

CASTOR

The very-forward calorimeter at LHC

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for the CMS / CASTOR Calorimeter Project

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The very forward CASTOR calorimeter of the CMS experiment



The CMS collaboration

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ABSTRACT: The physics motivation, detector design, triggers, calibration, alignment, simulation, and overall performance of the very forward CASTOR calorimeter of the CMS experiment are reviewed. The CASTOR Cherenkov sampling calorimeter is located very close to the LHC beam line, at a radial distance of about 1 cm from the beam pipe, and at 14.4 m from the CMS interaction point, covering the pseudorapidity range of $-6.6 < \eta < -5.2$. It was designed to withstand high ambient radiation and strong magnetic fields. The performance of the detector in measurements of forward energy density, jets, and processes characterized by rapidity gaps, is reviewed using data collected in proton and nuclear collisions at the LHC.

<https://doi.org/10.1088/1748-0221/16/02/P02010>

Physics

New physics in heavy ion collisions

Baryon-rich forward fragmentation region

Search for strangelets, penetrating particles, "centauro events"

Soft pp physics

Soft QCD

Diffraction

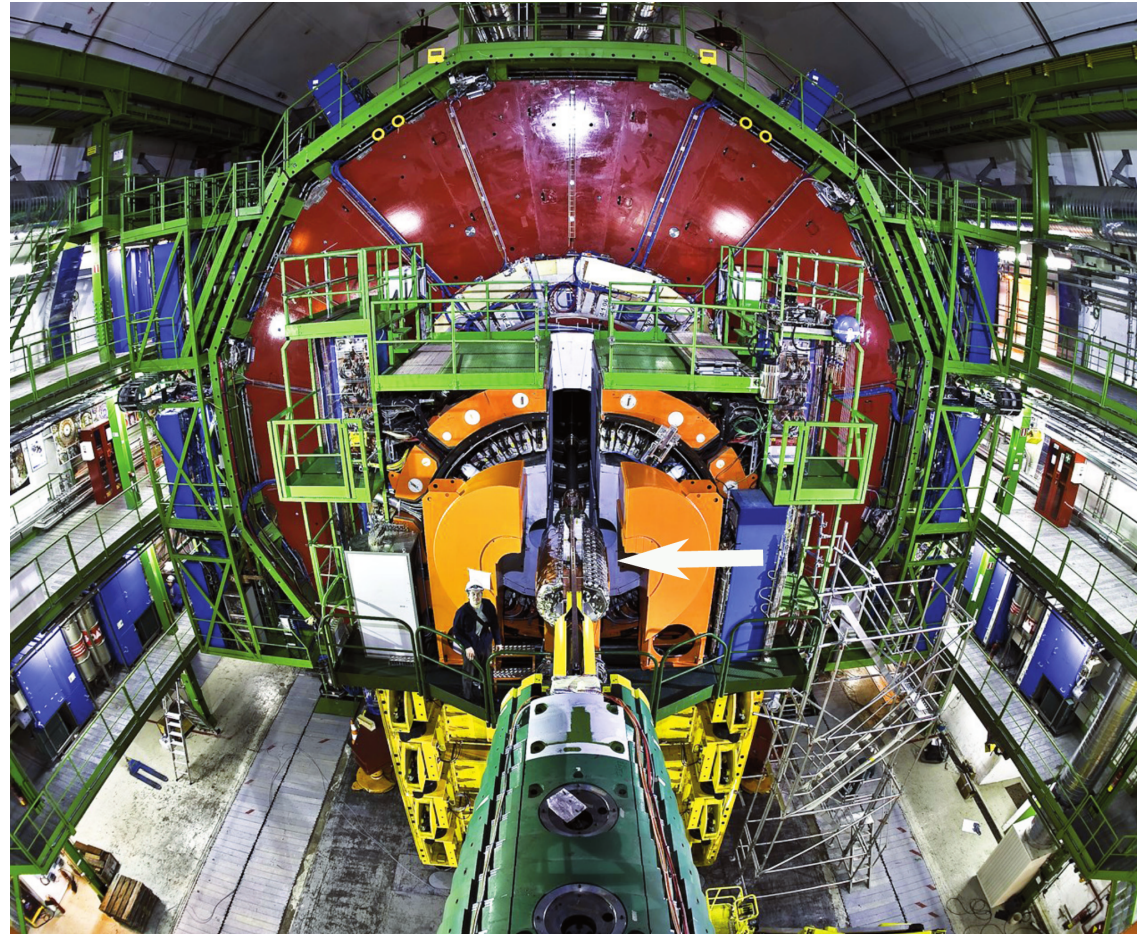
Low-x dynamics

Cosmic ray physics

Minimum bias pp QCD measurements

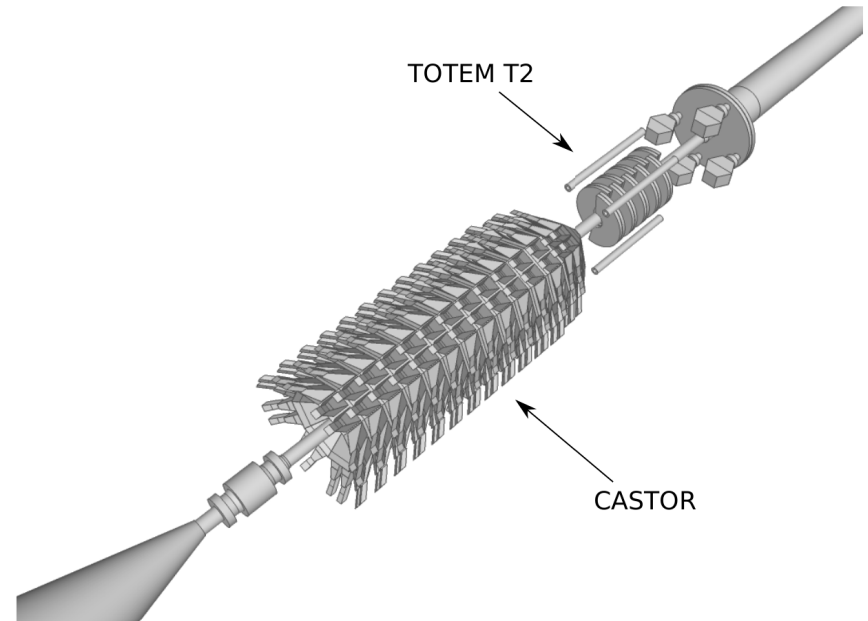
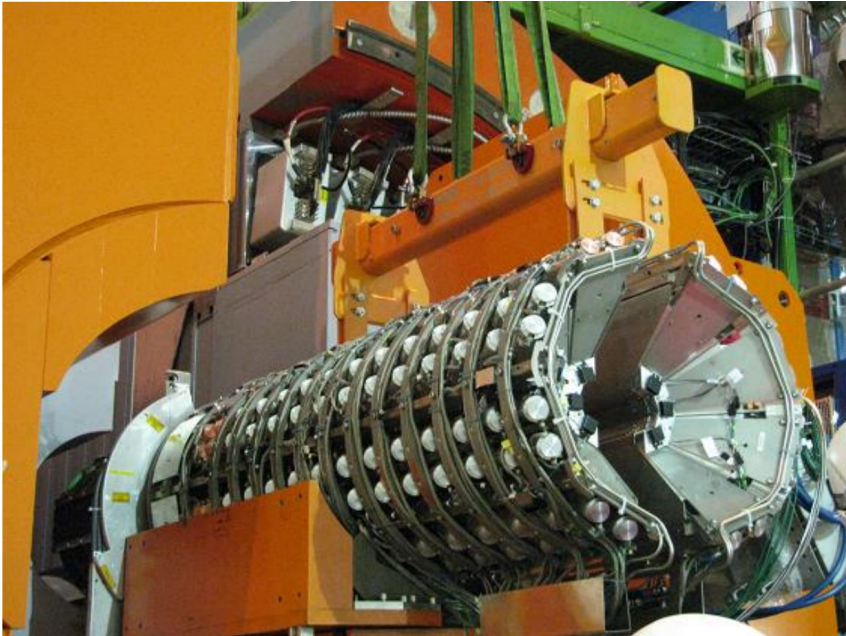
Minimum bias nucleus collisions

- E.M. Section:
 $20 X_0$
- Had. Section:
10 lambda-int
- 224 PMTs, 16 segments
in phi, one segment in
eta: $-6.6 < \text{eta} < -5.2$



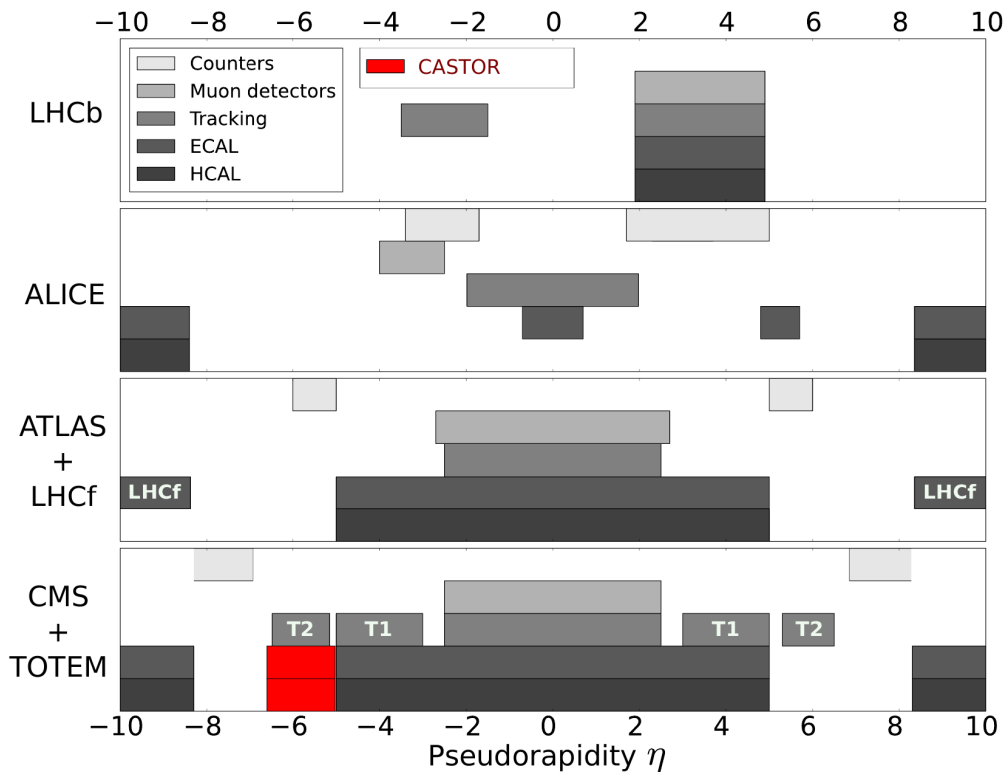
Location

- Embedded in CMS forward shielding, right after TOTEM / T2

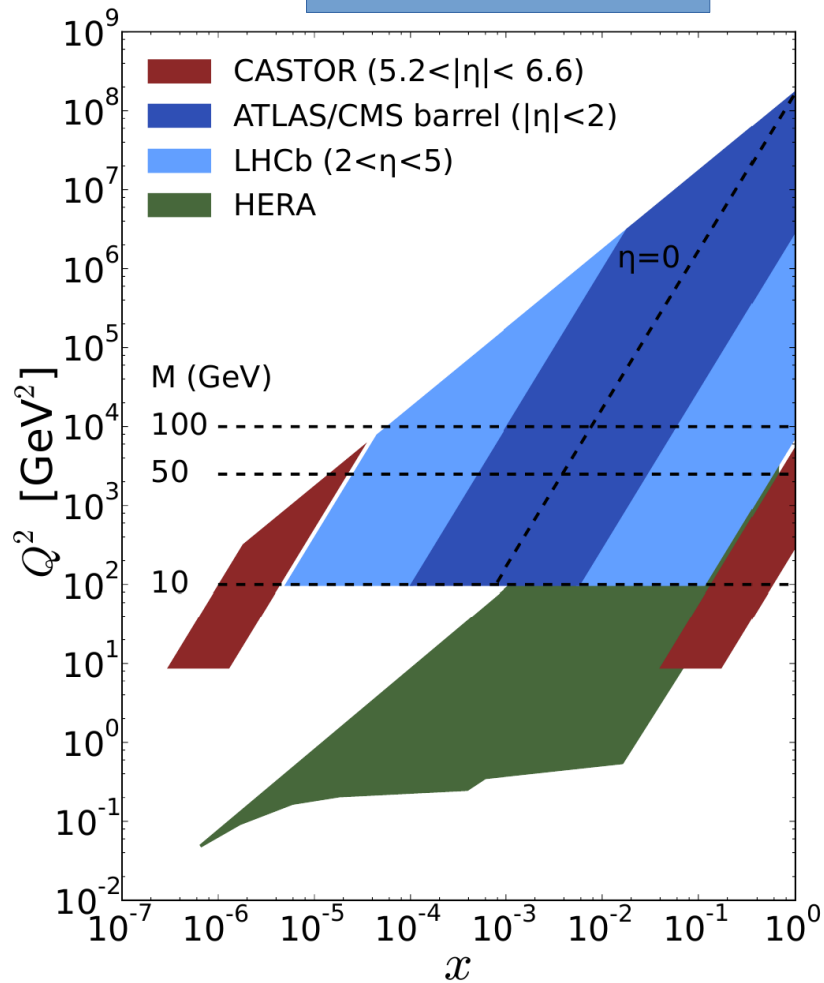


Acceptance

geometric



kinematic

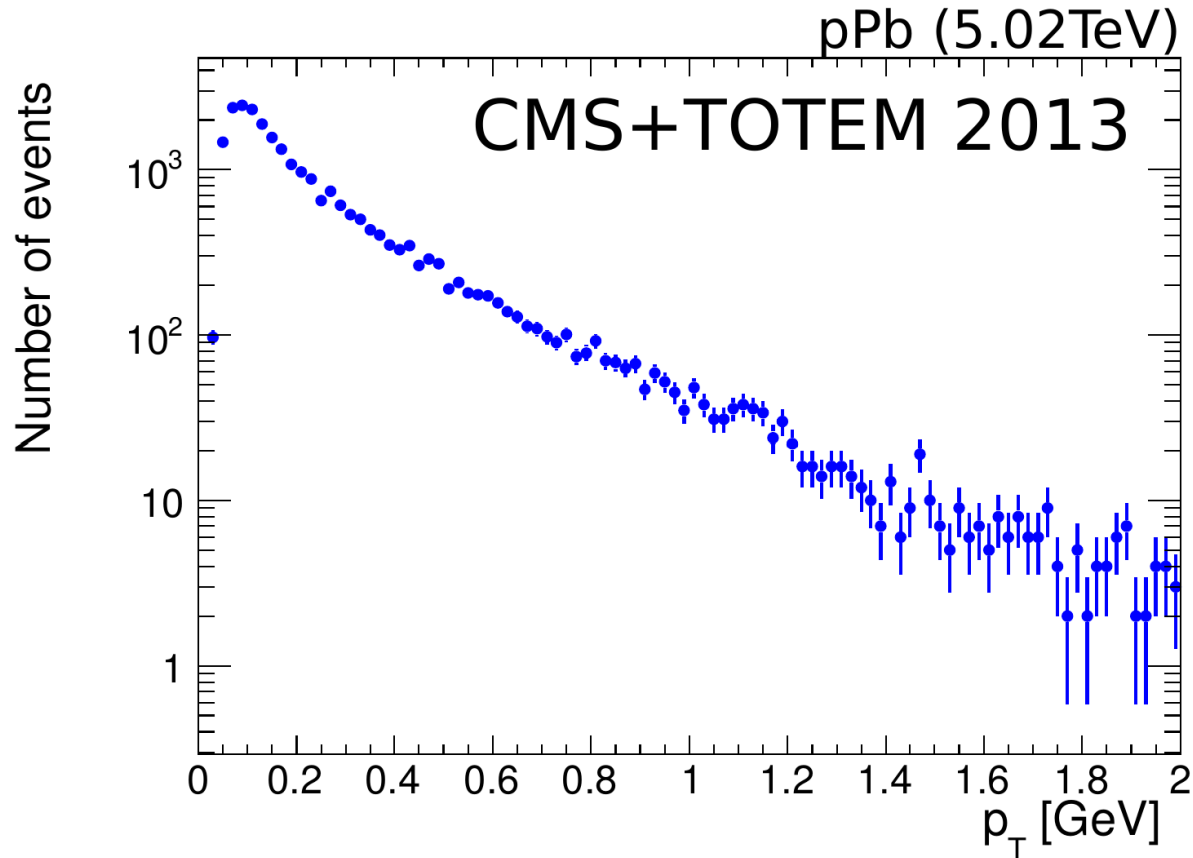


Data and Triggers

Year	$\sqrt{s_{NN}}$	Colliding system	CASTOR trigger(s)
2009	0.9 TeV	proton-proton	
2010	0.9 TeV	proton-proton	halo muon
	2.76 TeV	proton-proton	halo muon
	7 TeV	proton-proton	halo muon
	2.76 TeV	lead-lead	halo muon
2011	7 TeV	proton-proton	halo muon
	2.76 TeV	lead-lead	halo muon
2013	5.02 TeV	proton-lead	halo muon & e.m. cluster
	2.76 TeV	proton-proton	halo muon & e.m. cluster
2015	13 TeV	proton-proton	halo muon & jet
	5.02 TeV	proton-proton	halo muon & jet
	5.02 TeV	lead-lead	halo muon & jet
2016	5.02 TeV	proton-lead	halo muon & jet
	8.16 TeV	proton-lead	halo muon & jet
2018	5.02 TeV	lead-lead	halo muon & jet

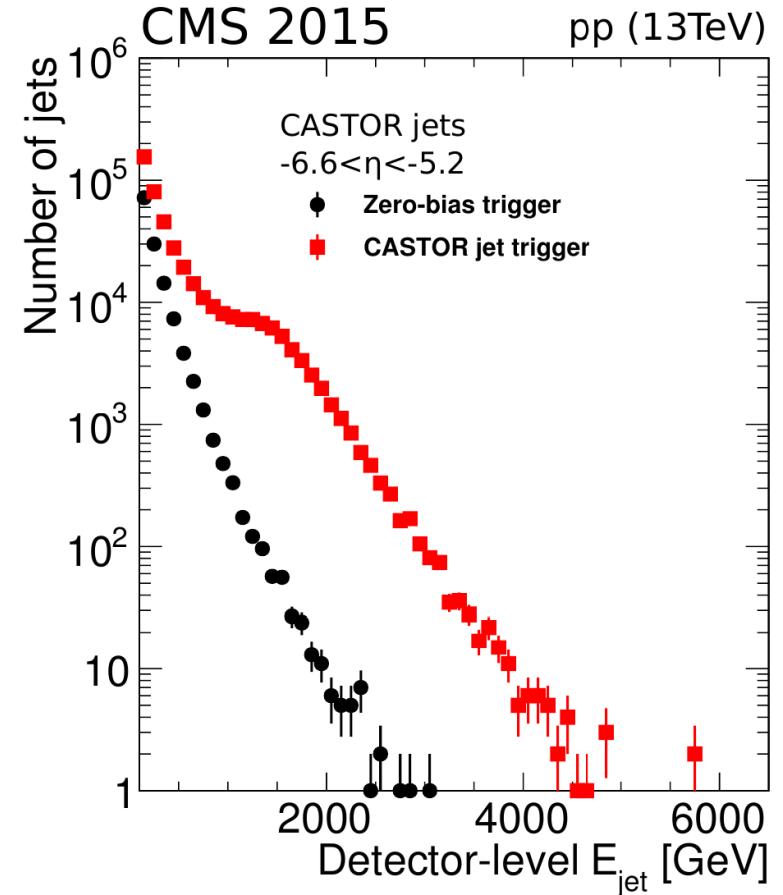
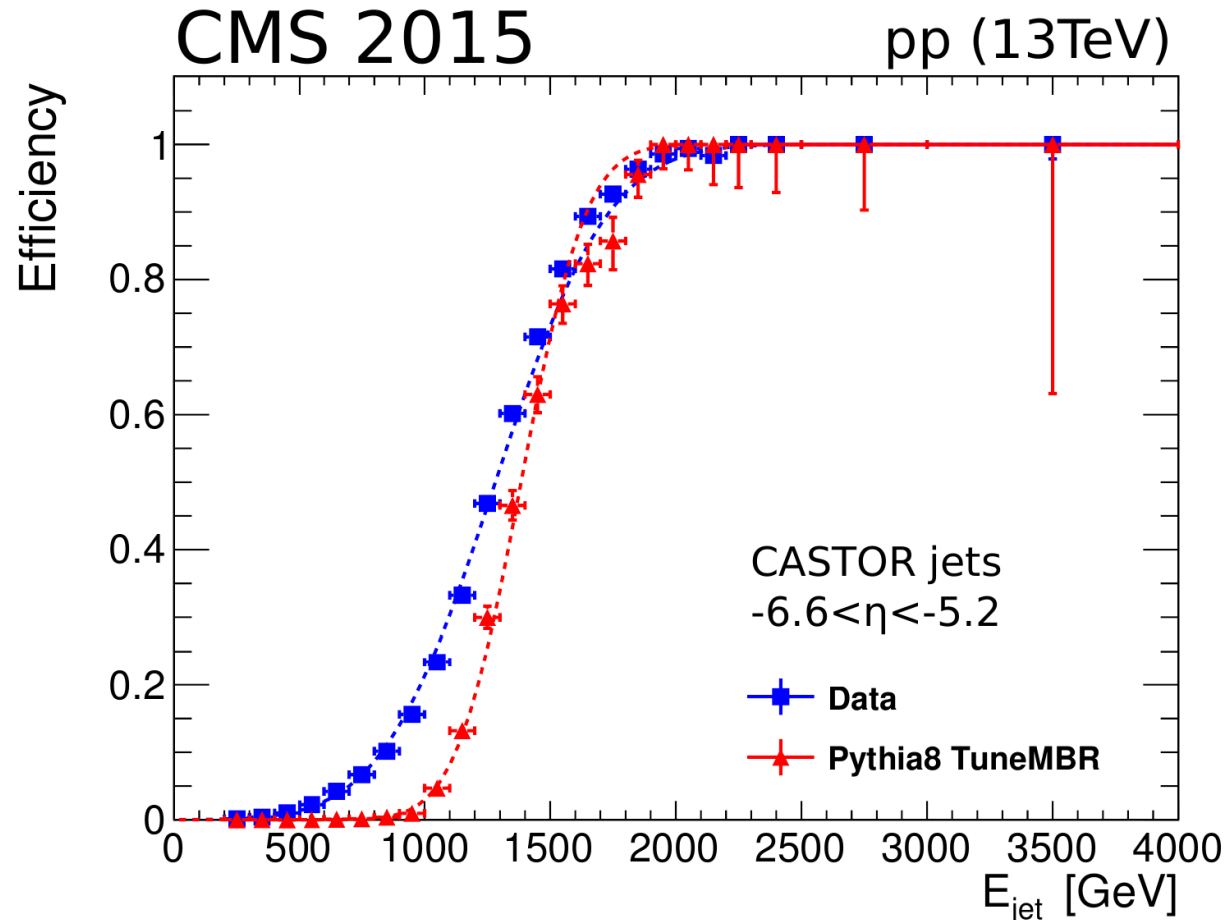
- Almost all LHC runs from Run1 and Run2 recorded.
- Since 2010: Halo muon trigger
- Since 2015: Jet trigger
- In 2013: e.m. trigger

Example, very forward electron candidates



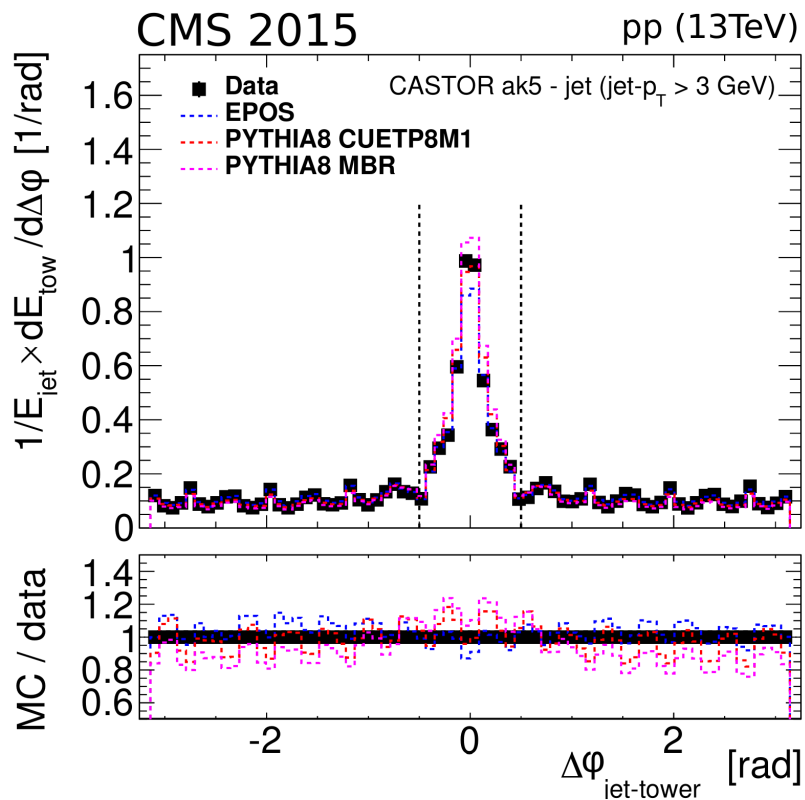
- Physics objects with e.m. trigger in CASTOR and a low-multiplicity trigger in TOTEM / T2
- Important: no physics nor acceptance corrections

Example jet triggers

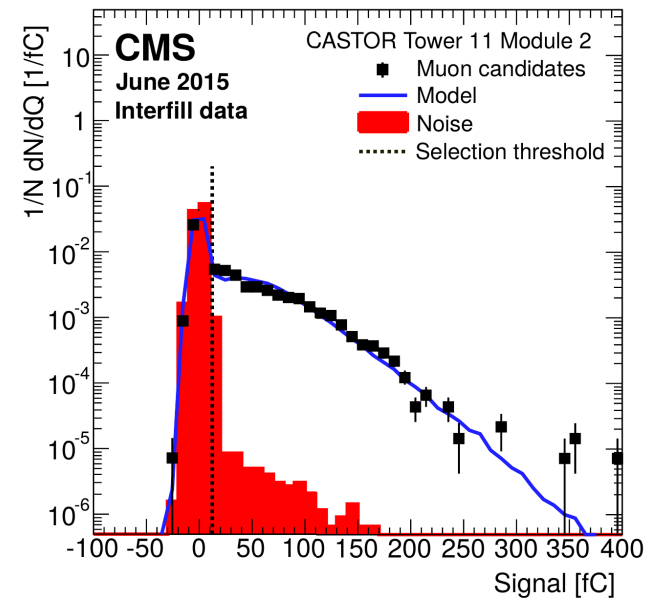
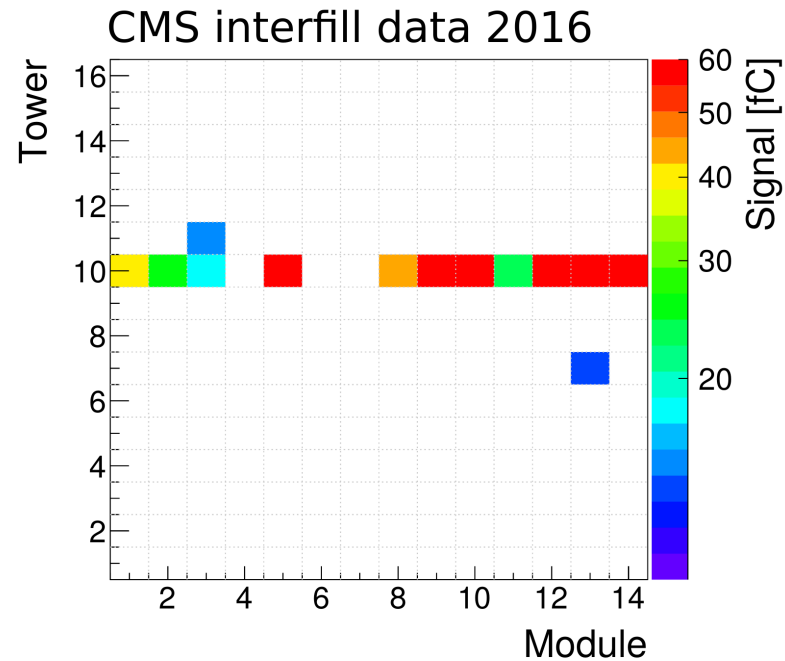
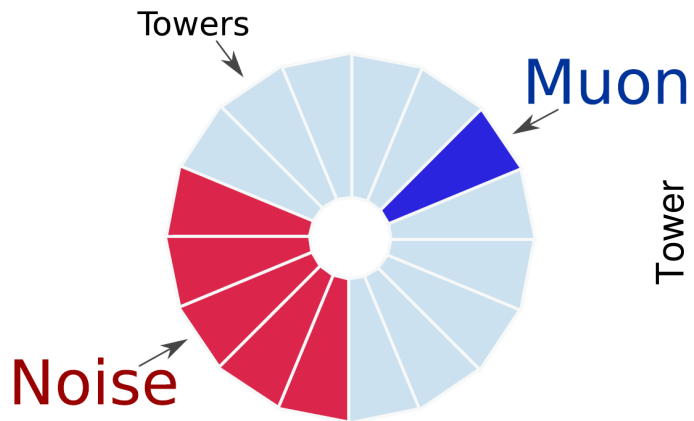


Observed jet shape, pp

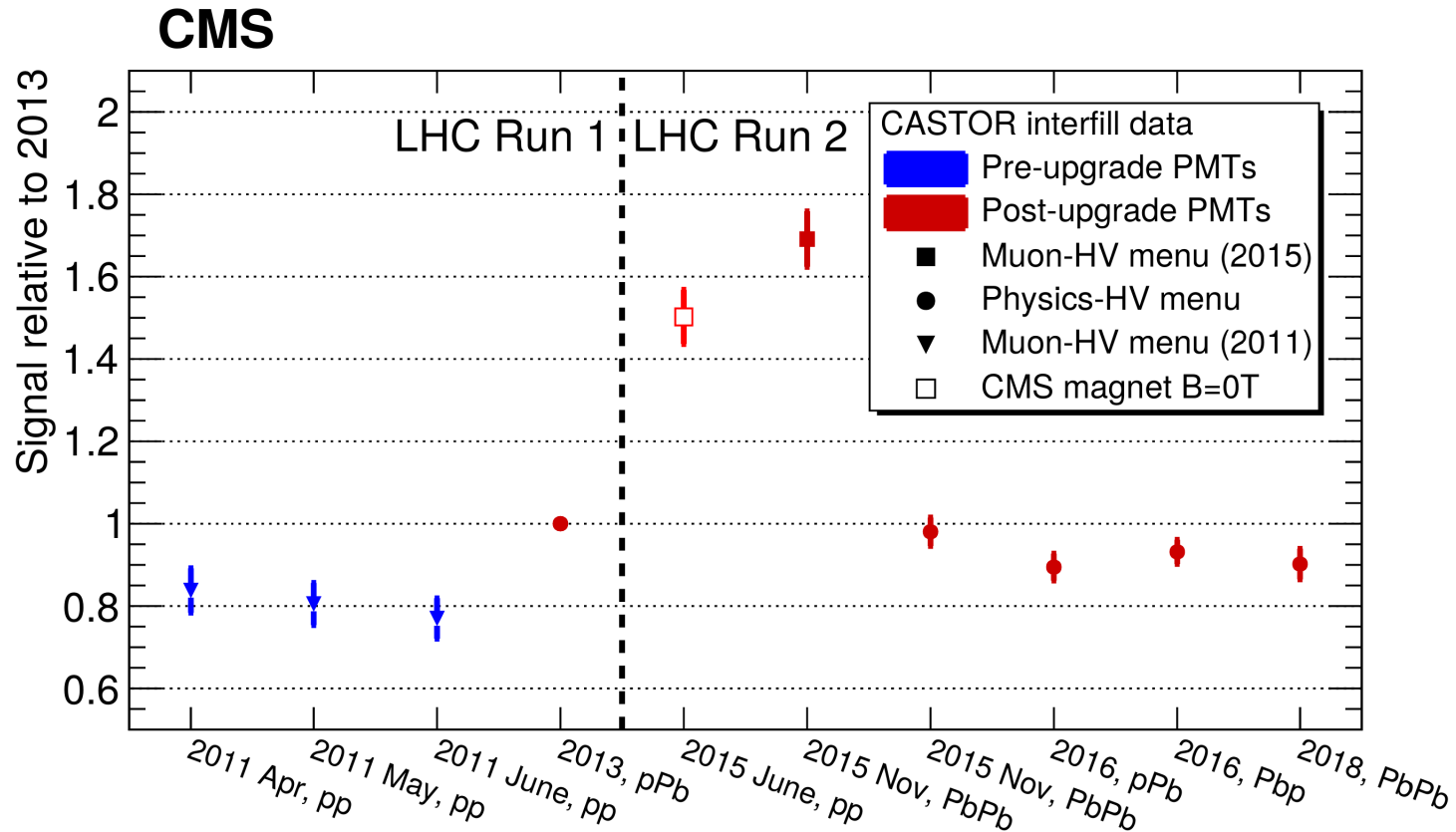
- Surprisingly good agreement on detector level between data and MC



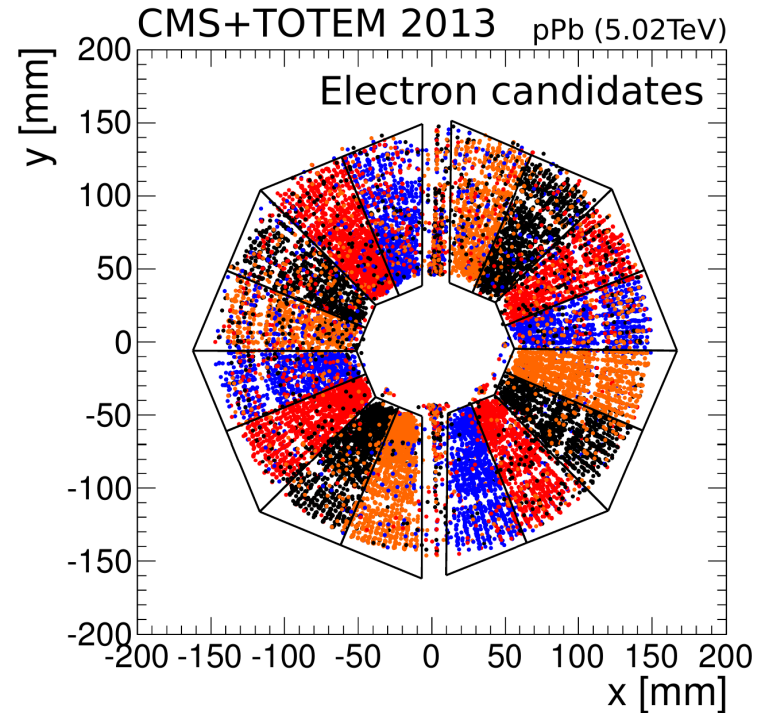
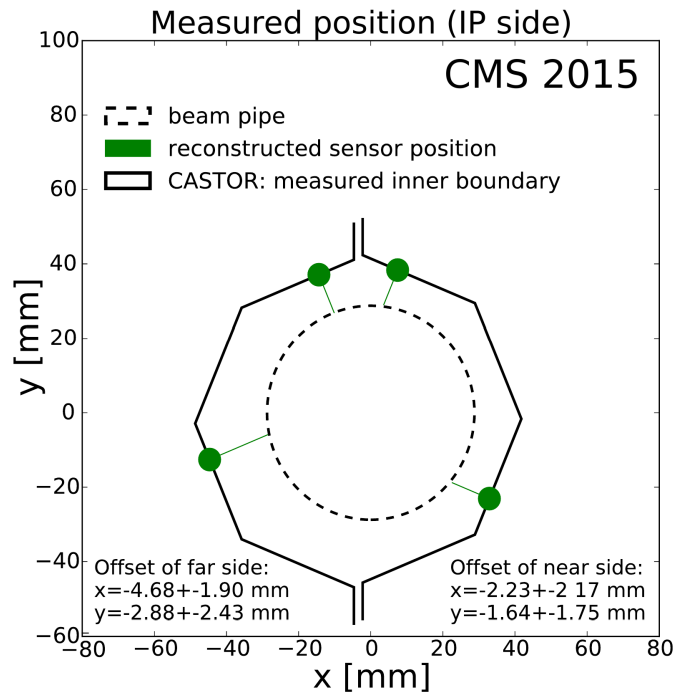
Beam-halo muon data



All-time calibration overview

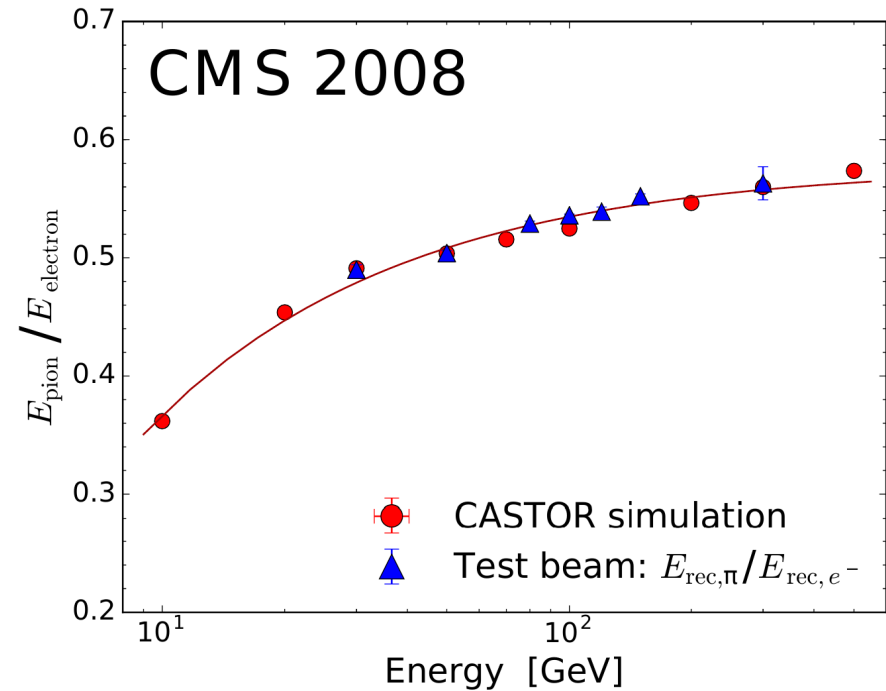
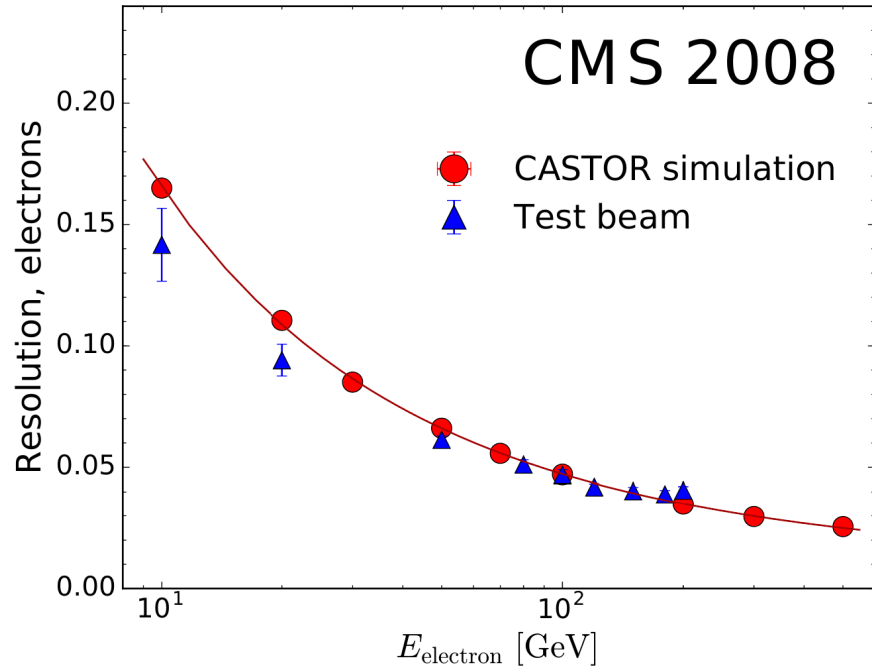


Alignment



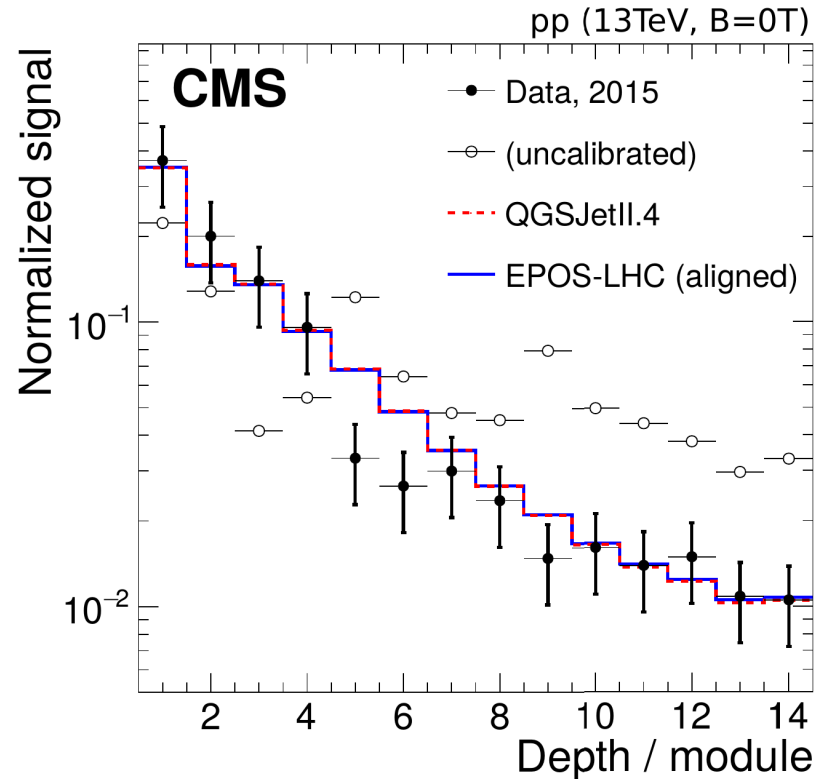
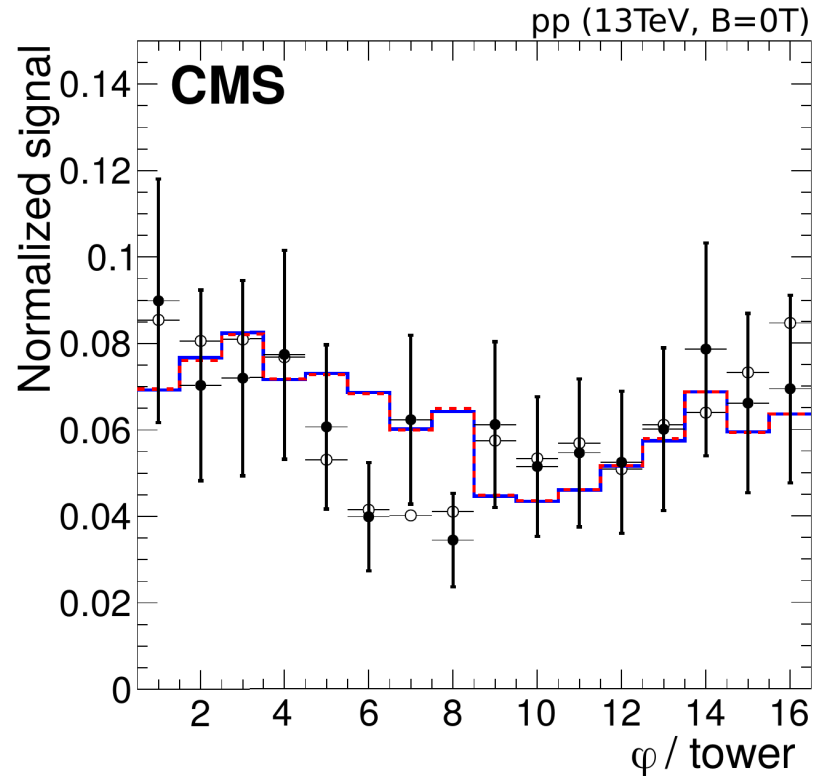
- Alignment precision on the level of a few mm, sufficient for most analyses

Test beam comparison

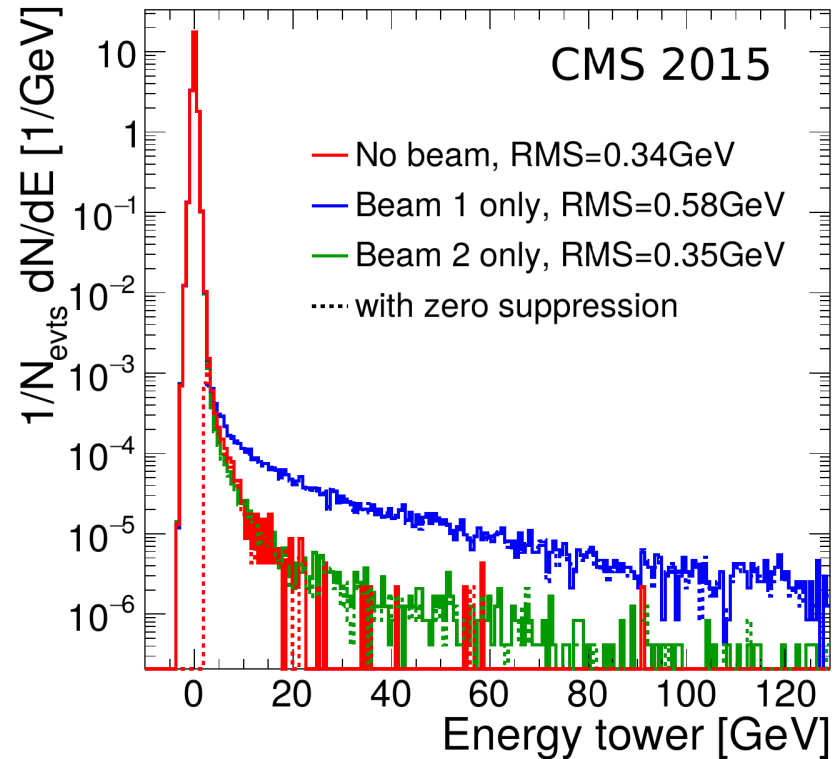
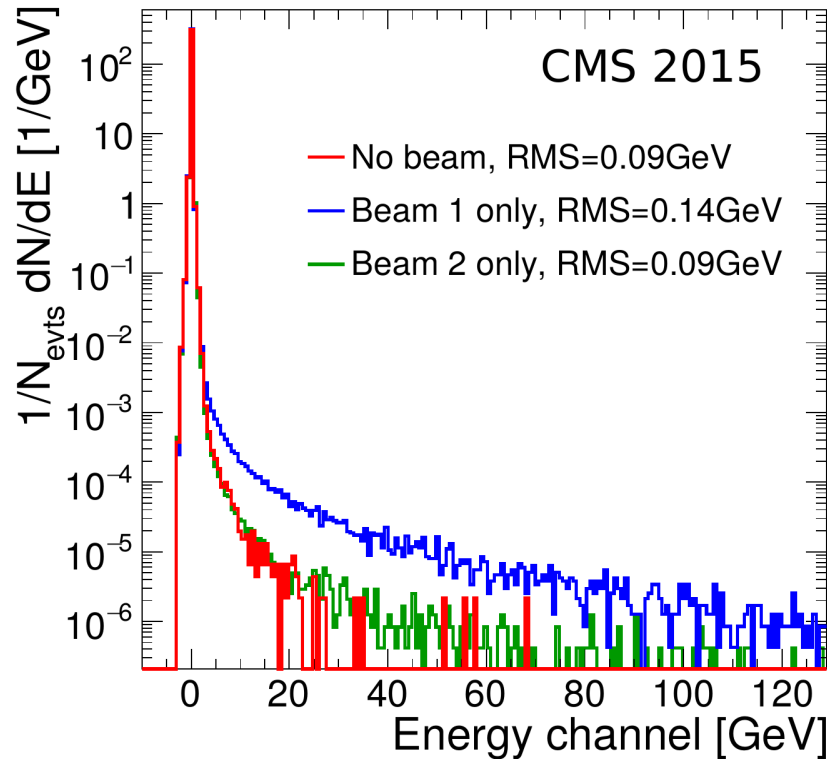


Simulations optimized to well reproduce test-beam data.

End-to-end data/MC comparison

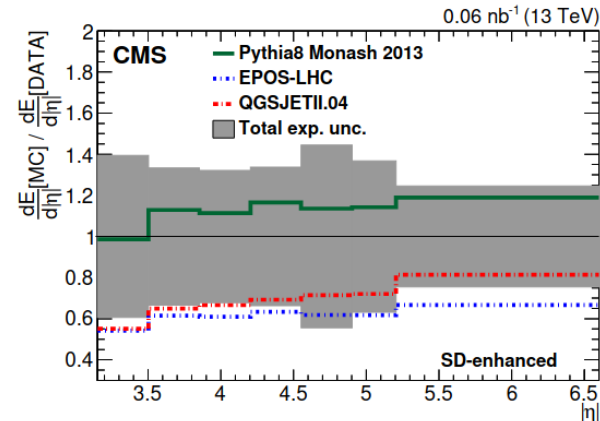
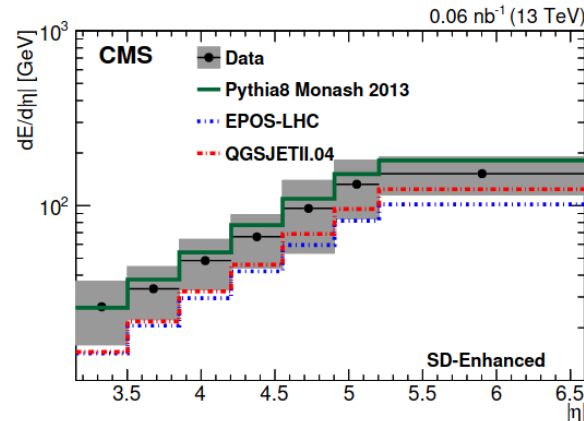
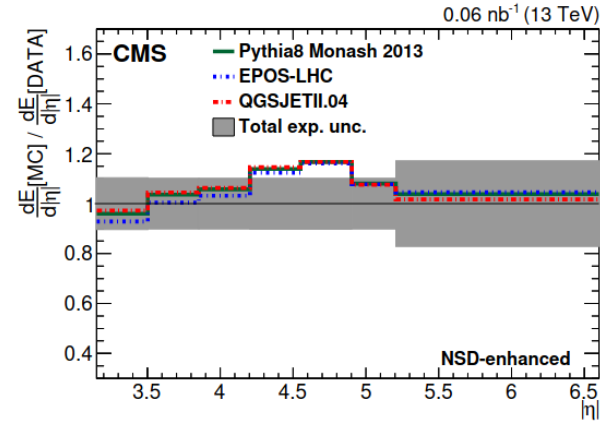
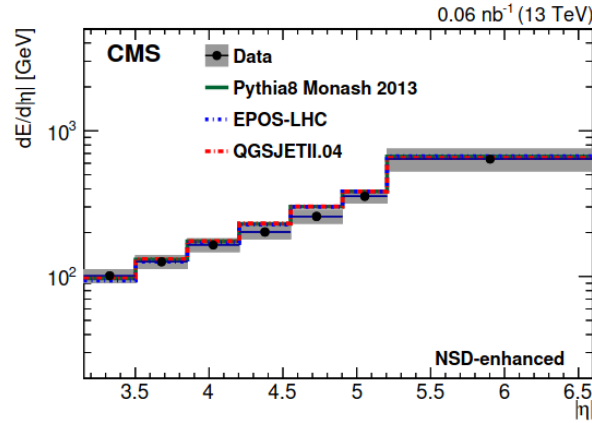


Noise studies

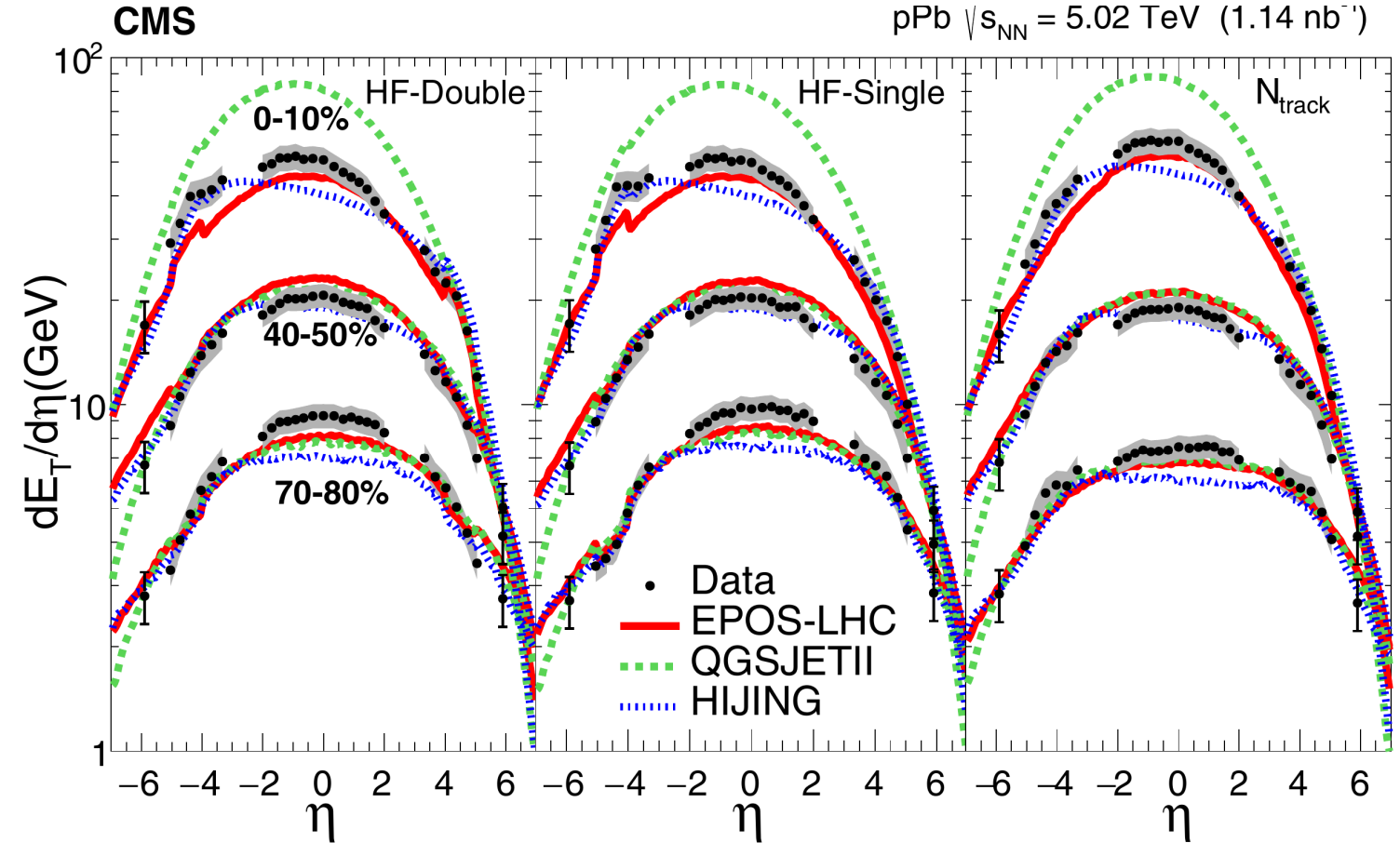


- Noise levels very low: great for tagging

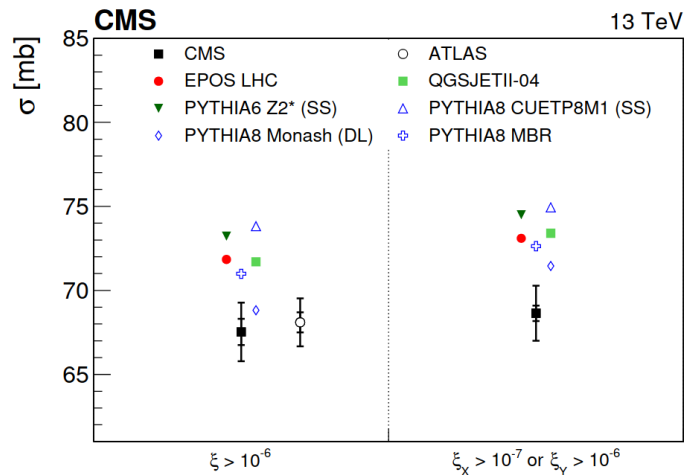
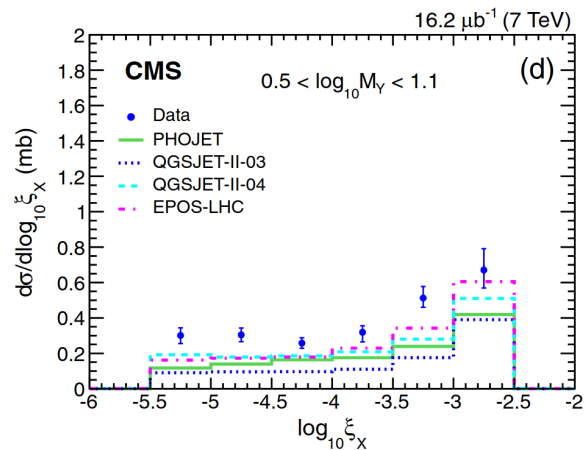
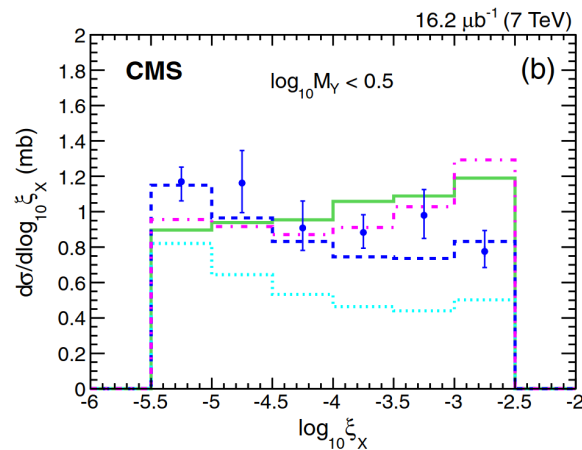
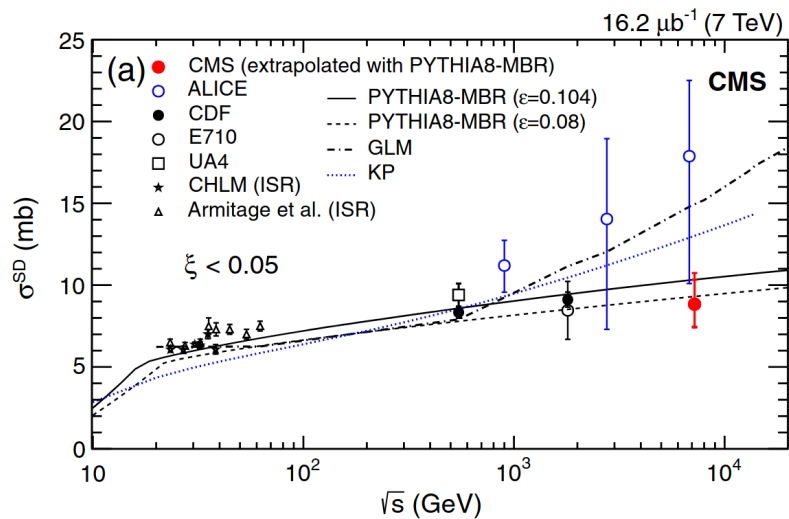
Measurement of the energy density as a function of pseudorapidity in proton-proton collisions at $\sqrt{s} = 13$ TeV



Centrality and pseudorapidity dependence of the transverse energy density in $p\text{Pb}$ collisions at $\sqrt{s_{NN}} = 5.02$ TeV

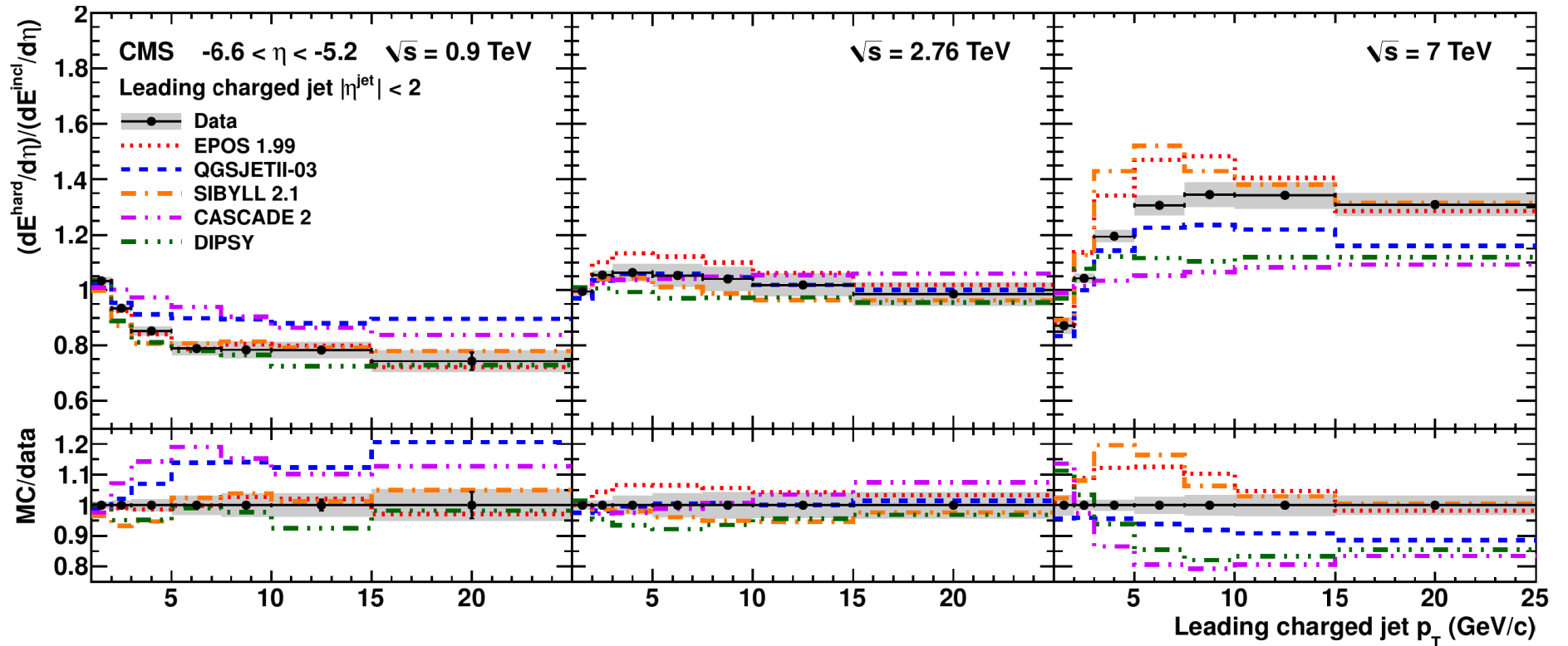


Cross sections, event tagging

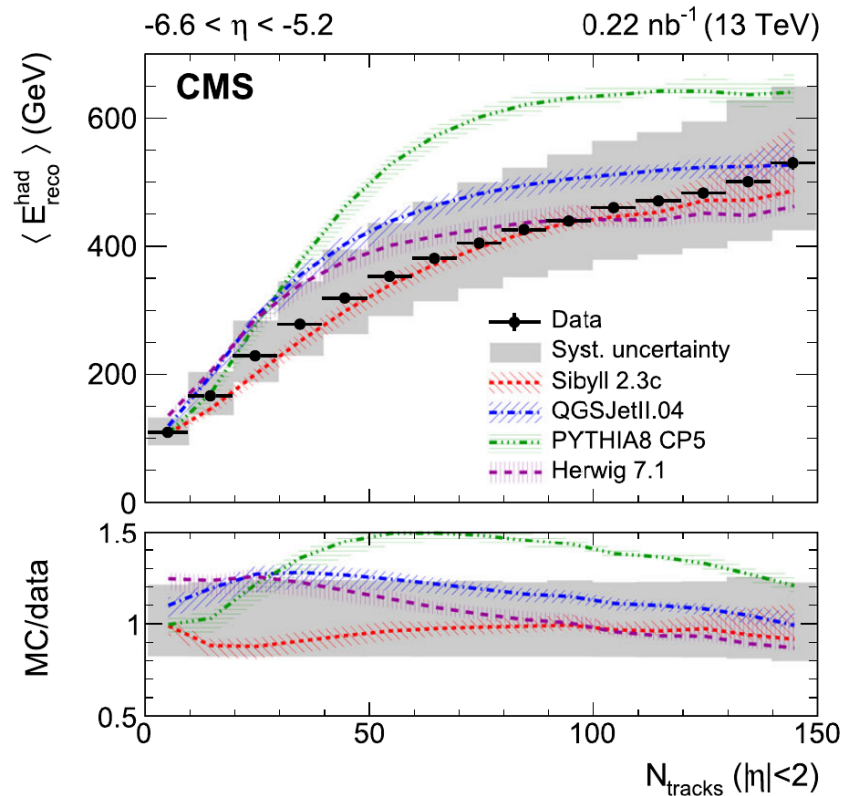
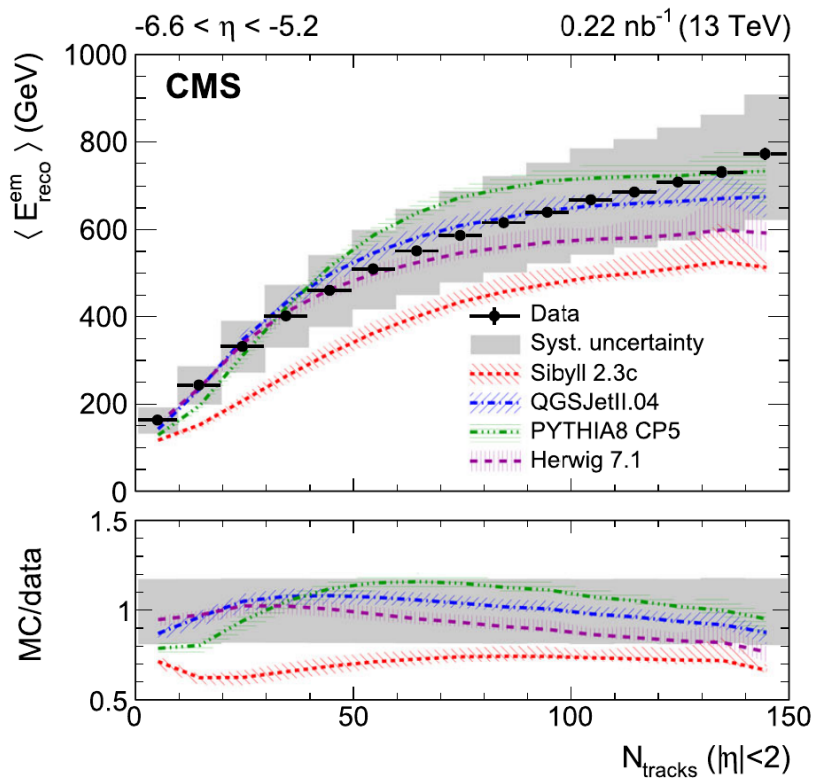


<https://doi.org/10.1103/PhysRevD.92.012003>
[https://doi.org/10.1007/JHEP07\(2018\)161](https://doi.org/10.1007/JHEP07(2018)161)

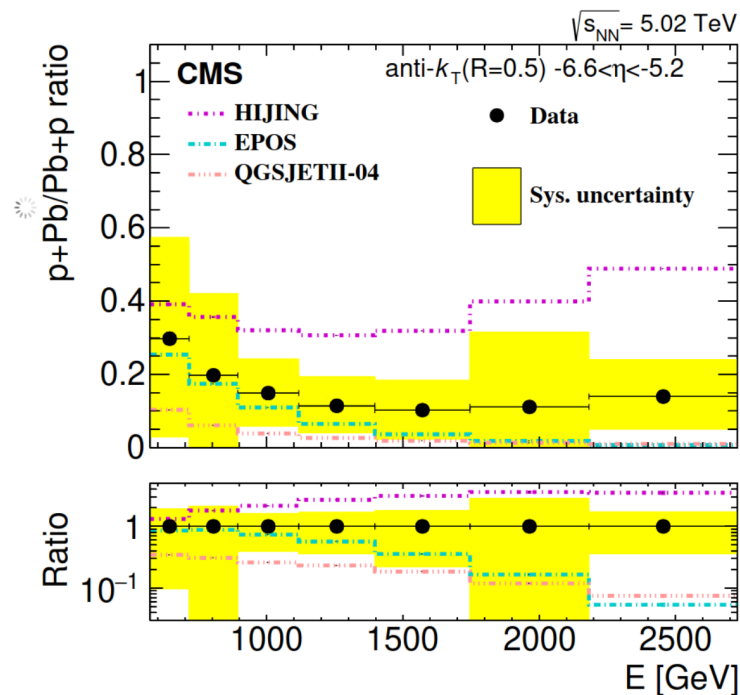
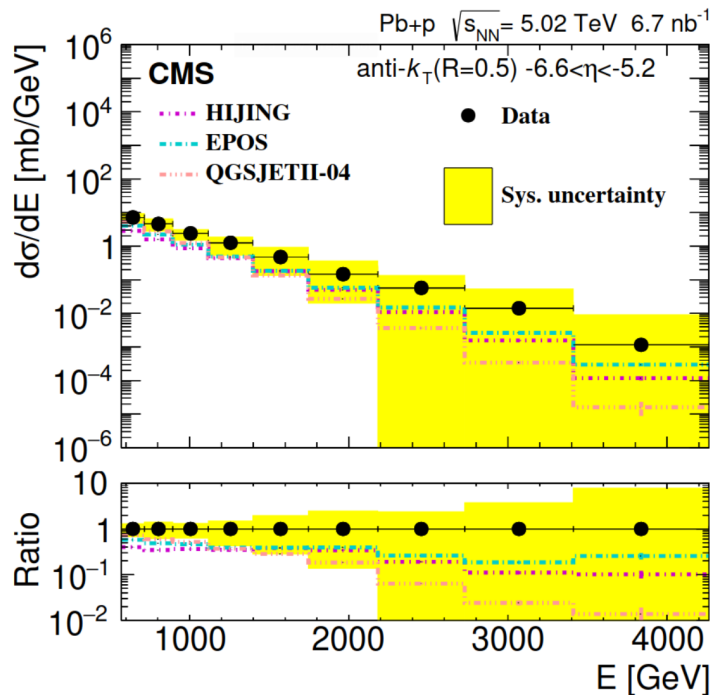
Study of the underlying event at forward rapidity in pp collisions at $\sqrt{s} = 0.9, 2.76,$ and 7 TeV



Measurement of the average very forward energy as a function of the track multiplicity at central pseudorapidities in proton-proton collisions at $\sqrt{s} = 13$ TeV



Measurement of inclusive very forward jet cross sections in proton-lead collisions at $\sqrt{s_{NN}} = 5.02$ TeV



Summary

- CASTOR has very successfully taken data in LHC Run1 and Run2
- Unique calorimeter data (e.m. + had) in $-6.6 < \eta < -5.2$
- A lot of results produced, data well understood
- Well documented
- Many more analyses could be done and only depend on renewed interest and manpower:

<http://opendata.cern.ch/docs/about-cms>

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/CASTOROpenData2010>