Prompt Photon at PHENIX

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High p_T prompt photon in polarized proton collision is a good probe to investigate ΔG, gluon polarization in the proton. Prompt photon production is dominated by the gluon Compton process. With the asymmetry (A_{LL}) measurement, we can obtain $\Delta G/G$ by using knowledge of the quark polarization and the asymmetry of elementary process. Detection of the prompt photon is experimentally challenging because of many background mainly from $\pi^0 \to 2\gamma$.

The prompt photon is detected by an EM calorimeter (EMCal) system at PHENIX. Parameters of the EMCal system are summarized in Table ??. Using these parameters we are studying the prompt photon measurement with PYTHIA5.7/JETSET7.4. For the background reduction, isolation cut is studied by using the generated events. Around each photon, isolation cone is defined with half angle $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$. All hadronic energy deposit in the cone is summed up and the sum is required to be less than a certain fraction of the photon energy. This cut discards background photon mainly from π^0 in the jet which is accompanied by other particles. On the other hand, the prompt photon is not accompanied by other particles and survives this cut.

We can impose other conditions, for instance, to use some constant value as the limit of energy in the cone, to use 1 central arm instead of isolation cone, etc. We need to consider that we cannot detect neutral hadron without detecting decay photons. There might be some theoretical issues in using any possible isolation cut to show the experimental result. We need to know how much uncertainty we have due to these cuts. This issue should be addressed to theorists.

For ΔG measurement, we need to know gluon's x value using p_T value of the prompt photon. Naive estimation of gluon's x is given by $x_T = 2p_T/\sqrt{s}$, but this shows the case that 2 colliding partons, i.e. gluon and quark, are balanced. From the simulation study, gluon's x value is estimated by specifying p_T region of the prompt photon. There is big difference between these two estimations. This uncertainty must be evaluated.

By considering yield and background, the accessible p_T ranges of prompt photon production are 10GeV/c < p_T <30GeV/c for $\sqrt{s}$=200GeV and 10GeV/c < p_T <40GeV/c for $\sqrt{s}$=500GeV. This correspond to 0.1< x <0.3 for $\sqrt{s}$=200GeV and 0.04< x <0.16 for $\sqrt{s}$=500GeV by using the x_T to evaluate the x value. The statistical errors on the $\Delta G/G$ in this region are 5–30% for $\sqrt{s}$=200GeV and 5-20% for $\sqrt{s}$=500GeV, although these will be affected by uncertainties in x value estimation.

All transparencies of this talk is accessible on the Web:
`http://www.phenix.bnl.gov/WWW/publish/goto/`

	η	ϕ	$\delta\eta$	$\delta\phi$	σ_E/E (%)	σ_x (mm)	σ_t (psec)
PbSc	± 0.35	$90° + 45°$	0.011	0.011	$7.8/\sqrt{E} \oplus 1.5$	$10./\sqrt{E}$	$70/\sqrt{E} \oplus 70$
PbGl	± 0.35	$45°$	0.008	0.008	$5.8/\sqrt{E} \oplus 1.0$	$5./\sqrt{E} \oplus 1.0$	$143/\sqrt{E} \oplus 75$

Table 1: Parameters of the PHENIX EMCal system. η and ϕ show pseudo-rapidity and azimuthal angle coverages. $\delta\eta$ and $\delta\phi$ show granularity per module. Energy resolution, position resolution and timing resolution are also listed.

PYTHIA Simulation

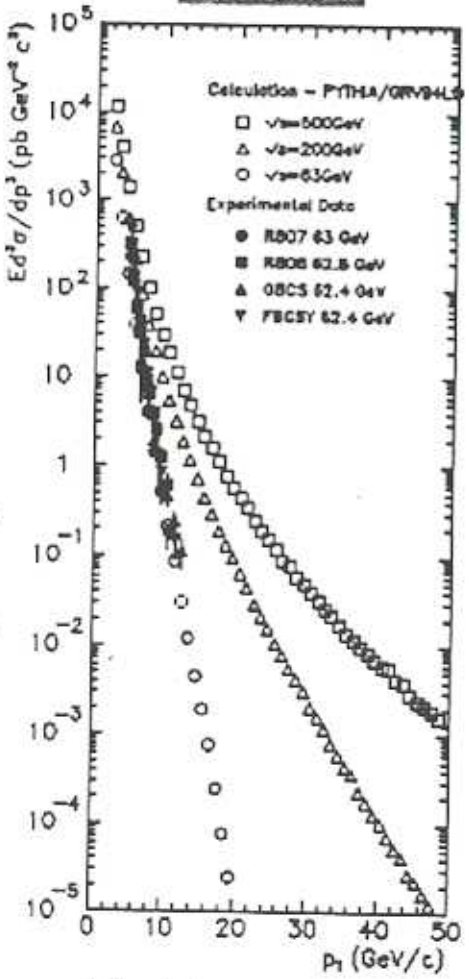
- PYTHIA5.7/JETSET7.4
  - PDFLIB GRV94LO
  - prompt photon production as a signal
  - QCD jet as a background
- Luminosity

$$\int Ldt = 320\, pb^{-1} \text{ for } \sqrt{s} = 200\, GeV$$

$$\int Ldt = 800\, pb^{-1} \text{ for } \sqrt{s} = 500\, GeV$$

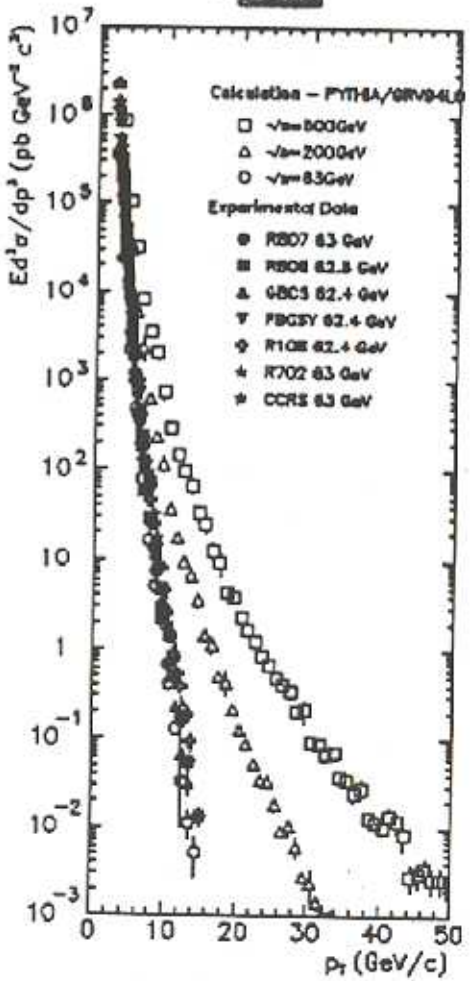
  - 10 weeks run with 70% efficiency and 70% pol.

photon



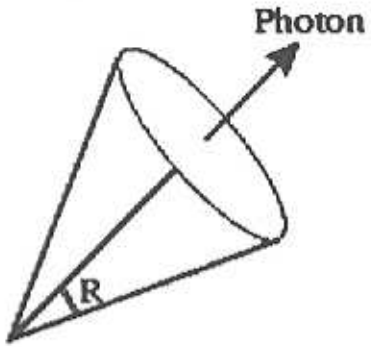
(a) photon cross section

π^0



(b) π^0 cross section

Isolation Cut



- Around each photon, a cone of a certain radius R is defined.

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

  - $\Delta\eta$: rapidity interval $\Delta\phi$: azimuthal angle
- Hadronic energy deposit in the cone (E_{sum}) is required to be less than a certain fraction of the photon energy (E_γ).

$$E_{sum} < \varepsilon \cdot E_\gamma$$

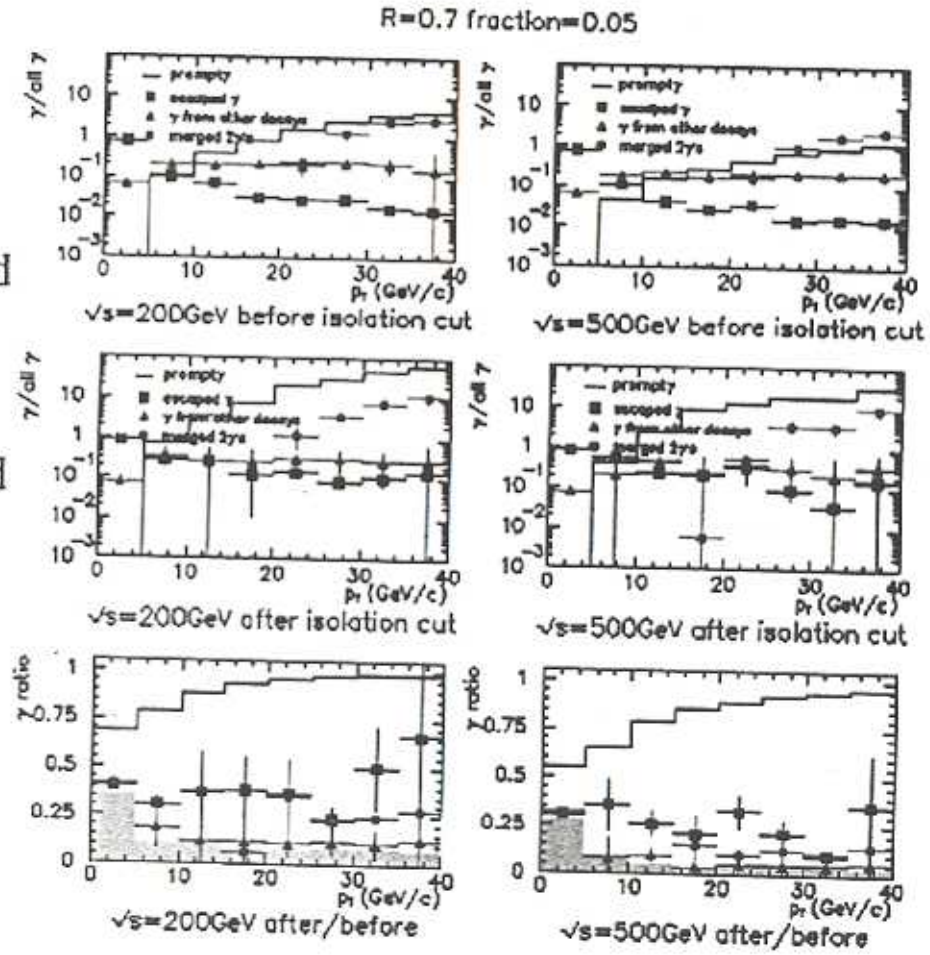
- other isolation cut
  - fixed value instead of fraction

$$E_{sum} < \text{const.}$$

  - neutral hadron (other than π^0) undetectable
  - 1 central arm instead of isolation cone ...
- theoretical issue ?
  - from experimental data to ΔG information directly ?
  - how much uncertainty ?

Isolation Cut

- background for prompt photon
  - before isolation cut
    - normalized by all background photon before isolation cut
  - after isolation cut
    - normalized by all background photon after isolation cut
- ratio before and after isolation cut
  - red line: prompt photon
  - yellow hatch: all background photon



* $\pi^0 \to 2\gamma$ is assumed to merge when 2γ angle is less than 0.01.

ΔG Measurement

- statistics
  - P_B: beam polarization ~70%
  - N^{++}: parallel spin direction
  - N^{+-}: anti-parallel spin direction
  - A_1^p: GS95

$$A_{LL} = \frac{1}{P_B^2} \cdot \frac{N^{++} - N^{+-}}{N^{++} + N^{+-}}$$

$$\delta A_{LL} = \frac{1}{P_B^2} \cdot \frac{1}{\sqrt{N^{++} + N^{+-}}}$$

$$\delta \frac{\Delta G}{G} = \frac{\delta A_{LL}}{A_1^p \cdot a_{LL}}$$

prompt photon

	$\sqrt{s}$ = 200GeV			$\sqrt{s}$ = 500GeV		
Photon p_T	Yield	Errors on A_{LL}	Errors on $\Delta G/G$	Yield	Errors on A_{LL}	Errors on $\Delta G/G$
10 – 15 GeV/c	1.0×10^5	0.0062	0.046	9.0×10^5	0.0022	0.045
15 – 20 GeV/c	1.3×10^4	0.0168	0.089	1.8×10^5	0.0059	0.059
20 – 25 GeV/c	2.7×10^3	0.0376	0.171	5.3×10^4	0.0081	0.081
25 – 30 GeV/c	5.9×10^2	0.0799	0.309	1.9×10^4	0.0115	0.115
30 – 35 GeV/c				7.7×10^3	0.0141	0.141
35 – 40 GeV/c				3.3×10^3	0.0198	0.198

Table 1: Prompt photon yield and error estimation.

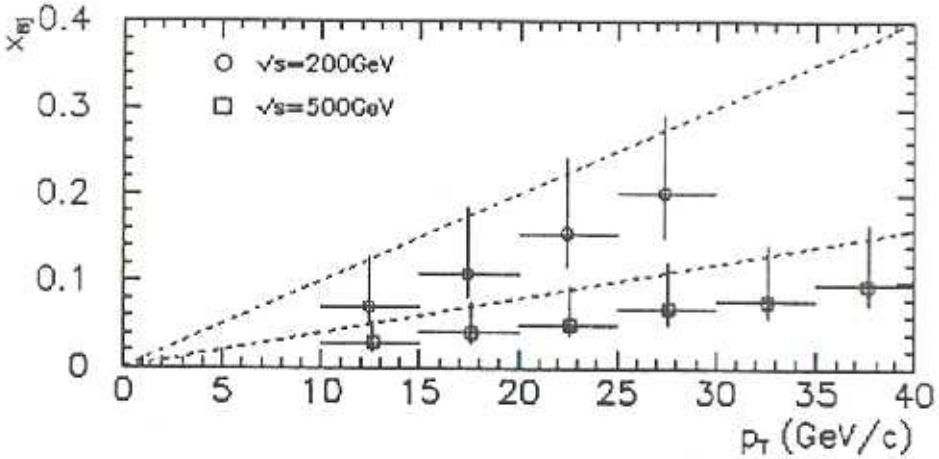
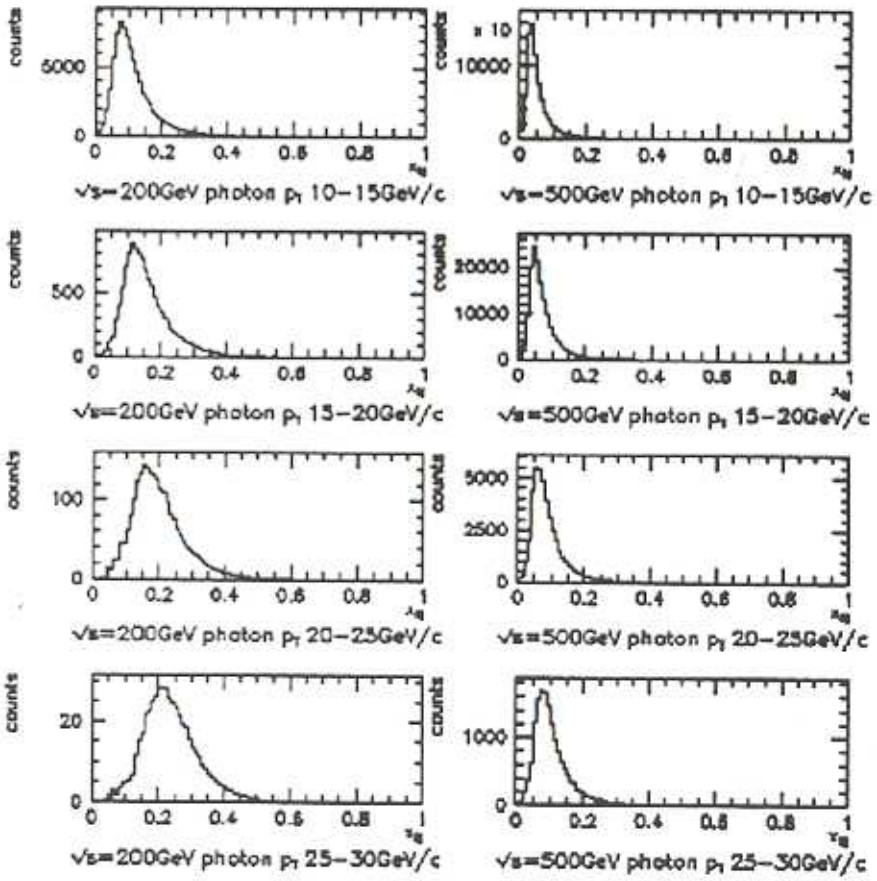
inclusive π^0

	$\sqrt{s}$ = 200GeV	$\sqrt{s}$ = 500GeV
10 – 15 GeV/c	5.6×10^5	1.2×10^7
15 – 20 GeV/c	4.2×10^4	1.5×10^6
20 – 25 GeV/c	4.9×10^3	2.5×10^5
25 – 30 GeV/c	8.5×10^2	7.4×10^4
30 – 35 GeV/c		1.9×10^4
35 – 40 GeV/c		7.1×10^3

Table 2: Inclusive π^0 yield estimation.

ΔG Measurement

- p_T vs gluon's x
  - naïve formula ?

$$x_T = \frac{2p_T}{\sqrt{s}}$$

  - or evaluation with simulation ?