Hard Photoproduction in A-A Collisions

Diffractive Physics(->e^+e^-) with Heavy Ions at RHIC

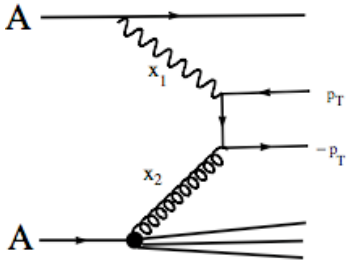
PHENIX

Probing small x structure of nuclei and protons at LHC

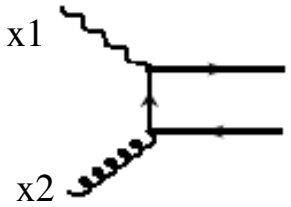
(with M.Strikman and R.Vogt)

Can one continue HERA program with higher $s_{\gamma N}$ at LHC?

Electron beam ->Z=82 at 5.5 TeV/n
Pb target (AA) or proton (pA)
L=4 10^{26} (AA) and 7 10^{29} (pA) $cm^{-2}s^{-1}$



Probing small x structure in the Nucleus with γN->jets, heavy flavor.



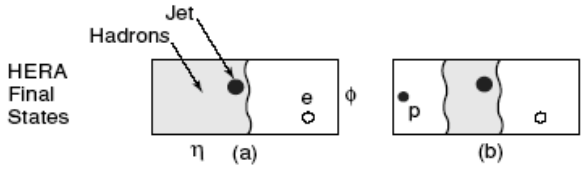
di-jet photoproduction-> parton distributions,x2 by γ with momentum fraction, x1

$4p_t^2/s=x1*x2$

$\langle y\rangle \sim -1/2*\ln(x1/x2)$

Signature: rapidity gap in γ direction(FCAL veto)

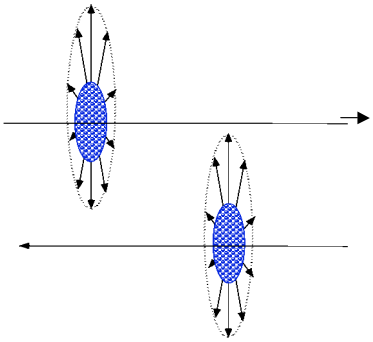
ATLAS coverage to $|\eta|<5$ units. P_t ~2 Gev "rapidity gap" threshold



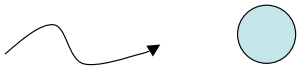
Analogous upc interactions and gap structure

diffractive Non-diffractive

RHIC and LHC as high Luminosity γ-Hadron colliders



$\gamma_{beam}^{Rhic}=100$



$S=2m_A\omega'$

=>Nucleus at rest,effective lorentz $\gamma_{eff}=2*\gamma_{beam}^2-1$

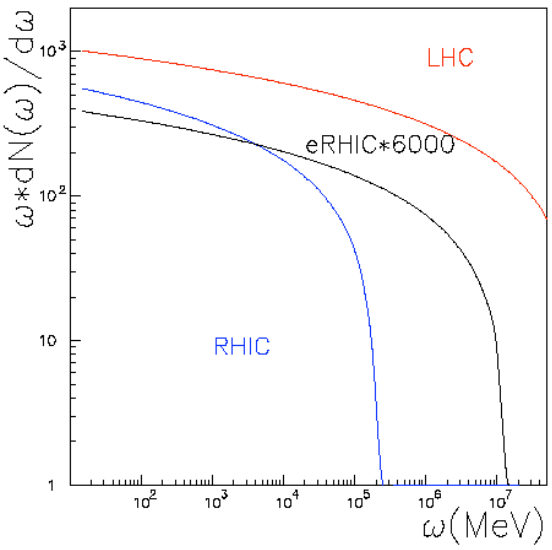
Heavy Ions

$$\omega\frac{1}{2}\frac{dN(\omega)}{d\omega}=\frac{2\alpha Z^2}{\pi}\ln\left(\frac{0.681\overline{hc\gamma_{eff}}}{R_{nucleus}\bullet\omega}\right)$$

e-Hadron collider

$$\omega\frac{dN(\omega)}{d\omega}=\frac{2\alpha}{\pi}\ln\left(\frac{\overline{m_e\bullet\gamma_{eff}}}{\omega}\right)$$

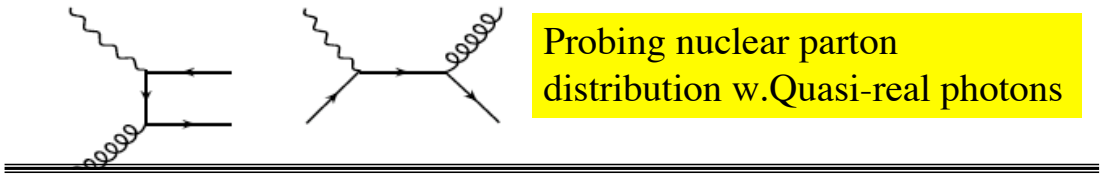
Equivalent Photon spectrum in target nucleus frame



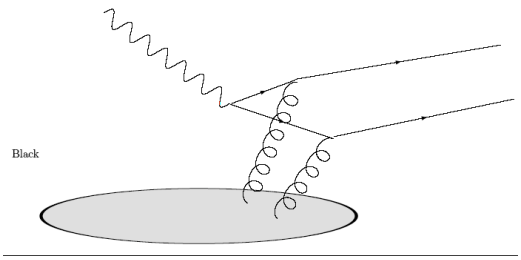
"Quasi-real" γ spectra compared to an e-hadron collider

->100 TeV @ LHC

$$S_{NN}^2 \frac{d^2\sigma^{\rm dir}_{\gamma A\to {\rm jet}+{\rm jet}+X}}{dTdUd^2b} = 2\int dz \int_{k_{\rm min}}^{\infty} dk \frac{d^3N_\gamma}{dkd^2b} \int_{x_{2_{\rm min}}}^{1} \frac{dx_2}{x_2}\left[\sum_{i,j,l=q,\bar{q},g} F_i^A(x_2,\mu^2,\vec{b},z) s^2 \frac{d^2\sigma_{\gamma i\to jl}}{dtdu}\right]$$



Probing nuclear parton distribution w.Quasi-real photons



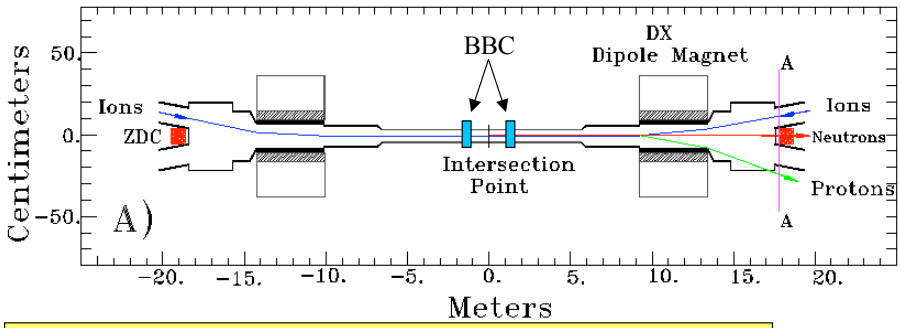
Diffractive J/Psi production (like 2-gluon exchange)
t-distribution measures size of gluon source
eg-Kowalski and Teaney hep/ph/0304189

Topics in Diffraction

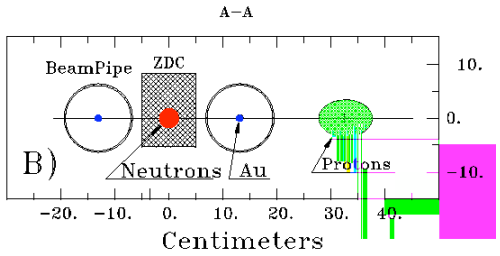
- Total Cross Sections
  - RHIC methodology uses calculable EM cross sections to calibrate (eg Coulomb Dissociation, γ+d->n+p)
- "Peripheral γ-A interactions"
  - Diffractive Vector meson production
  - γγ->e^+e^-
- Deep inelastic γ-A interactions
  - -dijet, jet+γ, Heavy Flavor production
- Other Forward Physics, eg pp->n+X

PHENIX

Forward Instrumentation



•All AuAu Interactions->low p_t neutron "spectators"
•Peripheral Coulomb Interactions->neutron tag from Au*->n+X
•Deuteron Photodissociation_> n+p in forward calorimeters



PHENIX Diffractive Data

AuAu σ_{tot}: Coulomb + Geometrical

dAu σ_{tot} " :Original system for Diffraction Dissociation
"Free Dissociation"+ Geometrical

$\gamma\gamma \rightarrow e^+e^-$: High Mass continuum (m_{ee} above ~2 GeV)

γAu-> J/psi+Au coherent photoproduction

Sebastian White, BNL

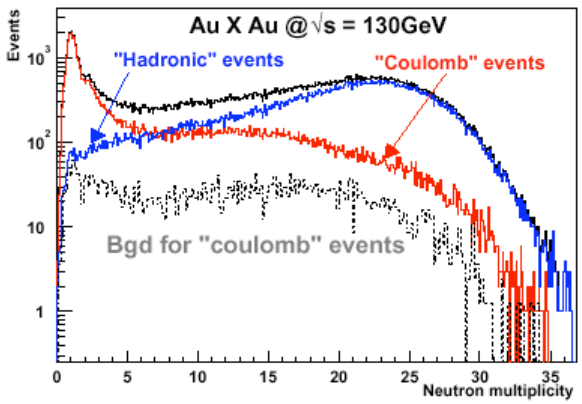
Run I

PRL

TABLE I. Cross sections calculated and derived from the data. The errors quoted on measurements include the uncertainty of the BBC cross section [8]

Cross Section	Calculated Value(1)	Calculated Value(2)	Measured
σ_{tot}	10.83 ± 0.5Barns	$11.19 \pm$	N.A.
σ_{geom}	$7.09 \pm xx$	$7.29 \pm$ xx	N.A.
$\frac{\sigma_{geom}}{\sigma_{tot}}$	0.67	0.65	0.661 ± 0.014
electromagnetic			
$\frac{\sigma(1n,Xn)}{\sigma_{tot}}$	0.125	xx	$0.117 \pm 0.003 \pm 0.002$
$\frac{\sigma(1n,1n)}{\sigma_{1n,Xn}}$	0.329	xx	$0.345 \pm 0.01 \pm 0.006$
$\frac{\sigma(2n,Xn)}{\sigma_{1n,Xn}}$	xx	0.327	$0.345 \pm 0.011 \pm 0.01$

(1)Baltz & SNW
(2)Bondorff et al.
Meas.=Chiu et al.

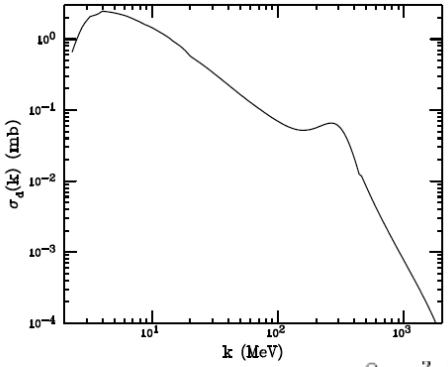


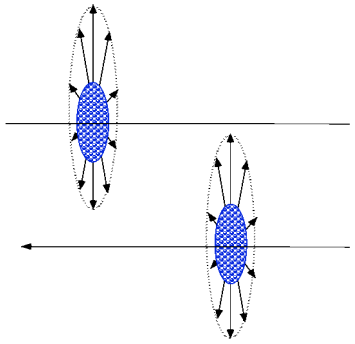
d-Au Inelastic cross section

Author	Calculated value(barn)
Kopeliovich	1.93 (uses non-diffractive,Gribov)
Kharzeev Levin,Nardi	2.26 ±0.1
STAR "standard"	2.36 (also find 7.1 b for AuAu Whereas vernier-> 6.1 barn)
PHENIX "standard"	2.18+-0.17
D. d'Enterria	2.32 +-.17 (n skin issue)
This work	**2.26(±1.6% ± 5.0% ± 4.5%)**

d->n+p dissociation process(2)

2) Coulomb Dissociation (Fermi '25):

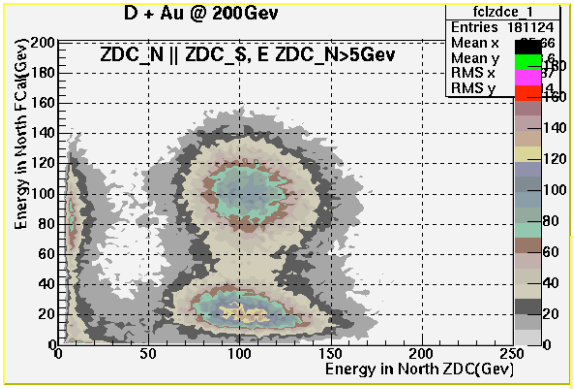




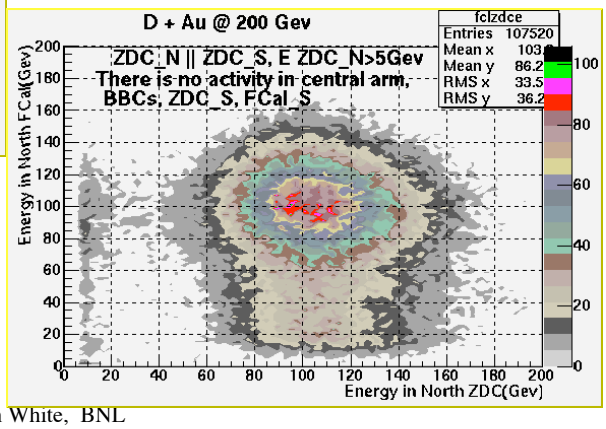
$$I(\nu) = \frac{8\pi c\varepsilon^2\nu^2}{v^4}\left\{K_0^2\left(\frac{2\pi\nu b}{v}\right) + K_1^2\left(\frac{2\pi\nu b}{v}\right)\right\} \quad (4)$$

=>$\sigma_{c.d.}$=1.24 barn (+/-5%, Klein &Vogt '03)

ZDC N or S trigger , ie at least 1 n from either d or Au beam, (no rapidity gaps bias)



<----Inclusive data set



Cut on central activity--> &Au fragmentation

PHENIX measurement of deuteron dissociation

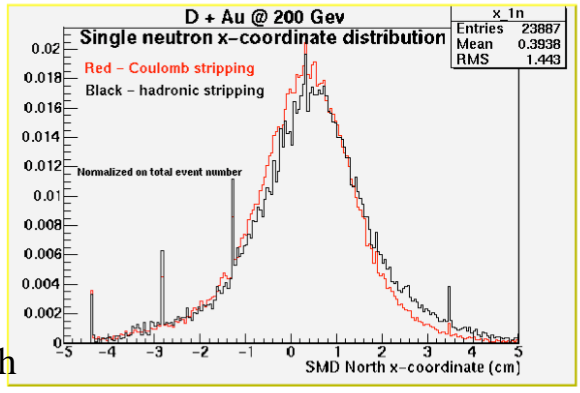
PHENIX used 2 types of min bias triggers:

1)BBCN*S=coinc of $3<|\eta|<4$
(excludes "rapidity gaps")

And

2)ZDC N or S= >0 n, either beam
(includes "gap" events,
~12M events recorded)

Our measurement is from 2) which includes d+Au->n+p+Au

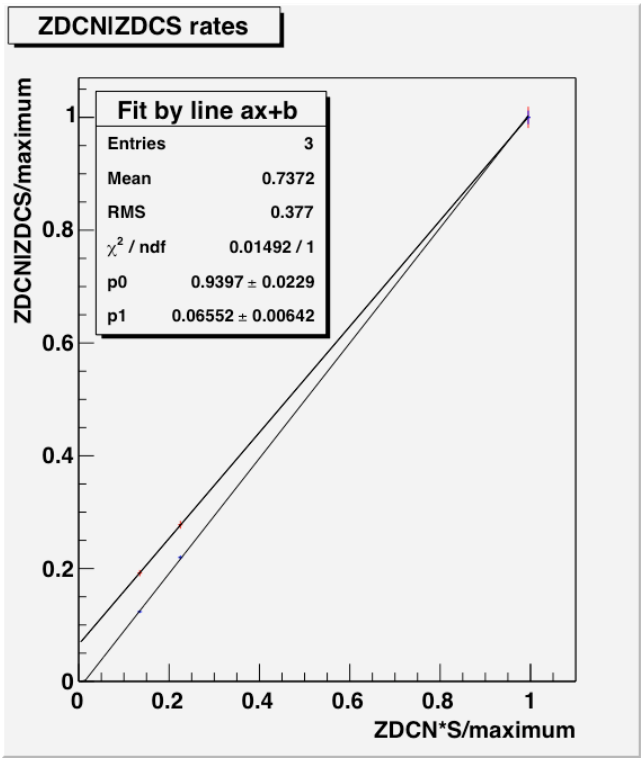


Impact position of neutrons
For both free dissociation
And stripping

How to measure accelerator background to d+Au->n+p ?

Separate beams through beam steering and measure rates:

Red(upper)=raw trigger
Blue(lower)=cuts added



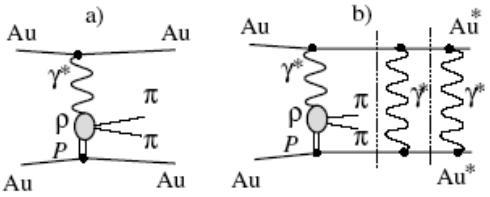
RHIC γγ Physics and vector Meson Photoproduction

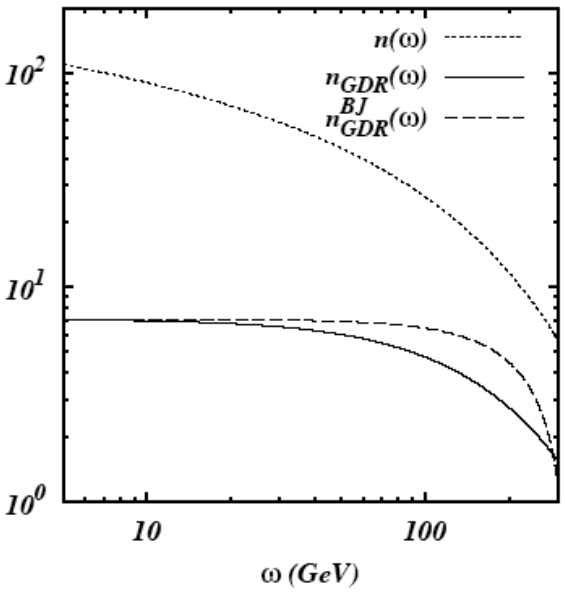
"Tagged" photon spectrum

Strength of interaction

$$\eta = \frac{Z_1 Z_2 e^2}{\hbar v} \approx Z_1 Z_2 \alpha$$

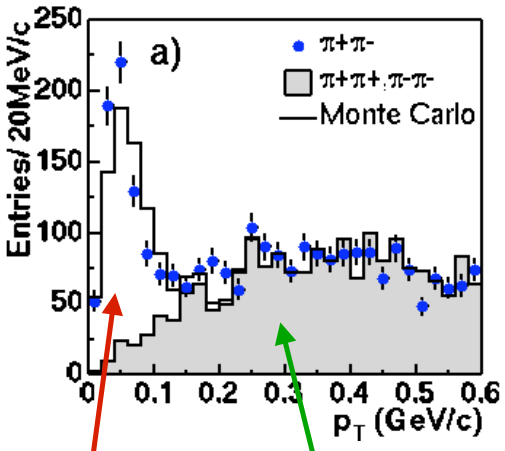
2nd γ exchange leads to hardened photon beam (implemented in "STARlight" and in Strikman,Vogt,and SNW)
(seeG.Baur et al. Nucl-th/03070310)





ρ photoproduction: STAR Collaboration at RHIC $\sqrt{s_{nn}}$ =130 GeV
(C. Adler et al., Phys. Rev. Lett. 89(2002)272302)

p_T spectrum shows clear coherent signal



Cross section	STAR (mb)	Ref. [5] (mb)
$\sigma^{\rho}_{xn,xn}$	28.3 ± 2.0 ± 6.3	27
$\sigma^{\rho}_{1n,1n}$	2.8 ± 0.5 ± 0.7	2.6
$\sigma^{\rho(\text{inc. overlap})}_{xn,xn}$	39.7 ± 2.8 ± 9.7	···
$\sigma^{\rho}_{xn,0n}$	95 ± 60 ± 25	···
$\sigma^{\rho}_{0n,0n}$	370 ± 170 ± 80	···
$\sigma^{\rho}_{\text{total}}$	460 ± 220 ± 110	350

Large exp. uncertainty in luminosity and trigger efficiency.

background, like-sign pairs

Signal+background, unlike-sign pairs

High Mass e^+e^- in PHENIX

PHENIX trigger

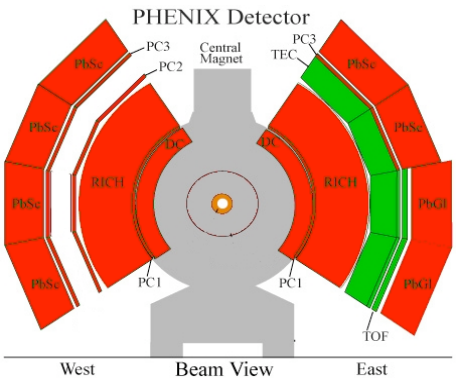
UPC: (ZDCN || ZDCS) && (!BBCLL1noVtx) && (ERT2x2)

Sensitive to γ +A → A*+J/psi (→ e^+e^-):

- Veto on BBC (|y| ~3-4) [exclude periph. nuclear & beam-gas]
- Neutron(s) in at least one ZDC [from Au* Coulomb de-excitation]
- Large energy (>0.8 GeV) cluster in EMCal [e^+e^- decay from J/_]

Total data set: 1352 PRDFFs * 0.8 GB/file ~ 1.04 TB, 8.4M events

Total equivalent sampled luminosity: $L_{int} \approx 120\ \mu b^{-1}$



CERN- April-23-08 Sebastian White, BNL

Global cuts: |zvtx| < 30 cm, track multiplicity <15

Single-track cuts:

- $N_0 \geq 2$ [# of RICH phototubes fired by e^+e^-].
- $E_1 > 0.8$ GeV || $E_2 > 0.8$ GeV [ERT threshold].
- No dead-warn tower around assoc. EMCal cluster [CNT-EMC matching. e+e- candidates].

Pair cuts: $arm_1 \neq arm_2$ [back-to-back di-electrons]

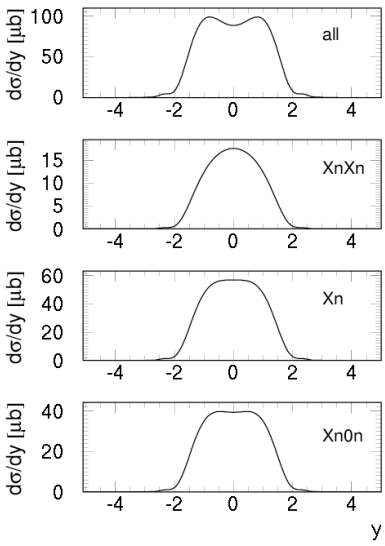
Background subtraction: [unlike-sign] - [like-sign]

Full GEANT MC for J/psi & high-mass $e^+ e^-$ continuum based on physics input from Starlight model

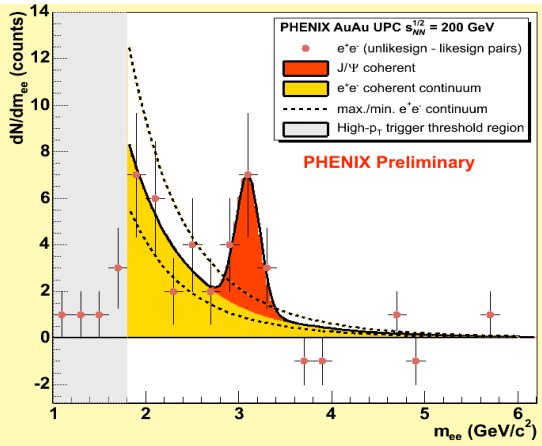
ZDC trigger bias

~60% of all J/psi with 1 neutron tag

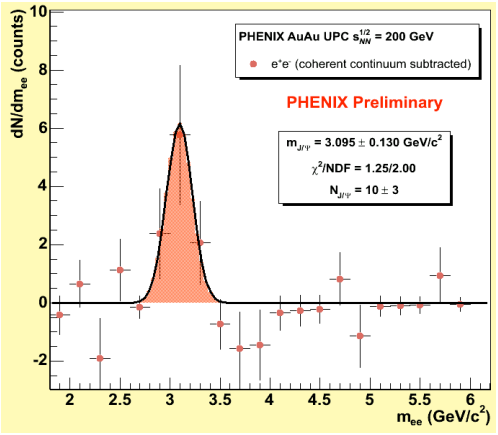
~20% with 2 arm n tag



J.Nystrand/STARlight

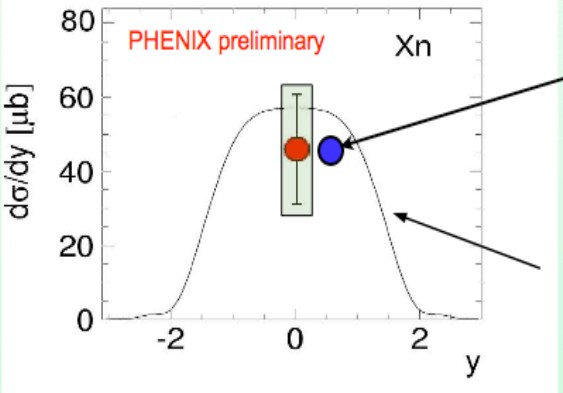


Dominant uncertainty in signal extraction from continuum fit



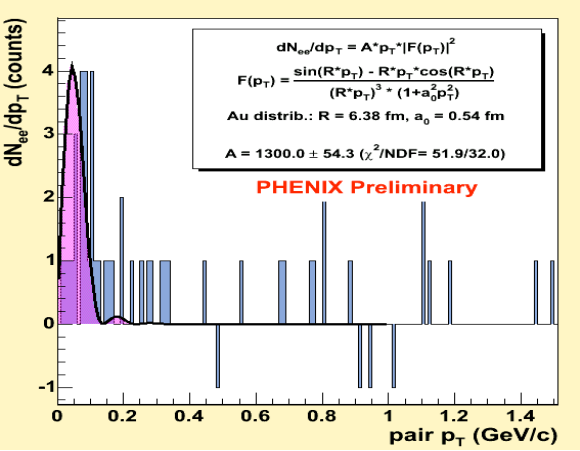
J/psi after continuum subtracted

$d\sigma_{J/\psi}/dy|_{y=0}$ = 44 ± 16 (stat) ± 18 (syst) μb



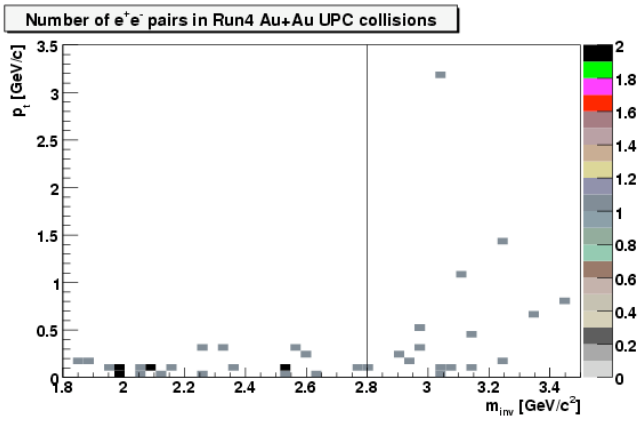
MS, Tverskoy, Zhalov - coherent + quasielastic, σ_{eff} (J/ψ N)=3 mb

Nystrand, coherent



-Clear coherent peak consistent with Au form factor

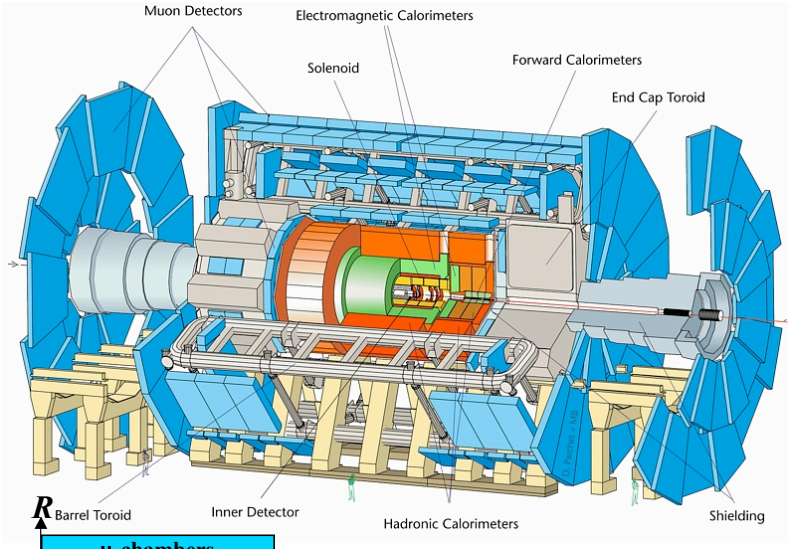
-cp.inclusive J/psi (<pt>~ 1 GeV/c)



Hard Photoproduction at LHC

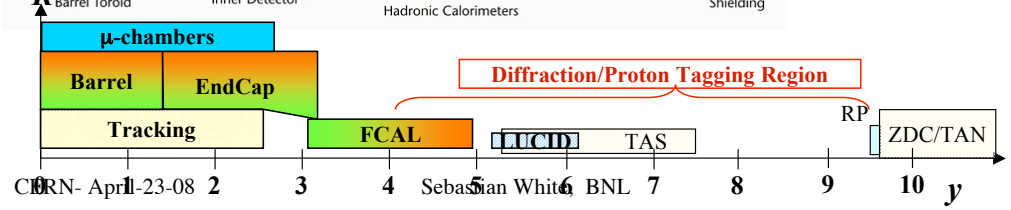
With Pb-Pb and p-Pb collisions

The ATLAS Detector

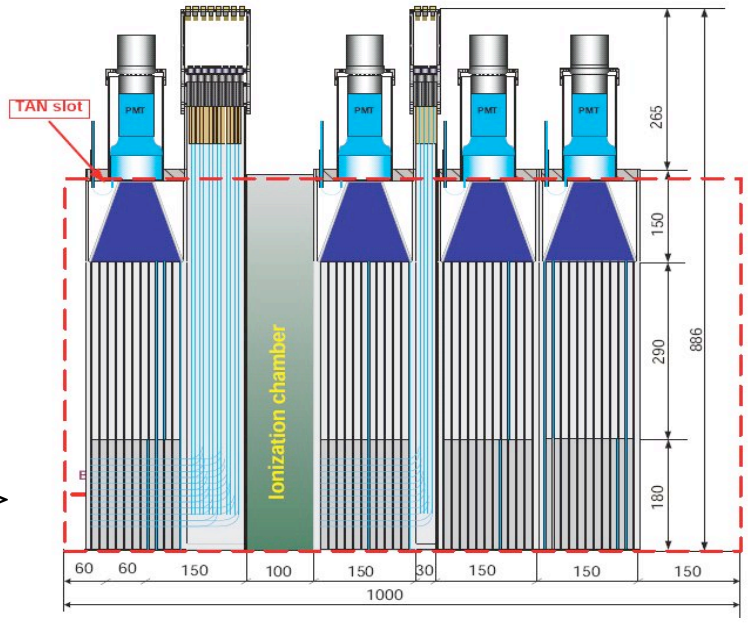


Detector:
fully hermetic to η=5
Highest segmentation
Superior jet en resolution
(50%/sqrt(E))
Excellent b-tagging

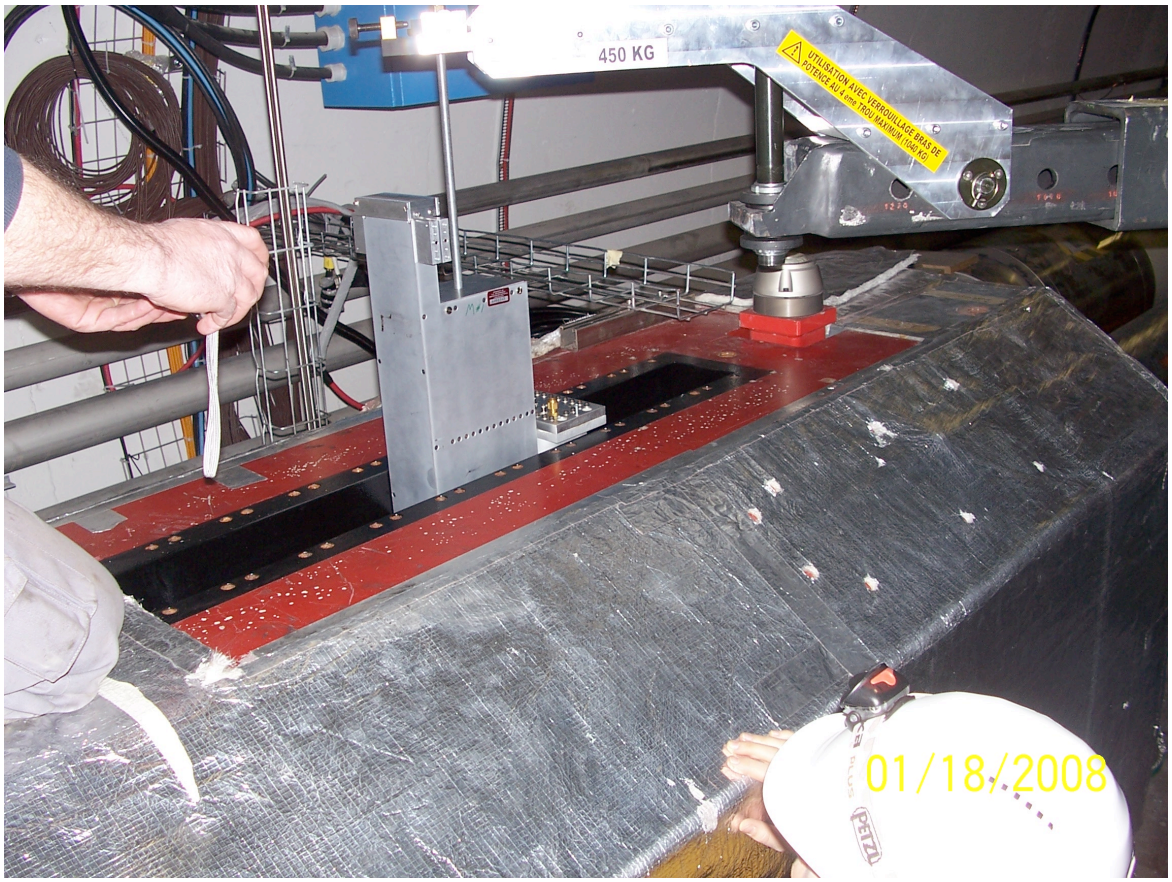
Collaboration:
Heavy Ion LOI in May '04
Use existing detector + ZDC
Collaborative work on ZDC
with LHC commissioning

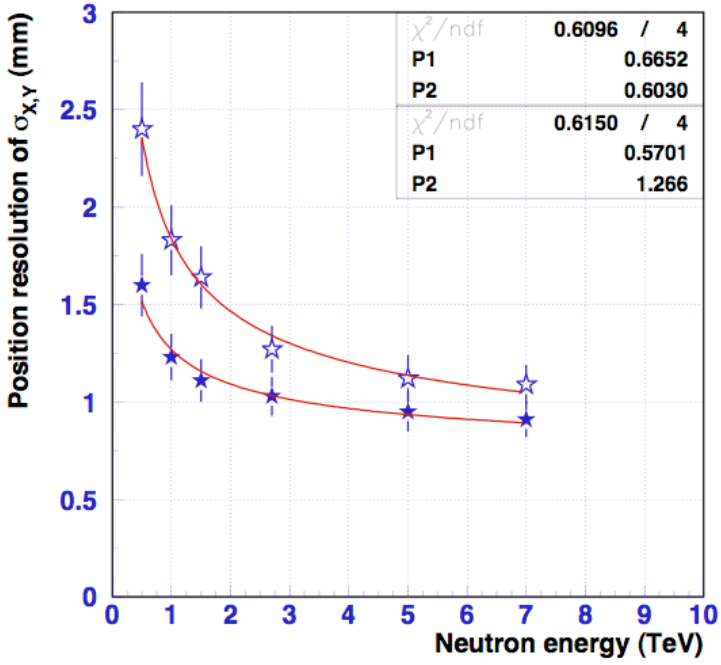


ZDC modules in the TAN

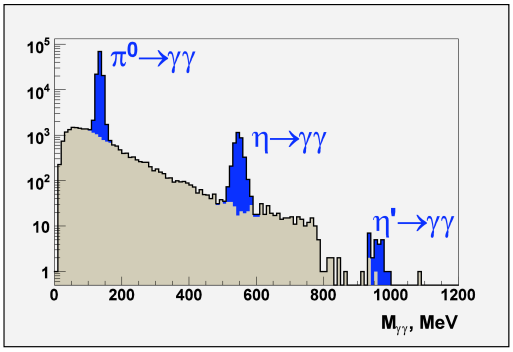


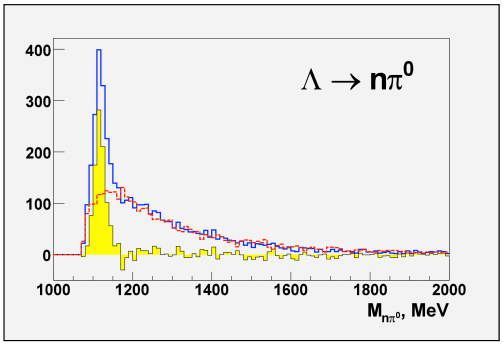
Beam ->


450 KG
01/18/2008


Position resolution of $\sigma_{x,y}$ (mm)
Neutron energy (TeV)
χ^2/ndf 0.6096 / 4
P1 0.6652
P2 0.6030
χ^2/ndf 0.6150 / 4
P1 0.5701
P2 1.266
0
0.5
1
1.5
2
2.5
3
0 1 2 3 4 5 6 7 8 9 10

Di-γ reconstructed in ZDC from 10^6 PYTHIA events





ATLAS physics with UltraPeripheral Collisions

ATLAS is the highest resolution and granularity LHC calorimeter

UPC physics takes full advantage of strengths

-no pileup and negligible underlying event activity

FCAL allows rapidity gap at level of Et~2 GeV

ZDC neutron tag always present in inclusive

ie γ+Pb->jj+X

ZDC tag at ~20% level in diffractive

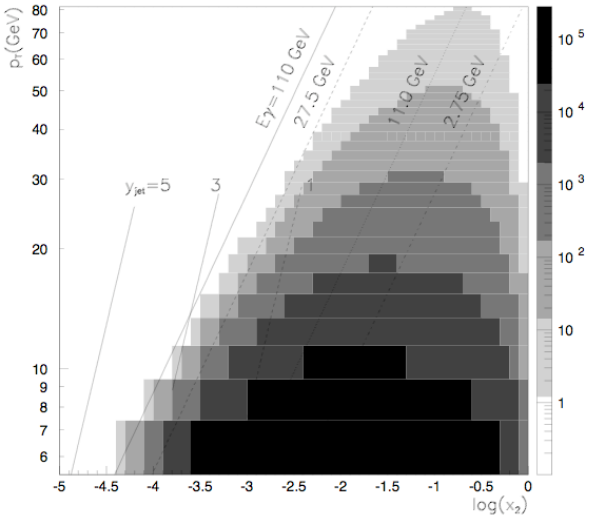
ie γ+Pb->jj+ Pb

ATLAS dijet photoproduction

Min. pt issue for detailed simulation

Also diffractive rates from

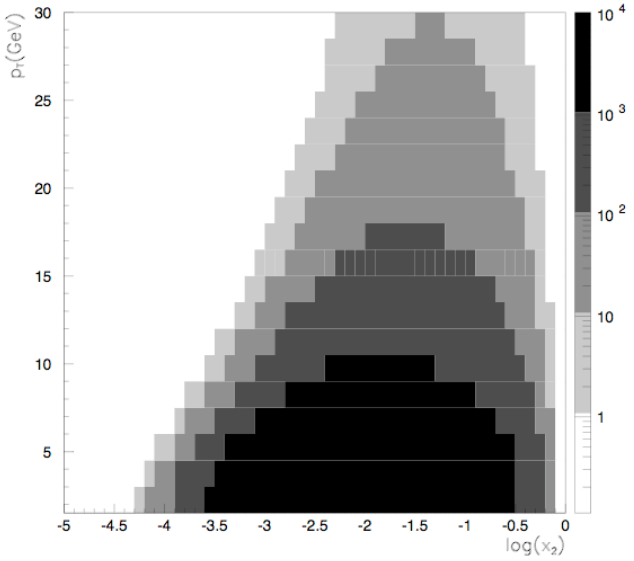
•Frankfurt, Guzey and Strikman Phys.lett. B 586, pp41-52(2004) "leading twist nuclear Diffractive parton distribution functions (nDPDF's)"



ATLAS b-quark jet production

Event yields from a 1 month HI (Pb-Pb) run at nominal Luminosity (4 10^{26} $cm^{-2}s^{-1}$). Counts per bin of δpt=1.5 GeV δx2/x2=+/- 0.25

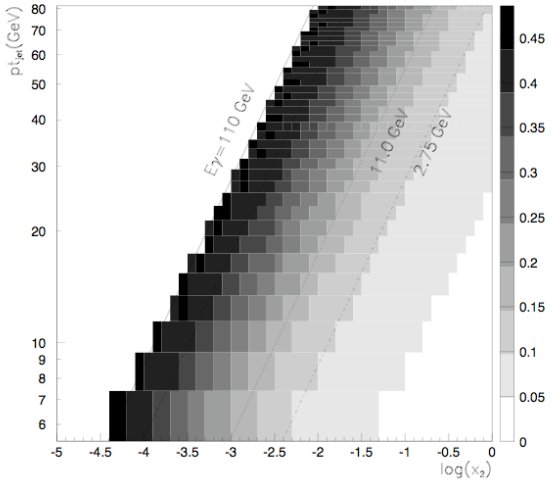
b-jet from soft lepton tag or detached vertex



ATLAS ZDC tag fraction

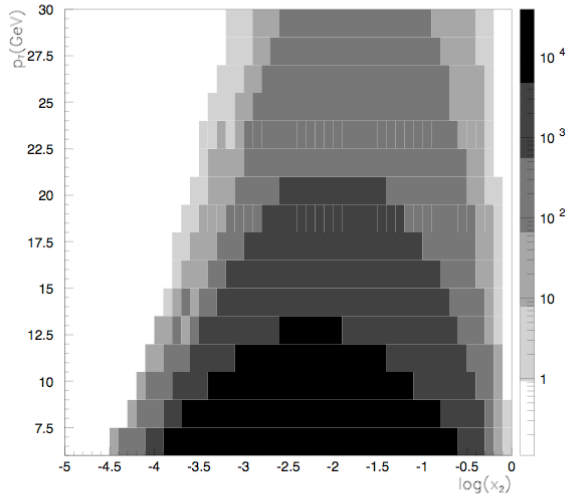
Fraction of diffractive events with additional γ exchanges leading to 2 arm ZDC tag

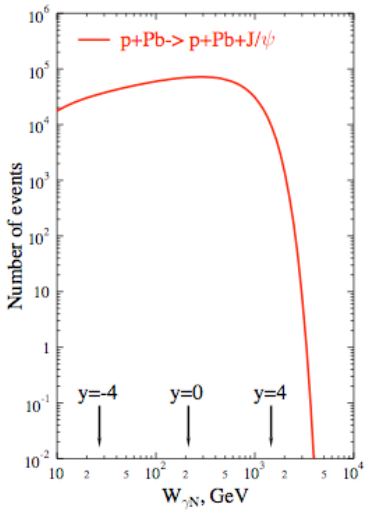
Note that directly correlated With E γ which is strongly Correlated with impact param.

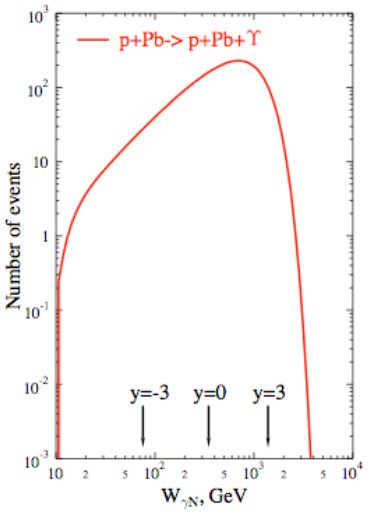


ATLAS jj photoproduction (p+Pb)

Event yields from a 1 month p+Pb run at nominal Luminosity (7 10^{29} $cm^{-2}s^{-1}$). Counts per bin of δpt=1.5 GeV δx2/x2=+/- 0.25







Zhalov & MS 05

Number of γ+p →V+N events per unit rapidity for a standard proton-lead run - branching of decay to muons is included. Comparable number of coherent γ+A →V+A is not shown.

Sufficient to check pQCD prediction of $\sigma \sim W^{1.6}$ for Upsilon production determination of the t-slope provided protons could be detected (420 m proposal)

Summary

- Large cross section diffractive processes used to normalize AuAu and dAu data in PHENIX
- High mass e+e- and J/Psi diffractive photo-production data collected in PHENIX
- Rapidity gap and n-tag powerful tool in Heavy Ions
- Photoproduction measurements with ATLAS will explore a wide range of topics in Diffraction