STAR Physics Program with the TOF

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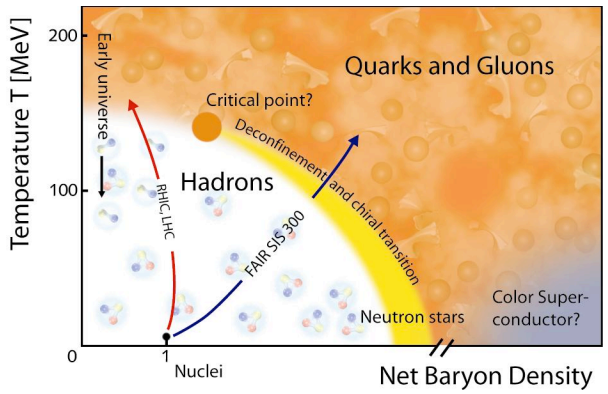
STAR Physics Focus

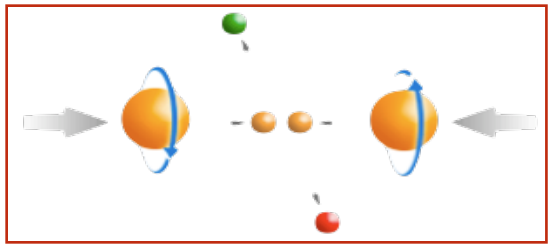


1) At 200 GeV top energy

- Study ***medium properties, EoS***
- pQCD in hot and dense medium

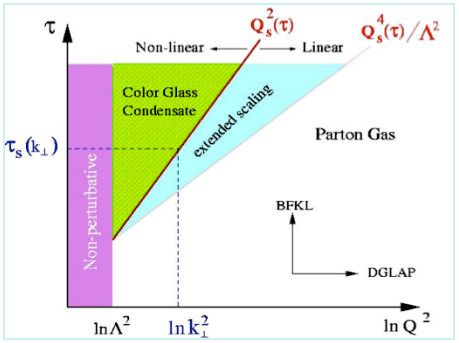
2) RHIC beam energy scan

- Search for the ***QCD critical point***
- Chiral symmetry restoration



Polarized spin program

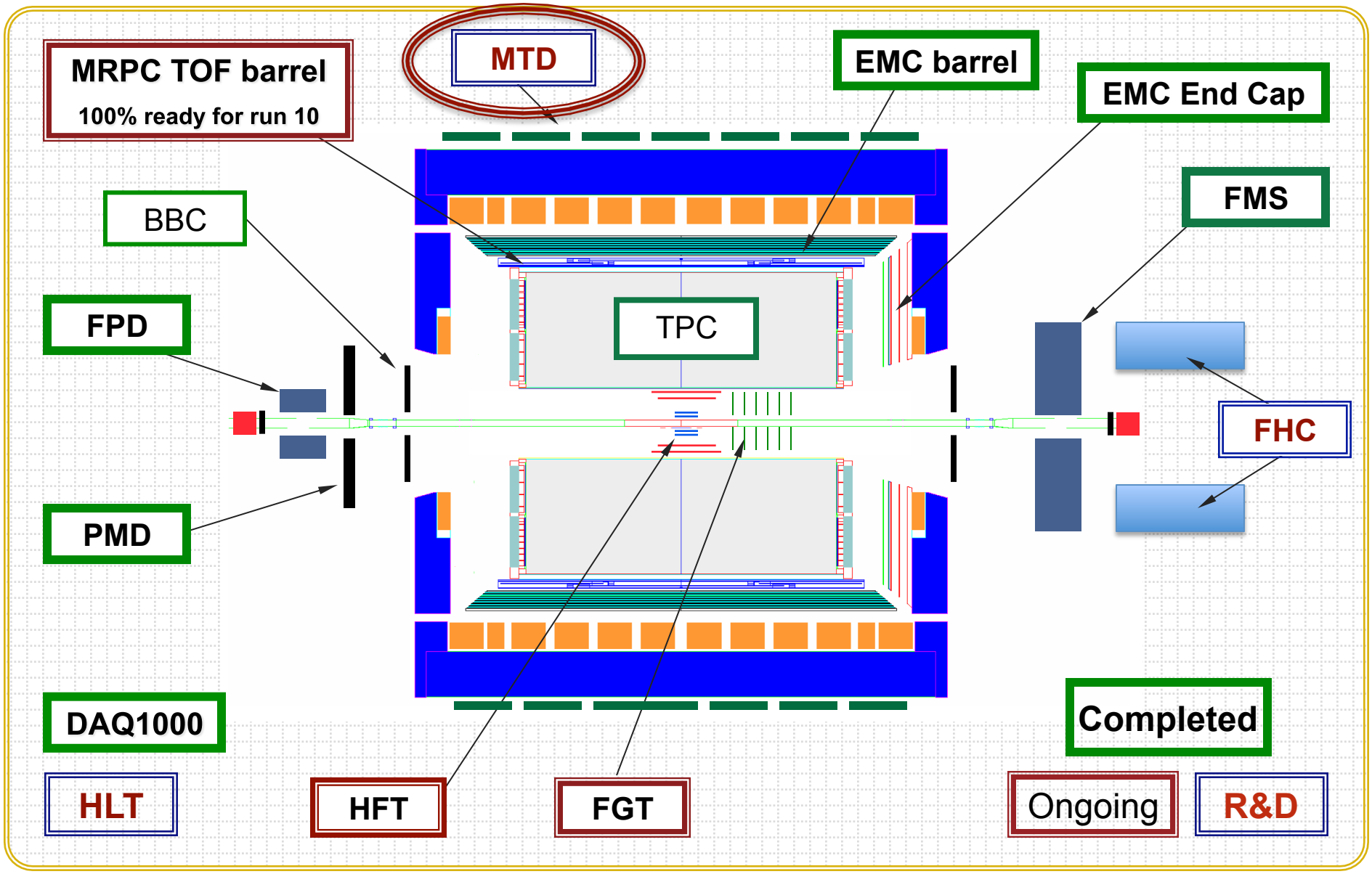
- Study ***proton intrinsic properties***



Forward program

- Study low-x properties, search for ***CGC***
- Study elastic (inelastic) processes (pp2pp)
- Investigate ***gluonic exchanges***

STAR Detector

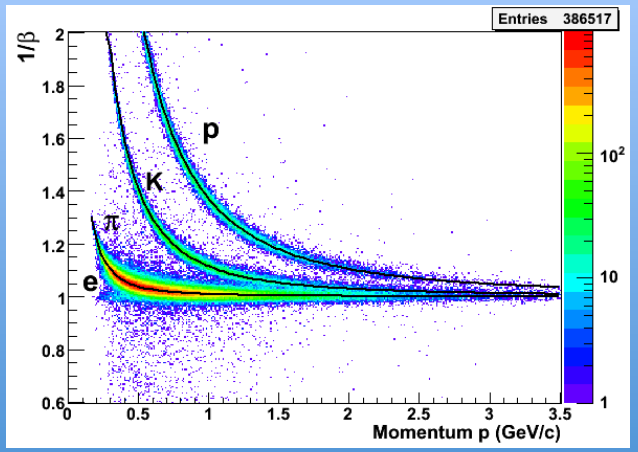


STAR: Physics with TOF

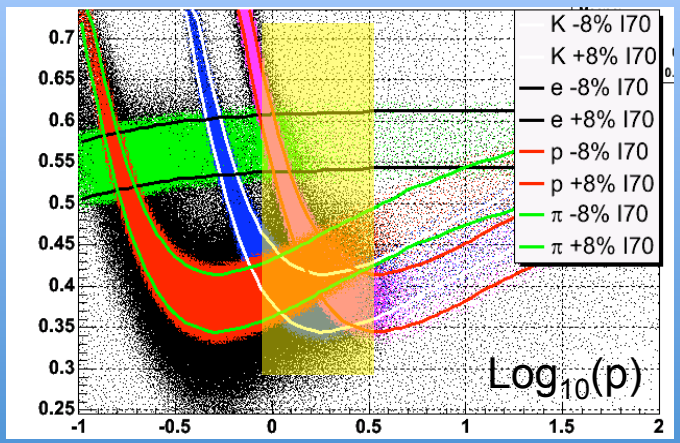
1) Significant improvement in PID. With TPC, PID will be extended to p_T ~ 15 GeV/c
2) Correlations with PID hadrons; resonances (up to Ω); trigger with high p_T hadrons …
3) Beam energy scan program: event-by-event K/π analysis and net-proton Kurtosis
4) 2π electron and di-electron analysis; heavy flavor program

…

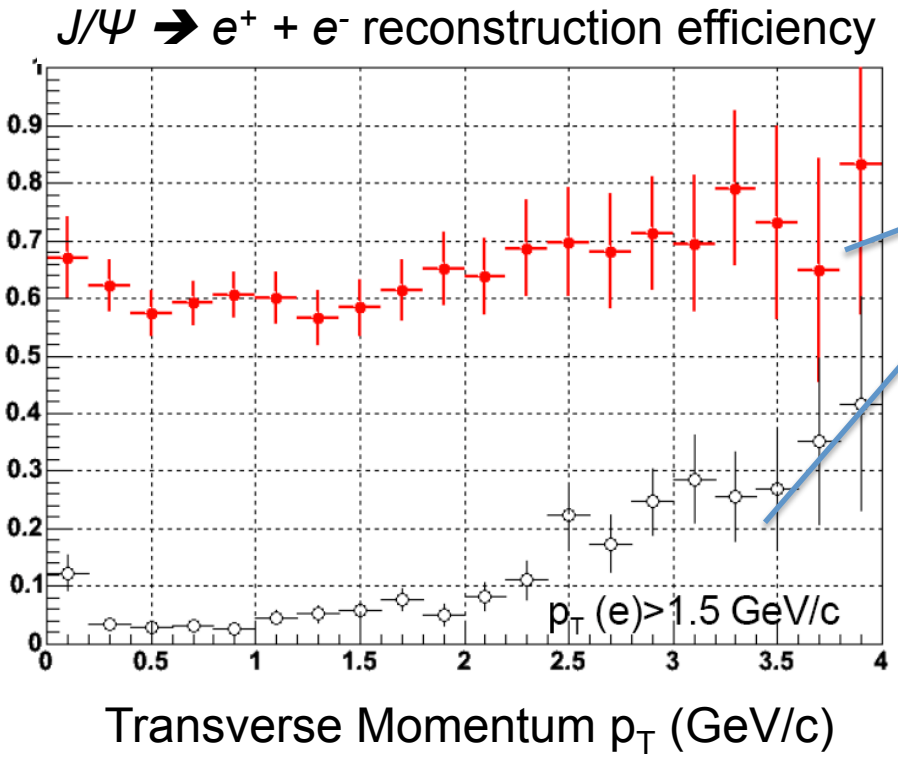
STAR TOF



STAR TPC+TOF



Heavy Flavor Efficiency Improvement

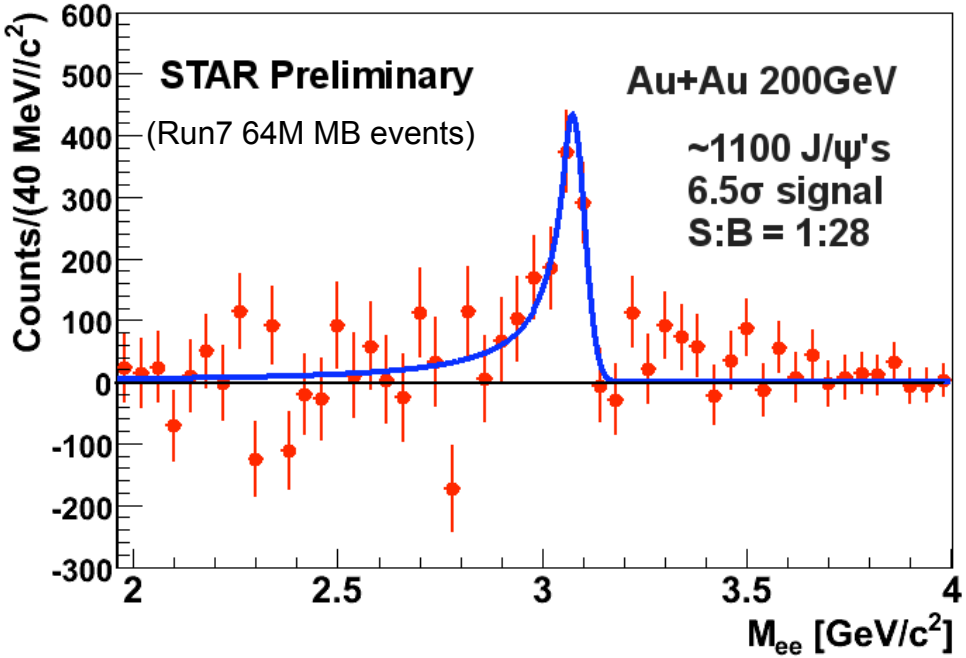


red: with STAR TOF
black: without STAR TOF

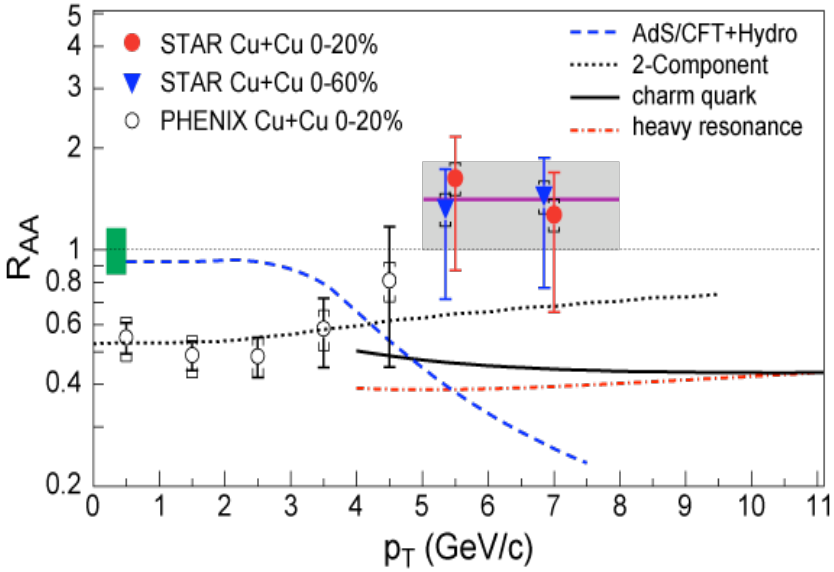
Acceptance: *10-30* times larger compared with PHENIX

Crucial for enhancing future ***heavy flavor*** measurements

Current Measurements with J/Ψ



STAR submitted to PRL 0904.0439

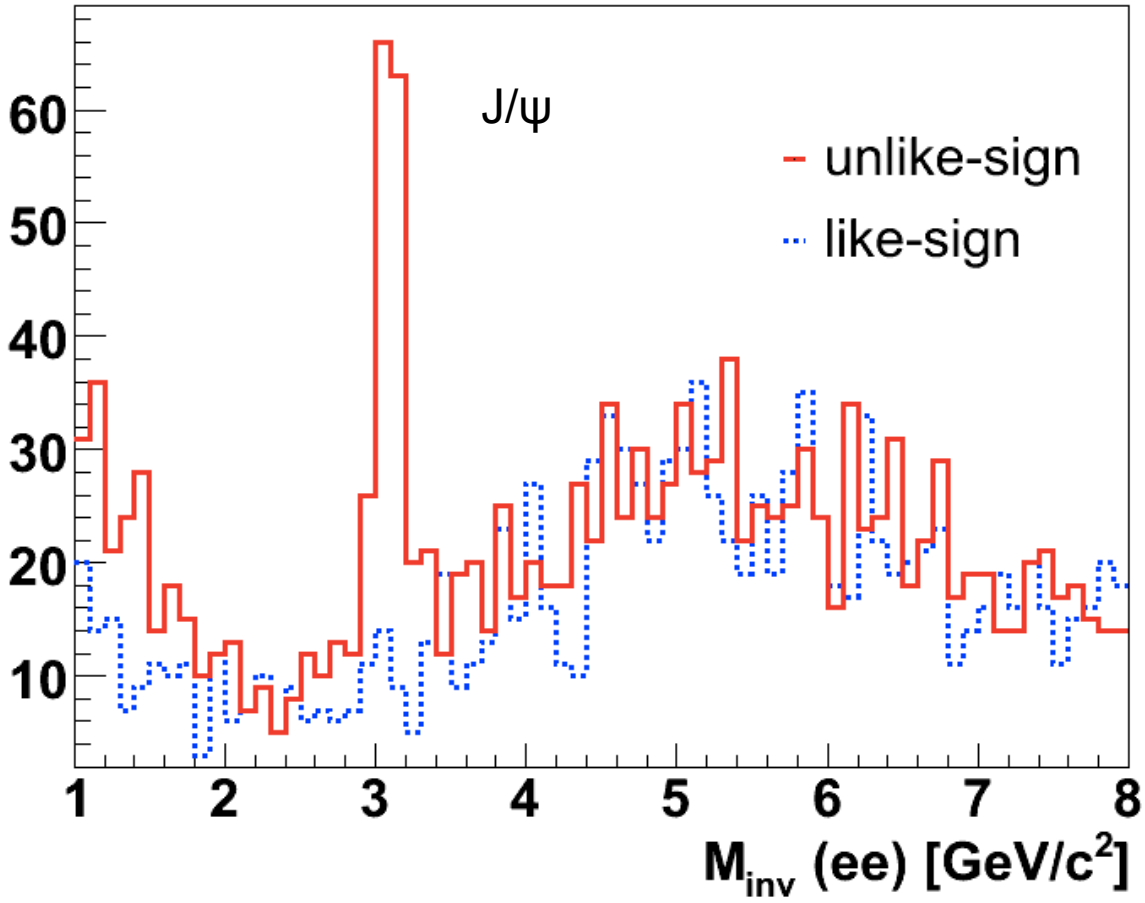


Run10, $\sqrt{s_{NN}}$ = *200* GeV Au+Au collisions:

1) Measure the v_2 of *J/Ψ*, with the help of HLT
2) Measure the R_{AA} of *J/Ψ* at high transverse momentum p_T > 5 GeV/c

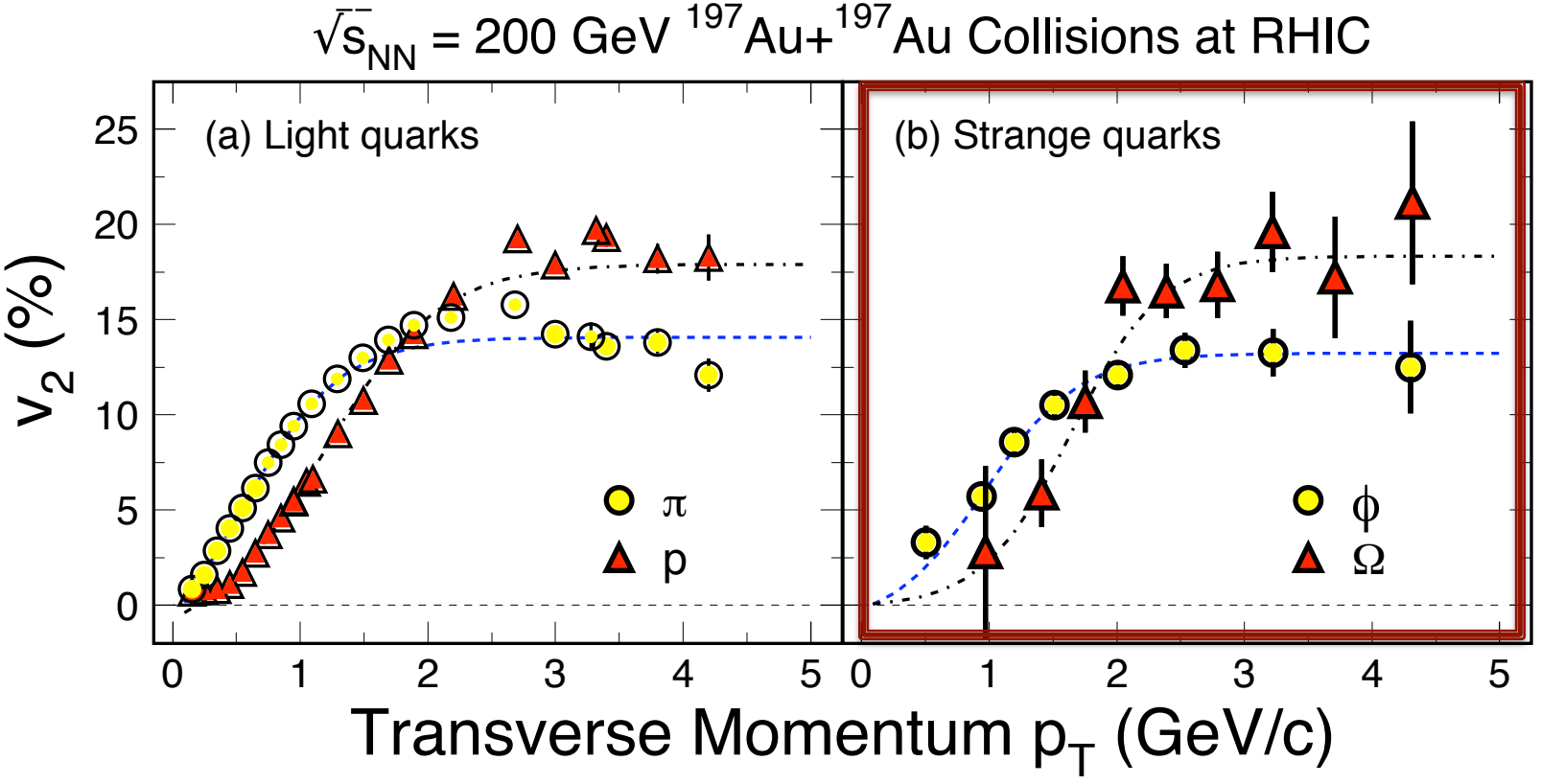
STAR High Level Trigger and TOF

Run9 p+p 200 GeV, May 19 - 25



1) Fast filtering for quick data analysis. Run10: try J/ψ v_2
2) Online QA
3) TOF: improve STAR trigger capabilities: vertex, pile-up rejection capability…

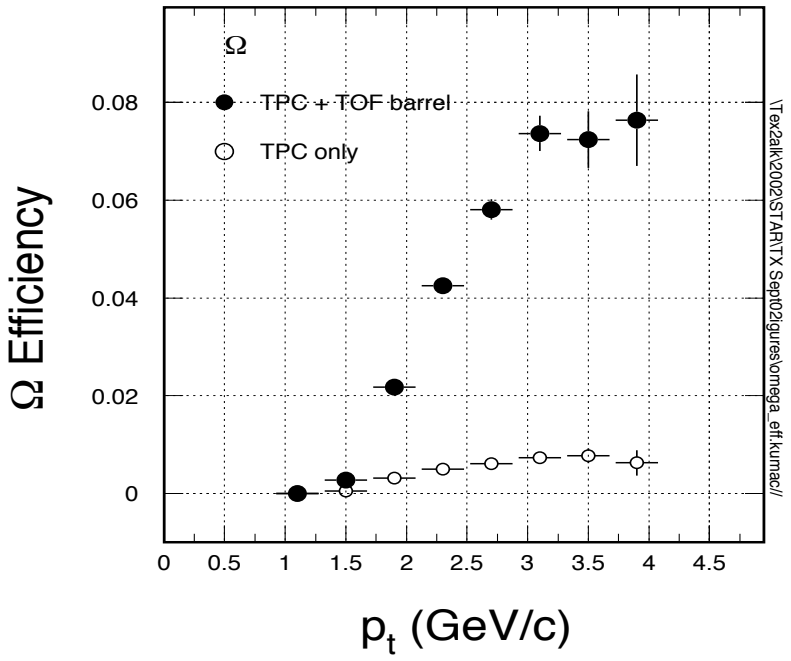
Partonic Collectivity at RHIC

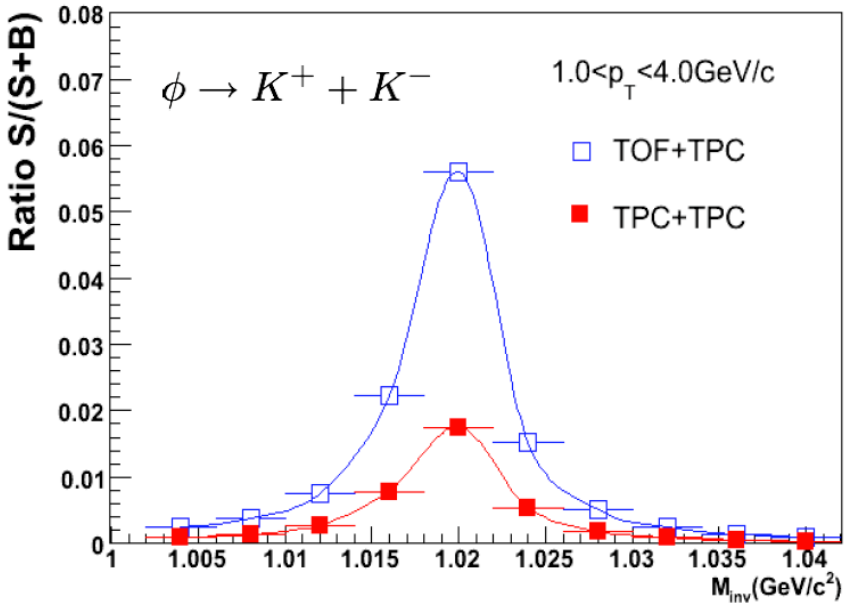


Low p_T (≤ 2 GeV/c): hydrodynamic mass ordering
High p_T (> 2 GeV/c): number of quarks ordering
s-quark hadron: smaller interaction strength in hadronic medium
light- and s-quark hadrons: similar v_2 pattern

=> Collectivity developed at partonic stage!

Reconstruction Efficiency Improvement





TOF:

1) Increase efficiency for all resonances
2) Extend the p_T reach

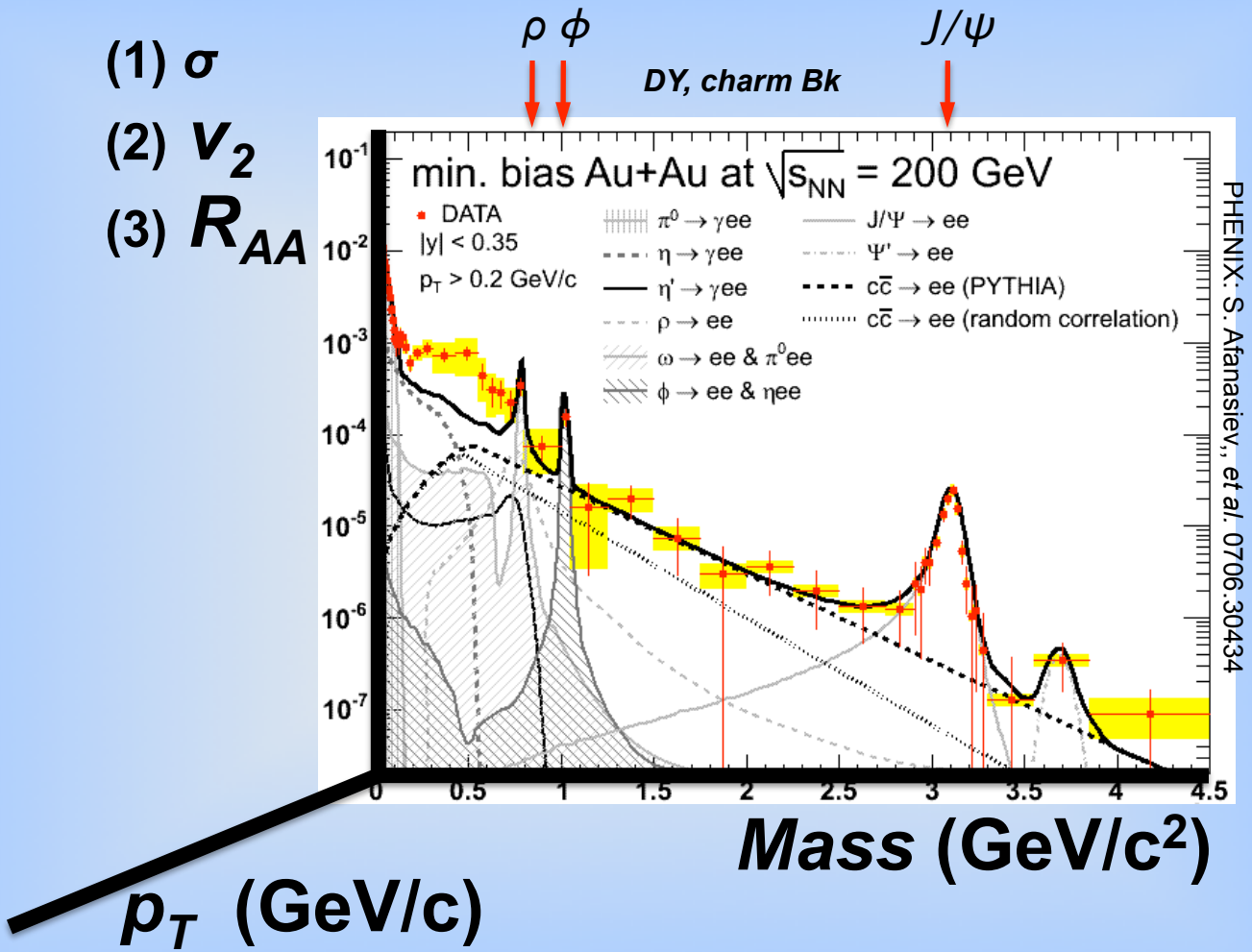
= EOS parameters: ***temperature and collective velocities***

The di-Lepton Program at STAR

(1) σ

(2) v_2

(3) R_{AA}

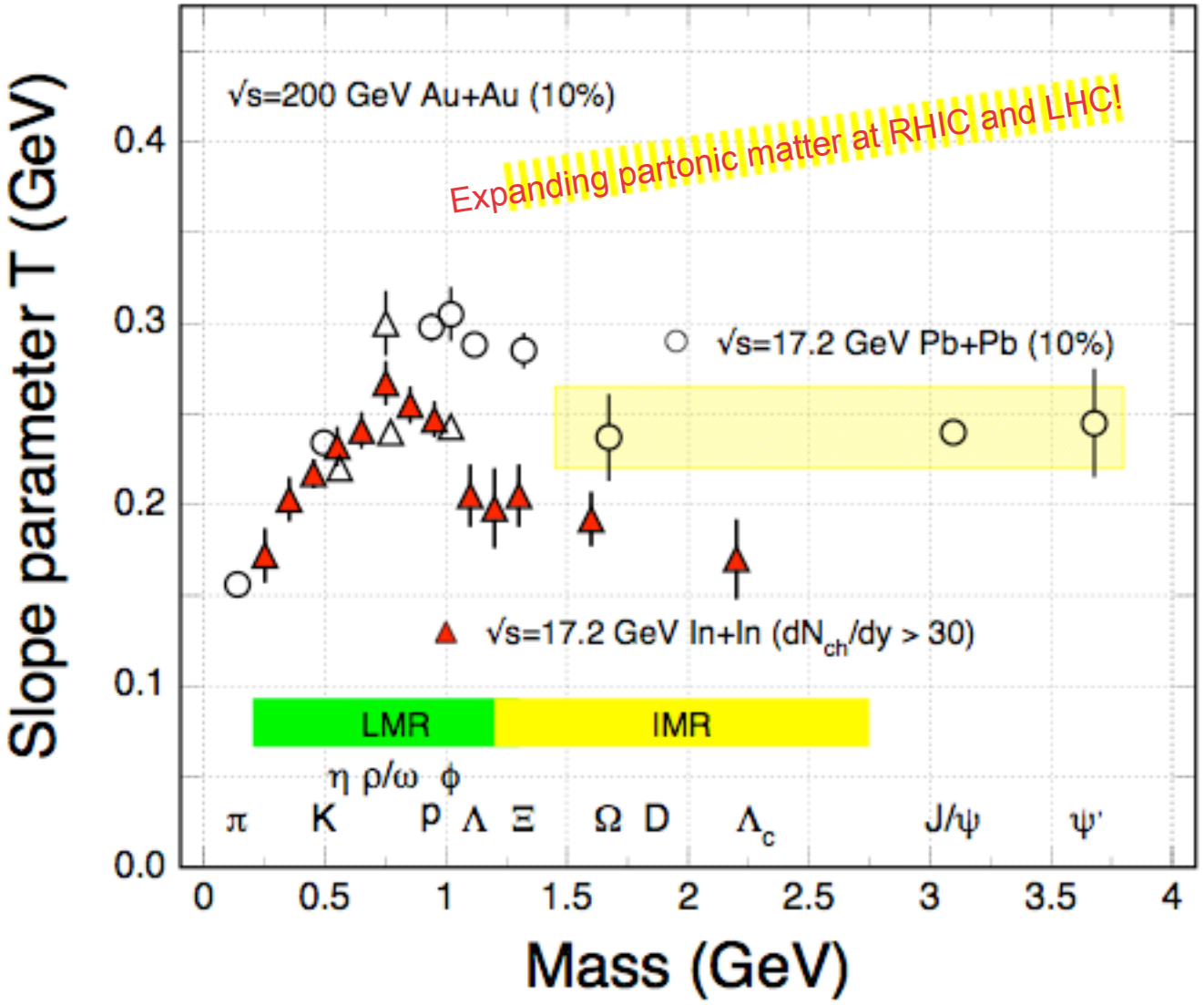


✓ **Chiral Symmetry Restoration**

✓ **Direct Radiation from The Hot/Dense Medium**

*** TOF is Crucial for the physics.**

Direct Radiation



Di-leptons allow us to measure the direct radiation from the matter with medium effects, no hadronization!

- Low mass region:
  $\rho, \omega, \phi \Rightarrow \mathbf{e^-e^+}$
  $m_{inv} \Rightarrow \mathbf{e^-e^+}$

  medium effect
  Chiral symmetry

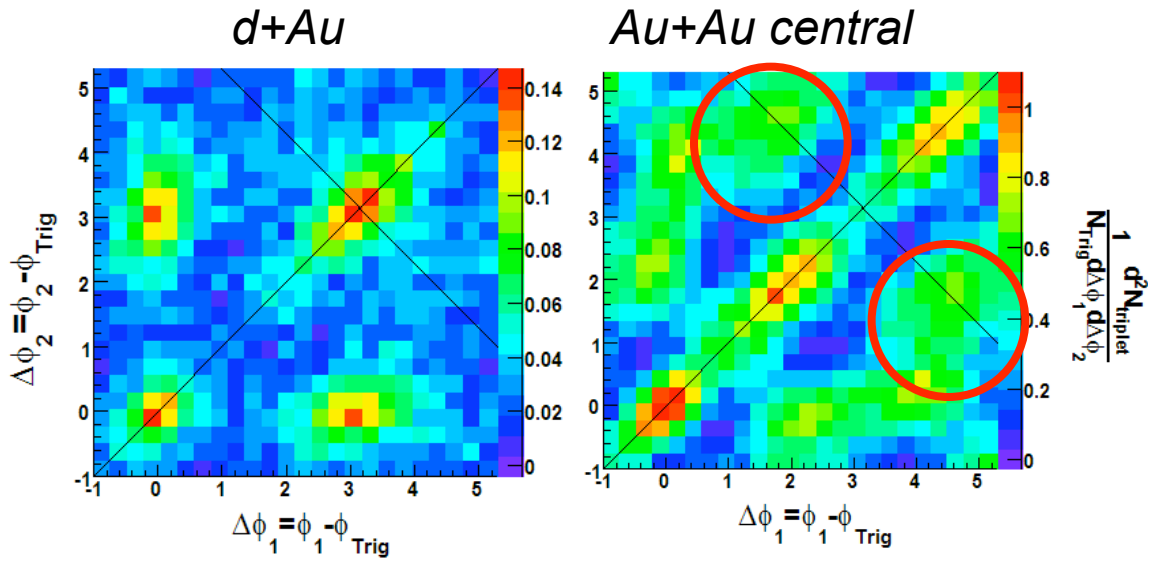
- High mass region:
  $\mathbf{J/\psi \Rightarrow e^-e^+}$
  $m_{inv} \Rightarrow \mathbf{e^-e^+}$

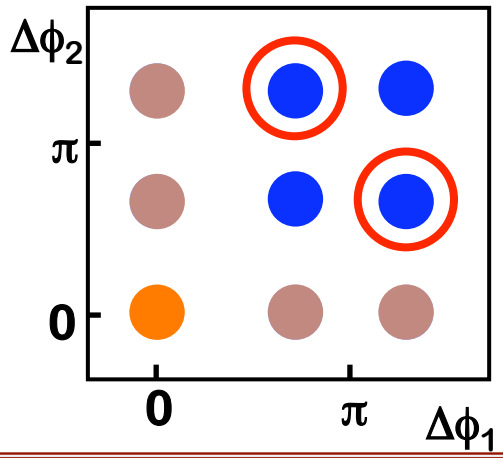
  Direct radiation

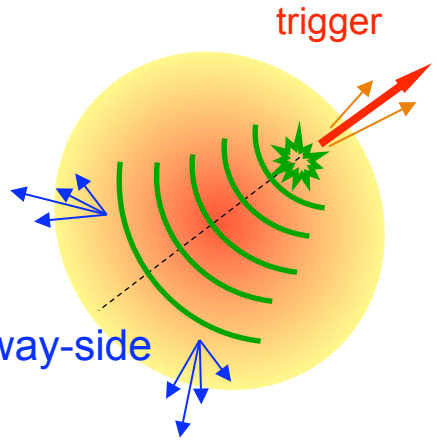
Multi-particle Correlations in STAR

-- evidence of conical emission

STAR: PRL **102**, 052302(2009)







= STAR large acceptance for correlation analysis

= Search for Mach cone with identified hadrons =>

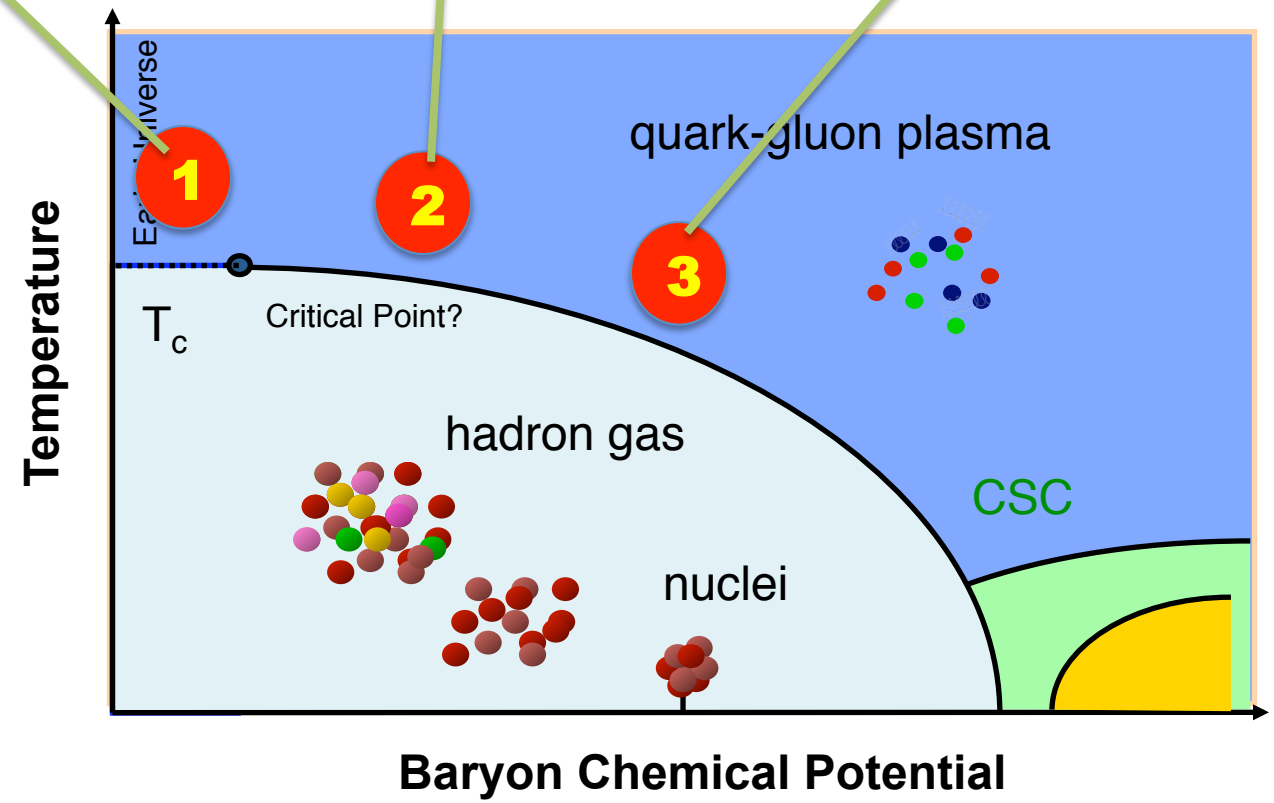
Properties of the EoS

RHIC Beam Energy Scan Program

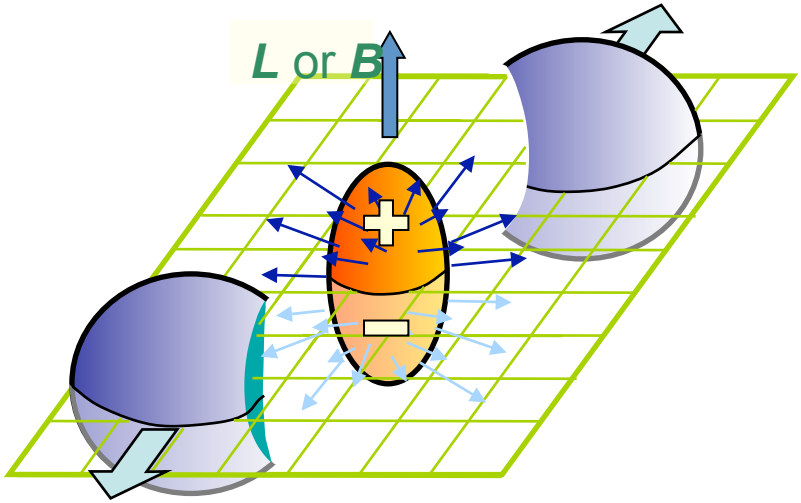
1 **Energy Frontier**
T_C
LHC, RHIC

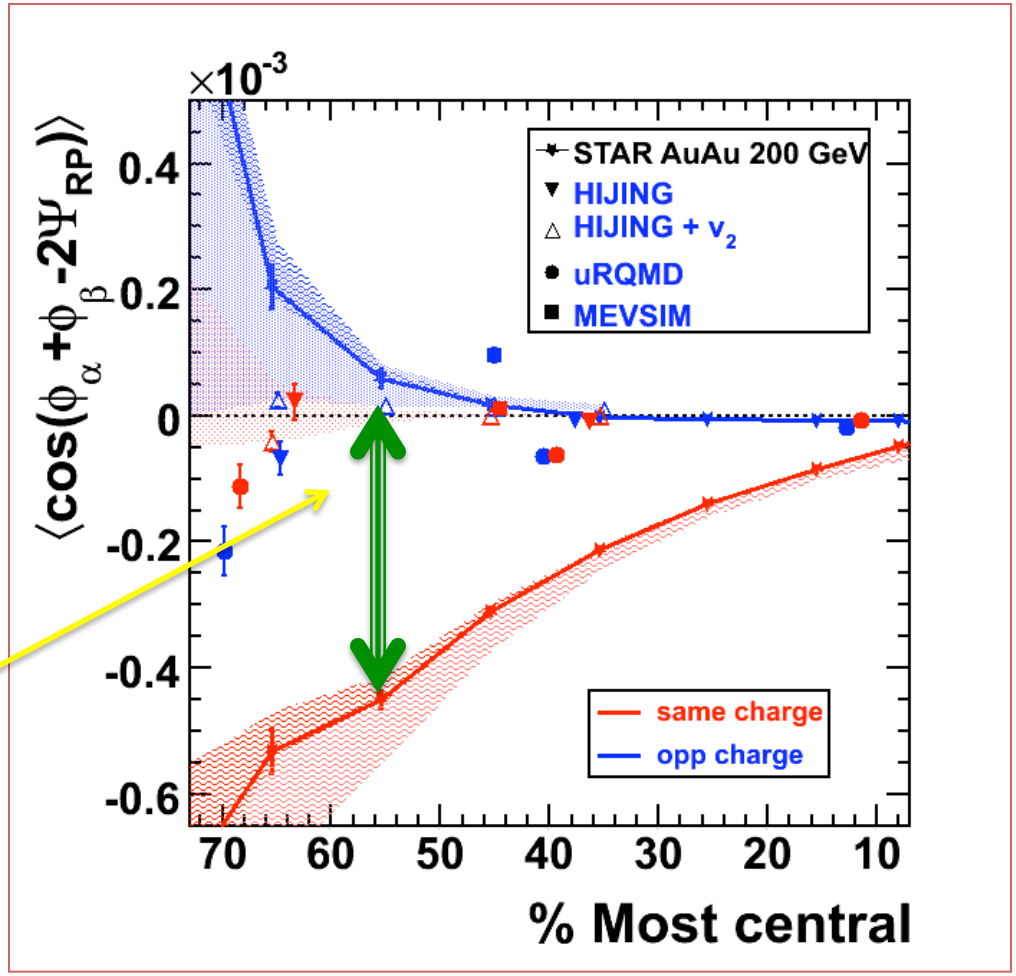
2 **Density Frontier**
T_E
RHIC, FAIR

3 **Baryon Density**
1st order pha. tran.
FAIR, NICA



Search for Local Parity Violation …



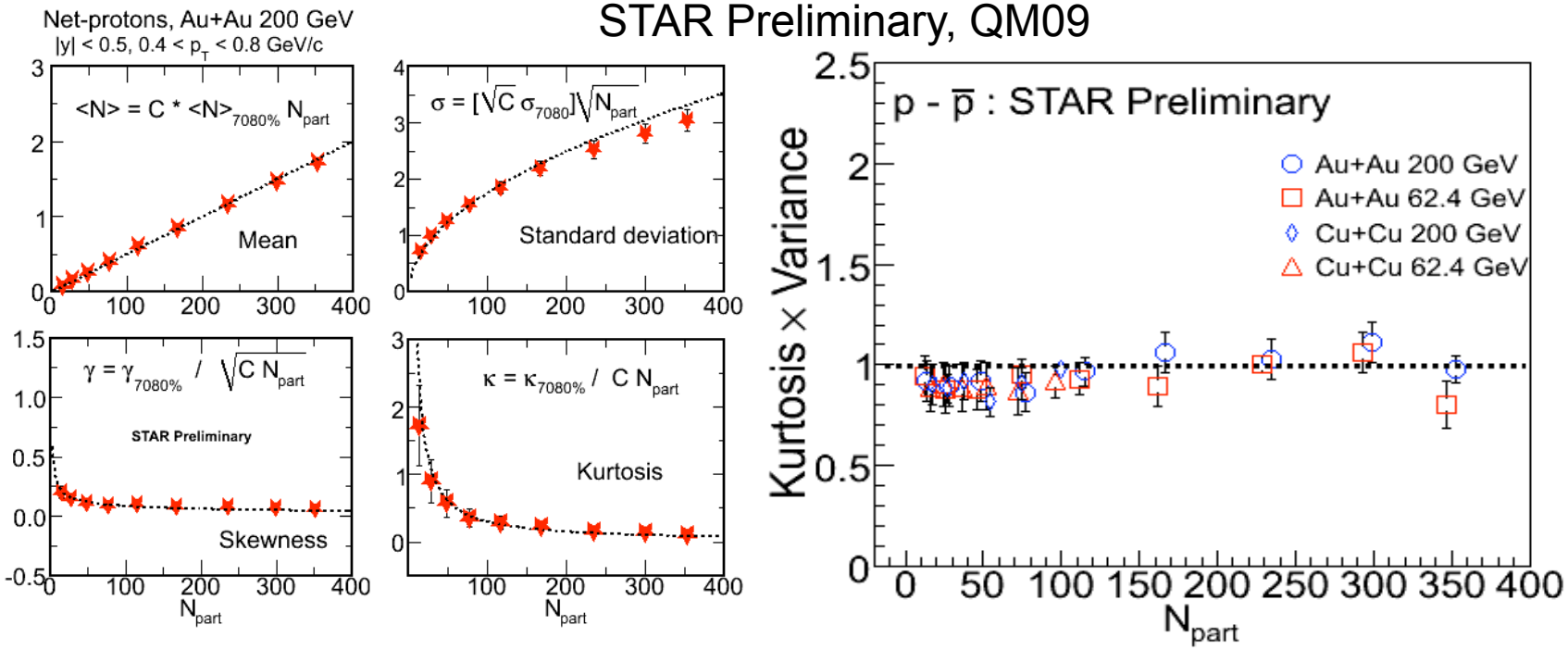


The separation between the same-charge and opposite-charge correlations.

- Strong EM fields
- De-confinement and Chiral symmetry restoration

- PID LPV analysis with TOF
- RHIC BES: disappearance

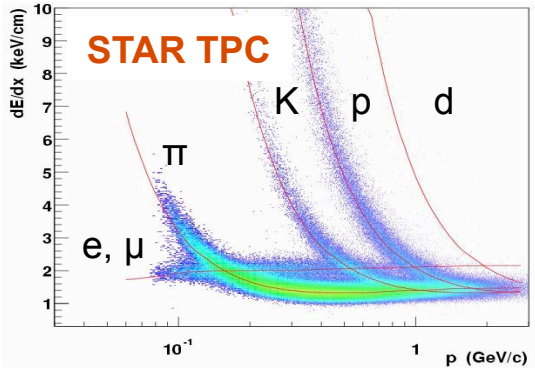
High Moment Analysis (BES)

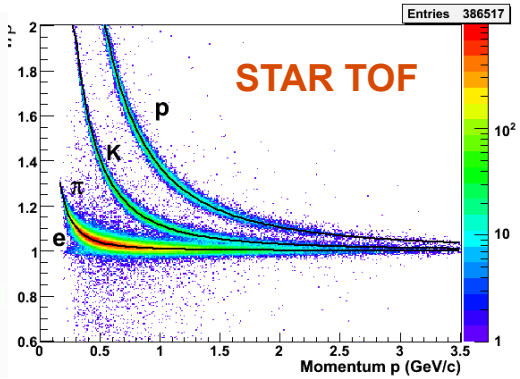


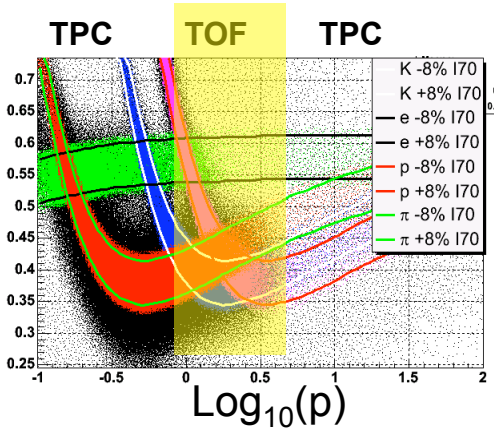
1) High moments are more sensitive to critical point related fluctuations

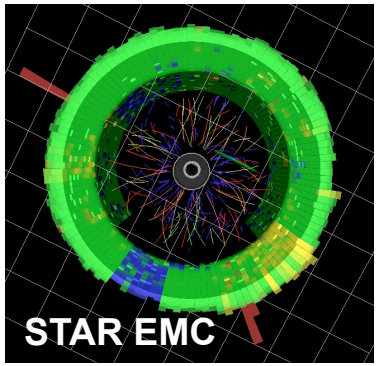
2) The 4th moment, Kurtosis, is directly related to the corresponding thermodynamic quantity: susceptibility for conserved quantum numbers such as Baryon number, charge, strangeness…

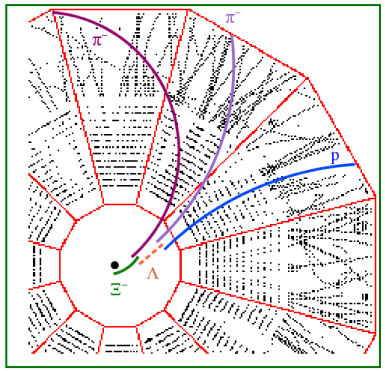
Particle Identification at STAR

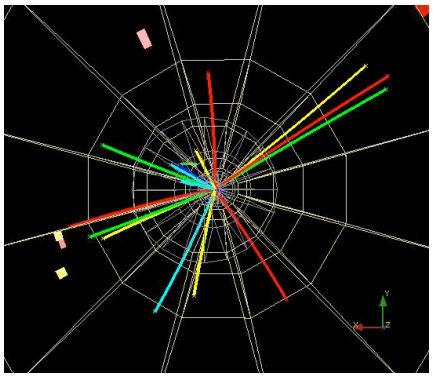


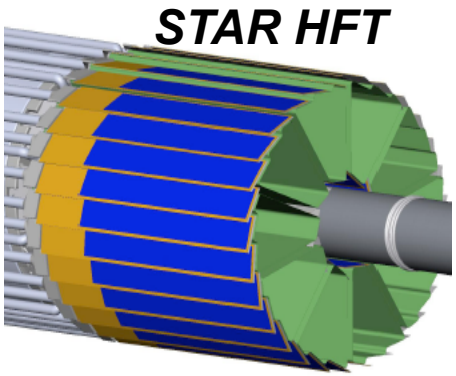








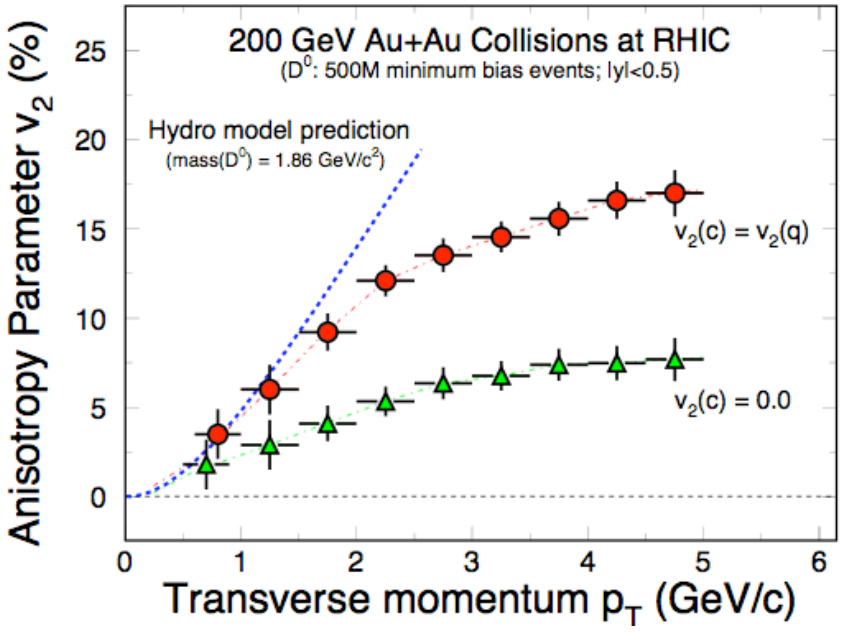




Neutral particles **Strange hyperons** **Jets** **Heavy Quark Hadrons**

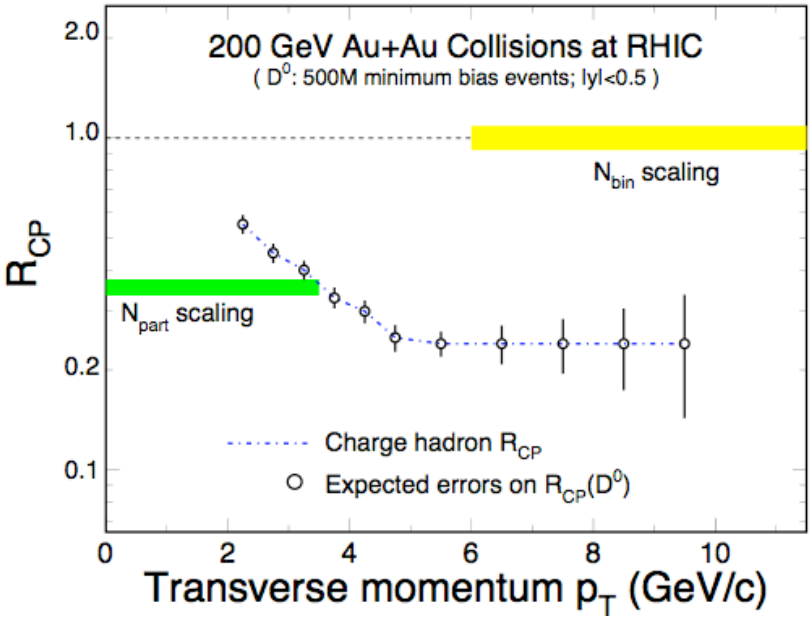
Multiple-fold correlations among the identified particles!

HFT: Charm Hadron v_2 and R_{AA}



- 200 GeV Au+Au m.b. collisions (500M events).
- Charm hadron collectivity ⇨ drag/diffusion constants ⇨

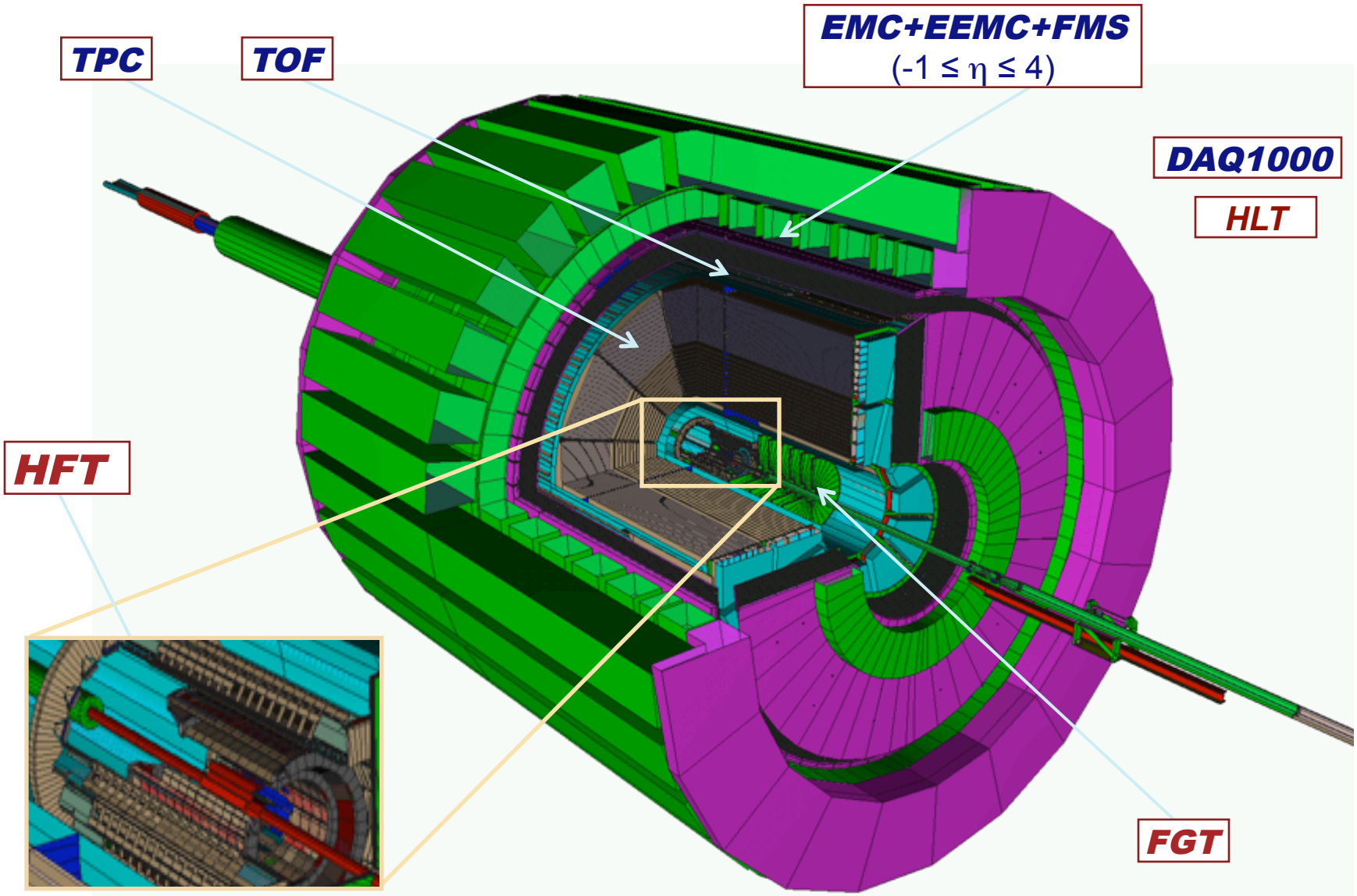
Medium properties!



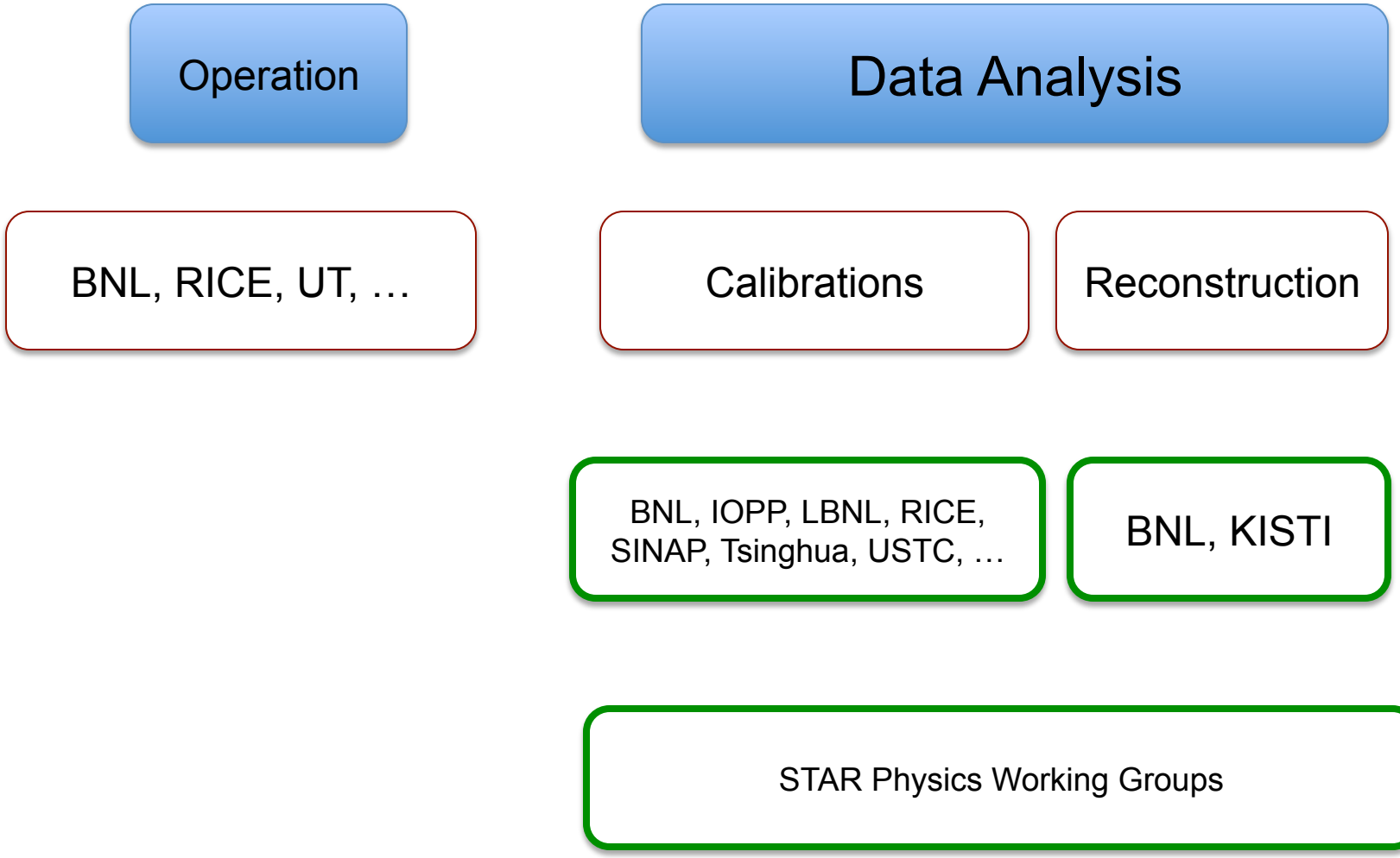
- 200 GeV Au+Au m.b. collisions (|y|<0.5 500M events)
- Charm hadron R_{AA} ⇨

- Energy loss mechanism!
- QCD in dense medium!

STAR Detectors: *Full 2π particle identification!*



TOF Operation and Data Analysis



Summary

TOF is a key upgrade at STAR . It greatly extends STAR's PID capabilities for multiple physics topics, including:

- Thermalization at RHIC

- QCD phase boundary and critical point

- In-medium properties

- Study gluon-rich phenomena at RHIC

STAR thanks DoE NP and NNSFC for their support!