28 October 2004
Division of Nuclear Physics
Chicago

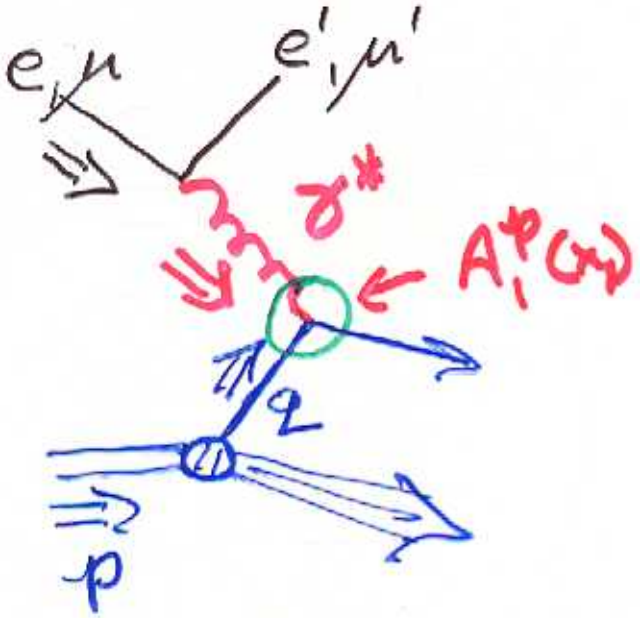
Measurement of direct photon cross section for pp collisions, root(s)=200 GeV, PHENIX

Takuma Horaguchi for the PHENIX Collaboration
(presented by Gerry Bunce)

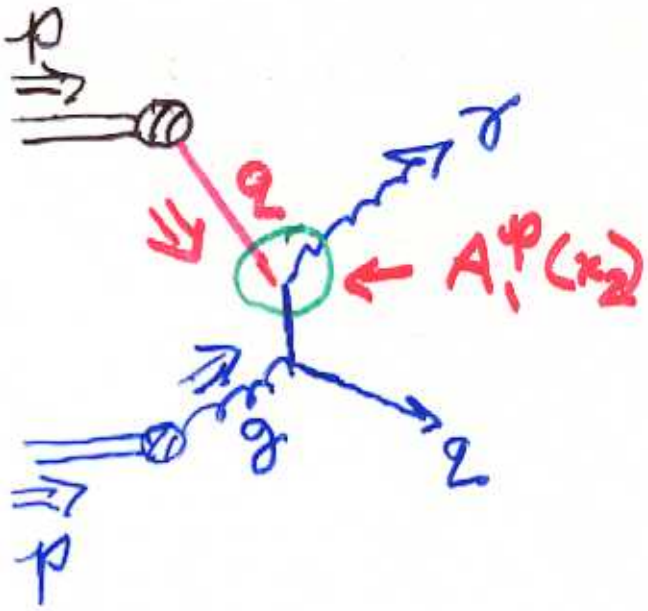
Based on presentation by Kensuke Okada
to Spin 2004, Trieste

We present a measurement of the direct photon production at RHIC, for p_T = 5-16 GeV/c.

DIS with $\vec{\gamma}^*$



DIS with $\vec{q}$, $\vec{g}$ (?)



Spin structure of proton:

$$\frac{1}{2} = \int_0^1 dx \cdot \left[\underbrace{\frac{1}{2} \sum_{q_i} (\Delta q + \Delta \bar{q})(x, \mu^2)}_{\text{DIS } \gamma^*:\ \sim 0.25} + \Delta g(x, \mu^2) \right] + L(\mu^2)$$

DIS with $\vec{q}$:

$$A_{LL} \equiv \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$

$$\cong \frac{\Delta g}{g}(x_1) \cdot \underset{\substack{\uparrow \\ \geq .2 \text{ for} \\ x_2 > .1}}{A_1^p(x_2)} \cdot \underset{\substack{\uparrow \\ .6 \text{ for} \\ \text{mid-rapidity}}}{\hat{a}(qg \to \gamma q)}$$

Data

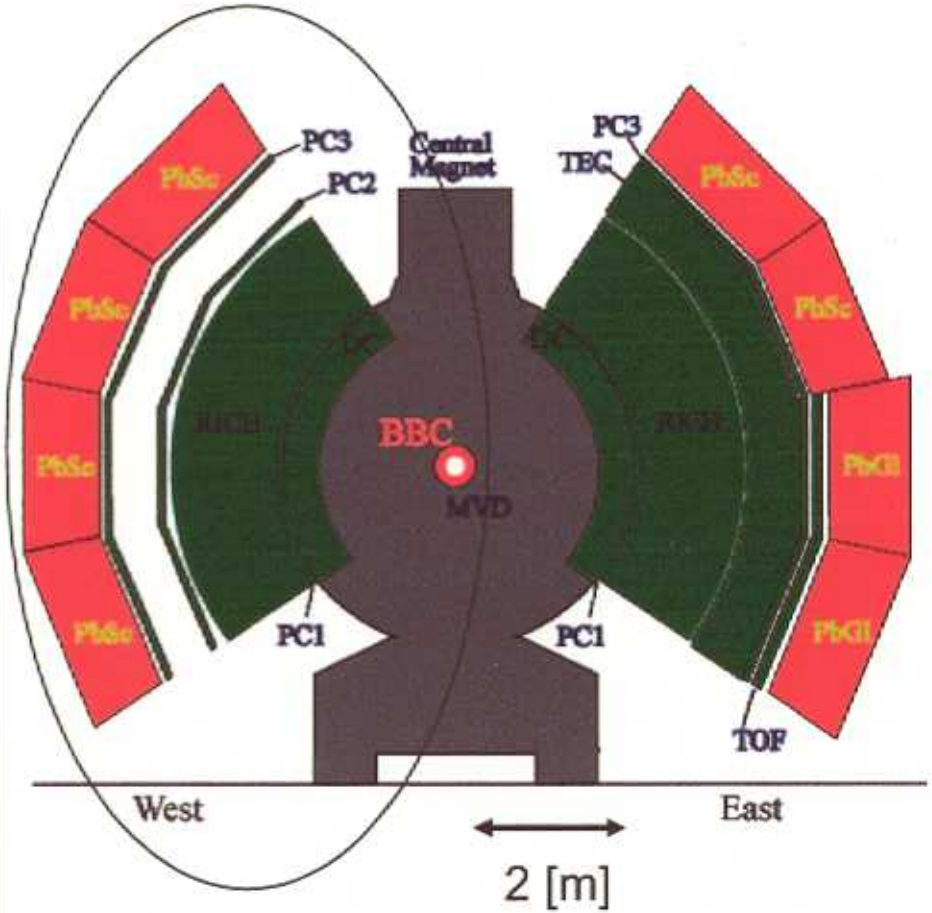
RHIC run3 p+p

2003 April-May
$\sqrt{s}$=200GeV Proton-proton collisions
Luminosity= 266nb^{-1}

RHIC-PHENIX detector

Central Arm (West)
(Rapidity |y|<0.35)
Electromagnetic Calorimeter (EMCal)
Photon detection
High granularity (~10*10mrad^2)
Drift chamber (DC)
Charged hadron veto
Beam forward / backward
(Rapidity 3.1<|y|<3.9)
Beam-beam counter (BBC)
Triggering and vertex determination

BBC and EMCal Trigger for the data taking



Analysis procedure

Prompt photon signal = All EMCal clusters – known contributions
Signal / Noise = 0.2~1 (pT 5~17GeV/c) without π^0 tag

Non photon contributions (hadronic shower)

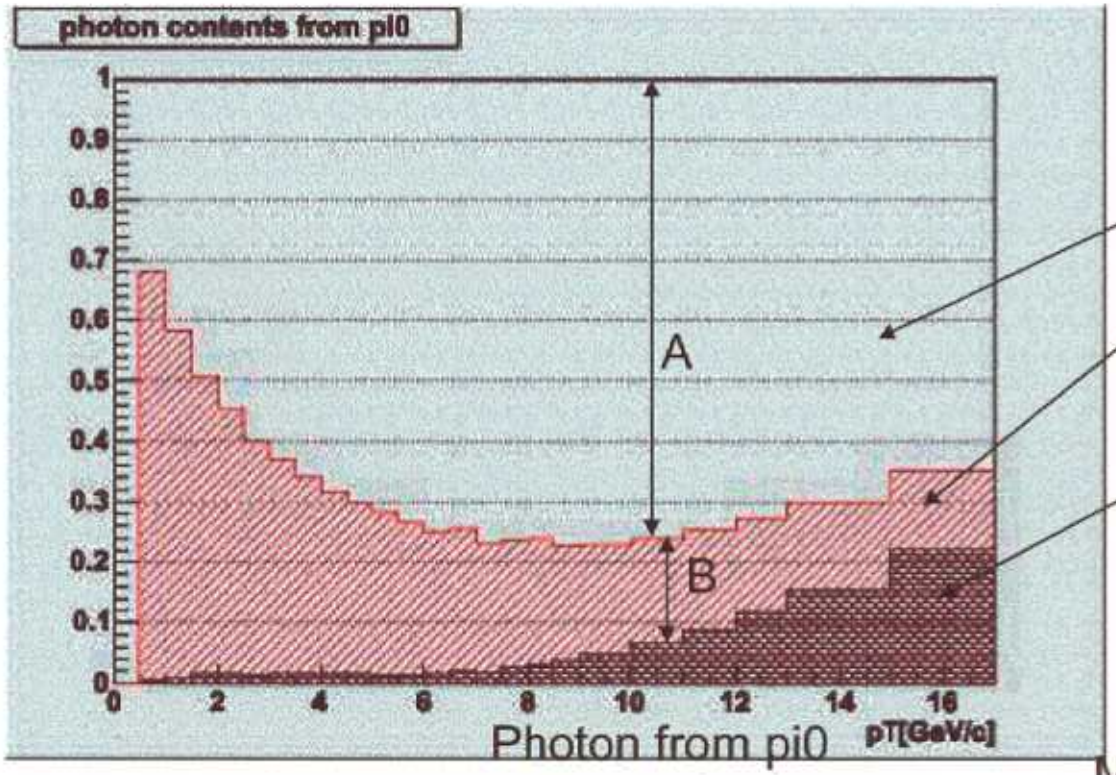
Electromagnetic shower shape requirement
Charged hadron veto with drift chamber tracking

Photon contributions

π^0 with both photons seen in detector
—Eliminate using a π^0 tag.
π^0 with only on photon seen in detector
—Estimate based on photon tagged as π^0
Photonic decay of η,ω etc.
—Estimate to be 23±5% of the total π^0 contributions
(=Production * Br($h \rightarrow \gamma$))

pi0 photon missing ratio (with MC)

Input: pi0 spectra, Energy resolution, Shower size from measurements
The same MC used in pi0 cross section measurement.



This figure shows components of photon from pi0.

(A) 2 photons tagged as pi0

(B) 1photon (the partner missing)

Merged photons
(to be discarded by the shower shape cut
And those have almost double energy)

Miss/ tag (=B/A)
40% at 5GeV/c
20% at 10GeV/c

π^0 tag

Reason to miss the partner		Our efforts to recover them
—Out of EMCal Arm	→	Assign edges only for partner search (guard veto region)
—EMCal bad area	→	Careful definition
—Less than the minimum E	→	Set E_{min} as low as possible (at 150MeV)
—Photon conversions	→	Charged veto with DC tracks, not with a detector in front of the EMCal
—Photon merging	→	In our pT region, those are rejected by the EM shower shape cut.

From MC,
γ from missed π^0 / from tagged π^0
= 40% @ pT=5GeV/c
= 20% @ pT=10GeV/c

Now we are ready to obtain prompt photon yield.

Cross section calculation

Factors

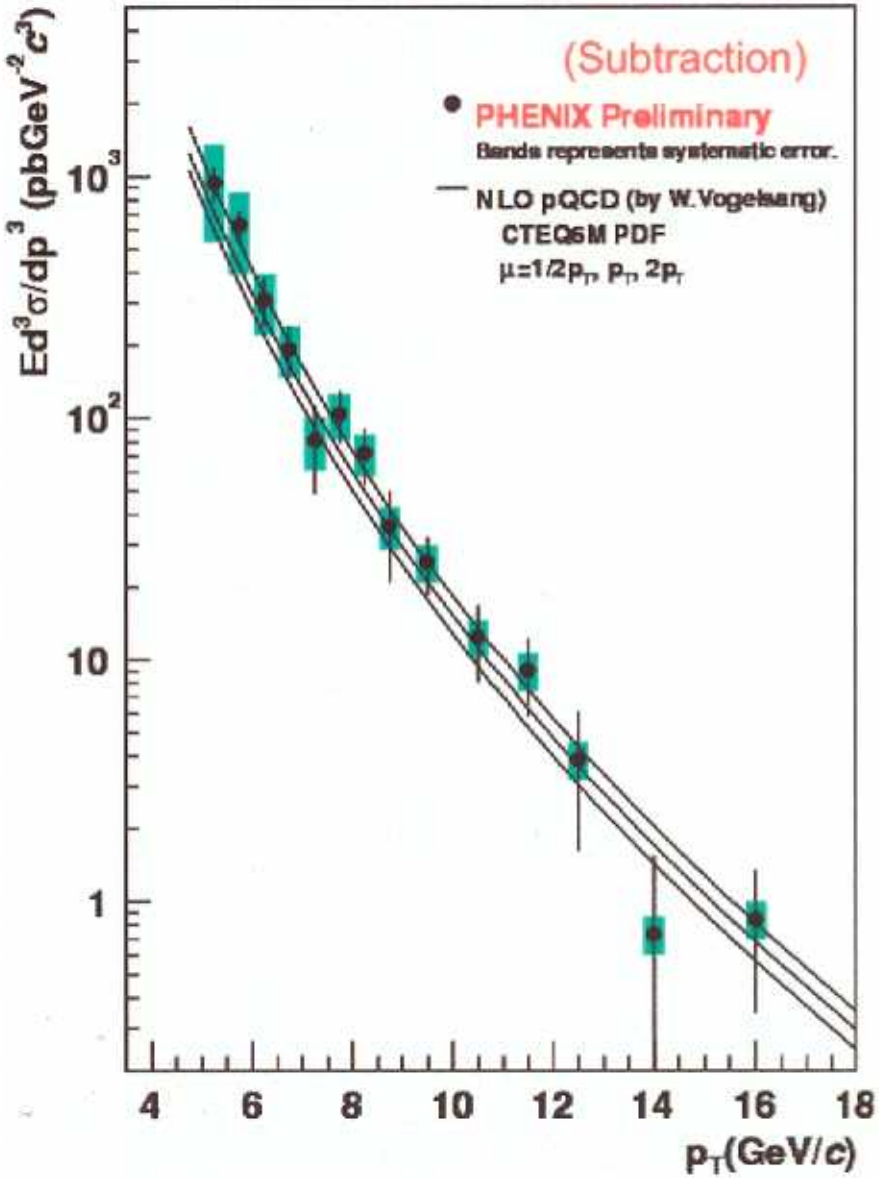
1/Luminosity: 1/266nb^{-1} (=5.450e9 events/20.5mb)
1/bbc_bias: 1/0.785
1/(acceptance+smearing): 1/0.0982
1/(shower shape cut efficiency): 1/0.98
1/(Conversion probability): 1/0.97

Systematic error sources

For π^0 tagging (subtraction) method	Lowest 5-5.5 [GeV/c]	Highest 15-17 [GeV/c]	
Pi0 photon estimation	30%	5	Point to point
Non pi0 hadron contribution	27	6	
Photon acceptance and smearing	10	10	
Photon conversion effect	1	1	
Luminosity measurement	12	12	global
BBC trigger bias	3	3	
Total (quadratic sum)	43%	18	

* Errors on the backgrounds result in enlarged errors on the signal, especially at low-pT region.
* With the isolation cut, those are less thanks to high S/N ratio.

Result with NLO pQCD calculation



Bands represent systematic errors.

Errors on the backgrounds result in enlarged errors on the signal, especially at low-pT region.

- NLO-pQCD calculation
  - CTEQ6M PDF.
  - Gluon Compton scattering + fragmentation photon
  - Set Renormalization scale and factorization scale pT/2,pT,2pT

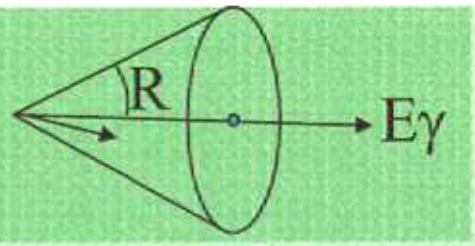
The theory calculation shows a good agreement with our result.

Analysis procedure (+isolation cut)

Isolation cut in this analysis

$$R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.5$$

$$E_{sum}(R < 0.5) < E_\gamma \times 0.1$$



We expect that the isolation cut around well-identified high-pT photons reduces the background from hadronic decays (π^0, η, ω …)

In addition, the isolation cut could separate photon production processes.

Total prompt photons
= photons (gluon Compton scattering) + photons (fragmentation)

Obtained by the subtraction method

Pass the isolation cut

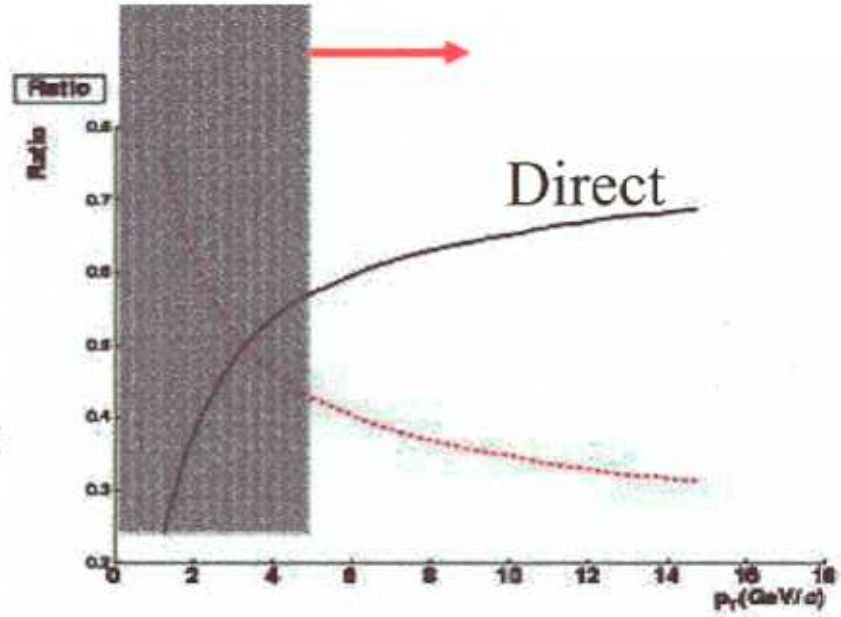
Mostly eliminated by the isolation cut

Yes, it's not so simple. (cancellation of infrared divergences, underlying parton picture)
In this analysis, we compare with/without the isolation cut
<u>without efficiency correction</u>.

Bias on Physics Process

- Two processes
  - Direct
  - Fragmentation

- Direct photon measurement at pT>5GeV/c is dominated by direct process.
  - The difference between two methods is small.



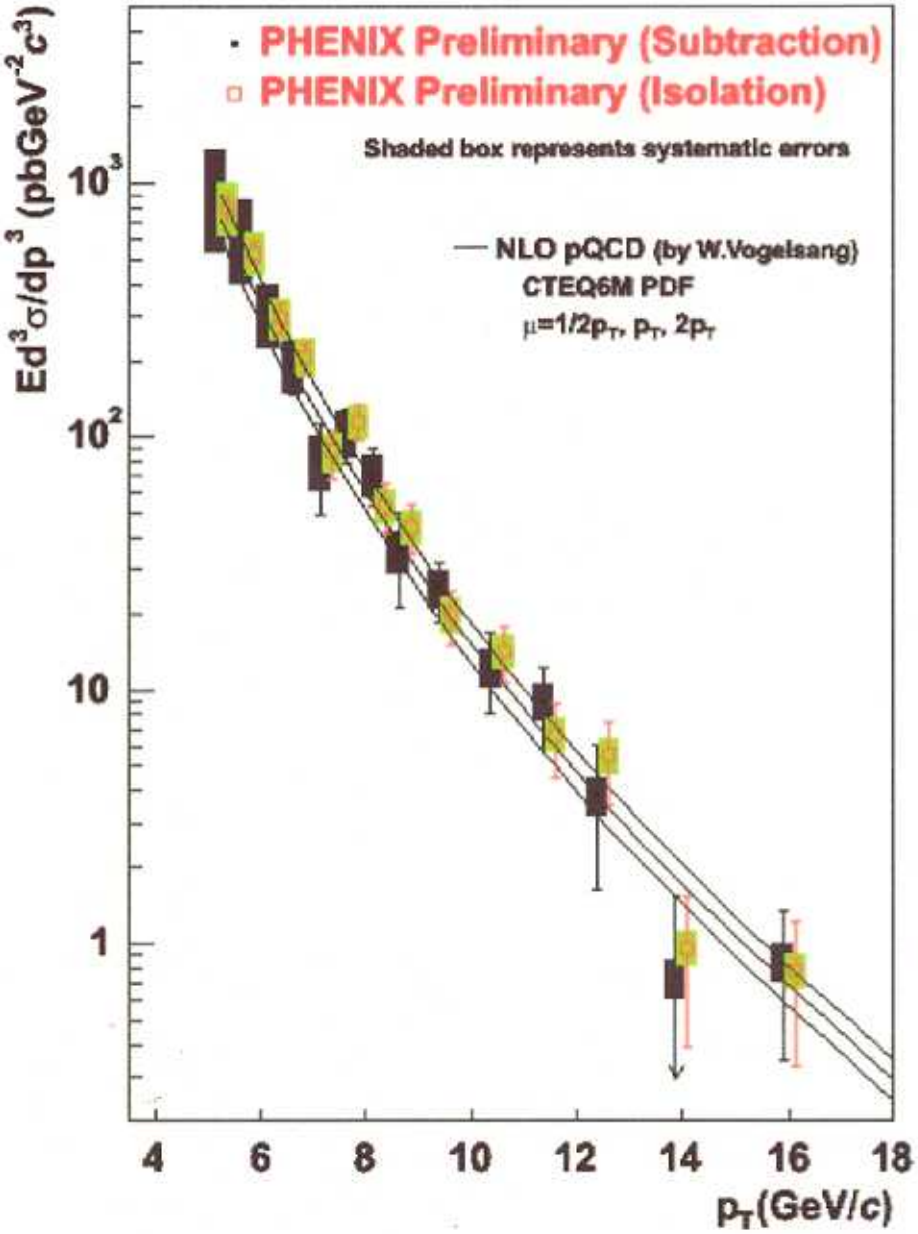
Private communication with W.Vogelsang

Fragmentation

Systematic error sources

For isolation cut method	Lowest 5-5.5 [GeV/c]	Highest 15-17 [GeV/c]	
Pi0 photon estimation	16%	2	Point to point
Non pi0 contribution	8	1	
Photon acceptance and smearing	10	10	
Photon conversion effect	1	1	
Luminosity measurement	12	12	global
BBC trigger bias	3	3	
Total (quadratic sum)	24%	16	

Comparison to NLO pQCD calculation



- NLO-pQCD calculation
  - Private communication with W.Vogelsang
  - CTEQ6M PDF.
  - direct photon + fragmentation photon
  - Set Renormalization scale and factorization scale pT/2,pT,2pT

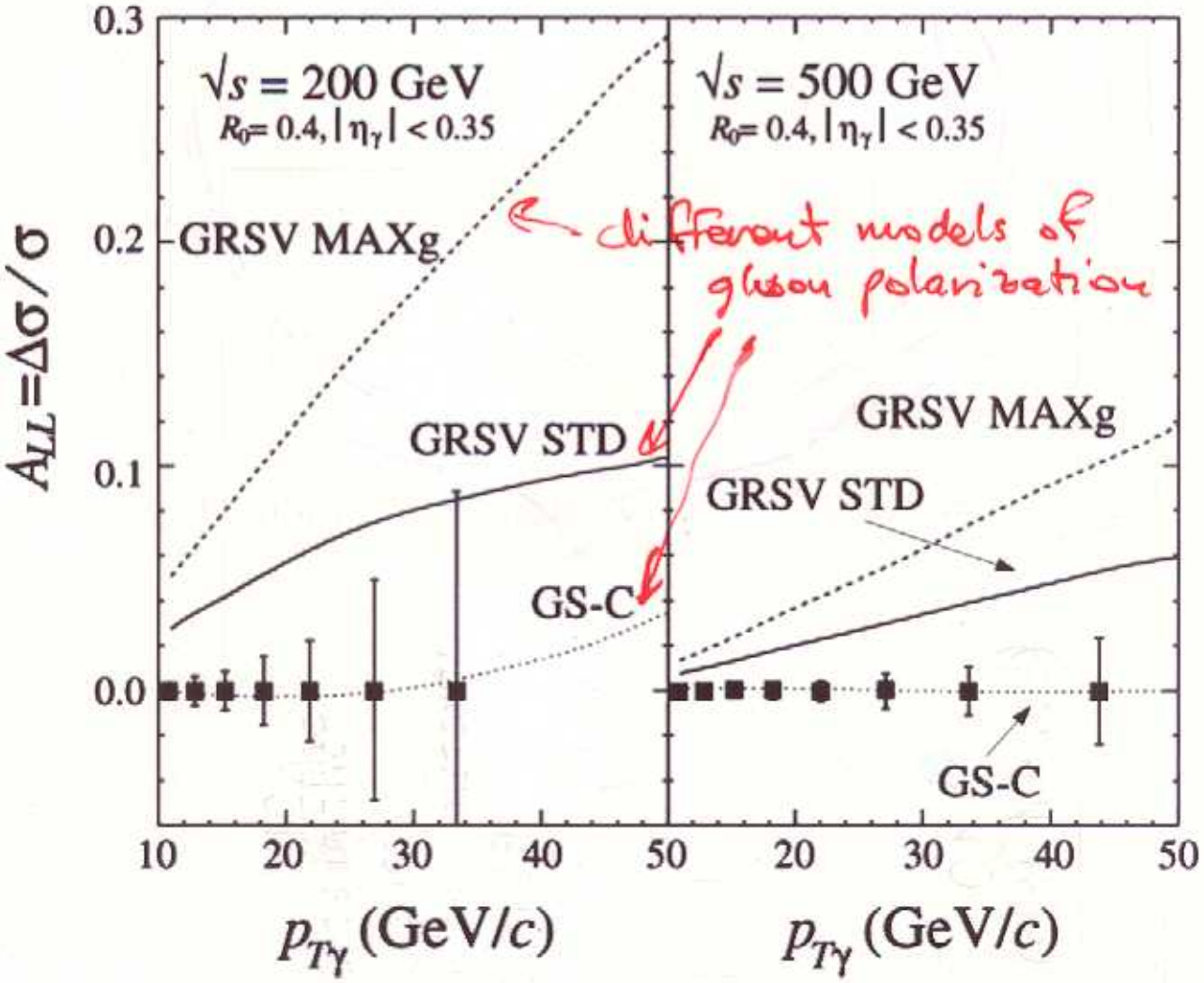
The theory calculation shows a good agreement with our result.

(RBRC)

Sensitivity at PHENIX for gluon pol.

$\int L\,dt = 320\ pb^{-1}$ $\sqrt{s} = 200$
$= 800\ pb^{-1}$ 500

$P_{beams} = 70\%$



$p\uparrow + p\uparrow \to \gamma + X : A_{LL}$