RHIC Energy Scan Program

Plans and Status

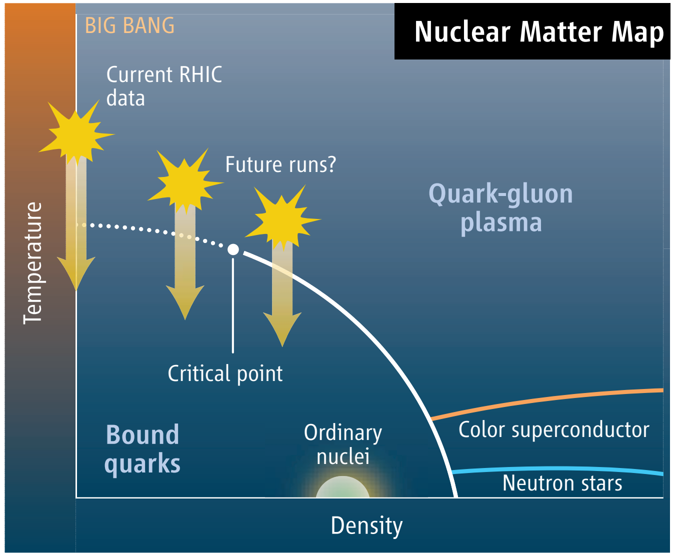
Tim Schuster

H-QM Helmholtz Research School
Quark Matter Studies

Johann Wolfgang Goethe
Universität
Frankfurt am Main

Outline

- A landmark study: Explore the phase diagram of strongly interacting matter
- RHIC capabilities for the study:
  - Accelerator status
  - Experimental status, planned upgrades
- What do we know? What to look for? Physics observables in the energy scan



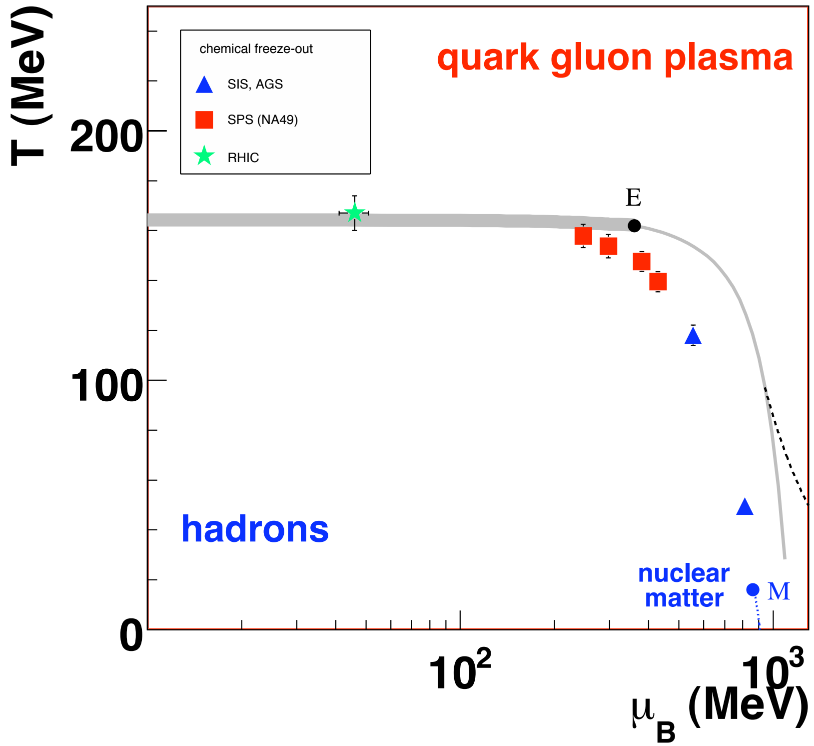
Landmark study. Physicists have seen a smooth transition from bound quarks to quark-gluon plasma (dotted line). They now hope to find the point beyond which the transition becomes violent (white line).

Science 312 (2006)

Motivation

Explore the phase diagram of strongly interacting matter

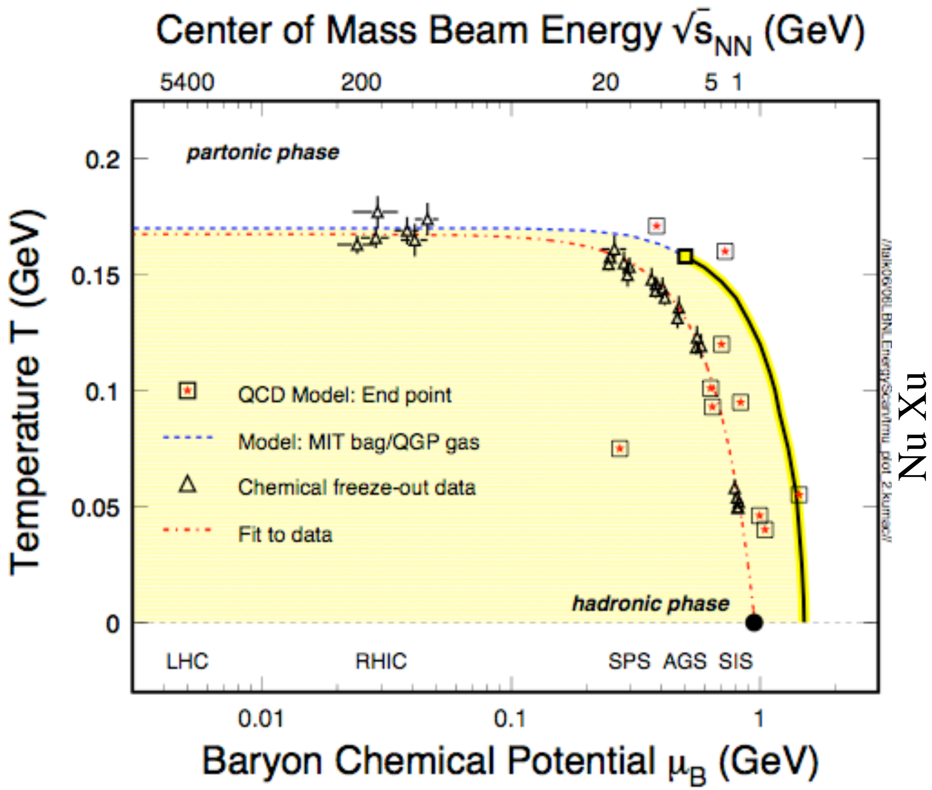
- Theoretical constraints:
  - T = 0 First order phase transition
  - $\mu_B = 0$, $T = T_C$ Crossover
  - Critical Point at finite μ_B
- Experimental constraints
  - Signatures for deconfinement at RHIC and top SPS
  - Disappearance of these signatures at SPS energies?



Introduction RHIC @ BNL

- Has already explored an important part of the phase diagram:
  - Signatures for deconfinement
  - Studying properties of deconfined matter
- Energy/System size scan up to now

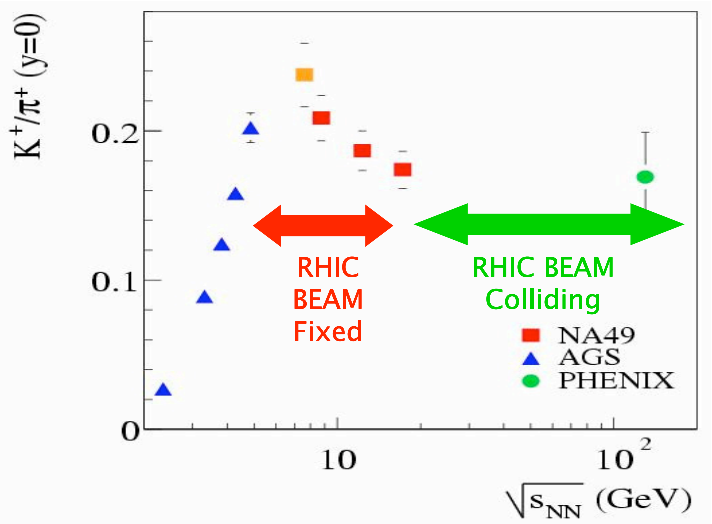
	200	130	62.4	20
Au+Au	✓	✓	✓	✓
Cu+Cu	✓		✓	✓
p+p	✓			

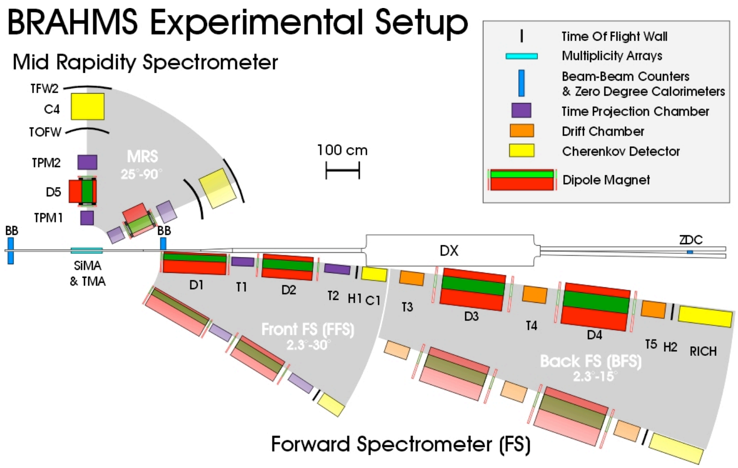


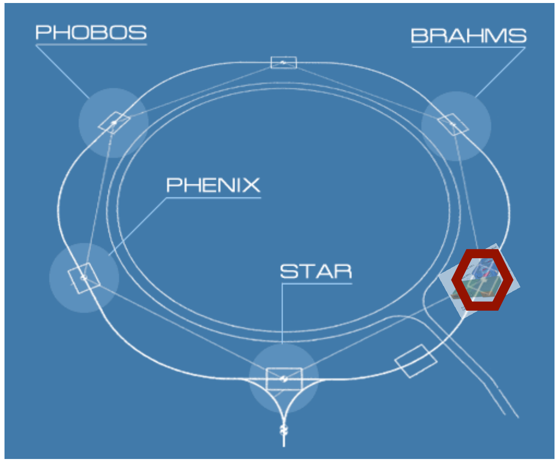
Critical point and 1st order phase transition line are *the* landmarks - are they accessible at RHIC?

First Ideas for RHIC-Low Energy

- Fixed target RHIC program
  $10 < E_{\mathrm{Beam}} < 100\ A\mathrm{GeV}$
- Cross-check the structures seen in hadron production excitation functions
- Use BRAHMS, NA49 detector?







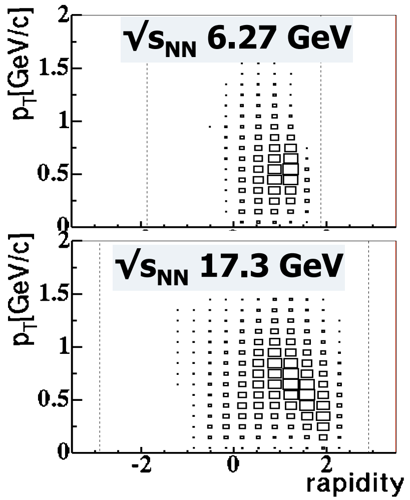
F. Videbaek: CPOD Workshop Bergen 2005

Fixed Target vs Collider Mode

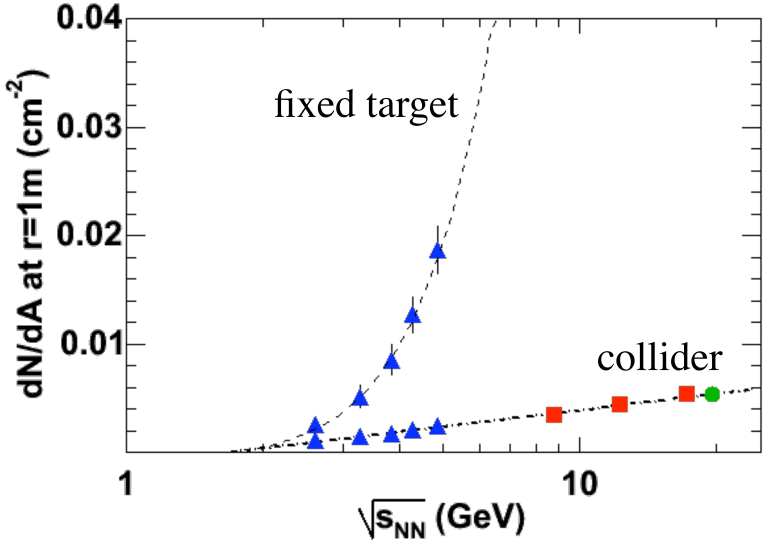
Advantages of collider mode over fixed target:

- Acceptance stays constant with energy
- Spatial track density rises slower

NA49 acceptance



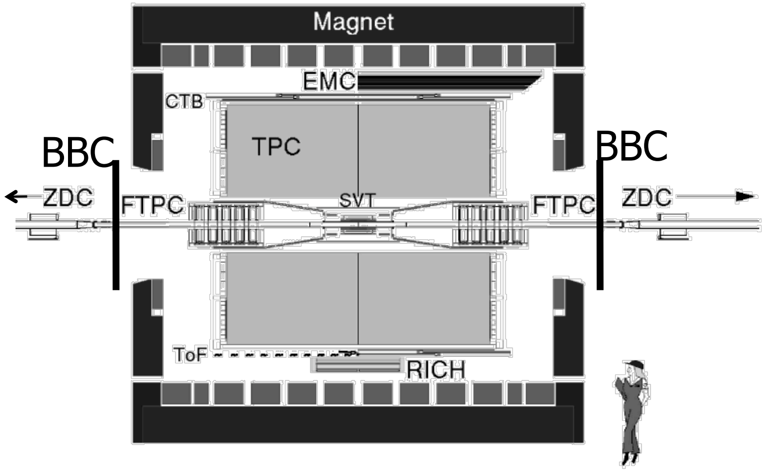
C. Roland



G. Roland

Accelerator Collider Mode

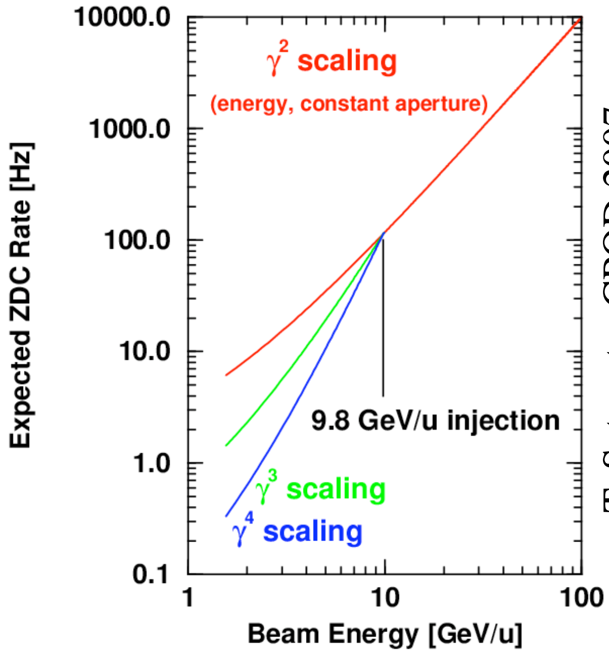
Potential collider mode drawbacks:



Trigger

Zero Degree Calorimeters not usable at low energy

→ Beam Beam Counters receive sufficient hits to be used ✓



T. Satogata: CPOD 2007

Rate

Injection energy from AGS: 9.8 GeV/u per beam ($\sqrt{s_{NN}}$ = 19.6 GeV)

γ^2 scaling of luminosity at higher energies.

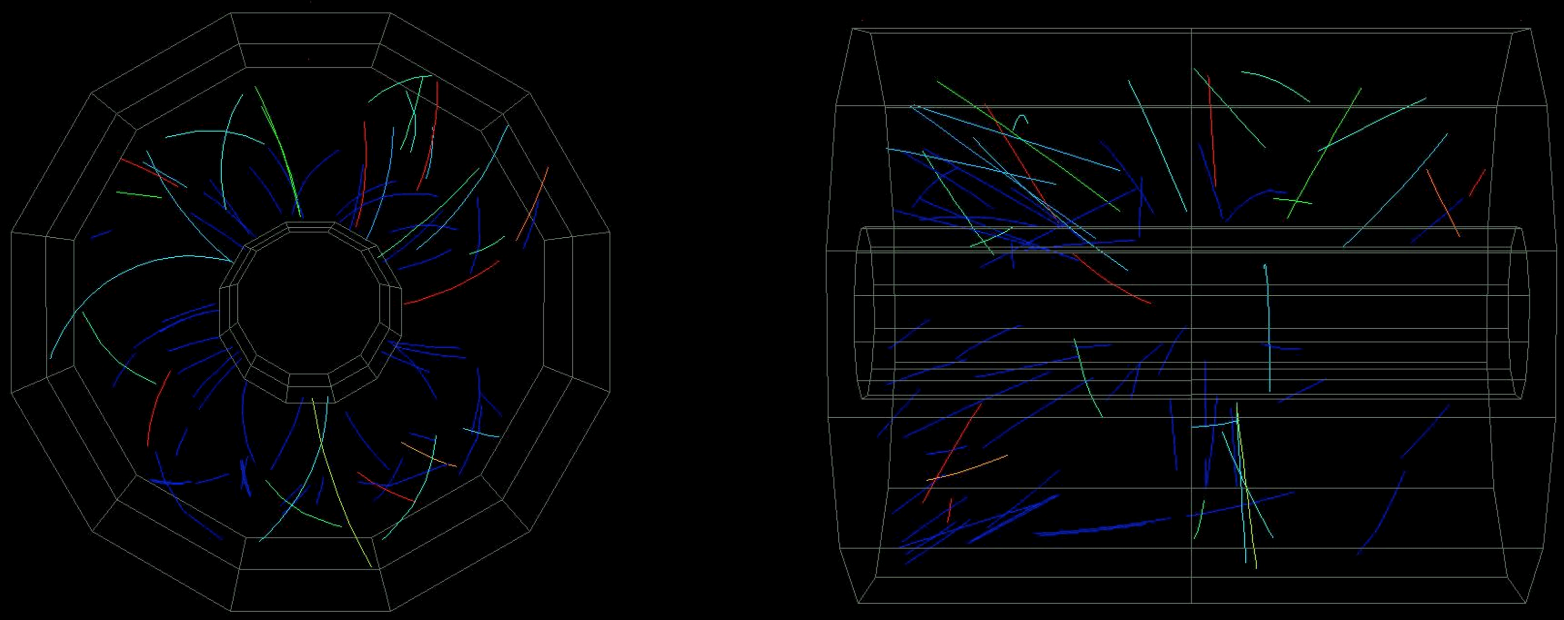
Scaling for energies below normal injection energy unknown

Accelerator Status

First test runs below standard injection energy:

- June 2006: $\sqrt{s}$ = 22.5 GeV p+p
- July 2007: $\sqrt{s_{NN}}$ = 9.2 GeV Au+Au

Au+Au collisions @ $\sqrt{s_{NN}}$ = 9.2 GeV seen in the STAR detector on June 7, 2007:



Jeff Landgraf, AGS-RHIC users meeting 2007 STAR preliminary

Were successful - optimistic scaling for rates at low energies holds!

Accelerator Status

First test run below design injection energy exceeded optimistic estimate for low energy luminosity

Planned energy scan: Au+Au at 7 energies (NA49 + 2)

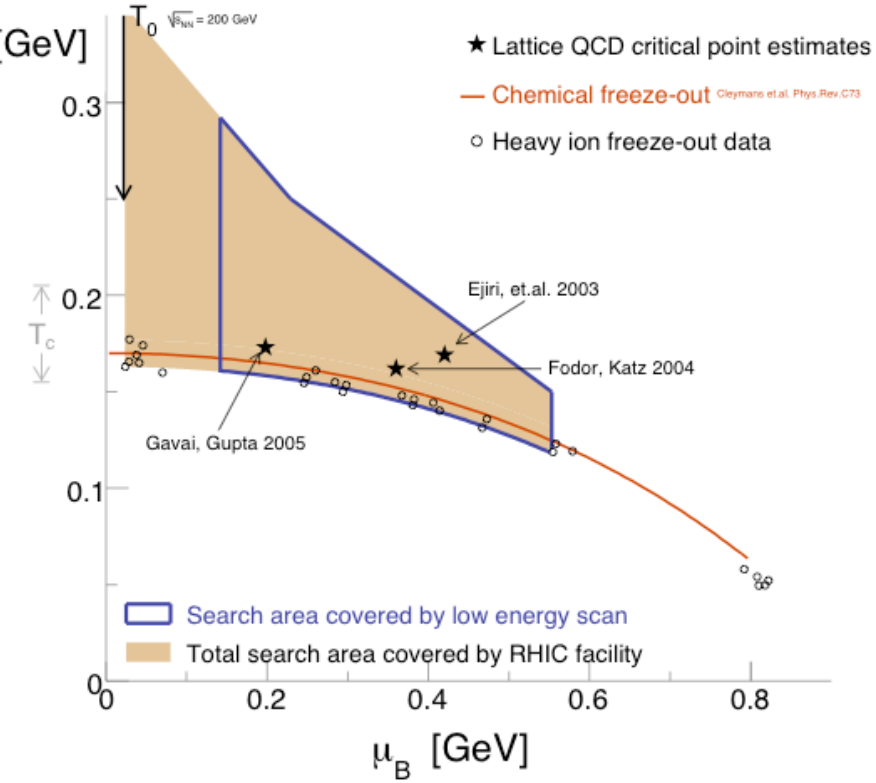
$\sqrt{s_{NN}}$	E_{Lab}	BBC Coinc. Rate	Days / M Events	Desired Statistics	Beam Days
4.6 GeV	10 *A*GeV	3 Hz	9	5M	45
6.3 GeV	20 *A*GeV	7 Hz	4	5M	20
7.6 GeV	30 *A*GeV	13 Hz	2	5M	10
8.8 GeV	40 *A*GeV	20 Hz	1.5	5M	7.5
12 GeV	80 *A*GeV	54 Hz	0.5	5M	2.5
18 GeV	158 *A*GeV	> 100 Hz	0.25	5M	1.5
28 GeV	410 *A*GeV	> 100 Hz	0.25	5M	1.5

= 3 months of run X

- Test run at $\sqrt{s_{NN}}$ = 5 GeV (at the end of run VIII) will show the scaling for lower energies
- Electron cooling in AGS (RHIC) would increase luminosity by another factor of 10 (100)

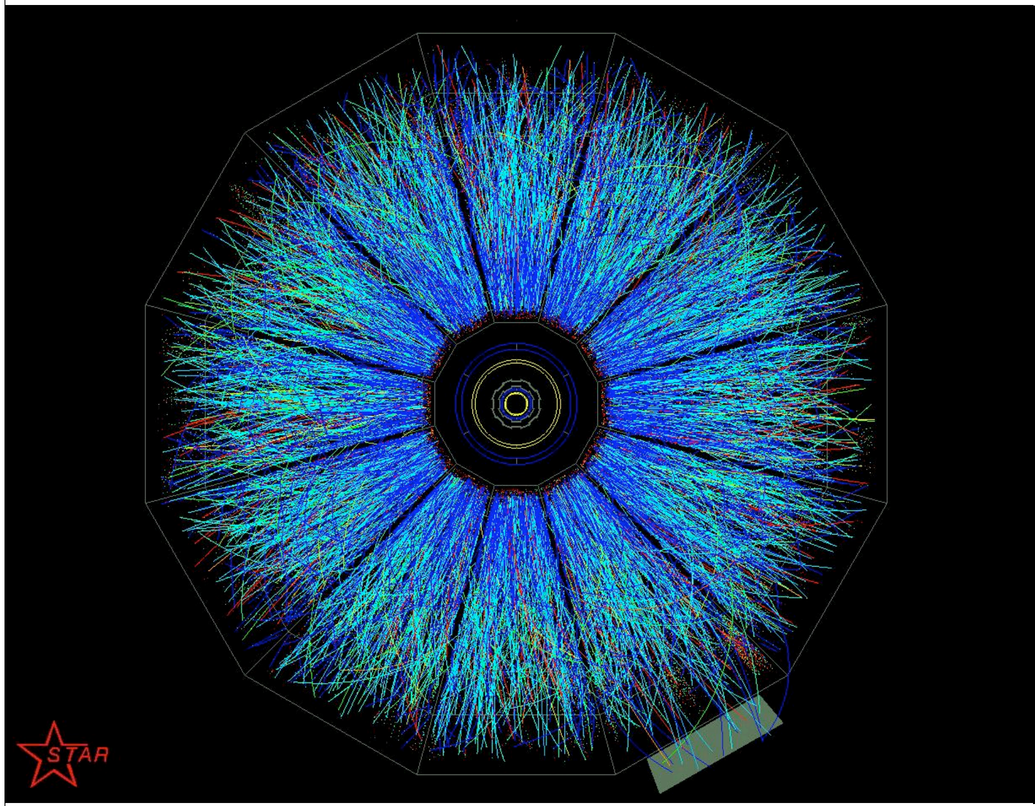
Conclusion

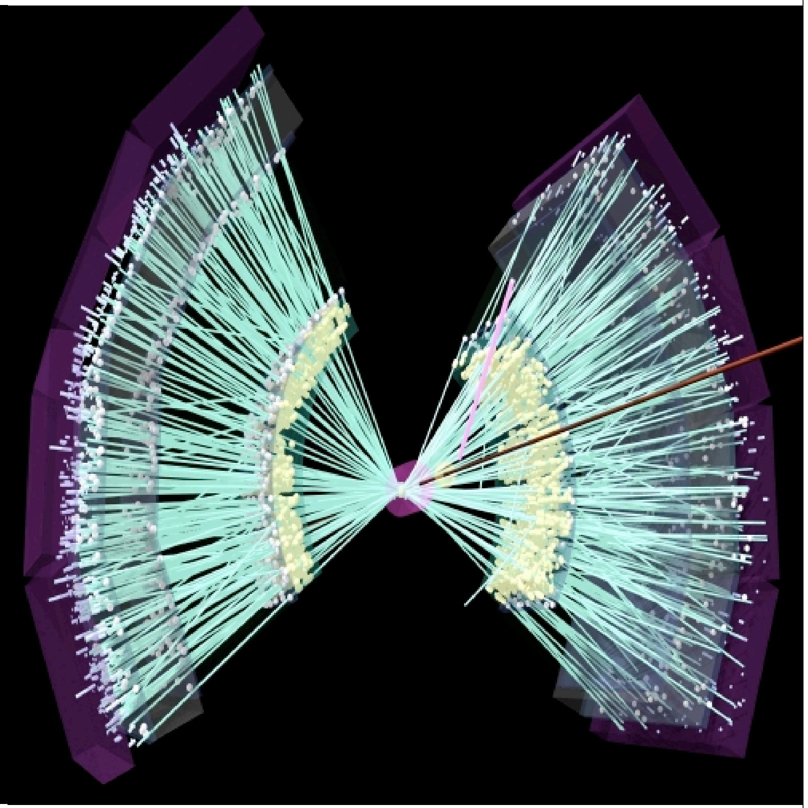
Paul Sorensen



- RHIC is capable to extend existing program into the low energy region in collider mode
- Theoretical predictions see critical point in energy range $5 < \sqrt{s_{NN}} < 20$ GeV
- RHIC gives access to the whole range with sufficient statistics

Experiments STAR and PHENIX





- Two commissioned, proven detectors: STAR and PHENIX
  ...with forming low energy working groups
- Large acceptance: 2π (STAR) and wide p_T range for PID

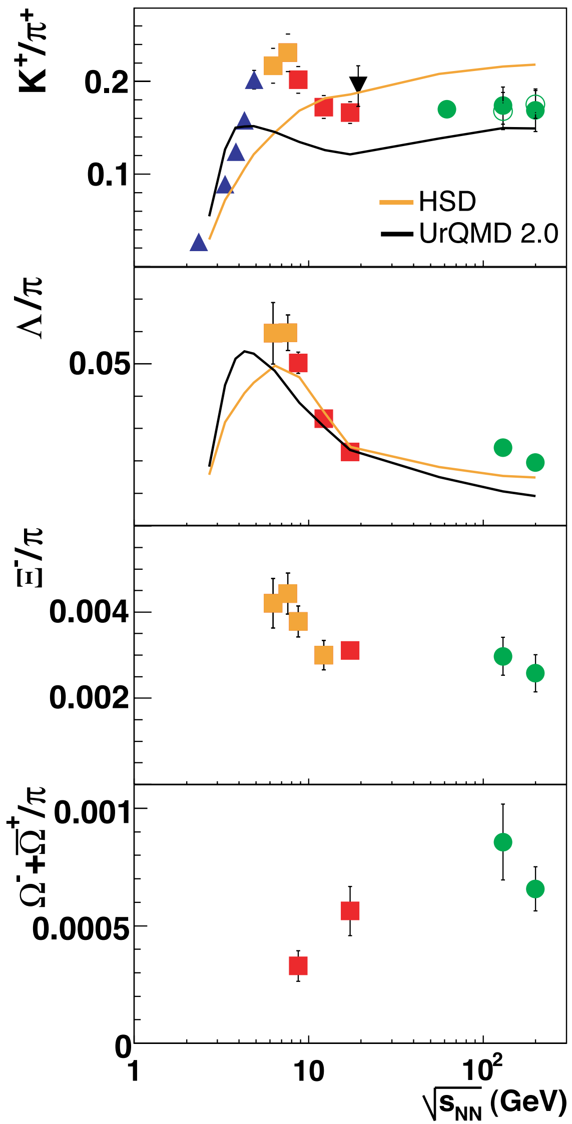
Observables

- Spectra and yields
- Fluctuations
  - K/π
  - <p_T>
- Flow
  - v_2 scaling behavior
  - Ω and φ v_2
  - Disappearance of proton v_2 at 40 GeV?
- HBT
- Heavy flavor mesons, di-leptons

Physics Observables

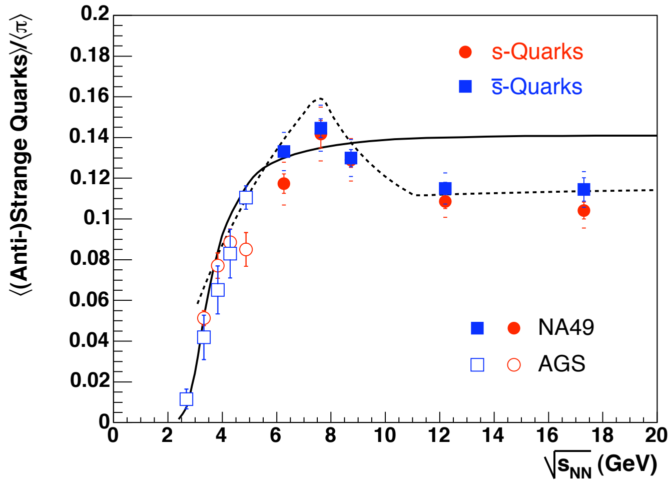
- Spectra and yields
- Fluctuations
  - K/π
  - <p_T>
- Flow
  - v_2 scaling behaviour
  - Ω and φ v_2
  - Disappearance of proton v_2 at 40 GeV?
- HBT
- Heavy Flavor Mesons, Di-Leptons

Spectra and Yields



Non-monotonous structures in SPS energy region

Not only kaons, general strangeness feature:



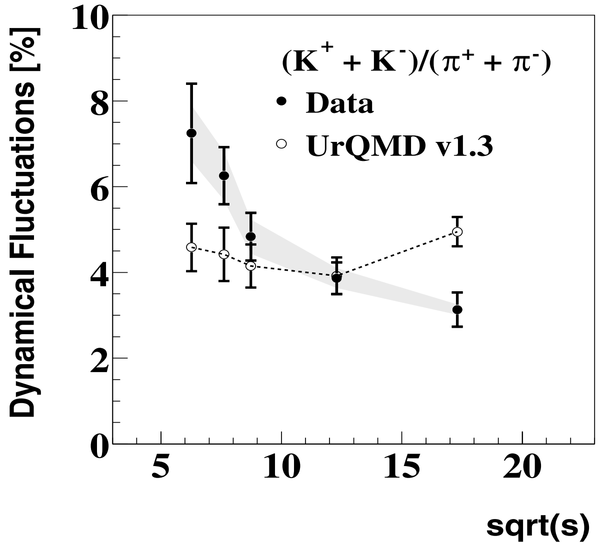
— HGM: PR C60, 054908 (1999)
····· SMES: APP B30, 2705 (1999)

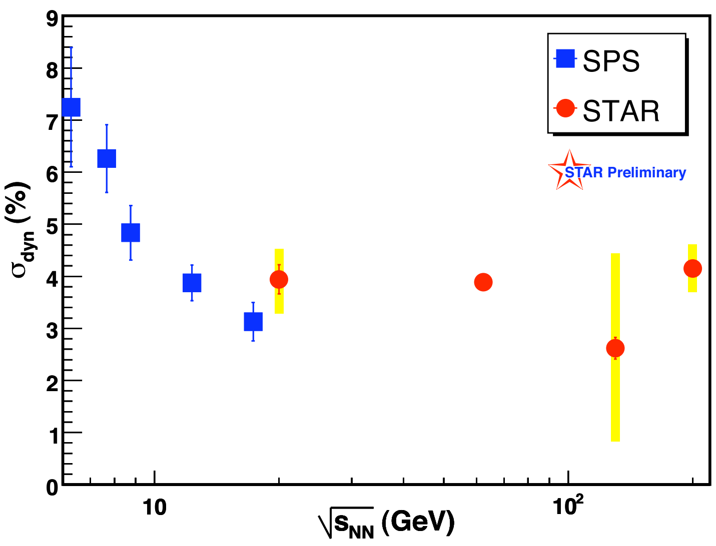
Interpretation under discussion - Systematic re-measurement of all strange hadrons for $5 < \sqrt{s_{NN}} < 200$ GeV will hopefully solve the issue

Current SPS data seen as "*suggestive but inconclusive*" (Paul Sorensen)

Hyperons at AGS energies: FAIR? NICA?

K/π Fluctuations





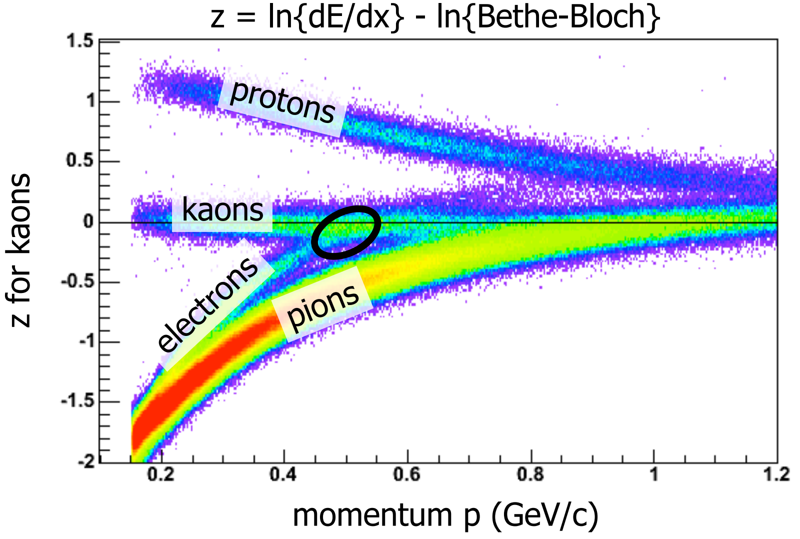
- Positive dynamical fluctuations, rising fast towards low SPS energies
- Only excitation function of a fluctuation observable not being described by hadronic model

K/π Separation: STAR TOF

Measurement is tricky at RHIC:

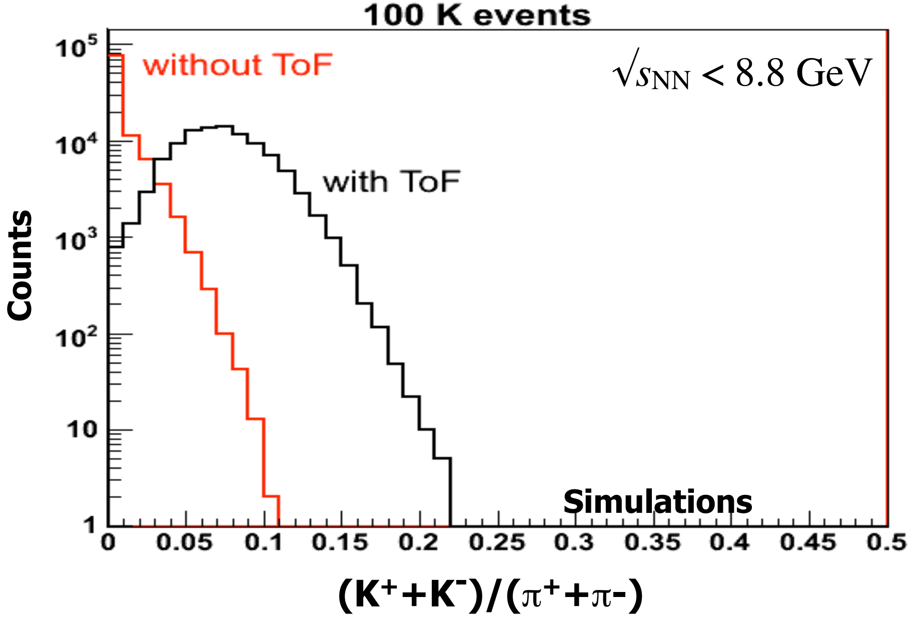
- Kaon efficiency in collider lower (due to decay, $c\tau = 3.7$m)
- K/π separation by dE/dx in TPC ambiguous above $p = 0.5$ GeV/c
- Misidentification has large impact on flucuations
- STAR TOF will enhance unambiguous kaon sample - full barrel TOF completed in 2009

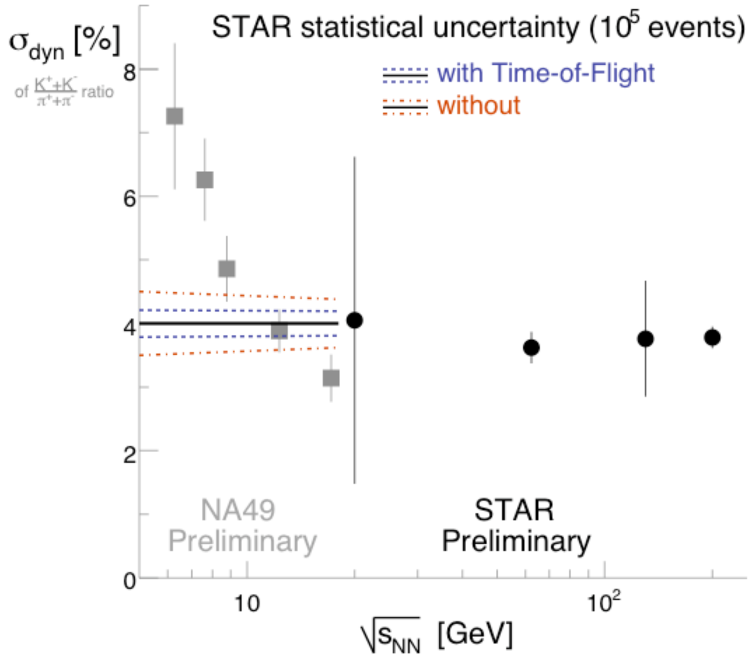
dE/dx from TPC:



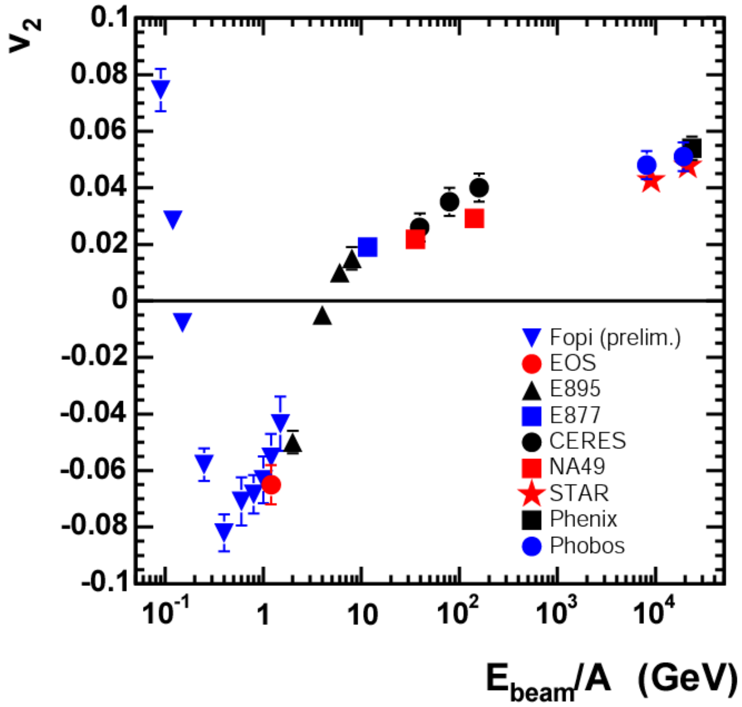
K/π Separation: STAR TOF

STAR TOF will enhance unambiguously identified kaon sample - important for hadron ratio event by event analysis



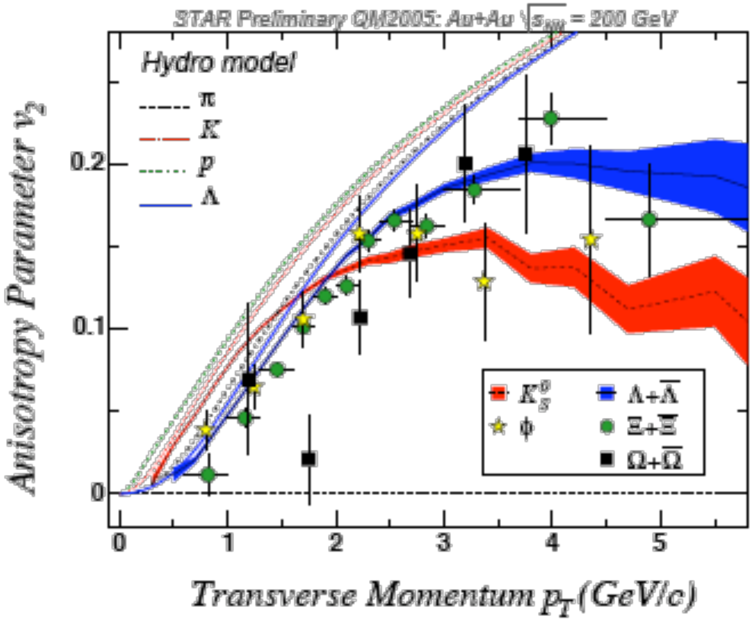


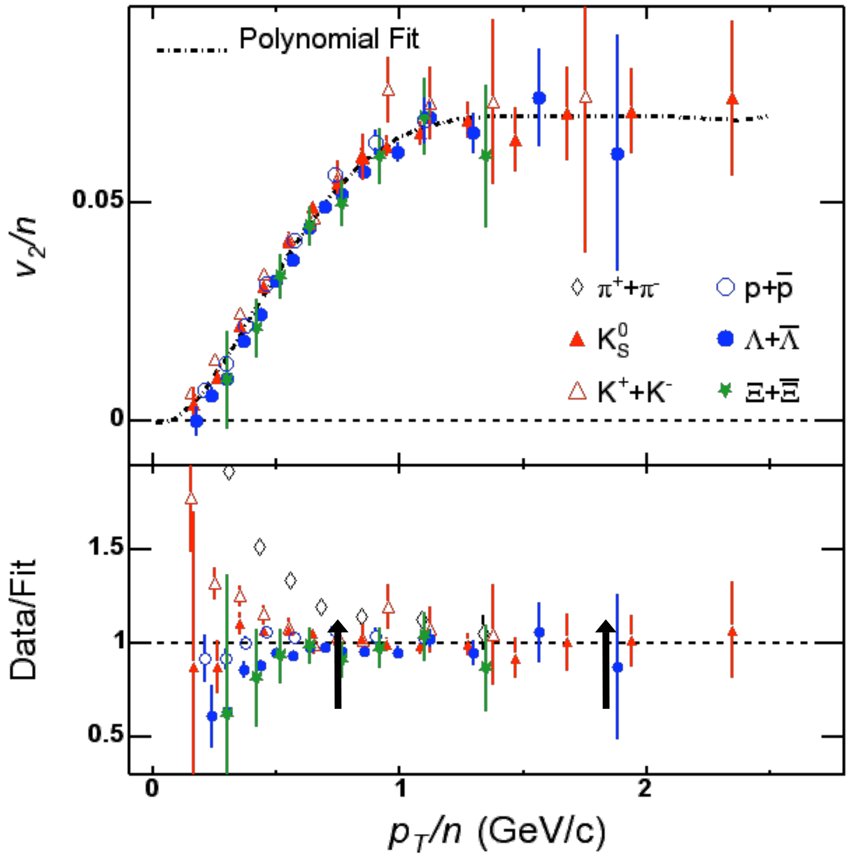
Observables Flow



Probe the early stage of the collision:

Test for initial pressure and degrees of freedom



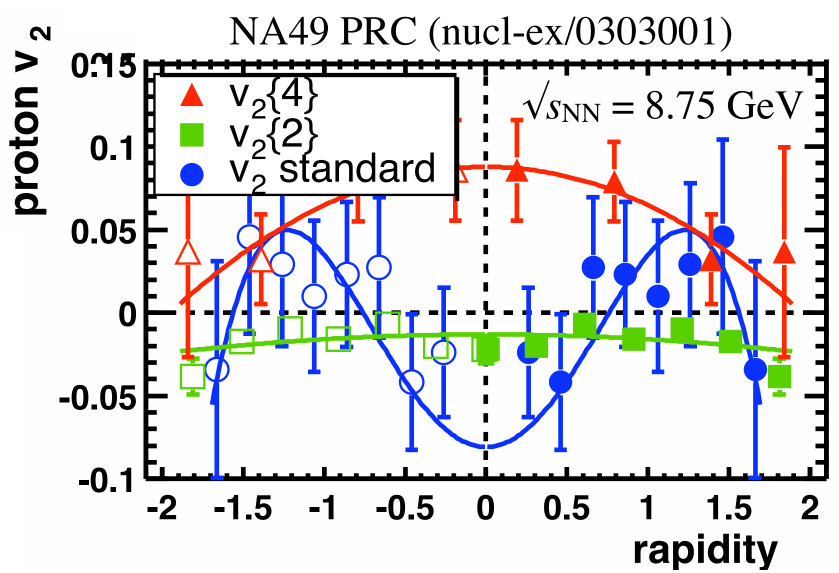


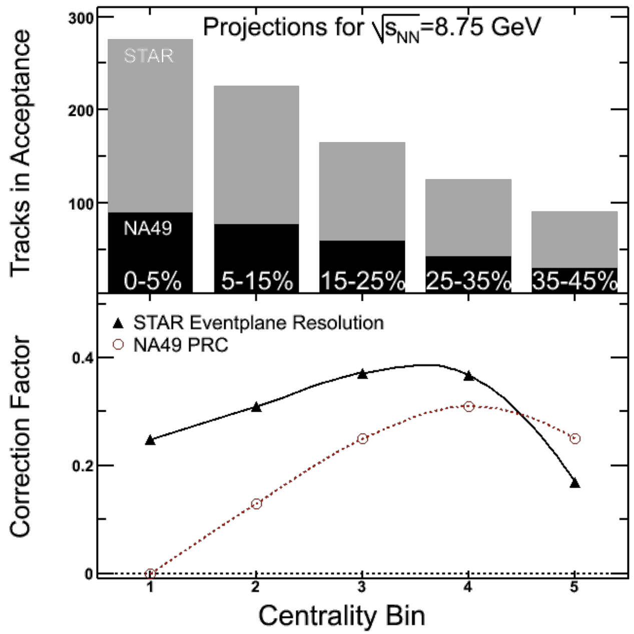
PRL **92** (2004) 052302; PRL **91** (2003) 182301

- Large Ω and φ v_2
- Quark number scaling

Do these signatures disappear at lower energies?

Observables Flow





Proton v_2 collapse as signal for deconfinement

- Difference between methods: Depends on v_2 fluctuations and non-flow contributions
- Azimuthally symmetric detector STAR can measure event-by-event flow vector
- STAR event plane resolution makes measurement with smaller error possible
- Event plane detector as upgrade under discussion

Comparison of Programs

Large worldwide efforts to scan the phase diagram:

- The RHIC energy scan will provide a systematic study over a wide energy range (total covered range: $5 < \sqrt{s_{NN}} < 200$ GeV) with large acceptance independent of energy
- CBM at FAIR will add the measurement of rare probes at lower energies
- The program at SPS adds the complementary system size scan and a larger rapidity coverage