Ultra Peripheral Collisions at RHIC

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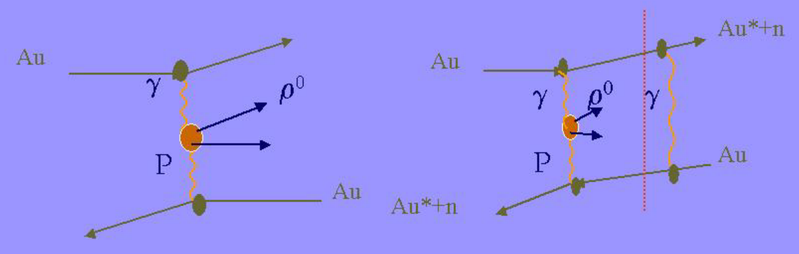
A relativistic heavy ion acts as a strong source of photons. In an Ultra Peripheral Collision the two ions 'miss' each other, and interact electromagnetic via their photon fields. Several processes can take place: two photons yield an electron-positron pair, or a photon emitted by the projectile ion fluctuates into a vector meson which scatters diffractively off the target ion.

Physics Topics

- $\gamma A \rightarrow VA$ coherent vector meson production
  - Non-local interference of unstable particles
  - Production cross sections
- $\gamma\gamma \rightarrow$ leptons, mesons
  - Strong Field QED $Z^*\alpha \sim 0.6$

Two Processes

$Au+Au \rightarrow Au+Au+\rho^0$ and $Au+Au \rightarrow Au^*+Au^*+\rho^0$



Coherent Coupling to both nuclei:
photon~Z^2, Pomeron~$A^{4/3}$

Small transverse momentum:

$p_t \sim 2h\gamma/R_A \sim 60$ MeV/c

Exclusive production of vector mesons

Large cross section:

380 mb for Au @130GeV/nucl.

Nuclei may be mutually excited

Nuclear Excitation

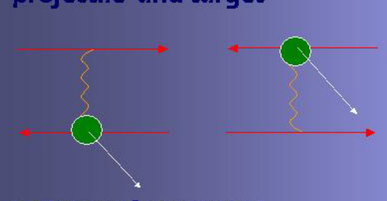
In addition to ρ^0 production, nuclei can exchange one or more separate photons and become mutually excited.

- Factorizes as function of impact parameter
- Estimates:
  - Given a ρ^0, probability of mutual excitation ~1%
  - Given a mutual excitation, probability of ρ^0 ~ 0.1%
- Decay yields neutrons in Zero Degree Calorimeter (ZDC) -> minimum bias trigger

An Example : Interference

Fundamental Quantum Mechanics at Work

Can't differentiate between projectile and target

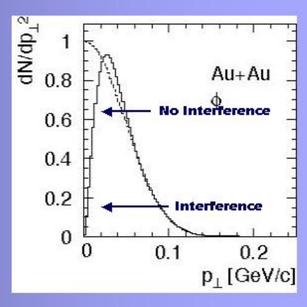


2-slit interferometer !

$\rho, \omega, \phi, J/\psi$ negative parity:

destructive interference at $p_t = 0$

Expected Signal



First Goal - Proof of Principle

Observe exclusive ρ^0 production in Ultra Peripheral Au Au Collisions

Two Data Sets

Ultra Peripheral Collisions Trigger

~ 7 hours of dedicated data collection

1-2 Hz to tape

30,000 triggers

Minimum Bias Trigger

For processes with nuclear excitation coincident neutron signals in ZDC

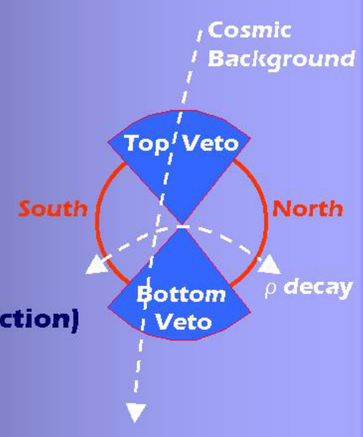
~500,000 trigger

Analyze both data sets separately

Ultra Peripheral Collisions Trigger

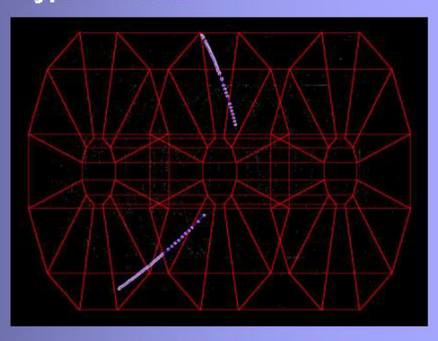
Level 0
- Back to back hits in Central Trigger Barrel
- Coincidence 1 North + 1 South hit
- Veto on top + bottom (reject cosmic rays)
- Rate 20-40 Hz

Level 3 (online reconstruction)
- Vertex position
- Charged multiplicity
- Accepted 1-2 Hz



Experimental Signature

Typical Event :



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

Event Selection Criteria

- Vertex within interaction region
  - $|z_{vertex}| < 200$ cm and $|x,y_{vertex}| < 2$ cm
- 2 tracks with net charge zero
- Opening angle < 3.0 rad

(reject cosmic background)

- Pion Identification for both tracks via dE/dx
- For data from minimum bias trigger:

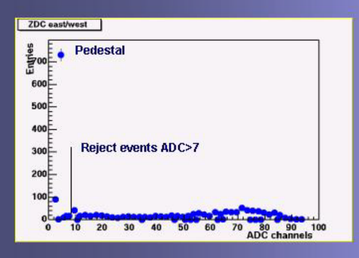
  ADC signal of ZDC < 30
  (reject background from hadronic peripheral collisions)
- For data from ultra peripheral trigger:

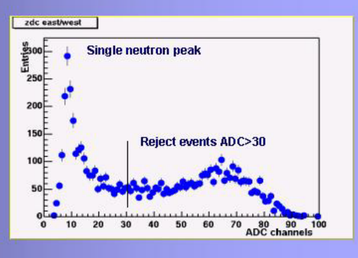
  ADC signal of ZDC <8 (reject signals above pedestal)

ZDC Signals

Ultra Peripheral Trigger
- Pedestal peak at ADCsum = 4
- Higher ADC values usually in east or west only (beam gas events ?)

Minimum Bias Trigger
- Single neutron peak around ADC =9 coincident in east and west
- Higher ADC values from hadronic peripheral events



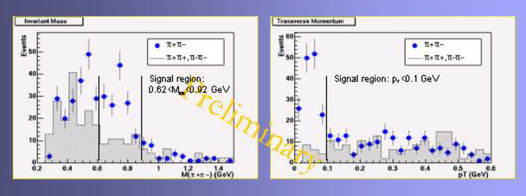


First Results

Invariant Mass & Transverse Momentum Spectra

Peripheral Trigger: $M_{\pi\pi}$ & p_T

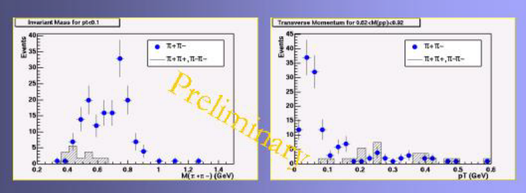
Process $Au+Au \rightarrow Au+Au+\rho^0$



Select Signal:

Low p_T region p_T<0.1

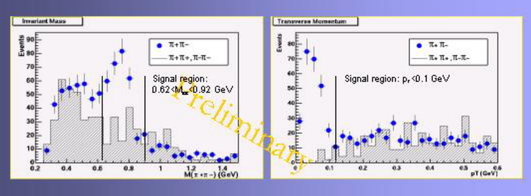
ρ invariant mass region 0.62<M<0.92



Observe about 100 ρ^0 events in the data for the peripheral trigger

Minimum Bias Trigger: M_{pp} & p_T

Process $Au+Au \rightarrow Au^*+Au^*+\rho^0$



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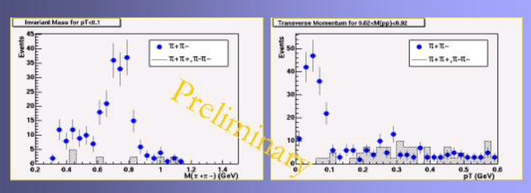


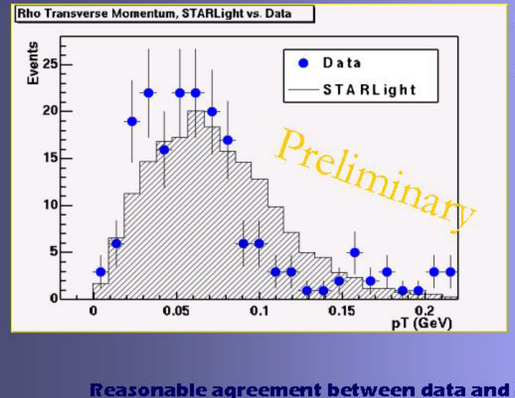
Observe about 200 ρ^0 events in ~500,000 events for the minbias trigger, a rate of 0.5*10^-3 is consistent with expectations

Comparison: Monte Carlo Simulation vs. Data

STARlight - Monte Carlo Generator for Ultra Peripheral Collisions

- Simulates photon-photon, photon-Pomeron, photon-meson interactions
- Simulates rapidity, transverse momentum and angular distributions

ρ^0 Transverse Momentum Spectrum



Data:
Minimum bias trigger
0.62<Mππ<0.92 GeV)

Not yet addressed by the Monte Carlo:
- Background
- Full spectrometer simulation
- Interference

Reasonable agreement between data and Monte Carlo

Clear Signals at the ρ^0 mass and at low transverse momentum for both processes.

Conclusion

Observation of exclusive ρ^0 production in both peripherally triggered and minimum bias data sets demonstrates existence of both interactions

$Au + Au \rightarrow Au + Au + \rho^0$

$Au + Au \rightarrow Au^* + Au^* + \rho^0$.

First observation of Ultra Peripheral Collisions in heavy ion interactions