First measurement of the forward rapidity gap distribution in pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV with the CMS experiment

Michael Murray$^1$ and Dmitry Sosnov

$^1$ The University of Kansas, Lawrence, US

for the CMS collaboration

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Physics relevance

Diffraction

**Diffractive collisions**: special inelastic collisions in which no quantum numbers are exchanged between colliding particles; characterized by a Rapidity Gap, caused by $t$-channel pomeron(s) ($t\, P$) exchange.

**Rapidity Gap ($\Delta \eta$)**: the rapidity regions free of final-state particles

**Latest pA diffraction**: were done by HELIOS with $\sqrt{s} = 27$ GeV

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Problems studied with diffraction

- Nature of the pomeron in QCD
- Small-$x$ problem and “saturation” of parton densities
- Cross sections of inelastic diffractive processes are very sensitive to nonlinear saturation effects, which get more important for scattering off nuclei.
- Diffraction of hadrons on nuclear targets at very high energies is also relevant for cosmic-ray physics.

The CMS Detector

- **Tracker**: $|\eta| < 2.5$
- **ECAL and HCAL**: $|\eta| < 3.0$
- **Forward Hadron Calorimeter (HF)**: $3.0 < |\eta| < 5.2$
Data and event topologies

Event topologies of interest

Data, MC event generators

Data : CMS, pPb $\sqrt{s_{NN}} = 8.16$ TeV, 6.4 $\mu b^{-1}$ (2016)

HIJING :
- hard parton scatterings: perturbative QCD
- soft interactions: string excitations

EPOS-LHC : Gribov-Regge theory for the parton interactions; Gluon saturation — phenomenological implementation

QGSJET II-04 : Gribov-Regge theory for the parton interactions; Gluon saturation via higher order pomeron-pomeron interactions

The generators do not include photon ($\gamma$) exchange processes

Rapidity Gap ($\Delta \eta^F$)

- Central region (bins of 0.5 in $\eta$):
  - For $|\eta| < 2.5$:
    - No charged particles with $p_T > 0.2$ GeV
    - The total energy of all particles less than 6 GeV
  - For $2.5 \leq |\eta| < 3.0$:
    - The total energy of neutral hadrons less than 13.4 GeV
- No detectable activity at the HF acceptance on the side of $\Delta \eta^F$
• PPb topology: predictions of EPOS-LHC and QGSJET II is 2 and 4 times below the data.
• The EPOS-LHC and QGSJET II shapes are similar to the data
• The HIJING prediction falls at large $\Delta \eta_F$

• IPp+γp topology: all the generators are more than a factor of 5 below the data
• This suggests a very strong contribution from $\gamma p$ events which is not yet implemented in the considered event generators
Summary

- Forward rapidity gap distribution $\frac{d\sigma}{d\Delta\eta^F}$ from pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV have been measured for the first time for both pomeron-lead (lPPl) and pomeron-/$\gamma$-proton (lPp+$\gamma$p) topologies.

- For the lPPl topology case, where the $\gamma$-exchange contribution should be negligible:
  - Predictions of EPOS-LHC is about a factor of 2 and QGSJET II a factor of 4 are below the data.
  - However, for both of those generators, the shape of the $\frac{d\sigma}{d\Delta\eta^F}$ spectrum is similar to that of the data.
  - The rapidity spectrum from the HIJING generator falls at large $\Delta\eta^F$ in contrast to the data.

- For the lPp+$\gamma$p case:
  - The cross section of EPOS-LHC and QGSJET II are lower than data by more than a factor of 5.
  - This suggests a very strong contribution from $\gamma$p events which is not yet implemented in the considered event generators.

- These data may be of significant help in the modeling of ultrahigh-energy cosmic ray air showers.
Thank you for attention!