Heavy ion physics with CMS and ATLAS

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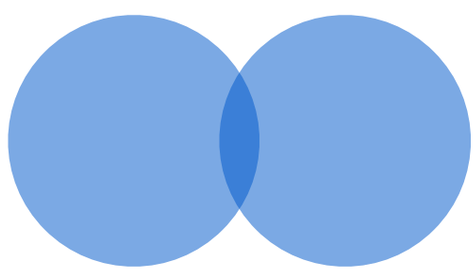
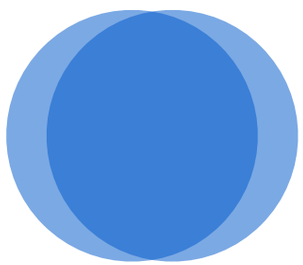
Geometry

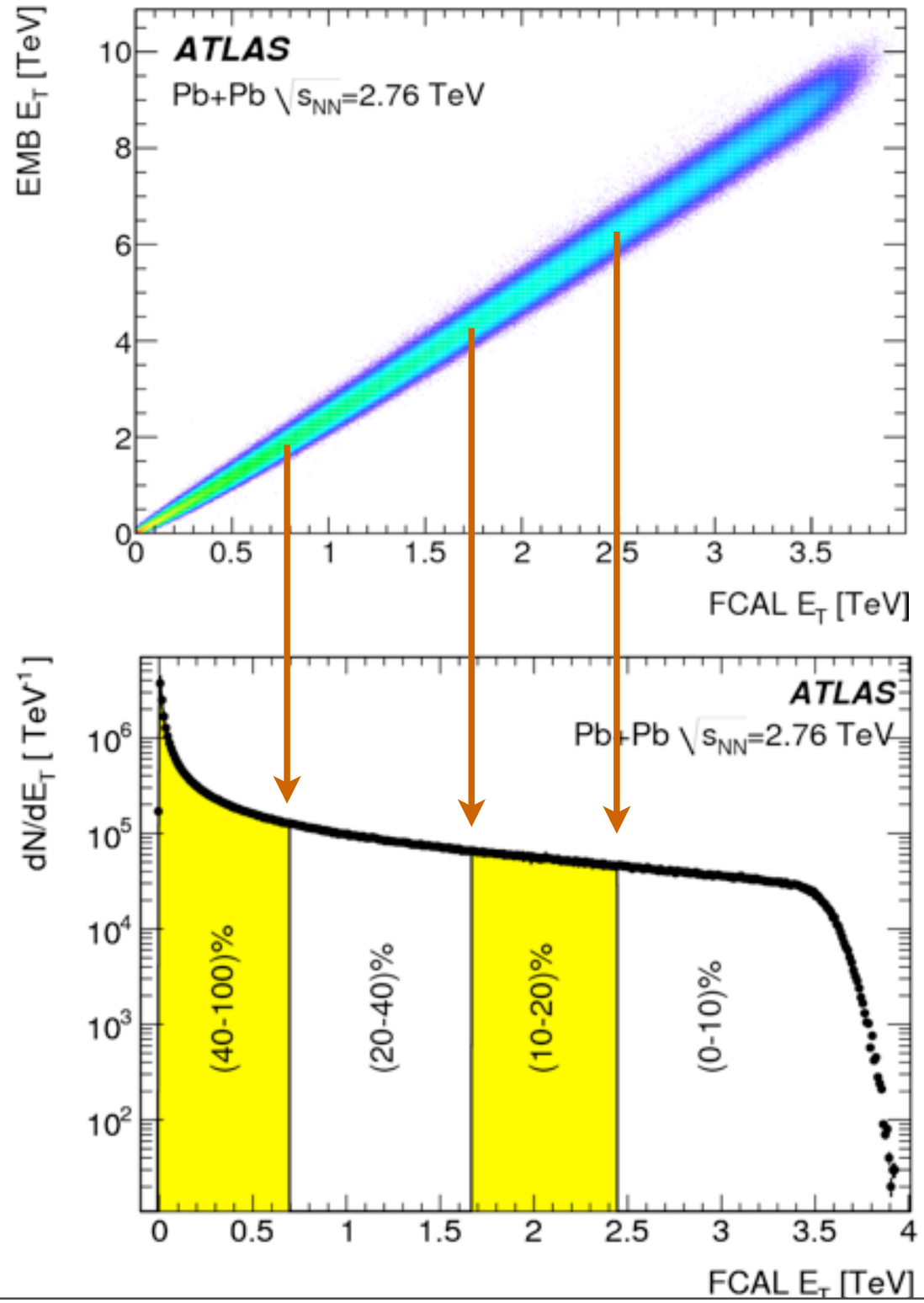
- Centrality of the collision has large impact on the physics in heavy ion collisions
- Total energy in the forward calorimeter used to define centrality bins
- For each centrality bin we can estimate geometrical parameters:
  - number of participating nucleons
  - number of binary collisions
  - event shape

Peripheral collision



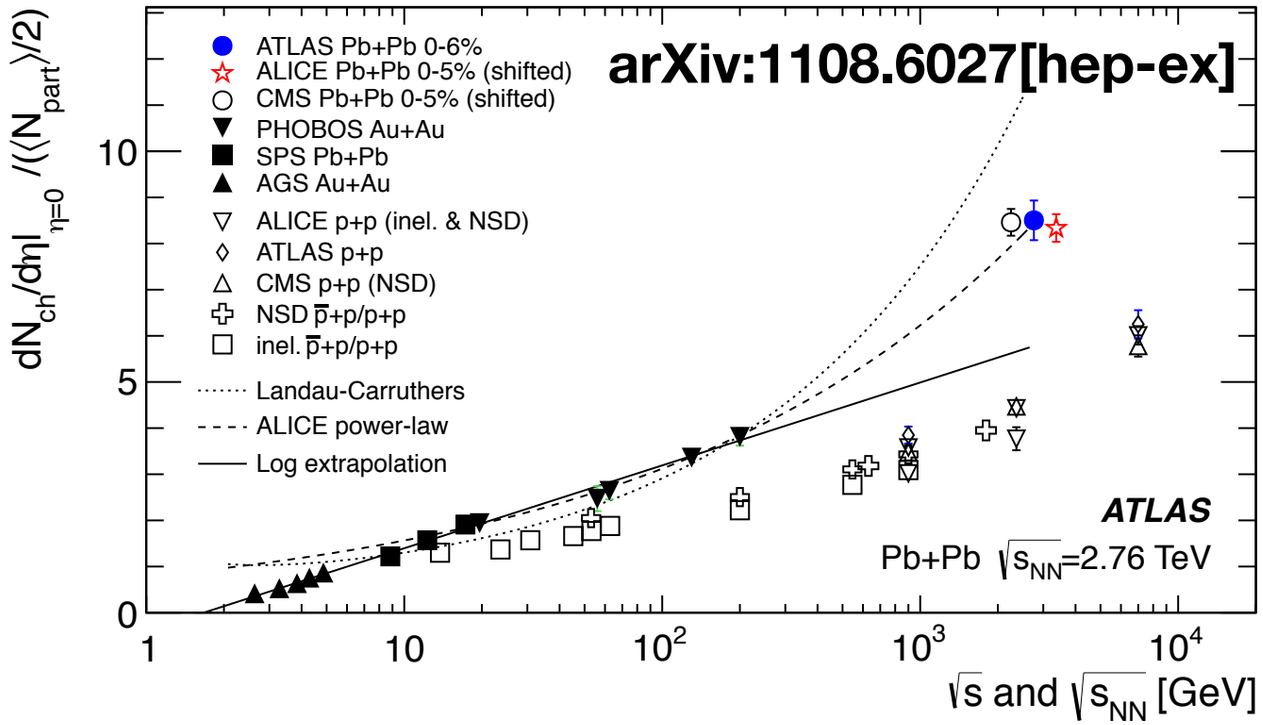
Central collision

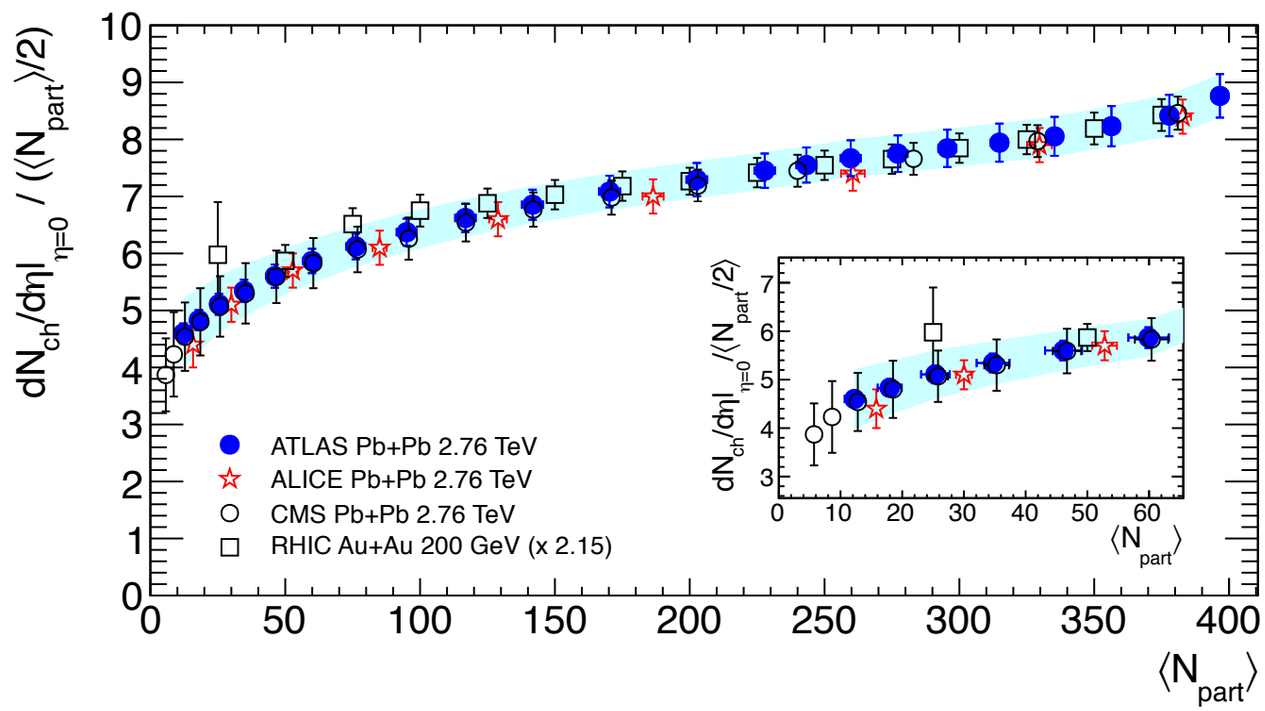




Charged particle multiplicity

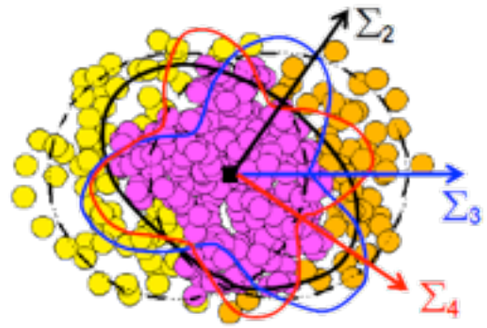
- ATLAS, CMS and ALICE have consistent results
- For central PbPb collisions the multiplicity grows faster with √S than for pp collisions
- Log-scaling (seen up to RHIC energies) is ruled out
- Multiplicity as function of number of participants has the same shape as observed at RHIC energies



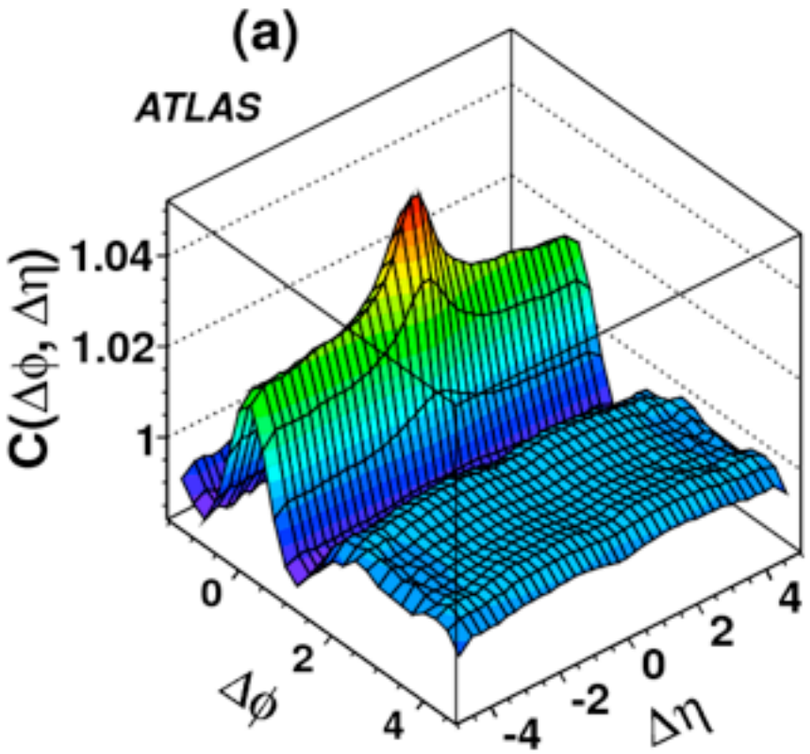


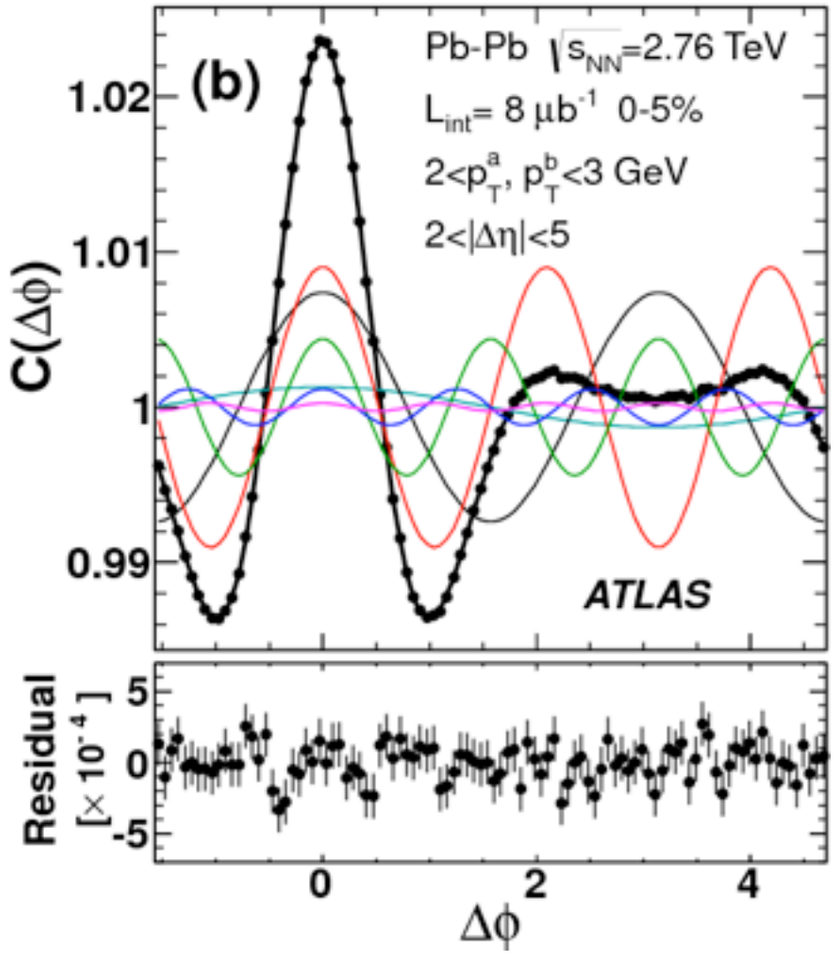
Particle flow

- Collective respond to the initial state geometry
  - Fourier analysis of the azimuthal angular distribution wrt to the event plane
- Strong dependance on |Δη|



$$\frac{dN}{d\varphi} \propto \left(1 + \sum_n 2v_n \cos\left(n[\phi - \Phi_n]\right)\right)$$

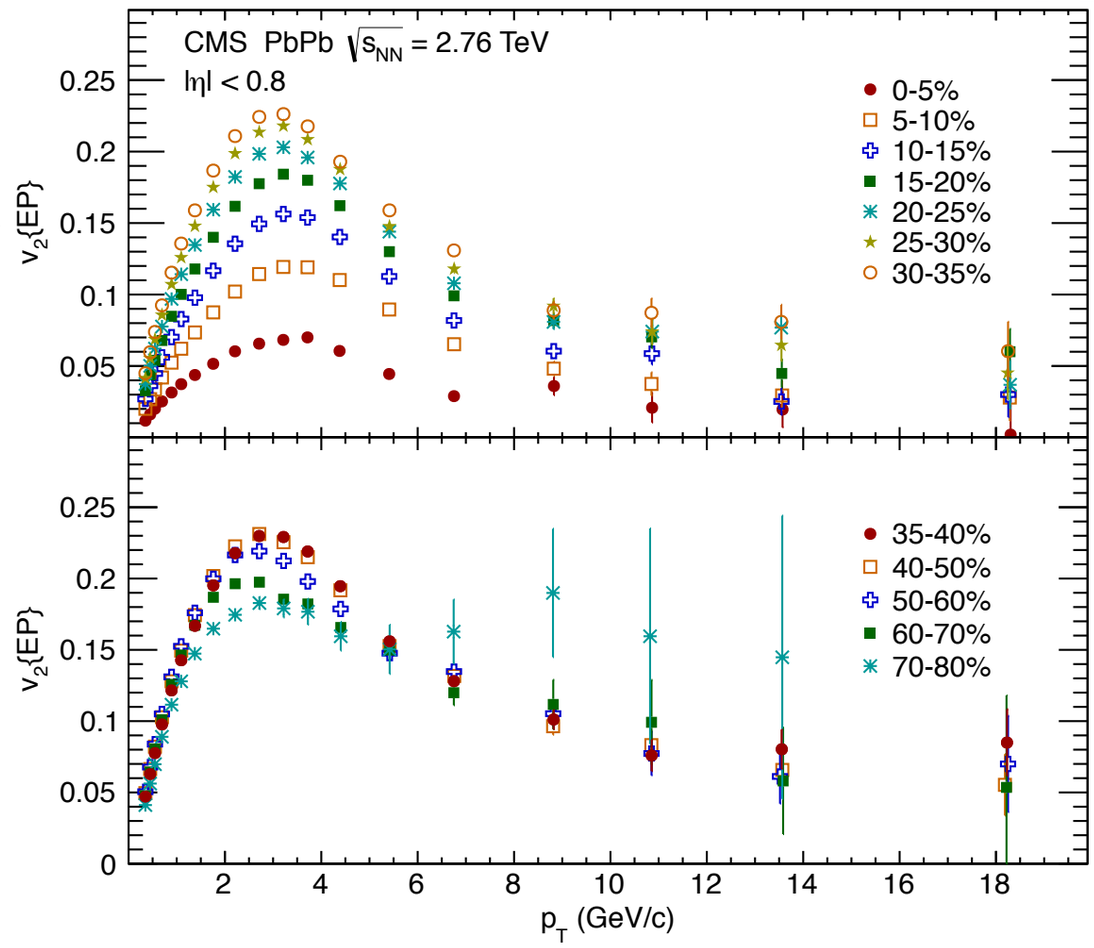


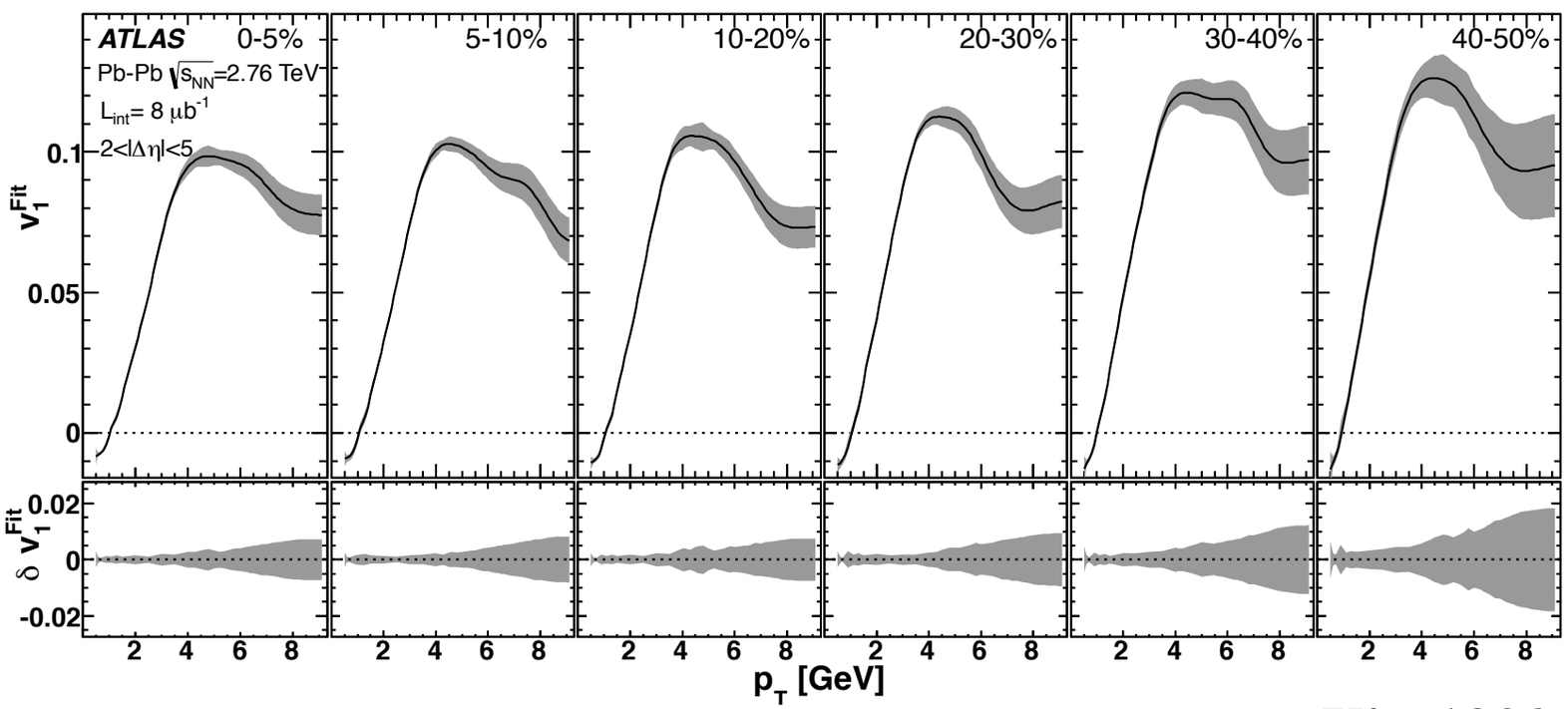


arXiv:1203.3087

Particle flow

- ATLAS and CMS provide a full set of harmonic flow coefficients v_2-v_6 measured up to 20 GeV in momentum, centrality and rapidity
- v_1 measured by ATLAS

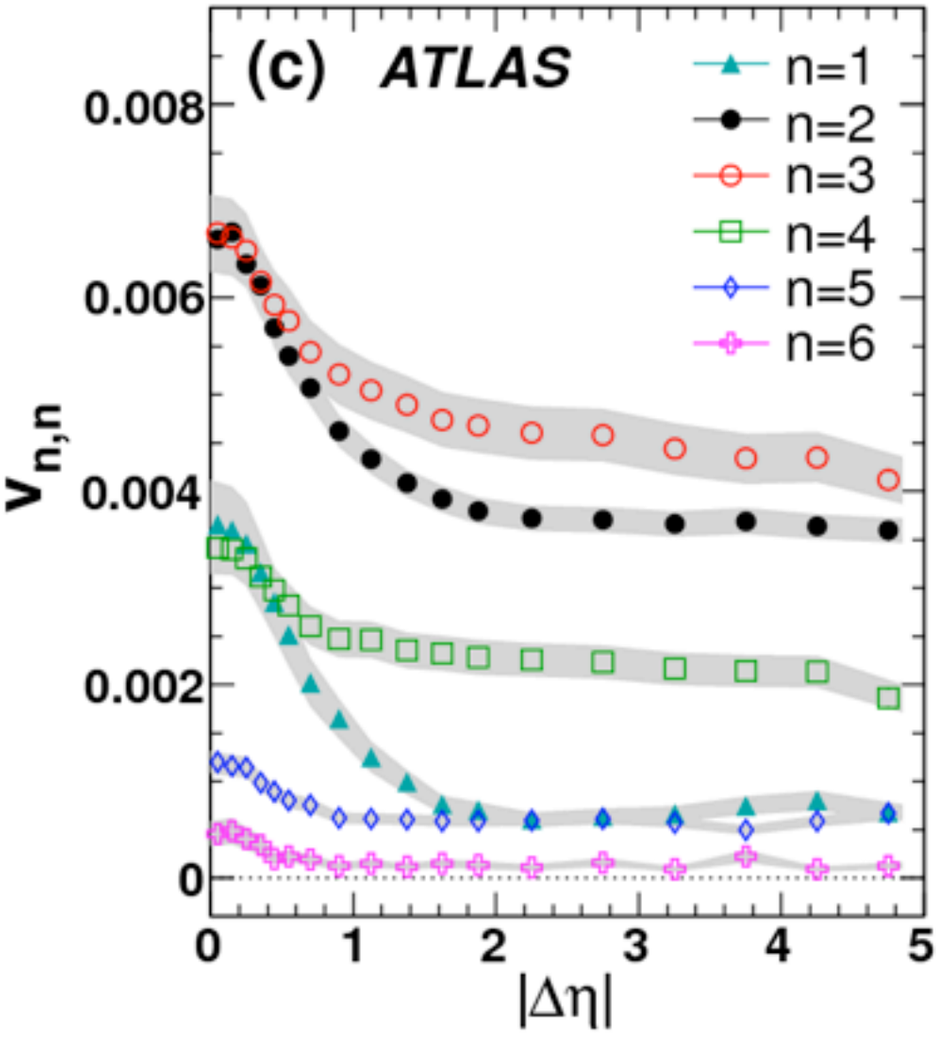




CERN-PH-EP-2011-222

arXiv:1203.3087

Factorization of harmonic flow coefficients

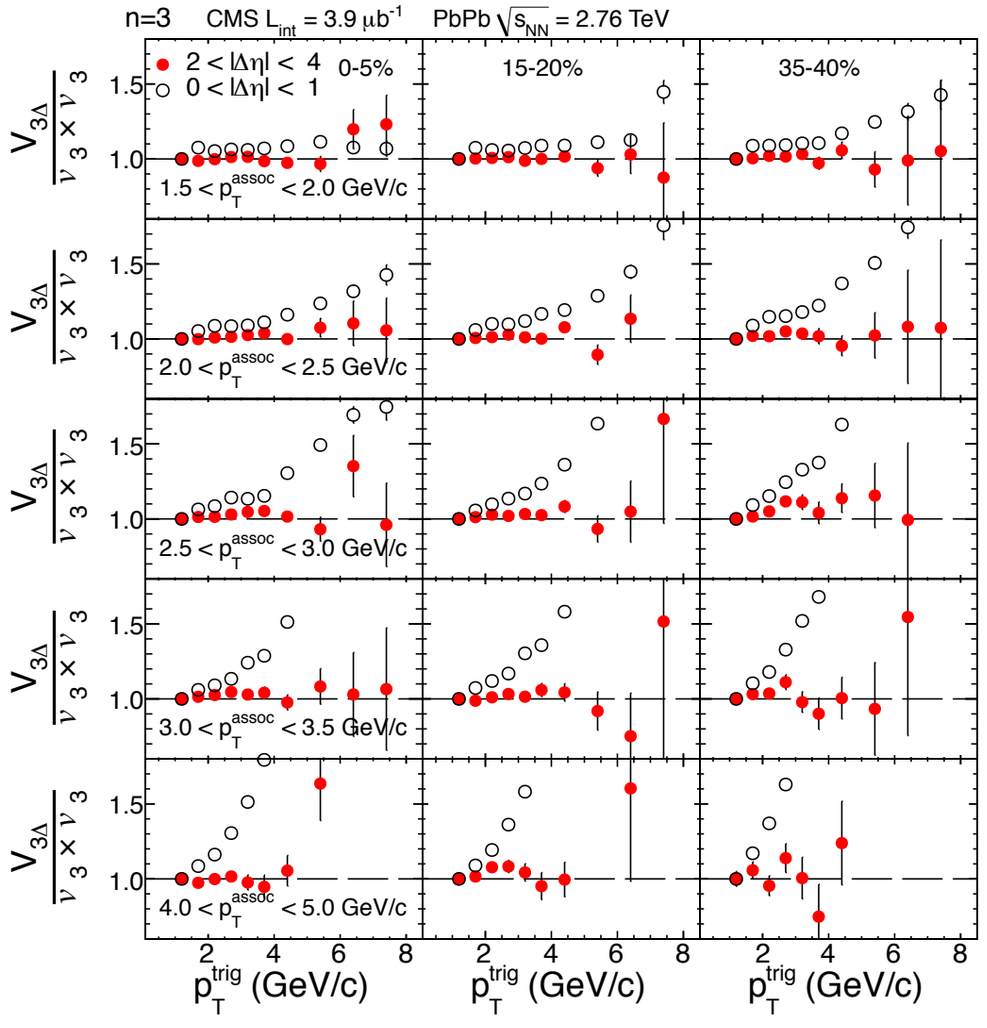


arXiv:1203.3087

Factorization

$$v_{n,n}\left(p_T^a,\eta^a,p_T^b,\eta^b\right)=v_n\left(p_T^a\right)\times v_n\left(p_T^b\right)$$

requires weak eta dependence and low contributions from resonances and jets



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Factorization of v_3 works well for $|\Delta\eta| > 2$ but breaks down for smaller values due to jet production

Particle yields: Charged hadrons

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2N_{A+A}/dydp_T}{d^2N_{p+p}/dydp_T}$$

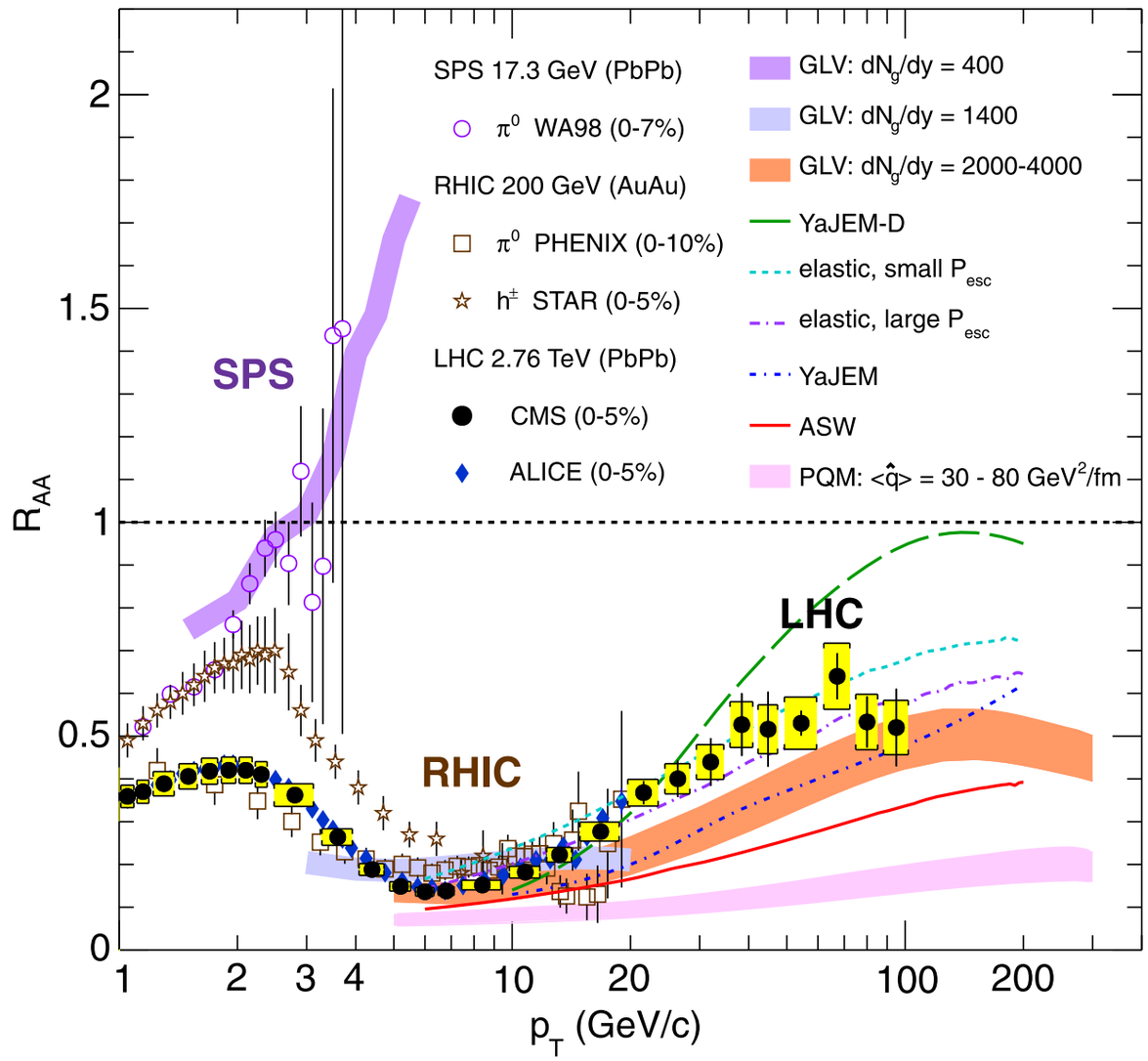
Heavy Ions

Geometry

protons

- No suppression seen at SPS
- Suppression of hadrons largest at 7 GeV

arXiv:1202.2554v1



Particle yields: Photons

- No suppression observed for photons at ATLAS and CMS
- LHC results probe much higher energy range than RHIC

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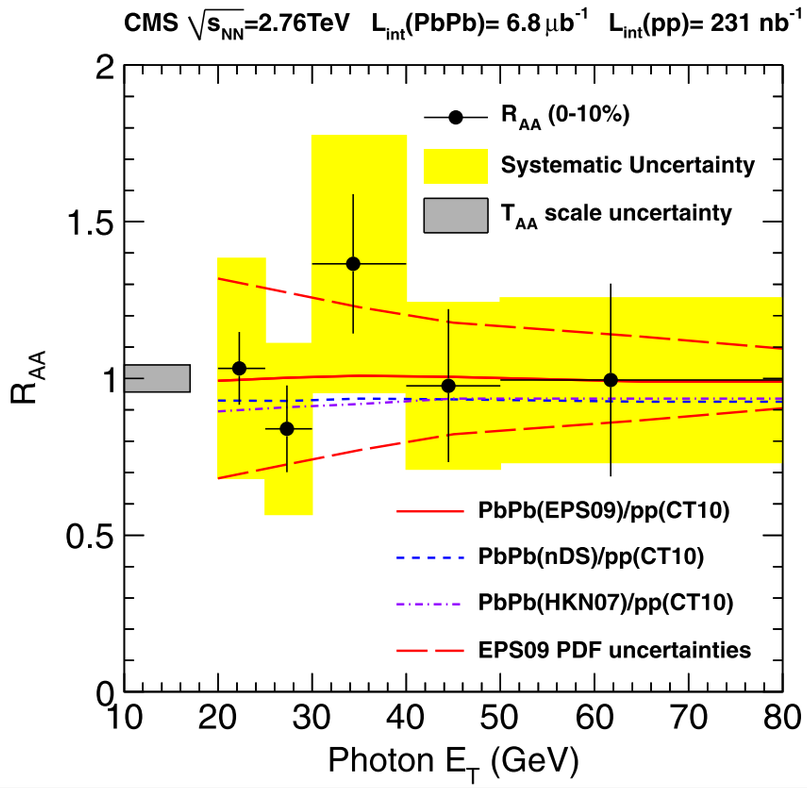
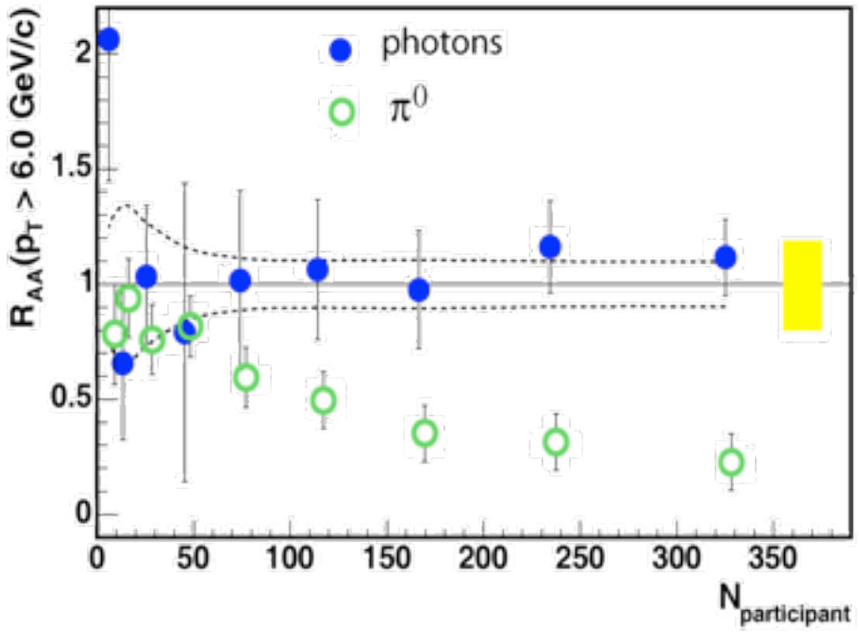
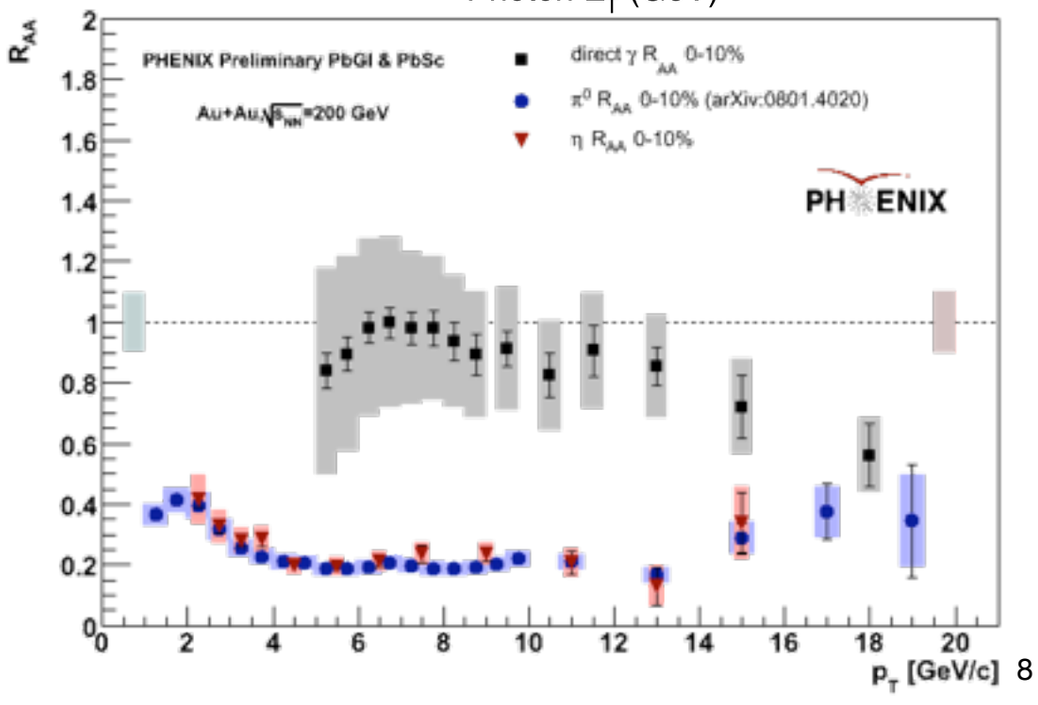






Particle yields: Gauge bosons

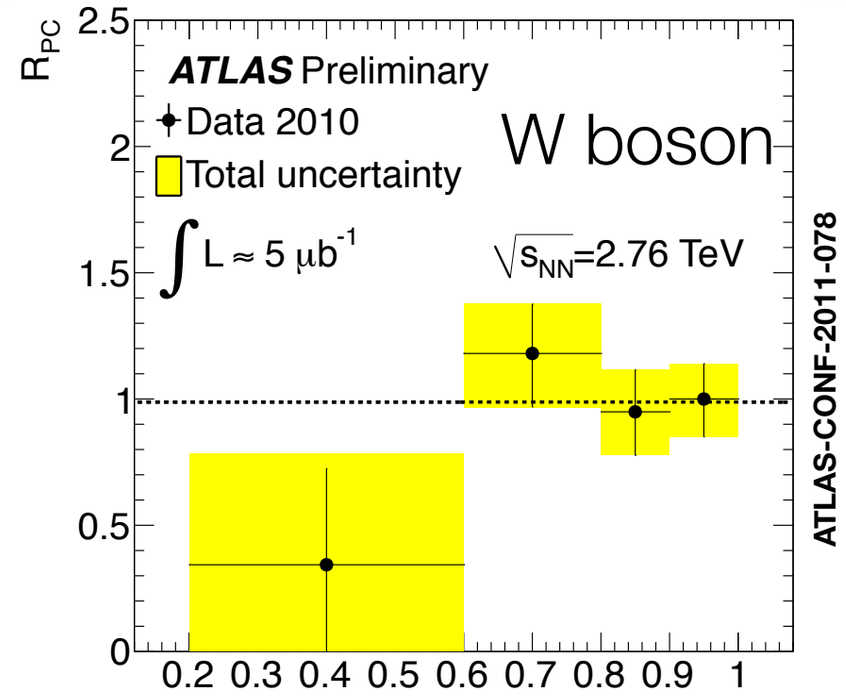
$$R_{CP} = \frac{\left\langle N_{coll}^{periph} \right\rangle}{\left\langle N_{coll}^{centr} \right\rangle} \frac{d^2 N_{A+A}^{centr} / dydp_T}{d^2 N_{A+A}^{periph} / dydp_T}$$

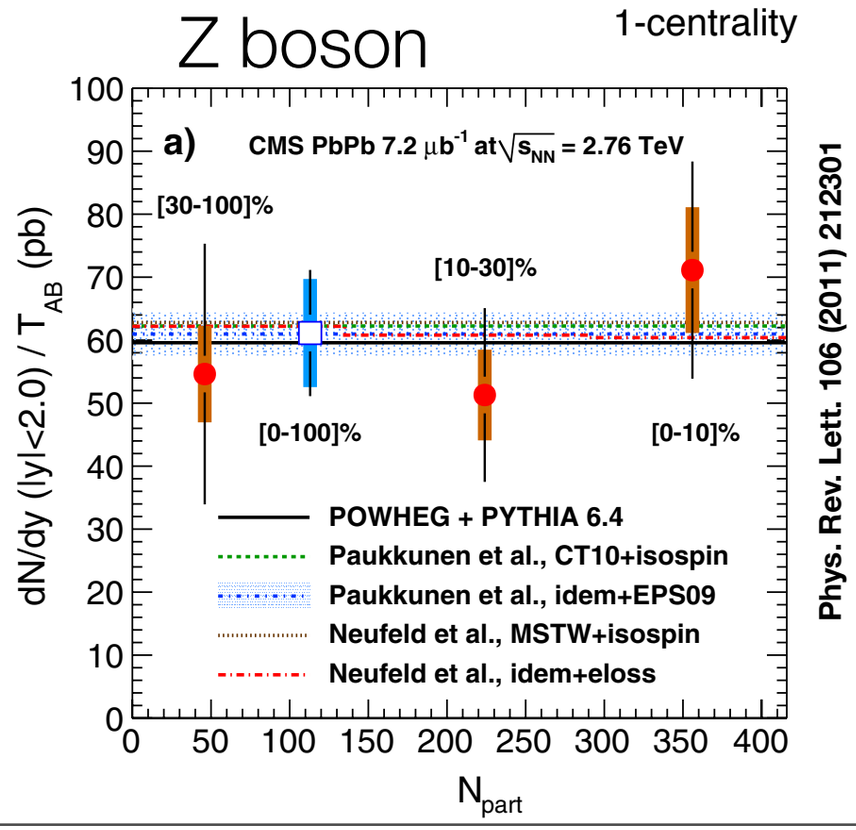
Heavy Ions central

Heavy Ions Peripheral (p+p – like)

- W yield measured by fitting the muon pt spectrum with a signal + background template
- Decay of the Z boson into two muons provides a very clean signature even for the most central events
- Observed yields compatible with no suppression

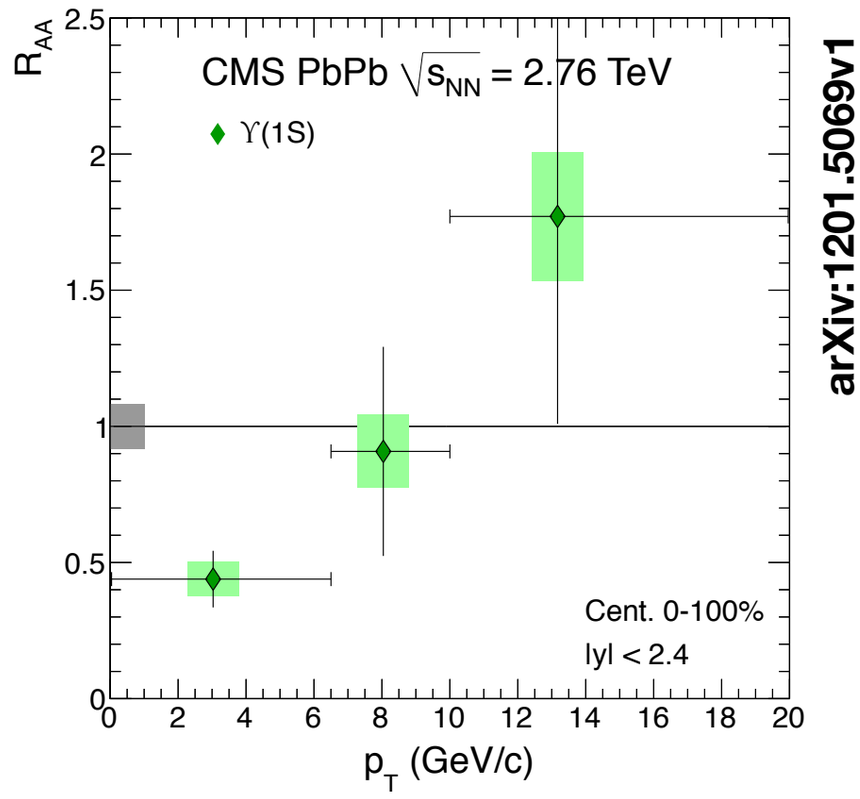
2011 data will provide more accurate measurements



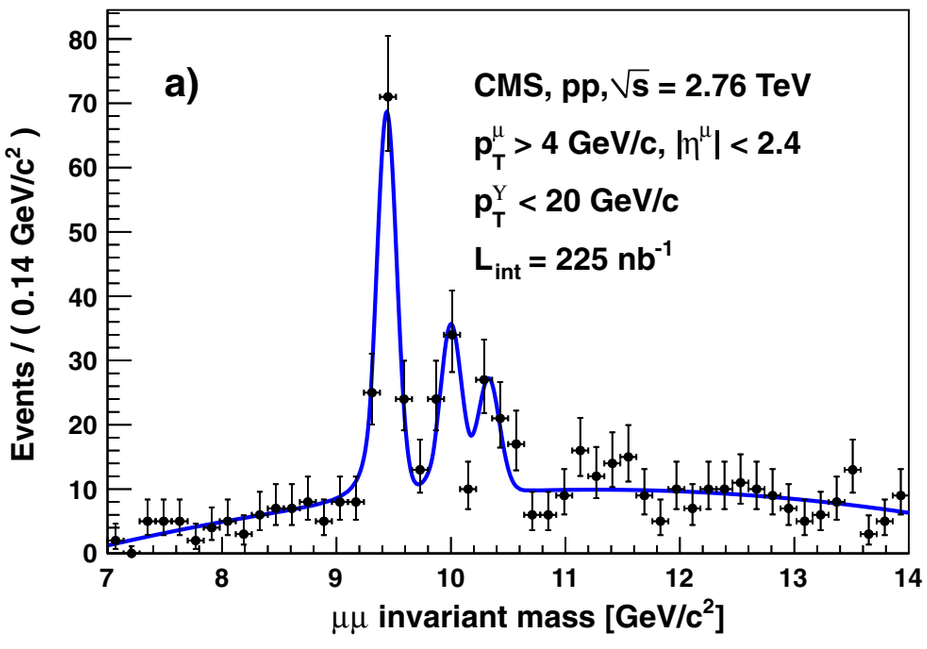


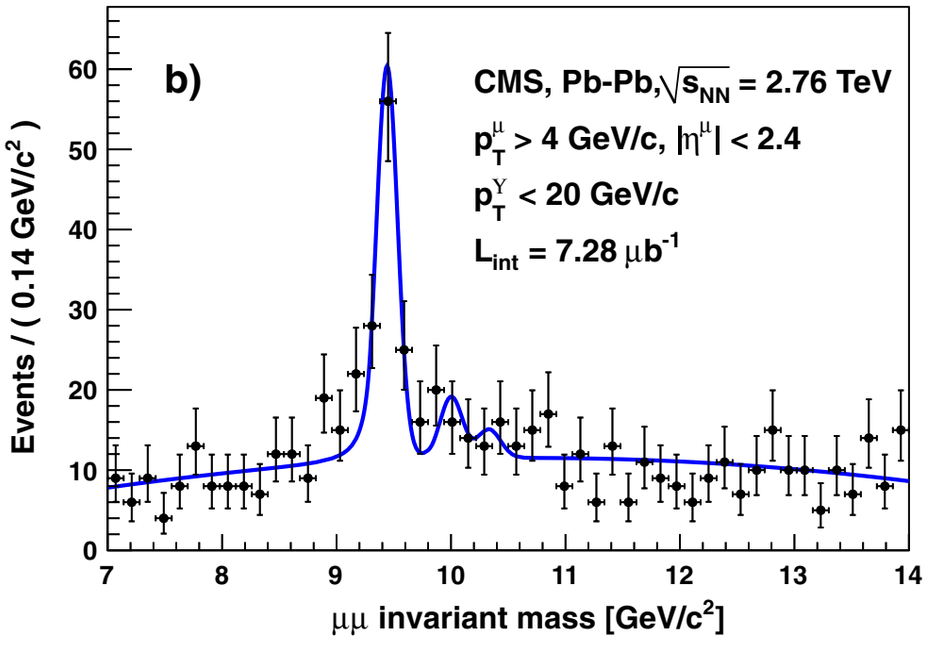
Particle yields: Upsilon

- 2010 CMS results consistent with the disappearance of higher Y-states in central HI collision
- Suppression of the Y ground state at low pt



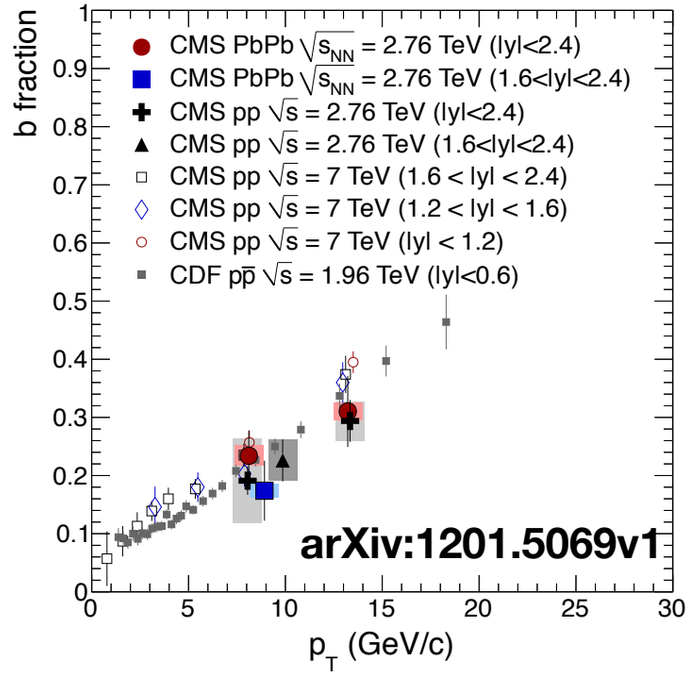
PRL 107, 052302 (2011)

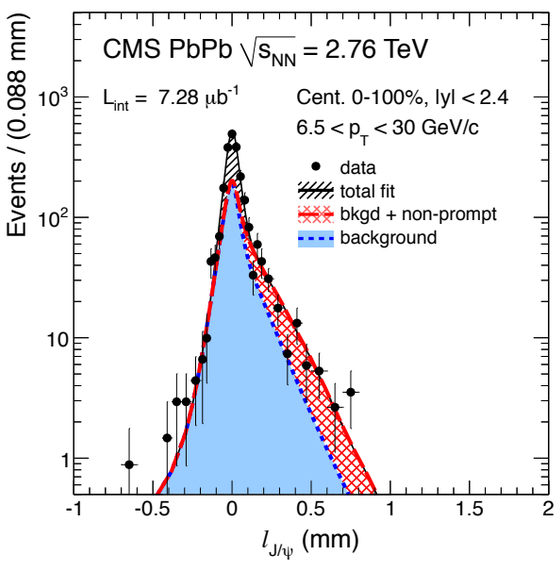


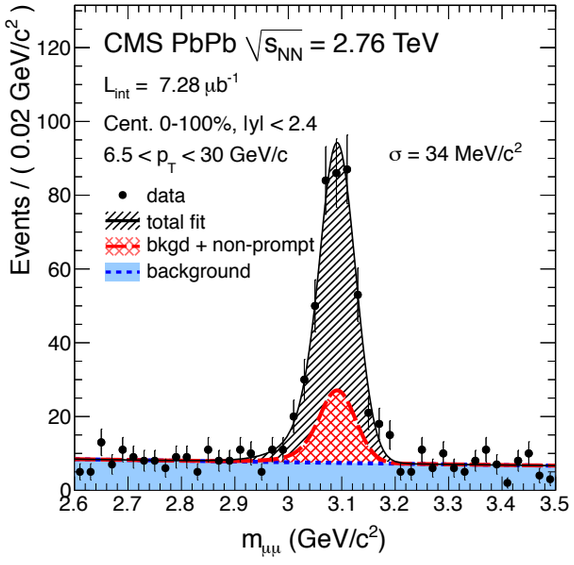


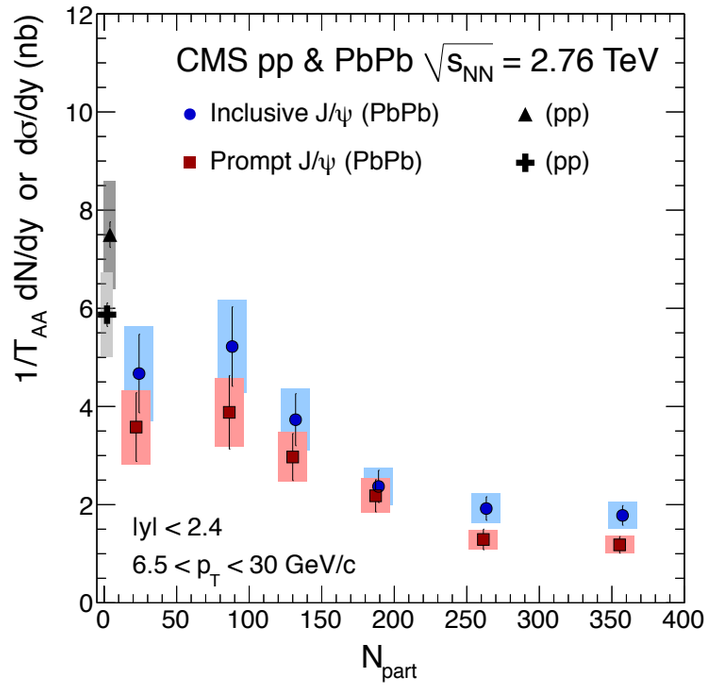
Particle yields:
J/Psi

- Secondary vertex reconstruction allows measurement of proper time of J/Psi from B-decays
- b-fraction measured in Pb+Pb similar to the measured fraction in PP collisions
- Both prompt and non-prompt Jpsi component show a significant suppression

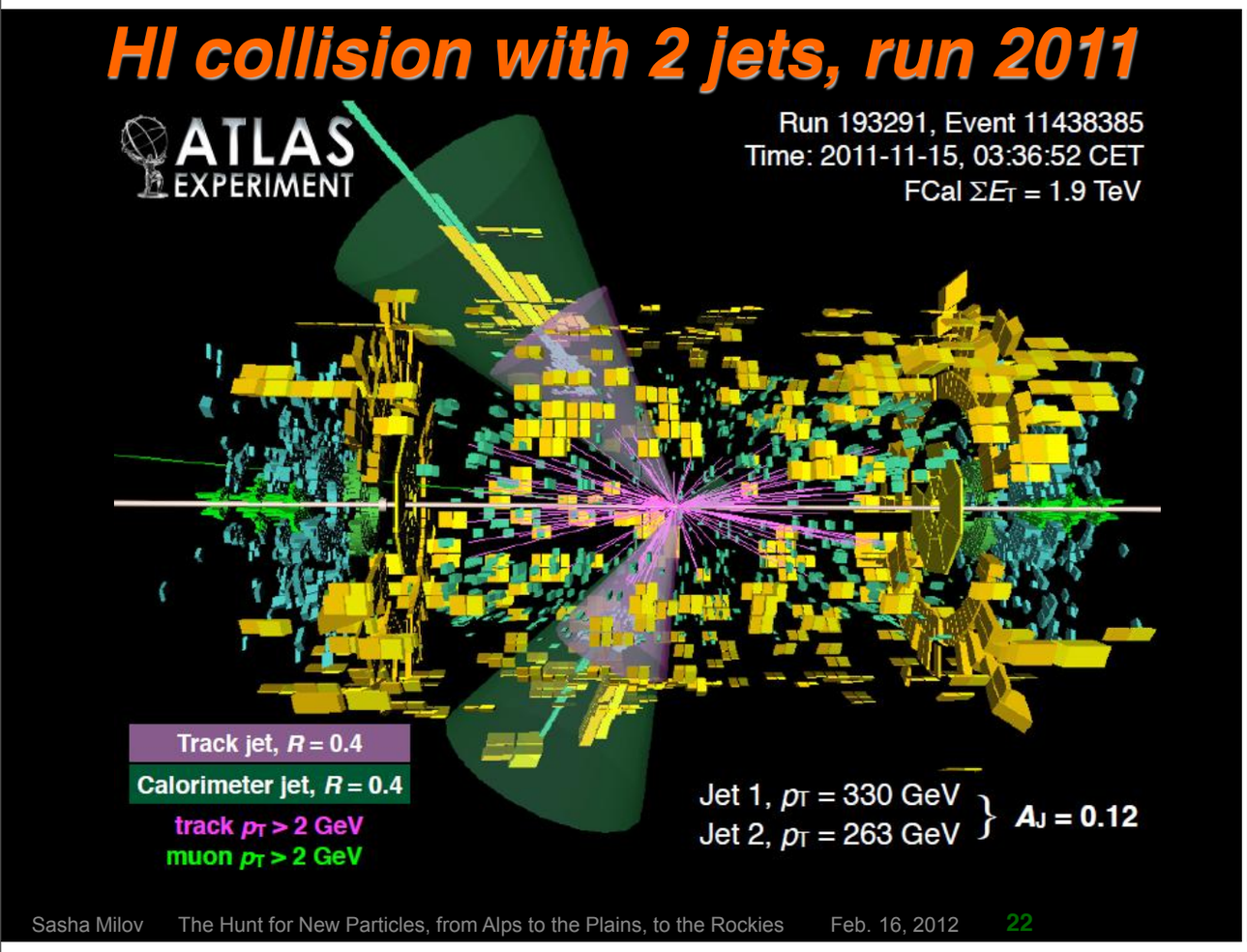


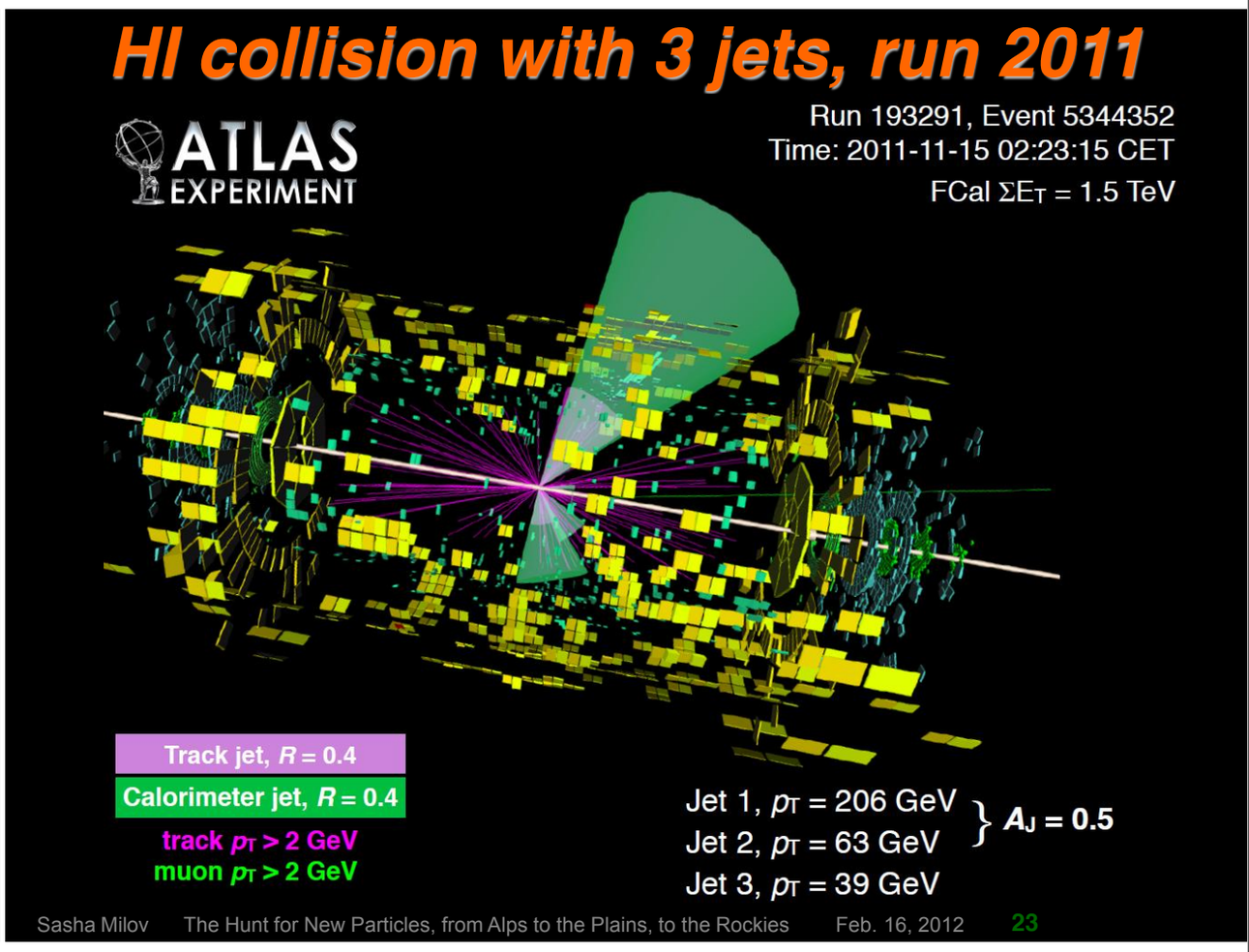






Particle yields:
Jets

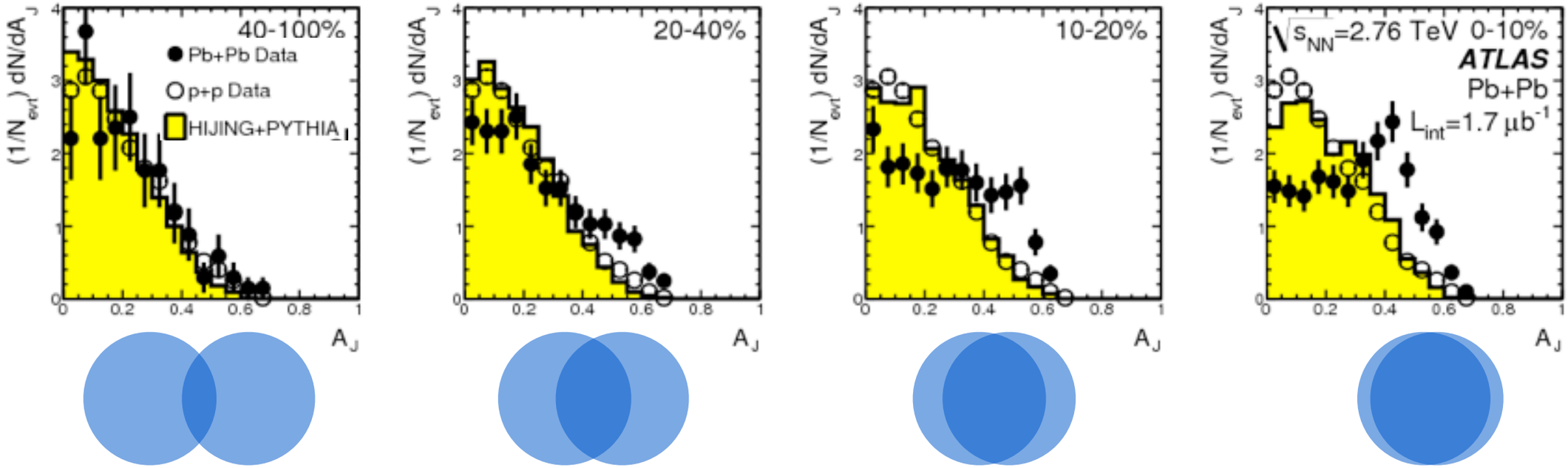




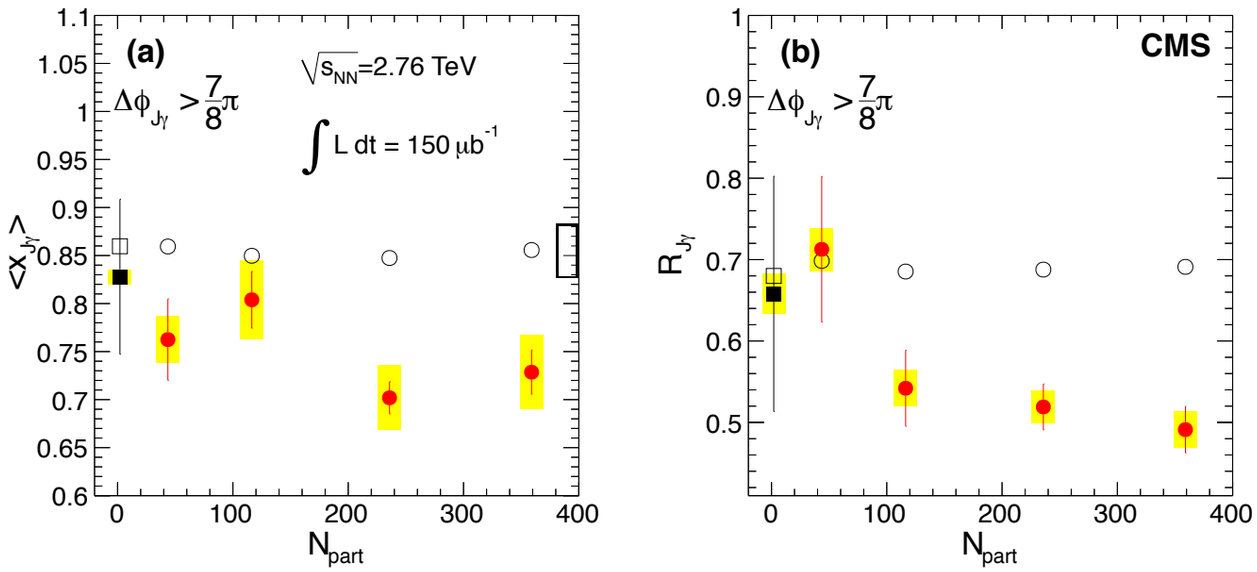
$$A_J = \frac{E_{T,jet1} - E_{T,jet2}}{E_{T,jet1} + E_{T,jet2}}$$

Particle yields: Jets

Phys.Rev.Lett. 105 (2010) 252303



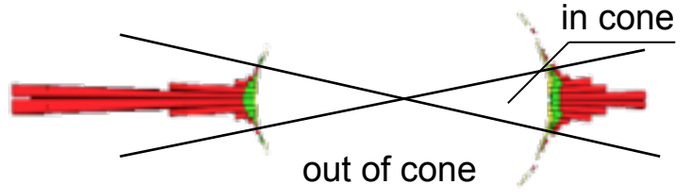
- December 2010: first observation of jet suppression
- Also observed in photon + jet final state



arXiv:1205.0206

Jet suppression: where did the energy go?

Missing $p_T^{||} = \Sigma\ -p_T^{track} \cos(\phi_{track} - \phi_{leading\ jet})$



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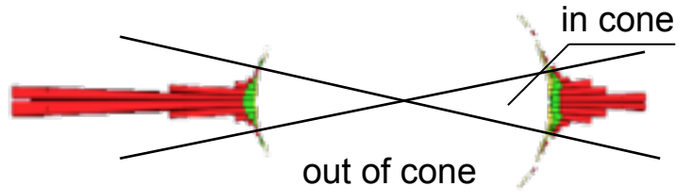

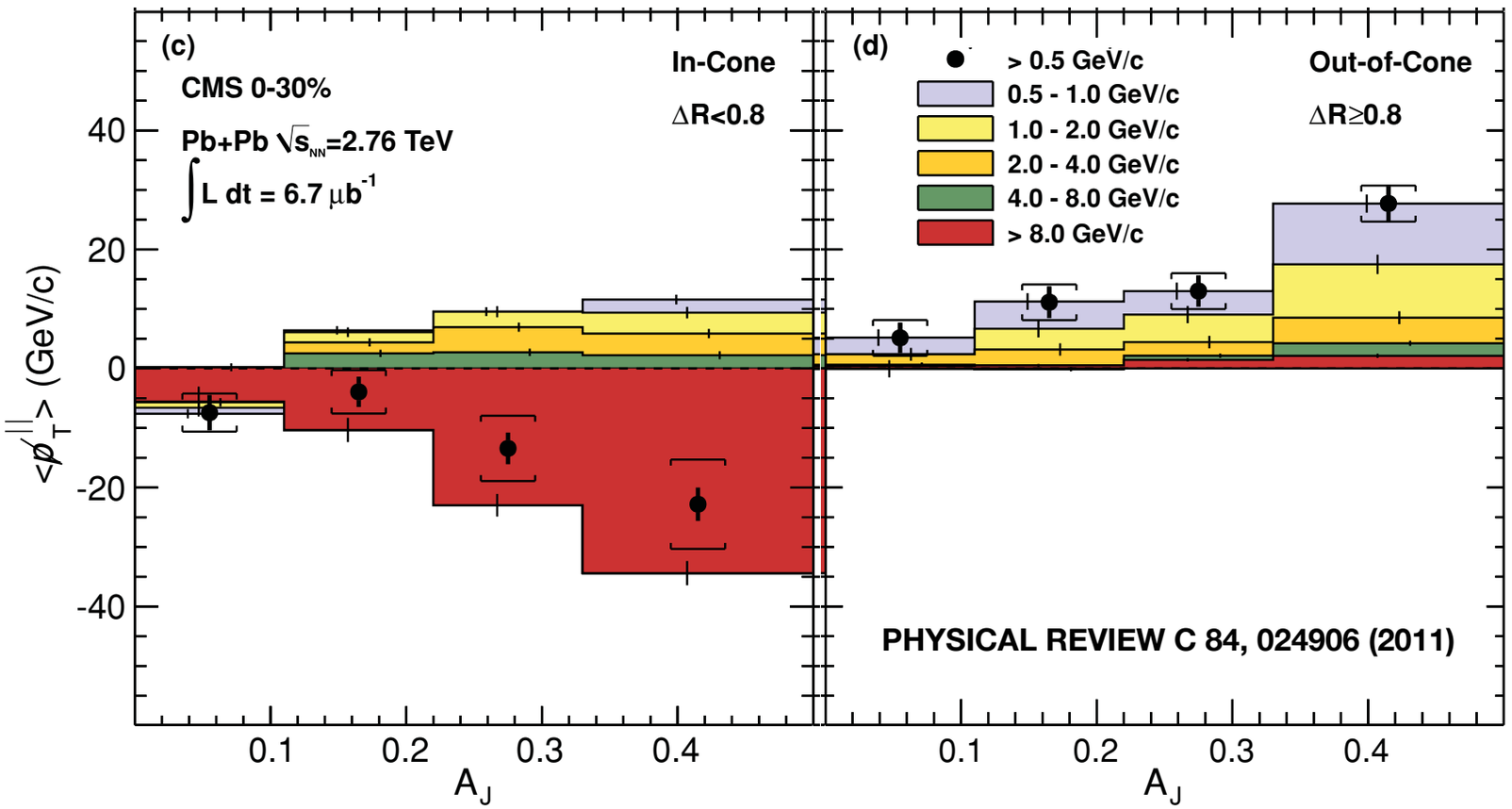

- Inside and outside cone tracks are unbalanced

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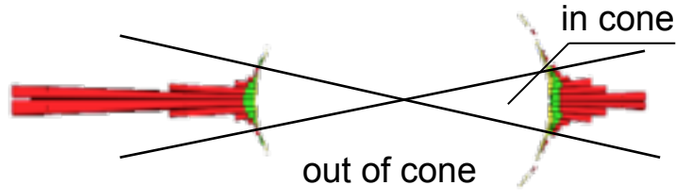

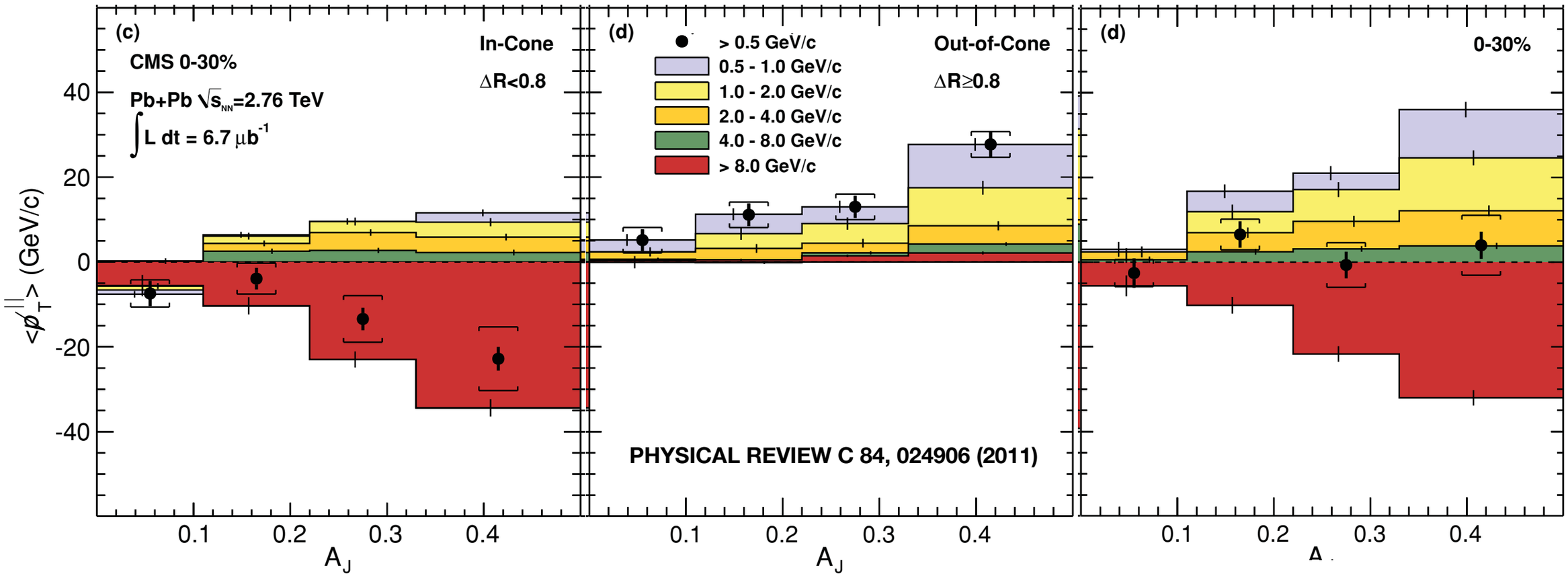

- Inside and outside cone tracks are unbalanced
- Summing the two restores the balance

Conclusion

- ATLAS and CMS both have very successful heavy ion programs
  - consistent results between the experiments
  - CMS published 9 papers, ATLAS 5
- Main results
  - observation of jet suppression
  - evidence of the disappearance of higher Upsilon states
  - first observation of B suppression
- High expectations for 2011 data analysis: many results will turn for ‘hints’ into solid measurements
  - statistics in 2011 about 20 times larger than in 2010, analyses well underway
- 2012 program: p-Pb collisions