Recent Results and Future Prospects in Central Exclusive Production at STAR

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On behalf of STAR Collaboration

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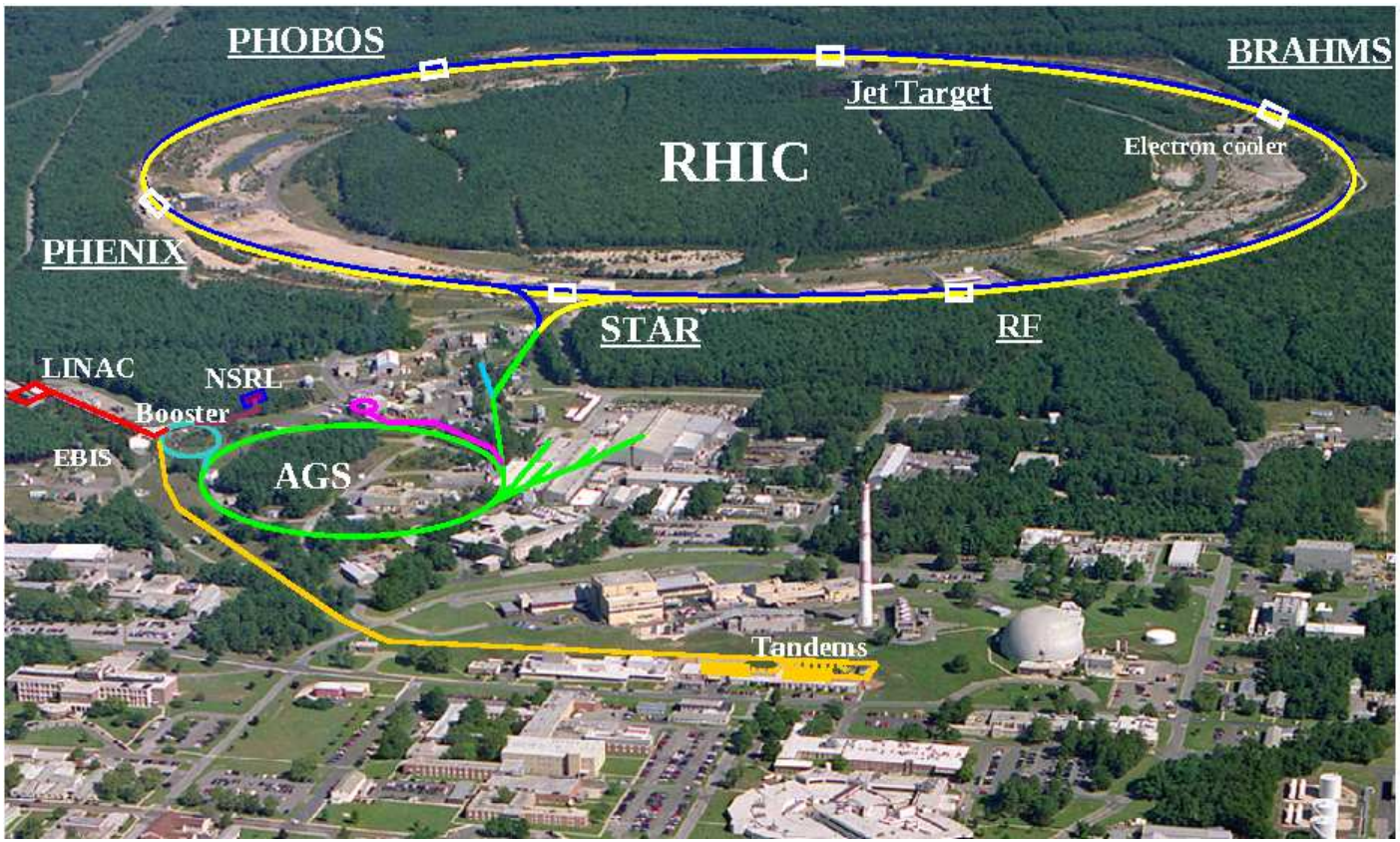
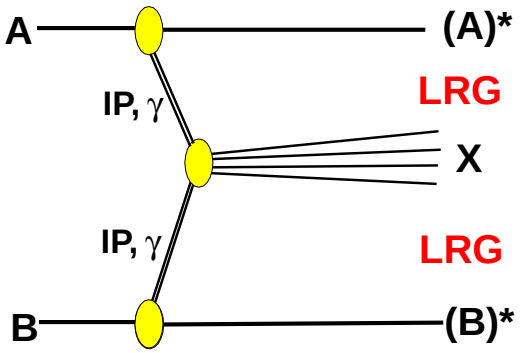
RHIC

AA: Au-Au, Cu-Cu, Cu-Au, d-Au, U-U up to $\sqrt{s_{NN}} = 200$ GeV
polarized proton-proton: up to $\sqrt{s} = 510$ GeV

this talk: $p + p \rightarrow p + p + X$; $\quad X \rightarrow \pi^+ + \pi^-$



Central Exclusive Production in Colliders



Central Exclusive Production (CEP):

$$A + B \to (A)^{\star} \;\; gap \;\; X \;\; gap \;\; (B)^{\star}$$

where X is a simple centrally produced system.

ee from LEP to ILC: $\gamma\gamma \to l^+l^-$

ep HERA: $\gamma\gamma \to l^+l^-$; $\gamma I\!P \to$ vector mesons

pp ISR, TEVATRON, RHIC, LHC:
$\gamma\gamma \to l^+l^-$; $\gamma I\!P \to$ vector mesons; $I\!P I\!P \to$ hadrons
this talk: $I\!P I\!P \to \pi^+\pi^-$

AA RHIC, LHC: $\gamma\gamma \to l^+l^-$; $\gamma I\!P \to$ vector mesons; $I\!P I\!P \to$ hadrons

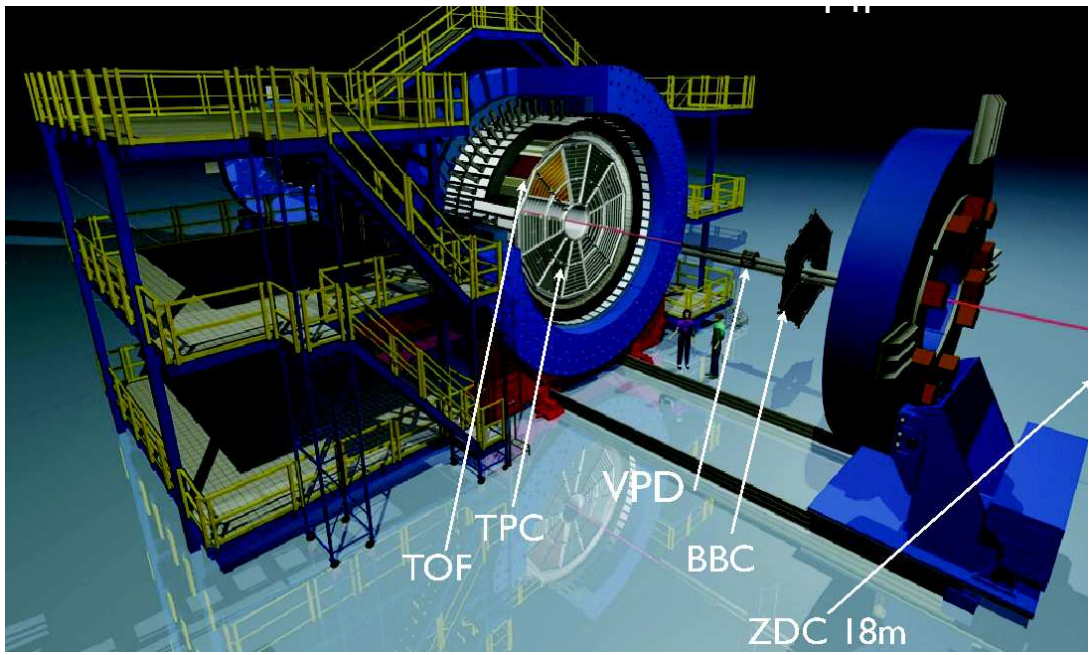
Physics Motivation for low mass CEP studies

- Constrain DPE models of $pp \to ppX \quad X \to \pi^+\pi^-$
  - Regge pole
    B. R. Desai et al., Double pomeron exchange in high-energy pp collisions, Nucl. Phys. B142 (1978) 258
  - QCD Regge theory
    L.A. Harland-Lang et al., The phenomenology of CEP at hadron collider arXiv:1204.4803
    P.Lebiedowicz et al., Exclusive $pp \to pp\pi\pi$ from the threshold to LHC, Phys. Rev. D81(2010)036003
- Spectroscopy
  - understanding mass spectrum: quantum number filter (spin, parity, isospin).
  - common believe that lightest glueball should be a scalar with mass in the range $1 - 2$ GeV.

CEP with STAR detector

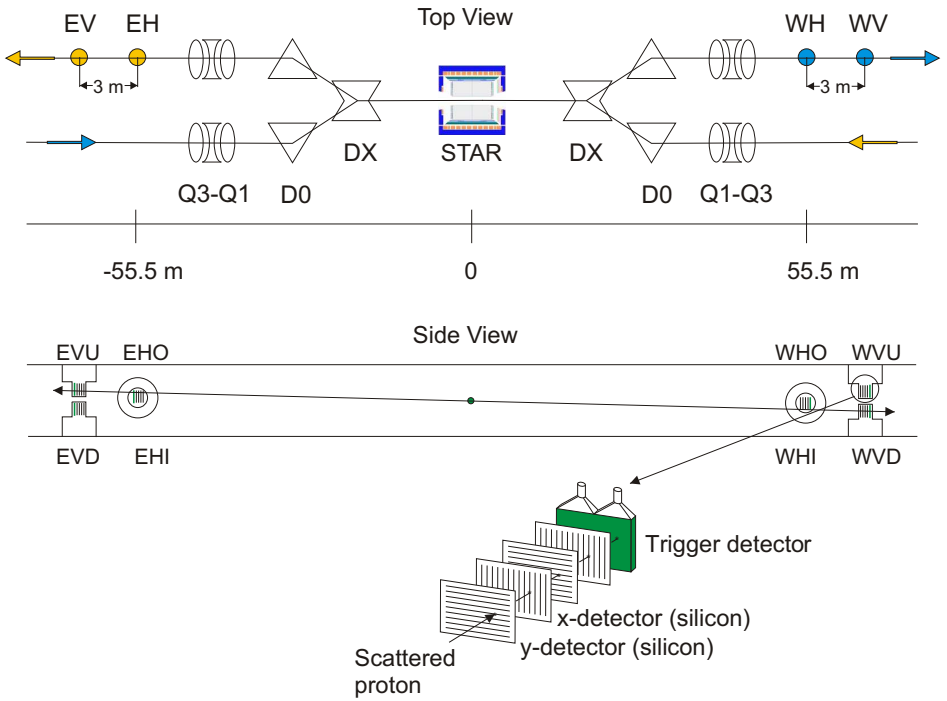
preliminary reults: $pp \to ppX, \quad X = \pi^+\pi^-$

possible extension: $pp \to (p)^\star \ \ gap \ \ X \ \ gap \ \ (p)^\star$



- high resolution tracking with TPC: $-1 < \eta < 1$
- particle identification: TPC dE/dx
- central state tagging/triggering: ToF
- forward proton tagging : Roman Pots RP
- possible rapidity gap: BBC veto, $2.1 < \eta < 5.2$

Forward proton tagging at STAR

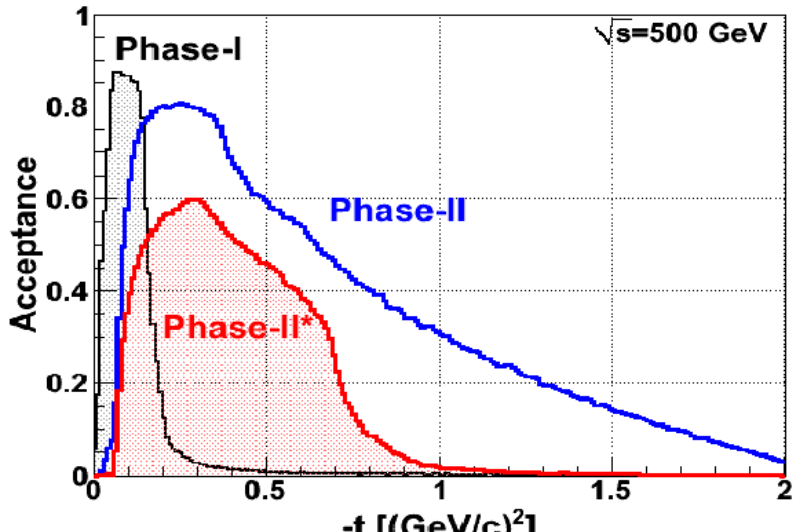


current setup(I)

- 8 Roman Pots (4 stations)
- with 4 silicon strip layers
- full angular coverage
- need special beam optics
- data at $\sqrt{s} = 200$ GeV
- $0.003 < -t < 0.035$ GeV^2

Upgrade to be installed 2014 (II*)

- 4 Roman Pots (2 stations)
- possible extension (II)
  6 Roman Pots (3 stations)
- limited angular coverage
- no special runs needed
- larger statistics
- $0.1 < -t < 1(2)$ GeV^2



CEP in pp collisions 2009 data, $\sqrt{s} = 200$ GeV

$$pp \to ppX, \quad X = \pi^+\pi^-$$

- both scattered protons detected with Roman Pots
- produced state X fully measured with TPC
- acceptance limits kinematics:

$$0.003 < -t_1, -t_2 < 0.035 \text{ GeV}^2$$

$$0.5 < M_{\pi\pi} < 2.3 \text{ GeV}$$

- in principle both $I\!P I\!P$ and $\gamma I\!P$ contribute but:

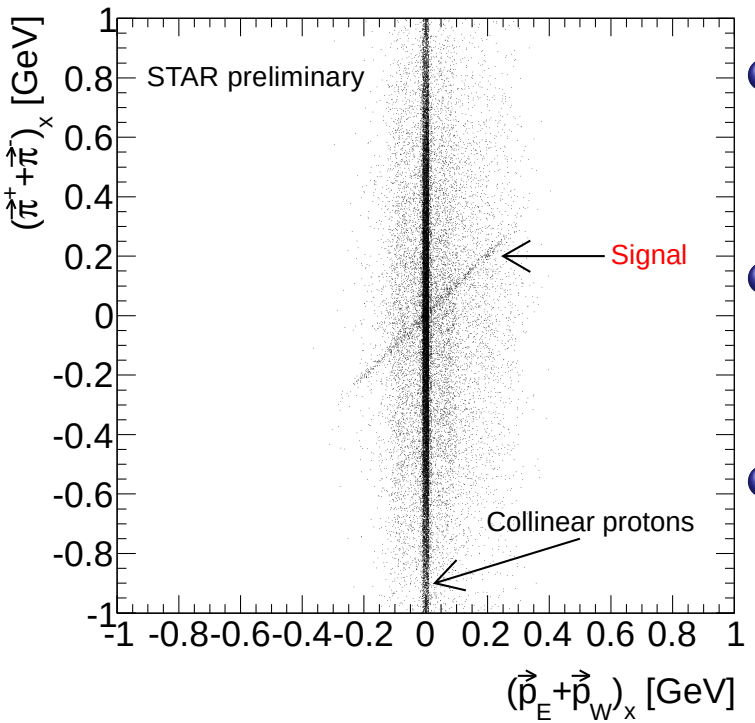
$$-t(\gamma) \ll -t(I\!P)$$

  - $\gamma I\!P \to \rho$ expected much smaller cross section than $I\!P I\!P$
  - data dominated by low mass production via Double Pomeron Exchange

CEP in pp collisions 2009 data, $\sqrt{s} = 200$ GeV

Data selection:

- two protons (one on each side of STAR)
- two TPC tracks from primary vertex:
  - $p_T > 150$ MeV
  - $|\eta| < 1.0$

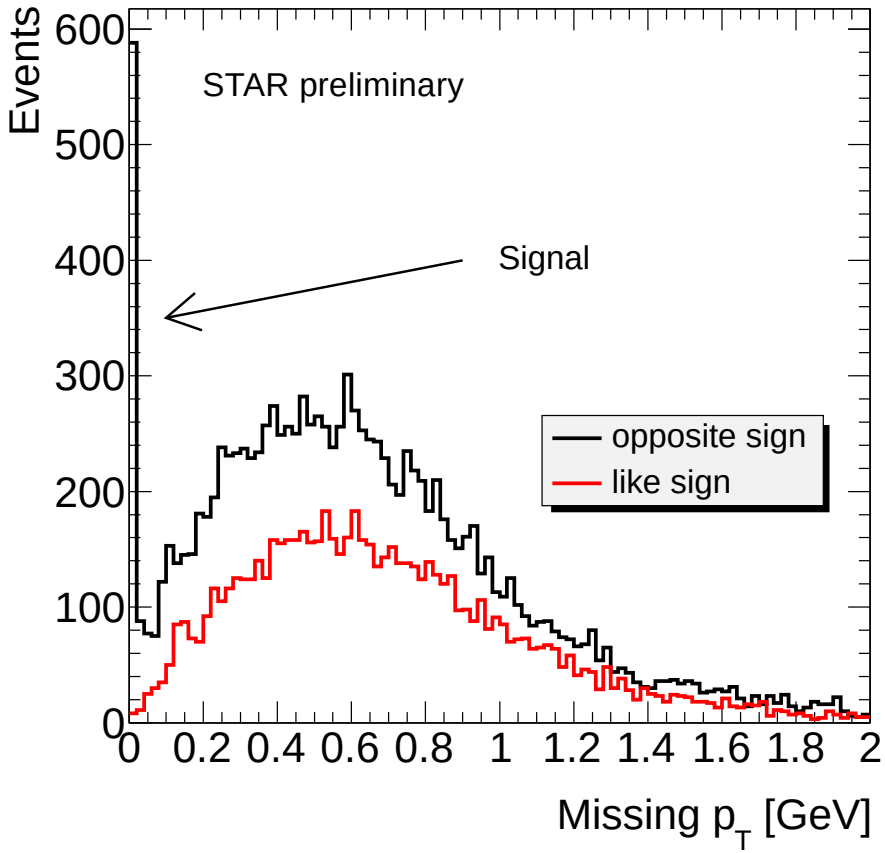


- data contains elastic $pp \rightarrow pp$ events with overlap with TPC tracks not belonging to the same interaction vertex (collinear line)
- this overlap events can not be removed by momentum balance in the back-to-back pion pairs configuration (cosmics)
- remove collinear proton tracks with $\Delta\Theta > 0.15$ mrad cut to remove cosmics

$$\Delta\Theta = \sqrt{(\Theta_E^X - \Theta_W^X)^2 + (\Theta_E^Y - \Theta_W^Y)^2}$$

CEP in pp collisions 2009 data, $\sqrt{s} = 200$ GeV

Data selection:

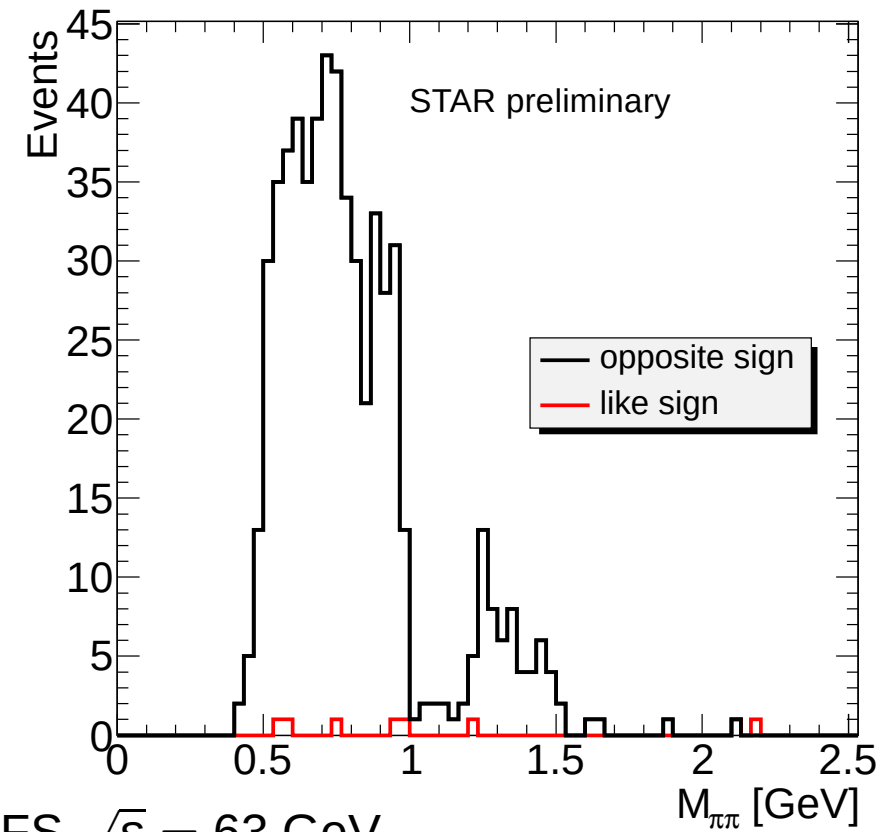


- transverse momentum balance

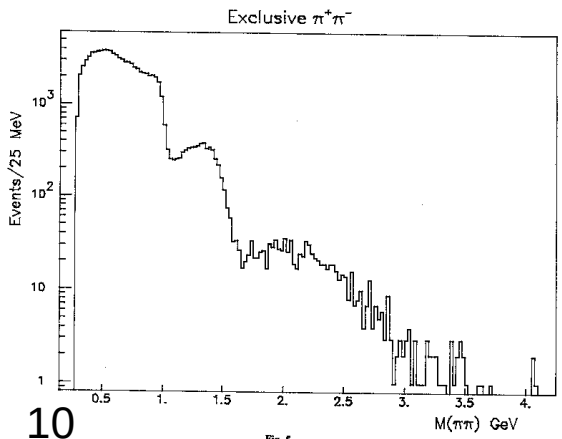
$$p_T^{miss} = |(\vec{p}_E + \vec{p}_W + \vec{\pi^+} + \vec{\pi^-})_T|$$

- requirement of $p_T^{miss} < 0.02$ GeV very efficient in reduction of the non-exclusive background, characterized by large fraction of like-sign tracks
- almost no like-sign background in the signal region

CEP in pp collisions 2009 data, $\sqrt{s} = 200$ GeV



AFS $\sqrt{s} = 63$ GeV

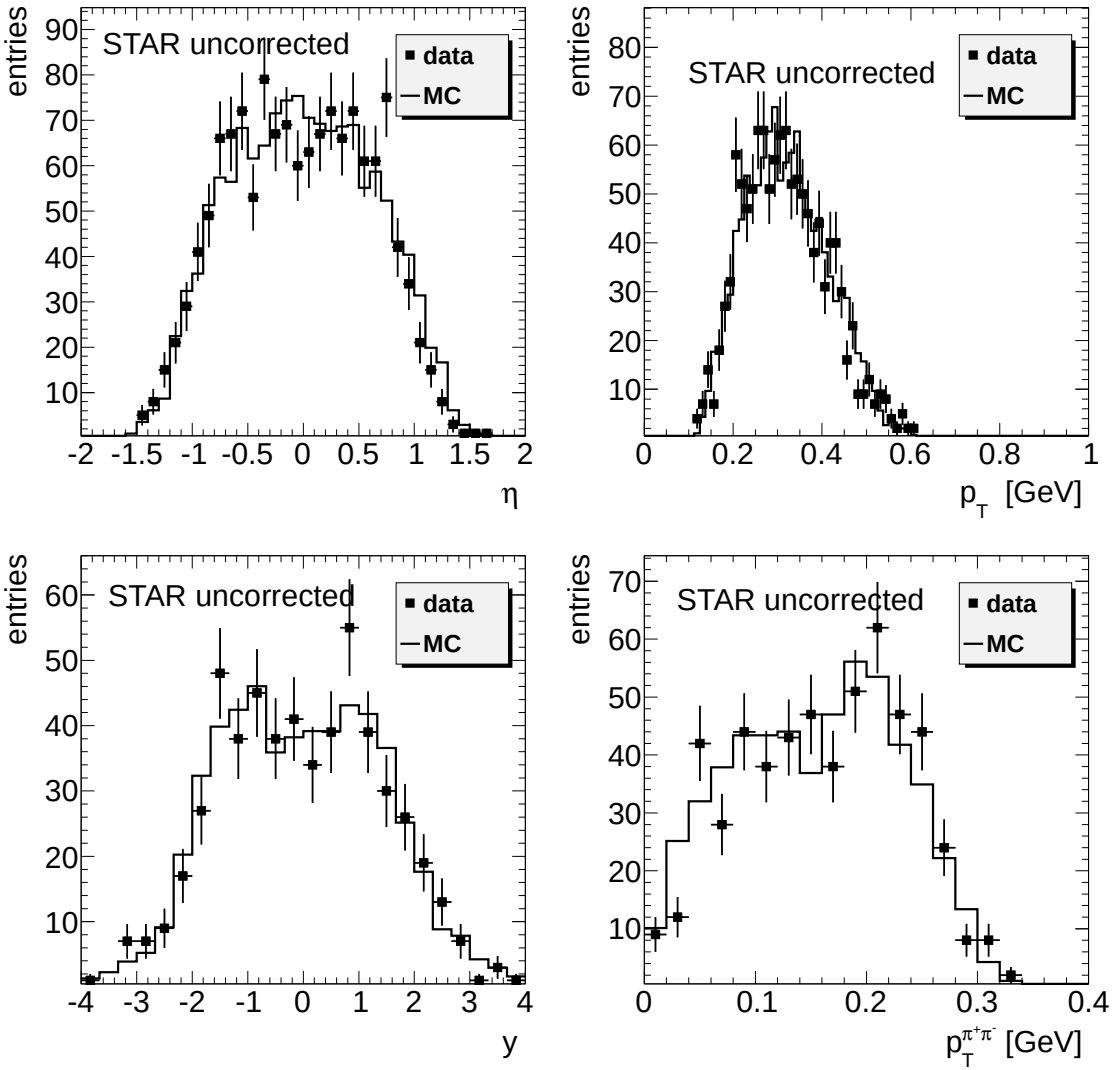


- two TPC tracks from primary vertex:
  - $p_T > 150$ MeV
  - $|\eta| < 1.0$
- $p_T^{miss} < 0.02$ GeV
- $\Delta\Theta > 0.15$ mrad
- $|dE/dx - (dE/dx)_\pi| < 3\sigma$

- similar to published data by Axial Field Spectrometer Nuclear Physics B264 (1986) 154
- dominated by low mass pairs <1 GeV
- characteristic cross section drop at 1 GeV due to $f_0(980)$ in final state.

CEP in pp collisions 2009 data, $\sqrt{s} = 200$ GeV

Comprison of uncorrected STAR data with MC simulation for $M_{\pi\pi} < 1$ GeV



Simple model inspired by Regge theory with full detector simulation

$$\frac{d\sigma}{dt_1\, dt_2\, dM_X^2\, dy} \propto e^{bt_1} e^{bt_2} \frac{1}{M_X^2}$$

$$M_X^2 = \xi_1 \xi_2 s$$
$$y = \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$$
$$\xi_i = \frac{E_{beam} - E_i}{E_{beam}}$$

- very good agreement
- allow calculation of acceptance
- measurement of differential cross sections possible.

CEP in pp collisions (rapidity gap trigger)

Rapidity gap events:

$$p + p \rightarrow Y \;\; gap \;\; X \;\; gap \;\; Y$$

$$p + p \rightarrow p \;\; X \;\; gap \;\; Y$$

- larger acceptance than tagging both protons
- access to the very small $-t$ ($\gamma I\!P$ and $\gamma\gamma$ processes)

In 2013 we have taken several test runs

- Trigger:
  - low multiplicity of TOF hits to trigger on central state X
  - no signals in BBC on both STAR sides (gaps of one unit in rapidity)
- small signal/background < 10%
- analysis in progress to work out more reliable trigger for 2015 runs.

Summary and outlook

- measurement of the CEP of $\pi^+\pi^-$ pairs in *pp* collisions at $\sqrt{s} = 200$ GeV using Roman Pot tagging of the diffractively scattered protons has been shown
- very small non-exclusive background, estimated by like-sign content of the two-pion sample, has been demonstrated
- further studies of the 200 GeV sample (cross section, interpretation of the mass spectrum, angular distributions, spin dependence, comparison with models) in progress
- preparation for the analogous measurement at 200(500) GeV in 2015 in progress (30-40 times larger statistics, PWA possible)
- possible trigger based on rapidity gap method instead of proton tagging gives access to the very small $-t$ ($\gamma I\!P$ and $\gamma\gamma$ CEP)