Event Selection in Peripheral Pb+Pb Collisions with ATLAS

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Background

- **Heavy Ion physics:** the study of the **quark-gluon plasma (QGP)**, which is produced through collisions of heavy nuclei at relativistic energies.
- **Jet quenching:** the suppression of high-p_T partons during their passage through the QGP.
- **Peripheral** Pb+Pb collisions: collisions in which the nuclei do not collide head on and not all nucleons participate.
  - These collisions produce smaller QGP regions, where jet quenching effects should be less pronounced.

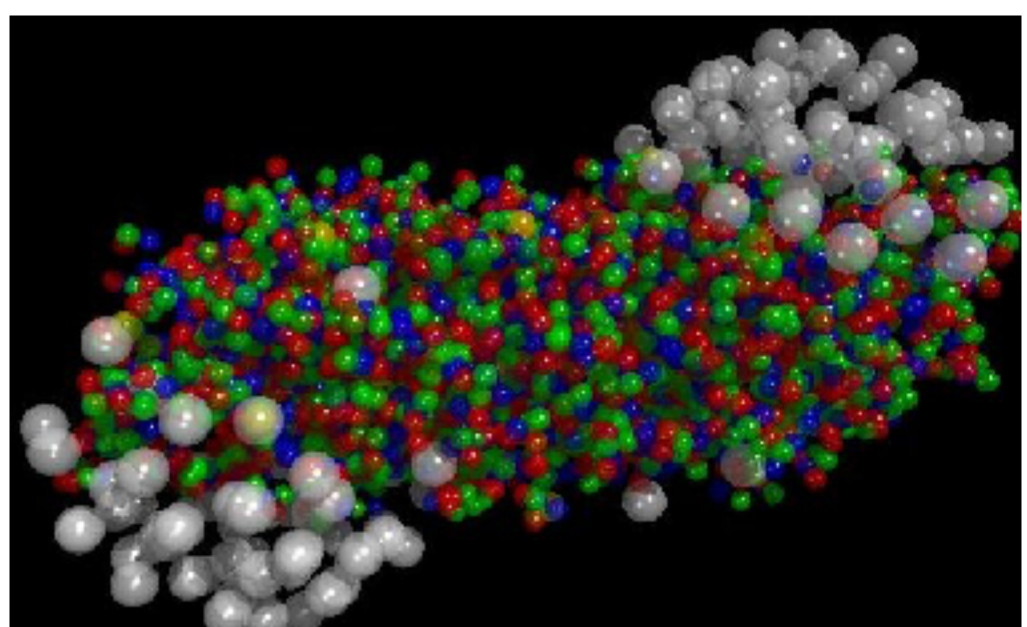


Image: https://home.cern/news/press-release/cern/new-state-matter-created-cern

R_{AA} and UPCs

- **Nuclear modification factor R_{AA}**: the ratio of Pb+Pb p_T spectra to pp p_T spectra.
  - The spectra of increasingly peripheral Pb+Pb collisions should resemble the spectra of pp collisions (i.e. R_{AA}= 1).
- **Ultra-peripheral collisions (UPCs)**: nuclei don't overlap within their classical radius.
  - Include **photonuclear (γ+A)** collisions.
  - p_T spectra are different from hadronic collisions for reasons unrelated to jet quenching, should be rejected to avoid bias in R_{AA} measurement.

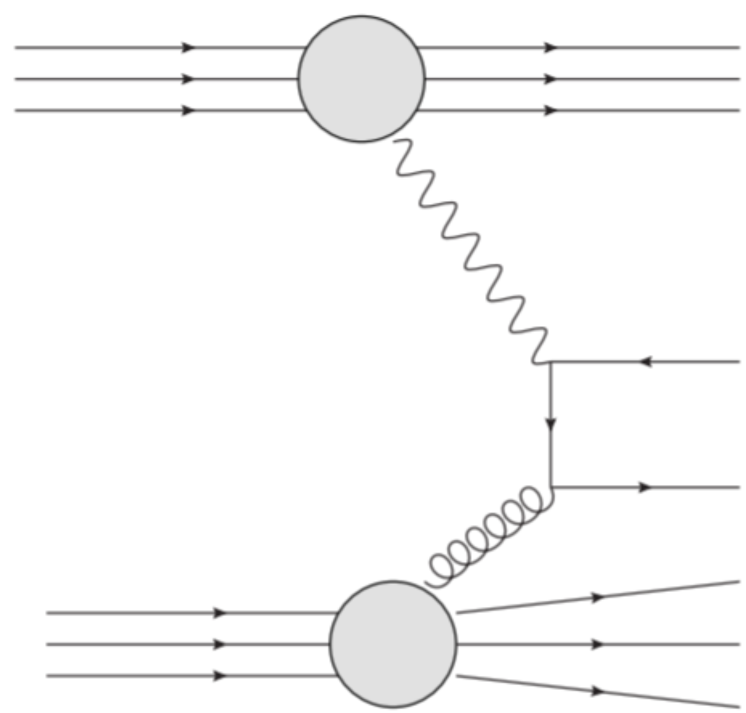


Diagram from Blair Seidlitz, CU Boulder

Definitions

- **Charged particle multiplicity (N_{ch})**: Number of charged tracks that:
  - pass the MinBias working point
  - are associated with a primary vertex
  - have $p_T > 0.5$ GeV
- **Zero degree calorimeter (ZDC)**
  - **XnXn:** events with at least one neutron in the ZDC on both sides of the detector.
  - **0nXn:** events with at least one neutron in the ZDC on only one side of the detector.

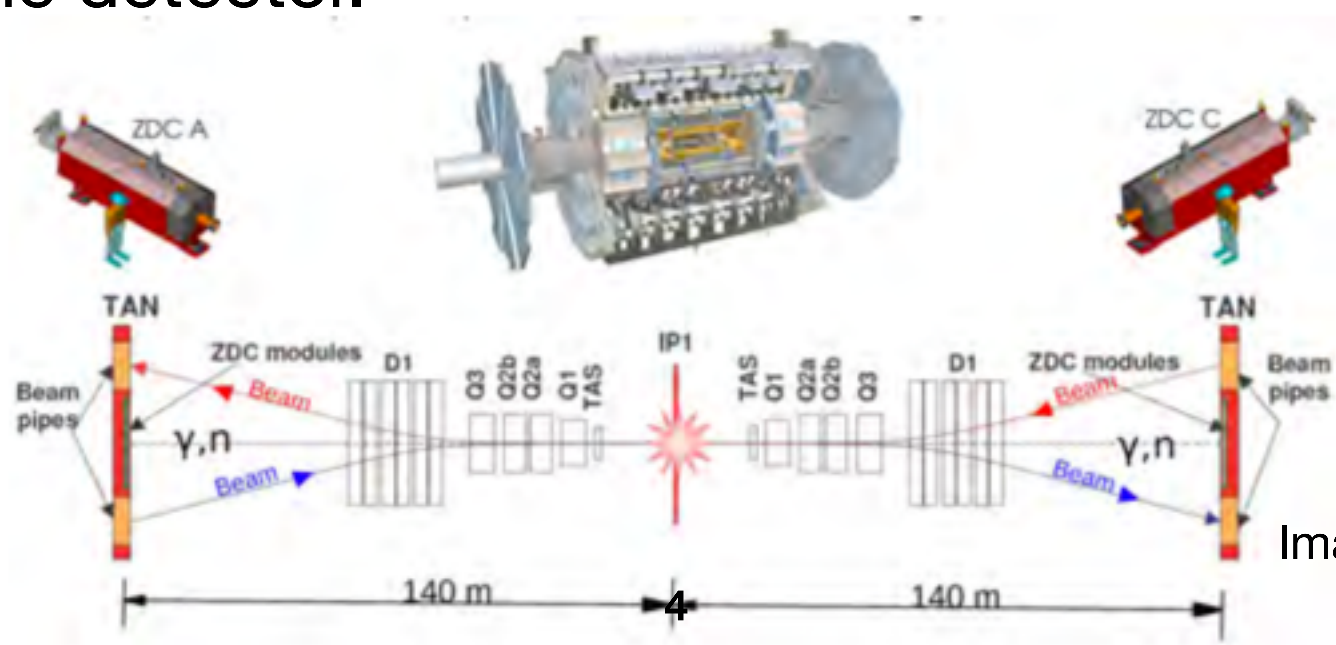
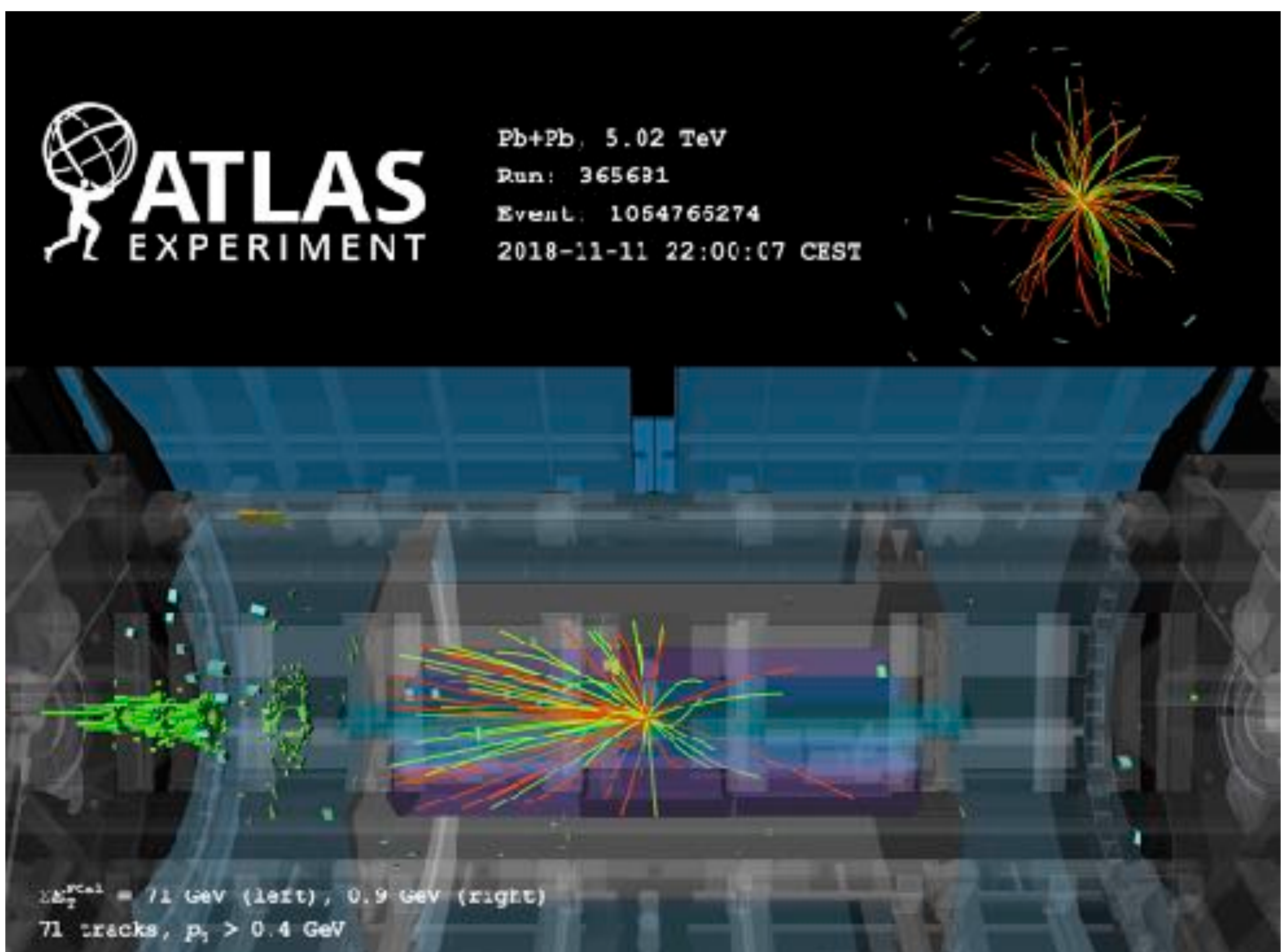
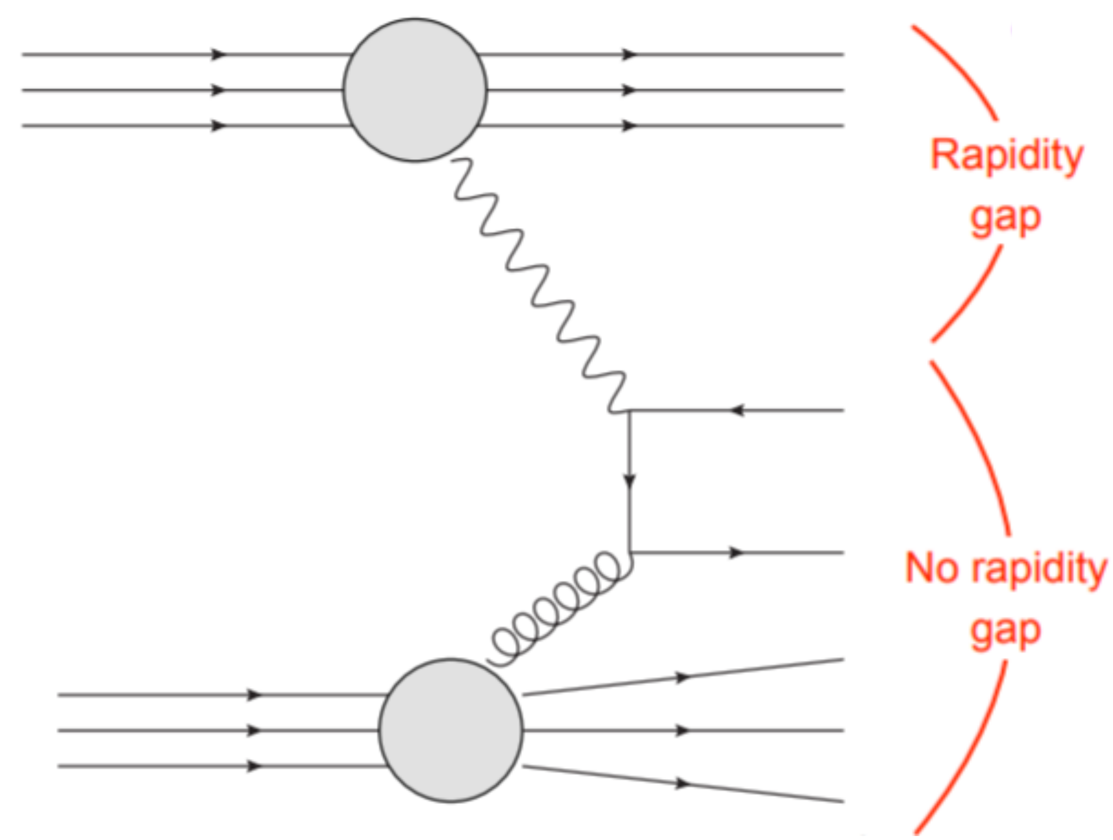


Image: https://ieeexplore.ieee.org/document/6829811

Gap Variables

- **Pseudorapidity gap variables** (sum η gaps A+C)
  - In -4.9 < η < 4.9, calculate sum of differences in η between tracks and clusters.
  - Can be used to quantify contamination of UPC events in XnXn and hadronic events in 0nXn.



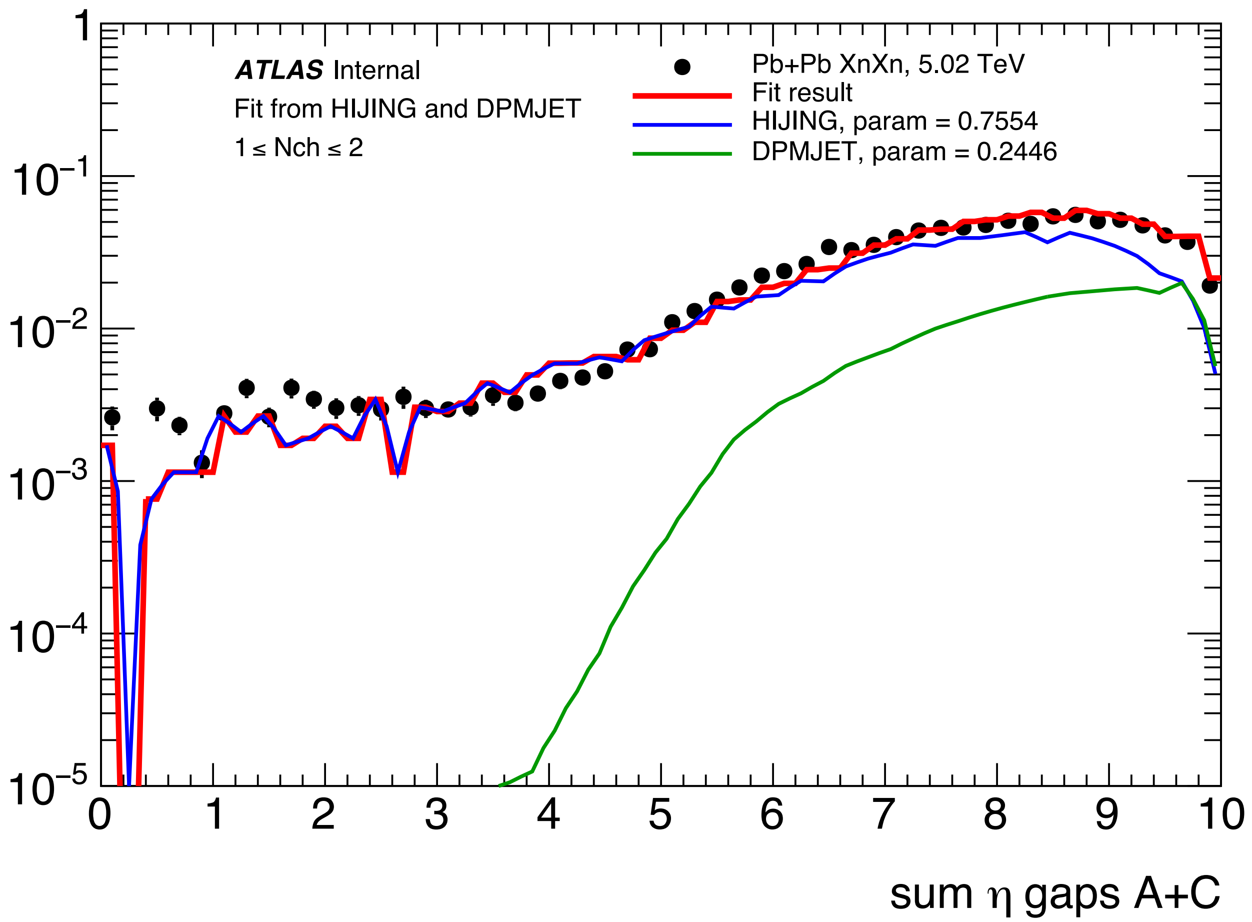


Simulation and Fitting

- **MC generators used**:
  - **HIJING** and **EPOS** for peripheral Pb+Pb
  - **DPMJET** for γ+A
- Two component fits to XnXn and 0nXn 5.02 TeV Pb+Pb data in various N_{ch} slices using HIJING and DPMJET or EPOS and DPMJET
  - I will be showing and focusing on the HIJING fits.

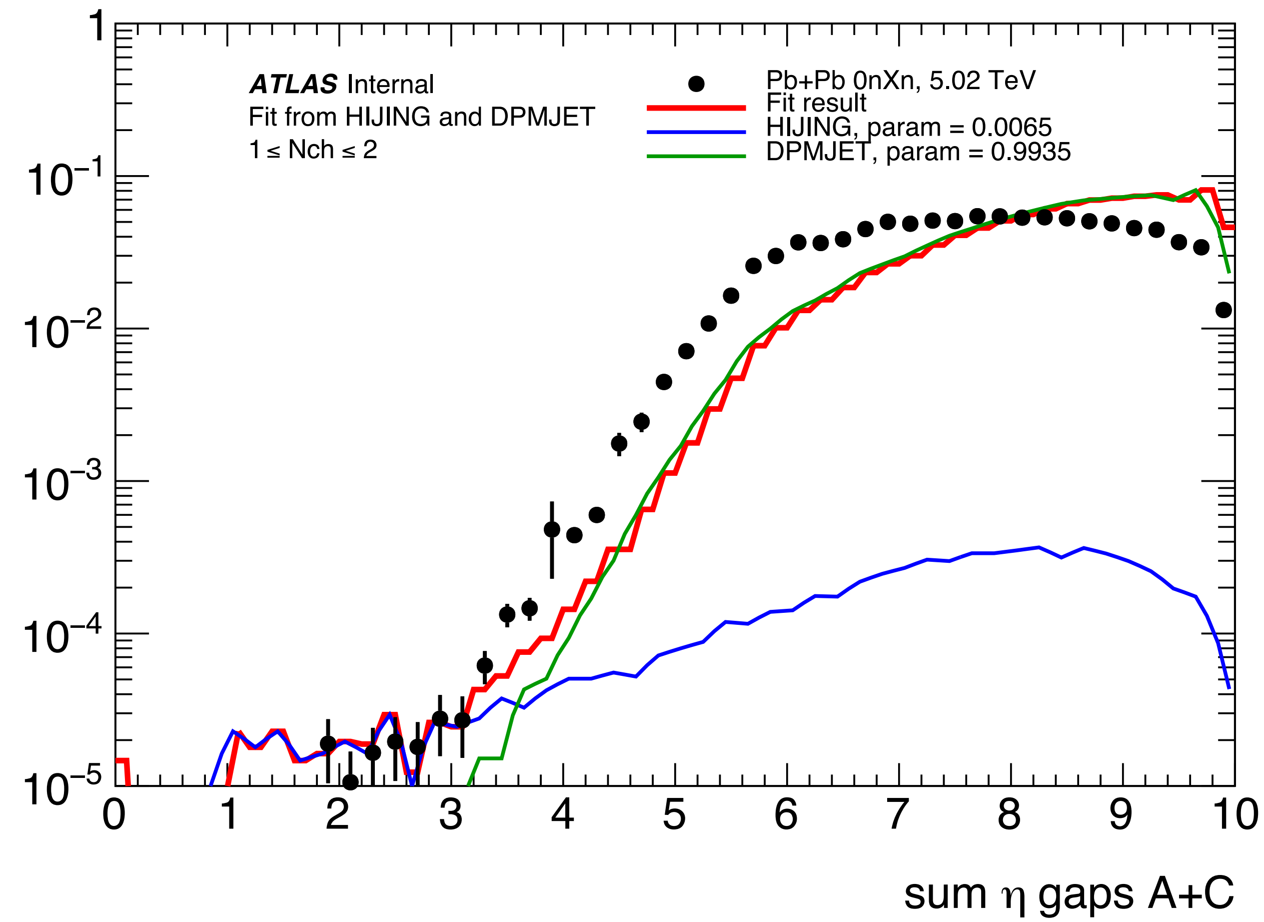
N_{ch} = 1-2

XnXn



Peripheral: 76%
UPC: 24%

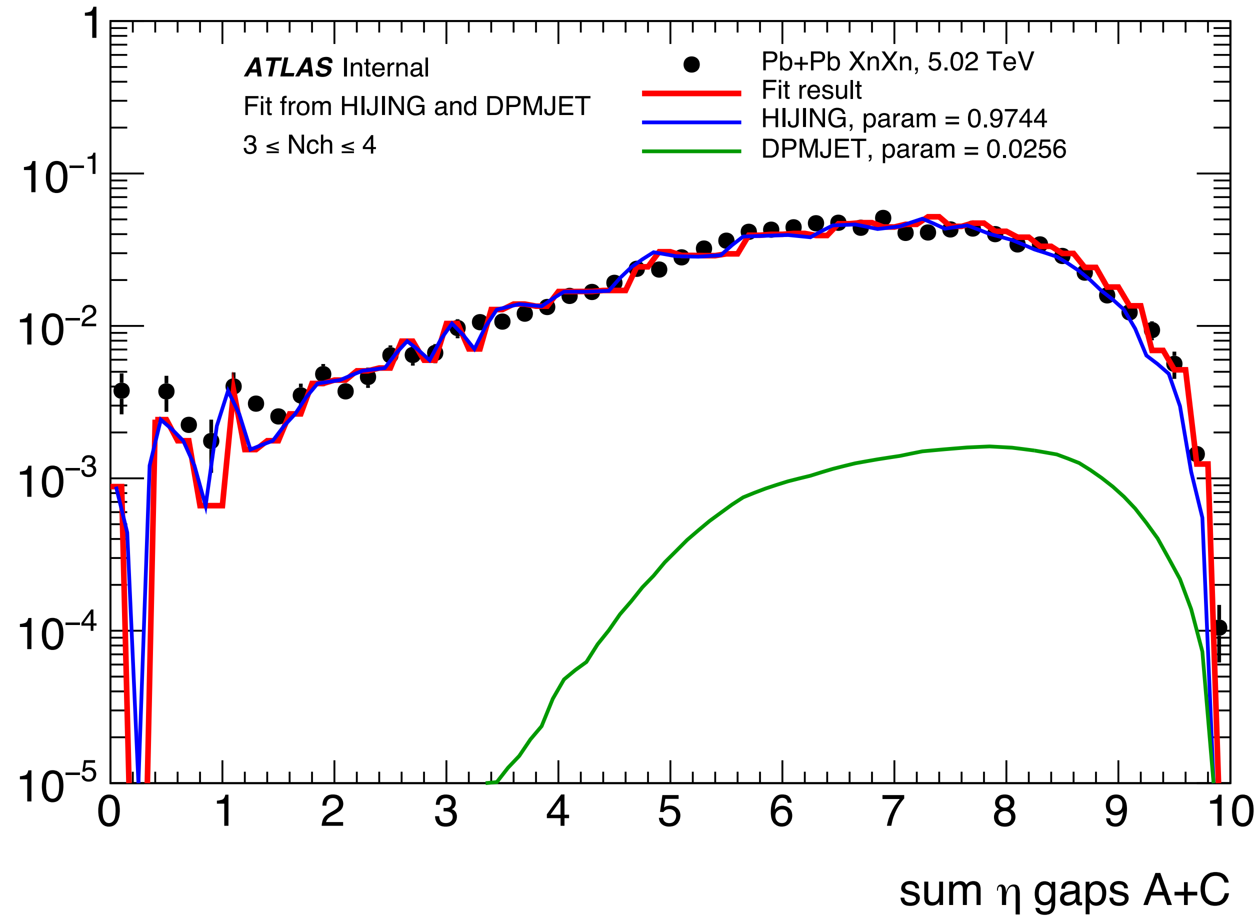
0nXn



Peripheral: 1%
UPC: 99%

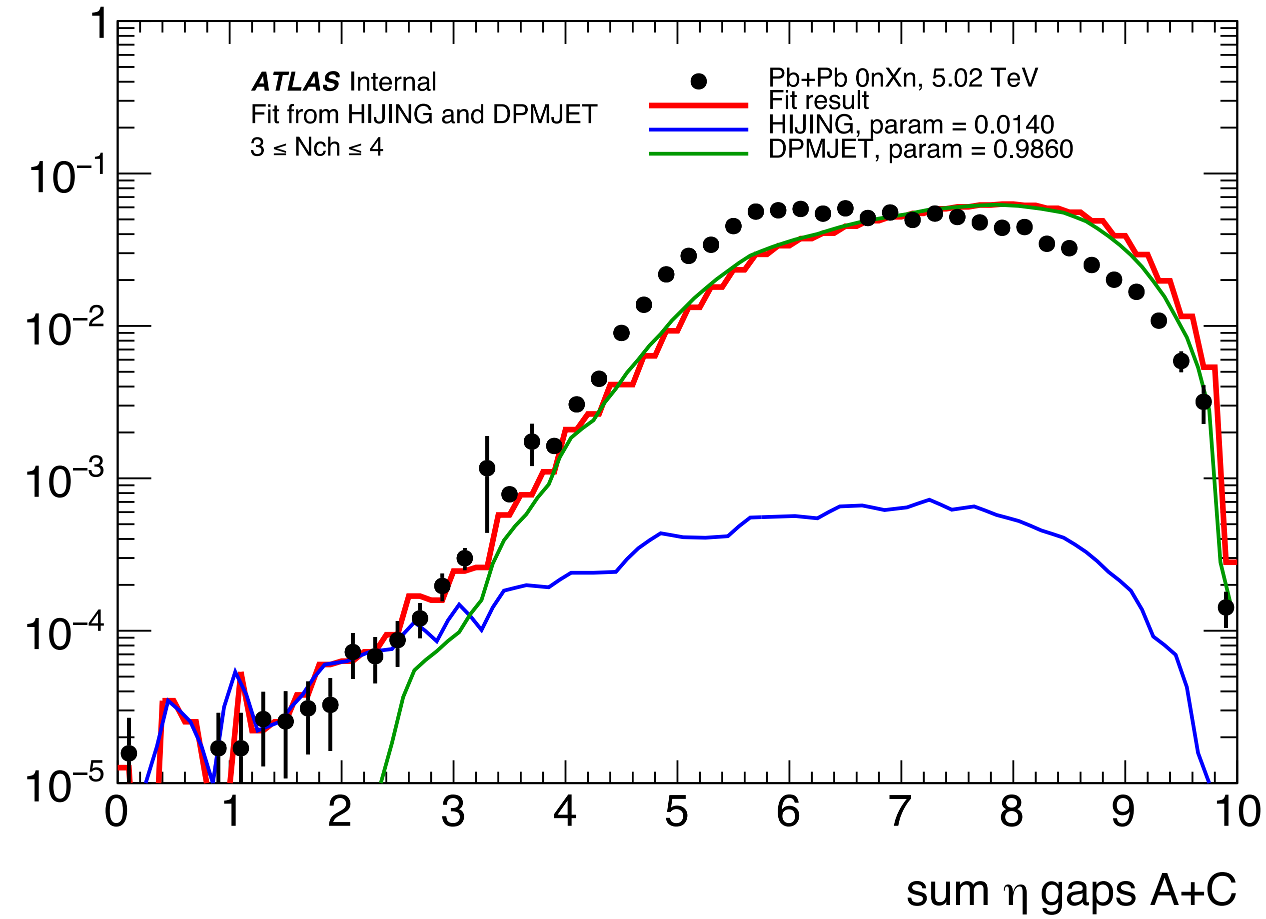
N_{ch} = 3-4

XnXn



Peripheral: 97%
UPC: 3%

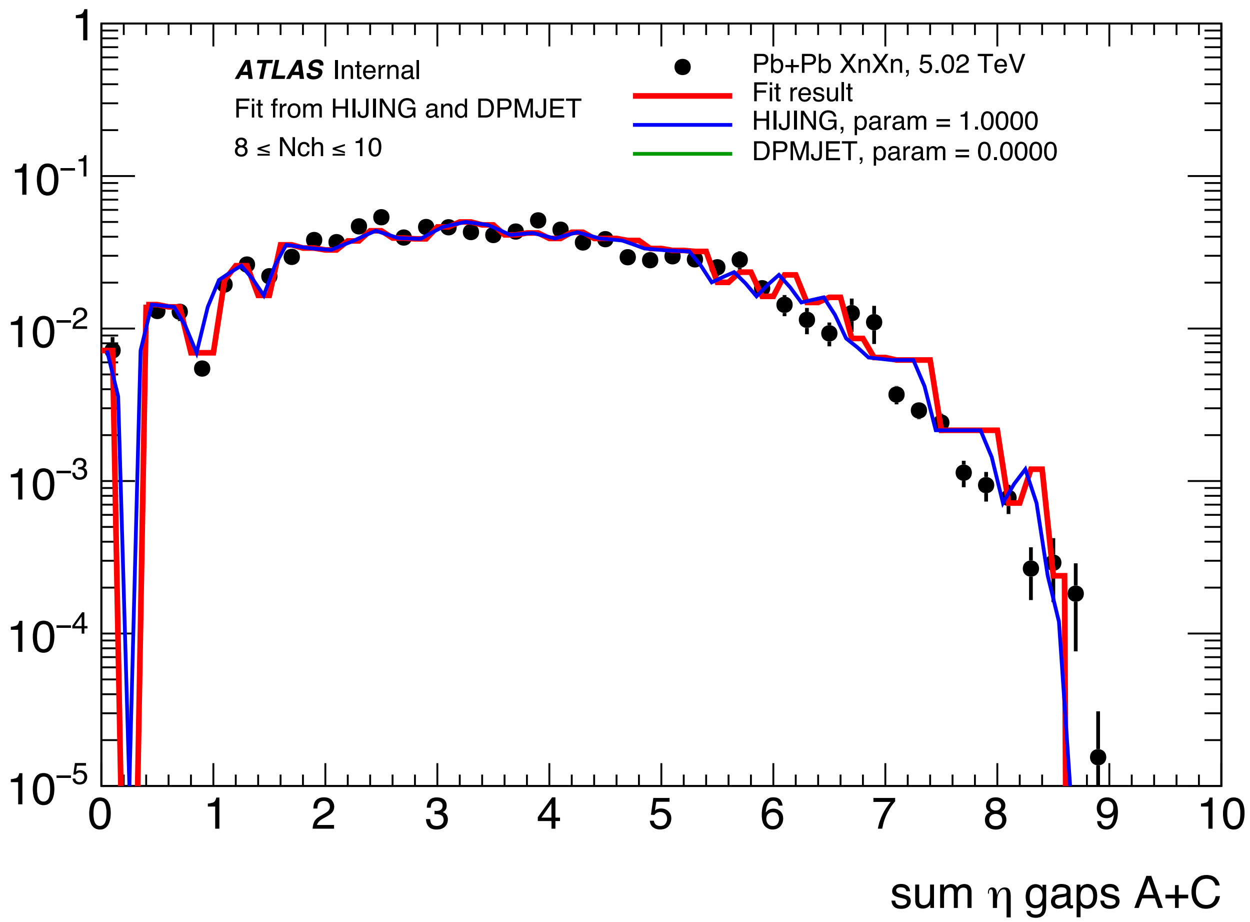
0nXn



Peripheral: 1%
UPC: 99%

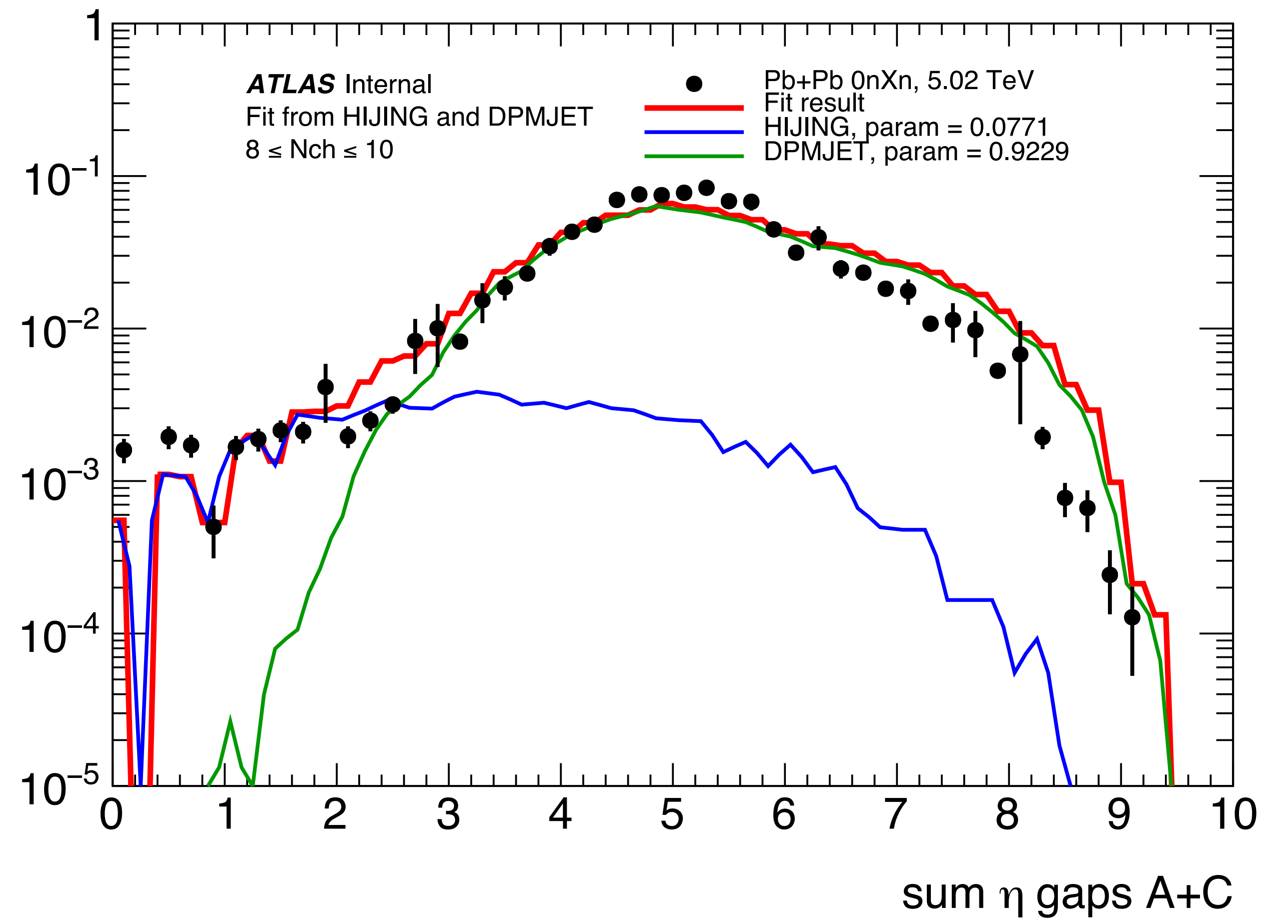
N_{ch} = 8-10

XnXn



Peripheral: 100%
UPC: 0%

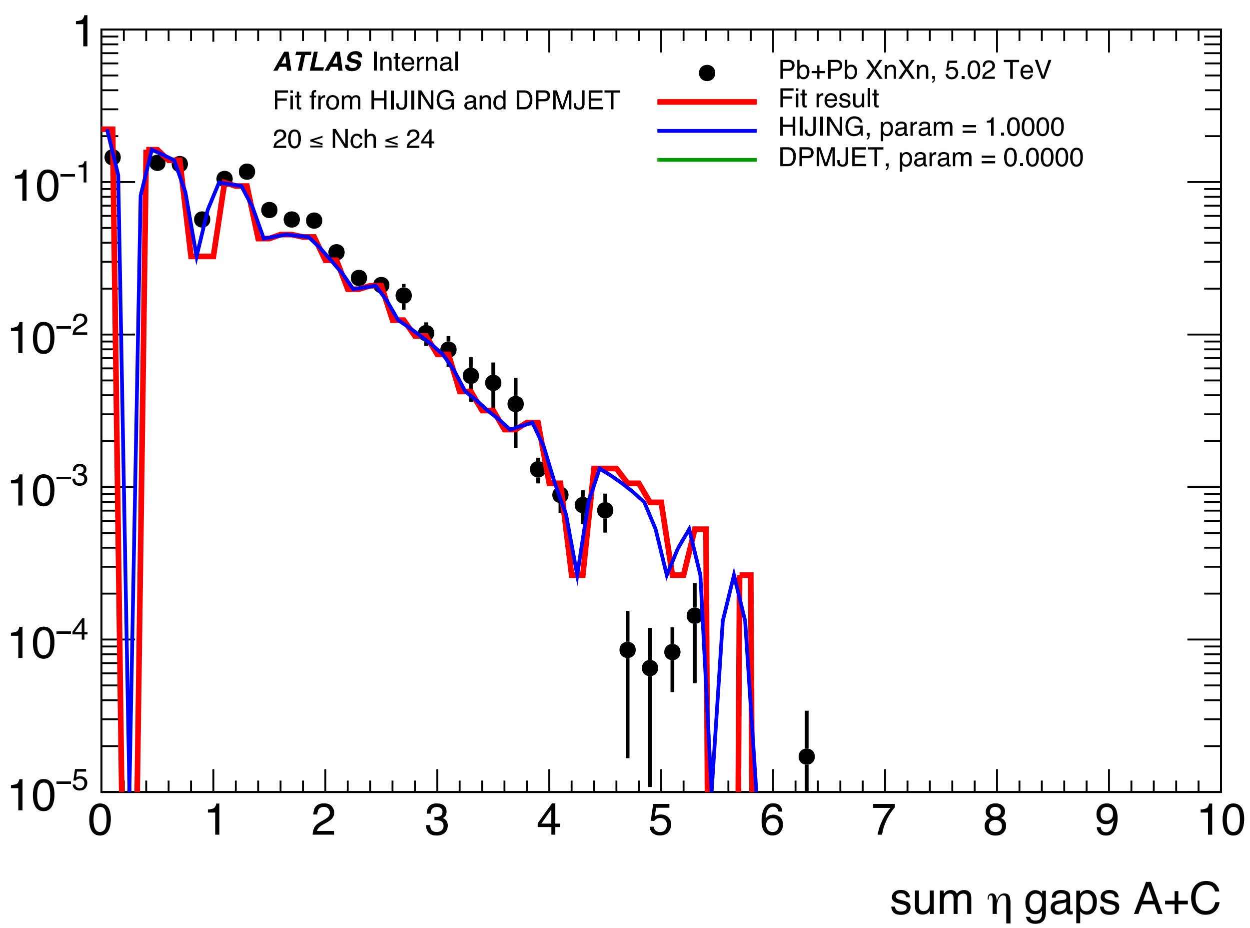
0nXn



Peripheral: 8%
UPC: 92%

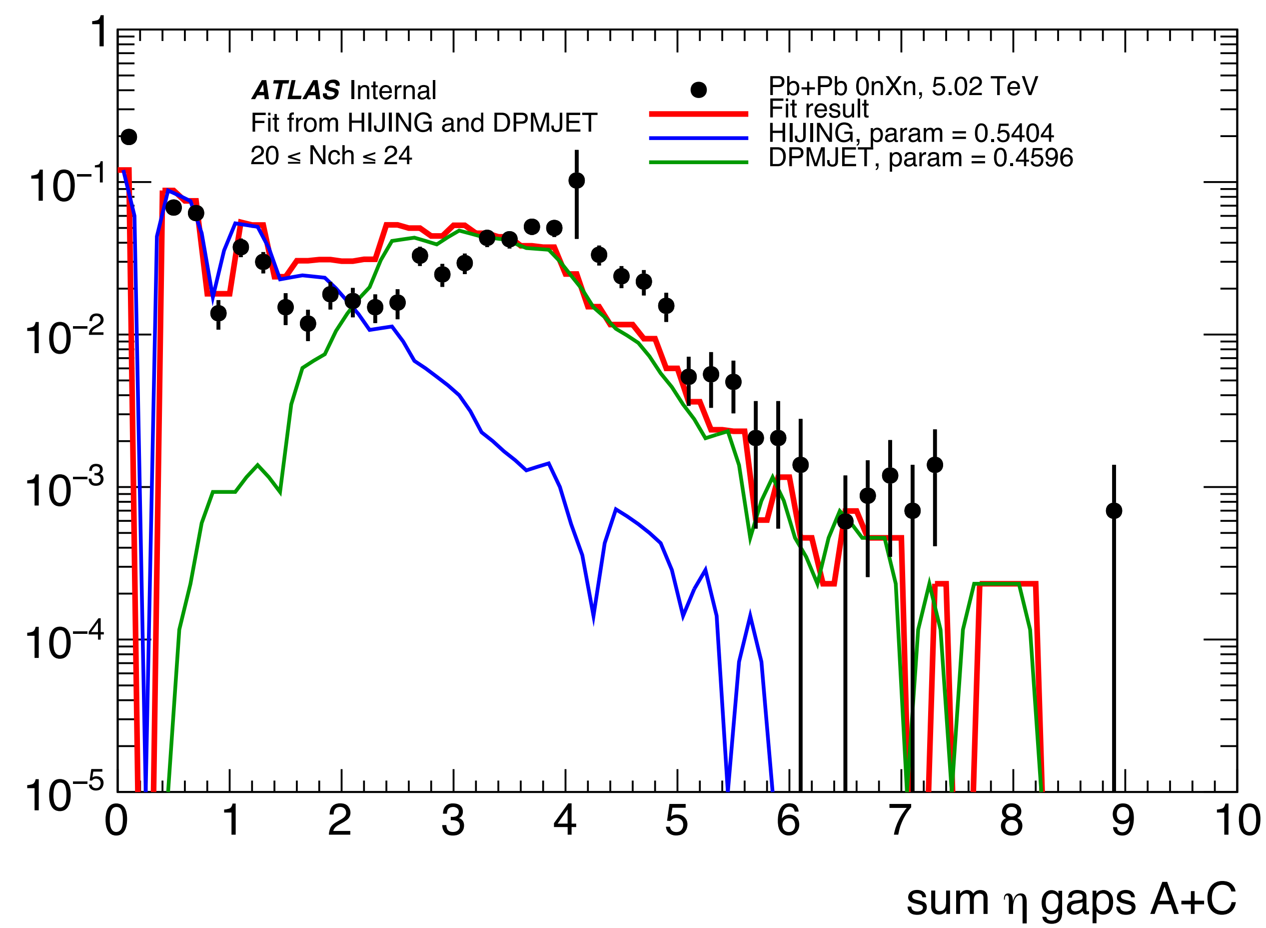
N_{ch} = 20-24

XnXn



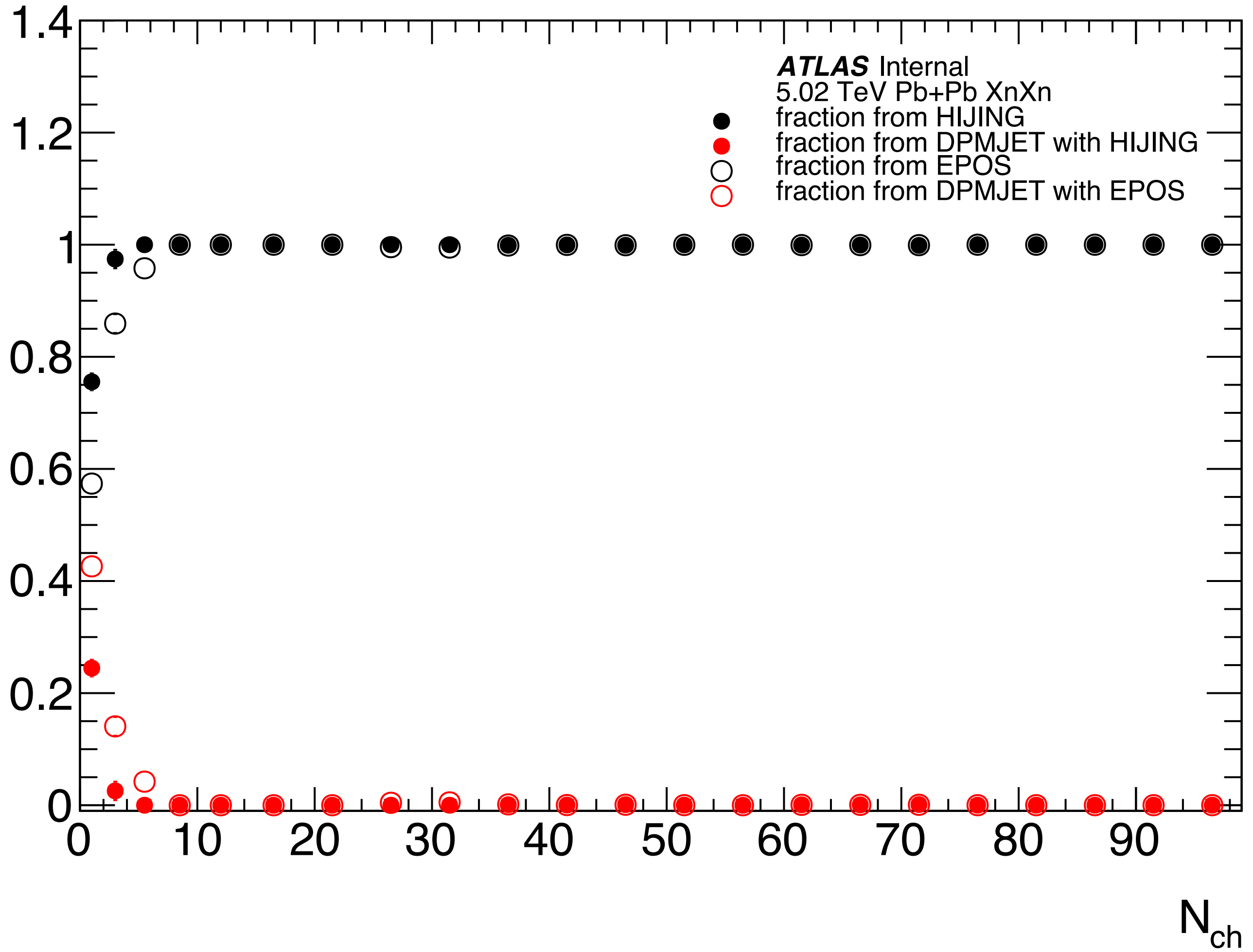
Peripheral: 100%
UPC: 0%

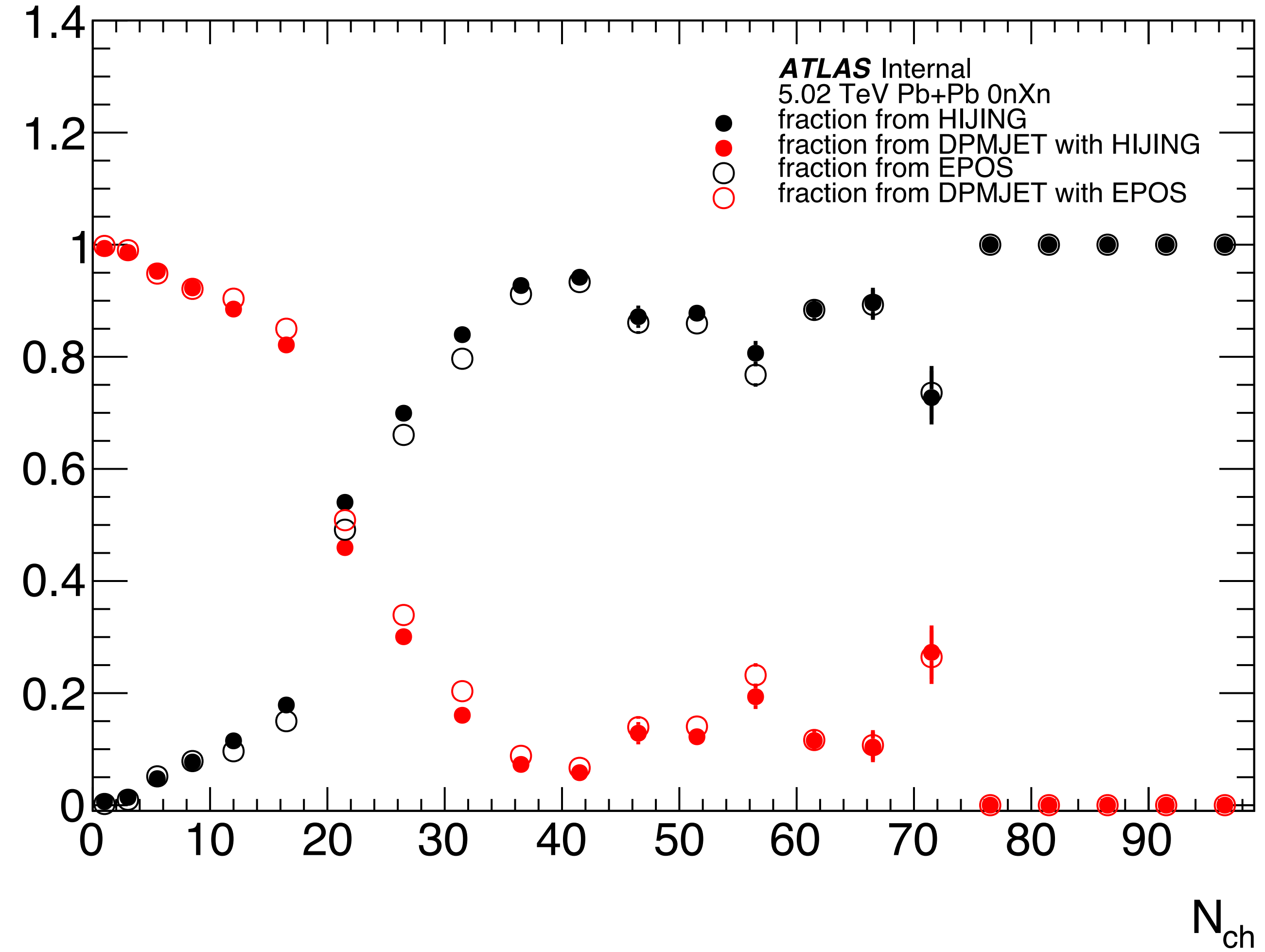
0nXn



Peripheral: 54%
UPC: 46%

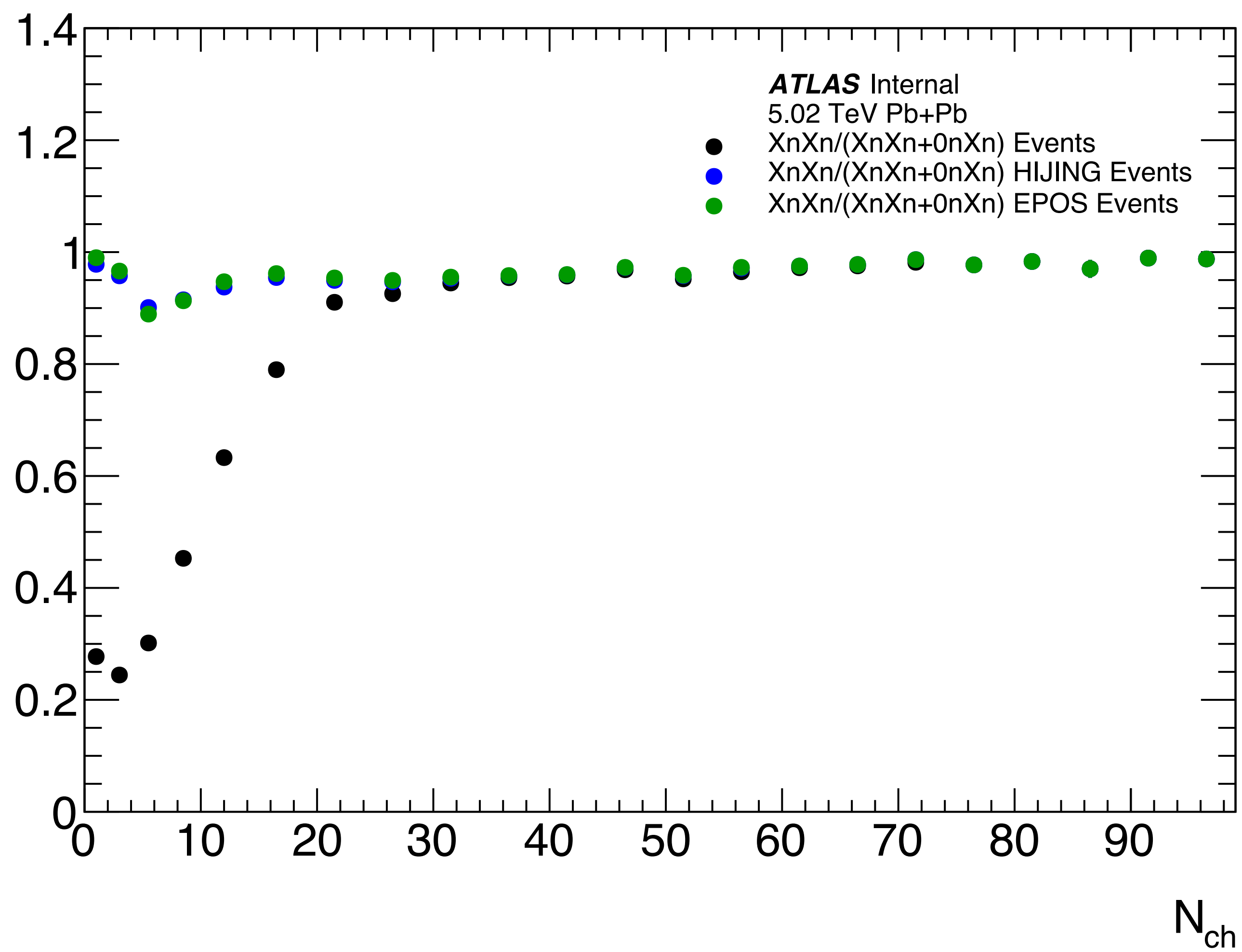
Results





- Contribution from each model in all N_{ch} slices.
    - Above N_{ch}=75, DPMJET statistics are so low that there is assumed to be no UPC contribution.
- EPOS predicts greater UPC contribution than HIJING at low N_{ch} in XnXn.
- Fluctuations in 0nXn have no obvious cause- could be due to mismatch in shape between DPMJET and data causing tension in the fit.

Results



- Fractions of XnXn/total events for data, data fit from HIJING, and data fit from EPOS.
- Assuming the fraction shown is equal to 1 for $N_{ch} > 100$, we use this to calculate the events from HIJING and EPOS that are rejected when XnXn was required.
- 1.7% of HIJING events and 1.4% of EPOS events are in 0nXn and are therefore rejected.

Conclusions

- UPCs dominate in low N_{ch} 0nXn data.
  - 0nXn selection combined with a minimum sum-of-gaps requirement is enough for a reasonably clean UPC sample.
- We see very little contribution from UPCs in XnXn data for $N_{ch} > 10$.
  - XnXn selection alone is enough for a reasonably UPC-free sample except at very low N_{ch}.
- About 1-2% of hadronic Pb+Pb collisions are rejected if XnXn is required.

The goal of this project, to quantify contamination, was achieved using two different models. It has been documented in an ATLAS note which can be found here: https://cds.cern.ch/record/2778445

Possible future studies

- What effect does the XnXn requirement have on the p_T spectra given that roughly 1-2% of non-UPC events do not pass it?
- Less model dependent checks such as exclusive ρ-meson production in XnXn and 0nXn have been suggested.

Acknowledgements

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