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Odderon Detection

via $K0_s$ regeneration at LHC

(140m from ATLAS IP, using LHCf–type detectors)

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Abstract: ***We investigate the possibility of the Odderon exchange detection at LHC with $K0_S$ regeneration measurement using (~1 TeV) neutral $K0_L$ mesons originating from p+p (13.6 TeV) collisions at the ATLAS Interaction Point (IP). The regenerator material considered is metallic Pb or Cu, placed at distance ~140m from the IP, behind (or in) TAN absorber. LHCf type of calorimeter [1] is assumed to be capable of detecting the $K0_S$ energy and "decay vertex" position from $K0_S$ meson decays to $\pi^0\pi^0 \rightarrow (2\gamma + 2\gamma)$ pairs at distance L = 5-150 m from the regenerator. We recalculate the regeneration parameters from the published paper [2], which suggested the possibility of Odderon detection using 2 TeV $K0_S$ regeneration in liquid hydrogen (LH_2) at the SSC and UNK colliders. Our estimates for thick Pb, C and Cu regenerators include $K0_L$ absorption.***

Odderon observation in 2021: TOTEM + D0

In March 2021, Odderon discovery [4] has been announced by CERN and Fermilab, based on data from TOTEM and D0 collaborations. Elastic *p+p* scattering data from TOTEM exp. (~3-7-8-13 TeV) were *extrapolated* and compared with elastic *anti-p+p* interactions data at $\sqrt{s}$ =1.96 TeV energy, measured by D0 experiment. C-odd gluonic exchange (significance 5σ) was found, and interpreted as the Odderon *discovery* [4].

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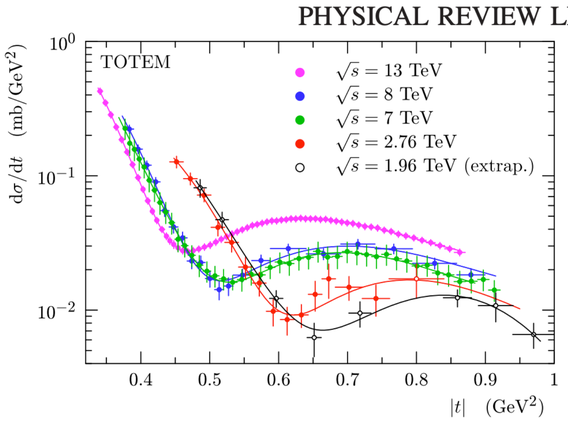


FIG. 1. The TOTEM measured pp elastic cross sections as functions of $|t|$ at 2.76, 7, 8, and 13 TeV (filled circles), and the extrapolation (discussed in the text) to 1.96 TeV

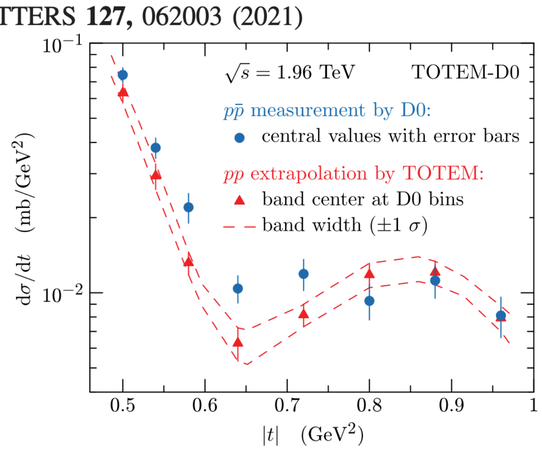


FIG. 4. Comparison between the D0 $p\bar{p}$ measurement at 1.96 TeV and the extrapolated TOTEM pp cross section, rescaled

First indications of C-odd contribution (besides C-even gluon exchange) to the elastic p+p and anti-p+p scattering came from the ISR data at CERN.

Odderon phase shift in $K0_s$ regeneration

Direct Odderon observation is possible via comparing [5] particle and anti-particle elastic scattering, which can be done also with mesons = kaons [2]. Regeneration of $K0_L$ neutral kaon (superposition of *K0* and *anti-K0* mesons) on nuclei is sensitive to the presence of C-odd interaction. A suggestion to observe odderon-induced phase shift in $K0_s$ regeneration at TeV energies was submitted to Physics Letters [3], and modified version published in [2].

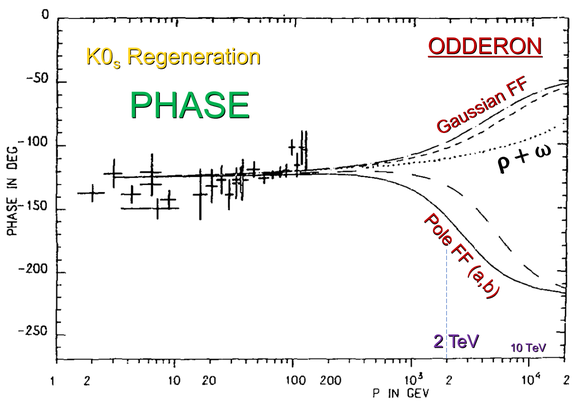


Fig.5 from ref. [2]: Energy dependence of K^0_s regeneration **phase** (points are FNAL data) extrapolated to E < 10 TeV, using two different Odderon form-factor parametrizations.

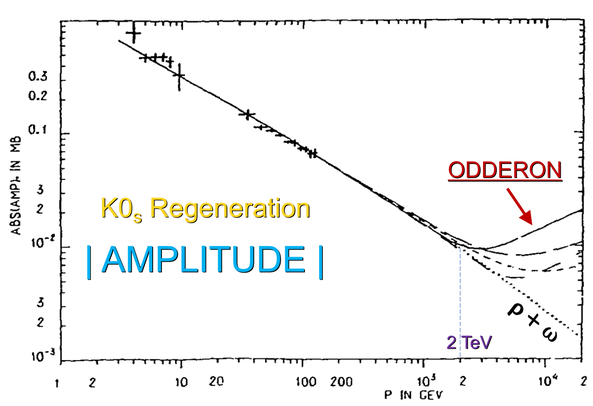


Fig.4 from ref. [2]: Energy dependence of K^0_s regeneration **amplitude** (points are FNAL data) extrapolated to ~20 TeV using two different Odderon form-factor parametrizations.

Intensity of $[\, K^0_L + \varrho K^0_s \,] \rightarrow \pi^0\pi^0$ decays (after regenerator) is given by:

$$I(\tau) = I_o \Gamma_s B^s_{\pi\pi} \left[|\varrho|^2 e^{-\tau/\tau_s} + \underbrace{|\eta|^2 e^{-\tau/\tau_L}}_{\text{CP violating}} + 2|\varrho||\eta| e^{-(\tau/\tau_s + \tau/\tau_L)/2} \underbrace{\cos(\tau \Delta m c^2/\hbar + \Phi)}_{\text{mass diff.}} \right]$$

$K0_S \rightarrow \pi\pi$ — Regeneration |Amplitude|²

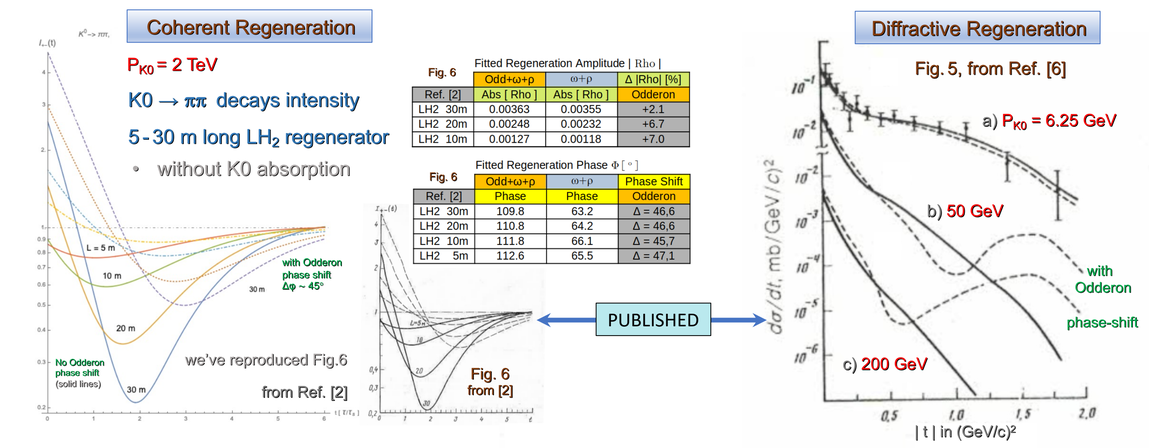
$K0_L \rightarrow \pi\pi$ — Regen. |Amplitude|

the interference term — Regeneration Phase

Regeneration amplitude depends on regenerator thickness and nuclei type.

Reproducing the LH_2 regeneration plots

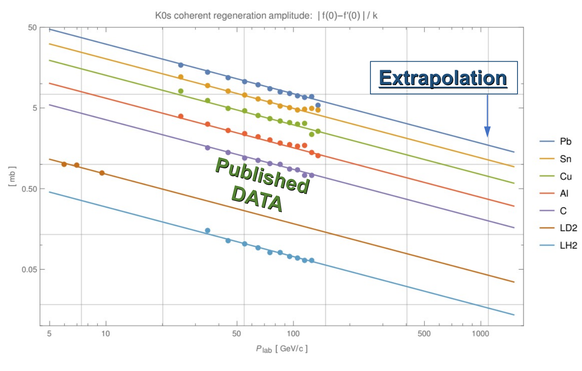
Publication [2] (and preprint [3]) assume 45° (or 15°) odderon-induced phase shifts, without considering K0 absorption in the regenerator.

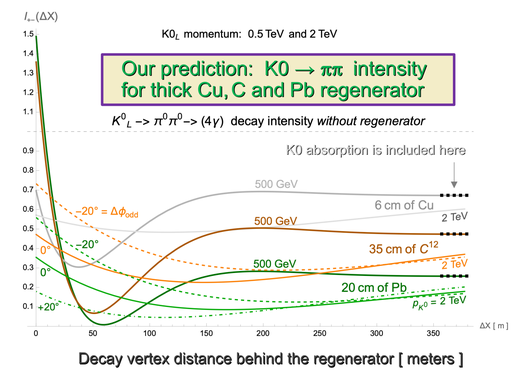


Diffractive $K0_s$ regeneration for p_{K0} = 6.25 - 200 GeV was studied in [6].

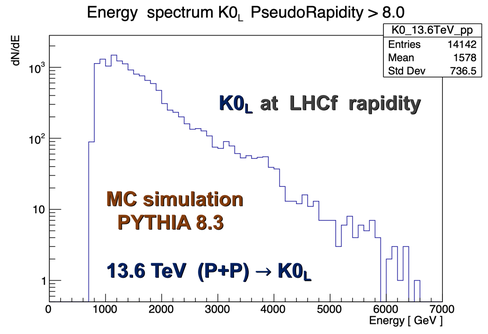
Our prediction for thick C,Cu,Pb regenerators

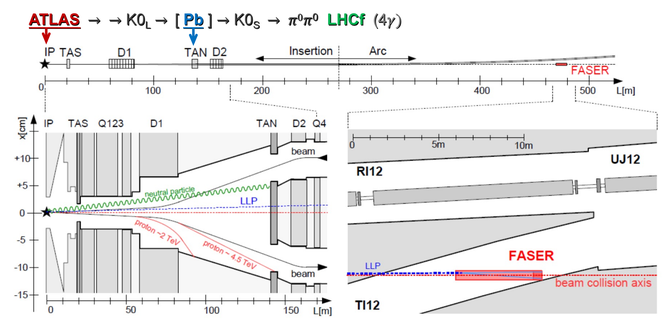
Parametrizing the energy dependence of the regeneration |amplitude| for different regenerator materials (Pb, Sn, Cu, Al, C, LH_2), and extrapolating to TeV momentum of $K0_L$ beam, allows us to make the prediction for thick Cu, C^{12} and Pb regenerators at energy 0.5 - 2 TeV. Our predictions extend the original studies [2,3] by including the $K0_L$ *absorption*.





Regeneration of ~TeV $K0_s$ produced at LHC (p+p)





We suggest to consider the Odderon detection at LHC using $K0_s$ regeneration at high (~TeV) energy.

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