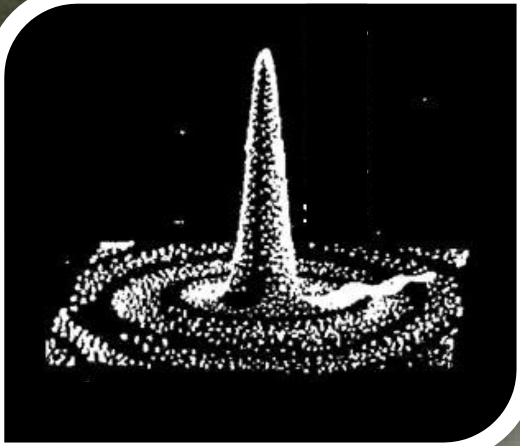


The 17th Conference on Elastic and Diffractive Scattering

Blois 2017 EDS

26-30.června 2017, Praha

Diffractive Scattering: Problems in Theory and Praxis

Vladimir A. Petrov

A.A. Logunov Institute for High Energy Physics,

NRC "Kurchatov Institute",

Protvino, Russia

Axiomatic Quantum Field Theory

Basics:

Causality, Unitarity, Spectrum Condition, Asymptotic Completeness, positive definite metric of Hilbert space, Poincare´ invariance

Relation of Fields and Observables:

Lehmann-Symanzik-Zimmermann

and/or

Bogoliubov- Medvedev – Polivanov

reduction formulas

Problems

- Is it possible to check (micro) causality?

"Causality does not tell us about the world, but about our definitions and our own psychology" (John D. Norton)

Causality ⟹ Analyticity ⟹ Dispersion Relations

$$ReT(s,0) = P_{N-1}(s) + \frac{(s-s_0)^N}{\pi}\int ds' \frac{Im\,T(s',0)}{(s'-s_0)^N(s'-s)}$$

Problems

- Is it possible to check unitarity and other premises of AQFT?

General answer: NO.

- What Do We Gain from AQFT?

1. A model for the model construction
(clear and mathematically consistent formulation of basic assumptions → Popper falcifiability)
2. Bounds for possible behaviour of amplitudes

Bounds

Froissart - Martin upper bound

$$\sigma_{tot}(s) \leq \frac{\pi}{m_\pi^2}\, ln^2(s/s_0)$$

Martin - Roy upper bounds

$$\bar{\sigma}_{tot}(s) \leq \frac{\pi}{m_\pi^2}[ln\left(\frac{s}{s_0}\right) + \frac{1}{2}\, ln\, ln\left(\frac{s}{s_0}\right) + 1]^2$$

$$\bar{\sigma}_{inel}{}^{\pi^0\pi^0}(s) \leq \frac{\pi}{4m_\pi^2}[ln\left(\frac{s}{s_1}\right) + \frac{1}{2}\, ln\, ln\left(\frac{s}{s_1}\right) + 1]^2$$

W. Heisenberg(1952):

$$\sigma_{inel}(s) \approx \frac{\pi}{4m_\pi^2}\, ln^2\left(\frac{s}{m_\pi^2}\right)$$

Do the Bounds Bound Anything?

$$s_0 = \frac{\sqrt{2}m_\pi^2}{17\pi\sqrt{\pi}} = 2.9 \cdot 10^{-4} GeV^2$$

$$\bar{\sigma}_{tot}\left(\sqrt{s} = 7TeV\right) \leq 51349.82\ mb$$

$$s_1 = \frac{m_\pi^2}{34\pi\sqrt{2\pi}} = 7.2 \cdot 10^{-5} GeV^2$$

$$\bar{\sigma}\ _{inel}{}^{\pi^0\pi^0}\left(\sqrt{s} = 7TeV\right) \leq 14150.00\ mb$$

Heisenberg:

$$\sigma_{inel}^{NN}\left(\sqrt{s} = 7TeV\right) = 7422.08\ mb \quad vs\ exp: \sim 73\ mb$$

Two Schools in Model Construction

"People of Principle":

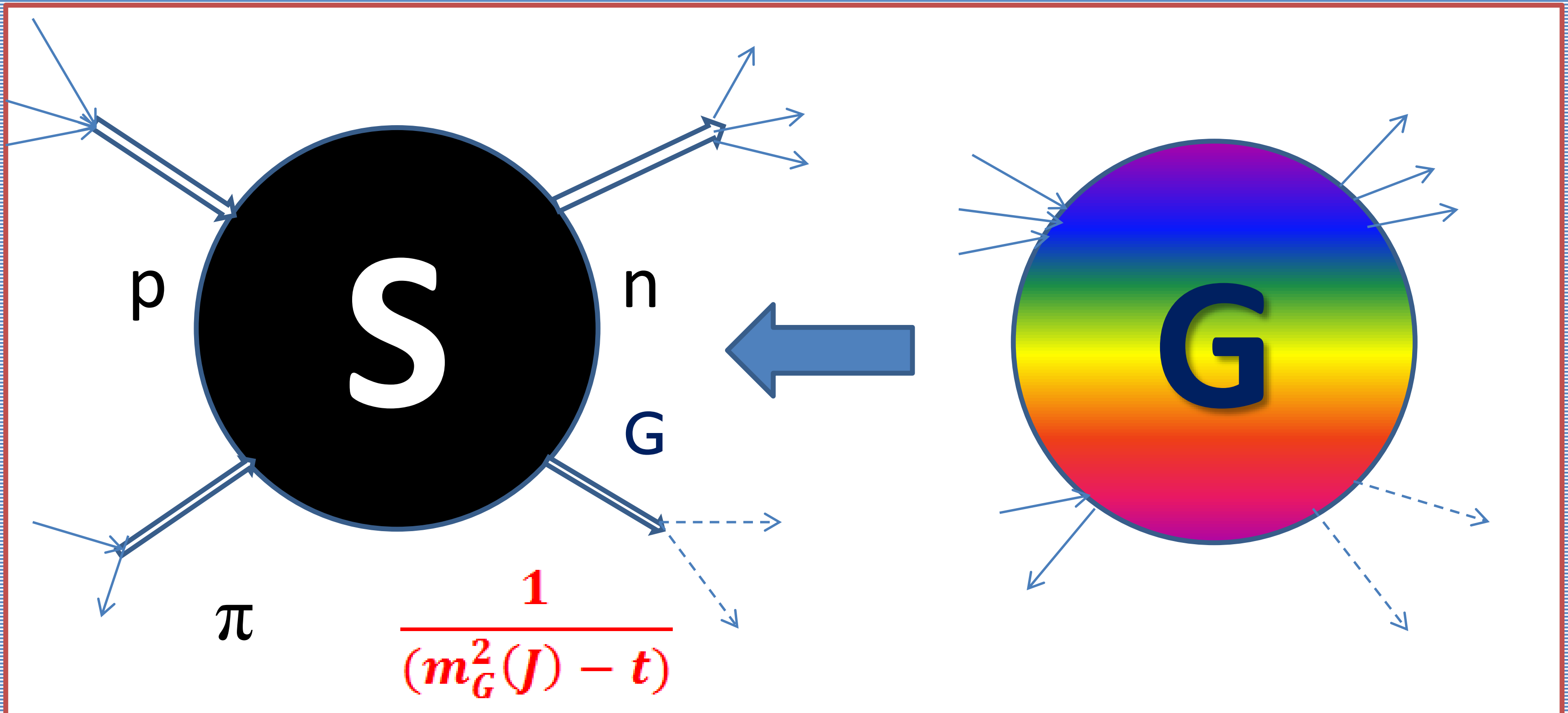
Respect analyticity and h.e.bounds. Motivate the choice of parameters as much as possible.

"Practical People":

Use any trial functions and parameters.

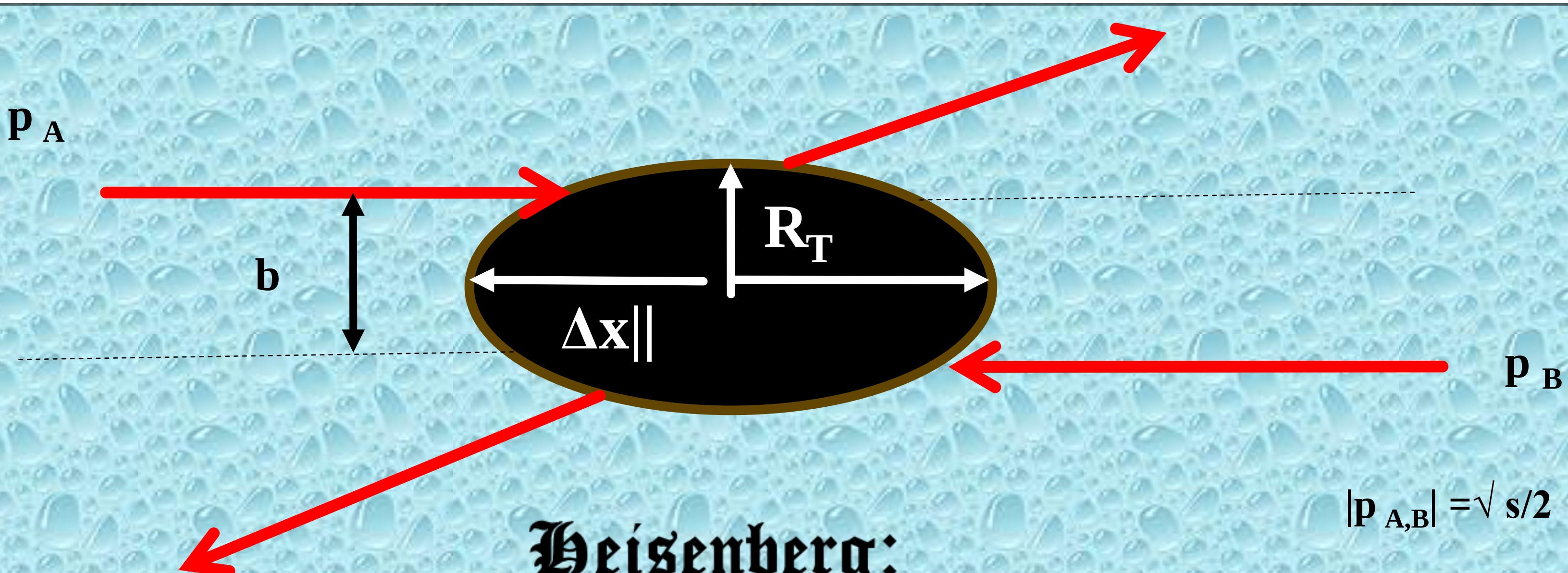
The only criterion is the best fit of the data.

QCD, the Fundamental Theory of Strong Interactions



Hadronic S-Matrix from Partonic Green Functions

Diffraction: Characteristic Scales



Heisenberg:

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

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

$$(\Delta x)^2 \equiv \langle x^2\rangle - \langle x\rangle^2$$

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

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

What Have We Got from QCD ?

Regge trajectories at $-t \to \infty$:

$$\alpha_P(t) = 1 + const \cdot \frac{g_s^2(t)}{4\pi} + \ ....$$

$$\alpha_P\left(-t = O(10^4\ GeV^2)\right) \approx 1.3$$

[L. Lipatov - R. Kirschner]

♥ "Hard" vs "Soft" Pomerons

Regge trajectories at $t = 0$ ("intercepts"):

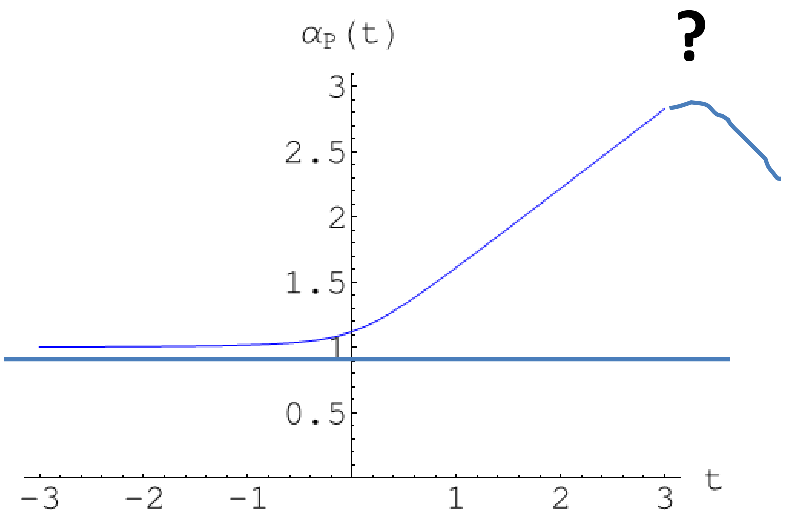
$$\alpha_P(0) = \frac{3\ln 2}{\pi^2} g^2 \left(1 - \frac{5}{\pi^2} g^2\right)$$

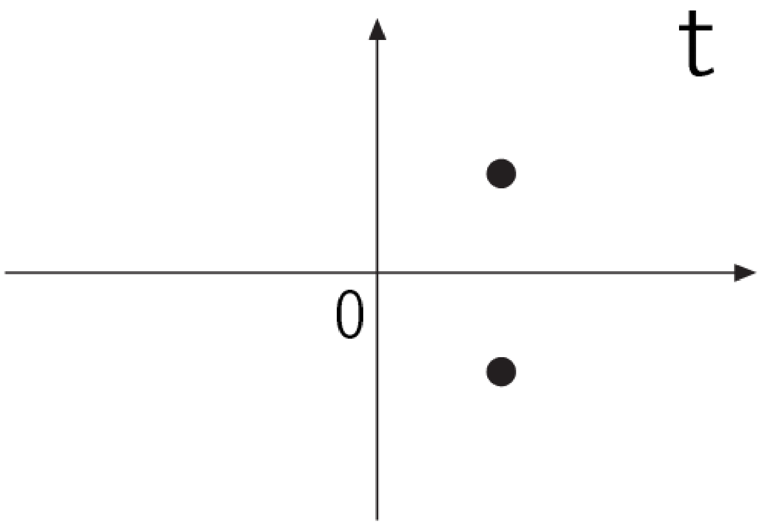
[Fadin-Lipatov; Camici-Ciafaloni]

♠ Asymptotically free theories lead to an infinite series of Pomerons [Lovelace, Cardy, Heckathorn, Lipatov]

▪ RG ⟶ $\frac{\partial \alpha_P(0)}{\partial g^2} = 0 \quad \alpha_P'(0) = \frac{const}{\Lambda^2_{QCD}} \, |_{g^2 \to 0} \sim exp\ (\frac{1}{\beta_0 g^2})$

Causality Violation?

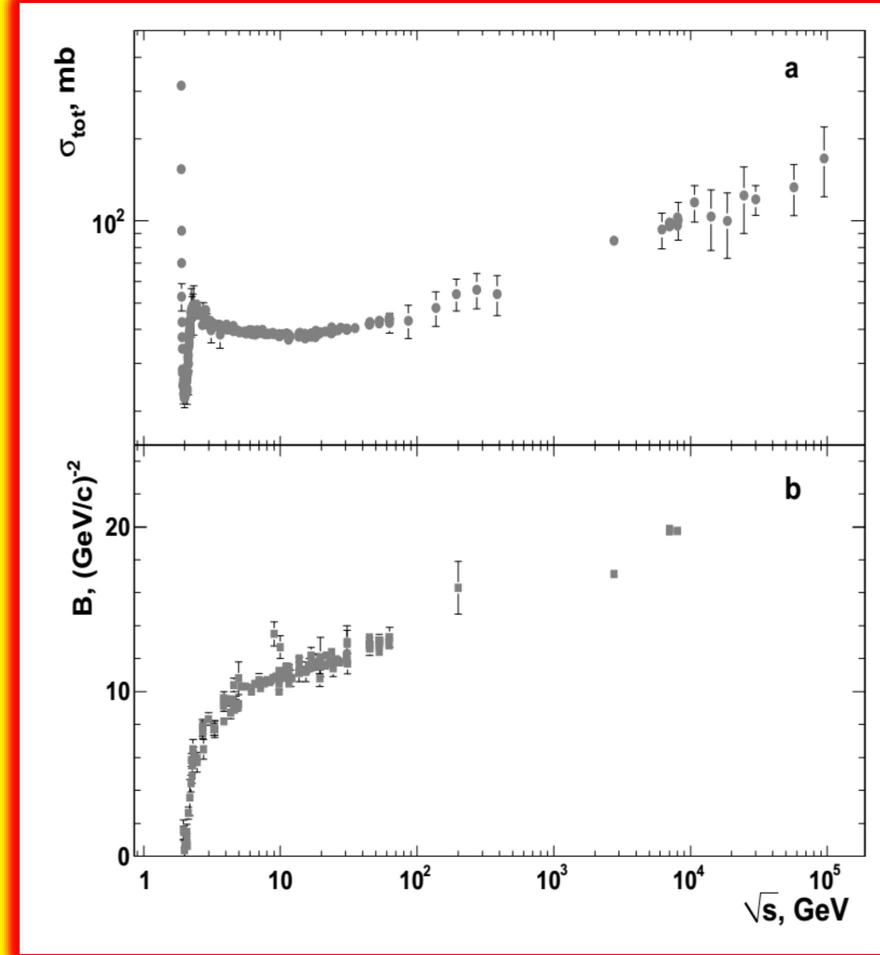




Where Lies "Asymptopia"?

$$\sigma_{tot}(s) \to 8\pi\alpha_P{}'(0)\,(\alpha_P(0)-1)ln^2 s + \cdots$$

$$B(s,0) \to \alpha_P{}'(0)\,(\alpha_P(0)-1)ln^2 s + \cdots$$

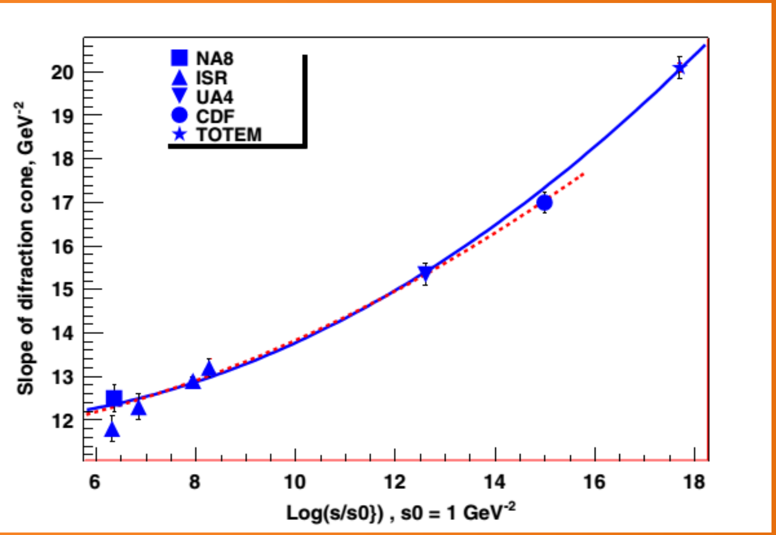


Something "Froissart-like"

(Shchegelsky-Ryskn)

$$\sigma_{tot}(s) = \sigma_0 + \sigma_1 ln^2(\frac{s}{s_0})$$

$$B(s,0) = B_0 + B_1 ln^2(\frac{s}{s_0})$$



$$\frac{\sigma_1}{B_1} = 5 \div 10 \; instead \; of \; 8\pi \approx 25$$

Asymptopia is still not here. Where?

Size Seems to Matter

Asymptopia: Interaction Radius vs Proper Nucleon Sizes

$$R_{int}{}^2 \approx 2B(s,0)$$

$$B(s,0) \gg r_N^2 \cong 11GeV^{-2} \approx (0.66fm)^2$$

$$B = 3r_N^2 \; @\sqrt{s} = 10^3 - 10^4 \; TeV$$

conclusions

- ▼AQFT : a feasible ground and example for model cooking
- ♦ QCD: one waits (more than 40 years!)for at least 2 real numbers: the intercept and the slope
- ☼ Ideal: the very Regge trajectory(ies?)
- ◙ LHC is not "Asymptopia" and actually is extremely far from it (fortunately?)