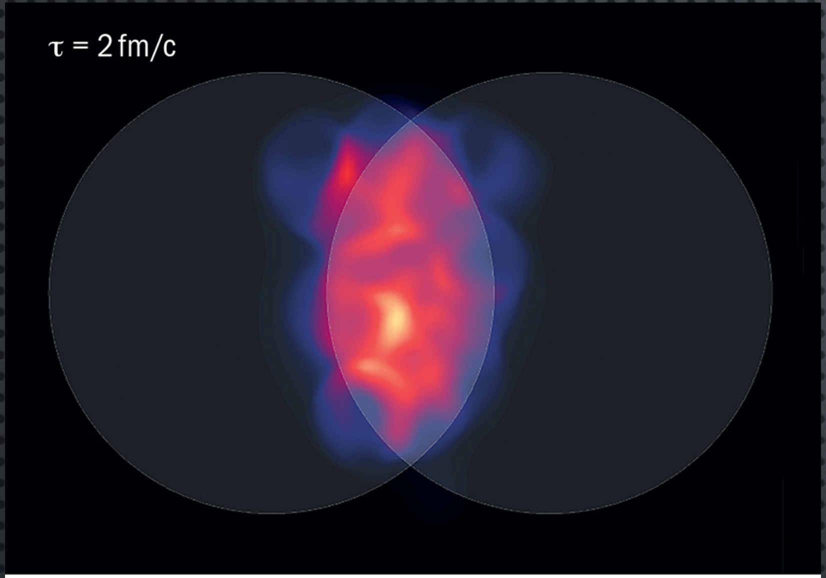
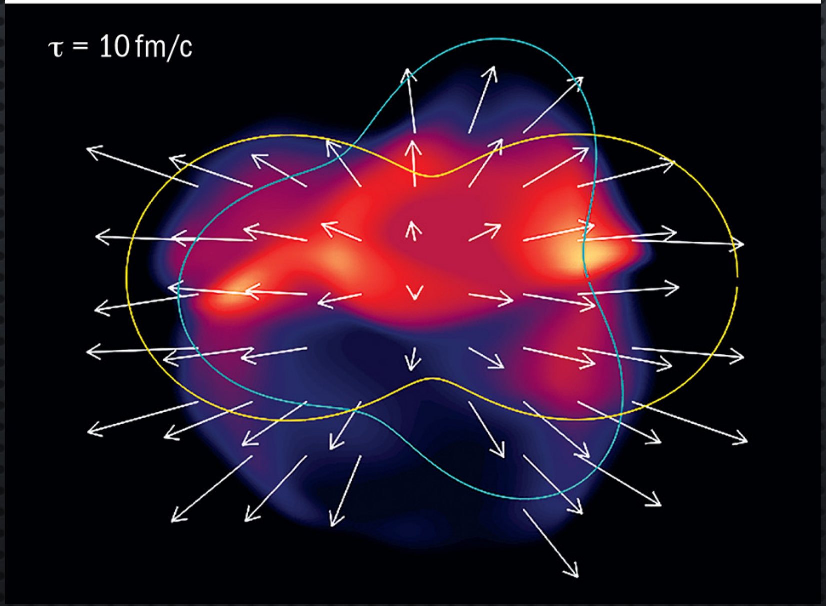
Longitudinal decorrelation measurements from pp to A+A with the ATLAS detector

Jamie Nagle, University of Colorado Boulder

20th International Conference on Strangeness in Quark Matter
13-17 June 2022 Busan, Republic of Korea

Flow in Heavy Ion Collisions





Spatial geometry of the initial state translates into momentum anisotropy in the final state

How does this picture translate from large systems (e.g., PbPb, AuAu, XeXe) to small systems (e.g., pp, pPb, OO)?

What about a full 3-dimensional picture?

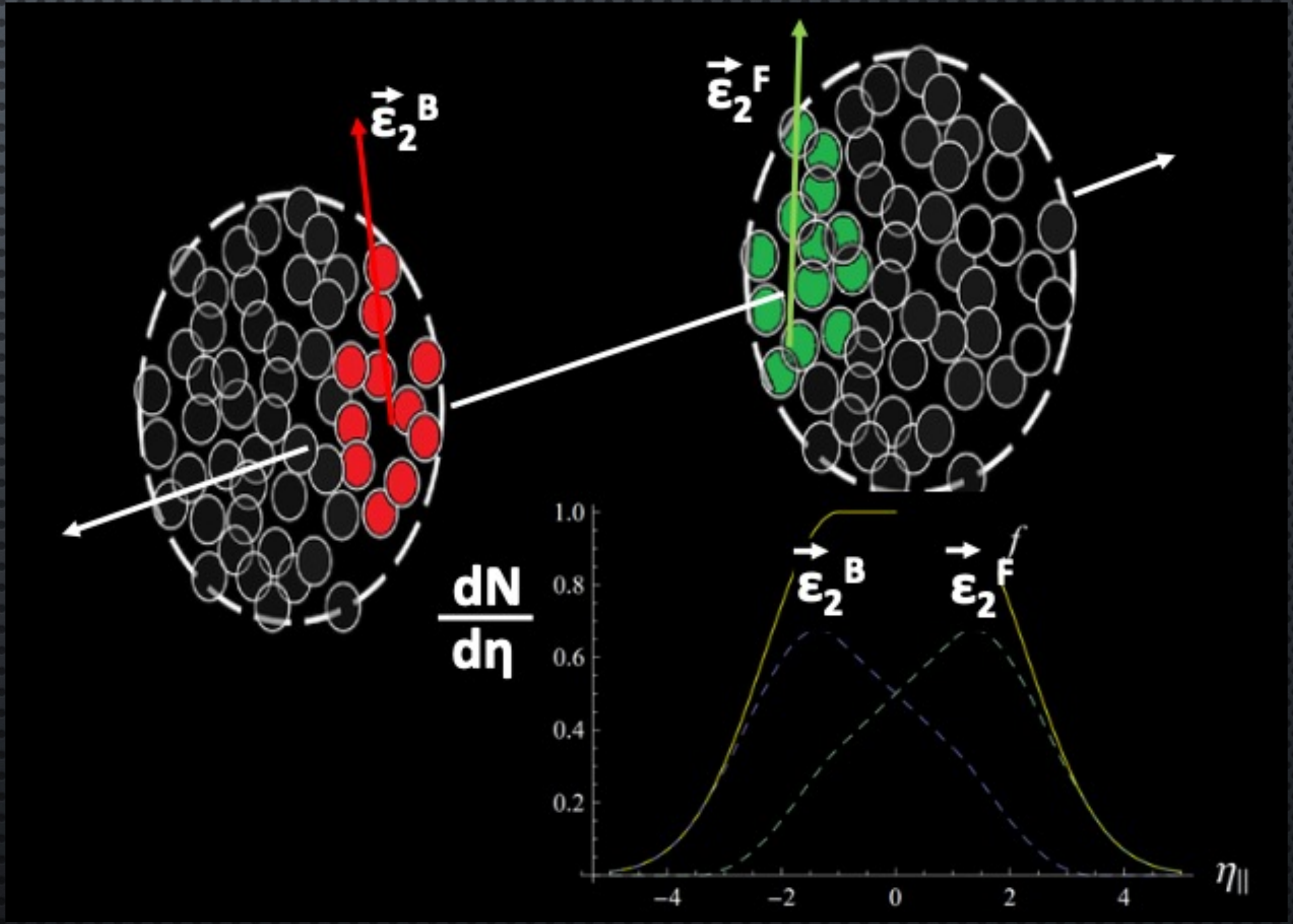
https://cerncourier.com/a/going-with-the-flow/

Pseudorapidity dependent geometry

Torqued fireballs in relativistic heavy-ion collisions

Piotr Bożek,[1,2,*] Wojciech Broniowski,[1,3,†] and João Moreira[4,‡]
[1] *The H. Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, PL-31342 Kraków, Poland*
[2] *Institute of Physics, Rzeszów University, PL-35959 Rzesz ow, Poland*
[3] *Institute of Physics, Jan Kochanowski University, PL-25406 Kielce, Poland*
[4] *Centro de Física Computacional, Department of Physics, University of Coimbra, 3004-516 Coimbra, Portugal*
(Dated: 15 November 2010)

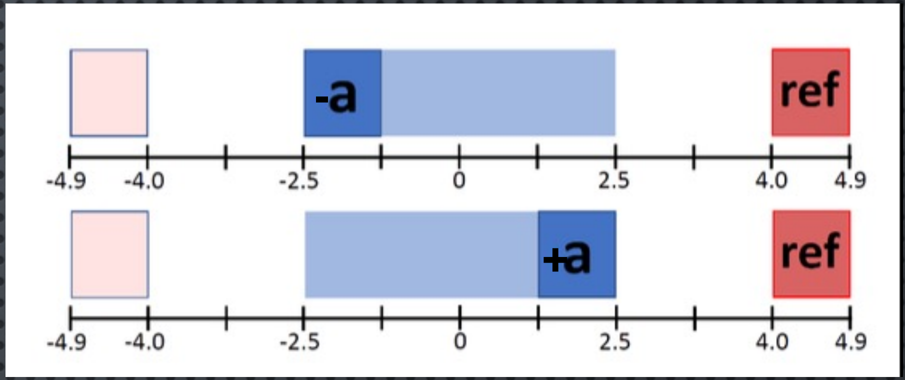
Phys.Rev.C 83 (2011) 034911, e-Print: 1011.3354 [nucl-th]



Can we constrain the initial deposition of energy in both the transverse and longitudinal directions?

How to quantify?

Measure two-particle correlations between particle pairs (**-a** and **ref**) and (**+a** and **ref**)

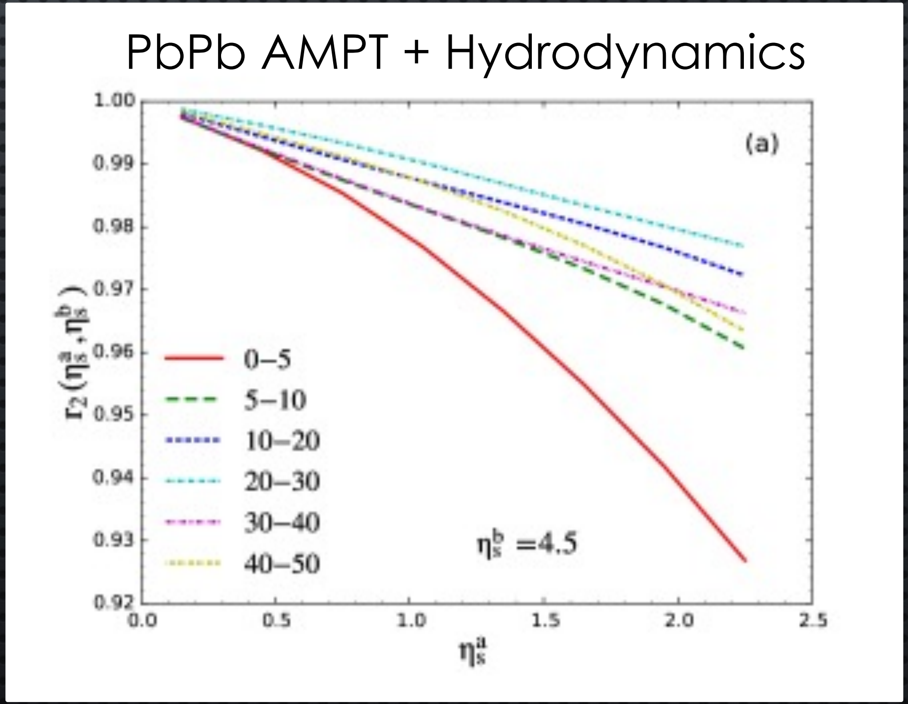


Calculate ratio of Fourier coefficients as r_n

$$r_n(|\eta^a|) = \frac{v_{nn}(-|\eta^a|)}{v_{nn}(|\eta^a|)}$$

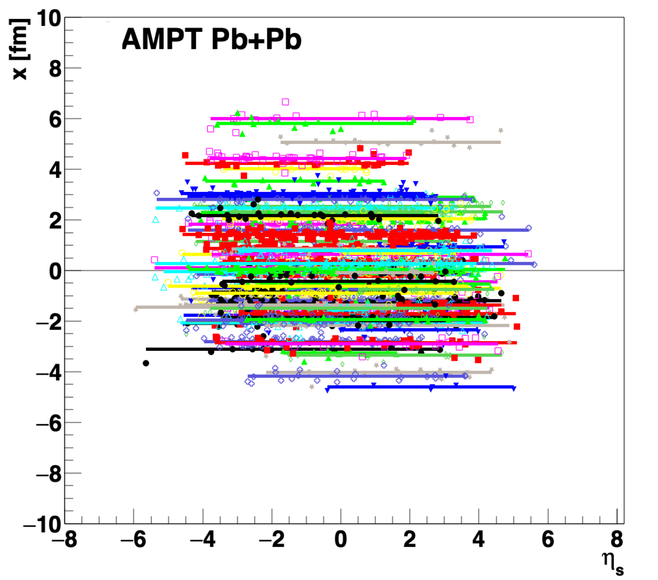
Then calculate the “linear” slope F_n

$$r_n(|\eta^a|) = 1 - 2F_n|\eta^a|$$



Xiang-Yu Wu, Long-Gang Pang, Guang-You Qin, and X-N Wang
Phys. Rev. C **98**, 024913

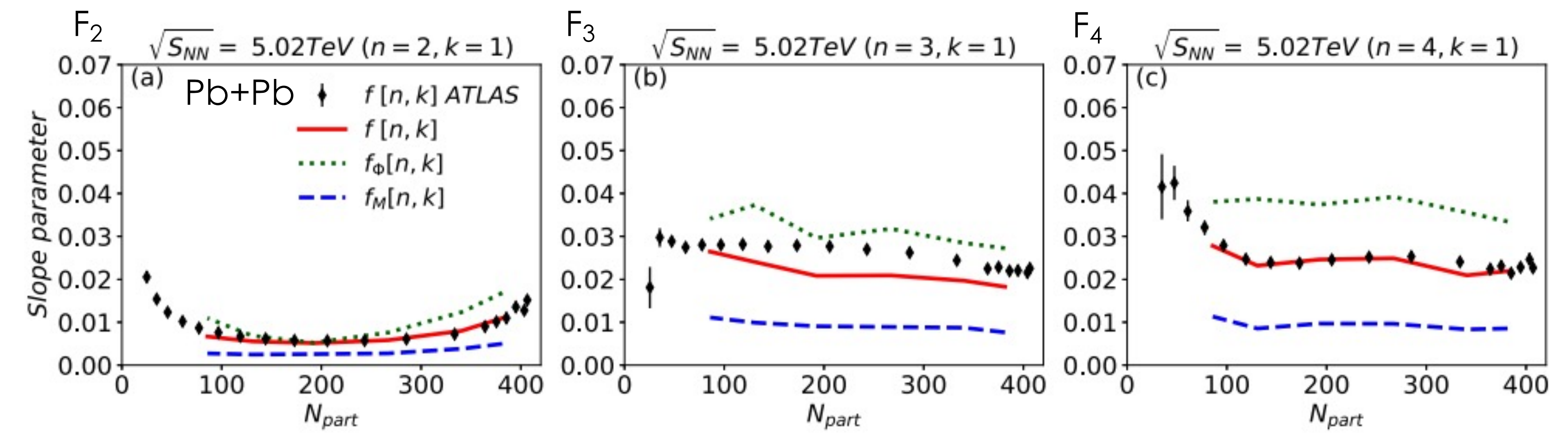
Pb+Pb: ATLAS Data and Theory



η-dependent geometry from strings in AMPT
Decorrelation via ϕ (direction) and M (magnitude) and both together

Reasonable agreement with ATLAS measurement!

* Note that this is not the overall decorrelation, but the relative decorrelation between (**-a** and **ref)** & (**+a** and **ref**)



https://link.springer.com/article/10.1140/epjc/s10052-018-5605-7

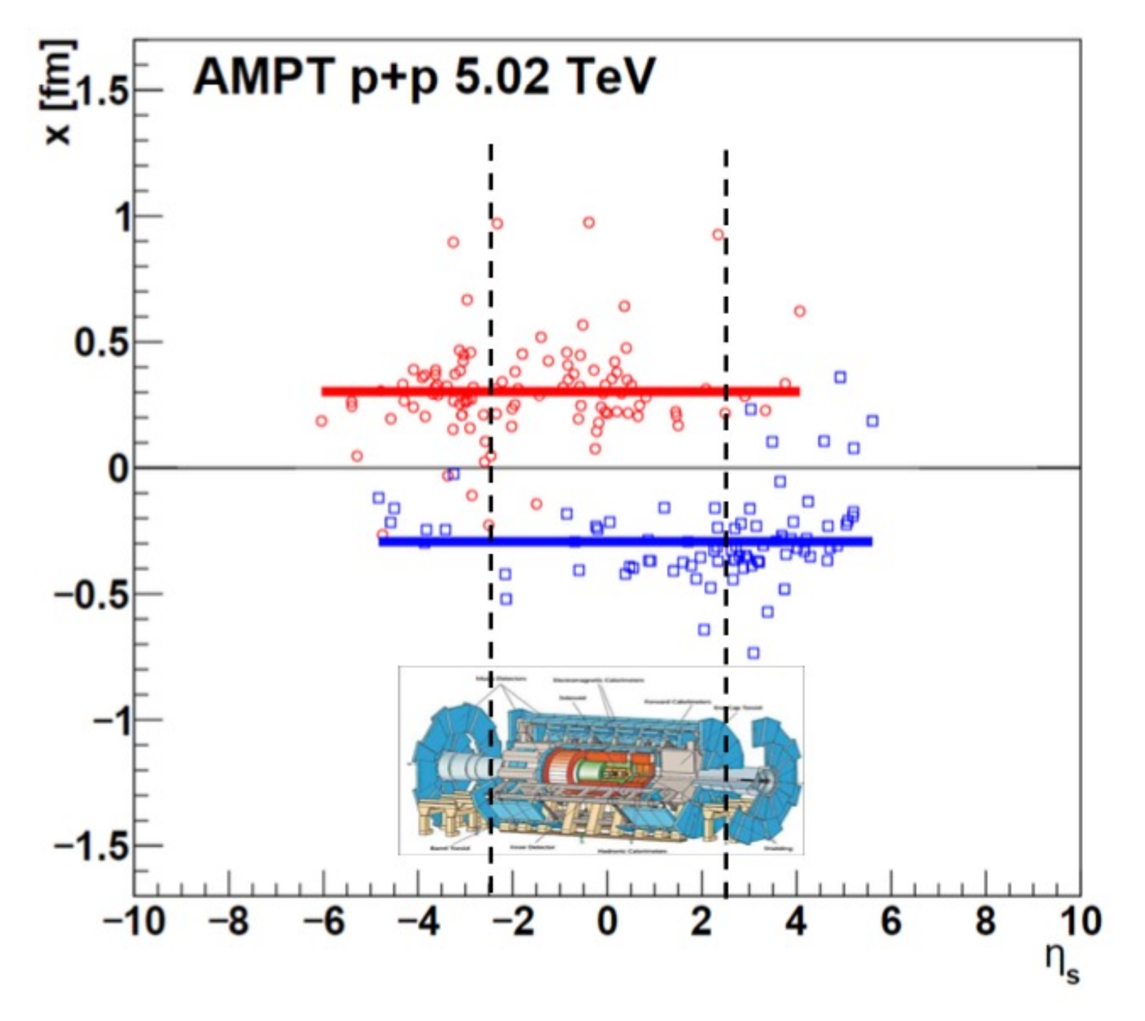
What about smaller systems?

Single string per participant produces a simple geometry in pp collisions

One can have large geometry variations with pseudorapidity due to fluctuations in the initial partons emitted

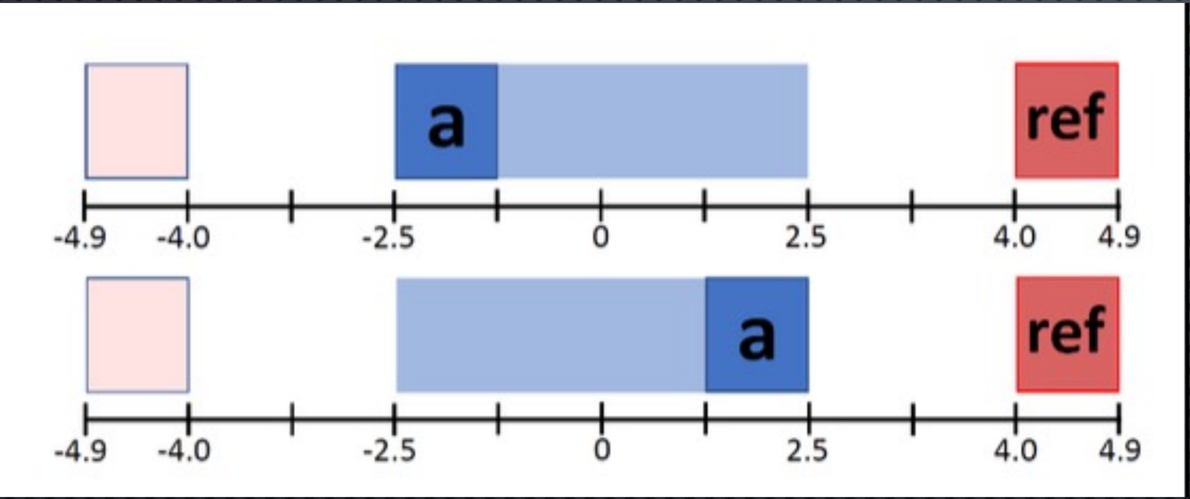
However, the relative decorrelation between (**-a** and **ref)** & (**+a** and **ref**) will be the same and hence $F_n \cong 0$

Nice, testable prediction.



ATLAS Analysis

ATLAS Data Sets:
pp 13 TeV, pp 5.02 TeV, XeXe 5.44 TeV



a-objects are reconstructed charged tracks
ref-objects are calorimeter clusters (pp) and calorimeter towers (XeXe)

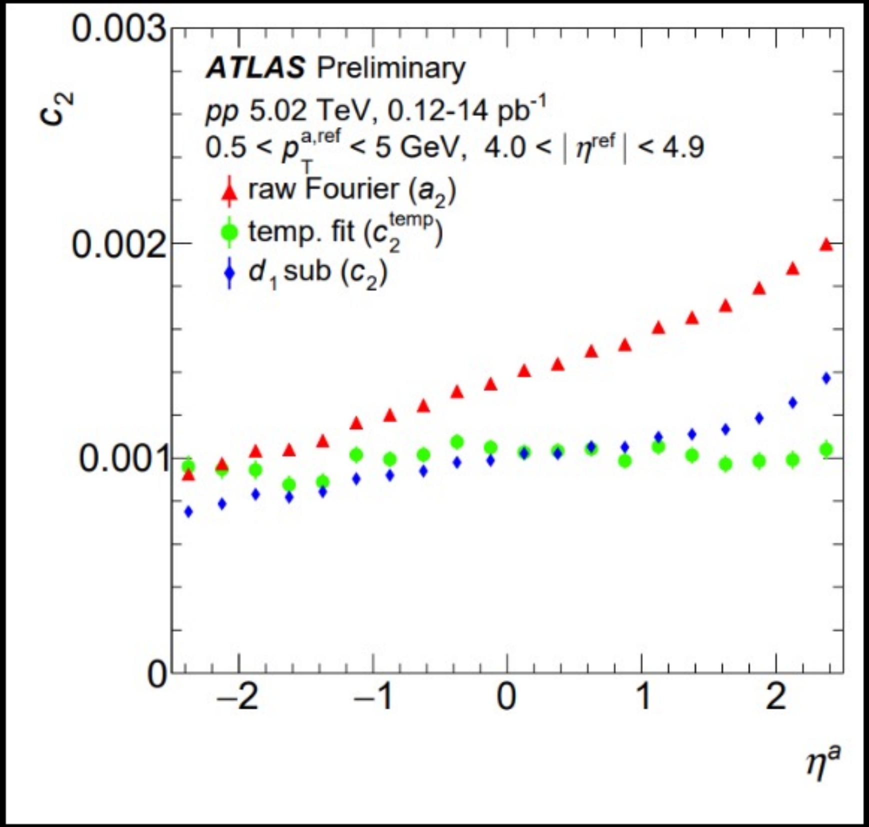
Step #1:
Two-particle correlations between midrapidity and reference forward rapidity and measure the Fourier moments

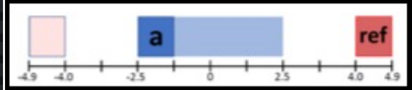
Step #2:
(New) Must also perform a non-flow subtraction for each correlation

Step #3:
Calculate r_n and F_n

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-020/00

$v_{2,2}(\eta_a)$ and non-flow subtraction





Raw Fourier moments a_2

$$Y(\Delta\phi,\eta^a) = G\left\{1 + 2\sum_{n=1}^{4} a_n(\eta^a)\cos(n\Delta\phi)\right\}$$

flow **non-flow**

$$Y(\Delta\phi,\eta^a) = G\left\{1 + 2\sum_{n=1}^{4} (c_n(\eta^a) + d_n(\eta^a))\cos(n\Delta\phi)\right\}$$

η-dependent template fit (temp. fit)

$$Y^{\mathrm{HM}}(\Delta\phi,\eta^a) = F^{\mathrm{temp}}(\eta^a)Y^{\mathrm{LM}}(\Delta\phi,\eta^a) + G^{\mathrm{temp}}(\eta^a)\left\{1 + 2\sum_{n=2}^{4} c_n^{\mathrm{temp}}(\eta^a)\cos(n\Delta\phi)\right\}$$

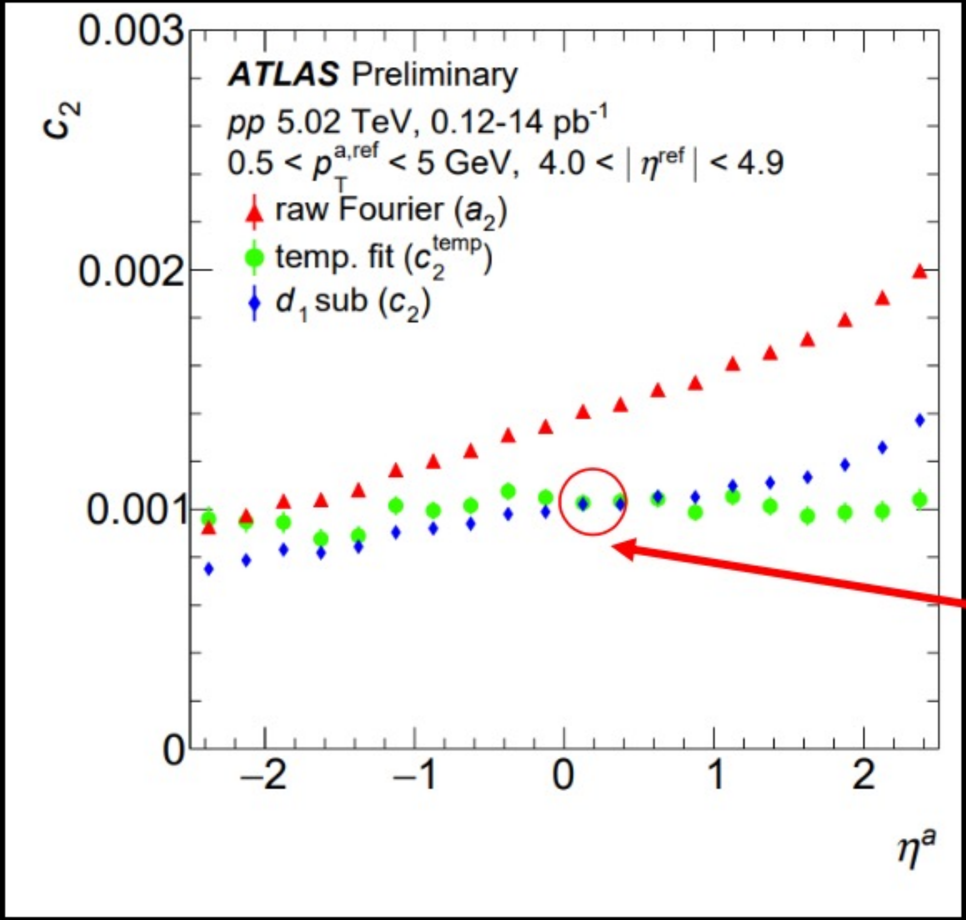
Use low multiplicity 2PC in same η^a slice as a *template* for non-flow

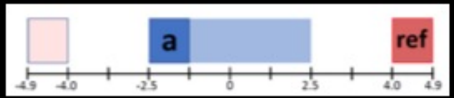
Low multiplicity reference N_{ch} = 40-60

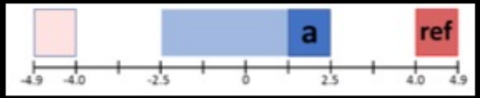
Dominant effect is non-flow, i.e., when particle-a is close to particle-ref, there is a larger “dijet/jet” contribution

Decorrelation is the remaining η_a dependence!

$v_{2,2}(\eta_a)$ and non-flow subtraction







ATLAS-CONF-2022-020

d_1 scaling subtraction (d_1 sub.)

$$c_2(\eta^a) = a_2(\eta^a) - a_1(\eta^a)\frac{d_2|_{\eta^a=0}}{d_1|_{\eta^a=0}}(1 + [F_2^d - F_1^d]\eta^a)$$

η^a independent non-flow shape
from mid-rapidity template fit results

η^a dependent correction
Build in η^a dependence
with non-flow model from
LM events

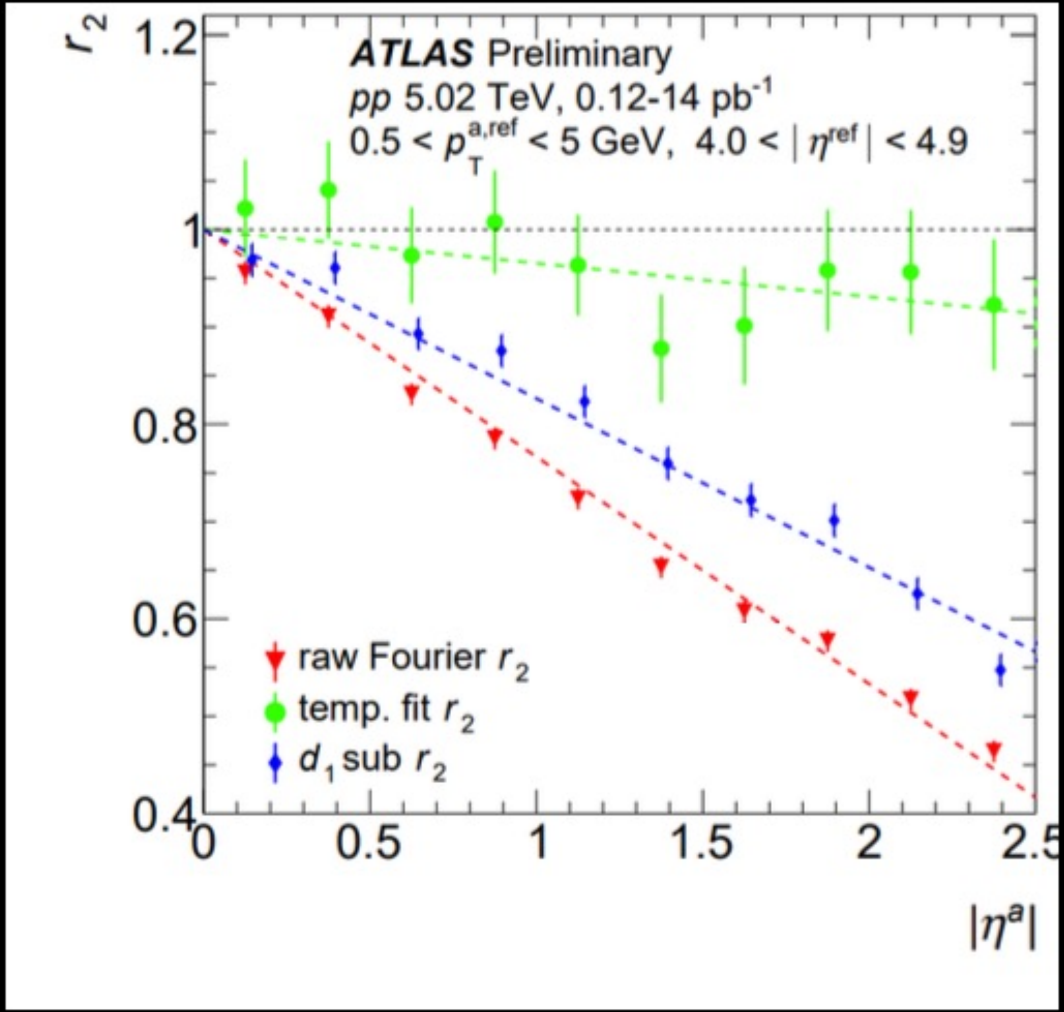
$$r_2(|\eta^a|) = \frac{v_{2,2}(-|\eta^a|)}{v_{2,2}(|\eta^a|)}$$

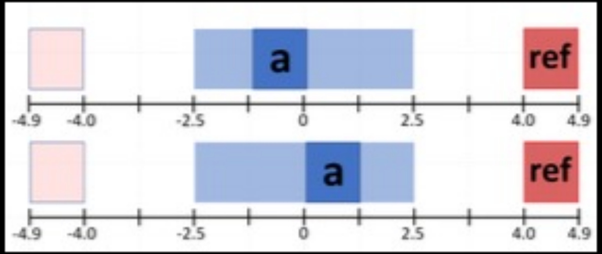
$$r_2(|\eta^a|) = 1 - 2F_2|\eta^a|$$

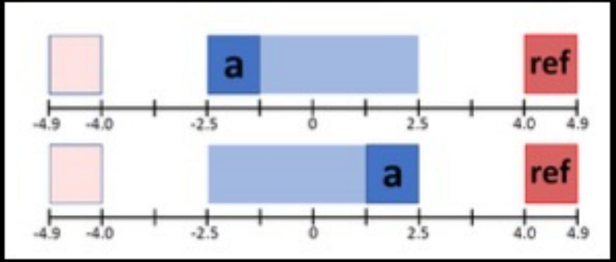
Raw Fourier F_2: combination of decorrelation and η_a-dependent nonflow (i.e., dijets,jets)

Template Fit F_2: subtracts off ~85% of the raw decorrelation as nonflow

d_1 subtraction F2: subtracts off ~25% of raw decorrelation as nonflow







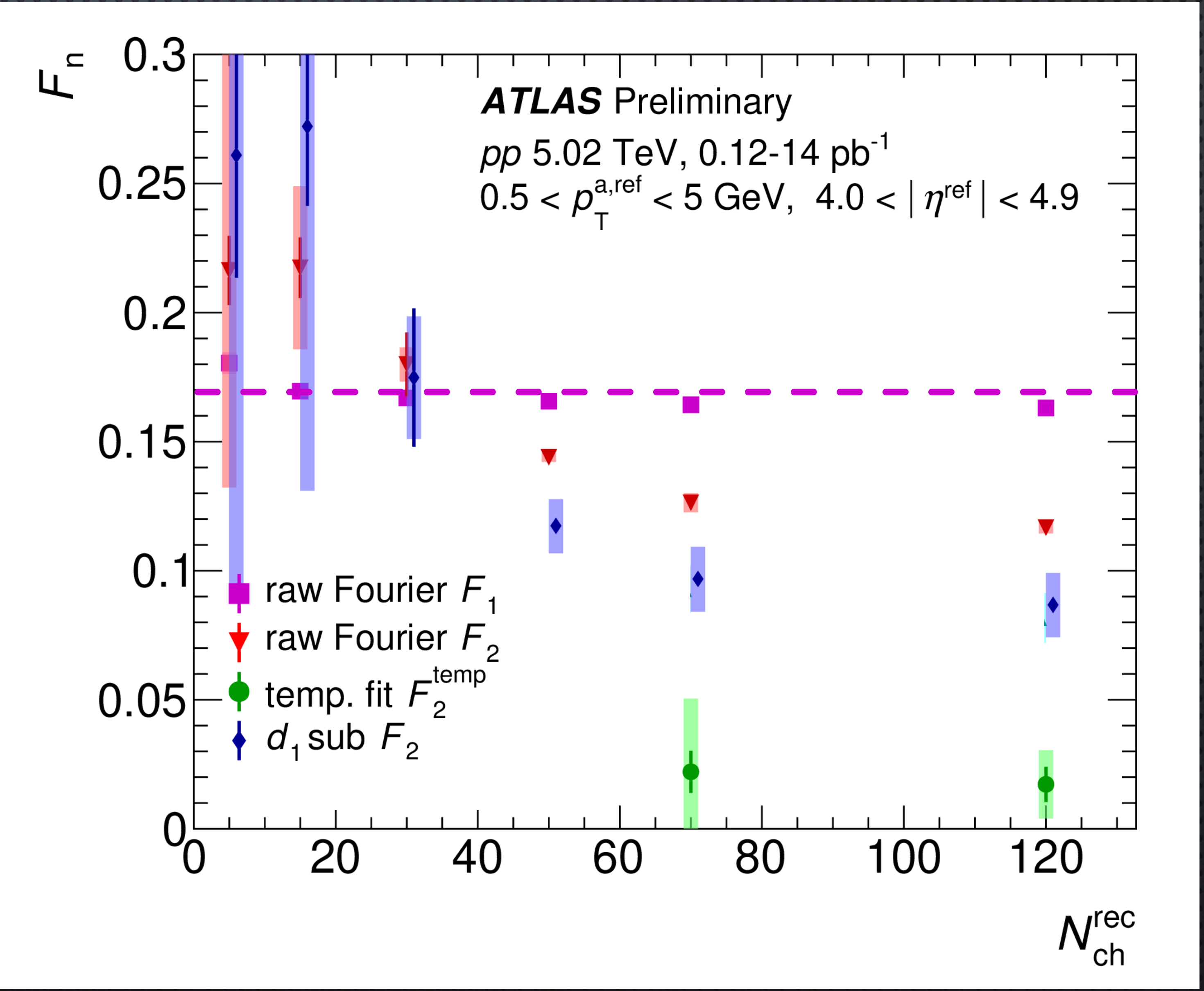
Quantification

Raw F_1 – essentially all nonflow and hence independent of N_{ch}

Raw Fourier F_2: combination of decorrelation and η_a-dependent nonflow (i.e., dijets, jets)

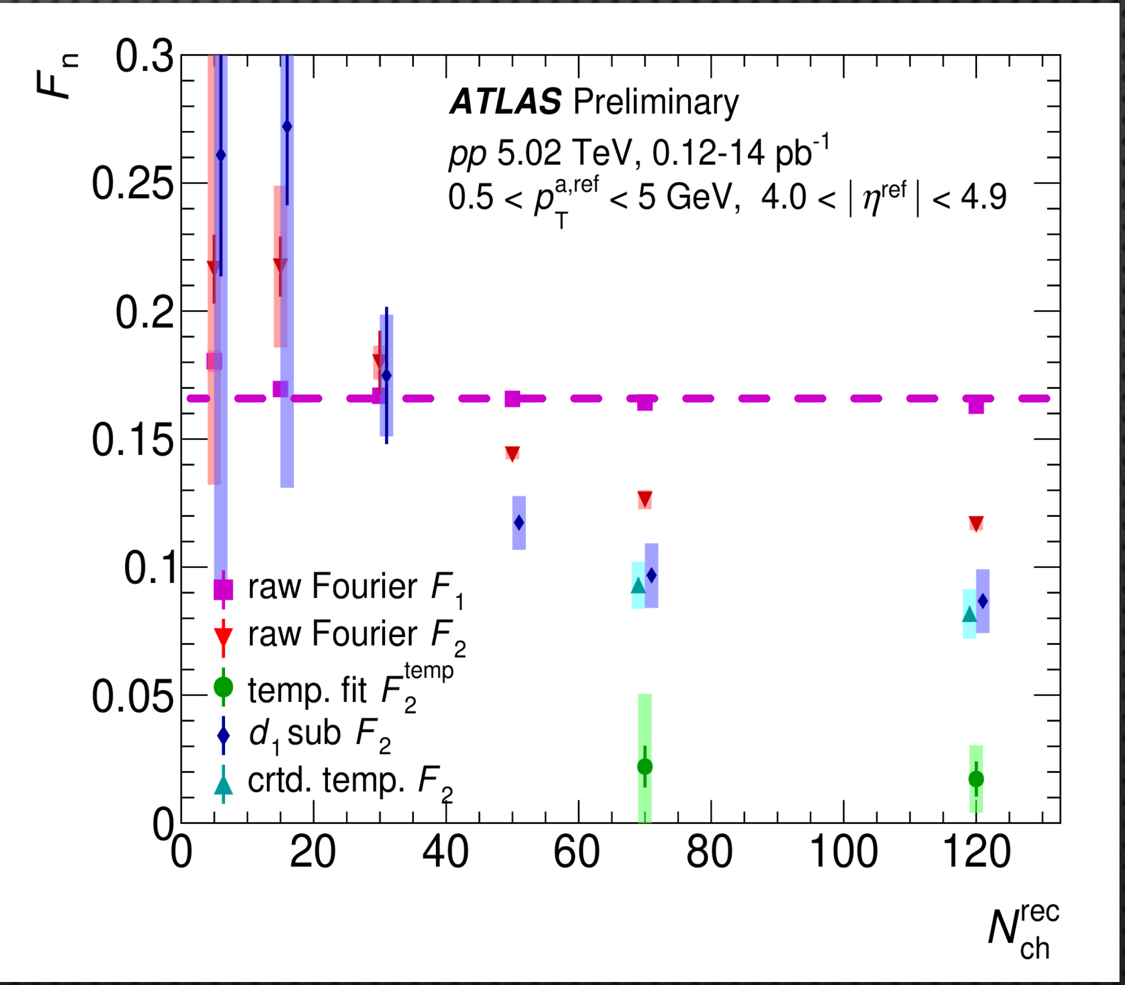
Template Fit F_2: subtracts off ~85% of the raw decorrelation as nonflow

d_1 subtraction F_2: subtracts off ~25% of the raw decorrelation as nonflow



Where does the truth lie?

	Template fit F_2	d_1-scaling subtracted:
N_{ch}-independent non-flow shape	✓	✓
First moment is all non-flow	✓	✓
N_{ch}-independent mid-rapidity flow	✓	✓
F_n at N_{ch}=0-20 is all non-flow	X	✓
N_{ch}-independent flow decorrelation	✓	X



One new method added ("corrected template") that corrected for the last assumption in the template fitting method

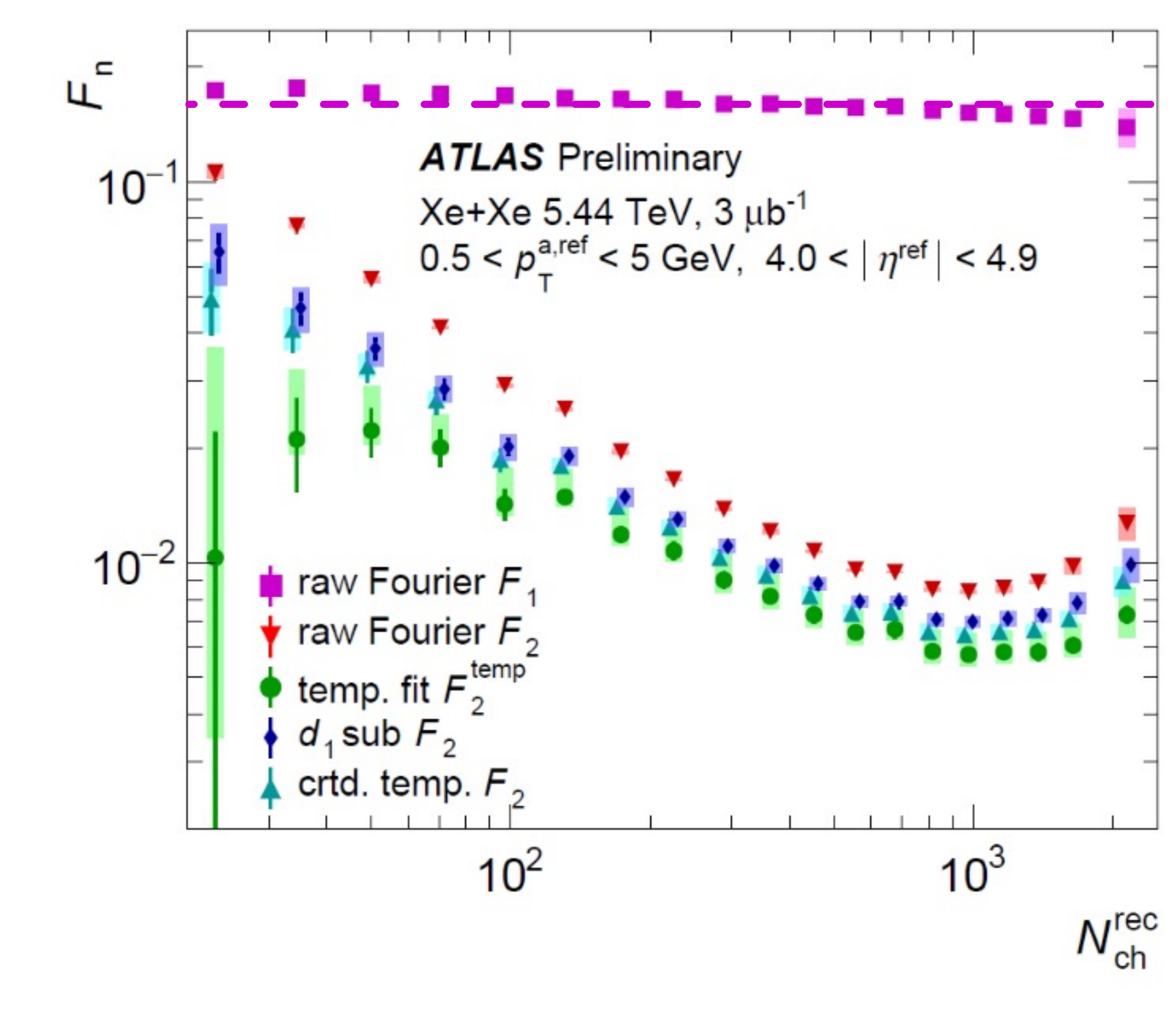
Xe+Xe Results

Raw F_1 – essentially all nonflow and hence independent of N_{ch}

Raw Fourier F_2: combination of decorrelation and η_a-dependent nonflow (i.e., dijets, jets)

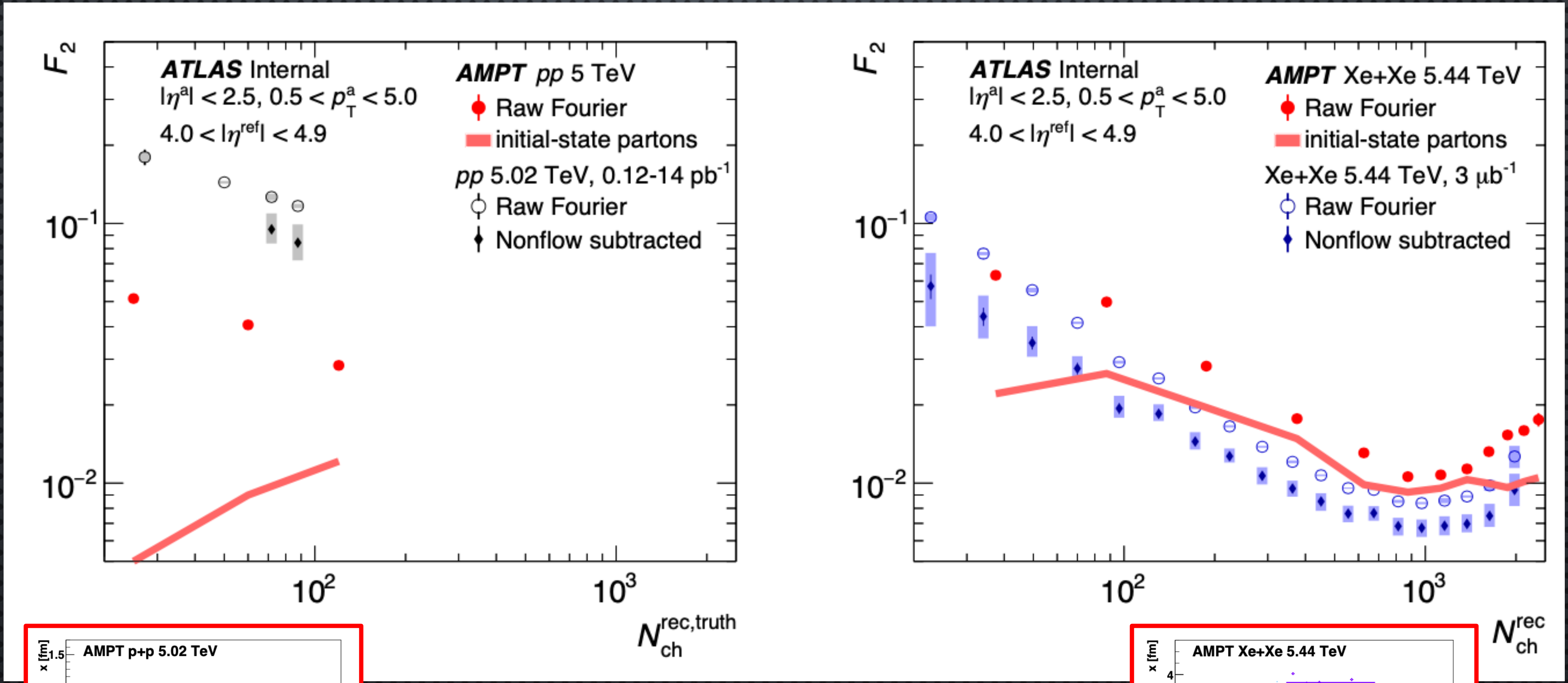
Template Fit F_2: subtracts off ~30% of the raw decorrelation as nonflow

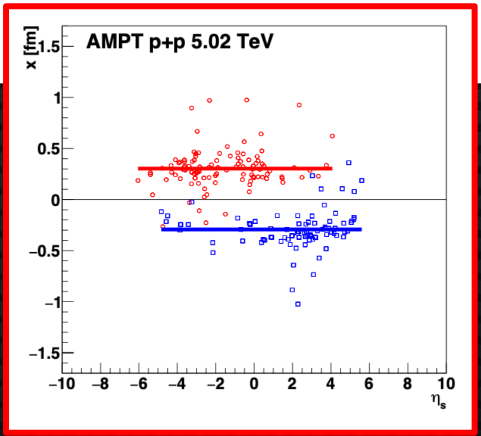
d_1 subtraction F_2: subtracts off ~20% of the raw decorrelation as nonflow



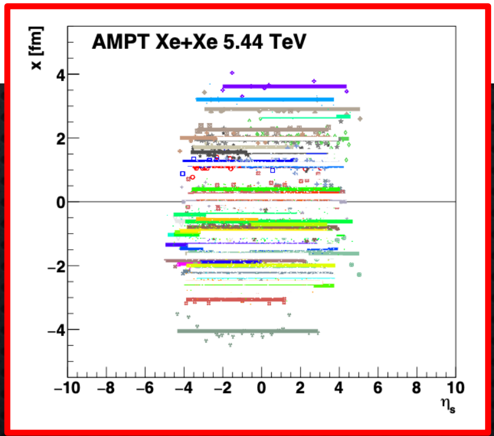
Much smaller nonflow subtraction contribution; however, quantitative results are sensitive even in the most central collisions.

pp and Xe+Xe longitudinal decorrelations



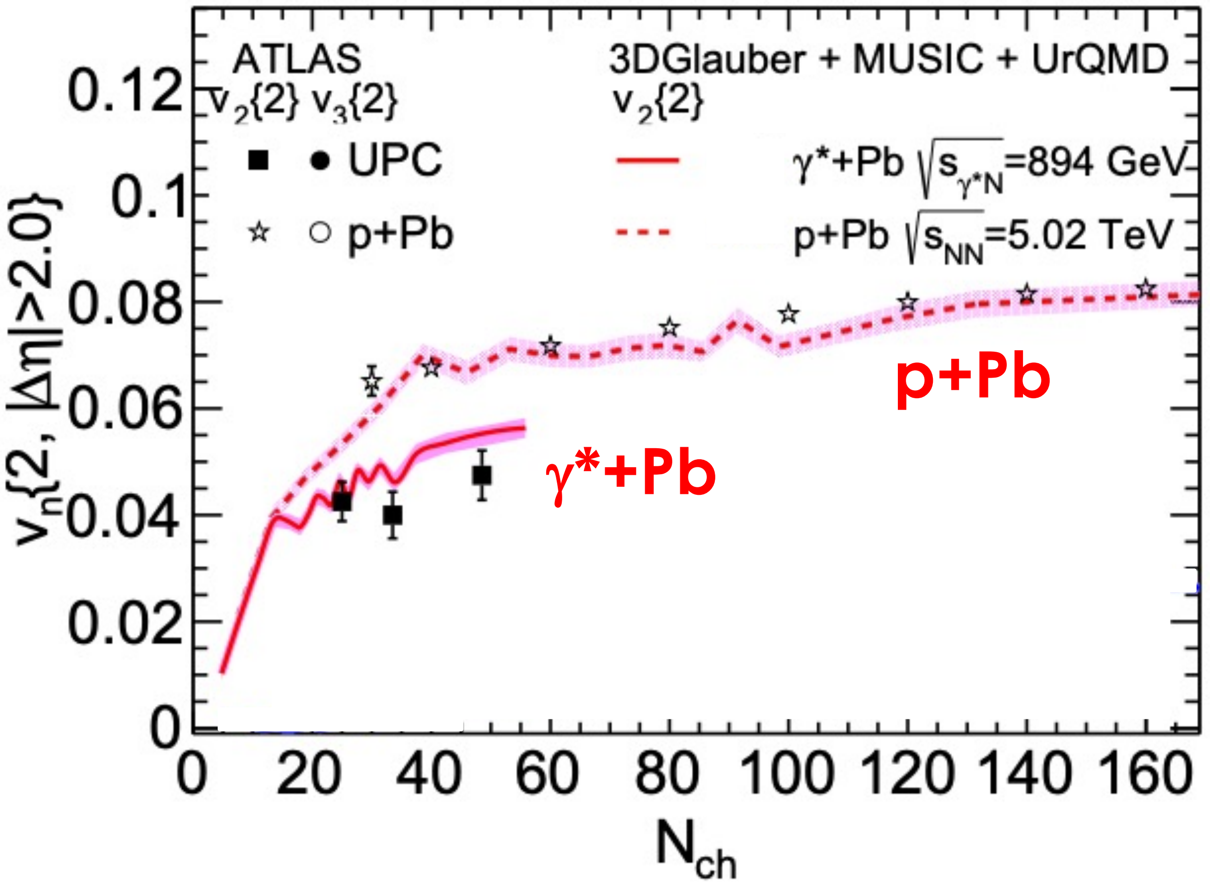


$$r_2(|\eta^a|) = \frac{\vec{\varepsilon}_2(-|\eta_s^a|) \cdot \vec{\varepsilon}_2(\eta_s^{ref})}{\vec{\varepsilon}_2(|\eta_s^a|) \cdot \vec{\varepsilon}_2(\eta_s^{ref})}$$



Ultraperipheral Collisions

ATLAS, Phys. Rev. C 104, 014903 (2021)



Collectivity in Ultra-Peripheral Pb+Pb Collisions at the Large Hadron Collider

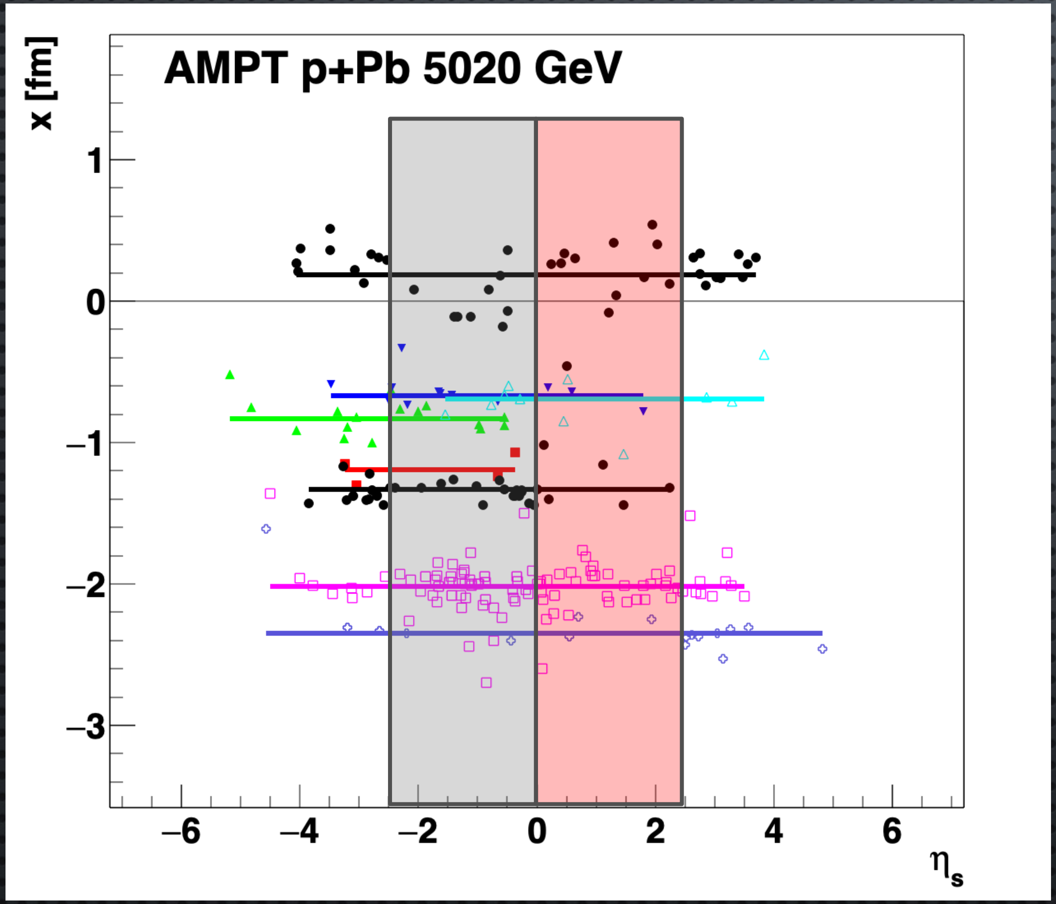
Wenbin Zhao,[1] Chun Shen,[1,2] and Björn Schenke[3]

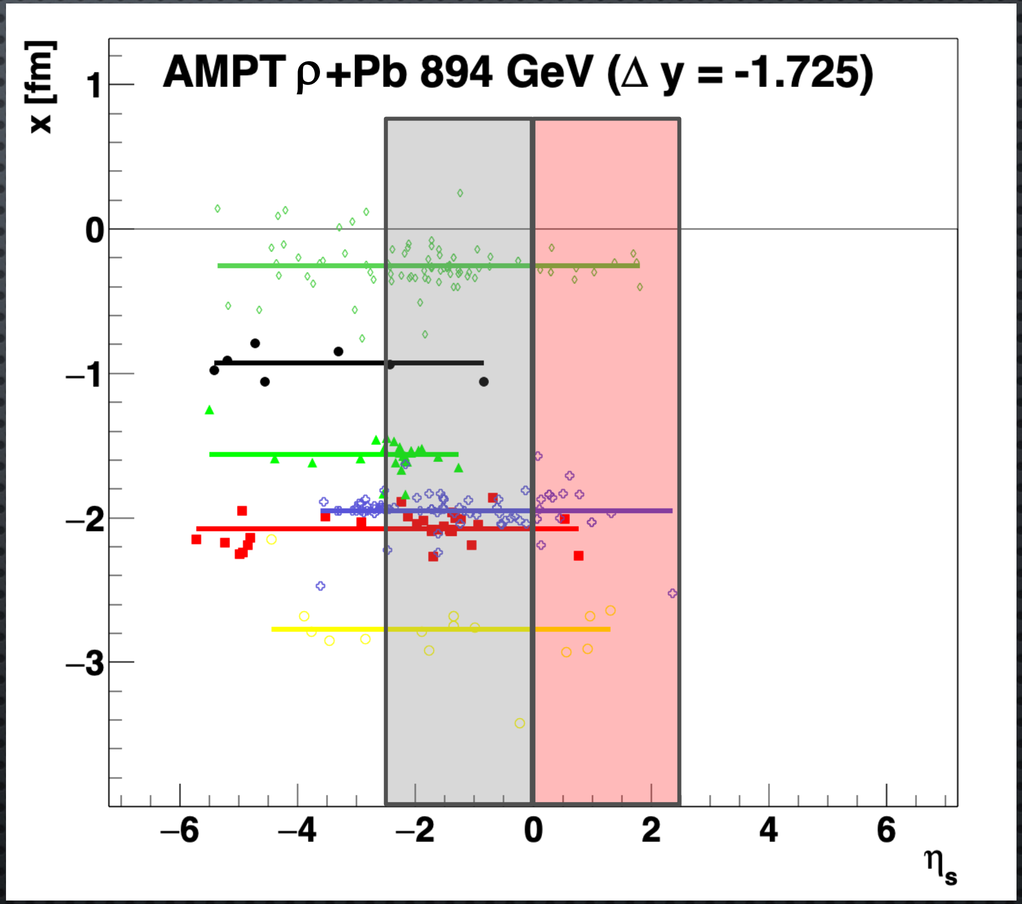
Treat γ^* + Pb
at single E = 894 GeV,
two valance quarks
(vector meson dominance),
regular min. bias impact
parameter

A lot of simplifications… but

What really matters to making
v_2 (γ^*Pb) < v_2 (pPb)?

What really matters to making $v_2(\gamma^*Pb) < v_2(pPb)$?





v_2 is from a two-particle correlation with $|\Delta\eta| > 2$ gap.

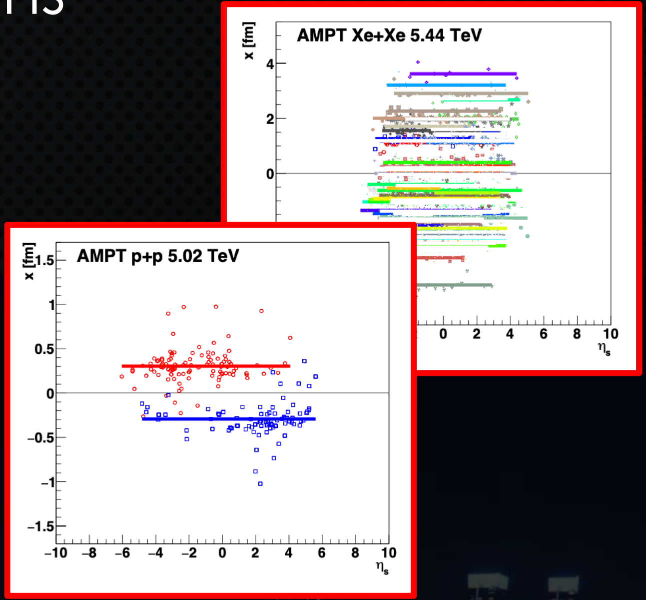
γ^*Pb is like ρPb at 894 GeV, but shifted in rapidity

<u>Much larger longitudinal decorrelation!</u>

Summary

- Preliminary ATLAS results for longitudinal decorrelations from pp 5.02, 13 TeV and Xe+Xe 5.44 TeV shown

- Theoretical calculations (string type) capture key decorrelation features in Xe+Xe mid to central; however, pp and peripheral Xe+Xe substantially underpredict the data

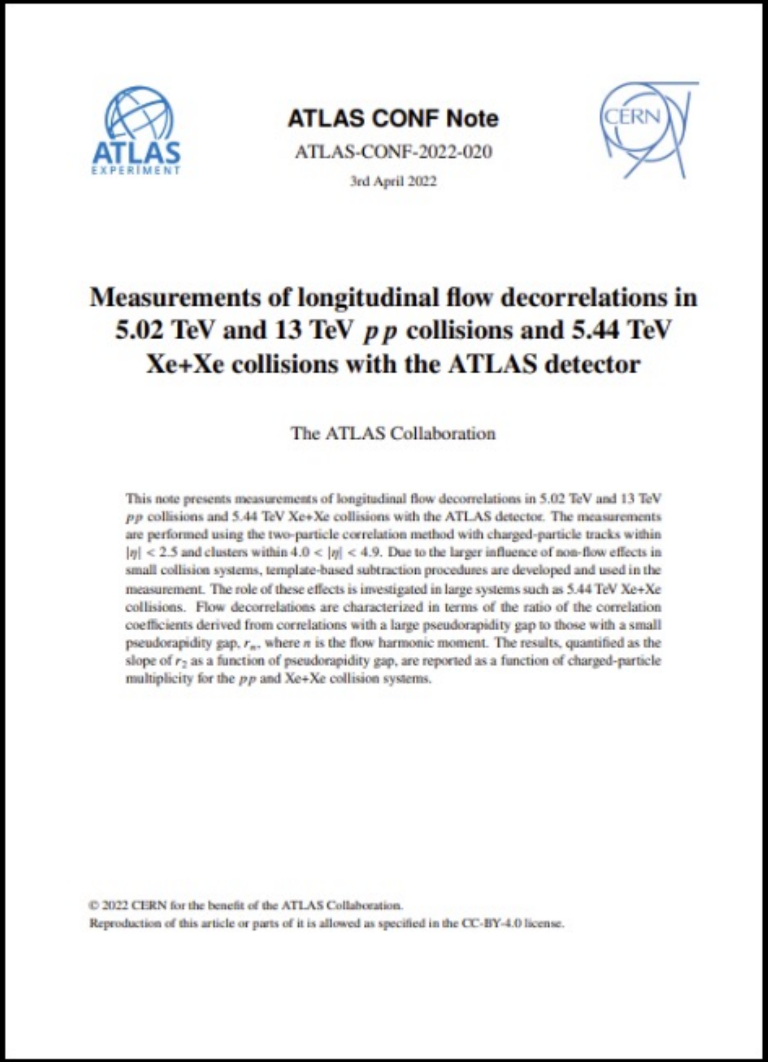


- Future tests on nonflow subtraction assumptions are an important next step combined with additional theoretical comparisons for initial state longitudinal geometry

* See Blair Seidlitz's talk at Quark Matter 2022 for additional details
https://indico.cern.ch/event/895086/contributions/4716148/

EXTRA SLIDES

That was a lot… Want more?



ATLAS CONF Note

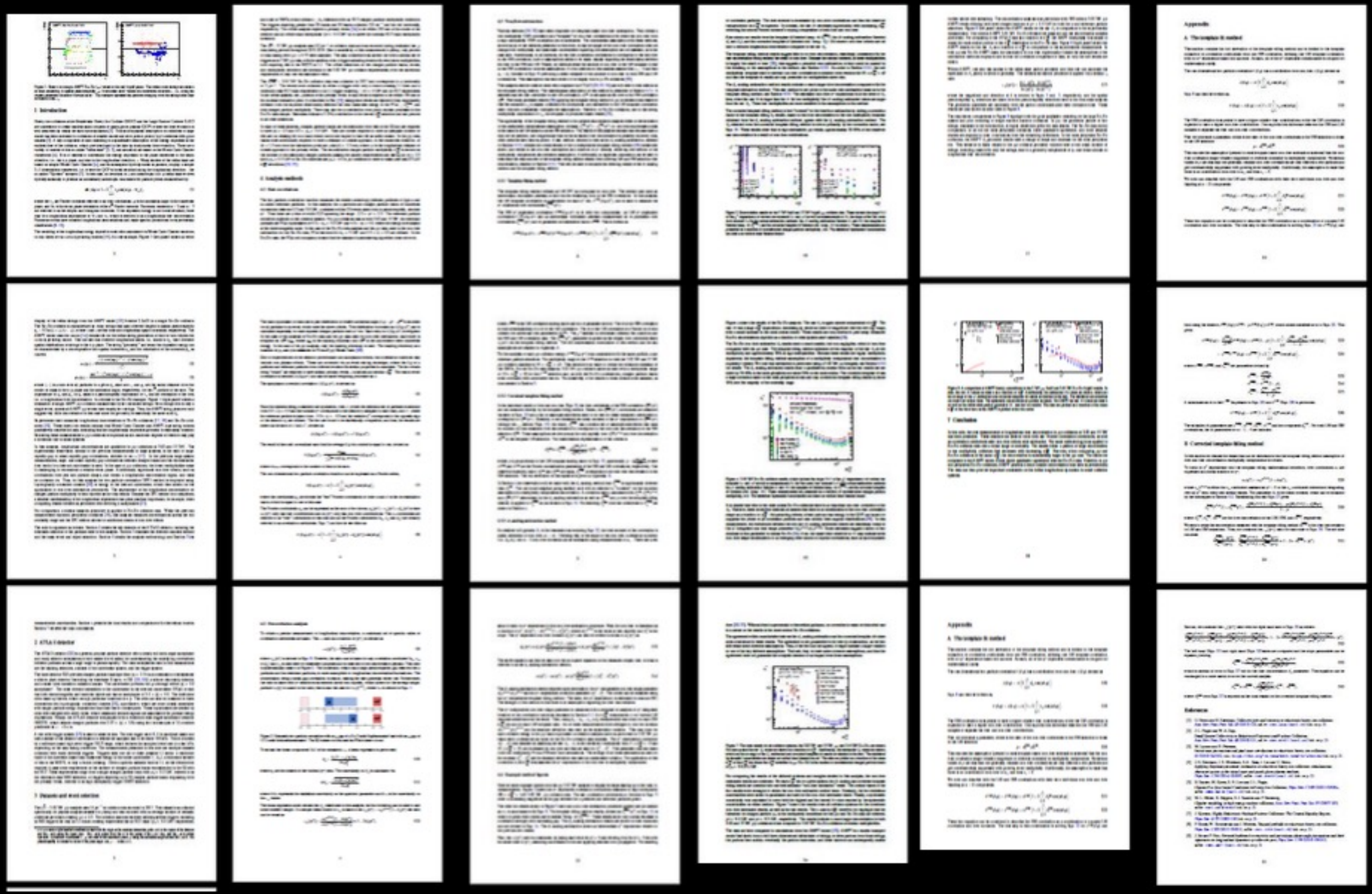
ATLAS-CONF-2022-020

3rd April 2022

Measurements of longitudinal flow decorrelations in 5.02 TeV and 13 TeV pp collisions and 5.44 TeV Xe+Xe collisions with the ATLAS detector

The ATLAS Collaboration

This note presents measurements of longitudinal flow decorrelations in 5.02 TeV and 13 TeV pp collisions and 5.44 TeV Xe+Xe collisions with the ATLAS detector. The measurements are performed using the two-particle correlation method with charged-particle tracks within $|\eta| < 2.5$ and clusters within $4.0 < |\eta| < 4.9$. Due to the larger influence of non-flow effects in small collision systems, template-based subtraction procedures are developed and used in the measurement. The role of these effects is investigated in large systems such as 5.44 TeV Xe+Xe collisions. Flow decorrelations are characterized in terms of the ratio of the correlation coefficients derived from correlations with a large pseudorapidity gap to those with a small pseudorapidity gap, r_n, where n is the flow harmonic moment. The results, quantified as the slope of r_2 as a function of pseudorapidity gap, are reported as a function of charged-particle multiplicity for the pp and Xe+Xe collision systems.



ATLAS-CONF-2022-020

Longitudinal decorrelation measurements from pp to A+A with the ATLAS detector

14 Jun 2022, 20:30
20m
GBR3

Talk | Bulk matter phenom... | PA-Bulk matter pheno...

Speaker

James Lawrence Nagle (University of Colora...

15' + 5' (Q&A)

Description

This talk presents new measurements of longitudinal flow decorrelations in 5.02 TeV and 13 TeV pp collisions and 5.44 TeV Xe+Xe collisions with the ATLAS detector. The measurements are performed using the two-particle correlation method with charged-particle tracks within |eta| < 2.5 and clusters within 4.0 < |eta| < 4.9. Due to the larger influence of non-flow effects in small collision systems, template-based subtraction procedures are developed and applied to the measurement. These effects are observed to play a role even in large systems such as 5.44 TeV Xe+Xe collisions. Flow decorrelations are characterized in terms of the ratio of the correlations with a large pseudorapidity gap to those with small pseudorapidity gap, r_n, where n is the flow harmonic moment. Results are reported for the slope of r_2 as a function of pseudorapidity gap as a function of charged-particle multiplicity for the pp and Xe+Xe collision systems. This gives some of the first detailed information on the correlation between longitudinal and transverse energy deposition in pp collisions.

Primary authors

ATLAS Collaboration
James Lawrence Nagle (University of Colora...

Presentation materials

There are no materials yet.