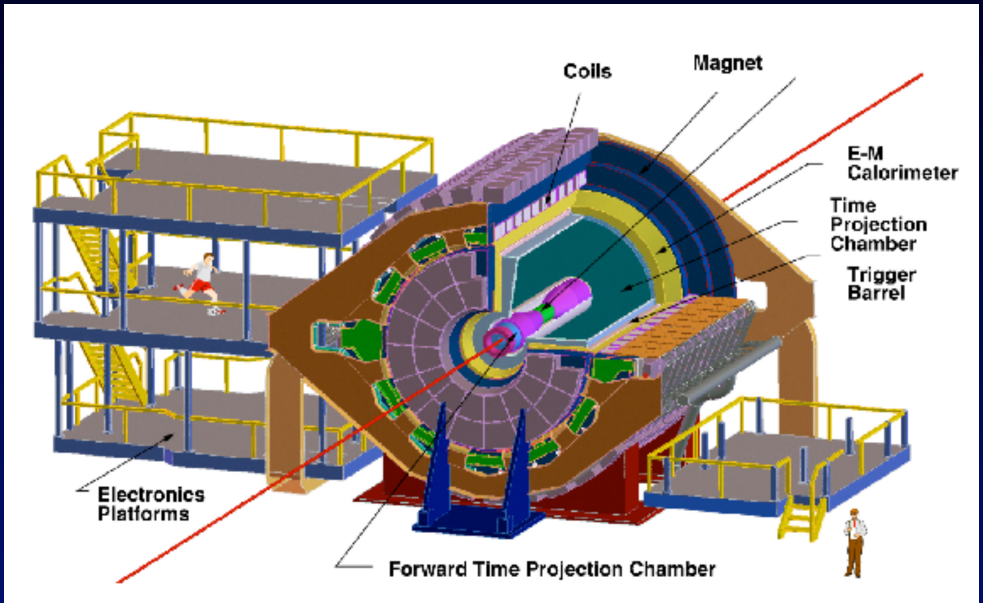
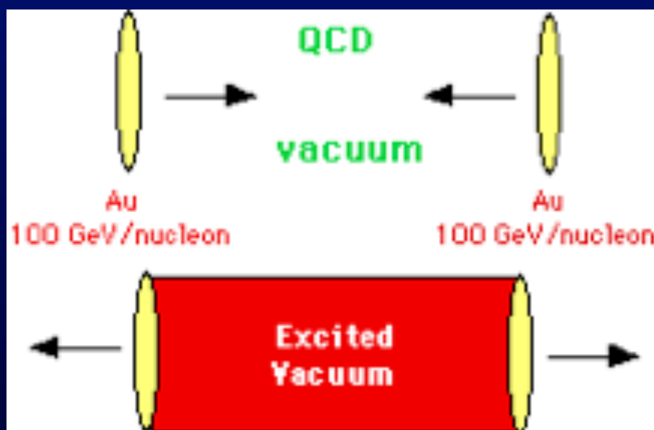
Analysis of fixed target collisions with the STAR detector

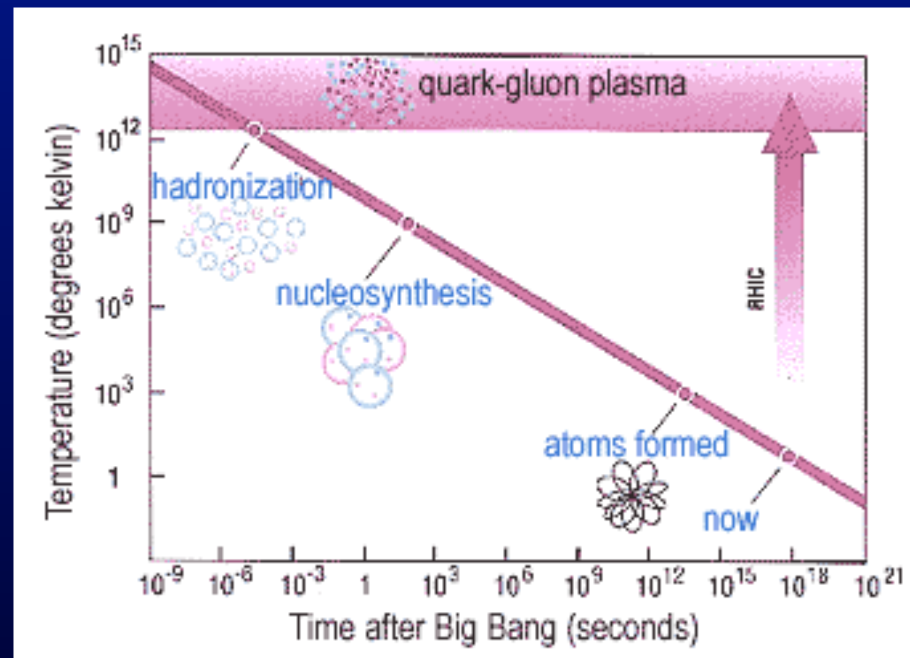


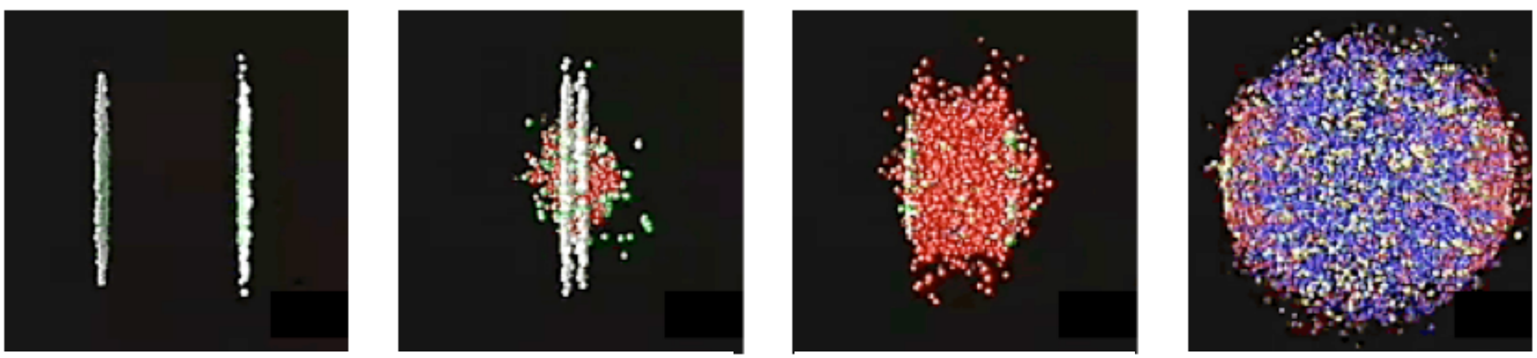
Brooke Haag for the STAR Collaboration
Hartnell College / University of California, Davis
Presented at the Meeting of the California Section of the APS
November 11, 2011

Creating mini-big bangs in the laboratory

Goal: Use relativistic collisions of nuclei to create hot dense matter which reproduces the earliest stages of the universe

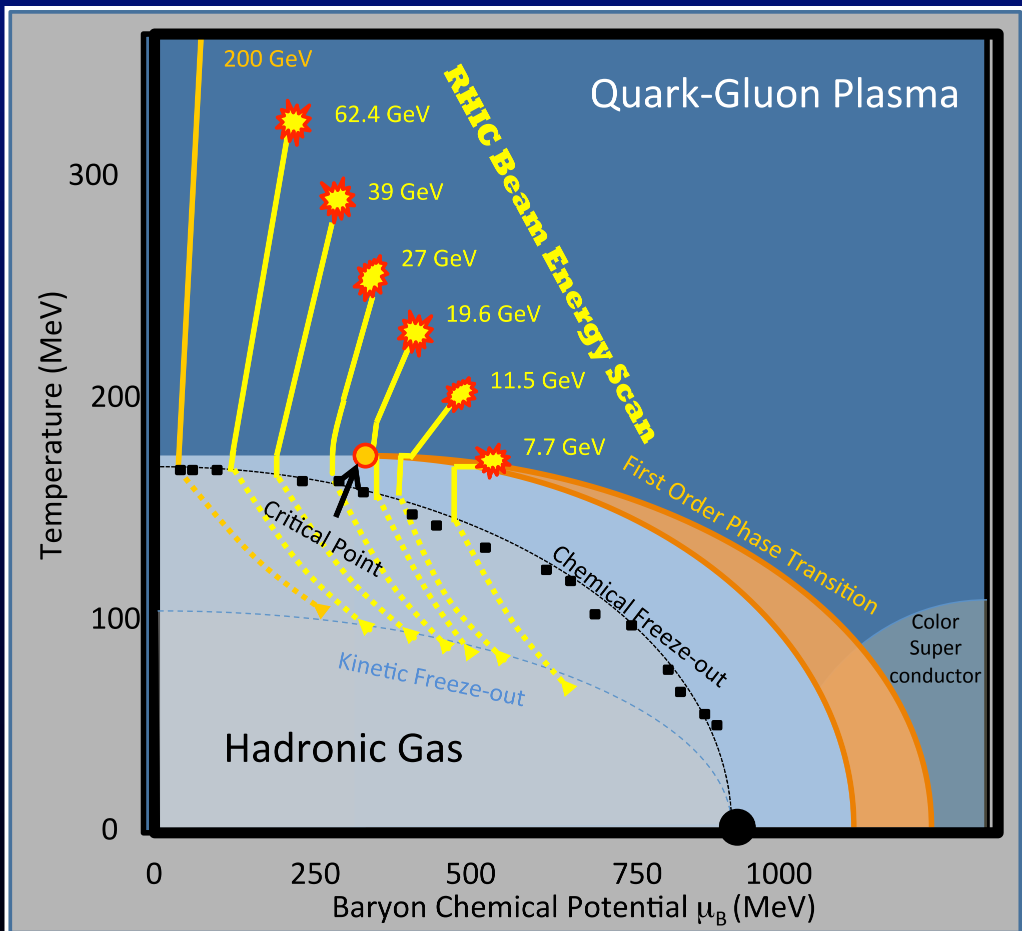






ions about to collide ion collision plasma creation hadron production

QCD phase diagram

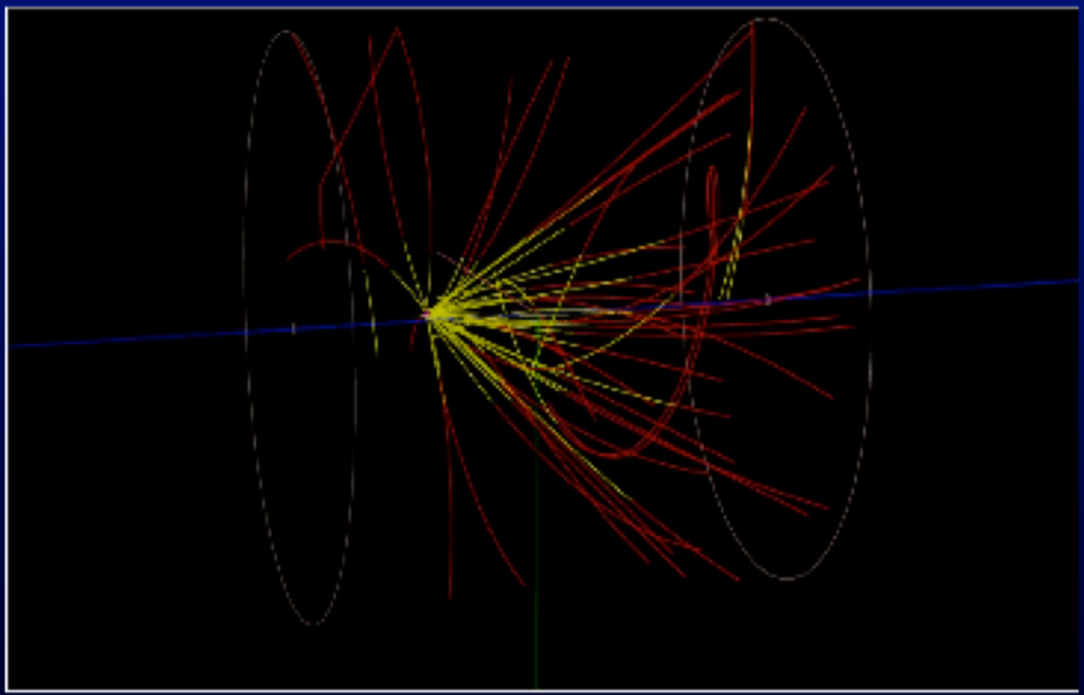


- We have created a new state of matter at $\sqrt{(s_{NN})}$ = 200 GeV consistent with the QGP !

- In 2010 (and continuing through 2011) an extensive beam energy scan was undertaken at RHIC with a major goal to find the critical point.

- Fixed target collisions could extend the physics analysis to even lower √s.

STAR has fixed target events

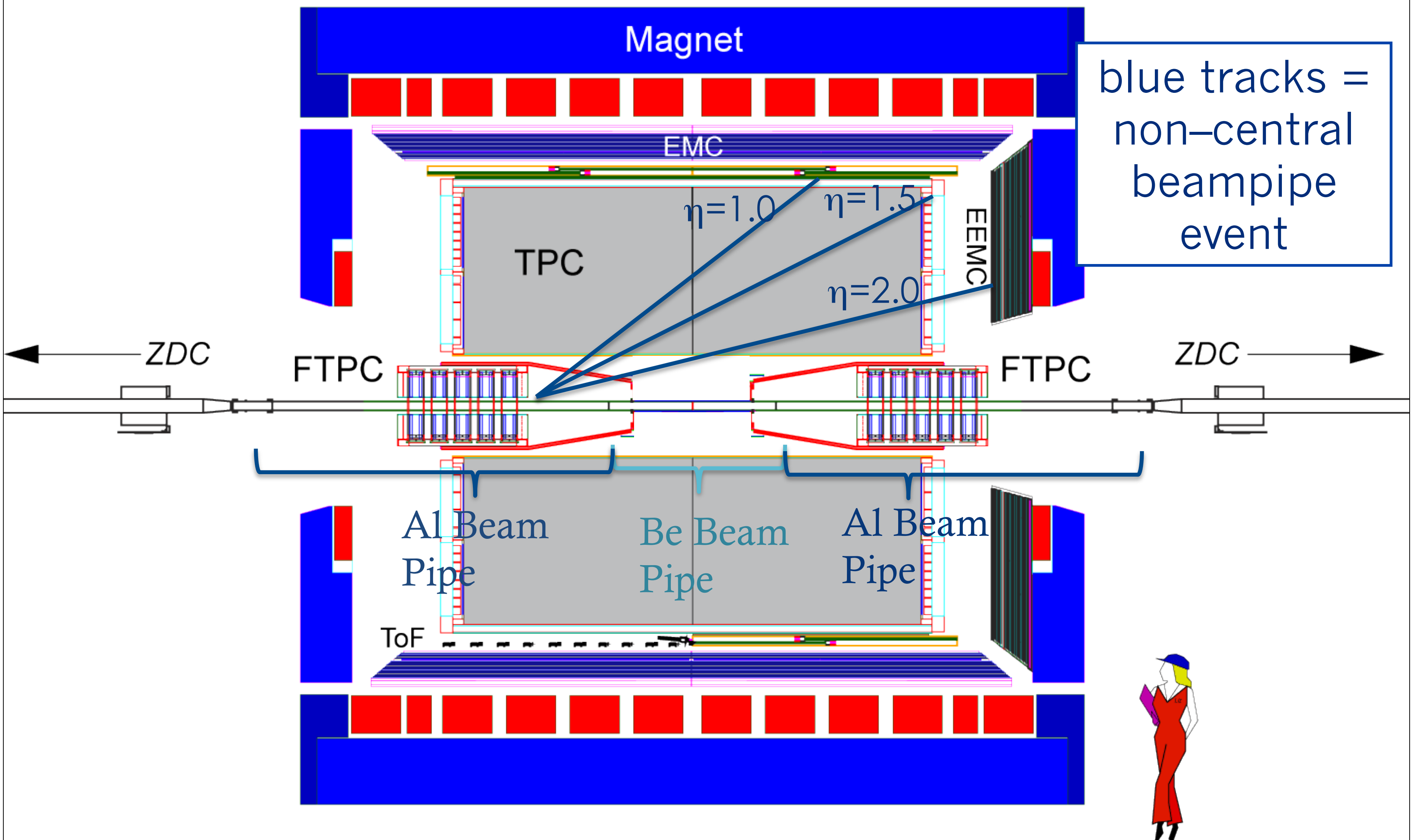


- gold beam ions collide with aluminum beam pipe atoms

- the events are asymmetrical

- acceptance is not optimal ...

STAR detector array



blue tracks = non–central beampipe event

Kinematic Calculations

Collision Energy (GeV)	Single Beam Energy	Single Beam P_z (GeV/c)	Fixed Target $\sqrt{s}$	Single Beam Rapidity	Center of Mass Rapidity
19.6 Au+Au	9.8	9.76	4.47 Au+Al	3.04	1.52
11.5 Au+Au	5.75	5.67	3.53 Au+Al	2.51	1.25
7.7 Au+Au	3.85	3.74	2.99 Au+Al	2.10	1.05

$\sqrt{(s_{NN})}$ = center of mass energy

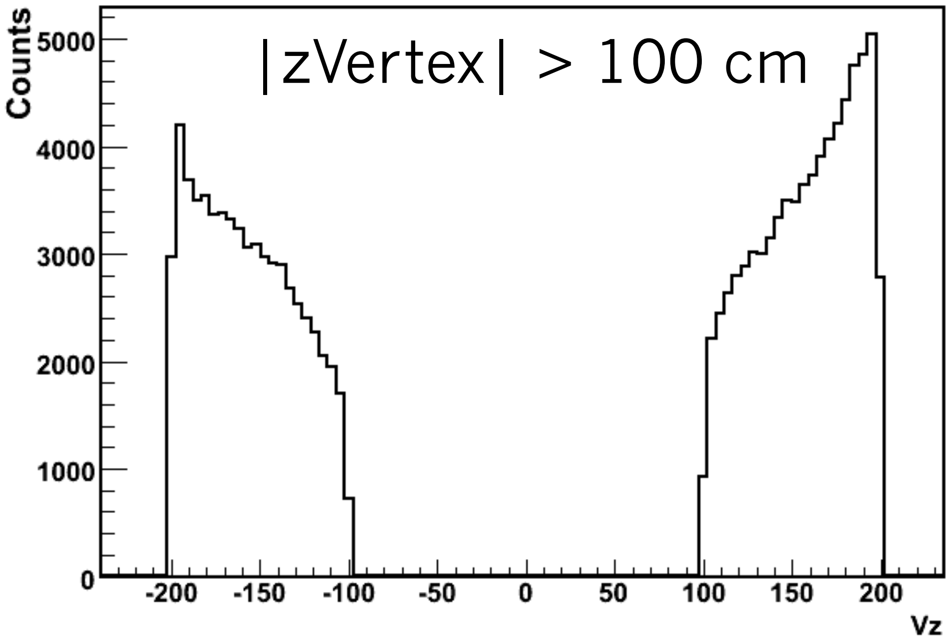
- $\sqrt{(s_{NN})} = \sqrt{(2m^2 + 2Em)}$
  $m = 0.9315\ GeV/c^2$; $E = 9.8\ GeV$
- $\sqrt{(s_{NN})} = 4.47\ GeV$
- $p_z = \sqrt{(E^2 - m^2)} = 9.76\ GeV/c$

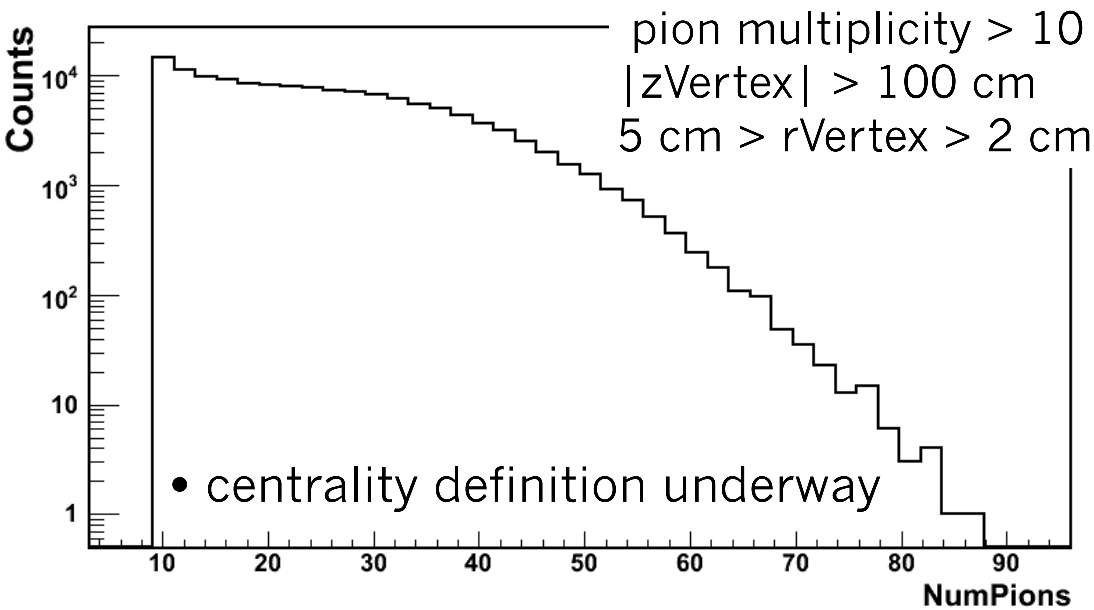
rapidity (y)

- $y_{beam} = 0.5*[\ln(E + p_z)/(E - p_z)]$
- $y_{beam} = 3.0$
- $y_{cm} = 1.5$

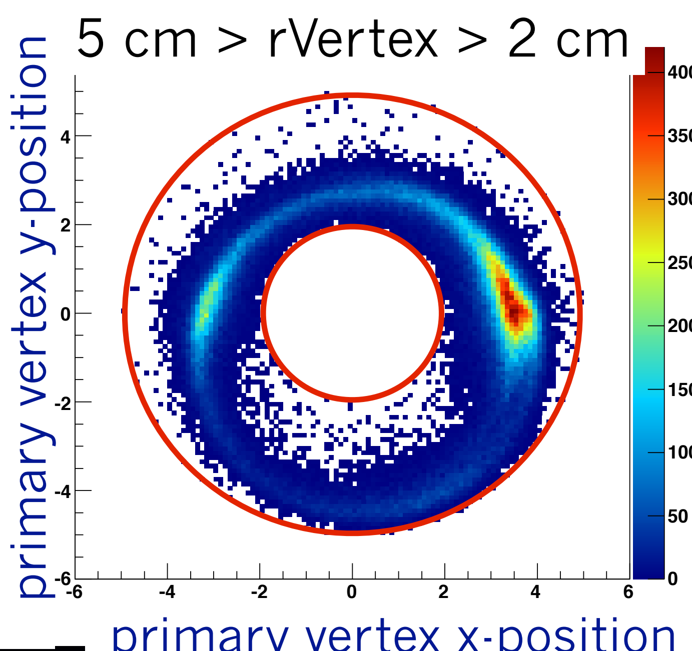
Event Selection

- Run 11 – 19.6 Au+Au collider data
- Au+Al $\sqrt{s_{NN}}$ = 4.5 GeV
- 137k events pass selection cuts from 146 M total Au+Au triggered events

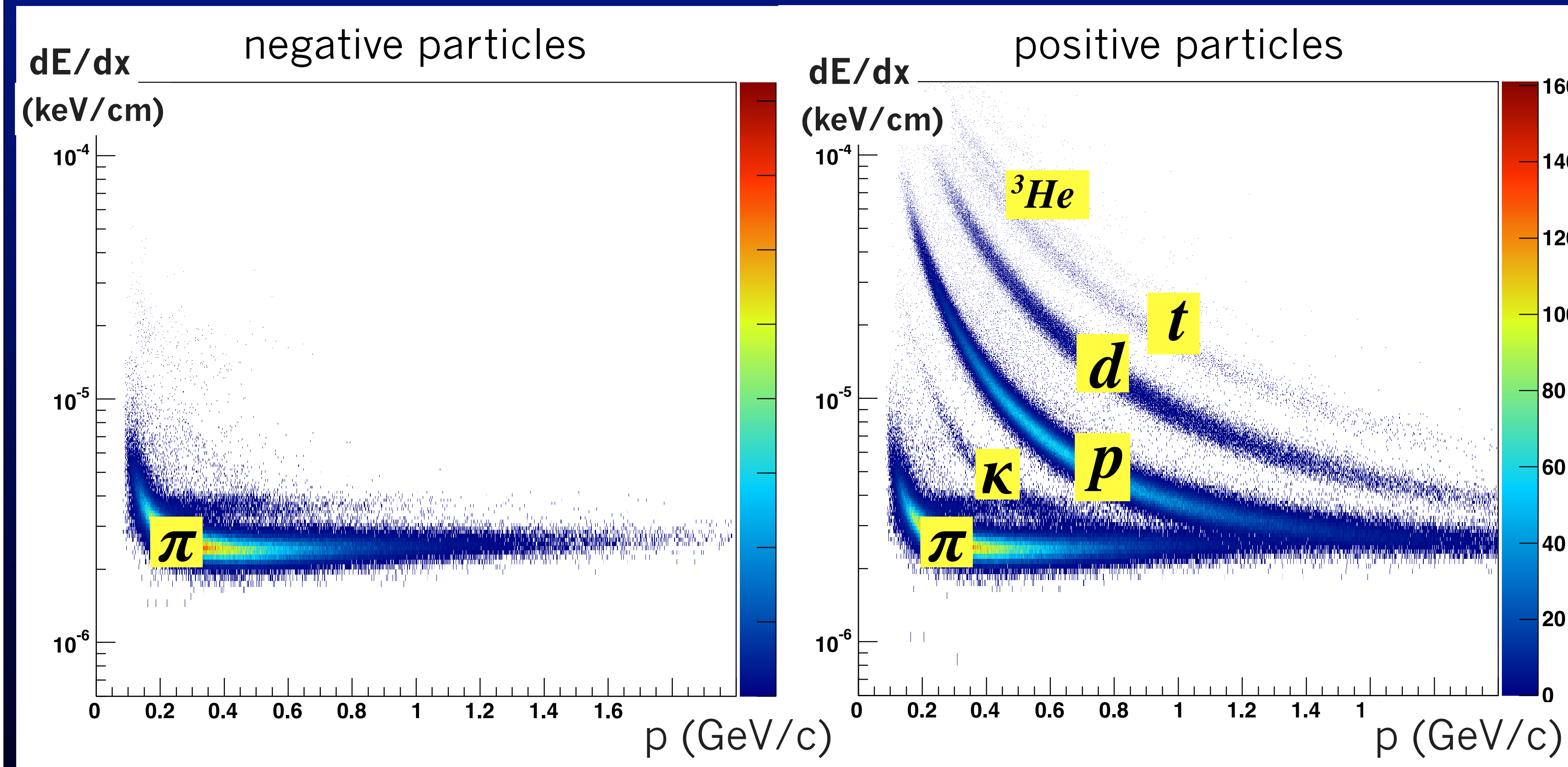




- centrality definition underway

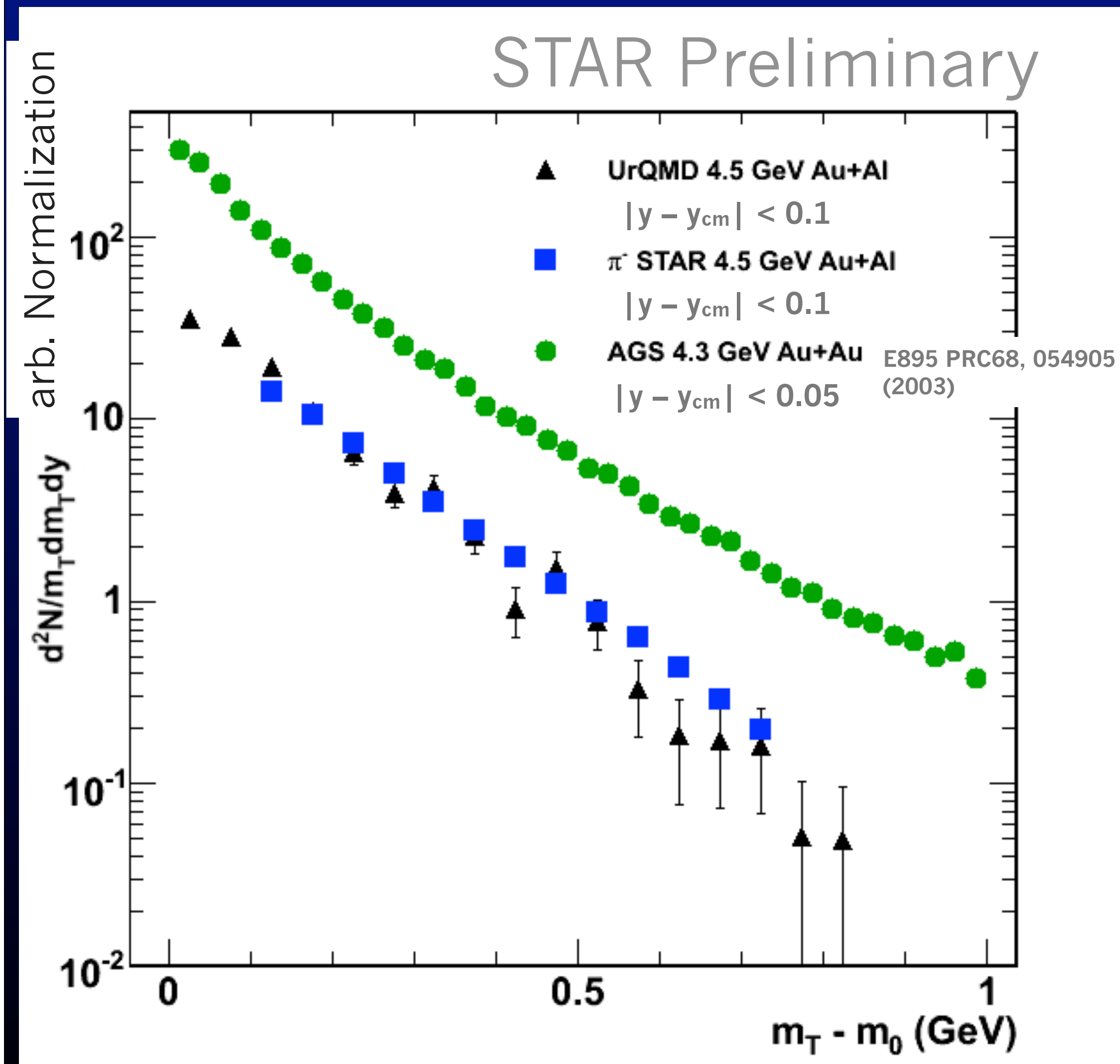


Particle identification via dE/dx



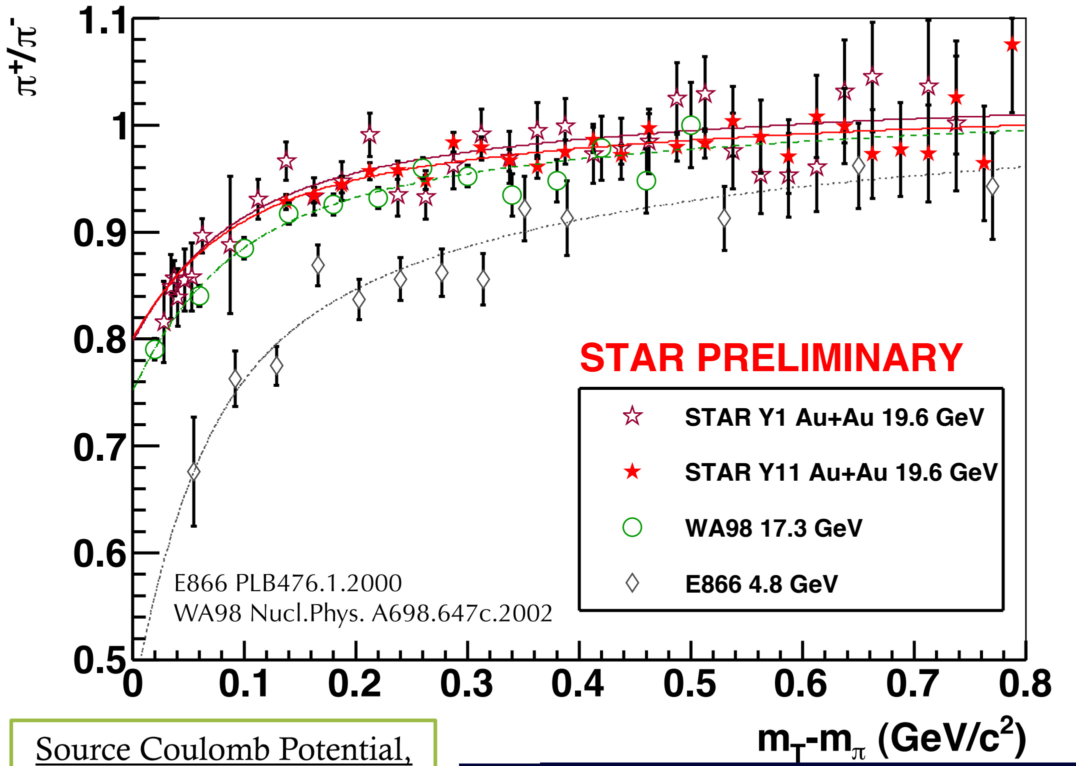
- dE/dx from beampipe events as per selection criteria in slide 7
- particle bands are well separated

π^- spectra comparisons



- uncorrected STAR data points
- slopes of π^- spectra STAR data, AGS data, and UrQMD compare reasonably
- AGS yields are predictably above STAR for Au+Au (AGS) vs. Au+Al (STAR)

π^+/π^- yield ratios



Source Coulomb Potential, V_c (MVolts)
Y1: 8.54 +/- 0.78
Y11: 8.07 +/- 0.61
WA98: 9.83 +/- 0.63
E866: 16.32 +/- 1.92

Overall Pion Ratio, R
Y1: 0.960 +/- 0.005
Y11: 0.953 +/- 0.002
WA98: 0.935 +/- 0.004
E866: 0.771 +/- 0.011

- Net positive charge in the collision zone
  - expanding spherical source → effective potential
- Extracted parameters include initial ratio R and the full coloumb potential Vc
- Coulomb potential (Vc) of the source modifies momentum distribution
  - greater effect for low–momentum π
- R–primordial ratio from initial yields, unmodified by the coloumb source

STAR Au+Al 4.5 GeV π^+ measurement pending

Conclusions and Outlook

- We can do physics with STAR as a fixed target experiment !
  - We have been able to extract pion spectra for fixed target collisions at lab rapidity
    - working to understand detector efficiency at high rapidities via simulated events
    - checking pion contamination, stability of multiplicity as a function of zVertex
  - Yields and slopes compare favorably with published data in this energy range
  - We **can** extend the search for the critical point to lower energies
    - We have more fixed target data at $\sqrt{(s_{NN})}$ of 3.0 and 3.5 GeV

Backup Slides

Source Coulomb Potential

$$\frac{\pi^+}{\pi^-}(m_T - m_\pi) = R\frac{\exp\left[\left(E+V_{\text{eff}}\right)/T_\pi\right]-1}{\exp\left[\left(E-V_{\text{eff}}\right)/T_\pi\right]-1}\cdot J$$

Ratio as a function of transverse kinetic energy with transformed B-E distribution

$$J = \frac{E-V_{\text{eff}}}{E+V_{\text{eff}}}\frac{\sqrt{\left(E-V_{\text{eff}}\right)^2-m_\pi^2}}{\sqrt{\left(E+V_{\text{eff}}\right)^2-m_\pi^2}}$$

Jacobian of the transformation

$$V_{\text{eff}}\left(\gamma_\pi\beta_\pi\right) = V_C\left(1-e^{-E_{\max}(\gamma_\pi\beta_\pi)/T_p}\right)$$

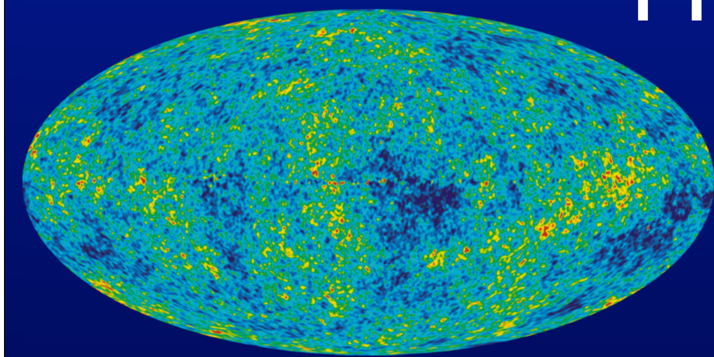
Effective Coulomb potential accounting for the reduced charge seen by low momentum π

$$E_{\max}\left(\gamma_\pi\beta_\pi\right) = \sqrt{\left(m_p\gamma_\pi\beta_\pi\right)^2+m_p^2}-m_p$$

Maximum kinetic energy of the corresponding π velocity

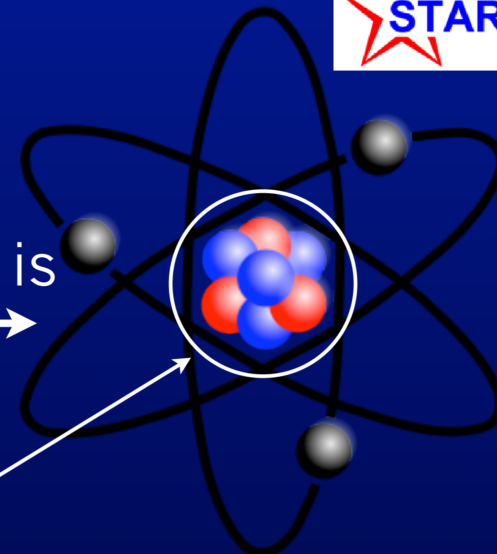
- Net positive charge in the collision zone
  - Expanding spherical source → effective potential
- Coulomb potential (V_c) of the source modifies momentum distribution
  - Greater effect for low-momentum π
- R – primordial ratio from initial yields, unmodified by the coulomb source
- Extracted parameters include initial ratio R and the full coulomb potential V_c

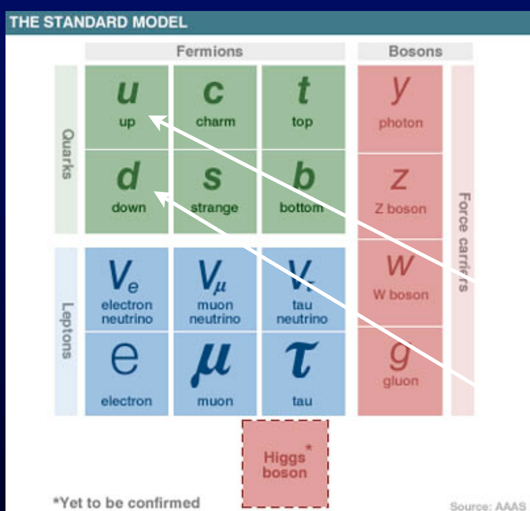
The Basics



matter in the universe is

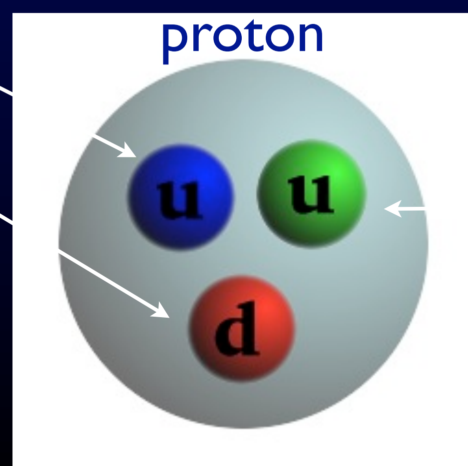
made of atoms





nucleus = protons
+ neutrons

nucleons are hadrons
(made of quarks)



mesons = 2 quarks
baryons = 3 quarks