Precision RENORM Soft and Hard Diffraction Predictions: A Tool for Deciphering Cross Section Measurement Discrepancies

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https://indico.cern.ch/event/663474/overview

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- Diffraction
  - SD1 $p_1p_2 \rightarrow p_1$+gap+X_2 Single Diffraction / Dissociation –1
  - SD2 $p_1p_2 \rightarrow X_1$+gap+p_2 Single Diffraction / Dissociation - 2
  - DD $p_1p_2 \rightarrow X_1$+gap+X_2 Double Diffraction / Double Dissociation
  - CD/DPE $p_1p_2 \rightarrow$ gap+X+gap Central Diffraction / Double Pomeron Exchange

- Renormalization→Unitarization
  - **RENORM Model**
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- **Total Cross Section**:
  - **Unique prediction, based on a spin-2 tensor glue-ball model** ⇐ σ_{tot}
- **References**

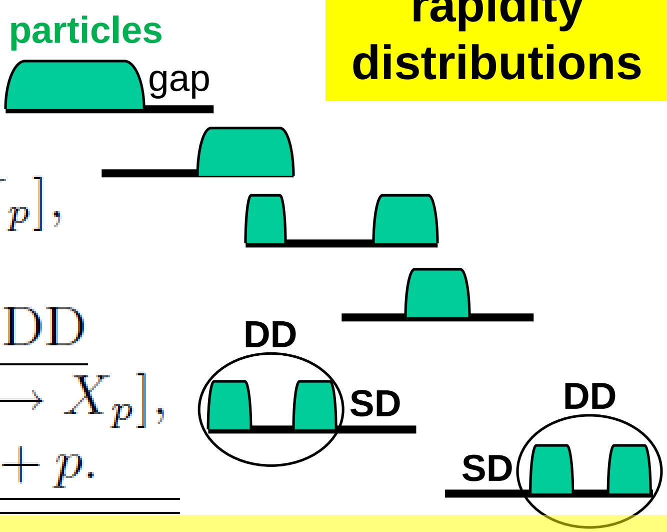
- MBR MC Simulation in PYTHIA8, KG & R. Ciesielski, **http://arxiv.org/abs/1205.1446**
- EDS BLOIS 2015 Borgo, Corsica, France Jun 29-Jul 4, https://indico.cern.ch/event/362991/
  KG, Updated RENORM/MBR-model Predictions for Diffraction at the LHC, http://dx.doi.org/10.5506/APhysPolBSupp.8.783
- Moriond 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
- MIAMI-2017, Dec. 13-19, https://cgc.physics.miami.edu/Miami2017/Goulianos2017.pdf
- NPQCD 2018, Paris, Jun. https://www.brown.edu/conference/15th-workshop-non-perturbative-quantum-chromodynamics/

Similar talk ⇓

RENORM: Basic and Combined Diffractive Processes

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

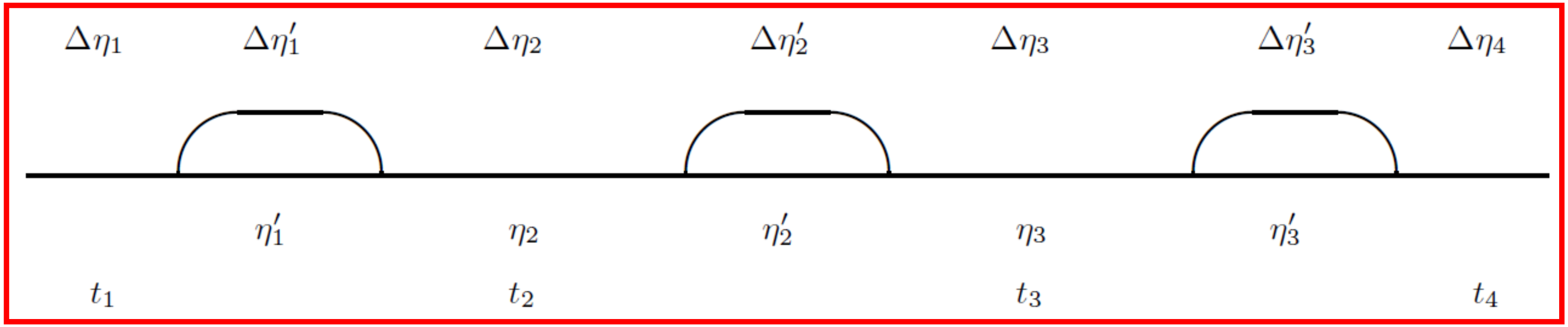
rapidity distributions



Cross sections analytically expressed in arXiv::

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

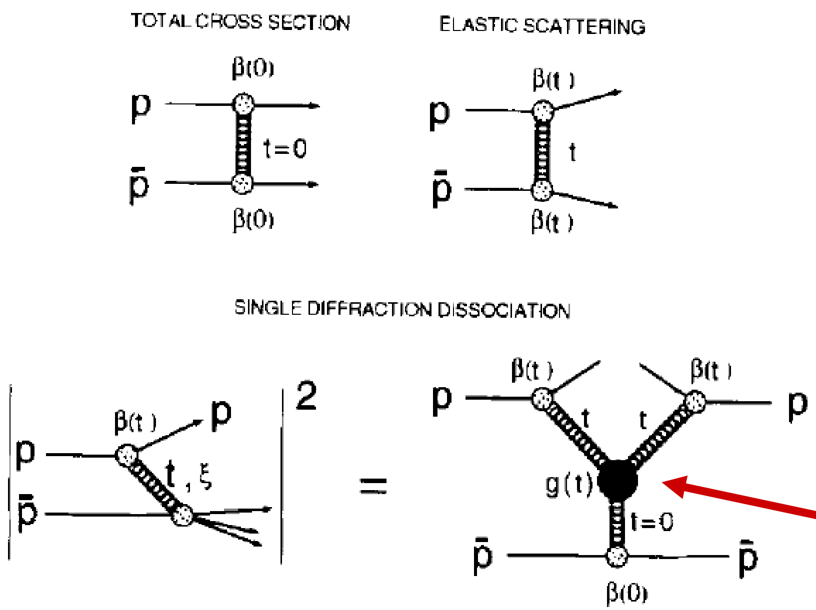
4-gap diffractive processes-Snowmass 2001



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?**

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

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

$$\frac{d\sigma_{el}}{dt} = \frac{\beta_1^2(t)\beta_2^2(t)}{16\pi}\left(\frac{s}{s_0}\right)^{2[\alpha(t)-1]}$$

$$= \frac{\sigma_T^2}{16\pi}\left(\frac{s}{s_0}\right)^{2\alpha' t} F^4(t) \approx \frac{\sigma_T^2}{16\pi} e^{b_{el}(s)t} \quad (2)$$

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

$$\frac{d^2\sigma_{sd}}{dt\,d\xi} = \frac{\beta_1^2(t)}{16\pi}\xi^{1-2\alpha(t)}\left[\beta_2(0)\,g(t)\left(\frac{s'}{s_0'}\right)^{\alpha(0)-1}\right]$$

$$= f_{\mathcal{P}/p}(\xi,t)\,\sigma_T^{\mathcal{P}\bar{p}}(s',t) \quad (4)$$

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)

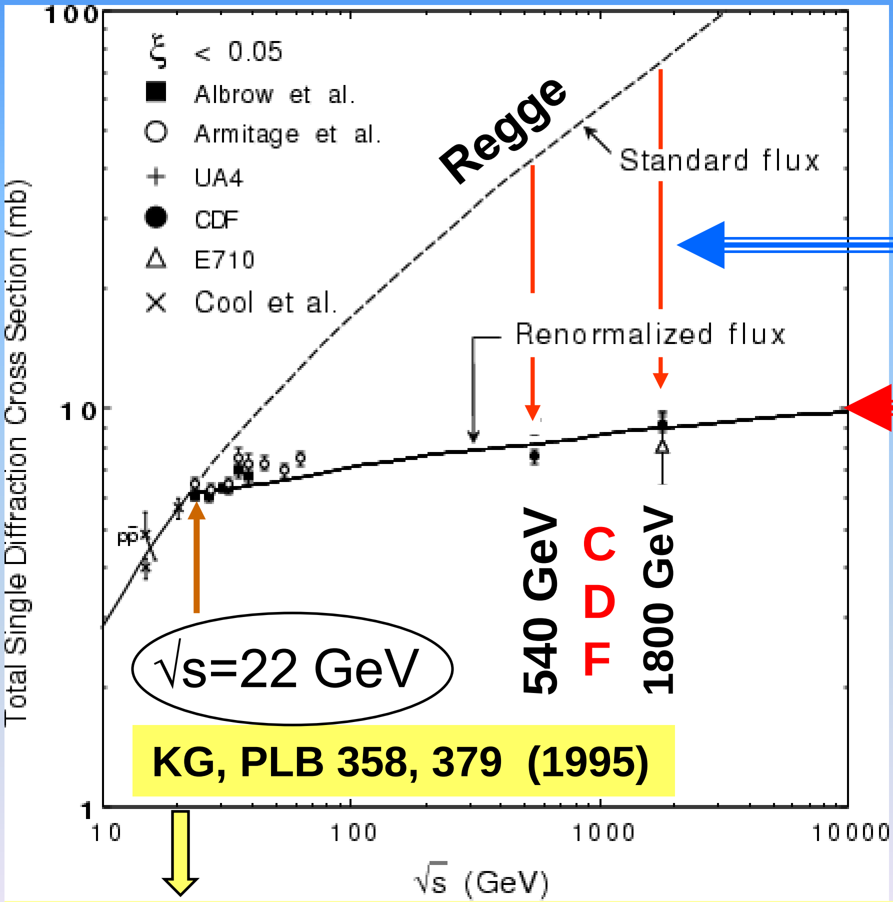
- the unitarity limit is already reached at $\sqrt{s}$ ~ 2 TeV

- need unitarization

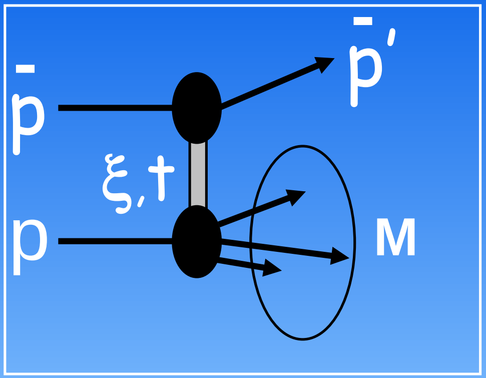
* similarly for $(d\sigma_{el}/dt)_{t=0}$ w.r.t. σ_t, but this is handled differently in RENORM

FACTORIZATION BREAKING IN SOFT DIFFRACTION

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



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



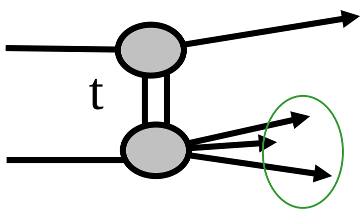
Factor of ~8 (~5) suppression at √s = 1800 (540) GeV

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

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

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

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

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

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

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

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

← affects only the *s*-dependence

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

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

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

M^2 - Distribution: Data

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

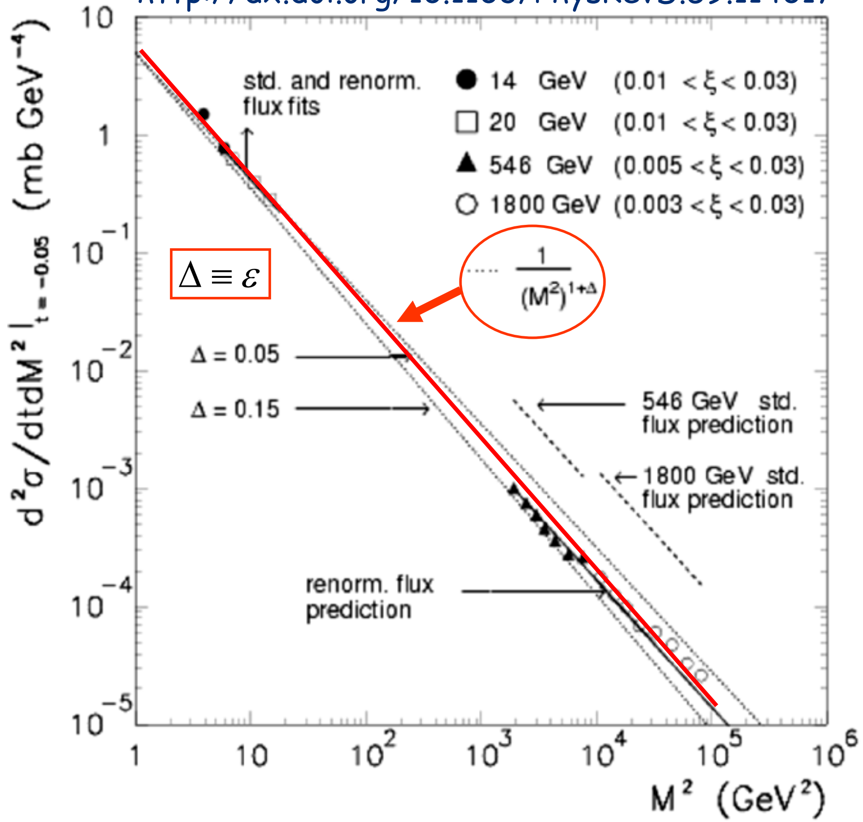
http://physics.rockefeller.edu/publications.html

KG&JM, PRD 59 (1999) 114017

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

Regge ➔ data

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



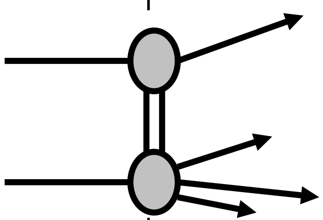
➔ factorization breaks down to ensure M^2-scaling

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}

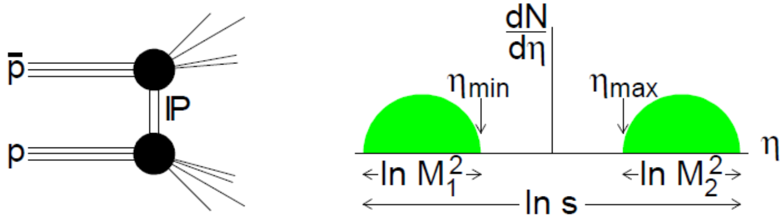
$s_o^{-\varepsilon/2} \cdot g_{PPP}(t)$

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



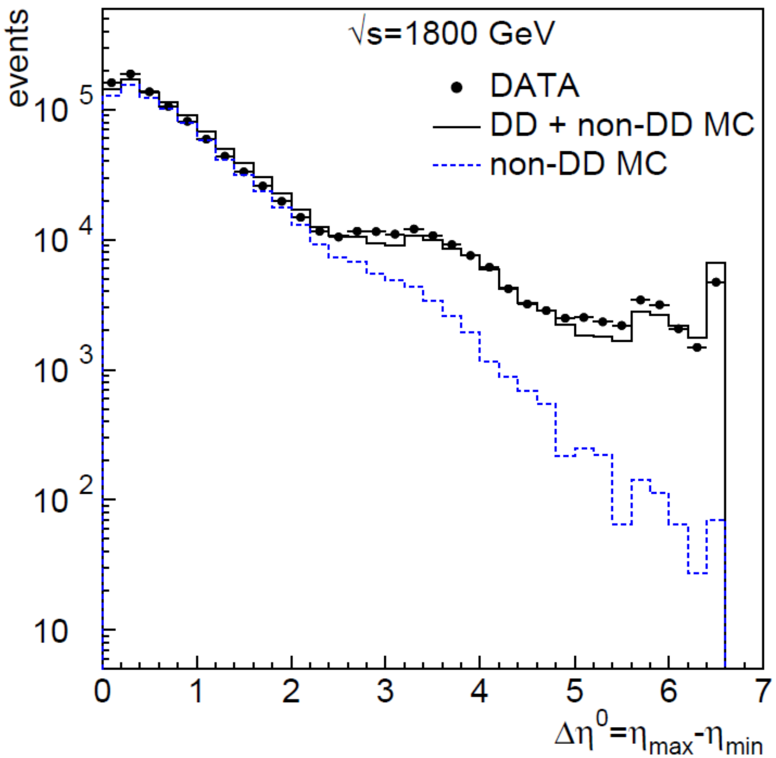
Regge factorization

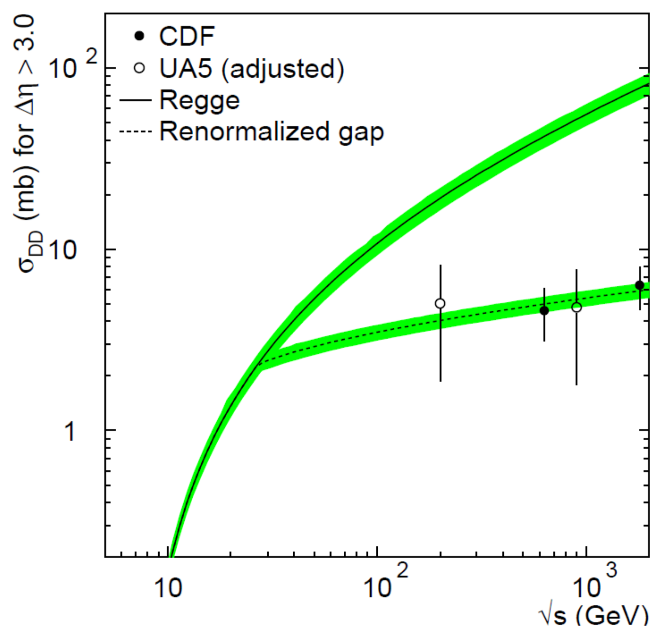
$$\frac{d^3\sigma_{DD}}{dt\,dM_1^2\,dM_2^2} = \frac{d^2\sigma_{SD}}{dt\,dM_1^2}\,\frac{d^2\sigma_{SD}}{dt\,dM_2^2} \Big/ \frac{d\sigma_{el}}{dt}$$

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

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

gap probability — x-section



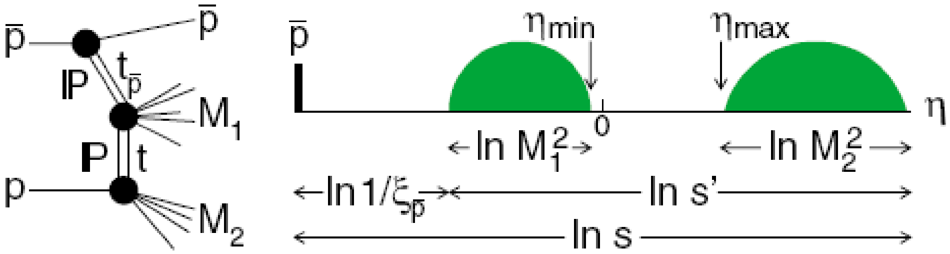


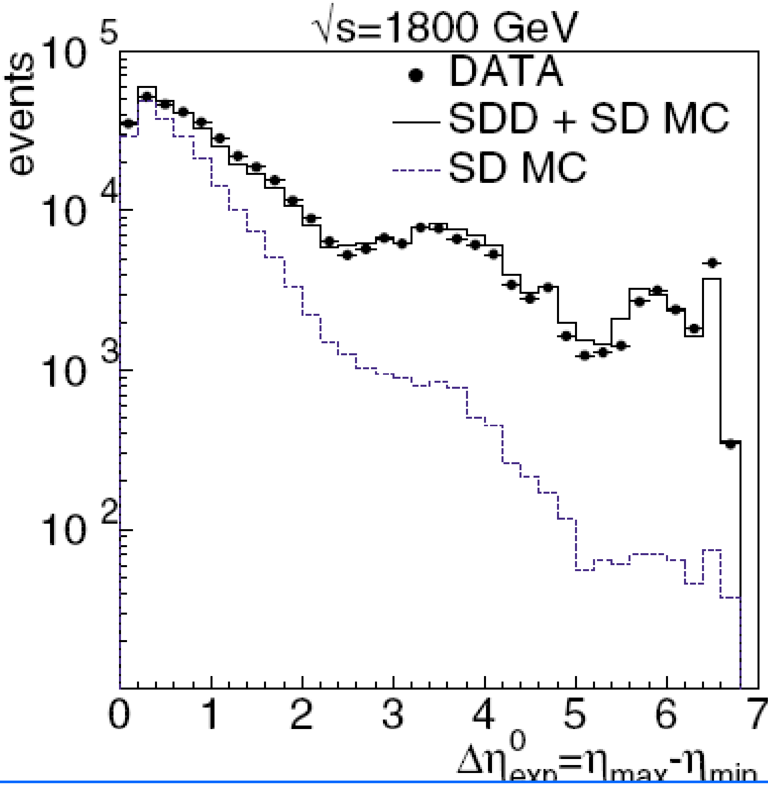
←Regge

Regge
← RENORM

x-section divided by integrated gap prob.

SDD at CDF





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

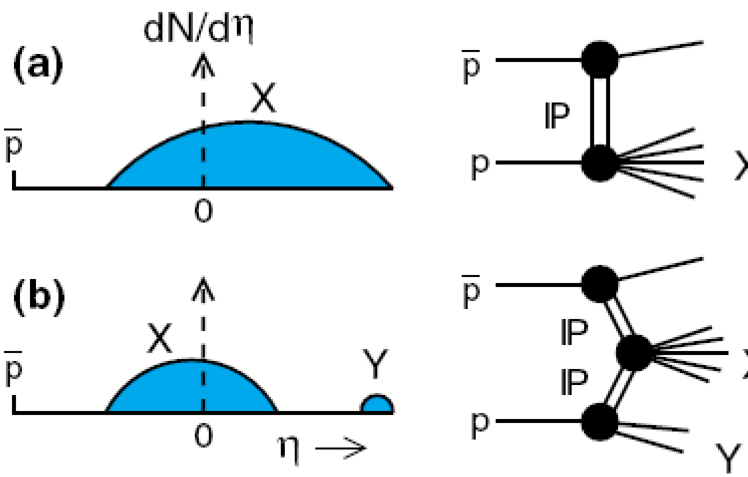
http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.91.011802

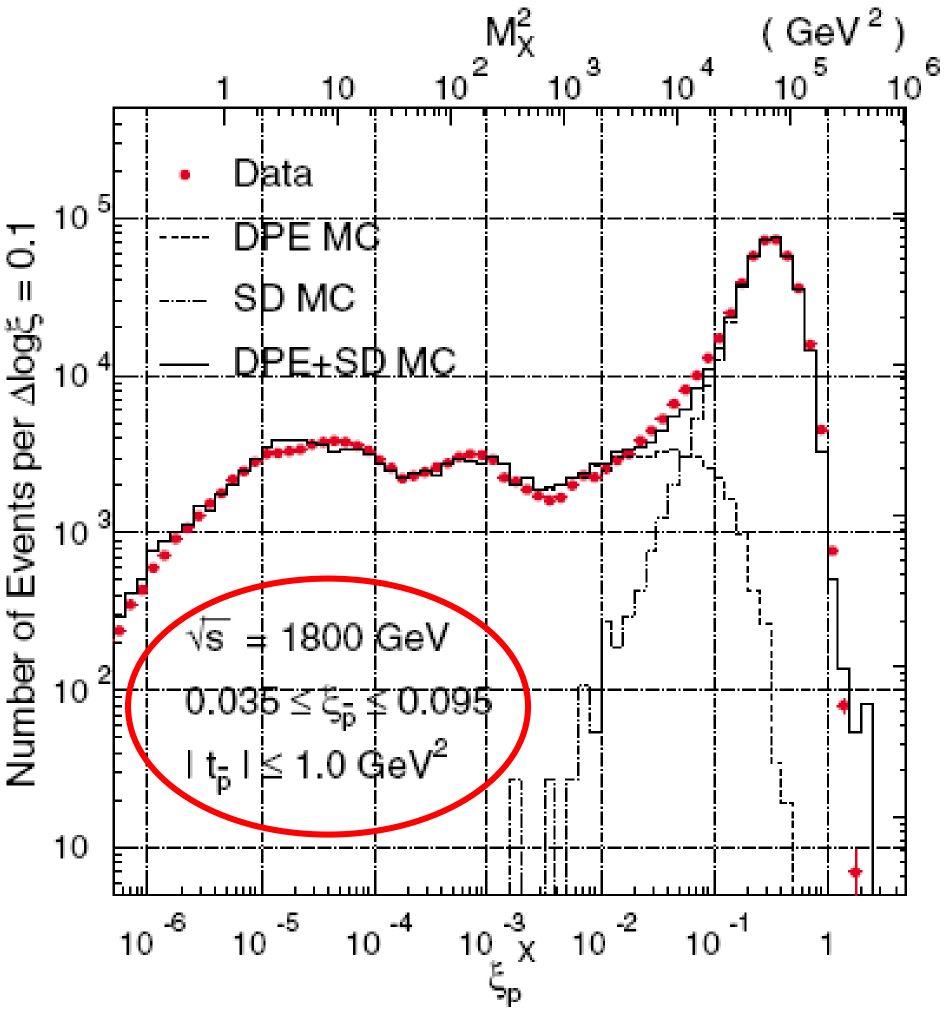
- Excellent agreement between data and MBR (MinBiasRockefeller) MC

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

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

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

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

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

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

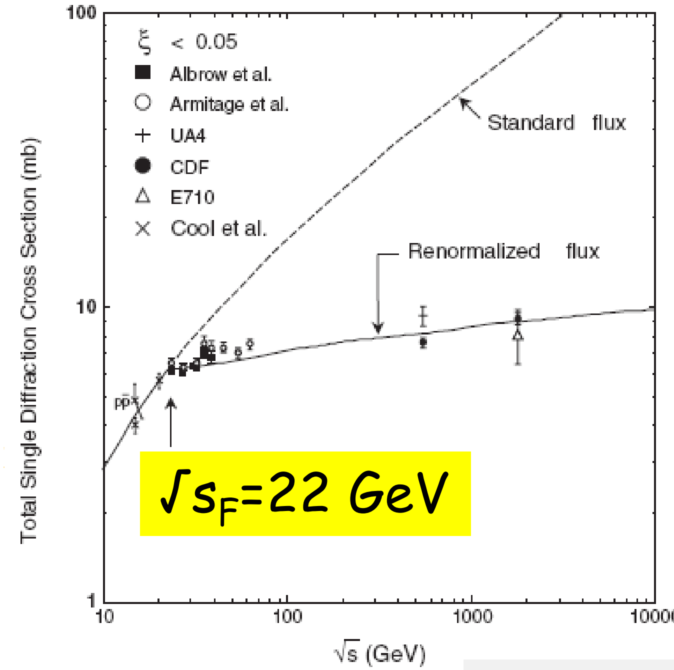
$$\sqrt{s^{\mathrm{CDF}}} = 1.8 \text{ TeV},\ \sigma_{\mathrm{tot}}^{\mathrm{CDF}} = 80.03 \pm 2.24 \text{ mb}$$

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

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

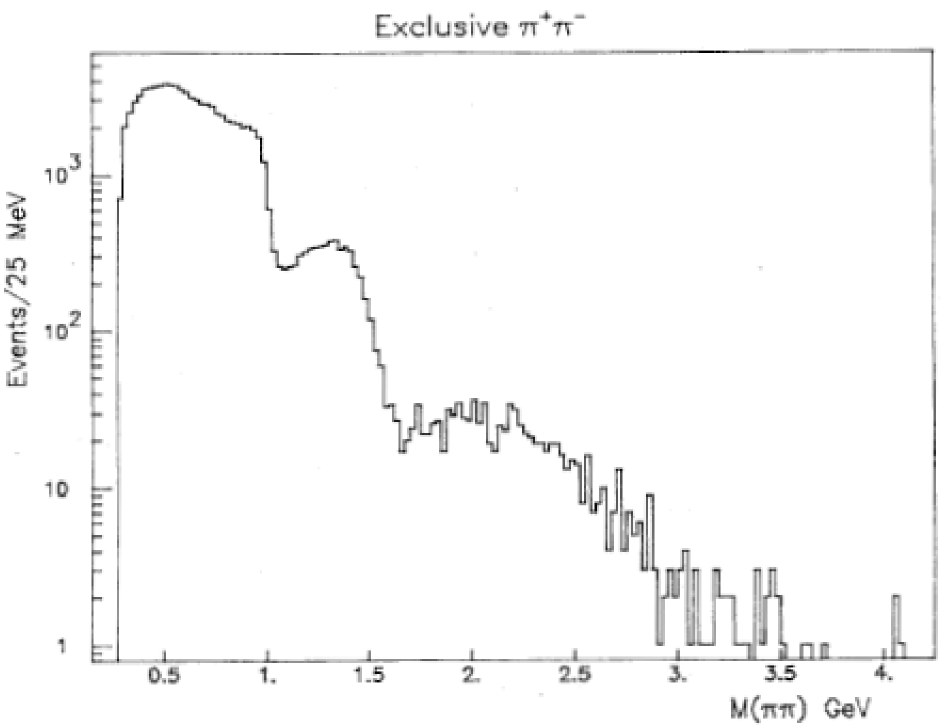
Uncertainty is due to s_o

Reduce Uncertainty in s_0

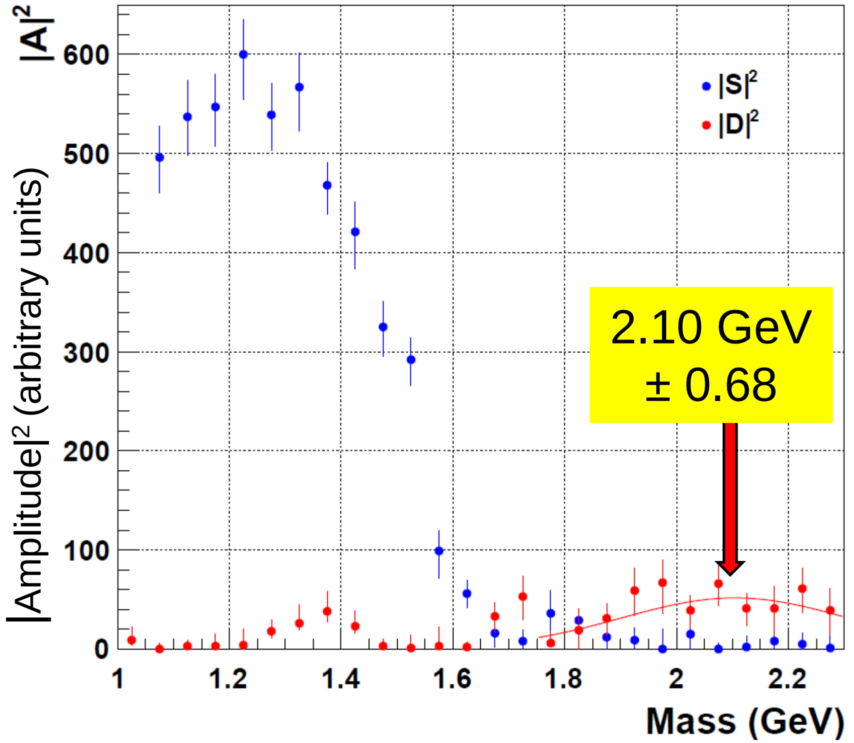
2015

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

- ❑ $\langle M_{tgb} \rangle = \sqrt{s_0} = 2.10 \pm 0.68$ GeV
  - ❑ ➔$s_0 = 4.42 \pm 0.34$ GeV^2

20% increase in s_o
➔x-sections decrease

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

√s	MBR/Exp	Reference → next slide	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
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 ± 0.9(exp)±3.8(extr)±6.6(lumi)
	ATLAS_ALFA_fit	(h) ICHEP16	xxx	xxx	79.3 ± 0.6(exp)±2.5(extr)±1.3(lumi)
	CMS	(h) ICHEP16	xxx	xxx	71.3 ± 0.6(exp)±2.7(extr)±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

First Experimental Hint for the Odderon

Excerpt from the thesis of Richard Breedon, Rockefeller University,1988

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:

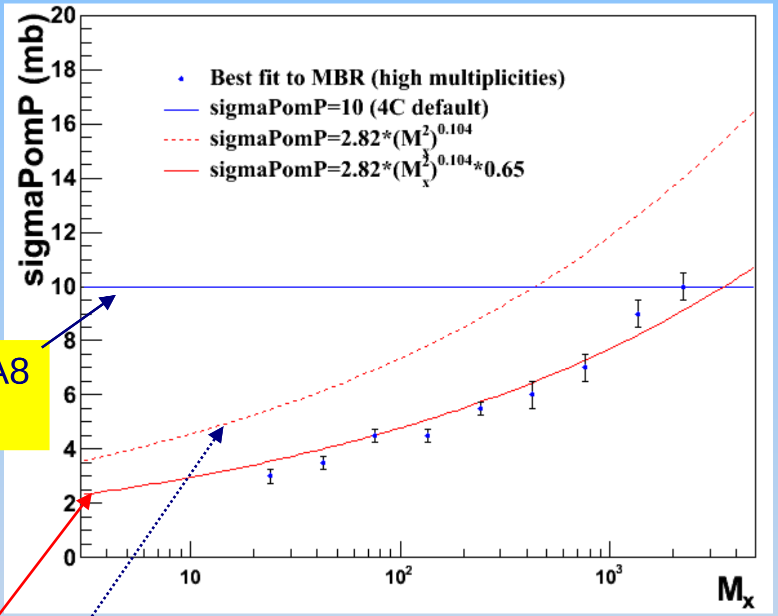
$$\rho_- = \Delta\rho \frac{-\sigma(\bar{p}p)}{\Delta\sigma} + \rho(pp) \quad (10.4)$$

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

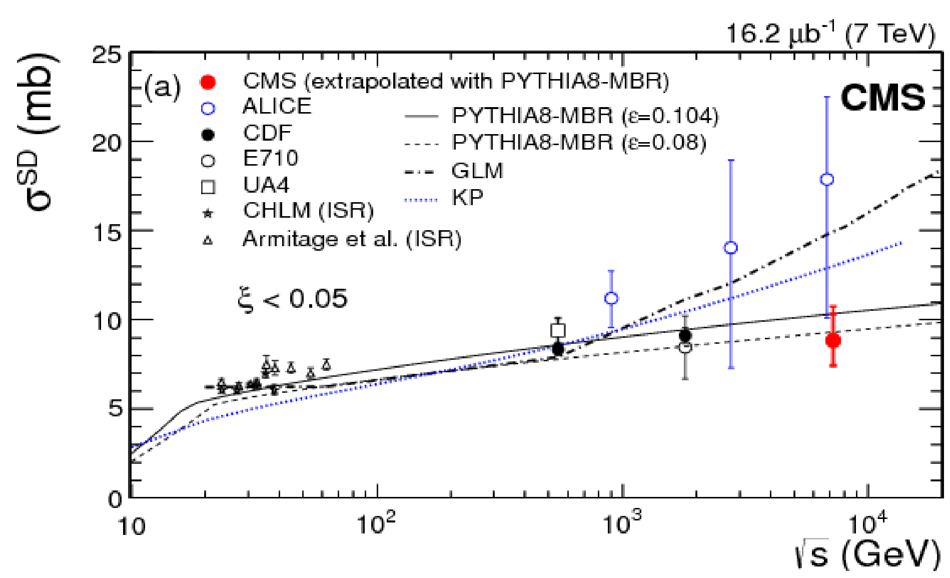
$\sigma^{Pp}(s)$ expected from Regge phenomenology for s_0=1 GeV^2 and DL t-dependence.

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

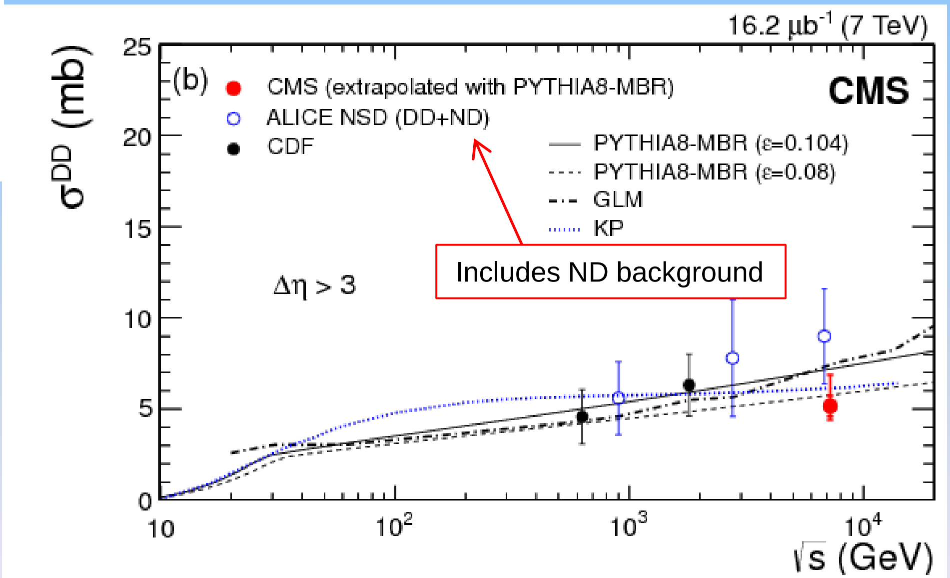
SD and DD x-Sections vs Models

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

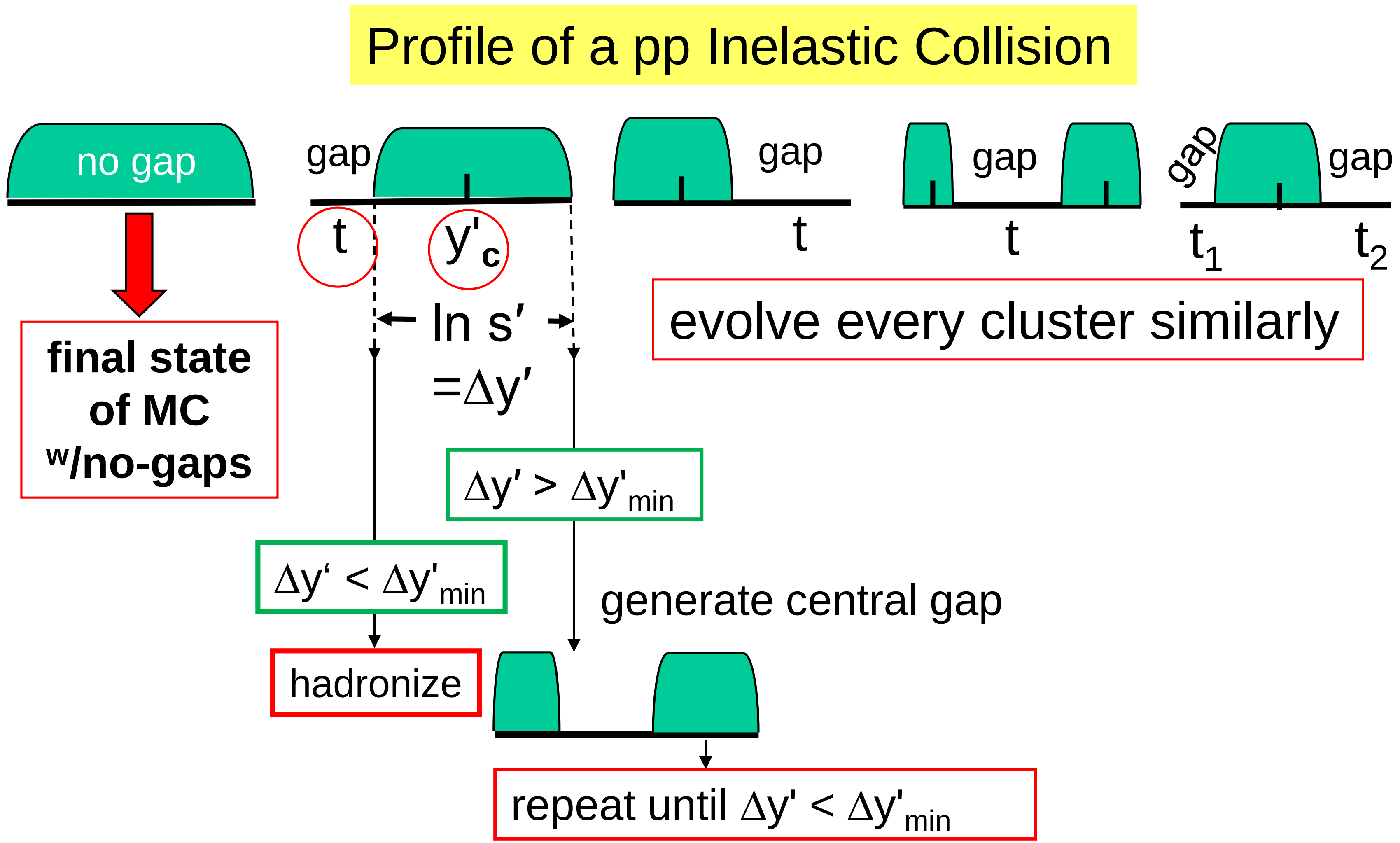


Single Diffraction

Double Diffraction



Monte Carlo Algorithm - Nesting



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!