Two-particle azimuthal correlations in photo-nuclear Pb+Pb collisions with ATLAS

ATLAS, PRC 104 (2021) 014903

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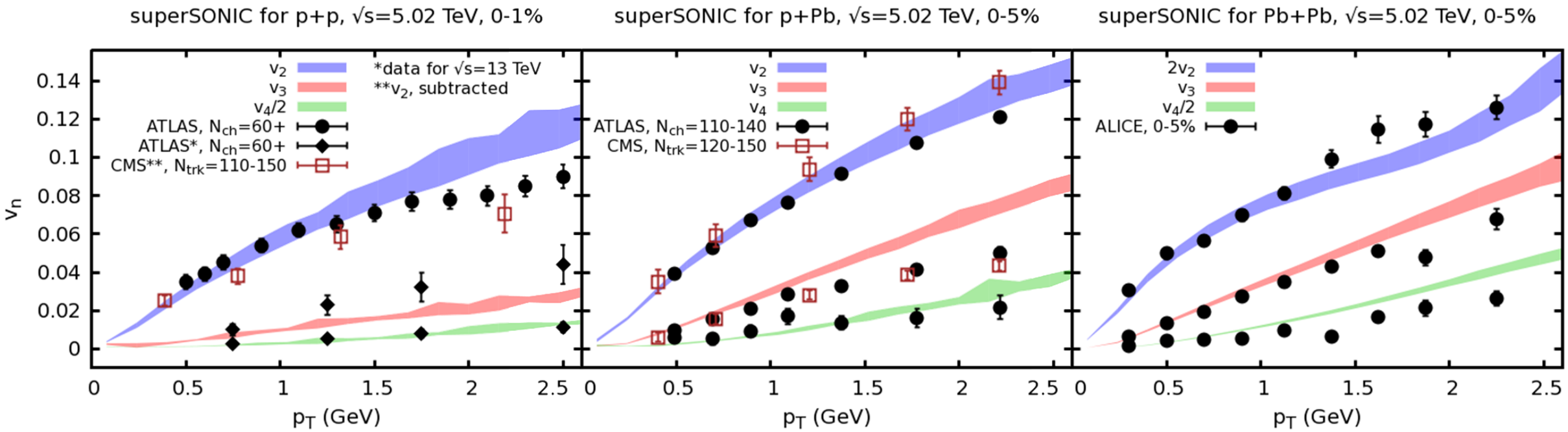
for the ATLAS Collaboration

XXIXth International Conference on
Ultrarelativistic Nucleus-Nucleus Collisions
6 April 2022
Krakow, Poland

Collectivity in small systems

Seemingly universal collective behavior in AA, *p*A, and *pp*,
well described within a unified hydrodynamic paradigm!



What's the smallest system that exhibits this behavior?
(What are the minimal conditions?)

Can we learn by looking at exotic collision systems, with
qualitatively different initial states?

What should we see at the Electron-Ion Collider?

Photo-nuclear collisions

A "direct" process:

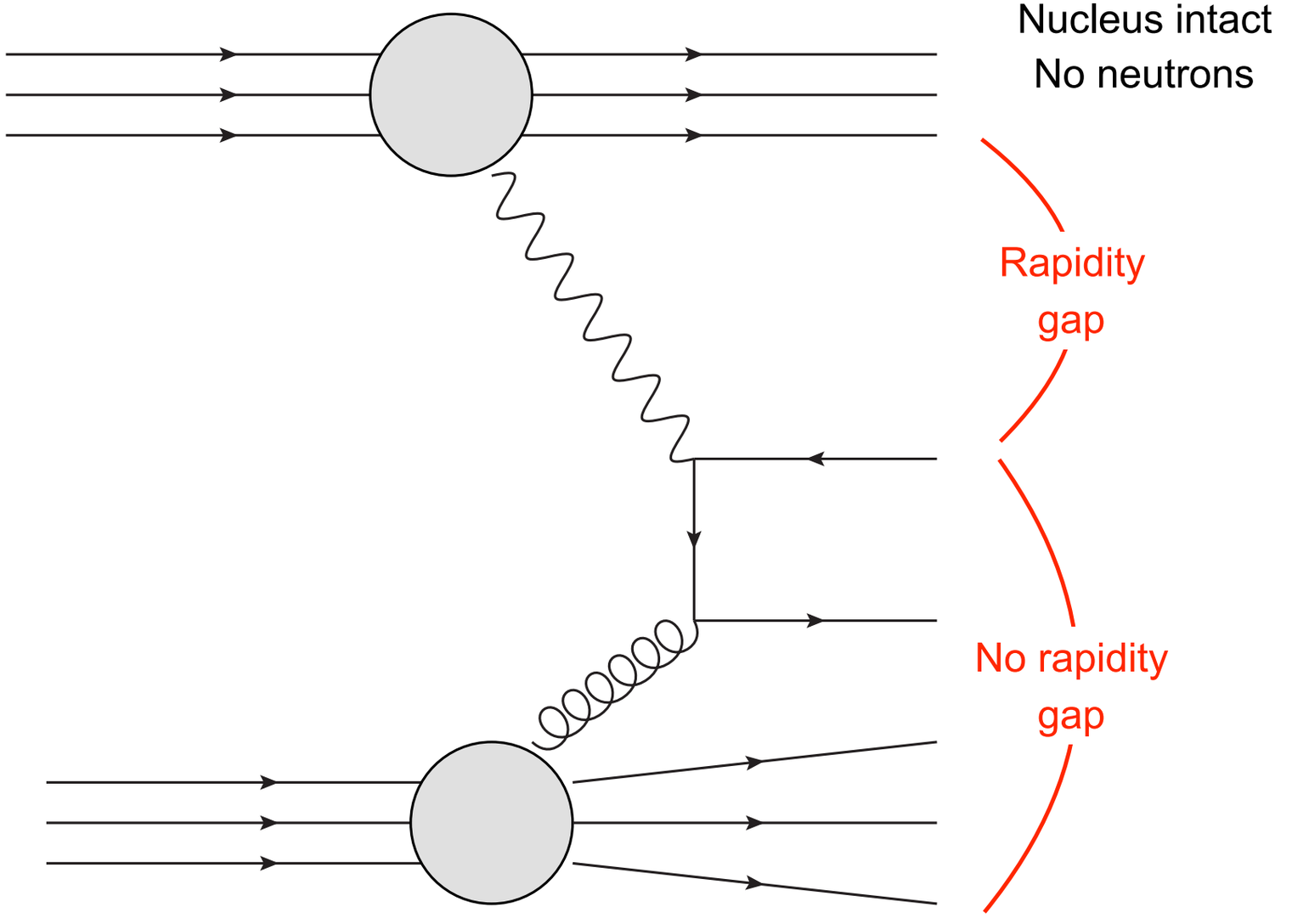
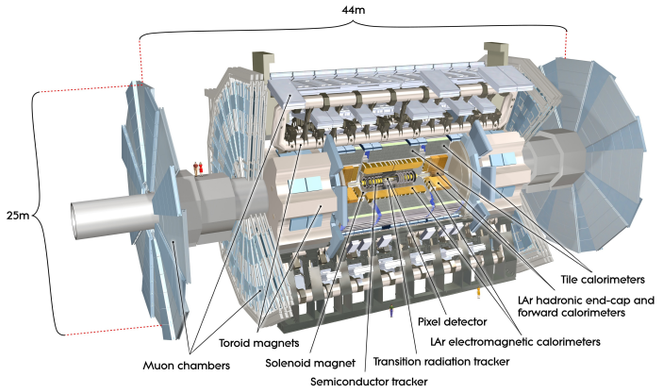


Photo-nuclear collisions



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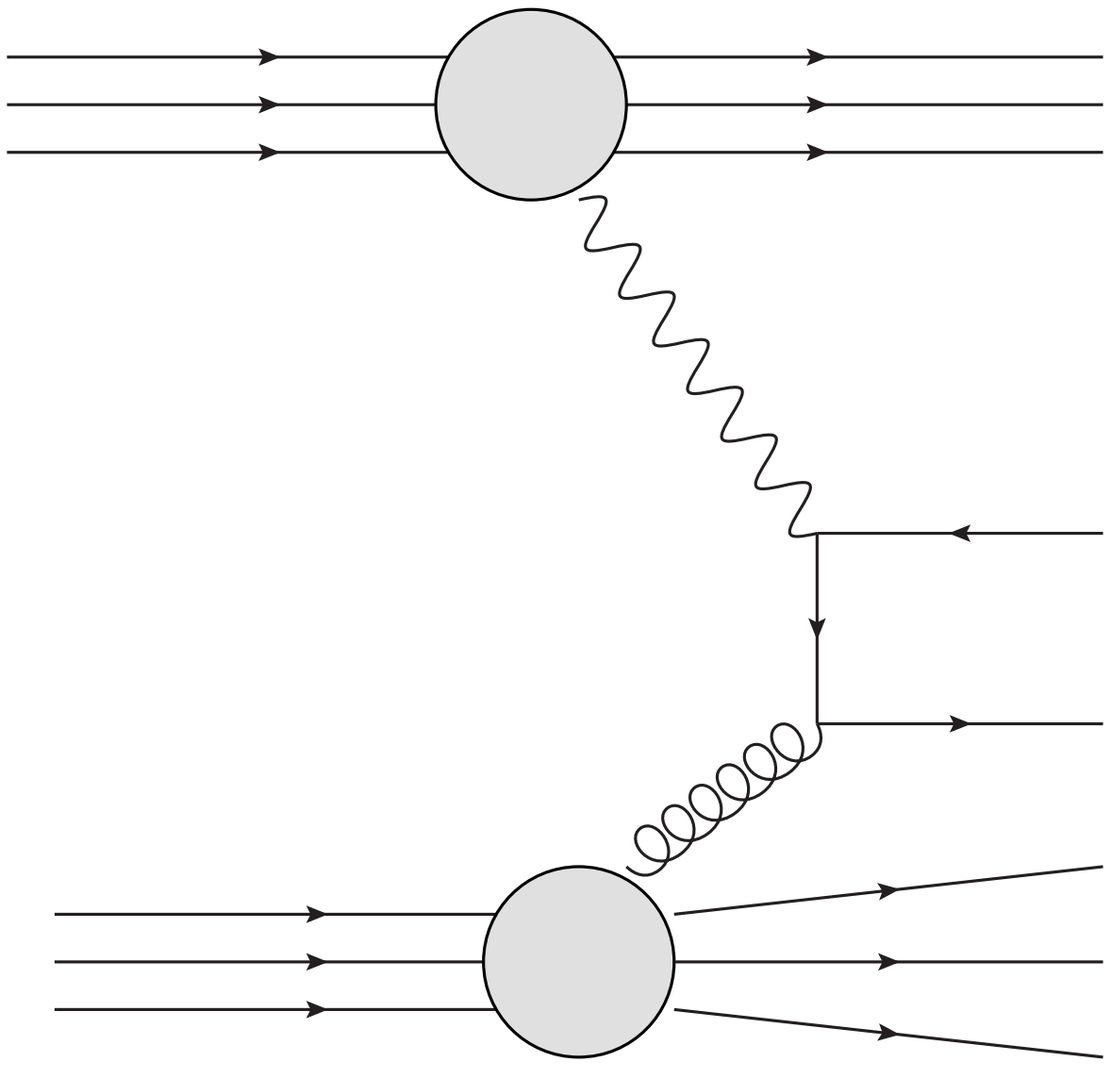
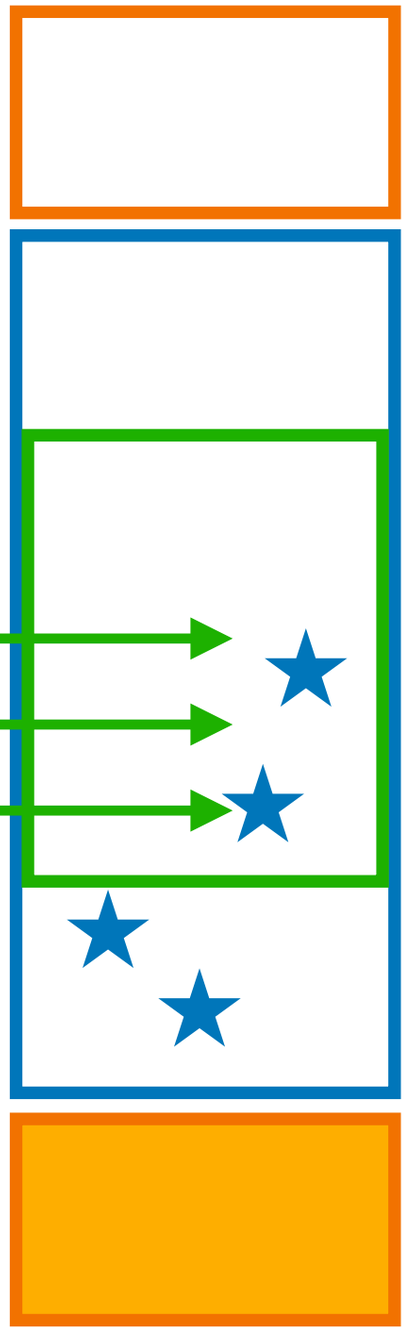


Nucleus intact
No neutrons

Rapidity gap

No rapidity gap

Nucleus breaks up
Multiple neutrons



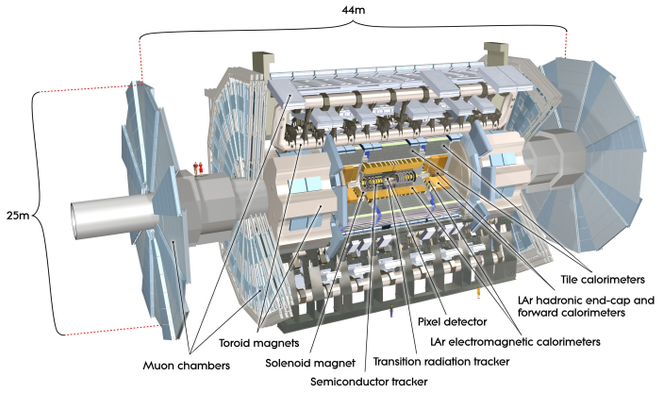
ZDC veto ($\eta > 8.3$)

tracks in ID ($|\eta| < 2.5$)

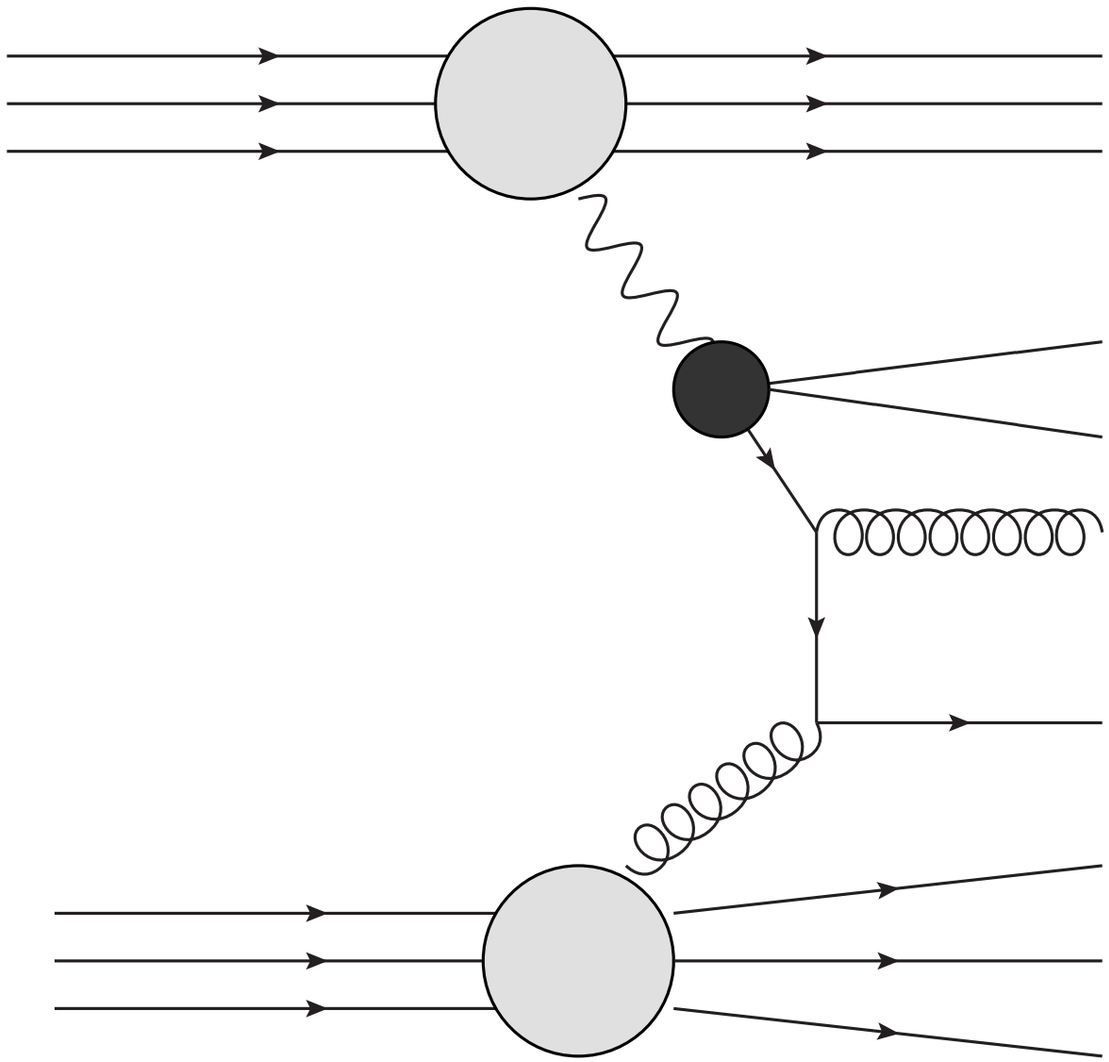
clusters in calorimeter ($|\eta| < 4.9$)

ZDC signal ($\eta < -8.3$)

Photo-nuclear collisions



A "resolved" process:

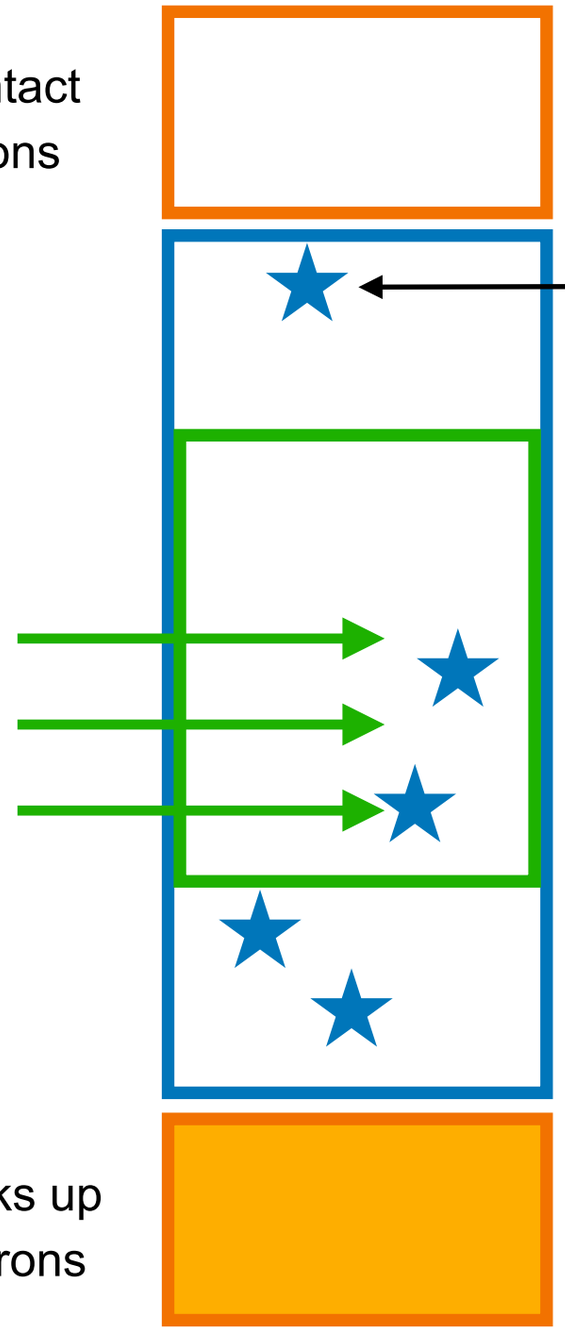


Nucleus intact
No neutrons

Gap partially filled

No rapidity gap

Nucleus breaks up
Multiple neutrons



ZDC veto ($\eta > 8.3$)

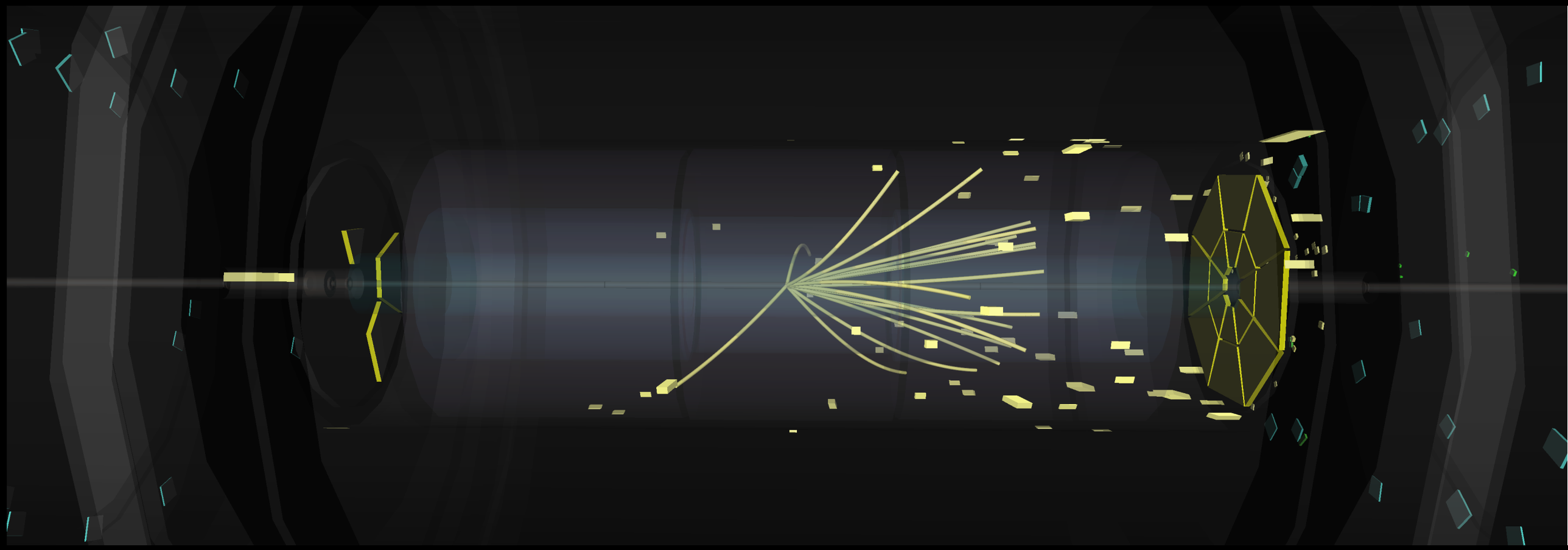
pieces of photon remnant

tracks in ID ($|\eta| < 2.5$)

clusters in calorimeter ($|\eta| < 4.9$)

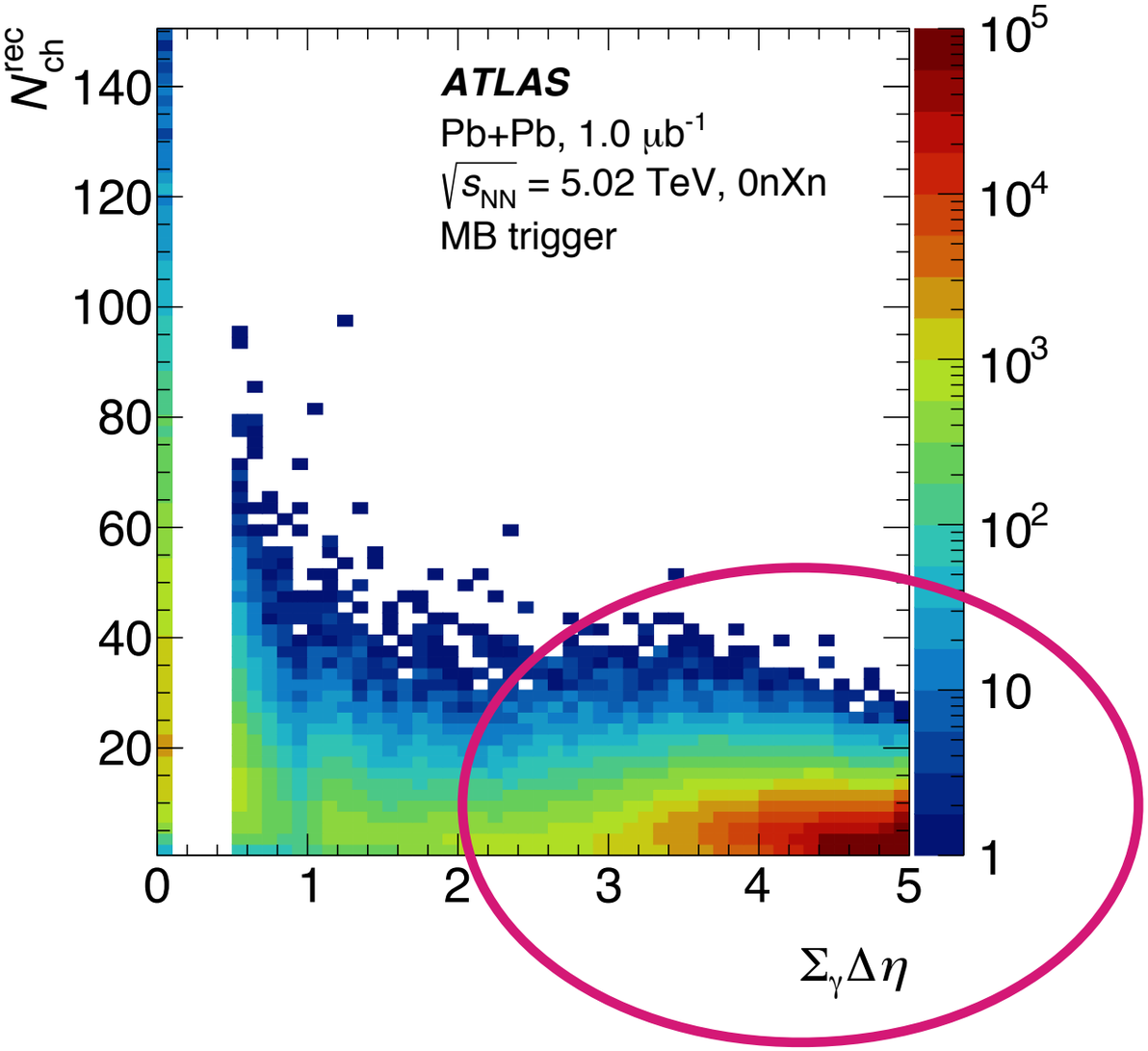
ZDC signal ($\eta < -8.3$)

Photo-nuclear events in data



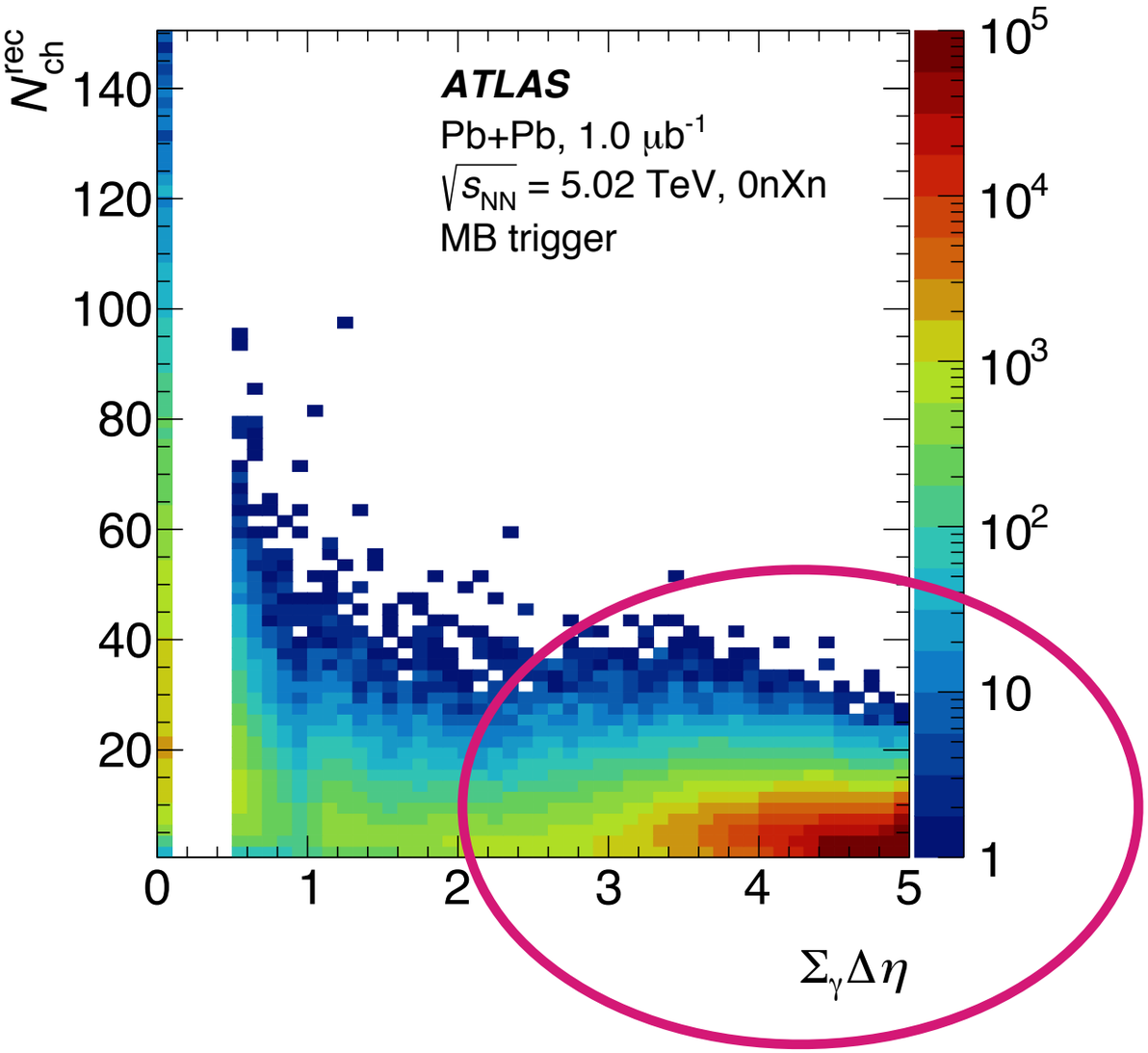
- Characterically asymmetric topologies
- Surprisingly high multiplicities (within large ATLAS acceptance)
- Large luminosity 2018 Pb+Pb dataset, 1.7 nb^{-1}

Event selection



Select events with large photon-side sum-of-gaps

Event selection



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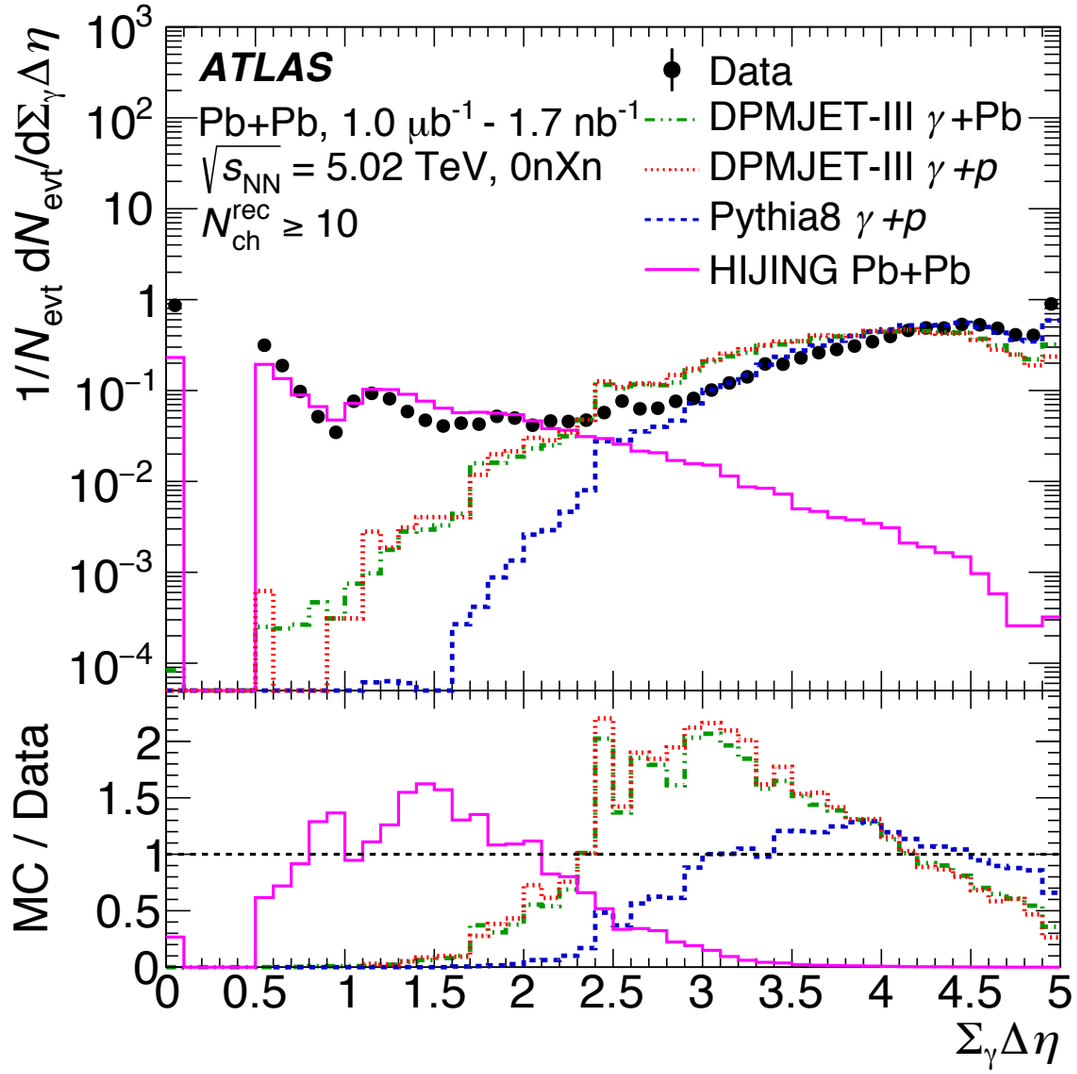
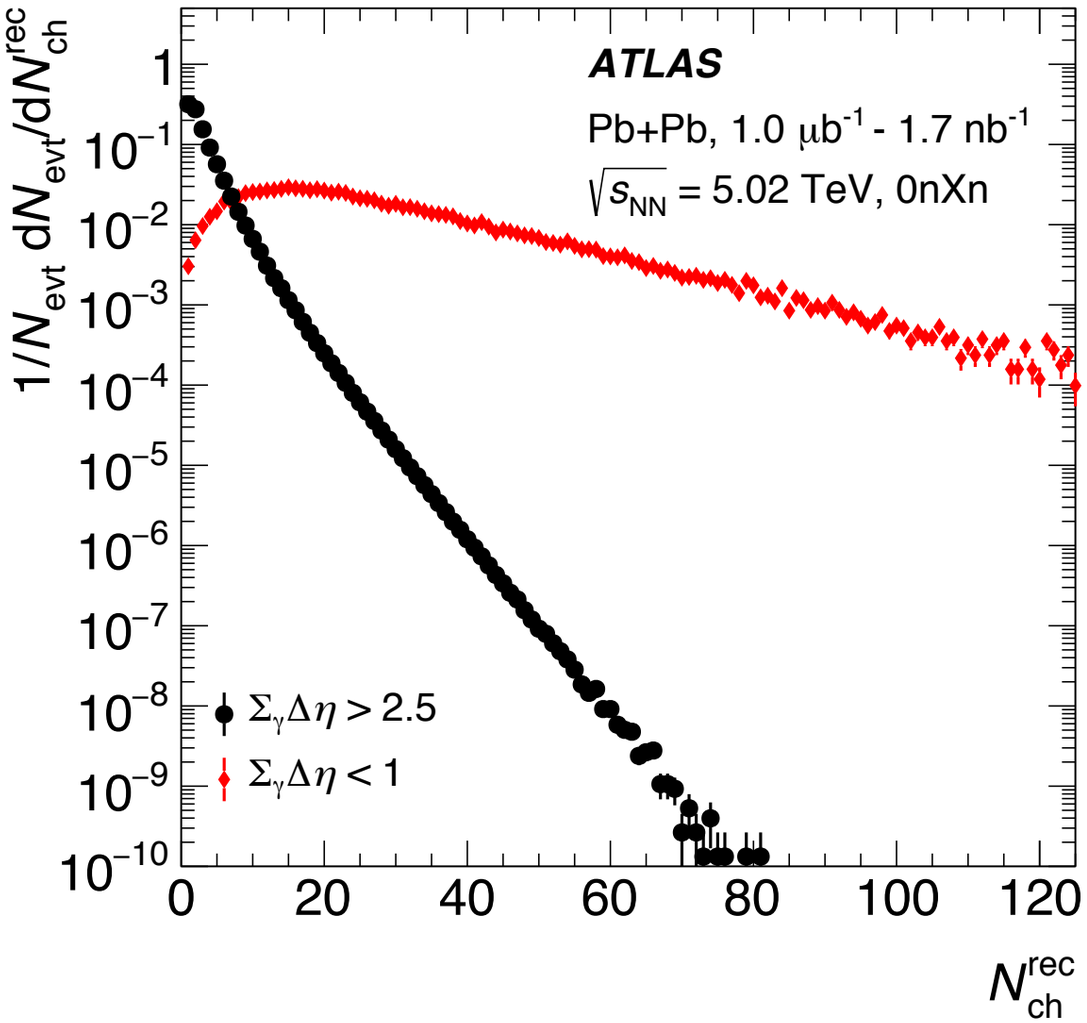


Comparison with **DPMJET** and **Pythia** (to model ɣ+A) and **HIJING** (to model peripheral Pb+Pb):

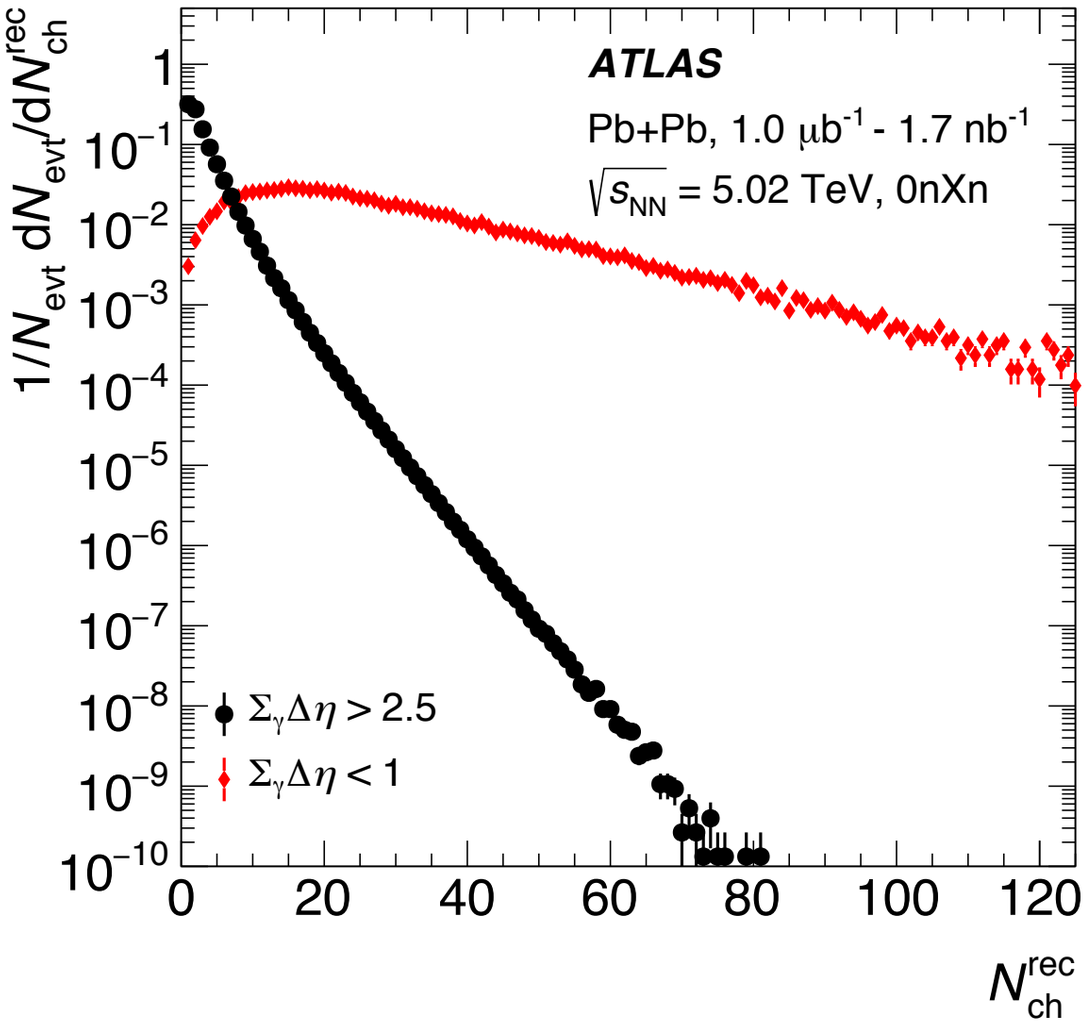
ɣ+A dominates at $\Delta\eta > 2.5$

Properties of γ+A events

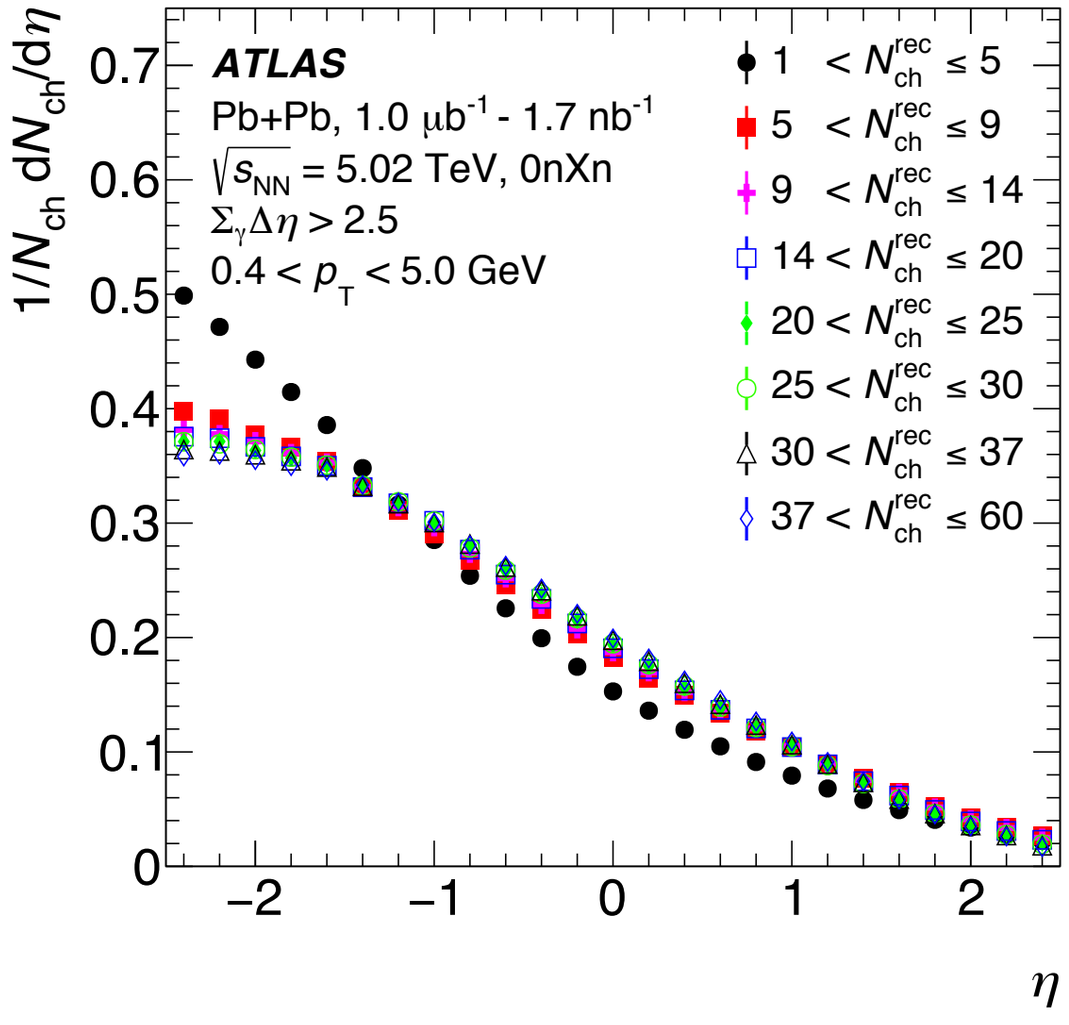


Steeply falling multiplicity distribution for **γ+A** events - specialized trigger used to collect large statistics!

Properties of γ+A events

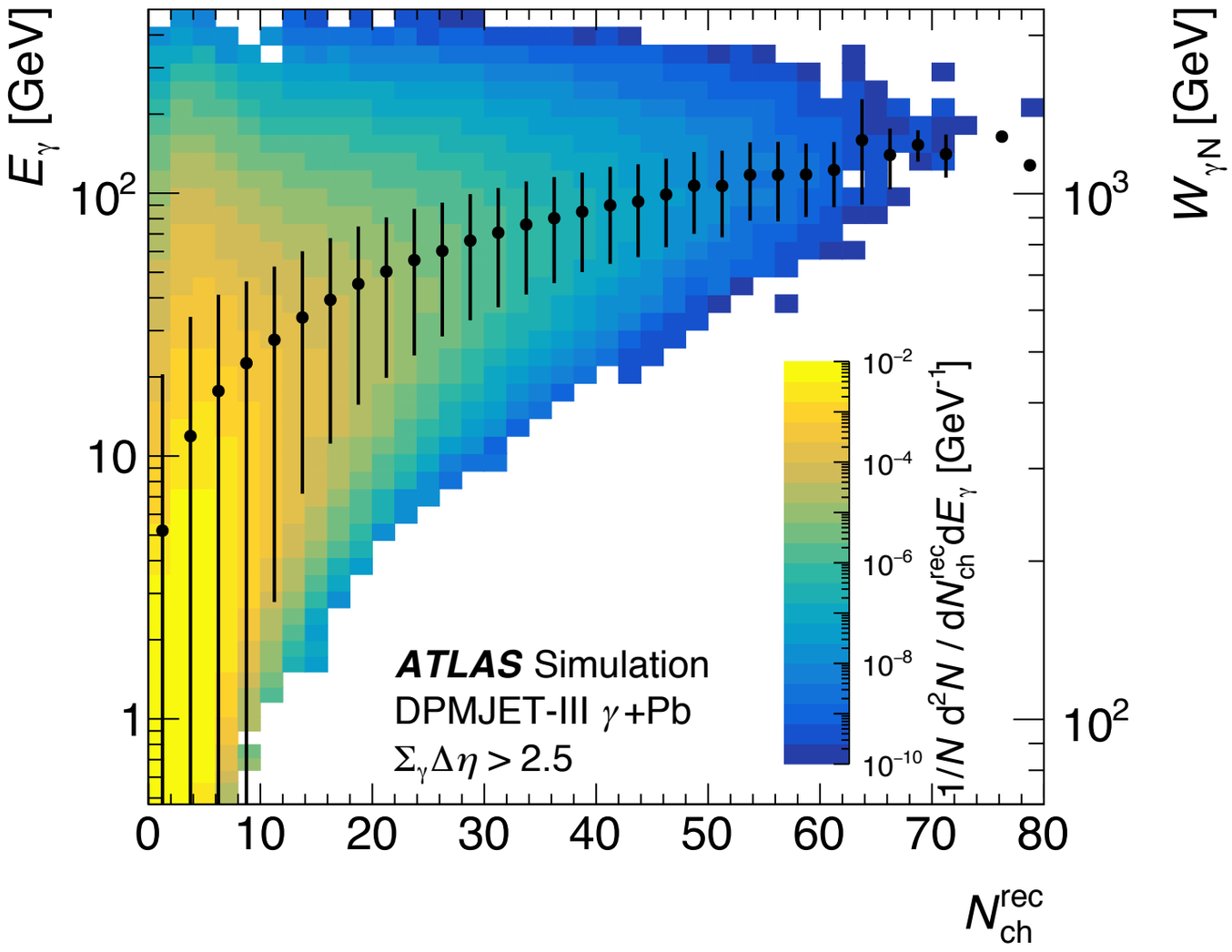


Steeply falling multiplicity distribution for **γ+A** events - specialized trigger used to collect large statistics!



Asymmetric dN/dη distribution - similar to p+A collisions!

What are we selecting?



According to DPMJET,

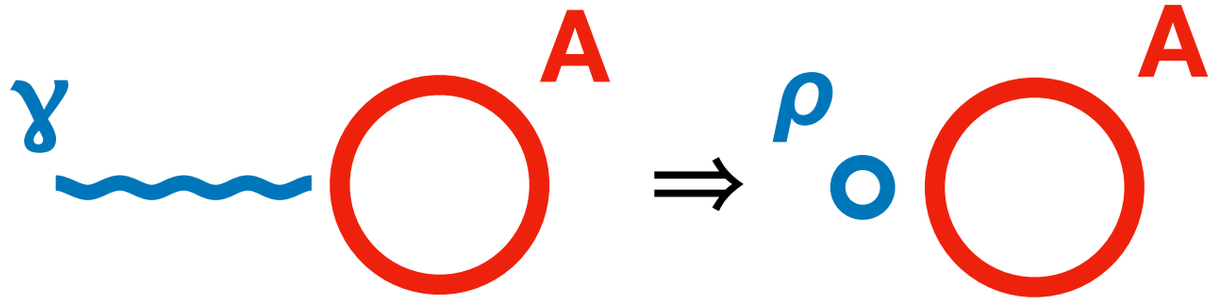
@ N_{ch} = 15:

$\langle E_\gamma \rangle$ ~ 30 GeV, $\sqrt{s}_{\gamma N}$ ~ 600 GeV

@ N_{ch} = 30:

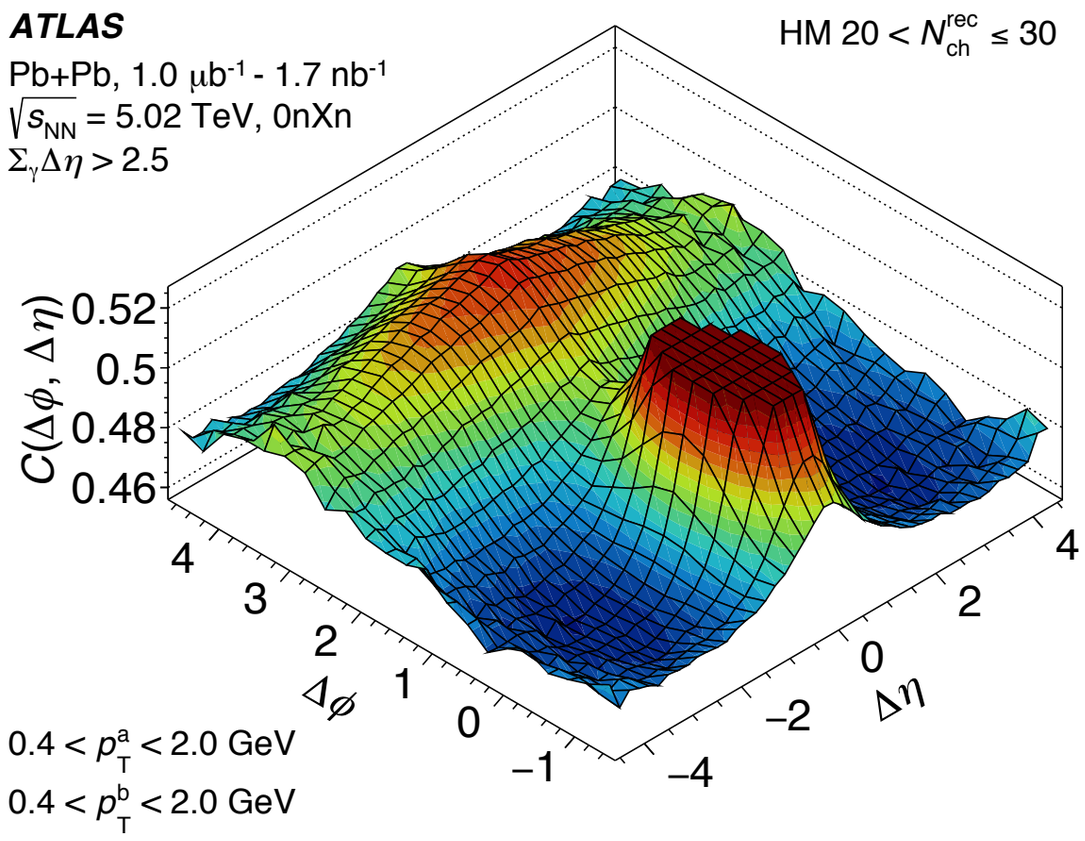
$\langle E_\gamma \rangle$ ~ 60 GeV, $\sqrt{s}_{\gamma N}$ ~ 800 GeV

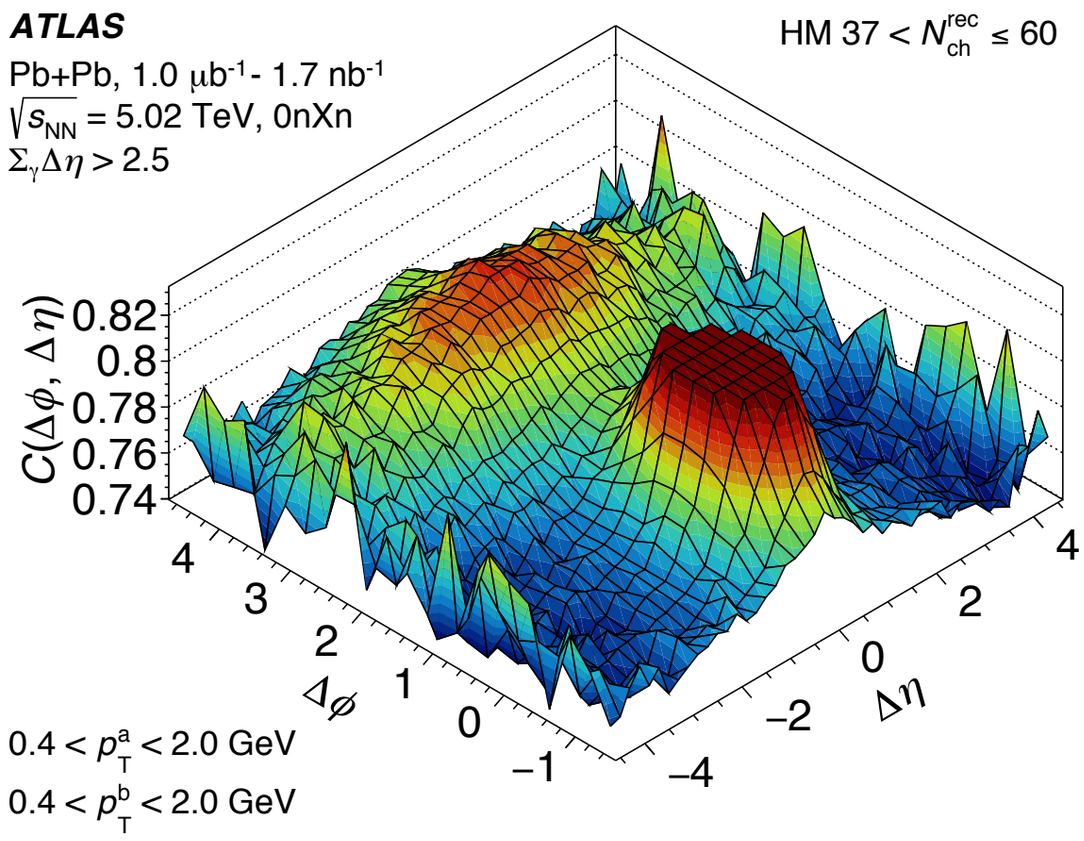
Vector Meson Dominance (VMD) paradigm - most of these proceed as, e.g., ρ+A interactions



Two-particle correlations in γ+A

"Standard" two-particle correlation analysis,
$p_T^{a,b}$ = 0.4-2 GeV, $|\Delta\eta| > 2$ between pairs





lower-multiplicity events *higher-multiplicity events*

Similar structures in 2-D correlation function as in hadronic collisions!

Δϕ modulation

ATLAS “template” method:

Assume non-flow contribution is similar at high- and low-multiplicities

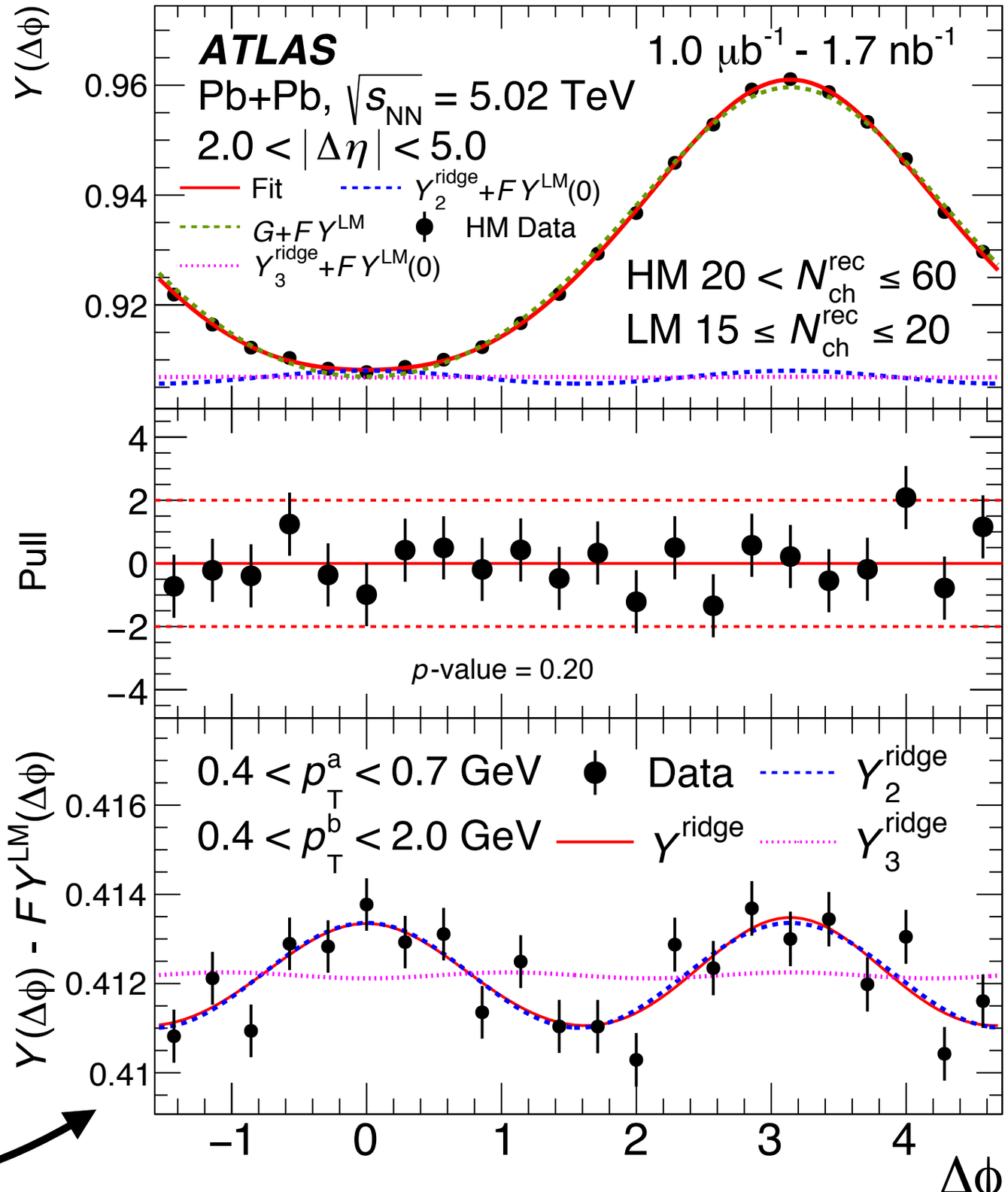
high-multiplicity Δϕ distribution

-

scaled low-multiplicity Δϕ distribution

=

reveal flow-like modulation of the bulk!

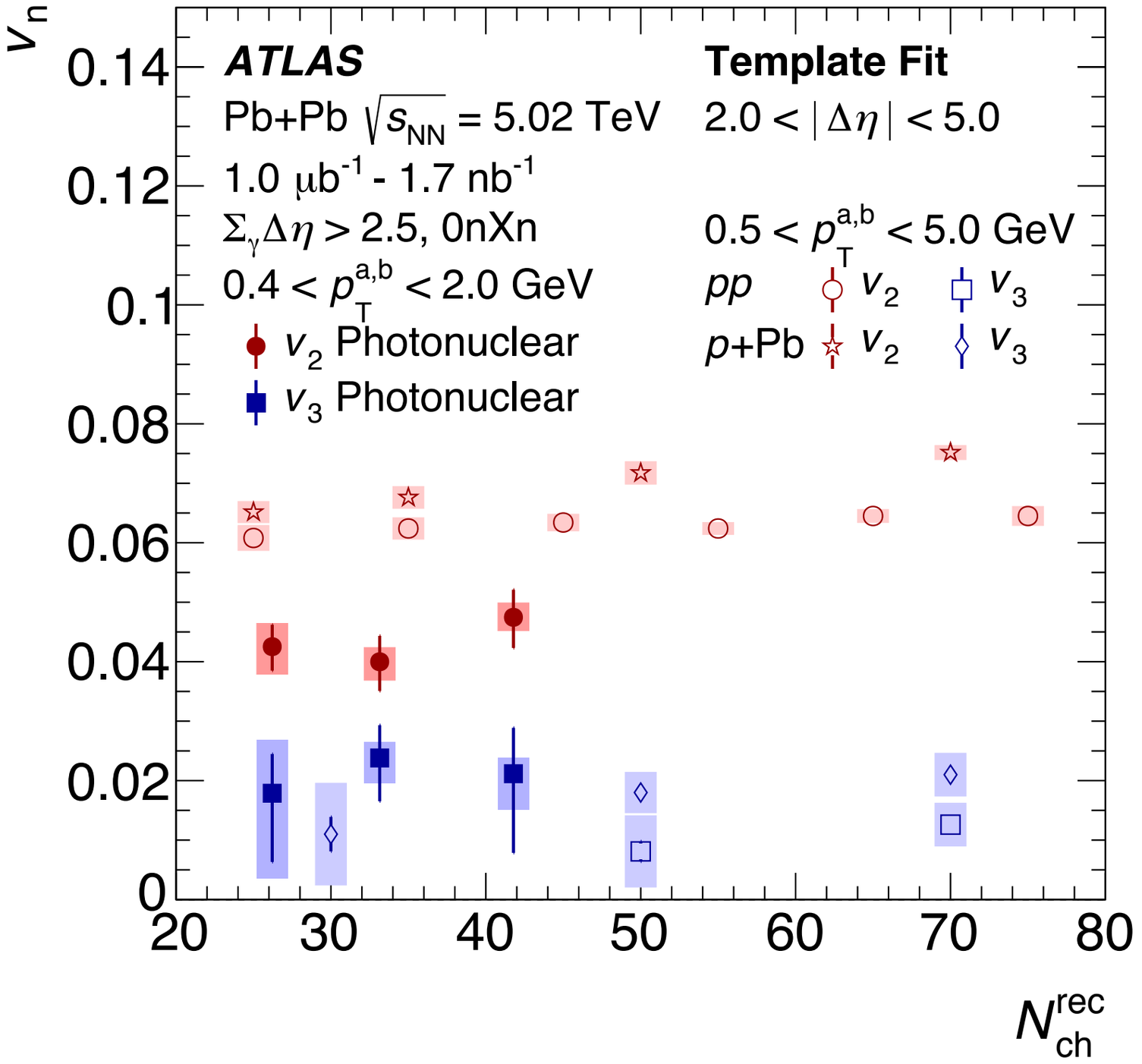


v_2 and v_3 vs. multiplicity

p_T-integrated v_2 of ~4%

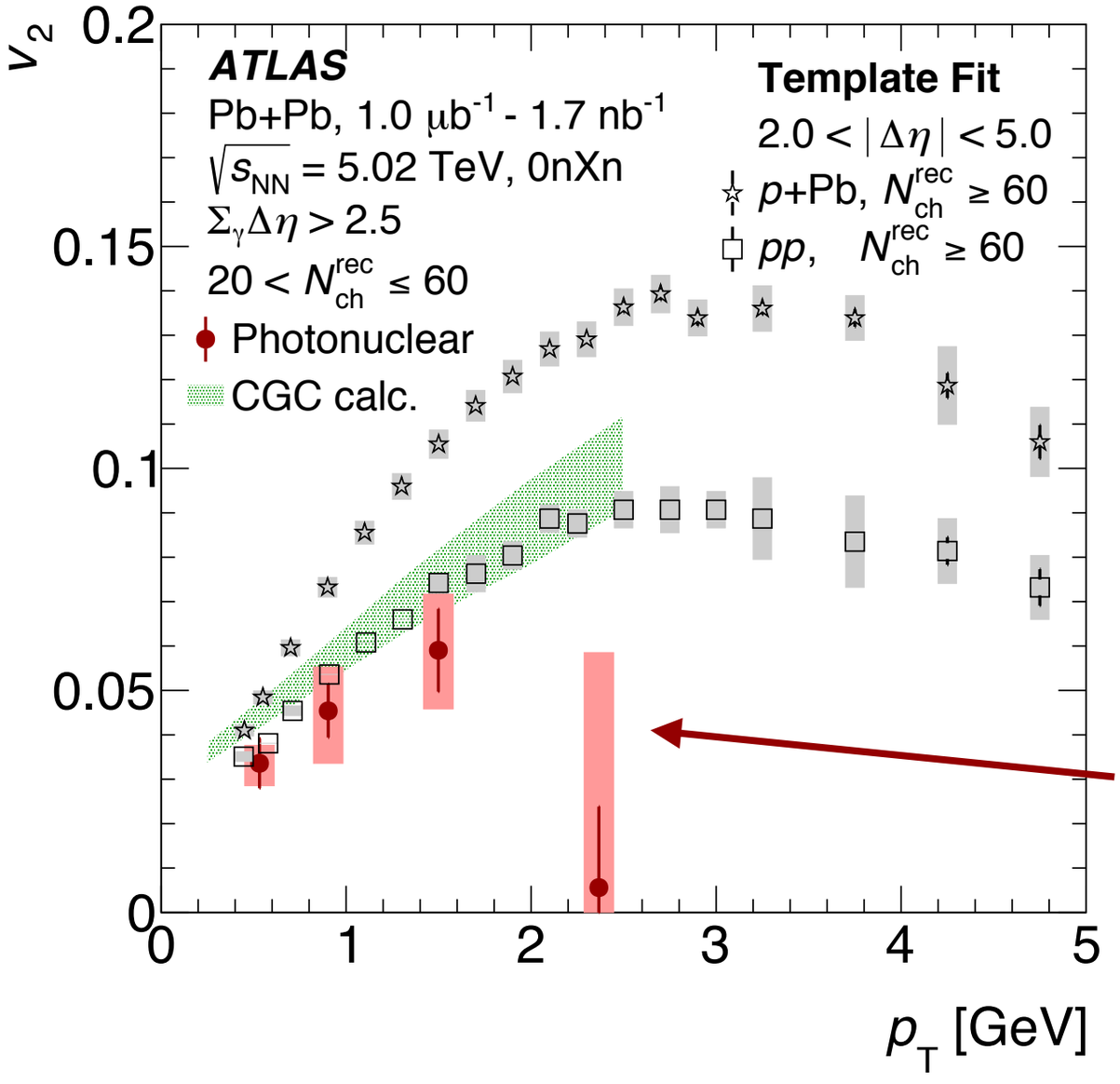
multiplicity-independent within uncertainties

lower than that in *pp* or *p*+Pb collisions



p_T-integrated v_3 of ~2% with significant uncertainties

v_2 vs. p_T



p+Pb

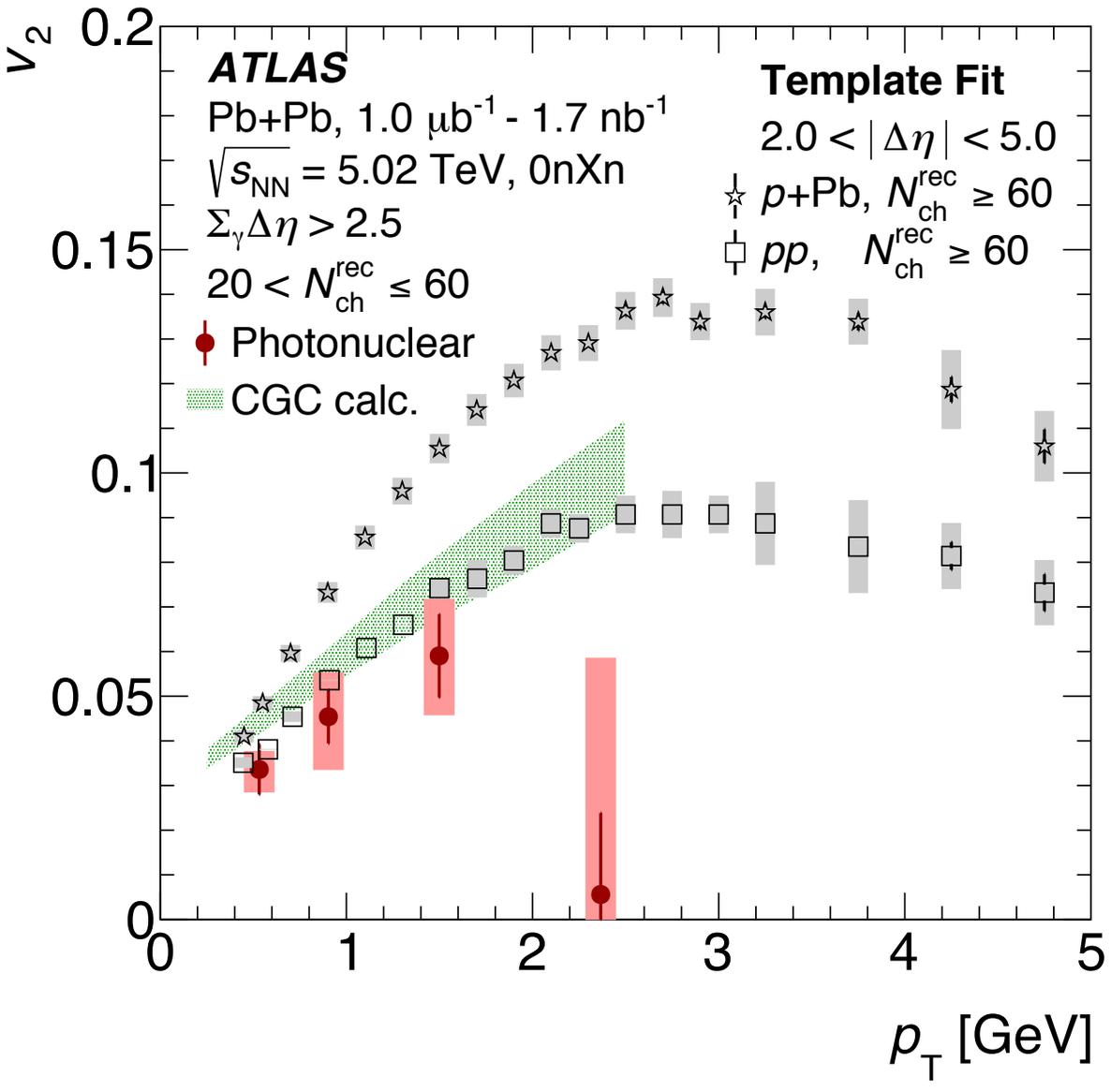
pp

γ+A

similar $v_2(p_T)$ as in pp, but within larger uncertainties

significantly smaller than in p+Pb

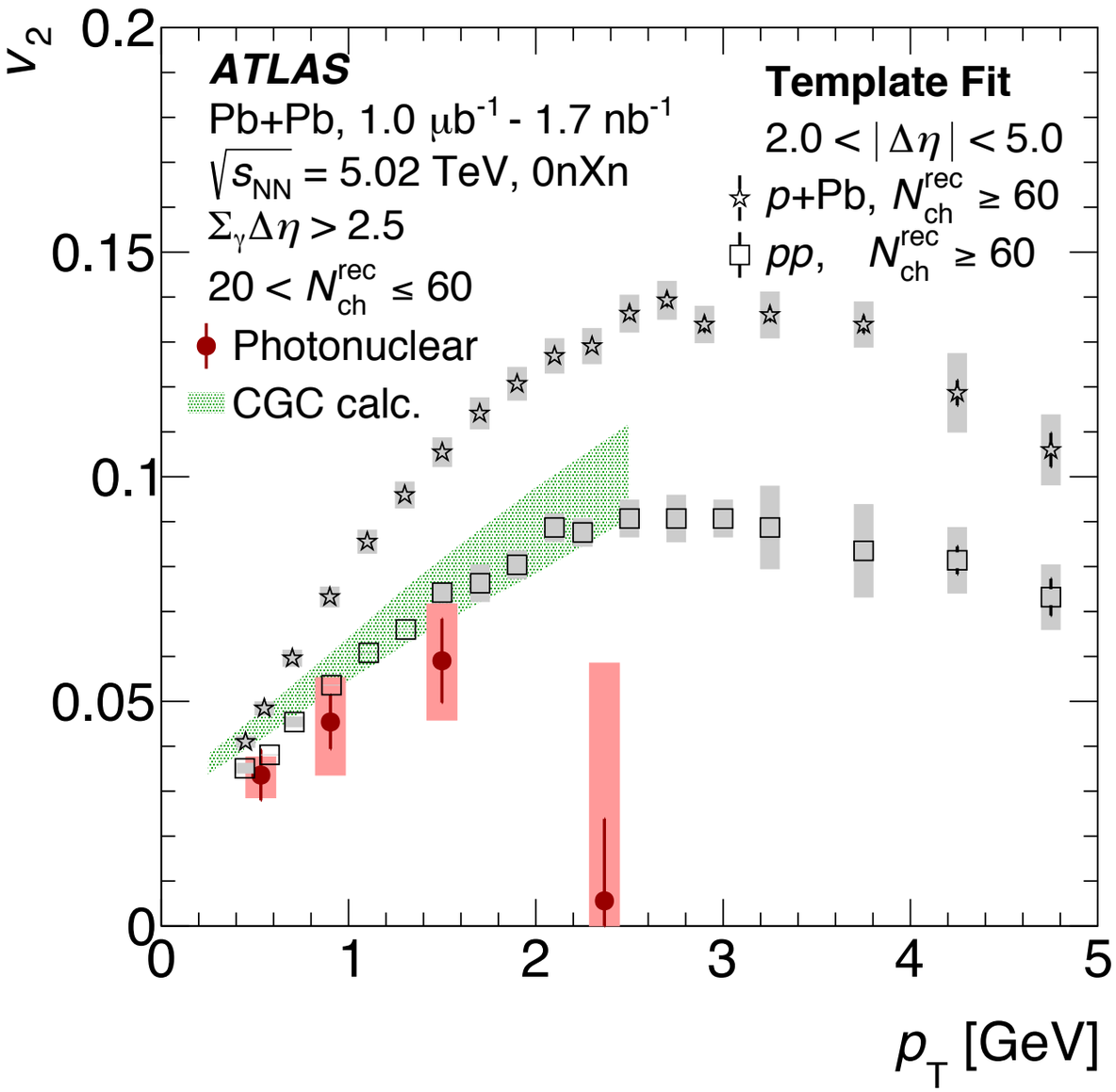
Model comparison - initial state



Paper claim: use ɣ+A as benchmark for **CGC signal** in EIC!

Shi et al., PRD 103, 054017 (2021)

Model comparison - initial state



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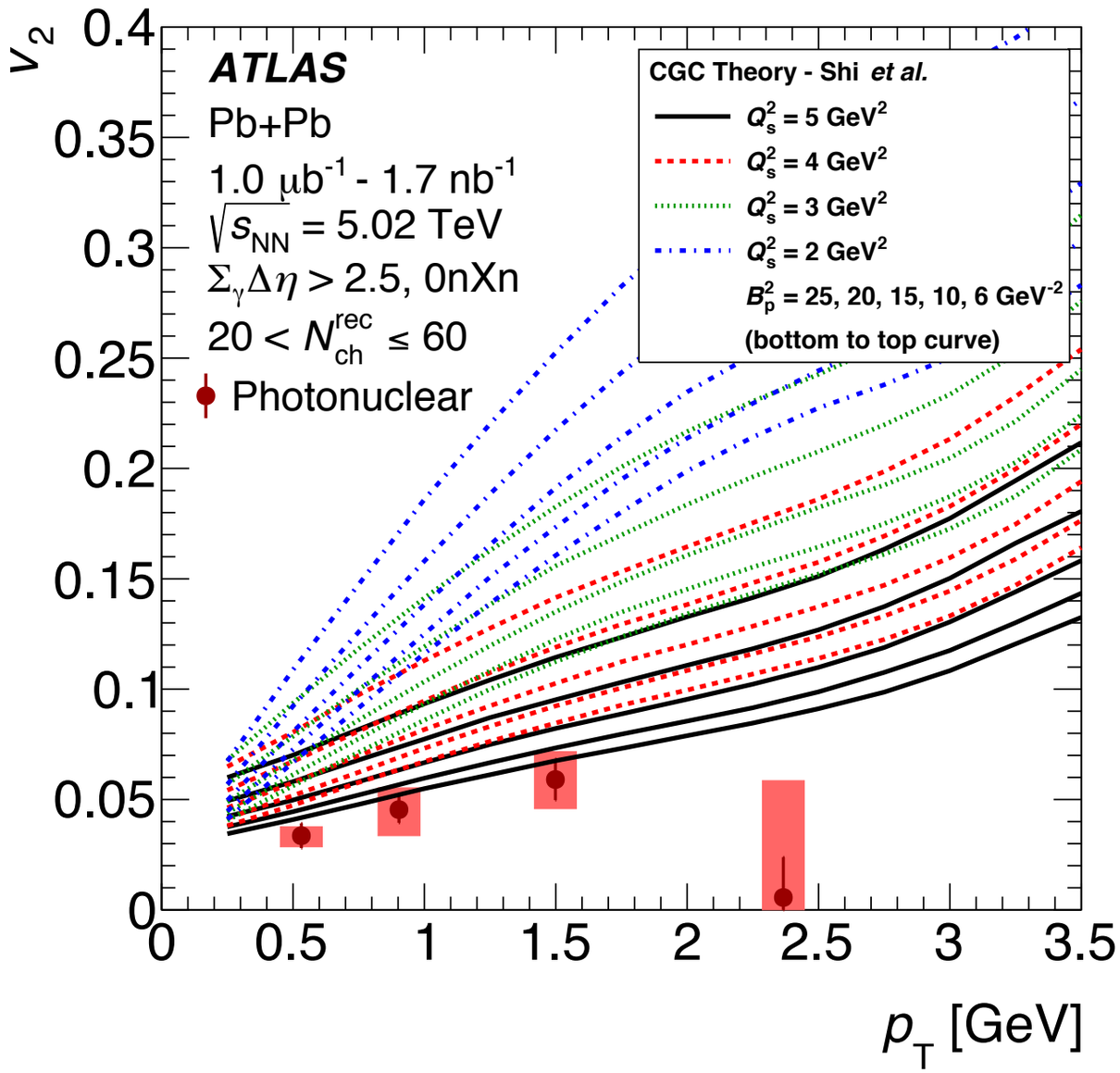
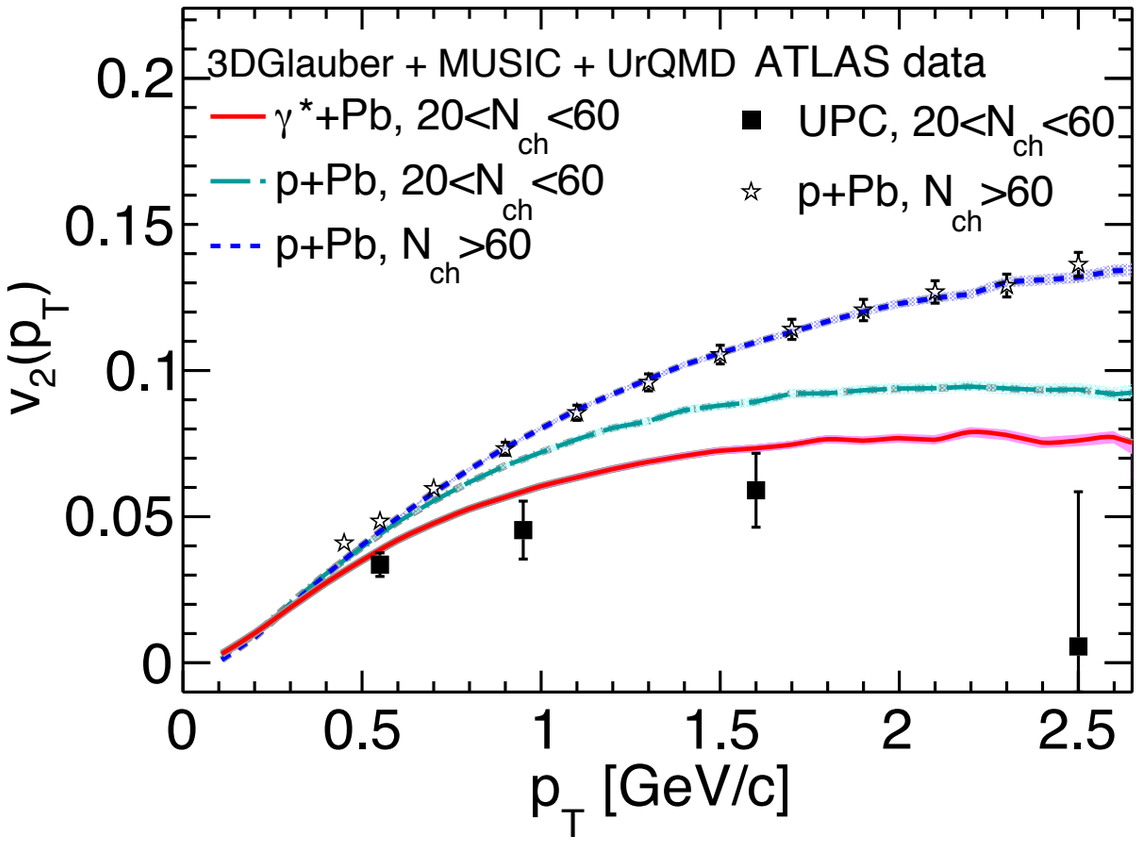


Predictions sensitive to Q_s^2 and B_p^2 - which are process dependent (e.g. HF flow).

How to constrain?

Model comparison - final state

Zhao, Shen, Schenke, nucl-th/2203.06094



Full (3+1)D dynamical simulation - important given extreme asymmetry of system!

Model comparison - final state

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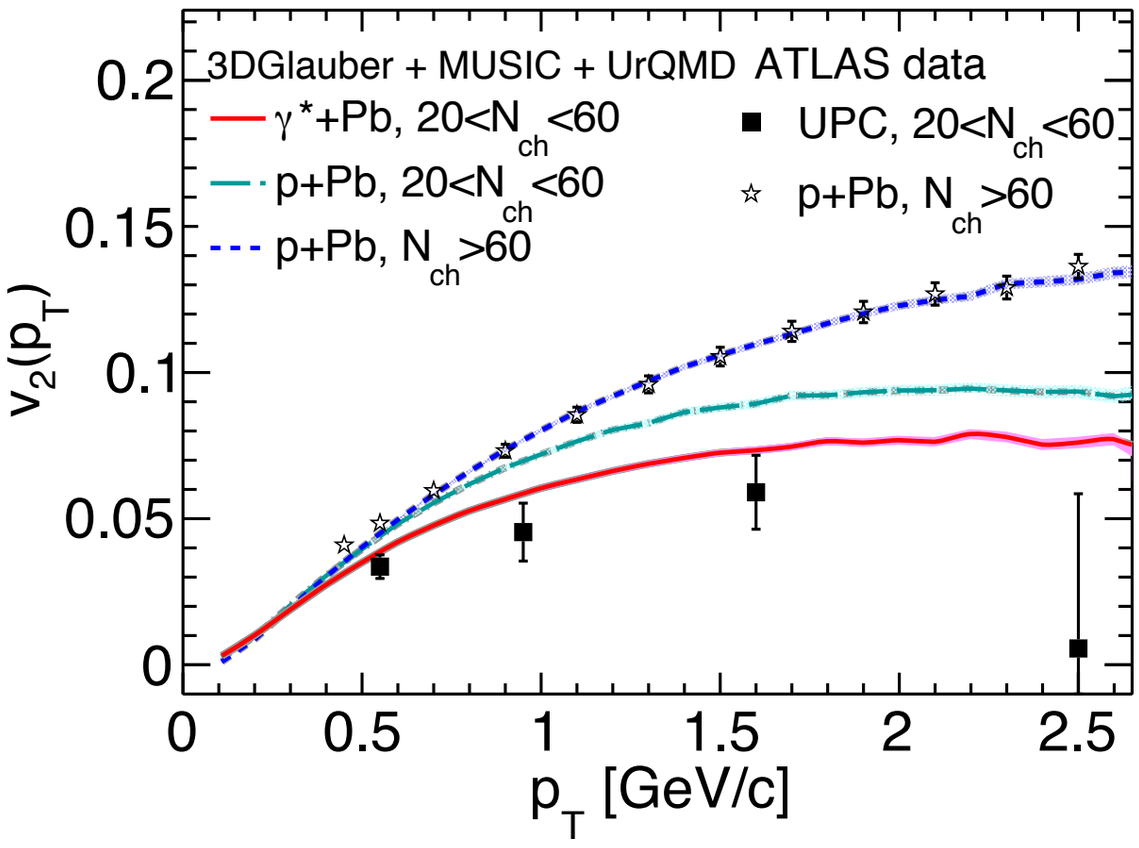


Full (3+1)D dynamical simulation - important given extreme asymmetry of system!

Paper claim: γ+Pb < *p*+Pb flow hierarchy from significantly *larger longitudinal decorrelation* & *large rapidity boost*

⇒ dial up photon Q^2 in model to predict EIC!

Note: single γ energy, ρ modeled with simple 2-constituent quark PDF

⇒ what are the impacts?

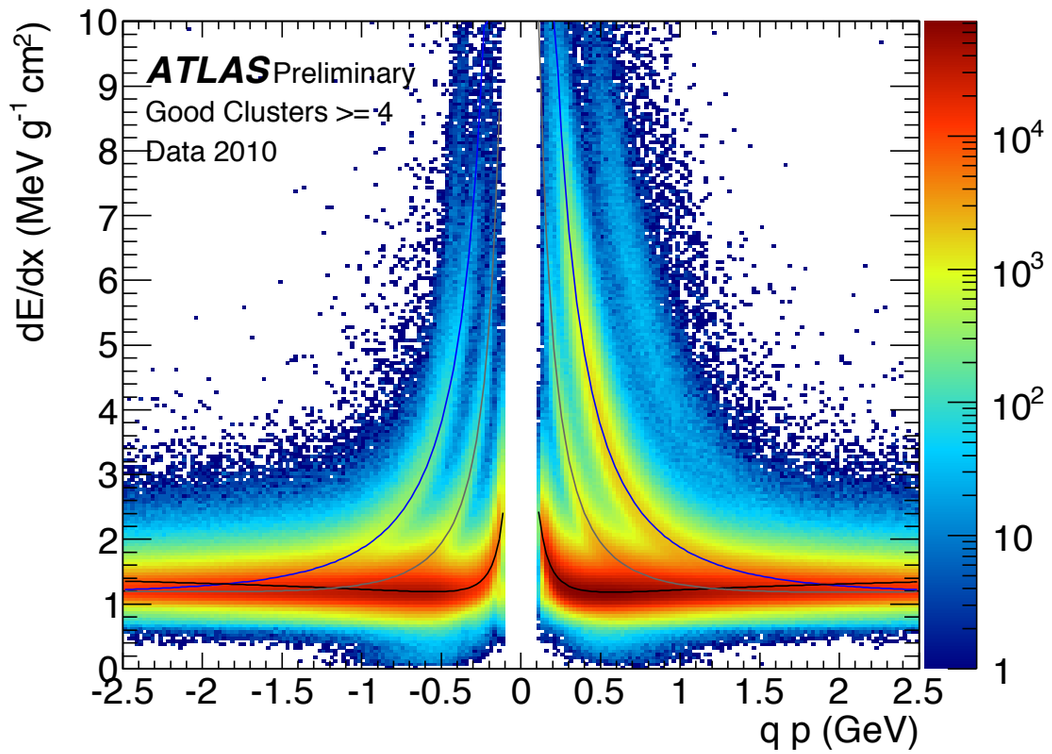
Next: γ+A chemistry?

Presence of strong final-state interactions?

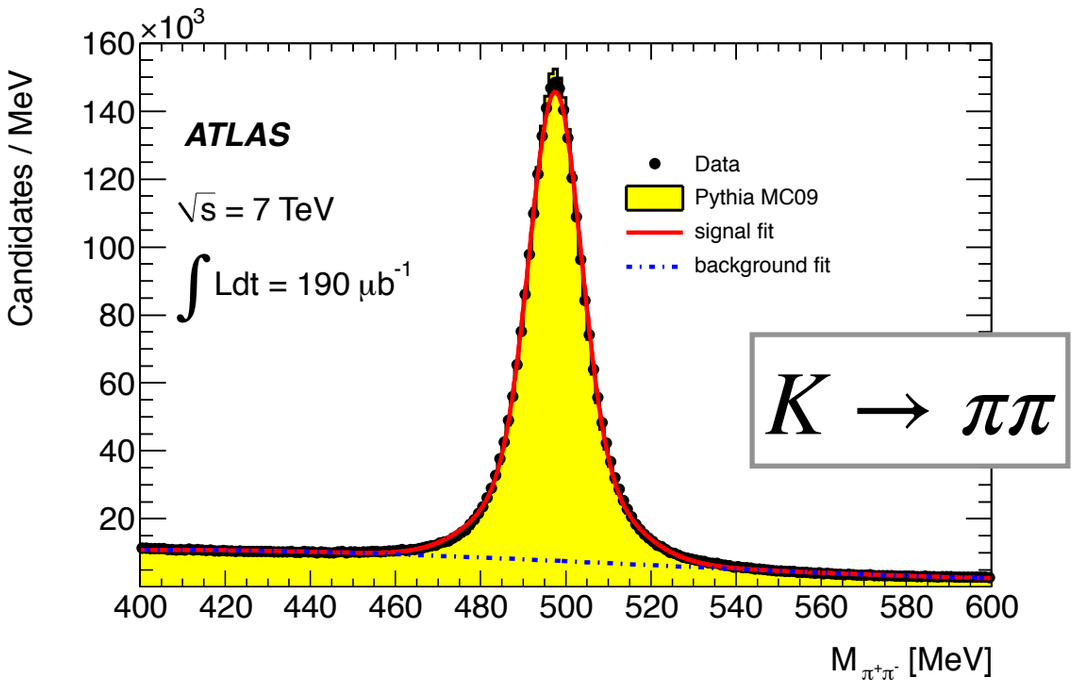
$\Longrightarrow$ study identified particle production!

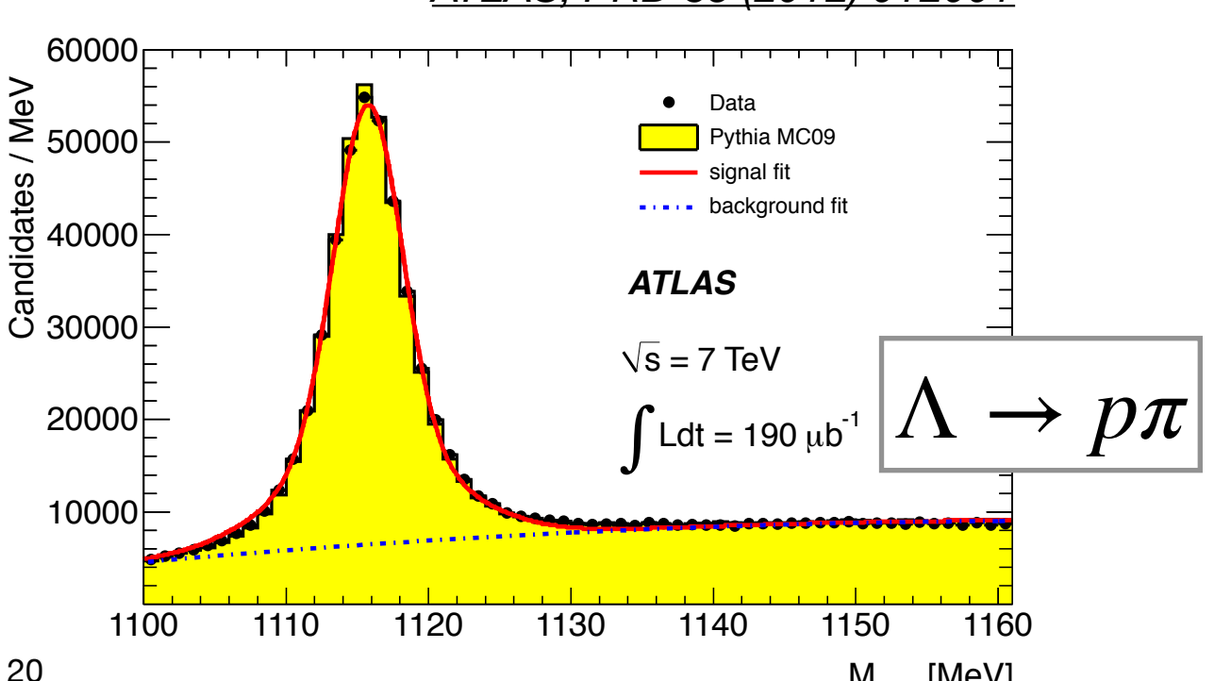
ATLAS has ample capabilities for this

ATLAS-CONF-2011-016



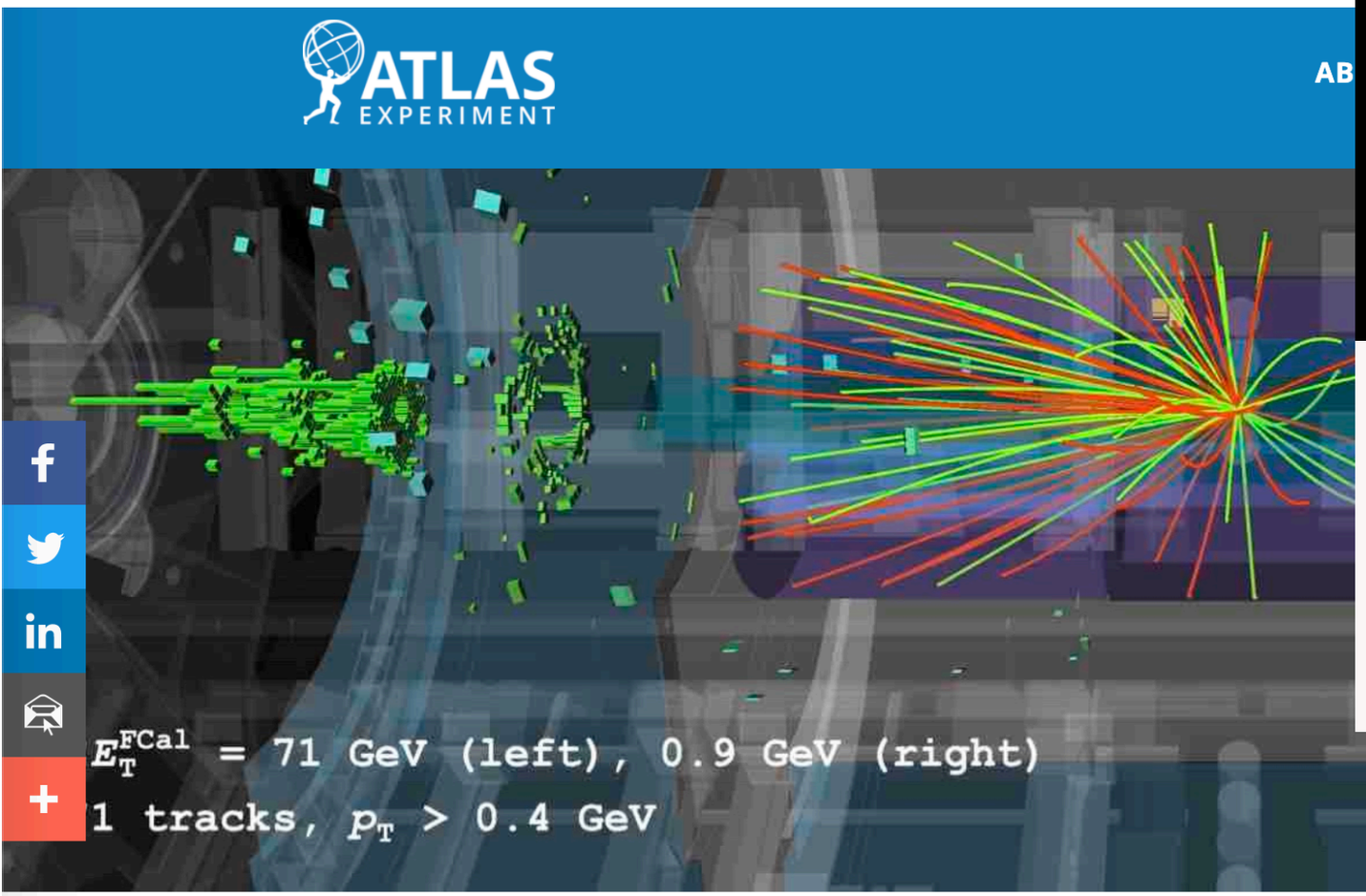
ATLAS, PRD 85 (2012) 012001

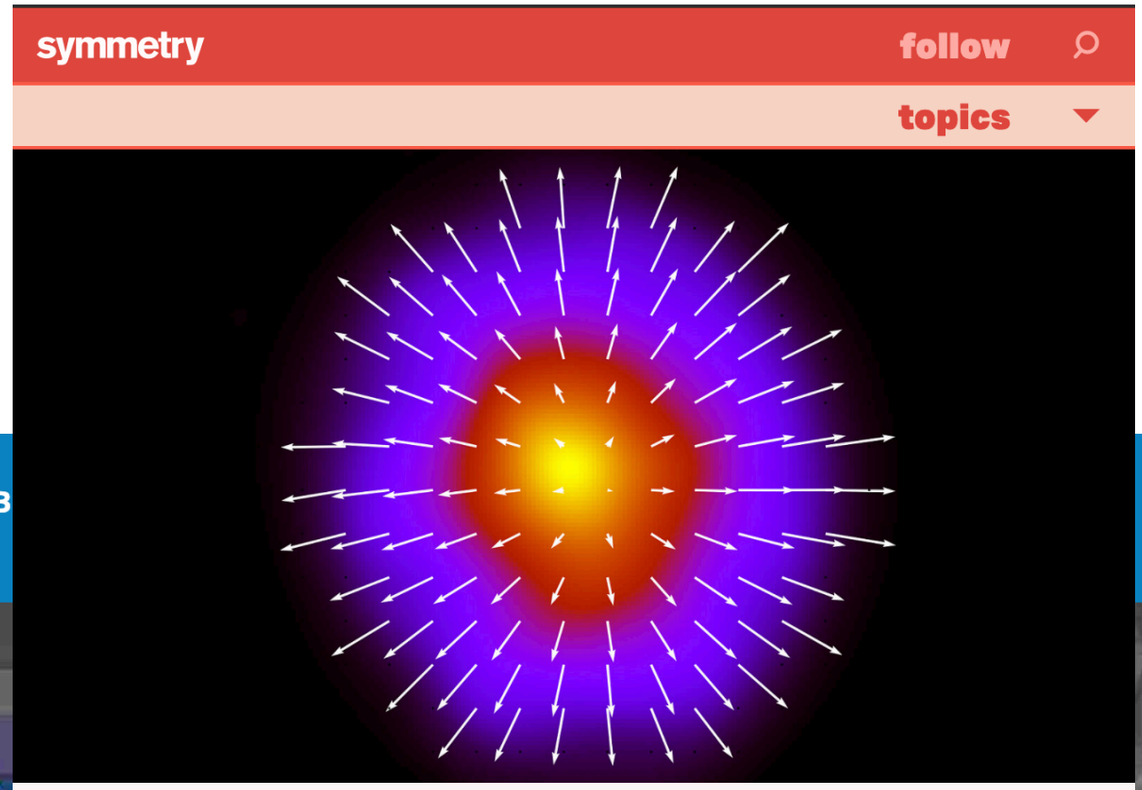




Thank you - Dziękuję!

PRC 104 (2021) 014903 or
ATLAS Results Page





Courtesy of Christopher Plumberg

Can light melt atoms into goo?

08/24/21 | By Sarah Charley

The ATLAS experiment at CERN sees possible evidence of quark-gluon plasma production during collisions between photons and heavy nuclei inside the Large Hadron Collider.

Feedback

Updates > Briefing > Studying “Little Bangs”: exotic collisions probe the size of quark-gluon plasma

Physics Briefing

Tags:
heavy ion,
physics results

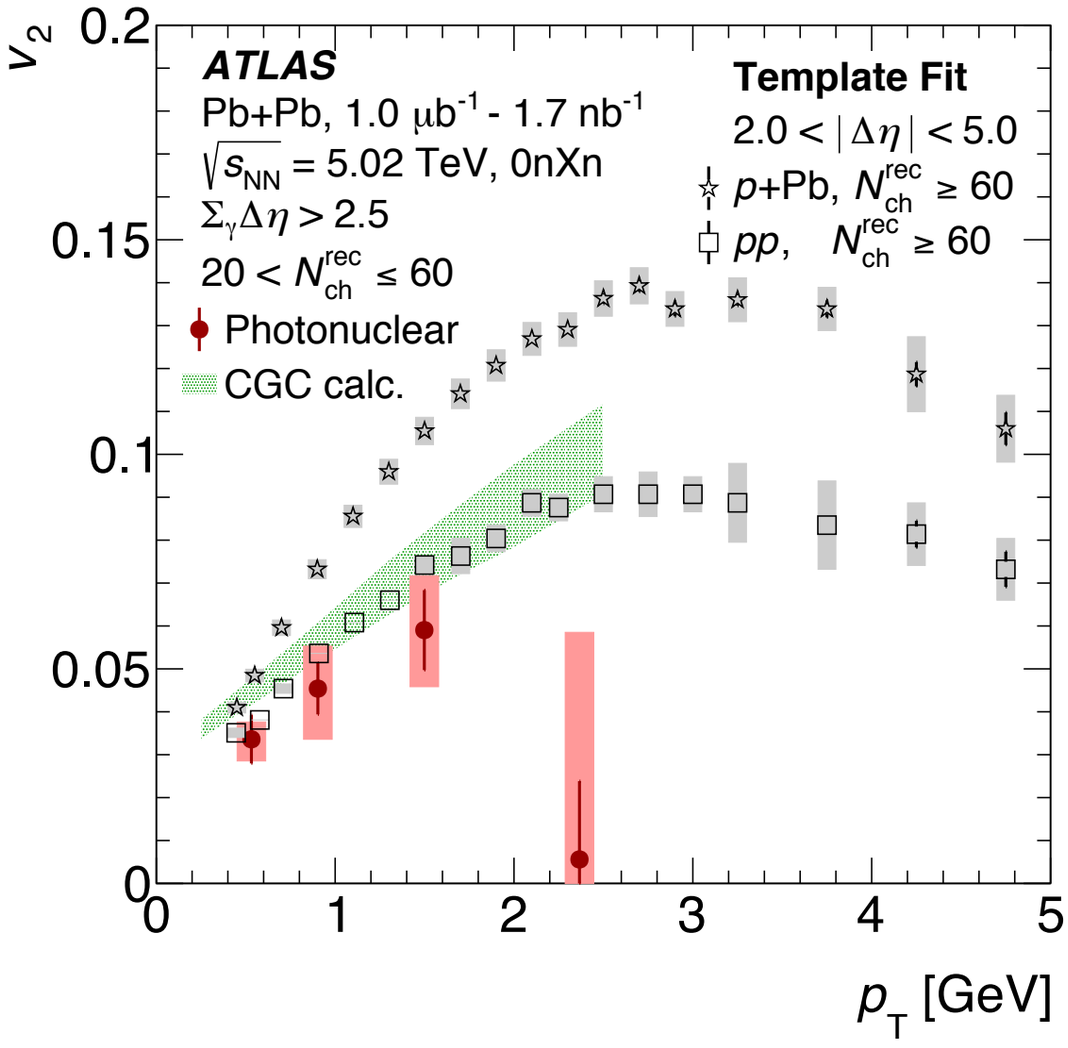
Studying “Little Bangs”: exotic collisions probe the size of quark-gluon plasma

13th July 2021 | By ATLAS Collaboration

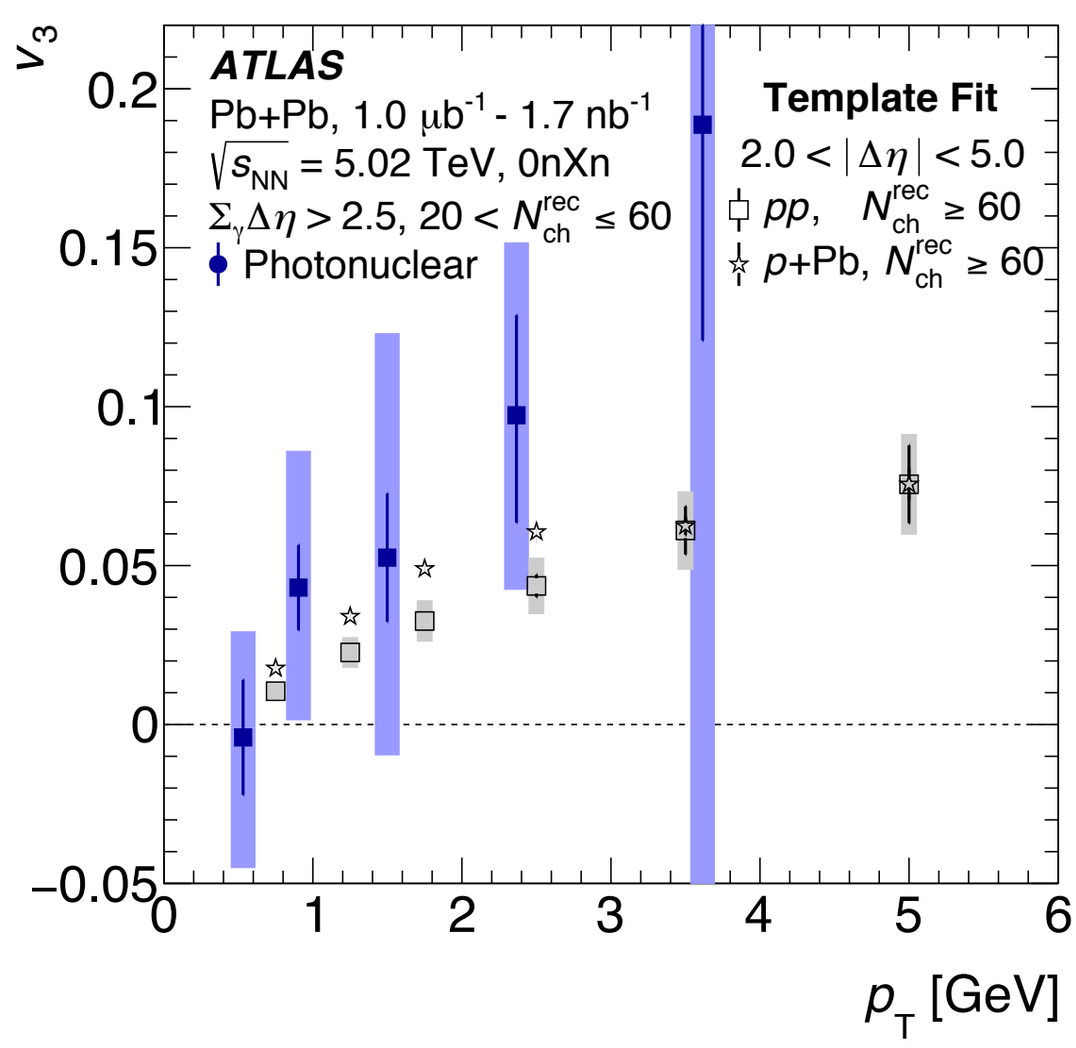
RESEARCH CORPORATION *for* SCIENCE ADVANCEMENT

backup

v_2 and v_3 vs. p_T

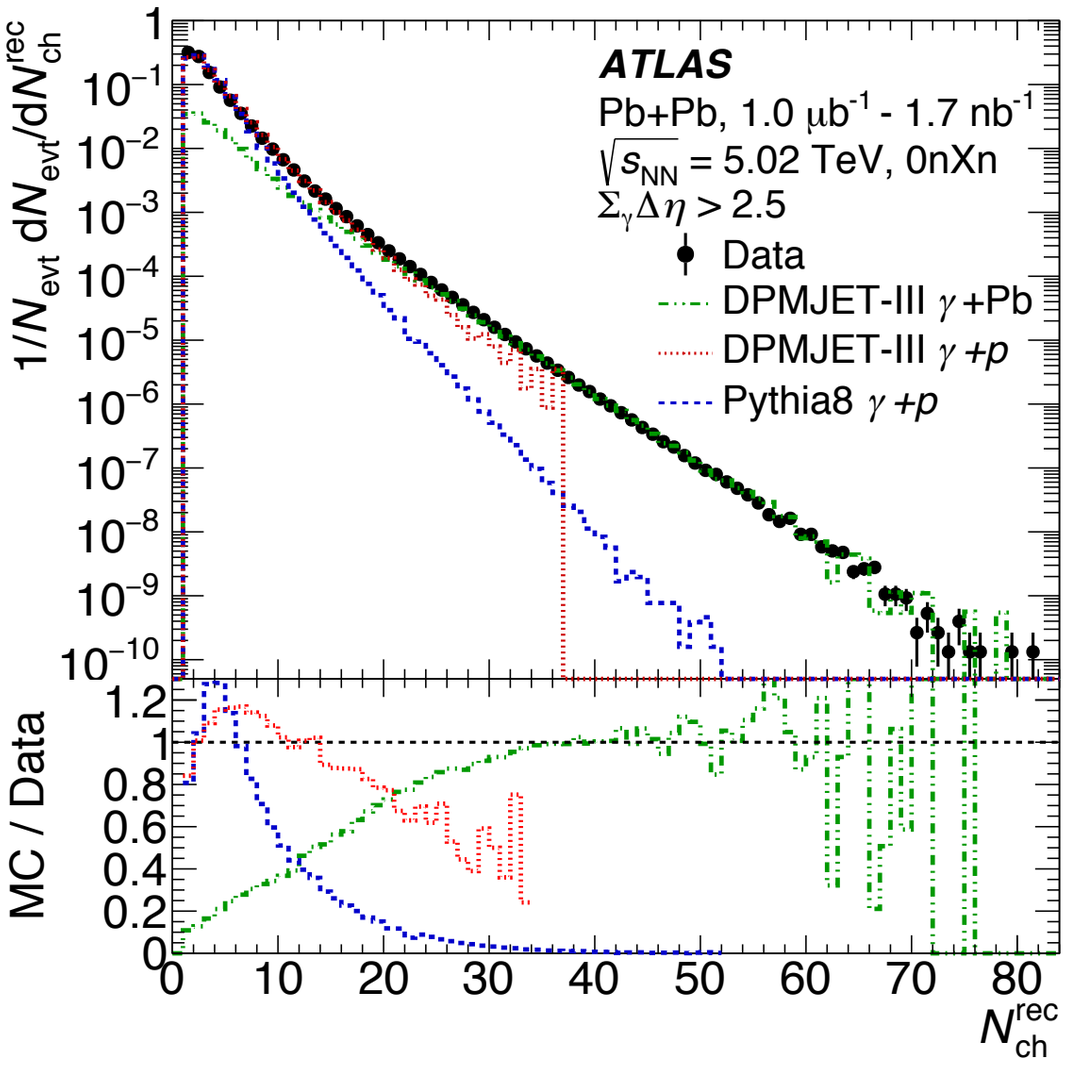


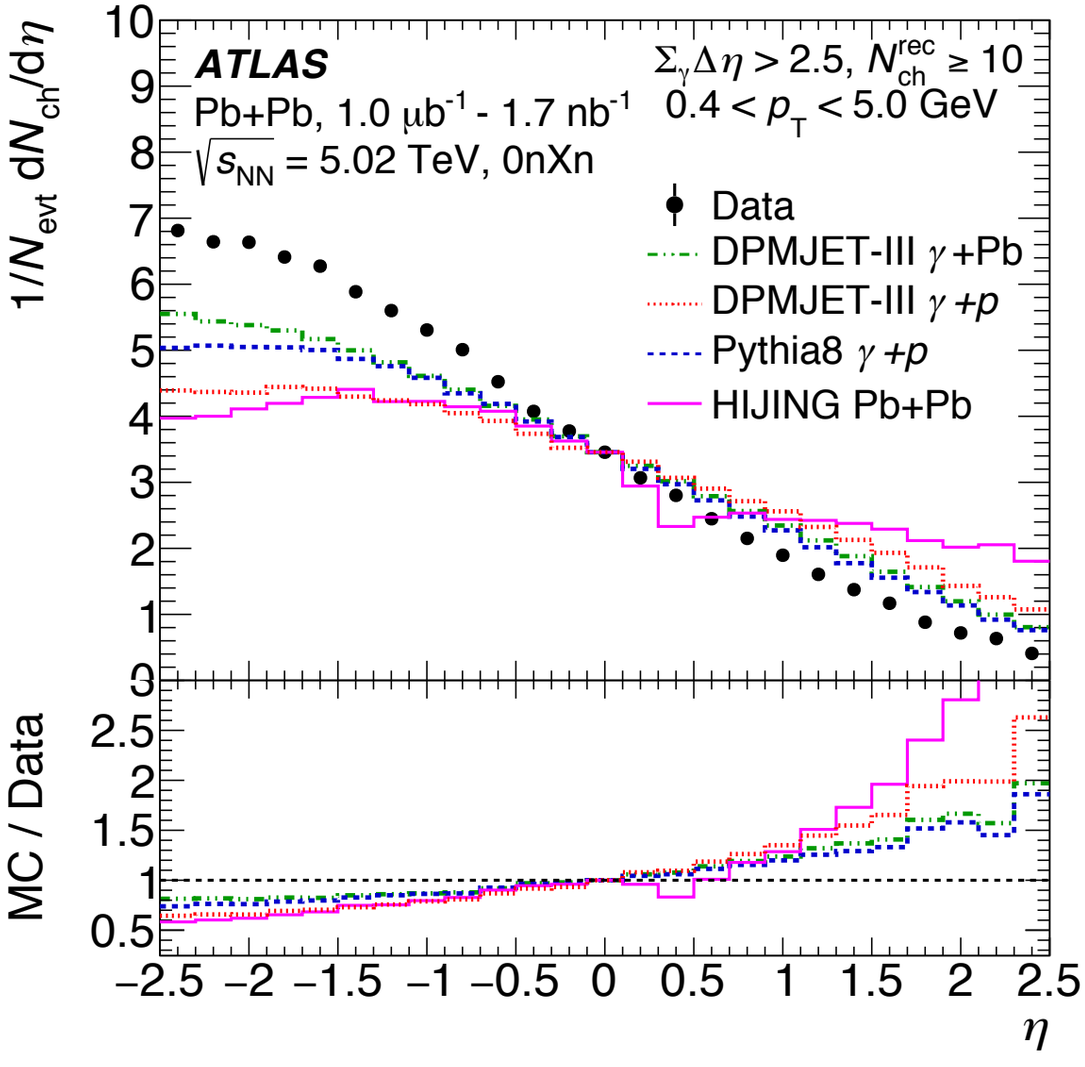
similar $v_2(p_T)$ as in pp, but within significant uncertainties



only weak constraint on $v_3(p_T)$

Data/MC comparisons

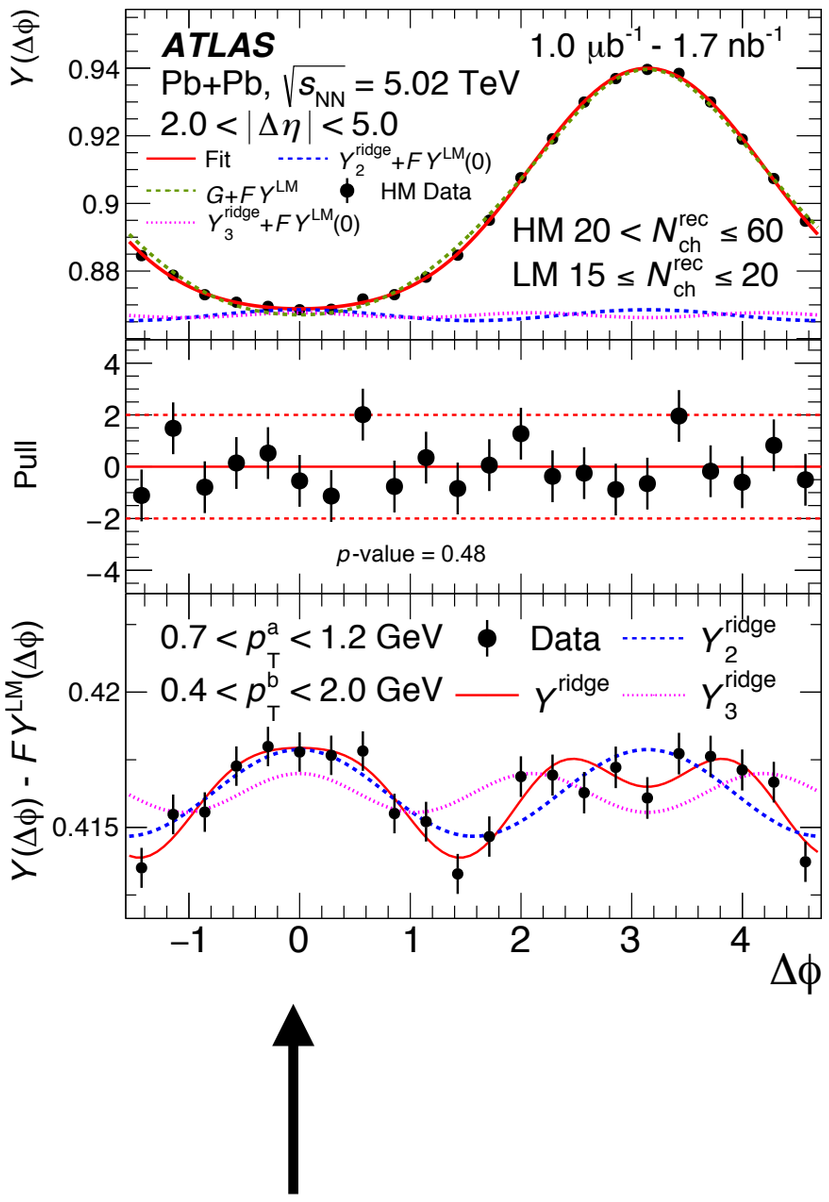


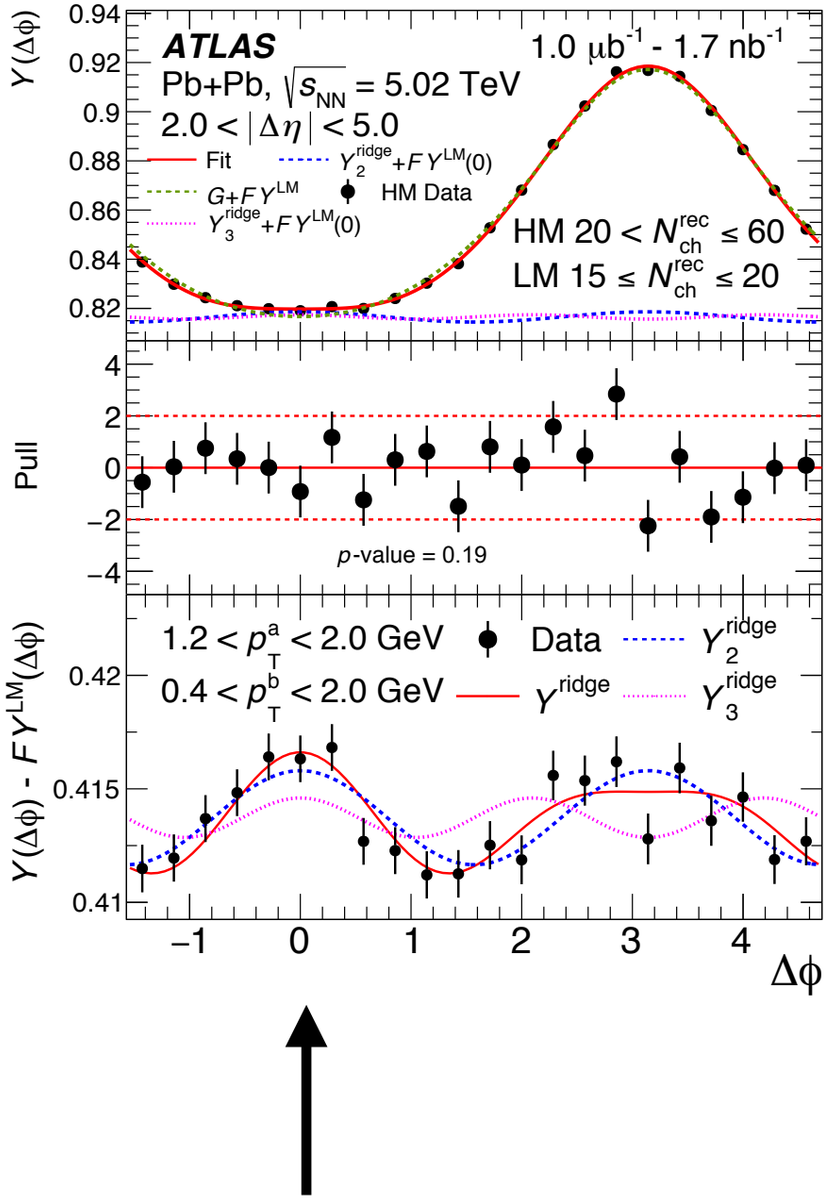


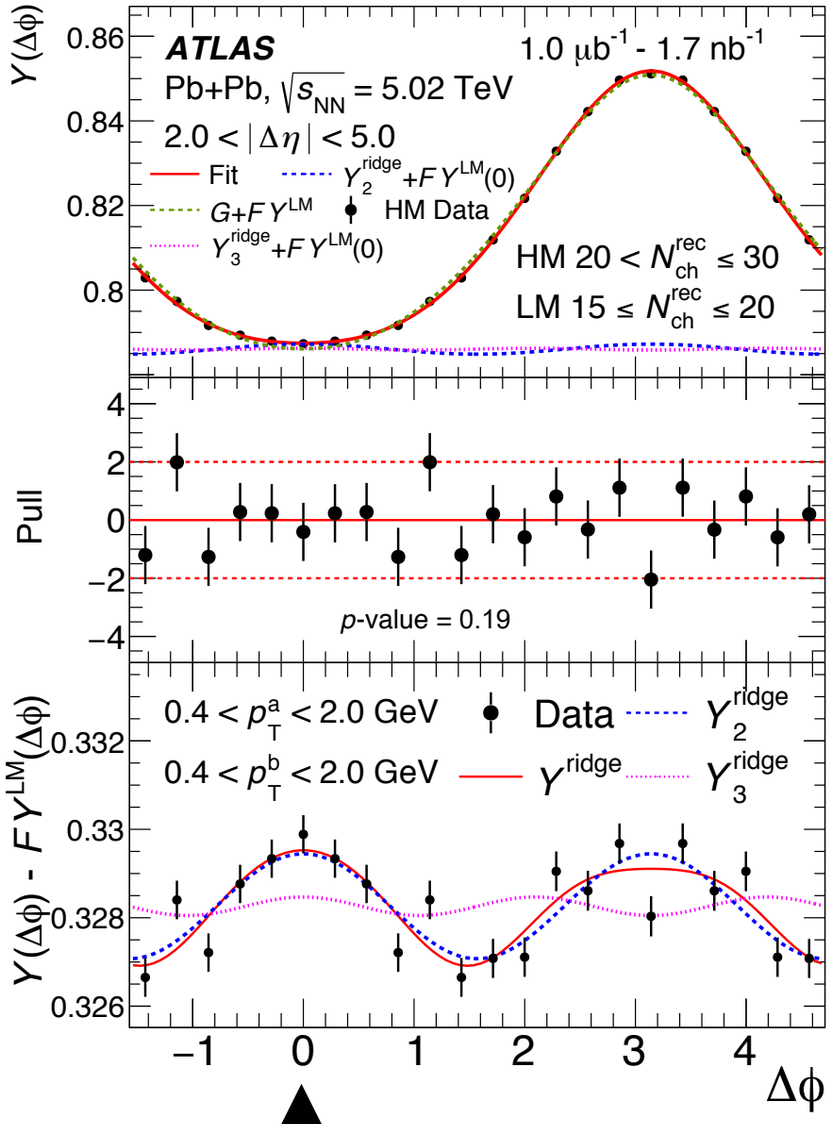
Comparison of multiplicity distribution (left) and normalized dN/dη distribution (right) to **DPMJET ɣ+*p***, **DPMJET ɣ+A**, **PYTHIA ɣ+*p***

Input for our theory colleagues to model these interesting collisions!

Δϕ modulation - more examples







After careful non-flow subtraction, see robust signal of a near-side ridge!