

Precision RENORM diffraction Predictions at LHC: A puzzle solving tool?



Miami 2017

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<http://physics.rockefeller.edu/dino/my.html>

What puzzle?

CONTENTS

□ Diffraction

- SD1 $p_1 p_2 \rightarrow p_1 + \text{gap} + X_2$ Single Diffraction / Dissociation -1
- SD2 $p_1 p_2 \rightarrow X_1 + \text{gap} + p_2$ Single Diffraction / Dissociation - 2
- DD $p_1 p_2 \rightarrow X_1 + \text{gap} + X_2$ Double Diffraction / Double Dissociation
- CD/DPE $p_1 p_2 \rightarrow \text{gap} + X + \text{gap}$ Central Diffraction / Double Pomeron Exchange

□ Renormalization \rightarrow Unitarization

➤ **RENORM Model**

□ **Triple-Pomeron Coupling: unambiguously determined**

g_{PPP}

□ **Total Cross Section:**

➤ **Unique prediction, based on a spin-2 tensor glue-ball model**

σ_{tot}

□ References

- MBR MC Simulation in PYTHIA8, KG & R. Ciesielski, <http://arxiv.org/abs/1205.1446>

Special thanks to Robert Ciesielski, my collaborator in the PYTHIA8-MBR project

- EDS BLOIS 2015 Borgo, Corsica, France Jun 29-Jul 4, <https://indico.cern.ch/event/362991/>
- KG, Updated RENORM/MBR-model Predictions for Diffraction at the LHC, <http://dx.doi.org/10.5506/APhysPolBSupp.8.783>
- Moriond QCD 2016, La Thuile, Italy, March 19-26, <http://moriond.in2p3.fr/QCD/2016/>
- NPQCD16, Paris, June, <https://www.brown.edu/conference/14th-workshop-non-perturbative-quantum-chromodynamics/>
- **DIFFRACTION 2016**, Catania, Sep.2-8 2016 <https://agenda.infn.it/conferenceDisplay.py?confId=10935>

similar talk

RENORM: Basic and Combined Diffractive Processes

acronym basic diffractive processes

SD _{\bar{p}} $\bar{p}p \rightarrow \bar{p} + \text{gap} + [p \rightarrow X_p],$

SD _{p} $\bar{p}p \rightarrow [\bar{p} \rightarrow X_{\bar{p}}] + \text{gap} + p,$

DD $\bar{p}p \rightarrow [\bar{p} \rightarrow X_{\bar{p}}] + \text{gap} + [p \rightarrow X_p],$

DPE $\bar{p}p \rightarrow \bar{p} + \text{gap} + X_c + \text{gap} + p,$

2-gap combinations of SD and DD

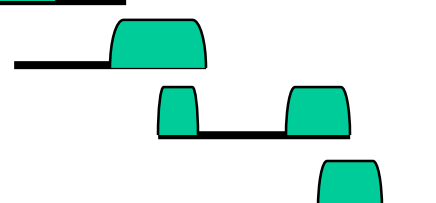
SDD _{\bar{p}} $\bar{p}p \rightarrow \bar{p} + \text{gap} + X_c + \text{gap} + [p \rightarrow X_p],$

SDD _{p} $\bar{p}p \rightarrow [\bar{p} \rightarrow X_{\bar{p}}] \text{gap} + X_c + \text{gap} + p.$

particles



rapidity distributions



DD

SD

DD

SD

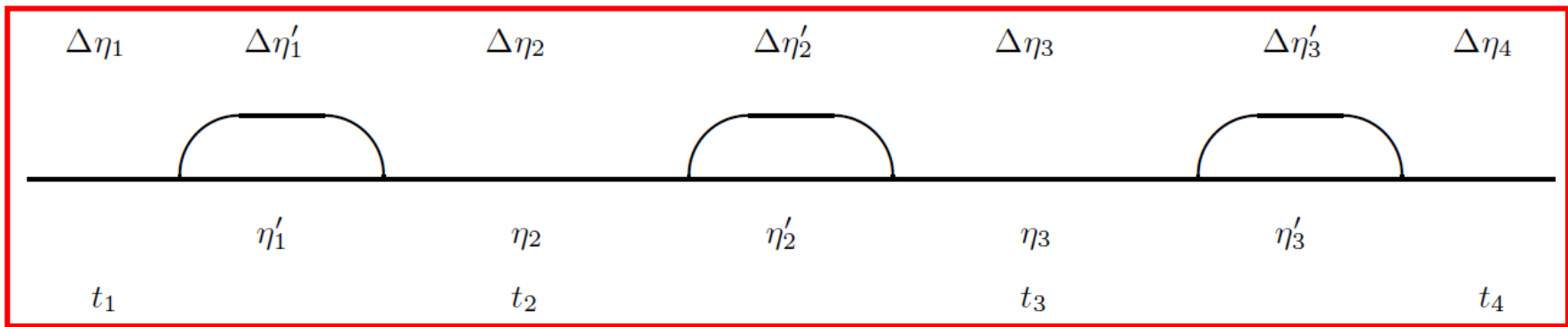
BASIC

COMBINED

Cross sections analytically expressed in arXiv:

<http://arxiv.org/abs/hep-ph/0110240>

4-gap diffractive processes-Snowmass 2001

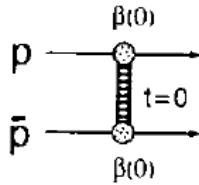


Regge Theory: Values of s_0 & g_{PPP} ?

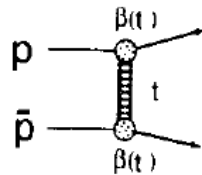
KG-PLB 358, 379 (1995)

<http://www.sciencedirect.com/science/article/pii/037026939501023J>

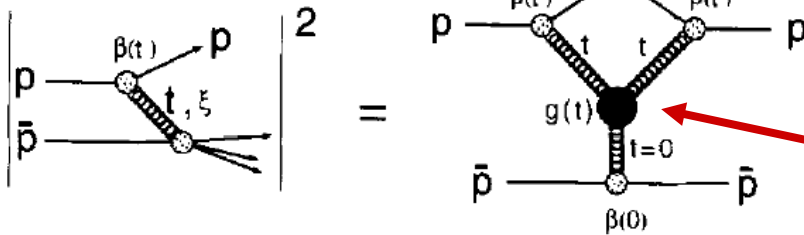
TOTAL CROSS SECTION



ELASTIC SCATTERING



SINGLE DIFFRACTION DISSOCIATION



Parameters:

- s_0, s_0' and $g(t)$
- set $s_0' = s_0$ (universal Pomeron)
- determine s_0 and g_{PPP} – **how?**

$$\alpha(t) = \alpha(0) + \alpha' t \quad \alpha(0) = 1 + \epsilon$$

$$\sigma_T = \beta_1(0) \beta_2(0) \left(\frac{s}{s_0} \right)^{\alpha(0)-1} = \sigma_0^{p\bar{p}} \left(\frac{s}{s_0} \right)^\epsilon \quad (1)$$

$$\begin{aligned} \frac{d\sigma_{el}}{dt} &= \frac{\beta_1^2(t) \beta_2^2(t)}{16\pi} \left(\frac{s}{s_0} \right)^{2[\alpha(t)-1]} \\ &= \frac{\sigma_T^2}{16\pi} \left(\frac{s}{s_0} \right)^{2\alpha' t} F^4(t) \approx \frac{\sigma_T^2}{16\pi} e^{b_{el}(s)t} \end{aligned} \quad (2)$$

$$F^4(t) \approx e^{b_{0,el} t} \Rightarrow b_{el}(s) = b_{0,el} + 2\alpha' \ln \left(\frac{s}{s_0} \right) \quad (3)$$

$$\frac{d^2 \sigma_{sd}}{dt d\xi}$$

$$\begin{aligned} &= \frac{\beta_1^2(t)}{16\pi} \xi^{1-2\alpha(t)} \left[\beta_2(0) g(t) \left(\frac{s'}{s_0} \right)^{\alpha(0)-1} \right] \\ &= f_{P/p}(\xi, t) \sigma_T^{P\bar{p}}(s', t) \end{aligned} \quad (4)$$

Theoretical Complication: Unitarity!

$$\left(\frac{d\sigma_{el}}{dt}\right)_{t=0} \sim \left(\frac{s}{s_0}\right)^{2\epsilon}, \quad \sigma_t \sim \left(\frac{s}{s_0}\right)^\epsilon, \quad \text{and} \quad \sigma_{sd} \sim \left(\frac{s}{s_0}\right)^{2\epsilon}$$

□ σ_{sd} grows faster than σ_t as s increases *

→ **unitarity violation at high s**

(also true for partial x-sections in impact parameter space)

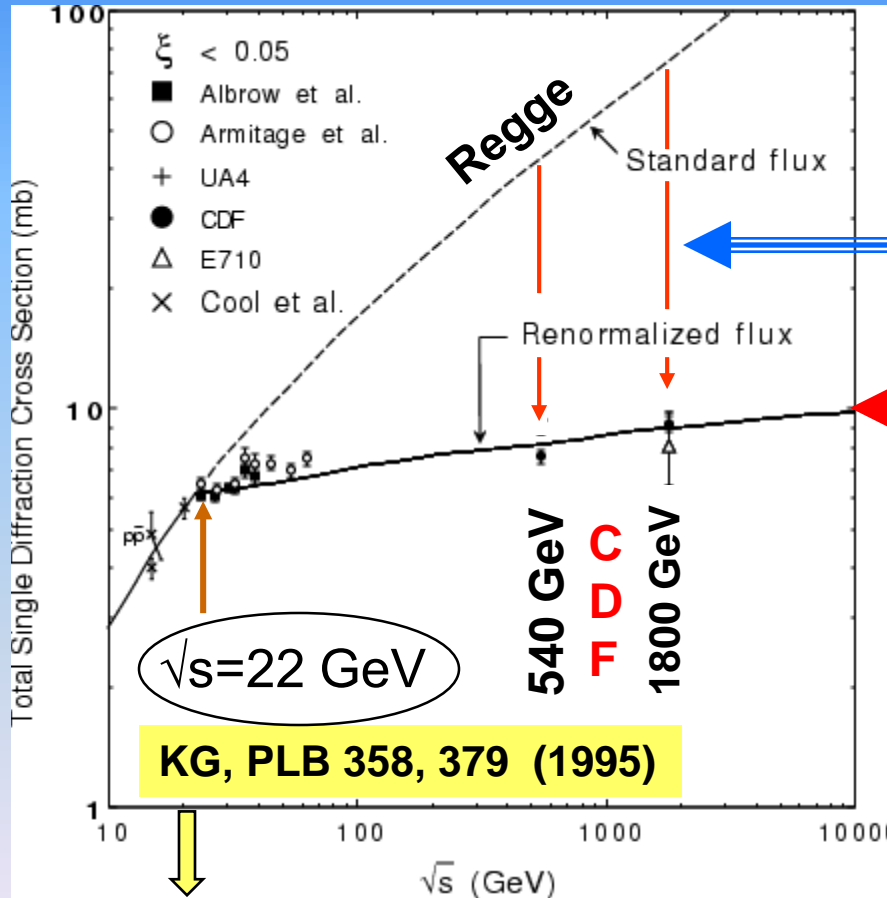
□ **the unitarity limit is already reached at $\sqrt{s} \sim 2$ TeV**

□ **need unitarization**

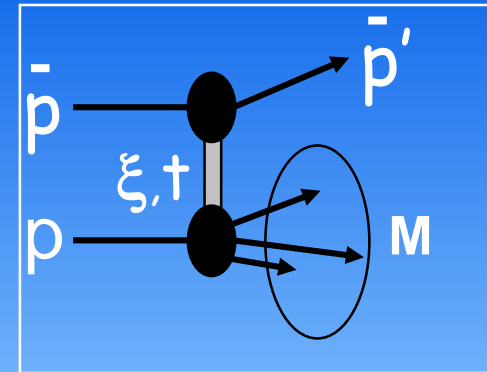
* similarly for $(d\sigma_{el}/dt)_{t=0}$ w.r.t. σ_b but this is handled differently in RENORM

FACTORIZATION BREAKING IN SOFT DIFFRACTION

Diffraction x-section suppressed relative to
Regge prediction as \sqrt{s} increases



<http://www.sciencedirect.com/science/article/pii/037026939501023J>



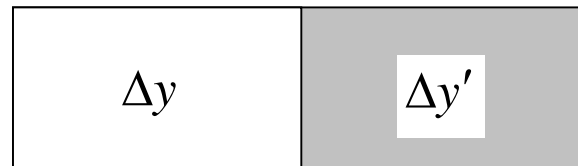
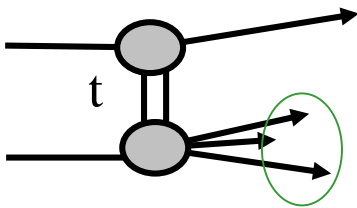
Factor of ~ 8 (~ 5)
suppression at
 $\sqrt{s} = 1800$ (540) GeV

RENORMALIZATION

Interpret flux as gap
formation probability
that saturates when it
reaches unity

Single Diffraction Renormalized - 1

KG → CORFU-2001 <http://arxiv.org/abs/hep-ph/0203141>



2 independent variables: $t, \Delta y$

color factor $\kappa = \frac{g_{IP-IP-IP}(t)}{\beta_{IP-p-p}(0)} \approx 0.17$

$$\frac{d^2 \sigma}{dt d\Delta y} = C \cdot F_p^2(t) \cdot \left\{ e^{(\varepsilon + \alpha' t) \Delta y} \right\}^2 \cdot \kappa \cdot \left\{ \sigma_o e^{\varepsilon \Delta y'} \right\}$$

gap probability

sub-energy x-section

Gap probability → (re)normalize it to unity

Single Diffraction Renormalized - 2

color factor

$$\kappa = \frac{g_{IP-IP-IP}(t)}{\beta_{IP-p-p}(0)} \approx 0.17$$

Experimentally →

$$\kappa = \frac{g_{IP-IP-IP}}{\beta_{IP-p}} = 0.17 \pm 0.02, \quad \varepsilon = 0.104$$

KG&JM, PRD 59 (114017) 1999

<http://dx.doi.org/10.1103/PhysRevD.59.114017>

QCD: $\kappa = f_g \times \frac{1}{N_c^2 - 1} + f_q \times \frac{1}{N_c} \xrightarrow{Q^2 = 1} \approx 0.75 \times \frac{1}{8} + 0.25 \times \frac{1}{3} = 0.18$

Single Diffraction Renormalized - 3

$$\frac{d^2 \sigma_{sd}(s, M^2, t)}{dM^2 dt} = \left[\frac{\sigma_0}{16\pi} \sigma_0^{IPp} \right] \frac{s^{2\epsilon}}{N(s, s_0)} \frac{e^{bt}}{(M^2)^{1+\epsilon}}$$

$$b = b_0 + 2\alpha' \ln \frac{s}{M^2} \quad s_0^{\text{CMG}} = (3.7 \pm 1.5) \text{ GeV}^2$$

$$N(s, s_0) \equiv \int_{\xi_{\min}}^{\xi_{\max}} d\xi \int_{t=0}^{-\infty} dt f_{IP/p}(\xi, t) \xrightarrow{s \rightarrow \infty} \sim s_0^\epsilon \frac{s^{2\epsilon}}{\ln s}$$

← affects only the s-dependence

$$\frac{d^2 \sigma_{sd}(s, M^2, t)}{dM^2 dt} \xrightarrow{s \rightarrow \infty} \sim \ln s \frac{e^{bt}}{(M^2)^{1+\epsilon}}$$

$$\sigma_{sd} \xrightarrow{s \rightarrow \infty} \sim \frac{\ln s}{b \rightarrow \ln s} \Rightarrow \text{const}$$

set $N(s, s_0)$ to unity
→ determines s_0

M² - Distribution: Data

→ $d\sigma/dM^2|_{t=-0.05} \sim$ independent of s over 6 orders of magnitude!

<http://physics.rockefeller.edu/publications.html>

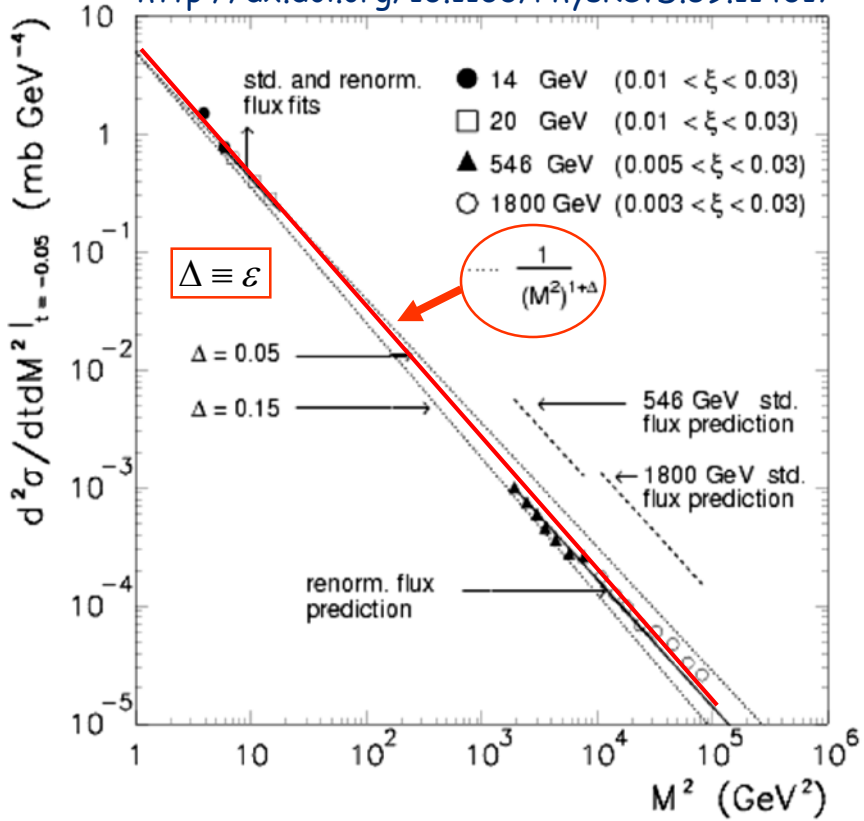
KG&JM, PRD 59 (1999) 114017

<http://dx.doi.org/10.1103/PhysRevD.59.114017>

Regge

data

$$\frac{d\sigma}{dM^2} \propto \frac{s^{2\epsilon} \rightarrow 1}{(M^2)^{1+\epsilon}}$$



→ factorization breaks down to ensure M²-scaling

Scale s_0 and PPP Coupling

Pomeron flux: interpreted as gap probability

→ set to unity: determines g_{PPP} and s_0

KG, PLB 358 (1995) 379 <http://www.sciencedirect.com/science/article/pii/037026939501023J>

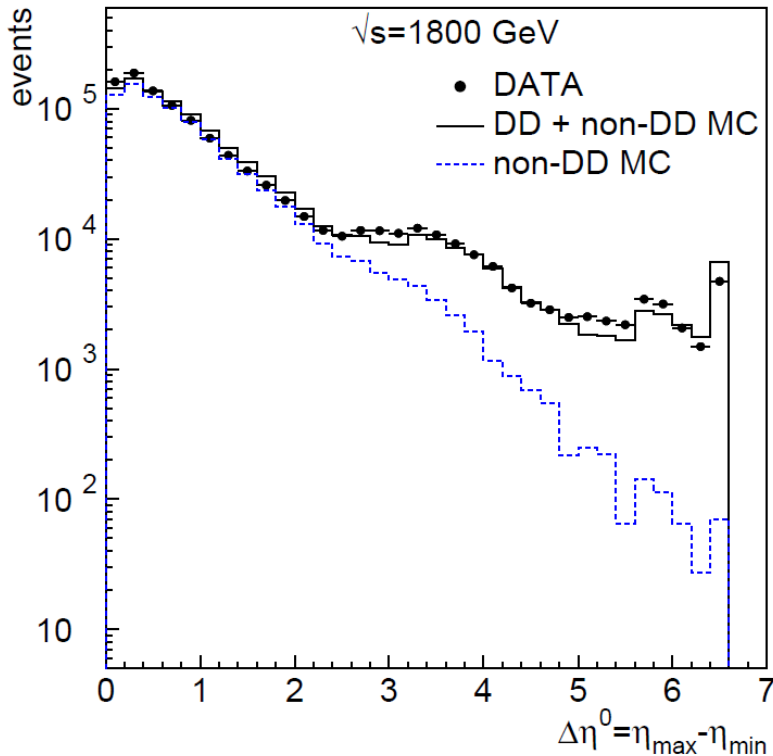
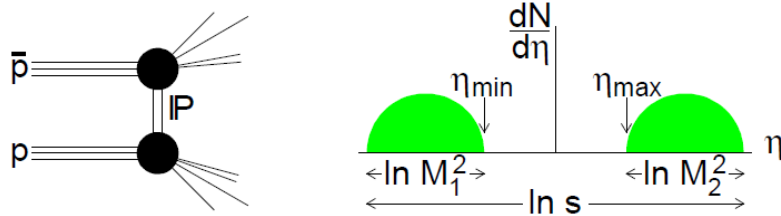
$$\frac{d^2 \sigma_{SD}}{dt d\xi} = f_{IP/p}(t, \xi) \sigma_{IP/p}(s\xi)$$

Pomeron-proton x-section

- Two free parameters: s_0 and g_{PPP}
- Obtain product $g_{PPP} s_0^{\epsilon/2}$ from σ_{SD}
- Renormalize Pomeron flux: determines s_0
- Get unique solution for g_{PPP}

DD at CDF

<http://physics.rockefeller.edu/publications.html>
<http://dx.doi.org/10.1103/PhysRevLett.87.141802>



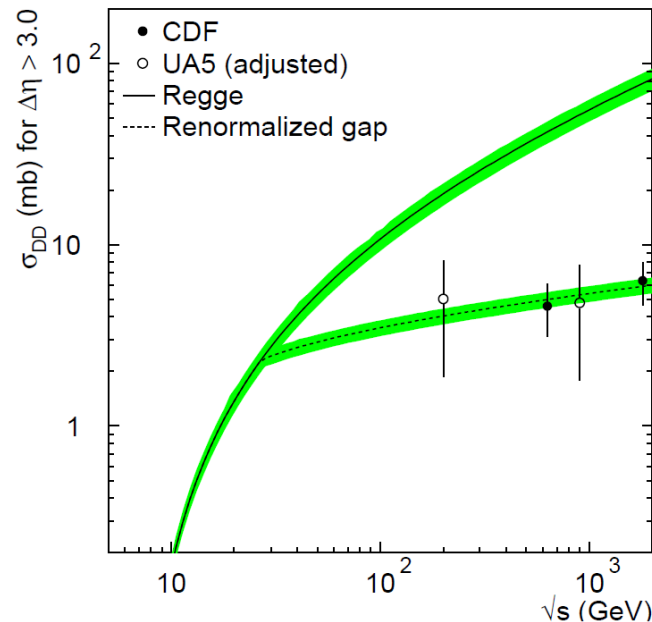
Regge factorization

$$\frac{d^3\sigma_{DD}}{dt dM_1^2 dM_2^2} = \frac{d^2\sigma_{SD}}{dt dM_1^2} \frac{d^2\sigma_{SD}}{dt dM_2^2} / \frac{d\sigma_{el}}{dt}$$

$$= \frac{[\kappa\beta_1(0)\beta_2(0)]^2}{16\pi} \frac{s^{2[\alpha(0)-1]} e^{b_{DD}t}}{(M_1^2 M_2^2)^{1+2[\alpha(0)-1]}}$$

$$\frac{d^3\sigma_{DD}}{dt d\Delta\eta d\eta_c} = \left[\frac{\kappa\beta^2(0)}{16\pi} e^{2[\alpha(t)-1]\Delta\eta} \right] \left[\kappa\beta^2(0) \left(\frac{s'}{s_0} \right)^\epsilon \right]$$

gap probability x-section

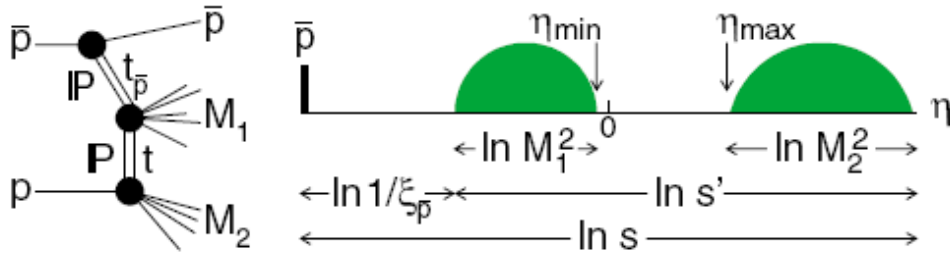


← Regge

Regge
← RENORM

x-section
divided by
integrated
gap prob.

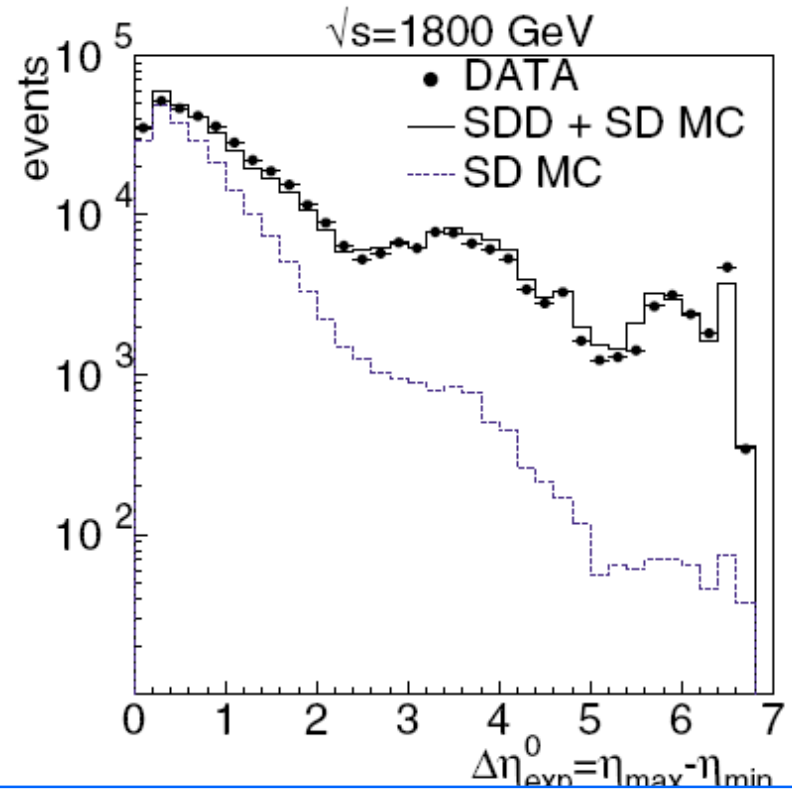
SDD at CDF



<http://physics.rockefeller.edu/publications.html>

<http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.91.011802>

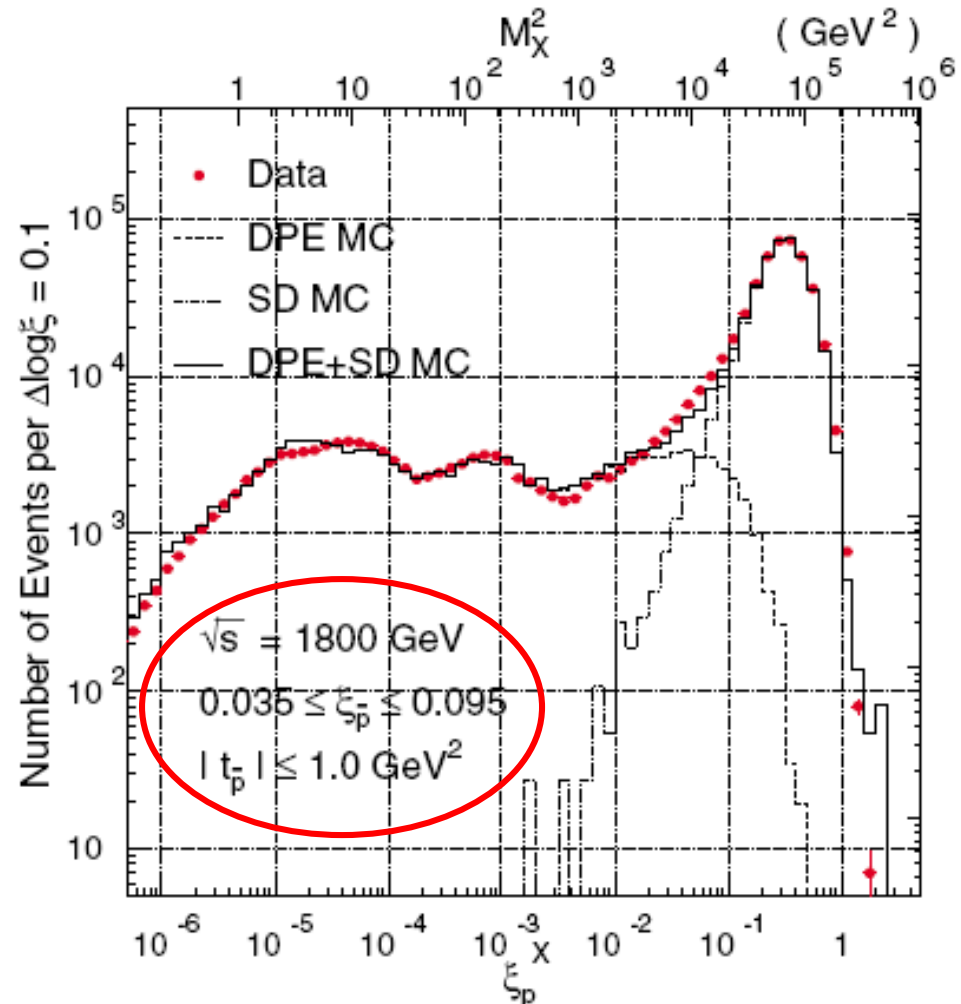
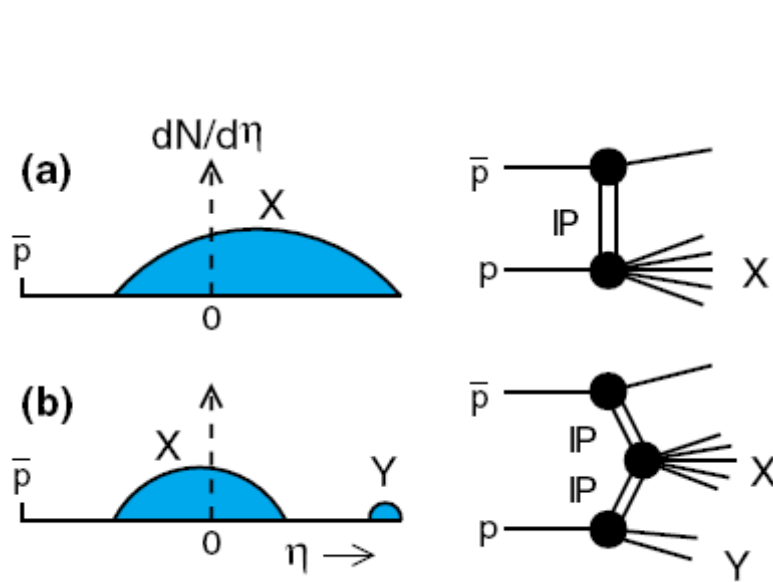
- Excellent agreement between data and MBR (MinBiasRockefeller) MC



$$\frac{d^5\sigma}{dt_{\bar{p}} dt d\xi_{\bar{p}} d\Delta\eta d\eta_c} = \left[\frac{\beta(t)}{4\sqrt{\pi}} e^{[\alpha(t_{\bar{p}})-1]\ln(1/\xi)} \right]^2 \times \kappa \left\{ \kappa \left[\frac{\beta(0)}{4\sqrt{\pi}} e^{[\alpha(t)-1]\Delta\eta} \right]^2 \kappa \left[\beta^2(0) \left(\frac{s''}{s_0} \right)^\epsilon \right] \right\}$$

CD/DPE at CDF

<http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.91.011802>



- Excellent agreement between data and MBR-based MC
- ➔ Confirmation that both **low and high mass x-sections** are correctly implemented

RENORM Diffractive Cross Sections

MBR MC Simulation in PYTHIA8 → <http://arxiv.org/abs/1205.1446>

$$\begin{aligned} \frac{d^2\sigma_{SD}}{dtd\Delta y} &= \frac{1}{N_{\text{gap}}(s)} \left[\frac{\beta^2(t)}{16\pi} e^{2[\alpha(t)-1]\Delta y} \right] \cdot \left\{ \kappa\beta^2(0) \left(\frac{s'}{s_0} \right)^\epsilon \right\}, \\ \frac{d^3\sigma_{DD}}{dtd\Delta y dy_0} &= \frac{1}{N_{\text{gap}}(s)} \left[\frac{\kappa\beta^2(0)}{16\pi} e^{2[\alpha(t)-1]\Delta y} \right] \cdot \left\{ \kappa\beta^2(0) \left(\frac{s'}{s_0} \right)^\epsilon \right\}, \\ \frac{d^4\sigma_{DPE}}{dt_1 dt_2 d\Delta y dy_c} &= \frac{1}{N_{\text{gap}}(s)} \left[\prod_i \left[\frac{\beta^2(t_i)}{16\pi} e^{2[\alpha(t_i)-1]\Delta y_i} \right] \right] \cdot \kappa \left\{ \kappa\beta^2(0) \left(\frac{s'}{s_0} \right)^\epsilon \right\} \end{aligned}$$

$$\beta^2(t) = \beta^2(0) F^2(t)$$

$$F^2(t) = \left[\frac{4m_p^2 - 2.8t}{4m_p^2 - t} \left(\frac{1}{1 - \frac{t}{0.71}} \right)^2 \right]^2 \approx a_1 e^{b_1 t} + a_2 e^{b_2 t}$$

$$\alpha_1=0.9, \alpha_2=0.1, b_1=4.6 \text{ GeV}^{-2}, b_2=0.6 \text{ GeV}^{-2}, s'=s e^{-\Delta y}, \kappa=0.17, \kappa\beta^2(0)=\sigma_0, s_0(\text{units})=1\text{GeV}^2, \sigma_0=2.82 \text{ mb or } 7.25 \text{ GeV}^{-2}$$

Total, Elastic, and Total Inelastic x-Sections

$$\sigma_{\text{ND}} = (\sigma_{\text{tot}} - \sigma_{\text{el}}) - (2\sigma_{\text{SD}} + \sigma_{\text{DD}} + \sigma_{\text{CD}})$$

CMG → R.J.M. Covolan¹, J. Montanha², K. Goulios³ **PLB 389, 196 (1996)**
The Rockefeller University, 1230 York Avenue, New York, NY 10021, USA

<http://www.sciencedirect.com/science/article/pii/S0370269396013627>

$$\sigma_{\text{tot}}^{p\pm p} = \begin{cases} 16.79s^{0.104} + 60.81s^{-0.32} \mp 31.68s^{-0.54} & \text{for } \sqrt{s} < 1.8 \\ \sigma_{\text{tot}}^{\text{CDF}} + \frac{\pi}{s_0} \left[\left(\ln \frac{s}{s_F} \right)^2 - \left(\ln \frac{s^{\text{CDF}}}{s_F} \right)^2 \right] & \text{for } \sqrt{s} \geq 1.8 \end{cases}$$

KG MORIOND-2011 <http://moriond.in2p3.fr/QCD/2011/proceedings/goulios.pdf>

$$\sqrt{s^{\text{CDF}}} = 1.8 \text{ TeV}, \quad \sigma_{\text{tot}}^{\text{CDF}} = 80.03 \pm 2.24 \text{ mb}$$

$$\sqrt{s_F} = 22 \text{ GeV} \quad s_0 = 3.7 \pm 1.5 \text{ GeV}^2$$

$$\sigma_{\text{el}}^{p\pm p} = \sigma_{\text{tot}}^{p\pm p} \times (\sigma_{\text{el}}/\sigma_{\text{tot}})^{p\pm p}, \text{ with } \sigma_{\text{el}}/\sigma_{\text{tot}} \text{ from CMG}$$

➤ small extrapolation from 1.8 to 7 and up to 50 TeV

Diffractive and Total pp Cross Sections at LHC



Konstantin Goulios
The Rockefeller University
<http://eds09.web.cern.ch/eds09/>

2009



- Use the Froissart formula as a *saturated* cross section

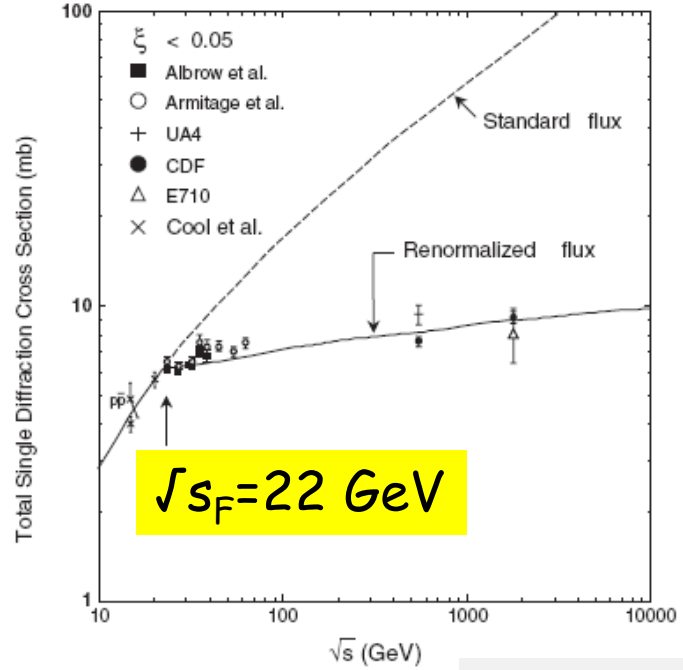
$$\sigma_t(s > s_F) = \sigma_t(s_F) + \frac{\pi}{m^2} \cdot \ln^2 \frac{s}{s_F}$$

- This formula should be valid above the *knee* in σ_{sd} vs. \sqrt{s} at $\sqrt{s_F} = 22$ GeV therefore valid at $\sqrt{s} = 1800$ GeV.
- Use $m^2 = s_o$ in the Froissart formula multiplied by $1/0.389$ to convert it to mb^{-1} .
- Note that contributions from Reggeon exchanges at $\sqrt{s} = 1800$ GeV are negligible, as can be verified from the global fit of **CMG**
- Obtain the total cross section at the LHC:

$$\sigma_t^{\text{LHC}} = \sigma_t^{\text{CDF}} + \frac{\pi}{s_o} \cdot \left(\ln^2 \frac{s^{\text{LHC}}}{s_F} - \ln^2 \frac{s^{\text{CDF}}}{s_F} \right)$$

98 ± 8 mb at 7 TeV
109 ± 12 mb at 14 TeV

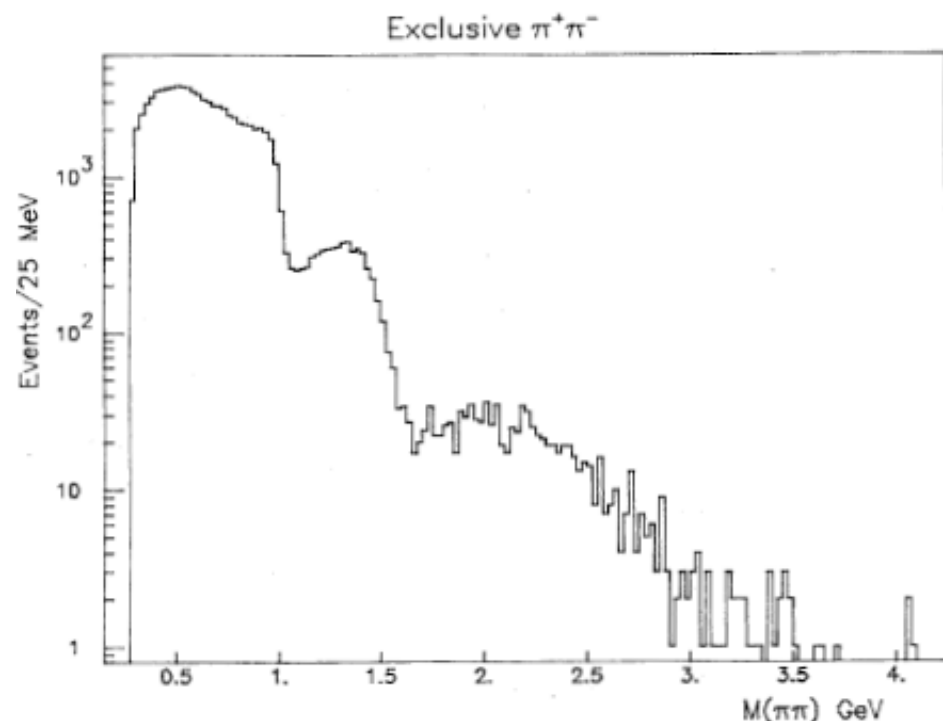
Uncertainty is due to s_o



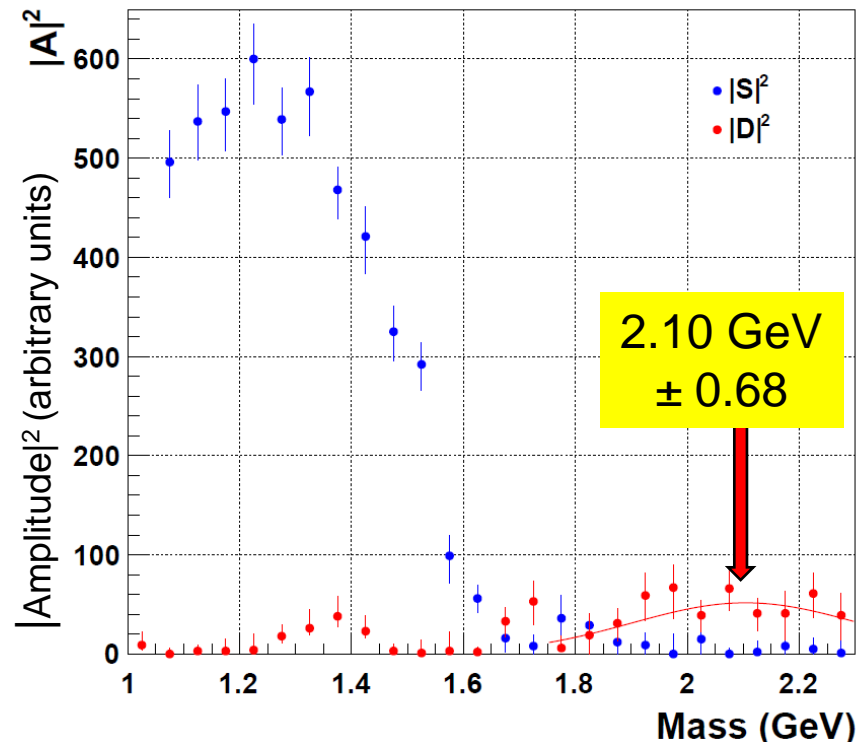
Reduce Uncertainty in s_0

<http://workshops.ift.uam-csic.es/LHCFPWG2015/program>

EDS 2015: <http://dx.doi.org/10.5506/APhysPolBSupp.8.783>



Review of CEP by Albrow, Coughlin, Forshaw <http://arxiv.org/abs/1006.1289>
Fig from **Axial Field Spectrometer** at the CERN Intersecting Storage Rings



Data: Peter C. Cesil, AFS thesis
(courtesy Mike Albrow)
→ analysis: S and D waves

Conjecture: tensor glue ball (spin 2)

Fit: Gaussian

□ $\langle M_{\text{tgb}} \rangle = \sqrt{s_0} = 2.10 \pm 0.68$ GeV

□ $\rightarrow s_0 = 4.42 \pm 0.34$ GeV²

20% increase in s_0
→ x-sections decrease

Predictions vs Measurements ^{with/reduced} Uncertainty in s_0

From my Moriond-2016 Talk

\sqrt{s}	MBR/Exp	σ_{tot}	σ_{el}	σ_{inel}
7 TeV	MBR	95.4±1.2	26.4±0.3	69.0±1.0
	TOTEM totem-lumInd	98.3±0.2±2.8 98.0±2.5	24.8±0.2±1.2 25.2±1.1	73.7±3.4 72.9±1.5
	ATLAS	95.35±1.36	24.00±0.60	71.34±0.90
8 TeV	MBR	97.1±1.4	27.2±0.4	69.9±1.0
	TOTEM	101.7±2.9	27.1±1.4	74.7±1.7
13 TeV	MBR	103.7±1.9	30.2±0.8	73.5±1.3
	ATLAS		$\sigma_{\text{inel}}=73.1\pm0.9(\text{exp})\pm6.6(\text{lumi})\pm3.8(\text{extra.})\text{mb}$	

- ❑ RENORM/MBR with a **tensor-Pomeron model** predicts measured cross sections to the ~1% level
- ❑ **Test of RENORM/MBR:** ATLAS results using the ALFA and RP detectors to measure the cross sections

Stay tuned!

Totem 7 TeV <http://arxiv.org/abs/1204.5689>

Totem-Lum-Ind 7 TeV <http://iopscience.iop.org/article/10.1209/0295-5075/101/21004>

Atlas 7 TeV: <http://arxiv.org/abs/1408.5778>

Totem 8 TeV <http://dx.doi.org/10.1103/PhysRevLett.111.012001>

Atlas13 TeV Aspen 2016 Doug Schafer <https://indico.cern.ch/event/473000/timetable/#all.detailed>

Atlas/Totem 13TeV DIS15 <https://indico.desy.de/contributionDisplay.py?contribId=330&confId=12482>

Predictions vs Measurements w/reduced Uncertainty in s_0 #1

ICNFP 2016

Slide from my ICNFP-2016 Talk

\sqrt{s}	MBR/Exp	Reference → next slide	S_{tot}	S_{el}	S_{inel}
7 TeV	MBR		95.4±1.2	26.4±0.3	69.0±1.0
	ATLAS	1	95.35±1.36	24.00±0.60	71.34±0.90
	TOTEM	2	101.7±2.9	27.1±1.4	74.7±1.7
	TOTEM_Lum_Ind	3	98.0±2.5	24.00±0.60	72.9±1.5
8 TeV	MBR		97.1±1.4	27.2±0.4	69.9±1.0
	TOTEM	4	101.7±2.9	27.1±1.4	74.7±1.7
13 TeV	MBR		103.7±1.9	30.2±0.8	73.5±1.3
	ATLAS	5 & 6		◦	73.1±0.9 (exp) ±6.6 (lumi) ±3.8 (extr)
	CMS	7			71.3±0.5 (exp) ±2.1 (lumi) ±2.7 (extr)

CONT →

Caveat (slide from my ICNFP-2016 talk)

The MBR σ_{el} is larger than the ATLAS and the TOTEM_lum_Ind measurements by ~ 2 mb at $\sqrt{s}=7$ TeV, which might imply a higher MBR prediction at $\sqrt{s}=13$ TeV by 2-3 mb. Lowering the MBR σ_{el} prediction would lead to a larger σ_{inel} . This interplay between σ_{el} and σ_{inel} should be kept in mind as more results of σ_{el} and σ_{tot} at $\sqrt{s} = 13$ TeV become available.

- ❑ RENORM/MBR with a **tensor-Pomeron model** predicts measured cross sections to the $\sim 1\%$ level
- ❑ **Test of RENORM/MBR:** ATLAS results using the ALFA and RP detectors to measure the cross sections

Stay tuned!

- 1) Atlas 7 TeV: <http://arxiv.org/abs/1408.5778>
- 2) Totem 7 TeV <http://arxiv.org/abs/1204.5689>
- 3) Totem-Lum-Ind 7 TeV <http://iopscience.iop.org/article/10.1209/0295-5075/101/21004>
- 4) Totem 8 TeV <http://dx.doi.org/10.1103/PhysRevLett.111.012001>
- 5) Atlas13 TeV Aspen 2016 D. Schafer <https://indico.cern.ch/event/473000/timetable/#all.detailed>
- 6) Atlas 13TeV DIS-2016 M. Trzebinski <https://indico.desy.de/contributionDisplay.py?contribId=330&confId=12482>
- 7) CMS 13TeV DIS-2016 H. Van Haeveermaet <https://indico.desy.de/contributionDisplay.py?contribId=105&confId=12482>

MBR vs. ICHEP 2016 cross-section results

\sqrt{s}	MBR/Exp	Ref. # → slide 19	S_{tot}	S_{el}	S_{inel}
7 TeV	MBR		95.4±1.2	26.4±0.3	69.0±1.0
	ATLAS	1	95.35±1.36	24.00±0.60	71.34±0.90
	TOTEM	2	101.7±2.9	27.1±1.4	74.7±1.7
	TOTEM_Lum_Ind	3	98.0±2.5	24.00±0.60	72.9±1.5
8TeV	MBR		97.1±1.4	27.2±0.4	69.9±1.0
	TOTEM	4	101.7±2.9	27.1±1.4	74.7±1.7
	ATLAS-ALFA fit	ICHEP16	96.1±0.9	24.3±0.4	
13 TeV	MBR		103.7±1.9	30.2±0.8	73.5±1.3
	ATLAS ALFA-fit-result	5 & 6 ICHEP16			73.1±0.9 (exp) ±6.6 (lumi) ±3.8 (extr) 79.3±0.6(exp) ±1.3(lumi) ±2.5(extr)
	CMS	7+ICHEP16			71.3±0.5 (exp) ±2.1 (lumi) ±2.7 (extr)

← ATLAS vs. MBR in excellent agreement at 8 TeV

✓ Tomáš Sýkora, ICHEP16 x-sections summary talk <http://ic hep2016.org/>

☐ At 13 TeV MBR is happy between the ATLAS and CMS ICHEP results

➔ awaiting settlement between the two experiments – keep tuned!

MBR vs. ICHEP 2016 cross-sections

\sqrt{s} (TeV)	Input source	Reference*	σ_{tot} (mb)	σ_{el} (mb)	σ_{inel} (mb)
7	MBR	a	95.4 ± 1.2	26.4 ± 0.3	69.0 ± 1.0
	ATLAS	b	95.35 ± 1.36	24.00 ± 0.60	71.34 ± 0.90
	TOTEM	c	101.7 ± 1.36	27.1 ± 1.4	74.7 ± 1.7
	TOTEM_Lum_ind	d	98.0 ± 2.5	24.00 ± 0.60	72.9 ± 1.5
8	MBR	a	97.1 ± 1.4	27.2 ± 0.4	69.9 ± 1.0
	TOTEM	e	101.7 ± 2.9	27.1 ± 1.4	74.8 ± 1.7
	ATLAS_ALFA_fit	(h) ICHEP16	96.1 ± 0.9	24.3 ± 0.4	xxx
13	MBR	a	103.7 ± 1.9	30.2 ± 0.8	73.5 ± 1.3
	ATLAS	f&g	xxx	xxx	$73.1 \pm 0.9(\text{exp}) \pm 3.8(\text{extr}) \pm 6.6(\text{lumi})$
	ATLAS_ALFA_fit	(h) ICHEP16	xxx	xxx	$79.3 \pm 0.6(\text{exp}) \pm 2.5(\text{extr}) \pm 1.3(\text{lumi})$
	CMS	(h) ICHEP16	xxx	xxx	$71.3 \pm 0.6(\text{exp}) \pm 2.7(\text{extr}) \pm 0.1(\text{lumi})$

*Reference:

(a) <http://arxiv.org/abs/1205.1446>

(b) <http://arxiv.org/abs/1408.5778>

(c) <http://arxiv.org/abs/1204.5689>

(d) <http://iopscience.iop.org/article/10.1209/0295-5075/101/21004>

(e) <http://dx.doi.org/10.1103/PhysRevLett.111.012001>

(f) M. Trzebinski (ATLAS), DIS-2016 [7]-(a)

(g) H. Van Haevermaet (CMS), DIS-2016 [7]-(b)

(h) T. Sykora, *Cross sections summary*, ICHEP16 [8]

DIS-2017: MBR vs. TOTEM @ 2.76 TeV

<https://indico.cern.ch/event/568360/>

(from talk by Frigyes Nemes, slide #20)



TOTEM

σ_{tot} [mb]	σ_{el} [mb]	σ_{inel} [mb]
84.7 ± 3.3	21.8 ± 1.4	62.8 ± 2.9



MBR → 85.2 21.7 63.5
Syst. Uncertainty ~1.5% due to that in s_0

- ❑ Excellent agreement between TOTEM and MBR at 2.76 TeV
- ❑ Awaiting forthcoming results at 13 TeV from ATLAS, CMS, TOTEM

LHCC-2017: MBR vs. TOTEM @ 13 TeV

<https://indico.cern.ch/event/679087/> (from talk by K. Osterberg)



$$\sigma_{\text{tot}} = 110.6 \pm 3.4 \text{ mb}, \sigma_{\text{inel}} = 79.5 \pm 1.8 \text{ mb}, \sigma_{\text{el}} = 31.0 \pm 1.7 \text{ mb}$$

$$103.7 \pm 1.9$$

$$73.5 \pm 1.3$$

$$30.2 \pm 0.8$$

Conventional models (COMPETE) not able to describe simultaneously TOTEM σ_{tot} & ρ measurements \Rightarrow data compatible with t-channel exchange of a colourless QCD 3 gluon $J^{PC} = 1^{--}$ bound state ?

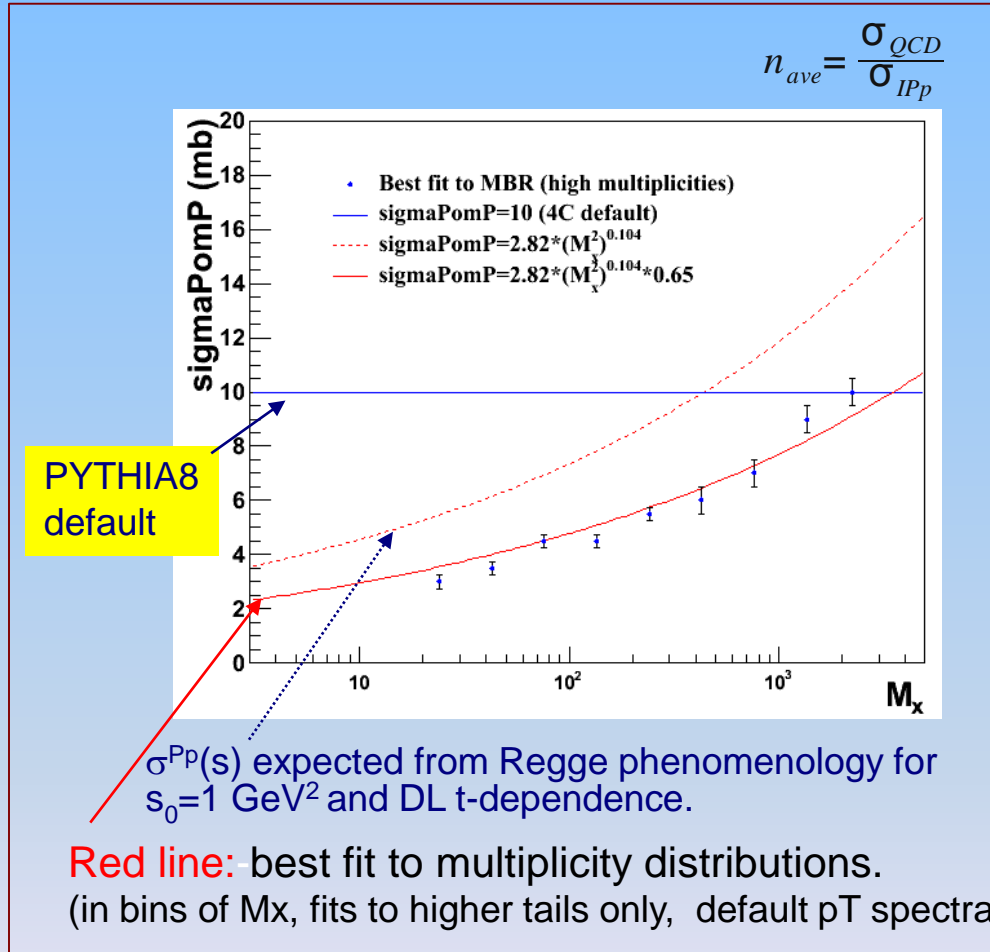
Physics quantity	Value		Total uncertainty
	$\rho = 0.14$	$\rho = 0.1$	
$B [\text{GeV}^{-2}]$	20.36		$5.3 \cdot 10^{-2} \oplus 0.18 = 0.19$
$\sigma_{\text{tot}} [\text{mb}]$	109.5	110.6	3.4
$\sigma_{\text{el}} [\text{mb}]$	30.7	31.0	1.7
$\sigma_{\text{inel}} [\text{mb}]$	78.8	79.5	1.8
$\sigma_{\text{el}}/\sigma_{\text{inel}}$	0.390		0.017
$\sigma_{\text{el}}/\sigma_{\text{tot}}$	0.281		0.009

**TOTEM paper \rightarrow
CERN-EP-2017-321
10 December 2017**

- Reasonable agreement between TOTEM and MBR predictions
- Possible Odderon effects not included in MBR

Pythia8-MBR Hadronization Tune

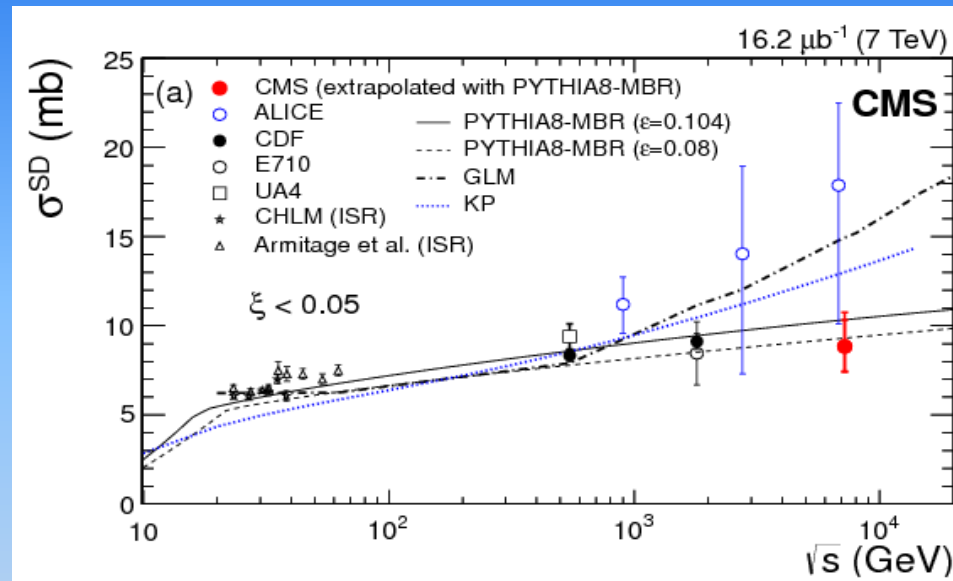
An example of the diffractive tuning of PYTHIA-8 to the RENORM-NBR model



R. Ciesielski, "Status of diffractive models", CTEQ Workshop 2013

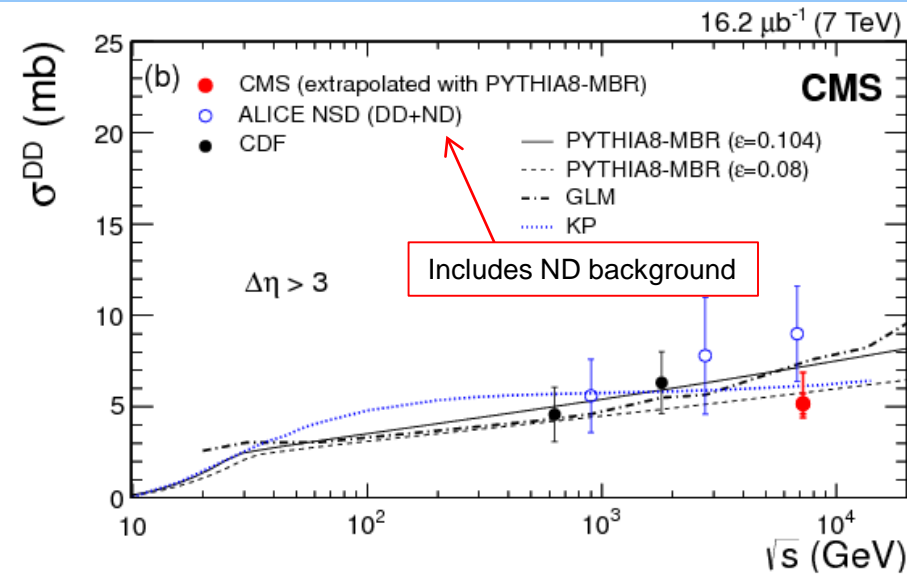
SD and DD x-Sections vs Models

<http://journals.aps.org/prd/abstract/10.1103/PhysRevD.92.012003>



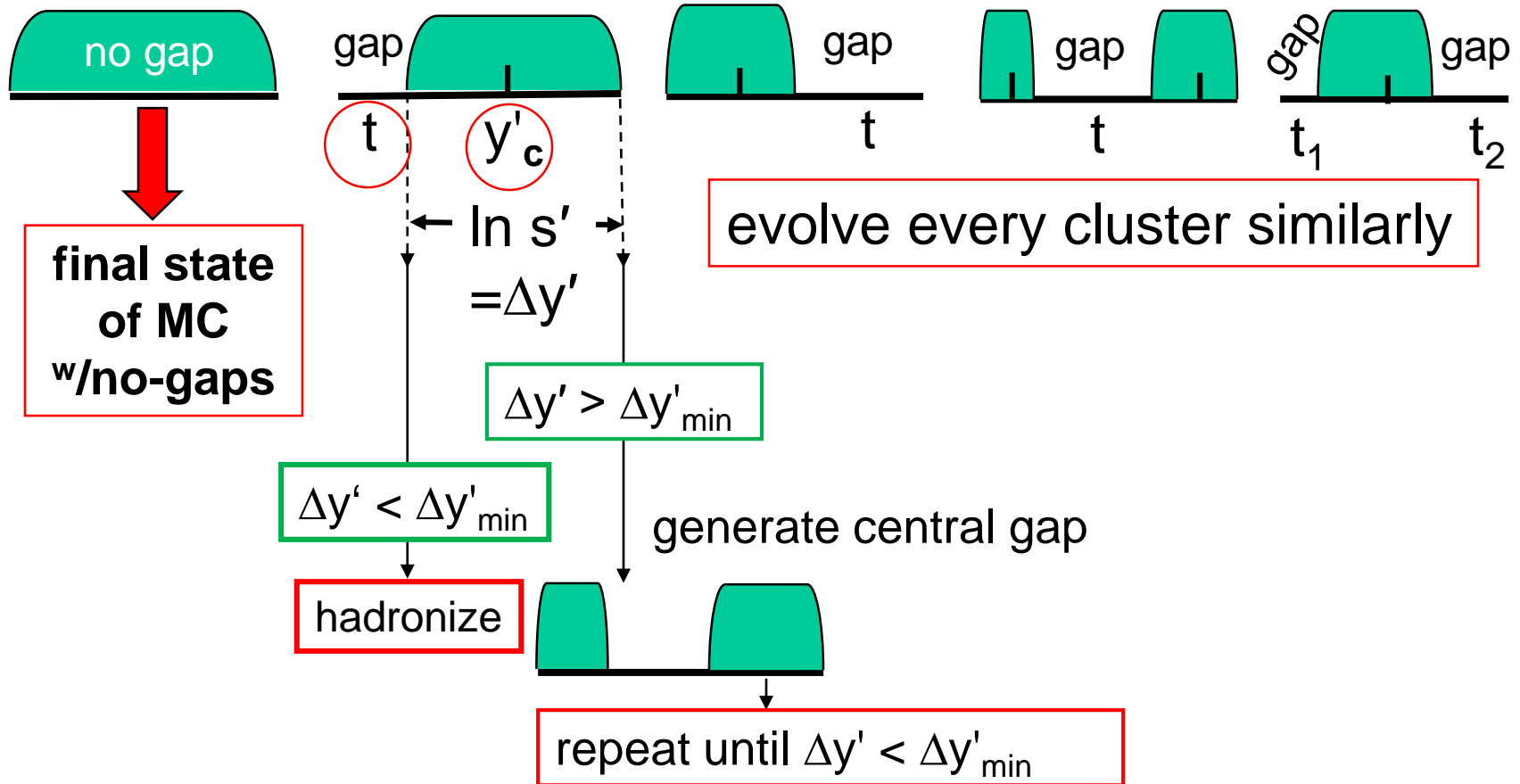
Single Diffraction

Double Diffraction



Monte Carlo Algorithm - Nesting

Profile of a pp Inelastic Collision



SUMMARY

- ❑ Review of RENORM predictions of diffractive physics
 - basic processes: SD1, SD2, DD, CD (DPE)
 - combined processes: multigap x-sections
 - ND → no diffractive gaps: the only final state to be tuned
 - ❑ Monte Carlo strategy for the LHC – “nesting”
- ❑ Precision RENORM σ_{tot} prediction ^W/tensor glue-ball model
- ❑ **ICHEP 2016**
 - ❑ At 8 TeV ATLAS and MBR in excellent agreement
 - ❑ Disagreement between TOTEM and MBR persists
 - ❑ At 13 TeV MBR lies comfortably (!) between the ATLAS and CMS
- ❑ **LHCC-201: NEW → TOTEM RESULTS at 8 and 13 TeV vs. MBR**
 - ❑ Agreement at 8 TeV, compatibility at 13 TeV
- ❑ **NESTING in MC simulation**

Thank you for your attention!