Diffraction Results at LHC: Solving a Puzzle Using Precision RENORM Predictions

Konstantin Goulianos
The Rockefeller University
http://physics.rockefeller.edu/dino/my.html

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  - DD $p_1p_2 \rightarrow X_1$+gap+X_2 Double Diffraction / Double Dissociation
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- **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**
- MIAMI-2017, Dec. 13-19, https://cgc.physics.miami.edu/Miami2017/Goulianos2017.pdf ← similar talk
- 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

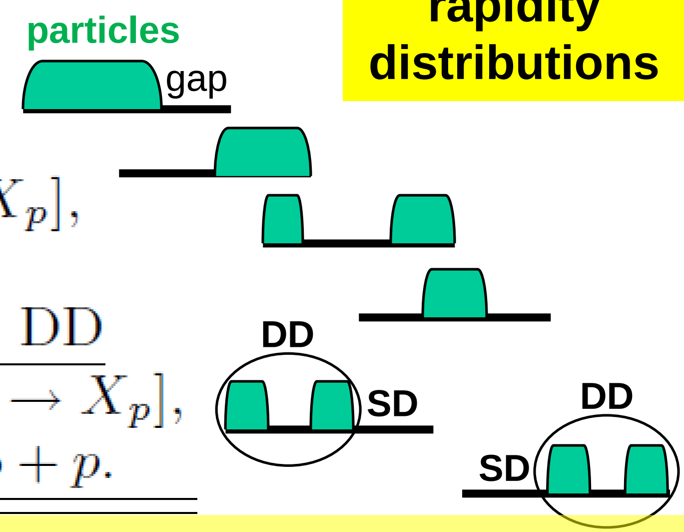
RENORM: Basic and Combined Diffractive Processes

BASIC

acronym	basic diffractive processes
$\mathbf{SD}_{\bar p}$	$\bar pp \to \bar p + \text{gap} + [p \to X_p],$
$\mathbf{SD}_p$	$\bar pp \to [\bar p \to X_{\bar p}] + \text{gap} + p,$
$\mathbf{DD}$	$\bar pp \to [\bar p \to X_{\bar p}] + \text{gap} + [p \to X_p],$
$\mathbf{DPE}$	$\bar pp \to \bar p + \text{gap} + X_c + \text{gap} + p,$
	2-gap combinations of SD and DD
$\mathbf{SDD}_{\bar p}$	$\bar pp \to \bar p + \text{gap} + X_c + \text{gap} + [p \to X_p],$
$\mathbf{SDD}_p$	$\bar pp \to [\bar p \to X_{\bar p}]\text{gap} + X_c + \text{gap} + p.$

COMBINED

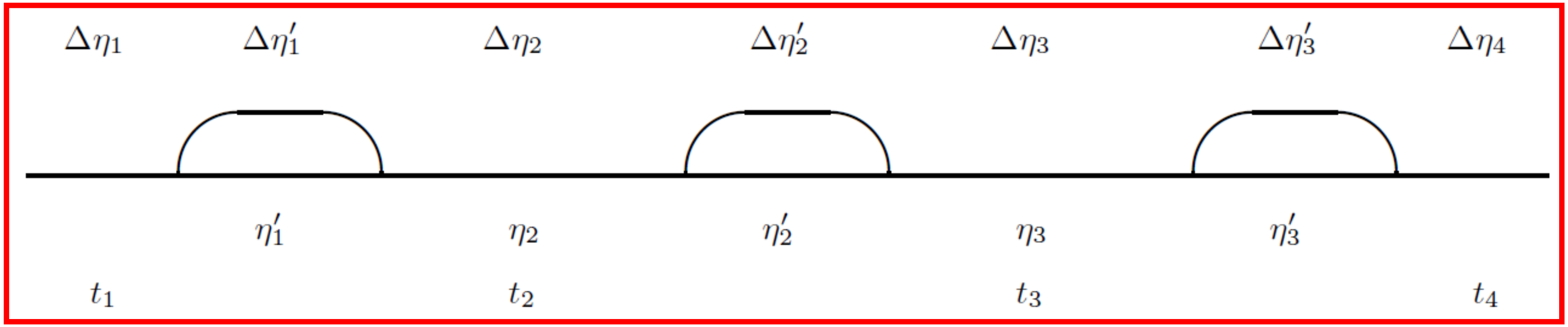
rapidity distributions



Cross sections analytically expressed in arXiv::

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

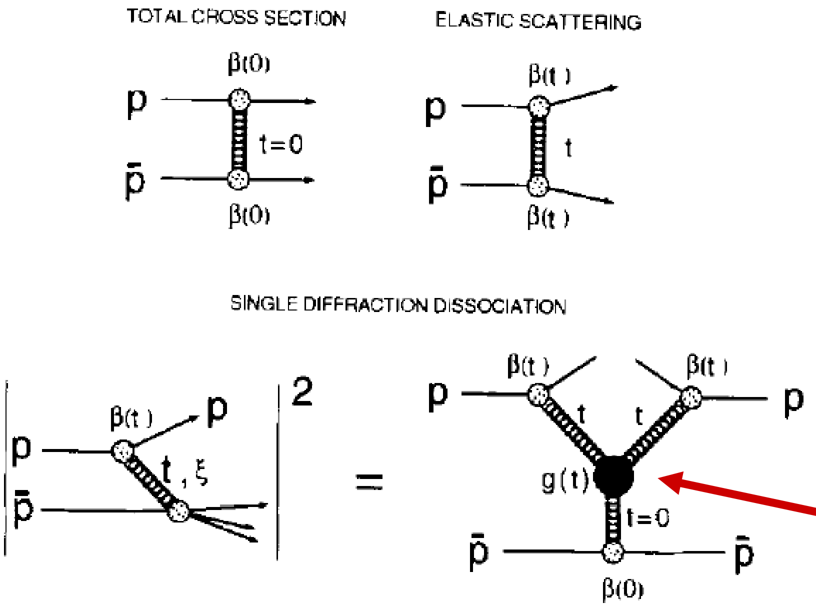
4-gap diffractive processes-Snowmass 2001



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

KG-PLB 358, 379 (1995)

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



Parameters:

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

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

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

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

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

$$\frac{d^2\sigma_{sd}}{dt\,d\xi} = \frac{\beta_1^2(t)}{16\pi}\xi^{1-2\alpha(t)}\left[\beta_2(0)\, g(t)\left(\frac{s'}{s'_0}\right)^{\alpha(0)-1}\right] = f_{\mathcal{P}/p}(\xi,t)\,\sigma_T^{\mathcal{P}\bar{p}}(s',t) \quad (4)$$

Theoretical Complication: Unitarity!

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

- ❑ 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)

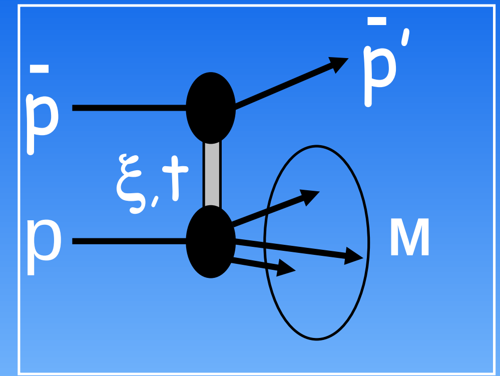
- ❑ the unitarity limit is already reached at $\sqrt{s}$ ~ 2 TeV

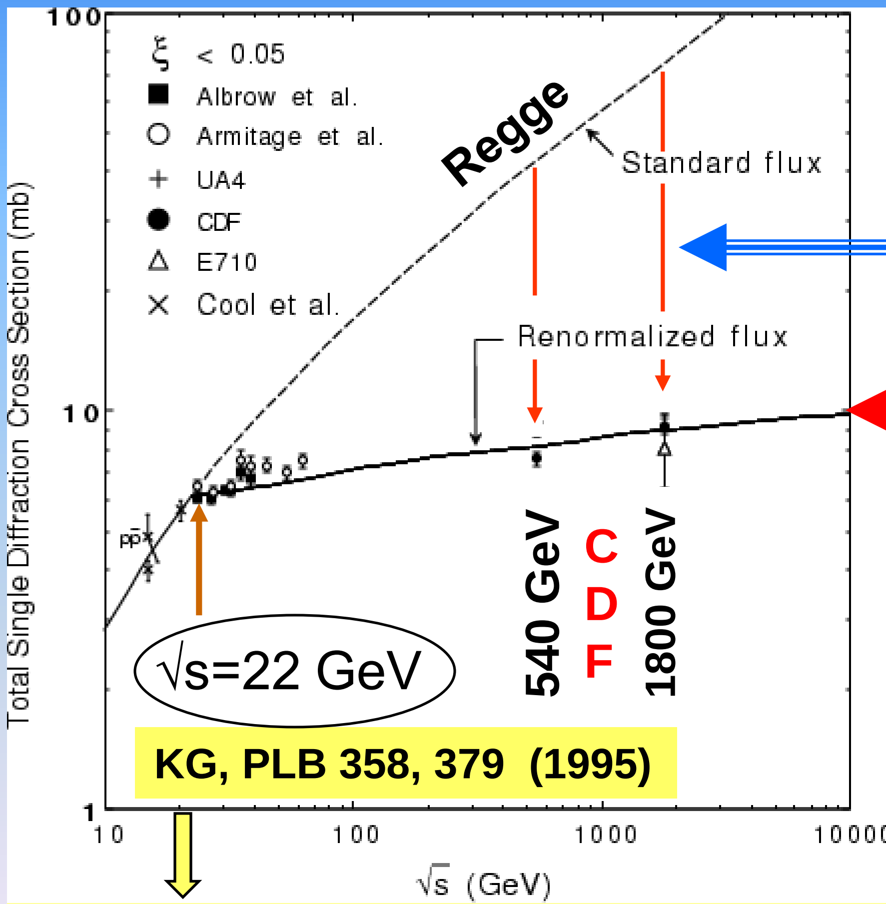
- ❑ need unitarization

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

FACTORIZATION BREAKING IN SOFT DIFFRACTION

Diffractive x-section suppressed relative to Regge prediction as √s increases





Factor of ~8 (~5) suppression at √s = 1800 (540) GeV

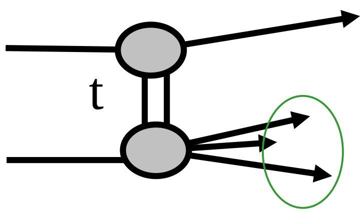
RENORMALIZATION

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

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

Single Diffraction Renormalized - 1

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



2 independent variables: $t, \Delta y$

color factor

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

$$\frac{d^2\sigma}{dt\, d\Delta y} = \underbrace{C \cdot F_p^2(t) \cdot \left\{ e^{(\varepsilon+\alpha' t)\Delta y} \right\}^2}_{\text{gap probability}} \cdot \kappa \cdot \underbrace{\left\{ \sigma_o\, e^{\varepsilon\, \Delta y'} \right\}}_{\text{sub-energy x-section}}$$

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 ➔

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

KG&JM, PRD 59 (114017) 1999
http://dx.doi.org/10.1103/PhysRevD.59.114017

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

Single Diffraction Renormalized - 3

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

$$b = b_0 + 2\alpha' \ln\frac{s}{M^2}$$

$$s_o^{\mathrm{CMG}} = (3.7 \pm 1.5)\ \mathrm{GeV}^2$$

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

← affects only the *s*-dependence

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

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

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

M^2 - Distribution: Data

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

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

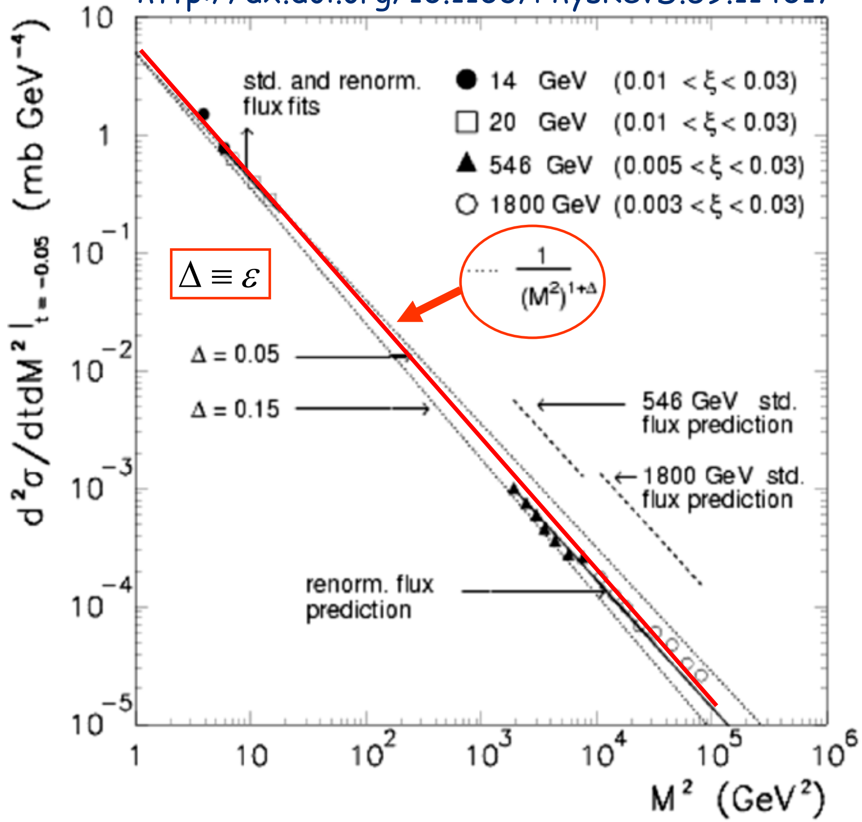
KG&JM, PRD 59 (1999) 114017

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

Regge

data

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

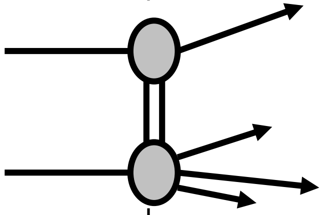


➔ factorization breaks down to ensure M^2-scaling

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



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

s_o^{ε}

$s_o^{-\varepsilon/2} \cdot g_{PPP}(t)$

Pomeron-proton x-section

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

DD at CDF

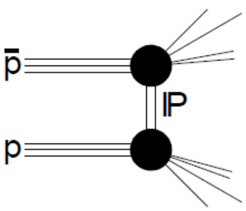
http://physics.rockefeller.edu/publications.html

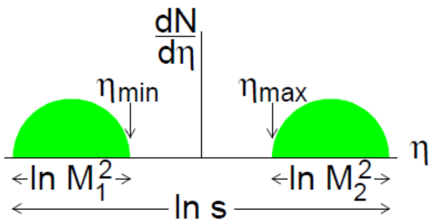
http://dx.doi.org/10.1103/PhysRevLett.87.141802

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

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

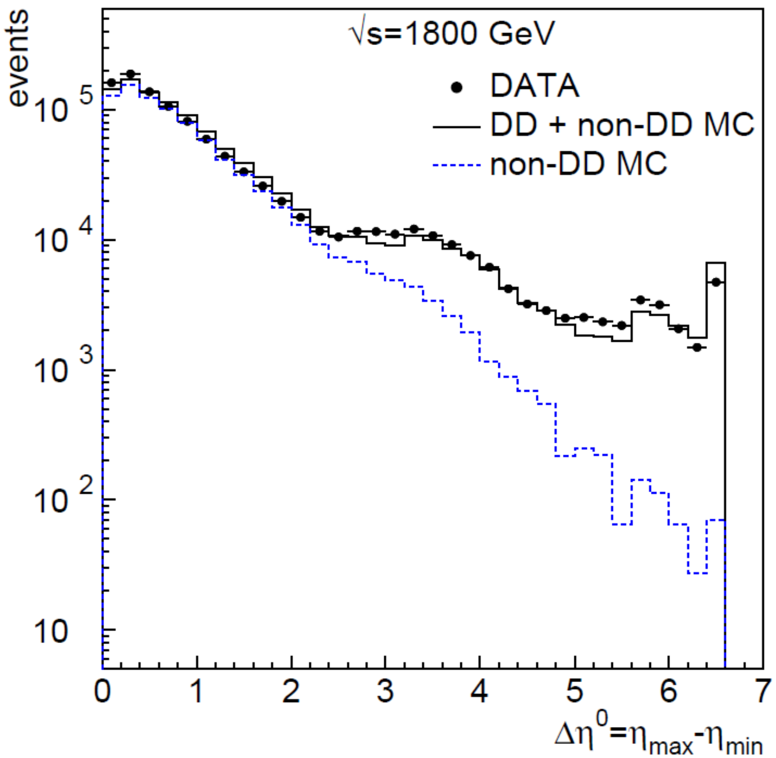
Regge factorization

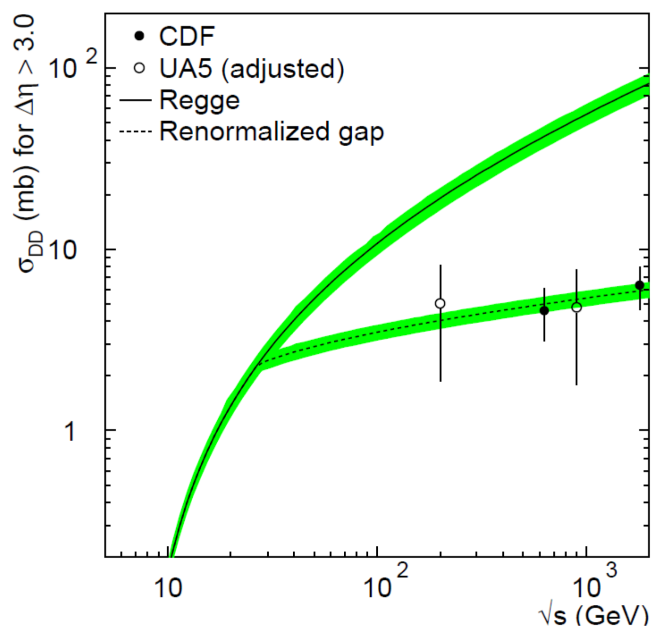




$$\frac{d^3\sigma_{DD}}{dt\,d\Delta\eta\,d\eta_c} = \left[\frac{\kappa\beta^2(0)}{16\pi}\,e^{2[\alpha(t)-1]\Delta\eta}\right]\left[\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right]$$

gap probability   x-section



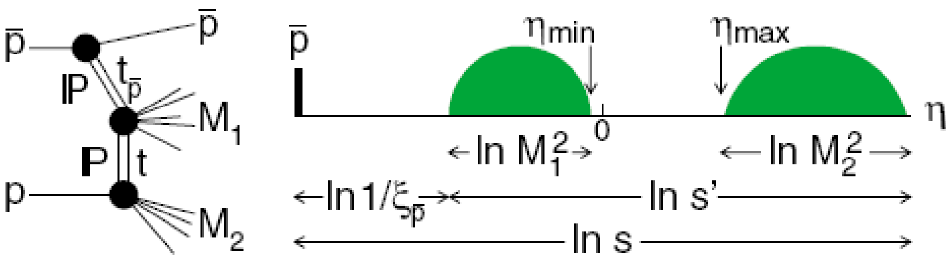


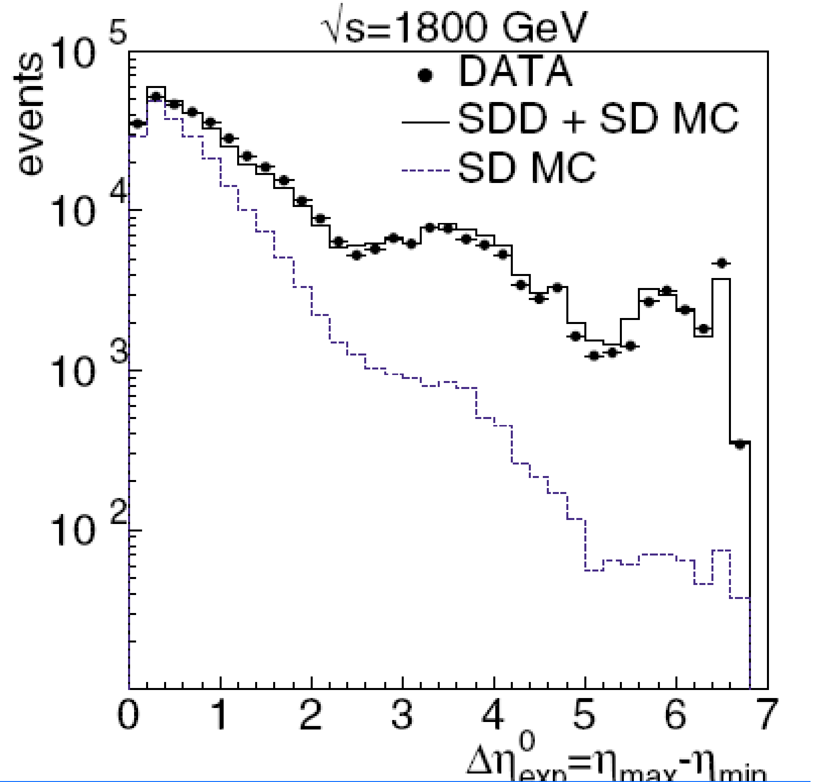
← Regge

Regge
← RENORM

x-section divided by integrated gap prob.

SDD at CDF





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

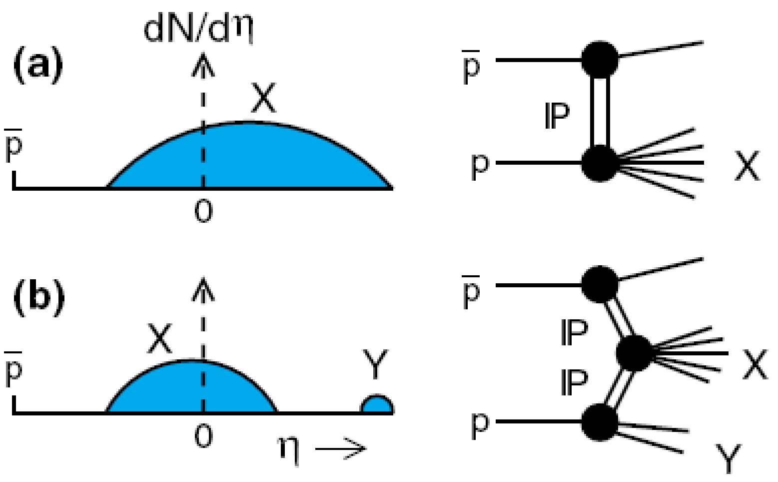
http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.91.011802

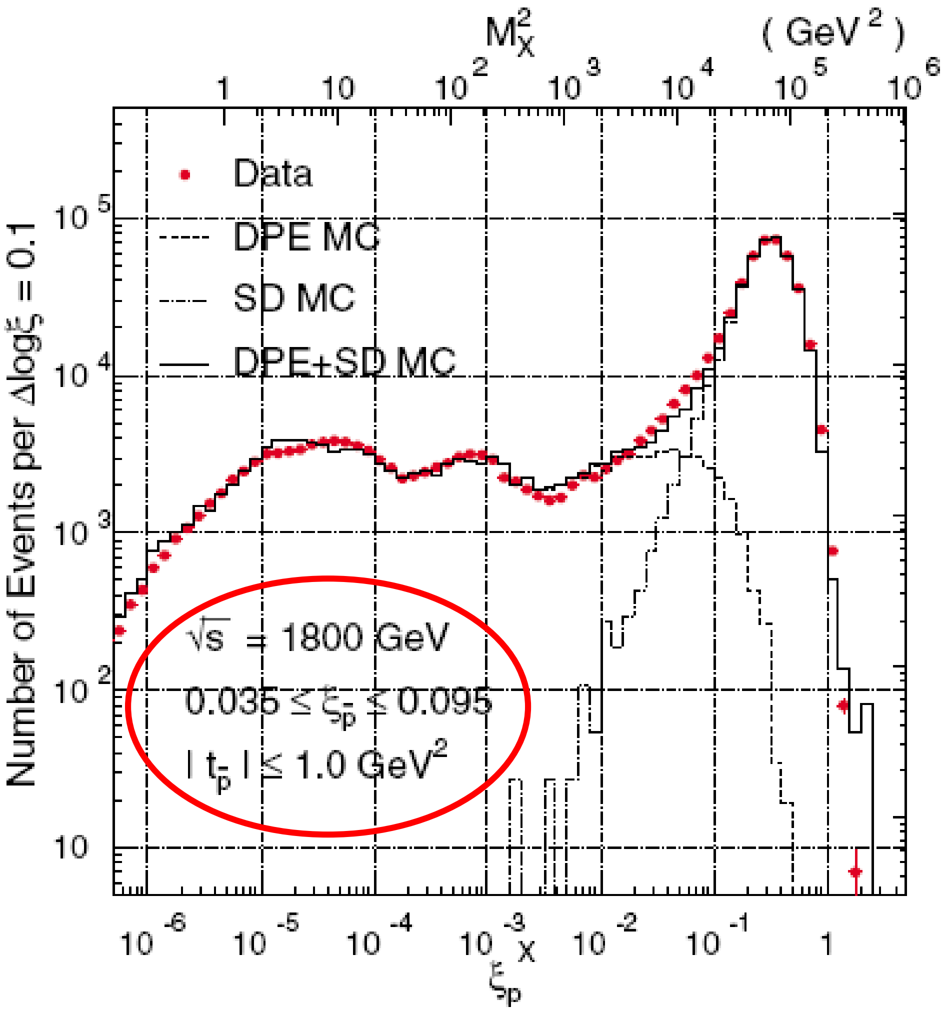
- Excellent agreement between data and MBR (MinBiasRockefeller) MC

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

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 Difractive Cross Sections

MBR MC Simulation in PYTHIA8➔http://arxiv.org/abs/1205.1446

$$\frac{d^2\sigma_{SD}}{dt d\Delta y} = \frac{1}{N_{\rm gap}(s)}\left[\frac{\beta^2(t)}{16\pi}e^{2[\alpha(t)-1]\Delta y}\right]\cdot\left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\},$$

$$\frac{d^3\sigma_{DD}}{dt d\Delta y dy_0} = \frac{1}{N_{\rm gap}(s)}\left[\frac{\kappa\beta^2(0)}{16\pi}e^{2[\alpha(t)-1]\Delta y}\right]\cdot\left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\},$$

$$\frac{d^4\sigma_{DPE}}{dt_1 dt_2 d\Delta y dy_c} = \frac{1}{N_{\rm gap}(s)}\left[\Pi_i\left[\frac{\beta^2(t_i)}{16\pi}e^{2[\alpha(t_i)-1]\Delta y_i}\right]\right]\cdot\kappa\left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\}$$

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

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

α_1=0.9, α_2=0.1, b_1=4.6 GeV^{-2}, b_2=0.6 GeV^{-2}, s'=s $e^{-\Delta y}$, κ=0.17,
$\kappa\beta^2(0)=\sigma_0$, s_0(units)=1GeV^2, σ_0=2.82 mb or7.25 GeV^{-2}

Total, Elastic, and Total Inelastic x-Sections

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

CMG➔ R.J.M. Covolan [1], J. Montanha [2], K. Goulianos [3]
The Rockefeller University, 1230 York Avenue, New York, NY 10021, USA
PLB 389, 196 (1996)

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

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

KG MORIOND-2011 http://moriond.in2p3.fr/QCD/2011/proceedings/goulianos.pdf

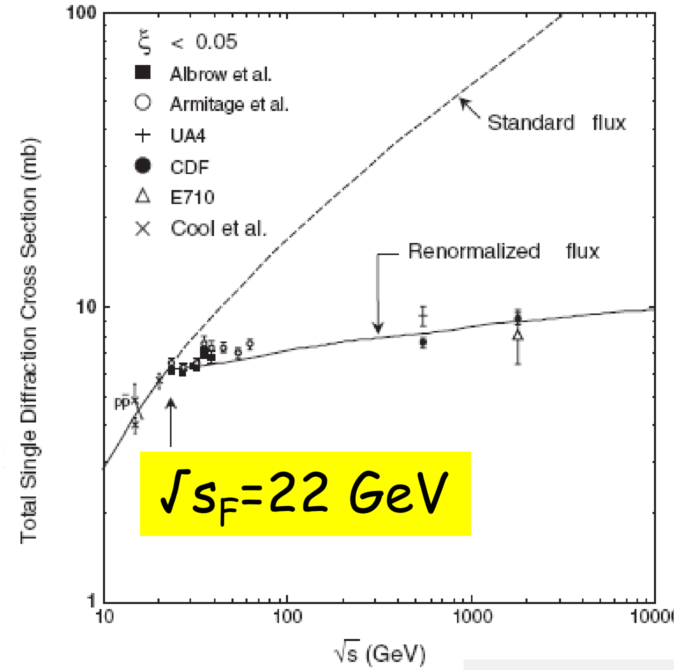
$$\sqrt{s^{\rm CDF}} = 1.8 \text{ TeV}, \ \sigma_{\rm tot}^{\rm CDF} = 80.03 \pm 2.24 \text{ mb}$$

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

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

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

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:

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

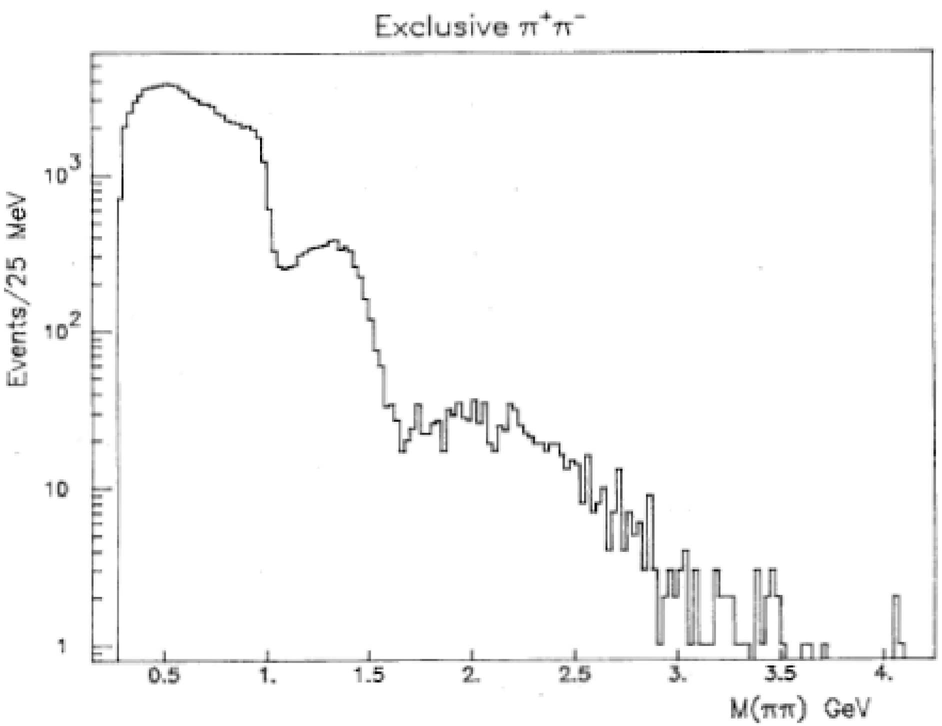
98 ± 8 mb at 7 TeV
109 ±12 mb at 14 TeV

Uncertainty is due to s_o

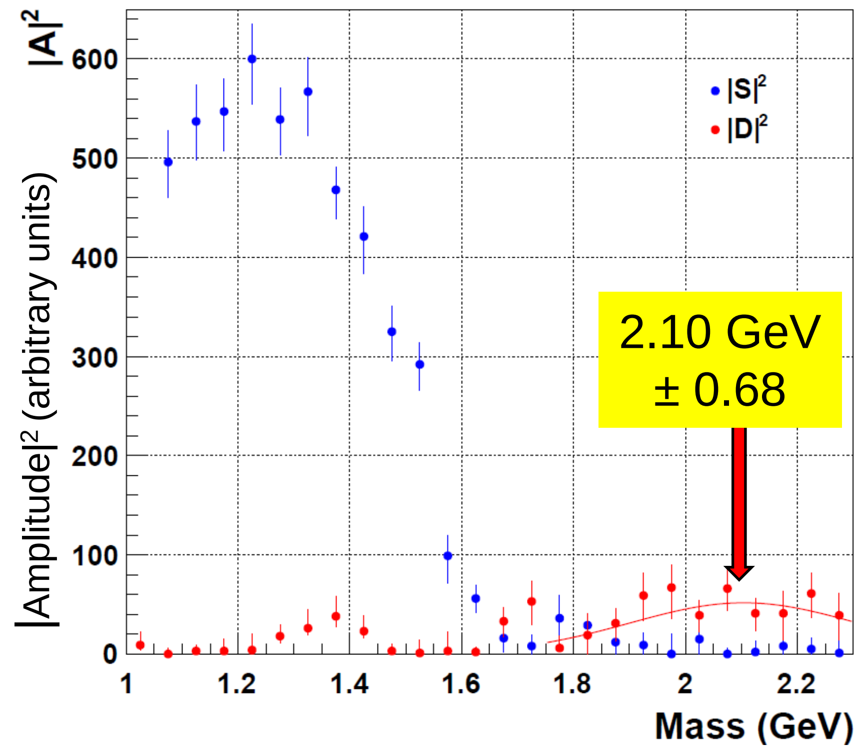
Reduce Uncertainty in s_0

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



20% increase in s_o
→x-sections decrease

Data: Peter C. Cesil, AFS thesis
(courtesy Mike Albrow)
→analysis: S and D waves
Conjecture: **tensor glue ball** (spin 2)
Fit: Gaussian
- $\langle M_{tgb}\rangle = \sqrt{s_0} = 2.10 \pm 0.68$ GeV
  - → $s_0 = 4.42 \pm 0.34$ GeV^2

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

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		σ_{inel}=73.1±0.9(exp)±6.6(lumi) ±3.8(extra.)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_o #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 →

Predictions vs Measurements ʷ/reduced Uncertainty in s_o #2

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 ~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 ttps://indico.desy.de/contributionDisplay.py?contribId=330&confId=12482

7) CMS 13TeV DIS-2016 H. Van Haevermaet https://indico.desy.de/contributionDisplay.py?contribId=105&confId=12482

MBR vs. ICHEP 2016 cross-section results

$\sqrt{s}$	MBR/Exp	Ref. # cf. slide19	σ_{tot}	σ_{el}	σ_{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 **96.1±0.9**	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) **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://ichep2016.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	$73.1 \pm 0.9(exp) \pm 3.8(extr) \pm 6.6(lumi)$
	ATLAS_ALFA_fit	(h) ICHEP16	xxx	xxx	$79.3 \pm 0.6(exp) \pm 2.5(extr) \pm 1.3(lumi)$
	CMS	(h) ICHEP16	xxx	xxx	$71.3 \pm 0.6(exp) \pm 2.7(extr) \pm 0.1(lumi)$

*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)

σ_{tot} = 110.6 ± 3.4 mb, σ_{inel} = 79.5 ± 1.8 mb, σ_{el} = 31.0 ± 1.7 mb

103.7±1.9 **73.5±1.3** **30.2±0.8**

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

TOTEM paper➔
CERN-EP-2017-321
10 December 2017

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

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

10.4 Discussion

This section concludes with an example of how theoretical considerations may be examined using these results. A. Martin has pointed out [10.6] that by taking $E = \frac{1}{2}(F(pp) - F(\bar{p}p))$ at $t = 0$ and defining the quantity $\rho_- = \mathrm{Re}\, F_- / \mathrm{Im}\, F_-$, one can demonstrate from the optical theorem the following identity:

$$\rho_- = \Delta\rho \frac{-\sigma(\bar{p}p)}{\Delta\sigma} + \rho(pp) \qquad (10.4)$$

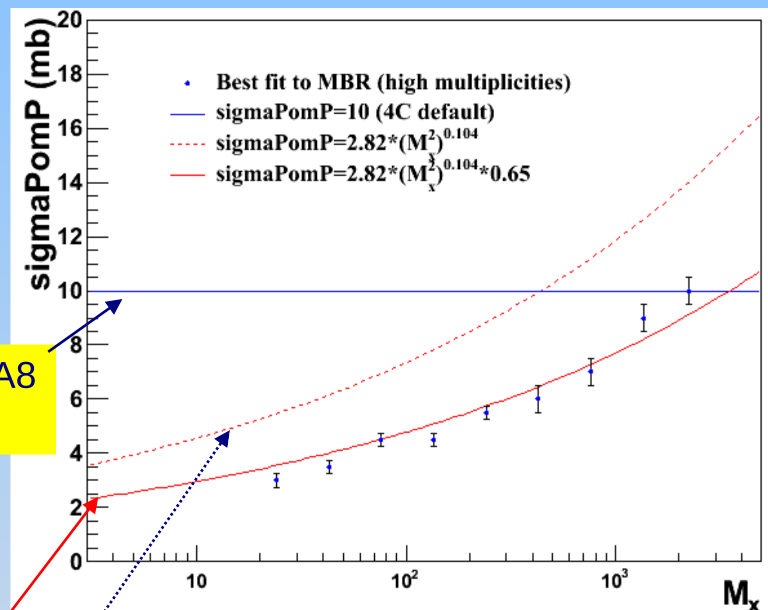
Additionally, it is possible to prove using dispersion relations that if $\Delta\sigma \sim E^{-\alpha}$ then $\rho_- = \cot(\pi\alpha/2)$. If one uses the value $\alpha = 0.56 \pm 0.01$ which Amos et al. found in applying the Amaldi-type parametrization of Eq. 3.15, then $\rho_- = 0.827 \pm 0.026$. Using $\Delta\sigma = 1.94$ mb, the UA6 measurements inserted into Eq. 10.4 give $\rho_- = 0.84 \pm 0.34$, consistent with the assumption that $\Delta\sigma \to 0$ aymptotically as $E^{-\alpha}$ On the other hand, the fit assuming a significant odd-under-crossing amplitude of Ref. 3.7 predicts for the UA6 energy $\rho_{odd}(pp) = -0.007$ and $\rho_{odd}(\bar{p}p) = 0.054$ yielding $\Delta\rho = 0.061$. This demonstrates a difference between the UA6 result and the odderon prediction of 0.022 ± 0.014 which, while not suggestive, does not rule out the possibility of an odd-under-crossing amplitude dominating at high energies.

A definitive answer awaits precise comparisons of pp and $\bar{p}p$ at higher energies.

Pythia8-MBR Hadronization Tune

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

$$n_{ave} = \frac{\sigma_{QCD}}{\sigma_{IPp}}$$



PYTHIA8 default

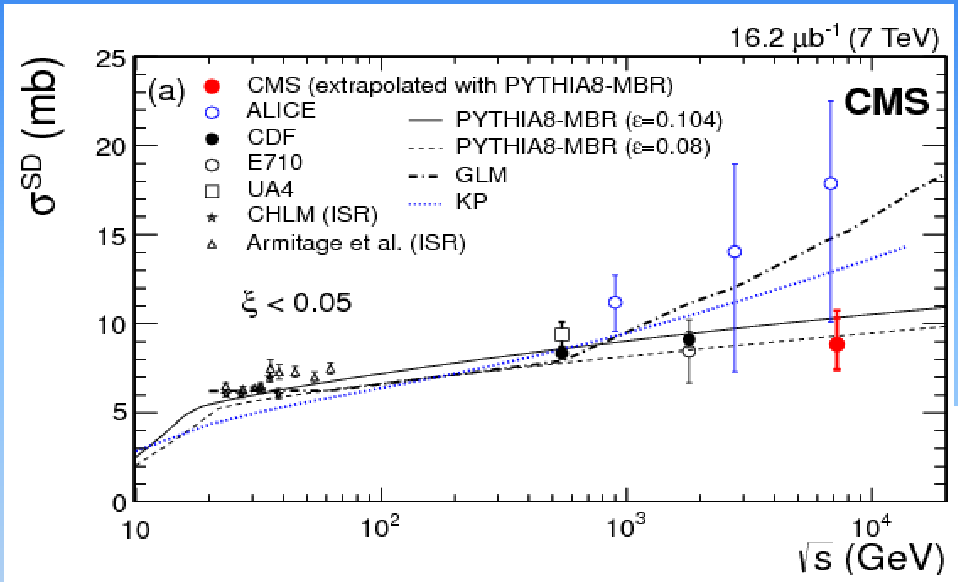
$\sigma^{Pp}(s)$ expected from Regge phenomenology for s_0=1 GeV^2 and DL t-dependence.

Red line: best fit to multiplicity distributions.
(in bins of Mx, fits to higher tails only, default pT spectra)

R. Ciesielski, “Status of diffractive models”, CTEQ Workshop 2013
https://indico.cern.ch/event/262192/contributions/1594778/attachments/463480/642352/CTEQ13diffraction.pdf

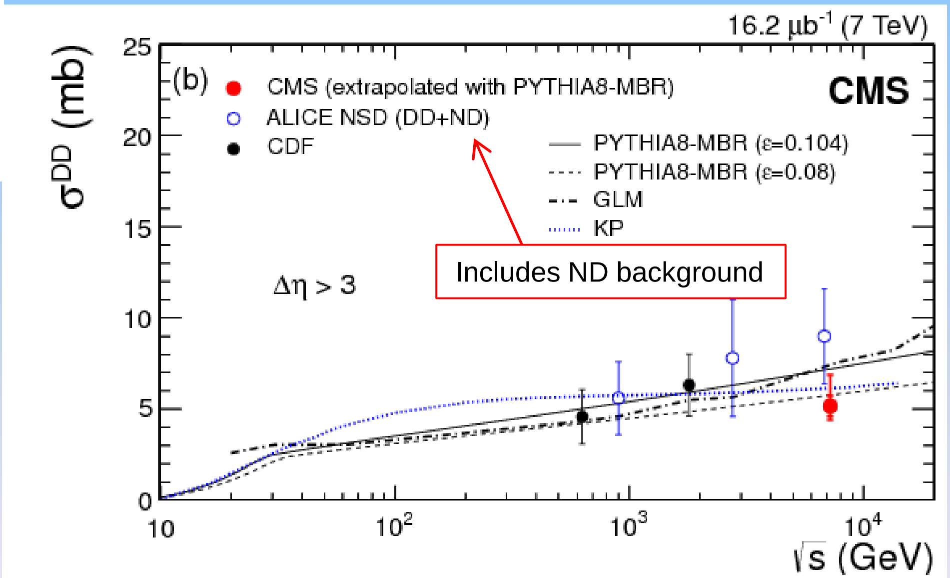
SD and DD x-Sections vs Models

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



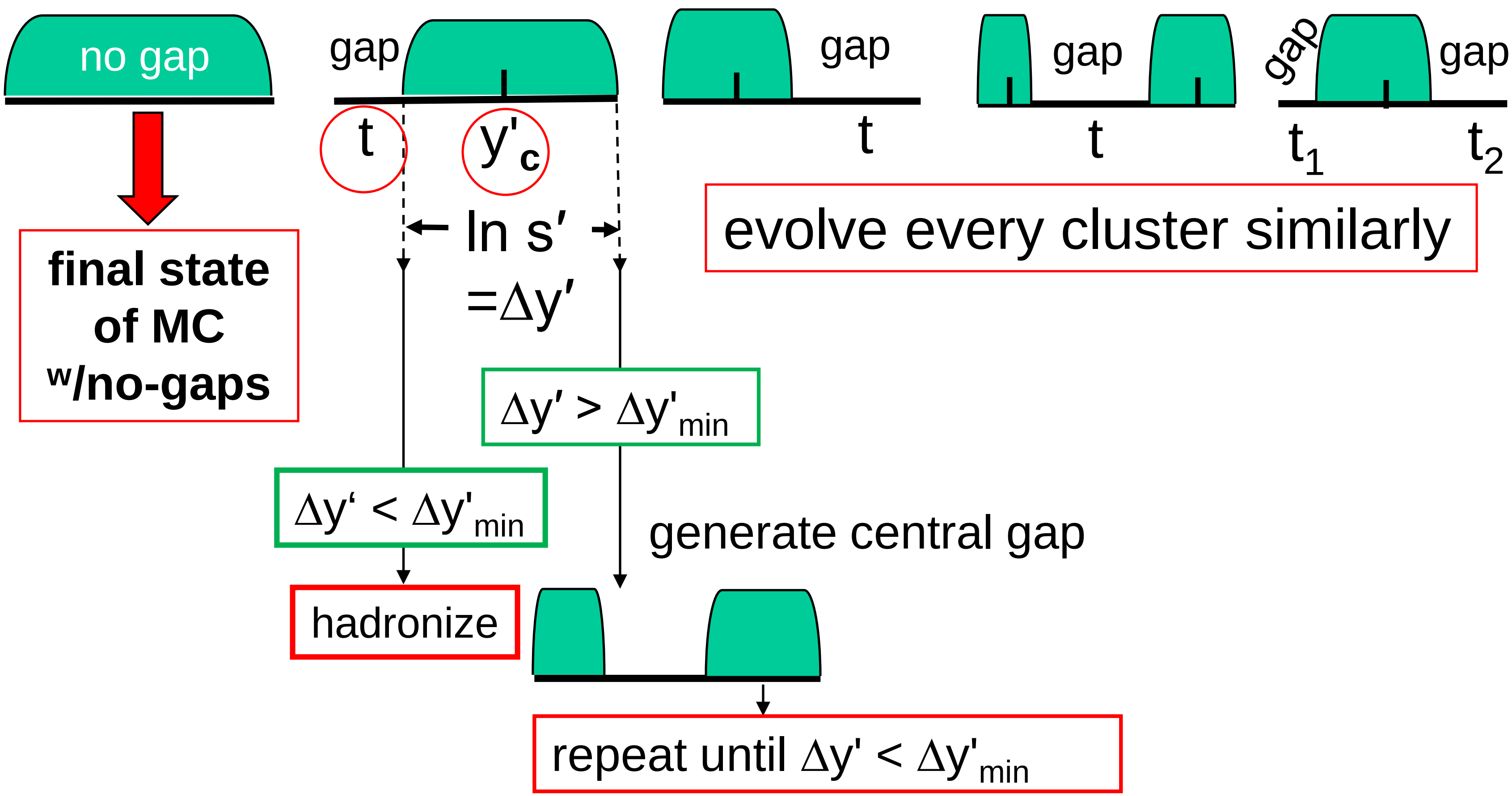
Single Diffraction

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 betweenTOTEM 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!