Precision RENORM / MBR Diffraction Predictions Confront Recent LHC Data

Member of

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

Low x 2017, Bari, Italy https://indico.cern.ch/event/609299/

CONTENTS

- 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**
- **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**

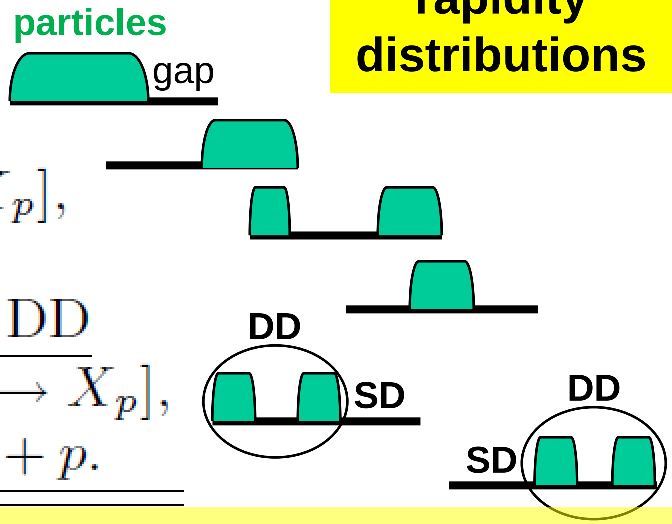
Special thanks to Robert Ciesielski, my collaborator in the PYTHIA8-MBR project

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

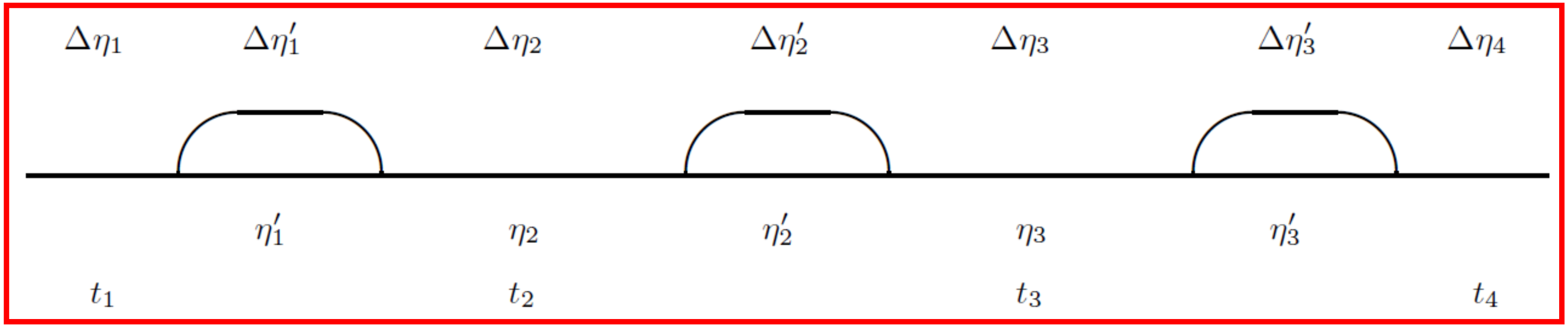
rapidity distributions



Cross sections analytically expressed in arXiv::

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

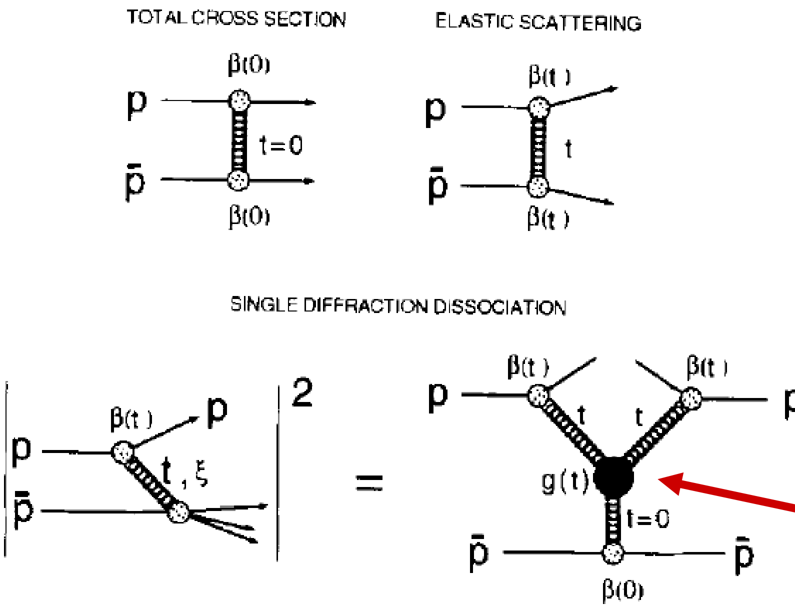
4-gap diffractive processes-Snowmass 2001



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

KG-PLB 358, 379 (1995)

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



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

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

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

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

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

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

$$= \frac{\beta_1^2(t)}{16\pi}\,\xi^{1-2\alpha(t)}\left[\beta_2(0)\,g(t)\left(\frac{s'}{s'_0}\right)^{\alpha(0)-1}\right]$$

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

Parameters:

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

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)

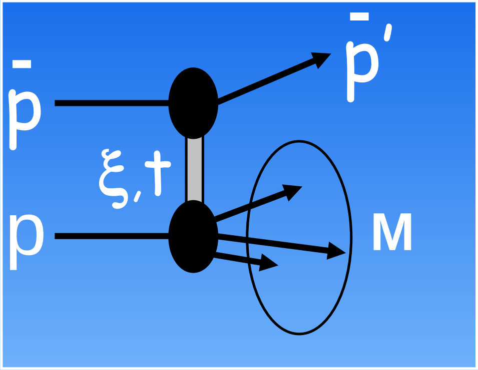
❑ the unitarity limit is already reached at √*s* ~ 2 TeV

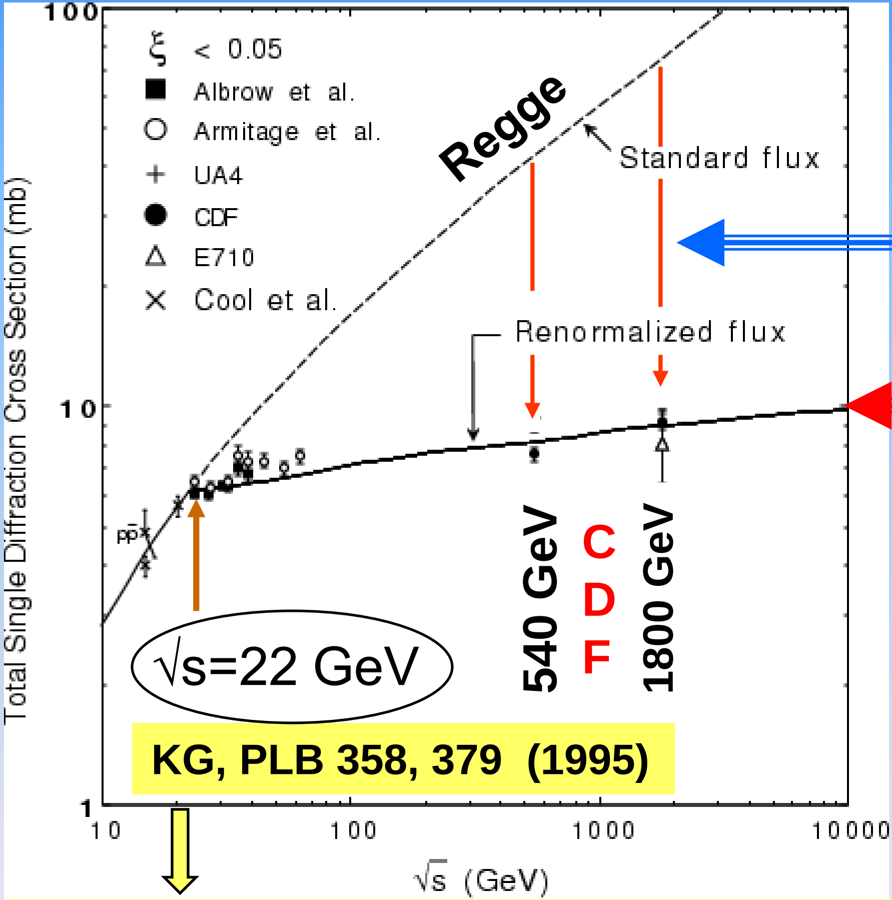
❑ need unitarization

* 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





KG, PLB 358, 379 (1995)

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

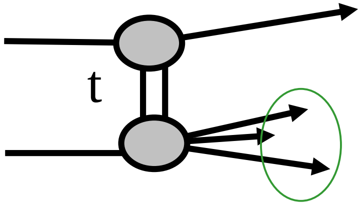
Factor of ~8 (~5) suppression at √s = 1800 (540) GeV

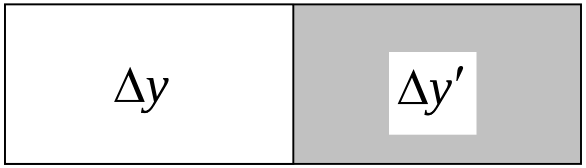
RENORMALIZATION

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 ➔ (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 ➔

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

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

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

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

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

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

← affects only the *s*-dependence

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

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

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

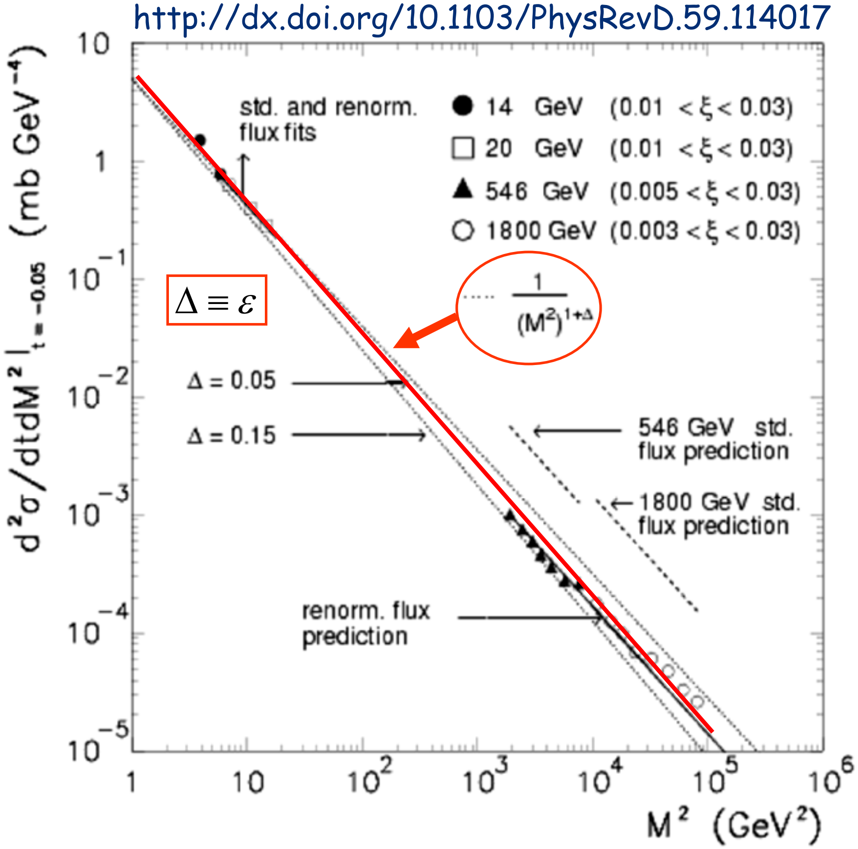
KG&JM, PRD 59 (1999) 114017

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

Regge

data

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

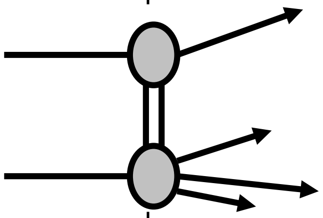


➔ factorization breaks down to ensure M^2-scaling

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



s_o^{ε}

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

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

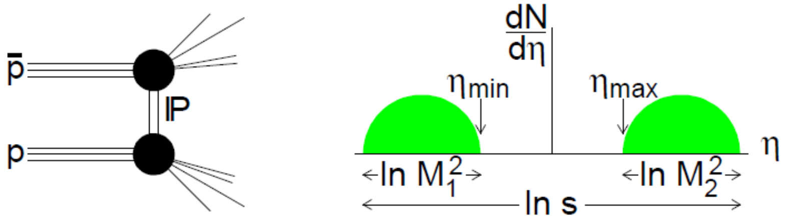
Pomeron-proton x-section

- ☐ 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



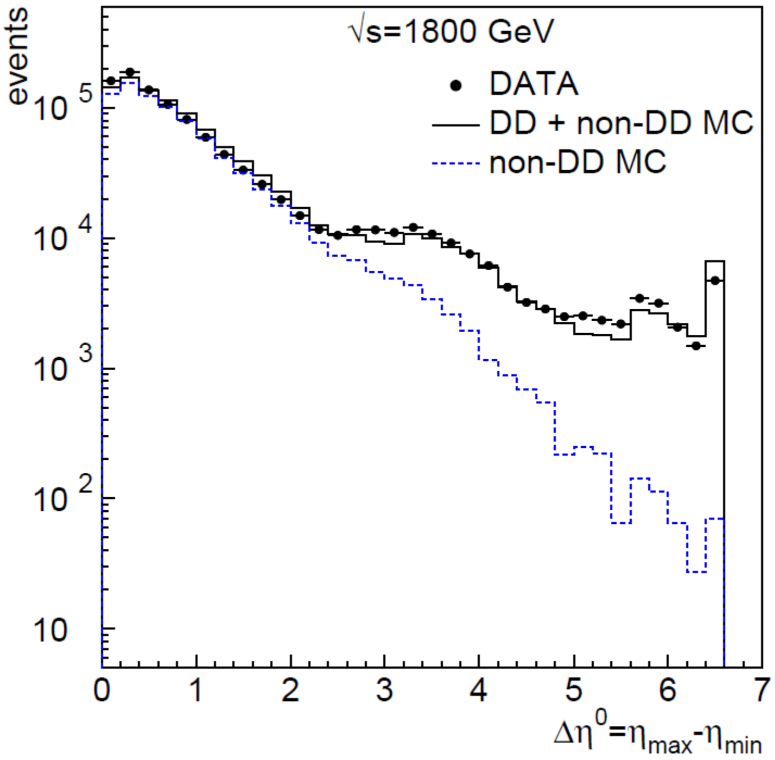
Regge factorization

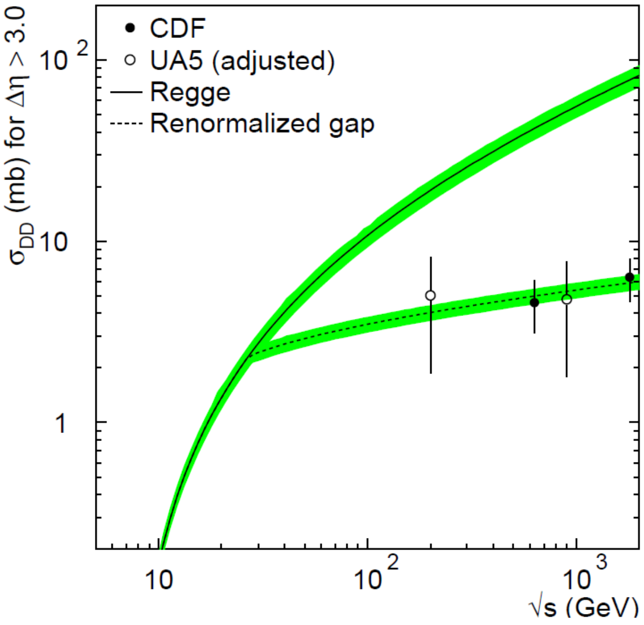
$$\frac{d^3\sigma_{DD}}{dt\,dM_1^2\,dM_2^2} = \frac{d^2\sigma_{SD}}{dt\,dM_1^2}\,\frac{d^2\sigma_{SD}}{dt\,dM_2^2} \Big/ \frac{d\sigma_{el}}{dt}$$

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

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

gap probability   x-section



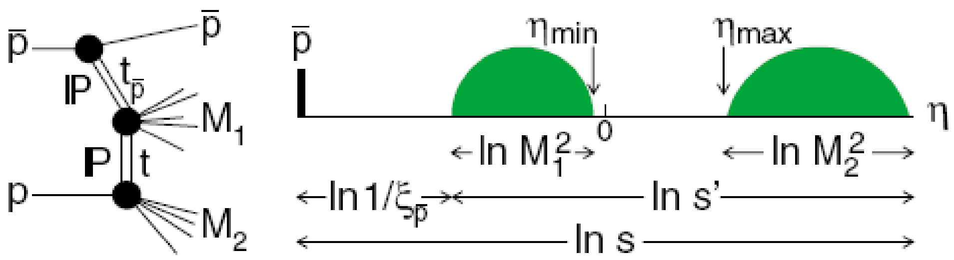


← Regge

Regge
← RENORM

x-section
divided by
integrated
gap prob.

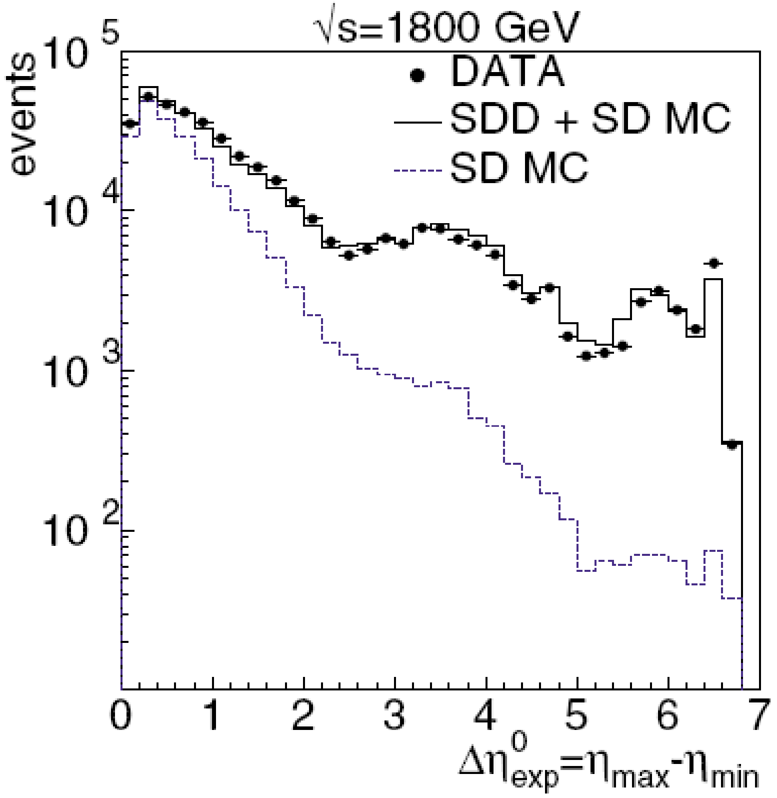
SDD at CDF



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

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

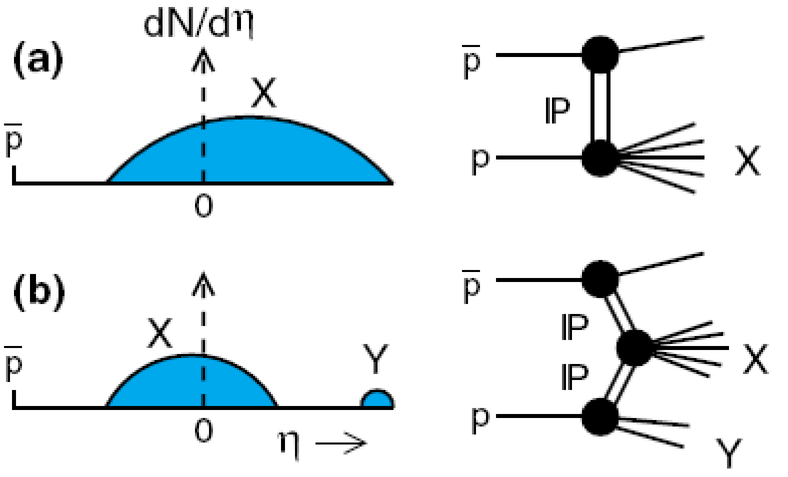
- Excellent agreement between data and MBR (MinBiasRockefeller) MC

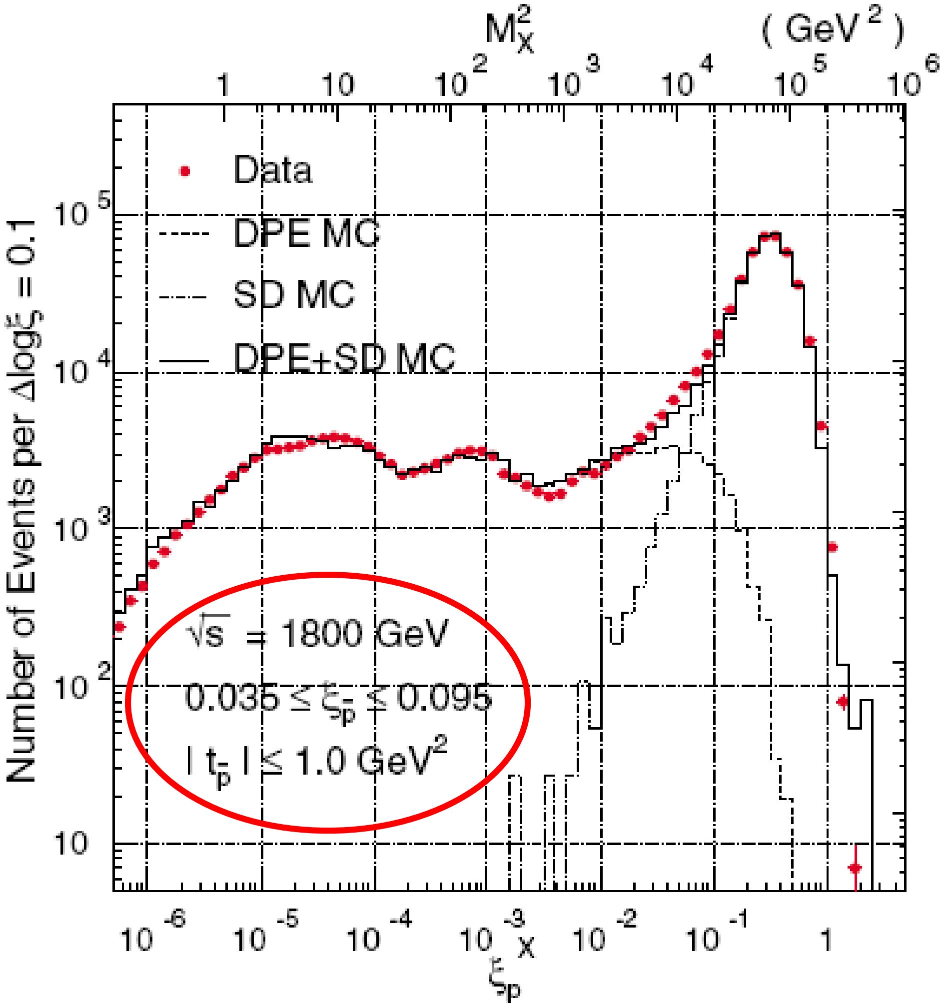


$$\frac{d^5\sigma}{dt_{\bar p}\,dt\,d\xi_{\bar p}\,d\Delta\eta\,d\eta_c} = \left[\frac{\beta(t)}{4\sqrt{\pi}}\, e^{[\alpha(t_{\bar p})-1]\ln(1/\xi)}\right]^2 \times \kappa\left\{\kappa\left[\frac{\beta(0)}{4\sqrt{\pi}}\, e^{[\alpha(t)-1]\Delta\eta}\right]^2 \kappa\left[\beta^2(0)\left(\frac{s''}{s_\circ}\right)^{\epsilon}\right]\right\}$$

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

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

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

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

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

$$F^2(t) = \left[\frac{4m_p^2 - 2.8t}{4m_p^2 - t}\left(\frac{1}{1-\frac{t}{0.71}}\right)^2\right]^2 \approx a_1e^{b_1t} + a_2e^{b_2t}$$

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}

Diffractive and Total pp Cross Sections at LHC

Konstantin Goulianos

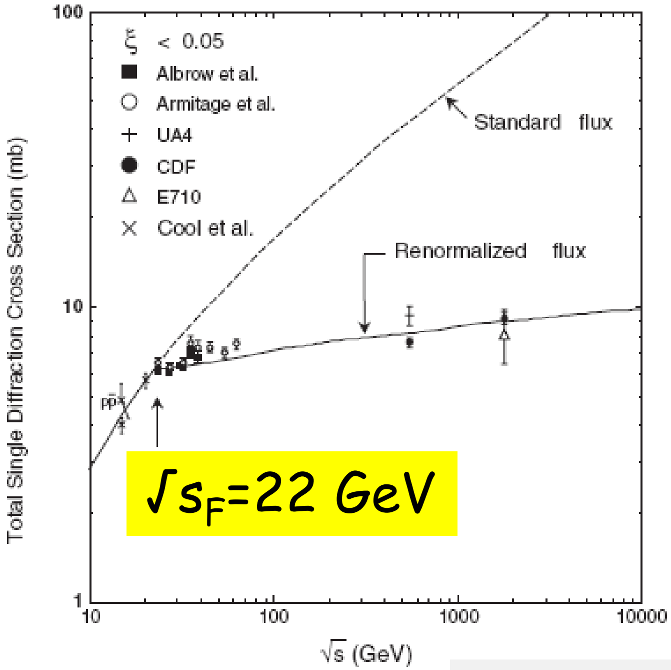
The Rockefeller University

http://eds09.web.cern.ch/eds09/

CERN

EDS '09

2009



$\sqrt{s_F}=22$ GeV

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

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

- 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 CGM.

- Obtain the total cross section at the LHC:

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

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

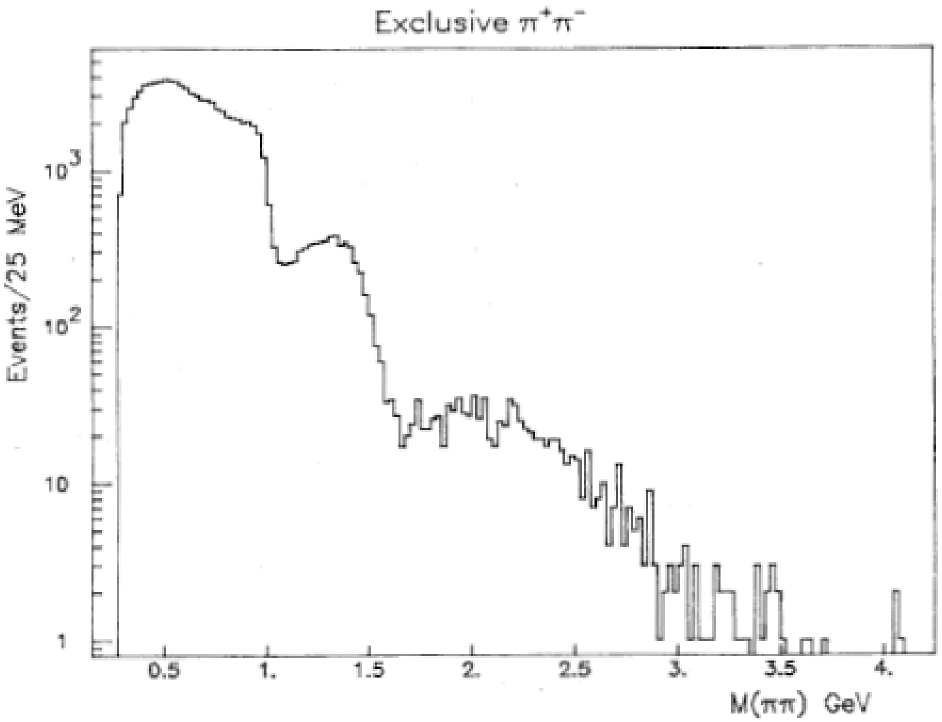
Uncertainty is due to s_o

2015

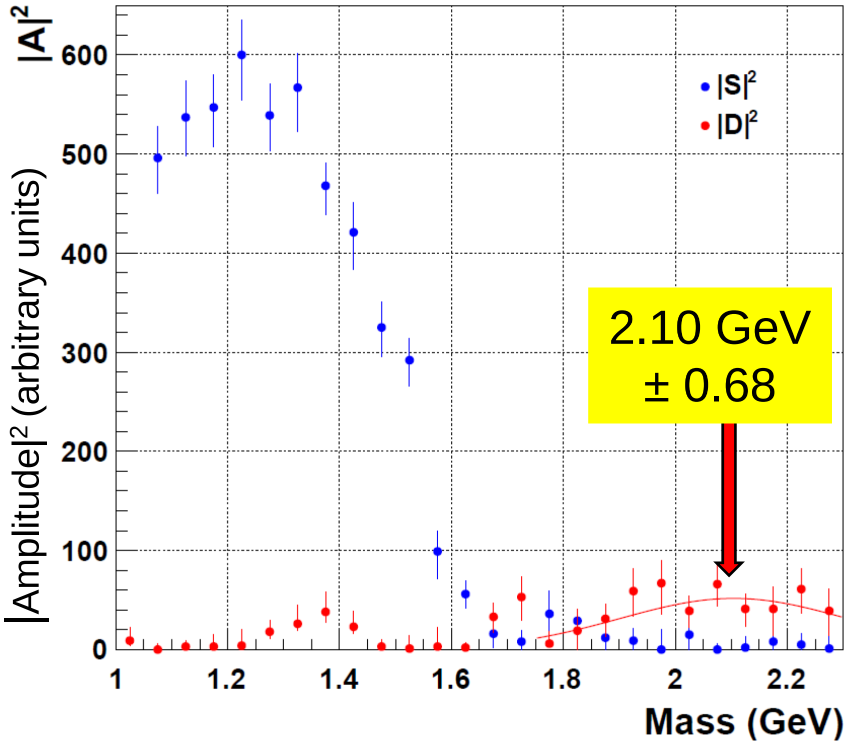
Reduce Uncertainty in s_0

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



2.10 GeV
± 0.68

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

Conjecture: **tensor glue ball** (spin 2)

Fit: Gaussian

- ❑ $<M_{tgb}>=\sqrt{s_0}=2.10\pm0.68$ GeV
  - ❑ $\rightarrow s_0=4.42\pm0.34$ GeV^2

20% increase in s_o
→x-sections decrease

Predictions vs Measurements $^{\text{with}}$/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. #** ➔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 **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)**

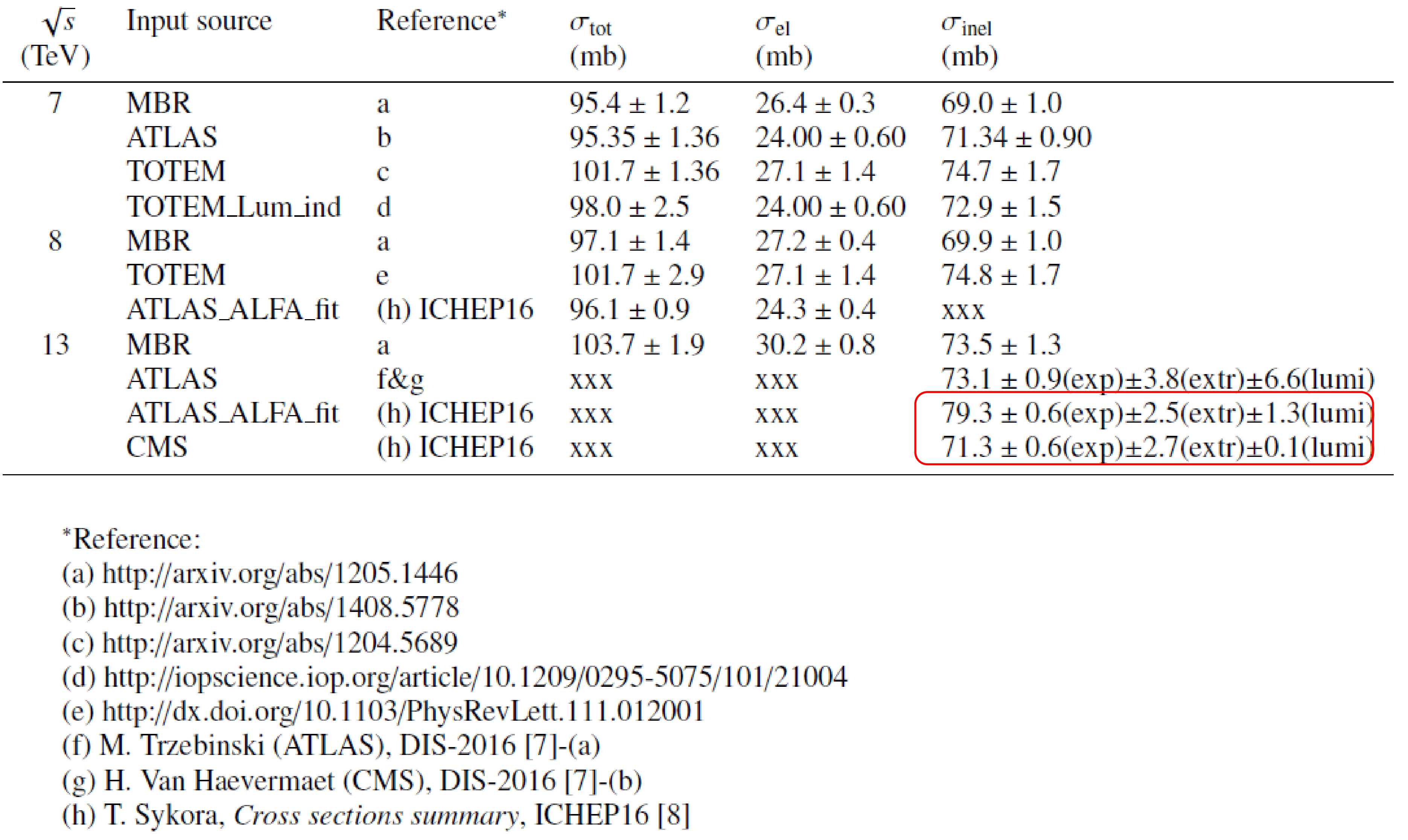
🡐ATLAS vs. MBR in excellent agreement at 8 TeV

✓ 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)

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

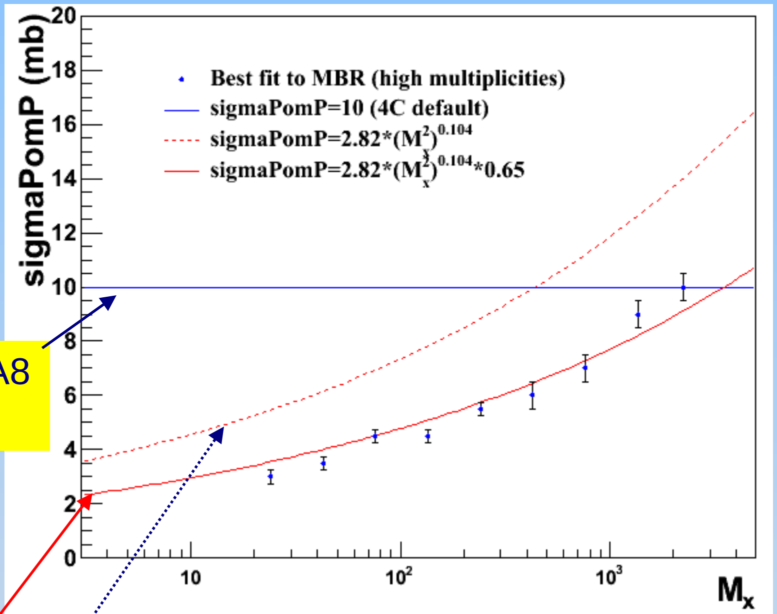
MBR➔ 85.2 21.7 63.5
Syst. Uncertainty ~1.5% due to that in s_0

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

Pythia8-MBR Hadronization Tune

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

$f_{\Lambda D} = \frac{\sigma}{\sigma_{H\,\Pi}}$



PYTHIA8 default

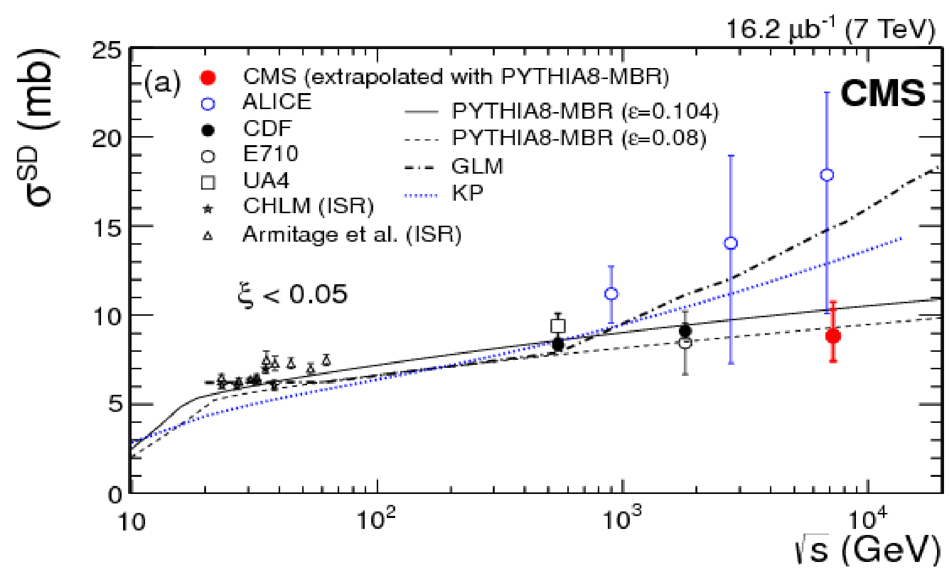
$\sigma^{Pp}(s)$ expected from Regge phenomenology for s_0=1 GeV^2 and DL t-dependence.

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

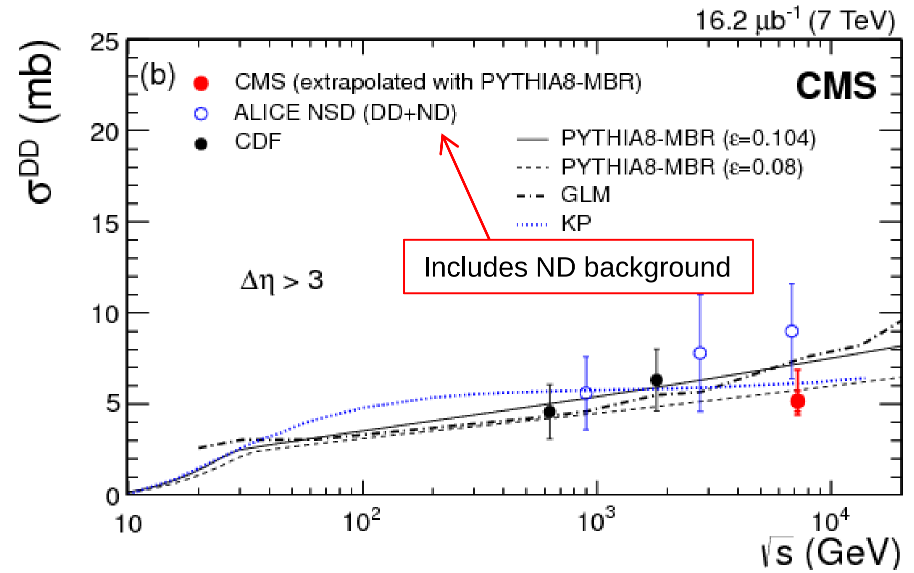
SD and DD x-Sections vs Models

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



Single Diffraction

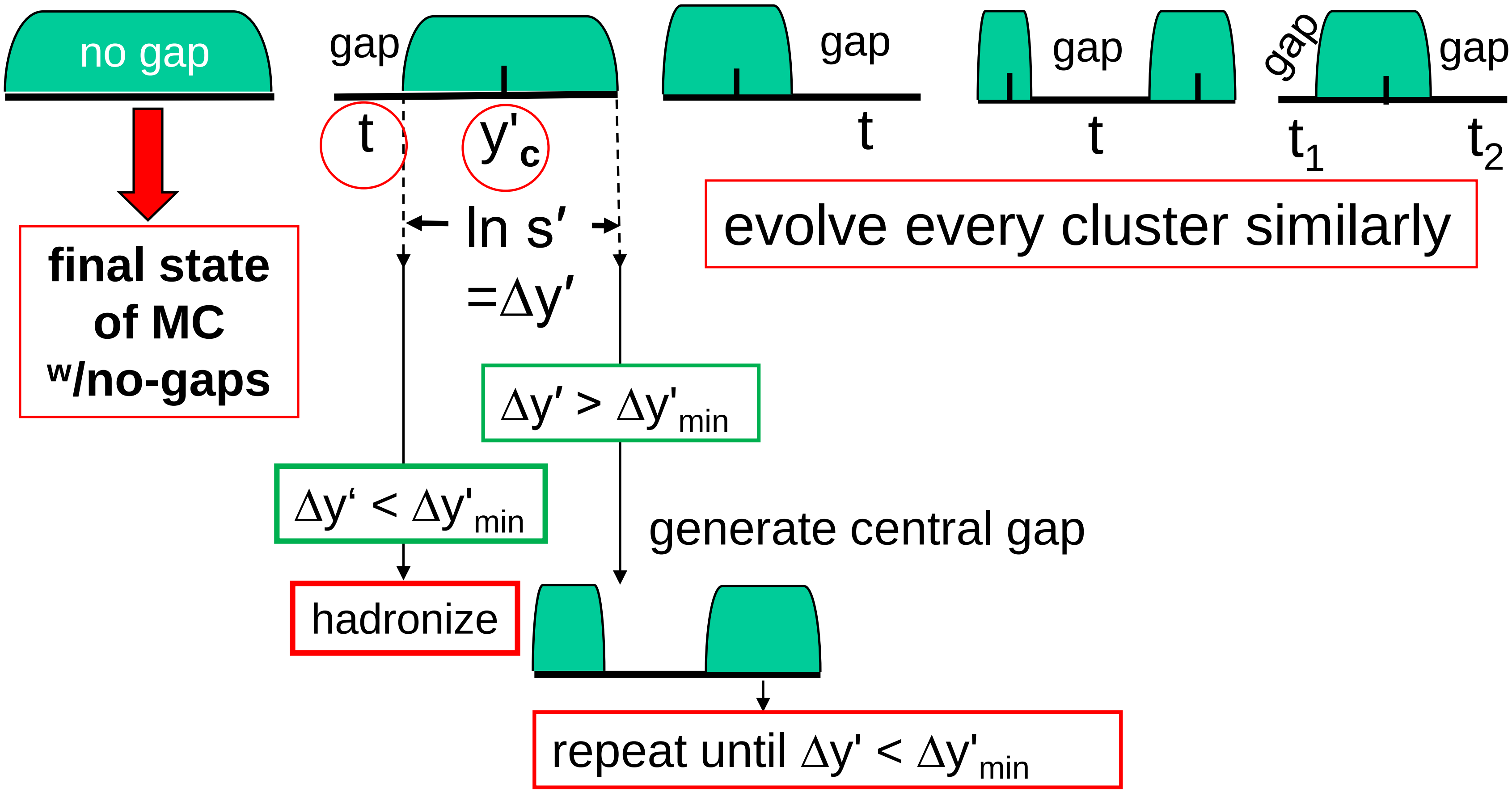
Double Diffraction



Includes ND background

Monte Carlo Algorithm - Nesting

Profile of a pp Inelastic Collision



final state of MC ^{w}/no-gaps

evolve every cluster similarly

$\Delta y' > \Delta y'_{min}$

$\Delta y' < \Delta y'_{min}$

generate central gap

hadronize

repeat until $\Delta y' < \Delta y'_{min}$

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
  - DisagreementTOTEM 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!