# Probing the Initial State with Coherent Vector Meson Scattering in STAR Ultraperipheral Au-Au Collisions

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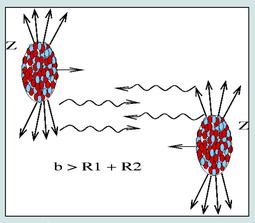
***Abstract***

Ultraperipheral collision events are effectively photoproduction on nuclear targets. These events provide an ideal proving ground for new programs in e+A physics. For the first time, STAR has collected a large enough sample of rho mesons to study their diffractive interaction with Au nuclear targets in detail. The transverse momentum distribution of rho mesons is sensitive not only to the distribution of nucleons in the target, but the dominance of Pomeron exchange at RHIC energies makes this distribution sensitive to the gluon distribution in nuclei. We will describe our latest work on diffractive scattering of rho mesons on Au nuclei and its comparison to several calculations based on different gluon exchange mechanisms. We will also present recent results of the measurement of J/Ψ photoproduction in 200 (GeV) AuAu collisions at RHIC. The $p_T$ distribution of the J/Ψ mesons peaks at very low $p_T$ , consistent with expectations for coherent Photoproduction. Both the photoproduction cross section and the J/ψ rapidity distribution are expected to show the effects of gluon shadowing. We will present a measurement of the ratio of J/Ψ to rho meson cross sections in 200 GeV AuAu collisions, as well as a distribution of J/Ψ rapidity within | y |< 1. The measured results will be compared to theoretical models.

## Ultraperipheral Collisions

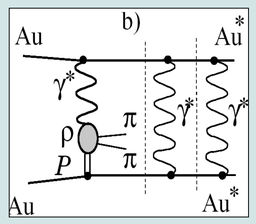
**Nuclei miss each other and interact via long range electromagnetic fields**

- Weizsacker-Williams: field of almost-real photons
- Virtuality $Q^2 < (h/R_A)^2$
- Max photon energy ~ $\gamma h/R_A$ ~ 3 GeV with gold at RHIC
- Photon flux ~ $Z^2$
  - Higher flux with heavy ions → greater probability of multi-photon interactions



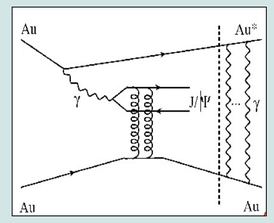

**Vector meson production**

- Photons fluctuate into quark-antiquark pairs
  - Scatter elastically from the other nucleus and emerge as real vector mesons
- Cross sections are large
  - Coherent production → low momentum transfer, ~ $\hbar/R_A$




**Interest in heavy vector mesons**

- J/Ψ, Ψ', Υ
  - Probe short distance scales
  - Scattering may be described via 2-gluon exchange
  - Sensitive to gluon distribution at
    - $x = M_V/2\gamma m_p \exp(\pm y)$ → $x \approx 10^{-2}$ and $Q^2 \approx M_V^2$
  - Directly probe 'new phases of matter' like color glass condensate

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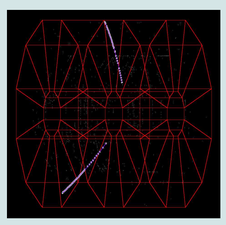
## Trigger and Event Selection

**UPC_main Triggers for 2010 dataset: 39 M events**

- At least 1 neutron in each zero degree calorimeter
  - Selects events with mutual Coulomb dissociation
- Low multiplicity
- BBC veto 2<|η|<5

**Analysis criteria**

- Hits on TPC > 14
- At least one track matches a TOF hit
- Pair $p_T$ < 0.15 GeV coherent production



A typical UPC event

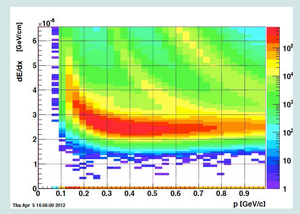
## Additional cuts used

**J\Ψ**

- $|Z_{vertex}| < 100$cm
- NO Particle Identification
- Vector meson rapidity: 0.05 < |y| < 1
  - Lower limit reduces cosmic rays
  - Upper limit from STAR TPC acceptance

**$\rho^0$ scattering**

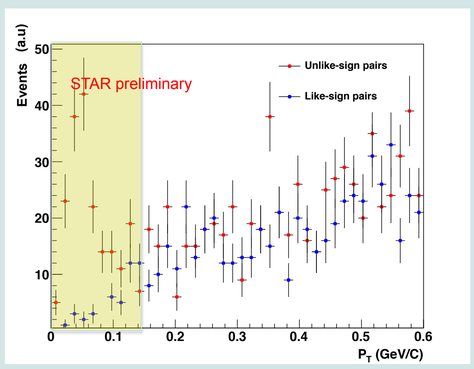
- Pion selection with TPC dE/dx
- Only two tracks out of selected vertex. Exclusive production.




## J/Ψ Analysis

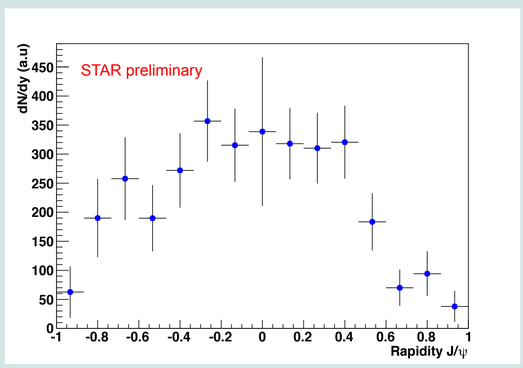
Pair $p_T$:

- Opposite-sign pairs with $3.0 < m_{INV} < 3.2$
- For analysis, only events with $p_T$ < 0.15 GeV are used




Pair rapidity:

- Efficiency-corrected
- Statistical errors only



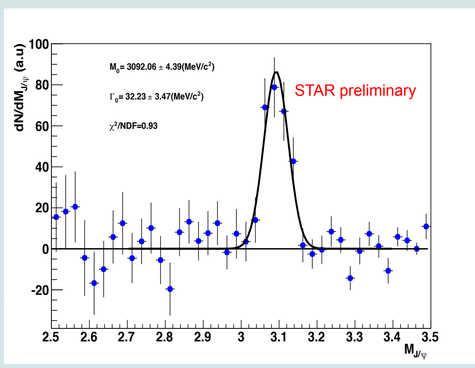

Systematics underway

Pair Invariant mass:

~ 245 J/Ψ

- Like-sign Background subtracted
- Efficiency-corrected

J/Ψ is fit with a Gaussian for J/Ψ Signal and a 1st order polynomial for background




Systematics underway

## Diffractive pattern produced by elastic $\rho^0$ scattering off Au nuclei

Ramiro Debbe (BNL) :

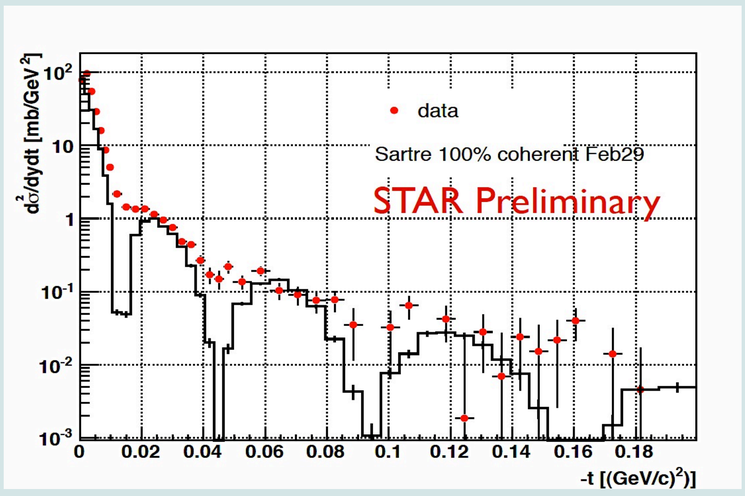
The diffraction pattern is evident up to its third peak, the slope of the first peak as well as the location of the peaks is consistent with the coherent interaction with an object with dimensions comparable to the Au nucleus.

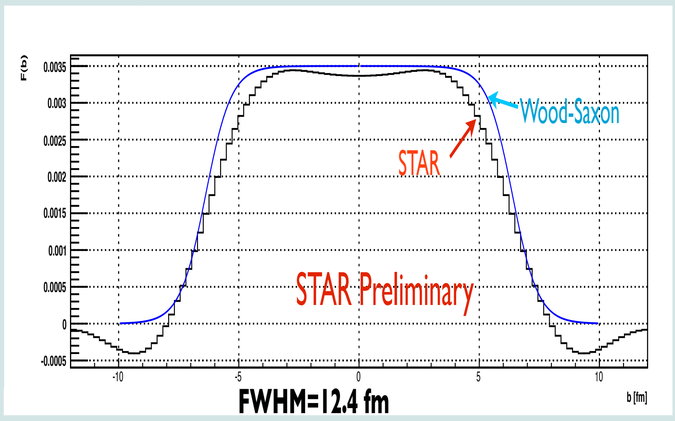
$$f(b) = \int_0^{2\sqrt{t_{max}}} \sqrt{F(x^2)}\, J_0(xb/\hbar c)\, \frac{x}{2\pi}\, dx$$

Fourier transformation of $d^2\sigma/dtdy$ relates to the partonic form factor of Au nuclei which agrees with the Wood-Saxon distribution.

Sartre is an event generator based on an impact parameter dependent dipole model T.Ulrich and T.Toll

INT-PUB-11-034, arXiv:1108.1713 [nucl-th]




Blue smooth curve is Wood-Saxon with parameters listed in table.

| Nucleus | A | R | a | w |
|---|---|---|---|---|
| C | 12 | 2.47 | 0 | 0 |
| O | 16 | 2.608 | 0.513 | -0.051 |
| Al | 27 | 3.07 | 0.519 | 0 |
| S | 32 | 3.458 | 0.61 | 0 |
| Ca | 40 | 3.76 | 0.586 | -0.161 |
| Ni | 58 | 4.309 | 0.516 | -0.1308 |
| Cu | 63 | 4.2 | 0.596 | 0 |
| W | 186 | 6.51 | 0.535 | 0 |
| **Au** | **197** | **6.38** | **0.535** | **0** |
| Pb | 208 | 6.68 | 0.546 | 0 |
| U | 238 | 6.68 | 0.6 | 0 |

H. DeVries, C.W. De Jager, C. DeVries, 1987 ATOMIC DATA AND NUCLEAR DATA TABL

## Conclusions

- STAR measured photoproduction of J/Ψ mesons in UPCs with 2010 data.
- Study of heavy vector mesons like J/Ψ will help us to understand initial state for central collisions.
- Diffraction pattern in $\rho^0$ has dips where predicted by Sartre, and that the size extracted from a Fourier transform is consistent with the expected size of a Au nucleus.

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