Recent forward physics and diffraction results from CMS

Gabor Veres (CERN)
on behalf of the CMS Collaboration

ISMD 2015 Conference, Wildbad Kreuth, Germany
October 5th, 2015

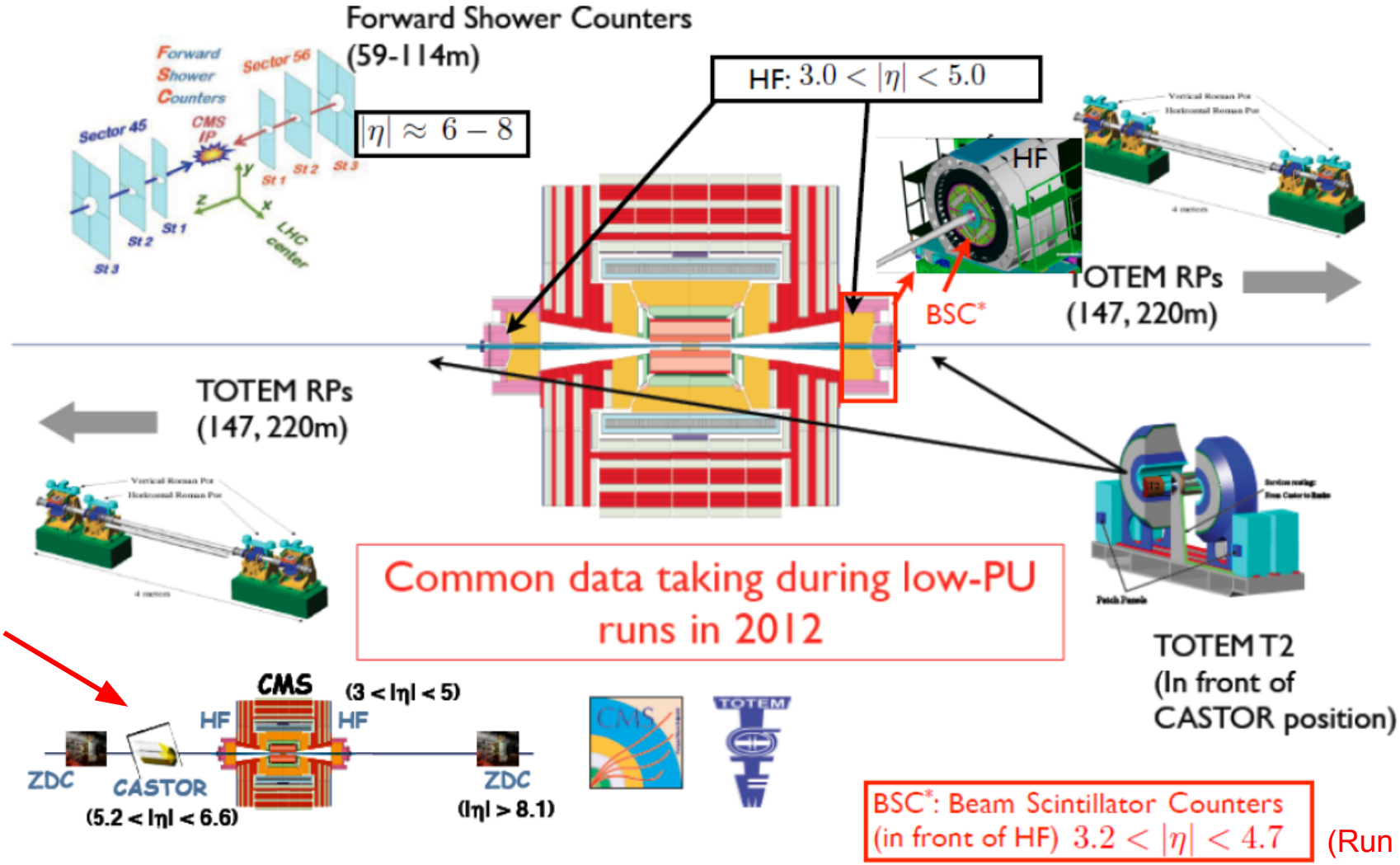
gabor.veres@cern.ch

Outline

- CMS: forward instrumentation
- Diffraction:
  - single- and double-diffractive (RG) cross sections
  - DD-dominated sample: xsec using a central rapidity gap
  - forward rapidity gap cross sections
- Hard color-singlet exchange (CSE):
  - dijet events with a large rapidity gap
  - fraction of CSE events measured
    - as a function of the subleading jet p_T
    - as a function of the rapidity gap

CMS and TOTEM Experiments

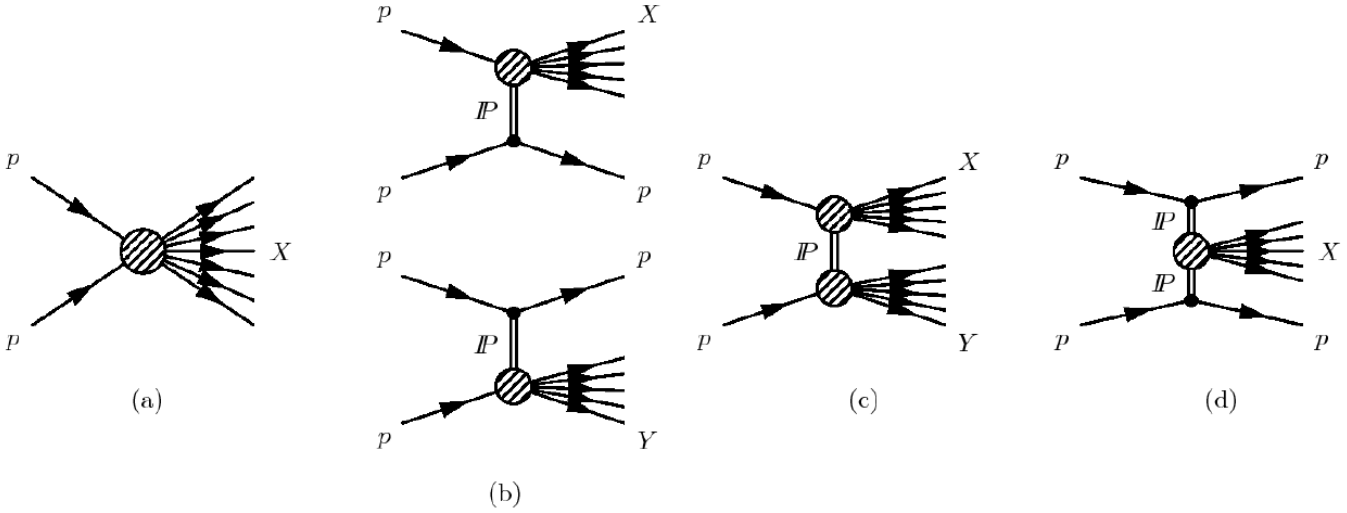
- **Excellent instrumentation at high η ("forward")**



gabor.veres@cern.ch

Soft diffraction at 7 TeV

- Diffraction: ~22% of inelastic cross section (14 mb/64.5 mb)
- Large rapidity gap (LRG). Pomeron: color singlet
- Predictions based on Regge theory, extrapolations to LHC
- Important to improve models, event generators, MB and UE predictions, etc.
- SD and DD separated with CASTOR: -6.6<η<-5.2



non-diffractive (ND) | single dissociation (SD) | double dissociation (DD) | central diffraction (CD)

Models, MC simulations

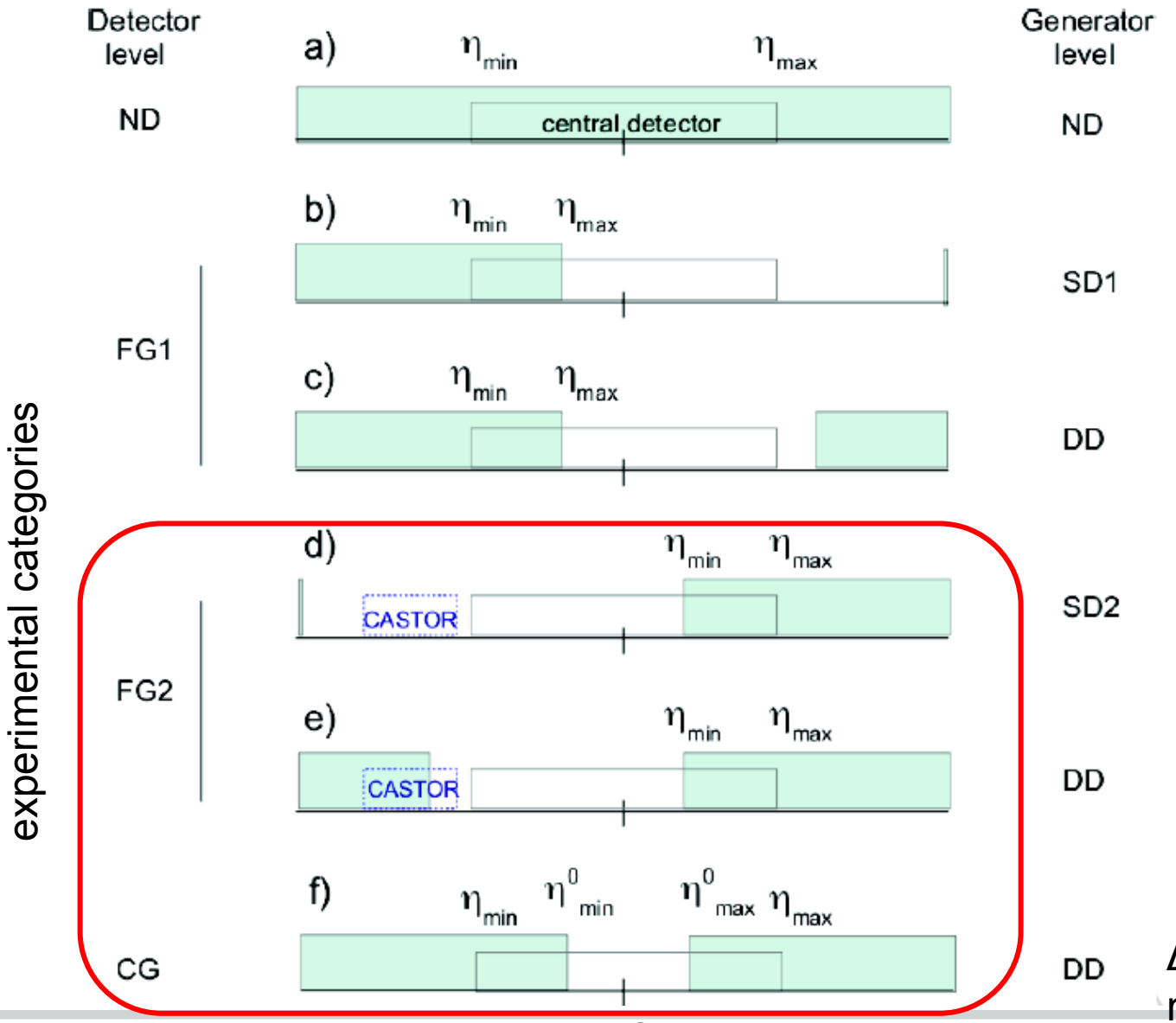
Used for corrections: resolutions, acceptance, migration, etc.

- PYTHIA 8.165: inelastic events
- PYTHIA-MBR: extract cross sections (extrapolation to low mass). Phenomenological renormalized Regge model. Successful at CDF. DD ↓15%
- PYTHIA 8 4C: Schuler-Sjostrand model, diffractive cross section adjusted: SD ↓10%, and DD ↓12%

- M_X, M_Y: separated by the largest rapidity gap

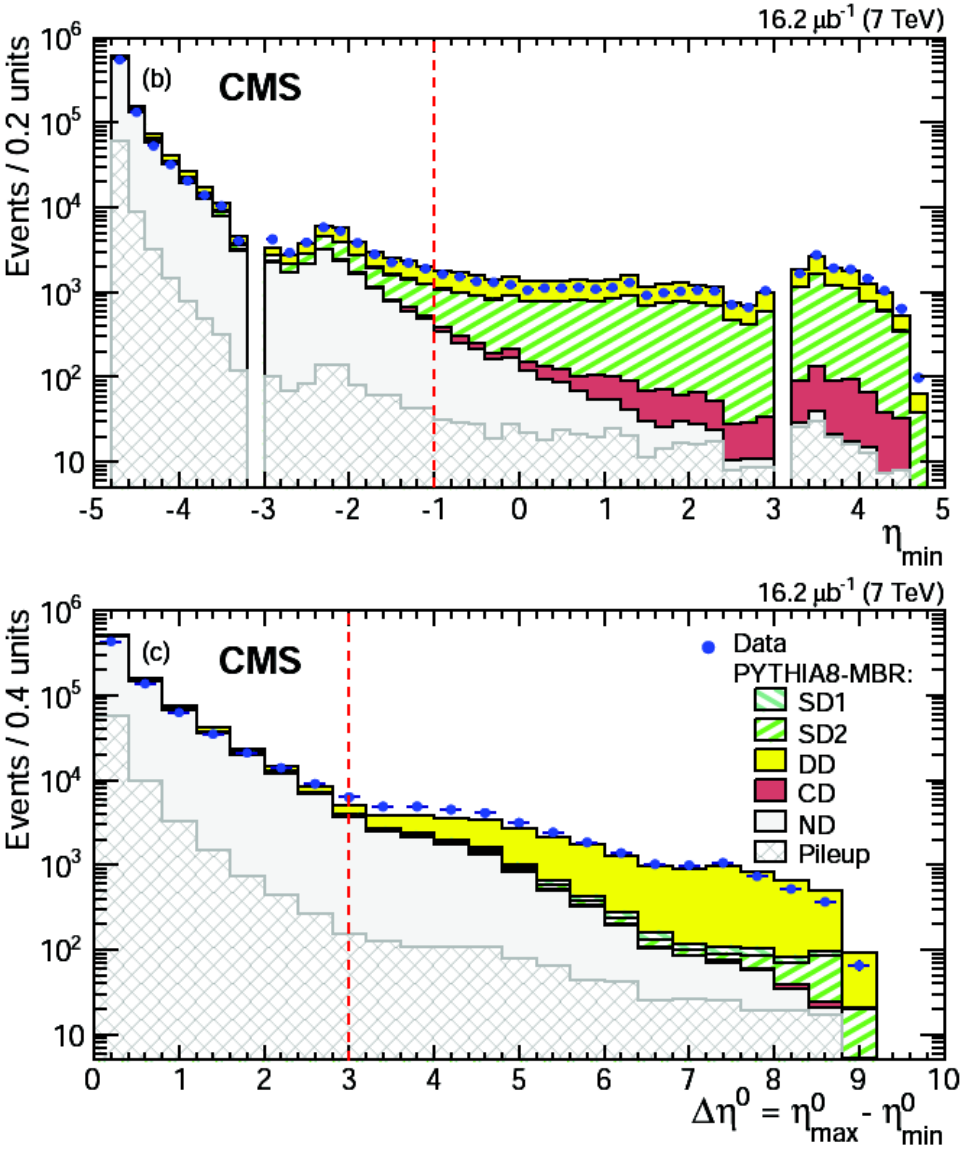
- Data:
  - 2010, 16.2/μb, pileup=0.14
  - trigger: zero bias + any BSC hit (and at least 2 Particle Flow objects). Acceptance: 90% if M_X or M_Y>12.6 GeV
  - no vertex required

Diffractive topologies



η_{min} and $\Delta\eta^0$ distributions

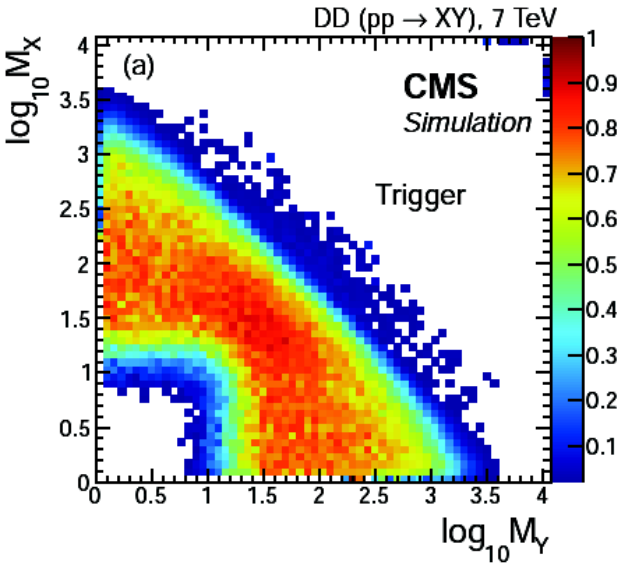
- Distribution of η_{min} and $\Delta\eta^0$ in the selected events:
- ND: exponential suppression of rapidity gap
- large gaps: dominated by diffractive events
- cuts to enhance SD and DD: η_{min}>-1 and $\Delta\eta^0$ >3.



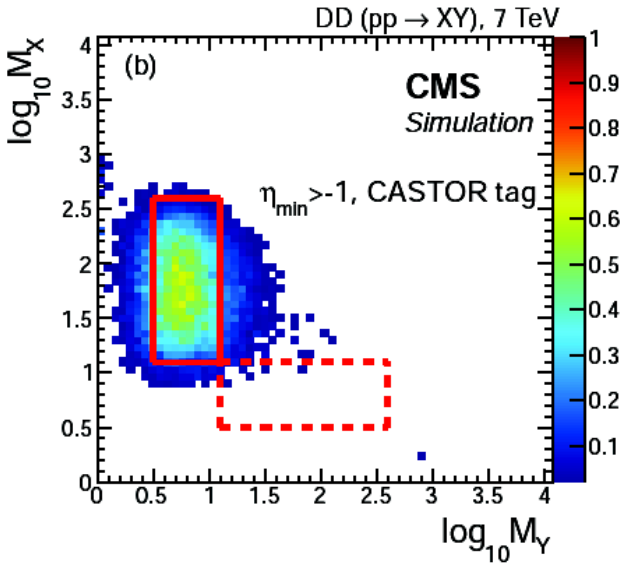
PRD 92, 012003

Acceptance

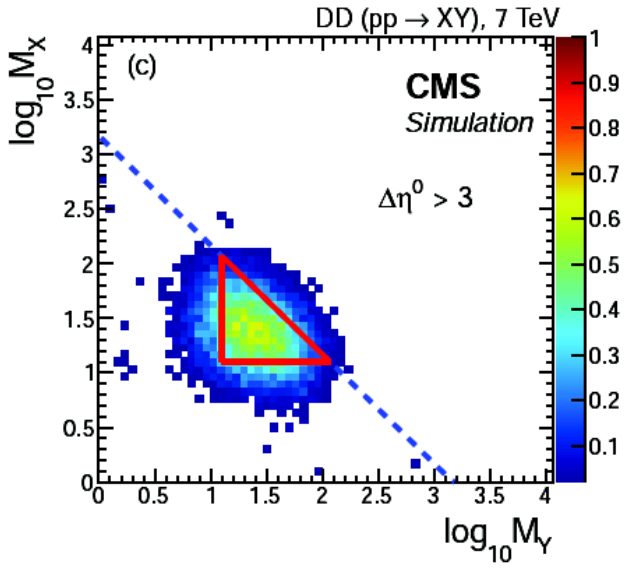
Based on PYTHIA 8 MBR for true DD events:



Trigger selection



FG2 with CASTOR tag



CG selection

Forward RG xsec: variables

The forward rapidity gap xsec is measured vs ξ_X:

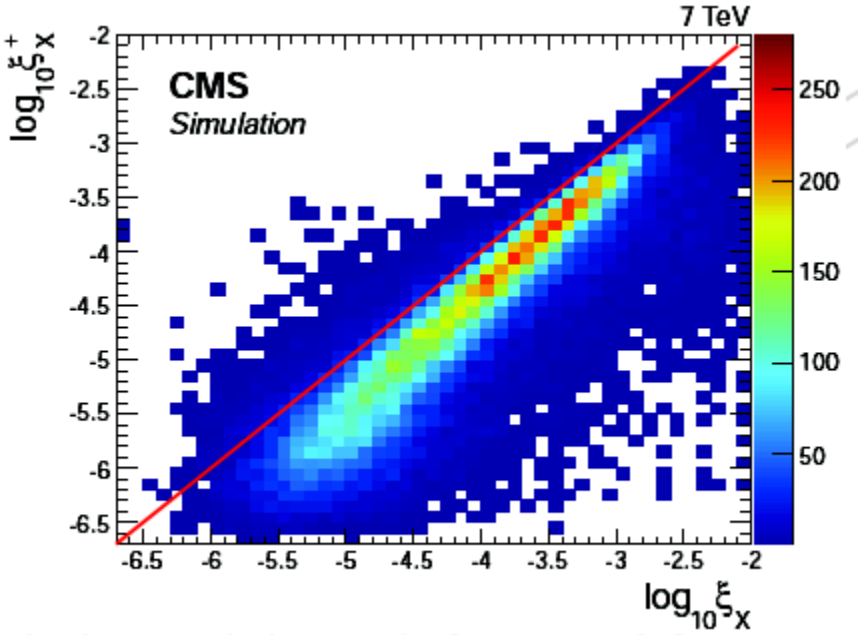
$$\xi_X = \frac{M_X^2}{s}$$

Experimentally, this is approximated by (using PF objects in the detector, where the dissociated system is in the + or - side):

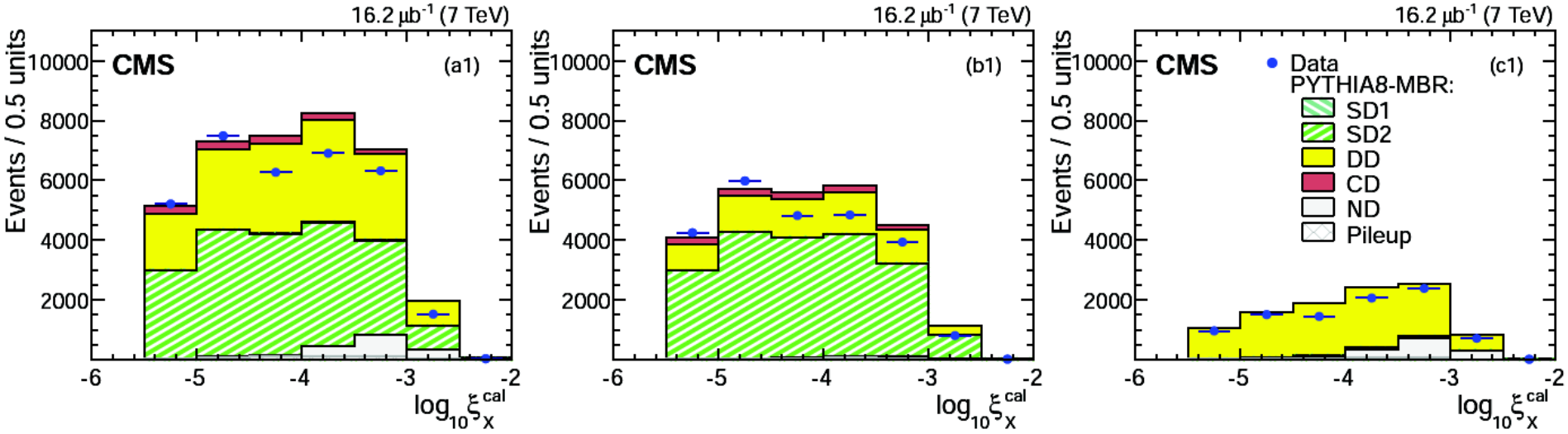
$$\xi^{\pm} = \frac{\sum(E^i \mp p_z^i)}{\sqrt{s}}$$

The correlation of reconstructed and generated variables for SD2 events:

(correction using MBR)



ξ distributions in the FG2 sample



FG2 sample

FG2 sample, with empty CASTOR

SD dominates

FG2 sample, with some energy in CASTOR

DD dominates

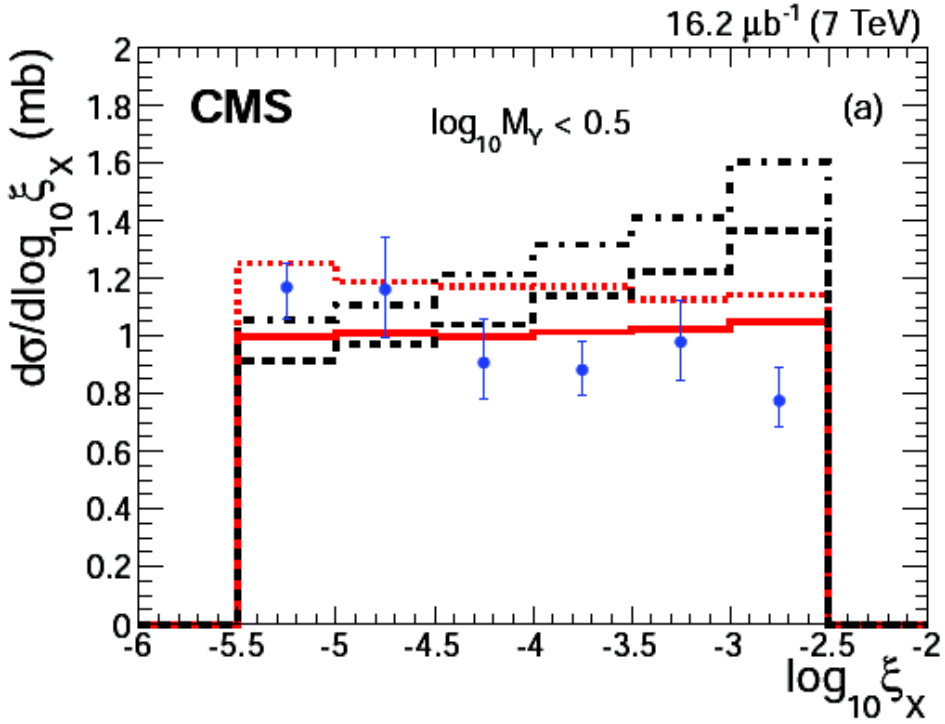
PRD 92, 012003

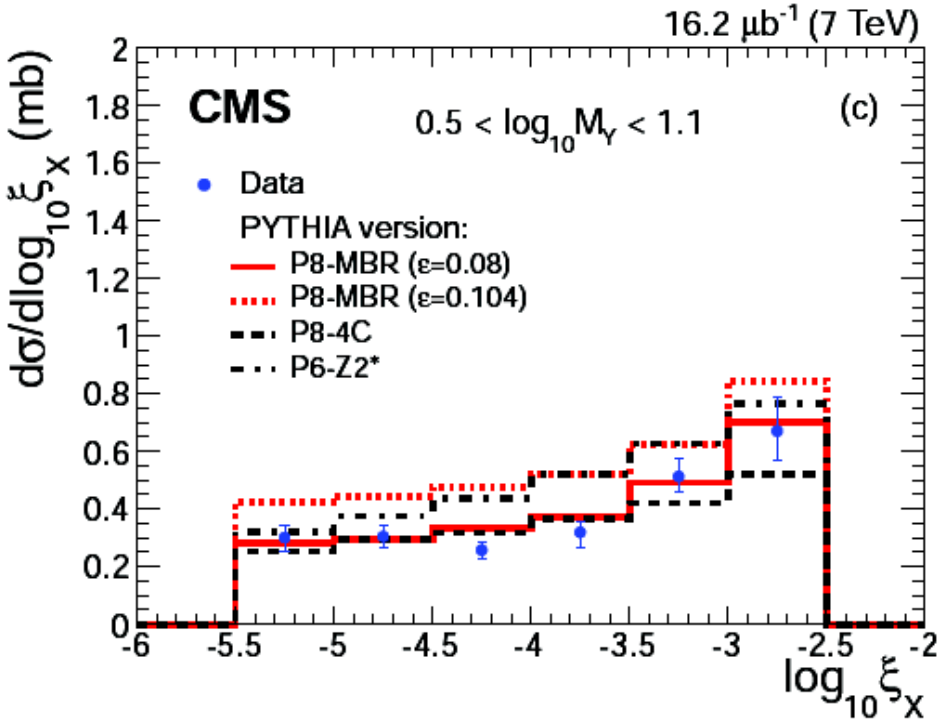
Forward Gap cross sections

FG2 sample. Unfolded, pileup and acceptance corrected.

SD "enhanced": empty CASTOR.

DD "enhanced": with CASTOR tag





PYTHIA 8 MBR gives the best description of the data.

Integrals: $2.99 \pm 0.02\,(\text{stat})^{+0.32}_{-0.29}\,(\text{syst})\,\text{mb}$ $1.18 \pm 0.02\,(\text{stat}) \pm 0.13\,(\text{syst})\,\text{mb}$

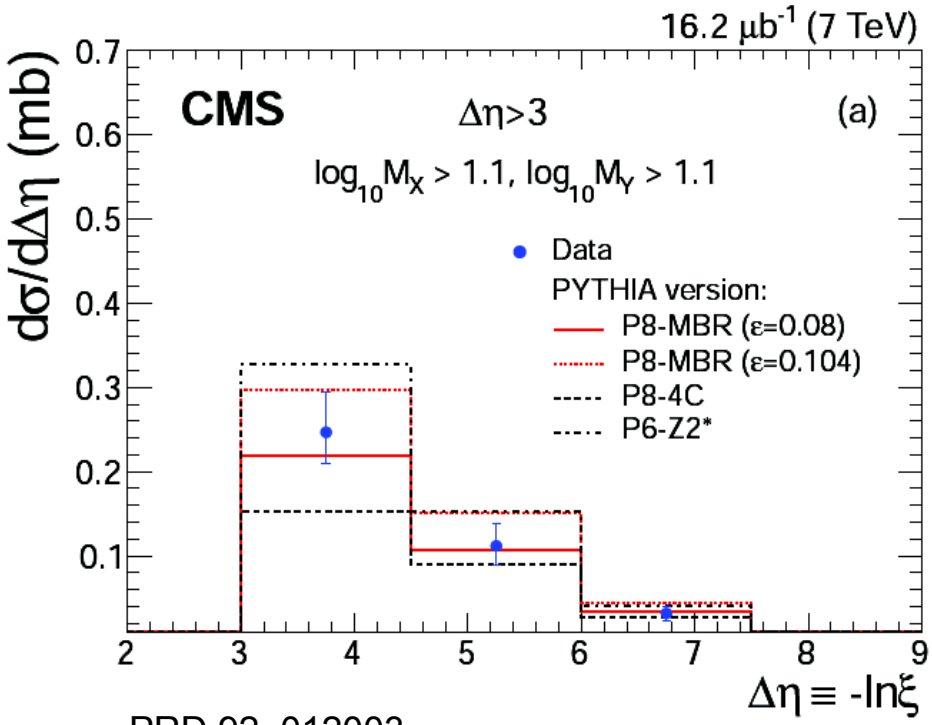
Double diffractive-enhanced xsec

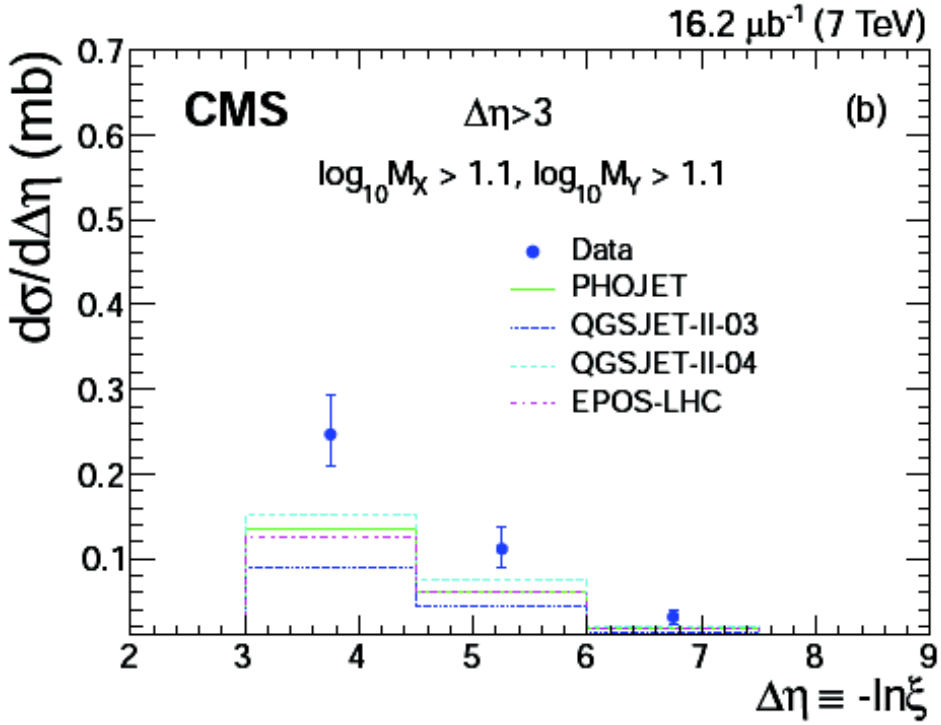
Variables: $\Delta\eta = -\log\xi$ $\xi = M_X^2 \cdot M_Y^2 / (s \cdot m_p^2)$

Detector level: $\Delta\eta^0 = \eta^0_{max} - \eta^0_{min}$

Correction to translate between the two: from MC (MBR)

Integral: $0.58 \pm 0.01\,(\text{stat})^{+0.13}_{-0.11}\,(\text{syst})\,\text{mb}$





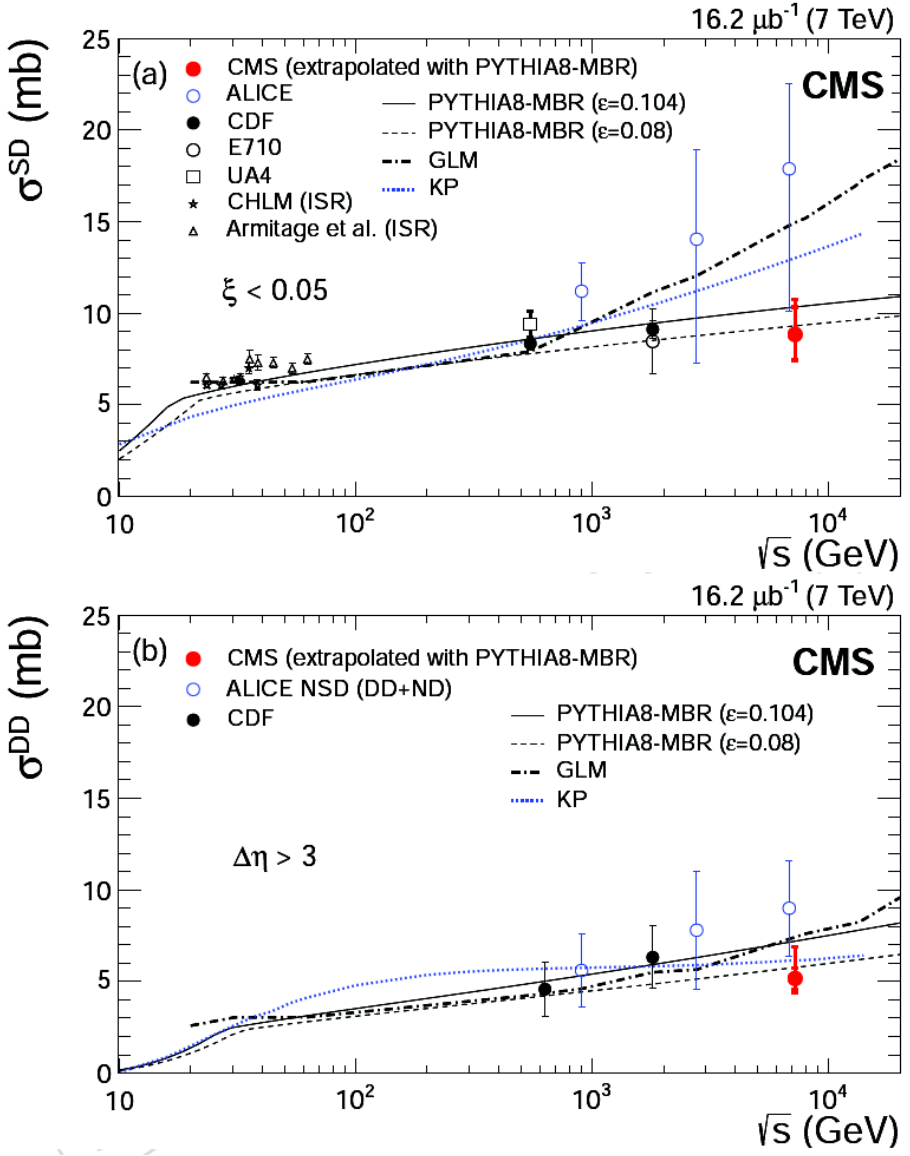
PRD 92, 012003

Total diffractive cross sections at 7 TeV

- Background subtraction.
  Main bg sources:
  - no-CASTOR: DD
  - CASTOR: ND

Measurements extrapolated to total single (SD) and double (DD) diffractive cross sections:

- using PYTHIA 8 MBR
- extrapolation around a factor of 2 needed



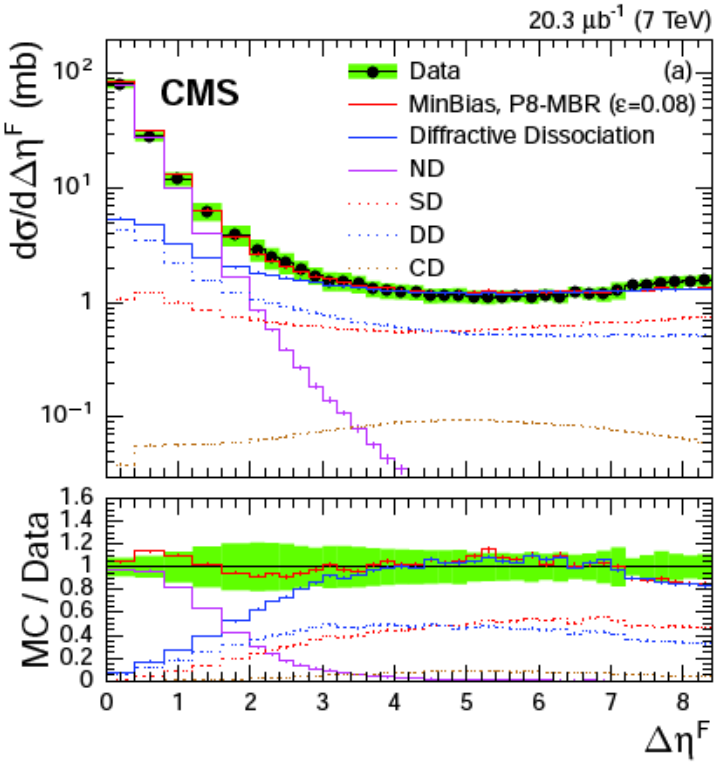
PRD 92, 012003

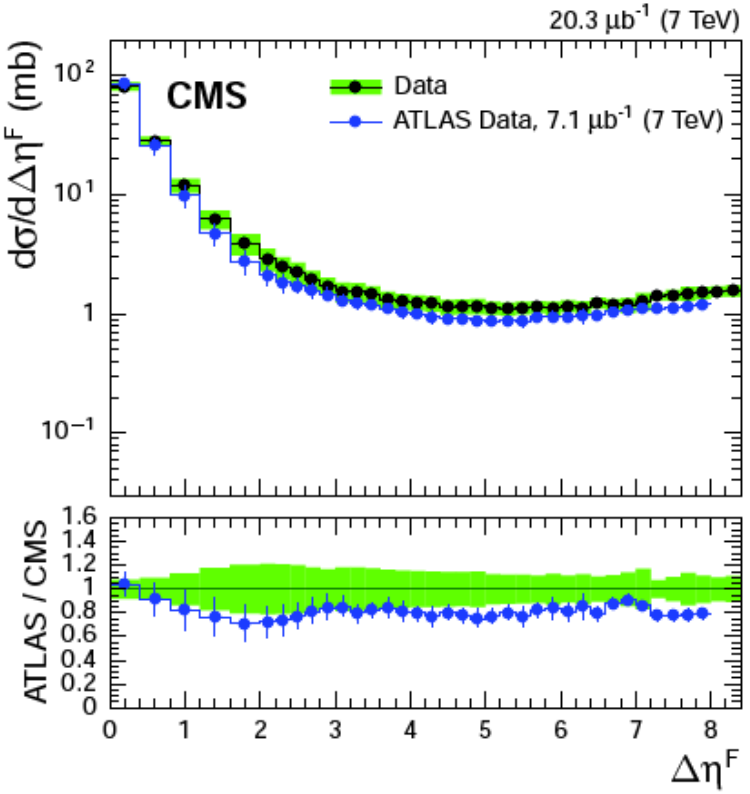
Rapidity gap cross section

Forward rapidity gap: largest distance between detector edge (|η|=4.7) and first Particle Flow object: $\Delta\eta^F$

Correction for bg (circulating beams), migrations.

PU=0.0066. Particle level cut: p_T>200 MeV/c, |η|<4.7.

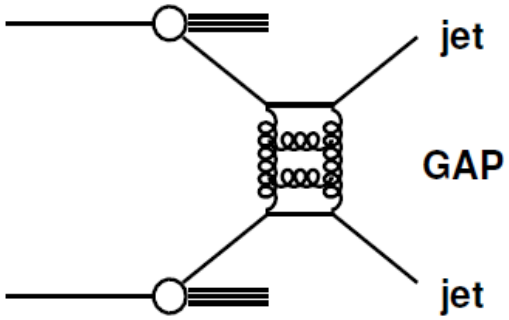




PRD 92, 012003

Dijets with large rapidity gap, 7 TeV

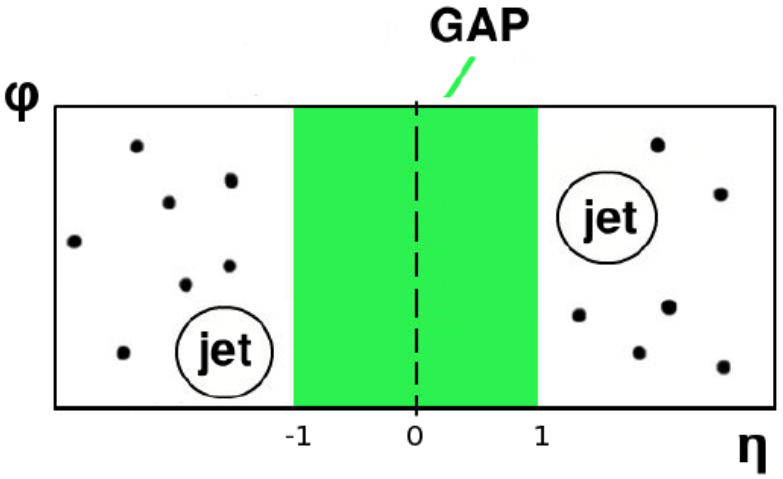
- Dijet production: normally quark or gluon exchange → color field →hadron production between the two jets (in η)
- BFKL model: experimentally accessible with two jets with large rapidity gap, and no particles between them.
- Color singlet exchange (CSE): Pomeron or gluon ladder
- Data:
  - jets: p_T>40 GeV, 1.5<|η|<4.5
  - particles (veto): |η|<1, p_T>200 MeV
  - Data: 2010, 8/pb, pileup = 1.16 - 1.60
  - vertex: 0 or 1

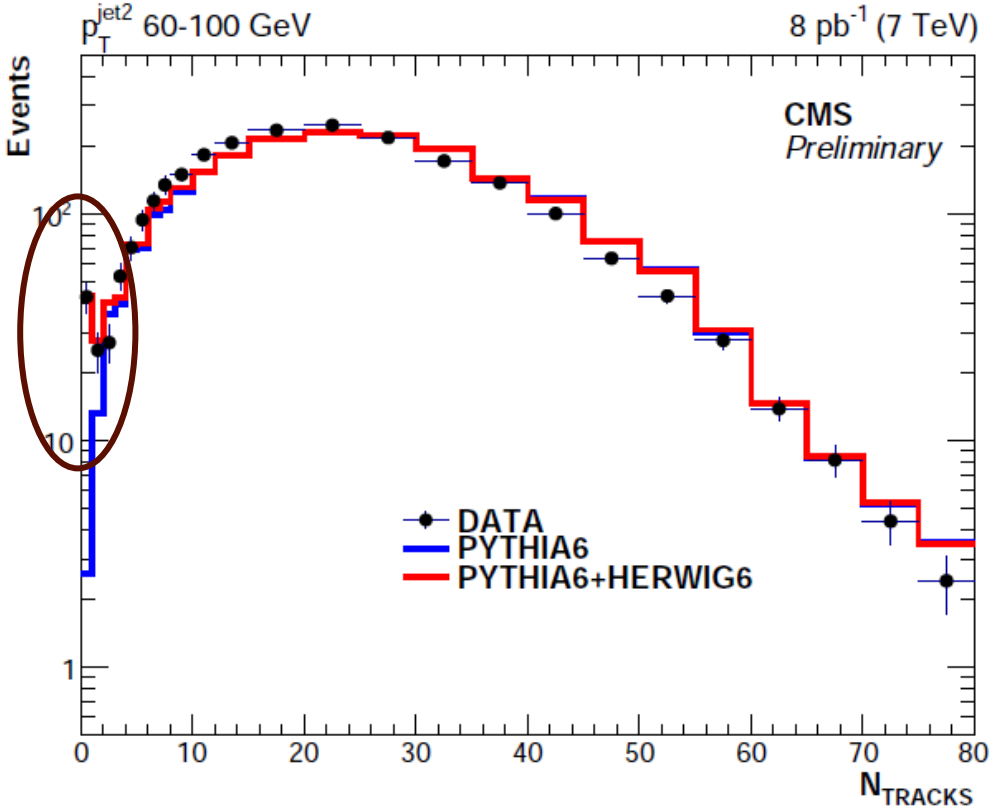


- MC:
  - dijets: PYTHIA 6 Z2* (LO DGLAP), MPI, ISR, FSR
  - jet-gap-jet MC: Herwig6 (CSE Muller-Tang, LL BFKL), no MPI. (JIMMY: MPI). Reweighting.

Charged particle multiplicity in the gap

Multiplicity measured in the gap:

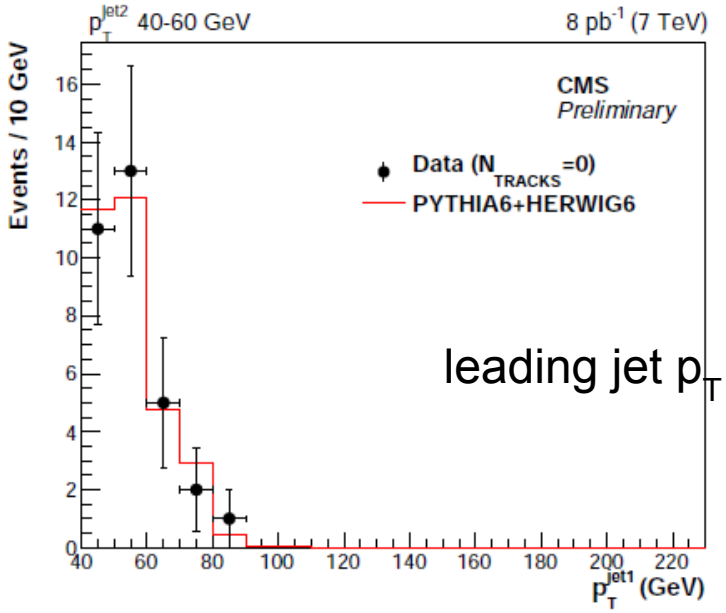


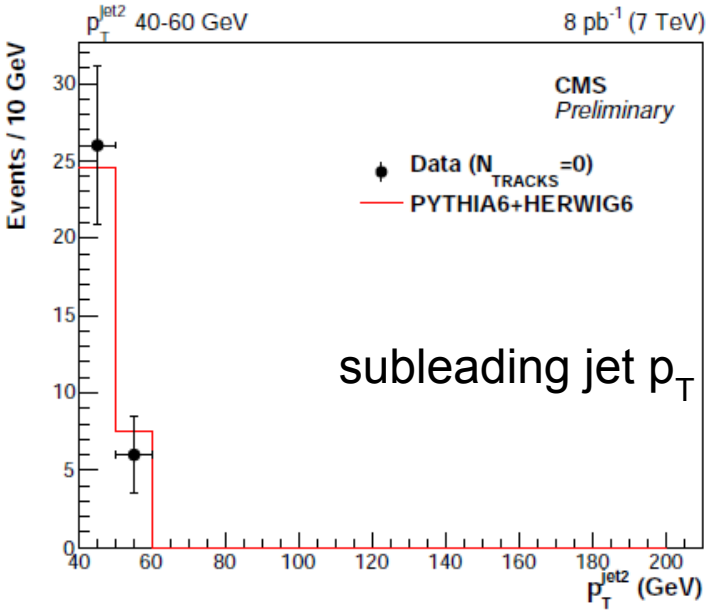


Data shows large excess at 0 particles. Not described by DGLAP, but HERWIG6 reproduces it.

CMS-PAS-12-001

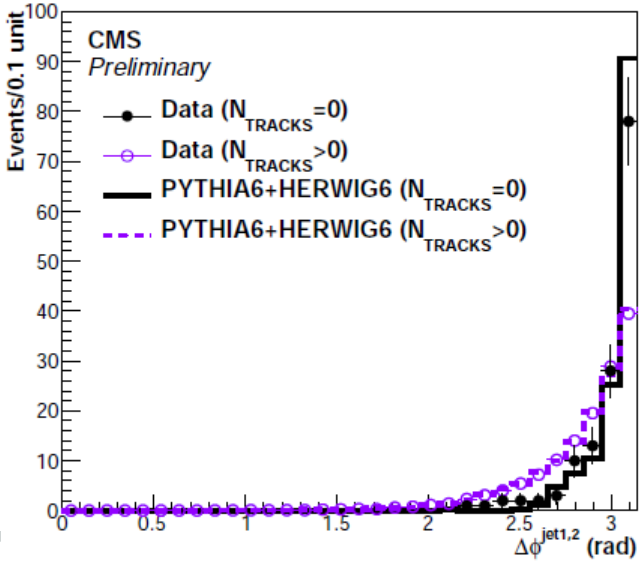
CSE event features





- Jet p_T distributions (in events with a gap) are described by HERWIG6.

- Dijets with a gap are more back-to-back.

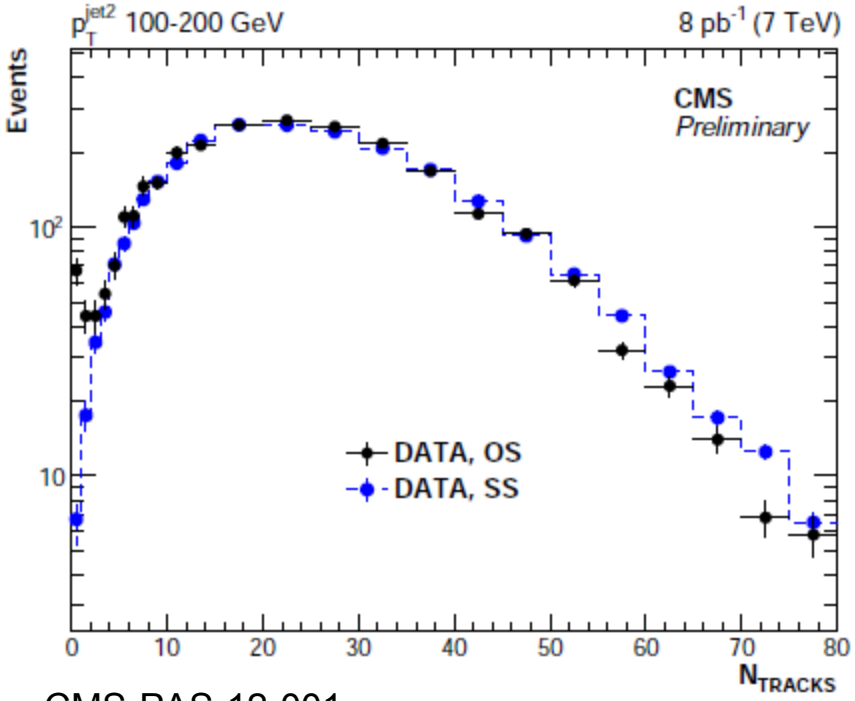


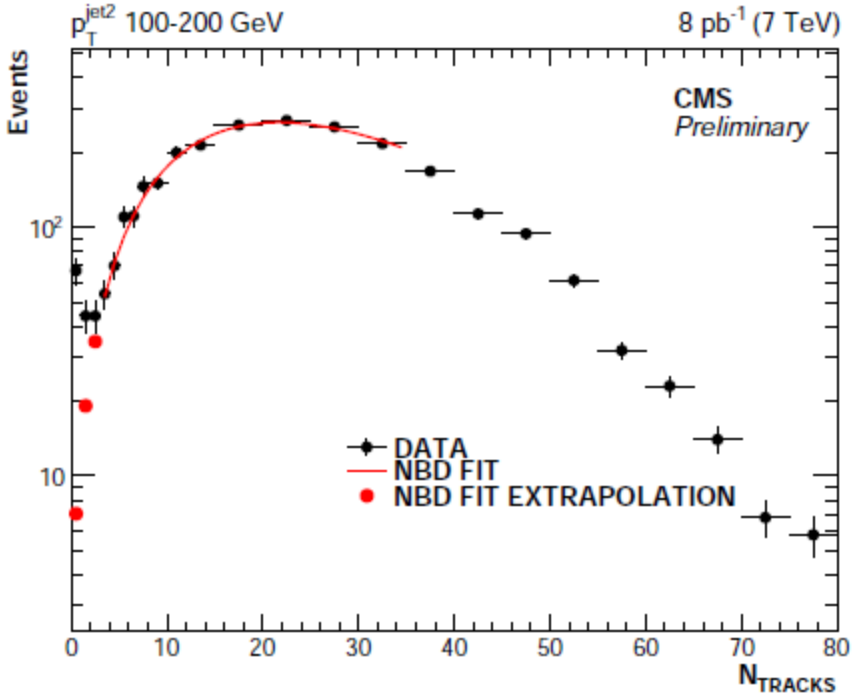
gabor.veres@cern.ch

CSE fraction

- Definition: $$f_{\mathrm{CSE}} = \frac{N_{\mathrm{events}}(\mathrm{S}) - N_{\mathrm{bkg}}(\mathrm{S})}{N_{\mathrm{events}}}$$

- Background subtraction:
  - "same-sign" sample: jets in the same η hemisphere
  - Negative Binomial fit to the "opposite sign" sample

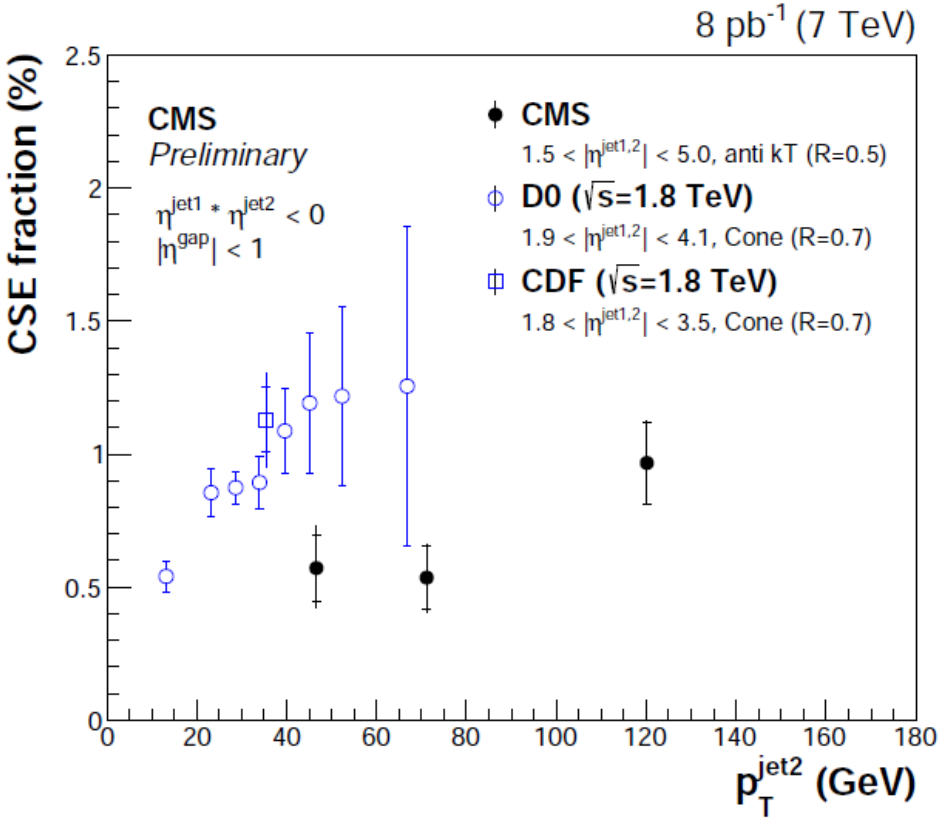


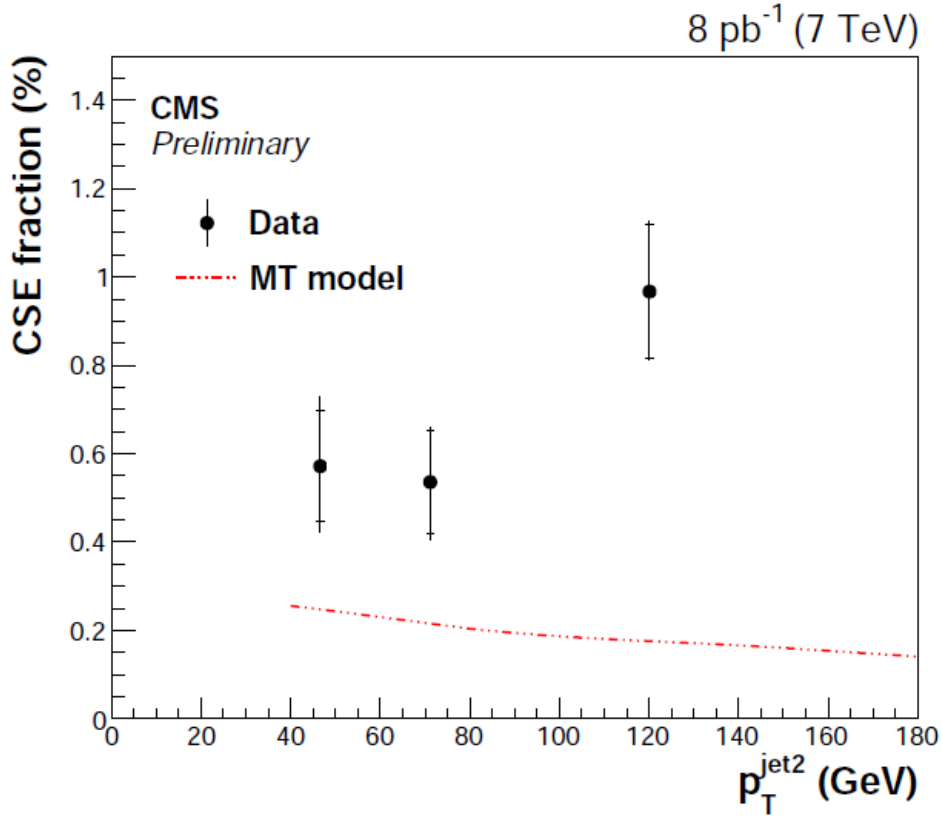


CMS-PAS-12-001

CSE fraction vs. subleading jet p_T

- Factor of ~2 lower than at Tevatron at 1.8 TeV
  - (stronger rescattering at high energy)
- modest increase with subleading jet p_T

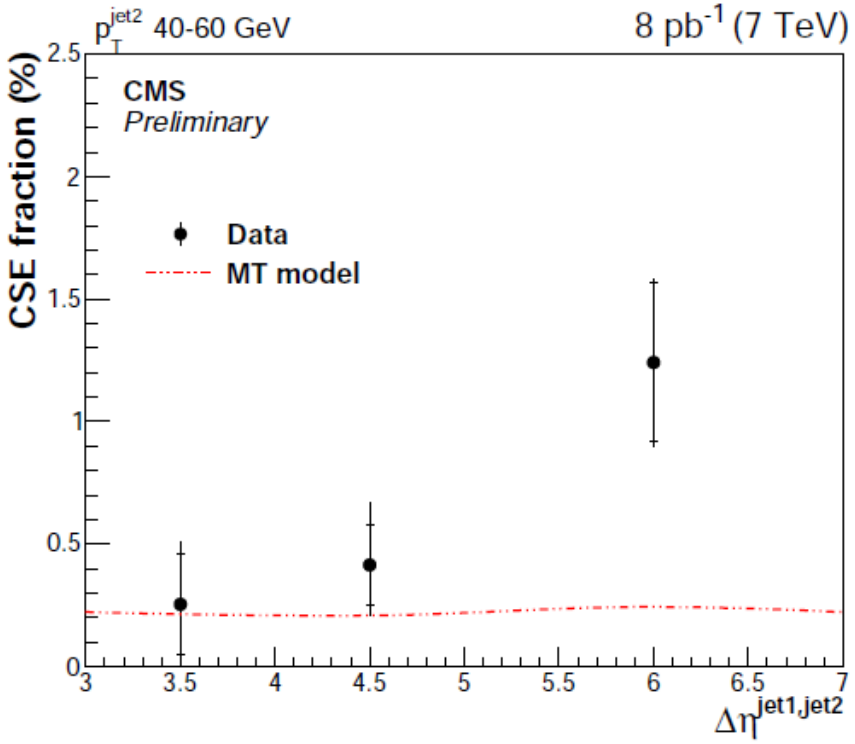


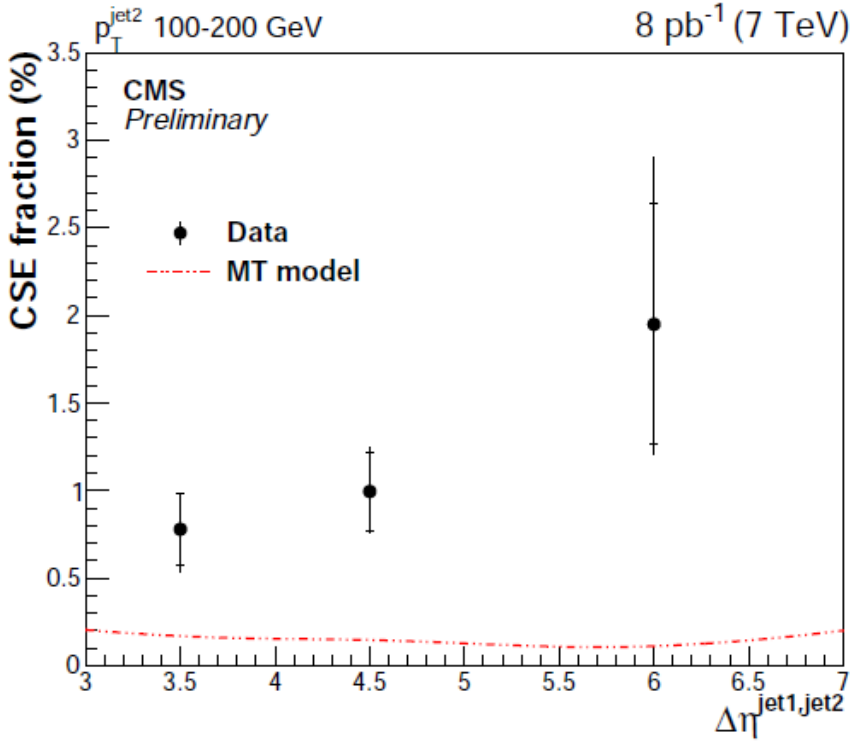


CMS-PAS-12-001

CSE fraction vs. rapidity gap

- Fraction increases with Δη
- Muller-Tang model does not reproduce this increase and underestimates the data





CMS-PAS-12-001

Summary

- CMS has an active forward and diffractive physics program
- CMS forward instrumentation is unique, complemented by the TOTEM experiment and the CASTOR calorimeter
  - a joint physics program and data taking is underway
  - CT-PPS will take off next year: tagging diffraction and CEP at high luminosity. Common CMS-TOTEM data with Roman Pot coincidences this year (next week).
- SD and DD cross sections measured at 7 TeV
  - gap cross sections measured as a function of “fractional proton momentum loss” and central and forward gap width
- Jet-gap-jet events at 7 TeV:
  - first time at the LHC
  - dijet events with a gap are not consistent with LO DGLAP
  - CSE observed.
  - CSE fraction rises with p_T^2 and decreases with energy

END