Overview of CMS HI Results

- Summary of QM 2011 Presentations -

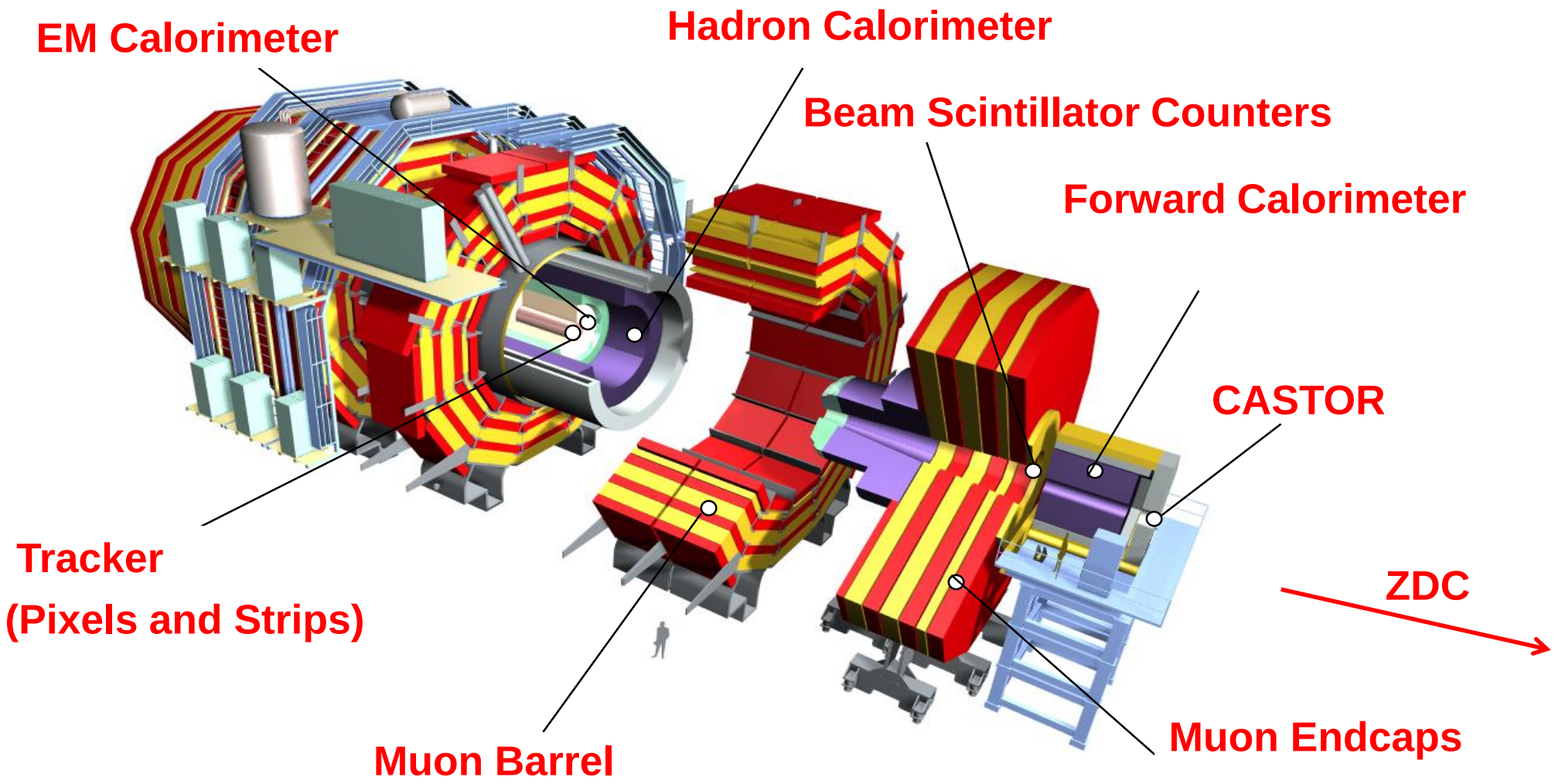
Byungsik Hong

(Korea University)

for the CMS Collaboration

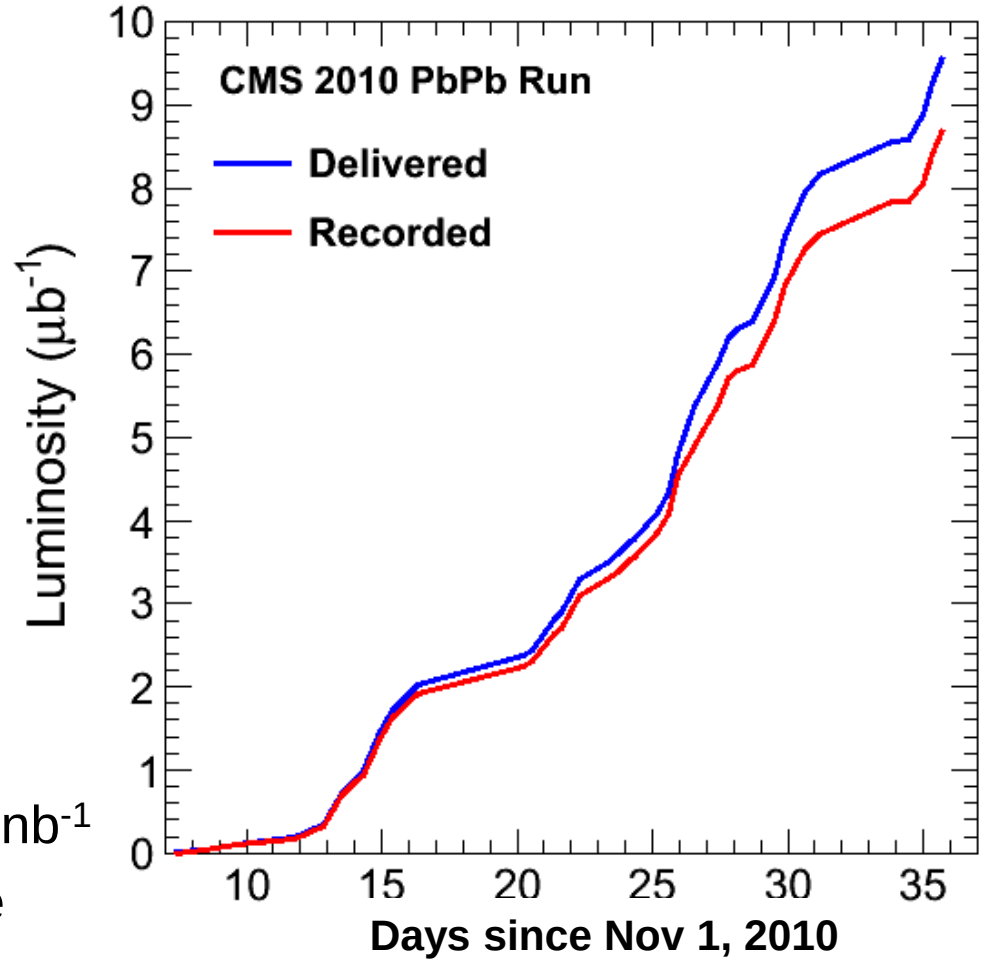
Disclaimer: The slides are mostly from Bolek Wyslouch's plenary presentation.

CMS Detector System



Data taking during PbPb run

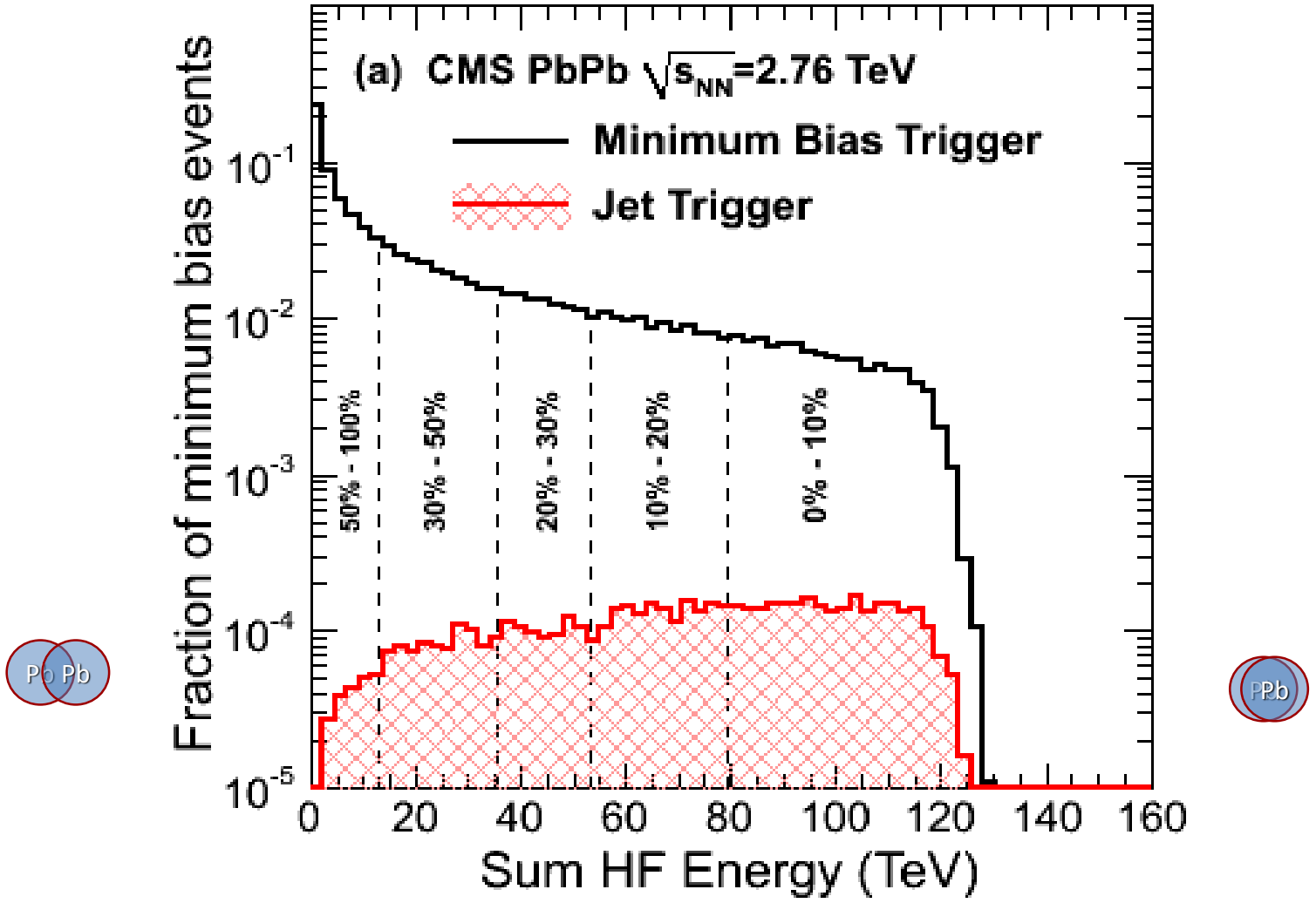
- CMS configured in a dedicated mode for heavy ions
  - Turn off zero suppression
  - Taking data at up to 220 Hz
  - 12 MB event size
- Triggering on minimum bias, jets, muons and photons
  - ALL rare probes written to tape
  - ~half of minimum bias written
- Recorded luminosity PbPb 8.7 μb^{-1}
- Recorded luminosity pp@2.76 TeV 241 nb^{-1}
- Total PbPb data volume ~0.89 PetaByte



Note: luminosities will be rescaled by few% after complete analysis of Van der Meer scans

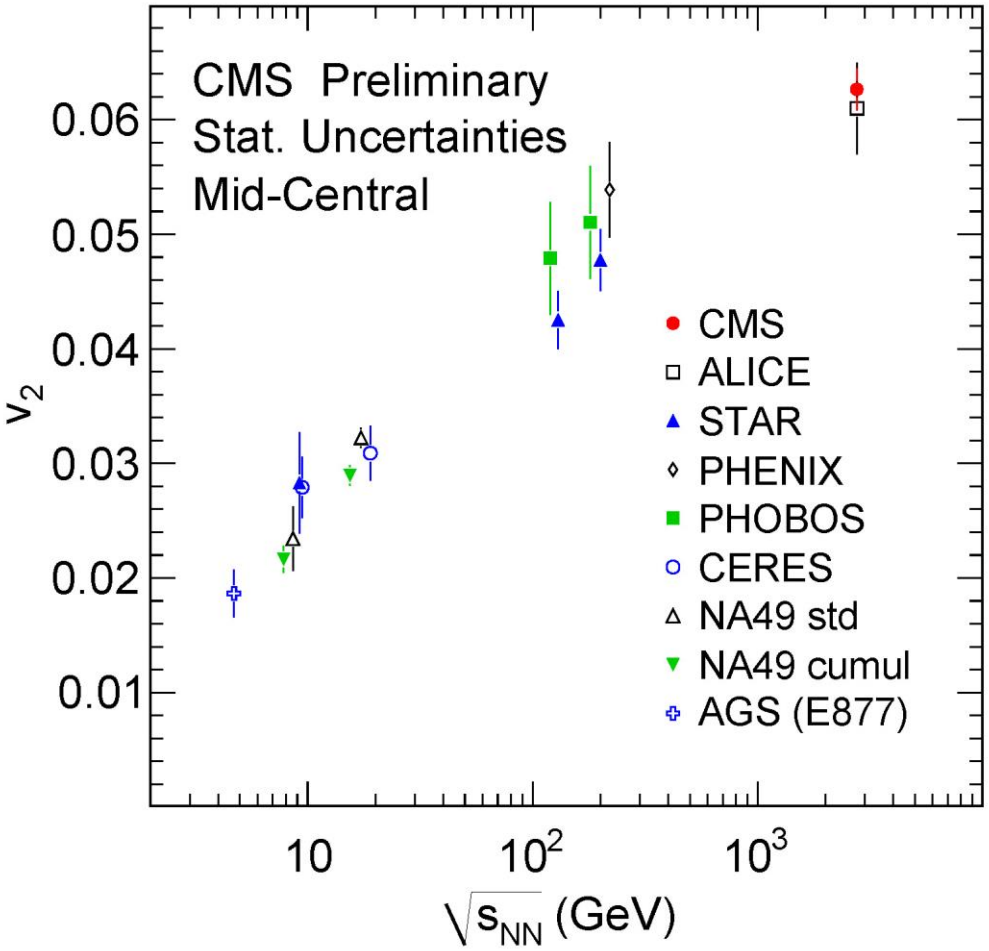
Centrality

- Hadron-Forward (HF) calorimeter energy deposits in $3<|\eta|<5$
- Notice the increase of the fraction of high-p_T triggers with centrality

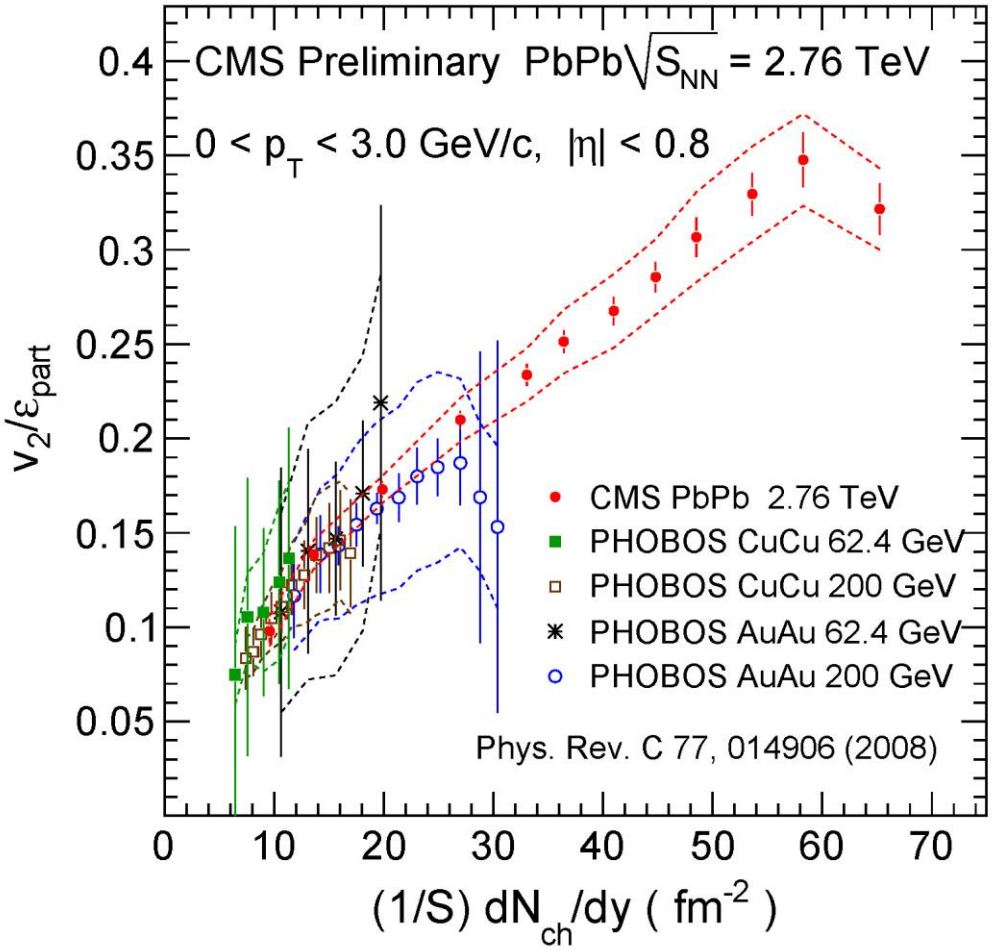


Azimuthal anisotropy: Elliptic flow

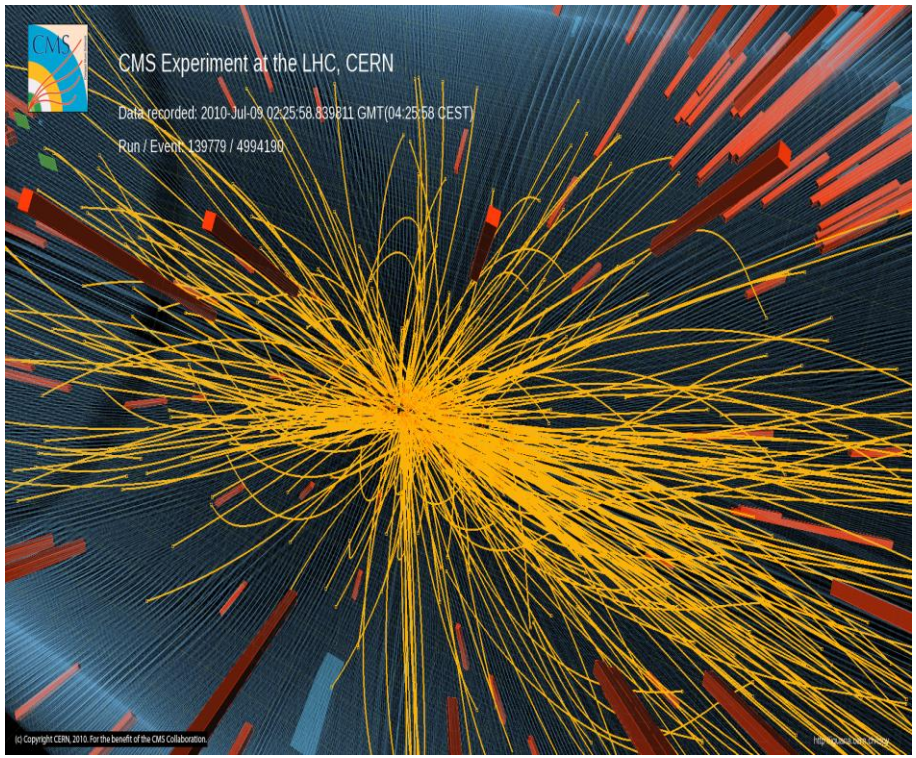
- Energy Dependence
  - CMS: 20-30%, v_2{LYZ}
  - Extrapolated to p_T=0



- Participant eccentricity scaling vs. transverse density

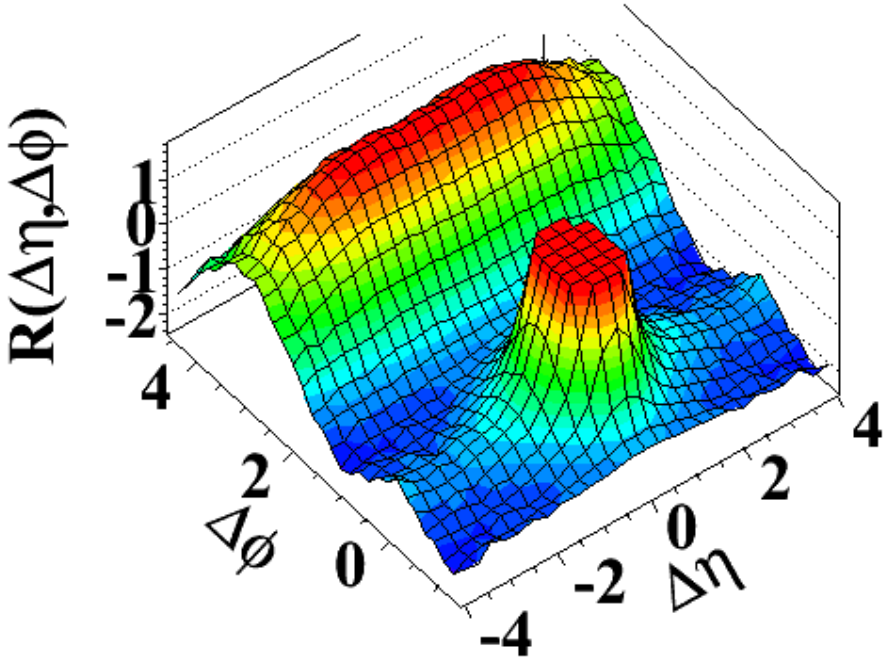


Ridge in high multiplicity pp



Intermediate p_T: 1-3 GeV/c

High multiplicity pp (N≥110)



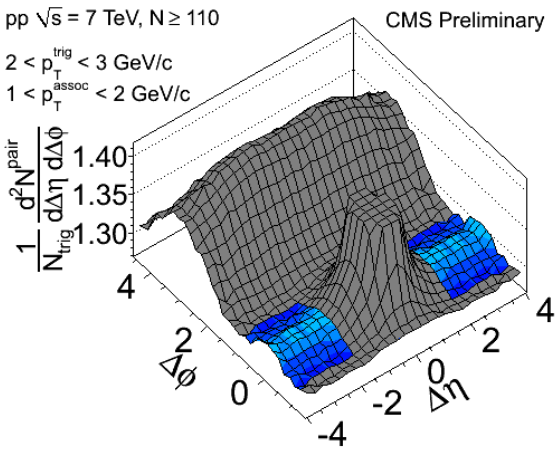
- ~350k top multiplicity events (N>110) out of 50 billion collisions!
- Real-time tracking in High Level Trigger, CPU intensive
- Heavy-ion like effect in pp collisions

JHEP 09 (2010) 091

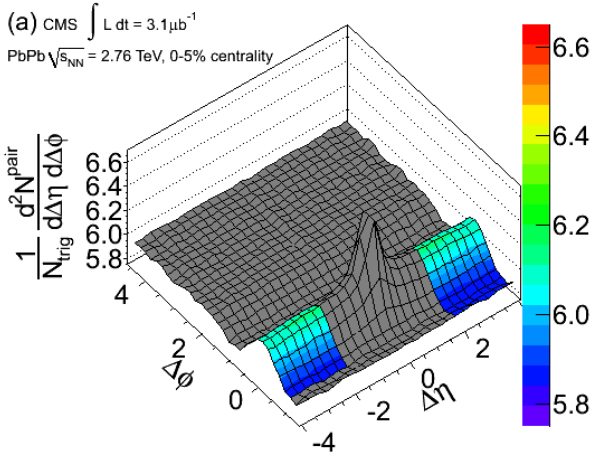
D. Velicanu (TODAY), J. Callner (Tue), Wei Li (Thu)

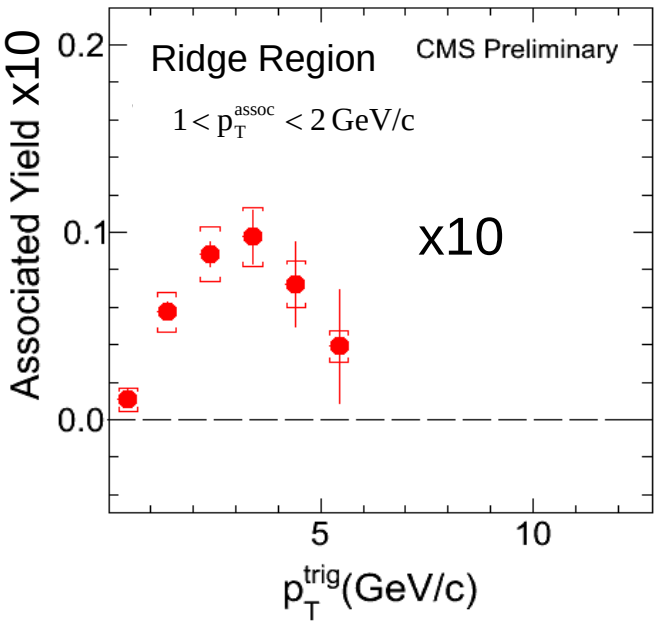
Ridge in pp and PbPb

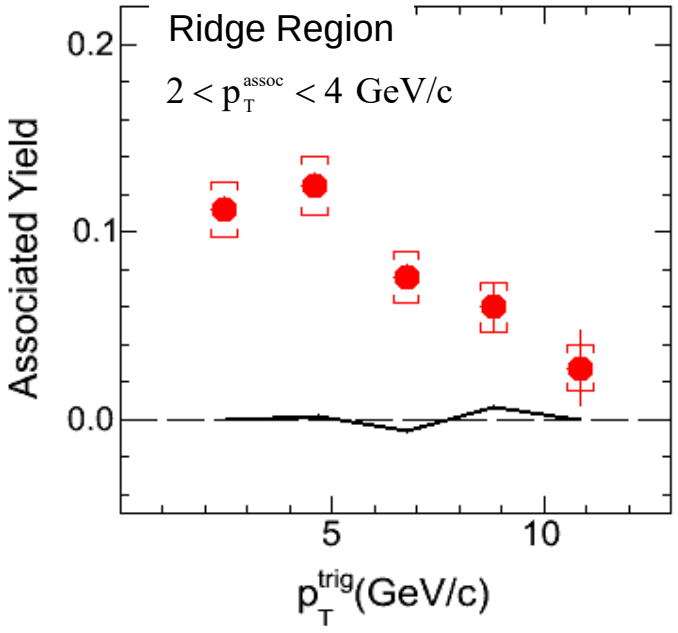
CMS pp 7 TeV, N ≥ 110



CMS PbPb 2.76 TeV, 0-5%







arXiv:1105.2438

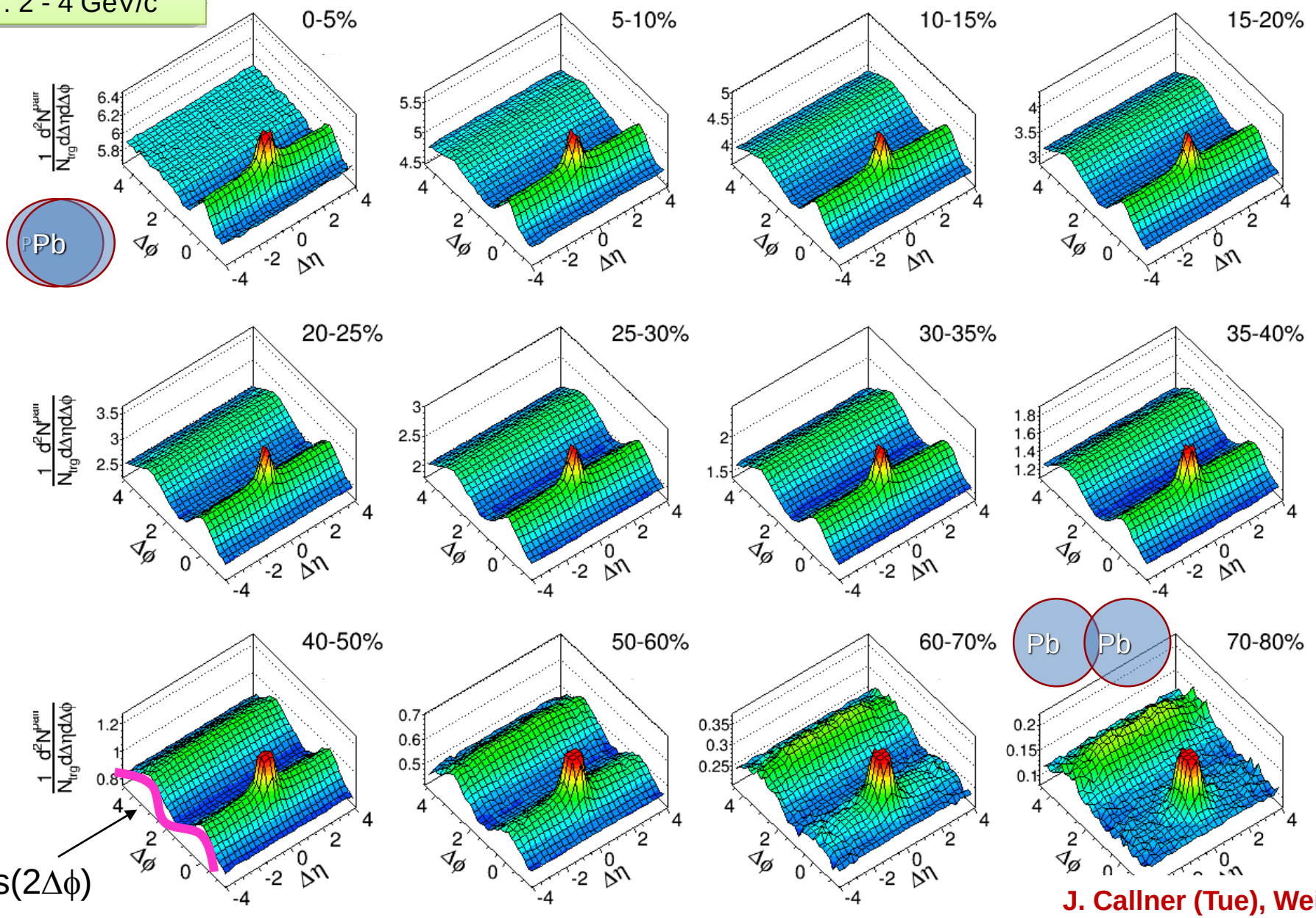
D. Velicanu (TODAY), J. Callner (Tue), Wei Li (Thu)

Triggered dihadron centrality dependence in PbPb

p_T^{trig}: 4 - 6 GeV/c
p_T^{assoc} : 2 - 4 GeV/c

PbPb 2.76 TeV

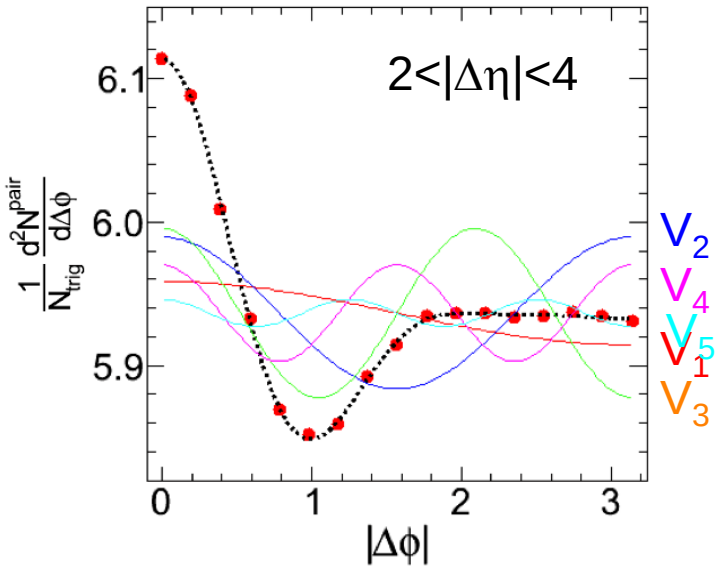
CMS Preliminary

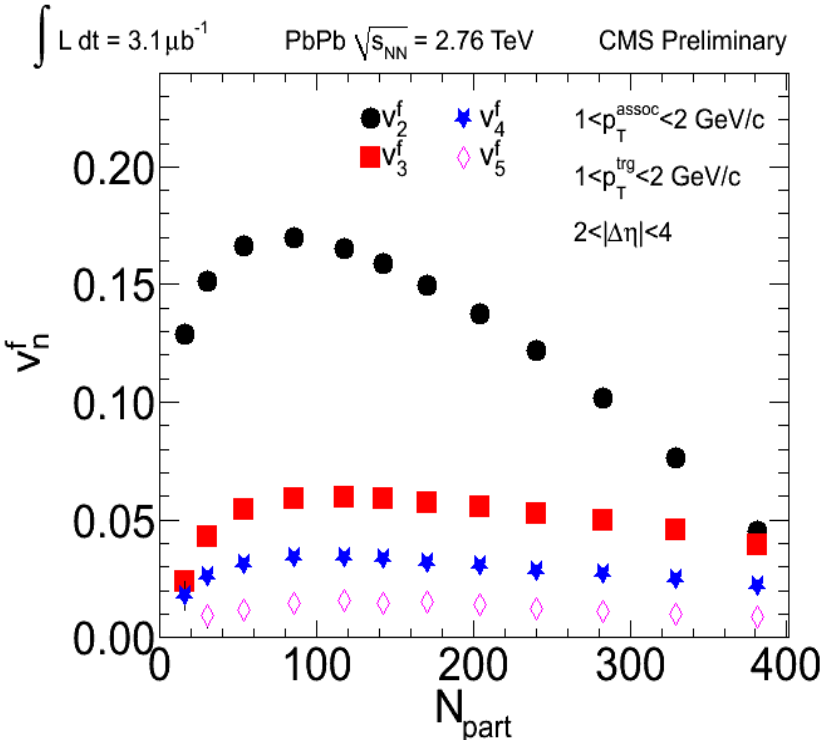


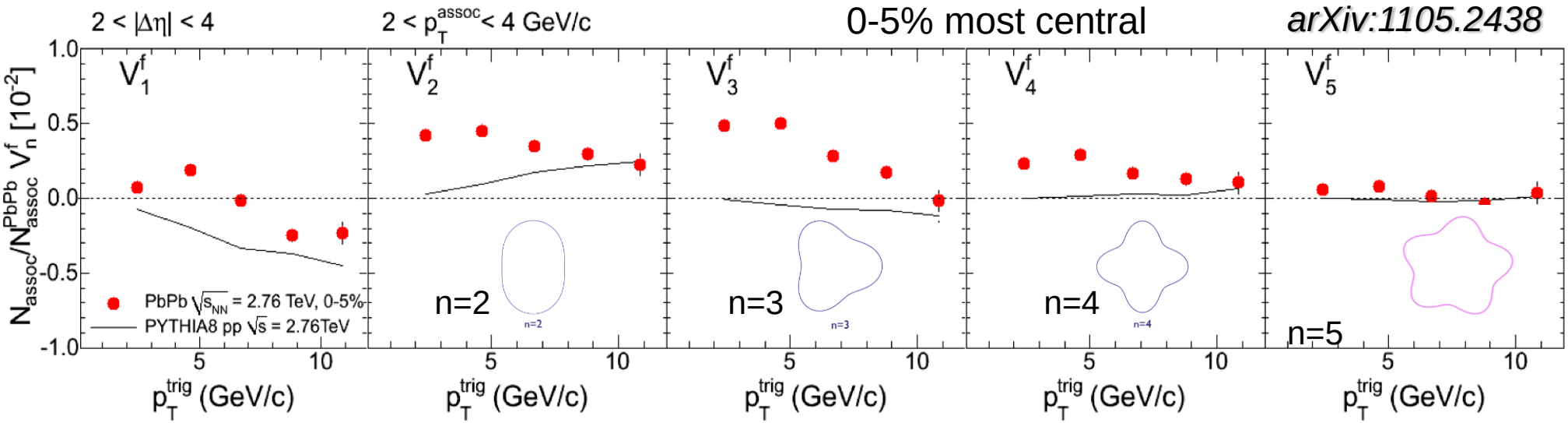
J. Callner (Tue), Wei Li (Thu)

Fourier decomposition of Δϕ correlations

$$\frac{1}{N_{trig}}\frac{dN^{pair}}{d\Delta\phi} = \frac{N_{assoc}}{2\pi}\left(1 + 2\sum_{n=1} V_n^f \cos(n\Delta\phi)\right)$$







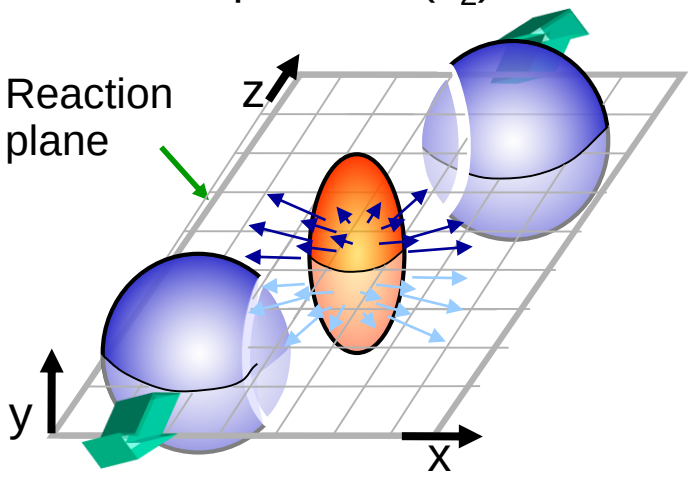
arXiv:1105.2438

J. Callner (Tue), Wei Li (Thu)

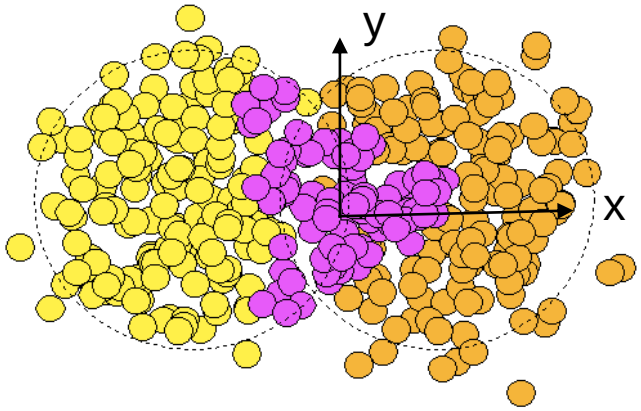
Alternative approach: Fourier analysis

It was recently realized that the ridge may be induced just by higher order flow terms (v_2, v_3, v_4, v_5, …)

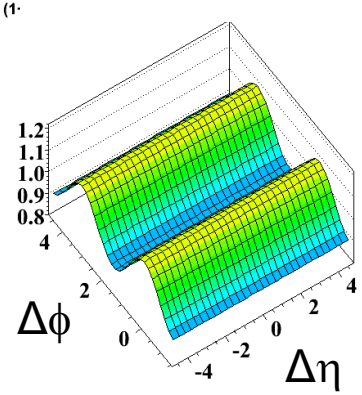
Elliptic flow (v_2)



Triangular flow (v_3) from event-by-event fluctuation

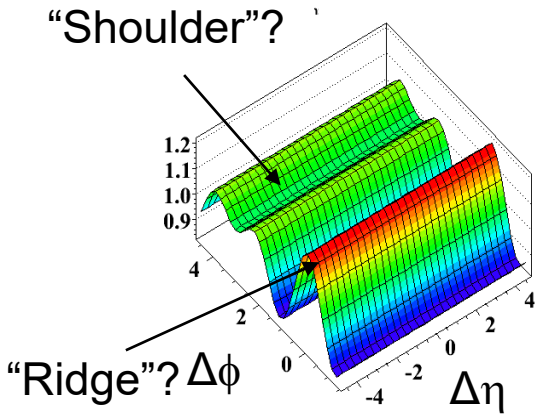


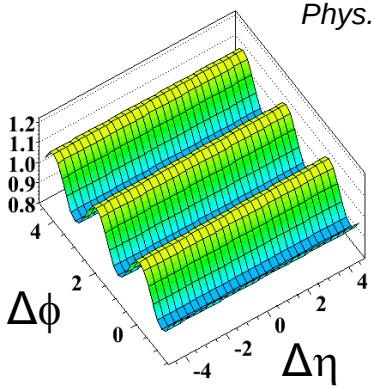
Phys. Rev. C81:054905, 2010



~ $V_2 \cos(2\Delta\phi)$

Add V_2 and V_3

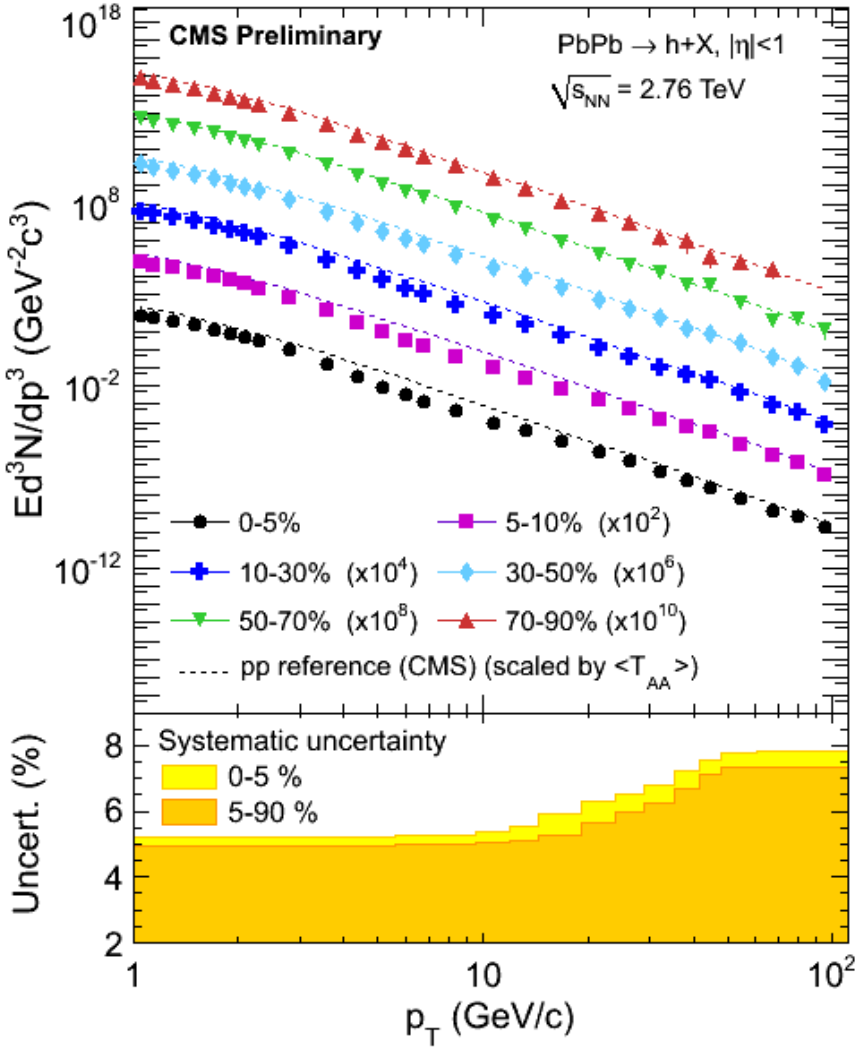


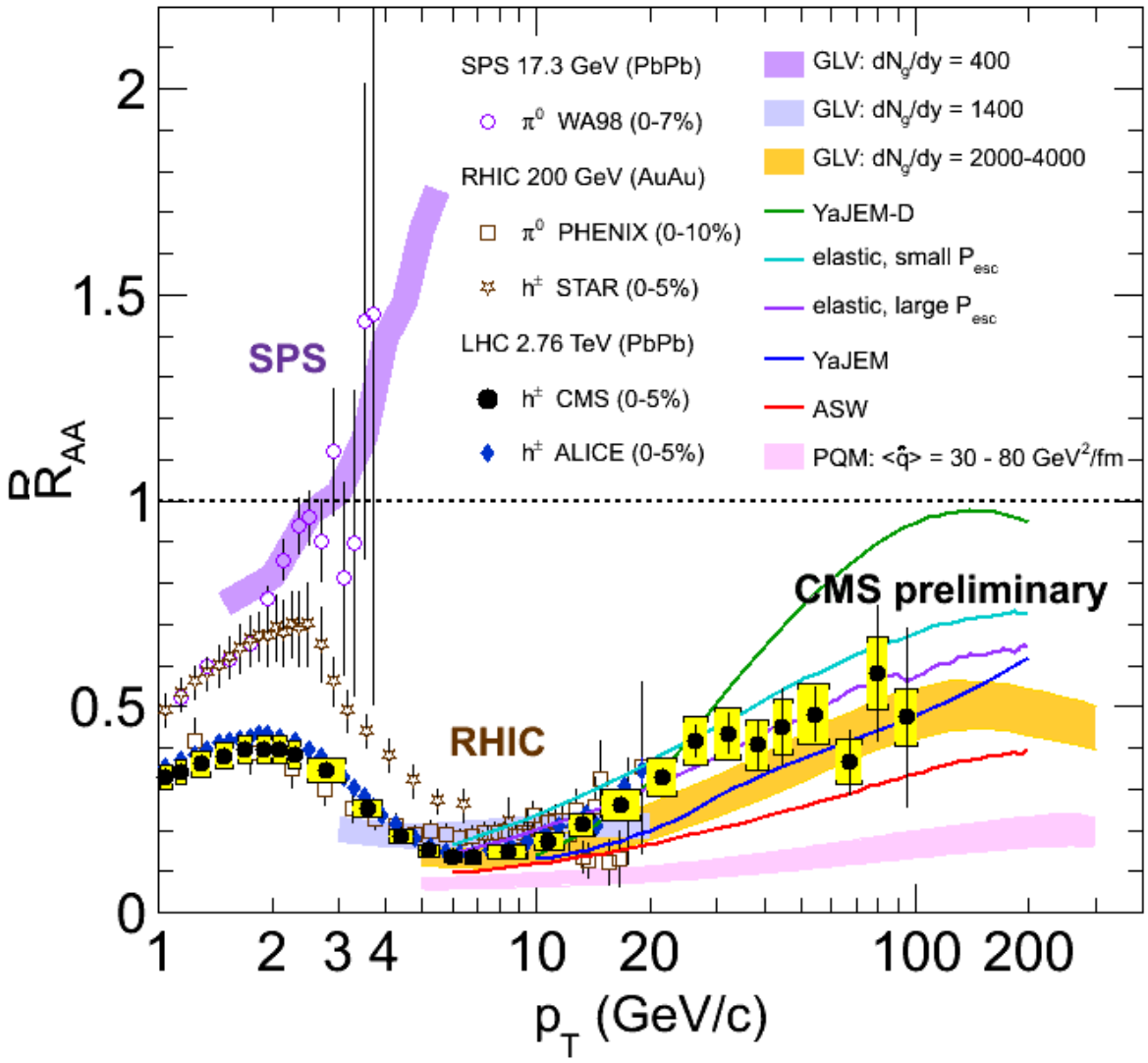


~ $V_3 \cos(3\Delta\phi)$

High p_T charged hadron suppression

- Measuring charged tracks up to p_T~100 GeV/c
- Using jet triggers to enhance statistics at high p_T

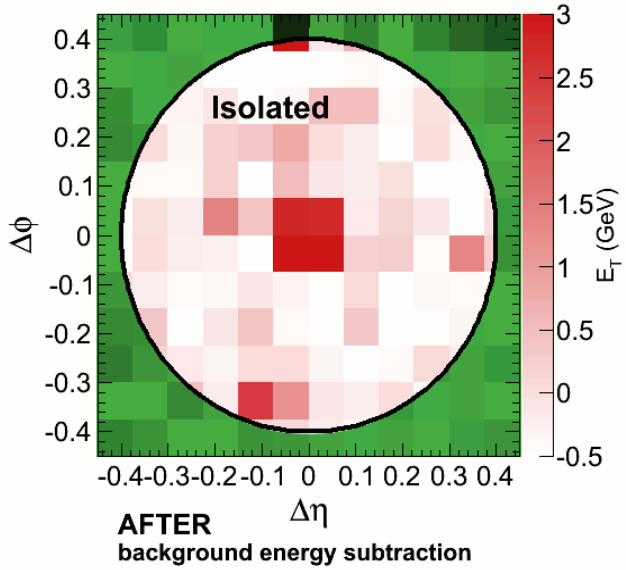




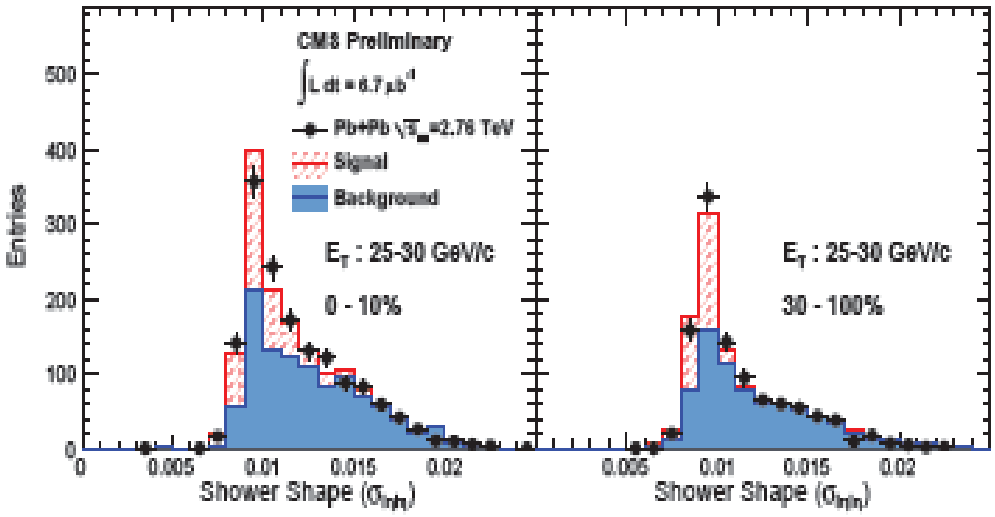
Y-J Lee (Wed) A. Yoon (Thu)

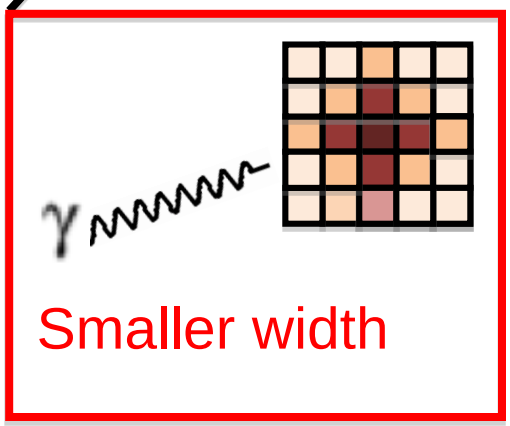
Isolated photons

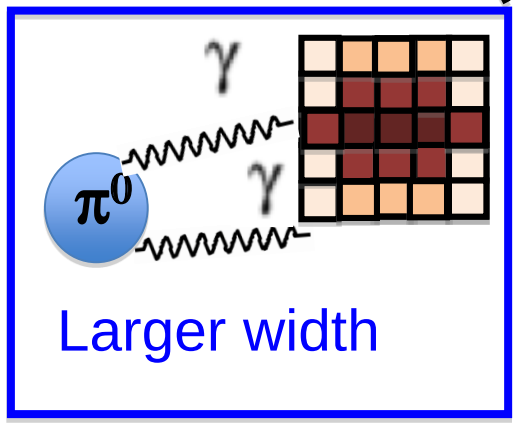
- Colorless probes
  - Check suppression
  - Nuclear parton distribution function
  - Initial state
- Photon selection
  - Identify isolated electromagnetic clusters
    - E_{HCAL}/E_{ECAL} <0.2
    - Energy in cone (R<0.4) less than 5 GeV
  - Transverse shower shape



Transverse shower shape using high ECAL granularity

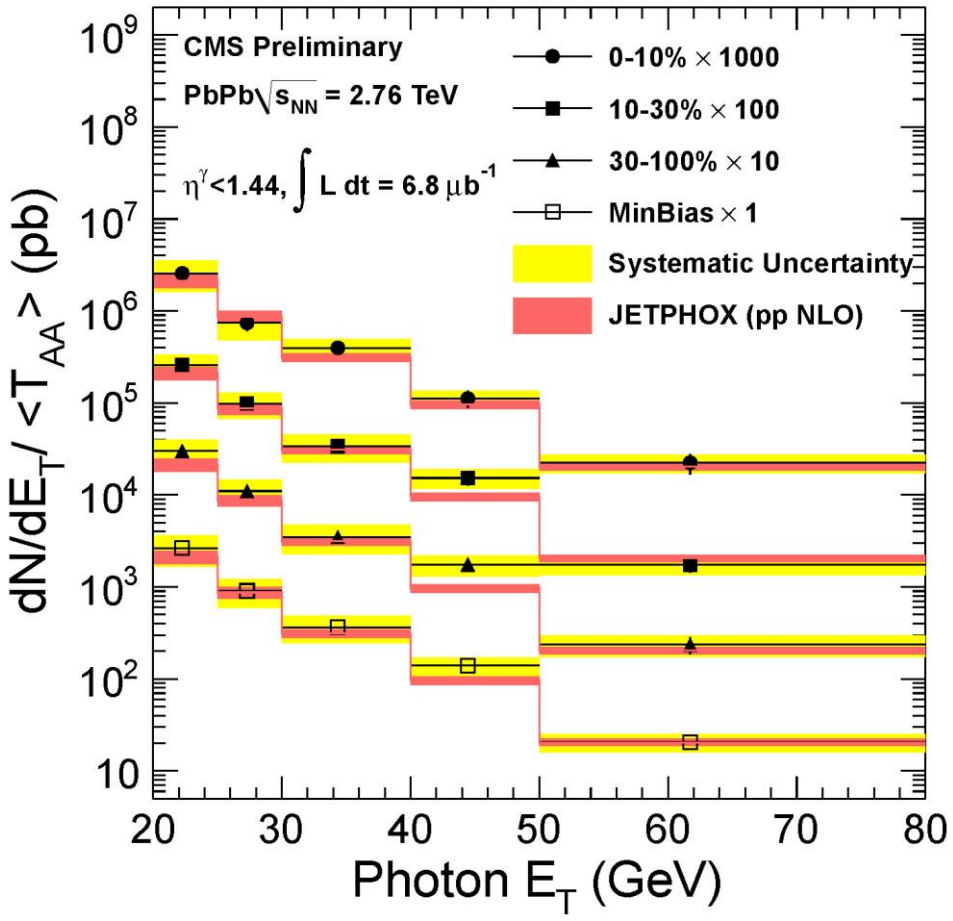


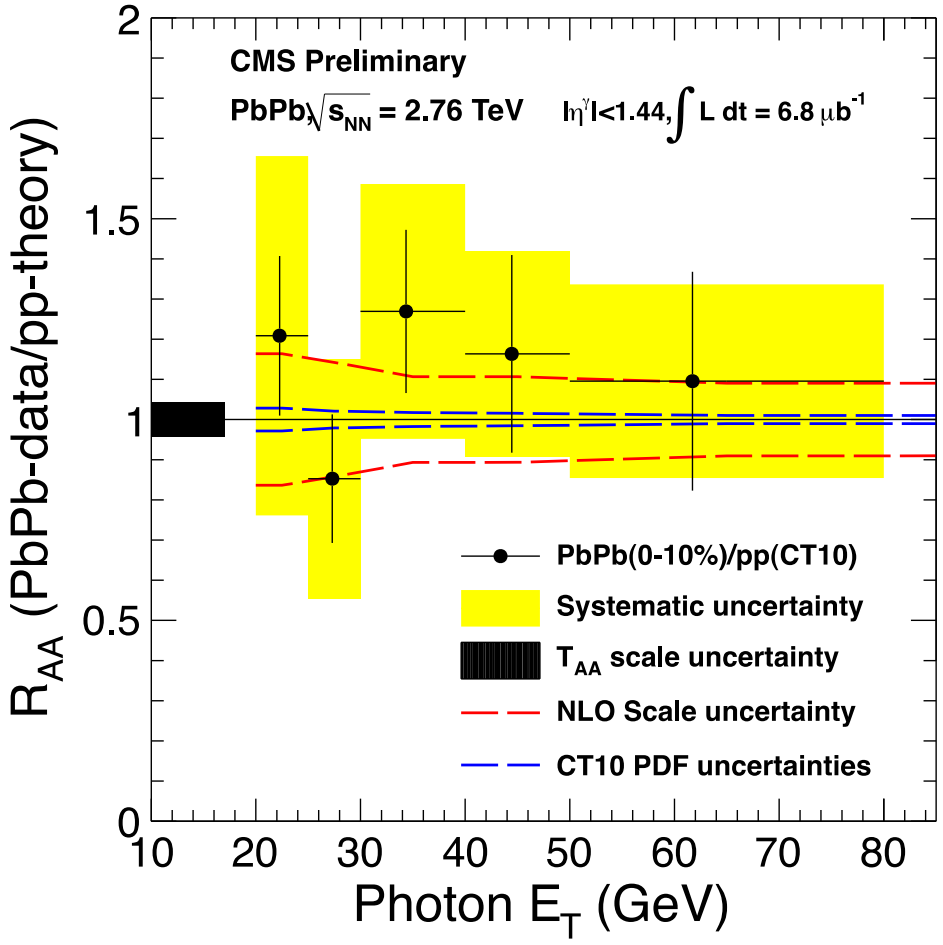




Y-J Lee (Thu), Y Kim (Fri)

Unsuppressed isolated high p_T photons





Confirmation of collisional scaling

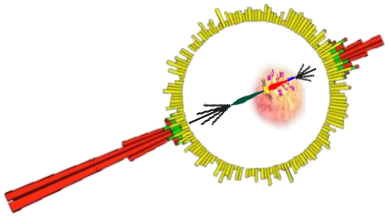
No nuclear modifications seen

Y-J Lee (Thu), Y Kim (Fri)

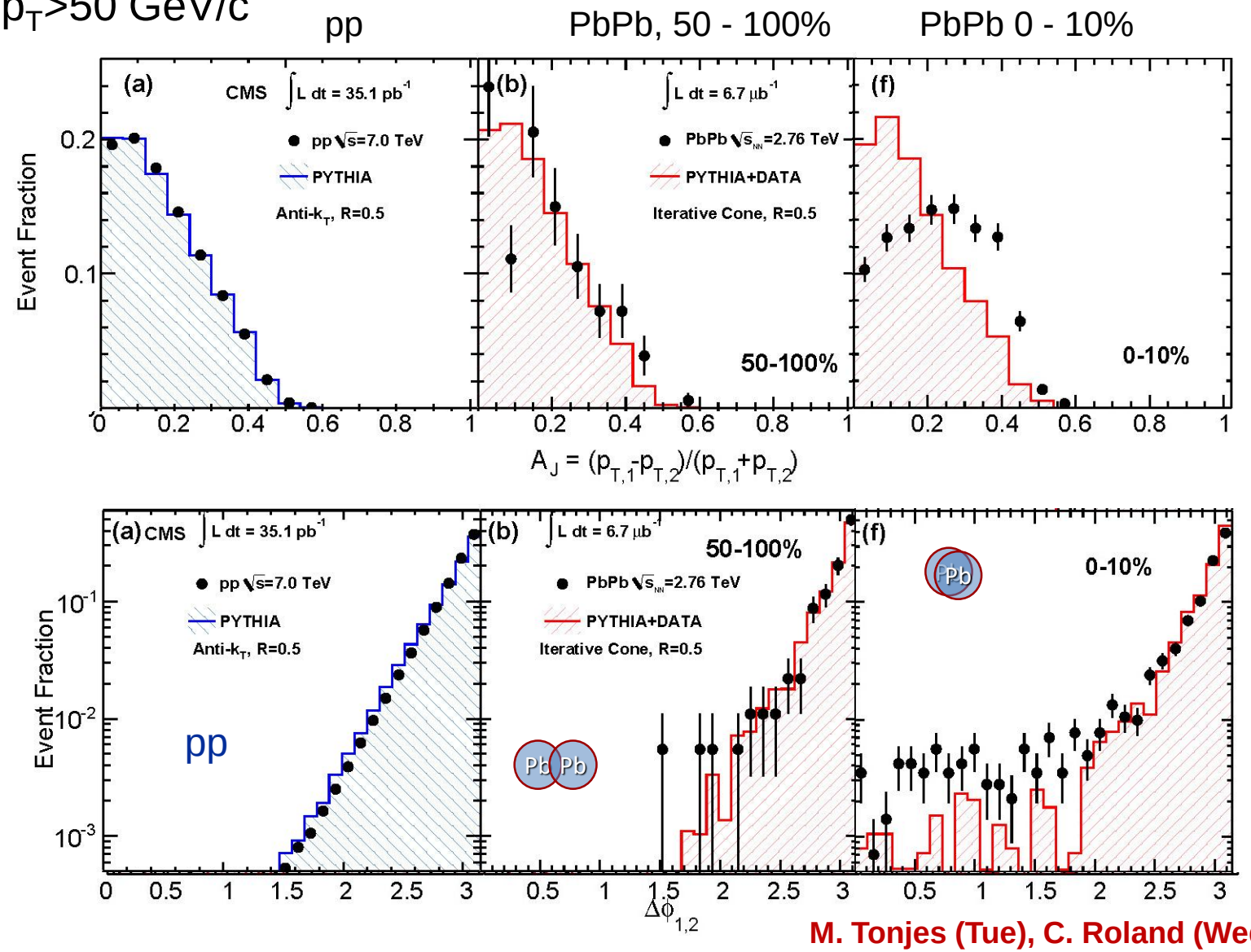
Jet quenching via large dijet energy imbalance

- Dijets, calorimeters only
  - Leading p_T>120 GeV/c
  - Sub-leading p_T>50 GeV/c

p_T imbalance, increasing with centrality



Back-to-back $\Delta\phi\sim\pi$ for all centralities

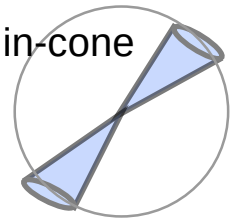


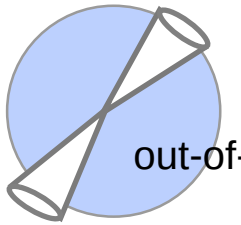
arXiv:1102.1957

M. Tonjes (Tue), C. Roland (Wed)

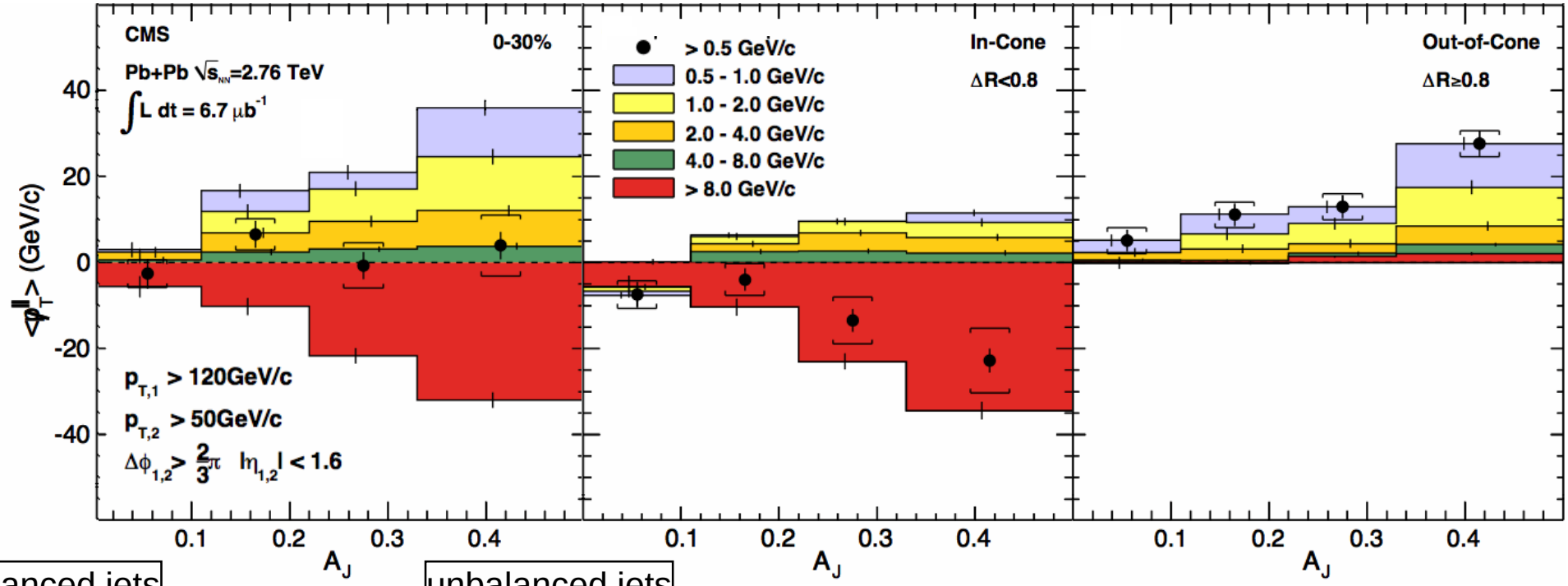
Where is the energy? spread out low p_T particles

$$\not{p}_{\mathrm{T}}^{\parallel} = \sum_{\mathrm{Tracks}} -p_{\mathrm{T}}^{\mathrm{Track}} \cos\left(\phi_{\mathrm{Track}} - \phi_{\mathrm{Leading\ Jet}}\right)$$





0-30% Central PbPb



balanced jets

unbalanced jets

Low p_T, full acceptance
Momentum is balanced

In-cone large momentum imbalance at high p_T
Consistent with calorimetry

Out-of-cone low p_T particles balance the complete event

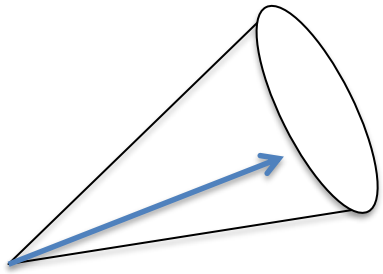
The momentum difference in the dijet is balanced by low p_T particles at large angles relative to the away side jet axis.

arXiv:1

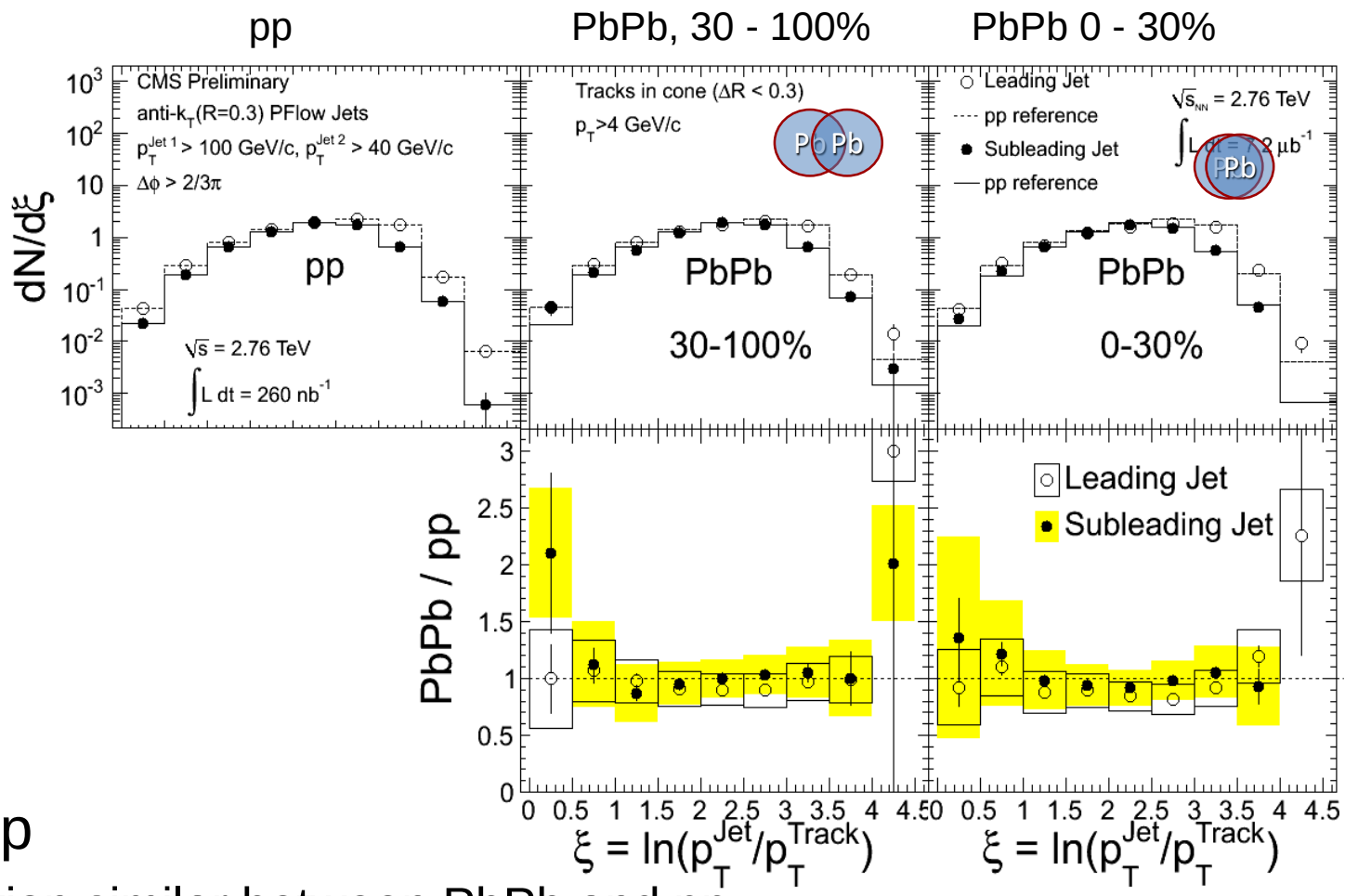
nd (Wed)

Jet fragmentation function, PbPb ≈ pp

- Updated jet algorithm: Particle Flow, Anti-k_T , R=0.3
- Charged tracks, p_T^{Track} >4 GeV/c, jets with p_T^{Jet} =40-300 GeV/c



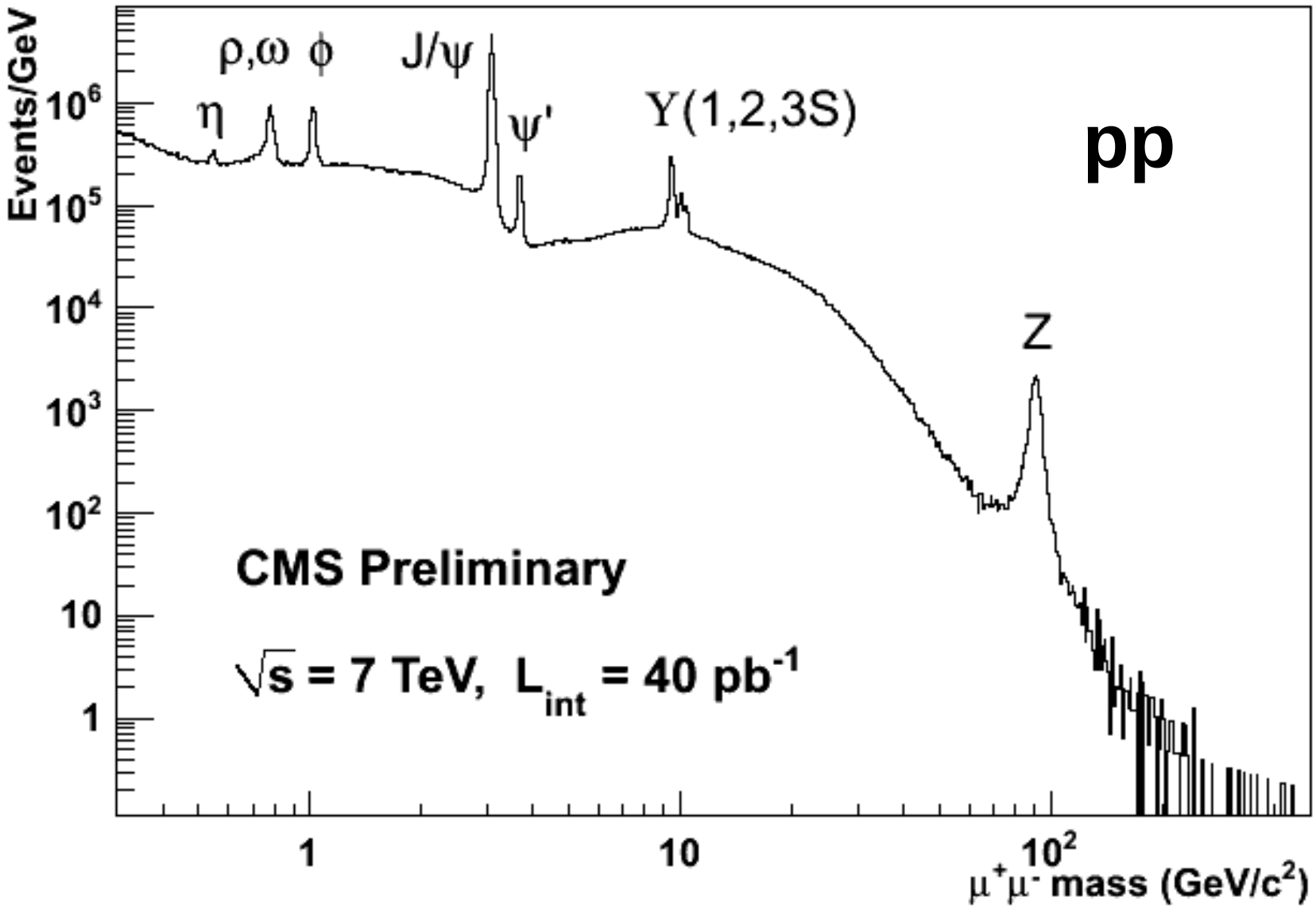
$$\xi = \ln\left(\frac{p_T^{Jet}}{p_T^{Track}}\right)$$



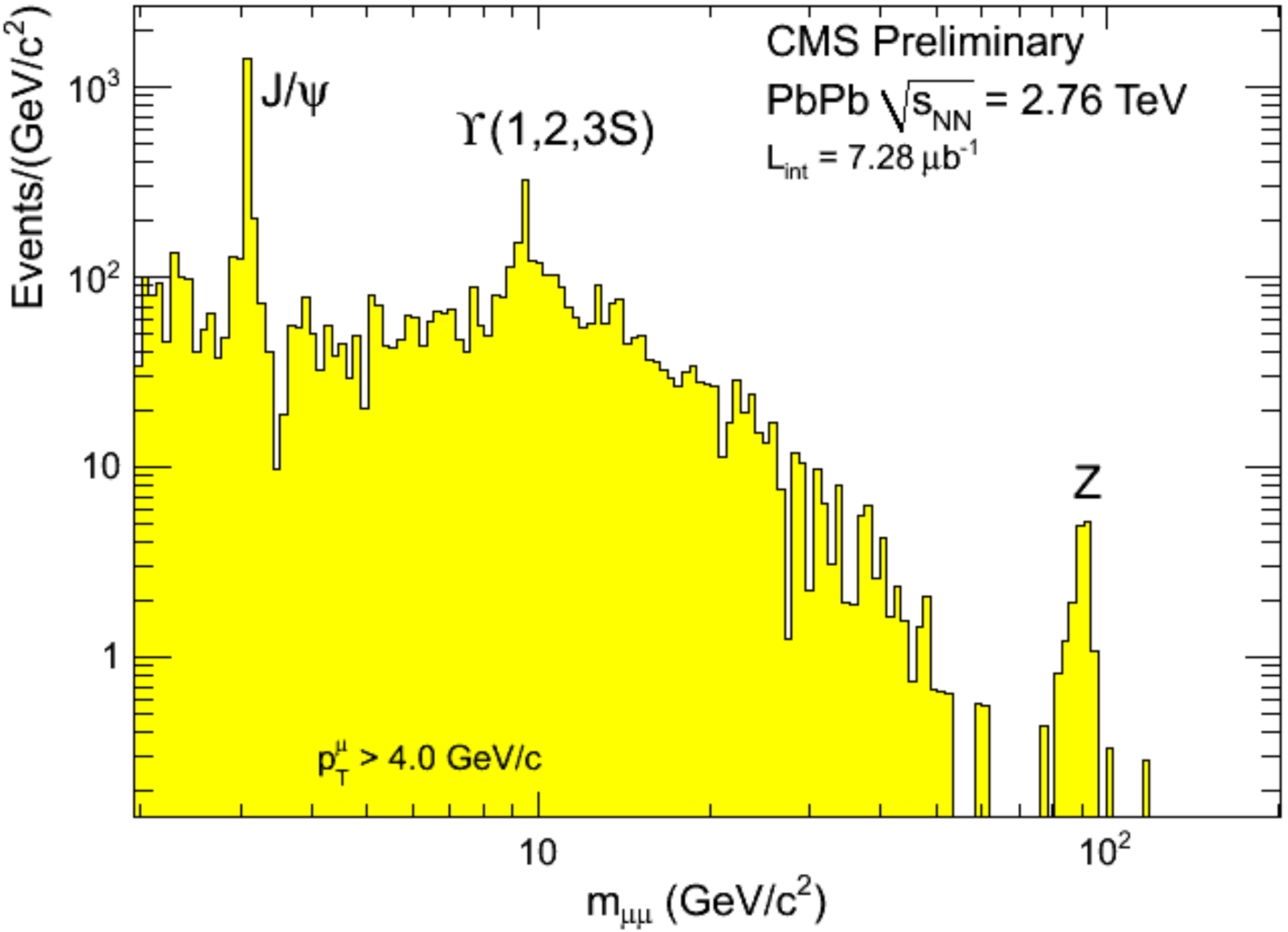
- Compare PbPb to pp
  - Fragmentation function similar between PbPb and pp
  - Fragmentation pattern independent of energy lost in medium

Y. Yilmaz (Fri), C. Roland (Wed), M. Nguyen (Fri)

Compact Muon Solenoid: $\mu^+\mu^-$ invariant mass in pp

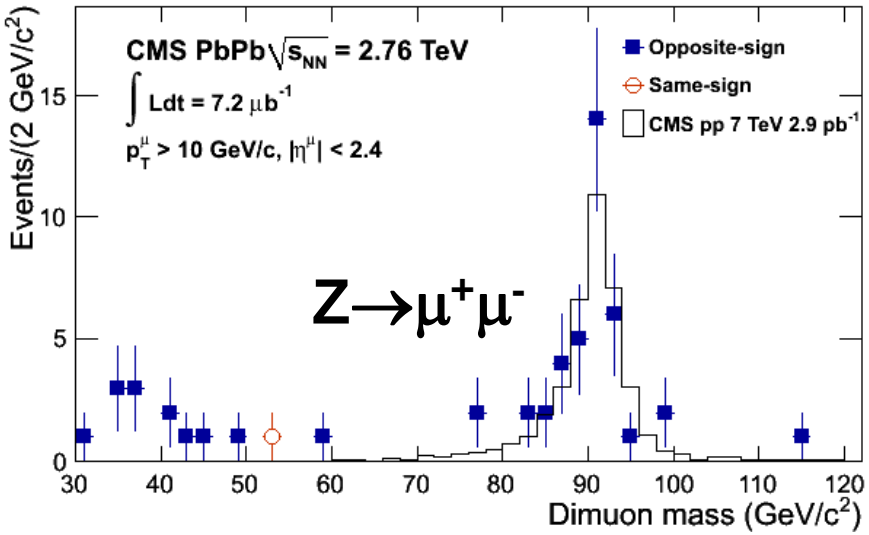


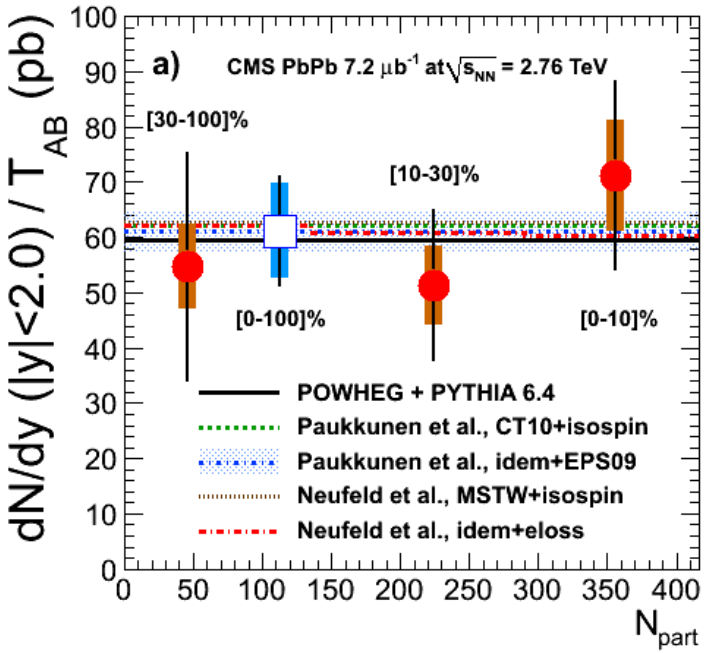
Compact Muon Solenoid: $\mu^+\mu^-$ invariant mass in PbPb



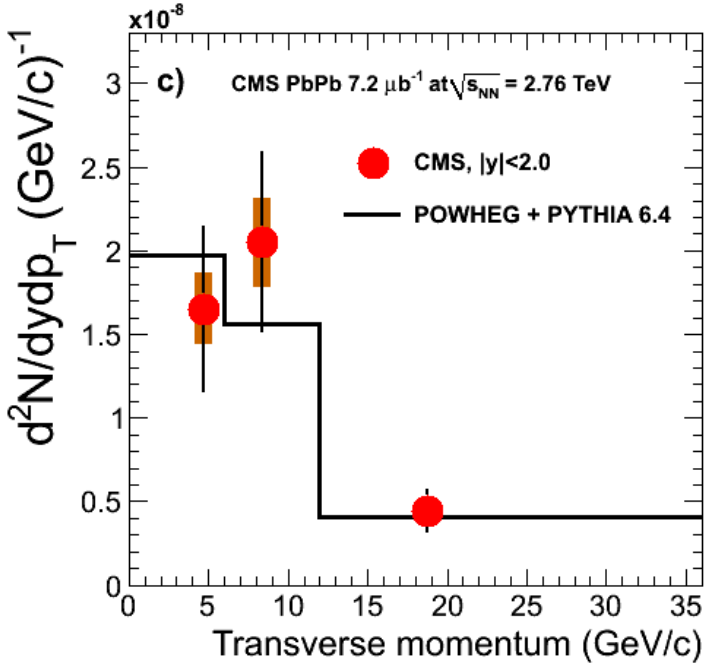
Z. Hu (TODAY), T. Dahms (Tue), C. Silvestre (Fri), J. Robles (Fri), M. Jo (Poster), D.H.Moon (Poster), H. Kim (Poster)

Z bosons show collisional scaling





No significant dependence on centrality



p_T dependence consistent with pp

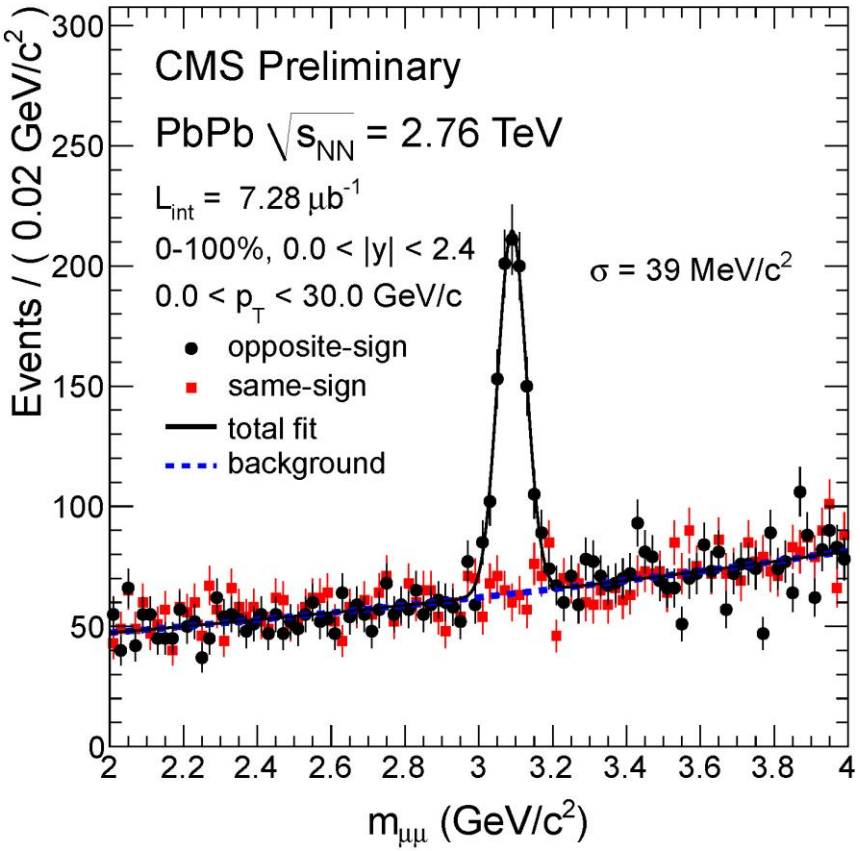
arXiv:1102.5435 accepted by PRL

J Robles (Thu)

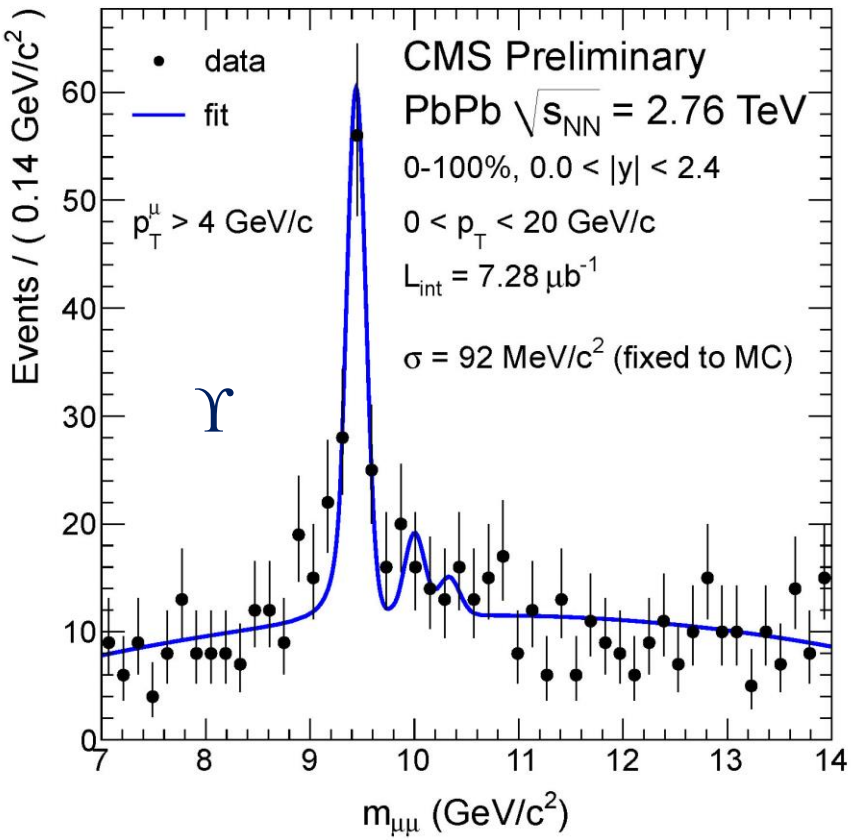
J/ψ and ϒ

- J/ψ and ϒ observed in $\mu^+\mu^-$ channel
- CMS muon acceptance $|\eta|<2.4$, $p_{T\mu}>2$-4 GeV/c
- Excellent mass resolution ~1%, comparable to pp

$N_{J/\psi}$ =734±54



N_{Υ} =86±12

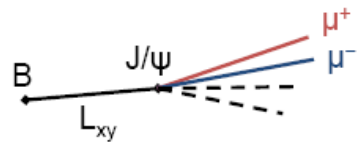


Z. Hu (TODAY), T. Dahms (Tue), C. Silvestre (Fri)

J/ψ: prompt and from B decays

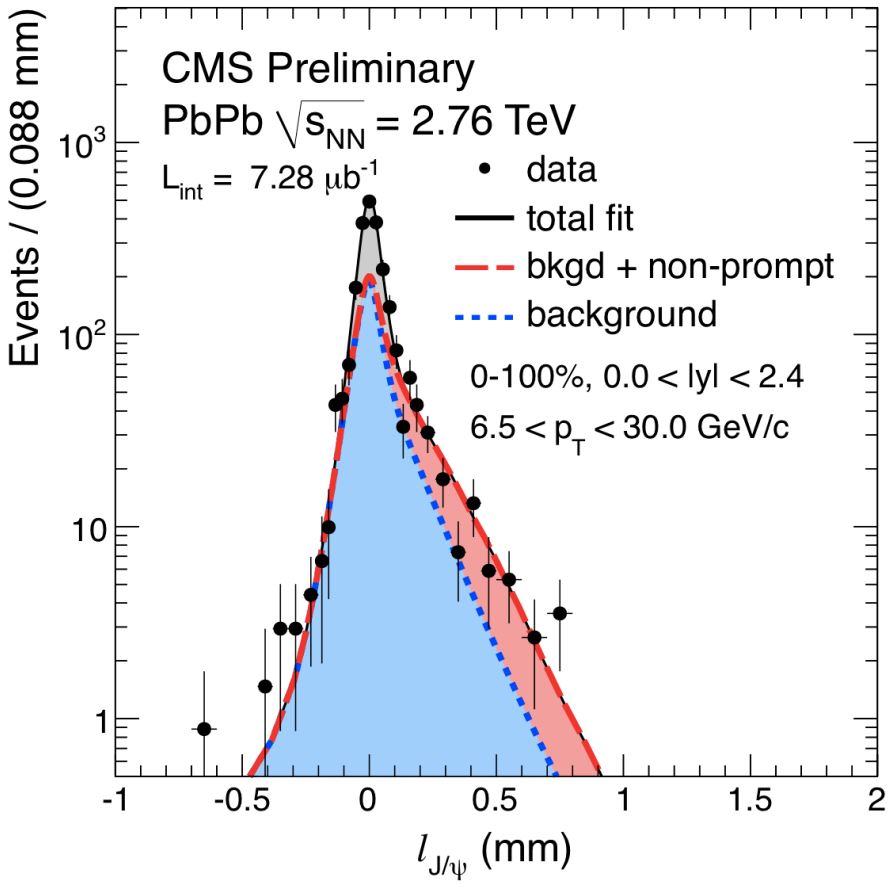
- Use separation of primary and $\mu^+\mu^-$ vertices in plane transverse to beam
- Long B decay times lead to displaced vertices

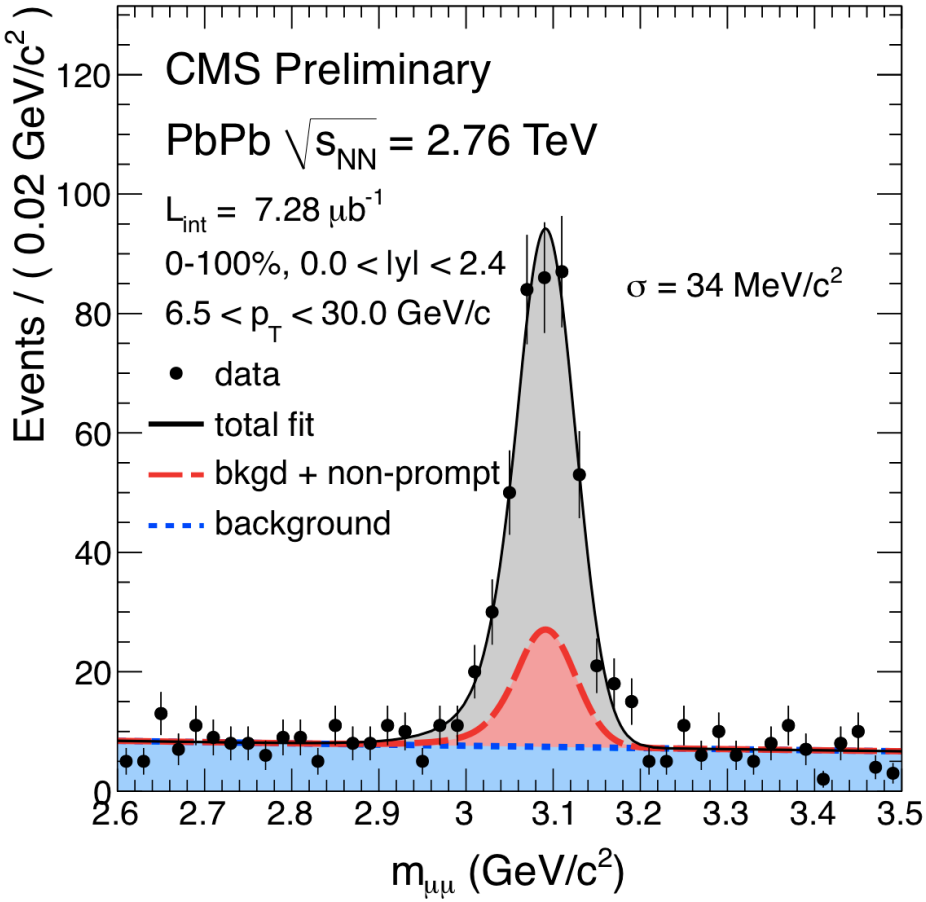
$$\ell_{J/\psi} = L_{xy}\frac{m_{J/\psi}}{p_T}$$



- Separate:
  - Prompt J/ψ production
  - Non-prompt J/ψ from B decays

조미희: Flash Talk에 선정

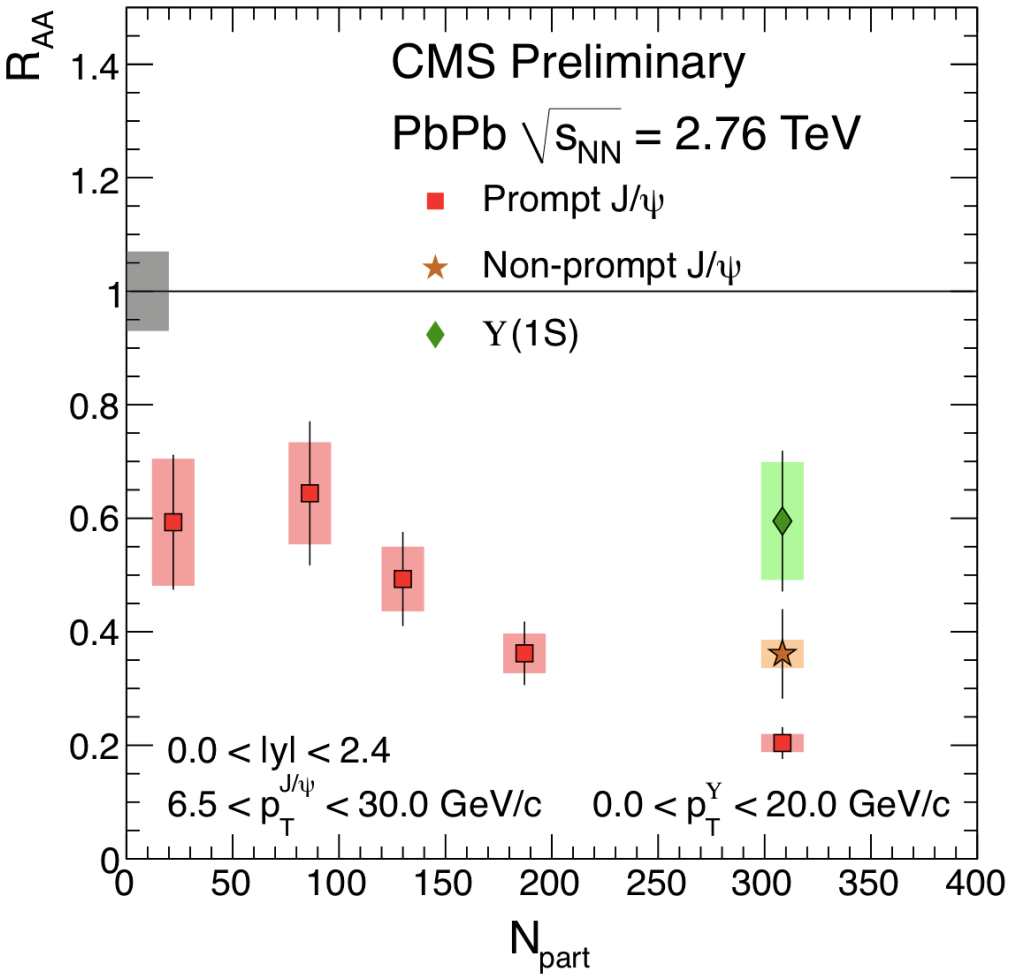




T. Dahms (Tue), C. Silvestre (Fri)

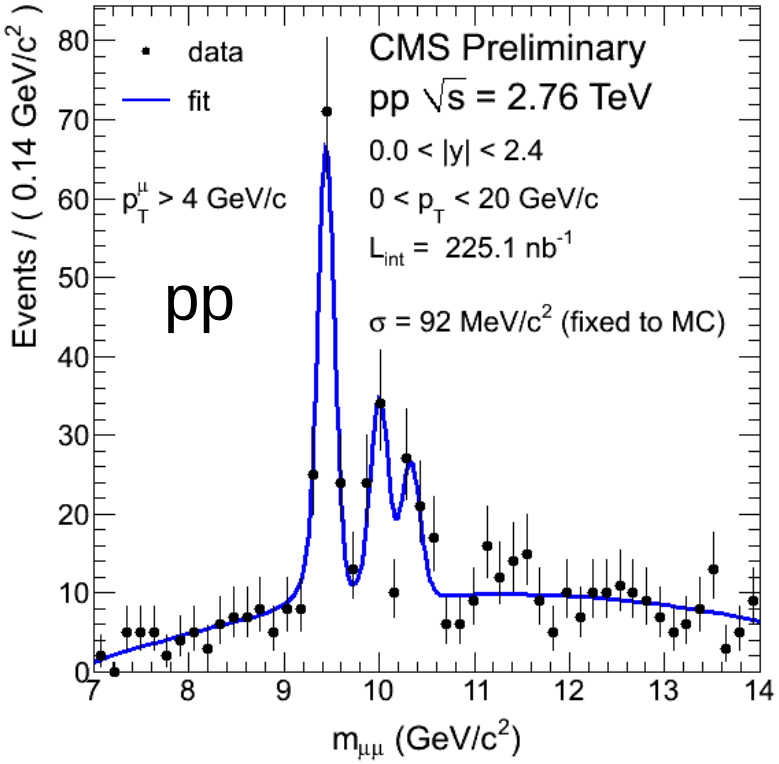
All quarkonia suppressed: R_{AA} vs. centrality

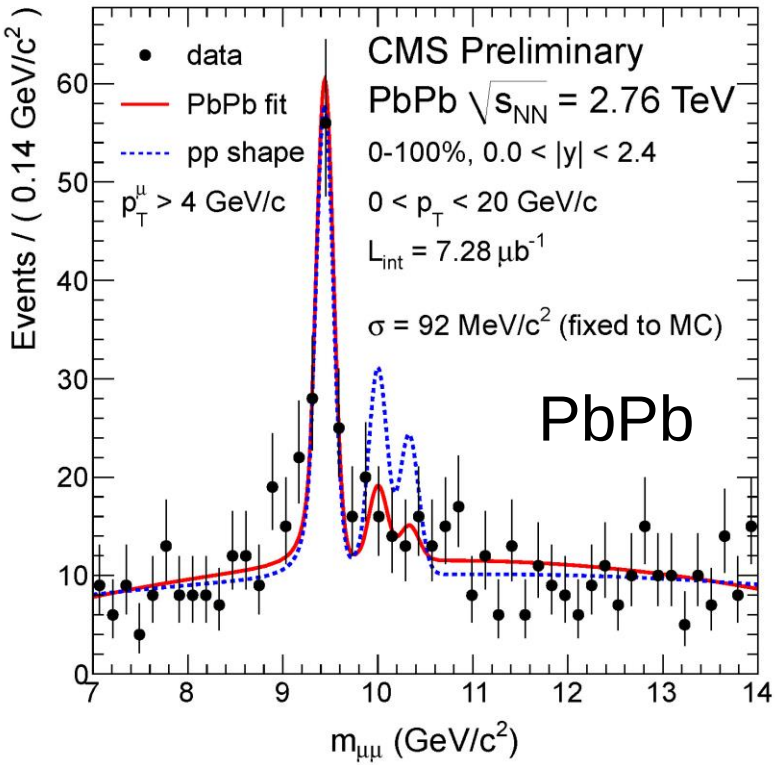
- Non-prompt J/ψ suppression is a measure of b-quark quenching
- High p_T J/ψ is strongly suppressed at the LHC
- Inclusive ϒ(1S) is suppressed



Z. Hu (TODAY), T. Dahms (Tue), C. Silvestre (Fri)

Suppression of excited ϒ states





$$\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{pp} = 0.78^{+0.16}_{-0.14} \pm 0.02$$

$$\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{PbPb} = 0.24^{+0.13}_{-0.12} \pm 0.02$$

$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

- Excited states ϒ(2S,3S) relative to ϒ(1S) are suppressed
- Probability to obtain measured value, or lower, if the real double ratio is unity, has been calculated to be less than 1%

Z. Hu (TODAY), C. Silvestre (Fri)

Summary

- CMS experiment performed flawlessly during the 2010 heavy ion run period at LHC
- CMS has obtained significant statistics of hard probes
- CMS conducted detailed measurements of global properties of medium in PbPb and pp collisions
- Our measurements indicate consistent view of the hot and dense medium
  - Strong collective effects in the medium
  - No quenching of weakly and electromagnetically interacting probes
  - Strong quenching of partons, including b-quarks
  - Suppression of quarkonia, including excited states of the Υ

- Thanks to CERN for fantastic LHC performance!

For more info click here: CMS Heavy Ion Results