ATLAS Measurements of the ridge(s) in p+Pb collisions

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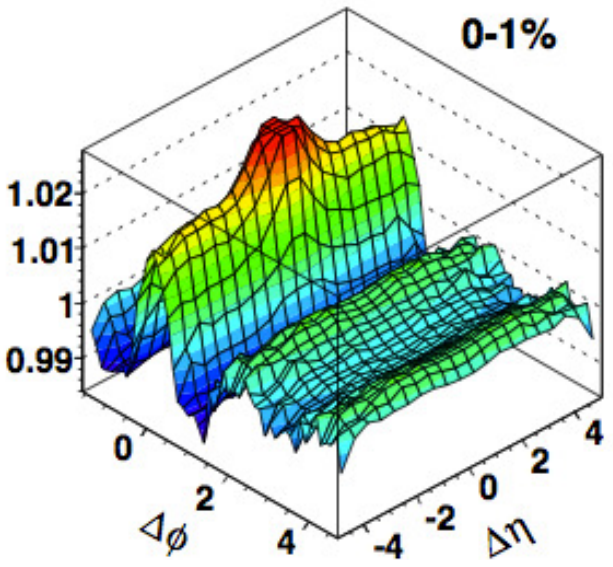
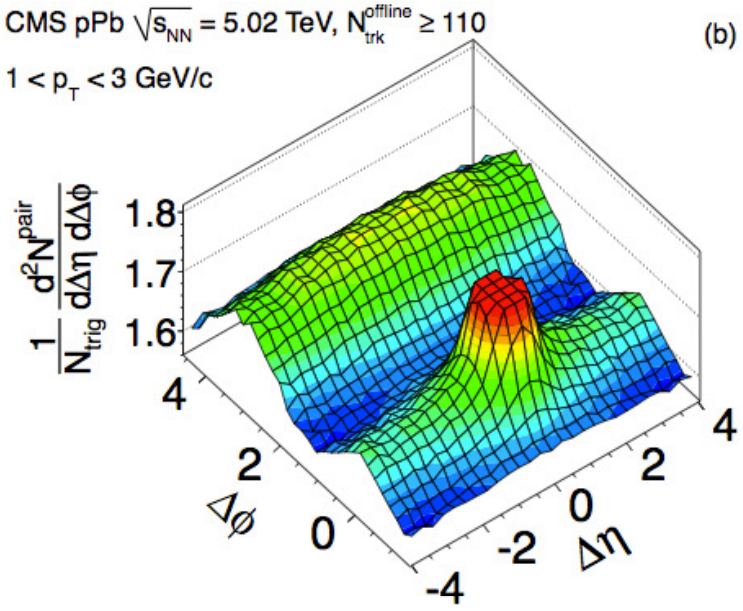
ECT* Trento
7th May 2013

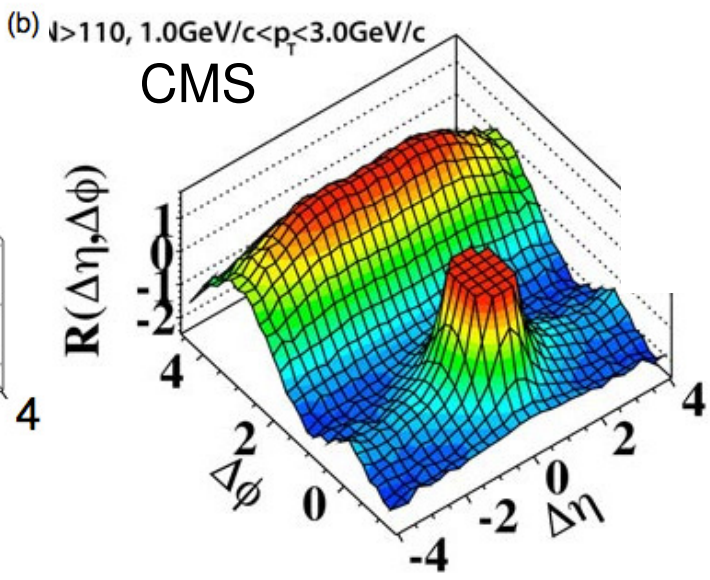
Ridges in Pb-Pb, p-p and p+Pb



Pb+Pb ridge



p+Pb ridge



p+p ridge

- Two-particle correlations show long range correlation structure along $\Delta\eta$ at $\Delta\phi=0$.

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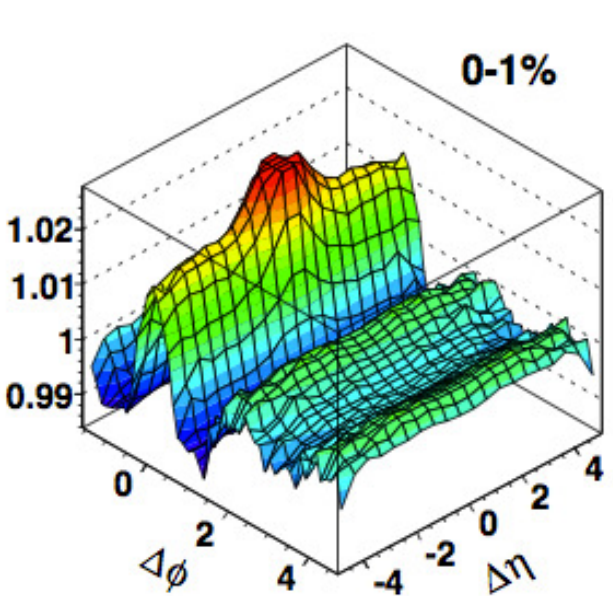

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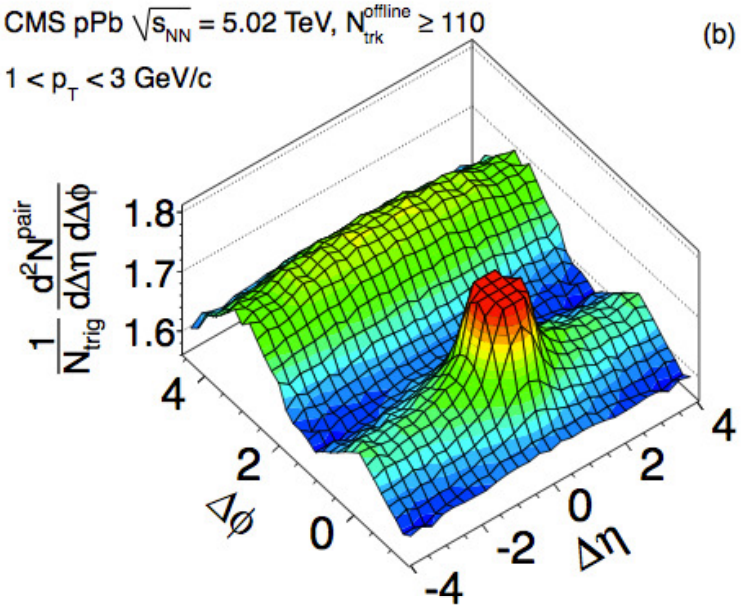

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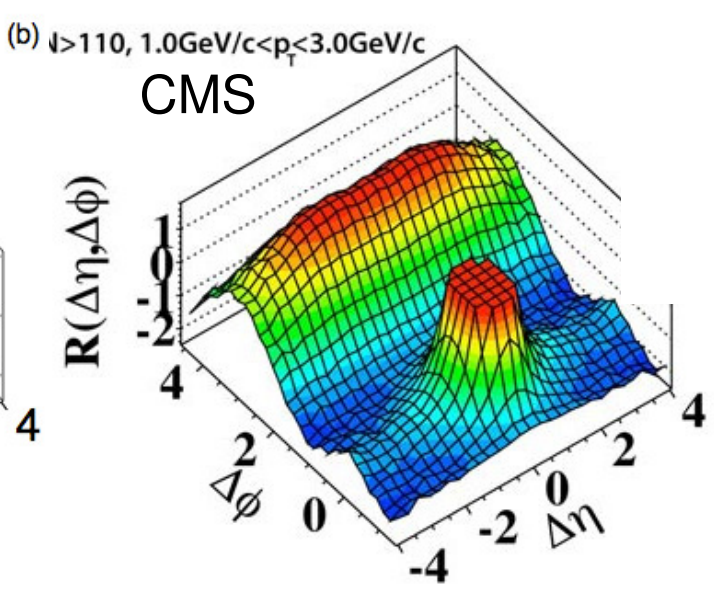
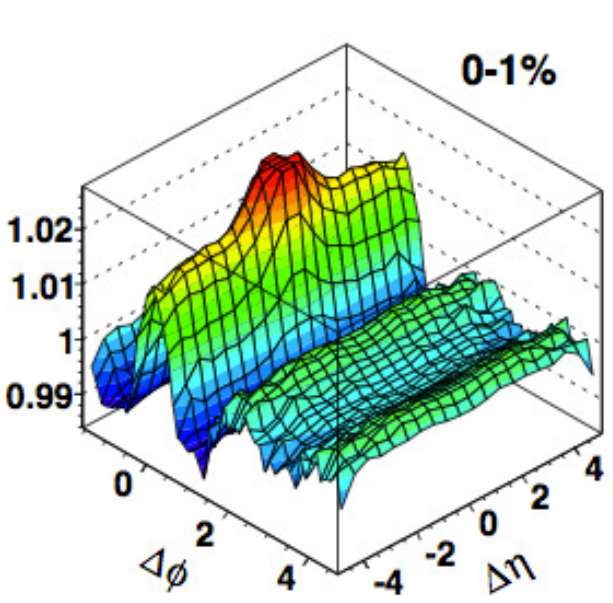


p+p ridge

- Two-particle correlations show long range correlation structure along $\Delta\eta$ at $\Delta\phi=0$.
- Is there an effective mechanism that rules them all? Is it initial state effect, final state effect or both?
  - Final state effect may not imply hydro.

Ridges in Pb-Pb, p-p and p+Pb



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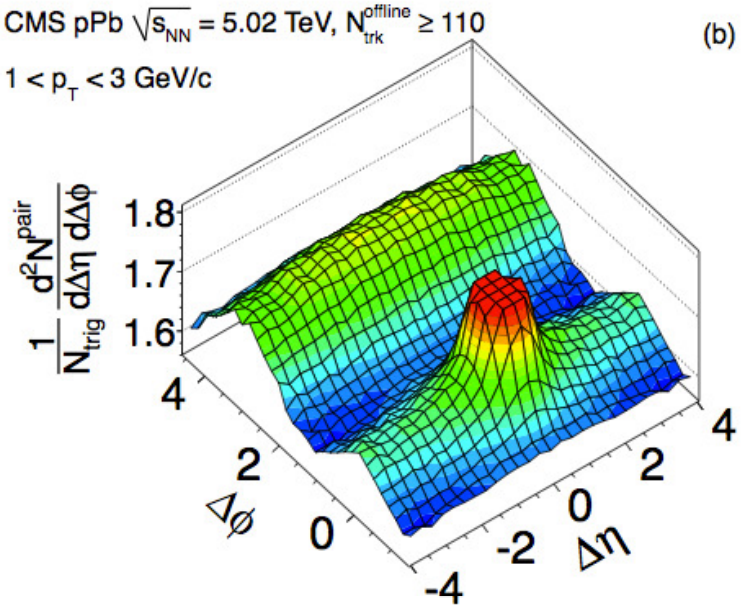

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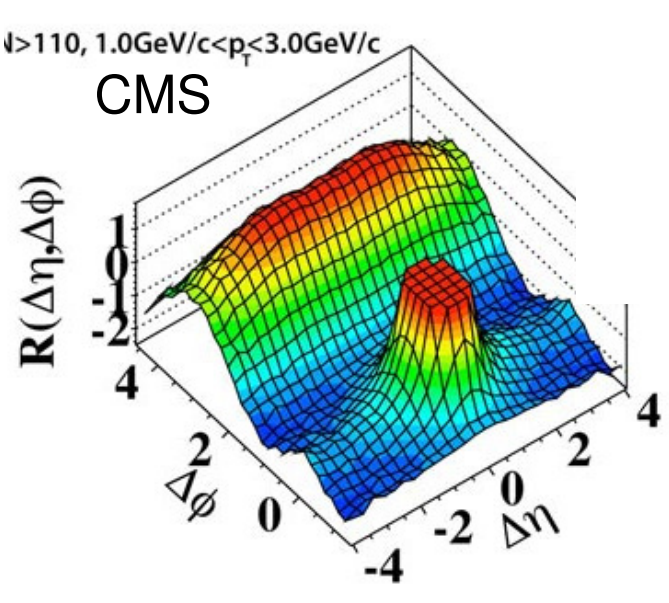

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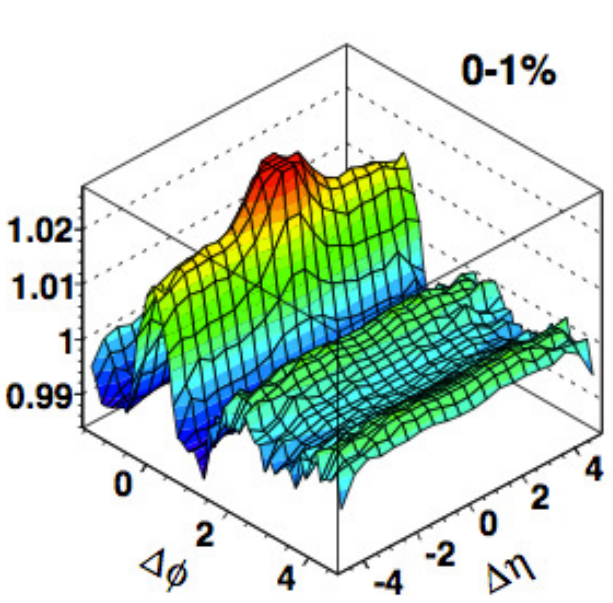
- Is there an away-side ridge in pp and pPb?

Ridges in Pb-Pb, p-p and p+Pb



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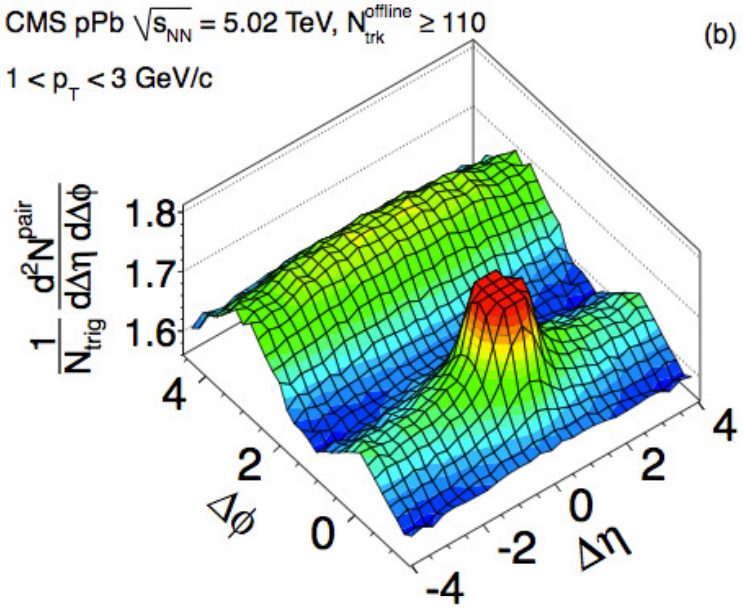

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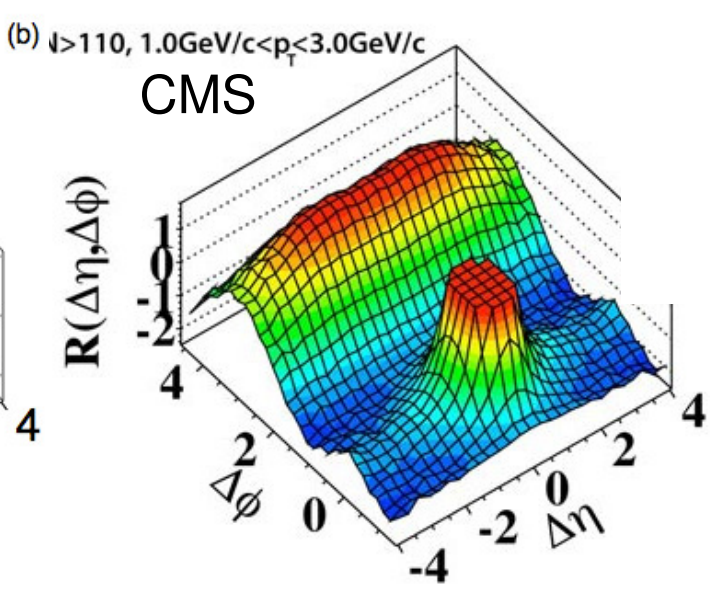
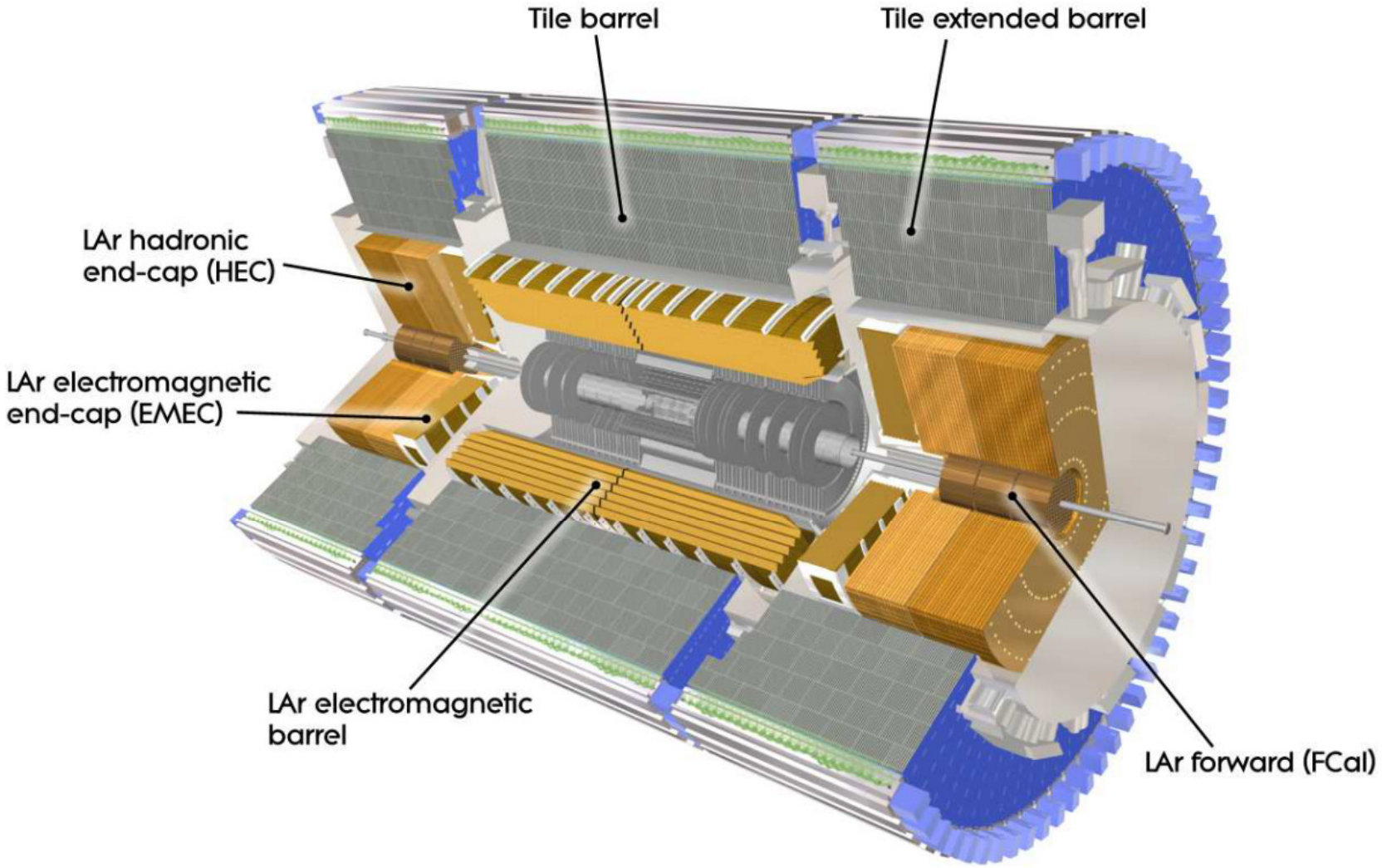


p+p ridge

- Two-particle correlations show long range correlation structure along $\Delta\eta$ at $\Delta\phi=0$.
- Is there an effective mechanism that rules them all? Is it initial state effect, final state effect or both?
  - Final state effect may not imply hydro.
- Is there an away-side ridge in pp and pPb?
- What is its detailed p_T, η, and centrality dependence?

ATLAS Detector



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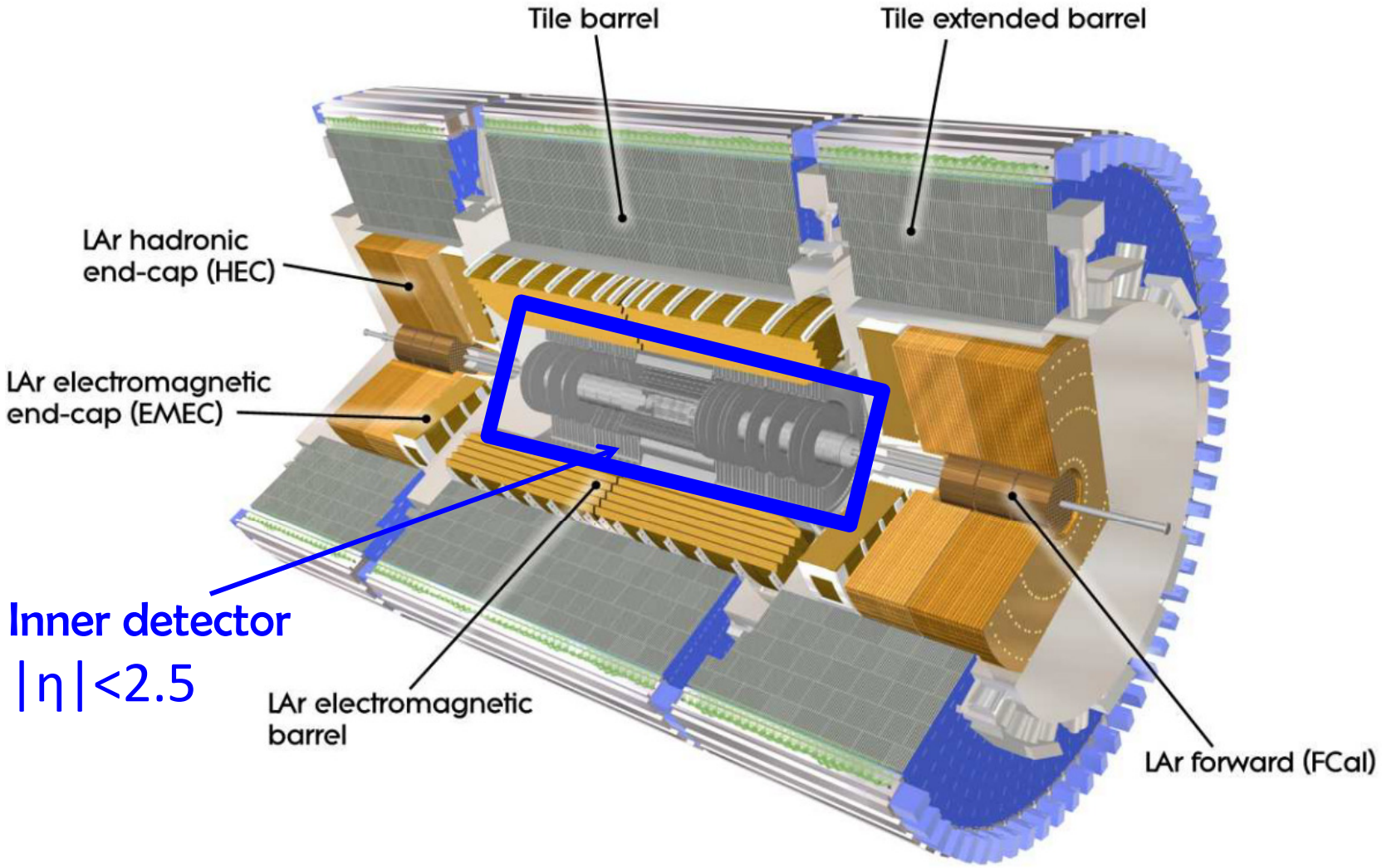
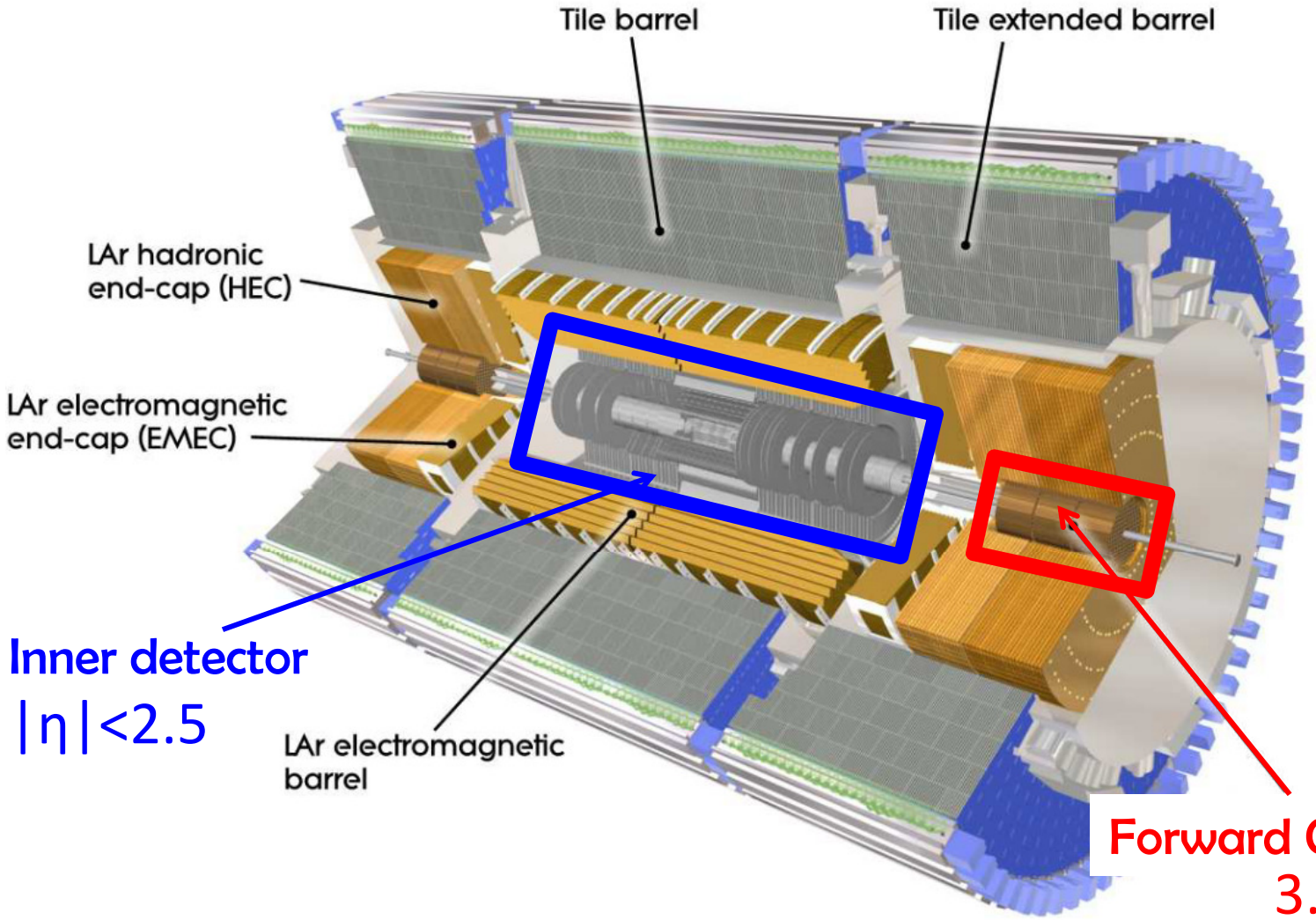


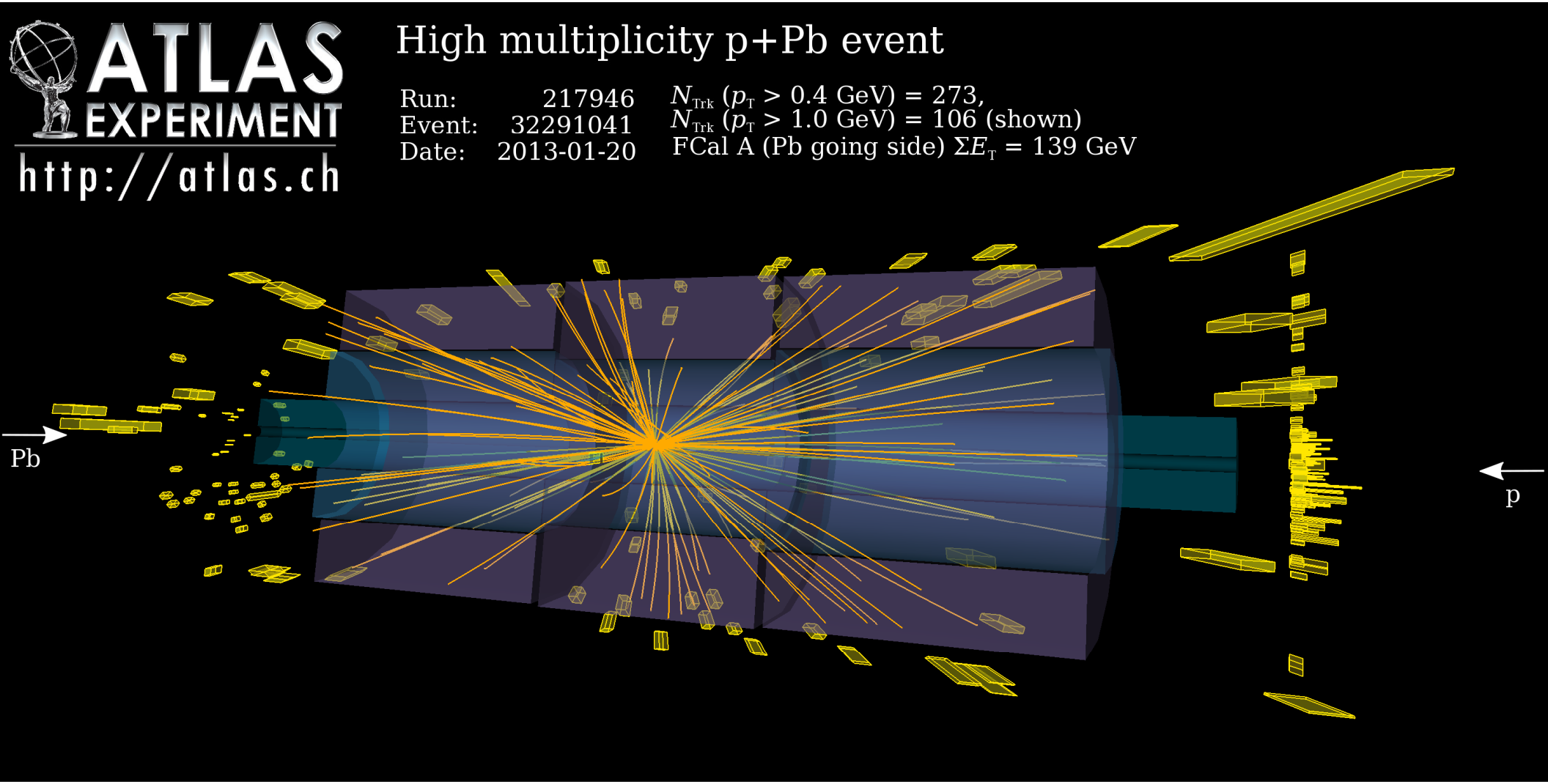
- Tracking coverage : |η|<2.5

ATLAS Detector



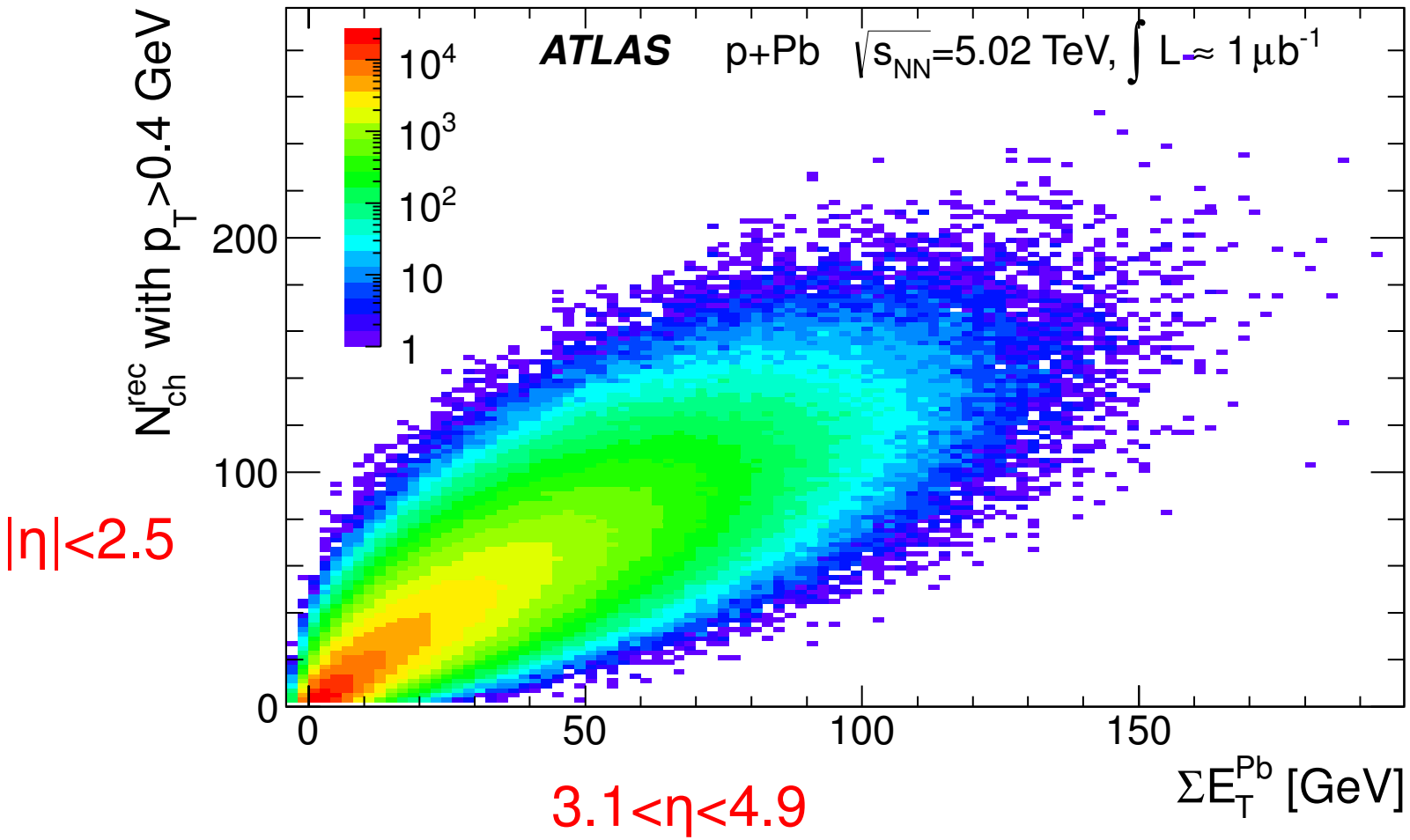
- Tracking coverage : |η|<2.5
- FCal coverage : 3.2<|η|<4.9 used to determine Centrality (Pb side only)

High multiplicity event



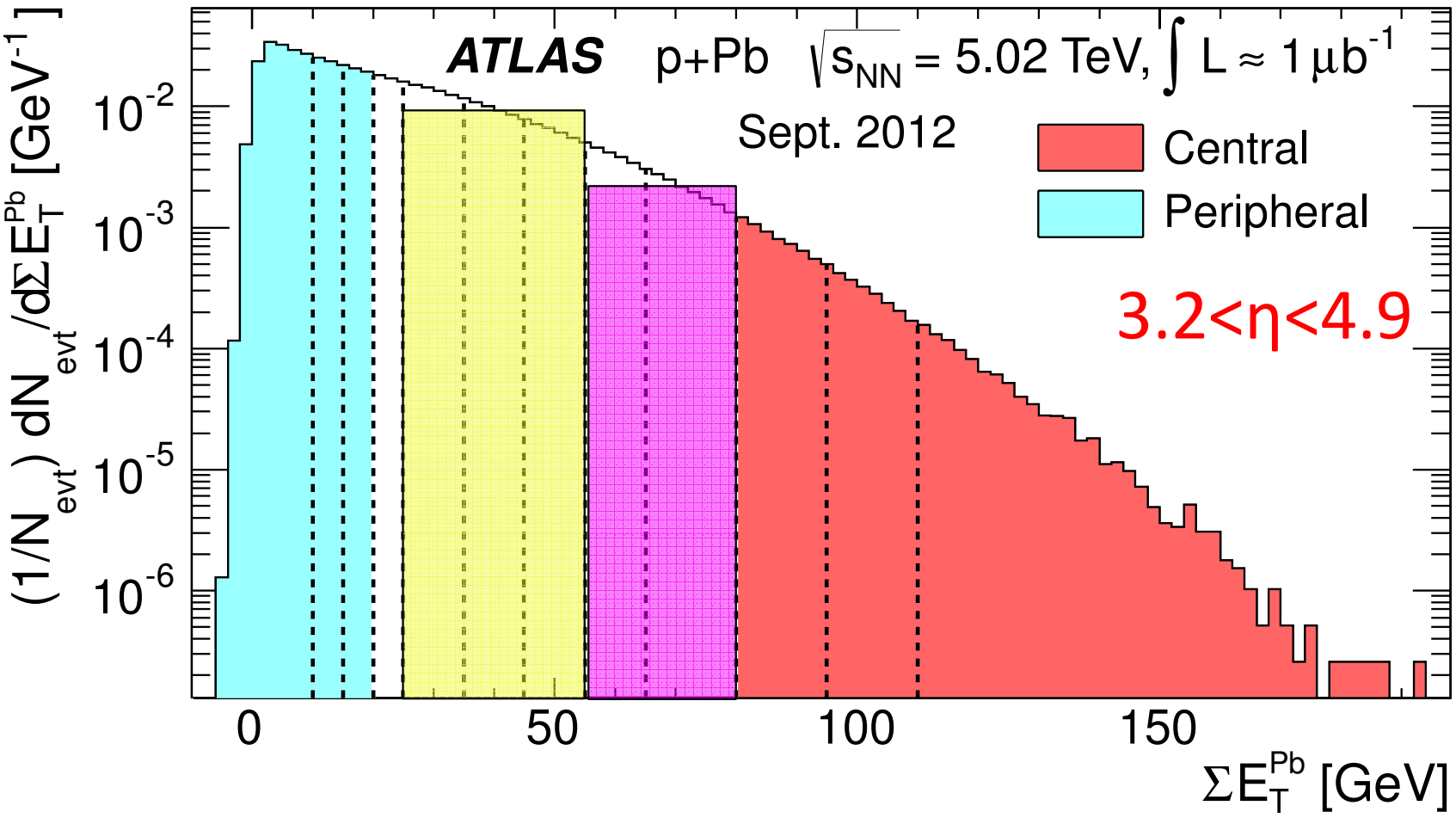
contains 273 tracks with p_T>0.4 GeV, but only p_T>1 GeV tracks are shown

Event activity : N_{ch} vs ΣE_T(Pb)



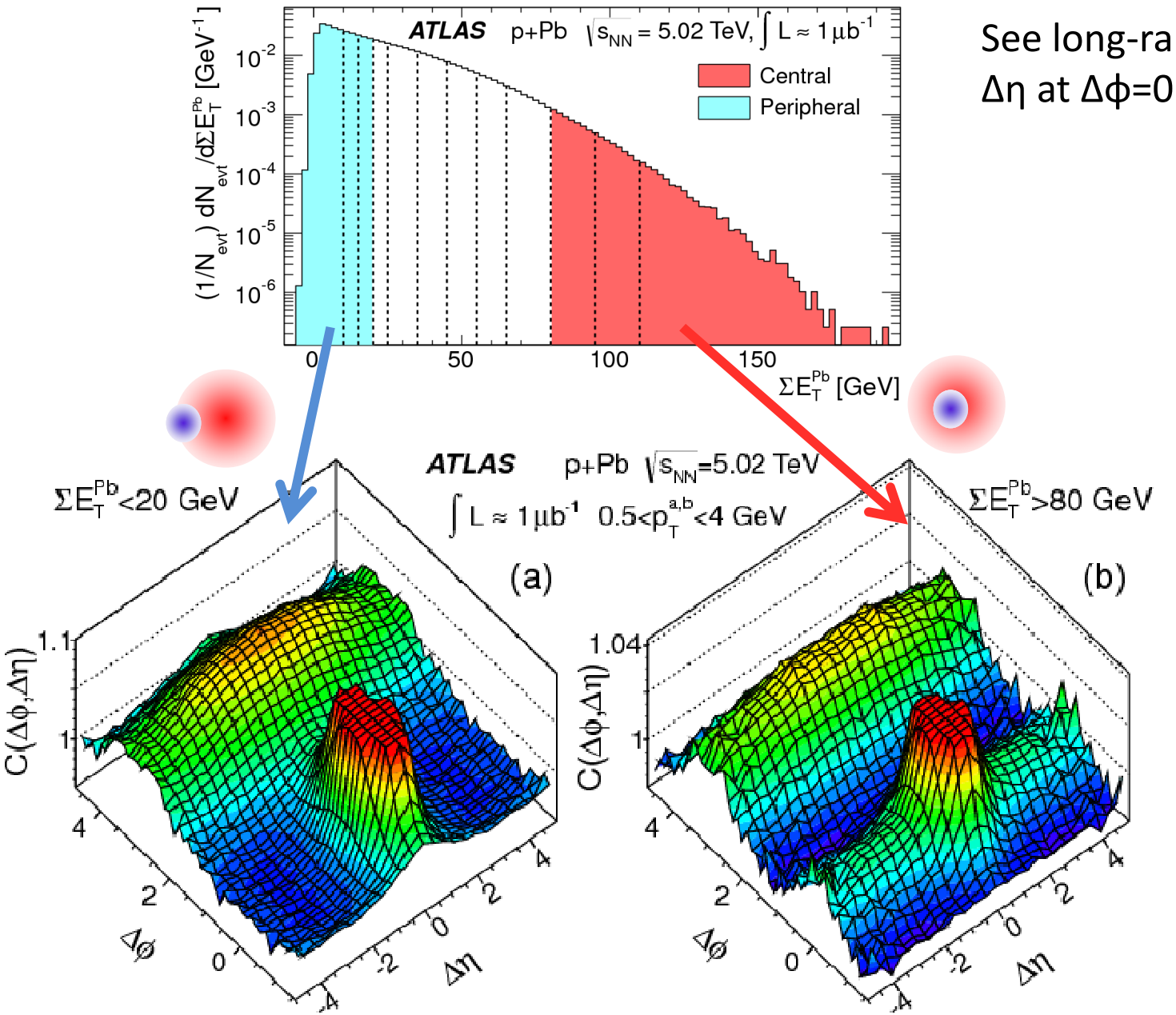
- Broad correlation between ΣE_T(Pb) with N_{ch},
  - but overall along diagonal
- No overlap between Fcal and tracking detectors => no auto-correlation bias in event activity definition

Event activity classes (centrality)



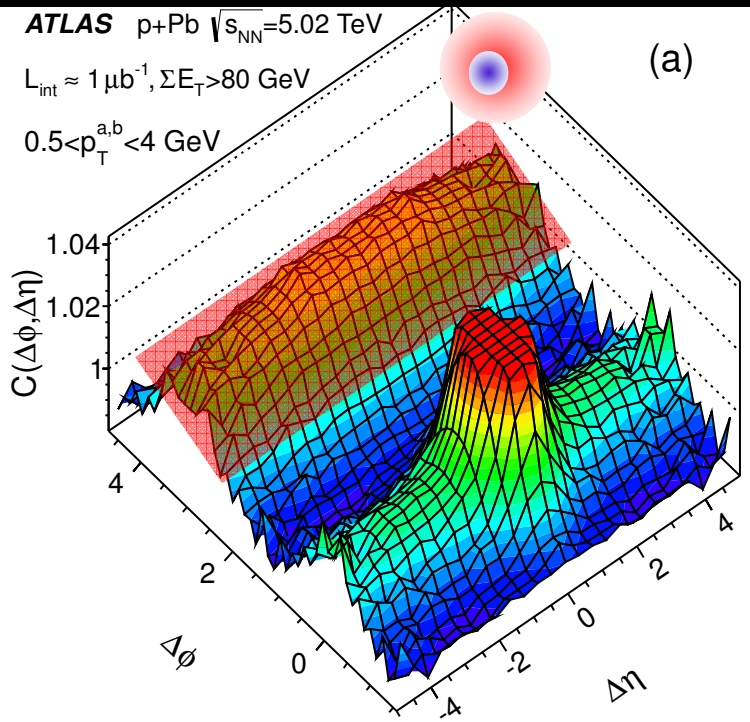
- Classes made by dividing ΣE_T in Pb-going side into 12 fine classes.
- Four coarse classes:
  - >80 GeV (0-2%), 55-80 GeV (2-9%), 25-55 GeV (9-39%) and <20 GeV (48-100%)

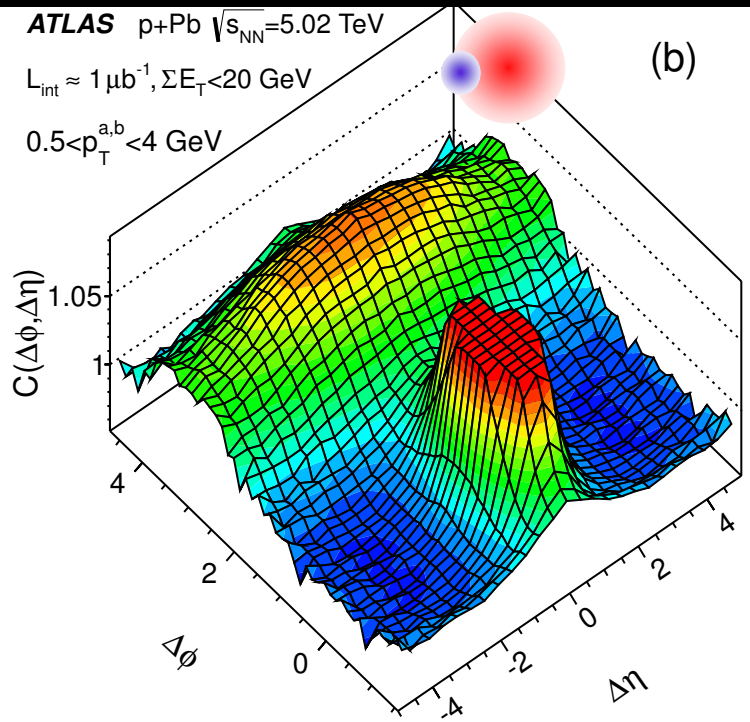
Near side ridge in p-Pb



See long-range correlations along Δη at Δϕ=0 in central p-Pb events

Ridge on away side ?





Subtracting a pedestal and integrated over away side

$$\int \left[C\left(\Delta\phi, \Delta\eta\right) - \xi_{\mathrm{ZYAM}} \right] d\,\Delta\phi$$

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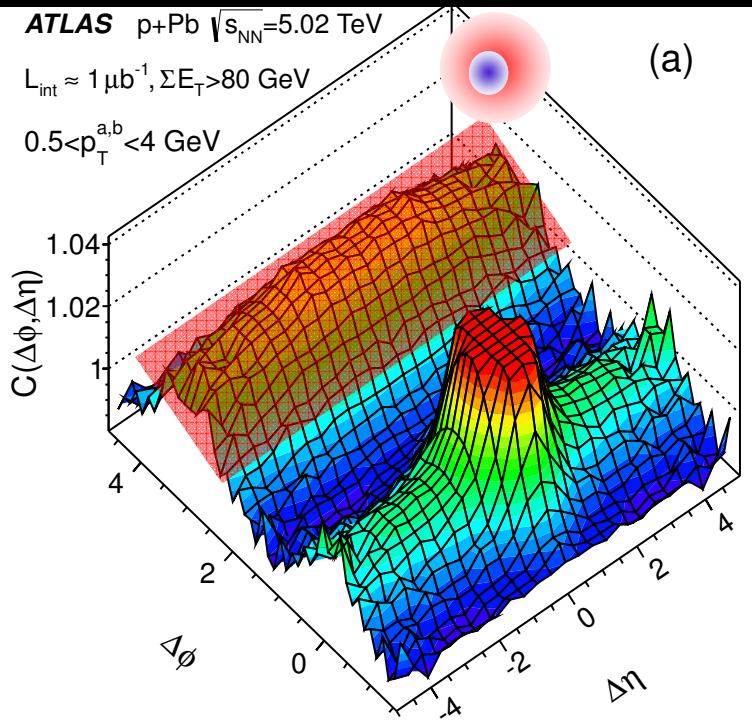
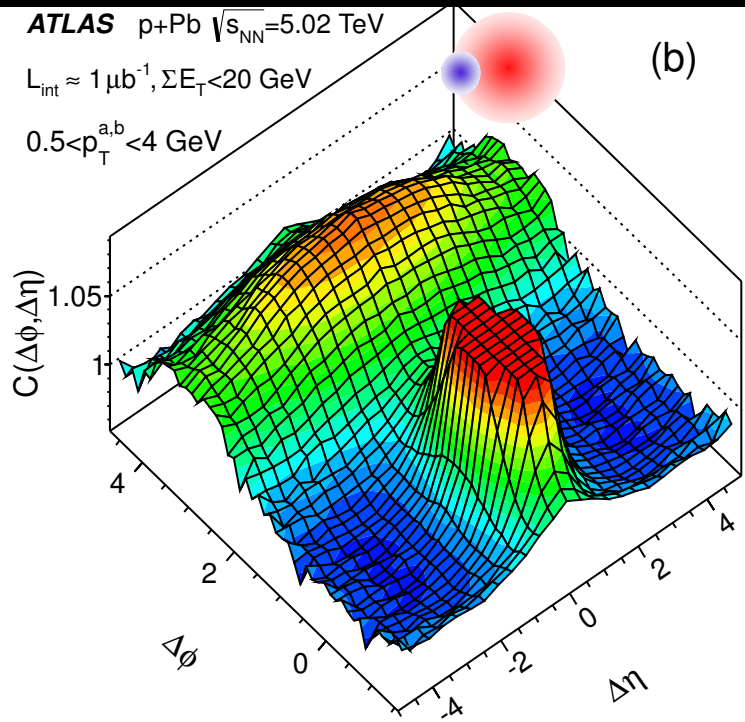
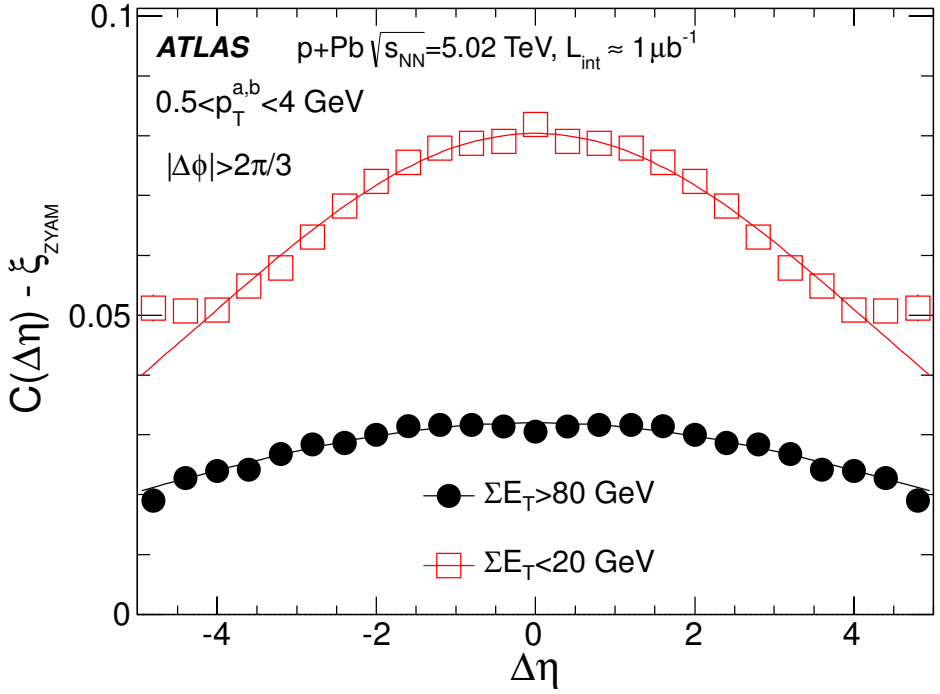




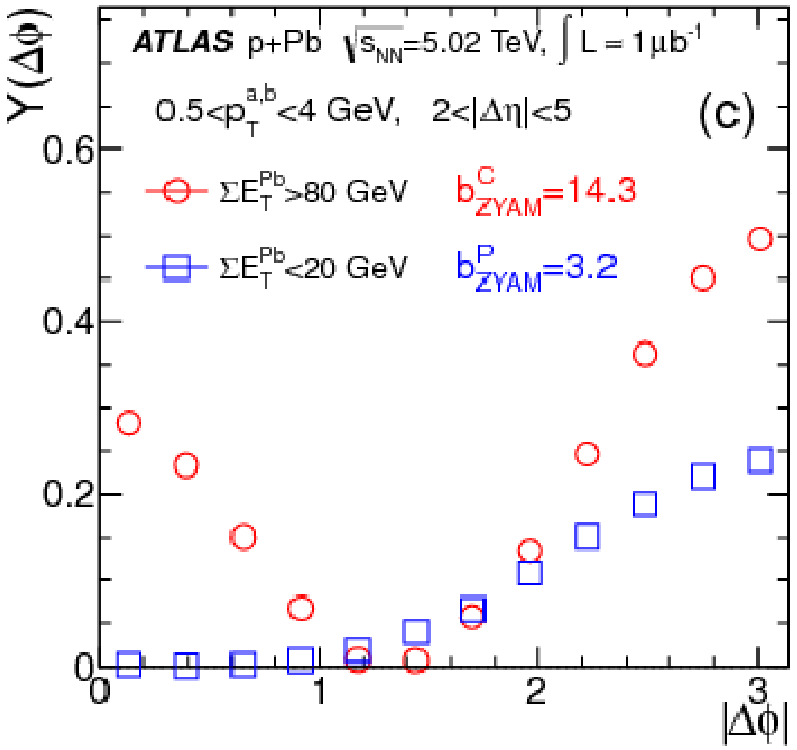
Subtracting a pedestal and integrated over away side

$$\int \left[C\left(\Delta\phi,\Delta\eta\right) - \xi_{\mathrm{ZYAM}} \right] d\Delta\phi$$

- Away-side is broadened along Δη, for central events.
- Is there an away-side ridge?



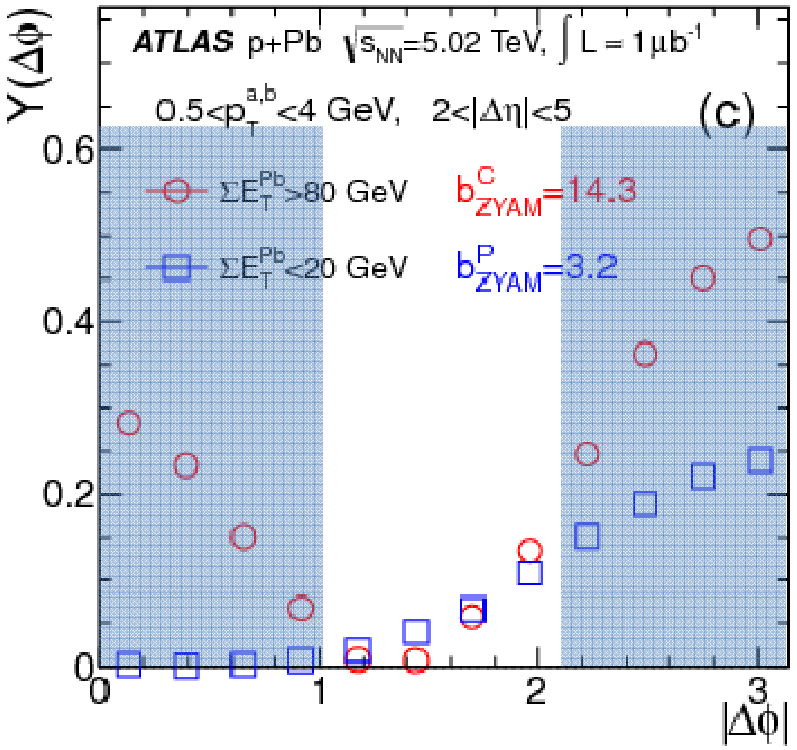
Per Trigger Yields



Y(ΔΦ)=(Number of pairs)/(Number of triggers) – Pedestal(ZYAM)

- Compare central PTY with peripheral PTY for $2<|\Delta\eta|<5$
- In peripheral case see away-side jet contribution
- See ridge on near side in central events
- Excess is also seen on away side

Per Trigger Yields



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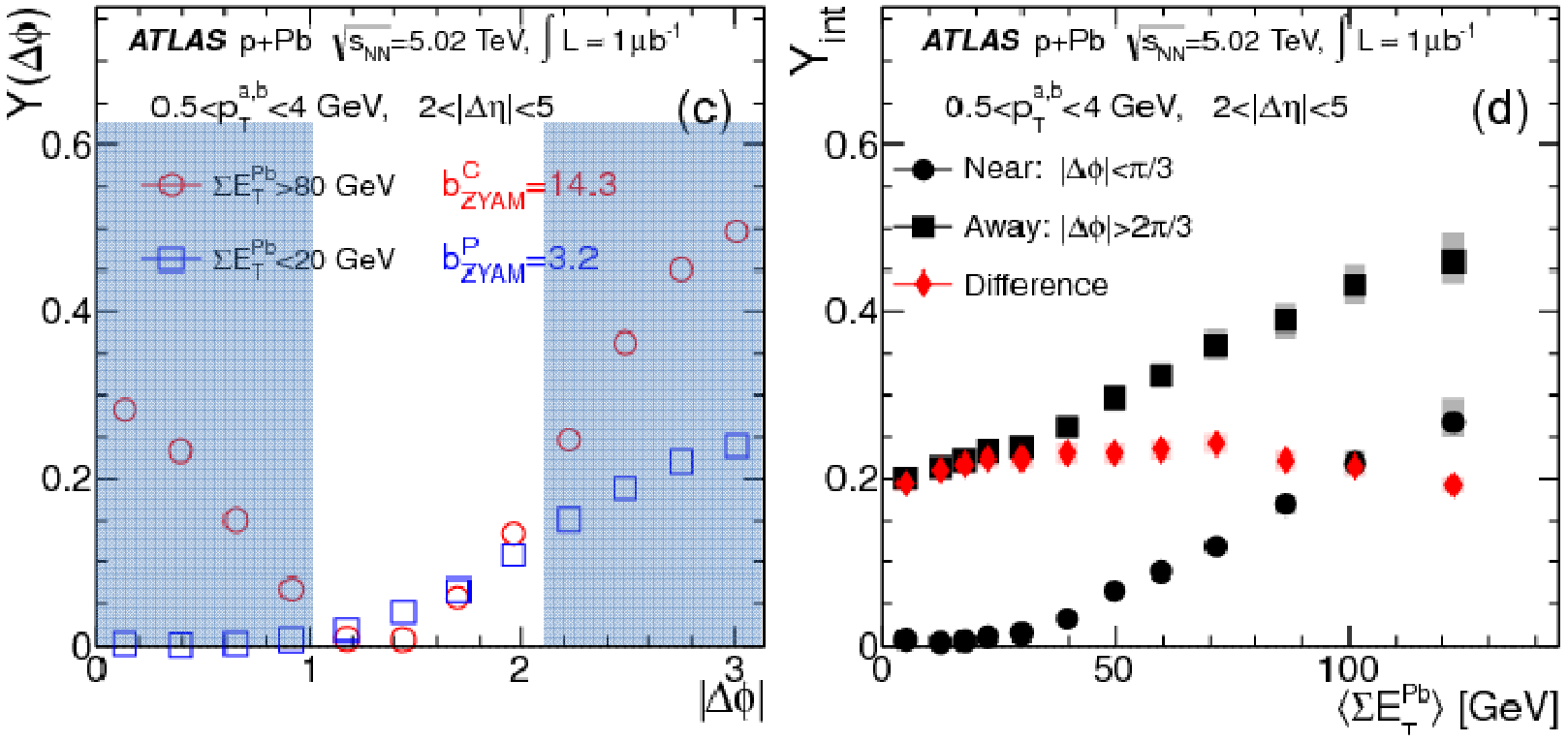

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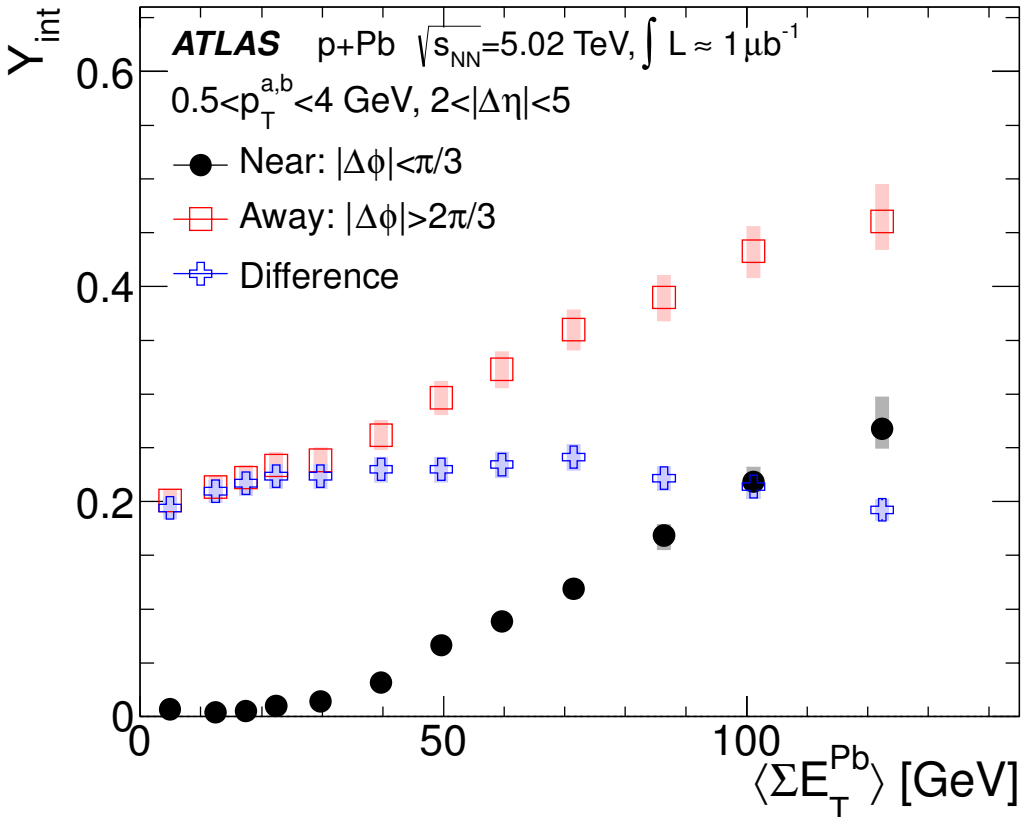
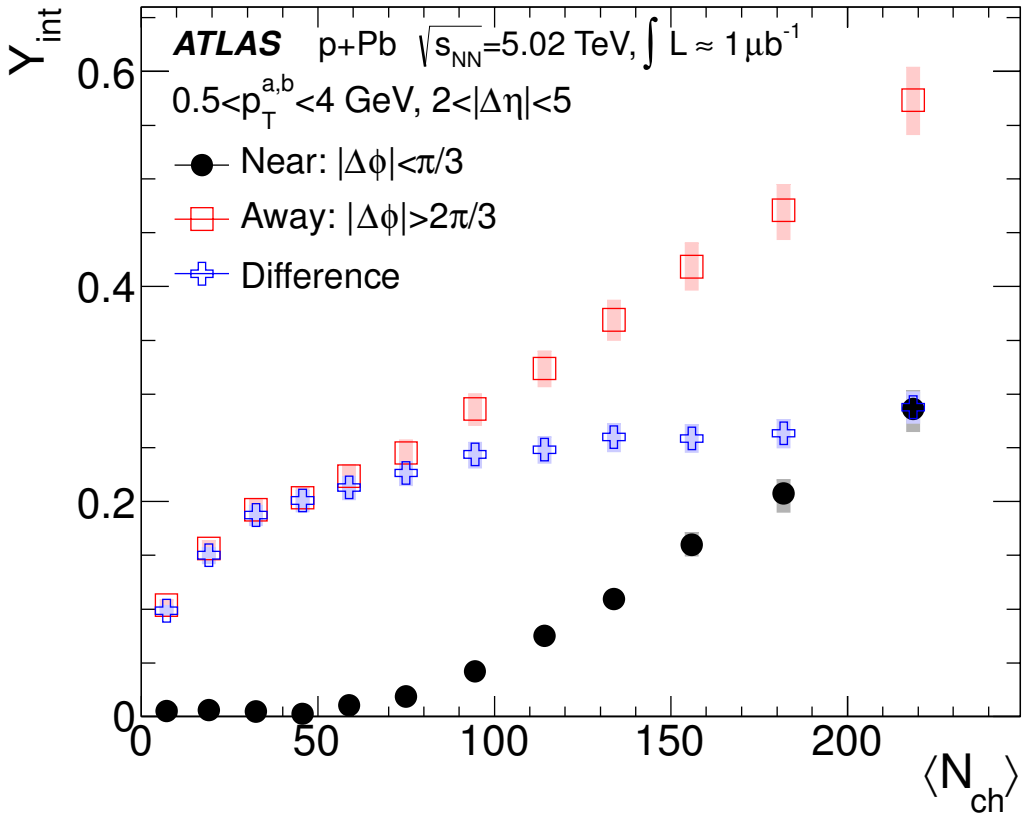
- Excess is symmetric

Auto-correlation bias for N_{ch} based result





- clear drop in the away-side yield for events explicitly required to have small N_{ch} : Auto-correlation bias

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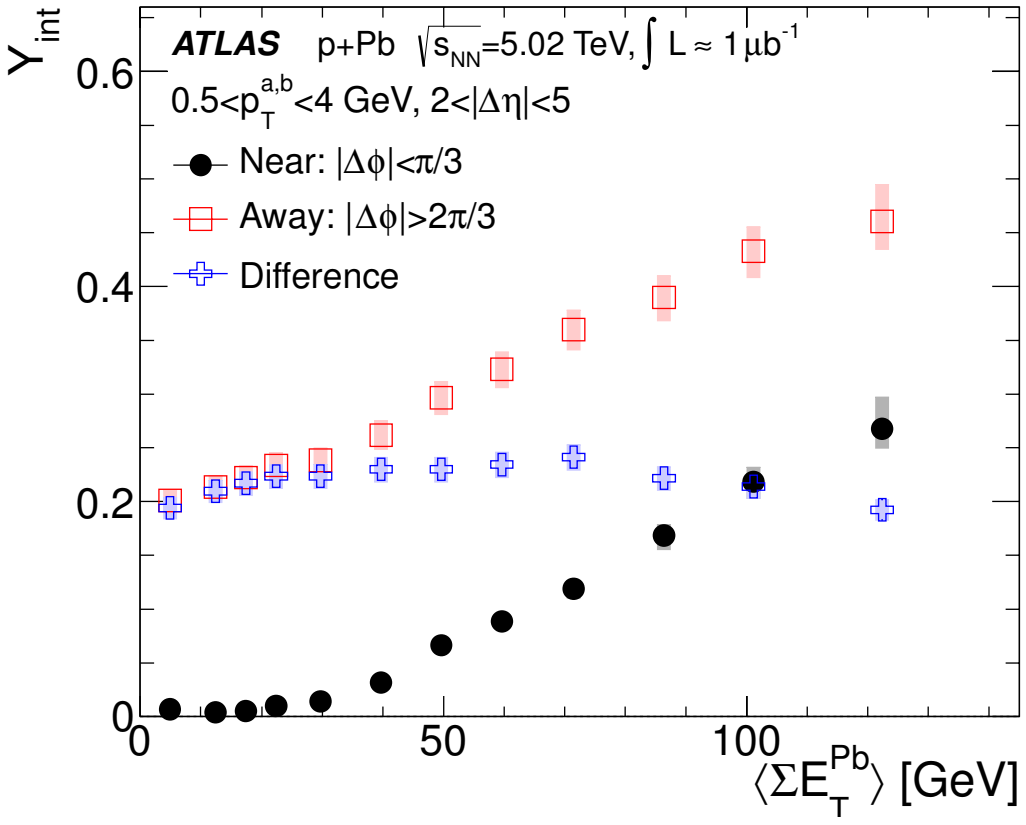

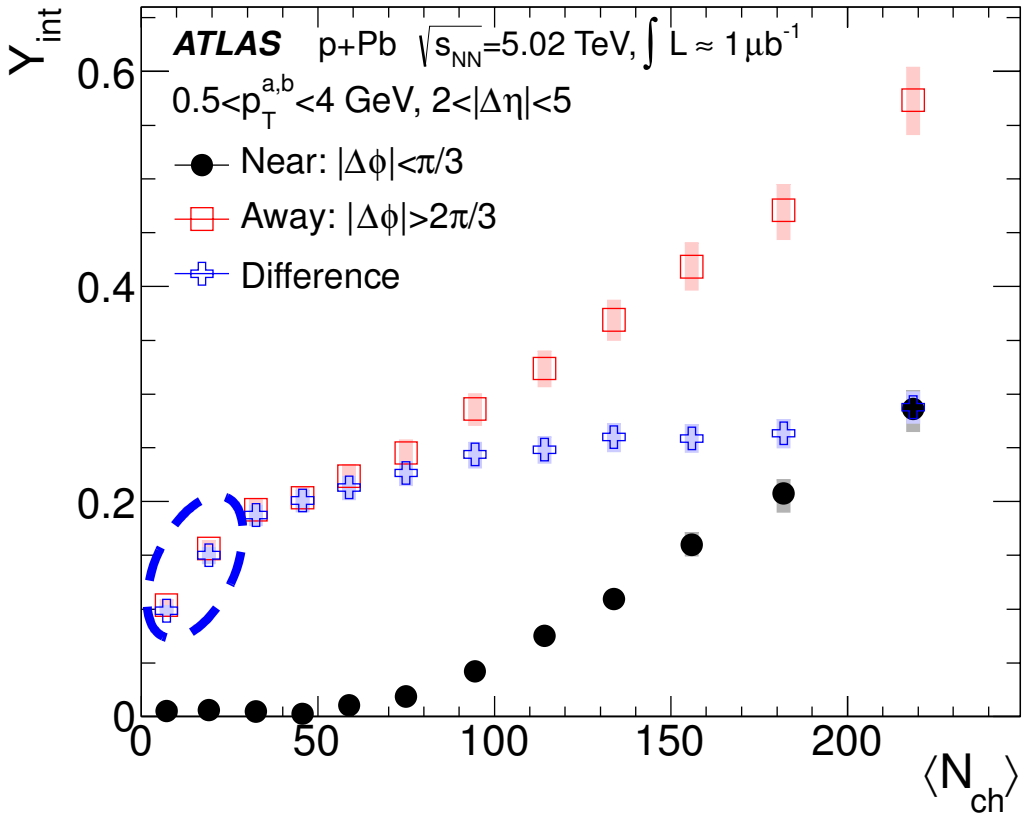

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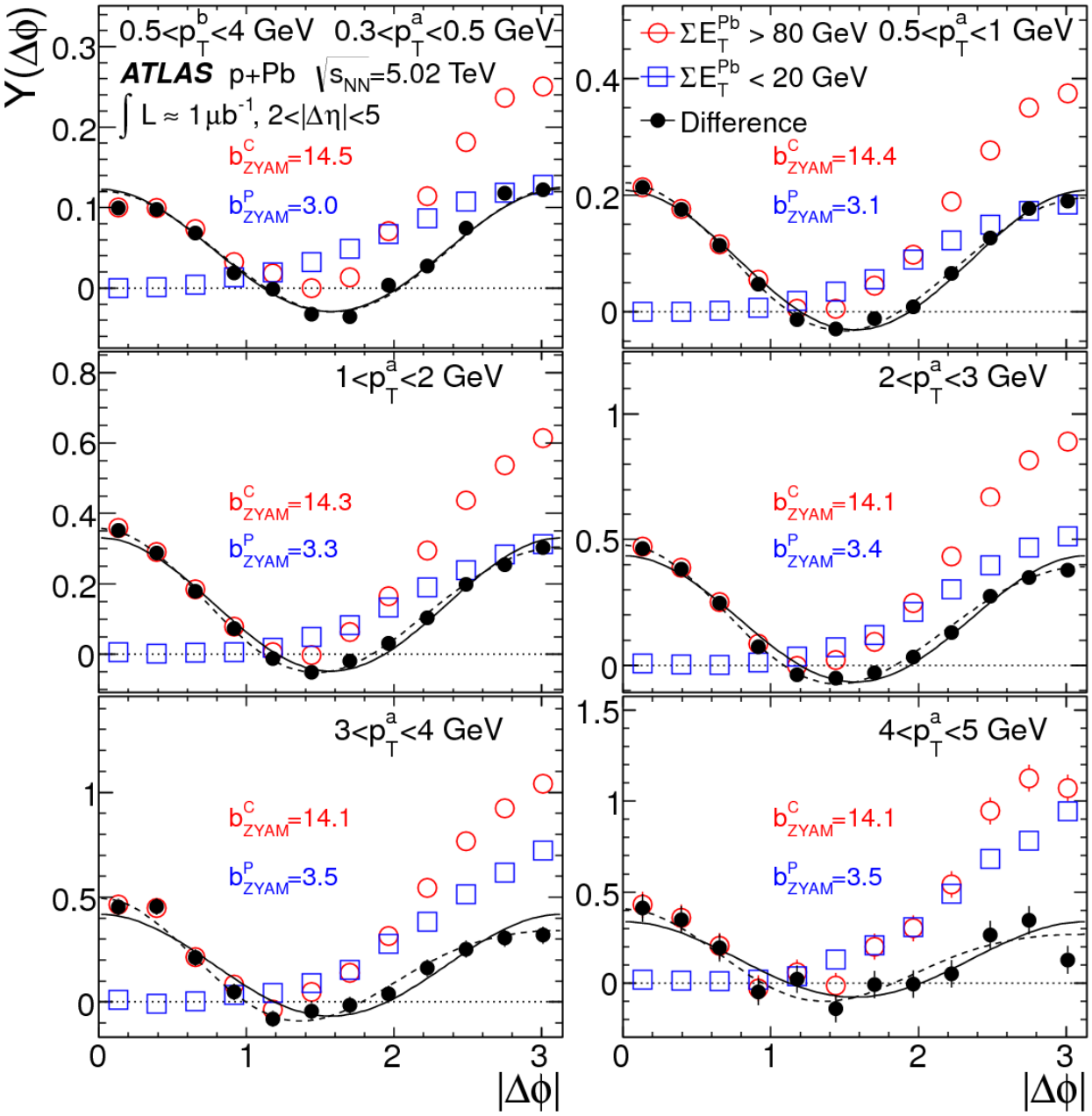
PTY for different trigger p_T

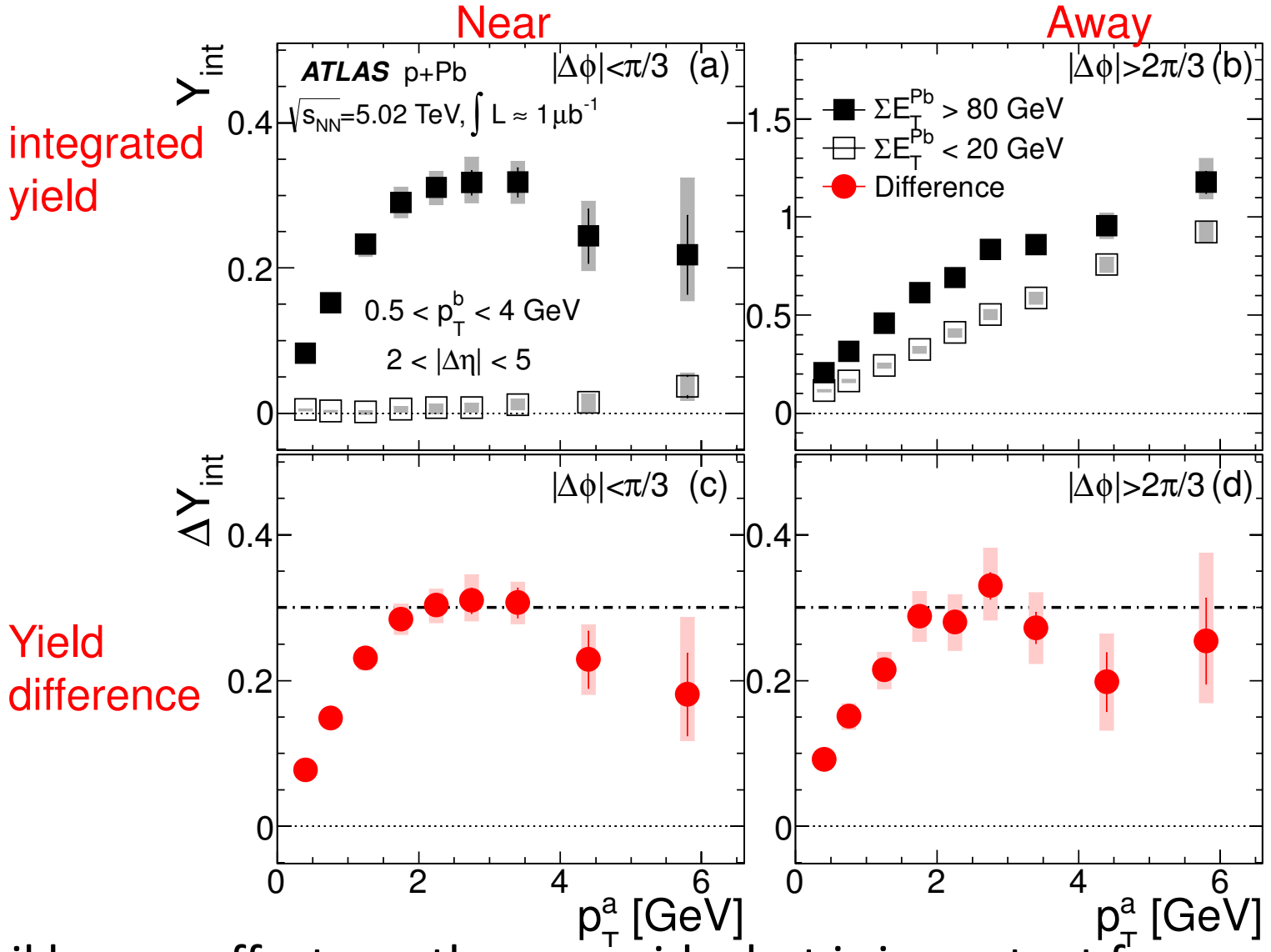


$$\Delta Y(\Delta\phi) = Y(\Delta\phi)^{Central} - Y(\Delta\phi)^{Peripheral}$$

$\Delta Y(\Delta\phi)$ is very well described by:

$$a_0 + a_2 \cos(2\Delta\phi)$$

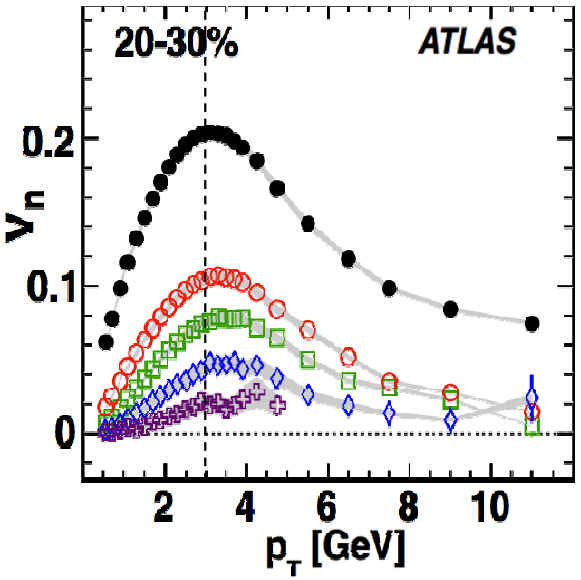
p_T dependence of ridge yield



- Subtraction of recoil has no effects on the near-side, but is important for the away-side. Yield difference is symmetric

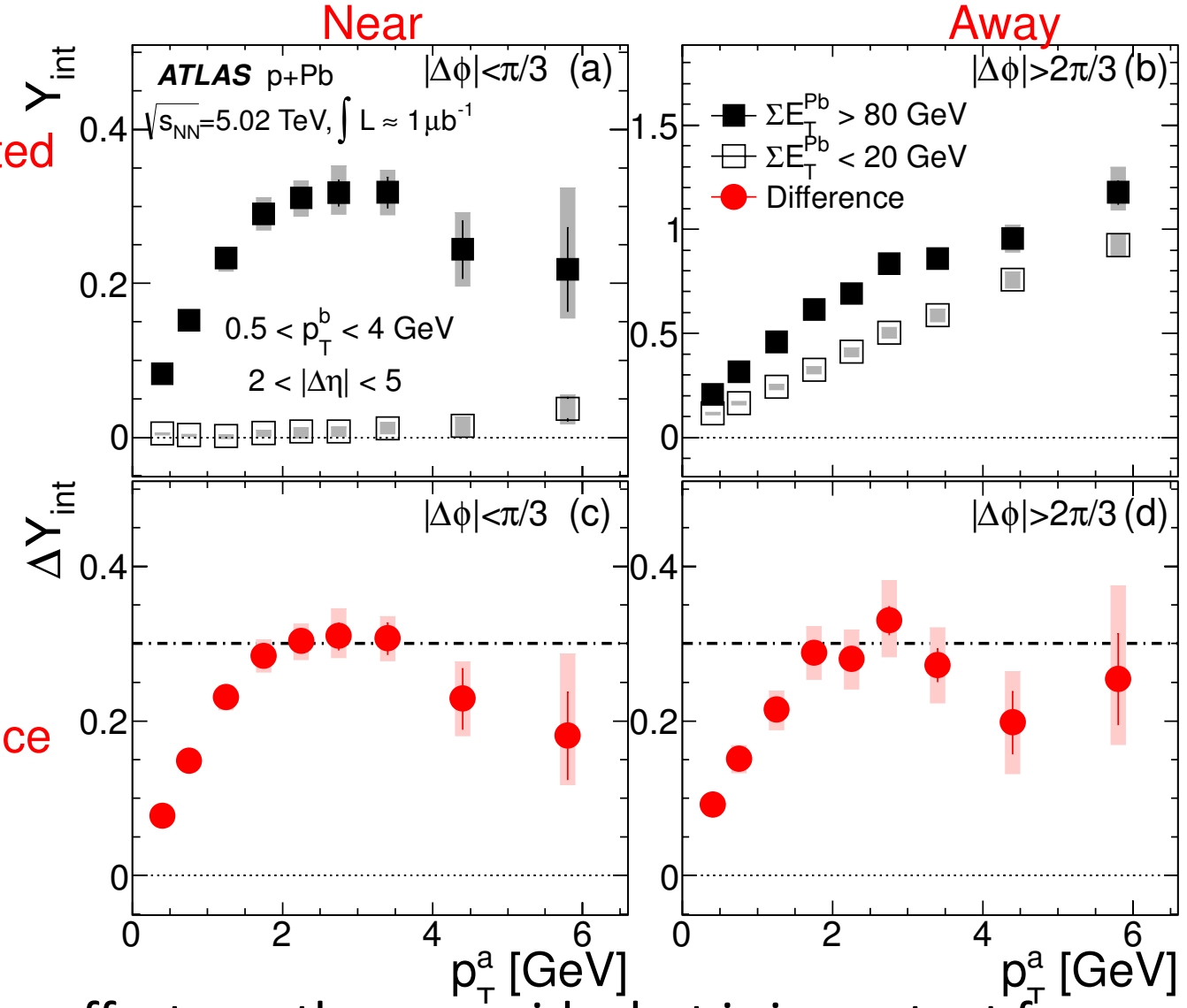
  Ridge persists to at least 6 GeV!

p_T dependence of ridge yield



integrated yield

Yield difference

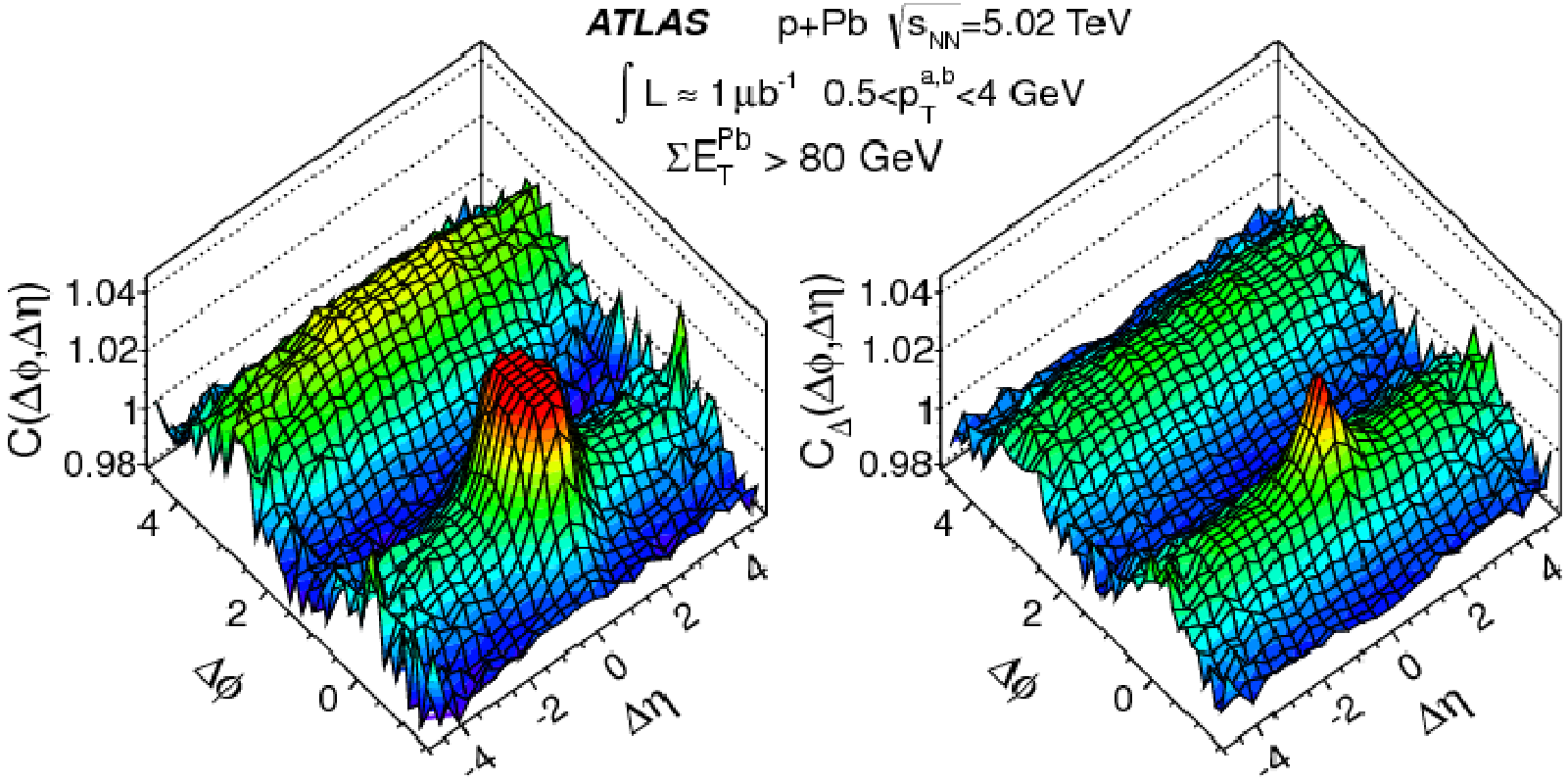


- Subtraction of recoil has no effects on the near-side, but is important for the away-side. Yield difference is symmetric

  Ridge persists to at least 6 GeV!, similar p_T dependence as Pb+Pb ridge : suggestive of hydrodynamic origin

Recoil subtracted correlation function

Remove the recoil on the per-trigger level, then convert the remainder back into a 2D correlation function



$$C \propto \left(PTY^{Central} + Pedestal^{Central} - PTY^{Peripheral} \right)$$

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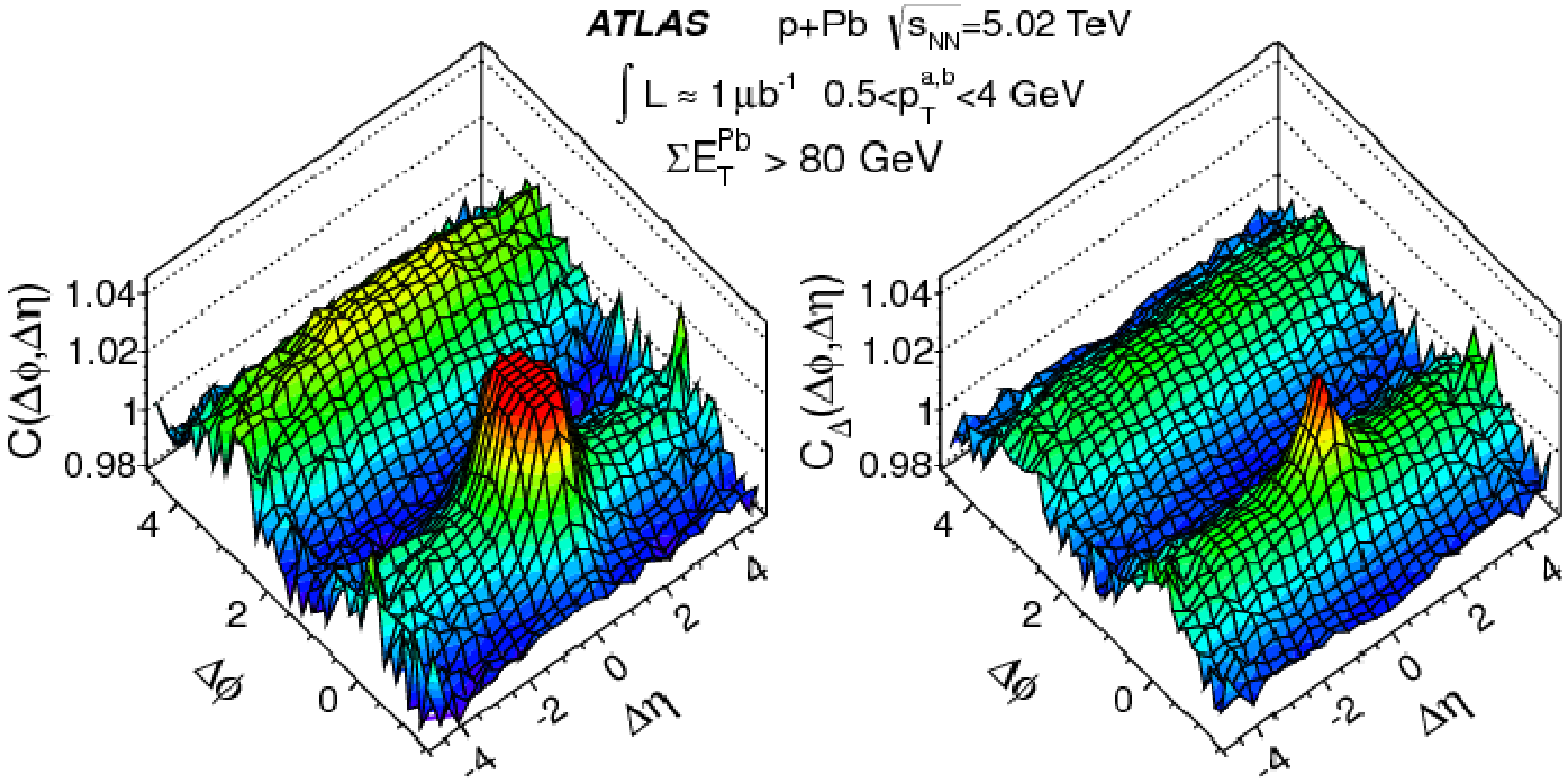
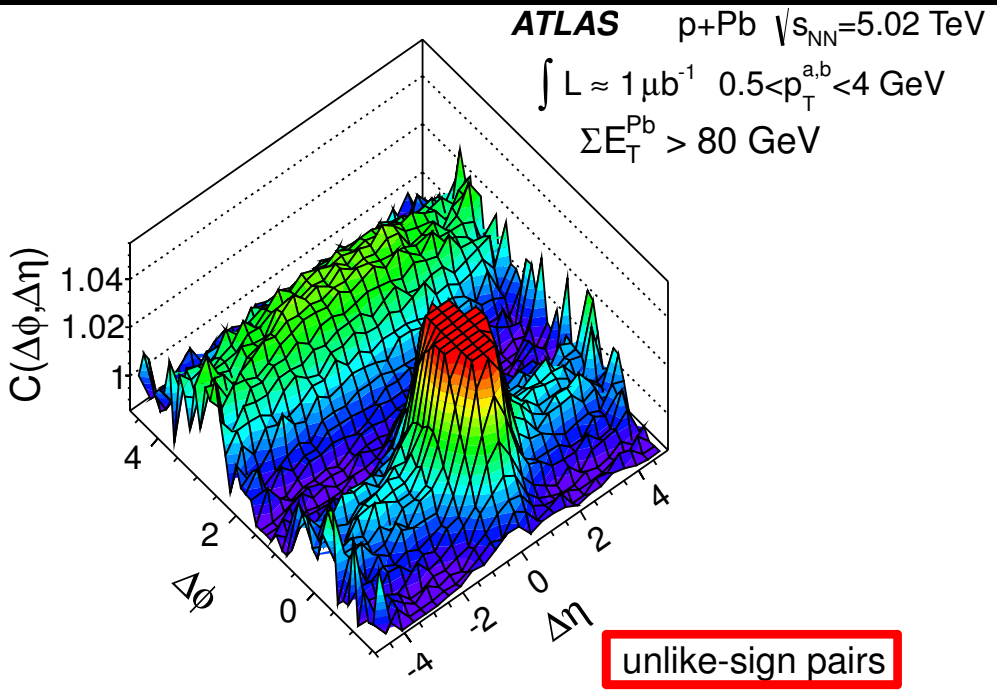


$$C \propto \left(PTY^{Central} + Pedestal^{Central} - PTY^{Peripheral} \right)$$

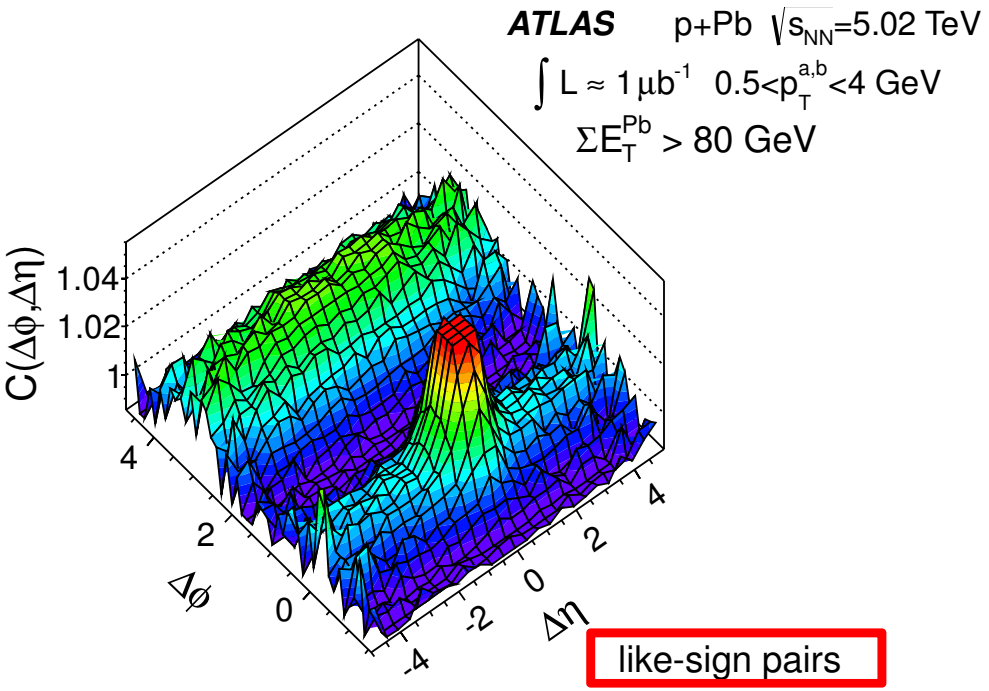
Ridge remains symmetric to Δη=5 and ~ constant, and for all FCal E_T classes

The near-side removal of short-range correlations not complete!
(about 5-10% signal remain)

After recoil removal: charge dependence



unlike-sign pairs



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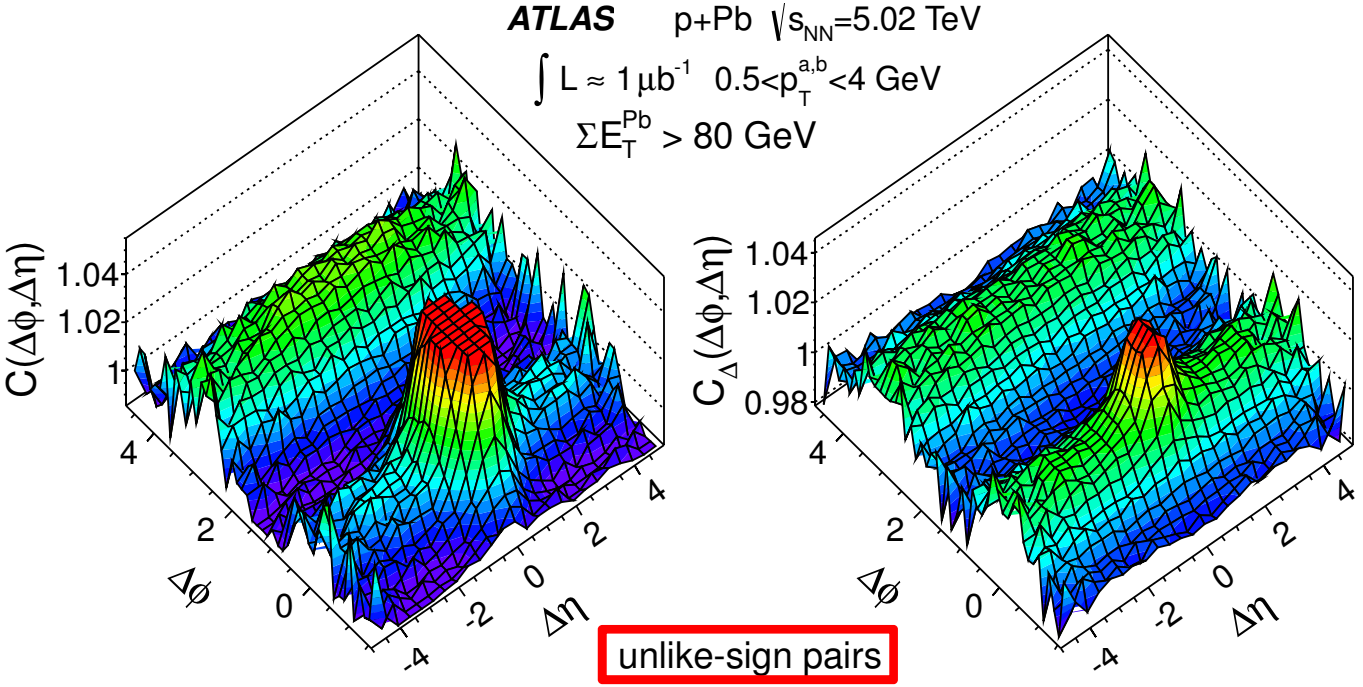
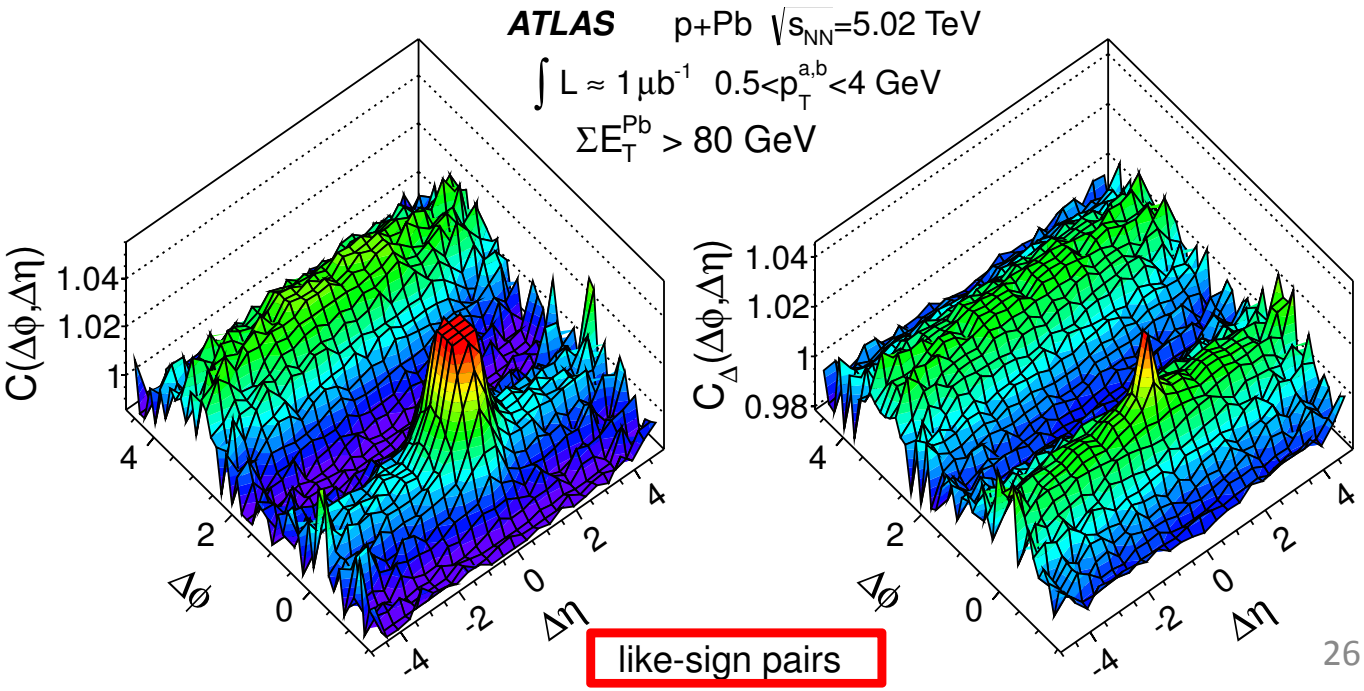
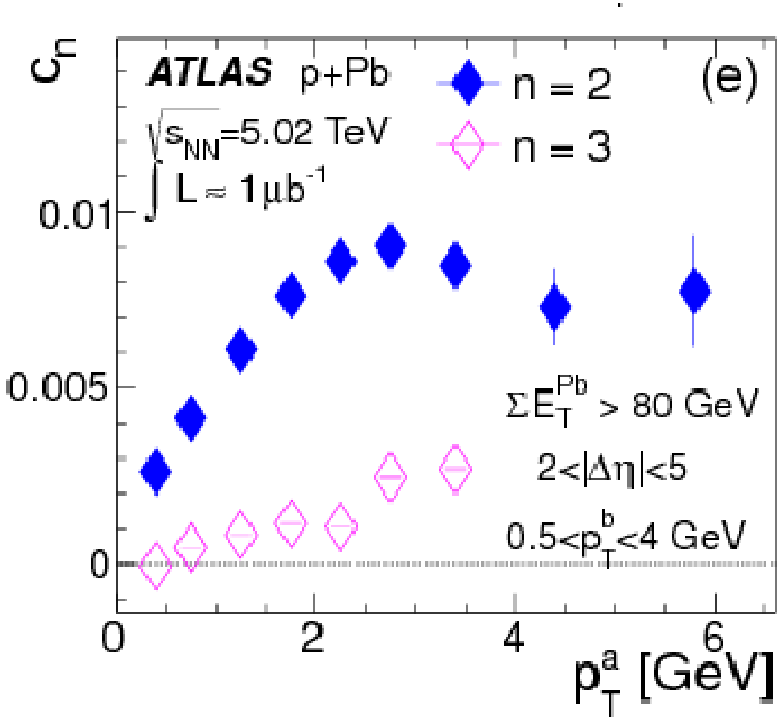




Ridge magnitude and its symmetry do not dependent on charge combinations

Peripheral subtracted correlation function

Extract anisotropy c_n from correlation function: $c_n \leftrightarrow v_{n,n}$



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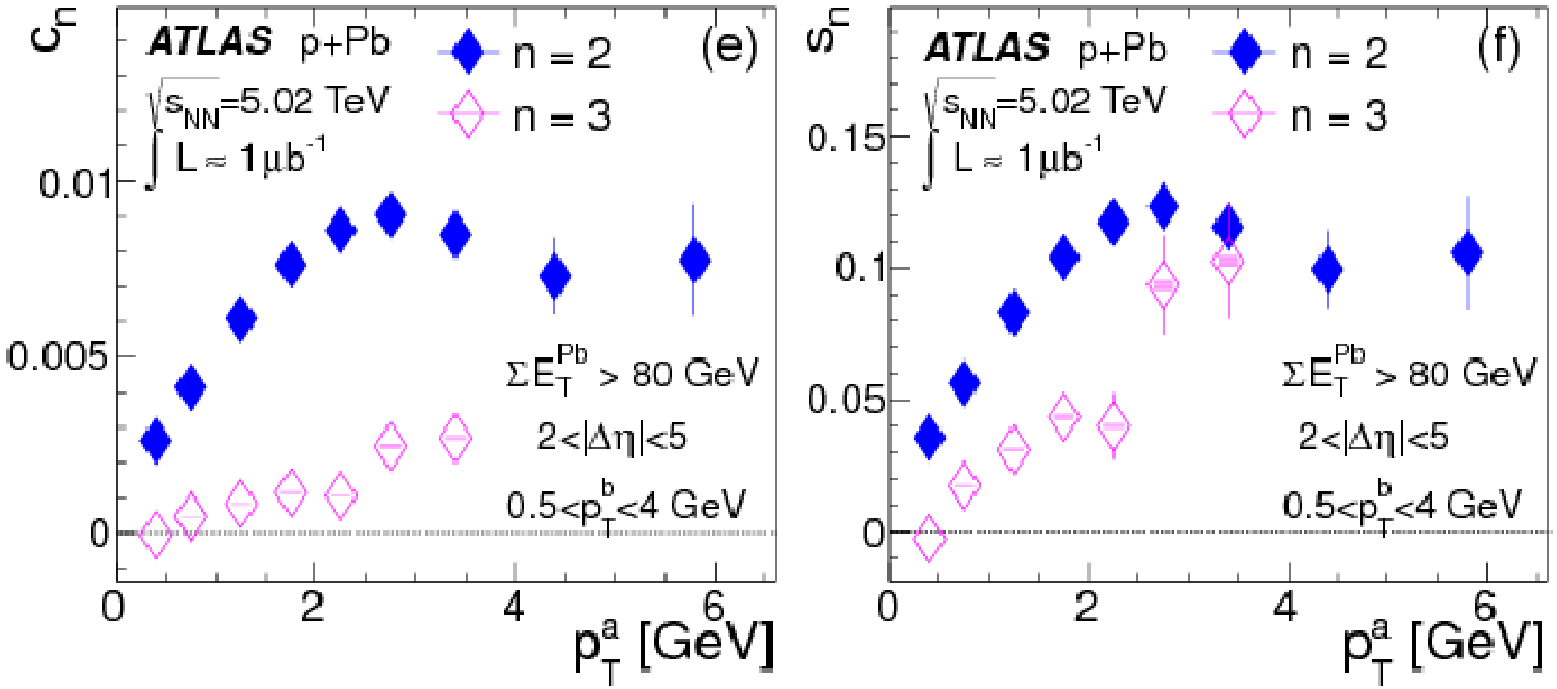
Factorize c_n (as in Heavy Ion 2PC's): $c_n(p_T^a, p_T^b) = s_n(p_T^a) s_n(p_T^b)$

$$s_n(p_T^a) = c_n(p_T^a, p_T^b) / \sqrt{c_n(p_T^b, p_T^b)}$$



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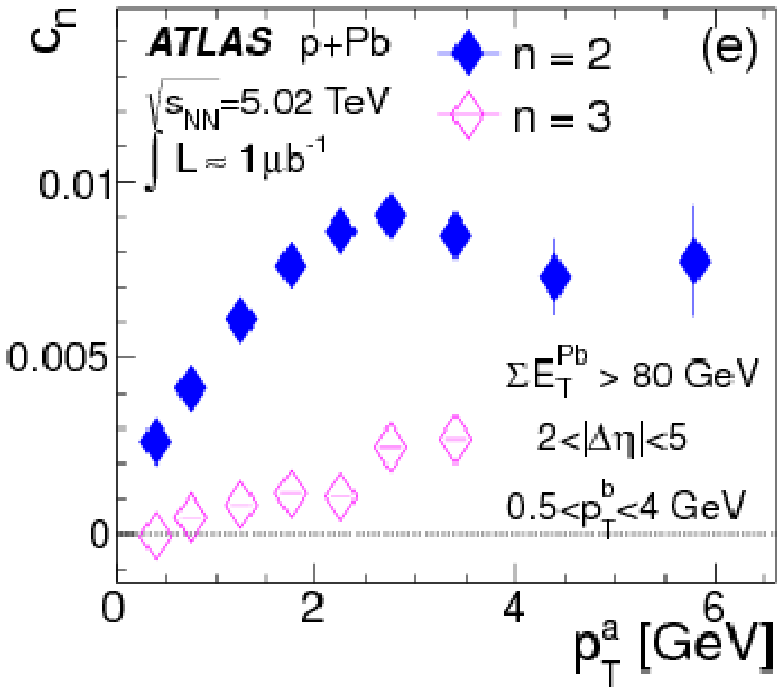
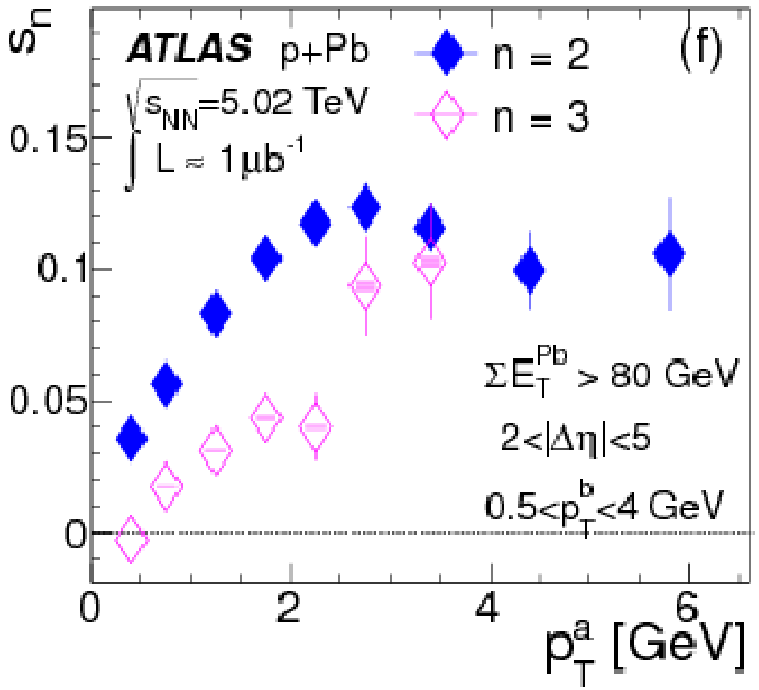
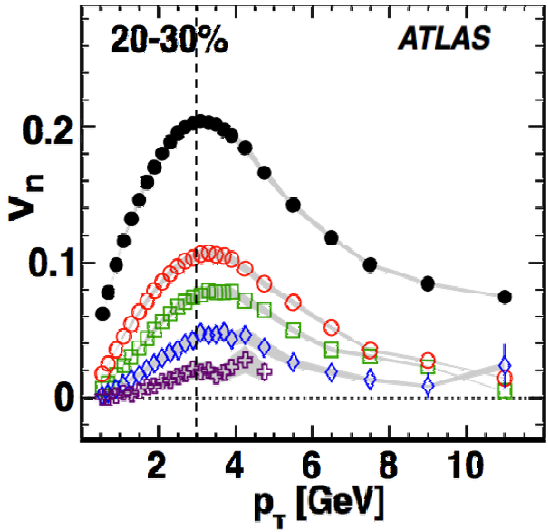
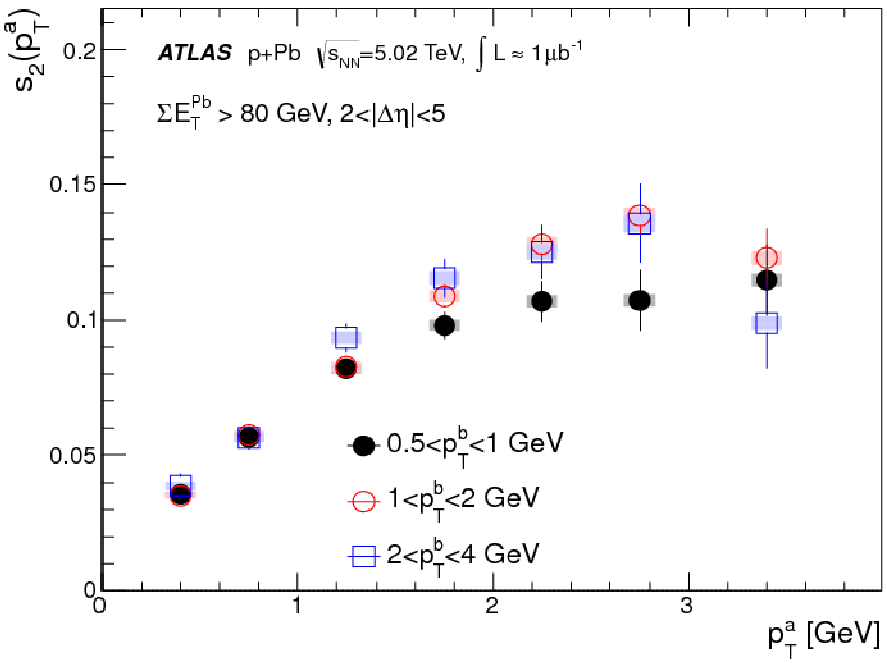
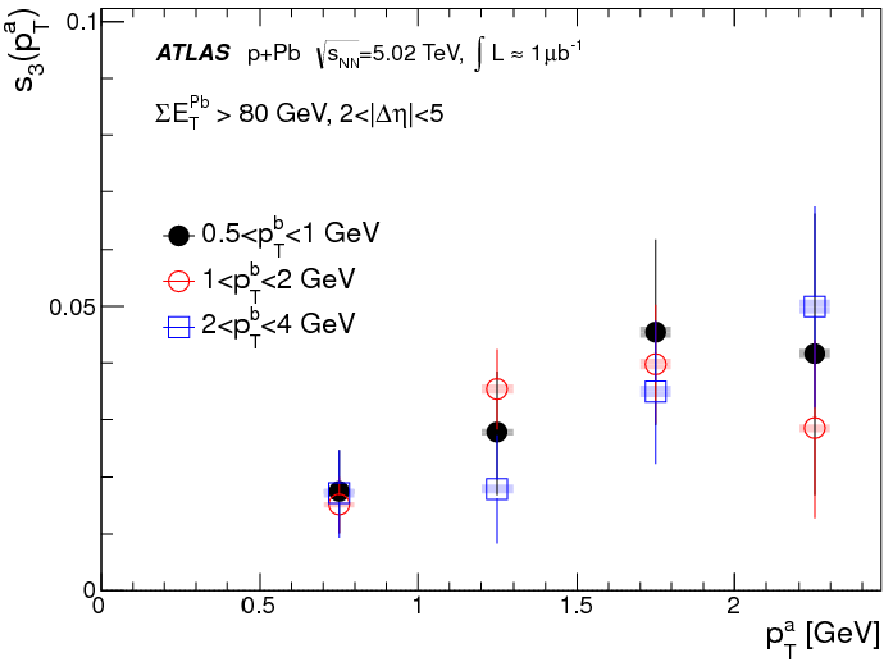






Factorization of s_n

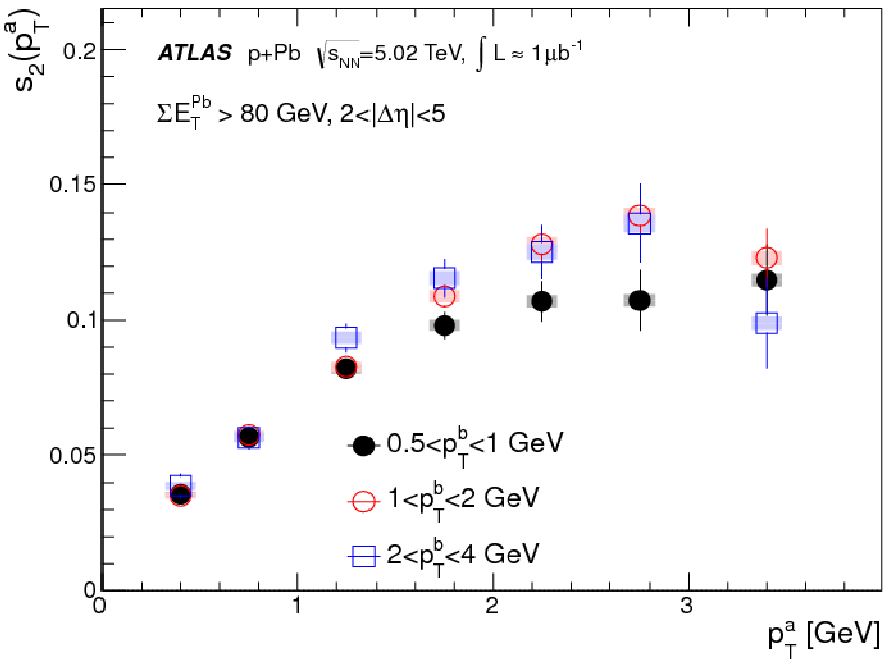


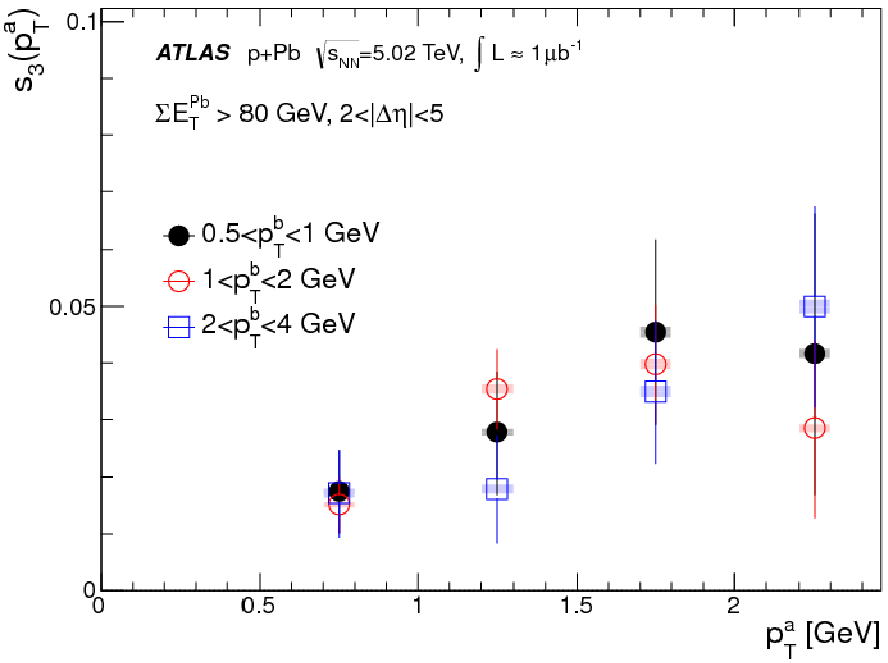


- Check whether we get the same answer using different ref. p_T.

$$c_2(p_{\mathrm{T}}^{\mathrm{a}}, p_{\mathrm{T}}^{\mathrm{b}}) = s_2(p_{\mathrm{T}}^{\mathrm{a}}) s_2(p_{\mathrm{T}}^{\mathrm{b}})$$

Factorization of s_n



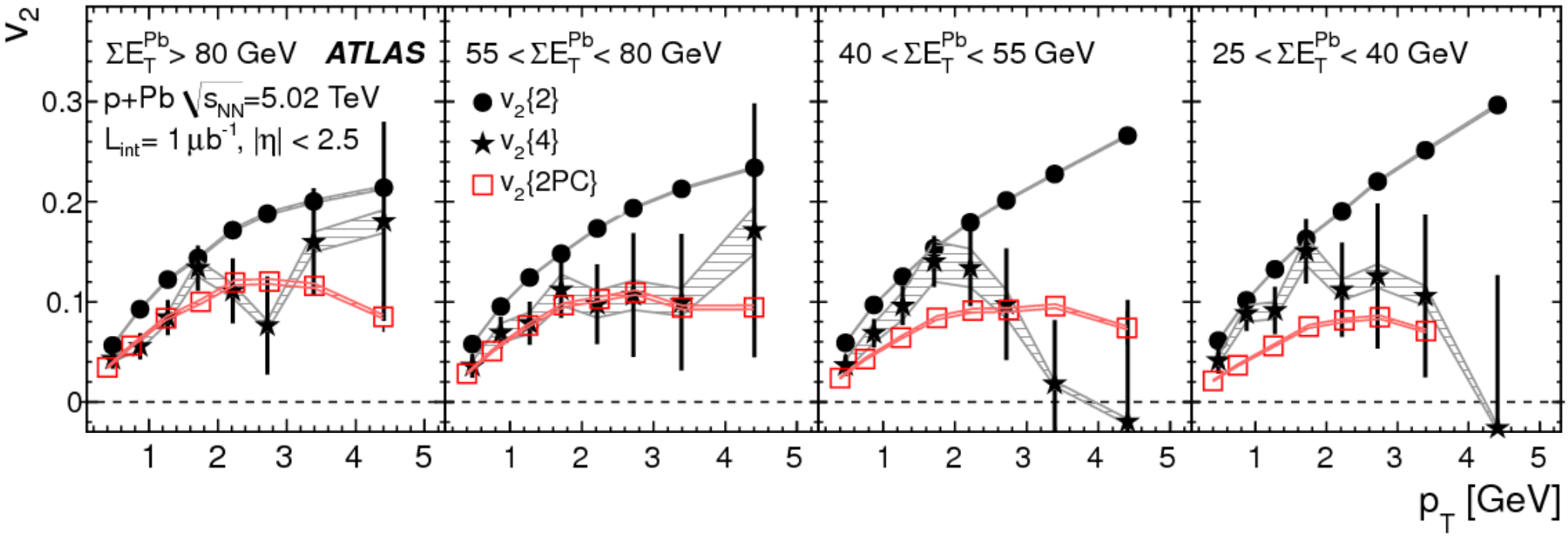


- Check whether we get the same answer using different ref. p_T.

$$c_2(p_{\mathrm{T}}^{\mathrm{a}}, p_{\mathrm{T}}^{\mathrm{b}}) = s_2(p_{\mathrm{T}}^{\mathrm{a}}) s_2(p_{\mathrm{T}}^{\mathrm{b}})$$

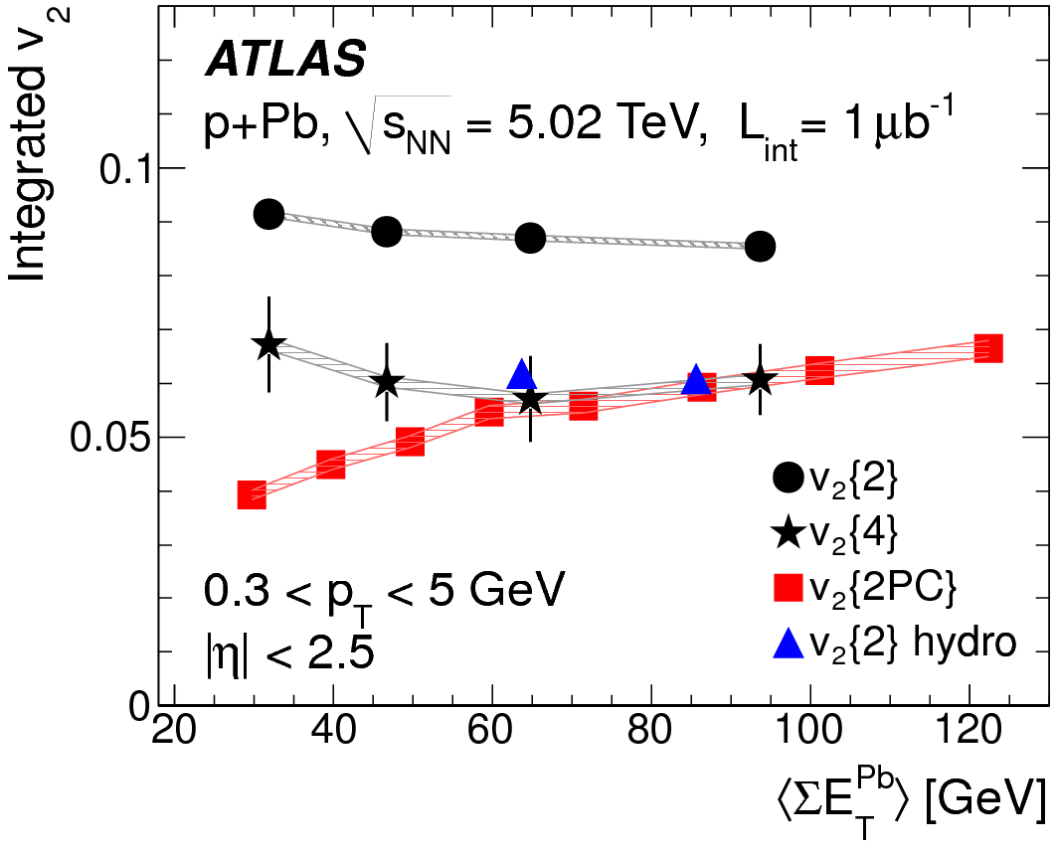
The factorization is valid at 10-20% level for s_2!

Measurement of correlations via cumulants[32]



- Can also study the long correlations via 2 and 4–particle cumulants
- 4-particle cumulants suppresses short range two –particle correlations (jets, resonance decays etc)
  - Peripheral subtraction not necessary
- $v_2\{4\}$ centrality and p_T dependence similar to the results from 2PC for central events
  - Some deviation for peripheral events

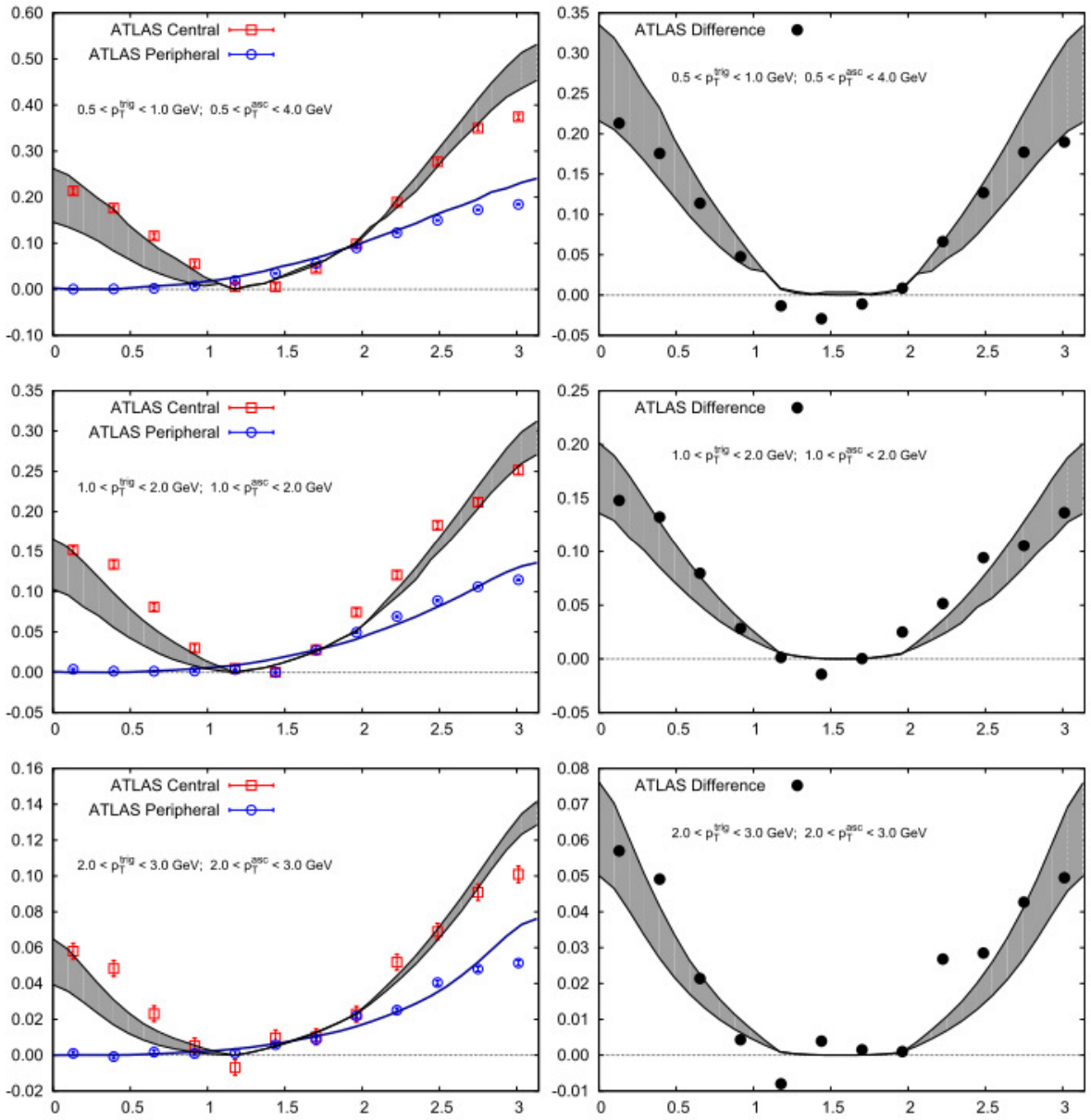
Comparison to hydro calculations



Hydro calculations: P. Bozek and W. Broniowski, Phys. Lett. B 718 (2013) 1557

$v_2\{4\}$ and results from 2PC consistent with hydro calculations

Comparison to CGC calculations



Also possible from initial stage saturation effects (C.G.C)

Ridge magnitude and p_T dependence is well described

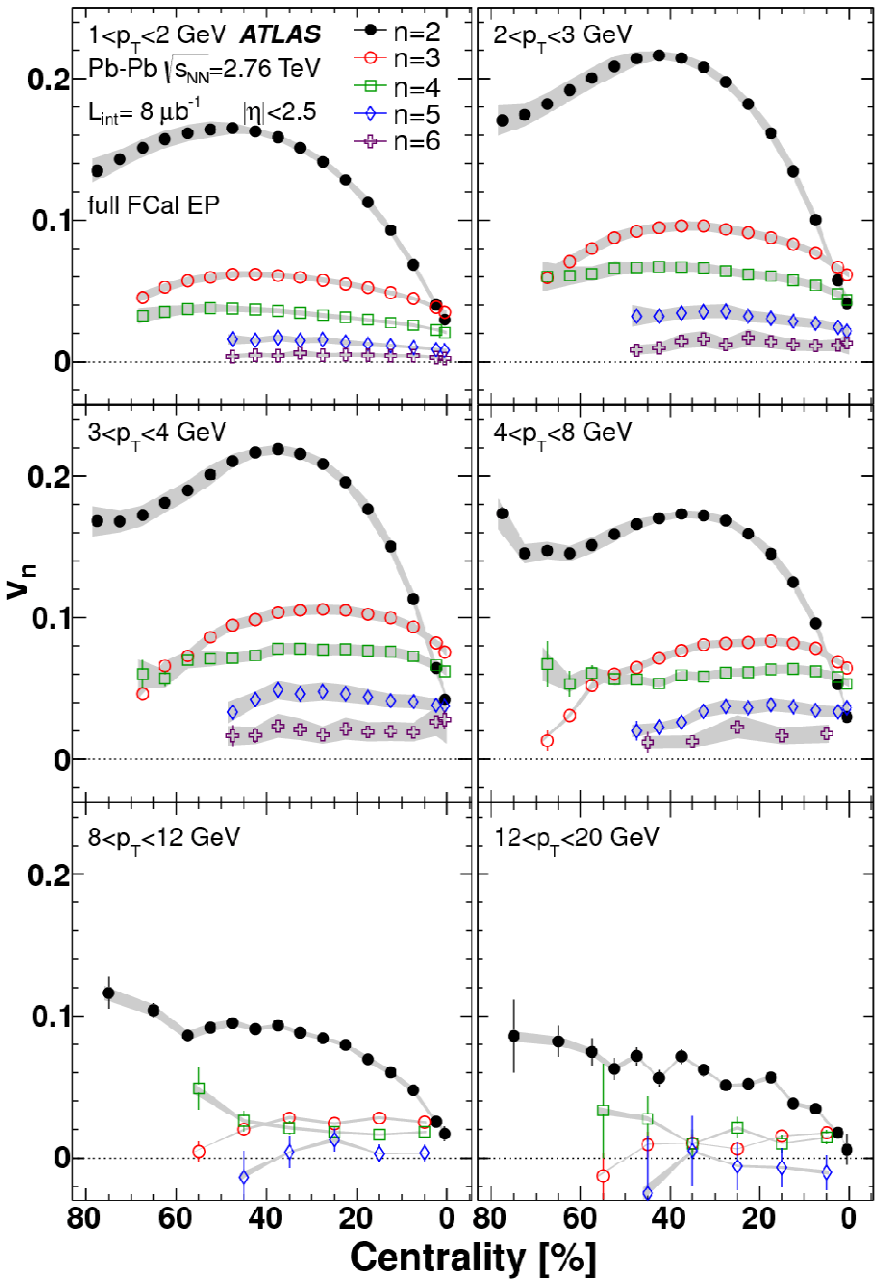
Kevin Dusling, Raju Venugopalan (arXiv 1302.7018)

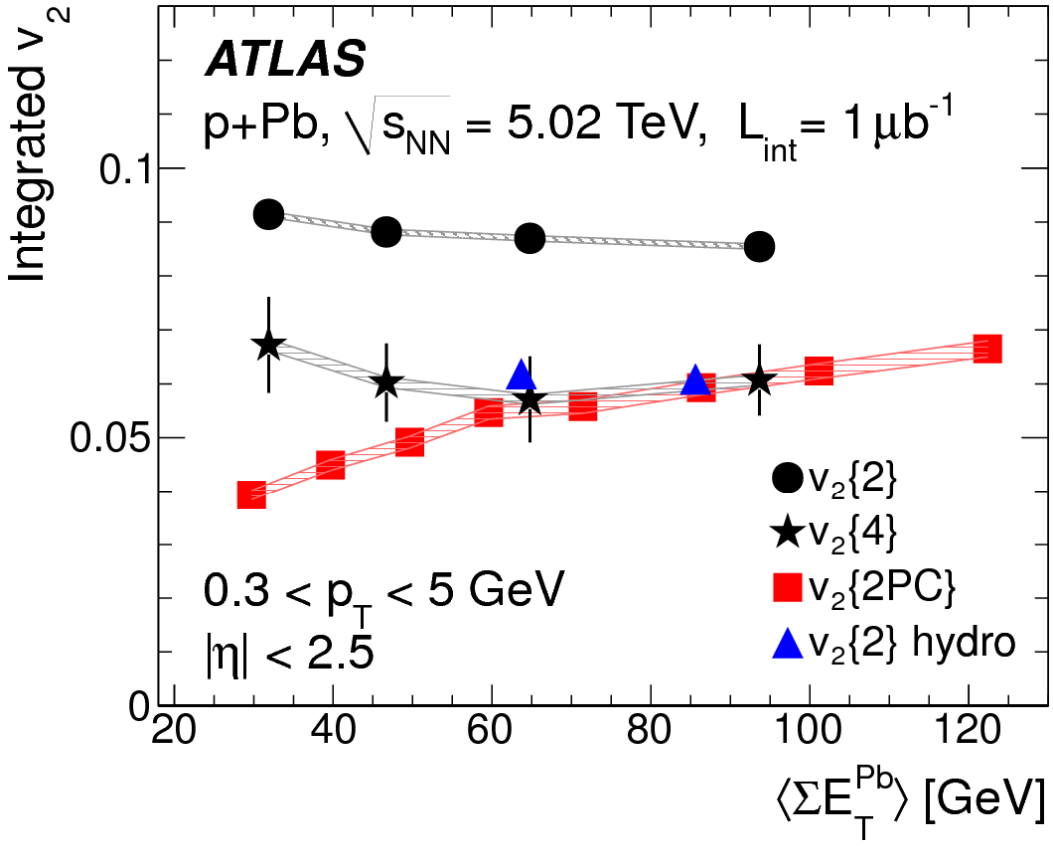
Summary

- long-range correlations(ridges) are seen in central p-Pb events.
- The ridge is also present on the away side.
- Magnitude is almost flat out till $|\Delta\eta|=5$ and increases with centrality.
- Shape largely described by a $\cos(2\Delta\phi)$ component
- p_T dependence of the ridge is similar to that seen in HI collisions
  - Magnitude as quantified by 2nd harmonic coefficient (c_2) increases till ~3GeV then drops
  - Suggests similar origin of ridge in p-Pb
- Also possible from initial stage effects (C.G.C)

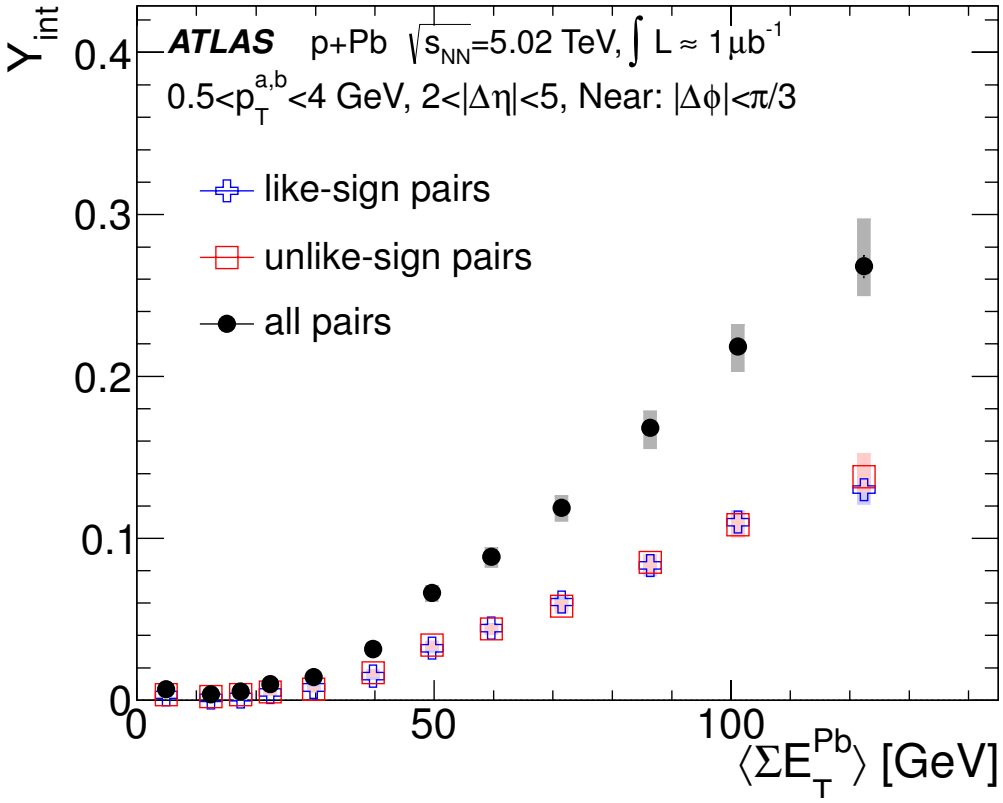
BACKUPS

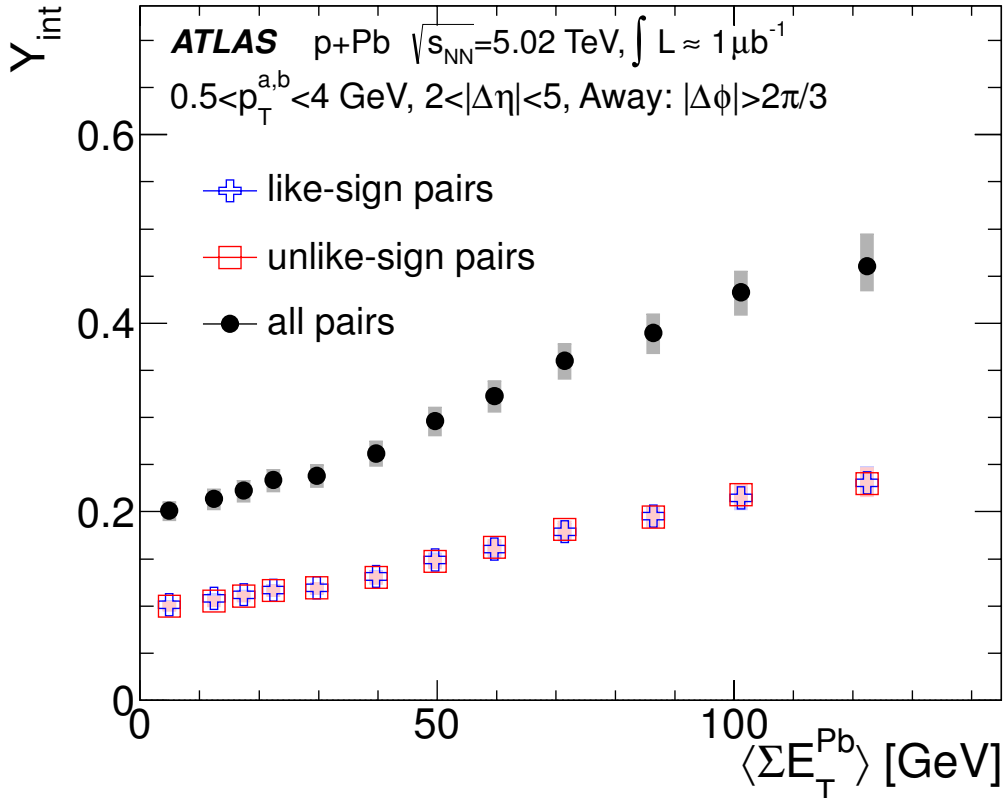
Centrality Dependence





charge dependence of the yield

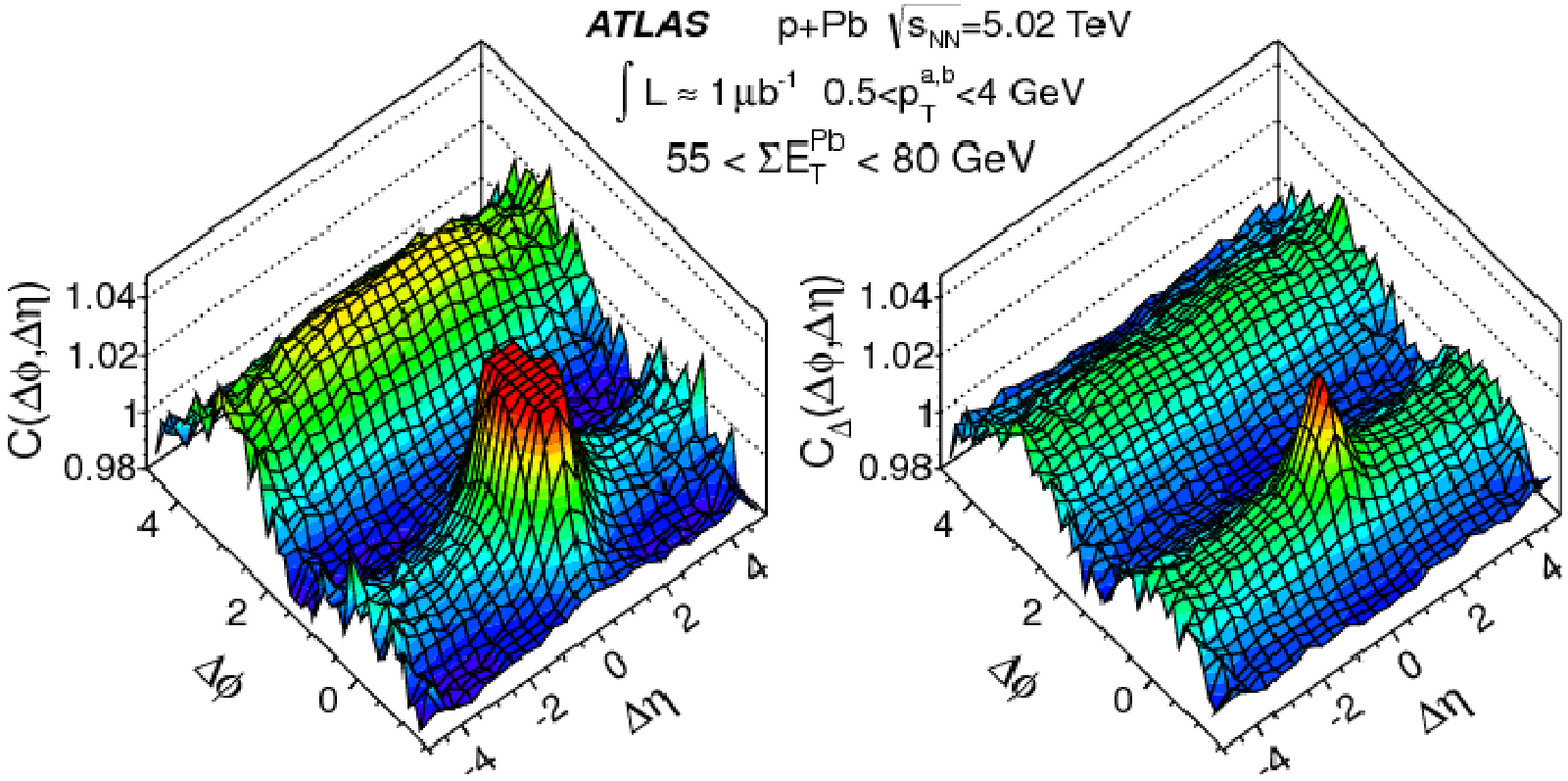




No change dependence of the per-trigger yield

Recoil subtracted correlation function

Remove the recoil on the per-trigger level, then convert the remainder back into a 2D correlation function



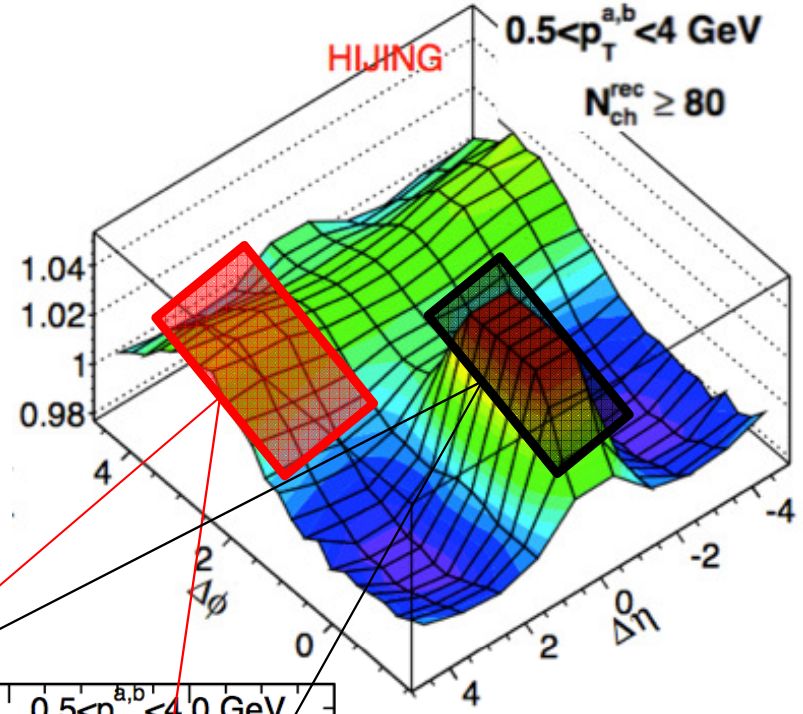
$$C \propto \left(PTY^{Central} + Pedestal^{Central} - PTY^{Peripheral} \right)$$

Ridge remains symmetric to Δη=5 and ~ constant, and for all FCal E_T classes

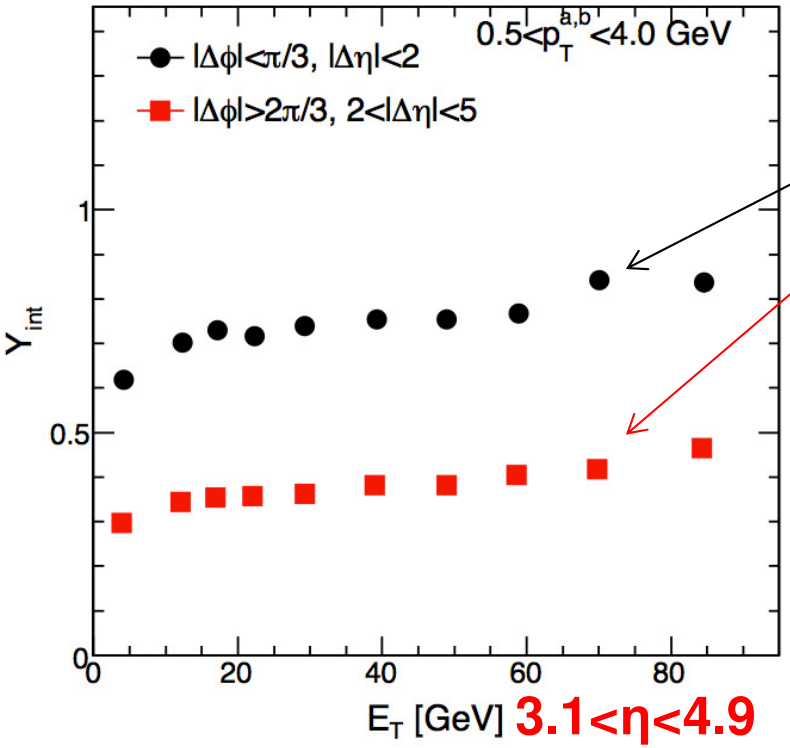
The near-side removal of short-range correlations not complete!
(about 5-10% signal remain)

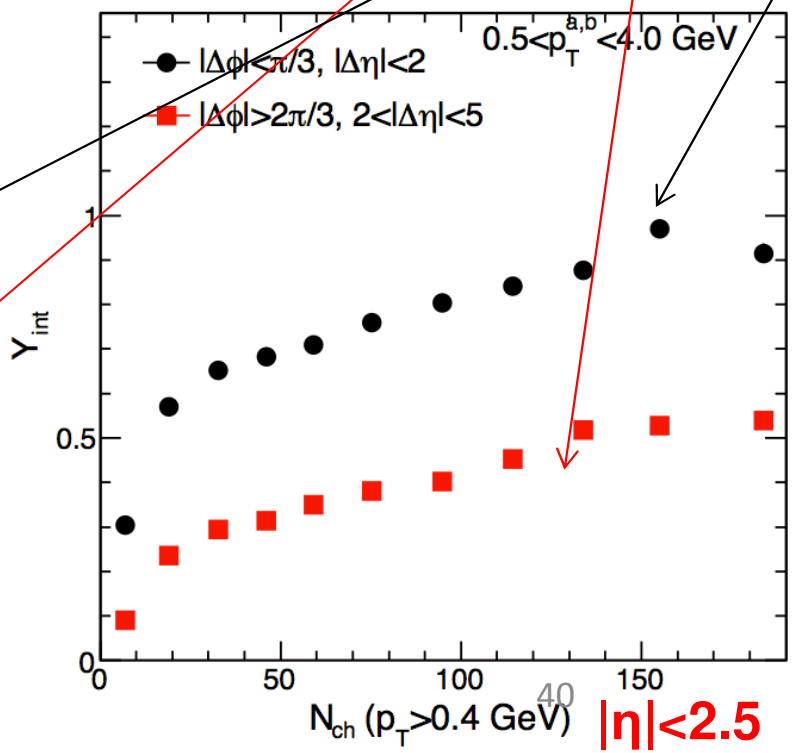
Illustrate bias with HIJING simulation

- Hijing has no ridge, mostly short range correlations.



Clear bias effects in N_{ch} based selections





Parameters

$\Sigma E_{\mathrm{T}}^{\mathrm{Pb}}$ range [GeV]	> 110	95-110	80-95	65-80	55-65	45-55	35-45	25-35
Percentage [%]	0.21	0.45	1.24	3.11	3.99	6.37	9.71	13.80
$\langle \Sigma E_{\mathrm{T}}^{\mathrm{Pb}} \rangle$ [GeV]	122.4	101.2	86.4	71.4	59.6	49.7	39.7	29.7
$\langle N_{\mathrm{ch}} \rangle$	183.1±8.2	159.9±7.2	141.3±6.4	122.5±5.5	107.2±4.8	93.3±4.2	78.8±3.6	63.3±2.9
$\sigma_{N_{\mathrm{ch}}}$	37.0±2.1	33.1±1.9	31.5±1.8	29.6±1.7	27.6±1.6	25.9±1.5	24.1±1.4	21.8±1.2
$\Sigma E_{\mathrm{T}}^{\mathrm{Pb}}$ range [GeV]	20-25	15-20	10-15	< 10	> 80	55-80	25-55	< 20
Percentage [%]	8.67	10.11	11.98	30.36	1.90	13.47	29.88	52.45
$\langle \Sigma E_{\mathrm{T}}^{\mathrm{Pb}} \rangle$ [GeV]	22.4	17.4	12.4	4.9	94.4	64.8	37.3	9.0
$\langle N_{\mathrm{ch}} \rangle$	51.0±2.3	41.8±1.9	31.7±1.5	15.9±0.7	150.3±6.8	113.9±5.1	74.7±3.4	24.5±1.1
$\sigma_{N_{\mathrm{ch}}}$	19.6±1.1	17.9±1.0	15.7±0.9	11.8±0.7	35.2±2.0	29.4±1.7	26.1±1.5	17.5±1.0