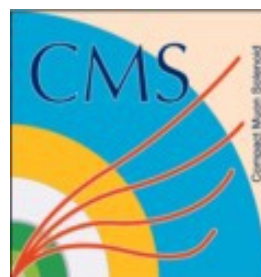# Diffractive processes in pp collisions at 7 TeV measured with the CMS experiment
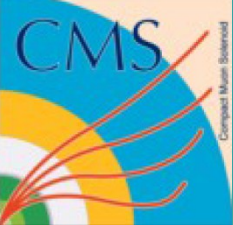
**Grzegorz Brona
(University of Warsaw)
on behalf of**
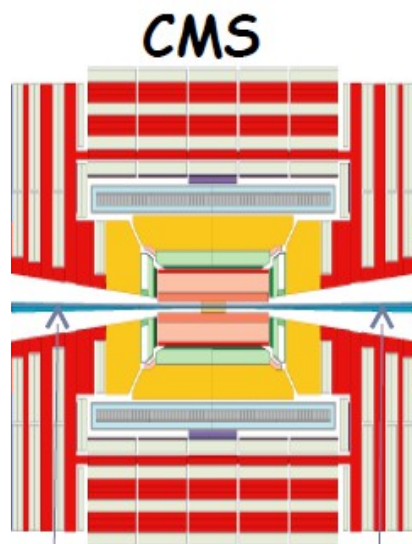
CMS Collaboration

28.04.2015

DIS 2015

Dallas, USA

- CMS detector at forward rapidities

- Soft diffraction – topologies

- Events with forward gap

- Events with central gap

- Cross section of the single and double dissociation

- Forward rapidity gap cross section

- Summary
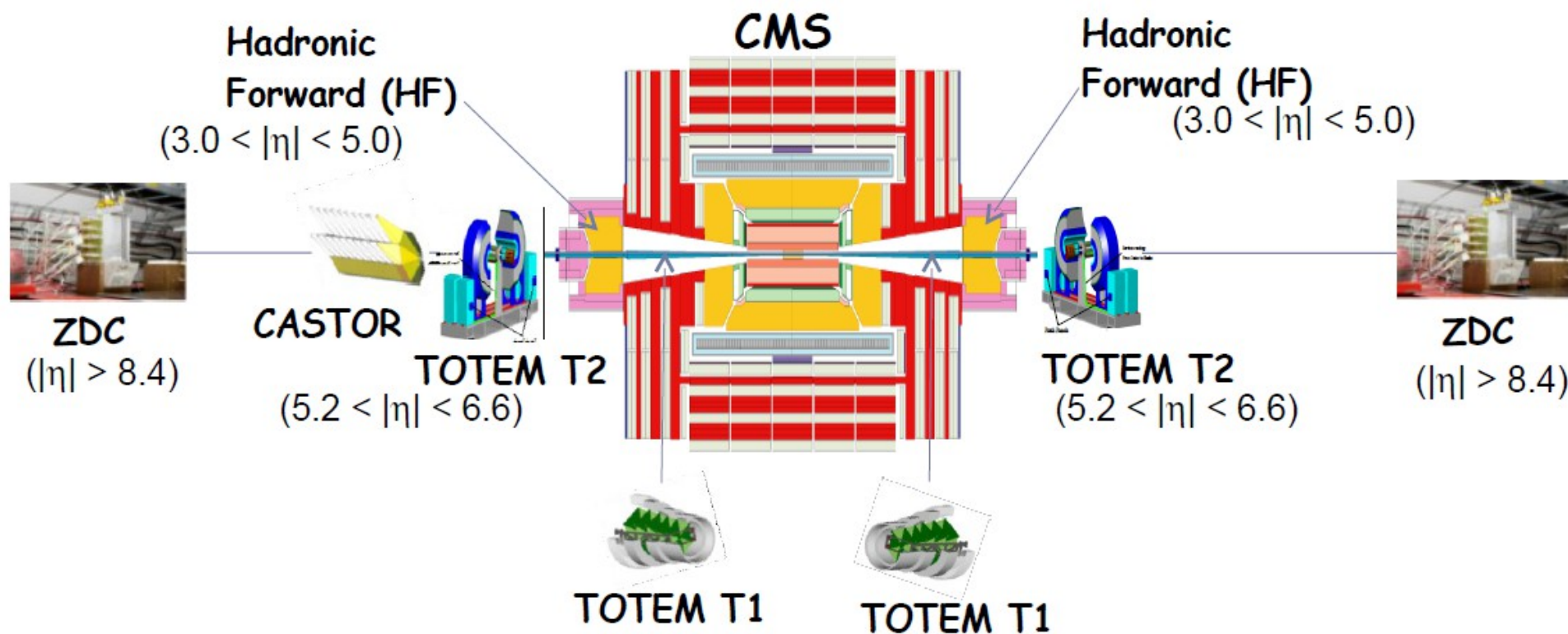
- Tracker $|\eta|<2.4$, $p_T > 100$ MeV
- Electromagnetic calorimeter ECAL
- Hadronic Calorimeter HCAL
- Muon chambers

CMS at forward rapidities

Hadronic Forward (HF) (3.0 < |η| < 5.0)

ZDC (|η| > 8.4)

CASTOR

TOTEM T2 (5.2 < |η| < 6.6)

CMS

Hadronic Forward (HF) (3.0 < |η| < 5.0)

ZDC (|η| > 8.4)

TOTEM T2 (5.2 < |η| < 6.6)

TOTEM T1   TOTEM T1

- Tracker $|\eta|<2.4$, $p_T > 100$ MeV
- Electromagnetic calorimeter ECAL
- Hadronic Calorimeter HCAL
- Muon chambers

- **H**adronic **F**orward calorimeters (HF) $3<|\eta|<5$
- Very Forward Calorimeter (CASTOR) $5.2<|\eta|<6.6$
- **Z**ero **D**egree **C**alorimeter (ZDC)
- **B**eam **S**cintillator **C**ounters BSC: $3.2<|\eta|<4.7$
- **F**orward **S**hower **C**ounters FSC: $6<|\eta|<8$

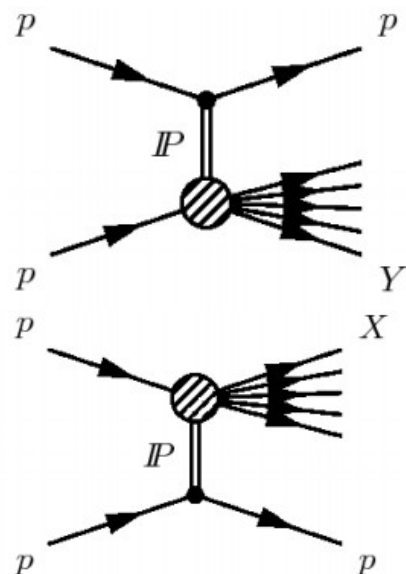+ Totem (T1/T2 tracking detectors and RP roman pots) separate experiment
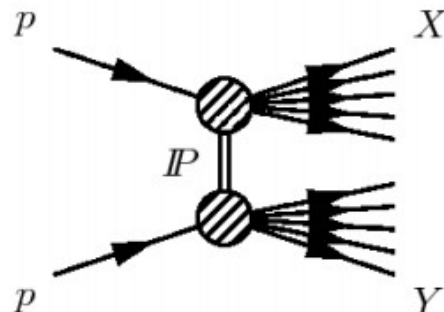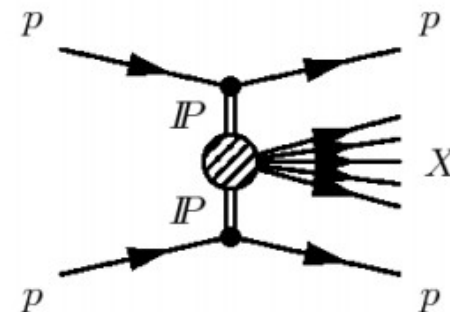
Soft Diffraction
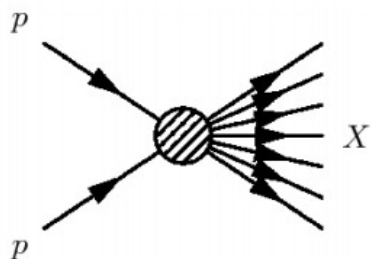
non-diffraction

single diffractive dissociation (SD)

double diffractive dissociation (DD)
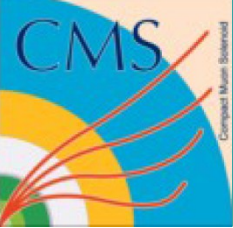
central diffraction

send to PRD,
arXiv:1503.08689
CMS-PAS-FSQ-12-005

Selection:
* ~20 µb^{-1} of low pile-up data (µ=0.14), from 2010
* Online: activity in either of the BSC – Minimum Bias trigger
* No vertex requirement (low diffractive masses 12<Mx<100 GeV accepted)
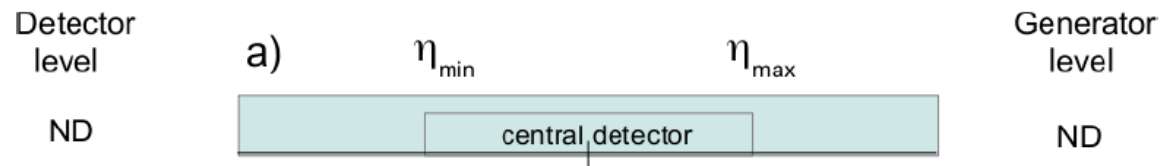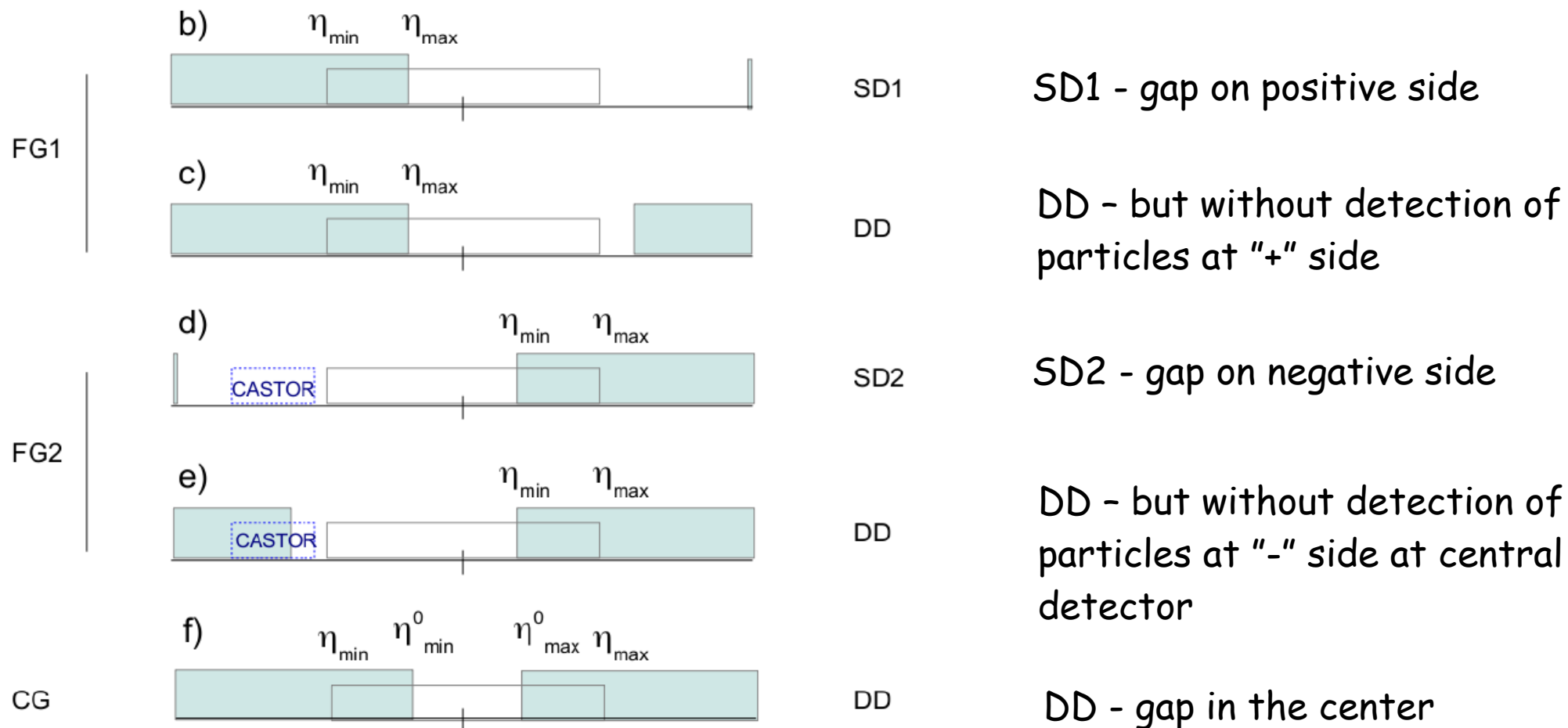* Diffractive offline selection: Large Rapidity Gaps within |η|<4.7

Monte Carlo:

- PYTHIA8-4C
  - diffraction generated according to Schuler&Sjostrand model from PYTHIA6
  - SD and DD cross sections scaled down by 10% and 12%

- PYTHIA8-MBR (Minimum Bias Rockefeler model)
  - diffraction generated based on renormalized Regge theory model
  - developed for CDF
  - linear parametrization of the Pomeron trajectory $\alpha(t) = 1 + \varepsilon + \alpha' t$
  - $\alpha' = 0.25 \text{ GeV}^{-2}$, $\varepsilon = 0.08$ or 0.104
  - DD cross section scaled down by 15%
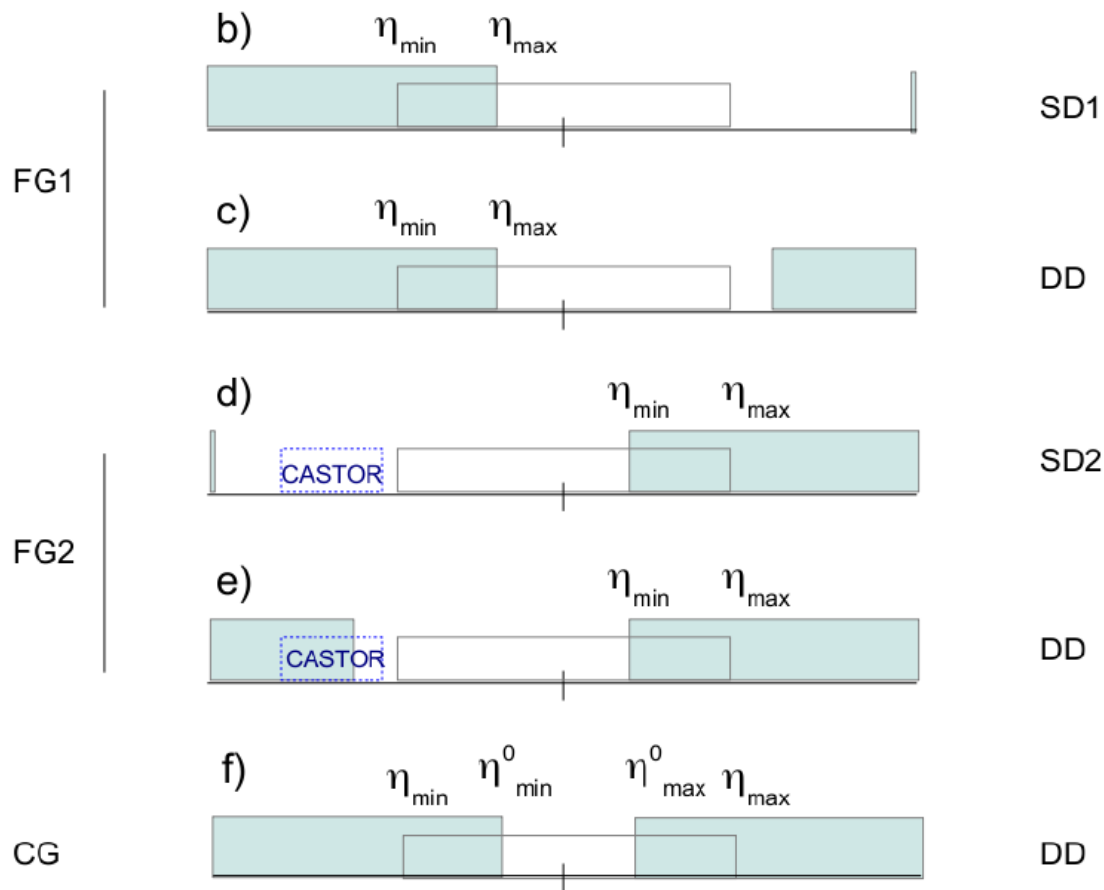
- PYTHIA6-Z2*

- PHOJET

- QGSJET-II

- EPOS

cosmic rays MC

Three experimental topologies based on the position of the LRG without CASTOR information

SD1 - gap on positive side

DD – but without detection of particles at "+" side

SD2 - gap on negative side

DD – but without detection of particles at "-" side at central detector

DD - gap in the center

- η_{max} (η_{min}) highest (lowest) η of the particle candidate with $|\eta|<4.7$
- $\Delta\eta = \eta^0_{max} - \eta^0_{min}$
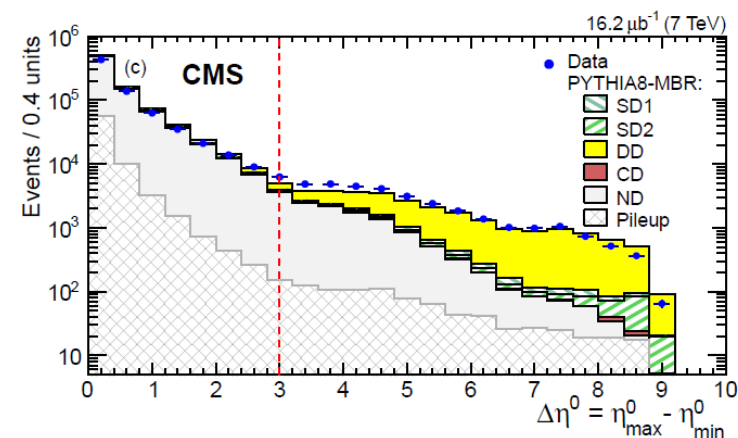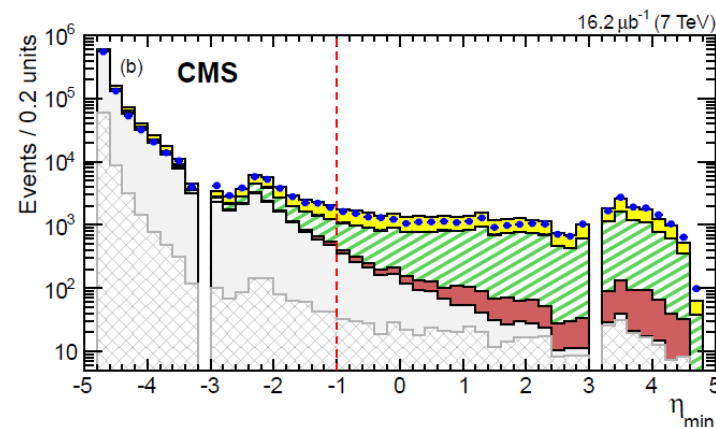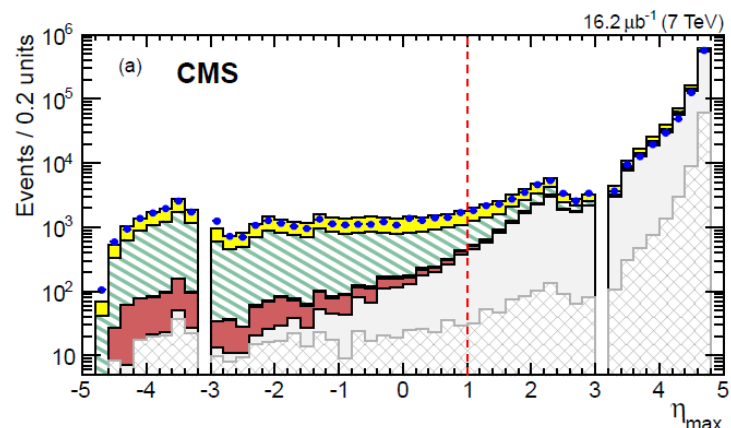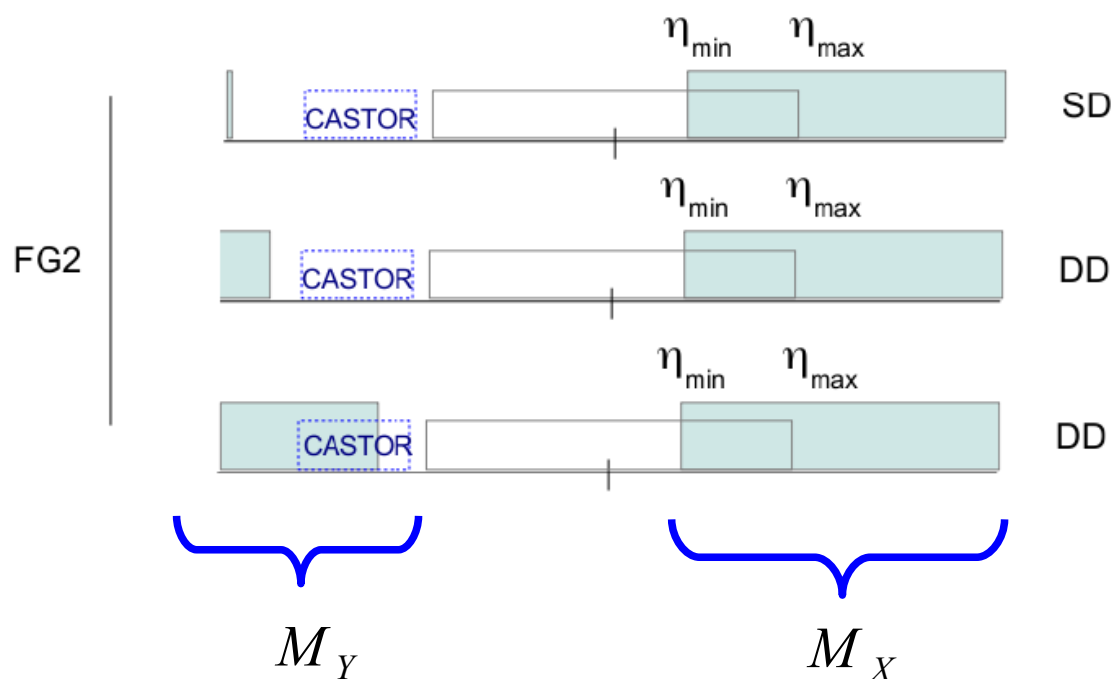
$$\log_{10} M_Y < 0.5$$

$$0.5 < \log_{10} M_Y < 1.1$$

$$M_X, M_Y \text{ in GeV}$$

- Variable ξ defined as:

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

- Reconstructed:

$$\xi_X^{rec} = \frac{\sum(E^i - p_z^i)}{\sqrt{s}}$$

- And corrected for undetected particles: (PYTHIA 8 MBR)

$$\log_{10} \xi_X^{cal} = \log_{10} \xi_X^{rec} + C(\xi_X^{rec})$$

Detector level distributions
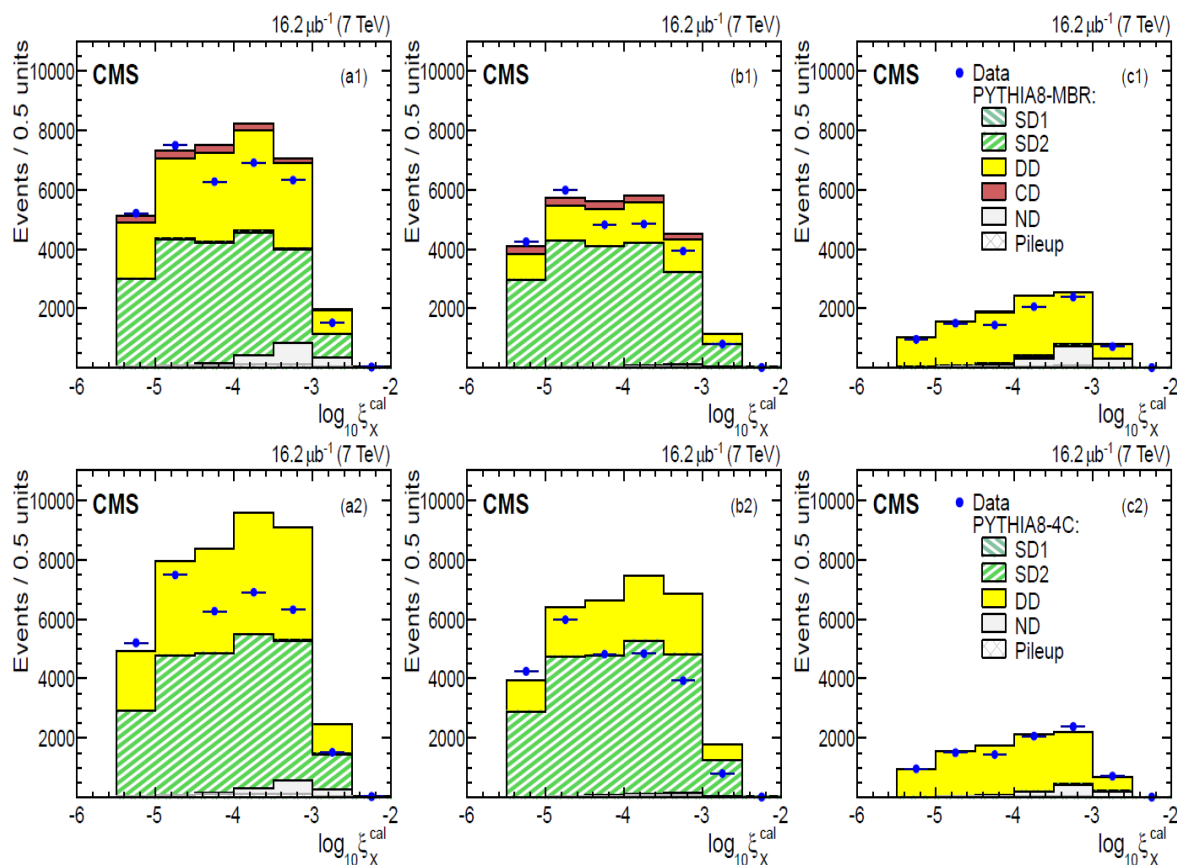
Cross section measured in bins of ξ_X

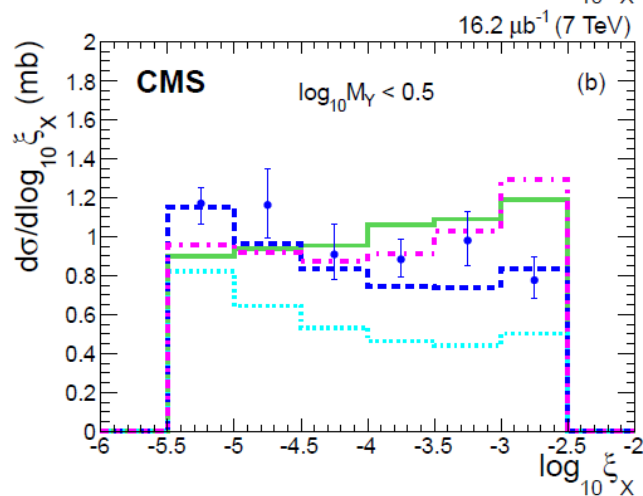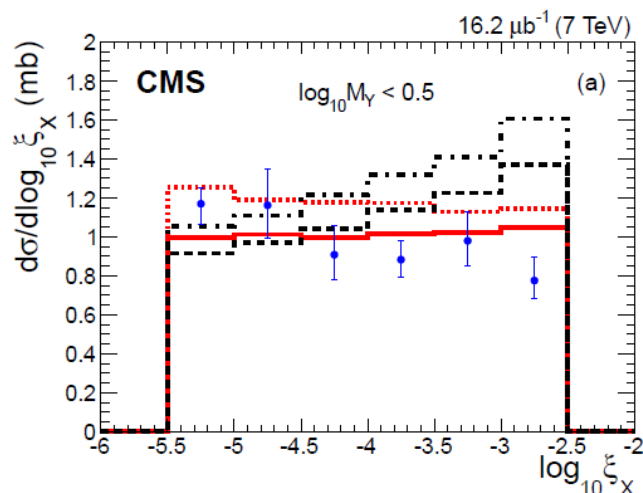full sample   no-CASTOR tag   CASTOR tag

- Data unfolded (acceptance and migration corrections)
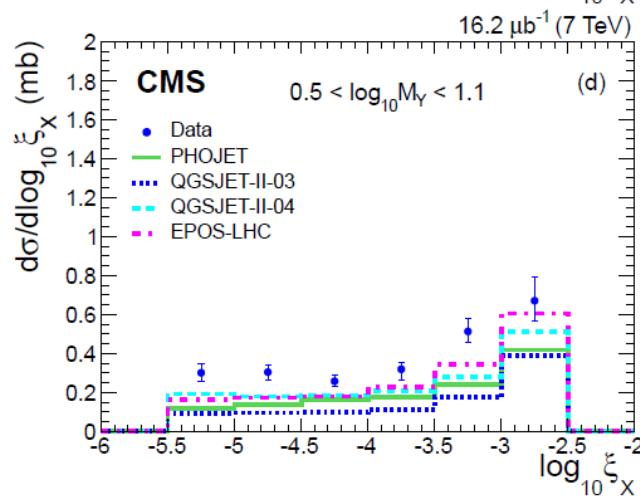
- PYTHIA 8 MBR

- Corrections for pile-up

Forward gap

no-CASTOR tag   Castor tag
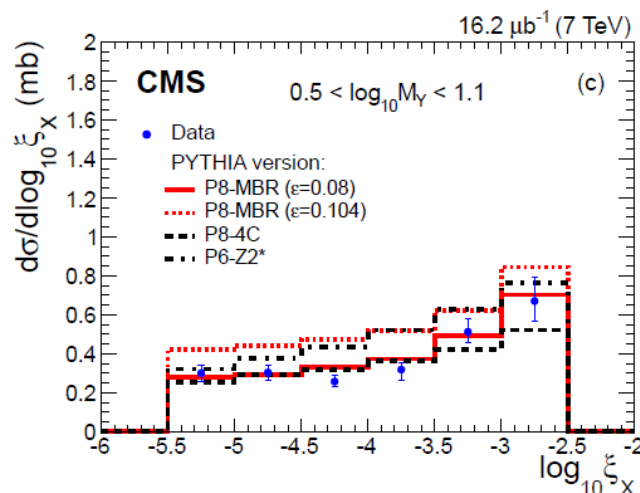
- Data with tag favor ε = 0.08

- P8-4C and P6-2Z* higher than data in no-CASTOR tag

- P8-4C and P6-2Z* predicts raising behavior in no-CASTOR tag

- PHOJET, QGSJET, EPOS cannot describe data in tag sample

Central gap

$$\Delta\eta = \eta^0_{max} - \eta^0_{min}$$
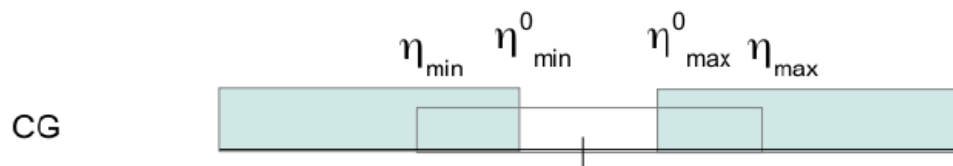
CG η_{min} η^0_{min} η^0_{max} η_{max} DD

Range: $\log_{10} M_X > 1.1$

$\log_{10} M_Y > 1.1$

- Reconstructed: $\Delta\eta_{rec}$

- And corrected for detector effects: $\Delta\eta_{cal} = \Delta\eta_{rec} - C$

- Unfolding (response matrix from PYTHIA MBR)

- P8-MBR describes the data

- P8-4C underestimates

- P6-Z2* overestimates

- PHOJET, QGSJET, EPOS underestimates

Integrated cross section measured for 3 samples:

- FG2, no-CASTOR tag $\quad -5.5 < \log_{10} \xi_X < -2.5 \qquad \log_{10} M_Y < 0.5$

- FG2, CASTOR tag $\quad -5.5 < \log_{10} \xi_X < -2.5 \qquad 0.5 < \log_{10} M_Y < 1.1$
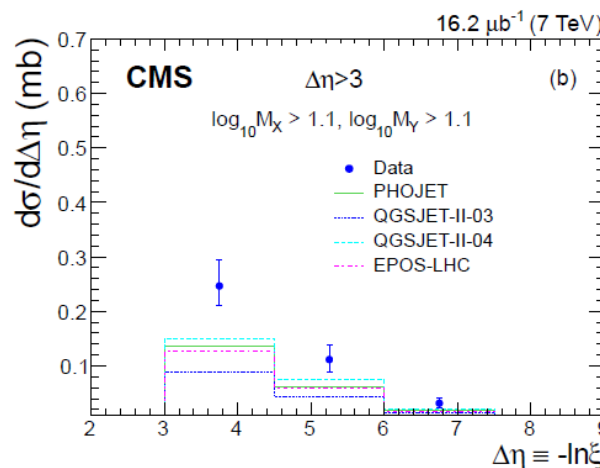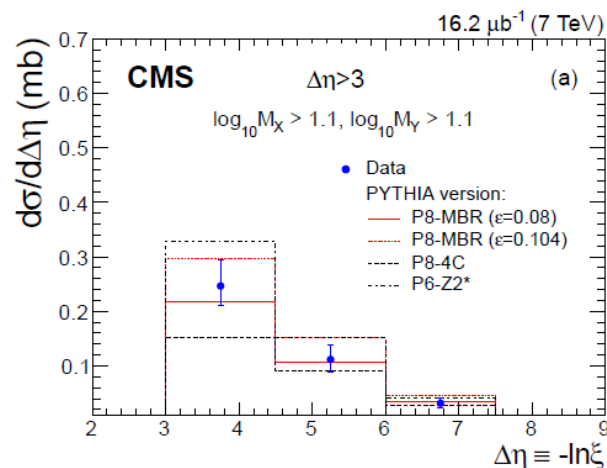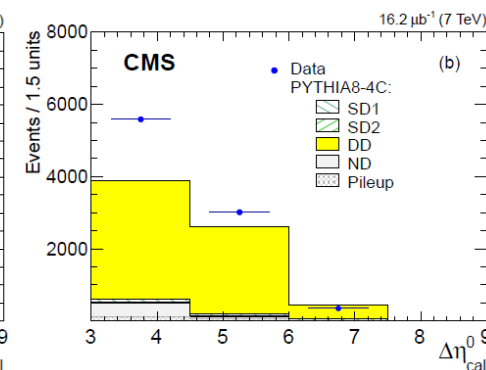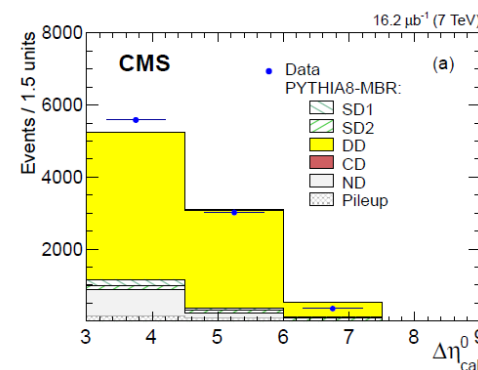
- CG $\qquad\qquad \Delta\eta > 3 \qquad \log_{10} M_X > 1.1 \qquad \log_{10} M_Y > 1.1$

Cross section	$\sigma_{\text{no-CASTOR}}$ (mb) SD dominated	σ_{CASTOR} (mb) DD dominated	σ_{CG} (mb) DD dominated
Data	$2.99 \pm 0.02^{+0.32}_{-0.29}$	$1.18 \pm 0.02 \pm 0.13$	$0.58 \pm 0.01^{+0.13}_{-0.11}$
PYTHIA 8 MBR	3.05	1.24	0.54
PYTHIA 8 4C	3.31	1.10	0.40
PYTHIA 6 Z2*	3.86	1.52	0.78
PHOJET	3.06	0.63	0.32
QGSJET-II 03	2.63	0.48	0.22
QGSJET-II 04	1.70	0.78	0.37
EPOS	2.99	0.85	0.31

From no-CASTOR tag sample, visible SD cross section:

- Substraction of DD component → from PYTHIA 8 MBR

- $\sigma^{SDvis} = 4.06 \pm 0.04\,(stat)^{+0.69}_{-0.63}\,(syst)\,mb$ $\qquad -5.5 < \log_{10} \xi_X < -2.5$

From CASTOR tag sample, visible DD cross section:

- $\sigma^{DDvis}_{CASTOR} = 1.06 \pm 0.02\,(stat) \pm 0.12\,(syst)\,mb$ $\qquad -5.5 < \log_{10} \xi_X < -2.5$

$$0.5 < \log_{10} M_Y < 1.1$$

From CG sample, visible DD cross section:

- $\sigma^{DDvis}_{CG} = 0.56 \pm 0.01\,(stat)^{+0.15}_{-0.13}\,(syst)\,mb$ $\qquad \Delta\eta > 3$

$$\log_{10} M_X > 1.1$$
$$\log_{10} M_Y > 1.1$$

Extrapolation to the not observed region: PYTHIA 8 MBR (ε = 0.08)

$$\sigma^{SD} = 8.84 \pm 0.08\,(stat)^{+1.49}_{-1.38}\,(syst)^{+1.17}_{-0.37}\,(extr)\,mb \qquad \xi_{X(Y)} < 0.05$$

$$\sigma^{DD} = 5.17 \pm 0.08\,(stat)^{+0.55}_{-0.57}\,(syst)^{+1.62}_{-0.51}\,(extr)\,mb \qquad \Delta\eta > 3$$
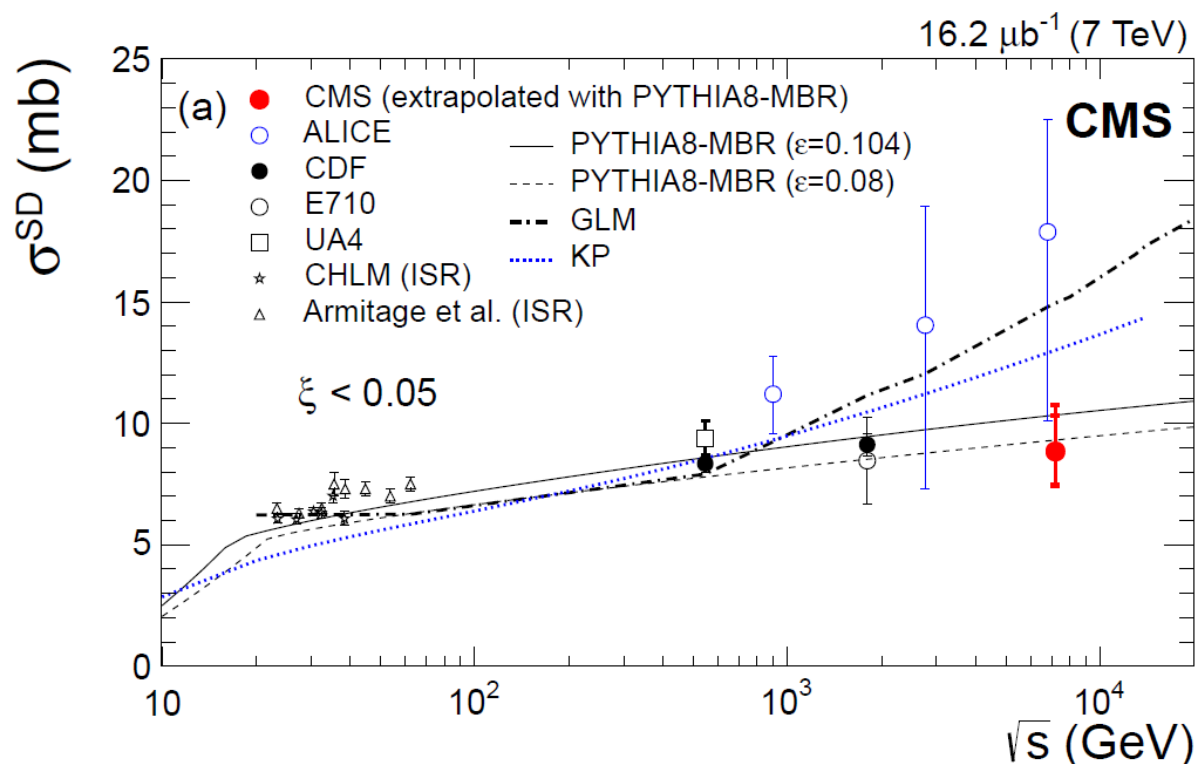
CMS results consistent with MBR predictions – SD cross section weakly rising with energy
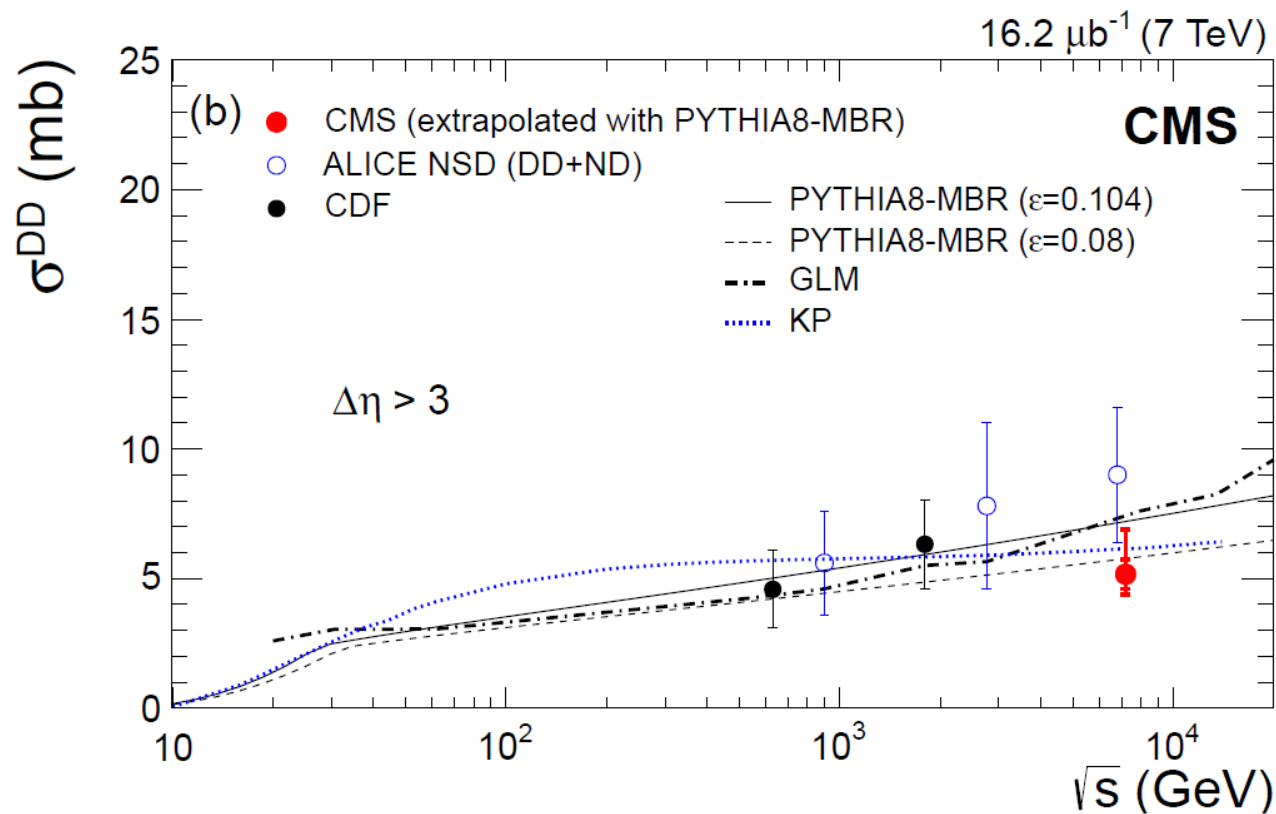
CMS results consistent with MBR and KP model predictions – DD cross section weakly rising with energy

- Forward rapidity gap – the largest of the two empty regions extending from the edge of the detector acceptance (|η|=4.7) to the nearest particle candidate

$$\Delta\eta^F = max\left(\eta_{min}-(-4.7),\eta_{max}-(4.7)\right)$$
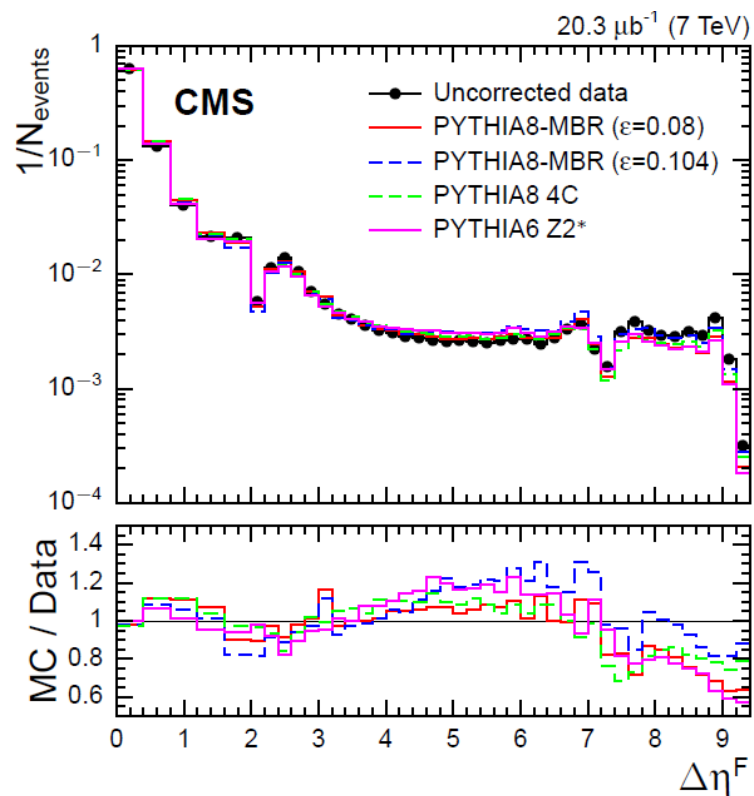
- Unfolding done with PYTHIA 8 MBR with demand of at least 1 stable particle with p_T>200 MeV and |η|<4.7

- Exponential falling non-diffractive contribution
- Diffractive plateau at $\Delta\eta_F > 3$
- mixture of SD and DD events
- Best described: PYTHIA8+MBR with 0.08 intercept.
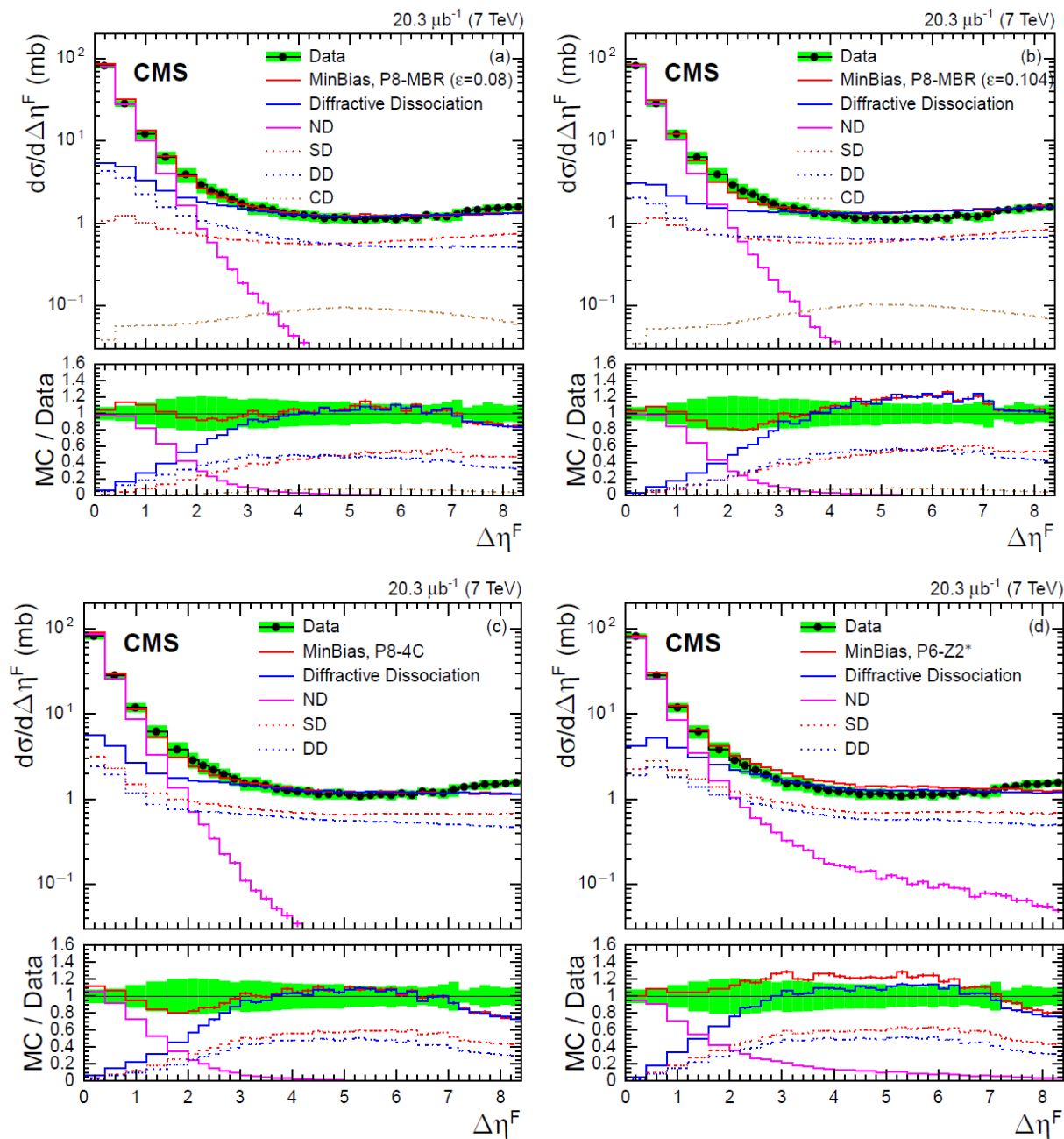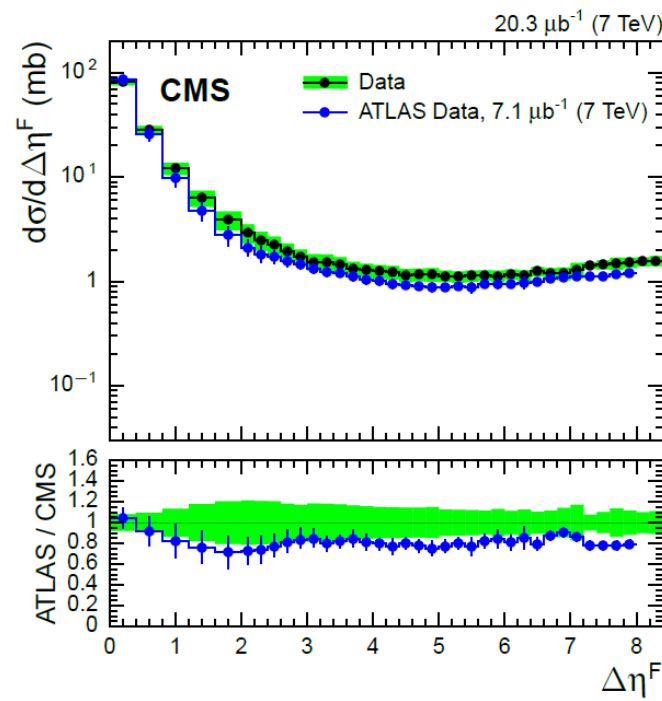
Differences in acceptance

- CMS performed measurement of diffractive dissociation cross section in pp

- Extrapolation of the SD and DD to the regions ξ < 0.05 and $\Delta\eta$ > 3 gave:

$$\sigma^{SD} = 8.84 \pm 0.08\,(stat)^{+1.49}_{-1.38}\,(syst)^{+1.17}_{-0.37}\,(extr)\,mb$$

$$\sigma^{DD} = 5.17 \pm 0.08\,(stat)^{+0.55}_{-0.57}\,(syst)^{+1.62}_{-0.51}\,(extr)\,mb$$

- PHOJET, QGSJET, EPOS predict too few DD events

- PYTHIA8-4C, PYTHIA6-Z2*, PHOJET, EPOS do not predict ξ_X dependence for SD

- PYTHIA8-MBR describes the data in all the measured regions

- Data are consistent with SD and DD cross sections weakly rising with energy

Spares

Extrapolation
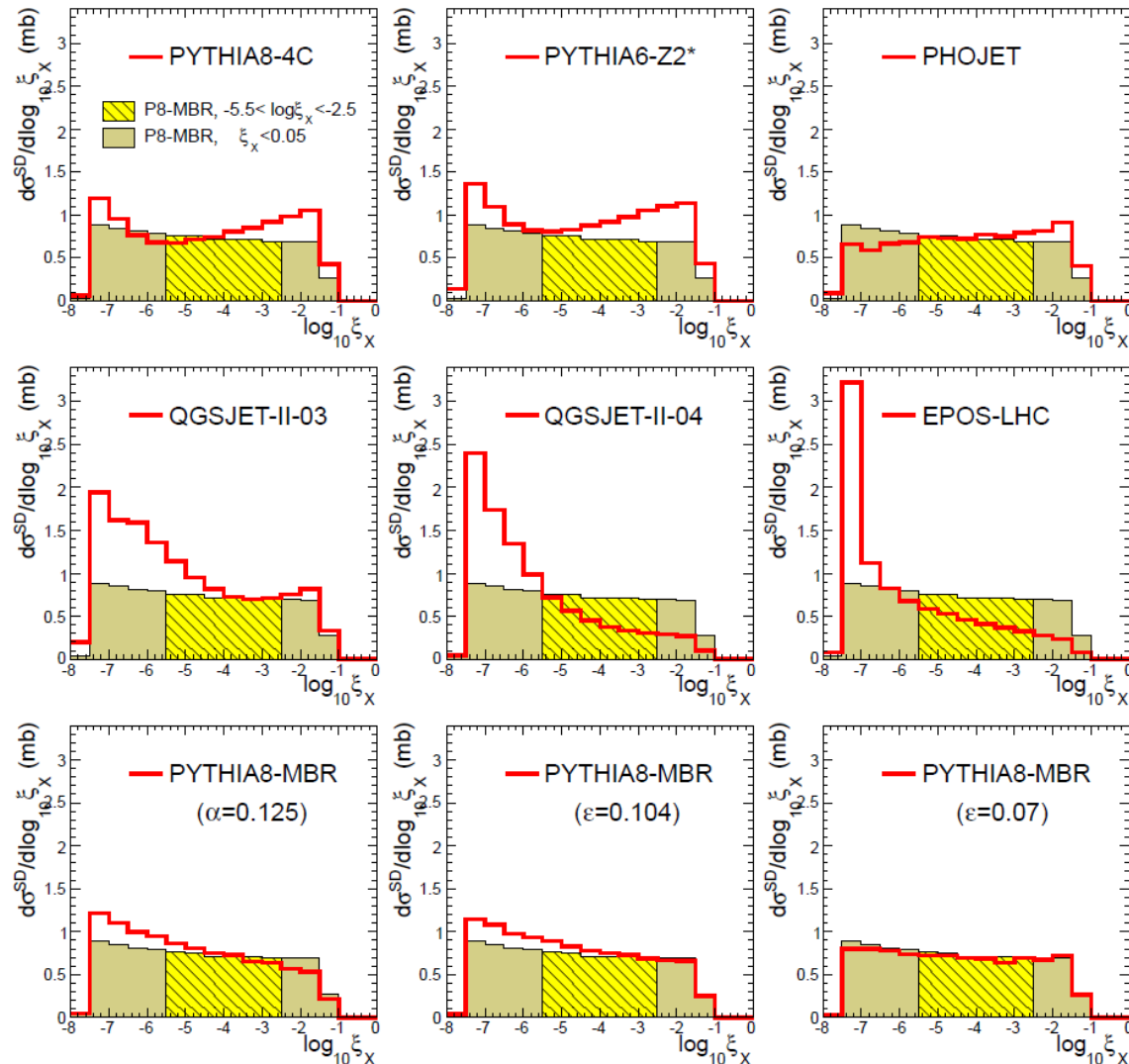
i	MC model	f^{SD}	f^{SD}_{MBR}
1	PYTHIA 8 MBR ($\varepsilon = 0.08$)	2.18 (1.00)	2.18 (1.00)
2	PYTHIA 8 4C	2.32 (1.06)	2.51 (1.15)
3	PYTHIA 6 Z2*	2.29 (1.06)	2.89 (1.34)
4	PHOJET	2.06 (0.95)	2.18 (1.00)
5	QGSJET-II 03	2.72 (1.25)	3.19 (1.46)
6	QGSJET-II 04	3.62 (1.66)	2.30 (1.06)
7	EPOS	3.44 (1.58)	2.15 (0.99)
8	PYTHIA 8 MBR ($\alpha' = 0.125$)	2.27 (1.04)	2.34 (1.07)
9	PYTHIA 8 MBR ($\varepsilon = 0.104$)	2.23 (1.03)	2.42 (1.11)
10	PYTHIA 8 MBR ($\varepsilon = 0.07$)	2.16 (0.99)	2.09 (0.96)

i	MC model	f^{DD}	f^{DD}_{MBR}
1	PYTHIA 8 MBR ($\varepsilon = 0.08$)	1.92 (1.00)	1.92 (1.00)
2	PYTHIA 8 4C	2.52 (1.32)	1.86 (0.97)
3	PYTHIA 6 Z2*	2.39 (1.25)	2.15 (1.13)
4	PHOJET	1.80 (0.94)	0.60 (0.31)
5	QGSJET-II 03	—	—
6	QGSJET-II 04	2.04 (1.07)	0.94 (0.49)
7	EPOS	4.73 (2.47)	1.93 (1.01)
8	PYTHIA 8 MBR ($\alpha' = 0.125$)	1.97 (1.03)	2.32 (1.21)
9	PYTHIA 8 MBR ($\varepsilon = 0.104$)	2.00 (1.04)	2.37 (1.24)
10	PYTHIA 8 MBR ($\varepsilon = 0.07$)	1.88 (0.98)	1.73 (0.90)