Measurement of high-p_T azimuthal anisotropy in charged hadron production from 2.76 TeV PbPb collisions at CMS

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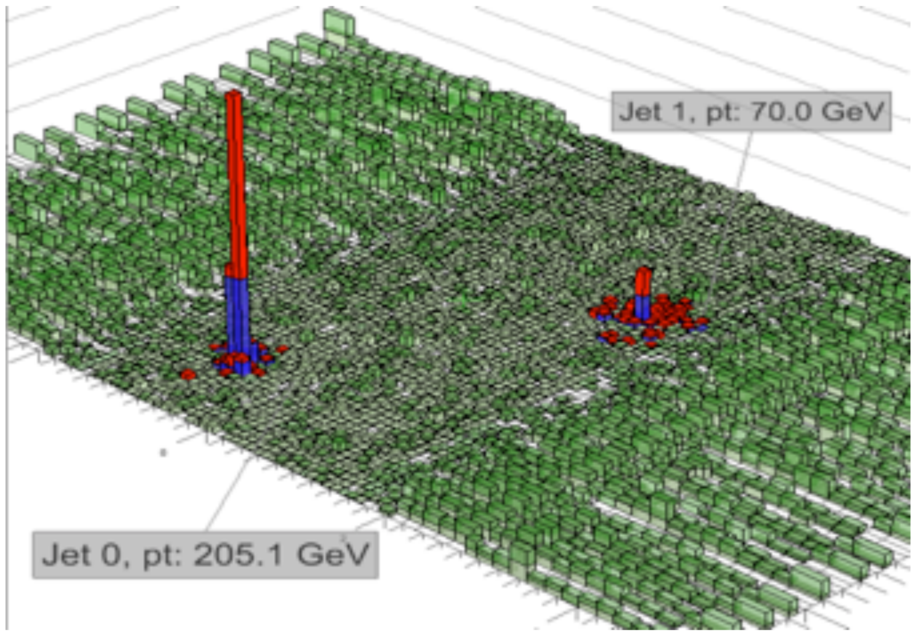
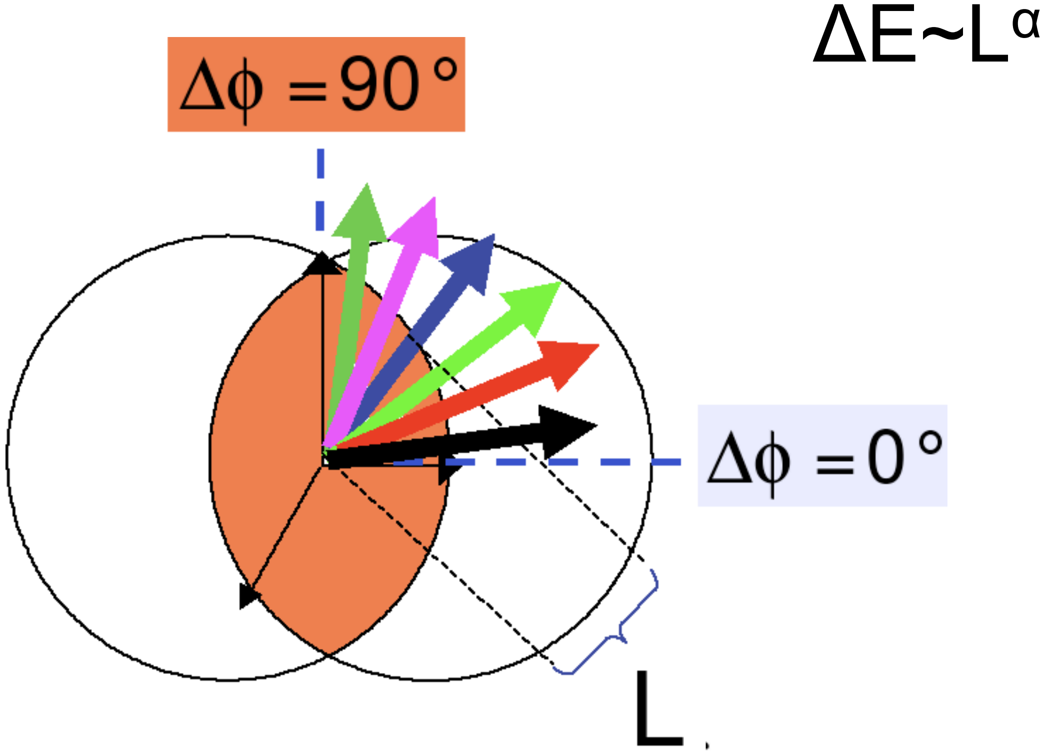
Jet Quenching and Azimuthal Anisotropy

Path length (L) dependence of jet energy loss (ΔE)



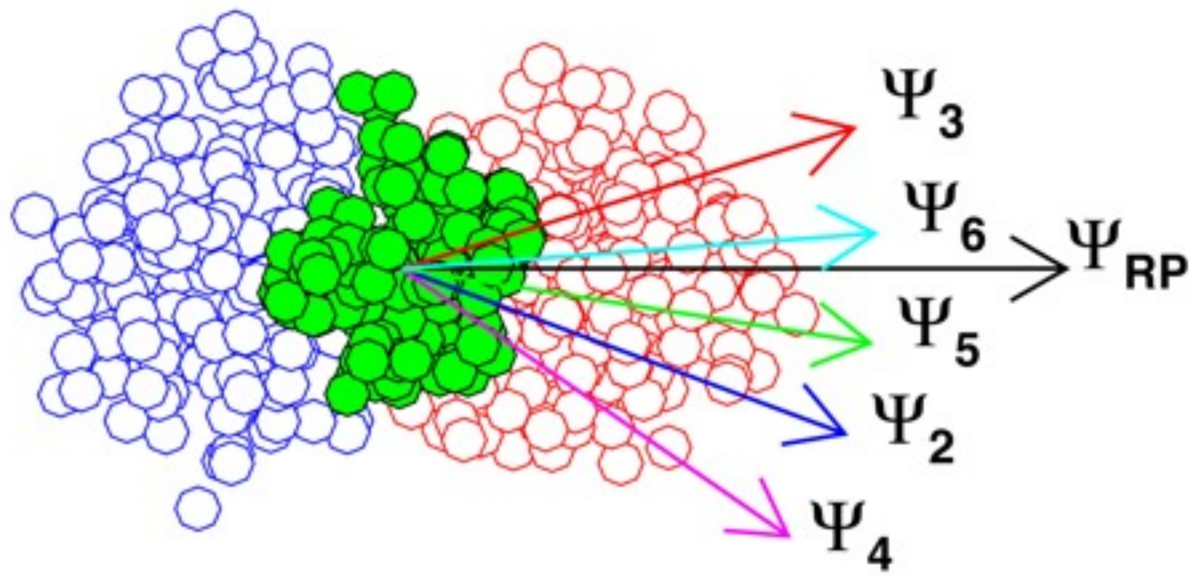


Fourier decomposition of charged hadron yields:

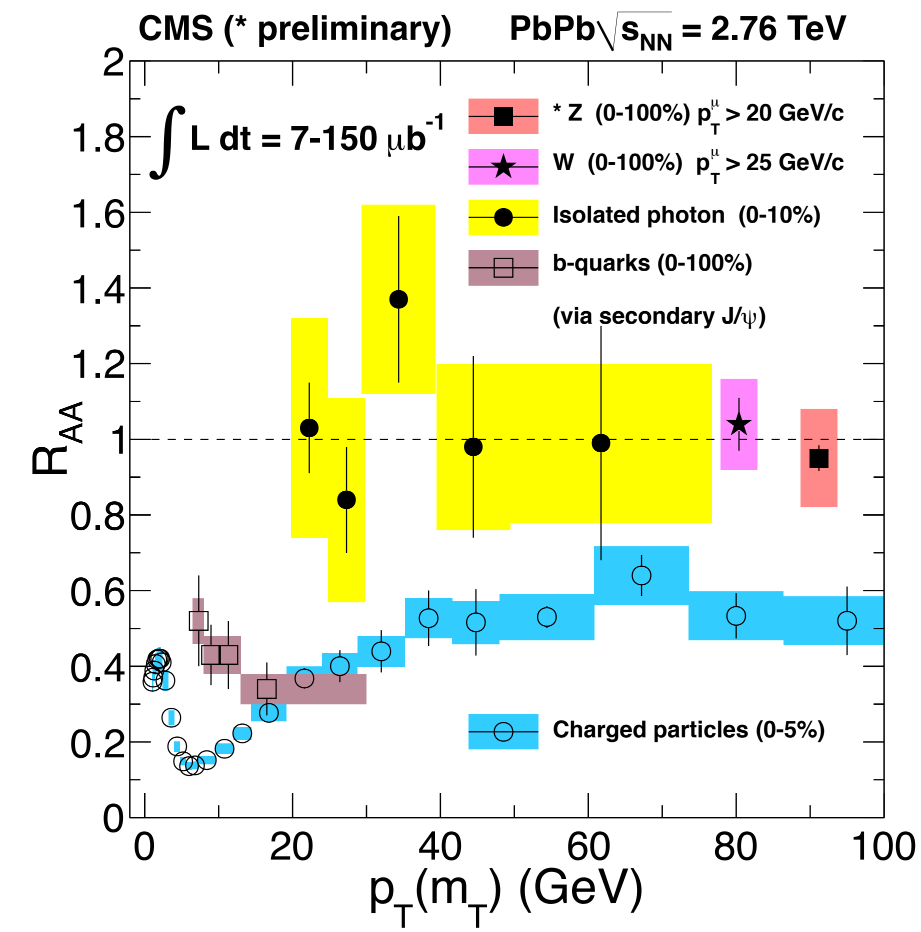
$$\frac{d^3N}{p_T dp_T d\eta d\phi} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T d\eta}\left(1 + \sum_{k=1}^{\infty} 2v_{n=km}(p_T,\eta)cos[n(\phi - \Psi_m)]\right)$$

Azimuthal anisotropy (v_2, v_3, v_4) of high p_T jets

Physics Motivation



$$R_{AA} = \frac{\sigma_{pp}^{inel}}{\langle N_{coll} \rangle} \frac{d^2 N_{AA}/dp_T d\eta}{d^2 \sigma_{pp}/dp_T d\eta}$$



<u>$\Delta E \sim L^{\alpha}$</u>

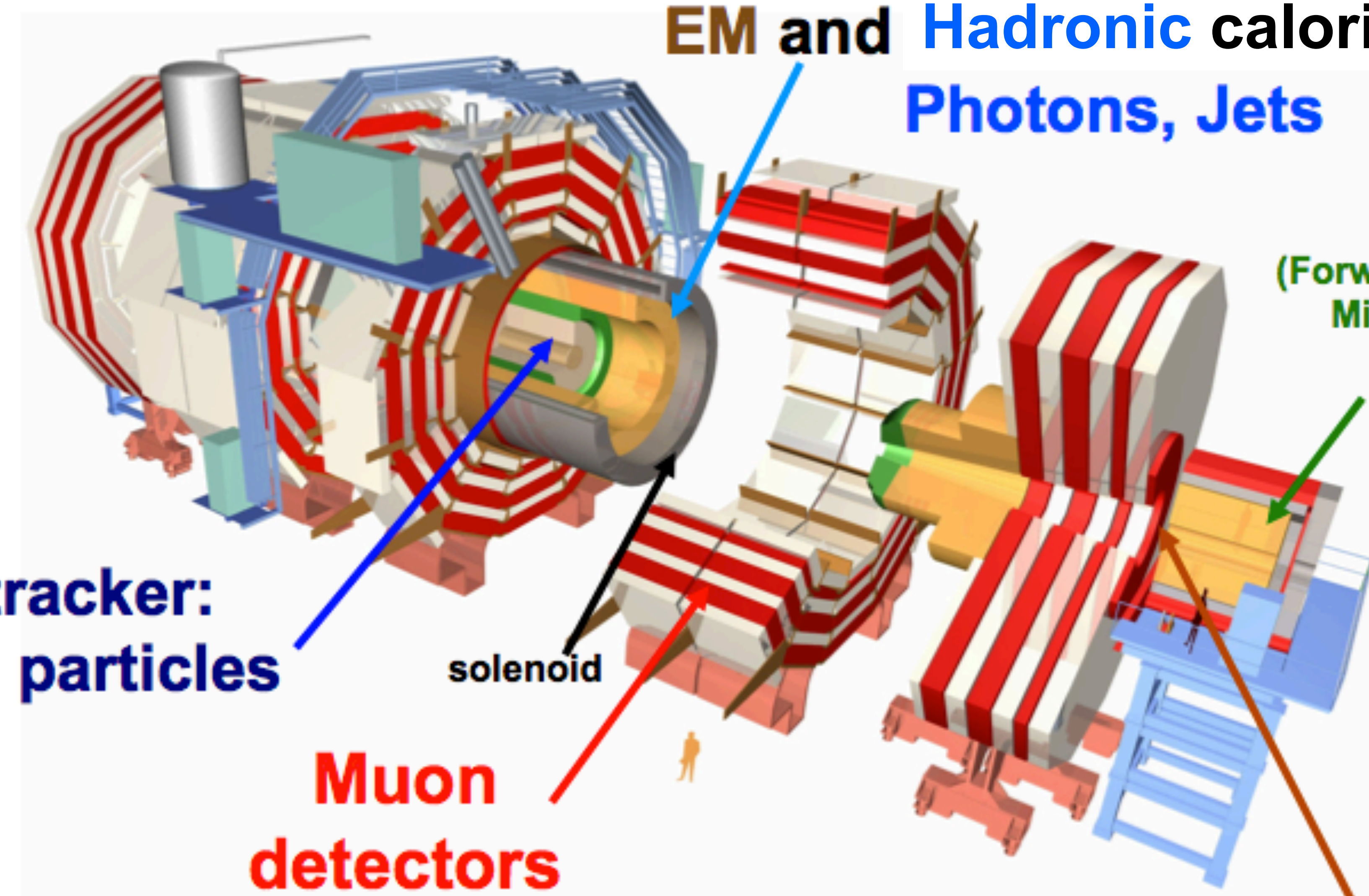
α = 1 for pQCD, collisional
α = 2 for pQCD, radiative
α = 3 for AdS/CFT

<u>Initial Conditions:</u>
-Glauber
-Color Glass Condensate

Phys. Usp. B 52, 659 (2009)
Nucl. Phys. A784, 426 (2007)
Phys. Rev. C 82, 024908 (2011)
Phys. Rev. C 84, 034904 (2011)
Phys. Rev. C 83, 024908 (2011)

Phys. Lett. B (2012) 710 256
Phys. Rev. Lett. (2011) 106 312301
Eur. Phys. J. C. (2012) 72 1945
JHEP 1205 (2012) 063

CMS Detector



Muon	|η|< 2.4
Hadronic Calorimeter	|η|< 5.2
EM Calorimeter	|η|< 3.0
Tracker	|η|< 2.5

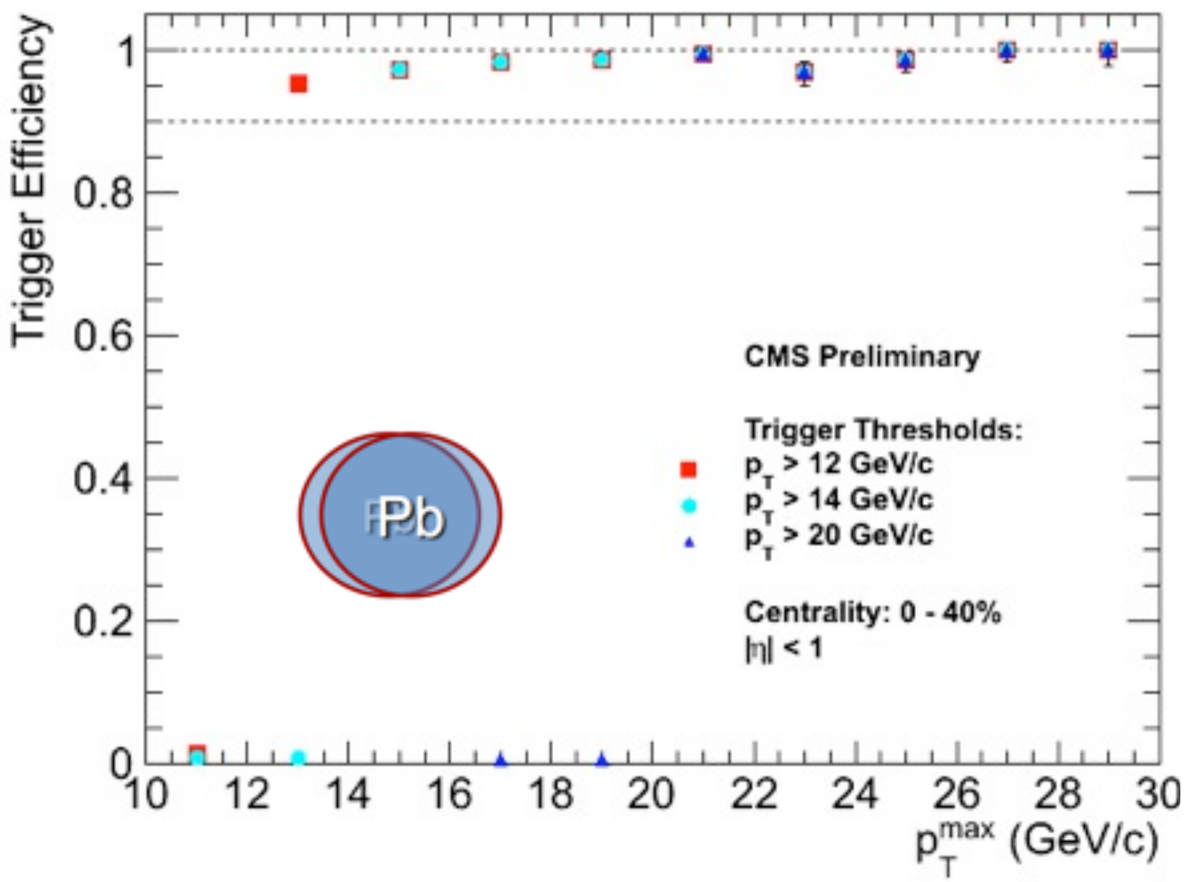
Unprecedented kinematic range and acceptance

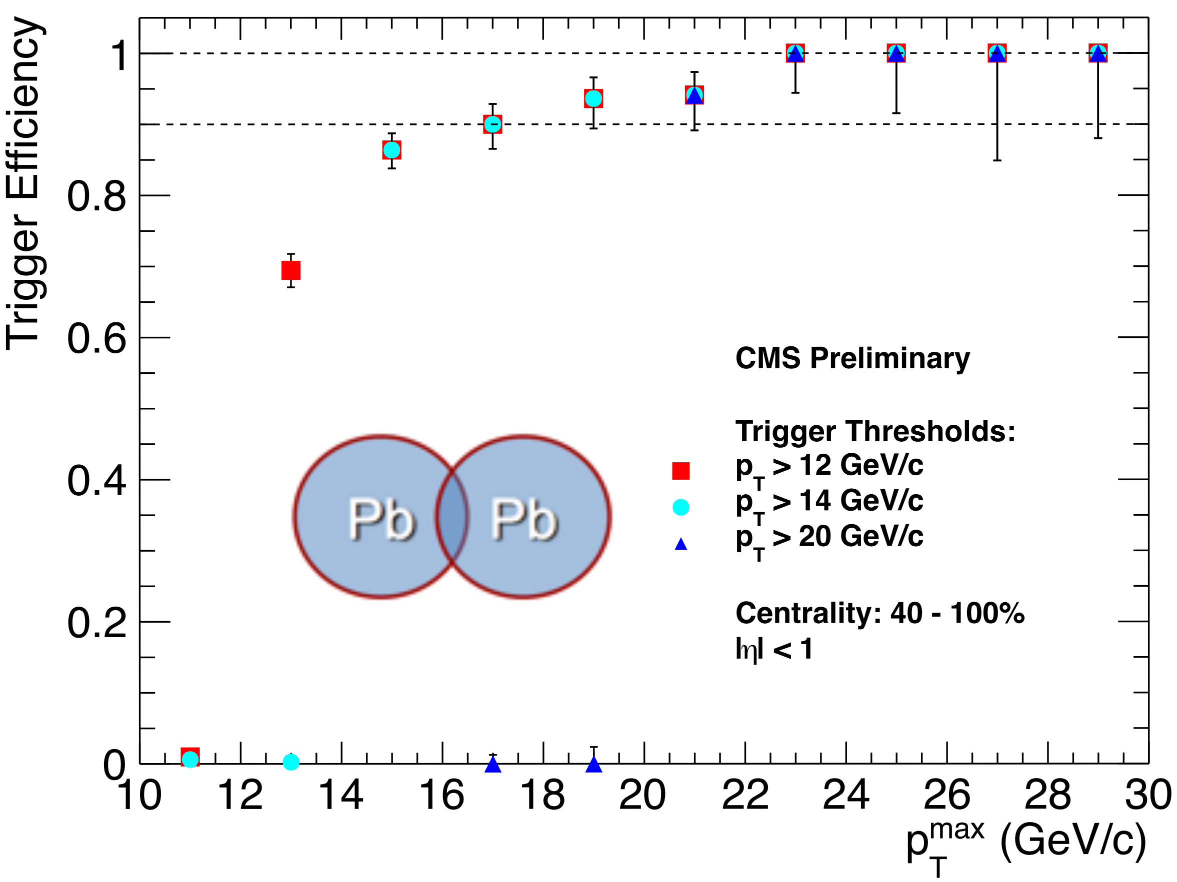
High p_T Single Track Trigger

- Full 2011 HI Data set: L_{int} = 150 μb^{-1}
- Single-Track High-p_T Triggers

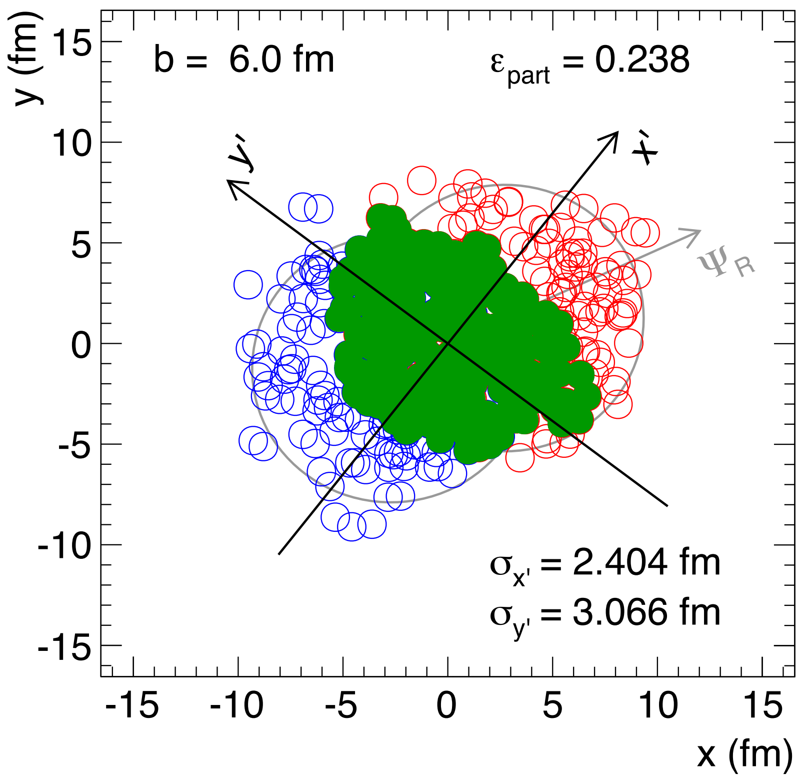
(Total # of events: ~1.55M with p_T > 20 GeV/c)

All triggers are at least 95% efficient (0-40%)





Event Plane Formalism



Event Plane

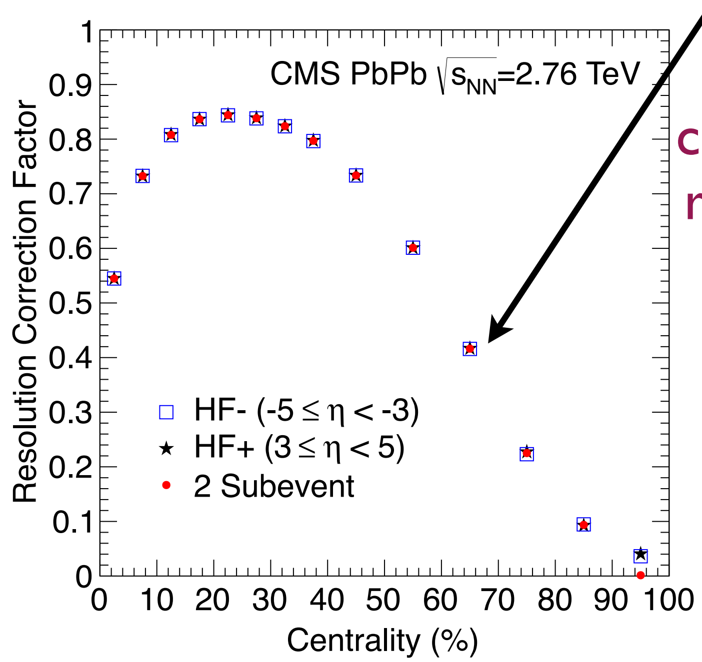
Experimentally observable, used to estimate the true participant plane.

$$\Psi'_n = \frac{1}{n}\tan^{-1}\frac{\sum_i w_i \sin(n\varphi_i)}{\sum_i w_i \cos(n\varphi_i)}$$

v₂ Coefficient

$$v_2^{obs}\{EP\} = \langle \cos 2(\varphi - \Psi_2)\rangle = \frac{1}{N_{ev}}\sum_j \left[\frac{1}{M_j}\sum_i \cos 2\left(\varphi_i^j - \Psi_2^j\right)\right]$$

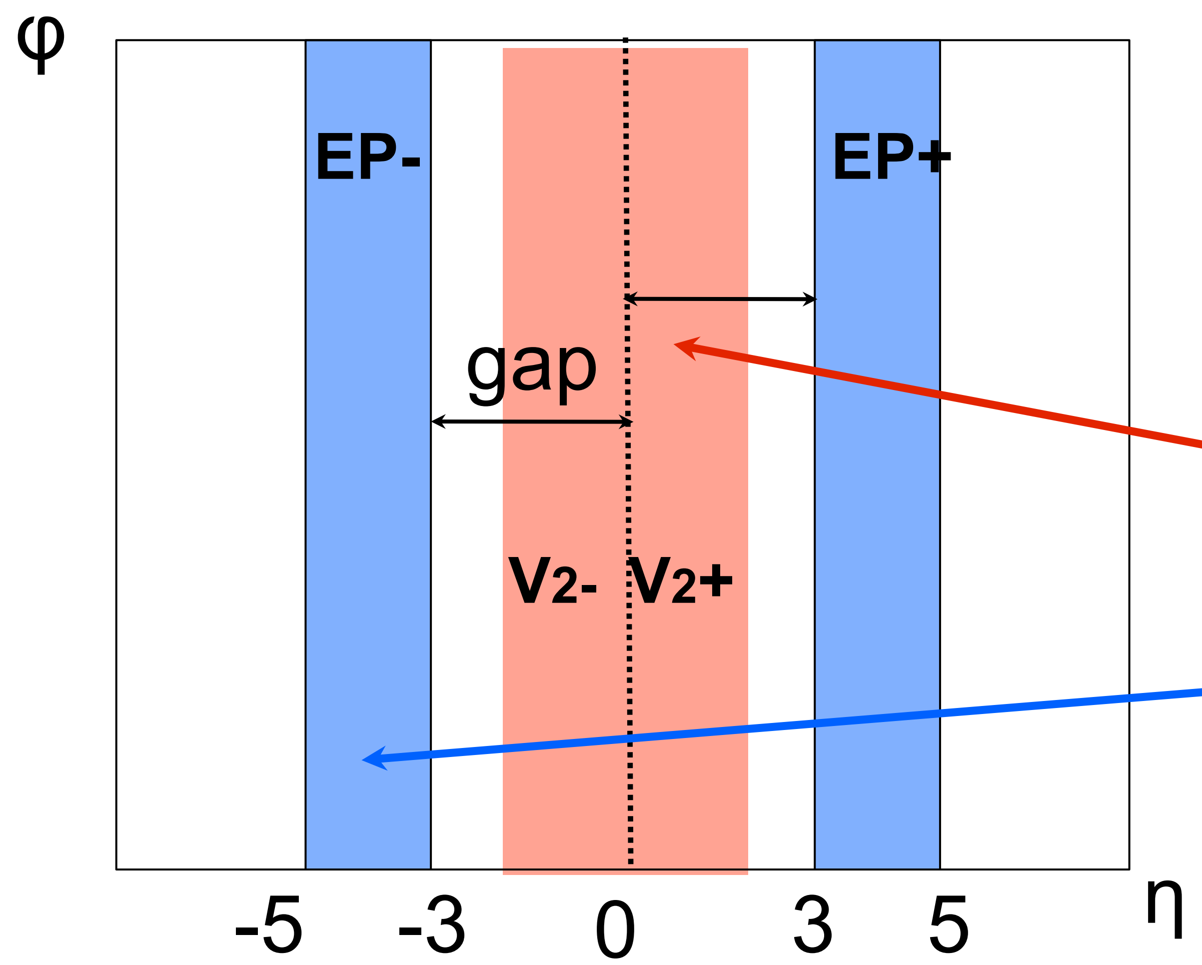
$$v_n\{EP\} = \frac{v_n^{obs}\{EP\}}{R}$$

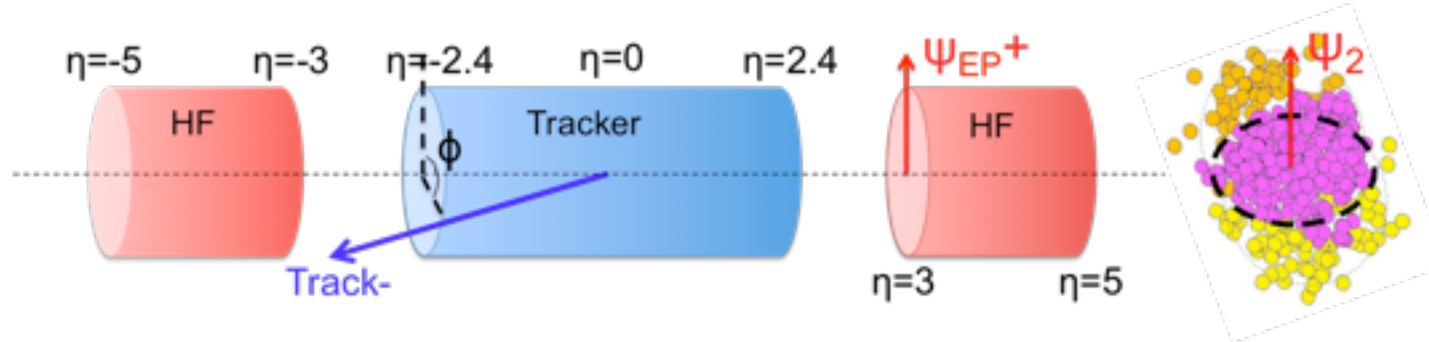


Need to correct for Ψ_{EP} resolution (R).

Resolution Correction: (3-subevent method)

Avoiding Di-Jet Correlations





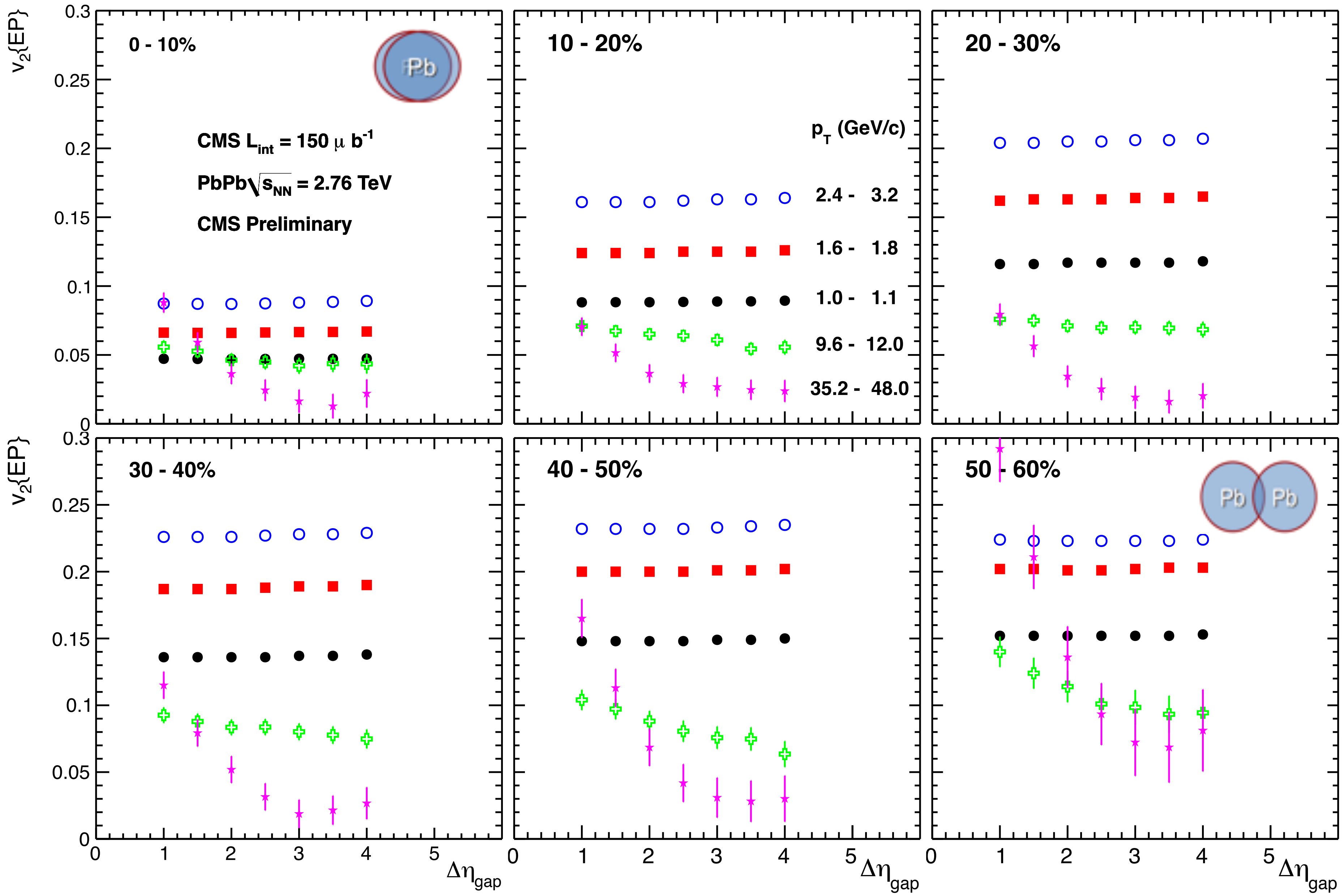
<u>To calculate v2 :</u>
v_2+ with EP- and v_2- with EP+

Particles from the positive η region are correlated with the event plane calculated in the negative η region.

<u>Event Planes:</u>
EP+ (3<η<5)
EP- (-5<η<-3)
Hadronic Forward Calorimeters used for determining the Event Plane.

This minimizes systematic effects that result from back-to-back di-jets

η-Gap Study



Based on this study we conclude that the gap size of 3 is sufficient to suppress most of the back-to-back di-jet effects

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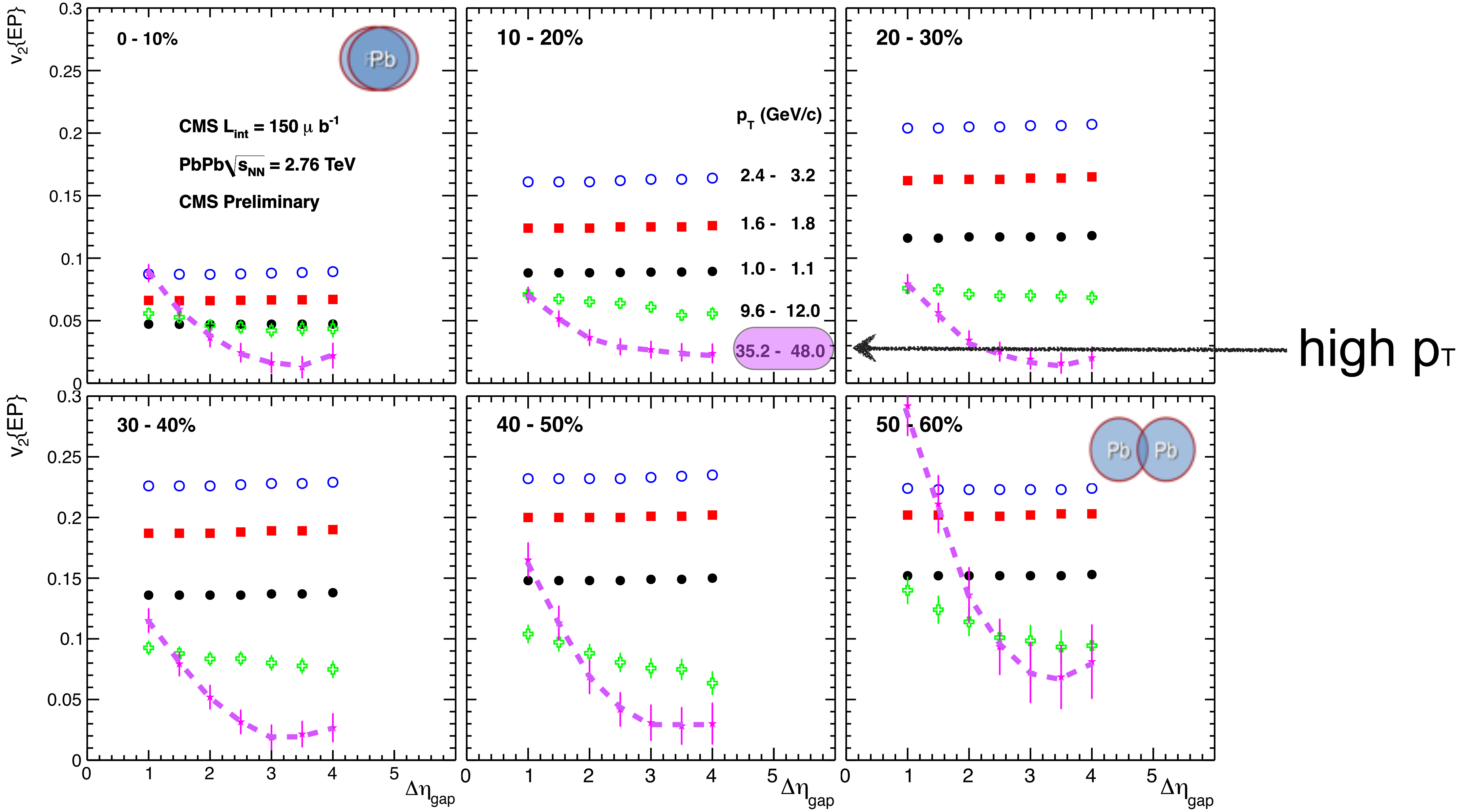

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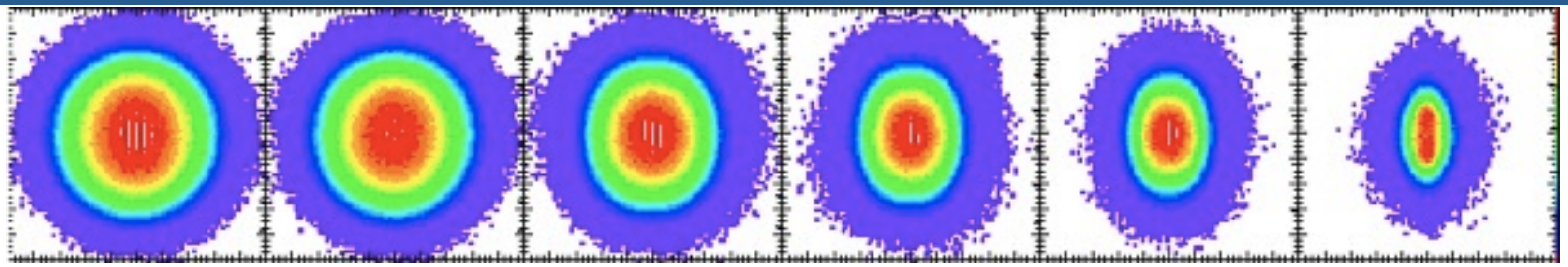
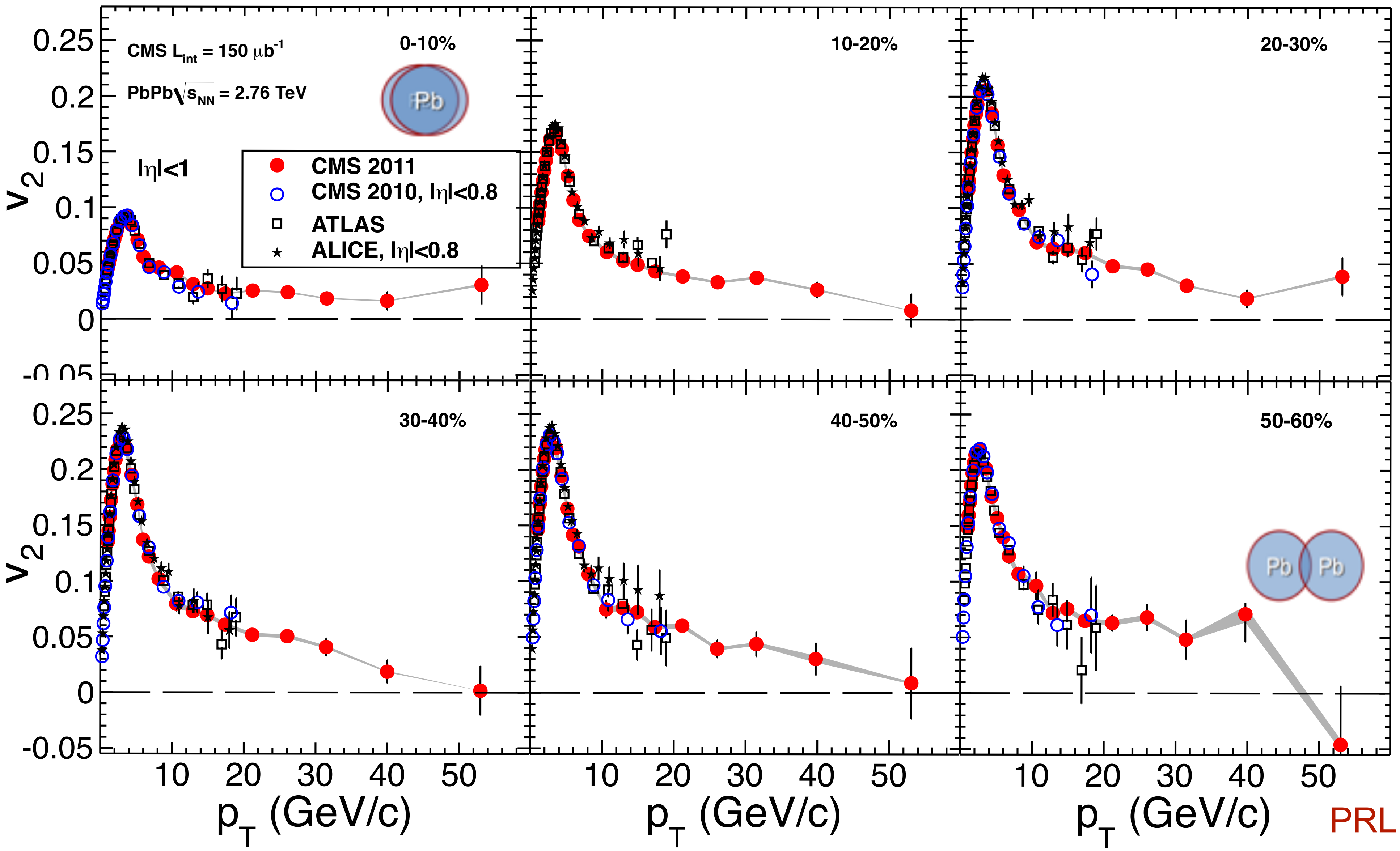
v_2 as a function of p_T ($|\eta|<1$)

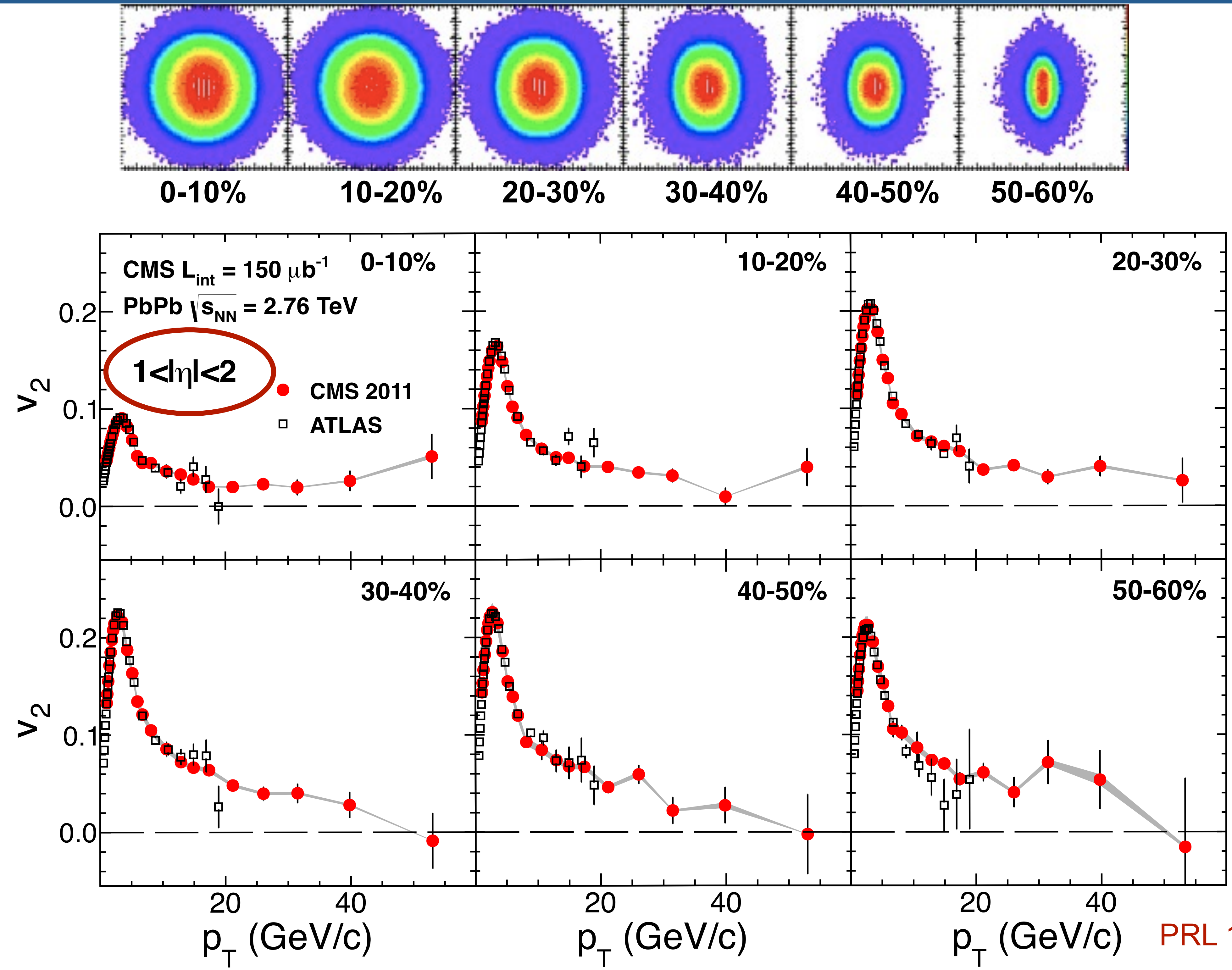




PRL 109, 022301(2012)

- First v_2 measurements for p_T > 20GeV/c
- Gradual decrease of v_2 above p_T ~ 10 GeV/c

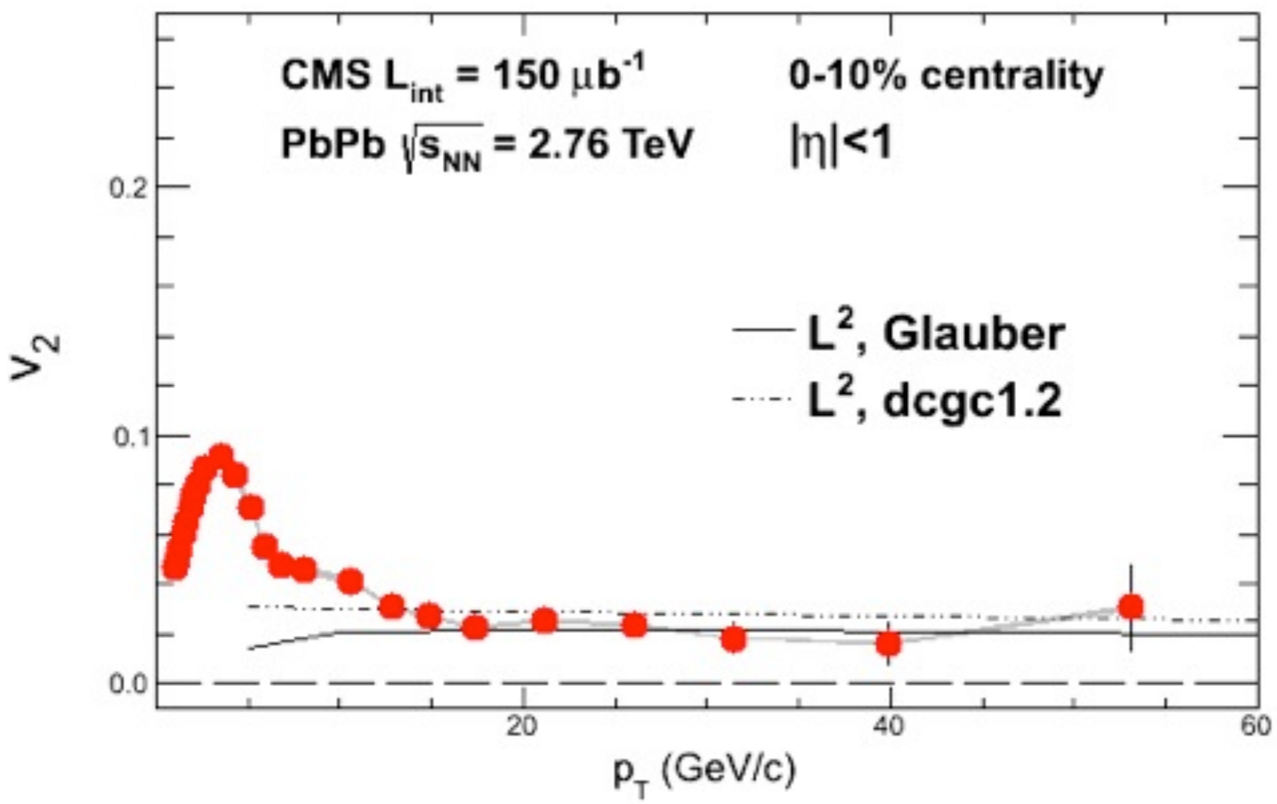
v_2 as a function of p_T (1<|η|<2)

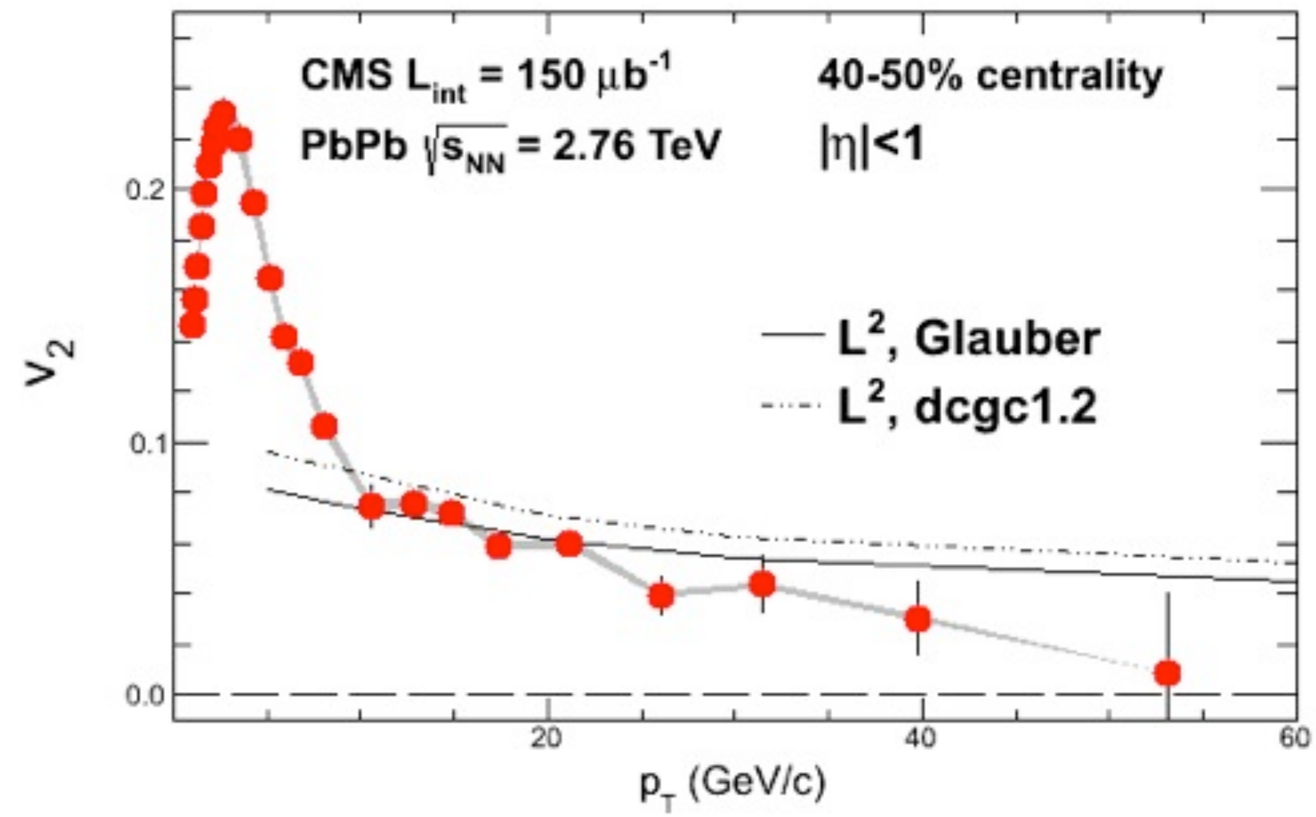


PRL 109, 022301(2012)

Theory Comparison

Data: PRL 109.022301(2012)

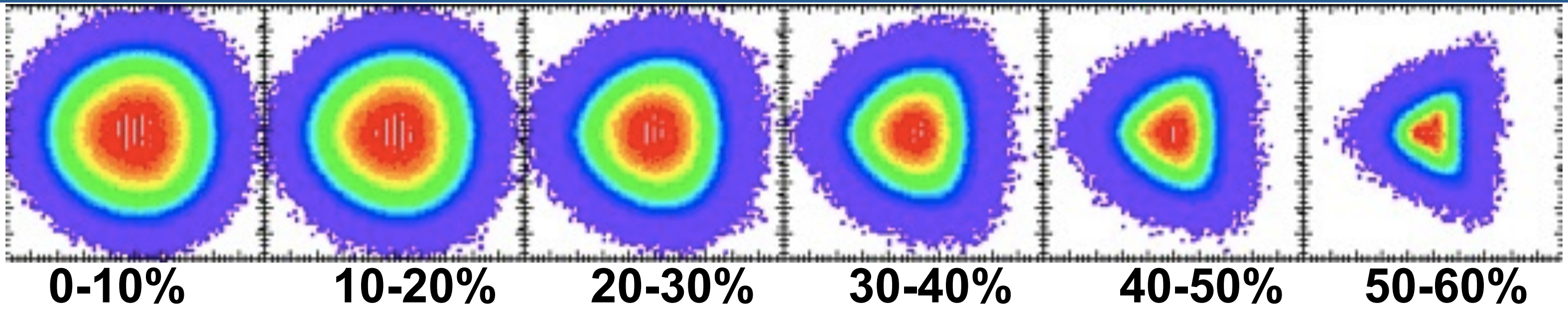




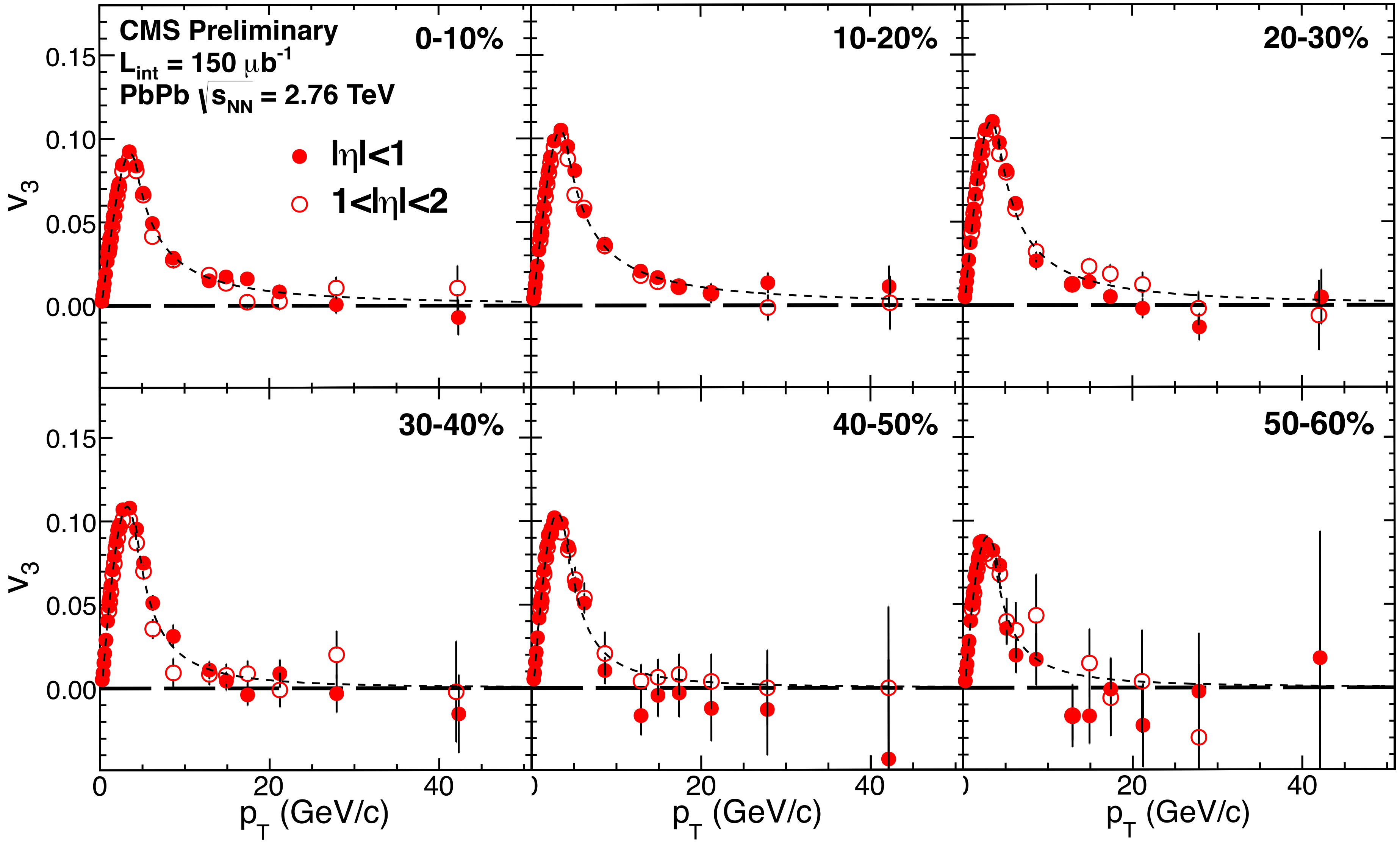
Theory: B.Betz,M.Gyulassy;arXiv:1201.0281

-Data can constrain different theoretical scenarios

Higher Harmonics Results (v_3)



GLAUBER

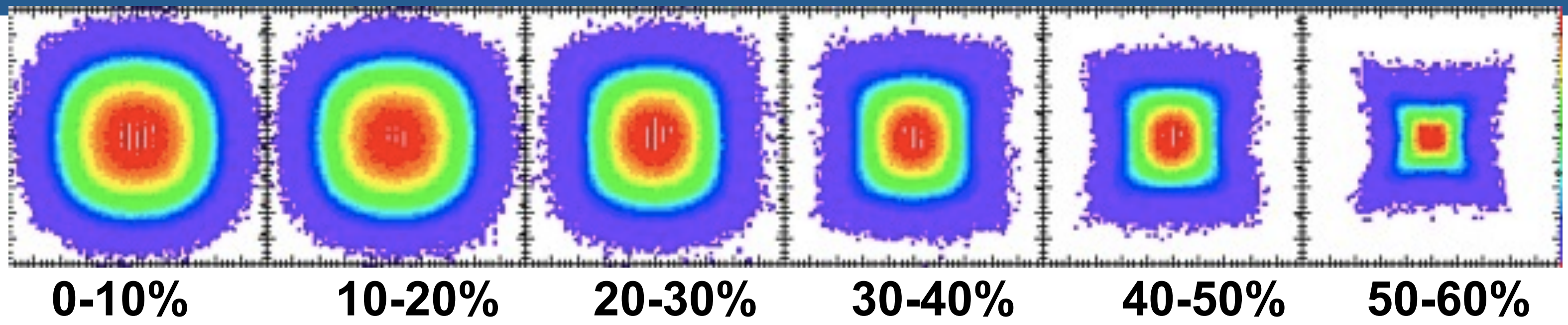


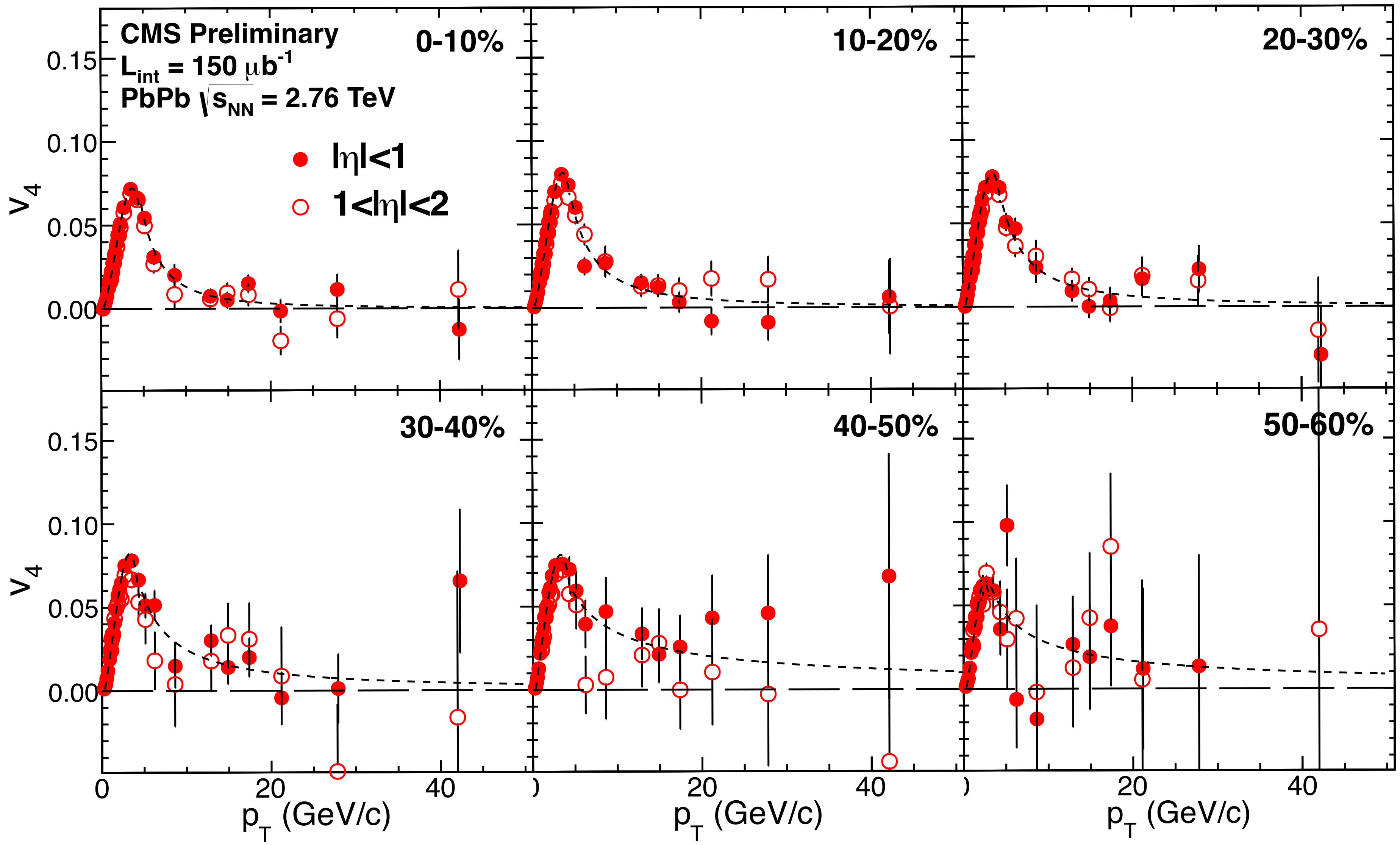
PAS HIN-12-010

NEW RESULTS!!!

-Small v_3 signal above 20 GeV/c.

Higher Harmonics Results (v_4)

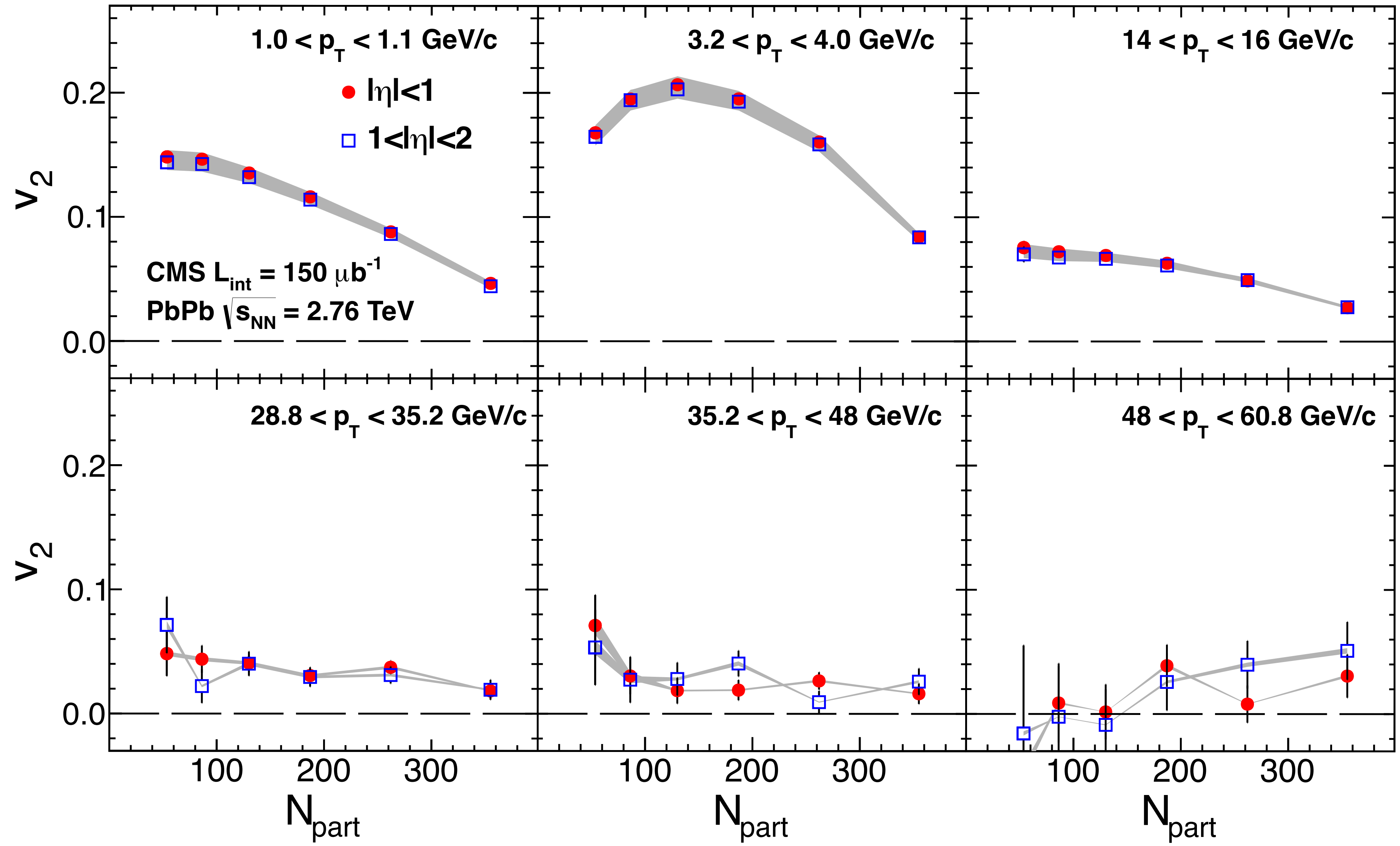


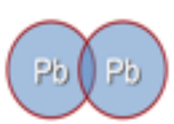


PAS HIN-12-010

NEW RESULTS!!!

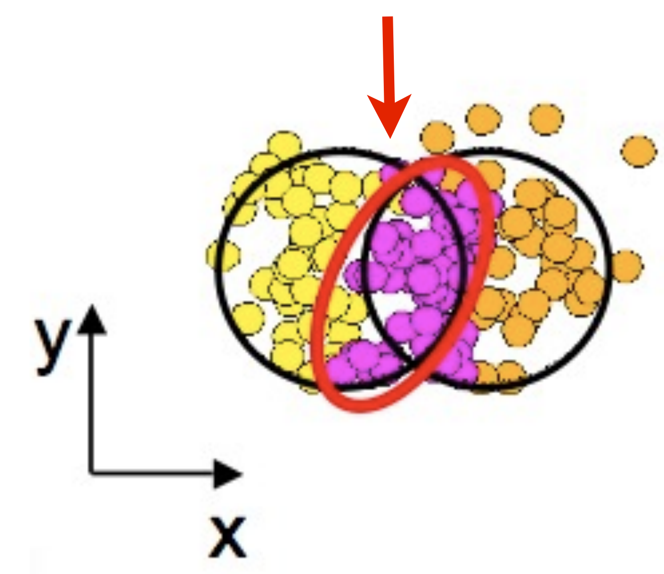
v_2 as a function of centrality





$$\varepsilon_{part} = \frac{\sqrt{(\sigma_y^2 - \sigma_x^2)^2 + 4\sigma_{xy}^2}}{\sigma_y^2 + \sigma_x^2}$$

participants



ε_{part}: 0.09 (0-10%) to 0.46 (50-60%)

- Significant non-zero v_2 up to p_T~48 GeV/c for all the centralities.
- For p_T > 48 GeV/c v_2 is consistent with 0 for all the centralities.

Summary

- The v_2 azimuthal anisotropy coefficient is determined over a wide coverage in p_T: $1 < p_T < 60$ GeV/c as a function of collision centrality based on the 2011 data sample.

- The v_3 and v_4 coefficients are obtained up to $p_T \sim 40$ GeV/c.

- Above $p_T \sim 10$GeV/c v_2 values show a gradual decrease with p_T, being consistent with zero only above $p_T \sim 48$ GeV/c for all the centralities. The v_3 and v_4 asymmetries are small above 20 GeV/c.

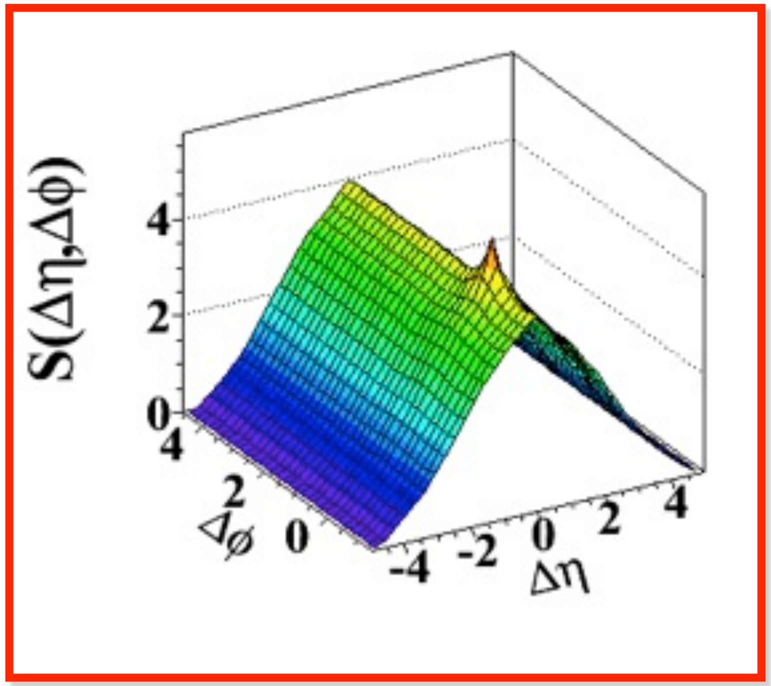
- Centrality dependence of v_2 is observed for both very low and high-p_T particles. It is consistent with path-length-dependent energy loss observed at high-p_T up to $p_T \sim 35$ GeV/c.

BACKUP

Di-hadron Correlations Formalism

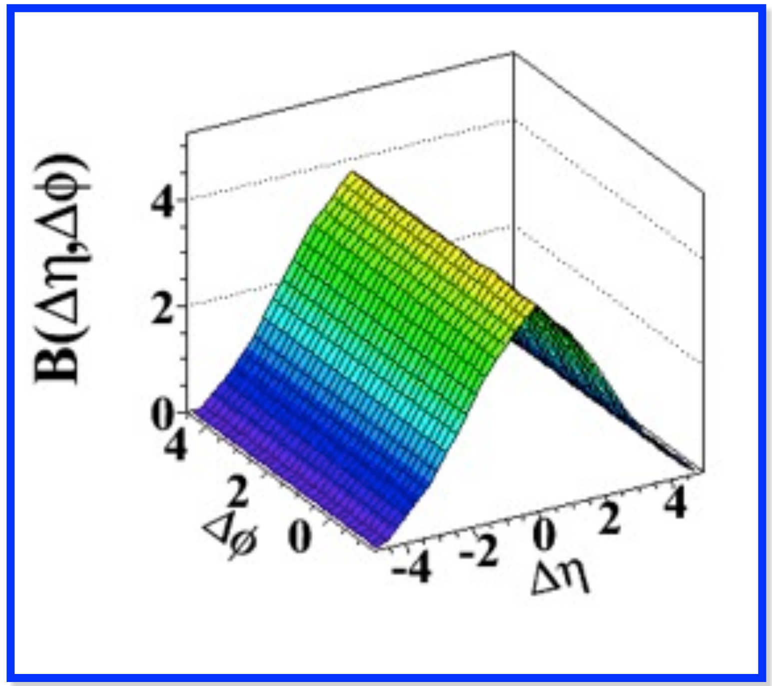
Signal pair distribution:

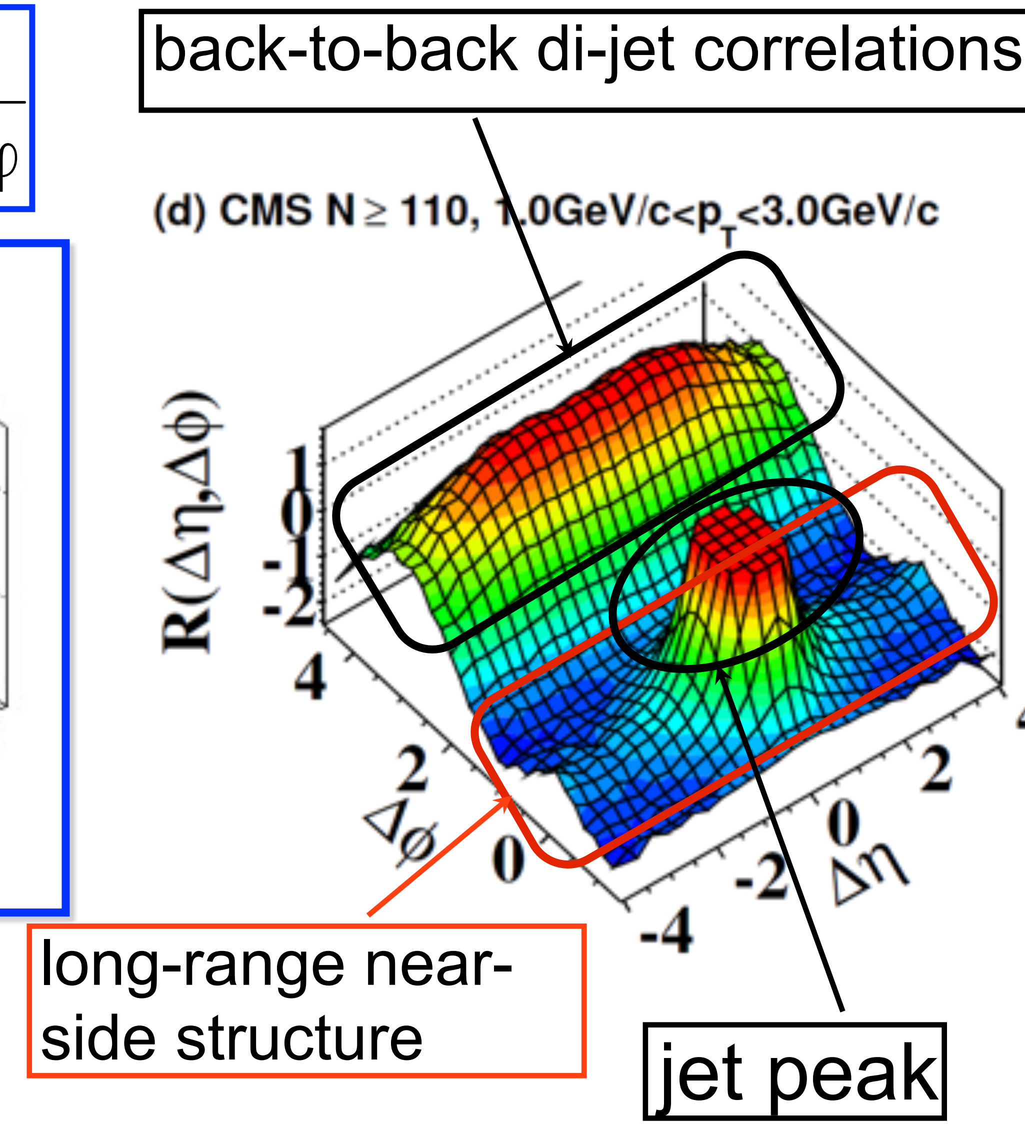
$$S(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}} \frac{d^2N^{same}}{d\Delta\eta d\Delta\varphi}$$



Background pair distribution:

$$B(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}} \frac{d^2N^{mix}}{d\Delta\eta d\Delta\varphi}$$



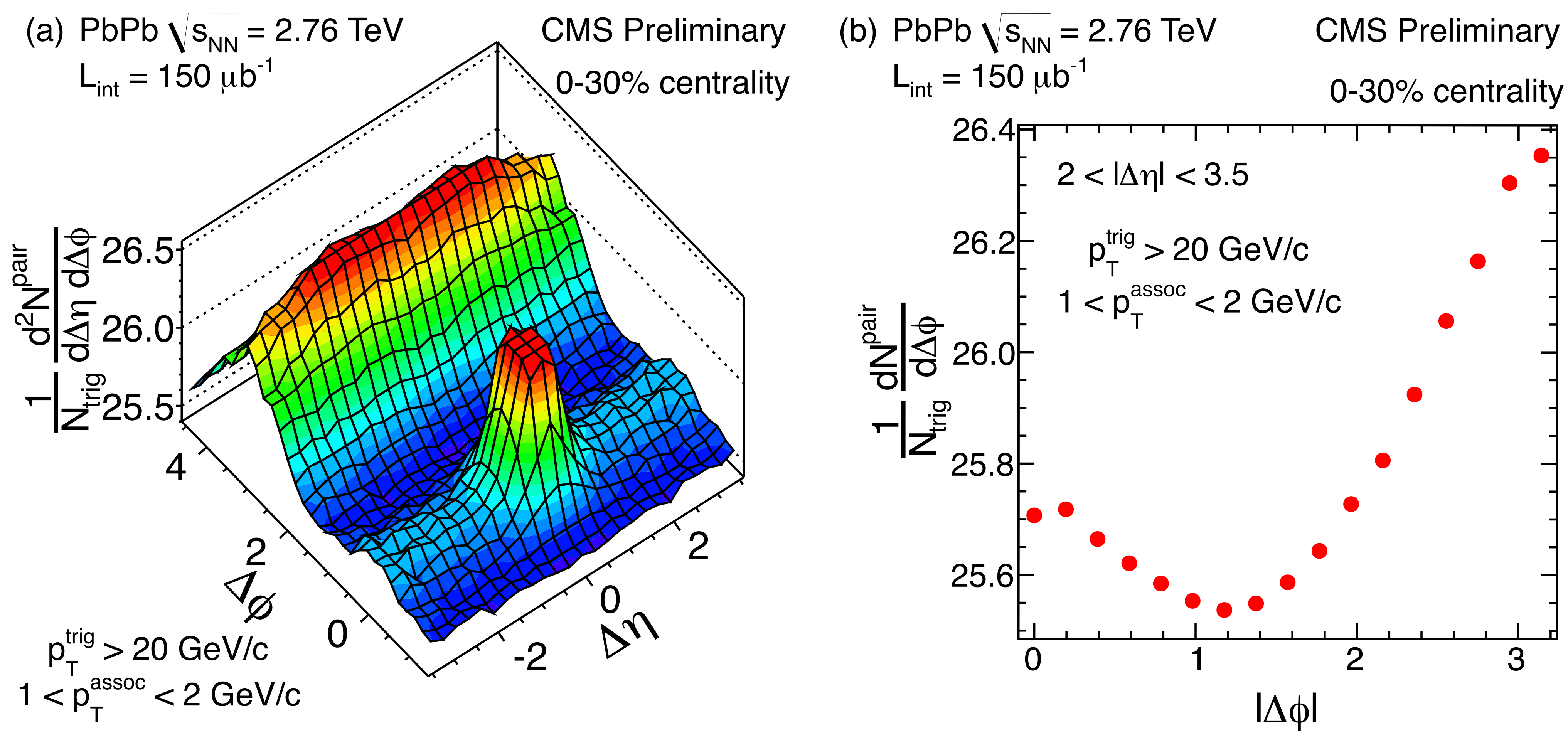


$$\Delta\eta = \eta^{assoc} - \eta^{trig}$$
$$\Delta\phi = \phi^{assoc} - \phi^{trig}$$

Associated hadron yield per trigger:

$$\frac{1}{N_{trig}} \frac{d^2N^{pair}}{d\Delta\eta d\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}$$

Azimuthal Correlations at High p_T



- Clear and significant long-range near-side structure is observed for the first time for p_T^{trig} > 20 GeV/c.