Future Physics Program with Tagged Forward Protons at RHIC

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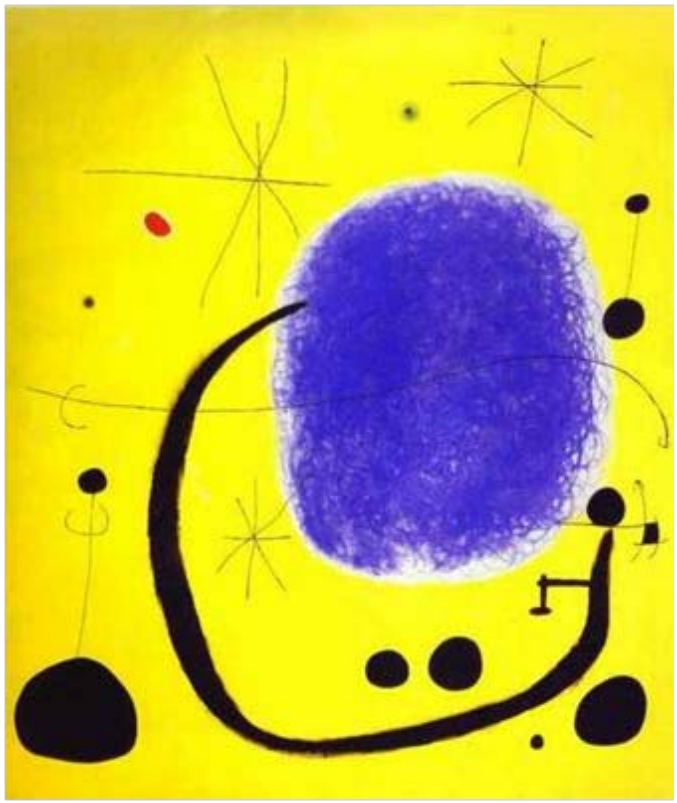
For STAR Collaboration
BNL



April 29, DIS09, Madrid

Relativistic Heavy Ion Collider (RHIC): THE QCD Factory

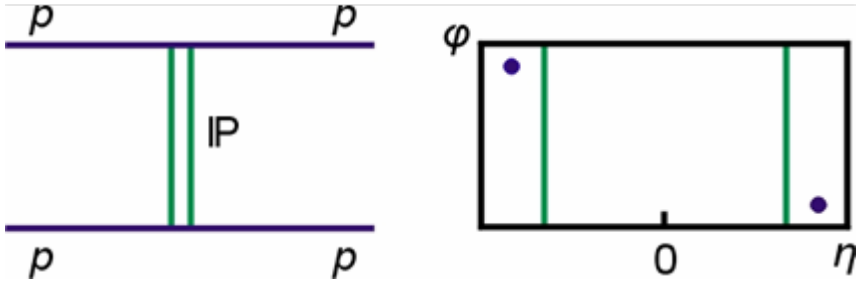
QCD is the theory of strong interaction:
"Theoretical evidences" vs. current and future Experimental QCD measurements at RHIC

- Confinement/ phase of QCD - QGP
- Distribution of spin in the nucleon - Spin sum rule
- Parton splitting limit - Saturated gluon state (Color Glass Condensate…)
- Gluonic degree of freedom in Hadrons – exotica (glueballs…)
- Nature of diffractive processes – structure of Pomeron, Odderon…

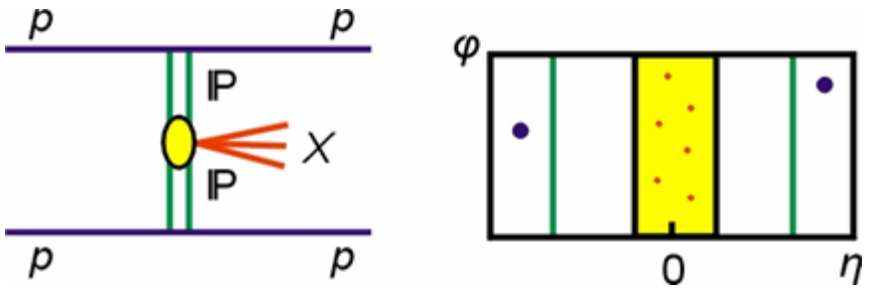
Further investigation at eRHIC

near Future Program with tagged forward protons at RHIC studying:

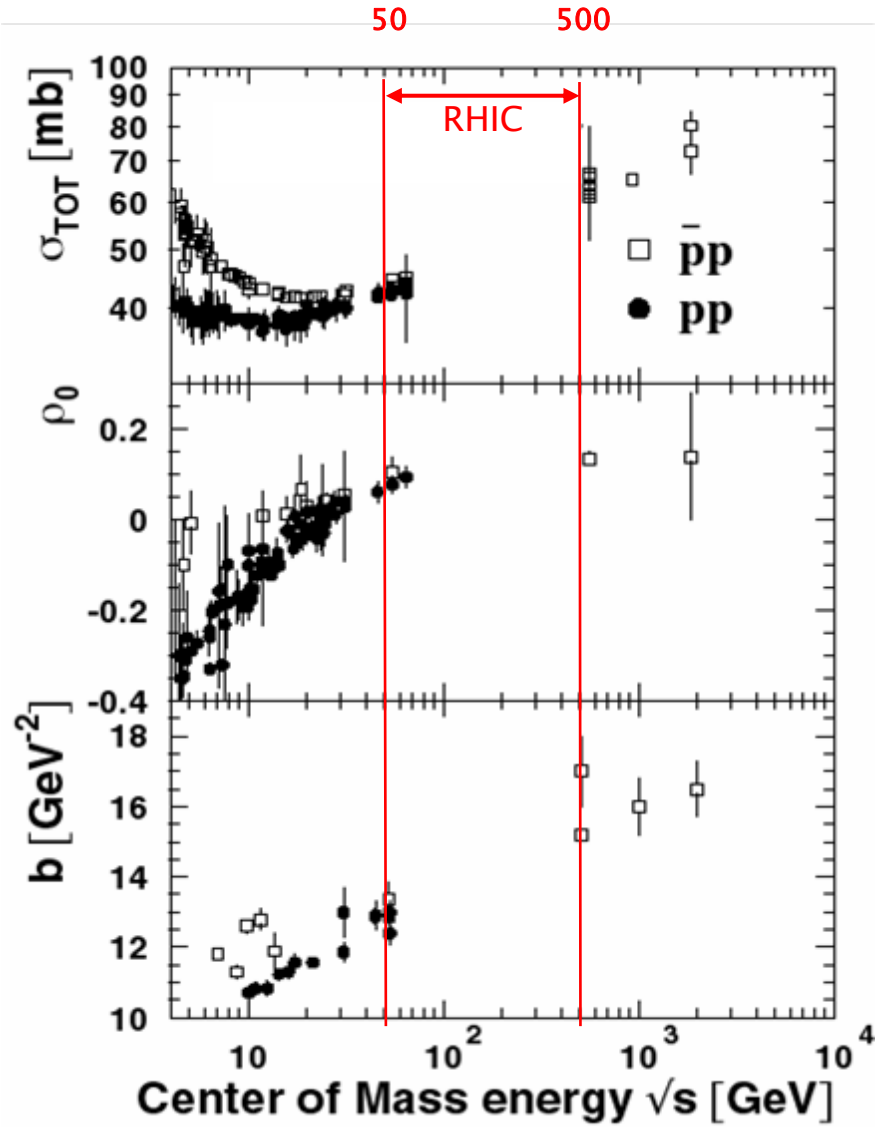
- Elastic scattering for understanding structure of Pomeron and Odderon



- Central production for searching for glueballs in Double Pomeron Exchange (DPE) processes

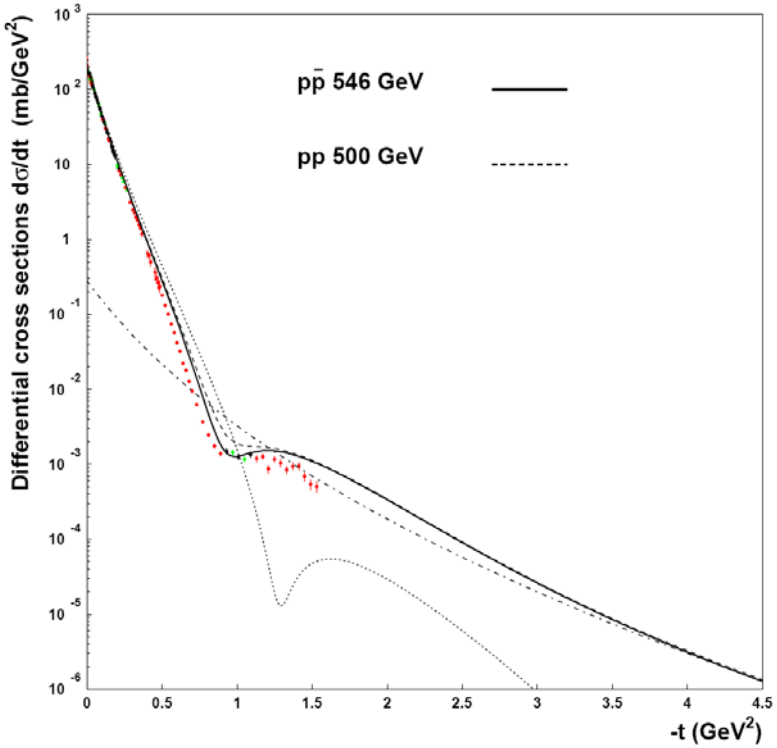


Summary of the Existing Elastic Data (unpolarized)



- Highest energy so far:
  - pp: 62 GeV (ISR)
  - $\bar{p}p$: 1.8 Tev (Tevatron)
- RHIC energy range:
  - 50 GeV ≤ √*s* ≤ 500 GeV
- Elastic measurements: Details on the nature of elastic scattering at the energy are NOT well understood in the energy range: Unique measurements in **wide t-range** with **polarized** beams

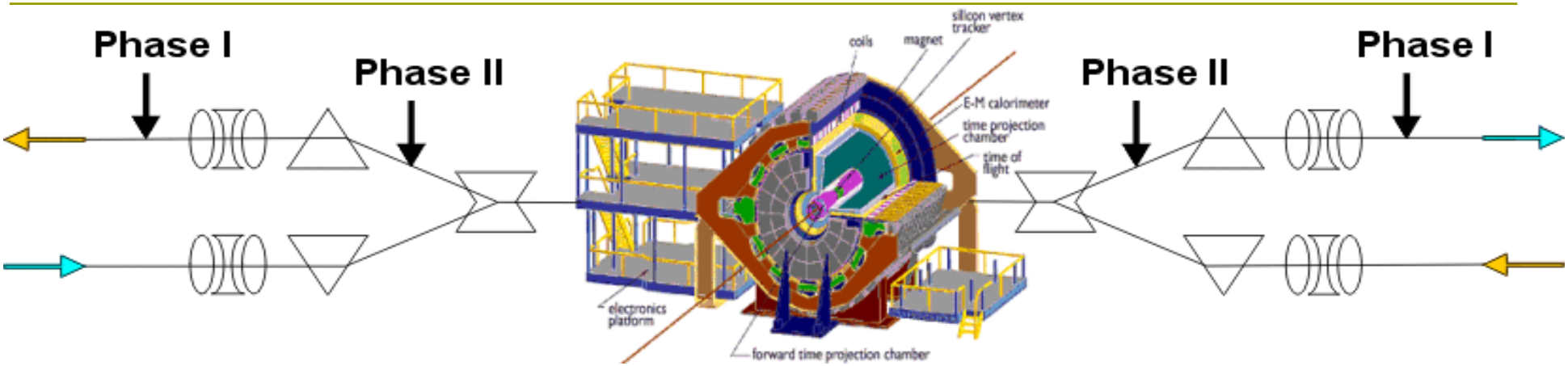
Can Odderon be identified at RHIC?



hep-ph/0210437 M. Islam et al.

- Odderon is a counterpart of pomeron (C=1) with C=-1: "RHIC is the machine to find it" (E. Leader, Odderon Workshop (2005)) by measuring
  - $\Delta\sigma_{pp} - \Delta\sigma_{pbarp} \neq 0$ (~3mb)
  - $d\sigma/dt_{pp} \neq d\sigma/dt_{pbarp}$
  - Shape of Asymmetries: A_{NN}
  - Centrally produced C=-1 particle

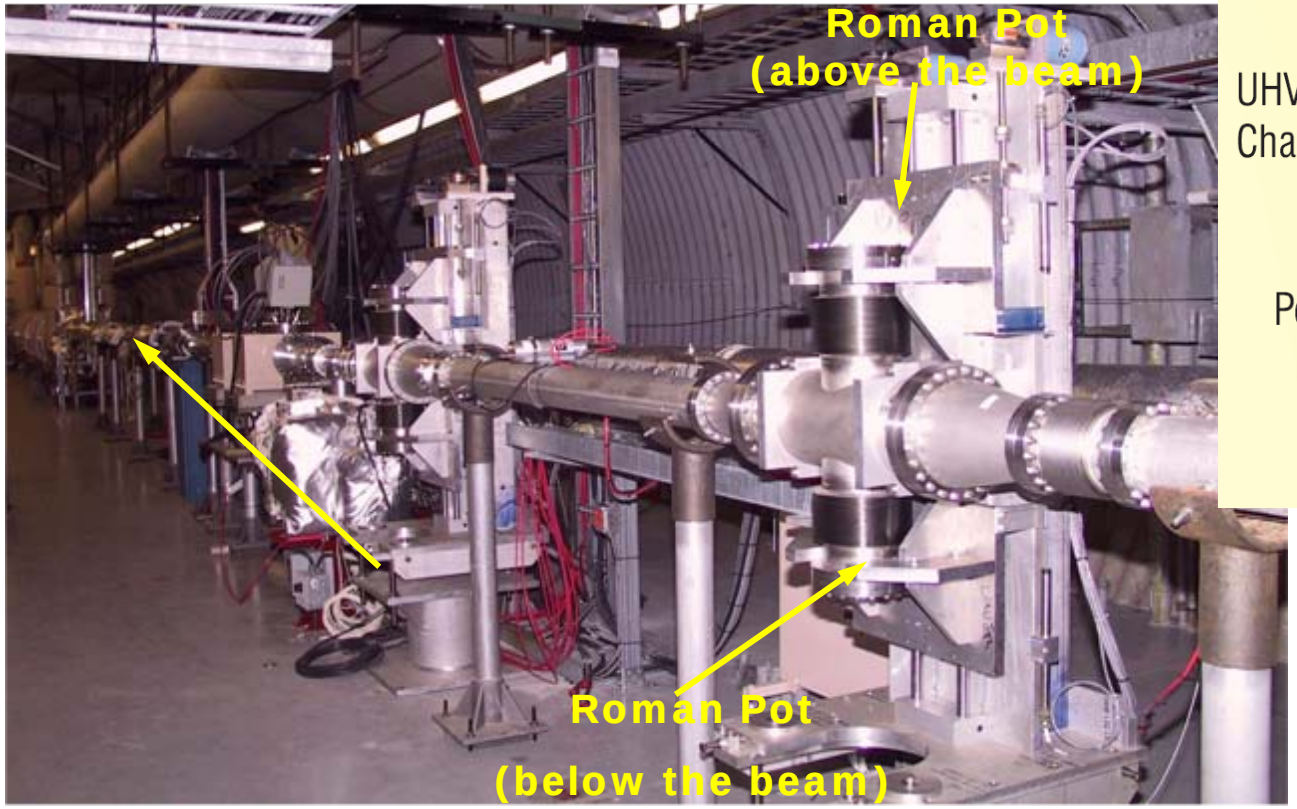
Implementation at RHIC - Detectors

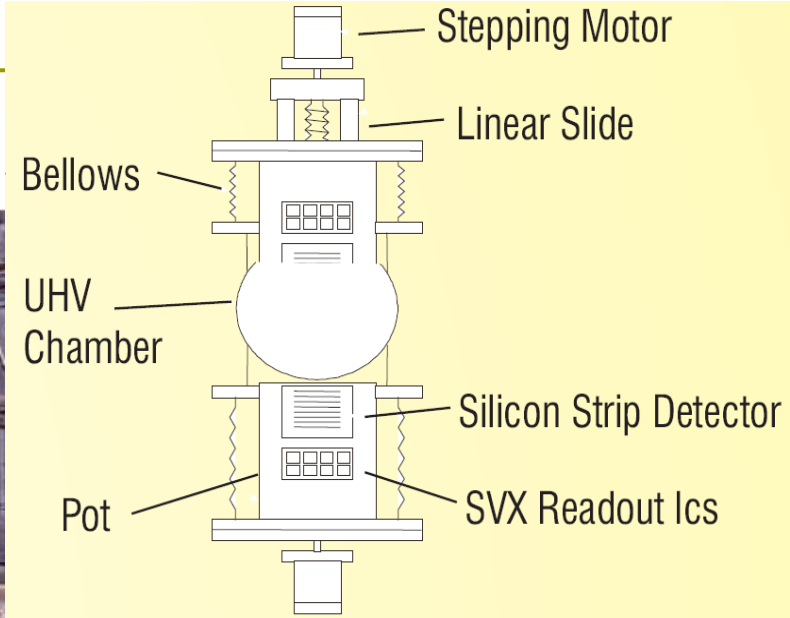


- Need detectors (Roman Pots) to measure forward protons: small t (four-momentum transfer) and ξ (= 1-x_F)
- Detector with good acceptance and particle ID (**STAR**) to measure centrally produced system

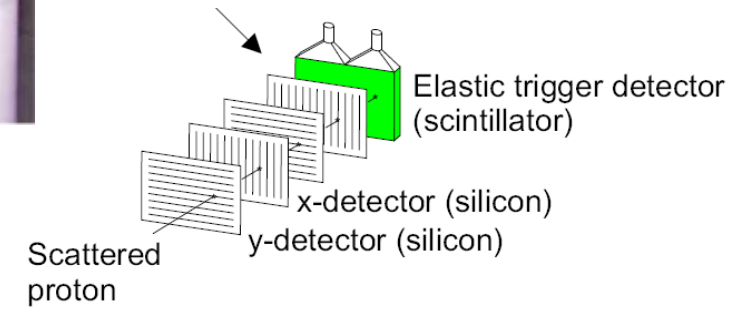
Roman Pots used (2002-2003) for pp2pp experiment at RHIC

pp2pp set-up





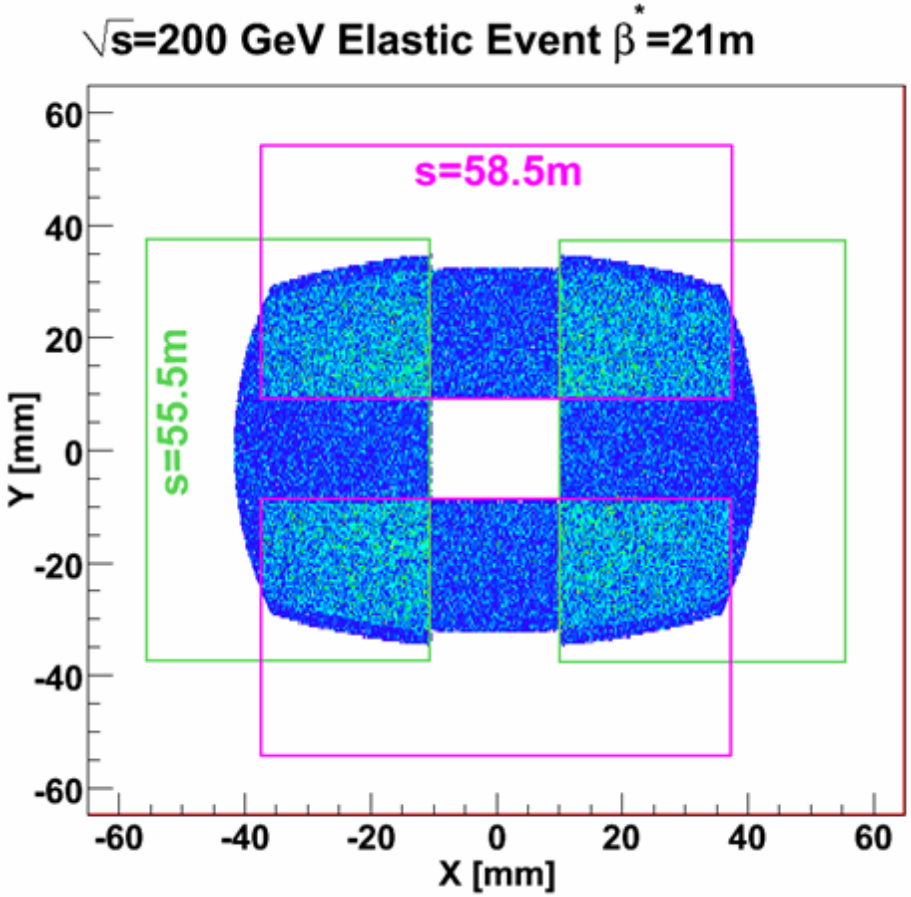
Roman Pot Detector System



Now RPs moved to STAR

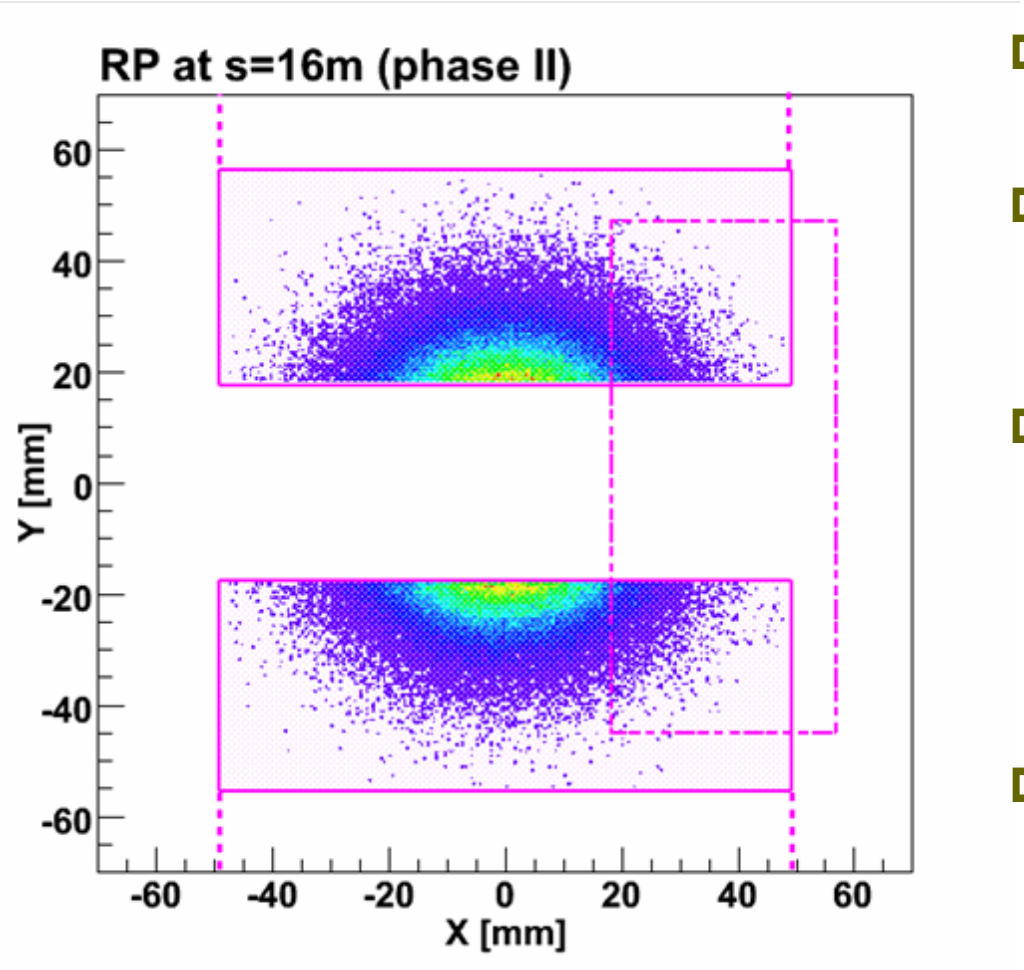
- Vertical AND Horizontal RP setup for a complete ϕ coverage

Roman Pots (Phase I)



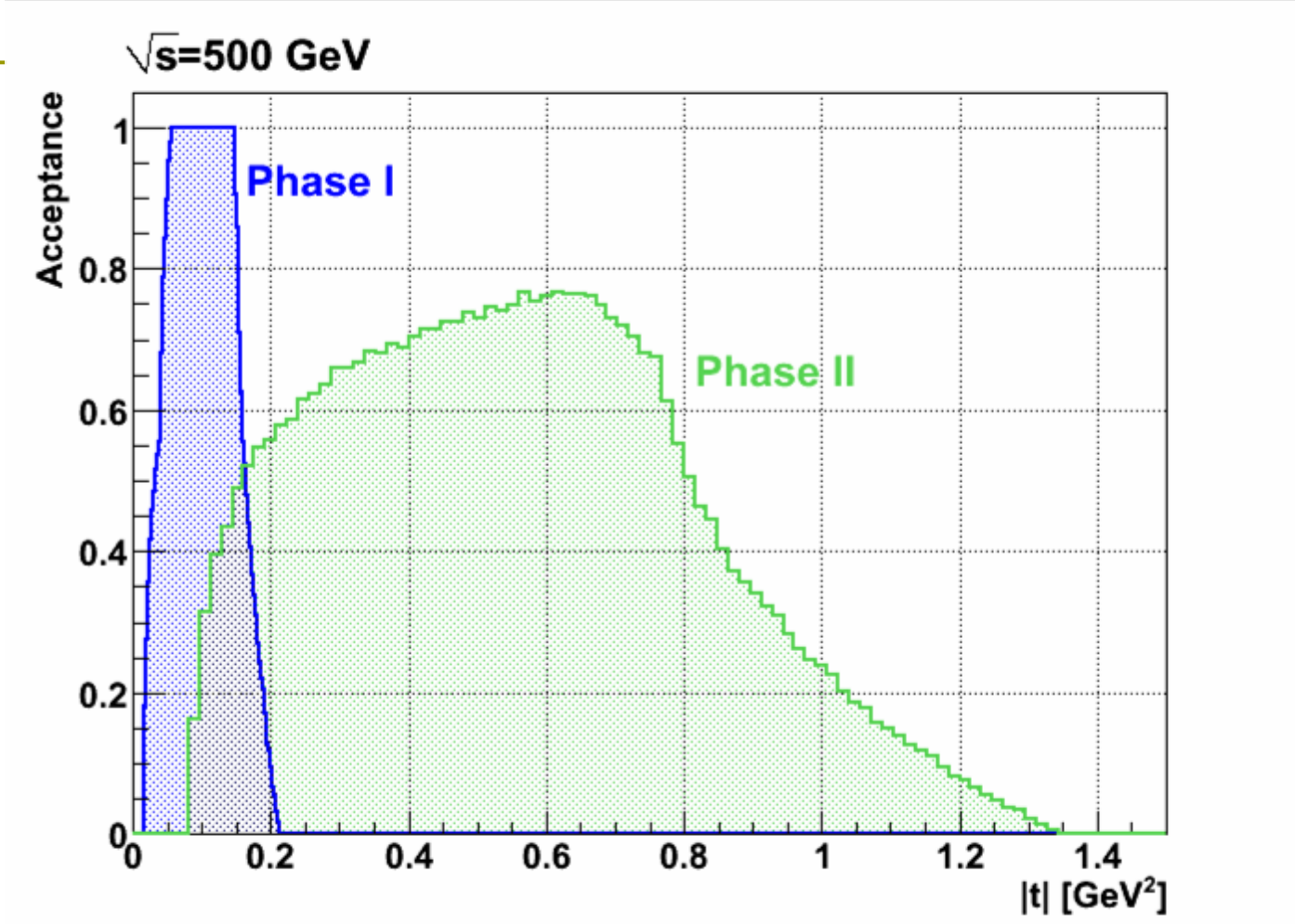
- Phase I: 8 Roman pots at ±55.5, ±58.5m from the IP
- Require special beam tune :large β* (21m for √s=200 GeV) for minimal angular divergence
- Ready to run in 2009: Will be focusing small-t processes ($0.002<|t|<0.03$ GeV^2)

Roman Pots (Phase II)



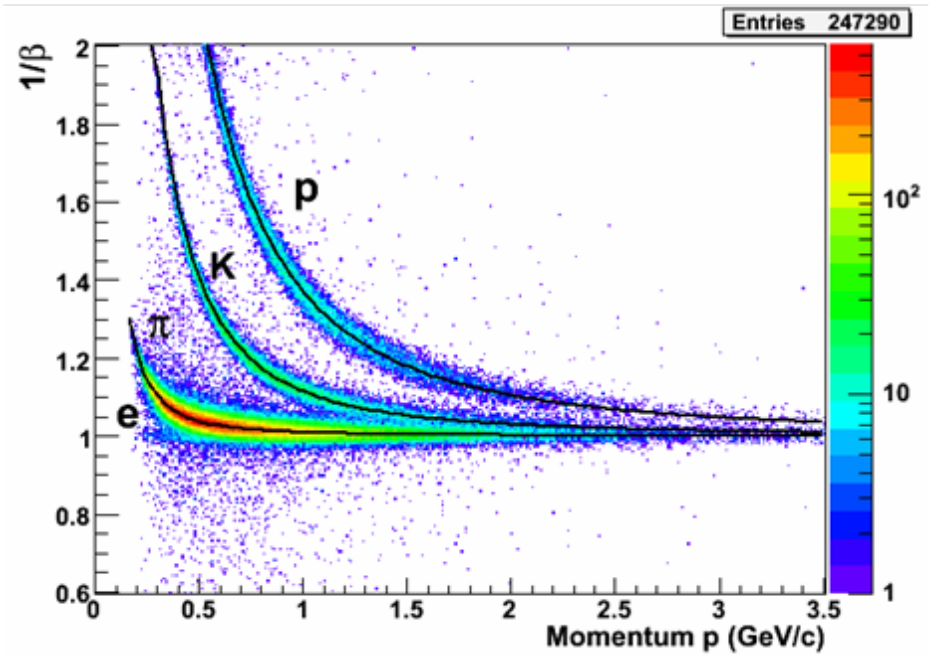
- Phase II: 8(12) Roman Pots at ±13 and ±16m
- Planed to be implemented in 2010-2011
- Doesn't require special beam tune: main set-up for central DPE processes requiring wide-t coverage and high-luminosity
- 2π coverage will be limited due to machine constraint

t-Acceptance of Roman Pots



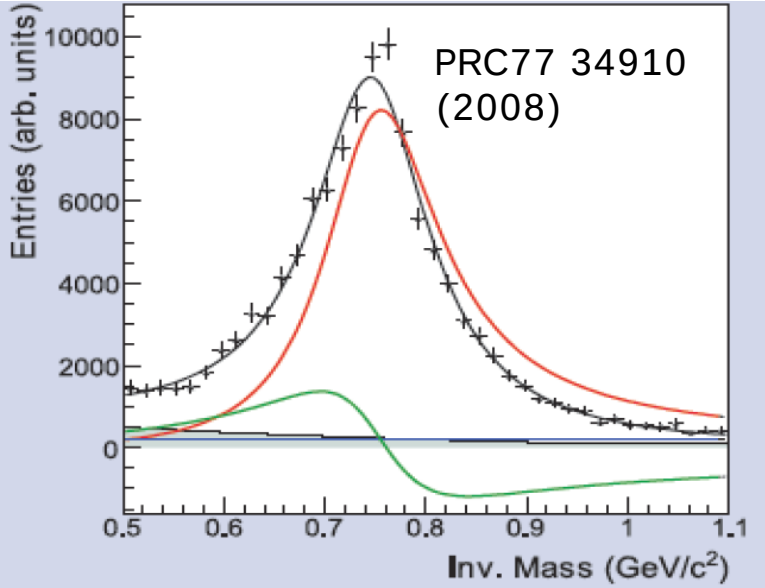
- Phase I set-up focuses on low-t (installed)
- Phase II covers higher-t range

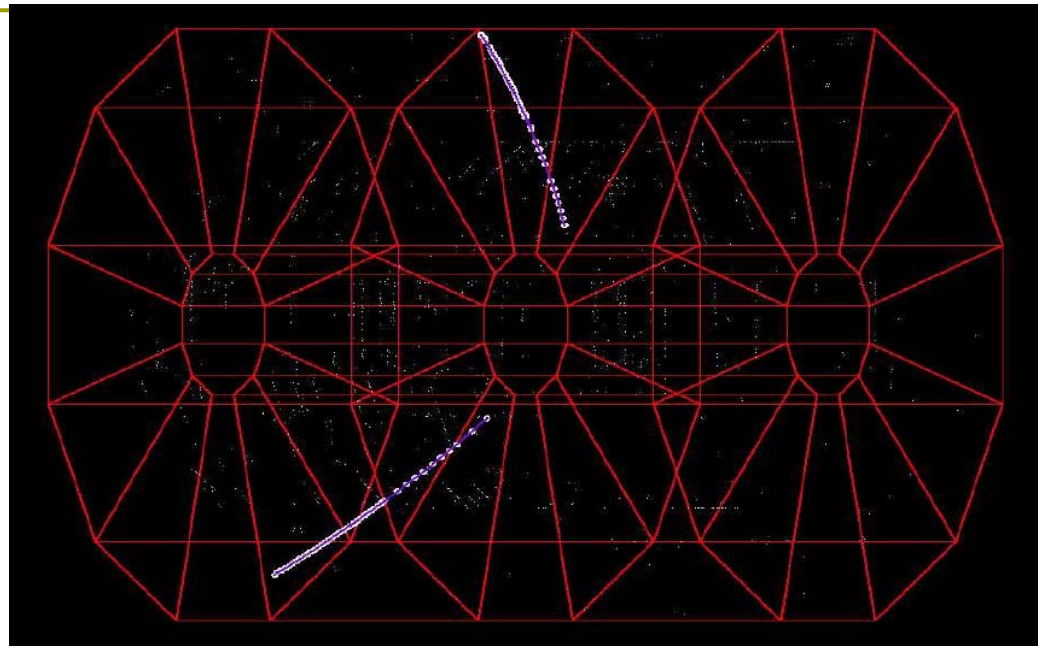
Trigger and Data Reconstruction

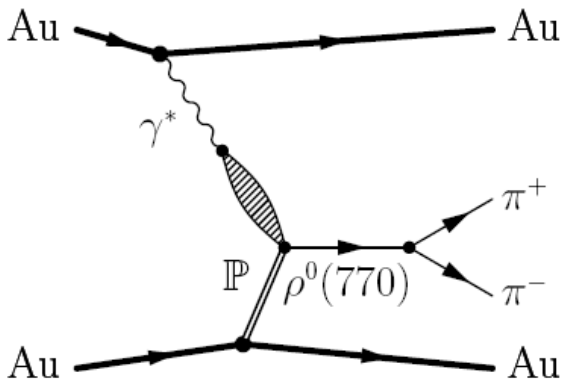


- Trigger
  - Elastic (collinear) and inelastic trigger
  - Multiplicity trigger using TOF barrel for selecting low multiplicity ($0<N<6$) central events as used in STAR UPC Trigger
  - Rapidity gap trigger using Beam-Beam counters
- Reconstruction
  - Scattered proton momentum momentum reconstruction using RPs and beam transport
  - STAR TPC tracking in $|y|<1$ with TOF barrel and TPC PID (π/K separation up to~ 1.6 GeV/c)

Ultra-Peripheral Collision (UPC) program with AuAu in STAR

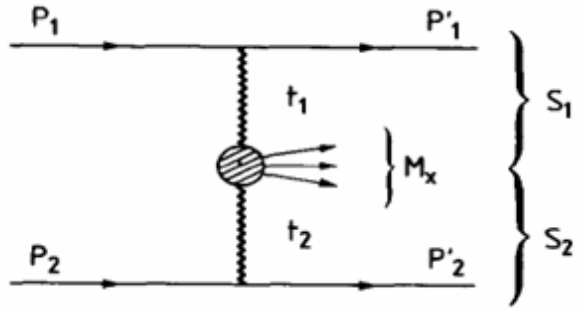






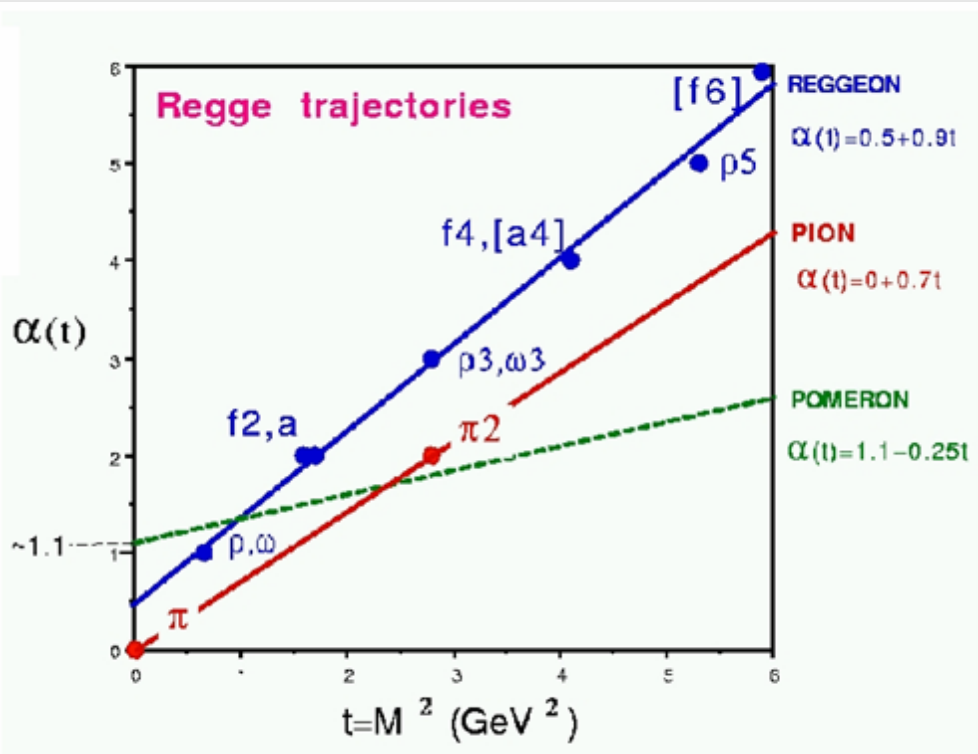
- Complementary program with central production in p+p
  - Spectroscopy in photoproduction
  - Common machinery: trigger, data reconstruction…

Inelastic Process: DPE $p_1p_2 \rightarrow p_1', M_X p_2'$



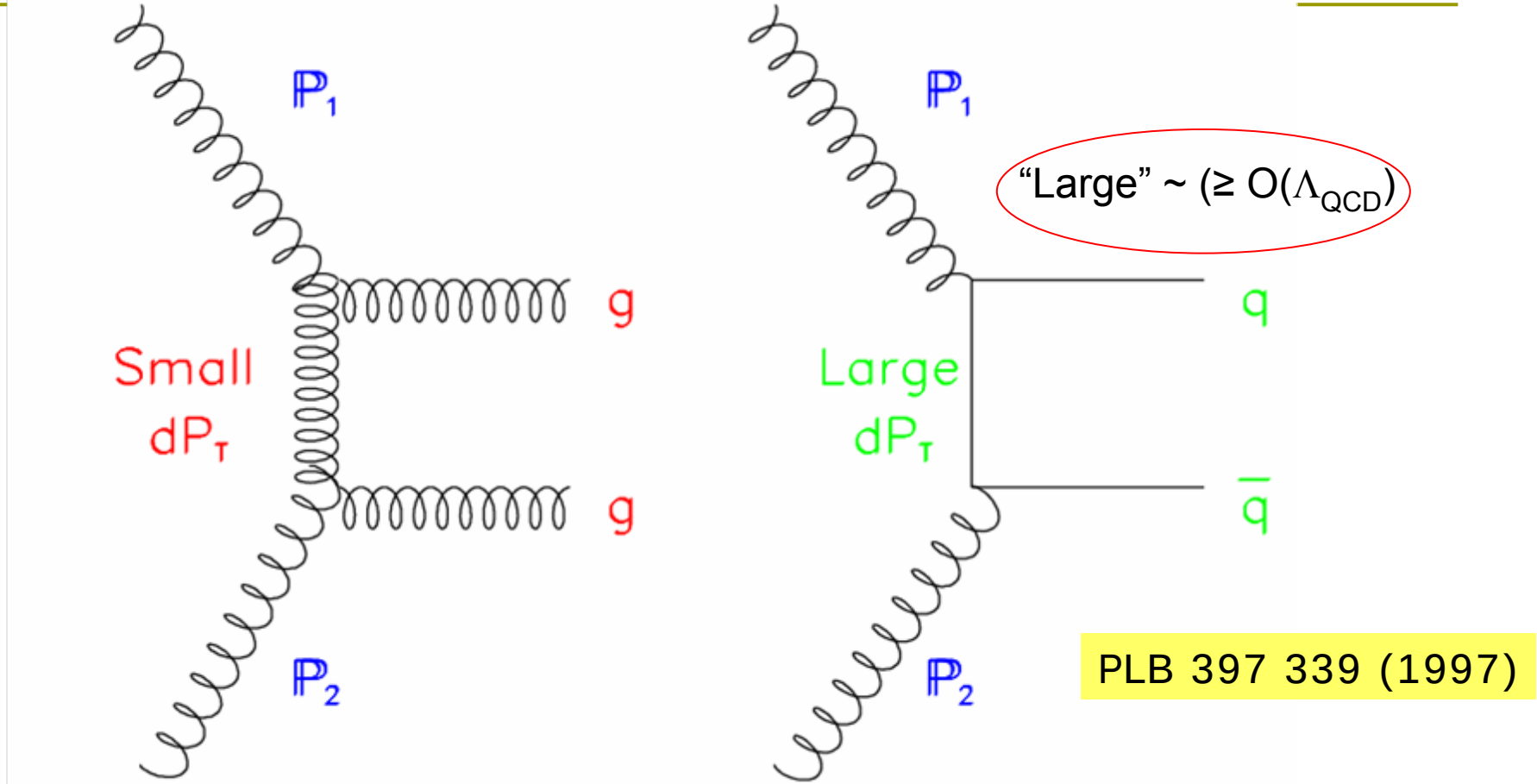
- Exclusive process with "small" momentum transfer: $-t_1(p_1 \rightarrow p_1')$ and $-t_2(p_2 \rightarrow p_2')$
- M_X is centrally (nearly at rest) produced via a Double Pomeron Exchange/Fusion
- Pomeron is considered to be made of two gluons: natural place to look for gluon bound state
- $M_X(\sim 1 - 3\ \mathrm{GeV}/c^2) \rightarrow \pi^+\pi^-,\ \pi^+\pi^-\pi^+\pi^-,\ K^+K^-$
- Lattice cal.: Lightest glueball $M(0^{++}) = 1.5\text{-}1.7\ \mathrm{GeV}/c^2$
- Search for glueball (gg) candidates in M_x
- Candidates with conventional quantum numbers: need (kinematic) "filtering"

Quantum number "filter" for PP



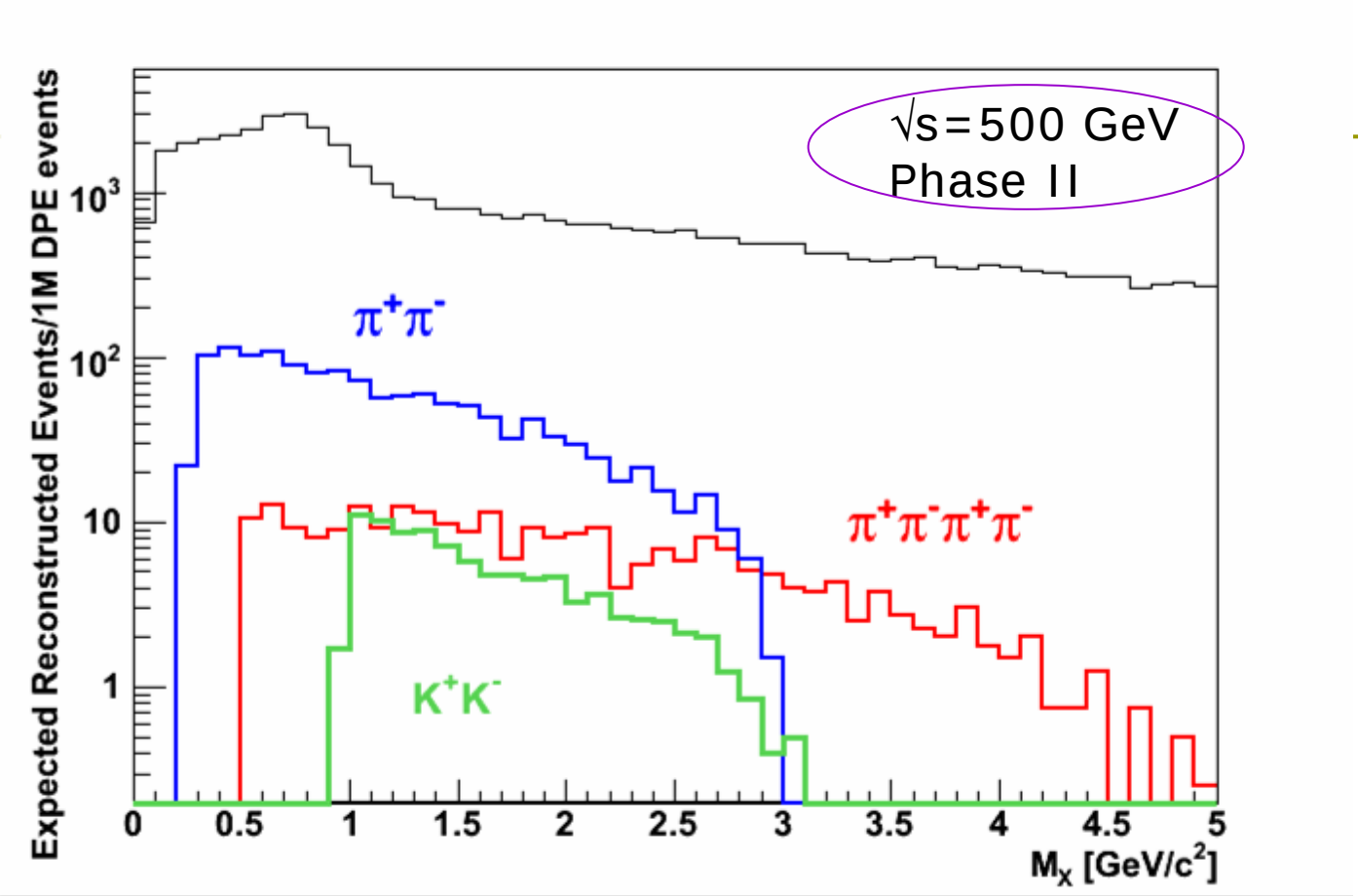
- Pomeron has vacuum Quantum number (P=C=+1, colorless)
- DPE cannot produce I=1 state such as ρ(770) (Isospin conservation)
  - B=Q=S=0, $I^G J^{PC}$ = $0^+ even^{++}$
  - $f_J(1710)$ $0^+ even^{++}$
  - …

Kinematic "filter" (dp_T) for "gg" (F. Close et al./W102)



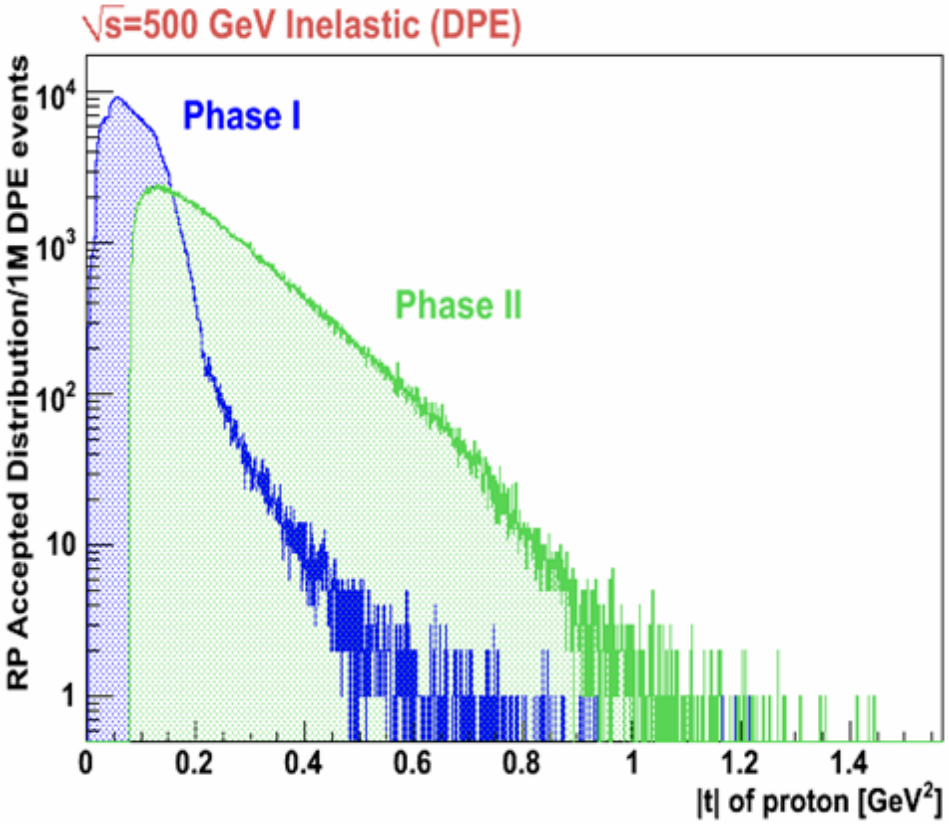
- Coupling of the exchange particles to the final state mesons for gluon exchange (small dp_T) and quark exchange (large dp_T)
- Spin-dependence of the coupling can be studied at RHIC

Acceptance and expected yields in M_X



- Expected reconstructed phase-space including BR per 1M DPE events
- M_x=1-3 GeV/c^2 is kinematically well accessible in pion and Kaon decay channels
- High-Mx reconstruction is limited by PID (π/K separation up to ~ 1.6 GeV/c)
- Expected Trigger rate for DPE: 80 Hz at $\mathcal{L}=1\times10^{31}cm^{-2}s^{-1}$
- To collect 100K K^+K^- sample, needs ~200 hr of running time
- Phase I setup is expected to produce an exploratory data sample of ~100K $\pi^+\pi^-$ with 2 days of running with special beam tune (β^*=21m) this year

Phase II and beyond



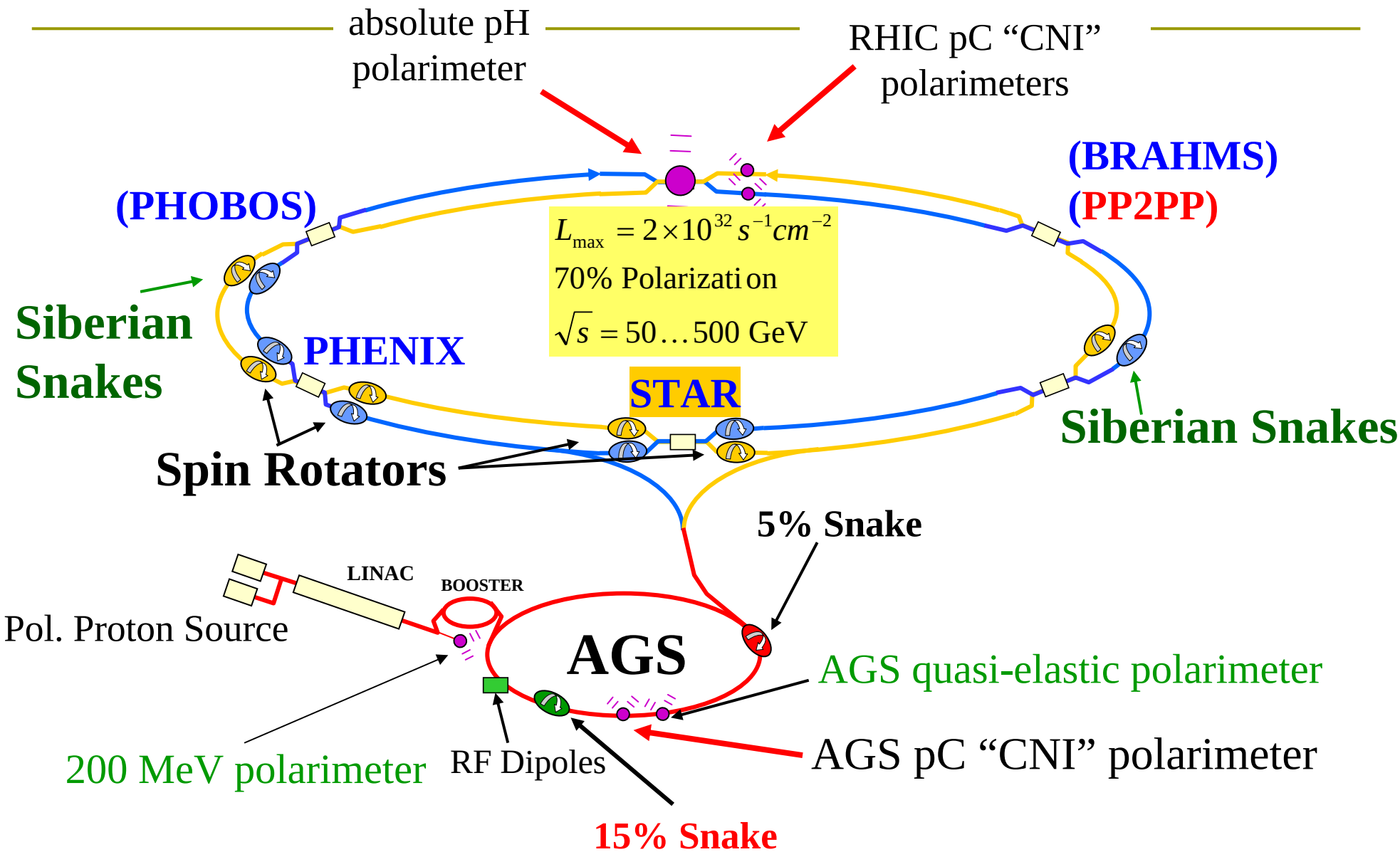
- Phase I and II set-up covers $0.002 < t < 1.3$ GeV^2
- Depending on the physics needs/requirements deduced from first measurements, further upgrade will be pursued
- Possibilities of new measurements: central production of exclusive Charmonium?

Looking "Forward"

- New rich physics program at RHIC with tagged forward protons have been initiated.
- Unique machine and detector capabilities enable us explore important aspect of our understanding of strong interaction.

Backup Slides

RHIC as $p^{\uparrow}p^{\uparrow}$ Collider



dp_T "filter": WA102

dp_T < 0.2 GeV/c | 0.2< dp_T< 0.5 | dp_T > 0.5 GeV/c

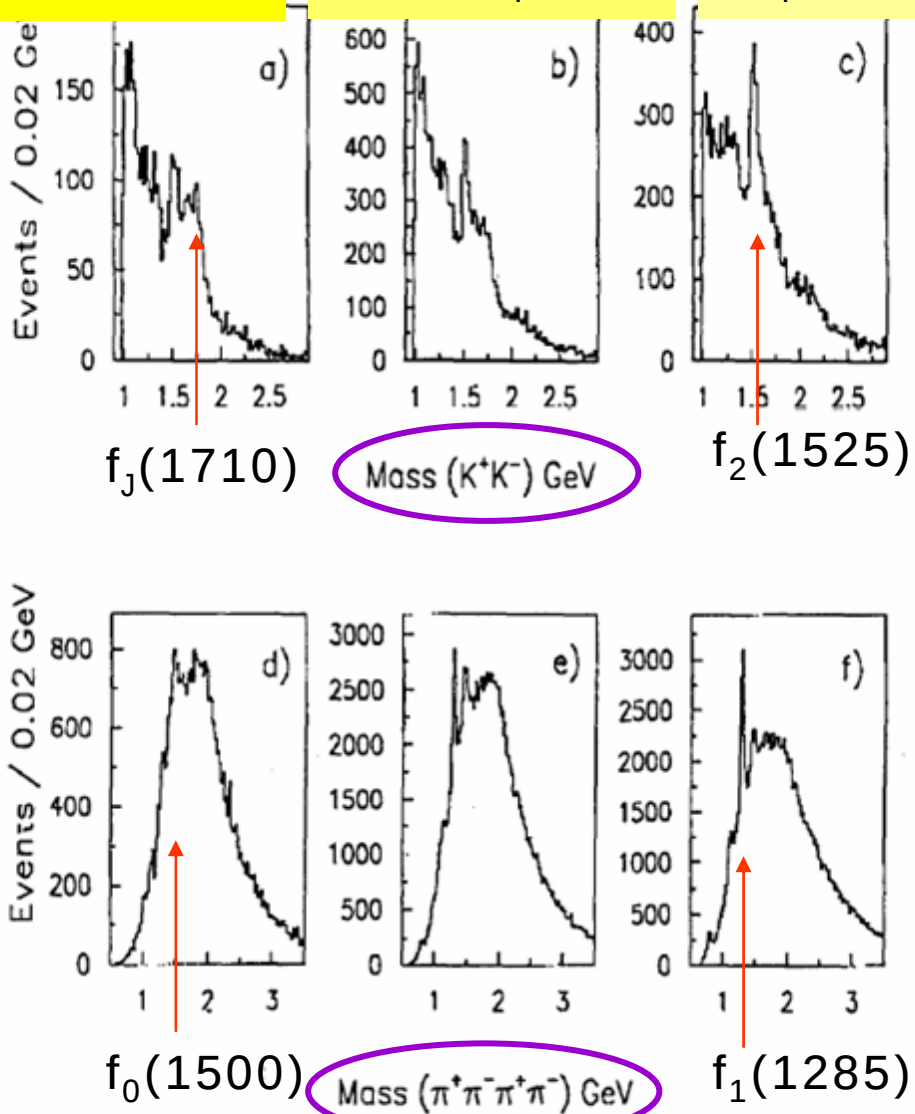


Fig. 3. K^+K^- mass spectrum for a) $dP_T < 0.2$ GeV, b) $0.2 < dP_T < 0.5$ GeV and c) $dP_T > 0.5$ GeV and the $\pi^+\pi^-\pi^+\pi^-$ mass spectrum for d) $dP_T < 0.2$ GeV, e) $0.2 < dP_T < 0.5$ GeV and f) $dP_T > 0.5$ GeV.

Inclusive Double Pomeron interaction at ISR

Z. Phys. C – Particles and Fields 42, 387–395 (1989)

Table 1. Cross-Sections for exclusive reactions. The quoted errors do not include a global systematic error (estimated as a *factor of 1.5*) which results from an overall uncertainty in the acceptance and the liminosity calibration

Reaction	Number of events	Cross section [μb]
(1) $pp \to pp(\pi^+\pi^-)$	16400	79.0 ± 13.0
(2) $pp \to pp(2\pi^+ 2\pi^-)$	5800	46.0 ± 10.0
(3) $pp \to pp(3\pi^+ 3\pi^-)$	1900	32.0 ± 9.0
(4) $pp \to pp(K^+K^-)$	560	6.5 ± 1.7
(5) $pp \to pp(K^+K^-\pi^+\pi^-)$	150	10.0 ± 3.3
(6) $pp \to pp(p\bar{p})$	120	0.8 ± 0.17
(7) $pp \to pp(p\bar{p}\pi^+\pi^-)$	65	1.3 ± 0.36

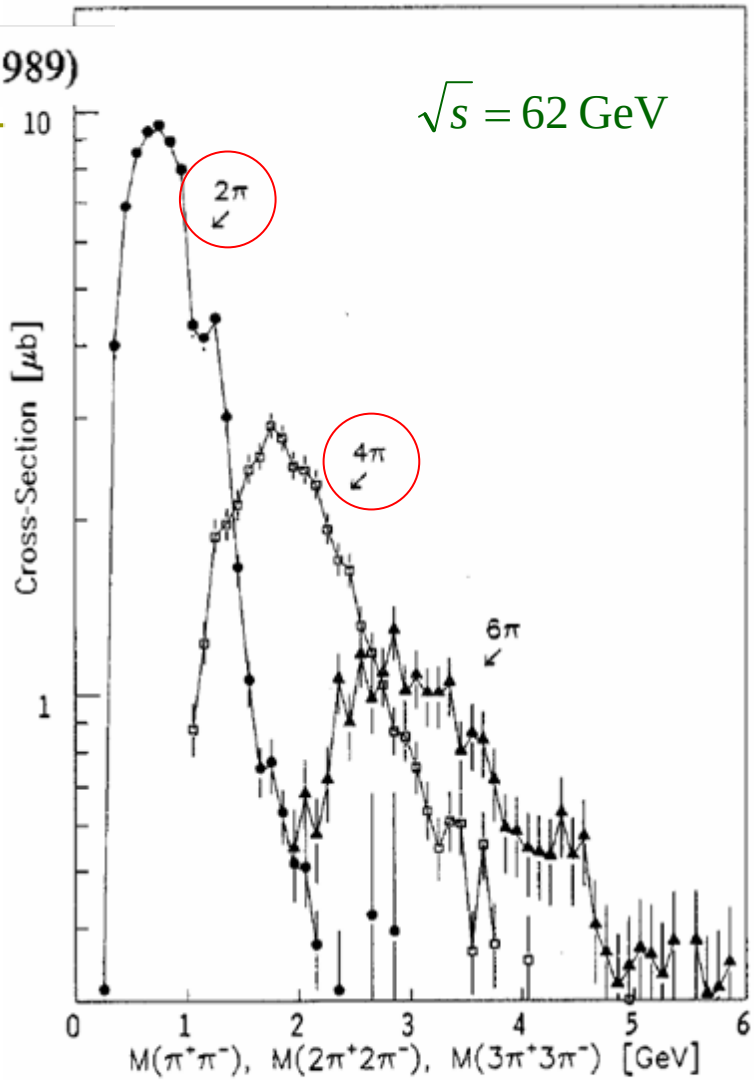


Fig. 3. Invariant mass distributions for the central $\pi^+\pi^-$, $2\pi^+2\pi^-$, and $3\pi^+3\pi^-$ systems from reactions (1–3) respectively (in μb per 100 MeV bin). This figure, and all subsequent figures, show data which have been acceptance corrected