Correlations in UPC according to ATLAS

Miniworkshop difrakce a UPC 2019

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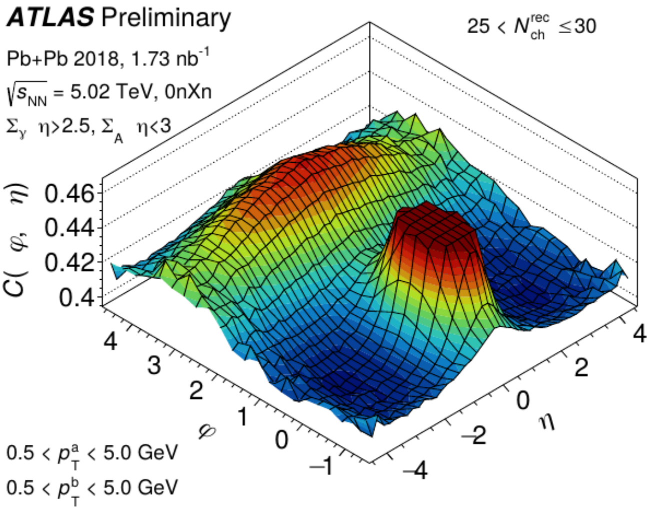
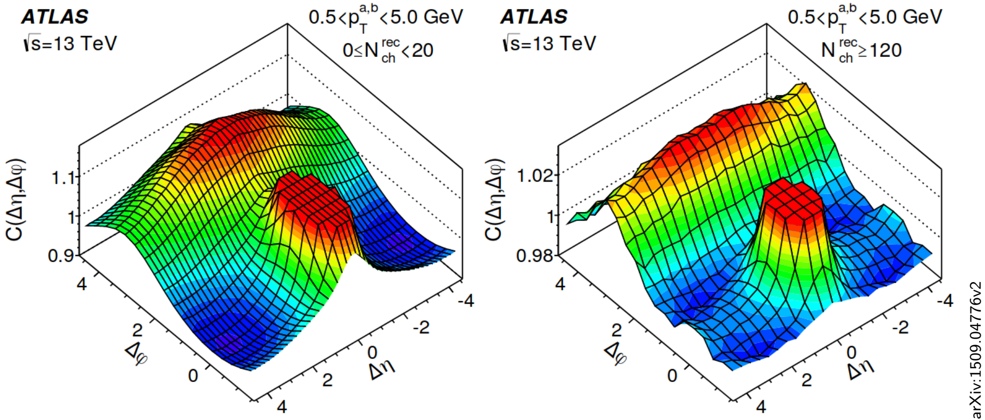
Content



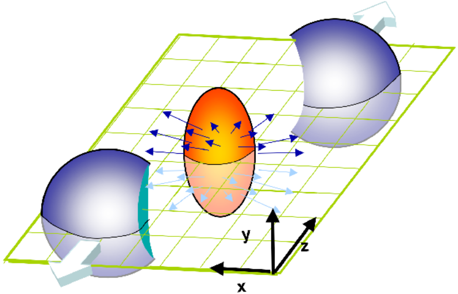
ATLAS Preliminary
Pb+Pb 2018, 1.73 nb⁻¹
$\sqrt{s_{NN}}$ = 5.02 TeV, 0nXn
Σ_γ η>2.5, Σ_A η<3
$25 < N_{ch}^{rec} \leq 30$
$C(\varphi, \eta)$
0.46
0.44
0.42
0.4
4
3
2
1
0
−1
φ
−4
−2
0
2
4
η
$0.5 < p_T^a < 5.0$ GeV
$0.5 < p_T^b < 5.0$ GeV

Collective flow



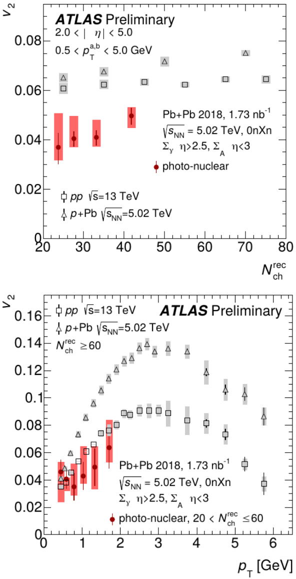
- Collective behaviour seen in Pb+Pb, *p*+Pb and *pp* at LHC and RHIC.
- Manifests as ridge (see talk by KKG for more details).
- Question: Can we see the same in photo-nuclear reactions?

QGP or?



- These can be signatures of QGP,
  - Spatial non-uniformities of initial state $\rightarrow$ hydrodynamic expansion $\rightarrow$ final state momentum-space anisotropies (ridge)
- or momentum correlations in the initial state.
  - Lead ion system is already complicated enough.
  - Do we see a footprint of the "beam" complexity?
- Tested in collision systems with "simple" beam.
  - e^+e^- and *ep* collisions showed no ridge.
- Study of γ+A interactions.
  - Typical multiplicity larger than e^+e^- or *ep*, but smaller than *pp*.

This paper results



- v_2 somehow represents the flow.
- We see, there is some flow in γ+A.
- Relatively large systematics (Can ALICE do better?).
- Comparison to p+Pb and pp is shown.
- Similar p_T and multiplicity dependence.
- Overall smaller magnitude.
- That's all we can say.
- For better figures google ATLAS-CONF-2019-022

Technicalities

Can we measure it at ALICE?

Data and detector coverage

- Pb+Pb collected in 2018.
- $\sqrt{s_{\text{NN}}} = 5.02$ TeV.
- $\mathscr{L} = 1.73\text{nb}^{-1}$
- Detectors ($|\eta| < 5$):
    - zero-degree calorimeter ($|\eta| > 8.3$),
    - forward calorimeters ($3.2 < |\eta| < 4.9$),
    - inner-detector system (silicon pixel) ($|\eta| < 2.5$),
    - transition radiation tracker ($|\eta| < 2$).
    - central-barrel EM calorimeters ($|\eta| < 3.2$),
    - central-barrel LAr presampler ($|\eta| < 1.8$),
    - central-barrel Hadronic calorimeter ($|\eta| < 1.7$).
- Axial magnetic field of 2 Tesla.

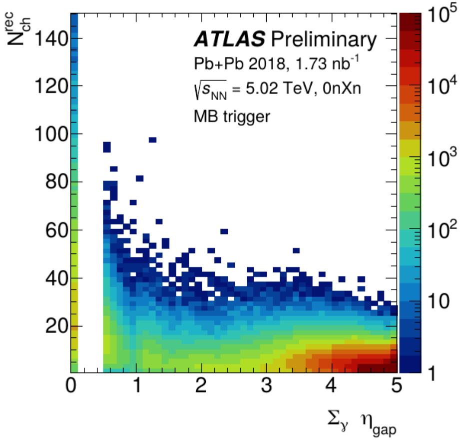
Data selection

Introducing the magical cut!

Trigger and offline cuts

- Final rate of accepted events: 1-4 kHz (ALICE was set to 8 kHz).
- Several triggers:
  - Online trigger:
    - ZDC have at least 1 neutron in Pb-going side and 0 in γ-going side (0NXN),
    - max energy in the calorimeter of 200 GeV,
    - minimum Bias required at least 1 track with $p_T > 0.4$ GeV,
    - high multiplicity triggers (HMT) needs 15, 25 and 35 tracks from the same vertex,
    - HMT needs max energy of FCal in γ-going side (separate peripheral events),
    - special trigger to look for physics background - energy in both ZDC sides.
  - Offline selections:
    - Some quality criteria on track based on *pp* data-taking,
    - tracks have $p_T > 0.4$ GeV,
    - tracks have $|\eta| < 2.5$,
    - DCA less than 1.5 mm,
    - vertex is $z < 90$ mm.

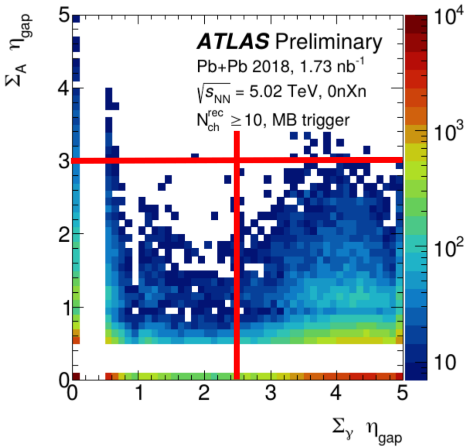
Reconstructed pseudorapidity gap quantities (yes, its a name)



- 3 competing processes:
  - Photo-nuclear collision (we want them),
  - peripheral hadronic Pb+Pb collisions,
  - dissociative $\gamma\gamma \to X$.
- Use rapidity gaps to distinguish.
- Hard to find a large one amongst many fragments.
- Introduction of sum of gaps as follows:
  - Order tracks and clusters in η,
  - Include $\Delta\eta$ of adjacent tracks to final sum if > 0.5.

$$\Sigma_\gamma \Delta\eta_{\mathrm{gap}}, \qquad \Sigma_A \Delta\eta_{\mathrm{gap}} \tag{1}$$

Reconstructed pseudorapidity gap quantities (yes, its a name)



- 3 competing processes:
  - Photo-nuclear collision (we want them),
  - peripheral hadronic Pb+Pb collisions,
  - dissociative $\gamma\gamma \to X$.
- Rapidity gap above some value in γ-going direction removes peripheral events.
- Some maximum rapidity gap in *Pb*-going direction removes $\gamma\gamma \to X$ events.

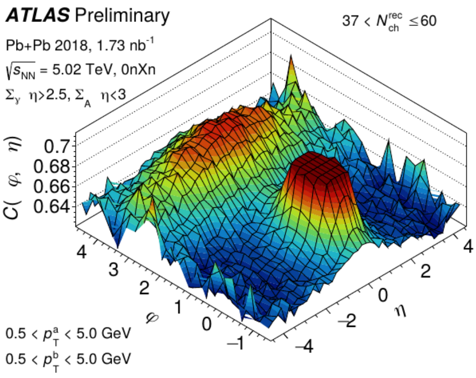
$$\Sigma_\gamma \Delta\eta_{gap} > 2.5, \qquad \Sigma_A \Delta\eta_{gap} < 3 \tag{2}$$

Non-flow subtraction

Beauty and the Beast!

What is correlation function and how you measure it

- Correlation is a function of pair relative separation in pseudorapidity and azimuth.



$$\Delta\phi = \phi^a - \phi^b, \qquad \Delta\eta = \eta^a - \eta^b \tag{3}$$

$$Y(\Delta\phi, \Delta\eta) = \frac{1}{N_a}\left\langle \frac{\mathbf{d}^2 N_{pair}}{\mathbf{d}\Delta\phi \cdot \mathbf{d}\Delta\eta} \right\rangle_{\mathrm{evt}} \tag{4}$$

- Integration over pseudorapidity (avoid the jet).

$$Y(\Delta\phi) = \int_{|\Delta\eta|=2.}^{|\Delta\eta|=5.} (\Delta\phi, \Delta\eta) \tag{5}$$

How to get the flow coefficients

$$v_{n,n} = v_n^2 \tag{6}$$

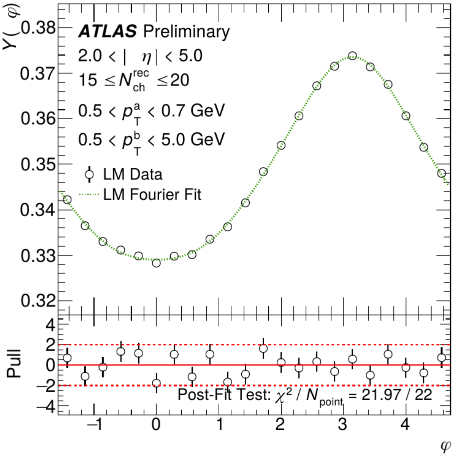
- You want the coefficients (v_2 and v_3) of the fourrier decomposition of the correlation function.
- To remove non-flow effects, ATLAS standardly uses this template fit.

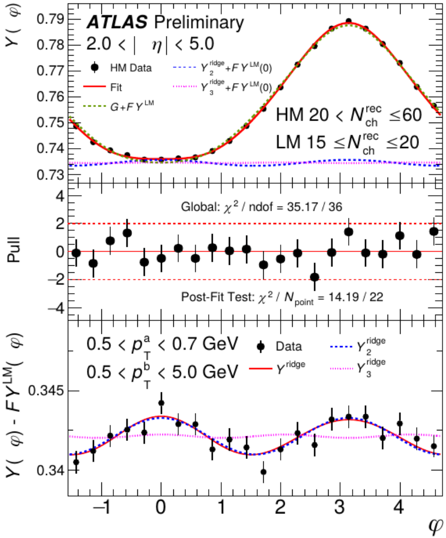
$$Y^{\mathrm{HM}}(\Delta\phi) = LY^{\mathrm{LM}}(\Delta\phi) + G\left\{1 + 2\sum_{n=2}^{3} v_{n,n}\cos(n\Delta\phi)\right\} \tag{7}$$

$$= LY^{\mathrm{LM}}(\Delta\phi) + Y^{\mathrm{ridge}}(\Delta\phi) \tag{8}$$

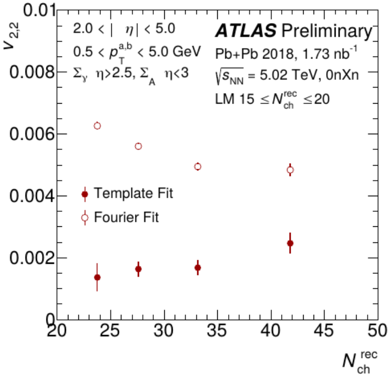
- HM means high multiplicity, LM means low multiplicity.

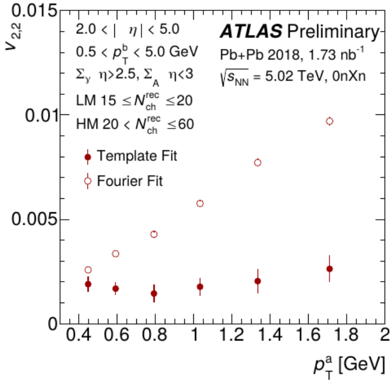
Non-flow subtraction





Fourrier vs. template fits





- Fourrier coeff. of simultanoues fit contains the background, mainly jet contribution.
- Hint: Higher p_t or low number of tracks corresponds to more jet-like event.

Systematic uncertainties

Dominant contributions taken from paper

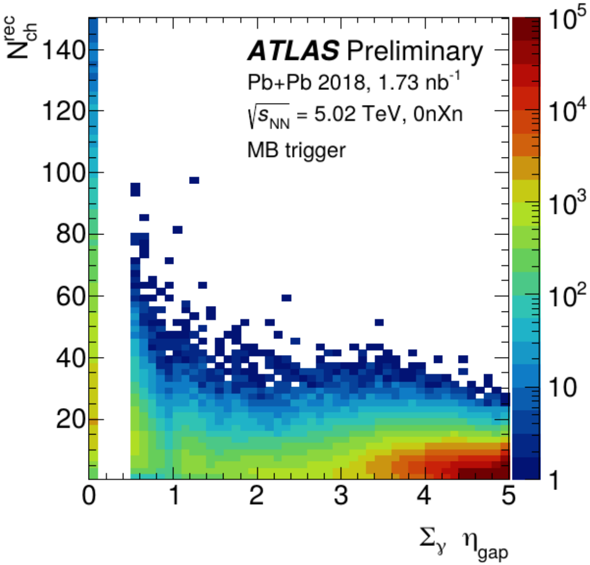
Systematics

- Dominant uncertainties:
  - pair pseudorapidity difference (5-15%),
    - Pair chosen from $2.0 < |\Delta\eta| < 5.0$.
    - Lower bound to avoid jet-like contribution.
    - Varied from 1.8 to 2.2.
  - low multiplicity reference (10-35%),
    - Y^{LM} chosen from events with 15-20 tracks.
    - i.e. distribution of photon energies can be different than in Y^{HM}
    - Analysis redone with Y^{LM} chosen from events with 10-15 tracks.
  - exclusion of tracks from $\Sigma_{\gamma}\Delta\eta_{\mathrm{gap}}$ (5-10%).
    - Investigating effect of these excluded tracks to the two-particle correlation.
- Other contributions:
  - trigger efficiency, event selection, acceptance effects in correlation function, reconstruction inefficiency, low multiplicity shape parametrisation, multiplicity dependence of flow coefficients, $\Delta\phi$ binning

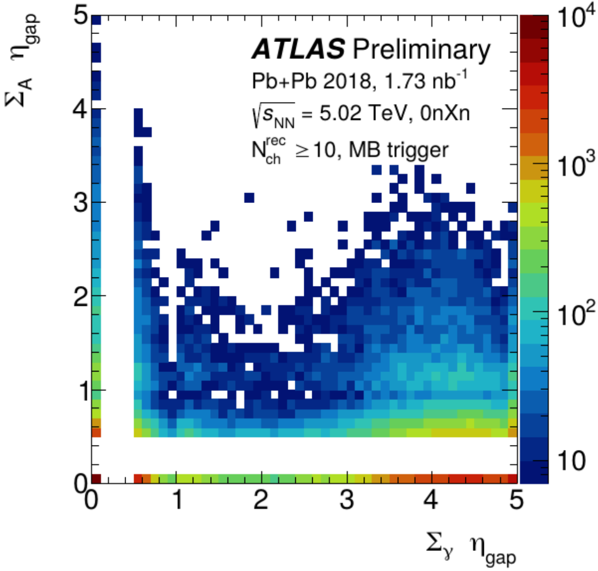
What about ALICE?

Open discussion

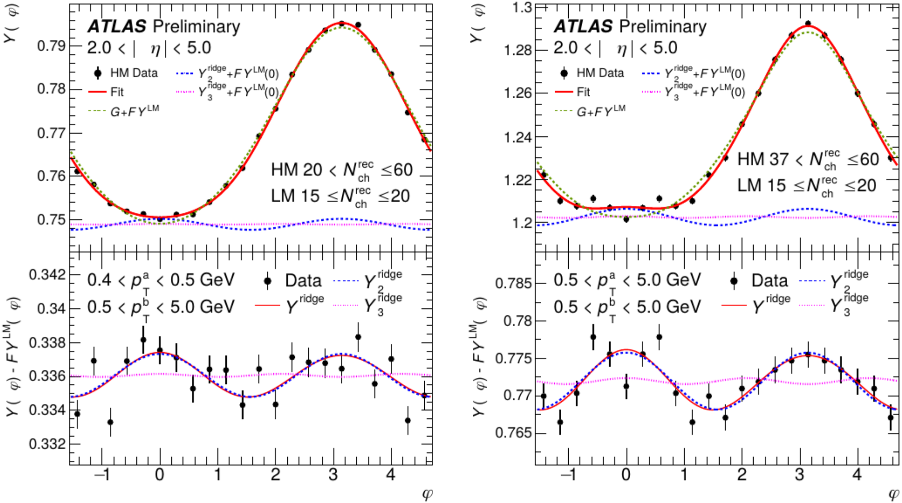
BACK UP



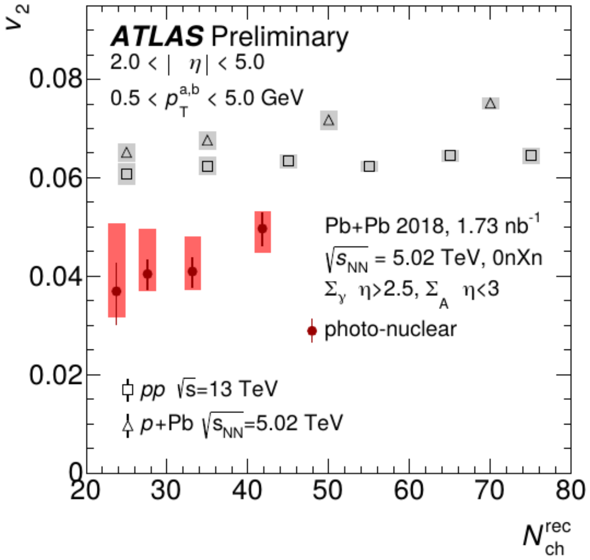
ATLAS Preliminary
Pb+Pb 2018, 1.73 nb^{-1}
$\sqrt{s_{NN}}$ = 5.02 TeV, 0nXn
MB trigger
N_{ch}^{rec}
$\Sigma_\gamma\ \eta_{gap}$
0
1
2
3
4
5
20
40
60
80
100
120
140
1
10
10^2
10^3
10^4
10^5

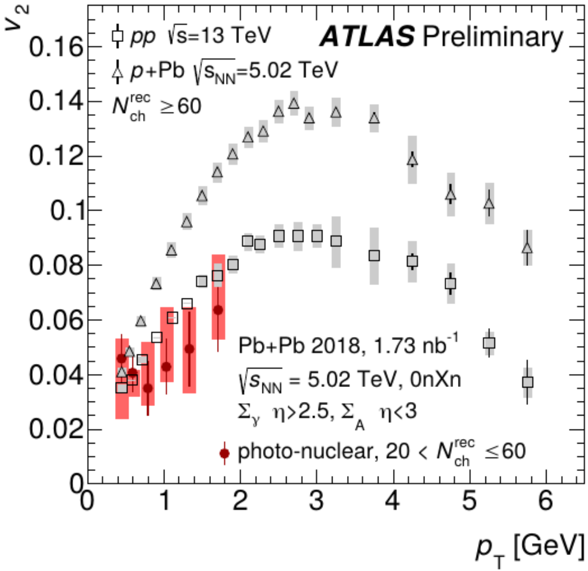


ATLAS Preliminary
Pb+Pb 2018, 1.73 nb^{-1}
$\sqrt{s_{NN}}$ = 5.02 TeV, 0nXn
$N_{ch}^{rec} \geq 10$, MB trigger
$\Sigma_A \ \eta_{gap}$
$\Sigma_\gamma \ \eta_{gap}$



ATLAS Preliminary
2.0 < |η| < 5.0
HM Data
Fit
G+FY^LM
Y_2^ridge+FY^LM(0)
Y_3^ridge+FY^LM(0)
HM 20 < N_ch^rec ≤60
LM 15 ≤N_ch^rec ≤20
0.4 < p_T^a < 0.5 GeV
0.5 < p_T^b < 5.0 GeV
Data
Y^ridge
Y_2^ridge
Y_3^ridge
Y(φ)
Y(φ) - FY^LM(φ)
φ
ATLAS Preliminary
2.0 < |η| < 5.0
HM 37 < N_ch^rec ≤60
LM 15 ≤N_ch^rec ≤20
0.5 < p_T^a < 5.0 GeV
0.5 < p_T^b < 5.0 GeV


ATLAS Preliminary
2.0 < | η| < 5.0
0.5 < $p_T^{a,b}$ < 5.0 GeV
Pb+Pb 2018, 1.73 nb^{-1}
$\sqrt{s_{NN}}$ = 5.02 TeV, 0nXn
Σ_γ η>2.5, Σ_A η<3
photo-nuclear
pp √s=13 TeV
p+Pb $\sqrt{s_{NN}}$=5.02 TeV
v_2
0.08
0.06
0.04
0.02
0
20
30
40
50
60
70
80
N_{ch}^{rec}


ATLAS Preliminary
pp √s=13 TeV
p+Pb √s_NN=5.02 TeV
N_ch^rec ≥60
Pb+Pb 2018, 1.73 nb^-1
√s_NN = 5.02 TeV, 0nXn
Σ_γ η>2.5, Σ_A η<3
photo-nuclear, 20 < N_ch^rec ≤60
v_2
p_T [GeV]
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0
1
2
3
4
5
6