Measurements of particle spectra in diffractive $p + p$ collisions with the STAR detector at RHIC

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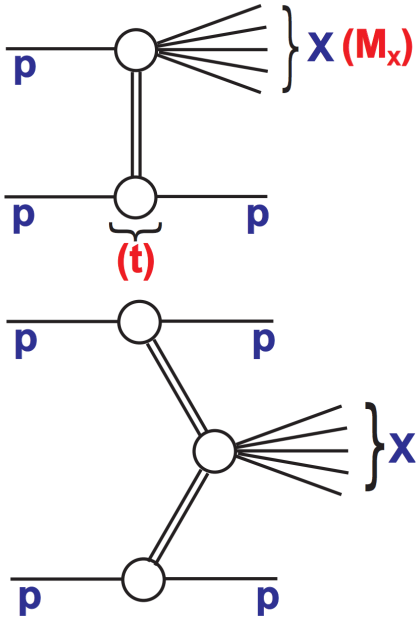
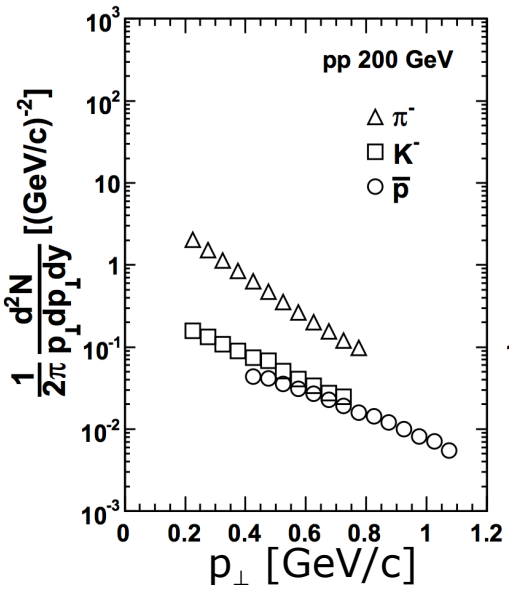
Outline

1. Physics Motivation
2. Experimental setup in 2015
3. Inclusive charged particle spectra
4. Particle identification
5. Antiparticle-particle ratios
6. Summary

Motivation





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

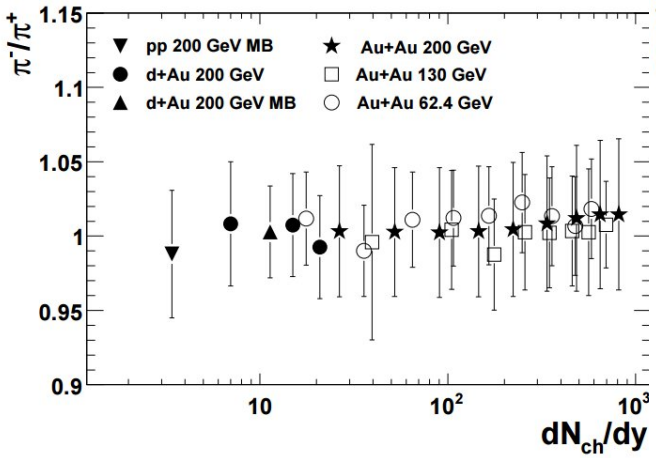
- Study the **S**ingle **D**iffractive **D**issociation and **C**entral **D**iffraction processes:

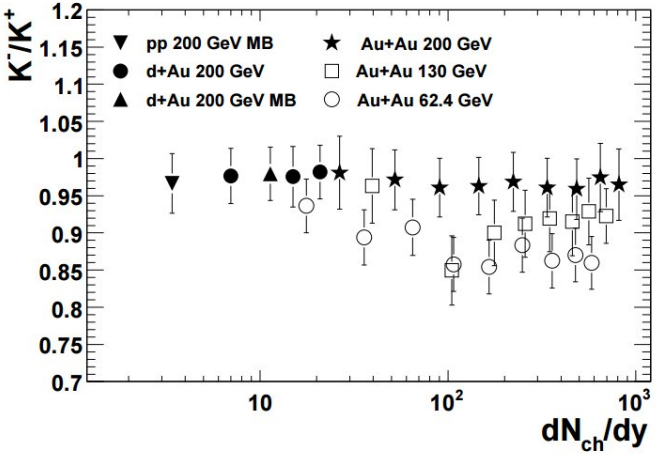
$$p + p \to p + X \qquad \text{(SD)}$$
$$p + p \to p + X + p \qquad \text{(CD)}$$

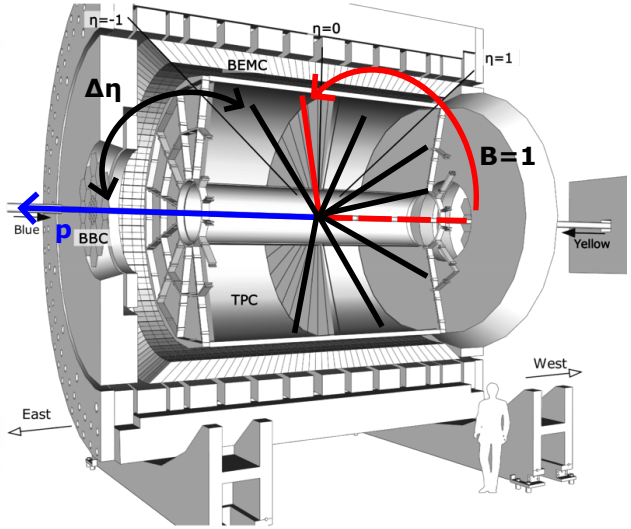
where the interaction between protons is mediated by a colorless object (Pomeron in the Regge Theory) and the final state consists of one (two) proton(s) in SD (CD) and system X, which are separated in rapidity.

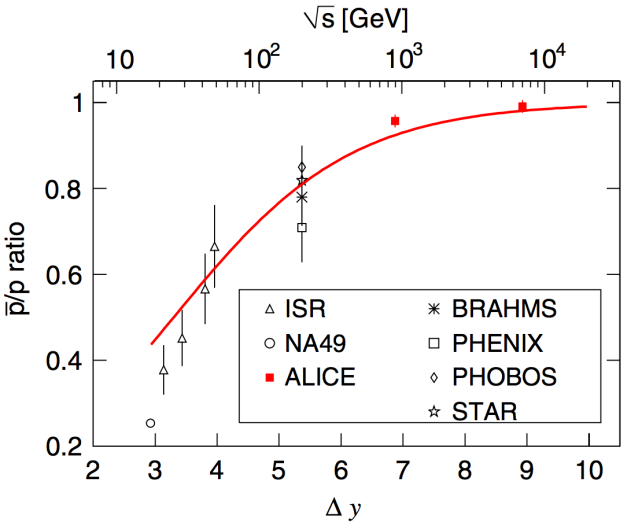
- Study of inclusive charged-particle spectra in proton–proton collisions, which provide insight into the strong interaction in the low-energy, non-perturbative region of QCD (can tune MC generators).
- Study of identified particle spectra (π, K, p) in diffractive events and compare them with model predictions 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 (STAR, PRC 79 (2009) 034909) and LHC (ALICE, EPJC 75 (2015) 226). But no measurement dedicated only for diffractive events.

Antiparticle-to-particle ratios and baryon number transfer in non-diffractive processes





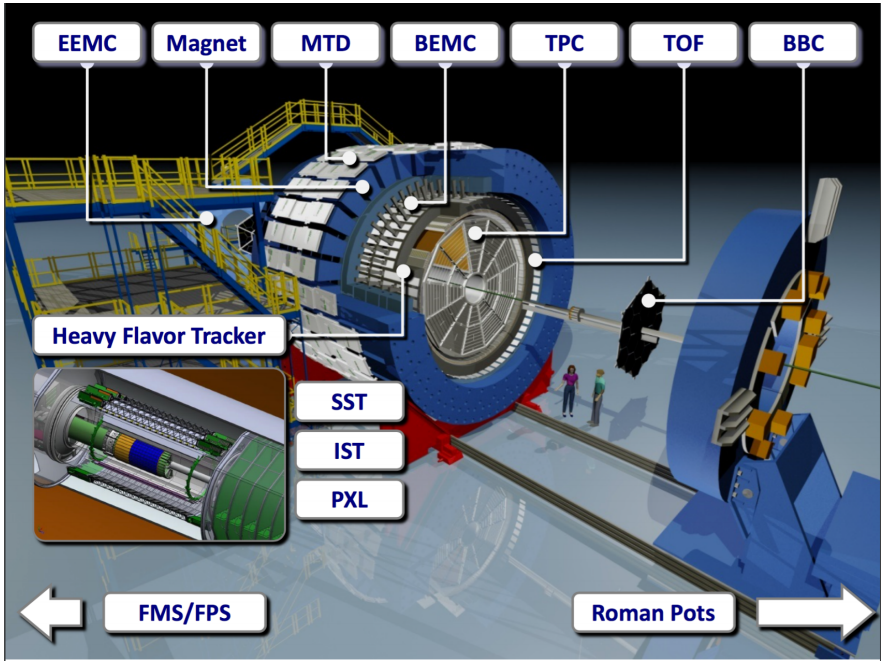


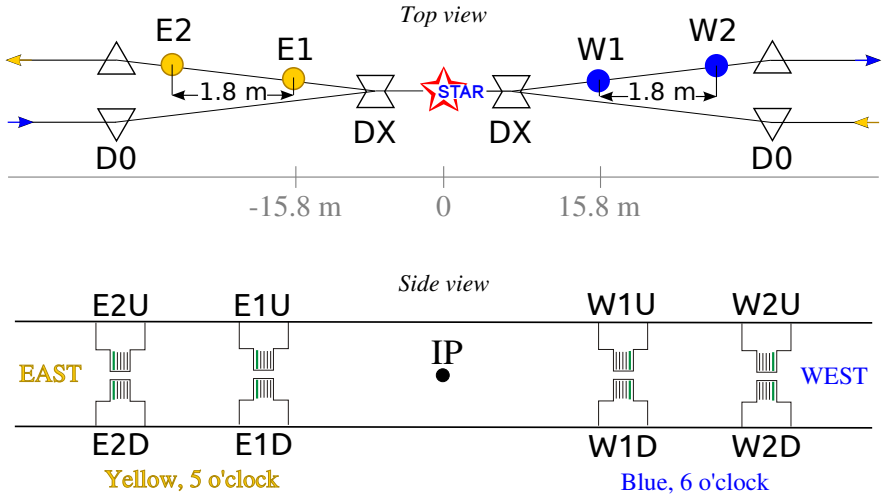


ALICE, PRL 105 (2010) 072002
Red curve: exponentially suppressed BN transfer as a function of transfer size in rapidity space
$\Delta y = y_{beam} - y$, model fitted to the data

- Antiparticle/particle ($\pi^-/\pi^+, K^-/K^+, \bar{p}/p$) ratios as a function of the charged particle multiplicity measured at STAR (STAR, PRC 79 (2009) 034909).
- The π^-/π^+ ratio ~ 1 for all measured collision systems and collision energies, the K^-/K^+ ratios close to 1 in $p+p$, $d+Au$ and $Au+Au$ collisions at 200 GeV.
- Measure the asymmetry in the production of protons and antiprotons in SD which may indicate a baryon number (BN) transfer from forward to midrapidity region:
  - A sizeable baryon-antibaryon asymmetry in photon-proton (B. Kopeliovich, B. Povh, arXiv:hep-ph/9810530) and proton-proton (LHC and RHIC, LHS plot) interactions.
- No $p-\bar{p}$ assymetry expected in CD. Good to monitor asymmetry due to detector efficiencies.

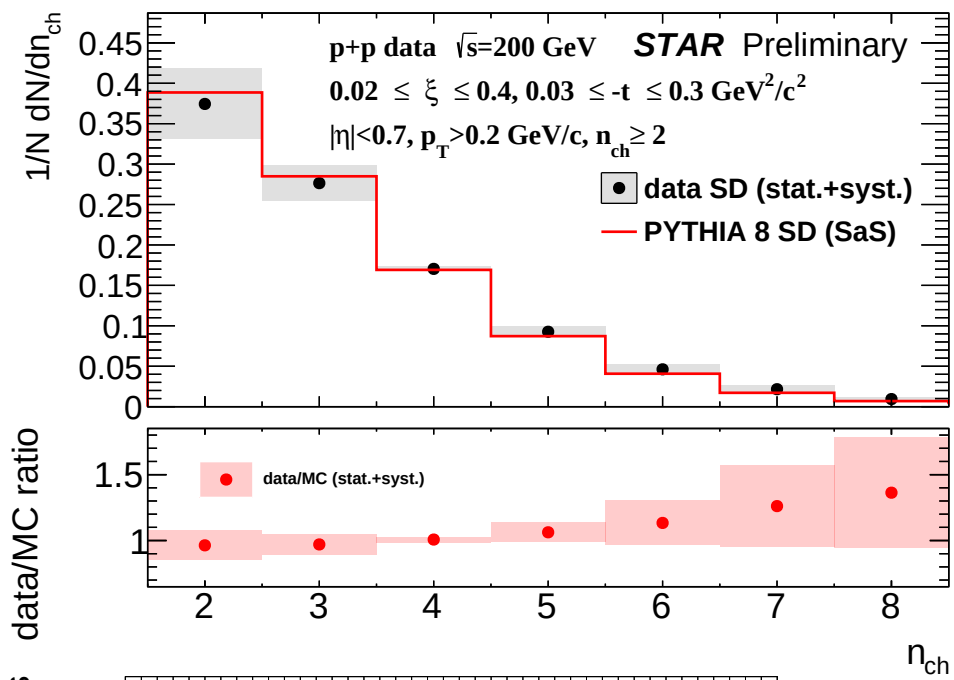
Diffraction at STAR

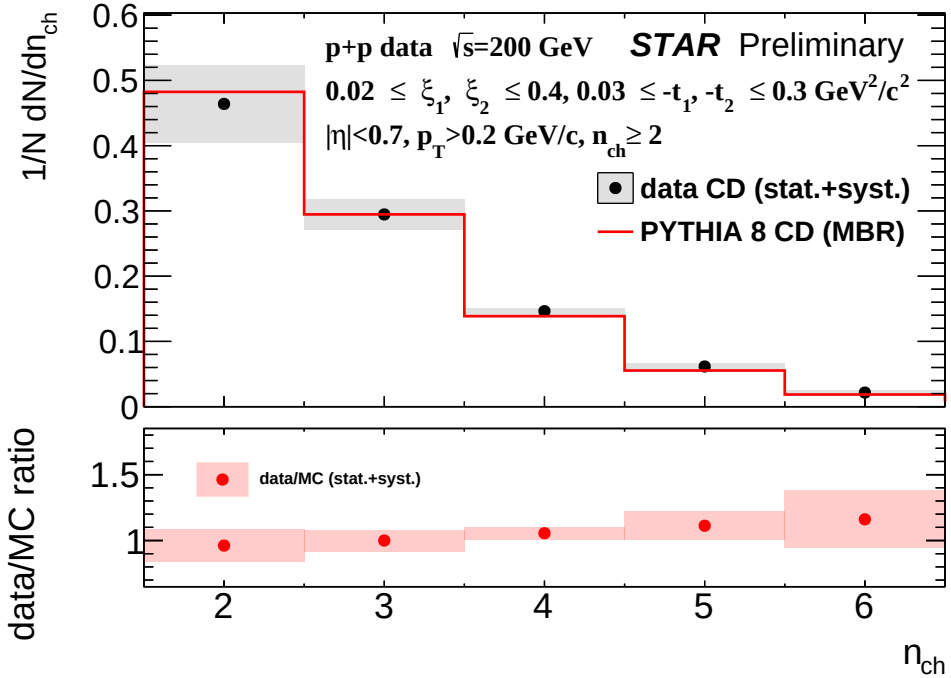


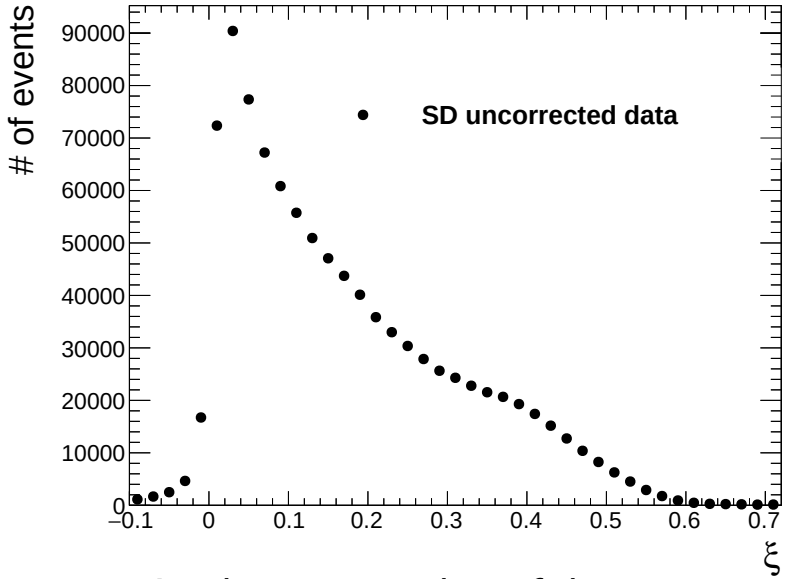


- Measuring diffraction at STAR:
  - 4 Roman Pot stations to tag forward protons ($0.03 < -t < 0.3$ GeV$^2/c^2$)
  - BBC veto on the proton side - proton tagged in RP not sufficient for clean selection of diffractive events. Additionally, as tagger of diffractive state X in SD events.
  - TPC and TOF for tracking and particle identification.
- Aim of the study:
  - Measure charged-particle multiplicities, their p_T and η spectra **(this talk)**.
  - Measure the p_T spectra of $\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$ and calculate the **particle/antiparticle ratios** **(this talk)** in $p+p$ collisions 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 midrapidity region.

Charged-particle multiplicities





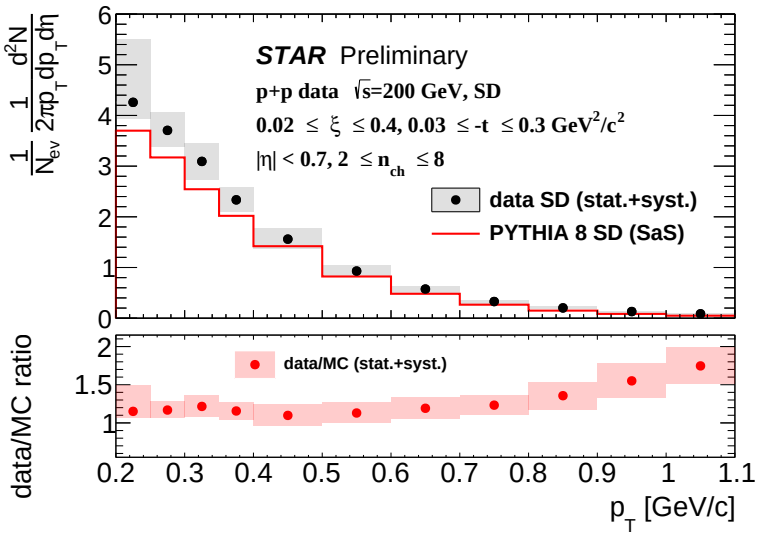


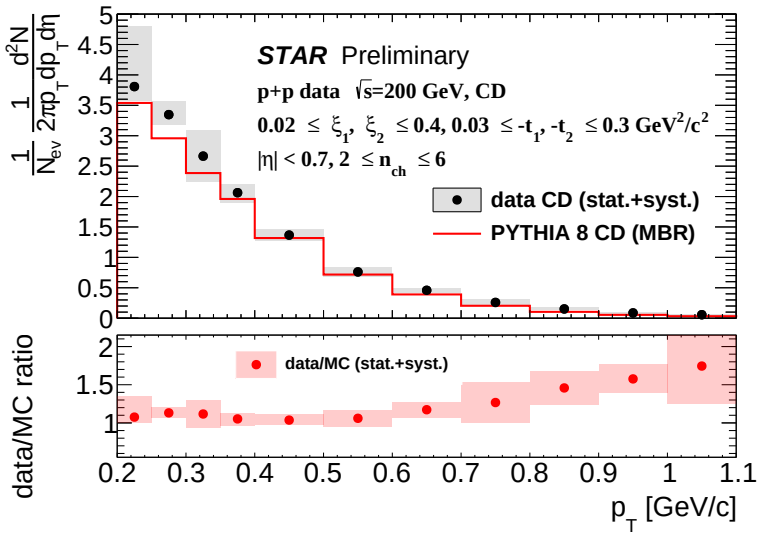
Fractional momentum loss of the proton

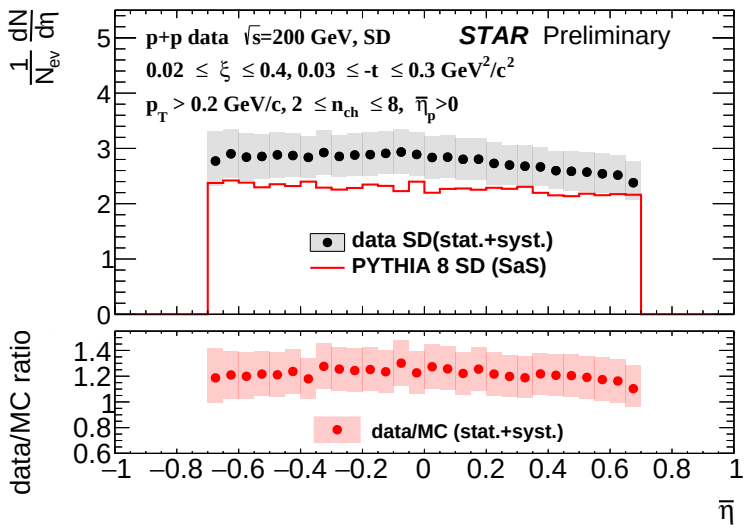
$\xi = M_X^2/s$

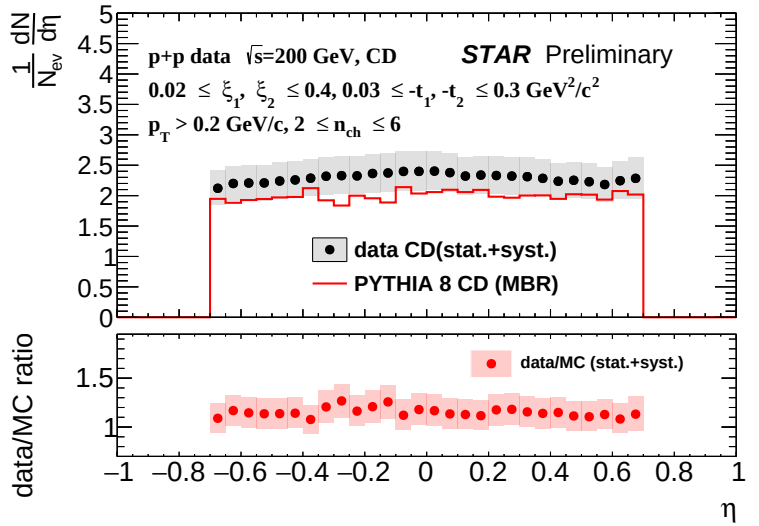
- $0.02 \leq \xi \leq 0.4$, $|\eta| < 0.7$, $p_T > 0.2$ GeV/c
- PYTHIA 8.186 (SD - SaS Pomeron flux (default), CD - MBR Pomeron flux), 4C tune (default).
- Unfold the distribution of tracks into the distribution of particles using Bayes theorem.
- PYTHIA 8 fairly good describes data.
- Comparison with different generators, e.g. EPOS, PYTHIA 8 (different tunes) is also planned.

Inclusive charged-particle η and p_T spectra





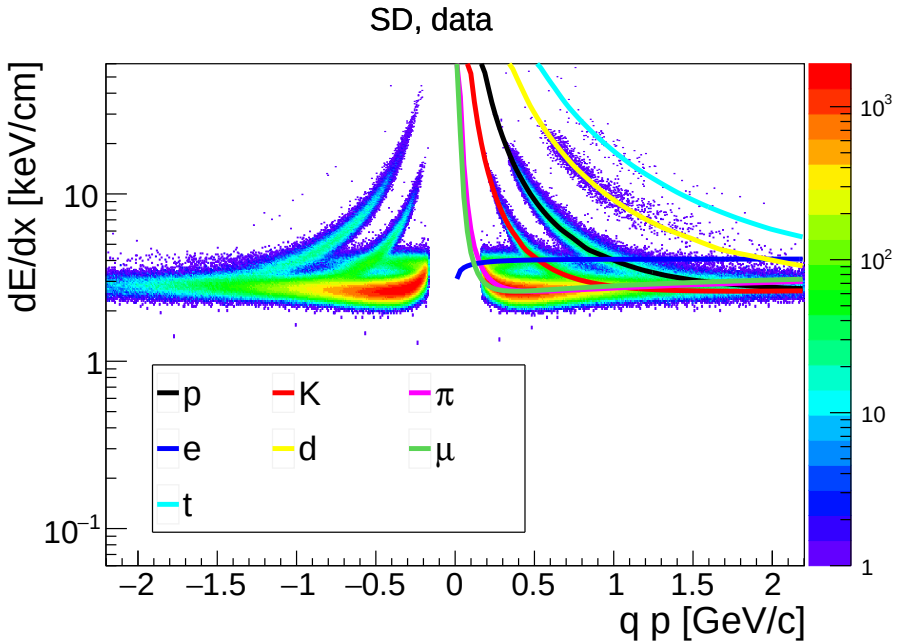


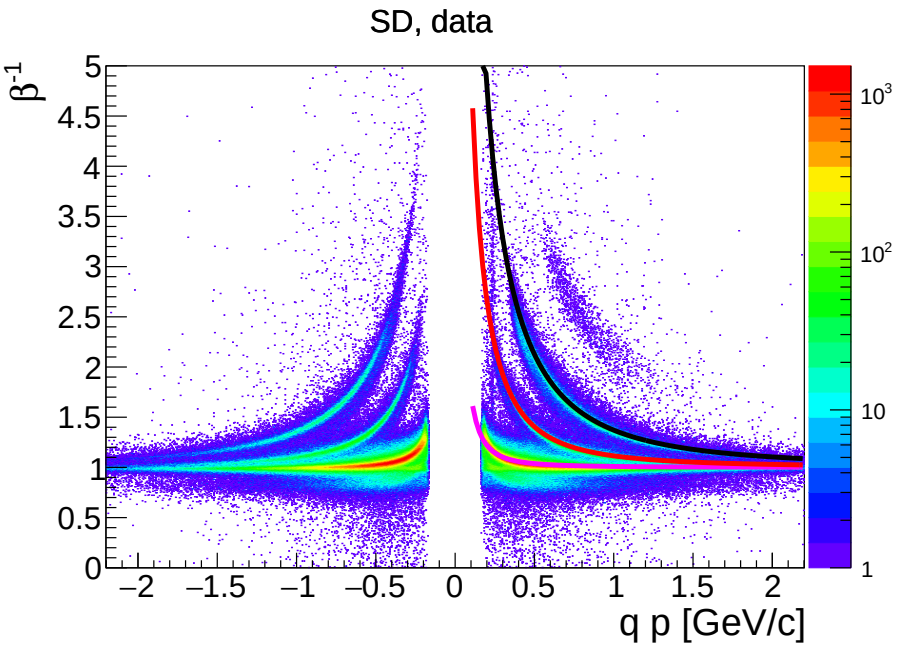


- $0.02 \leq \xi \leq 0.4$, $|\eta| < 0.7$, $p_T > 0.2$ GeV/c, $n_{ch} \geq 2$, SD (CD) $n_{ch} \leq 8$ ($n_{ch} \leq 6$)
- PYTHIA 8.186 (SD - SaS PomFlux (default), CD - MBR PomFlux), 4C tune (default).
- PYTHIA 8 underestimates charged-particle density especially for relatively high-p_T.
- $\eta(\bar{\eta})$ charged-particle density in CD and SD up to 5% above PYTHIA 8 expectation.

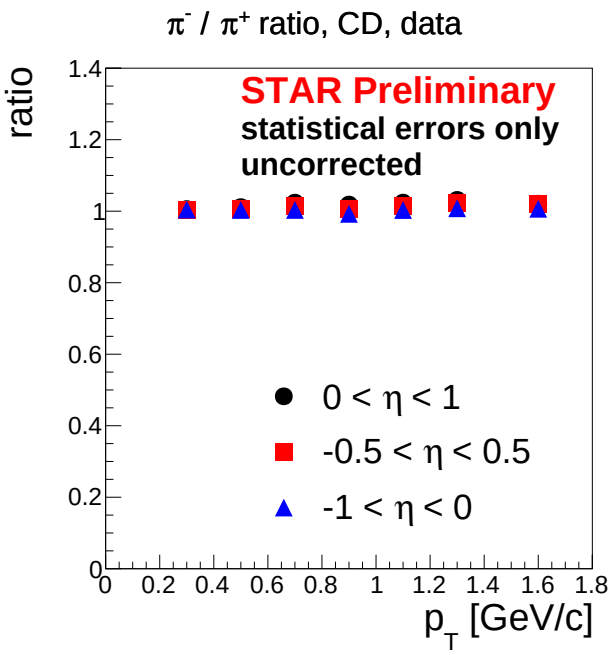
Identified particle spectra

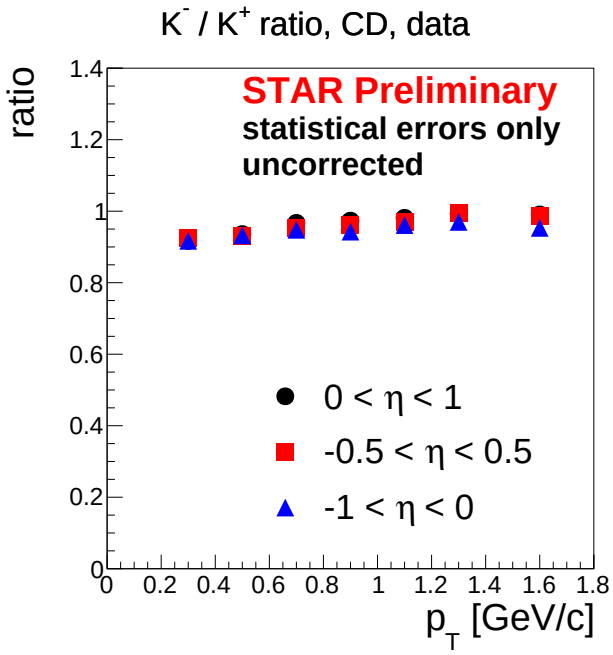
- Study of particle spectra as a function of p_T in three η bins in CD (SD).
- Proton kinematics limited by acceptance:
  - $0.03 < -t < 0.3$ GeV$^2/c^2$
  - $\xi < 0.6$
- Diffractive system X registered in TPC:
  - $|\eta| < 1.0$;
  - $p_T > 0.15$ GeV/c;
  - at least two primary TPC tracks matched with TOF hits;
- Combine the information from TPC (dE/dx) and TOF (β^{-1}) to identify the particles.
- Number of events used in analysis:
  - **SD**: 19M events ∼55% of the collected triggers;
  - **CD**: 497M events ∼90% of the collected triggers.

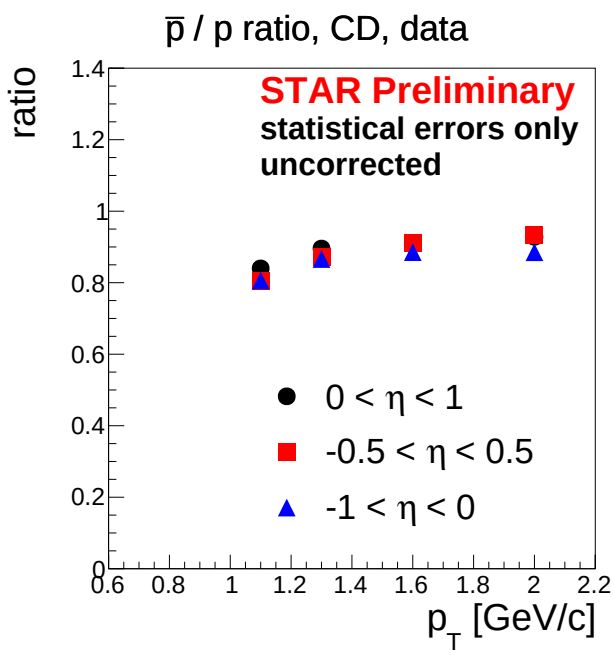




Antiparticle-to-particle ratios in CD

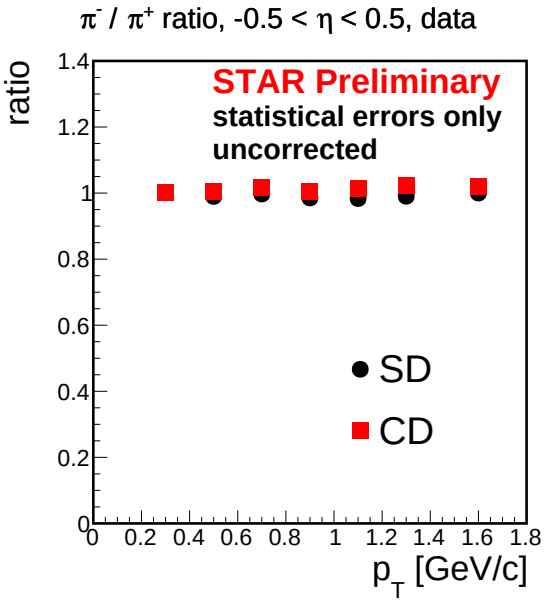


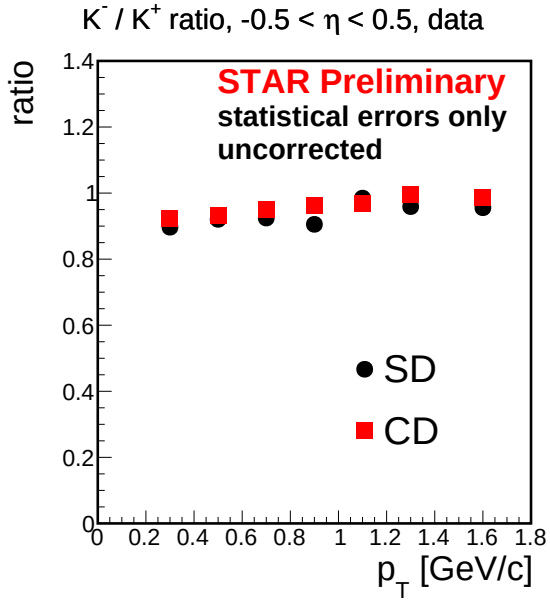


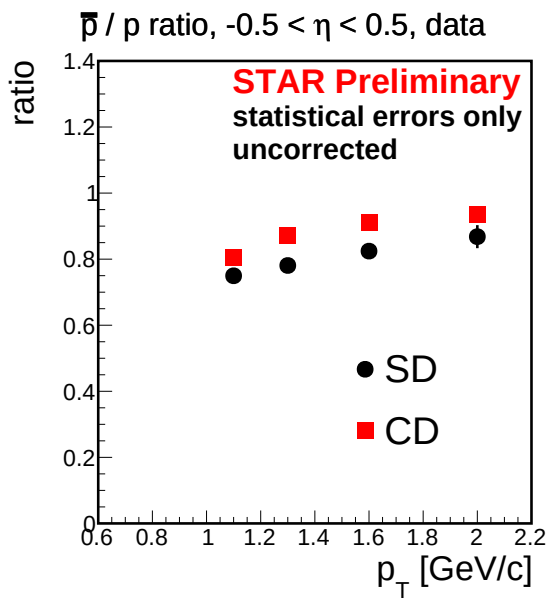


- Uncorrected ratios for some effects: TPC track reconstruction efficiency, TOF matching efficiency, vertex reconstruction efficiency, RP efficiency and acceptance, background from secondary interactions.
- Effects that do not cancel out: TPC track reconstruction efficiency and background from secondary interactions.
- π^-/π^+ and K^-/K^+ ratios $\sim$ 1 and consistent with STAR non-diffractive measurements (STAR, PRC 79 (2009) 034909).
- $\bar{p}/p$ ratio < 1:
  - TPC track reconstruction efficiency smaller for $\bar{p}$ than p ($\bar{p}$ absorption).
  - At $p_T > 1$ GeV/c background from secondary interactions expected to be small.
- No difference in ratios between analyzed η ranges.

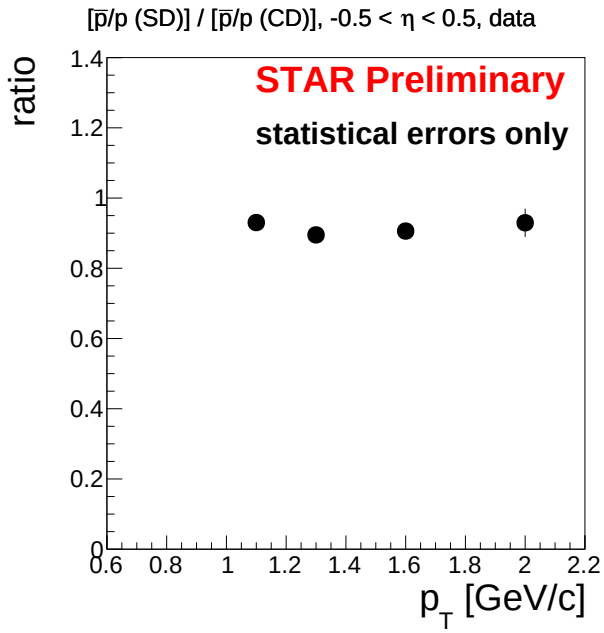
Comparison of antiparticle-to-particle ratios for SD and CD



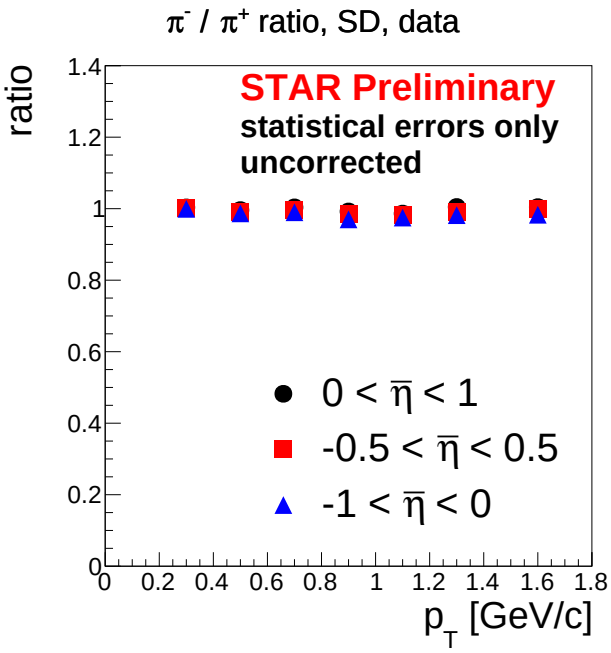


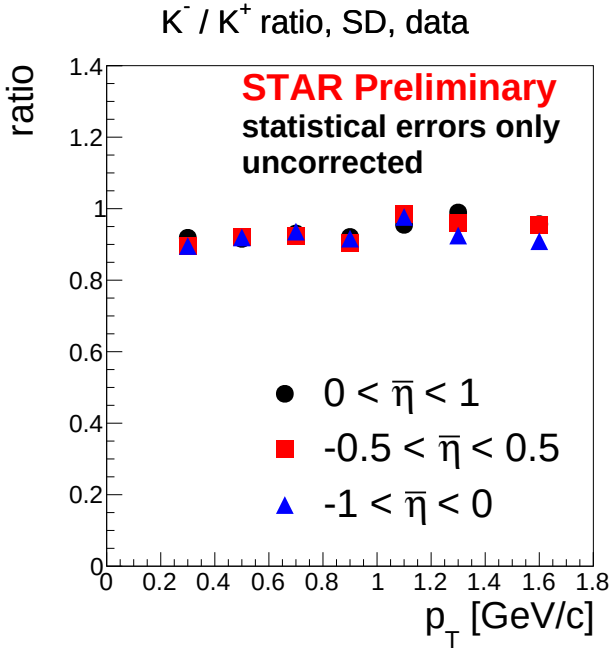


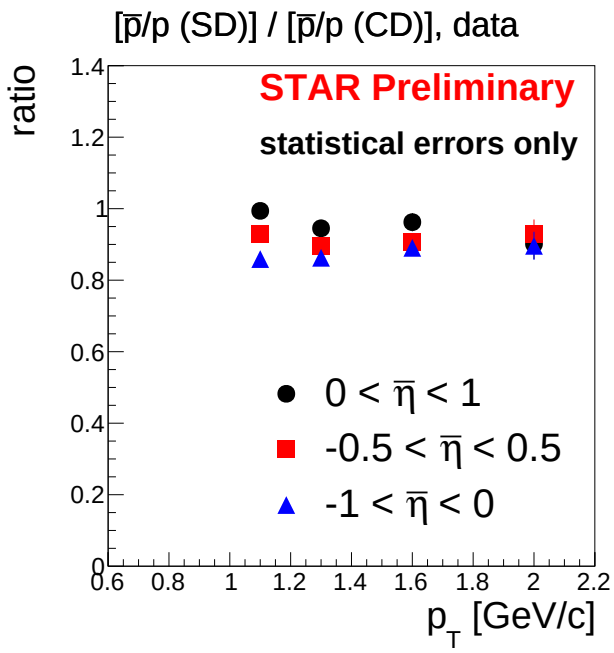
- $-0.5 < \eta < 0.5$
- The same π^-/π^+ and K^-/K^+ ratios for CD and SD.
- $\bar{p}/p$ in CD used as a correction between $\bar{p}$ and p. The ratio: $\frac{\bar{p}/p(SD)}{\bar{p}/p(CD)}$ close to the true $\bar{p}/p$ ratio for SD.
- $\bar{p}/p$ ratio in SD about $0.9-0.95$ and greater than STAR non-diffractive measurements (STAR, PRC 79 (2009) 034909).

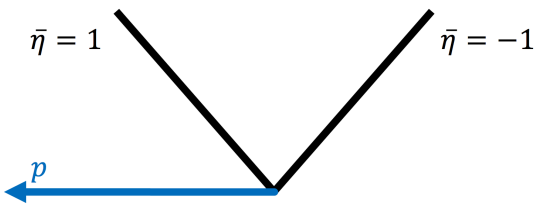


Antiparticle-to-particle ratios in SD









- $\bar{\eta}$ - 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.
- May indicate that baryon number transfer is smaller in the outgoing proton direction in SD.

Summary

- Measurements of charged-particle production in diffraction at $\sqrt{s} = 200$ GeV have been shown.
- Preliminary results on inclusive charged-particle spectra shows that PYTHIA 8 underestimates SD and CD charged-particle density for high-p_T, whereas η charged-particle density in SD and CD are underestimated up to 5% by PYTHIA 8.
- 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 is in progress.
- Comparisons with different generators, e.g. PYTHIA 8, EPOS, are also planned to understand the collision dynamics and mechanism.