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Diffraction Scattering: Problems in Theory and Praxis

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LHC: 2009 - 2017

- "Old Physics":

- Completion of the SM with Higgs

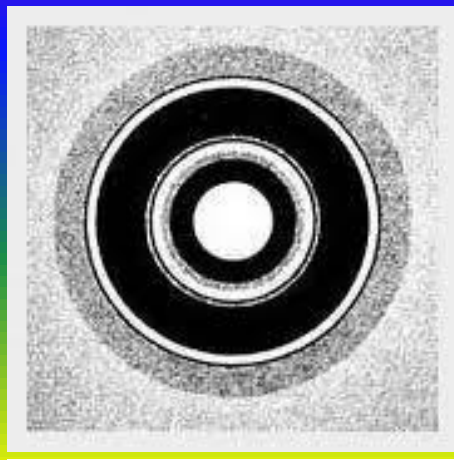
- "New Physics":

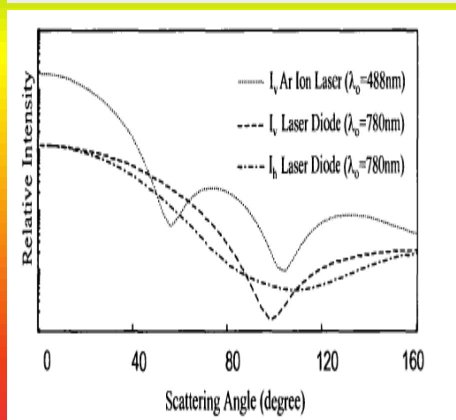
- Supersymmetry:
- "Stringy effects"
- Dark matter ("dark photons")
- Lepto-quarks
- Compositeness
- Extra dimensions
- ....

NONE

What Is Diffraction Scattering ?

Light scattering off a polystirene latex particle

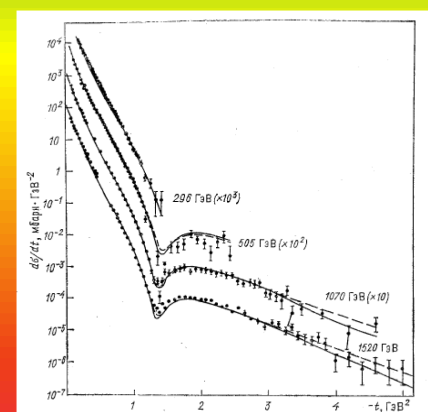




$E = 1.6 \div 2.5$ eV

$R = 0.5\ \mu m = 5 \cdot 10^{-7} m = 5 \cdot 10^{8}$ fm

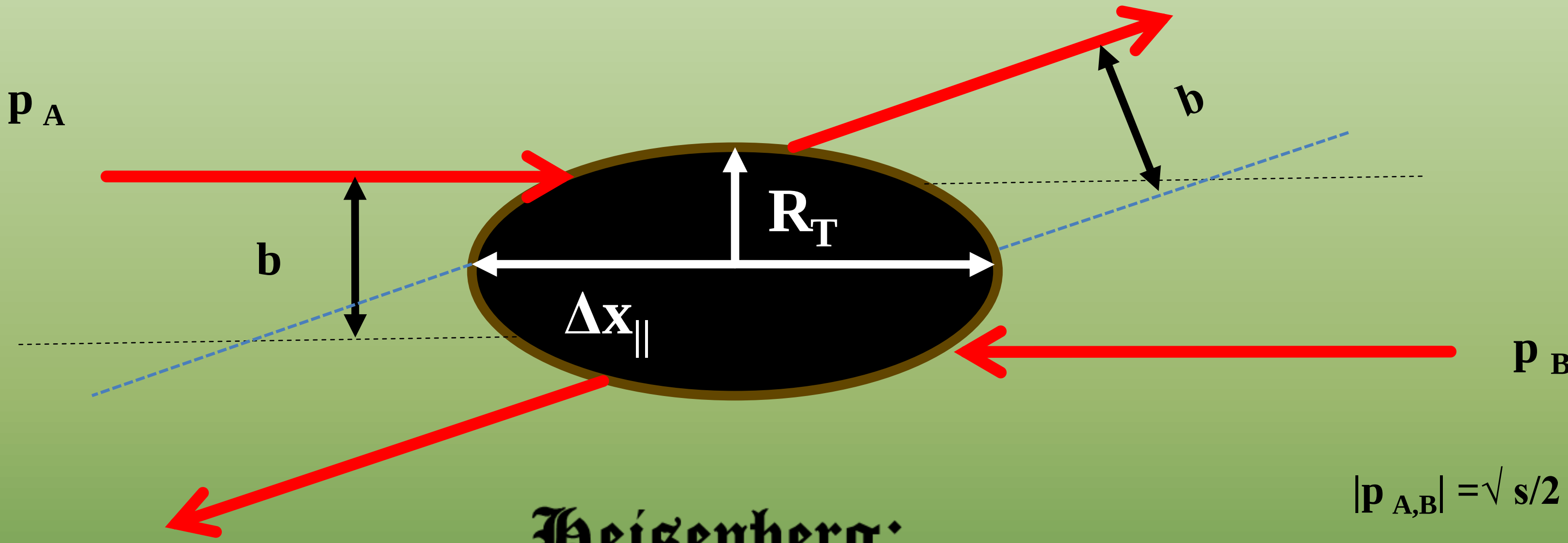
Proton-proton scattering



$E = 2.96 \cdot 10^{11}$ eV $\div\ 1.52 \cdot 10^{12}$ eV

$R = 1.6 \cdot 10^{-15}$ m $= 1.6 \cdot$ fm

Diffraction: Characteristic Scales



$|p_{A,B}| = \sqrt{s}/2$

Heisenberg:

$$\langle b^2 \rangle^{1/2} = R_T = \Delta x_\perp > 1/\sqrt{<-t>} \approx 1 \text{ fm}$$

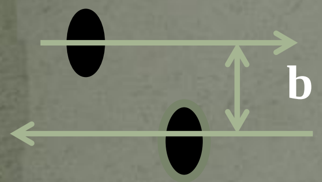
$$\Delta x_{||} > \sqrt{s} / (2 \sqrt{< t^2 > - < t >^2}) \approx 10^4 \text{ fm at LHC}$$

$$(\Delta x)^2 \equiv < x^2 > - < x >^2$$

$\langle b^2 \rangle(\text{LHC}) \approx 2B \approx 40 GeV^{-2} \approx (1.25\, fm)^2$

$r_{Compton}(\text{Higgs}) = 1.6 \cdot 10^{-3}$ fm

Transverse Interaction Region



The slope parameter: $B(s) = d\{d\,\sigma/dt\}/dt\,|_{t=0}$

$\rightarrow$ **$d\sigma/dt = [d\sigma/dt]_{t=0}\, e^{Bt}$**

Physical meaning :

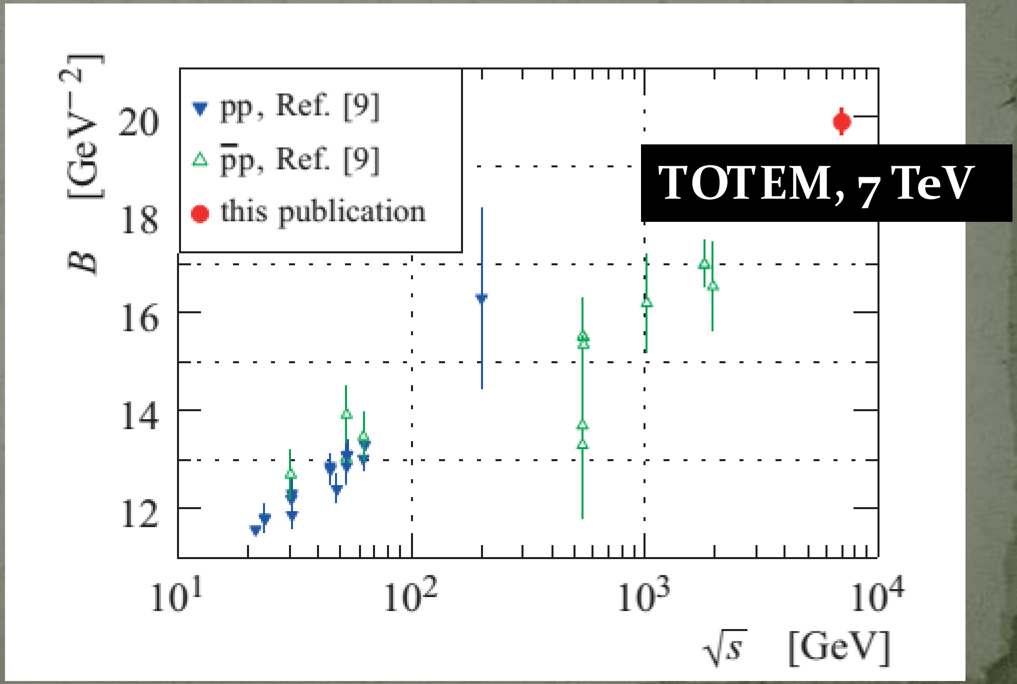
$$2B(s) \approx \langle b^2 \rangle = \Delta x_T^{\,2}$$

LHC (TOTEM (2012)- ATLAS(ALFA, 2014) 7 TeV:

$$\langle b^2 \rangle^{1/2} \cong 1.26 \pm 0.01\ (fm)$$

U-70 (IHEP (1971)) 0.01 TeV:

$$\langle b^2 \rangle^{1/2} \cong 0.88 \pm 0.02\ (fm)$$

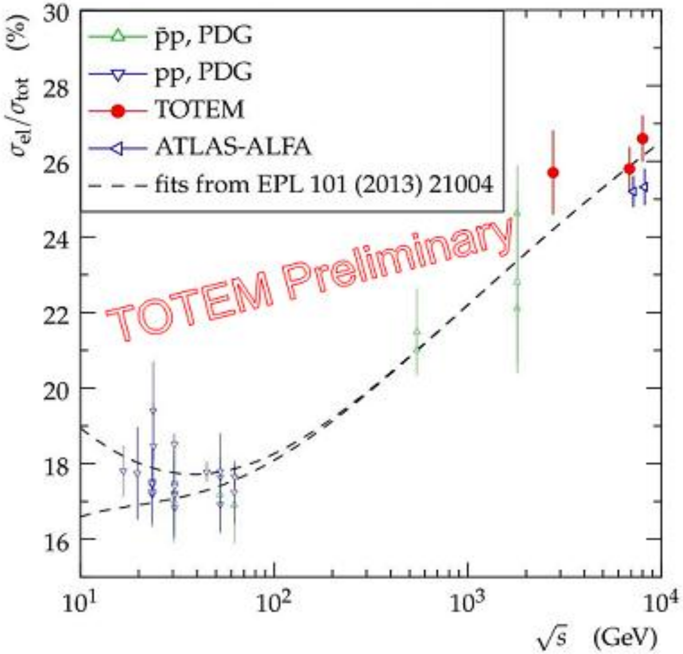


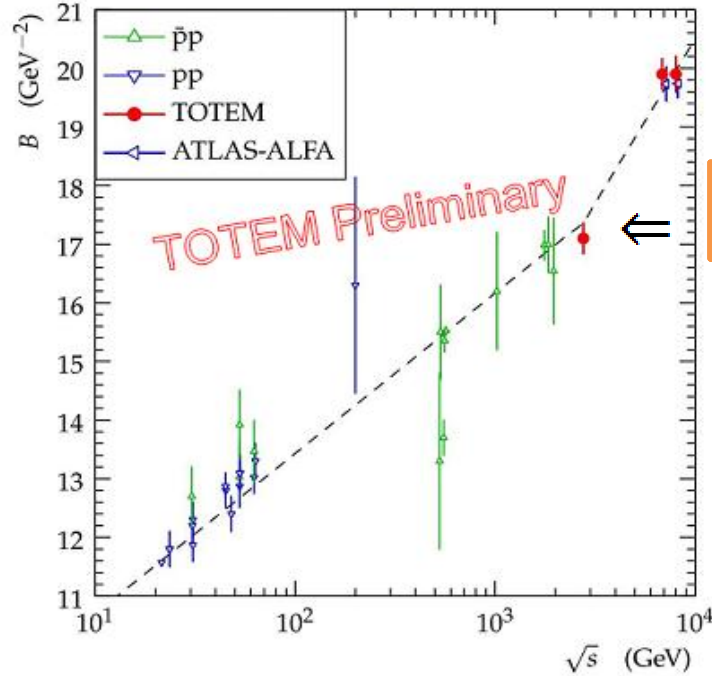
$$\langle b^2 \rangle \approx 2B(s)$$

$<r^2> \approx 3\ B(s = (2760\ \text{GeV})^2) \approx 1/m_\pi^{\ 2}$!
$m_{\text{effective}}(\text{gluon}; \sqrt{s} = 2760\ \text{GeV}) \approx m_\pi$

$\sigma_{el} / \sigma_{tot}$ = (25.7 ± 1.1) %

B = 17.10 ± 0.26 GeV^{-2}
assume $d\sigma_{el}/dt \propto e^{-B|t|}$





⇐ Surprise !

Comparison with 1.8 TeV: B_{CDF} = 16.98 ± 0.25 GeV^{-2}
B_{E710} = 16.99 ± 0.47 GeV^{-2}

Theory: Basic Notions

- ReggeTrajectory α (t), Regge residue β(t)

$$T(s,t) = \beta(t)(e^{-\frac{i\pi}{2}}s)^{\alpha(t)}$$

- Small angles ($-t \approx p^2\theta^2 \ll s$):

$$\alpha(t) = \alpha(0) + \alpha'(0)t + \cdots$$

$$\alpha(0) < 1 \qquad \sigma_{tot} \Rightarrow 0$$

$$\alpha(0) = 1 \qquad \sigma_{tot} \Rightarrow const$$

$$\alpha(0) > 1 \qquad \sigma_{tot} \Rightarrow \infty$$

QCD = Fundamental Theory of Strong Interactions

QCD predictions:

$$\alpha(t)|_{-t\to\infty} \approx 1 + \frac{4N_c ln2}{\pi}\frac{g_s^2(t)}{4\pi} + \ldots$$

$$\frac{g_s^2(t)}{4\pi} \sim \frac{1}{ln(-\frac{t}{\Lambda^2})}$$

$$\alpha(t) = F\left(\frac{t}{\Lambda^2}\right) = \Phi(g_s^2(t))$$

$$\Lambda^2 = \mu^2 \exp\left(\int \frac{dg_s^2}{\beta(g_s^2)}\right)$$

$$g_s^2(0) = g_*^2 < \infty\ ?$$

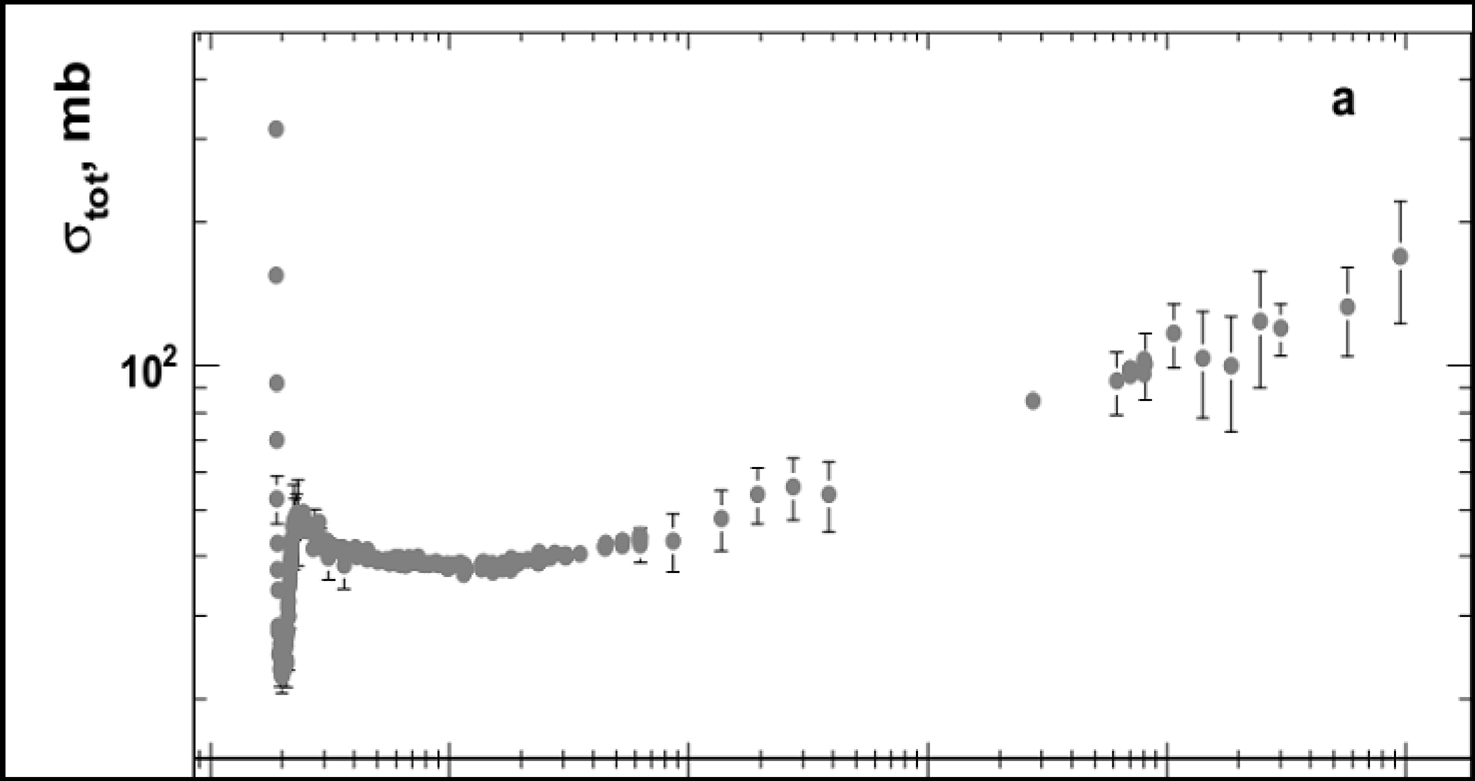
$$\beta(g_*^2) = 0$$

Trace anomaly:

$$\theta_\mu^\mu = \frac{\beta(g_s^2)}{4g_s^2} F^{\alpha\beta}F_{\alpha\beta}$$

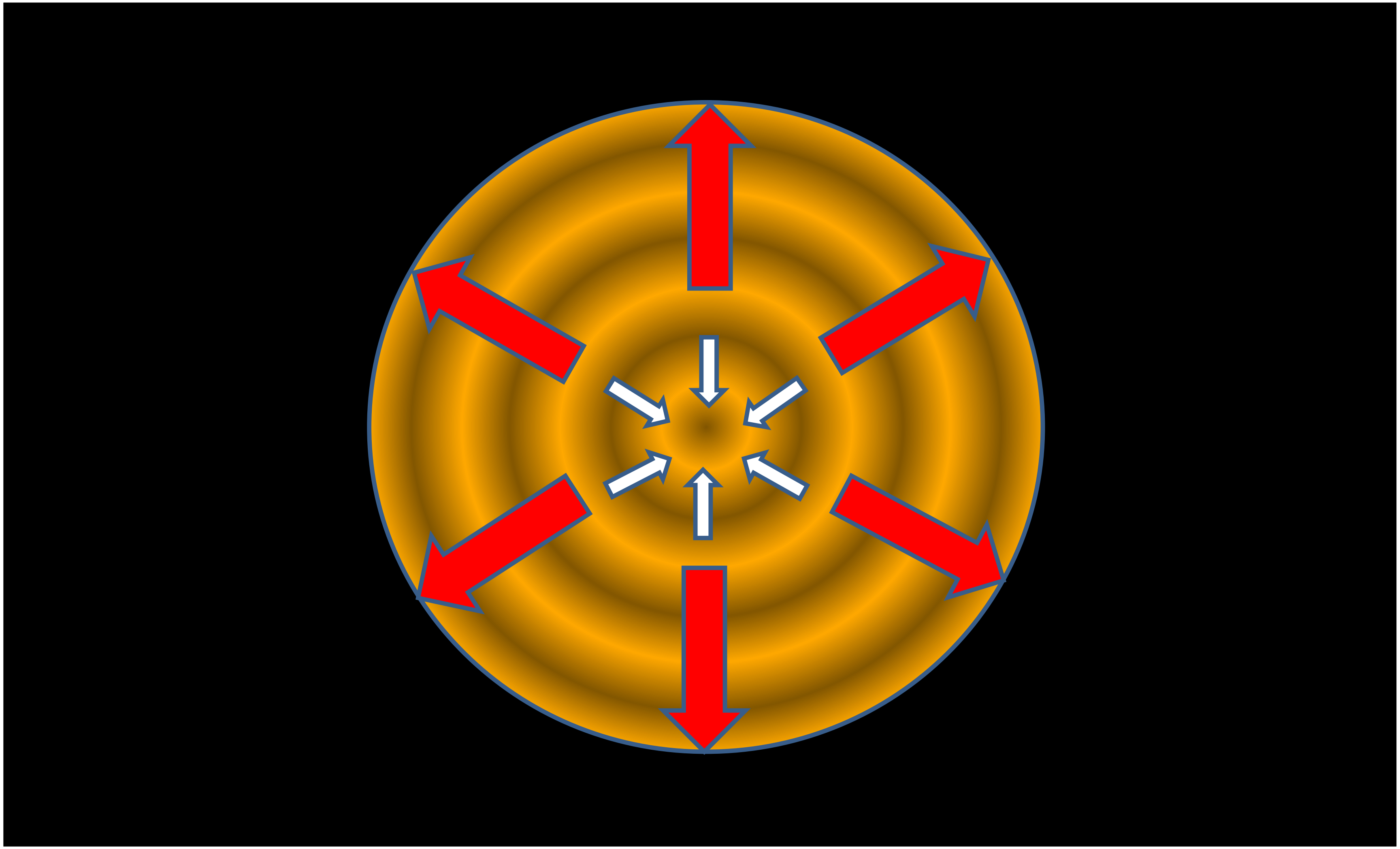
$$\theta_\mu^\mu(g_s^2(0)) = 0$$

$$\alpha(0) = ?$$



$\alpha(0) > 1!$

QUO VADIS?



Conclusion

To explain Diffraction Scattering of Nucleons is to resolve the most acute problem of the SM:

Large distance behavior of QCD