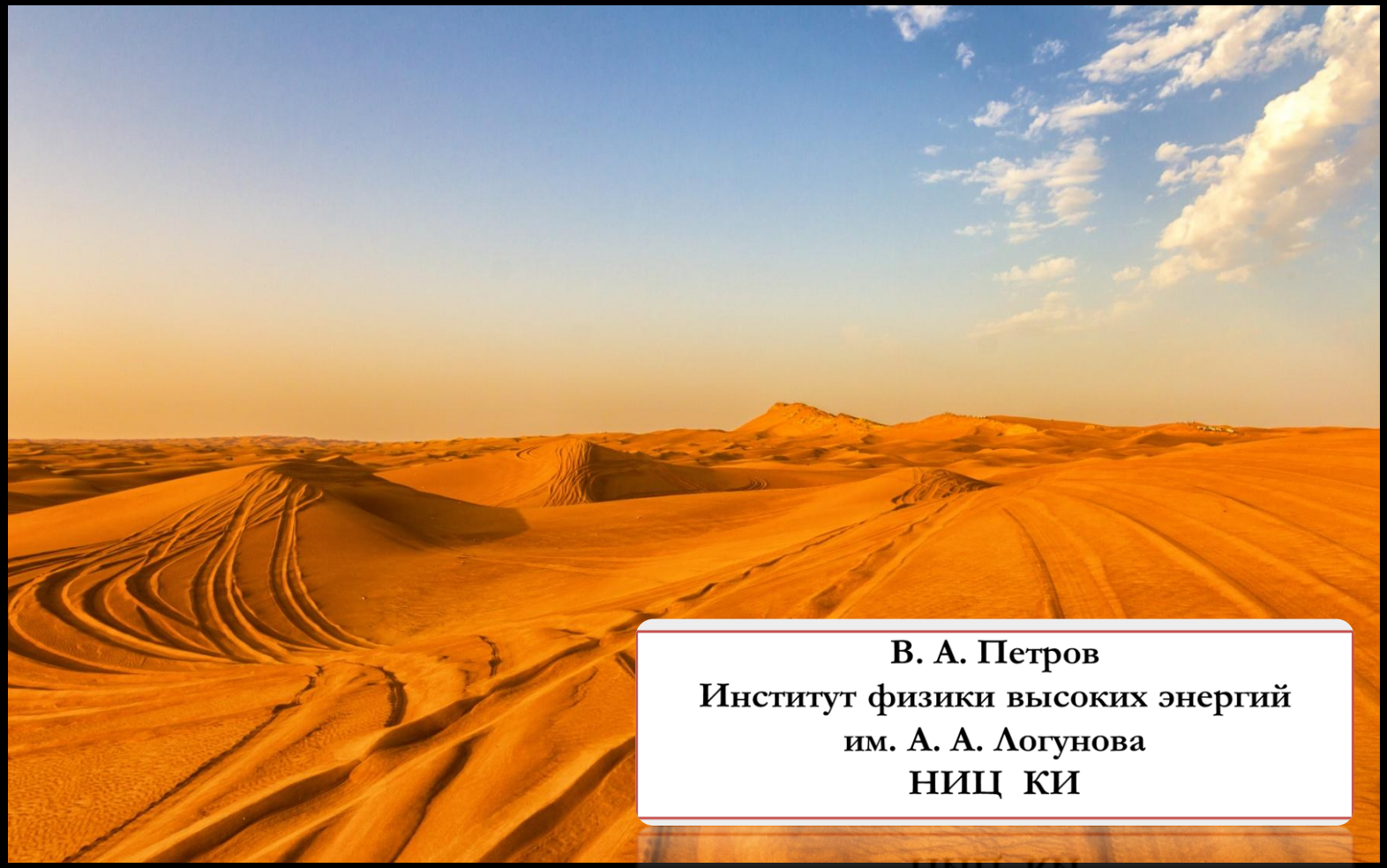
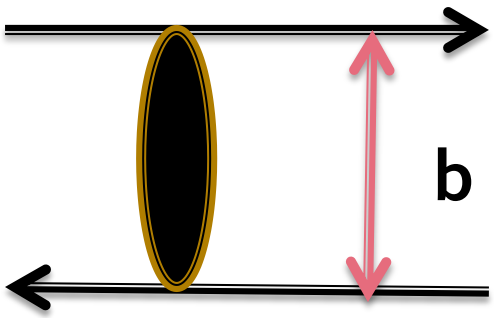
Размер имеет значение
или
где лежит «асимптопия»?



В. А. Петров
Институт физики высоких энергий
им. А. А. Логунова
НИЦ КИ

Семинар ОТФ, 5 июня 2018 г.

РАЗМЕР ЧЕГО



$$\langle b^2 \rangle = \int d^2b\, w(b^2)\, b^2$$

$$w(b^2) = \mathrm{Im}\,\tilde{\mathrm{T}}(s,b)\left[\int db^2\, \mathrm{Im}\,\tilde{\mathrm{T}}(s,b)\right]^{-1}$$

$$\mathcal{A}_{el}(s,t) = 4s\int d^2b e^{iqb}\tilde{T}\,(s,b)$$

$$2B(s) = \langle b^2\rangle_{\mathrm{tot}} - 2\rho(s)\frac{\partial\Phi}{\partial t}(s,0)$$

$$\boldsymbol{\rho = \mathrm{ctg}\,\Phi(s,0)}$$

$$B(s,t) \equiv \frac{1}{d\sigma/dt}\frac{\partial[d\sigma/dt]}{\partial t} = \frac{\partial \ln[d\sigma/dt]}{\partial t}$$

$$\Phi(s,t) = \arg\mathcal{A}_{el}(s,t)$$

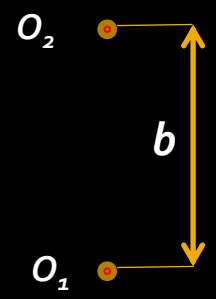
$$B(s) = B(s,t=0)$$

Elementary Geometry of Collision

High Energies

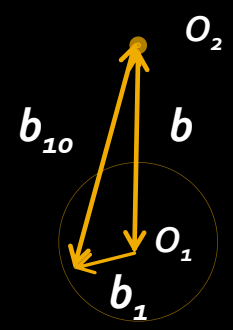
Pointlike particle

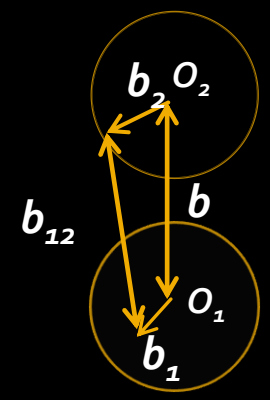
Pointlike particle



Pointlike particle

Extended particle

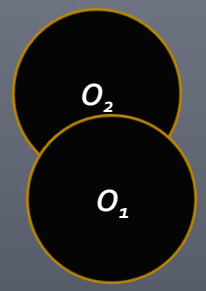




$$\langle b_1 b_2 \rangle = \langle b_1 b_{12} \rangle = \langle b_2 b_{12} \rangle = 0$$

$$\langle b^2 \rangle = \langle b_1^2 \rangle + \langle b_2^2 \rangle + \langle b_{12}^2 \rangle \geq \langle b_1^2 \rangle + \langle b_2^2 \rangle$$

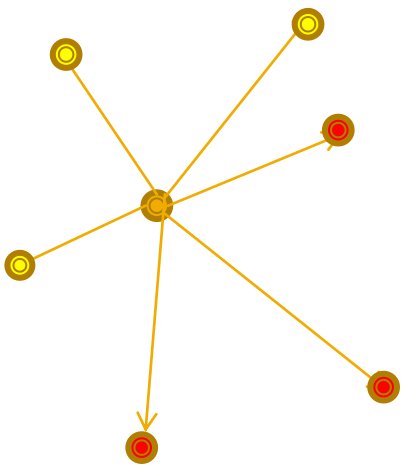
Low Energies



$$\langle b_1 b_2 \rangle \neq 0$$
$$\langle b_1 b_{12} \rangle \neq 0$$
$$\langle b_2 b_{12} \rangle \neq 0$$

ЗАРЯДОВЫЙ РАДИУС И ИСТИННЫЙ РАДИУС

$$F(\boldsymbol{q}) = F(0) - \frac{\boldsymbol{q}^2}{6}\langle \boldsymbol{r}^2\rangle_{charge} + \cdots \quad \langle \boldsymbol{r}^2\rangle_{charge} = -\frac{\partial F(\boldsymbol{q})}{\partial \boldsymbol{q}^2}\Big|_{\boldsymbol{q}^2=0}$$



$$\langle \boldsymbol{r}^2\rangle_{charge} = \sum_{k=1}^{\nu} e_k N_k \langle \boldsymbol{x}^2\rangle_k \ngeq 0$$

$$\langle \boldsymbol{r}^2\rangle_{true} = \frac{1}{\nu}\sum_{k=1}^{\nu} \langle \boldsymbol{x}^2\rangle_k \geq 0$$

$$r_e^2(proton)(ep\ \text{CODATA}) = 0.7700 \pm 0.0089 fm^2 = (\mathbf{0.8775 \pm 0.0051\ fm})^2$$

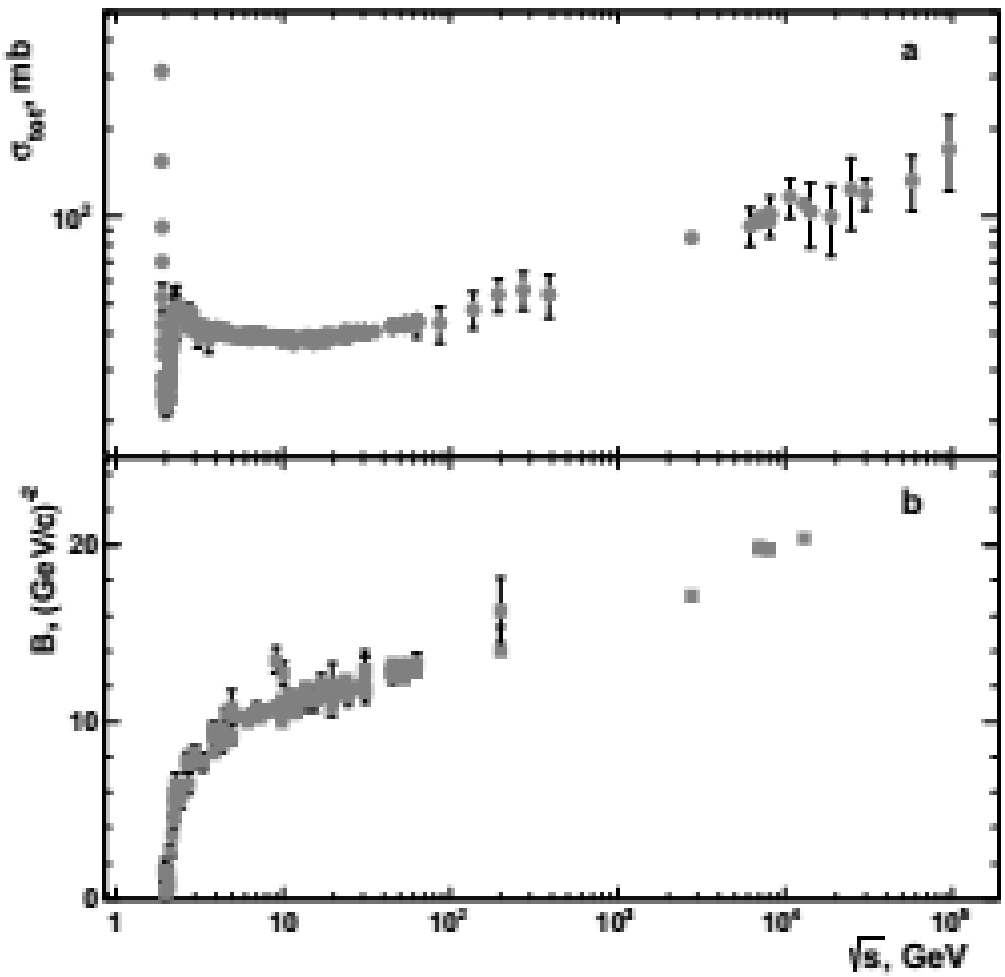
$$\langle \boldsymbol{r}^2\rangle_{true}(\boldsymbol{proton}) = 0.6539 \pm 0.0092 fm^2 = (0.8086 \pm 0.0070 fm)^2$$

(V.A.P. & V. Okorokov)

International Journal of Modern Physics A
Vol. 33, No. 13 (2018) 1850077 (27 pages)

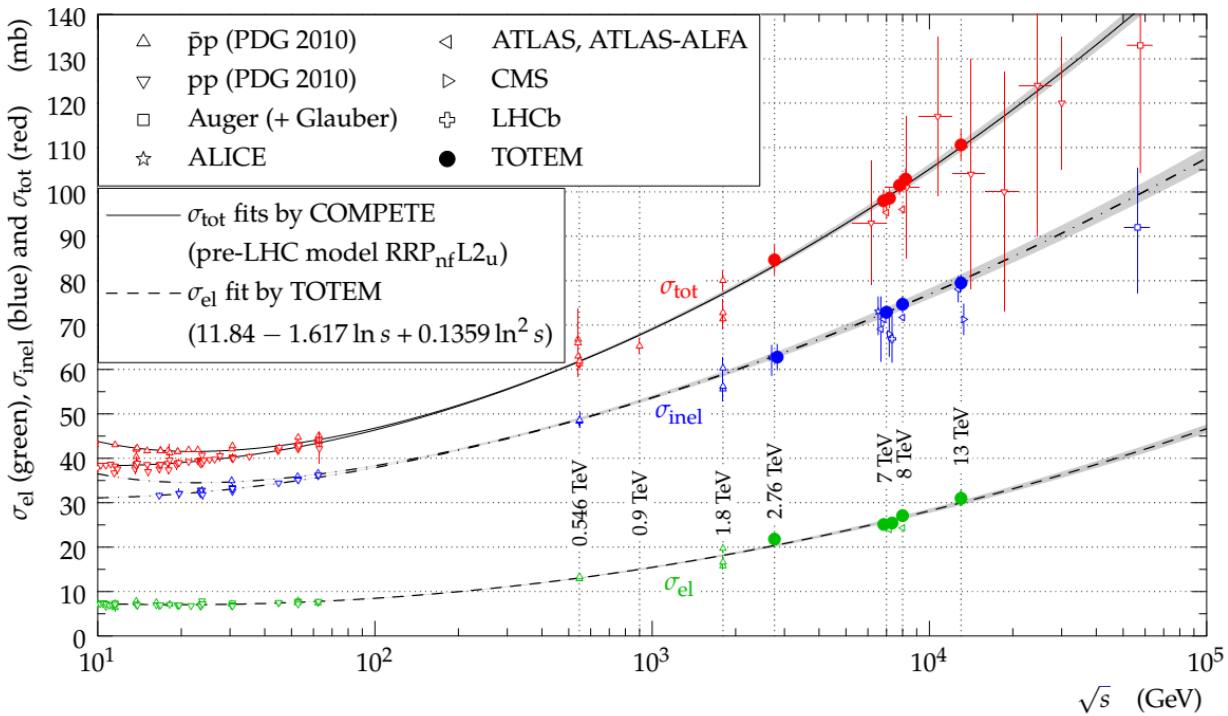
$$\langle r^2\rangle_{true}(proton) = \frac{3}{2}\langle b^2\rangle(proton)$$

$$\langle \boldsymbol{b}^2\rangle(\boldsymbol{proton}) \cong \mathbf{11.2}\,\boldsymbol{GeV}^{-2}$$


a
b
σ_{tot}, mb
10^2
B, (GeV/c)$^{-2}$
20
10
0
1
10
10^2
10^3
10^4
10^5
$\sqrt{s}$, GeV

LHC

- cross-section measurement at $\sqrt{s}$ = 13 TeV (assuming ρ = 0.10): !
  σ_{tot} = (110.6 ± 3.4) mb , σ_{inel} = (79.5 ± 1.8) mb , σ_{el} = (31.0 ± 1.7) mb
- cross-section evolution with energy



$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \frac{dN_{el}/dt|_{t=0}}{N_{el} + N_{inel}}$$

$$\rho = \left. \frac{\Re \mathcal{A}_{el}}{\Im \mathcal{A}_{el}} \right|_{t=0}$$

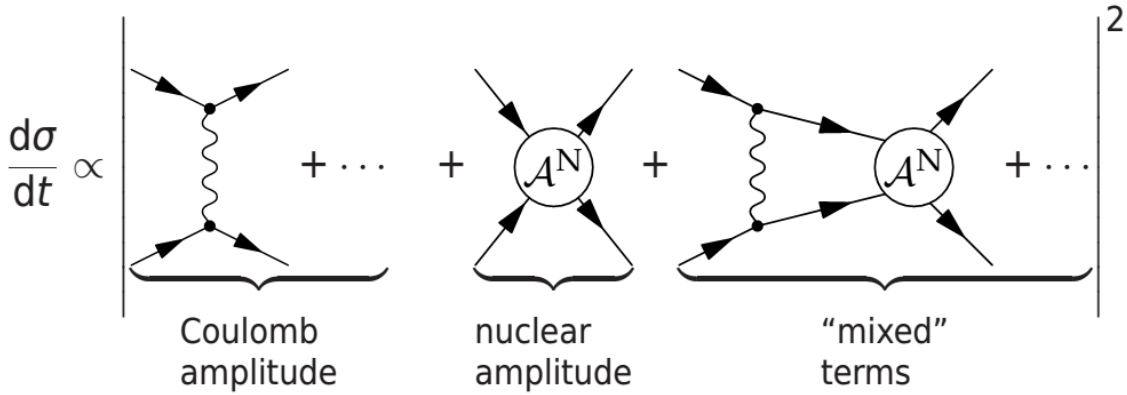
$$\rho = \mathrm{ctg}\, \Phi(s, 0)$$

- σ_{tot} compatible with COMPETE [1] prediction, asymptotically $\ln^2(s)$

Как измерить фазу?

Coulomb-nuclear interference

- observed cross-section

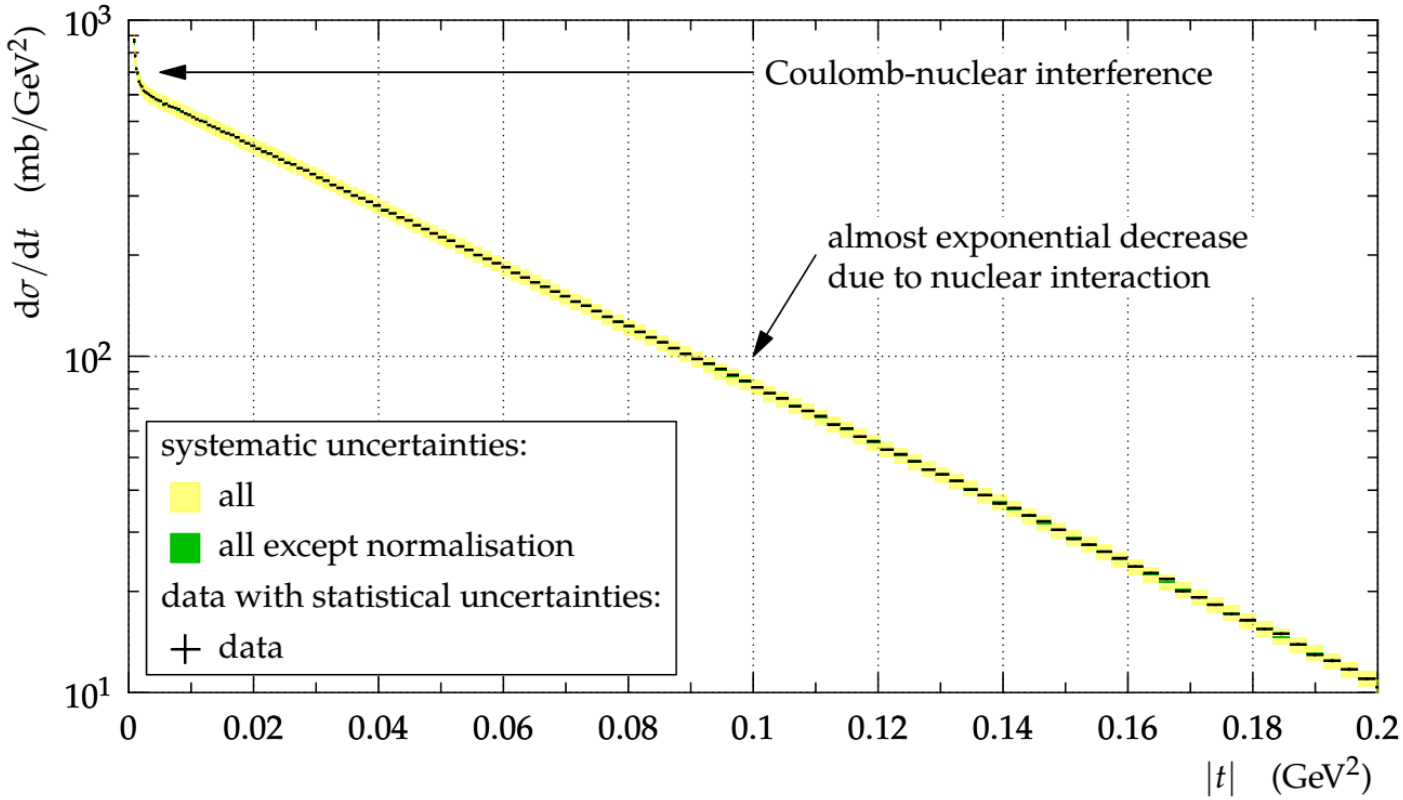


- our modelling
  - "*interference formula*" = summation for practical applications
    - considered: West-Yennie [2], Cahn [3] and Kundrát-Lokajíček [4]
  - *Coulomb amplitude*: QED + experimental form factors
  - *modulus of* $\mathcal{A}^N$: empirical guidance $\Rightarrow$ at low $|t|$: $a \exp\left(\sum_{n=1}^{N_b} b_n t^n\right)$
  - *phase of* $\mathcal{A}^N$
    - assume slow variation with $|t|$ (more exploration in a forthcoming study)
    - same assumption as in pre-LHC determinations $\Rightarrow$ fair comparison

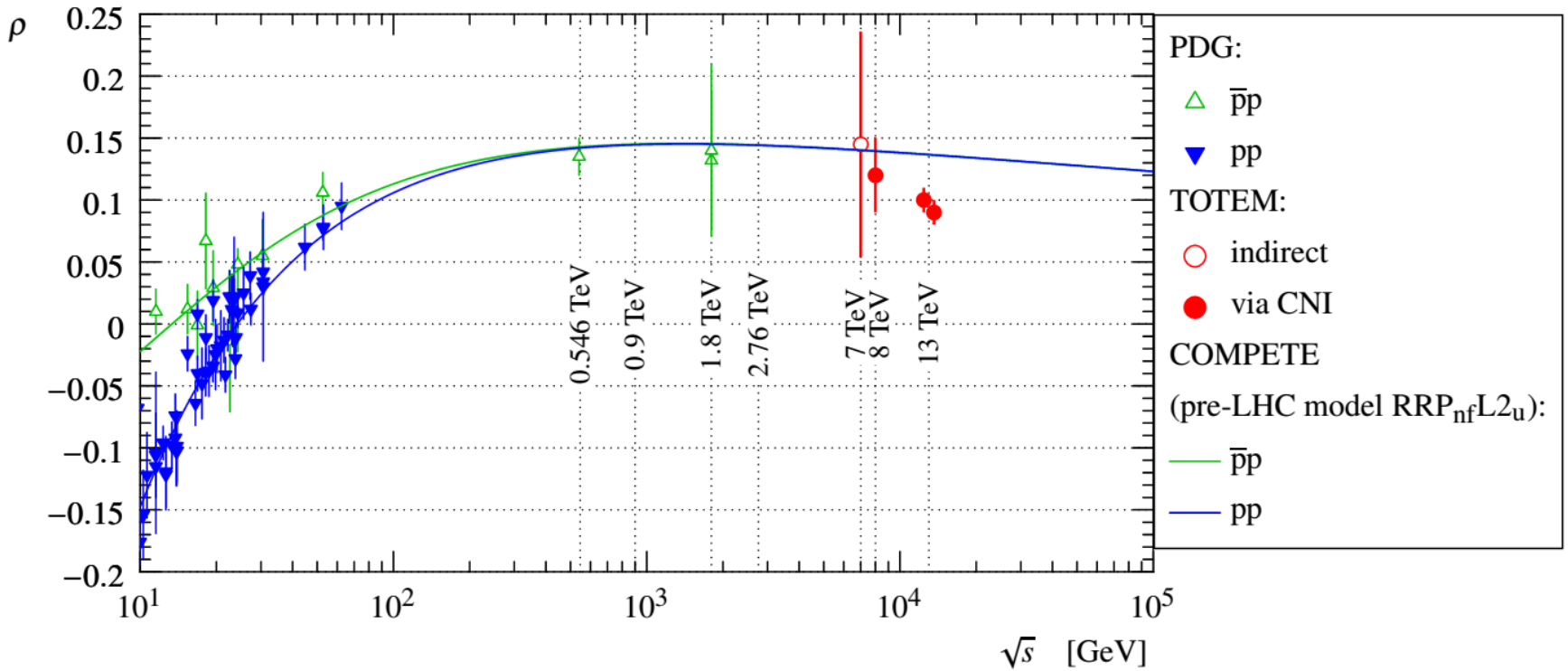
Wrong

(V.A.P. Eur.Phys.J. C78 (2018) no.3, 22)

- TOTEM data, $\sqrt{s}$ = 13 TeV, β^* = 2500 m:



Odderon?



⇒ *13 TeV measurement significantly lower than extrapolations (more than 4 σ effect)*

CERN Courier Mar 23, 2018
Oddball antics in proton–proton collisions

百花齐放，百家争鸣

ПУСТЬ РАСЦВЕТАЮТ СТО ЦВЕТОВ,
ПУСТЬ СОПЕРНИЧАЮТ СТО ШКОЛ!

МАО-ЦЗЕ ДУН (1957)

V. A. Schegelsky and M. G. Ryskin, *Phys. Rev. D* **85**, 094024 (2012)

$$\sigma_{\rm tot}^{pp} = \sigma_0 + 2\alpha'_{\mathbf{P}}(0)\ln(s/s_0) + c_2\ln^2(s/s_0)$$

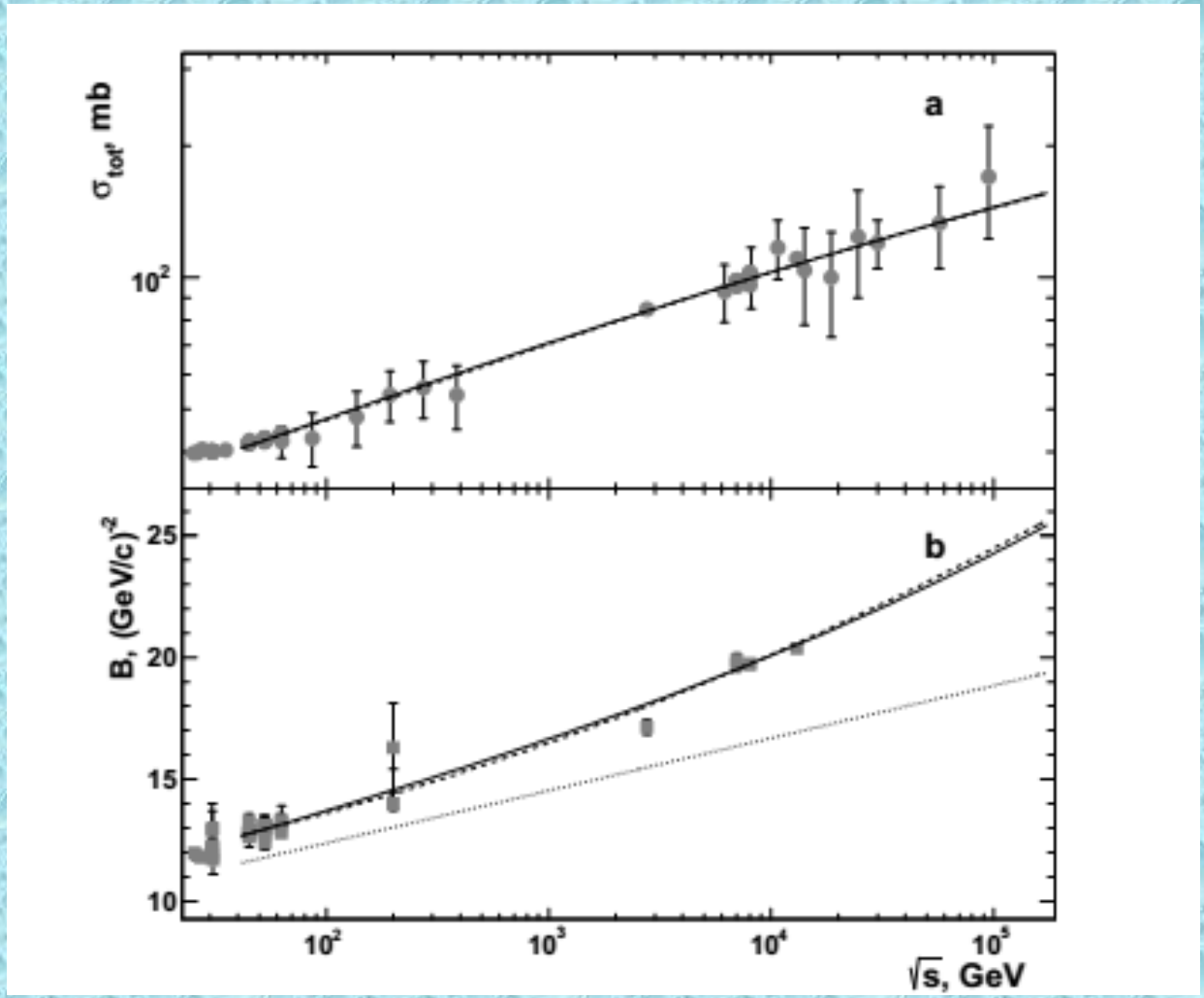
$$B(s) = b_0 + 2\alpha'_{\mathbf{P}}(0)\ln(s/s_0) + b_2\ln^2(s/s_0)$$

V. A. Petrov and V. A. Okorokov, Int. J. Mod. Phys. A **33**, 1850077 (2018)

$$\sigma_{\rm tot}^{pp}(s) = 2\pi\langle b^2\rangle_{pp}^{1\mathbf{P}}[\mathbf{C} + \ln\xi - \mathrm{Ei}(-\xi)]$$

$$B(s) \approx r_0^2 + 2\alpha'_{\mathbf{P}}(0)\ln(s/s_0) + 0.109\frac{g^2(s/s_0)^{\Delta}}{4\pi s_0}$$

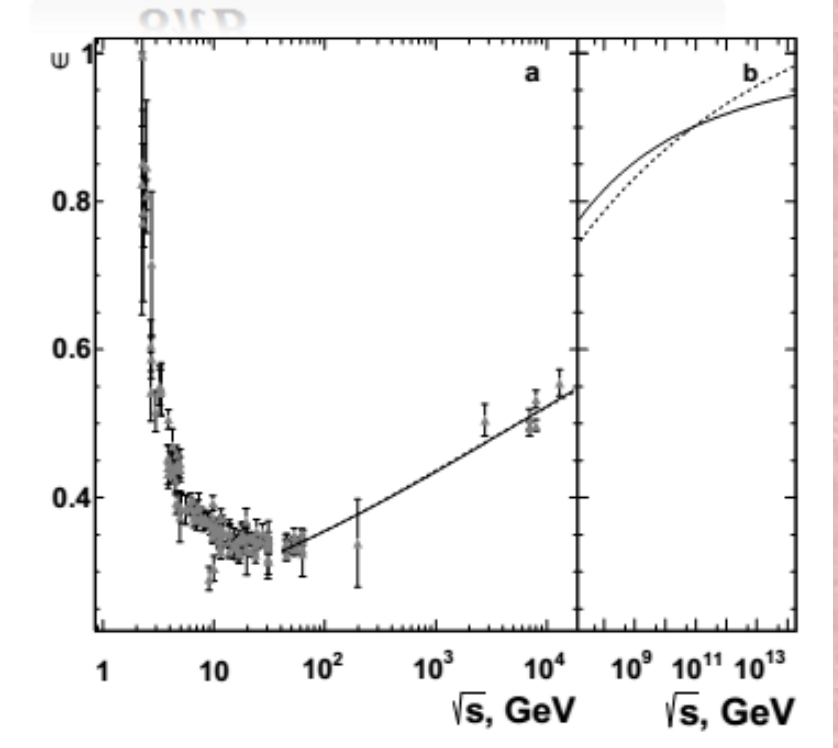
$$\xi(s) = \frac{g^2}{4\pi}\frac{(s/s_0)^{\Delta}}{s_0\left[r_0^2 + 2\alpha'_{\mathbf{P}}(0)\ln(s/s_0)\right]}$$


a
b
σ_{tot}, mb
10^2
B, $(GeV/c)^{-2}$
25
20
15
10
10^2
10^3
10^4
10^5
$\sqrt{s}$, GeV

« Индекс асимптотичности »

$$\varepsilon = \frac{\sigma_{tot}}{8\pi B}$$

$$\varepsilon = \frac{\sigma_{tot}}{8\pi B} \to 1 \text{ при } \sqrt{s} \to \infty$$

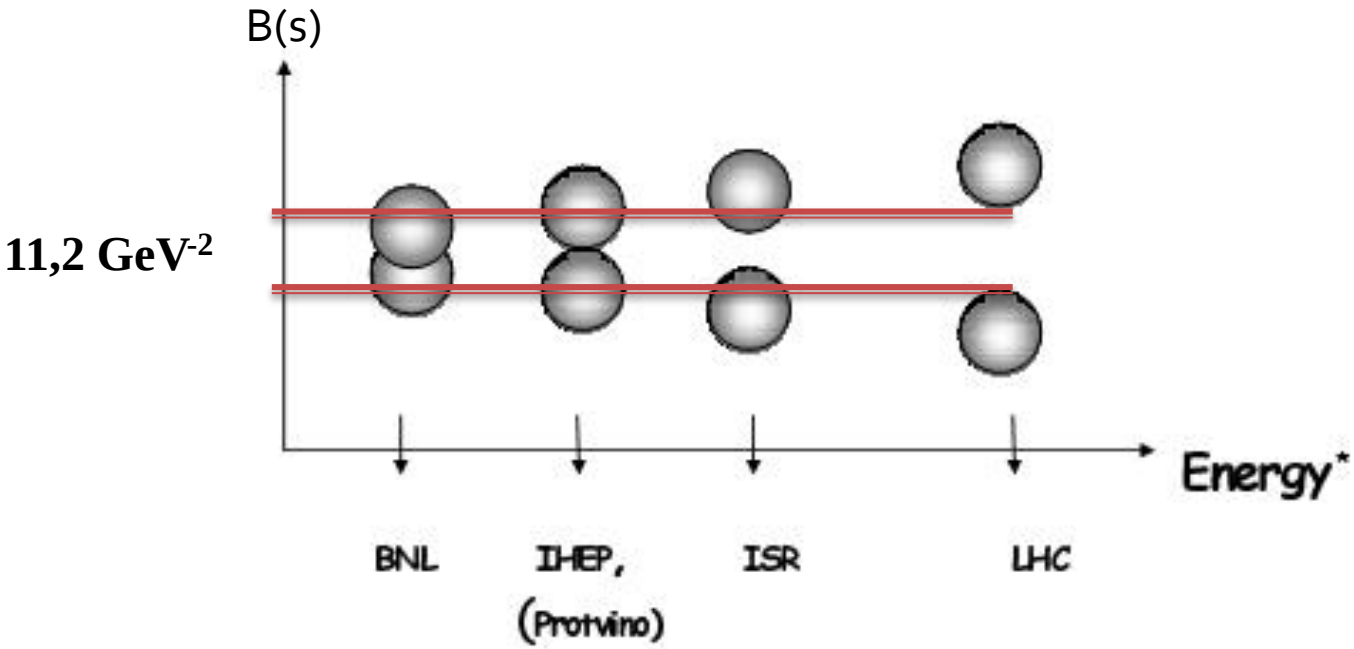


$$\frac{\langle b^2 \rangle}{2} \approx B(s) \gg \langle b^2 \rangle (proton) \approx 11 GeV^{-2}$$

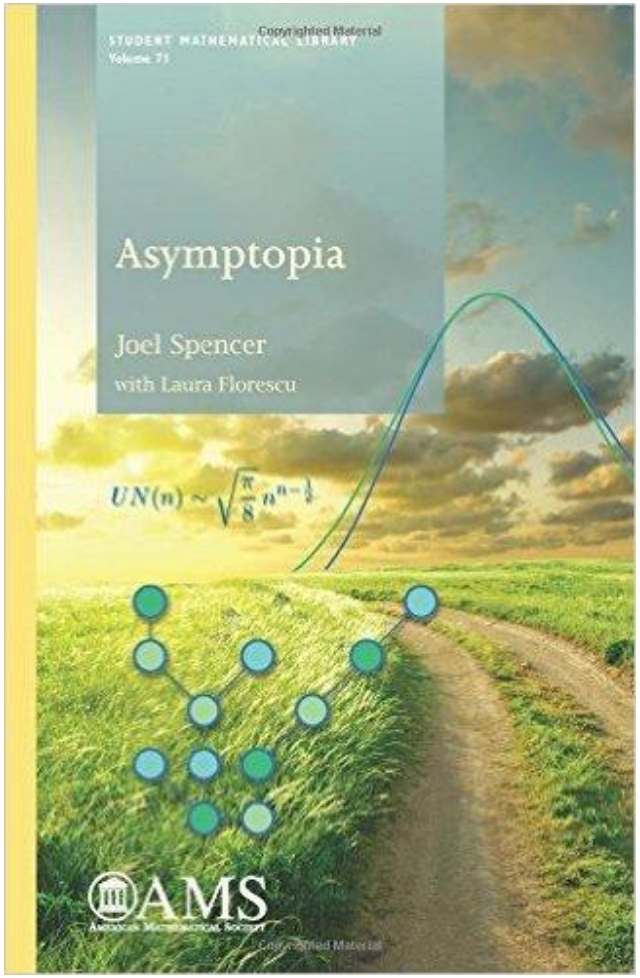
?

$$\frac{\langle b^2 \rangle}{2} \approx 3B(s) \text{ при } \sqrt{s} = 10^4 \text{ TeV}$$

IT'S A LONG WAY TO TIPPERARY…



Не только мы…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Volume 71
Asymptopia
Joel Spencer
with Laura Florescu
$UN(n) \sim \sqrt{\frac{\pi}{8}}\, n^{n-\frac{1}{2}}$
AMS
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We economists trudge relentlessly toward Asymptopia, where data are unlimited and estimates are consistent, where the laws of large numbers apply perfectly and where the full intricacies of the economy are completely revealed. But it's a frustrating journey, since, no matter how far we travel, Asymptopia remains infinitely far away.

Edward E. Leamer

Tantalus on the Road to Asymptopia

We **physicists** trudge relentlessly toward Asymptopia, where data are unlimited and estimates are consistent, where the laws of large numbers apply perfectly and where the full intricacies of the **theory** are completely revealed. But it's a frustrating journey, since, no matter how far we travel, Asymptopia remains infinitely far away.

(Plagiarism of) V. A. Petrov

- **Мы, экономисты, неуклонно стремимся достичь Асимптопии, где данные не ограничены, а оценки согласованы, где законы больших чисел прекрасно применимы и где полностью раскрываются все тонкости экономики. Но это разочаровывающее путешествие, так как, как бы далеко мы ни продвигались, Асимптопия остается бесконечно далекой.**

Эдвард Э. Лимер, Тантал на пути к Асимптопии

- **Мы, физики, неуклонно стремимся достичь Асимптопии, где данные не ограничены, а оценки согласованы, где законы больших чисел прекрасно применимы и где полностью раскрываются все тонкости теории. Но это разочаровывающее путешествие, так как, как бы далеко мы ни продвигались, Асимптопия остается бесконечно далекой.**