Review of diffraction at the LHC

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EDS-Blois 2015, the 16th Conference on Elastic and Diffractive Scattering
29 June – 4 July, 2015, Borgo, Corsica

Outline

Diffraction at the LHC

- Inclusive measurements
- Hard diffraction
- Exclusive processes

Will only minimally cover HERA results, as they will be discussed on Thursday by:

- Alice Valcarova - Hard diffraction at HERA
- Marta Ruspa - Exclusive processes at HERA

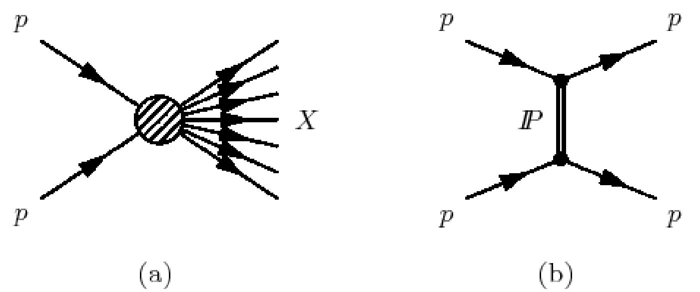
Motivation

- Measure fundamental quantities in HEP:
  total, elastic, diffractive cross sections
- Understand mechanism of diffractive processes
- Study interplay between soft and hard physics
  - Test phenomenological models in soft regime
  - Test pQCD in hard regime
- Search for new phenomena
  - BFKL dynamics
  - Saturation
  - Exotic QCD states, e.g. glueballs
  - BSM physics

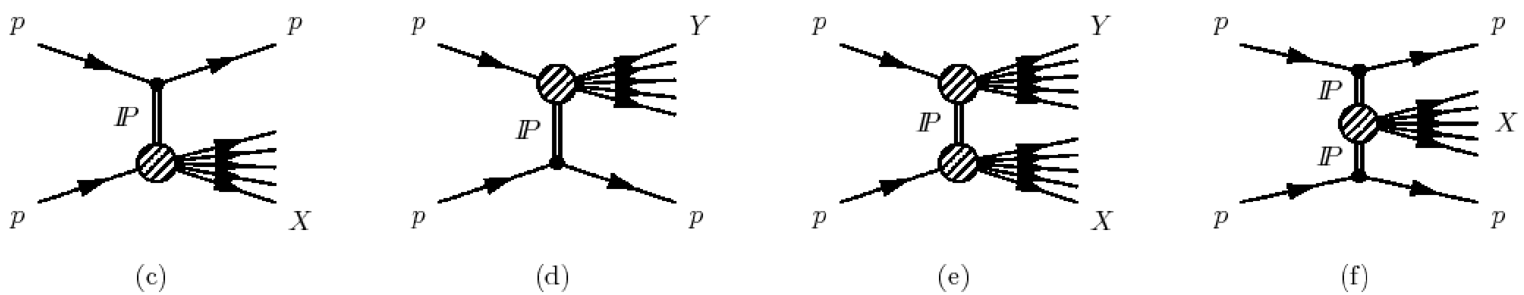
Main processes contributing to the total pp cross section

Non-diffractive
pp → X

(exponentially-suppressed rapidity gap)



Elastic
pp → pp



Single dissociation (SD)
pp → Xp , pp → pY

Double dissociation (DD),
pp → XY

Central diffraction (CD)
pp → pXp

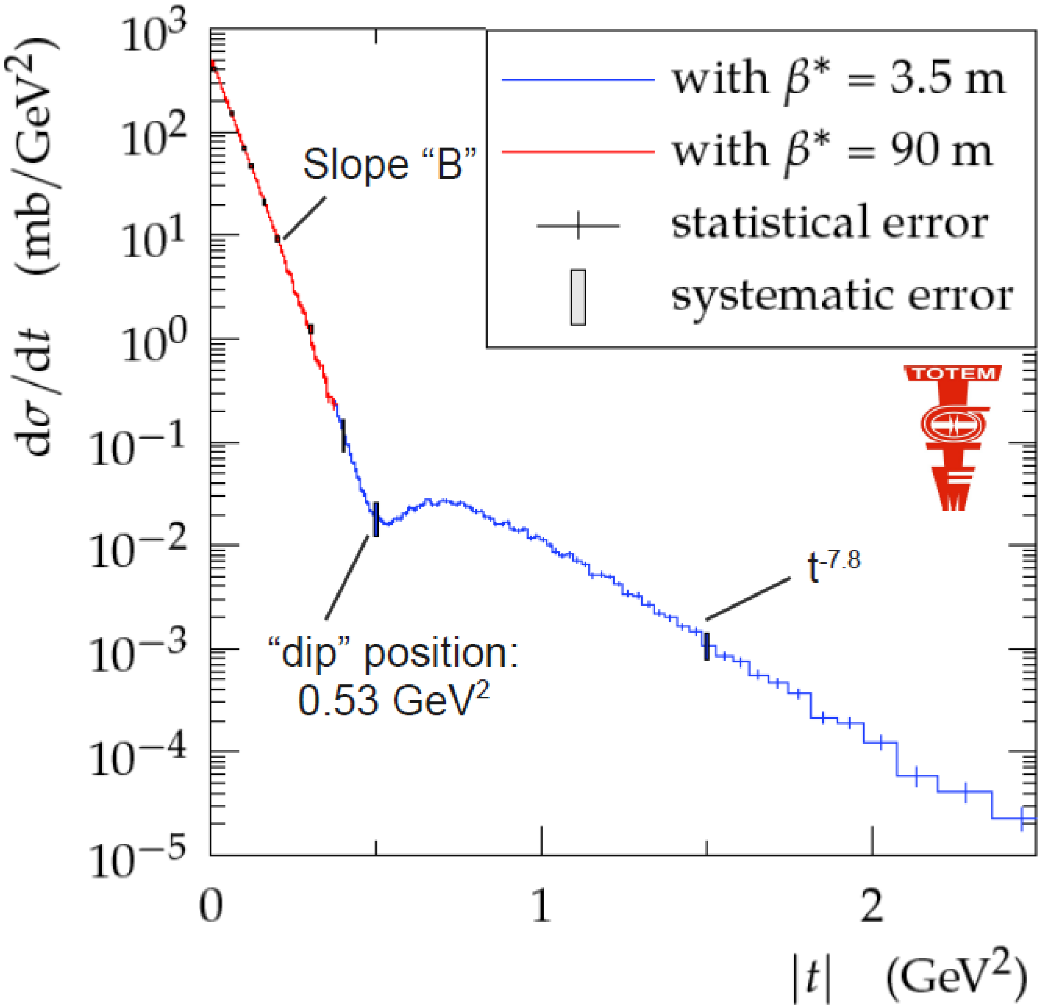
or **double-Pomeron exchange (DPE)**

Diffractive processes (SD, DD, CD) – about 20-30% of total-inelastic cross section.
Large rapidity gap (LRG) present in the final state.

Elastic scattering @7 TeV

Proton tagging at z=±220m (TOTEM RP) and z=±240m (ATLAS-ALFA)

EPL 95 (2011) 41001, EPL 101 (2013) 21001

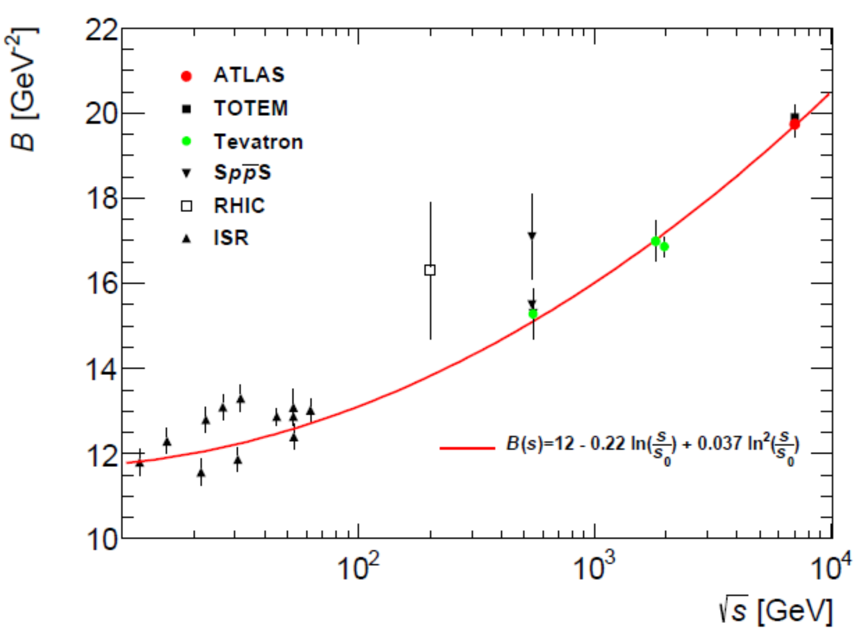


$$\frac{d\sigma_{el}}{dt} = \left.\frac{d\sigma_{el}}{dt}\right|_{t=0} e^{-B|t|}$$

ATLAS: $B = 19.7 \pm 0.3$ GeV^{-2}

TOTEM: $B = 19.9 \pm 0.3$ GeV^{-2}

NPB 889 (2014) 486



Forward peak, exponential in |t|

Power low dependence at higher |t|

Dip position ($R_p^2/4$) moves to lower |t| with energy

Shrinkage of the forward peak with energy

Optical theorem and total pp cross section

From elastic observables:

$$\sigma_{tot}^2 = \frac{1}{L} \frac{16\pi}{1+\rho^2} \frac{dN_{el}}{dt}\Big|_{t\to 0}$$

$$\rho = \frac{\mathrm{Re}(f_{el})}{\mathrm{Im}(f_{el})}\Big|_{t\to 0} = 0.14$$

ρ independent:

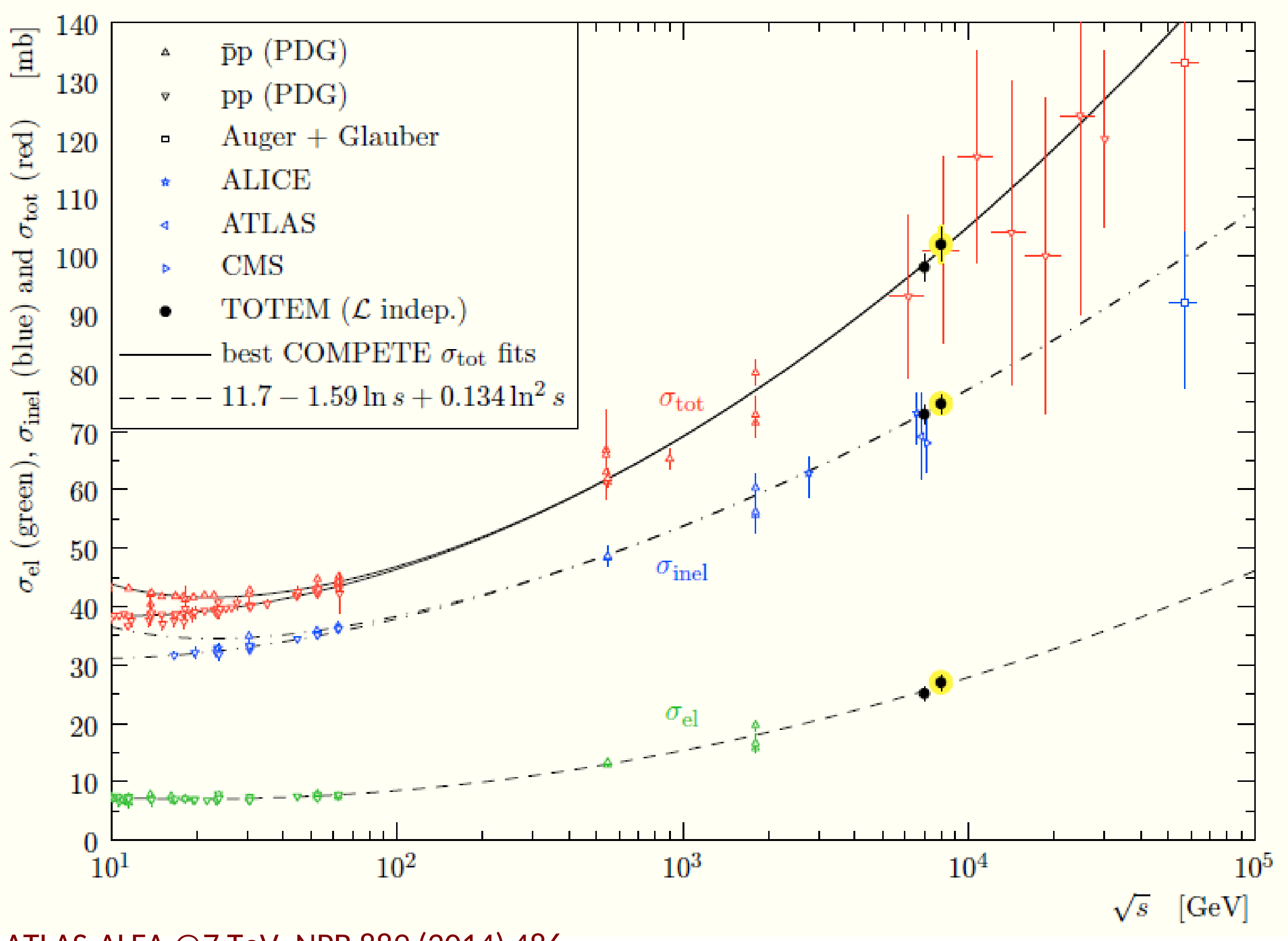
$$\sigma_{tot} = \frac{1}{\mathcal{L}} (N_{el} + N_{inel})$$

Luminosity independent:

$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \frac{dN_{el}/dt|_0}{N_{el} + N_{inel}}$$

All three methods in agreement.

EPL 101 (2013) 21004 (7 TeV) ; PRL 111 (2013) 012001 (8 TeV),



ATLAS-ALFA @7 TeV: NPB 889 (2014) 486

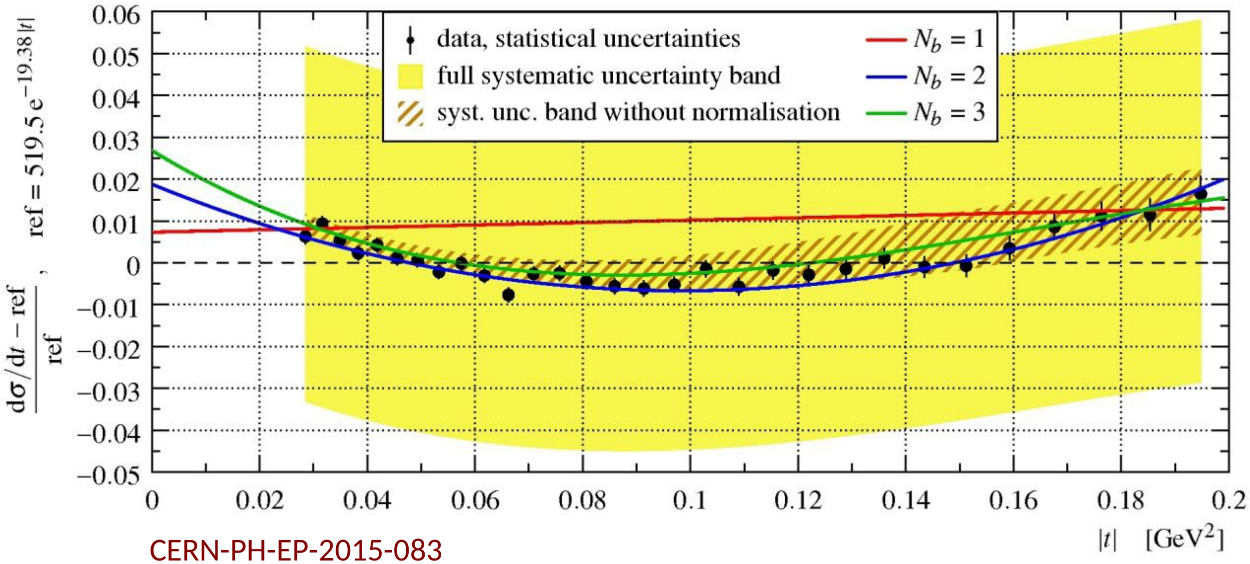
ATLAS: $\sigma_{tot} = 95.4 \pm 1.4$ mb

TOTEM: $\sigma_{tot} = 98.6 \pm 2.2$ mb

For an evolution of theory predictions before and after the LHC data, see Errol Gotsman's talk at DIFFRACTION 2014

Elastic at low and very low |t| - TOTEM

- High statistics dataset (β*=90m, 2012), 7 Mevt, 0.027 GeV2< |t| < 0.2 GeV2 (Coulomb effects negligible)



CERN-PH-EP-2015-083
arXiv:1503.08111

Relative deviation from exponential fit with

$B(t) = b_0$

$B(t) = b_0 + b_1 t$

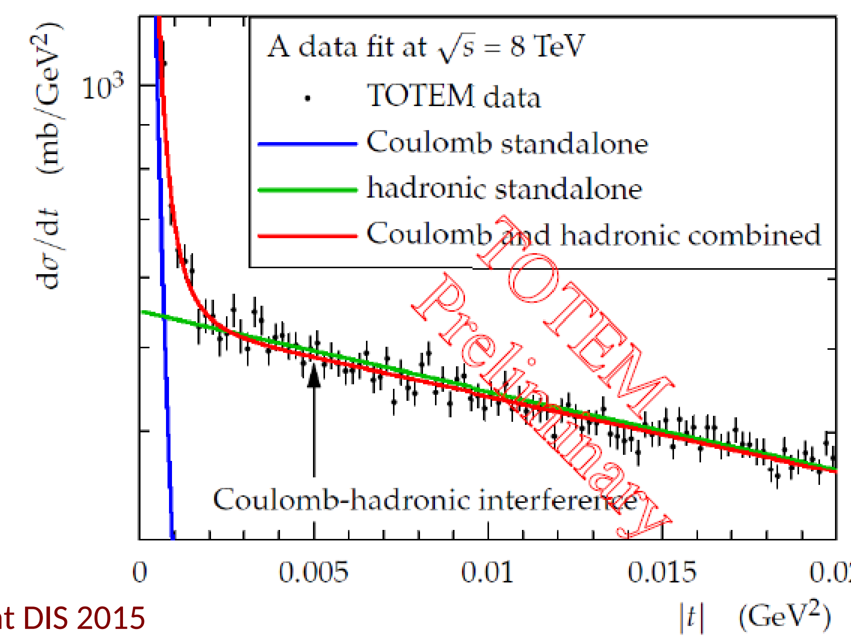
$B(t) = b_0 + b_1 t + b_2 t^2$

Pure exponential dependence excluded at 7.2 s significance.

- Very-low |t| dataset (β*=1000m, 2012), $|t| > 6*10^{-4}$ GeV^2

Constrain models of Coulomb-nuclear interference (nuclear phase Ψ, B(t))

$$F^{C+H} = F^C + F^H e^{i\alpha\Psi}$$



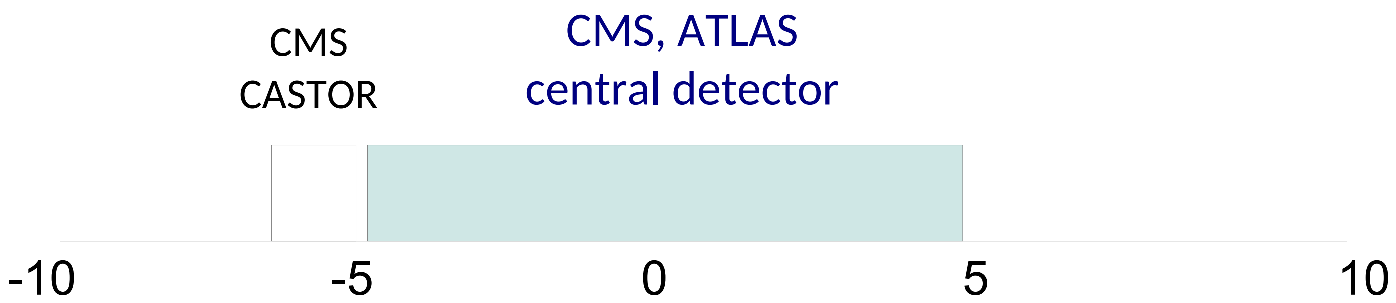
See e.g. Mario Deile at DIS 2015

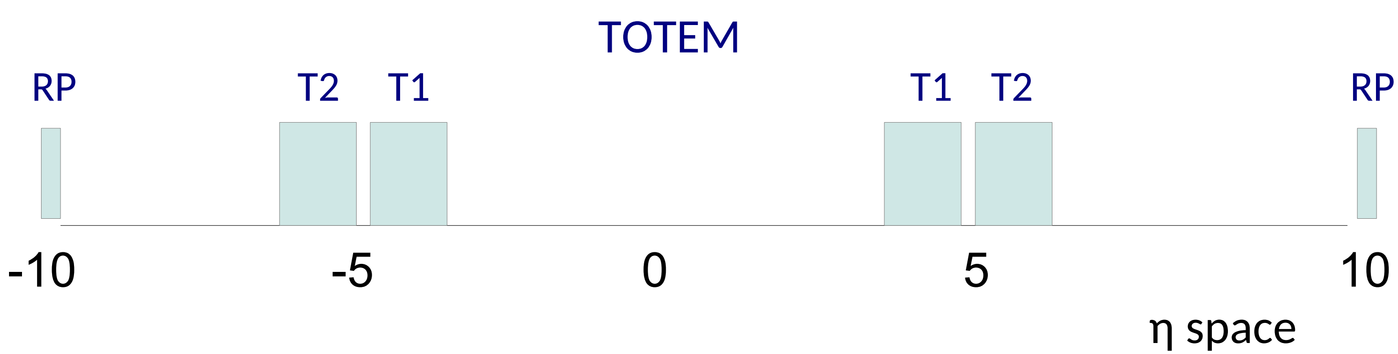
Diffractive results

Kinematic limit @7 TeV: $\eta = \pm 0.5 * \log(s/m^2) \approx \pm 10$

Detector coverage:

M_X (SD): ~3.4 ~12. ~1100 GeV

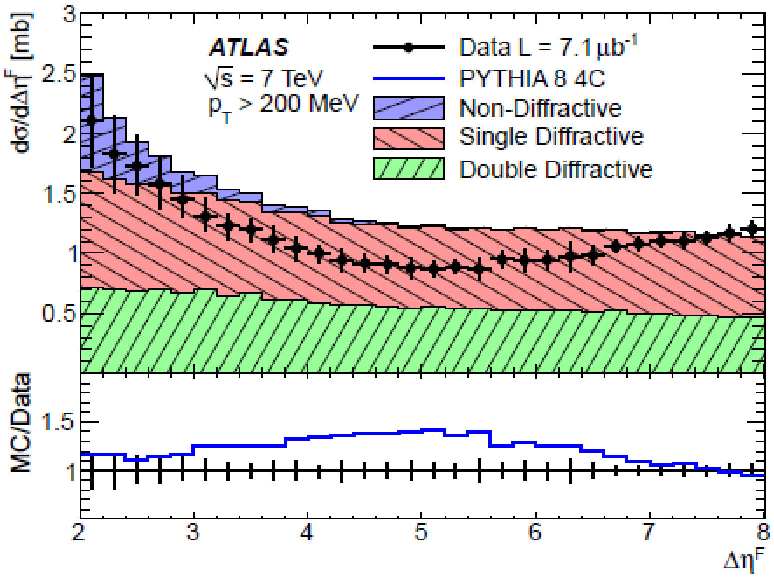


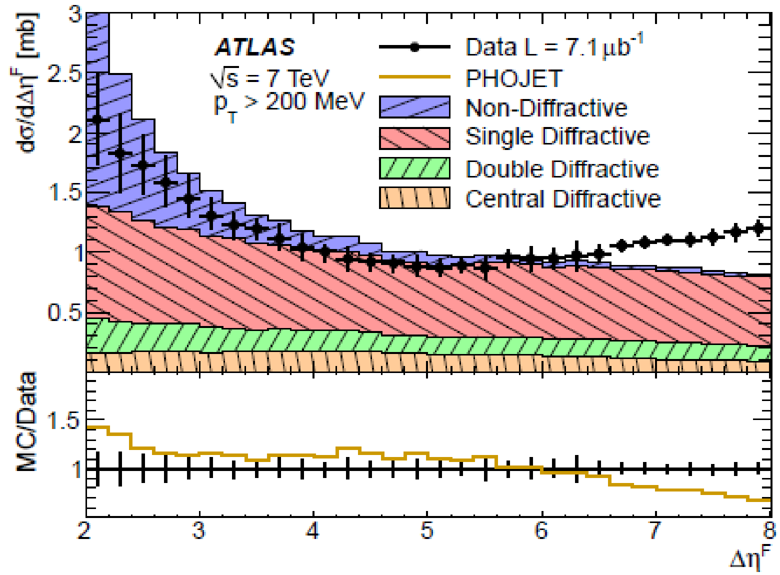


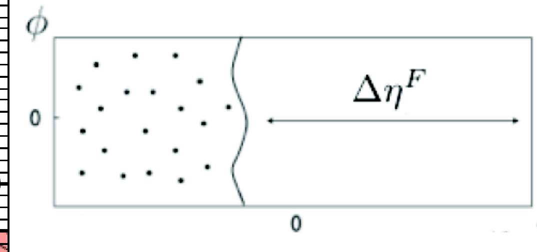
Diffractive results from ATLAS

Forward rapididy gap cross section

EPJC 72 (2012) 1926







distance to the detector edge

Diffractive events at high values of $\Delta\eta^F$

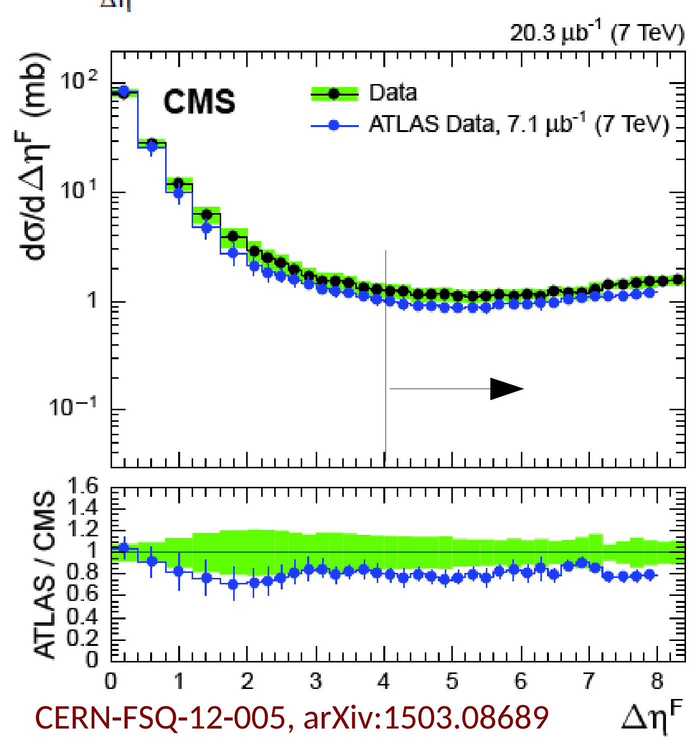
For $\Delta\eta^F > 3$ measured ~ 1 mb per unit of $\Delta\eta^F$

Test of diffraction models

No SD/DD separation possible

Similar results from CMS.

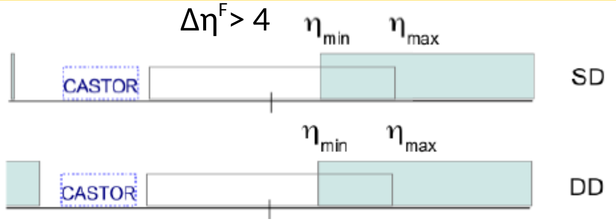
In addition, CMS uses CASTOR calorimeter ($-6.6<\eta< -5.2$) to separate SD/DD for events with $\Delta\eta^F > 4$.



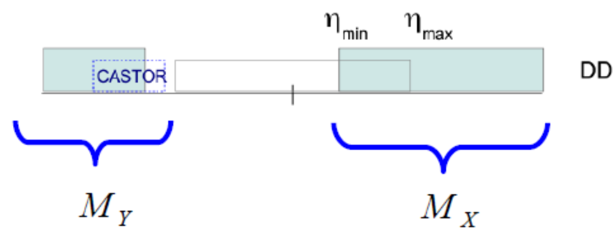
CERN-FSQ-12-005, arXiv:1503.08689

Diffractive results from CMS

CMS-FSQ-12-005, arXiv:1503.08689



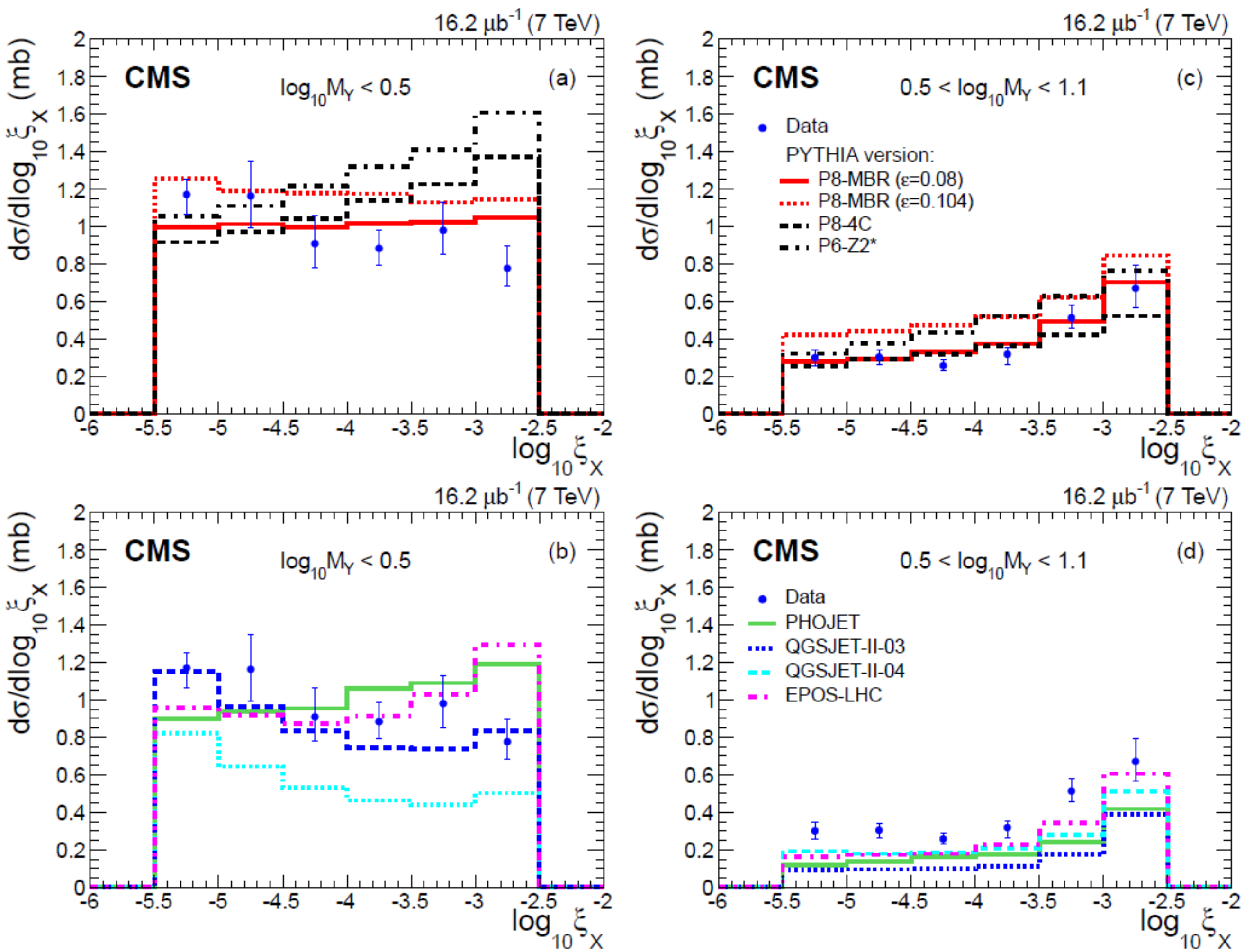
no CASTOR-tag (SD dominated)



CASTOR-tag (DD dominated)

Forward rapididy gap
+ CASTOR (-6.6<η< -5.2)

3,2 < M_X <12 GeV



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

For 12 < M_X < 394 GeV

Test of diffraction (and hadronization) models

PYTHIA8-MBR describes all aspects of the data

Details of PYTHIA8-MBR model in K.Goulianos talk

SD cross section from CMS

From background-subtracted (with small uncertainties) CASTOR-tag sample:

CMS-FSQ-12-005, arXiv:1503.08689

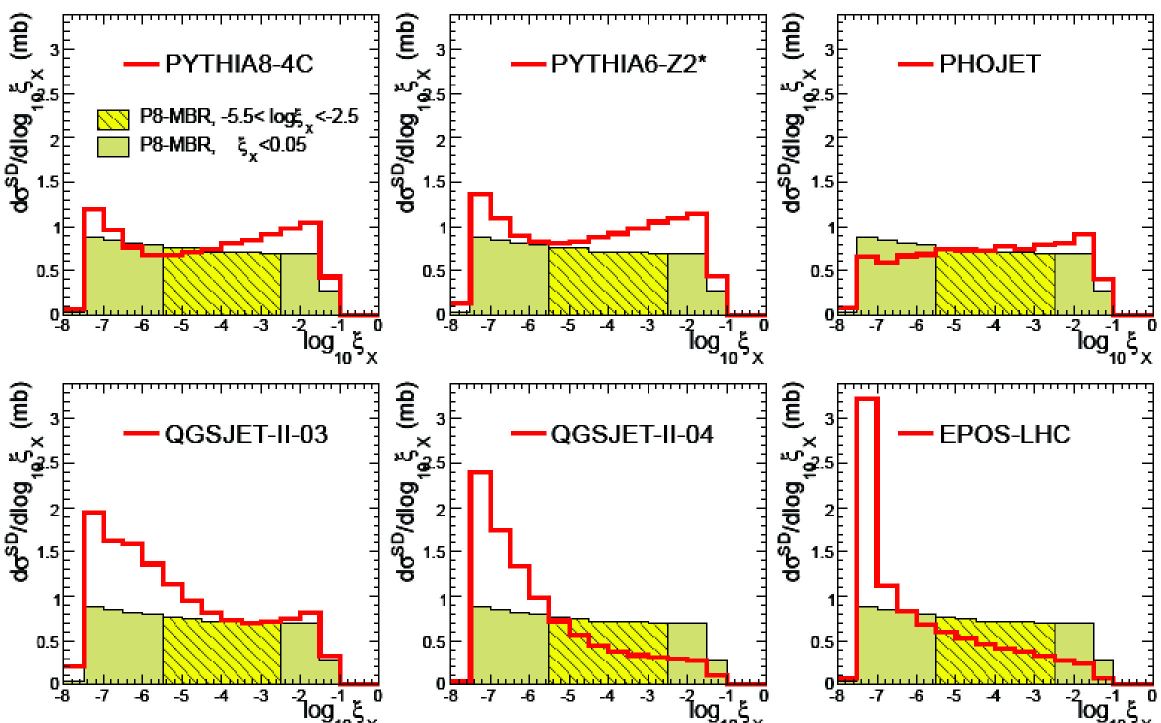
$$\sigma^{SDvis} = 4.06 \pm 0.04\,(stat)^{+0.69}_{-0.63}\,(syst)\,mb \qquad -5.5 < \log_{10}\xi_X < -2.5$$

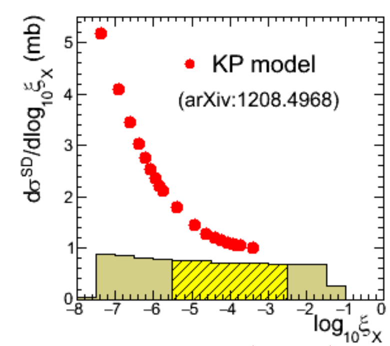
(12 < M_X < 394 GeV)

Extrapolated to the not observed region with PYTHIA8-MBR:
(from yellow to khaki on plots below)

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

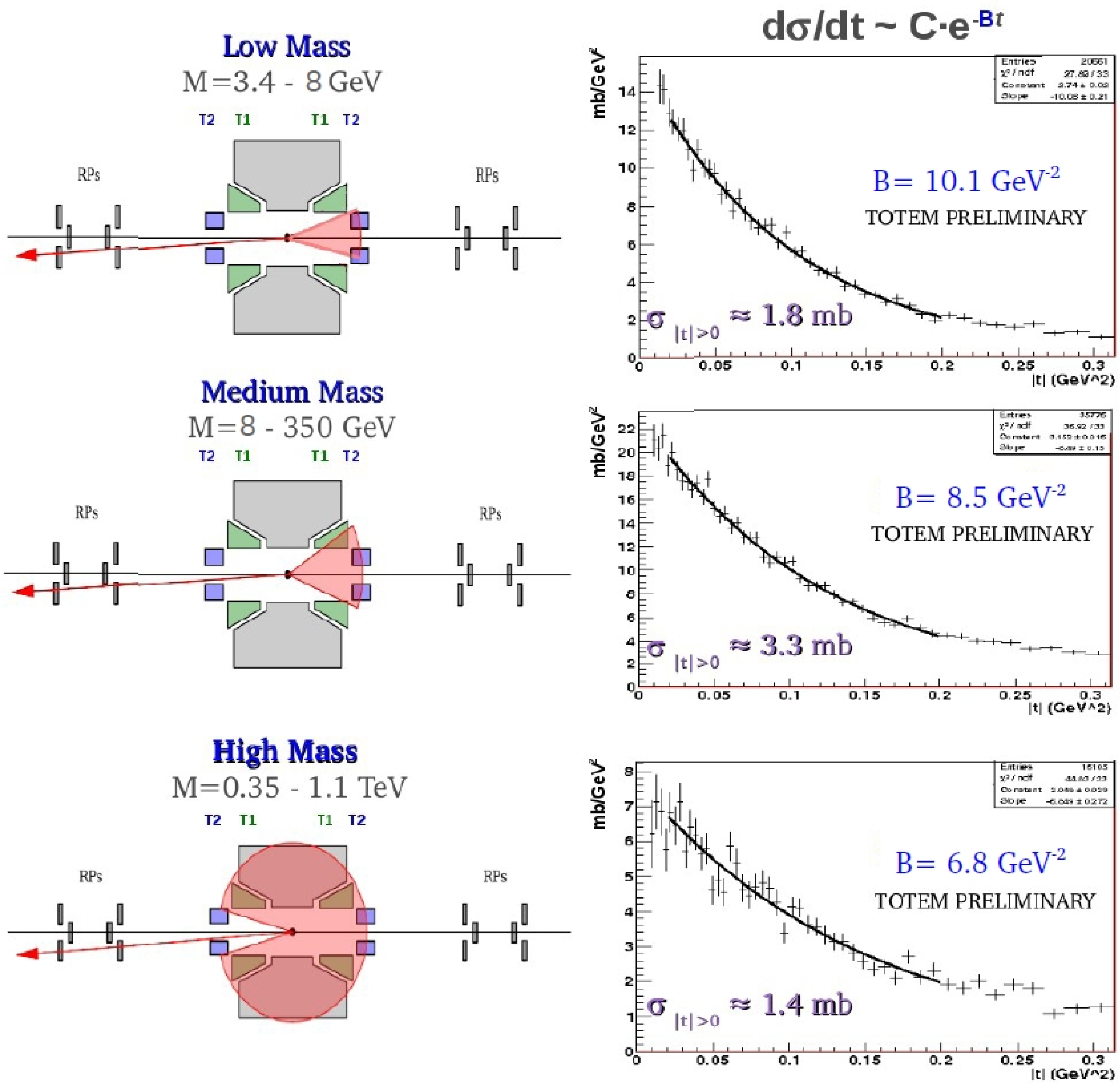
Large model variations, PYTHIA8-MBR describes the data in the visible region





used in EPJC 73 (2013) 2456

SD cross section from TOTEM



Proton tag + combinations of
T1 (3.1<|η|<4.7)
T2 (5.3<|η|< 6.5) detectors
to select different Mx bins

Integrated SD cross section @7 TeV

$\sigma_{SD} = 6.5 \pm 1.3$ mb
$(3.4 < M_{SD} < 1100$ GeV$)$

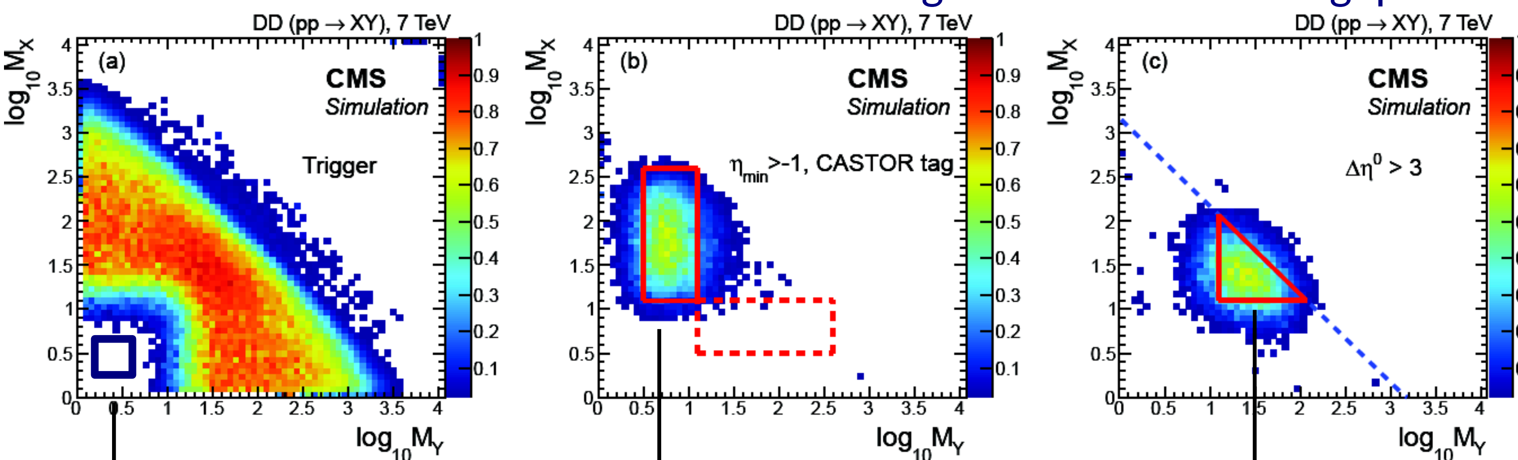
See e.g. Mirko Berretti talk
at DIFFRACTION 2014

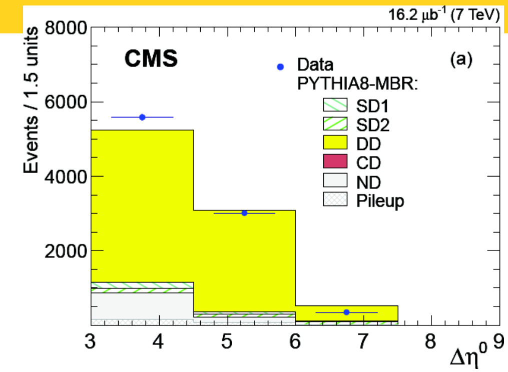
DD cross section from CMS and TOTEM

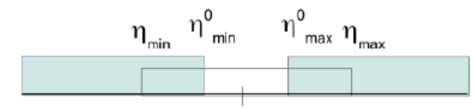
CMS-FSQ-12-005, arXiv:1503.08689

forward gap with CASTOR tag

central gap







$$\sigma^{DDvis}_{CASTOR} = 1.06 \pm 0.02\,(stat) \pm 0.12\,(syst)\,mb$$

for 12 < M_X < 394 GeV, 3.2 < M_Y < 12.6 GeV

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

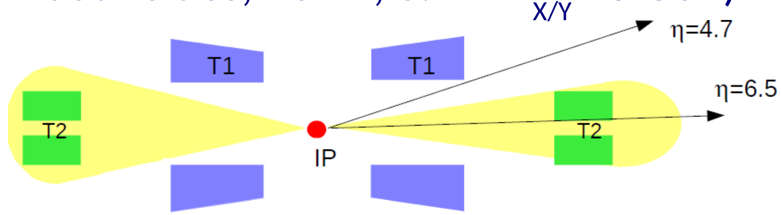
for Δη>3, M_X > 12.6 GeV, M_Y > 12.6 GeV

and extrapolated to Δη>3 with PYTHIA8-MBR:

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

PRL 111 (2013) 262001

TOTEM (T2 on both sides, no T1, 3.4< $M_{X/Y}$ < 8 GeV)

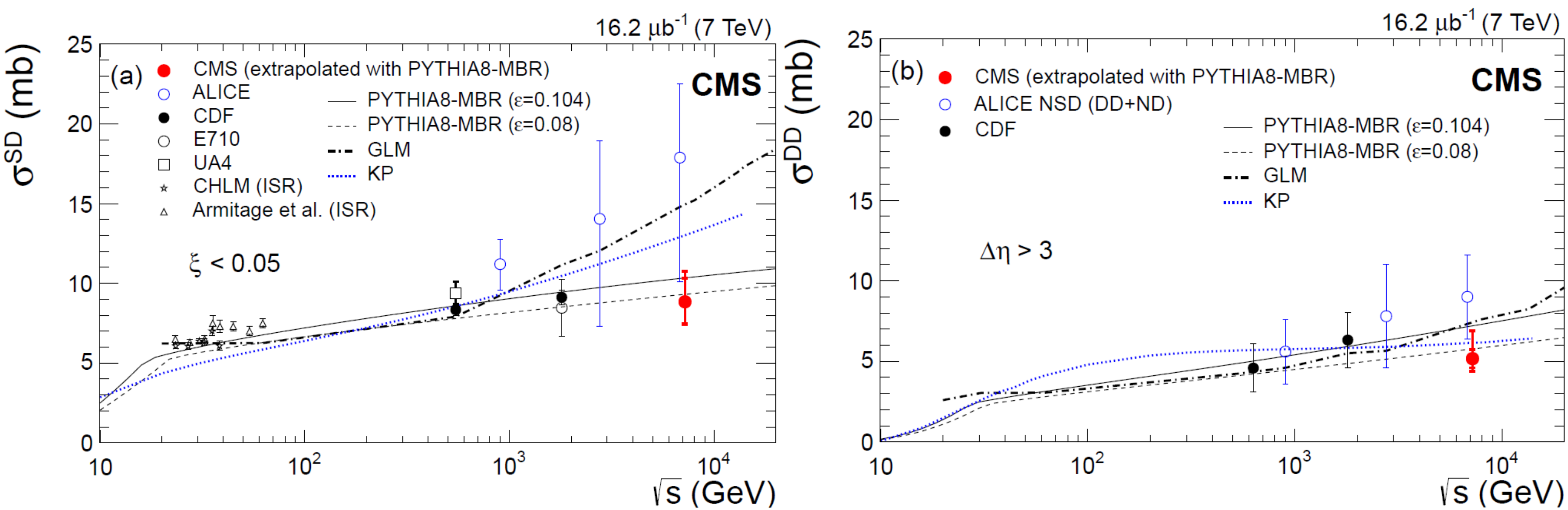


$$\sigma_{DD(4.7<|\eta_{min}|<6.5)} = 120 \pm 25\mu b$$

SD and DD cross sections

CMS-FSQ-12-005, arXiv:1503.08689
ALICE: EPJC 73 (2013) 2456

SD and DD cross section weakly rising with energy



TOTEM SD:

6.5 ± 1.3 mb – SD cross section for 3.4 < M_X < 1.1 GeV

\+ 2.62 ± 2.17 mb - T2-invisible cross section for M_X < 3.4 GeV (SD dominated) EPL 101 (2013) 21003

9.12 ± 2.53 mb for ξ<0.025 (extrapolation to ξ<0.05 compensated by DD in T2-invisible cross section)

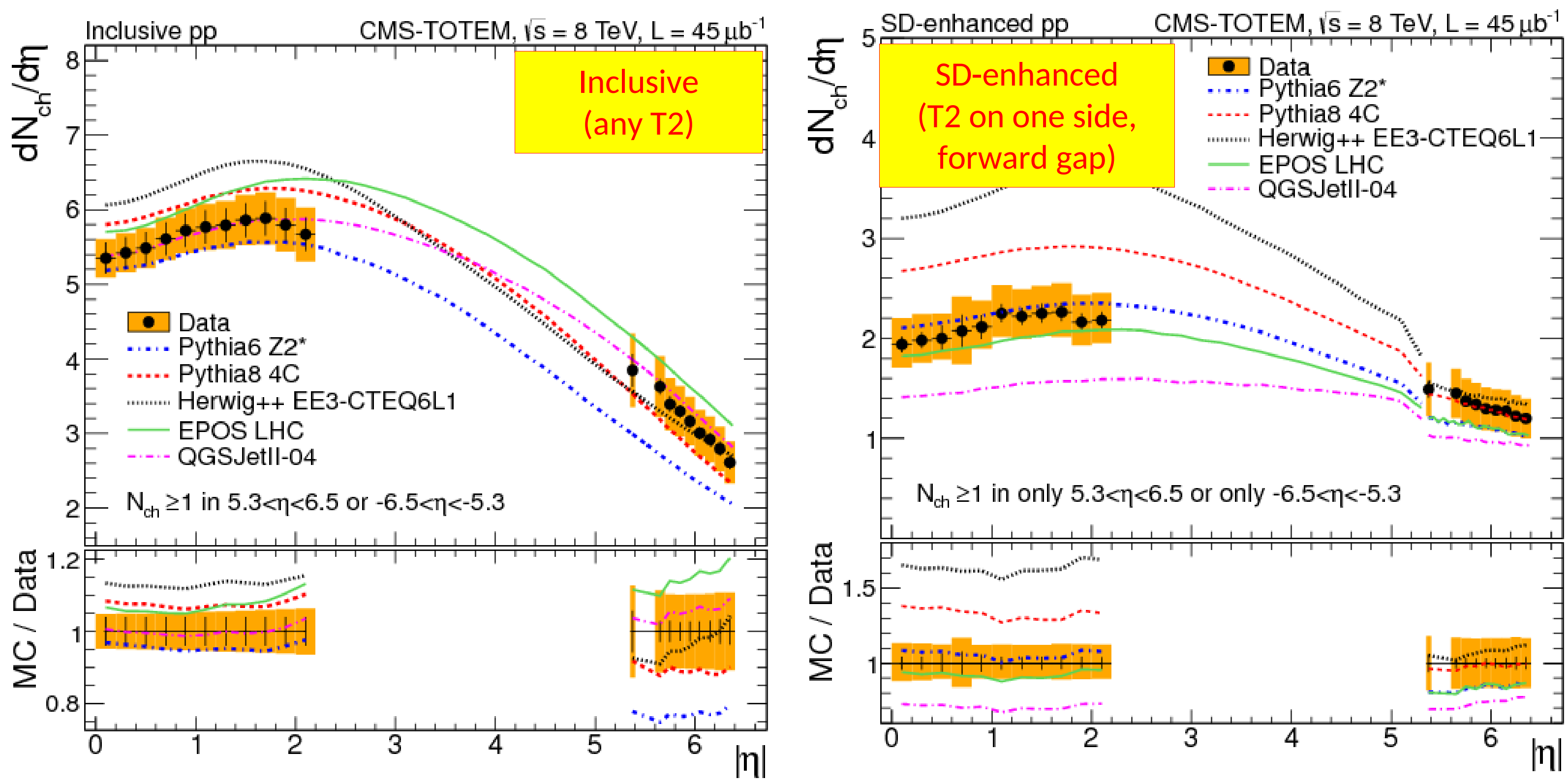
in agreement with extrapolated CMS SD cross section.

Central and forward $dN_{ch}/d\eta$

The first common CMS+TOTEM runs (2012, @8 TeV) and publication

Trigger based on activity in T2

EPJC 74 (2014) 2053



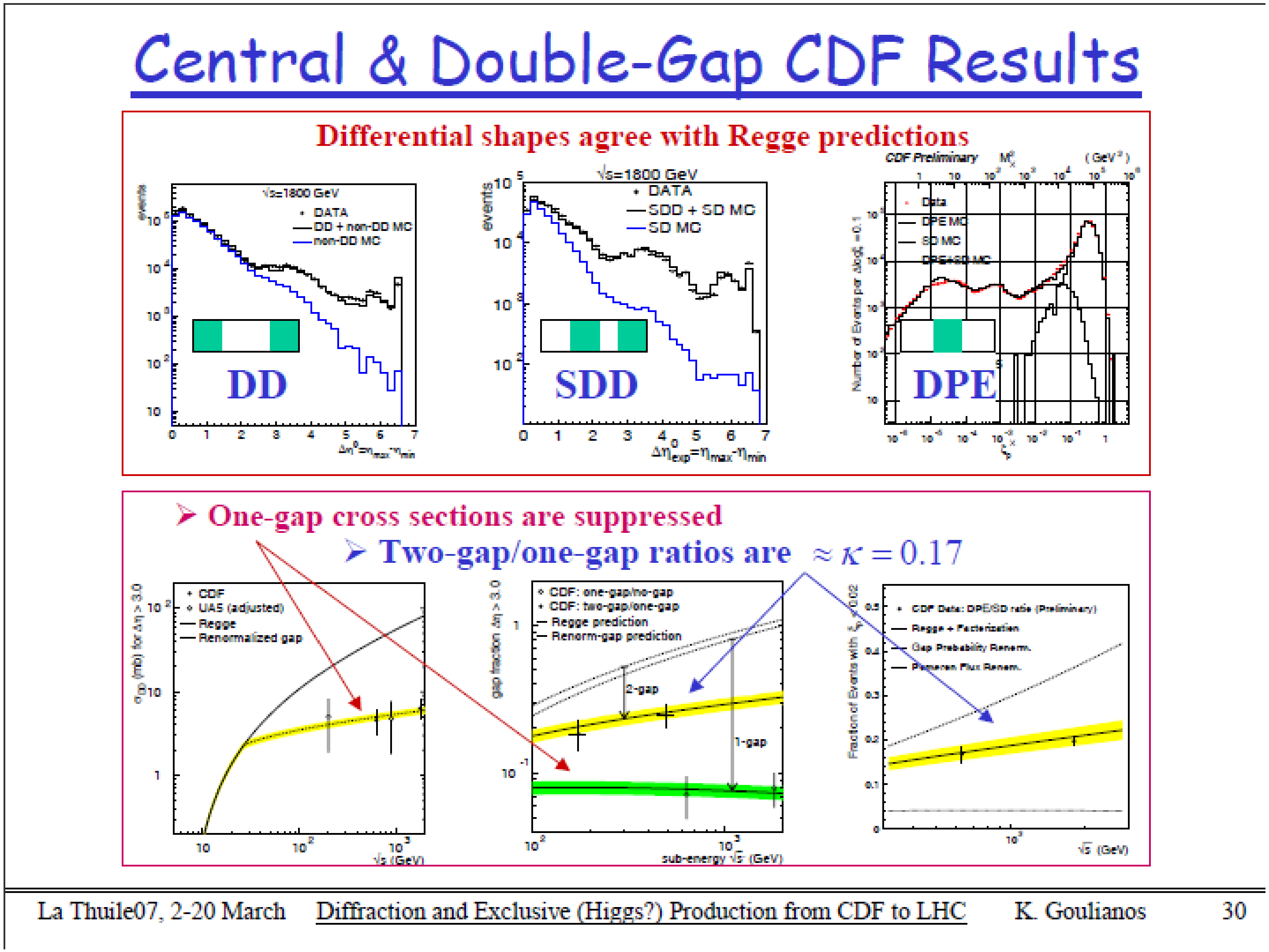
Multiplicity of SD-enhanced events significantly smaller than inclusive ones

No prediction able to describe $dN_{ch}/d\eta$ in the entire η range

Data can help constrain modelling of hadronic final state and diffractive scattering

Direct measurements of charged multiplicity spectra in proton dissociation systems?

Double- and Multi-gaps at the LHC?

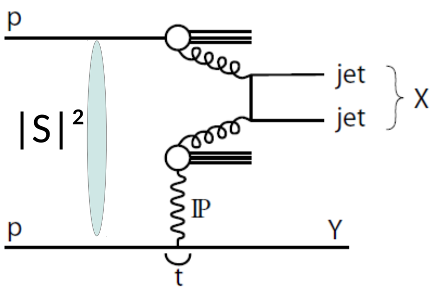


Will we measure them, as CDF did?

Fine-tuning of hadronization models, multiplicity spectra, etc.

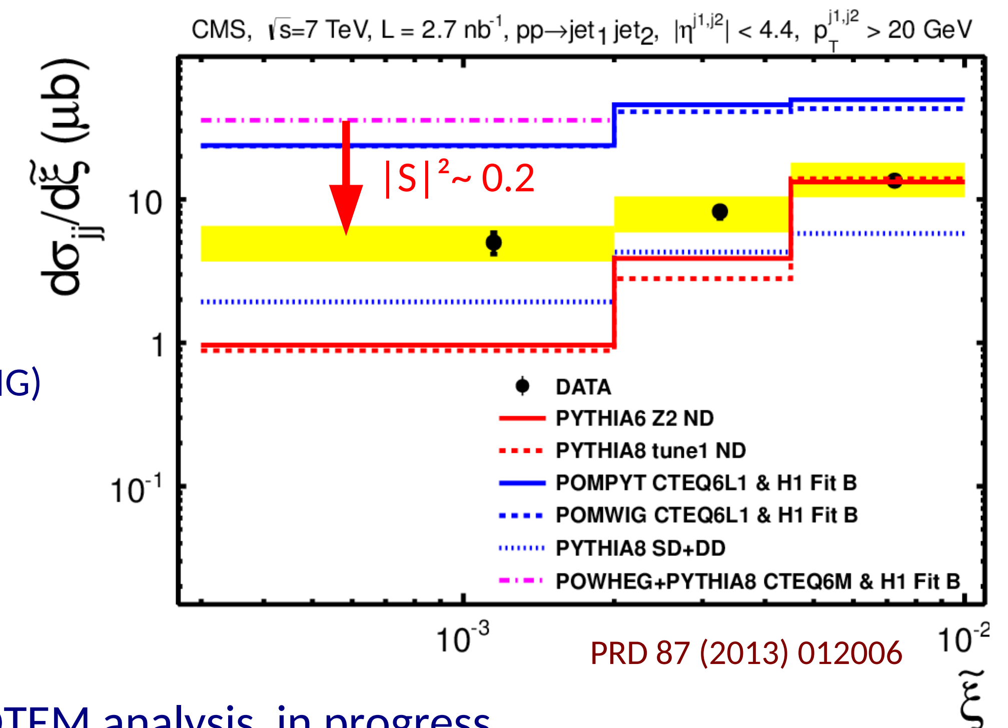
Hard diffraction at LHC

Diffractive dijets



Factorization breaking: NLO predictions based on HERA diffractive PDFs overestimate Tevatron diffractive dijet cross sections by ~0(10). Suppression factor $|S|^2$ due to rescattering effects.

Inclusive dijet cross section in 3 bins of ξ



PRD 87 (2013) 012006

Data/MC in the lowest ξ bin (0.0003< ξ<0.002):

0.21 ±0.07 (LO - POMPYT POMWIG)

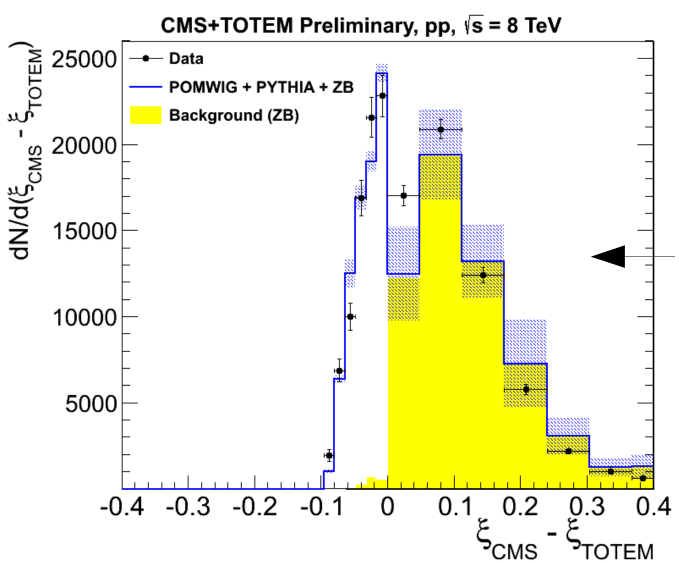
0.14 ±0.05 (NLO - POWHEG)

After proton-dissociation correction:

0.12 ±0.05 (LO)

0.08 ±0.04 (NLO).

CMS-DP-2015/05



Combined CMS+TOTEM analysis in progress

Proton tagging with TOTEM Roman Pots

No ND and p-diss background

Demonstrated good control of the background (PU and beam related)

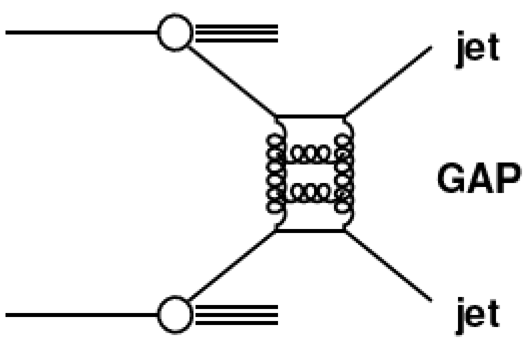
Measurement of the t dependence of the cross section

Plans for other measurements with p-tag @13 TeV (diffractive dijets, W, Z, J/psi)

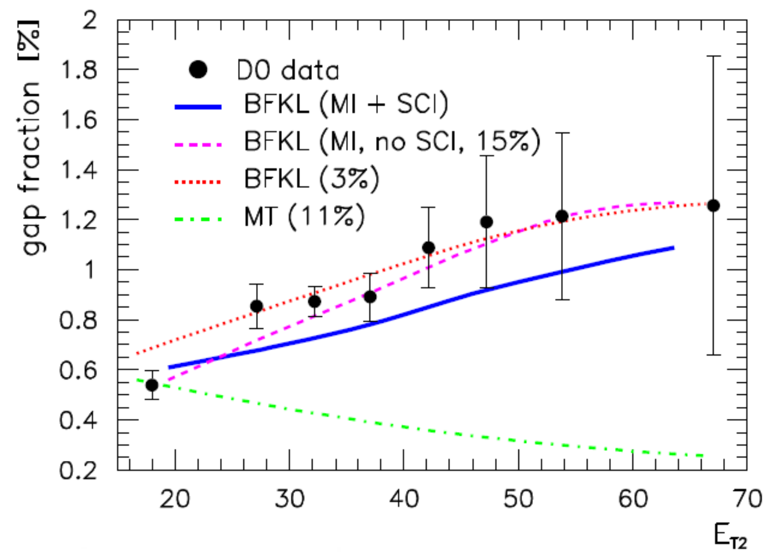
CMS-PAS-FSQ-14-001, TOTEM-NOTE-2014-02

Jet-gap-jet events

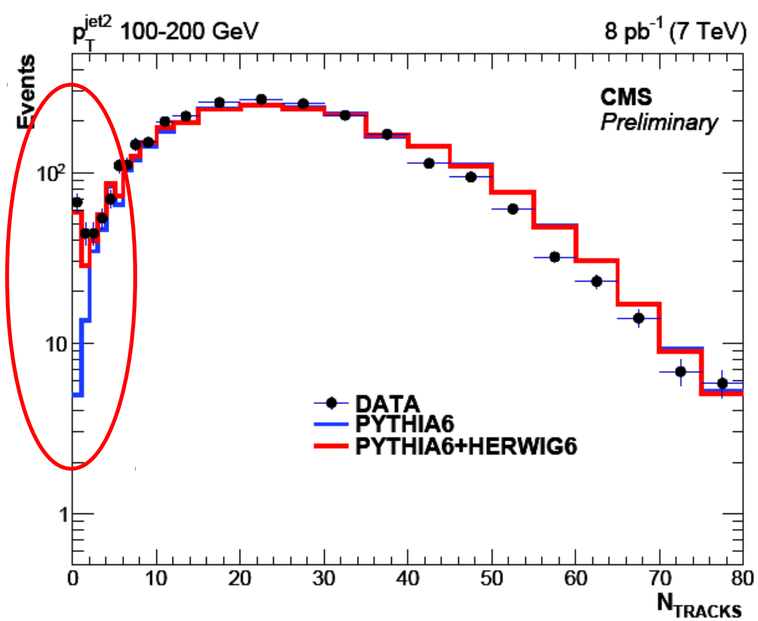
Jets separated by a large rapidity gap, color singlet exchange (CSE)
BFKL dynamics, rescattering processes
Events with gaps ~1% at Tevatron (CDF, D0)

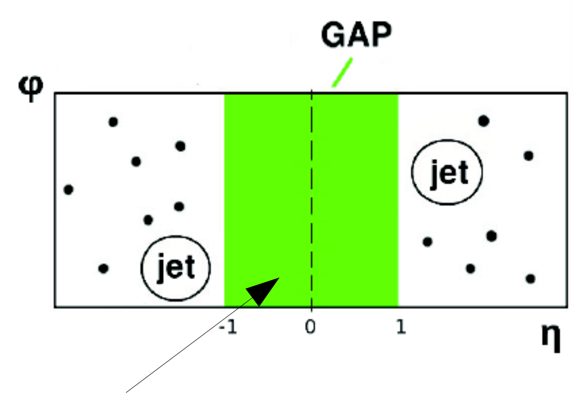


D0 data, compared to Enberg, Ingelman, Motyka model (NLL BFKL + MPI+SCI)
PLB 524 (2002) 273



CMS-PAS-FSQ-12-001



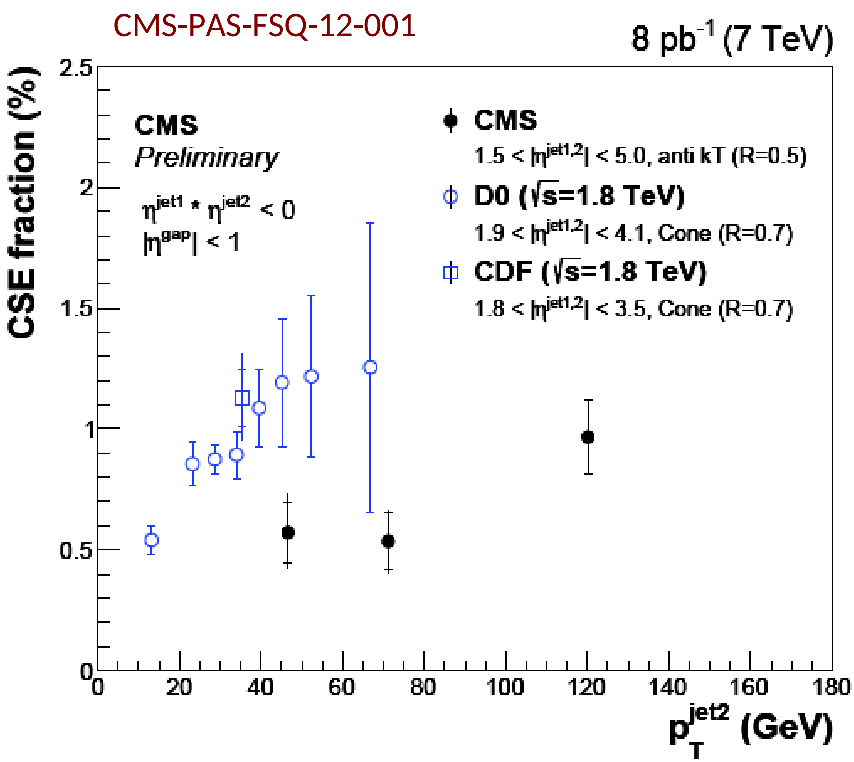


Two leading jets:
p_T>40 GeV
|η|>1.5

Charged multiplicity for |η|<1:
Clear excess of gap events over PYTHIA6 prediction (LO DGLAP), described by HERWIG (LL-BFKL, Mueller-Tang model)

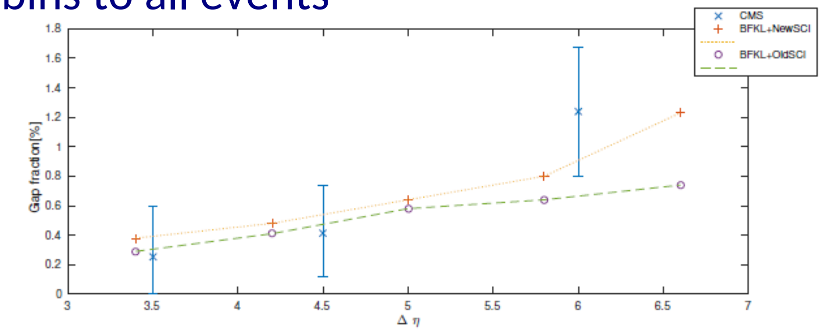
Jet-gap-jet events

Gap/CSE fraction := ratio of events in the lowest multiplicity bins to all events
Modest increase with jet energy and rapidity separation Δη

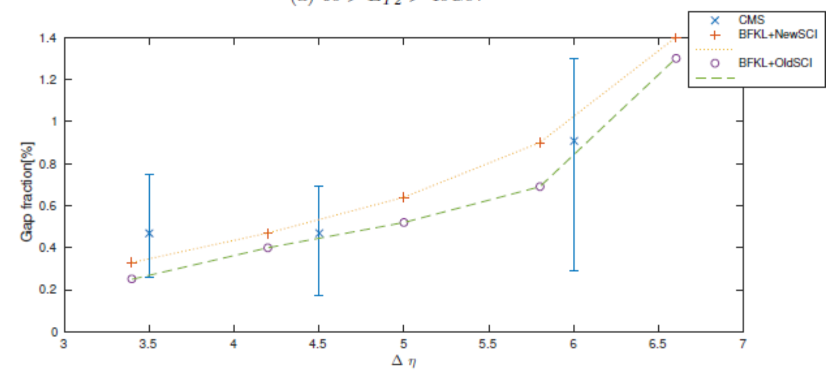


A factor ~2 suppression w.r.t. to 1.8 TeV data

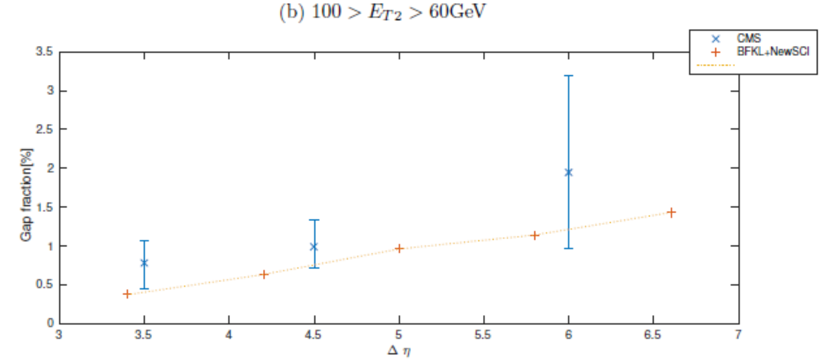
observed earlier: 2.5 ± 0.9 (D0) and 3.4 ± 1.2 (CDF)
decrease with √s = 0.63 → 1.8 TeV



(a) $60 > E_{T2} > 40\text{GeV}$



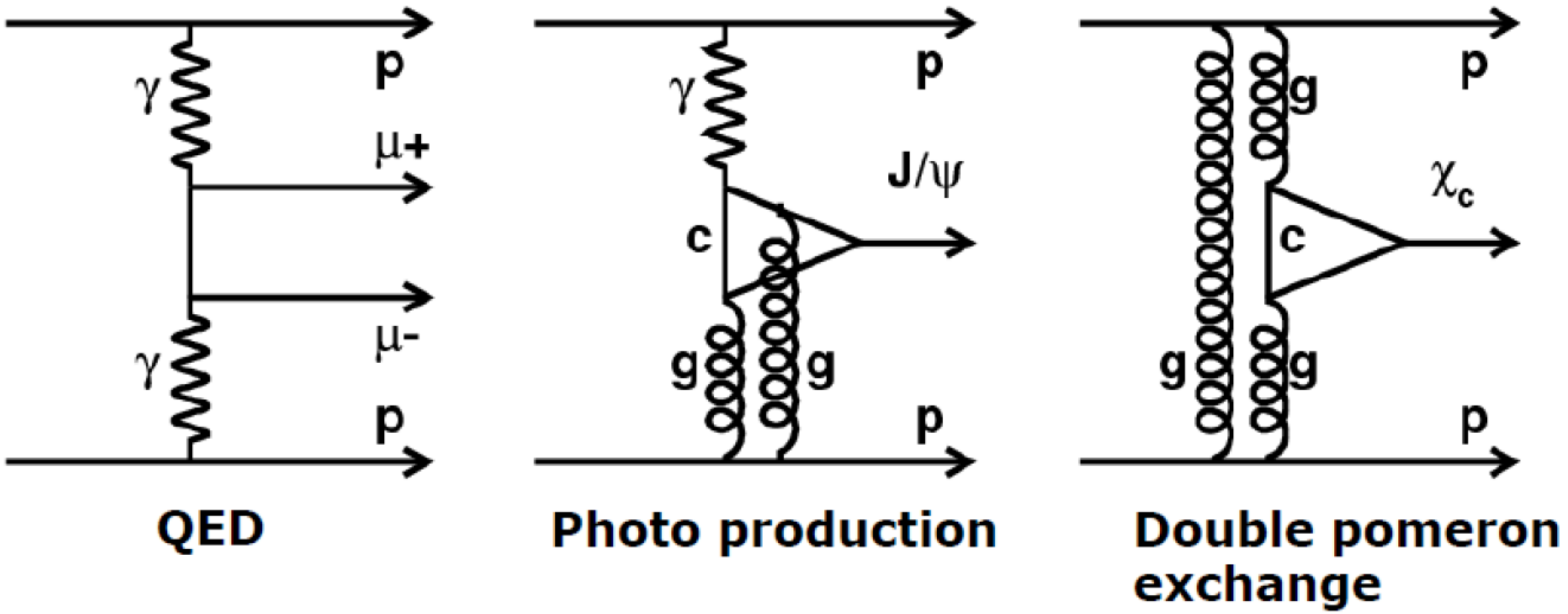
(b) $100 > E_{T2} > 60\text{GeV}$



(c) $200 > E_{T2} > 100\text{GeV}$

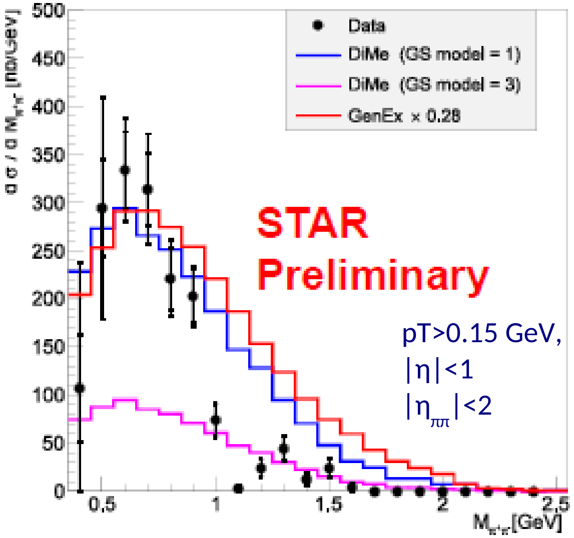
Preliminary predictions of Ekstedt, Enberg, Ingelman, Motyka with two models for SCI - color exchange between partons (old SCI) or strings (new SCI): good description of gap fractions vs Δη

CEP in pp collisions



$\pi^+\pi^-$ production in DPE

DPE (no valence quarks, spin selector) - production of isoscalars with $J^{PC} = 0^{++}, 2^{++}, \dots$, including glueballs



STAR @200 GeV: pions with p-tagging

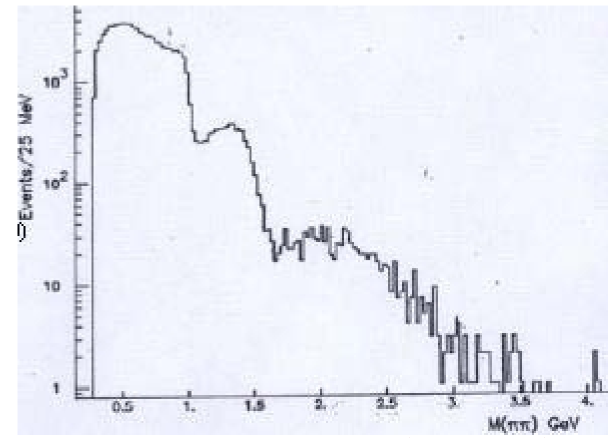
Resonance structure similar to that seen at ISR @63 GeV

$f_0(600)$, shouler from $f_0(980)$ interference,

some structure around 1.2-1.6 GeV

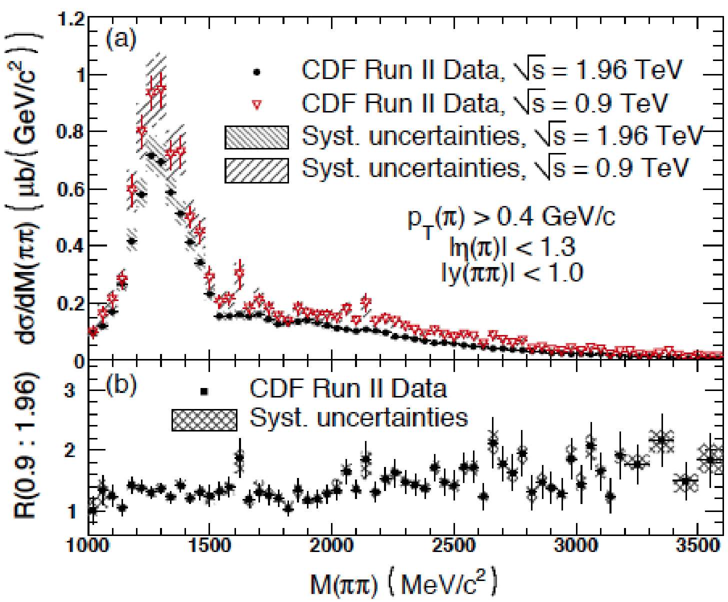
Increased statistics (30-40 times) expected from 2015 runs

See e.g. Jacek Turnau at DIS 2014



Axial Field Spectrometer (CERN ISR)

NPB 264 (1987) 154



PRD 91 (2015) 091101

CDF @0.9 and 1.96 TeV: dipions and no other activity in $|\eta|>5.9$

Resonance structure for $M(\pi\pi) > 1$ GeV

$f_2(1270)$, shoulder from $f_0(1370)$ interference, some structure around 1.4-2.4 GeV, data falls monotonically above 2.4 GeV

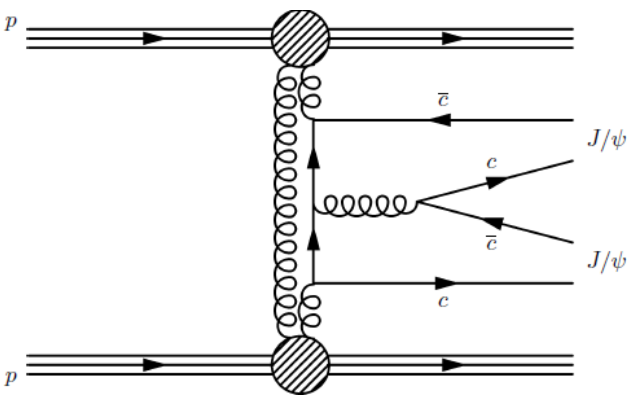
The cross section ratio R(0.9:1.96) = 1.28 for $1<M(\pi\pi)< 2$ GeV consistent with Regge phenomenology (~1/ln(s))

At LHC: ongoing CMS+TOTEM and ALICE analyses

Exclusive production of charmonium pairs in DPE

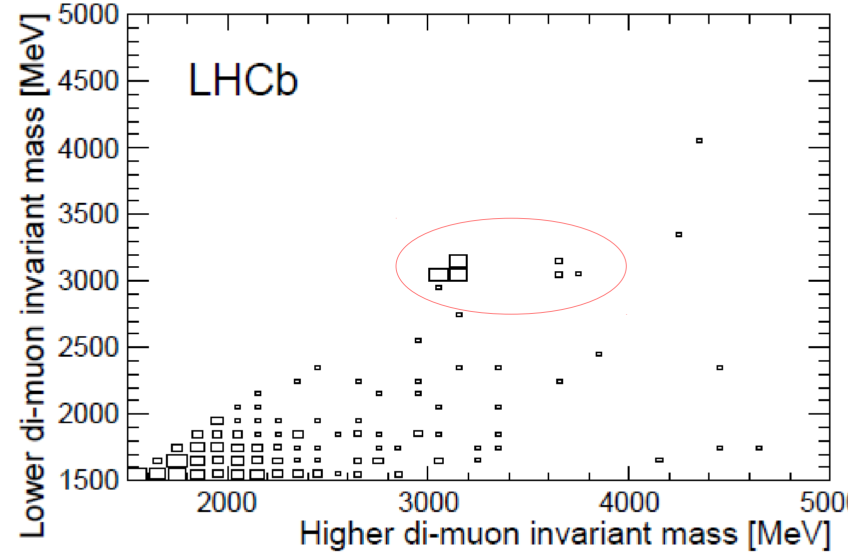
J. Phys. G: Nucl. Part. Phys. 41 (2014) 11502

First observation of the central exclusive production of J/Ψ+J/Ψ and J/Ψ+Ψ(2S) pairs.

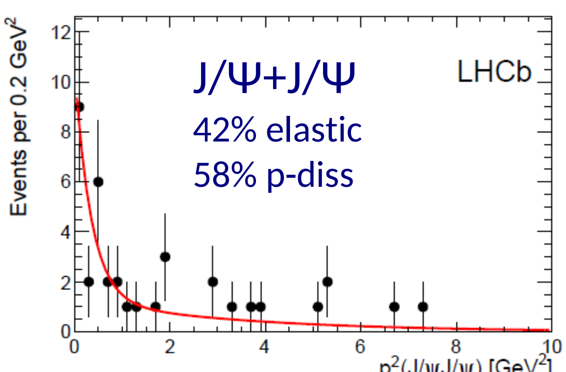


Four tracks,
at least 3 muons

57 J/Ψ+J/Ψ candidates
7 J/Ψ+Ψ(2S) candidates

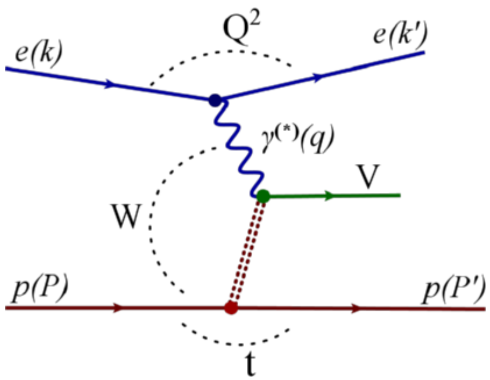


$$\sigma^{J/\psi\, J/\psi} = 58 \pm 10(\mathrm{stat}) \pm 6(\mathrm{syst})\,\mathrm{pb}$$
$$\sigma^{J/\psi\, \psi(2S)} = 63^{+27}_{-18}(\mathrm{stat}) \pm 10(\mathrm{syst})\,\mathrm{pb}$$



Cross section for elastic J/Ψ+J/Ψ production: 24 ± 9 pb
In agreement with predictions of Harland-Lang, Khoze, Ryskin, Stirling: 8 pb
(large theoretical uncertainties, factor of 2-3) EPJC 71 (2011) 1714

Reminder: γp→Vp at HERA

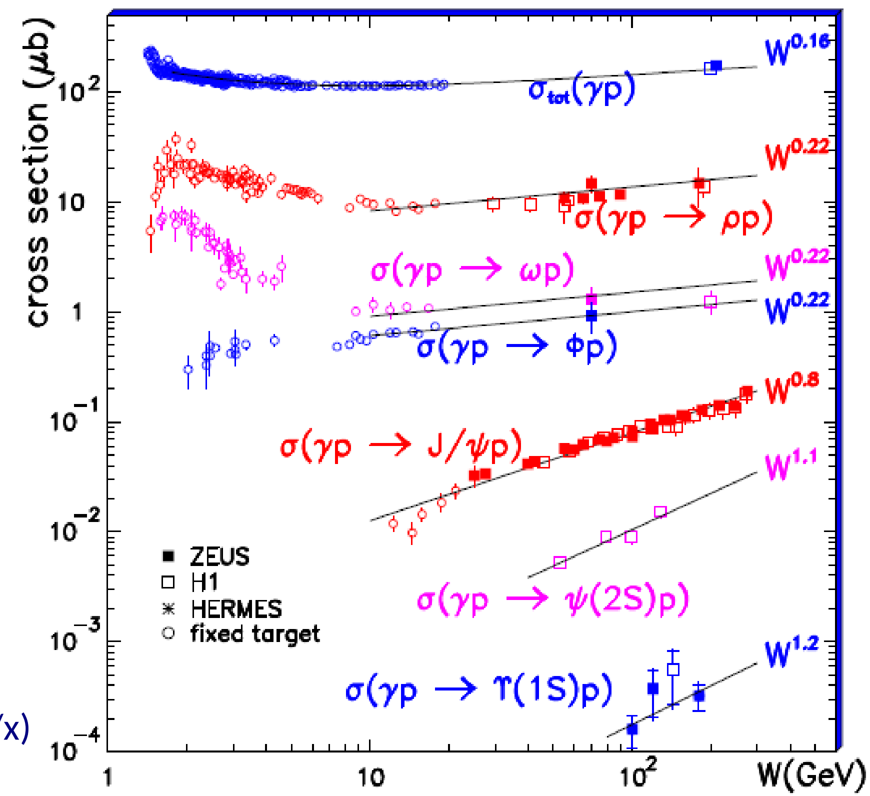


Harvest of VM results at HERA

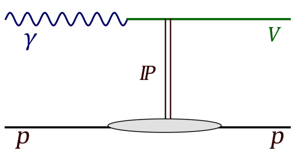
Observed transition from soft to hard with a hard scale (M_V,Q^2,t)

In the hard regime, validated pQCD description

photoproduction (Q^2=0)

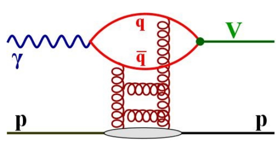


V mass provides hard scale



W^δ, δ=0.2

Regge with soft IP

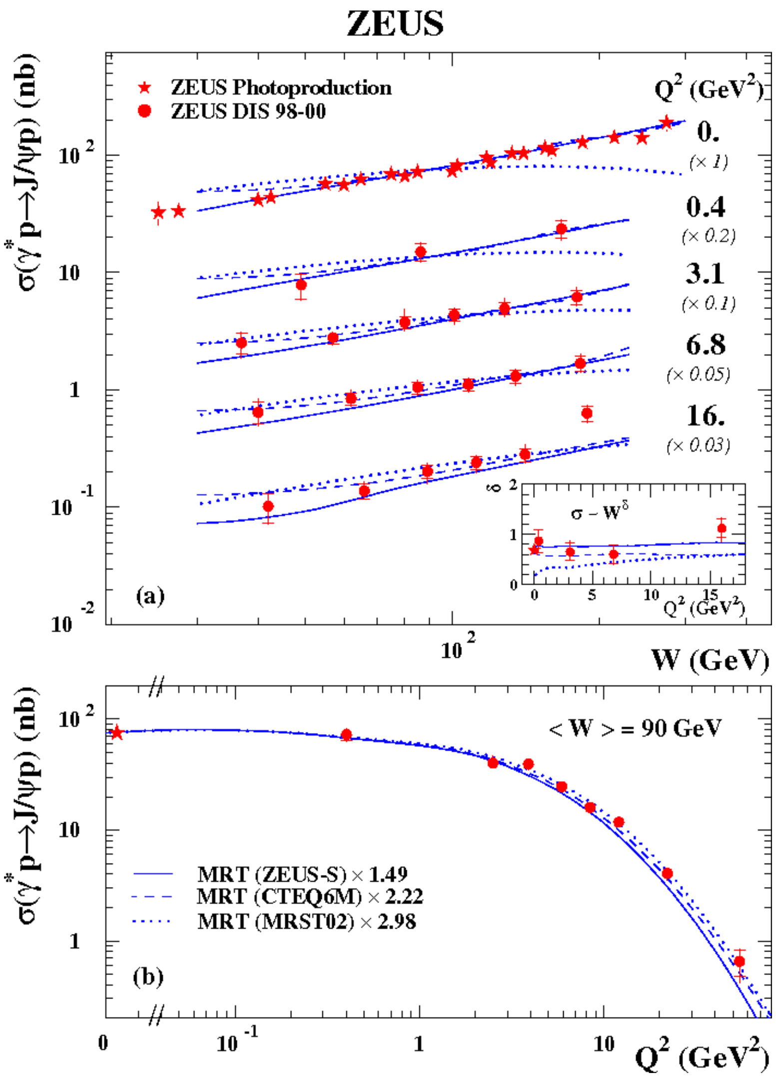


W^δ, δ=0.7-1.2

Gluons at low-x (W^2=1/x)

$\sigma \sim [xg(x,\mu^2)]^2$ Sensitive to gluon saturation at very low x (high W)

Reminder: γp→Vp at HERA



Exclusive production of J/Ψ (photoproduction and DIS)

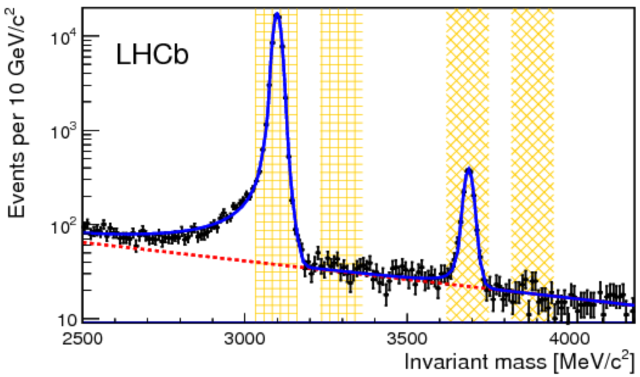
Cross sections as a function of W in bins of Q^2 compared to pQCD predictions (MRT model) with different gluon PDFs.

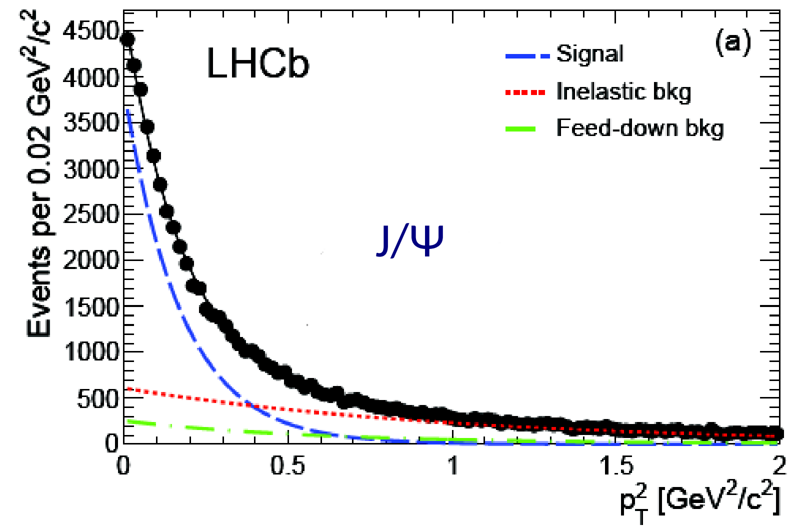
Sensitivity to gluon PDFs at lowx!

HERA data used by MNRT group to extract gluon PDFs and provide predictions for the LHC

Photoproduction of J/Ψ and Ψ(2S) in pp

J. Phys. G: Nucl. Part. Phys. 41 (2014) 055002



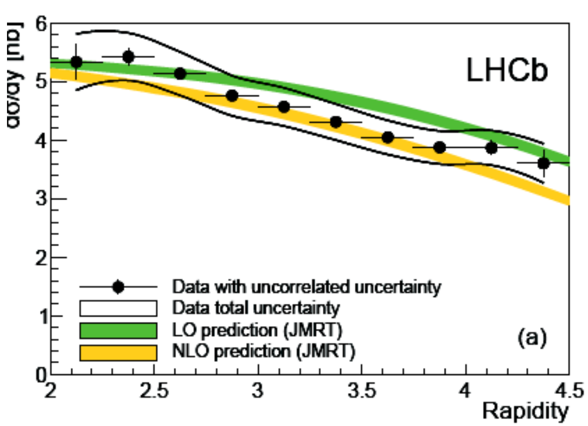


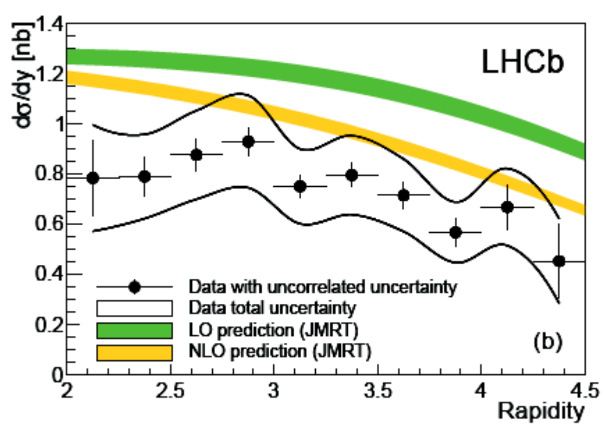
Two muons wth pT>400 MeV and no other activity
Inelastic background subtracted by fitting pT^2 specta
For J/Ψ: feed down from Xc and Ψ(2S) - 8% and 2.5%

Extracted b slopes of the exponential pT^2 dependence
Measured cross section as a function of VM rapidity

GeV^{-2}	b_s	b_{pd}
J/ψ	5.70 ± 0.11	0.97 ± 0.04
$\psi(2s)$	5.1 ± 0.7	0.8 ± 0.2

J/ψ $\psi(2S)$





Comparison to predictions of JMRT model
NLO in better agreement

Data also described by saturation models

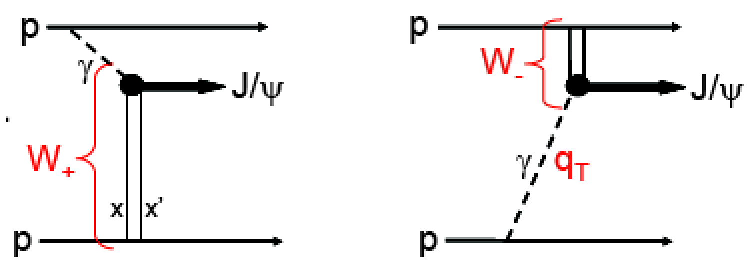
LHCb sensiticity x~10^{-5}

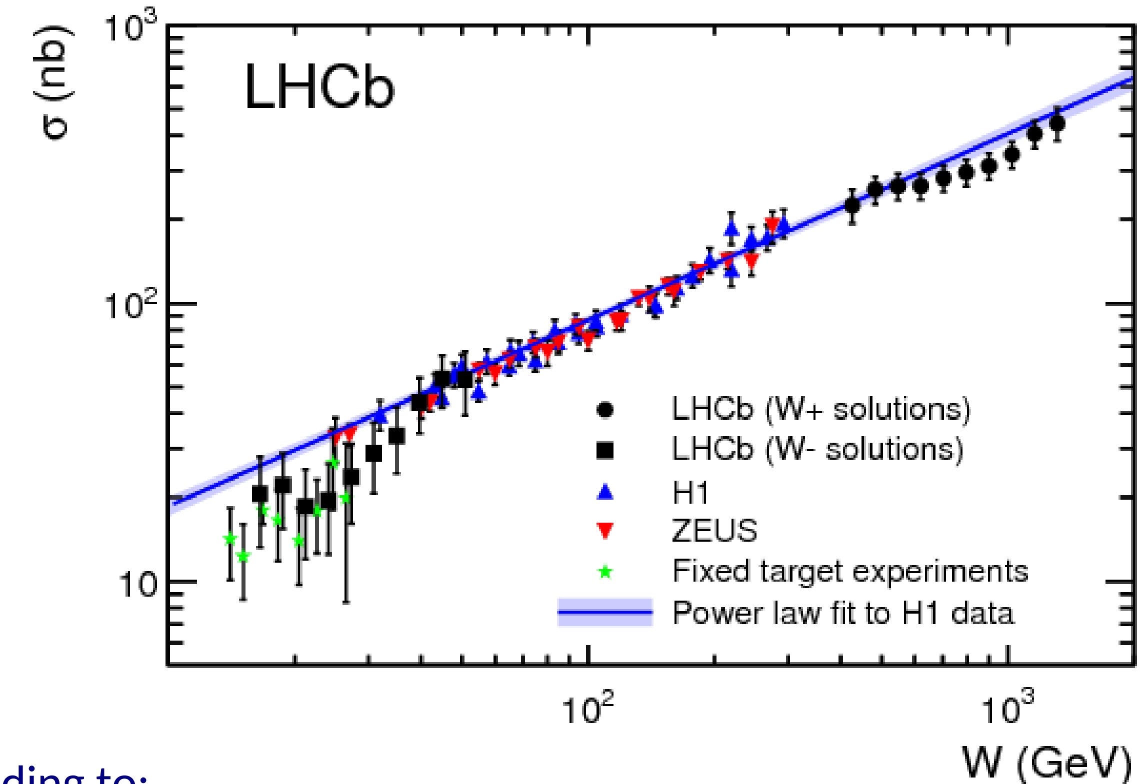
Photoproduction of J/Ψ and Ψ(2S) in pp

J. Phys. G: Nucl. Part. Phys. 41 (2014) 055002

Comparison to HERA data

Emitter/target ambiguity





Assume σ(W-) and extract σ(W+) according to:

$$\sigma_{\gamma p\rightarrow J/\psi p}(W) = 81(W/90GeV)^{0.67}$$

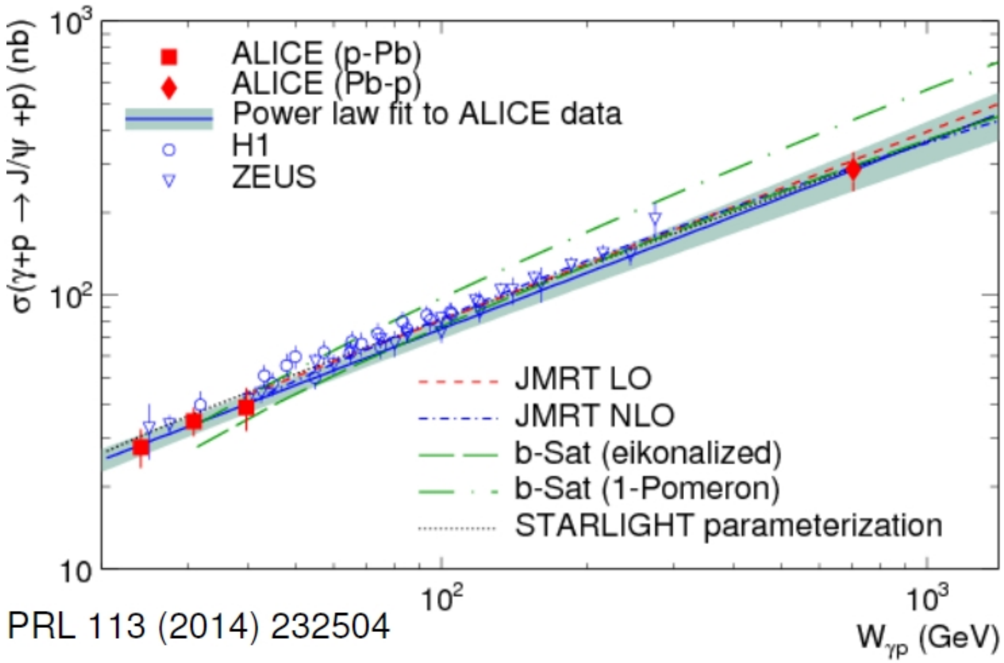
$$\frac{d\sigma}{dy}_{pp\rightarrow pJ/\psi p} = r_+ k_+ \frac{dn}{dk_+}\sigma_{\gamma p\rightarrow J/\psi p}(W^+) + r_- k_- \frac{dn}{dk_-}\sigma_{\gamma p\rightarrow J/\psi p}(W^-)$$

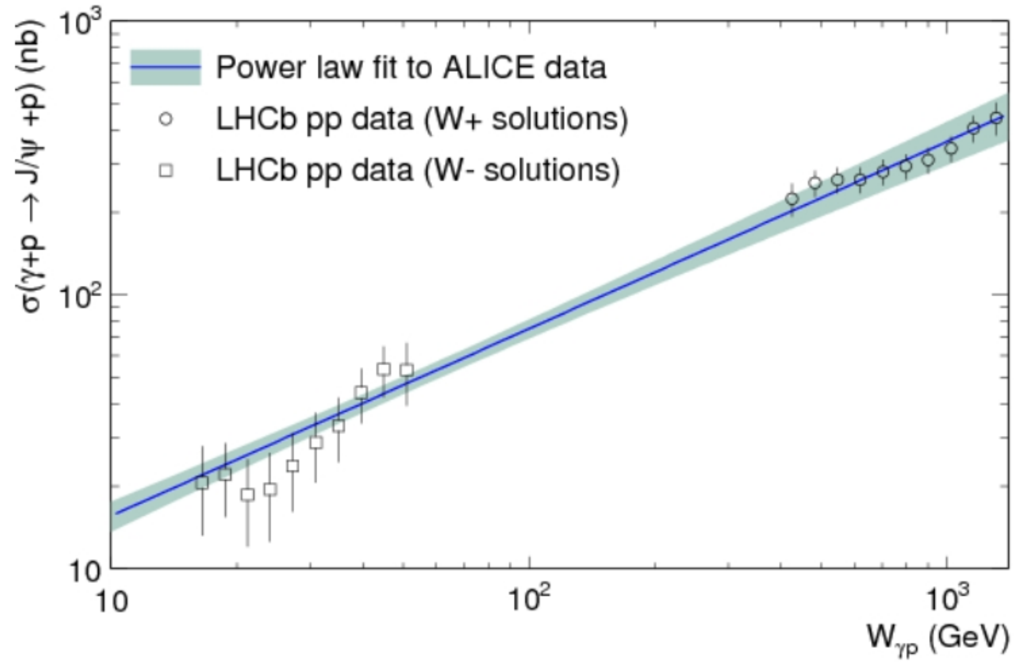
LHCb data in agreement with the extrapolation of the fit to the H1 data.

Photoproduction of J/Ψ in p-Pb

PRL 113 (2014) 232504

Pb: rich source of photons (flux~Z^2), negligible Xc background
W- from Pb-p, W+ from p-Pb





ALICE data compared to HERA and LHCb data, and to theory predictions

The result of a fit with $\sigma \propto W_{\gamma p}^{\delta}$ consistent with HERA measurements

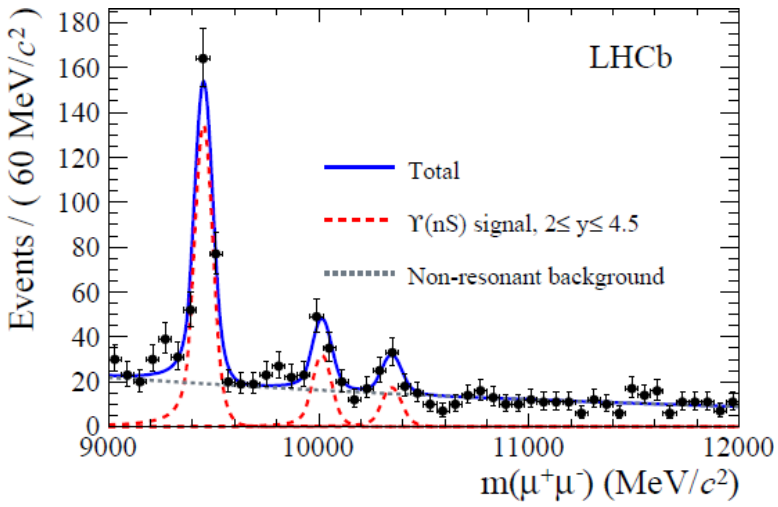
	ZEUS	H1	ALICE
δ	0.69 ± 0.04	0.67 ± 0.03	0.68 ± 0.06

LHCb solutions consistent with ALICE power-law fit

Data described by the JMRT model at LO and NLO, and saturation models

Photoproduction of Υ in pp

LHCb-PAPER-2015-011, arXiv:1505.08139

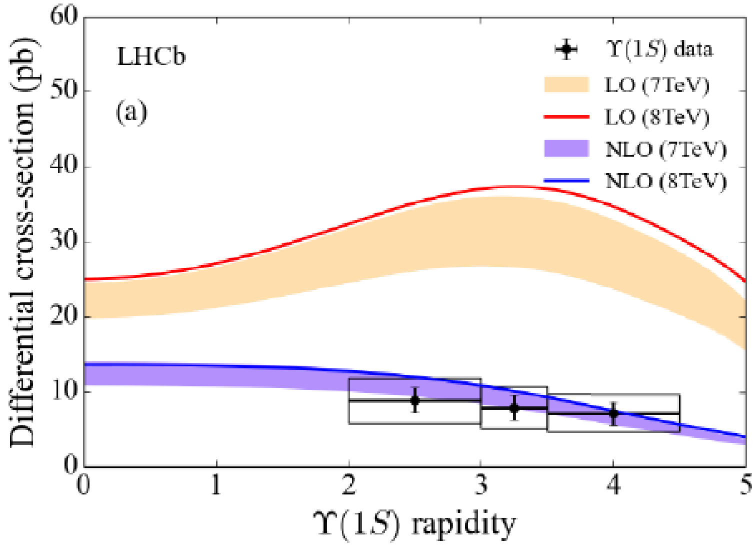


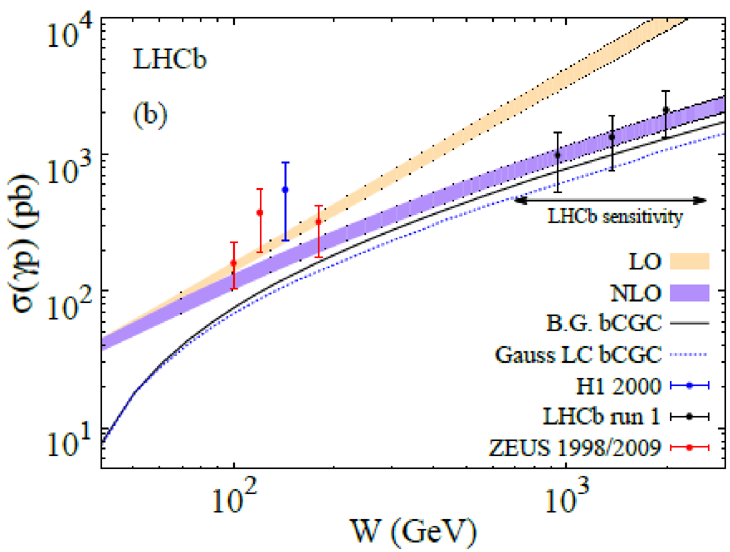
Two muons wth pT>400 MeV, 2<|η|<4.5 and no other activity

Inelastic background subtracted by fitting pT^2 specta

Feed down from X_b(mP)→ Υ(nS)γ - 20-50%

Measure cross section as a function of VM rapidity





Comparison to predictions of JMRT model.

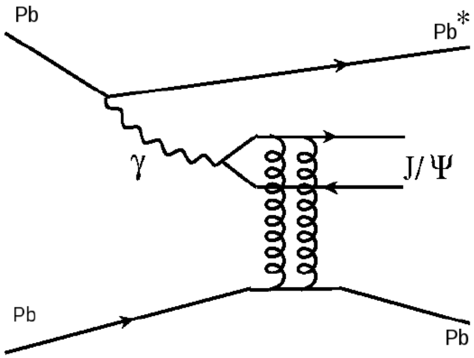
NLO in better agreement

W+ solution dominant

W- neglected

Run-2 @LHCb: HERSCHEL high rapidity shower counters to reduce inelastic background.

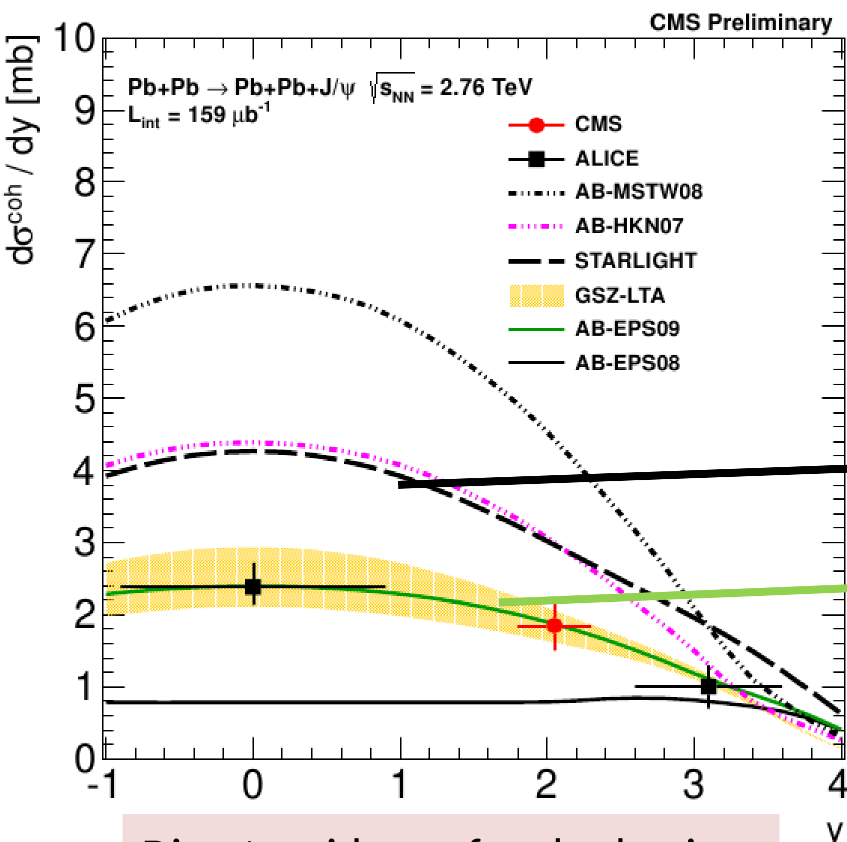
Photoproduction of J/Ψ in Pb-Pb collsions



PLB 718 (2013) 1273, EPJC 73 (2013) 2617
CMS-PAS-HIN-12-009

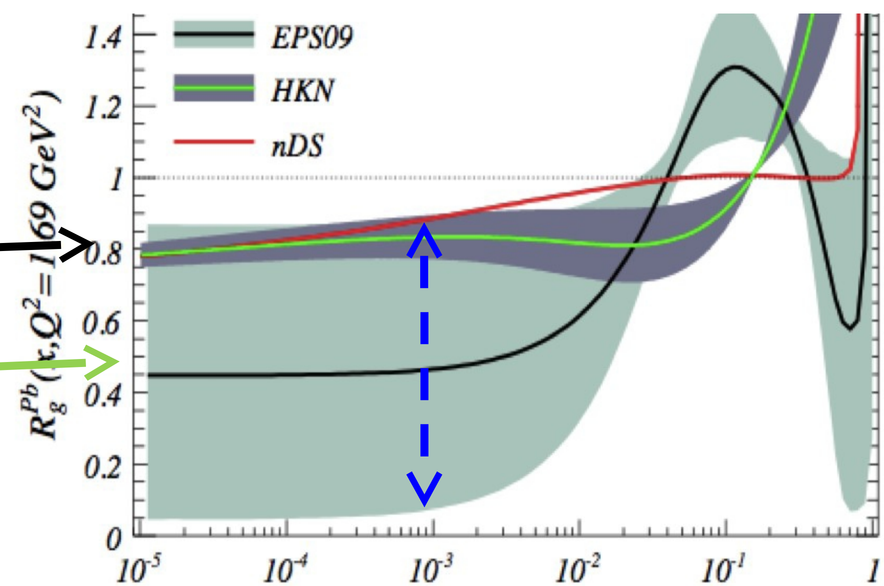
Is the nucleus gluon field equivalent to to those of A nucleons ?
→ hunting for shadowing

$$\left.\frac{d\sigma_{\gamma A\to J/\Psi A}}{dt}\right|_{t=0} = \xi_{J/\Psi}\left(\frac{16\pi^3\alpha_s^2\Gamma_{l+l-}}{3\alpha M^5_{J/\Psi}}\right)[xG_A(x,\mu^2)]^2$$ LO



Direct evidence for shadowing

Data can improve ~100% uncertainty



J. Phys. G: Nucl. Part. Phys. 39 (2012) 015010

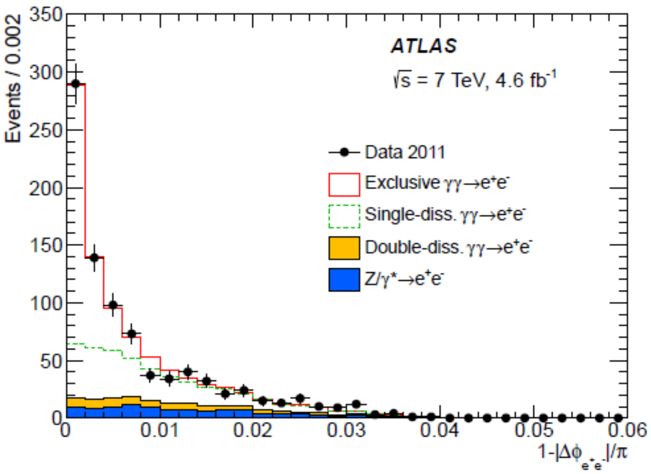
CMS

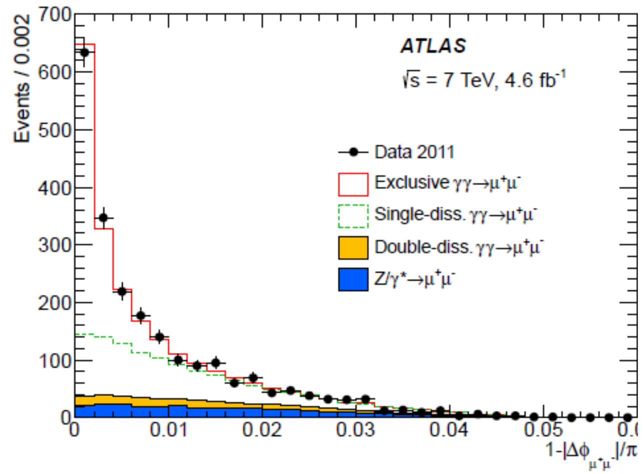
Exclusive γγ →ee/μμ production

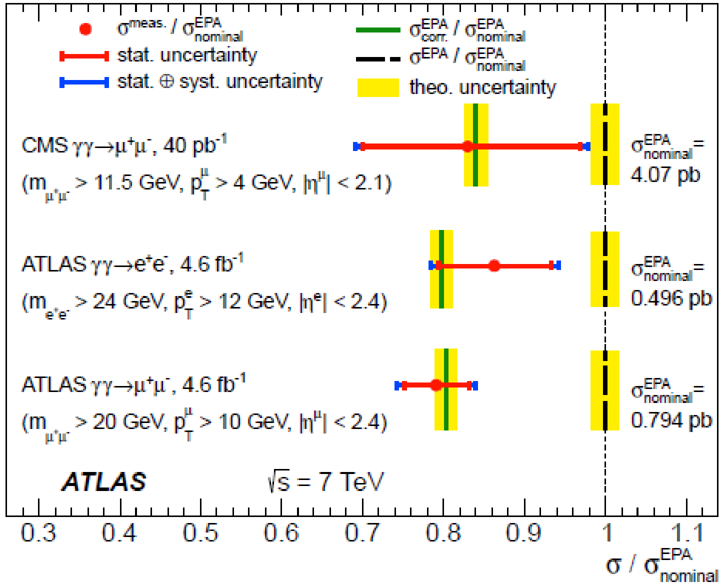
QED prediction for exclusive production has an uncertainty of ~2%

Suppression due to rescattering effects expected in pp collisions

CERN-PH-EP-2015-134 ,arXiv:1506.07098







Fits to dielectron and dimuon acoplanarity spectra with elastic and p-dissociation templates.

Templates from HERWIG++ (cross section from Equivalent Photon Approximation (EPA) = LO QED).

$$R^{\text{excl.}}_{\gamma\gamma\to e^+e^-} = 0.863 \pm 0.070\ (\text{stat.}) \qquad R^{\text{excl.}}_{\gamma\gamma\to\mu^+\mu^-} = 0.791 \pm 0.041\ (\text{stat.})$$

$$R^{\text{s-diss.}}_{\gamma\gamma\to e^+e^-} = 0.759 \pm 0.080\ (\text{stat.}) \qquad R^{\text{s-diss.}}_{\gamma\gamma\to\mu^+\mu^-} = 0.762 \pm 0.049\ (\text{stat.})$$

A suppression of about 20% is measured

In agreement with predictions of Dyndal and L. Schoeffel PLB 741 (2015) 66

Similar observation by CMS: $R^{excl}=0.91 \pm 0.03$ and $R^{s\text{-}diss}=0.72 \pm 0.02$ for $p_T^{\mu}>20$ GeV, $|\eta^{\mu}|<2.4$

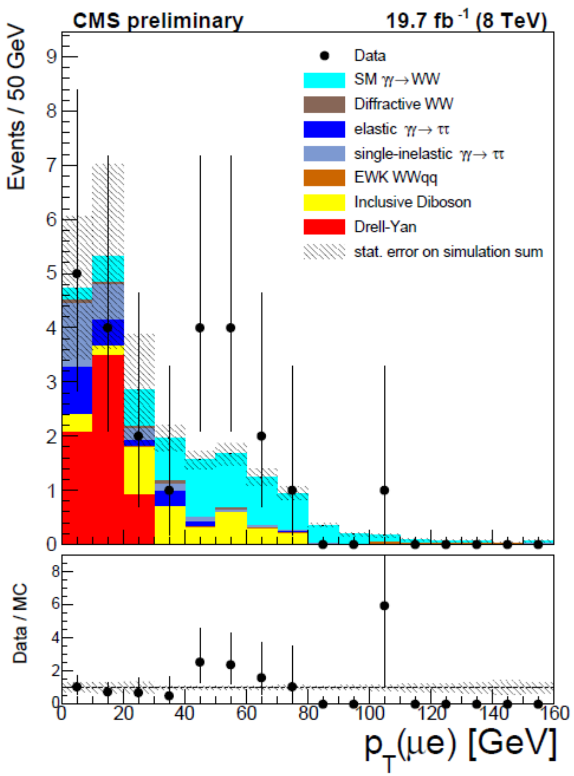
JHEP 07 (2013) 116

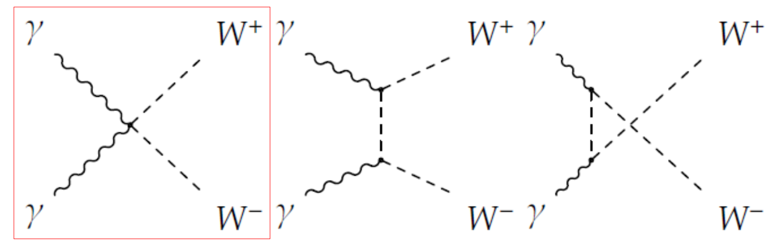
Exclusive γγ →WW production, limits on aQGC

JHEP 07 (2013) 116

CMS-PAS-FSQ-13-008

Update of 7 TeV ($L=5\ fb^{-1}$) analysis with $L=20\ fb^{-1}$ @ 8 TeV



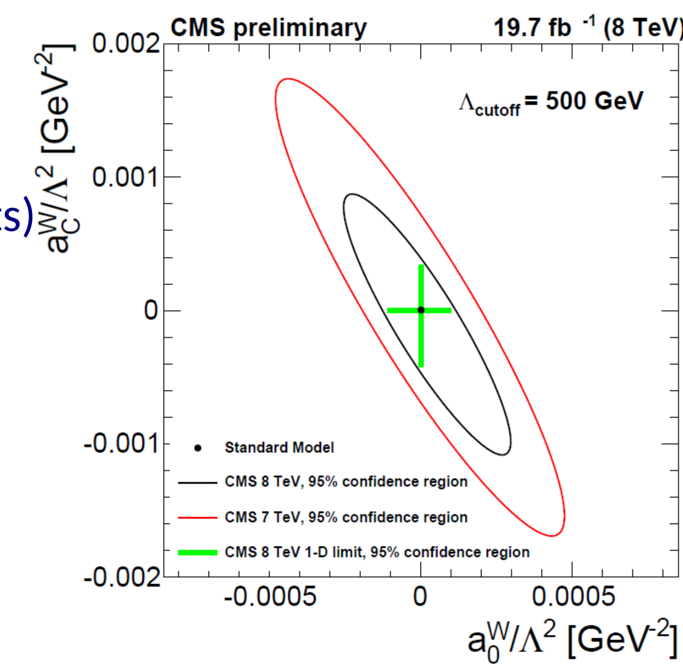


Effective Lagrangian with two additional dimention 6 terms:

$$\mathcal{L}_6^0 = \frac{e^2}{8}\frac{a_0^W}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_\alpha - \frac{e^2}{16\cos^2\Theta_W}\frac{a_0^Z}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}Z^\alpha Z_\alpha$$

$$\mathcal{L}_6^C = \frac{-e^2}{16}\frac{a_C^W}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_\beta + W^{-\alpha}W^+_\beta) - \frac{e^2}{16\cos^2\Theta_W}\frac{a_C^Z}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}Z^\alpha Z_\beta$$

Parameteres a_0^W and a_c^W, Λ – scale for new physics



In eμ channel for pT(eμ)>30 GeV: 13 events observed (SM: 8.8 events)

For Λ=500 GeV new constrains on aQGC 25% better than @7 TeV

(limits at @7 TeV 20 times better than Tevatron and ~O(100) than LEP)

~10x better limits if proton tagging and high Lumi

→ see CT-PPS talk by Margerita Obertino

Summary

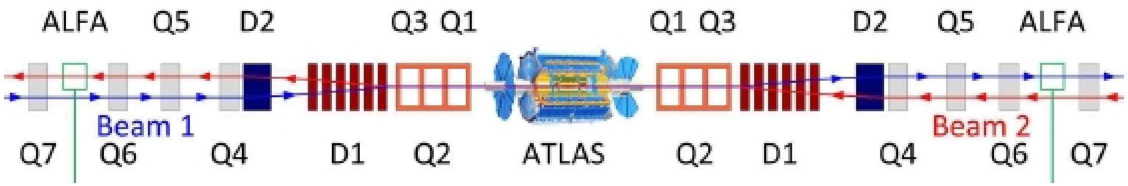
- Total, elastic and diffractive cross sections measured - important input for phenomenological models, MC tuning, and cosmic ray physics

- Hard diffraction results
  - BFKL color singlet exchange measured for the first time at the LHC
  - Hard diffraction still little studied at the LHC, proton tagging (CMS+TOTEM, CT-PPS, AFS) is crucial for expanding number of channels e.g. diffractive dijets, W, Z, J/Ψ

- Rich program for exclusive processes
  - HERA's vector mesons in full swing at increased energy (+ forward detectors to further reduce backgrounds, e.g. HERSCHEL @LHCb)
  - Saturation effect not yet seen
  - First observation of exclusive production of charmonium pairs in DPE
  - Exotic QCD states not yet seen, need more statistics
  - World most stringent limits on aQGC. And will get even better!

Looking forward to Run 2 data.

Elastic/Total pp cross section from ATLAS

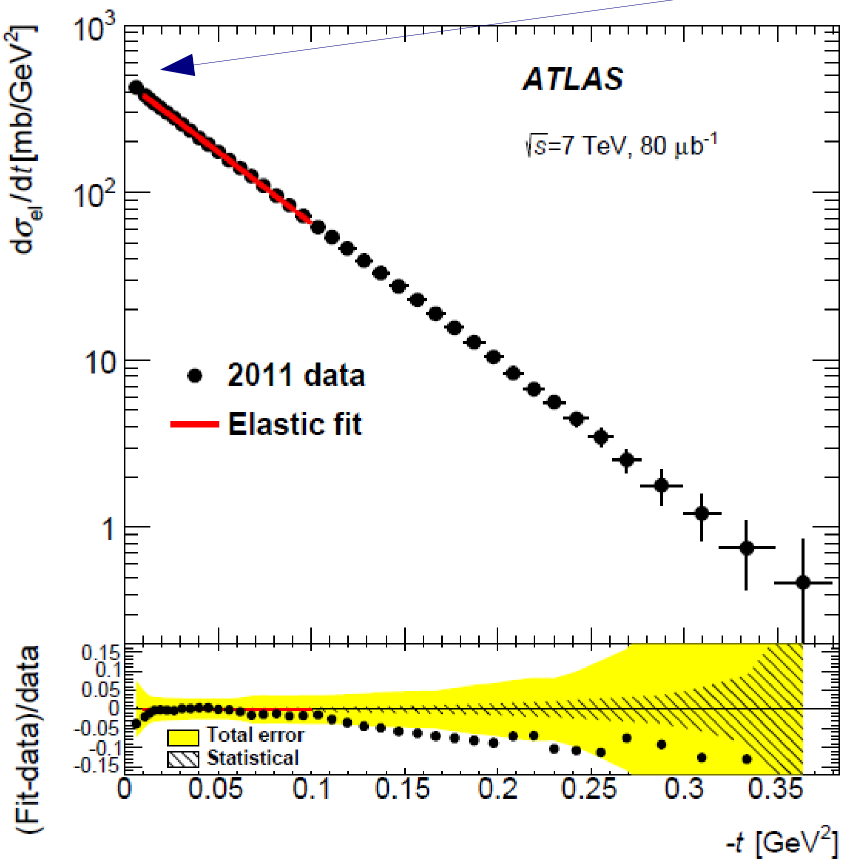


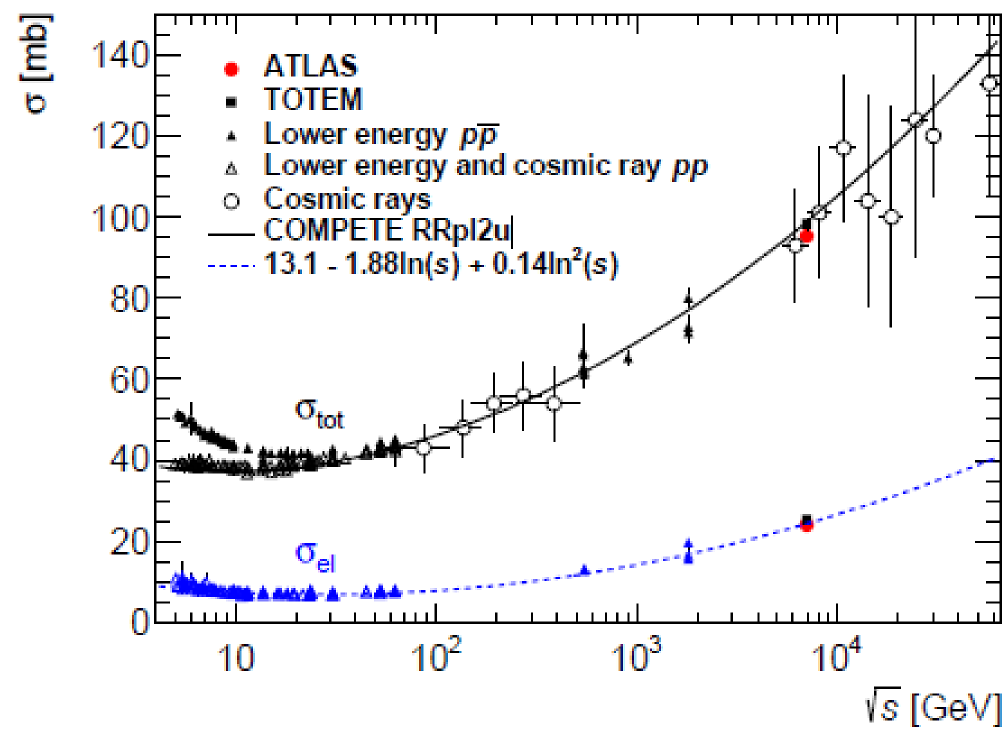
$$\sigma_{\text{tot}}^2 = \frac{1}{L} \frac{16\pi}{1+\rho^2} \frac{dN_{\text{el}}}{dt}\Big|_{t\to 0}$$

ALFA - tracking detectors with scintillating fibers at z= ±240 m

β*=90m optics, 700 kevts

$$\rho = \frac{\text{Re}(f_{\text{el}})}{\text{Im}(f_{\text{el}})}\Big|_{t\to 0} = 0.14$$





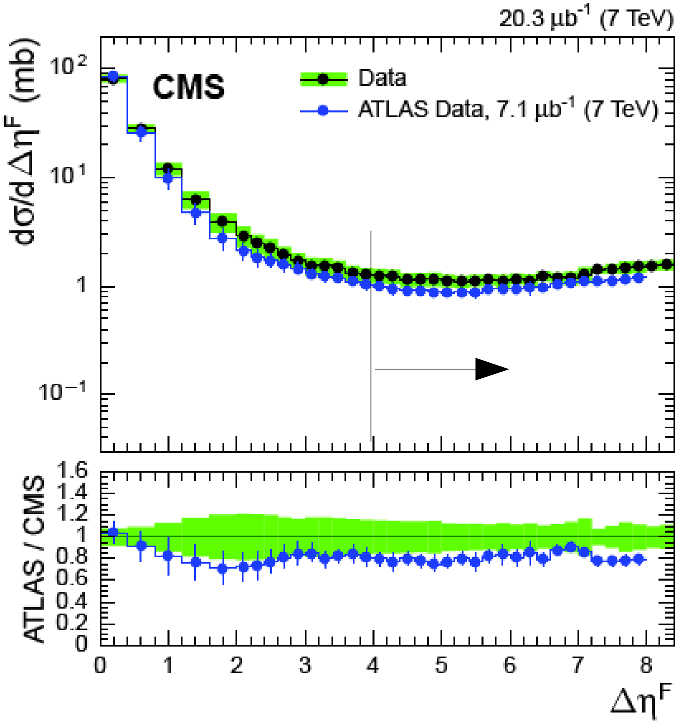
ATLAS: $\sigma_{\text{tot}} = 95.4 \pm 1.4$ mb $B = 19.7 \pm 0.3$ GeV^{-2}

TOTEM: $\sigma_{\text{tot}} = 98.6 \pm 2.2$ mb $B = 19.9 \pm 0.3$ GeV^{-2}

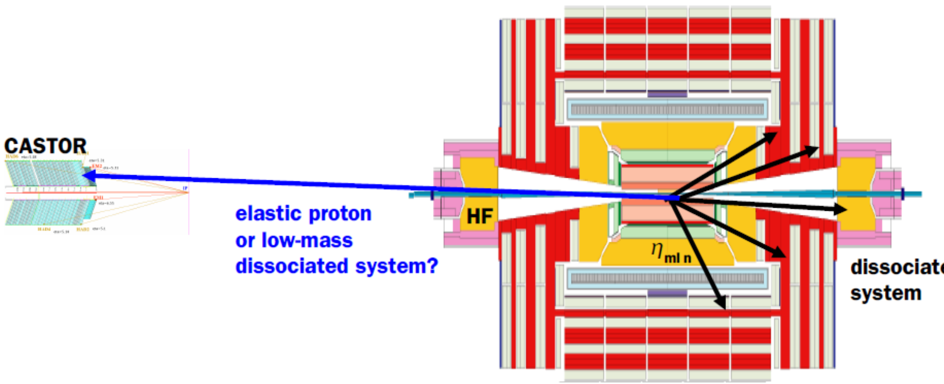
Exponential fit for 0.01 < |t| < 0.1 GeV^2

Diffractive results from CMS

CERN-PH-EP-2015-062, arXiv:1503.08689



SD/DD separation with CASTOR (-6.6<η<-5.2)



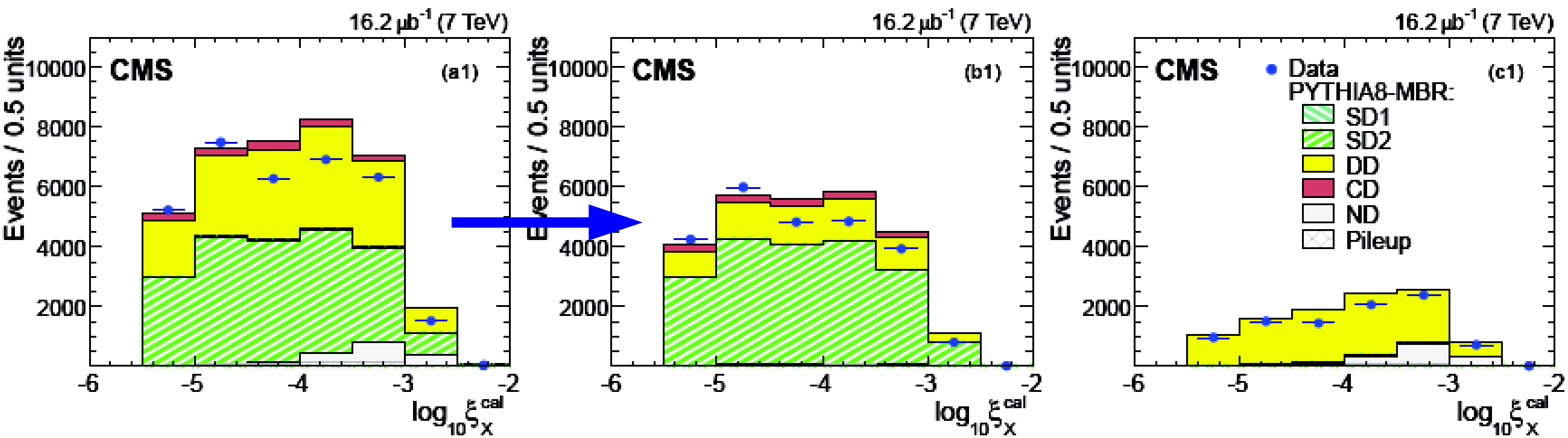
$\Delta\eta^F > 4 \approx \eta_{min} > -1$

All with $\eta_{min} > -1$

no CASTOR-tag (SD dominated)

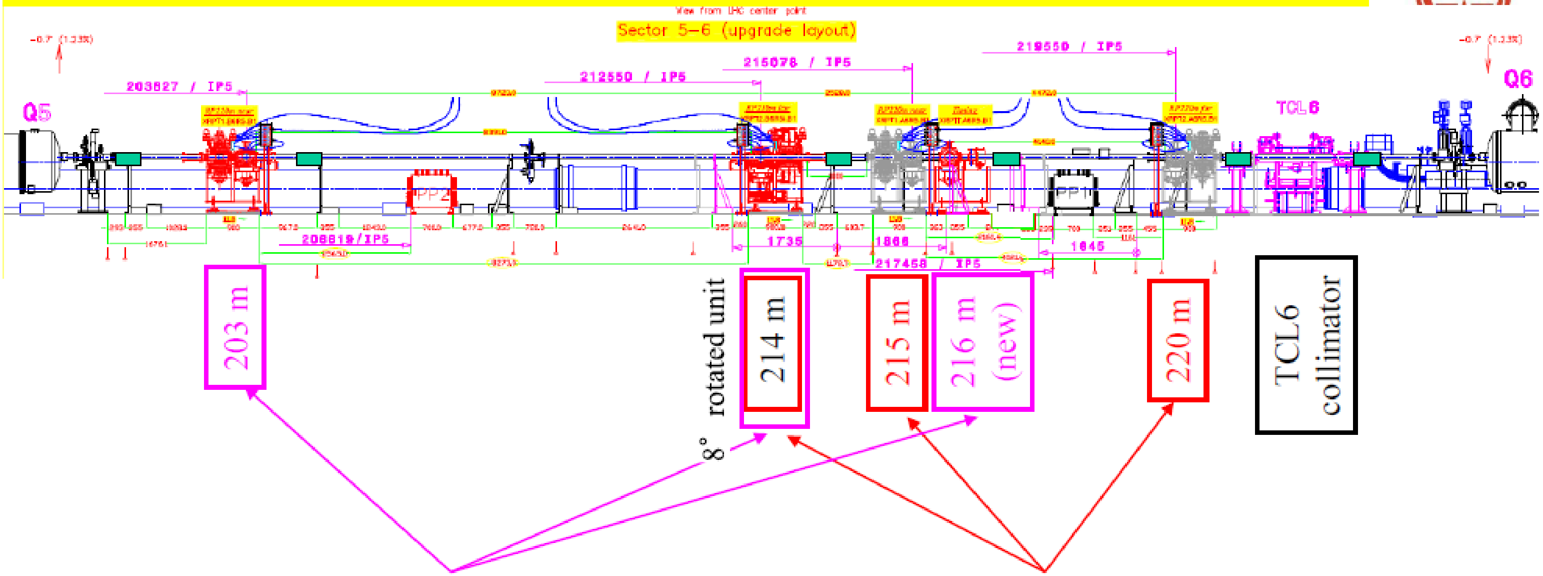
CASTOR-tag (DD dominated)

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



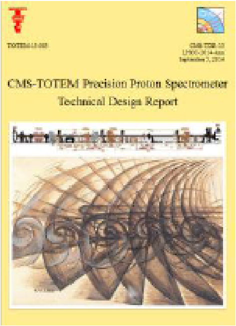
CMS+TOTEM, CT-PPS future plans

Two Upgrade Technical Design Reports



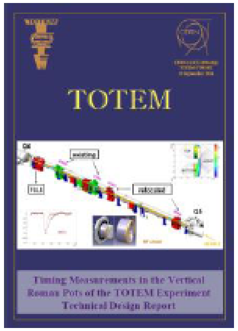
Operation at low β* (< 1 m), high luminosity, standard runs

Operation at high β* (19 m, 90 m, > 1 km), Low - medium luminosity, special runs



CMS-TOTEM Precision Proton Spectrometer (CT-PPS)

High statistics CEP:
DPE exclusive dijets,
photon-photon WW and
BSM EWK couplings.
2016-2017



Timing Measurements in the Vertical Roman Pots of the TOTEM Experiment

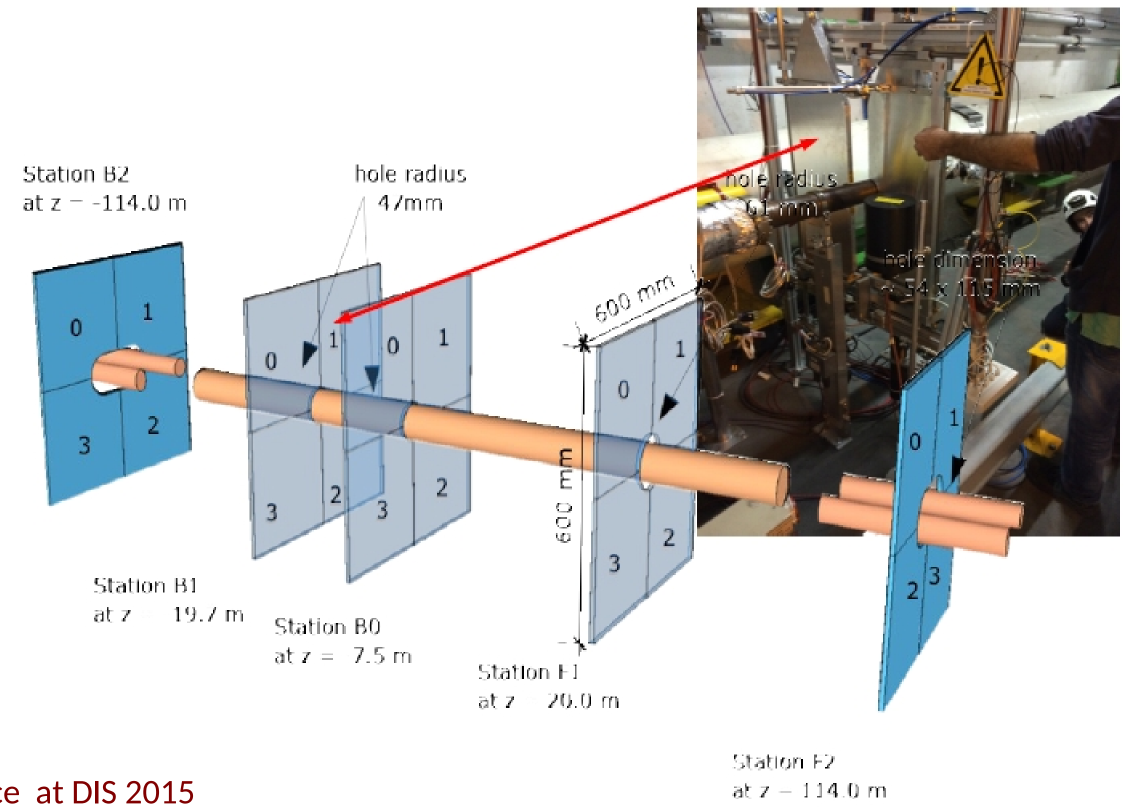
Diffractive processes with TOTEM+CMS,
e.g.: SD J/Psi, Y, W, Z, dijet
DPE dijets, hadron spectroscopy (gluballs)
2015-2016

Similar physics program for ATLAS-ALFA and AFP (ATLAS Forward Physics) project

HERSCHEL – Forward Shower Counters for LHCb

Future prospects

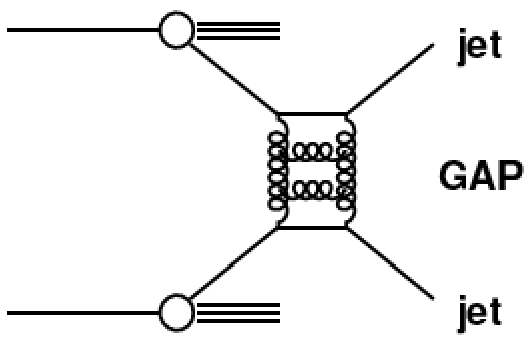
– HERSCHEL: High Rapidity Shower Counter
– Increase size of rapidity gap (to ± 9). Reduce inelastic backgrounds.
– Trigger for hadrons, photons, electrons as well as muons.
– Exclusive Λ, D, low mass resonances in analysis of continuum, glueballs, ...



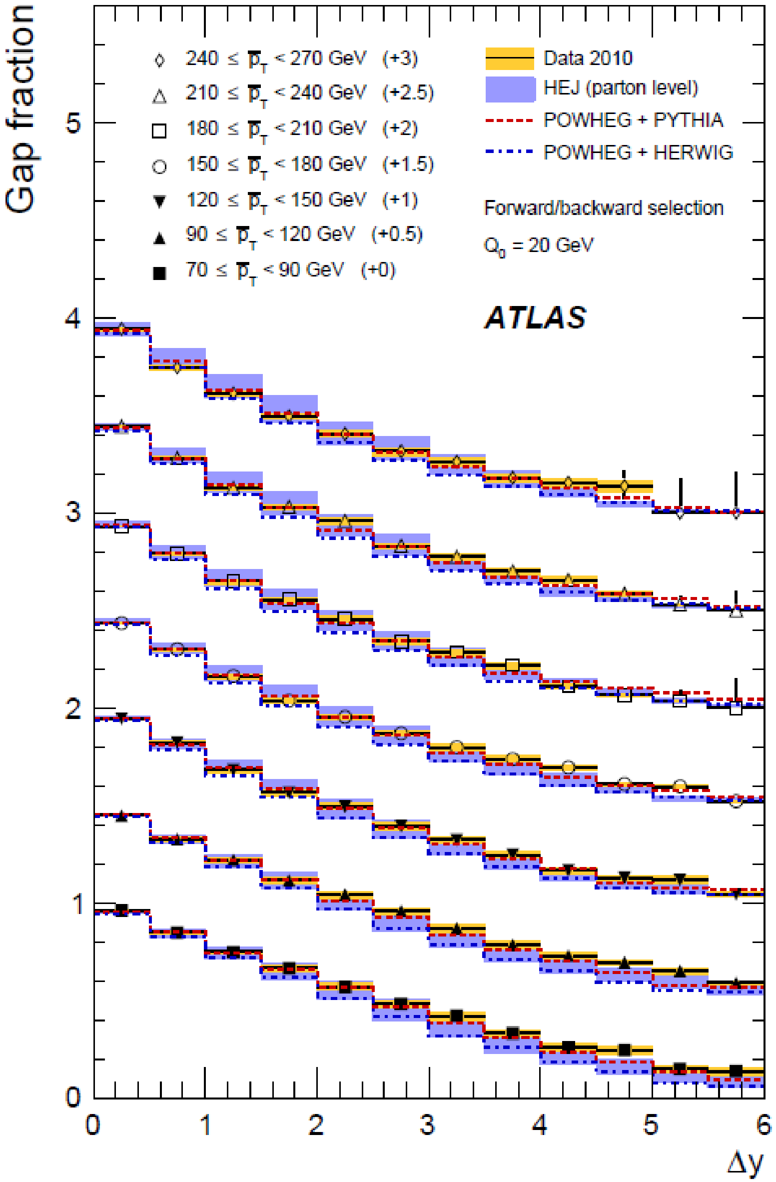
See e.g. R. Wallace at DIS 2015

Dijet events with jet veto from ATLAS

JHEP 1109 (2011) 053

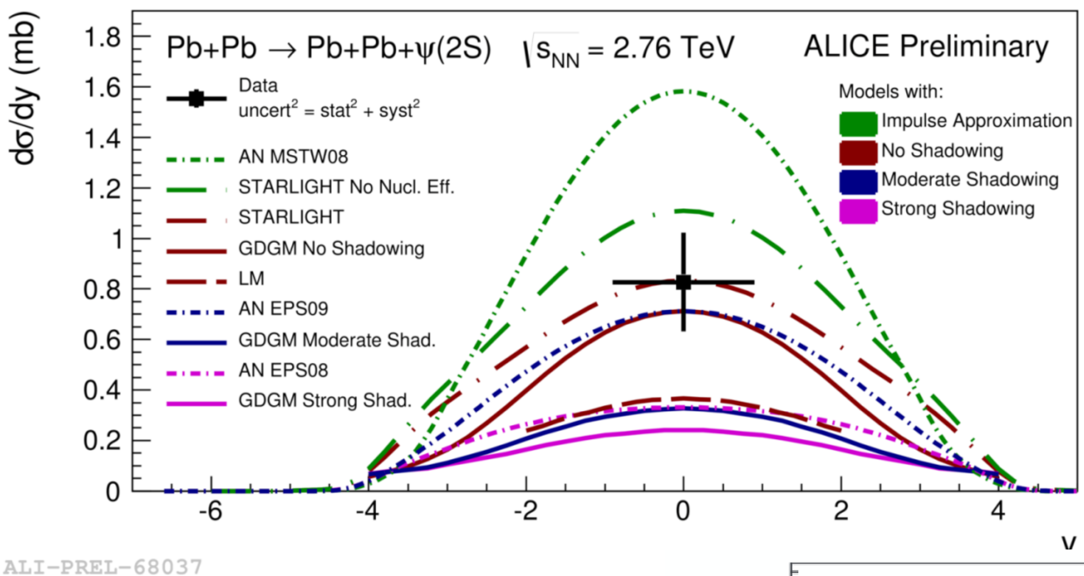


Gap := jet veto (pT>20 GeV)
for dijets with pT> 70 GeV.
Generally described by
POMHEG+PYTHIA (NLO DGLAP)



VM production in Pb-Pb and e-Pb collsions

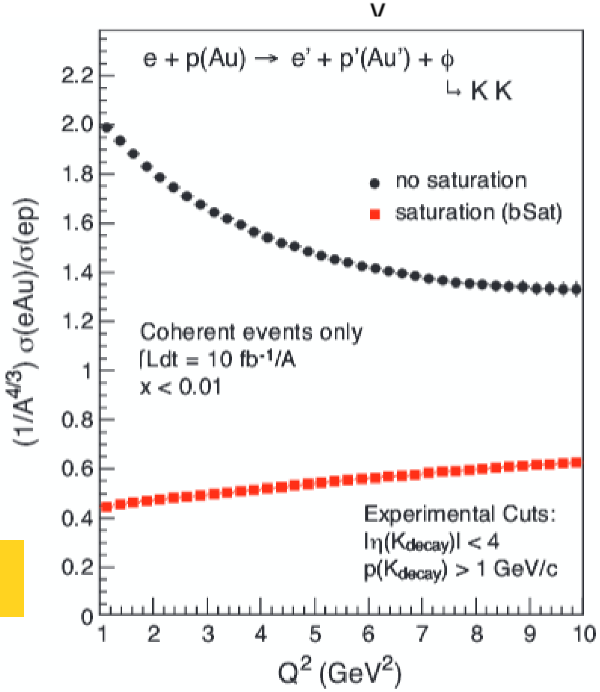
Other VM at LHC in Pb-Pb

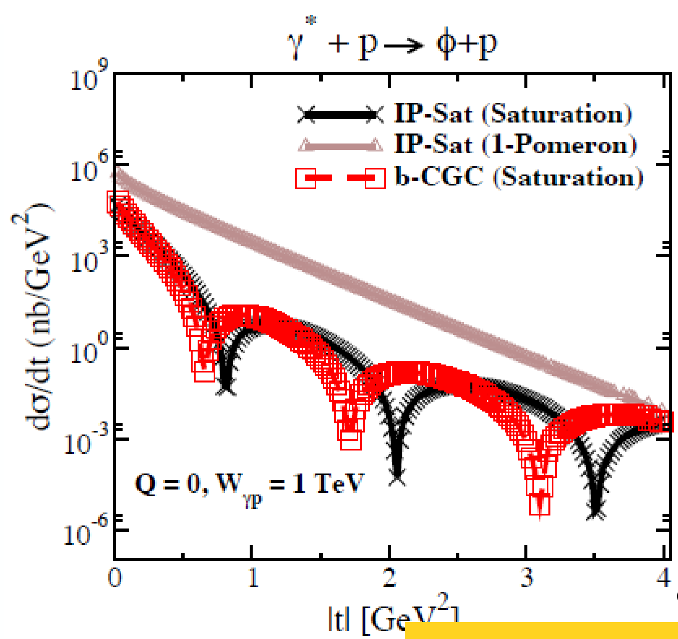


Very strong shadowing and
no-nuclear-effect disfavored.
But more statistics and more
theoretical effort required
(e.g. uncertainty of Ψ(2S) wave function).

Vector meson are a key tool to
study saturation at EIC:
Φ meson well suited for this job

T. Ullrich





A. Rezaeian