Heavy-Ion Meeting (HIM 2013-06)
Jeju Island, Korea, 28-29 June, 2013

Heavy-Ion Results on Hard Probes from CMS

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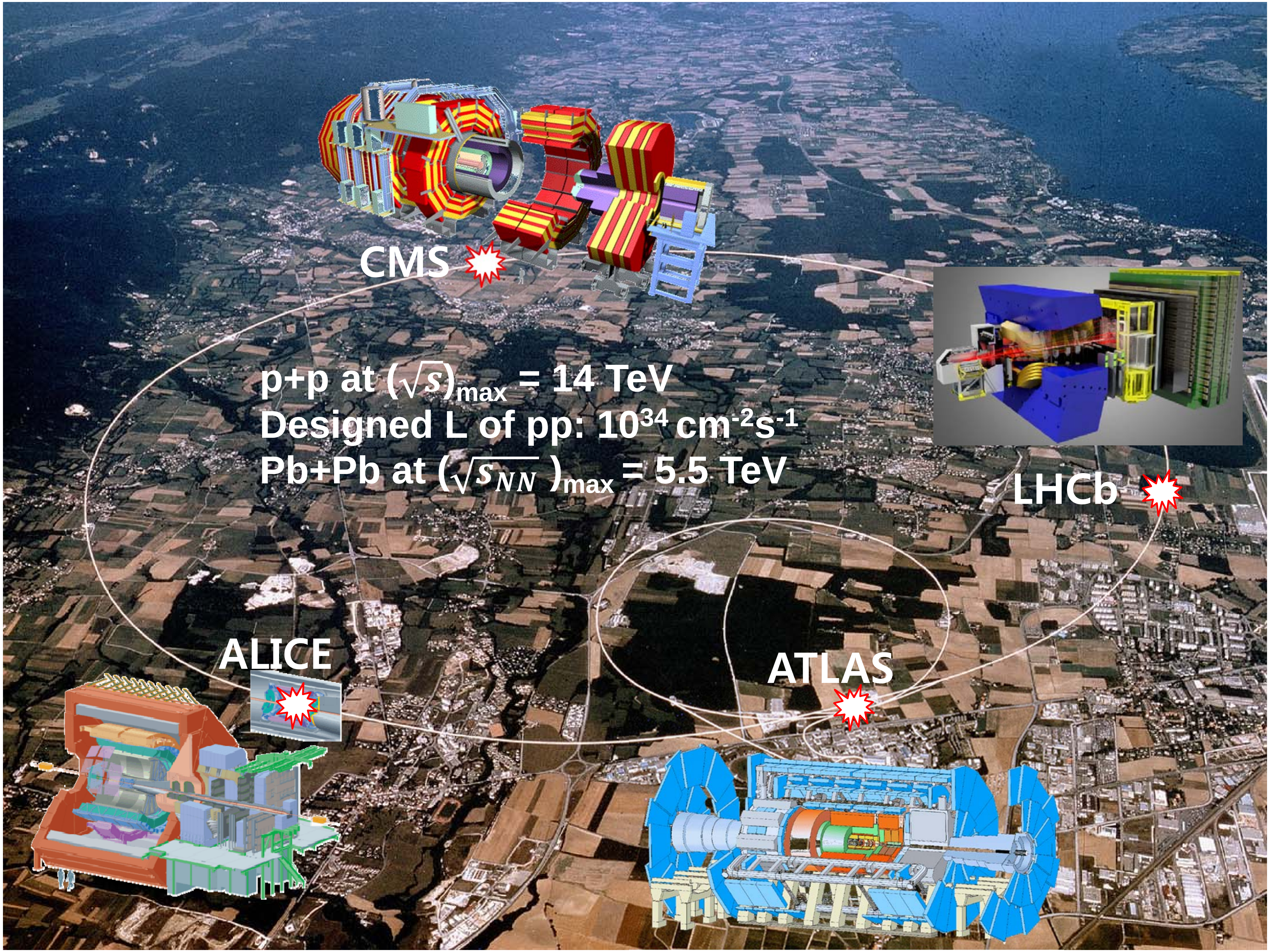
For the CMS Collaboration

Outline

1. Introduction
   – CMS detector
   – LHC heavy-ion run history
2. Experimental data
   – Two-particle correlations in PbPb
      • High-p_T dihadron correlation and dijet behavior
   – Dijet production in PbPb
      • Momentum imbalance
      • Modification of jet fragmentation and shapes
   – Dijet production in pPb for nPDF
   – Quarkonium production in PbPb
      • Prompt J/ψ, Non-prompt J/ψ, and $\psi(2S)$
      • $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$
3. Summary


CMS
p+p at $(\sqrt{s})_{max}$ = 14 TeV
Designed L of pp: 10^{34} $cm^{-2}s^{-1}$
Pb+Pb at $(\sqrt{s_{NN}})_{max}$ = 5.5 TeV
LHCb
ALICE
ATLAS

CMS Detector

Weight: 12,500 tons
Diameter: 15 m
Length: 22 m

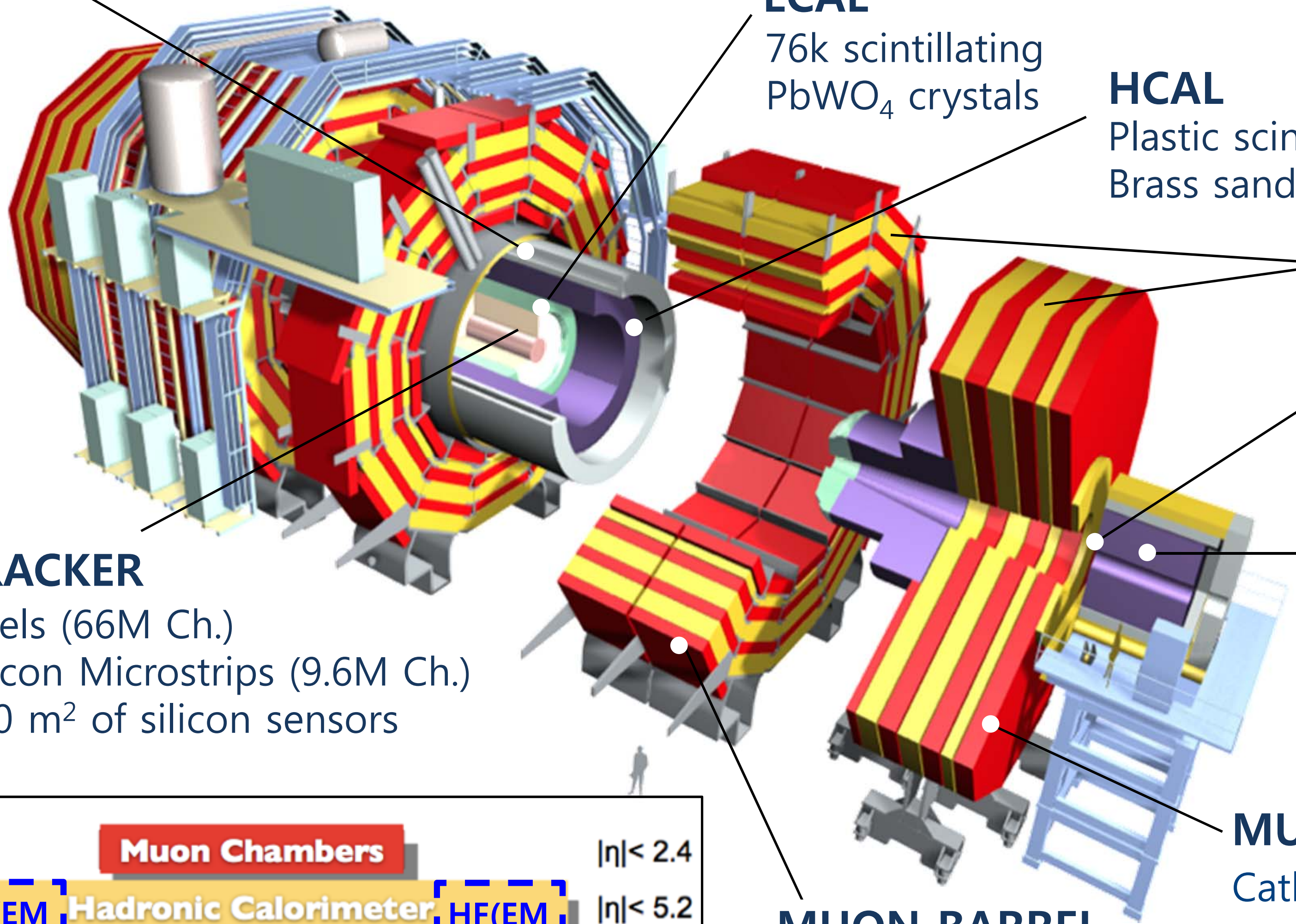
Superconducting Coil (3.8 T)

CALORIMETERS

ECAL
76k scintillating
$PbWO_4$ crystals

HCAL
Plastic scintillator/
Brass sandwich

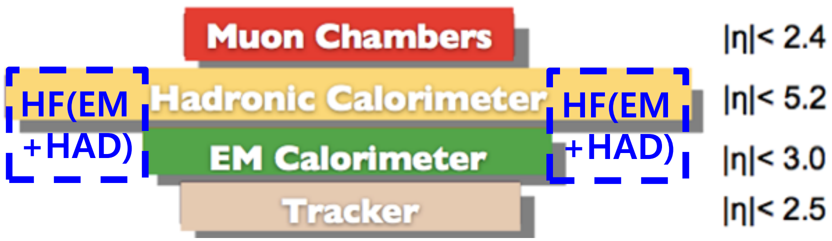
Steel YOKE



BSC
MB trigger

HF
MB trigger
Centrality in HI

TRACKER
Pixels (66M Ch.)
Silicon Microstrips (9.6M Ch.)
220 m^2 of silicon sensors



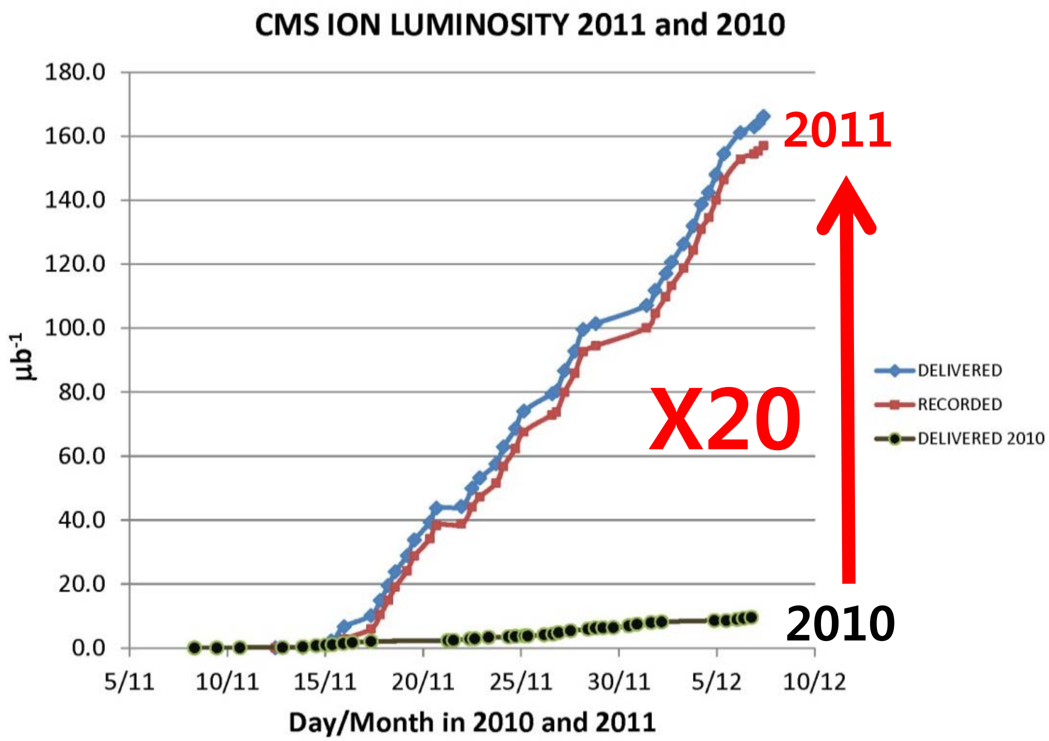
MUON BARREL
Drift Tube Chambers
Resistive Plate Chambers

MUON ENDCAPS
Cathode Strip Chambers
Resistive Plate Chambers

Heavy-Ion Runs at LHC & CMS

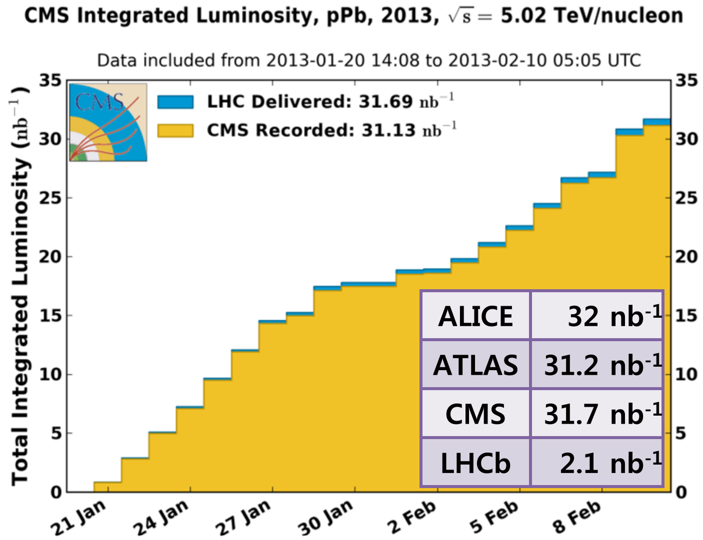
- 1st PbPb run @ $\sqrt{s_{NN}}$ = 2.76 TeV
  - Nov. - Dec. 2010
  - Recorded luminosity by CMS: 7.28 μb^{-1}

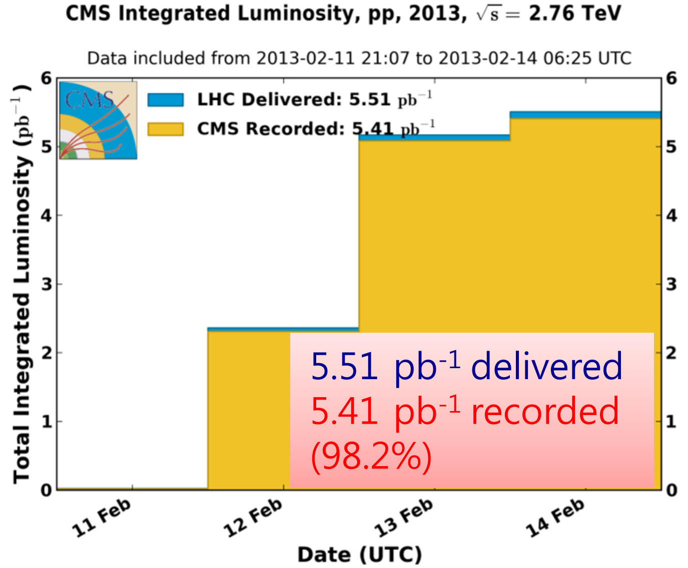
- 2nd PbPb run @ $\sqrt{s_{NN}}$ = 2.76 TeV
  - Nov. - Dec. 2011
  - Rec. Lum. by CMS: 150 μb^{-1}
    About 20 times more statistics than 2010 during similar beamtime



pp and pPb Runs at LHC

- 1^{st} pp run @ $\sqrt{s_{NN}}$ = 2.76 TeV
  - March 2011 (~1 week)
  - Rec. Lum. by CMS: 225 nb^{-1}
    - Equivalent to the number of hard probes in 2010 PbPb data
- pPb run @ $\sqrt{s_{NN}}$ = 5.02 TeV
  - Jan. - Feb. 2013
  - Rec. Lum. by CMS: 31.7 nb^{-1} (60B events)
  - Cold nuclear matter effect
- 2^{nd} pp run @ $\sqrt{s_{NN}}$ = 2.76 TeV
  - Feb. 2013 (3 days)
  - Rec. Lum by CMS: 5.41 pb^{-1} About 24 times more statistics than the first pp run

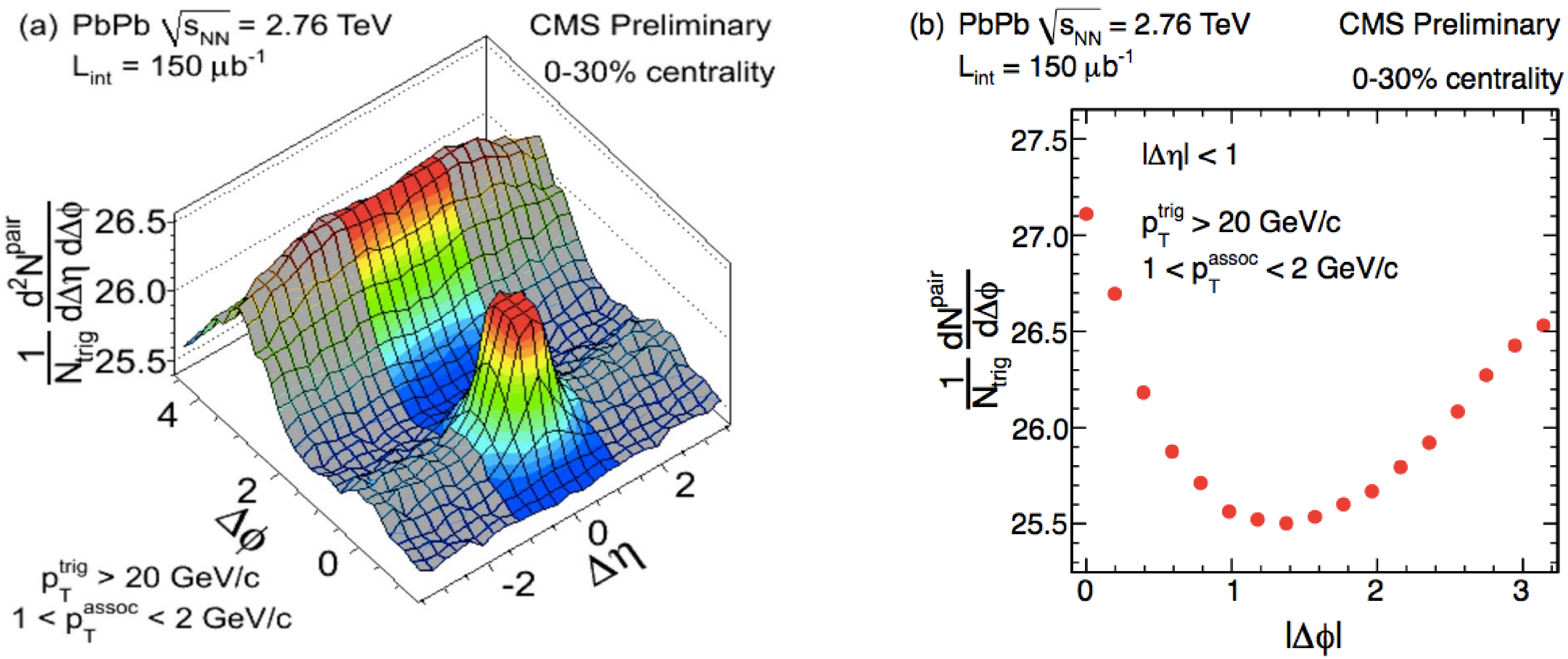




High-p_T Dihadron Correlation

CMS PAS HIN-12-010

$|\Delta\eta|<1$



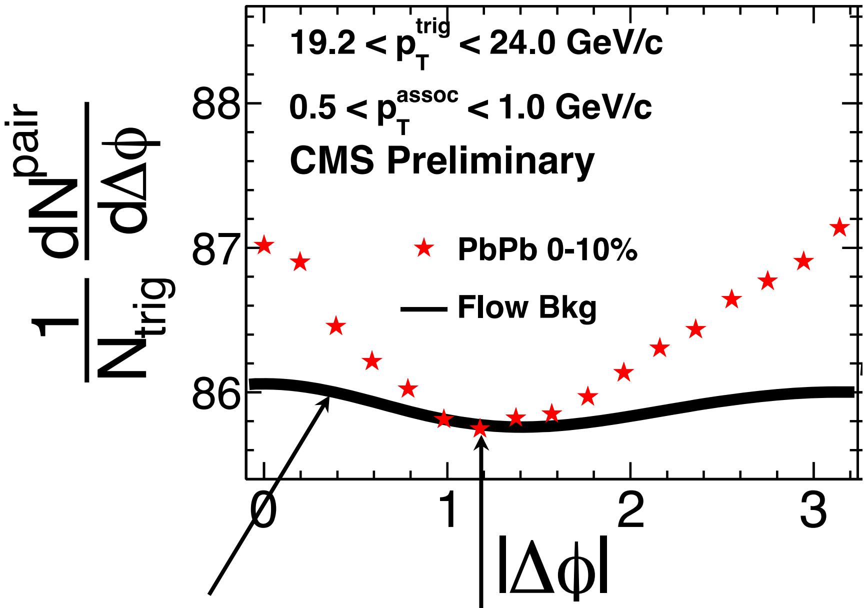
- Azimuthal correlation at high p_T near the jet components
  - Reflects the path-length dependence of parton energy loss
  - Quantitative constraint on various jet quenching models
  - Flow (v_2~v_4) from LR correlation needs to be subtracted for jet

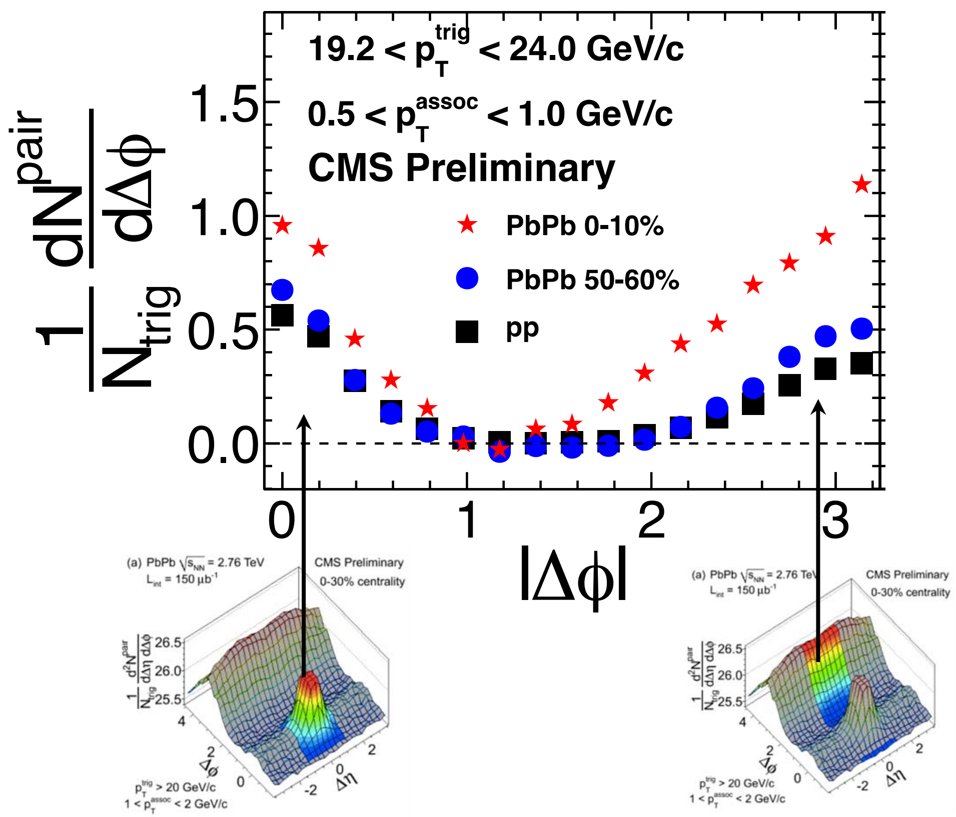
Dijet Behavior from High-p_T Correlation

- Need to subtract event-plane related correlations ($v_2 \sim v_4$) from dihadron correlation

CMS PAS HIN-12-010

Before ZYAM Subtraction → After ZYAM Subtraction



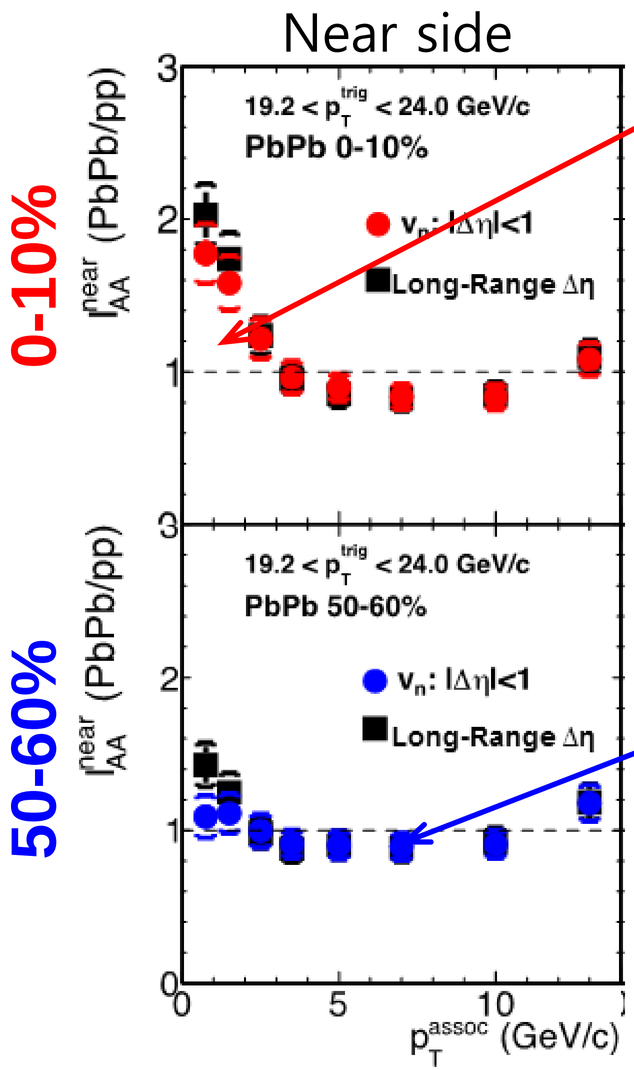


Flow Background

"Zero Yield At Minimum"

Dijet Behavior from High-p_T Correlation

CMS PAS HIN-12-010



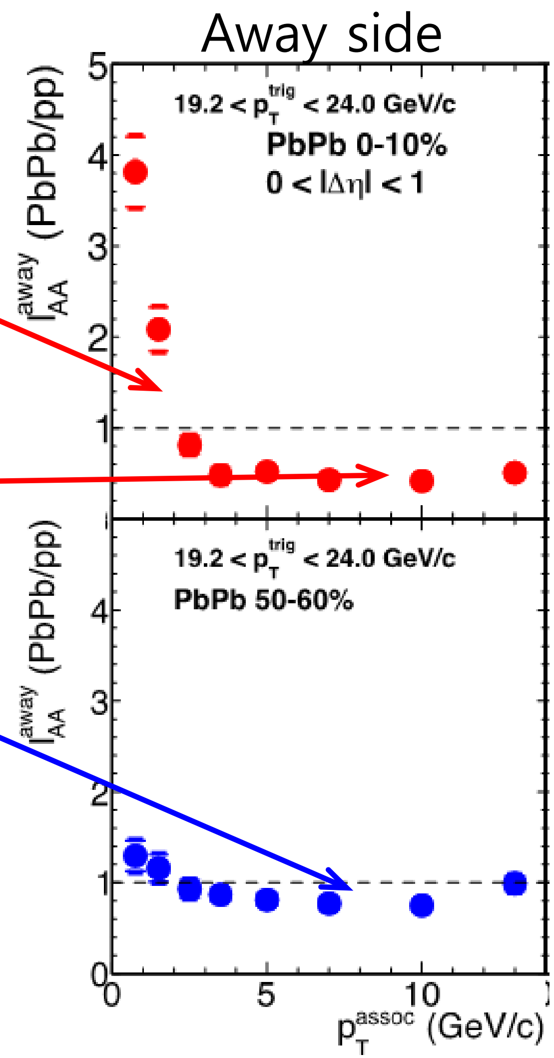
Some enhancement at low p_T

Significant enhancement (X4) at low p_T

Significant deficit (X0.5) at high p_T

No significant modification in perpheral events

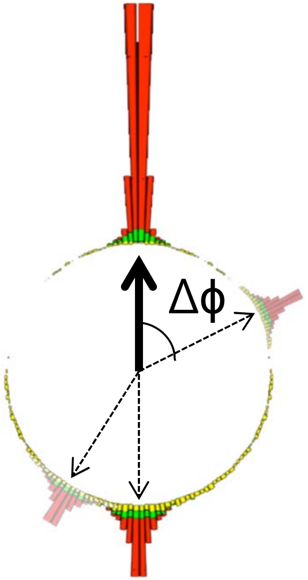
$$I_{AA}^{near(away)} = \frac{Y_{PbPb}^{near(away)}}{Y_{pp}^{near(away)}}$$

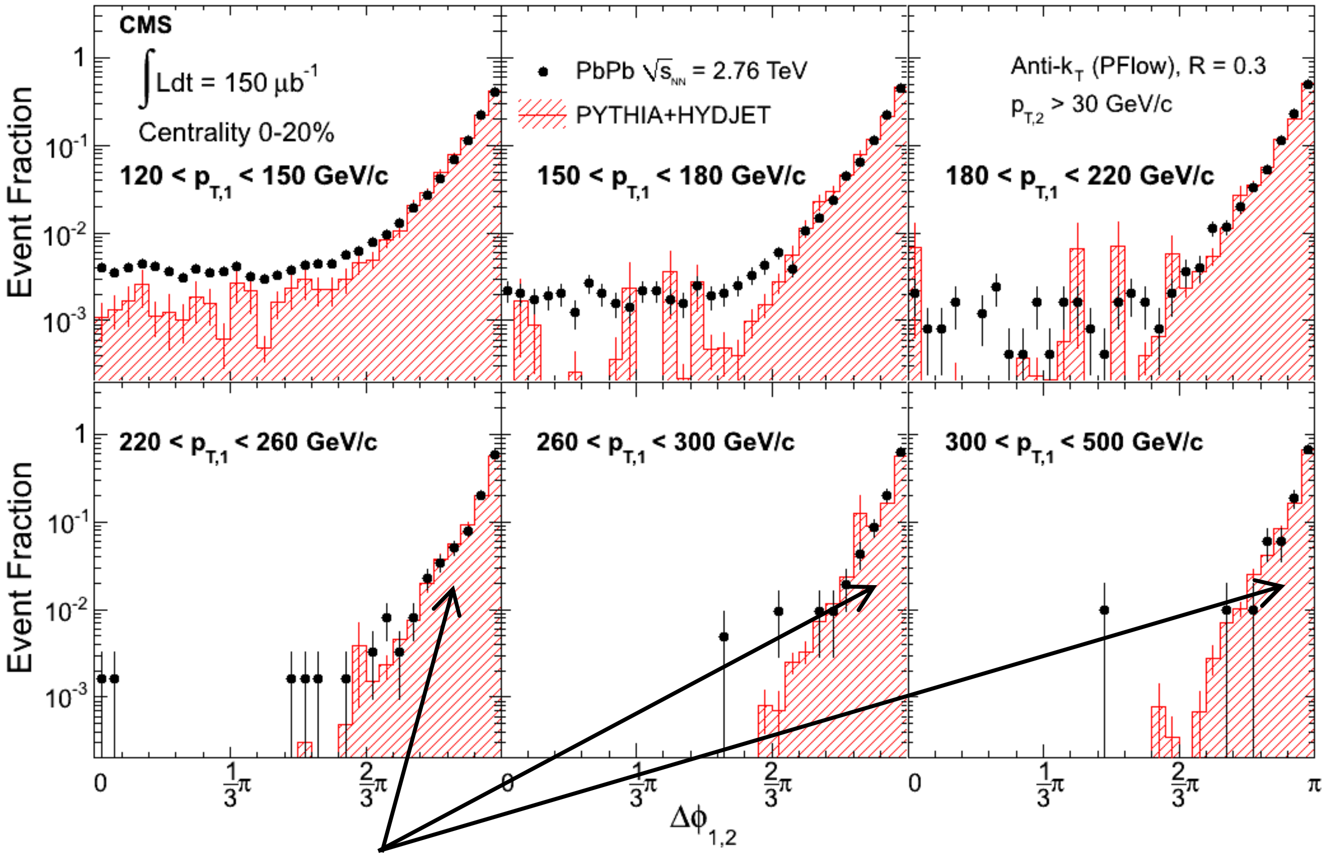


Dijet Angular Correlation

Now turn to the full jet reconstruction!

PLB 712, 176 (2012)

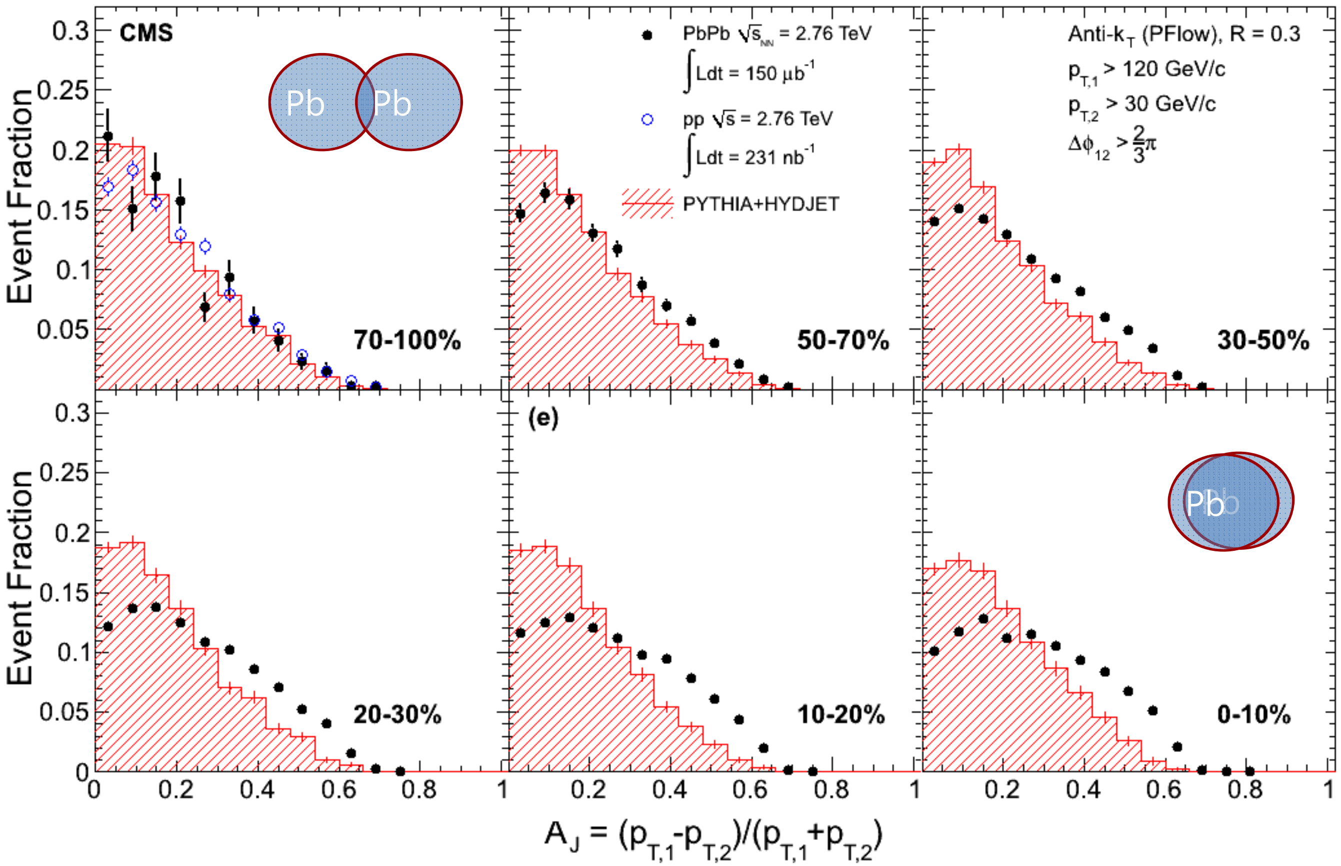


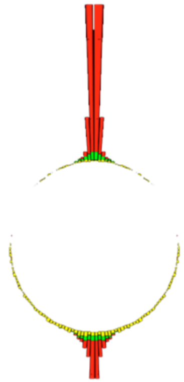


- Correlation peak in the data are reproduced by PYTHIA for all p_T ranges

Dijet Momentum Imbalance

PLB 712, 176 (2012)

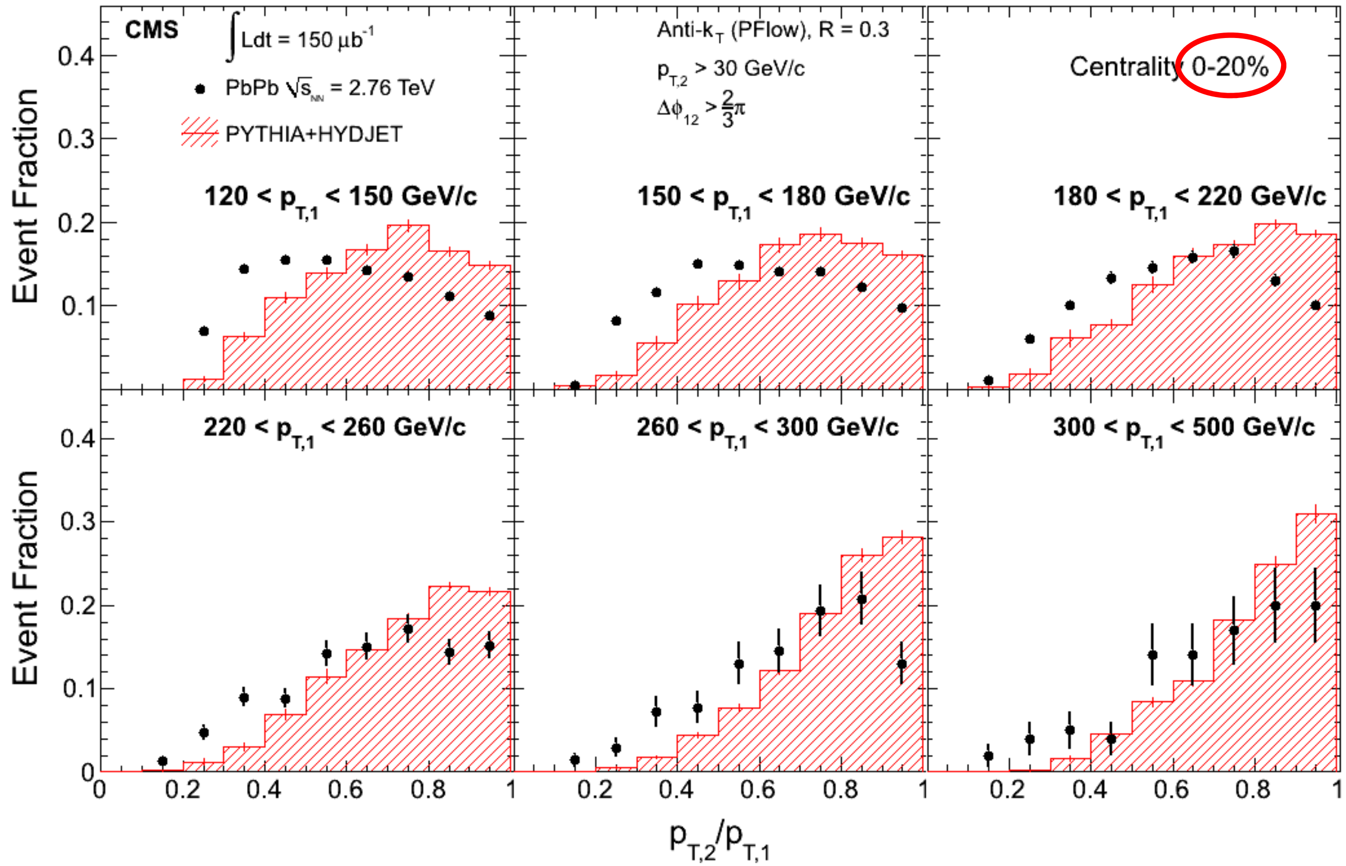


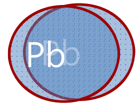


- Dijets in PbPb are more imbalanced than PYTHIA except the most peripheral events

Dijet Momentum Imbalance

PLB 712, 176 (2012)

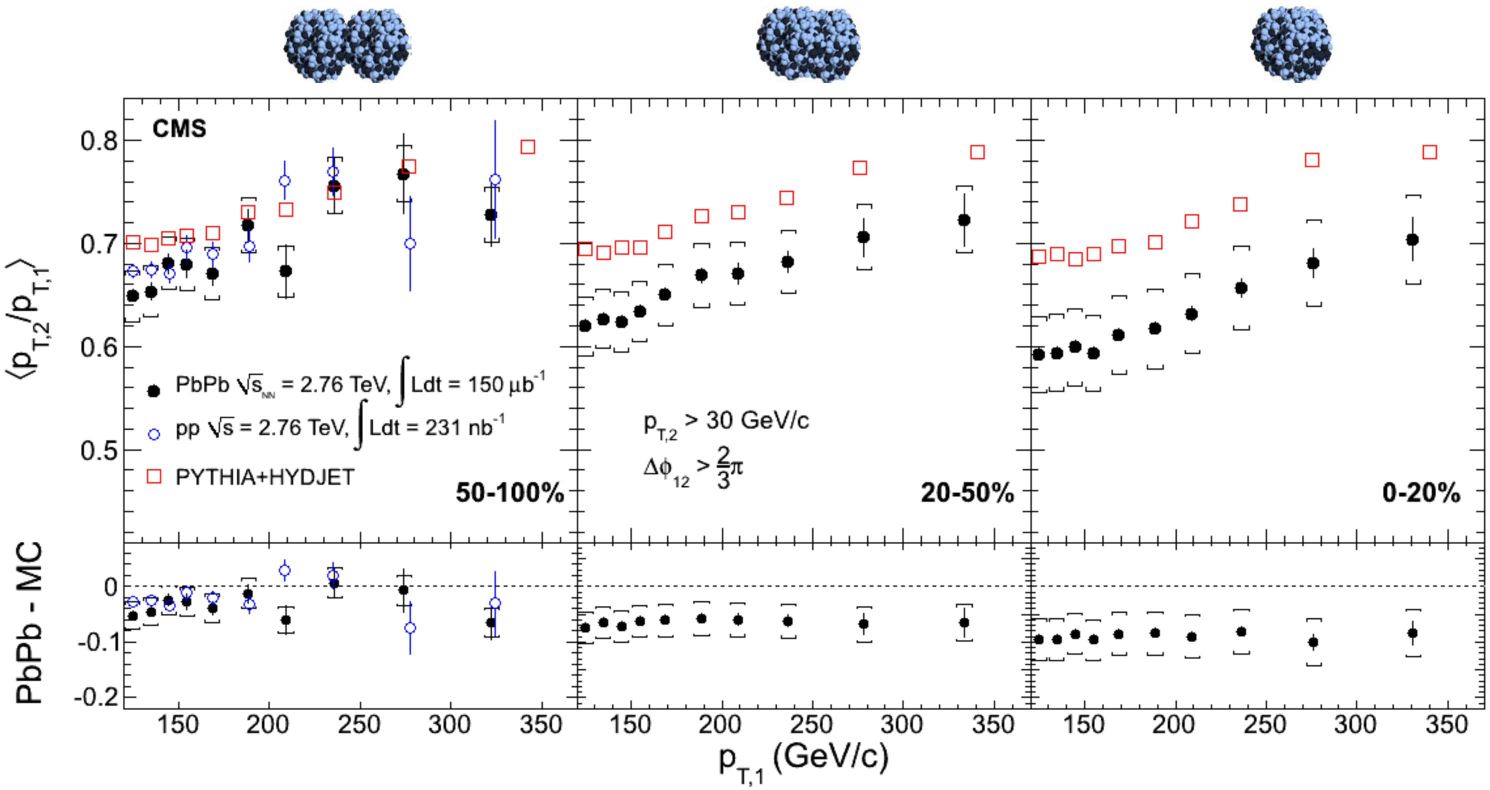




- Dijets in PbPb are more imbalanced than PYTHIA for all p_T in central collisions.

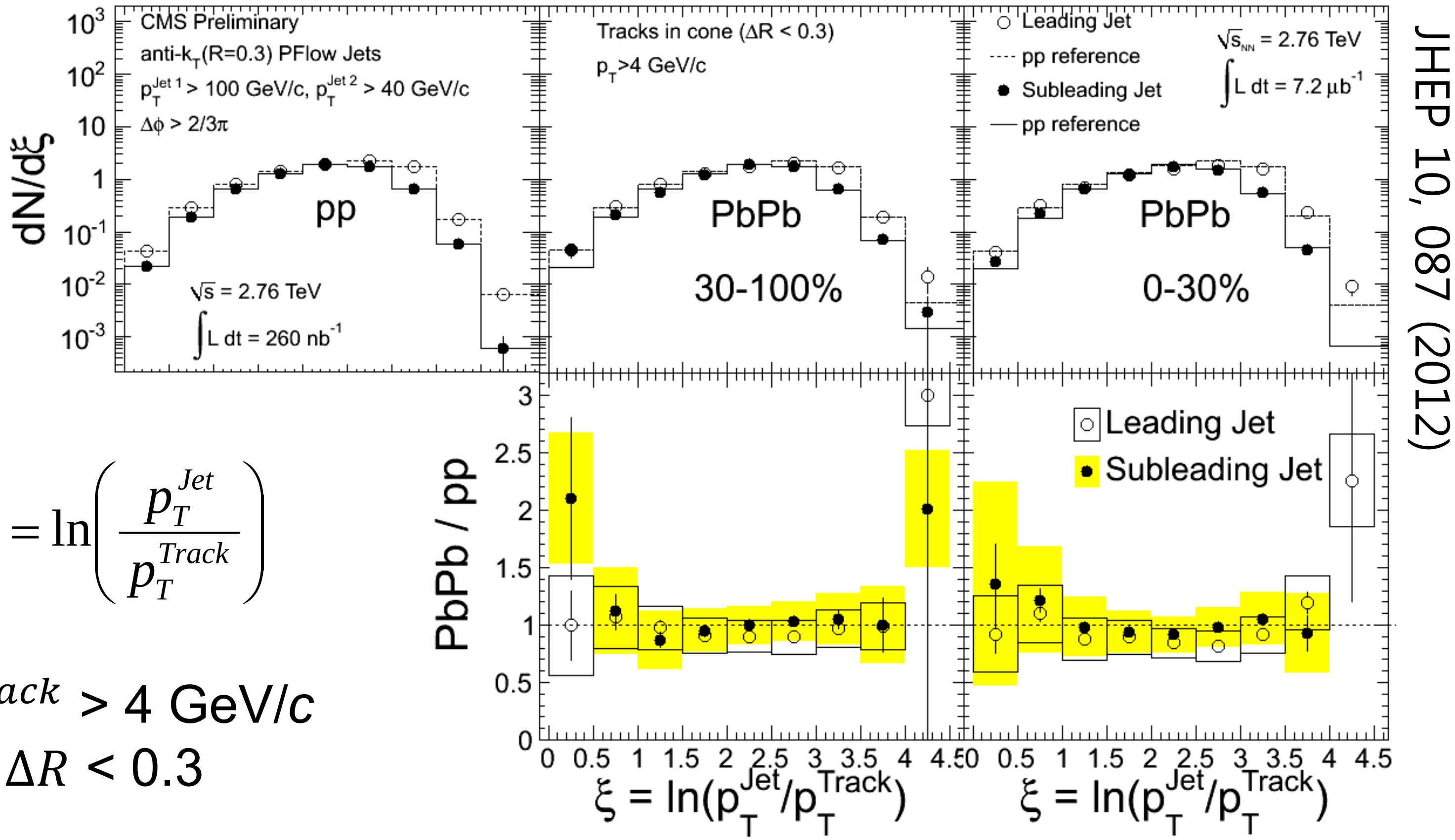
p_T-Dependence of Dijet Imbalance

PLB 712, 176 (2012)



- Energy loss is apparent except the most peripheral events
- Energy loss is larger for more central collisions
- No significant dependence on jet p_T

Modification of Jet Fragmentation?



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

$p_T^{Track} > 4$ GeV/c

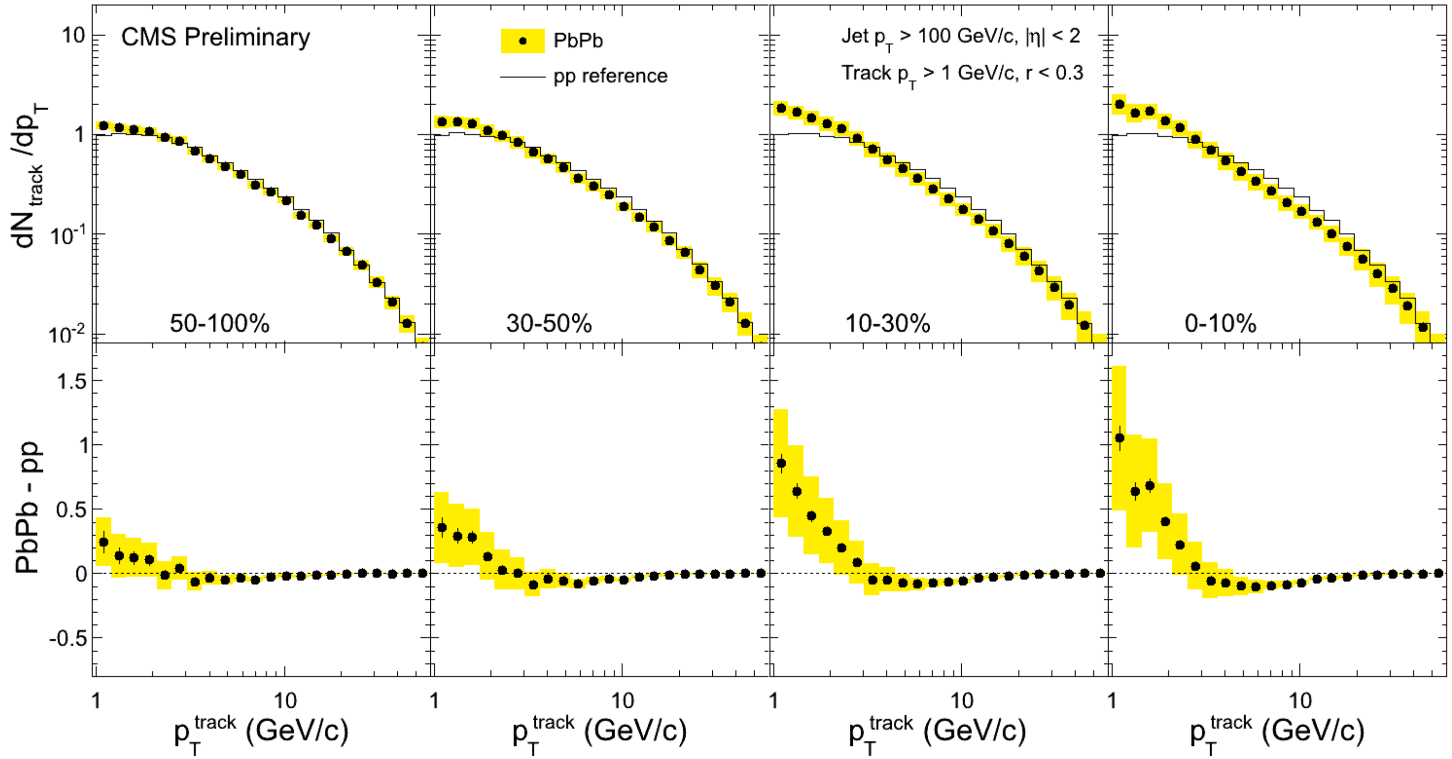
$\Delta R < 0.3$

- The jet fragmentation functions of leading and subleading (quenched) jet in PbPb are essentially unmodified within systematic errors for $p_T > 4$ GeV/c.

⇒ *This statement was based on 6.7 μb^{-1} from 2010 run!*

Modification of Jet Fragmentation?

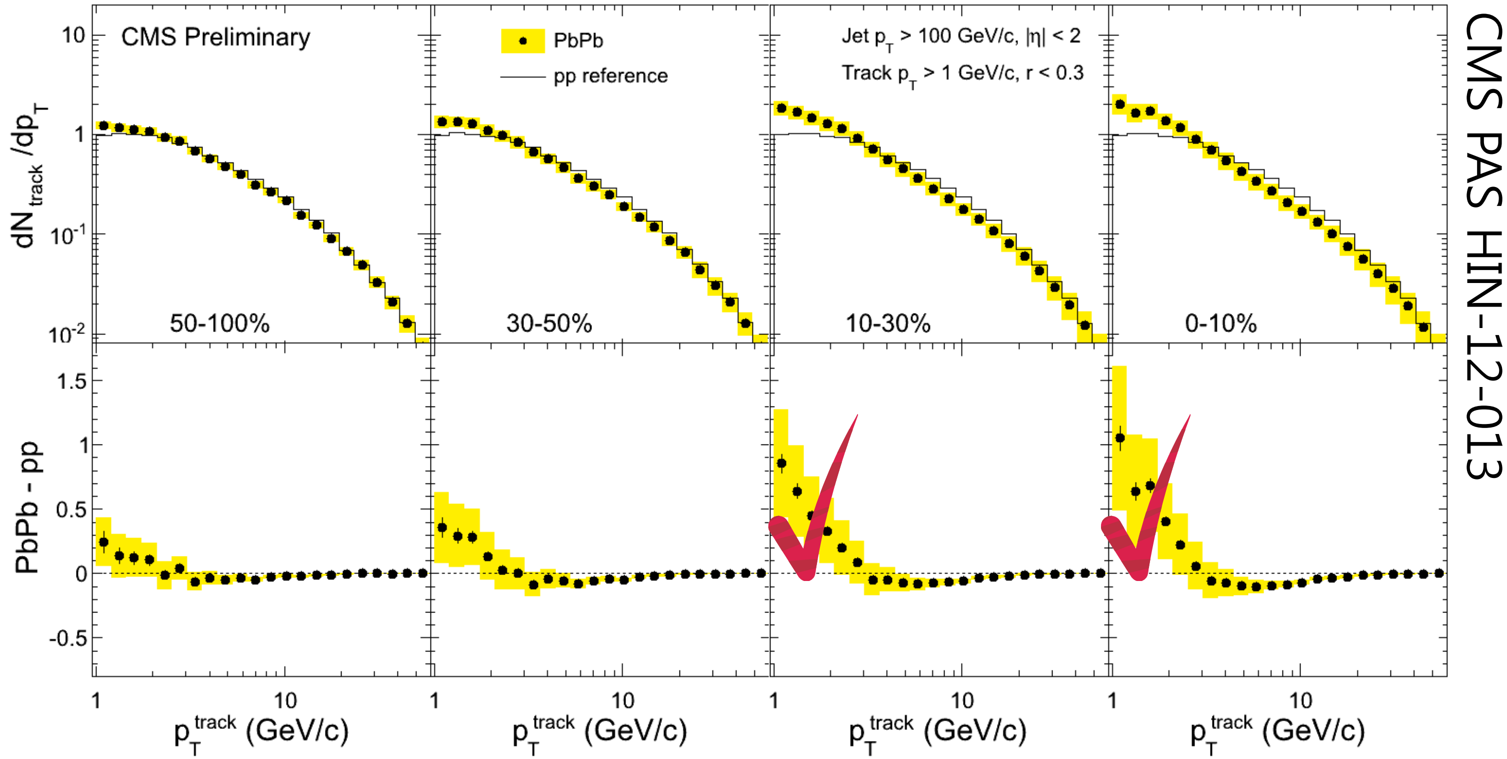
- Changes from 2010 to 2011 data analysis
  - ~20 times more statistics
  - Simplified jet selection: inclusive jet with p_T > 100 GeV/c
  - Lower p_T tracks down to 1 GeV/c



CMS PAS HIN-12-013

Modification of Jet Fragmentation?

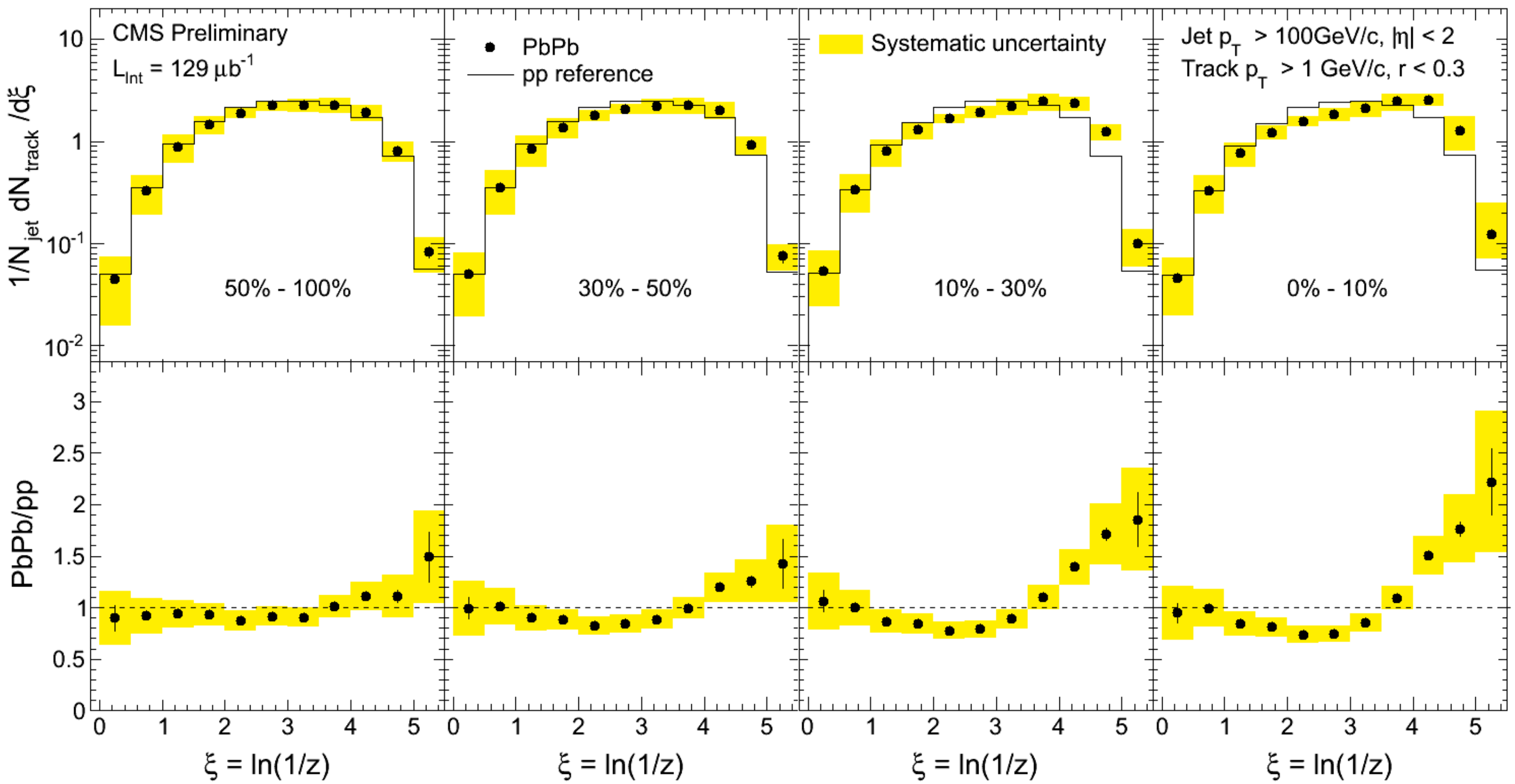
- Changes from 2010 to 2011 data analysis
  - ~20 times more statistics
  - Simplified jet selection: inclusive jet with p_T > 100 GeV/c
  - Lower p_T tracks down to 1 GeV/c



- Clear excess at low p_T compared to pp for central events!

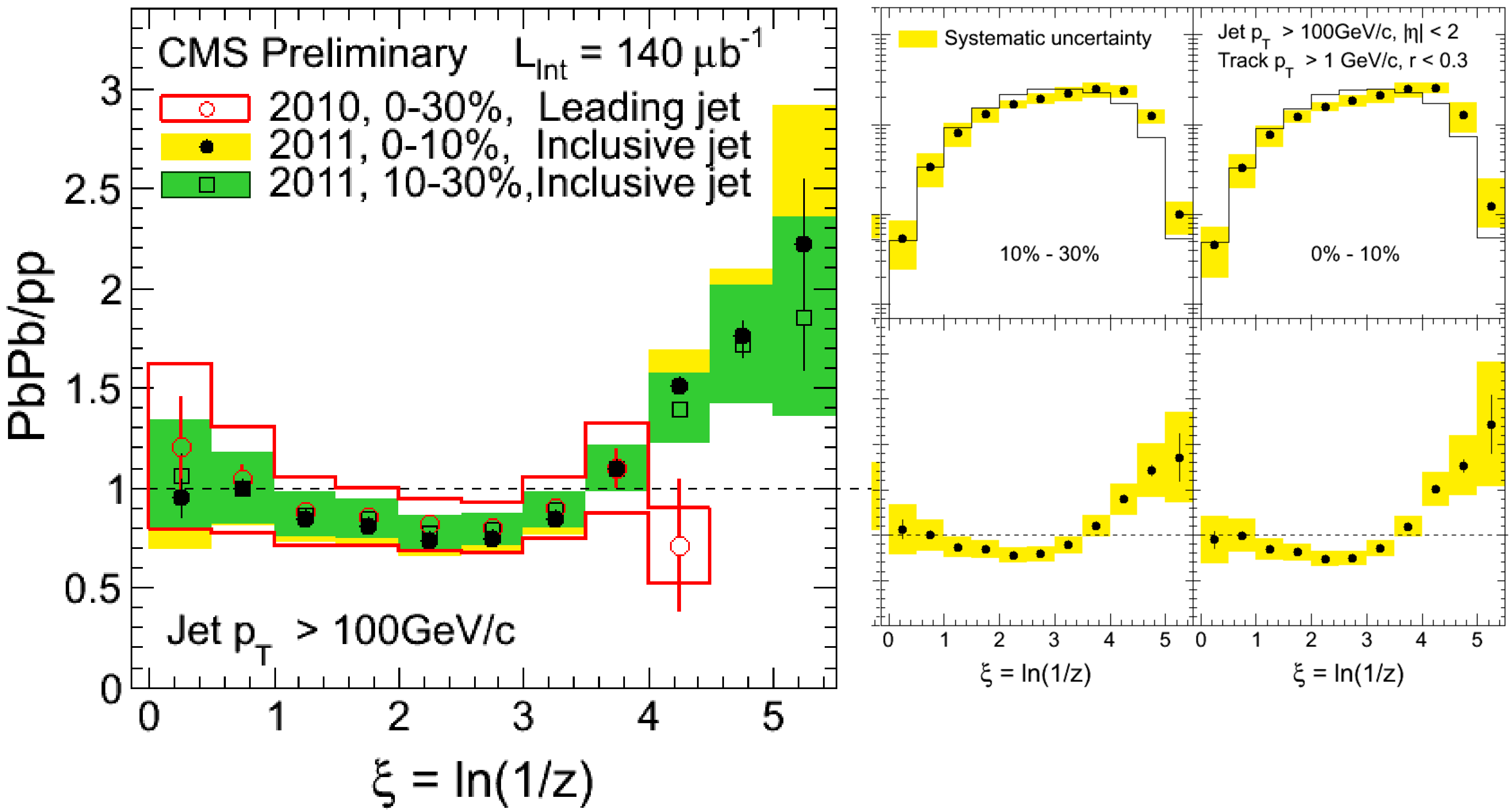
Modification of Jet Fragmentation?

CMS PAS HIN-12-013



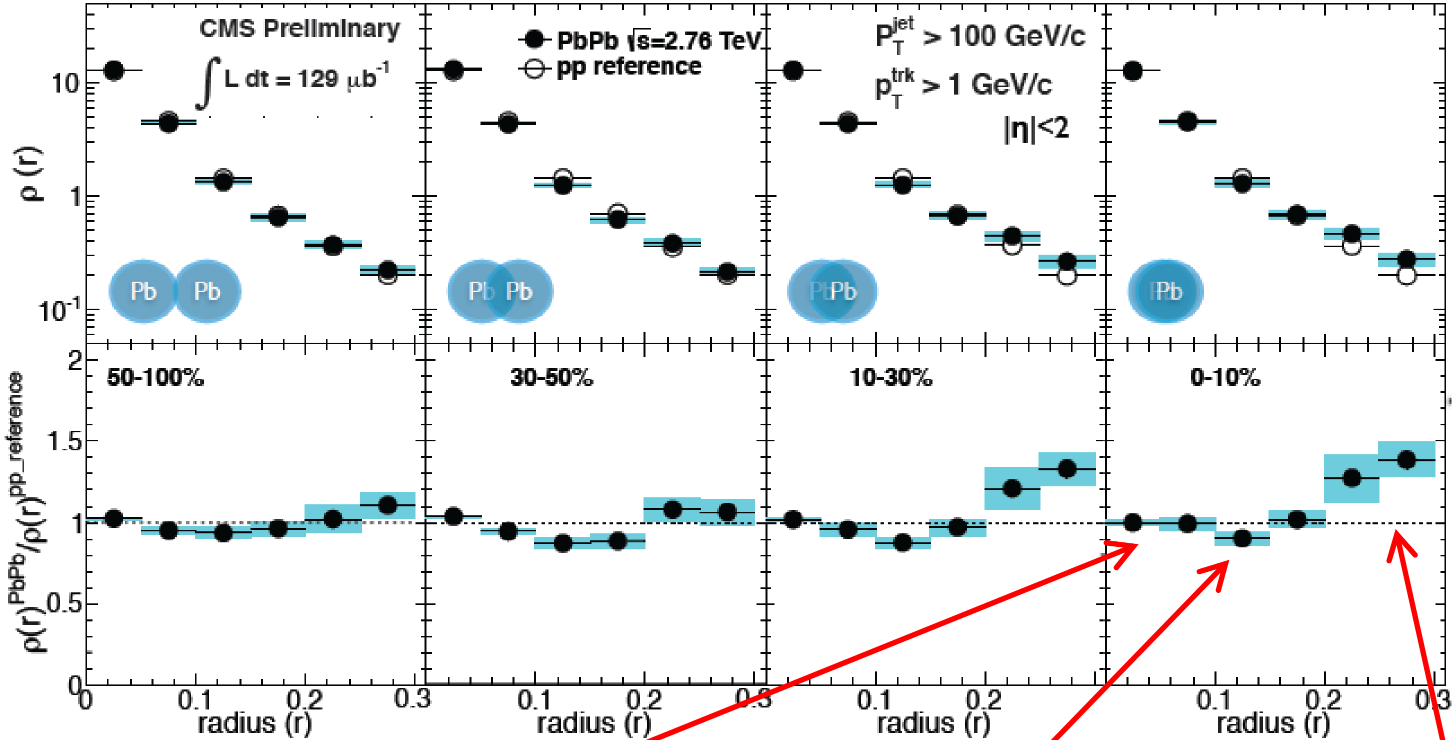
Modification of Jet Fragmentation?

CMS PAS HIN-12-013

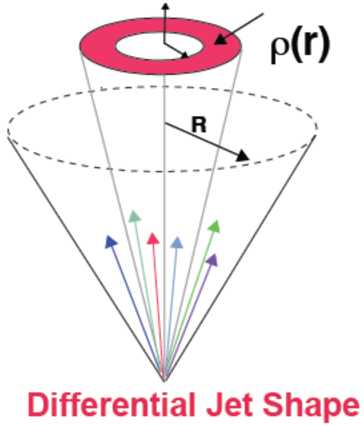


Modification in Jet Shapes

CMS PAS HIN-12-013



ρ(r): average fraction of jet p_T in an annulus in the η-ϕ plane



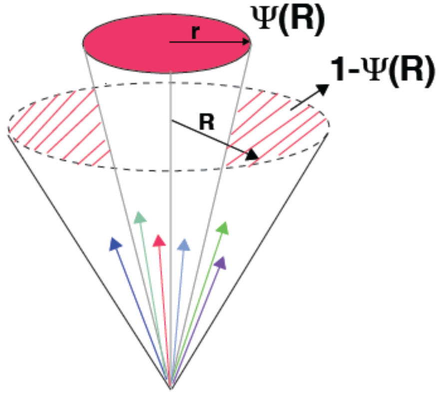
Same as pp close to the jet axis

A bit narrowing in between

Ratio > 1 in tail
⇒ Broadening in larger radii

Modification in Jet Shapes

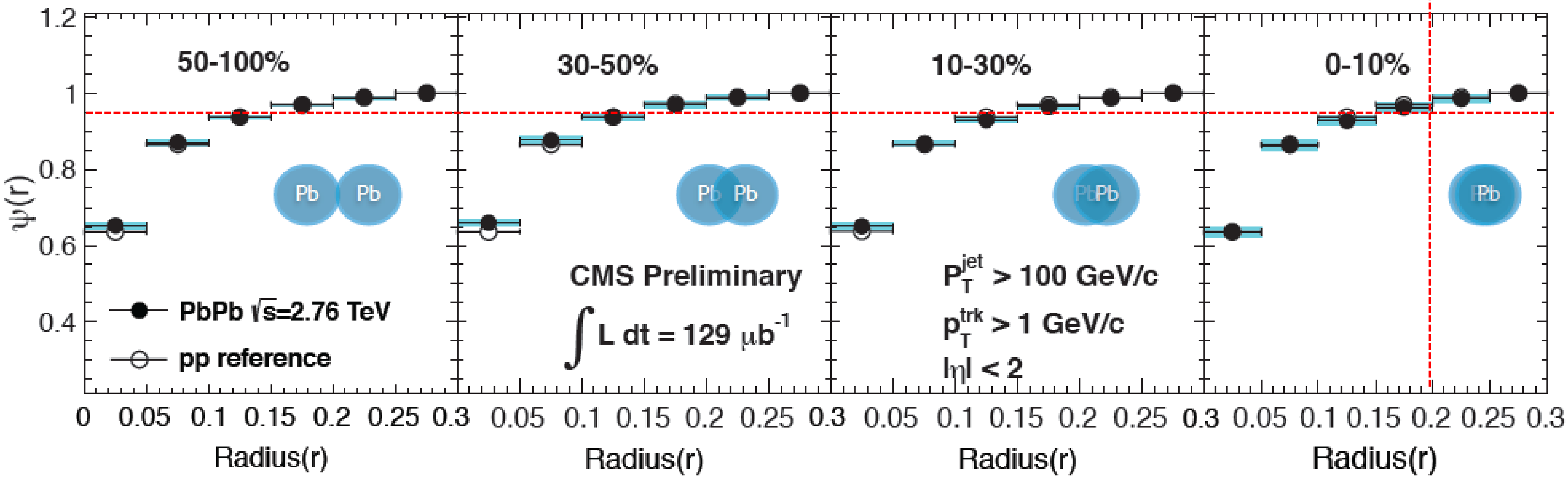
CMS PAS HIN-12-013



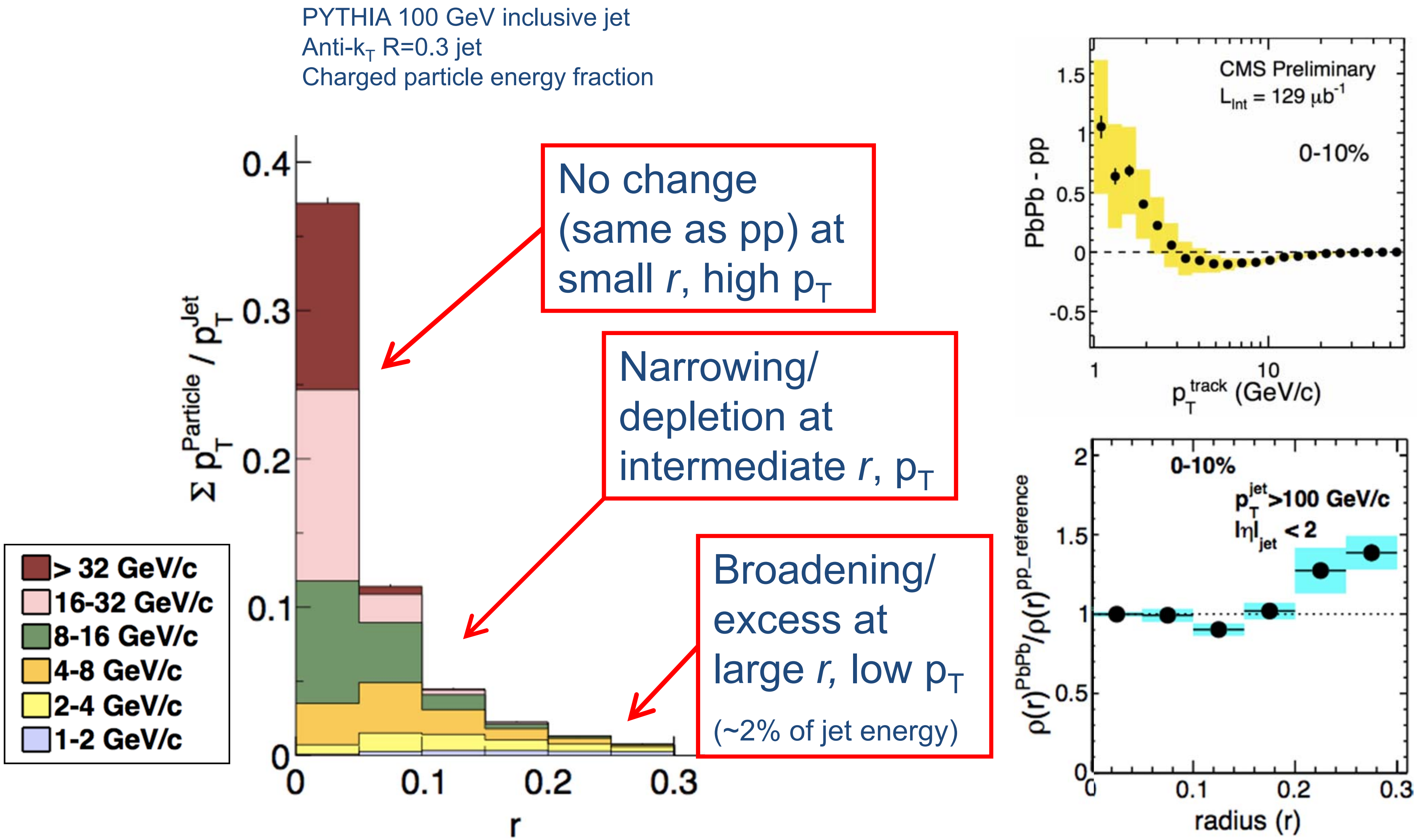
Integrated Jet Shape

$\Psi(r)$: average fraction of jet p_T inside the cone of radius r

More than 95% of the jet energy deposited in r < 0.2

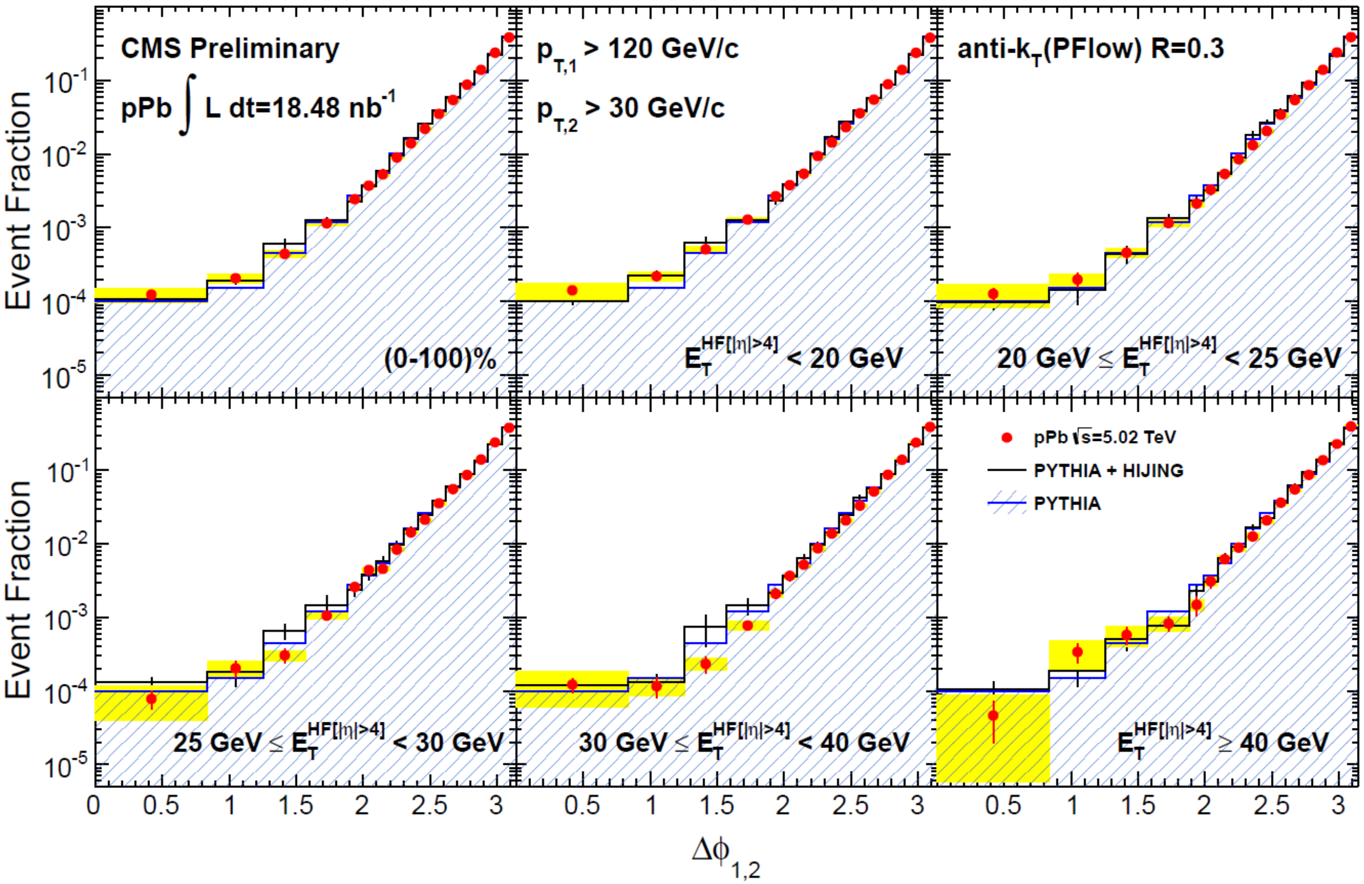


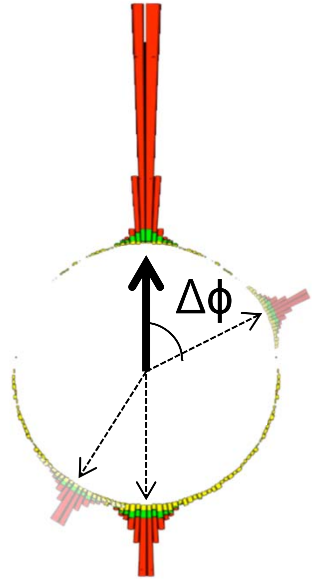
Anatomy of a Jet in PbPb

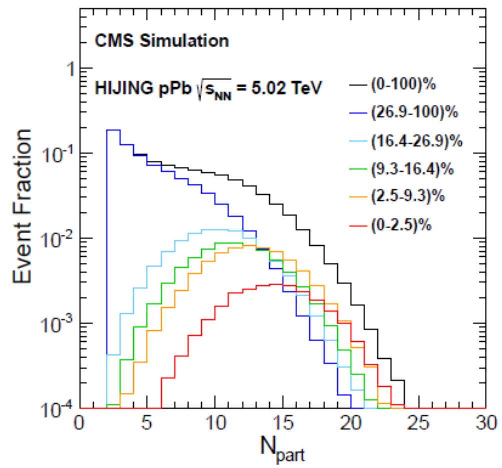


Dijet Angular Correlations in pPb

CMS PAS HIN-13-001



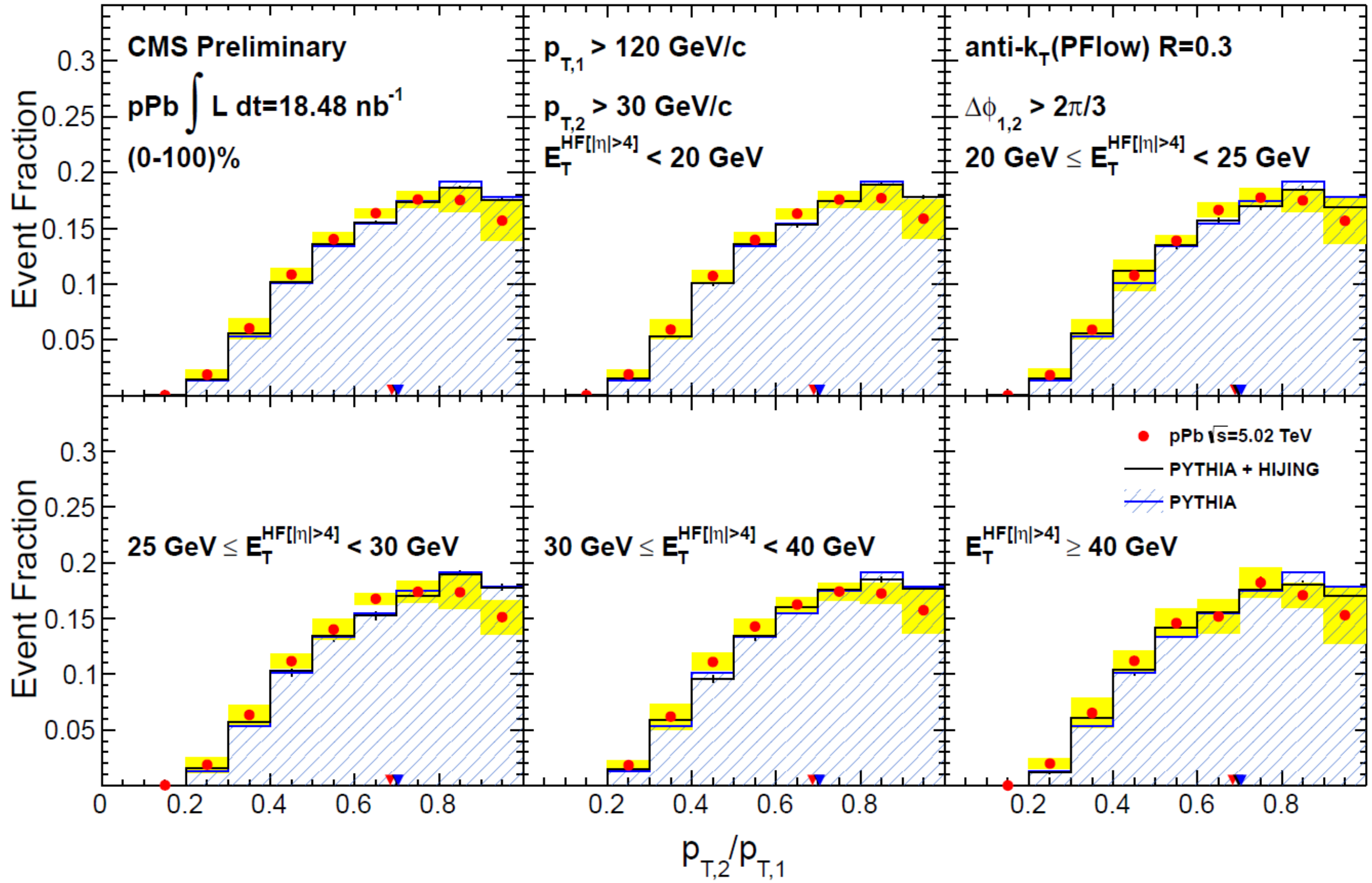




- $\Delta\phi$ distribution unchanged for all HF E_T bins

Dijet p_T Ratio Distributions in pPb

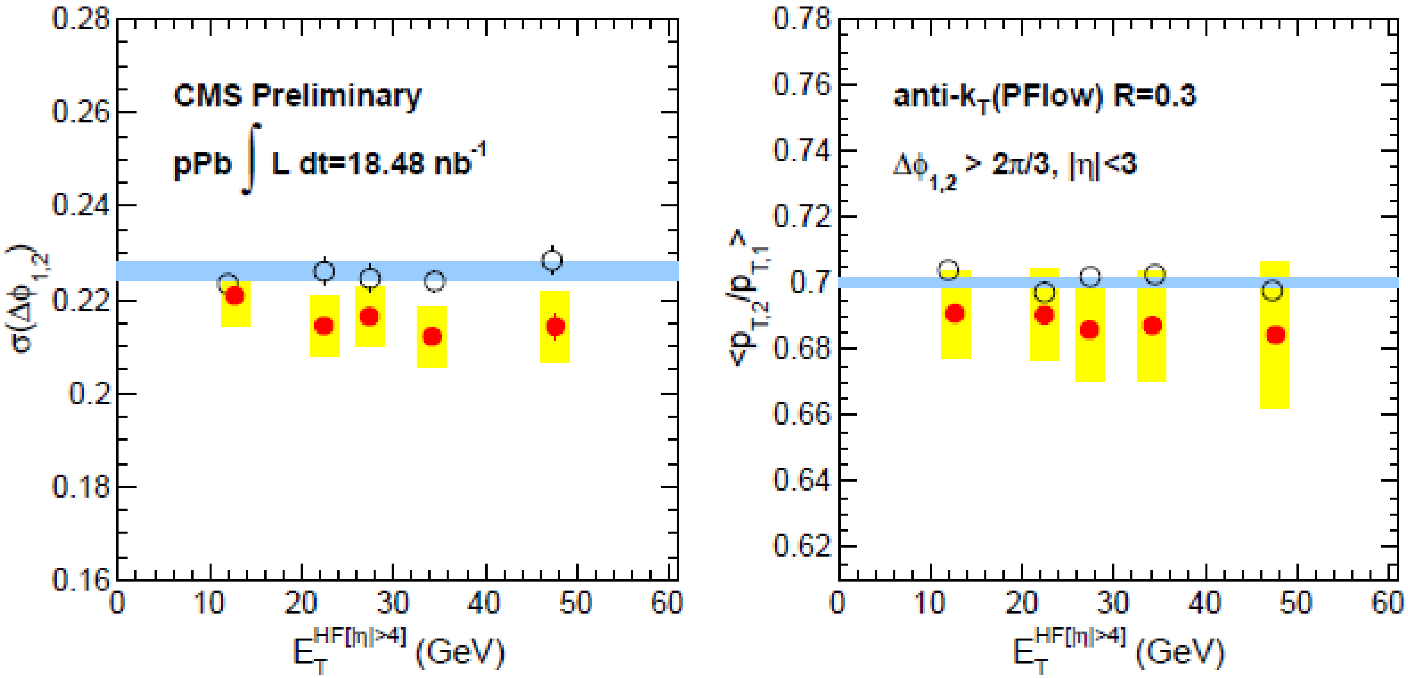
CMS PAS HIN-13-001



- No modification up to $E_T^{HF[|\eta|>4]}$ > 40 GeV (top 0~2.5%)
  - Not enough statistics in PbPb for the same $E_T^{HF[|\eta|>4]}$ interval

Summary of Dijet Properties in pPb

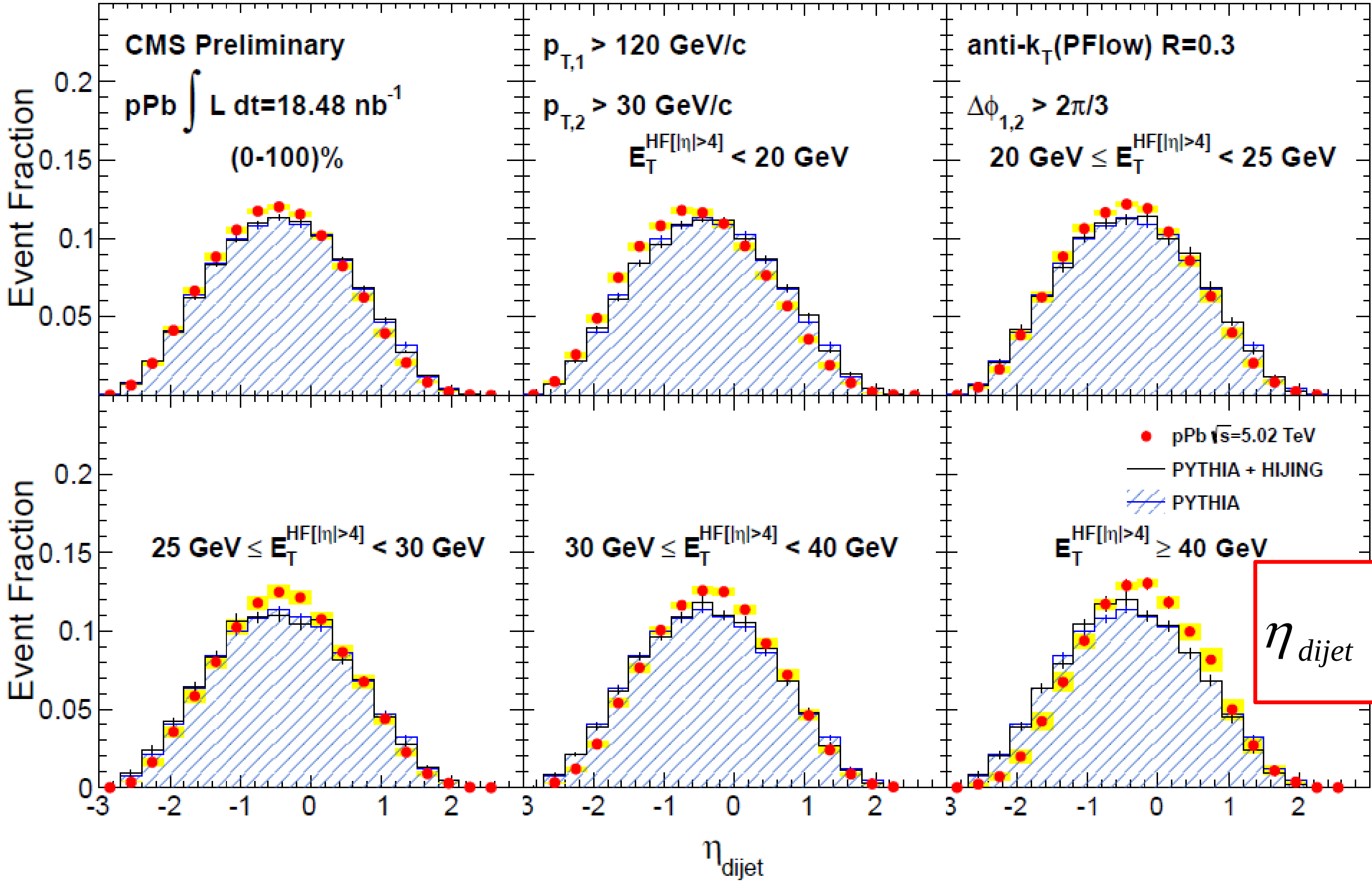
CMS PAS HIN-13-001



- With the present uncertainties, no change in the $\Delta\phi$ width and the p_T ratio values for all $E_T^{HF[|\eta|>4]}$ bins
- Deadly boring? What about the original purpose of pPb collisions for determining nPDF?

η_{dijet} Distributions in pPb

CMS PAS HIN-13-001

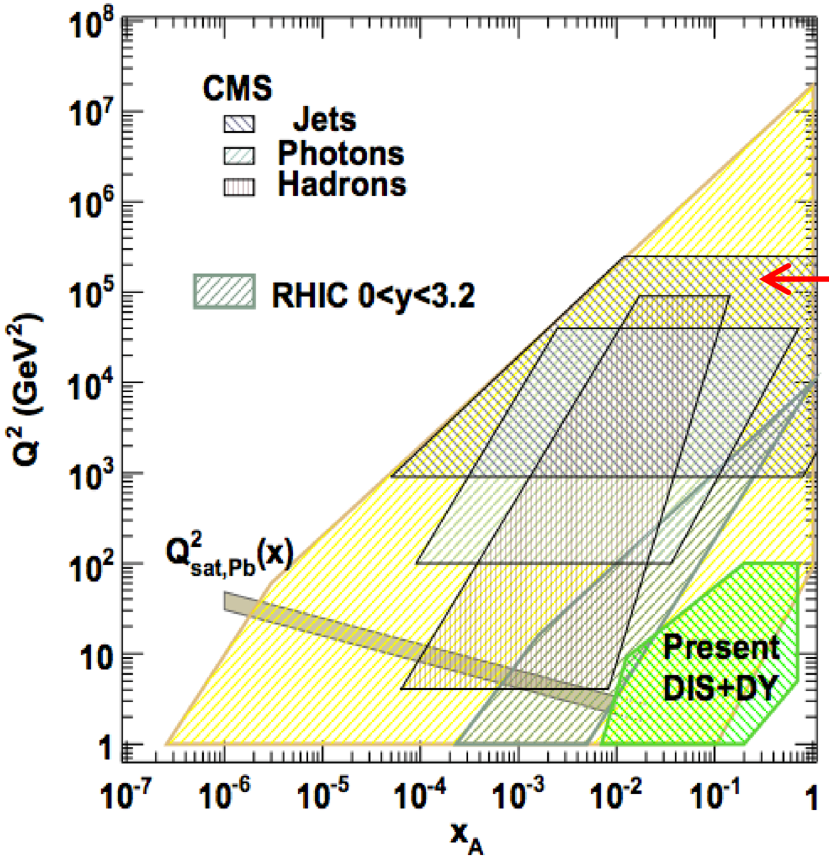


$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2}$$

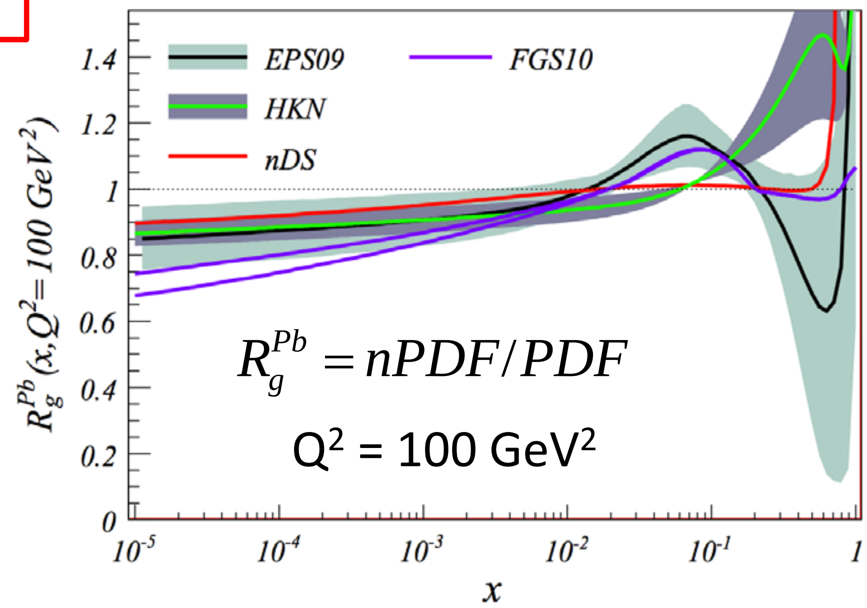
- η_{dijet} distributions plotted against PYTHIA references
- A systematic shift in the positive η_{dijet} direction vs. HF energy

Measuring nPDF using pPb

Kinematic reach for CMS
pPb @ √s = 8.8 TeV (0.1 pb^{-1})



Jets in CMS cover high Q^2 in $10^{-4}<x<1$



$R_g^{Pb} = nPDF/PDF$

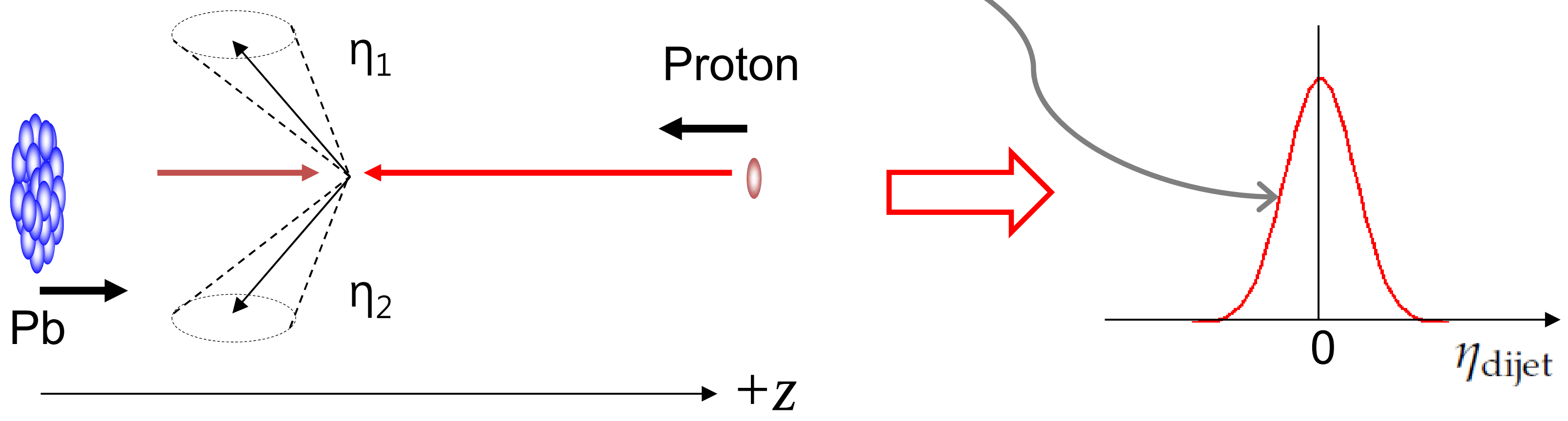
$Q^2 = 100\ GeV^2$

C. A. Salgado et al., J.Phys. G39 (2012) 015010

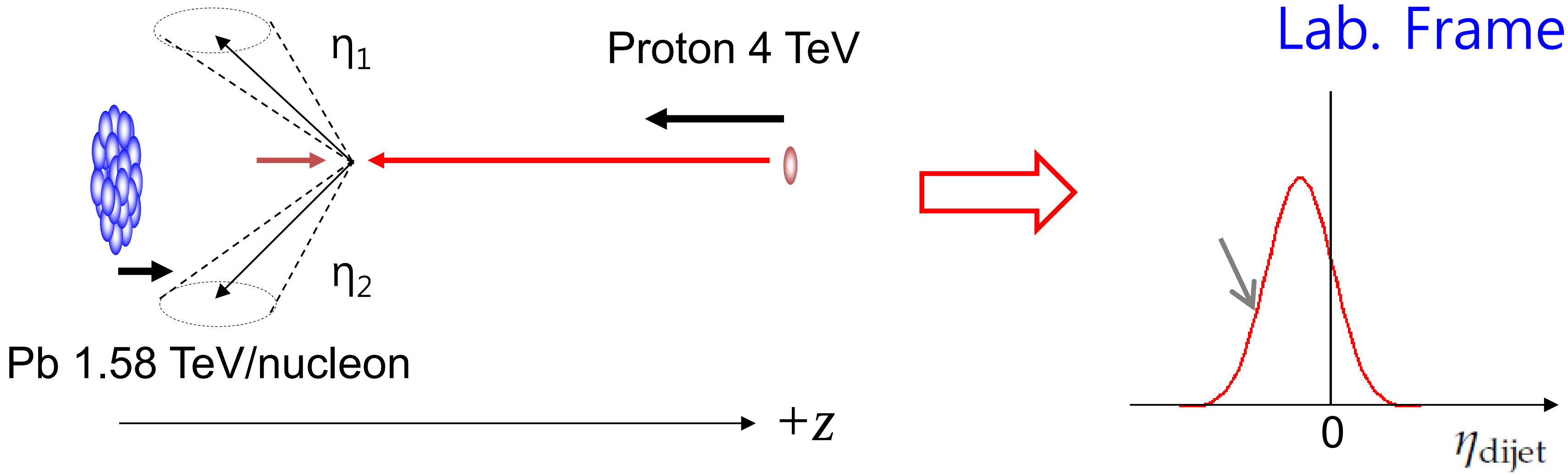
Some Kinematics in pPb

E.g., Low x from Pb/Large x from p

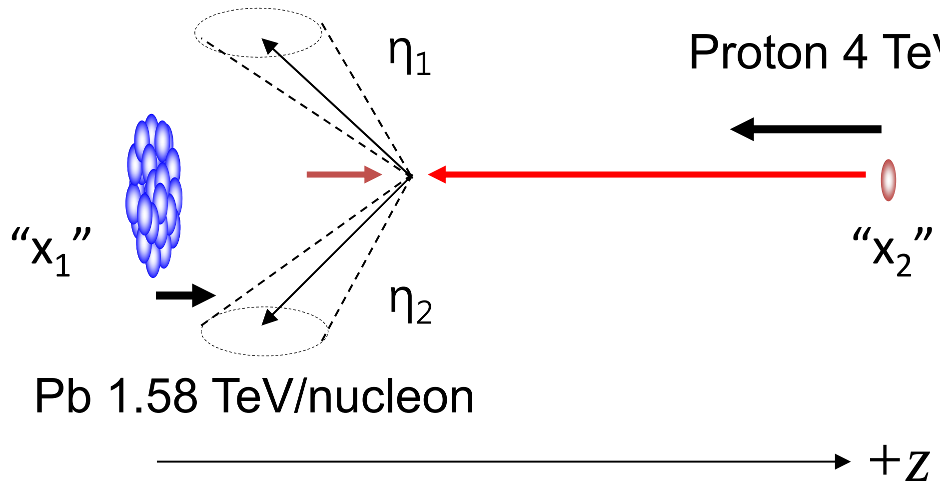
CM. Frame

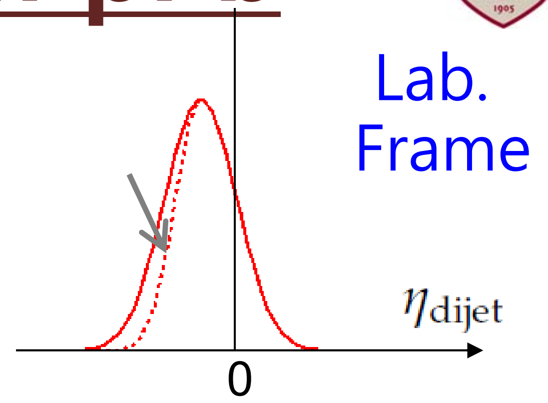


Lab. Frame

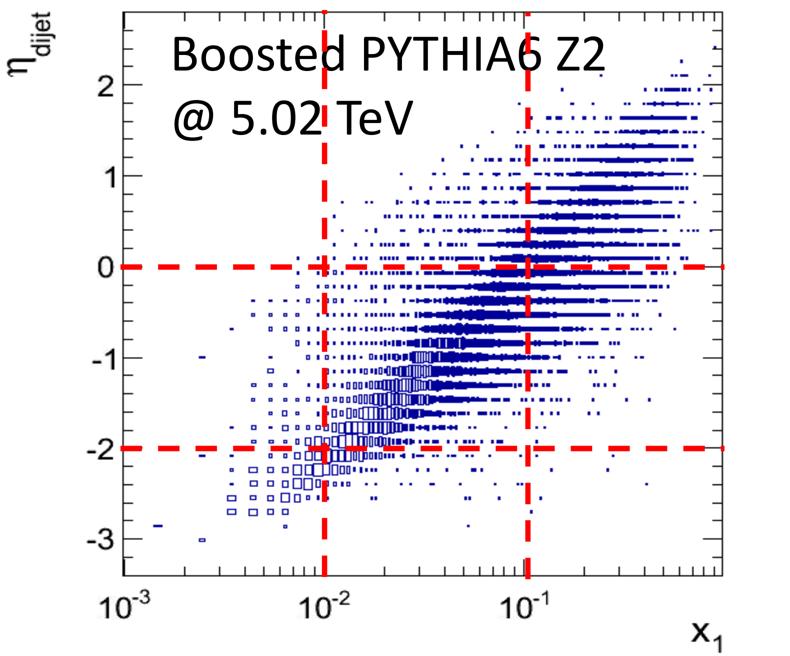


Some Kinematics in pPb

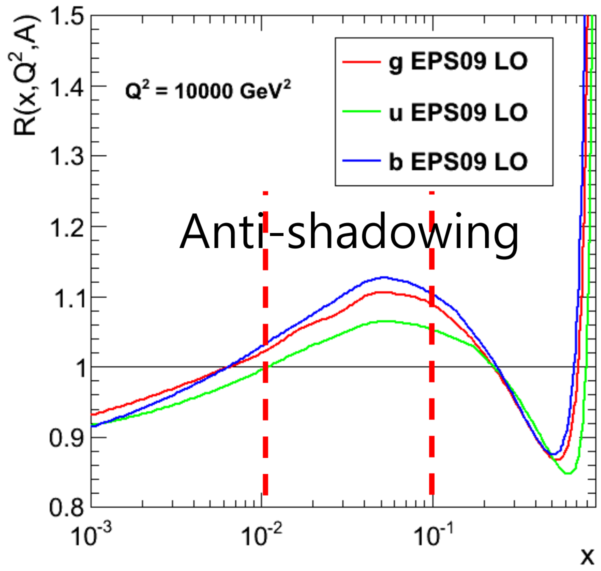




Suppression of low-x partons in Pb
⇒ Depletion of dijet with $\eta_{dijet} < 0$



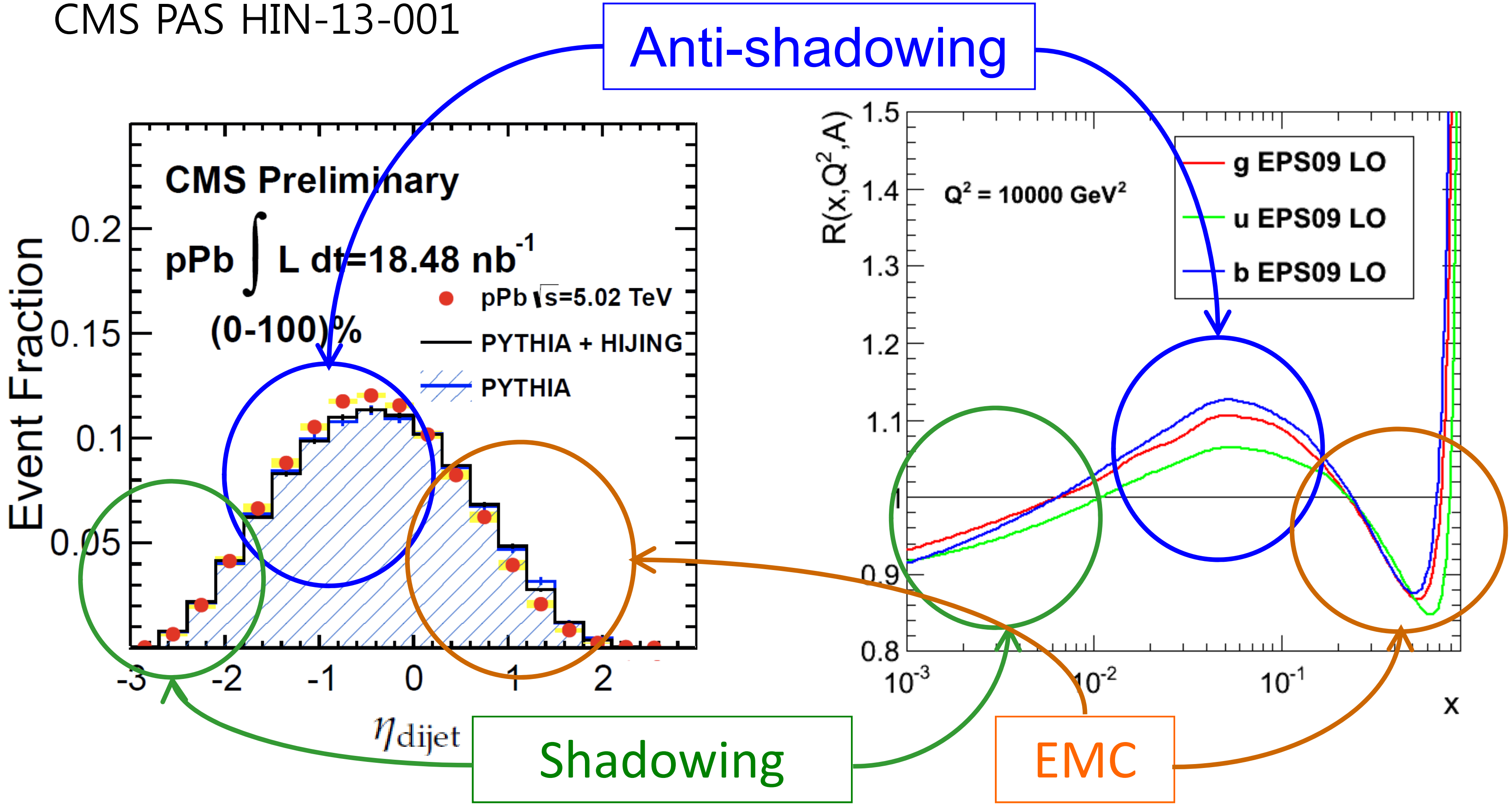
($p_{T,1}$>120 GeV/c, $p_{T,2}$>30 GeV/c, $|\Delta\varphi_{12}|$>2π/3)



François Arleo and Jean-Philippe Guillet
http://lapth.cnrs.fr/npdfgenerator/

η_{dijet} Distribution for Probing nPDF

CMS PAS HIN-13-001

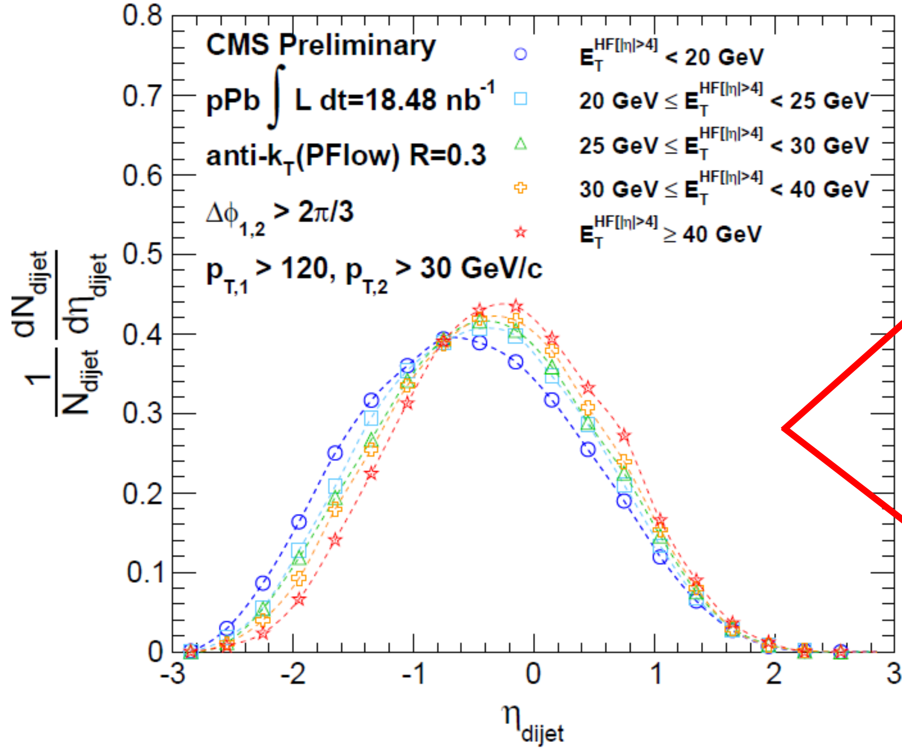


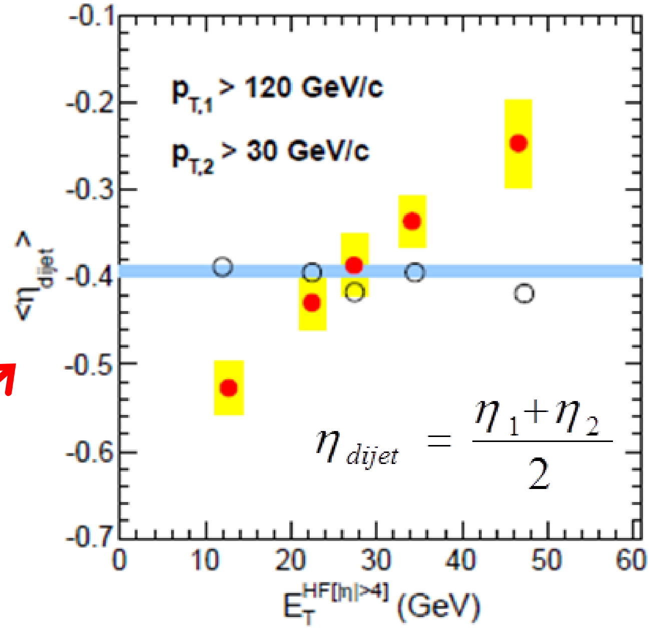
- Suppression and enhancement in the η_{dijet} distribution $\approx$ x dependence of the parton distributions in nuclei

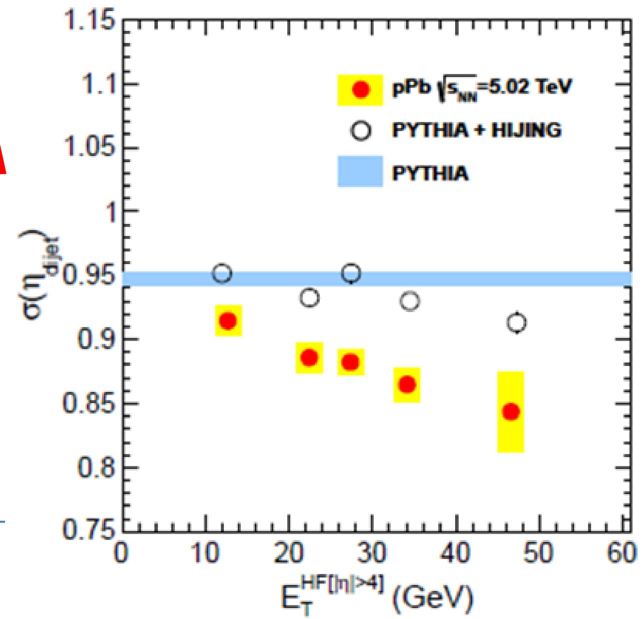
η_{dijet} in Different Event Classes

CMS PAS HIN-13-001

Normalized by N_{dijet}

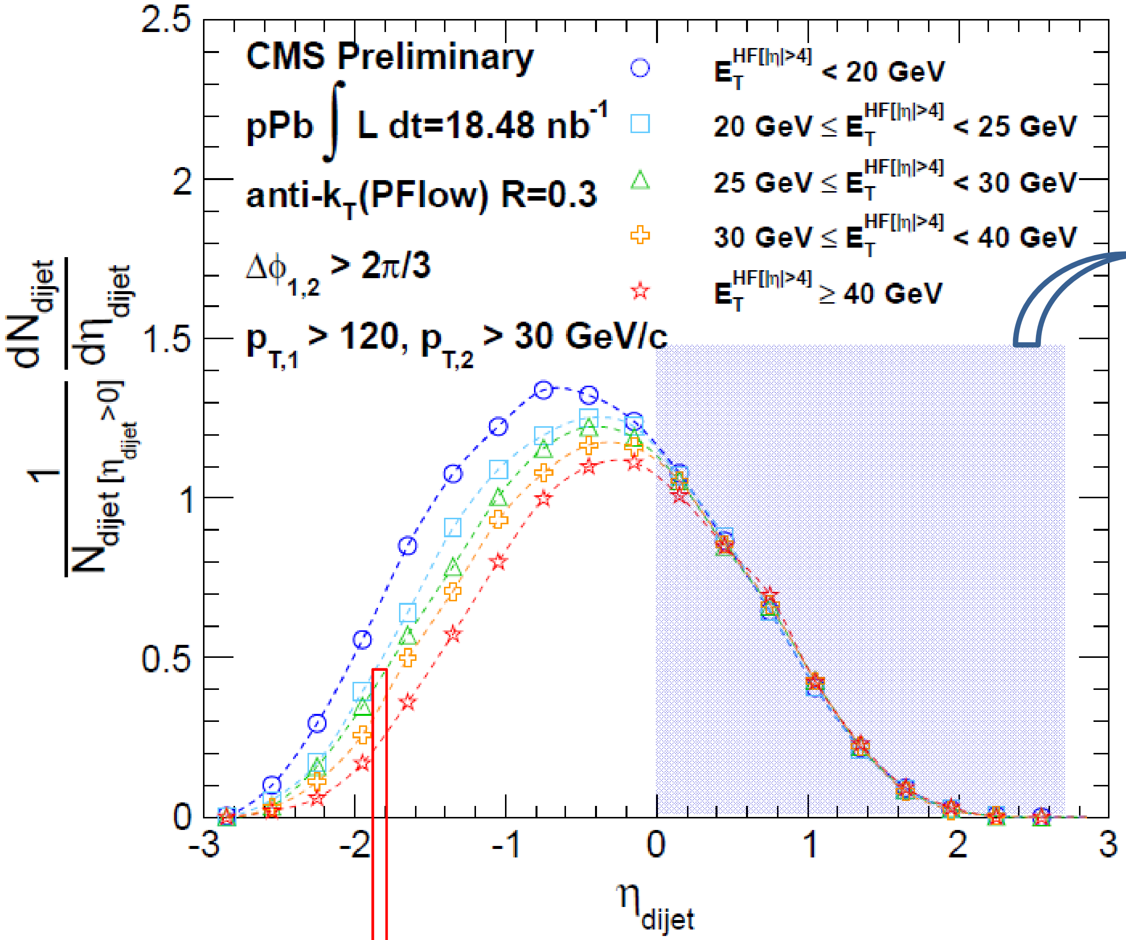






- As $E_T^{HF[|\eta|>4]}$ increases, $<\eta_{dijet}>$ also increases and partons with larger x in Pb are probed.

Normalized η_{dijet} Distributions



CMS PAS HIN-13-001

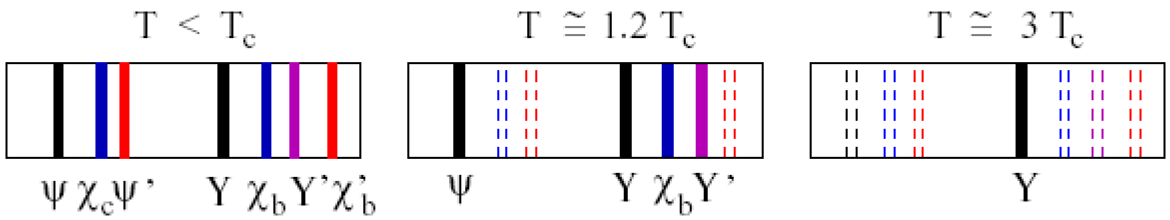
Normalized by the distribution of the area for $\eta_{dijet}>0$ to compare the shape

$\Rightarrow$ The same shape in "EMC region"?

Evolving "shadowing region": quantitative constraints on nPDF will be possible.

Quarkonium in Heavy Ions

- Powerful tool to probe QGP
  - Large mass requires a hard gg scattering at early stage
  - Color Debye screening causes sequential melting of various quarkonium states [Matsui & Satz, PLB 178, 416 (1986)]

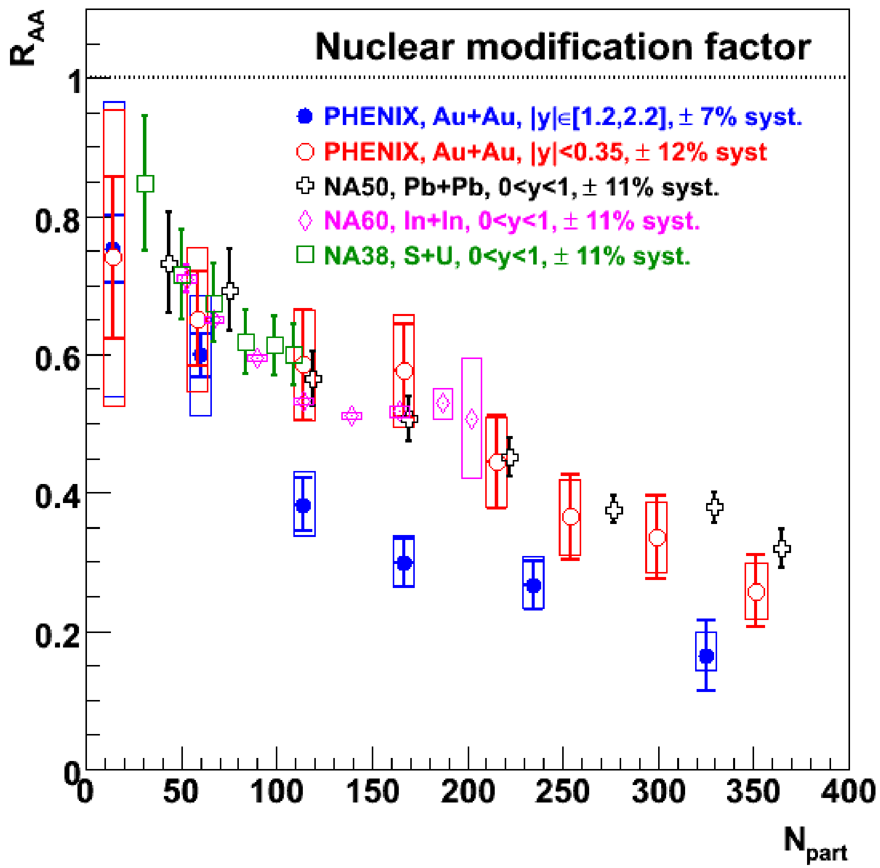


- Complications already in pp & pA
  - Nonperturbative hadronization is not well understood.
    - No model is available to explain the cross section and polarization simultaneously in pp.
  - Cold nuclear matter effect & breakup cross section
- Puzzles in AA collisions
  - Similar suppression at RHIC and SPS
  - More suppression in forward than in midrapidity at RHIC

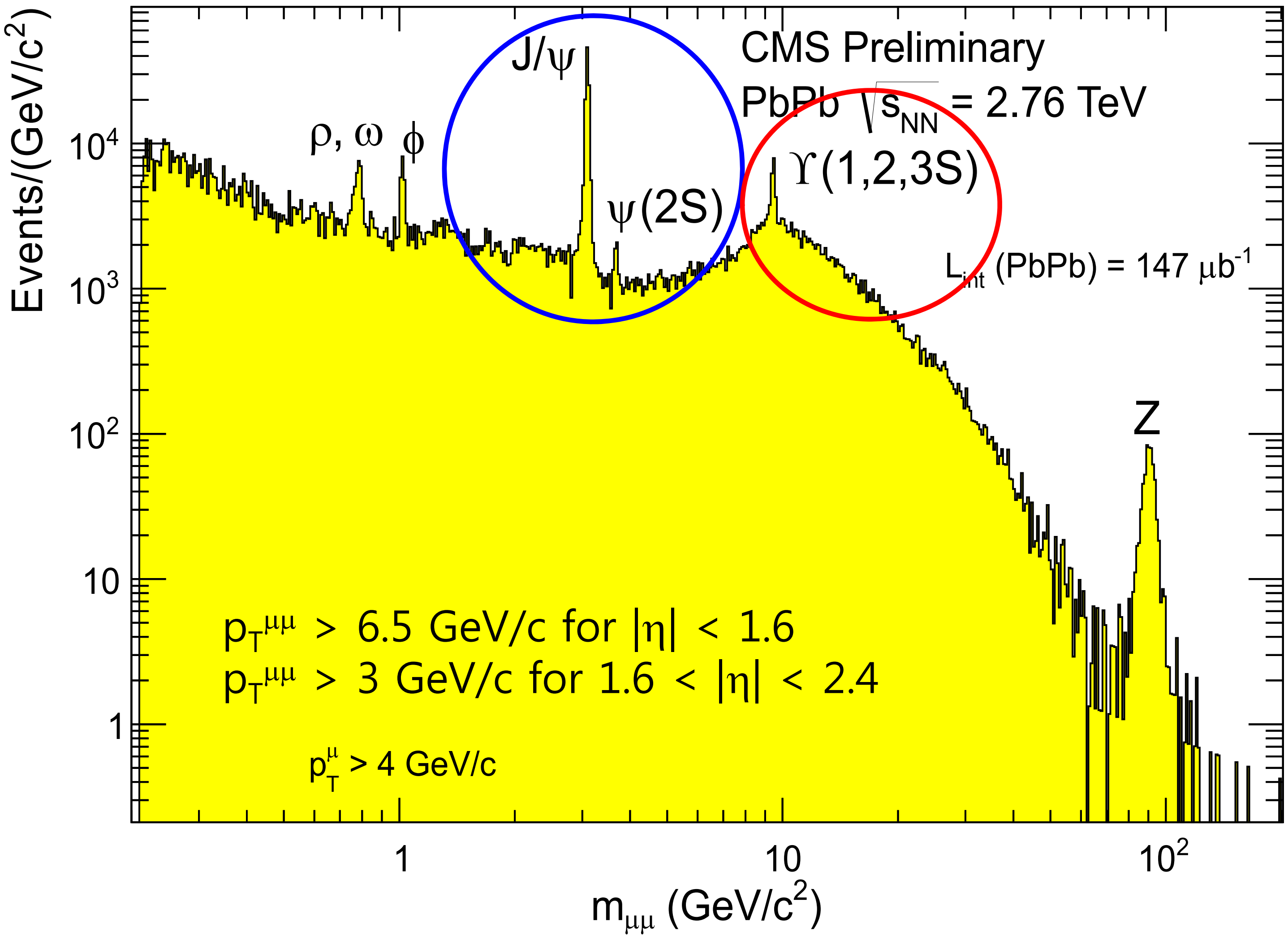
J/ψ at Lower Energies

- Two puzzles
  1) At mid-rapidity, similar suppression at RHIC & SPS (200 vs. 17 GeV), while density must be higher at RHIC.
  2) More suppression at forward rapidity where density must be lower.
- Possible explanations
  1) Cold: shadowing, saturation brings the forward yield down.
  2) Hot: recombination of uncorrelated $c\bar{c}$ brings the mid-rapidity yield up.

$$R_{AA}(p_T) = \frac{d^2N_{AA}/dp_T d\eta}{< T_{AA} > d^2\sigma_{NN}/dp_T d\eta}$$



$\mu^+\mu^-$ Invariant Mass Spectrum

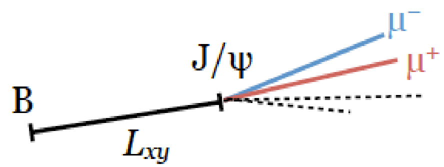


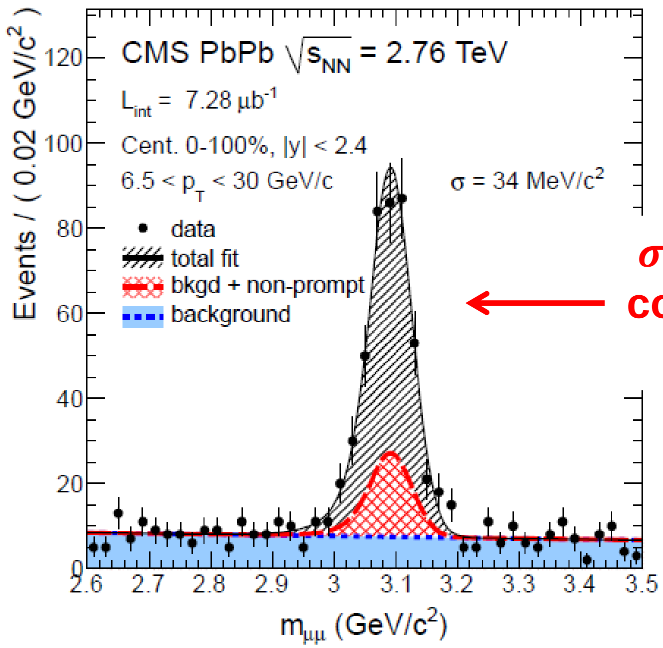
J/ψ Analysis

Inclusive J/ψ
- **Prompt J/ψ**
  - **Direct J/ψ**
  - **Feed-down from ψ' and χ_c**
- **Non-prompt J/ψ from B decays**

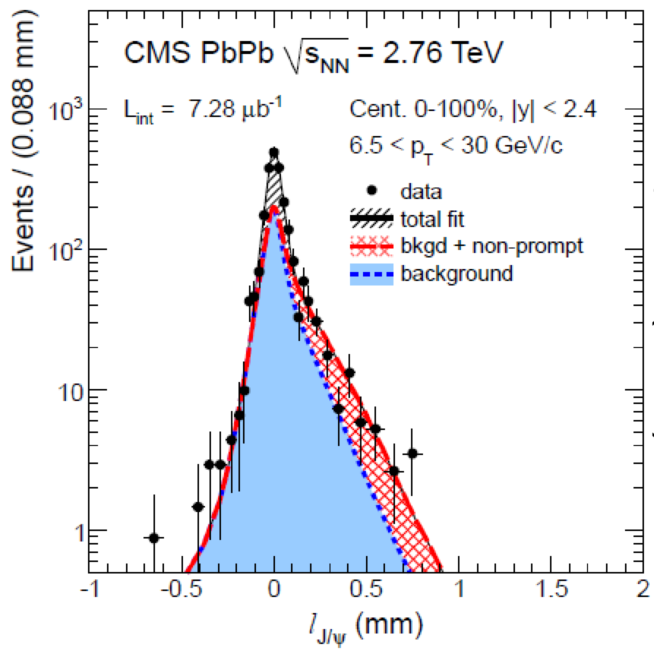
- Simultaneous fit
  - $\mu^-\mu^+$ invariant mass
  - Pseudo-proper decay length

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





σ_m=34 MeV comparable to pp



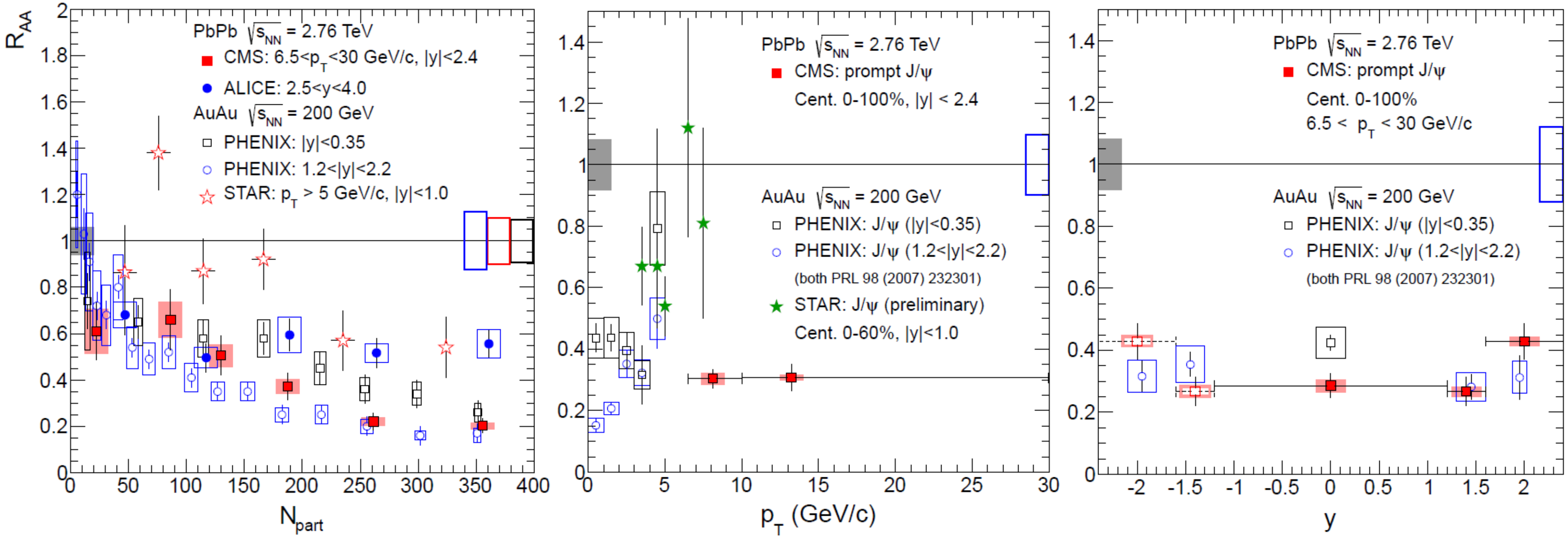
JHEP 05, 063 (2012)

Prompt J/ψ

JHEP 1205, 063 (2012)

L_{int} = 7.28 μb^{-1}

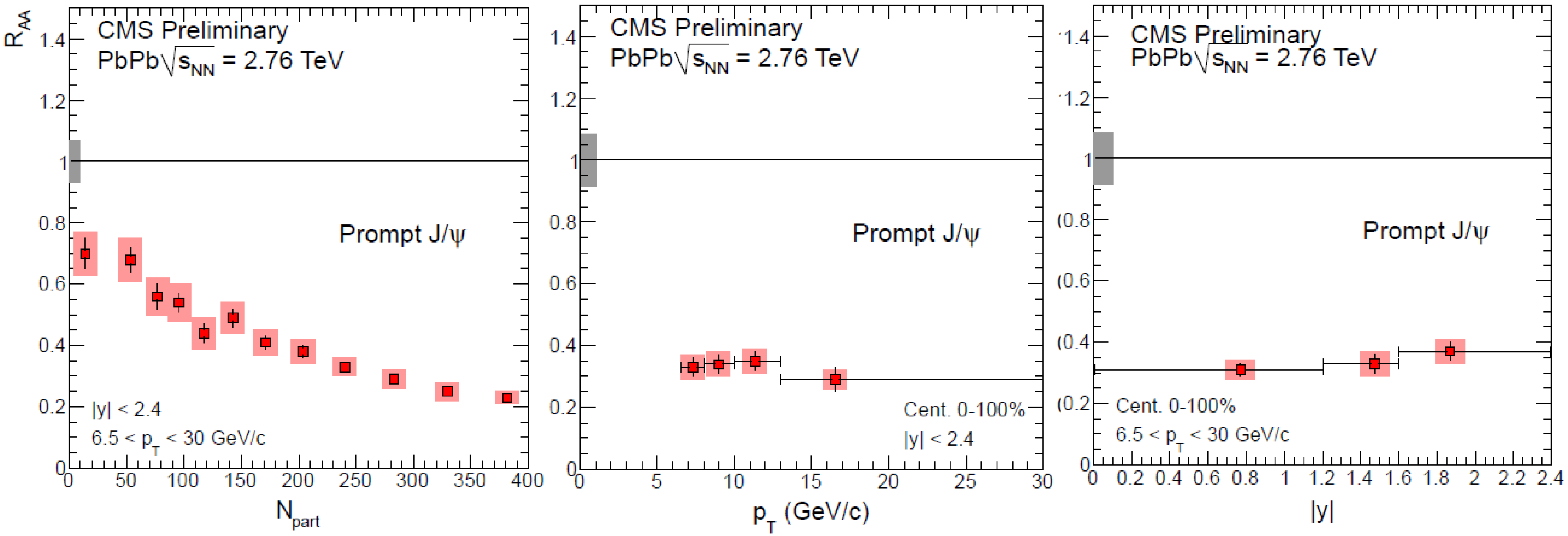
$$R_{AA}(p_T) = \frac{d^2N_{AA}/dp_T d\eta}{< T_{AA} > d^2\sigma_{NN}/dp_T d\eta}$$



- CMS measures J/ψ at high p_T > 6.5 GeV/c
  - Factor 5 suppression for the most central 10%
- CMS, ALICE, PHENIX and STAR measure different phase space
  - Require more systematic study for definite conclusions

Prompt J/ψ

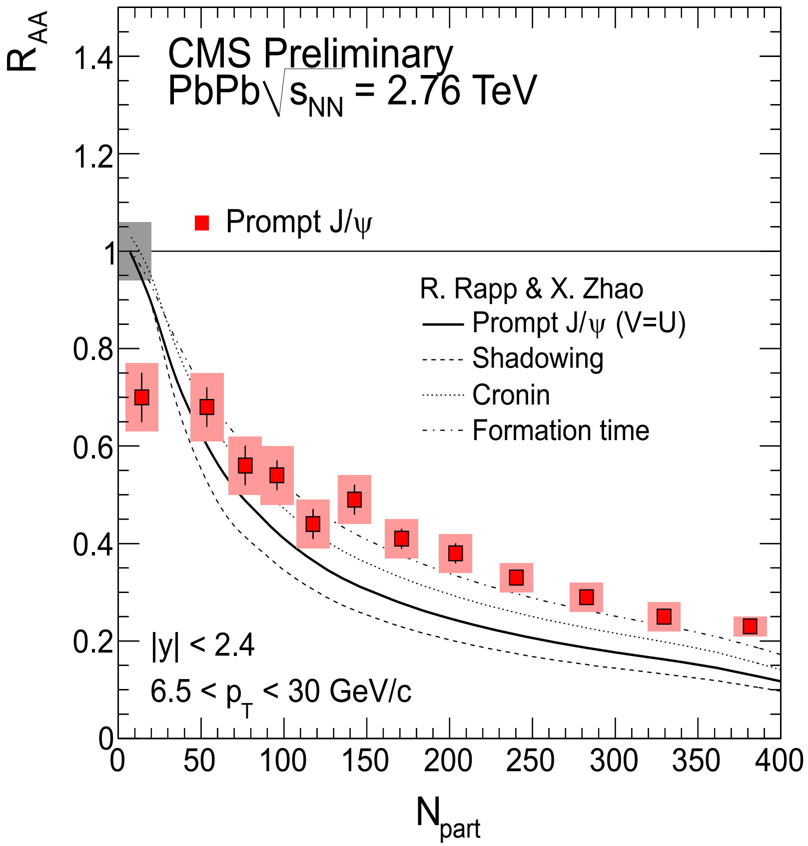
CMS PAS HIN-12-014, L_{int} = 150 μb^{-1}



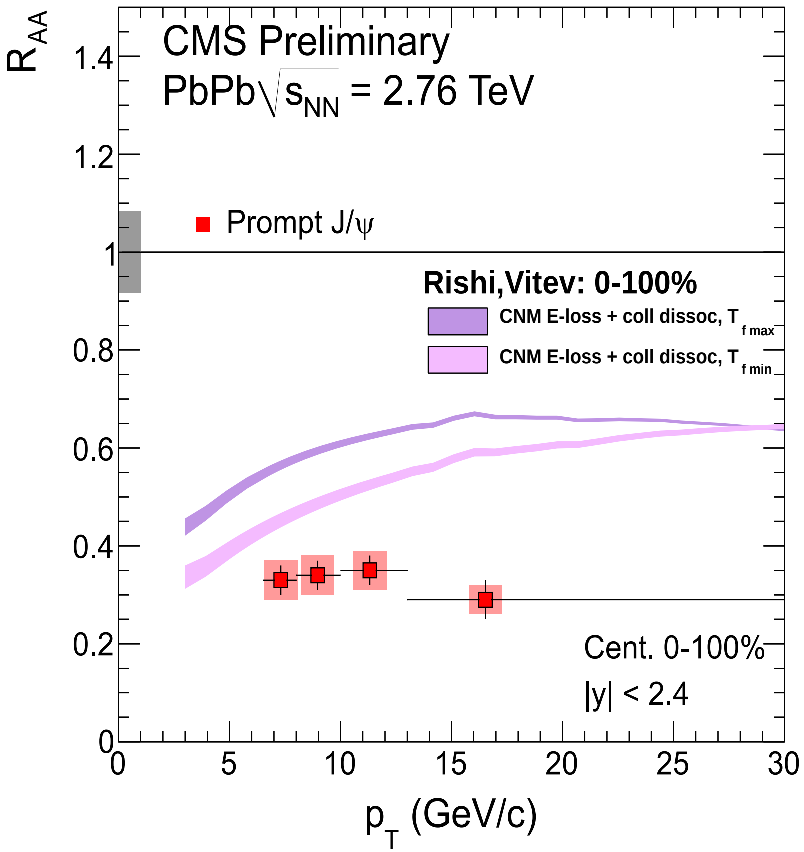
- CMS measures J/ψ at high p_T > 6.5 GeV/c
  - Factor 5 suppression for the most central 10%

Model Comparison for Prompt J/ψ

NPA 859, 114 (2011)+priv. comm.



arXiv:1203.0329+priv. comm.

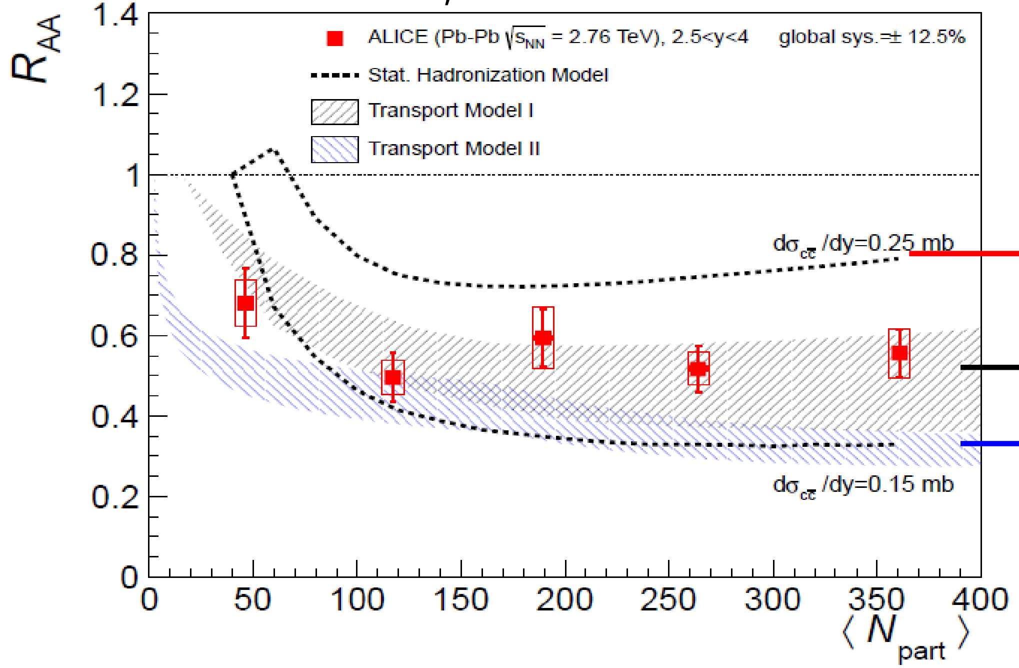


◀ No need for the regeneration component at high p_T

▶ Treatment of quarkonia energy loss similarly as open flavor energy loss, without color-octet included, is not supported by data

Need Recombination for Low p_T

ALICE, arXiv:1202.1383



Statistical Hadronization
Andronic et al.,
arXiv:1106.6321

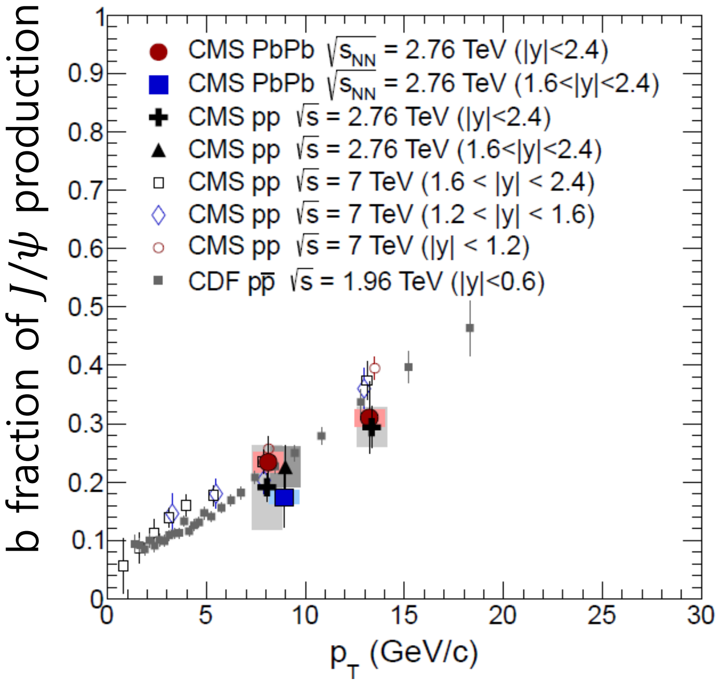
Transport Model I
Zhao & Rapp
NPA 859, 114 (2011)

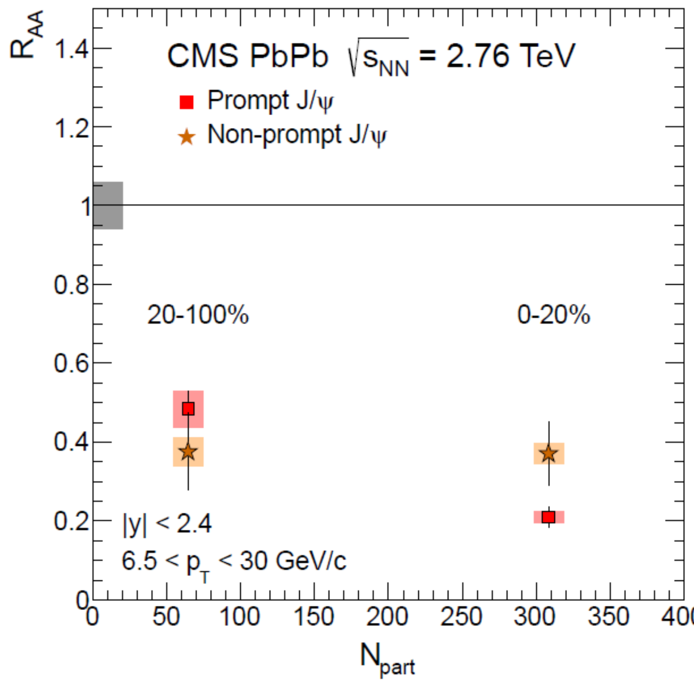
Transport Model II
Liu et al.,
PLB 678, 72 (2009)
– Upper limit: no shadowing
– Lower limit: with shadowing (artificially lower $d\sigma_{c\bar{c}}/dy$)

- Models are sensitive to $d\sigma_{c\bar{c}}/dy$
- The transport models are sensitive to the rate equation controlling the J/ψ dissociation and regeneration
  - For the most central collisions, recombination component is >50%

Non-prompt J/ψ

JHEP 1205, 063 (2012), L_{int} = 7.28 μb^{-1}

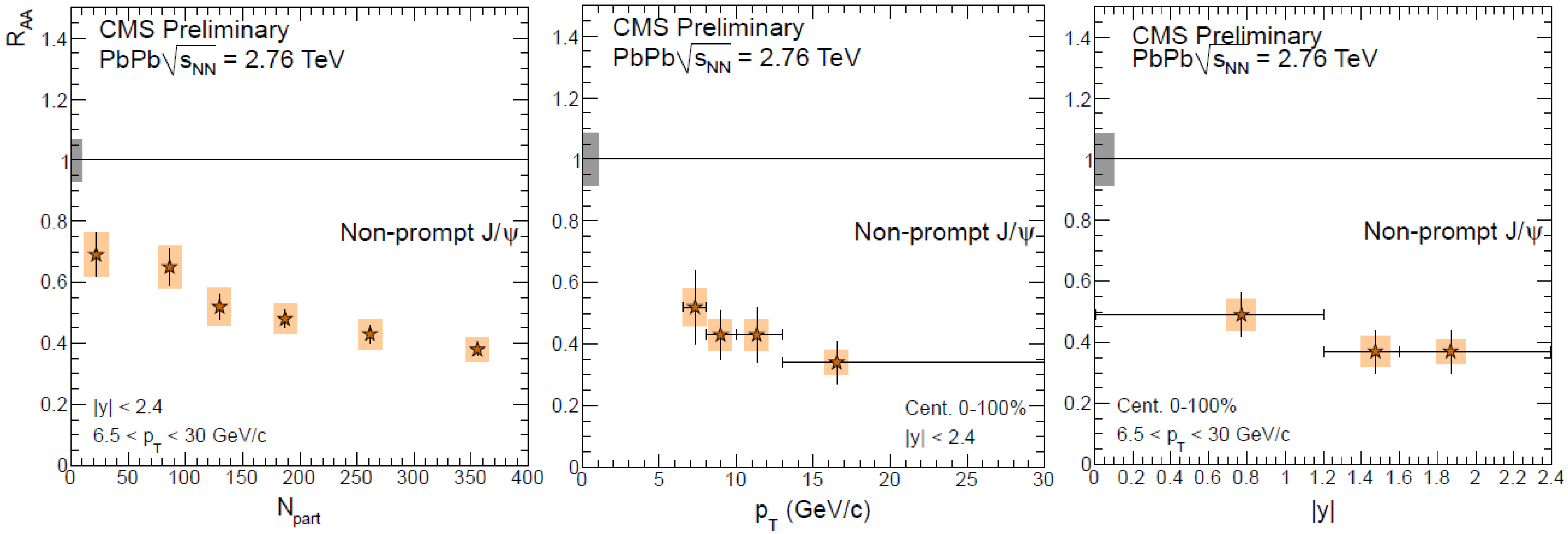




- Secondary J/ψ from B decay suppressed strongly
  - Factor ~3 suppression for the most central collisions
- b-quark energy loss in medium at low p_T

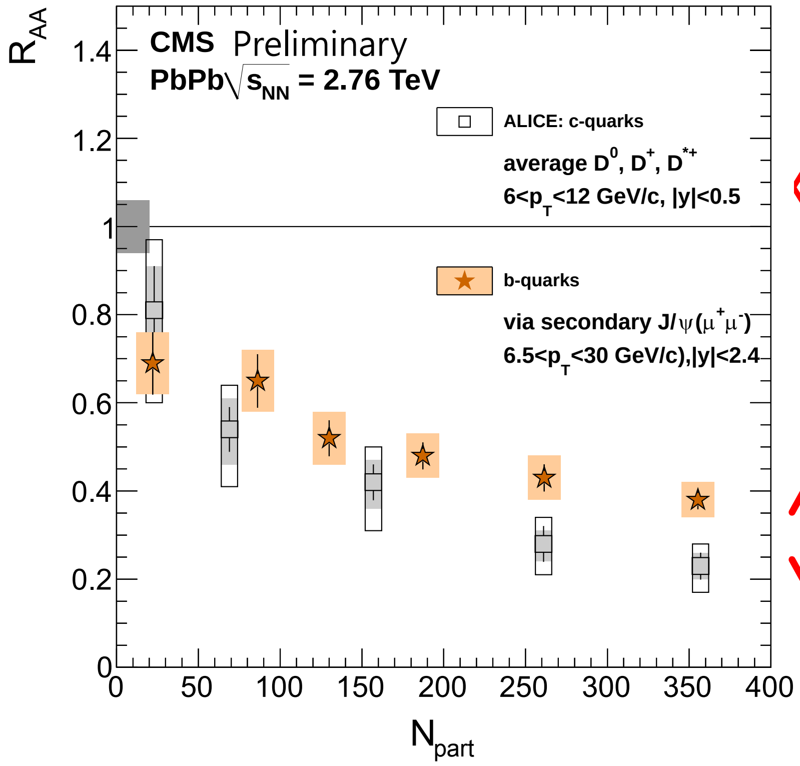
R_{AA} of Non-prompt J/ψ

CMS PAS HIN-12-014, L_{int} = 150 μb^{-1}



- Secondary J/ψ from B decay suppressed strongly
  - Factor ~3 suppression for the most central collisions
- b-quark energy loss in medium at low p_T

Comparisons for Non-prompt J/ψ



- Compare to ALICE D mesons

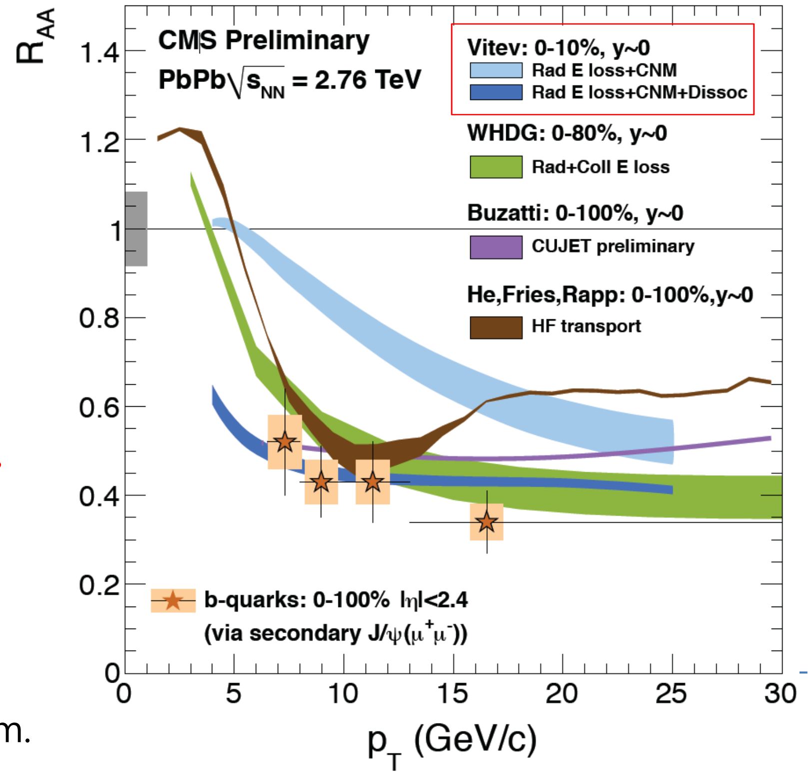
$$R_{AA}(B) > R_{AA}(D)$$

- Consistent with mass ordering
  - Dead cone effect?

CMS: PAS HIN-12-014
ALICE: JHEP 09, 112 (2012)

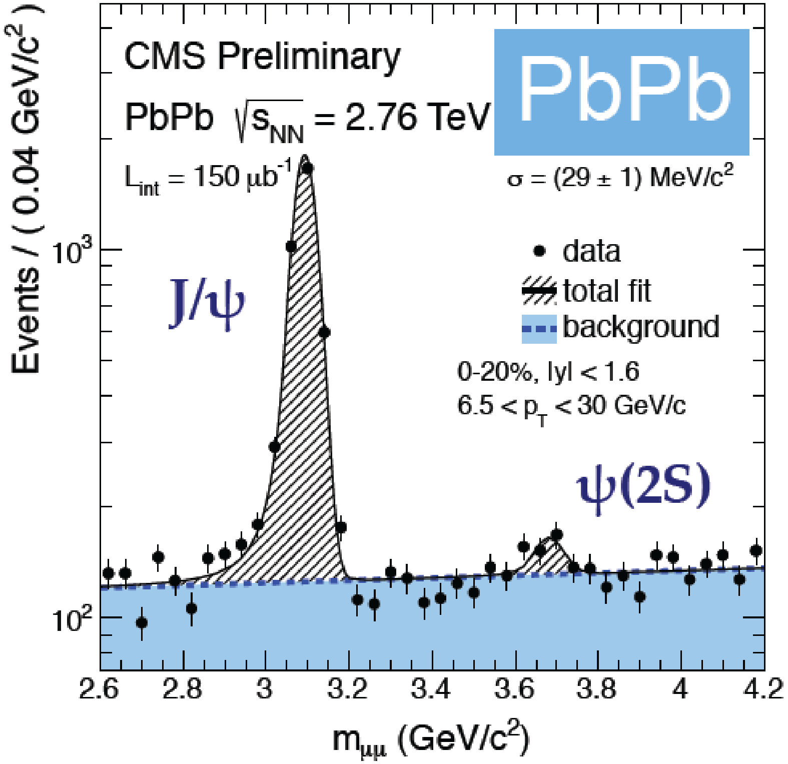
- Radiative energy loss is not enough to describe b-quark suppression

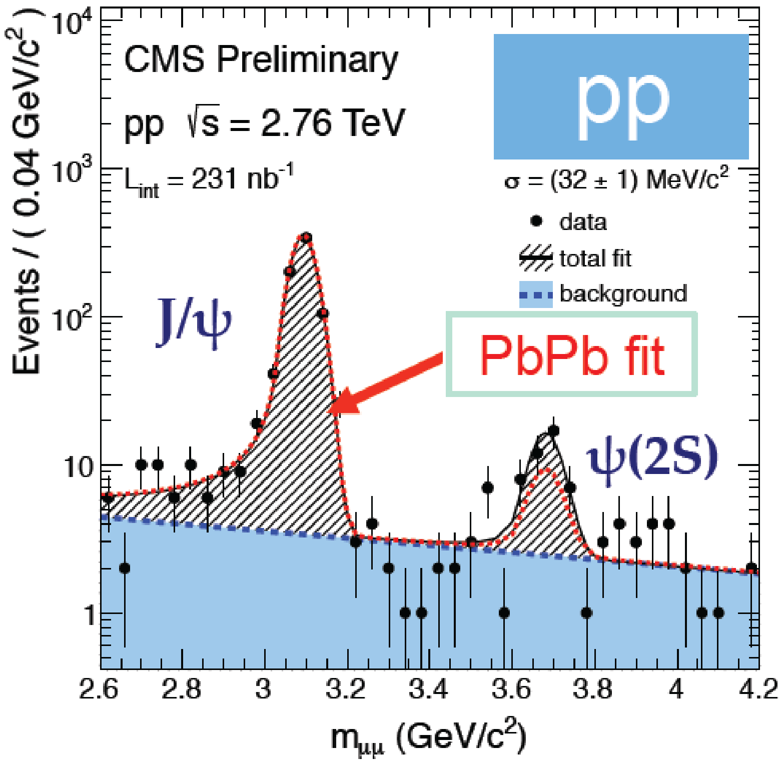
Vitev, J. Phys.G35, 104011 (2008)+private comm.
Horowitz, arXiv:1108.5876+private comm.
Buzzatti & Gyulassy, arXiv: 1207.6020+private comm.
He, Fries & Rapp, PRC86, 014903 (2012)+private comm.



Ψ(2S)

CMS PAS HIN-12-007

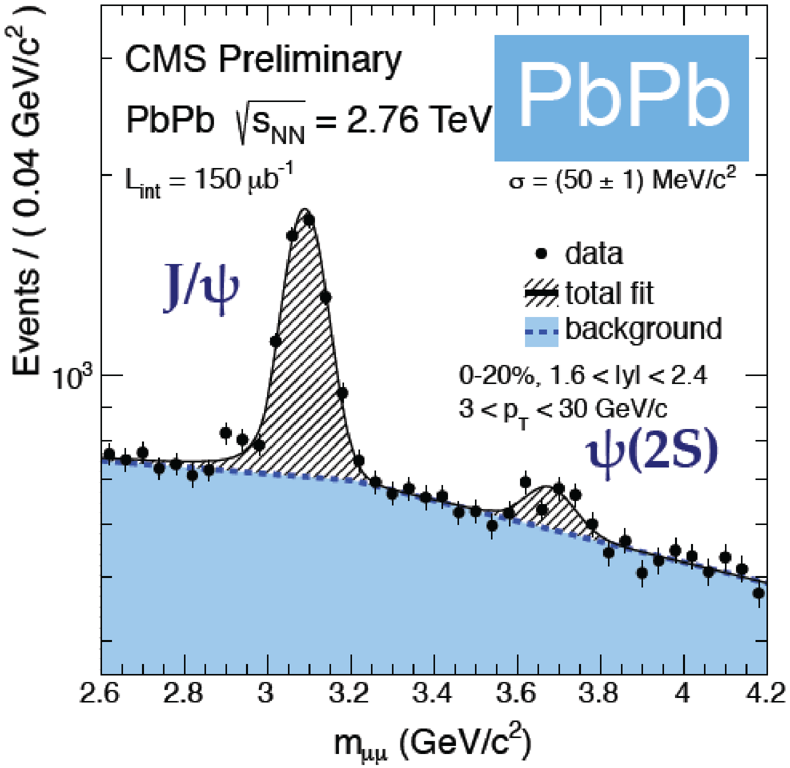


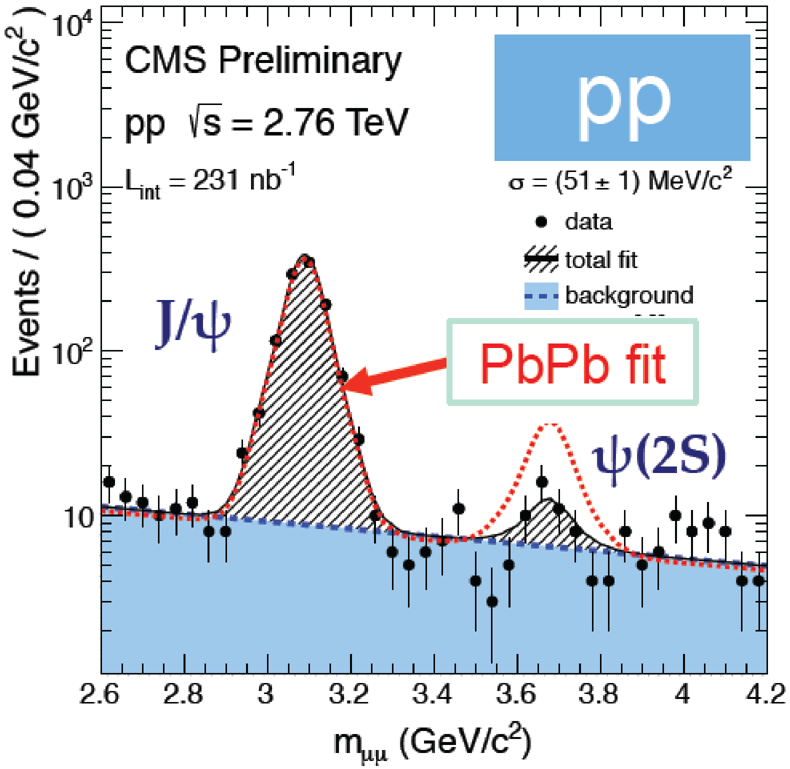


- $R_{\psi(2S)}$: raw yield ratio of ψ(2S) / J/ψ
- For 6.5 < p_T < 30 GeV/c and $|y|$ < 1.6
  $R_{\psi(2S)}$ in 0–20% PbPb ~2 times smaller than in pp

Ψ(2S)

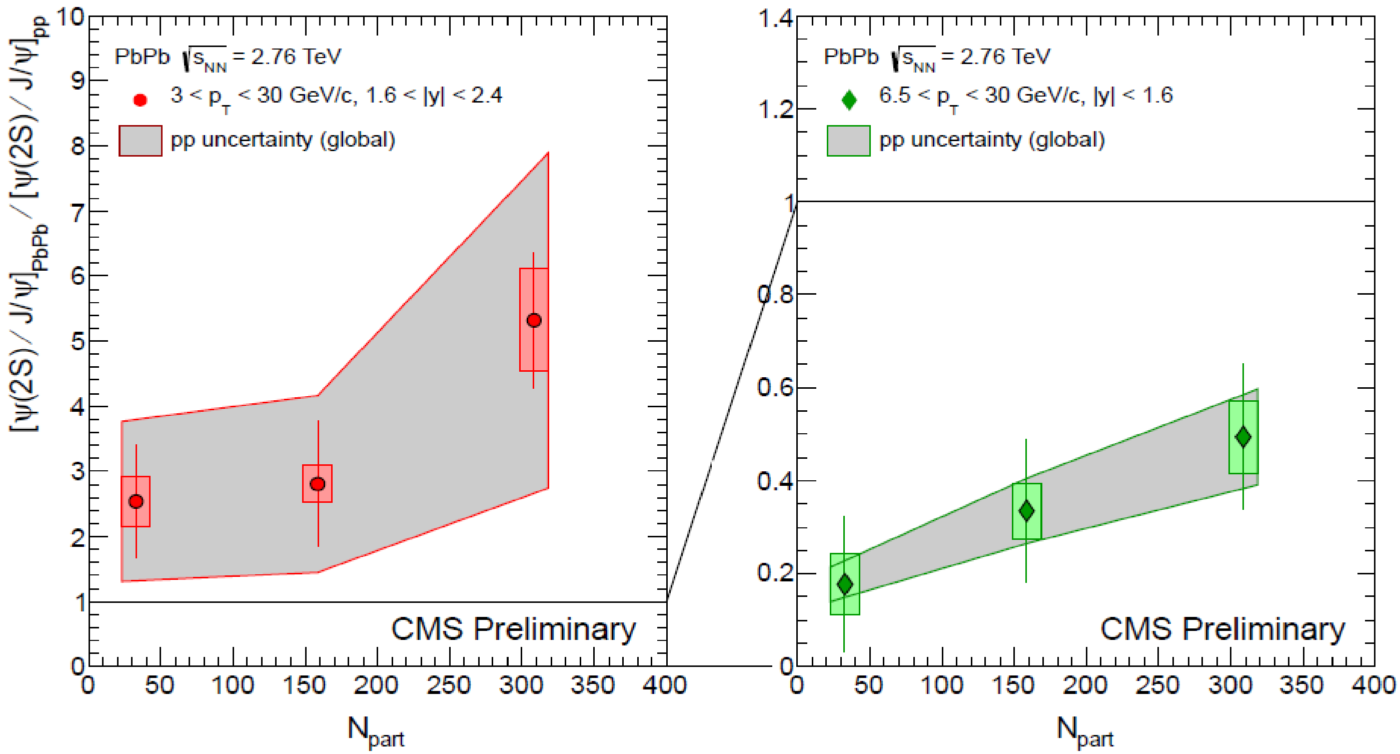
CMS PAS HIN-12-007





- For 3 < p_T < 30 GeV/c and 1.6 < $|y|$ < 2.4
  $R_{\psi(2S)}$ in 0–20% PbPb ~5 times larger than that in pp
  with LARGE systematic errors

Ψ(2S) / J/Ψ Double Ratio



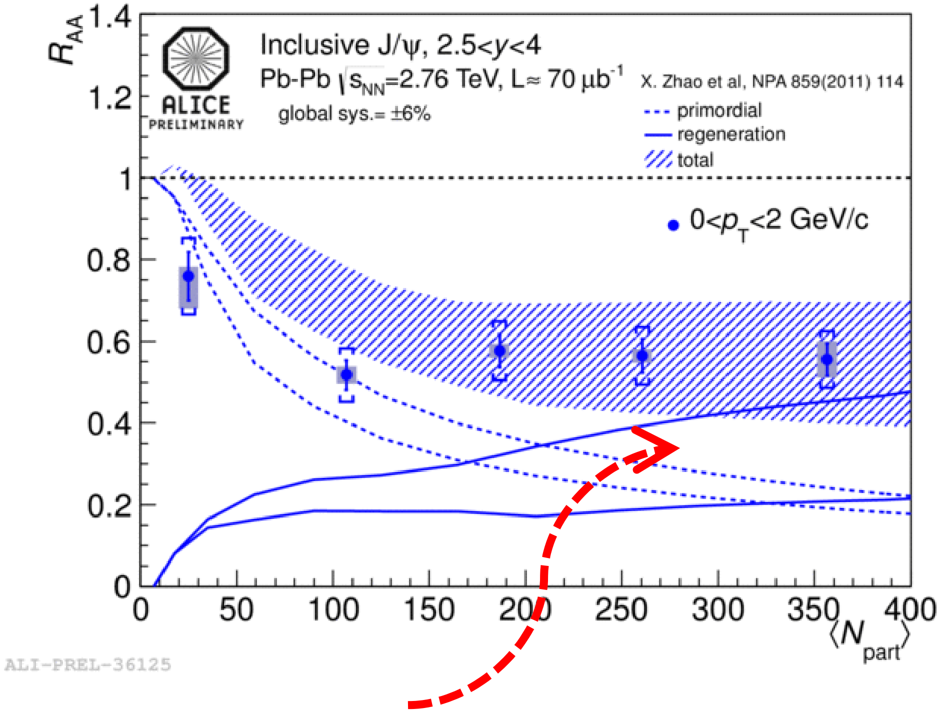
CMS PAS HIN-12-007

- For p_T>3 GeV/c & 1.6<$|y|$<2.4
  Indication of ψ(2S) being less suppressed than J/ψ (<2σ effect)
  Accuracy limited by pp statistics!
  (Need high-statistics 2013 data!)
- For p_T>6.5 GeV/c & $|y|$<1.6
  ψ(2S) are more suppressed than J/ψ

From J/Ψ To ϒ

ALICE, PRL 109, 072301 (2012)

(p_T > 0 GeV, 2.5 < y < 4)



- Recombination is significant for J/ψ at low p_T in central events

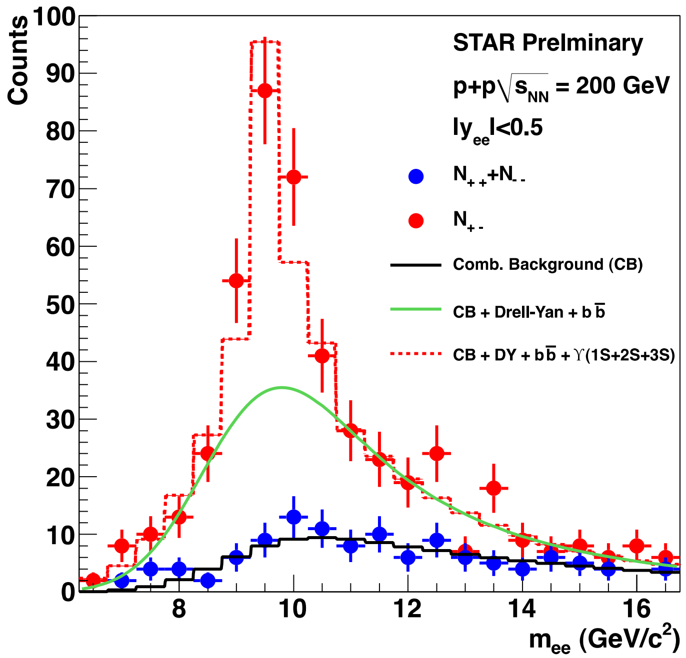
- Recombination is much smaller for ϒ than J/ψ
  - $\sigma_{b\bar{b}}/\sigma_{c\bar{c}} \cong 1/20$
    $\sigma_{c\bar{c}} = 6.10 \pm 0.93$ mb
    in pp at 7 TeV

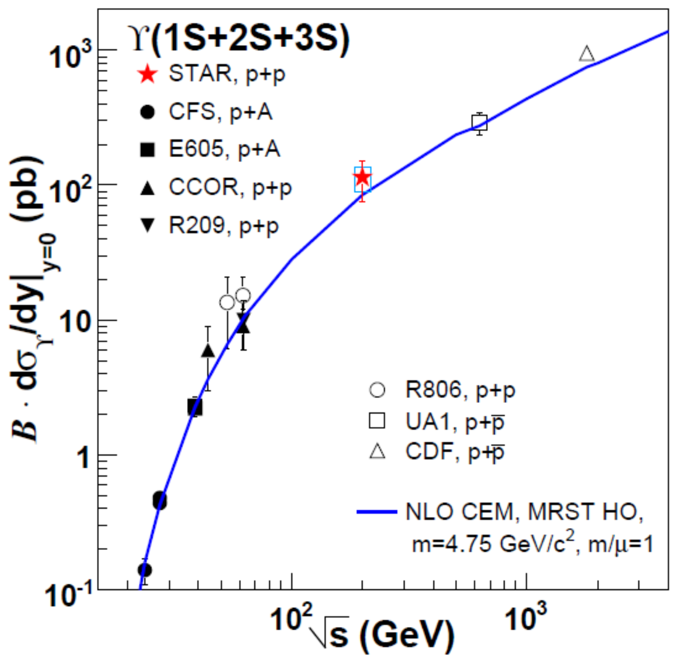
    [LHCb-CONF-2010-013]
- Co-mover absorption effect is smaller for ϒ than J/ψ
  - $\sigma_{h-\Upsilon}$ is expected to be significantly (about 5~10 times) smaller than $\sigma_{h-J/\psi}$
  - Absorption cross section $\sigma_{h-\Upsilon}$ ~0.2 mb at 150 MeV

    [Lin & Ko, PLB 503, 104 (2001)]

ϒ at Lower Energy

- Recent pp data at 200 GeV by dielectron channel at |y| < 0.5
- Consistent with the CEM calculations and world data trend

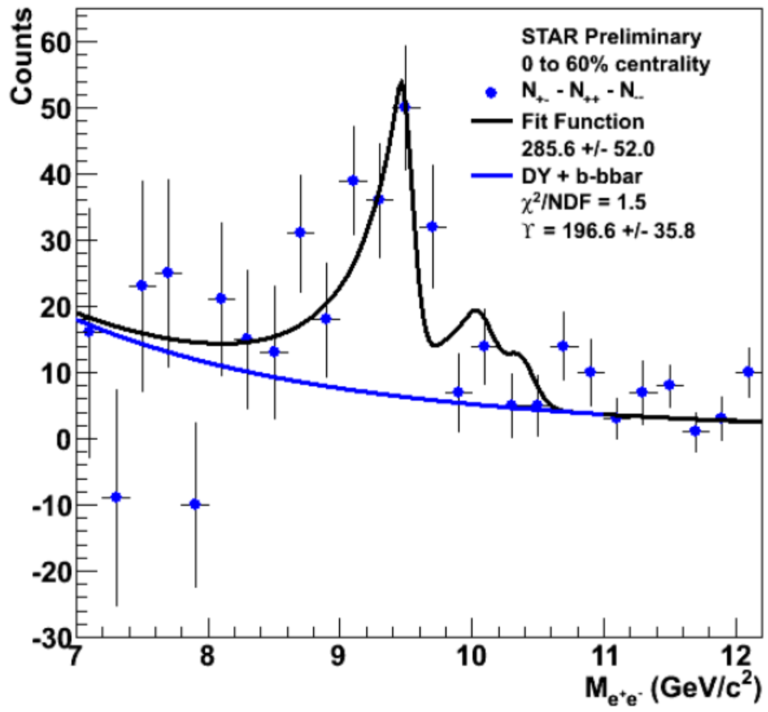




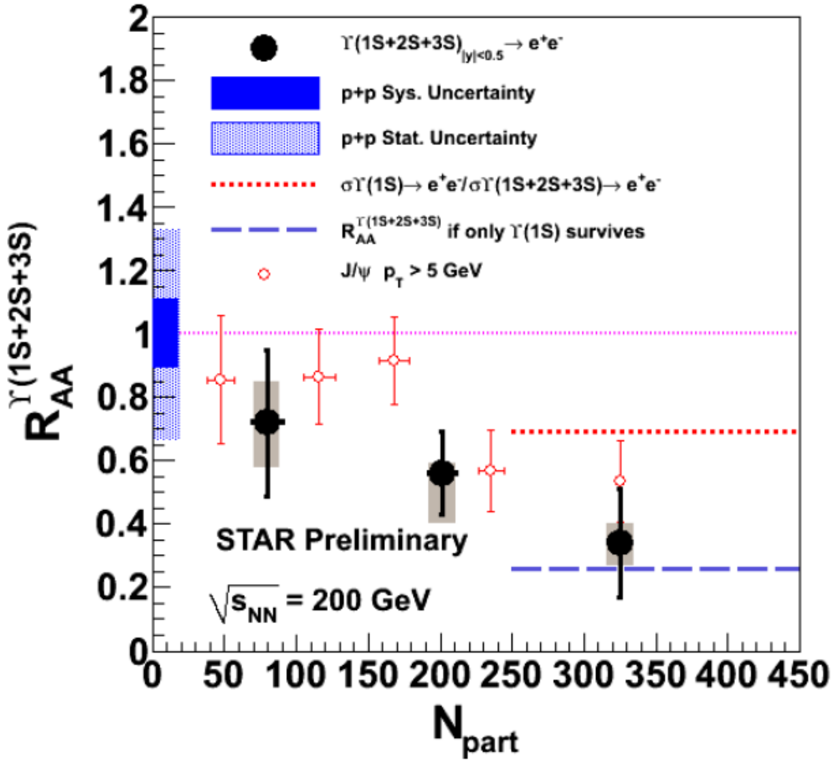
- Recent preliminary data presented by Manuel Calderon de la Barca Sanchez, 5th International Workshop on Heavy Quark Production in Heavy Ion Collisions (2012)
- Old data: PRD 82, 12004 (2010)

Υ at Lower Energy

First Υ data in AuAu from STAR,
arXiv:1109.3891



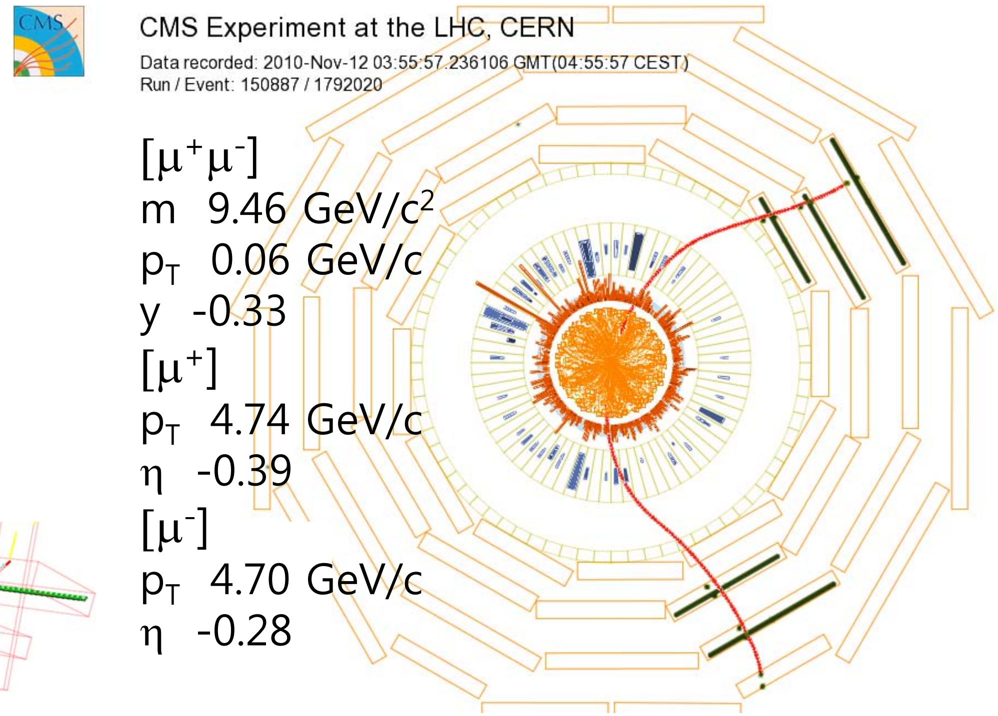
- Stronger suppression of Υ(1S+2S+3S) for more central collisions

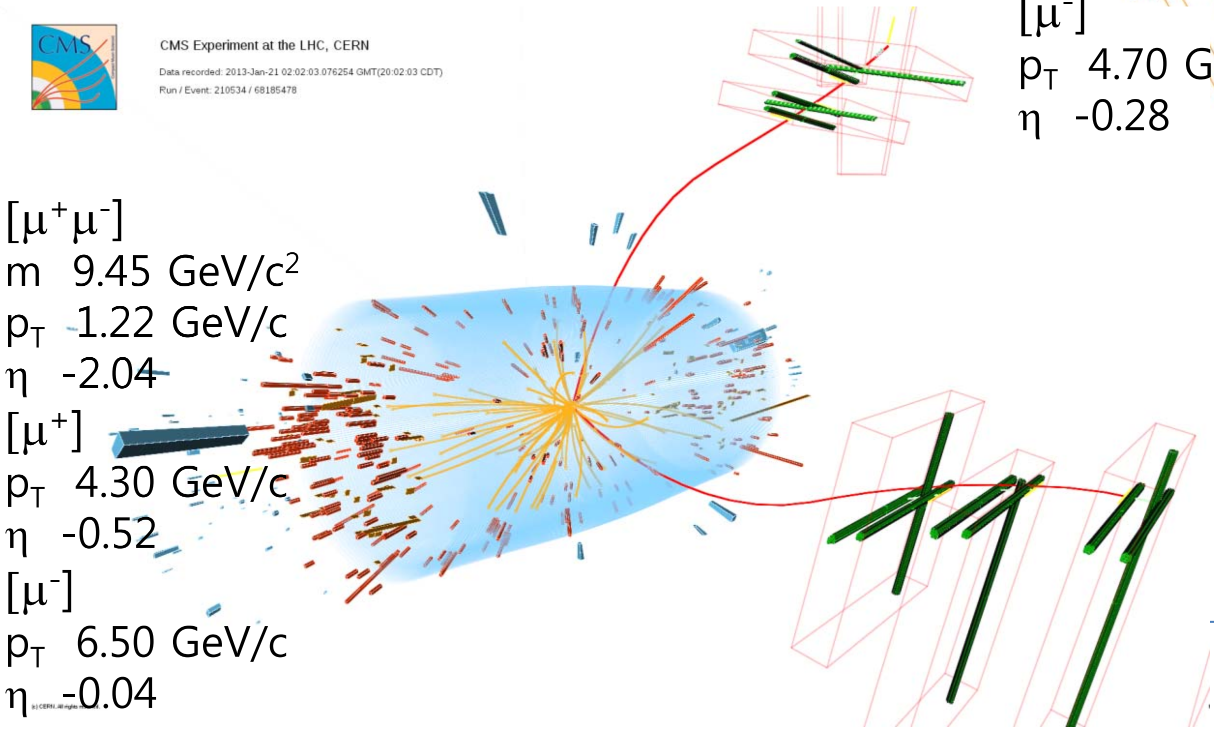


To be compared with CMS data

ϒ(1S) Candidates in PbPb & pPb

PbPb



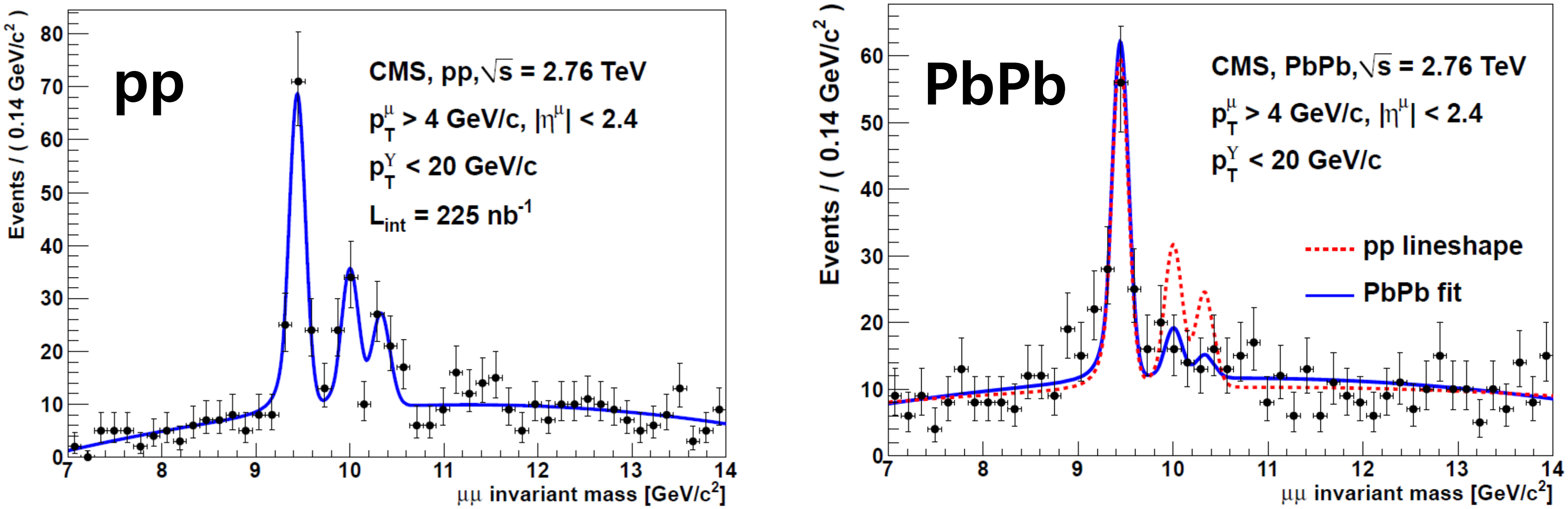


pPb

CMS DP-2013-001

Υ(2S+3S) Suppression in 2010

PRL 107, 052302 (2011), PbPb MinBias, L_{int} = 7.28 μb^{-1}

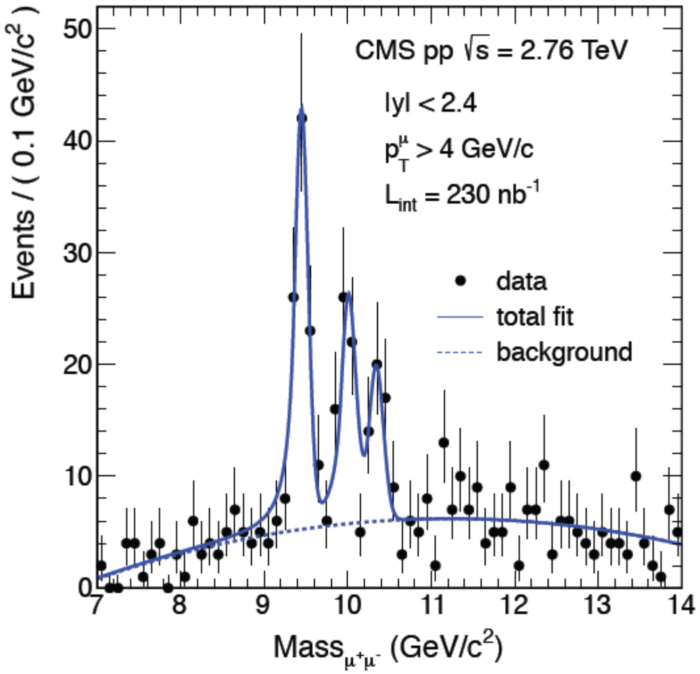


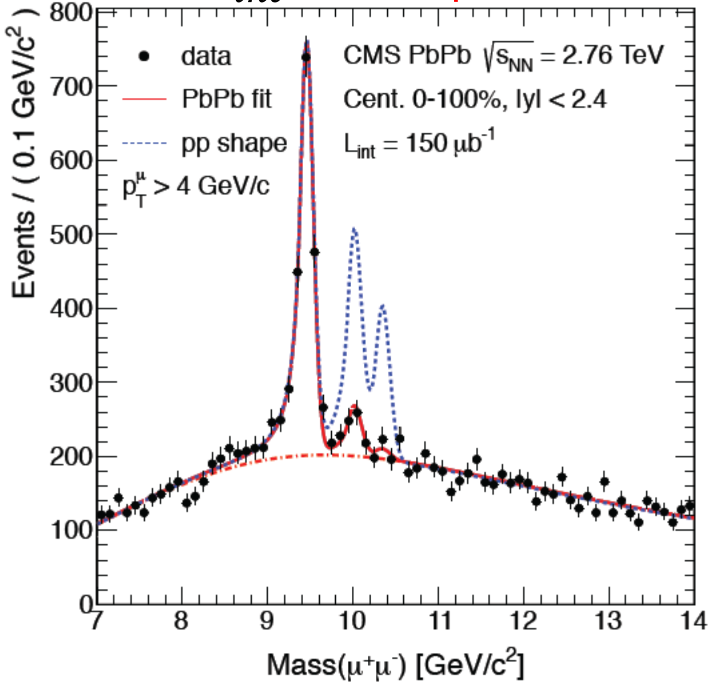
$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

- Probability to obtain the measured value, or lower, from the background fluctuation is 0.9% (2.4σ effect)

Υ(2S+3S) Suppression in 2011

PRL 109, 222301 (2012), PbPb MinBias, L_{int} = 150 μb^{-1}





$\Upsilon(2S)/\Upsilon(1S)\,|_{pp} = 0.56 \pm 0.13 \pm 0.02$

$\Upsilon(3S)/\Upsilon(1S)\,|_{pp} = 0.41 \pm 0.11 \pm 0.04$

$\Upsilon(2S)/\Upsilon(1S)\,|_{PbPb} = 0.12 \pm 0.03 \pm 0.02$

$\Upsilon(3S)/\Upsilon(1S)\,|_{PbPb} = 0.02 \pm 0.02 \pm 0.02$

($<$ 0.07 at 95% CL)

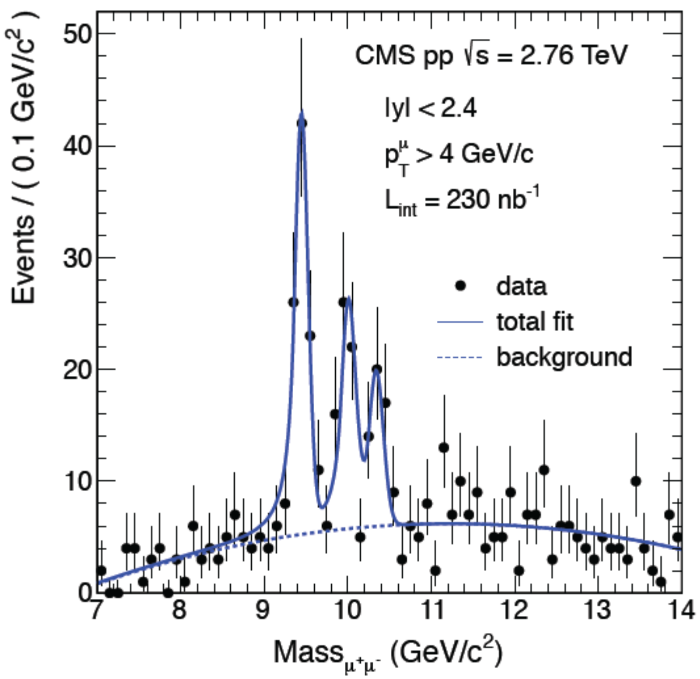
Ratios not corrected for acceptance and efficiency

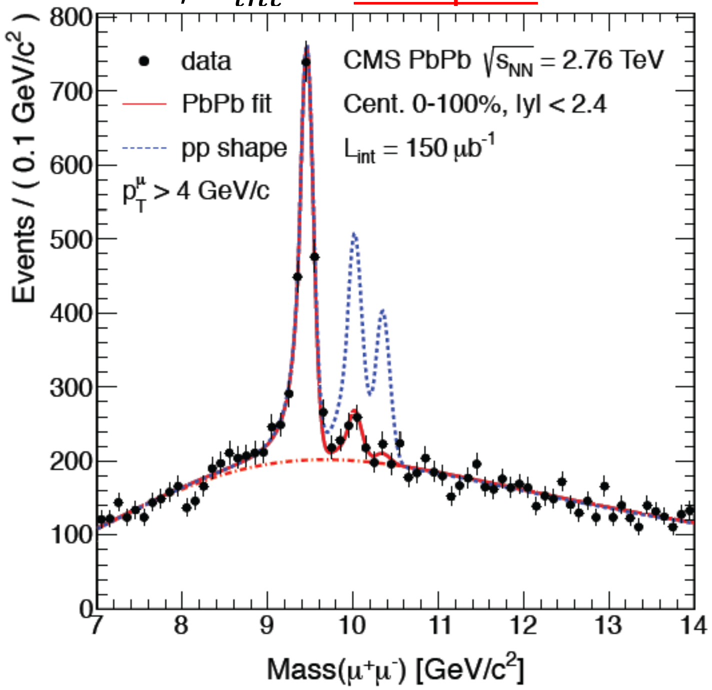
	pp	PbPb
$\Upsilon(1S)$	88±11	1317±73
$\Upsilon(2S)$	49±10	156±38

◀ Limited by pp statistics! Large pp statistics in 2013!

Υ(2S+3S) Suppression in 2011

PRL 109, 222301 (2012), PbPb MinBias, L_{int} = 150 μb^{-1}



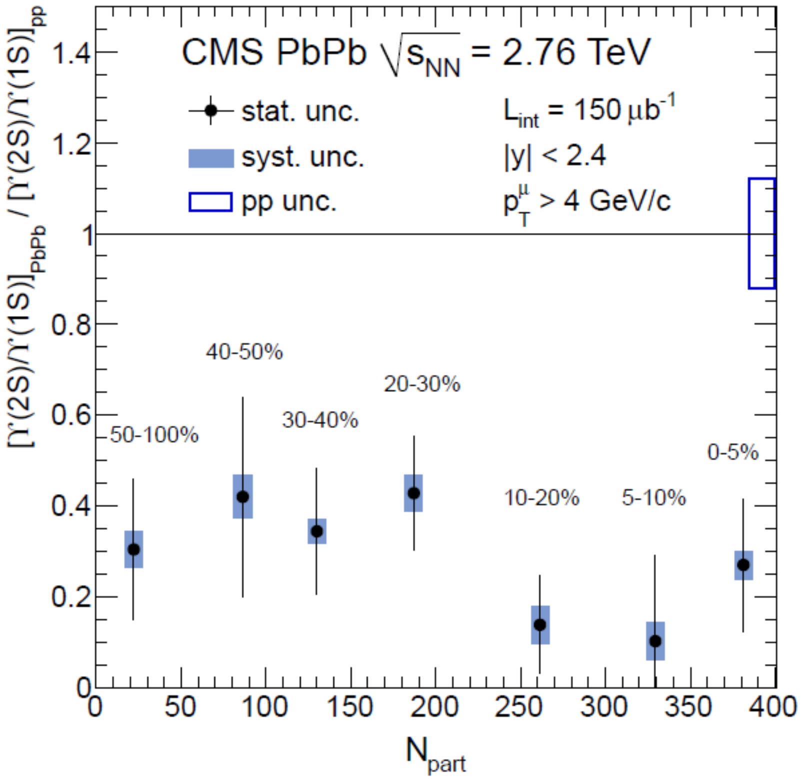


$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{pp}} = 0.15 \pm 0.05 \pm 0.03$$

- Observation of Υ(2S+3S) relative suppression (>5σ effect)

$\Upsilon(2S)$ and $\Upsilon(3S)$ Suppressions

PRL 109, 222301 (2012)



- Centrality integrated

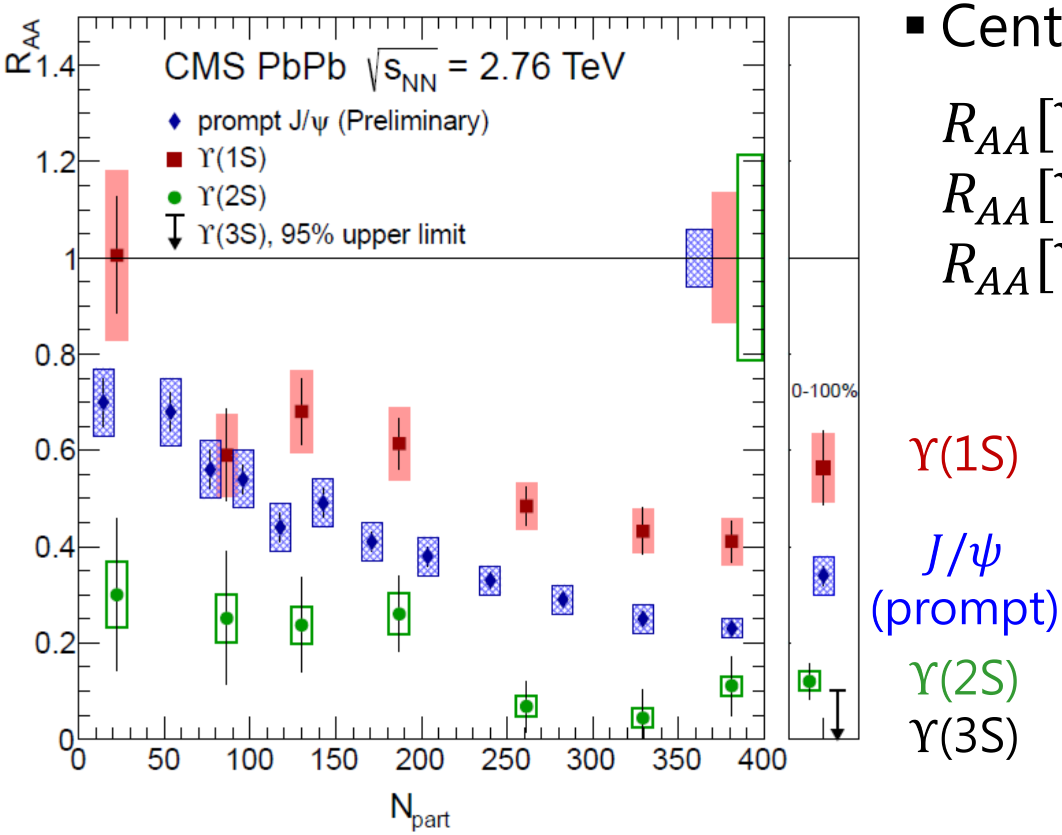
$$\frac{\Upsilon(2S)/\Upsilon(1S)|_{PbPb}}{\Upsilon(2S)/\Upsilon(1S)|_{pp}} = 0.21 \pm 0.07 \pm 0.02$$

$$\frac{\Upsilon(3S)/\Upsilon(1S)|_{PbPb}}{\Upsilon(3S)/\Upsilon(1S)|_{pp}} = 0.06 \pm 0.06 \pm 0.06$$
$$(< 0.17 \text{ at } 95\% \text{ CL})$$

- **Υ states are suppressed sequentially**
  $R_{AA}[\Upsilon(3S)] < R_{AA}[\Upsilon(2S)] < R_{AA}[\Upsilon(1S)]$
- $\Upsilon(2S)$ is suppressed even in the most peripheral bin.

$\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$ R_{AA}

PRL 109, 222301 (2012)



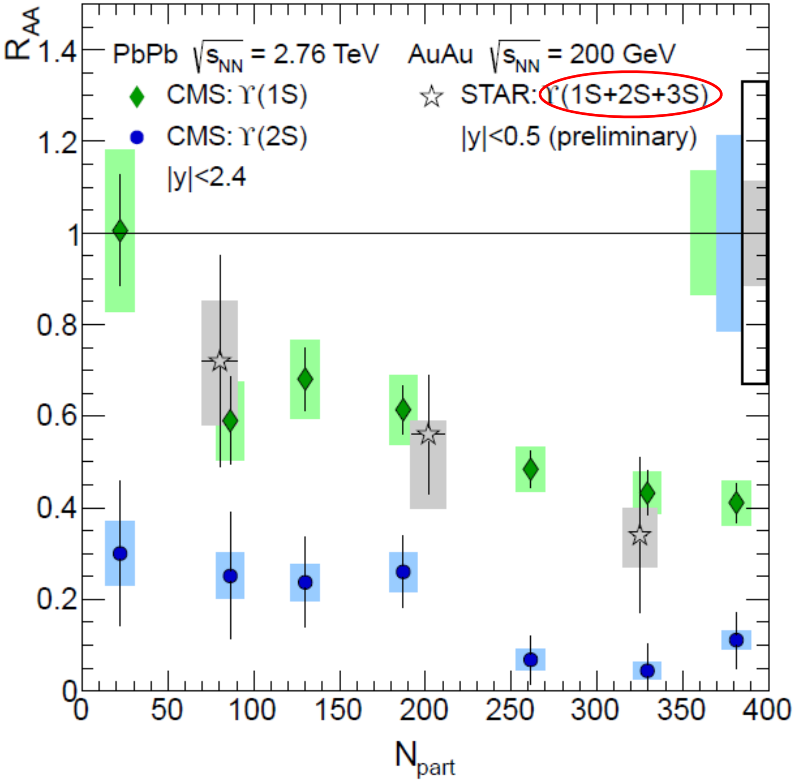
- Centrality integrated results

$$R_{AA}[\Upsilon(1S)] = 0.56 \pm 0.08 \pm 0.07$$
$$R_{AA}[\Upsilon(2S)] = 0.12 \pm 0.04 \pm 0.02$$
$$R_{AA}[\Upsilon(3S)] = 0.03 \pm 0.04 \pm 0.01$$
$$(<0.10 \text{ at } 95\% \text{ CL})$$

[Note] If the feed-down contribution ~50%, $\Upsilon(1S)$ suppression is consistent with the suppression of the excited states only.

- **Υ states are suppressed sequentially**
  $$R_{AA}[\Upsilon(3S)] < R_{AA}[\Upsilon(2S)] < R_{AA}[\Upsilon(1S)]$$
- $\Upsilon(1S)$ is not suppressed in the most peripheral bin.

Comparison to RHIC for Υ



- STAR data for Υ(1S+2S+3S) in AuAu at 200 GeV integrated for centrality

$$R_{AA}[\Upsilon(1S+2S+3S)] = 0.56 \pm 0.21^{+0.08}_{-0.16}$$

arXiv:1109.3891

PRL 109, 222301 (2012)

- CMS data for Υ(1S+2S+3S) integrated for centrality

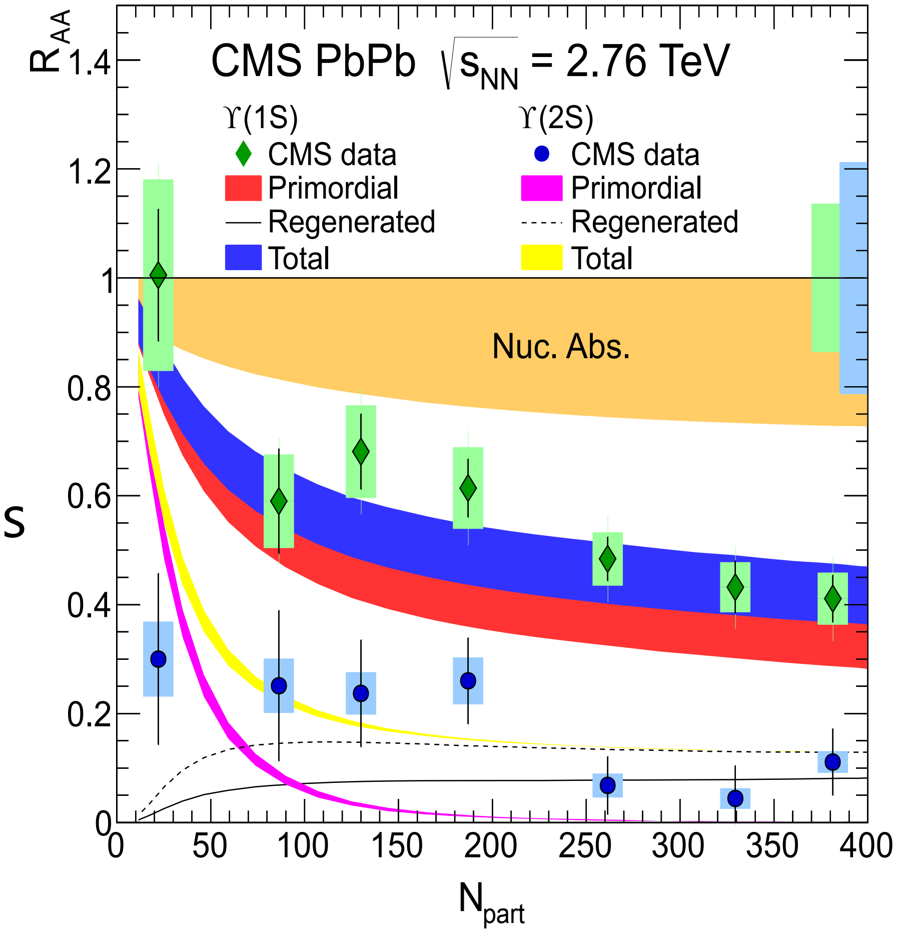
$$R_{AA}[\Upsilon(1S+2S+3S)] = \frac{\Upsilon(1S+2S+3S)|_{PbPb}}{\Upsilon(1S+2S+3S)|_{pp}}$$

$$= \frac{\Upsilon(1S)|_{PbPb}}{\Upsilon(1S)|_{pp}} \times \frac{1+\Upsilon(2S+3S)/\Upsilon(1S)|_{PbPb}}{1+\Upsilon(2S+3S)/\Upsilon(1S)|_{pp}} = 0.56 \times \frac{1+0.14}{1+0.97} \approx 0.32$$

More suppression at higher energy

Comparison to Model for ϒ

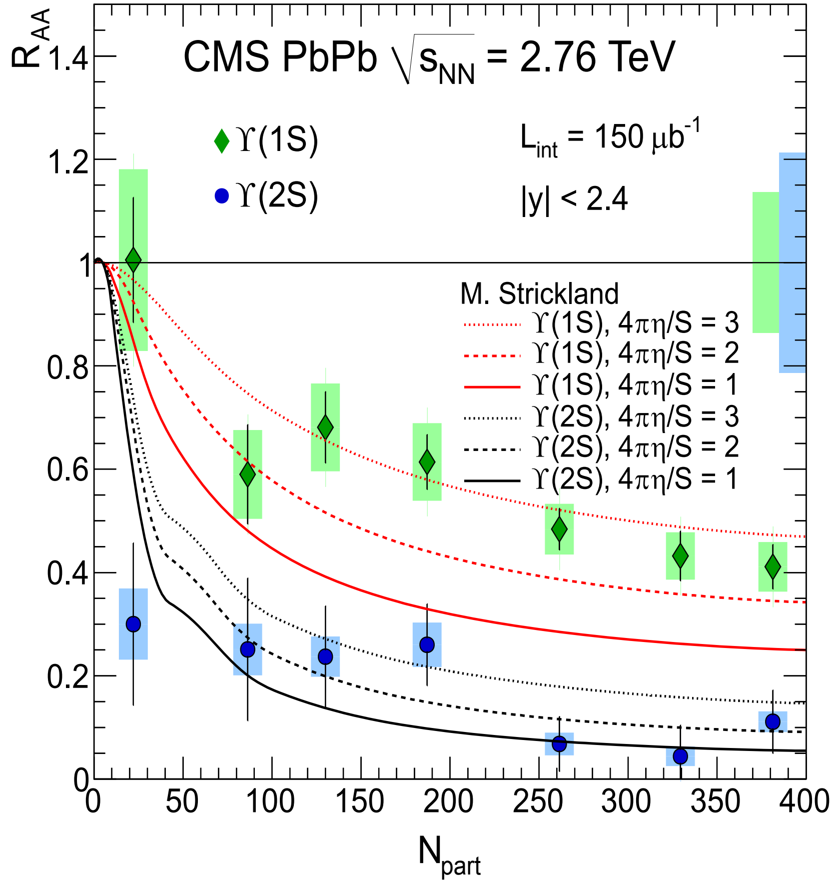
- Strong ϒ binding scenario
  - ⇒ Mostly consistent with data
  - ⇒ ϒ(1S): Small regeneration indicates the suppression is mostly primordial.
  - ⇒ ϒ(2S): Regeneration is dominant in central collisions
  - ⇒ Large uncertainty in nuclear absorption: pPb will help!
  - ⇒ T ≈ 610 MeV in this calculation
    - Are there any sensitivity to initial temperature?



Model calculations:
A. Emerick, X. Zhao & R. Rapp, EPJA 48, 72 (2012)

Comparison to Model for Υ

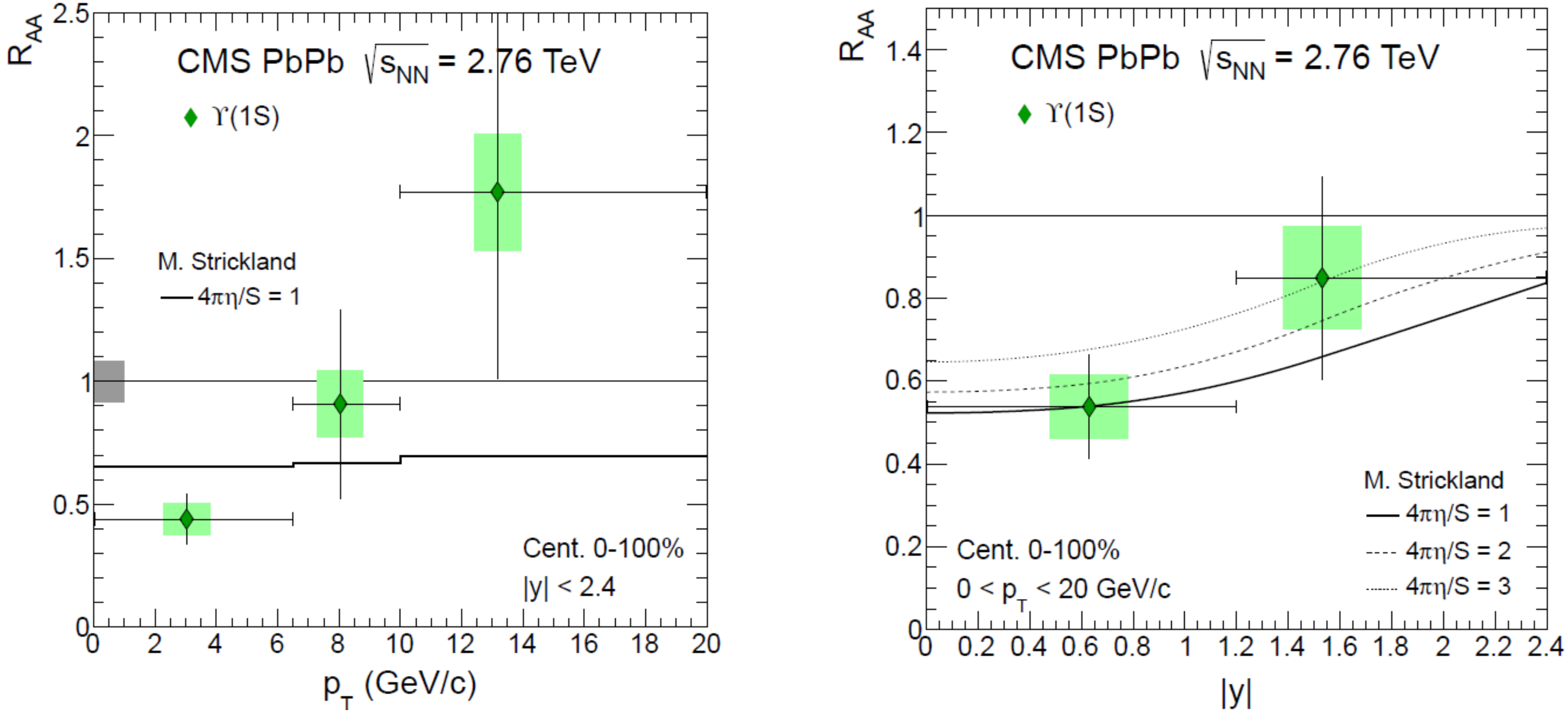
- AHYDRO: Anisotropic hydrodynamics model
- Incorporating lattice-based potentials, including the real and the imaginary parts
- Includes sequential melting and feed-down contributions
  $\Rightarrow$ ~50% feed-down from χ_b
- Dynamical expansion with variations in initial conditions for T_0 and η/S: data indicates
  $\Rightarrow$ $552 < T_0 < 580$ MeV
  $\Rightarrow$ $1 < 4\pi\eta/s < 3$



Model calculations:
M. Strickland and D. Bazow, NPA 879, 25 (2012)
M. Strickland, PRL 107, 132301 (2011)

$\Upsilon(1S)$ R_{AA} vs. p_T and y

Data: JHEP 05, 063 (2012), Model: M. Strickland, PRL 107, 132301 (2011)



- Obtained with 2010 PbPb (7.28 μb^{-1}) and 2011 pp (225 nb^{-1})
  - Clear suppression at low p_T
- High-statistics data sets: 2011 PbPb (150 μb^{-1}) and 2013 pp (5.41 pb^{-1})
  - The accuracy of the results will be greatly improved in the future.

Summary

1. Long-range dihadron correlation and dijet behavior
   - Jet enhancement at low p_T and deficit at high p_T
   - The effect is larger on away side
2. Dijet correlations
   - Jet fragmentation and shape is modified at large r and low p_T in PbPb
   - Dijet η distributions in pPb are useful to study nPDF
3. Quarkonium production
   - Prompt and non-prompt J/ψ are suppressed.
   - $\psi(2S)$ are more(less) suppressed than J/ψ at high(low) p_T: Analysis with high statistics pp data is ongoing.
   - Sequential melting of Υ(nS) is observed in PbPb

➢ More public heavy-ion results in our web
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN