Identified particle spectra in single diffractive dissociation process in pp at $\sqrt{s} = 200$ GeV measured with the STAR detector

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Outline

1. Motivation
2. Experimental setup in 2009
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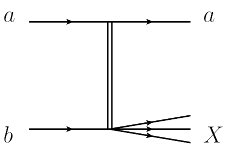
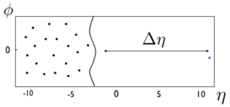
Motivation





- Single Diffractive Dissociation:

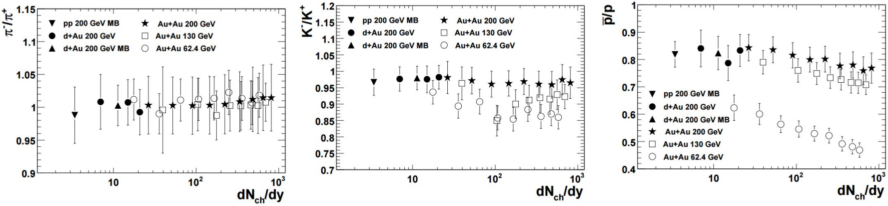
  $$a+b \rightarrow a+X$$

  where a and b denote hadrons, whereas X is a multi-particle state of the same quantum numbers as particle b.
- Regge Theory $\rightarrow$ colorless exchange mediated by the Pomeron.
- Experiments:

$pp(p\bar{p})$	ISR, SPS, TEVATRON, LHC, RHIC
ep	HERA
pA	LHC, RHIC

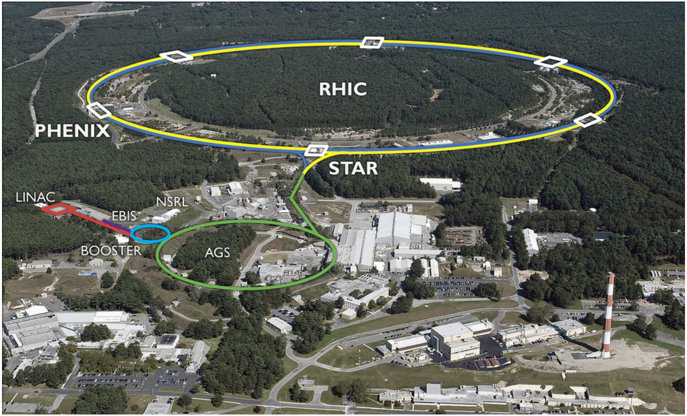
- Study of particle spectra in diffractive dissociation and compare it with non-diffractive dissociation.
- Measurement of baryon number transfer from forward to mid rapidity in SDD.
- Compare measurement with PYTHIA8 expectation.

Antiparticle-to-particle ratios in non-diffractive dissociation



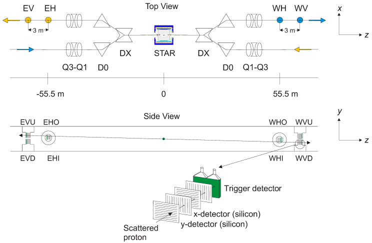
- Antiparticle/particle ($\pi^-/\pi^+, K^{/}K^+, \bar{p}/p$) ratios as a function of the charged particle multiplicity in pp, d+Au at 200 GeV and Au+Au collisions at 62.4 GeV, 130 GeV, and 200 GeV measured at STAR[1].
- The π^-/π^+ ratio ~ 1 for all measured collision systems and collision energies.
- 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 $0.75 - 0.9$.
- A sizeable baryon-antibaryon asymmetry in photon-proton interaction observed by the H1 Collaboration[2] for $p/\bar{p}$ with small momentum: $A = 2 \cdot \left(\frac{N_p - N_{\bar{p}}}{N_p + N_{\bar{p}}}\right) = (8.0 \pm 1.0 \pm 2.5)\,\%$ $\rightarrow$ net baryon number transported through phase space.
- Study particle/antiparticle ratios as a function of p_T in SDD process in pp collision at $\sqrt{s} = 200$ GeV.

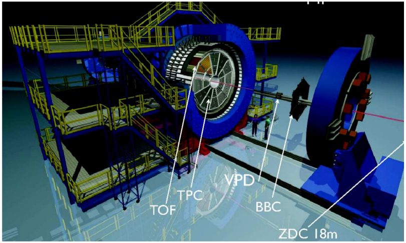
RHIC



- 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

Measuring SDD at STAR

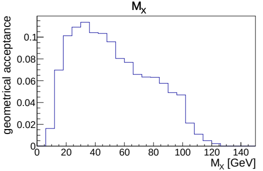




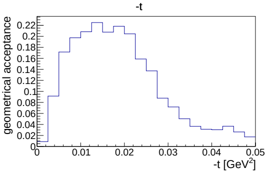
- Need detectors to tag forward protons and detector with good acceptance and particle ID to measure diffractive system
- 4 Roman Pot stations: $3 \cdot 10^{-3} < -t < 3 \cdot 10^{-2}$ GeV^2, $0 < \phi < 2\pi$
- TPC tracking and particle identifiaction (dE/dx): $-1 < \eta < 1$
- BBCs and ZDCs used for triggering and luminosity determination.
- TPC track matched with TOF hit - primary tracks and proton come from the same bunch crossing;

Selection of SDD events and kinematic range of the measurement

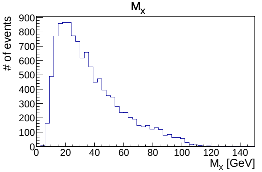
- Select events using trigger conditions:
  - one reconstructed proton in the Roman Pot (RP) station on west or east;
  - signal in BBC or ZDC on opposite side;
  - no signal in BBC and ZDC on the proton side;
- Diffractive system X registered in TPC:
  - $|\eta| < 1.0$;
  - $p_T > 0.15$ GeV/c;
  - primary TPC tracks ≥ 2 and one of them matched with TOF hit;
  - $|\text{z-vertex}| < 100$ cm;
  - Particle spectra analysis - $|\eta| < 0.5$;
- Acceptance limits kinematic range to:
  - diffractive system X:
    - $15 < M_X < 110$ GeV
  - proton kinematics:
    - $4 \cdot 10^{-3} < -t < 3 \cdot 10^{-2}$ GeV^2
    - $0.002 < \xi = \frac{\Delta p}{p} < 0.25$



Geometrical acceptance as a function of M_X

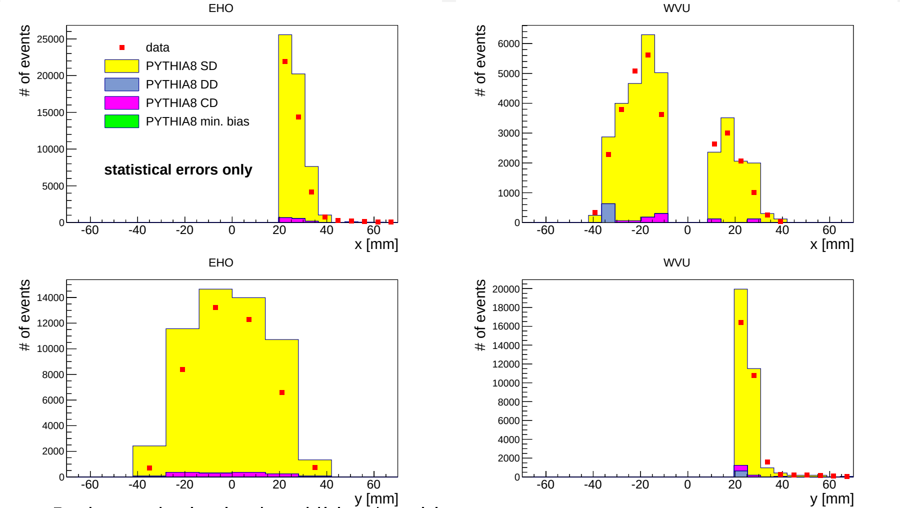


Geometrical acceptance as a function of $-t$



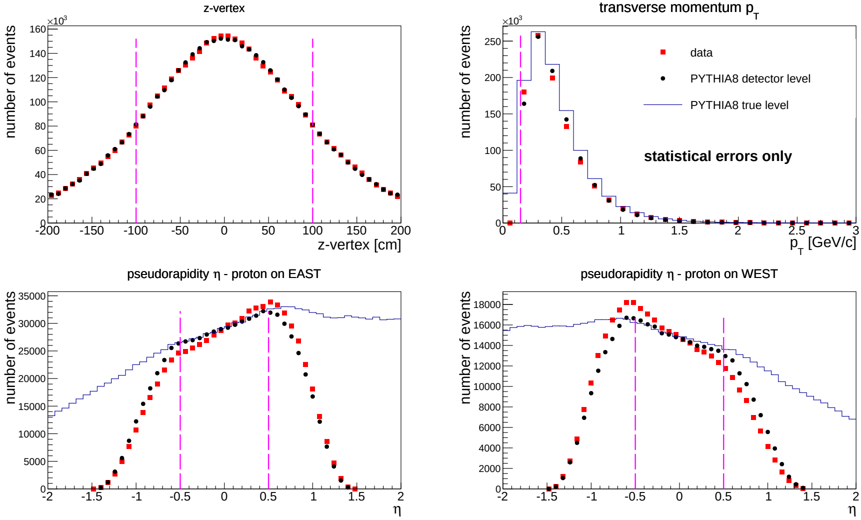
Mass of the diffractive system X

Comparison with simulations



- Background rejection by additional position cuts;
- Compare data with PYTHIA8 (Single Diffraction, Double Diffraction, Central Diffraction and Minimum Bias)
- PYTHIA8 normalized to the luminosity in data;
- Selected sample dominated by SD process.

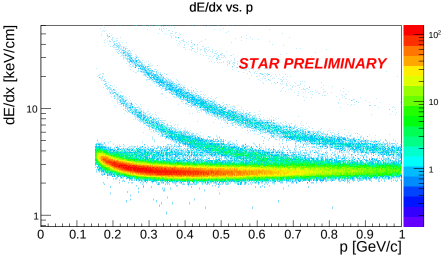
Compare data with MC: TPC primary tracks



- PYTHIA8 normalized to data - compare shape of the distributions;
- PYTHIA8 weighted with z-vertex;
- PYTHIA8 describes data well but small discrepancies in pseudorapidity

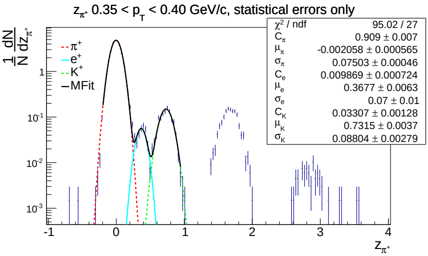
Particle identification

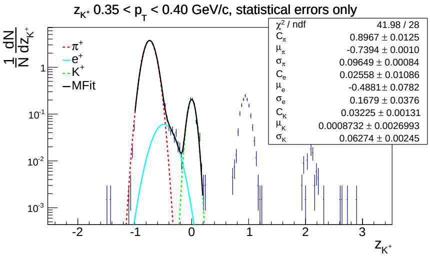
- Measure mass and momentum dependent energy loss (dE/dx);
- Convert dE/dx into momentum independent Gaussian variable z_i ($i = \pi, K, p$)[1];
- $z_i = ln\left(\frac{dE/dx}{(dE/dx)_i^{BB}}\right)$

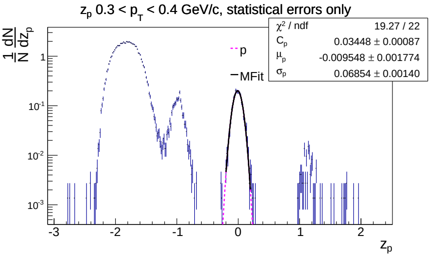


- $(dE/dx)_i^{BB}$ - the Bethe-Bloch inspired parameterization of dE/dx for the given particle type;
- $(dE/dx)_i^{BB} = A_i^{BB}\left(1 + \frac{m_i^2}{p^2}\right)$
- A_i^{BB} factor determined from data;
- The expected value of z_i for the particle in study around 0.

Extraction of raw particle yields

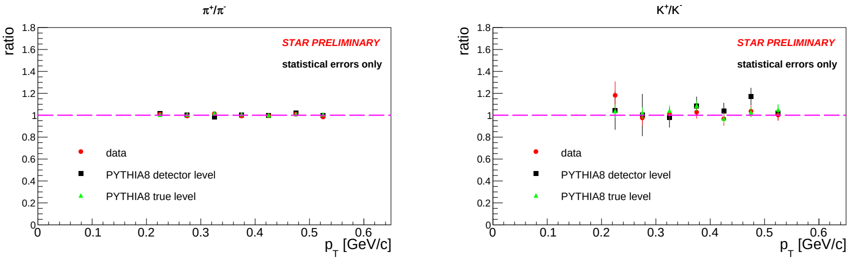






- Plot z_i distributions for a given particle in a given p_T range;
- The z_i distributions/peaks simultaneously fitted by multiple Gaussians to extract the raw particle yields;
- Contribution of electrons and deuterons.

Particle identification: pion and kaon



- π^+/π^- and K^+/K^- ratios consistent with STAR non-diffractive measurements.
- PYTHIA8 particle production model describes data well.

Proton background subtraction

- Proton sample contains background protons knocked out from the beam pipe and the detector materials by interactions of produced hadrons in these materials - nearly flat DCA tail in the proton distribution (DCA - the closest distance from the collision vertex to a track helix).
- Antiprotons do not have knock-out background - the flat DCA tail absent from their DCA distribution.
- Based on MC simulation studies made for the other analysis, i.e. [1], it was found that the description of the background protons:

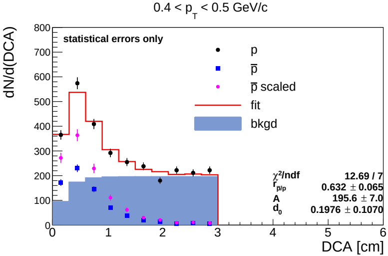
$$p_{bkgd}(DCA) \propto [1 - \exp(-DCA/d_0)]$$

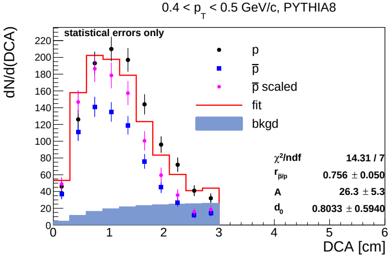
- Assuming that the shape of the background-subtracted proton DCA distribution is identical to that for the antiproton DCA distribution, the proton data can be fit by:

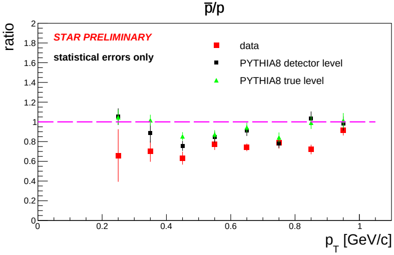
$$p(DCA) = \bar{p}(DCA)/r_{\bar{p}/p} + A \cdot p_{bkgd}(DCA)$$

  where the parameters d_0, $r_{\bar{p}/p}$ and A are free parameters.
- Above assumption is not strictly valid because the weak decay contributions to the proton and antiproton samples are in principle different. However, the difference in DCA distributions between p and $\bar{p}$ arising from weak decay contamination is small.

Proton background substraction

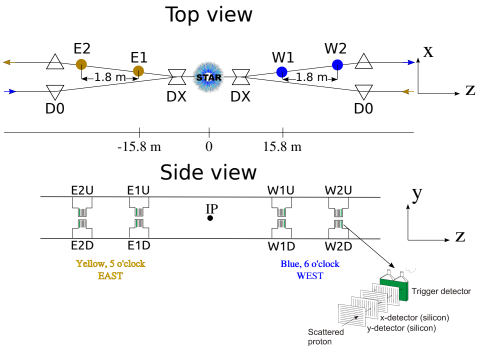






- $\bar{p}/p$ ratio below 1 for data and PYTHIA8;
- Discrepancy between data and PYTHIA8;
- $\bar{p}/p$ ratio about 0.8 and consistent with STAR non-diffractive measurements;
- Baryon number transport may be higher than expected by PYTHIA8 model but larger data sample needed.

Particle spectra in Run 15



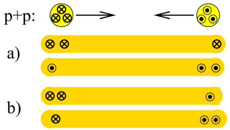
- New RP setup (STAR Phase II configuration) to be able to take data without special conditions to acquire large data samples.
- $0.03 \leq -t \leq 0.3$ GeV^2
- 35 mln SDD events collected $\rightarrow$ analysis in progress.
- We are looking forward to more data in pp run 2017 at $\sqrt{s} = 510$ GeV.

Summary

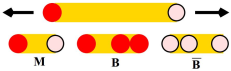
- Measurement of particle production in SDD at $\sqrt{s} = 200$ GeV has been shown;
- Preliminary results on π^+/π^- and K^+/K^- ratios are well reproduced by the PYTHIA 8 particle production model and agree with STAR previous non-diffractive measurements.
- Preliminary results on $\bar{p}/p$ ratio equals to ~ 0.8 and is consistent with STAR non-diffractive measurements.
- Preliminary results on $\bar{p}/p$ ratio may indicate that baryon number transport is higher than expected by PYTHIA 8 model but larger data sample is needed.
- Comparisons with different simulators, e.g. HIJING, are also planned to understand the dynamics of baryon number transport.
- We had a very successful data taking in just finished 2015 run in pp collisions.
- We are looking forward to more data in pp run 2017 at $\sqrt{s} = 510$ GeV.

Backup slide - Particle production in *pp* collision

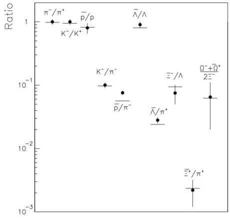
- The String Models[3]:
  - two protons create "excitations" in form of two strings, which consist of one quark on the one side and a diquark on the other side:
    1. Longitudial excitation - string consists only of one proton valence quarks;
    2. Color exchange - string created by joining a quark of one proton and a diquark from the other proton;
  - hadronization - break the string and form a pair of $q - \bar{q}$;
- Quark-Gluon Strings Model QGSM[4]:
  - based on nonperturbative notions, combining QCD with Regge theory and using parton structure of hadrons;
  - the baryon number cannot be transported over large rapidity space.
- The Multisource thermal model[5] - particles divided into sources described by Erlang distribution. The source is considered as a thermodynamic system of quantum ideal gas.



String formation mechanisms for pp collisions



The $q - \bar{q}$ fragments into hadrons



particle/antiparticle ratio in pp non-diffractive collision at 200 GeV

Literature

[1] B.I. Abelev *et al.*, *Systematic measurements of identified particle spectra in pp, d+Au, and Au+Au collisions at the STAR detector*, PHYSICAL REVIEW C79, 2009.

[2] B.Z. Kopeliovich, B. Povh, *Baryon Stopping at HERA: Evidence for Gluonic Mechanism*, *arXiv:hep-ph/9810530* [hep-ph].

[3] F.M. Liu *et al.*, *Constraints on Models for Proton-Proton Scattering from Multi-strange Baryon Data*, *arXiv:hep-ph/0202008* [hep-ph].

[4] A.B. Kaidalov, M.G. Poghosyan, *Spectra of particles produced in high-mass diffraction dissociation in the Model of Quark-Gluon Strings*, *arXiv:0910.1558* [hep-ph].

[5] Fu-Hu Liu *et al.*, *Transverse Momentum Distributions of Final-State Particles Produced in Soft Excitation Process in High Energy Collisions*, Advances in High Energy Physics, 2013.