

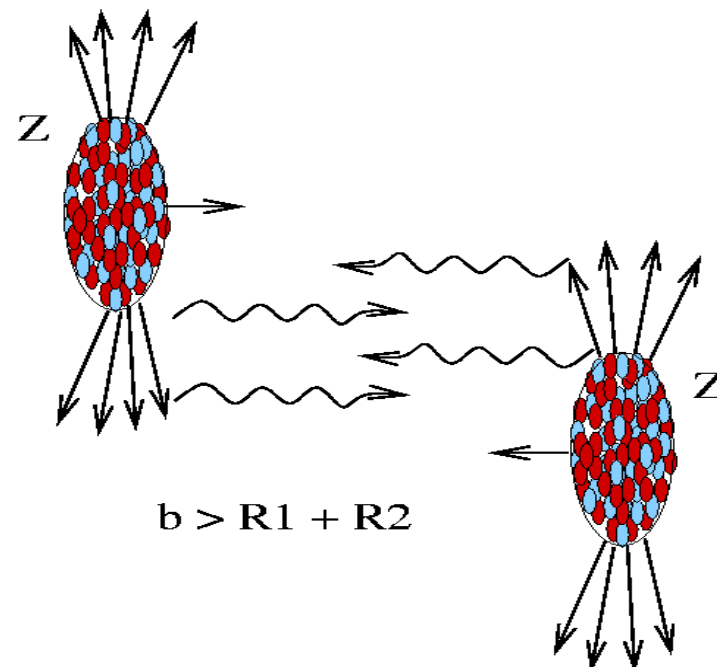
# Coherent Electromagnetic Interactions in Ultra-Peripheral Heavy Ion Collisions

Falk Meissner

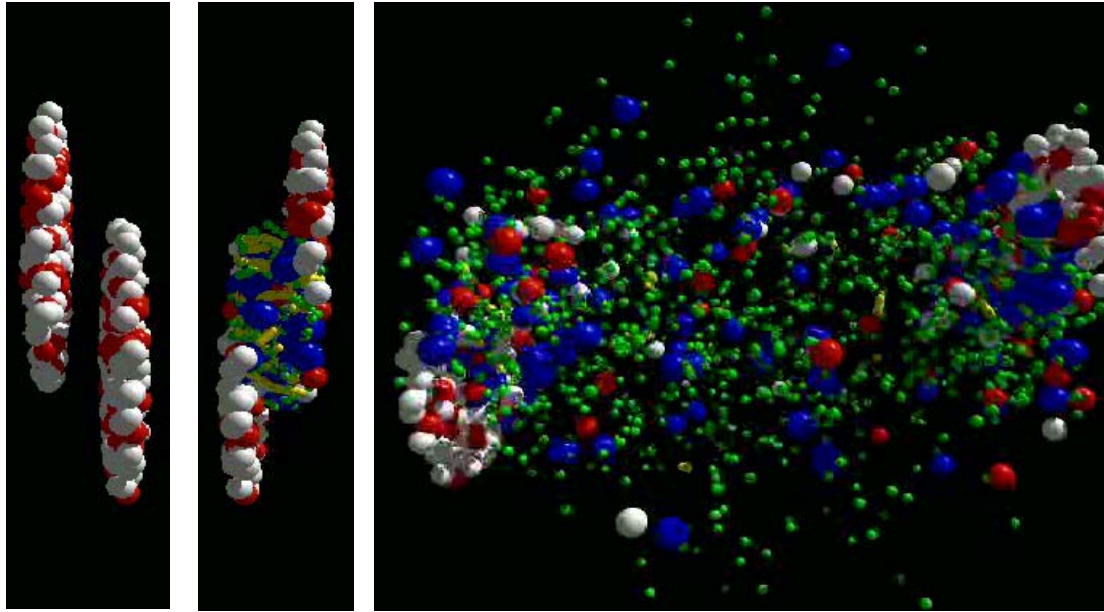
Lawrence Berkeley National Laboratory  
For the STAR Collaboration

Photon 2003  
April 2003

- 
- Ultra Peripheral Collisions
  - Exclusive Meson Production
  - Data Sets and Analysis
  - Cross Sections
  - Photon-Photon Interactions
  - Summary



# Heavy Ion Collision



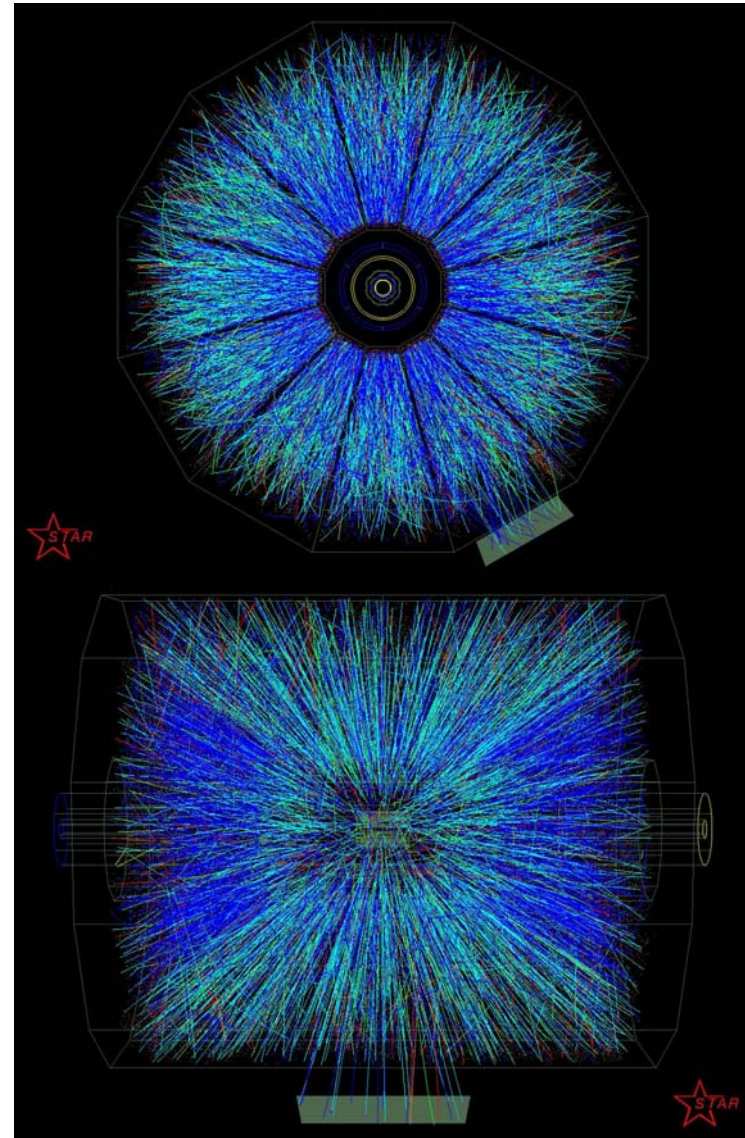
(Au Au, 200GeV/nucleon, University of Frankfurt)

## RHIC

2000 : AuAu @  $\sqrt{s_{NN}} = 130\text{GeV}$

2001 : AuAu,  $\bar{p}\bar{p}$  @  $\sqrt{s_{NN}} = 200\text{GeV}$

2003 : dAu,  $\bar{p}\bar{p}$  @  $\sqrt{s_{NN}} = 200\text{GeV}$



# Ultra-Peripheral Collisions

Nuclei 'miss' geometrically and  
via long range fields

interact

Coupling strength  $\Rightarrow$  large cross sections

- Photon- $\gamma \propto Z^2$

Equivalent Photon Approximation (Weizsaecker-Williams, Fermi)

- Pomeron-P  $\propto A^{4/3}$  (surface) to  $A^2$  (volume)

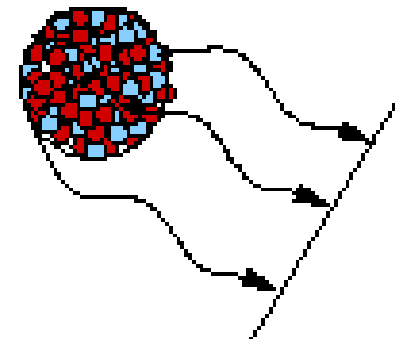
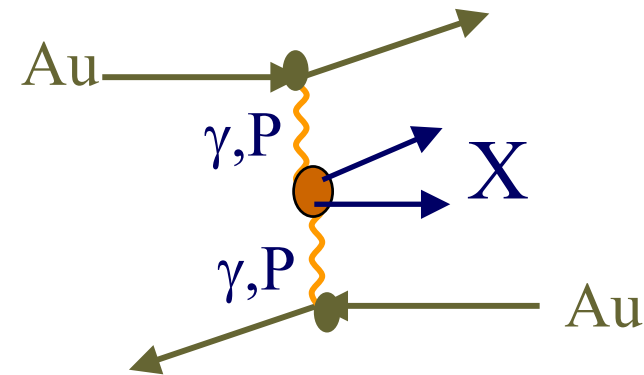
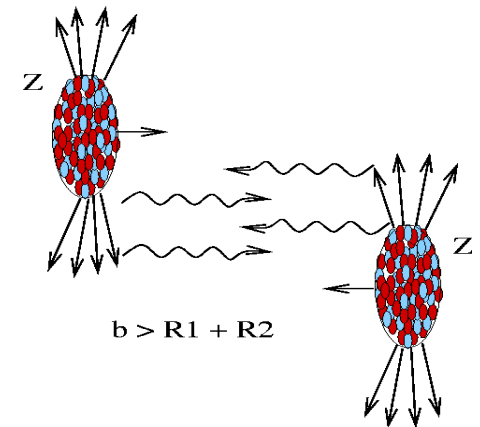
Coherent coupling to extended charge of both  
nuclei

- $\Lambda_\gamma, \Lambda_P > R_A$

$\Rightarrow$  **Small transverse momentum:**

$$p_T < h/2R_A \sim 90 \text{ MeV}$$

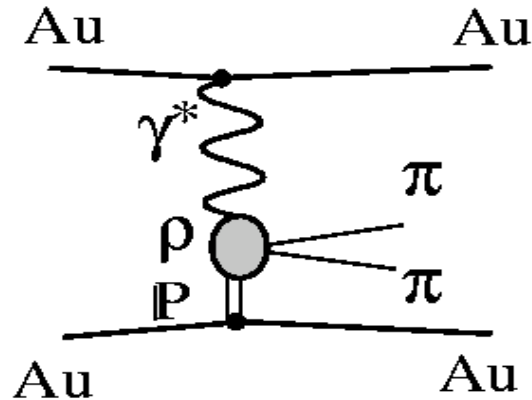
- Longitudinal component  
 $P_L < \gamma h/2R_A \sim 6 \text{ GeV}$
- Quasi Real Photons



# Exclusive Vector Meson Production $\gamma A \rightarrow VA$

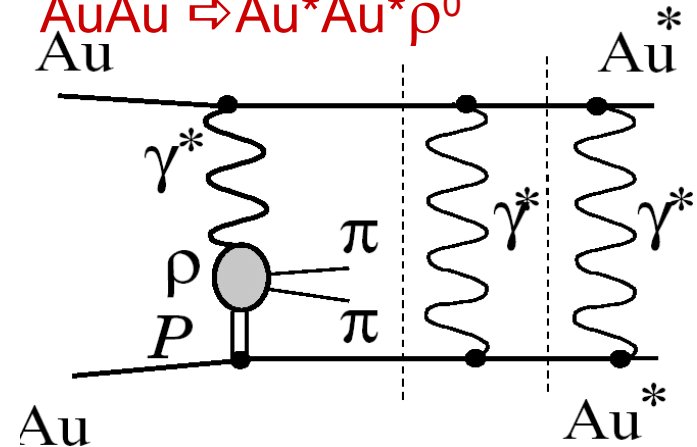
Exclusive  $\rho$  production

$AuAu \Rightarrow AuAu\rho^0$



... with nuclear excitation

$AuAu \Rightarrow Au^*Au^*\rho^0$



- Extrapolate  $\gamma p \rightarrow Vp$  to  $\gamma A \rightarrow VA$  with Glauber calculation

$\Rightarrow$  Large cross sections:

350 mb at  $s_{NN}^{1/2} = 130$  GeV

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

S.Klein, J.Nystrand, Phys. Rev C60 014903 (1999),

A. Baltz, S. Klein, J. Nystrand PRL 89, 012301 (2002)

- Factorize as function of impact parameter

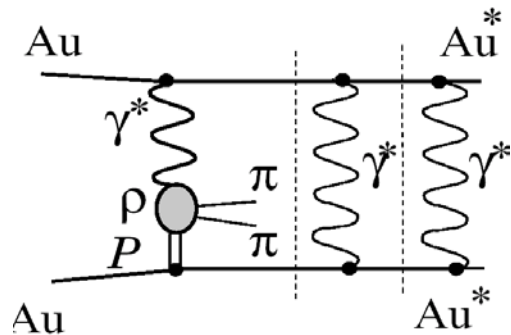
$$\sigma = \int d^2b P_{2GDR}(b) P_{\rho^0}(b)$$

- Nuclear breakup by single (1n1n) and multiple (xn) neutron emission
- single/multiple neutron emission selects different impact parameters

# Experimental Signature of UPC

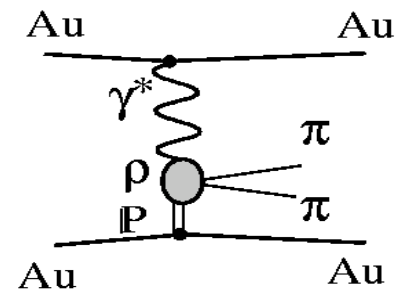
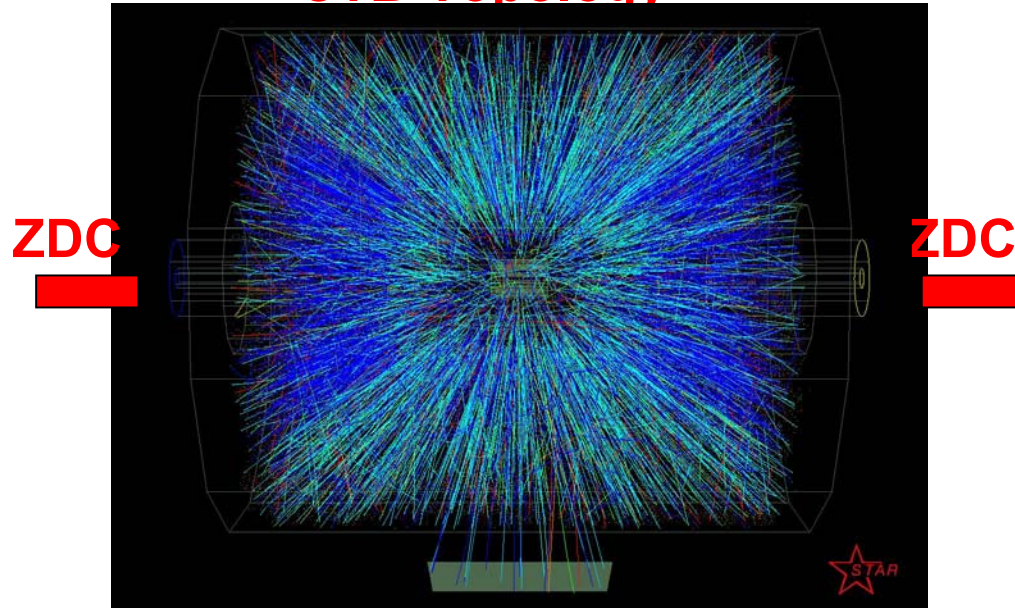
- Two oppositely charged tracks with vertex
- Low total  $p_T$
- Back-to-back in transverse plane

**Challenge: Trigger !**



Coincident signals from nucl. Breakup in zero degree calorimeters (ZDC)

**CTB-Topology**

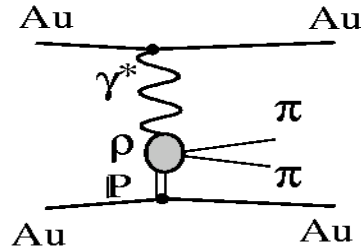


Topology requirements in central trigger barrel (CTB)

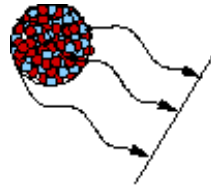


# Transverse Momentum & Invariant Mass Spectra

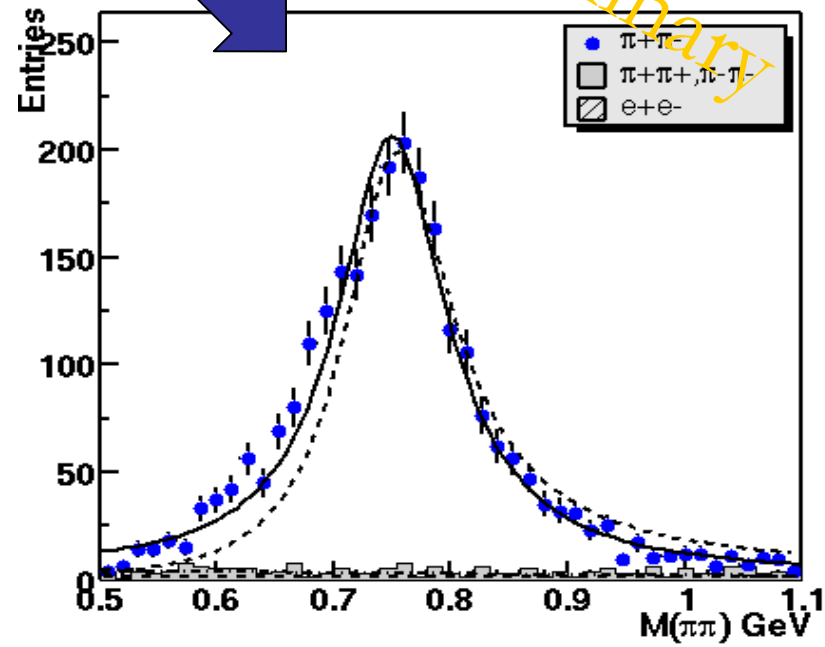
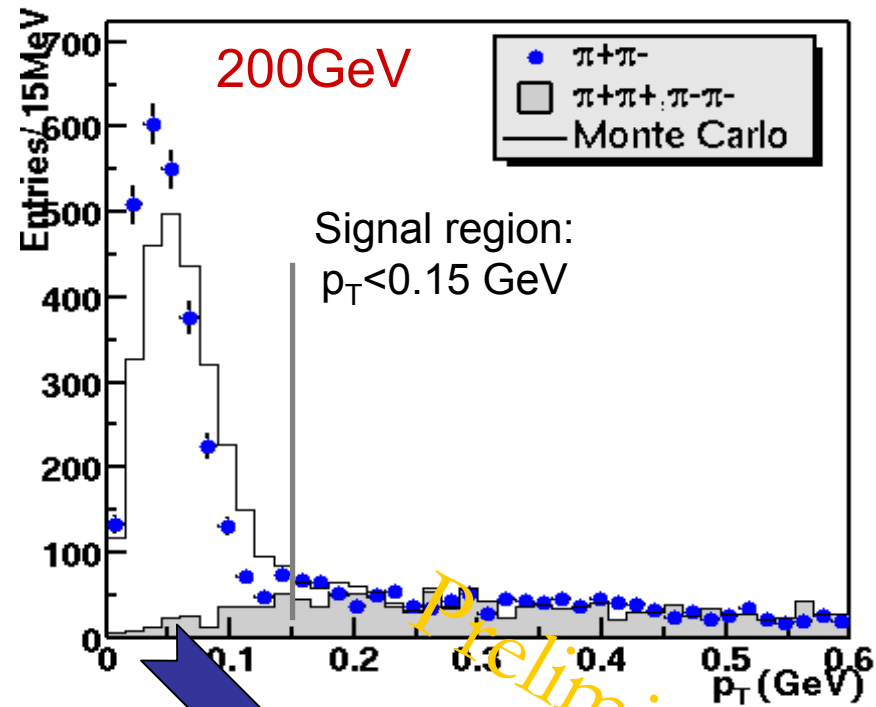
Topology Trigger  
 $AuAu \Rightarrow AuAu\rho^0$



- 2000: 130 GeV; 9hrs dedicated, 30k triggers
- 2001: 200 GeV; trigger mix 1.5M topology triggers
- Peak at low  $p_T$   
 $\Rightarrow$  coherent interaction
- Background model from like-sign pairs normalized to data



No neutron signal in ZDC  $\Rightarrow$   
 gold nuclei remain in ground state

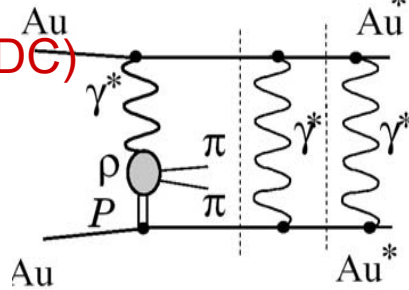


# Meson Production with Nuclear Break-up

Minimum Bias (ZDC)

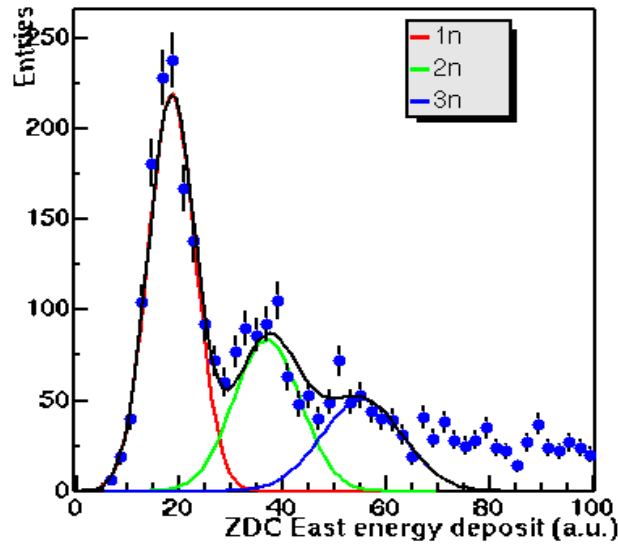
Trigger AuAu

⇒ Au\*Au\*ρ<sup>0</sup>

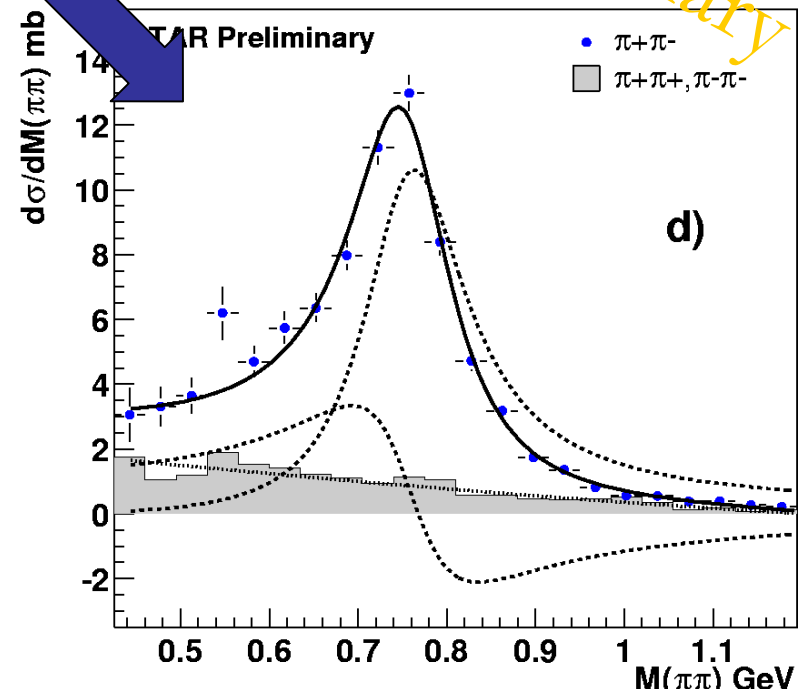
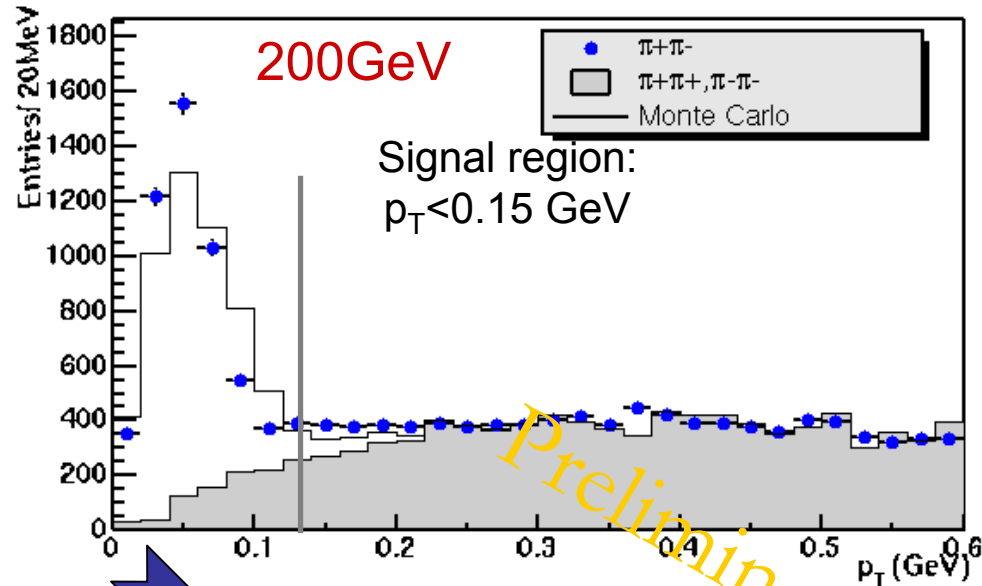


- 2000: ~400k triggers L~60/mb
- 2001: ~1.7M triggers L~250/mb
- Amplitude ratio  $\pi\pi/\pi$  similar to lepton nucleon scattering

## ZDC Response



Ph

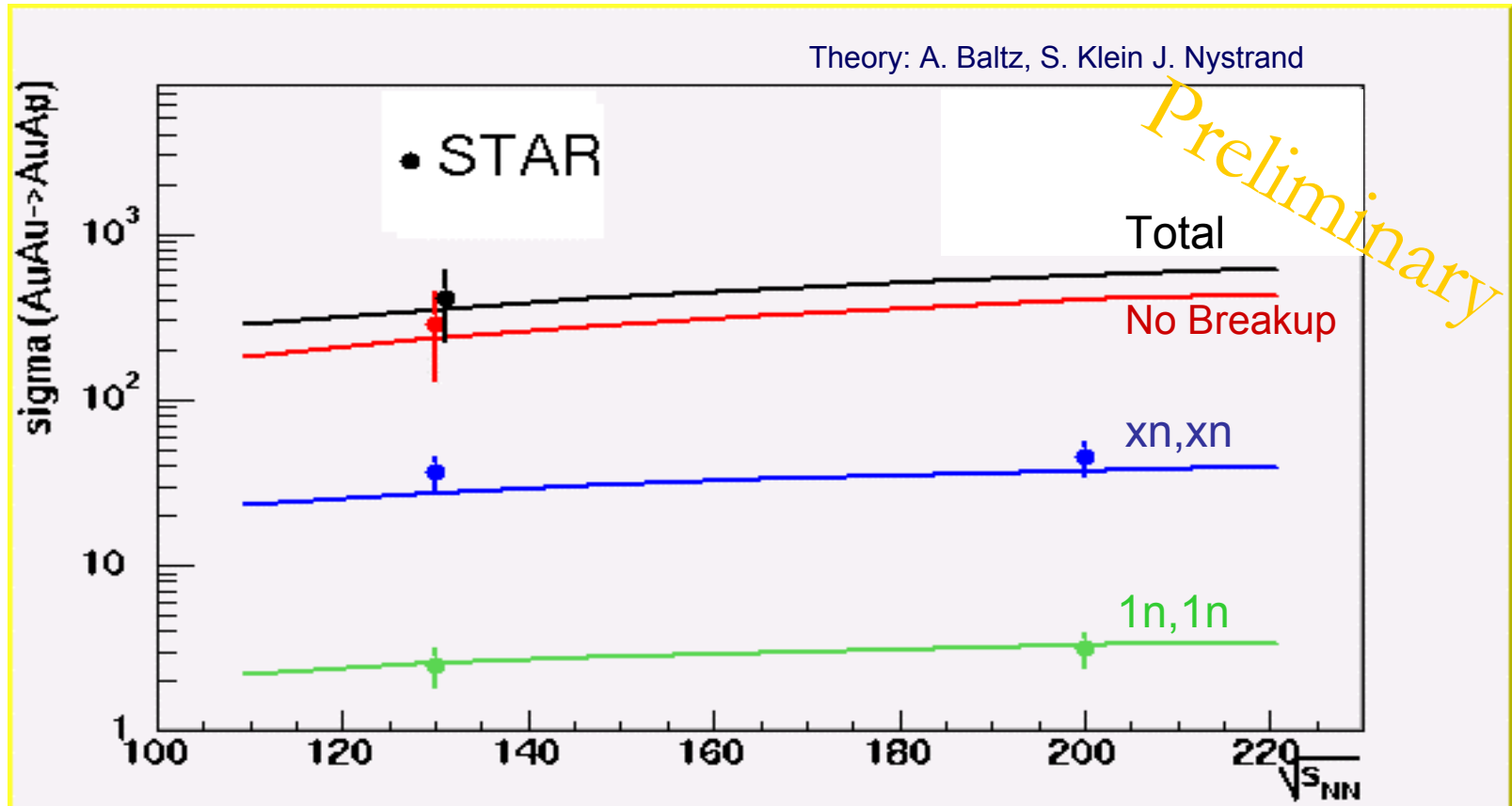


# Cross Section $\sigma$ ( $\text{AuAu} \rightarrow \text{Au}^{(*)}\text{Au}^{(*)}\rho$ )

130 GeV – PRL **89**, 272303 (2002), 200 GeV Preliminary

Luminosity normalization from 7.2b hadronic AuAu cross section

Systematic uncertainties ~20%





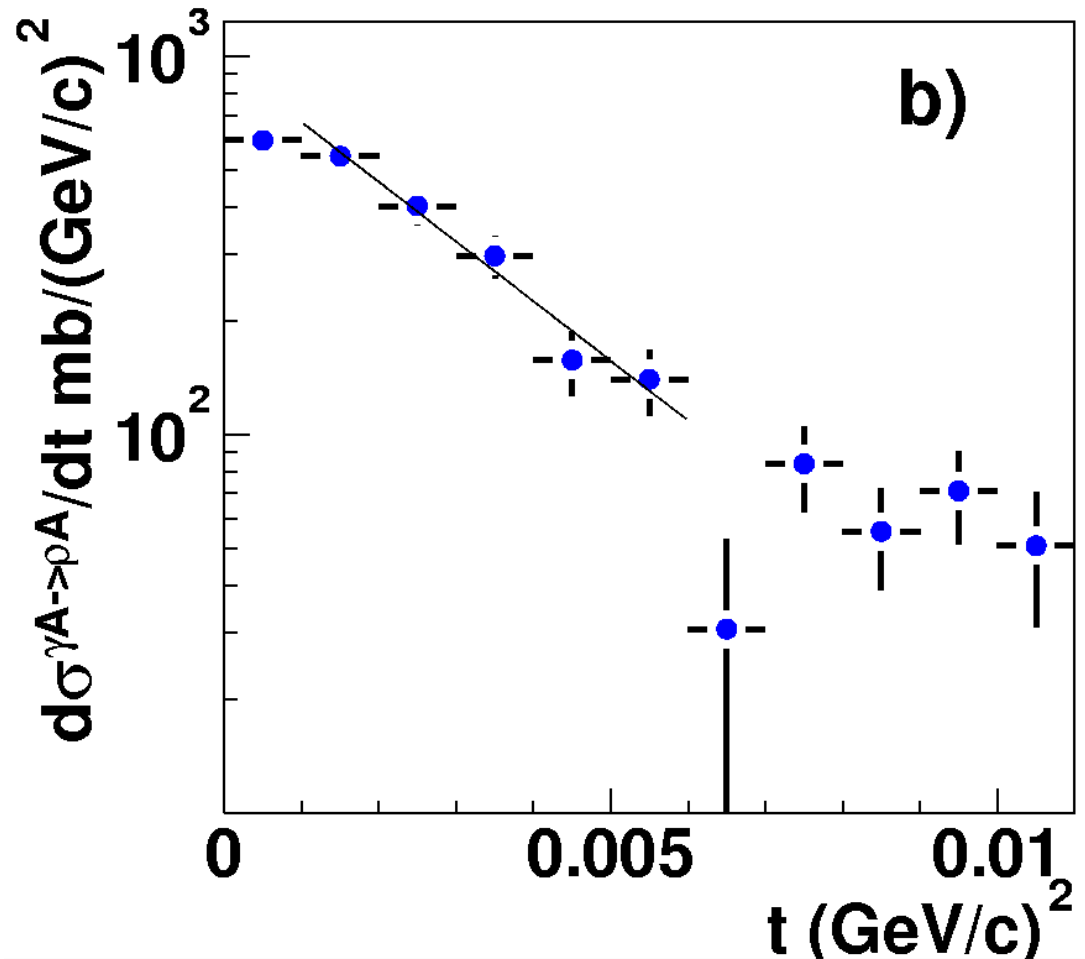
# t-Spectrum

Determination of  
Gold Radius

$$d\sigma^{\rho A} / dt \propto e^{-bt}$$

$$R_A = \sqrt{4b}$$

$$R_A = 7.5 \pm 2 \text{ fm}$$

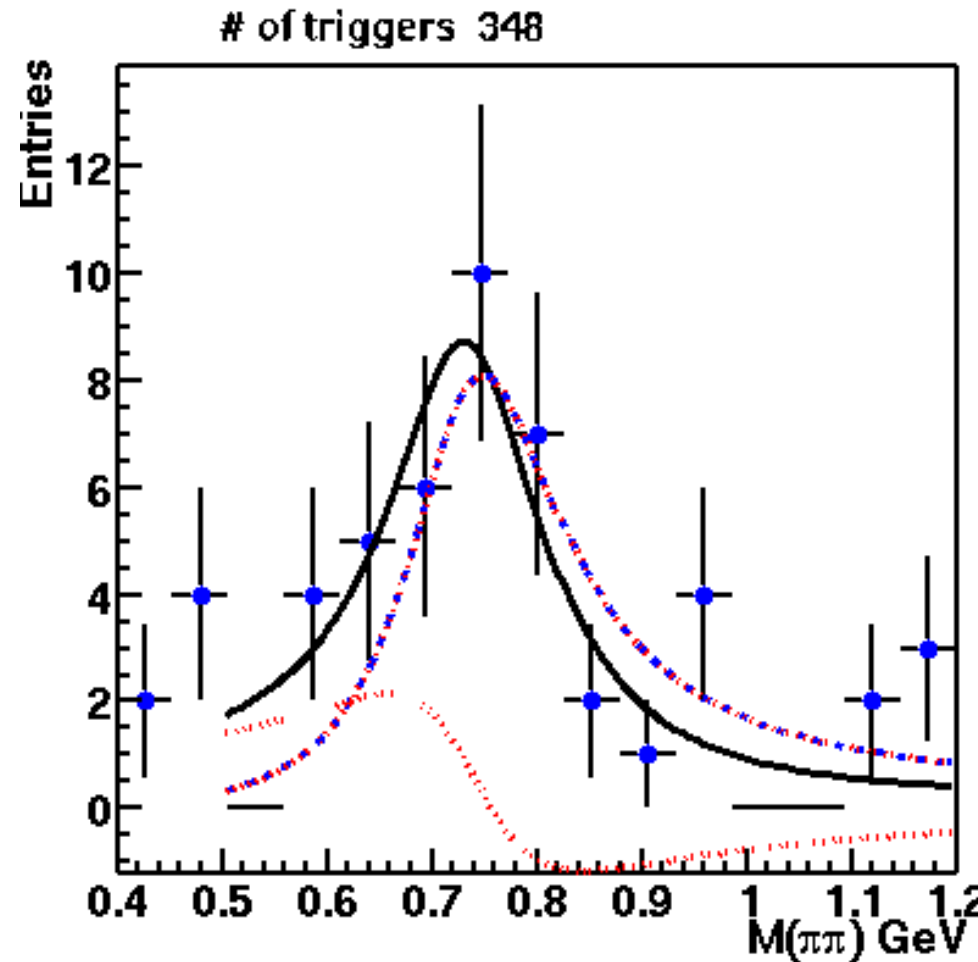


# Coherent Interactions in Deuterium-Gold

2003 dAu- $\rightarrow$   $\rho$ dAu

Golden photon torch on d

- $\sqrt{s} = 200\text{GeV}$
- Trigger on the breakup of the deuterium (ZDC)
- Level0 trigger purity 10% !!
- 0.9M events
- First results: clear signal (5 minute testrun) data is in production



# Two-Photon Interaction $AuAu \Rightarrow Au^*Au^*e^+e^-$

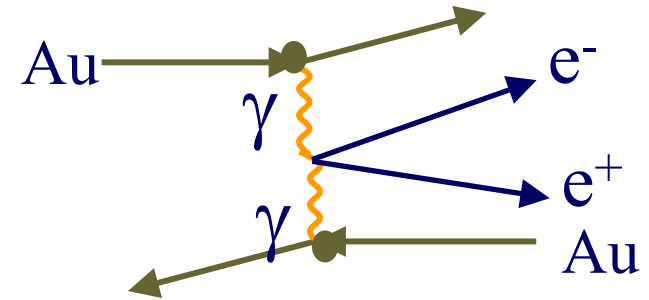
## Identified $e^+e^-$

via  $dE/dx$  only at low momentum  $p < 0.13$  GeV

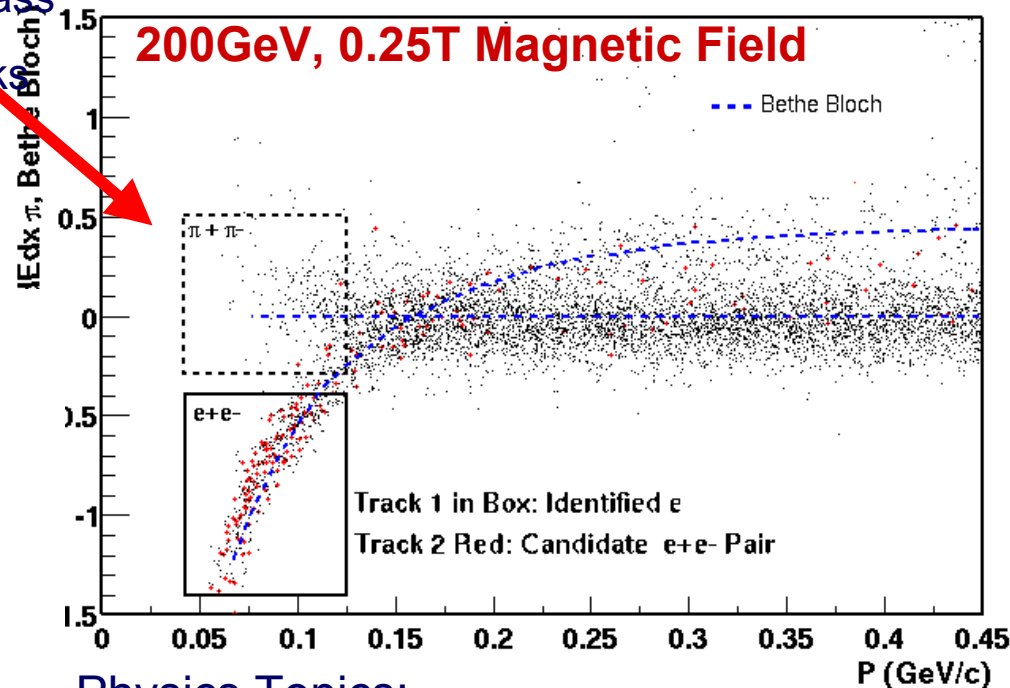
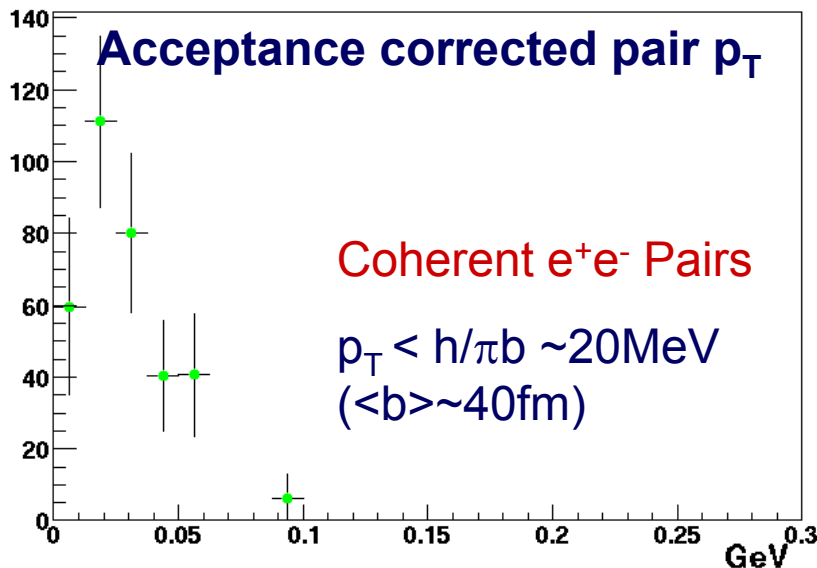
Small acceptance ( $\sim 10^{-6}$ ) for  $e^+e^-$  pairs

cross section is peaked in the forward region and at low (non-reconstructable) invariant mass

Magnetic field cuts off very low momentum tracks ( $< 60$  MeV) where cross section is large



Corrected  $e^+e^-$  pair  $P_T$



Physics Topics:

$\Rightarrow$  Validity of WWA and factorization

$\Rightarrow$  Strong field QED  $Z\alpha \sim 0.6$

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

# Cross-section

Within acceptance

$0.14 < M_{ee} < 0.26$  GeV,  $|\eta| < 1.15$

$$\sigma_{measured} = 6.0 \text{ mb} \pm 17\% \pm 18\%$$

$$\sigma_{predicted} = 7.8 \text{ mb}$$

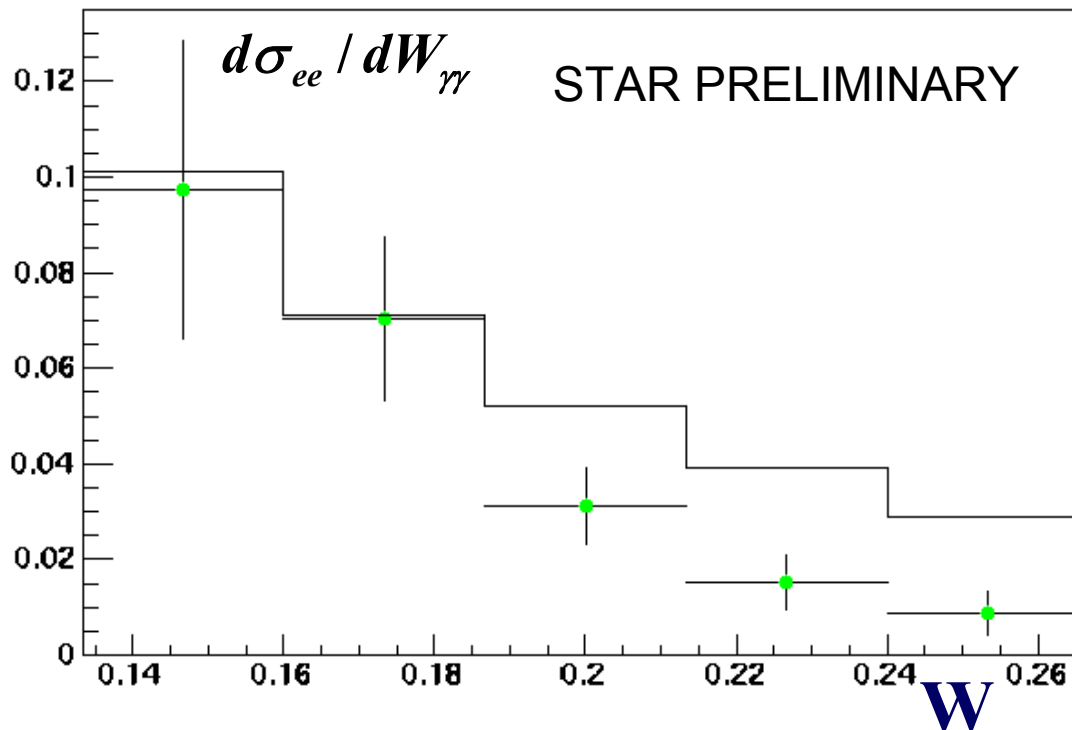
Total  $4\pi$  cross section 33kB!

Predictions

LO QED

S.Klein V.Morozov

Phd. Thesis V. Morozov



\* Normalized to total hadronic cross-section,

$$\mathcal{L} = 62 \text{ mbarn}^{-1}$$

10% systematic error

# Summary

- First measurements for coherent meson production in ultra-peripheral heavy ion collisions with and without nuclear excitation  
 $Au + Au \rightarrow Au + Au + \rho^0$  and  $Au + Au \rightarrow Au^* + Au^* + \rho^0$ .
- low  $p_T$  = coherent coupling
- Cross Sections agree with predictions  
=> Approximate factorization of rho-production and nuclear excitation  
=> Weizsaecker-Williams photon flux from large relativistic charges ok.  
=> Glauber extrapolation of  $\gamma N$  to  $\gamma Au$  ok
- Cross section for electron-pair production reproduced by LO calculations
- This is just the beginning; Future analysis topics:
  - Vector meson spectroscopy ,excited states ( $\rho^*$ , ...)
  - Multiple VM production
  - Hard diffraction - higher mass states  $J/\psi$
  - 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.**