Measurements of identified particle spectra in diffractive *pp* collisions with the STAR detector at RHIC

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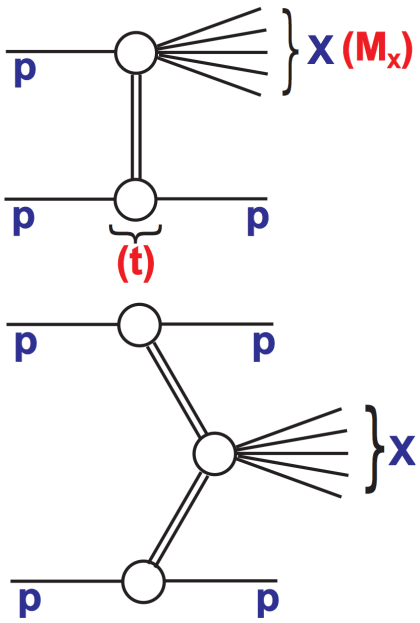
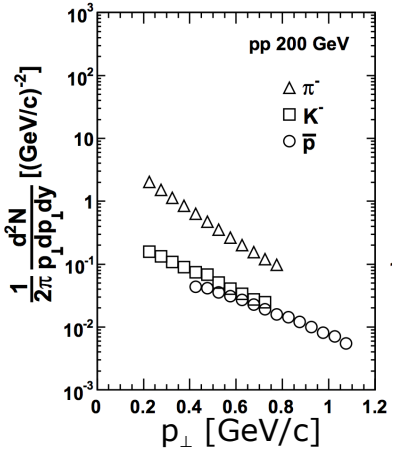
Diffraction 2016
Acireale , Italy, 2-8 September 2016

Outline

Motivation





STAR, $p + p \rightarrow X$ at $\sqrt{s} = 200$ GeV, $|y| < 0.1$
Phys. Rev. C 79 (2009), 034909.

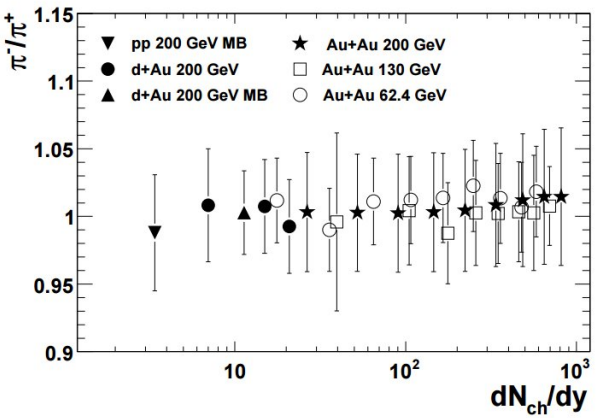
- Study the **S**ingle **D**iffractive **D**issociation and **C**entral **D**iffraction processes,

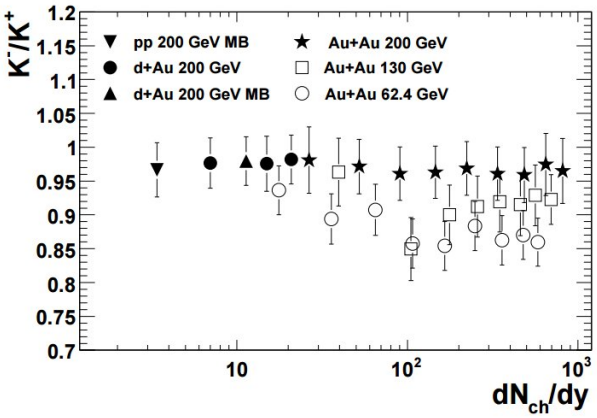
$$p + p \rightarrow p + X \qquad \text{(SD)}$$
$$p + p \rightarrow p + X + p \qquad \text{(CD)}$$

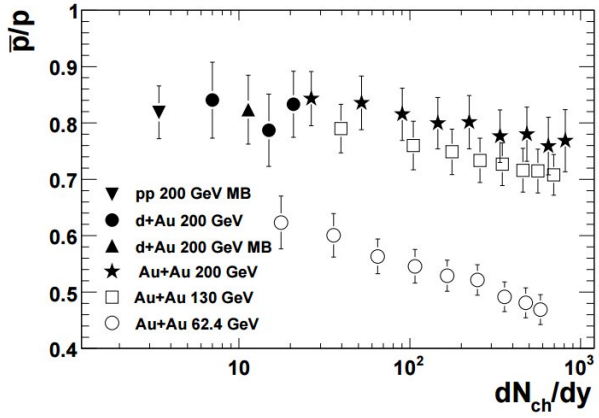
where the interaction between protons is mediated by a colorless object (Pomeron in the Regge Theory) and the final state consists of one (two) proton(s) in SD(CD) and system X, which are separated in the rapidity.

- Study of identified particle spectra (π, K, p) in diffractive events and compare them with model predictions and with non-diffractive measurements. Search for differences in proton-proton, Pomeron-proton and Pomeron-Pomeron fusion.
- Large sample of experimental data available on identified charged particle production at RHIC (Phys.Rev. C79 (2009) 034909) and LHC (EPJC 75 (2015) 226). But no measurement dedicated only for diffractive events.
- Identified particle p_T and η distributions spectrum gives us the information about collision dynamics - can check some phenomenological models, tune MC generators.

Antiparticle-to-particle ratios in non-diffractive processes at STAR

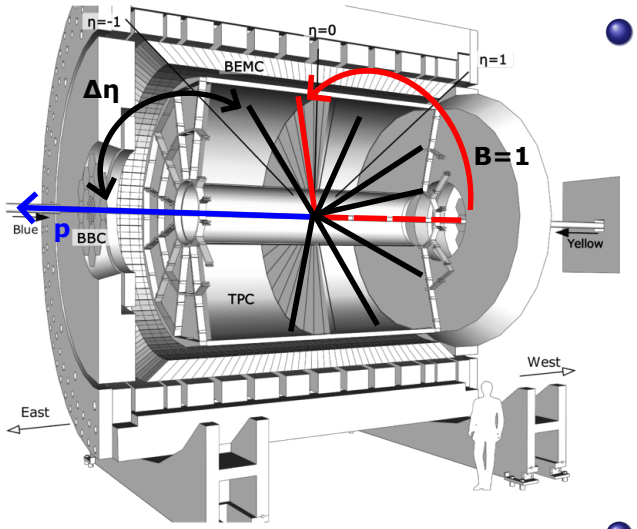


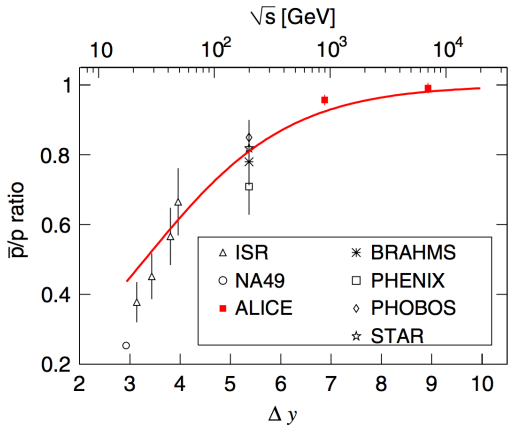




- Antiparticle/particle ($\pi^-/\pi^+, K^-/K^+, \bar{p}/p$) ratios as a function of the charged particle multiplicity (experimental measure of centrality) in *pp*, d+Au at 200 GeV and Au+Au collisions at 62.4 GeV, 130 GeV, and 200 GeV measured at STAR (Phys.Rev. C79 (2009) 034909).
- The π^-/π^+ ratio ~ 1 for all measured collision systems and collision energies.
- The K^-/K^+ ratios close to 1 in *pp*, d+Au and Au+Au collisions at 200 GeV.
- The $\bar{p}/p$ ratio in peripheral Au+Au at 200 GeV similar to that in pp and d+Au collisions at the same energy and varies between $0.75 - 0.85$.

Baryon number transfer

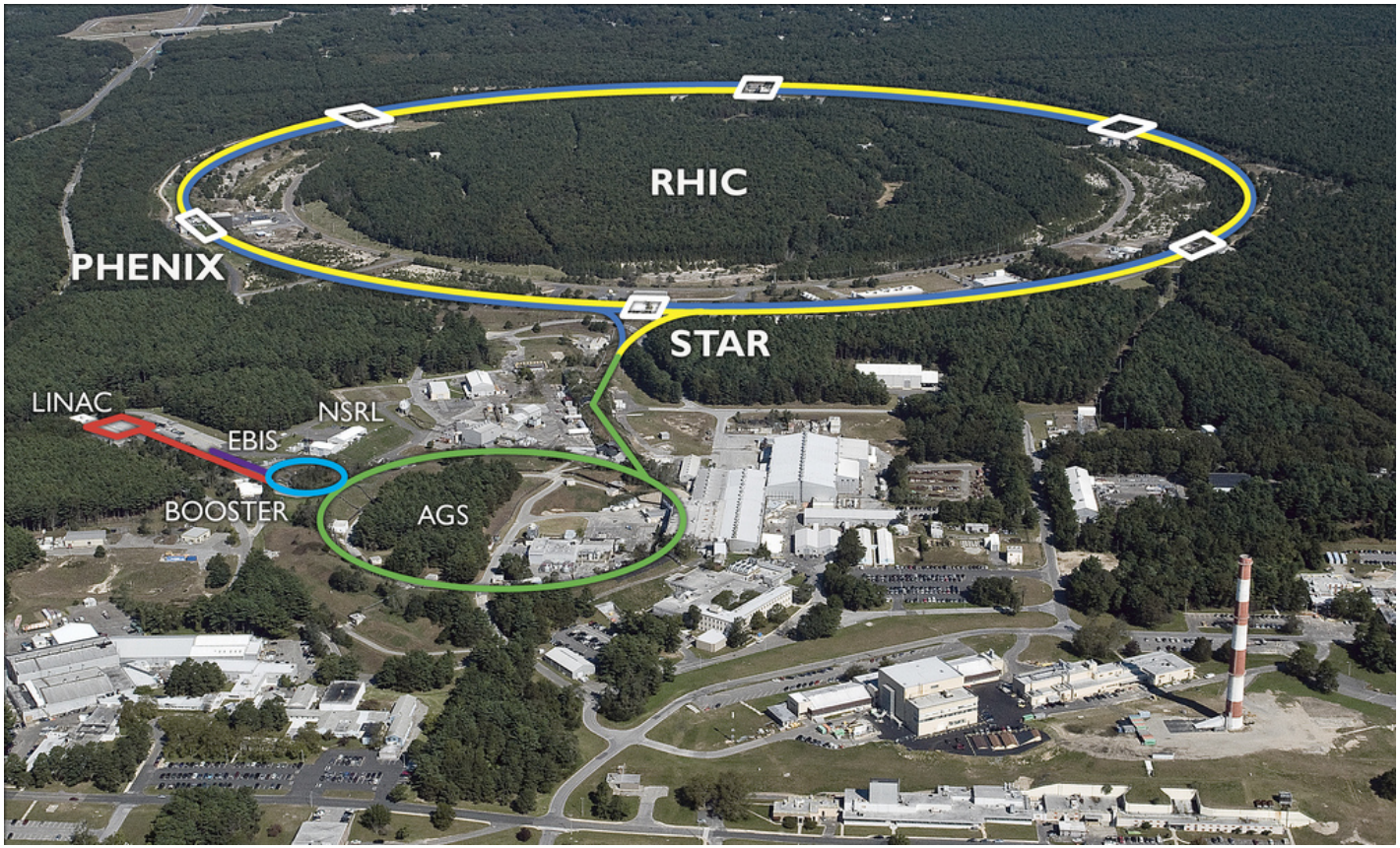




Phys. Rev. Lett. 105 (2010) 072002
Red curve: exponentially suppressed BN transfer as a function of Δy, model fitted to the data

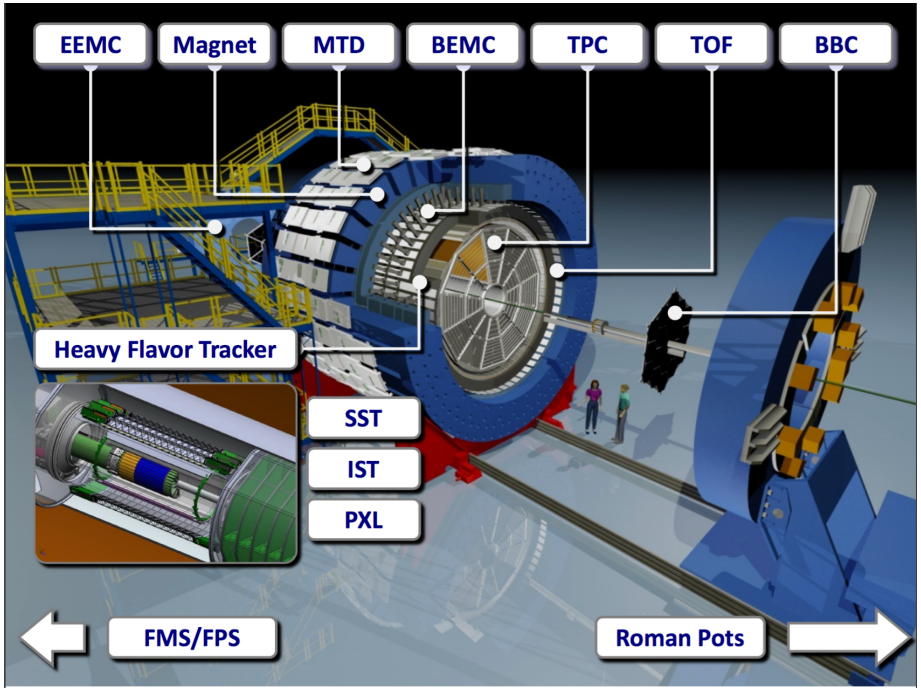
- Measure the asymmetry in the production of protons and antiprotons in SD which may indicate a baryon number (BN) transfer from forward to mid-rapidity region:
  - A sizeable baryon-antibaryon asymmetry in photon-proton (H1 Collaboration arXiv:hep-ph/9810530) and proton-proton (LHC and RHIC, LHS plot) interactions.
  - Similar effect can be studied in the proton-Pomeron collision where we have clean identification of the direction of initial $B = 1$ state.
- Models:
  - Net BN is uniformly distributed over available rapidity space (B. Z. Kopeliovich, B. G. Zakharov, Z. Phys. C 43 (1989) 241).
  - Transfer of BN is exponentially suppressed as a function of transfer size in rapidity space ($\Delta y = y_{beam} - y$) (G.C. Rossi, G. Veneziano, Nucl. Phys. B 123 (1977) 507).
  - Significant BN transfer close to the edge of rapidity gap ($\eta_{beam} - \Delta\eta$) where $\Delta\eta \approx -\ln(\xi); \xi = M_X^2/s$ (F. Bopp, arXiv:hep-ph/0002190).
- Therefore analysis is performed as a function of η and p_T.
- No $p - \bar{p}$ assymetry expected in CD. Good to monitor asymmetry due to detector efficiencies.

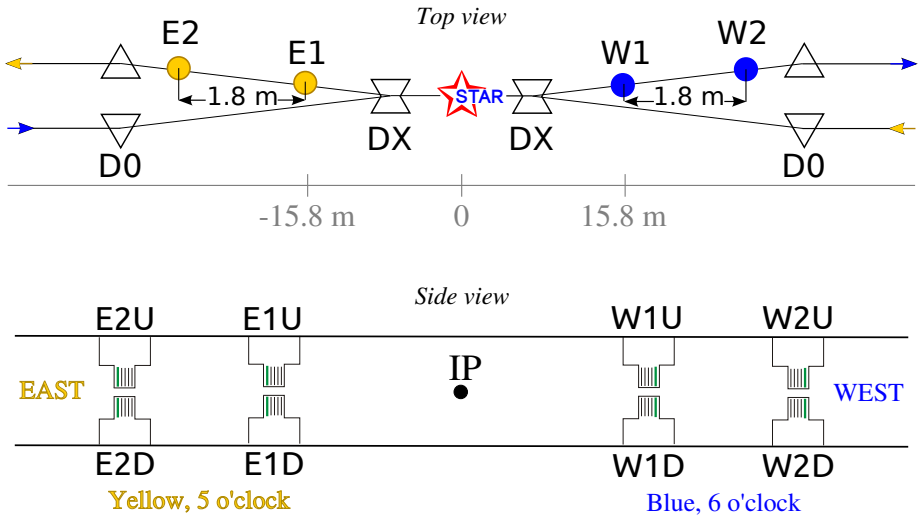
RHIC



- polarized proton-proton (transversely and longitudinally)
- polarized proton-A and AA : p+Al, p+Au, d+Au, h+Au, Cu+Cu, Cu+Au, Au+Au, U+U
- center-of-mass energy up to $\sqrt{s} = 510$ GeV for pp and $\sqrt{s_{NN}} = 200$ GeV for AA

Diffraction at STAR



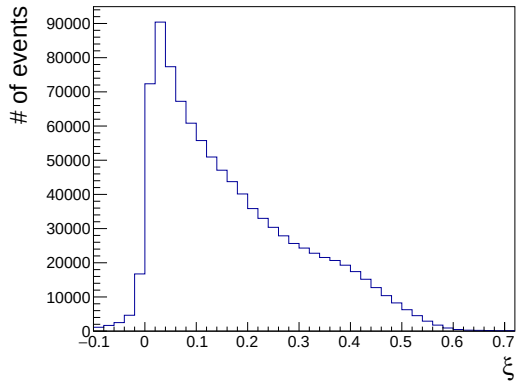


- Measuring diffraction at STAR:
  - 4 Roman Pot stations to tag forward protons ($0.03 < -t < 0.3$ GeV/c^2)
  - BBC veto on the proton side - proton tagged in RP not sufficient for clean selection of diffractive events. Additionally, as tagger of diffractive state X in SD events.
  - TPC and TOF for tracking and particle identification.
- Aim of the study:
  - Measure the p_T and η spectra of $\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$ and calculate the **particle/antiparticle ratios** **(this talk)** in pp collision at $\sqrt{s} = 200$ GeV.
  - Measure the asymmetry in the production of protons and antiprotons in SD which may indicate a baryon number transfer from forward to mid-rapidity region.

Selection of diffractive events and kinematic range of the measurement

- Event selection:
  - **SD**: one reconstructed proton in the RP station on west or east;
  - **CD**: two reconstructed protons in the RP stations on west and east;
  - **SD**: signal in BBC on the opposite side to the outgoing proton;
  - no signal in BBC and ZDC on the outgoing proton side;

- Diffractive system X registered in TPC:
  - $|\eta| < 1.0$;
  - $p_T > 0.15$ GeV/c;
  - at least two primary TPC tracks matched with TOF hit;
  - |z-vertex| < 100 cm;

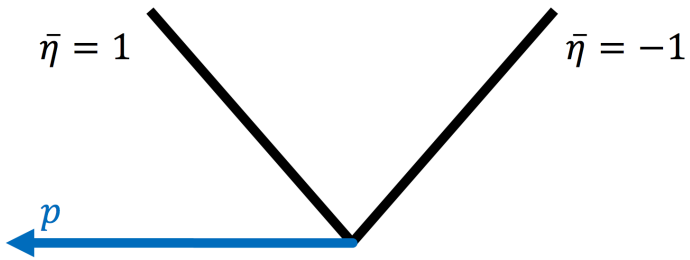


Fractional momentum loss of the proton

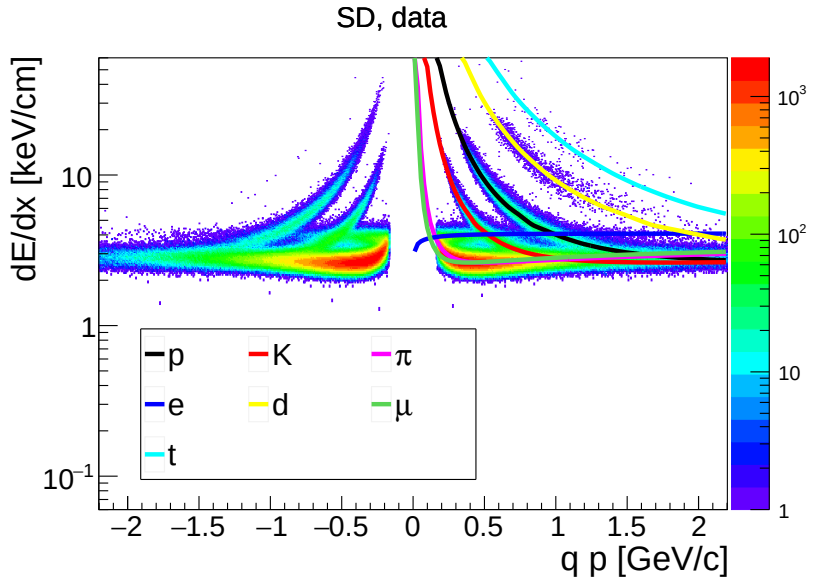
- Acceptance limits proton kinematics range to:
  - $0.03 < -t < 0.3$ GeV^2/c^2
  - $\xi = \frac{\Delta p}{p} < 0.6$
- Number of events used in analysis:
  - **SD**: 19M events $\sim$ 55% of the collected triggers;
  - **CD**: 497M events $\sim$ 90% of the collected triggers.

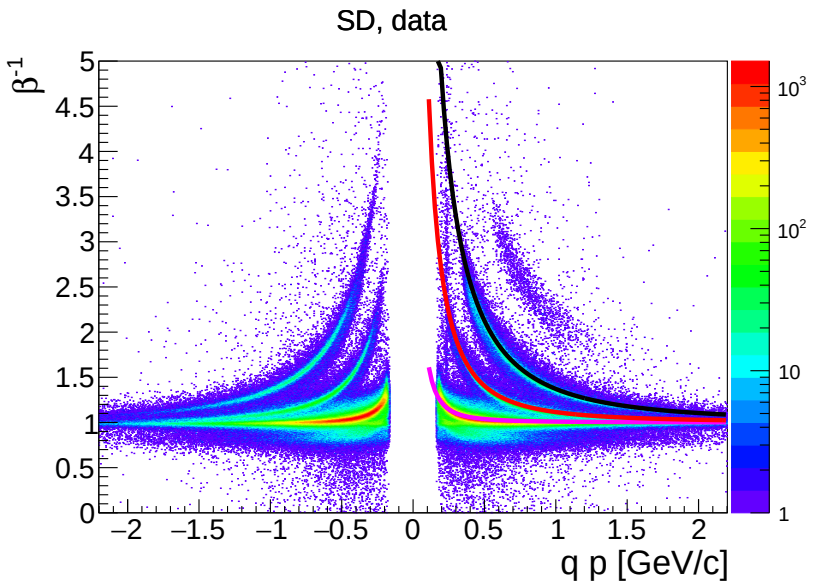
Particle identification

- Study of particle spectra as a function of p_T in three η ($\bar{\eta}$) bins in CD (SD).
- $\bar{\eta}$ - pseudorapidity relative to the beam axis of scattered proton:

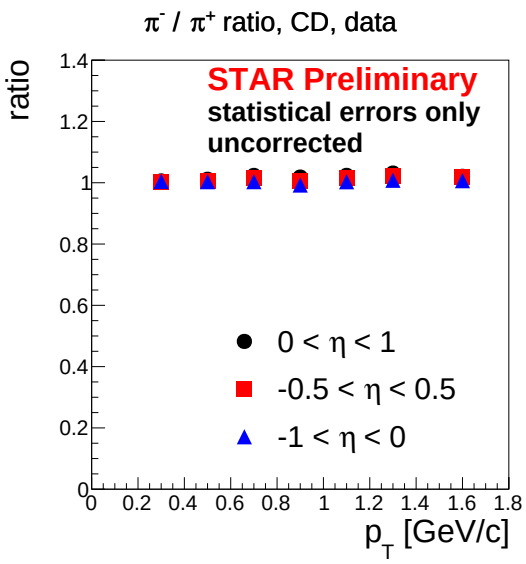


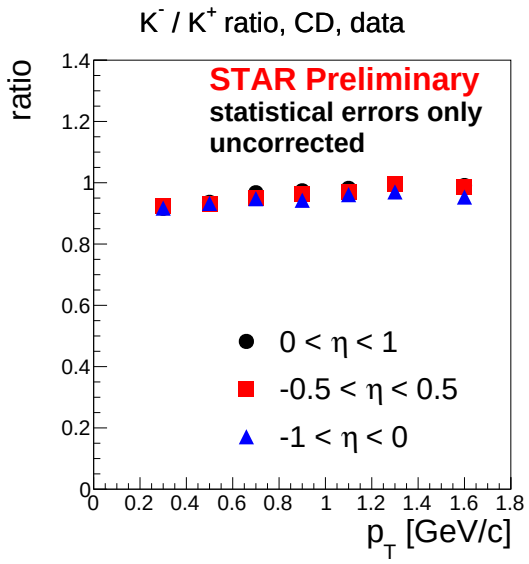
- Combine the information from TPC (dE/dx) and TOF to identify the particles.

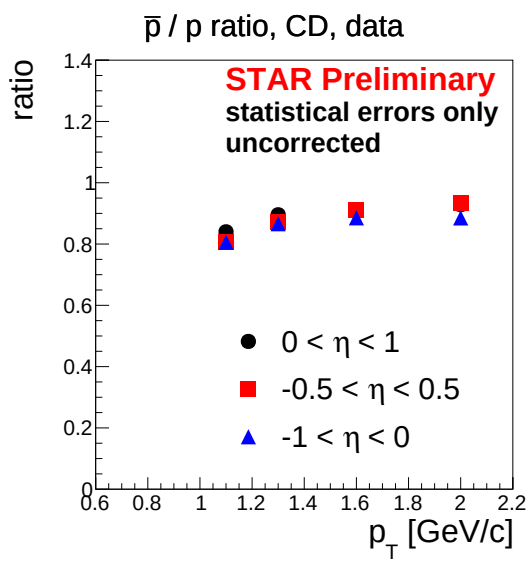




Antiparticle-to-particle ratios in CD

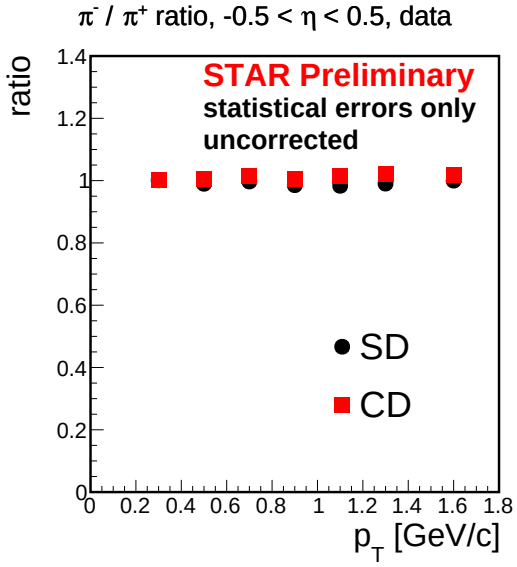


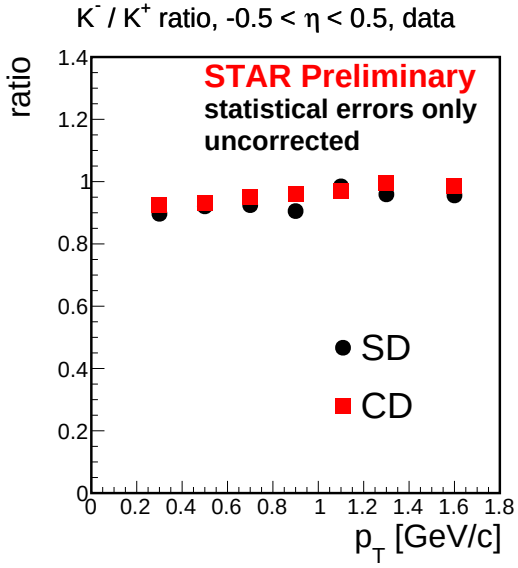


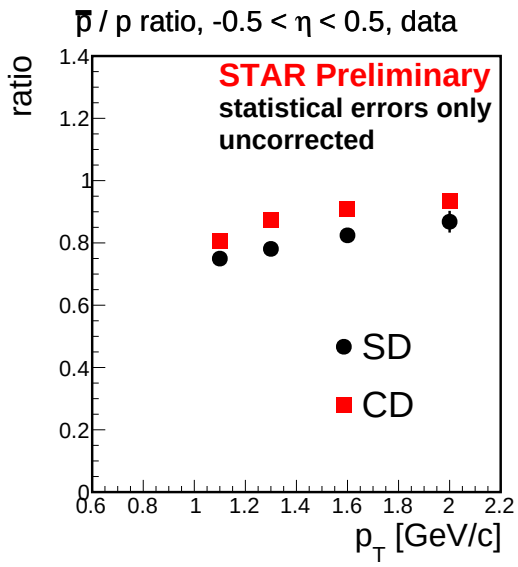


- Uncorrected ratios: many effects cancel out but some do not, e.g. TPC track reconstruction efficiency and background from secondary interactions.
- π^-/π^+ and K^-/K^+ ratios ~ 1 and consistent with STAR non-diffractive measurements.
- $\bar{p}/p$ ratio < 1:
  - TPC track reconstruction efficiency smaller for $\bar{p}$ than p.
  - At $p_T > 1$ GeV/c background from secondary interactions expected to be small.
  - $\bar{p}$ absorption.
- No difference in ratios between analyzed η ranges.

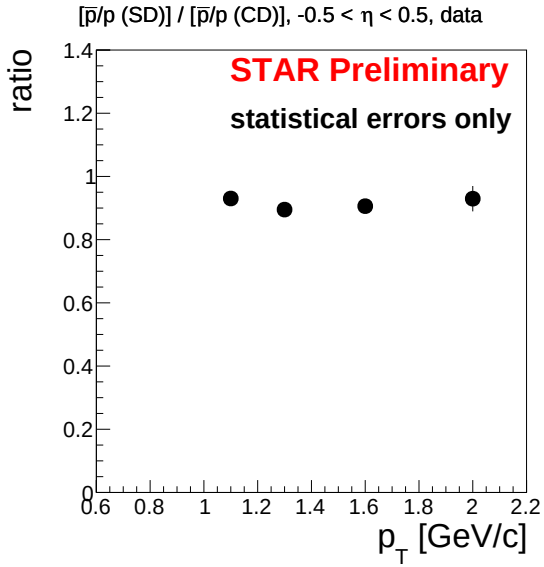
Comparison of antiparticle-to-particle ratios for SD and CD



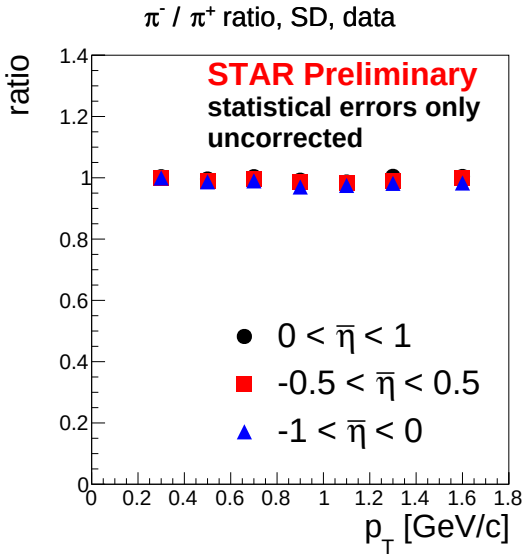


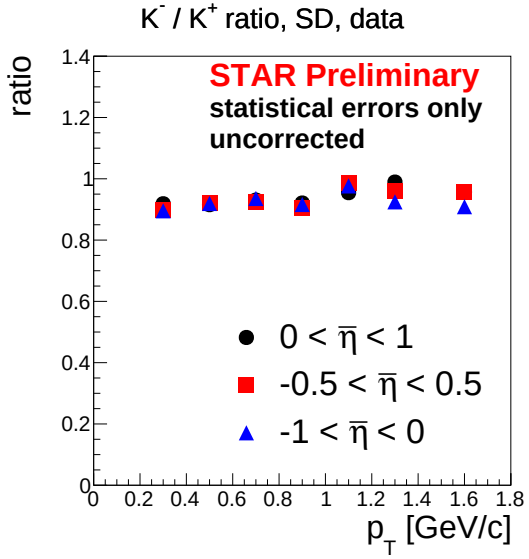


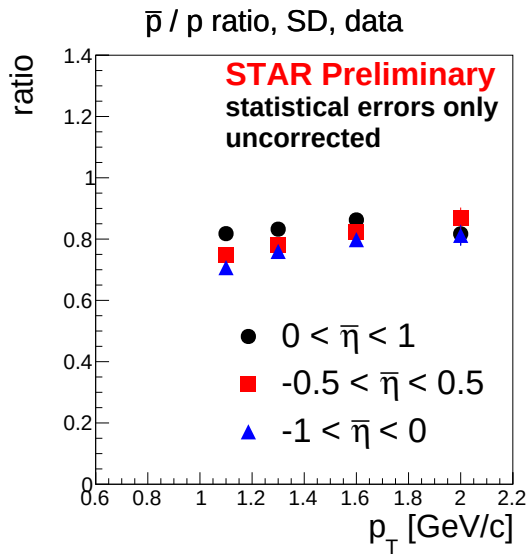
- $-0.5 < \eta < 0.5$
- The same π^-/π^+ and K^-/K^+ ratios for CD and SD.
- $\bar{p}/p$ in CD used as a correction between $\bar{p}$ and p. The ratio: $\frac{\bar{p}/p(SD)}{\bar{p}/p(CD)}$ close to the true $\bar{p}/p$ ratio for SD.
- $\bar{p}/p$ ratio in SD about $0.9 - 0.95$ and greater than STAR non-diffractive measurements.



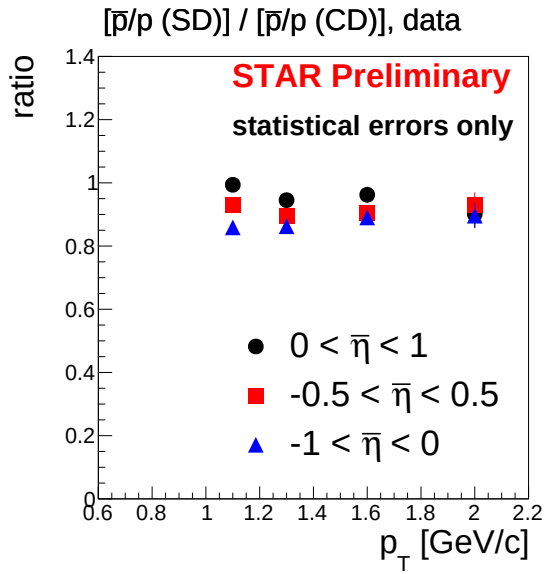
Antiparticle-to-particle ratios in SD







- $\bar{\eta}$ - pseudorapidity relative to the beam axis of scattered proton.
- π^-/π^+ and K^-/K^+ ratios ~ 1.
- $\bar{p}/p$ ratio depends on $\bar{\eta}$ interval: greater ratio closer to the outgoing proton direction.



Summary

- Measurement of particle production in diffraction at $\sqrt{s} = 200$ GeV has been shown.
- Preliminary results on π^+/π^- and K^+/K^- ratios in SD and CD agree with STAR previous non-diffractive measurements.
- SD preliminary results on $\bar{p}/p$ ratio $\sim 0.9 - 0.95$ are greater than STAR non-diffractive measurements.
- Preliminary results on $\bar{p}/p$ ratio in SD may indicate that baryon number transfer is smaller in the outgoing proton direction.
- Analysis of the full data sample, including all the corrections in progress.
- Comparisons with different generators, e.g. PYTHIA8, HIJING, are also planned to understand the dynamics of baryon number transport.
- We are looking forward to more data in pp run 2017 at $\sqrt{s} = 510$ GeV.