

# Precision RENORM / MBR Diffraction Predictions Tested by Recent LHC Results



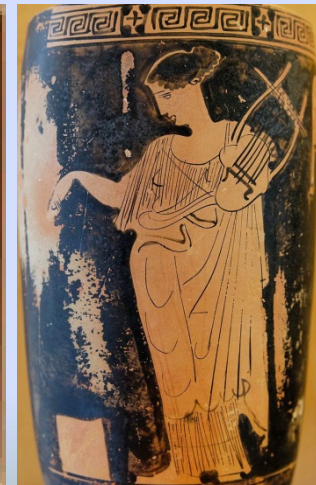
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<http://physics.rockefeller.edu/dino/my.html>

Member of



6<sup>th</sup> International Conference on New Frontiers in Physics ICNFP2017  
17-29 August 2017, Kolymbari, Crete, Greece → <http://indico.cern.ch/e/icnfp2017>



# 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  $p_1 p_2 \rightarrow p_1 + \text{gap} + X + \text{gap} + p_2$  Central Diffraction / DPE

## □ Renormalization $\rightarrow$ Unitarization

### ➤ **RENORM Model**

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



## □ **Total Cross Section:**

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



## □ **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>
- Low x 2017, Bari, Italy <https://indico.cern.ch/event/609299/>

### ➤ **THIS TALK: Updated experimental results**



# RENORM: Basic and Combined Diffractive Processes

acronym basic diffractive processes

**SD** <sub>$\bar{p}$</sub>   $\bar{p}p \rightarrow \bar{p} + \text{gap} + [p \rightarrow X_p],$

**SD** <sub>$p$</sub>   $\bar{p}p \rightarrow [\bar{p} \rightarrow X_{\bar{p}}] + \text{gap} + p,$

**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

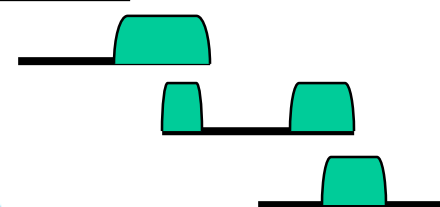
**SDD** <sub>$\bar{p}$</sub>   $\bar{p}p \rightarrow \bar{p} + \text{gap} + X_c + \text{gap} + [p \rightarrow X_p],$

**SDD** <sub>$p$</sub>   $\bar{p}p \rightarrow [\bar{p} \rightarrow X_{\bar{p}}] + \text{gap} + X_c + \text{gap} + p.$

particles



rapidity distributions



DD

SD

DD

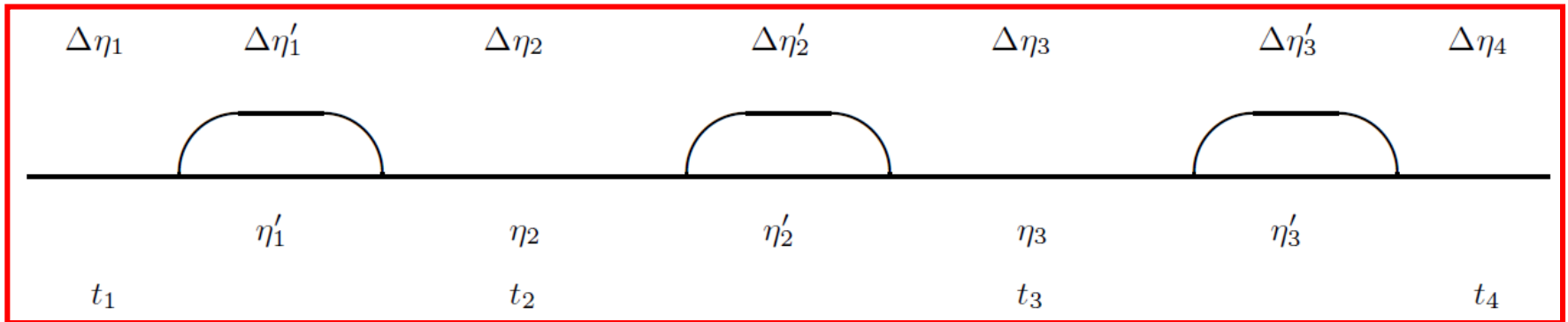
SD

BASIC  
COMBINED

Cross sections analytically expressed in arXiv:

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

4-gap diffractive processes-Snowmass 2001

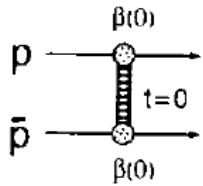


# Regge Theory: Values of $s_0$ & $g_{PPP}$ ?

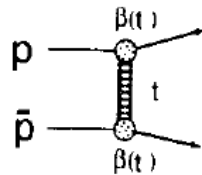
KG-PLB 358, 379 (1995)

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

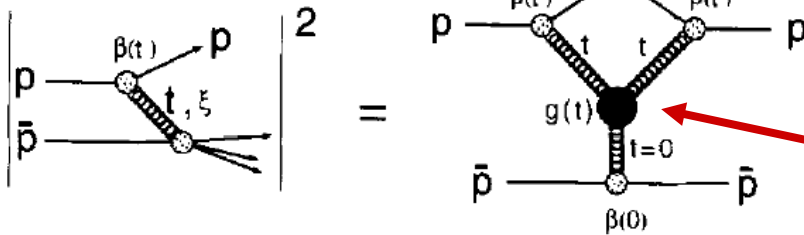
TOTAL CROSS SECTION



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!

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

□  $\sigma_{sd}$  grows faster than  $\sigma_t$  as  $s$  increases \*

→ **unitarity violation at high  $s$**

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

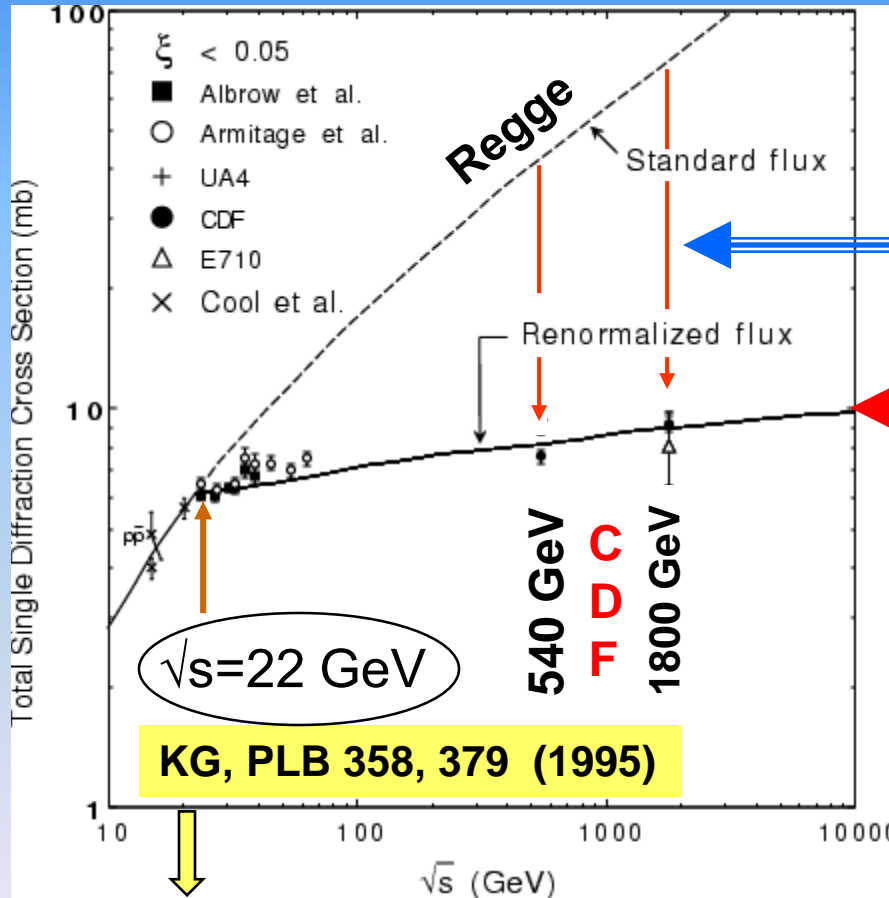
□ **the unitarity limit is already reached at  $\sqrt{s} \sim 2$  TeV**

□ **need unitarization**

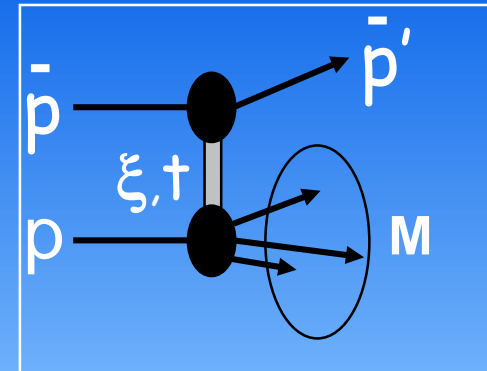
\* similarly for  $(d\sigma_{el}/dt)_{t=0}$  w.r.t.  $\sigma_b$  but this is handled differently in RENORM

# 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>



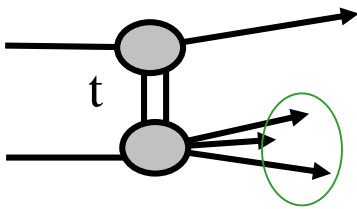
Factor of  $\sim 8$  ( $\sim 5$ )  
suppression at  
 $\sqrt{s} = 1800$  (540) GeV

**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 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

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

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

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

← renormalization 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  $N(s, s_o)$  to unity  
 → determines  $s_o$

# M<sup>2</sup> - Distribution: Data

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

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

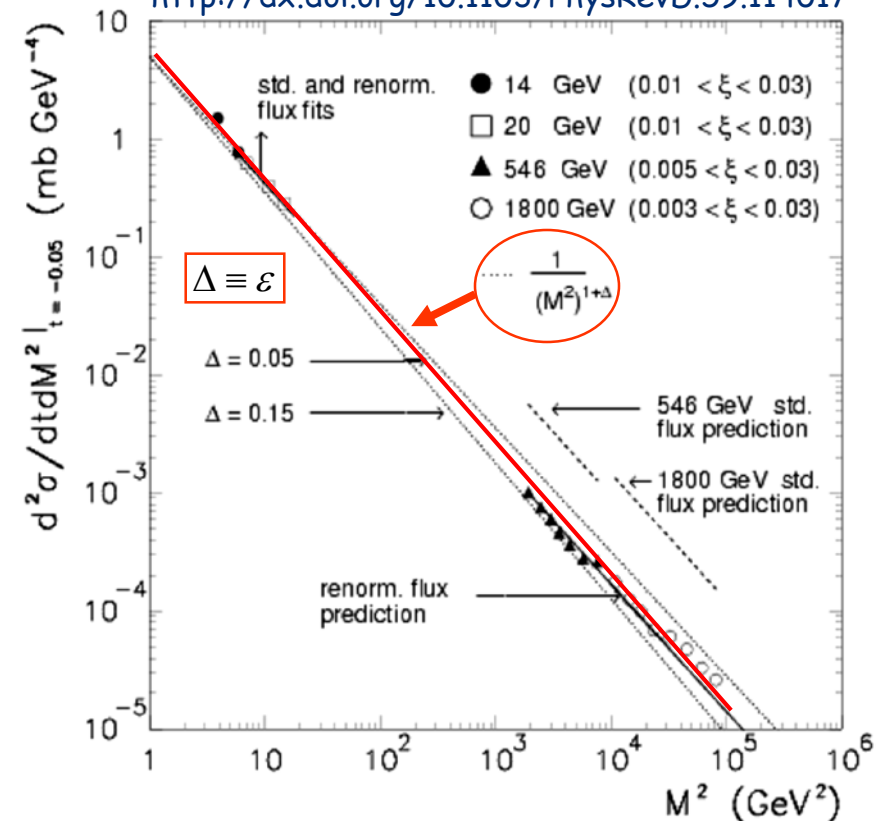
**KG&JM, PRD 59 (1999) 114017**

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

Regge

**data**

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



→ factorization breaks down to ensure M<sup>2</sup>-scaling

# Scale $s_0$ and $PPP$ Coupling

**Pomeron flux:** interpreted as a gap probability

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

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

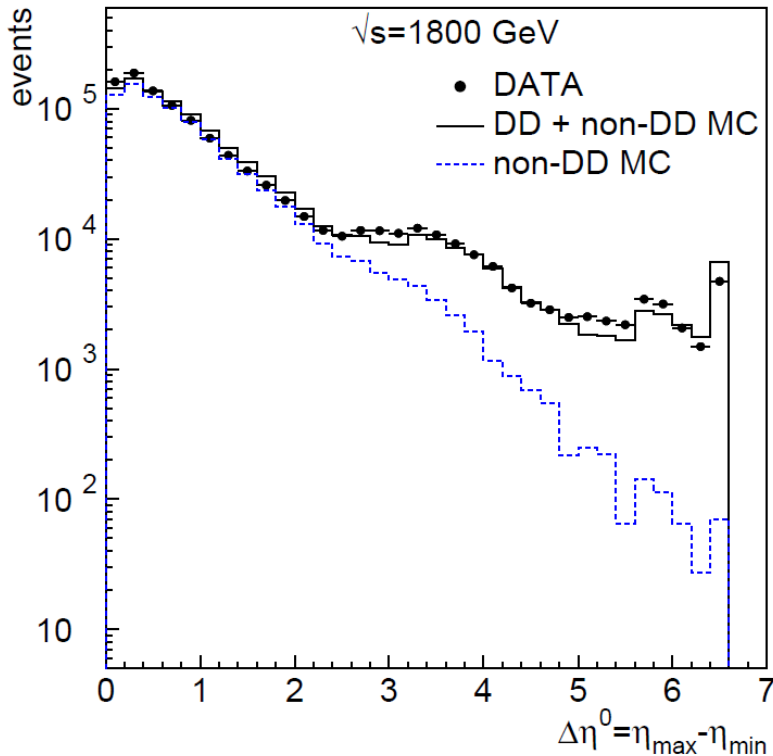
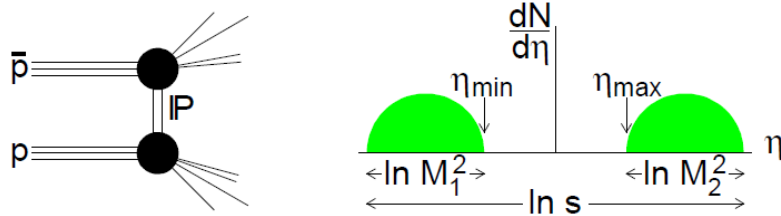
$$\frac{d^2 \sigma_{SD}}{dt d\xi} = f_{IP/p}(t, \xi) \sigma_{IP/p}(s\xi)$$

Pomeron-proton x-section

- Two free parameters:  $s_0$  and  $g_{PPP}$
- Obtain product  $g_{PPP} s_0^{\epsilon/2}$  from  $\sigma_{SD}$
- 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>



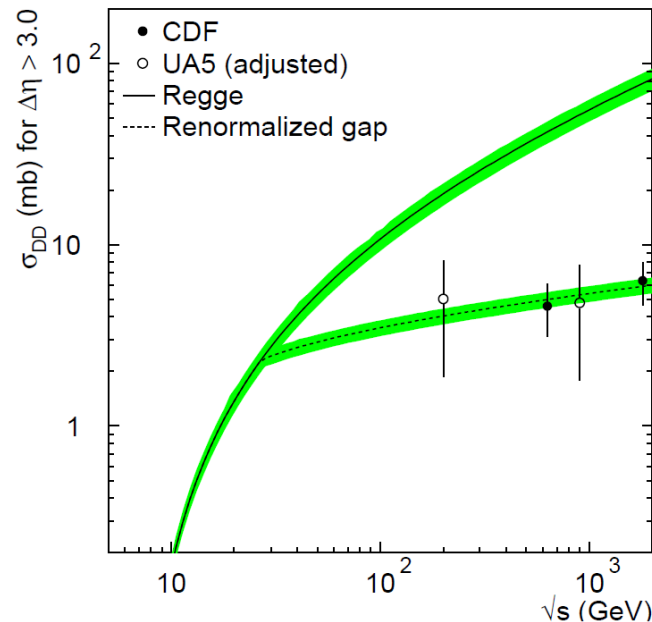
**Regge factorization**

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

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

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

gap probability x-section

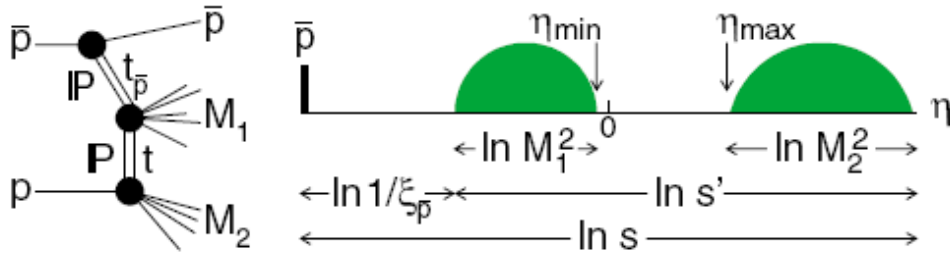


← **Regge**

← **RENORM**

x-section  
divided by  
integrated  
gap prob.

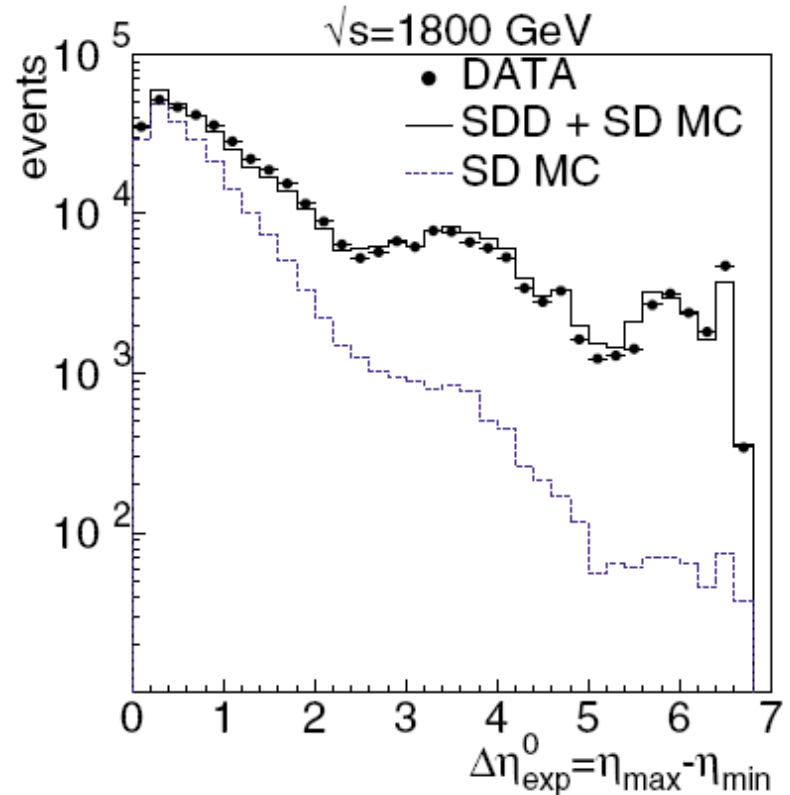
# SDD at CDF



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

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

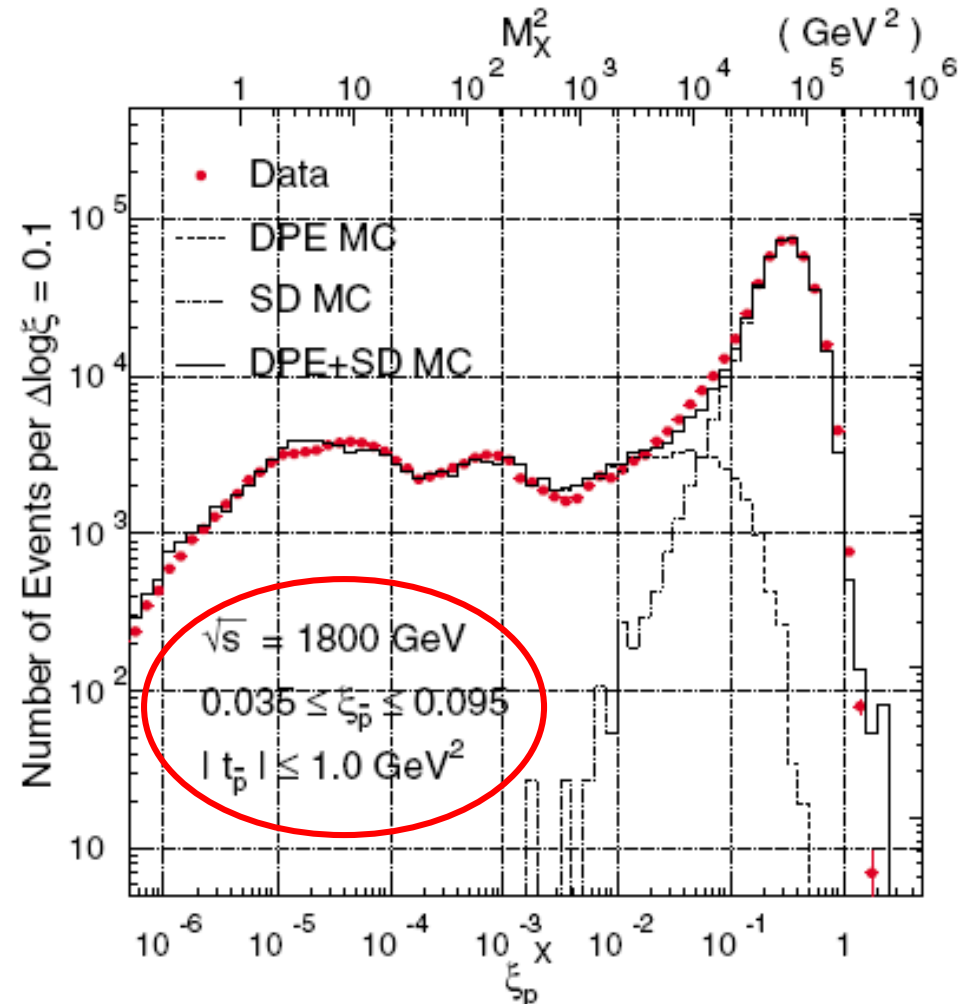
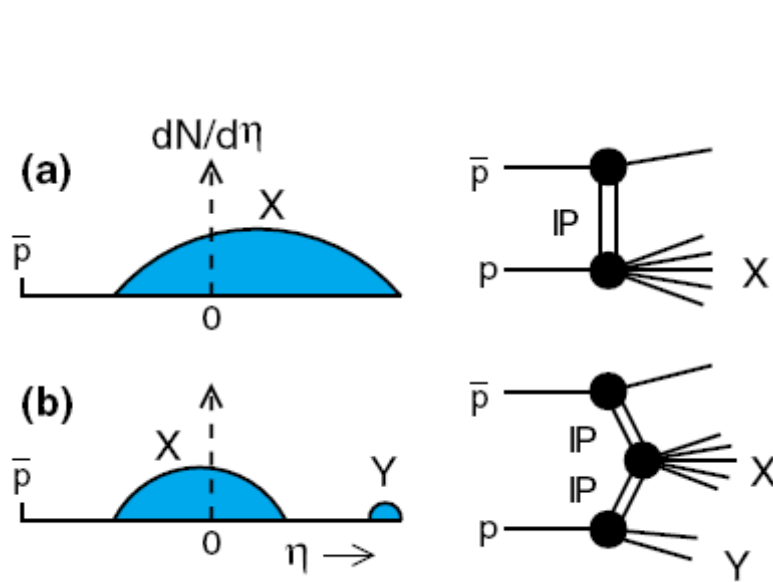
- Excellent agreement between data and MBR (MinBiasRockefeller) MC



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

# 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>

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

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

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

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

# 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. Covolan<sup>1</sup>, J. Montanha<sup>2</sup>, K. Goulios<sup>3</sup> **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>

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

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

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

➤ 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

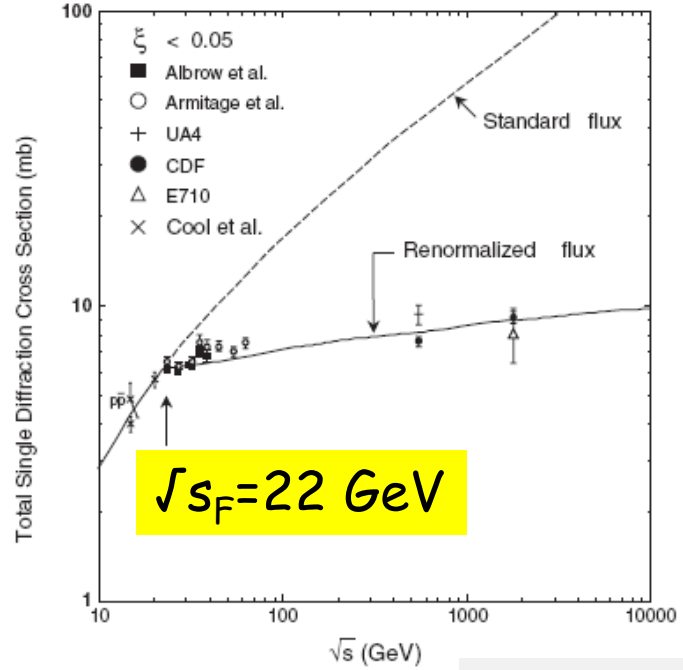
$$\sigma_t(s > s_F) = \sigma_t(s_F) + \frac{\pi}{m^2} \cdot \ln^2 \frac{s}{s_F}$$

- This formula should be valid above the *knee* in  $\sigma_{sd}$  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  $\text{mb}^{-1}$ .
- Note that contributions from Reggeon exchanges at  $\sqrt{s} = 1800$  GeV are negligible, as can be verified from the global fit of CGM.
- Obtain the total cross section at the LHC:

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

**$98 \pm 8$  mb at 7 TeV  
 $109 \pm 12$  mb at 14 TeV**

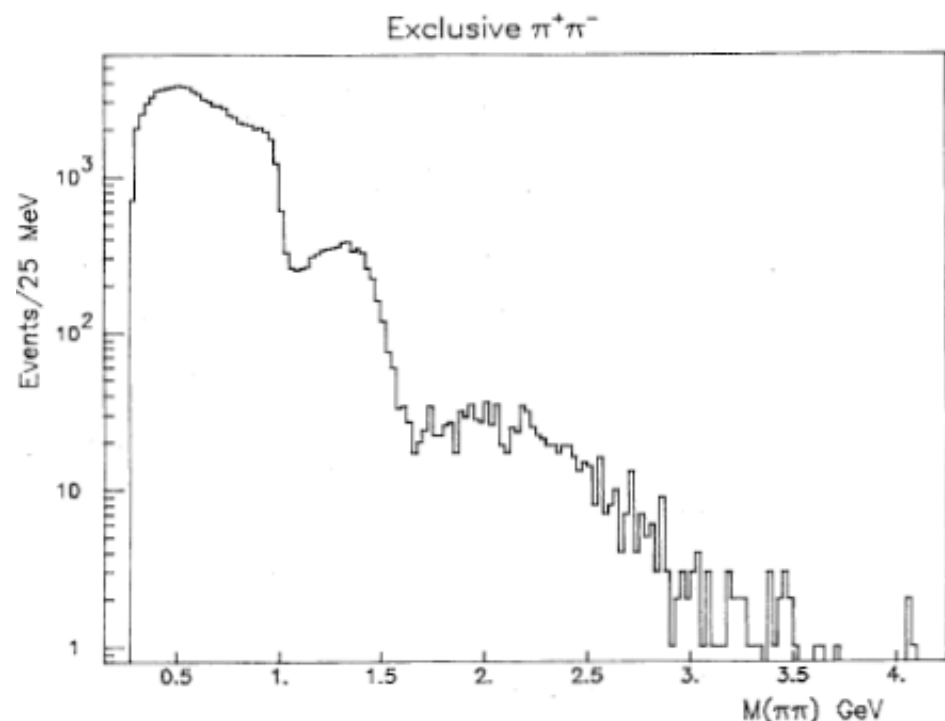
**Uncertainty is due to  $s_o$**



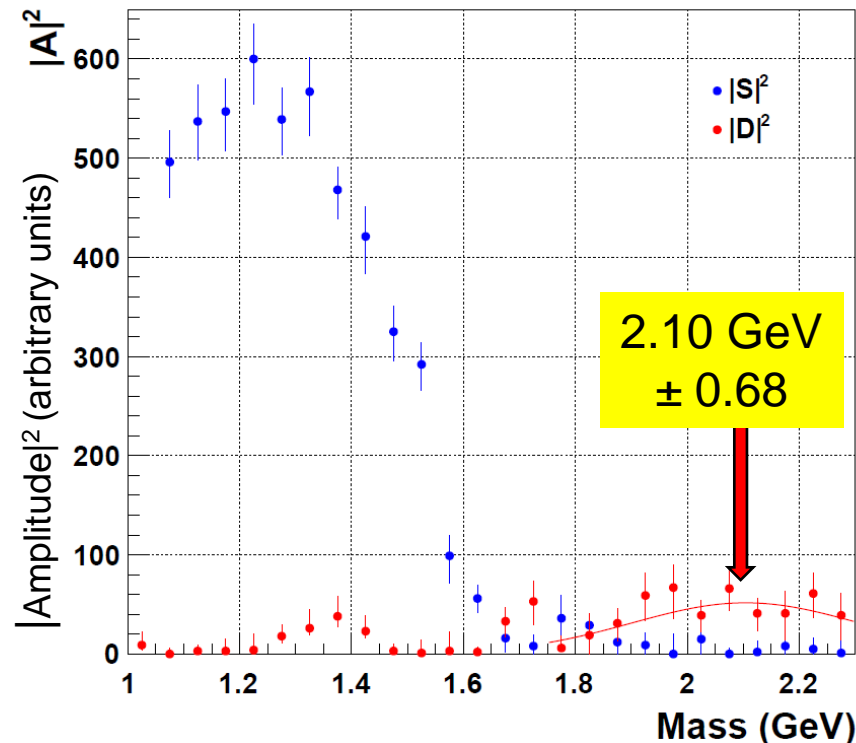
# Reduce Uncertainty in $s_0$

<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

□  $\rightarrow s_0 = 4.42 \pm 0.34$  GeV<sup>2</sup>

20% increase in  $s_0$   
→ x-sections decrease

# Predictions vs Measurements <sup>with/reduced</sup> Uncertainty in $s_0$

From my Moriond-2016 Talk

$\sqrt{s}$	MBR/Exp	$\sigma_{\text{tot}}$	$\sigma_{\text{el}}$	$\sigma_{\text{inel}}$
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  $\sigma_{el}$  is larger than the ATLAS and the TOTEM\_lum\_Ind measurements by  $\sim 2$  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  $\sigma_{el}$  prediction would lead to a larger  $\sigma_{inel}$ . This interplay between  $\sigma_{el}$  and  $\sigma_{inel}$  should be kept in mind as more results of  $\sigma_{el}$  and  $\sigma_{tot}$  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 ATLAS-ALFA fit	4 ICHEP16	101.7±2.9 <b>96.1±0.9</b>	27.1±1.4 24.3±0.4	74.7±1.7
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) <b>79.3±0.6(exp) ±1.3(lumi) ±2.5(extr)</b>
	CMS	7+ICHEP16			<b>71.3±0.5 (exp) ±2.1 (lumi) ±2.7 (extr)</b>

← 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*	$\sigma_{\text{tot}}$ (mb)	$\sigma_{\text{el}}$ (mb)	$\sigma_{\text{inel}}$ (mb)
7	MBR	a	$95.4 \pm 1.2$	$26.4 \pm 0.3$	$69.0 \pm 1.0$
	ATLAS	b	$95.35 \pm 1.36$	$24.00 \pm 0.60$	$71.34 \pm 0.90$
	TOTEM	c	$101.7 \pm 1.36$	$27.1 \pm 1.4$	$74.7 \pm 1.7$
	TOTEM_Lum_ind	d	$98.0 \pm 2.5$	$24.00 \pm 0.60$	$72.9 \pm 1.5$
8	MBR	a	$97.1 \pm 1.4$	$27.2 \pm 0.4$	$69.9 \pm 1.0$
	TOTEM	e	$101.7 \pm 2.9$	$27.1 \pm 1.4$	$74.8 \pm 1.7$
	ATLAS_ALFA_fit	(h) ICHEP16	$96.1 \pm 0.9$	$24.3 \pm 0.4$	xxx
13	MBR	a	$103.7 \pm 1.9$	$30.2 \pm 0.8$	$73.5 \pm 1.3$
	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

$\sigma_{\text{tot}}$ [mb]	$\sigma_{\text{el}}$ [mb]	$\sigma_{\text{inel}}$ [mb]
$84.7 \pm 3.3$	$21.8 \pm 1.4$	$62.8 \pm 2.9$

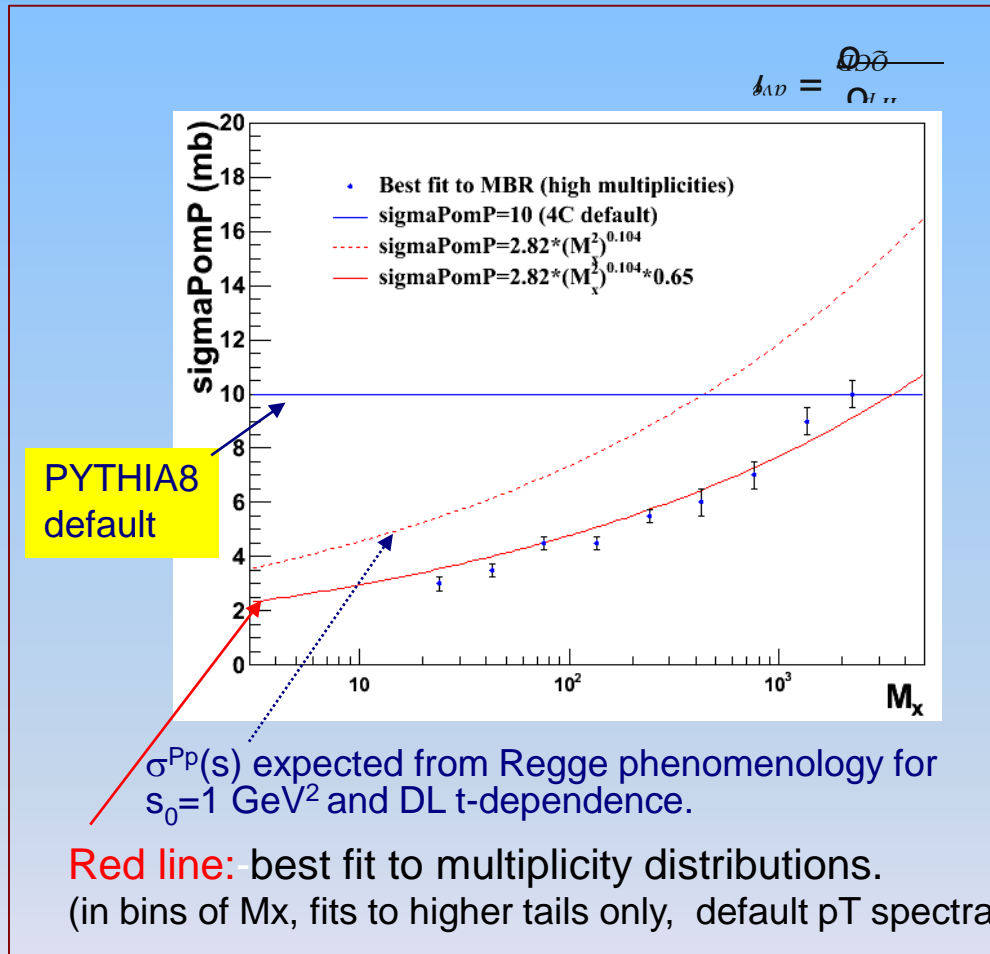


MBR → 85.2                      21.7                      63.5  
Syst. Uncertainty ~1.5% due to that in  $s_0$

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

# Pythia8-MBR Hadronization Tune

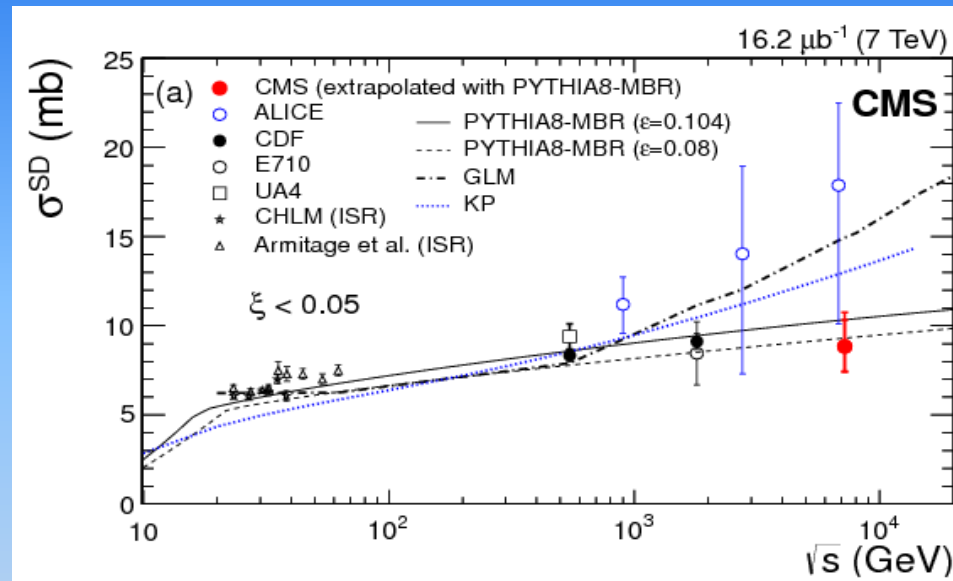
An example of the diffractive tuning of PYTHIA-8 to the RENORM-NBR model



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

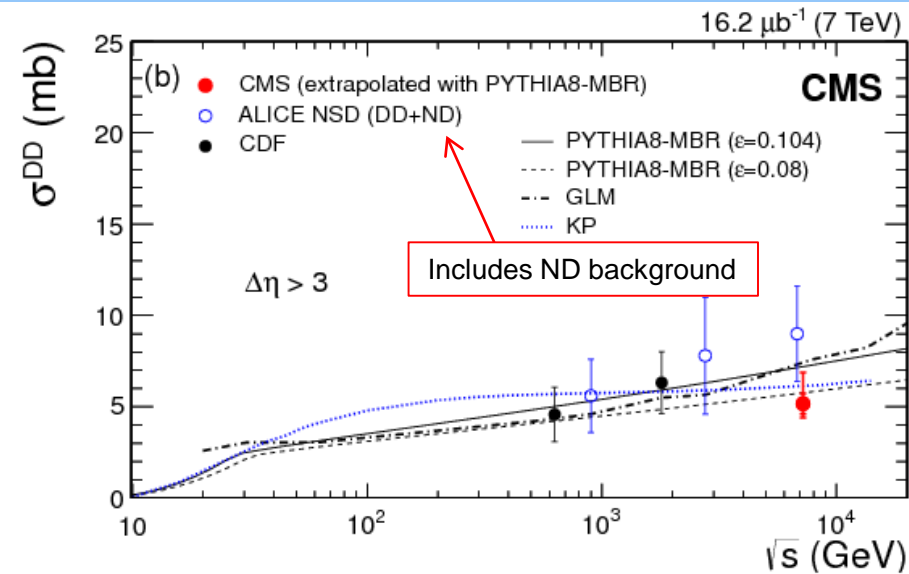
# SD and DD x-Sections vs Models

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



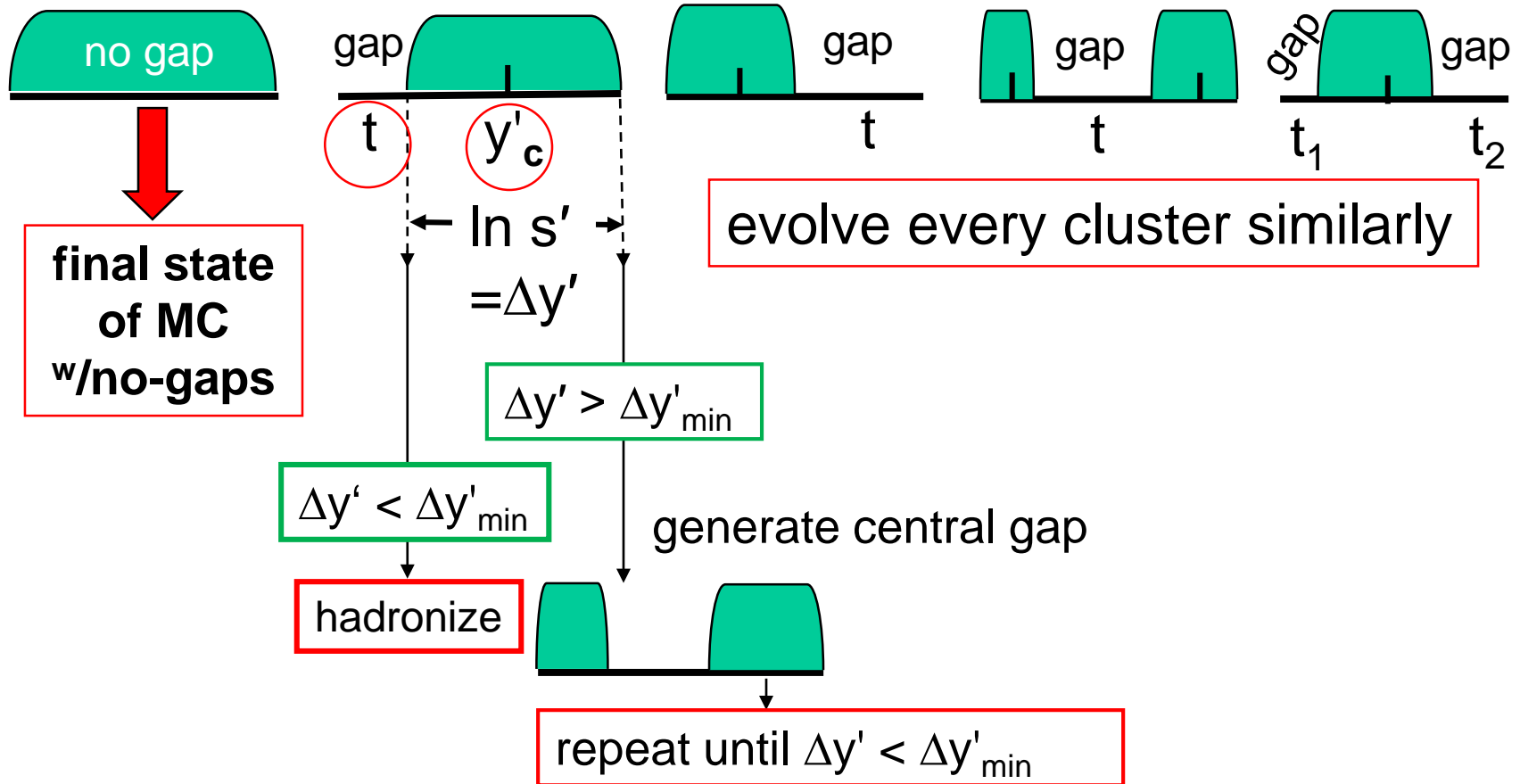
Single Diffraction

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  $\sigma_{\text{tot}}$  prediction <sup>W</sup>/tensor glue-ball model
- ❑ ICHEP 2016
  - ❑ At 8 TeV ATLAS and MBR in excellent agreement
  - ❑ Disagreement TOTEM and MBR persists
  - ❑ At 13 TeV MBR lies comfortably (!) between the ATLAS and CMS
- ❑ DIS 2017
  - ❑ TOTEM cross sections at 2.76 TeV in excellent agreement with MBR
- ➔ Awaiting the (re)analysis of existing data at 13 TeV to compare to MBR

*Thank you for your attention!*