

XXXIII International (ONLINE) Workshop on High Energy Physics  
"Hard Problems of Hadron Physics: Non-Perturbative QCD & Related Quests"

Non-perturbative Methods  
for Soft Hadron Scattering

# Quickie history of the LHC: 2009 - 2021

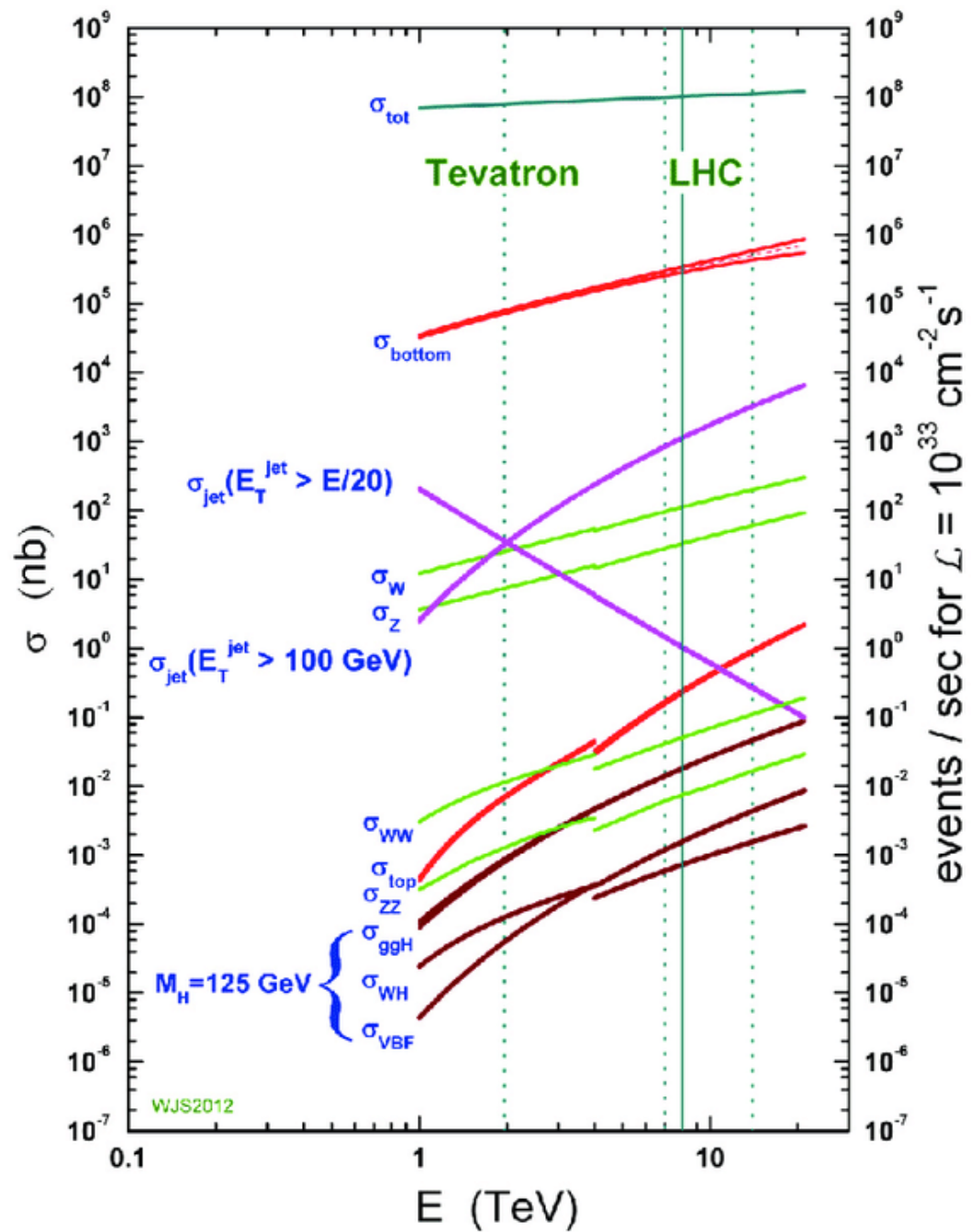
- "Old Physics":
  - Completion of the SM with Higgs
- "New Physics":
  - Supersymmetry:
  - "Stringy effects"
  - Dark matter ("dark photons")
  - Lepto-quarks
  - Compositeness
  - Extra dimensions
  - Micro Black holes

**DONE !**



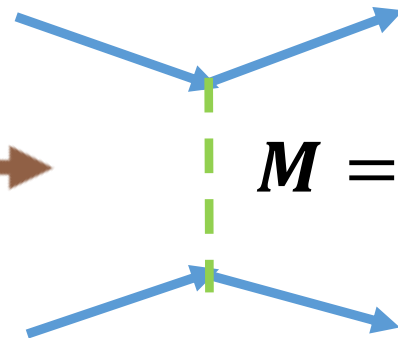
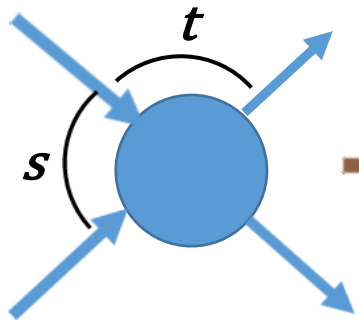
**NONE !**





# Reminder : Strong Forces at Low and High Energies

Low energy

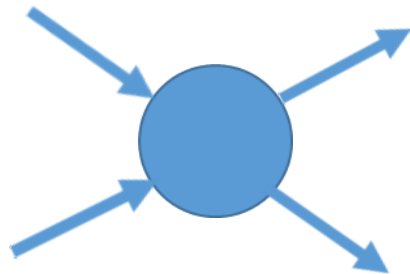


$$M = \pi, \rho, \omega, f, \dots$$

$$A_J(s, t) = g_J^2 \frac{s^J}{M_J^2 - t}$$

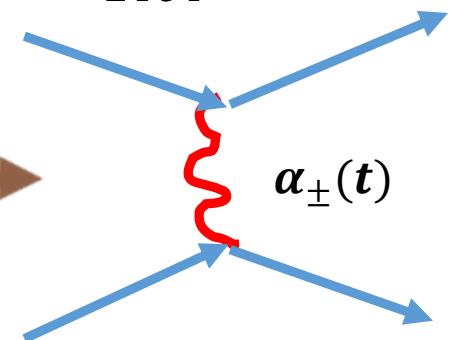
High energy

$$\alpha(M_J^2) = J \rightarrow V(r) = \pm g_J^2 \frac{s^{J-1} e^{-M_J r}}{4\pi r}$$

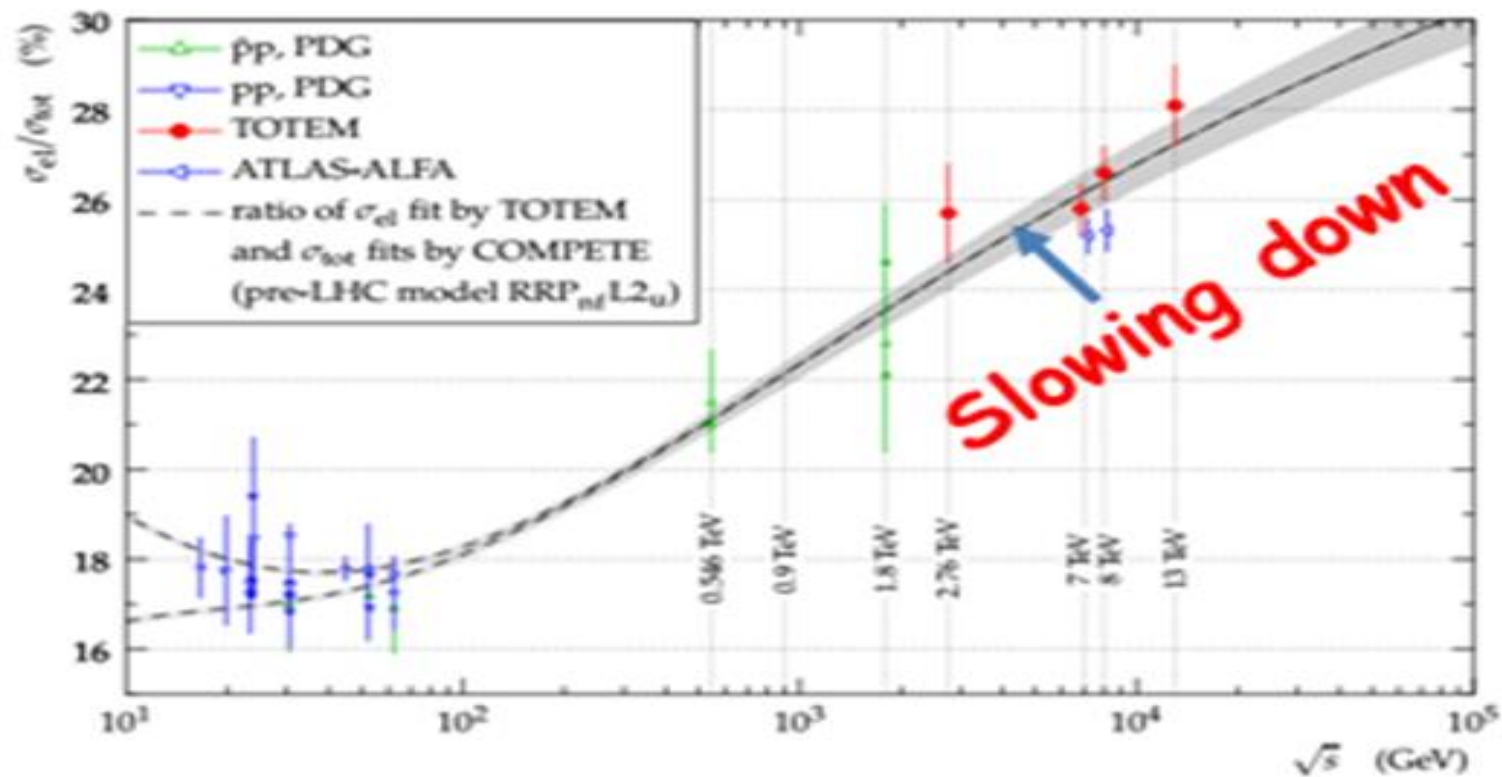


$$\sum_J$$

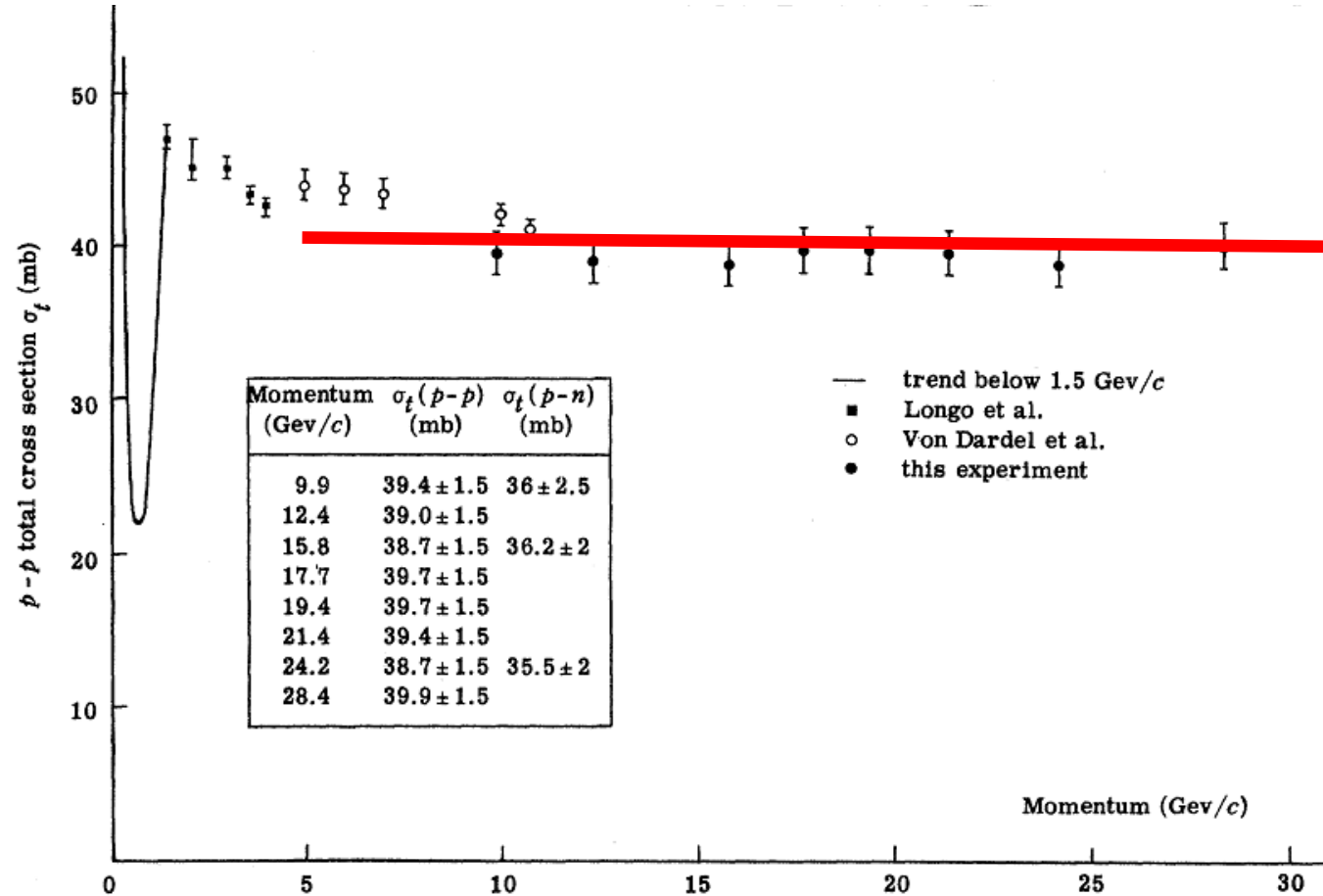
$$A_J(s, t) \rightarrow \pm s^{\alpha_{\pm}(t)}$$



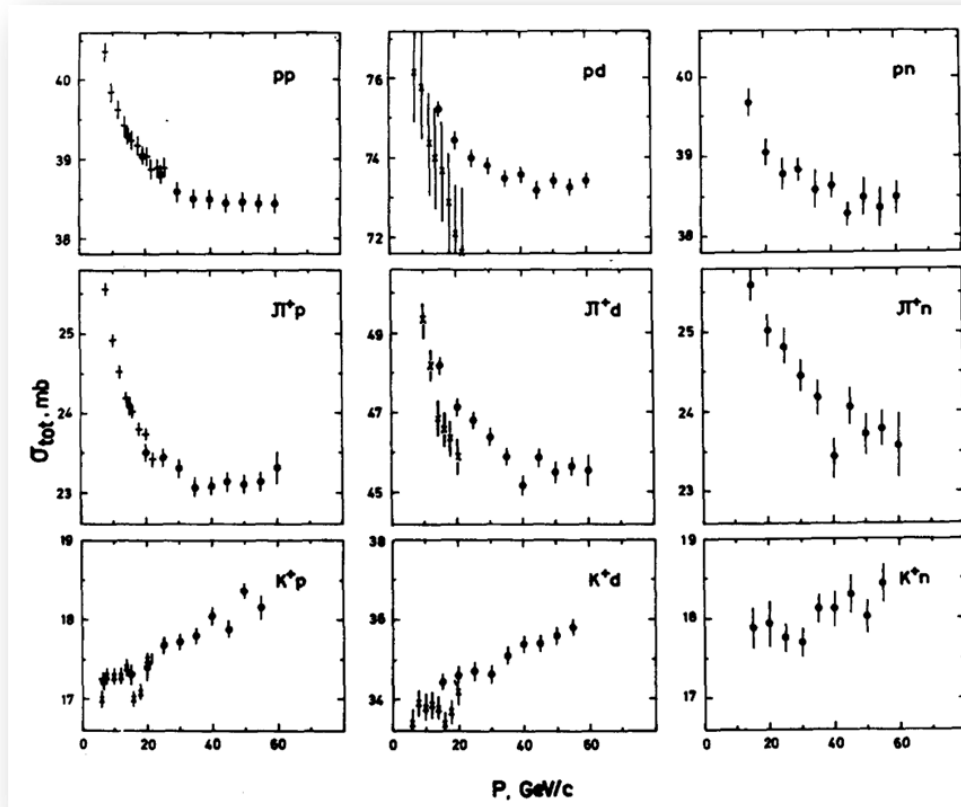
# To be scattered or absorbed?



# Prehistory (1953-70)



# Middle Age (1971-73)



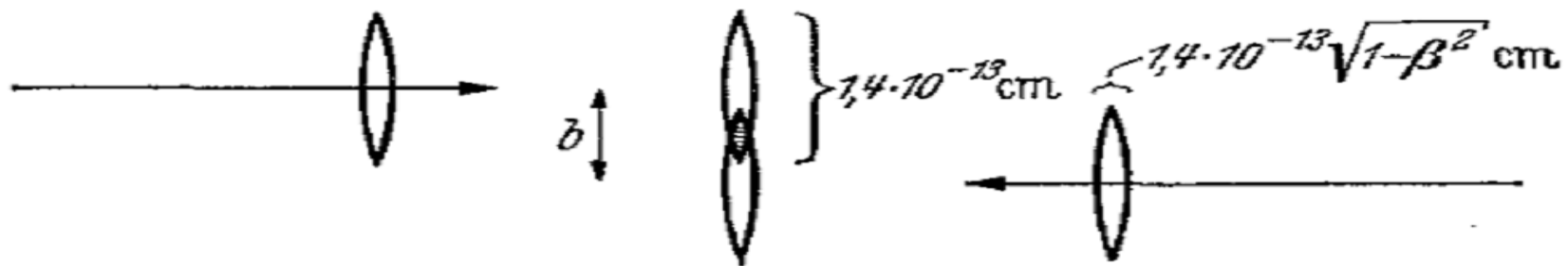
# Mesonenerzeugung als Stoßwellenproblem.

Von

W. HEISENBERG.

Mit 6 Figuren im Text.

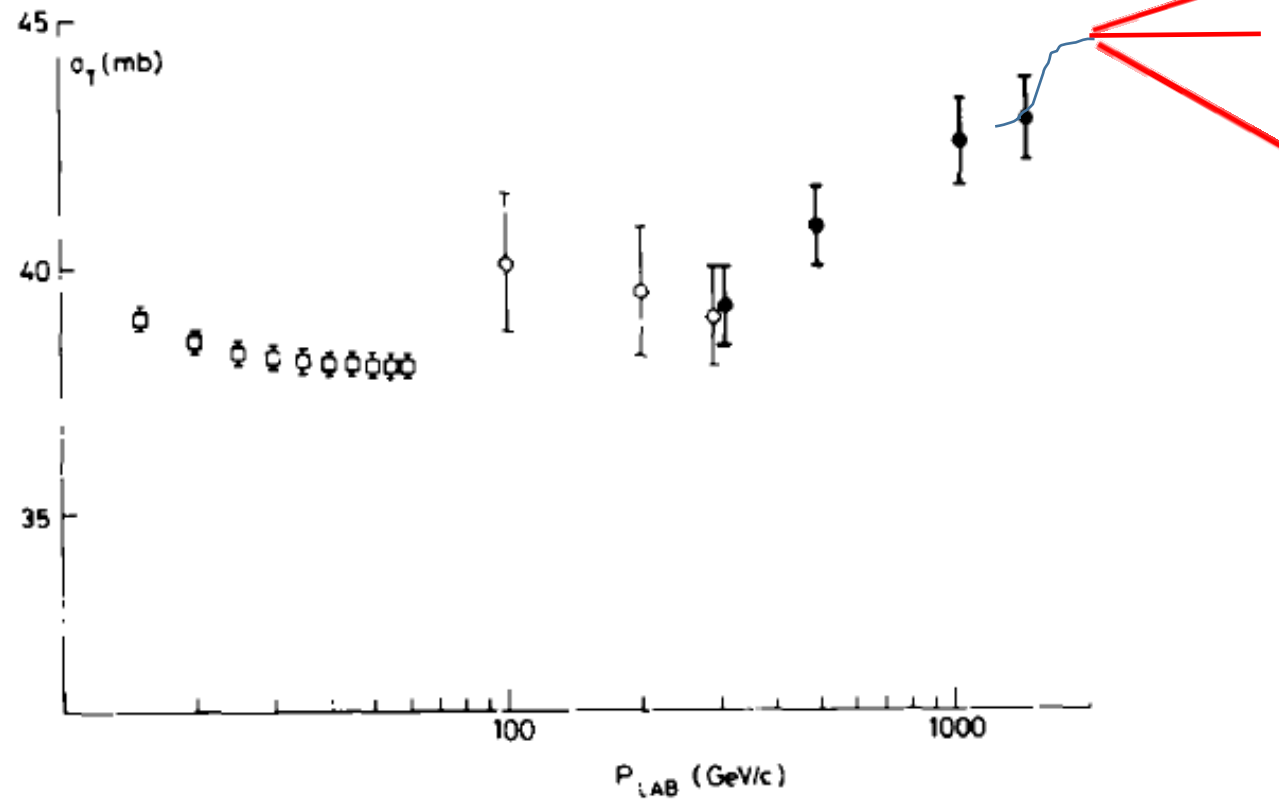
(Eingegangen am 5. Mai 1952.)



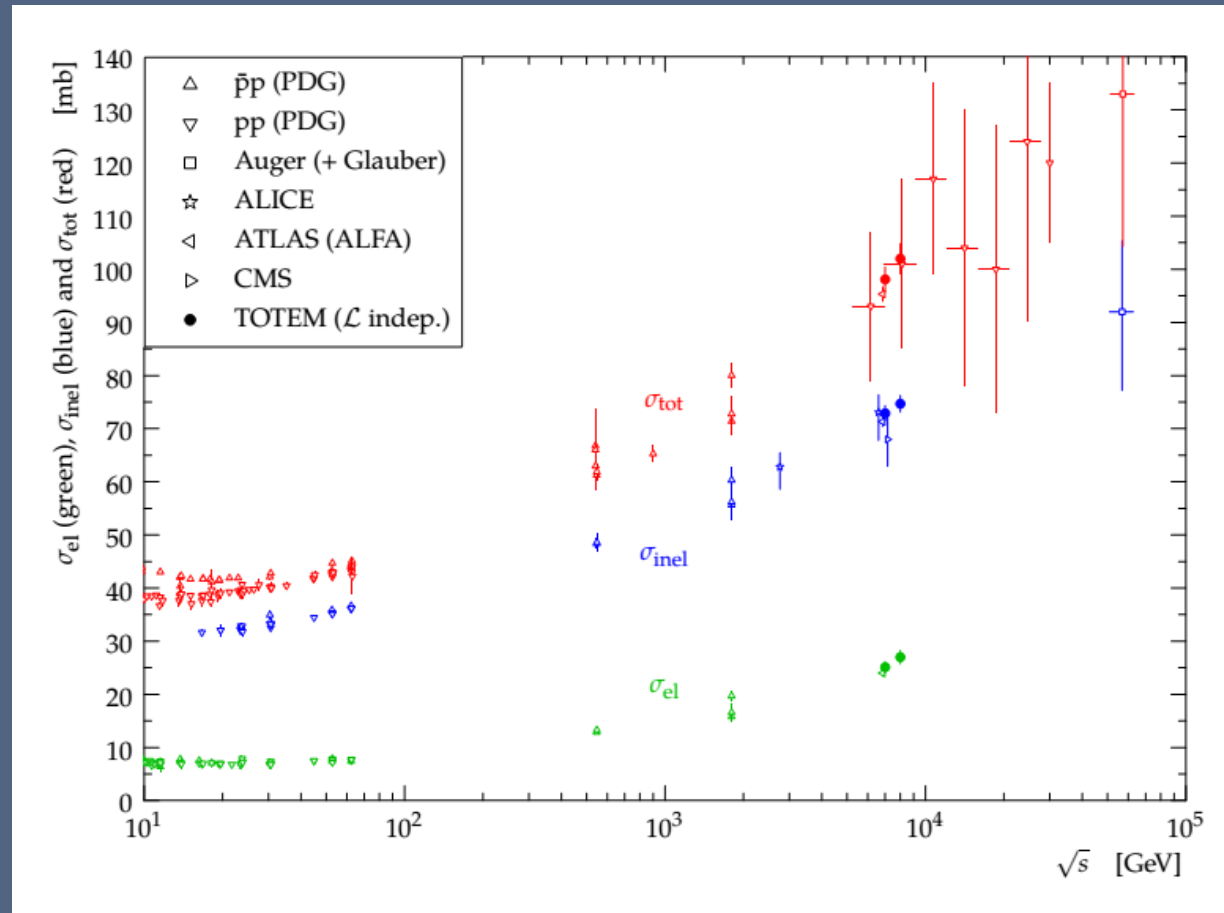


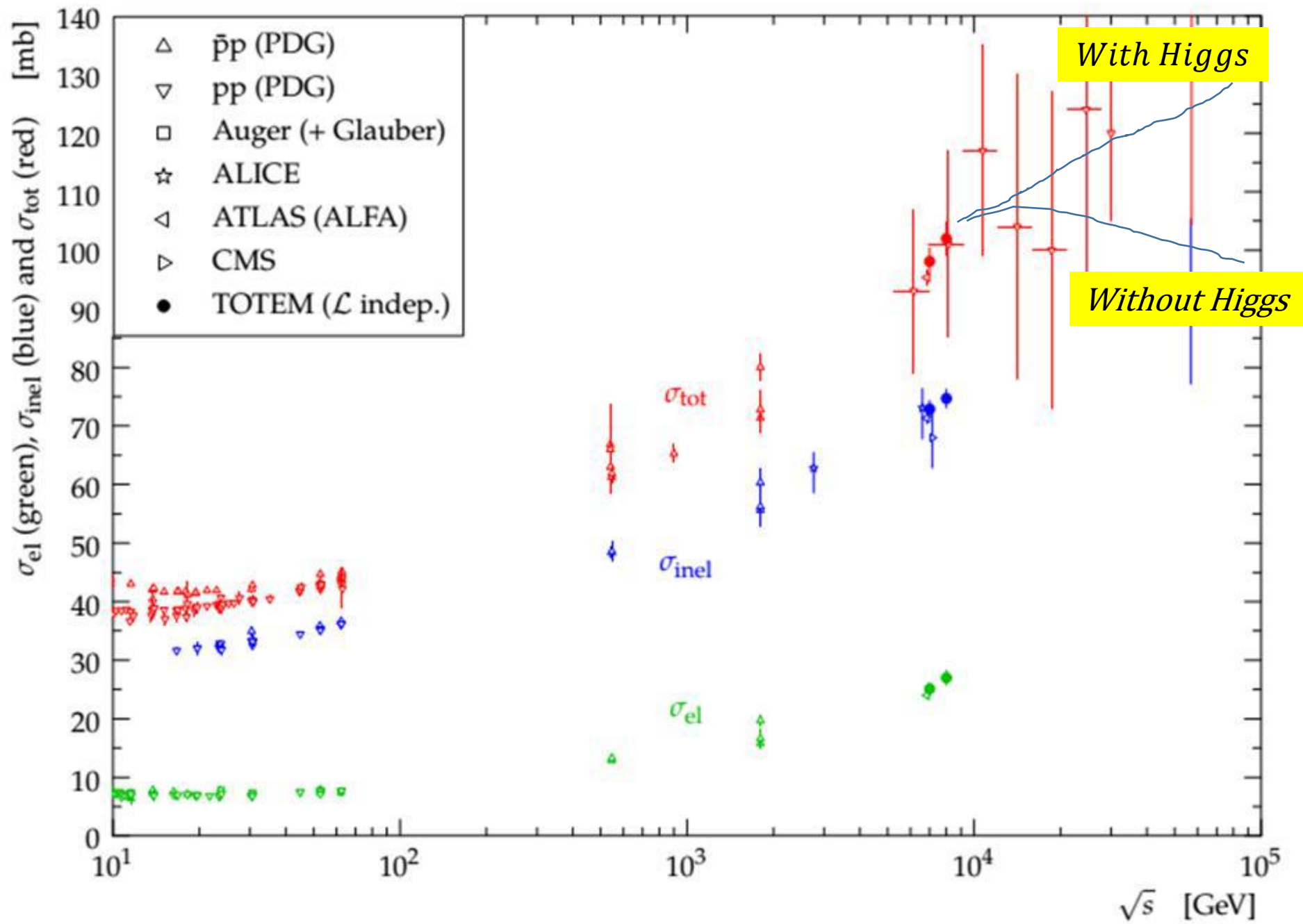
# New Era (1973-...)

?



# 2009-2021





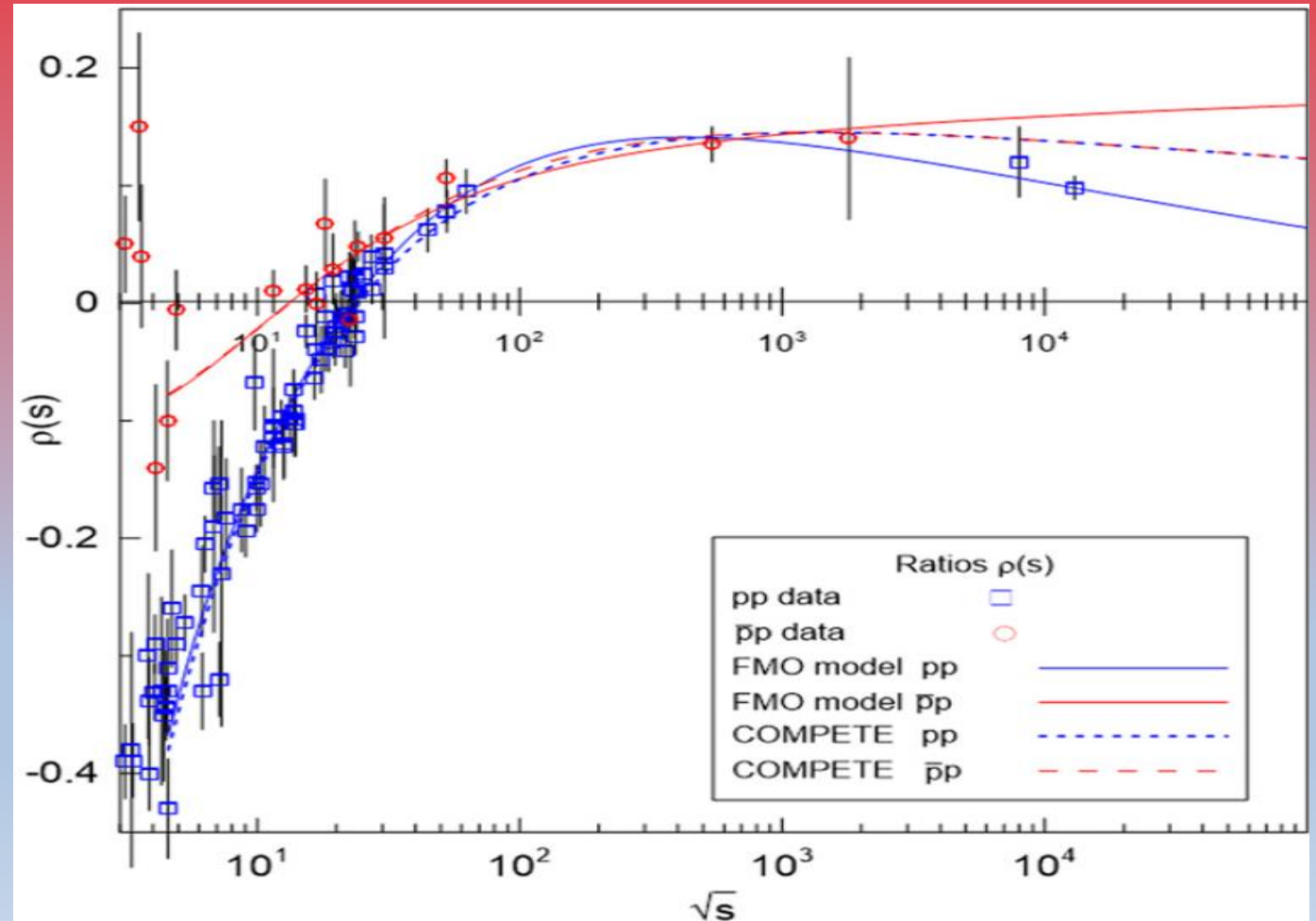
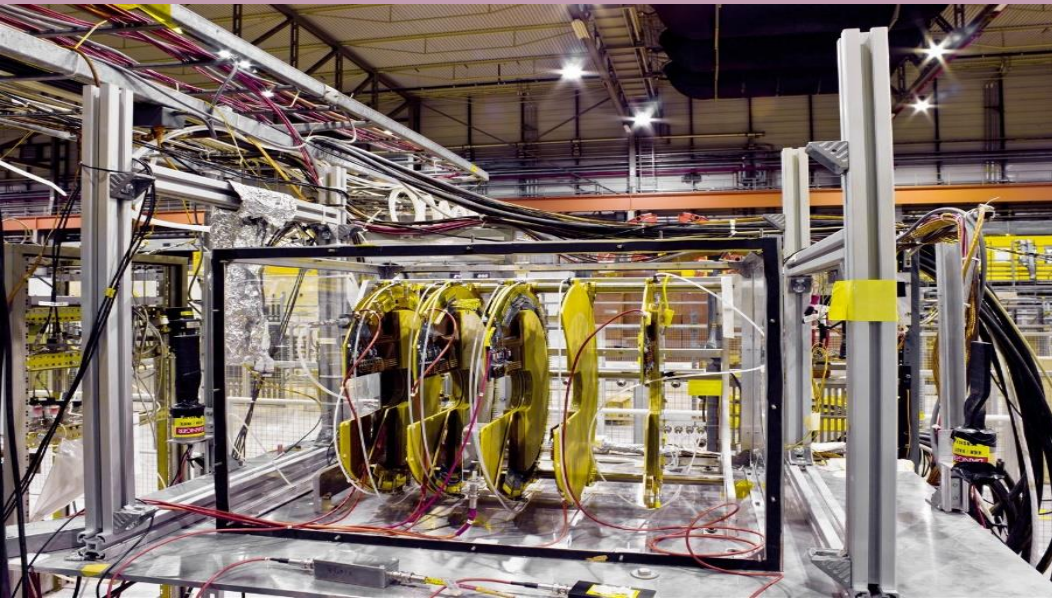
## STRONG INTERACTIONS NEWS

### Oddball antics in pp collisions

23 March 2018

$$T(s,t) = |T(s,t)|e^{i\Phi(s,t)}$$

$$\rho(s) = \cot \Phi(s, 0)$$





# Newsweek

Tech&Science

**Particle Physics: What's an Odderon,  
and Did CERN Just Reveal It Exists?**

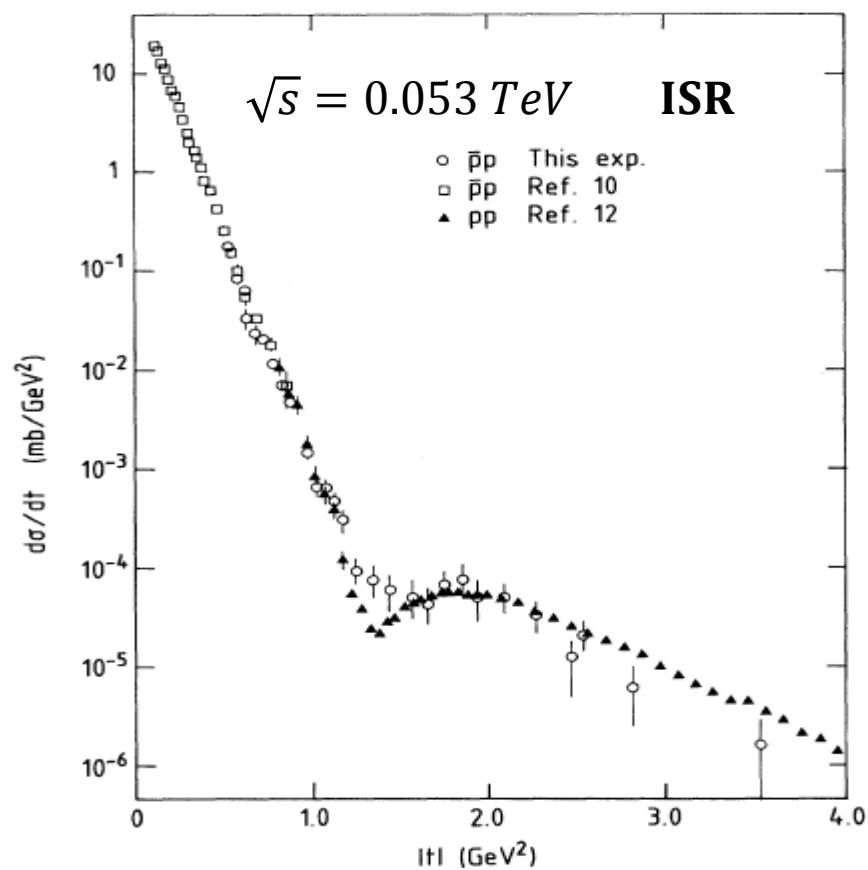
By **Kastalia Medrano** On 2/5/18 at 9:30 AM

# What is the Odderon?

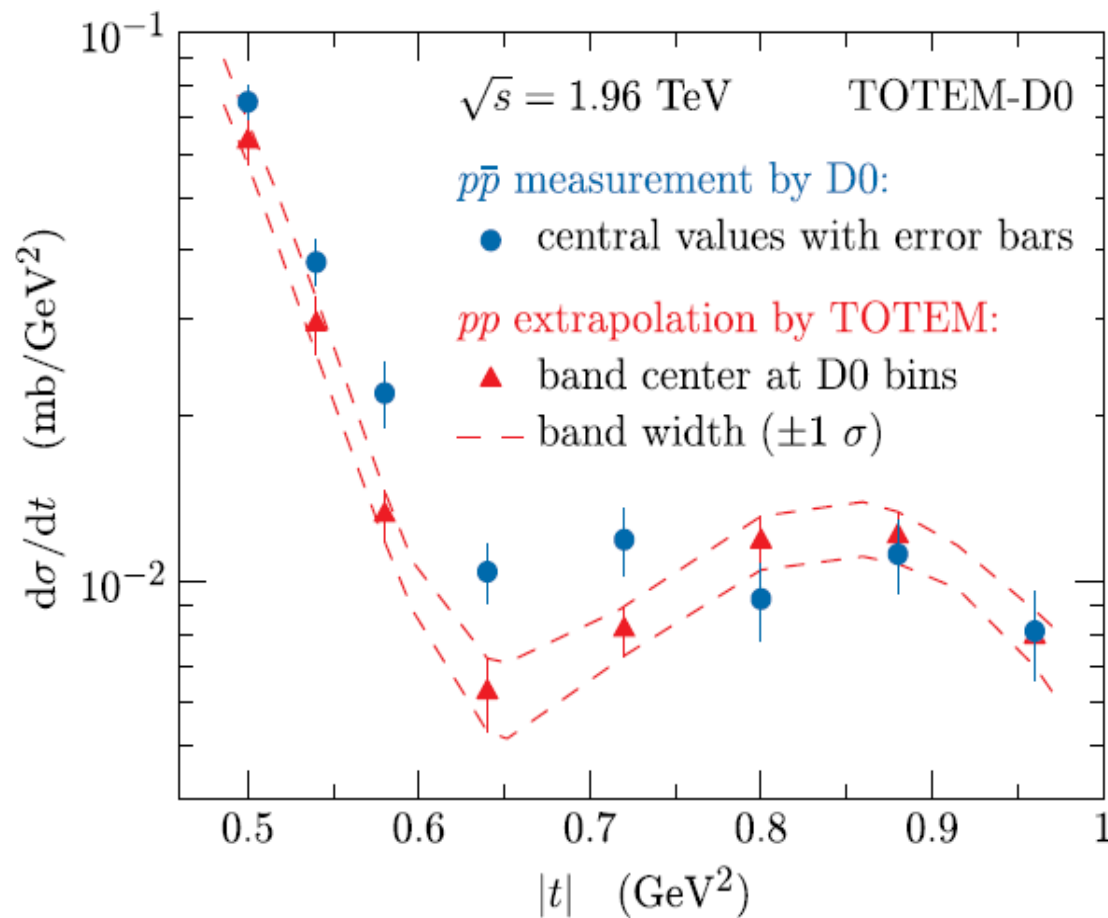
- Odderon is a rightmost singularity  $j_{\mathbb{O}}(t)$  of the C-odd part of the scattering amplitude  $T^-(j, t)$  in complex  $j$ -plane with  $j_{\mathbb{O}}(0) \leq 1$ .
- Odderon is a Regge-pole trajectory  $\alpha_{\mathbb{O}}(t)$  of negative signature with the intercept much higher than that of the  $\omega$  – Reggeon. Intercepts  $\alpha_{\mathbb{O}}(0) > 1$  are admitted. Unitarity implies that  $\alpha_{\mathbb{O}} \leq \alpha_{\mathbb{P}}$ .



# REPETITIO EST MATUR STUDIORUM



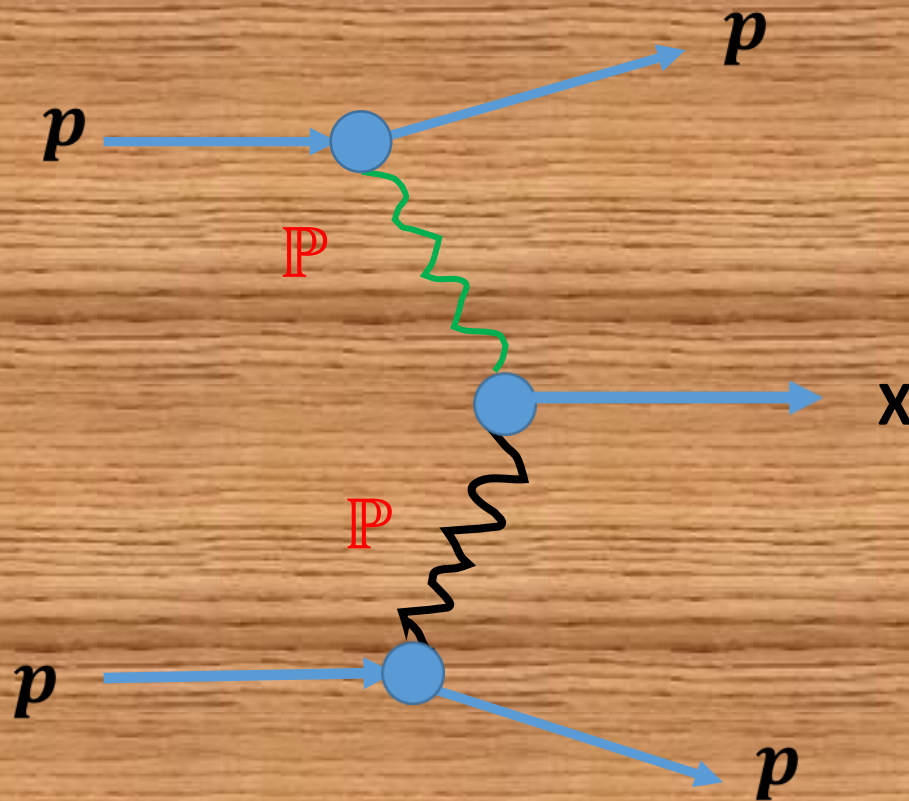
*A. Breakstone et al. (1985)*



*V.M. Abazov et al. (2021)*

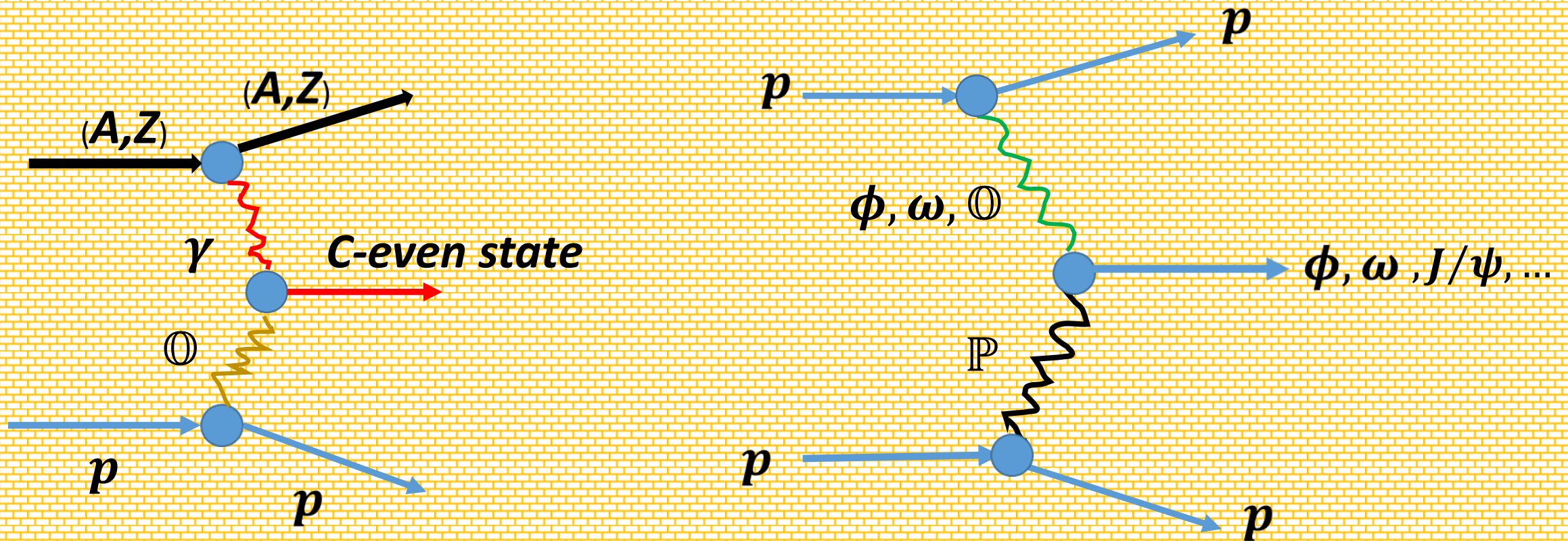
# Central Diffraction

- Exclusive central diffraction:





# Central Diffraction to to detect the $\Theta$ dderon?



QUO VADIS ?

