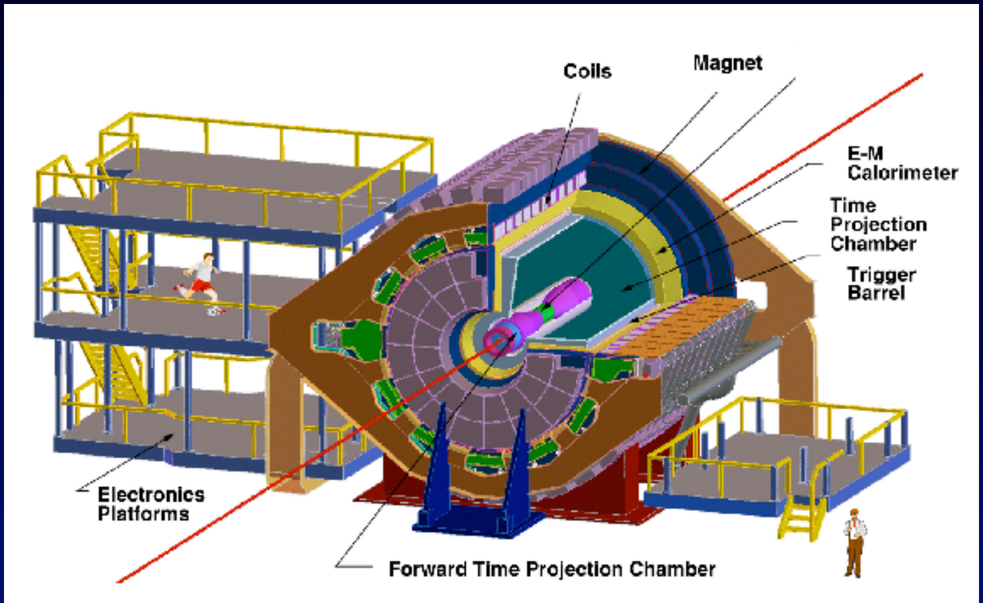
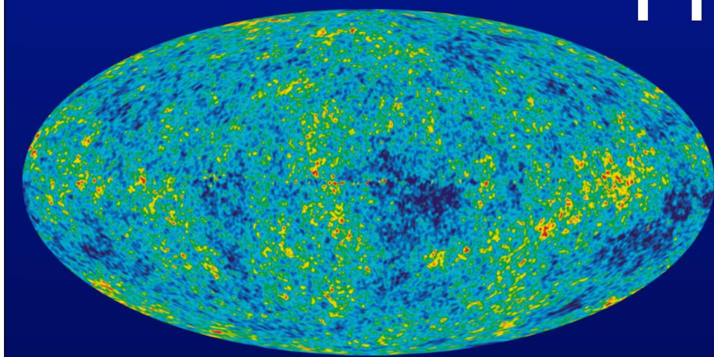
Analysis of fixed target collisions with the STAR detector



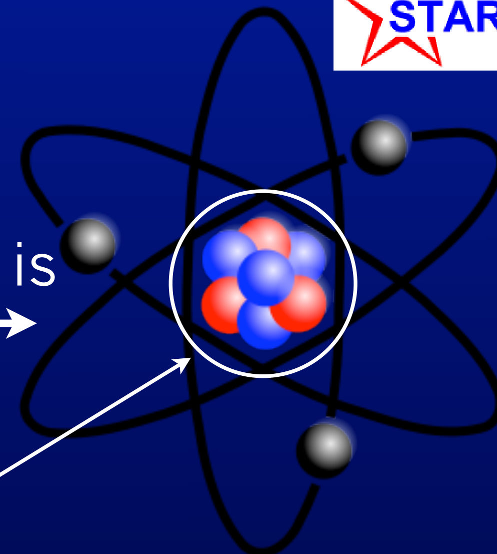
Brooke Haag for the STAR Collaboration
Hartnell College / University of California, Davis
Presented at the Meeting of the California Section of the APS
November 11, 2011

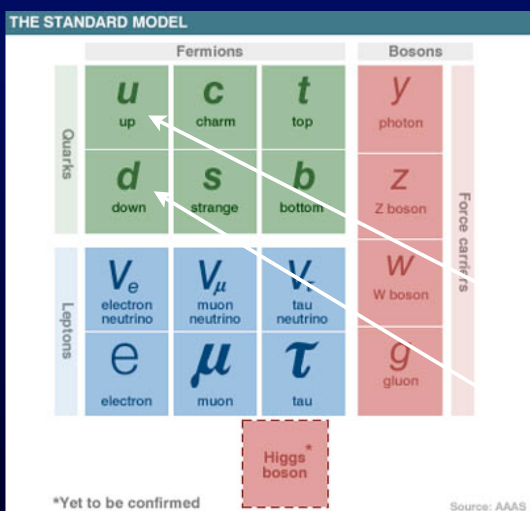
The Basics



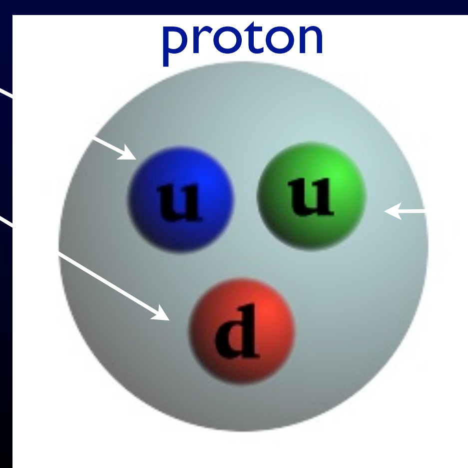
matter in the universe is

made of atoms





nucleus = protons
+ neutrons

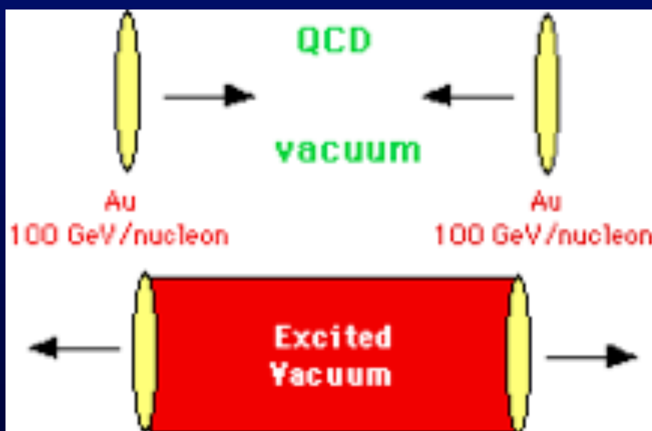


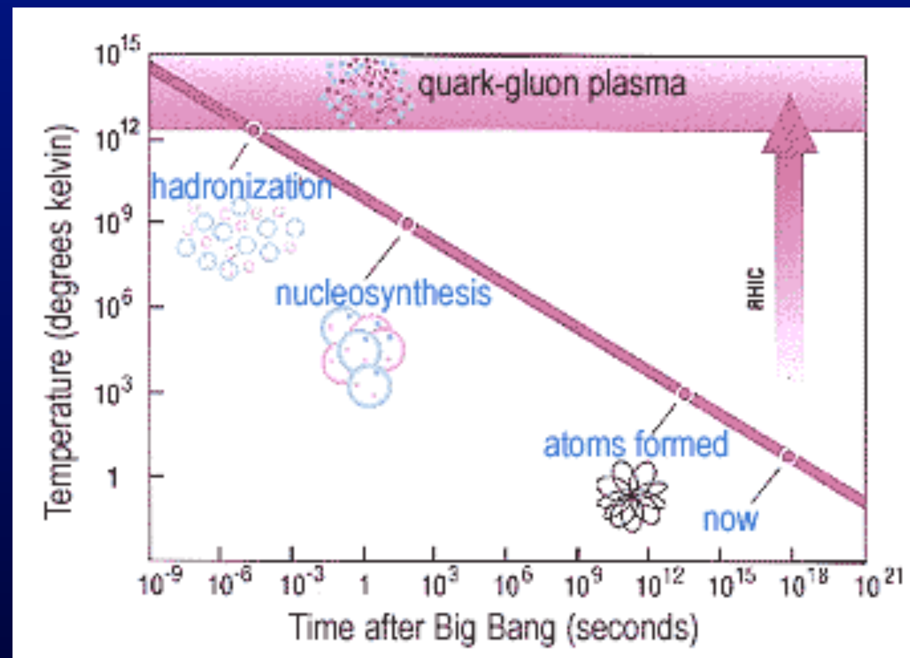
nucleons are hadrons
(made of quarks)

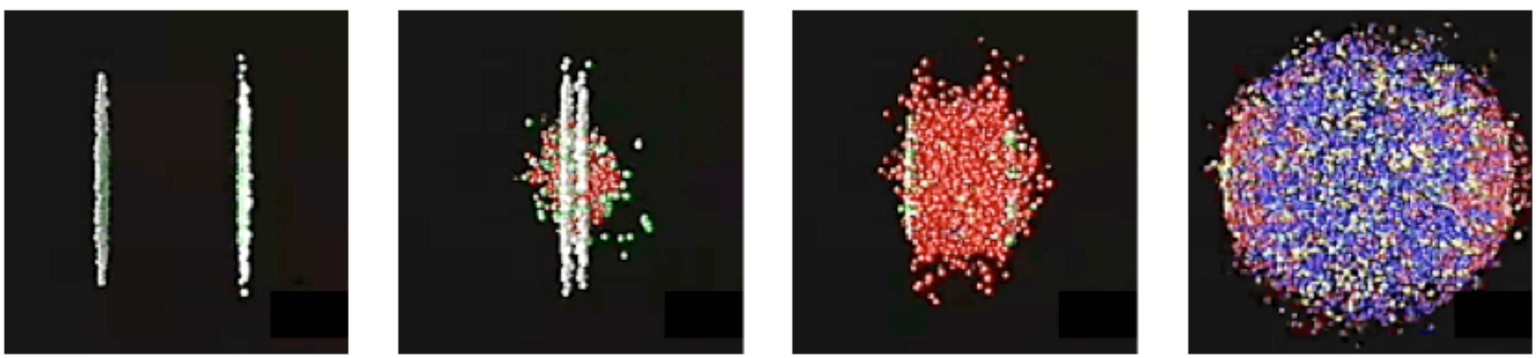
mesons = 2 quarks
baryons = 3 quarks

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

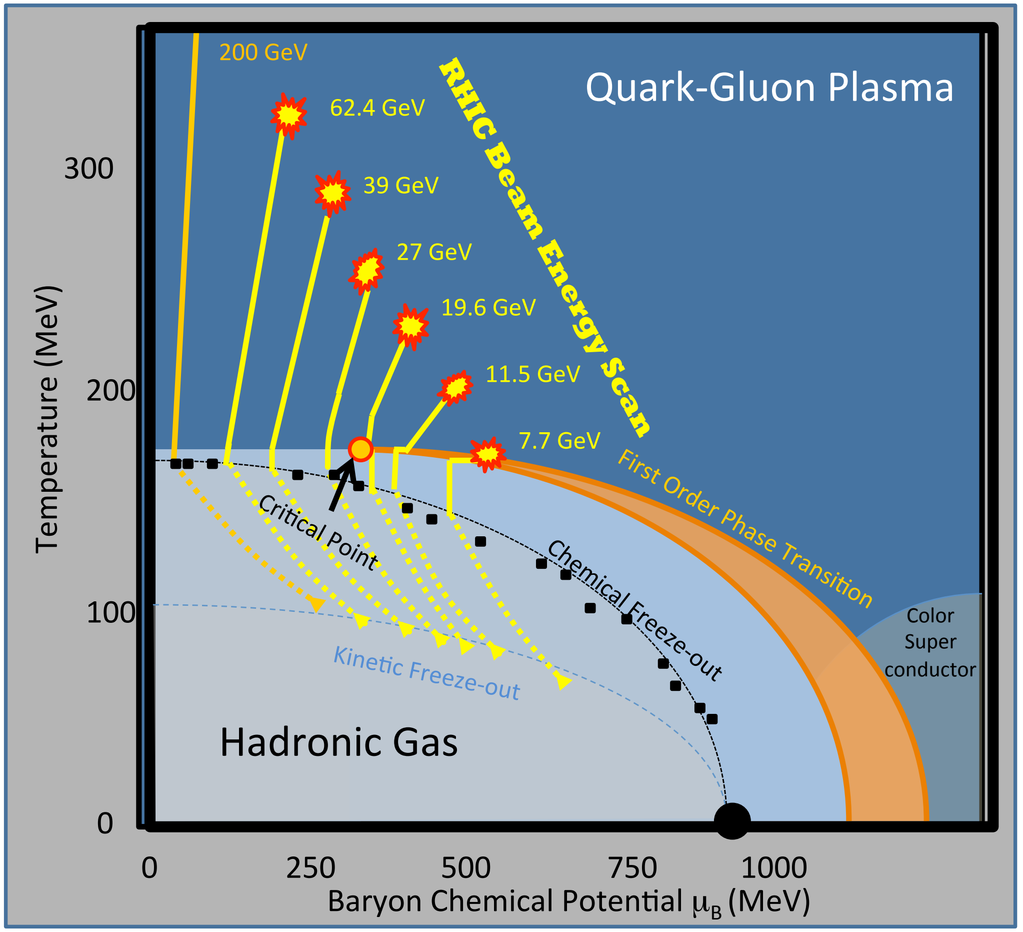






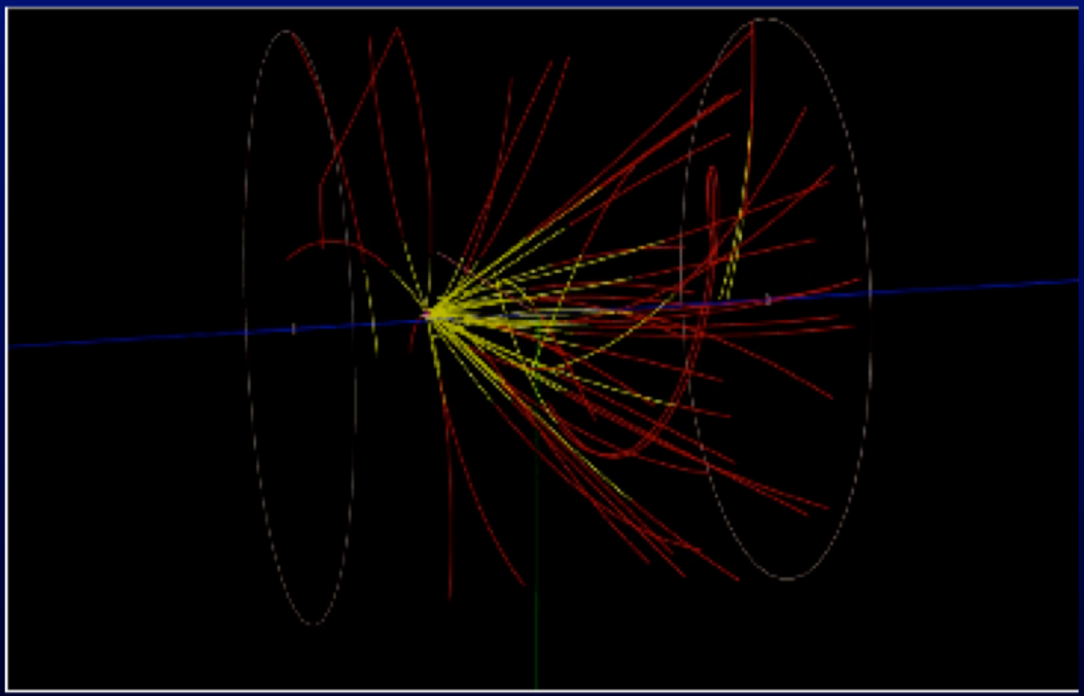
1. Ions about to collide* 2. Ion collision 3. Quarks, gluons freed 4. Plasma created

QCD phase diagram



- We have created a new state of matter consistent with the QGP !
- We have not located the critical point.
- Data were collected in the latest RHIC run in a critical point search.
- Fixed target collisions could extend the physics analysis to even lower √s.

STAR has fixed target events?

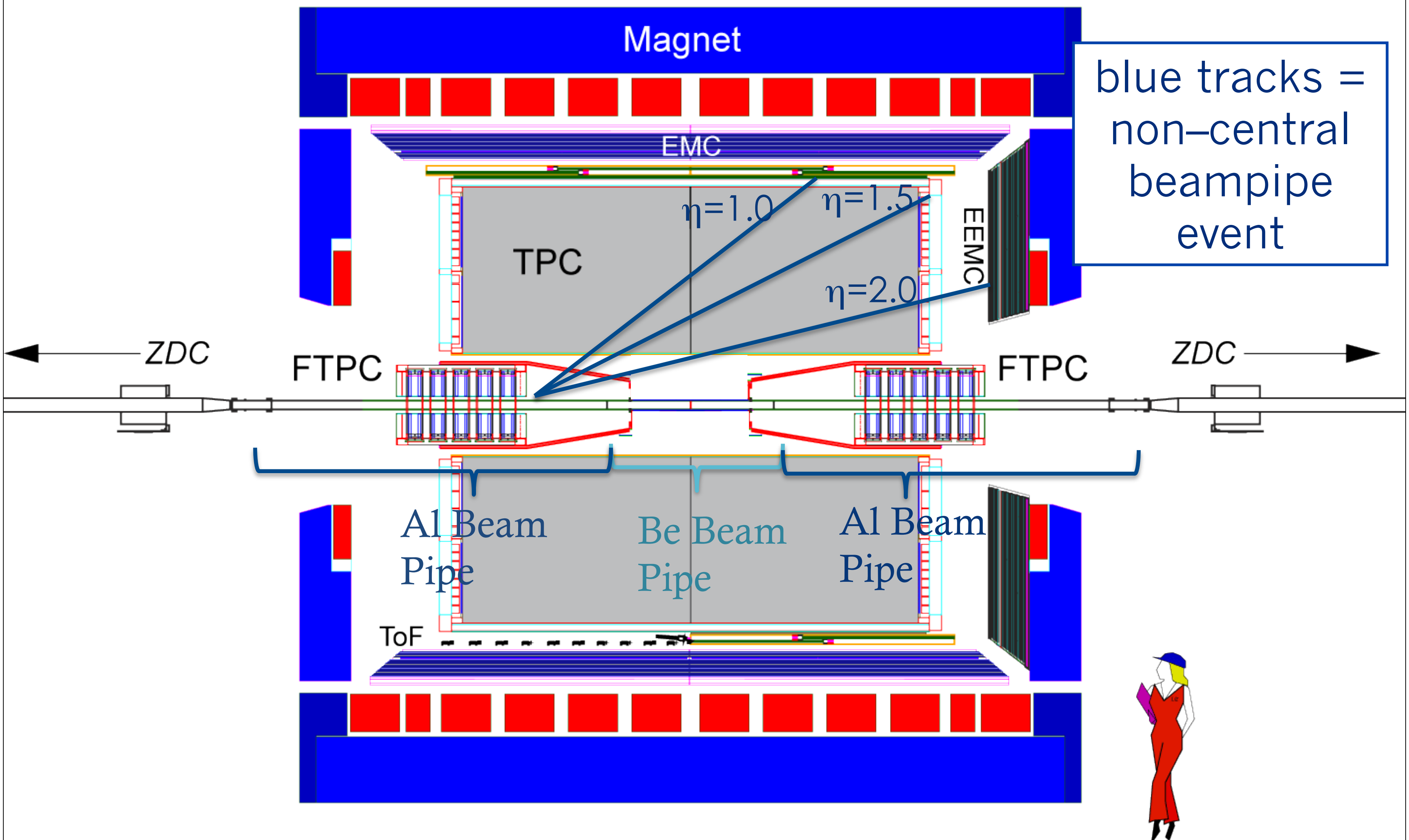


- gold beam ions collide with aluminum beam pipe atoms

- 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

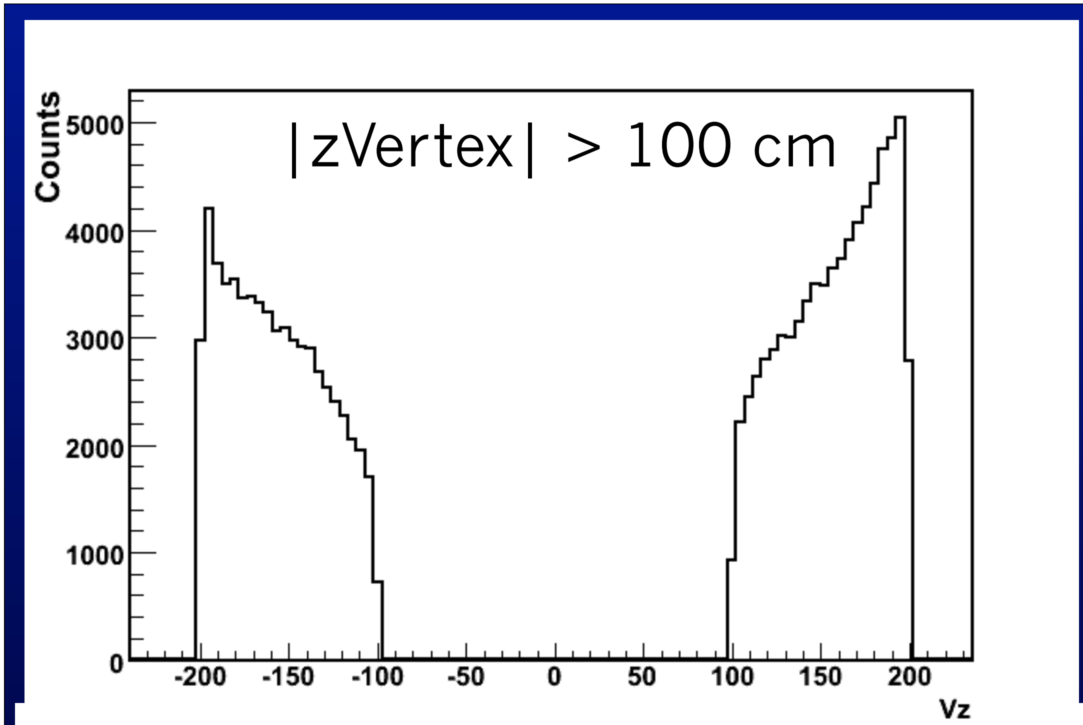
$\sqrt{s_{NN}}$ = center of mass energy

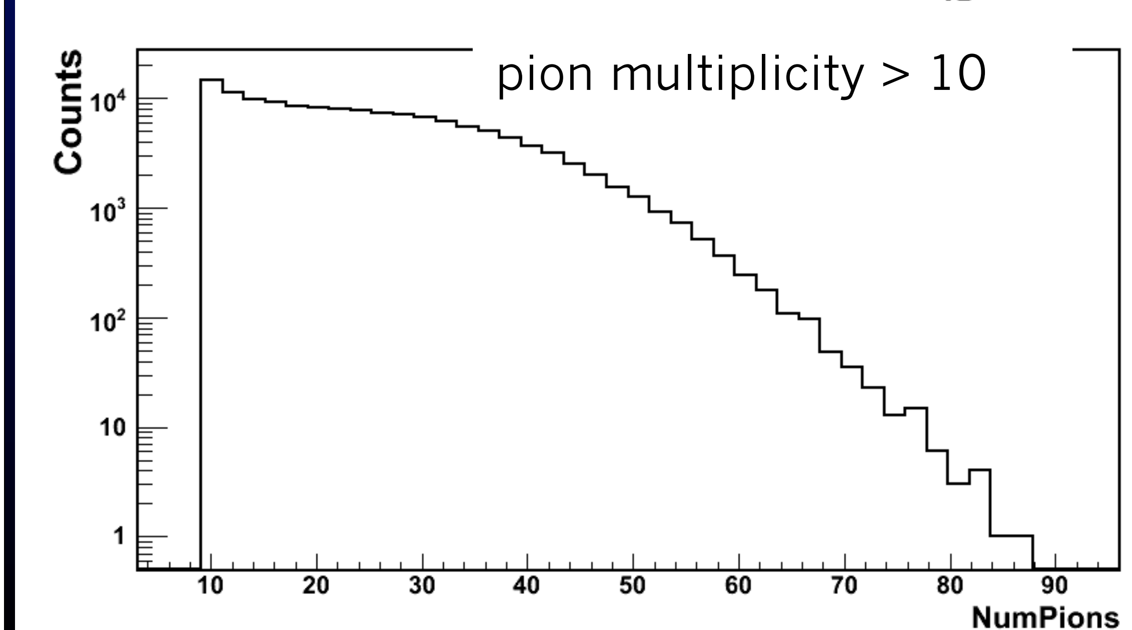
- $\sqrt{s_{NN}} = \sqrt{2m^2 + 2Em}$
  $m = 0.9315$ GeV/c^2 ; $E = 9.8$ GeV
- $\sqrt{s_{NN}} = 4.47$ GeV
- $p_z = \sqrt{E^2 - m^2} = 9.76$ GeV/c

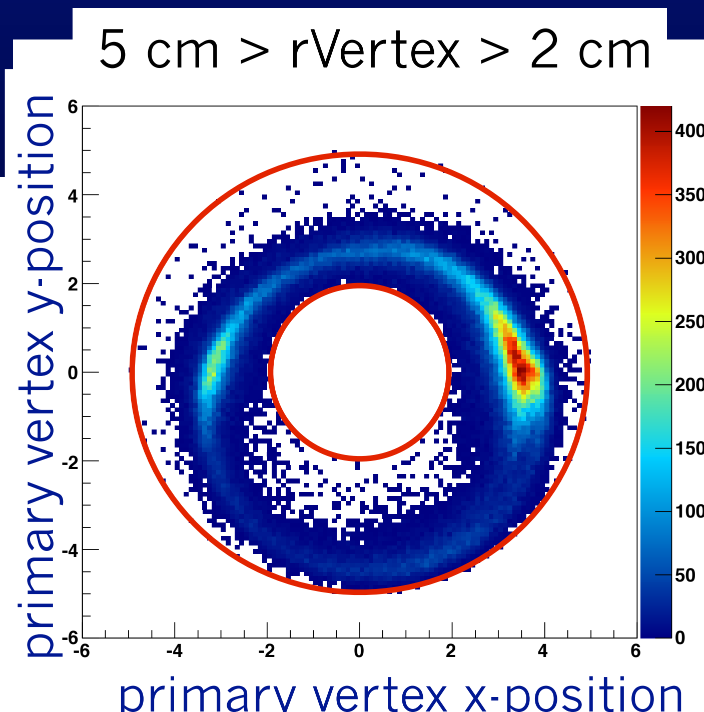
rapidity (y)

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

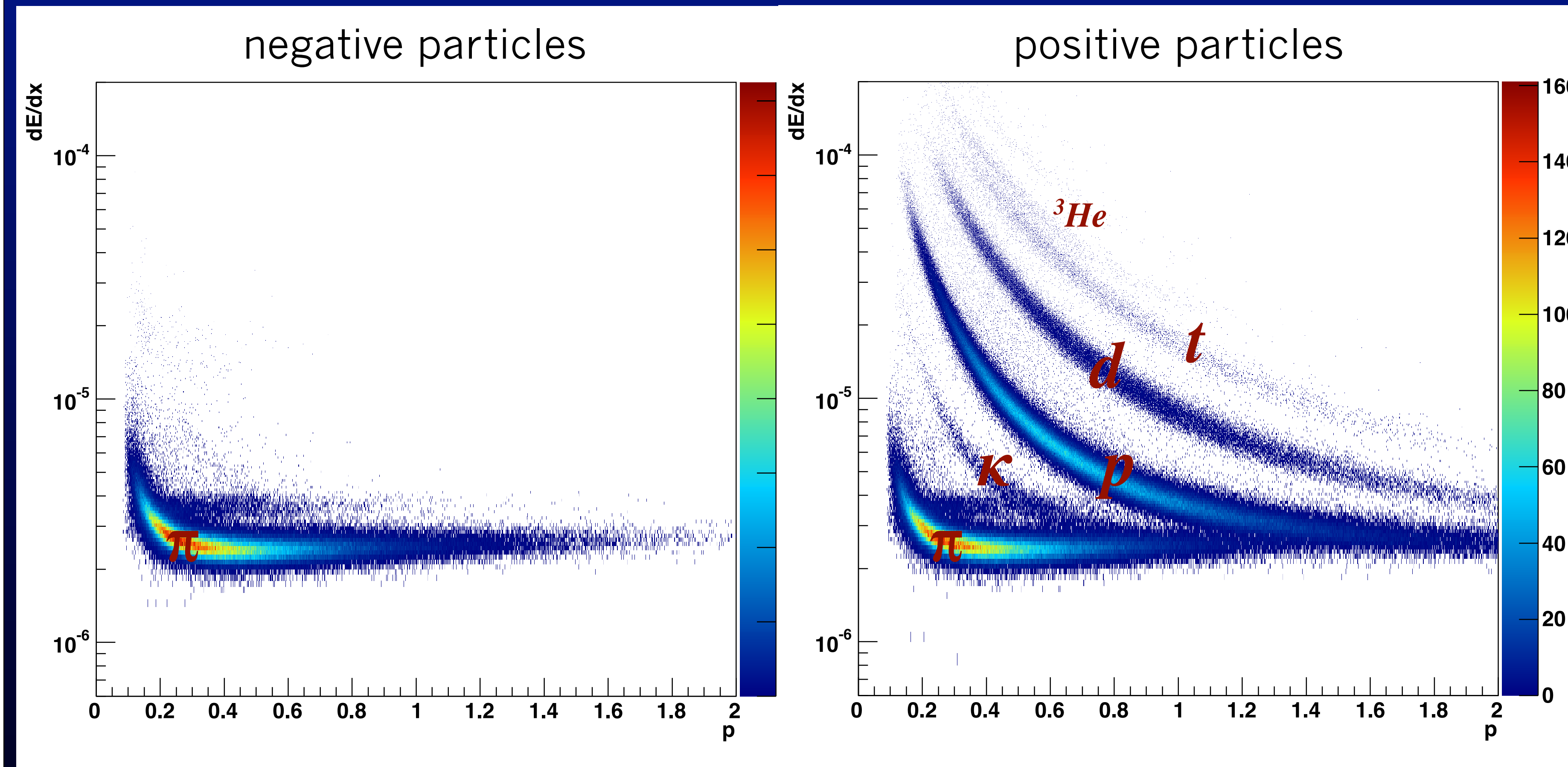
Event Selection:





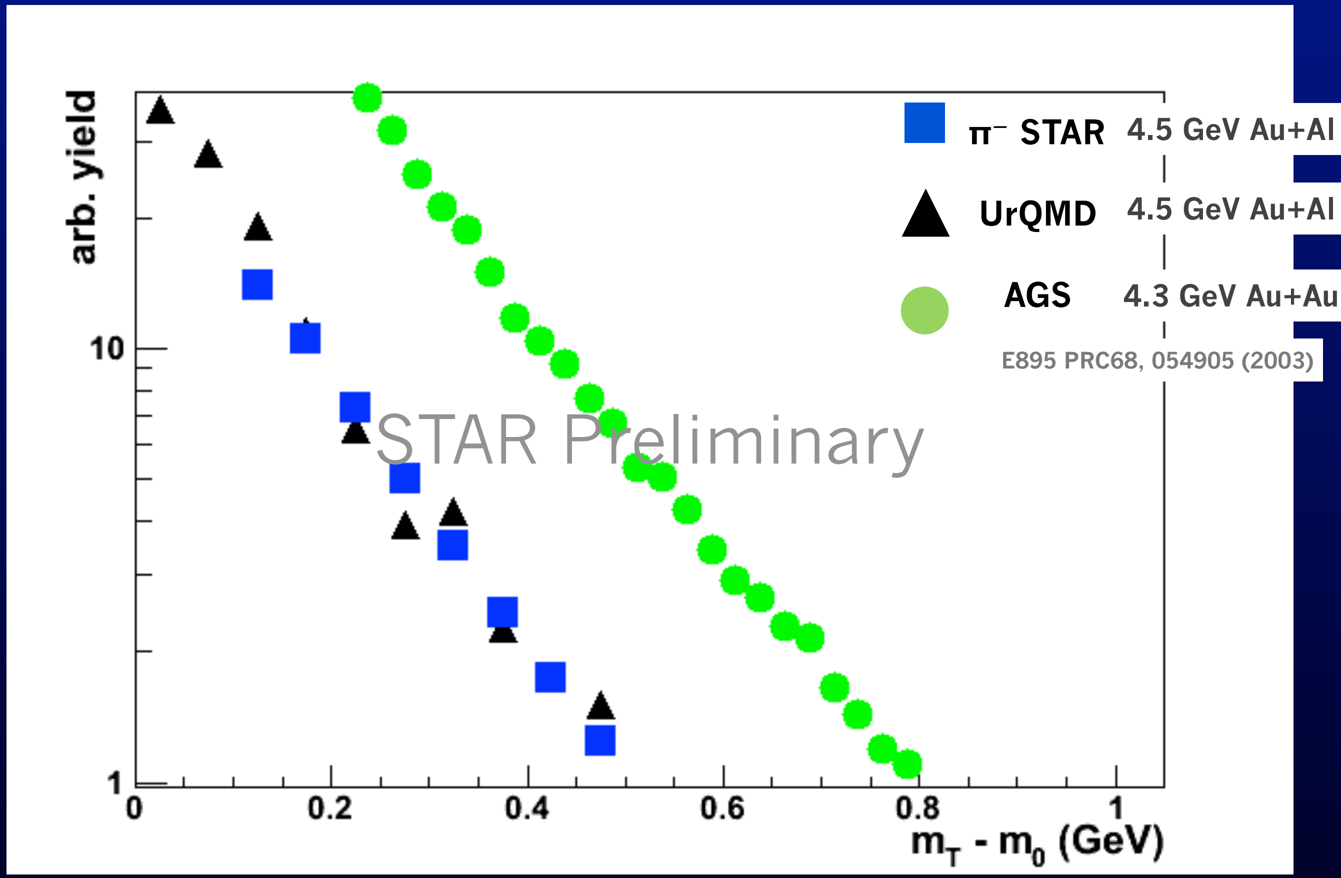


Particle identification via dE/dx



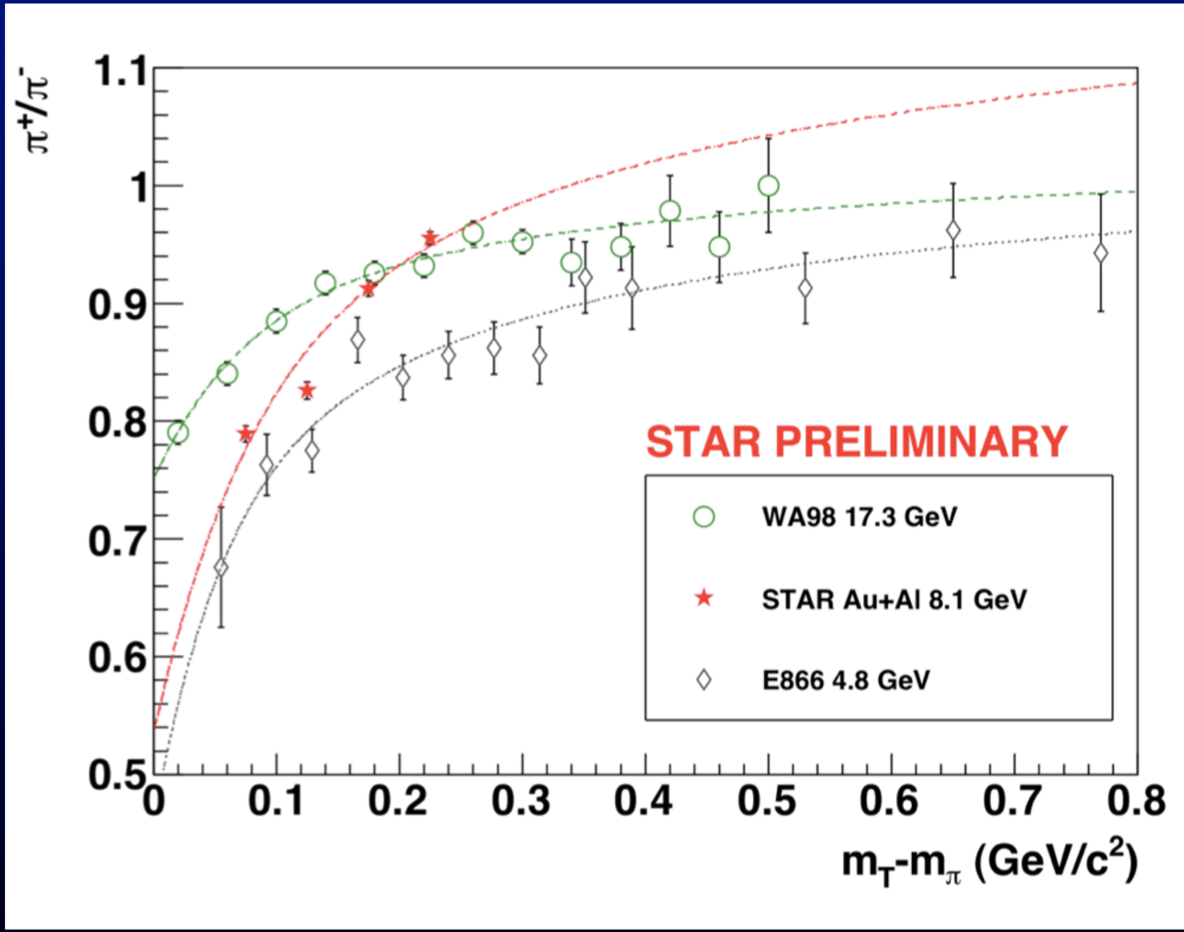
- particle bands are well separated

π^- spectra comparisons



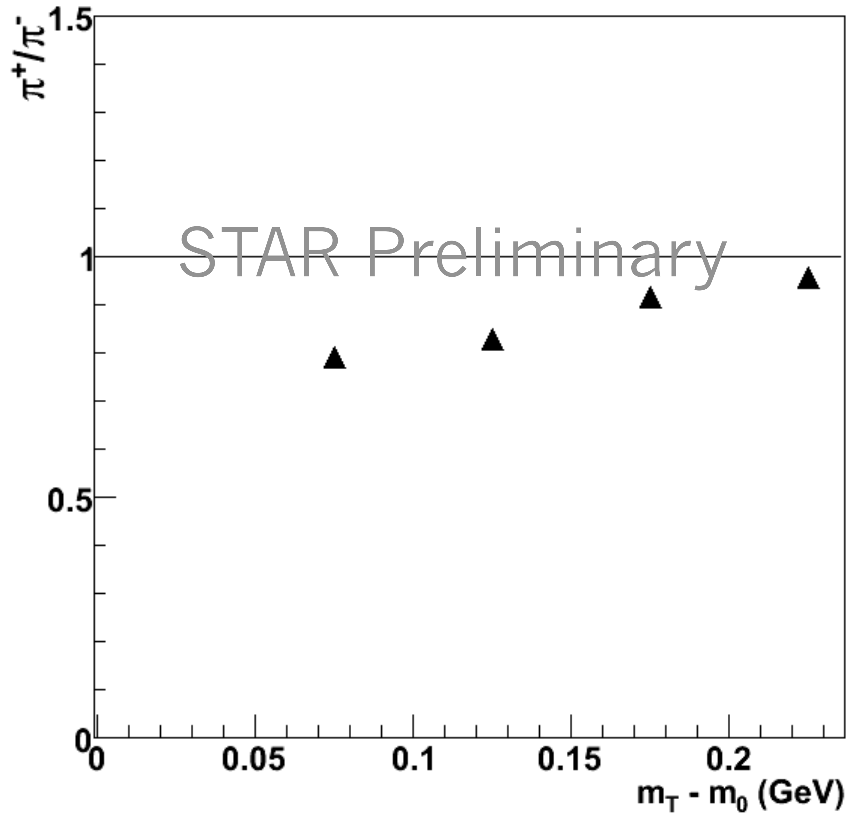
- slopes of π^- spectra STAR data, AGS data, and UrQMD compare reasonably
- AGS yields are predictably above STAR
  - Au+Au (AGS) vs. Au+Al (STAR)

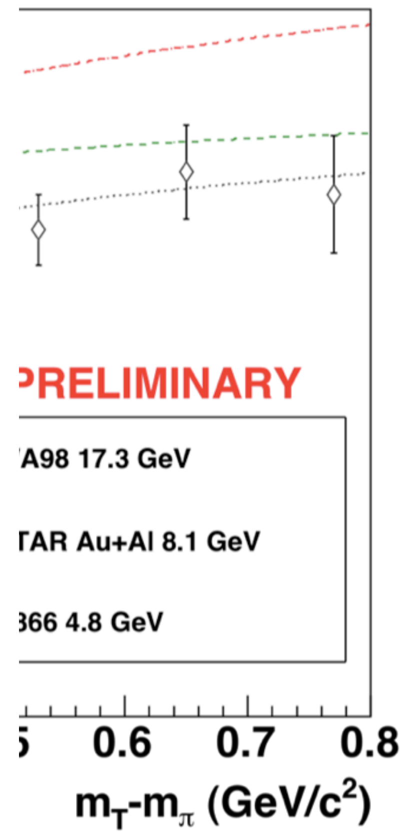
π^+/π^- yield ratios



Coulomb Potential:
WA98: 9.83486 +/- 0.625222
E866: 16.3202 +/- 1.92414
Au+Al: 23.1511 +/- 1.09593
Ratios:
WA98: 0.934634 +/- 0.00384297
E866: 0.771114 +/- 0.0114871
Au+Al: 0.938948 +/- 0.00420591

π^+/π^- yield ratios





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- $\sqrt{s}$ = 4.5 GeV ratio fit a work in progress

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
    - yields and slopes compare favorably with published data in this energy range
    - we **can** extend the search for the critical point to lower energies

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

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

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