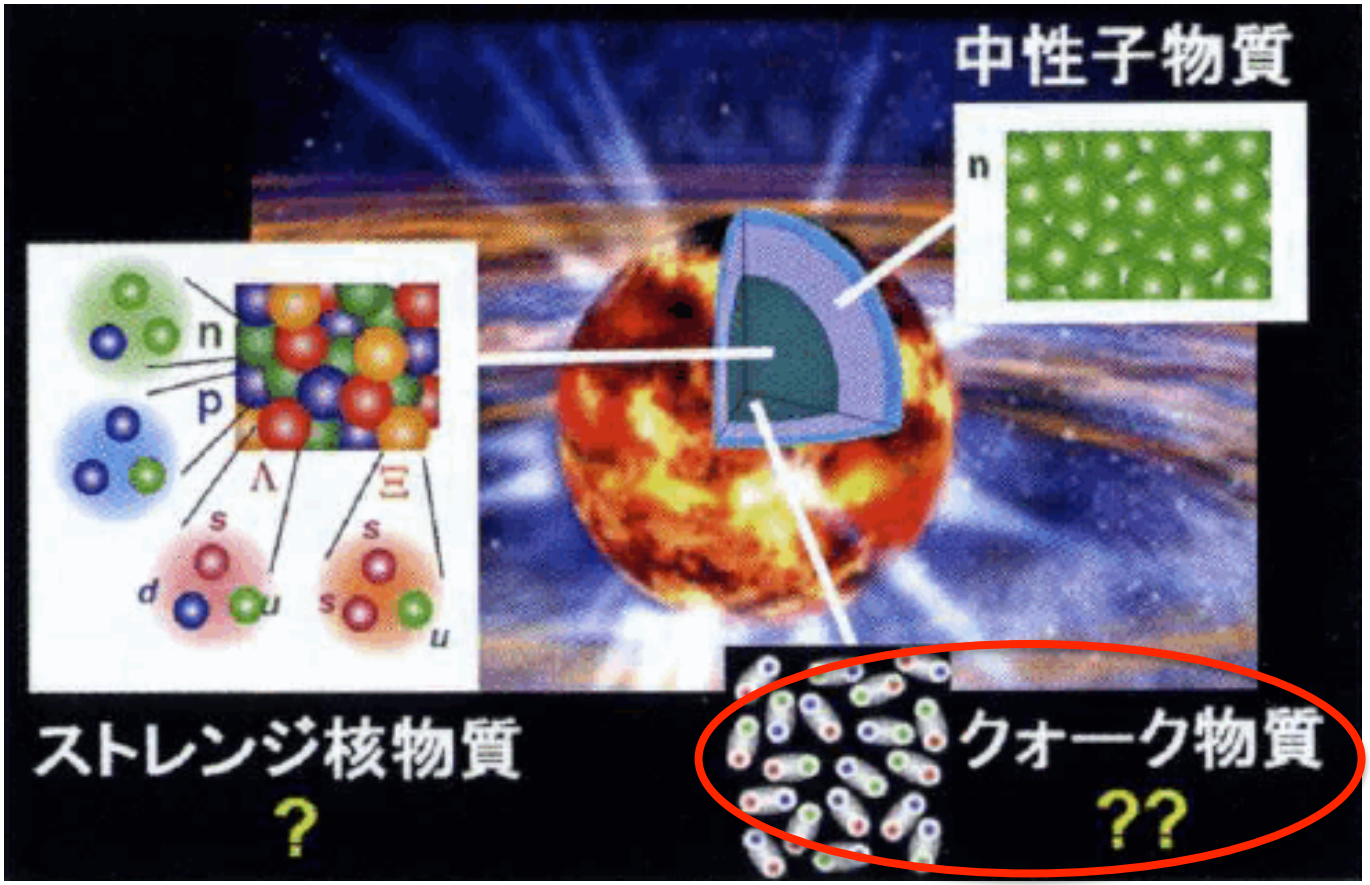
High-Energy Heavy-ion Collision Experiment

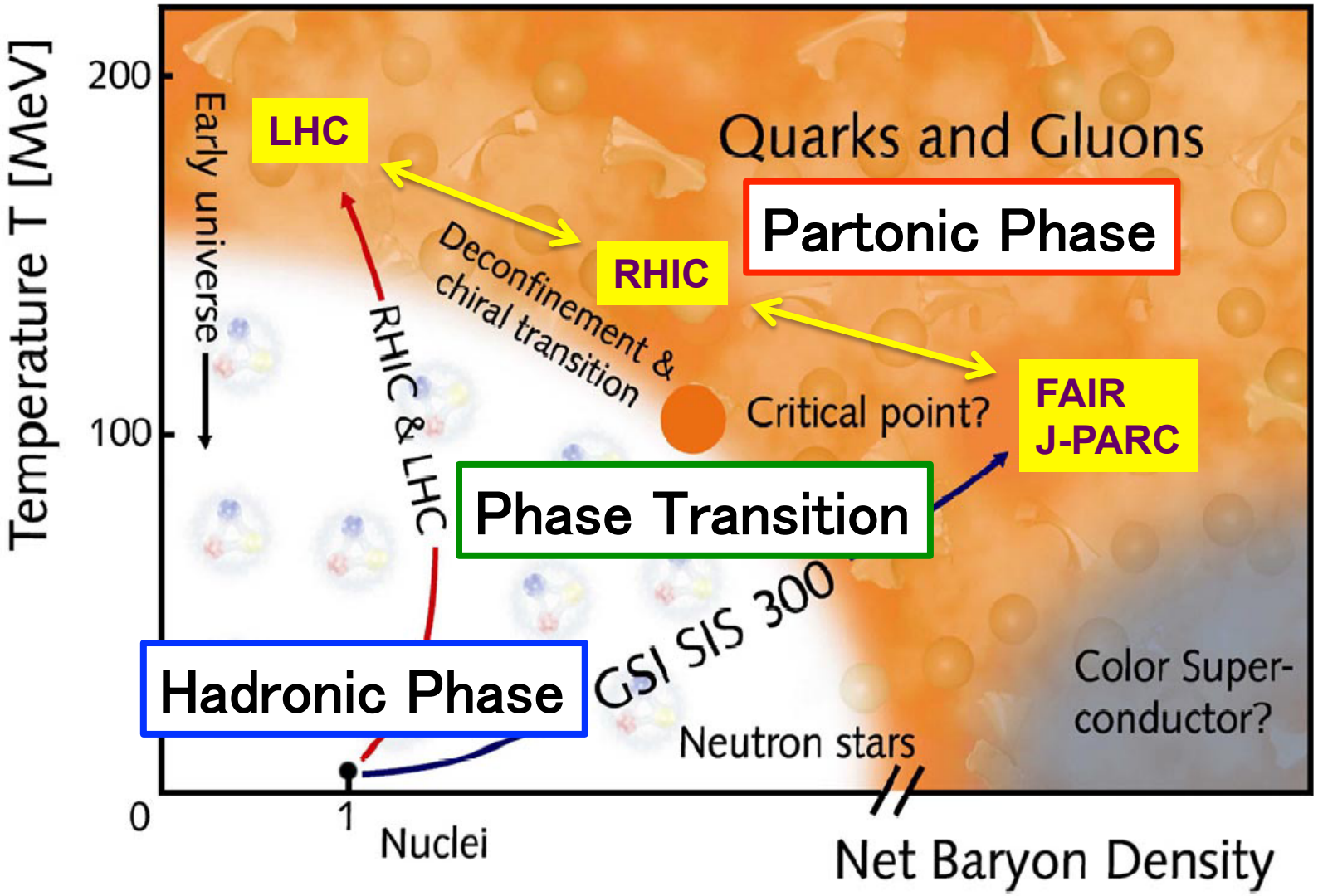
ShinIchi Esumi, Inst. of Physics, Univ. of Tsukuba



田村さん、大阪市立科学館発行 月刊「うちゅう」
2013年7月号より（画像の一部はNASAより。）

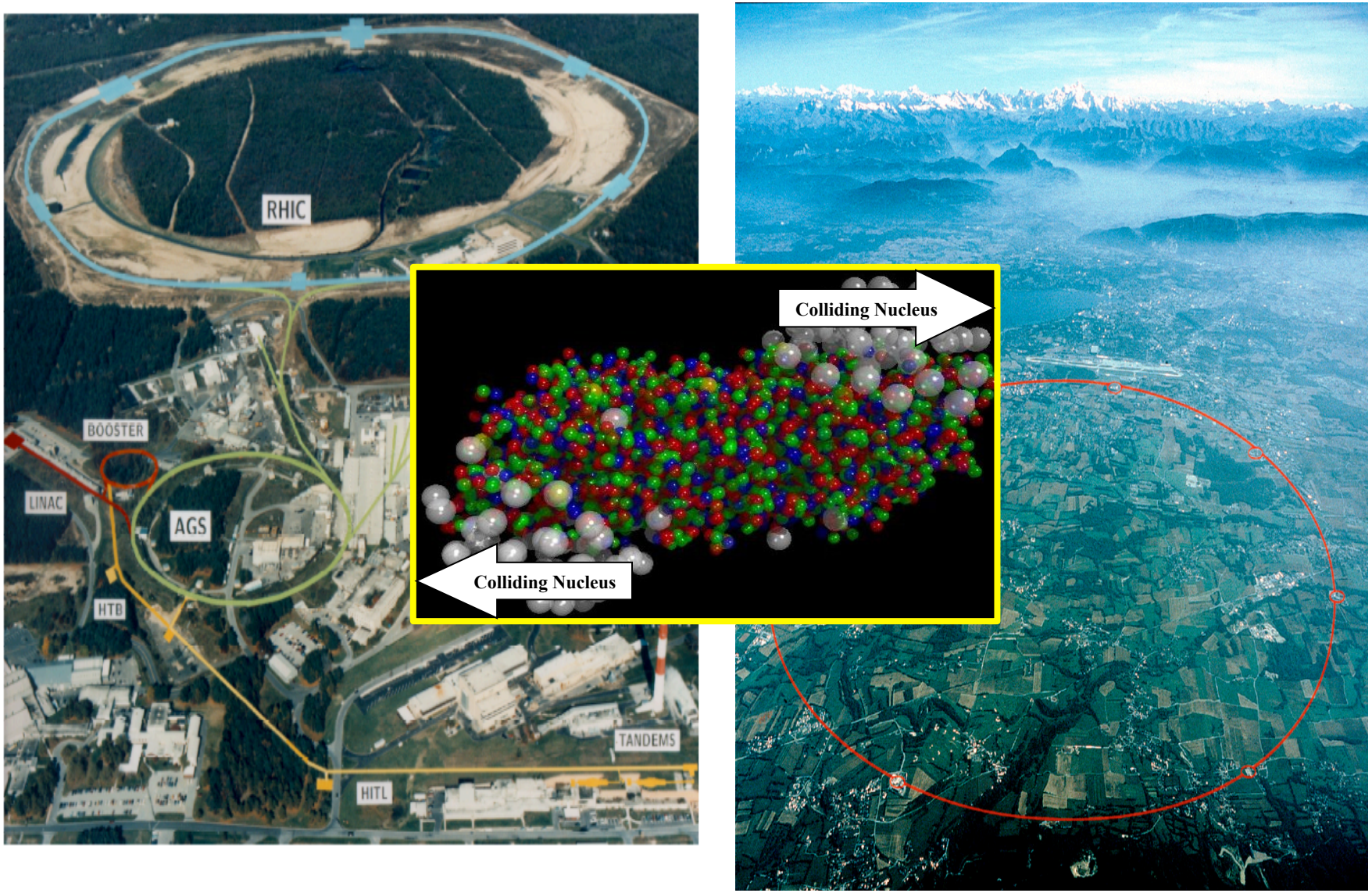
Quark Gluon Plasma??

Hadronic Phase –> Partonic Phase



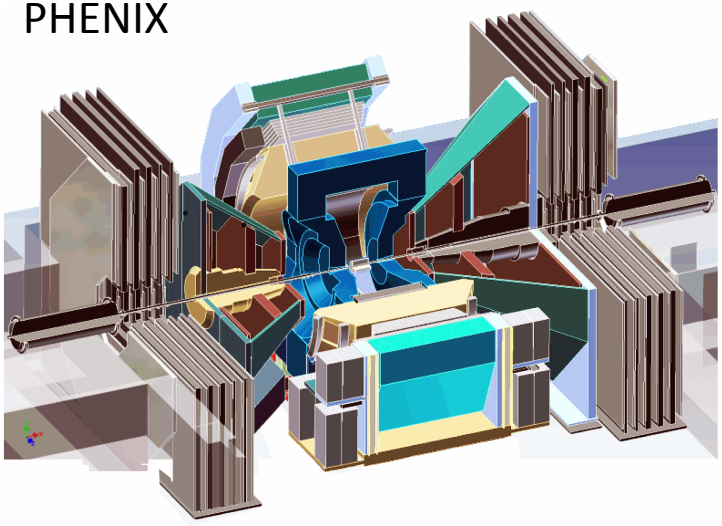
RHIC at BNL, sqrt(s_{NN}) = 10 – 200 GeV/c
(New York, USA)

LHC at CERN, sqrt(s_{NN}) = 0.5 – 5.5 TeV/c
(Geneva, Switzerland)

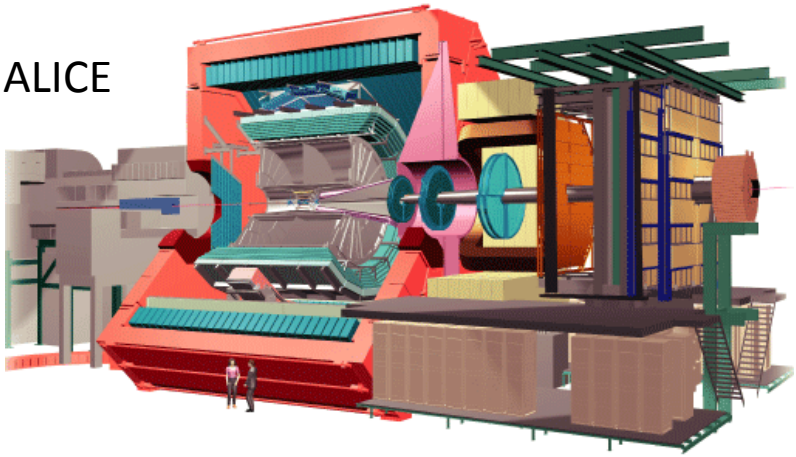


Experiments at RHIC and LHC

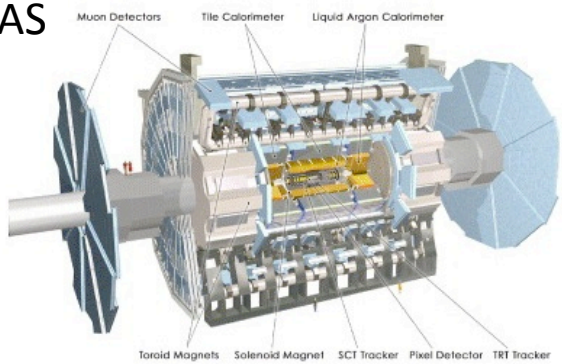
PHENIX



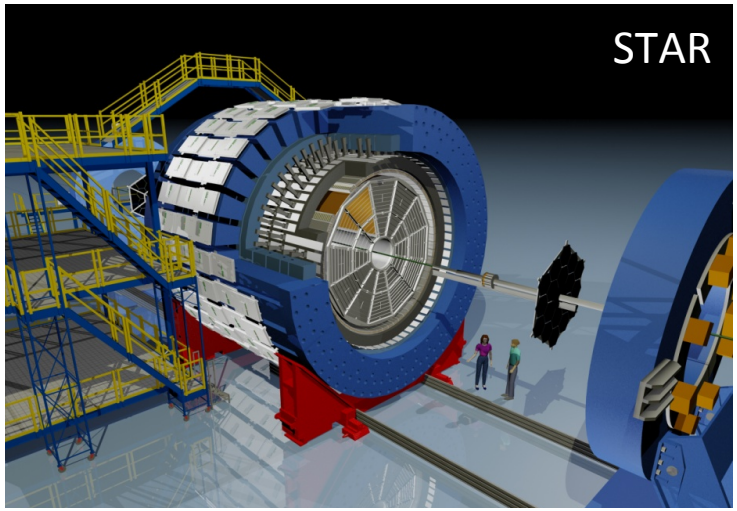
ALICE



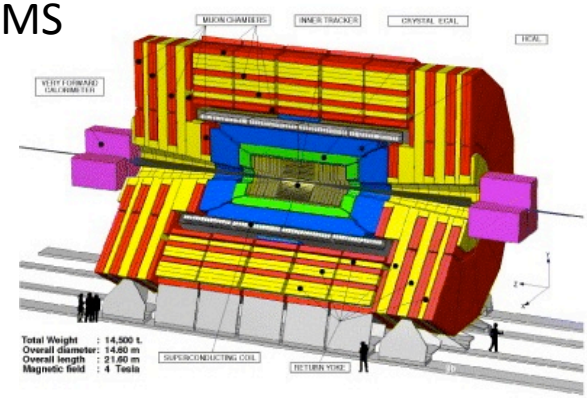
ATLAS

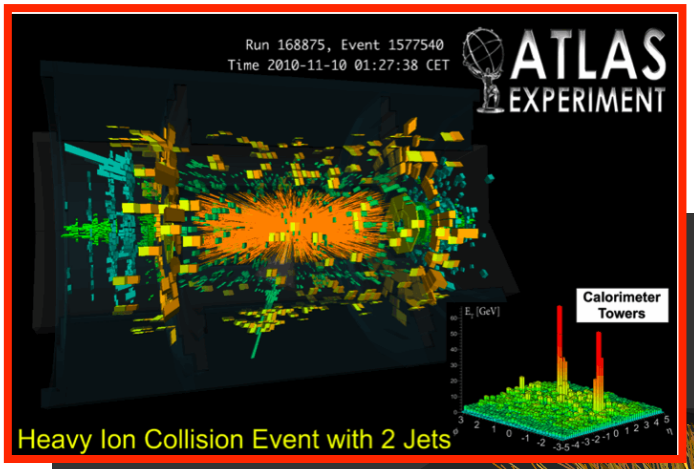


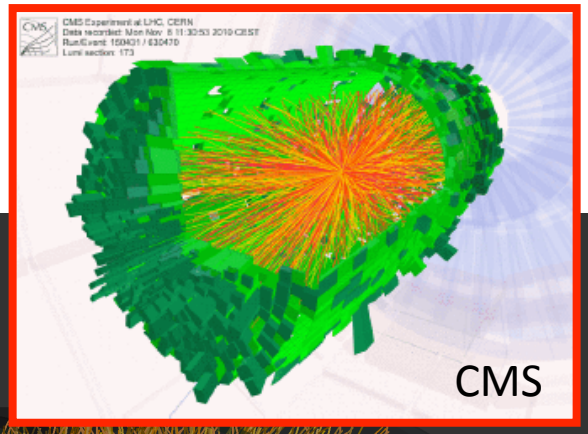
STAR

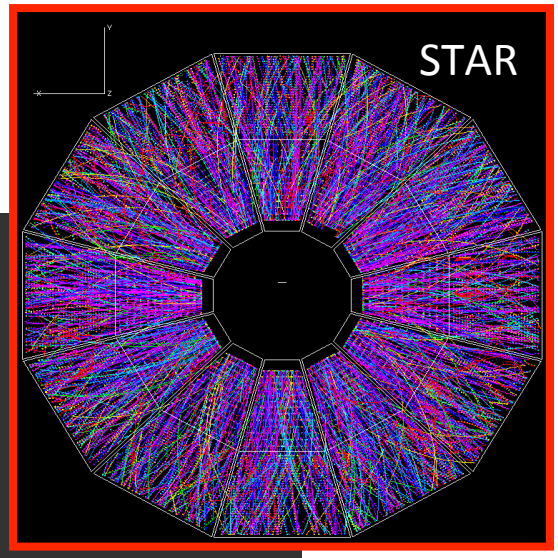


CMS





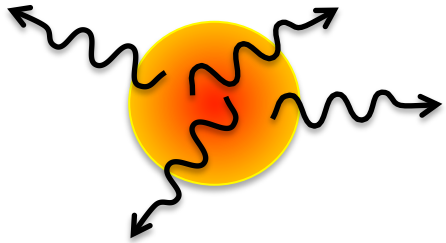


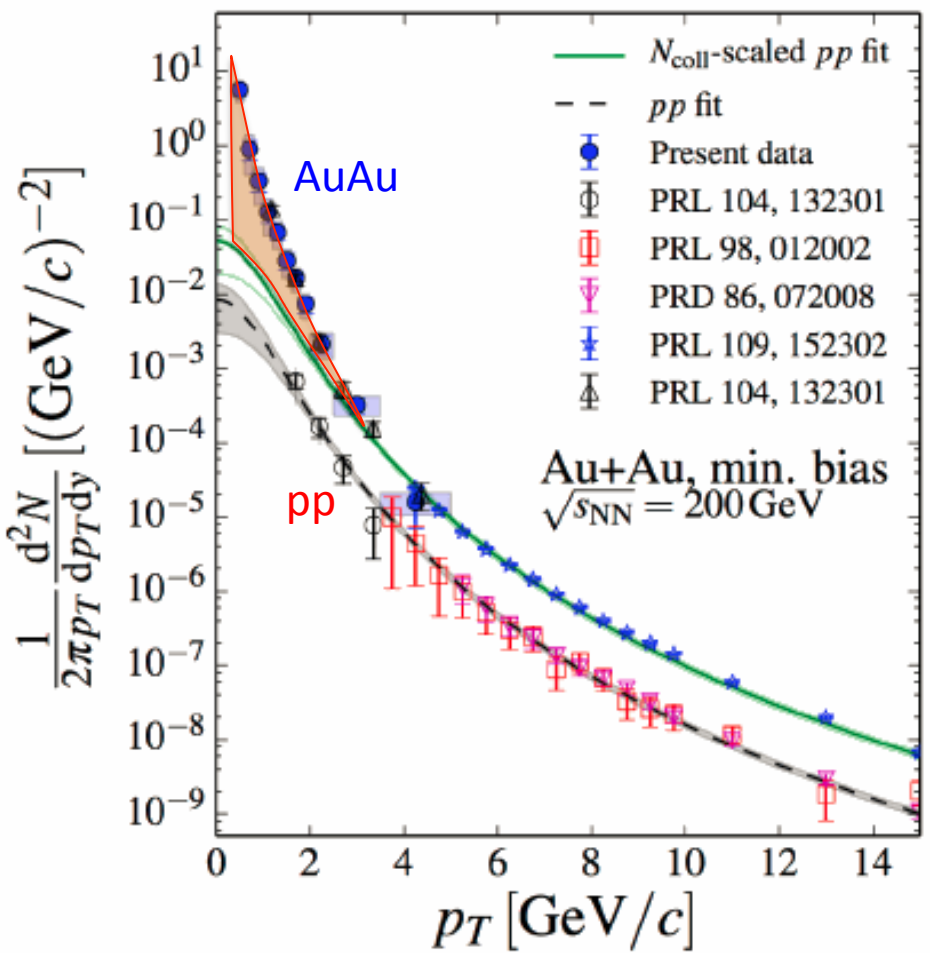


Experimental data

a few k to 10k particles per collision

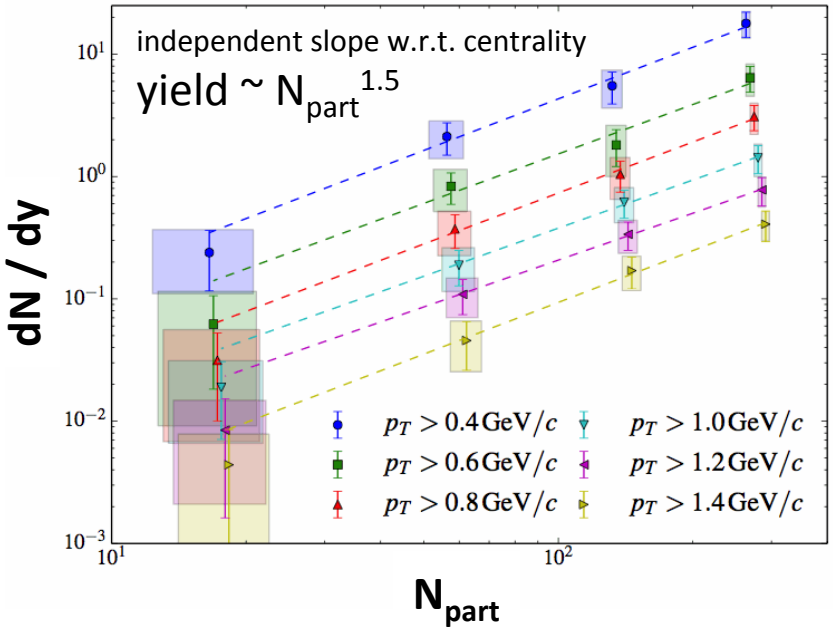
Enhanced thermal photon production at low p_T



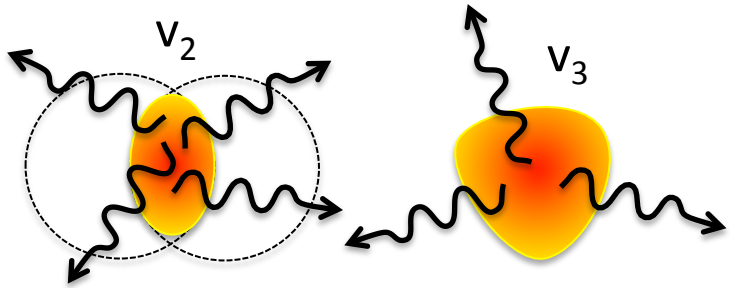


- Virtual and real photon measurements via internal and external conversion methods with electron pair measurements
- Real photon measurements with EMcal
- Initial temperature of 300~600MeV

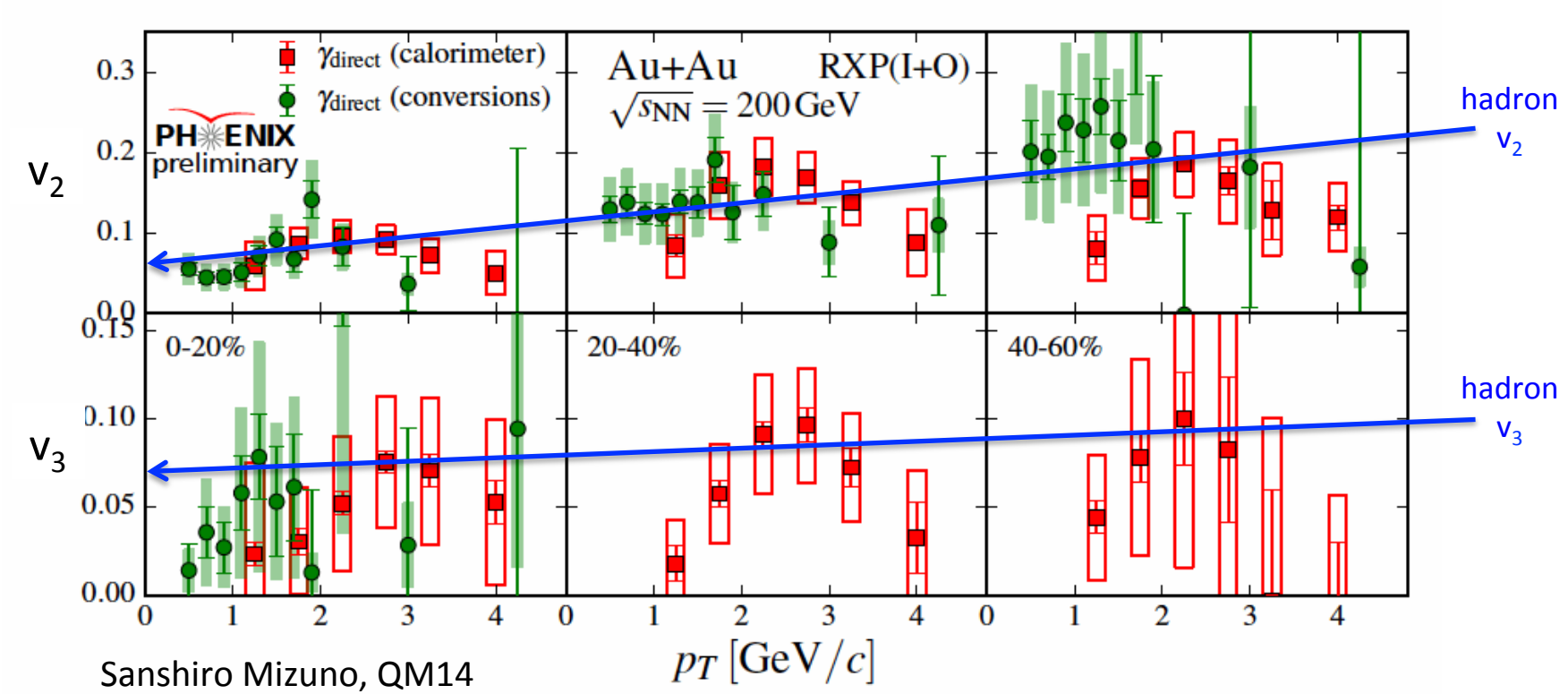
arXiv:1405.3940



Direct (thermal) photon v_2 and v_3



$v_n = < \cos n(\phi^{particle} - \Phi_n^{plane}) >$
(n=2 : elliptic flow), (n=3 : triangular flow)

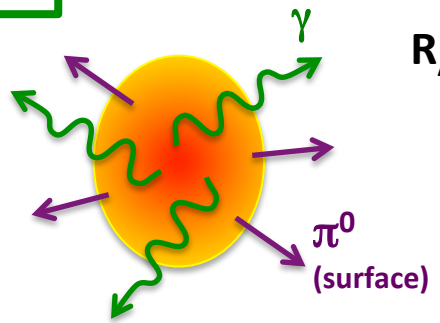


Sanshiro Mizuno, QM14

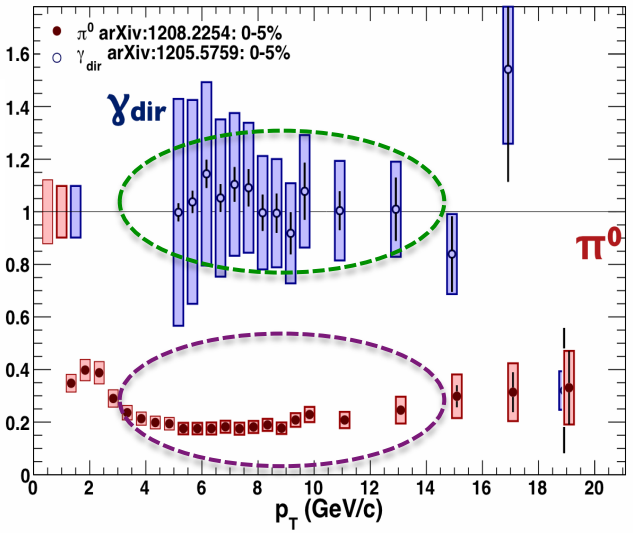
- comparable to hadron for both v_2 and v_3 at 2~3GeV/c
- significant contribution from photons from later stages (inconsistent with early photons from hotter period)
- flatter p_T dependence of v_2 at low p_T

High p_T direct photon as penetrating probe

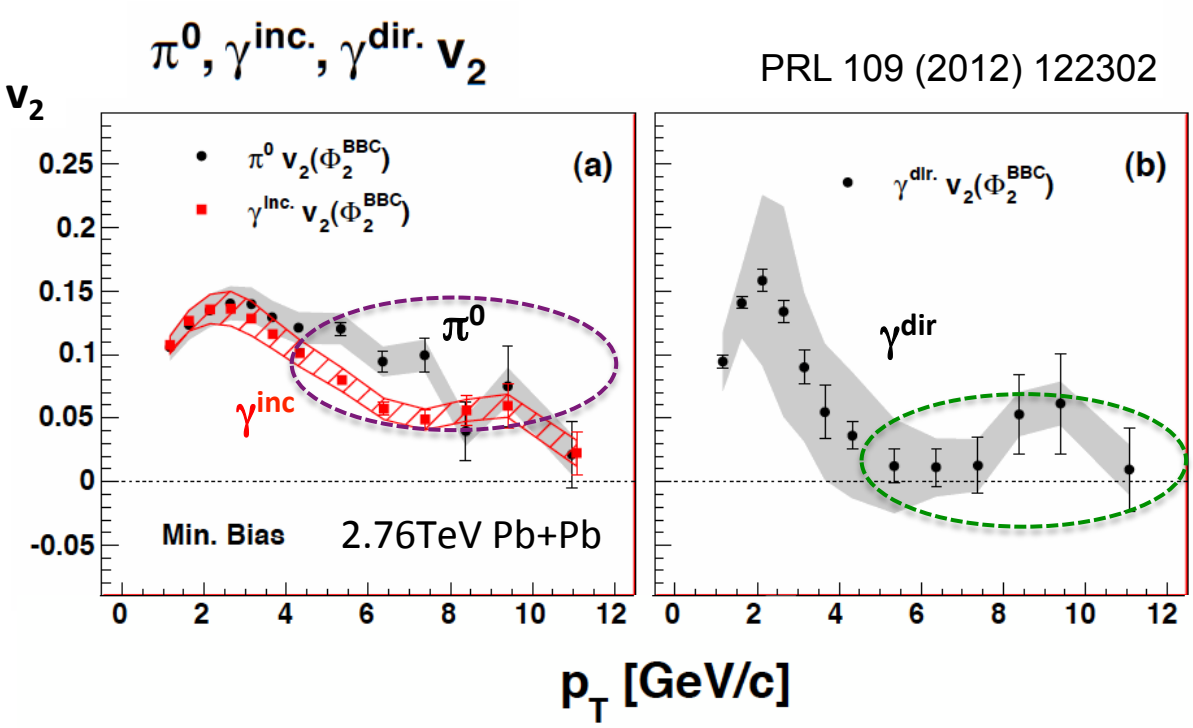
$p_T > 5$ GeV/c	hadron	γ^{dir}
R_{AA}	< 1	~ 1
v_2	> 0	~ 0



PRL 109 (2012) 152302



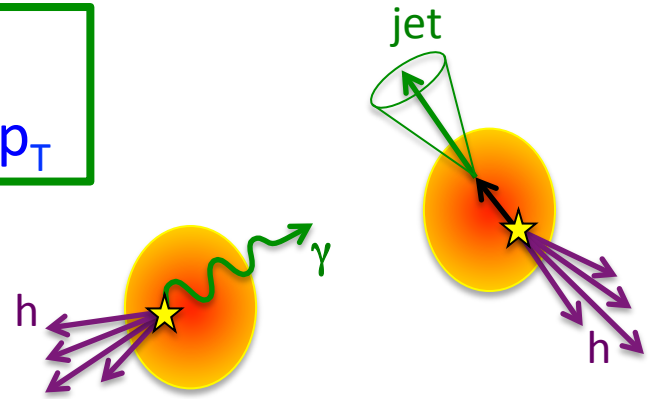
PRL 109 (2012) 122302



$$R_{AA} = \frac{N\,(A+A)}{N_{coll}\,N(p+p)}$$

relative yield with respect to a simple independent superposition of pp data

Energy loss at high p_T and re-distribution of the lost-energy at low p_T



(N_{PTY} = associate hadron yield per trigger γ)

$I_{AA} = N_{PTY}(AA) / N_{PTY}(pp)$

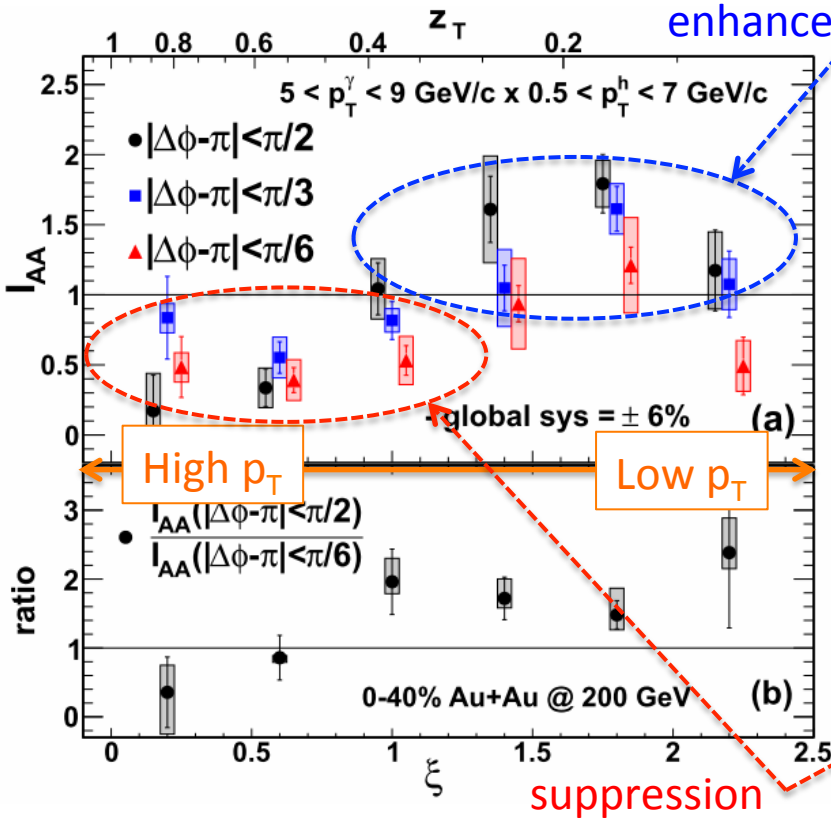
PRL 111 (2013) 032301

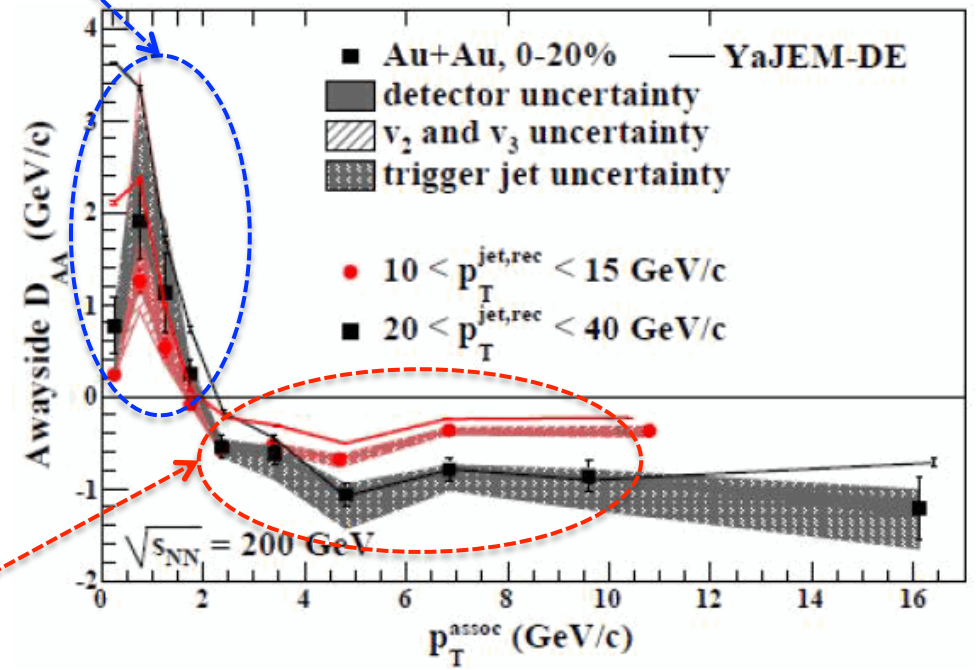
enhancement

(S_{PTY} = associate hadron p_T sum per jet)

$D_{AA} = S_{PTY}(AA) - S_{PTY}(pp)$

PRL 112 (2014) 122301



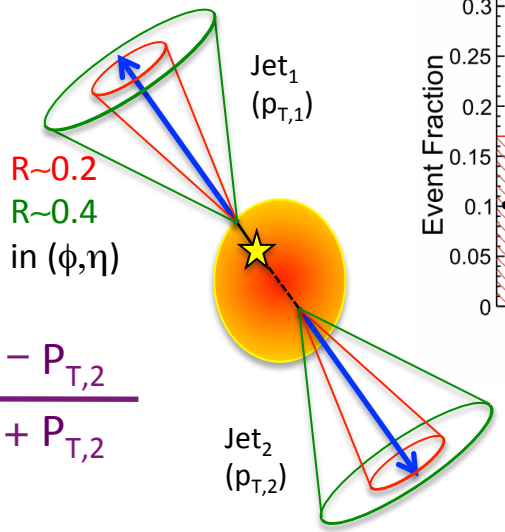


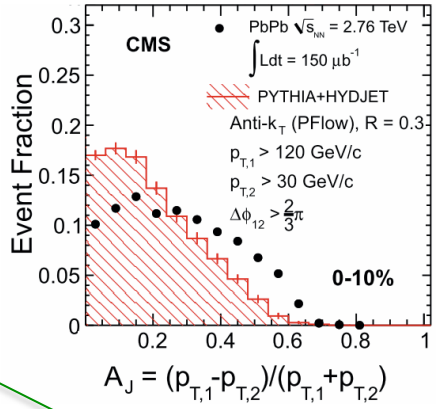
suppression

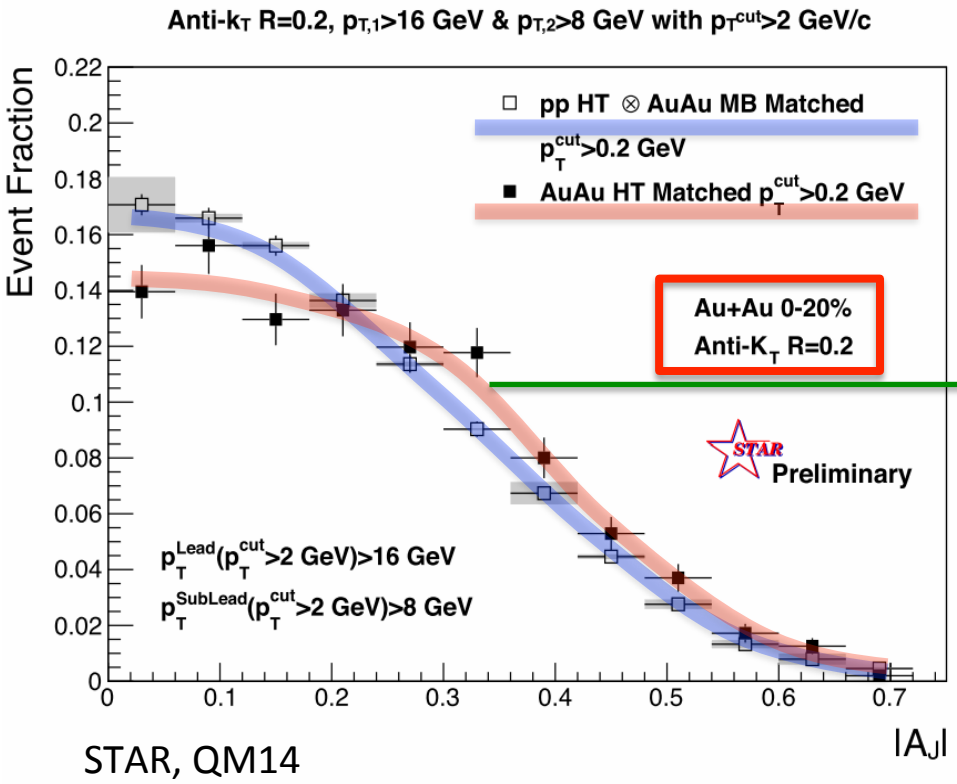
Jet quenching at RHIC vs LHC (A_J : di-jet energy asymmetry)

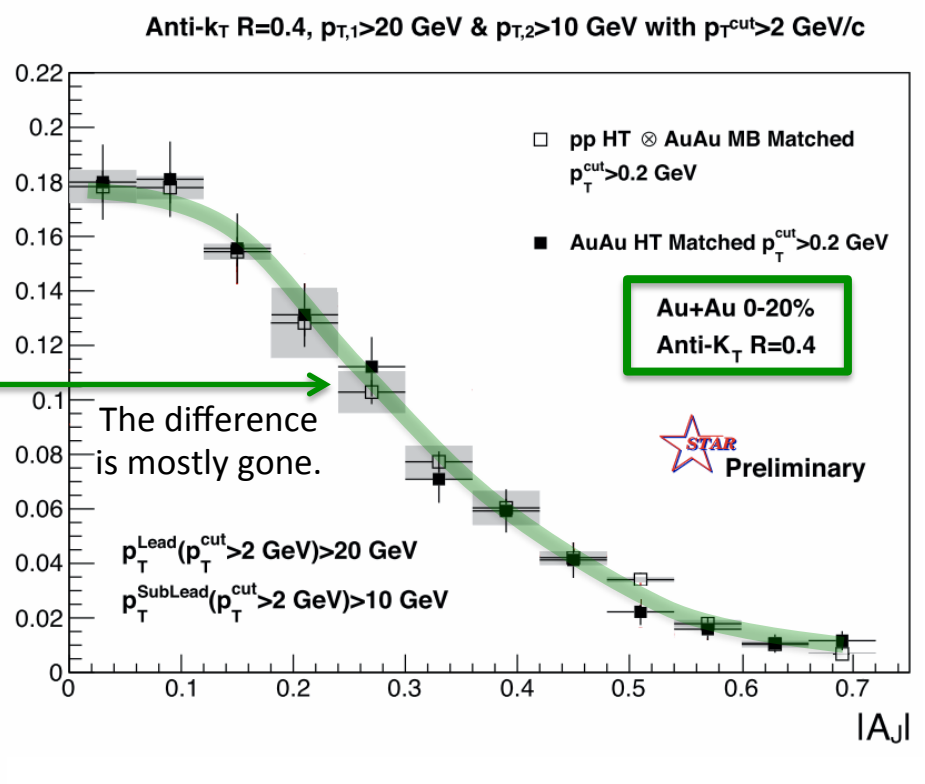
- visible effect with smaller jet cone R~0.2 at RHIC
- lower jet energy than LHC, smaller effect than LHC
- mostly recovered jet energy within larger jet cone R~0.4

$$A_J = \frac{P_{T,1} - P_{T,2}}{P_{T,1} + P_{T,2}}$$



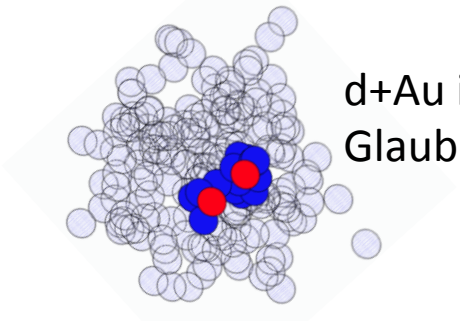




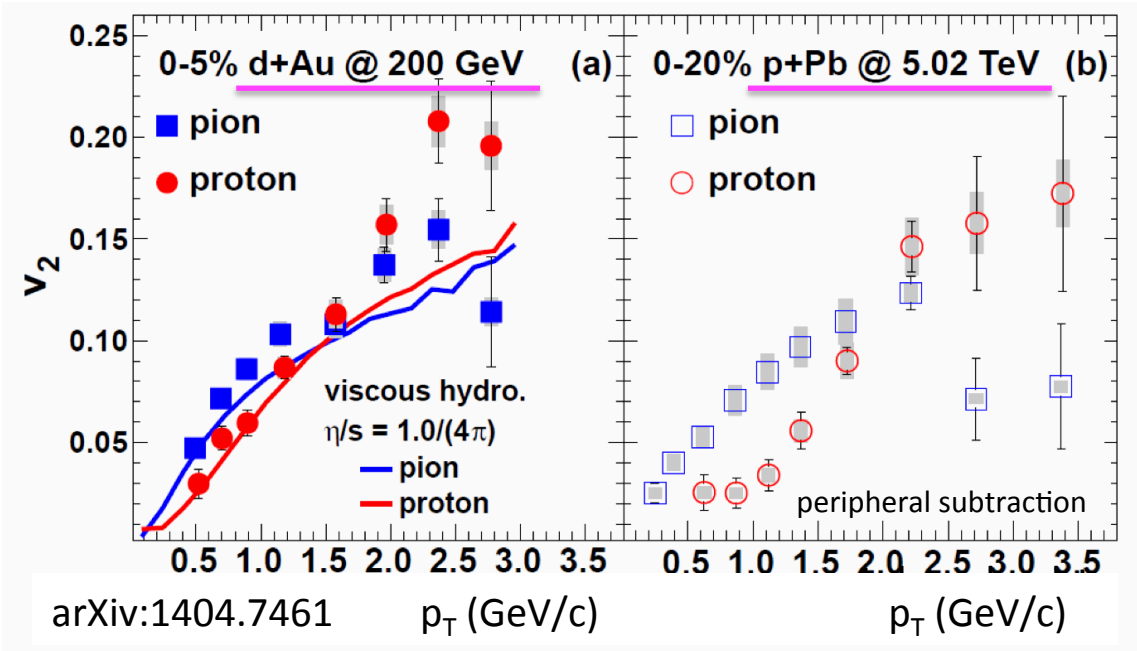


STAR, QM14

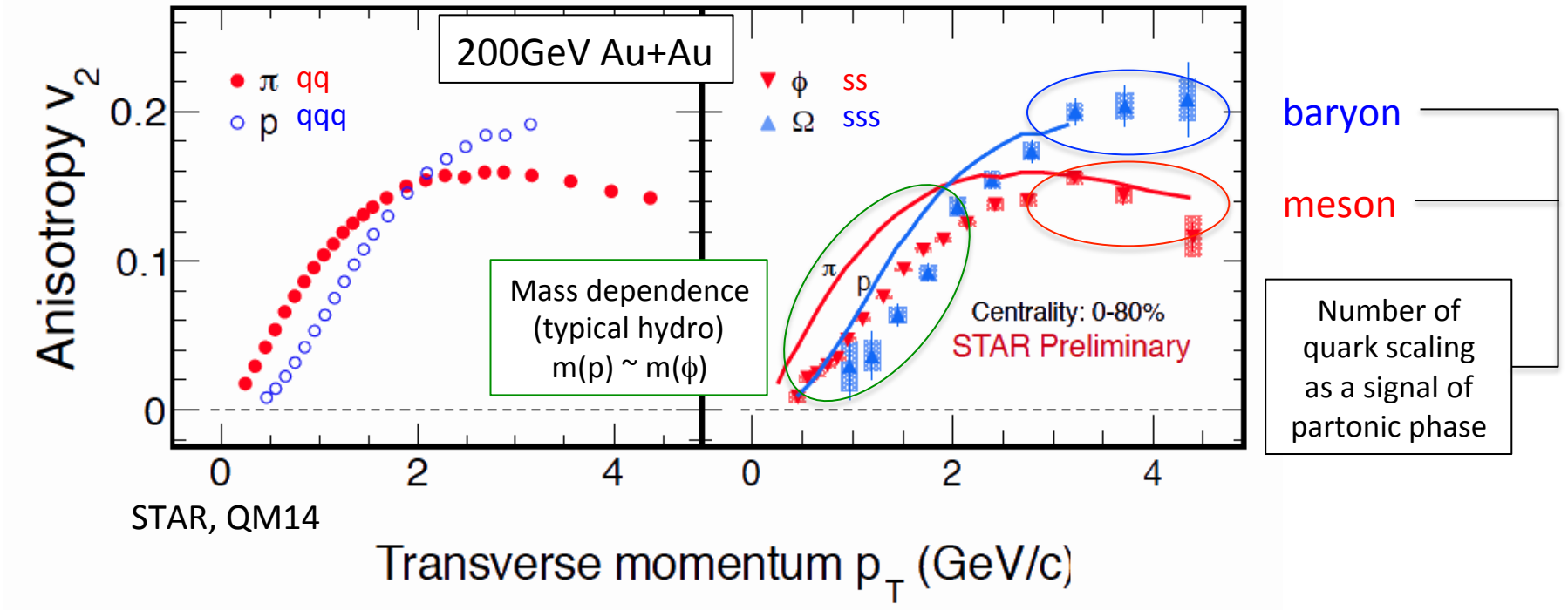
Elliptic flow in A+A
also in d+Au or p+Pb
in such a small system?



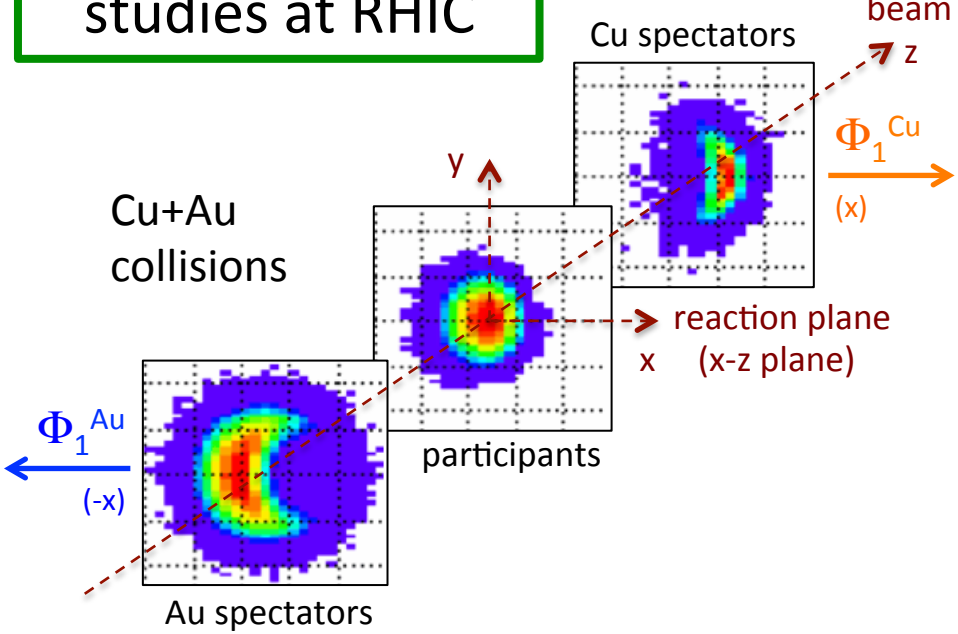
d+Au in
Glauber model

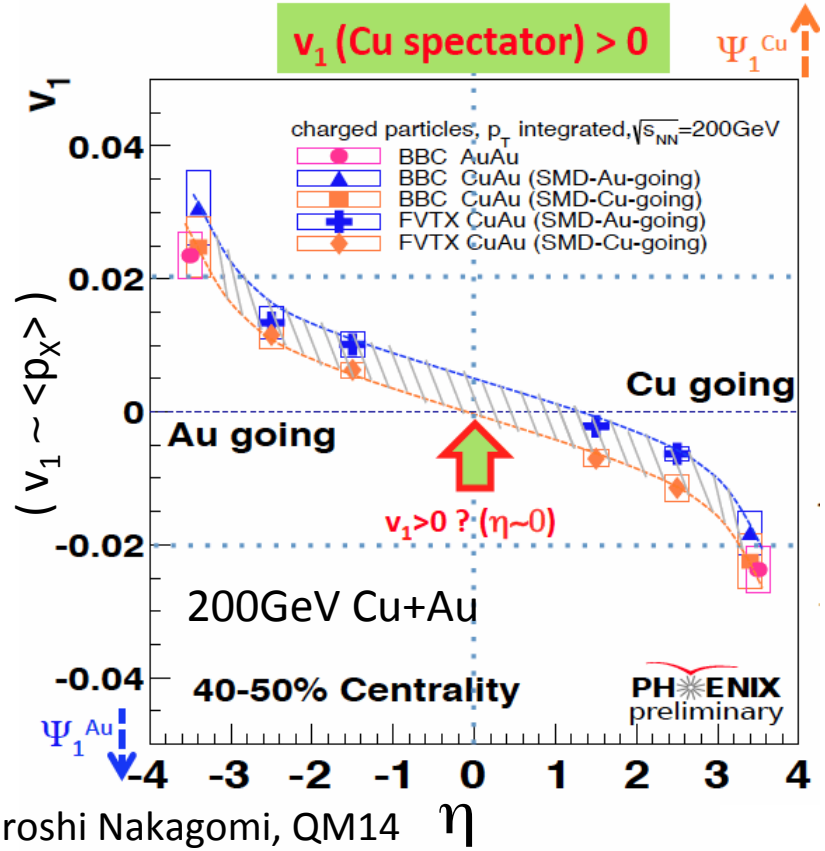


arXiv:1404.7461 p_T (GeV/c) p_T (GeV/c)

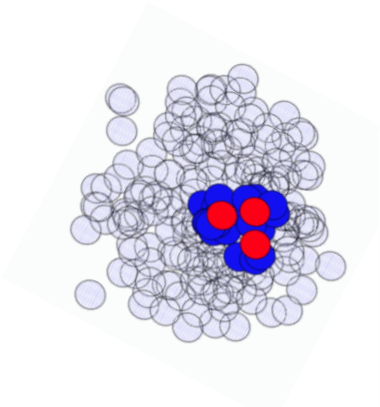


Various flow studies at RHIC



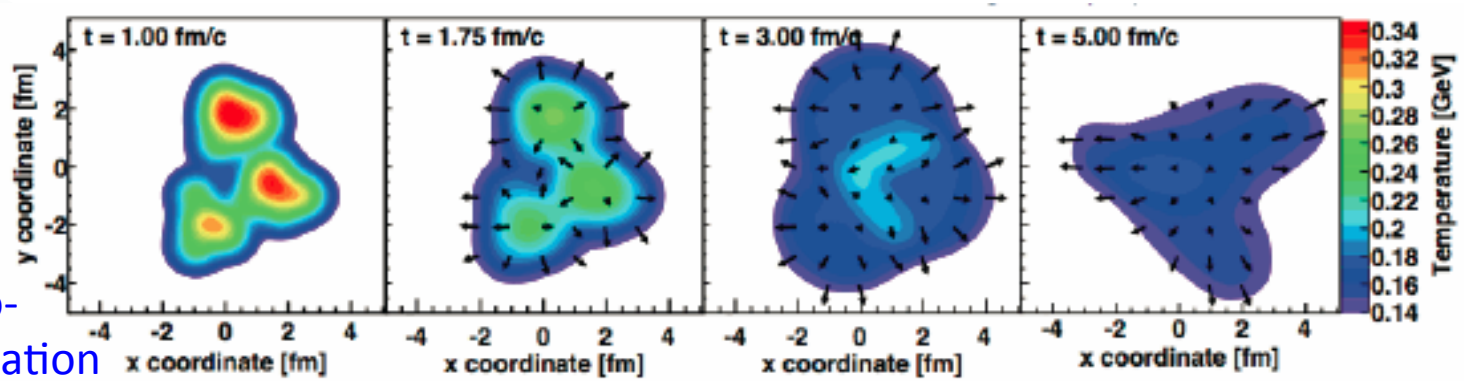


Hiroshi Nakagomi, QM14



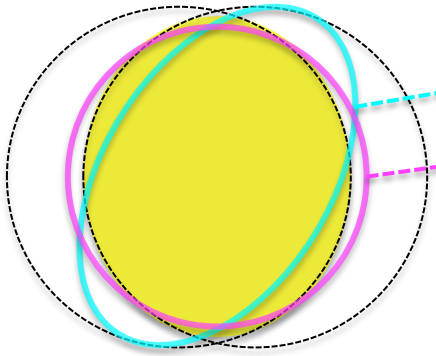
^{3}He+Au collision data
on tape in RHIC-RUN14

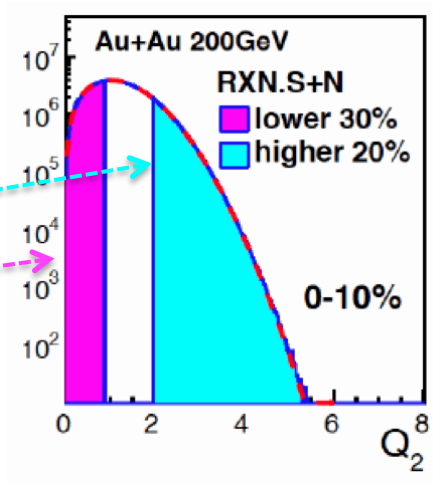
hydro-
calculation



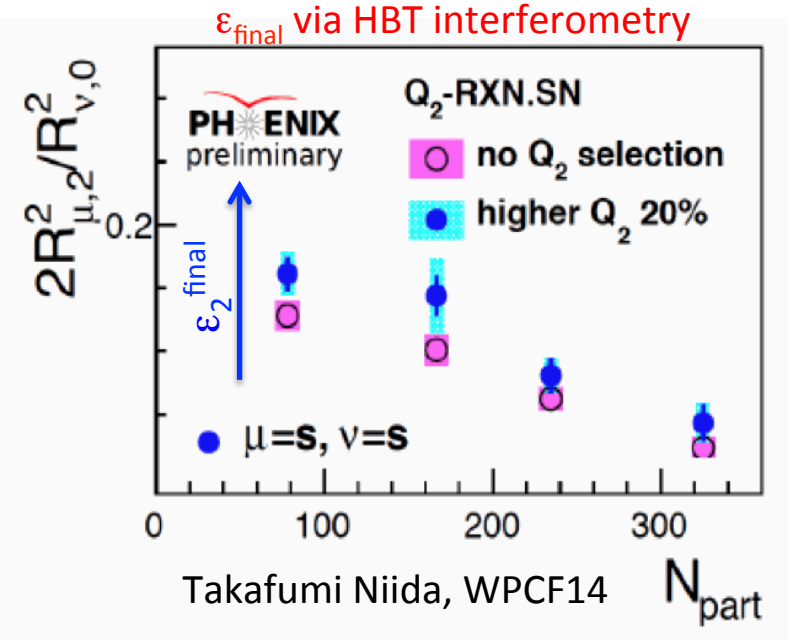
Event shape selection by Q_2 (~v_2)

relation of $\varepsilon_2^{initial} - v_2 - \varepsilon_2^{final}$ for a given centrality



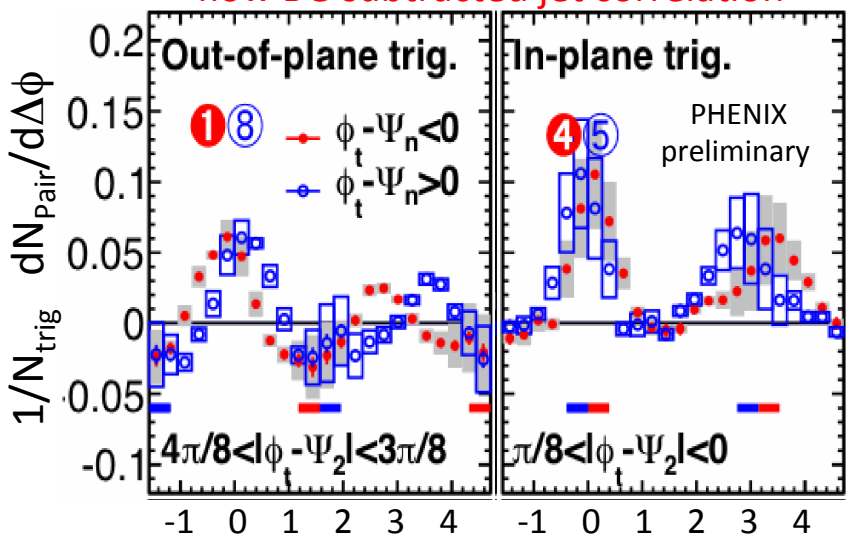


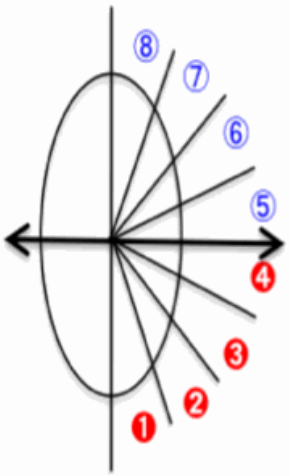
ε_{final} via HBT interferometry



Takafumi Niida, WPCF14

flow BG subtracted jet correlation

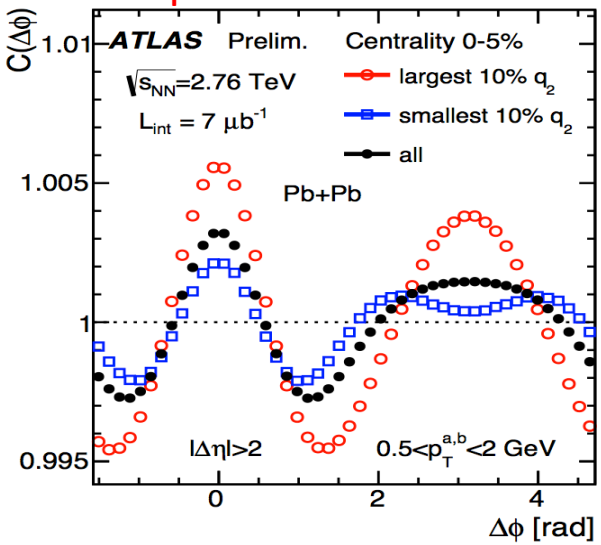




Takahito Todoroki, QM12

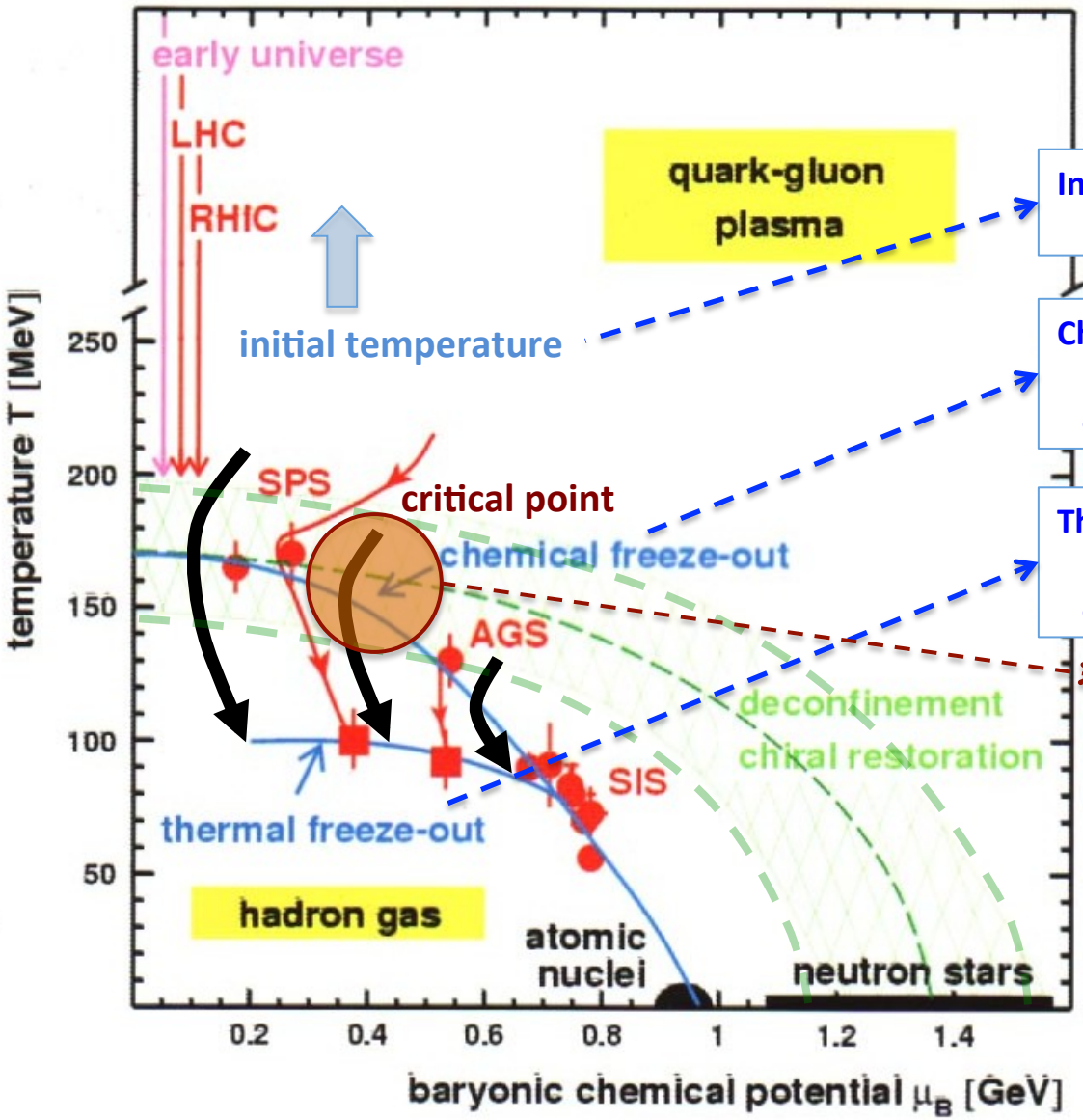
$\Delta\phi = \phi_{Asso.} - \phi_{Trig.}$

2-particle correlation



ATLAS, QM14

History of temperature before/after the phase transition



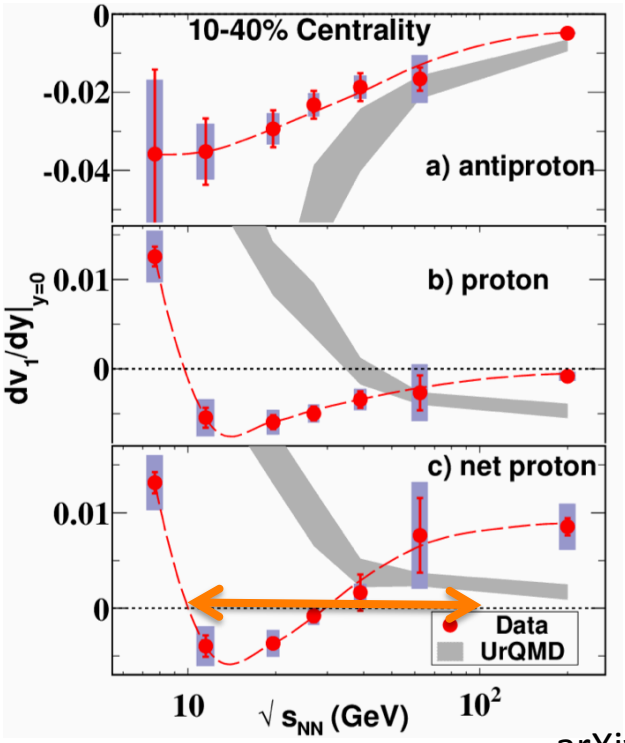
Initial temperature :
Direct thermal photon measurement

Chemical Freeze-out temperature :
Particle species, ratios are fixed
at the end of inelastic interactions

Thermal Freeze-out temperature :
Particle spectra are fixed
at the end of elastic interactions

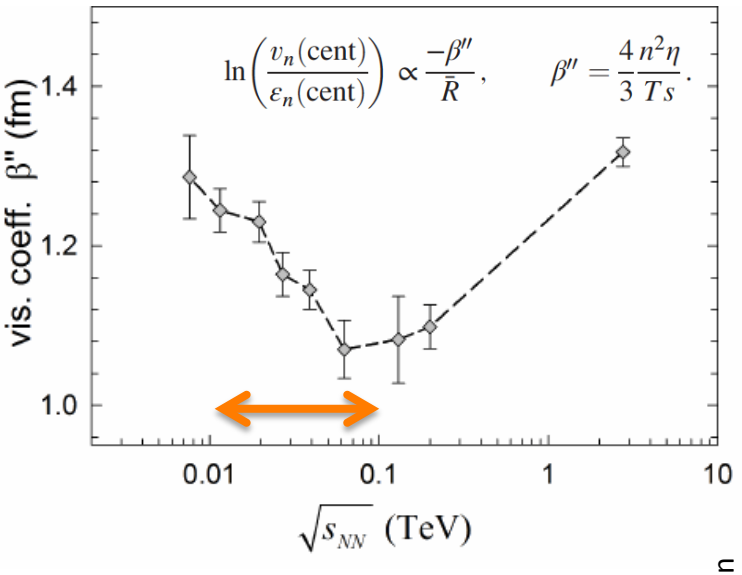
Critical Point :
1st order phase transition
non-monotonic behavior
expected fluctuation to diverge

PRL112 (2014) 162301

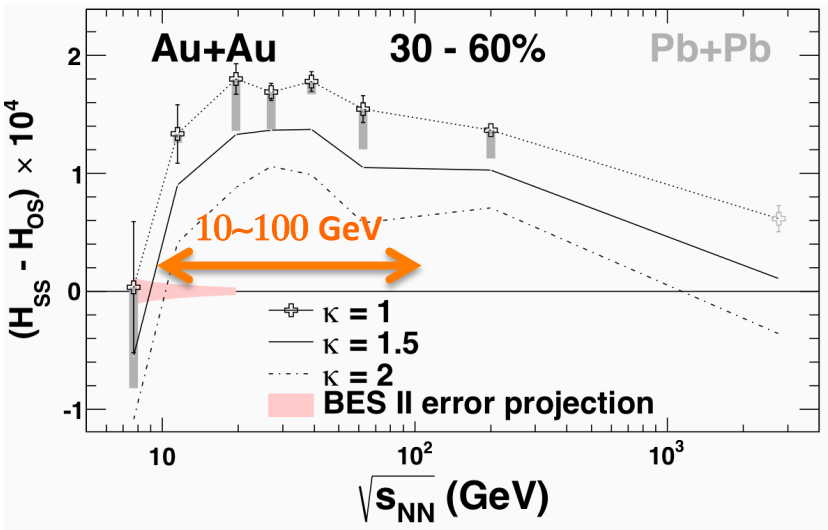


Beam energy dependence of v_1, v_2, HBT and charge asymmetry

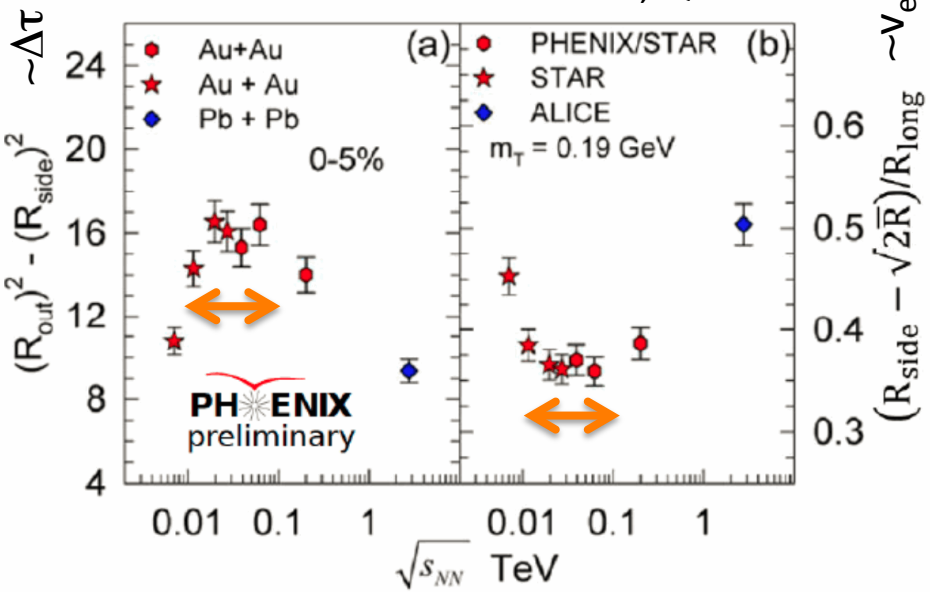
PRL 112 (2014) 082302



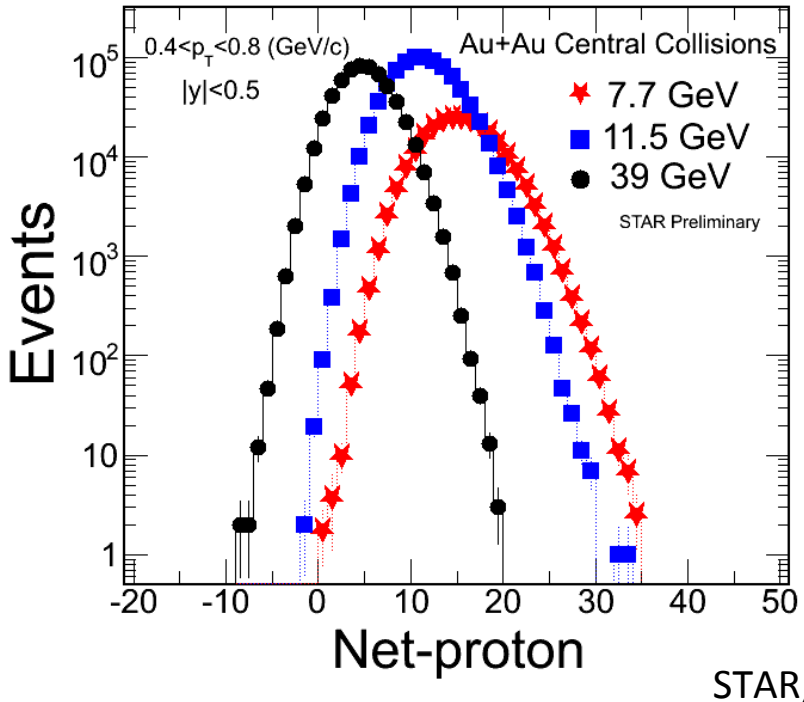
arXiv:1404.1433

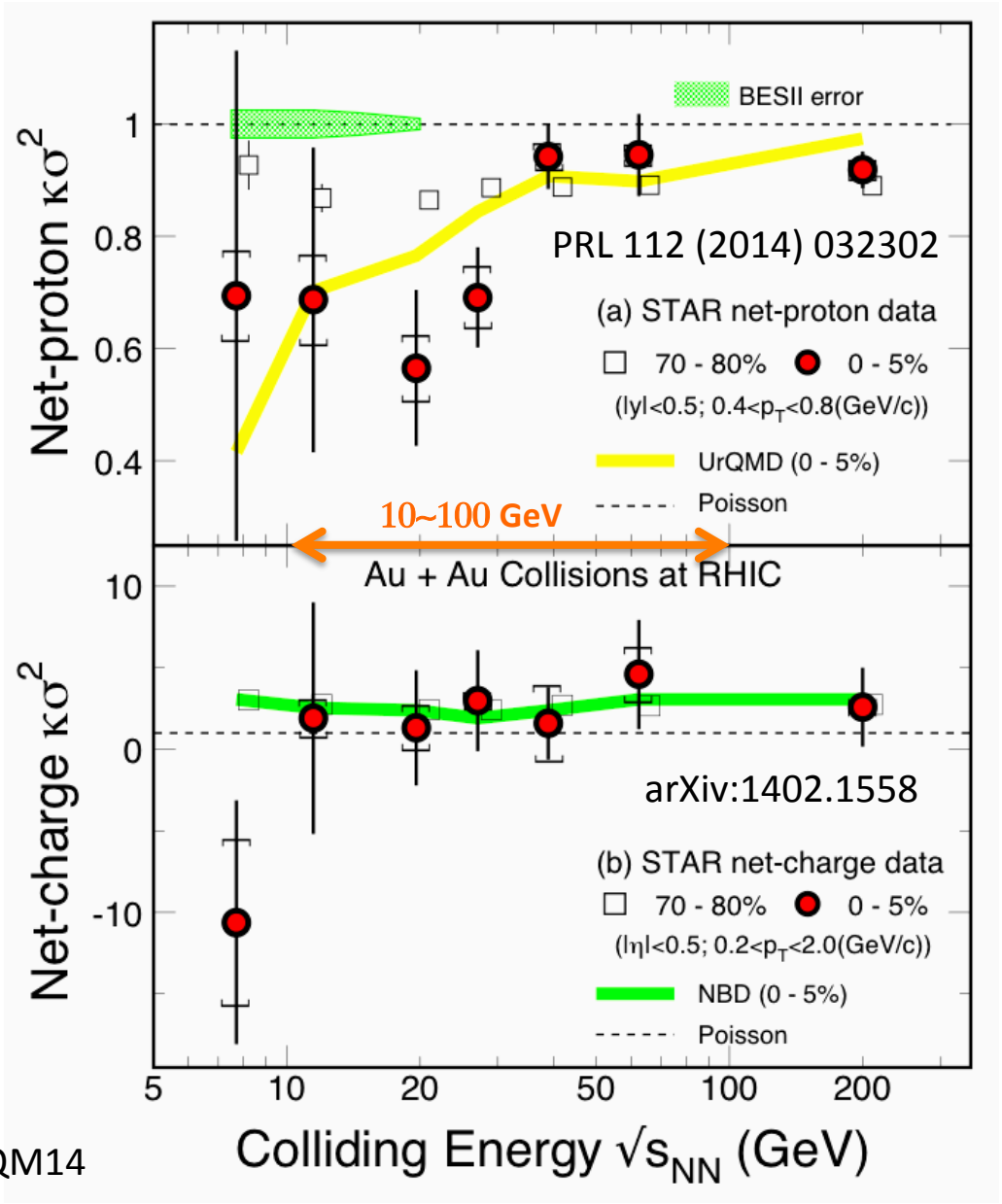


PHENIX, QM14



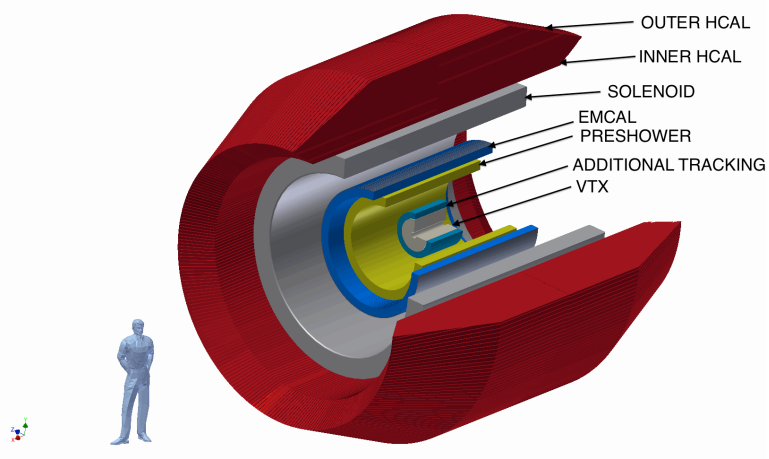
Fluctuation of conserved quantities such as net-baryon, net-charge distribution





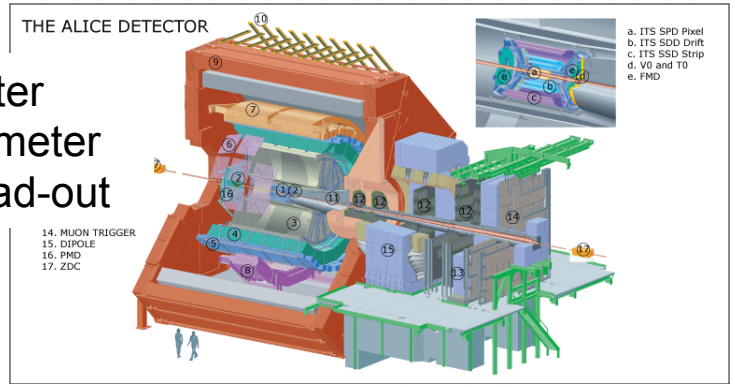
STAR, QM14

sPHENIX upgrade at RHIC-BNL (New York, USA)

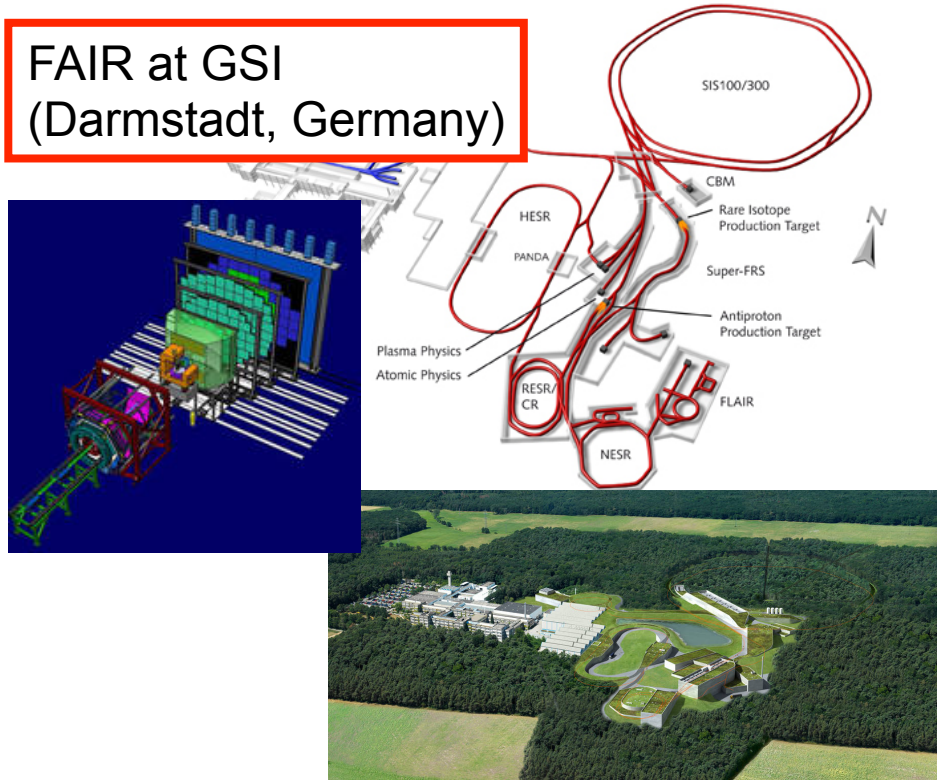


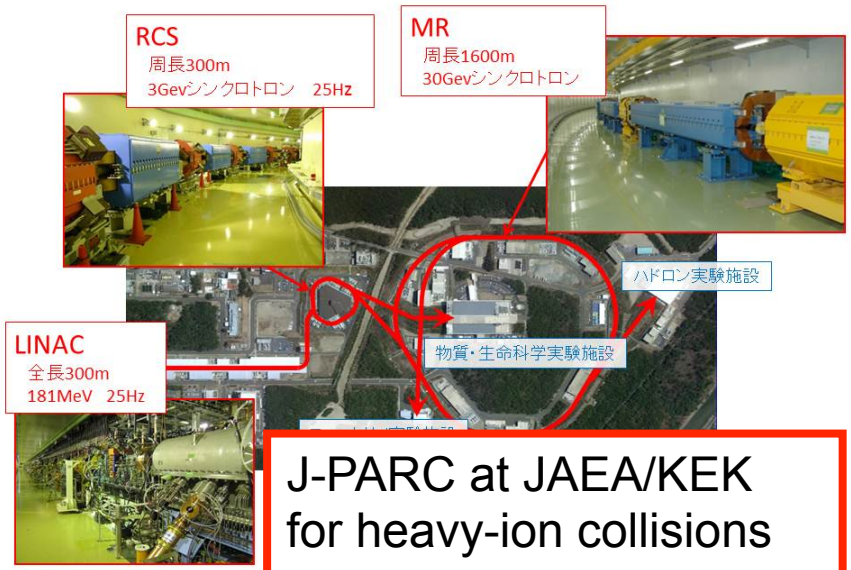
ALICE at LHC-CERN for Luminosity upgrade (Geneva, Switzerland)

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



FAIR at GSI (Darmstadt, Germany)





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

Summary

- Initial temperature and collective flow via thermal photons
- Partonic energy-loss using jets and prompt photons
- Collective flow even in small system
- Event shape selection as another control parameter
- Beam energy scan to search for a critical point