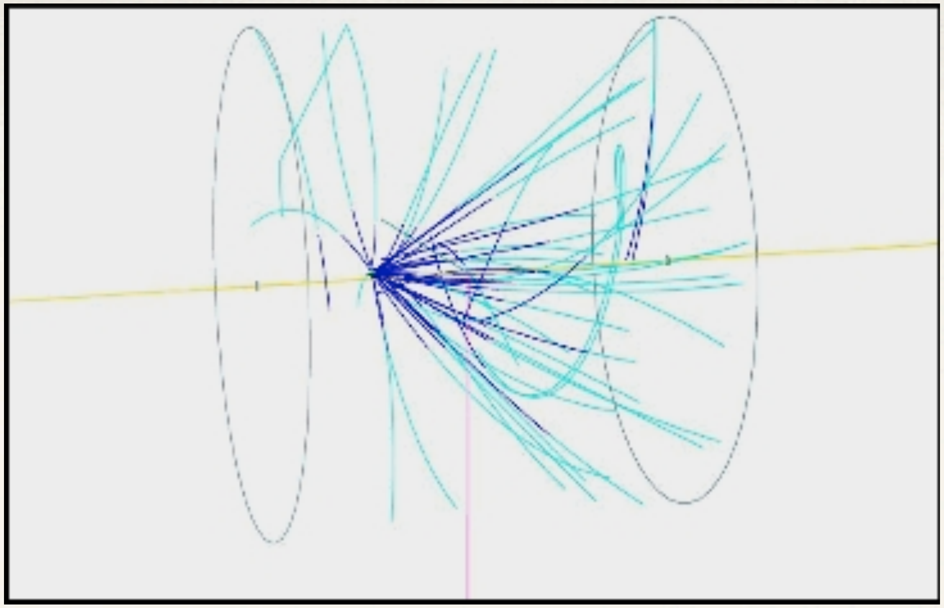
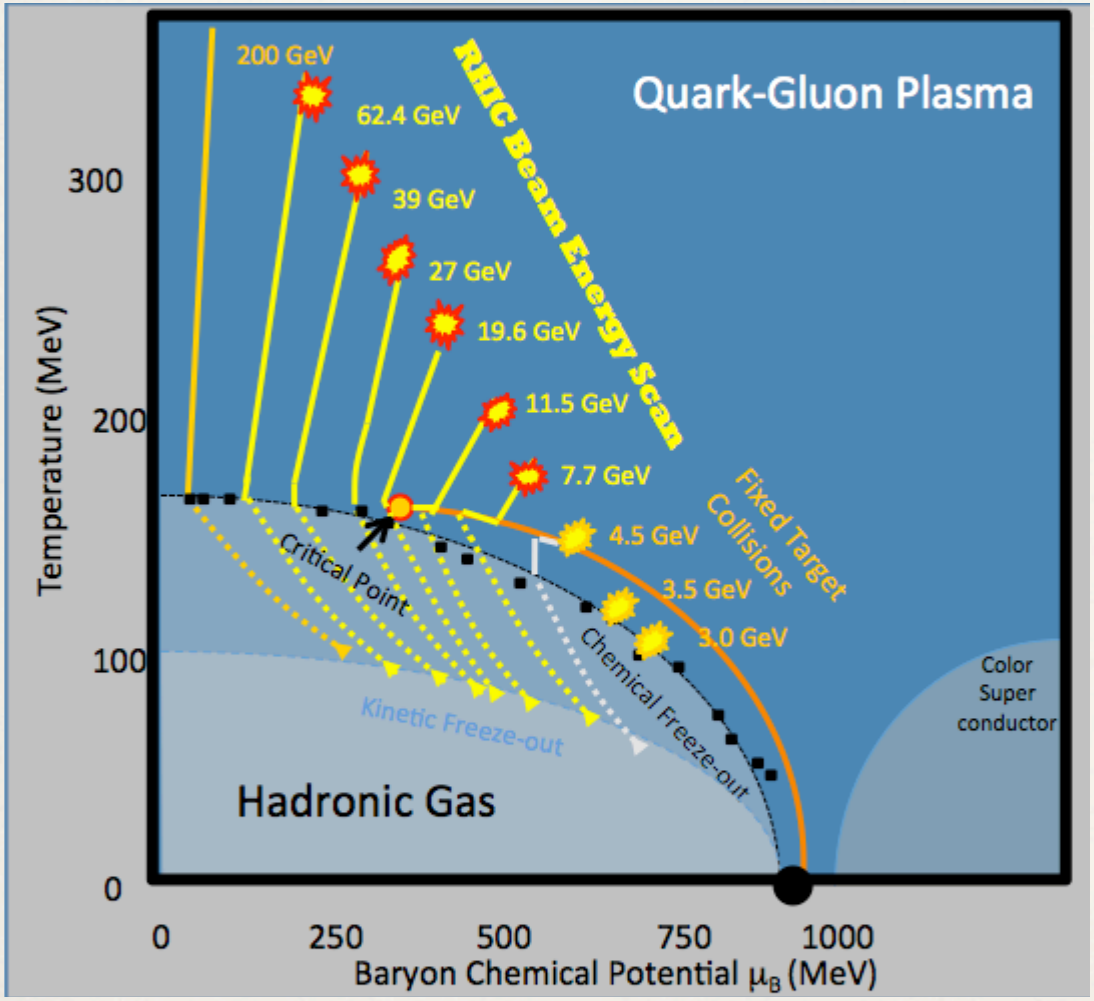


Analysis of fixed target collisions with the STAR detector

Brooke Haag for the STAR Collaboration
Hartnell College / University of California at Davis
Presented at the APS Physics April Meeting, Denver CO

April 14, 2013

QCD phase diagram



- We have created a new state of matter at $\sqrt{(s_{NN})}$ = 200 GeV consistent with the QGP !
- In 2010 and 2011 an extensive beam energy scan [1] was undertaken at RHIC with a major goal to find the critical point.
- Fixed target collisions will extend the physics analysis to even lower $\sqrt{s}$, higher μ_B

[1] http://arxiv.org/pdf/1007.2613.pdf

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)

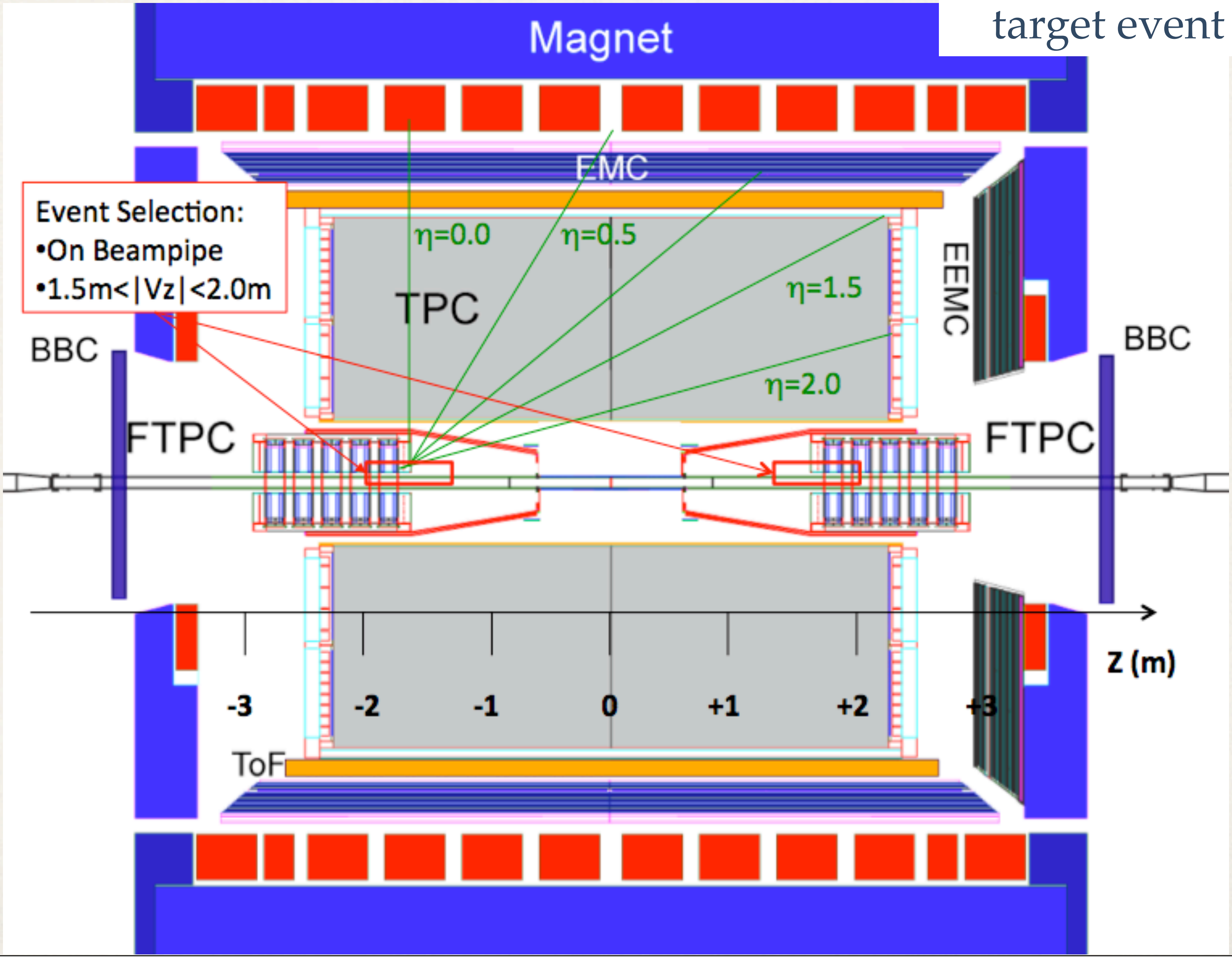
$$y_{beam} = 0.5*[\ln(E + p_z)/(E - p_z)]$$

$$y_{beam} = 3.0$$

$$y_{cm} = 1.5$$

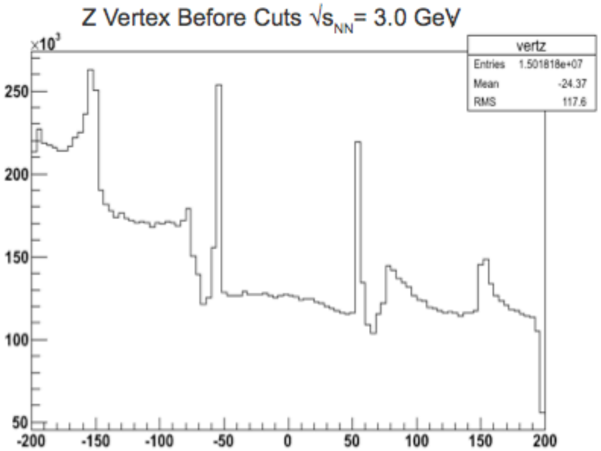
STAR Detector Array

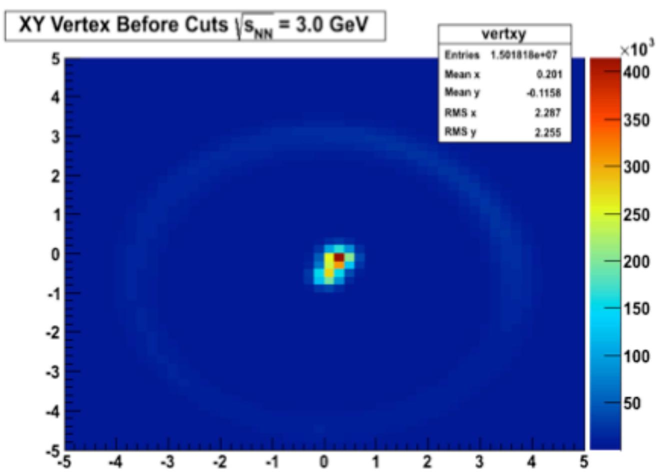
green tracks denote fixed target event



Event Selection

Before Cuts





Event Cuts

- Vertex Requirements -

$-200 \leq V_z \leq -150$ cm

$2 \leq V_R \leq 5$ cm

- Momentum -

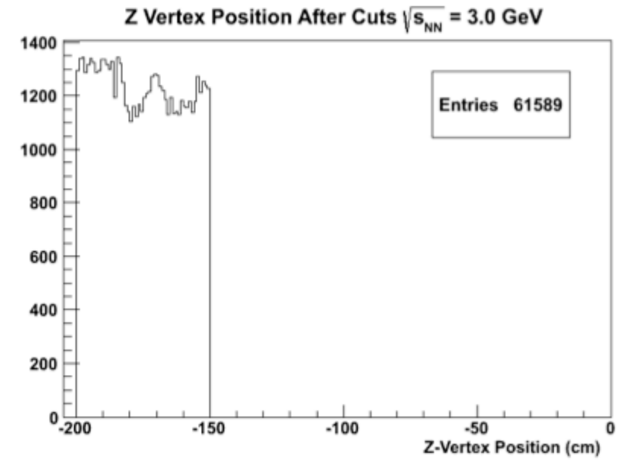
$$\sum_{Tracks} p_z > 0$$

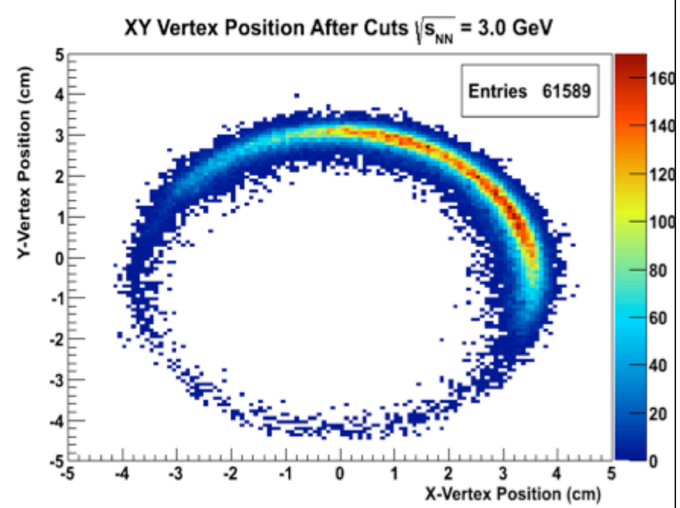
- Centrality Cut -

Top 10 %

Apply Cuts

After Cuts

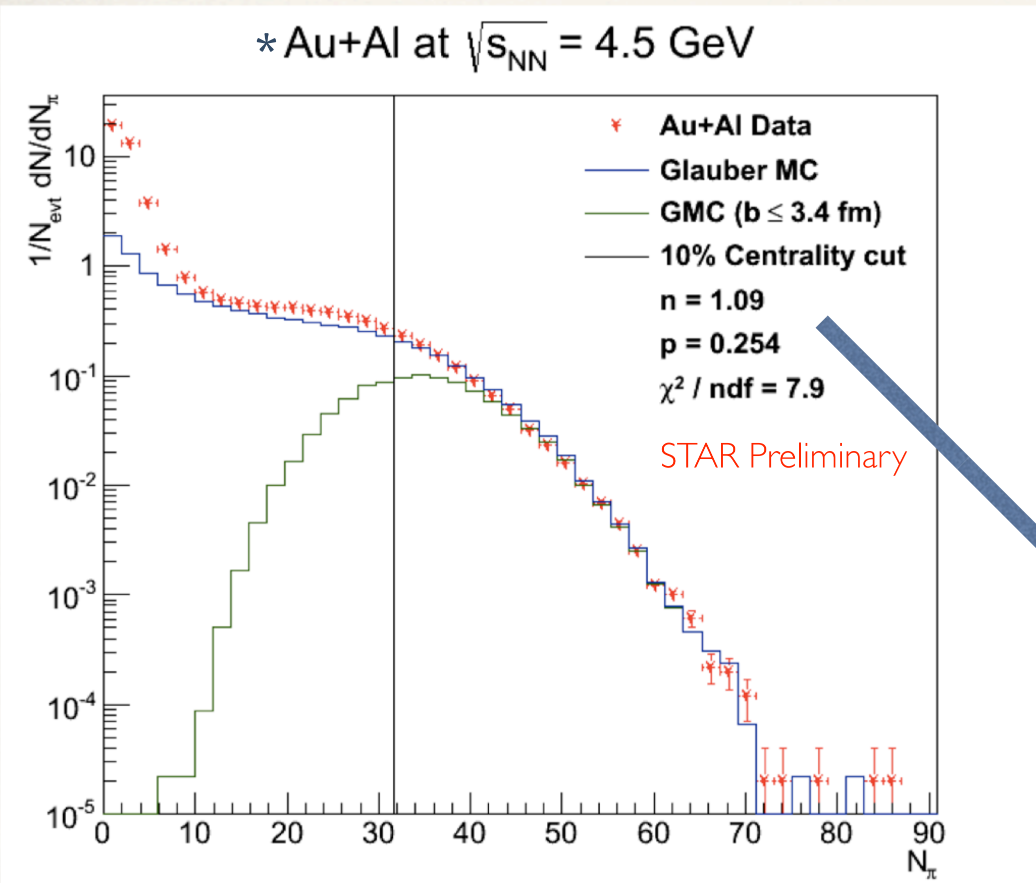


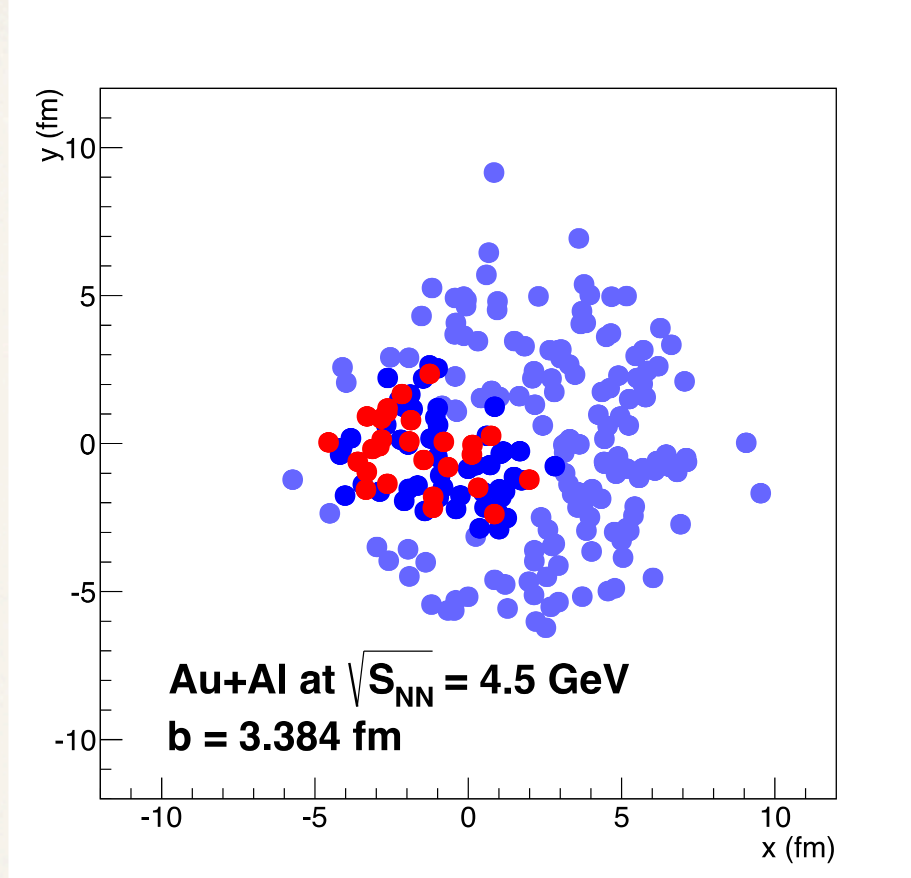


Centrality

* at very low multiplicity, we have light ions interacting

Fixed Target √s	2.99	3.53	4.47
Fixed Target y_{cm}	1.05	1.25	1.52
Events satisfying fixed target cuts	3.0 M	4.1 M	3.1 M
Au+Al top 10%	78 K	114 k	101 k





Number of pions is used to determine centrality via Glauber MC predictions

n, p are parameters of negative binomial fit

Centrality

Fixed Target $\sqrt{s}$	2.99	3.53	4.47
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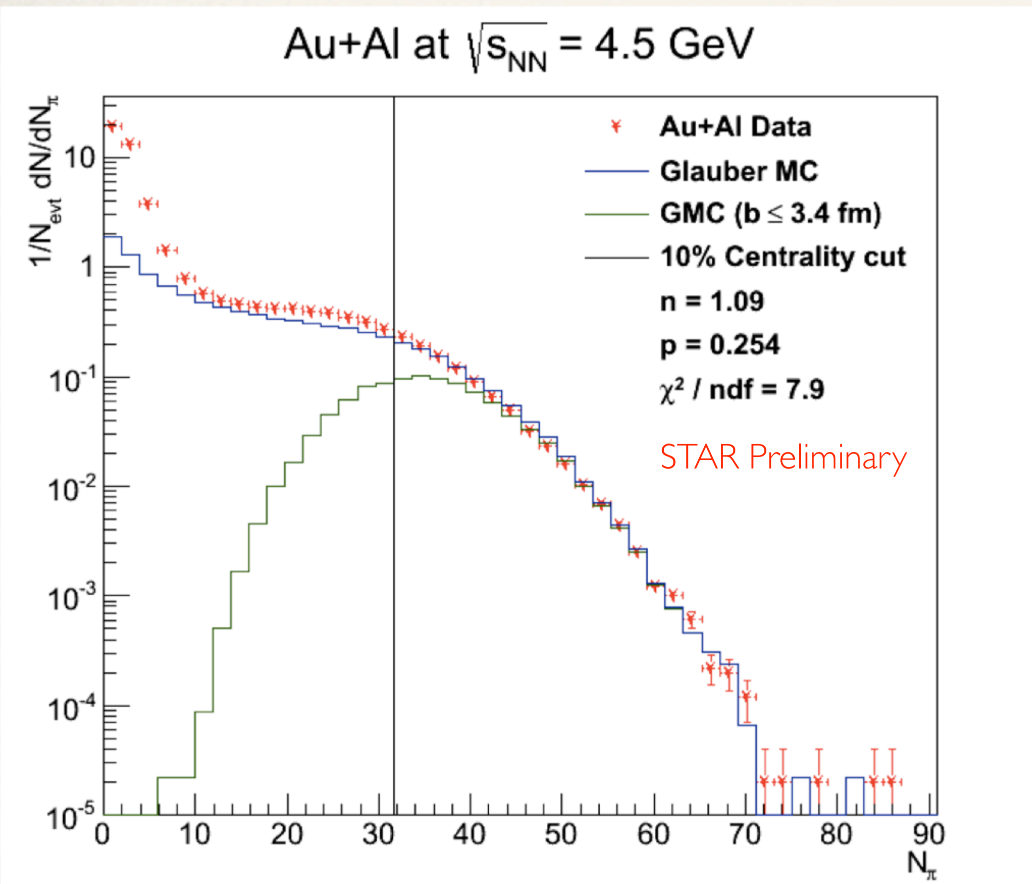
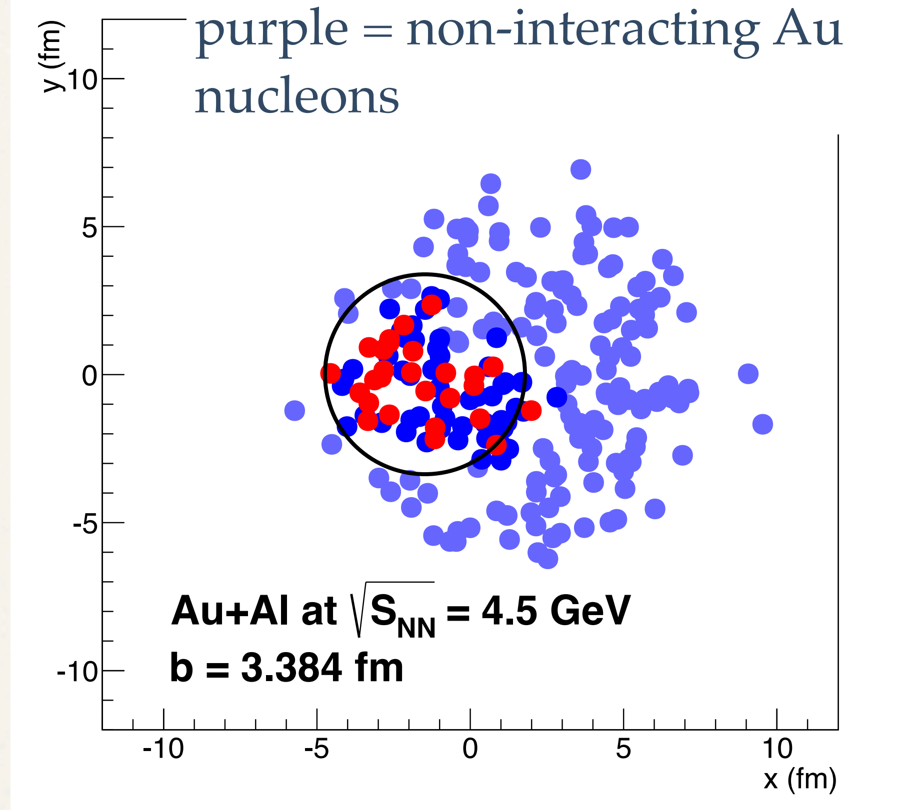


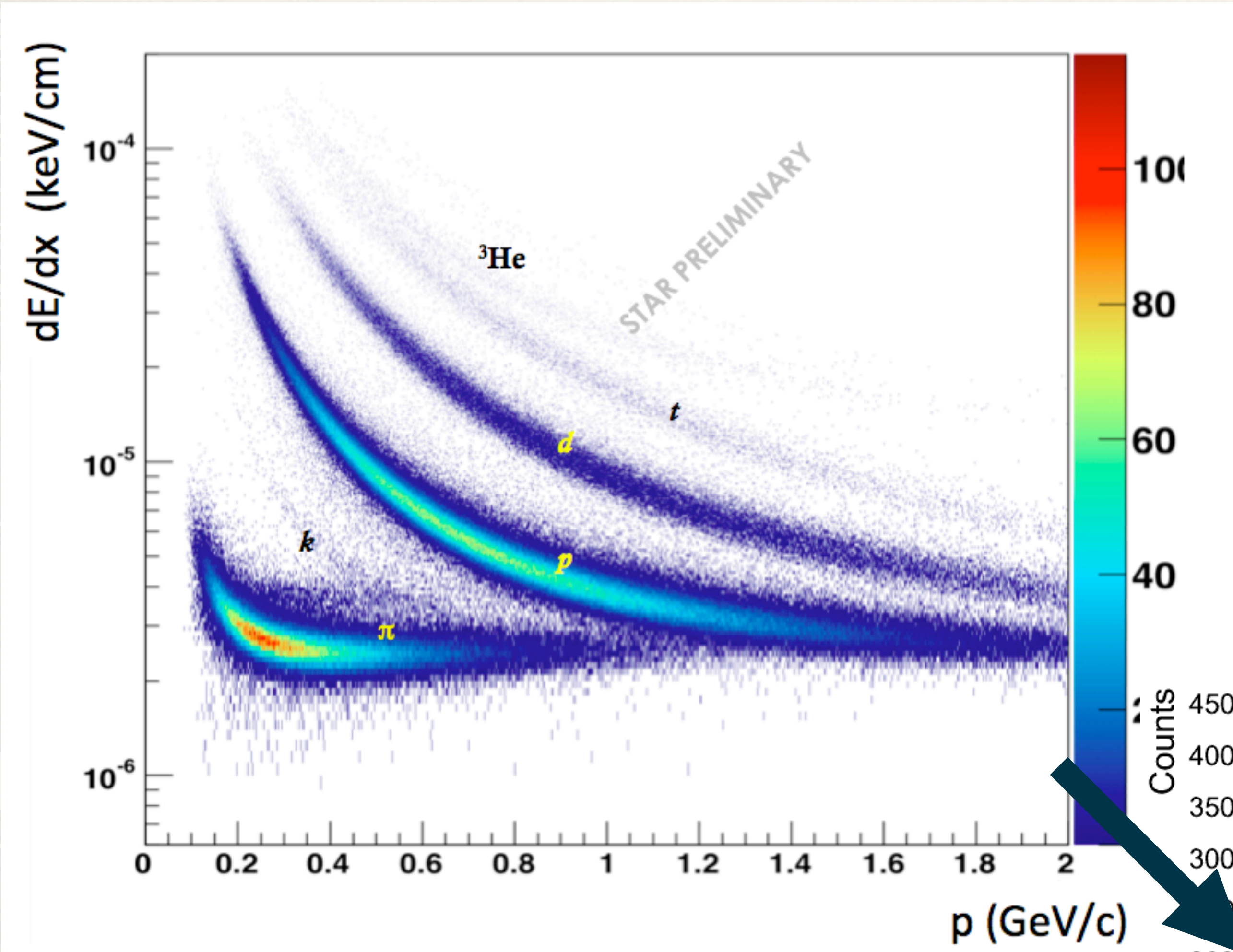
red = interacting Al nucleons
blue = interacting Au nucleons
purple = non-interacting Au nucleons



37 protons within radius of 3.4 fm gives Coulomb potential = 15 MeV

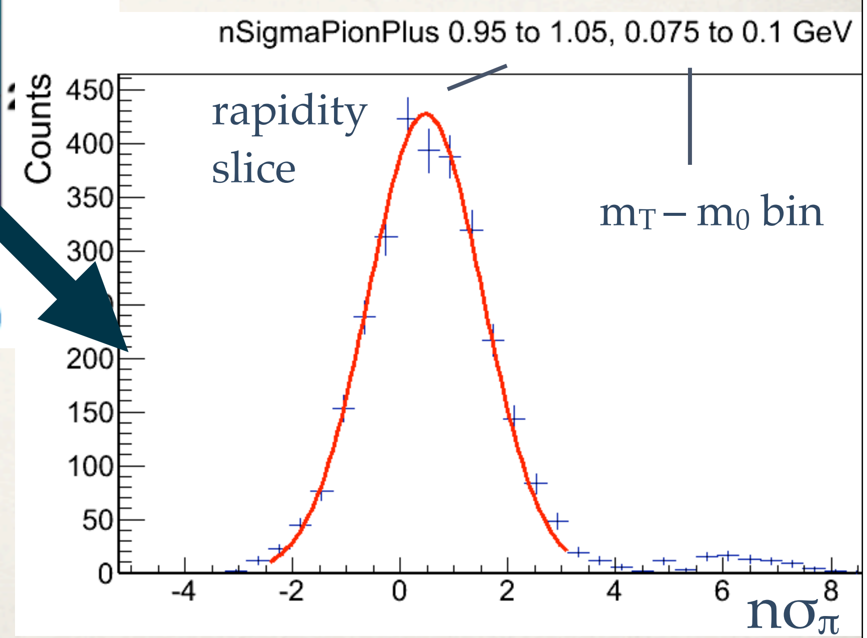
→ measure Coulomb boost of pions which will allow us to estimate # of interacting protons

Particle identification via dE/dx



energy loss in TPC from beampipe events as per event selection criteria

particle bands are well separated

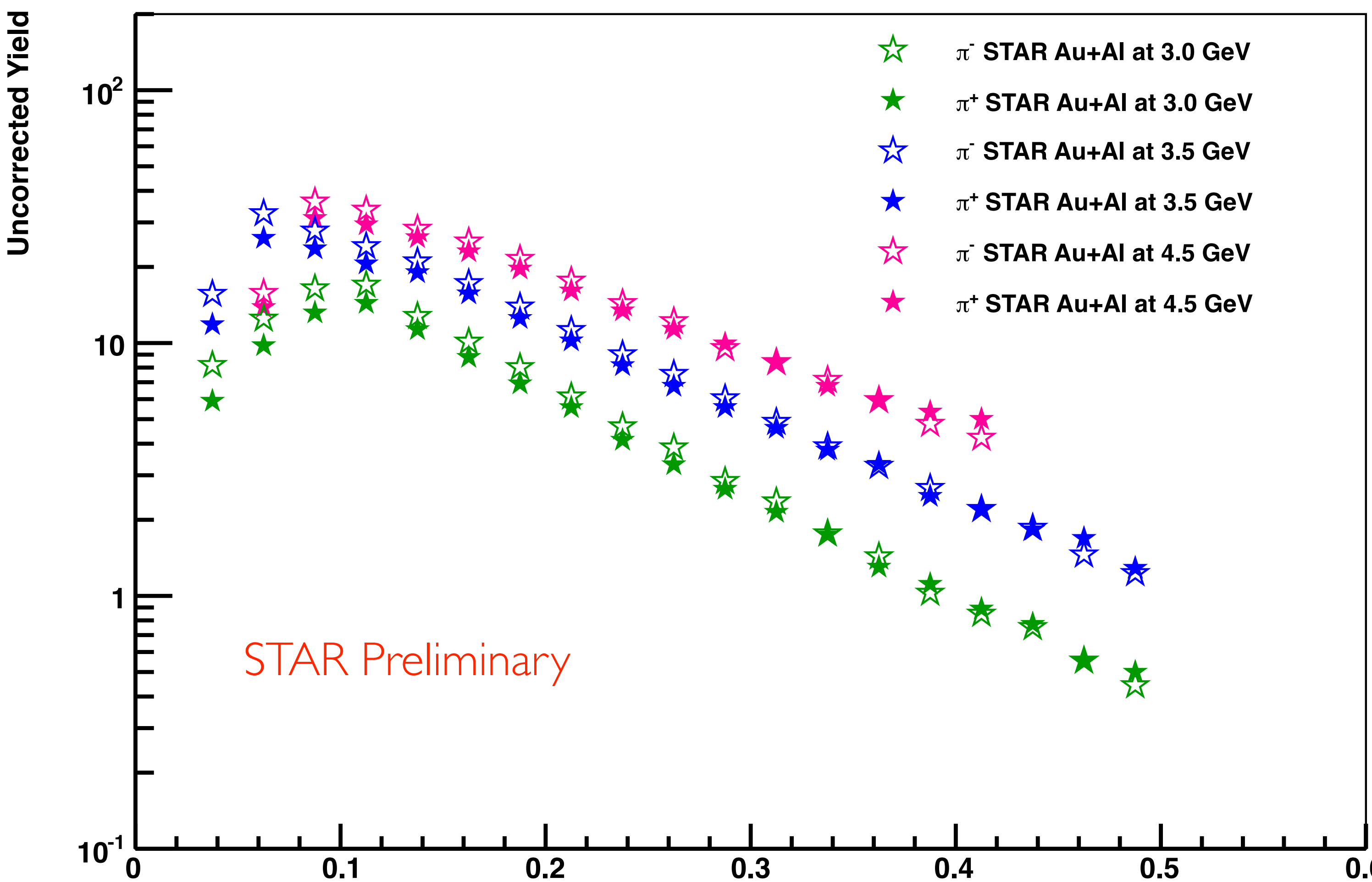


Gaussian fits for extracting yields

$$n\sigma = \frac{(dE/dx)_{observed} - (dE/dx)_{expected}}{\sigma_{dE/dx}}$$

pion spectra for $\sqrt{s_{NN}}$ = 3, 3.5, 4.5 GeV

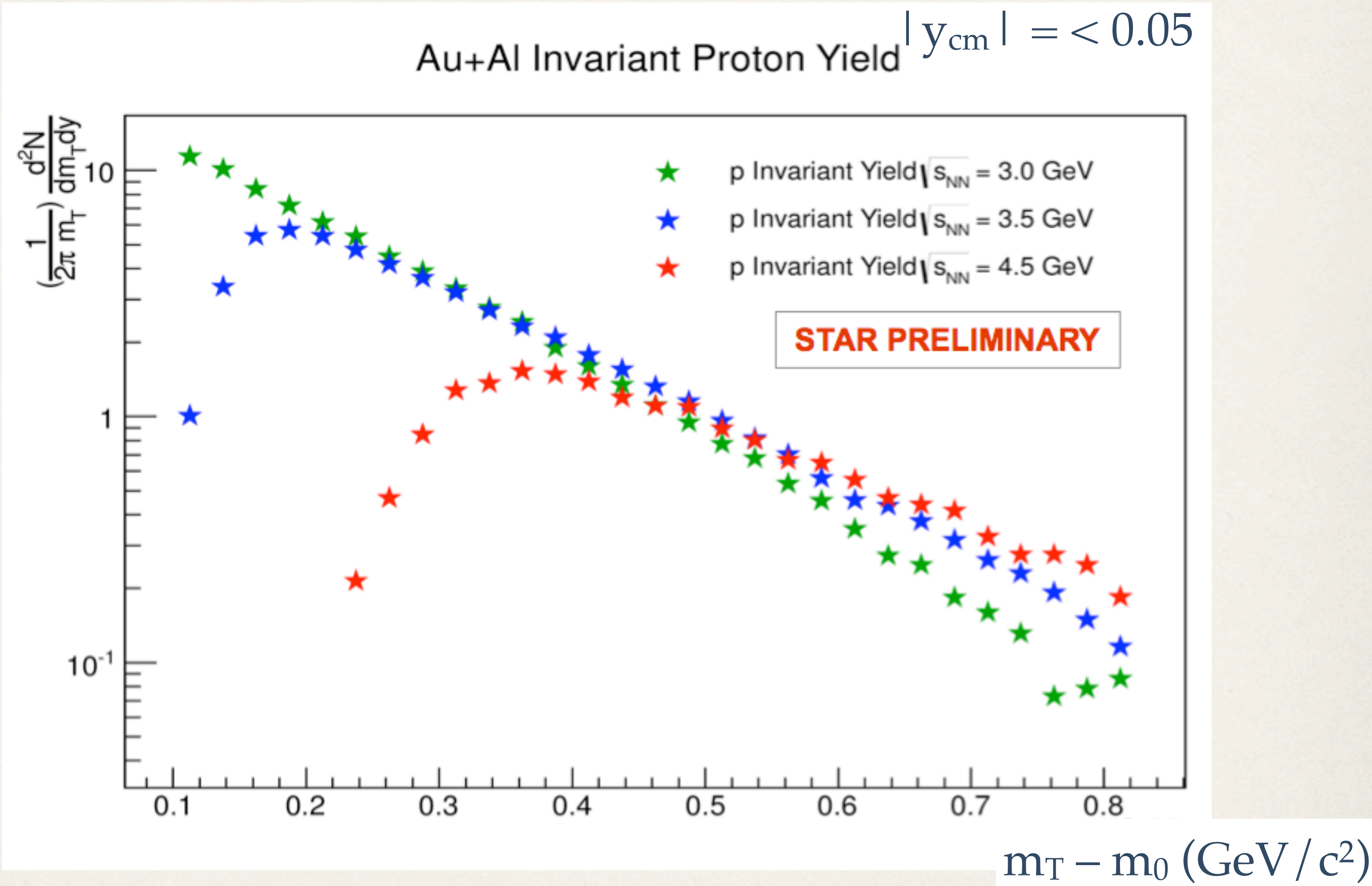
$|y_{cm}| =< 0.05$



$m_T - m_0$ (GeV / c^2)

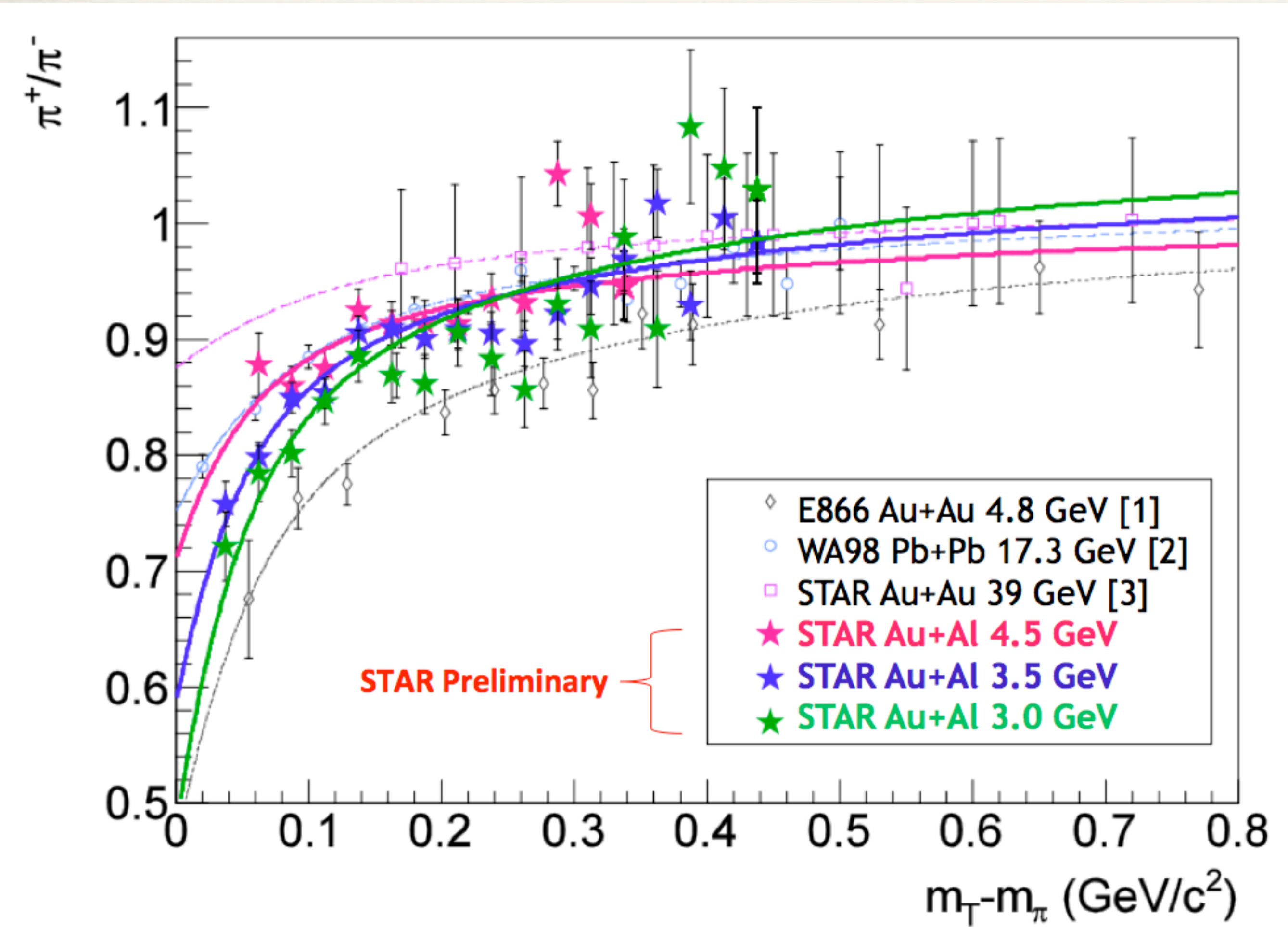
efficiency corrections pending

proton spectra for $\sqrt{s_{NN}}$ = 3, 3.5, 4.5 GeV



efficiency corrections pending

π^+/π^- yield ratios



* efficiency corrections pending
* only statistical errors on STAR data

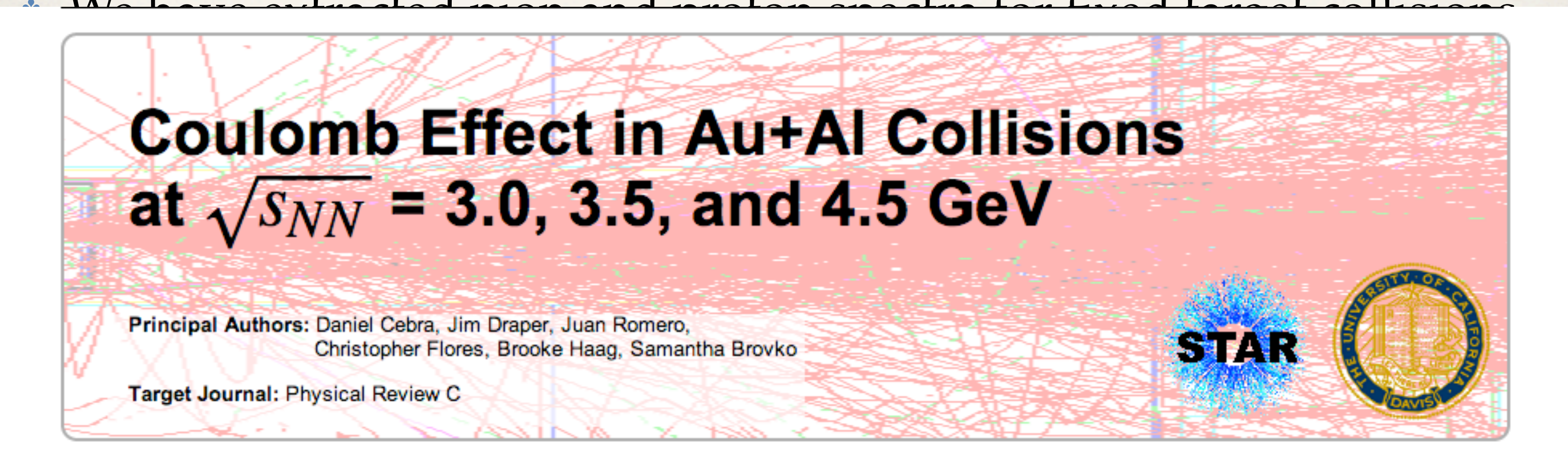
[1] L. Ahle *et al.* (E866) Nucl.Phys. **A610,** 139c (1996), and PRC57, R446 (1998).
[2] L. Rosselet *et al.* (WA98) Nucl.Phys. **A698,** 647c (2002).
[3] L. Kumar *et al.* (STAR) J.Phys.G; Nucl.Part.Phys. **38** (2011) 124145.
[4] G. Baym and P. Braun-Munzinger, Nucl. Phys. A610, 286c (1996).

- Net positive charge in the collision zone
  - Expanding spherical source → effective potential
  - Coulomb potential of the source modifies momentum distribution; greater effect for low–momentum π
- With efficiency corrections, we will be able to report extracted parameters from fits to data (shown at left) including initial pion ratio and the full Coulomb potential
- STAR fixed target data is consistent with former measurements and follows expected trends

Conclusions and Outlook

- We have extracted pion and proton spectra (uncorrected) for fixed target collisions with the STAR experiment via excellent particle identification in the TPC.
- Currently a fixed target program has approval. Installation in the next run. (See Daniel Cebra's talk)
- We can extend the BES program search for the critical point to lower energies.
- We have carried out fixed target physics with the STAR experiment; a paper is in the works!

Conclusions and Outlook



- We have carried out fixed target physics with the STAR experiment; a paper is in the works!

Backup

Coulomb Fit Function

$$\frac{\pi^+}{\pi^-}(m_T - m_0) = R\frac{e^{(E+V_{Eff})/T_\pi} - 1}{e^{(E-V_{Eff})/T_\pi} - 1} \cdot J$$

Initial Pion Ratio

From Pion Spectra Fit

Effective Potential due to reduced charge seen by low momentum pions

$$V_{Eff} = V_C(1 - e^{-E_{Max}(\gamma_\pi\beta_\pi)/T_p})$$

Coulomb Potential

Maximum kinetic energy of corresponding pion velocity

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

From Proton Spectra Fit

- Expanding spherical source with net positive charge
- Low momentum pions are overtaken by high momentum protons → Low momentum pions don't feel full potential

Jacobian of Transform

$$J = \frac{E - V_{Eff}}{E + V_{Eff}} \frac{\sqrt{(E - V_{Eff})^2 - m_\pi^2}}{\sqrt{(E + V_{Eff})^2 - m_\pi^2}}$$