

Search for Radial Flow using Identified Charged Hadrons in Small Systems at PHENIX

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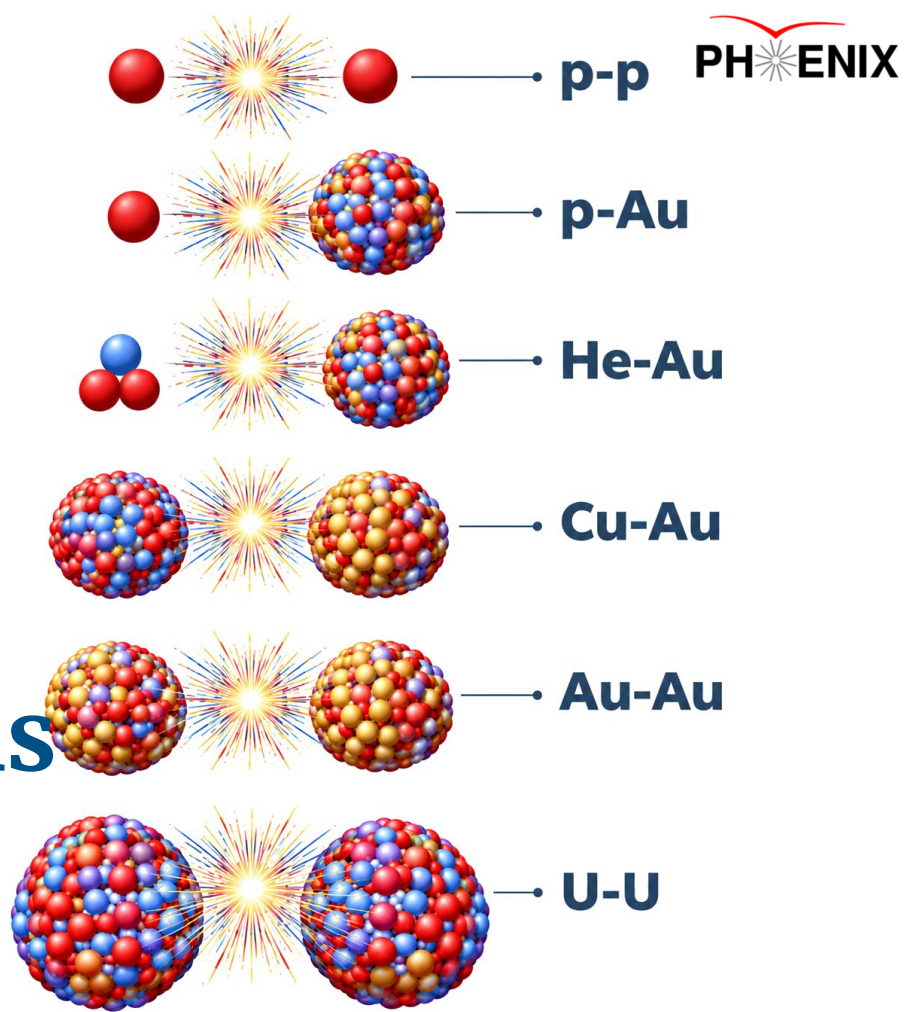


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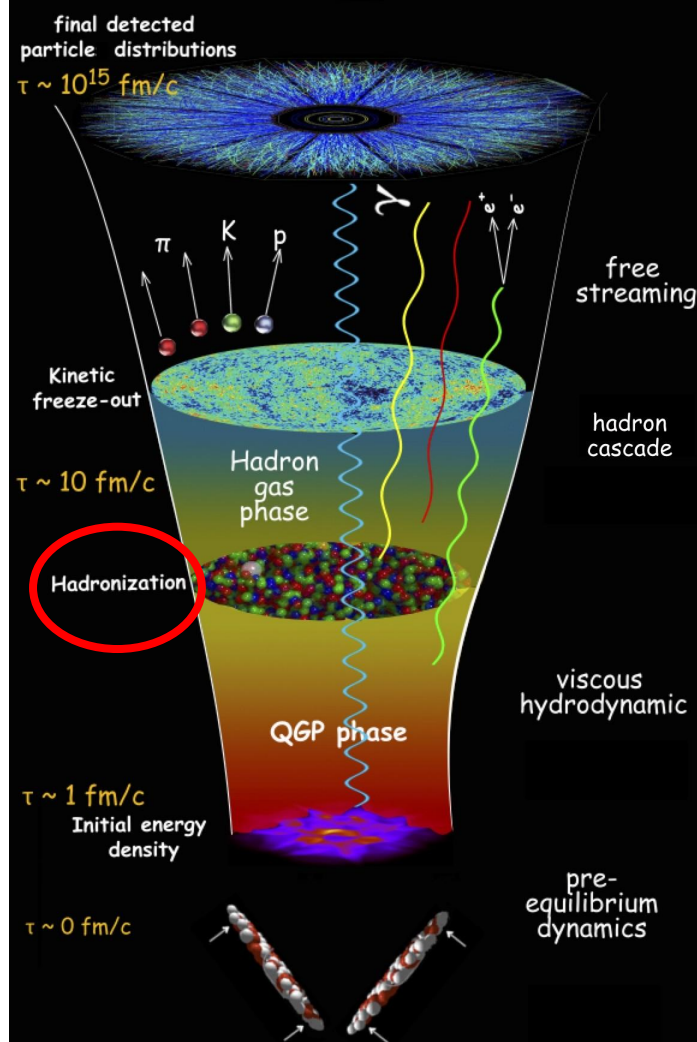
1. Heavy ion physics
2. PHENIX setup
3. Charged hadrons
4. Feed-down protons
5. Results





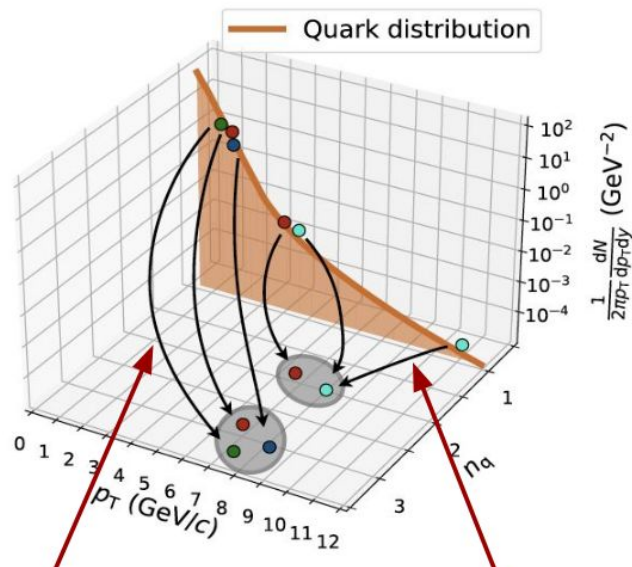
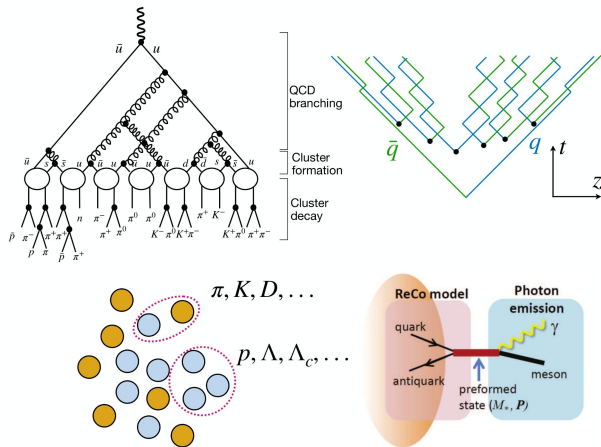
Heavy ion physics

- The quark-gluon plasma (QGP) comprises deconfined, strongly interacting quarks and gluons, at extremely high temperature and density
- This medium behaves as a strongly interacting fluid
- As the system cools and expands, it undergoes hadronization
- Particles produced after hadronization carry information about the medium



Hadronization

- Nearby quarks can combine through quark recombination to form mesons or baryons
- This would lead to enhancement in baryon versus meson production in the large systems, quantified using particle ratios and nuclear modification factor



Recombining quarks:

$$p_{\text{meson}} = p_{q1} + p_{q2}$$

$$p_{\text{baryon}} = p_{q1} + p_{q2} + p_{q3}$$

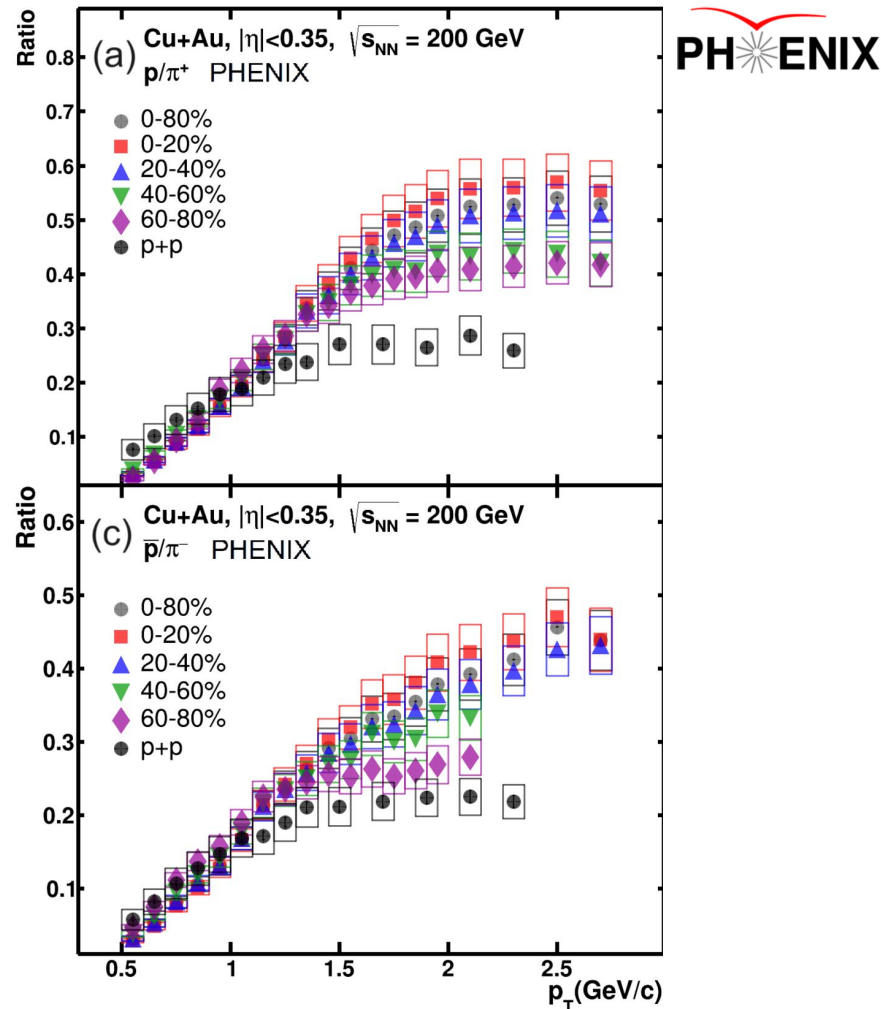
Fragmenting parton:

$$p_h = z \cdot p_q \text{ with } z < 1$$



Hadronization

- Nearby quarks can combine through quark recombination to form mesons or baryons
- This would lead to enhancement in baryon versus meson production in the large systems, quantified using particle ratios and nuclear modification factor
- Proton to pion ratios in large systems like Cu+Au, Au+Au, U+U show baryon enhancement in central collisions
- Small systems like p+Au have large systematic uncertainties to show this behaviour



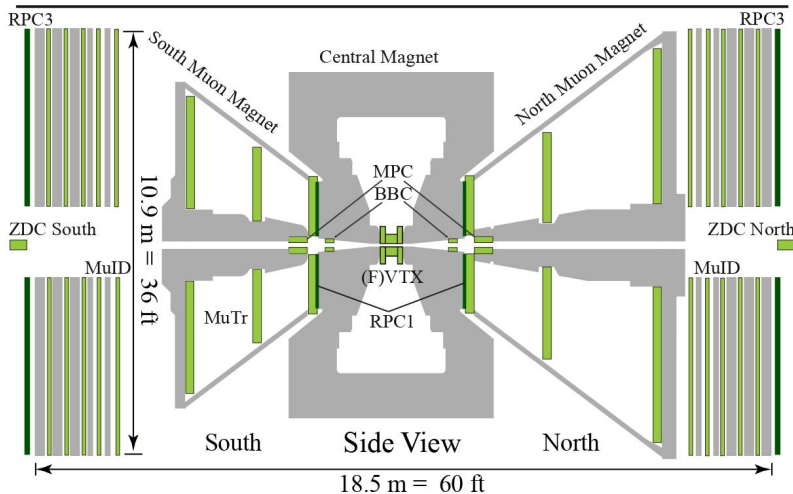
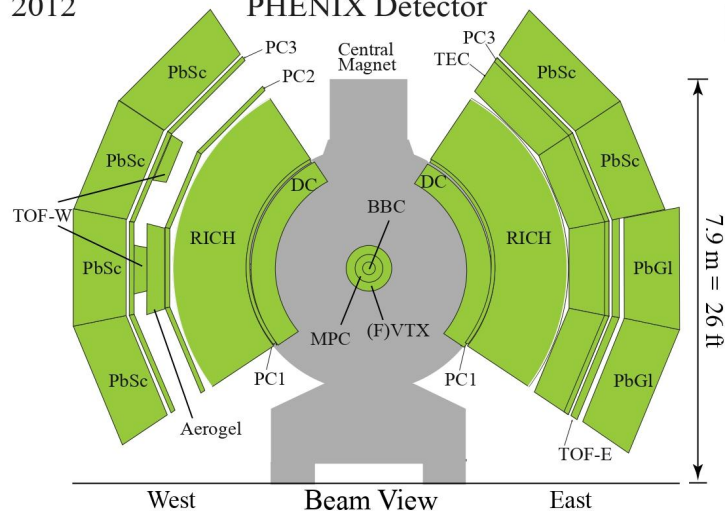


PHENIX setup

- Beam-Beam Counter BBC :
 - Minimum bias trigger
 - Event start time
 - Centrality
- Silicon Vertex Detector VTX :
 - Event vertex
- Time-of-Flight TOF :
 - Particle identification
- Drift Chamber DC :
 - Momentum + charge determination

2012

PHENIX Detector



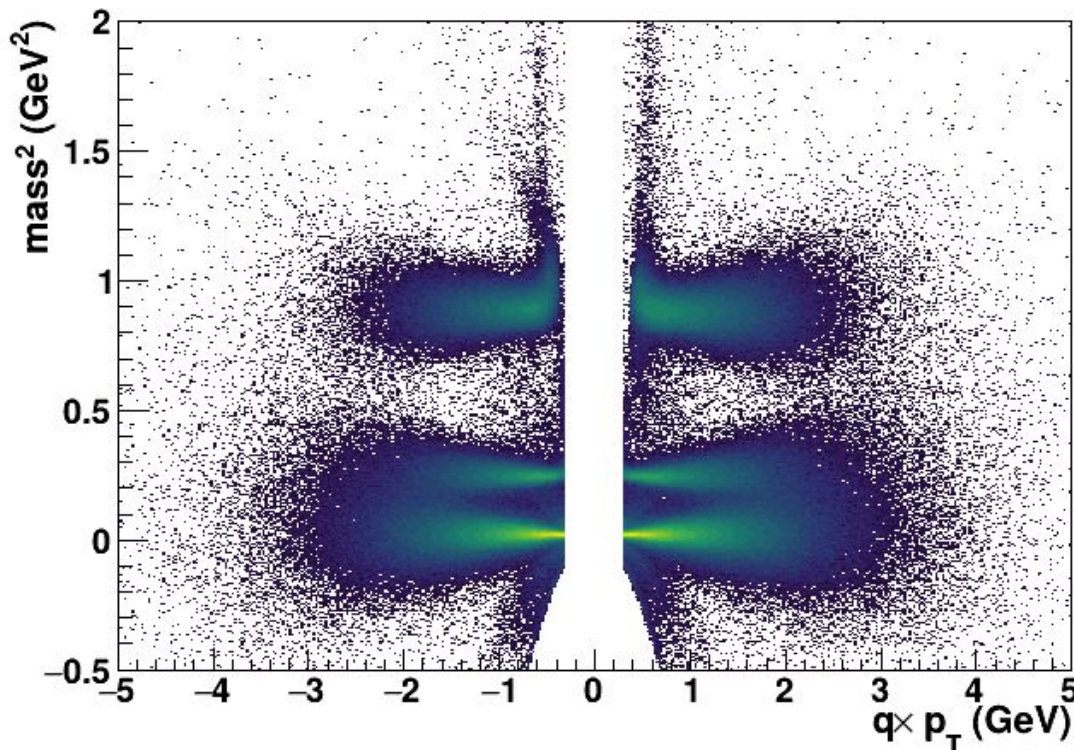


Charged hadron identification

- Charged particle identification using **time-of-flight** and **drift chamber**

$$m^2 = \frac{p^2}{c^2} \left(\frac{t_{TOF}^2}{(L/c)^2} - 1 \right)$$

- Spectra from p+p serve as a baseline reference





Corrections to raw data

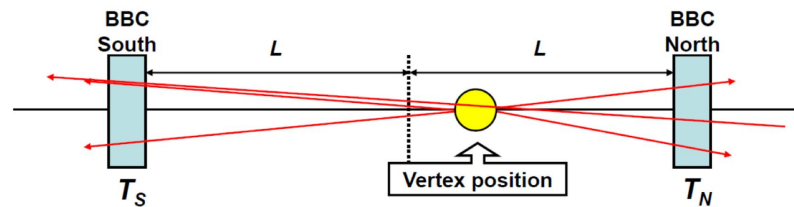
Reconstruction efficiency

Geometrical acceptance of detectors, based on full GEANT simulations of pions/kaons/protons

Pile-up events

Multiple collisions within same detector readout window, causing overlapping signals and contamination

Event vertex + timing

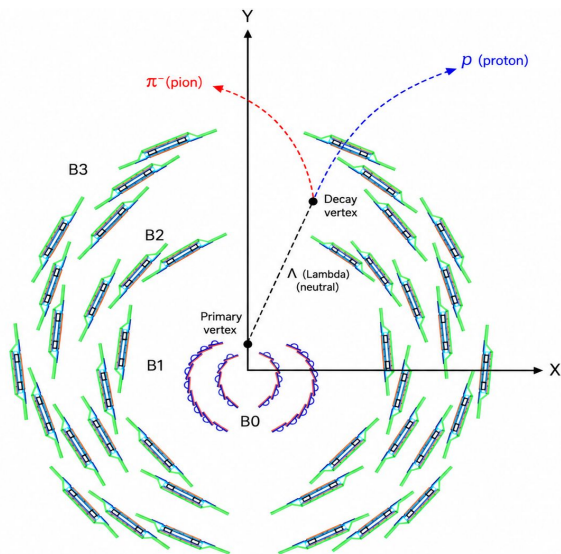


Weak decay correction

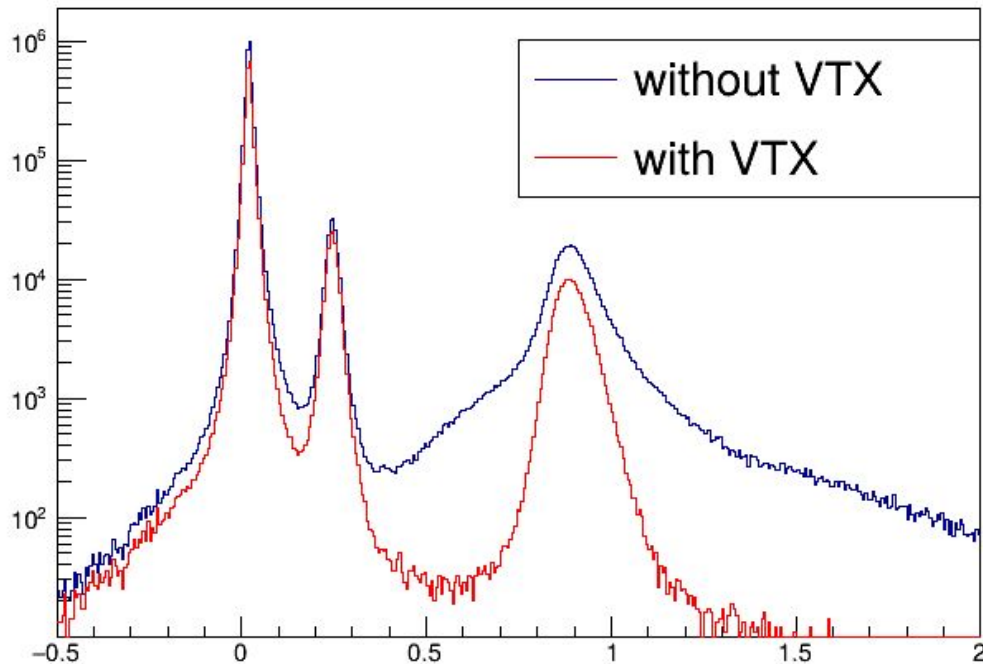
Feed-down protons from Λ decay after primary collision



Weak decay correction



$p_T = 0.4 - 1.0 \text{ GeV}$

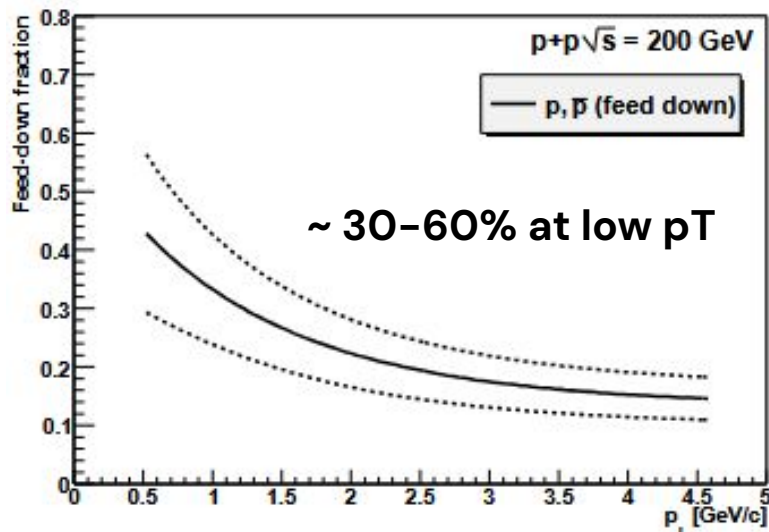


Silicon vertex tracker is used to identify and select primary tracks and reject conversions, thus significantly reducing feed-down protons to $\lesssim 1\%$

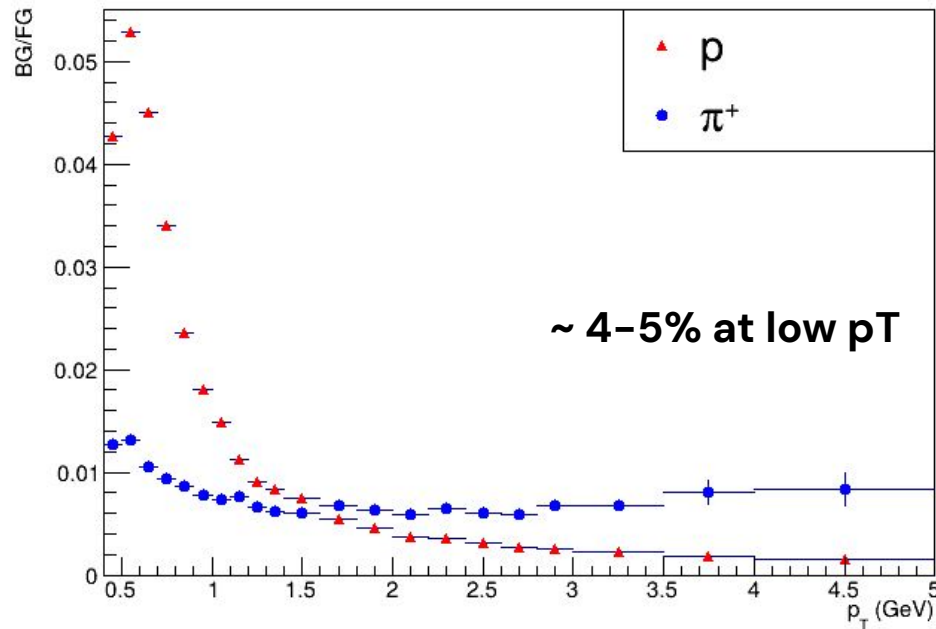


Feed-down suppression

- Lambda decay : $\Lambda^0 \rightarrow p + \pi^-$
- Kaon decay : $K^0_s \rightarrow \pi^+ + \pi^-$



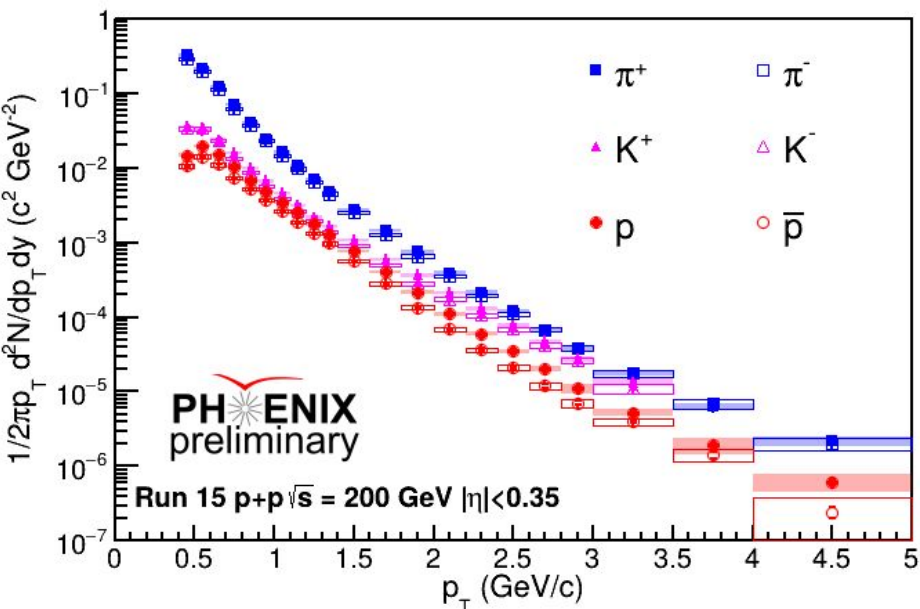
Phys. Rev. C 83, 064903, 2011



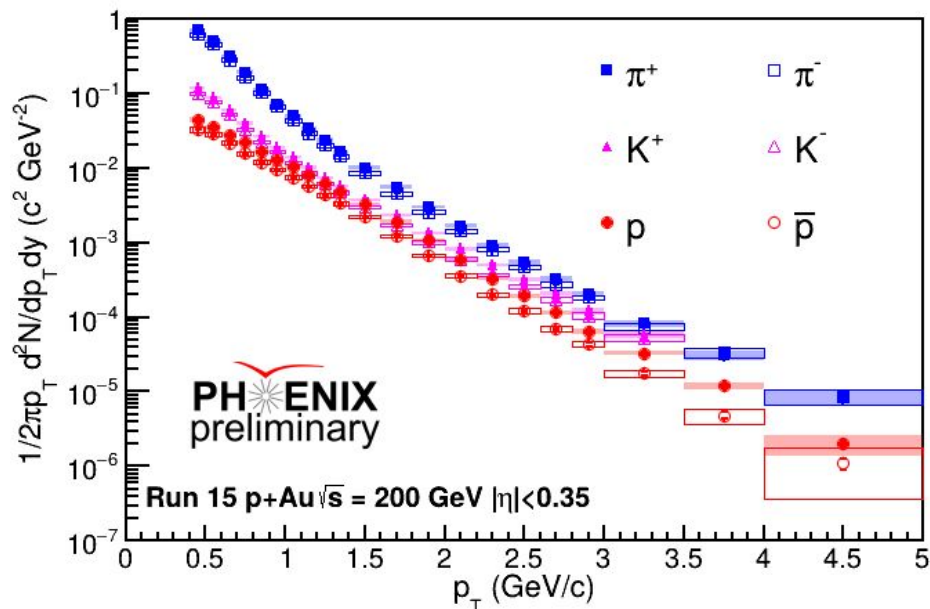
Fractions using VTX



Identified particle spectra



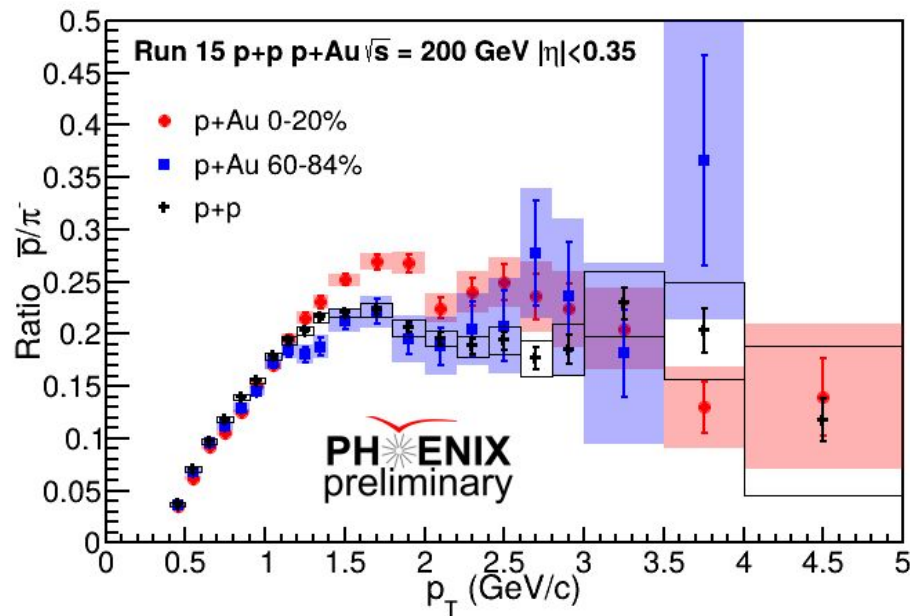
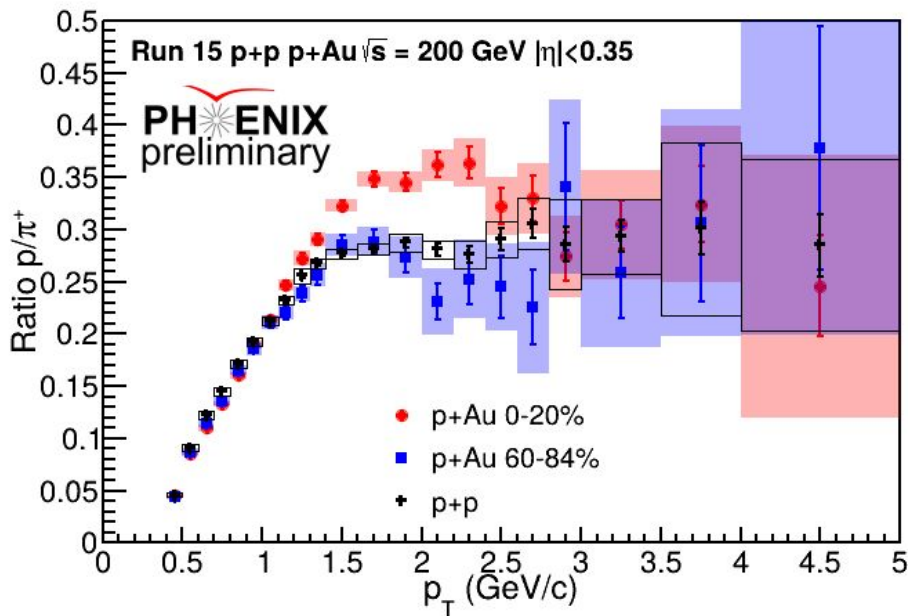
p+p $\sqrt{s} = 200 \text{ GeV}$



p+Au $\sqrt{s} = 200 \text{ GeV}$



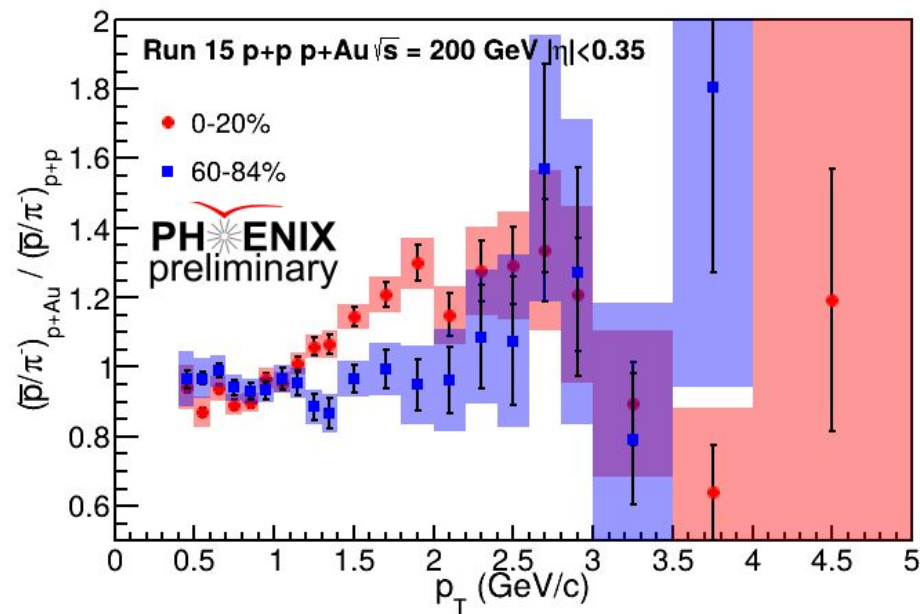
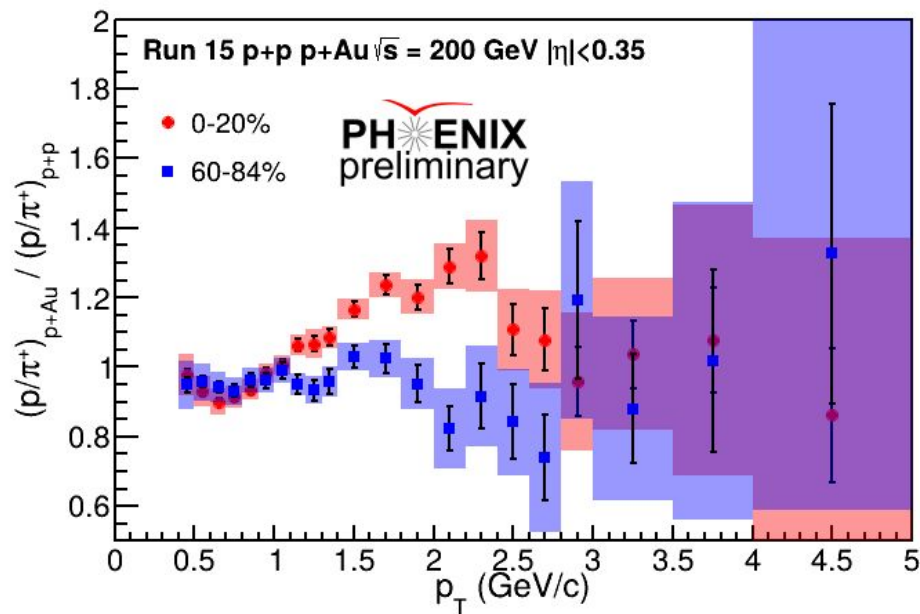
Particle ratios : proton to pion



- Central collisions show baryon enhancement



Particle ratios : proton to pion

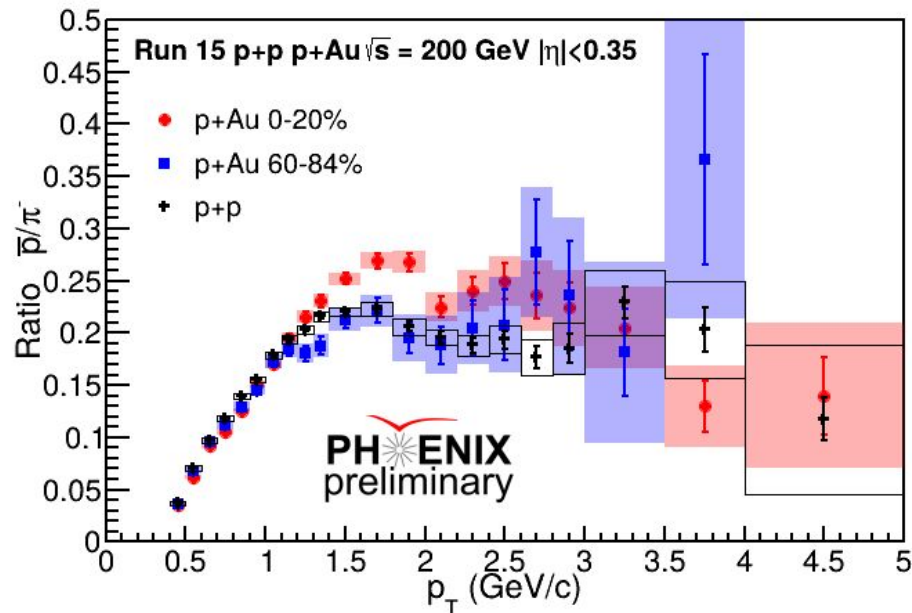
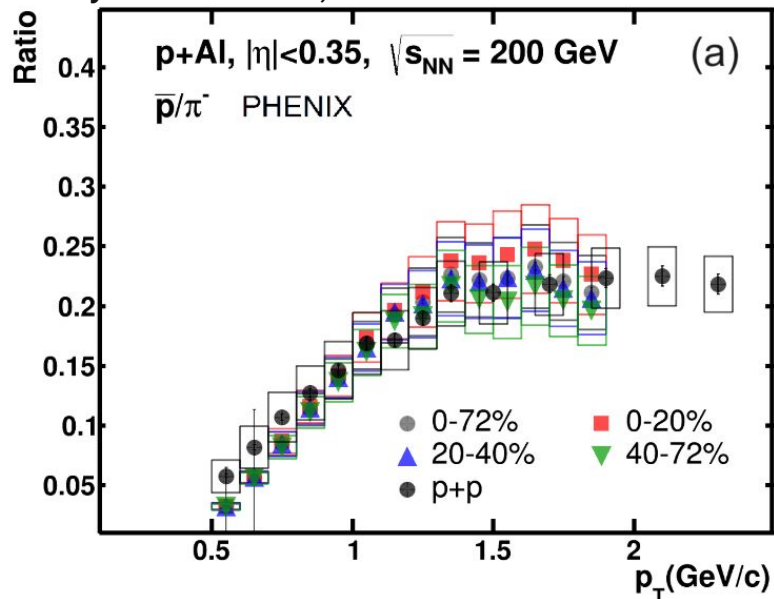


- Clear distinction between central and peripheral collisions



Systematic improvements

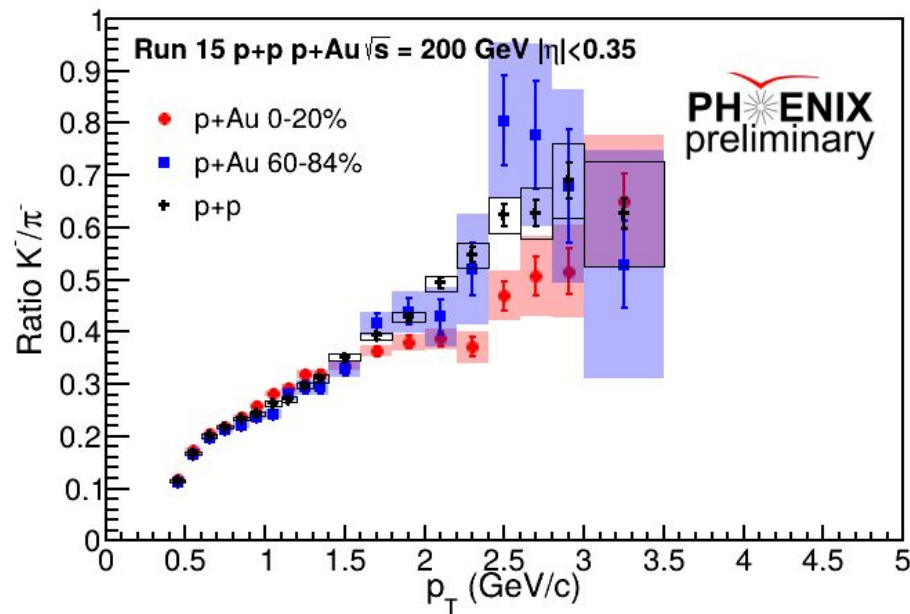
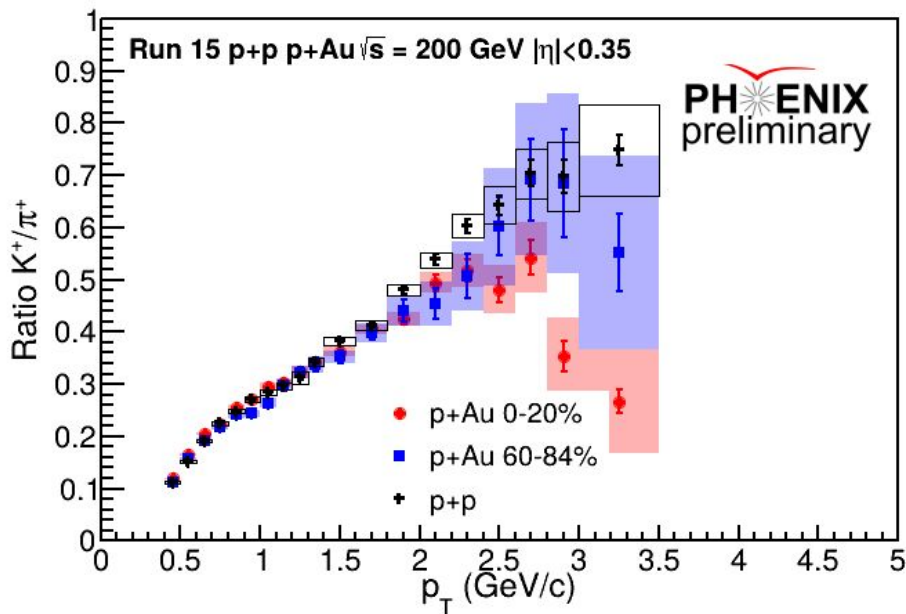
Phys. Rev. C 109, 054910



- Comparison with previous PHENIX results



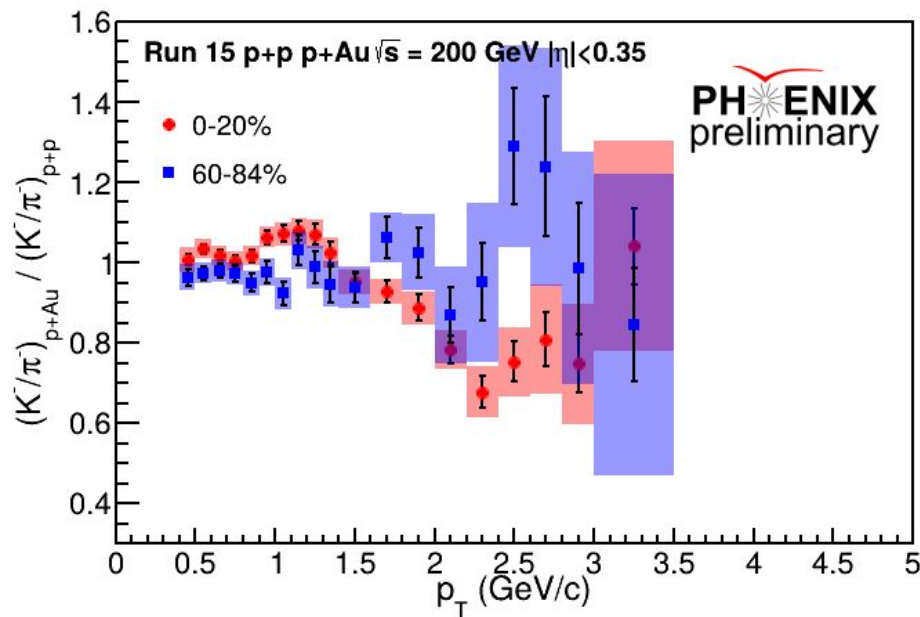
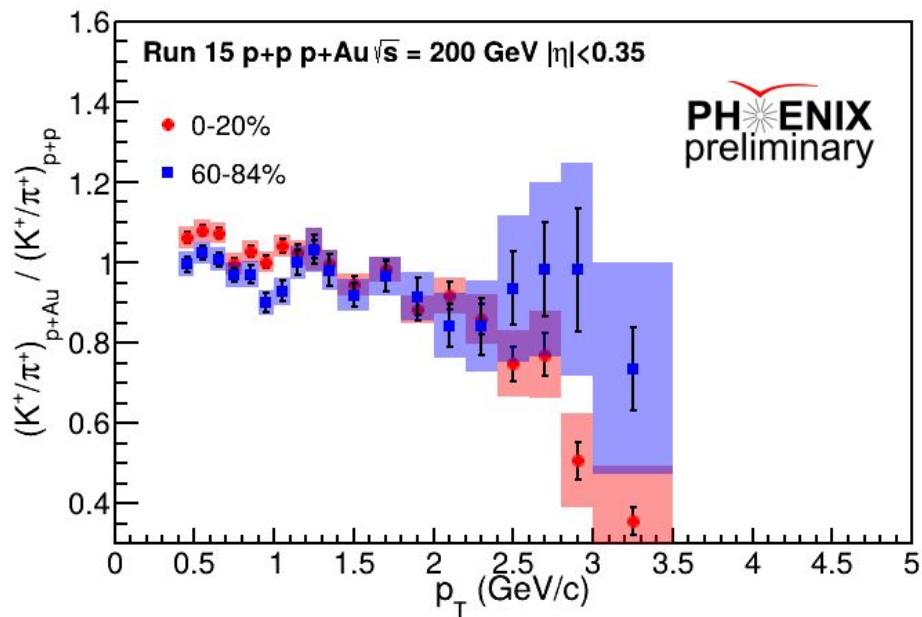
Particle ratios : kaon to pion



- Hint of kaon softening?



Particle ratios : kaon to pion

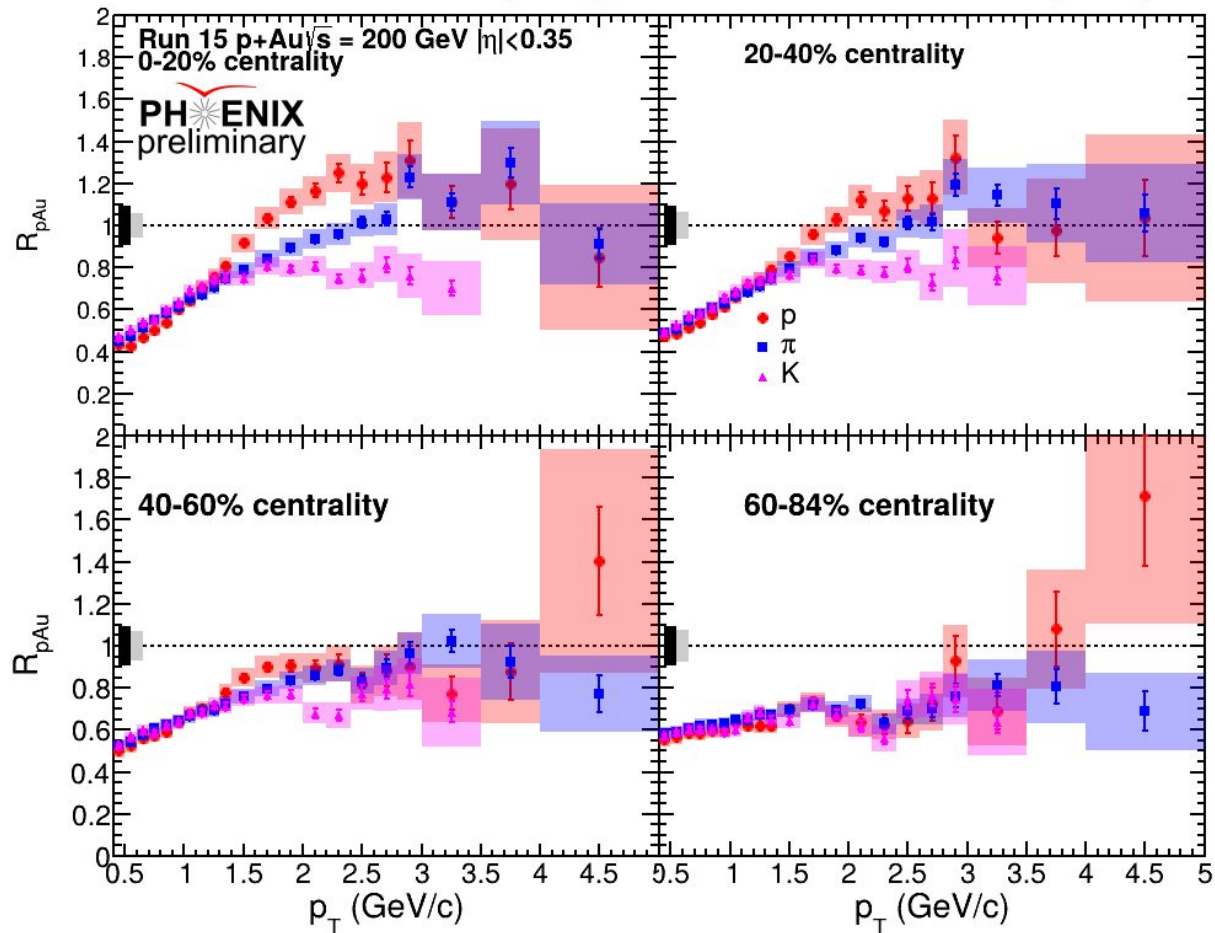


- Hint of kaon enhancement?



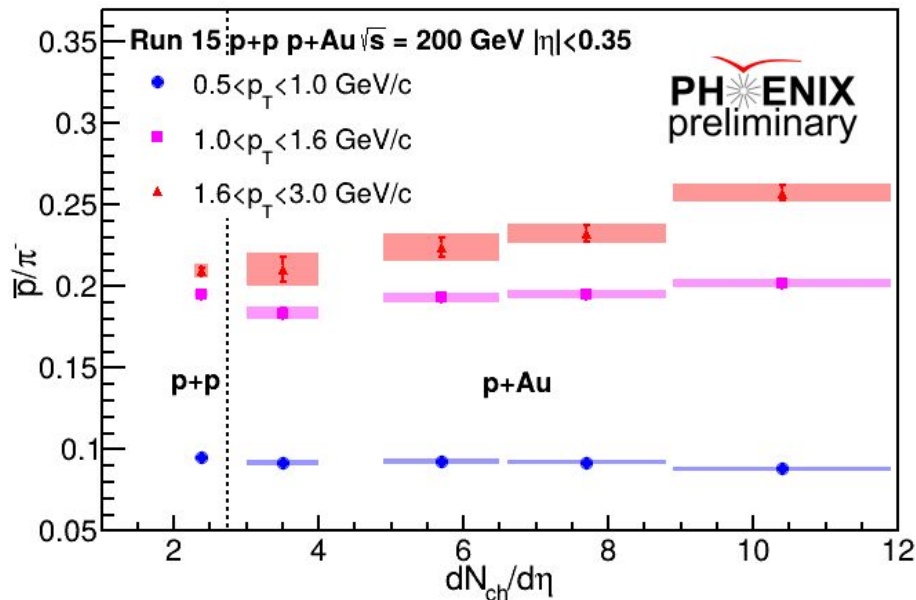
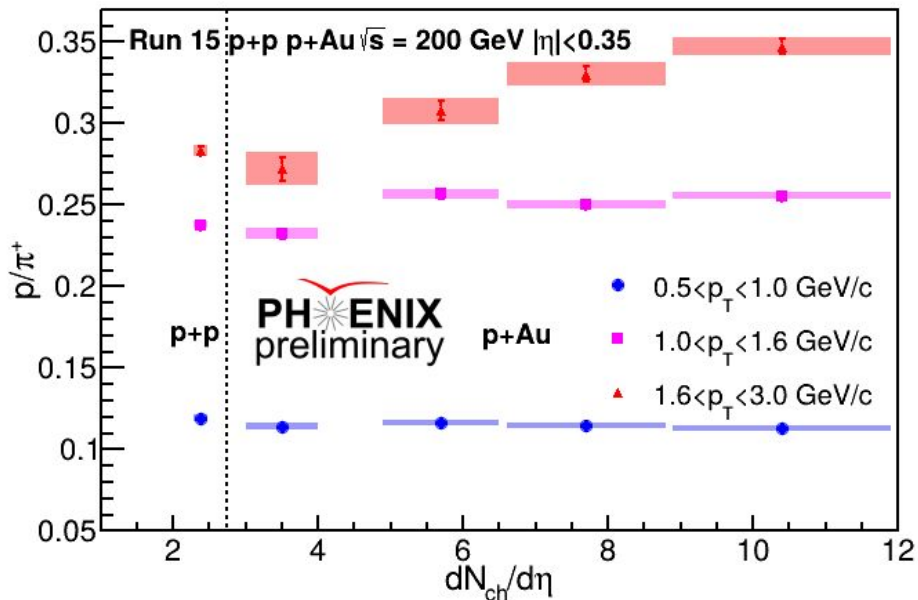
Nuclear Modification Factor

- Central collisions in p+Au show baryon enhancement in intermediate p_T regime
- This behavior steadily disappears as centrality increases
- This shows collective radial flow similar to that seen in large collision systems





Particle ratios vs charged particle multiplicity

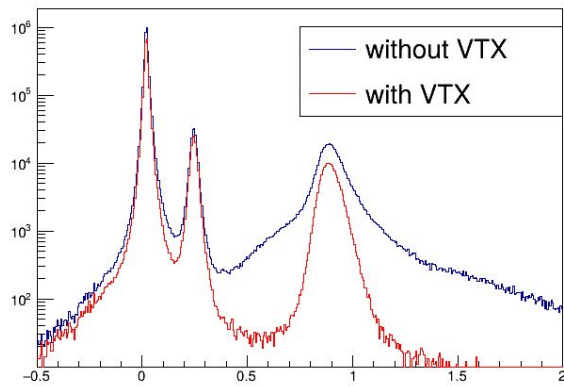


- Linear trend with system-size for mid/high p_T



Results summarized

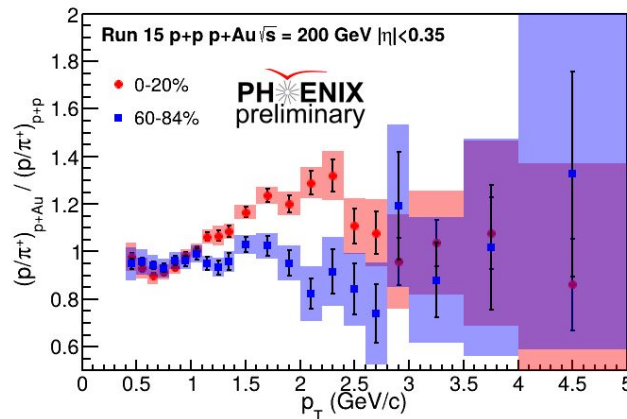
$p_T = 0.4 - 1.0 \text{ GeV}$



Feed-down rejection

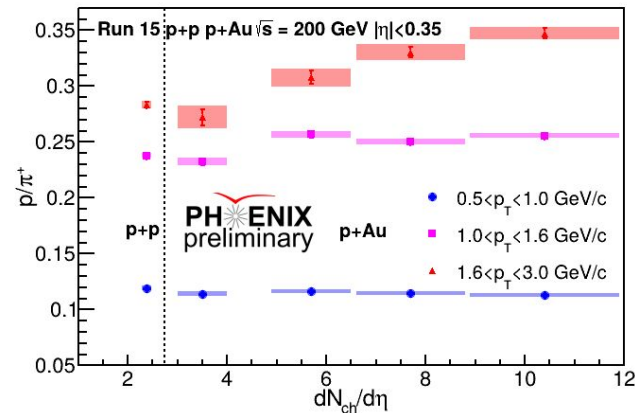
Silicon vertex tracker helps to reduce feed-down fraction to $\lesssim 1\%$

Prasad C. – MENU 2026



Baryon enhancement

Central collisions in p+Au show baryon enhancement, peripheral collisions consistent with p+p collisions



System-size dependence

Baryon-to-meson ratio steadily increases with system-size in mid/high p_T



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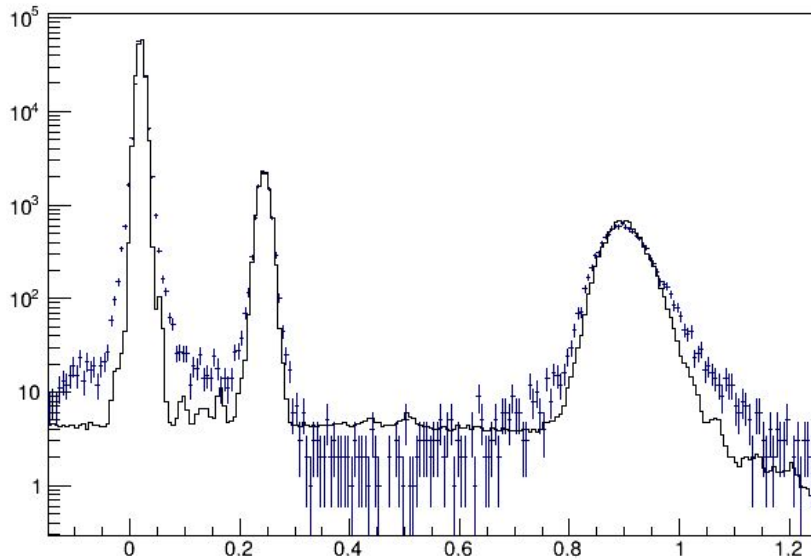
Thank you for your
attention

Chaitanya Prasad

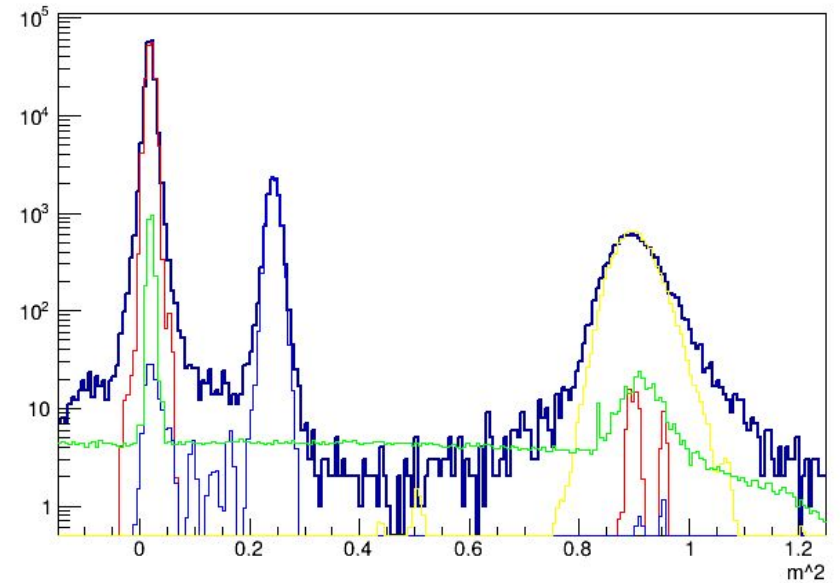
Backup slides

Template fits

$pT = 0.500000 - 0.600000$

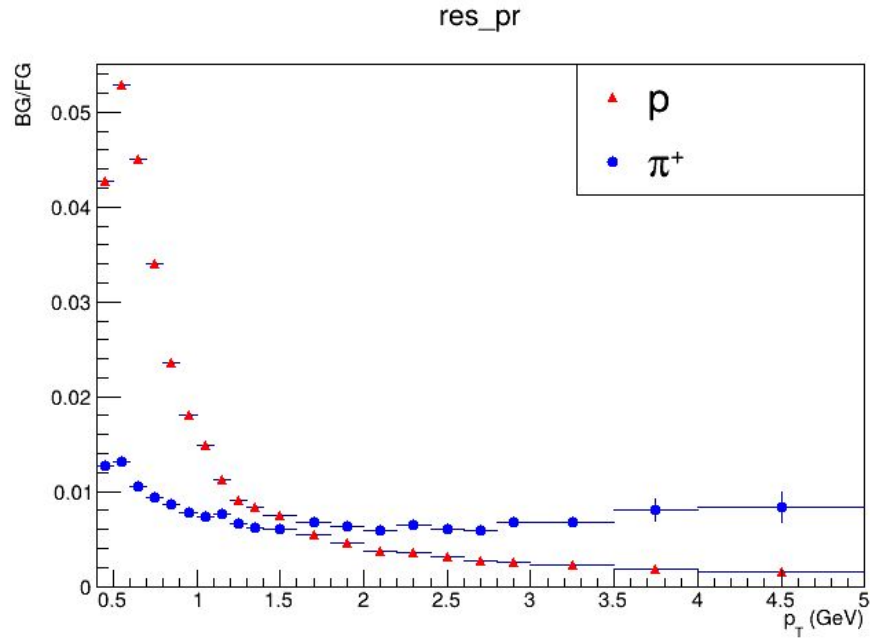


$pT = 0.500000 - 0.600000$

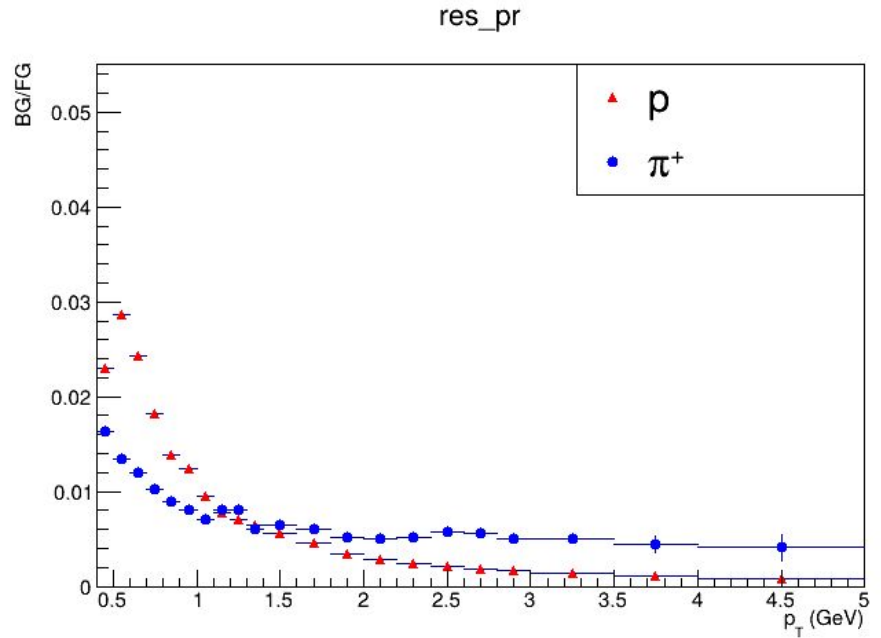


p+Au

Feed-down fractions

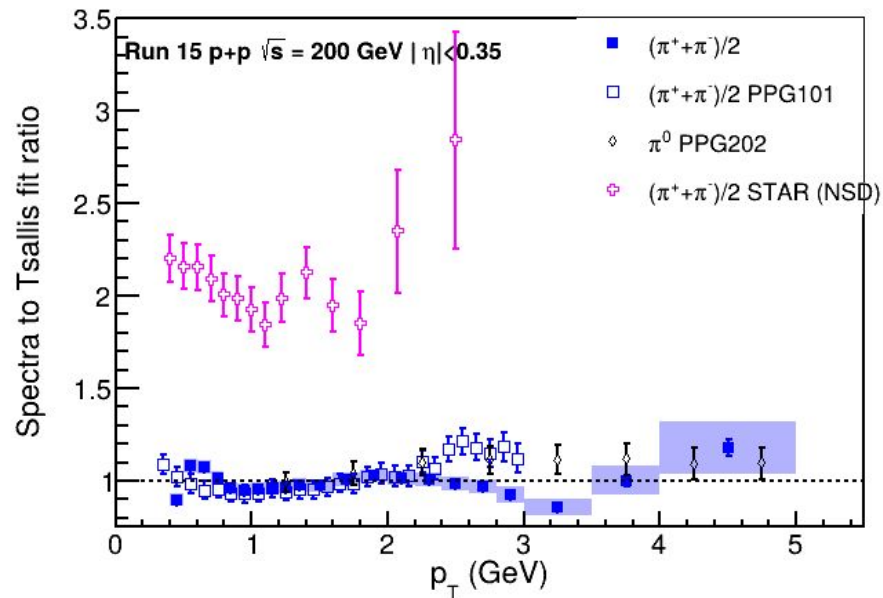


p+p

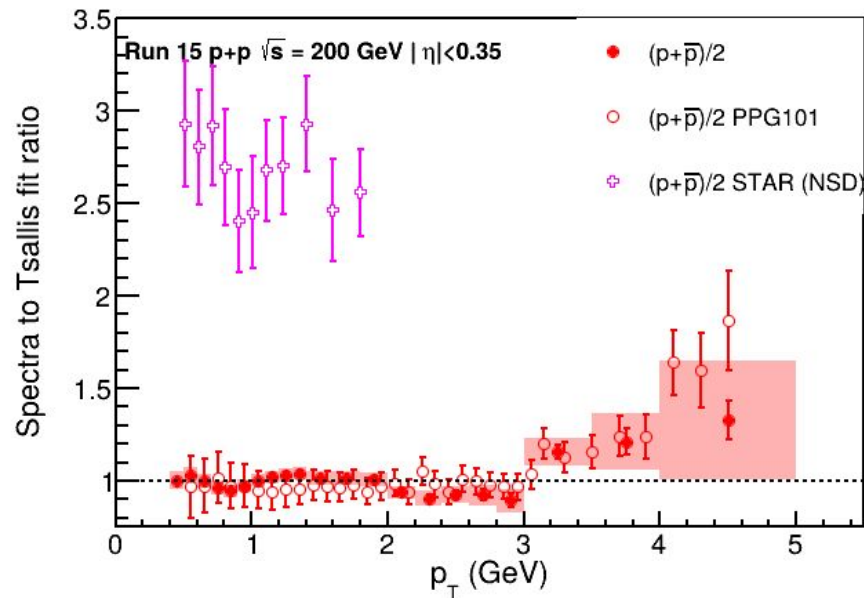


p+Au

Comparison with STAR



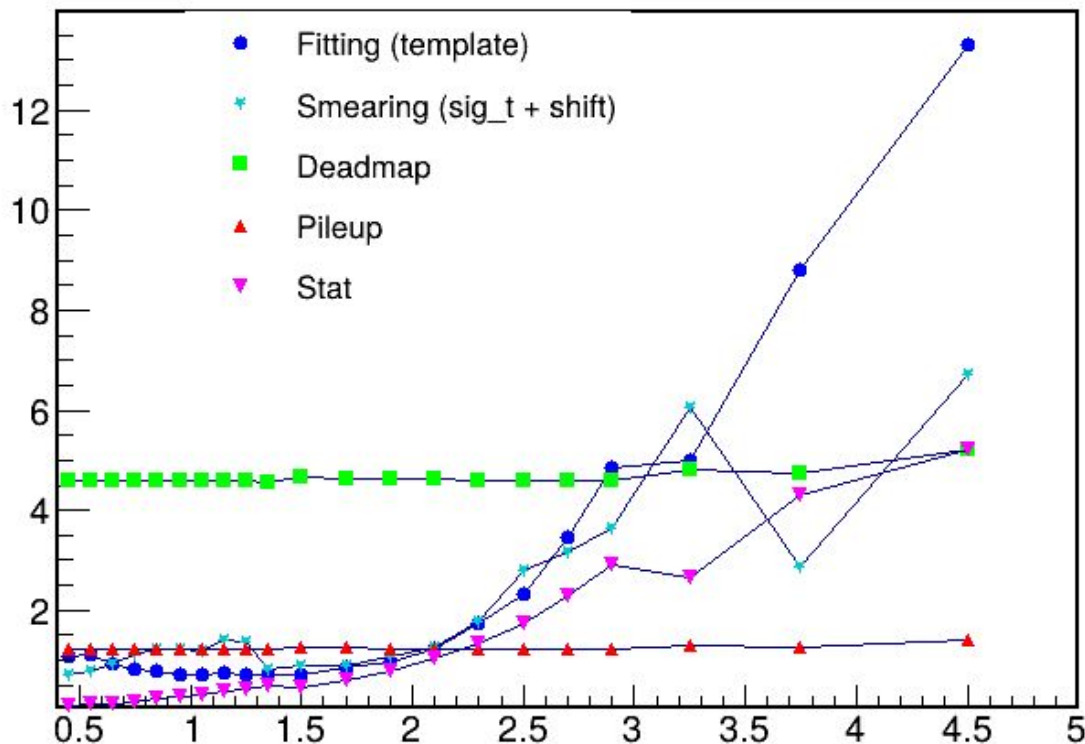
Pions



Protons

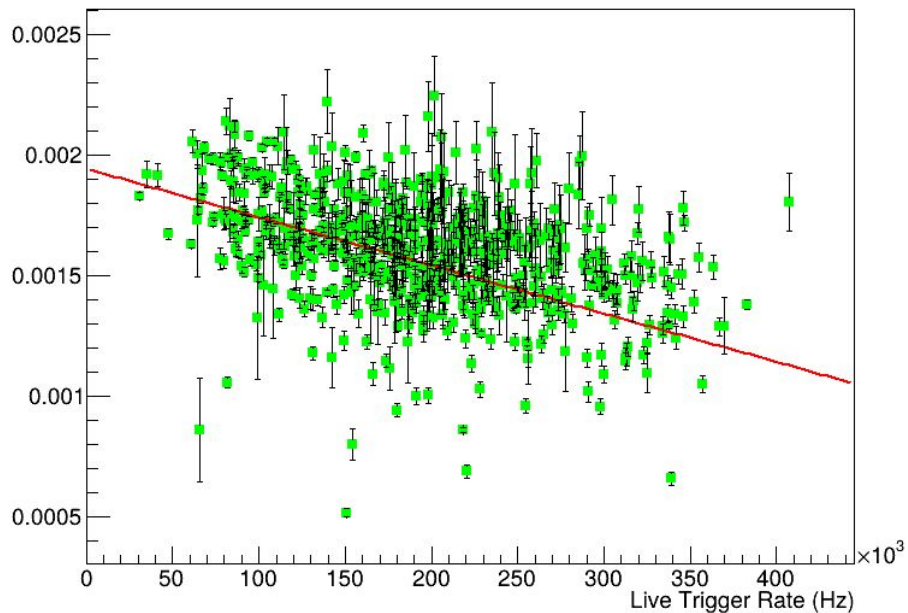
Systematic uncertainties

Percent error (π^+)



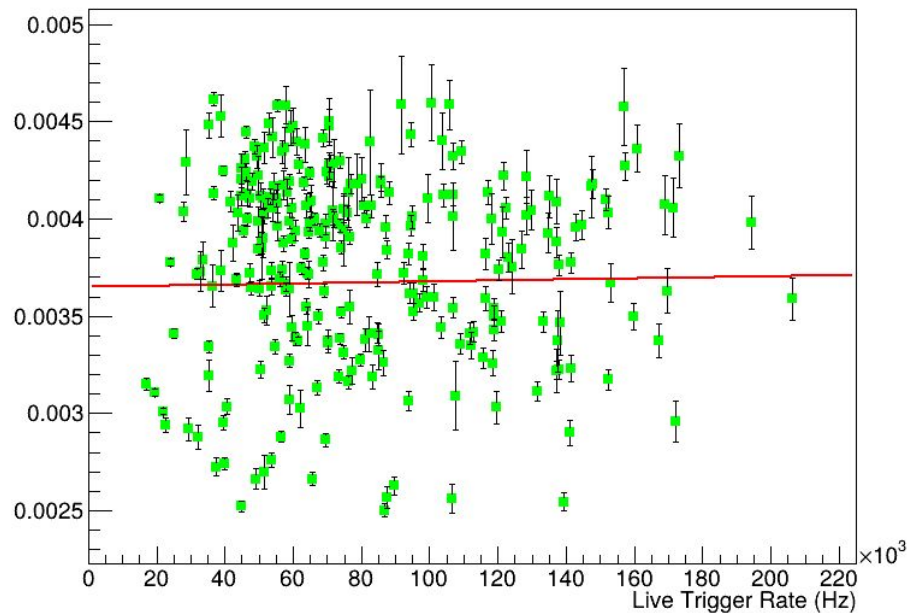
Pile-up effects

N_{π^-} / n_{evt} vs Trigger Rate



p+p

N_{π^-} / n_{evt} vs Trigger Rate



p+Au