

Highlights from CMS



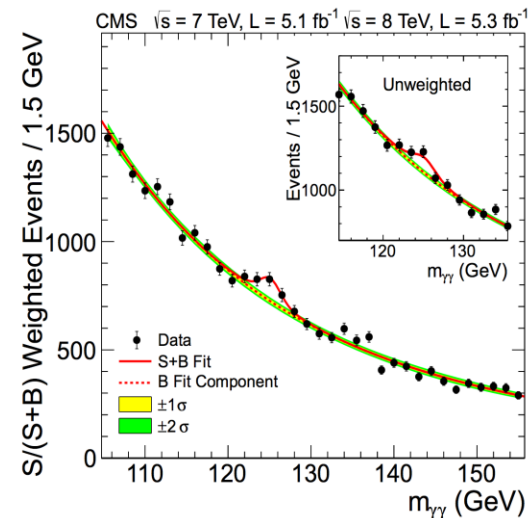
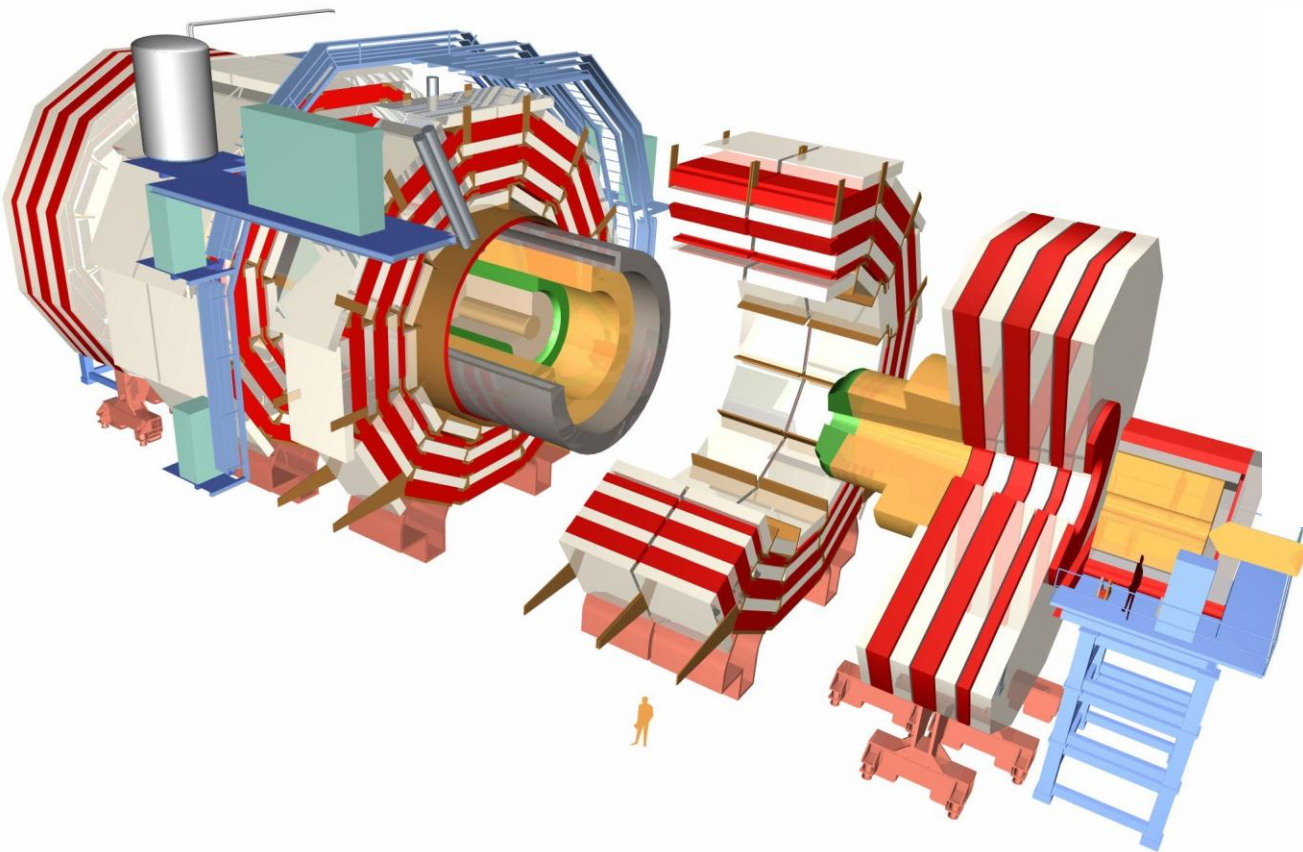
Gunther Roland
(MIT)



for the CMS Collaboration

Quark Matter conference, Washington DC
Aug 13th, 2012

CMS experiment



arXiv:1207.7235
Accepted by PLB

CMS excels at

- Resolution of tracking and calorimetry
- Trigger selectivity

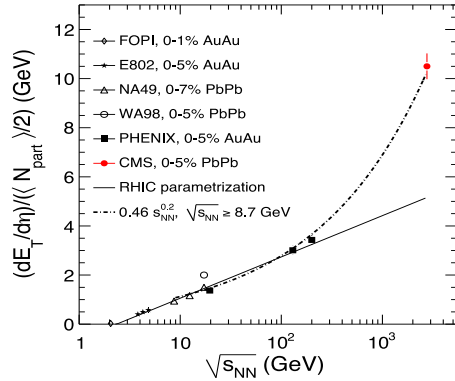
over a large range in rapidity and full azimuth

CMS highlights in five acts

- i. A bigger bang
Ultra-central collisions
- ii. A classicist view of jet quenching
The R_{AA} zoo
- iii. A new kind of PID
Parton ID, not particle ID
- iv. Anatomy of a jet
Jet shapes and fragmentation functions
- v. Lost and bound
Debye-screening and recombination

A bigger bang

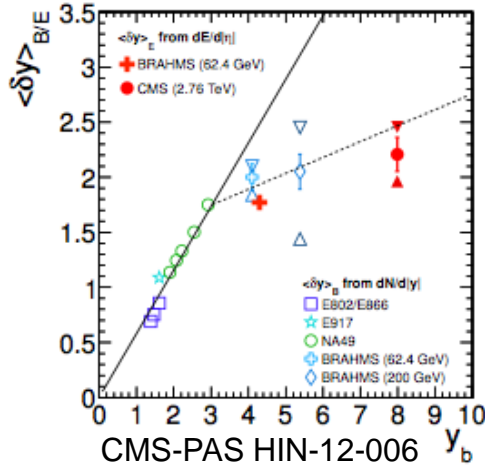
Transverse energy



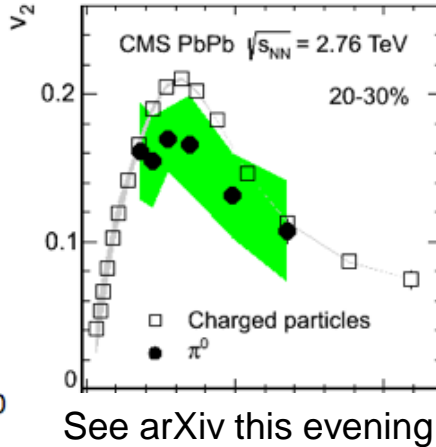
arXiv:1205.2488

Nuclear stopping

CMS PRELIMINARY

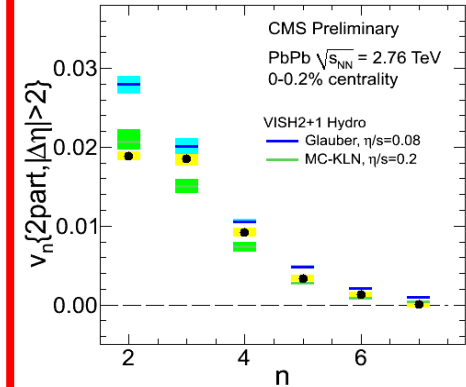


π^0 elliptic flow



See arXiv this evening

Ultra-central collisions

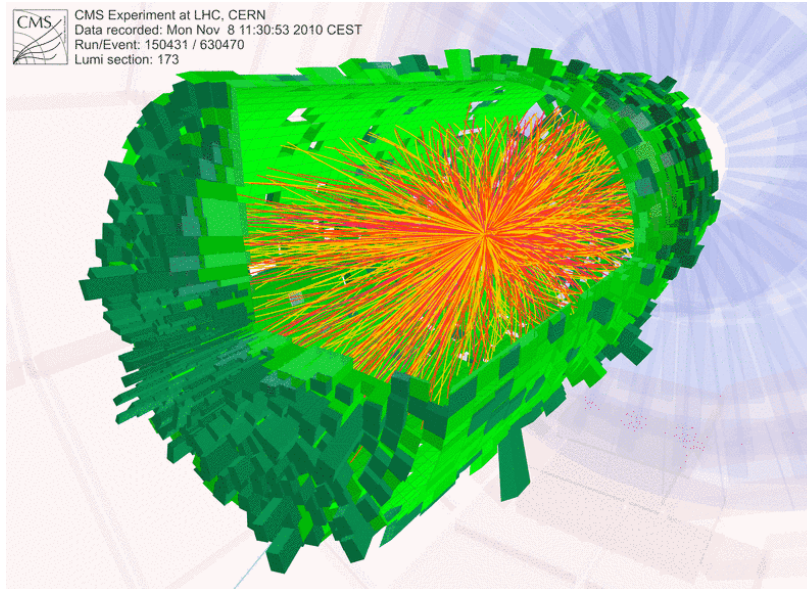


UCC trigger: **1.8M** most central events **out of 1B**

Parallel talks:

Magdalena Malek,
dE_T/dη (Wed)

Hauke Woehrmann
Energy flow (Wed)



Parallel talks:

Rylan Conway
High p_T correlations (Tue)

Shenquan Tuo
Bulk v_n (Fri)

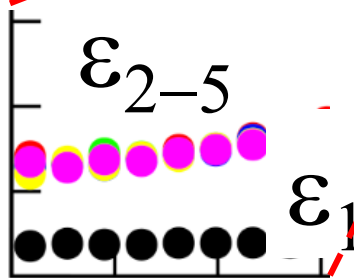
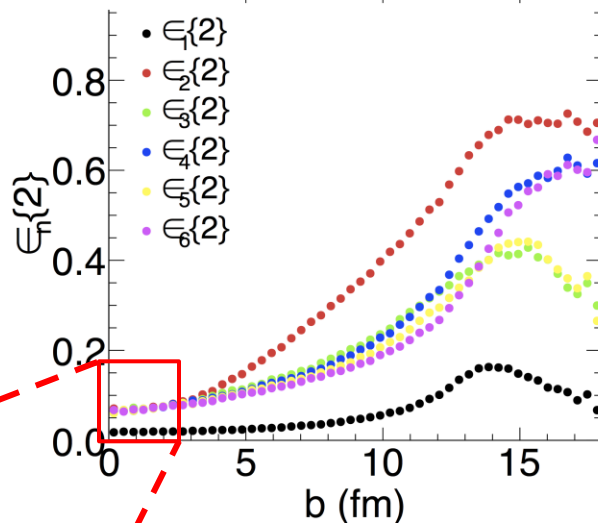
Eric Appelt
Bulk v_2 (Fri)

Ultra-central collisions

n^{th} order eccentricities vs b

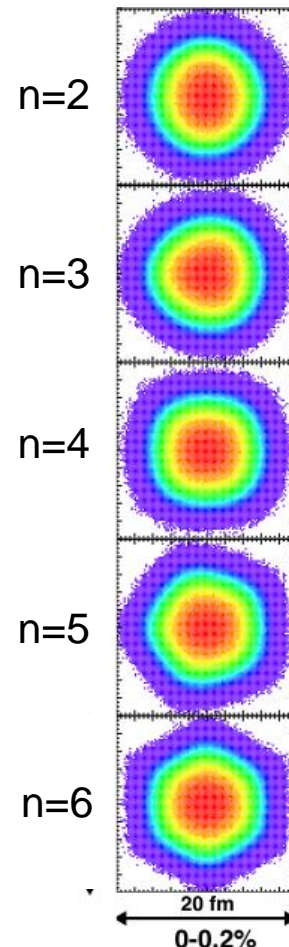
0.2% most central

PHOBOS Glauber MC



$b < 2\text{fm}$

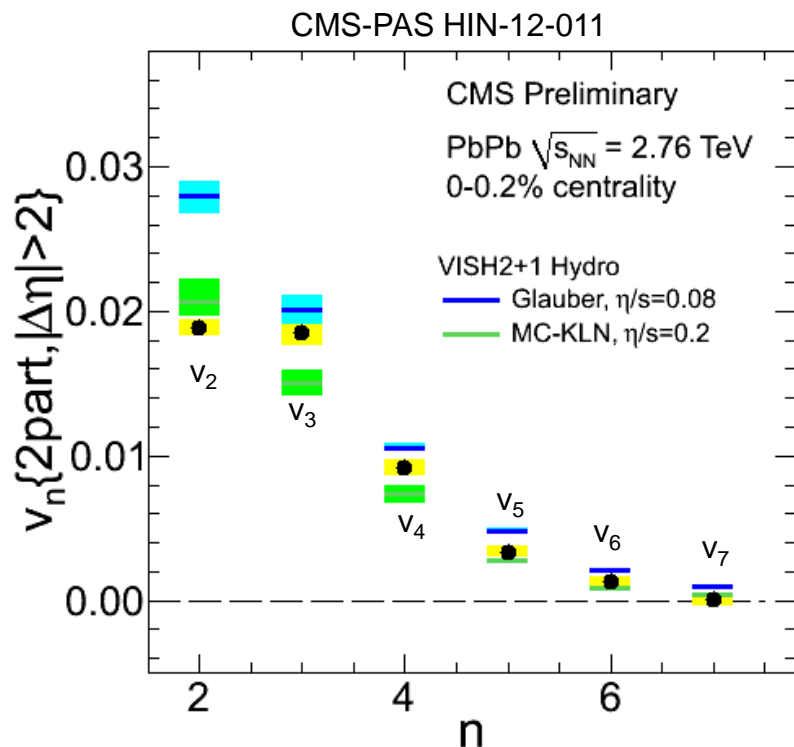
ϵ_2 - ϵ_5 converge in ultra-central collisions



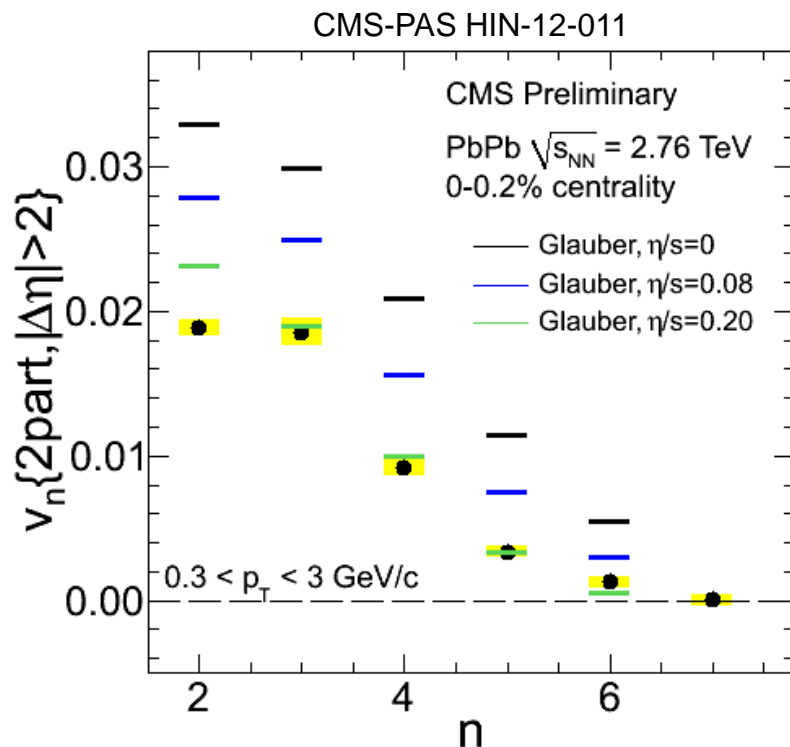
Participant distribution relative to the n^{th} order participant plane

Ultra-central collisions

Calculation by Heinz et al.



Calculation by Luzum et al.



Unique perspective on hydrodynamic flow

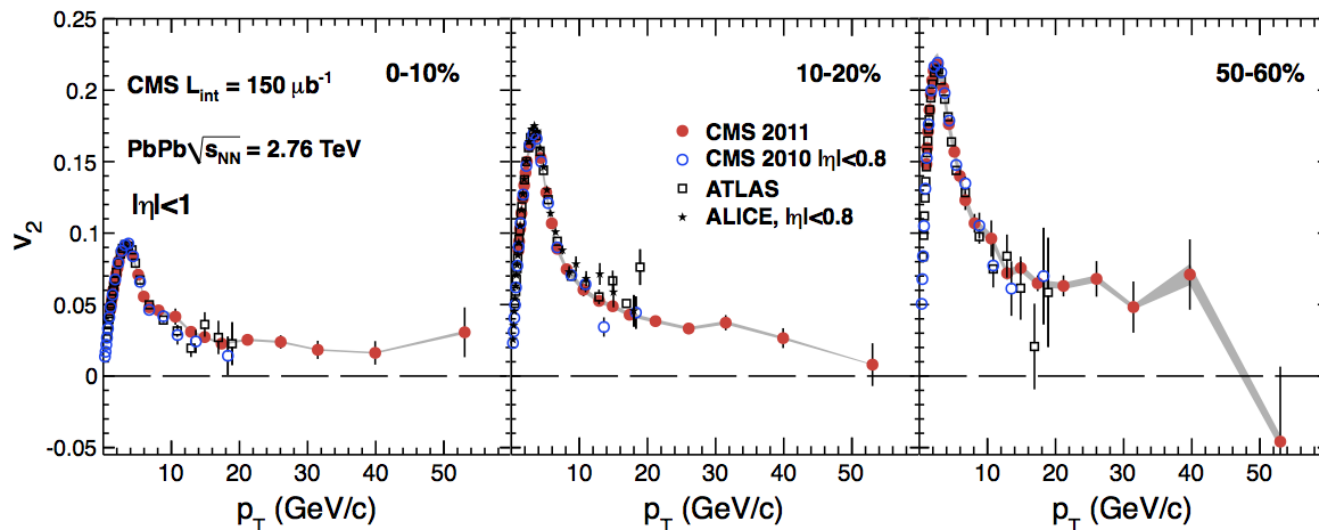
- Hierarchy of coefficients reproduced by hydro
- Some tension between v_2 and $v_{3..7}$

Parallel talk
Shenquan Tuo

Poster: Wei Li

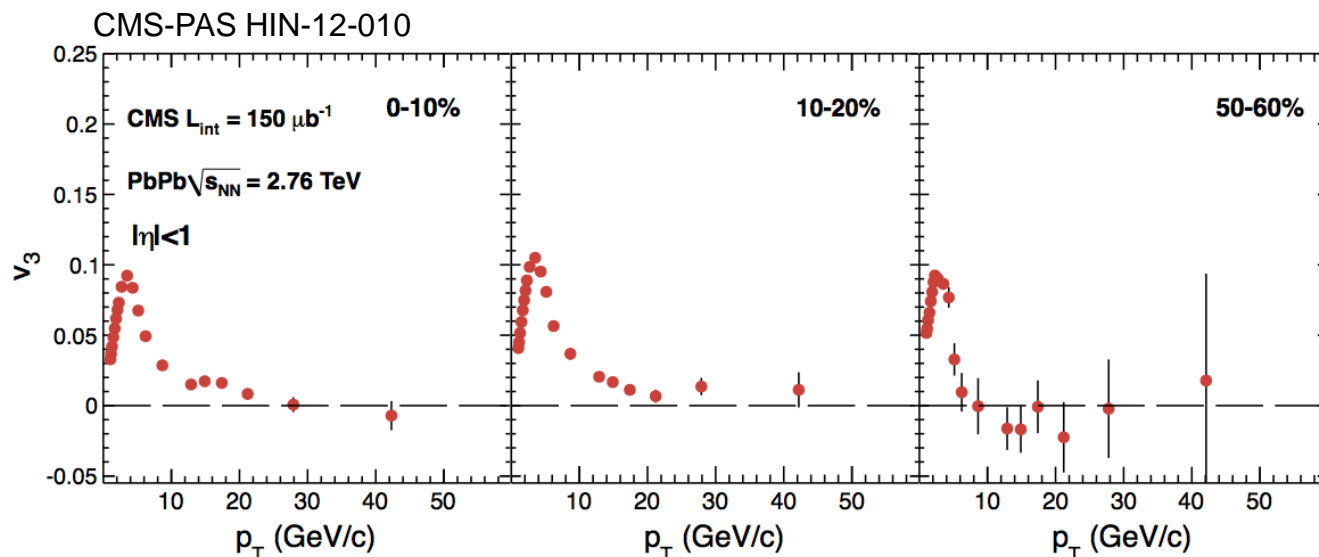
Note, AMPT 0-0.2%: $\langle b \rangle = 1.6$ fm, $RMS(b) = 0.6$ fm

Anisotropy at high p_T



v_2 persists to
 $p_T > 40 \text{ GeV}$

Pathlength-dependent
energy loss



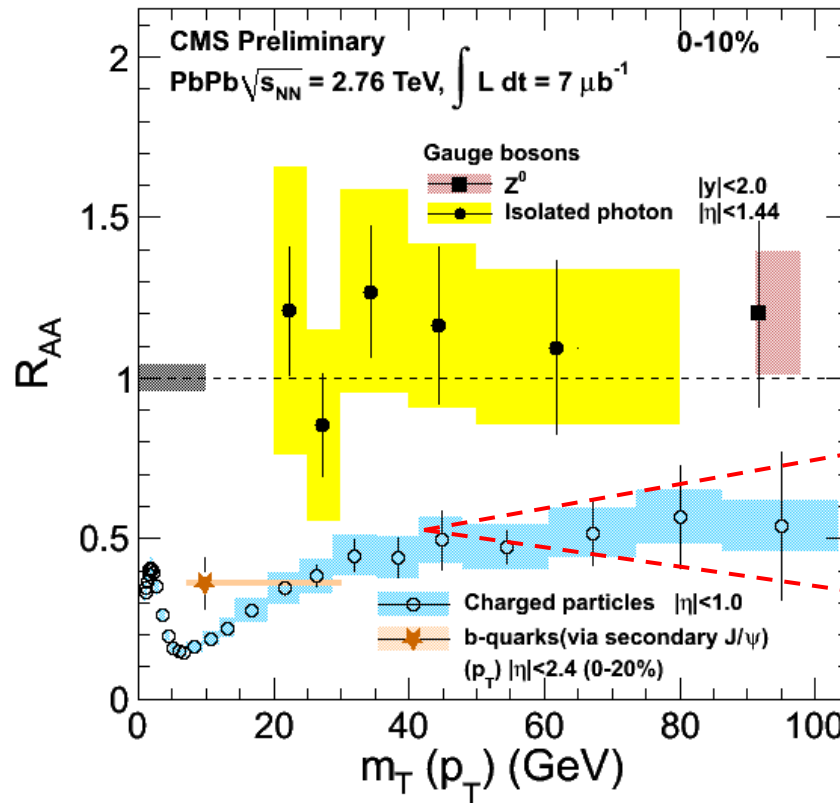
v_3 vanishes for
 $p_T > 20 \text{ GeV}$

Weaker correlation
of pathlength
and Ψ_3 plane

Parallel talks
Rylan Conway (Tue)
Victoria Zhukova (Tue)

A classicist view of jet quenching

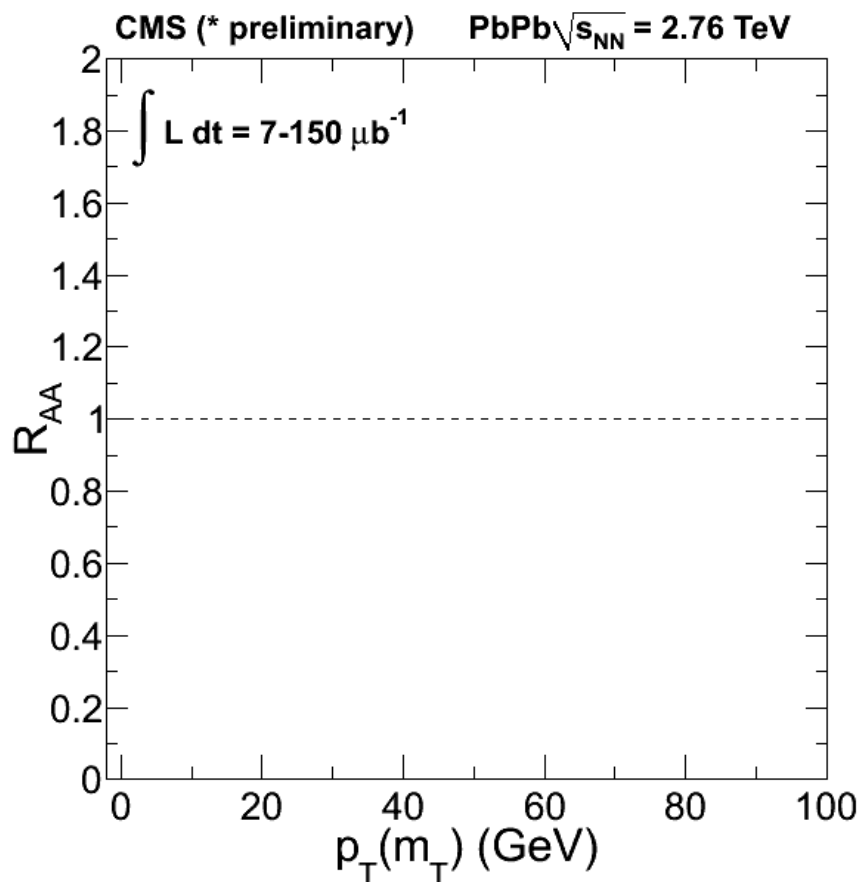
The CMS R_{AA} Zoo (QM'11)



Fate of charged hadron R_{AA} for $p_T > 60$ GeV?

R_{AA} remains a critical tool in the study of parton energy loss

A classicist view of jet quenching



Start from blank slate

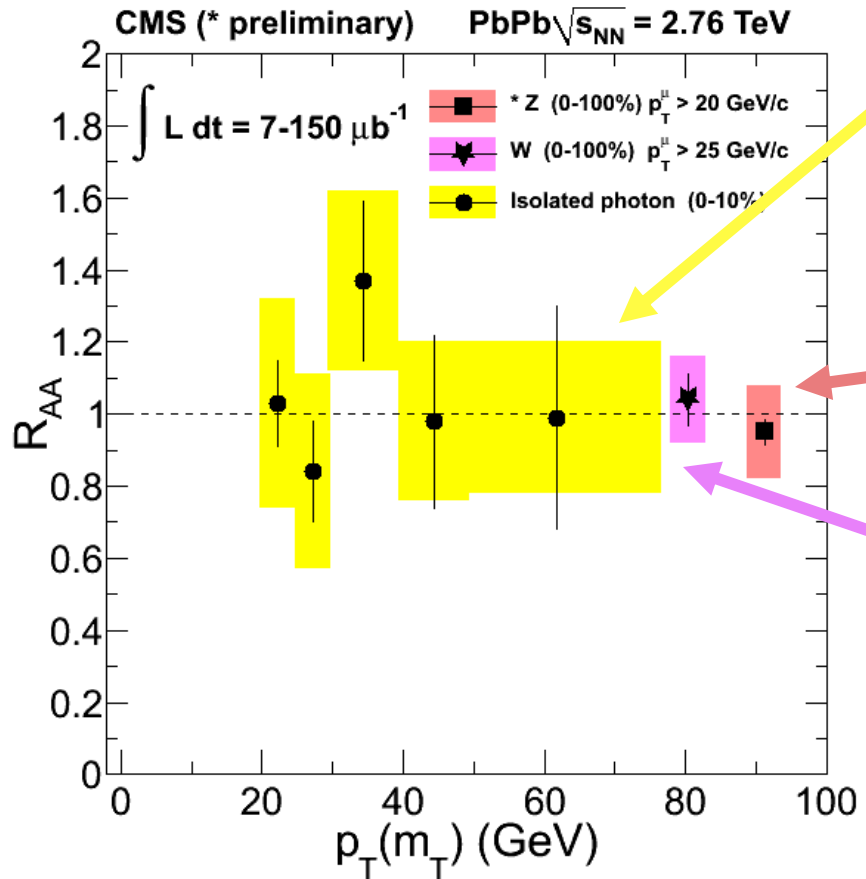
Repopulate R_{AA} Zoo with
new analyses (since QM'11)

(Non-) Suppression of colorless probes

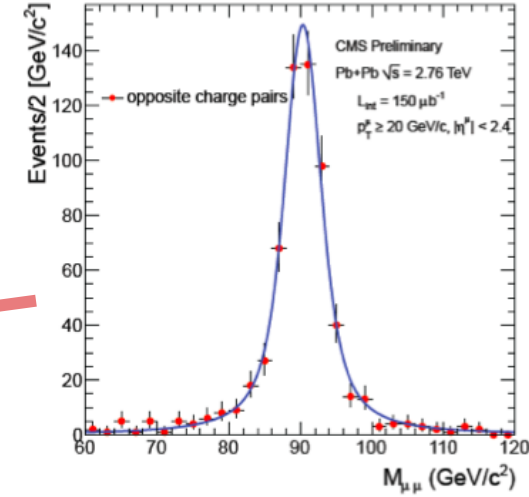
Parallel talk
George Stephans (Wed)

Isolated photon R_{AA} with
2.76 TeV pp reference

PLB 710 (2012) 256

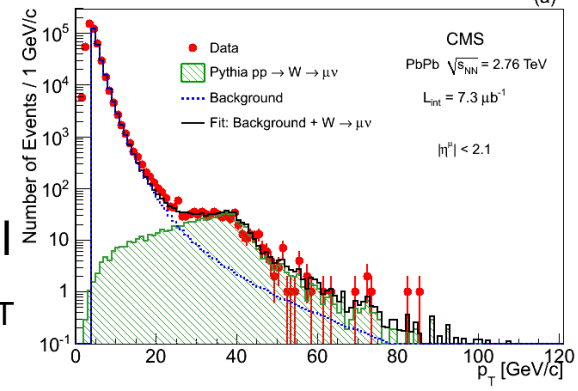


CMS-PAS HIN-12-008



$Z^0 \rightarrow \mu^+ \mu^-$

$W \rightarrow \mu \nu$ using
single muon recoil
against missing p_T



N_{coll} scaling confirmed

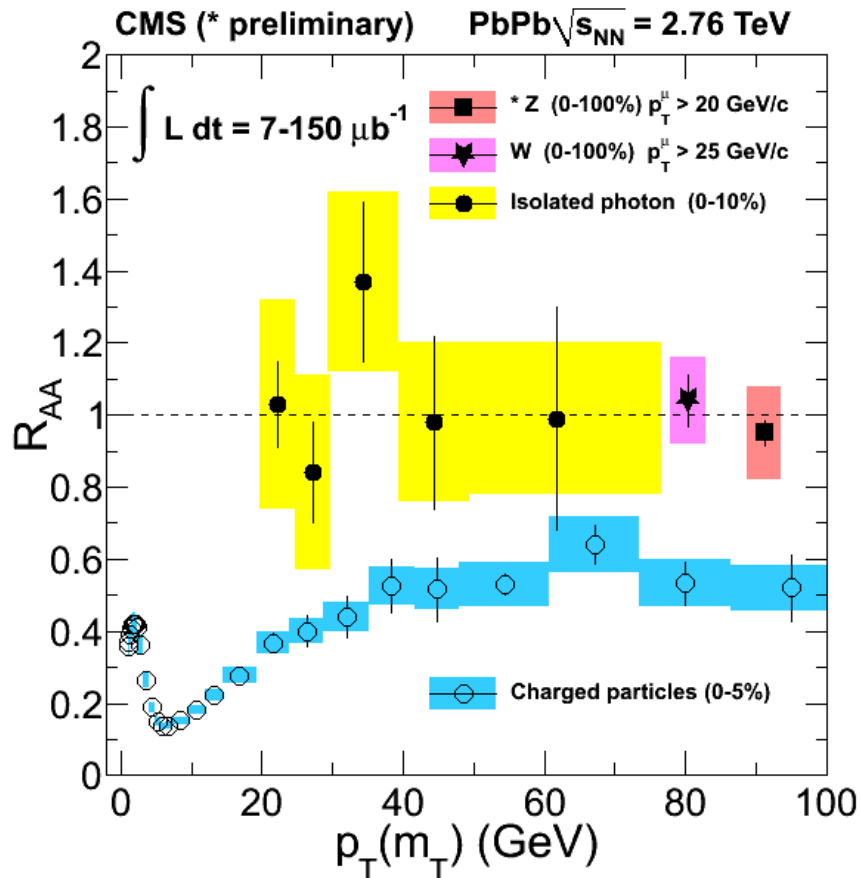
Parallel talk

Lamia Benhabib (Wed)

arXiv:1205.6334
Accepted by PLB



Suppression of charged particles



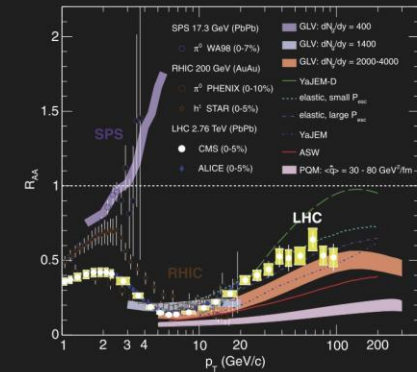
Charged hadron R_{AA} flat
from $p_T = 30 - 100$ GeV

EPJC 72 (2012) 1945
The European Physical Journal
volume 72 · number 3 · march · 2012

EPJ C

Recognized by European Physical Society

Particles and Fields



Measurements of the nuclear modification factor R_{AA} in central heavy-ion collisions at three different center-of-mass energies, as a function of p_T , for neutral pions, charged hadrons, and charged particles, compared to several theoretical predictions. From the CMS Collaboration: Study of high- p_T charged particle suppression in PbPb compared to pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV

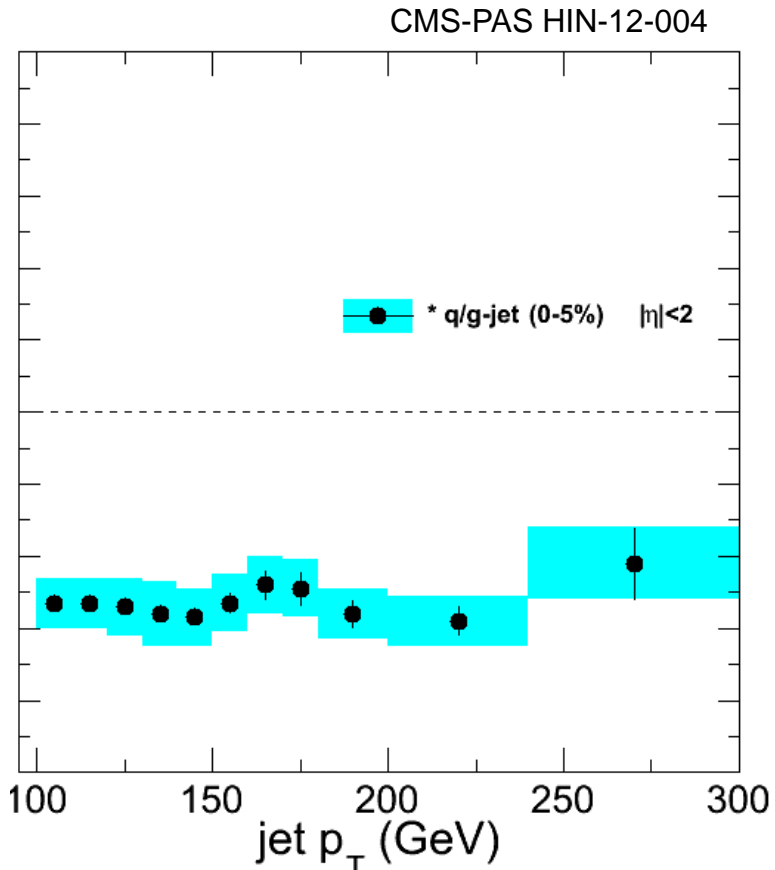
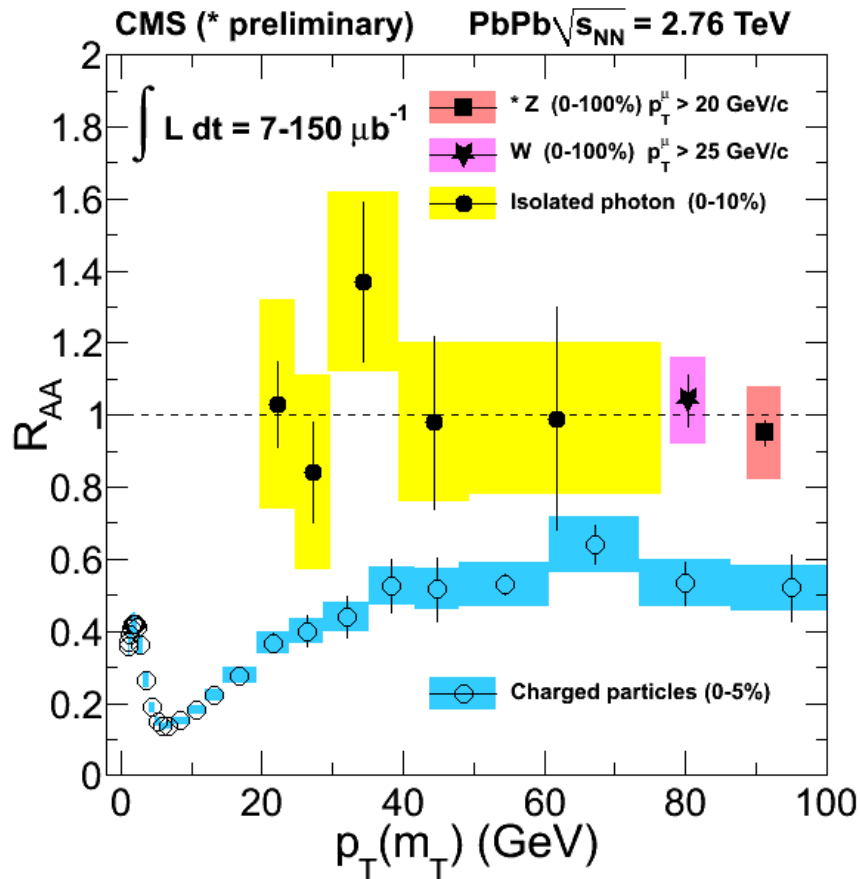


Springer

Added full 2011 jet-triggered data set
to charged hadron R_{AA} measurement

Suppression of inclusive jets

Fully unfolded inclusive jet R_{AA}
pp 2.76 TeV reference

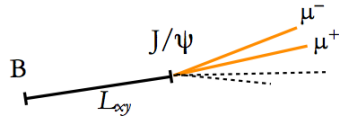


Like for charged particles,
high- p_T jet R_{AA} flat at ≈ 0.5

A new kind of PID

Parton ID, not particle ID: b-quark quenching

$6.5 < p_T < 30$ GeV:
Displaced $J/\psi \rightarrow \mu\mu$

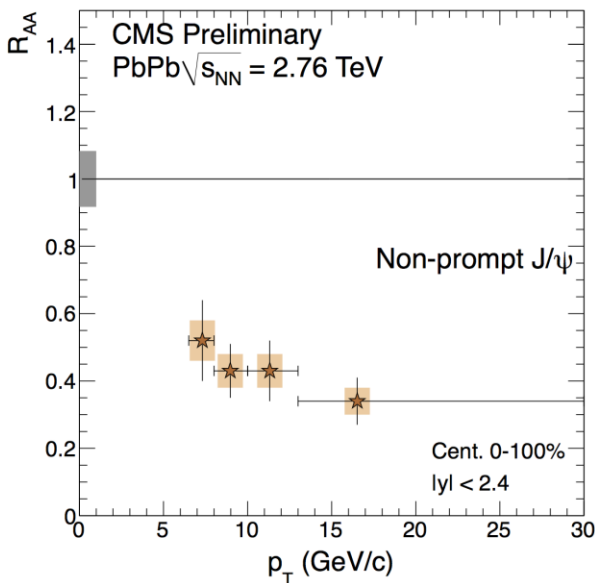


Obtain $B R_{AA}$

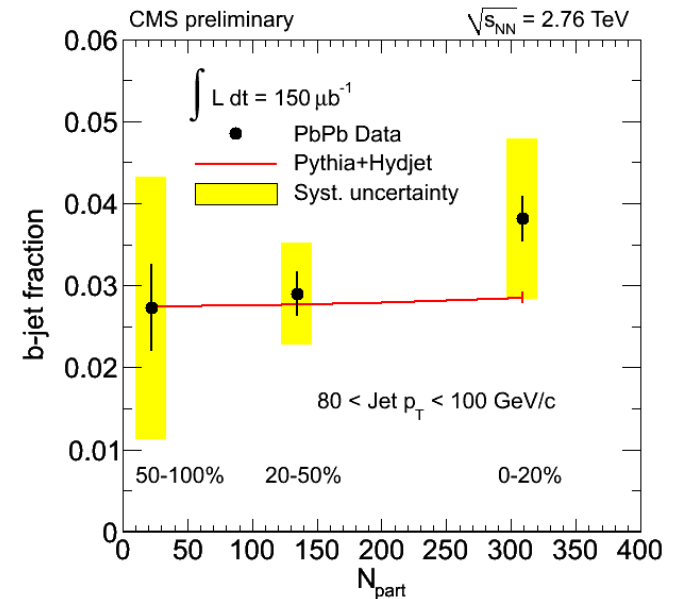
$p_T > 80$ GeV:
Jet + high mass
secondary vertex

Obtain *b-jet fraction*

CMS-PAS HIN-12-014



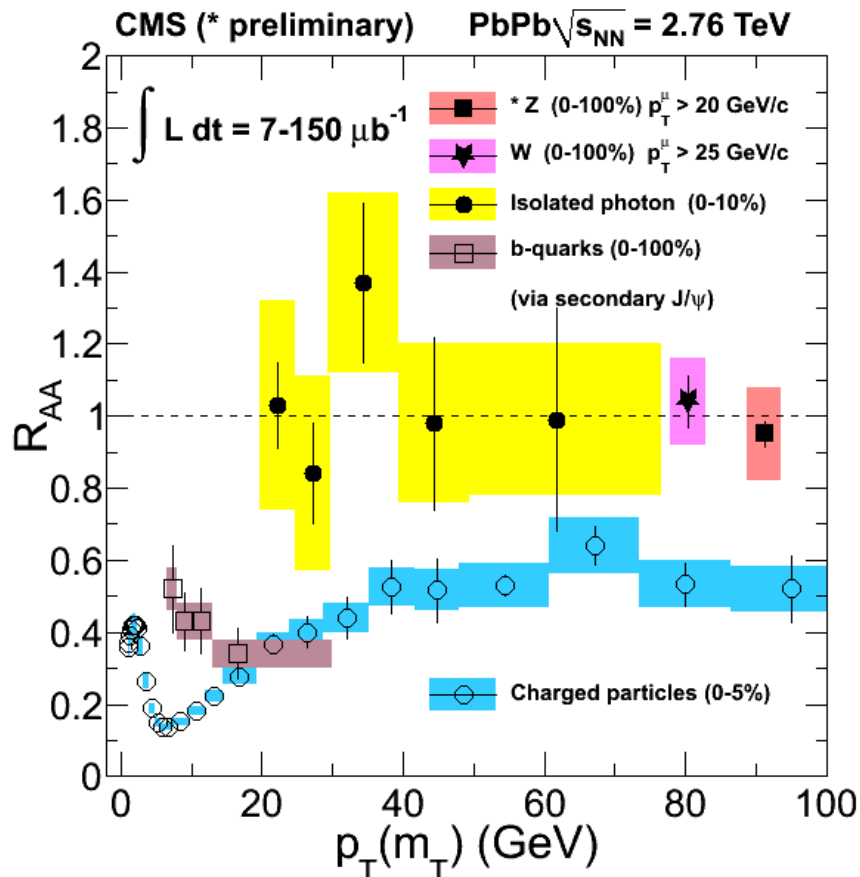
CMS-PAS HIN-12-003



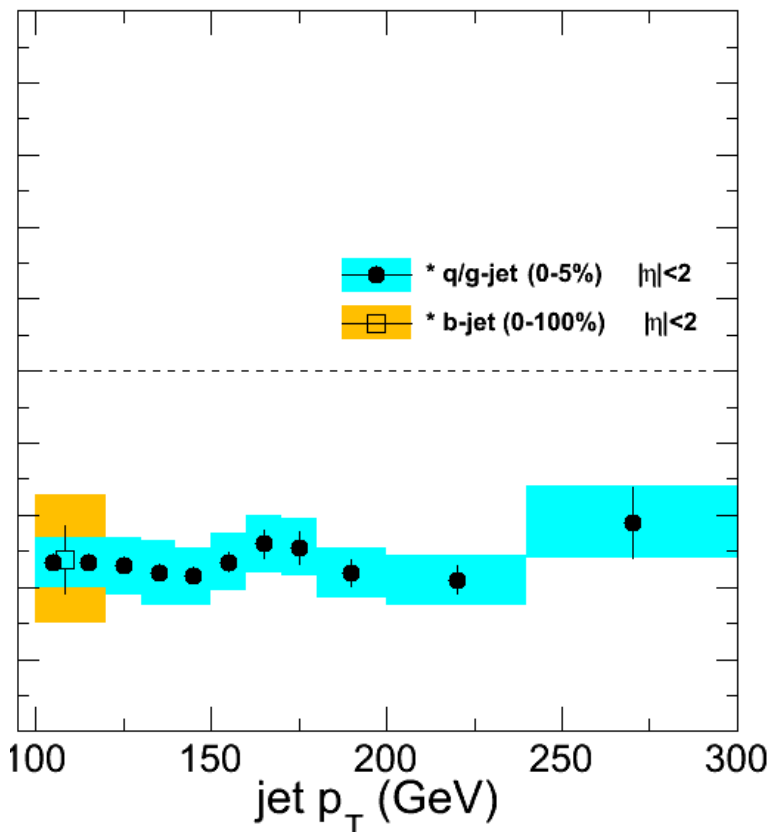
Parton ID: b-quarks

Parallel talk
Mihee Jo (Fri)

Parallel talk
Matt Nguyen (Tue) Poster
Jorge Robles



Distinct b-quark suppression pattern at low p_T



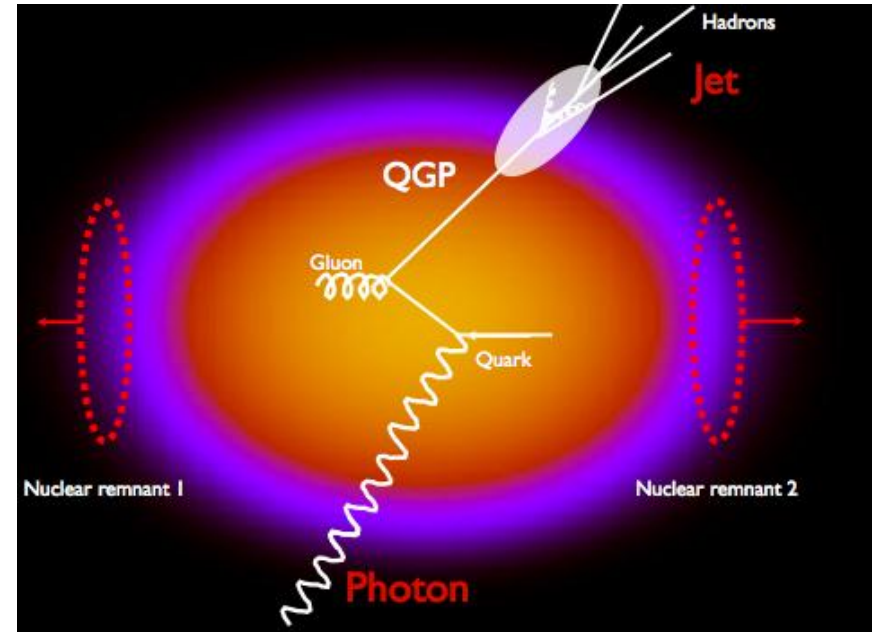
First observation of b-jet suppression at high p_T

γ +jet: u,d quark energy loss

CMS
CMS Experiment at LHC, CERN
Data recorded: Mon Dec 5 23:36:38 2011 EDT
Run/Event: 183013/43056273
Lumi section: 1114

Photon
(191 GeV)

Jet
(98 GeV)

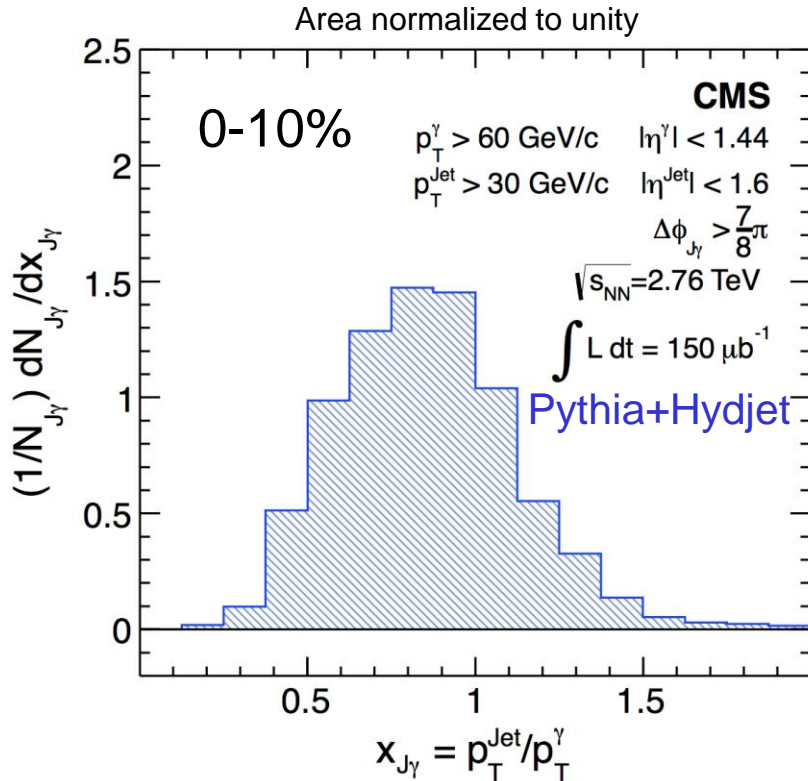


Photon tag:

- Identifies jet as u,d quark jet
- Provides initial quark direction
- Provides initial quark p_T

γ +jet: u,d quark energy loss

arXiv:1205.0206



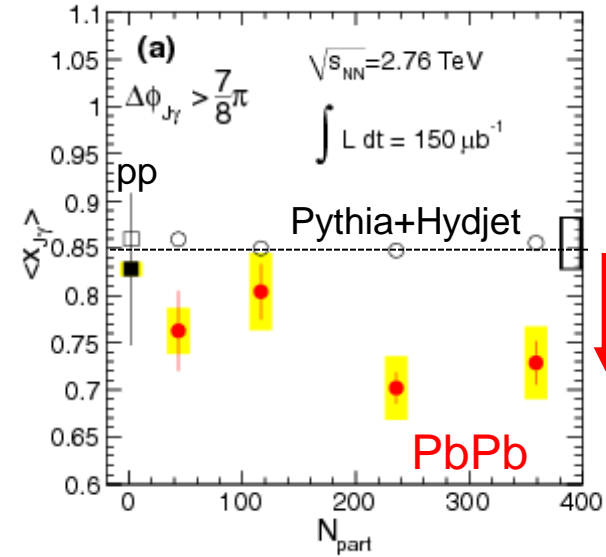
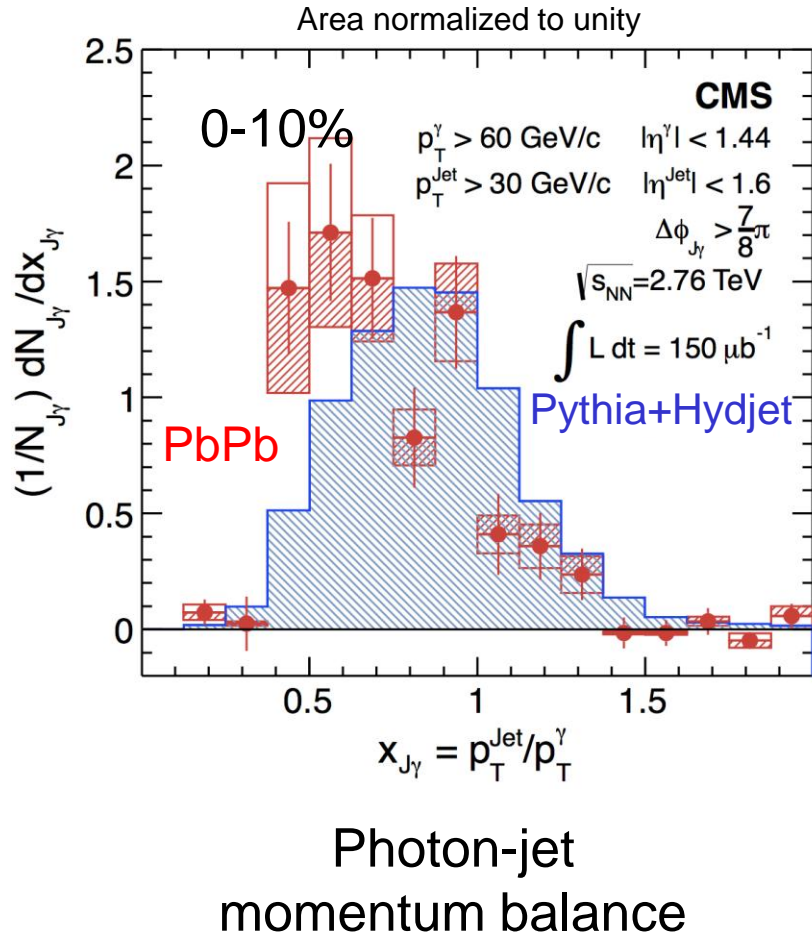
Photon-jet
momentum balance

Parallel talk

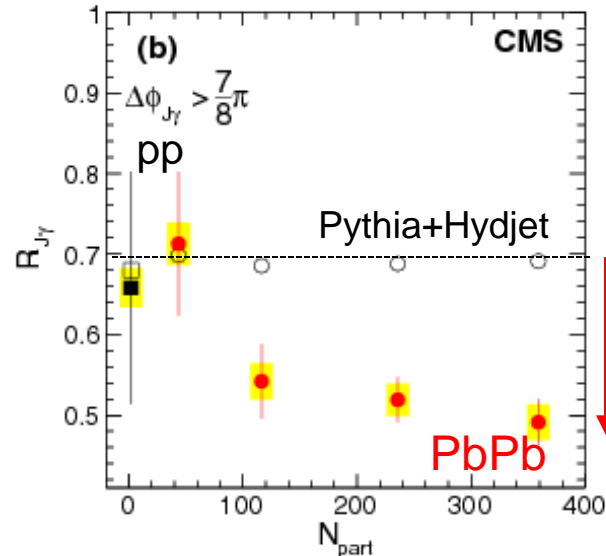
Yue Shi Lai (Tue)

γ +jet: u,d quark energy loss

arXiv:1205.0206



Jet-photon p_T balance drops by 14%

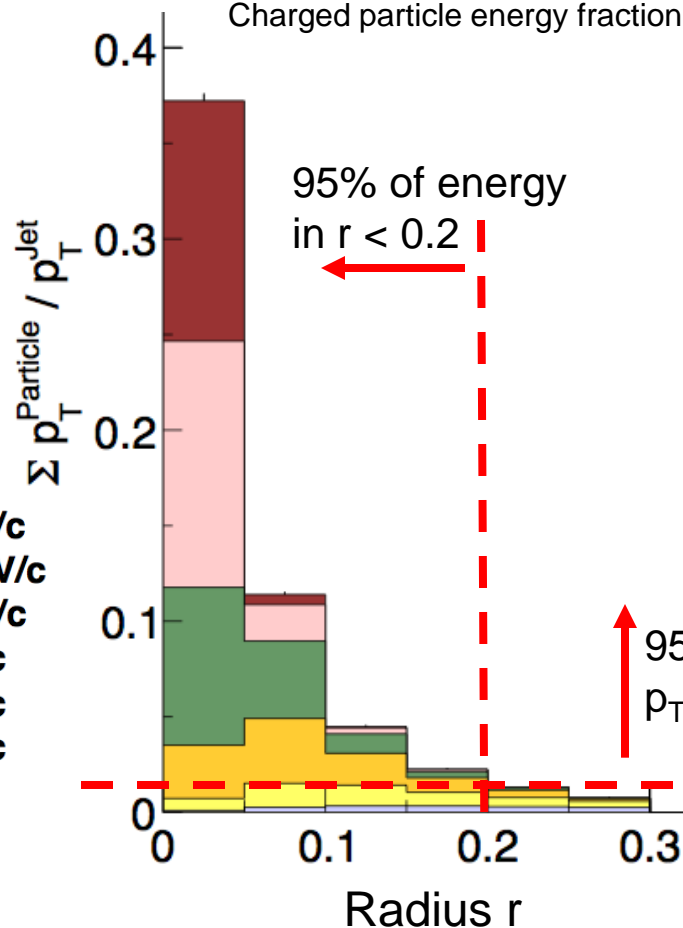


20% of photons lose jet partner

Parallel talk
 Yue Shi Lai (Tue)

Anatomy of a jet

PYTHIA 100 GeV inclusive jet
Anti- k_T $R=0.3$ jet
Charged particle energy fraction



Is the jet energy in PbPb redistributed in radius:
Differential jet-shapes

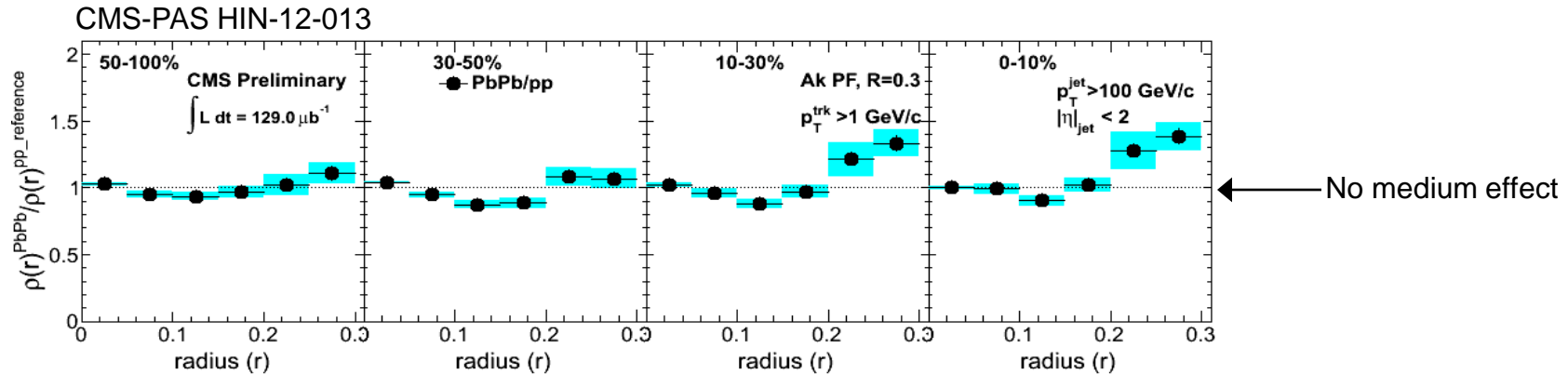
Is the jet energy in PbPb redistributed in particle p_T :
Fragmentation functions

Anatomy of a jet

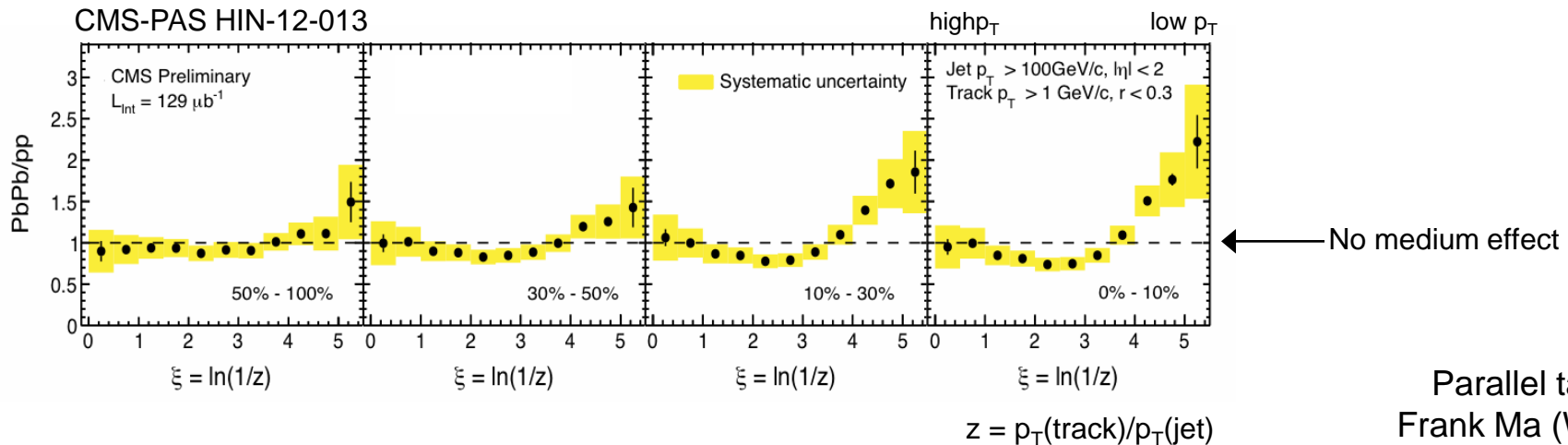
Parallel talk
Pelin Kurt (Wed)

Poster
Yaxian Mao

Ratio of PbPb/pp differential jet shapes



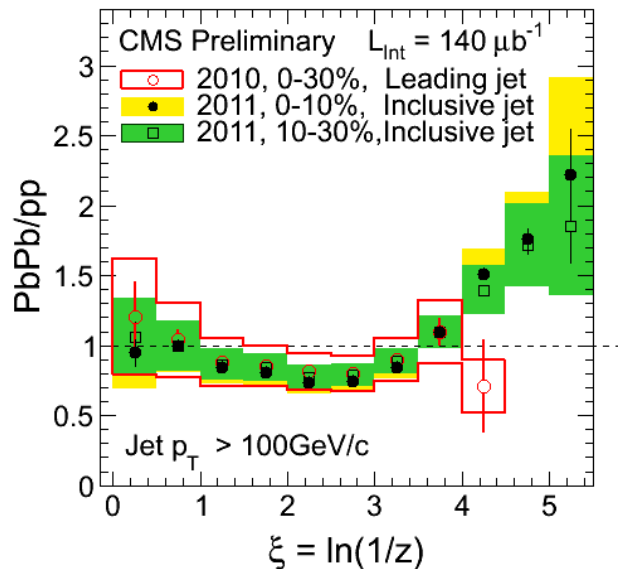
Ratio of PbPb/pp fragmentation functions



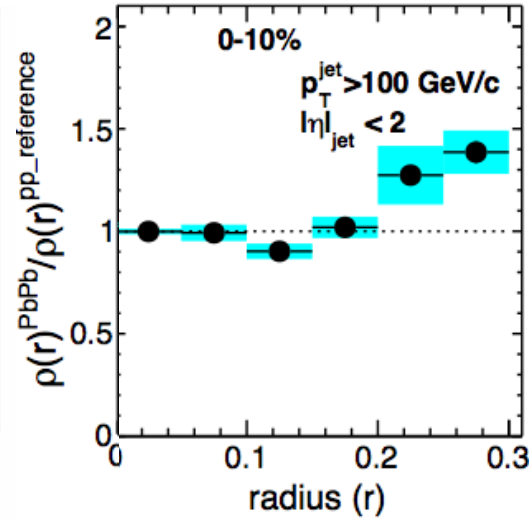
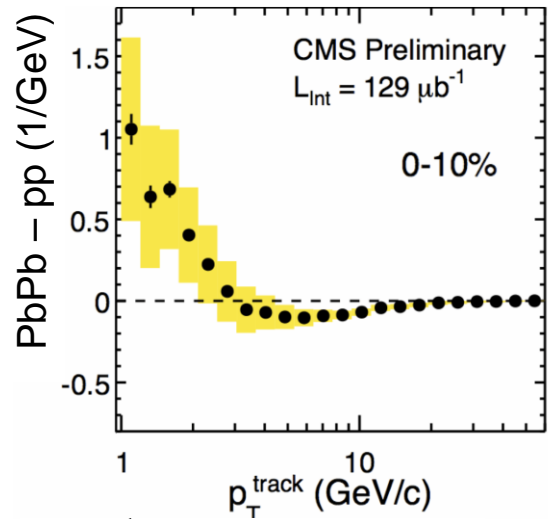
Parallel talk
Frank Ma (Wed)

A consistent view of jet quenching

arXiv:1205.5872



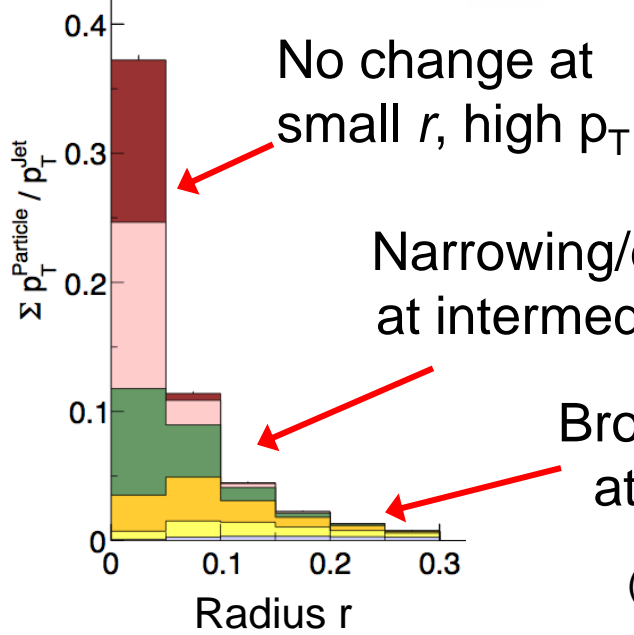
Change from “ ξ ” to “ p_T ”



Consistent with 2010 result

Recall (2010 vs 2011):

- Track $p_T > 4$ GeV vs $p_T > 1$ GeV
- Leading vs inclusive jet
- 0-30% vs 0-10% and 10-30%



No change at small r , high p_T

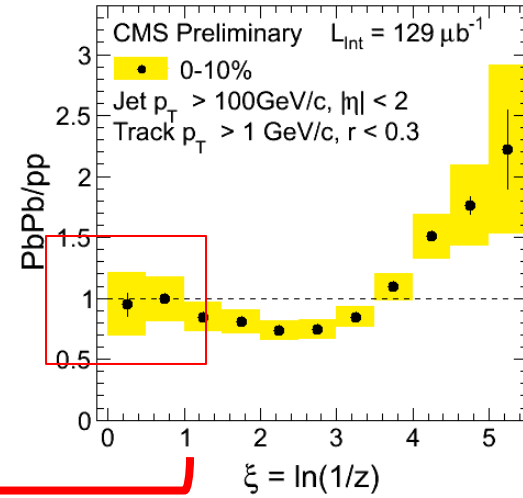
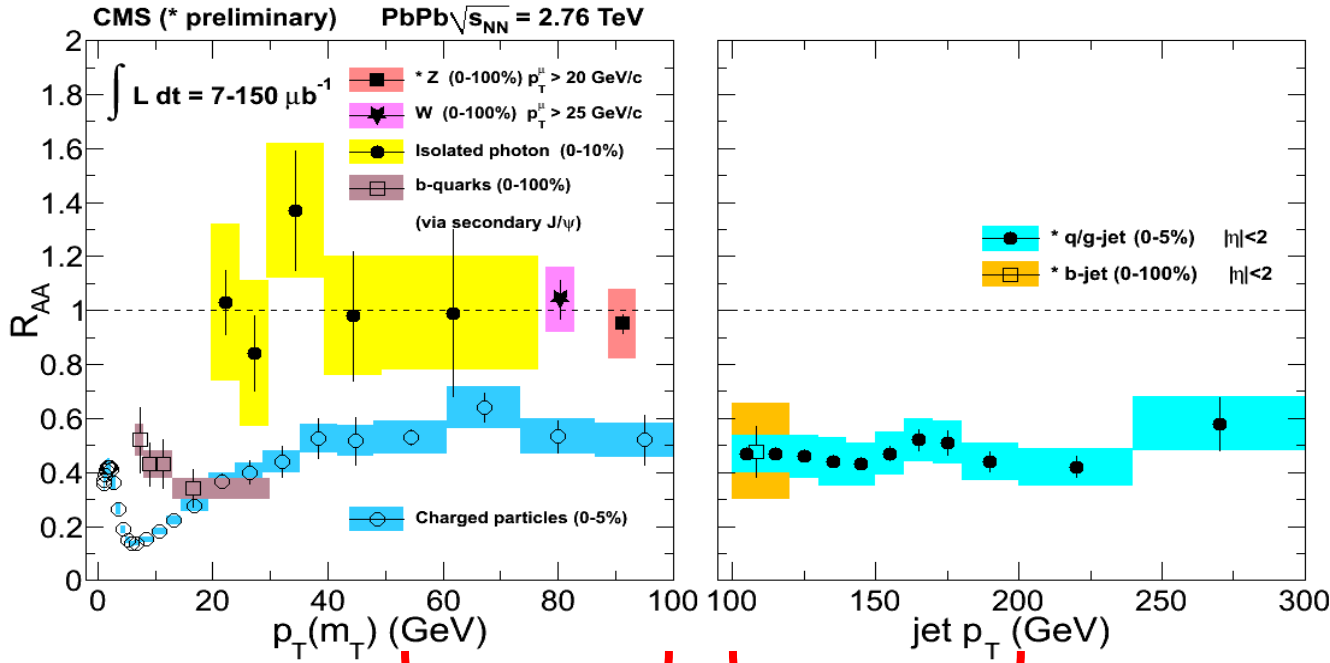
Narrowing/depletion at intermediate r , p_T

Broadening/excess at large r , low p_T

(~2% of jet energy)



A consistent view of jet quenching



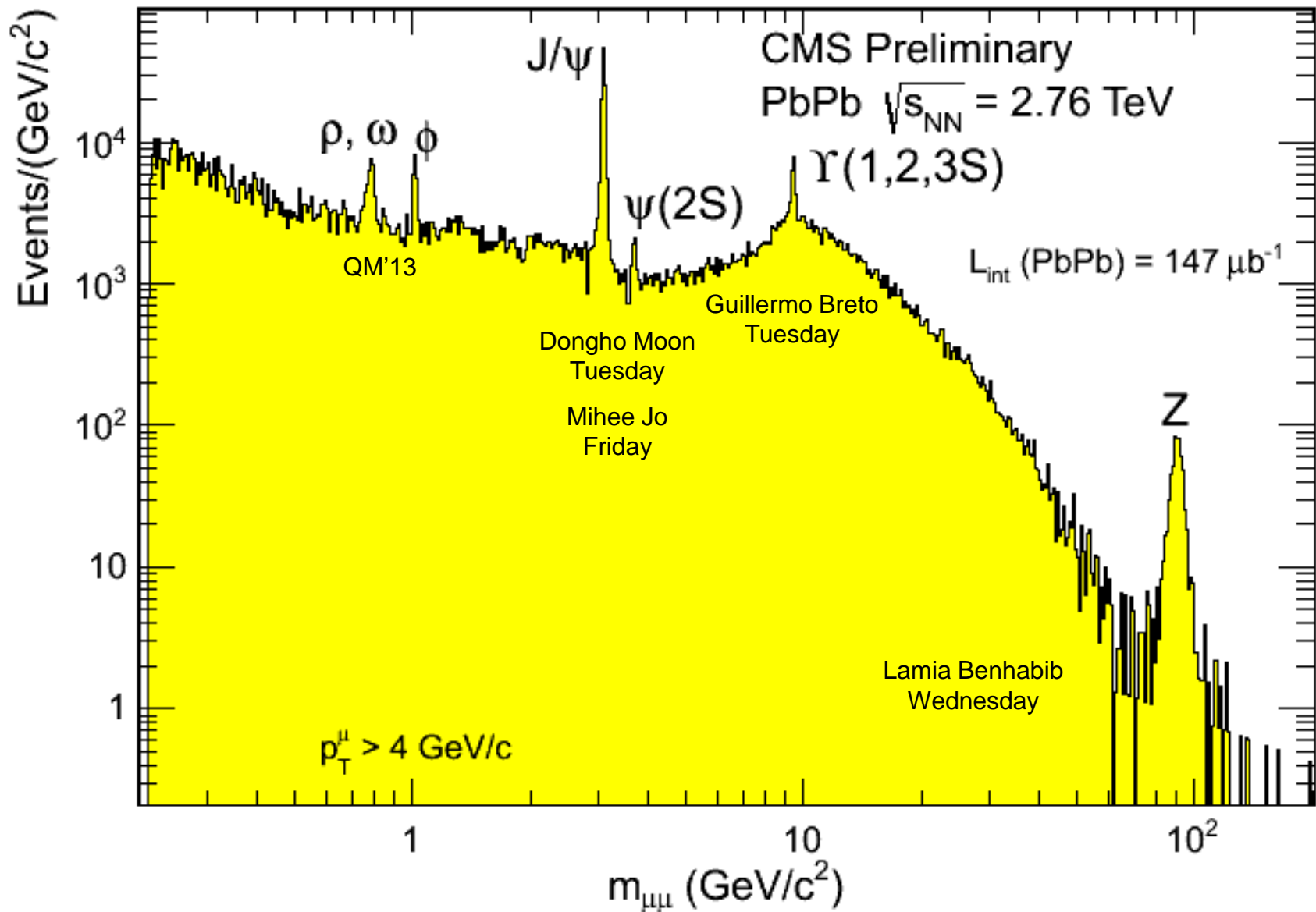
Charged particles from
 $p_T = 50-100$ GeV:
 $z = p_T(\text{track})/p_T(\text{jet}) = 0.4-0.6$
 $\rightarrow \xi < 1$

Looking at the same
 parton p_T range

PbPb fragmentation function = pp for $\xi < 1$

Consistent message from charged hadron R_{AA} ,
 inclusive jet R_{AA} and fragmentation functions!

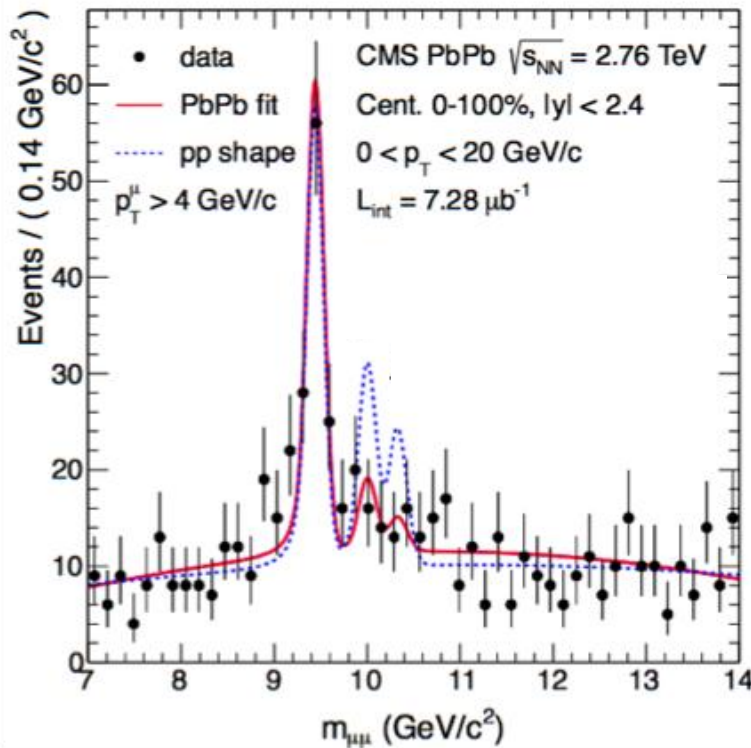
Dimuons: Lost and bound



Sequential Upsilon suppression

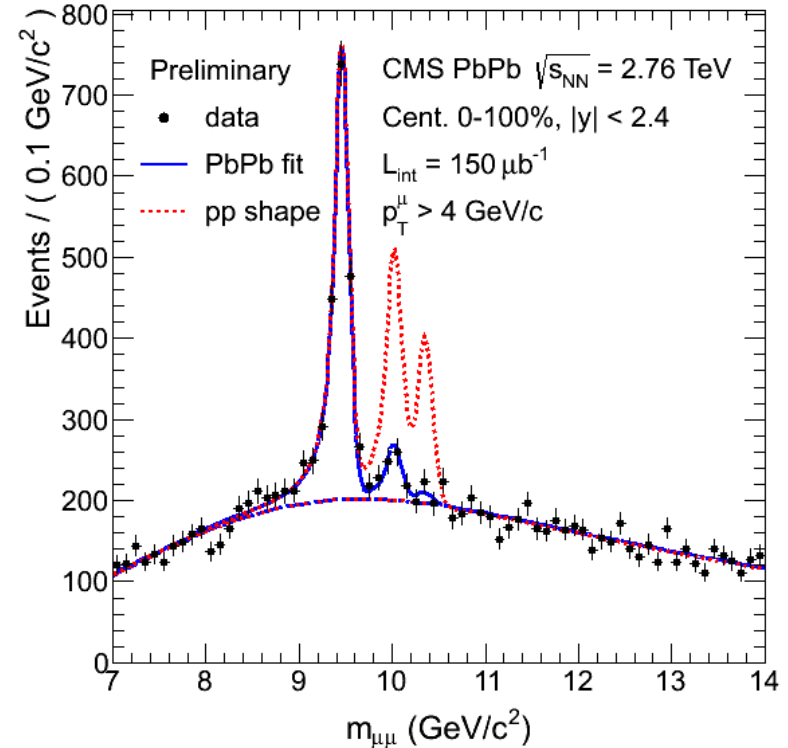
2010 data

PRL 107 (2011) 052302



Indication of suppression of (Y(2S)+Y(3S)) relative to Y(1S)
 → 2.4 σ significance

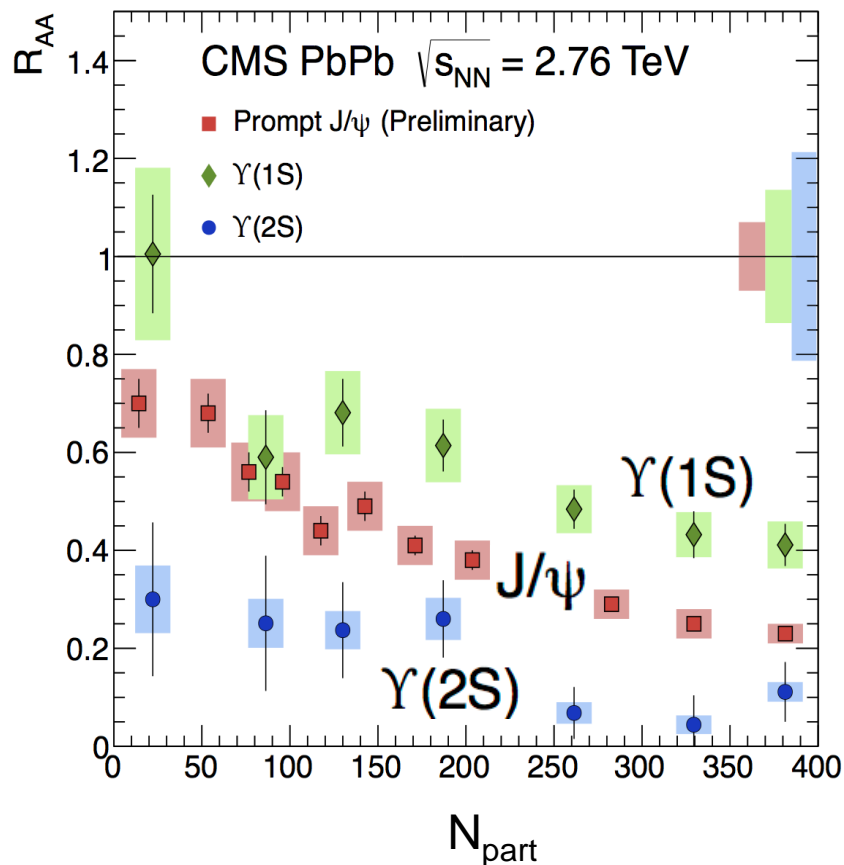
2011 data



Observation of sequential suppression of Y family
 → Detailed studies

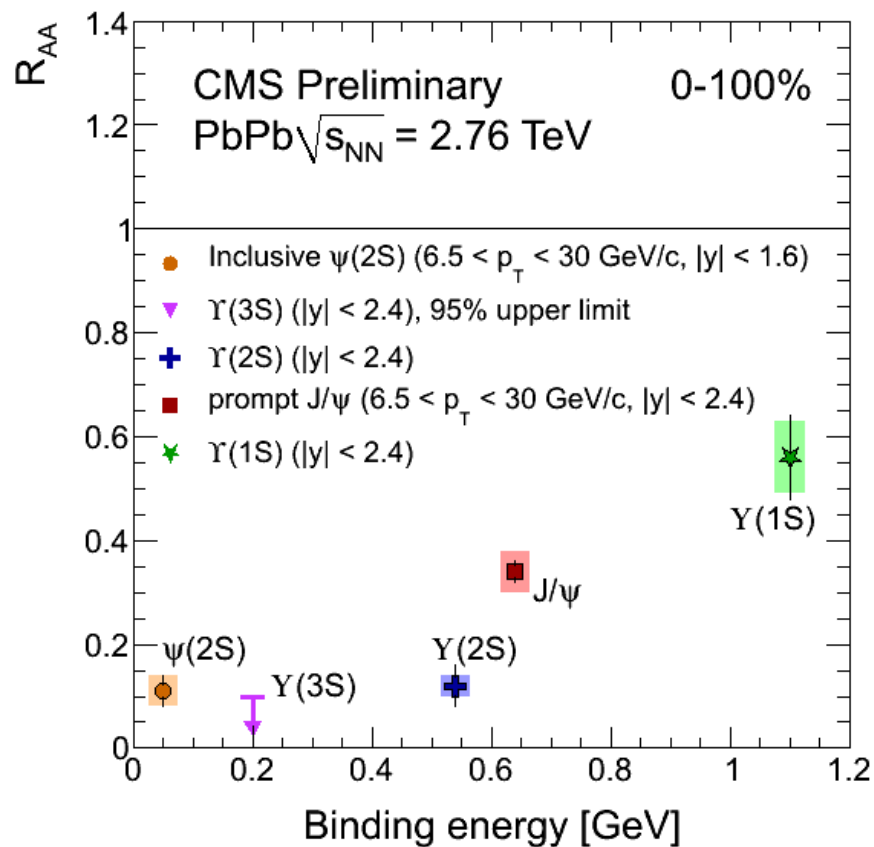
Building a quarkonium-thermometer

CMS-PAS HIN-11-011



Clear hierarchy in R_{AA} of different quarkonium states

Note: $6.5 < p_T < 30$ GeV for J/ ψ and $\psi(2s)$



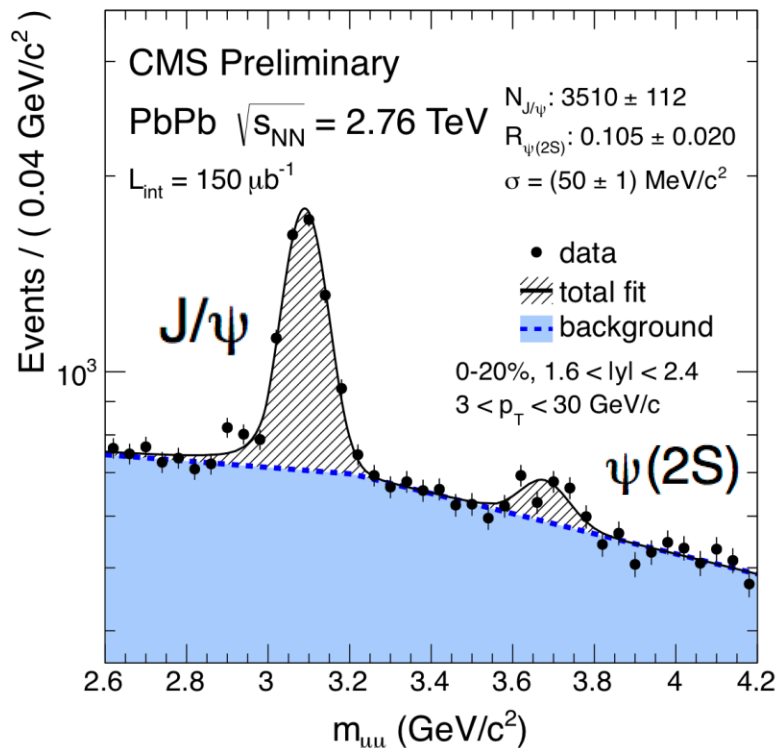
Expected in terms of binding energy

CMS-PAS HIN-12-014, HIN-12-007

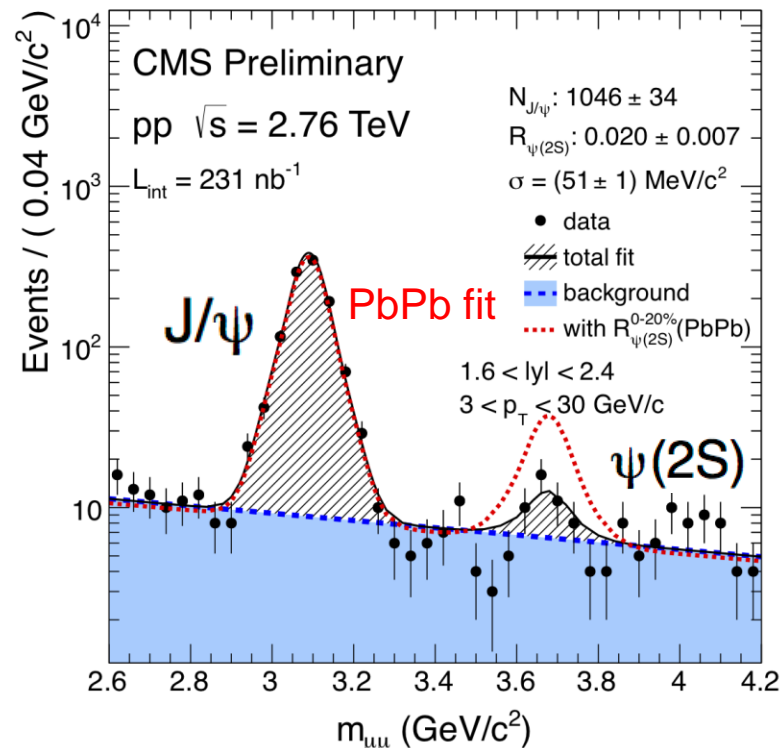
Lost and bound: J/ψ vs $\psi(2S)$

CMS-PAS HIN-12-007

PbPb ($p_T > 3\text{GeV}$)



pp ($p_T > 3\text{GeV}$)



Indication that loosely bound $\psi(2S)$ less suppressed than more tightly bound J/ψ for $p_T > 3\text{GeV}$

not more than 2σ significance, limited by pp statistics

Summary

- Rich harvest of new data and results since QM '11
- Highlights include:
 - Flow harmonics in ultra-central collisions
 - v_2 and v_3 for p_T of 40-60GeV
 - Nuclear modification factors
 - γ , Z^0 , W , charged hadrons, jets, b-tagged jets, $B \rightarrow J/\psi$
 - First results on γ -jet correlations
 - Detailed studies of jet fragmentation
 - Observation of sequential melting of the Y family and indications of un-melting of $\psi(2S)$
- Enjoy the excellent presentations our young colleagues have prepared!

QM '12 talks from CMS

Mon 12:25pm, Gunther Roland, **Experimental highlights**

Mon 5:15pm, Stephen Sanders, **Overview of results on flow and correlations**

Tue 9:30am, Gabor Veres, **Overview of results on jets**

Tue 2:15pm, Yue Shi Lai, Study of jet quenching using photon-jet events in PbPb collisions

Tue 2:15pm, Dongho Moon, Detailed measurements of charmonium suppression in PbPb collisions

Tue 3:15pm, Rylan Conway, Short- and long-range very-high- p_T triggered dihadron correlations in PbPb collisions

Tue 3:55pm, Victoria Zhukova, Azimuthal anisotropy of charged hadrons at very high p_T in PbPb collisions

Tue 4:45pm, Matthew Nguyen, Studies of jet quenching and b-jet tagging in PbPb collisions

Tue 4:45pm, Guillermo Rangel, Detailed measurements of bottomonium suppression in PbPb collisions

Tue 5:25pm, Marguerite Tonjes, Inclusive jet and charged hadron nuclear modification factors in PbPb collisions

Tue 5:45pm, Magdalena Malek, Pseudorapidity and centrality dependence of transverse energy flow in PbPb collisions

Wed 8:30am, Hauke Wohrmann, Studies of the nuclear stopping power in PbPb collisions

Wed 9:10am, Pelin Kurt, Jet shapes in pp and PbPb collisions

Wed 9:50am, Frank Ma, Jet fragmentation functions in PbPb and pp collisions

Wed 11:20am, George Stephans, Inclusive isolated photons in pp and PbPb collisions

Wed 12:00pm, Lamia Benhabib, Jet shapes in pp and PbPb collisions

Thu 9:45am, Raphael Granier de C., **Overview of results on photon and electroweak boson production**

Thu 11:05am, Camelia Mironov, **Overview of results on heavy flavor and quarkonia**

Fri 2:20pm, Eric Appelt, Elliptic azimuthal anisotropy of charged hadrons and neutral pions in PbPb collisions

Fri 3:40pm, Mihee Jo, Suppression of open bottom at high p_T via non-prompt J/psi decays in PbPb collisions

Fri 5:30pm, Shengquan Tuo, Studies of higher-order flow harmonics and factorization of dihadron correlations in PbPb collisions