Diffractive and Total pp Cross Sections at LHC

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EDS '09

13th International Conference on Elastic & Diffractive Scattering
(13th "Blois Workshop")
CERN, 29th June - 3rd July 2009

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References

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

CDF PRD 50, 5518 (1994) σ^{el} @ 1800 & 546 GeV

CDF PRD 50, 5535 (1994) σ^{D} @ 1800 & 546 GeV

CDF PRD 50, 5550 (1994) σ^{T} @ 1800 & 546 GeV

KG-PR Physics Reports 101, No.3 (1983) 169-219
Diffractive interactions of hadrons at high energies

KG-95 PLB 358, 379 (1995); Erratum: PLB 363, 268 (1995)
Renormalization of hadronic diffraction

CMG-96 PLB 389, 176 (1996)
Global fit to $p^{\pm}p$, $\pi^{\pm}$ and $K^{\pm}p$ cross sections

KG-09 arXiv:0812.4464v2 [hep-ph] 26 March 2009
Pomeron intercept and slope: the QCD connection

Strategy

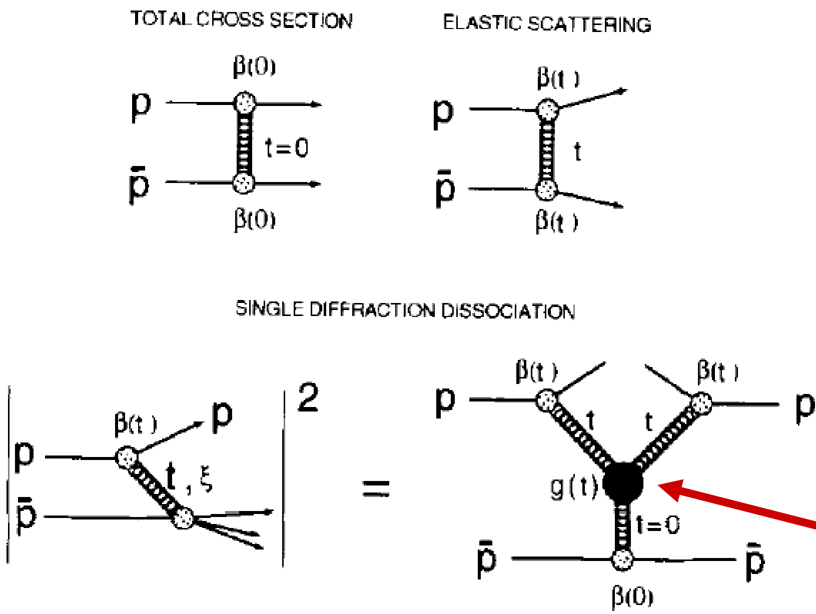
- Froissart bound $\sigma \leq \frac{\pi}{m^2} \cdot \ln^2 s$ (s in GeV^2)
- For $m^2 = m_\pi^2$ ➔ $\pi/m^2 \sim 10^4$ mb – large!
- If $m^2 = s_o$ = $(\text{mass})^2$ of a large **SUPER**glue**BALL**, the bound can be reached at a much lower s-value, s_F,

$$\Rightarrow \sigma(s > s_F) = \sigma(s_F) + \frac{\pi}{s_o} \cdot \ln^2 \frac{s}{s_F}$$

- Determine s_F and s_0 from σ_T^{SD}
- Show that $\sqrt{s_F} < 1.8$ TeV
- Show that at $\sqrt{s} = 1.8$ TeV Reggeon contributions are negligible
- Get cross section at the LHC as

$$\boxed{\sigma_{14000}^{LHC} = \sigma_{1800}^{CDF} + \frac{\pi}{\mathbf{s_0}} \cdot \ln^2 \frac{s^{LHC}}{s^{CDF}}}$$

Standard Regge Theory



(KG-95)

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

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

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

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

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

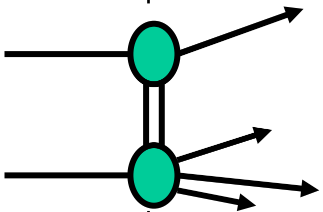
$$= f_{\mathcal{P}/p}(\xi,t)\;\sigma_T^{\mathcal{P}\bar{p}}(s',t) \qquad (4)$$

Parameters:

- ❑ s_0, s_0' and g(t)
- ❑ set $s_0' = s_0$ (universal IP)
- ❑ g(t) ➔ g(0) ≡ g_{PPP} see KG-PR
- ❑ determine s_0 and g_{PPP} – how?

Unitarity and Renormalization

Pomeron flux $\rightarrow s_0^{\varepsilon}$



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

Pomeron-proton x-section $\rightarrow s_0^{-\varepsilon/2}\cdot g_{PPP}(t)$

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

Single Diffraction

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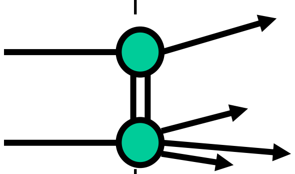
Pomeron flux

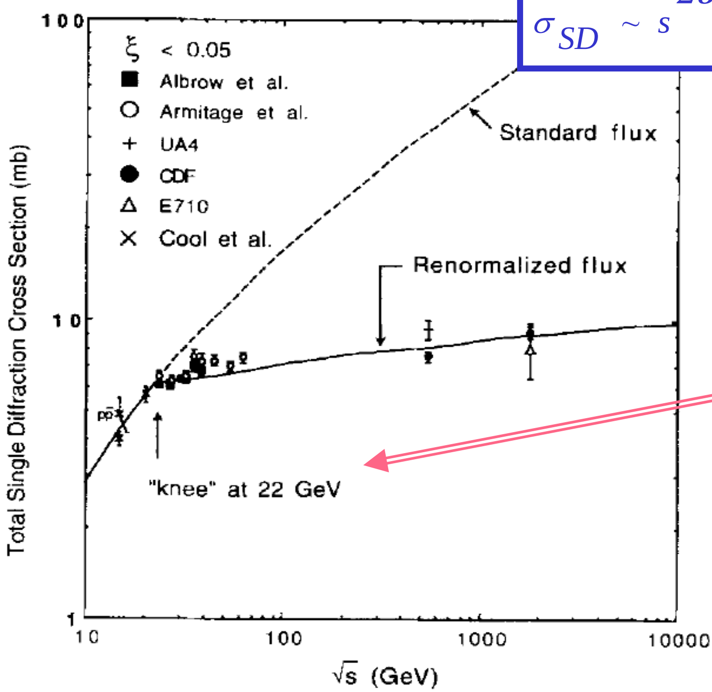


$$\frac{d^2\sigma_{SD}}{dt\,d\xi} = f_{IP/p}(t,\xi)\cdot\sigma_{IP-\bar{p}}(s\,\xi)$$

s_0^{ε} $\quad s_0^{-\varepsilon/2}\cdot g_{PPP}(t)$

$$\int_{\xi_{min}}^{0.1}\int_{t=-\infty}^{0} f_{IP/p}(t,\xi)\,d\xi\,dt \Rightarrow 1$$

$$\sigma_{SD} \sim s^{2\varepsilon}$$



Renormalization

- $\int_{\xi_{min}\approx 1/s}^{\zeta}\int_{t=-\infty}^{0} f_{IP/p}(t,\xi)\,d\xi\,dt \approx C\cdot s^{2\varepsilon}\cdot s_0^{\varepsilon} \Rightarrow 1$
- Flux integral depends on s and s_0
- "knee" √s-position determines s-value where flux becomes unity ➔ get s_o
- get error in s_o from error in √s-knee

$\delta s_o/s_o = -2\,\delta s/s = -4\,(\delta\sqrt{s})/\sqrt{s}$

The value of s_o - a bird's-eye view

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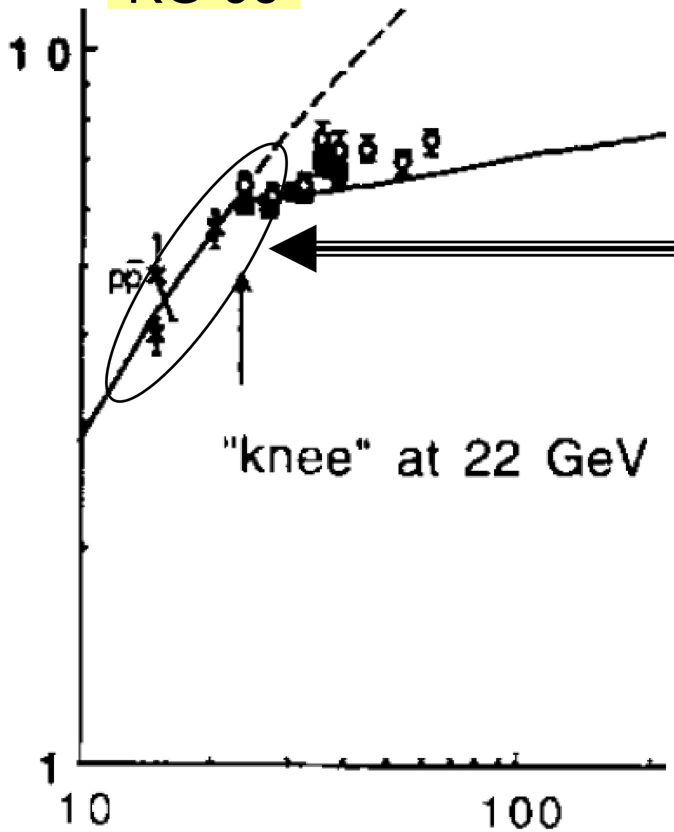

			√s (GeV)	
☒	Cool [KG]	FNAL	14	20
■	Albrow	ISR	23.3	26.9
o	Armitage	ISR	23.3	27.4

➔ error in knee position: ± 1 GeV

"knee" @ 22 ± 1 GeV ➔ s_0 = 1 ± 0.2 GeV

➔riple-Pomeron coupling:

$$g_{PPP}(t) = 0.69\ \text{mb}^{1/2} = 1.1\ \text{GeV}^{-1}$$

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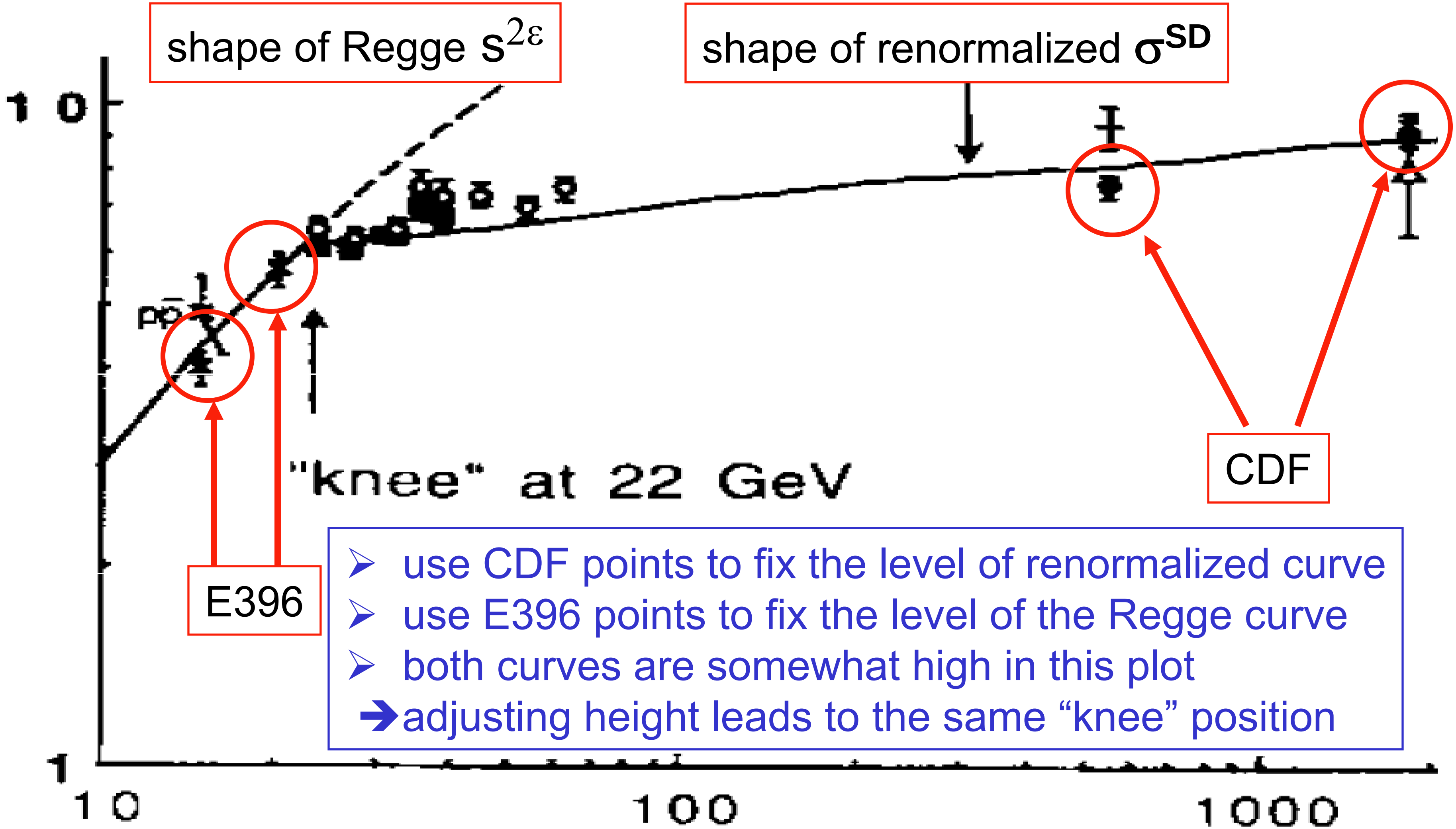
The value of s_o - limited edition



- use CDF points to fix the level of renormalized curve
- use E396 points to fix the level of the Regge curve
- both curves are somewhat high in this plot

➔ adjusting height leads to the same "knee" position

The SUPERBALL cross-section

- Froissart bound $$\sigma \le \frac{\pi}{m^2} \cdot \ln^2 s$$

- Valid above "knee" at √s = 22 GeV and therefore at √s = 1.8 TeV

- Use superball mass

  ➔ $m^2 = s_0 = (1 \pm 0.2)\ \mathrm{GeV}^2$

- At √s 1.8 TeV Reggeon contributions are negligible (see global fit)

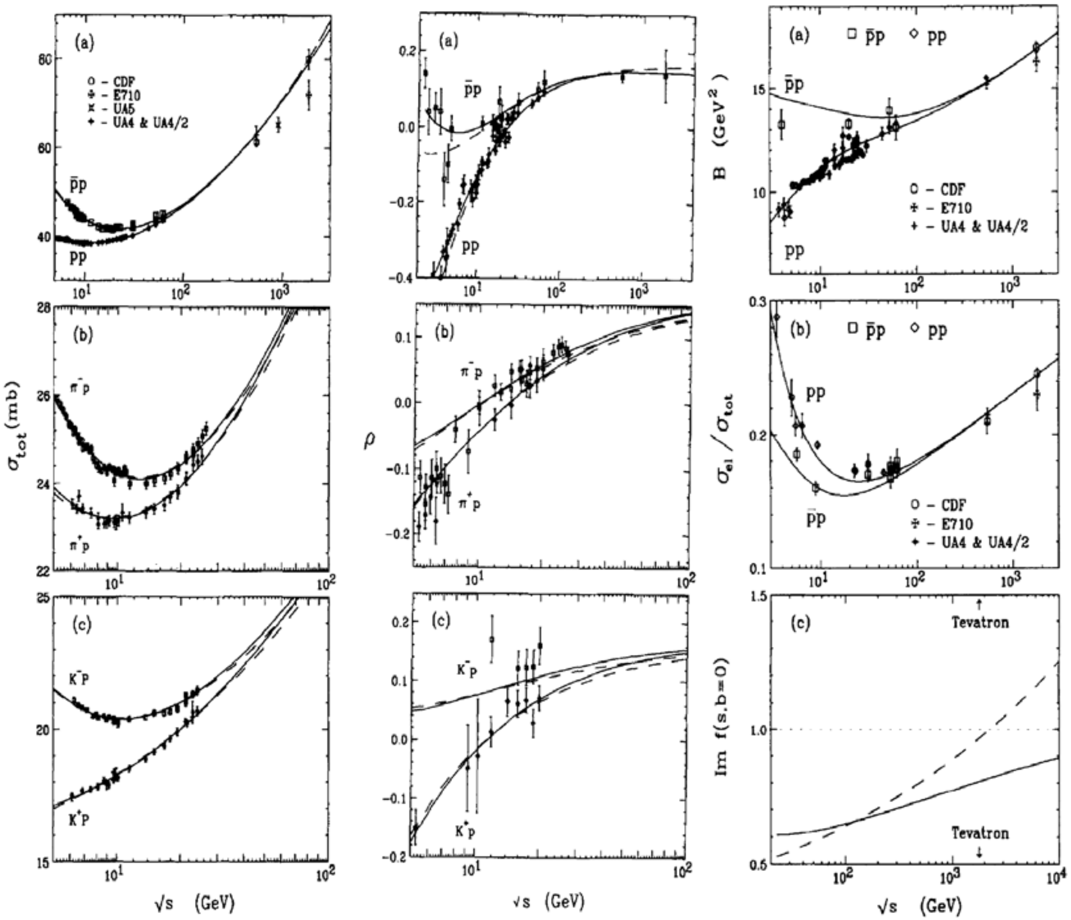
$$\sigma_{14000}^{\mathrm{LHC}} = \sigma_{1800}^{\mathrm{CDF}} + \frac{\pi}{s_0} \cdot \ln^2 \frac{s^{\mathrm{LHC}}}{s^{\mathrm{CDF}}} = (80.03 \pm 2.24) + (33 \pm 6) = 113 \pm 6\ \mathrm{mb}$$

➔ compatible with CGM-96 global fit result of 114 ± 5 mb (see next slides)

Global fit to p±p, π±, K±p x-sections

CMG-96 → A new determination of the soft pomeron intercept

R.J.M. Covolan[1], J. Montanha[2], K. Goulianos[3]



Use standard Regge theory

- INPUT

$$\alpha_{f/a} = 0.68 + 0.82\,t$$

$$\alpha_{\omega/\rho} = 0.46 + 0.92\,t$$

$$\alpha'_{\mathbb{P}} = 0.25\ \mathrm{GeV}^{-2}$$

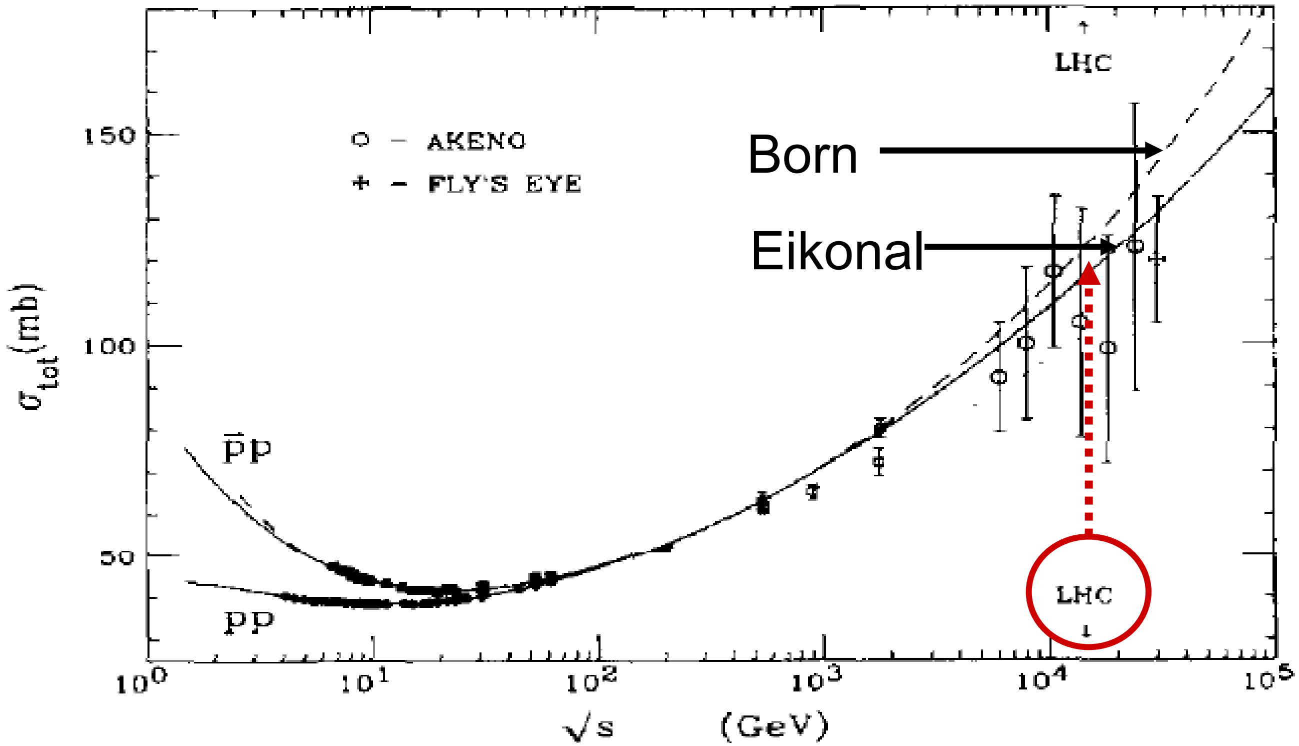
- RESULTS

$$\alpha_{0,\mathbb{P}}^{\mathrm{Born}} = 1.104 \pm 0.002\,,\quad \alpha_{0,\mathbb{P}}^{\mathrm{Eik}} = 1.122 \pm 0.002$$

$$\sigma_{\mathrm{tot}}^{p^{\pm}p} = 16.79\, s^{0.104} + 60.81\, s^{-0.32} \mp 31.68\, s^{-0.54}$$

negligible

σ^T at LHC from global fit



- σ @ LHC $\sqrt{s}$=14 TeV: 122 ± 5 mb Born, 114 ± 5 mb eikonal
  → error estimated from the error in ε given in CMG-96

Compare with **SUPERBALL** σ(14 TeV) = 113 ± 6 mb

caveat: s_o=1 GeV^2 was used in global fit!

Extra: the ratio of α'/ε

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$$\frac{d^2\sigma(s,M^2,t)}{dM^2dt} = \left[\frac{\sigma_0^{pp}}{16\pi}\sigma_0^{Pp}\right] \frac{s^{2\epsilon}}{N(s)} \frac{1}{(M^2)^{1+\epsilon}} e^{bt} \overset{s\to\infty}{\longrightarrow} \left[2\alpha' e^{\frac{\epsilon b_0}{\alpha'}} \sigma_0^{Pp}\right] \underbrace{\frac{\ln s^{2\epsilon}}{(M^2)^{1+\epsilon}}}_{b=b_0+2\alpha' \ln\frac{s}{M^2}} e^{bt}$$

The key!

$$\sigma_{sd} \overset{s\to\infty}{\longrightarrow} \sigma_0^{Pp} e^{\frac{\epsilon}{2\alpha'}b_0} s^{\epsilon} \frac{\sum_{n=1}^{\infty}\frac{(\ln s^{\epsilon})^n}{n\, n!}}{\sum_{n=1}^{\infty}\frac{(\ln s^{2\epsilon})^n}{n\, n!}} = 2\sigma_0^{Pp} e^{\frac{\epsilon}{2\alpha'}b_0} \Rightarrow \sigma_0^{pp}$$

$$\sigma_0^{Pp} = \kappa\sigma_0^{pp} \quad \Rightarrow \quad 2\kappa \exp\left(\frac{\varepsilon b_o^{sd}}{2\alpha'}\right) = 1 \qquad b_o^{sd} = \frac{R_p^2}{2} = \frac{1}{2m_\pi^2}$$

$$\frac{\alpha'}{\varepsilon} = -\frac{1/4m_\pi^2}{4\ln(2\kappa)} = 3.12 \pm 0.4\left(\frac{GeV}{c}\right)^{-2} \underset{\varepsilon=0.08}{\Longrightarrow} \alpha' = 0.25 \pm 0.03\left(\frac{GeV}{c}\right)^{-2}$$

SUMMARY

- Froissart bound $$\sigma \le \frac{\pi}{m^2} \cdot \ln^2 s$$

- Valid above the "knee" at √s = 22 GeV in σ_T^{SD} vs. √s and therefore valid at √s = 1.8 TeV of the CDF measurement

- Use superball mass s_0 (saturated dressed proton mass) in the Froissart- Martin formula, where s_0 is determined from setting the integral of the Pomeron flux to unity at √s = 22 GeV

  ➔ $m^2 = s_0 = (1 \pm 0.2)\ \text{GeV}^2$

- At √s 1.8 TeV Reggeon contributions are negligible (see global fit)

- $$\sigma_{14000}^{LHC} = \sigma_{1800}^{CDF} + \frac{\pi}{s_0} \cdot \ln^2 \frac{s^{LHC}}{s^{CDF}} = (80.03 \pm 2.24) + (33 \pm 6) = 113 \pm 6\ \text{mb}$$

- compatible with CGM-96 global fit result of 114 ± 5 mb


thank you

DISCUSSION