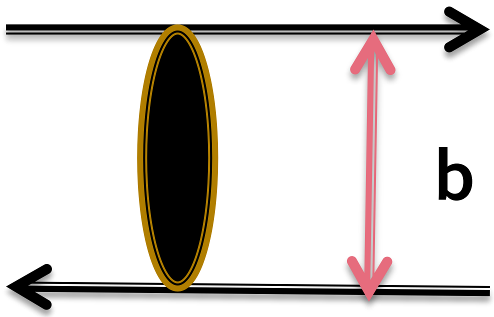
XIV-я Міжнародная школа-канферэнцыя
"Актуальныя праблемы фізікі мікрасвету"
(Гродна, Беларусь, 12-24 жніўня, 2018),
прысвечаная памяці прафесара Н.М. Шумейка.

Памер мае значэнне або дзе ляжыць" Асимптопия "?

The Size Seems to Matter or Where Lies "Asymptopia"?

V. A. Petrov
A.A. Logunov IHEP
NRC KI, Protvino, Russia

WHAT IS THE SIZE AND THE THE SIZE OF WHAT?



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

$$w(b^2) = \mathrm{Im}\,\tilde{\mathrm{T}}(s,b)\left[\int db^2\, \mathrm{Im}\,\tilde{\mathrm{T}}(s,b)\right]^{-1} \qquad \mathcal{A}_{el}(s,t) = 4s\int d^2b e^{iqb}\tilde{T}(s,b)$$

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

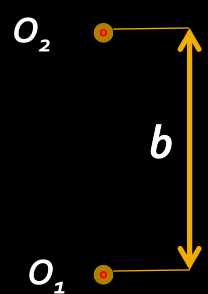
$$B(s,t) \equiv \frac{1}{d\sigma/dt}\frac{\partial[d\sigma/dt]}{\partial t} = \frac{\partial \ln[d\sigma/dt]}{\partial t} \qquad \Phi(s,t) = \arg \mathcal{A}_{el}(s,t)$$

$$B(s) = B(s, t=0) \qquad \boldsymbol{B(s) \approx 2\langle b^2 \rangle}$$

Elementary Geometry of Collision

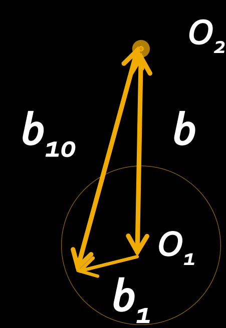
High Energies

Pointlike particle

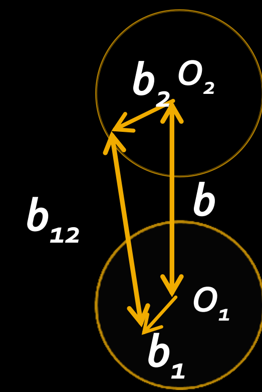


Pointlike particle

Pointlike particle



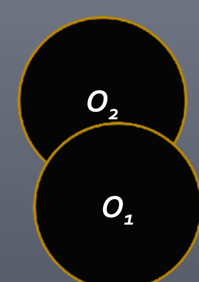
Extended particle



$<b_1 b_2> = <b_1 b_{12}> = <b_2 b_{12}> = 0$

$$< b^2 > = < b_1^2 > + < b_2^2 > + < b_{12}^2 > \geq < b_1^2 > + < b_2^2 >$$

Low Energies



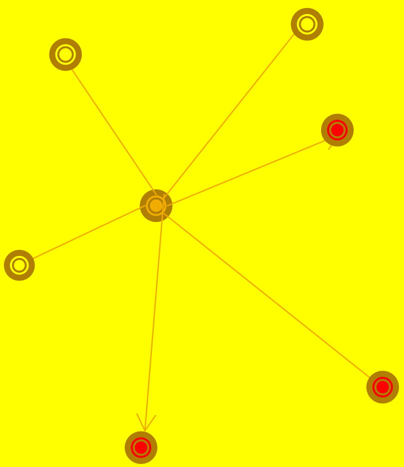
$< b_1 b_2 > \neq 0$

$< b_1 b_{12} > \neq 0$

$< b_2 b_{12} > \neq 0$

"Charge Radius" vs Genuine Radius

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



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

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

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

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

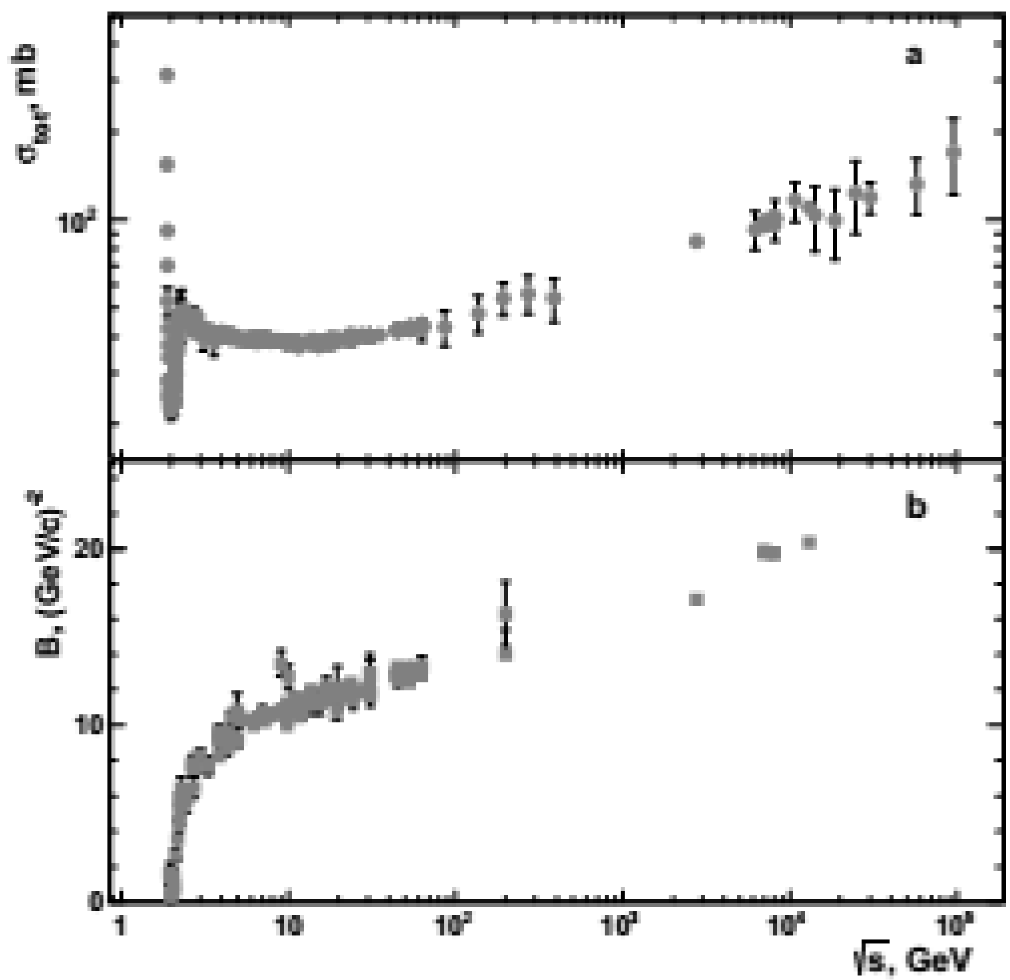
(V.A.P. & V. Okorokov)

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

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

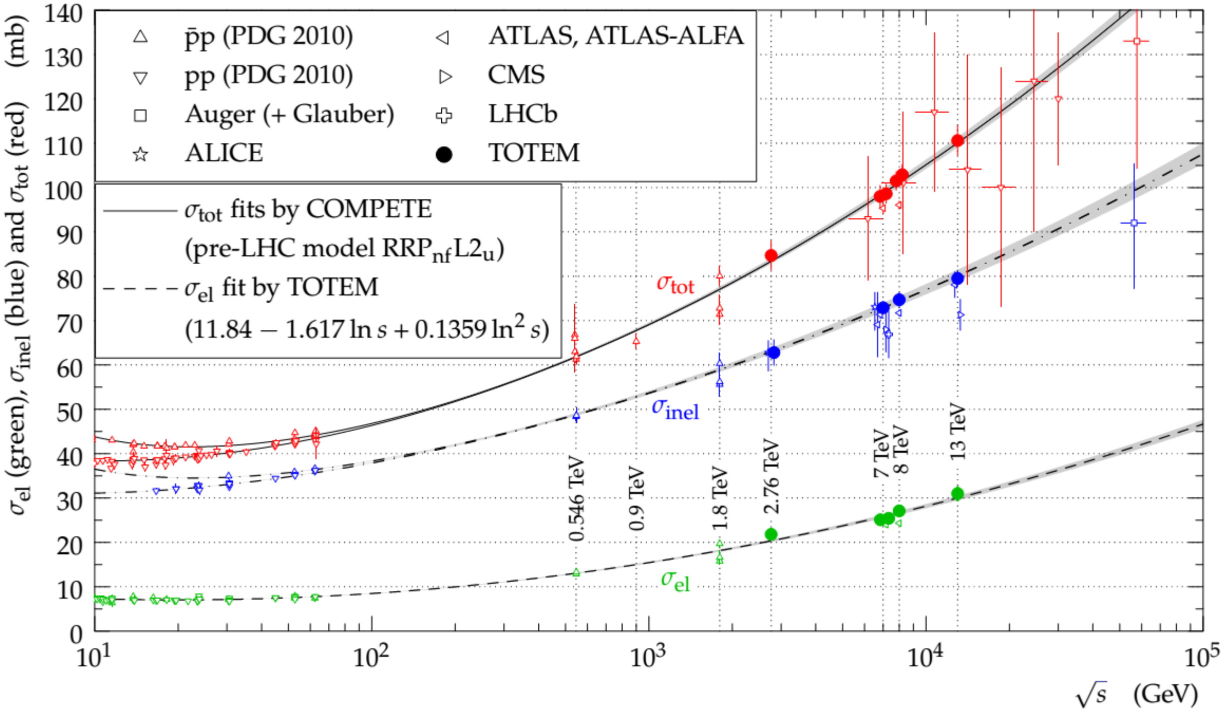
$$\langle \boldsymbol{b}^2\rangle(\boldsymbol{proton}) \cong \mathbf{11.2}\boldsymbol{GeV}^{-2}$$

Correlation : B(s) ↔ $\sigma_{tot}(s)$



LHC

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



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

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

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

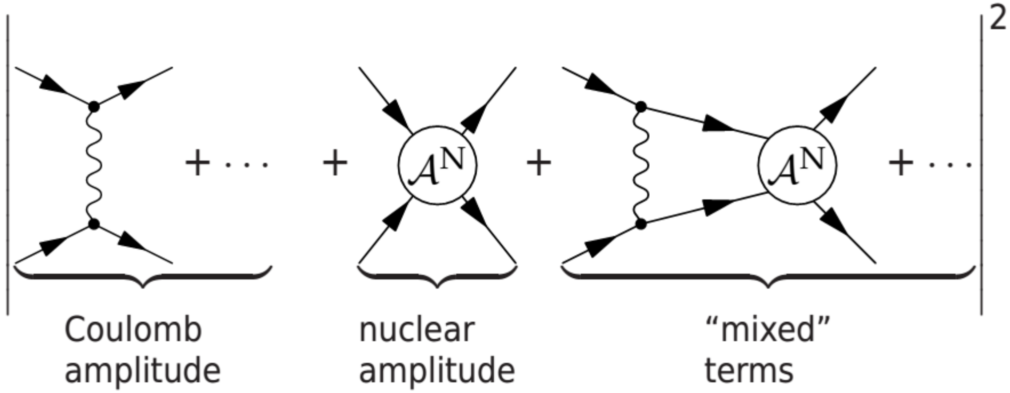
- σ_{tot} compatible with COMPETE [1] prediction, asymptotically $\ln^2(s)$

How to Measure the Phase?

Coulomb-nuclear interference

- observed cross-section

$\frac{d\sigma}{dt} \propto$

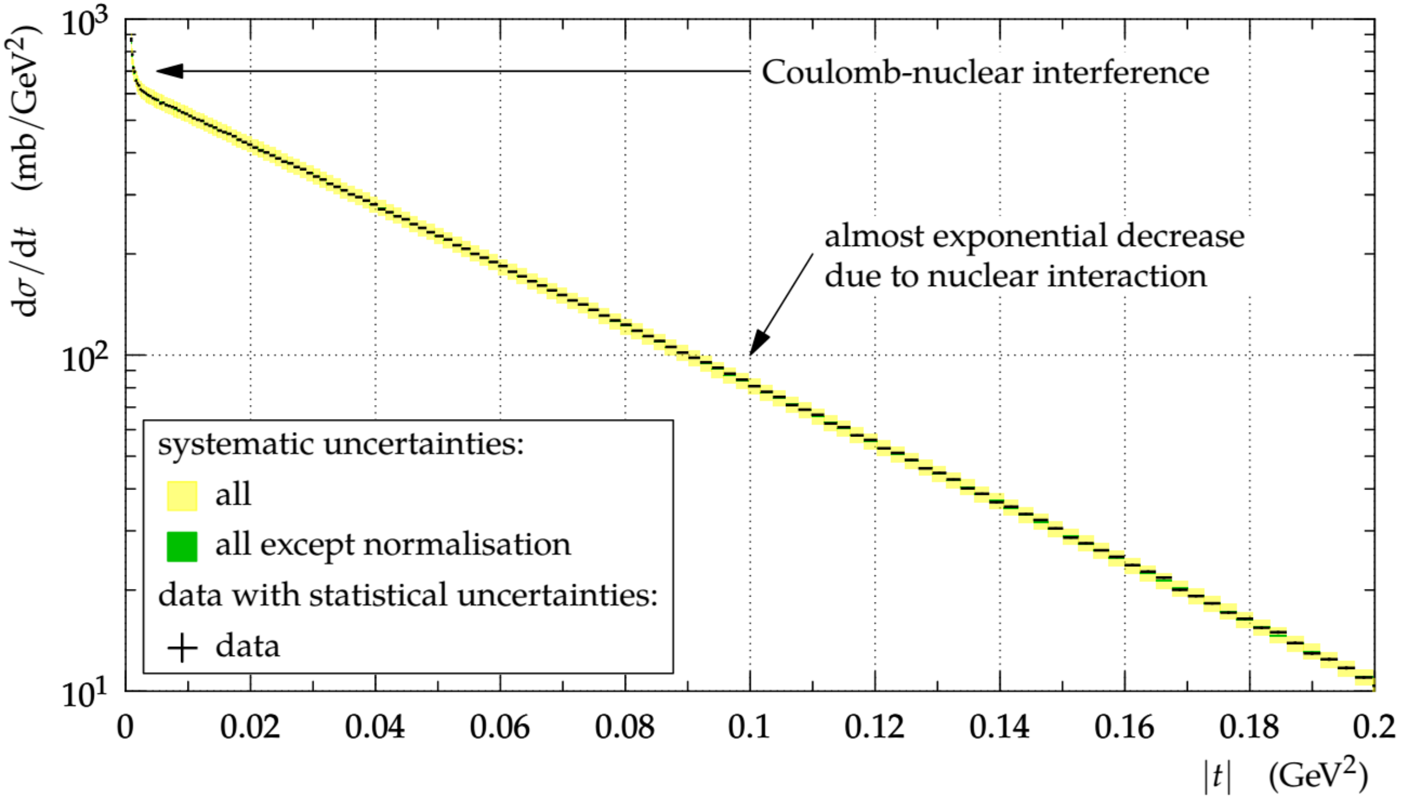


- our modelling
  - "*interference formula*" = summation for practical applications
    - considered: West-Yennie [2], Cahn [3] and Kundrát-Lokajíček [4]
  - *Coulomb amplitude*: QED + experimental form factors
  - *modulus of $\mathcal{A}^N$*: empirical guidance ⇒ at low $|t|$: $a \exp\left(\sum_{n=1}^{N_b}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

Wrong

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

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



百花齐放，百家争鸣

Let bloom a hundred flowers,
let the hundred schools compete!

Mao-Tse Dong (1957)

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

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

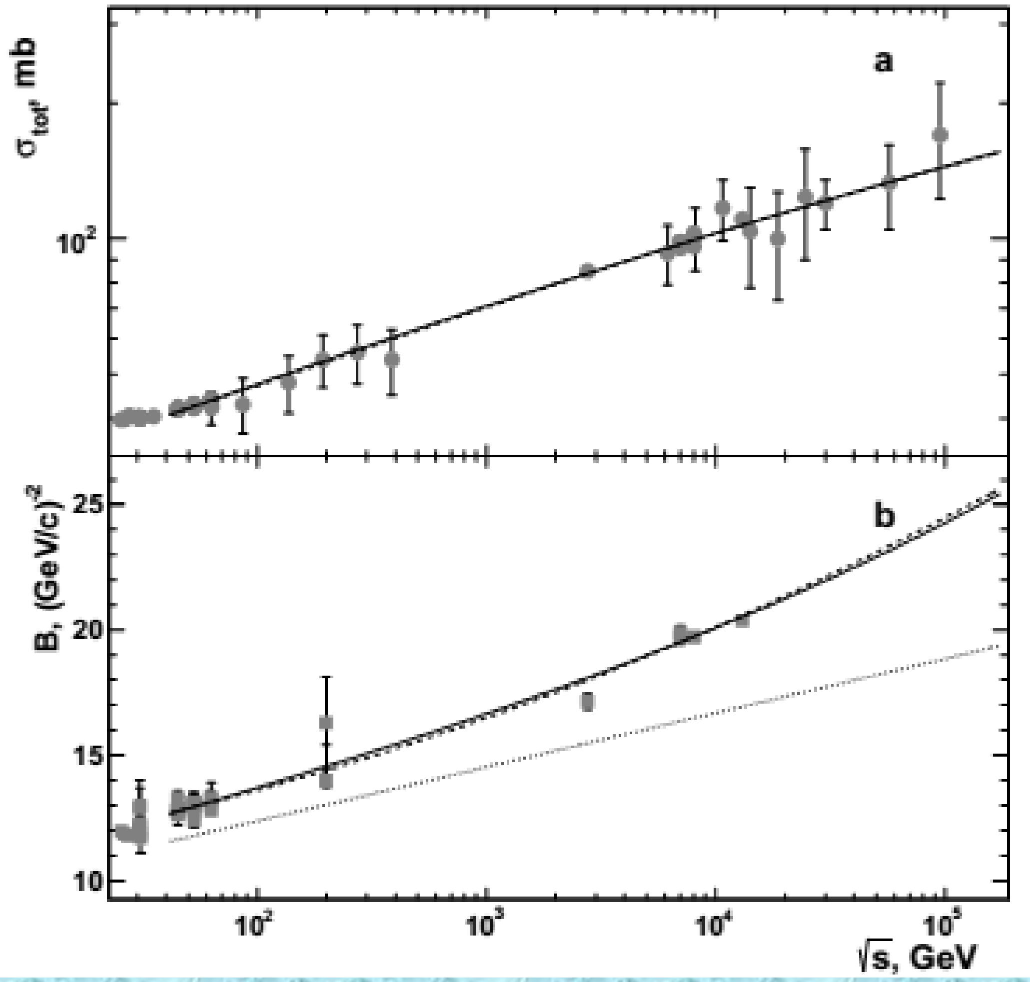
$$B(s) = b_0 + 2\alpha'_{\rm P}(0)\ln(s/s_0) + b_2 \ln^2(s/s_0)$$

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

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

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

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

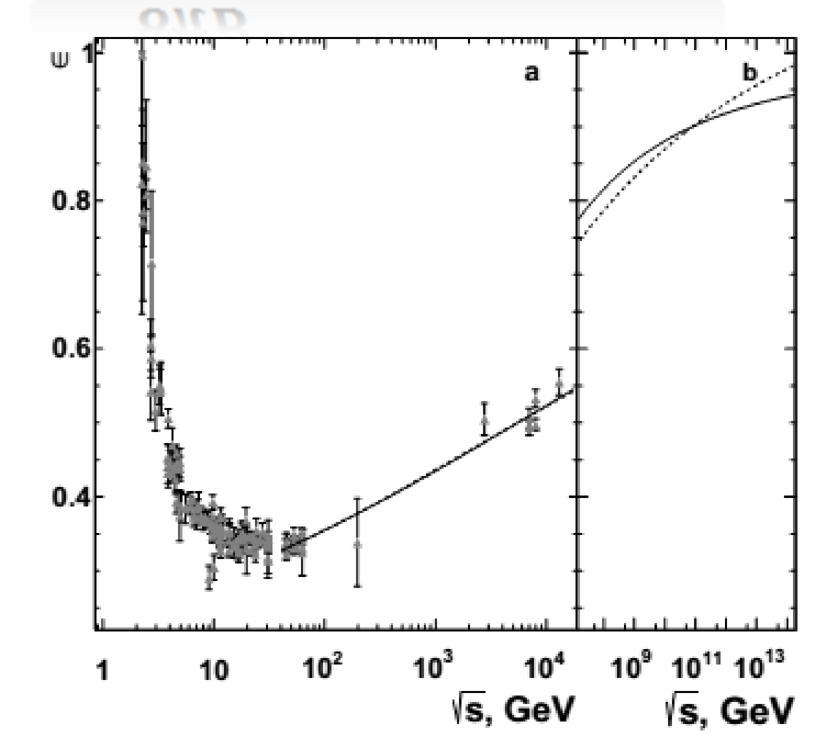


a
b
σ_{tot}, mb
10^2
B, $(GeV/c)^{-2}$
25
20
15
10
10^2
10^3
10^4
10^5
$\sqrt{s}$, GeV

« Индекс асимптотичности »

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

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



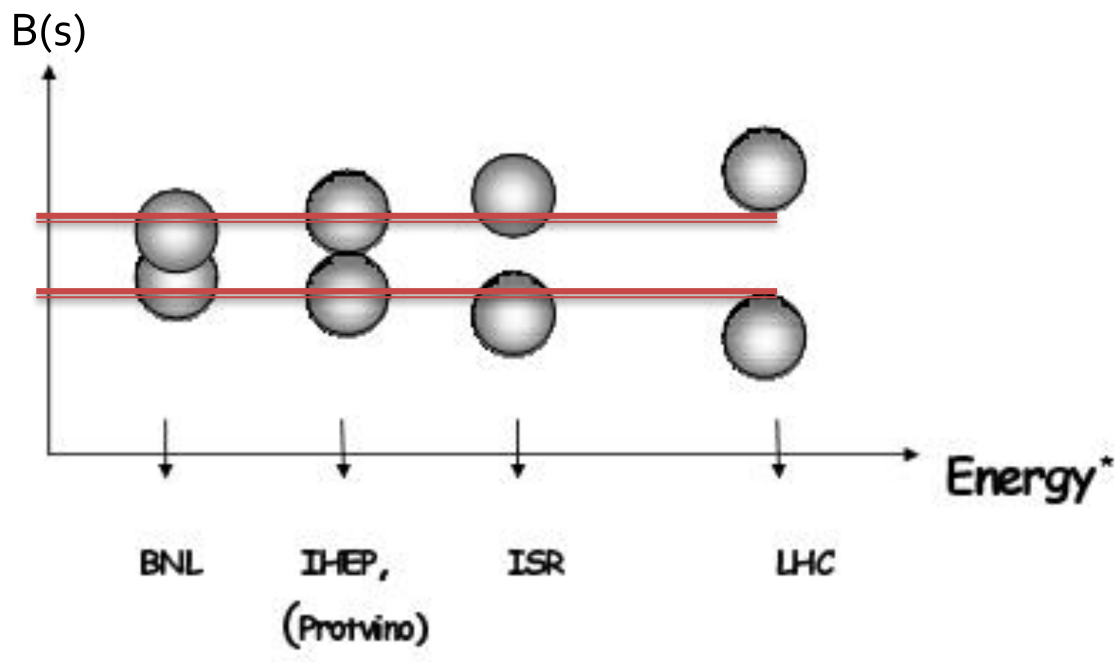
$$\frac{\langle b^2 \rangle}{2} \approx B(s) \gg \langle b^2 \rangle (proton) \approx 11 GeV^{-2}$$

?

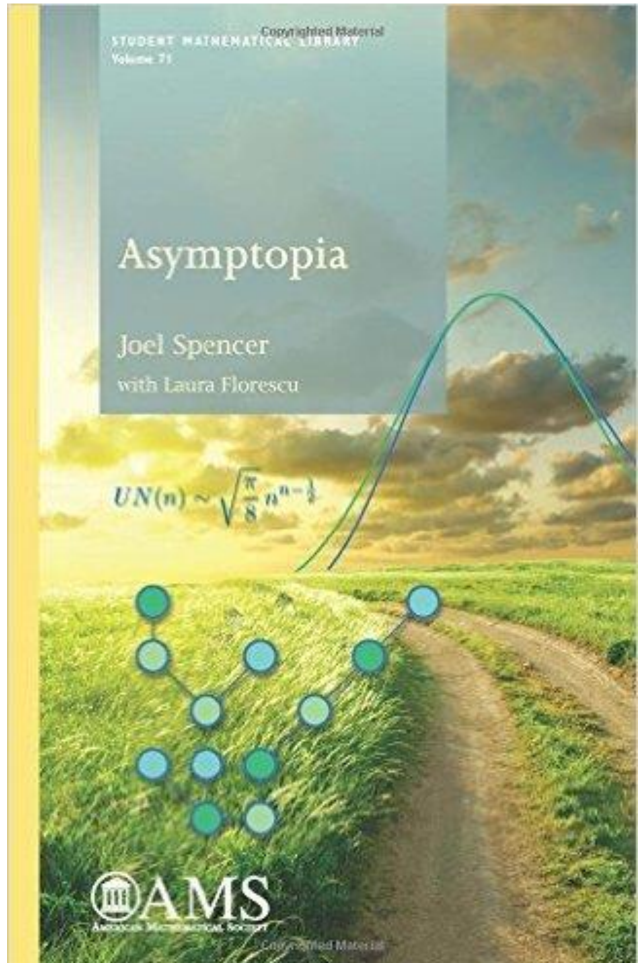
$$\frac{\langle b^2 \rangle}{2} \approx 3B(s) \text{ при } \sqrt{s} = 10^4 \text{ TeV}$$

IT'S A LONG WAY TO TIPPERARY…

11,2 GeV^{-2}



We Are Not Alone...



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.**

Résumé

- "Asymptopia" is unachievable (on our life scale)
- "Asymptopia" is not so much interesting place
- There are a lot of interesting things at any finite energy