Photoproduction in Ultra Peripheral Relativistic Heavy Ion Collisions with STAR

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for the STAR collaboration

Workshop on Photoproduction at collider energies: from RHIC and HERA to LHC

ECT* - Trento, January 15-19, 2007

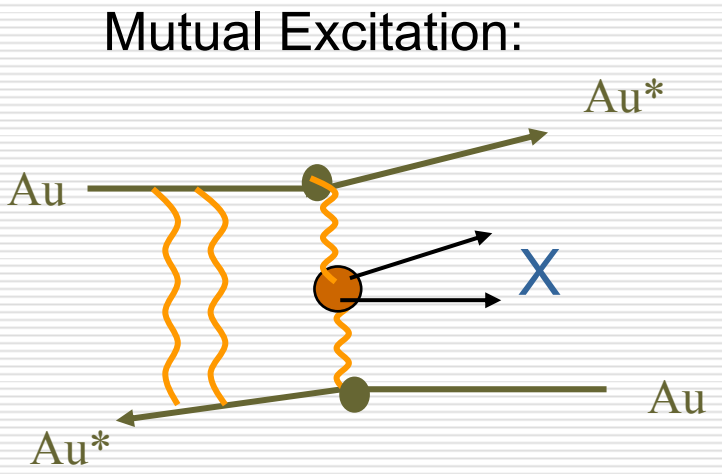
Outline

- Vector meson production
- STAR
  - Trigger and Data Sets
  - ρ^0 production
  - Interference
  - 4 prong analysis
  - dAu
  - e^+e^- pairs production
- Plans and Summary

Ultra Peripheral Collisions

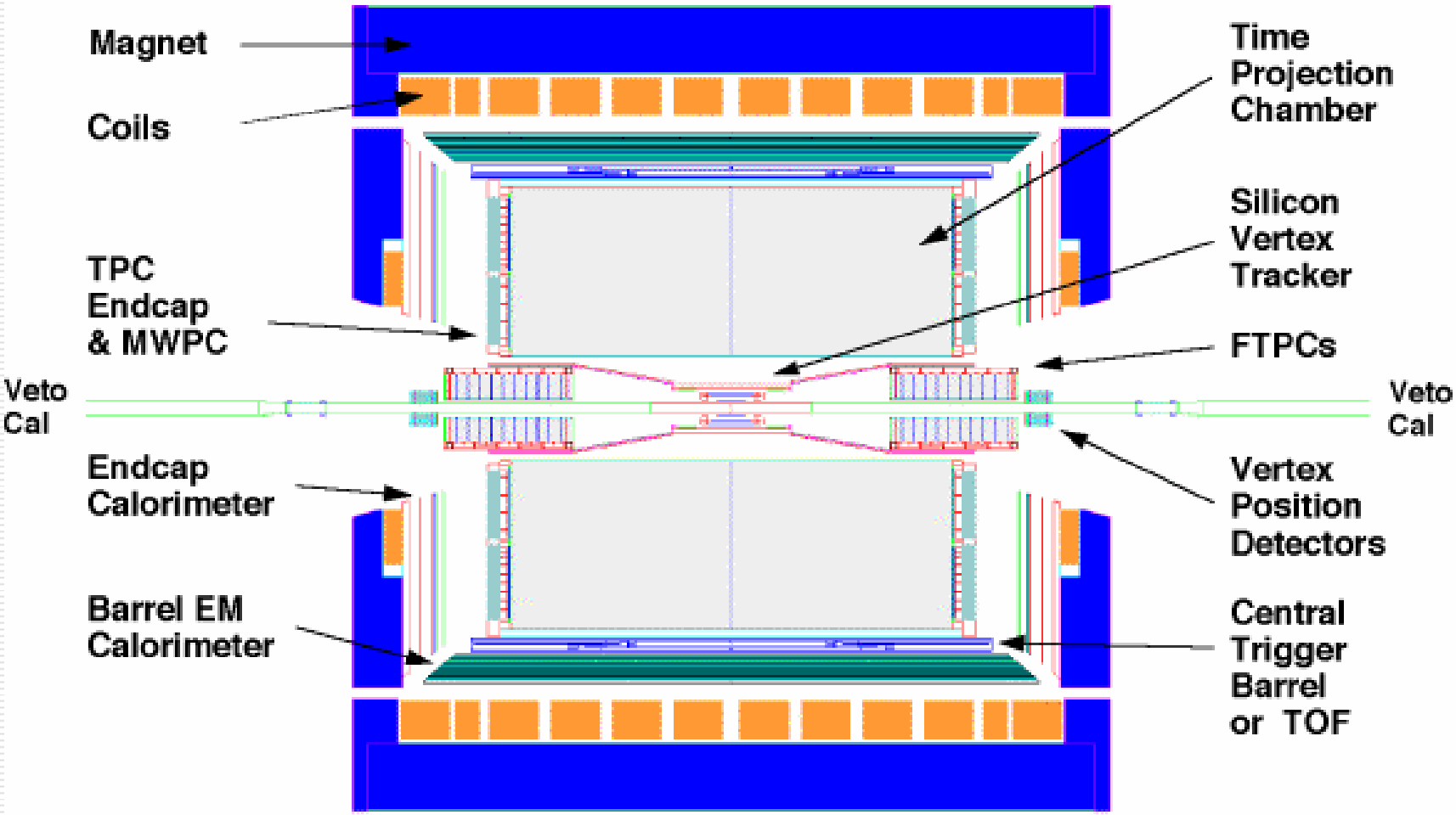
- Photonuclear interaction
- Two nuclei miss each

other: $b>2R_A$, electromagnetic dominates over strong interactions



- Photon emitted by nucleus fluctuates to virtual qq (bar) pair
- qq (bar) pair elastically scatters from nucleus (absorb part of photon wave function) and real vector meson emerges
  - coherence conditions limit $P_T<h/2R_A$ ~ 150 MeV

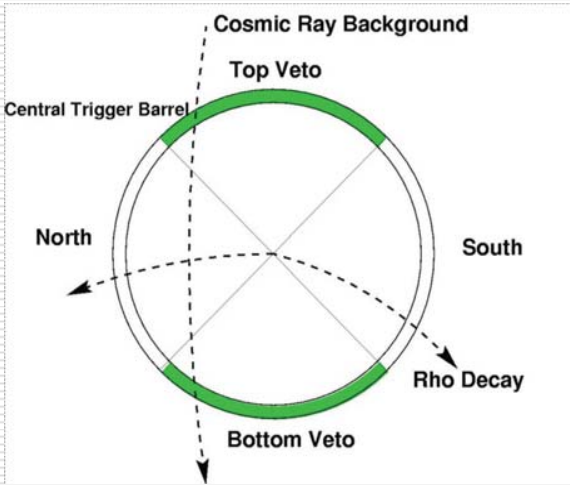
RHIC & STAR



located at BNL on Long Island, NY

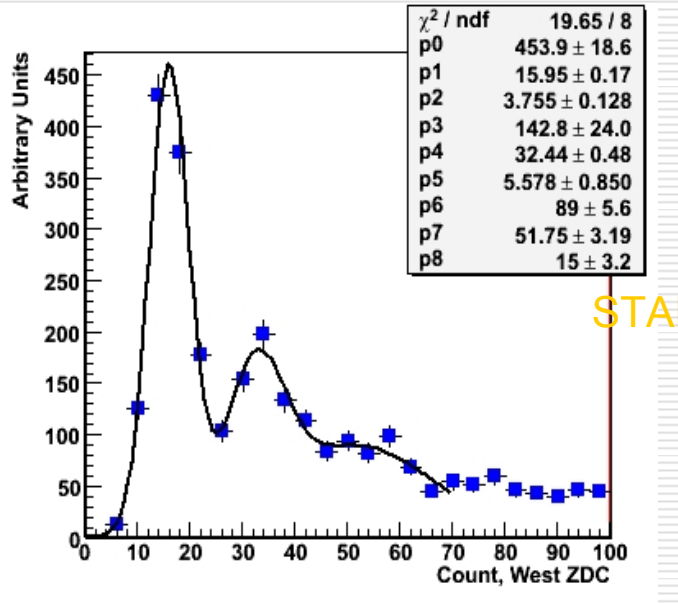
Trigger

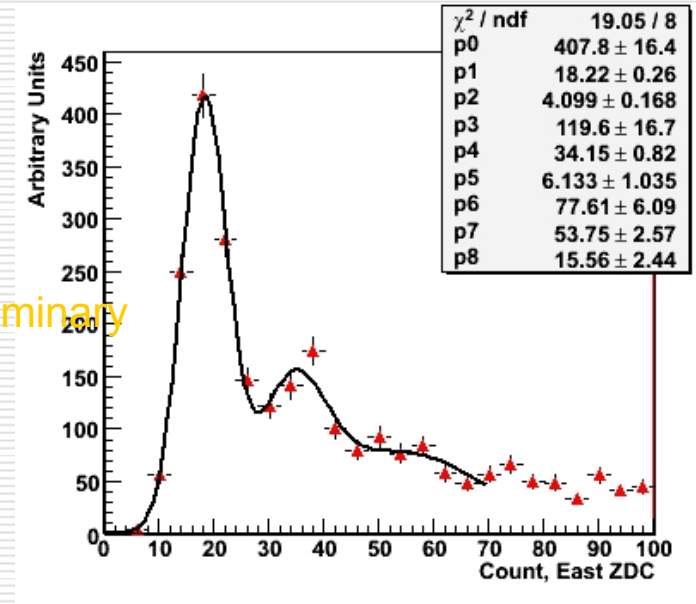
- Topology
  - Central trigger Barrel divided into 4 quadrants
  - ρ candidates with hits in North and South quadrants
  - Events with hits Top/Bottom are vetoed



- Minimum Bias
  - Events with low multiplicity selected with Central Trigger Barrel detector
  - At least one neutron in each of the Zero Degree Calorimeter
    - distinctive signature for nuclear breakup

Zero Degree Calorimeter





STAR Preliminary

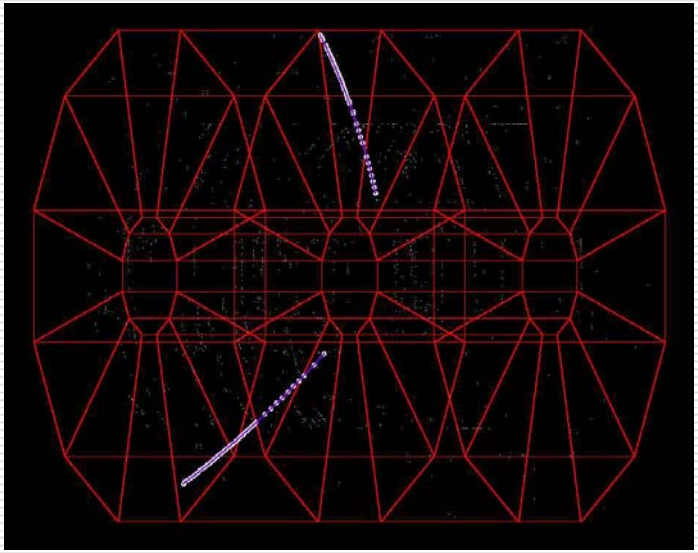
- ZDC spectra obtained with the minimum bias sample
- Allows to distinguish between different excited states of produced vector mesons (1n,2n,...)
- Acceptance ~ 100%

Data Samples

- Run 2000 130 GeV AuAu
  - Topology
  - Minimum bias
- Run 2001 200 GeV AuAu
  - Topology
  - Minimum bias
- Run 2004 AuAu
  - 200 GeV 4 prong
  - 200 GeV J/Ψ
  - 200, 62 GeV Minimum bias
- Run 2005 CuCu
  - 200 GeV J/Ψ
  - 200, 62 GeV Minimum bias

Data Sample

- Data taken in 2001 with energy $\sqrt{s}$ = 200 GeV

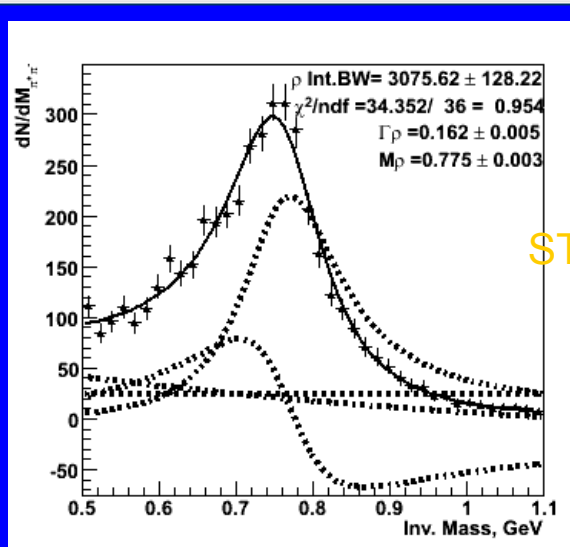


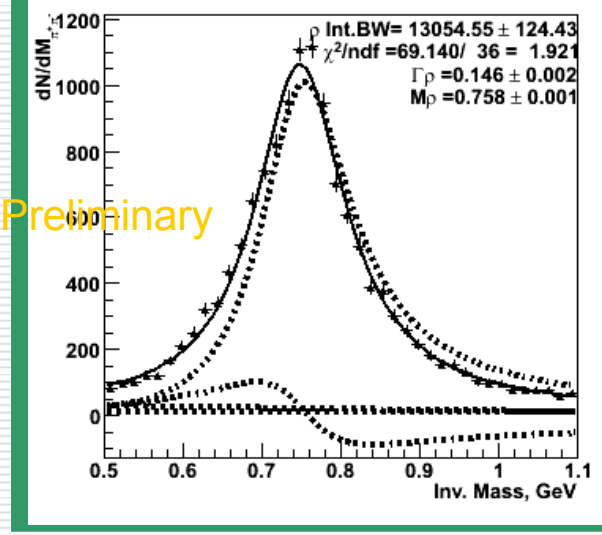
- Background
  - Beam gas
  - Peripheral hadronic interactions
  - Cosmics

Available Statistics

- Approximately 16 000 candidates in two samples

Minimum bias data



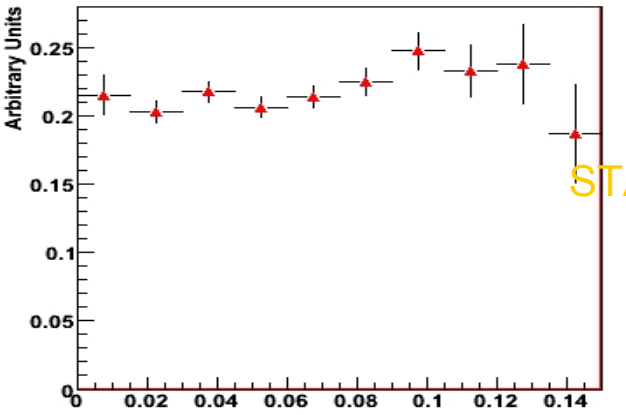


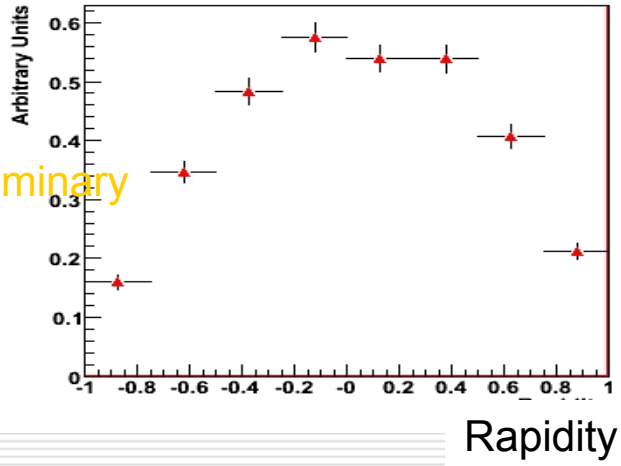
Topology sample

- Fitted with
  - Breit-Wigner function for the signal
  - Soding's interference term: direct $\pi^+\pi^-$ production
  - background described by the second order polynomial
- Background estimated with like sign pairs

Acceptance

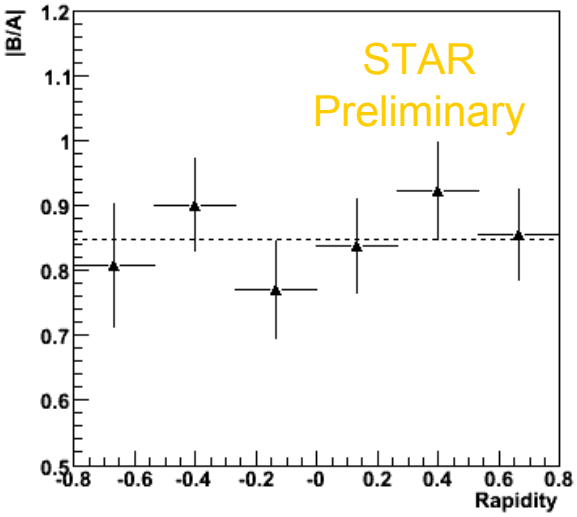
- The STARlight Monte Carlo
  - two-photon and photon-Pomeron interactions in peripheral heavy ion collisions.
- Detector response simulation
- Track reconstruction + Vertexing



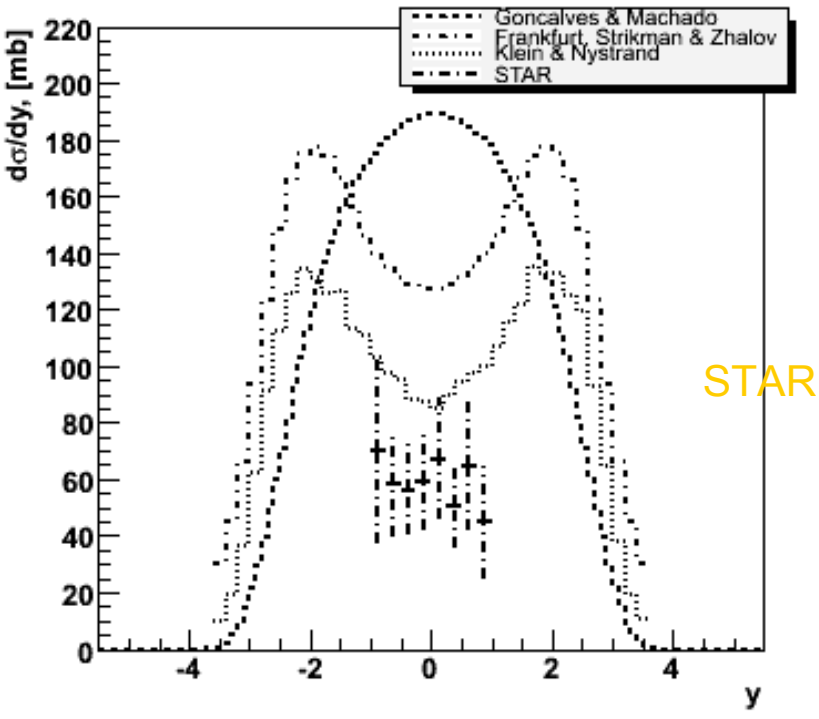


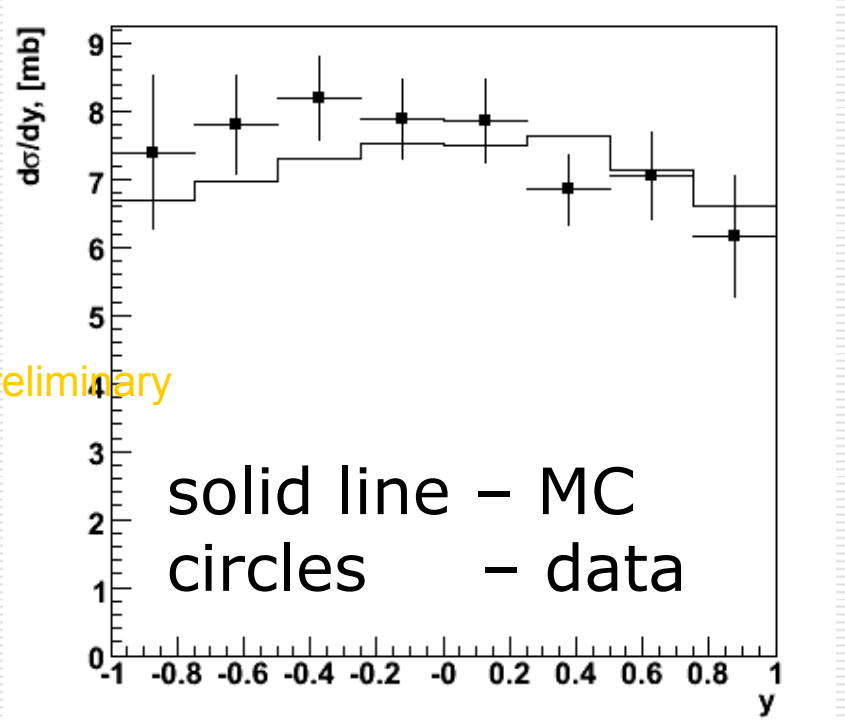
Direct Pion Production

- |B/A| - measure of non resonant to resonant production
  - Fit function of the invariant mass gives access to the direct pion production
  - |B/A| = 0.84 ± 0.11 GeV $^{-1/2}$ in agreement with previous STAR results |B/A| = 0.81 ± 0.28 GeV $^{-1/2}$
  - No angular dependence -> in agreement with ZEUS measurements
  - Acceptance stability cross check



Cross Section





ρ^0 total production cross section along with 3 theoretical models

ρ^0 production cross section for events with mutual excitation (AuAu, 200 GeV)

Cross Section Comparison

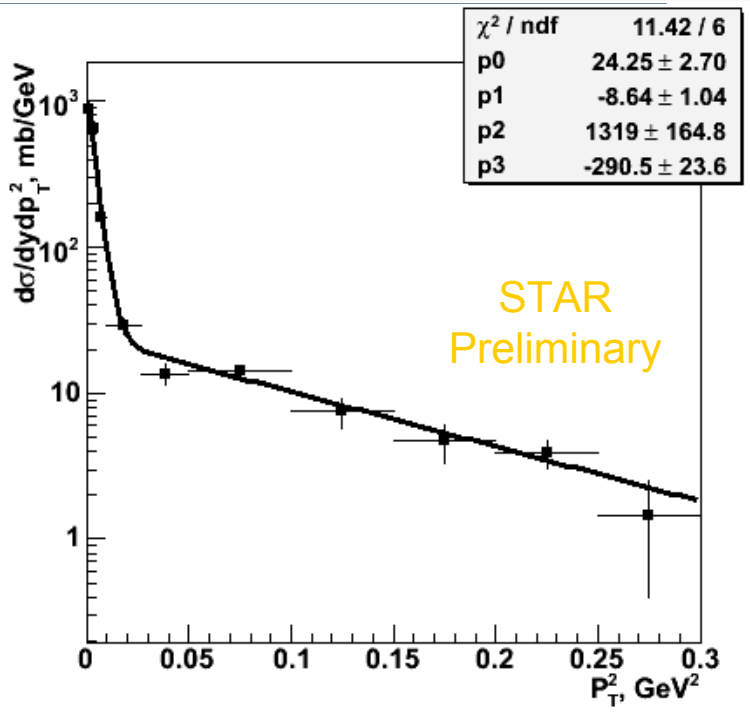
- ρ0 production cross was measured by STAR at 200 GeV and 130 GeV

	STAR $\sqrt{s}$=200GeV, mb	STAR $\sqrt{s}$=130GeV, mb
σ_{xnxn}	30.26±1.1±6.35	26.2±1.8±5.8
σ_{0nxn}	108.74±9.08±22.83	90±55±20
σ_{1n1n}	1.63±0.18±0.34	2.5±0.4±0.6
σ_{0n0n}	370.19±33.26±77.74	285±145±70
σ_{xnxn}	509.2±34.5±106.9	410±190±100

Cross Section

- Measured ρ^0 coherent plus incoherent production cross section
- Fit function:

$$\frac{d\sigma}{dt} = a * \exp(b * t) + c * \exp(d * t)$$



  - σ Incoherent/Coherent ~ 0.57
- d = 8.64 ±1.04 GeV^{-2}– access to the nucleon form factor; R_{AU}~5.9±2. fm
  - In agreement with previous STAR measurement

Spin Density Matrix

- 2-dimensional correlation of Φ_h vs $\cos(\Theta_h)$ allows to determine the ρ0 spin density matrix elements
  - Θ – polar angle between ion and direction of $\pi+$
  - Φ – azimuthal angle between decay plane and production plane
  - Fit function: K. Schilling and G. Wolf, Nucl. Phys. B61, 381 (1973)

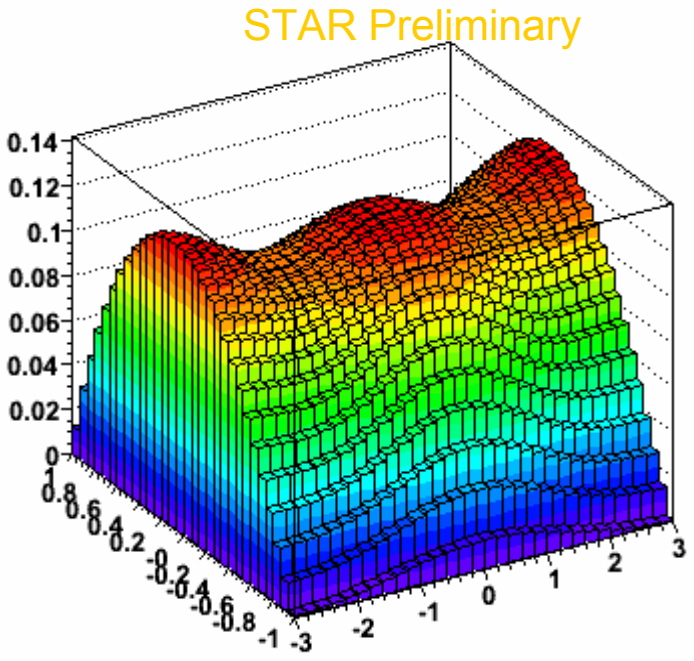
$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\Theta_h d\Phi_h} = \frac{3}{4\pi}\left[\frac{1}{2}(1-r^{04}_{00}) + \frac{1}{2}(3r^{04}_{00}-1)\cos^2\Theta_h - \sqrt{2}\Re e[r^{04}_{10}]\sin 2\Theta_h \cos\Phi_h - r^{04}_{1-1}\sin^2\Theta_h \cos 2\Phi_h\right] \quad (1)$$

  - r^{04}_{00} represents probability ρ0 having a helicity
  - r^{04}_{1-1} related to the level of interference helicity non flip & double flip
  - $\Re e[r^{04}_{10}]$ related to the level of interference helicity non flip & single flip
  - In case of s-channel helicity conservation r^{04}_{1-1} $\Re e[r^{04}_{10}]$ equal 0 and r^{04}_{00} small

Matrix Elements

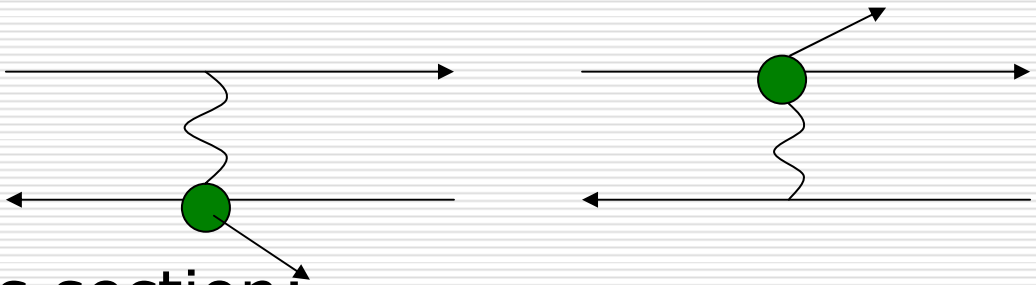
- Fit results are consistent with S-channel helicity conservation
- In agreement with ZEUS experiment measurements

Parameter	STAR	ZEUS
r_{00}^{04}	0.01±0.02	0.01±0.03
$\Re e[r_{10}^{04}]$	0.04±0.03	0.01±0.02
r_{1-1}^{04}	-0.03±0.02	-0.01±0.02



Interference

- Two possible scenarios:
  - Photon emitted by nucleus 1 and scattered from nucleus 2
  - Photon emitted by nucleus 2 and scattered from nucleus 1



- Cross section:
  - Due to ρ negative parity amplitudes subtracted
  - At mid rapidity cross section depends on the transverse momentum and impact parameter

$$\sigma = \sigma_0 (1 - \cos(p_T b))$$

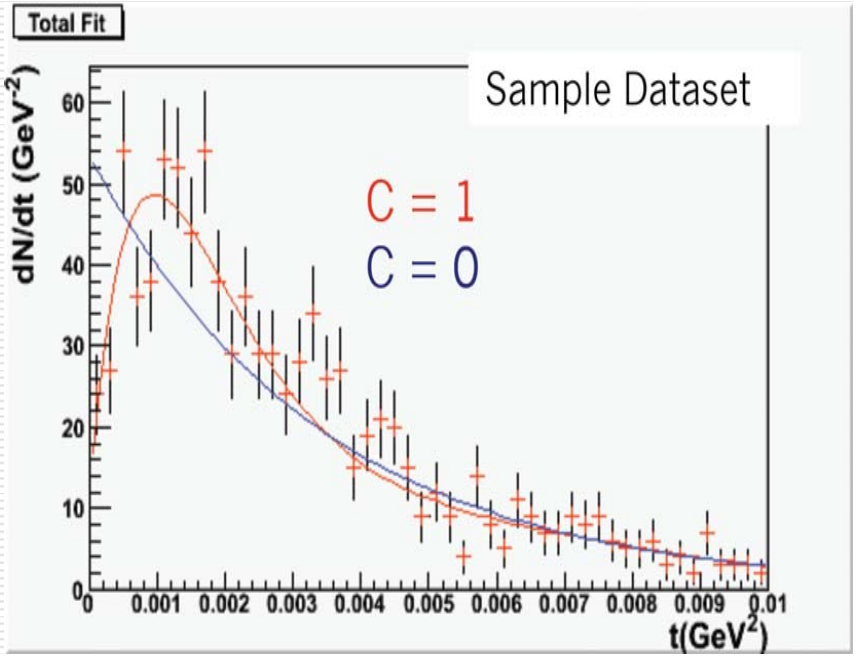
  - P_T spectra suppressed for P_T < h/<b>

Measuring the Interference

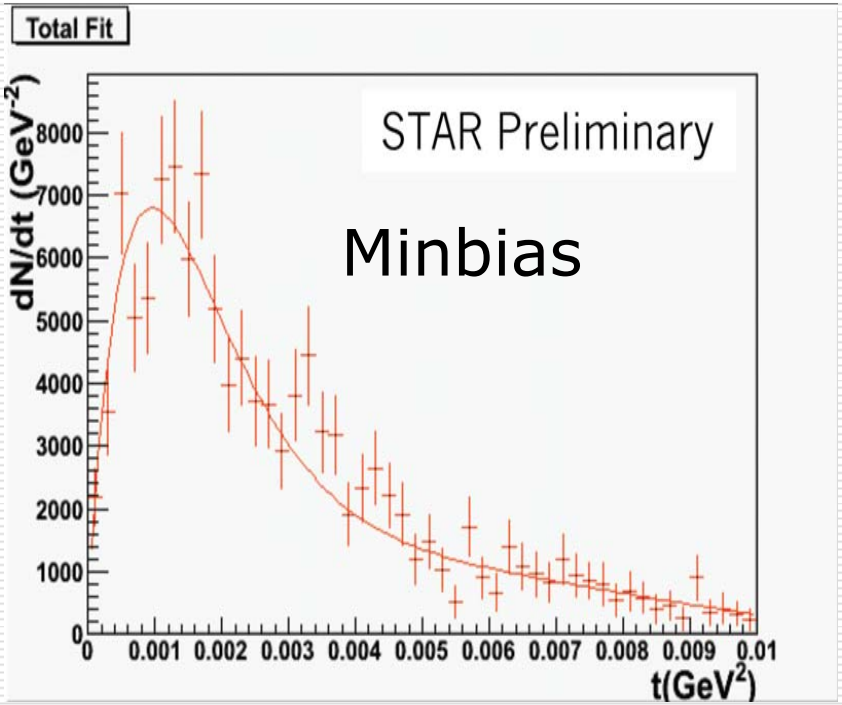
- Two samples topology and minimum bias
  - Differ in median impact parameter
    - topology ~ 46 fm
    - minimum bias ~ 16 fm
- Fit function: $\frac{dN}{dt} = Ae^{-kt}(1 + c[R(t) - 1])$
- c – degree of interference
  - c = 1 – interference
  - c = 0 – no interference
- R(t) – correction factor
  - MC int / MC no int

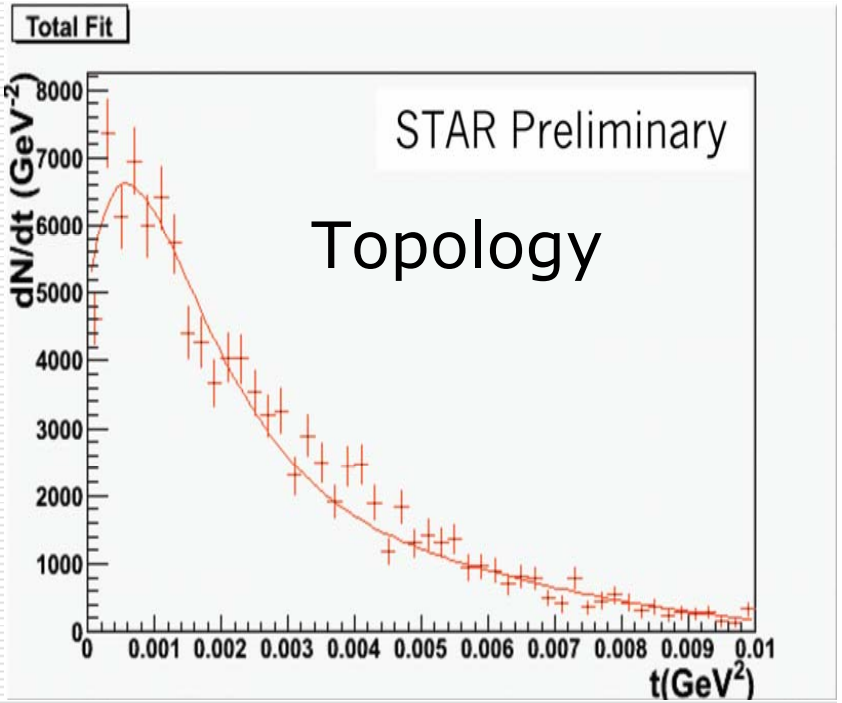
$$R(t) = a + \frac{b}{(t+0.012)} + \frac{c}{(t+0.012)^2} + \frac{d}{(t+0.012)^3} + \frac{e}{(t+0.012)^4}$$

Based on B. Haag presentation



Measuring the Interference





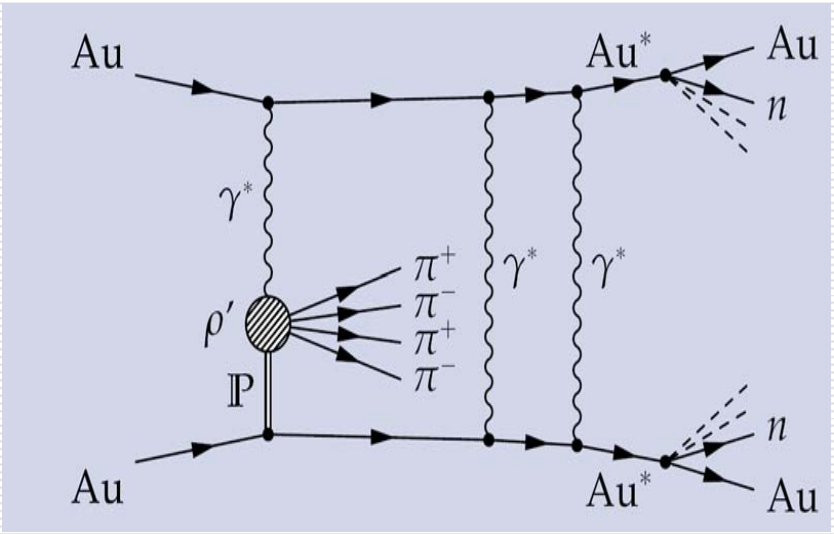
- Interference is largest at y ~ 0

Rapidity	c	X2/ndf
0.1<y<0.5	1.01±0.08	51/47

c	X2/ndf
0.93±0.11	80/47

ρ' production

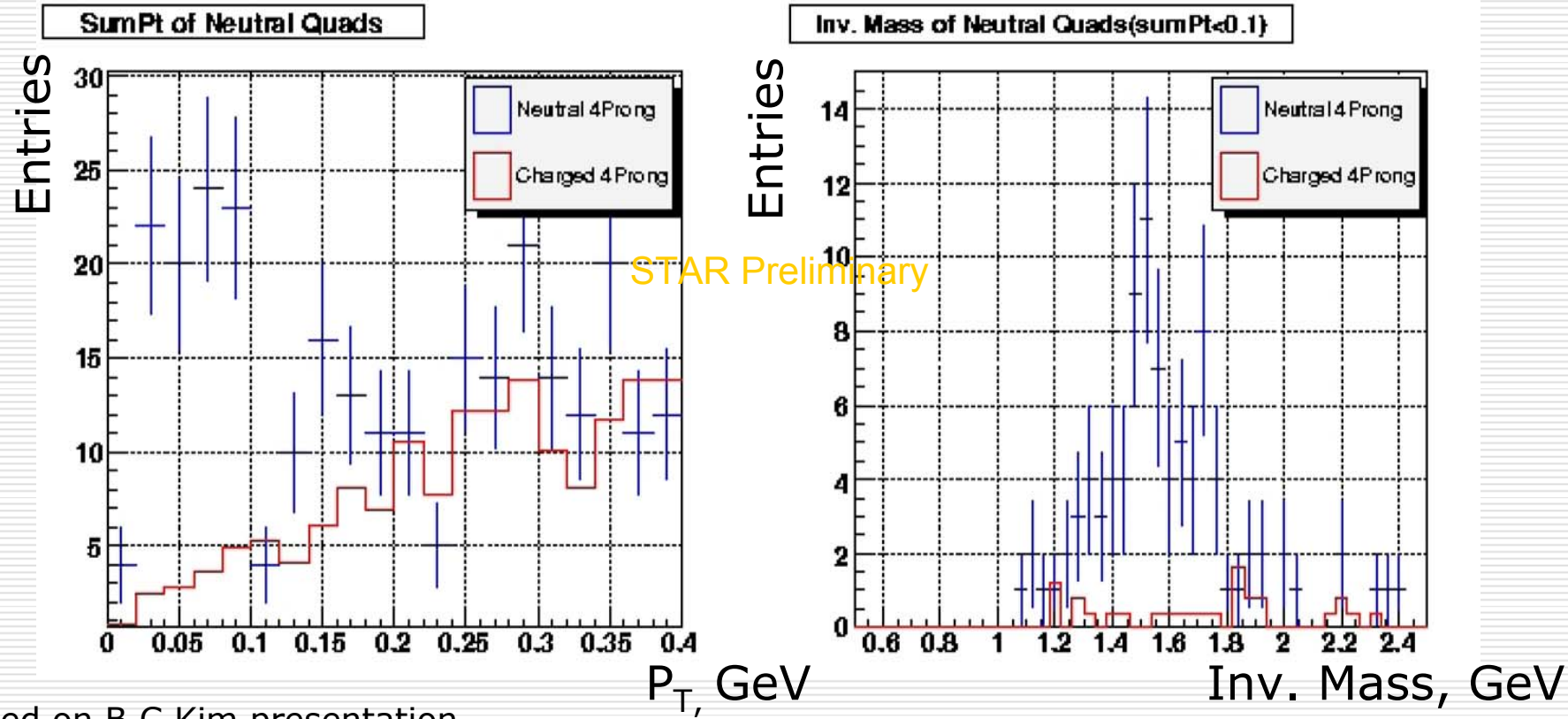
- γAu -> ρ(1450/1700) -> $\pi^+\pi^+\pi^-\pi^-$
- Signature
  - 4 charged tracks with $\Sigma Q = 0$
  - Low P_T
  - Hits in ZDC
- Trigger
  - Neutrons detected in ZDC
  - Cut on multiplicity



Based on B. Grube presentation

ρ' in 2004 Data

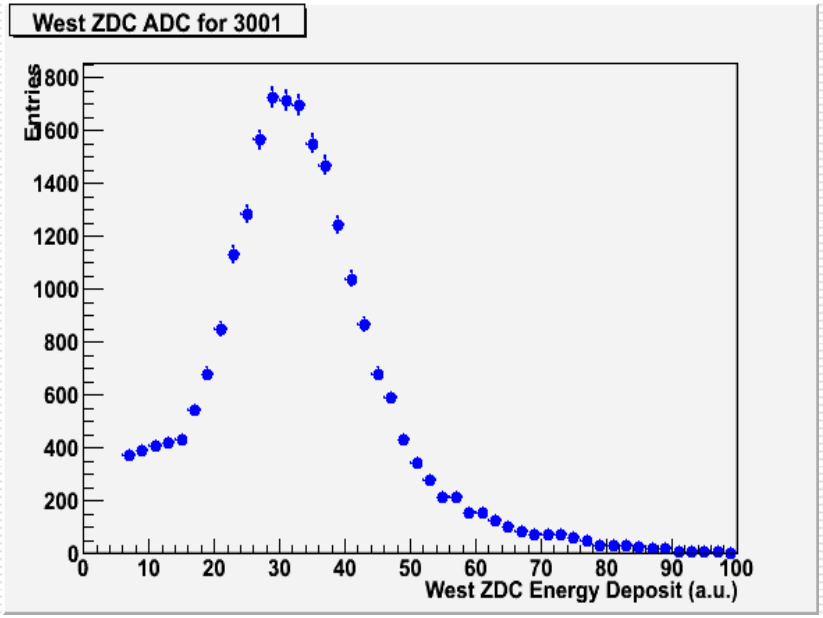
- Analyzed:3.9 *10^6 events
- ~123 ρ' candidates
- Signal $\pi^+\pi^-\pi^+\pi^-$ Background $\pi^+\pi^+\pi^+\pi^-$ plus low p_T

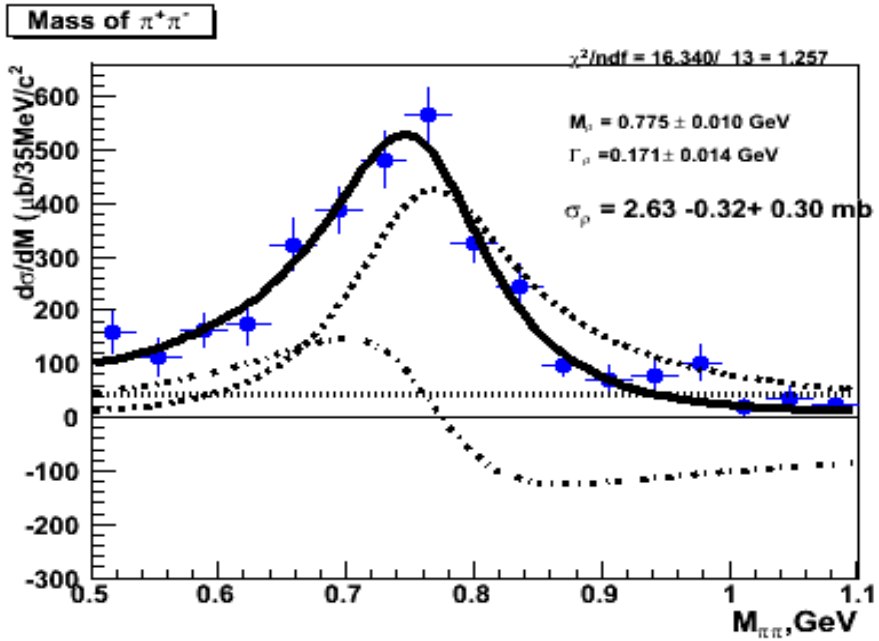


Based on B.C Kim presentation

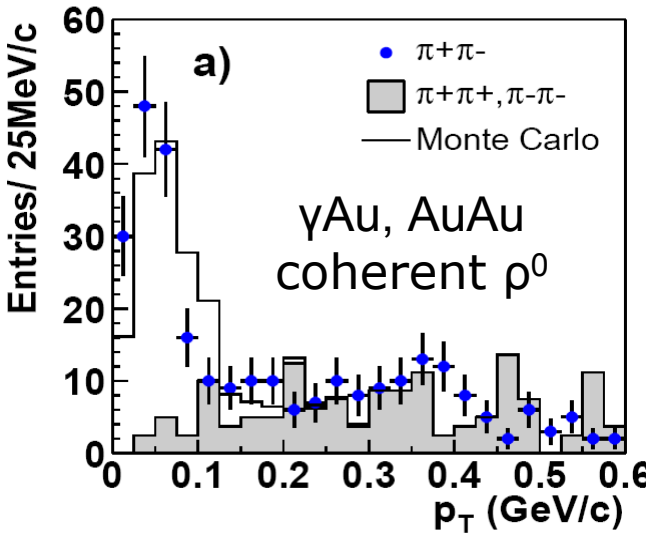
dAu->d(np)Aup Cross Section

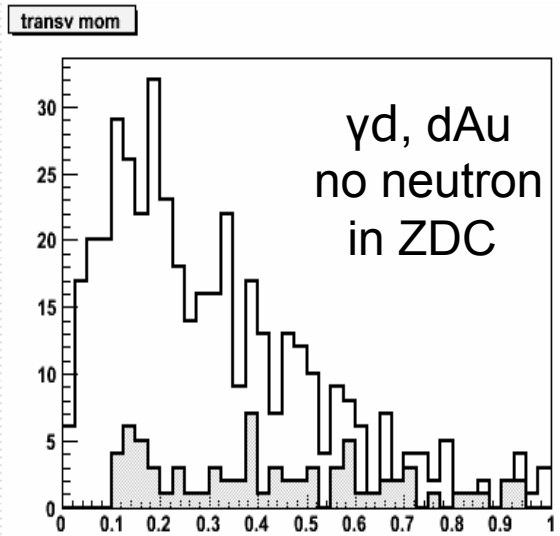
- Triggered with topology trigger + neutron registered in West ZDC
- Sample of 13400 events
- Fitted by BW + direct pions + BG
  - σ = 2.63±0.32±0.73 mb
  - mass width in agreement with PDG

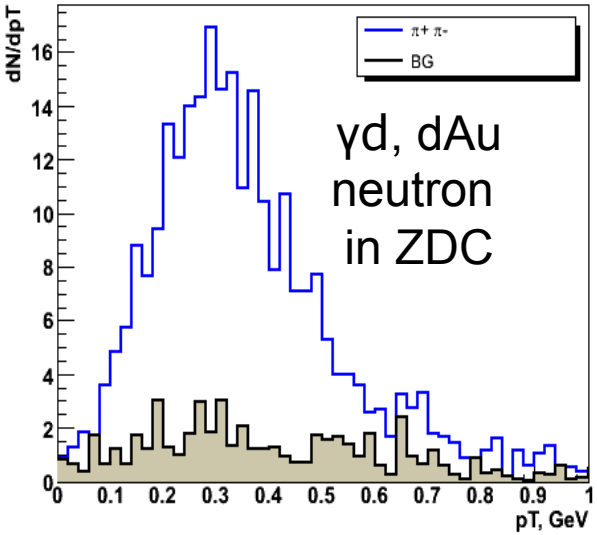




P_T in *dAu->d(np)Auρ*







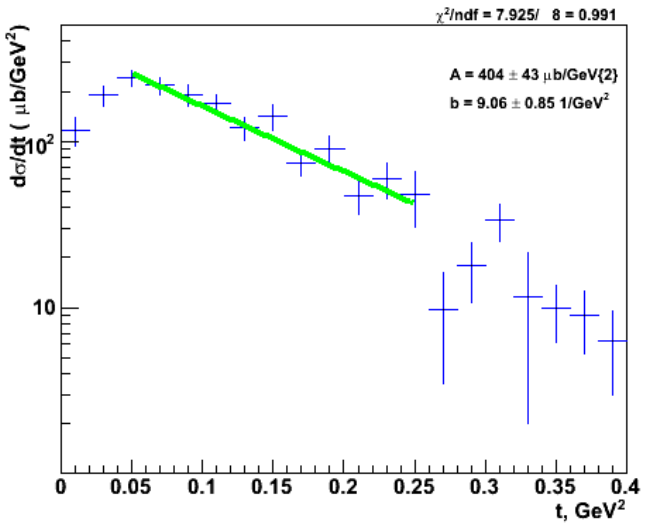
- P_T spectra reflects γd and no γAu interactions in dAu sample
- Coherent (deuteron stays in tact) and incoherent (deuteron dissociation) produced ρ0 are accessible in dAu sample

dAu->d(np)Aup t Spectra

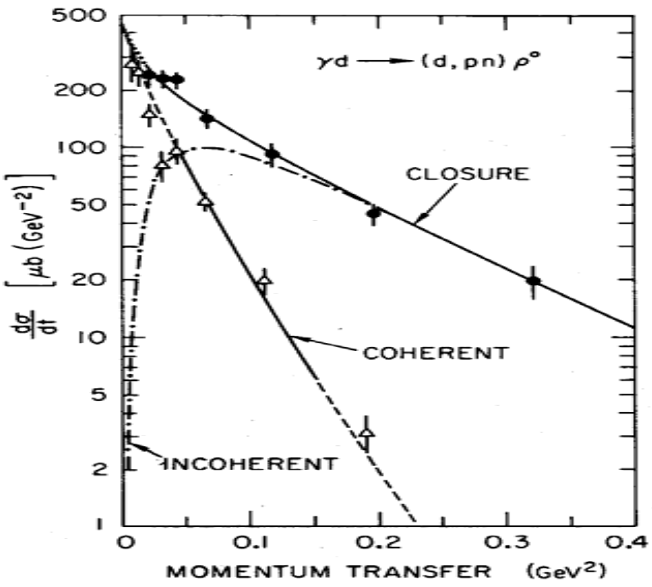
- Fit to the *t* spectra
- Fit function:

$F(t)=e^{-bt}$ – access to the nucleon form factor

  - b = 9.06±0.85 GeV^{-2}
  - Same as ZEUS

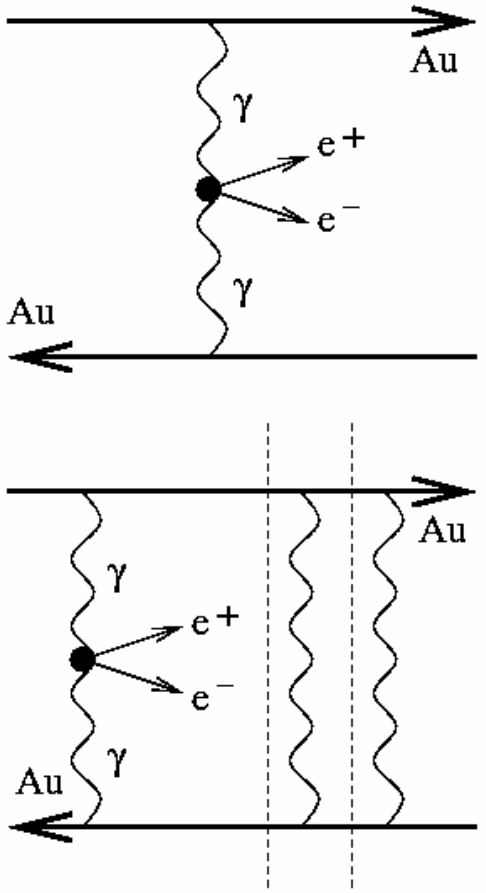


- Turndown at small t
  - The same behavior seen by γd experiment



e^+e^- Pairs Production

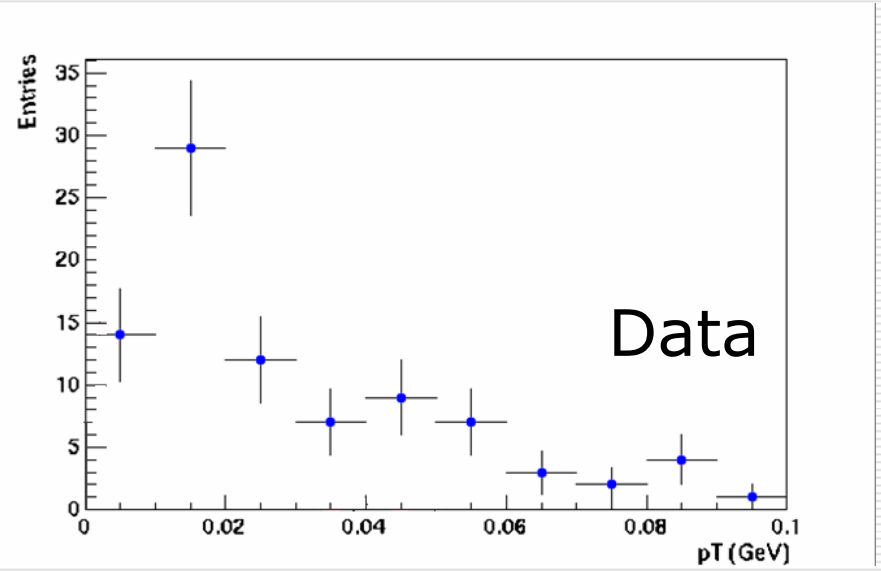
- Topology triggered
  - low P_T tracks don't reach CTB
- Minimum bias
  - In full field data, tracks curve strongly – no tracking possible
  - Half field data (0.25 T) – useful for analysis



Based on V. Morozov presentation

Peripheral e^+e^- Pairs

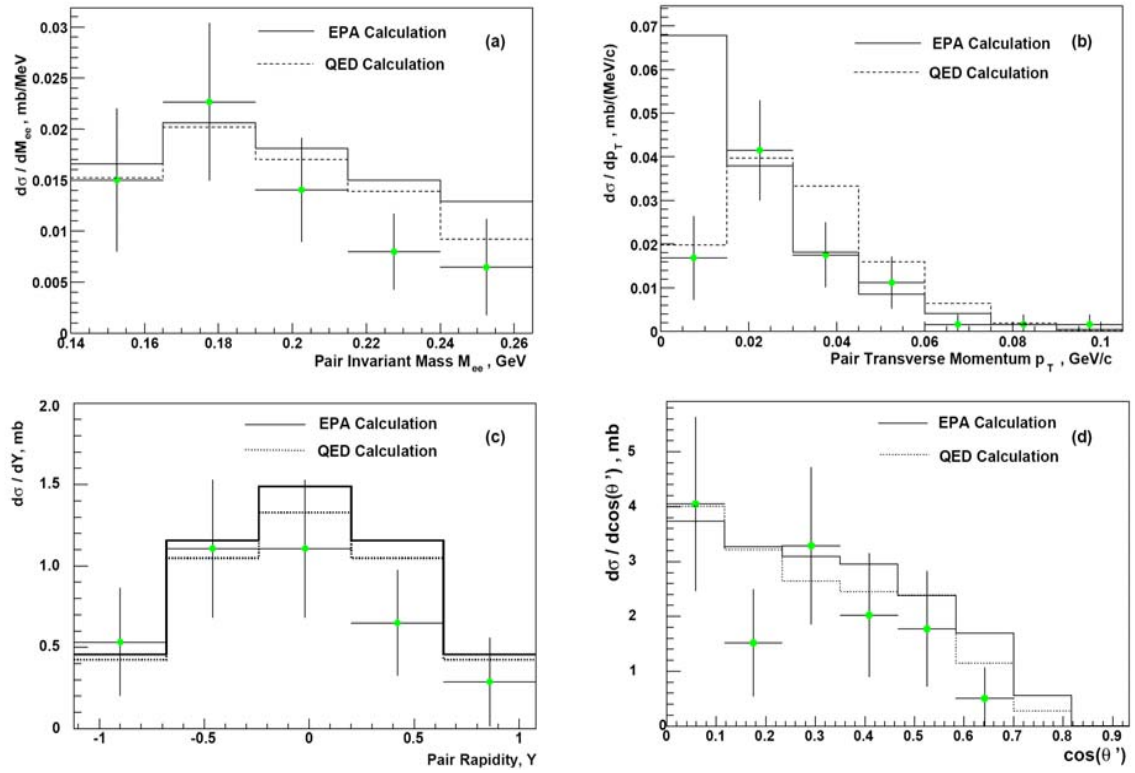
- Events selection is based on the dE/dx
- Background from the mis-identified $\pi^+\pi^-$ pairs and incoherent hadronic events
- P_T distribution well described by the lowest order quantum electrodynamics



Based on V. Morozov presentation

e^+e^- Pairs Cross Section

- Production cross section of the e^+e^- pairs as a function of invariant mass, transverse momentum, rapidity and cos(Θ)
  - two models : equivalent photons and lowest order QED
  - photon virtuality is required



Plans

- Improved trigger for the run 2007
  - Improved cluster finder for J/Ψ trigger
  - Monitoring of CTB
- TOF will replace CTB in the near future
  - Trigger simulation is underway
    - Triggering on multiplicity
    - Topology trigger
    - Possible PID

Summary

- STAR has measured coherent and incoherent photo production of ρ0 meson in AuAu 200 GeV
  - Differential cross section $d\sigma/dy$, $d\sigma/dt$ were obtained and compared to the theoretical models
  - P0 spin density matrix elements $r_{00}^{04}; \Re e[r_{10}^{04}]; r_{1-1}^{04}$ were obtained from the angular distribution of the decay pions in the helicity frame
    - Consistent with S-channel helicity conservation
- interference in ρ^0 production has been measured
- $\rho' \rightarrow \pi^+\pi^+\pi^-\pi^-$ production in AuAu 200GeV collisions has been observed
- incoherent ρ^0 meson photoproduction in dAu has been measured
  - Differential production cross is measured and found to be in agreement with previous measurements and theoretical models
- Cross section of e^+e^- pairs production has been measured