Первое измерение событий с провалами в быстротных распределениях в pA-взаимодействиях на БАК в эксперименте CMS

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**НАУЧНАЯ СЕССИЯ
СЕКЦИИ ЯДЕРНОЙ ФИЗИКИ
ОТДЕЛЕНИЯ ФИЗИЧЕСКИХ НАУК РАН,**
посвящённая 300-летию Российской академии наук

4 Апреля 2024

Strong interaction diffraction

Diffractive collisions are defined as special inelastic collisions in which no quantum numbers are exchanged between colliding particles

Diffraction process markers (observables):

- Fast particle ($\frac{E_{fin}}{E_{in}} = x \geq 0.9$) and slow particle(s) ($x \leq 0.9$)
- Rapidity gap ($\Delta\eta$) – the rapidity region free of final state particles (between slow and fast particles)

Diffractive scattering in proton-nucleus collisions:

- Sensitive to collective effects in nucleus: $\sigma_{diff} = f(A)$
- Diffraction of hadrons on nuclear targets at very high energies are valuable input, for example, for modelling of extensive cosmic ray shower

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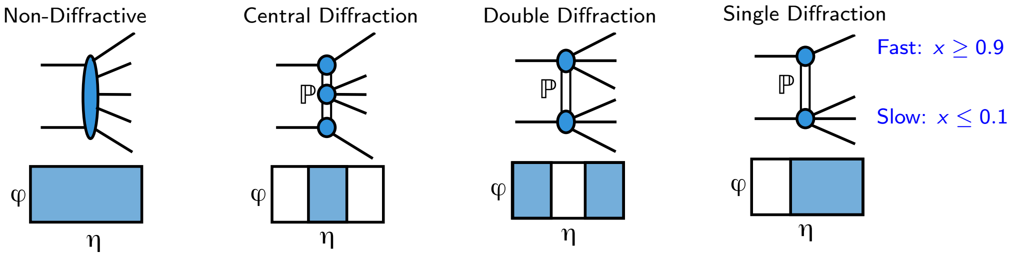
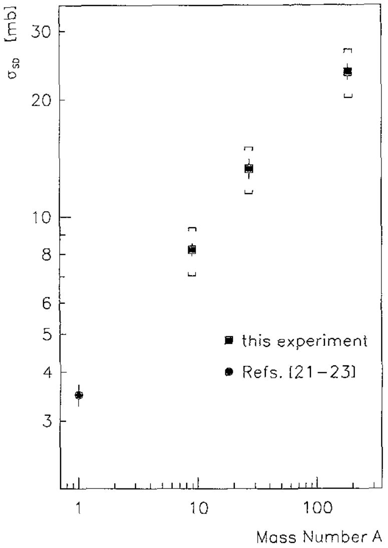


HELIOS results (Z. Phys. C 49 (1991) 355)

Main HELIOS results

- The latest (before LHC) measurements on diffraction in pA were done by HELIOS with $\sqrt{s} = 27$ GeV Z. Phys. C 49 (1991) 355
- The cross-section of single diffraction is proportional to the nuclear radius, $\sigma_{SD} = \sigma_0 \cdot A^{\alpha}$, $\alpha = 0.35$
  This suggests that diffractive dissociation of nuclei is a peripheral process, predominantly involving nucleons on the rim of the nucleus.



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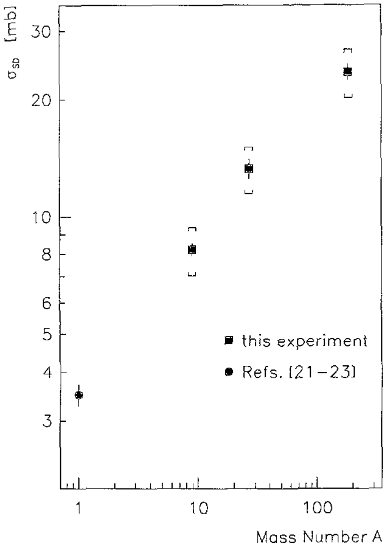
SPS vs LHC energies for pA:

$\sqrt{s} = 27$ GeV | $\sqrt{s} = 8000$ GeV

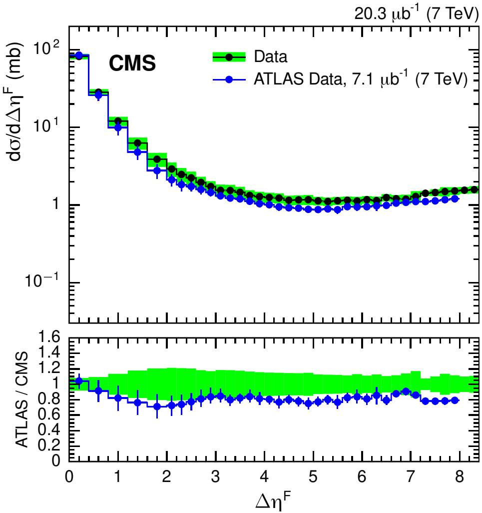
Center-of-mass system: 300 times

Laboratory system: 80000 times



- As a consequence of the color-less nature of pomeron, the diffractive processes are characterized characterized by a Rapidity Gap
- Rapidity Gap ($\Delta\eta$) – the rapidity region free of final state particles

rapidity gap was studied with **pp** collisions data by ATLAS EPJC 72 (2012) 1926, CMS PRD 92 (2015) 012003

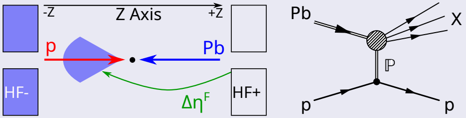


CMS analysis

CMS collaboration, "First measurement of the forward rapidity gap distribution in pPb collisions at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV",
Phys.Rev.D 108 (2023) 092004

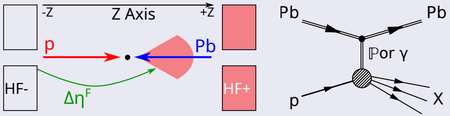
Event topologies

Named as "$\mathbb{P}$Pb $+\gamma Pb$ topology"



Lead dissociation

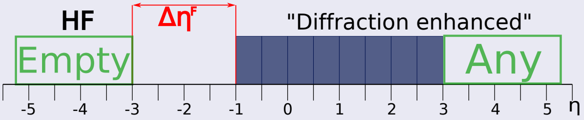
Named as "$\mathbb{P}$p $+\gamma p$ topology"



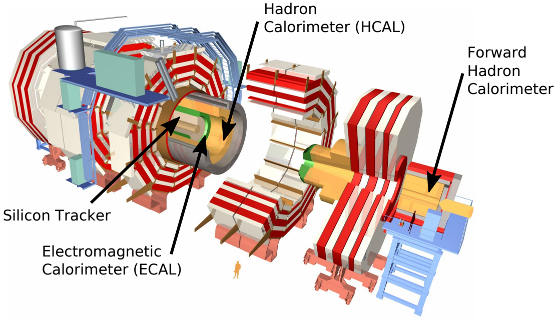
Proton dissociation

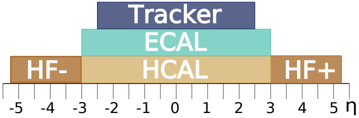
The photon flux from the Pb is enhanced by a factor of Z^2_{Pb} compared to that of protons

Rapidity gap selection



CMS Detector

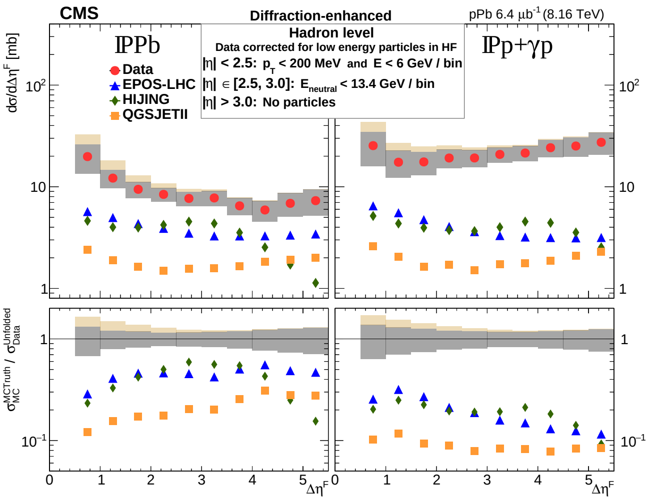




Calorimetry + tracking = Particle Flow (PF) objects

- Silicon tracker: $|\eta| < 2.5$
- ECAL and HCAL: $|\eta| < 3.0$
- Forward Hadron Calorimeter (HF):
  $3.0 < |\eta| < 5.2$
  has fine segmentation by η and ϕ into 432 HF Towers

- Zero Degree Calorimeter (ZDC): $|\eta| > 8.5$



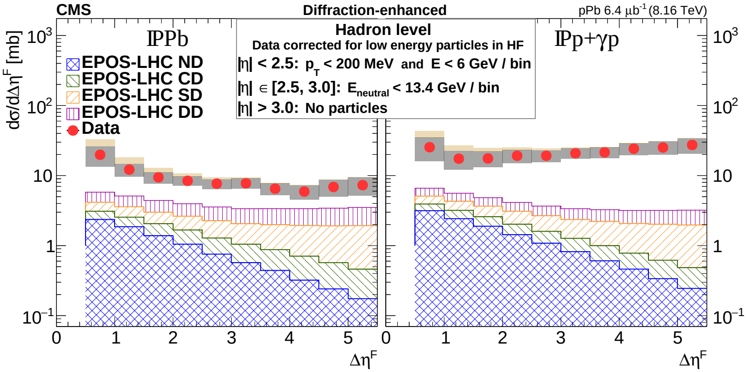
$(\mathbb{P}/\gamma)$-p topology

- The generators are more than a factor of 5 below the data

$(\mathbb{P}/\gamma)$-Pb topology

- Predictions of EPOS-LHC and QGSJET II are about a factor of 2 and 4 below the data
- The rapidity spectrum from the HIJING generator falls at large $\Delta\eta^F$ in contradiction to the data

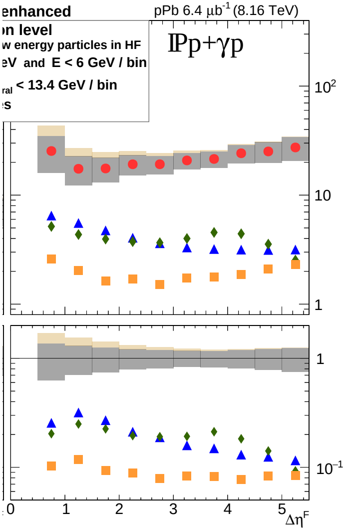
Used generators includes **only** pomeron exchange events



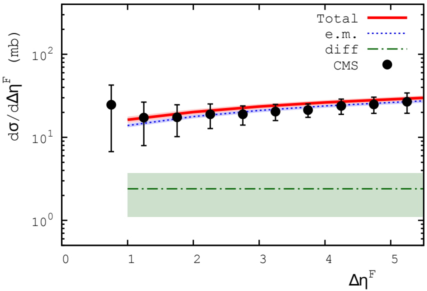
Stacked distributions:

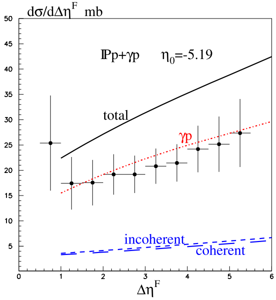
- ND: Non-Diffractive
- CD: Central Diffractive
- SD: Single Diffractive
- DD: Double Diffractive

For the pomeron exchange events, diffractive events dominates at high rapidity gap sizes



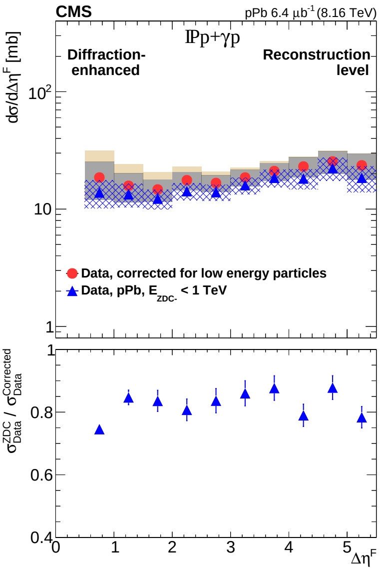
V. Guzey, M. Strikman, M. Zhalov, Phys.Rev.C. 106 (2022) L021901
(based on preliminary CMS results: CMS@DIS2021);
Khoze V. A., Ryskin M. G, EPJC 83 (2023) 11, 991





The difference between generator predictions and CMS data can be described by γp events!

Hadron-level pPb rapidity gap results: $(\mathbb{P}/\gamma)$-p topology events without lead break-up



The rapidity gap distributions with empty HF range adjacent to rapidity gap:

- The main rapidity gap distribution
- Events without Lead break-up (ZDC selection)

Fraction of events without nuclear break-up is independent of rapidity gap size!

Summary

- Forward rapidity gap distribution $\frac{d\sigma}{d\Delta\eta^F}$ from p-A collisions at the LHC ($\sqrt{s_{NN}} = 8.16$ TeV) have been measured for the first time for both ($\mathbb{P}/\gamma$)-A and ($\mathbb{P}/\gamma$)-proton topologies
- The performed measurements at $\sqrt{s}$ are about 300 times larger than the previous measurements (80000 in lab system).
- For ($\mathbb{P}/\gamma$)-A topology, the predictions of event generators (EPOS-LHC, QGSJET II) are about a factor of 2-4 below the data, but the shapes of the spectrum are similar to that of the data
- For ($\mathbb{P}/\gamma$)-p topology, the all used generators yeild the cross section values a factor of 5 smaller than the data due to the contribution from γp events (not implemented in the used event generators)
- This measurement changes relation between the common diffraction process markers: fast particle observable and rapidity gap observable
- Rapidity gap observable in p-A measured by CMS shows that electromagnetic contribution exceeds strong interaction diffraction
- These data may be of significant help in modeling ultrahigh-energy cosmic ray air showers

Thank you!