the STAR Physics Program

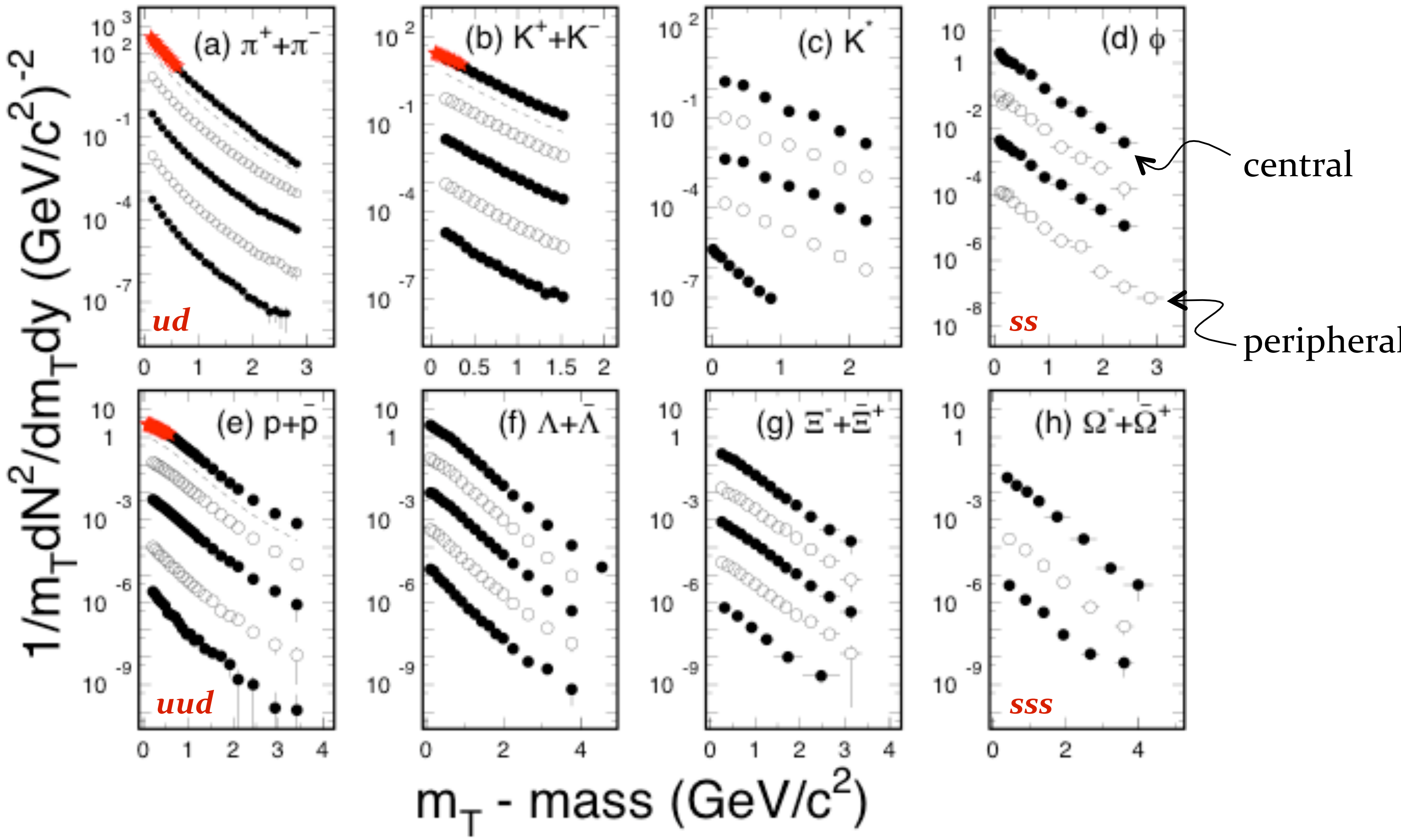
Highlights, Goals and the Future for STAR

Outline

- Highlights from the STAR experiment
  - Spectra and nuclear modification
  - Flow coefficients: m_T and quark number scaling
  - Di-hadrons and the ridge
- Heavy-Ion goals for the second decade of RHIC
  - Critical Point
  - Onset of Deconfinement
  - Characterization of QGP
- Timely, goal focused, and shovel-ready upgrades
  - DAQ Upgrade: DAQ1000
  - Barrel Time of Flight: TOF
  - Heavy Flavor Tracker: HFT
  - Forward Gem Tracker: FGT

Highlights: Hadron Spectra

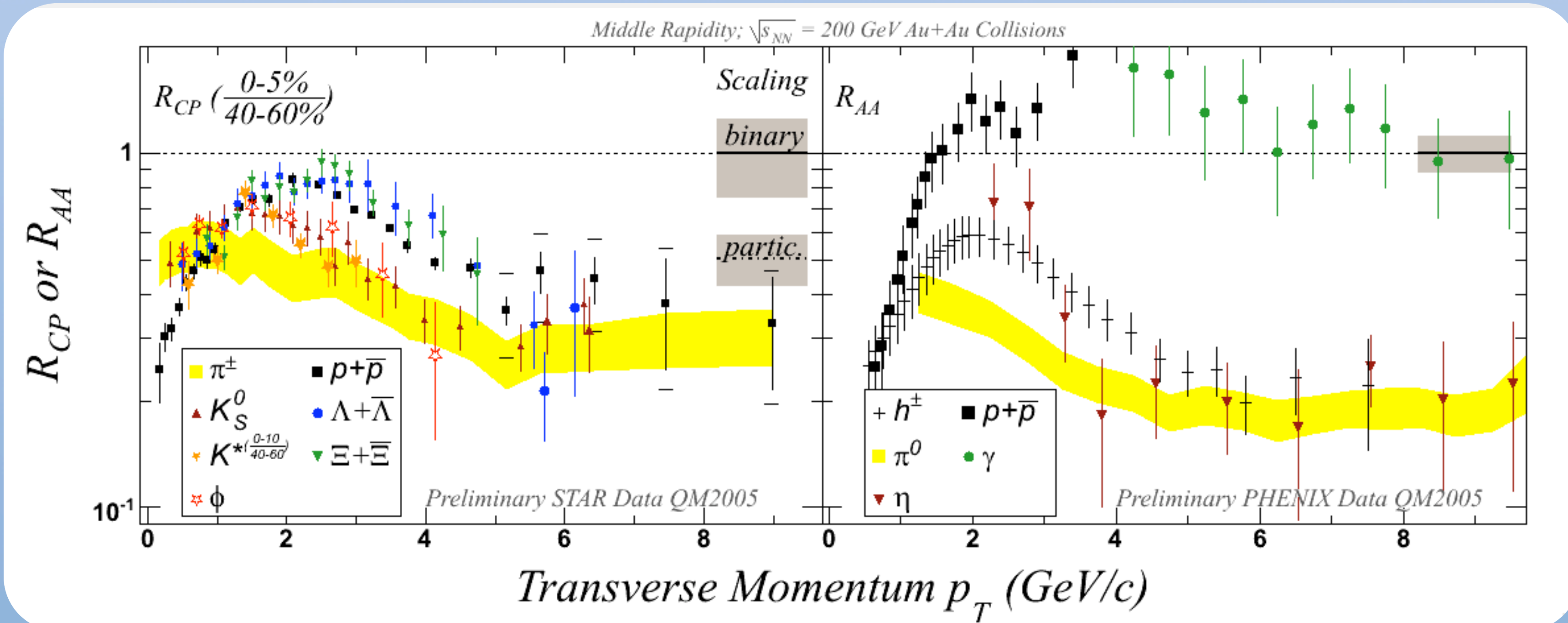
p+p and Au+Au collisions at 200 GeV



Spectra from light hadrons up to multi-strange hadrons

STAR white papers - Nucl. Phys. A757, 102(2005).

Highlights: Nuclear Modification



Phys.Rev.Lett.92:052302,2004

Key Features:

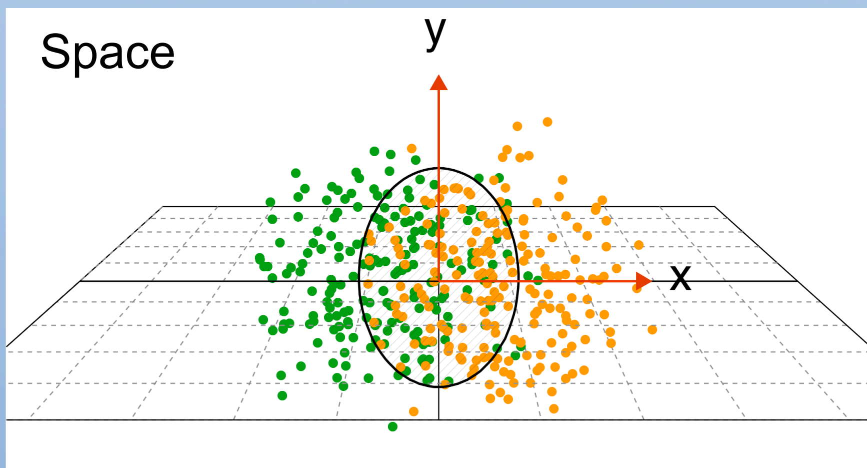
Suppression by a factor of 5 at $p_T > 6$ GeV/c

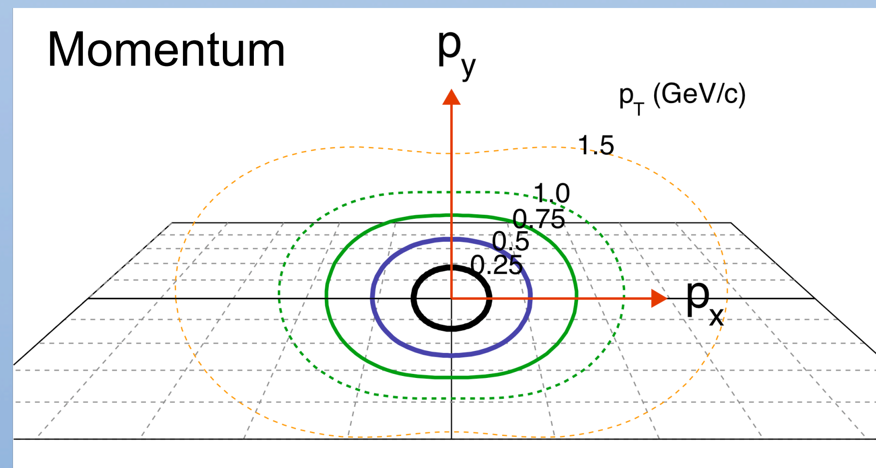
Centrality dependence at low p_T is governed by mass

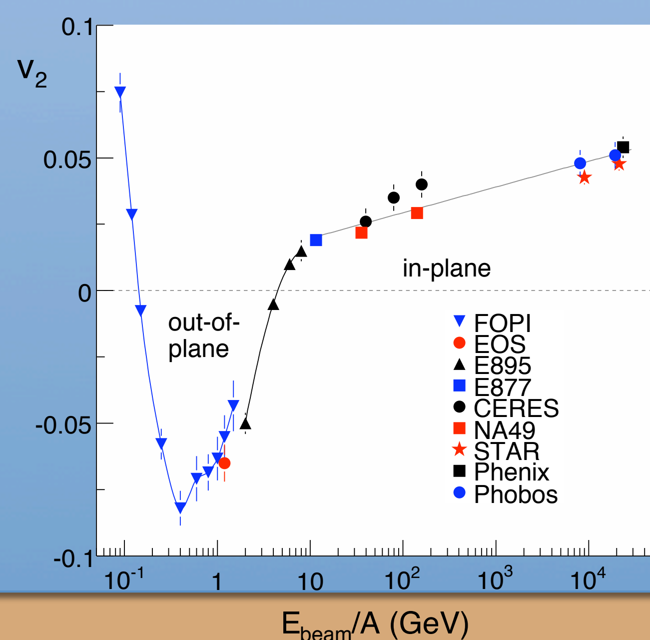
At intermediate p_T, centrality dependence governed by **number of constituent quarks**

Highlight: Elliptic Flow at RHIC

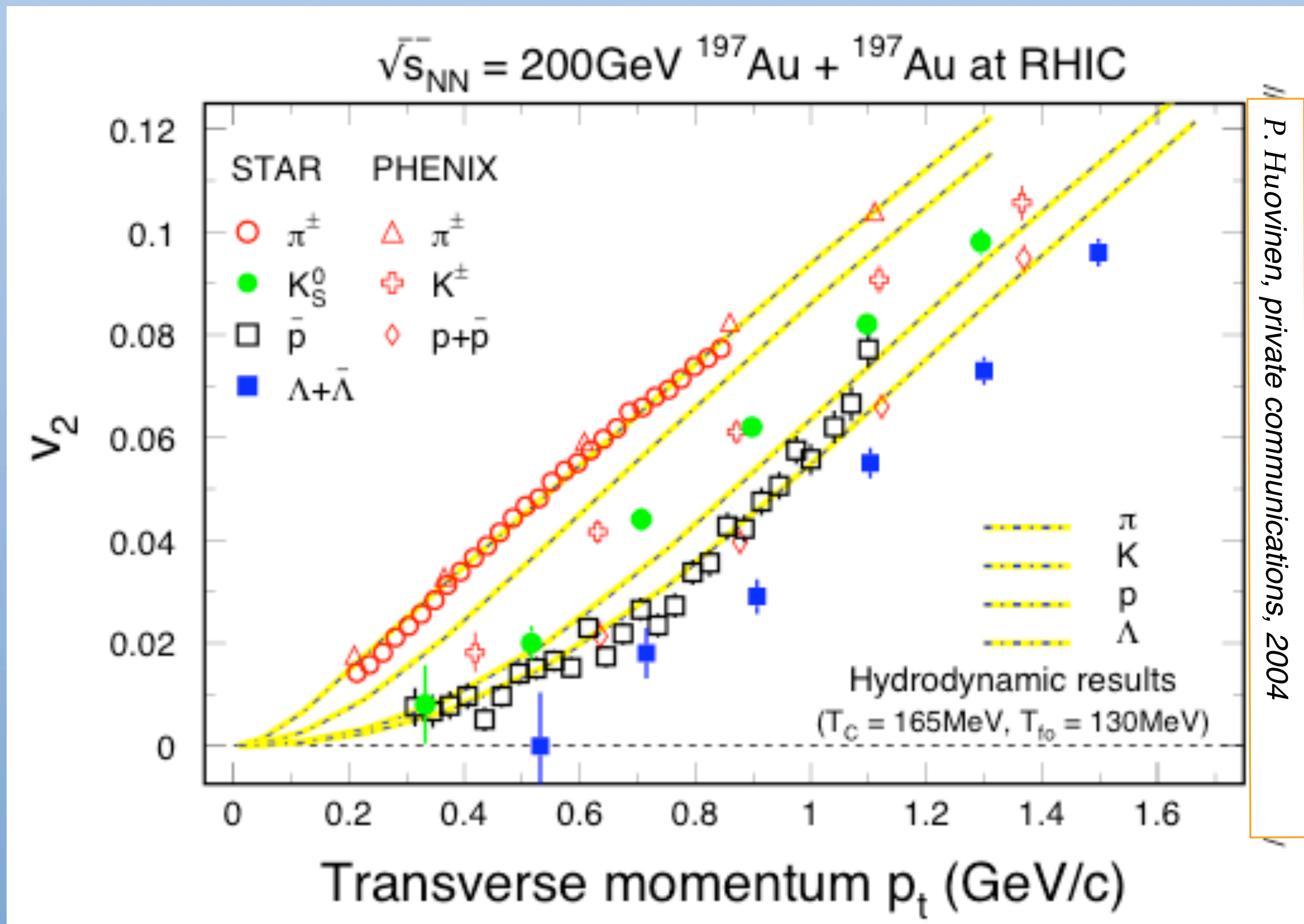
Large Elliptic Flow: A Signal of Strong Space-Momentum Correlations







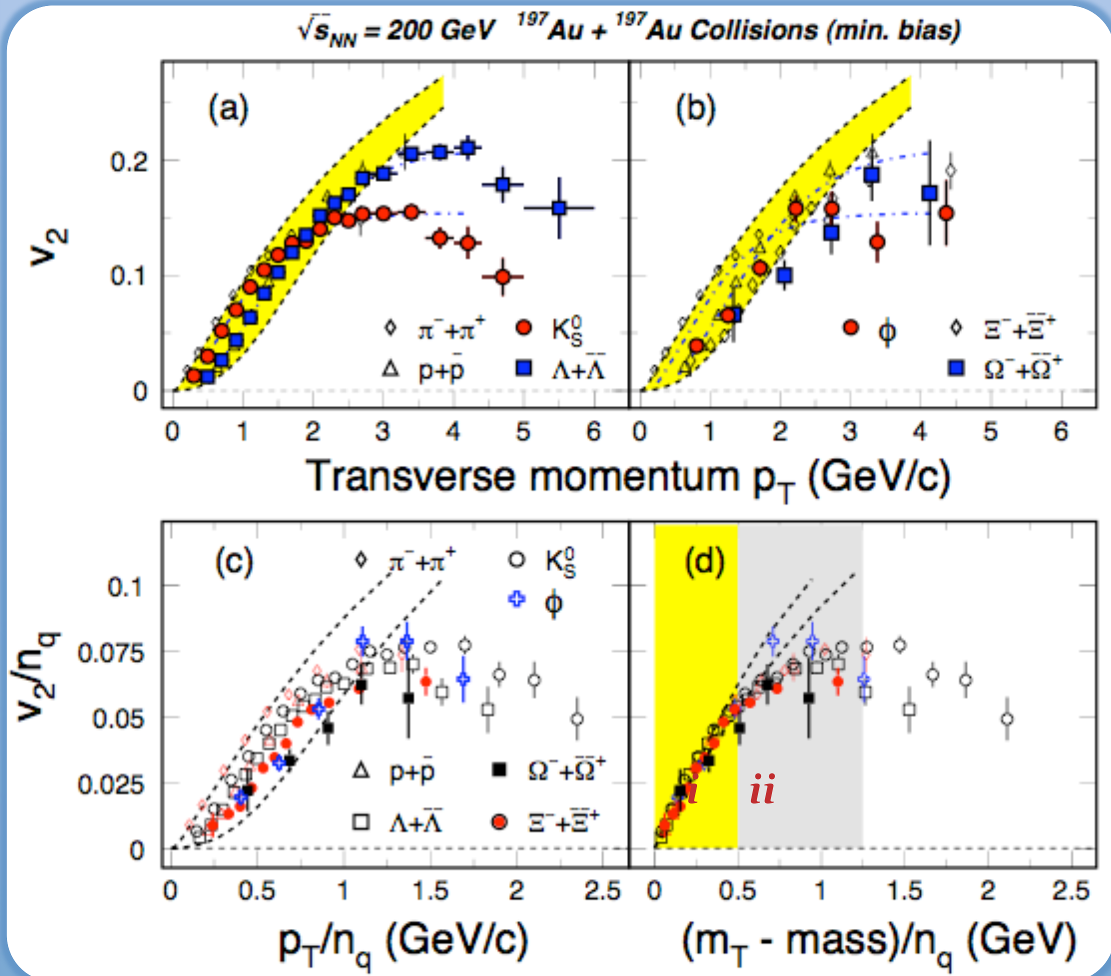
Highlights: Elliptic Flow



Phys.Rev.Lett.92:052302,2004

Mass ordering of $v_2(p_T)$: consistent with emission from a boosted source

Highlights: Flow Scaling



- v_2 of light hadrons and multi-strange hadrons
- scaling by the number of quarks

At RHIC:

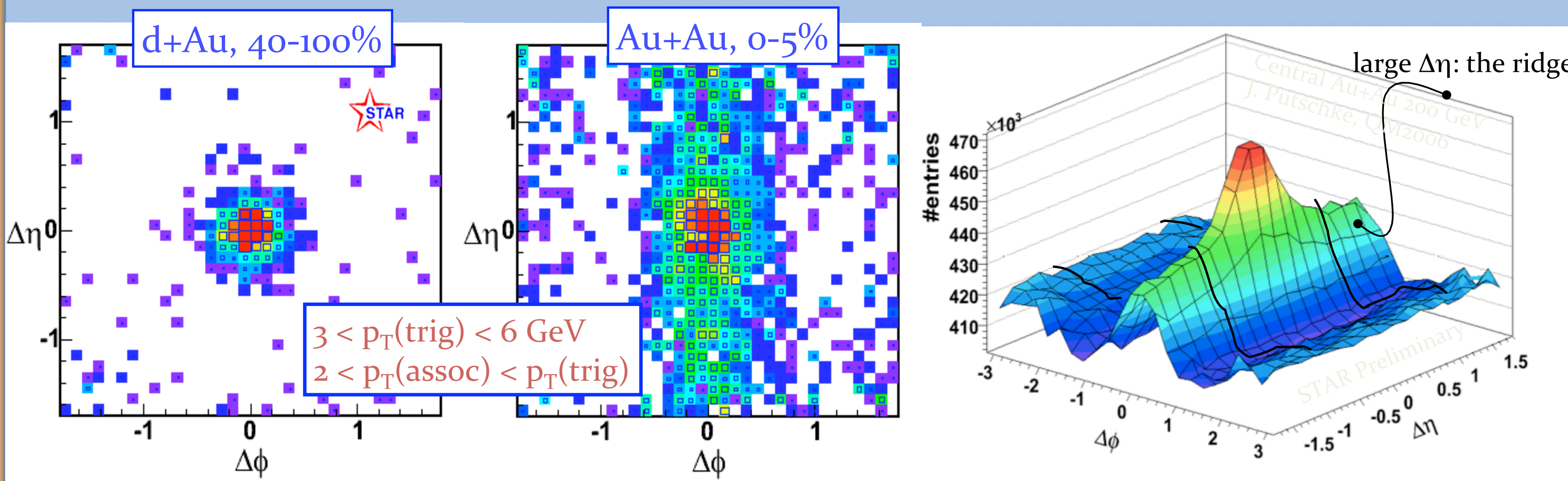
- ⇨ **N_q scaling** novel hadronization process
- ⇨ **φ and Ω flow** De-confinement

*PHENIX: PRL**91**, 182301(03)*
*STAR: PRL**92**, 052302(04), **95**, 122301(05) nucl-ex/0405022, QM05*

S. Voloshin, NPA715, 379(03)
*Models: Greco et al, PR**C68**, 034904(03)*
Chen, Ko, nucl-th/0602025
*Nonaka et al. **PLB583**, 73(04)*
*X. Dong, et al., Phys. Lett. **B597**, 328(04).*
*Fries, Greco, Sorensen, Ann.Rev.Nucl.Part.Sci **58***

Highlights: The Ridge

A structure unique to Au+Au collisions!



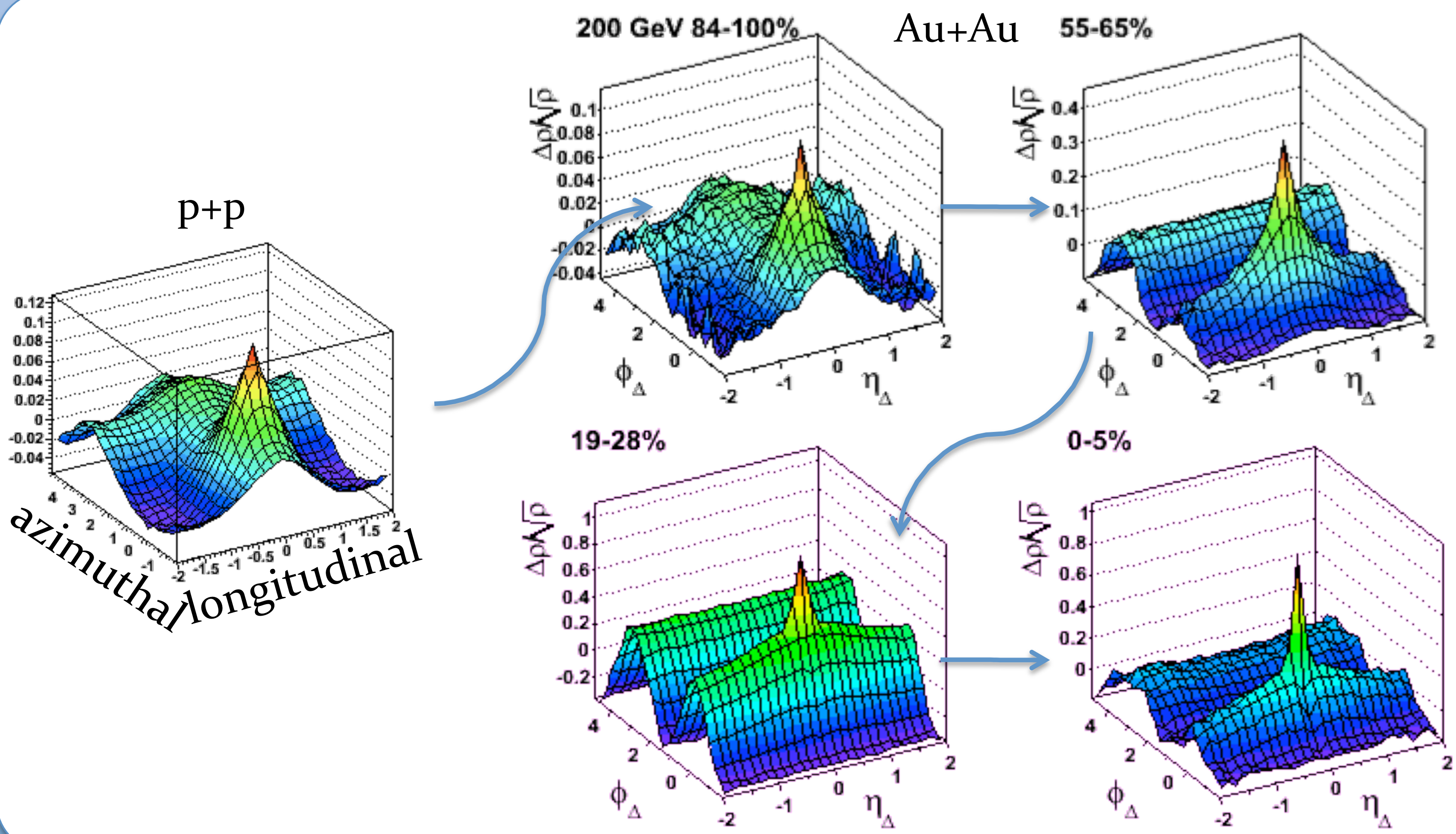
A "model independent" *conclusion:*

- Δη width of the ridge points to correlations from very early times
- short range bulk correlations would imply late/phase-boundary *(cross-over at RHIC...)*

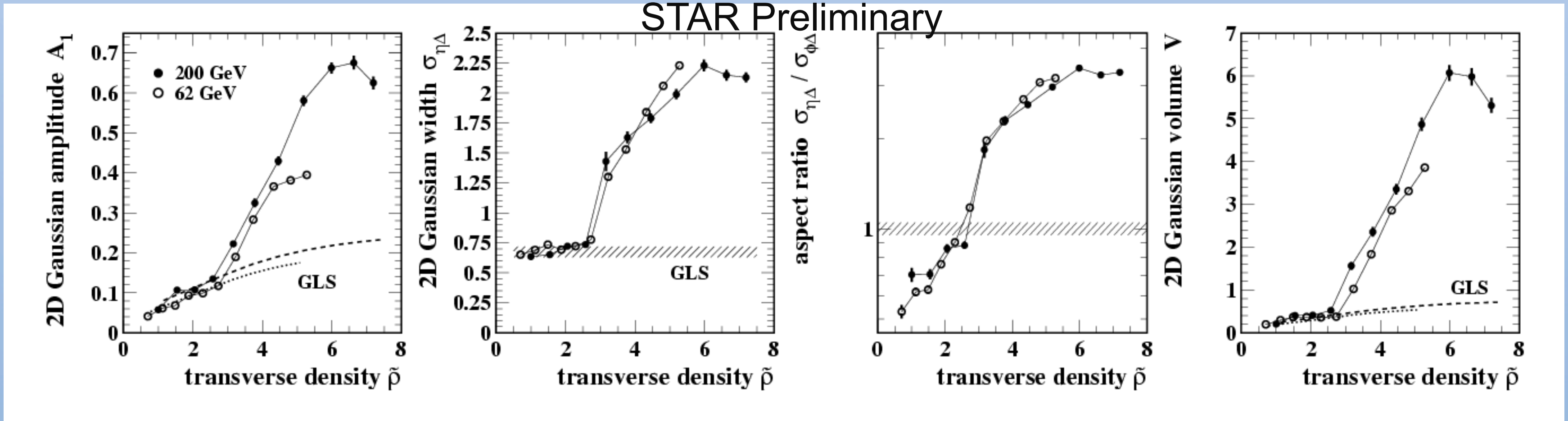
Highlights: 2-D Correlations

Correlations of all unique pairs of charged particles:

STAR can measure the ***charge sign, momentum***, and ***particle-type*** dependence



Highlights: Transition

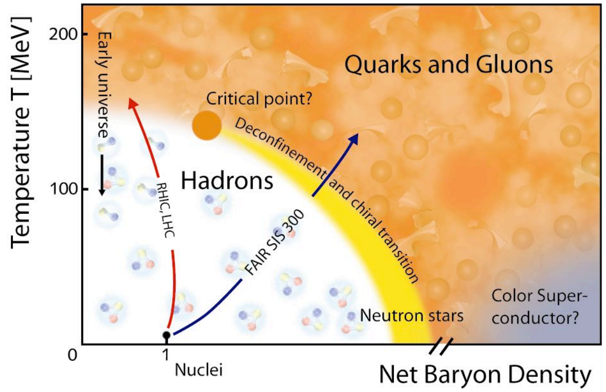


$$\tilde{\rho} = \frac{3}{2}\frac{dN_{ch}}{d\eta} / S \qquad \varepsilon_{BJ} = \frac{dE_T / dy\big|_{y=0}}{\pi R^2 \tau_0}$$

Apparent transition occurs at a fixed particle density, *perhaps related to the energy density*

Indicates the **onset** of new physics: QGP? Deconfinement? Glasma? Minijets? *Explanation not yet established.*

STAR's Focus in the 2nd Decade

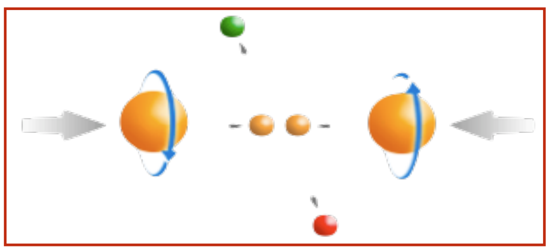


1) Heavy-ion program

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

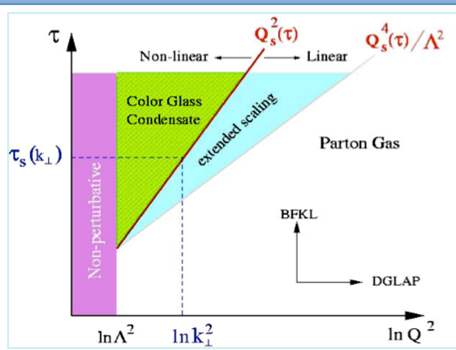
2) RHIC beam energy scan

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



Polarized spin program

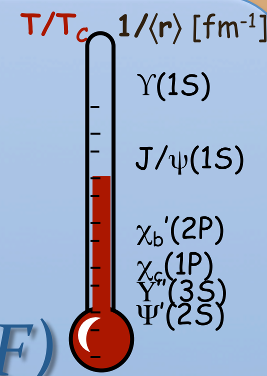
- Study ***intrinsic properties of the proton***



Forward program

- Low-x properties, search for ***CGC***
- Elastic (inelastic) processes (pp2pp)
- Investigate ***gluonic exchanges***

Studies of sQGP



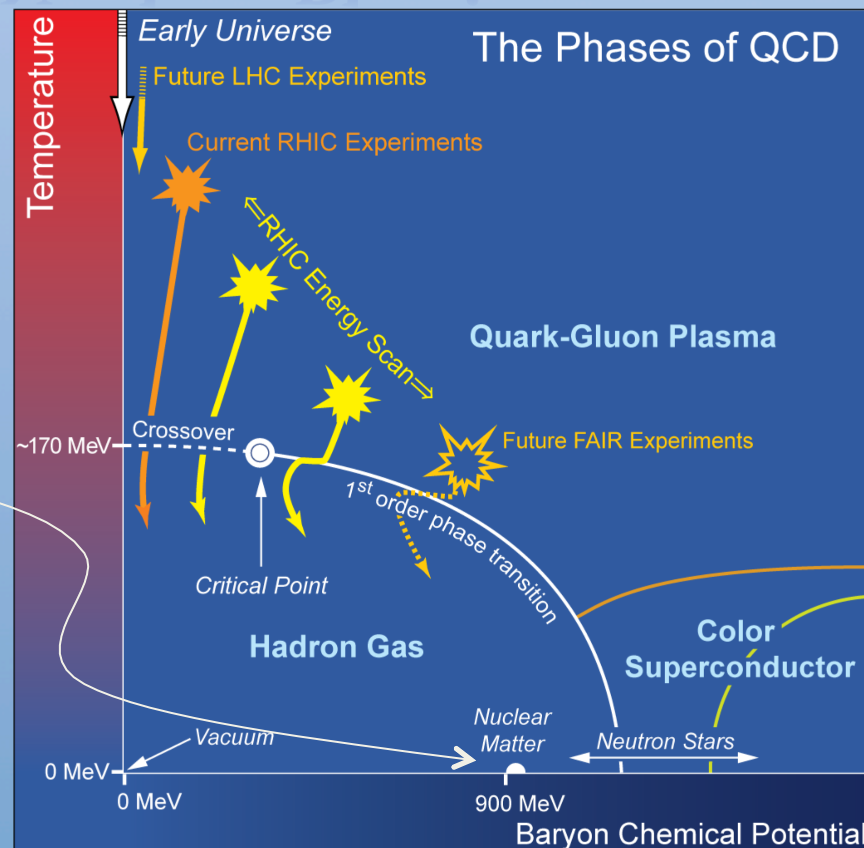
- Next Steps in Quantifying the sQGP
  - Quarkonium: *the QGP Thermometer*
  - Open Heavy-Flavor: *Transport Properties*
  - Jet Finding: *Understanding Energy Loss (FF)*
  - Fluctuations and Correlations: *Viscosity and Quantifying Incomplete Equilibration*
- Possible with Timely and Focused Upgrades
  - **TOF:** *Full Barrel PID (75% complete)*
  - **DAQ1000:** *Take advantage of RHICs Luminosity*
  - **HFT:** Open Heavy Flavor
  - **FGT:** Forward Tracking for W charge to access polarized sea

RHIC Beam Energy Scan

One Century of Nuclear Physics

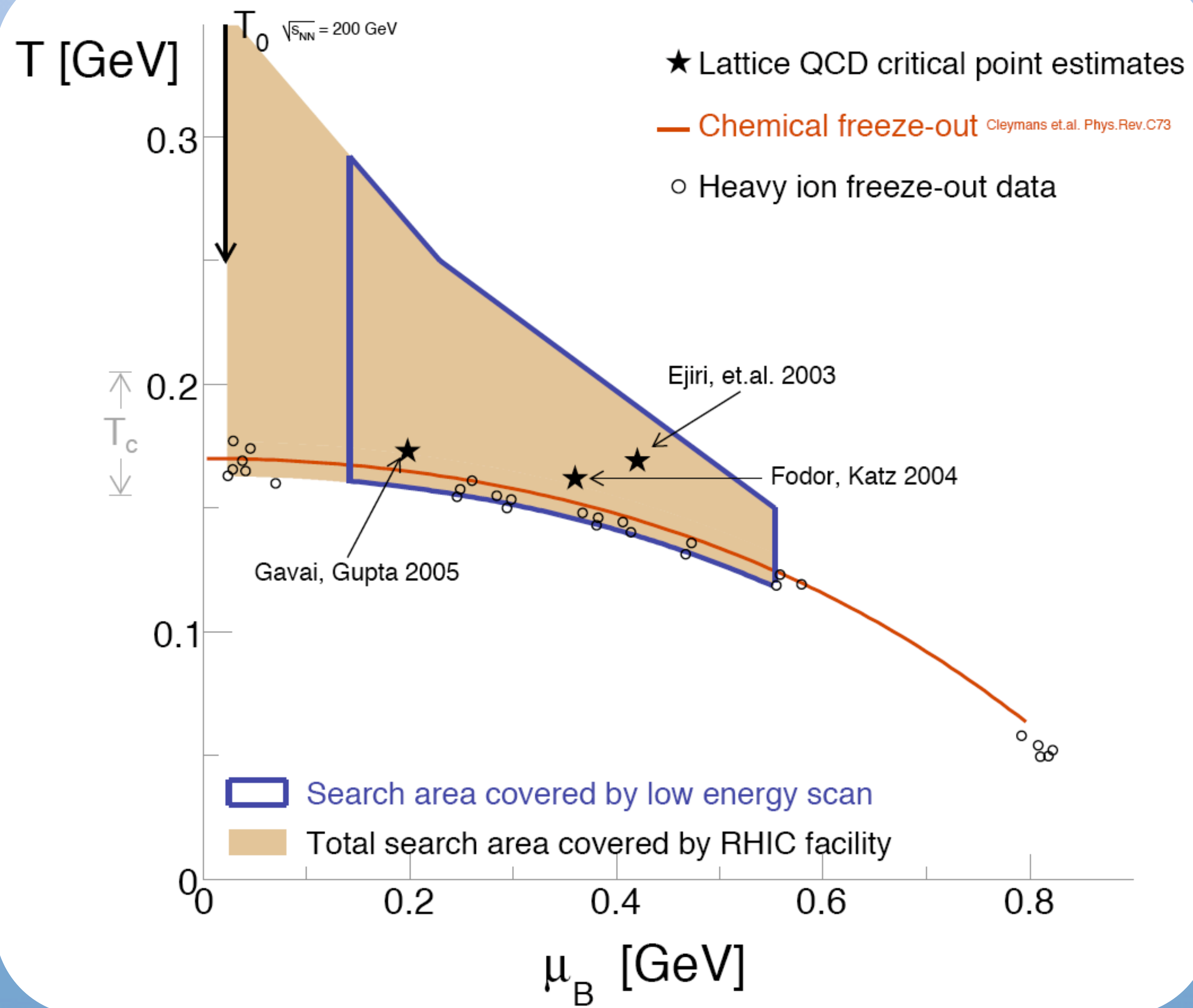
In 1911, Rutherford discovered the nucleus, making him the first nuclear physicist

100 years later, RHIC will scan for the next landmark on the nuclear matter phase diagram: **the critical point**

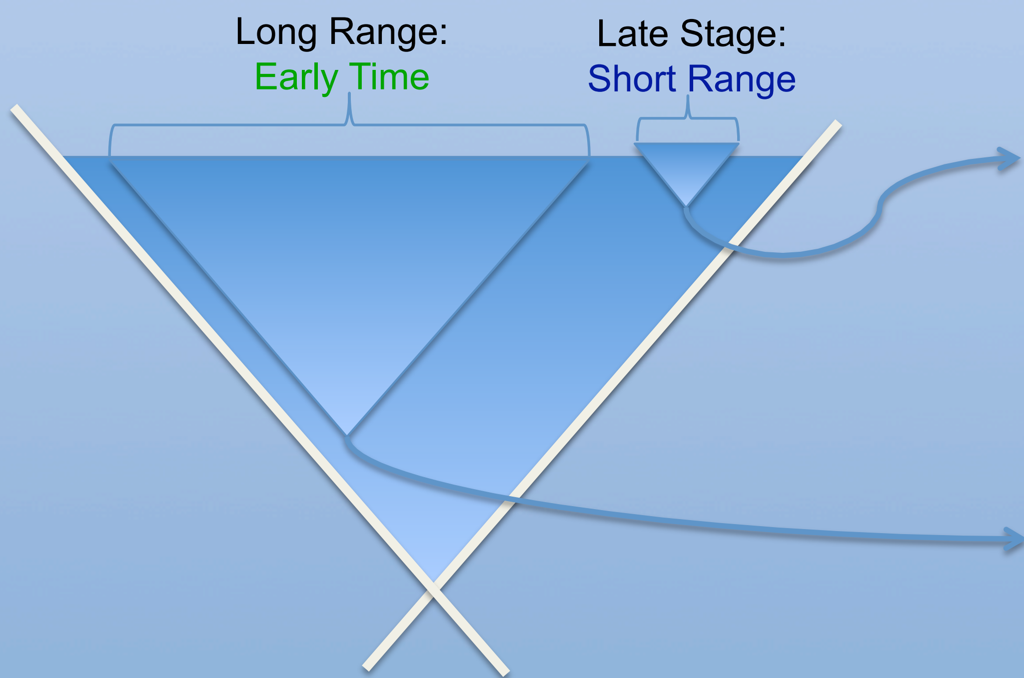


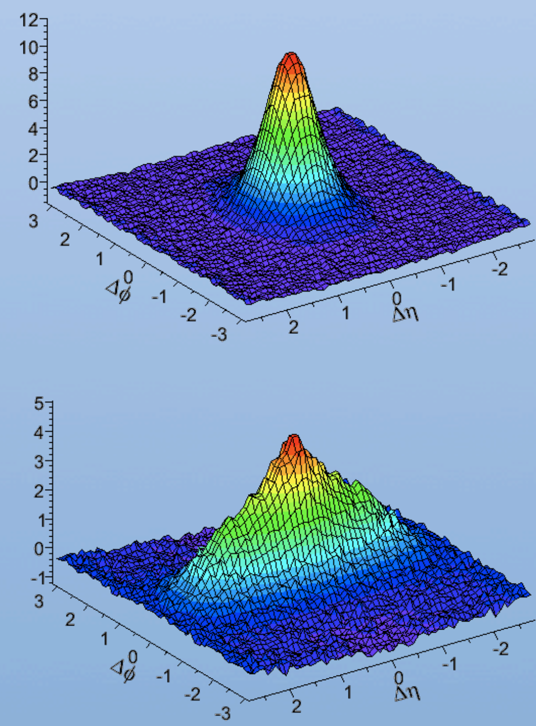
See Declan Keane's Talk Tomorrow

RHIC: Ideally Suited



Size Matters: Origin of Correlations





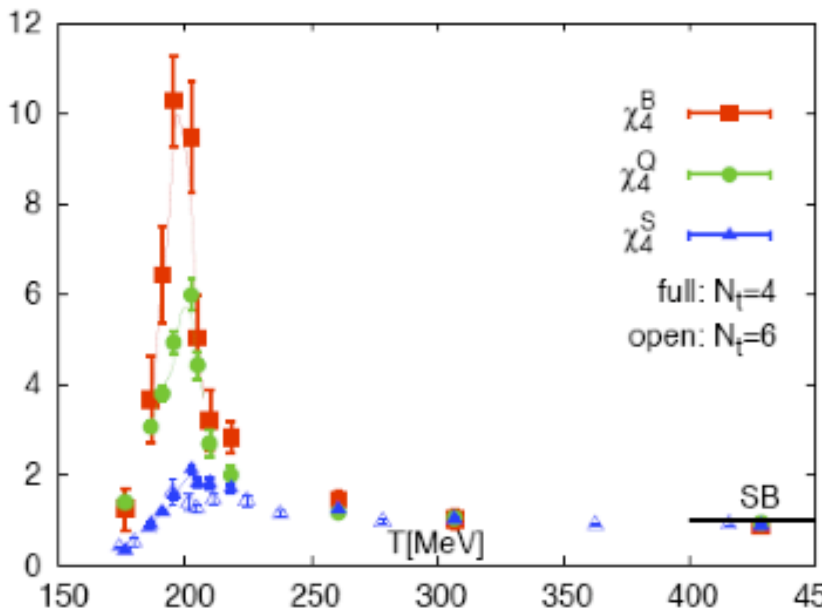
Unlike the ridge, *related by causality arguments*★ *to early times*, phase boundary correlations will be narrower in Δη

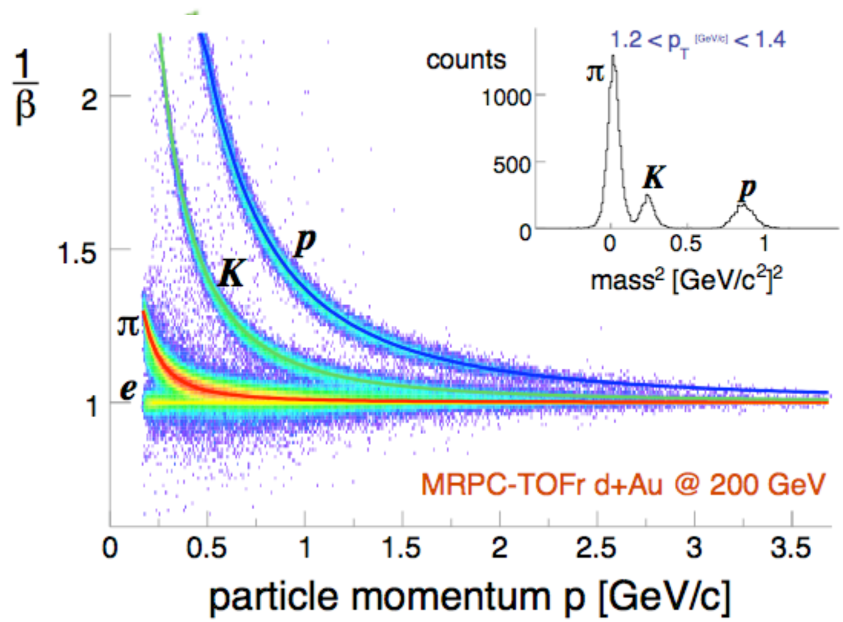
★Dumitru, Gelis, Venugopalan, McLerran: Nucl. Phys.A 810:91,2008

Good Δϕ Δη coverage needed to identify the source of correlations and fluctuations

PID matters: Phase Transitions

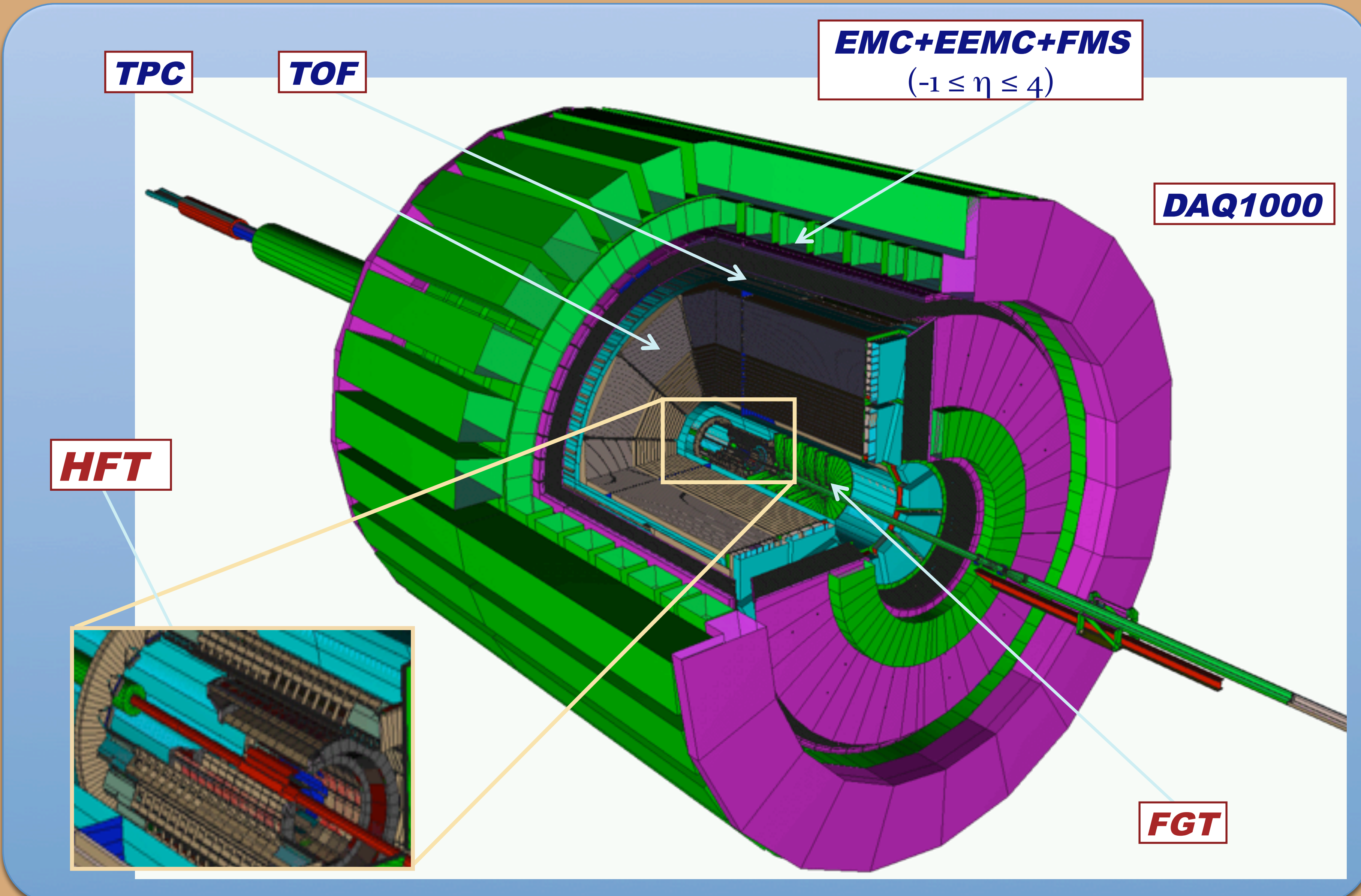
Rutherford's discovery of the nucleus in 1911 relied on state-of-the art technology developed by Hans Geiger to count alpha particles. The state-of-the-art technology at the heart of STAR's Time-of-Flight upgrade increases the possibility that STAR will locate that other landmark on the nuclear matter map: the critical point.



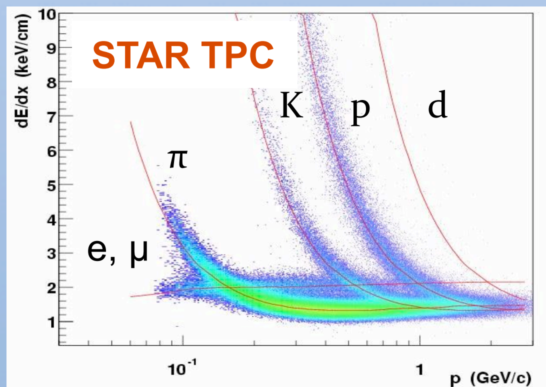


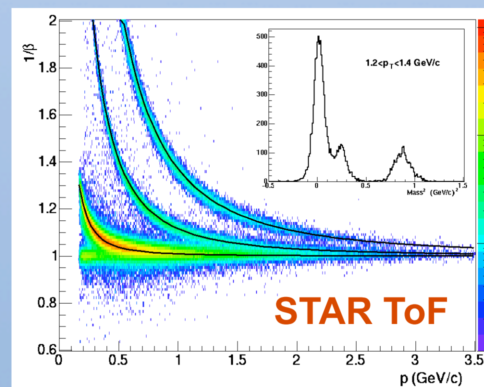
PID to measure moments of the distributions of conserved quantities

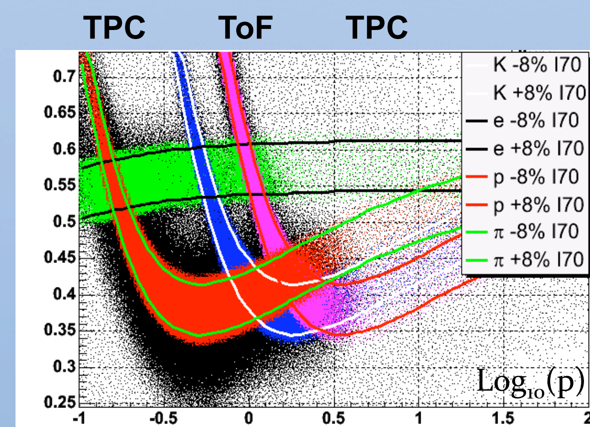
STAR Detectors: *Full 2π particle identification!*

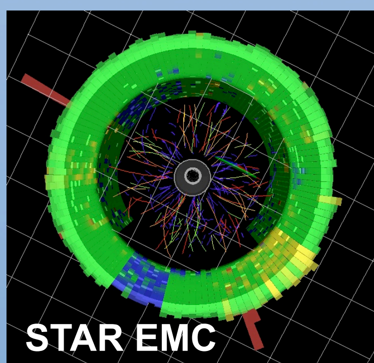


PID and Acceptance at STAR

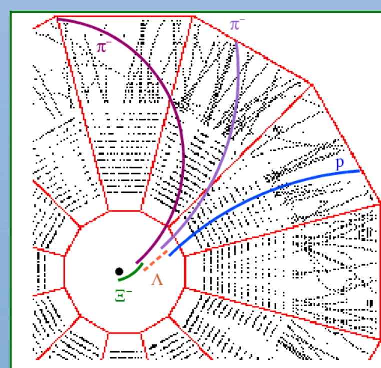




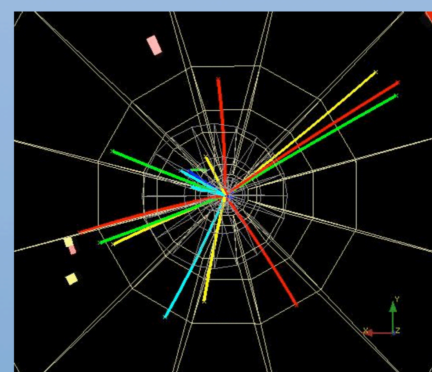




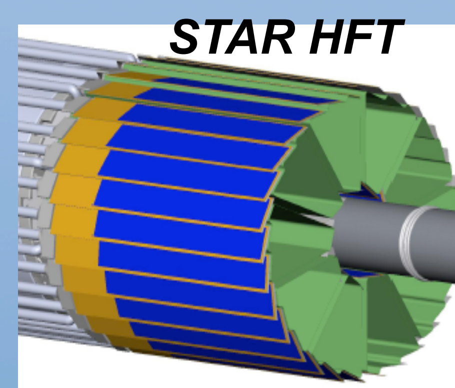
Neutral Particles



Strange Hyperons



Jets



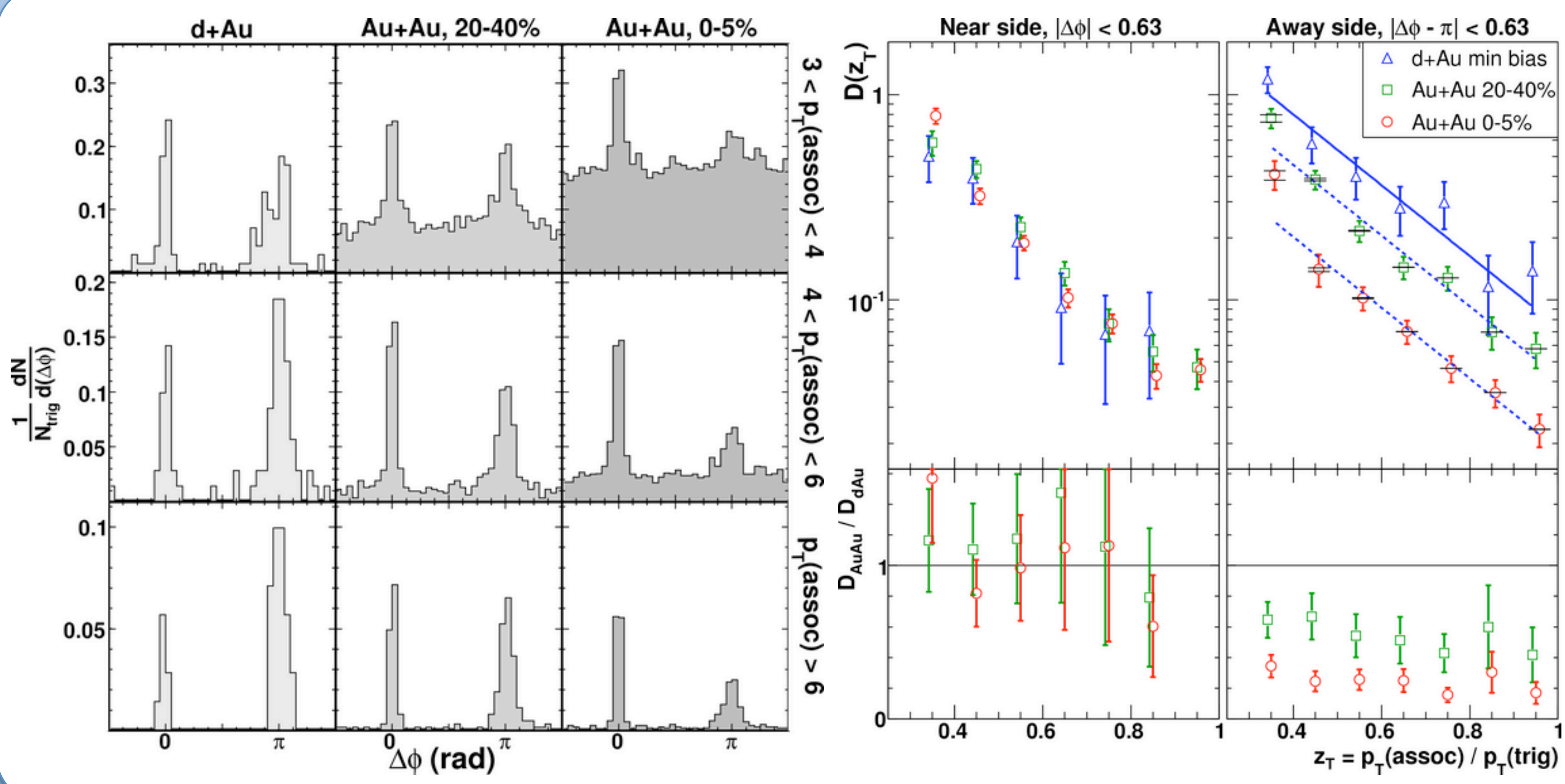
Open Heavy Flavor

Multiple-fold correlationsidentified for particles over large acceptance!

Summary

- THE FIRST DECADE OF RESEARCH AT STAR
  - Strongly Interacting Hot and Dense Matter Produced in 200 GeV Au+Au collisions
- THE NEXT DECADE
  - Characterize the Matter
  - Explore the QCD Landscape
  - RHIC Provides the Luminosity and Flexibility
  - STAR Detector Upgrades are Focused on Accomplishing Our Goals

Highlights: Dijet Suppression



Direct observation of Dijets through dihadron correlations
Away-side peak suppressed by a factor of 5