Recent CMS and CMS-TOTEM results on diffraction

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for the CMS and TOTEM Collaborations

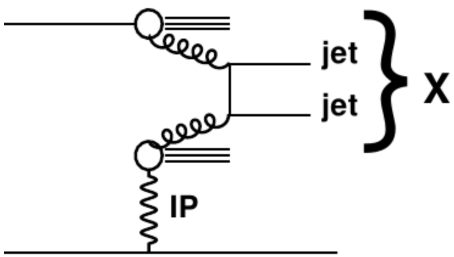
DIS2019: XVII International Workshop on Deep Inelastic Scattering

8-12 April 2019
Torino

outline

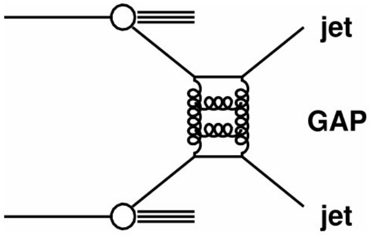
Single diffractive (SD) di-jet production

- Test of the Pomeron structure
- Access multiple parton interactions (MPI) via gap survival probability



Colour Singlet Exchange in jet-gap-jet events

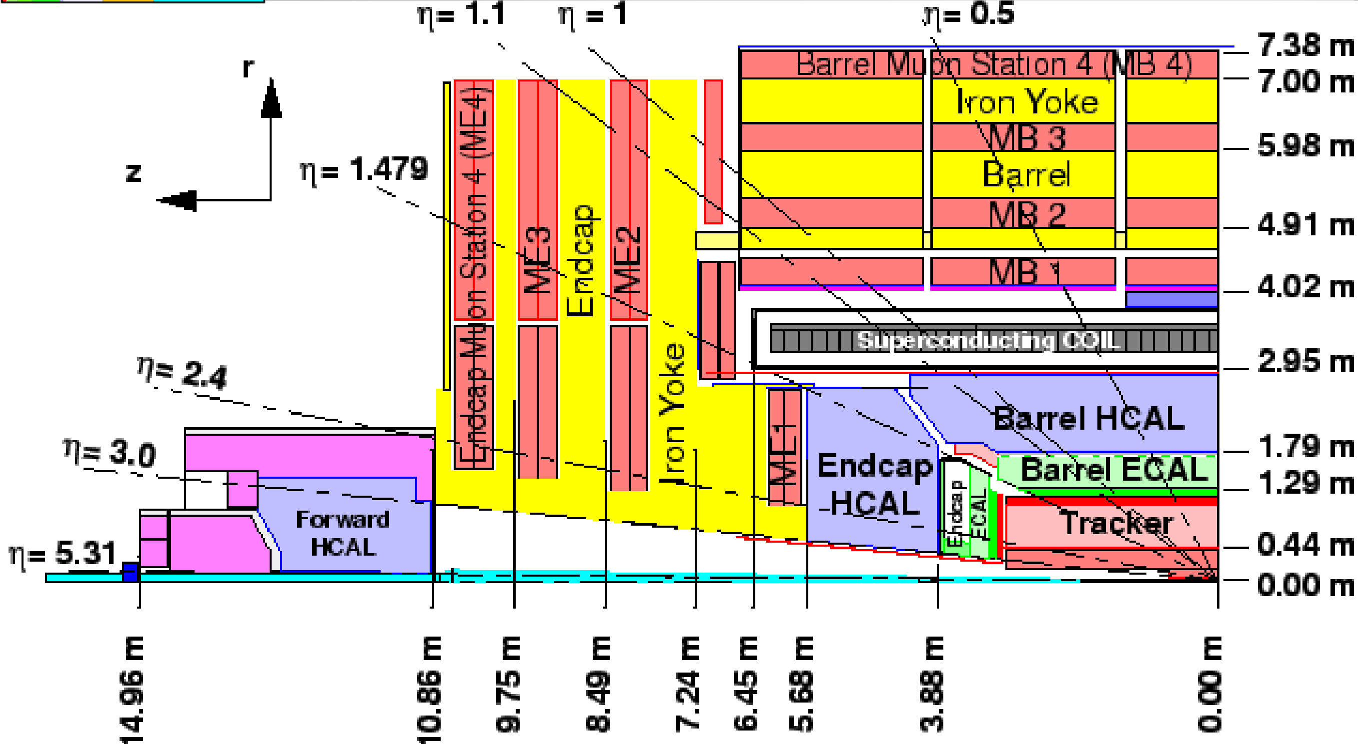
- Hard "BFKL Pomeron" probing the BFKL dynamics
- Affected by MPI and soft colour interaction (SCI)



outline

- **Rapidity gap based analysis (CMS-only):**
  - Possible for low ξ thanks to the large CMS detector acceptance
  - Blind to proton dissociation (SD vs ND/DD)
  - Gives quite rough estimate of ξ
- **Intact proton based analysis (CMS+TOTEM):**
  - Requires direct detection of the intact proton
  - Allows rejection of events with proton dissociation
  - Gives direct measurements of ξ and t for SD/CD cases
- In both cases, the studies are limited to the low pile-up collisions. Low cross-section central exclusive production processes are available with CT-PPS detector (not covered here)

the CMS detector



Muons

(CSC+DT+RPC)

$|\eta|<2.4$

Tracker

(Pixel+SiStrip)

$|\eta|<2.4$; $P_t>100$ MeV

ECAL

$PbWO_4$: $|\eta|<3$

HCAL

central: scint.+brass : $|\eta|<3$

$\Delta\eta \times \Delta\varphi = 0.087 \times 0.087$

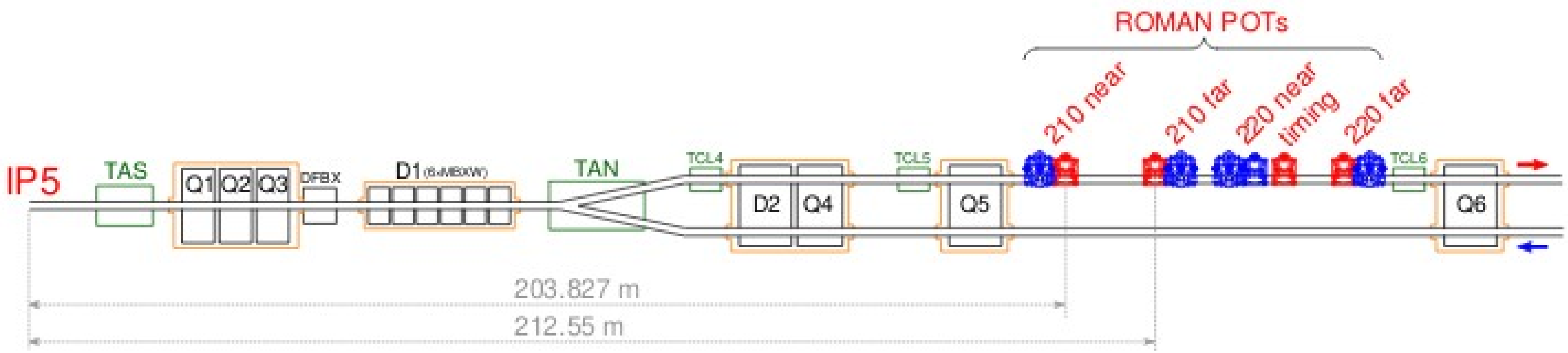
HF: steel+quartz : $2.9<|\eta|<5.2$

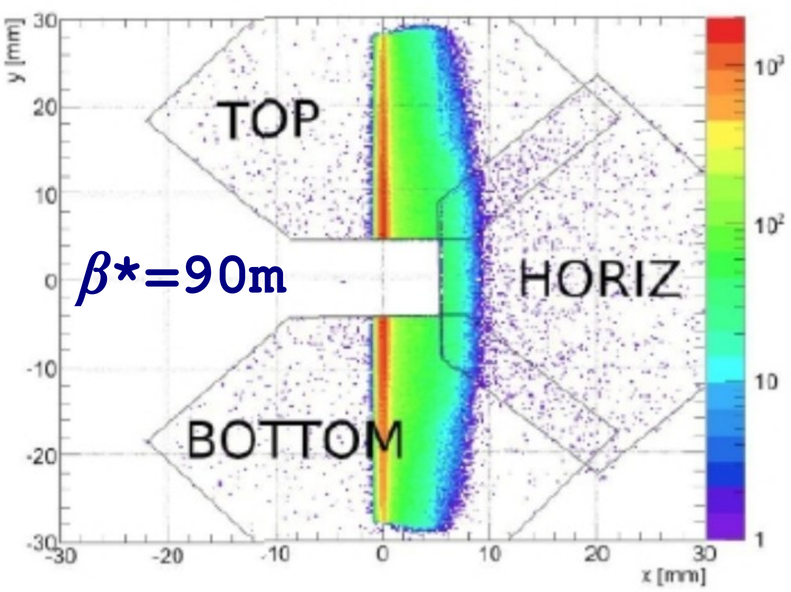
$\Delta\eta \times \Delta\varphi \sim 0.175 \times 175$

Calorimetry + tracking →

Particle Flow Objects

CMS–TOTEM low lumi runs



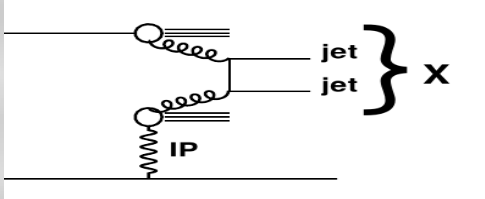


CMS–TOTEM low luminosity runs with high β* optics

- two tracking stations (near+far)@220m from IP
- Acceptance is defined by the beam optics

90 m : $0<\xi<0.1$, $0.03< |t|< 0.01$ GeV^2

SD di-jets, earlier studies



PRD 87 (2013) 012006 http://arxiv.org/abs/arXiv:1209.1805 ; FWD-10-004

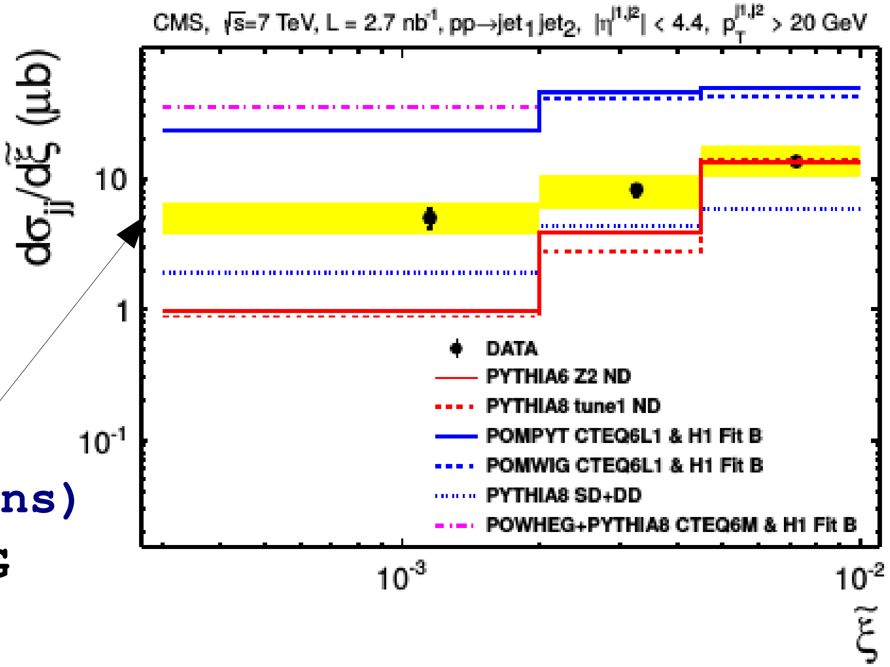
CMS-only analysis (2010)

$$\tilde{\xi}^{\pm} = C\,\frac{\sum (E \pm p_z)}{\sqrt{s}}$$

C-detector effect corrections ~1.45

Acceptance: $\xi < 10^{-2}$

Confirmation of the factorization breaking in pp collisions :



The ratio data/(bare diffractive MC) gives estimates for the gap survival probability (after MC-based corrections)

0.21 ± 0.07 from POMPYT and POMWIG

=> $\langle|S^2|\rangle = 0.12 \pm 0.05$

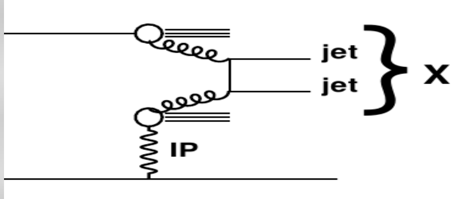
0.14 ± 0.05 from POWHEG

=> $\langle|S^2|\rangle = 0.08 \pm 0.04$

CMS+TOTEM (8 TeV, special b*=90m run in 2012)
Proton tagging with RP =>
much more precise studies + large acceptance

CMS+TOTEM

SD di-jets



CMS-PAS-FSQ-12-033; TOTEM-NOTE-2018-001

Trigger + offline selection:

CMS: di-jet events P_T>40 GeV in |η|<4.4 + primary vertex

AND

TOTEM: RP single arm track (acceptance: 0<ξ<0.1, 0.03< |t|<0.01 GeV²)

Observables: dσ/dt, dσ/dξ, where t and ξ are reconstructed from the proton track measured with Roman Pots

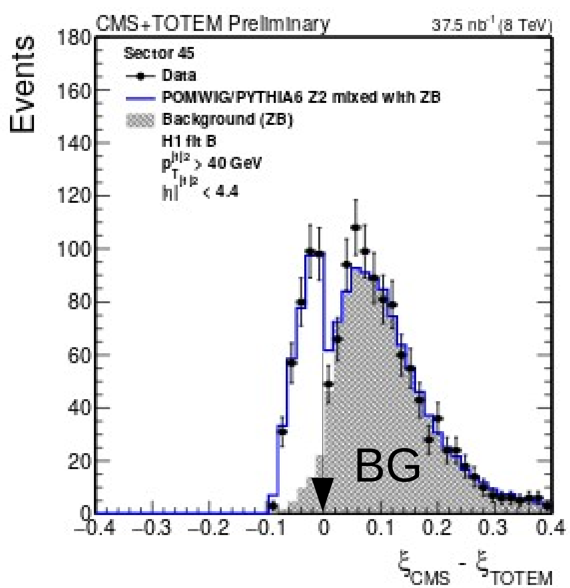
ratio of diffractive to inclusive yields R(x), where

$$x^{\pm} = \frac{\sum_{\text{jets}} (E^{\text{jet}} \pm p_z^{\text{jet}})}{\sqrt{s}}$$

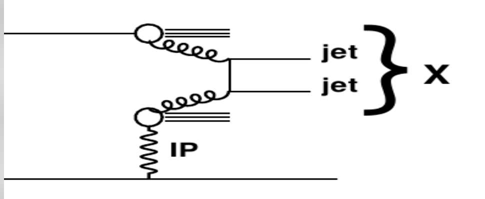
Background:

inclusive dijet with a fake or pile-uped single arm RP track

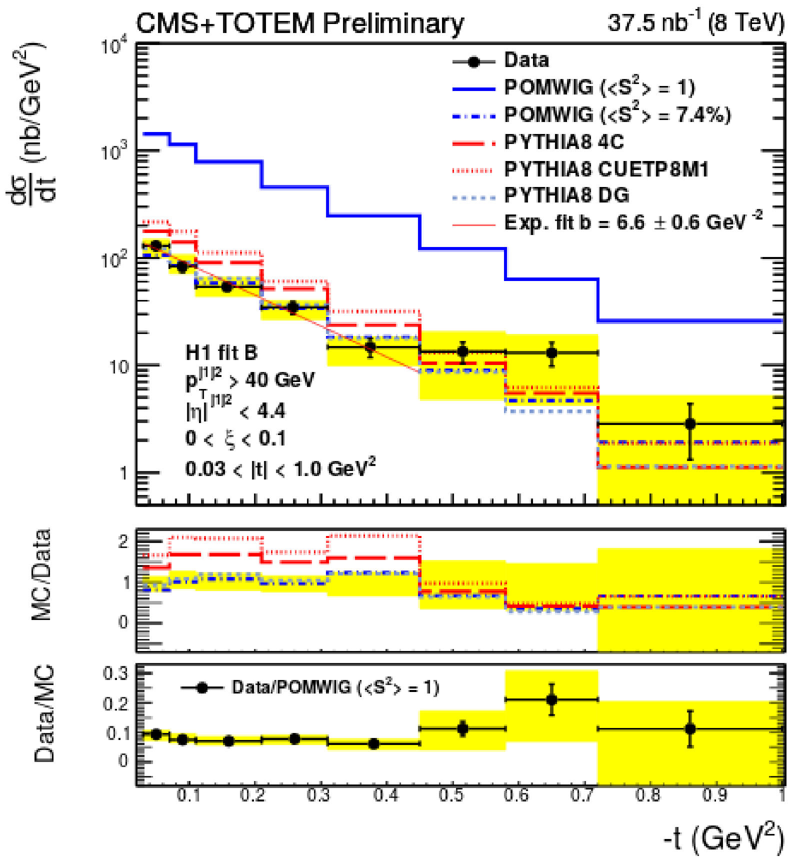
Rejected comparing ξ and ξ_{CMS}:

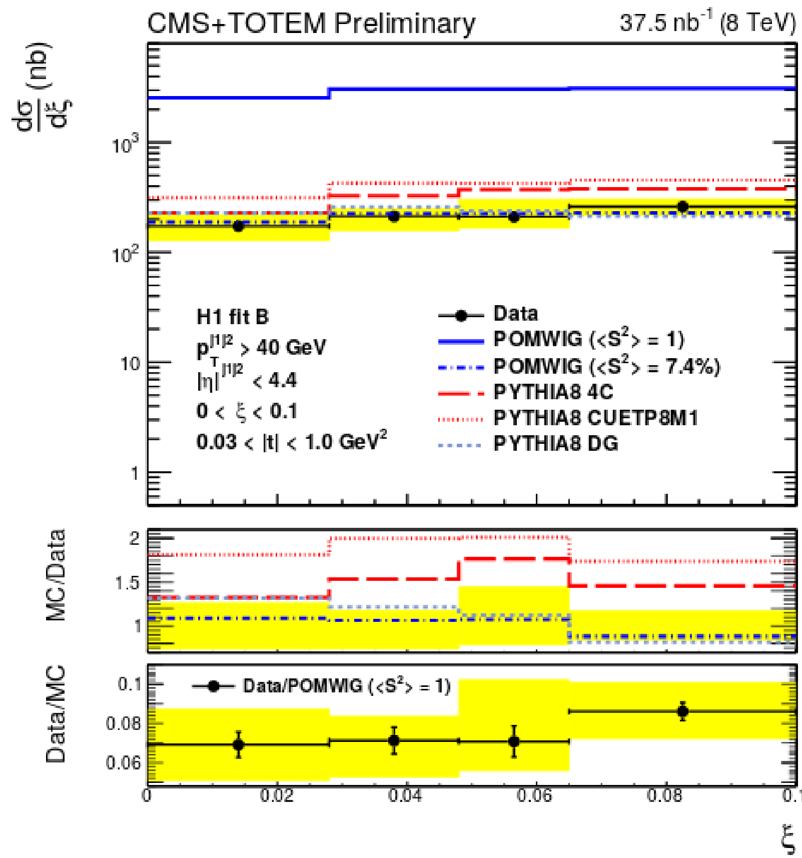


CMS+TOTEM SD di-jets



CMS-PAS-FSQ-12-033; TOTEM-NOTE-2018-001

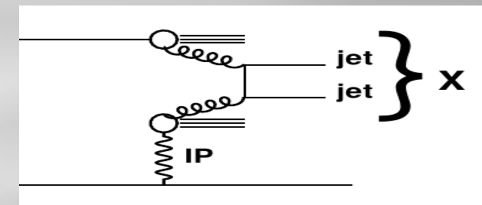




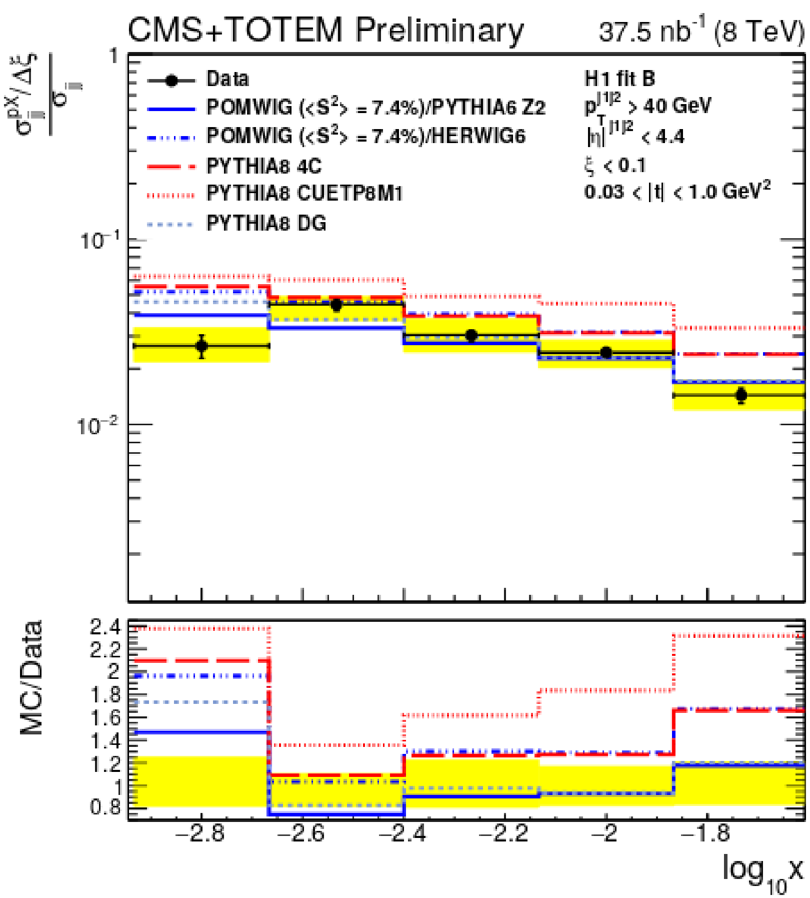
For the acceptance region:

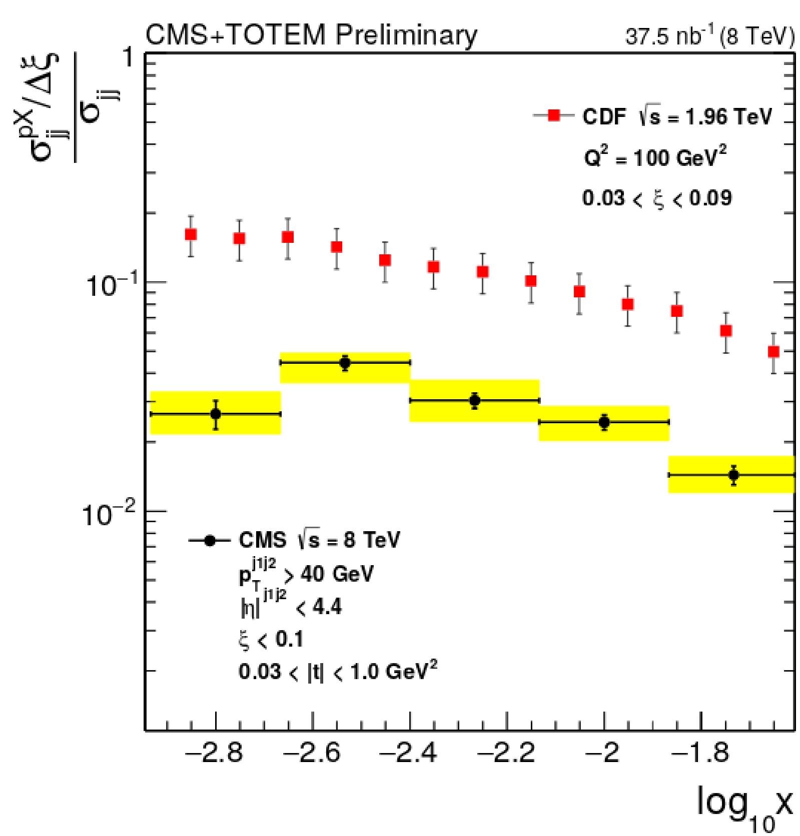
- **<S^2>=9±2** wrt POMWYG after dPDF normalization correction
- $\sigma_{jj}^{pX} = 21.7 \pm 0.9\,(\mathrm{stat})\,^{+3.0}_{-3.3}\,(\mathrm{syst}) \pm 0.9\,(\mathrm{lumi})\,\mathrm{nb}$
- $d\sigma/dt \propto \exp^{-b|t|}$: $b = 6.6 \pm 0.6\,(\mathrm{stat})\,^{+1.0}_{-0.8}\,(\mathrm{syst})\,\mathrm{GeV}^{-2}$ for 0.03<|t|<0.45 GeV^2

CMS+TOTEM SD di-jets



CMS-PAS-FSQ-12-033; TOTEM-NOTE-2018-001

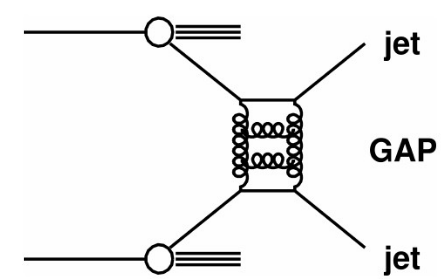




- POMWYG corrected for the gap survival probability describes the data
- Pythia8 with Dynamic Gap model (DG) accounts for the MPI and describes the data reasonably well without any further corrections
- SD to inclusive cross-section ratio decreases with cme as observed at TEVATRON

CSE in jet-gap-jet

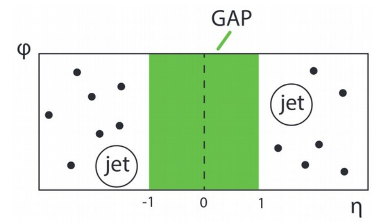
CMS-FSQ-12-001,
Eur. Phys. J. C 78 (2018) 242



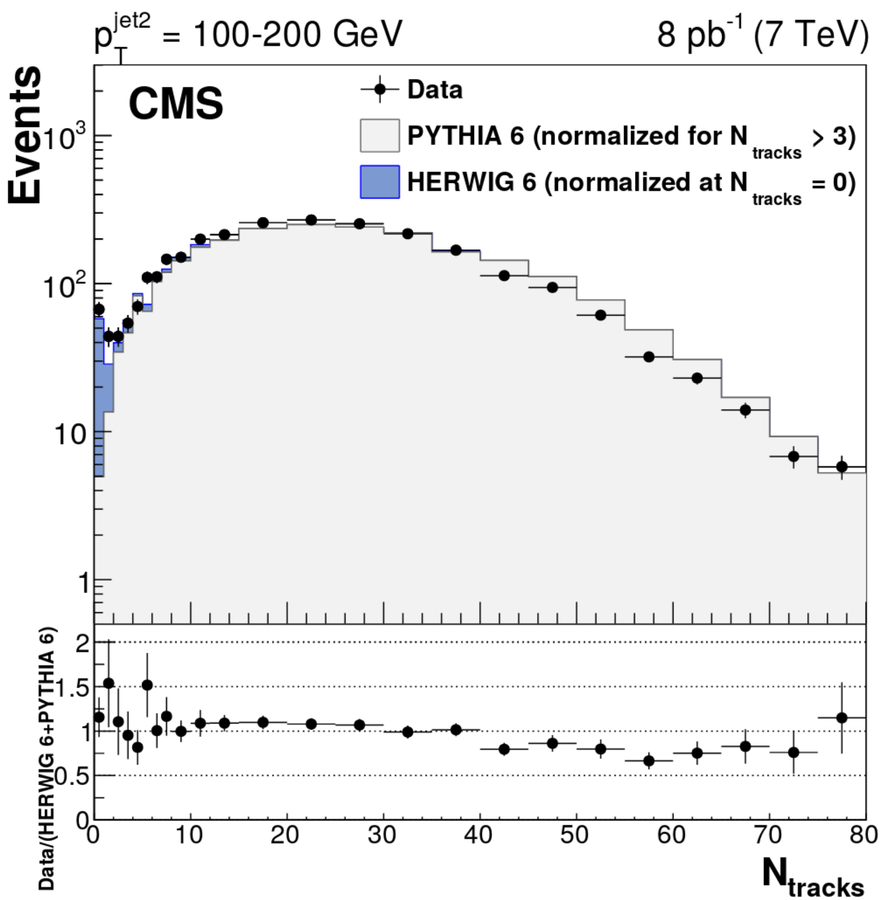
Colour singlet exchange – BFKL dynamics

Data: 8pb^{-1} at sqrt(s)= 7 TeV

Selection: 0 or 1 vtx,
2 jets with p_t > 40 GeV and $|\eta_{1,2}|$>1.5



Observable: charged particles multiplicity in the gap

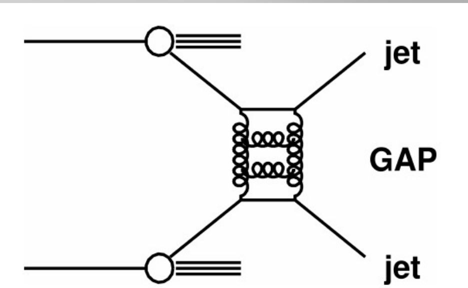


Pythia6 – LO DGLAP
Herwig6 – LL BFKL (Mueller-Tang)

Gap events – Pythia+Herwig

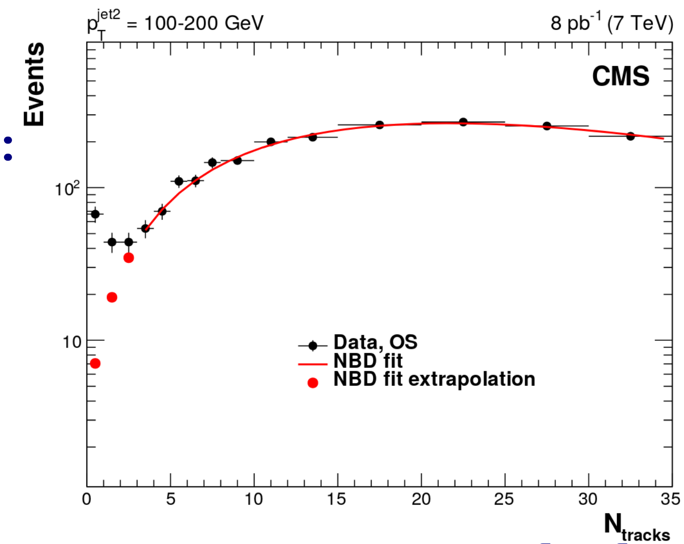
CSE in jet-gap-jet

CMS-FSQ-12-001,
Eur. Phys. J. C 78 (2018) 242



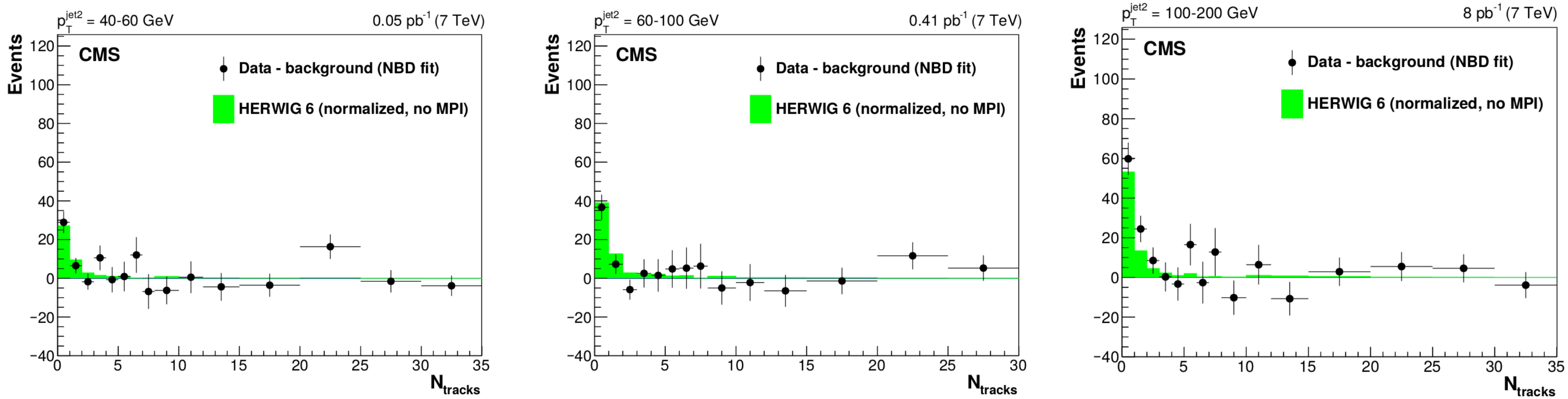
$N(CSE)=N(0)-N_{BG}(0)$

Background estimation:



$N_{BG}(0)$: Negative Binomial Distribution fit extrapolated to N=0

HERWIG (LL BFKL) vs BG corrected data



BG subtracted central track multiplicities are in good agreement with HERWIG6 prediction

CSE in jet-gap-jet

CMS-FSQ-12-001,
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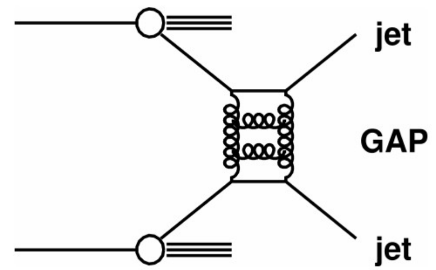
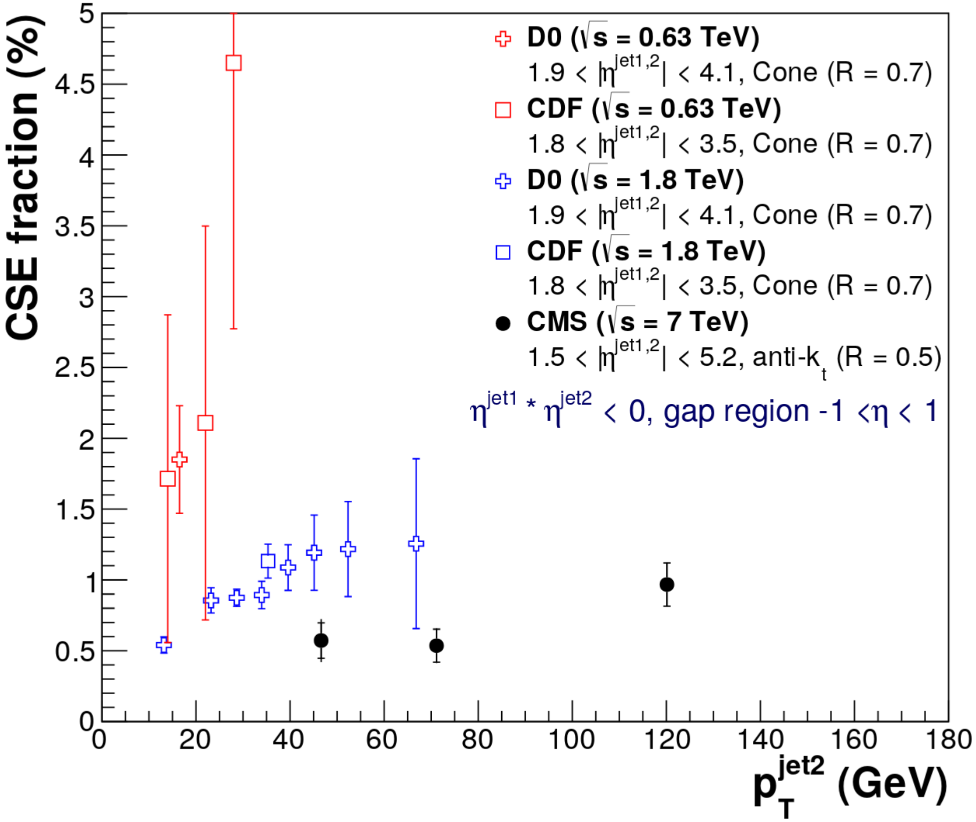


$N(CSE) = N(0) - N_{BG}(0)$

CSE fraction = N(CSE)/N



- Comparison to CDF/D0 @1.8 TeV:
  Suppression ~ factor 2
- CDF/D0 observation for 0.63 and 1.8 TeV:
  Decrease of CSE fraction with cme

CSE in jet-gap-jet

CMS-FSQ-12-001,
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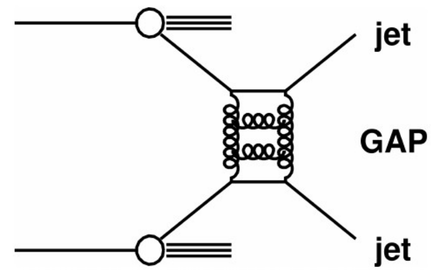
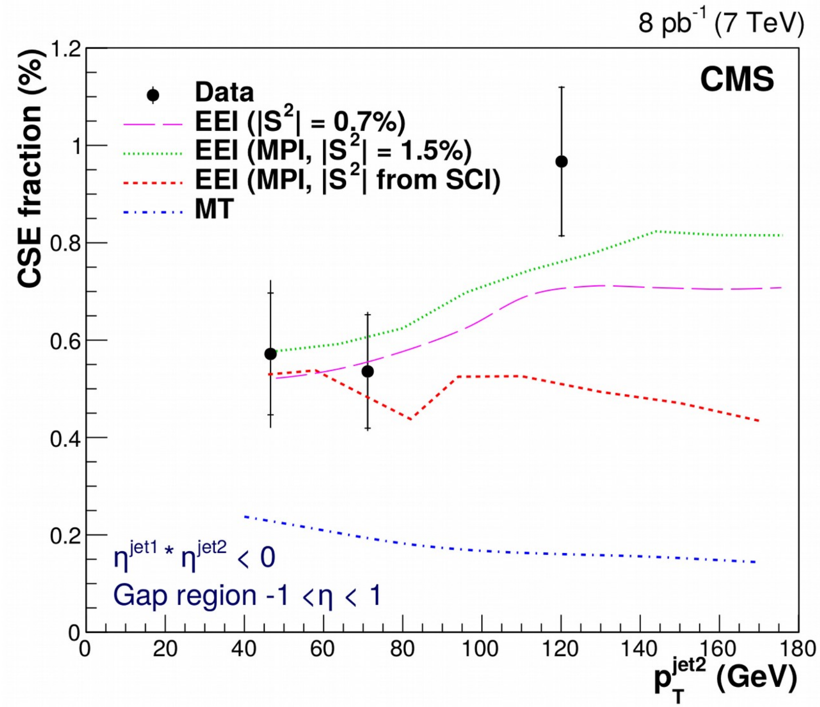


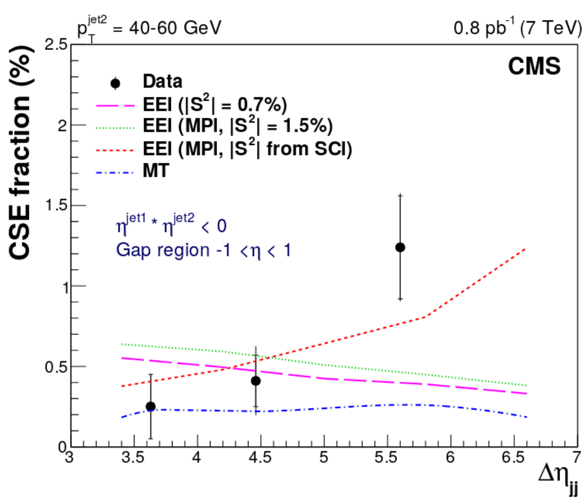
CSE fraction:

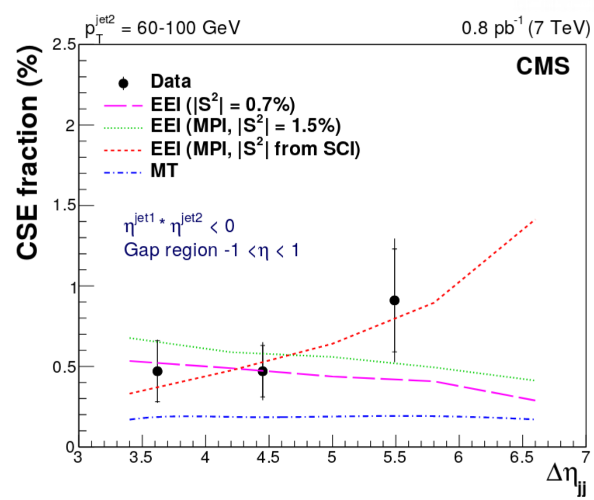
data vs Mueller-Tang (MT) vs Ekstedt, Enberg, and Ingelman (EEI) models

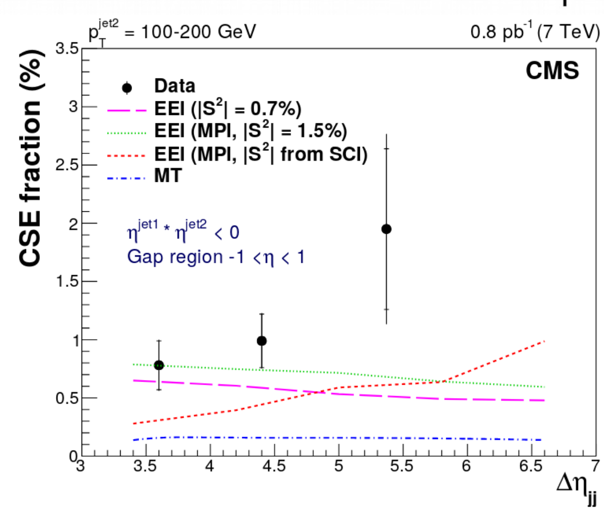
- CSE fraction vs second jet P_T:



- CSE fraction vs gap size:



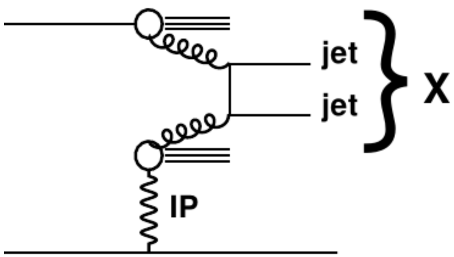




summary

Single diffractive (SD) di-jet production

- Pythia8 Dynamic Gap Model describes the data in the best way
- POMWIG with the corresponding $\langle S^2 \rangle$ correction describes the data as well
- Obvious profit from intact-proton based analysis for the acceptance and precision



Colour Singlet Exchange in jet-gap-jet events

- Fraction of CSE events is in a good agreement with earlier measurements and can in general be described with (N)LL-BFKL MC
- The gap size dependence is described in the best way with NLL-BFKL (EEI) accounting for MPI+SCI, but still deviates from the data for high P_T jets
- Results for 13 TeV are coming soon