Photon-Pomeron and Photon-Photon Interactions in Ultra-Peripheral Heavy Ion Collisions at STAR

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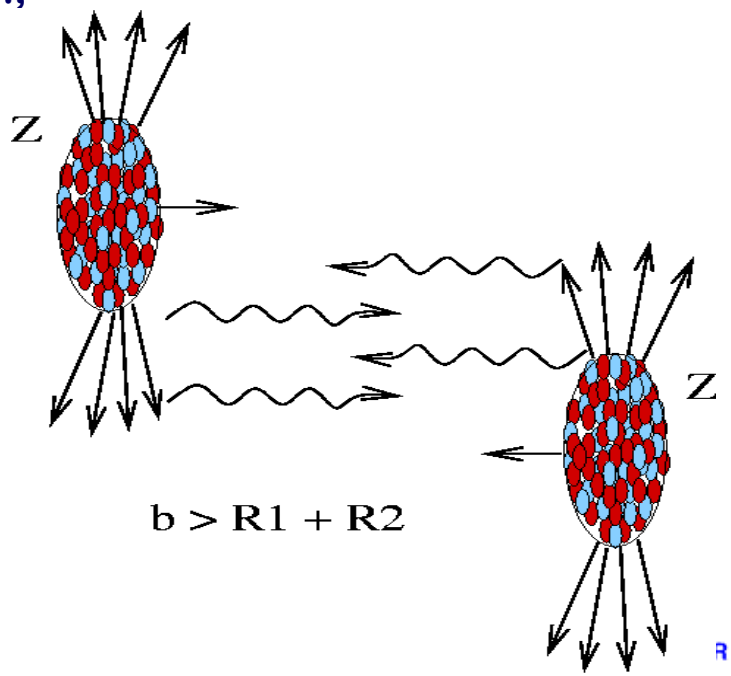
For the STAR Collaboration

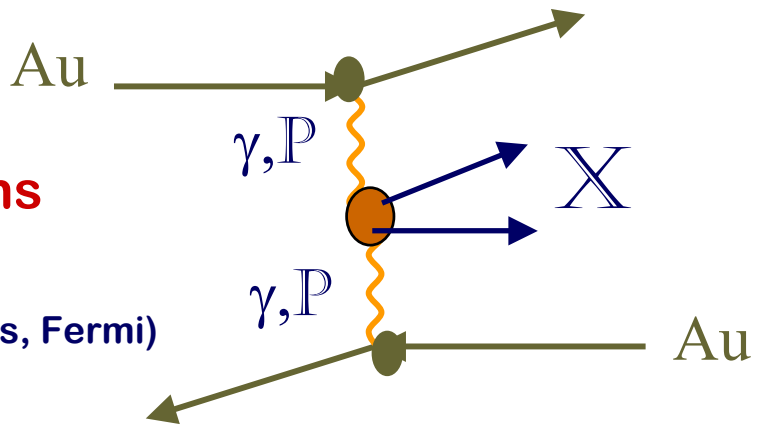
CERN Heavy Ion Forum,
March 2002

- Exclusive Meson Production
- Data Sets and Analysis
- Photon-Photon Interactions
- Cross Sections
- Outlook 2002 Data
- Summary



Ultra-Peripheral Collisions

Nuclei 'miss' geometrically and interact via long range fields



Coupling strength ⇨ large cross sections

- **Photon $\propto Z^2$**
  Equivalent Photon Approximation (Weizsaecker-Williams, Fermi)
- **Pomeron $\propto A^{4/3}$ (surface) to A^2 (volume)**

Coherent coupling to both nuclei

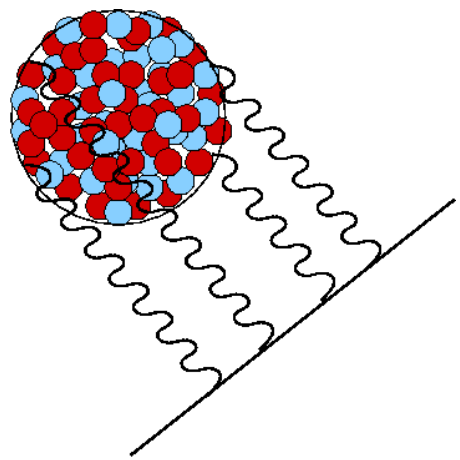
- **γ, ℙ: plane wave coupling to extended charge**
  Can't distinguish different points of origin
  Coherence condition from uncertainty principle:

⇒ **Small transverse momentum:**

$p_T < 2h/R_A \sim 60$ MeV

- **Longitudinal component**

$P_L < 2\gamma h/R_A \sim 6$ GeV

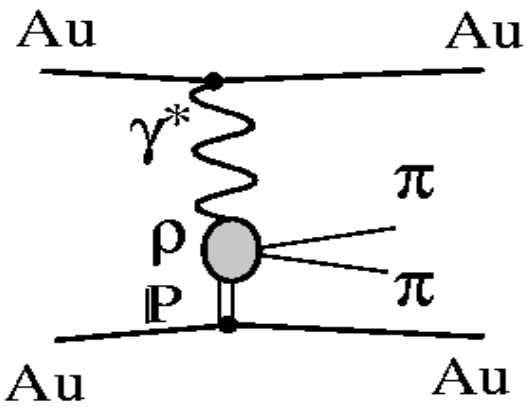


Nuclei may be mutually excited

Exclusive Vector Meson Production γA→VA

Exclusive ρ production

AuAu -> AuAuρ⁰



- Photon flux from WWA
- extrapolate γp->Vp to γA->VA with Glauber calculation

⇨ Large cross section:

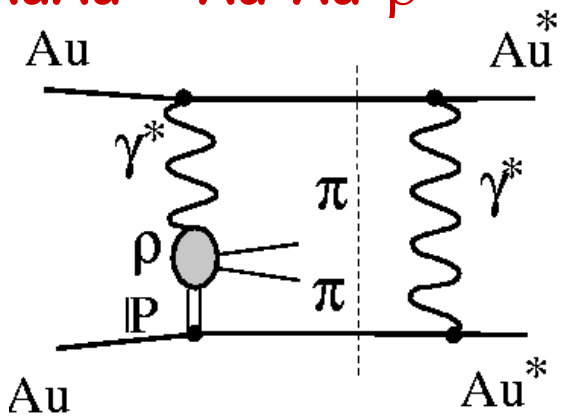
380 mb at $s_{NN}^{1/2}$=130 GeV/nuc. (350mb)

590 mb at $s_{NN}^{1/2}$=200 GeV/nuc.

S.Klein, J.Nystrand, Phys. Rev C50 014903 (1999)

… with nuclear excitation

AuAu -> Au*Au*ρ⁰

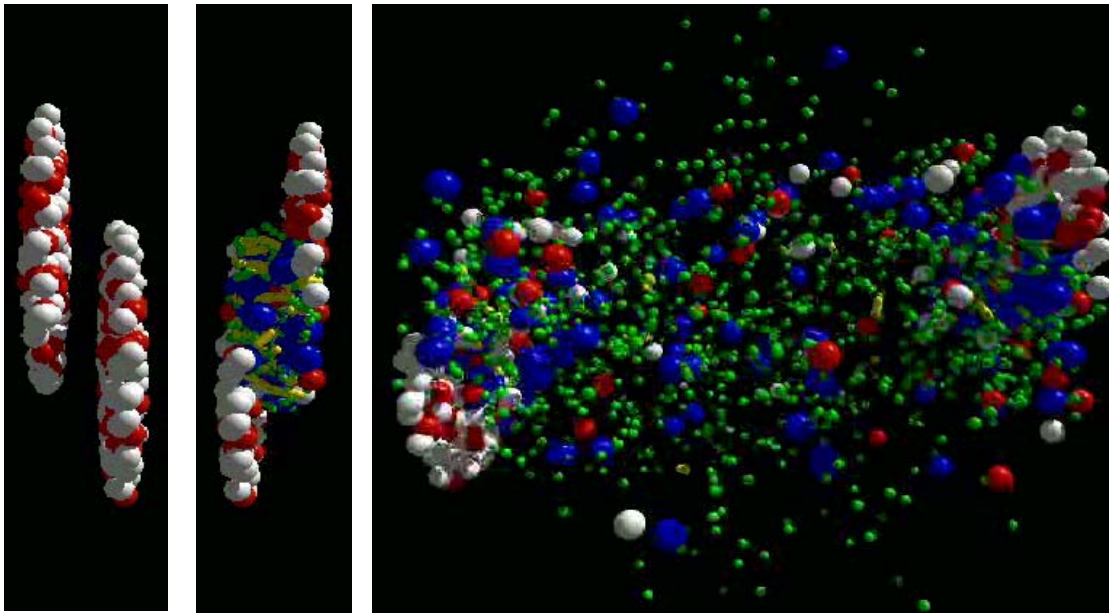


- Believed to factorize as function of impact parameter
- Gold decay by single (1n,1n) ○(3mb) and multiple (xn,xn) ○(27-28mb) neutron emission

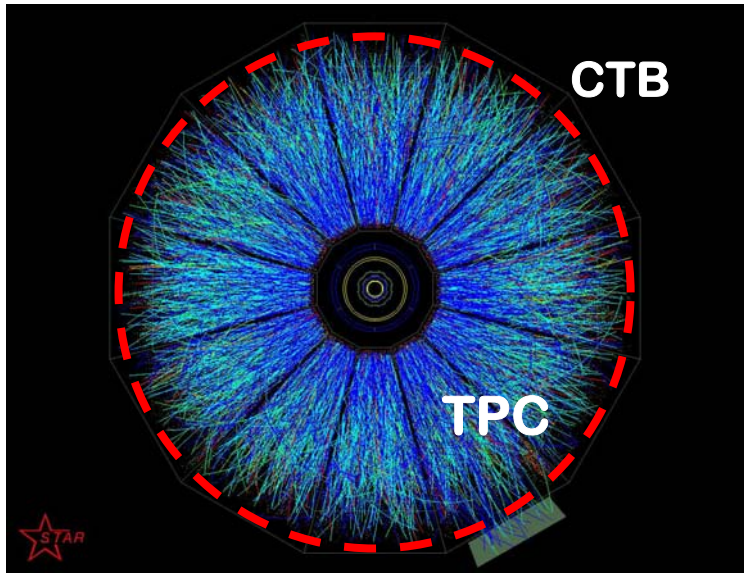
(A. Balz,S. Klein,J. Nystrand, priv. com.)

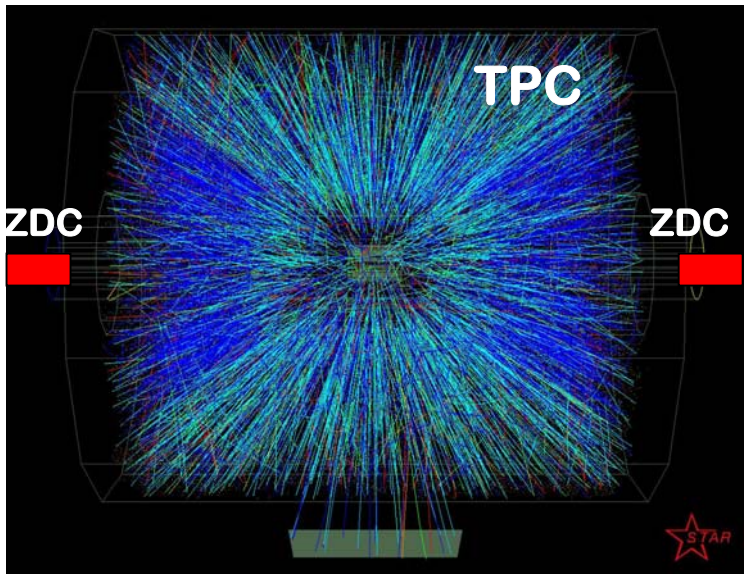
Selection of single/multiple neutron emission selects different ranges of impact parameter

Heavy Ion Collision / RHIC@BNL /



(Au Au, 200GeV/nucleon, University of Frankfurt)





RHIC

2000: AuAu @ $s_{NN}^{1/2}$=130 GeV/nuc.

2001: AuAu, pp @ $s_{NN}^{1/2}$=200 GeV/nuc.

~2000 tracks per Event

Triggers

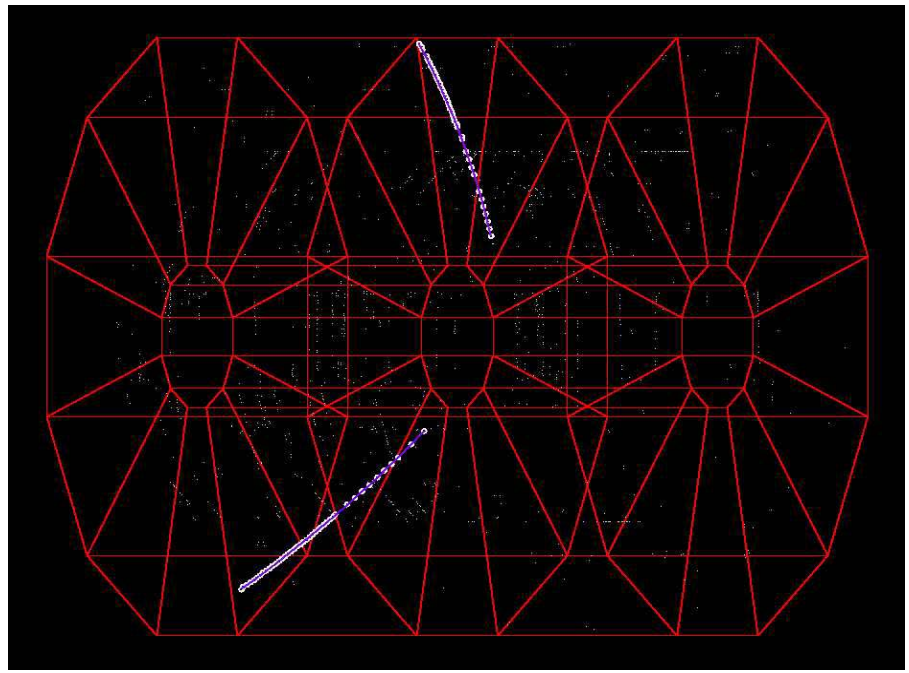
- Multiplicity in Central Trigger Barrel
- Neutron Deposit in Zero Degree Calorimeter

Experimental Signature of UPC

- Two oppositely charged tracks
- Low total p_T
- Back-to-back in transverse plane

Challenge: Trigger !

- Topology requirements in central trigger barrel
- ZDC coincidence (nucl. excitation)

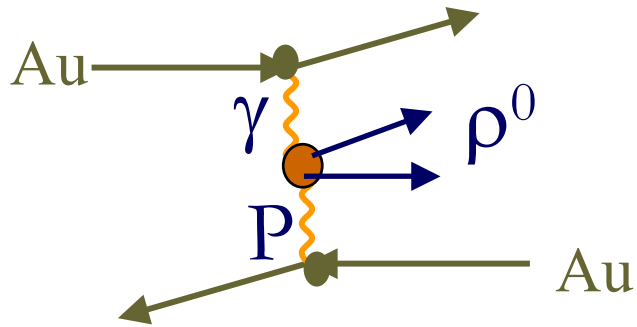


Major Backgrounds

Non-Physics/Trigger:
Pile-up, Cosmics, Beam Gas

Incoherent:
Peripheral hadronic events,
Incoherent photo-nuclear interactions

Coherent:
e^+e^- pairs, direct p^+p^- pair production



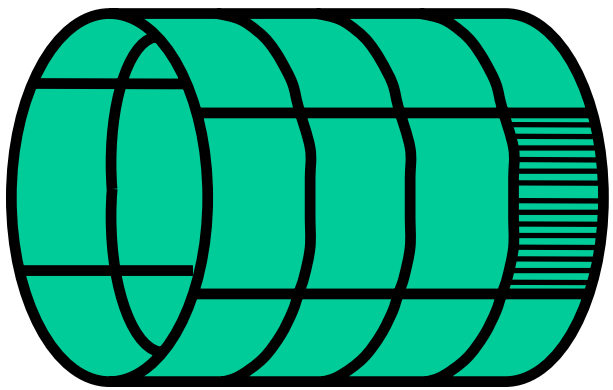
2001 Trigger and Data Sets

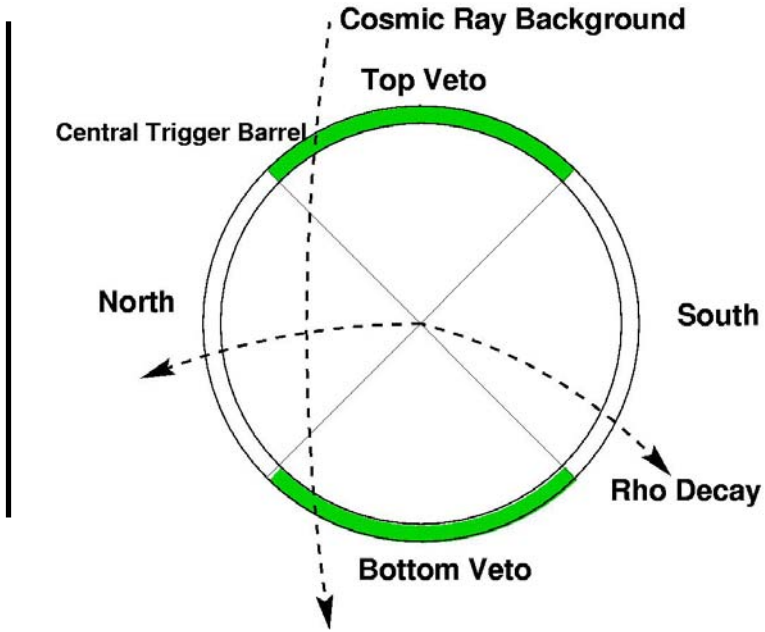
Minimum Bias Sample

- Coincident Signal in both ZDC's
- Select low multiplicity N_{tracks}<10
- ~800k triggers

Topology-Trigger

- CTB divided by readout in 16 'pixels' phi*eta = 1.5 * 0.5
- 9hrs, 30k triggers





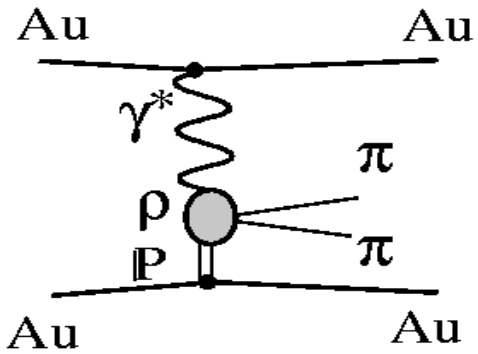
L0 CTB Trigger:
- Top-Bottom Veto
- 1-2 hit North and 1-2 South
- Output 20-40 Hz

L3 Trigger (online reconstruction)
- Vertex and Multiplicity
- Output: 1-2 Hz

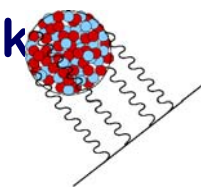
Transverse Momentum & Invariant Mass Spectra

Topology Trigger

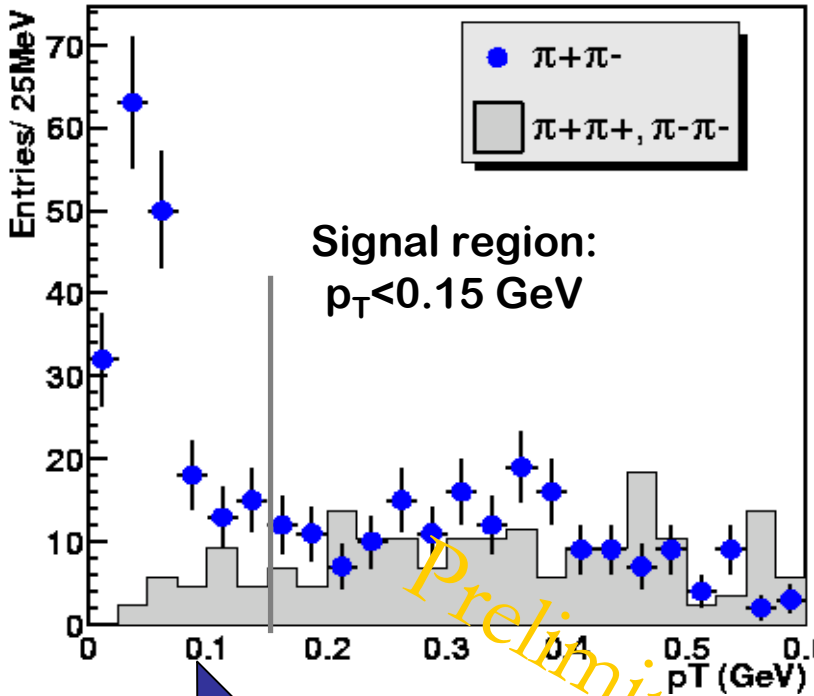
AuAu -> AuAuρ^0

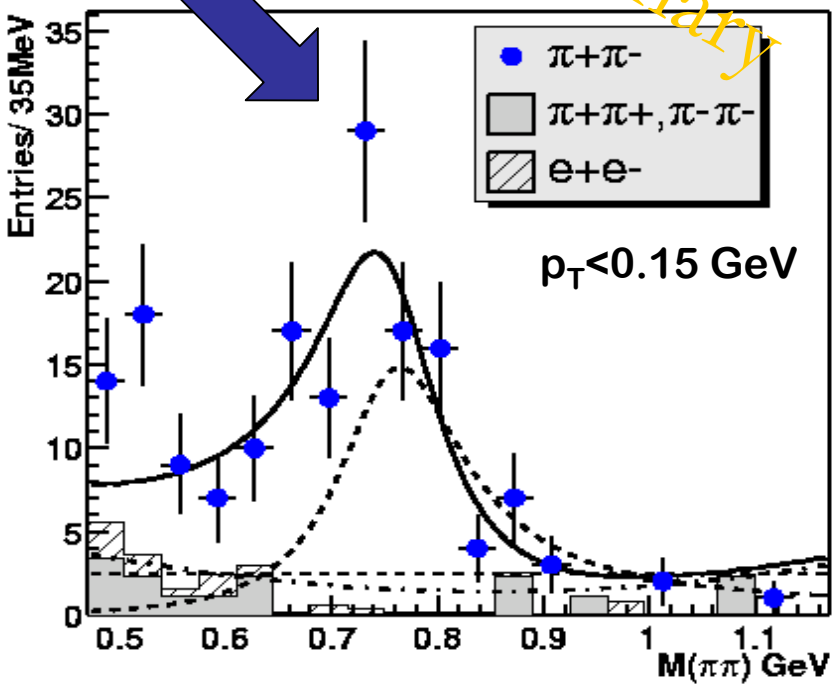


- Two track events, Vertex Requirements
- Peak at low p_T
  ⇨ coherent Interaction
- Background model from like pairs normalized to data



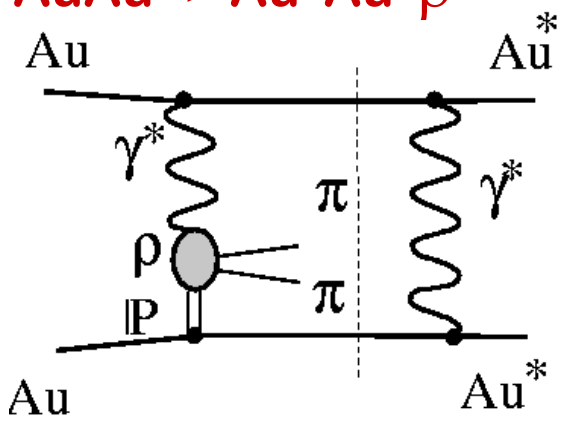
No neutron signal in ZDC ⇨
gold nuclei remain in ground state

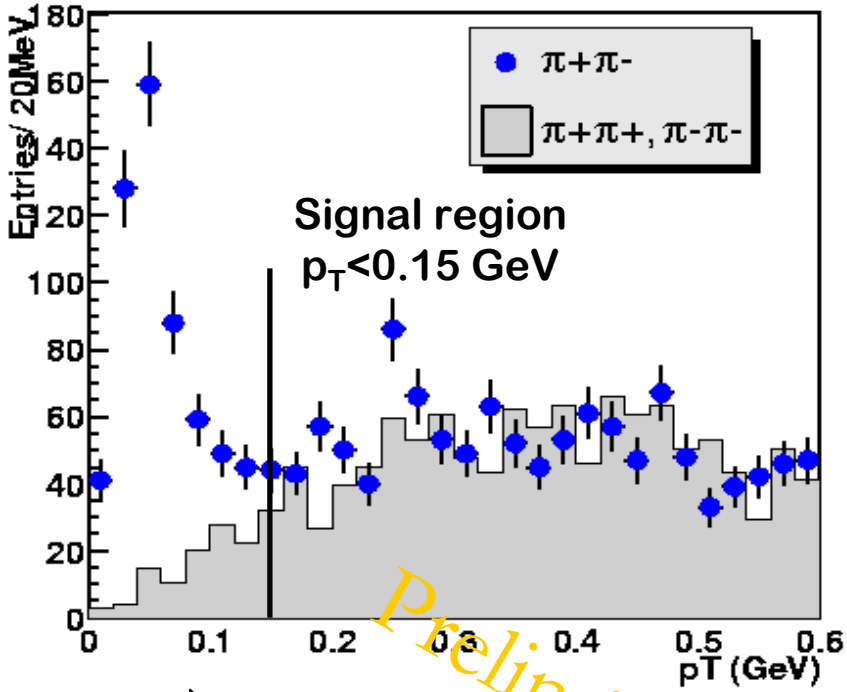




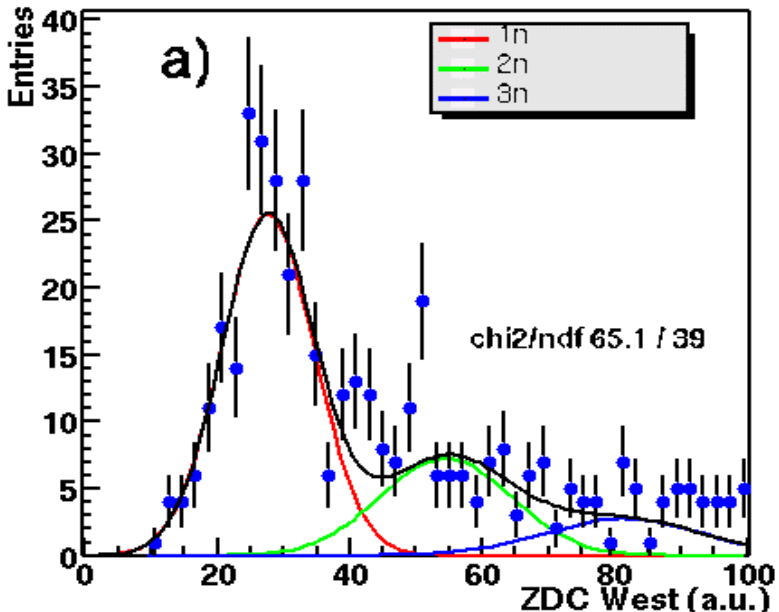
Meson Production with Nuclear Break-up

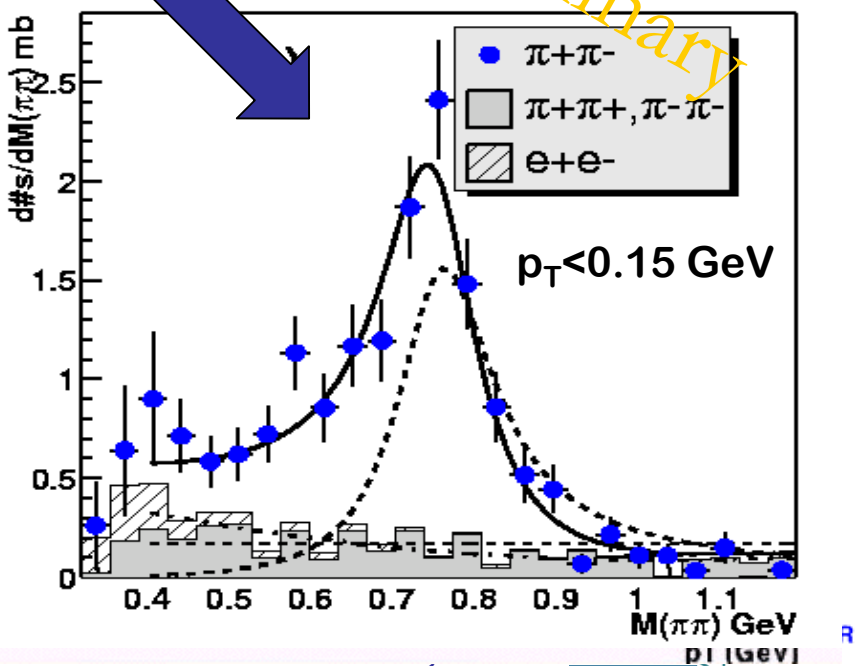
AuAu -> Au*Au*ρ^0





ZDC Response

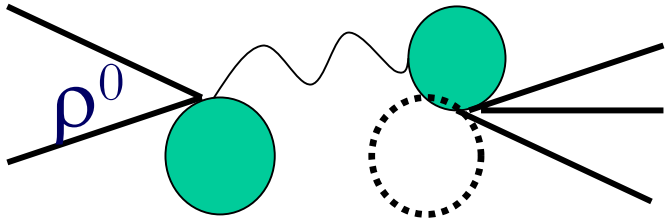




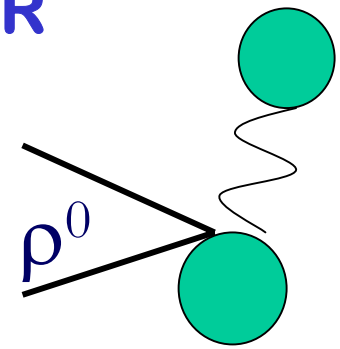
Separation Coloumb/Hadronic

UPC+hadronic b~2R

⇨ additional vertex tracks

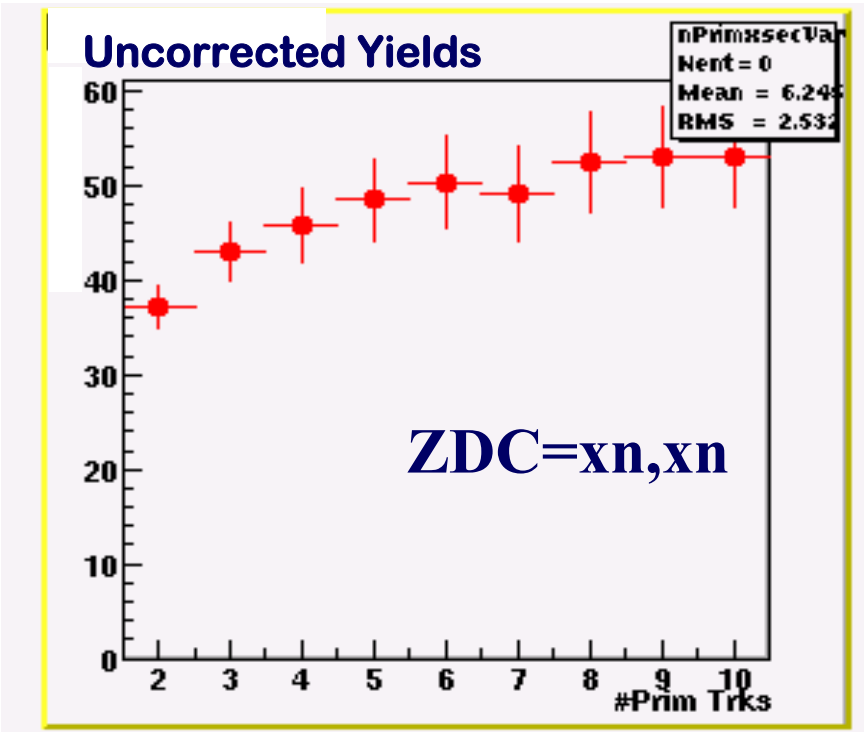


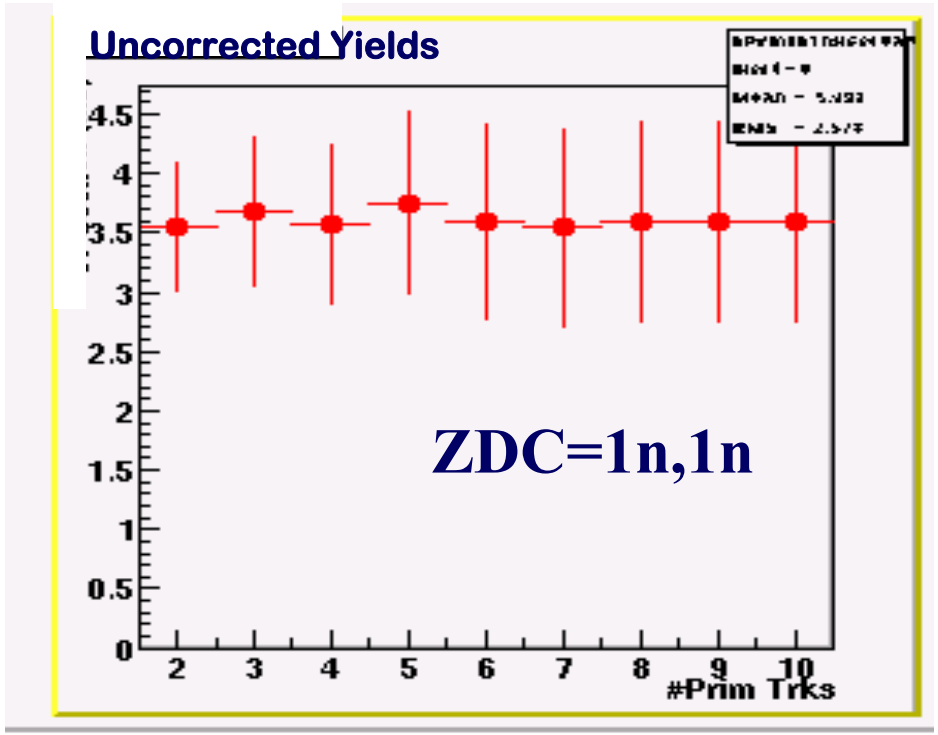
UPC b>2R



Events with additional vertex tracks contribute 40% to ρ signal

No contribution from overlap for single neutron (1n,1n) emission





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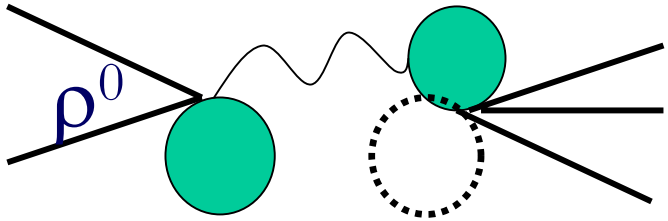

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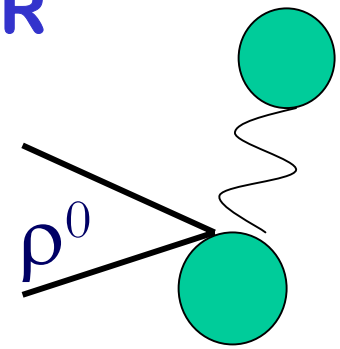
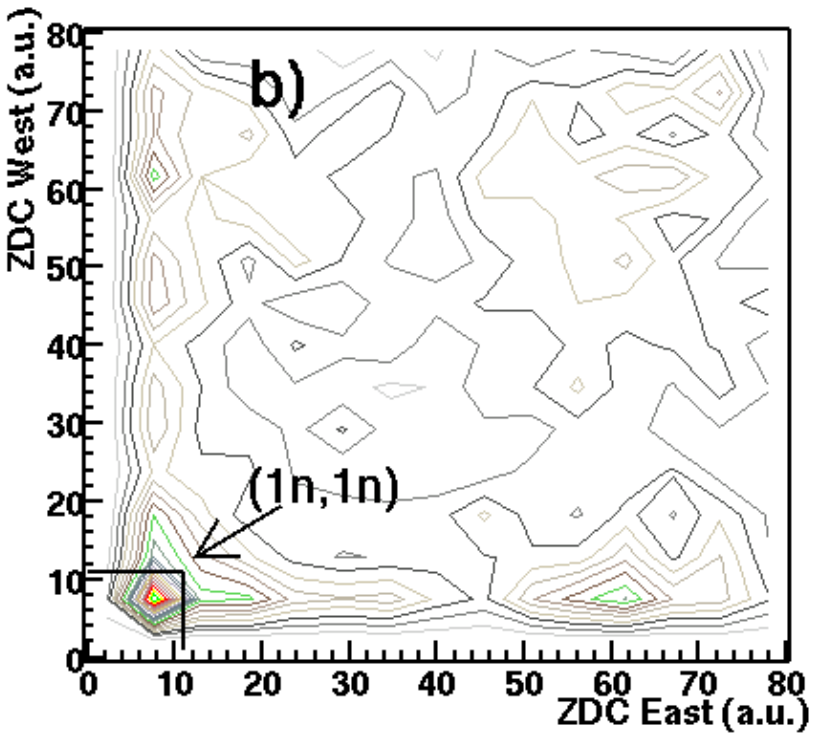




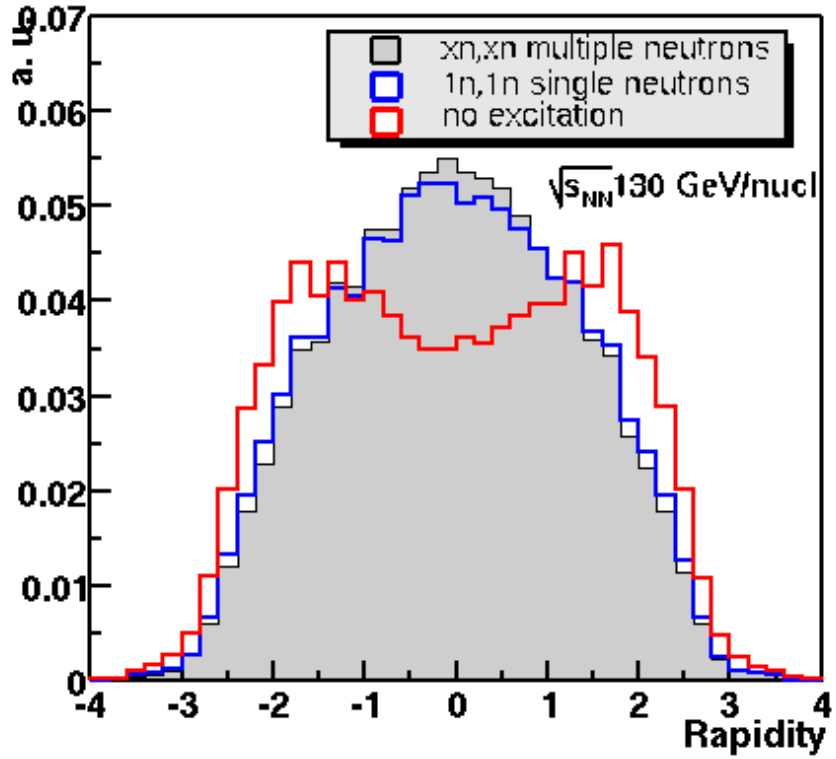
- Separation by ZDC signals
  ⇨ Impact parameter tagging.
- Hadronic AuAu:
  multiple neutrons in ZDC
- UPC: Coulomb excitation ⇨ GDR ⇨ single neutron emission
  ρ & (1n,1n) ~ 6% of ρ & (xn,xn)
- Compare to RHIC measurement of Coulomb Dissociation

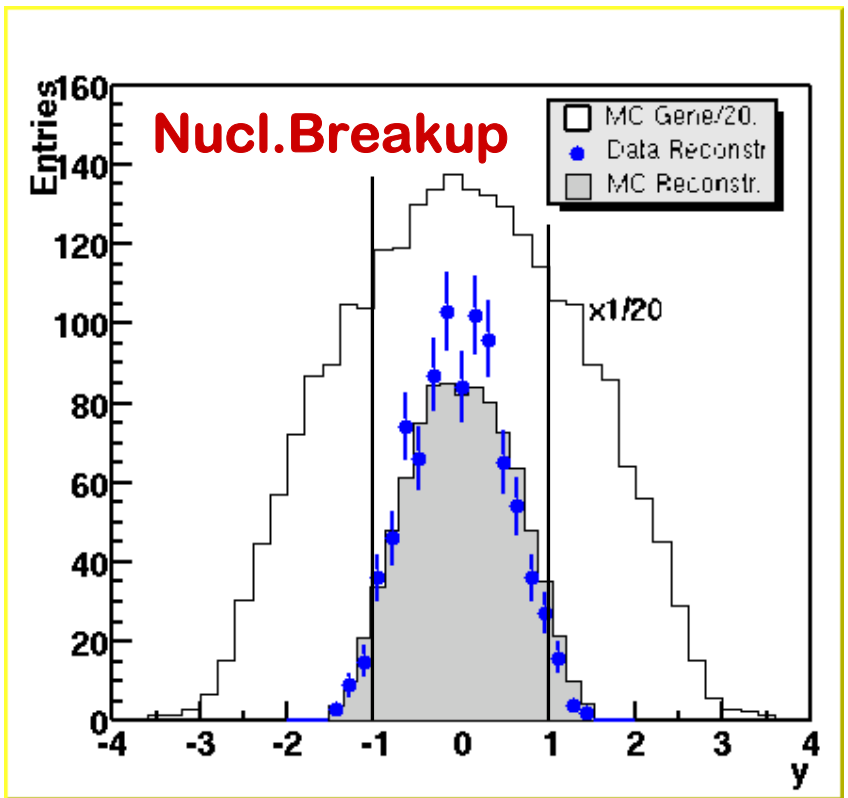
  $\sigma(1n,1n) = 4\%$ of σ_{Tot}

M.Chiu et.al nucl-ex/0109018

Rapidity Extrapolation

- Y-Distribution differs between ρ prod. with and without breakup
  (A. Balz,S. Klein,J. Nystrand, priv. com.)
- Included in MC simulation

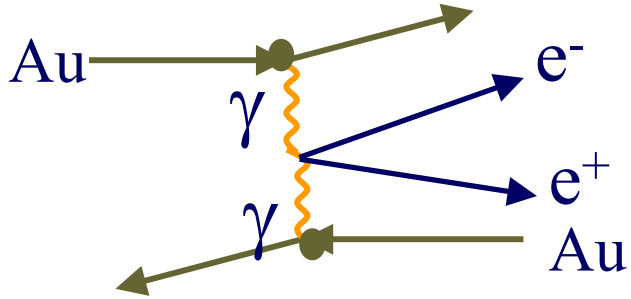




STAR Data

- Acceptance is flat in p_T and Mass
- Rapidity Acceptance only |y|<1
- Need to extrapolate
- All/|y|<1 = 2.0 for nucl. breakup

Electromagnetic Interaction $\gamma\gamma \rightarrow e^+e^-$

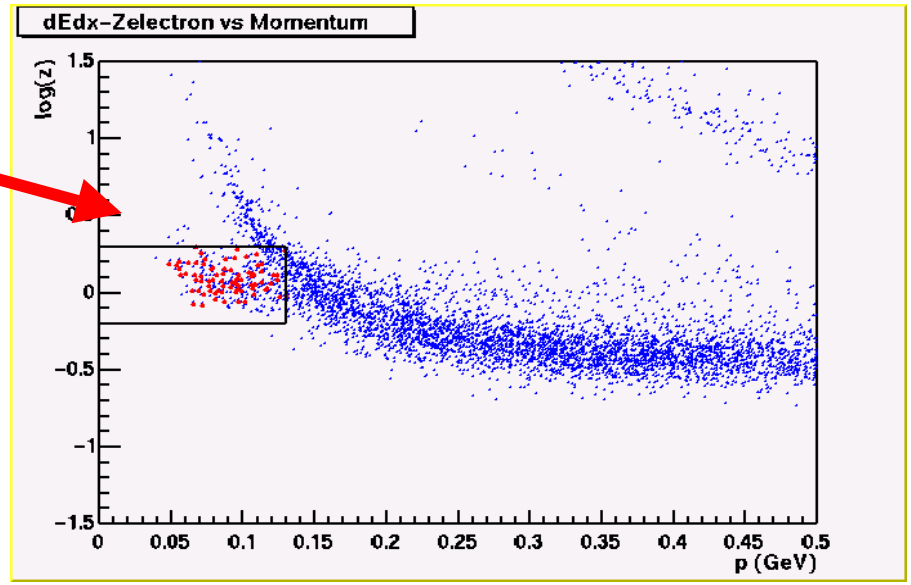


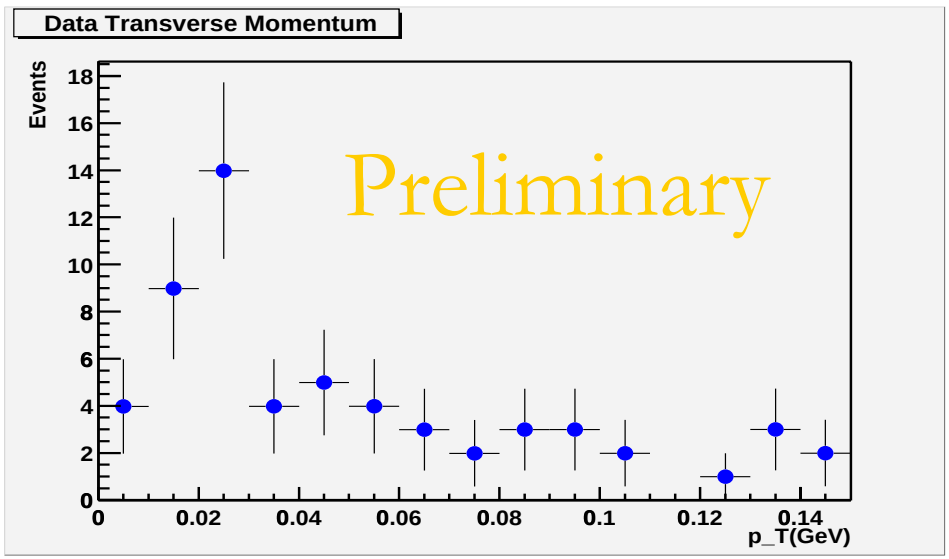
Identified e+e- Pairs

- Minimum bias trigger
- Calorimeter STAR in progress

⇨dE/dx for identification only at low momentum only p<0.13 GeV

- Here, background to ρ production
- Reconstruct e^+e^- in M($\pi\pi$) hypothesis
- MC simulation: extrapolate M($\pi\pi$) spectrum to all momenta.





e^+e^- Pairs are all at low p_T

⇒ AuAu->Au*Au*e^+e^-

Transv momentum $p_T < 2h/b$

Physics Topics:

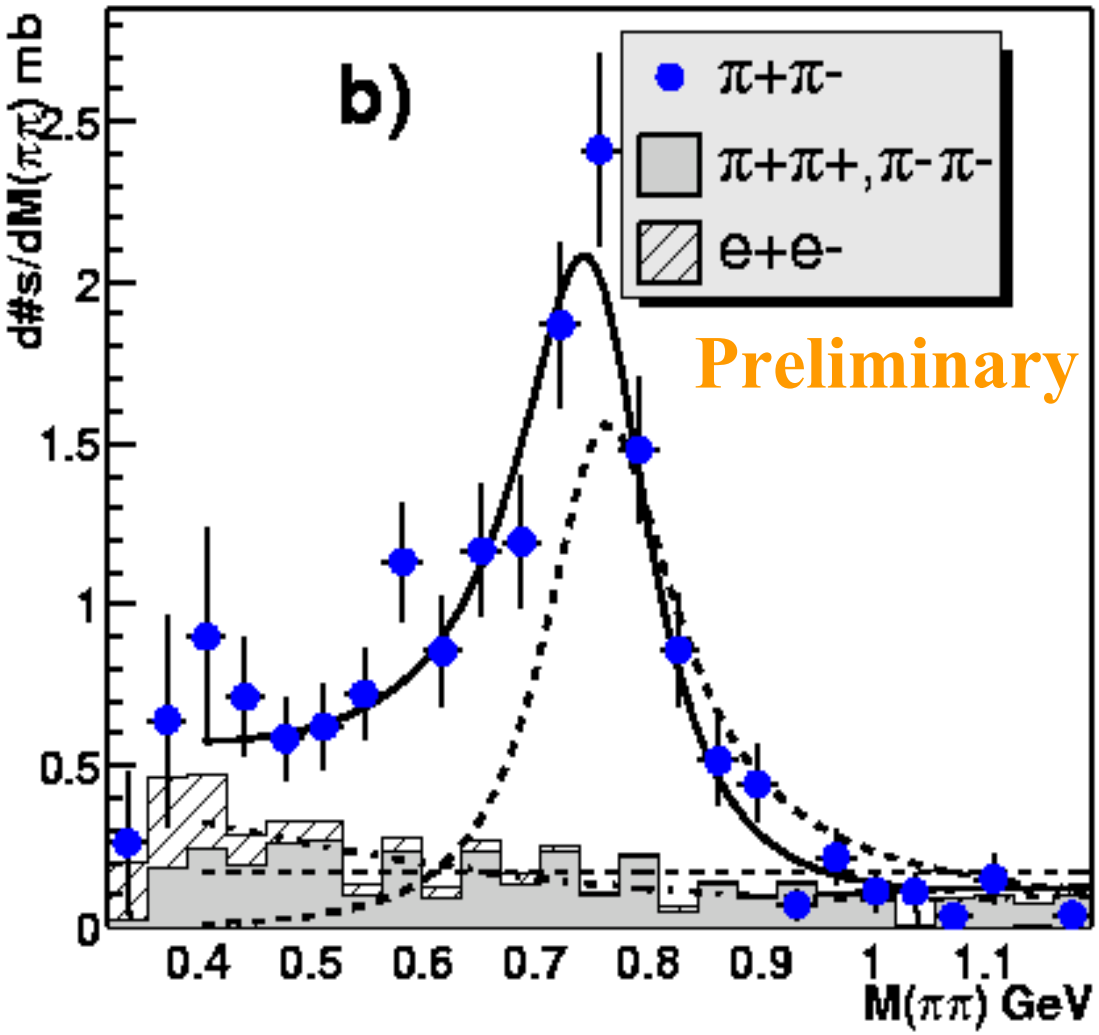
⇒Strong field QED $Z\alpha \sim 0.6$

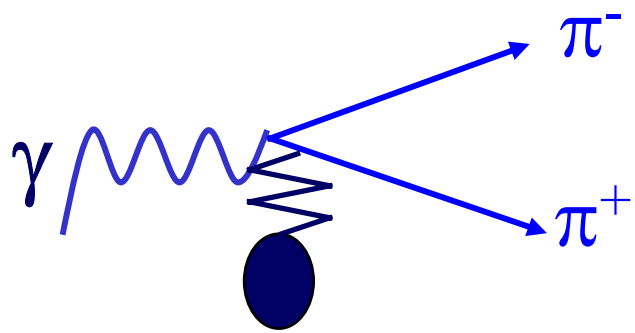
⇒Large cross section $\propto Z^4\alpha^4$

Falk Meissner, LBNL

ρ Mass Fit

$$\frac{d\sigma}{dM_{\pi\pi}} = \left| A \frac{\sqrt{M_{\pi\pi} M_\rho \Gamma_\rho}}{M_{\pi\pi}^2 - M_\rho^2 + i M_\rho \Gamma_\rho} + B \right|^2 .$$





$\gamma A \Rightarrow \pi^+ \pi^- A$

- Acceptance corrected
- Breit-Wigner+direct pion pair production+ BG
- Background contribution at low mass from e^+e^- pairs
- Amplitude ratio $|B/A|=0.86\pm0.15\ GeV^{-1}$

Cross Section Results

- Minimum bias data: luminosity normalization from 7.2b hadronic AuAu cross section
- Systematic uncertainties ~20%

  luminosity, overlap, vertex, tracking, simulations, single neutron peak selection

Preliminary

$$\sigma(AuAu \to Au^{*}_{1n} Au^{*}_{1n} \rho^{0}) = \mathbb{O}(\ \ 2\text{mb} +\text{-}35\%\ )$$

$$\sigma(AuAu \to Au^{*}_{xn} Au^{*}_{xn} \rho^{0}) = \mathbb{O}(\ 30\text{mb} +\text{-}25\%\ )$$

- Topology Trigger

  (2000 test trigger, efficiency triggers missing)

  Estimate

$$\sigma(\text{AuAu} \to \text{AuAu}\rho^{0}) \sim 250\ \text{mb} -50\% +100\%$$

Outlook 2001 Data

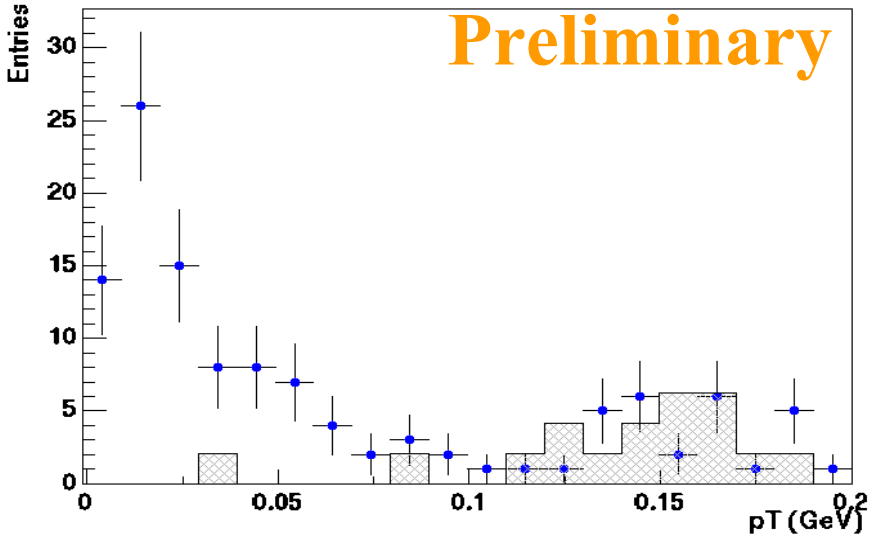
Full field acceptance smaller (1/2) than 2000

Identified electrons: Au Au-> Au*Au* e^+e^-

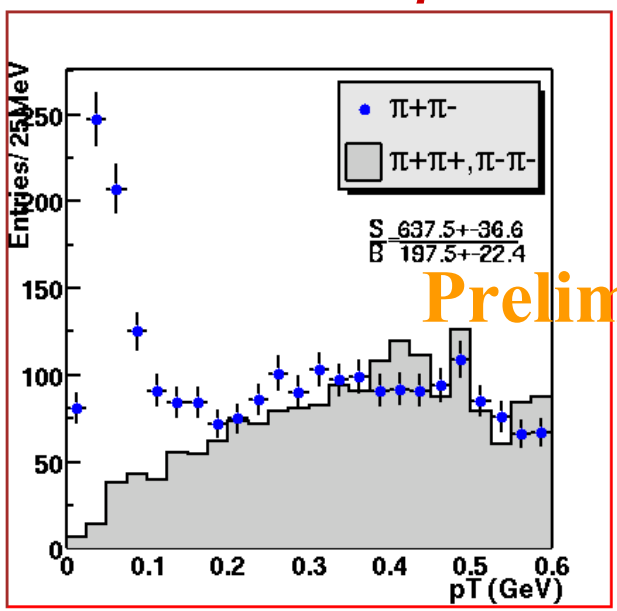
Minimum Bias Trigger

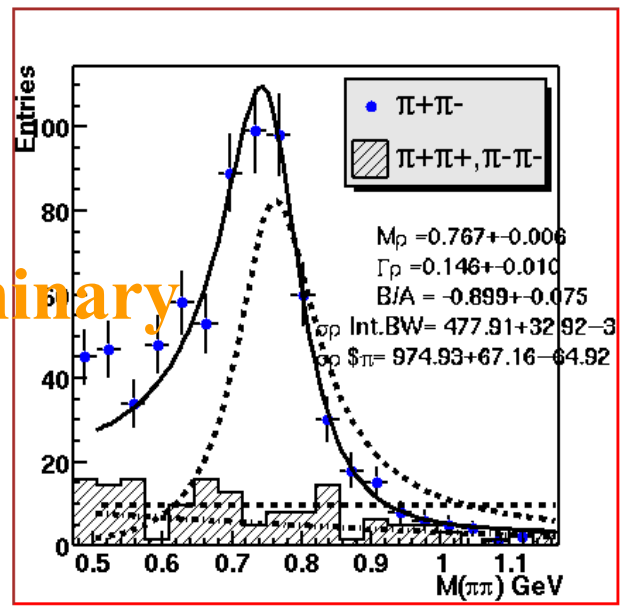
- ZDCcoincidence +low multiplicity
- About 10x more ρ statistics than 2000
- ~3000 ρ events

Plots: sub-sample of data ~25%



AuAu -> Au^*Au^*+ρ





Outlook 2001 Data

Topology Trigger

AuAu -> Au Au ρ

Programmed into digital trigger logic

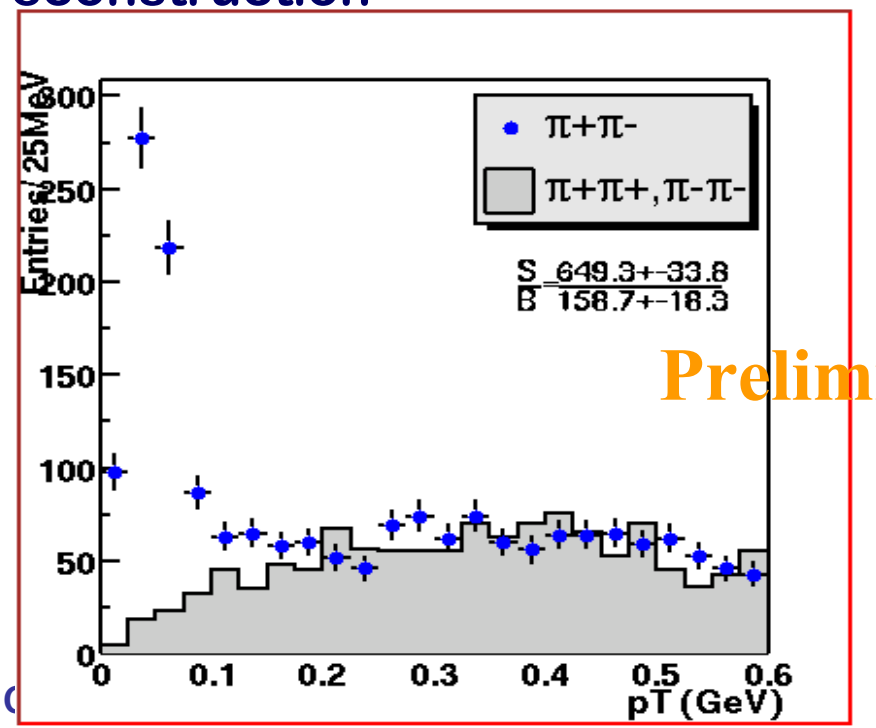
⇨ run in parallel to central trigger

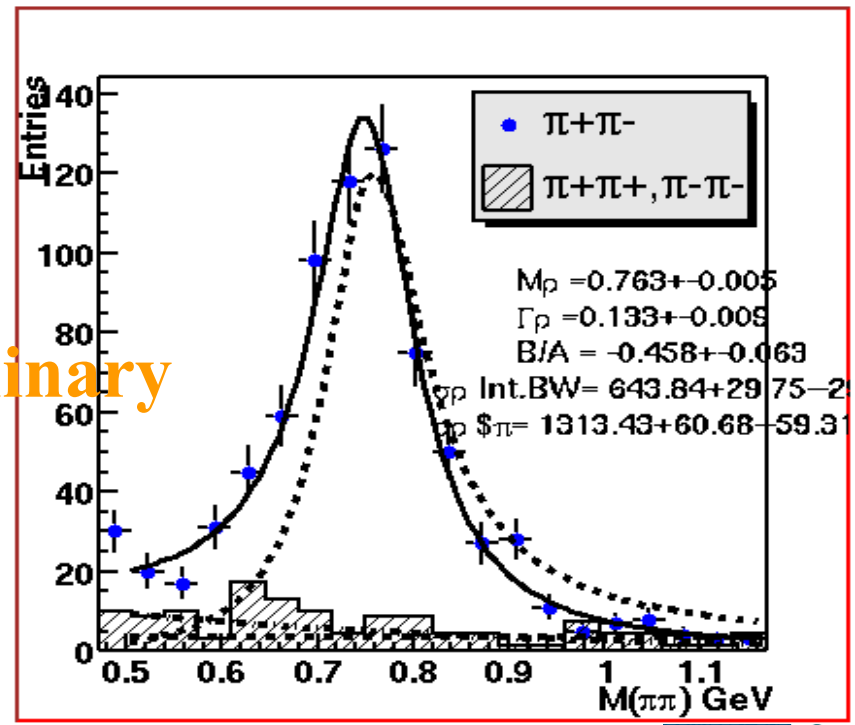
L0 rate ~ 2*central collisions trigger rate (20-40Hz)

10-15% accepted by online reconstruction

Plots correspond to 3% of data

Total ~25k ρ = x50 w.r.t. 2000!





Preliminary

Summary

First observation of coherent meson production in ultra-peripheral heavy ion collisions with and without nuclear excitation

Au + Au -> Au + Au + ρ^0 and Au + Au -> Au* + Au* + ρ^0 .

Cross Sections in order of predictions:
factorization ok, extrapolation of γN to γAu ok

- **Amplitude ratio of direct π to ρ production comparable to γN scattering**
- **Paper draft in collaboration review**
- **2001 successful data taking**

  Topology trigger x50; Minimum bias x10 w.r.t. 2000
- **Analysis topics:**

  Excited vector mesons (ρ^*) - 4 prong events, higher mass states J/ψ, $\phi(?)$, e+e- pairs, interference of decaying particles

RHIC is a good place to study diffractive and electromagnetic processes in heavy ion collisions. Lots of data and physics topics.