Physics with Tagged Forward Protons at RHIC

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1. Introduction - (qualitative) description of the processes;
2. What can be done at RHIC?
3. Summary

This is to start the discussion to include the above physics topic in RHIC II physics program.

Gluon saturation at small x & shadowing in nuclei

RHIC allows study of transition. LHC always saturated (except very high pT and y<-3)

Also important for AA initial state

Especially for LHC where always saturated at midrapidity

Models:
- gluon saturation, CGC
- leading twist shadowing (coherence)
- mass renorm. (Vitev)
- Sudakov suppr. (Kopeliovich)
- limiting fragmentation

LHC only 1-month/yr shared between pp, pA and AA – earliest pA 2010?

How to distinguish??
- correlations
- energy,rapidity dependence
- universality

polarized and diffractive pA are useful - need theoretical calculations.

need hard processes sensitive to gluons

Forward hadrons
- need forw. $\pi^0 \rightarrow$ STAR FMS
- hadron PID for $|y|>1$

compare open & closed

Heavy-quarks (c,b) & bound states

Direct photons for $|y|>1 \rightarrow$ PHENIX NCC

need cleaner way to get open-c, -b

wide kinematic range to understand physics & differentiate models

vertex detectors!

separating D & B in single-lepton spectra?
- use $B \rightarrow J/\psi X$ measurement
- very high statistics could allow seeing 2 $c\tau$'s

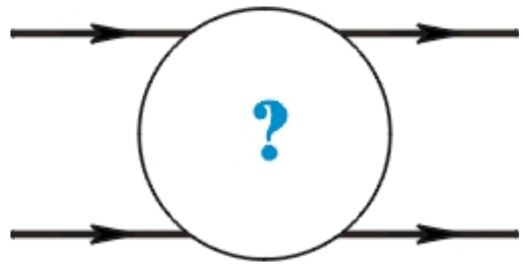
$D \rightarrow K\pi$ nice but difficult!

Onia – rare processes
- PHENIX onia
- Need STAR forward $J/\psi \rightarrow ee$

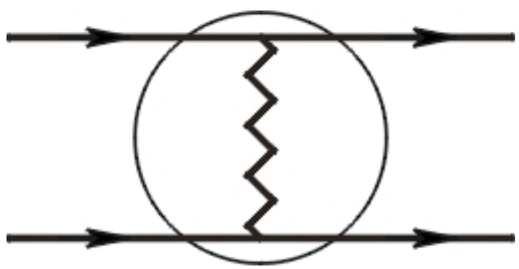
High Luminosities needed!

6/22/05
Wlodek Guryn

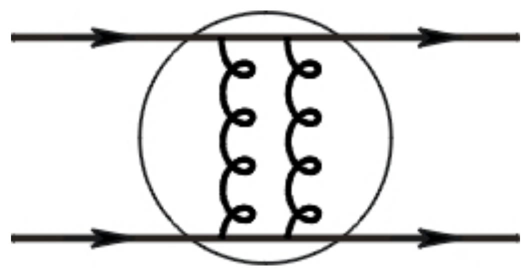
Physics Processes



In t-channel it is an exchange with quantum numbers of vacuum

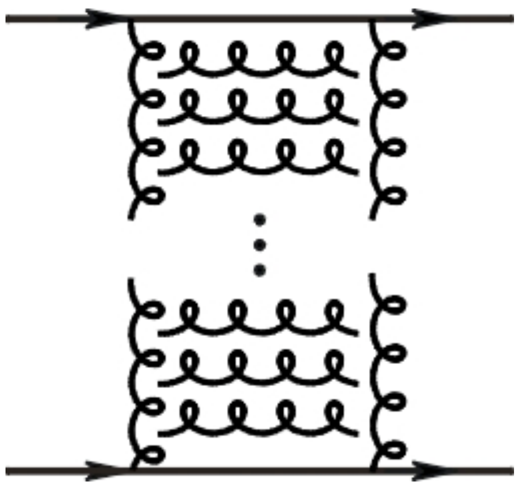


Non Pert. QCD

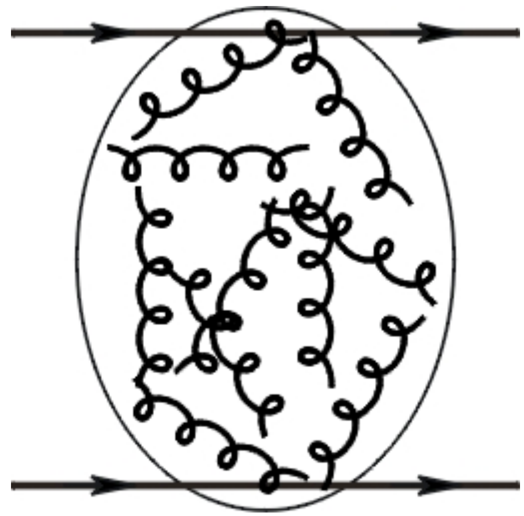


PQCD picture

Physics Processes:Elastic Scattering



Gluon Ladders

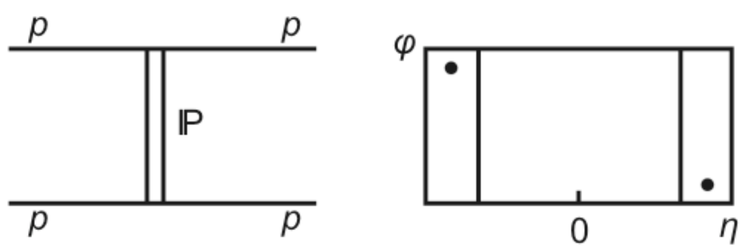


Gluonic Exchanges

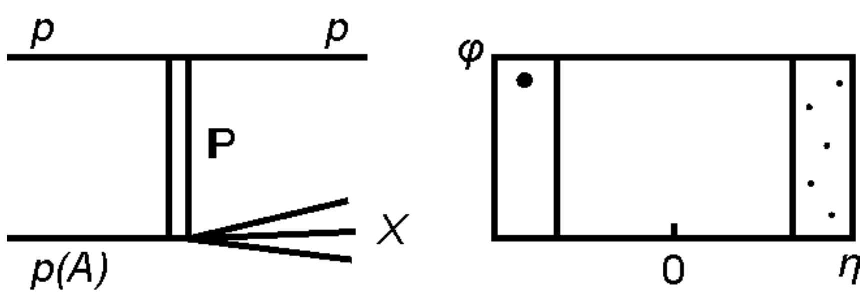
Physics processes tagged by forward protons are mediated by gloun rich exchanges

Elastic and Inelastic Processes

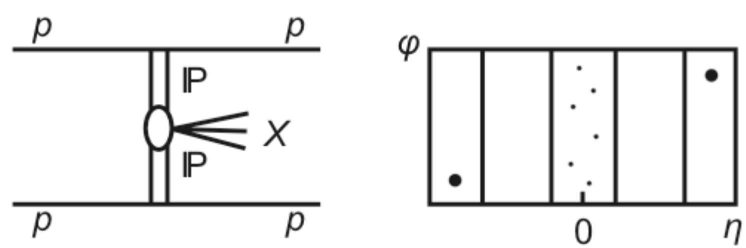
Elastic Scattering



Single Diffraction



Central Production



The common feature of these reactions is that the proton undergoes quasi-elastic or elastic scattering and that they occur via the exchange of colorless objects with the quantum numbers of the vacuum, historically called Pomeron exchange.

Process Description

In terms of QCD, Pomeron exchange consists of the exchange of a color singlet combination of gluons.

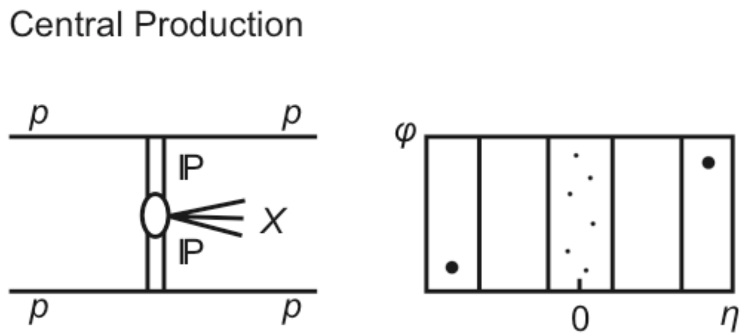
Hence, triggering on forward protons at high (RHIC) energies dominantly selects exchanges mediated by gluonic matter.

For each proton vertex one has: t, ξ and M_X

t is four-momentum transfer between the incoming and outgoing protons,
$\xi = \Delta p/p$ is the momentum fraction carried off by the Pomeron, and
M_X is invariantt mass of the system produced.

All above are small x QCD processes

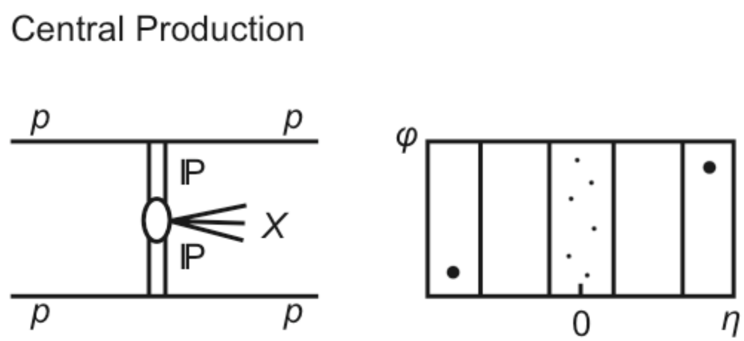
Central Production in DPE



In the double Pomeron exchange process each proton “emits” a Pomeron and the two Pomerons interact producing a massive system M_X.

The massive system could form resonances or consist of jet pairs. Because of the constraints provided by the double Pomeron interaction, glueballs, and other states coupling preferentially to gluons, will be produced with much reduced backgrounds compared to standard hadronic production processes.

Glueball Central Production in DPE

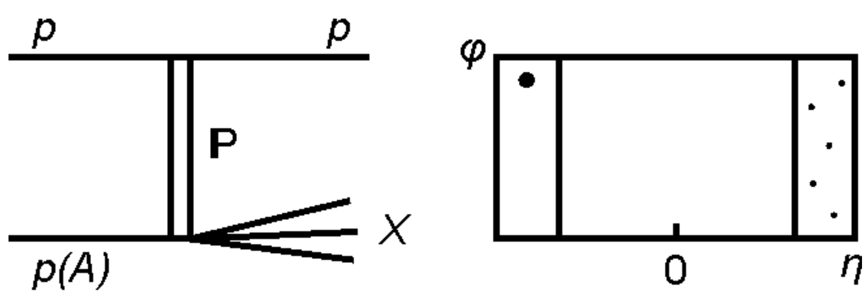


The idea that the production of glueballs is enhanced in the central region in the process $pp \rightarrow pM_Xp$ was first proposed by F.Close and was demonstrated by WA102 expt.

The pattern of resonances produced in central region depends on the vector difference of the transverse momentum of the final state protons $\bar{k}_{T1}$, $\bar{k}_{T2}$, with $dP_T \equiv |\bar{k}_{T1} - \bar{k}_{T2}|$. And when dP_T is large ($\geq \Lambda_{QCD}$) $\bar{q}q$ states are prominent and when dP_T is small the surviving resonances include glueball candidates.

p(d)A Scattering

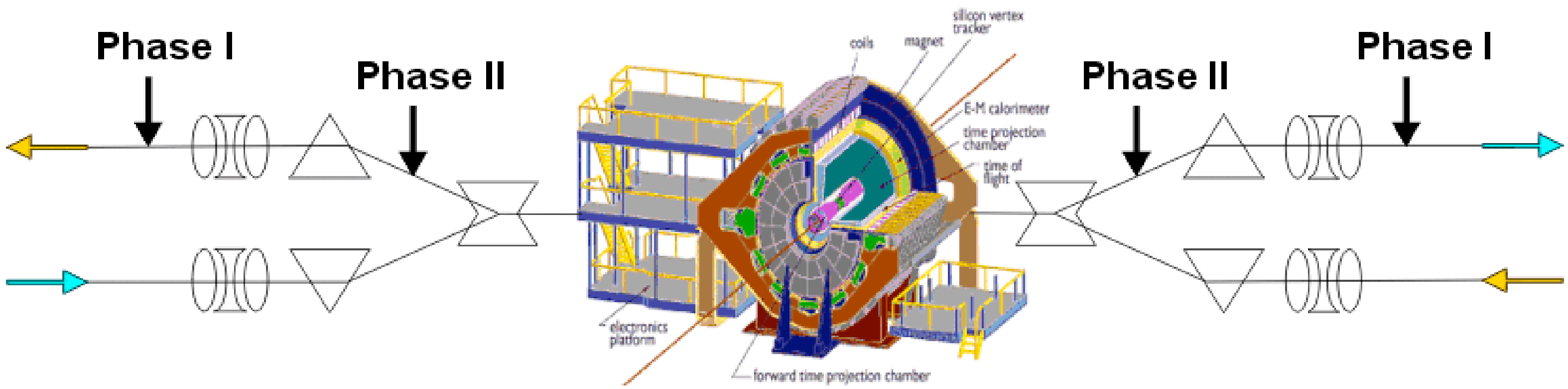
Single Diffraction



1. Study dependence on A and beam polarization of inclusive diffraction in p(d)A→ pA.
2. Due to spectator effects in deuteron Nucleus collisions dA→pX the p_T spectrum of the outgoing proton shows a clear diffractive pattern because of the absorption of the center of incoming wave [B.K.].
3. One can also study the size of the rapidity gap in the same reaction, where the size of the "rapidity gap" reflects the different contributions of various Fock configurations of the proton that scatters through the color field of the nucleus [R.V.].

Implementation

Need detectors to tag forward protons and good detector to measure central system



Roman Pots of pp2pp and STAR

Summary

The physics program with tagged forward protons hwith STAR at RHIC I and extending into RHIC II will:

1. Study elastic scattering and its spin dependence in unexplored t and $\sqrt{s}$ range;
2. Study the structure of color singlet exchange in the non-perturbative regime of QCD.
3. Search for diffractive production of light and massive systems in double Pomeron exchange process - glueballs.
4. Search for an Odderon - an eigenstate of CGC.
5. At RHIC II one would take advantage of smaller TPC, include more coverage to better characterize rapidity gaps.

More guidance from theory is needed - particularly for new phenomena.

Those studies will add to our understanding of QCD in the non-perturbative regime where calculations are not easy and one has to be guided by measurements.

Reconstruction of Momentum Loss ξ

Accelerator transport:

$$x_1 = a_1 x_0 + L_1 \Theta_x + \eta_1 \xi \,; \qquad \textbf{detection point 1}$$
$$x_2 = a_2 x_0 + L_2 \Theta_x + \eta_2 \xi \,; \qquad \textbf{detection point 2}$$

$$\begin{pmatrix} \Theta_x \\ \xi \end{pmatrix} = \frac{1}{Det} \begin{pmatrix} \eta_2; & -\eta_1 \\ -L_2; & -\mathrm{L}_1 \end{pmatrix} \begin{pmatrix} x_1 - a_1 x_0 \\ x_2 - a_2 x_0 \end{pmatrix} \Rightarrow$$

$$\delta\xi = \Delta p / p = \sqrt{A\,\delta x_0^2 + B\,\delta x^2} \leq 0.5\%$$

Mainly due to the vertex δx_0 resolution

One event per tagged proton pair, elastic events are used for alignment