STAR Highlights & FTPC Update

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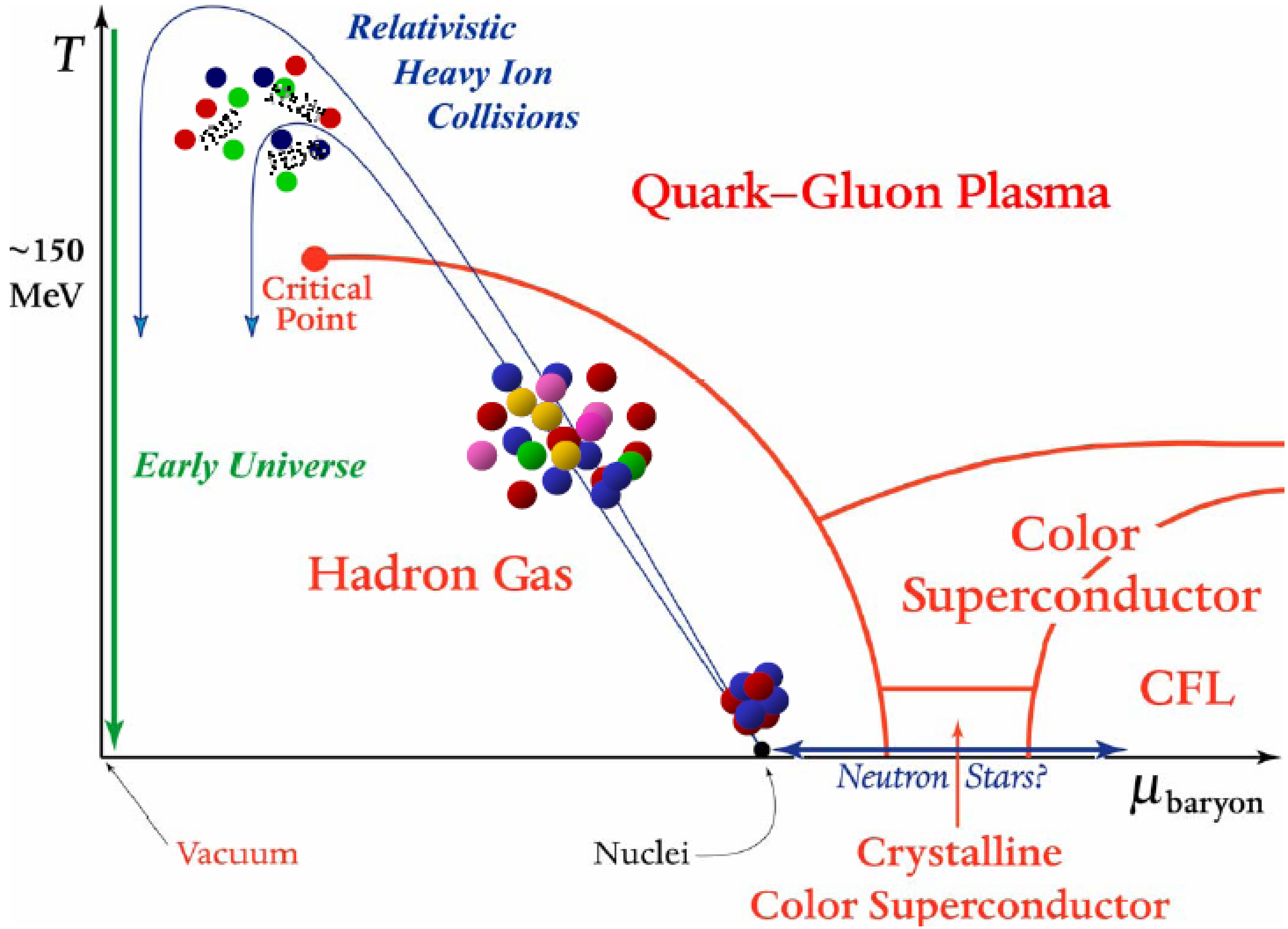
MPI Project Review, December 13&14, 2004

Outline

- Phases of Nuclear Matter
- Relativistic Heavy Ion Collisions
- The STAR detector
- Anisotropic Flow: Signs of Partonic Collectivity?
- Jets in the Dense Medium
- Forward Lambda Production in d+Au Collisions
- Conclusions & The Future

The Phase Diagram

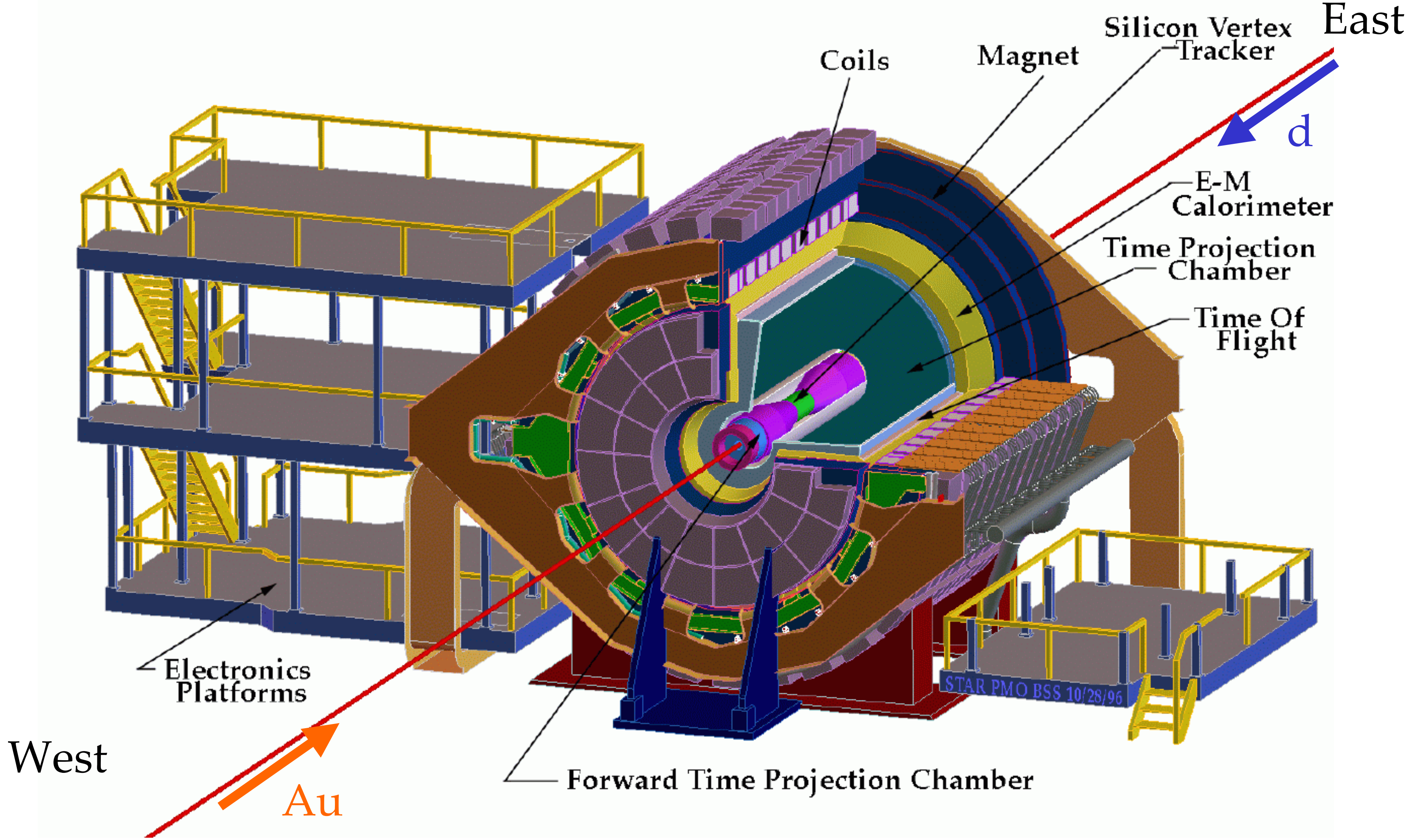


Relativistic Heavy Ion Collider

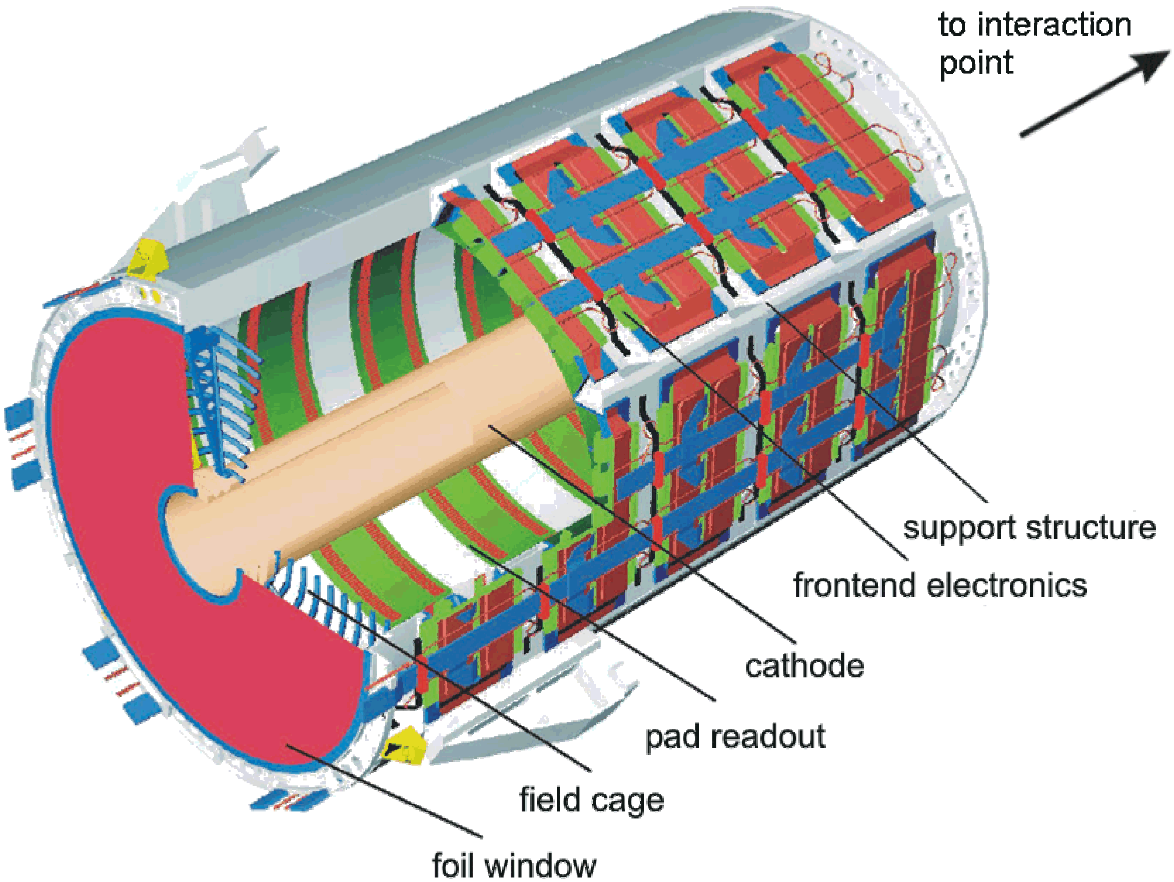
- 2 counter-circulating rings, 3.8 km circumference
- Any nucleus on any other
- Top energies (center of mass) :
  - 200 GeV/nucleon pair Au-Au.
  - 500 GeV polarized p-p
- Four experiments

- RHIC begun operation in 2000
- Since then: Au+Au at a variety of energies, p+p & d+Au at 200 GeV

The Solenoidal Tracker At RHIC



The STAR FTPCs



- coverage $2.5 < |\eta| < 4.0$
- 2 FTPCs in STAR
  10 rows per detector
  960 pads per row
  => 19200 channels
- inner radius 8 cm, outer radius 30 cm
- $150 \text{ cm} < |z| < 270 \text{ cm}$
- true radial electron drift
- magnetic field 0.5 T: tracking with momentum and charge determination
- no particle ID from dE/dx (maximum 10 points on track), momentum resolution ~ 15%

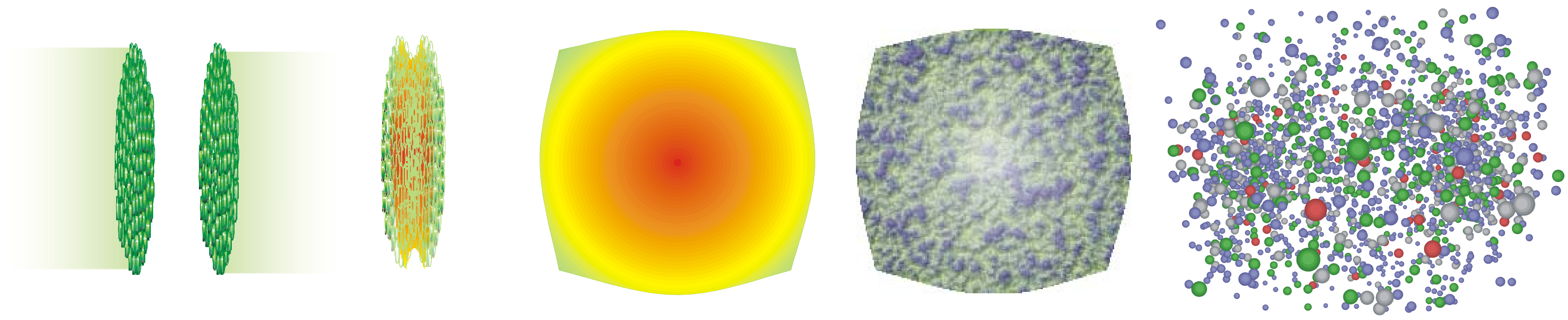
Relativistic Heavy Ion Collisions

Time

1) Initial Condition
- baryon transfer
- partonic dof

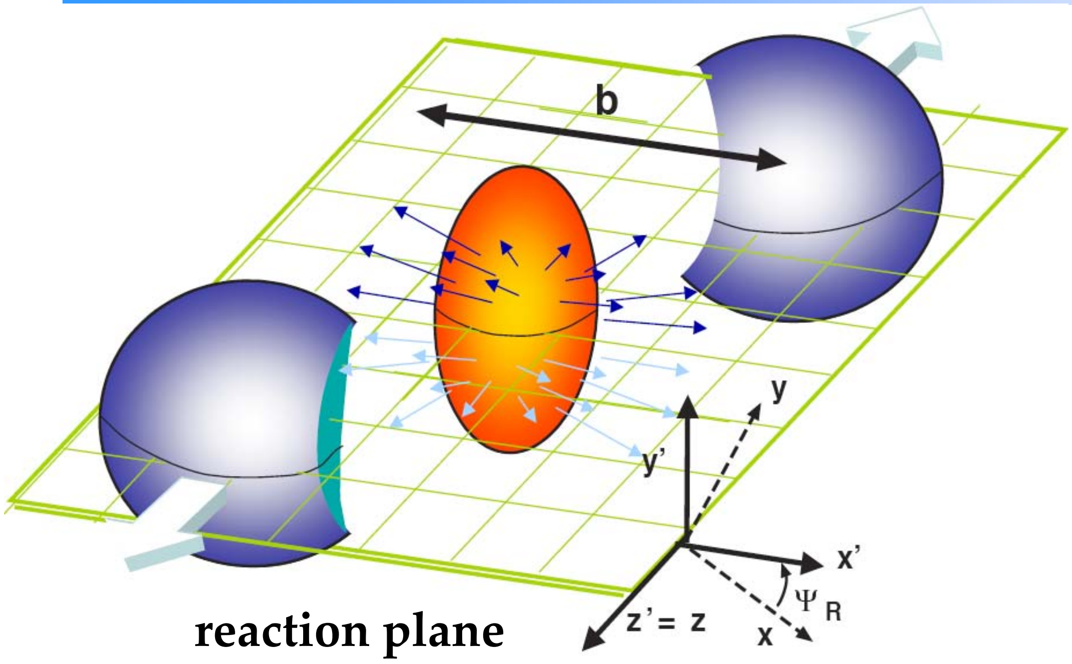
2) System Evolves
- parton/hadron expansion

3) Bulk Freeze-out
- hadronic dof
- interactions stop



- Observables probe different stages of the collision
- The bulk of the particles carries information from the freezeout, connection to earlier stages challenging

Anisotropic Flow

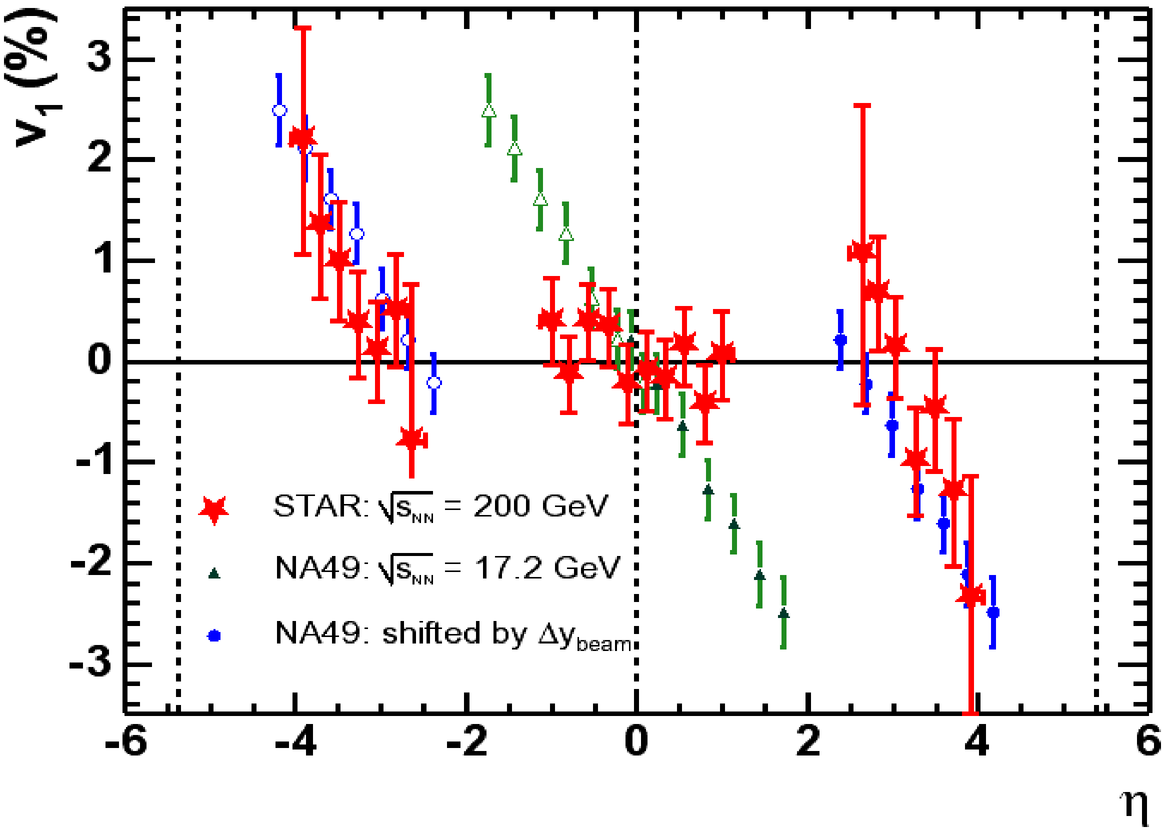


- Correlation with respect to the reaction plane
- Formation in the early phase of the reaction from a spatial asymmetry
- Shows collective behavior of produced particles

$$E\frac{dN^3}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}(1 + 2v_1\cos(\phi - \Psi_R) + 2v_2\cos(2(\phi - \Psi_R) + \ldots)$$

directed flow (v_1) — elliptic flow (v_2)

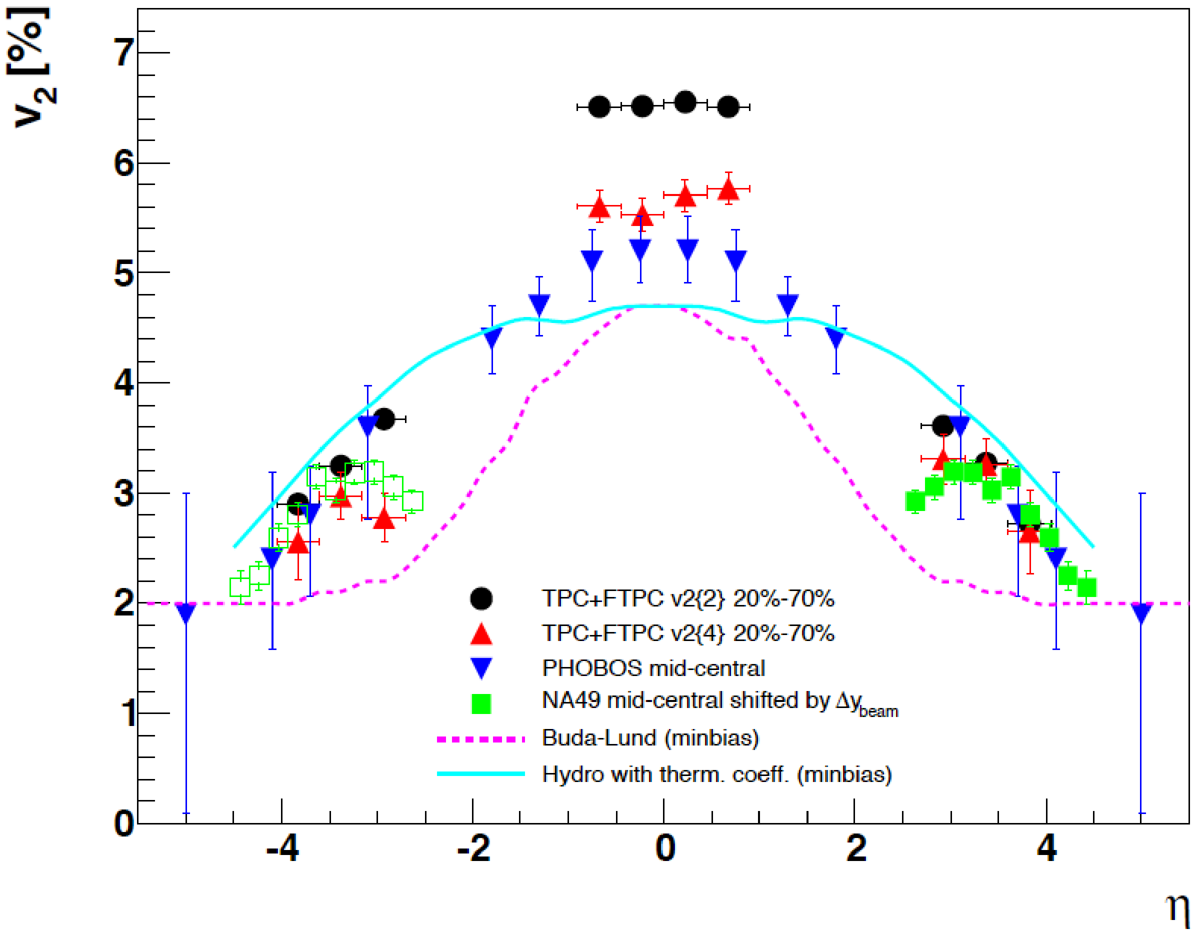
Directed Flow



- First measurement of directed flow at RHIC
- Consistent with "limiting fragmentation"

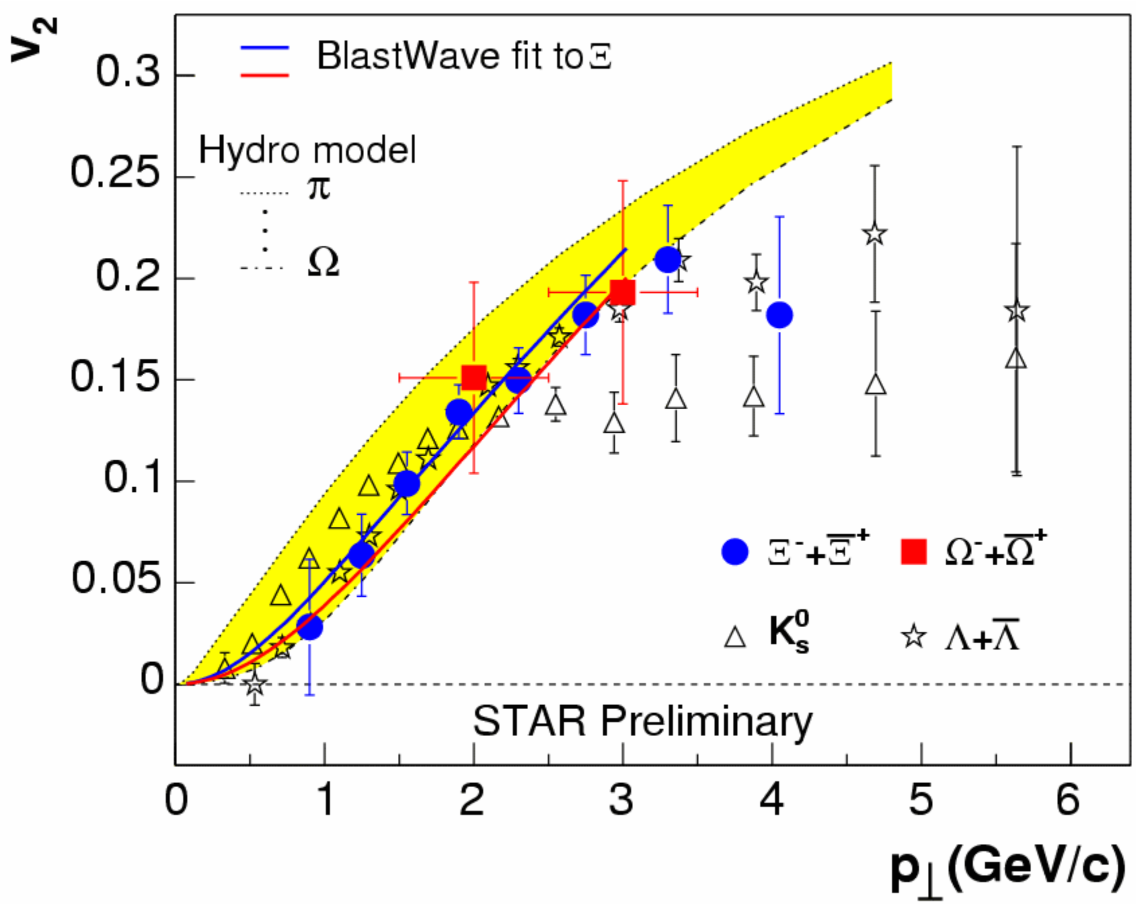
- FTPCs contribute significantly to the measurement

Elliptic Flow



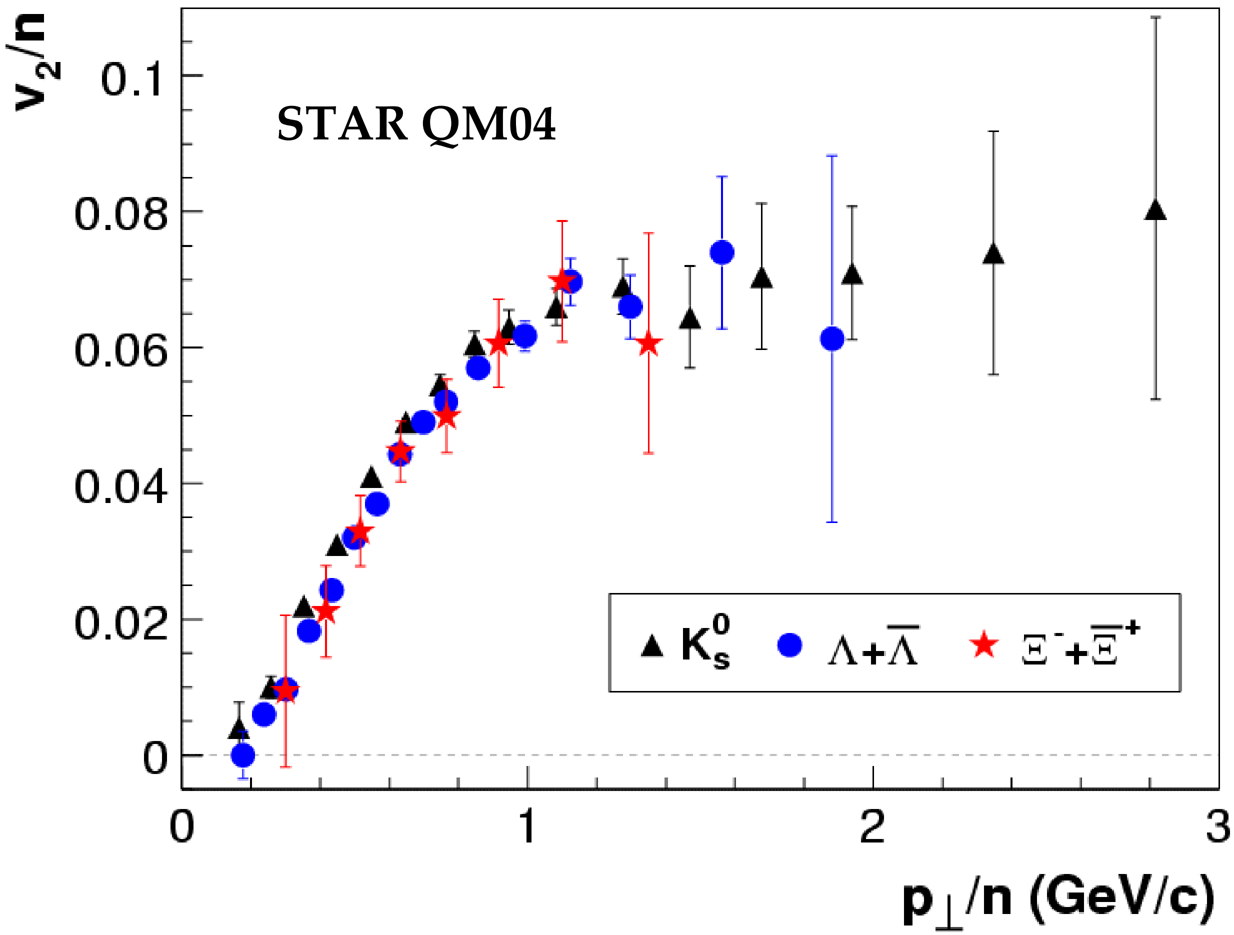
- Elliptic flow also measurable in the forward region
- Results are described by hydrodynamics: Collective behavior
- Good agreement with other experiments => We understand our detector!

Baryon / Meson Difference?



- Multi-strange baryons flow!
- Baryons reach higher v2 than mesons, they follow the hydrodynamic curve longer… Why?

A Sign of Partonic Degrees of Freedom?



- Rescaling with the number of quarks: Baryons and Mesons on a common curve!
- Indication of early partonic collectivity
- Partonic degrees of freedom?

Initial vs Final State

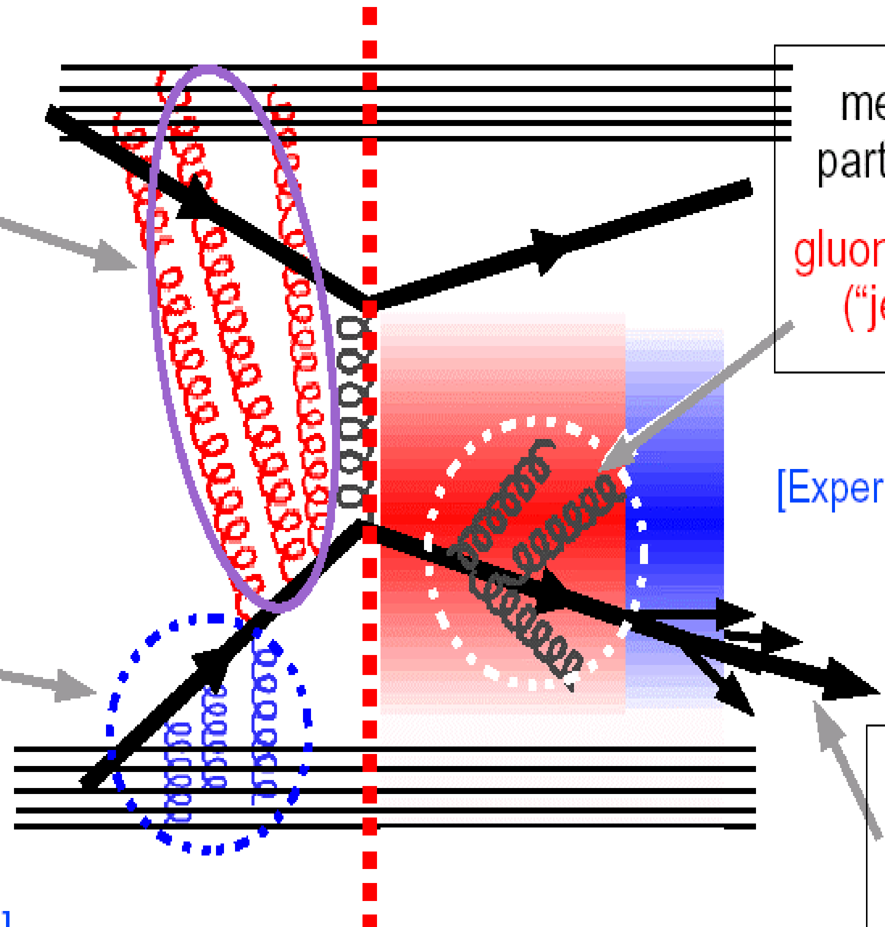
Initial-state effects:

p_T broadening:
("Cronin enhancement")
Soft & semi-hard extra k_T

[Experimental handle: p,d+A]

Leading-twist shadowing
(modified nuclear PDF)
OR
Gluon saturation in the highly non-linear regime of small-x

[Experimental handle: e+A, p,d+A]



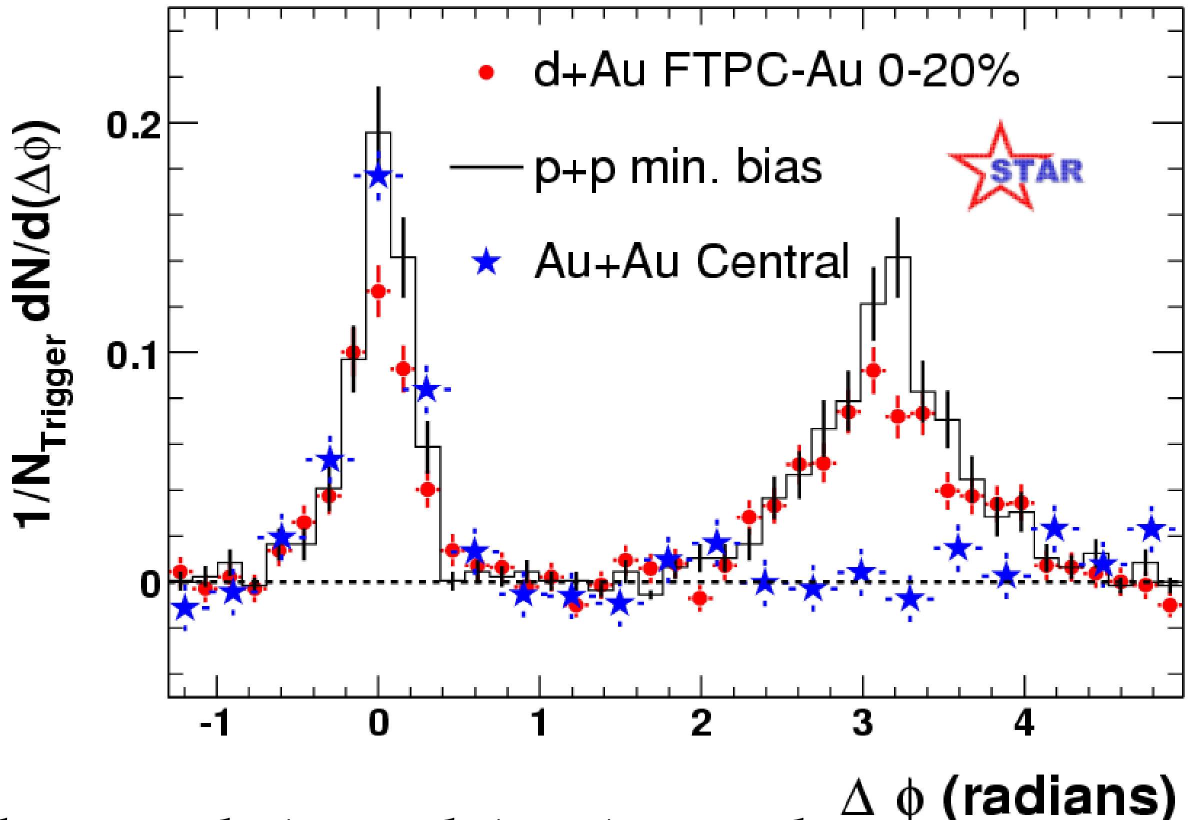
Final-state effects:

medium-induced parton energy loss:
gluon bremsstrahlung
("jet quenching")

[Experimental handle: A+A]

possible hadronic rescattering
(after/before hadronization ?)

Jets in p+p, d+Au and Au+Au

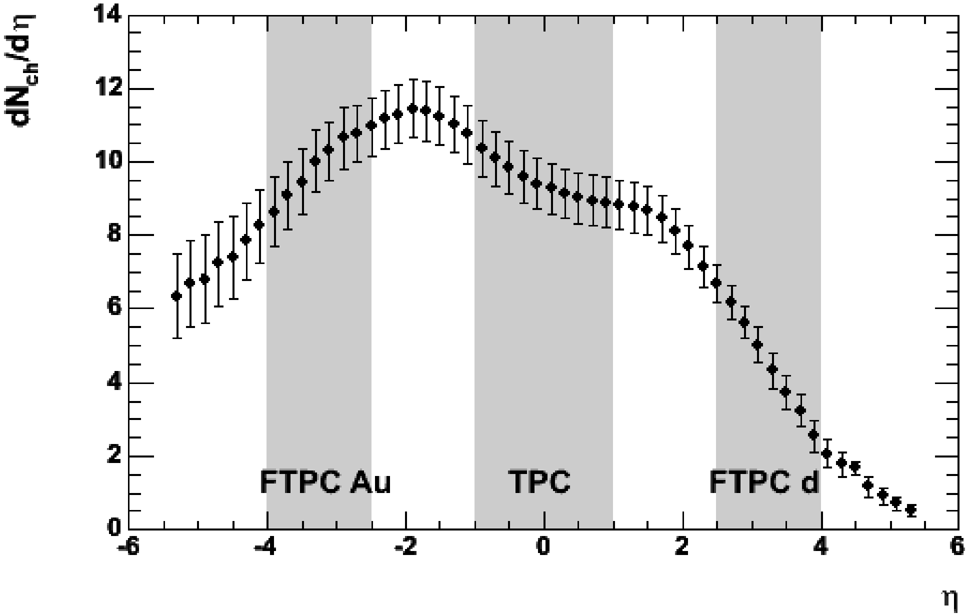


- Near side: p+p, d+Au and Au+Au similar
- Away side: Au+Au strongly suppressed

  => The suppression is a final state effect!

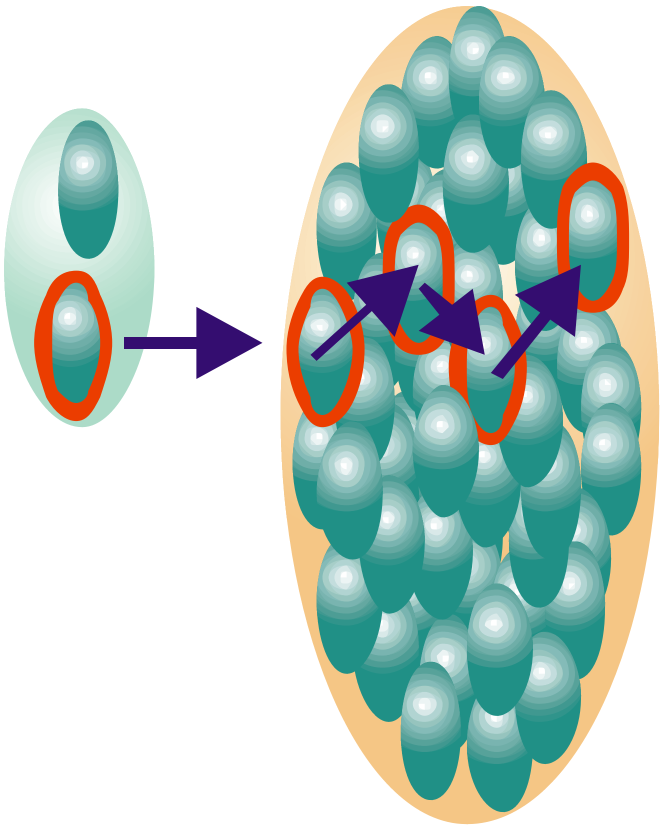
Why go forward? Why d+Au?

PHOBOS d+Au minbias, PRL **93**, 082301 (2004)



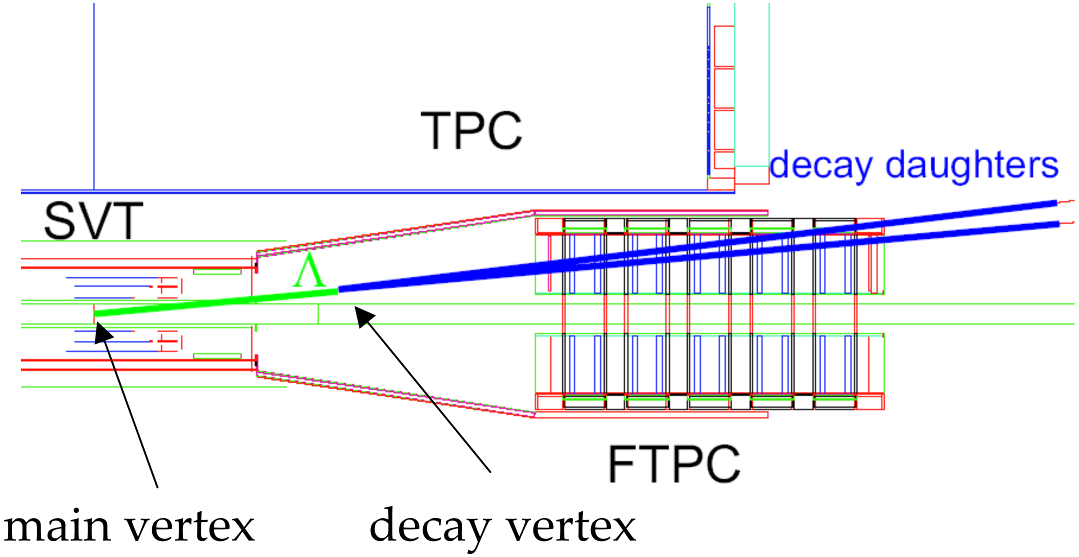
- Anti-Λ / Λ ratio < 1 at mid-rapidity (0.84 ± 0.05): Indicative of stopping
- Forward rapidity:
  - Sensitive to baryon transport
- Asymmetry in d+Au collisions:
  - Probe normally dense and cold medium on the Au side
  - Multiple collisions of two constituents on deuteron side

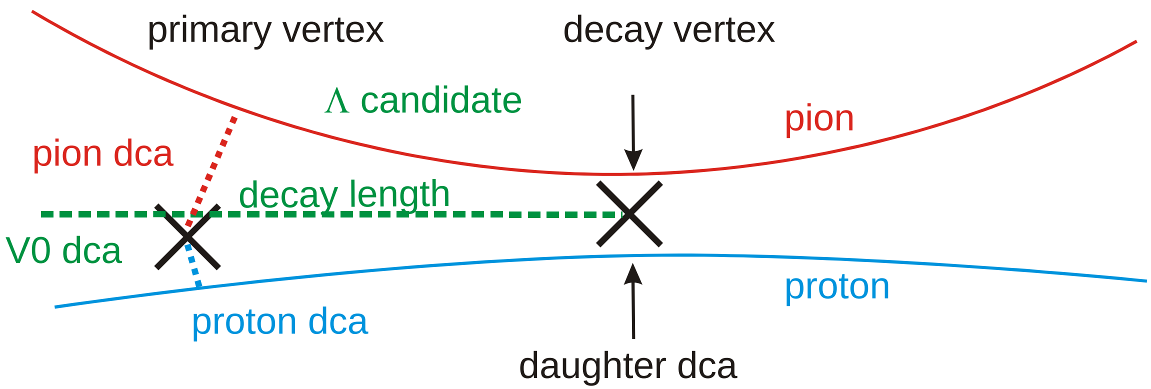
Geometry of d+Au Collisions



- Deuteron very loosely bound, radius ~ 2 fm, but wave function stretches far outwards
- Gold radius 7 fm
- Deuteron participants suffer multiple collisions
- Each participating gold nucleon only suffers one collision

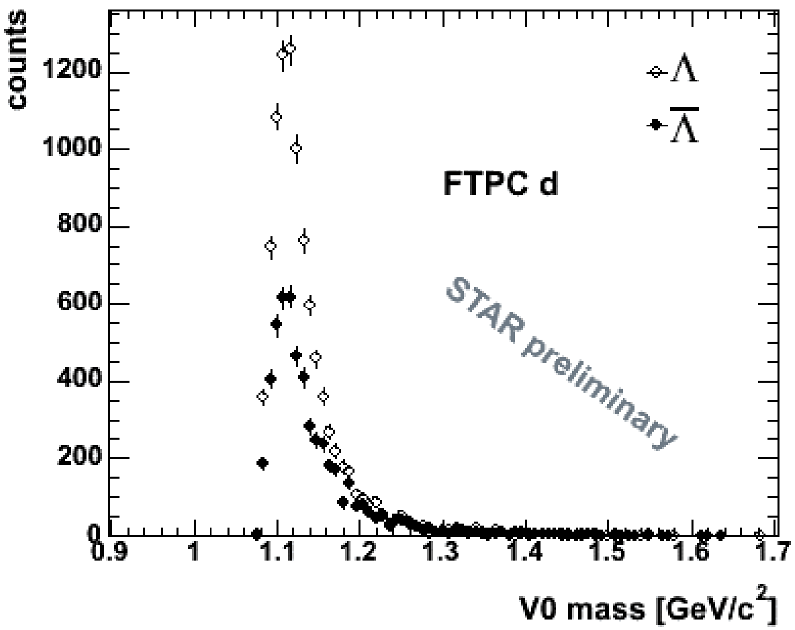
Forward Λs: Signal Extraction

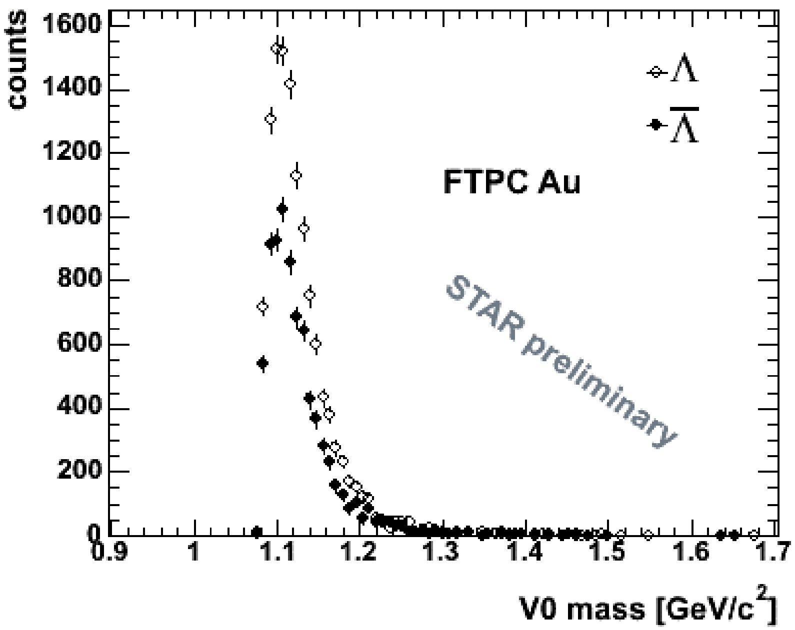




- Identification of Λ candidates (V0) by searching for a possible secondary vertex of a positive/negative pair
- Apply geometric cuts on pairs to reduce combinatoric background:
  - separation of tracks (daughter dca) < 0.25 cm
  - Proton dca < 2 cm
  - Pion dca > 2.5 cm/ 3 cm
  - dca of resulting Λ candidate < 1 cm
  - decay length > 5 cm

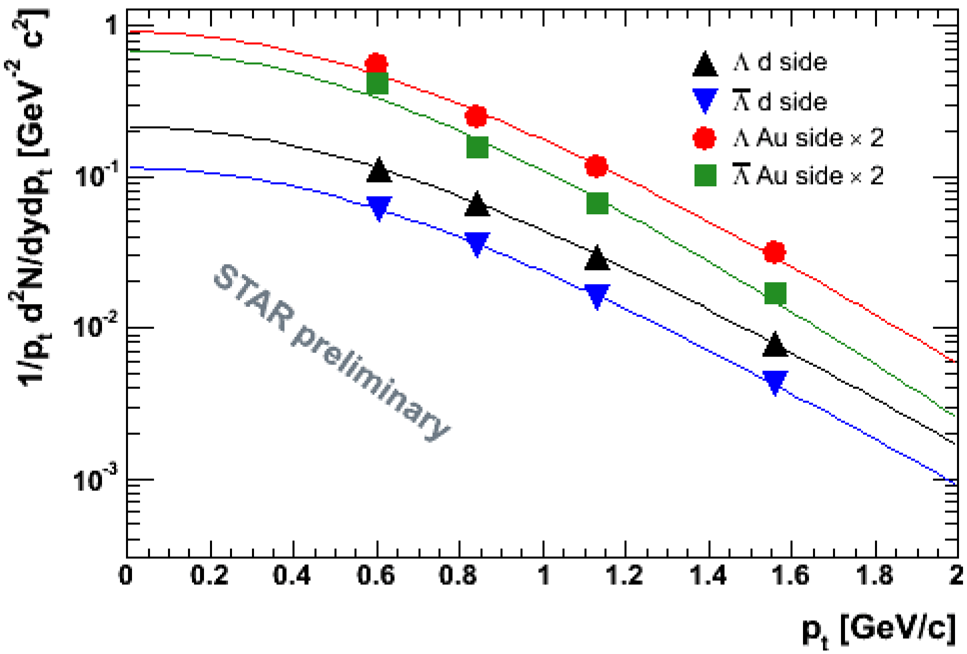
Invariant Mass





- Background subtracted invariant mass for Λ and Anti-Λ in both detectors
- The width and shape of the distributions is reproduced by simulations

Minimum Bias Spectra



Temperature parameter

Deuteron side Λ:
241 ± 4 (stat) ± 11 (syst) MeV
d side Anti-Λ:
242 ± 5 (stat) ± 15 (syst) MeV

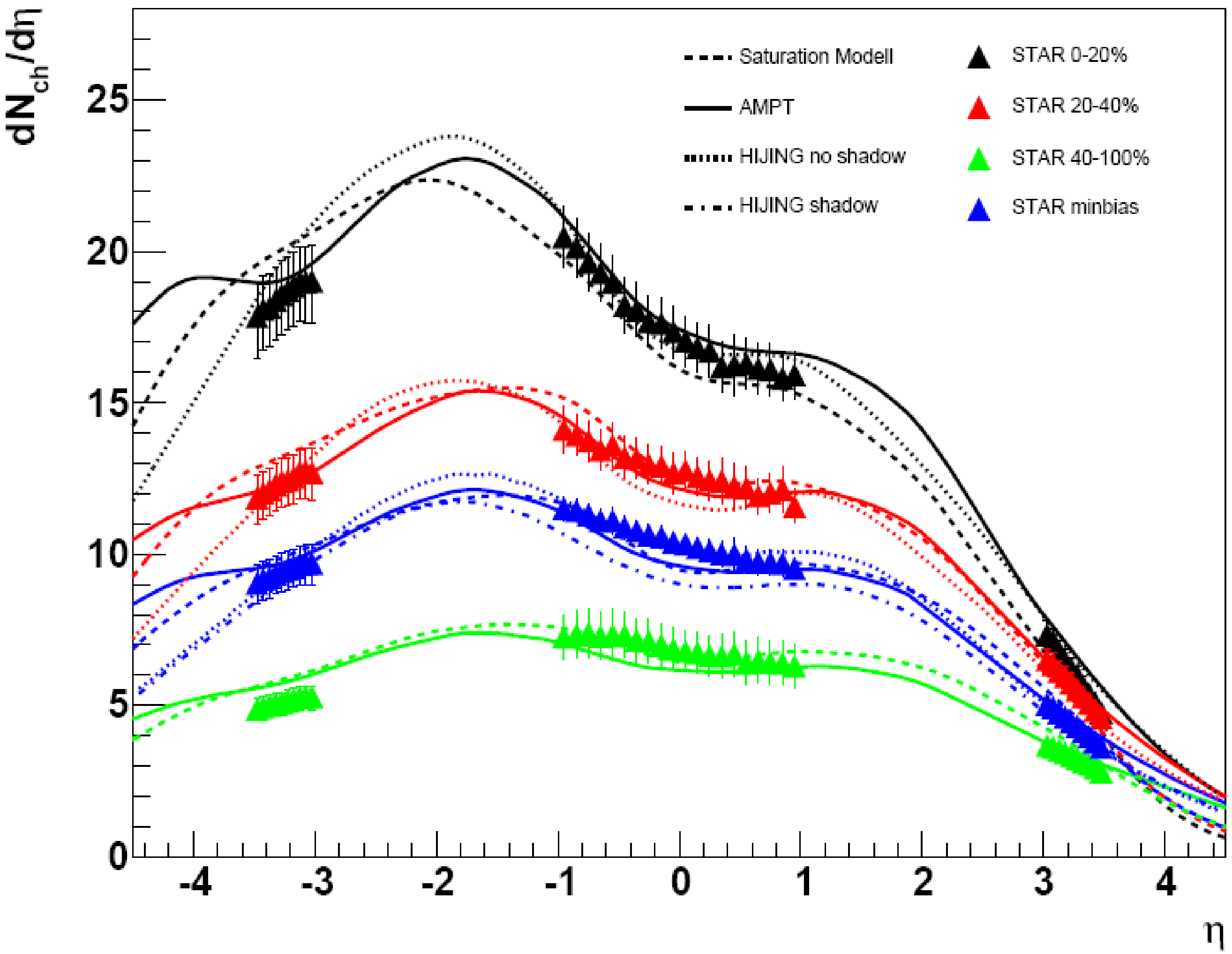
Au side Λ:
232 ± 5 (stat) ± 14 + 18 (syst) MeV
Au side Anti-Λ:
210 ± 4 (stat) ± 14 + 23 (syst) MeV

- Yield and inverse slope determined from m_t exponential fit
- 65% of the total yield covered
- Problematic first bin in FTPC Au, background & efficiency problems

Models

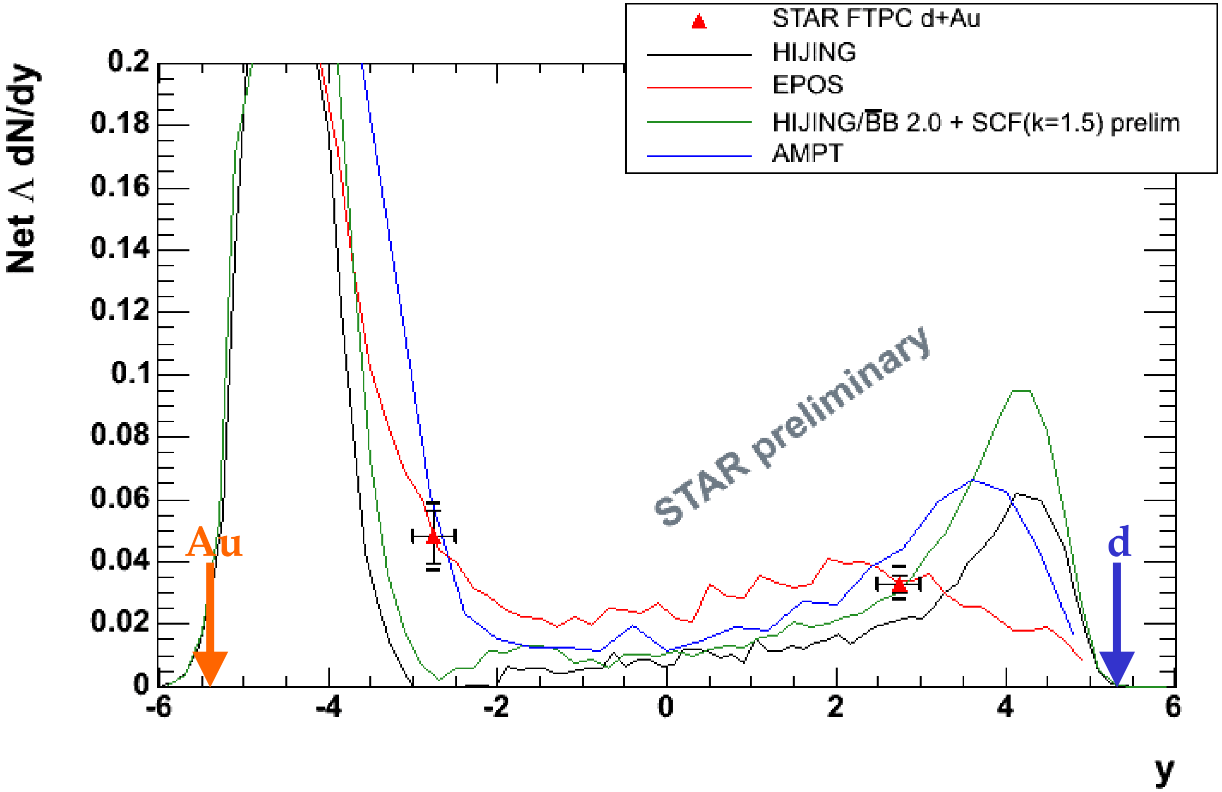
- HIJING (HIJING/BbarB)
  - fragmentation model based on strings and pQCD
  - Nucleus-nucleus collisions as superposition of nucleon-nucleon
  - Inclusion of baryon junctions in HIJING/BbarB
- EPOS
  - String model / parton cascades
  - Inclusion of nuclear initial state effects via target and projectile remnants
- AMPT
  - Multiphase model: Initial conditions from HIJING
  - Hadronic transport in the final stage of the collision

Charged Hadrons



- Both AMPT and HIJING give a good description of charged hadron distributions

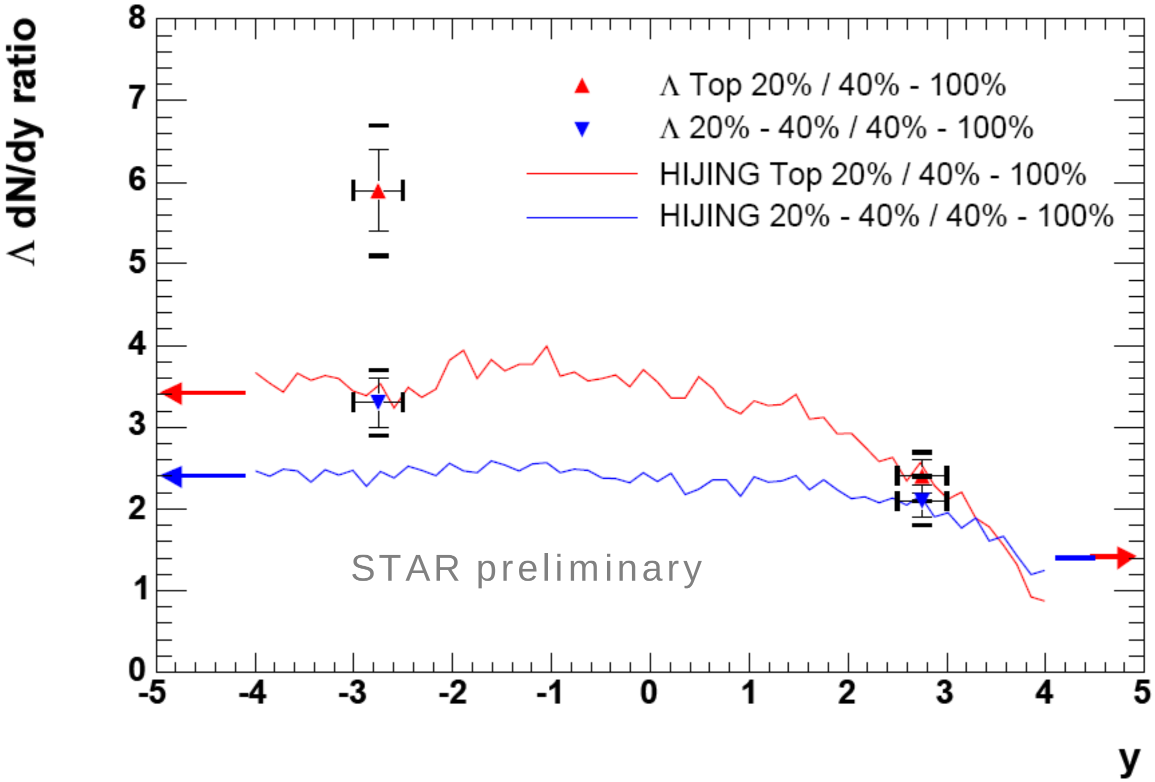
Net Λ (Λ – Anti–Λ)



- Baryon transport/stopping power of nuclear matter
- Directly related to the energy available for particle production and QGP formation

- From the model comparisons:
  - d side dominated by multiple collisions of the nucleons as they pass through the Au nucleus
  - Inclusion of nuclear effects necessary on the Au side

Centrality: Yield



Yield ratio central (mid-central) divided by peripheral events

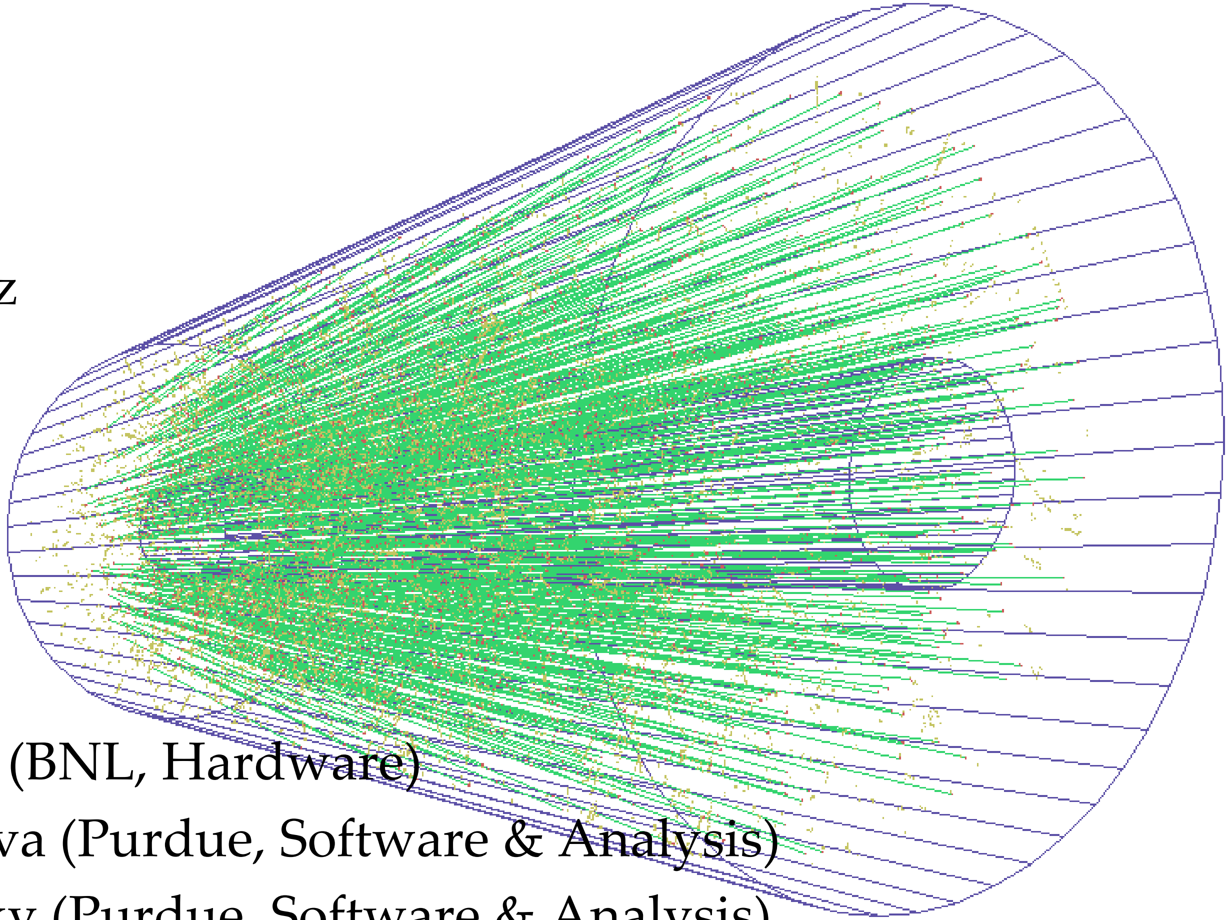
- Strangeness enhancement in N+N collisions as a signature for QGP formation
- Asymmetry increases with centrality
- Enhancement above WNM on the gold side

Summary

- Heavy Ion Collisions are used to probe the phase diagram of nuclear matter
- The matter produced in Au+Au collisions is very strongly interacting and shows signs of collectivity on the partonic level
- The Forward TPCs built at MPI contribute to STAR's success
  - Measurements of anisotropic flow
  - Particle spectra in d+Au and Au+Au (not shown)
  - Lambda production in d+Au collisions to investigate baryon transport and strangeness enhancement

A success coming to an end… at least in Munich

The Group



MPI Munich

- Volker Eckardt
- Joern Putschke
- Norbert Schmitz
- Janet Seyboth
- Peter Seyboth
- Frank Simon

The new crew

- Alexei Lebedev (BNL, Hardware)
- Brijesh Srivastava (Purdue, Software & Analysis)
- Terry Tarnowsky (Purdue, Software & Analysis)