Rapidity gaps in ultra-peripheral collisions

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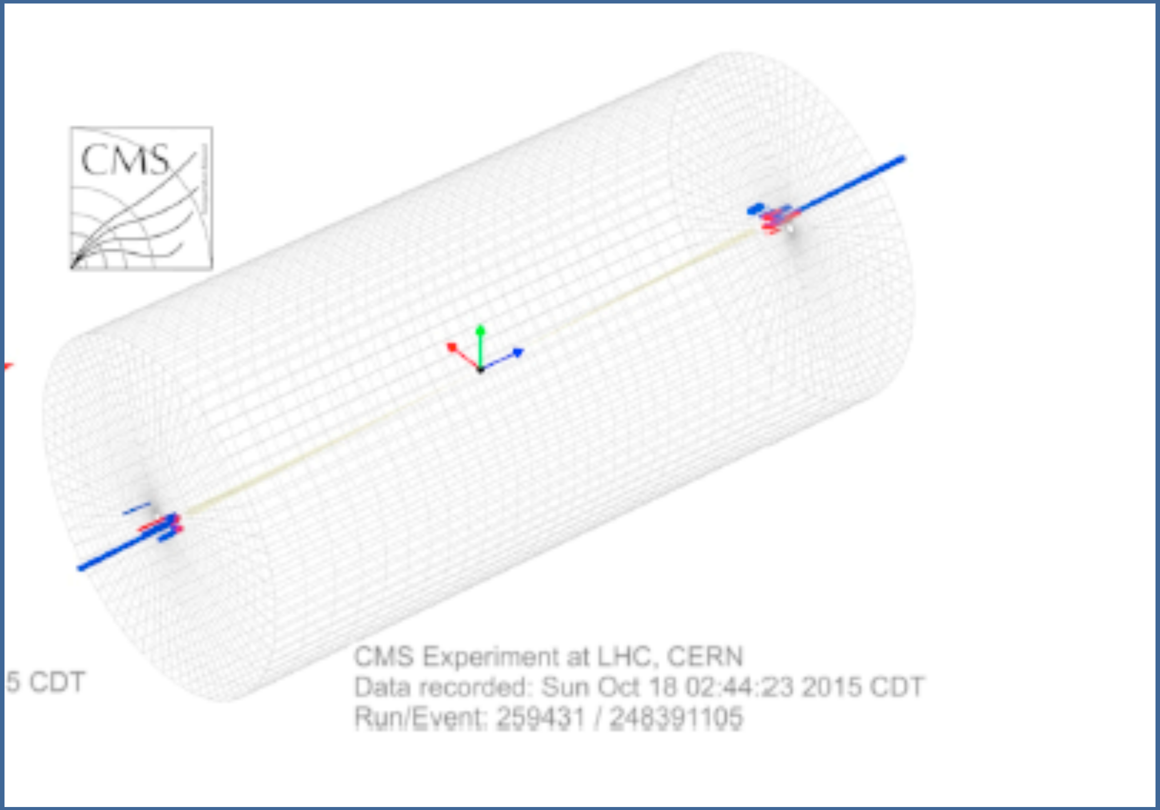

U.S. DEPARTMENT OF ENERGY Office of Science

CFNS Workshop on Target Fragmentation in UPCs
9th February 2022

Outline

- Rapidity gaps can serve as a signature for colorless interactions.
- This could include both diffraction and photo-nucleus collisions
  - Therefore gap topology can tag particular physics processes
- This talk will review
  1. The spectrum of rapidity gaps from pp, pPb, Pbp
  2. Angular correlations of particles from photon-p
  3. Angular correlations between jets in photon-lead
  4. Fraction of colorless interactions in di-jet events.

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Diffraction in pp

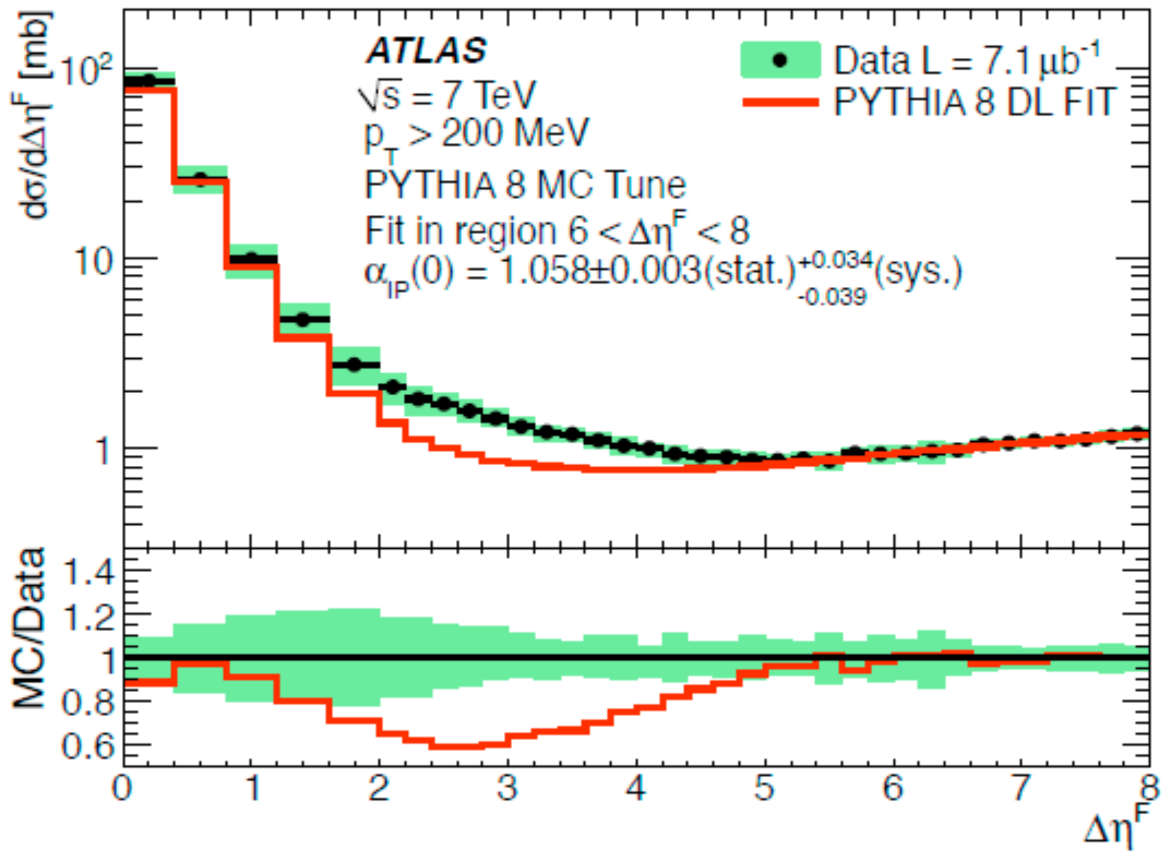


Fig. 9: Inelastic cross section differential in forward gap size $\Delta\eta^F$ for particles with $p_T > 200$ MeV. The data are compared with a modified version of the PYTHIA8 model with the DL flux, in which the Pomeron intercept $\alpha_{\mathbb{P}}(0)$ is determined from fits to the data in the region

Defining rapidity gaps

Look for a large angular region with no particles or energy.
The size of this region is called $\Delta\eta_F$

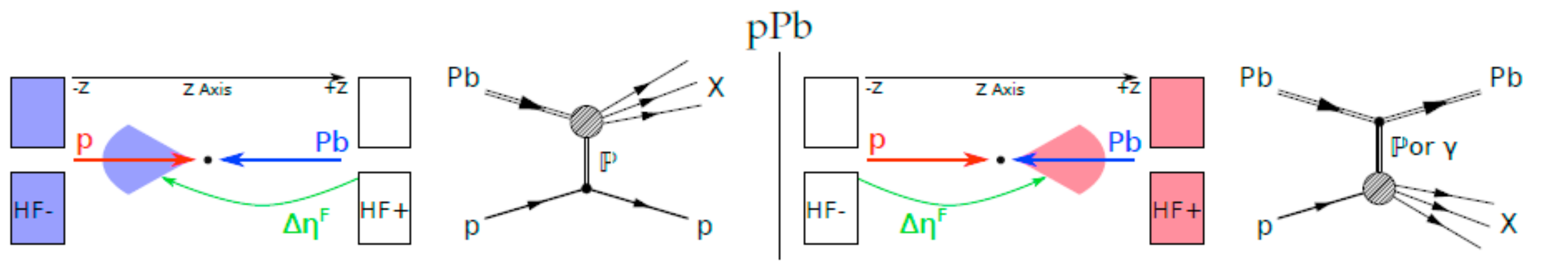
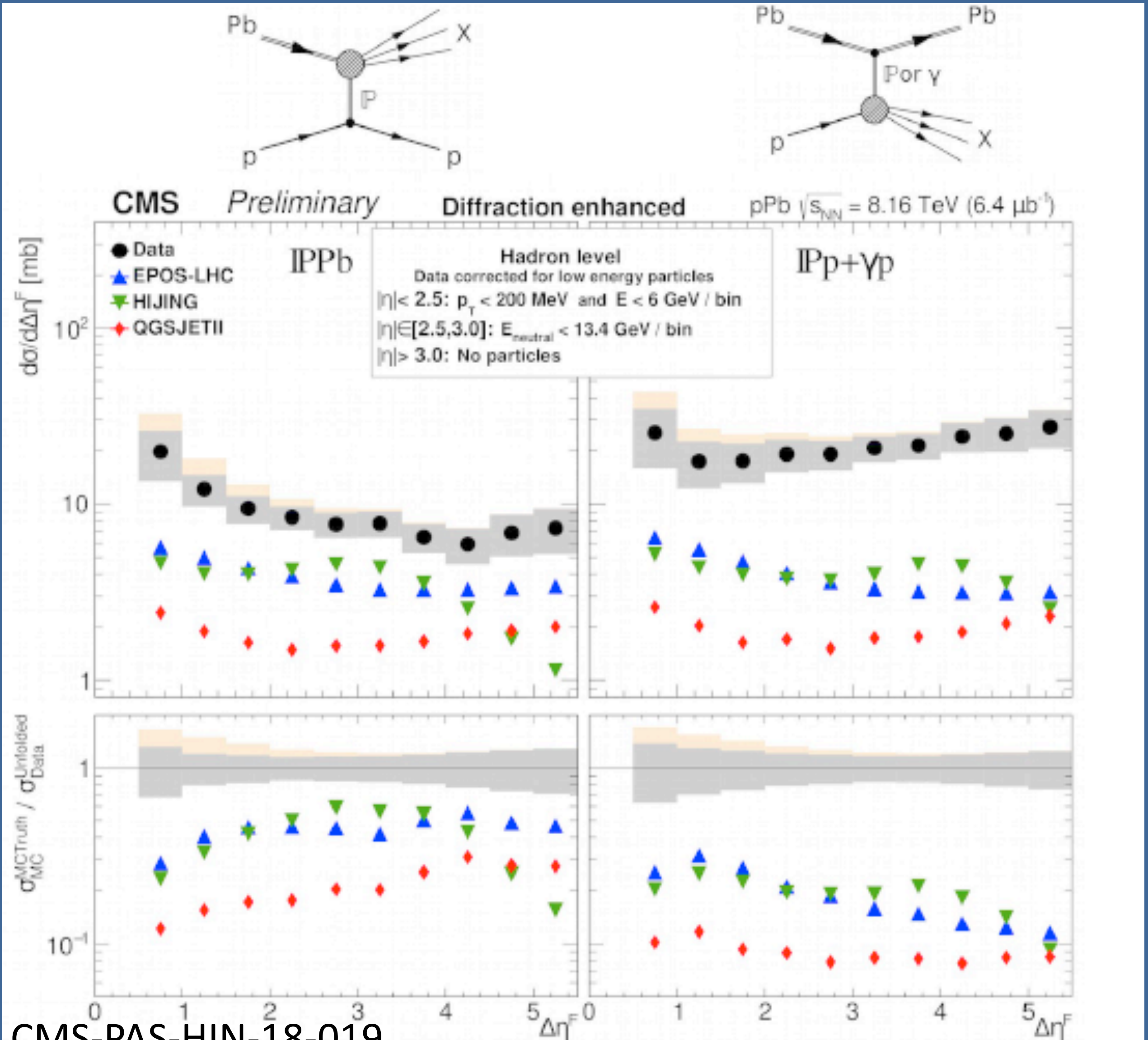


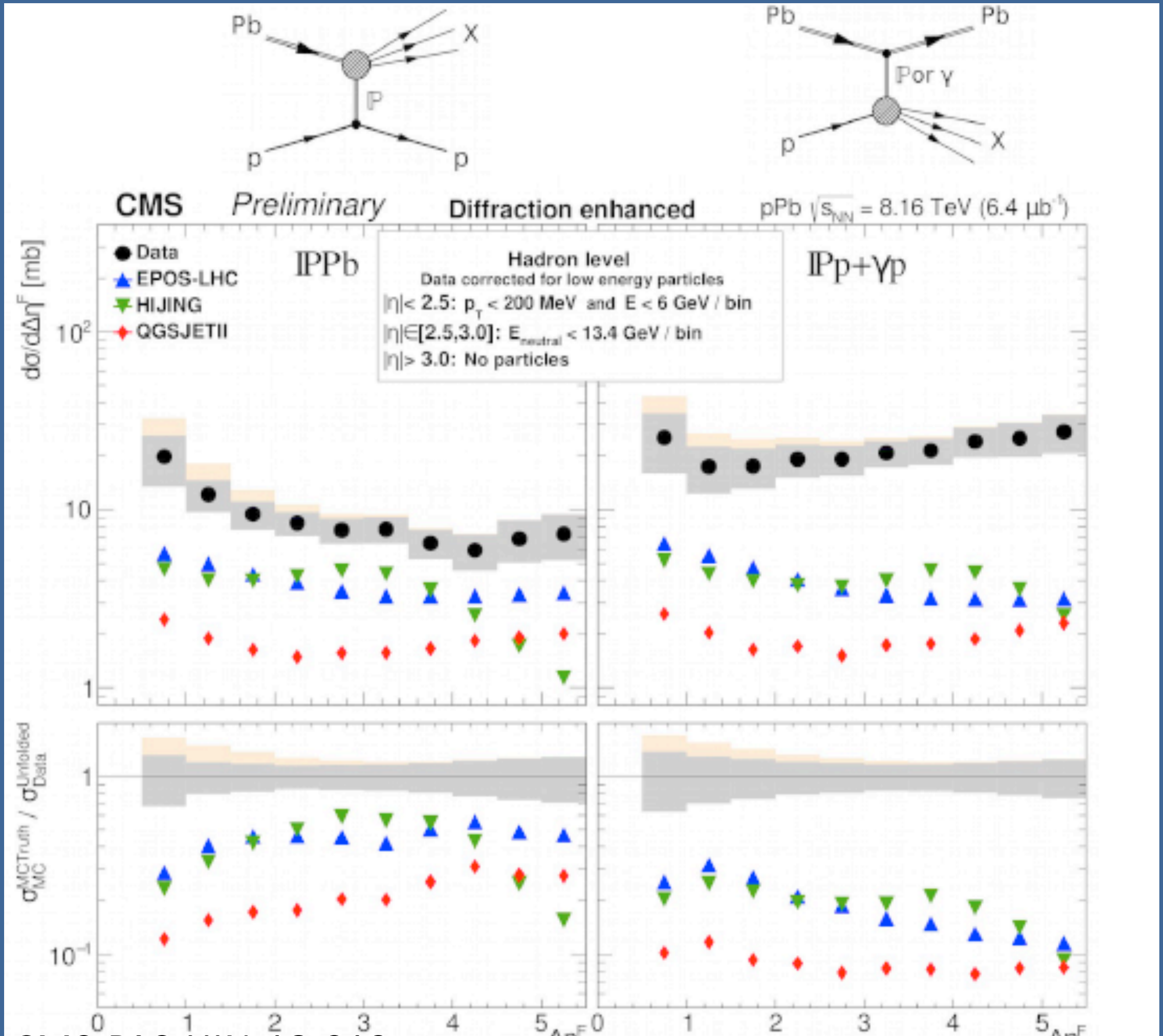
Figure 1: Topologies of pPb events with large rapidity gaps for ℙPb (left) and ℙp or γp (right). The blue and red cones indicate the products of diffractive dissociation for the lead ion and proton respectively. The regions free of final state particles are marked with green arrows. It is possible for γPb interactions to mimic the topology on the left but these are much suppressed compared to the γp case.

Diffraction in pPb much greater than predicted



CMS-PAS-HIN-18-019

Diffraction in pPb much greater than predicted



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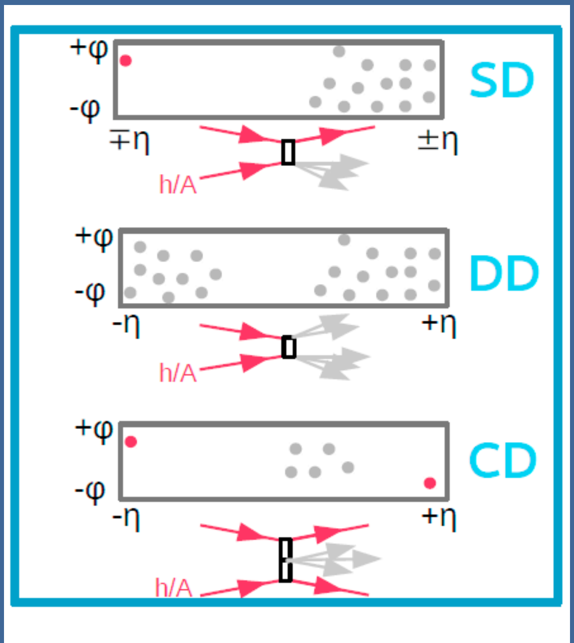
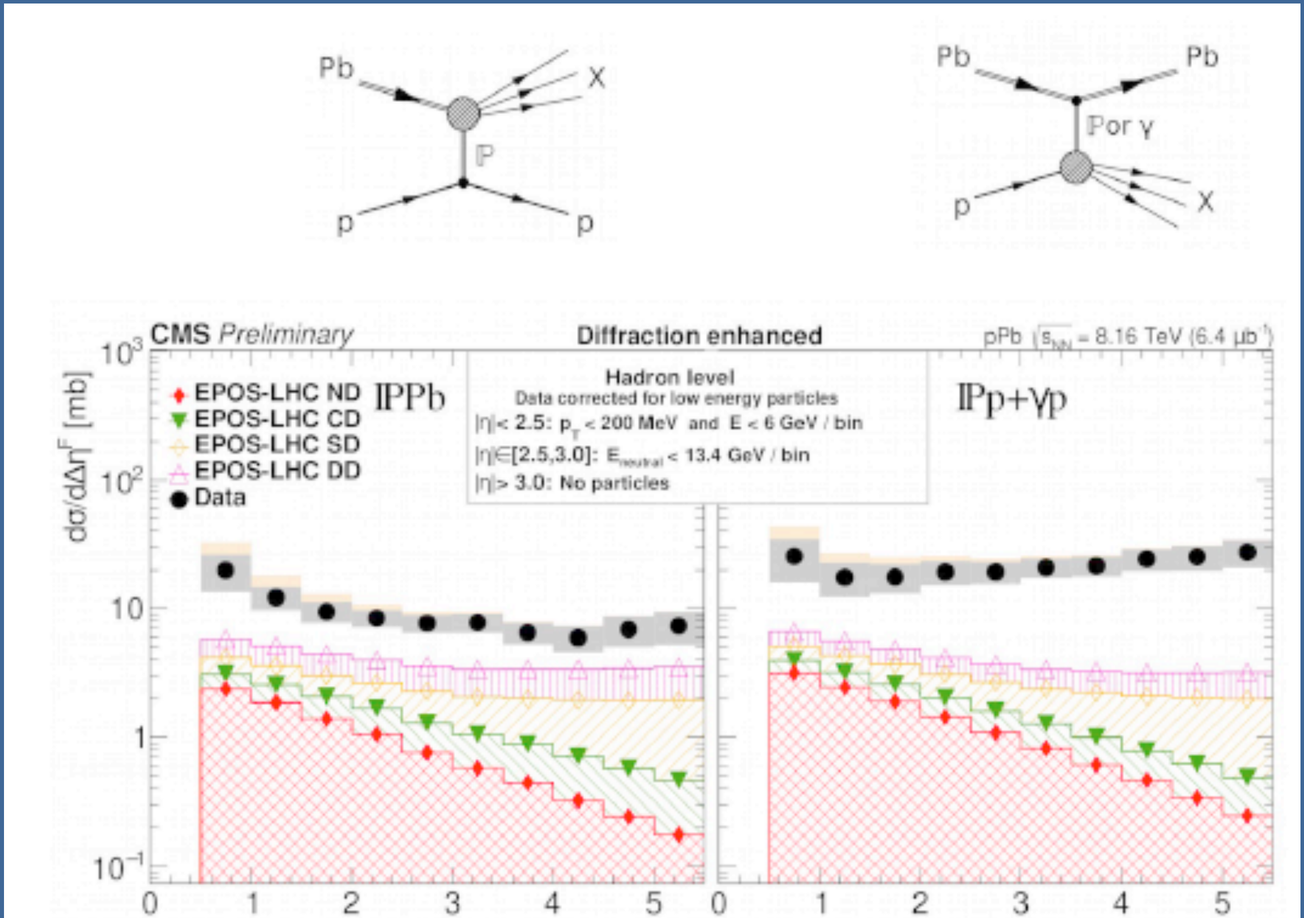
Data on proton going side suggest the need for ɣp interactions not included in EPOS.





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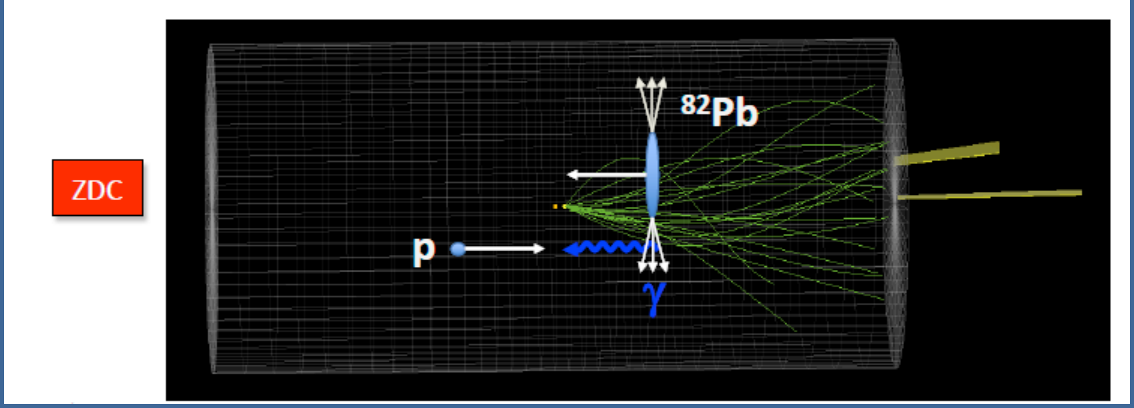
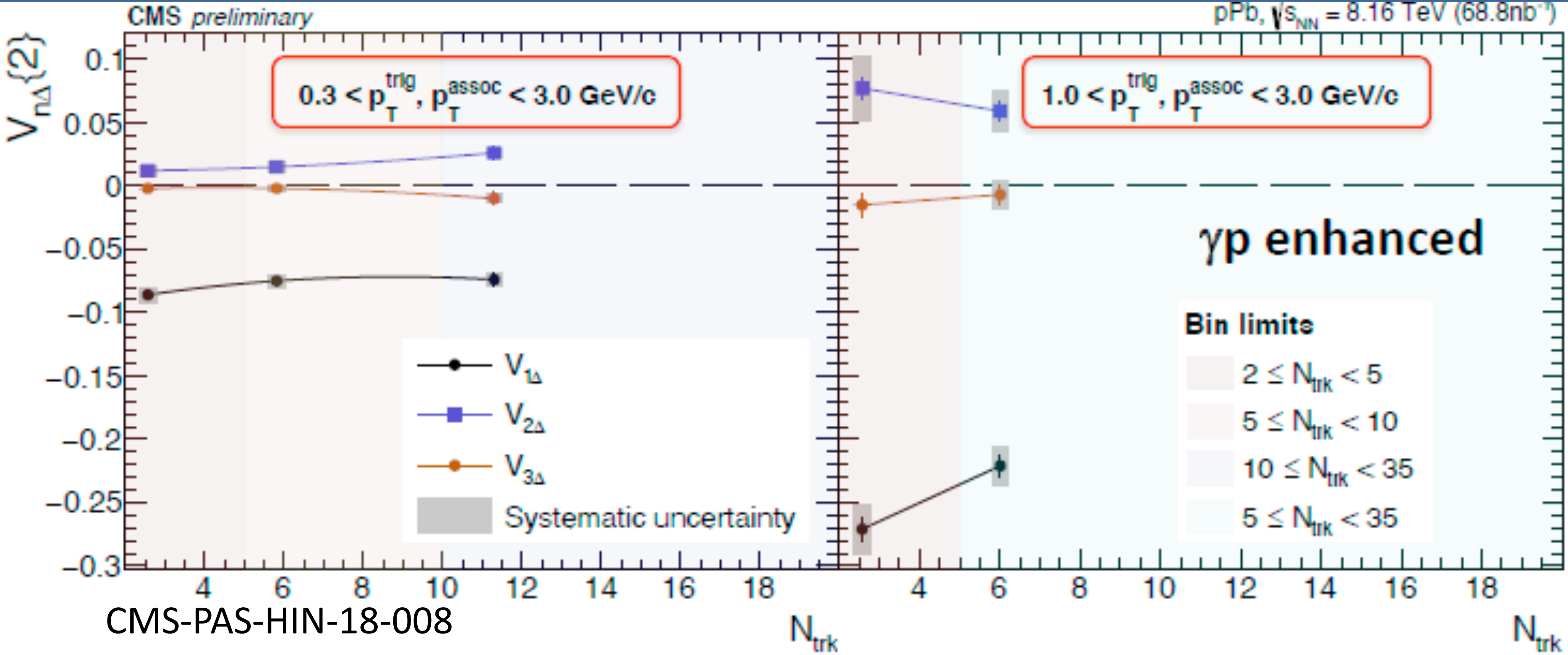
A significant v_2 is also seen in γp





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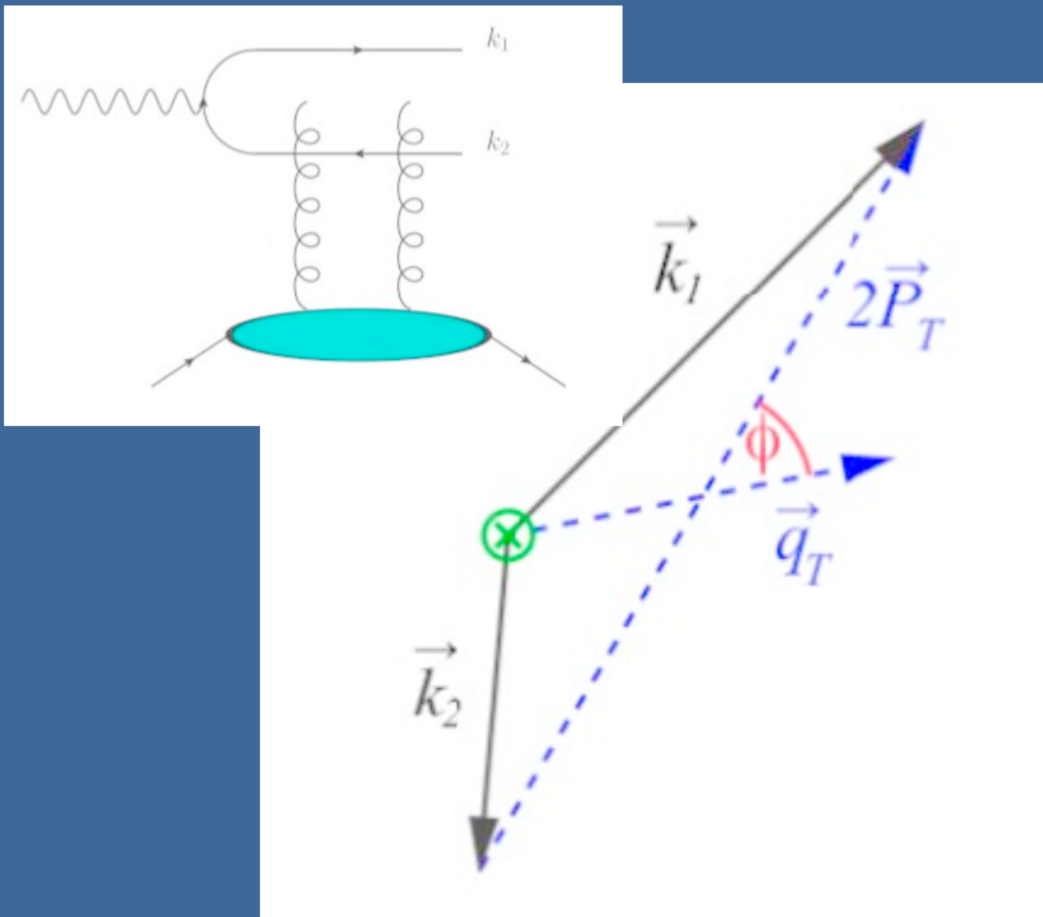
Angular correlations from γPb => dijets



Vector sum of 2 jets:

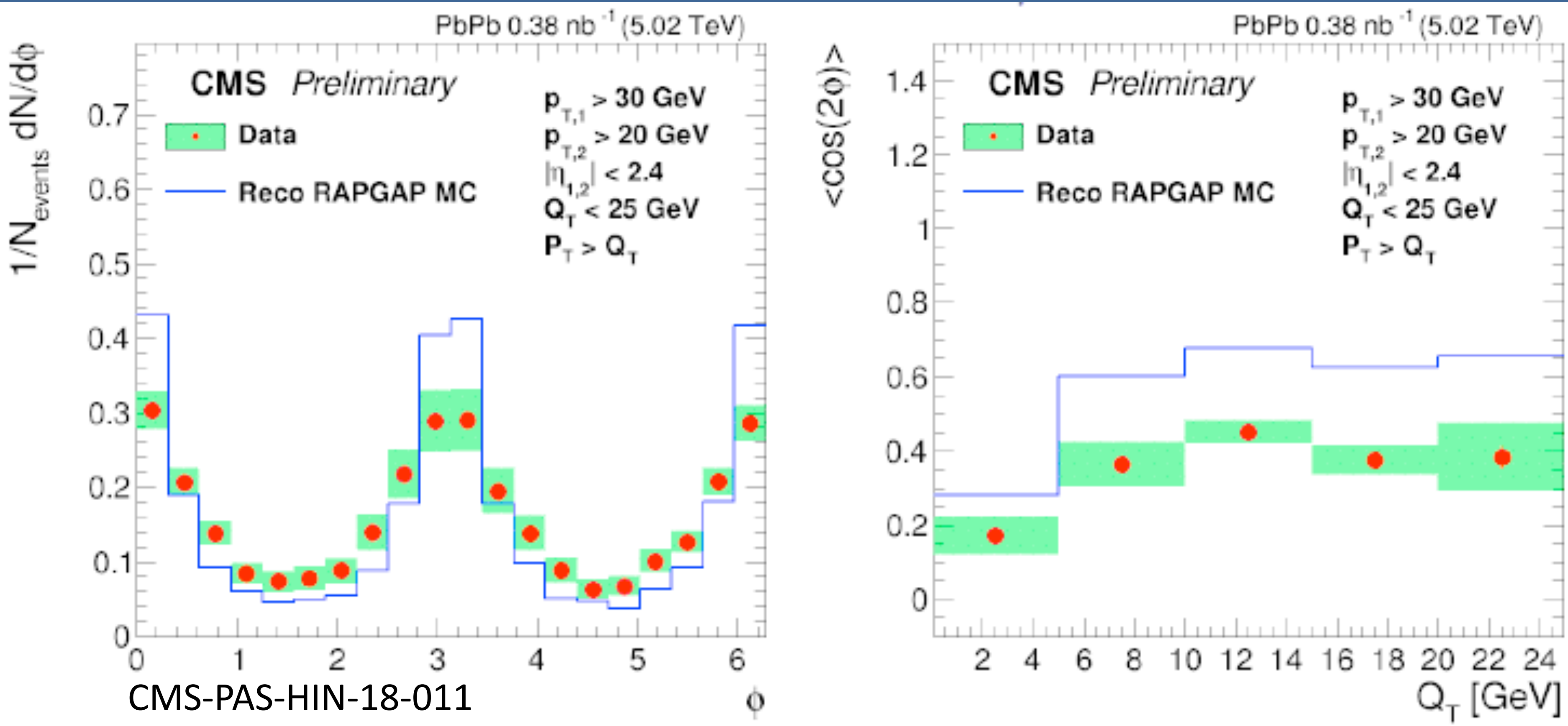
$$\vec{Q}_T = \vec{k}_1 + \vec{k}_2$$

Vector difference of 2 jets:

$$\vec{P}_T = \frac{1}{2}(\vec{k}_1 - \vec{k}_2)$$

Angular correlations depend upon the gluon Wigner distributions

Angular correlations from γPb => diets



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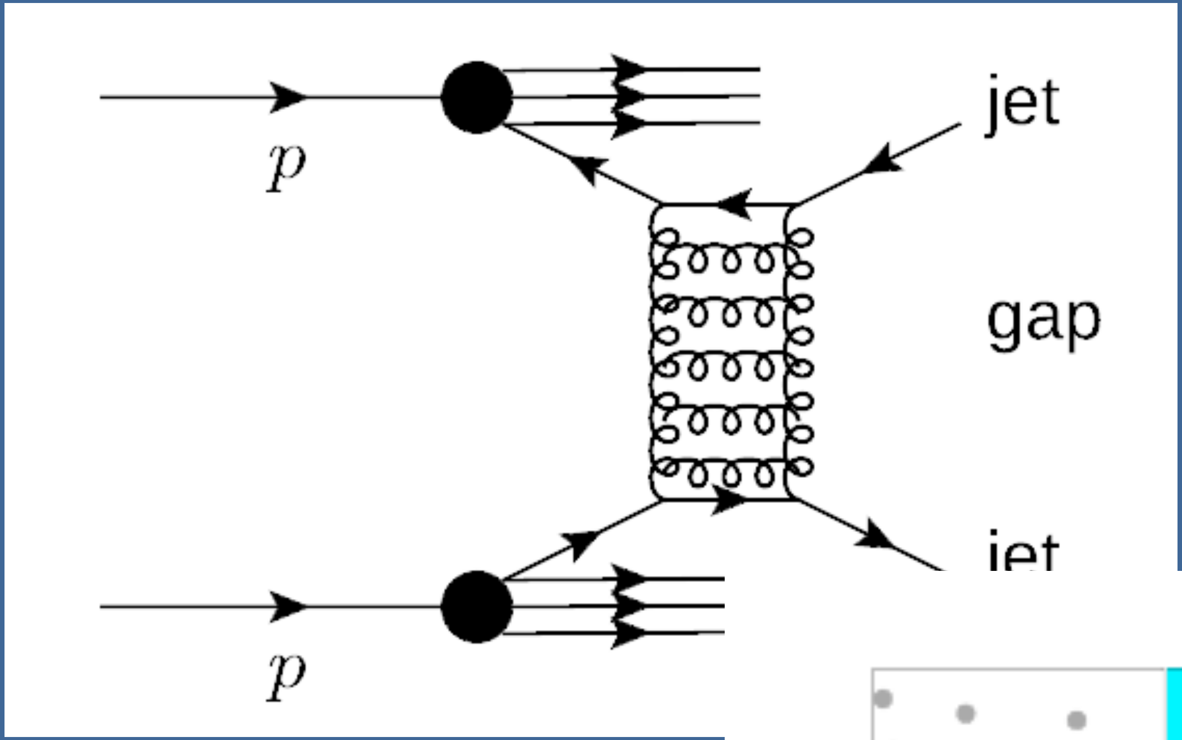
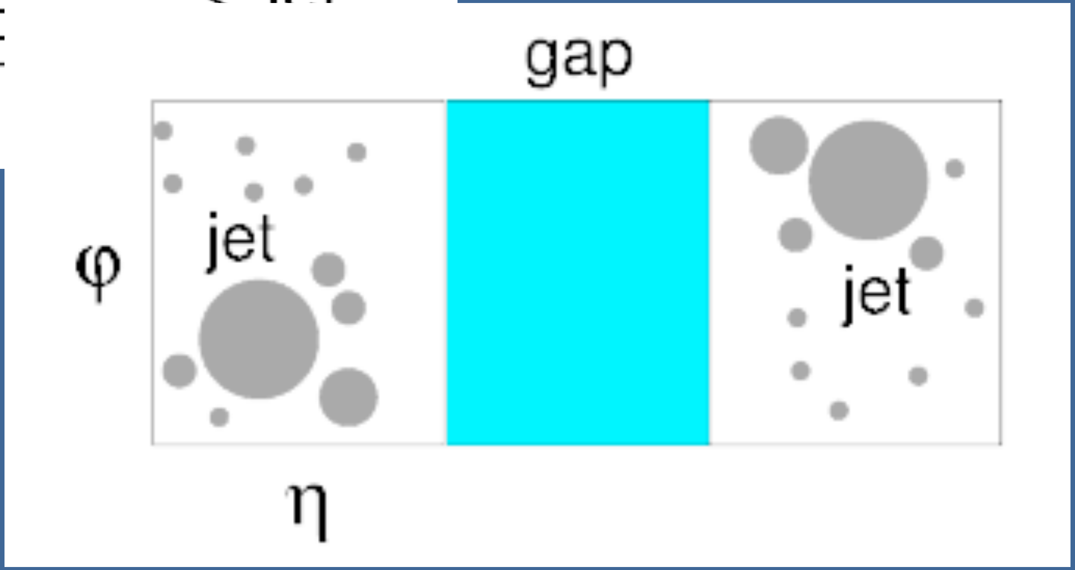
Non trivial angular correlations are present, suggesting. Need to unpack effects for final state radiation, gluon correlations.

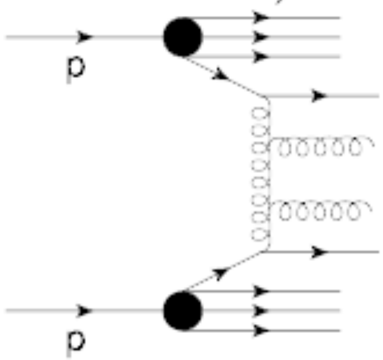
Jet-gap-Jet events (Mueller-Tang)

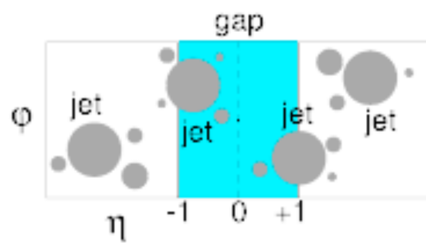


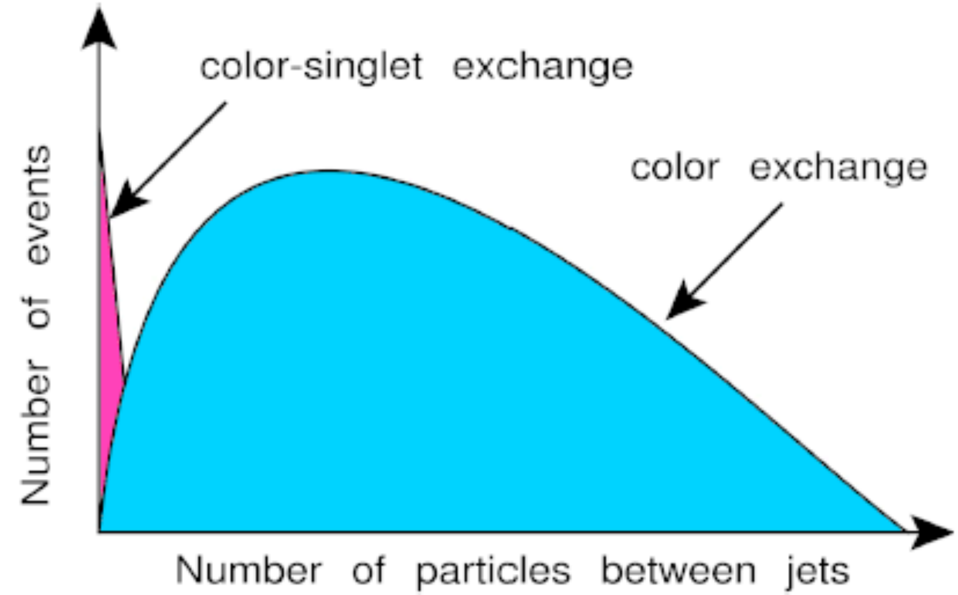


Colorless exchange makes fewer particles

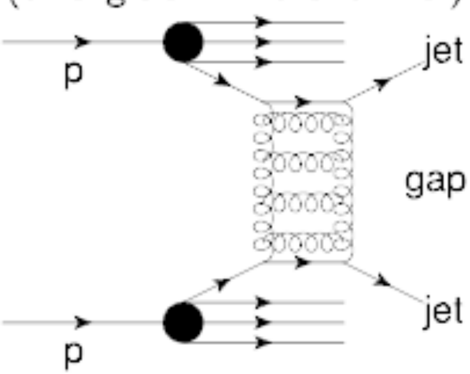
Color-exchange
(single-gluon in t-channel)

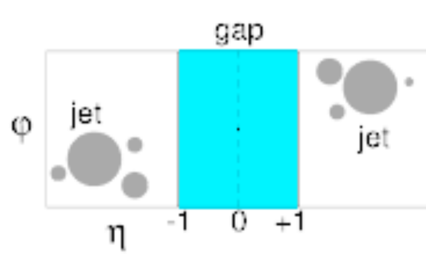






Color-singlet exchange
(two-gluon in t-channel)



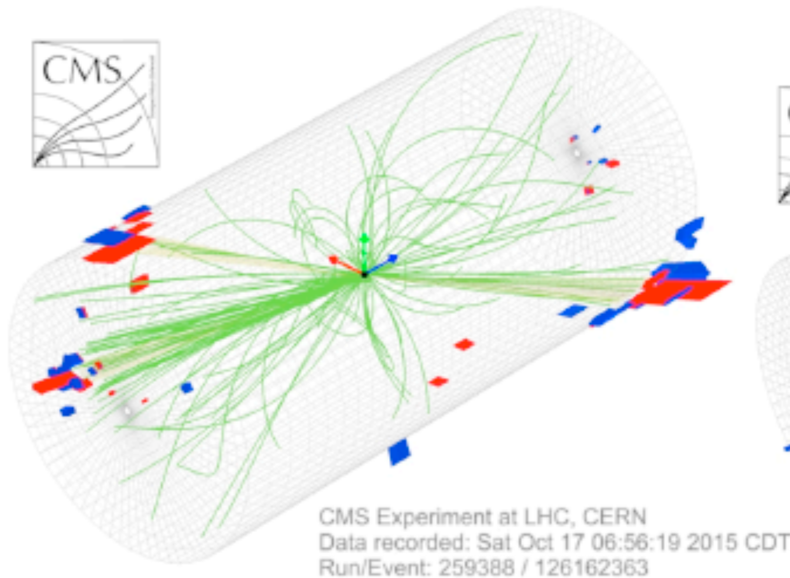


Color-exchange dijet fluctuations at low-multiplicities need to be properly treated.

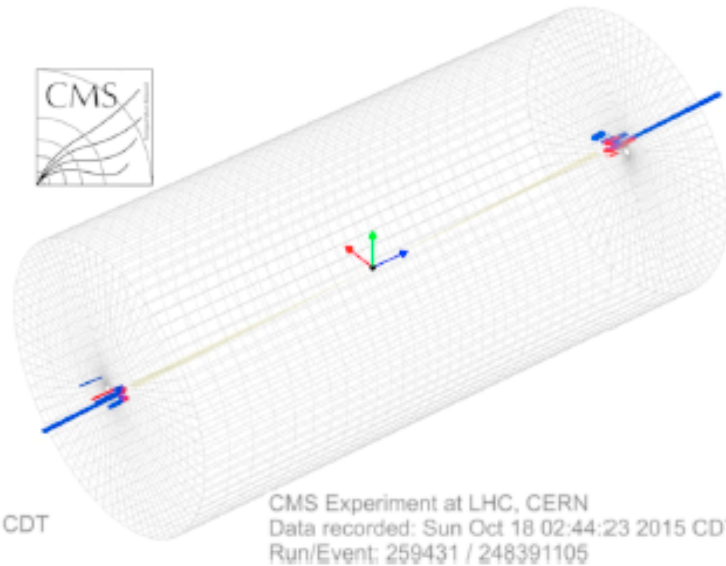
To avoid model-dependent Monte Carlo predictions, **we used data-based methods to estimate the fluctuations of color-exchange events.**

arXiv:2102.06945, Phys. Rev. D 104, 032009 (2021)

Examples of events



Color-exchange event candidate
(Background-like)

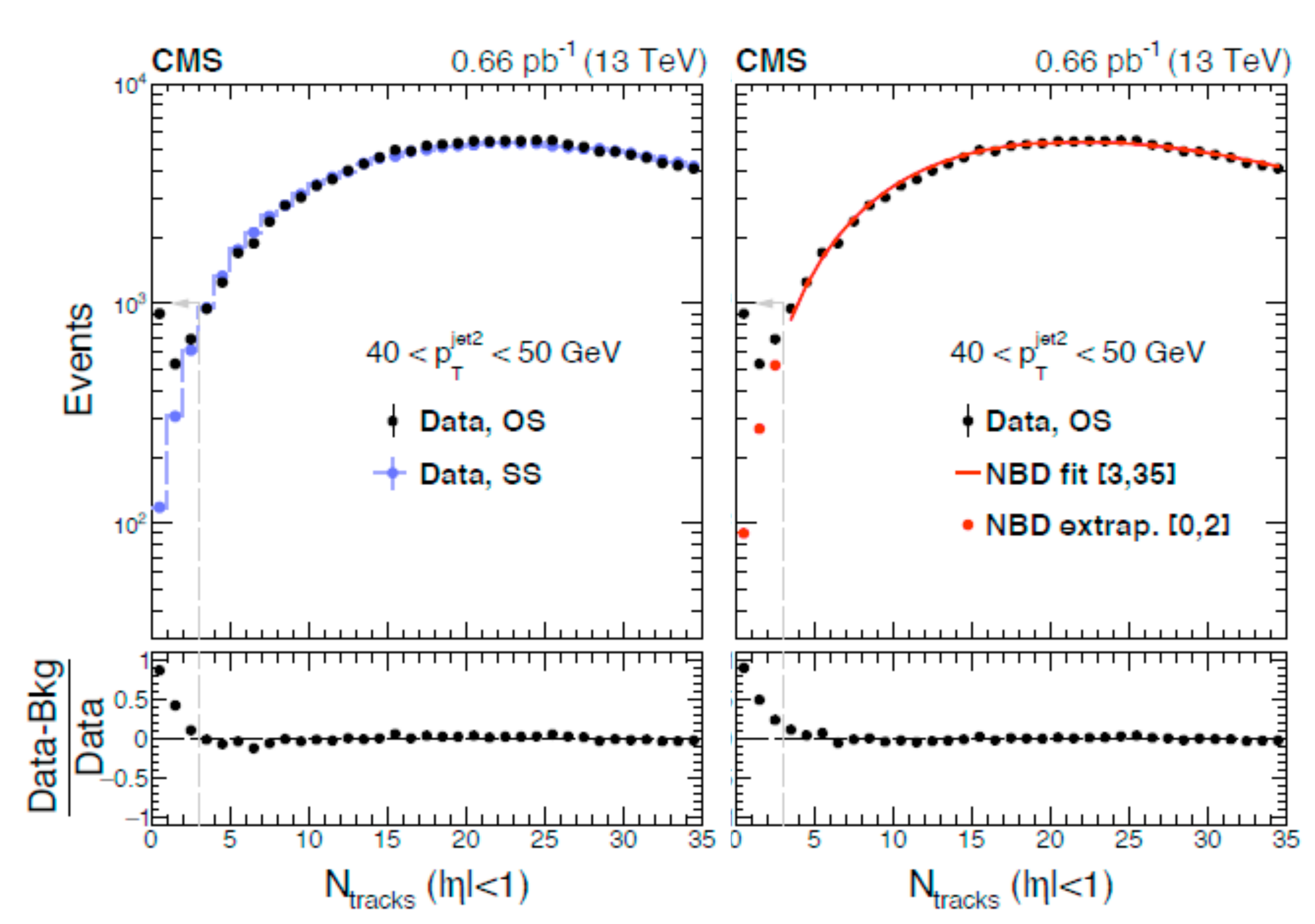


Color-singlet exchange event candidate
(Signal-like)

Leading two jets $p_T > 40$ GeV, all other jets $p_T > 15$ GeV, calorimeter towers with $E > 1$ GeV, charged particles with $p_T > 200$ MeV

arXiv:2102.06945, Phys. Rev. D 104, 032009 (2021)

Test



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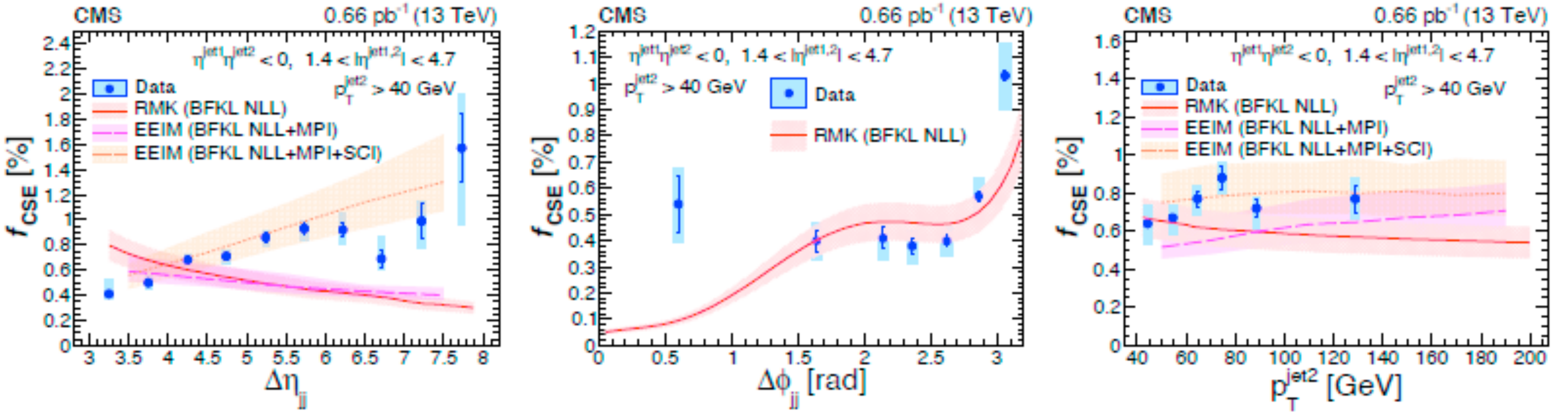
Color Singlet Exchange fraction vs rapidity difference phi difference and p_T^{jet2}



RMK and EEIM models are both based on BFKL evolution, resumed at NLO.

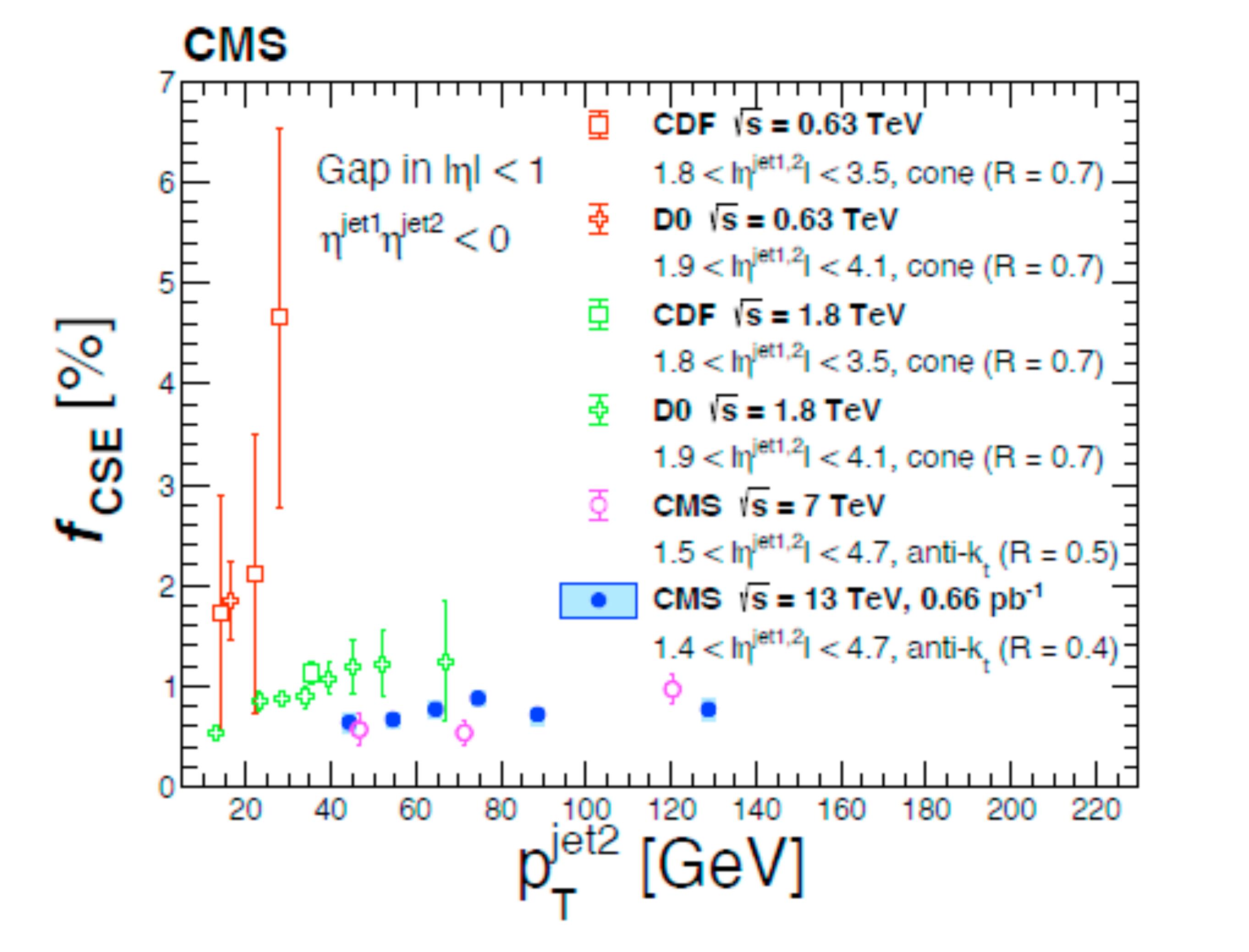
They have different gaps survival mechanisms.

RMK has $|S|^2 = 0.1$;

EEIM has multiple-parton interactions (MPI), and soft-color interactions (SCI).

arXiv:2102.06945, Phys. Rev. D 104, 032009 (2021)

Color Singlet Exchange fraction vs Energy



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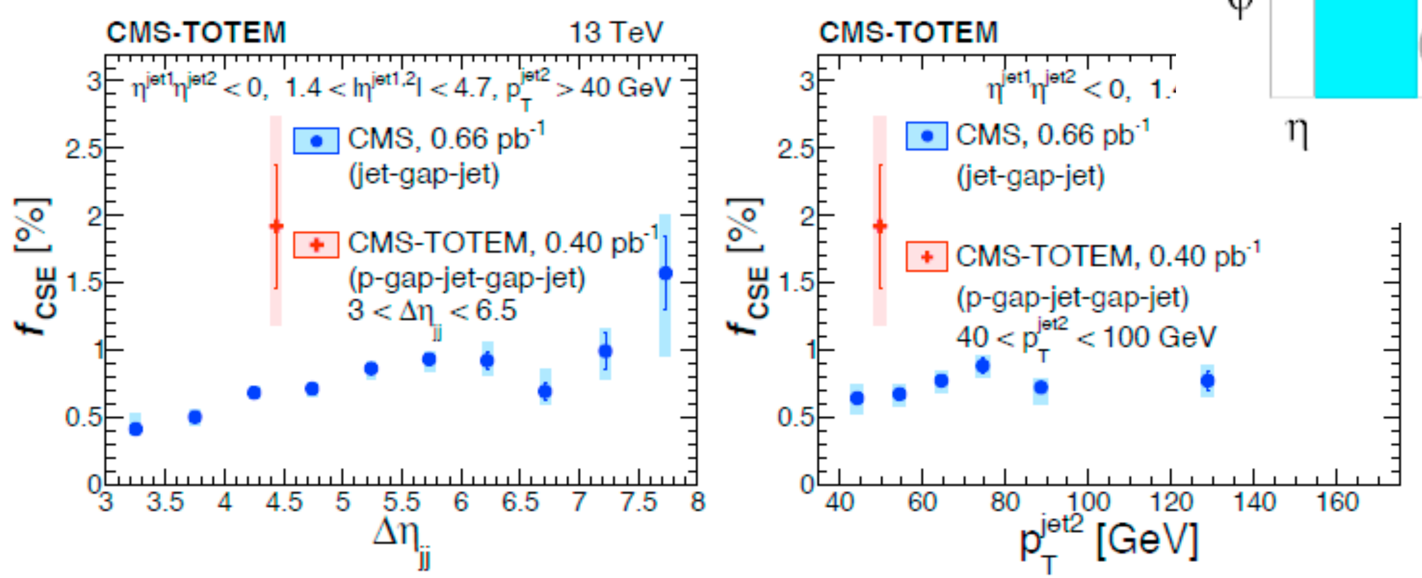
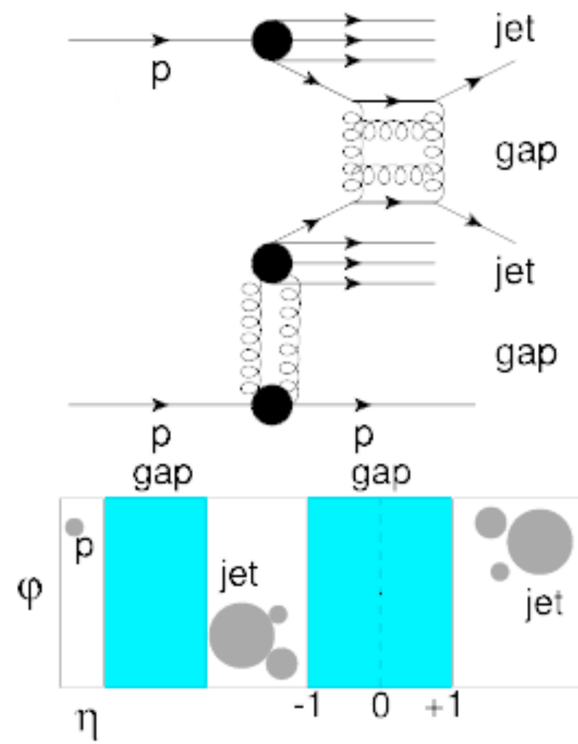
If 1 proton intact f_{cse} increases



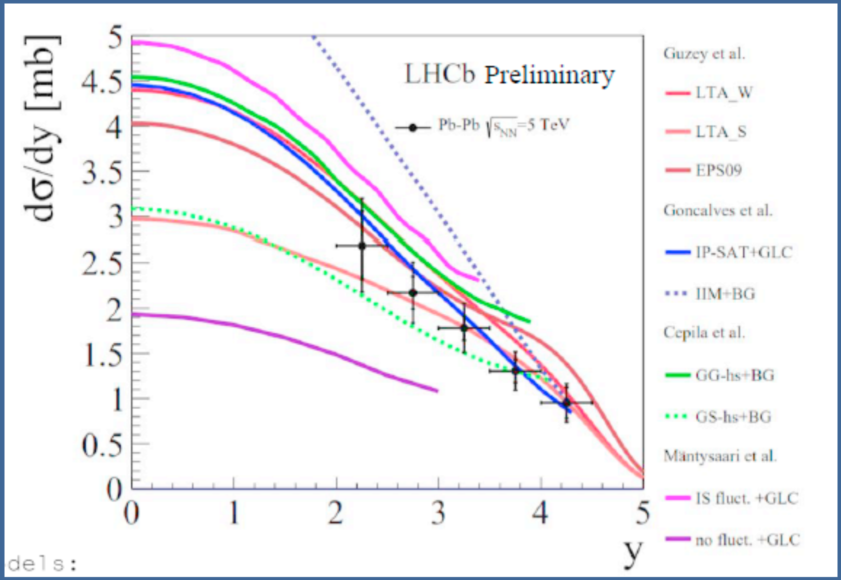


Summary

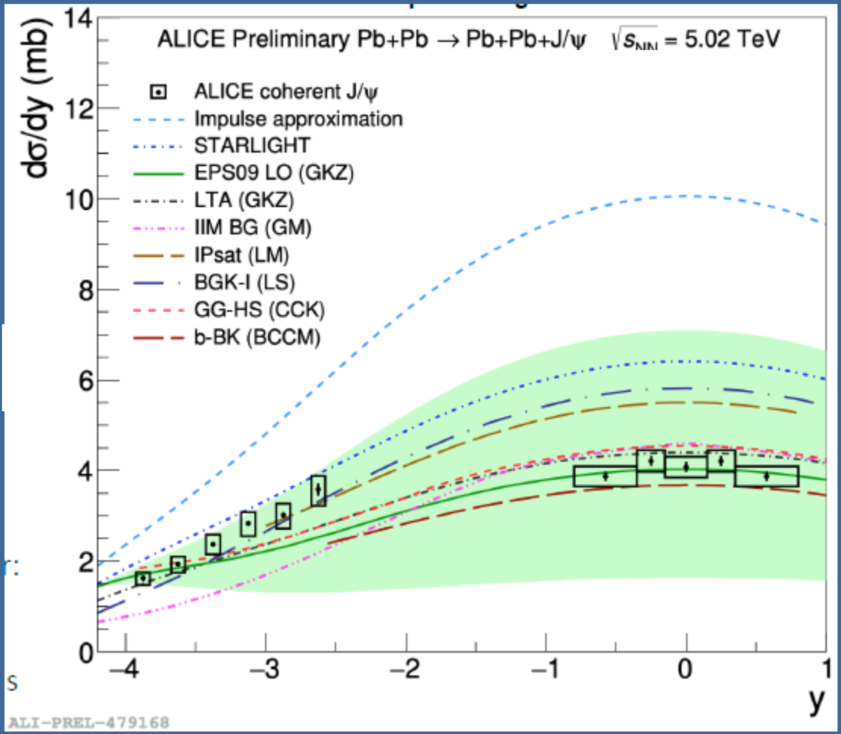
- Rapidity gap spectrum:
  - The pp data can be described by Pythia but none of the genera can describe pPb.
  - For pPb, photon-proton rate >> pomeron-proton rate
- Particles from photon-proton collisions show a significant V_2
  - Not yet clear if this reflects collectivity or jet - correlations.
- Jets from photon-lead collisions angular correlations
  - This may be due to final state radiation, gluon polarization or something else.
- About 0.6% of the time di-jet events from pp collisions are induced by colorless exchange. This fraction seems to increase if one of the protons stays intact.

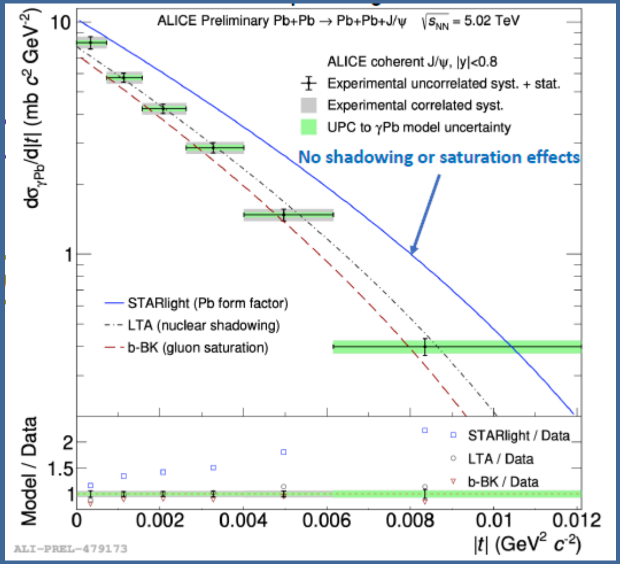
Backup

γPb => J/Ψ at 5TeV implies a lowering of gluon density



See Daniel Takaki's talk later today





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pPb, γPb show similar v_2 consistent with CGC