Global characteristics of the p-Pb collisions
- ridges and particle correlations-

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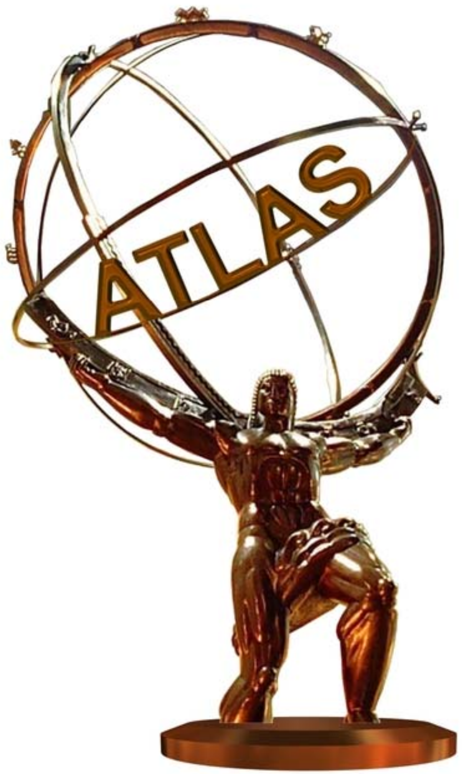


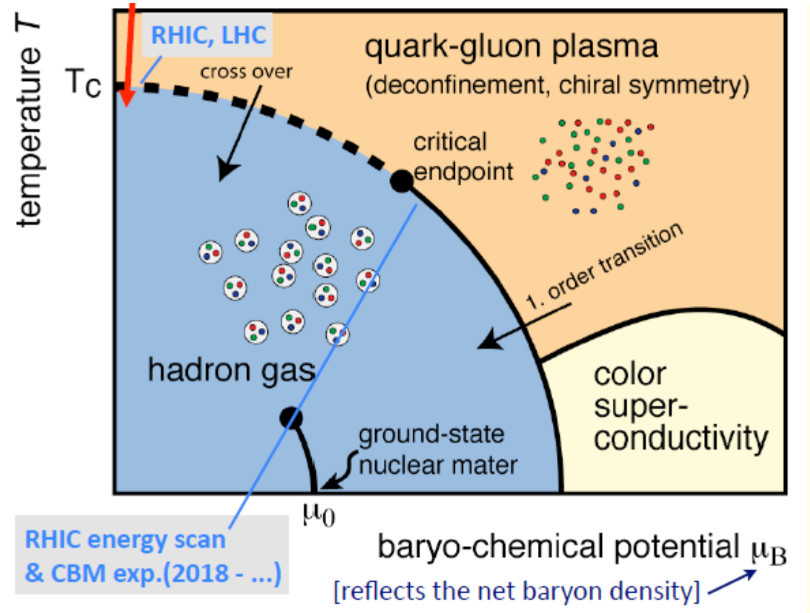
Outline

- Why p-Pb collisions?
- ATLAS detector
- Ridges in p-Pb (2 particle correlations)
- Multi particle correlations
- Comparison with models
- Conclusions

Why p-Pb collisions?

- Pb-Pb for QGP

Pb-Pb is not
an A^2 p-p interaction!



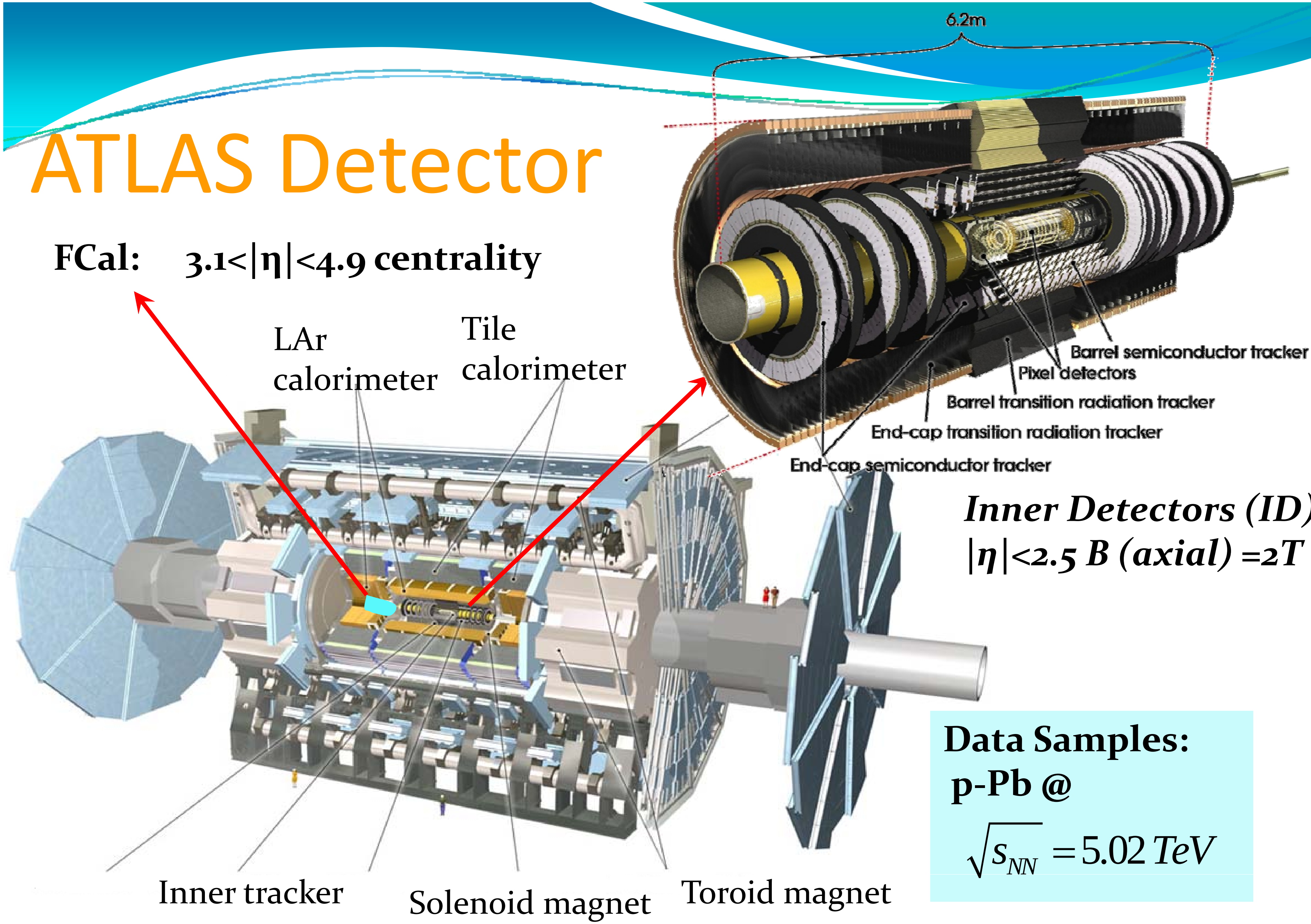
Need to disentagle:

- Initial/nuclear state effects → Nuclear PDF (pA only)
- Final state effects → Minimal in pp; p-Pb moderate; Pb-Pb dominant
- Collective effects → Absent in pp; p-Pb moderate; Pb-Pb maximum

2012-2013 LHC heavy ion program concentrated on p-Pb

ATLAS Detector

FCal: 3.1<|η|<4.9 centrality

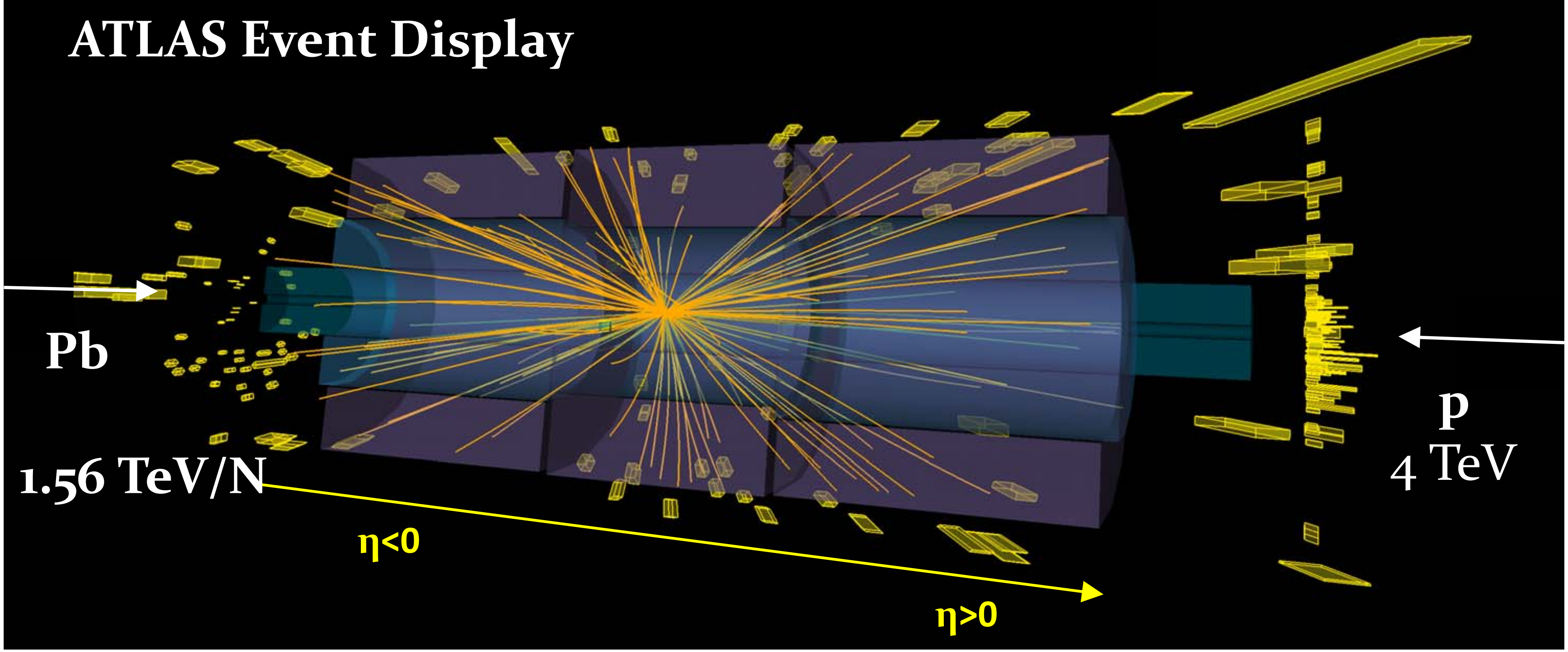


Inner Detectors (ID)
$|\eta|$<2.5 B (axial) =2T

Data Samples:
p-Pb @

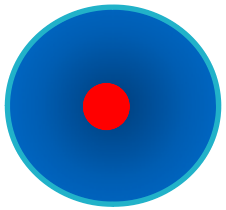
$$\sqrt{s_{NN}} = 5.02\,TeV$$

High multiplicity p+Pb event

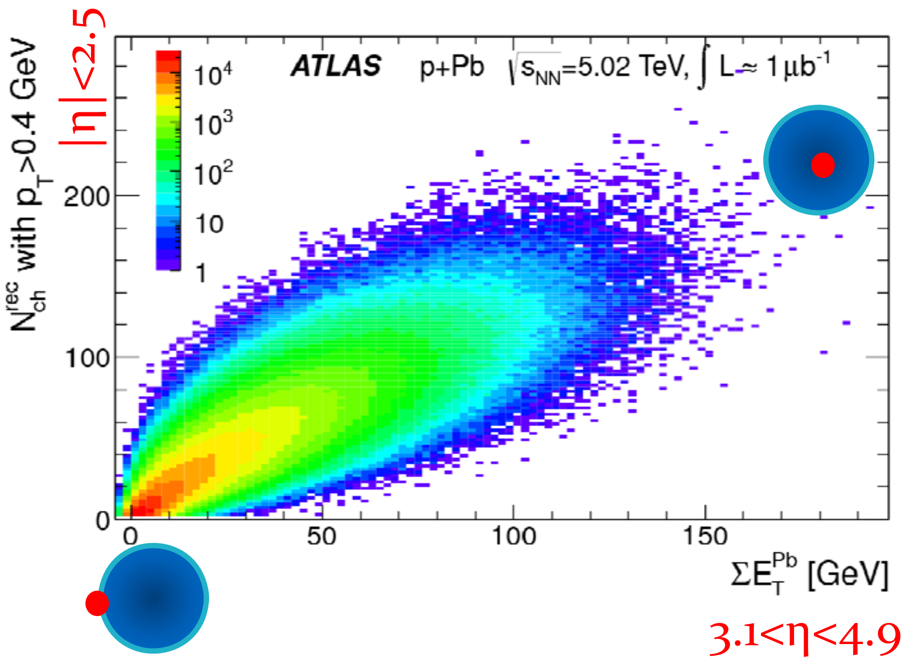


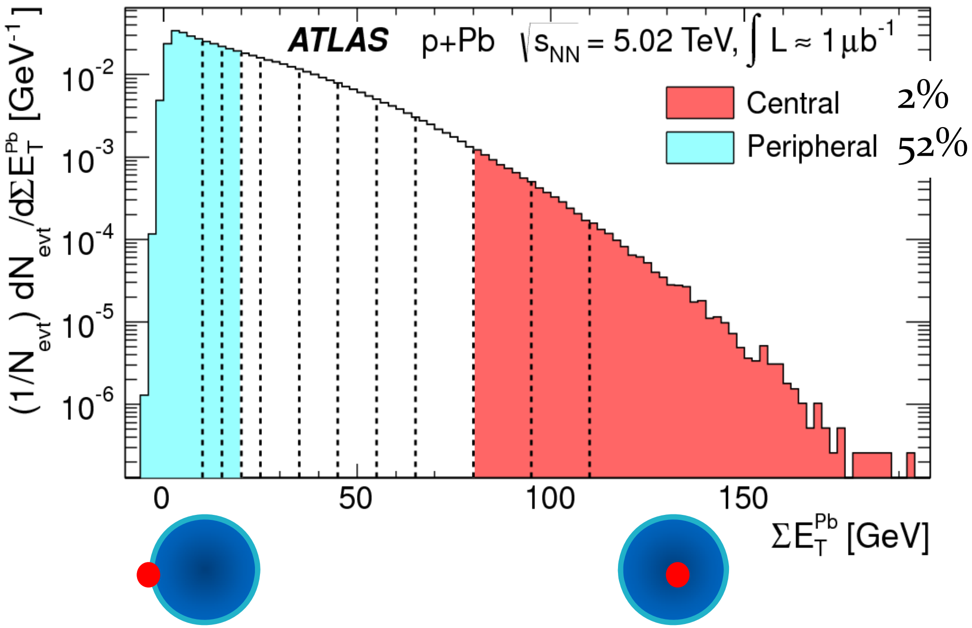
273 charged tracks with $p_T>0.4$ GeV
106 charged tracks with $p_T>1.0$ GeV (shown)
$\sum E_T = 139$ GeV (FCal - Pb going side)

Central collision



Event activity and centrality





- Event activity defined on FCal transverse energy
- No overlap between FCal and tracking detectors
  - no auto-correlation bias in event activity definition

Ridges in two particle correlations

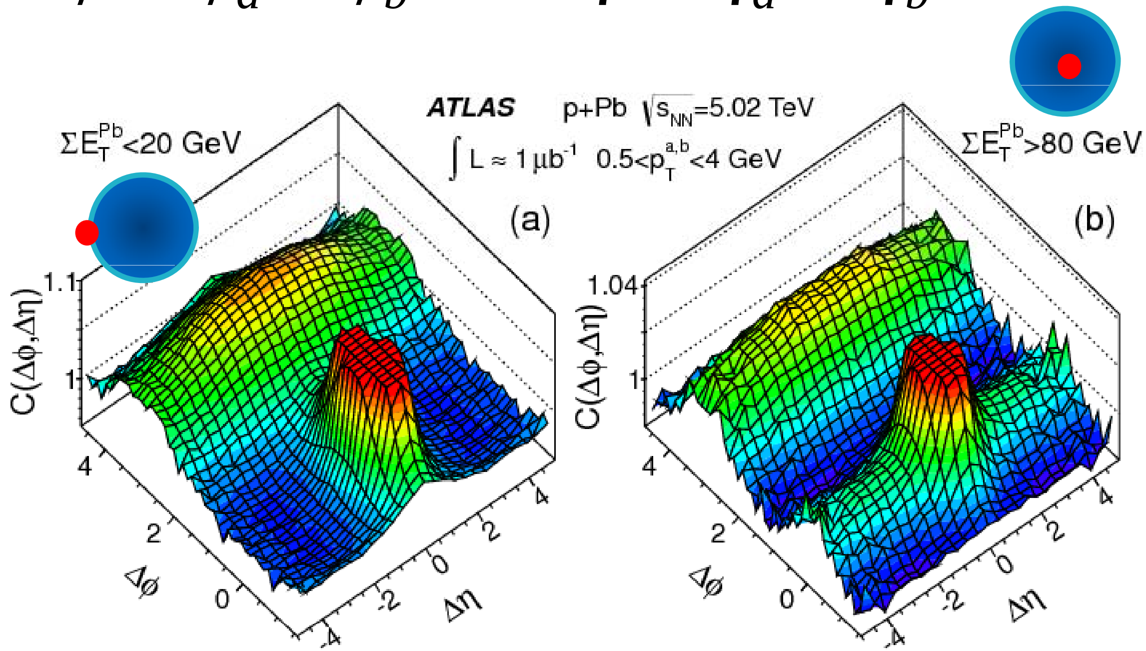
a- trigger particle
b- associated particle

$$\Delta\phi = \phi_a - \phi_b, \quad \Delta\eta = \eta_a - \eta_b$$

$S(\Delta\phi, \Delta\eta)$ – direct event

$B(\Delta\phi, \Delta\eta)$ – mixed event

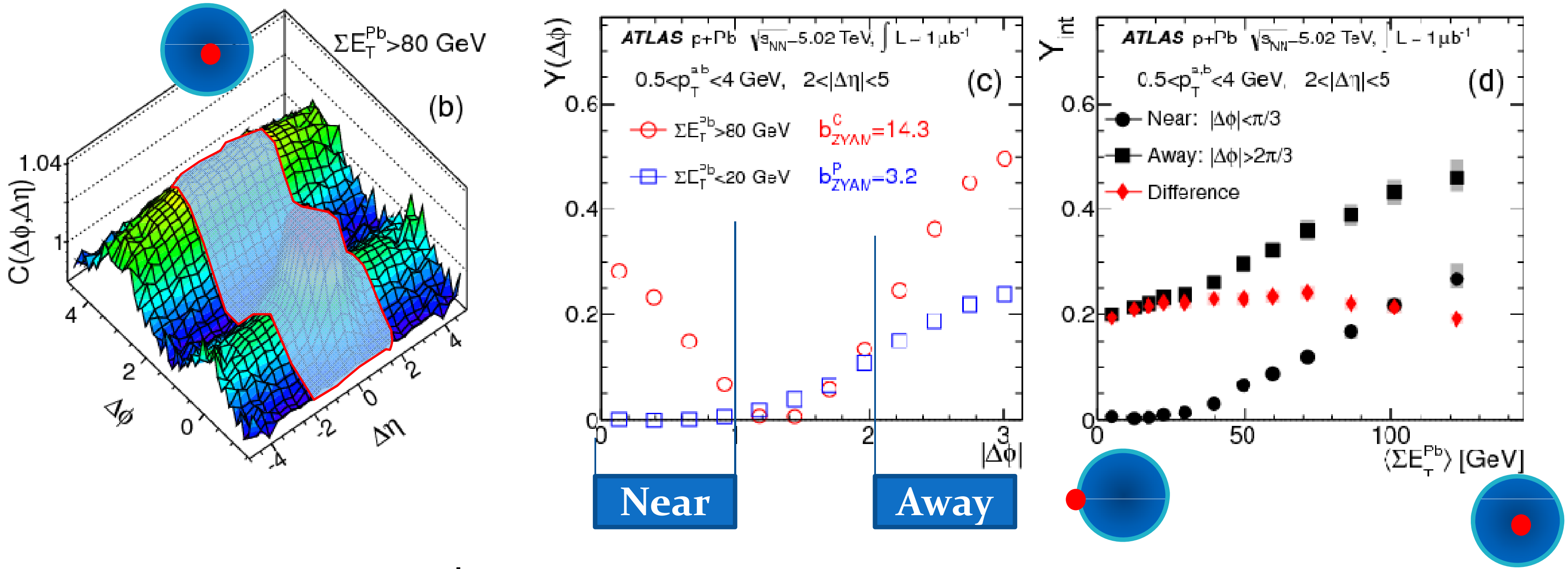
$$C(\Delta\phi, \Delta\eta) = \frac{S(\Delta\phi, \Delta\eta)}{B(\Delta\phi, \Delta\eta)}$$



Ridges seen obviously in Pb-Pb collisions, less obviously in p-p collisions .
Seen in p-Pb on the near side ($\Delta\phi\approx0$) and on the away side ($\Delta\phi\approx\pi$)!
Published on Phys Rev Lett 110 (2013) 182302

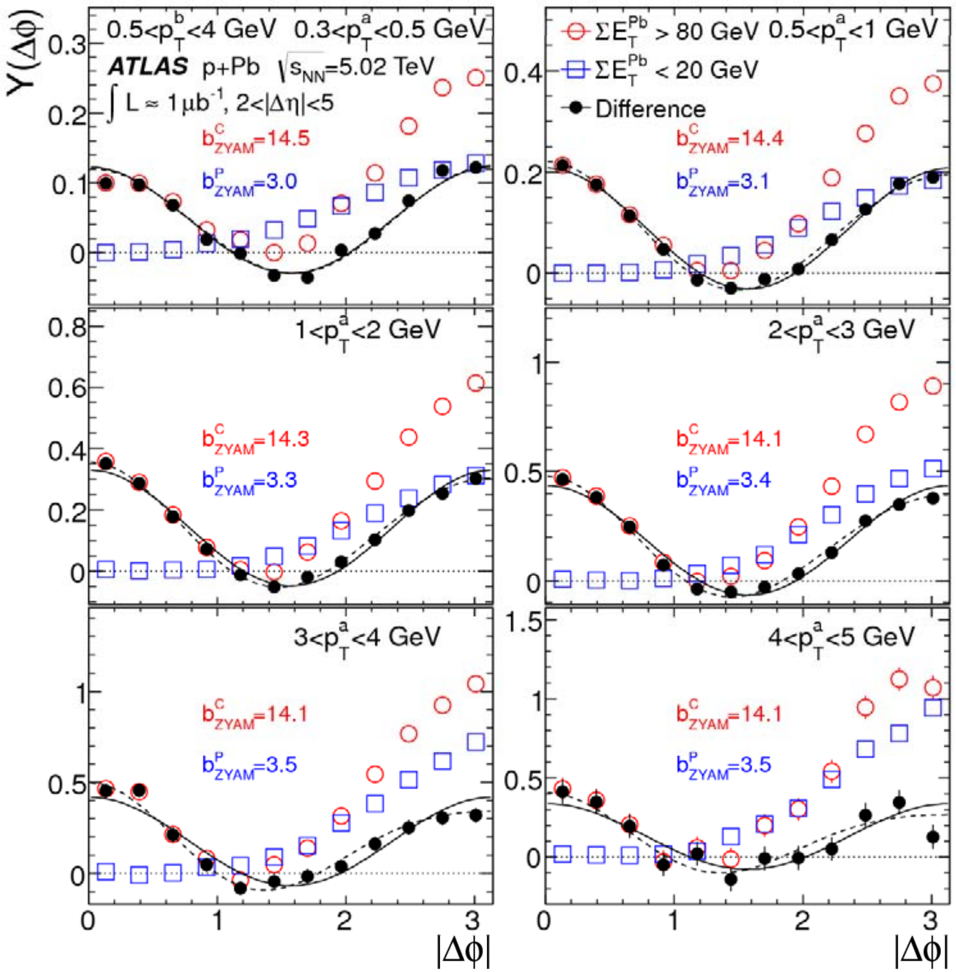
Long range correlations $2 < |\Delta\eta| < 5$

- Per Trigger Yield: $Y(\Delta\phi) = \left(\frac{\int B(\Delta\phi) d\Delta\phi}{\pi N_a} \right) C(\Delta\phi) - Pedestal$



- Near side (|Δϕ|<π/3) ridge in central events
- Away side (|Δϕ|>2π/3) ridge contribution also visible!

Per Trigger Yields at different p_T



- Analisys at different p_T of the trigger particle
- $\Delta Y(|\Delta\phi|) = Y_{central}(|\Delta\phi|) - Y_{perif}(|\Delta\phi|)$

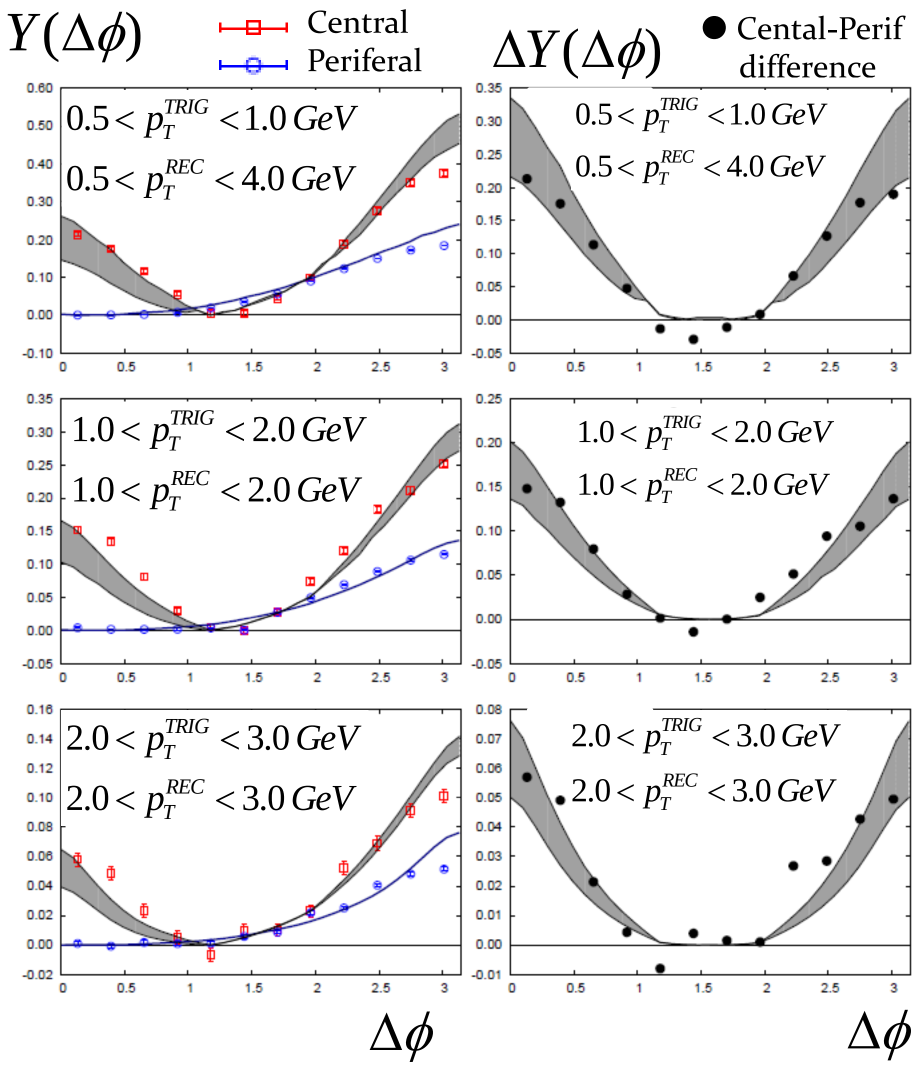
- Dominant behaviour:

$$\Delta Y(|\Delta\phi|) \approx a_0 + a_2 \cos 2|\Delta\phi|$$

Elliptic flow: $v_2(p_T) \propto a_2$

- Collective phenomena

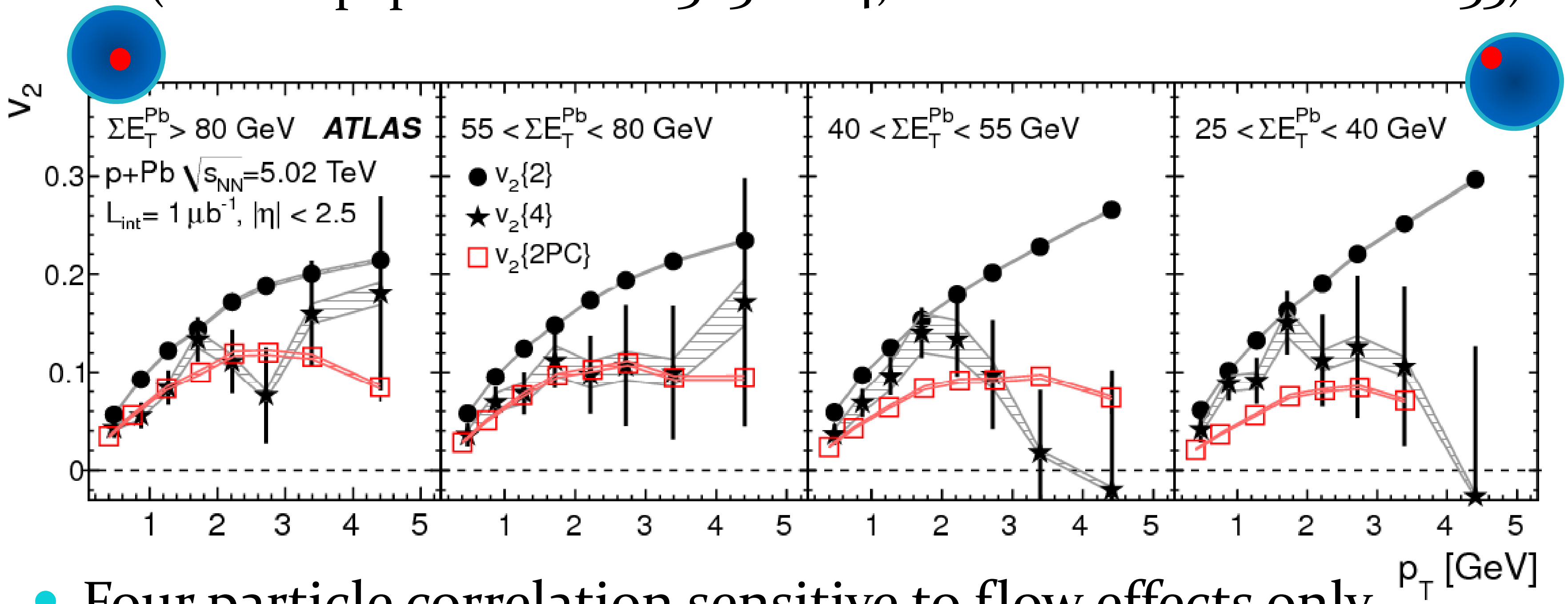
Comparison with a Color Glass Condensate model



- K. Dusling and R. Venugopalan, arXiv 1302.7018
- This CGC model describes well the ridges
- Yield and p_T dependence correctly taken into account
- Here the ridges are an initial state effect!

Elliptic flow results vs p_T

- v_2 from two and four particle cumulant method
  (ATLAS paper in arXiv:1303.2084, method in arXiv: 1010.0233)



- Four particle correlation sensitive to flow effects only
- $v_2\{4\}$ and 2PC (recoil subtracted) provide similar results

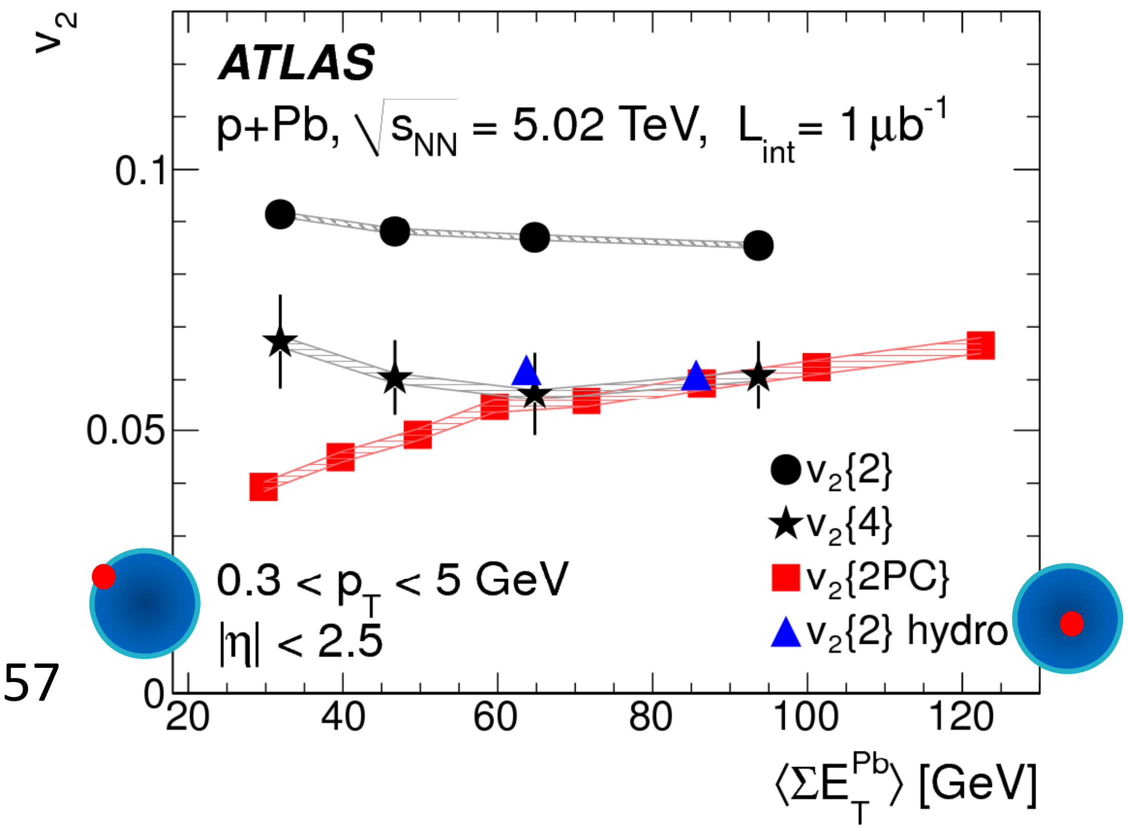
Elliptic flow vs centrality

ATLAS paper:

Arxiv:1303.2084

Hydro calculation:

Phys. Lett. B 718 (2013) 1557



- Hydro calculation compatible with v_2 {4} and v_2\{2PC\} (true flow effects → collective effect)

Conclusions

- First look on global characteristics of p-Pb collisions at 5.02 TeV

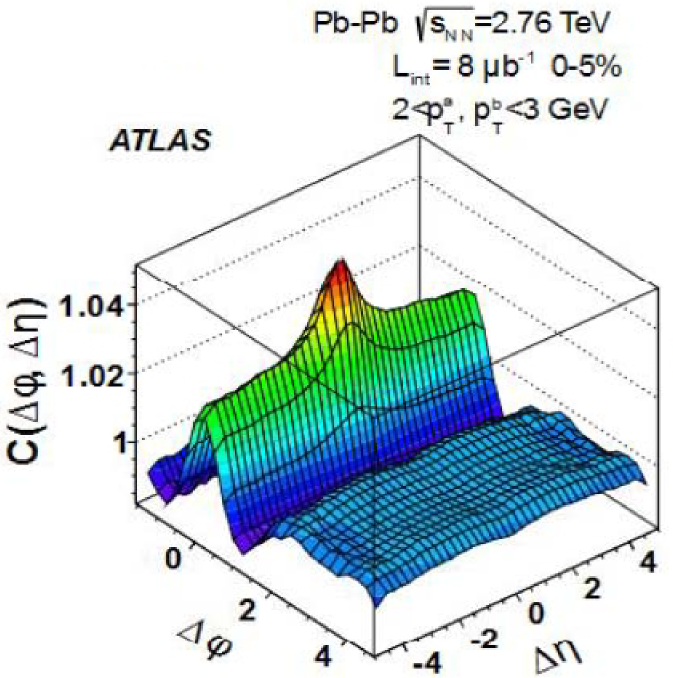
- First results on two and many particle correlations observed in p-Pb collisions
  - Ridges in p-Pb
    - Phys Rev Lett 110 (2013) 182302
  - Particle correlations
    - arXiv:1303.2084 – to appear on PLB

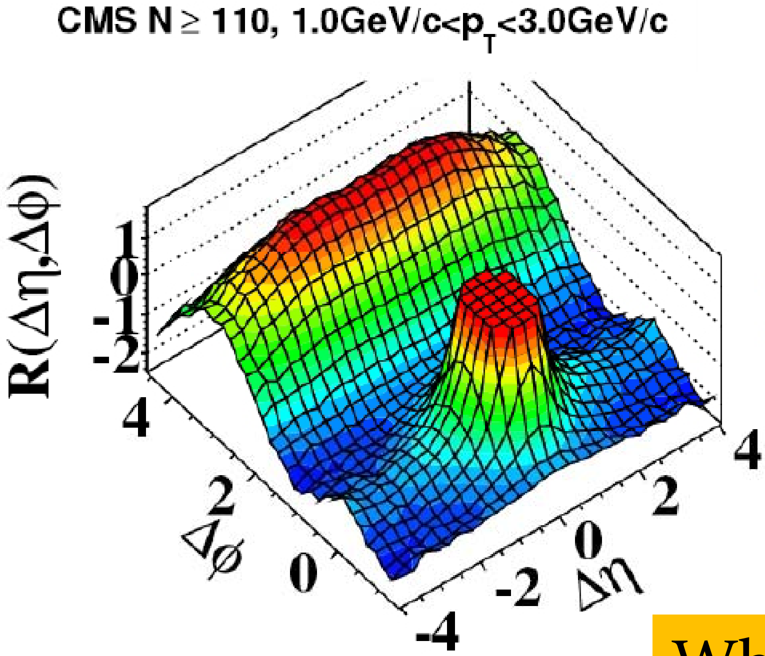
- Elliptic flow in agreement with an hydrodynamic model;
- Ridge yield and p_T dependence compatible with a CGC calculation

Back up

Ridge structures in Pb-Pb and pp

- Two particle long range correlations $\Delta\phi = \phi_a - \phi_b \quad \Delta\eta = \eta_a - \eta_b$





- Seen in HI collisions at RHIC and LHC
- Flow phenomena in Pb-Pb; initial state effect in p-p?

What about p-Pb?

Two and Four particle correlations

Invariant Yield $$E\frac{d^3N}{dp^3}=\frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1+2\sum_{n=1} v_n(p_T)\cos\left[n(\phi-\Phi_{RP})\right]\right)$$

Elliptic Flow: v_2

Coefficient extraction: $$v_n=\left\langle\cos\left[n(\phi-\Phi_{RP})\right]\right\rangle$$

Two particle correlations: $$corr_2\{2\}=\left\langle\exp\left[i(\phi_1-\phi_2)\right]\right\rangle_{trk}$$

$$v_2\{2\}=\sqrt{\left\langle corr_2\{2\}\right\rangle_{evt}}$$

Four particle correlations: $$corr_2\{4\}=\left\langle\exp\left[i(\phi_1+\phi_2-\phi_3-\phi_4)\right]\right\rangle_{trk}$$

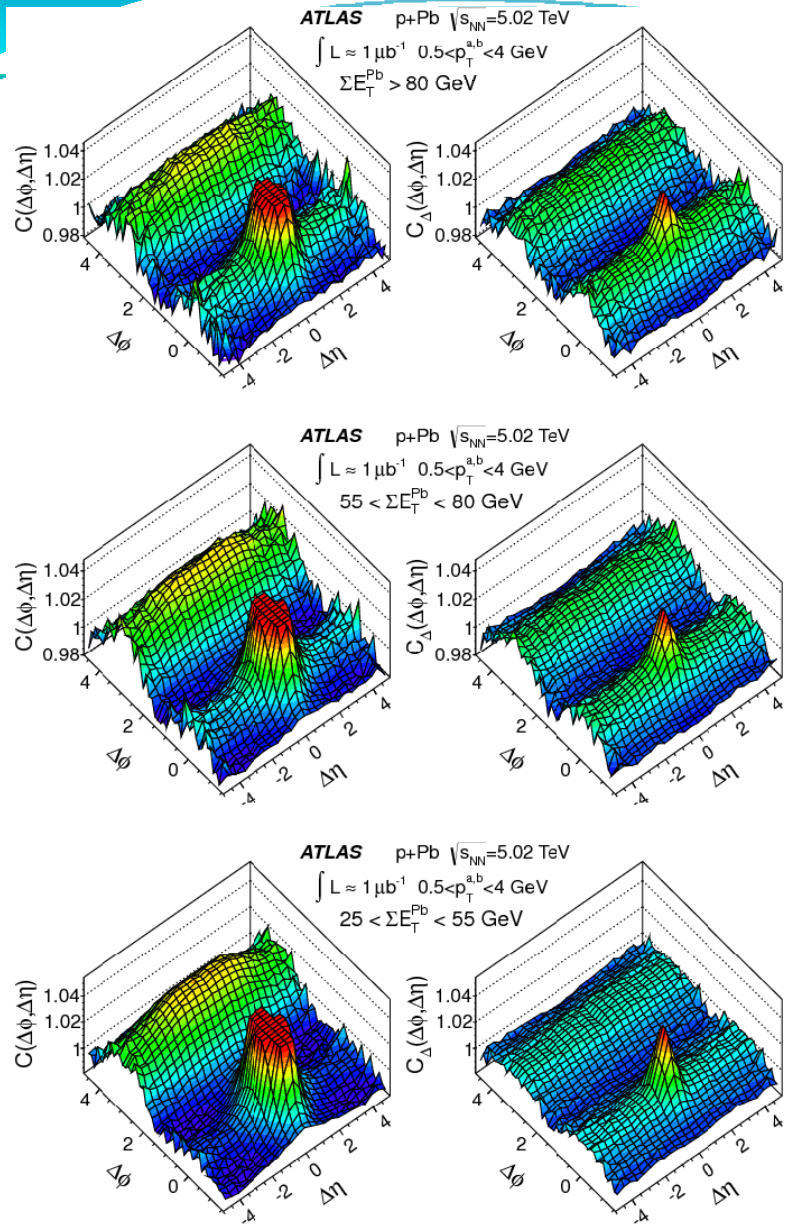
$$v_2\{4\}=\sqrt[4]{-\left(\left\langle corr_2\{4\}\right\rangle_{evt}-2\left\langle corr_2\{2\}\right\rangle_{evt}^2\right)}$$

- Flow vector method applied: arXiv: 1010.0233

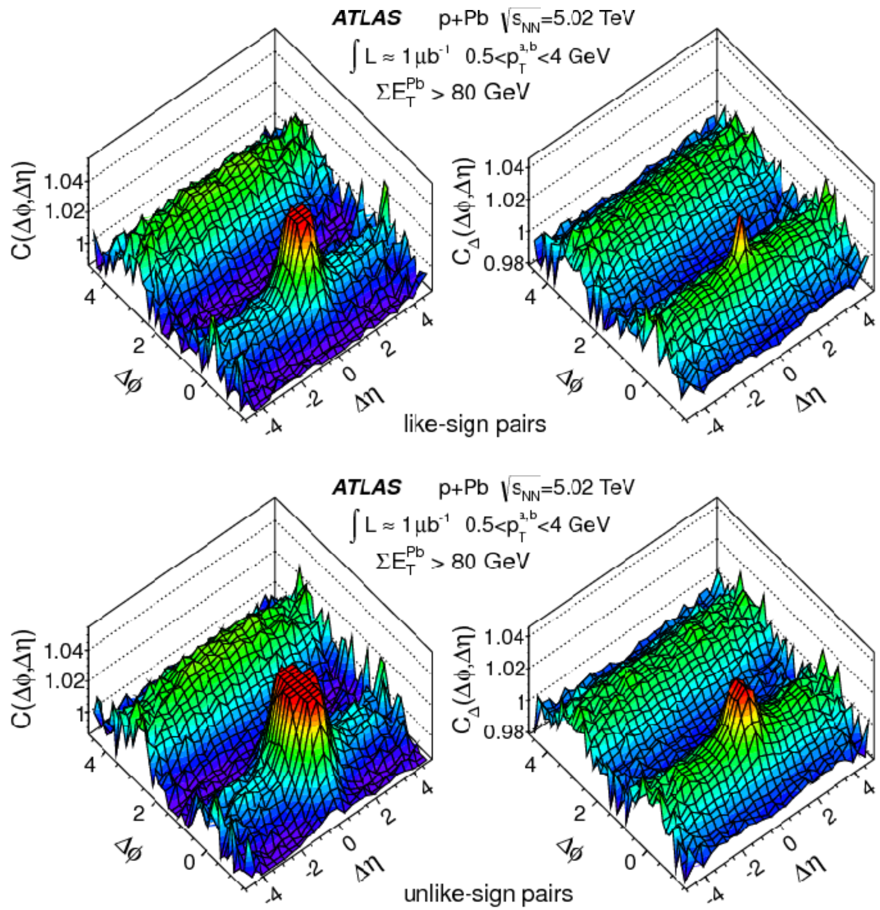
Data samples

Species	$\sqrt{s_{NN}}$	Luminosity	Year
Pb-Pb	2.76 TeV	160 μb^{-1}	2010-2011
p-Pb	5.02 TeV	1 μb^{-1}	2012 pilot run
p-Pb	5.02 TeV	30 nb^{-1}	2013
p-p	2.76 TeV	4.8 nb^{-1}	2011-2013
p-p	7 TeV	5.2 fb^{-1}	2010-2011
p-p	8 TeV	23.3 fb^{-1}	2012

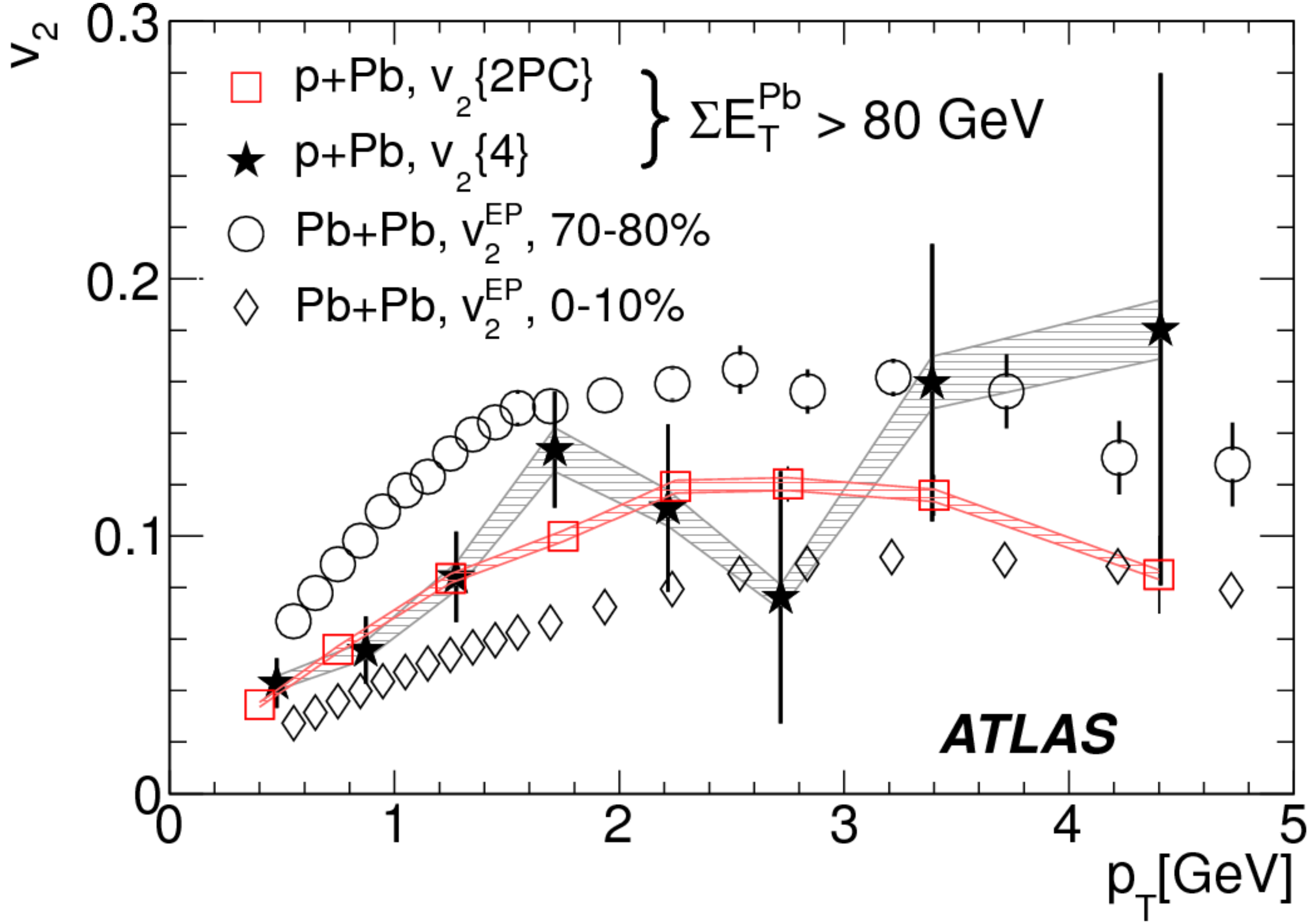
Periferal subtracted correlations



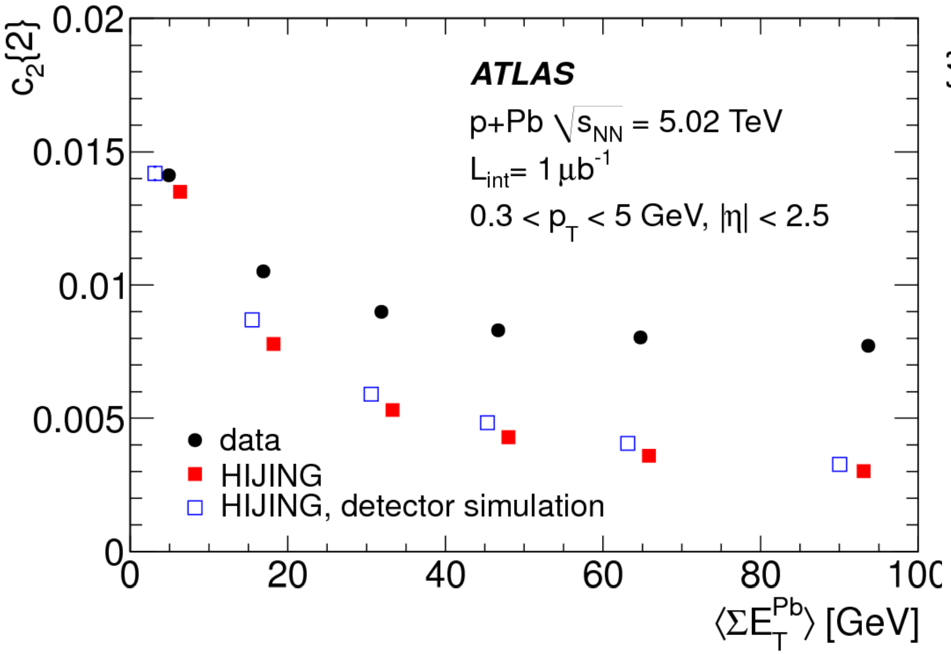
- Charge selection

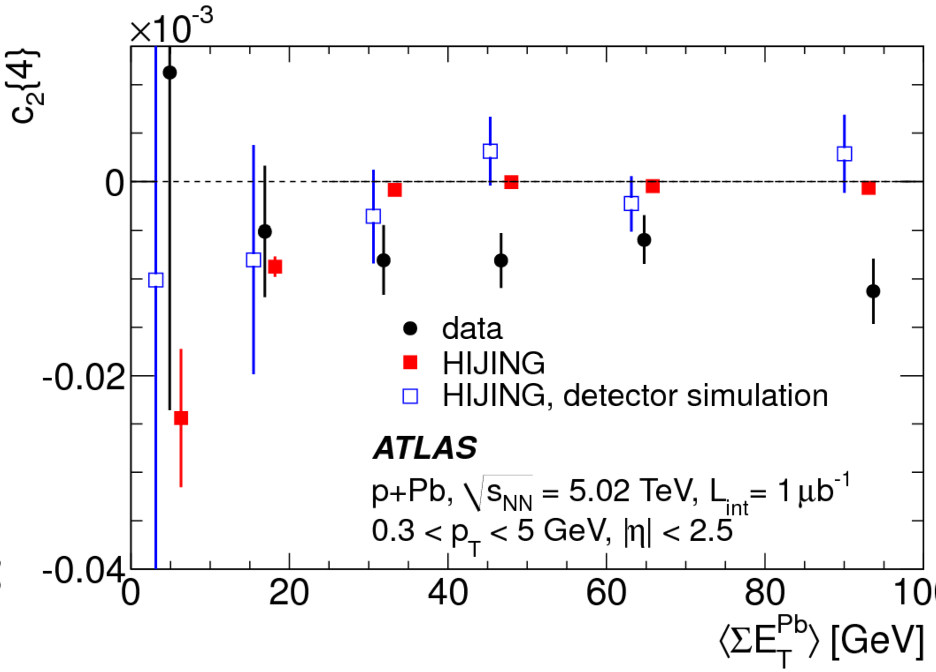


Central p-Pb vs Pb-Pb



Cumulant methods: comparison with HIJING



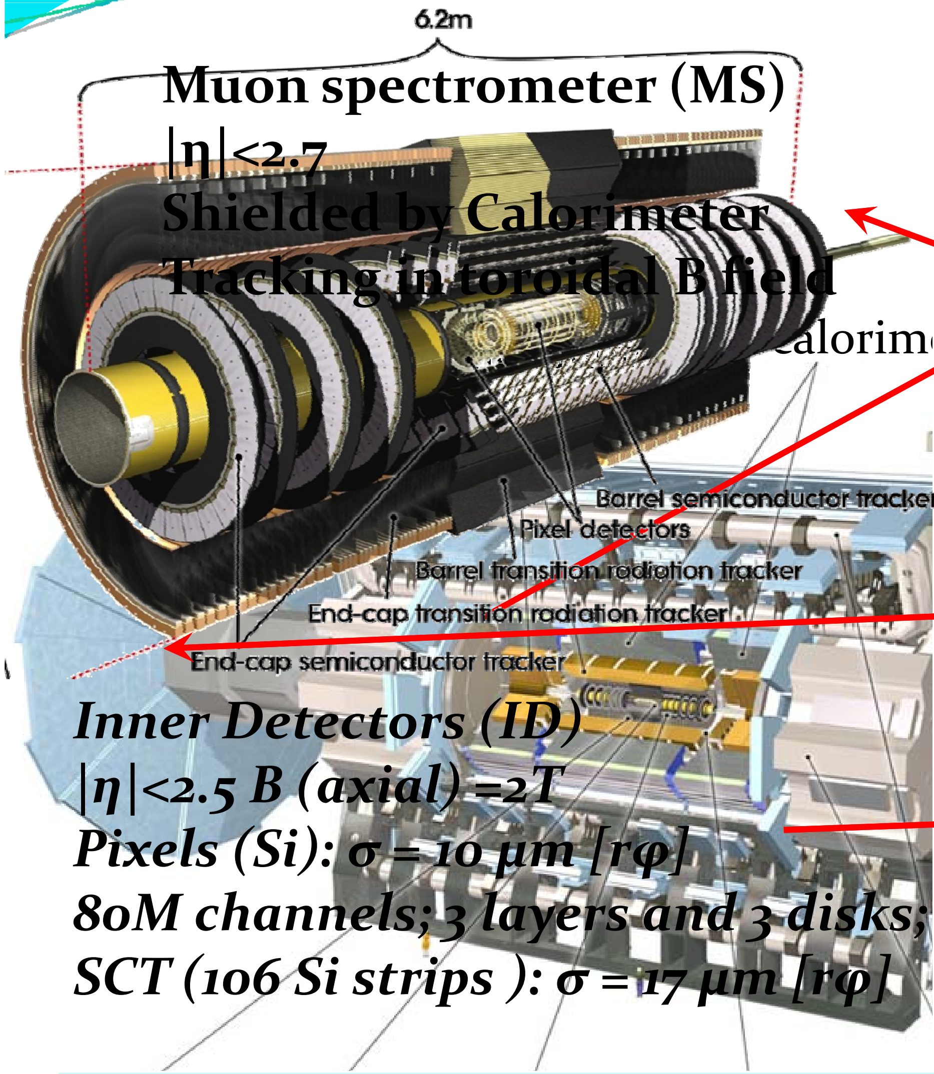


Transverse energy, centrality and charged track multiplicity

ΣE_T^{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
$\langle \Sigma E_T^{Pb} \rangle$ [GeV]	122.4	101.2	86.4	71.4	59.6	49.7	39.7	29.7
$\langle N_{ch} \rangle$	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
$\sigma_{N_{ch}}$	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
ΣE_T^{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
$\langle \Sigma E_T^{Pb} \rangle$ [GeV]	22.4	17.4	12.4	4.9	94.4	64.8	37.3	9.0
$\langle N_{ch} \rangle$	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
$\sigma_{N_{ch}}$	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

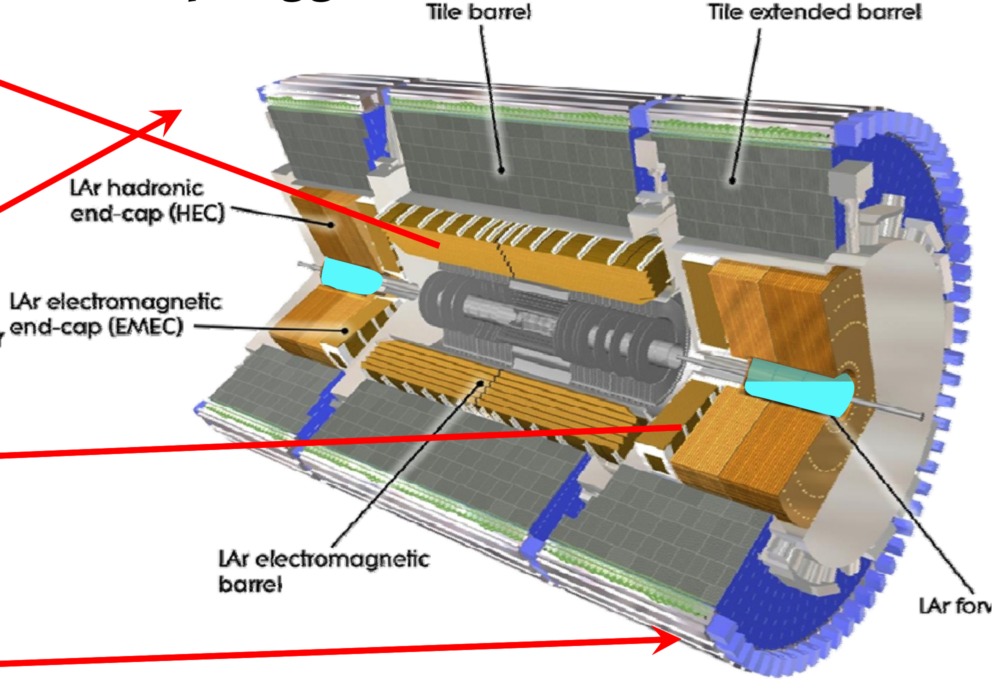
Slide 4 animation

ATLAS Detector



Muon spectrometer (MS)
|η|<2.7
Shielded by Calorimeter
Tracking in toroidal B field

EM calorimeter (LAr)
|η|<3.2, 3 layers + presampler, $22X_0$
e/γ trigger, identification



Inner Detectors (ID)
|η|<2.5 B (axial) =2T
Pixels (Si): σ = 10 μm [rφ]
80M channels; 3 layers and 3 disks;
SCT (106 Si strips): σ = 17 μm [rφ]

FCal: 3.1<|η|<4.9 centrality
MBTS: 2.1<|η|<3.9 timing

Data Samples: p-Pb @ $\sqrt{s_{NN}} = 5.02\ TeV$ L= 1 μb^{-1}, 30 nb^{-1}

ATLAS Detector

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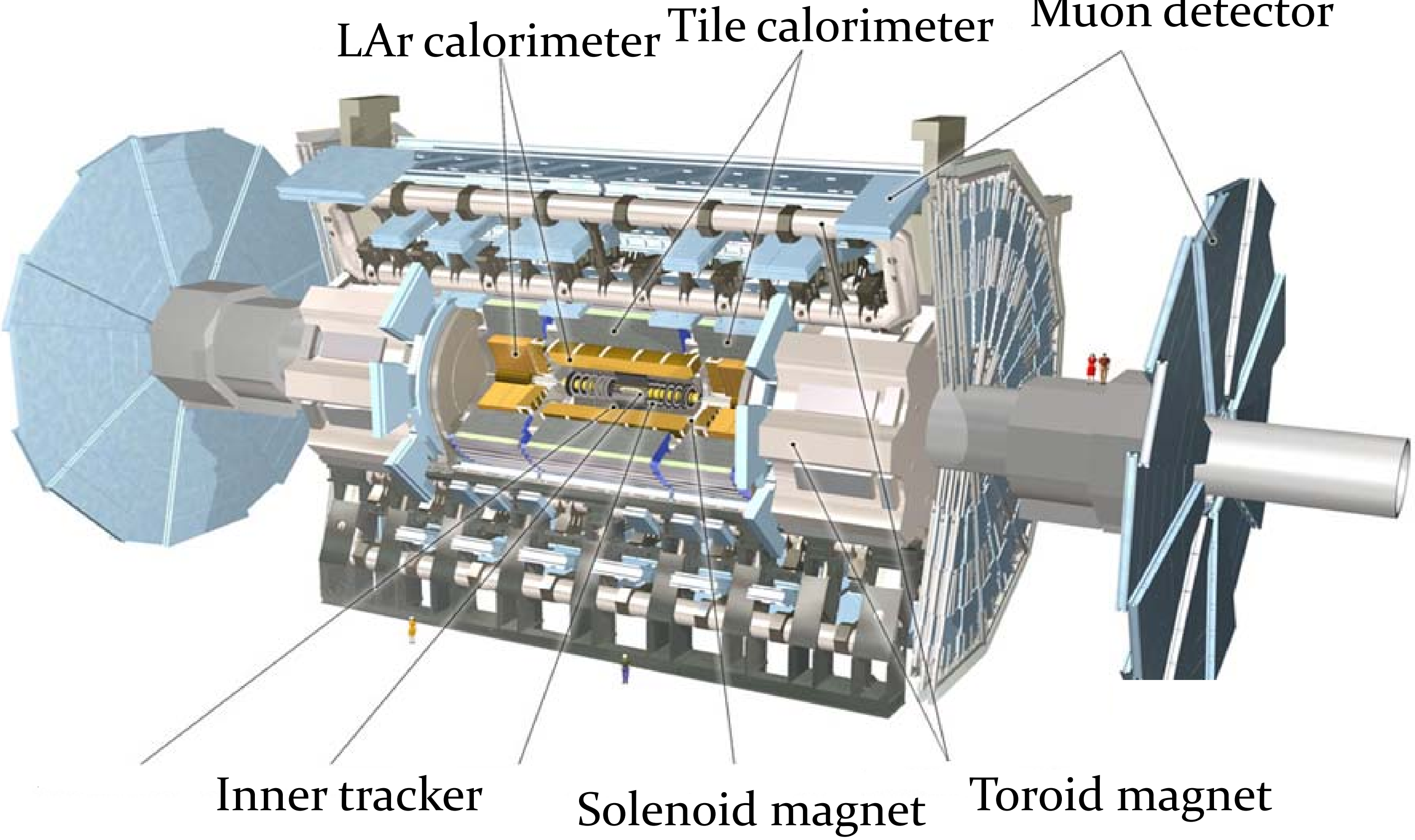
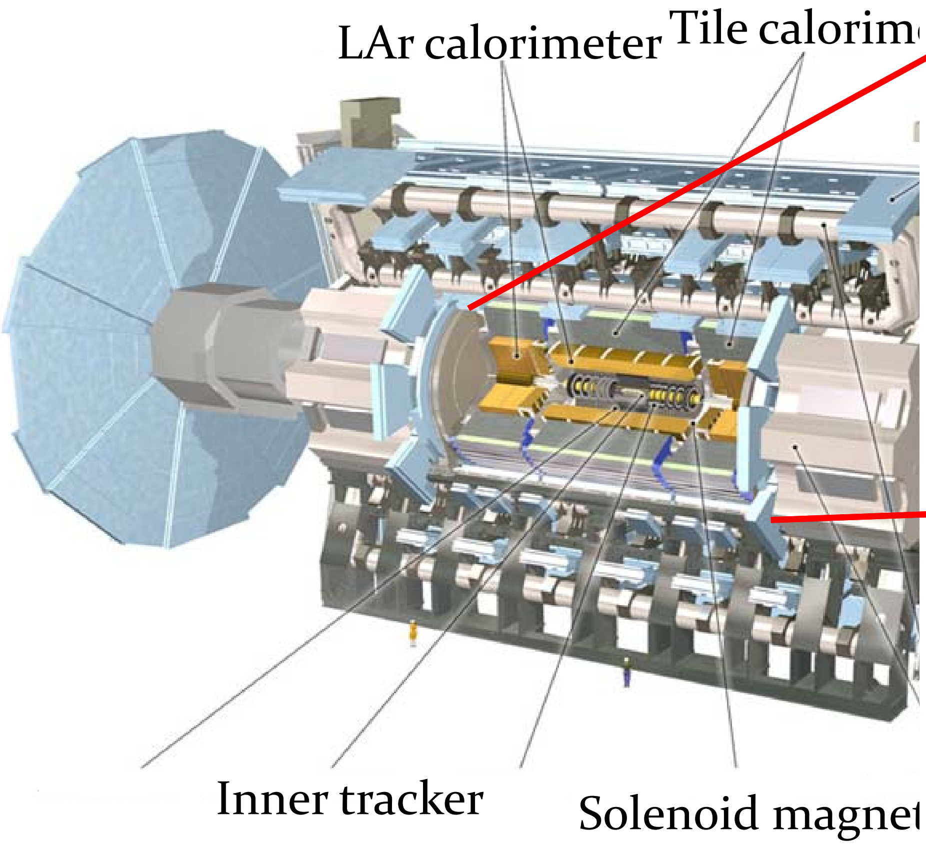
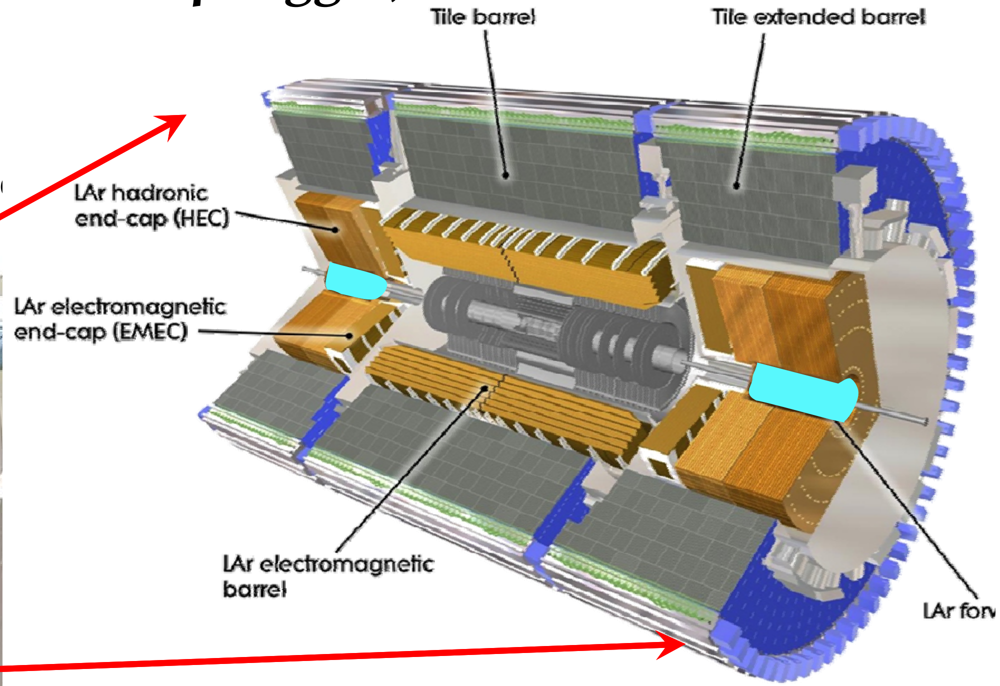


ATLAS Detector

EM calorimeter (LAr)
$|\eta|<3.2$, 3 layers + presampler, $22X_0$
e/γ trigger, identification





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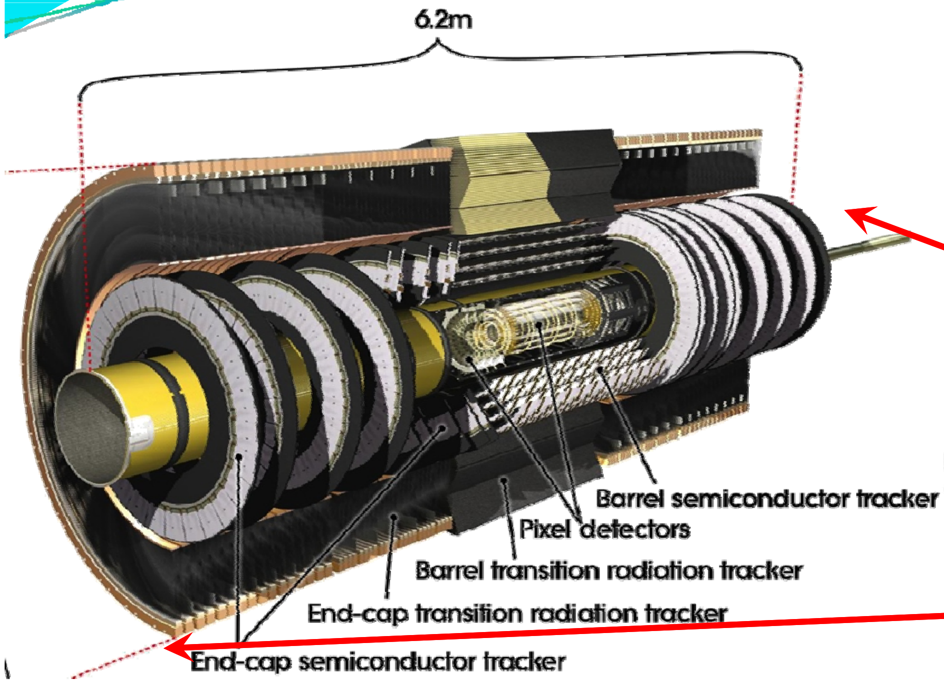

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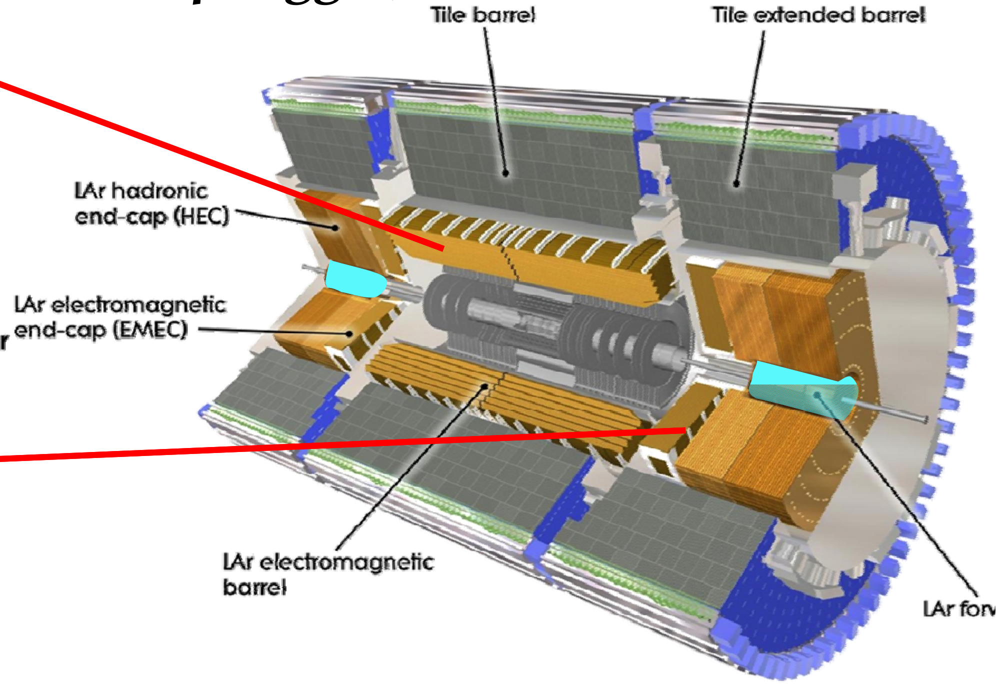

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