Recent results on Quark Gluon Plasma and Future Plans

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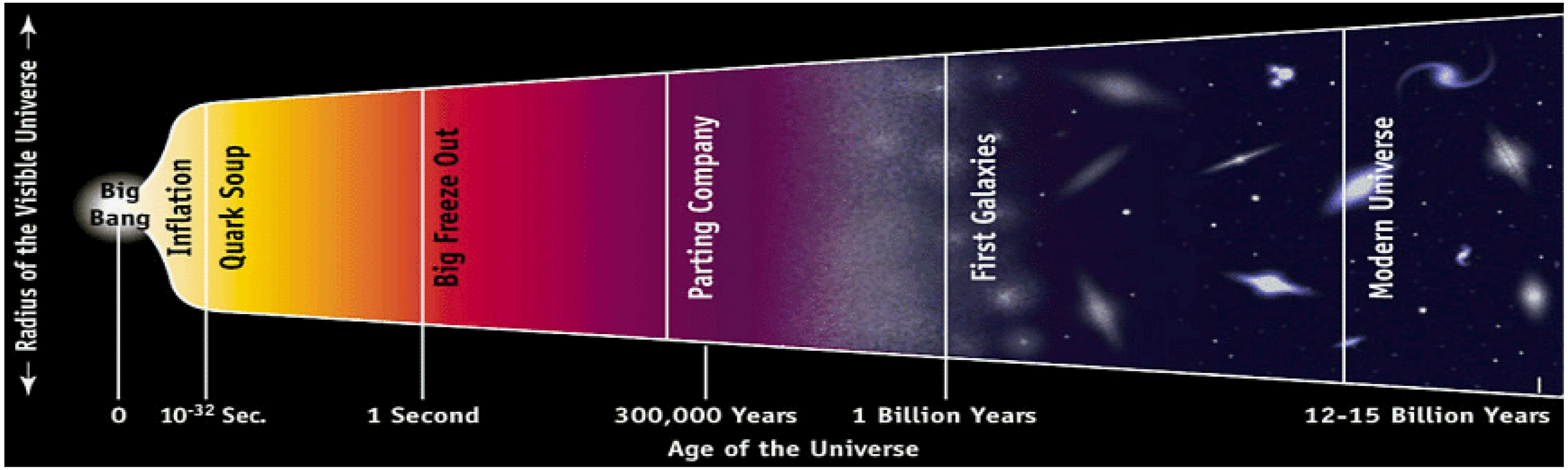
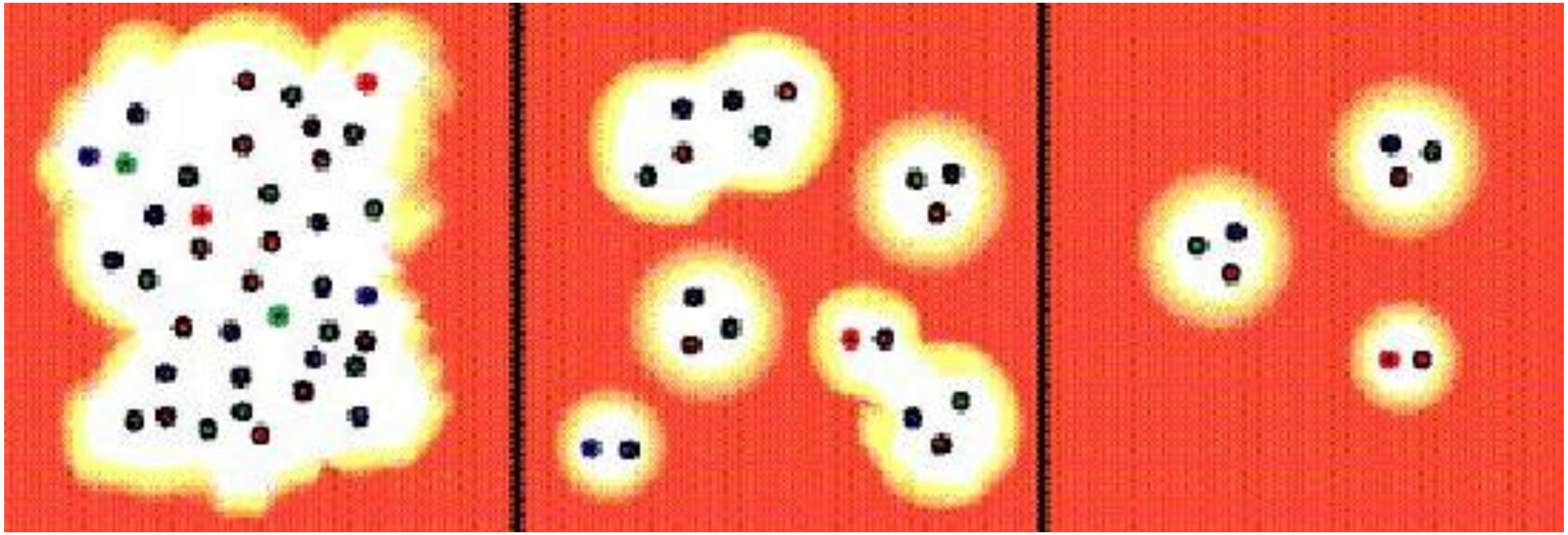
Contents

Quark Gluon Plasma (QGP)

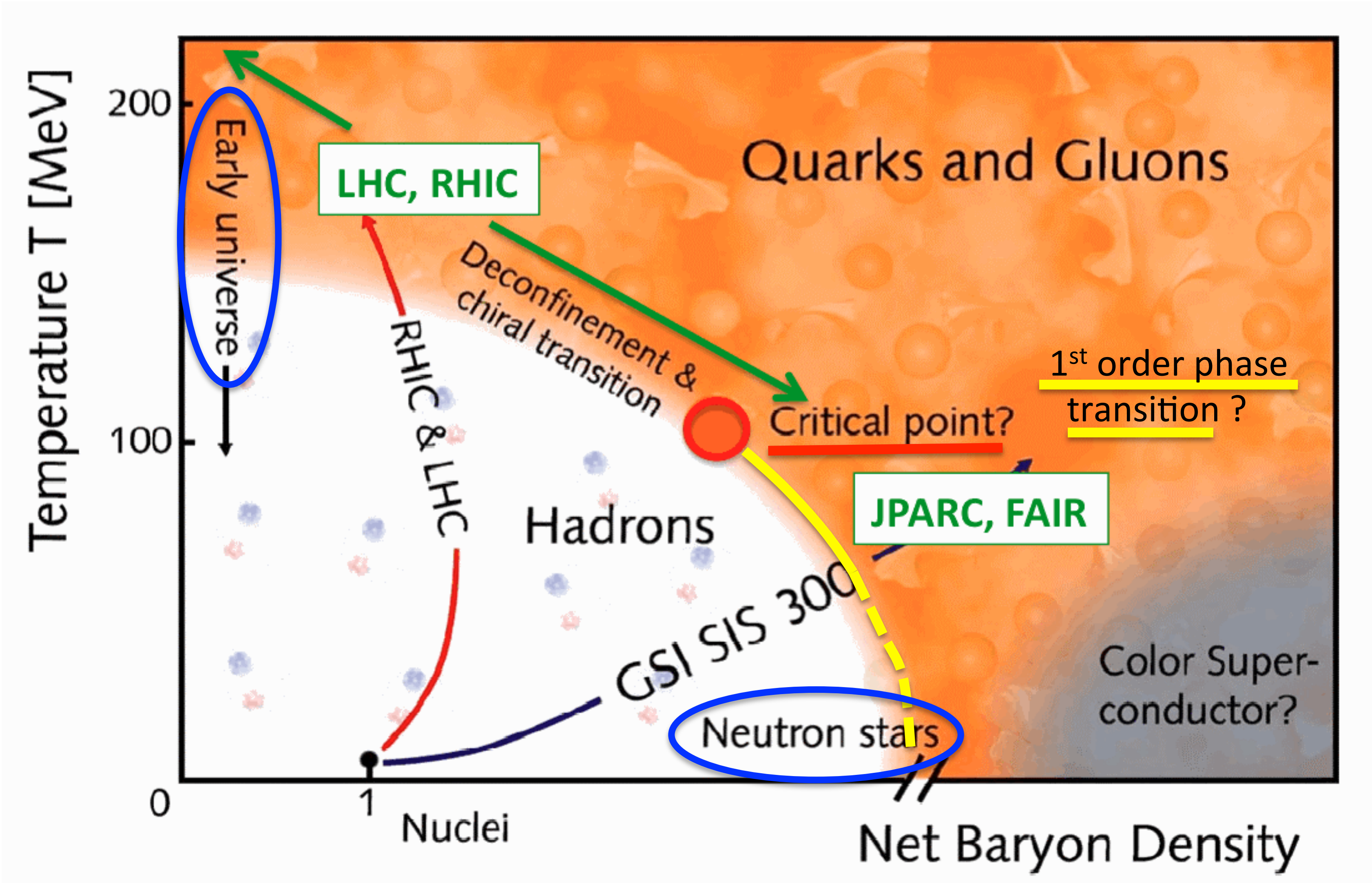


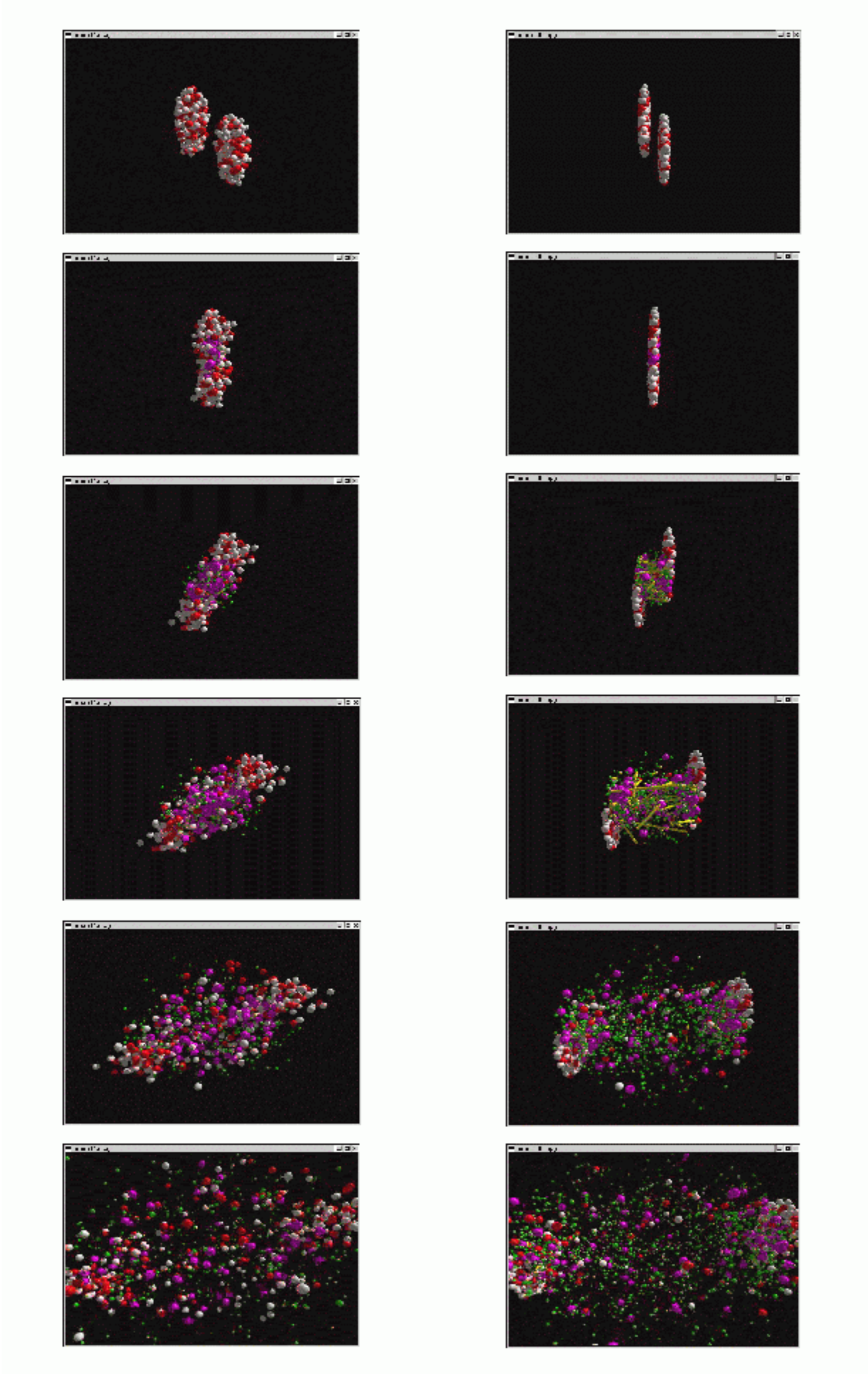


Quark Gluon Plasma

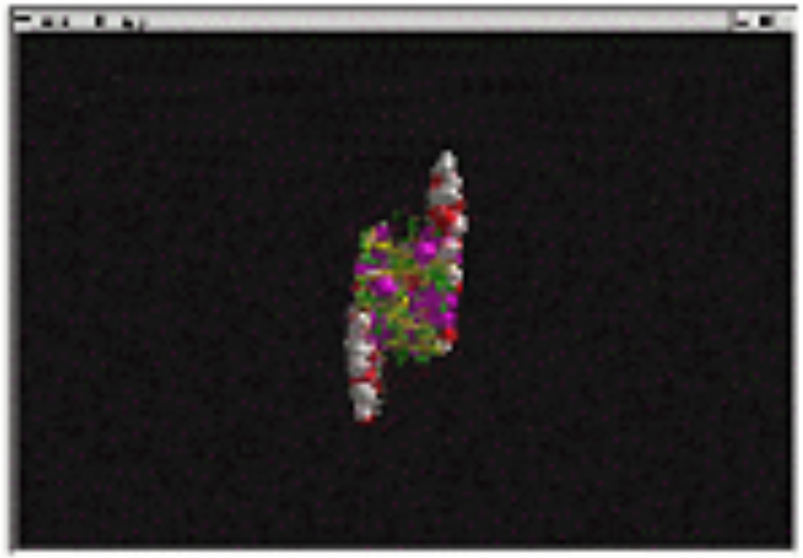
Hadrons

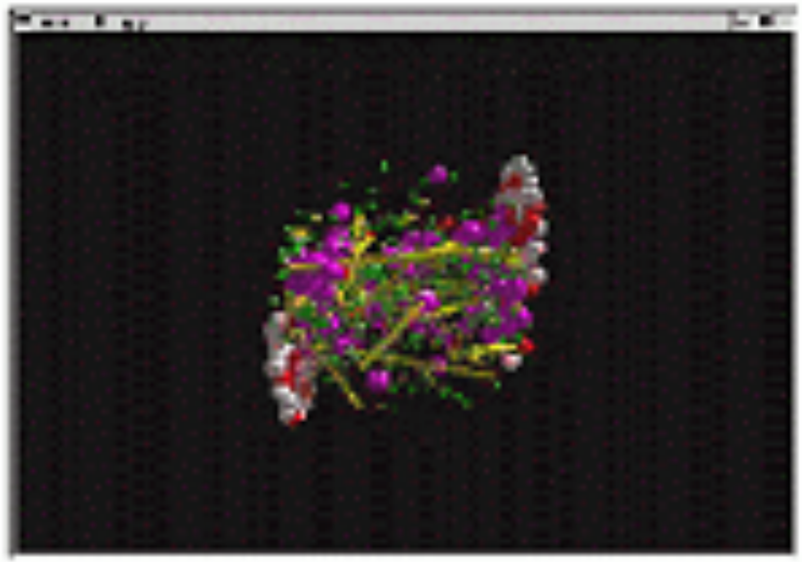
Phase-Diagram of QGP



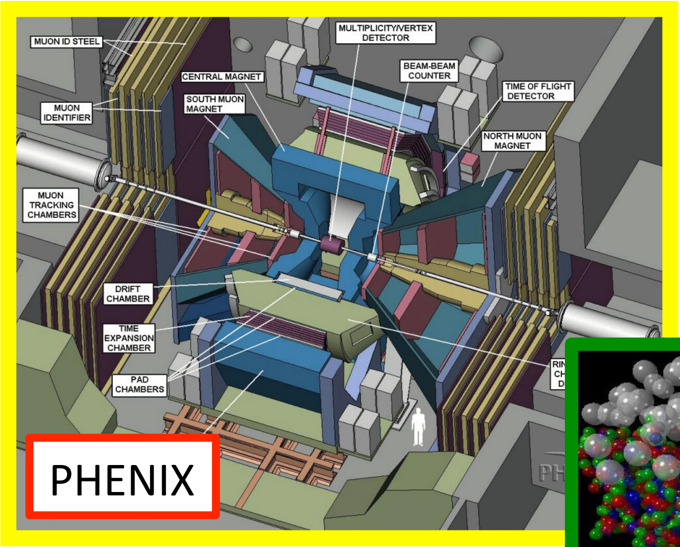


Heavy Ion collisions at Ultra-relativistic energy

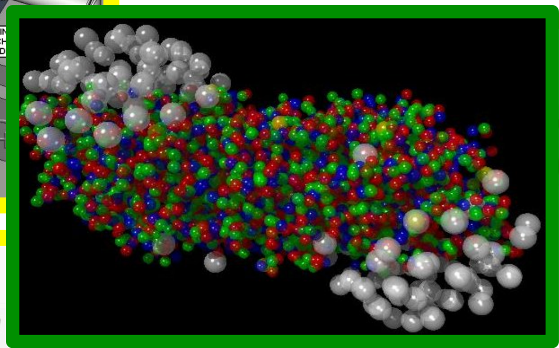


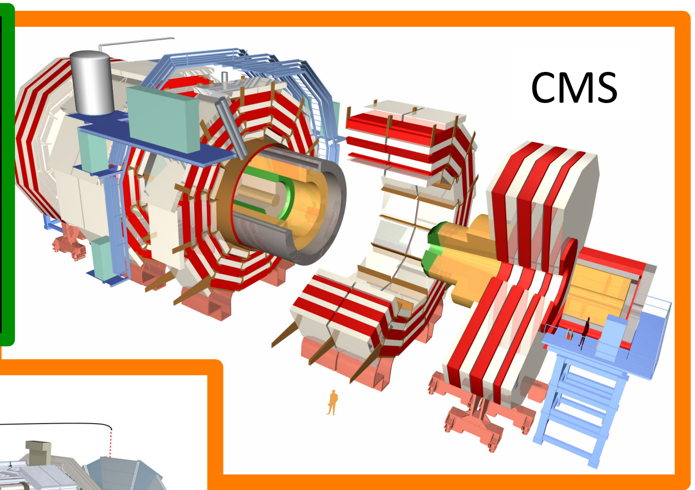


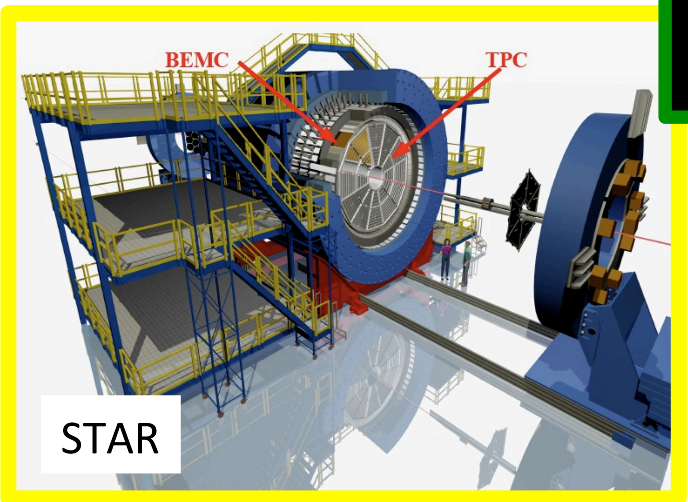
Relativistic Heavy-Ion Collider (RHIC) at BNL in New York
Large Hadron Collider (LHC) at CERN in Geneva

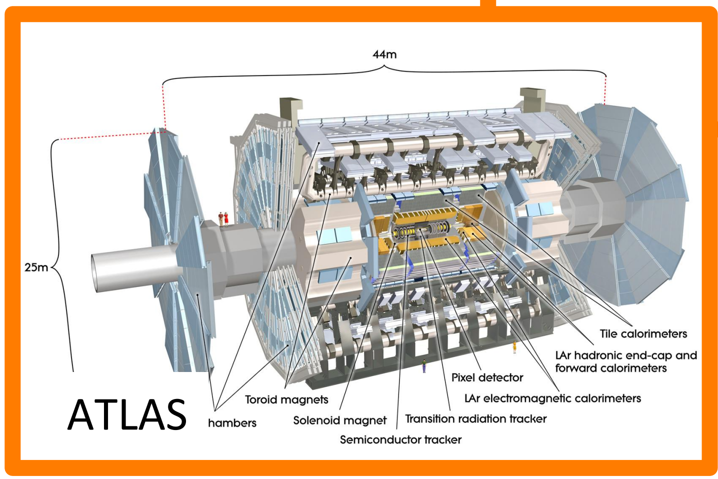

MUON ID STEEL
MULTIPLICITY/VERTEX DETECTOR
CENTRAL MAGNET
BEAM-BEAM COUNTER
SOUTH MUON MAGNET
TIME OF FLIGHT DETECTOR
MUON IDENTIFIER
NORTH MUON MAGNET
MUON TRACKING CHAMBERS
DRIFT CHAMBER
TIME EXPANSION CHAMBER
PAD CHAMBERS
PHENIX

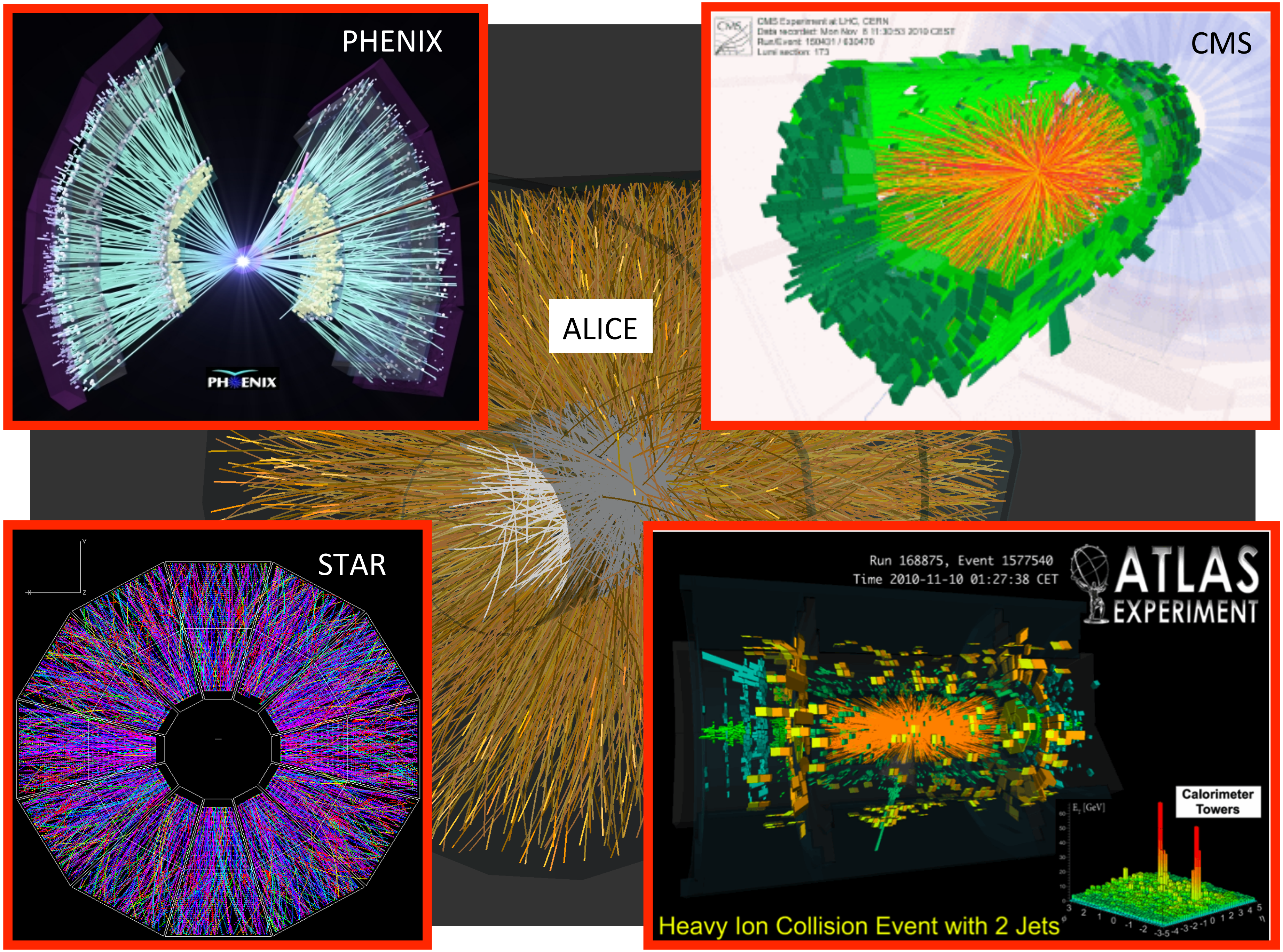

ALICE



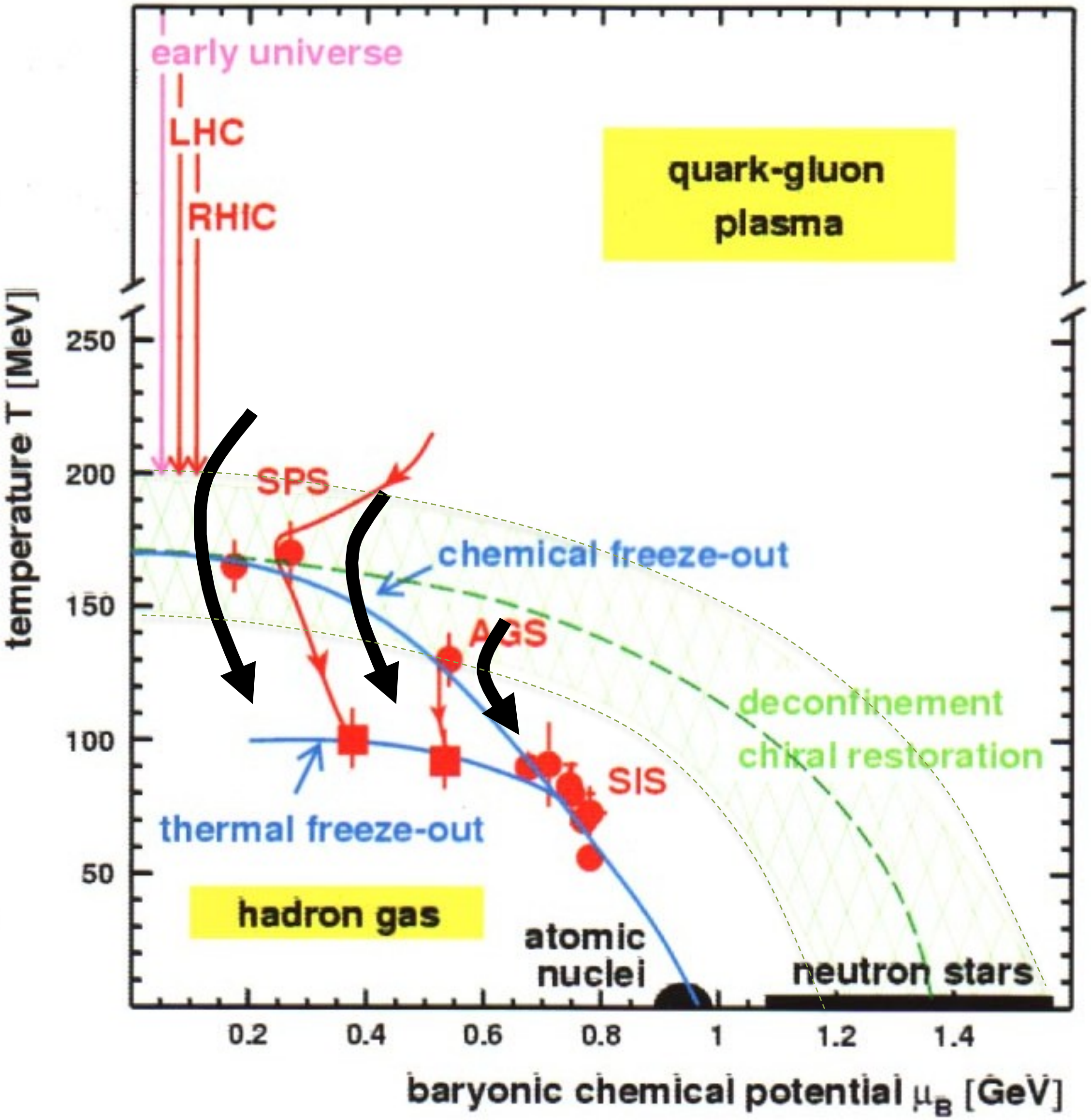

CMS


BEMC
TPC
STAR


44m
25m
Tile calorimeters
LAr hadronic end-cap and forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Transition radiation tracker
hambers
Solenoid magnet
Semiconductor tracker
ATLAS


PHENIX
PHENIX
CMS
ALICE
STAR
Run 168875, Event 1577540
Time 2010-11-10 01:27:38 CET
ATLAS
EXPERIMENT
Calorimeter
Towers
Heavy Ion Collision Event with 2 Jets

Chemical and Thermal Freeze-out



single particle p_T spectra, HBT measurements

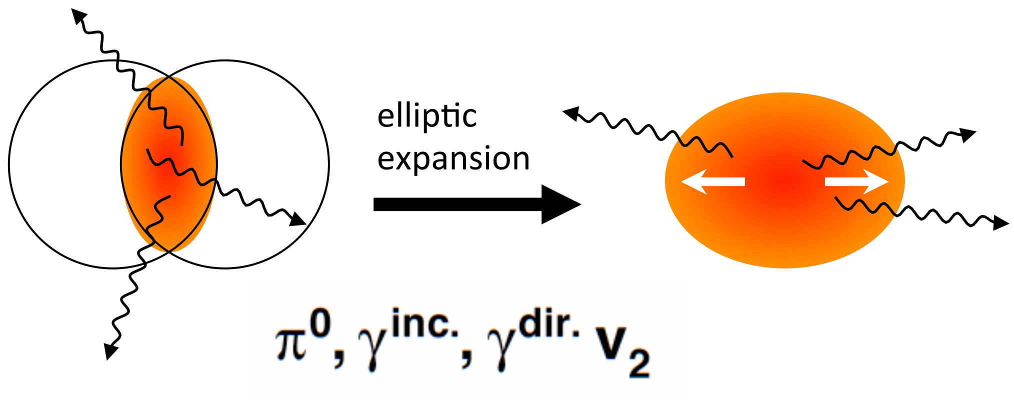
- Thermal freeze-out
- $T_{fo}^{(Th)}$ ~ 100MeV
- end of elastic interaction among hadrons
- local thermalization
- Radial expansion, flow

particle yield and ratio

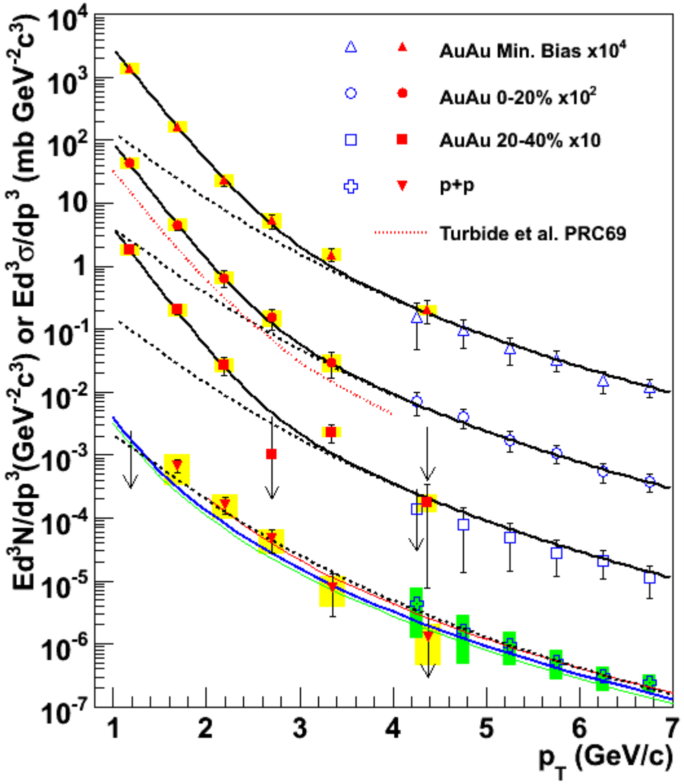
- Chemical freeze-out
- $T_{fo}^{(Ch)}$ ~ 170MeV
- end of inelastic interaction among hadrons
- close to the expected phase boundary

Thermal Photon Radiation and Collective Flow

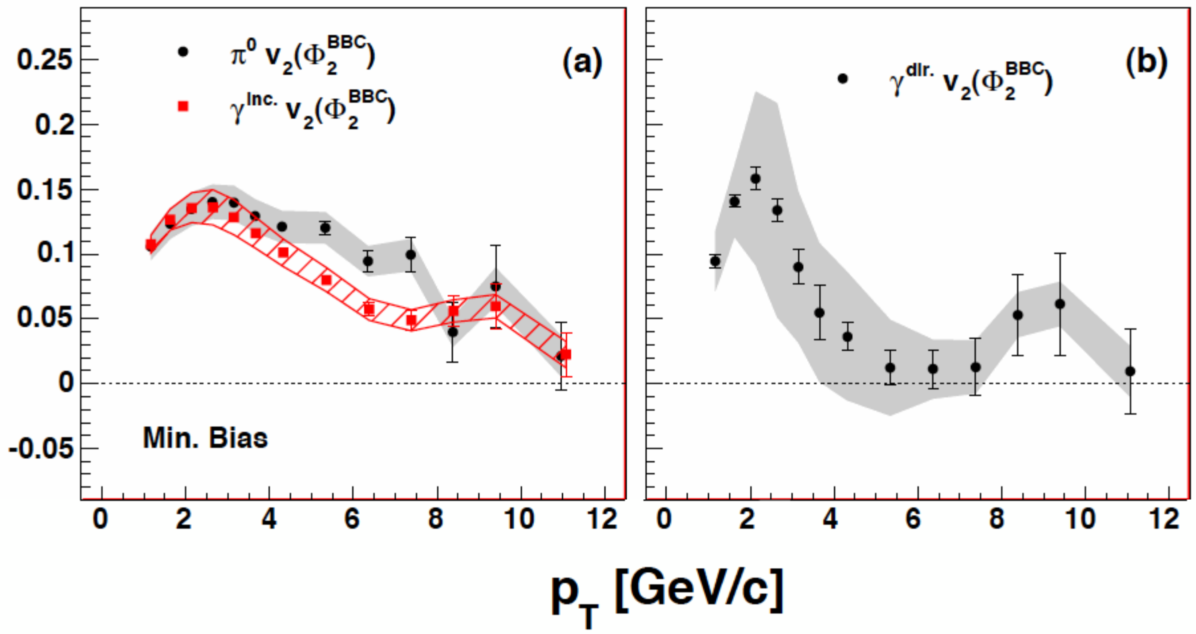
- significant low p_T photon excess with much higher temperature than T_f
- comparable v_2 with hadrons



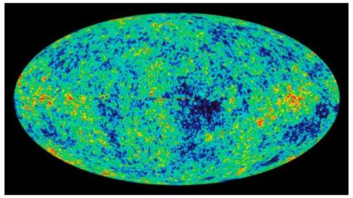
Phys. Rev. Lett. 104 (2010) 132301



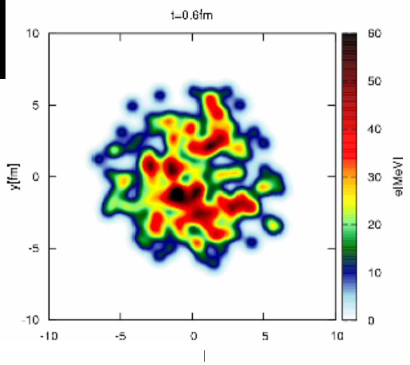
Phys. Rev. Lett. 109 (2012) 122302

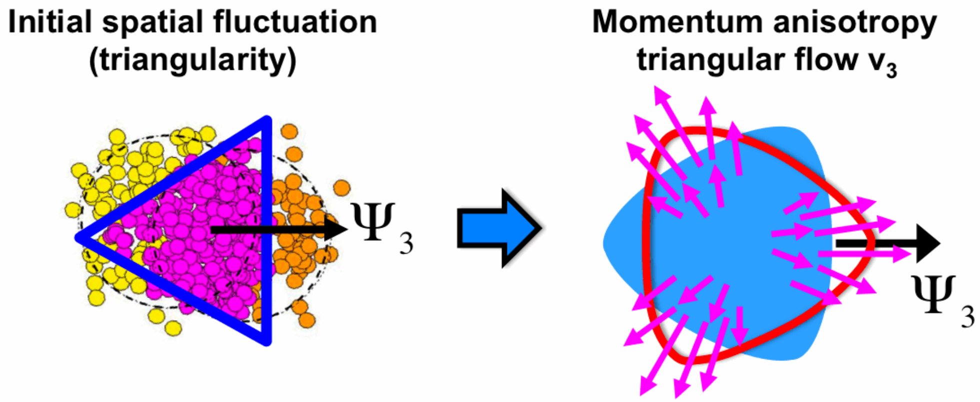


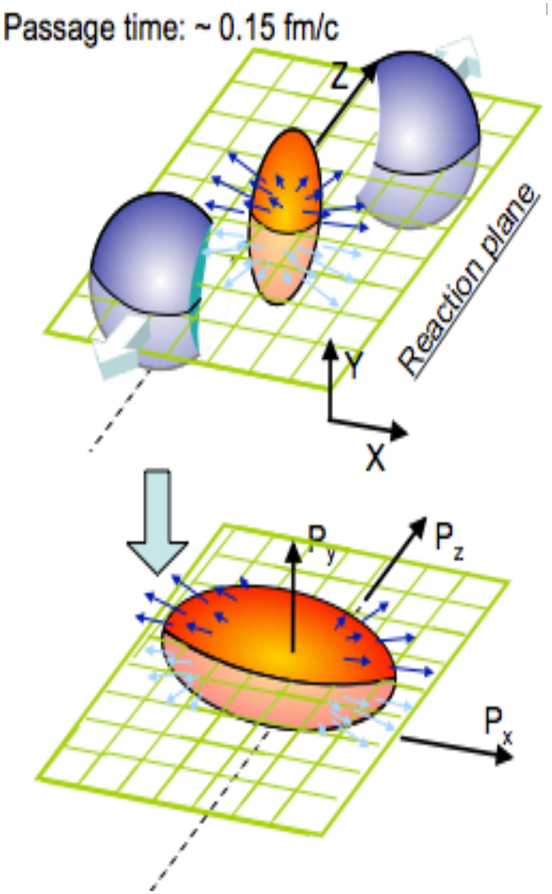
Initial Fluctuation and Higher Order Collective Flow

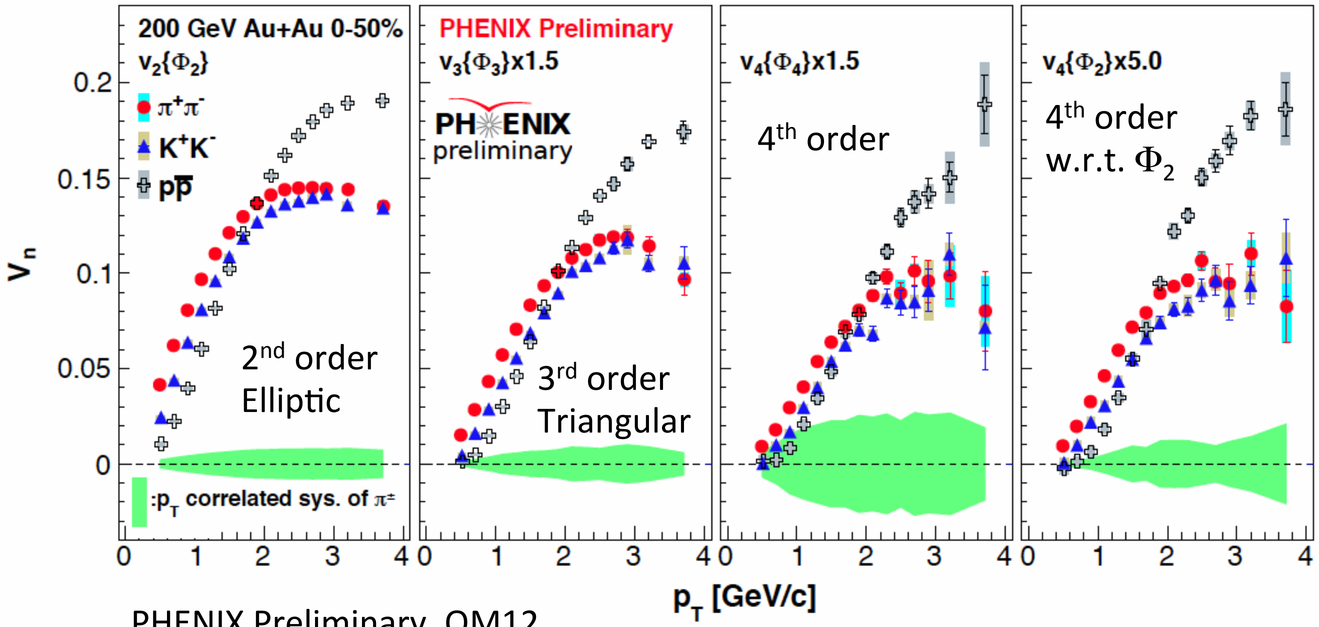


WMAP



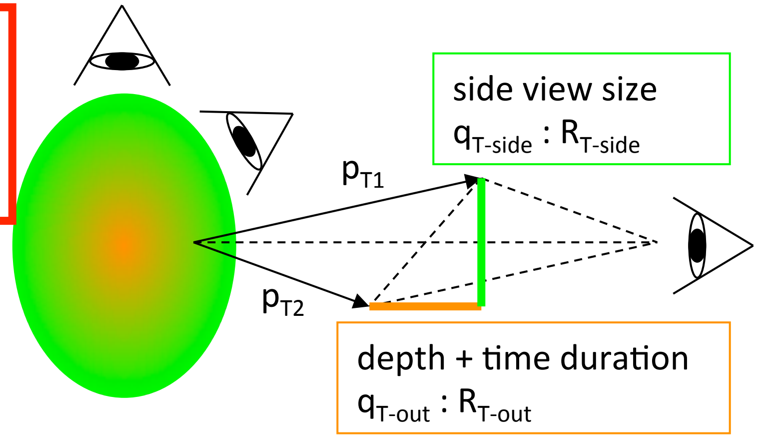






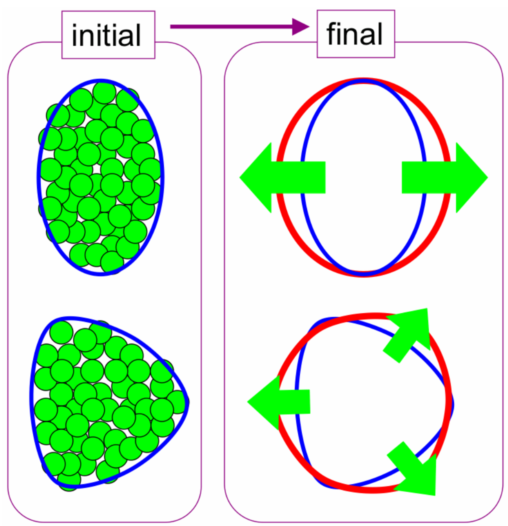
PHENIX Preliminary, QM12

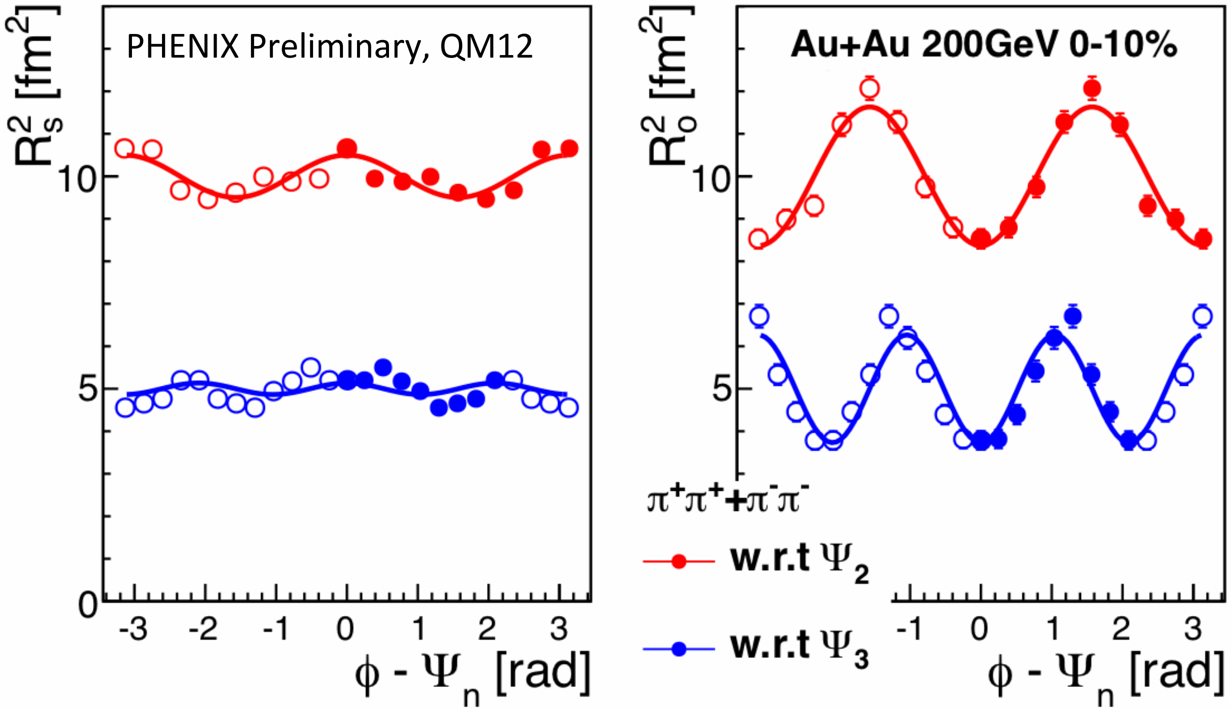
Geometrical Size and Shape at Freeze-out via Quantum Interferometry (multi-dimensional HBT) measurement



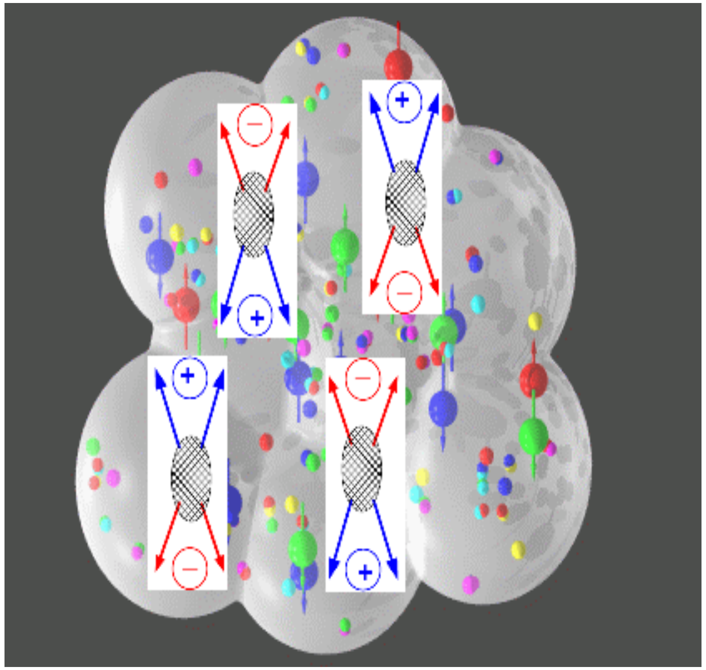
$R_{T\text{-side}}$ & $R_{T\text{-out}}$ vs $(\phi-\Phi_2)$ and $(\phi-\Phi_3)$
$R_{T\text{-side}}^{oscill.} < R_{T\text{-out}}^{oscill.}$ for n=2,3 (central)

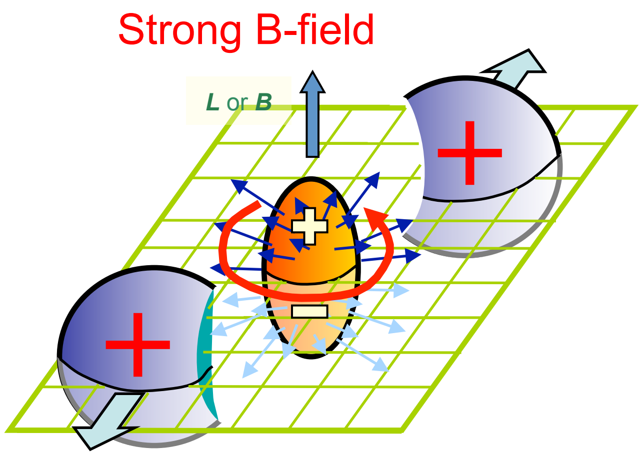
together with $v_n(p_T)^{PID}$
fitting with Blast Wave

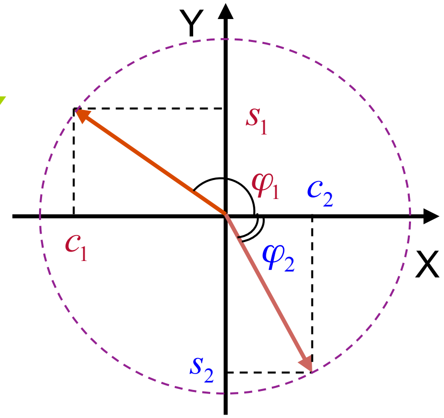


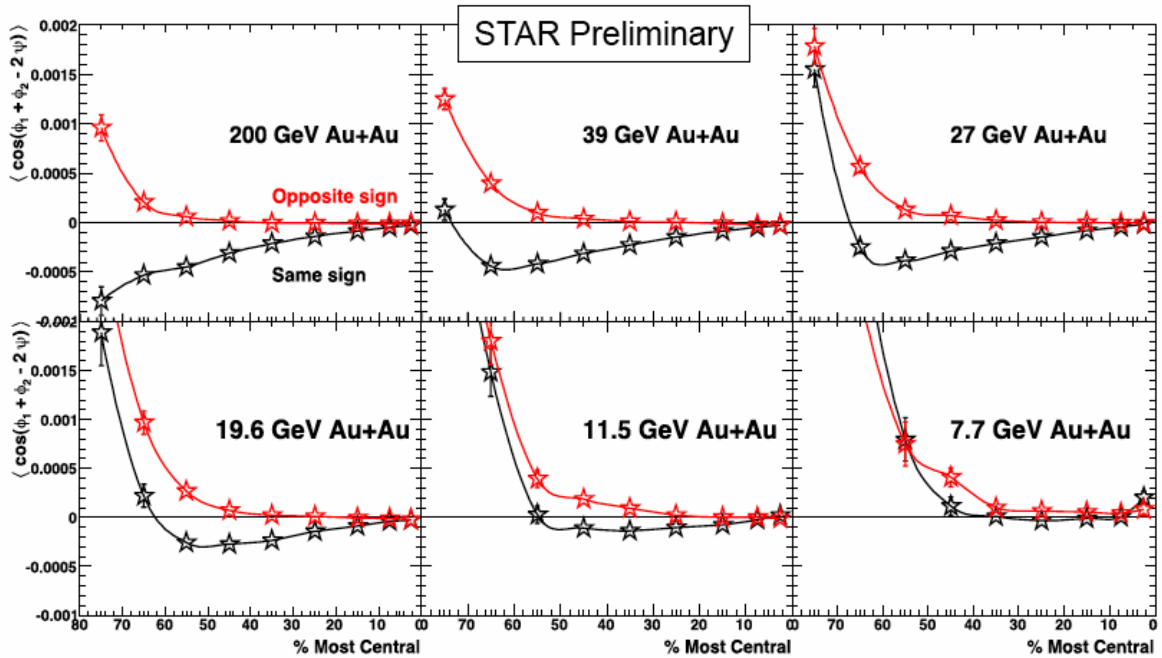


Strong B-field and Local Parity Violation in QGP
Charge Asymmetry Signal





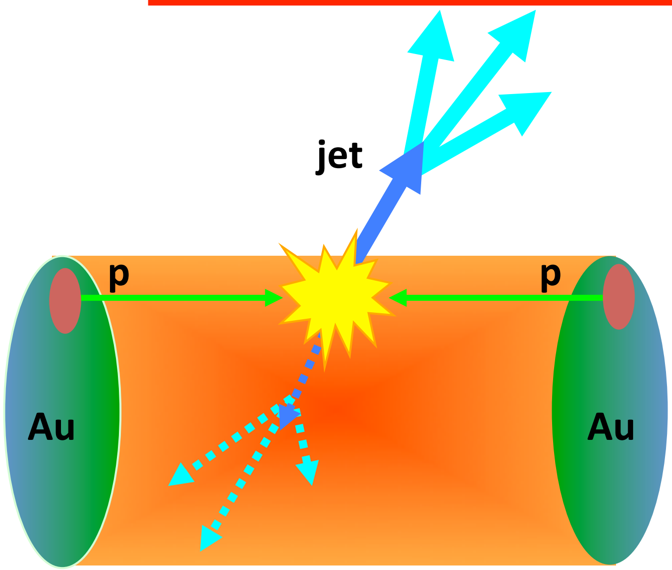




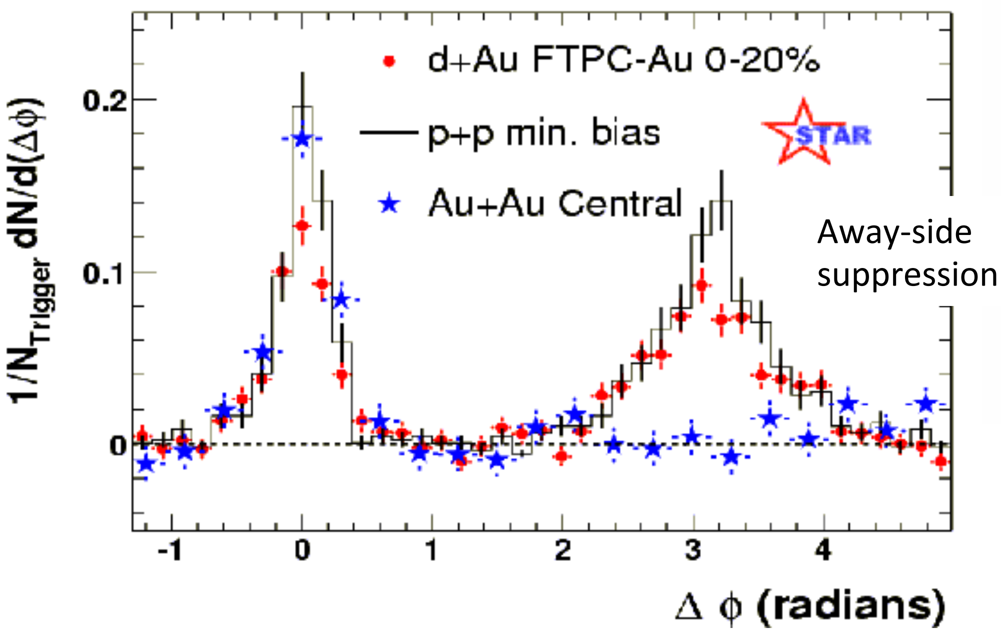
$dN/d\phi \sim 1 + 2v_n\cos(n(\phi-\Phi))$
$+ 2a_{+/-}\sin(\phi-\Phi) + \ldots$

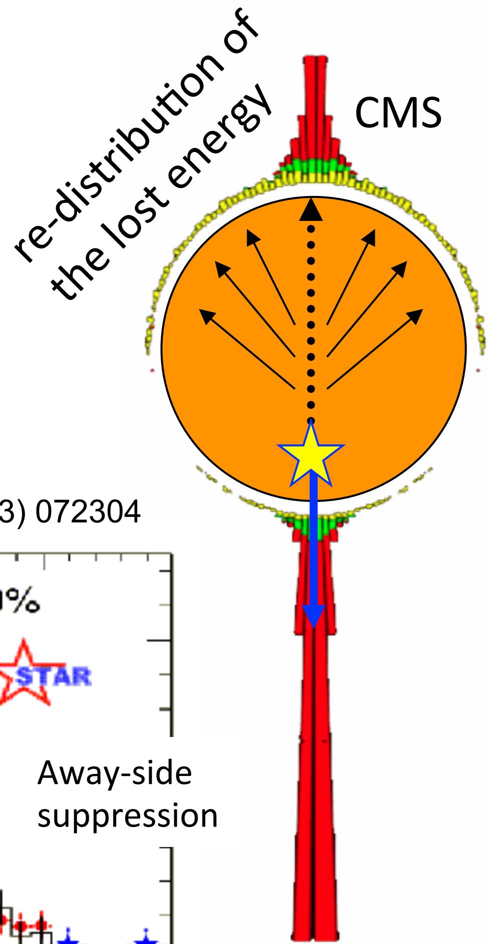
$\langle\cos(\phi_1+\phi_2-2\Phi)\rangle \sim -\langle a_1 a_2\rangle$

Energy Loss of Parton in QGP --- jet quenching ---

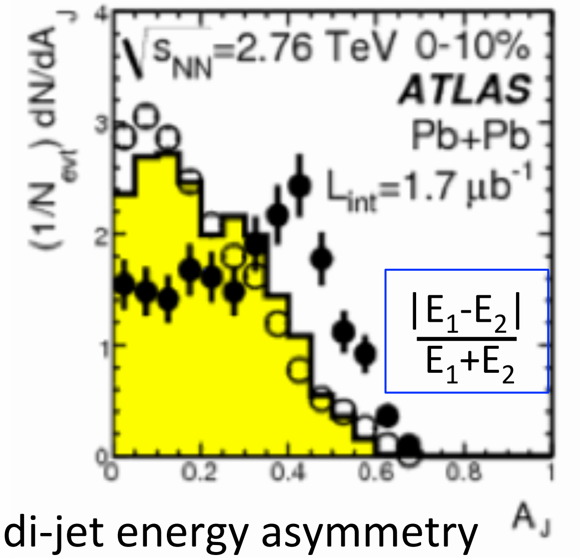


Phys. Rev. Lett. 91 (2003) 072304

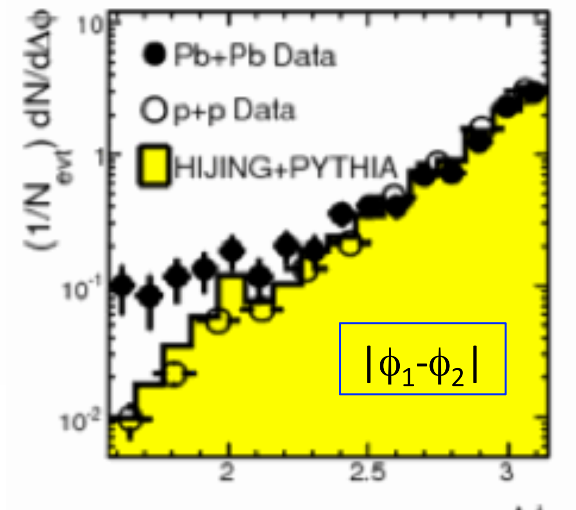




Phys. Rev. Lett. 105 (2010) 252303

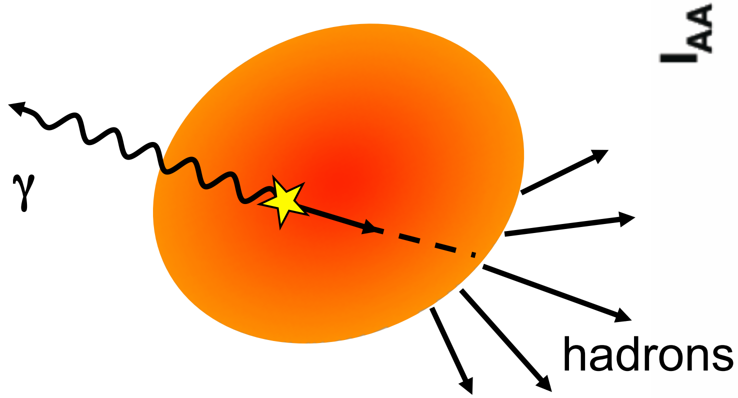


di-jet energy asymmetry

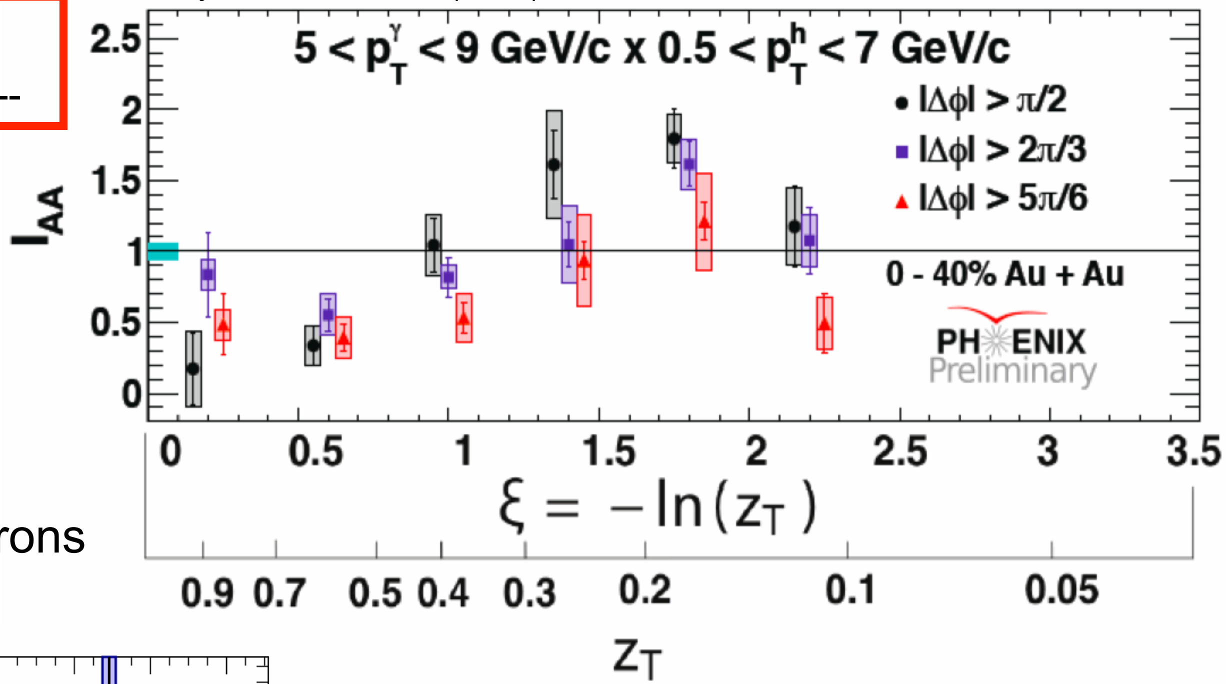


di-jet relative angle

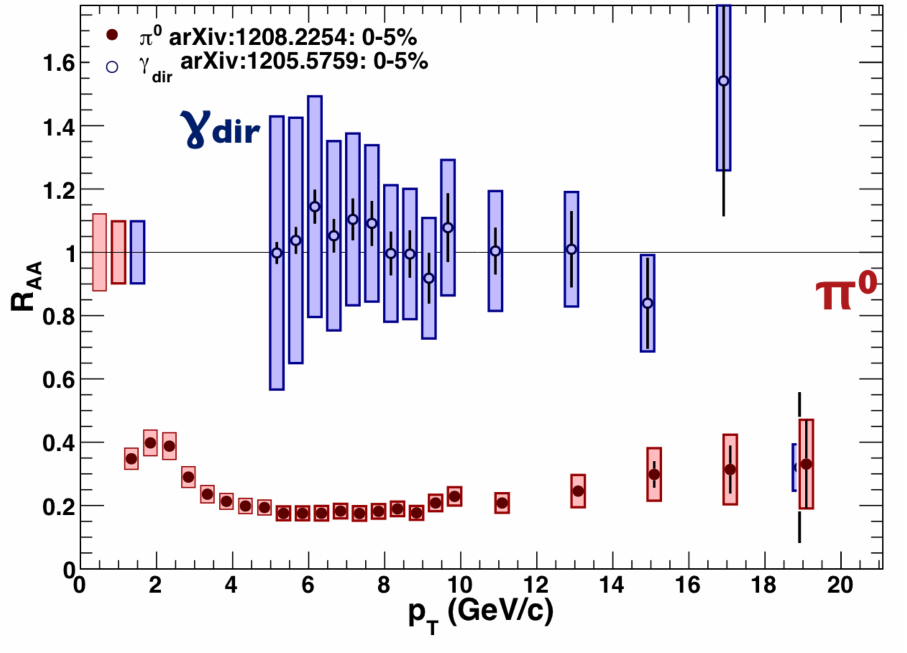
γ-Hadron Correlation
--- golden probe for jet-quenching ---



Phys. Rev. Lett. 111 (2013) 32301

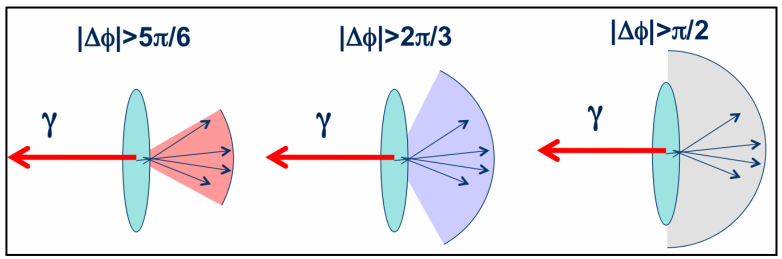


Phys. Rev. Lett. 109 (2012) 152302



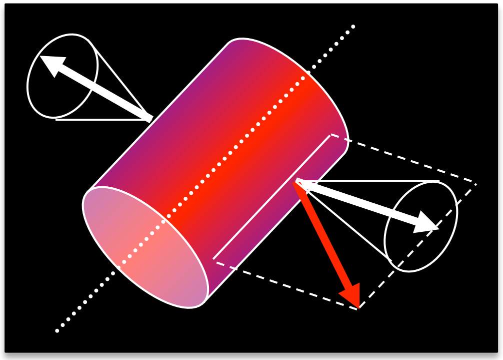
$$\xi \equiv -ln(z_T) \equiv -ln(p_T^{h^\pm} / p_T^{\gamma_{dir}})$$

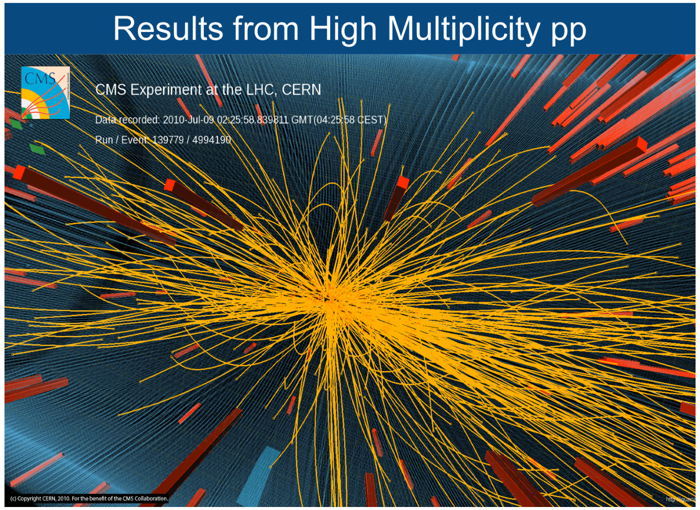
$$I_{AA} \equiv \frac{(1/N_{trig} dN/d\xi)_{AA}}{(1/N_{trig} dN/d\xi)_{pp}}$$

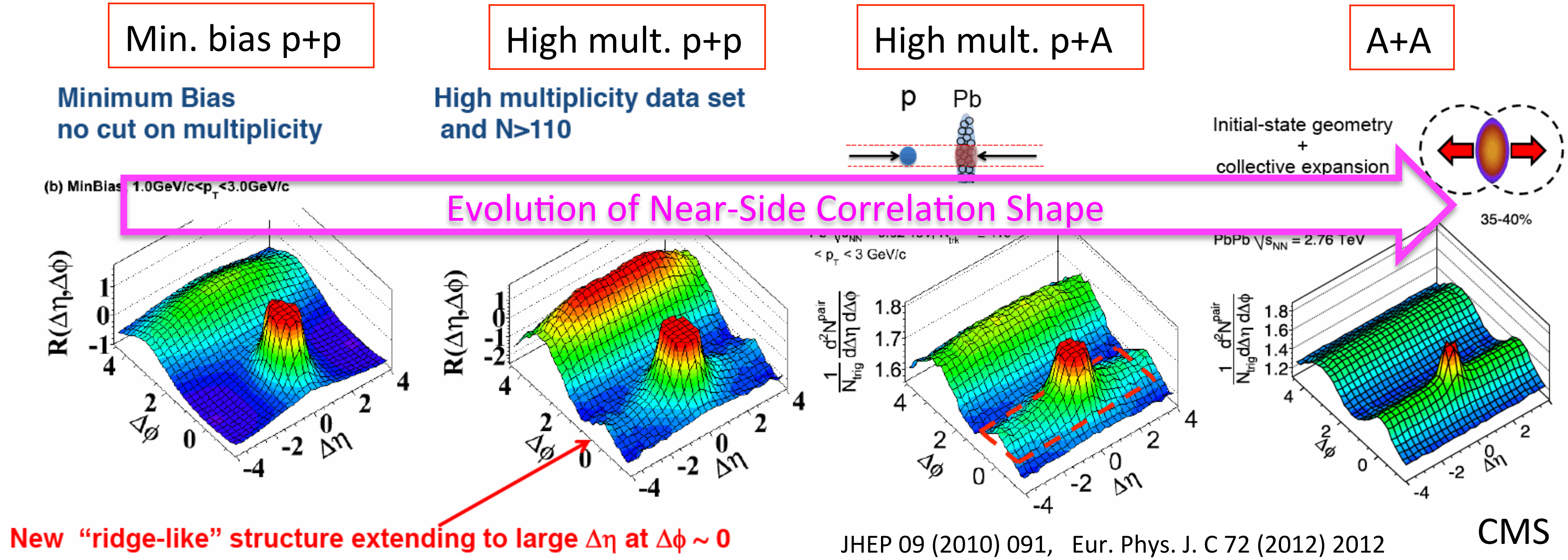


Ridge Structure (v_n) in Small System

High-temperature, High-density system might be created even in small system at high multiplicity event.
--- collective expansion
--- centrality/multiplicity dependence





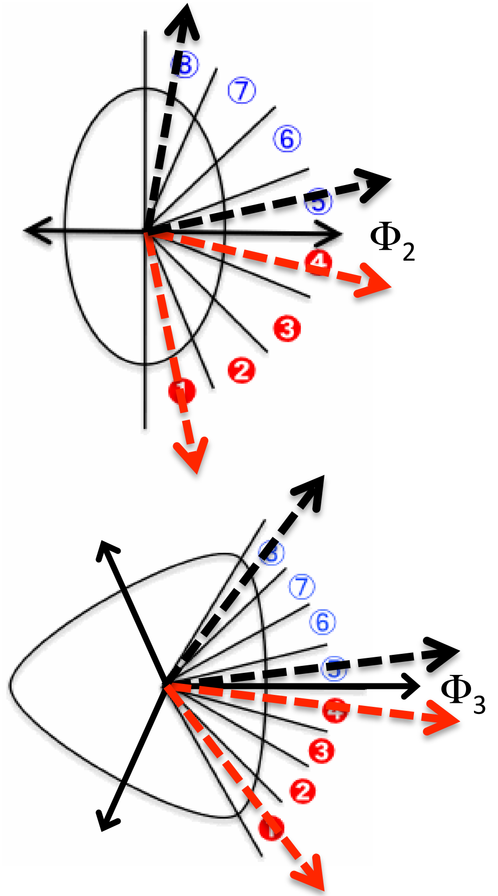


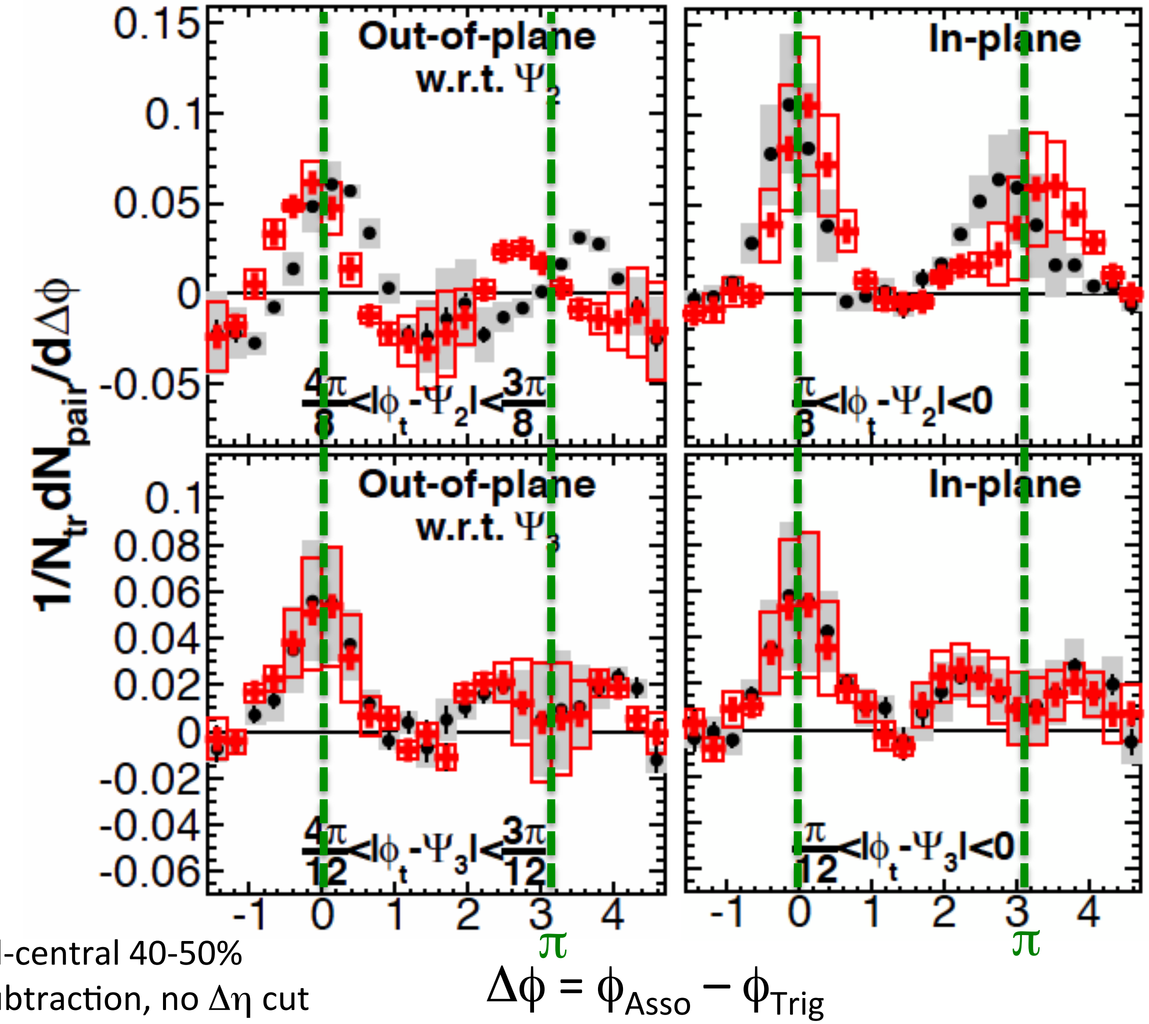
JHEP 09 (2010) 091, Eur. Phys. J. C 72 (2012) 2012
Phys. Lett. B 718 (2013) 795-814

CMS

Angular Dependence of Jet Shape --- hard-soft interplay ---

- strong Φ_2 dependence and left/right asymmetry (coupled with energy loss and collective flow)
- broader out-of-plane correlation than in-plane correlation (re-distribution of lost energy)
- some weak Φ_3 dependence





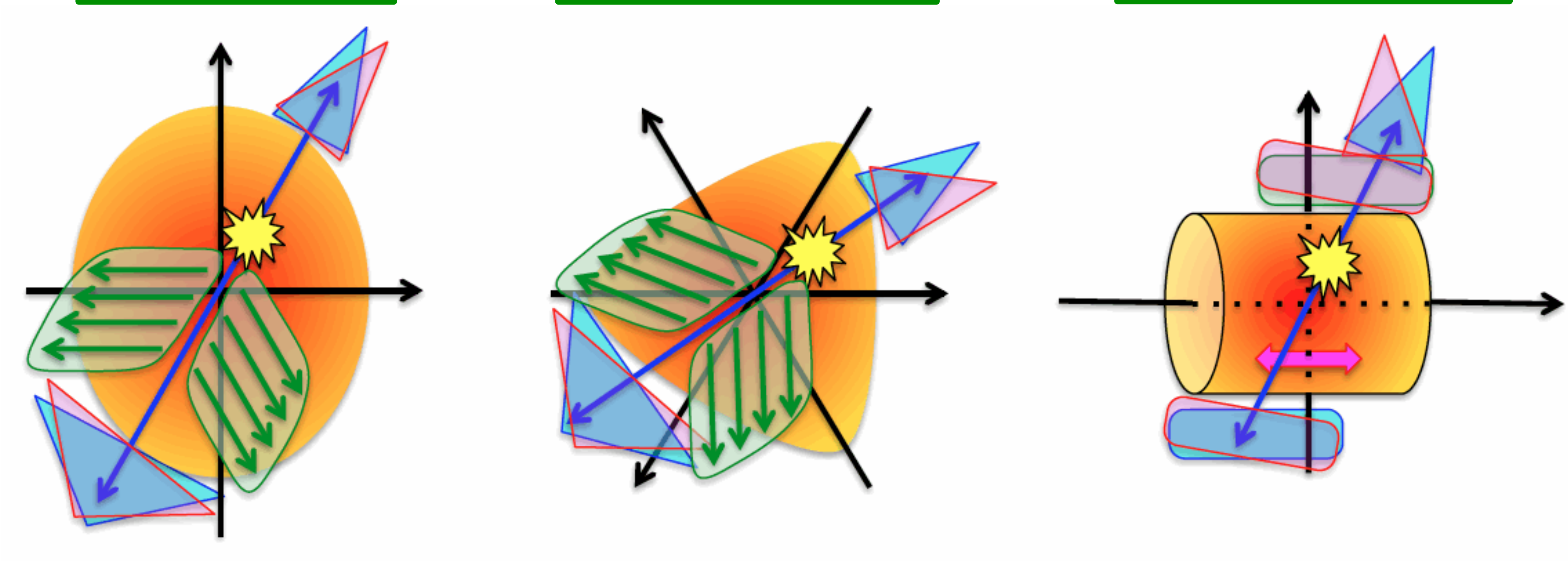
PHENIX Preliminary, QM12
Au+Au 200GeV, hadron-hadron, mid-central 40-50%
p_T : $(2\sim4)_{Trig}$ x $(1\sim2)_{Asso}$ (GeV/c), vn subtraction, no $\Delta\eta$ cut

Jet Fragmentation (multi-particle correlation) and Di-jet Analysis with respect to Bulk Geometry and/or Collectivity

with respect to Elliptic plane Φ_2

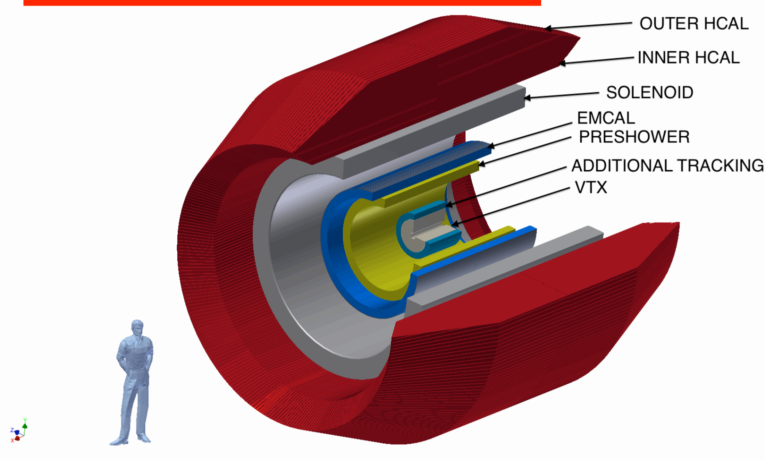
with respect to Triangular plane Φ_3

with respect to Longitudinal angle η



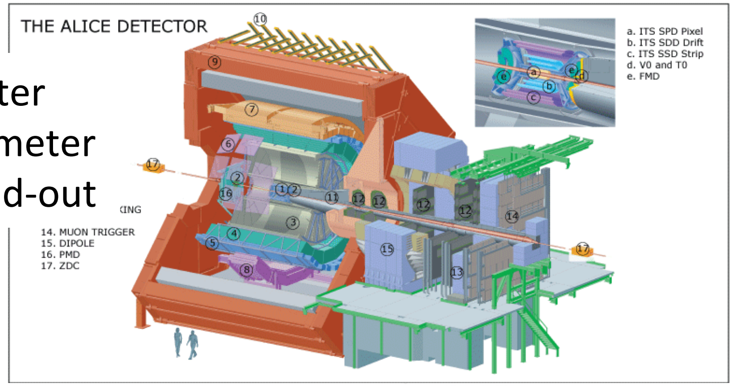
--- effects on the jet (hard) probes (jet suppression, modification)
--- effects on the bulk (soft) probes (re-distribution, re-heating)

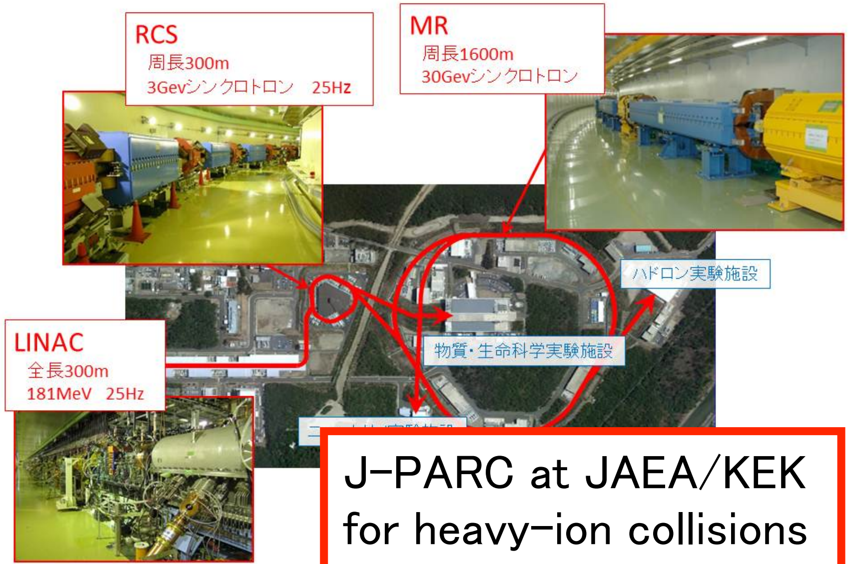
sPHENIX at RHIC-BNL (New York, USA)



ALICE at LHC-CERN for Luminosity upgrade (Geneva, Switzerland)

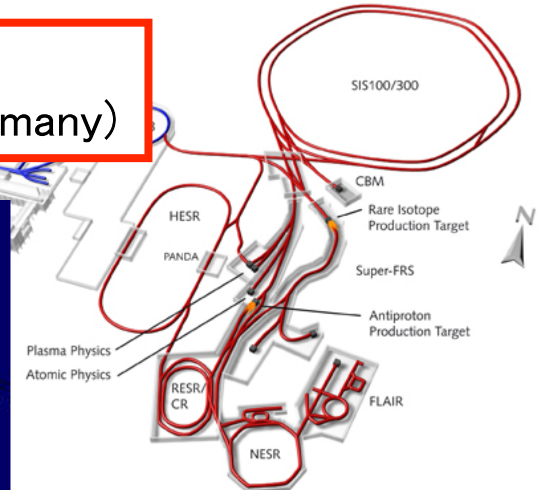
Di-jet calorimeter
Forward calorimeter
High-speed read-out

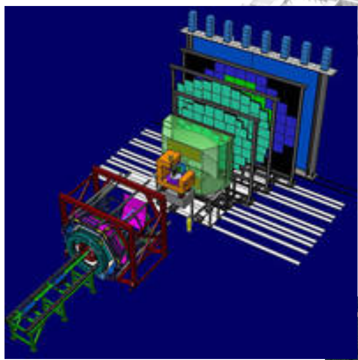




J-PARC at JAEA/KEK for heavy-ion collisions (Tokai, Japan)

FAIR at GSI (Darmstadt, Germany)

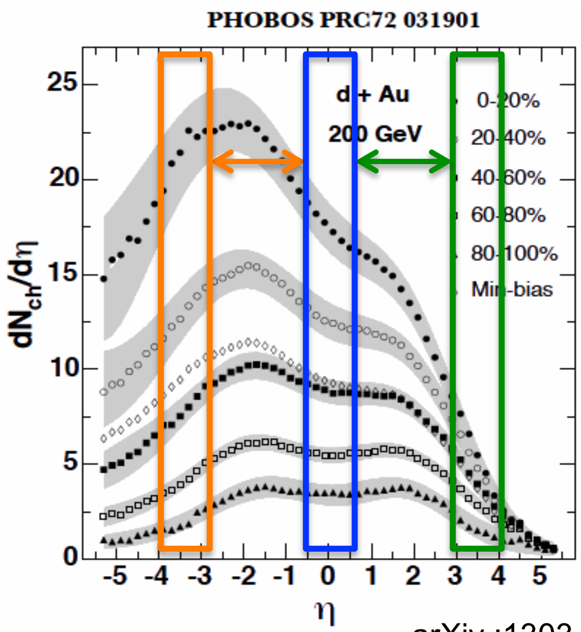




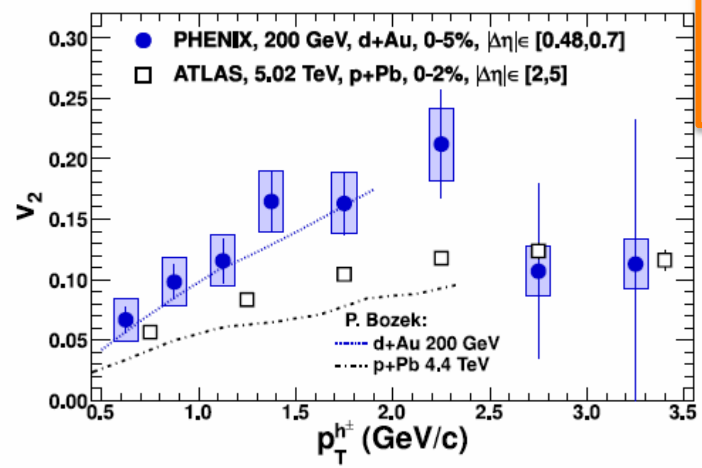
Summary

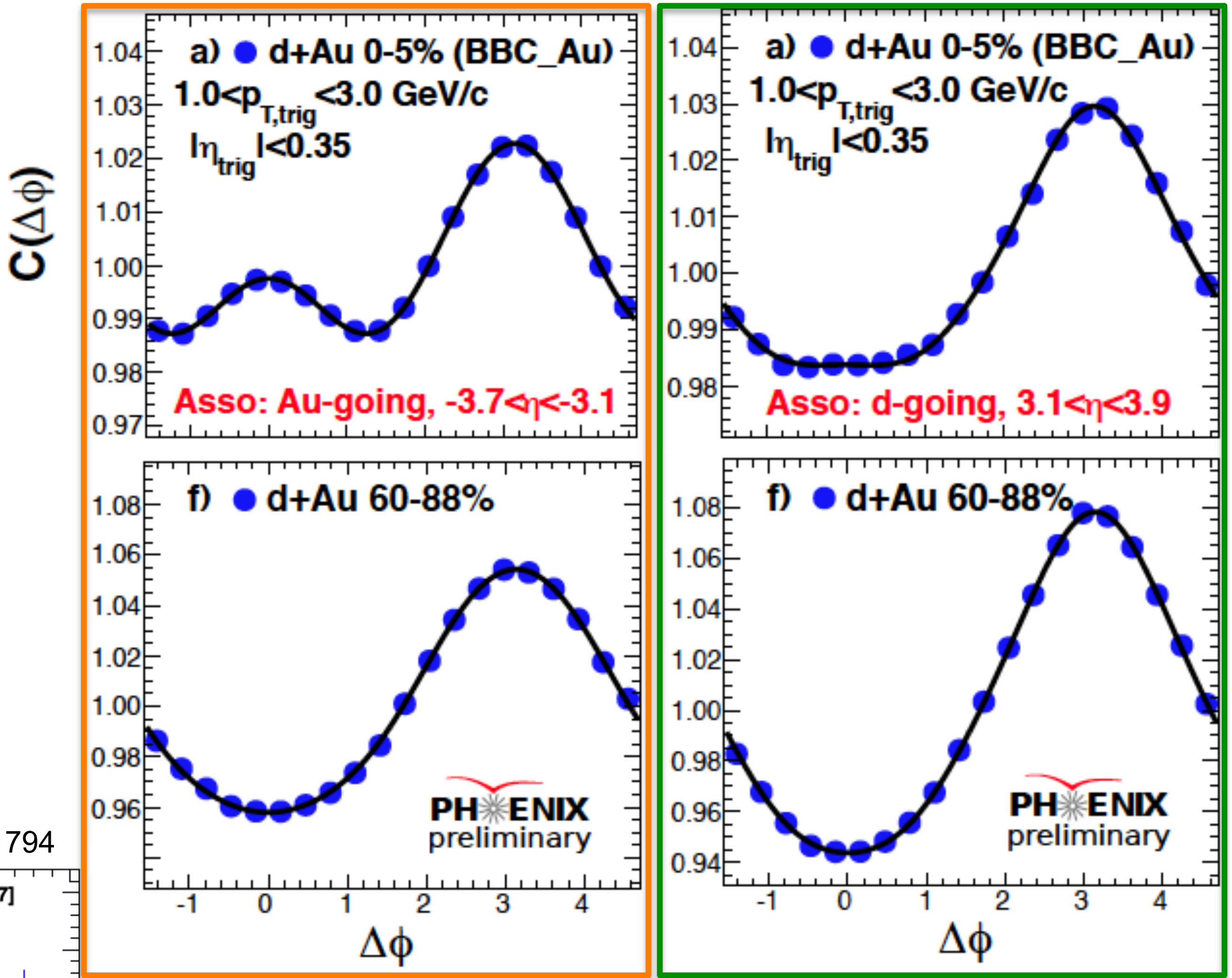
QGP and heavy ion experiments
Thermal and collective bulk (soft) measurements
Jet and correlation (hard) measurements
Interplay between hard and soft probes
Future plans

Ridge Structure (v_n) in d+Au at RHIC



arXiv :1303.1794





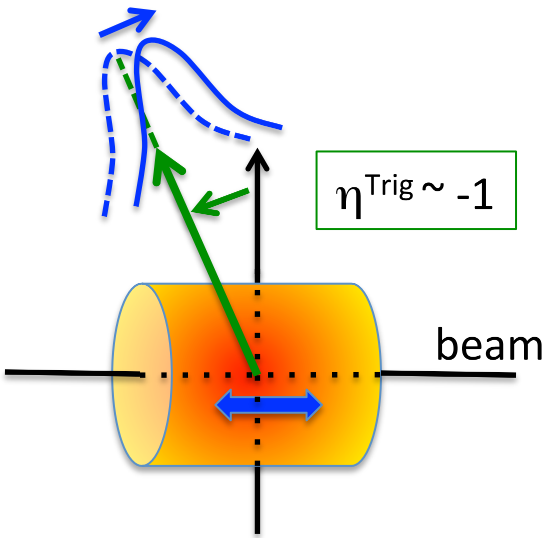
Backward-Central or Forward-Central

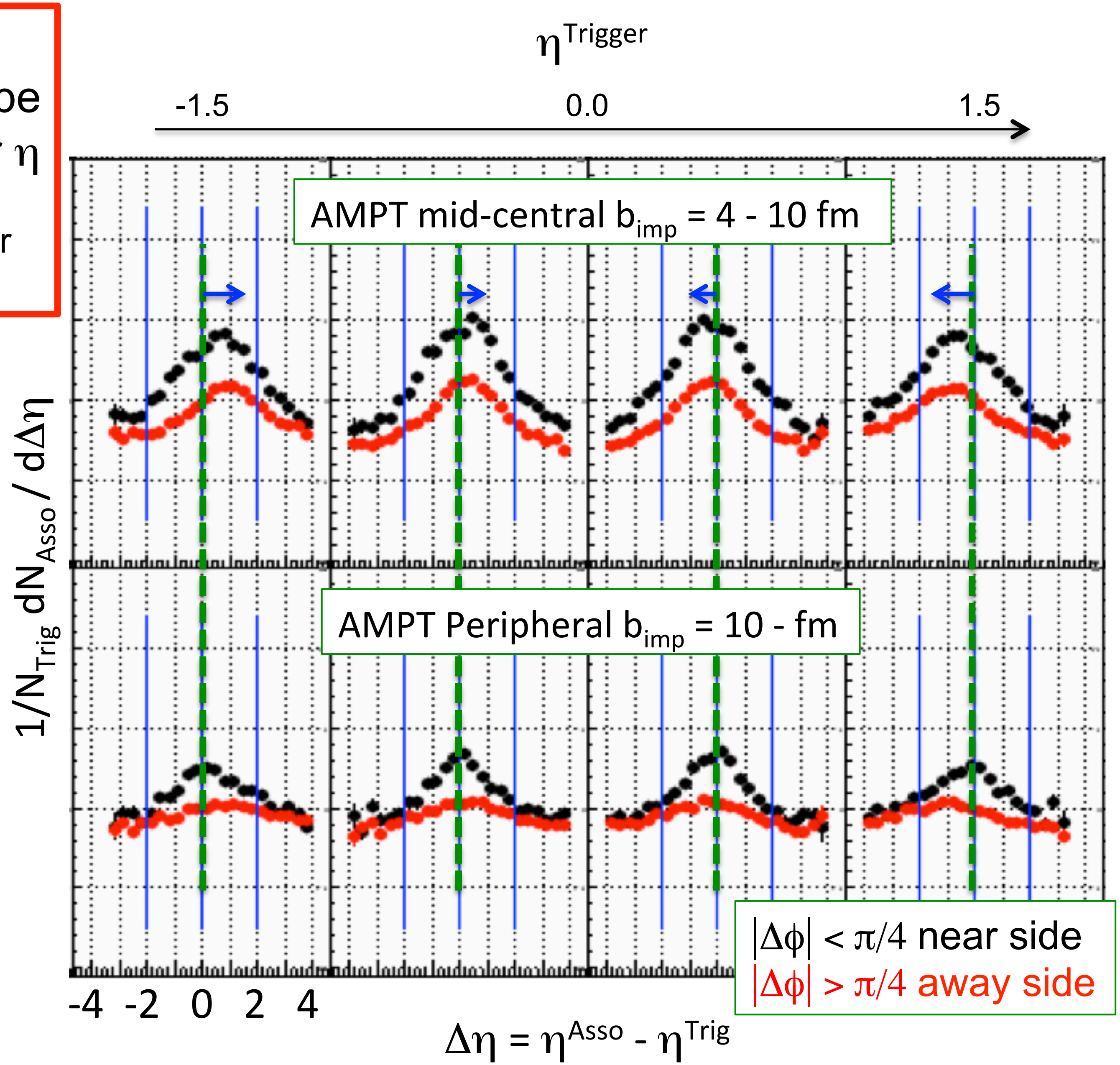
Two-particle correlations

Forward-Backward Asymmetry in $\Delta\eta$ Shape with respect to Trigger η

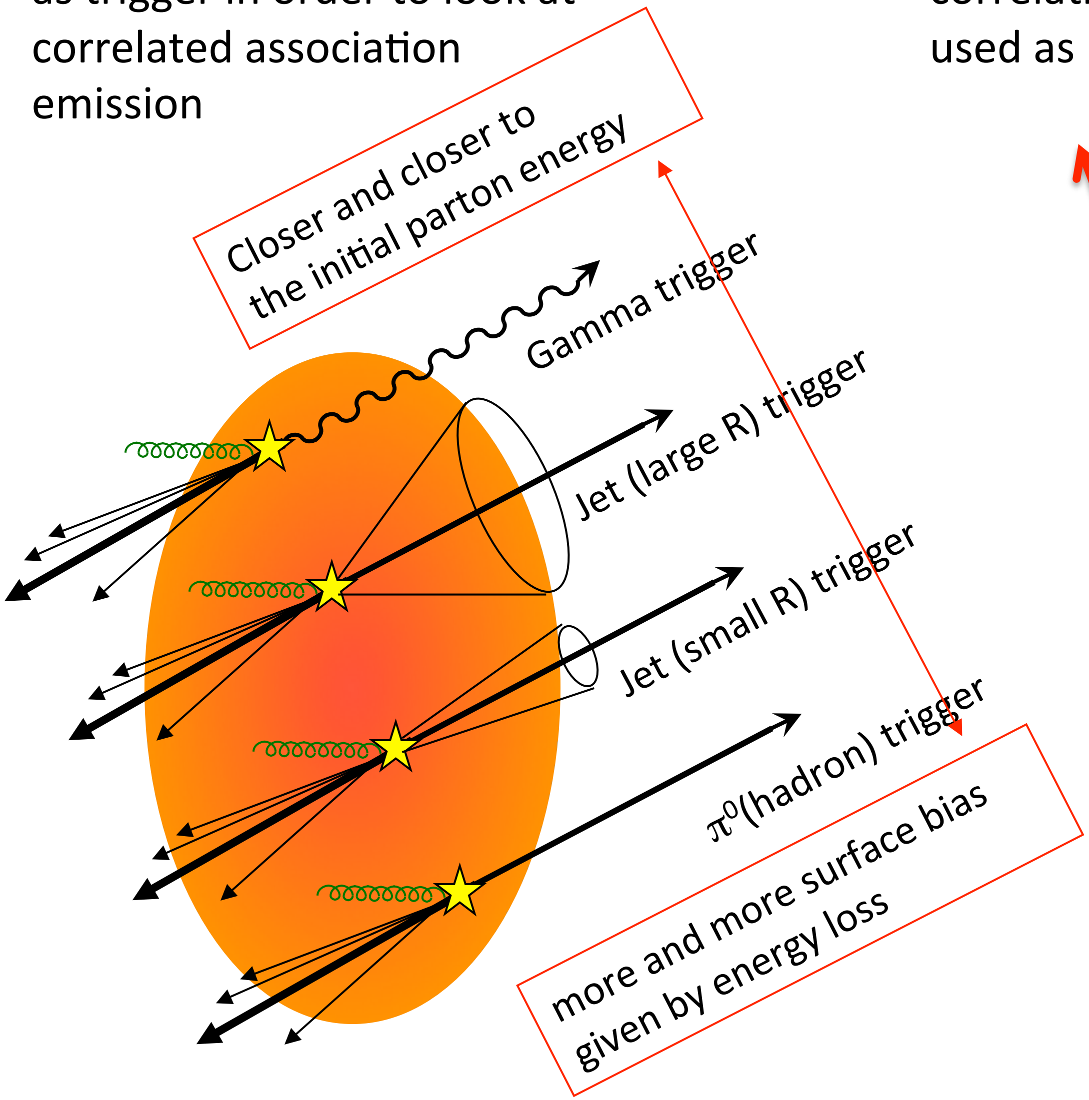
(associate yield per trigger with AMPT simulation)

Forward-backward asymmetry is visible in AMPT simulation. Near side $\Delta\eta$ peak is backward shifted w.r.t. trigger η direction.

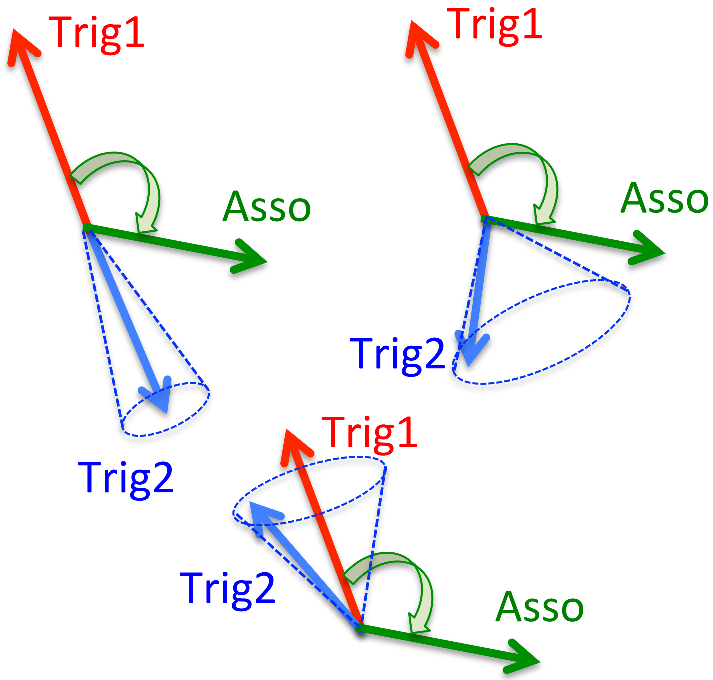




Use photons, Jets, single hadrons as trigger in order to look at correlated association emission



Multi-particle correlation like 2+1 particle correlation analysis (Trig1, Trig2, Asso) can be used as largely modified jet and di-jet signal.



Use "Trig2 relative to Trig1" as jet trigger condition, and look at distribution : "Associate relative to Trig1" without jet-reconstruction bias

To be used for Φ_n and η_{Trig} dependent analysis