Summary of “First results from Heavy Ion collisions at the LHC (ALICE, ATLAS, CMS)”

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Weekly Journal Club for Medium Energy Physics at IPAS

March 21, 2011

Slides Taken From

http://indico.cern.ch/conferenceDisplay.py?confId=114939

First results from Heavy Ion collisions at the LHC (ALICE, ATLAS, CMS)

chaired by Sergio Bertolucci (CERN)

Thursday 02 December 2010 from **17:15** to **18:55** (Europe/Zurich)
at CERN (500-1-001 - Main Auditorium)

Description Presentation of the first physics results from the 2010 heavy ion run of the LHC

Material Poster | Video in CDS

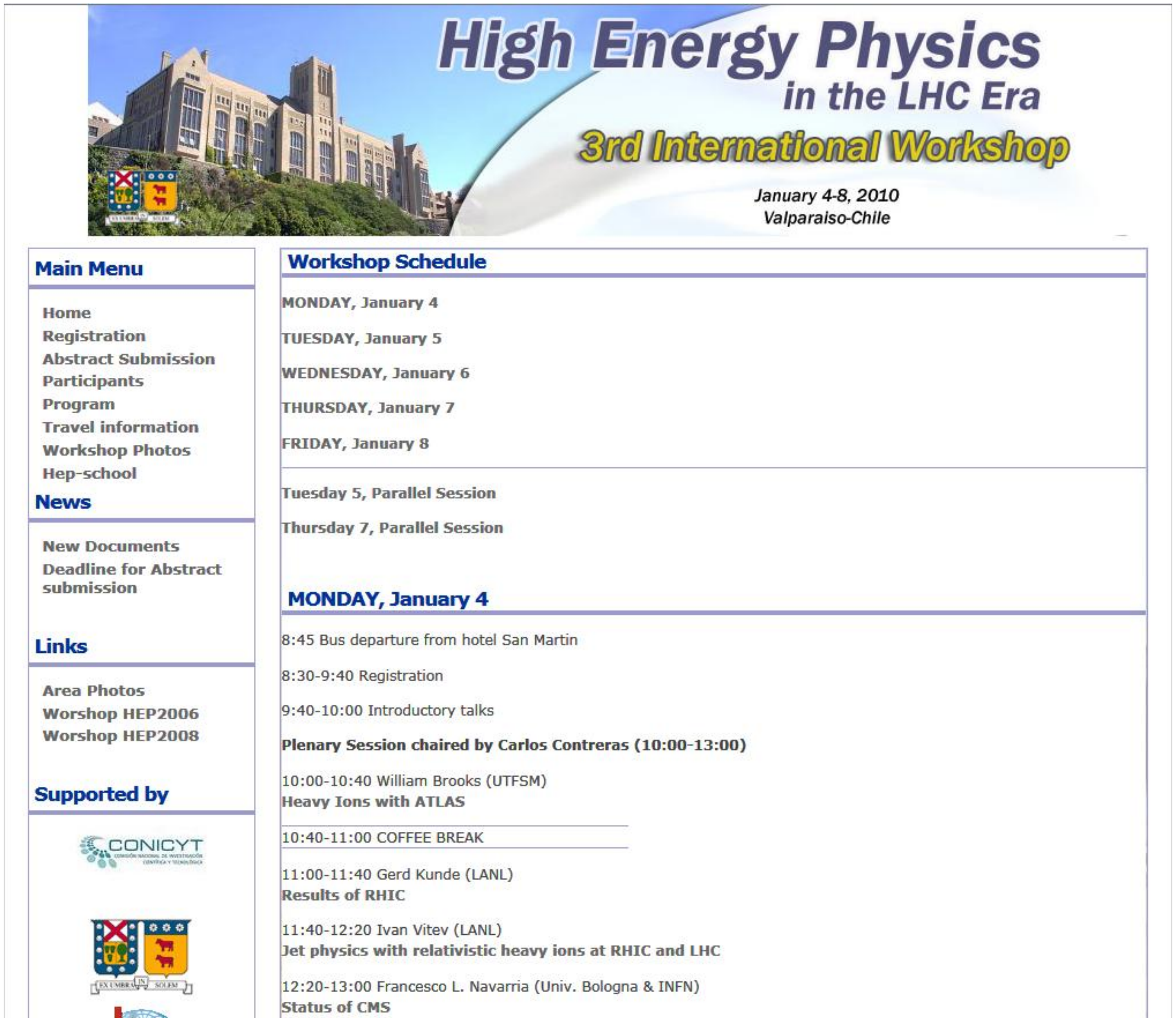
Thursday 02 December 2010

17:15 - 17:45 ATLAS *30'*
Speaker: Brian Cole (Physics Dept., Pupin Physics Lab.-Columbia University-Unknown)
Material: **Slides**

17:50 - 18:20 CMS *30'*
Speaker: Bolek Wyslouch (MIT)
Material: **Slides**

18:25 - 18:55 ALICE *30'*
Speaker: Juergen Schukraft (CERN)
Material: **Slides**

Slides Taken From
Gerd Kunde's talk in HEP2010


High Energy Physics
in the LHC Era
3rd International Workshop
January 4-8, 2010
Valparaiso-Chile

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Workshop Schedule

MONDAY, January 4
TUESDAY, January 5
WEDNESDAY, January 6
THURSDAY, January 7
FRIDAY, January 8

Tuesday 5, Parallel Session
Thursday 7, Parallel Session

MONDAY, January 4

8:45 Bus departure from hotel San Martin

8:30-9:40 Registration

9:40-10:00 Introductory talks

Plenary Session chaired by Carlos Contreras (10:00-13:00)

10:00-10:40 William Brooks (UTFSM)
Heavy Ions with ATLAS

10:40-11:00 COFFEE BREAK

11:00-11:40 Gerd Kunde (LANL)
Results of RHIC

11:40-12:20 Ivan Vitev (LANL)
Jet physics with relativistic heavy ions at RHIC and LHC

12:20-13:00 Francesco L. Navarria (Univ. Bologna & INFN)
Status of CMS

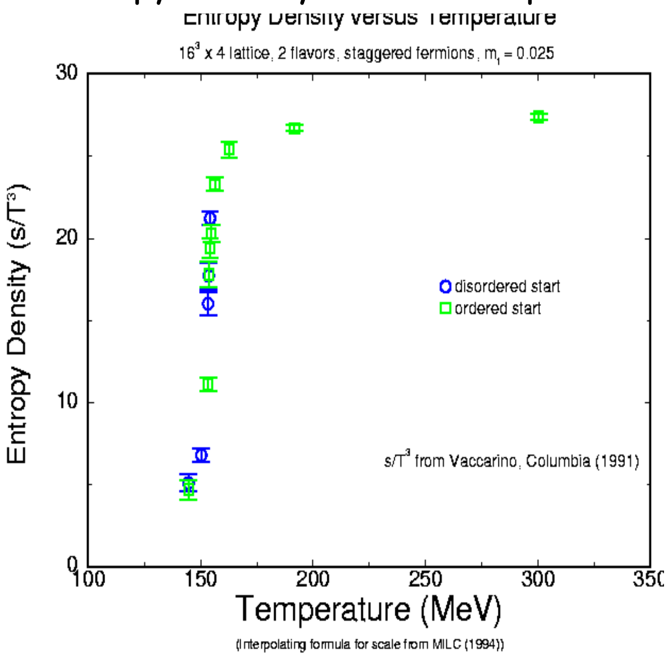
Observations of Relativistic Heavy-Ion Collisions before LHC.

New State of Matter?

Is there a state of matter where

- quarks and gluons are moving freely?
- the broken chiral symmetry is (partially) restored?

Entropy Density versus Temperature

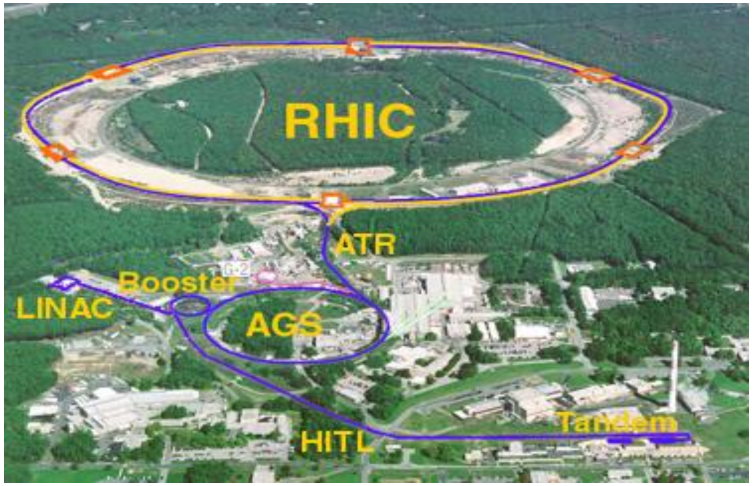


Lattice QCD suggests of a QCD phase transition beyond a region of
high energy and/or
high baryon density.

The question is that how do we realize it?

Relativistic Heavy Ion Programs

GSI

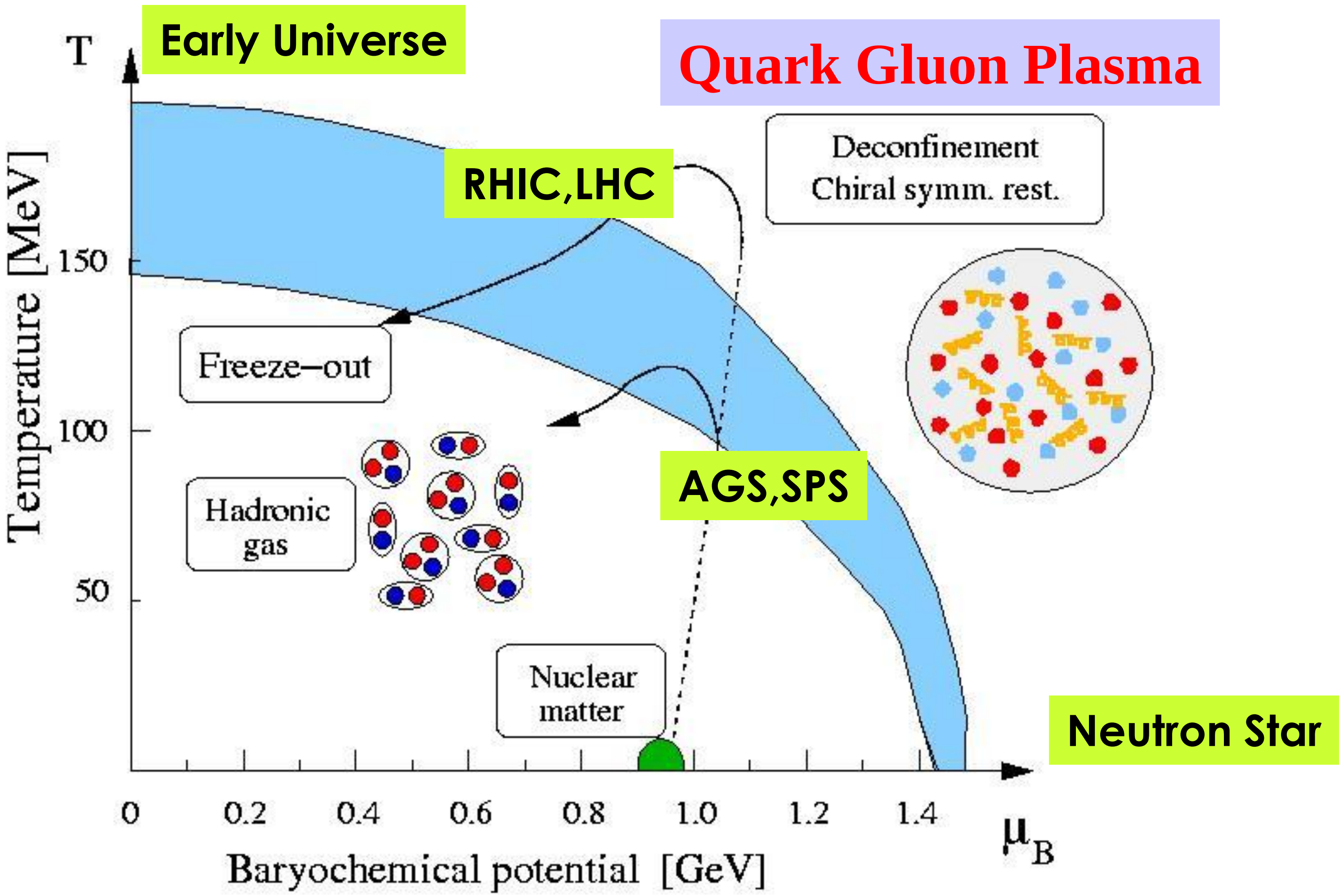


AGS & RHIC

SPS

LHC

QCD Phase Diagram



QGP Signatures

If QGP is formed:

- Strong gluon-gluon and gluon-quark interaction:

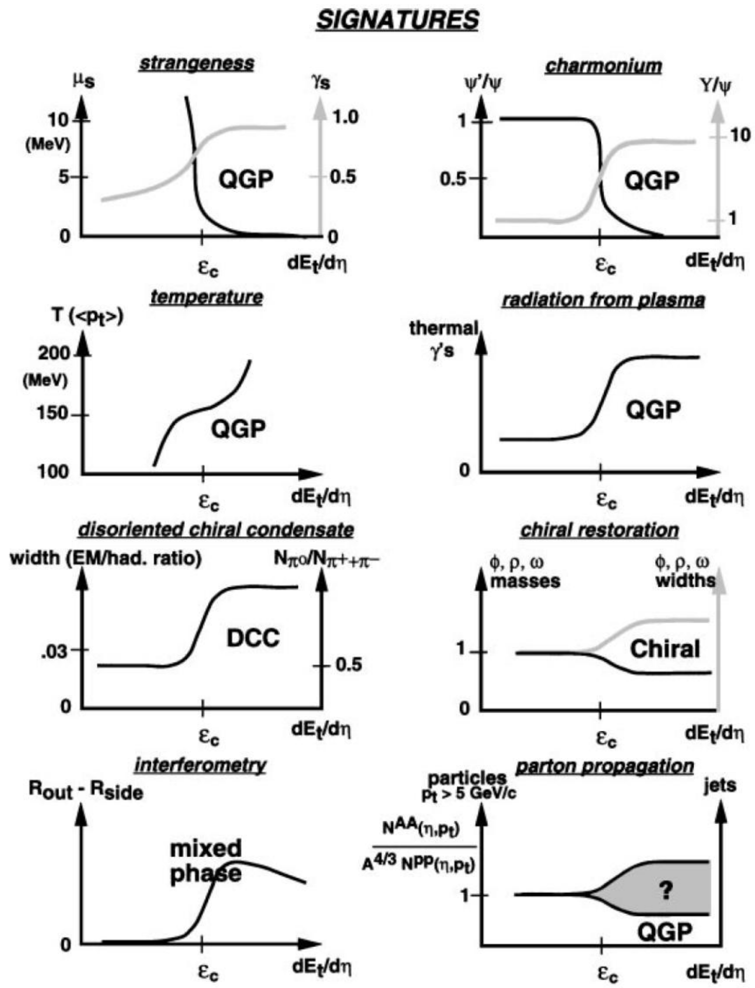
  → equilibrium achieved in a short time and an enhancement of strangeness and anti-baryon production.
- High temperature:

  → thermal radiation by direct photon.
- High density:

  → J/ψ screening, modification of vector mesons and jet quenching.
- Soft equation of state:

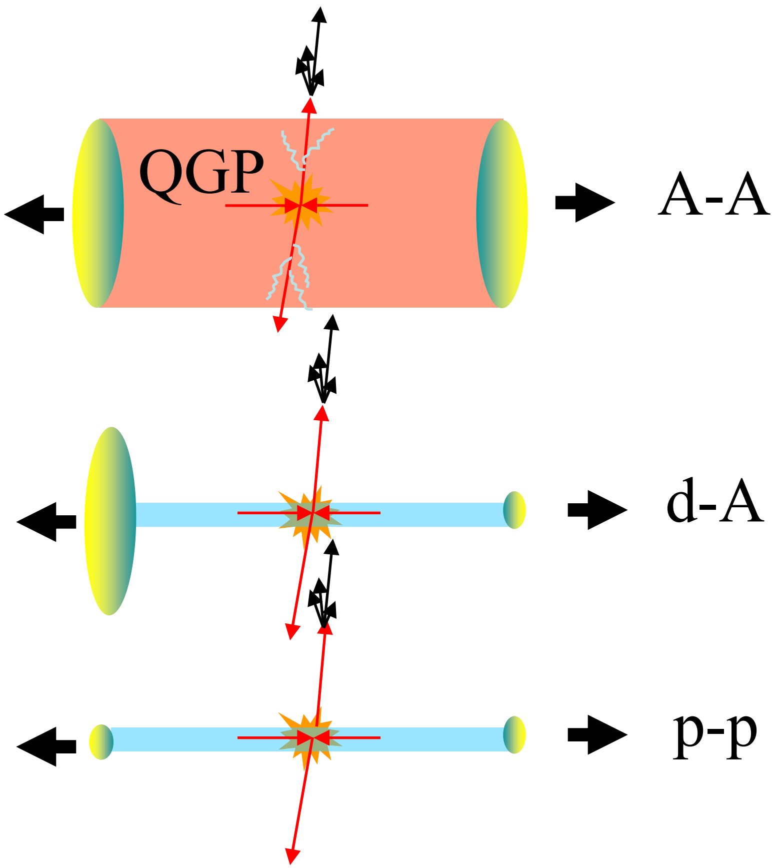
  → transverse expansion.

Signatures vs. Energy Density



Probing a New State of Matter

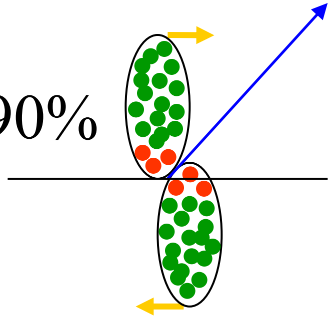
- A-A: "hot & dense" medium
  - Quark-Gluon-Plasma …
- d-Au: "cold" nuclear medium
  - Normal nuclear initial state effects
- p-p: perturbative Quantum Chromo Dynamics
  - Understand physics from "first principles"



Definitions I

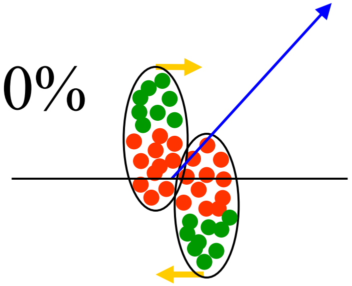
Impact Parameter & Collision Centrality

~90%

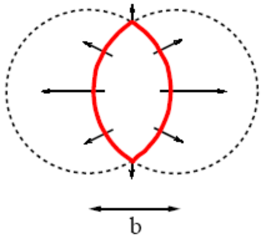


Peripheral is nearly like p-p, order 10 binary collisions

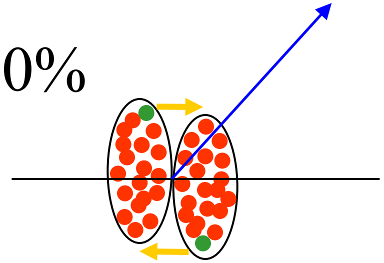
~50%



Mid-central has almond shaped overlap



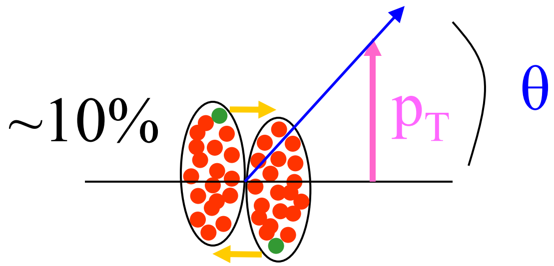
~10%



Central has highest energy density, most binary collisions, order 1000

Definitions II

- Transverse Momentum p_T
  - Was not present before collision



$$\eta = -\ln(\tan(\frac{\theta}{2}))$$

- Rapidity
  - Invariant measure of longitudinal velocity
  - Additive

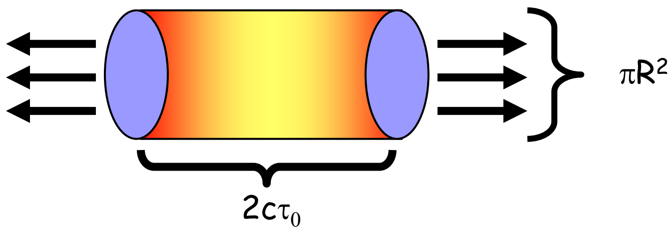
- Compare central A-A with peripheral or p-p

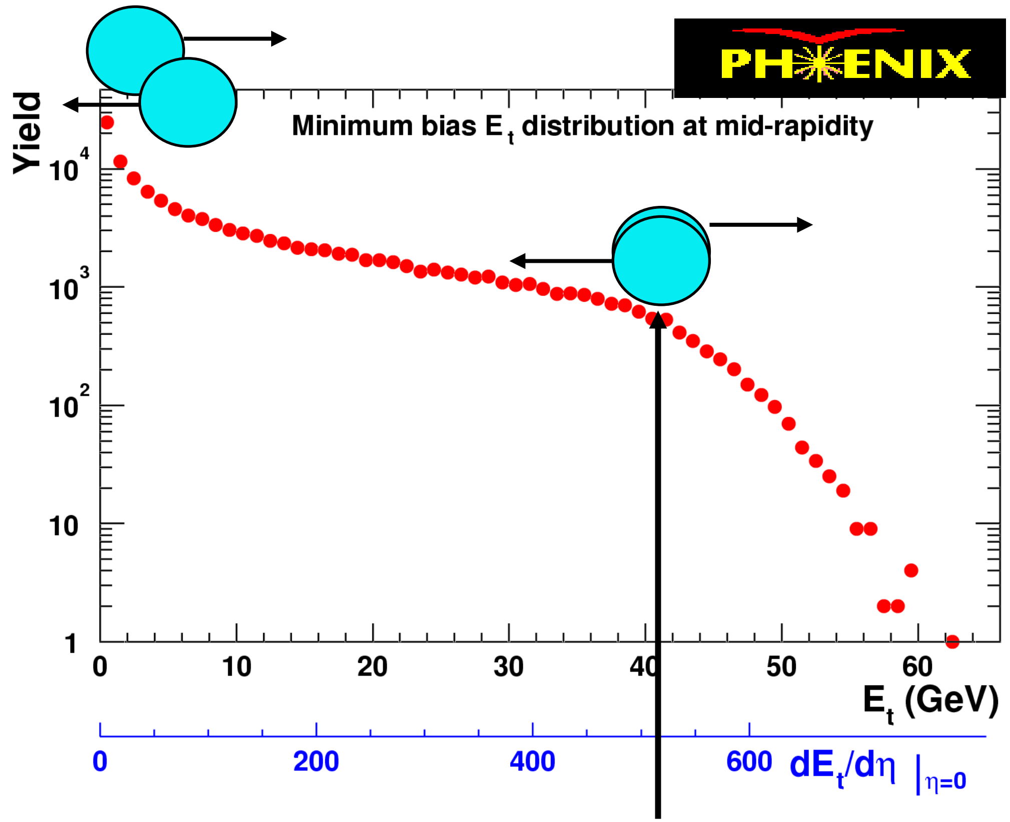
Is the Energy Density High Enough?

Bjorken Picture

PRL87, 052301 (2001)

Colliding system expands:





Energy ⊥ to beam direction

$$\varepsilon_{Bj} = \frac{1}{\pi R^2}\frac{1}{2c\tau_0}\left(2\frac{dE_T}{dy}\right)$$

per unit velocity || to beam

$\rightarrow \varepsilon \geq 5.5\ GeV/fm^3$ **(200 GeV Au+Au)**

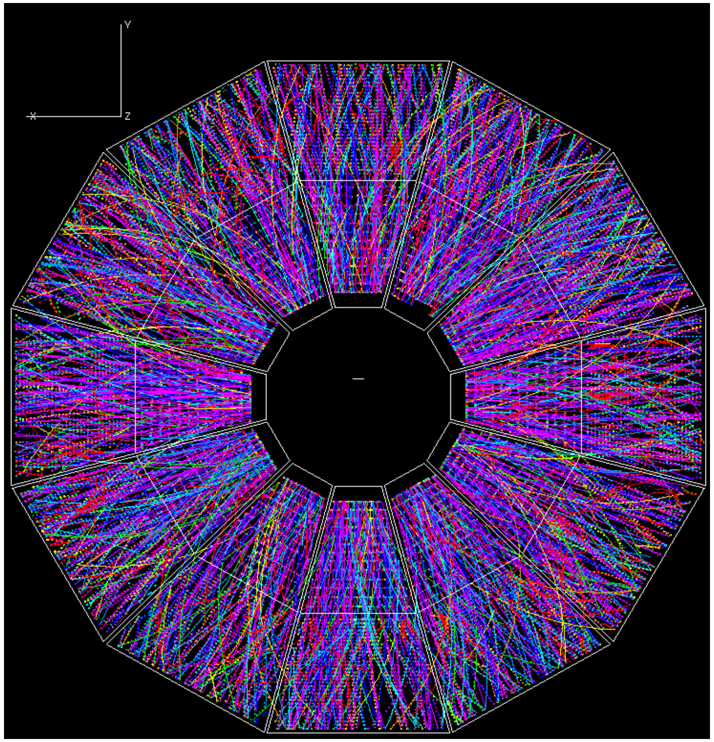
well above predicted transition!

value is lower limit:

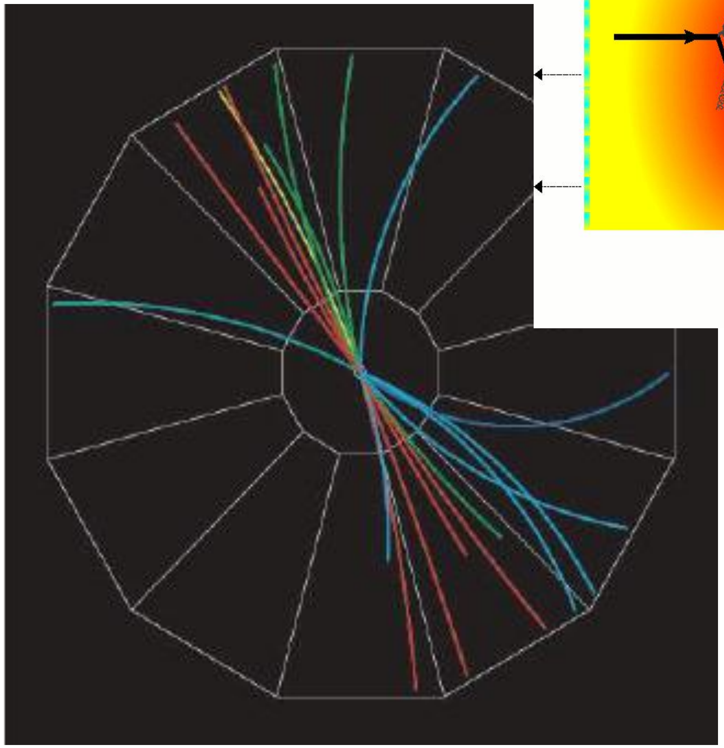
longitudinal expansion rate, formation time overestimated

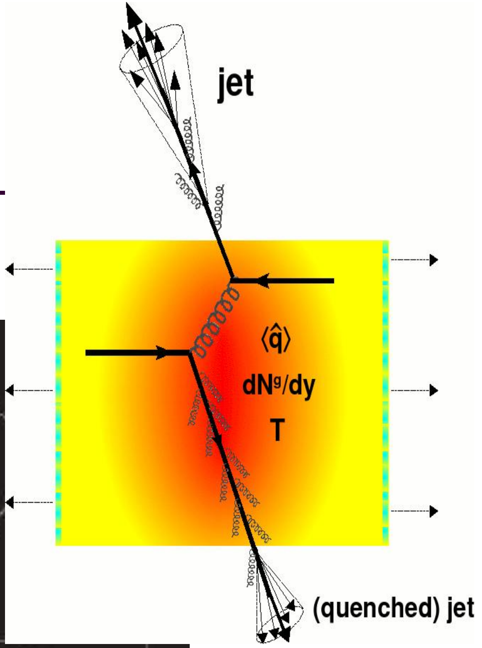
Jet Physics at RHIC

STAR Au+Au @ $\sqrt{s_{NN}}$ = 200 GeV



p+p @ $\sqrt{\underline{s}}$ = 200 GeV

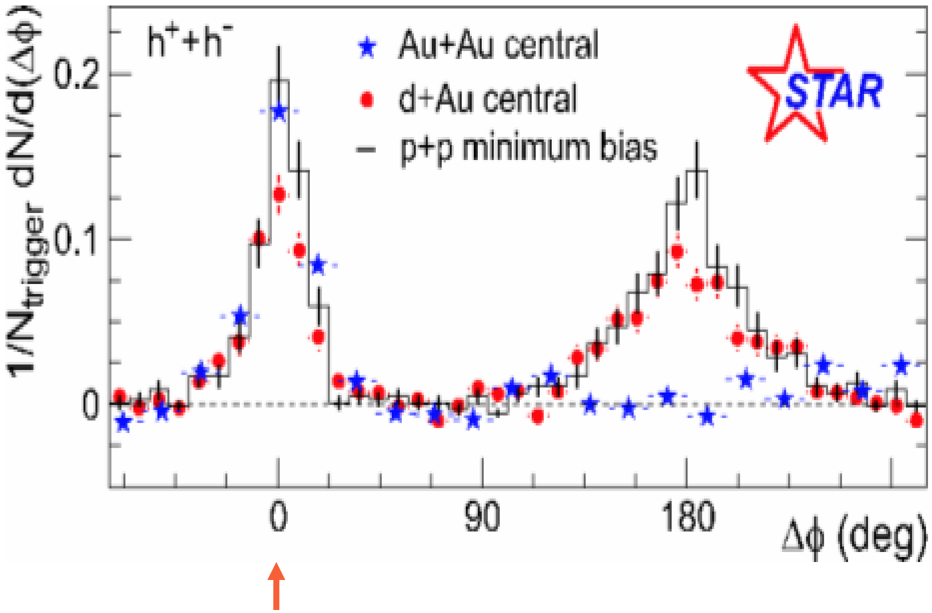


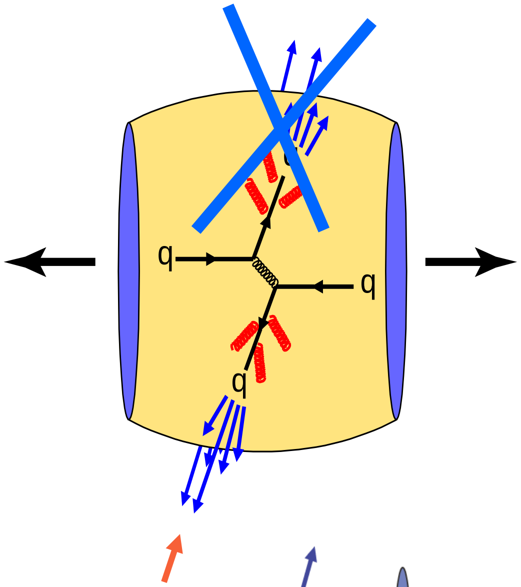


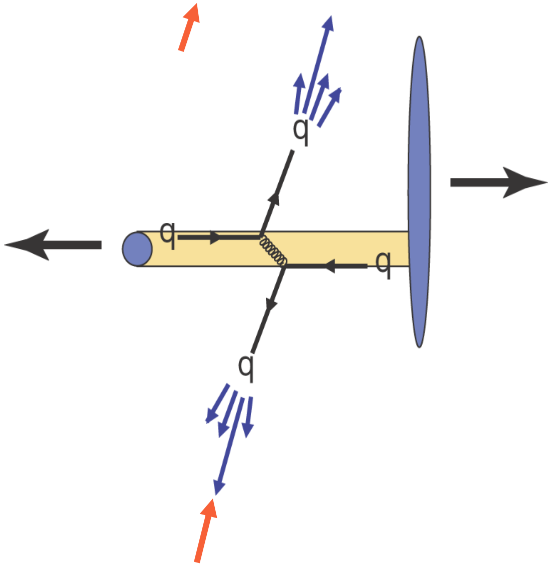
Standard jet reconstruction algorithms fail due to the large energy from the underlying event (125 GeV in R< 0.7) and the relatively low accessible jet energies (< 30 GeV).

RHIC experiments use leading particles as a probe.

Confirmation from Hadron Hadron Correlations

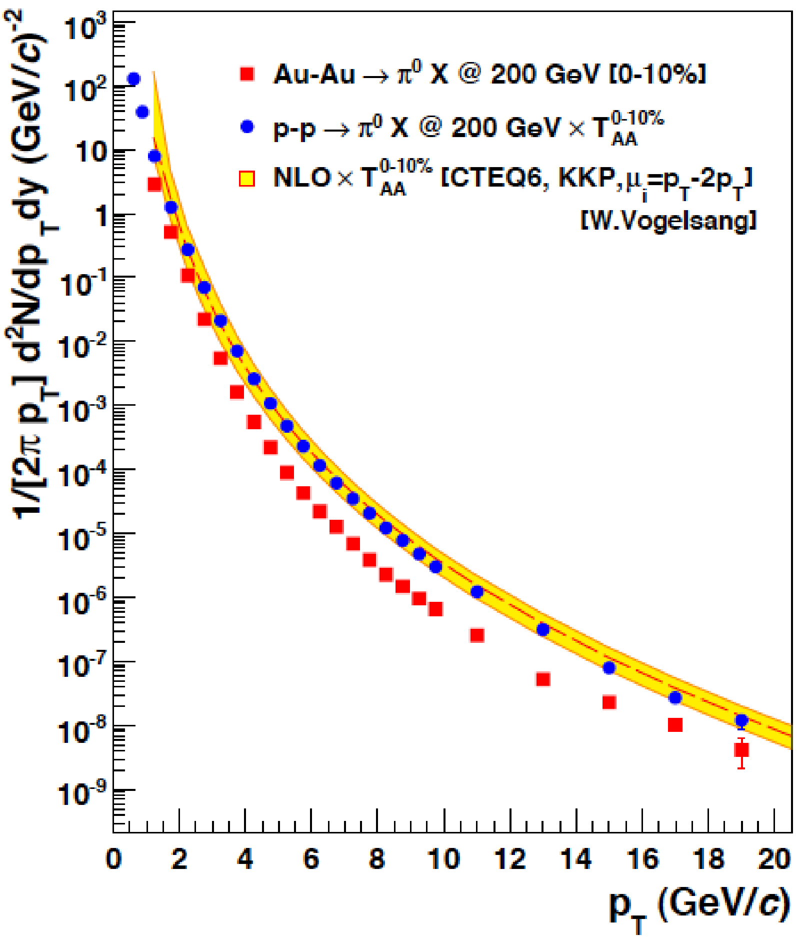






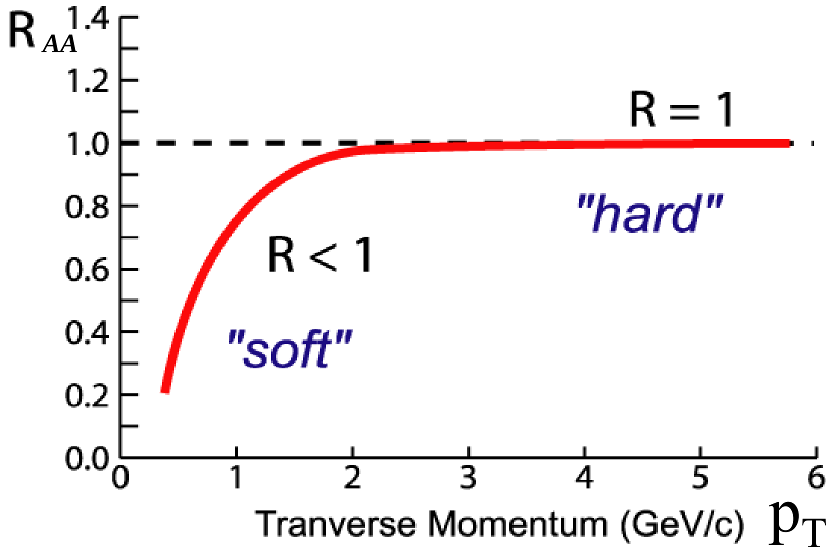
- Correlated high-pT particles
  - Confirm jet nature of single particles
  - Confirm jet suppression
  - Provide more versatile probe

Pt spectra and R_{AA}



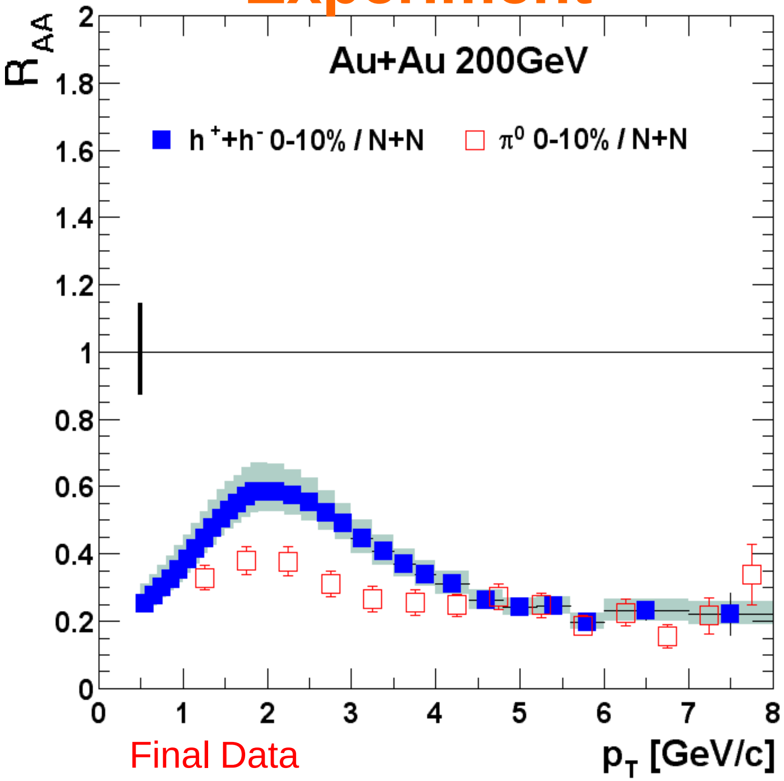
Nuclear Modification Factor

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



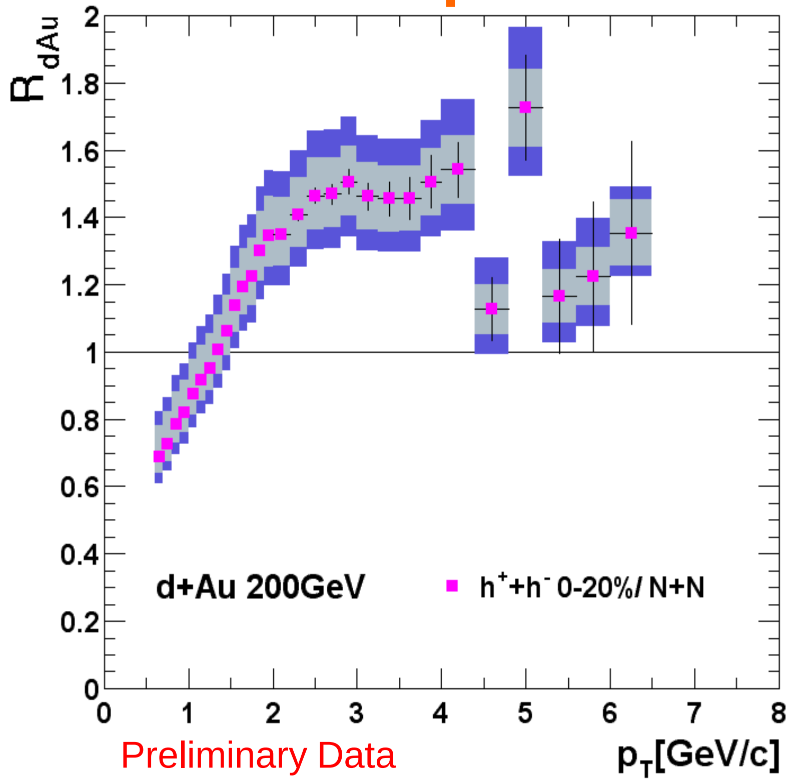
Nuclear Modification Factor

Au + Au Experiment



Final Data

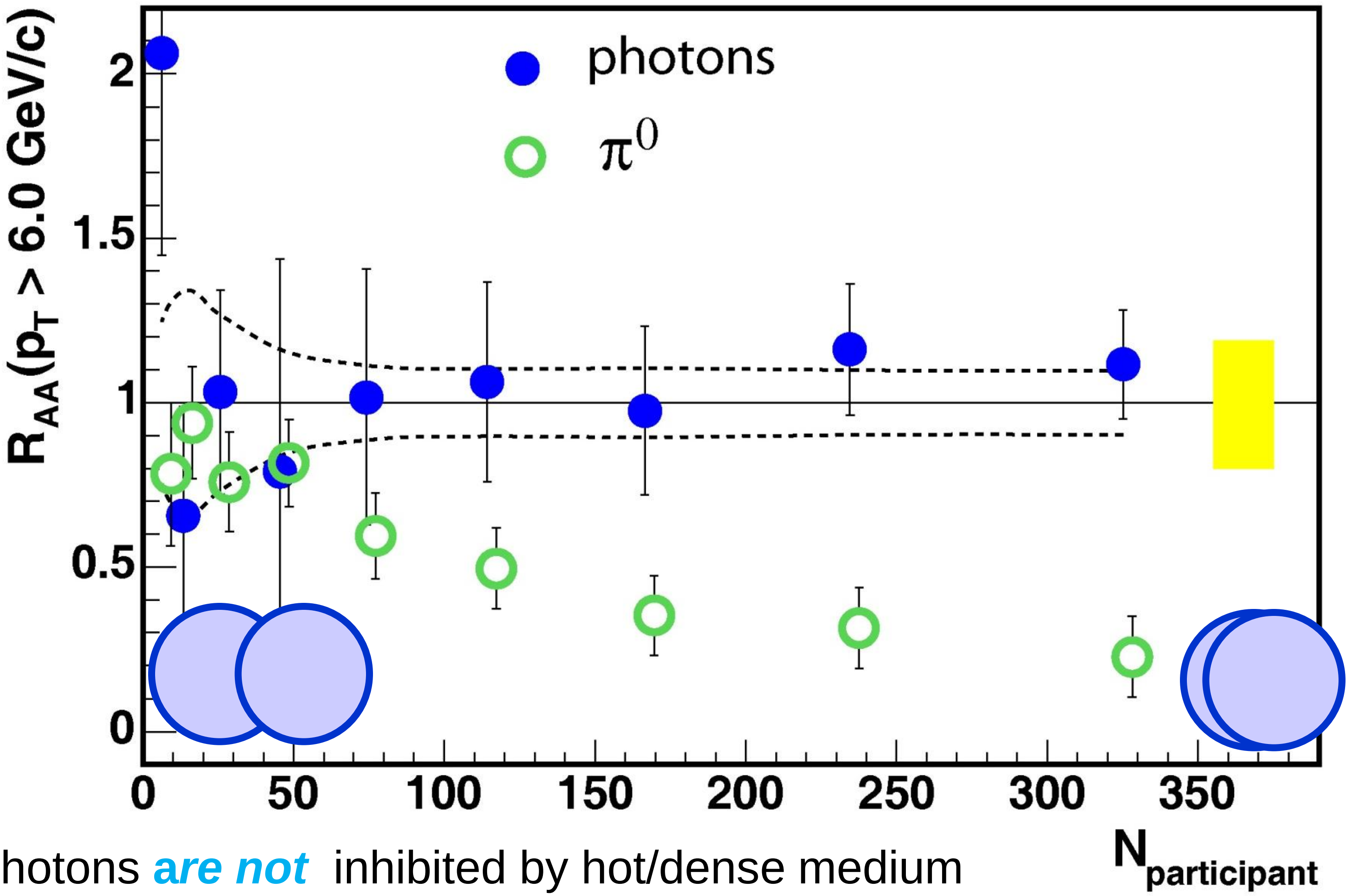
d + Au Control Experiment



Preliminary Data

- Dramatically different and opposite centrality evolution of Au+Au experiment from d+Au control.
- Suppression is clearly a final state effect.

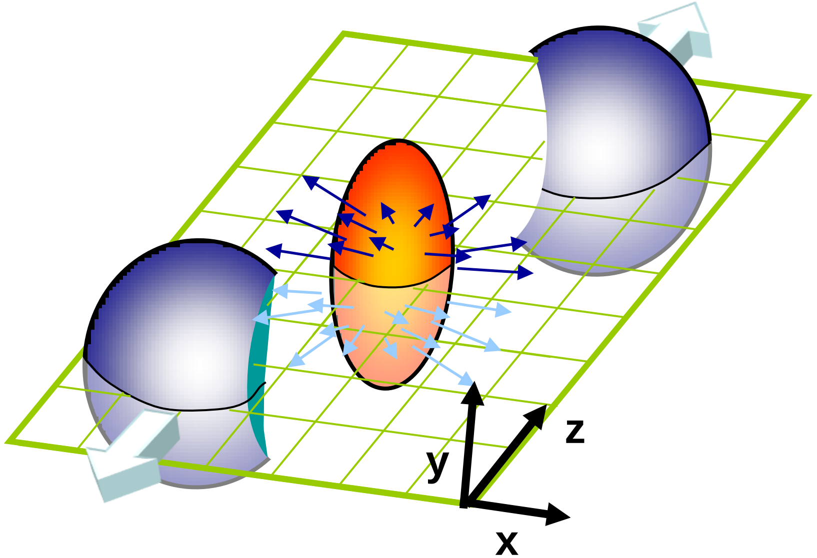
Electromagnetic versus Hadronic Probes

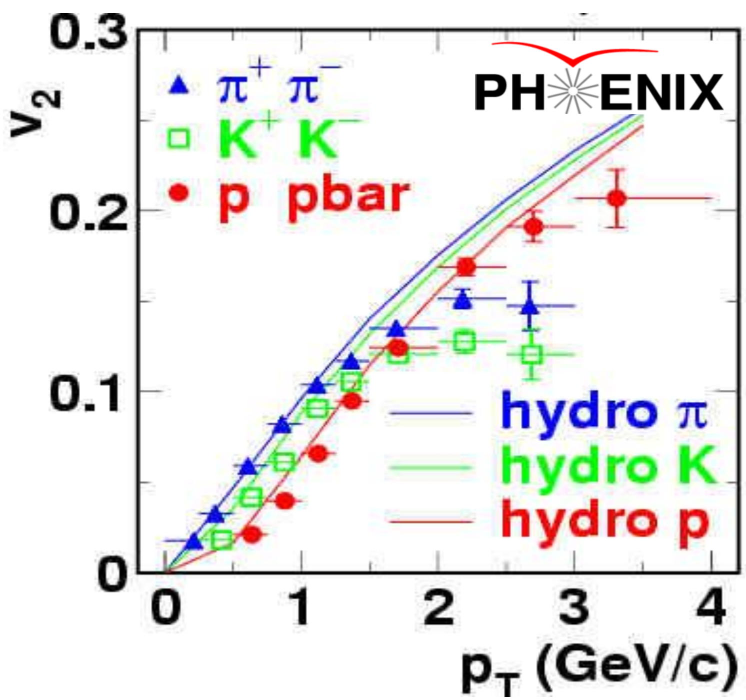


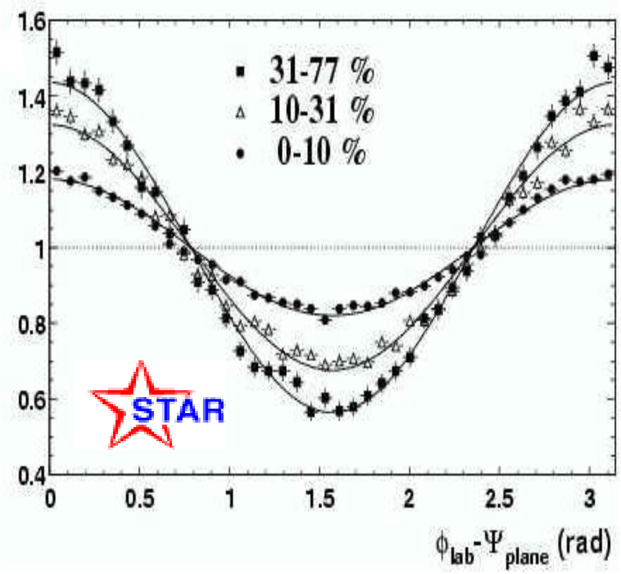
- Direct photons ***are not*** inhibited by hot/dense medium
- Pions (all hadrons) ***are*** inhibited by hot/dense medium

Hydrodynamics at RHIC

- Initial *azimuthal asymmetry* persists in the final state
  $dn/d\phi \sim 1 + 2\, v_2(p_T) \cos(2\phi) + \ldots$

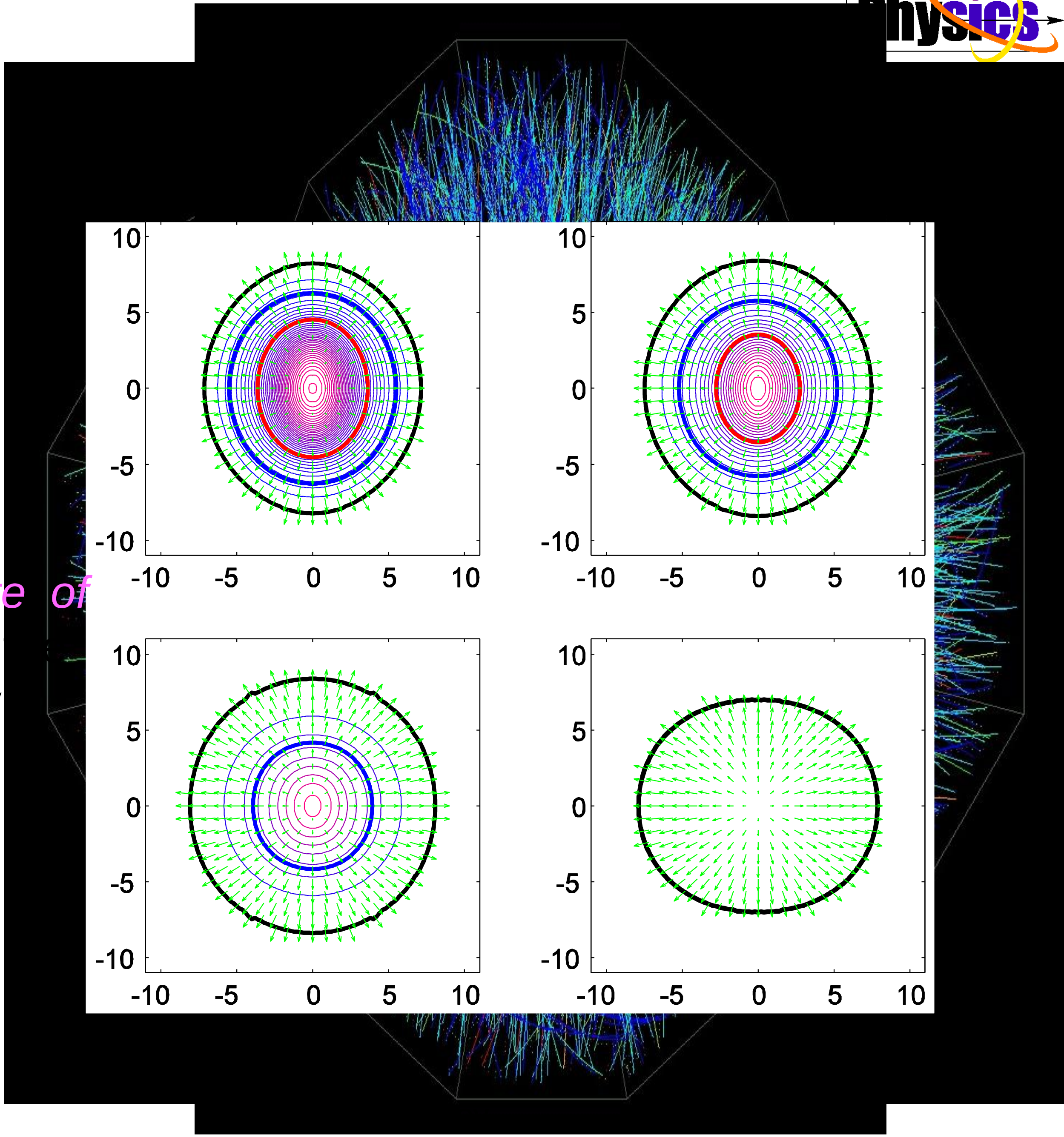




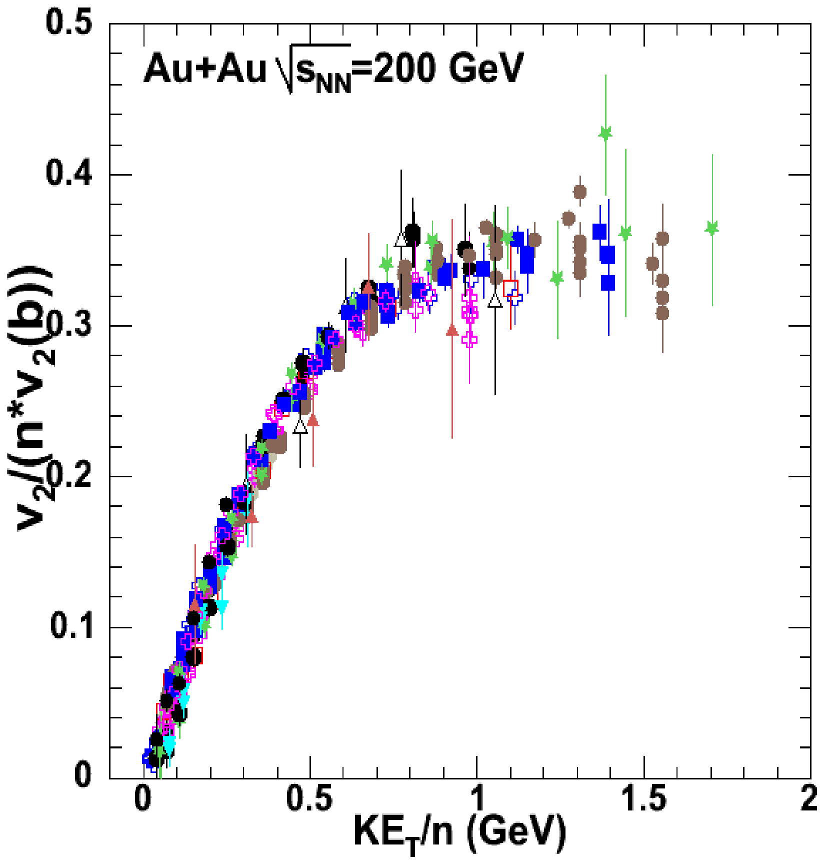


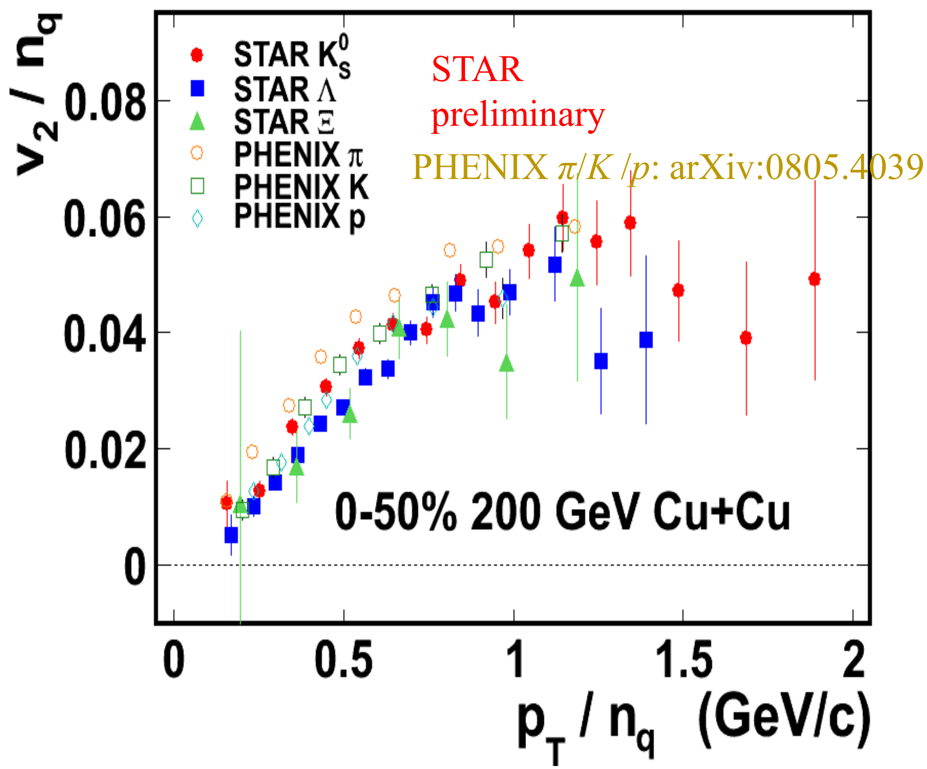
The "Flow"

- Value of v_2 in $dn/d\phi \sim 1 + 2\, v_2 \cos(2\,\phi)$ saturates at ~ 0.2
- Hydrodynamic calculations show this modulation is
  - characteristic of *a state of matter* established in the earliest (geometrically asymmetric) stage of the collision
  - in some sense is as strong as it can be



Quark Scaling of the Azimuthal Asymmetry





Empirical evidence for quark degree of freedom ? Recombination ?
Gyulassy: "One of the most remarkable 'I don't understand' phenomena"

Volume 178, number 4 PHYSICS LETTERS B 9 October 1986

Heavy Quarks at RHIC

J/ψ SUPPRESSION BY QUARK–GLUON PLASMA FORMATION ☆

T. MATSUI
Center for Theoretical Physics, Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

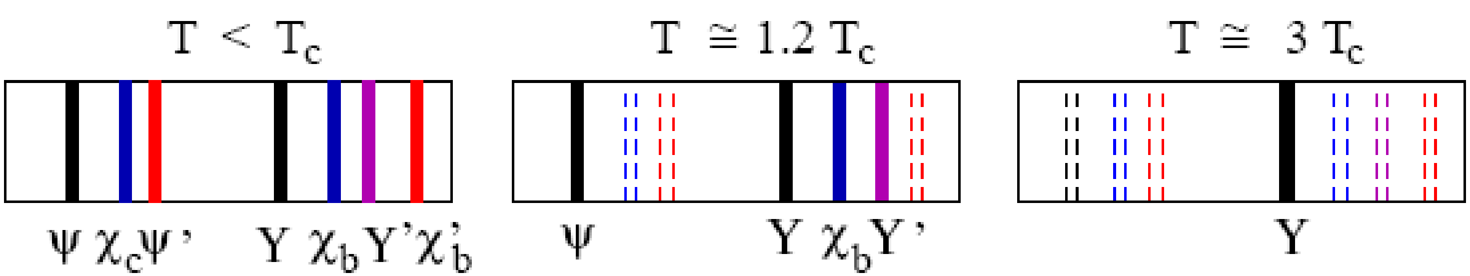
and

H. SATZ
Fakultät für Physik, Universität Bielefeld, D-4800 Bielefeld, Fed. Rep. Germany and Physics Department, Brookhaven National Laboratory, Upton, NY 11973, USA

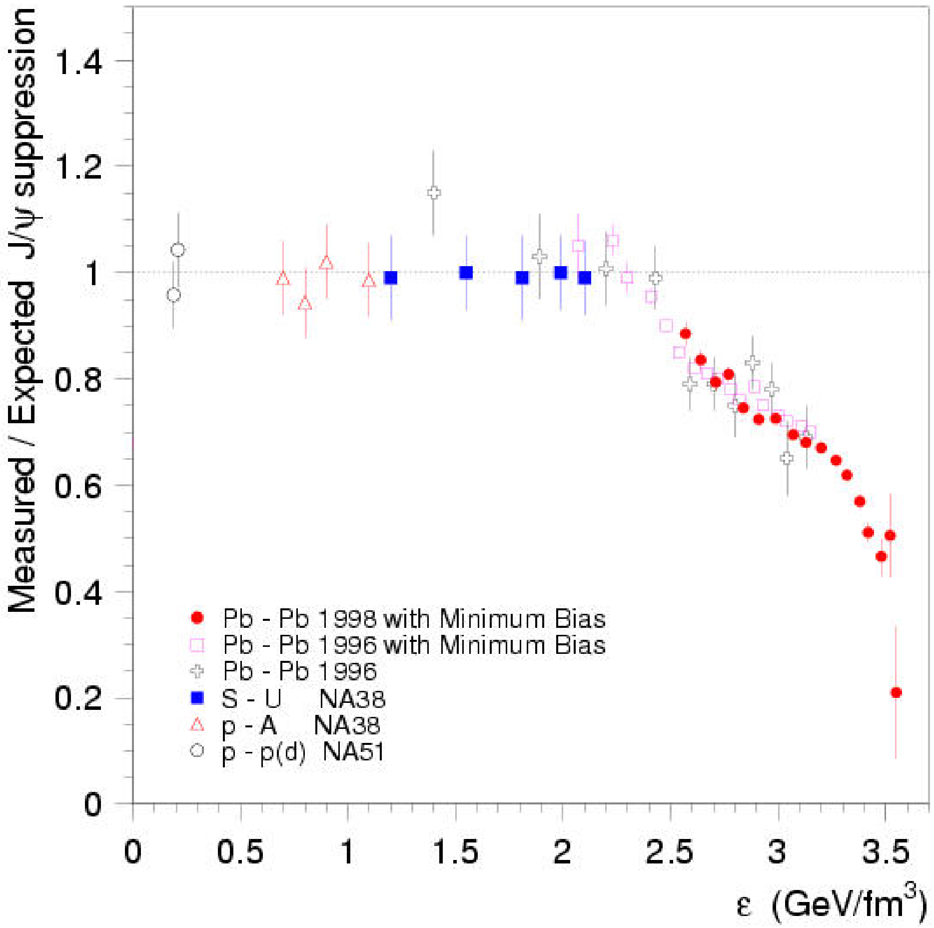
Received 17 July 1986

If high energy heavy ion collisions lead to the formation of a hot quark–gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, the temperature dependence of the screening radius, as obtained from lattice QCD, is compared with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. It is concluded that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark–gluon plasma formation.

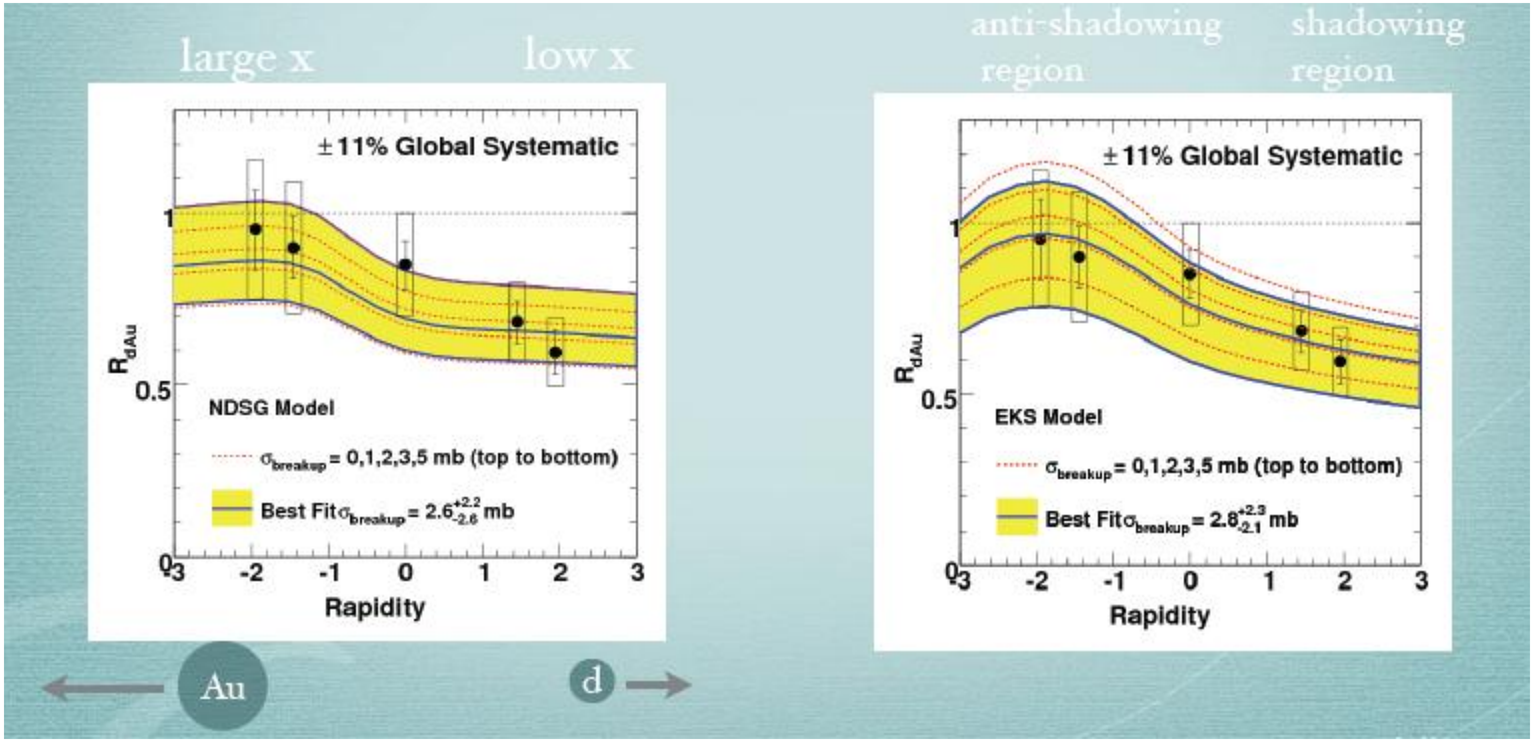
Recent Helmut Satz Talk:



SPS NA50 J/ψ Production

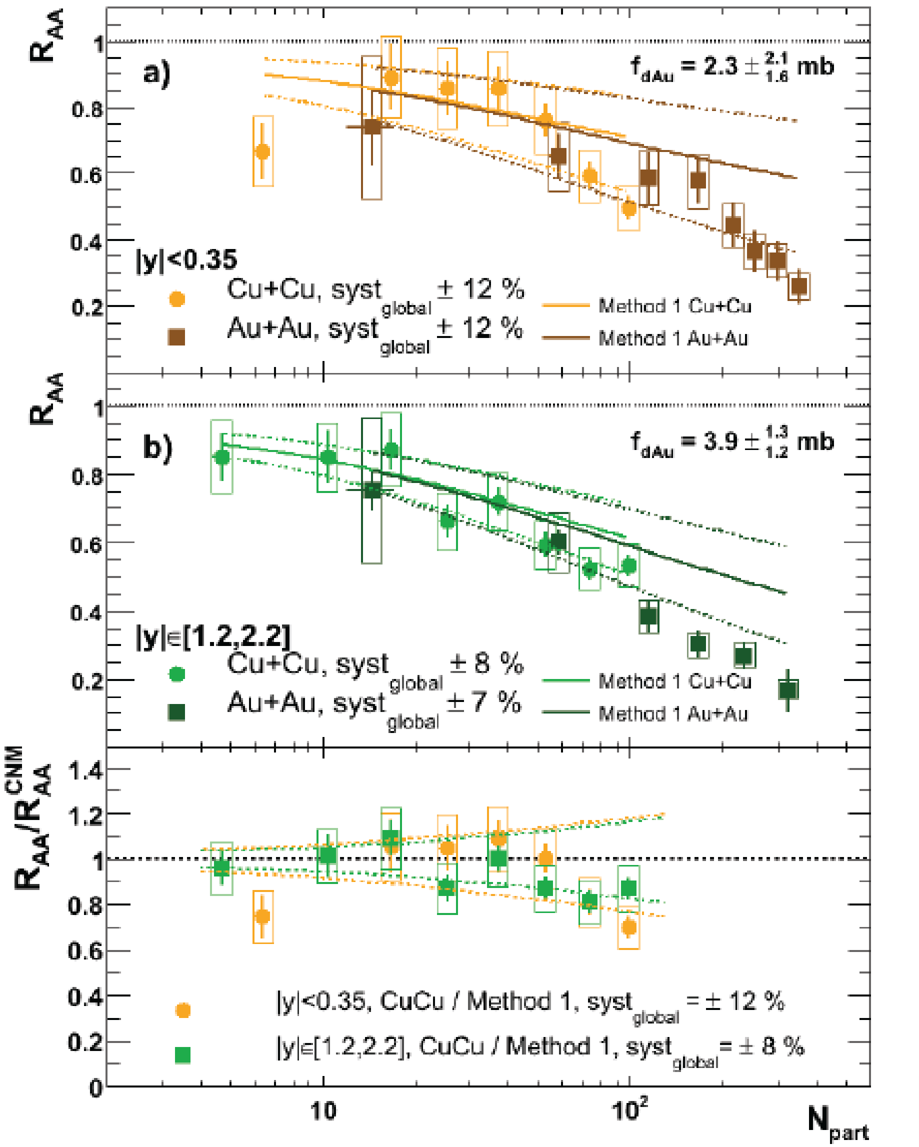


Cold Matter Effects (d-Au) are Important !



Already a significant suppression at y=0

The J/psi Results for AA



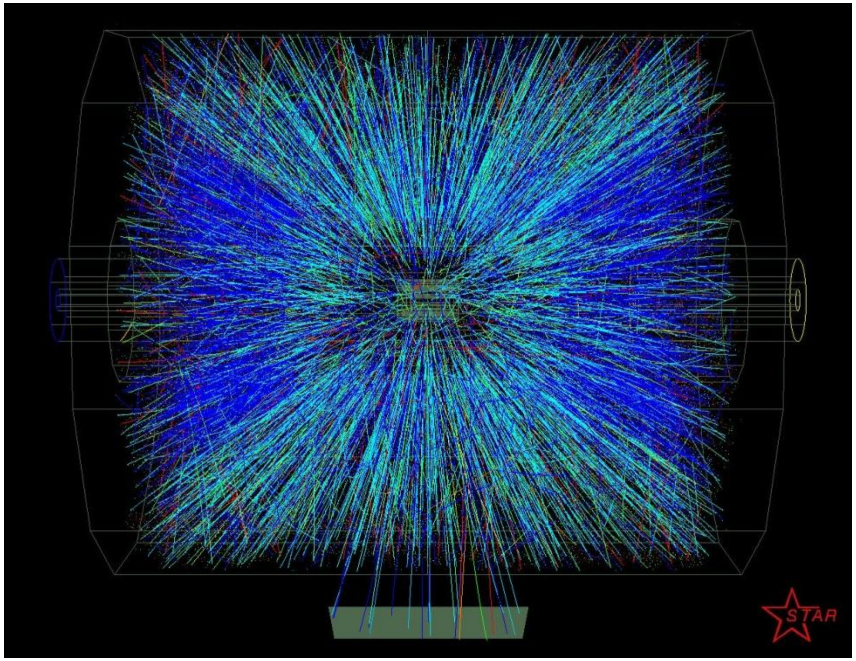
- R_{AA} Cu+Cu and Au+Au decreases significantly going from peripheral to central collisions
- matches well where Npart is identical
- suppression is larger at forward than at mid rapidity
- (CuCu currently revisited, assumed same breakup cross section for y=0 and |y|=1.7)

Phys. Rev. Lett. 101, 122301 2008

RHIC $\rightarrow$ LHC

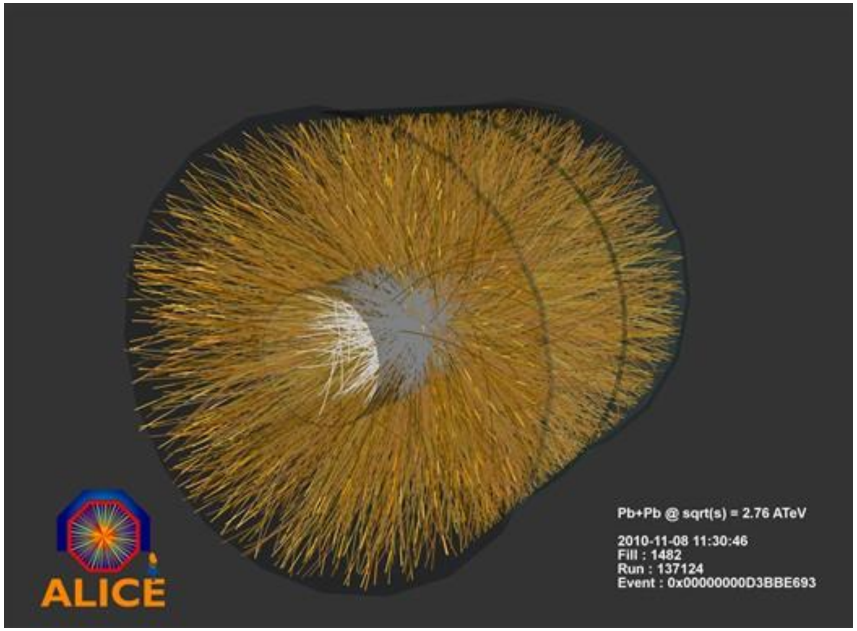
Au+Au at sqrt(s)=200 AGeV

2001



Pb+Pb at sqrt(s)=2.76 ATeV

2010, Nov 8th.



First Preprint Submitted on Nov 18th and Published on Dec 13th

APS » Journals » Phys. Rev. Lett. » Volume 105 » Issue 25 < Previous Article | Next Article >

Phys. Rev. Lett. 105, 252302 (2010) [11 pages]

Elliptic Flow of Charged Particles in Pb-Pb Collisions at $\sqrt{s_{NN}}$=2.76 TeV

Abstract | References | No Citing Articles

Download: PDF (361 kB) **Export:** BibTeX or EndNote (RIS)

K. Aamodt *et al.* (ALICE Collaboration)
Show All Authors/Affiliations

Received 18 November 2010; published 13 December 2010

See accompanying Viewpoint: *Physics*

We report the first measurement of charged particle elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV with the ALICE detector at the CERN Large Hadron Collider. The measurement is performed in the central pseudorapidity region ($|\eta|<0.8$) and transverse momentum range $0.2<p_t<5.0$ GeV/*c*. The elliptic flow signal v_2, measured using the 4-particle correlation method, averaged over transverse momentum and pseudorapidity is 0.087±0.002(stat)±0.003(syst) in the 40%–50% centrality class. The differential elliptic flow $v_2(p_t)$ reaches a maximum of 0.2 near p_t=3 GeV/*c*. Compared to RHIC Au-Au collisions at $\sqrt{s_{NN}}$=200 GeV, the elliptic flow increases by about 30%. Some hydrodynamic model predictions which include viscous corrections are in agreement with the observed increase.

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URL: http://link.aps.org/doi/10.1103/PhysRevLett.105.252302
DOI: 10.1103/PhysRevLett.105.252302
PACS: 25.75.Ld, 25.75.Gz, 25.75.Nq

See Also

See Also: K. Aamodt et al. (ALICE Collaboration), *Charged-Particle Multiplicity Density at Midrapidity in Central Pb-Pb Collisions at $\sqrt{s_{NN}}$=2.76 TeV*, Phys. Rev. Lett. **105**, 252301 (2010).

See Also: G. Aad et al. (ATLAS Collaboration), *Observation of a Centrality-Dependent Dijet Asymmetry in Lead-Lead Collisions at $\sqrt{s_{NN}}$=2.76 TeV with the ATLAS Detector at the LHC*, Phys. Rev. Lett. **105**, 252303 (2010).

CERN Press Release on Nov 26th, 2010

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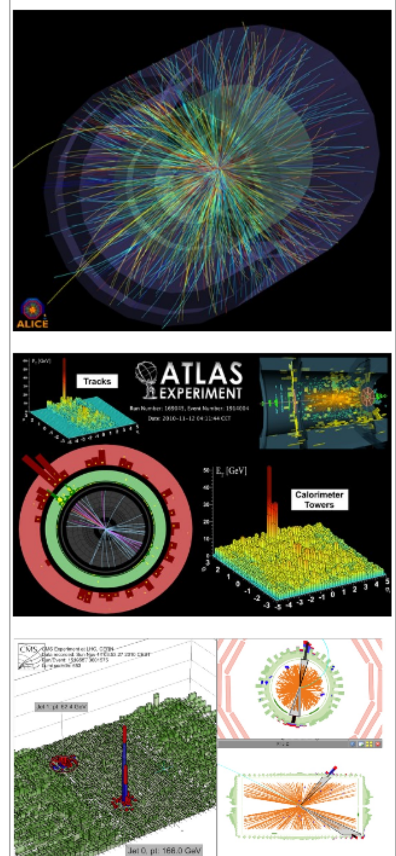
LHC experiments bring new insight into primordial universe

PR23.10
26.11.2010

Geneva, 26 November 2010. After less than three weeks of heavy-ion running, the three experiments studying lead ion collisions at the LHC have already brought new insight into matter as it would have existed in the very first instants of the Universe's life. The ALICE experiment, which is optimised for the study of heavy ions, published two papers just a few days after the start of lead-ion running. Now, the first direct observation of a phenomenon known as jet quenching has been made by both the ATLAS and CMS collaborations. This result is reported in a paper from the ATLAS collaboration accepted for publication yesterday in the scientific journal Physical Review Letters. A CMS paper will follow shortly, and results from all of the experiments will be presented at a seminar on Thursday 2 December at CERN[1]. Data taking with ions continues to 6 December.

"It is impressive how fast the experiments have arrived at these results, which deal with very complex physics," said CERN's Research Director Sergio Bertolucci. *"The experiments are competing with each other to publish first, but then working together to assemble the full picture and cross check their results. It's a beautiful*



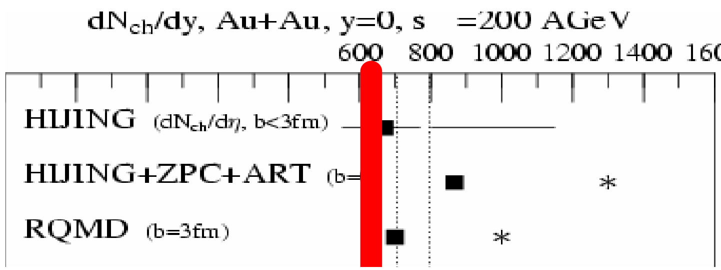
Event displays of heavy ion collisions from

Charge Multiplicities

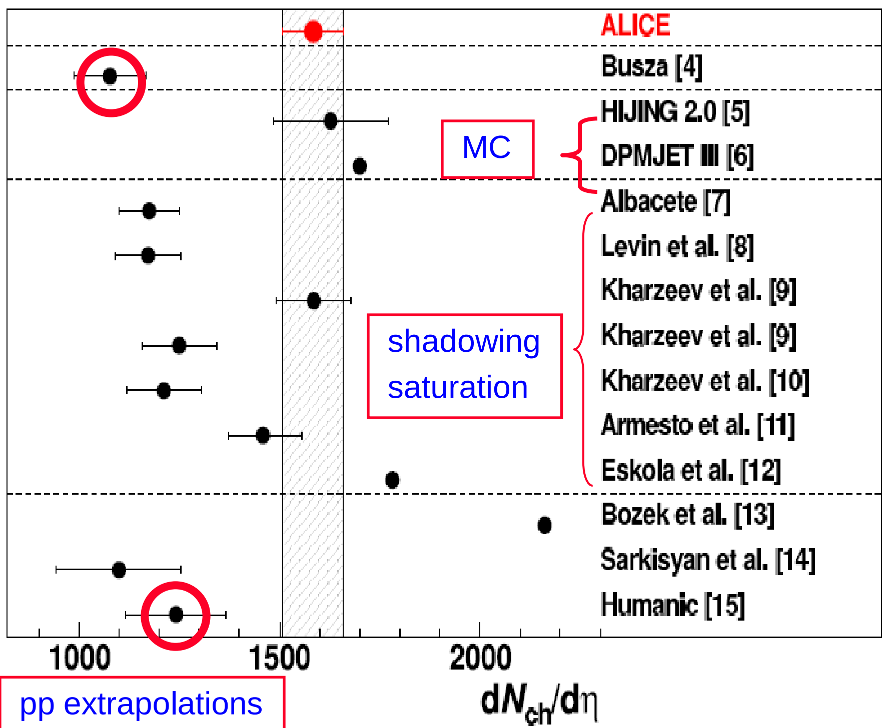
1) What's the Difference ?

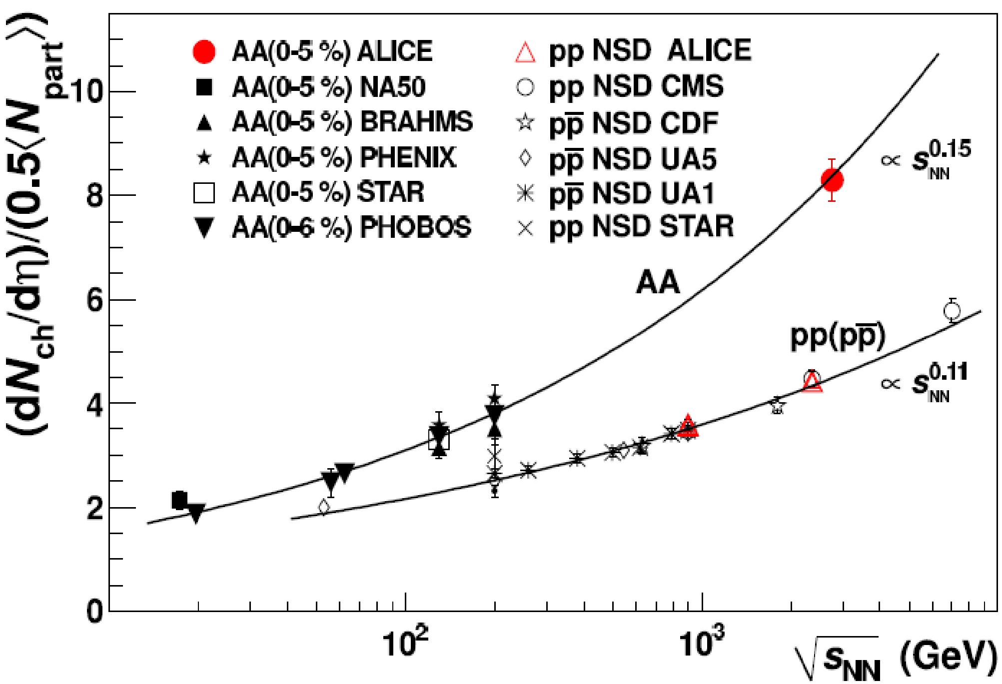
- Multiplicity and Energy density ε:
  - ⇨ **$dN_{ch}/d\eta$ ~ 1600 ± 76 (syst)**
    - ✪ somewhat on high side of expectations
    - ✪ growth with √s faster in AA than pp (√s dependent 'nuclear amplification')
  - ⇨ **Energy density ≈ 3 x RHIC** (fixed τ)
    - ✪ lower limit, likely τ_0(LHC) < τ_0(RHIC)

$$\varepsilon(\tau) = \frac{E}{V} = \frac{1}{\tau_0 A}\frac{dN}{dy} < m_t >$$



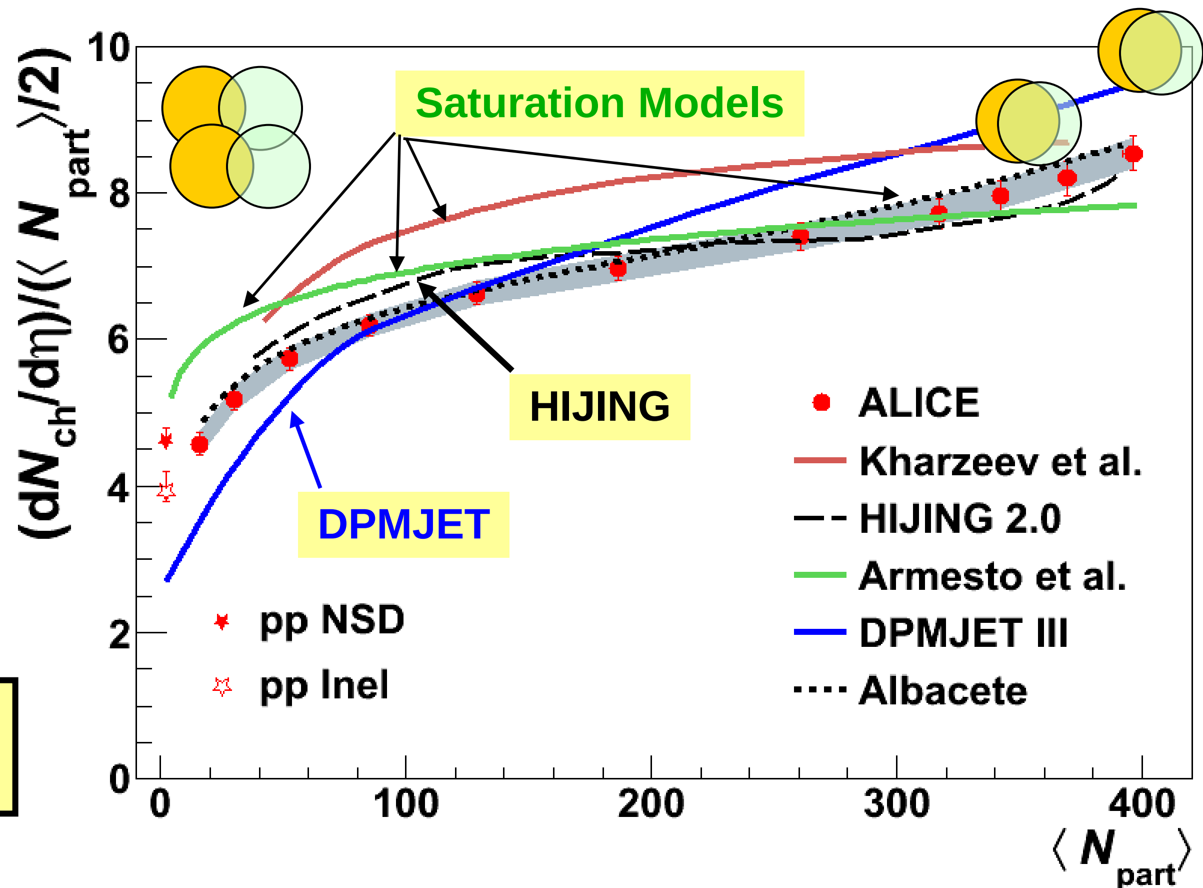
17 Nov: arXiv:1011.3916, acc. PRL





Who gets it right and why ?

- $dN_{ch}/d\eta$ as function of centrality (normalised to 'overlap volume' ~ $N_{participants}$)
  - ⇨ soft process dN_{ch}/d_{η} ~ number of scattered nucleons (strings, participants, …)
    - ✪ 'nuclear amplification' should be energy independent
  - ⇨ (very) hard processes dN_{ch}/d_{η} ~ number of nucleon-nucleon collisions
    - ✪ getting more important with √s & with centrality
  - ⇨ DPMJET MC
    - ✪ gets it right for the wrong reason
  - ⇨ HIJING MC
    - ✪ strong centr. dependent **gluon shadowing**
  - ⇨ Others
    - ✪ **saturation models:** Color Glass Condensate, 'geometrical scaling' from HERA/ photonuclear react.

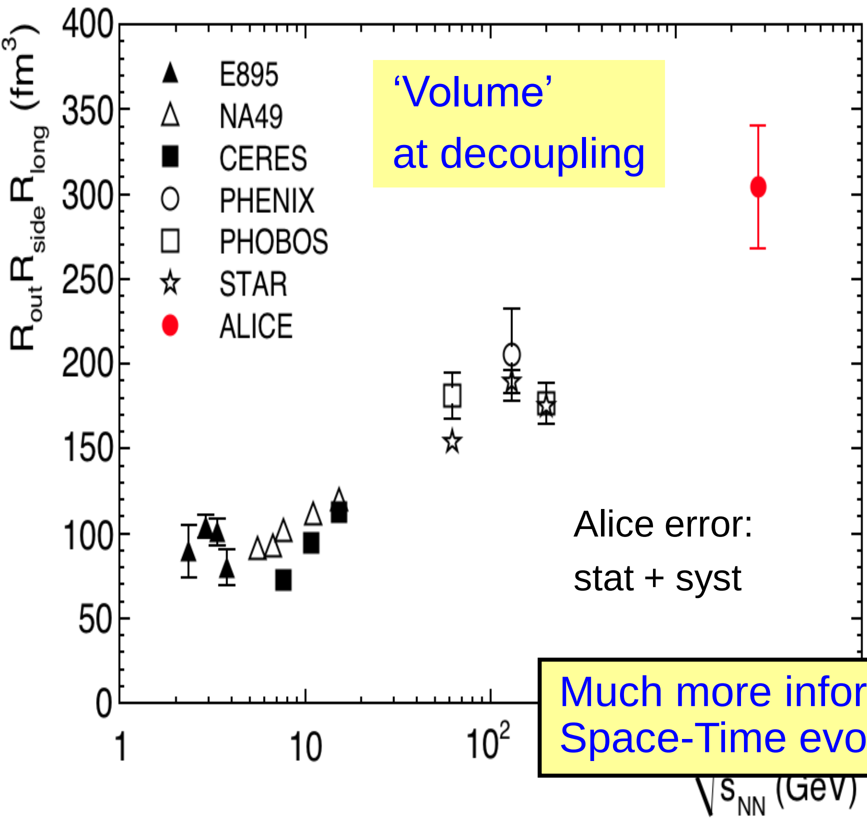


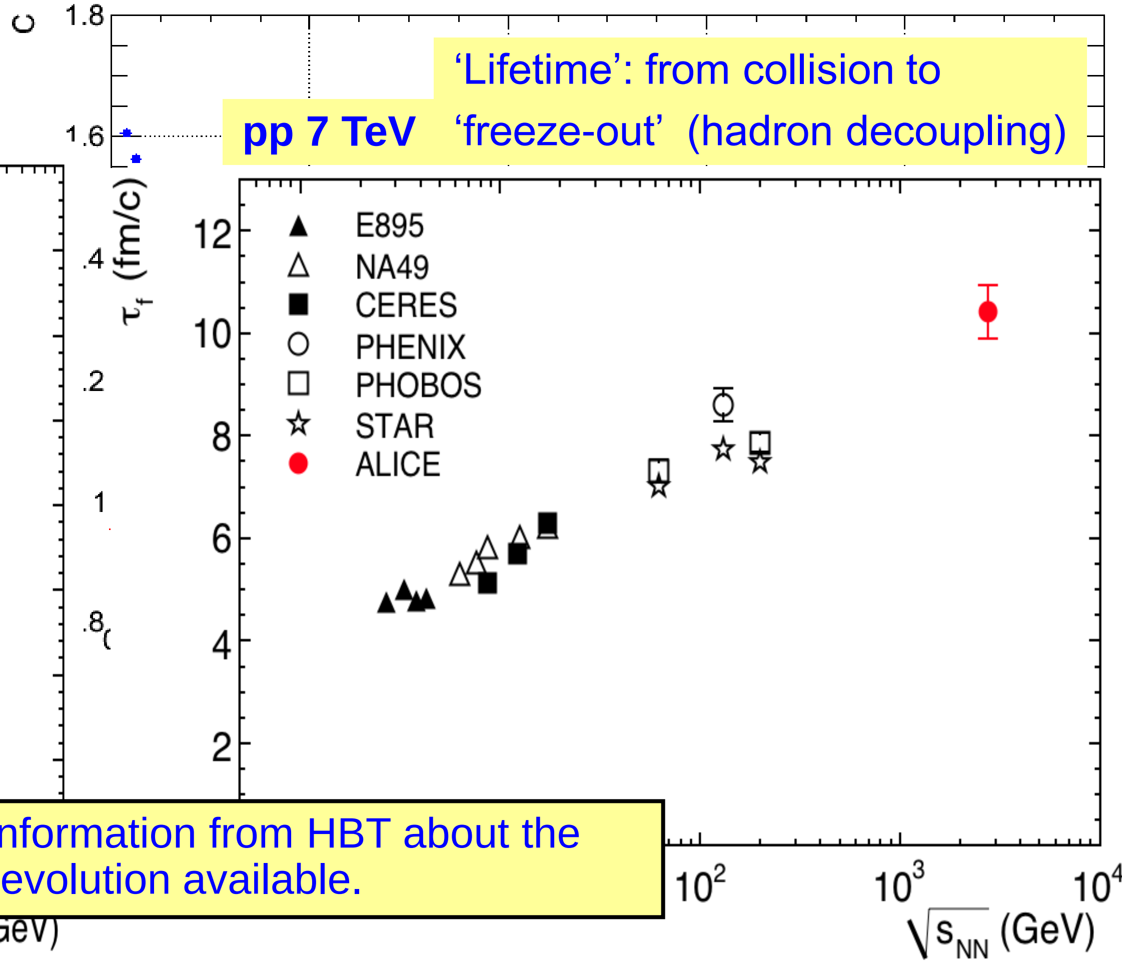
Important constraint for models sensitive to details of saturation

Two-Pion Bose–Einstein Correlations

What's the Difference ?

- Volume and lifetime:
  - ⇨ Identical particle interferometry (HBT, Bose-Einstein correlations) $(E,\vec{\mathbf{p}}) \xrightarrow{\text{F.T.}} (\tau,\vec{\mathbf{X}})$
    - ✪ QM enhancement of identical Bosons at small momentum difference
    - ✪ measures Space-Time evolution of the 'dense matter' system in heavy ions coll.
  - ⇨ **Volume ≈ 2 x RHIC** **(≈ 300 fm^3)**
    - ✪ 'comoving' volume !
  - ⇨ **Lifetime ≈ +20%** **(≈ 10 fm/c)**





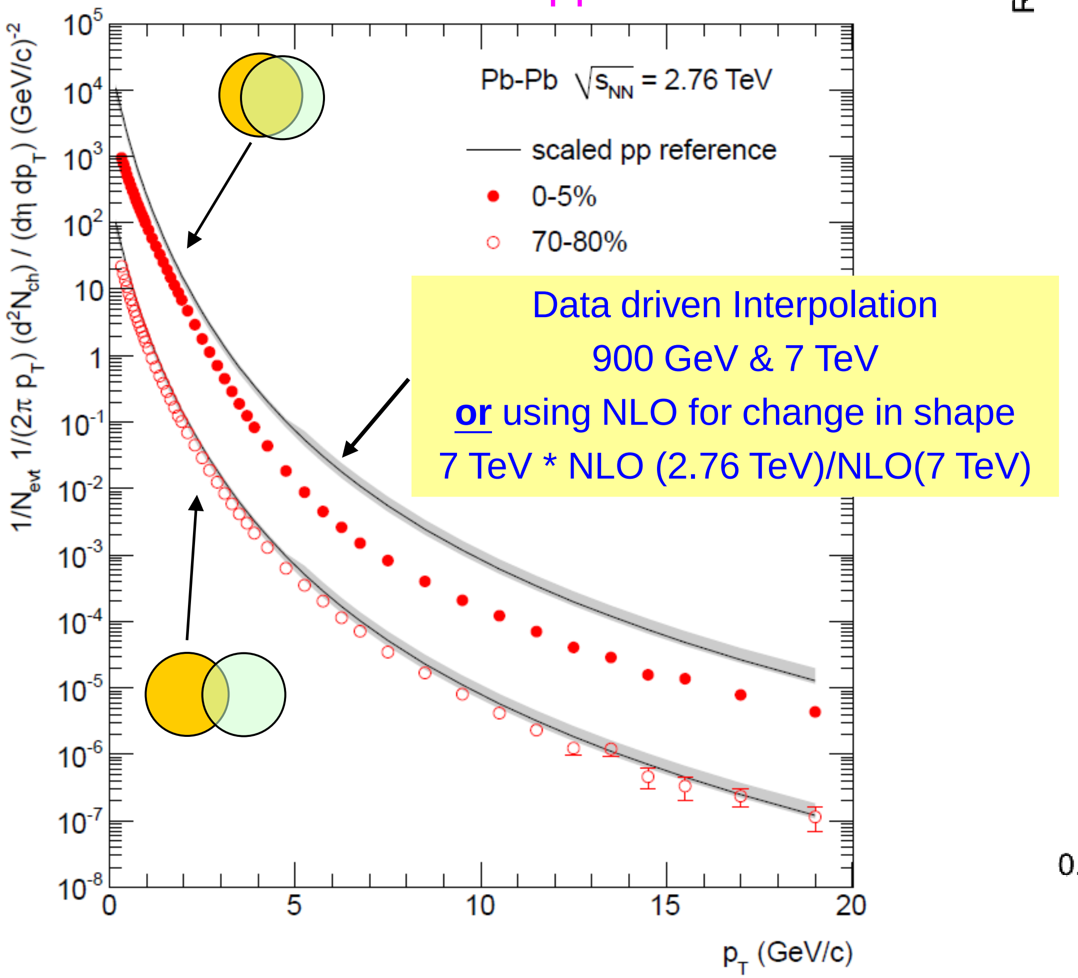
Much more information from HBT about the Space-Time evolution available.

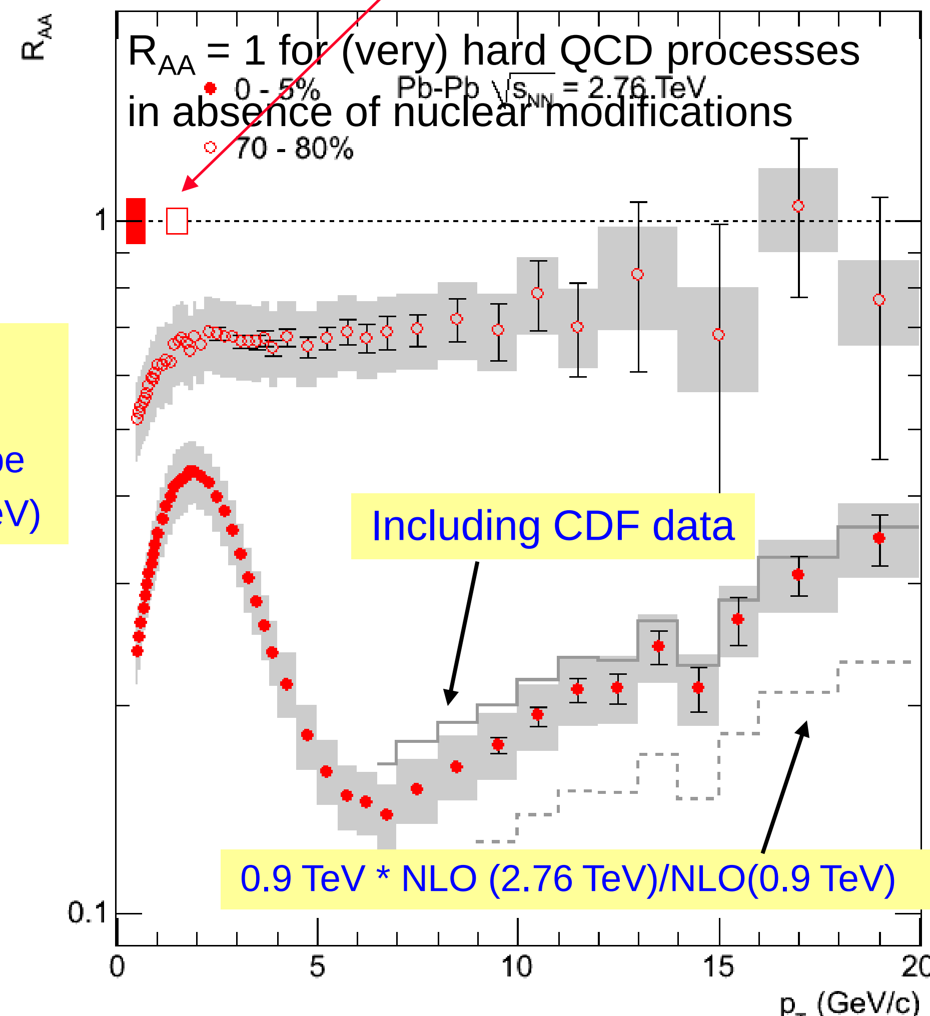
Suppression of Large-pt Charged Particles

'Jet Quenching' as seen by p_t spectra

- Suppression of high p_t particles (~ leading jet fragments)
  - ⇨ Minimum R_{AA} ~ 1.5 – 2 x smaller than at RHIC
  - ⇨ Rising with p_t ! (ambiguous at RHIC !)
  - ⇨ accuracy limited by pp reference
    => need pp at 2.76 TeV !

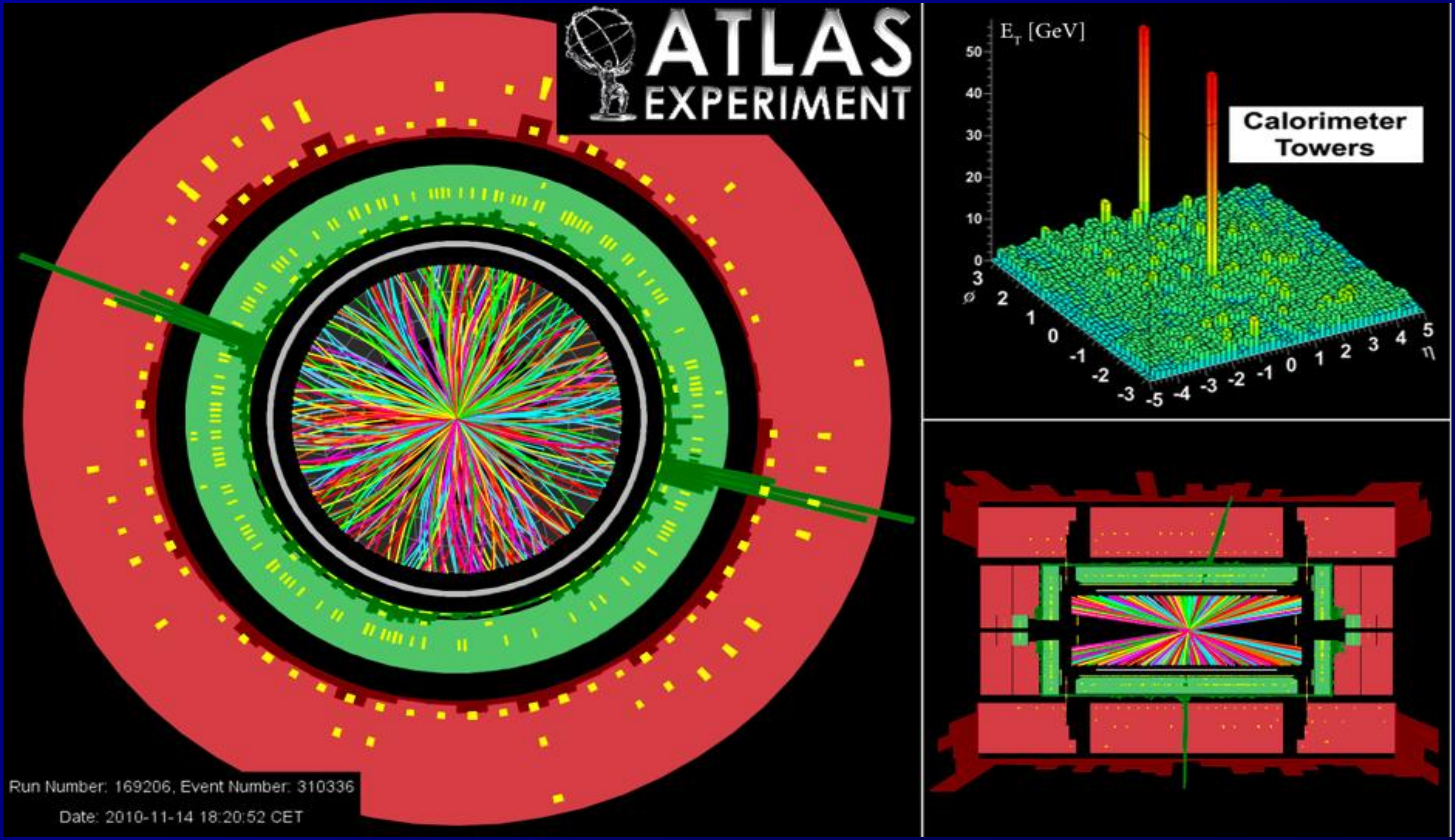
$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta dp_T}{\langle N_{coll}\rangle (1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta dp_T}$$



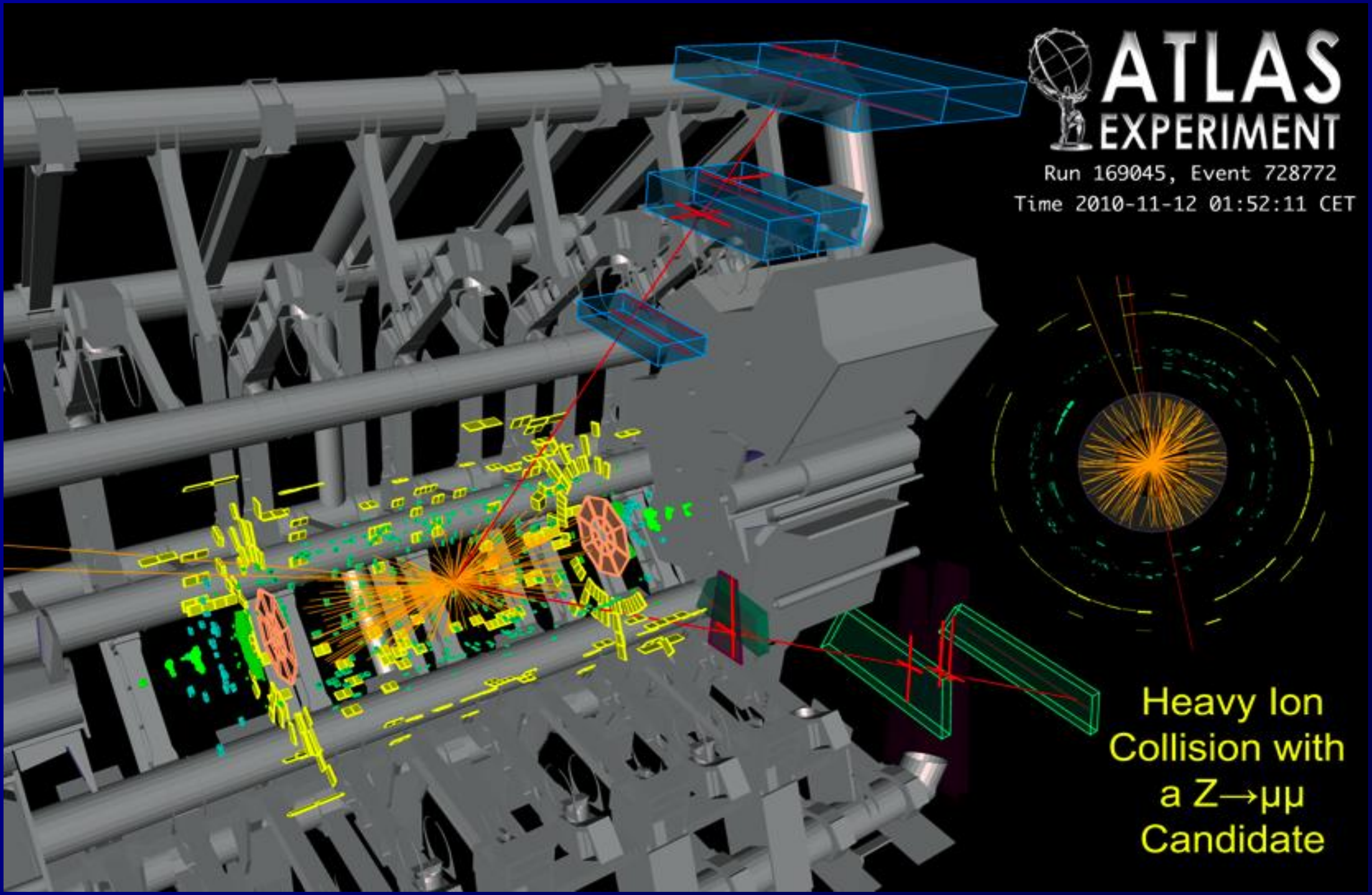


Z and J/psi

Tracking + Calorimetry: Z $\rightarrow e^+e^-$



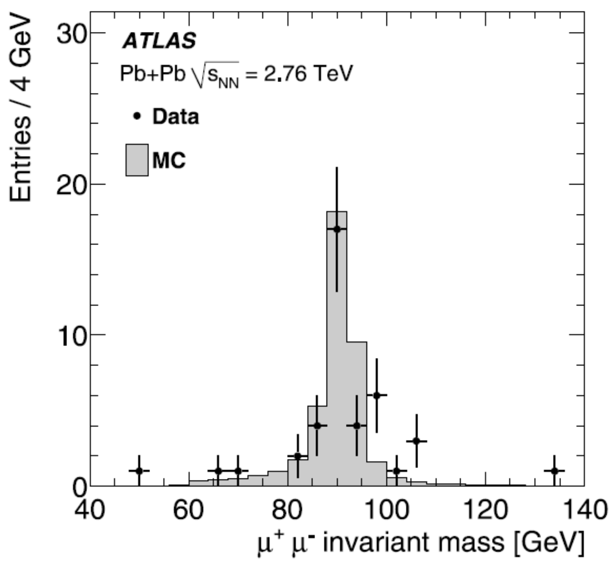
Muons: $Z \rightarrow \mu^+\mu^-$

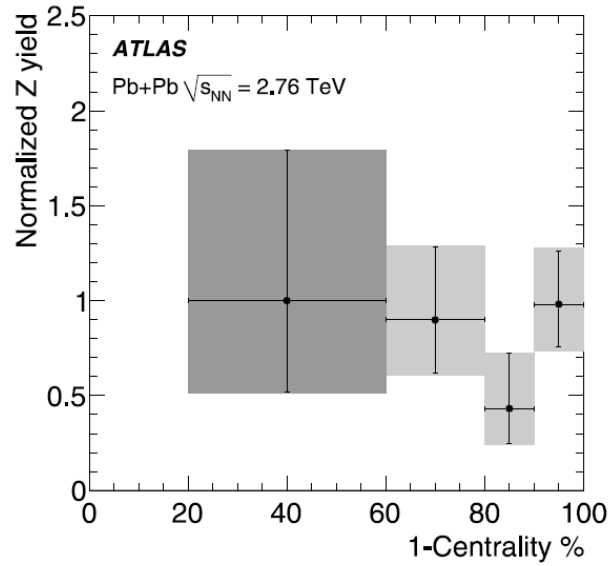


ATLAS Z

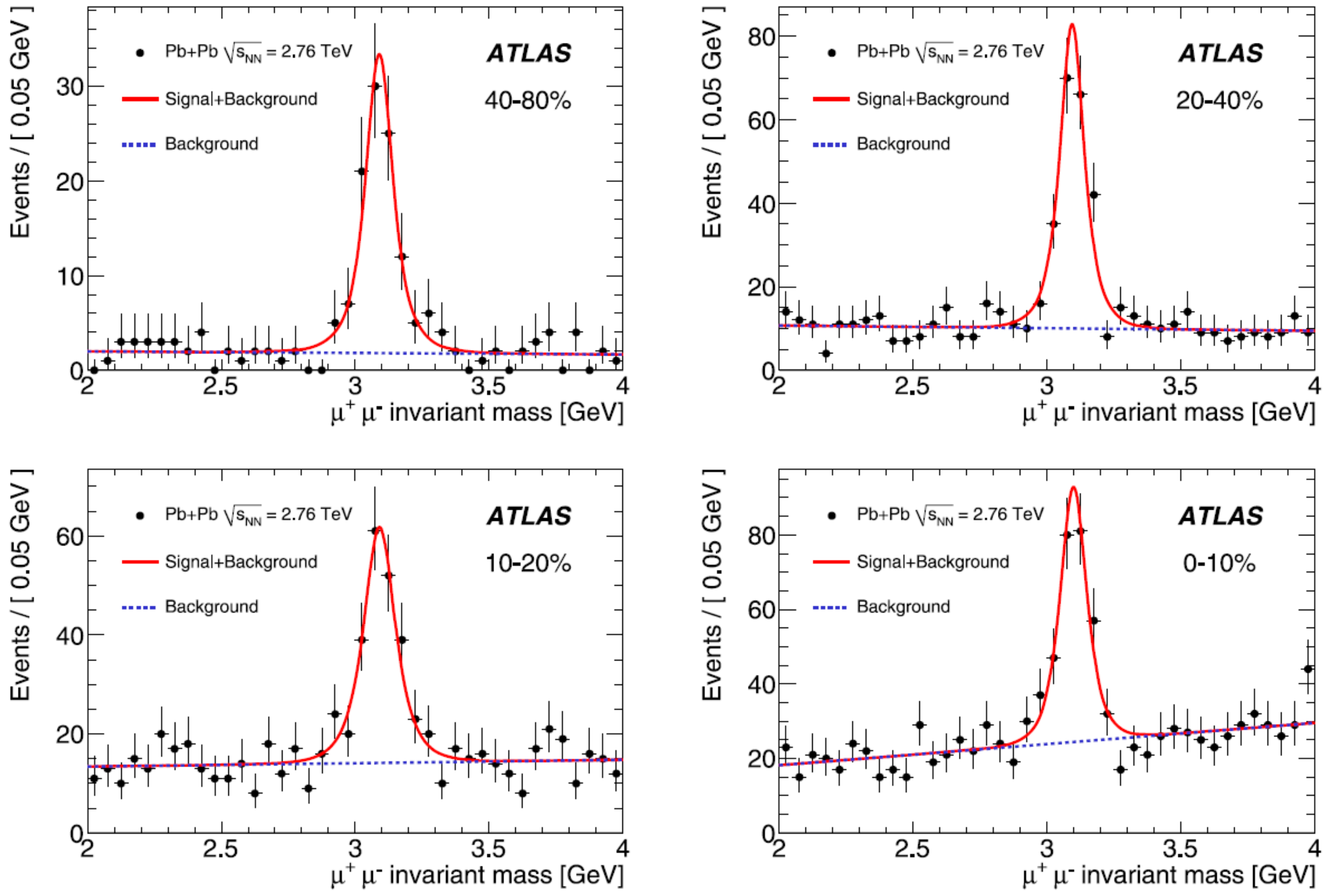
Table 3
The number of Z events per centrality bin and the relative efficiency corrections derived from the simulation.

Centrality	N(Z)	$\epsilon(Z)_c/\epsilon(Z)_{40-80}$
0–10%	19	0.99 ± 0.01
10–20%	5	0.97 ± 0.01
20–40%	10	0.98 ± 0.01
40–80%	4	1





ATLAS J/ψ

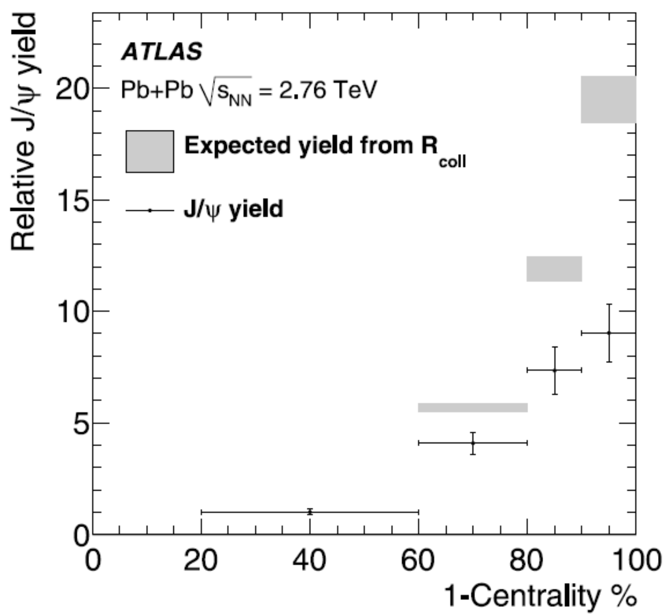


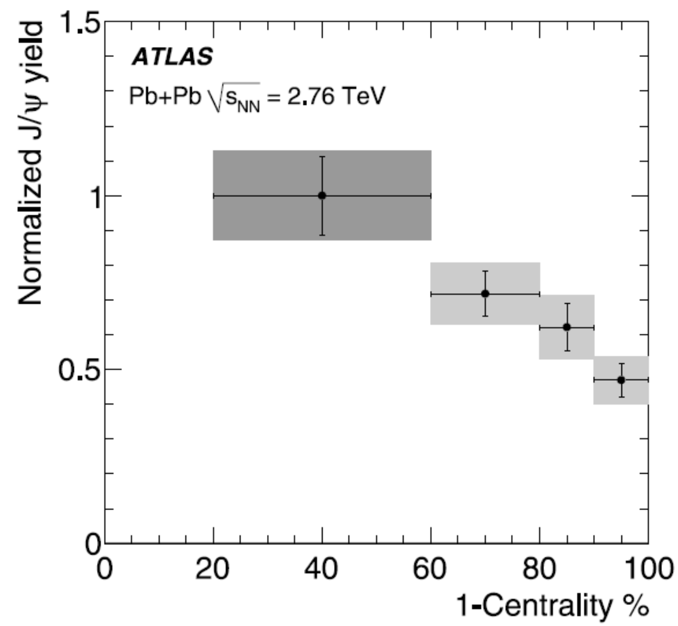
Pb+Pb $\sqrt{s_{NN}}$ = 2.76 TeV
Signal+Background
Background
ATLAS
40-80%
Events / [0.05 GeV]
$\mu^+ \mu^-$ invariant mass [GeV]
Pb+Pb $\sqrt{s_{NN}}$ = 2.76 TeV
Signal+Background
Background
ATLAS
20-40%
Events / [0.05 GeV]
$\mu^+ \mu^-$ invariant mass [GeV]
Pb+Pb $\sqrt{s_{NN}}$ = 2.76 TeV
Signal+Background
Background
ATLAS
10-20%
Events / [0.05 GeV]
$\mu^+ \mu^-$ invariant mass [GeV]
Pb+Pb $\sqrt{s_{NN}}$ = 2.76 TeV
Signal+Background
Background
ATLAS
0-10%
Events / [0.05 GeV]
$\mu^+ \mu^-$ invariant mass [GeV]

ATLAS J/ψ

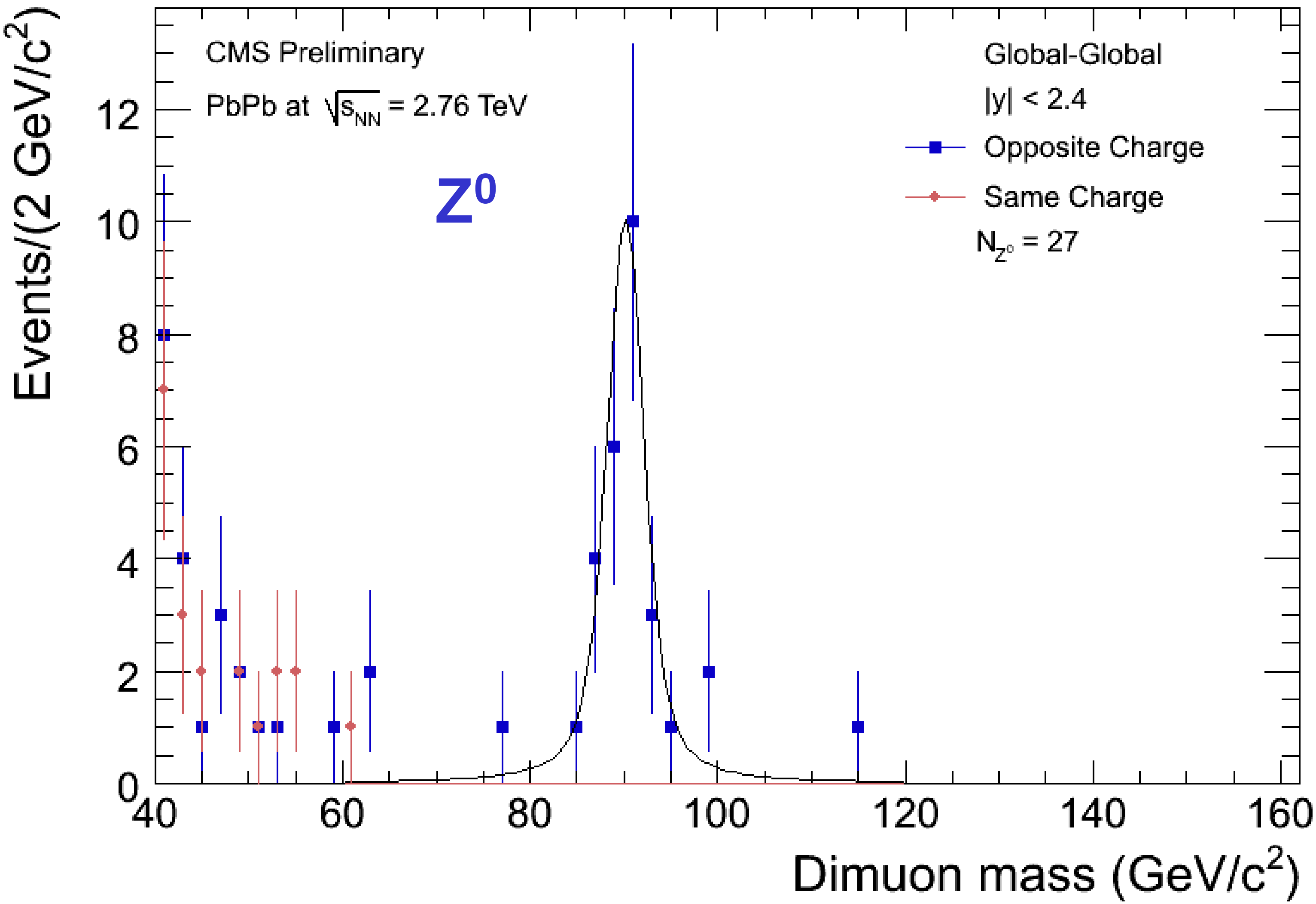
Table 2
The correction factors R_{coll}, together with the relative systematic uncertainty, stated as a 1σ value.

Centrality	R_{coll}	Uncertainty
0–10%	19.5	5.3%
10–20%	11.9	4.7%
20–40%	5.7	3.2%
40–80%	1.0	–

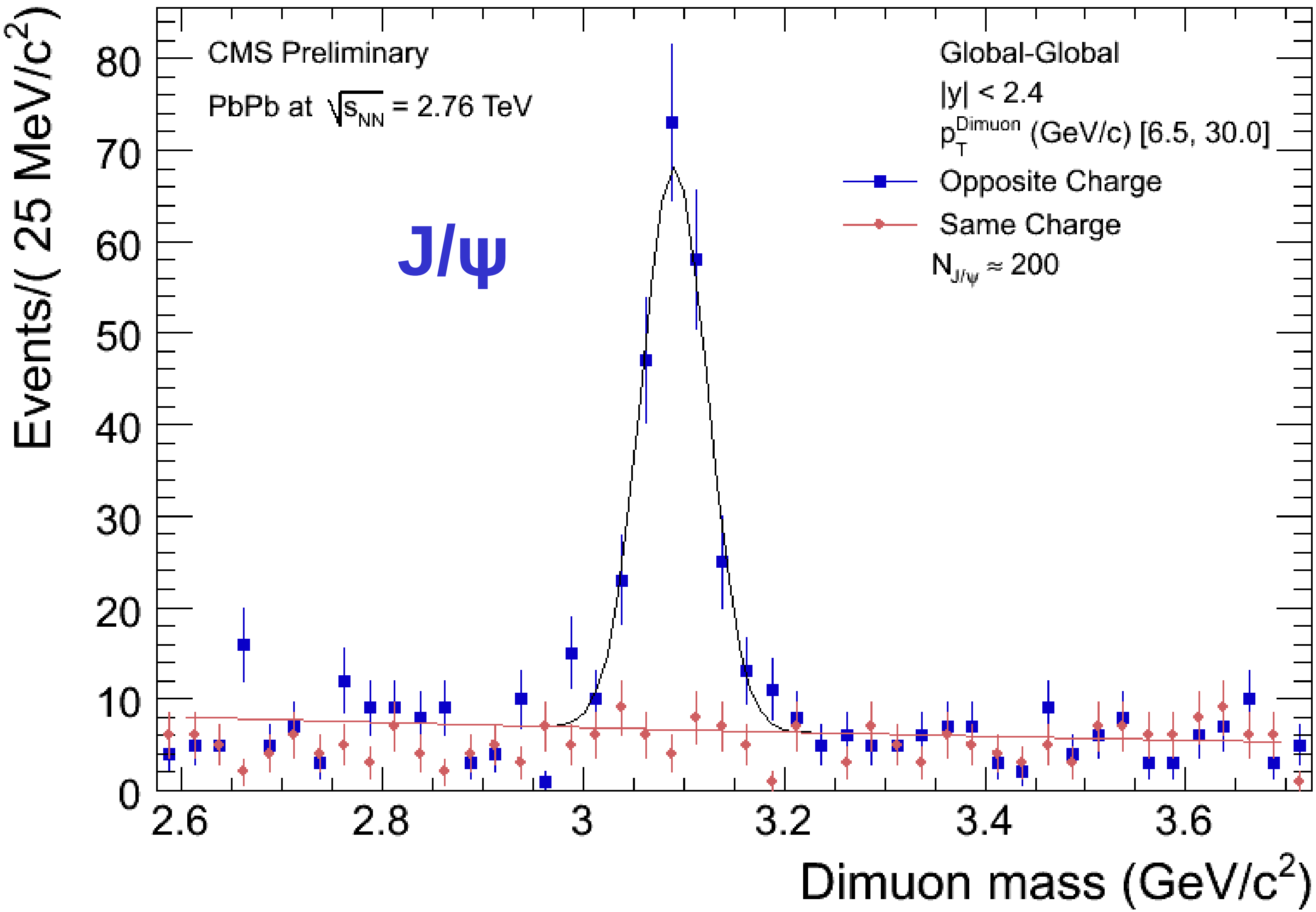




$Z^0 \rightarrow \mu^+\mu^-$

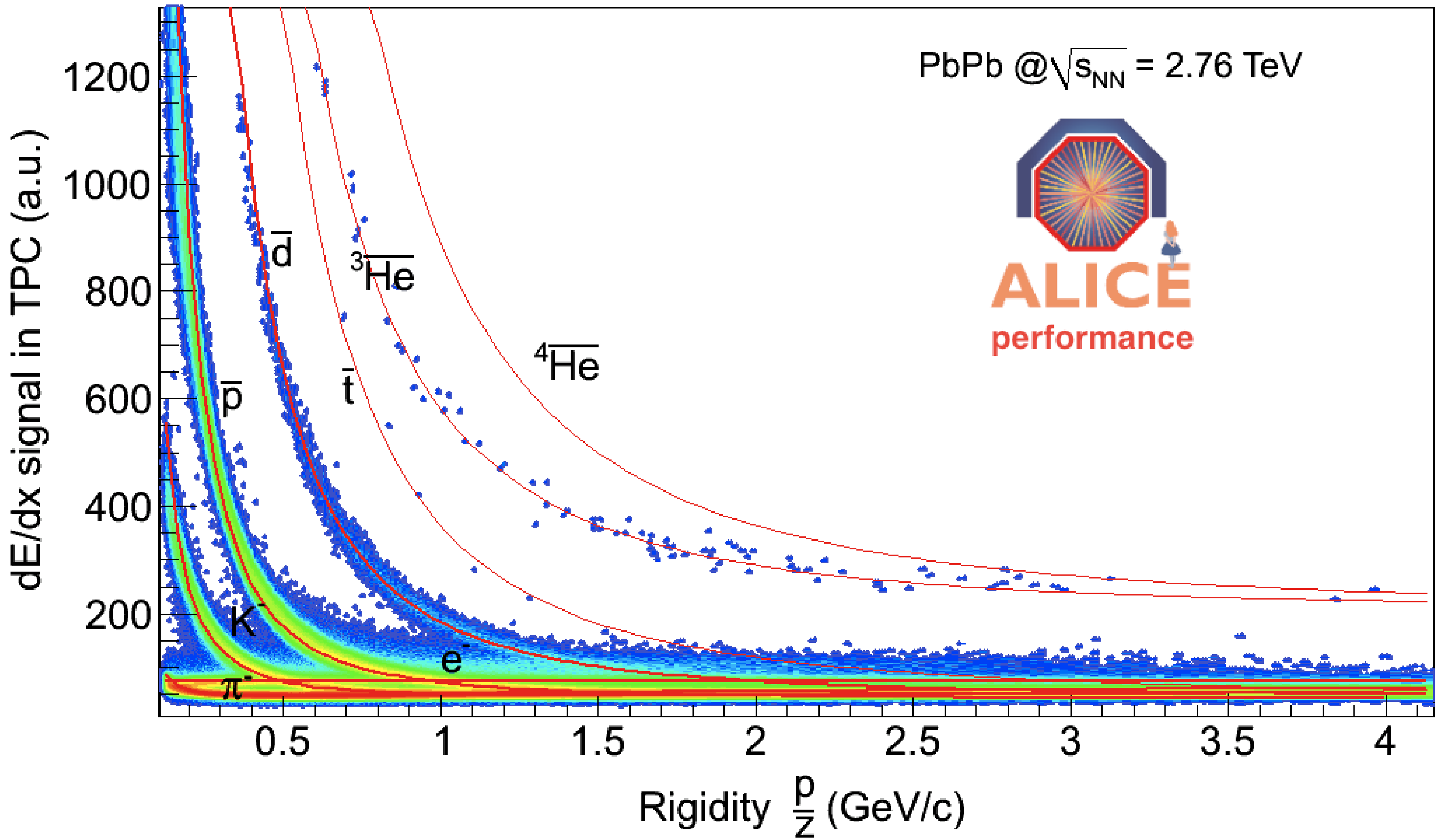


High p_T $J/\psi \rightarrow \mu^+\mu^-$



Observation of Anti-Nuclei

Anti-Nuclei



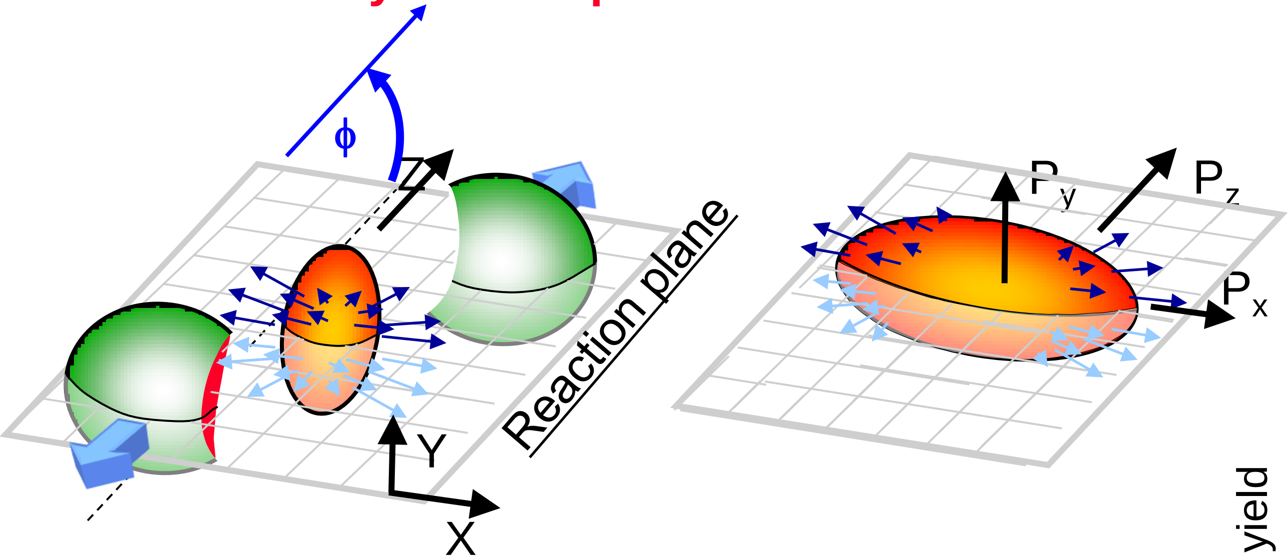
~ 2 M Pb-Pb Min Bias events

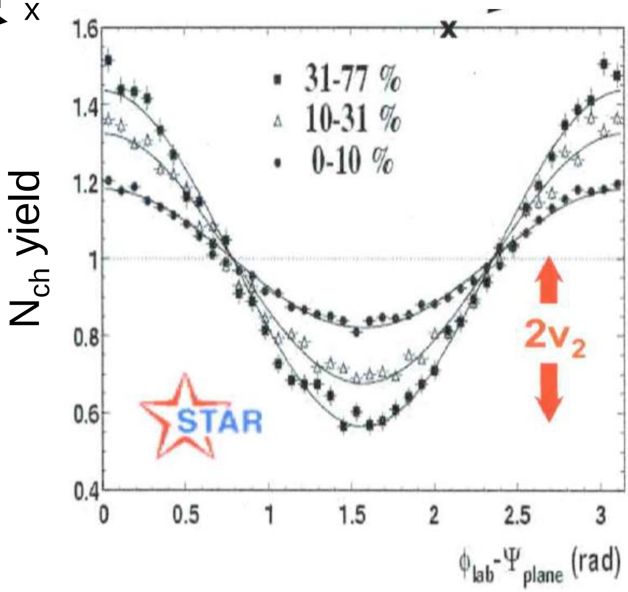
Elliptic Flow

- Elliptic Flow: one of the most anticipated answers from LHC

⇨ **<u>experimental observation:</u>** particles are distributed with azimuthally anisotropic around the scattering plane

⇨ **Are we sure Hydro interpretation is correct ?**





Elliptic Flow v_2 as interpreted by **Hydrodynamics**

Pressure gradient converts

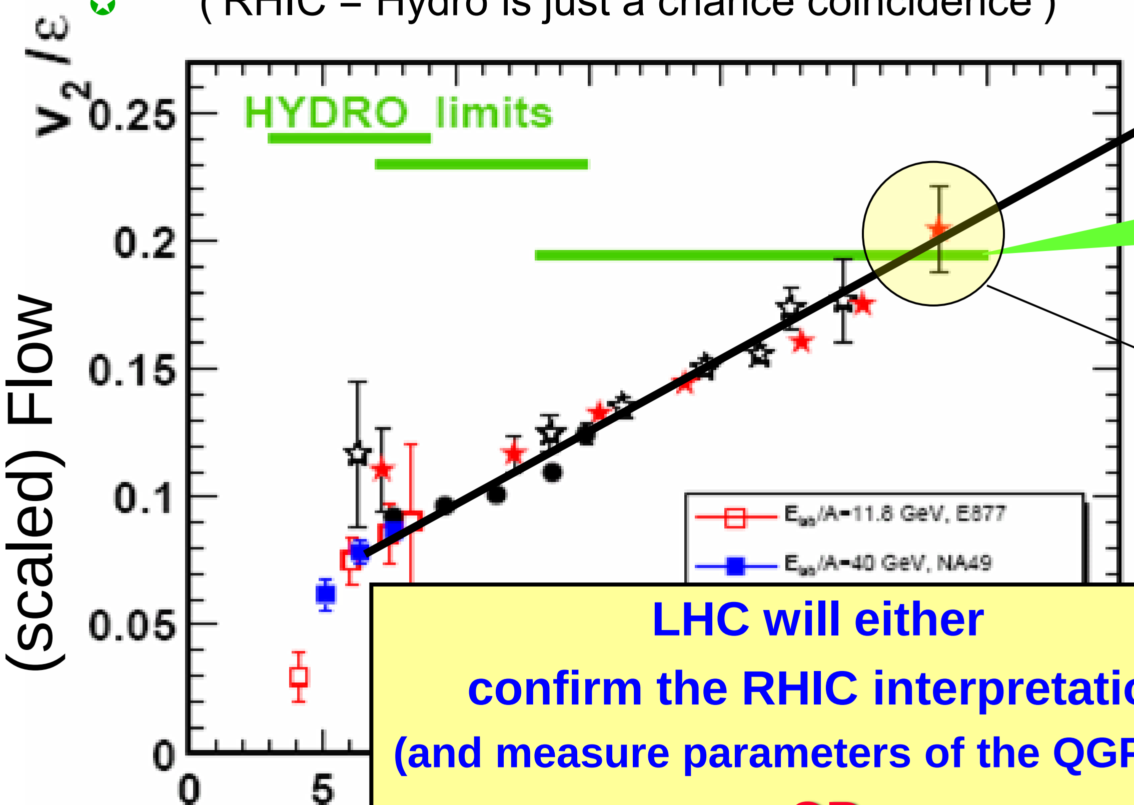
spatial anisotropy → momentum anisotropy

→ particle yield anisotropy

Testing the HI 'Standard Model'

- Hydro seems to work very well for first time at RHIC
  - ⇨ LHC prediction: modest rise (Depending on EoS, viscosity, speed of sound, $dN_{ch}/d\eta$, ..)
    - ('better than ideal is impossible')
  - ⇨ experimental trend & scaling predicts large increase of flow
    - ('RHIC = Hydro is just a chance coincidence')

LHC ?



BNL Press release, April 18, 2005:

Data = ideal Hydro

"Perfect" Liquid

New state of matter more remarkable than predicted – raising many new questions

LHC will either

confirm the RHIC interpretation

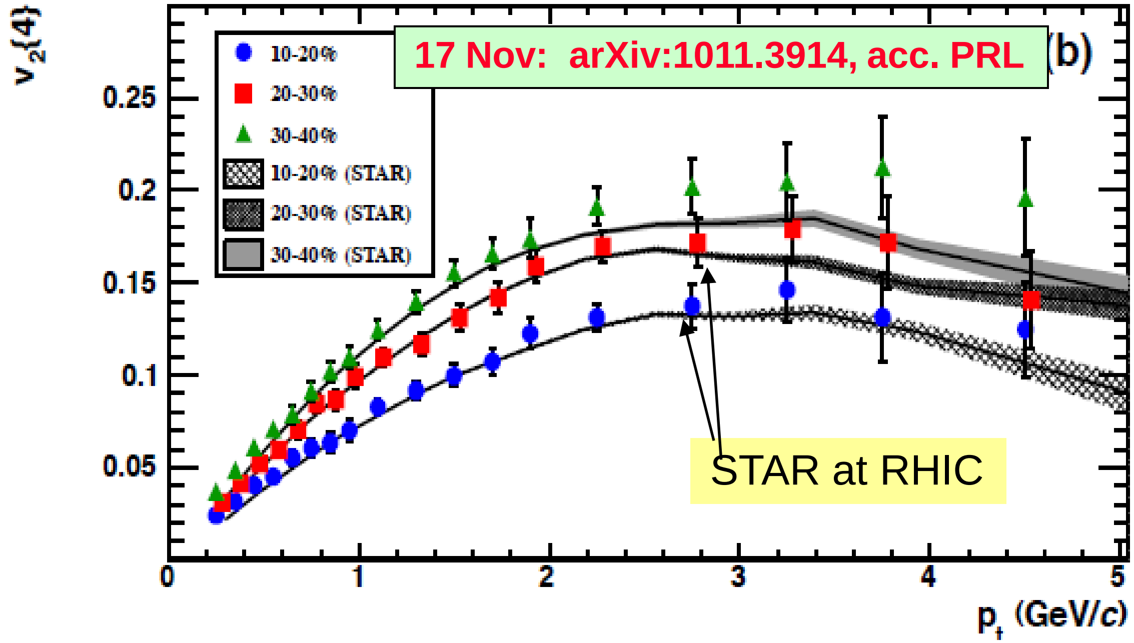
(and measure parameters of the QGP EoS)

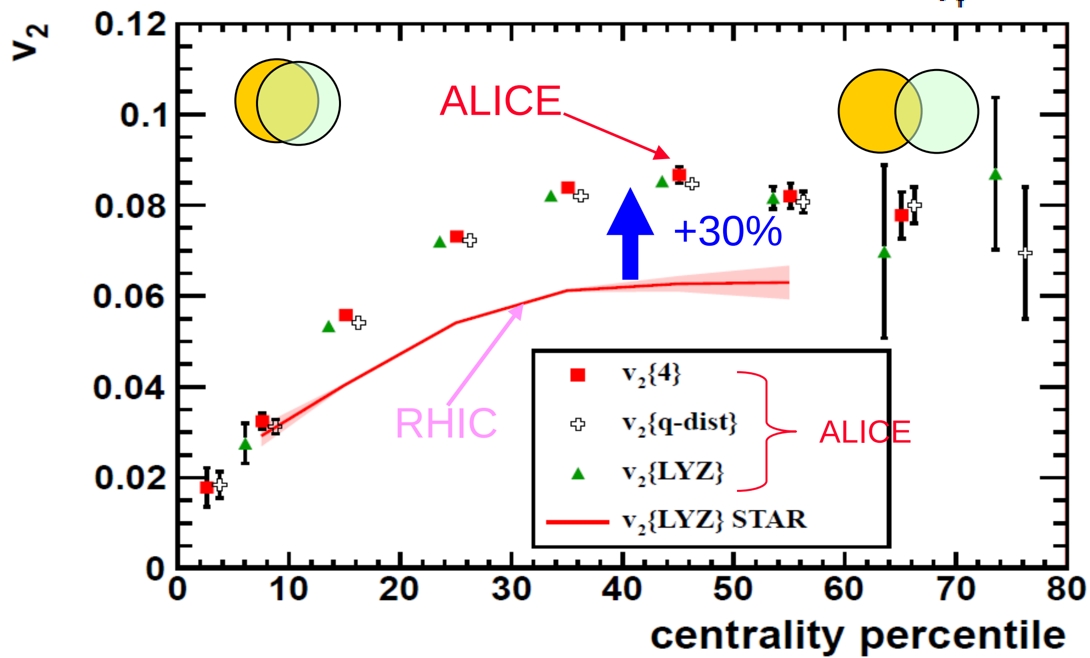
OR

Multiplicity **????????**

First Elliptic Flow Measurement at LHC

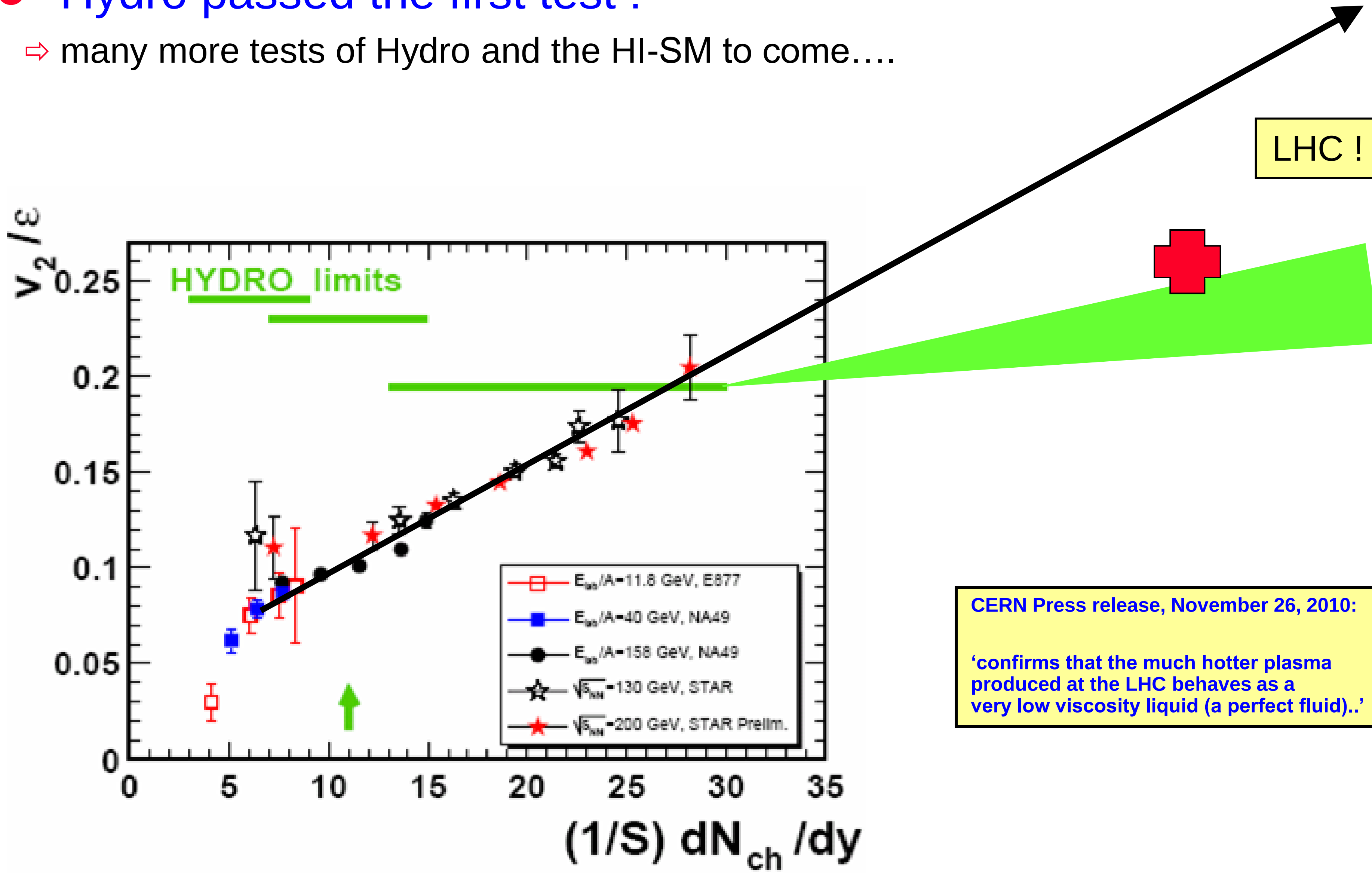
- v_2 as function of p_t
  - ⇨ **practically no change with energy !**
    - ✪ extends towards larger centrality/higher p_t ?
- v_2 integrated over pt
  - ⇨ **30% increase from RHIC**
  - ⇨ <p_t> increases with √s
    - ✪ pQCD powerlaw tail ?
  - ⇨ Hydro predicts increased 'radial flow'
    - ✪ very characteristic p_t and mass dependence; **to be confirmed !**





Testing the HI 'Standard Model'

- Hydro passed the first test !
  - ⇨ many more tests of Hydro and the HI-SM to come….



CERN Press release, November 26, 2010:

'confirms that the much hotter plasma produced at the LHC behaves as a very low viscosity liquid (a perfect fluid)..'

Dijet Asymmetry

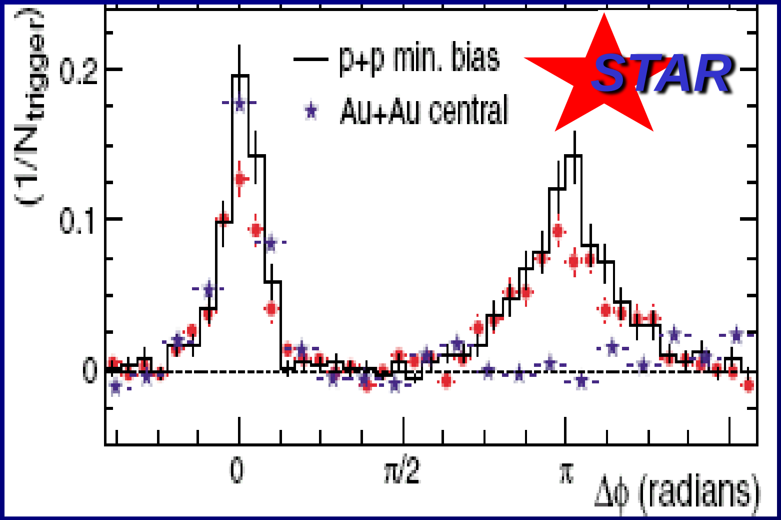
The paper: arXiv:1011.6182

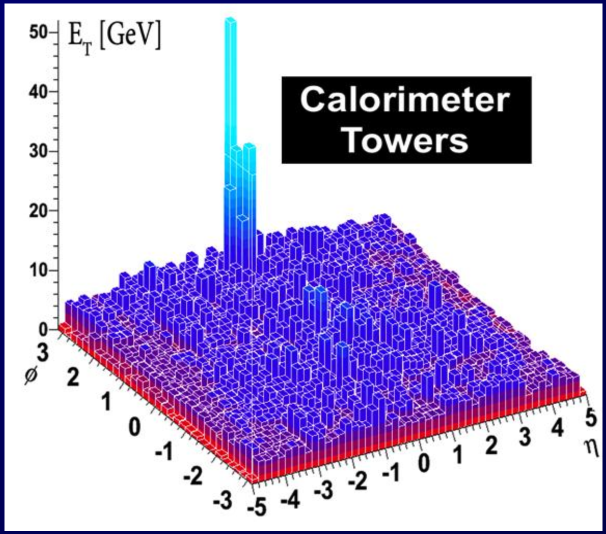
Observation of a Centrality-Dependent Dijet Asymmetry in Lead-Lead Collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS Detector at the LHC

G. Aad *et al.* (The ATLAS Collaboration)*

Using the ATLAS detector, observations have been made of a centrality-dependent dijet asymmetry in the collisions of lead ions at the Large Hadron Collider. In a sample of lead-lead events with a per-nucleon center of mass energy of 2.76 TeV, selected with a minimum bias trigger, jets are reconstructed in fine-grained, longitudinally-segmented electromagnetic and hadronic calorimeters. The underlying event is measured and subtracted event-by-event, giving estimates of jet transverse energy above the ambient background. The transverse energies of dijets in opposite hemispheres is observed to become systematically more unbalanced with increasing event centrality leading to a large number of events which contain highly asymmetric dijets. This is the first observation of an enhancement of events with such large dijet asymmetries, not observed in proton-proton collisions, which may point to an interpretation in terms of strong jet energy loss in a hot, dense medium.

- <u>Paper submitted on Nov 25, accepted by PRL</u>

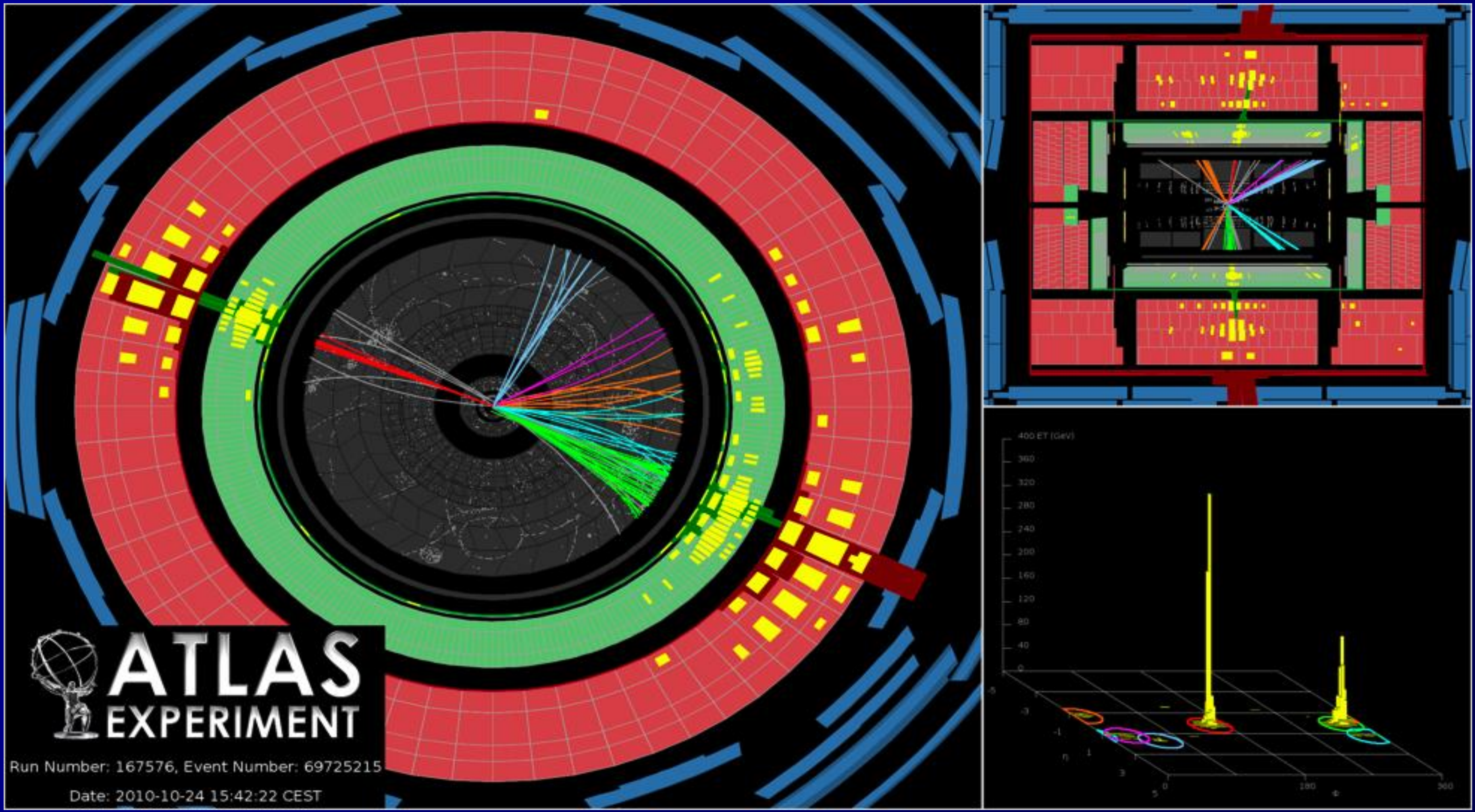




Indirect jet quenching @ RHIC

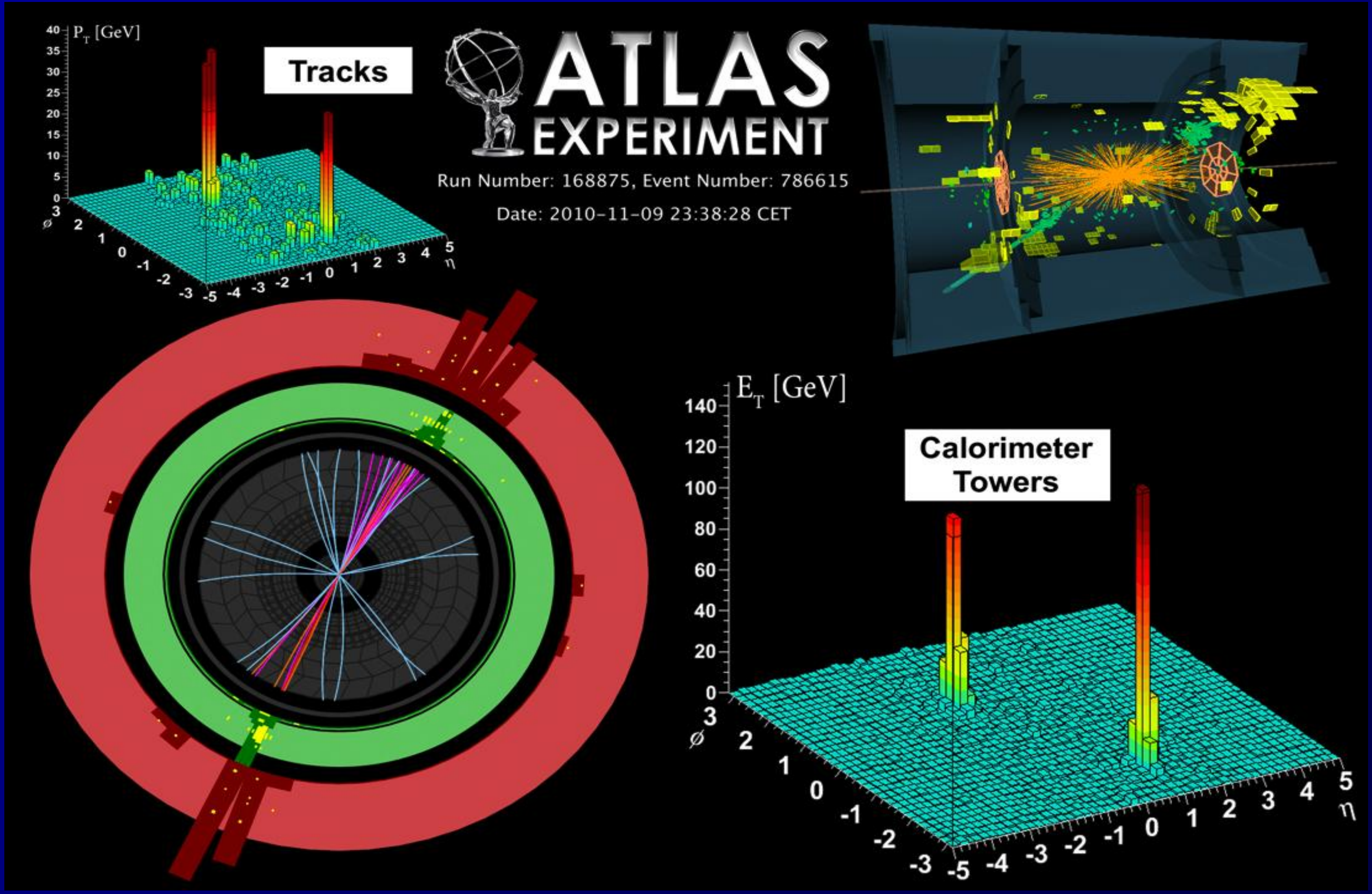
Direct quenching @ LHC?

“Baseline”: jets in p-p



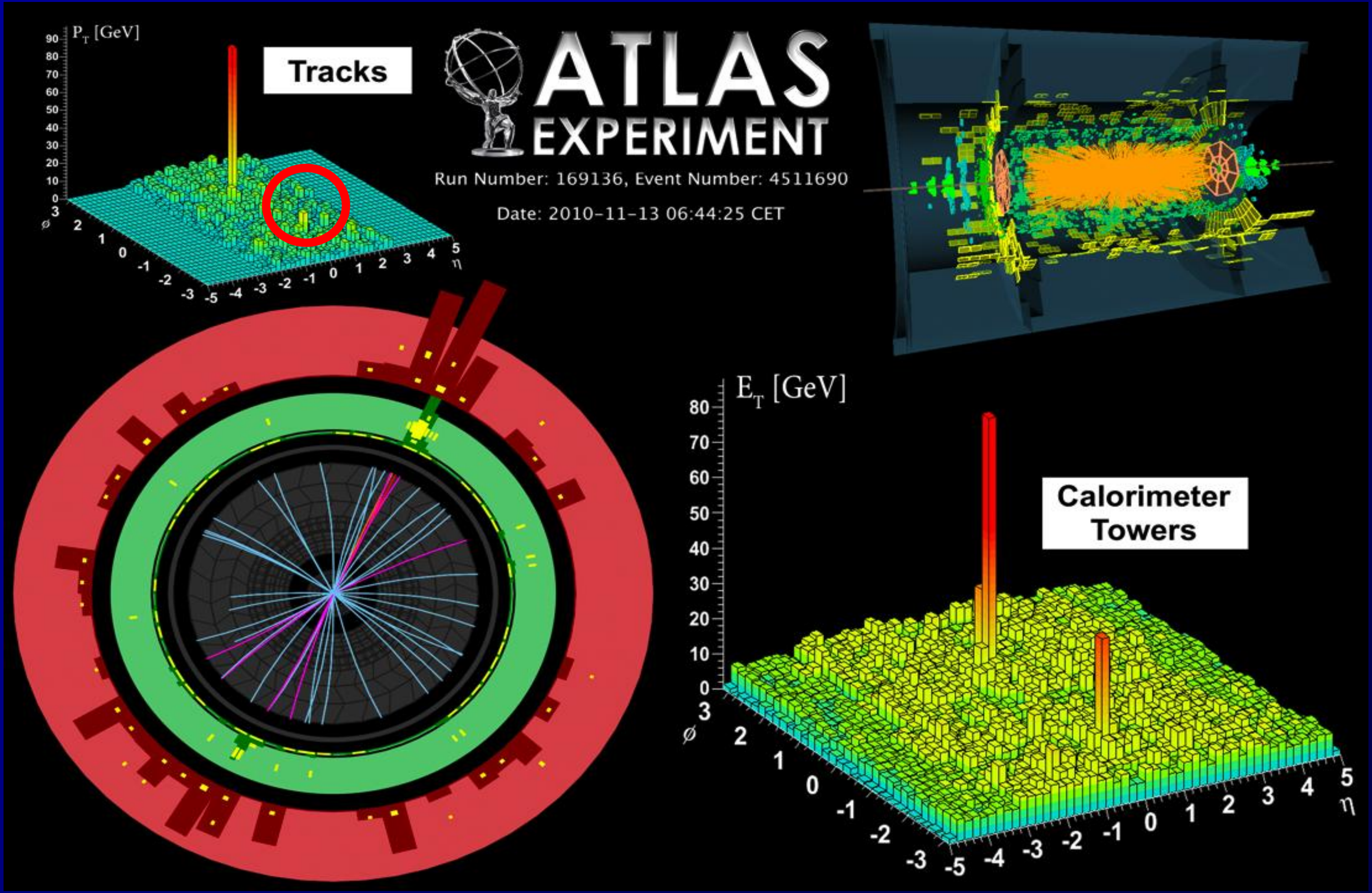
- Leading jet : p_T= 670 GeV, η = 1.9, φ = -0.5
- Sub-leading jet: p_T = 610 GeV, η = -1.6, φ = 2.8

A (more) symmetric dijet event



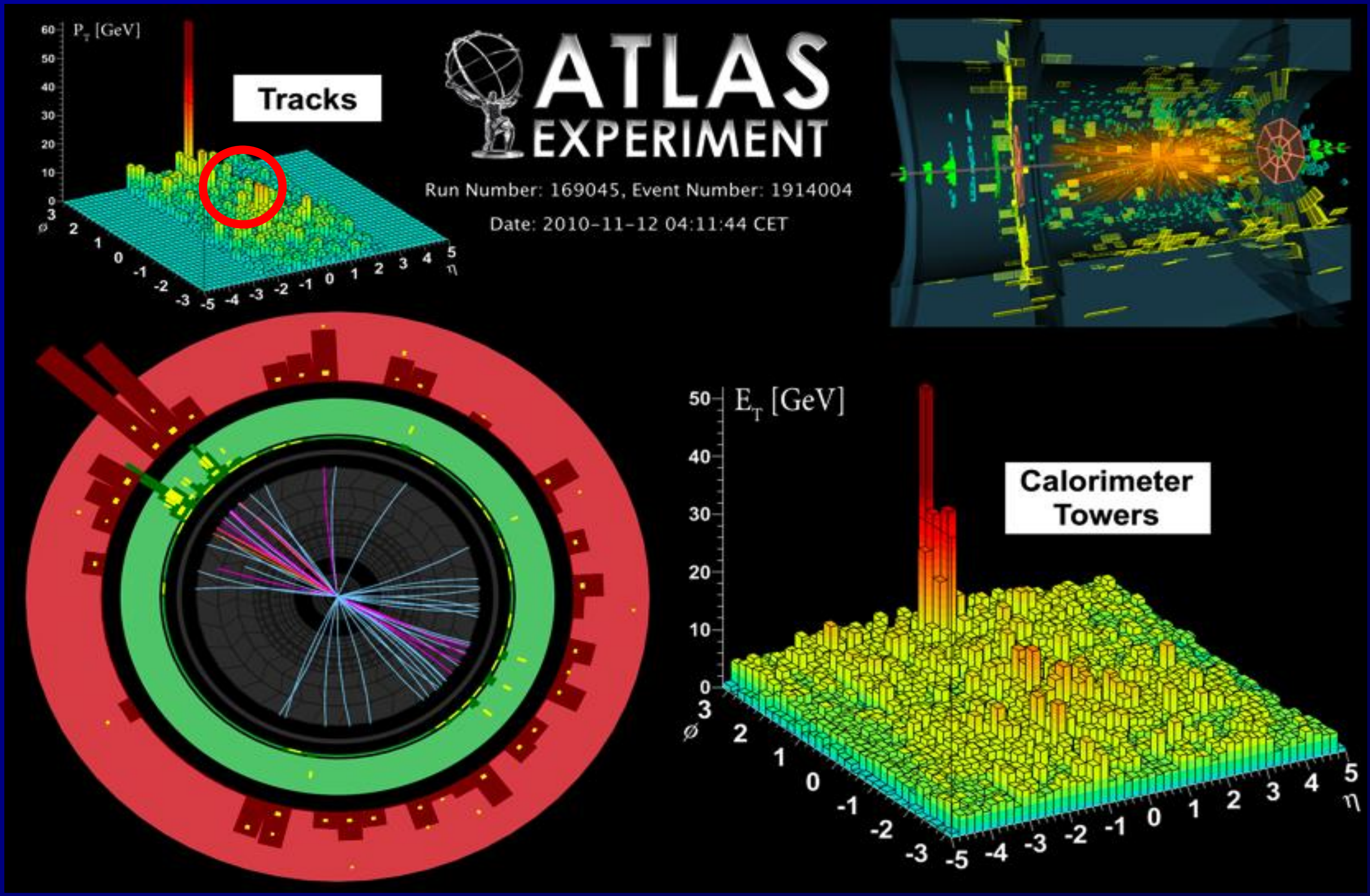
Peripheral, symmetric dijet event

An asymmetric event



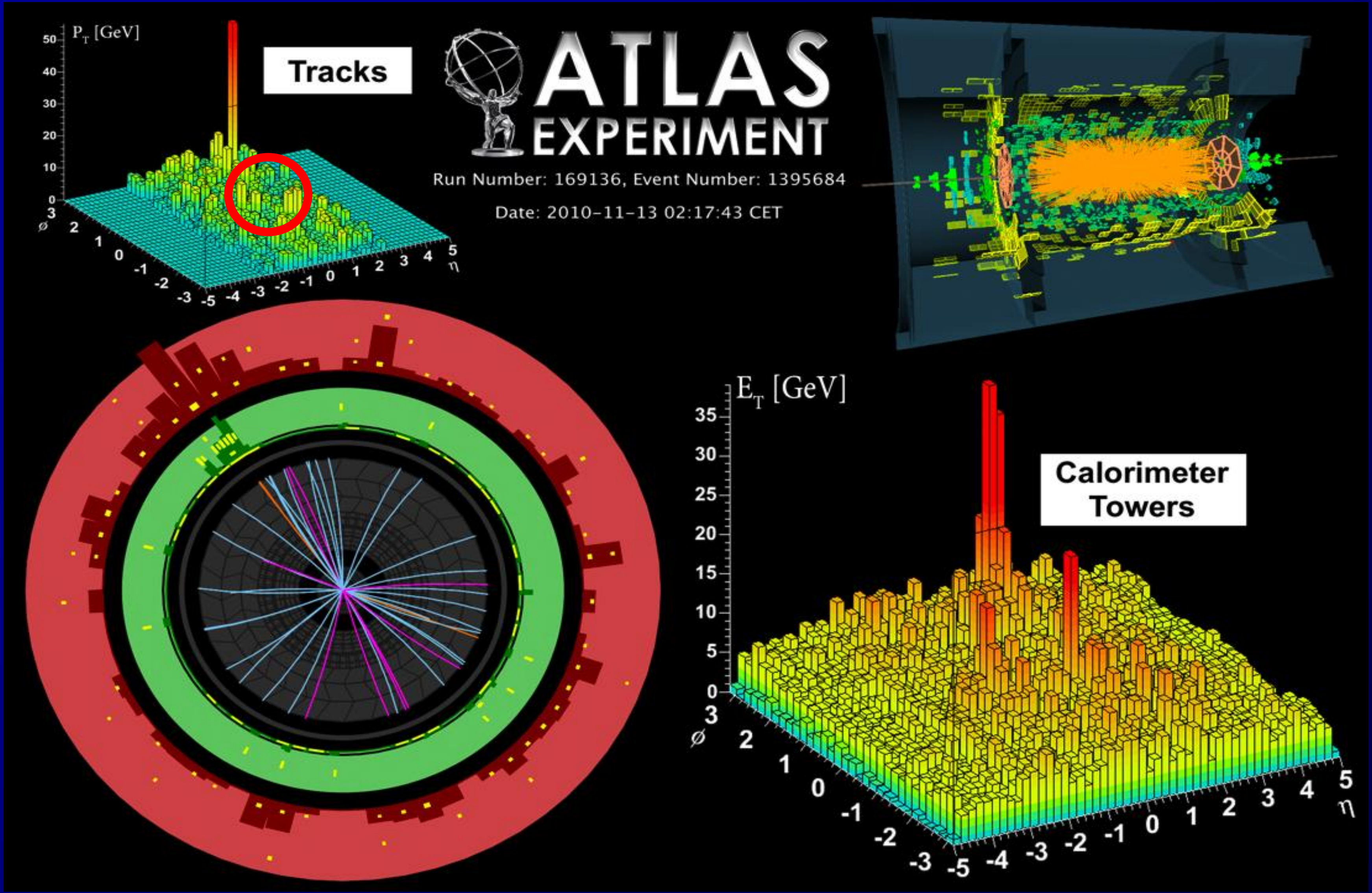
More central, asymmetric dijet event

Another asymmetric event



Even more central collision, more asymmetric dijet

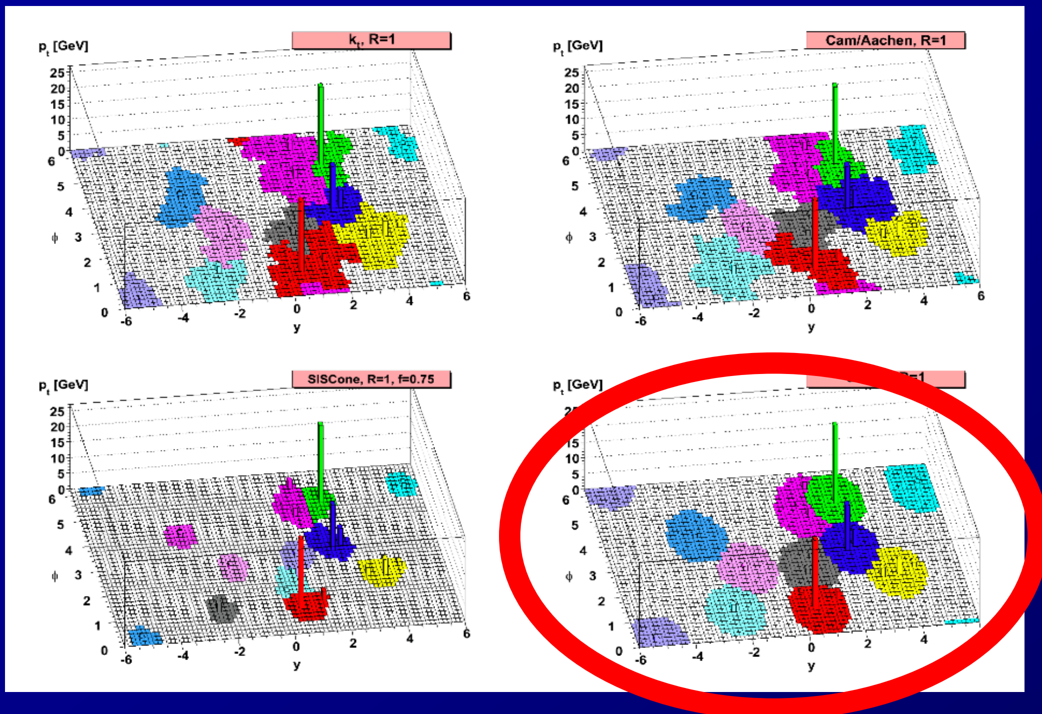
Yet another asymmetric event



Central event, with split dijet + additional activity

Jet reconstruction (1)

Cacciari, M., Salam, G. P. and Soyez, G., *The anti-kt jet clustering algorithm*, Journal of High Energy Physics, 2008, 063



Use anti-k_t clustering algorithm

cone-like but infrared and collinear safe

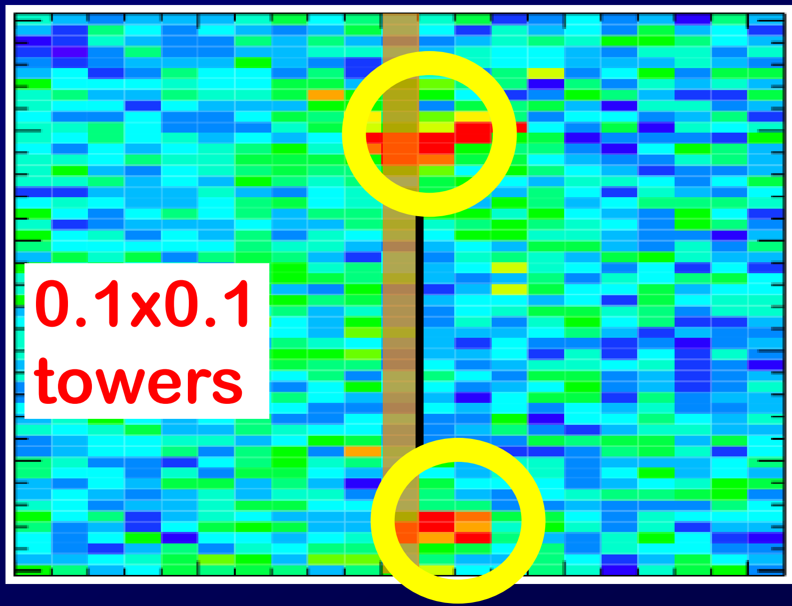
- **Perform anti-k_t reconstruction prior to any background subtraction**
  - R = 0.4 for main analysis
  - R = 0.2, 0.6 for cross-check (+ physics)
- **Input: Δη x Δφ = 0.1 x 0.1 towers**

Jet reconstruction (2)

- Take maximum advantage of ATLAS segmentation
  - Underlying event estimated and subtracted for each longitudinal layer and for 100 slices of Δη = 0.1
    - ® $E_{T\,sub}^{cell} = E_T^{cell} - \rho^{layer}(\eta) \times A^{cell}$
  - ρ is energy density estimated event-by-event
    - ® From average over $0 < \varphi < 2\pi$
- Avoid biasing ρ due to jets
  - Using anti-kt jets:
    - ® Exclude cells from ρ if

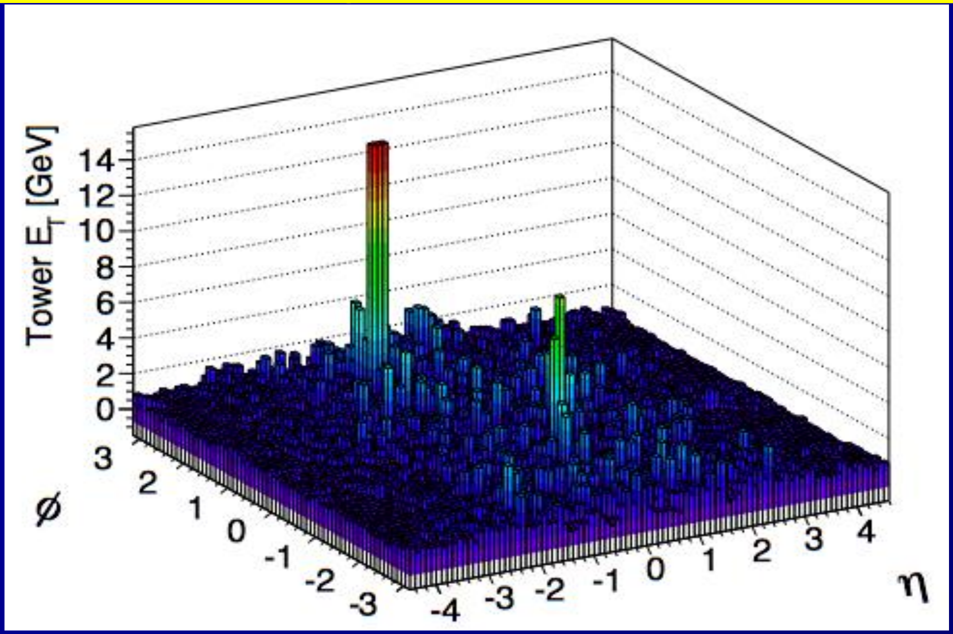
$$D = E_{T\,max}^{tower} / \langle E_T^{tower} \rangle > 5$$

  - Cross check
    - ® Sliding Window algorithm



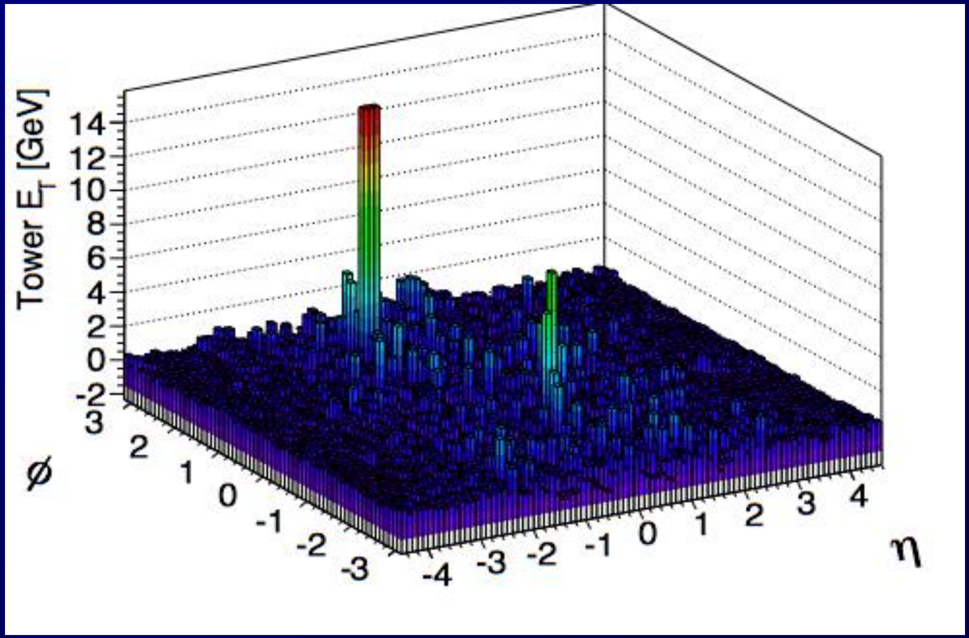
- NO jet removal on basis of D, or any other quantity

Dijet event before & after



- **Before subtraction**
  - ΣE_T in $\Delta\eta x \Delta\varphi$ = 0.1x0.1 towers

- **After subtraction, underlying event at zero**
- **Event structure, topology unchanged by subtraction.**



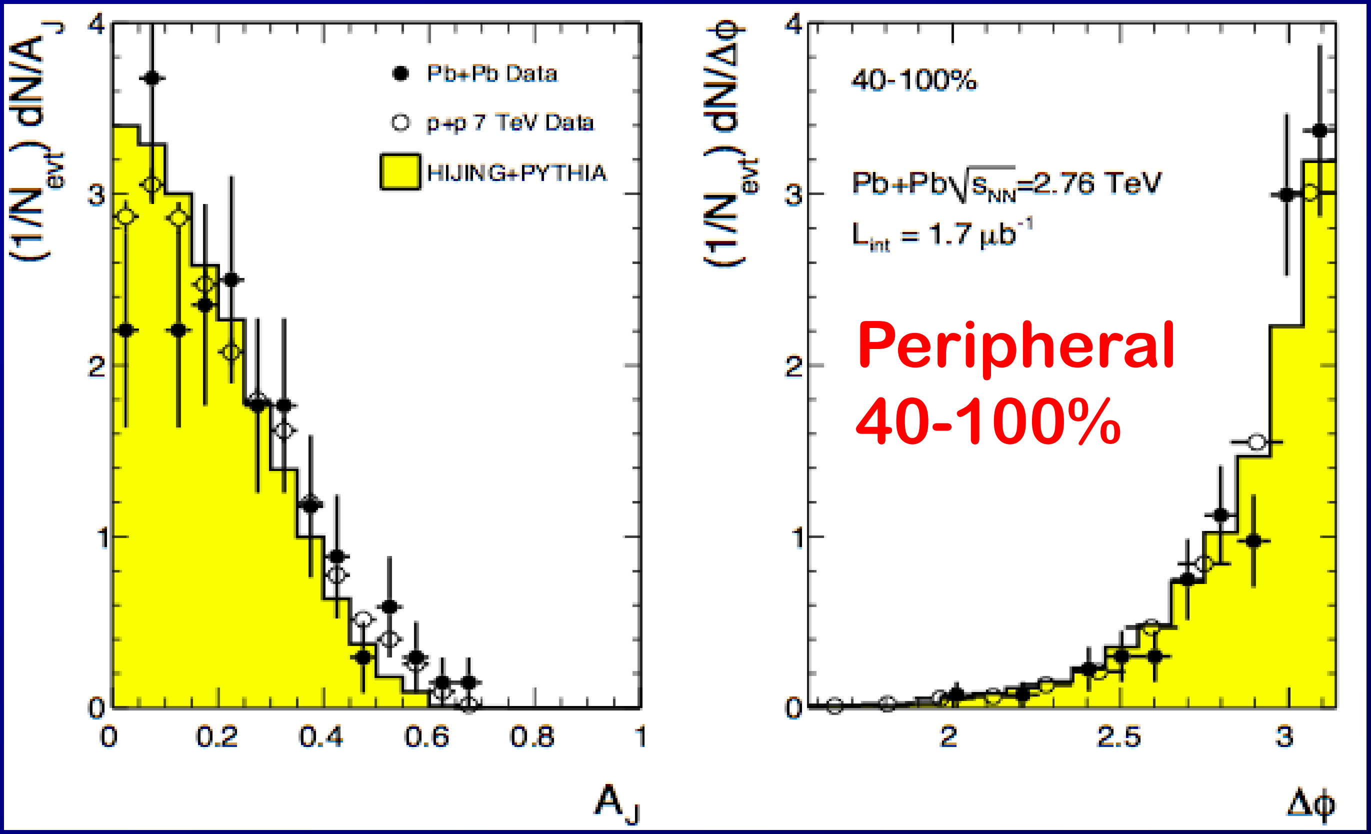
Dijet analysis

- Use R = 0.4 anti-kt jets
  – calibrated using energy density cell weighting
- Select events with leading jet, $E_{T1} > 100$ GeV, $|\eta| < 2.8$
  ® 1693 events after cuts in 1.7 μb^{-1}
- Sub-leading: highest E_T jet in opposite hemisphere, $\Delta\varphi > \pi/2$ with $E_{T2} > 25$ GeV, $|\eta| < 2.8$
  ® 5% of selected have no sub-leading jet
- Introduce new variable to quantify dijet imbalance
  – Not used before in jet quenching literature:
    ® Asymmetry:

$$A \equiv \frac{E_{T1} - E_{T2}}{E_{T2} + E_{T1}}$$

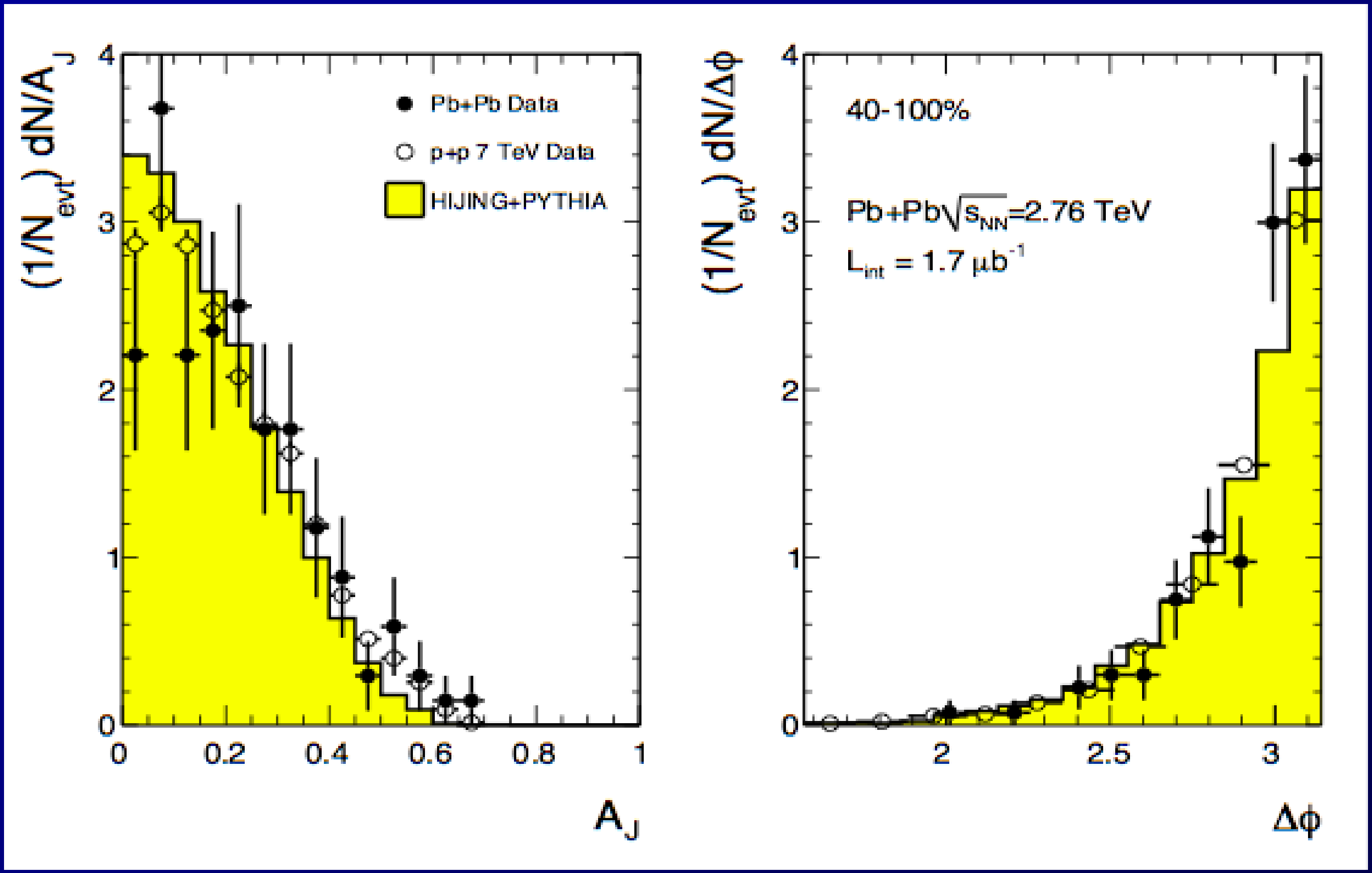
- Robust variable:
  – Residual subtraction errors cancel in numerator
  – Absolute jet energy scale errors cancel in ratio.

Dijets: comparison to p+p, HIJING + PYTHIA

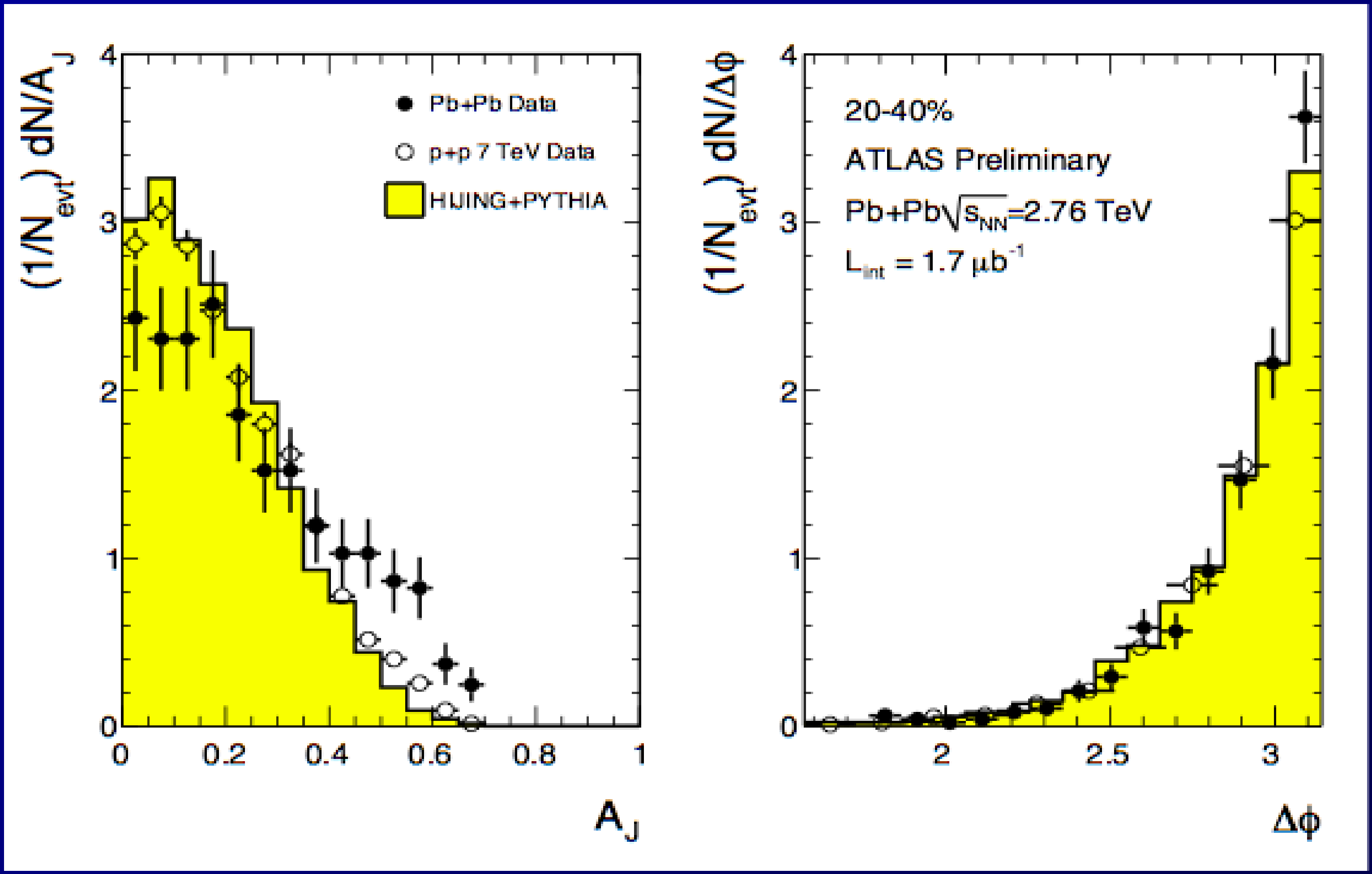


- Pb+Pb di-jet asymmetry (A_J), acoplanarity ($\Delta\varphi$)
  - Compare to p+p data
  - And PYTHIA (7 TeV) dijet events embedded in HIJING
    - ® No HIJING quenching, flow added in afterburner
- Data agrees with p+p, MC in peripheral Pb+Pb.

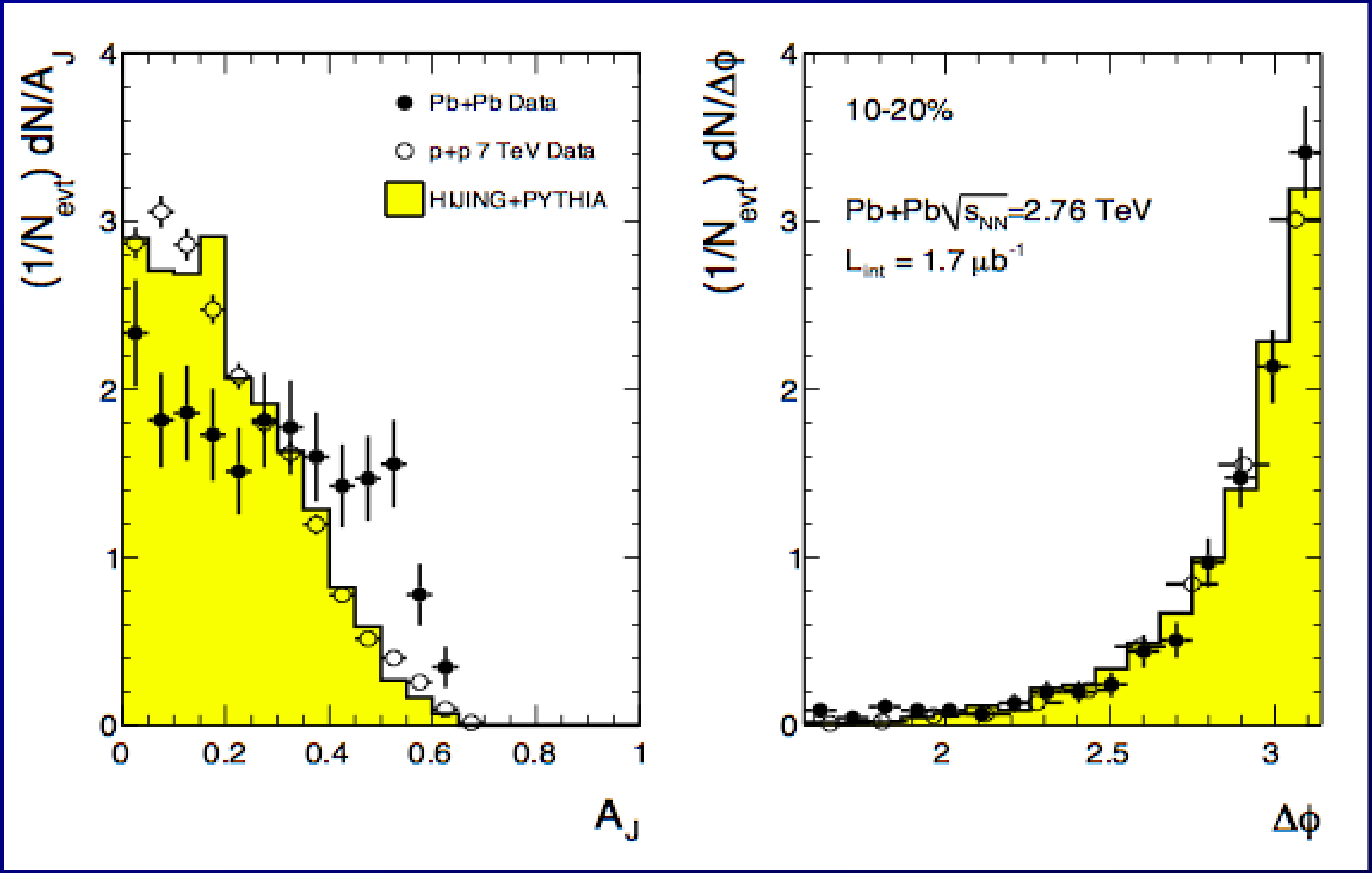
Pb+Pb, 40-100% - Peripheral



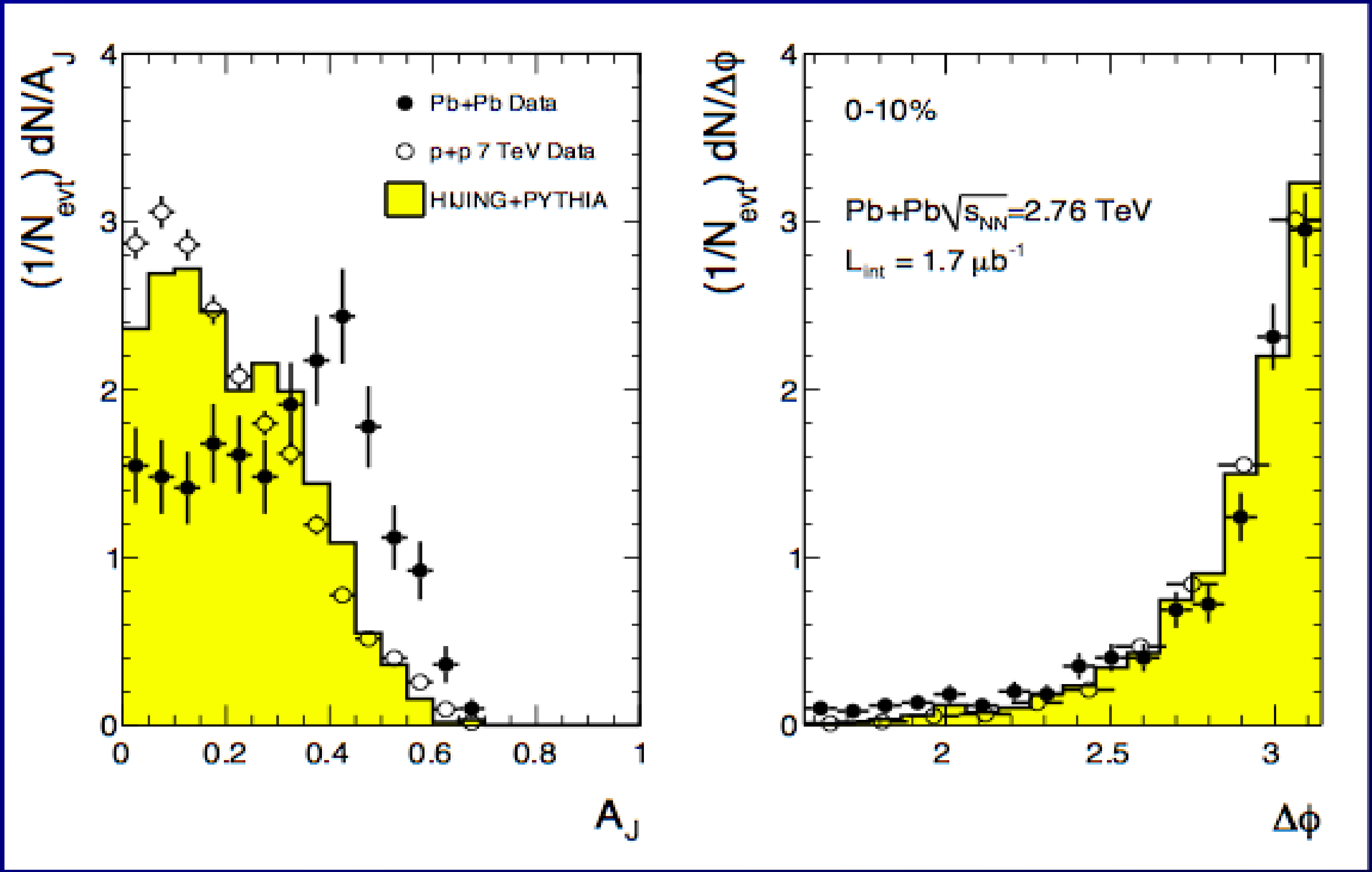
Pb+Pb 20-40% - semi-central



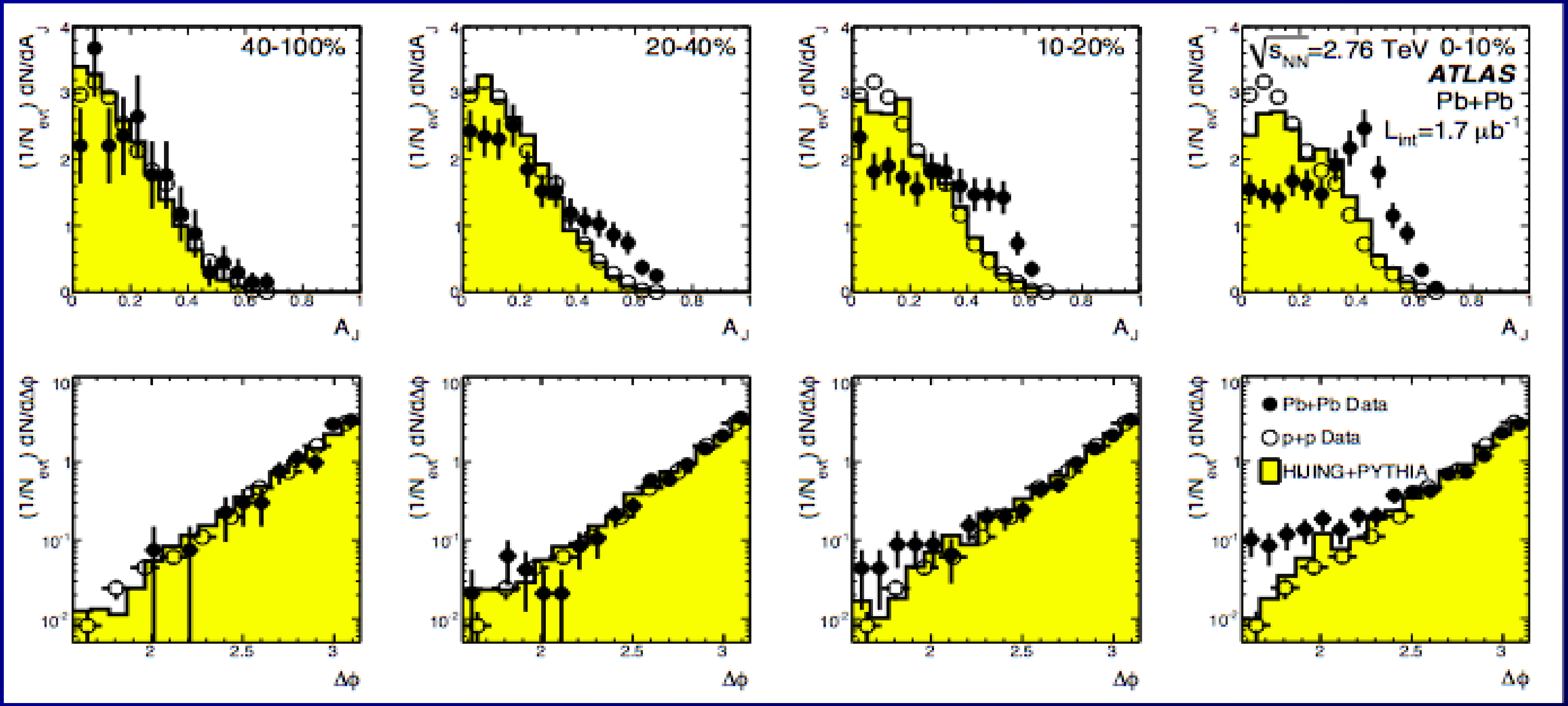
Pb+Pb, 10-20% - more central



Pb+Pb, 0-10% - central

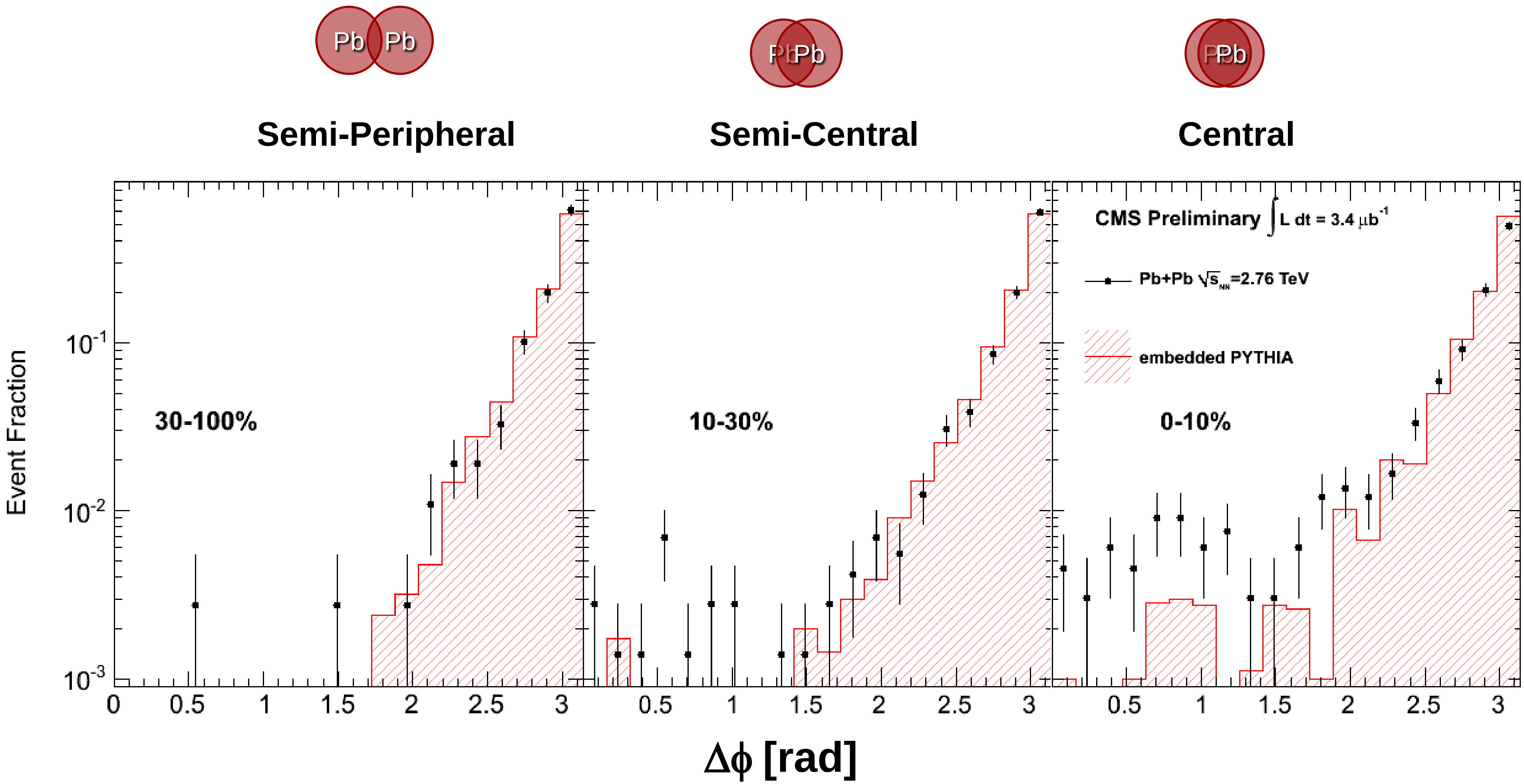


Full centrality range: paper plots



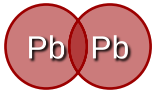
- For more central collisions, see:
  - Reduced fraction of jets with small asymmetry
  - Increased fraction of jets with large asymmetry
    - ® For all centralities, $\Delta\phi$ strongly peaked at π
    - ® Possible small broadening in central collisions

Azimuthal dijet correlation



Select back-to-back dijets with $\Delta\phi > 2.5$ for further study

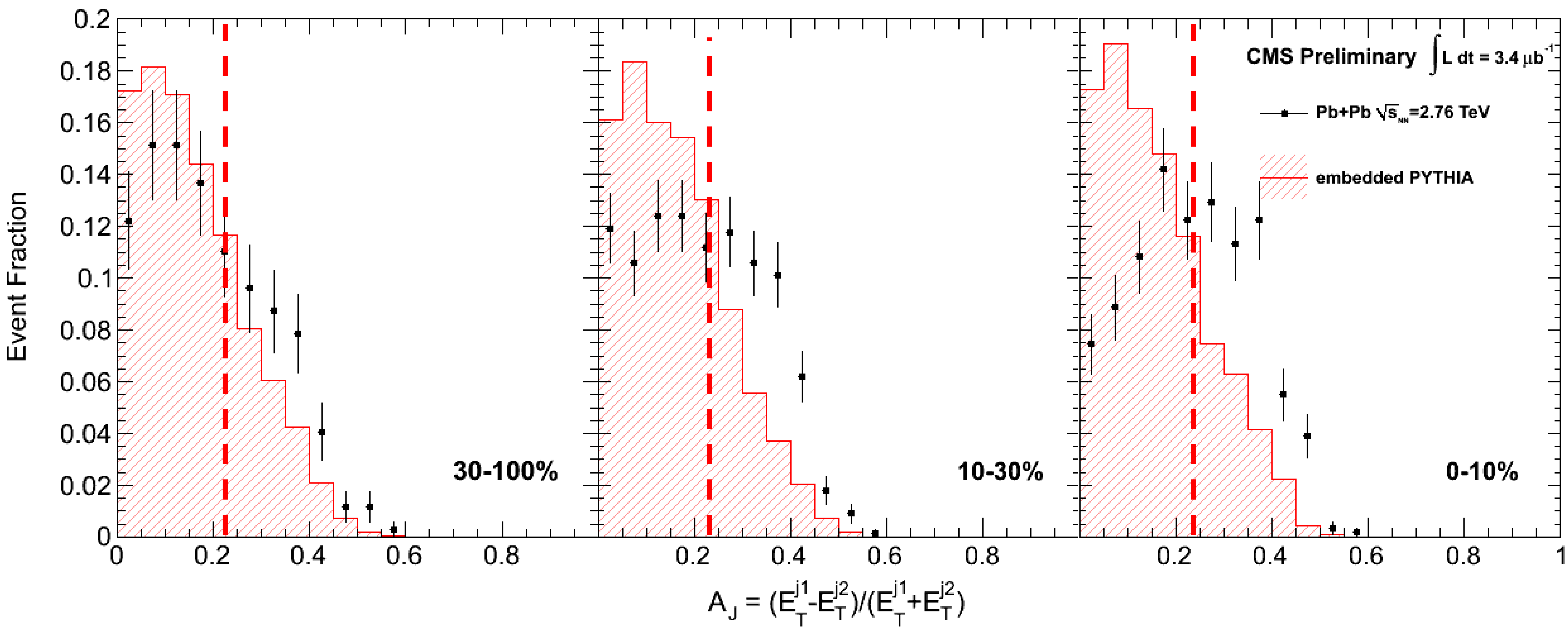
Dijet energy imbalance



Semi-Peripheral

Semi-Central

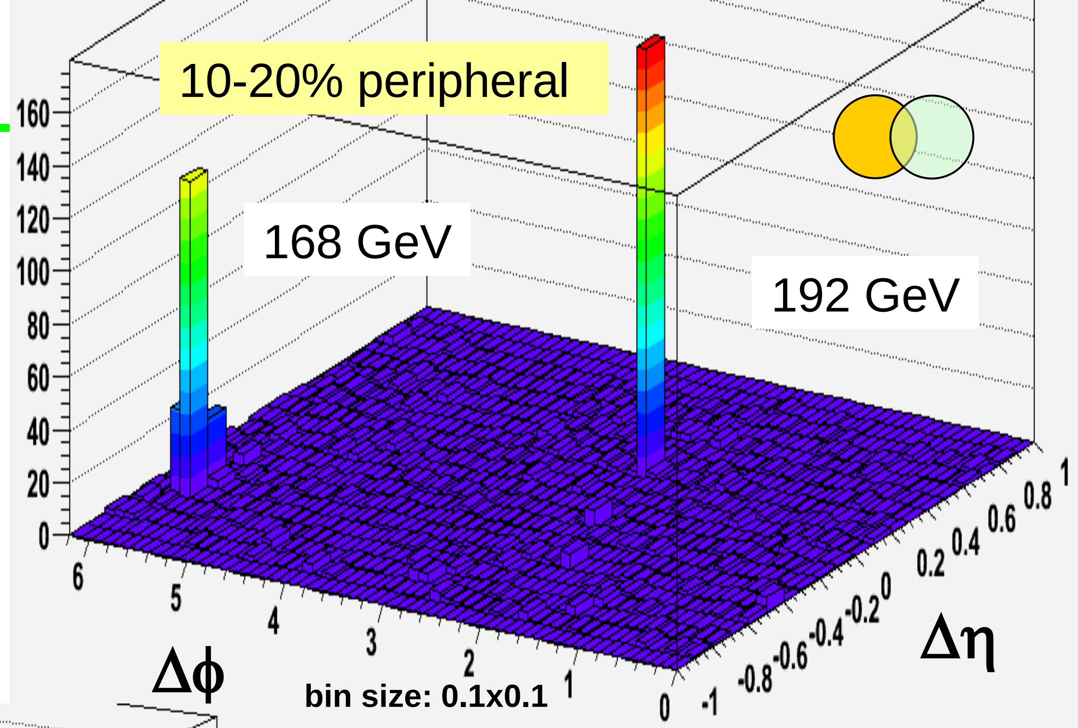
Central

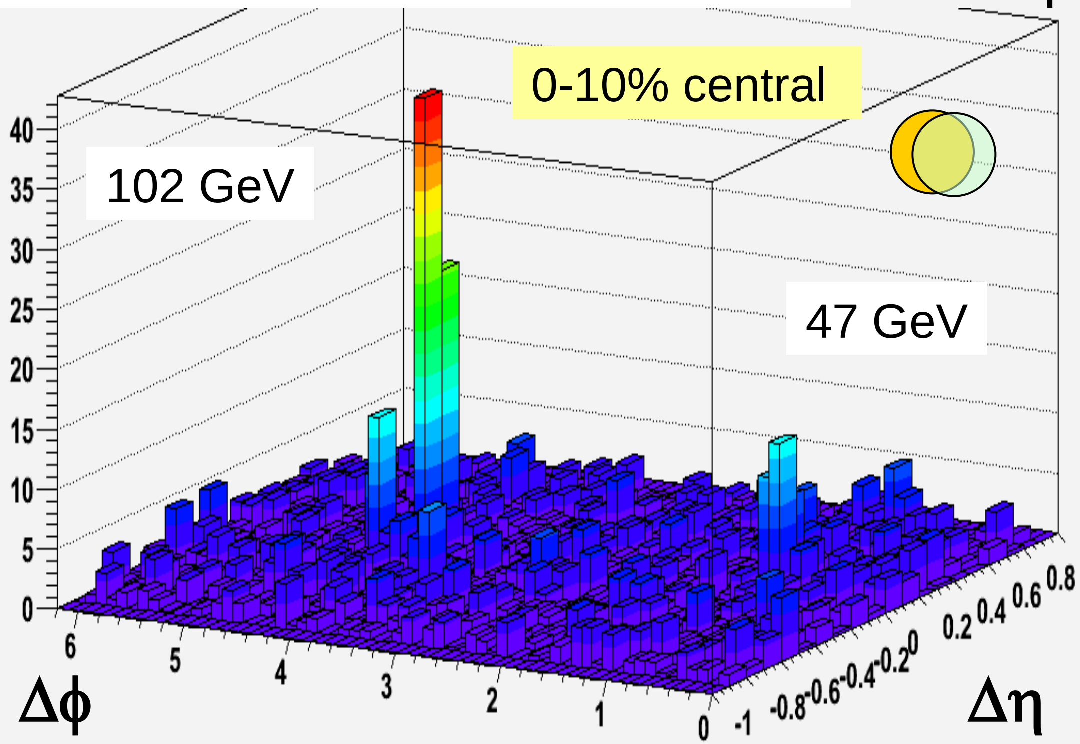


A significant dijet imbalance, well beyond that expected from unquenched MC, appears with increasing collision centrality

Charged Jets

- Jets in ALICE (TPC)
  - ⇨ we see qualitatively a similar effect
  - ⇨ quantitative analysis is ongoing
    - small acceptance (statistics), => need full 2010 data
    - try to include low p_t (study p_t-cut off dependence of imbalance)





Personal Comments

- The first HI collision happened on Nov 8^{th} , 2010 and about one week later, the first preprint was posted on Nov 17^{th}. The data analysis is super-fast, probably reflecting the readiness of the experiments at LHC.
- The charged multiplicity is within a smooth extrapolation from the measurements at lower energies.
- Observation of an imbalance of di-jet energies is definitely new and exciting. This probe has the origin of hard processes and can be evaluated on a solid QCD calculation. However due to the subtleties of jet-finding and jet-reconstruction in the “dirty” HI environment and the dynamic evolution of the geometry of interaction medium, more systematic studies in comparison with data from p+p and p+A, are definitely needed.

References

Slides Taken From
http://indico.cern.ch/conferenceDisplay.py?confId=114939

First results from Heavy Ion collisions at the LHC (ALICE, ATLAS, CMS)

chaired by Sergio Bertolucci (CERN)

Thursday 02 December 2010 from **17:15** to **18:55** (Europe/Zurich)
at CERN (500-1-001 - Main Auditorium)

Description Presentation of the first physics results from the 2010 heavy ion run of the LHC

Material Poster | Video in CDS

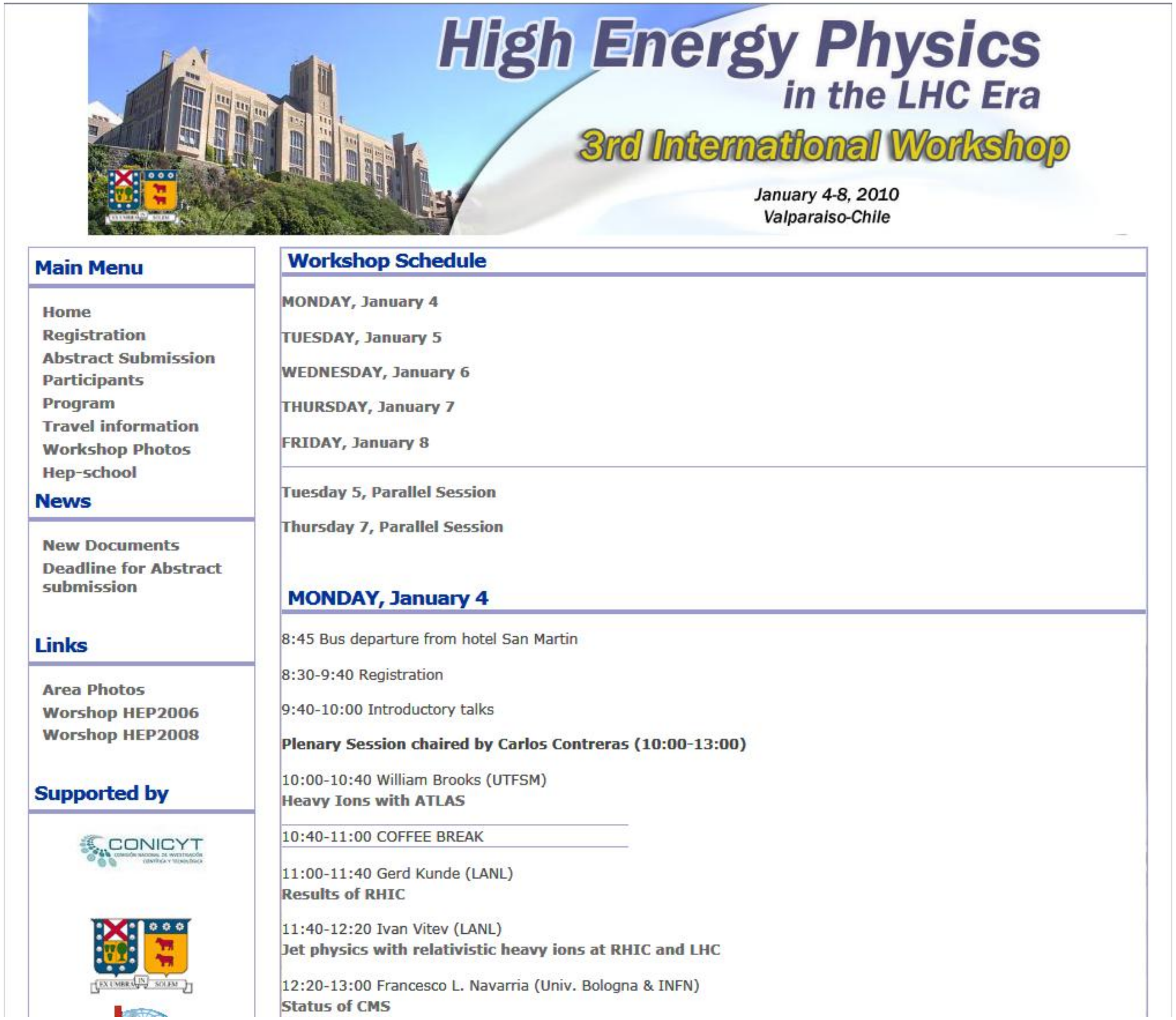
Thursday 02 December 2010

17:15 - 17:45 ATLAS *30'*
Speaker: Brian Cole (Physics Dept., Pupin Physics Lab.-Columbia University-Unknown)
Material: **Slides**

17:50 - 18:20 CMS *30'*
Speaker: Bolek Wyslouch (MIT)
Material: **Slides**

18:25 - 18:55 ALICE *30'*
Speaker: Juergen Schukraft (CERN)
Material: **Slides**

Slides Taken From
Gerd Kunde's talk in HEP2010



High Energy Physics
in the LHC Era
3rd International Workshop
January 4-8, 2010
Valparaiso-Chile

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Workshop Schedule

MONDAY, January 4
TUESDAY, January 5
WEDNESDAY, January 6
THURSDAY, January 7
FRIDAY, January 8

Tuesday 5, Parallel Session
Thursday 7, Parallel Session

MONDAY, January 4

8:45 Bus departure from hotel San Martin

8:30-9:40 Registration

9:40-10:00 Introductory talks

Plenary Session chaired by Carlos Contreras (10:00-13:00)

10:00-10:40 William Brooks (UTFSM)
Heavy Ions with ATLAS

10:40-11:00 COFFEE BREAK

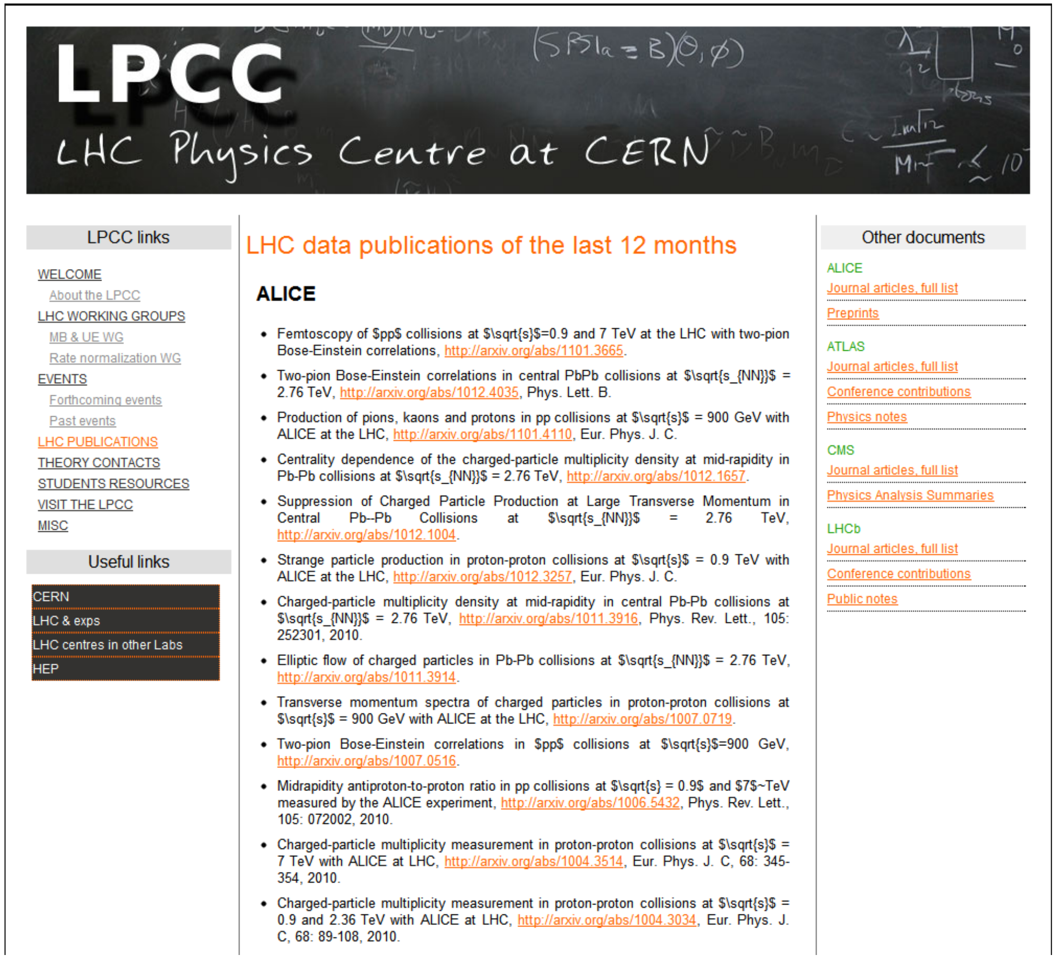
11:00-11:40 Gerd Kunde (LANL)
Results of RHIC

11:40-12:20 Ivan Vitev (LANL)
Jet physics with relativistic heavy ions at RHIC and LHC

12:20-13:00 Francesco L. Navarria (Univ. Bologna & INFN)
Status of CMS

LHC data publications of the last 12 months

http://lpcc.web.cern.ch/LPCC/index.php?page=lhc-articles



LPCC

LHC Physics Centre at CERN

LPCC links

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Useful links

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LHC data publications of the last 12 months

ALICE

- Femtoscopy of pp collisions at $\sqrt{s}$=0.9 and 7 TeV at the LHC with two-pion Bose-Einstein correlations, http://arxiv.org/abs/1101.3665.
- Two-pion Bose-Einstein correlations in central PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1012.4035, Phys. Lett. B.
- Production of pions, kaons and protons in pp collisions at $\sqrt{s}$ = 900 GeV with ALICE at the LHC, http://arxiv.org/abs/1101.4110, Eur. Phys. J. C.
- Centrality dependence of the charged-particle multiplicity density at mid-rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1012.1657.
- Suppression of Charged Particle Production at Large Transverse Momentum in Central Pb--Pb Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1012.1004.
- Strange particle production in proton-proton collisions at $\sqrt{s}$ = 0.9 TeV with ALICE at the LHC, http://arxiv.org/abs/1012.3257, Eur. Phys. J. C.
- Charged-particle multiplicity density at mid-rapidity in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1011.3916, Phys. Rev. Lett., 105: 252301, 2010.
- Elliptic flow of charged particles in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1011.3914.
- Transverse momentum spectra of charged particles in proton-proton collisions at $\sqrt{s}$ = 900 GeV with ALICE at the LHC, http://arxiv.org/abs/1007.0719.
- Two-pion Bose-Einstein correlations in pp collisions at $\sqrt{s}$=900 GeV, http://arxiv.org/abs/1007.0516.
- Midrapidity antiproton-to-proton ratio in pp collisions at $\sqrt{s} = 0.9$ and 7~TeV measured by the ALICE experiment, http://arxiv.org/abs/1006.5432, Phys. Rev. Lett., 105: 072002, 2010.
- Charged-particle multiplicity measurement in proton-proton collisions at $\sqrt{s}$ = 7 TeV with ALICE at LHC, http://arxiv.org/abs/1004.3514, Eur. Phys. J. C, 68: 345-354, 2010.
- Charged-particle multiplicity measurement in proton-proton collisions at $\sqrt{s}$ = 0.9 and 2.36 TeV with ALICE at LHC, http://arxiv.org/abs/1004.3034, Eur. Phys. J. C, 68: 89-108, 2010.

Other documents

ALICE
- Journal articles, full list
- Preprints

ATLAS
- Journal articles, full list
- Conference contributions
- Physics notes

CMS
- Journal articles, full list
- Physics Analysis Summaries

LHCb
- Journal articles, full list
- Conference contributions
- Public notes

Publication - ALICE

- Two-pion Bose-Einstein correlations in central PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1012.4035, **Phys.Lett. B696, 328-337 (2011)**.
- Centrality dependence of the charged-particle multiplicity density at mid-rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1012.1657, **Phys. Rev. Lett. 106, 032301 (2011).**
- Suppression of Charged Particle Production at Large Transverse Momentum in Central Pb--Pb Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1012.1004, **Phys.Lett. B696, 30-39 (2011)**.
- Charged-particle multiplicity density at mid-rapidity in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1011.3916, **Phys. Rev. Lett. 105, 252301 (2010).**
- Elliptic flow of charged particles in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1011.3914, **Phys. Rev. Lett. 105, 252302 (2010)**.

Publication - ATLAS

- Measurement of the centrality dependence of $J/{\psi}$ yields and observation of Z production in lead-lead collisions with the ATLAS detector at the LHC, http://arxiv.org/abs/1012.5419, **Phys.Lett.B697, 294-312 (2011)**.
- Observation of a Centrality-Dependent Dijet Asymmetry in Lead-Lead Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with the ATLAS Detector at the LHC, http://arxiv.org/abs/1011.6182, **Phys. Rev. Lett. 105, 252303 (2010)**.

Publication - CMS

- Study of Z boson production in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1102.5435.
- Observation and studies of jet quenching in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, http://arxiv.org/abs/1102.1957.