Coherent Interactions in Ultra-Peripheral Collisions at PHENIX

- Introduction to Ultra-Peripheral Collisions; Experience from RHIC
- PHENIX : first look at Run4 AuAu data

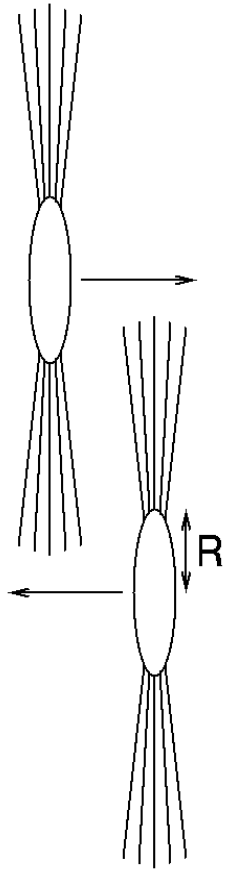
David Silvermyr, ORNL
for the PHENIX collaboration

OAK RIDGE NATIONAL LABORATORY

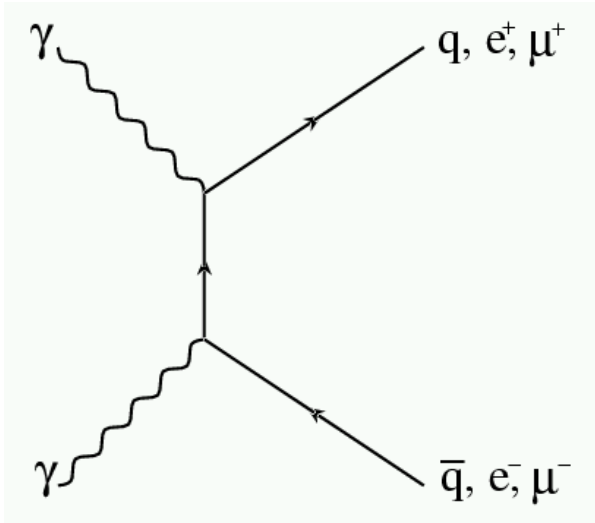
DNP '04

PHENIX

An ultra-peripheral collision



Particles can be produced if a photon from one nucleus interacts with a photon from the other ($b > 2R$). In principle any fermion pair can be created: $e^+ e^-$, $\mu^+ \mu^-$, or $q\bar{q}$



Large charge of heavy ions => large number of eq. photons.

Two-photon interactions: $\sigma_{AA} = Z_1^2 * Z_2^2 * \sigma_{NN}$

Two-photon interaction not the only possibility: $\Rightarrow$ The photon tends to fluctuate to a vector meson (ρ, ω, ϕ). Vector Meson Dominance.

Two-photon interactions (and any coherent process) will be significant only at very high energies:

Max CM energies at different accelerators, determined by the coherence requirement:

$$W \approx 2\,\gamma_{CM}\,(hc/R)$$

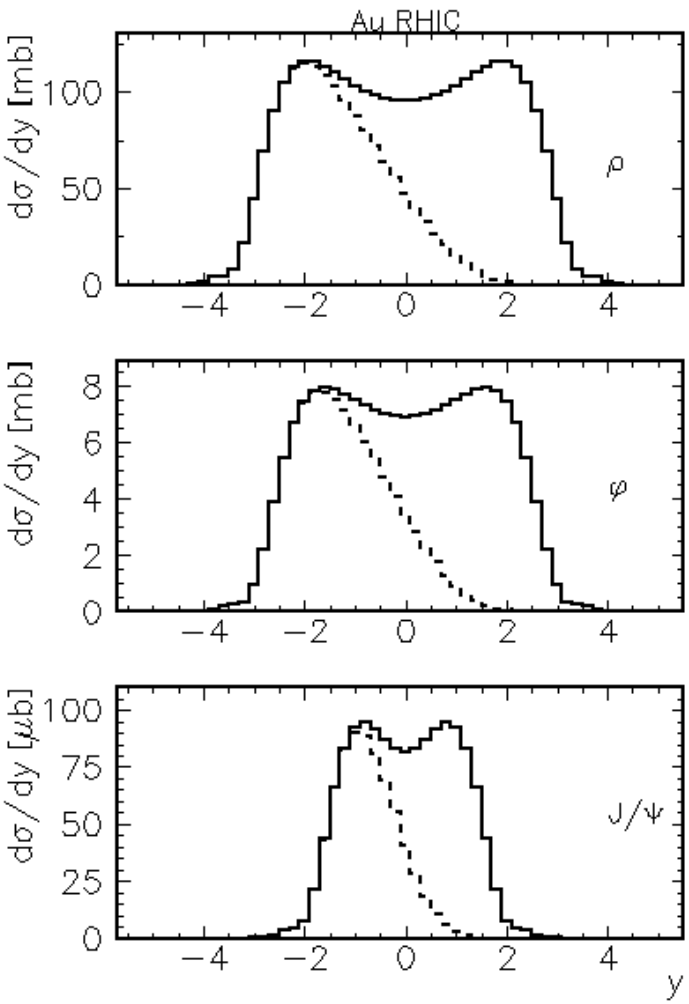
For Au/Pb

	γ_{CM}	W [GeV]
BNL AGS	3	0.1
CERN SPS	9	0.5
RHIC	100	6
LHC	2,940	160

RHIC is the first heavy-ion accelerator where significant particle production can occur in ultra-peripheral collisions!

A model [STARLight] predicts cross sections, rapidity and p_T distributions of e.g. vector mesons.

For Au+Au 200 GeV at RHIC:



	σ [mb]	(req. Xn)
ρ	590	(170)
ω	59	(17)
ϕ	39	(13)
J/ψ	0.29	(0.16)

[Baltz, Klein, Nystrand: PRC 60(1999)014903, PRL 89(2002)012301]

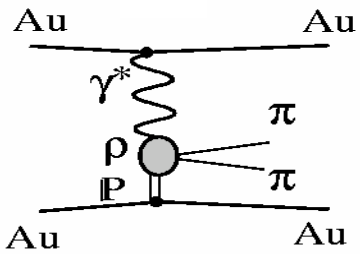
Cross sections in the 0.3-600 mb range!
Requiring neutron coinc. lowers σ by factor 1.8 – 3.5.

Photonuclear part dominates over γ+γ
The p_T distribution determined by the nuclear Form Factor, $p_T \sim 1/R$

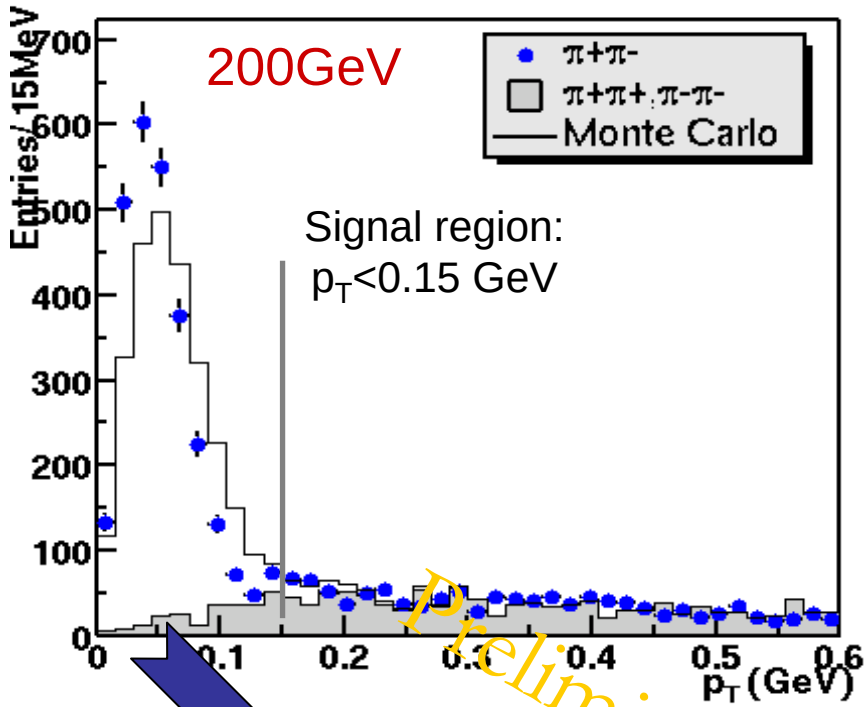
STAR Result

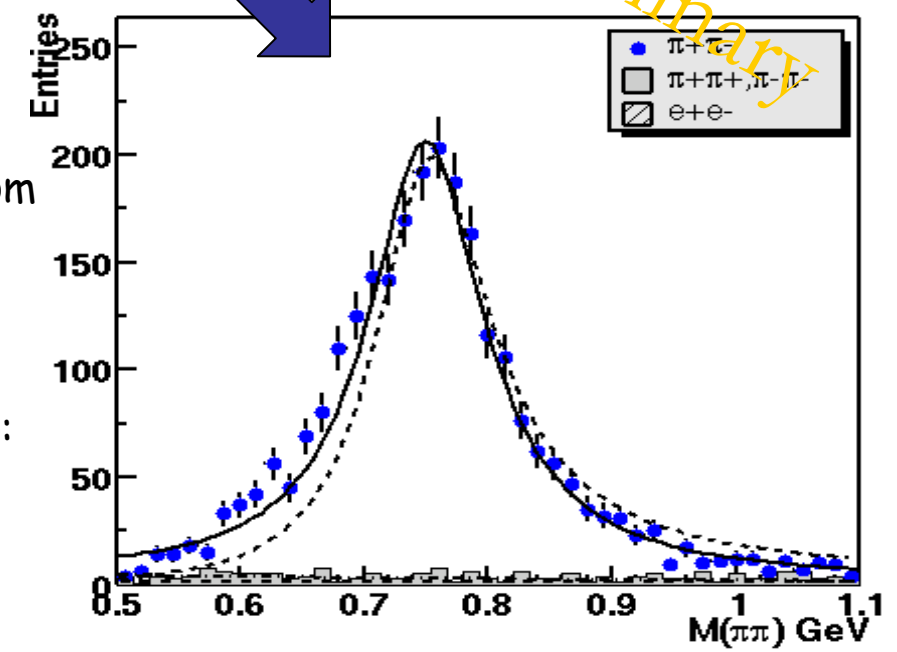
Topology Trigger

AuAu ⇨ AuAuρ^0



- Peak at low pT ⇨ coherent interaction



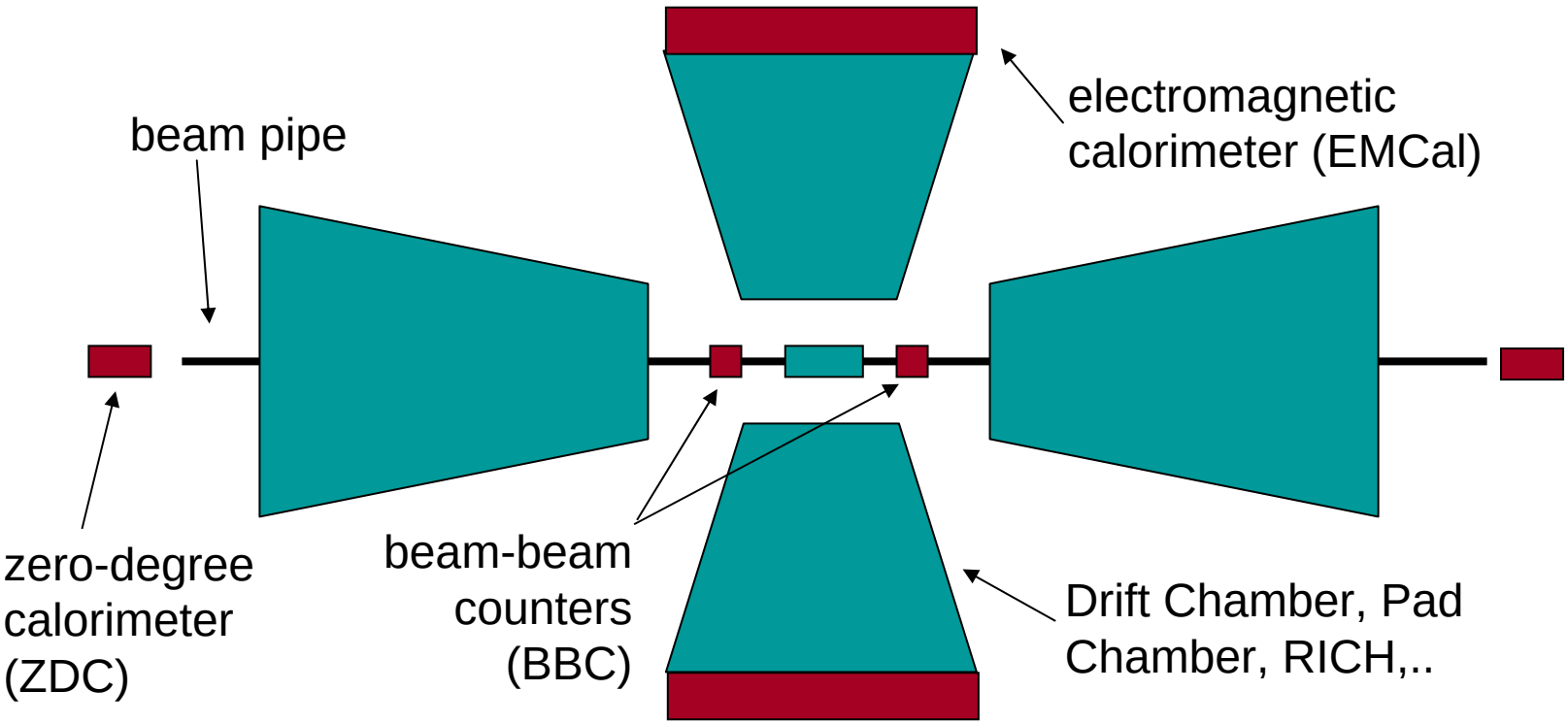


Cross-sections consistent with expectations from STARLight

[PRL 89(2002)272302;

also see e^+e^- low M_{inv} continuum result (52 pairs): PRC **70** (2004) 031902(R)]

PHENIX (bird's eye view)



L1 UltraPeripheral Trigger:
- veto on BBC (|y| ~3-4)
- neutron(s) in at least one ZDC
- large energy (0.8 GeV) cluster in EMCal.

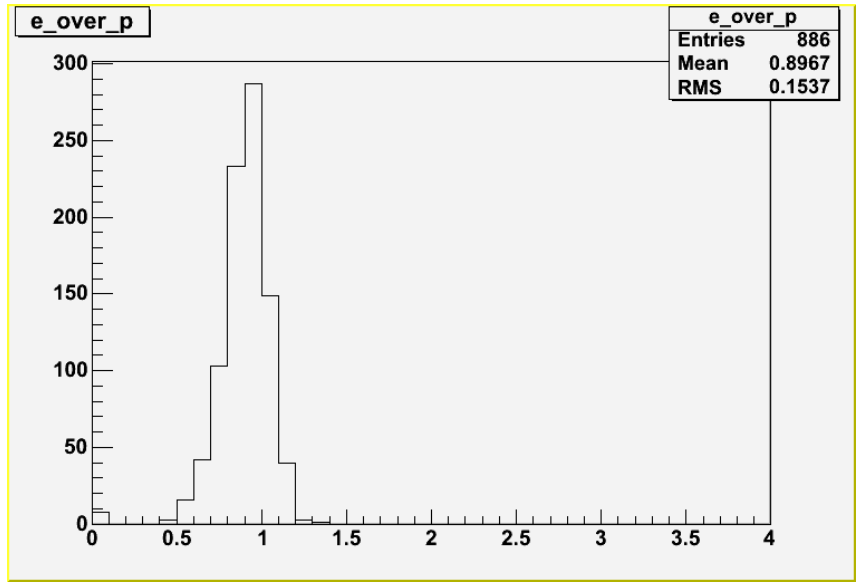
Goal:
Via electron channel, look for heavier vector meson (J/Ψ) and continuum at higher M_{inv}.

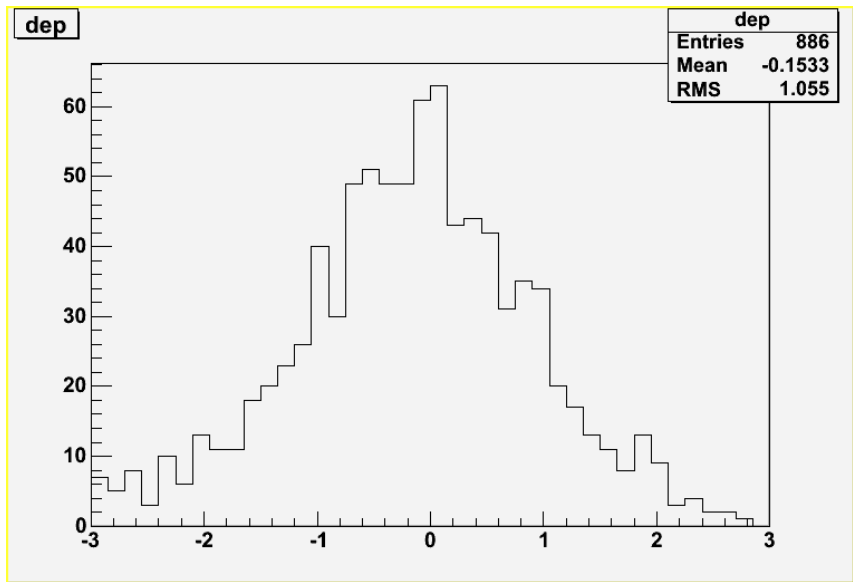
Electron Id

Cut away high mult. events.
Look for di-electrons in the central arm.

Example of electron cut : Compare reconstructed Energy and momentum

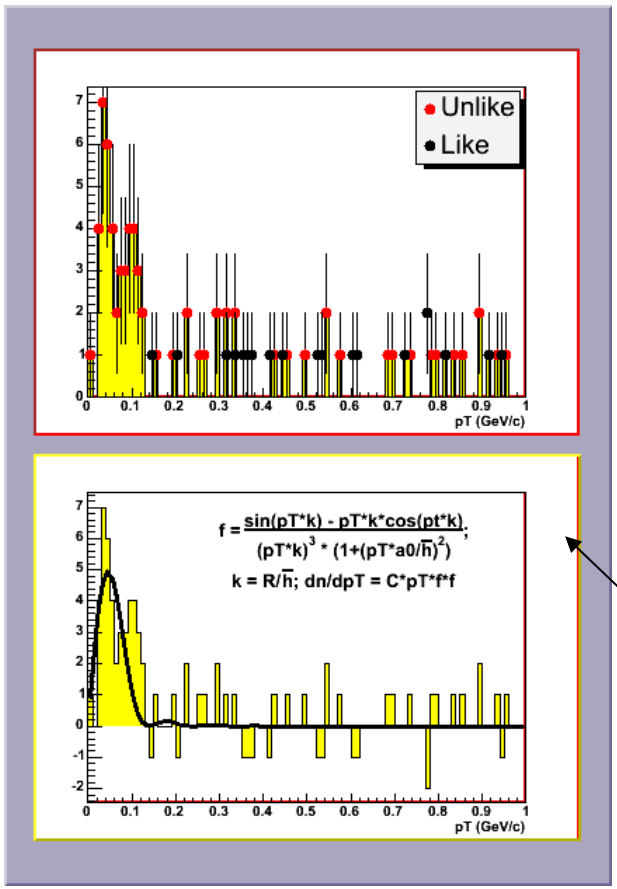
Chosen variable
dep = (E-p)/sigma,
where sigma is mom-dependent.

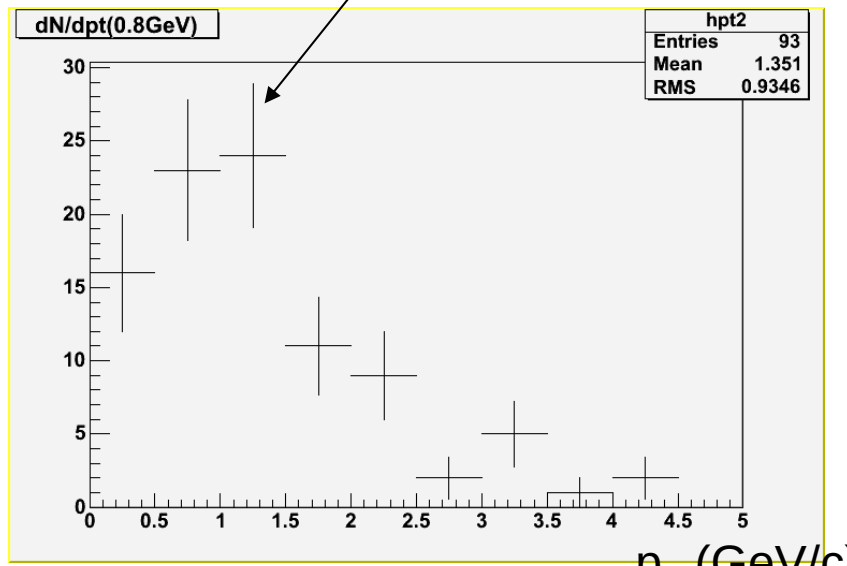




p_T Distributions

J/Ψ in pp: Peaks much later than UPC events..





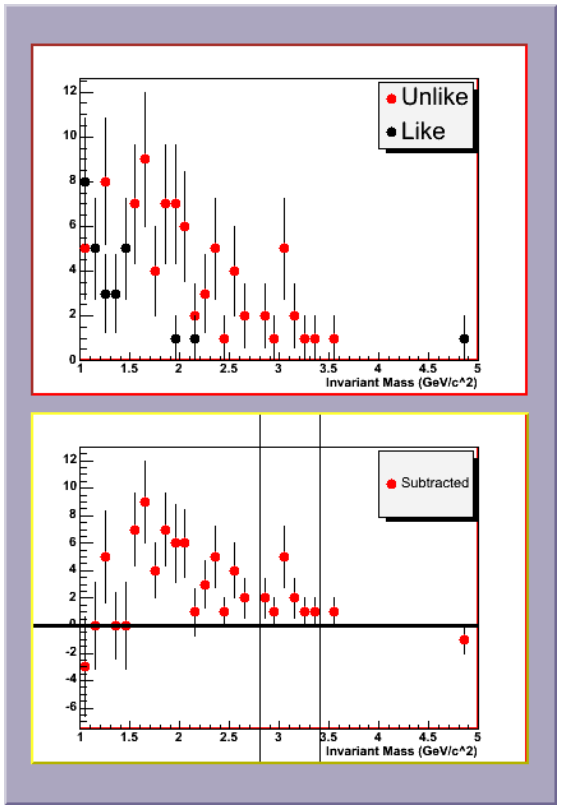
p_T for all di-electron combinations.
Fit is for Au nuclear form factor.

Coherent events are expected to have a peak at low p_T w. shape given by nuclear form factor (see e.g. nucl-th/0112055) [somewhat more complicated for $\gamma+\gamma$ continuum]

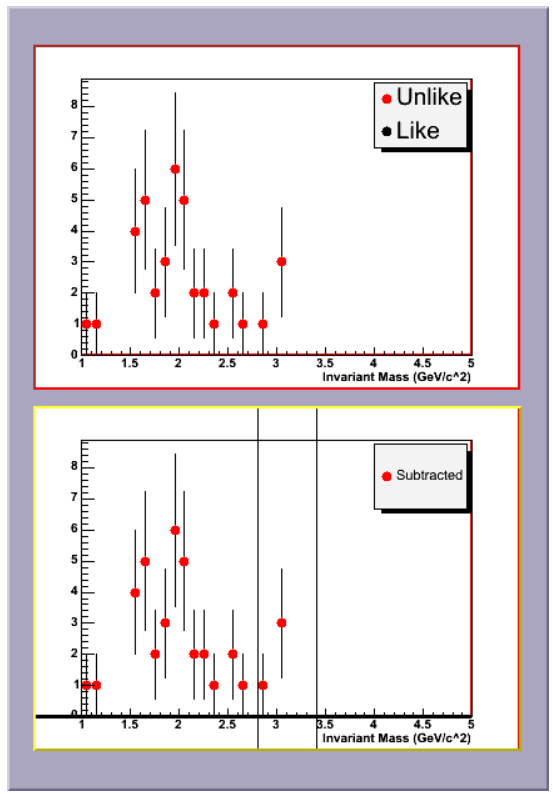
Approx. agreement with expectations seen => coherence observed!

M_{inv} Distributions

[with same electron cuts as for p_T distr..]



[+ p_T < 150 MeV ⇔ coherence requirement]



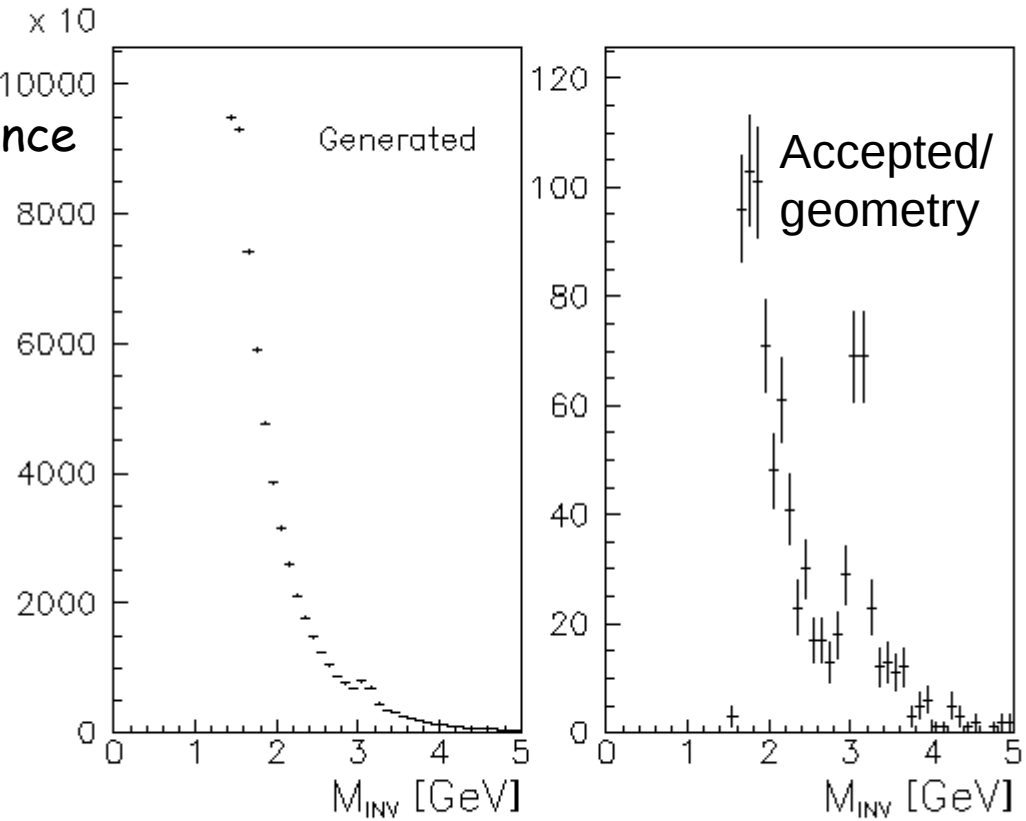
Note that with E_{th}=0.8 GeV, coherent di-electron acceptance starts at ~1.6 GeV.

Hint of J/Ψ-signal seen? + maybe coherent $\gamma+\gamma \rightarrow e^+e^-$ as the falling shape?

STARLight shape

The e^+e^- continuum and $J/\Psi \rightarrow e^+e^-$ contributions from a STARLight calc., based on an undisclosed luminosity.., and a simple acceptance filter (not GEANT-based) are shown.

The absolute yields can not be compared to what was shown on the previous slides.



Summary and Outlook

- Many interesting things to investigate in ultra-peripheral collisions. First chance at RHIC.

- We see something that could be J/Ψ, and high mass di-lepton continuum.. The candidates pT distribution is consistent with expectations for coherent events..

- Overall yield is unfortunately low. Hopefully this will improve with final calibrations and perhaps a better vertex reconstruction for these events.
Will work on simulation comparisons and correction estimates.

- Also have some runs without E>0.8 GeV cut in trigger. Could look at low M_{inv} continuum and ρ for those runs.

PHENIX

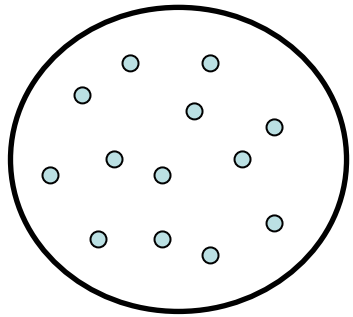
12 Countries; 58 Institutions; 480 Participants*

Brazil	University of São Paulo, São Paulo
China	Academia Sinica, Taipei, Taiwan
	China Institute of Atomic Energy, Beijing
	Peking University, Beijing
France	LPC, University de Clermont-Ferrand, Clermont-Ferrand
	Dapnia, CEA Saclay, Gif-sur-Yvette
	IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay
	LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau
	SUBATECH, Ecòle des Mines at Nantes, Nantes
Germany	University of Münster, Münster
Hungary	Central Research Institute for Physics (KFKI), Budapest
	Debrecen University, Debrecen
	Eötvös Loránd University (ELTE), Budapest
India	Banaras Hindu University, Banaras
	Bhabha Atomic Research Centre, Bombay
Israel	Weizmann Institute, Rehovot
Japan	Center for Nuclear Study, University of Tokyo, Tokyo
	Hiroshima University, Higashi-Hiroshima
	KEK, Institute for High Energy Physics, Tsukuba
	Kyoto University, Kyoto
	Nagasaki Institute of Applied Science, Nagasaki
	RIKEN, Institute for Physical and Chemical Research, Wako
	RIKEN-BNL Research Center, Upton, NY
	Rikkyo University, Tokyo, Japan
	Tokyo Institute of Technology, Tokyo
	University of Tsukuba, Tsukuba
	Waseda University, Tokyo
S. Korea	Cyclotron Application Laboratory, KAERI, Seoul
	Kangnung National University, Kangnung
	Korea University, Seoul
	Myong Ji University, Yongin City
	System Electronics Laboratory, Seoul Nat. University, Seoul
	Yonsei University, Seoul
Russia	Institute of High Energy Physics, Protovino
	Joint Institute for Nuclear Research, Dubna
	Kurchatov Institute, Moscow
	PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg
	St. Petersburg State Technical University, St. Petersburg
Sweden	Lund University, Lund

USA	Abilene Christian University, Abilene, TX
	Brookhaven National Laboratory, Upton, NY
	University of California - Riverside, Riverside, CA
	University of Colorado, Boulder, CO
	Columbia University, Nevis Laboratories, Irvington, NY
	Florida State University, Tallahassee, FL
	Florida Technical University, Melbourne, FL
	Georgia State University, Atlanta, GA
	University of Illinois Urbana Champaign, Urbana-Champaign, IL
	Iowa State University and Ames Laboratory, Ames, IA
	Los Alamos National Laboratory, Los Alamos, NM
	Lawrence Livermore National Laboratory, Livermore, CA
	University of New Mexico, Albuquerque, NM
	New Mexico State University, Las Cruces, NM
	Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
	Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
	Oak Ridge National Laboratory, Oak Ridge, TN
	University of Tennessee, Knoxville, TN
	Vanderbilt University, Nashville, TN

*as of January 2004

Coherence



Many scattering centra

Total scattering amplitude:

$$F(k,k') = \sum_{i=1}^{A} f_i(k,k') e^{iq\cdot xi} \longrightarrow \underbrace{\int \rho(x) e^{iq\cdot x} d^3x}$$

$A \cdot F(q)$

F(q) – Nuclear Form Factor

t = $\mathbf{q}^2$; For small mom. transfers:

$$\left.\frac{d\sigma}{dt}\right|_{\gamma A} = A^2 \left.\frac{d\sigma}{dt}\right|_{\gamma p} |F(t)|^2$$

$\sim 4 \cdot 10^4$ for Au..
(assuming no shadowing)

$\rightarrow$ 0 for q > 1/R
1/R ~ 30 MeV/c for Au

Cuts

For each event:

|zvertex| <= 30 cm
ntracks <= 5

// at least one BBC side should be really quiet
(bbcsq== 0 || bbcnq== 0)
// at least one ZDC side should have a real neutron
(zdcse>=30 || zdcne>=30)

For each electron/track:

fabs(dep)<3 // E over p
emc_match<4 // z and phi emc match
disp<5 // ring cut