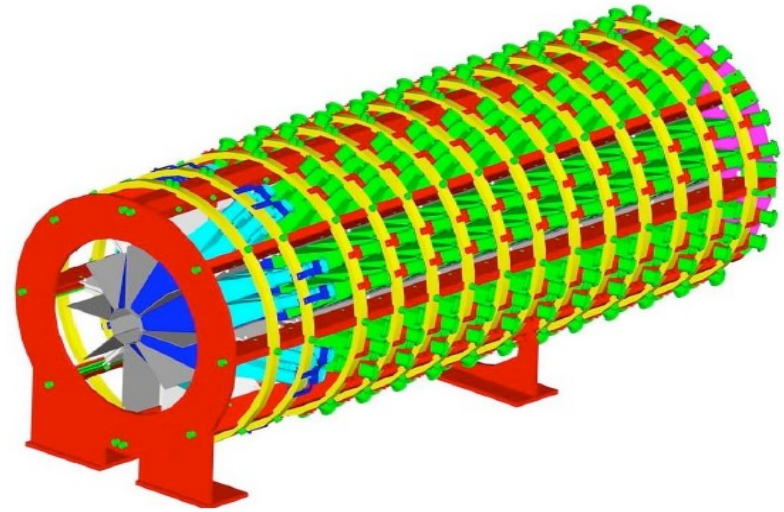
R. Ulrich (KIT) for the CASTOR group



- The detector
- Present results
- Preparation for Run 2
- Physics potential in Run 2

The Calorimeter

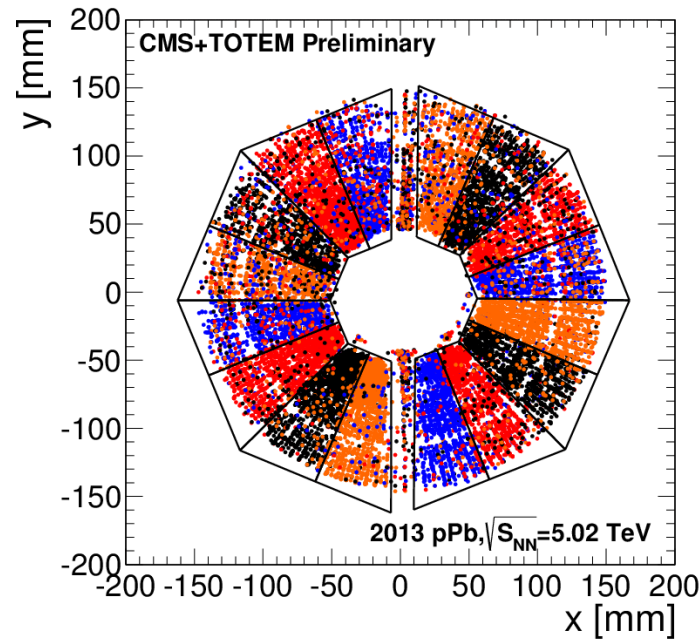
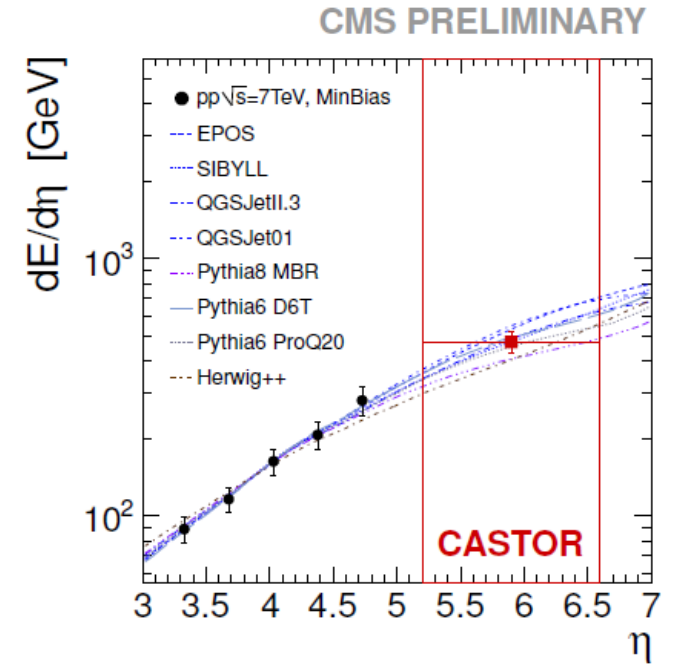
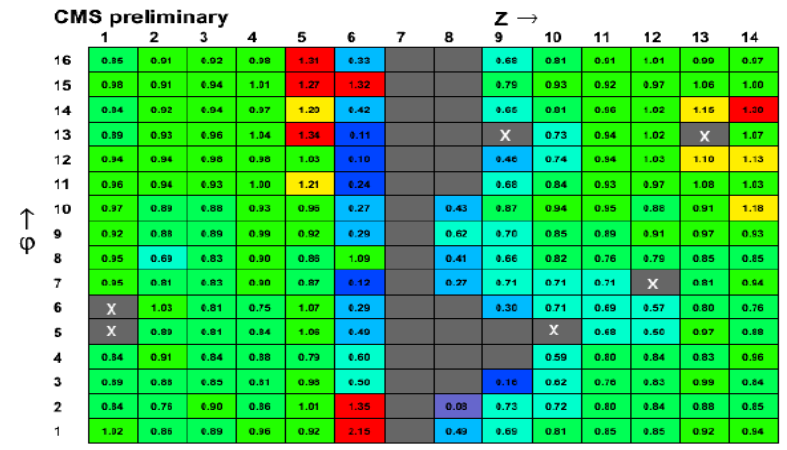
- CMS $-6.6 < \eta < -5.2$ (14.5m from IP)
- Tungsten-Quartz Cherenkov Calorimeter
- EM ($20X_0$) + HAD Section ($10 I_1$)
- 16 Phi Segments, 14 z-Segments
- Upgrade with magnetic field resistant + radiation hard PMTs





Big challenges

- Magnetic fields
- Energy scale
- Calibration (Muons)
- Alignment
- Radiation damage



Recent Developments

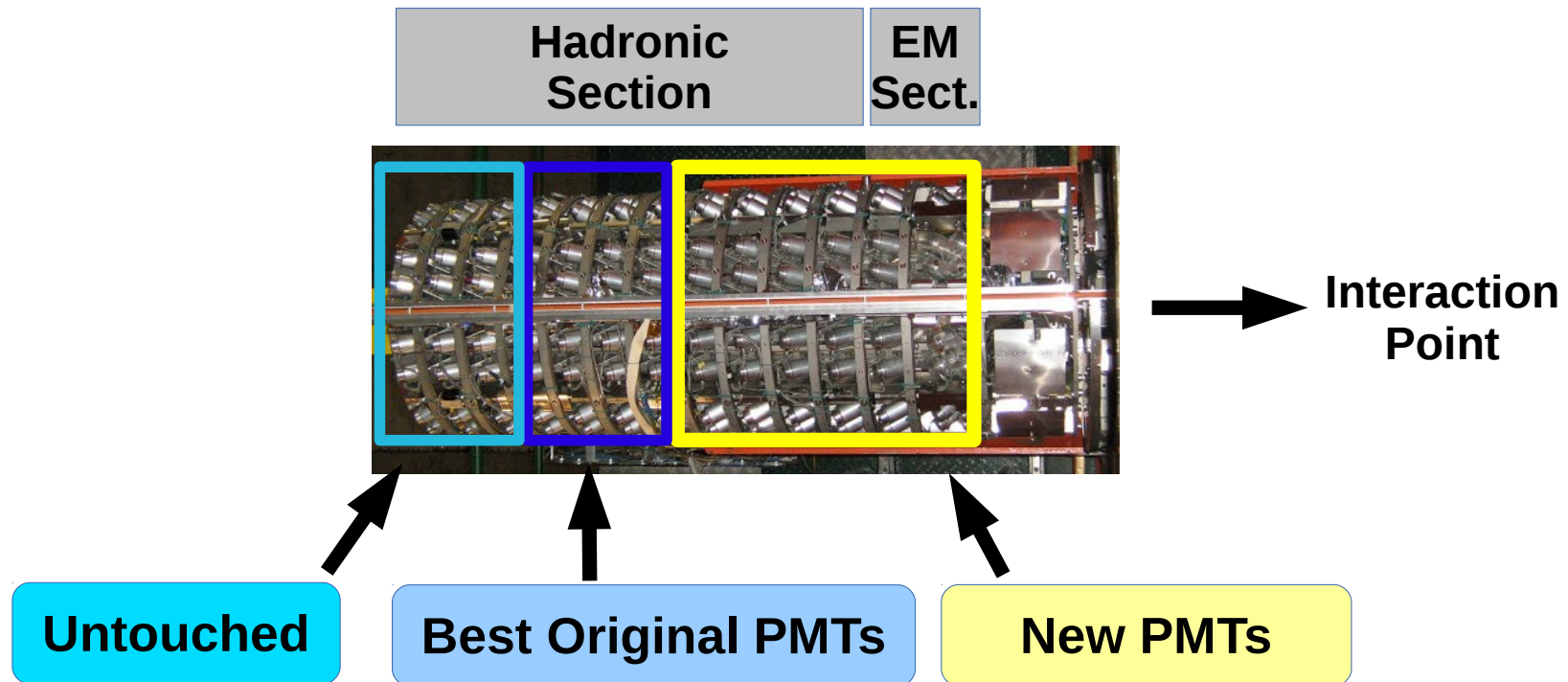
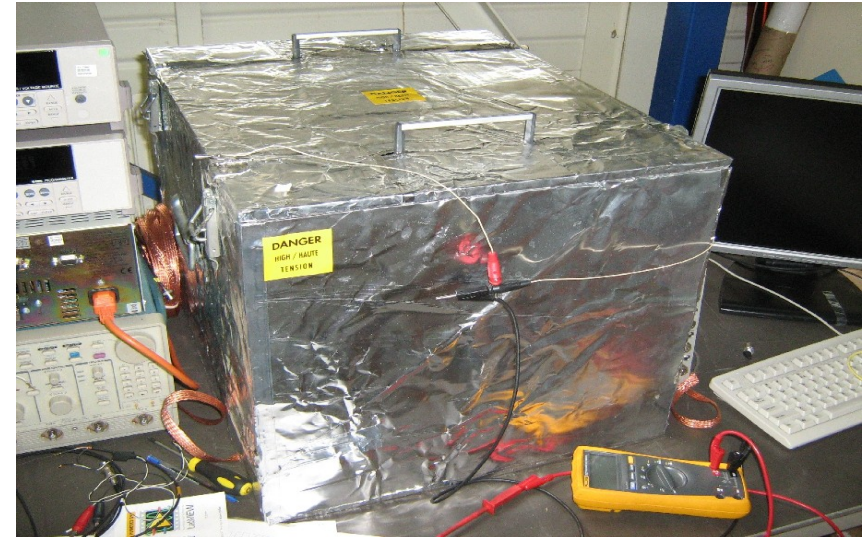
- Installation Jan 2014
- Data taking pPb and pp, [CMS-DP-Note](#)
- Trigger delivered to L1, combined with TOTEM on algo level, combined data CASTOR+T2

[CMS-DP-Note](#)

- Data taking at SX5 is ongoing
- Trigger development for run 2

Upgrade of PMTs

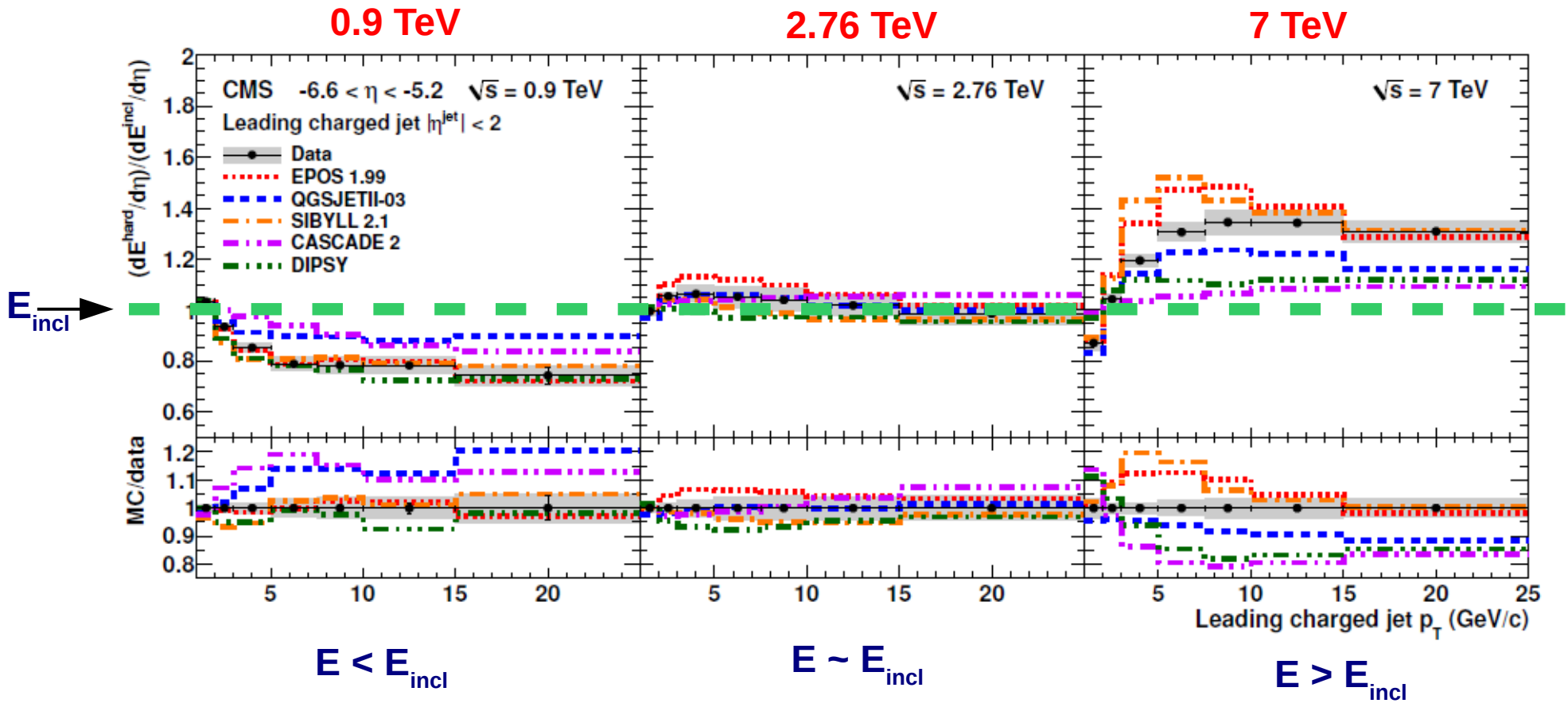
- During 2012 CASTOR was not installed
- Characterized 270 PMTs → (replaced 96, refurbished 64)
- CASTOR installed in YETS 2012/2013



Physics Case, Global Overview

- **pp:** low- x QCD, Jets, MN-Jets, UE, Drell-Yan, diffraction
- **Heavy Ion:** forward physics, saturation, event plane, centrality, exotic events, photo-diffraction
- **Cosmic rays:** Forward particle production at high energies, MB, nuclear effects
(essentially a combination of pp and HI topics with a focus on MB and low- x /diffraction)

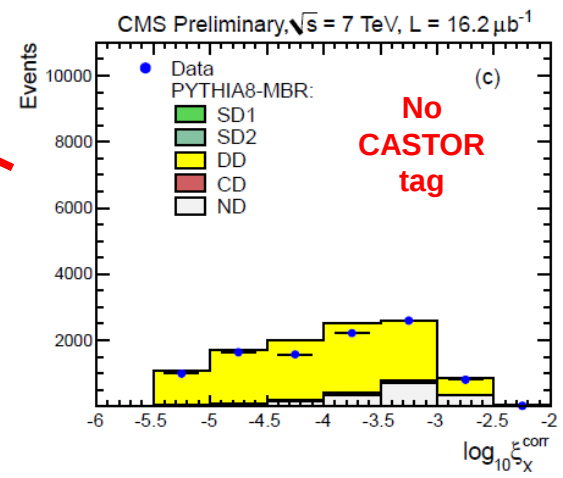
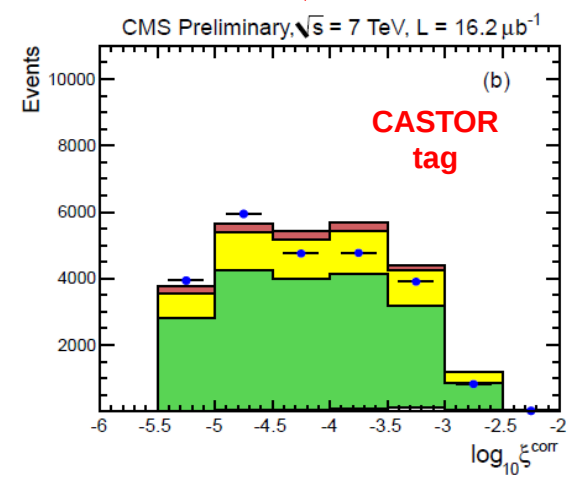
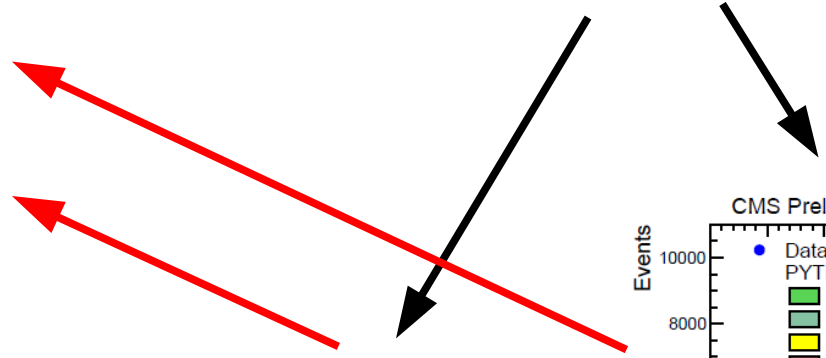
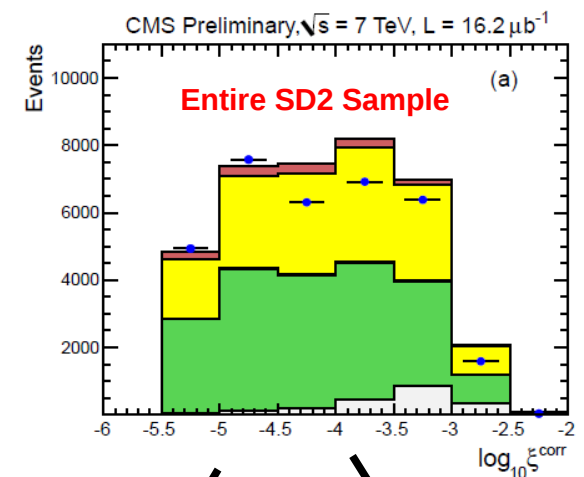
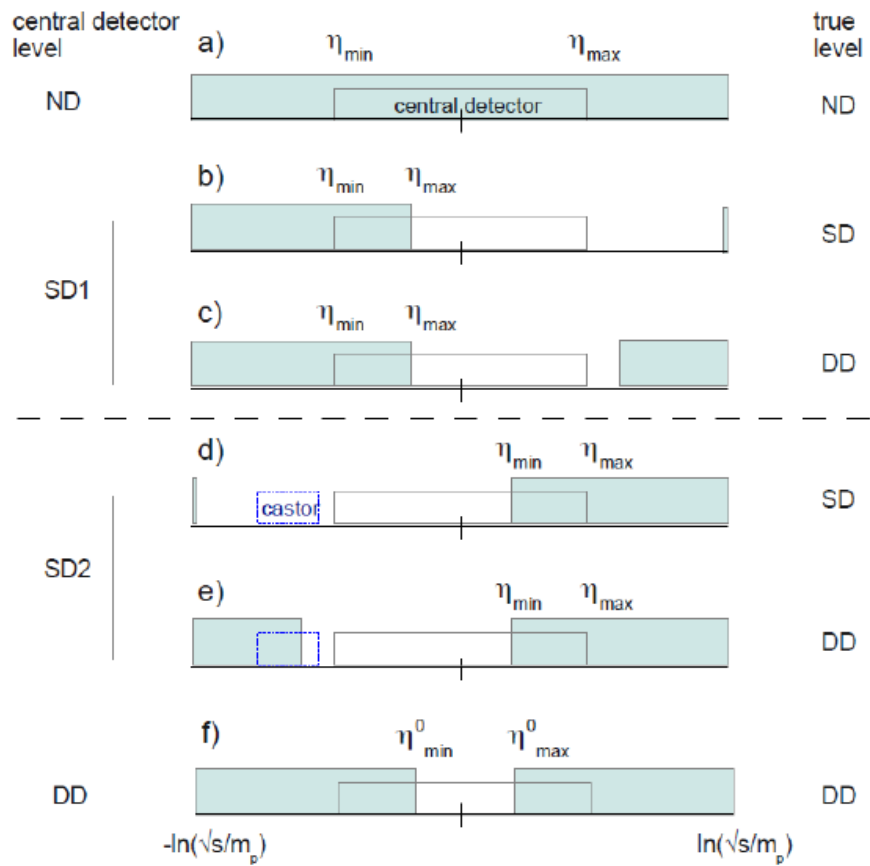
Underlying Event in Very Forward Direction



JHEP 04 (2013) 072

Event generator authors are eager to get more such results!

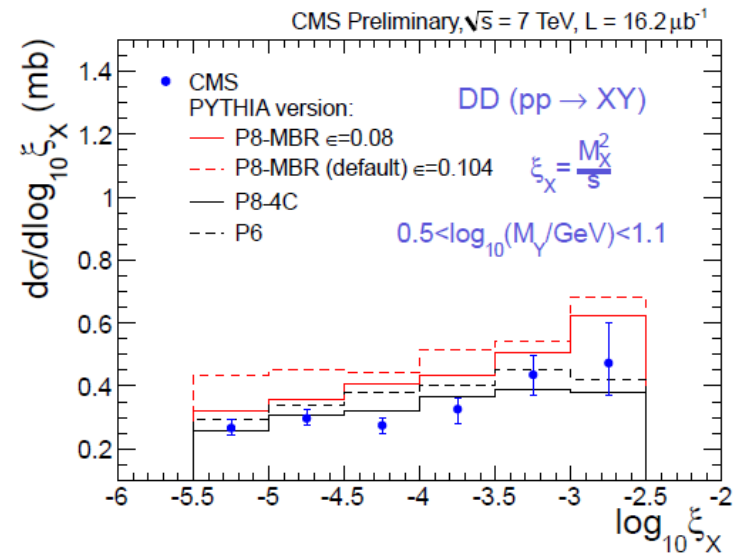
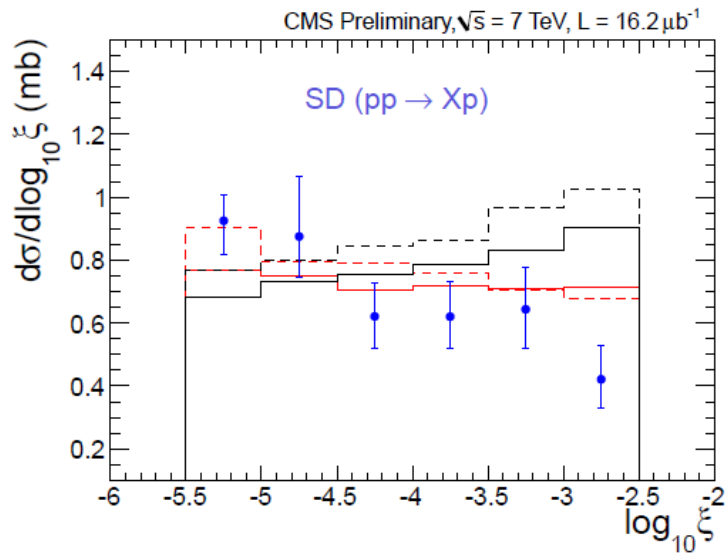
Classification of Soft Diffraction



CMS-FSQ-12-005

Detailed Studies of Diffraction

- Based on CMS:



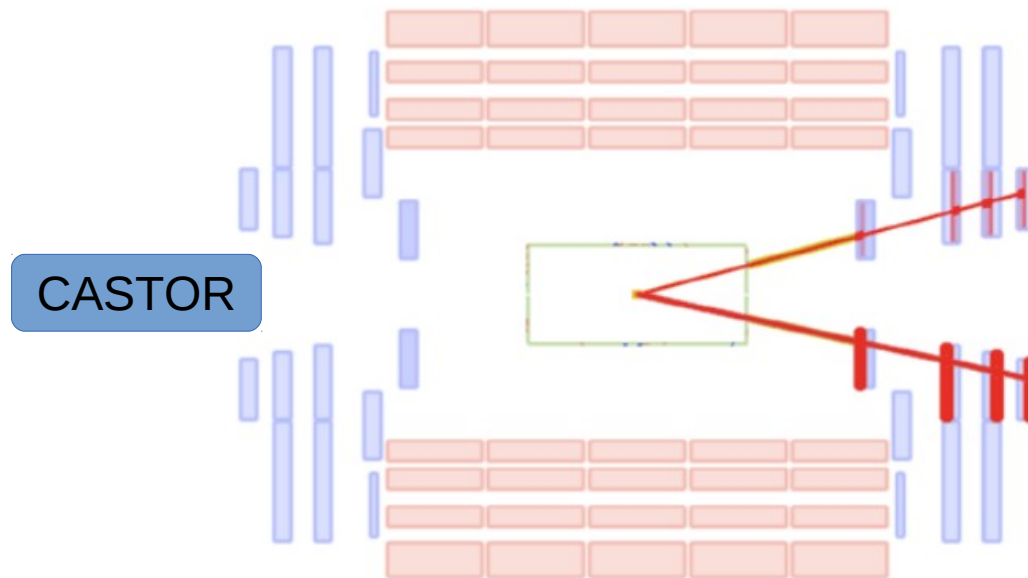
CMS-FSQ-12-005

- Even more potential if combined with TOTEM

Diffractive Z



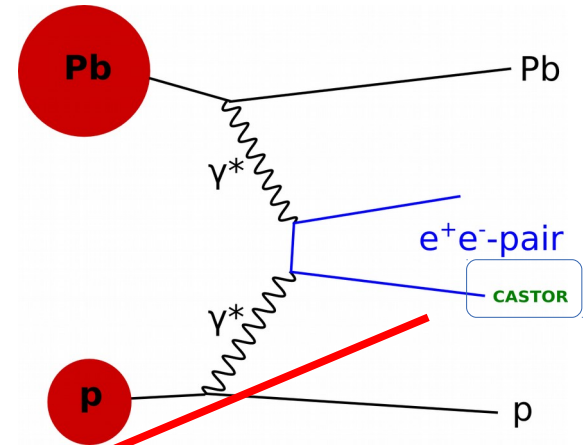
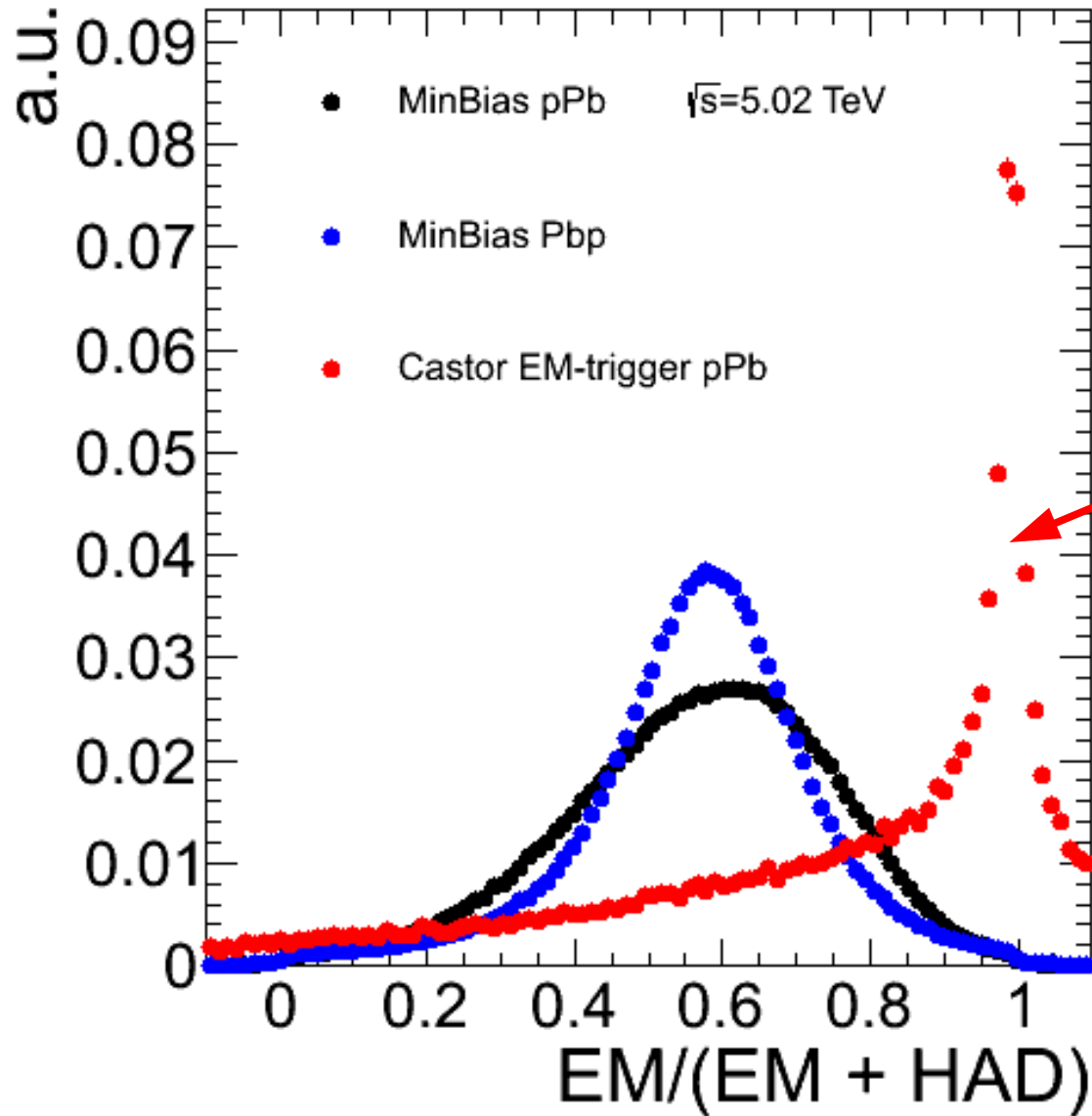
CMS Experiment at LHC, CERN
Data recorded: Sun Oct 17 03:36:27 2010 CEST
Run/Event: 148031 / 144375047
Lumi section: 167



Large Rapidity using CASTOR as tagger

Many other similar studies could be done: **CASTOR as gap-detector**

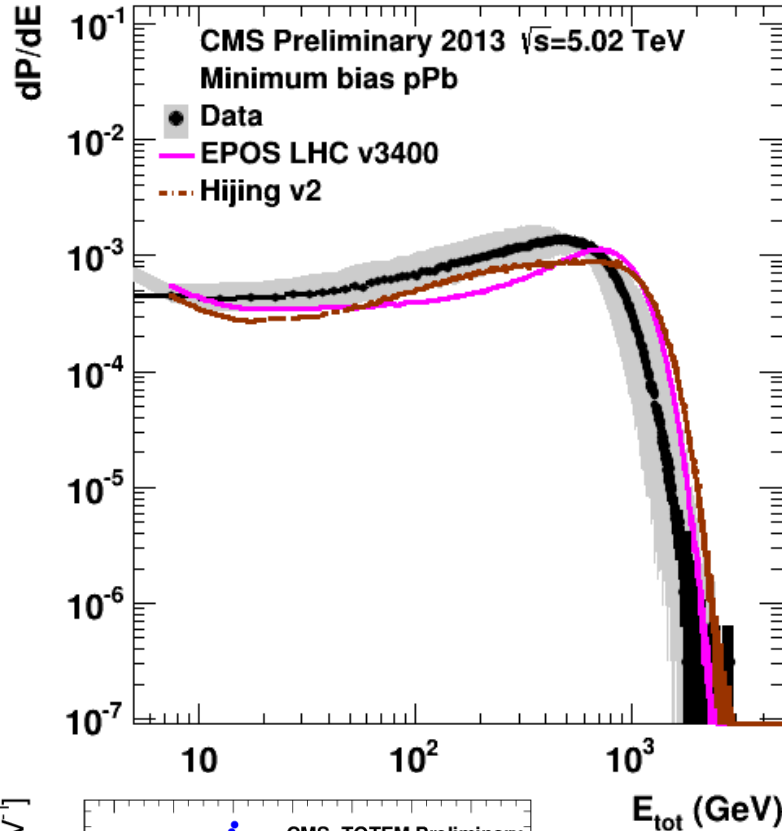
Photon exchange



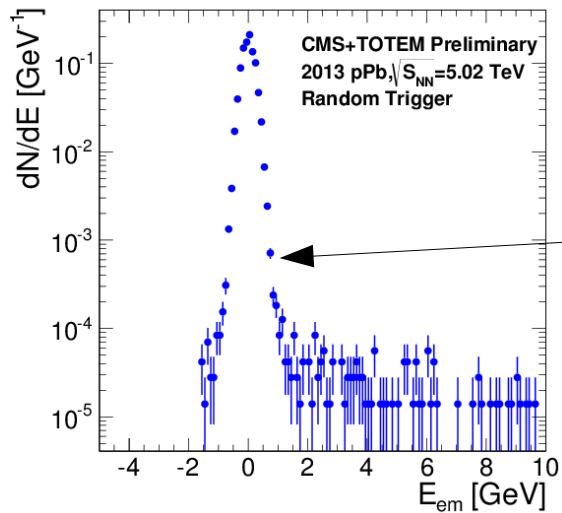
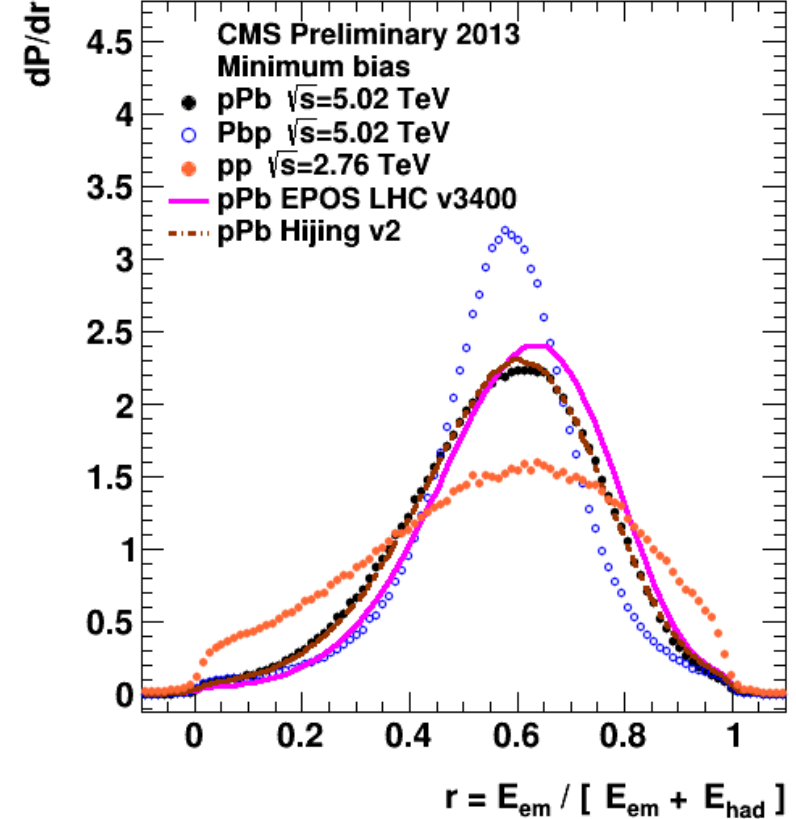
Dedicated trigger
 for very forward
 electrons

Proton-Lead Data 2013

Energy distribution



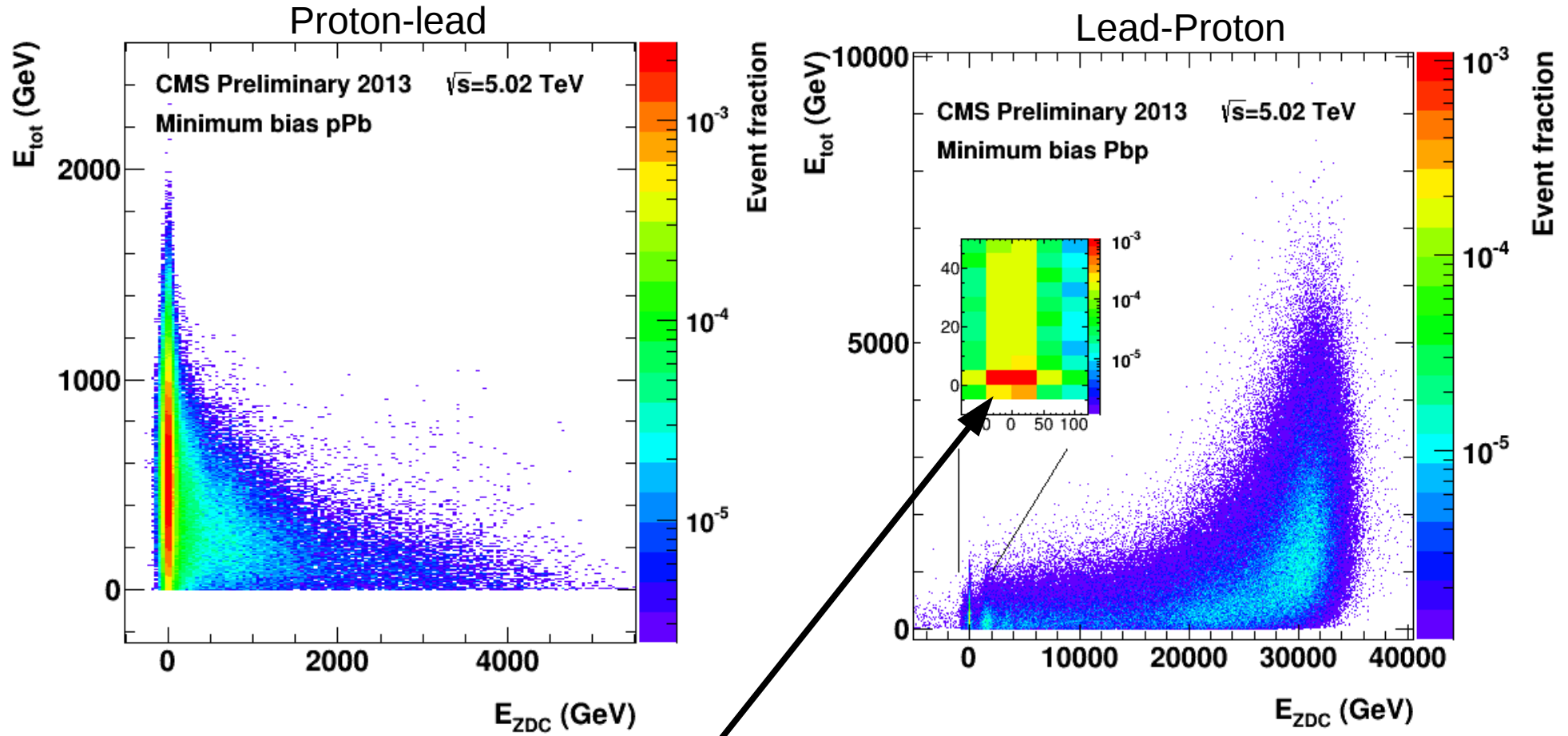
Charge Ratio



Noise study

TWiki CastorDPResultsCMSDP2013035
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/CastorDPResultsCMSDP201303513-006>

CASTOR + ZDC



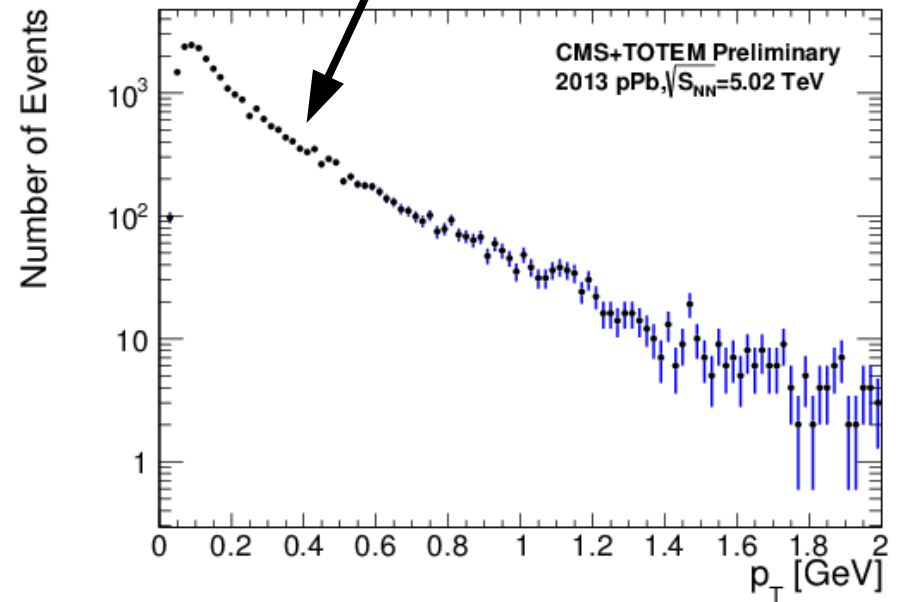
- Photo-hadronic collisions

Very forward electrons

- CMS Trigger 99 (2013)
 - CASTOR EM & Had-Veto
+ T2 low multiplicity
- Sensitive to Electrons

After Offline event selection:
**Sample of excellent isolated
 electron candidates**

Detector level
 Electron p_T -Spectrum measured
 by **CASTOR + T2**

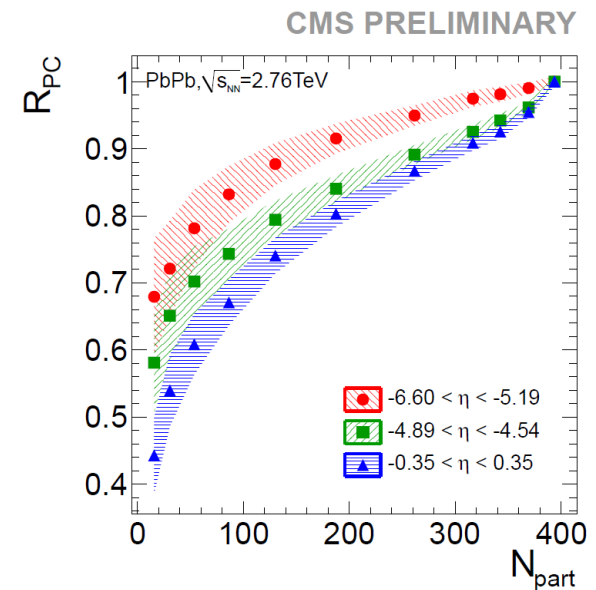
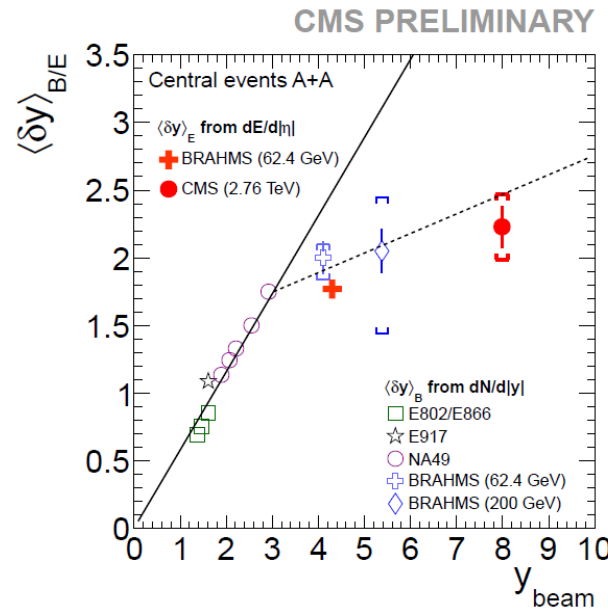
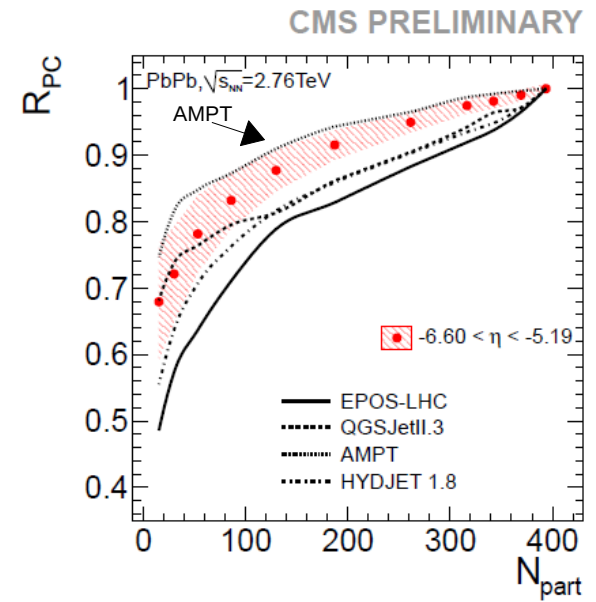
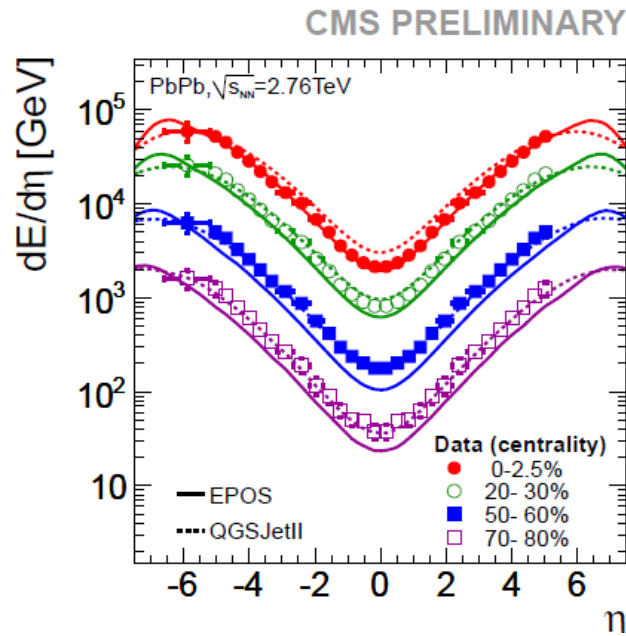


Very forward energy flow in PbPb

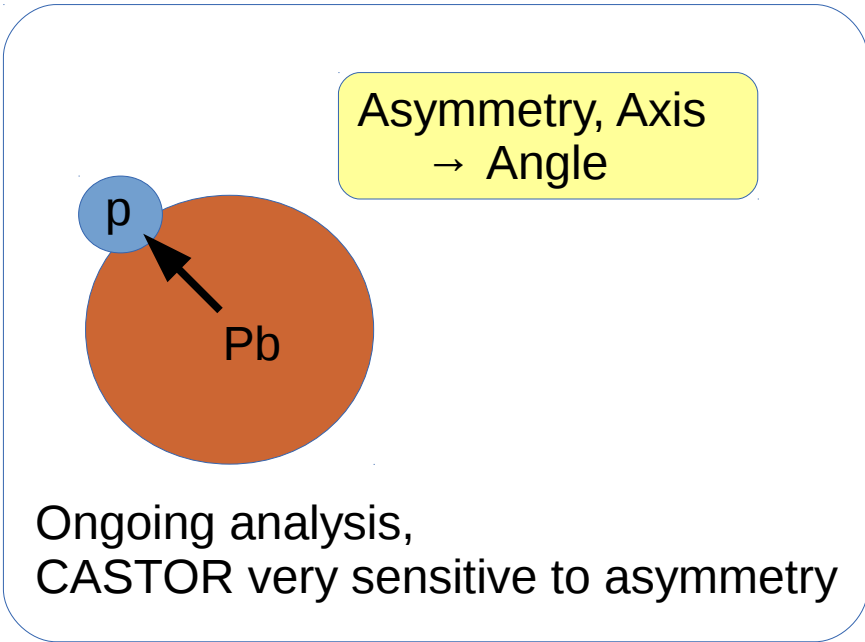
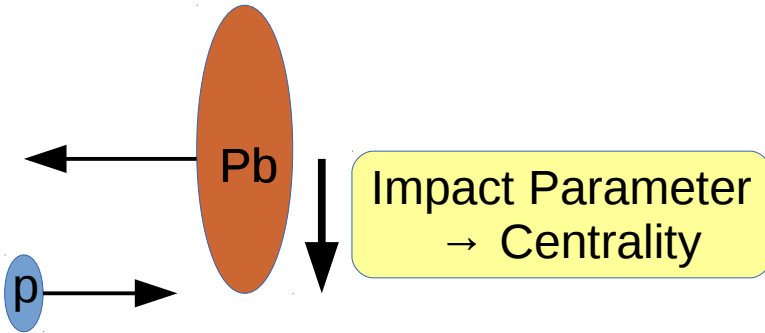
- Characterize partonic medium at low-x
- Probe models in very difficult region
- Sensitive to saturation

CMS-HIN-12-006

Nucl.Phys.A 904–905 (2013)



Heavy Ion Collision Geometry



CMS Preliminary
pPb $\sqrt{s_{NN}} = 5.02$ TeV

Ratio of $dN_{ch}/d\eta$ from different centrality variables

84-100%

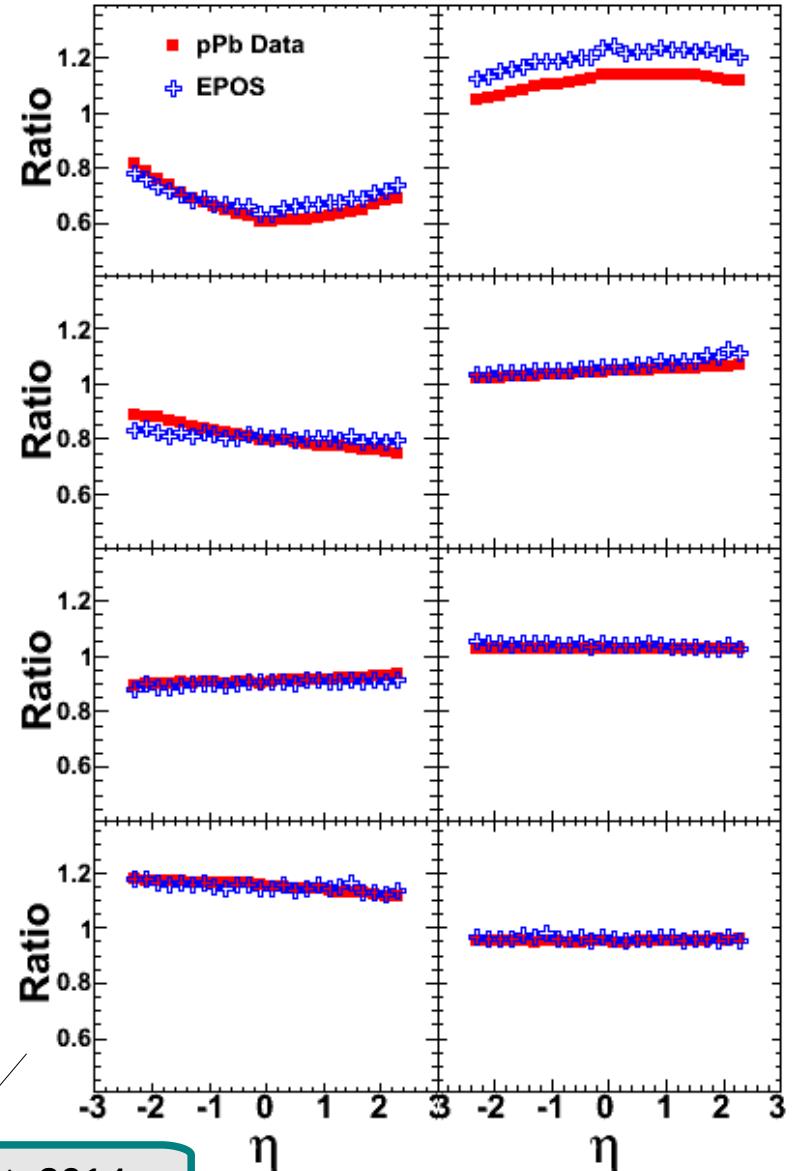
0-5%

$$\frac{N_{\text{pixel}}}{HF E_T \eta < -4}$$

$$\frac{HF E_T |\eta| > 4}{HF E_T \eta < -4}$$

$$\frac{HF E_T \eta < -2.9}{HF E_T \eta < -4}$$

$$\frac{\text{Castor E}}{HF E_T \eta < -4}$$



Common Data with TOTEM

- Muons, **PbPb: 2011**, 2013
- Electrons, pPb and pp: 2013
- DN Katerina, Hauke

TOTEM T2

CMS CASTOR

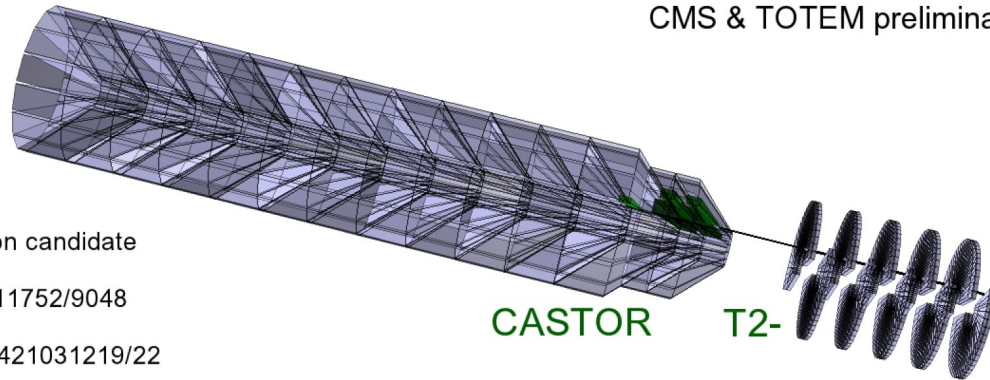


HI CASTOR muon interfill run 182882, TOTEM run 7338

New level of Experimental Detail

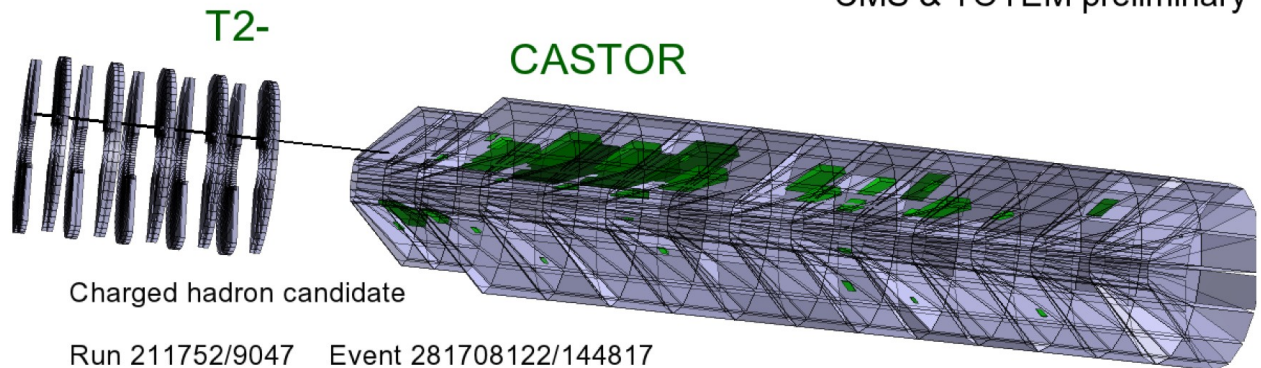
CMS & TOTEM preliminary

Electron candidate
Run 211752/9048
Event 421031219/22



Castor: sector 12, $E = 322.624$ GeV
(2 neighbour sectors and 3 modules)
T2: $\phi = -1.90424$, $\eta = -5.97295$.

CMS & TOTEM preliminary



Charged hadron candidate

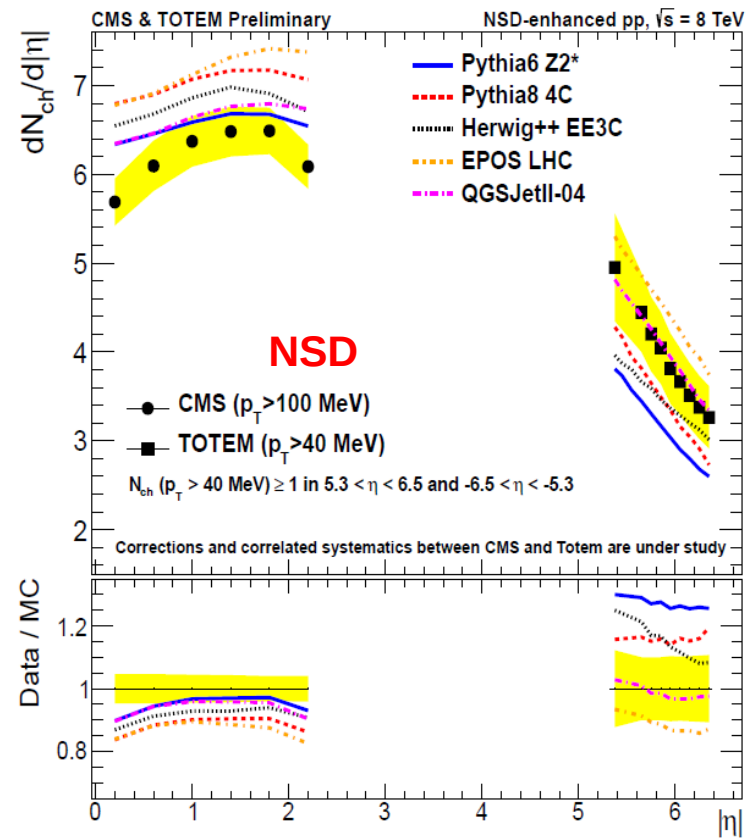
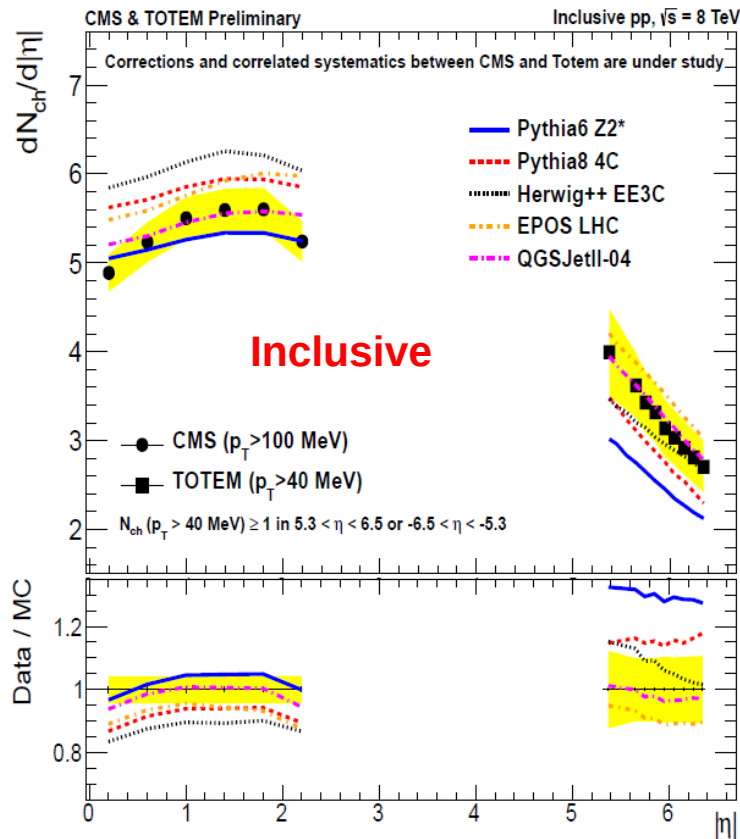
Run 211752/9047 Event 281708122/144817

Castor: central (most energetic) sector 9
 $E = 205$ GeV (sectors 8,9,10)
T2: $\phi = -2.935$; $\eta = -5.69$

Summary, First Part...

- CASTOR detector in good shape
 - Data picked up by several analyzers:
 - Diffraction
 - Rapidity Gaps
 - Photo-Diffraction
 - Underlying Event
 - Minimum Bias, Energy Flow
 - **And more !**
- **Unique data, unique phase-space**
- Provide triggers for the main physics purpose

CMS + TOTEM, Model Tuning



CMS-FSQ-12-026

- First public CMS + TOTEM result from 8 TeV data
- **At 13 TeV: For the first time, do $dN/d\eta$ and $dE/d\eta$ at the same time, from $-6.6 < \eta < 5.2$**

Trigger Development Plans

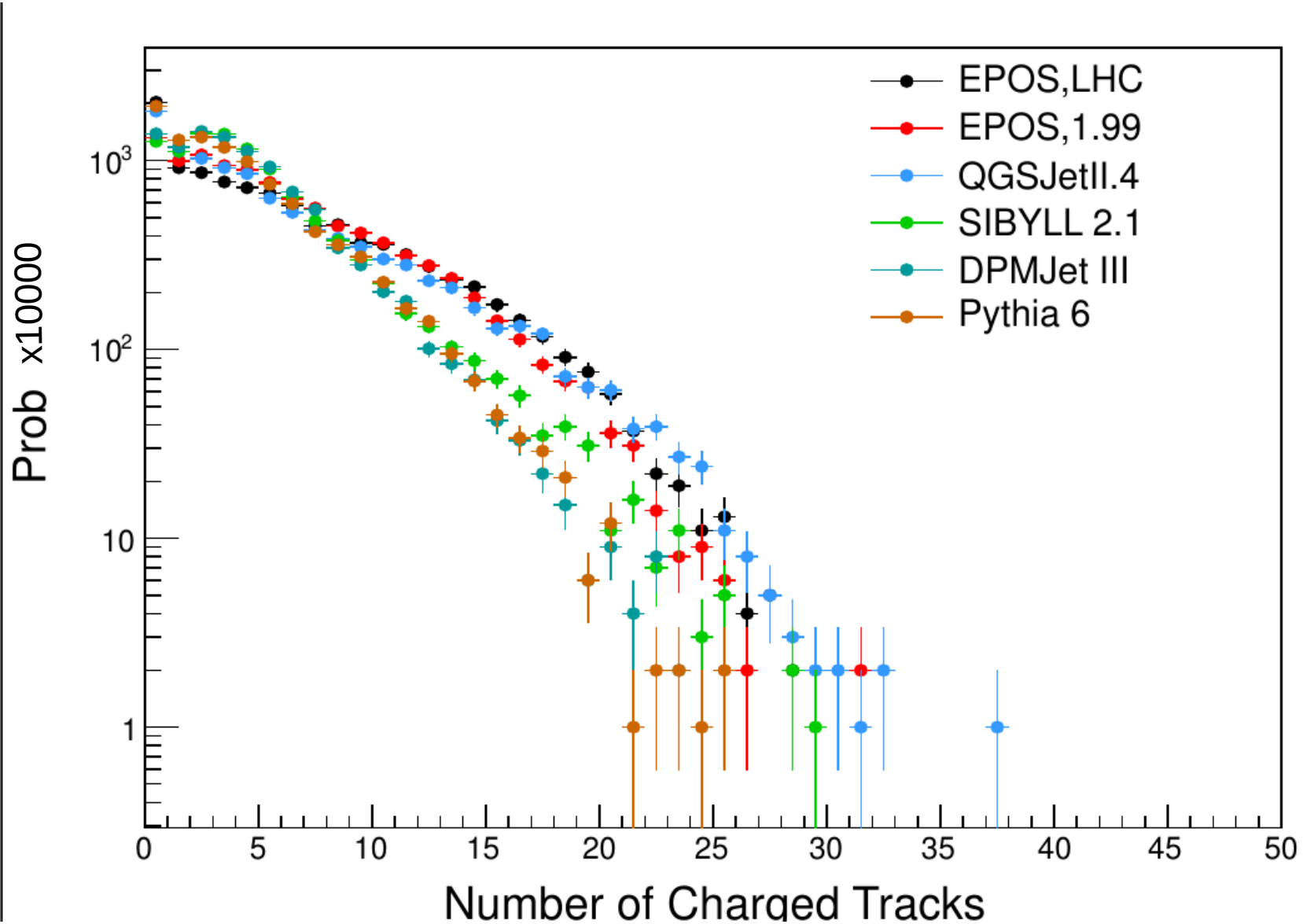
- Jet Trigger, different thresholds
- Isolated Electron trigger, different thresholds
- Rapidity Gap trigger
- Muon trigger

- Very exciting tool to study several **key questions of forward physics** at LHC
- **Additional help welcome ...**

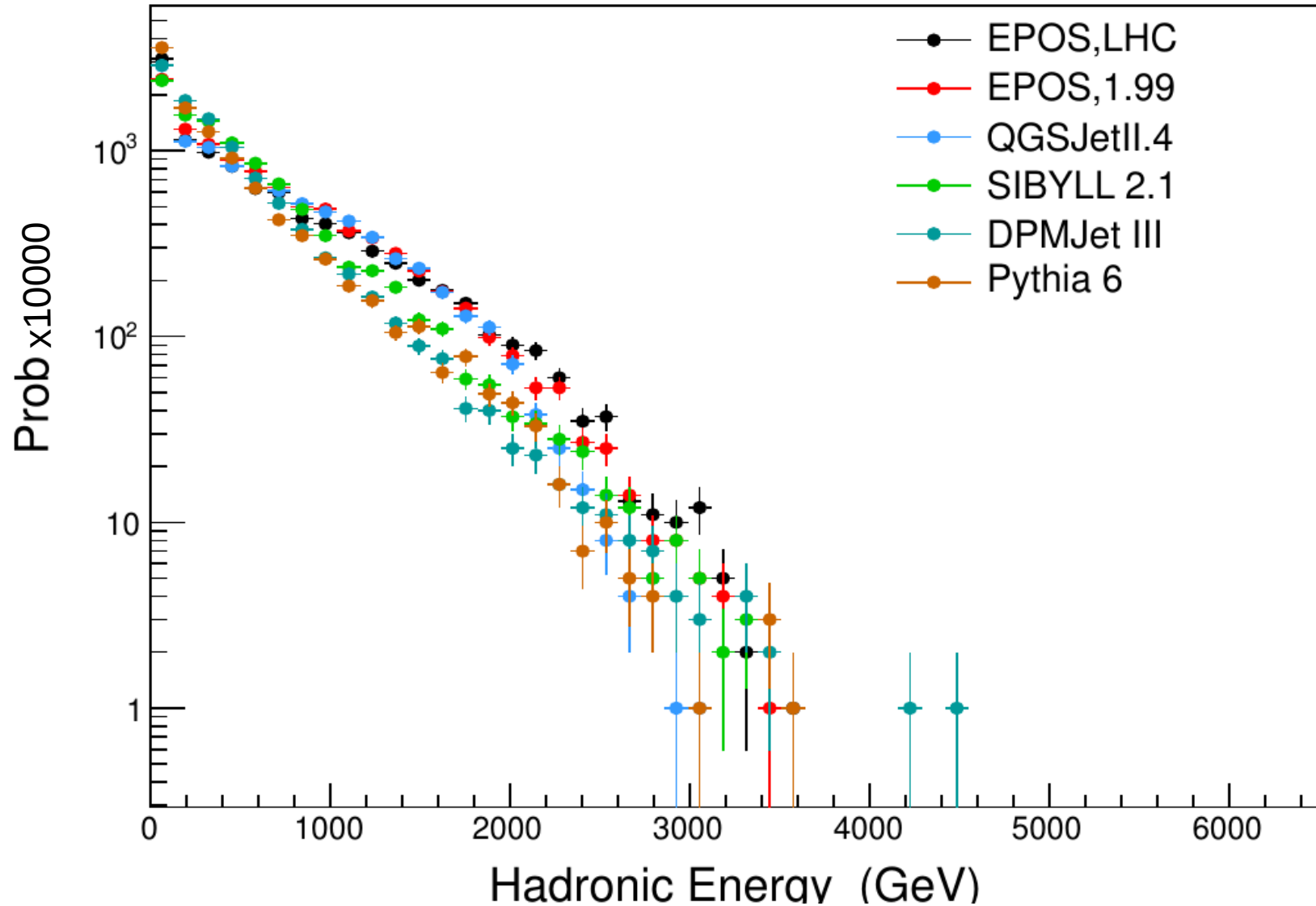
In 2013 CASTOR for the first time provided a trigger to CMS (and TOTEM)

- Some Generator Level Plots are following
- Full detector simulations are available since last week for trigger development, not yet used

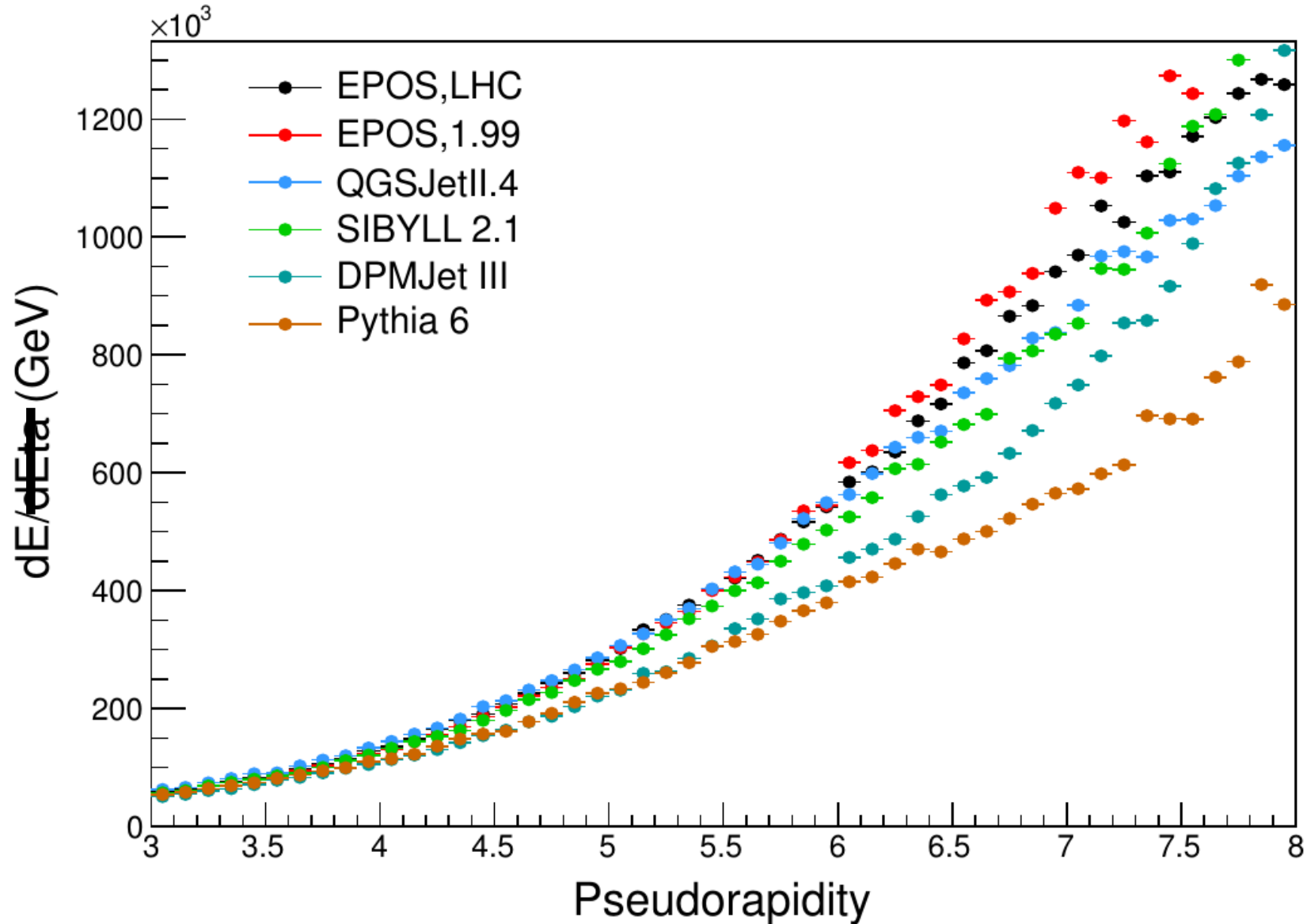
Charged Particle Multiplicity, T2



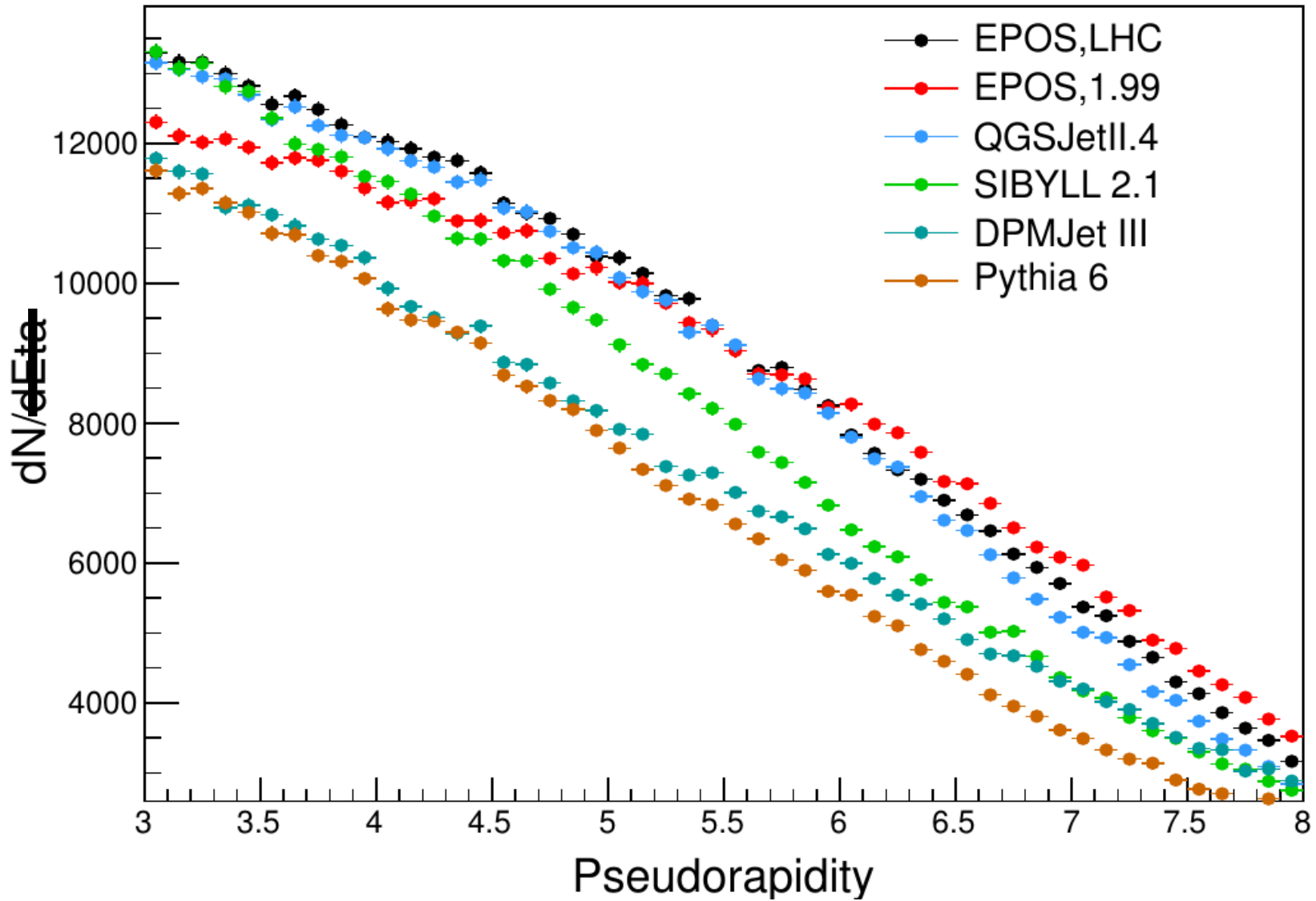
Hadronic Energy in CASTOR



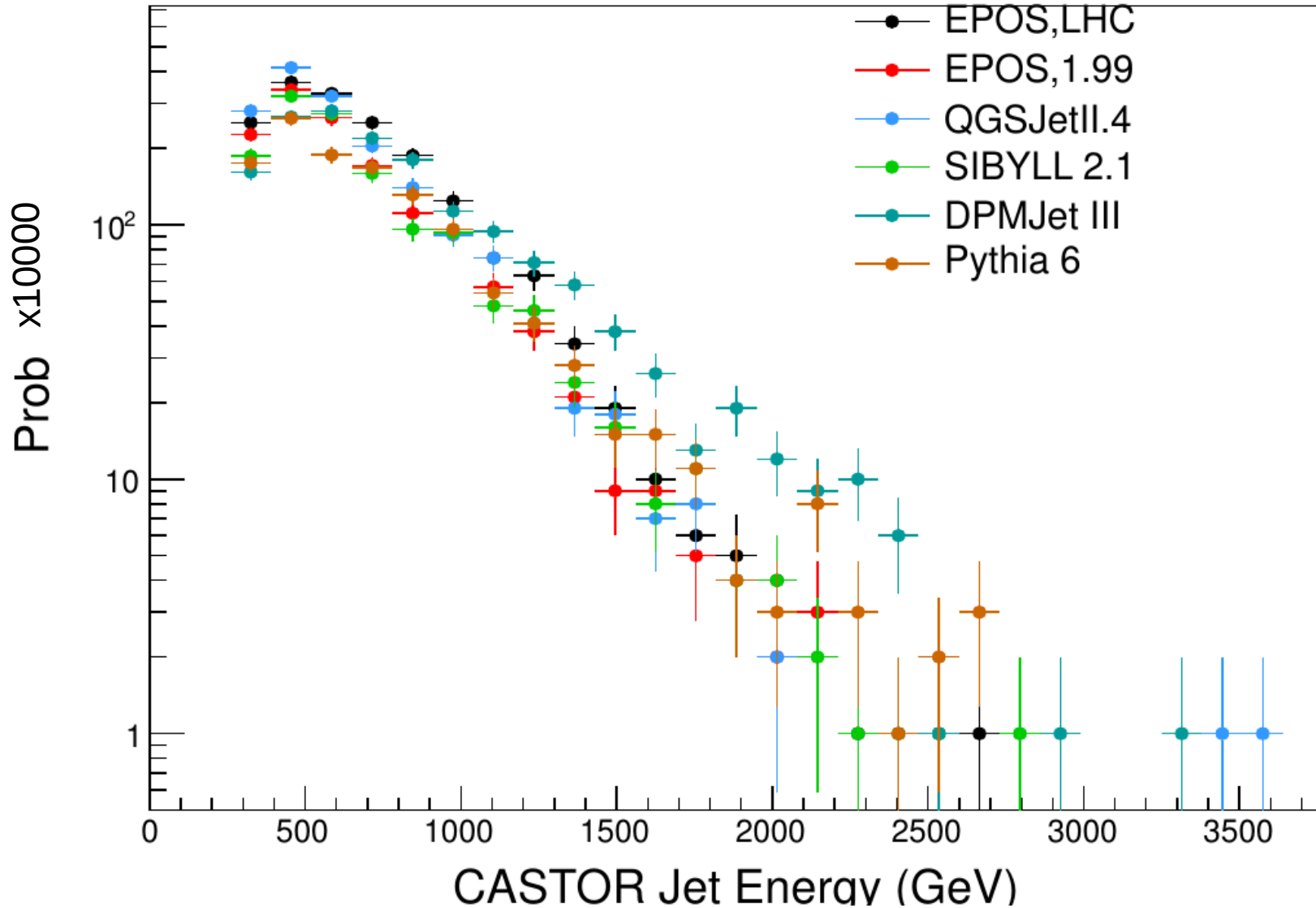
Energy Flow



Charged Particle Flow



Forward Jet Spectrum



- Many more pots should be done (and will be) to search for the most discriminating and interesting measurements

Run 2, Summary (rough)

	Low pileup ($\lambda \ll 1$)	Medium pileup ($\lambda < 1$)	High pileup ($\lambda > 1$)
10 to 20 hours, interfill		Interfill muons with T2	Interfill muons!
$\ll 1$ pb	dE/deta		w/o CASTOR
1 pb	Diffraction		
10 pb		Drell Yan, Jets cross sections, MN	
more	Diffraction Z and similar	Diffraction Z and similar	

Average energy in one MB collision at 13TeV: $\langle E(7\text{TeV}) \rangle * 2 = 1 \text{ TeV}$

Lambda	P(0)	P(1)	PU	"typical Energy/evt": $\langle E \rangle * \text{int}(\lambda)$	
0.05	95%	0.5%	4.5%	1 TeV	EXCELLENT
0.5	60%	30%	10%	1 TeV	
1	37%	37%	26%	1 TeV	OK
5	0.7%	3.4%	95.9%	5 TeV	NOT OK...

Summary

CASTOR exists...

- It is a well understood detector (with issues)
 - Support always welcome
- Diverse physics case
- First public results are available, and getting more rapidly
- **CASTOR is a low pileup detector and needs de-installation for high pileup running**
- Trigger from CASTOR could give access to a new specific range of event classes
- Combination of data with T2 is excellent and by far not exploited so far

I certainly forgot to mention some things or had to simplify reduce at some point...

I want to thank all collaborators who contribute and contributed to CASTOR since many years

Their hard work made it possible that CASTOR produces results now, and will do in the coming years.