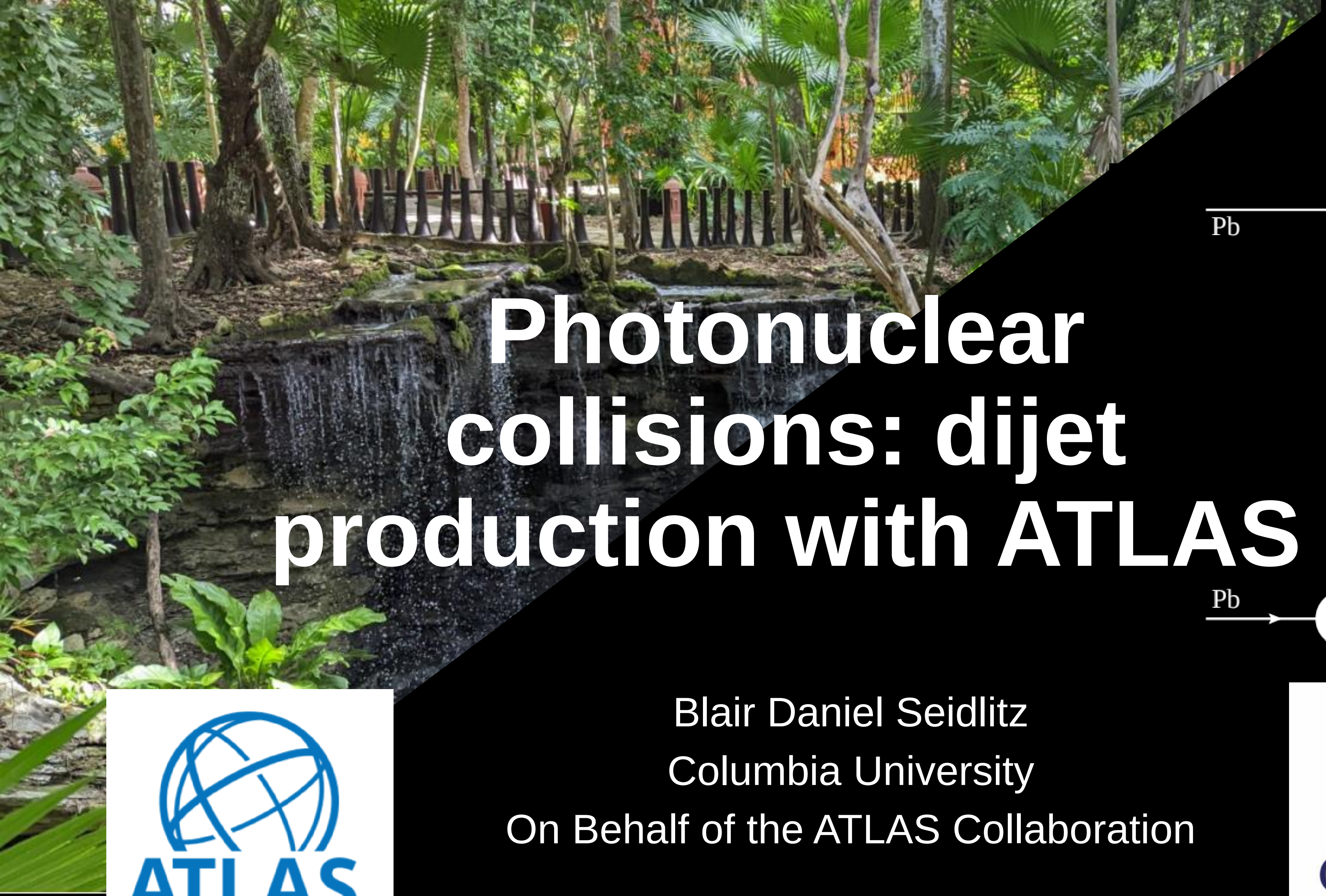
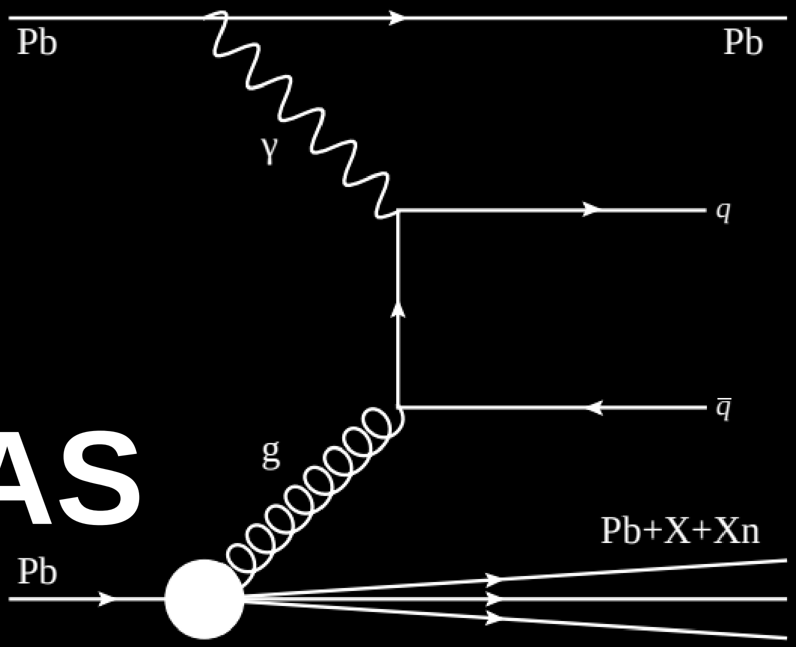


Photonuclear collisions: dijet production with ATLAS

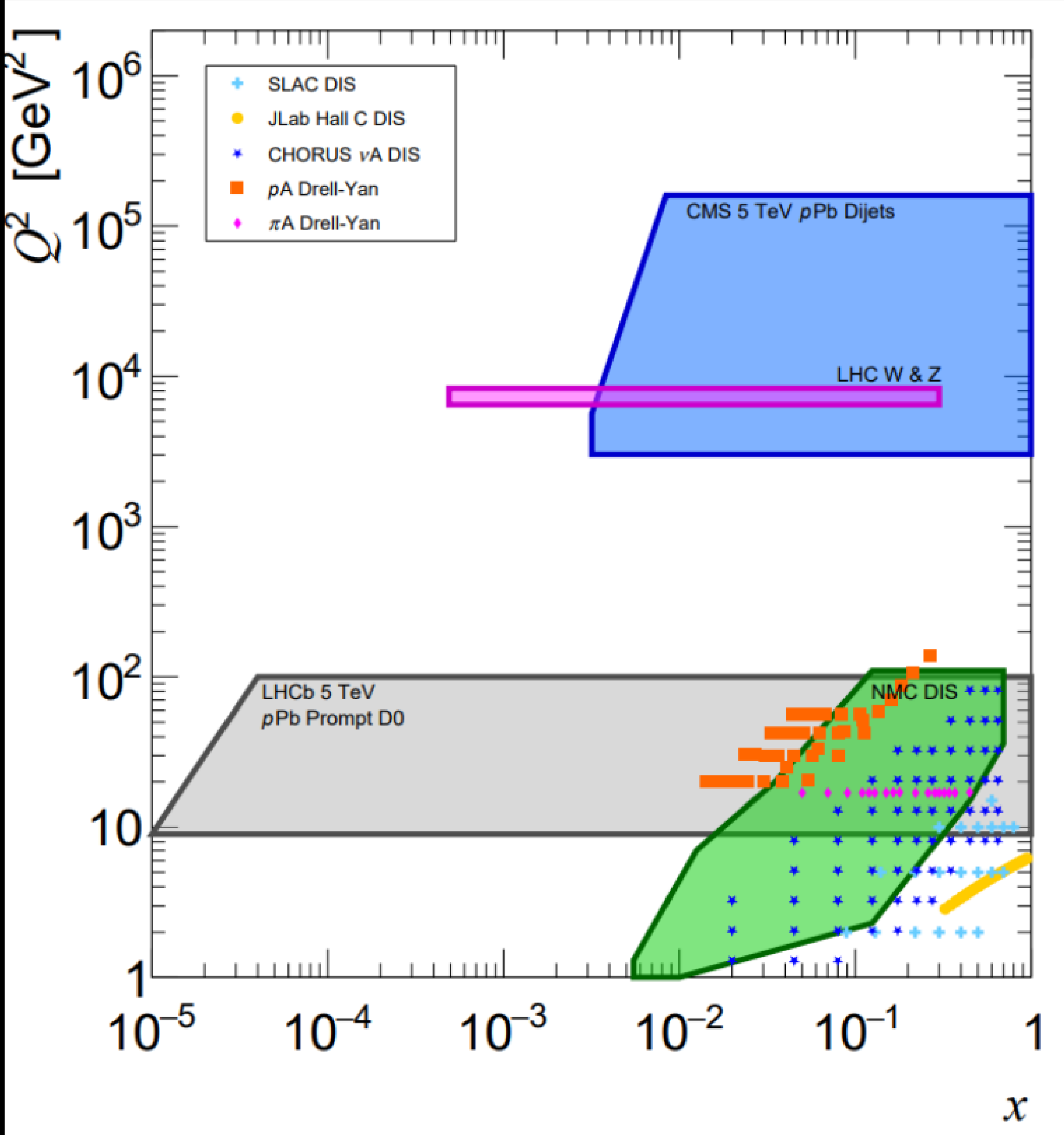


Blair Daniel Seidlitz
Columbia University
On Behalf of the ATLAS Collaboration

UPC Dec. 11th, 2023

Motivation

- **After the turn-on of the LHC, specific areas of the nuclear parton distribution functions (nPDFs) have been probed.**
- **These specific regions of x^2 and Q² are limited and leave a large amount of the phase space unexplored.**
  - poorly constrained at low-x and intermediate Q^2

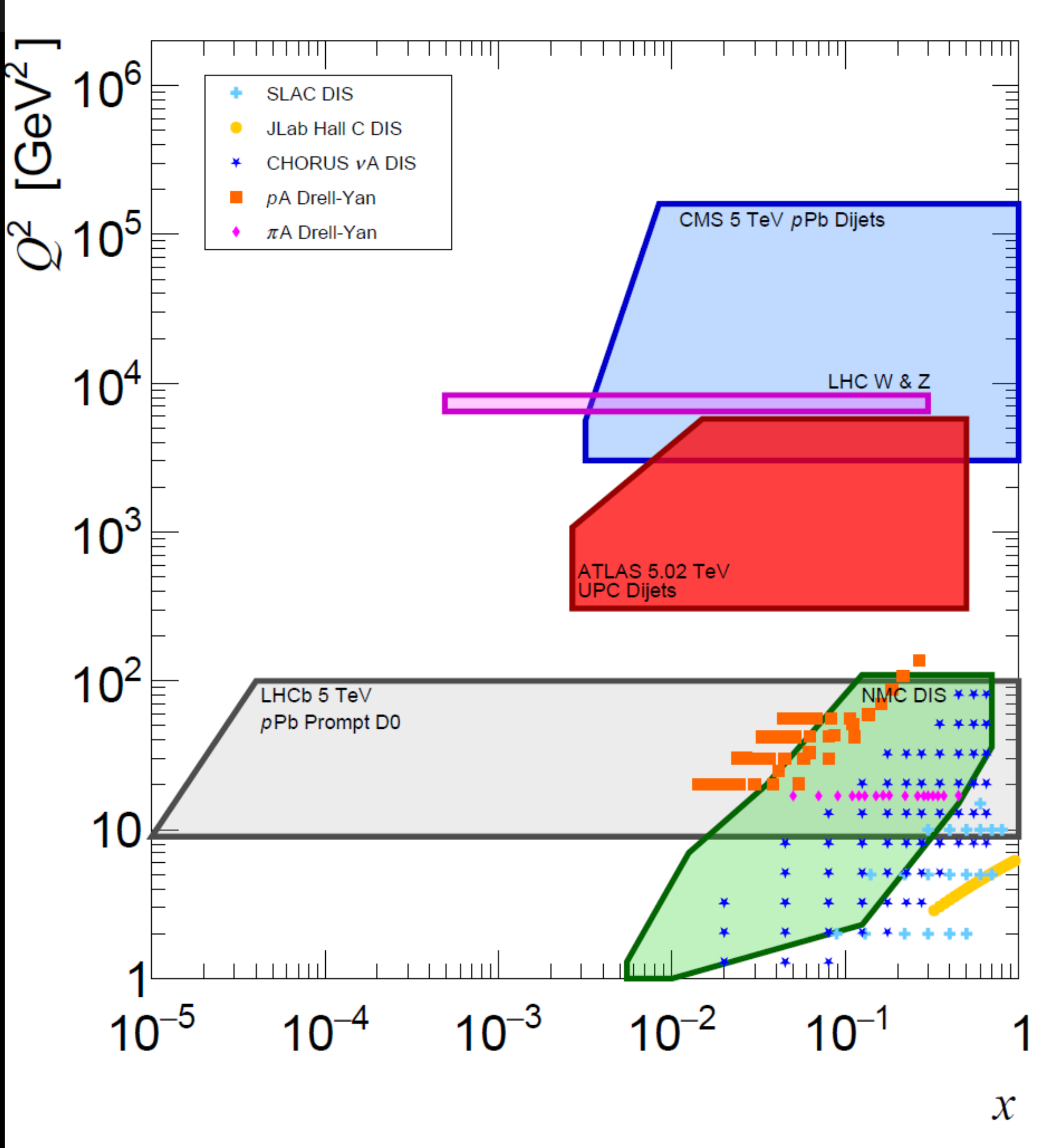


arXiv:2112.12462

Motivation

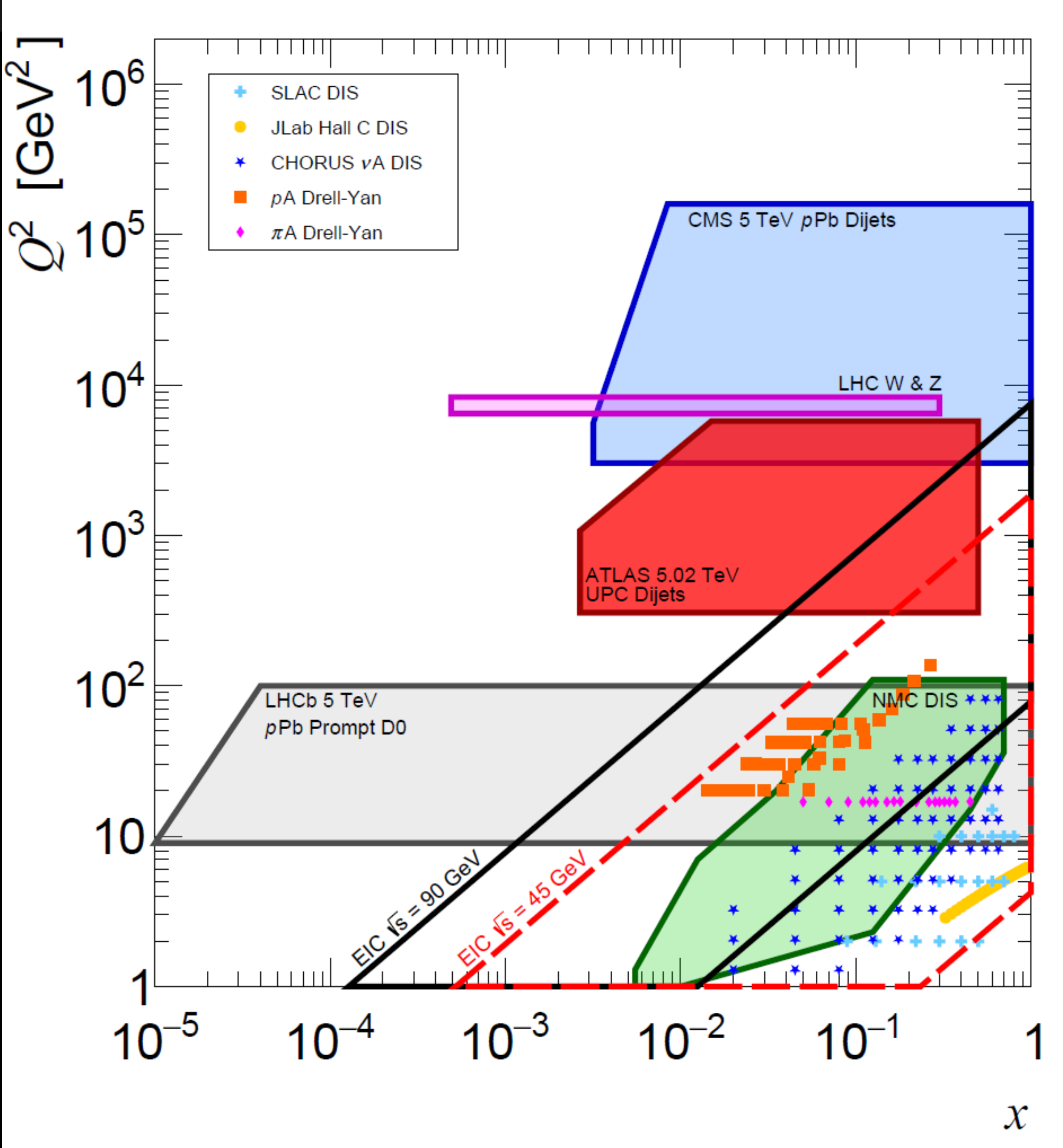
- We can explore a relatively large phase space with photonuclear dijet production.

- Provides a clean probe at a well regulated scale of this kinematic region, similar to DIS



Motivation

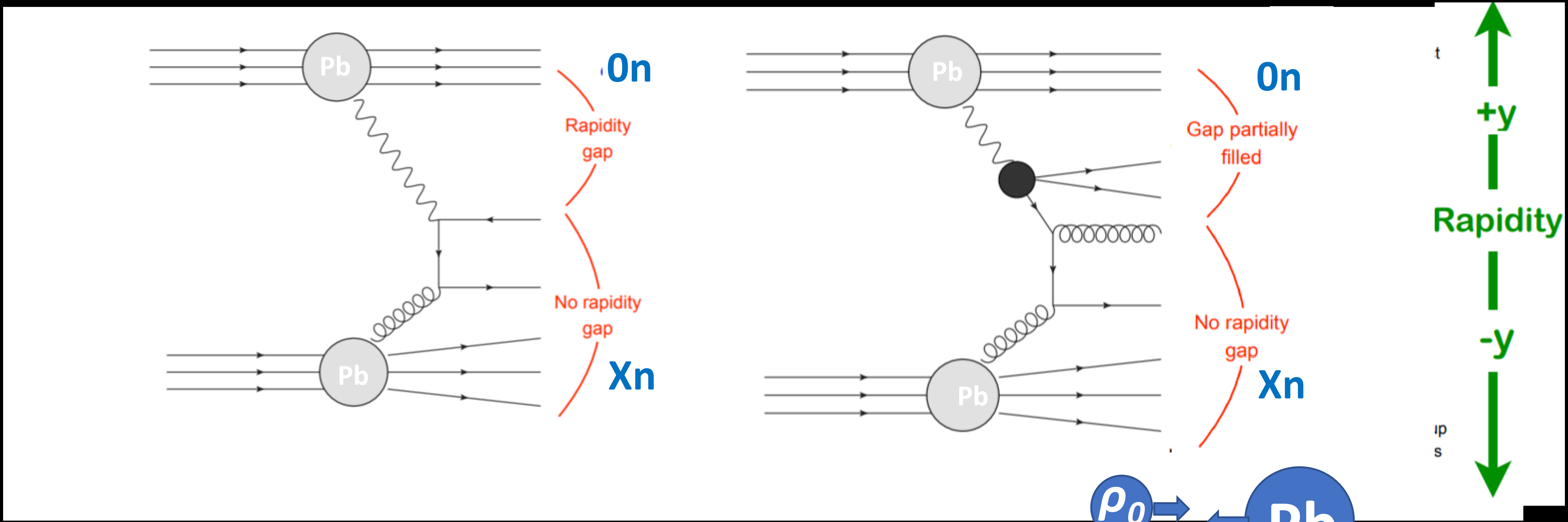
- ➢Photonuclear dijets at the LHC has some overlap is with EIC
- ➢As well as coving a unique part of phase space of its own.

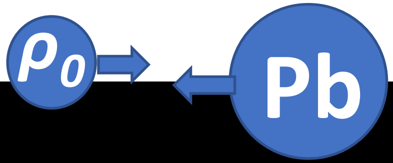


Photonuclear interactions

Direct γA collisions
Photon couples directly to nuclear parton

Resolved γA collisions
photon virtually resolved into hadronic state



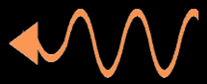


Select events based on primarily
- Single-sided nuclear breakup "**0nXn**" (zero-degree calorimeter ZDC)
- Rapidity gaps

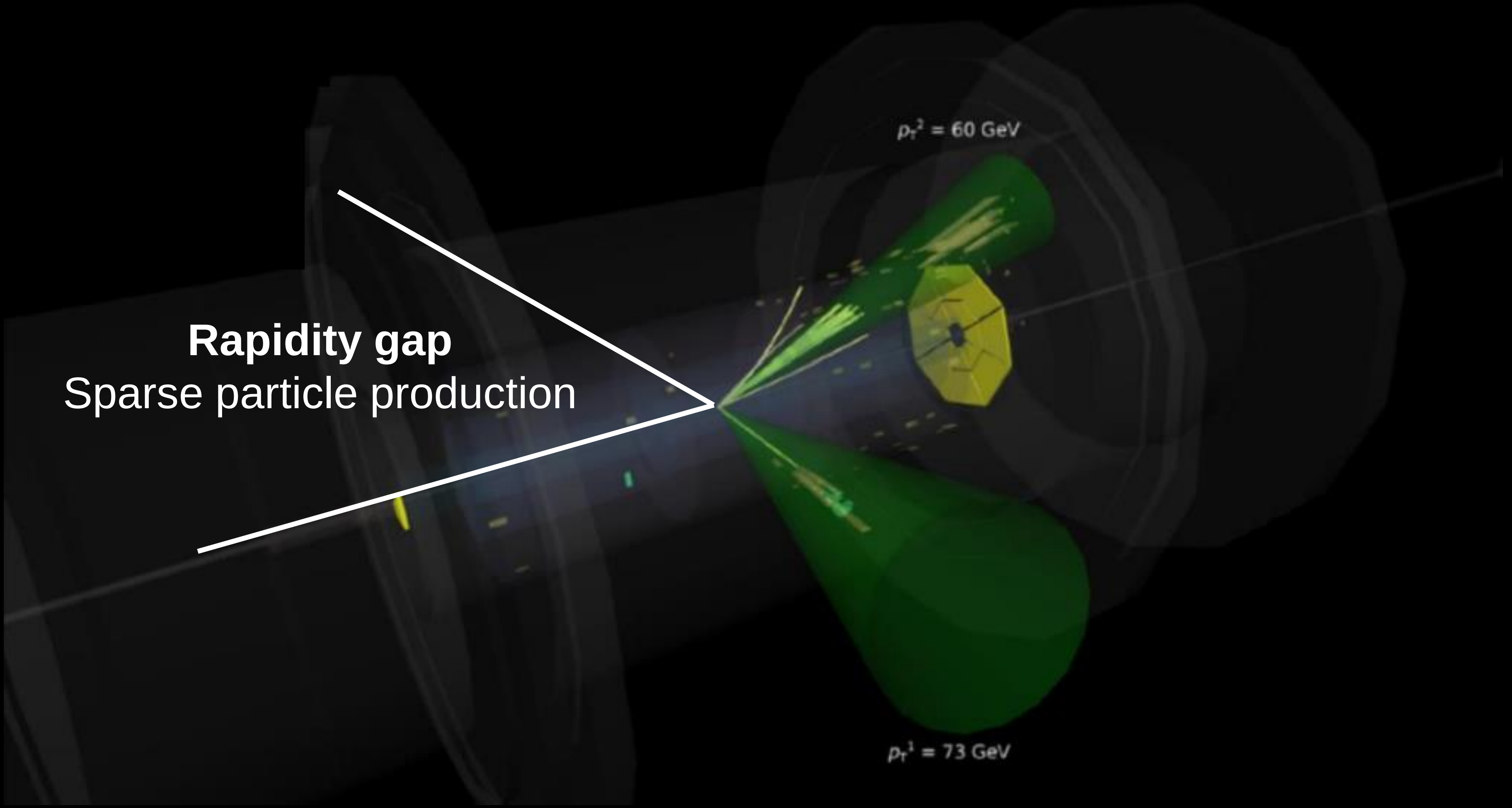
Selection on dijets enriches the direct "DIS-like" events

Event topology

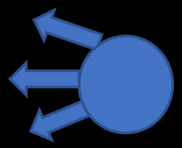
photon going direction



0n

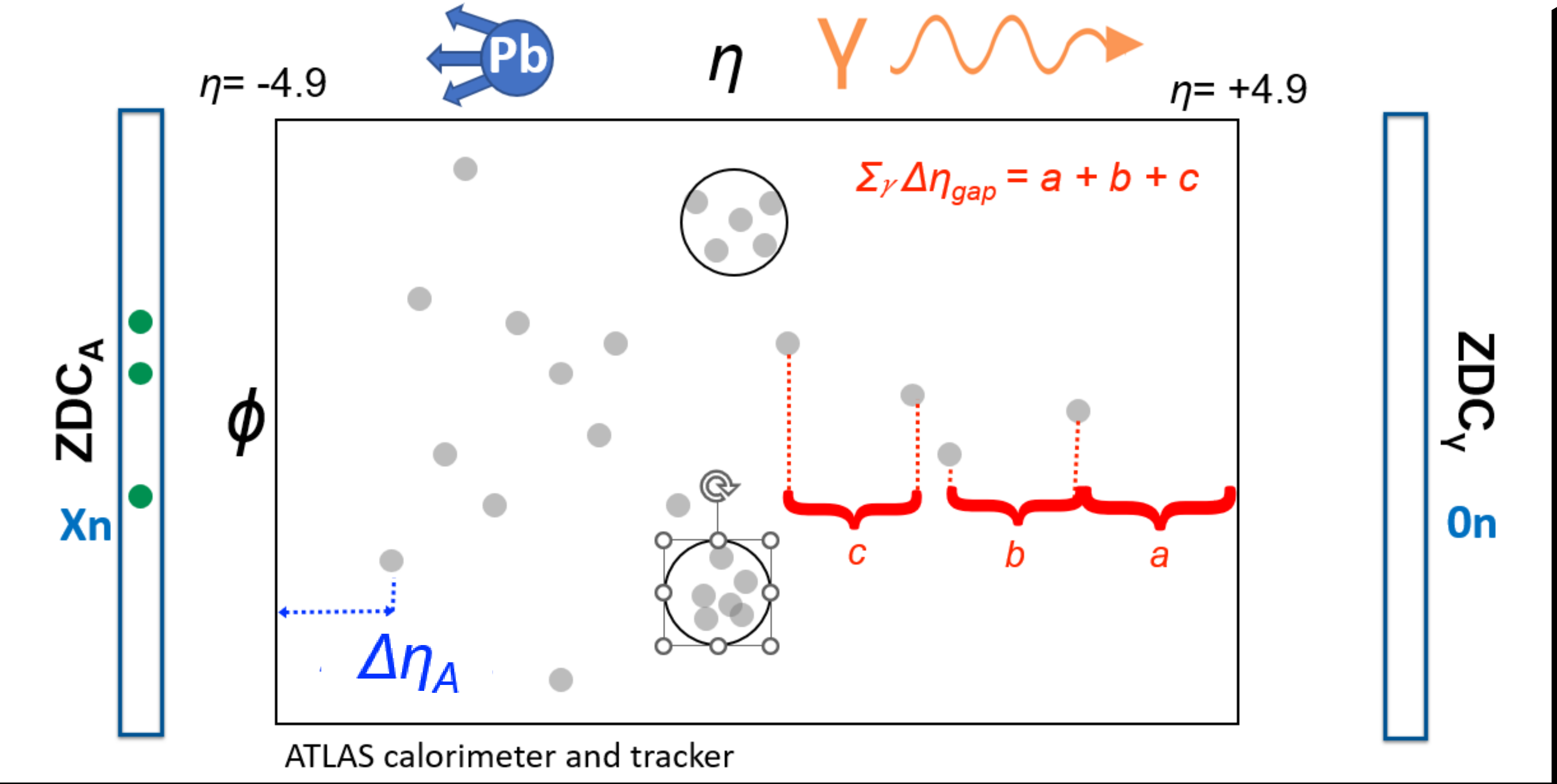


Rapidity gap
Sparse particle production

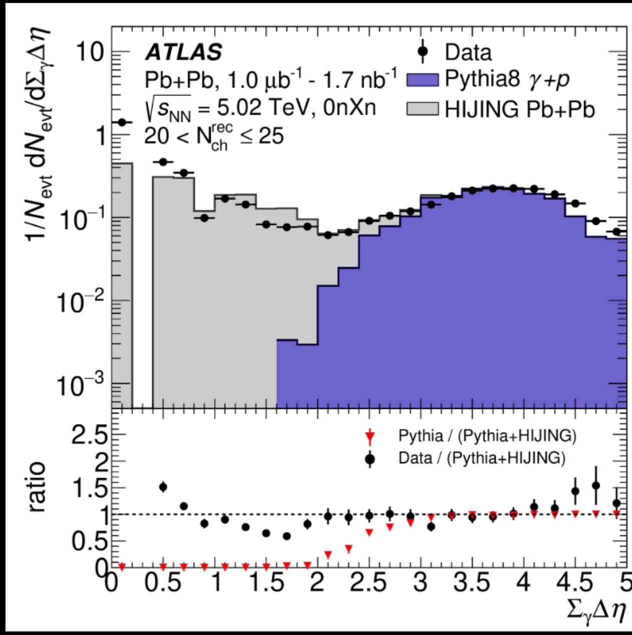


Xn

Quantifying rapidity gaps



- **Sum pf gaps criteria retains high efficiency for resolved photonuclear events which may have a photon fragment forward of the dijets.**
  - These interesting physics variables are interesting in their own right and can be used to separate direct and resolved.
  - Also can be used to understand hadronic background.

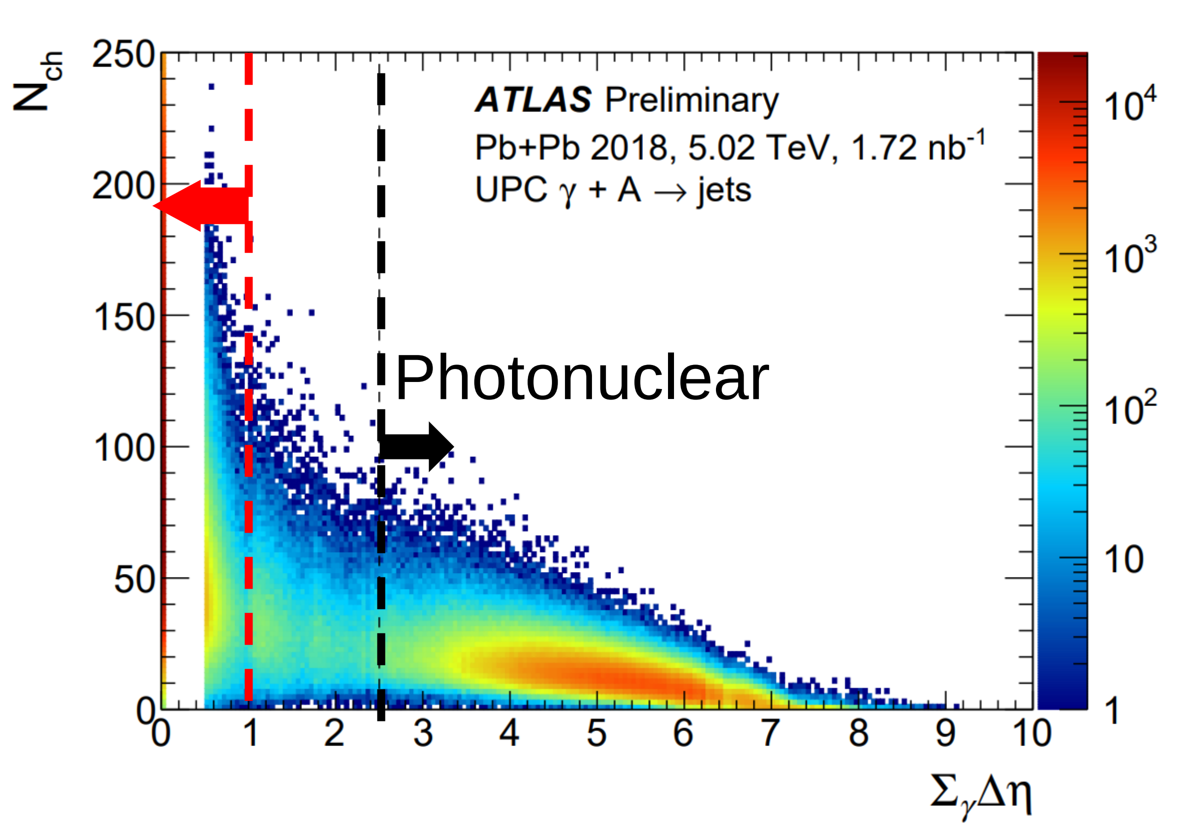


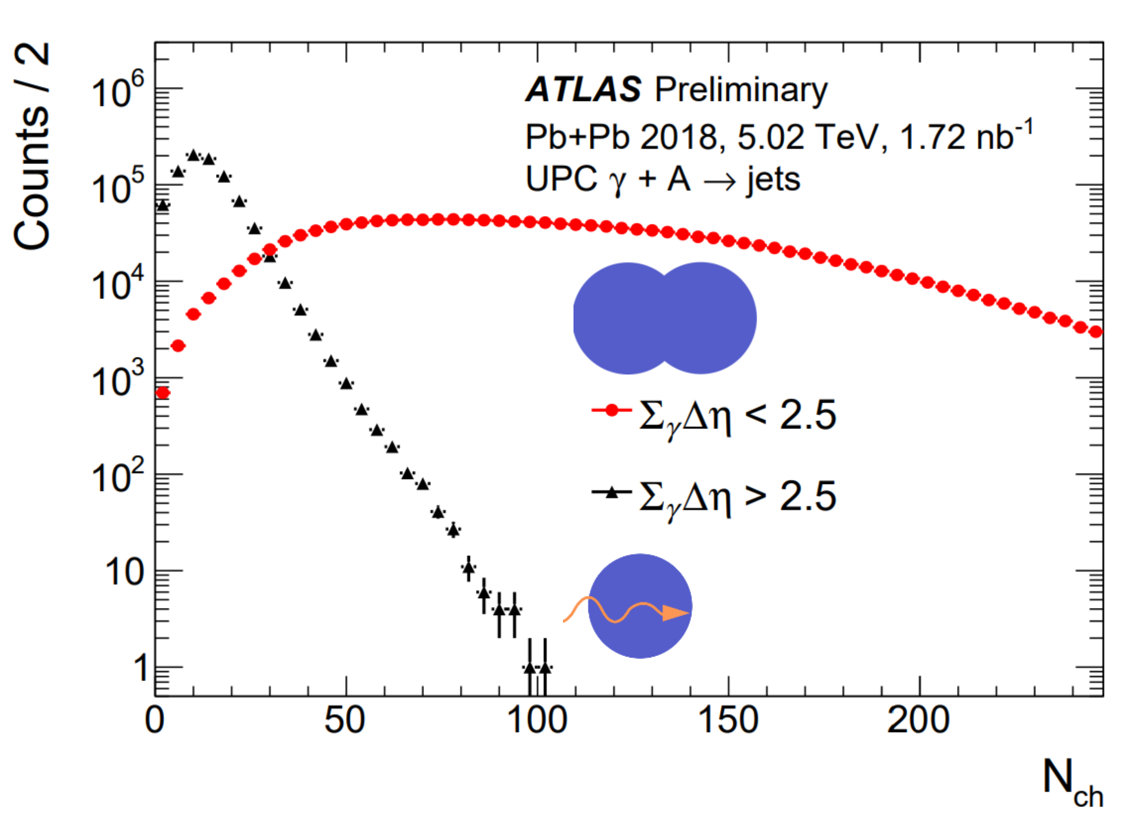
- **Detector roll out with schematic event**

Event Selection $\Delta\eta_A < 3$ $\Sigma_\gamma \Delta\eta_{gap} > 2.5$

arXiv:2101.10771

Selecting photonuclear events





Clear separation between photonuclear events with large gaps and a steeply falling multiplicity distribution and "hadronic" dijet events which no rapidity gap and a broad multiplicity distribution

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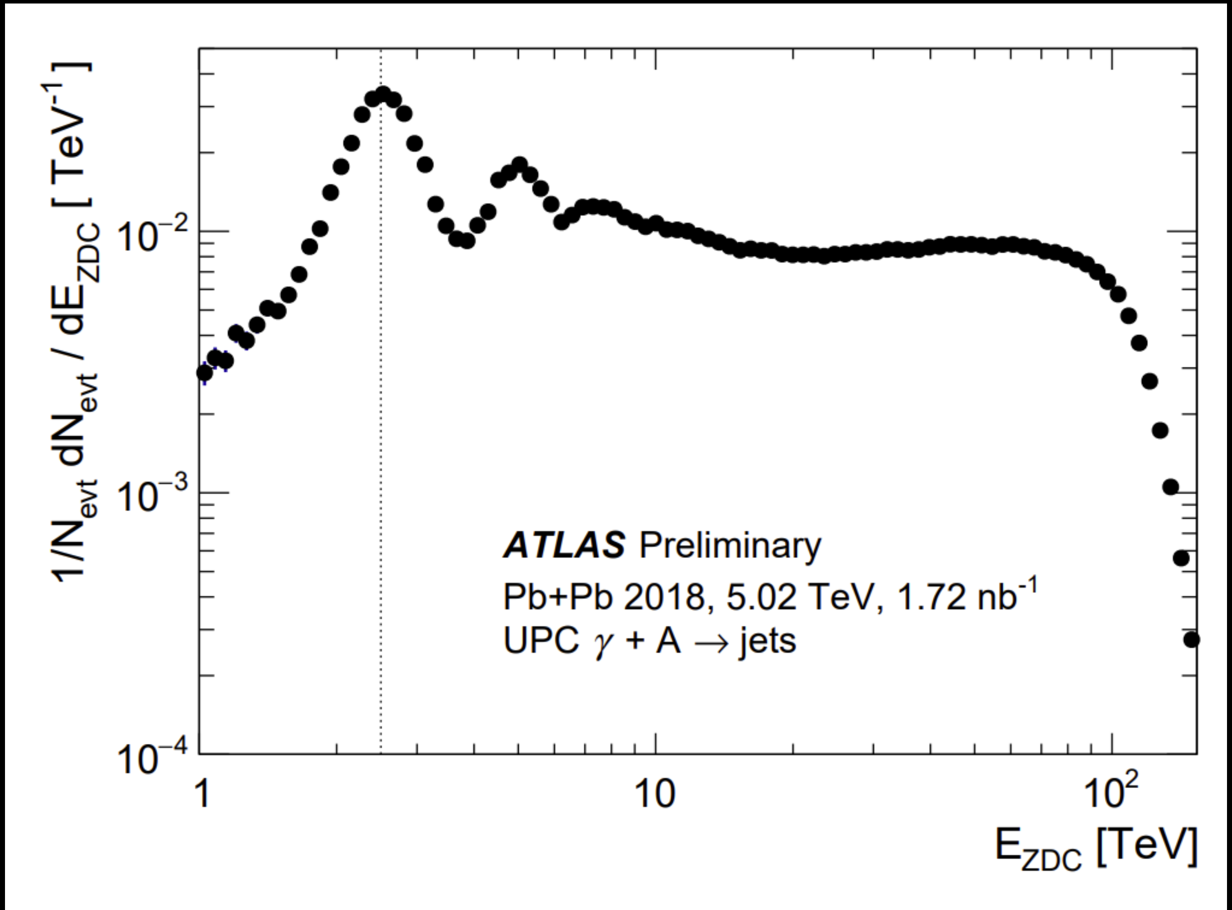
ZDC information



- Observed uncorrected Pb-going ZDC energy distribution
- Further studies could be related to “centrality” of scattering center
- This is a glimpse into ZDC-based physics at the EIC.

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Nuclear “emitter” Breakup

- **The photonuclear jet requirements select events with the highest energy photons.**
  - $E_\gamma \propto 1/b \rightarrow$ Biases towards lower impact parameter collisions
  - Much higher probability of breakup due to additional EM interactions
  - Sensitive to the details of nuclear structure for low-*b* collisions

$$f_{\text{no BU}} \equiv \frac{d\sigma/dz_\gamma|_{0nXn}}{d\sigma/dz_\gamma|_{XnXn} + d\sigma/dz_\gamma|_{0nXn}}$$

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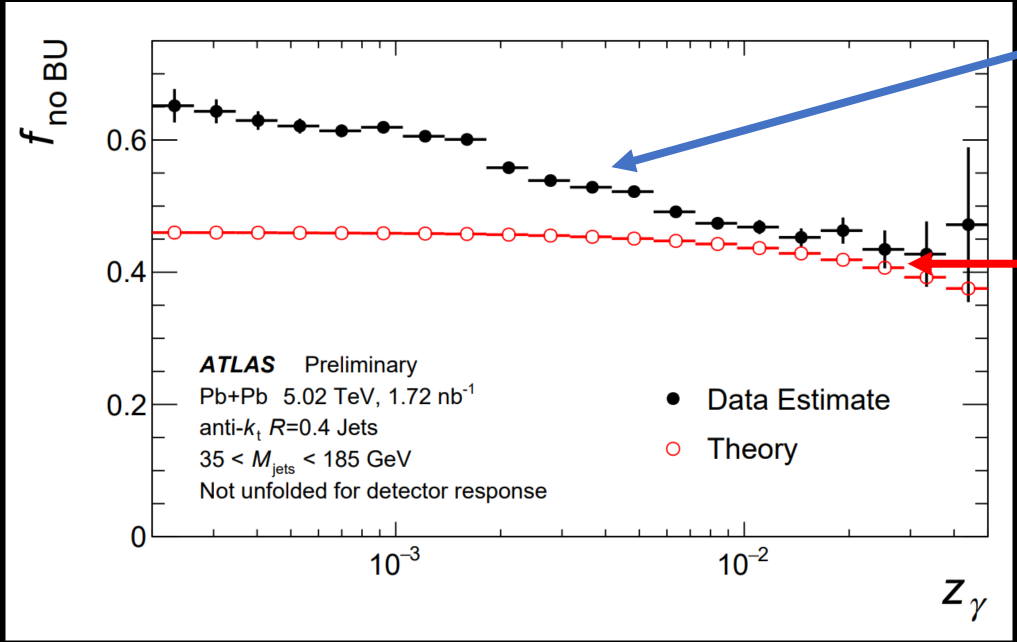


Studies of dijet events with large gaps on one side estimate about 50% of photo-nuclear jet production breaks up!

Basic theoretical modeling predicts an even higher rate. STARLight model of probability of EM breakup as function of b is used along side the pythia model

Future theoretical and modeling improvements of the breakup scenario will help make precision measurements of this part of phase space, which includes include higher backgrounds.

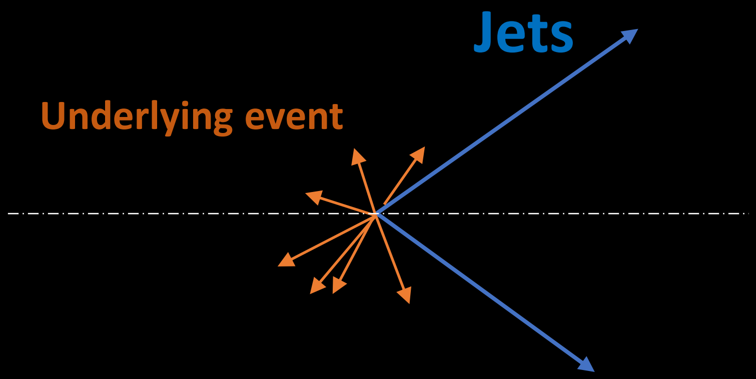
kinematics

- ***H_T*: scaler sun of jet *p_T* -tightly correlated with *Q^2***
- ***x_A*: fraction of nucleons momentum carried by the struck parton**
- ***z_γ*: the fraction of "nucleon's" momentum carried by photon or resolved parton.**
  - In the case of direct, it is a scaled photon nergy
  - In the resolved case the addition of x (vector meson)
  - In DIS language: UPC photon energy distribution convolved with photon structure function.

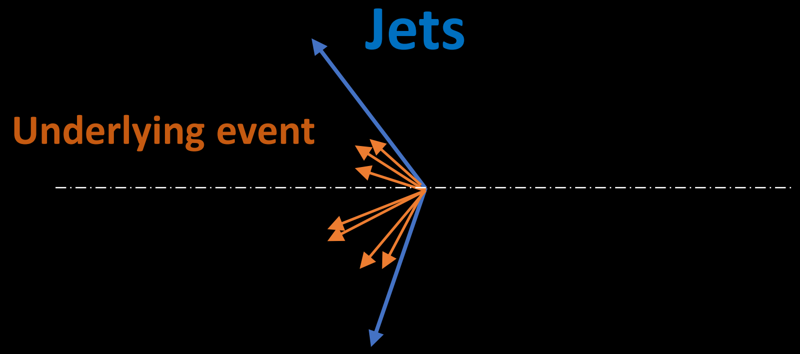
$$H_T \equiv \sum_i p_T^i$$

$$x_A \equiv \frac{M_{jets} e^{-y_{jets}}}{\sqrt{s_{NN}}}$$

$$z_\gamma \equiv \frac{M_{jets} e^{+y_{jets}}}{\sqrt{s_{NN}}}$$



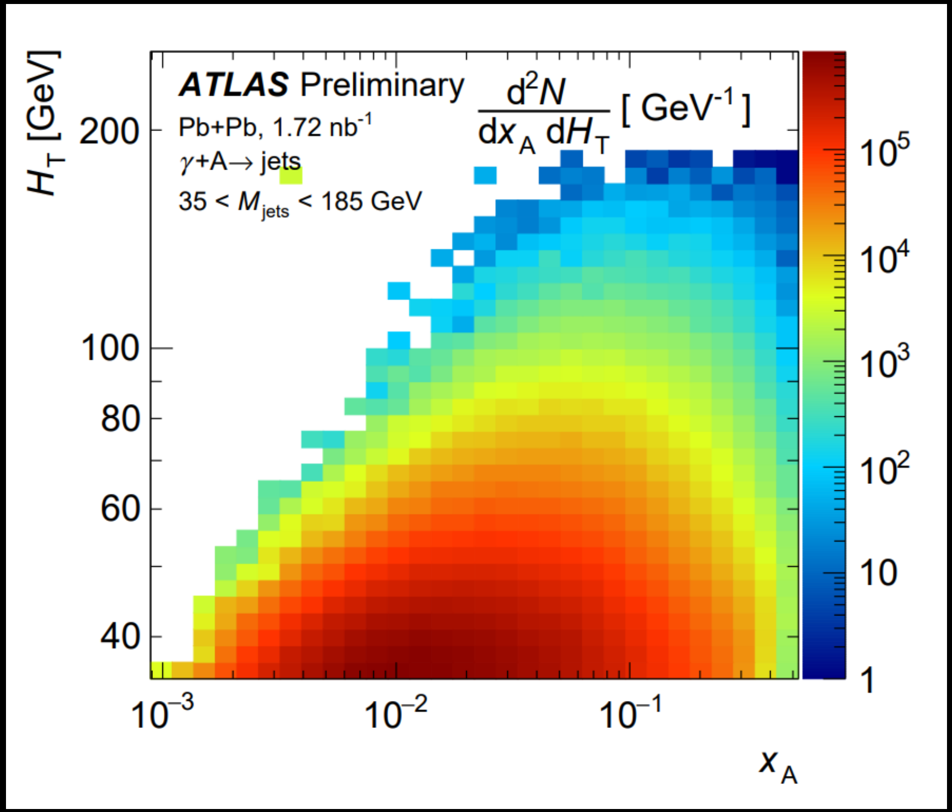
Large z_γ low x_A

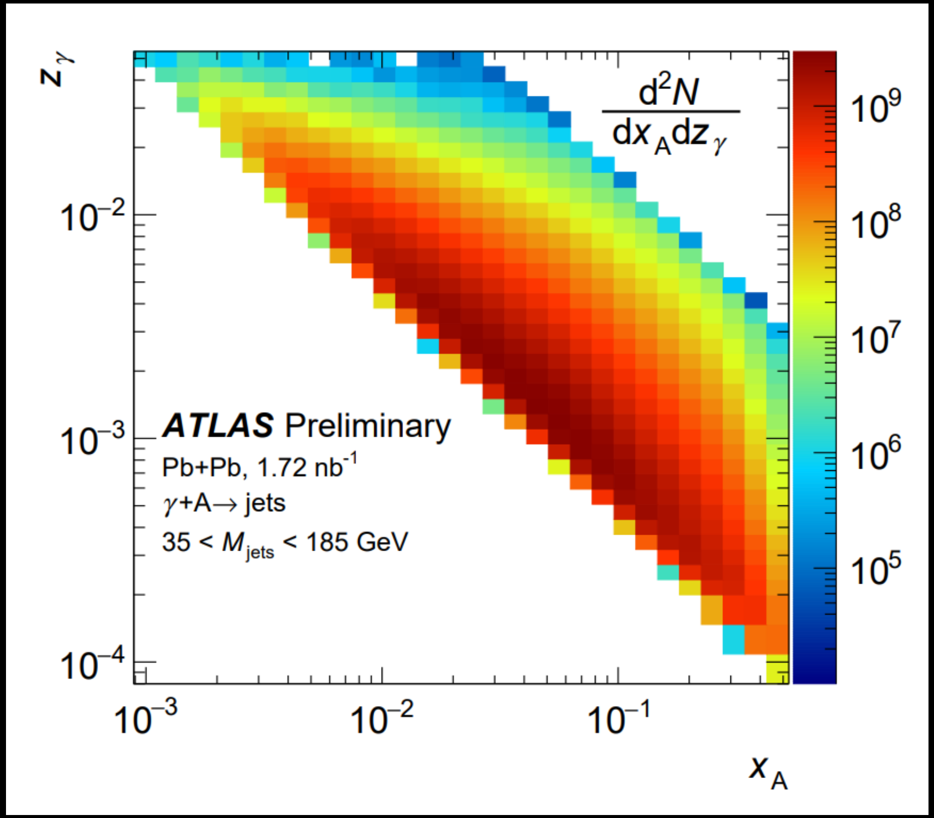


low z_γ high x_A

Raw yields

- Two R = 0.4 anti-k_T particle flow jets with p_T > 15 GeV





$$H_T \equiv \sum_i p_T^i$$

$$x_A \equiv \frac{M_{jets} e^{-y_{jets}}}{\sqrt{s_{NN}}}$$

$$z_\gamma \equiv \frac{M_{jets} e^{+y_{jets}}}{\sqrt{s_{NN}}}$$

- x_A and z_γ are highly correlated – delicate unfolding problem

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Systematics

- **Measurement uncertainties are systematics dominated in most bins**
- **Dominated in most bins by the low-μ jet calibration**
  - A key part of the jet calibration is the so-called *insitu* calibration which measures jets relative to precisely measured reference objects, in this case Z bosons
  - Preliminary version, used here, translates uncertainties from high-luminosity pp data.
  - The final version will come from low luminosity pp, which much precisely matches the conditions of UPC dijets.
  - Tis will reduce this uncertainty considerably

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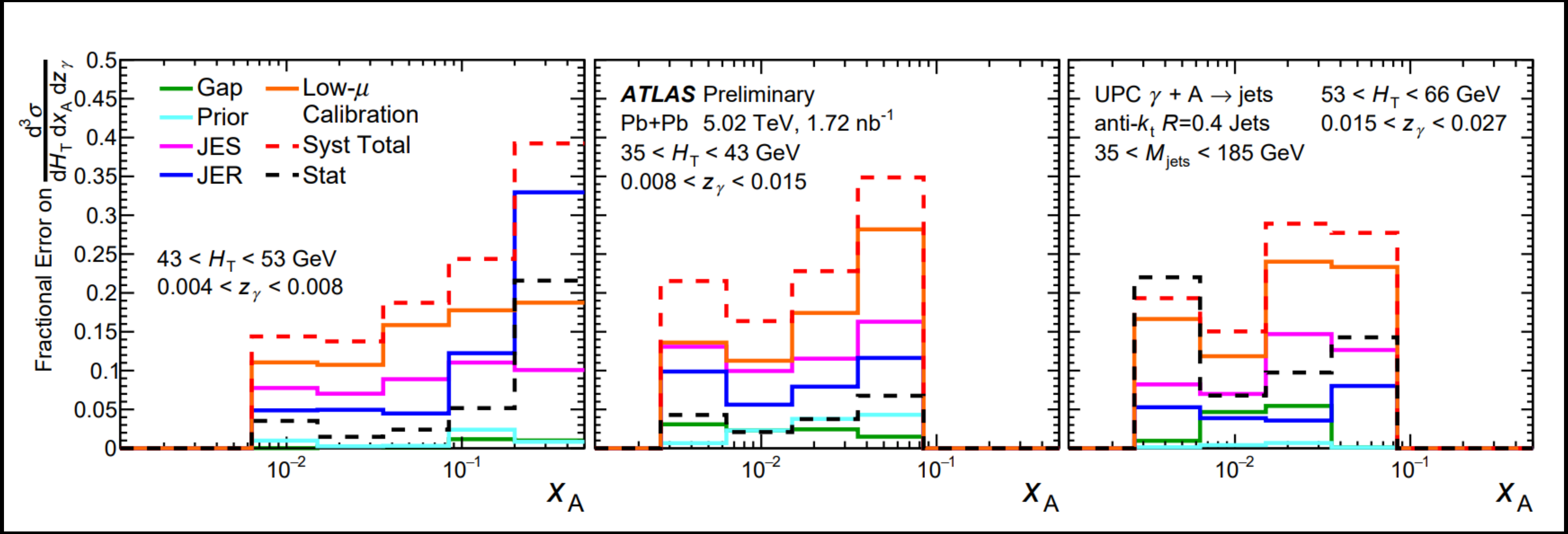
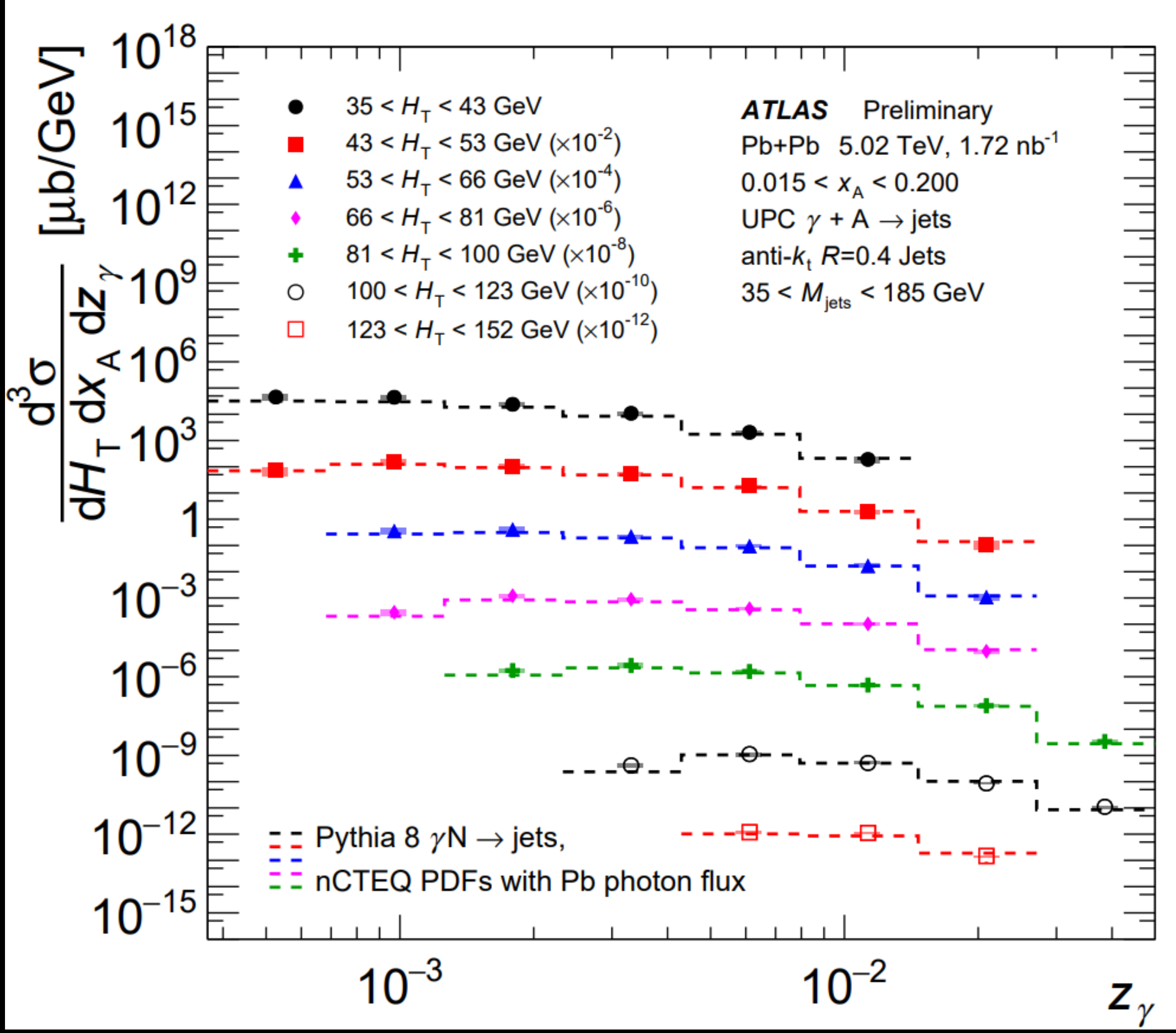
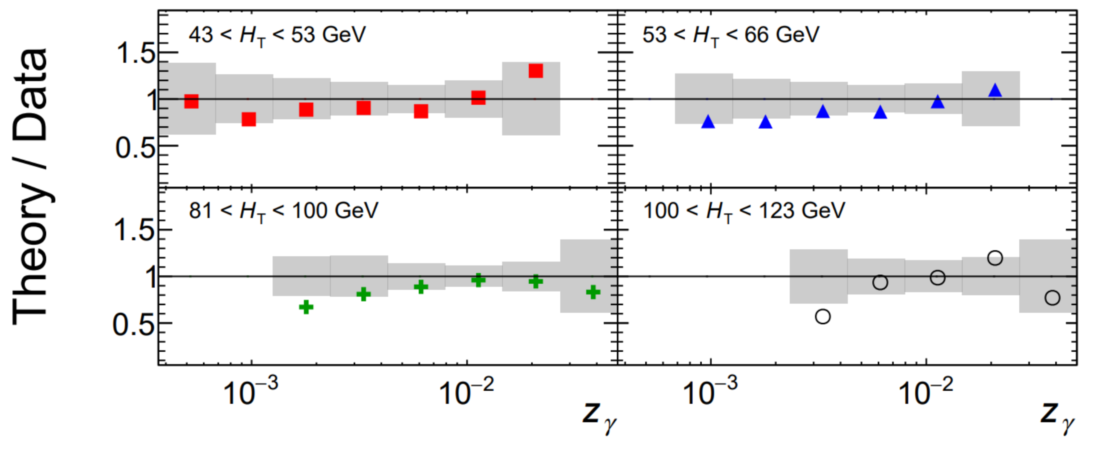


Results

- **The distribution of z_γ values for large x_A in bins of H_T (right) demonstrates the measured photon flux.**
  - The breakup model performs well within systematic uncertainties.
  - Disagreements appear to arise more at low z_γ, where the breakup model tends to over-correct.





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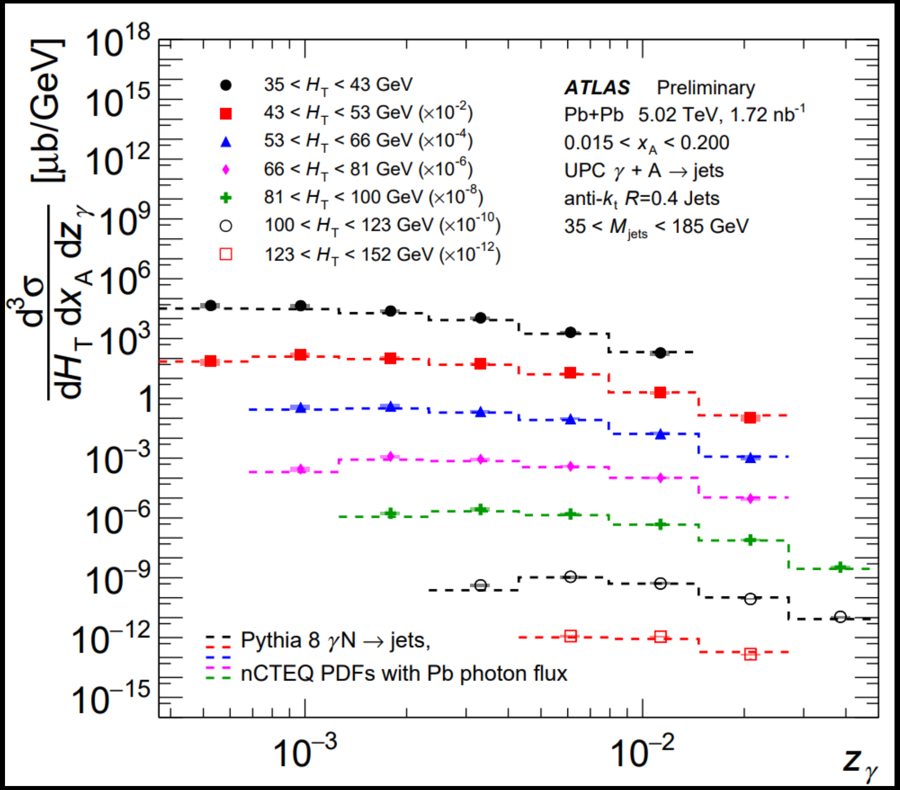
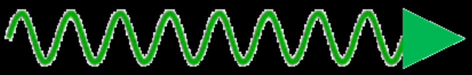
Scanning in photon energy

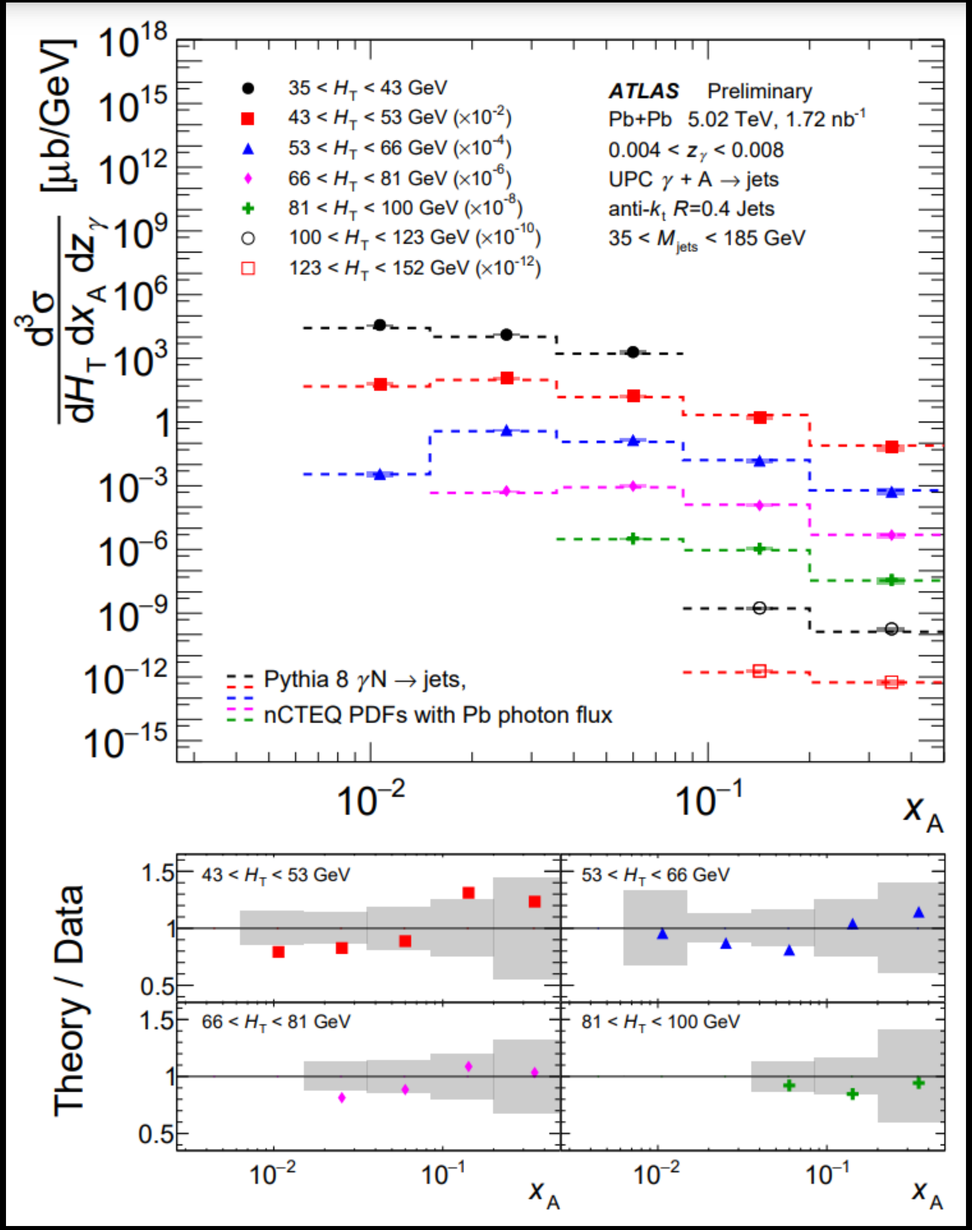
- At intermediate photon energies, we can access higher-x partons



Photon Energy

$0.004 < z_\gamma < 0.008$





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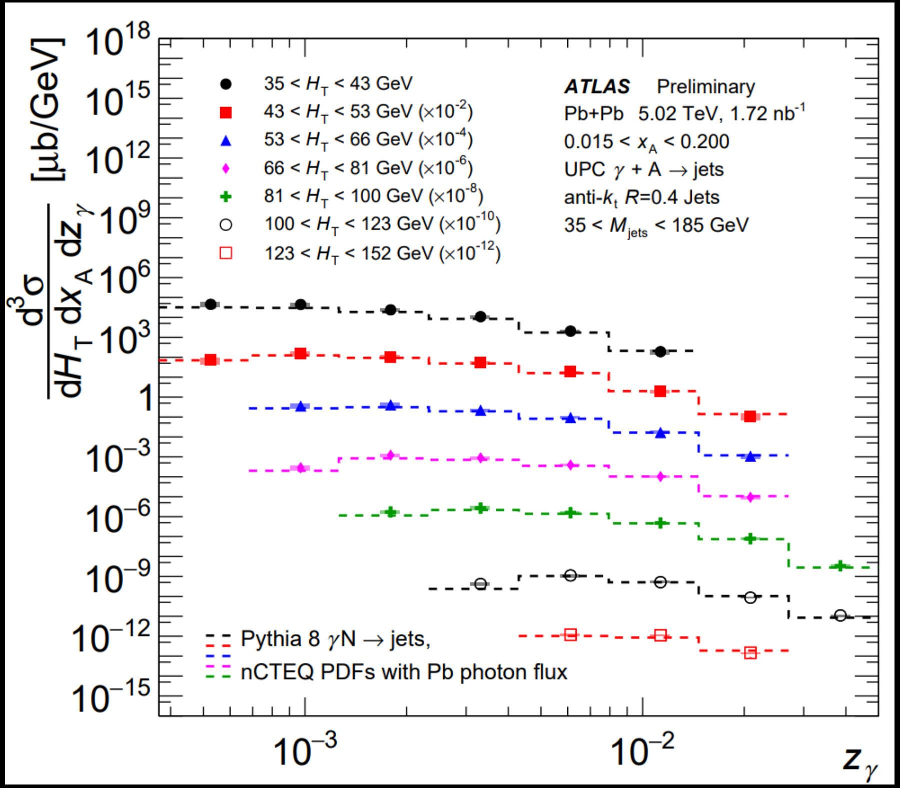
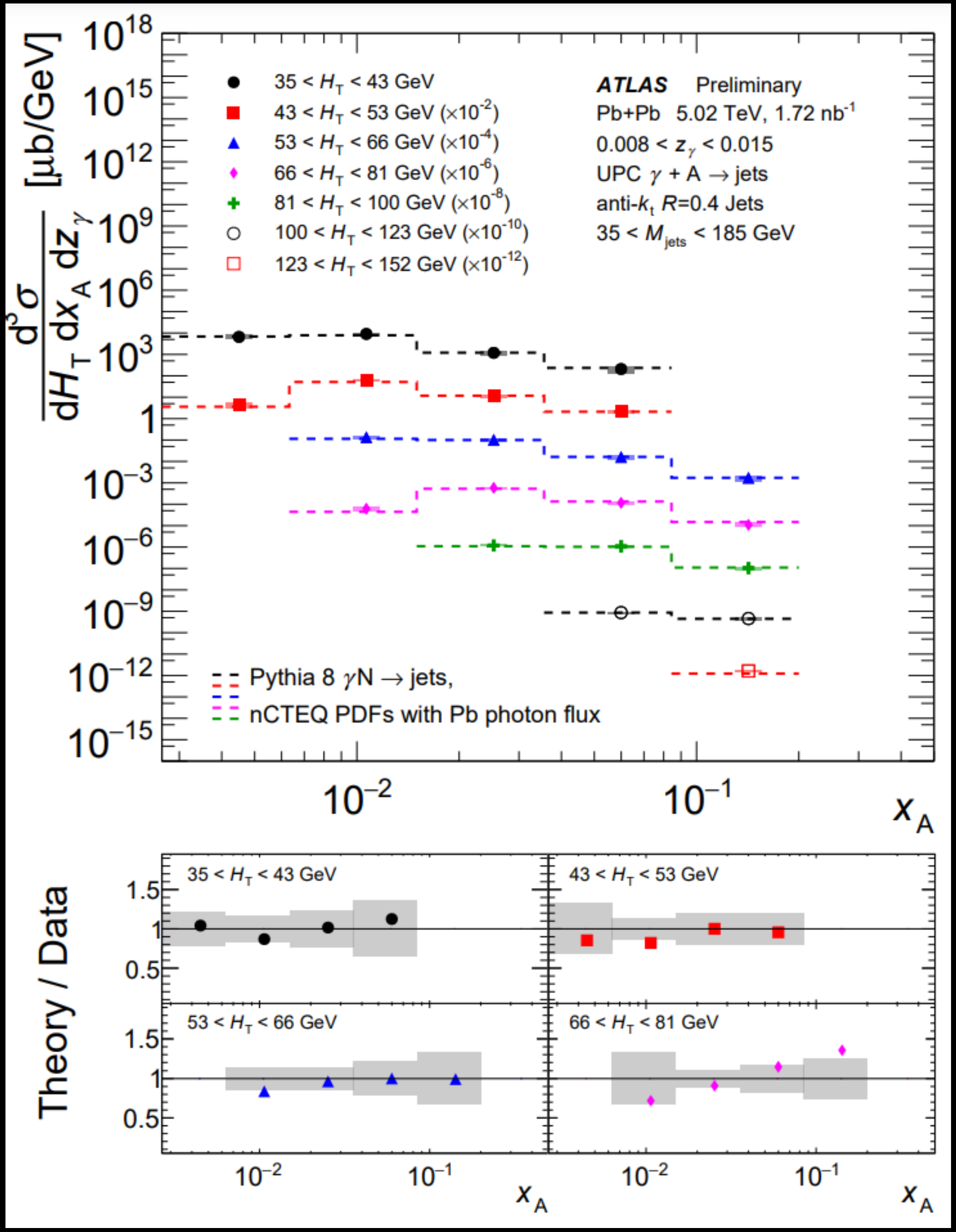
Scanning in photon energy

- Going higher in photon energy opens the low-x shadowing region
- Results are quite consistent with the theoretical model



Photon Energy

$0.008 < z_\gamma < 0.015$



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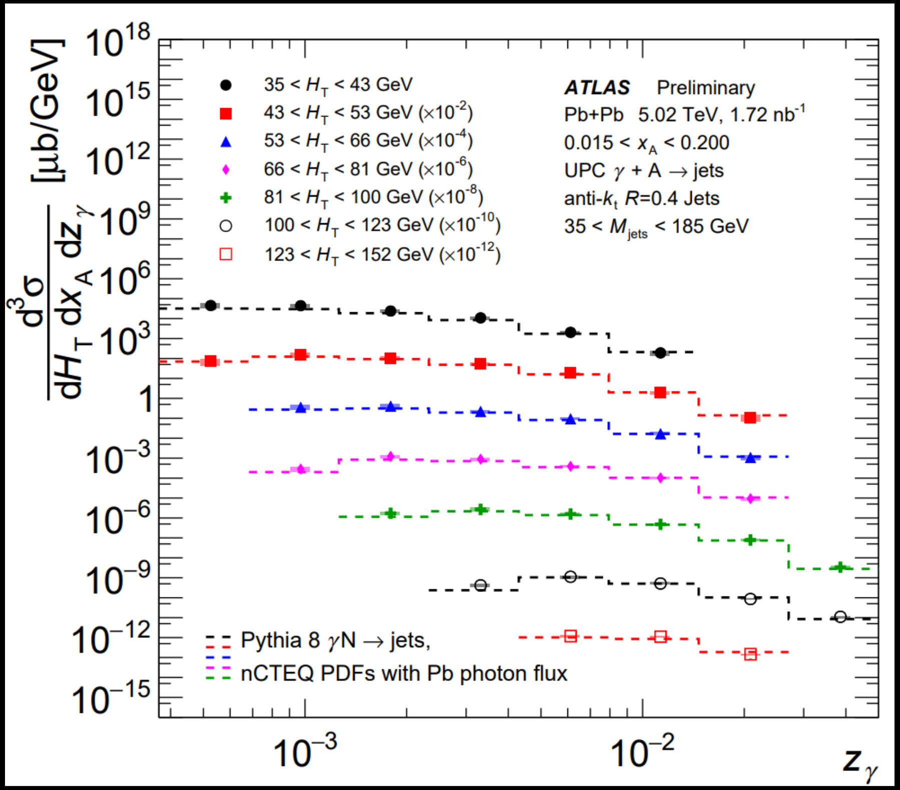
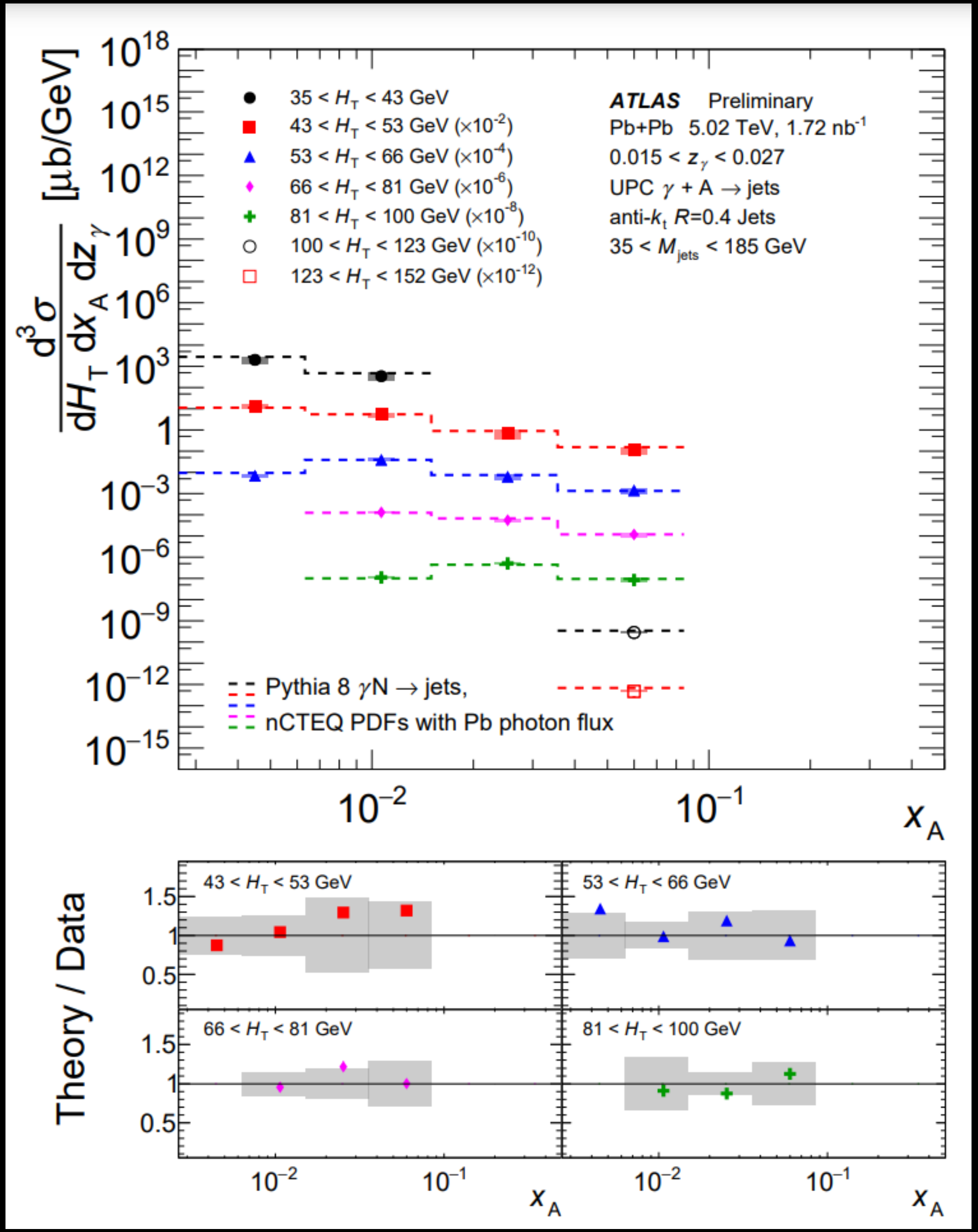
Scanning in photon energy

➢ **Most energetic photons gives access to the lowest x_A PDFs**



Photon Energy

$0.015 < z_\gamma < 0.027$



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Observing 0n0n exclusive dijets

- Dijet production in 0n0n ZDC topology with gaps on both sides
- Observe 10x the prediction of Pythia8 ***γγ→qq***
- Broader rapidity distribution (as well as a coplanarity distribution)

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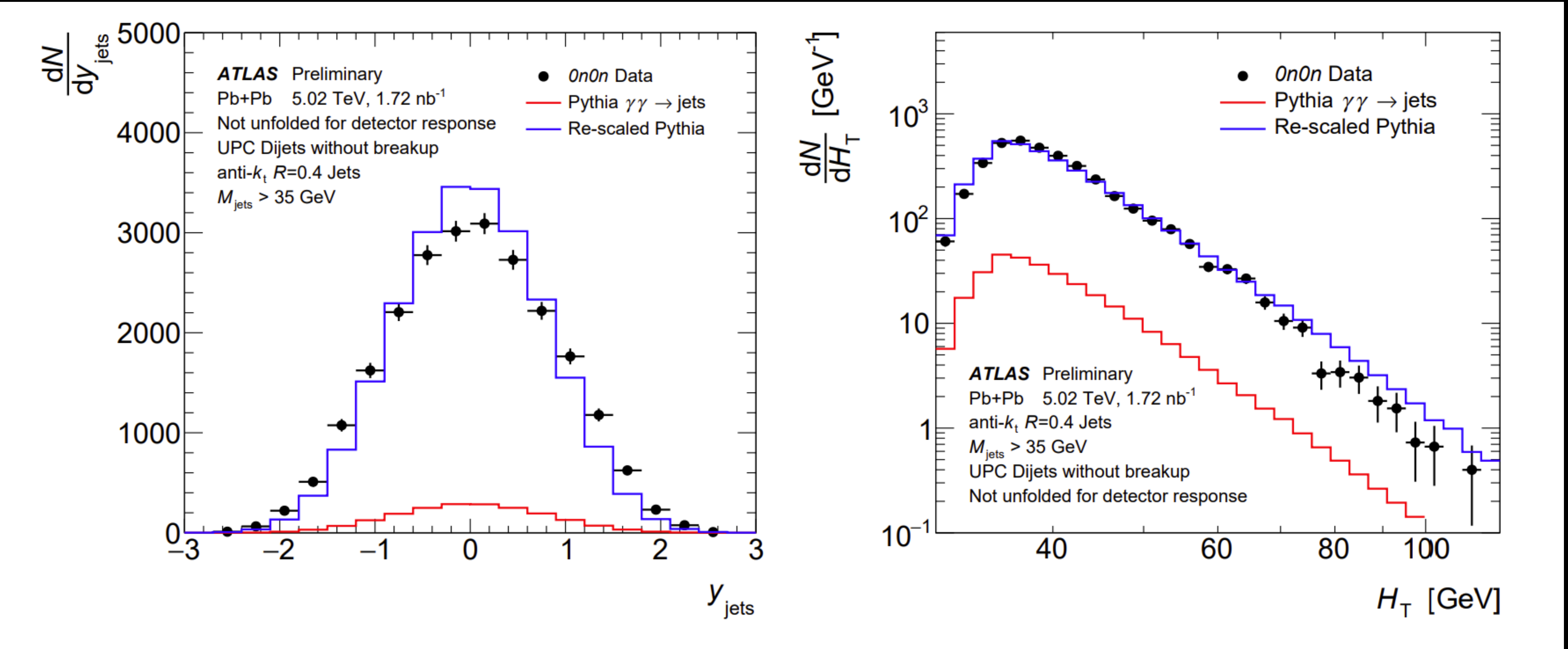
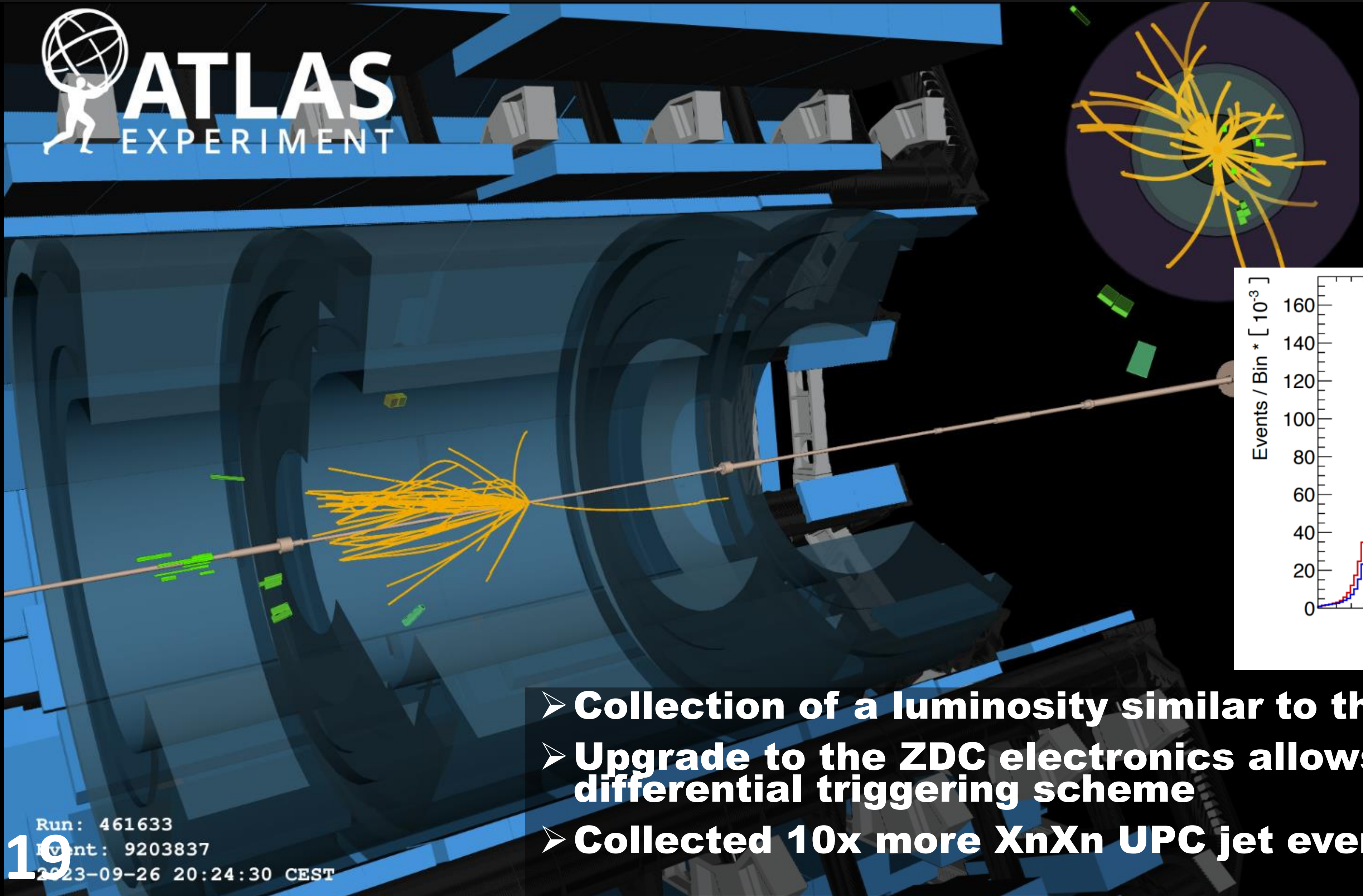
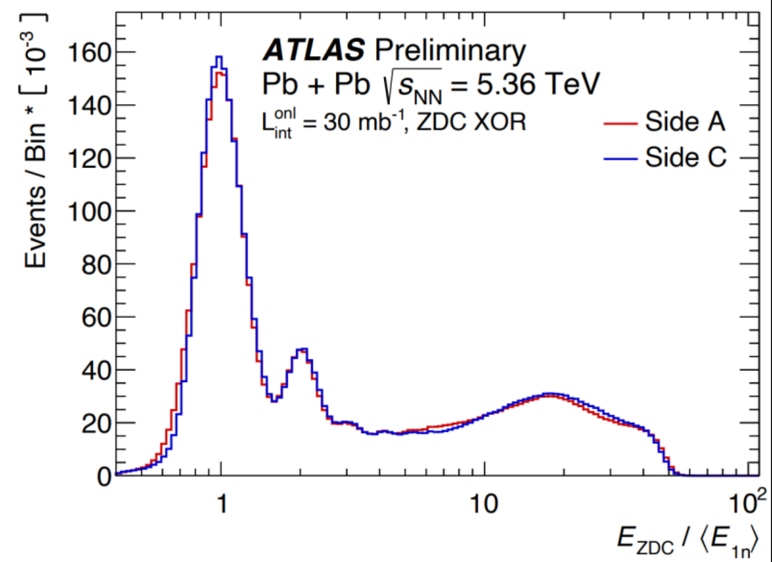


2023 5.36 TeV Pb+Pb Run





- Collection of a luminosity similar to that of 2018
- Upgrade to the ZDC electronics allows for a more differential triggering scheme
- Collected 10x more XnXn UPC jet events to probe breakup

Conclusion

- **Photonuclear dijet production was measured by ATLAS in 5.02 TeV Pb+Pb collisions with 2018 data**
  - **Particle-flow jets** allow the measurement to be extended even lower in jet p_T while maintaining systematic control
  - This measurement has been **fully unfolded** for detector response for the first time.
- **Paper with final results will be coming out in the next few months**
  - Sizable reduction of systematic uncertainties will be achieved
- **With Run 3 data and the robust measurement shown here, ATLAS is well positioned to do more differential studies in the future**
  - Detailed measurements of the breakup case
  - Direct vs resolved separated
  - Angular correlations
  - Measurements of exclusive dijet production

Thank You!