Direct photons at PHENIX

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Introduction

- **Our PHENIX paper**
  http://arXiv.org/abs/hep-ex/0609031 is recently accepted by PRL.

  Title: Measurement of direct photon production in *p+p* collisions at √s=200GeV

- **Most figures are from 200GeV *p+p* collisions at PHENIX.**

Motivation

Direct photon production process is important.

- ***p+p* collisions**

  One of the simplest processes

  Test on pQCD calculation

- ***N+N* collisions**

  Electromagnetic probe for the media

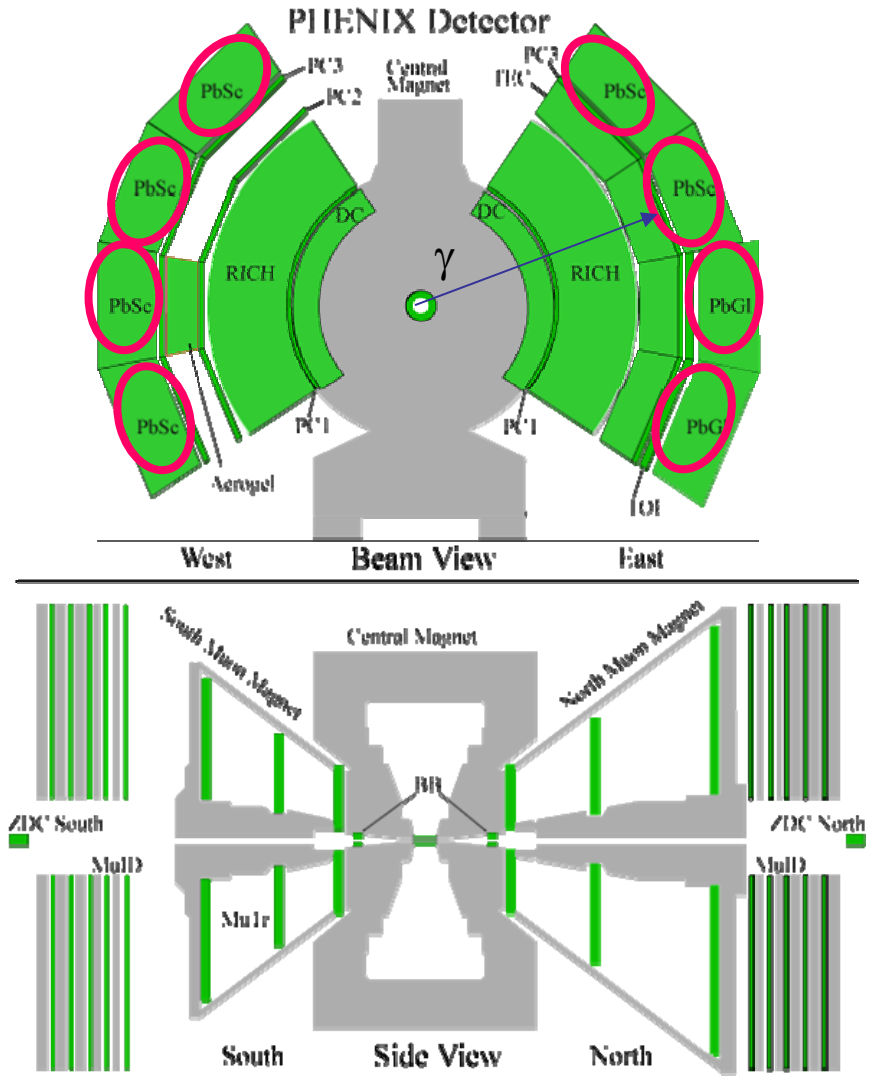
  Brings information of the initial state

- **Polarized *p+p* collisions**

  Probe for gluon polarization via gluon Compton scattering.

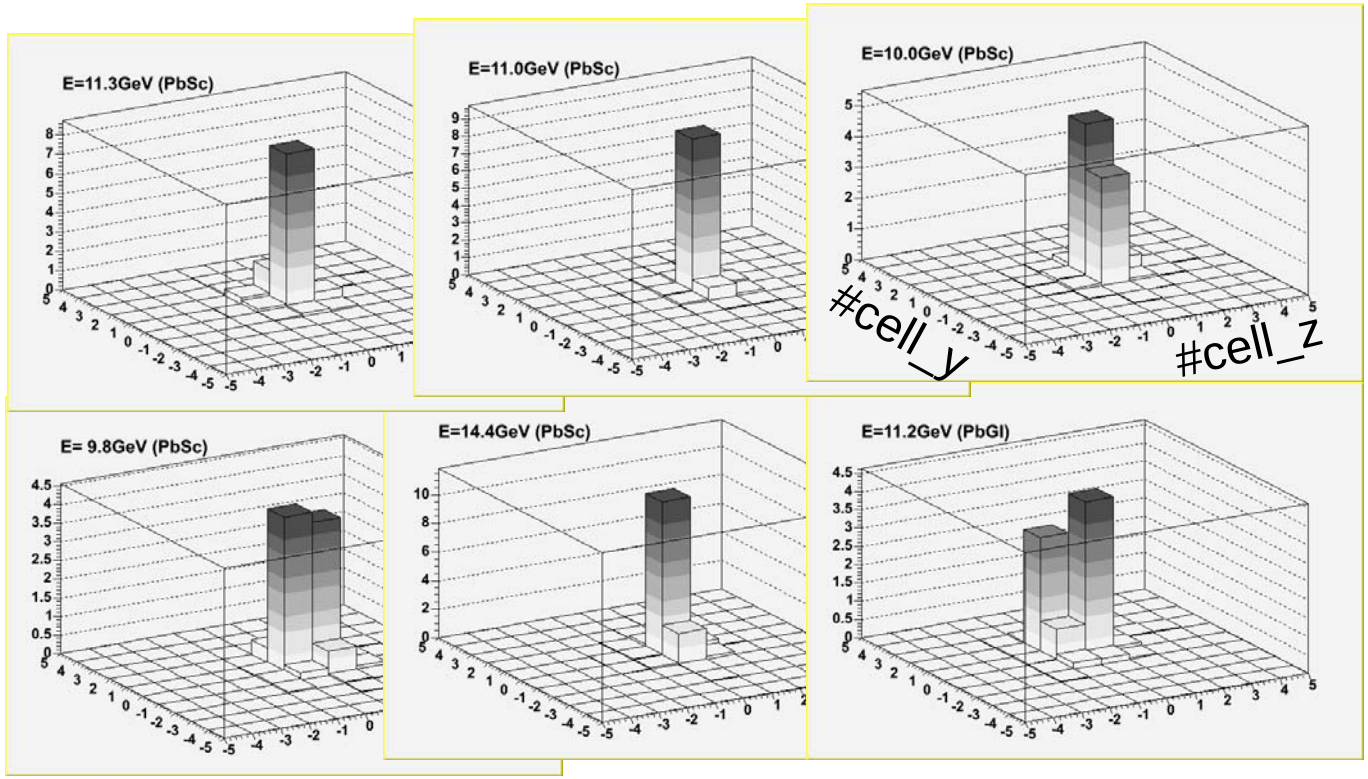
The PHENIX detector

- **Electromagnetic calorimeter (EMCal)**
  - Mid-rapidity region
  - photon detection
    - coverage:
      - $0.5\pi * 0.7 * 2$arms
    - segmentation:
      - $d\phi * d\eta = 0.01 * 0.01$
- **Beam-beam counters (BBC)**
  - Luminosity measurement
  - Vernier scan
    - (beam size measurement)



The PHENIX detector (EMCal)

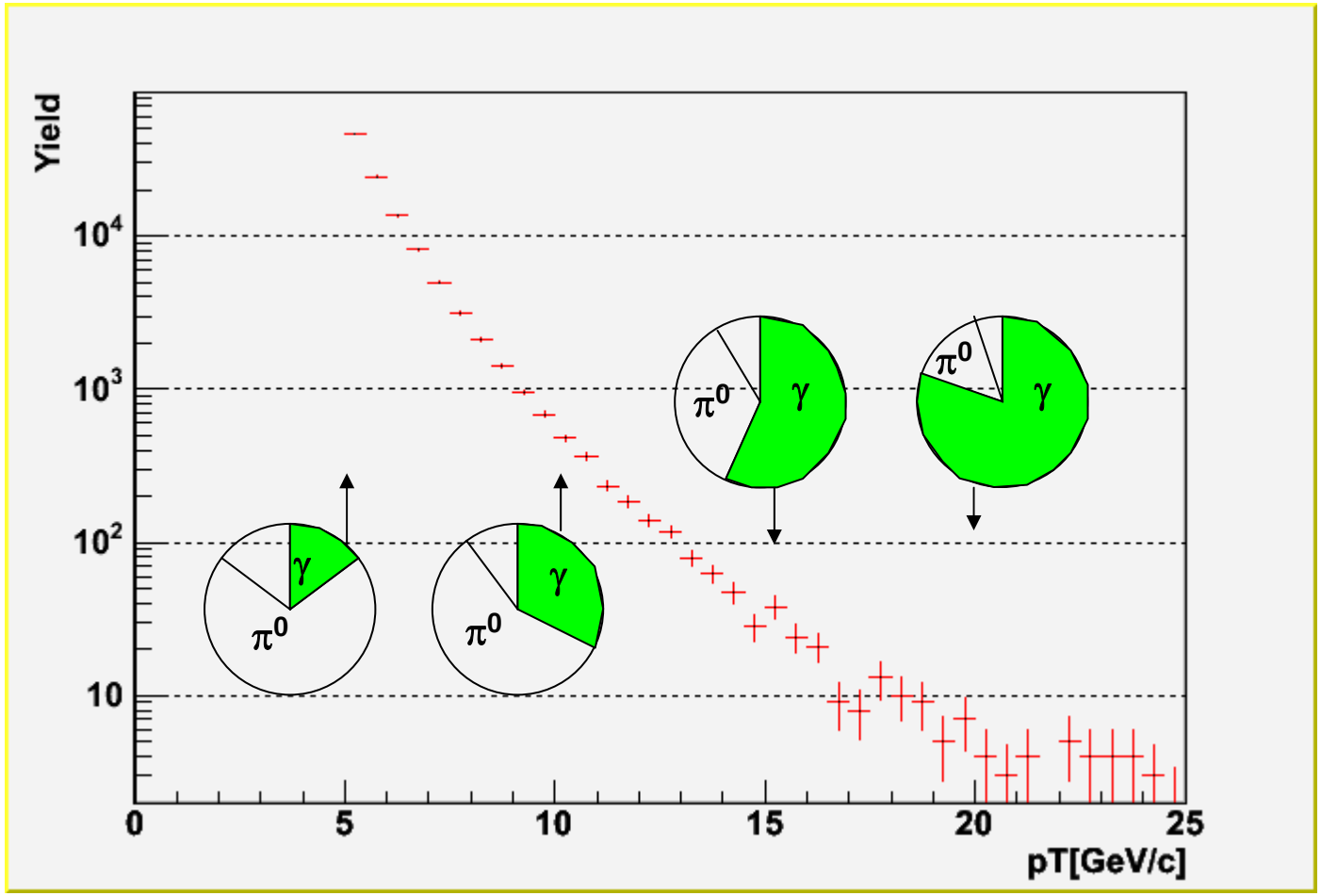
- **How do ~10GeV photon clusters look like in the EMCal?**



- π^0 2gamma distance
  > 28 tower / $E\pi^0$ [GeV]

You may think it is easy

Clusters from other sources (hadronic decays, albedos)



Small S/N

π^0 2γ into one tower

Task for experimentalists (1)

Method 1 (Cocktail) PHENIX traditional

1. Double ratio

$$r \equiv \left(\gamma/\pi^0\right)_{Measured} \Big/ \left(\gamma/\pi^0\right)_{MC}$$

shows the significance of the direct photon signal (r=1 → no signal)

2. Direct photon spectra

Need to multiply the inclusive photon spectra ($Y\gamma$)

$$Y_{direct} = \left(1 - \frac{1}{r}\right) Y_{\gamma}$$

Task for experimentalists (2)

- **Method 2 (pi0 tagging)**

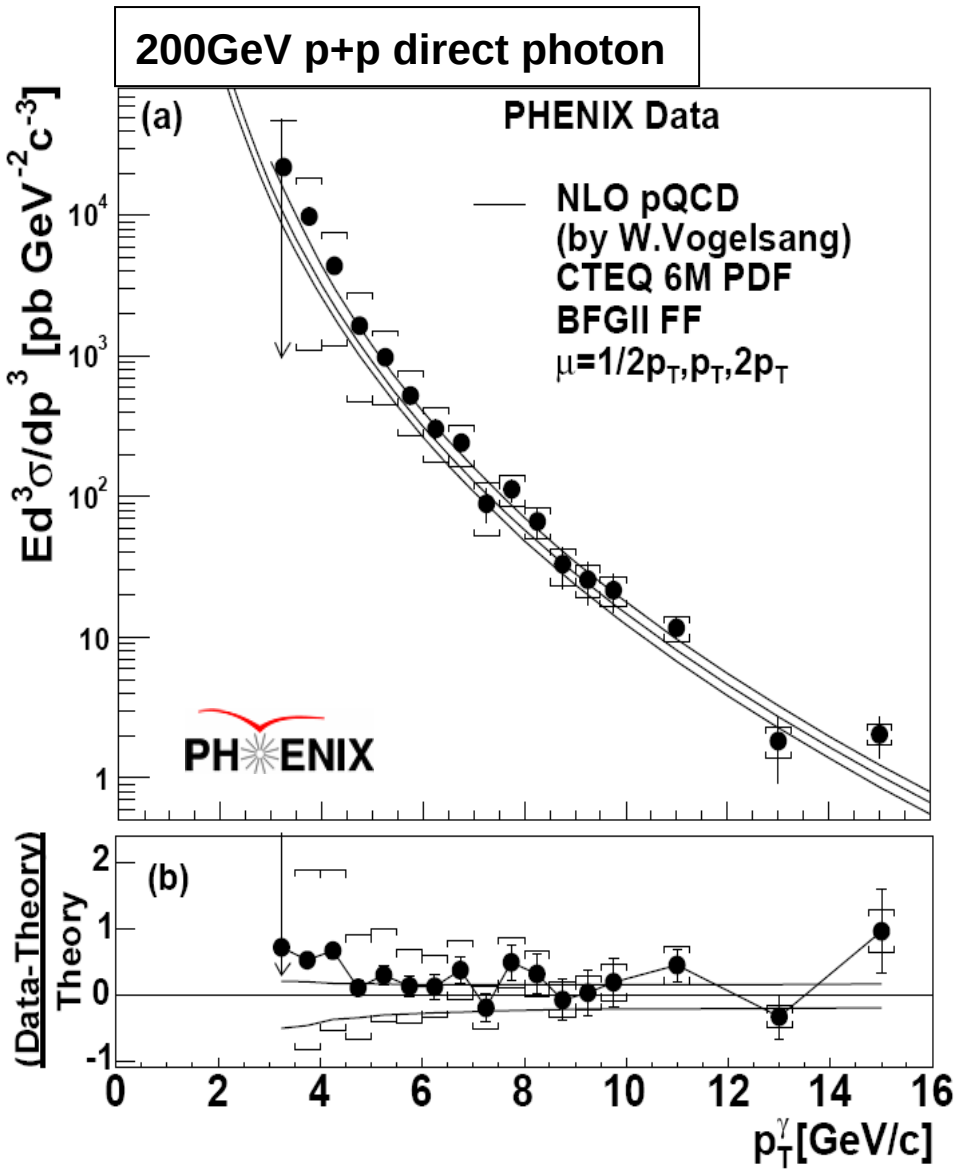
  Why can't we obtain it in one step?

$$\boxed{Y_{direct} = Y_{\gamma} - RY_{\pi^0}}$$

- **Materials are same in the two methods.**
  A good cross check.

  We averaged them in the final result.

Direct photon spectra



hep-ex/0609031
Recently accepted by PRL

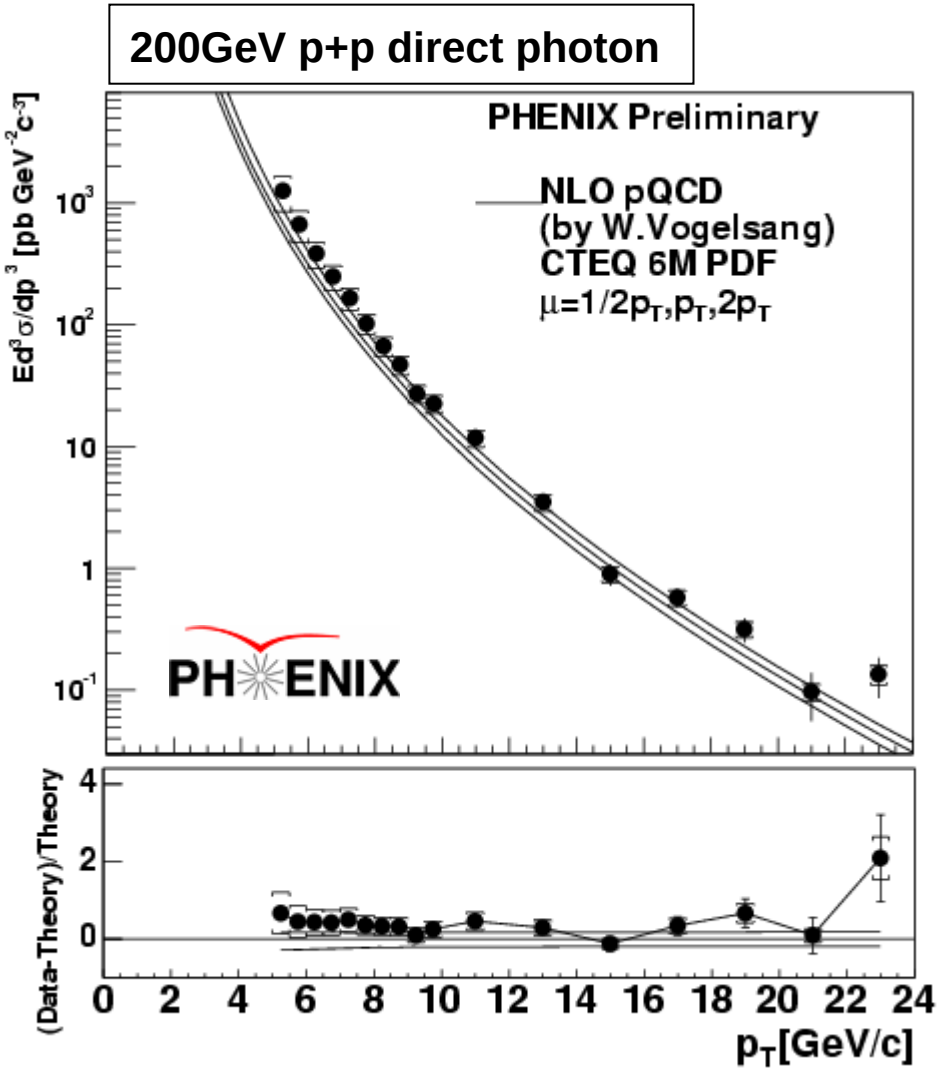
2 methods are combined

pQCD describes the result well

TABLE I: Relative systematic uncertainties of the direct photon spectra.

p_T [GeV/c]	4.5-5	7.5-8	10-12
Signal fraction	9%	27%	49%
(a) Global	16.8%	14.9%	14.9%
(b) Inclusive photons	12.3%	4.7%	3.1%
(c) Photons from π^0	30.1%	10.7%	6.5%
(d) Other hadrons	21.4%	6.7%	3.8%
(e) Non-linearity (+ remaining)			
(e_1) π^0 tagging	42.7%	6.8%	5.4%
(e_2) cocktail	69.5%	20.4%	13.4%
Total	71.6%	25.2%	19.8%

Update with x10 statistics

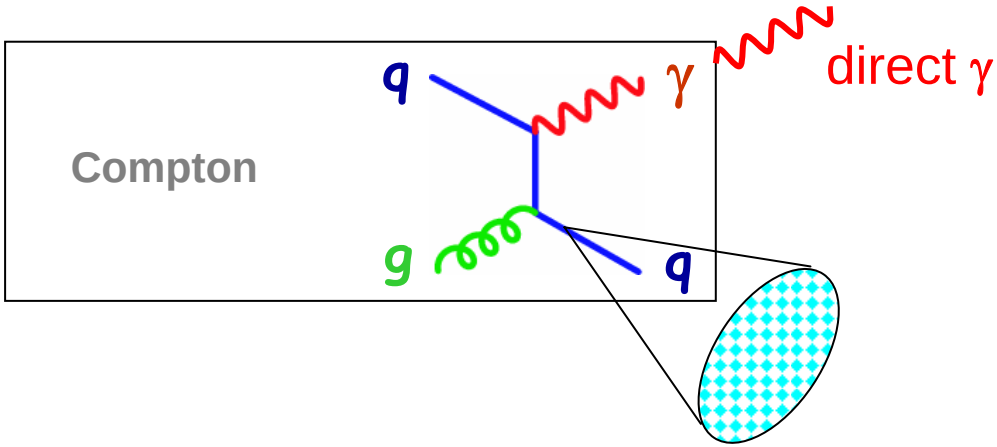


with Run5 data (L=2.5/pb)

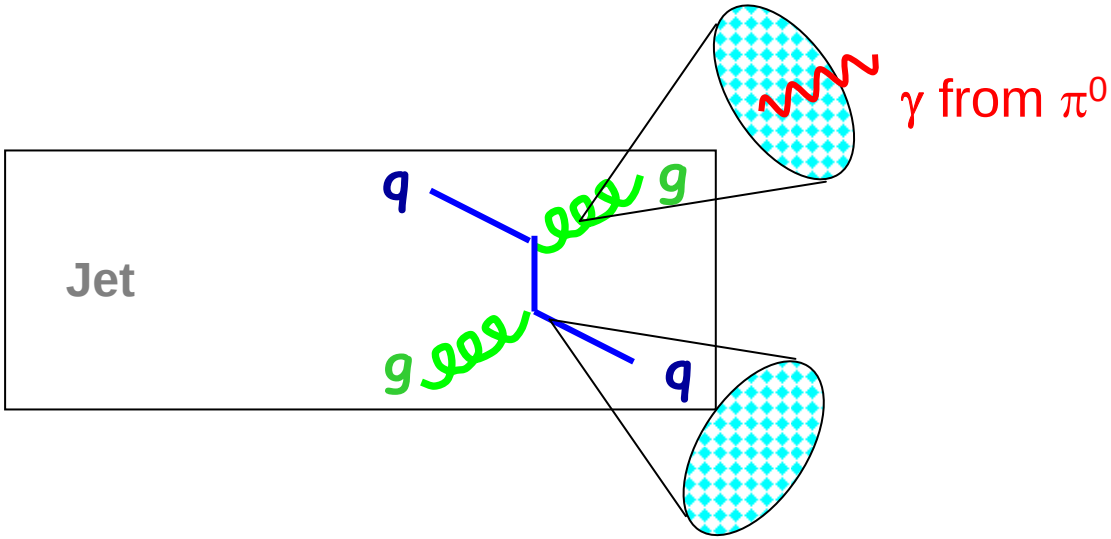
pi0 tagging method

Confirmed the previous result
Extended the pT region

Direct photon event structure



They should look different !

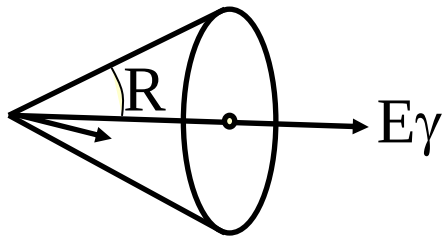


A bonus of π^0 tagging method

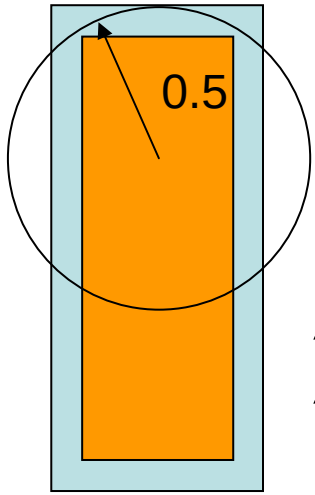
- **Photon isolation cut**

  Though our detectors aren't large enough,
  an isolation cut is applied. We set fringes.

$0.1E\gamma > E_{cone}$ (R=0.5rad)



E_{cone} : photon energy
+ charged particle momentum

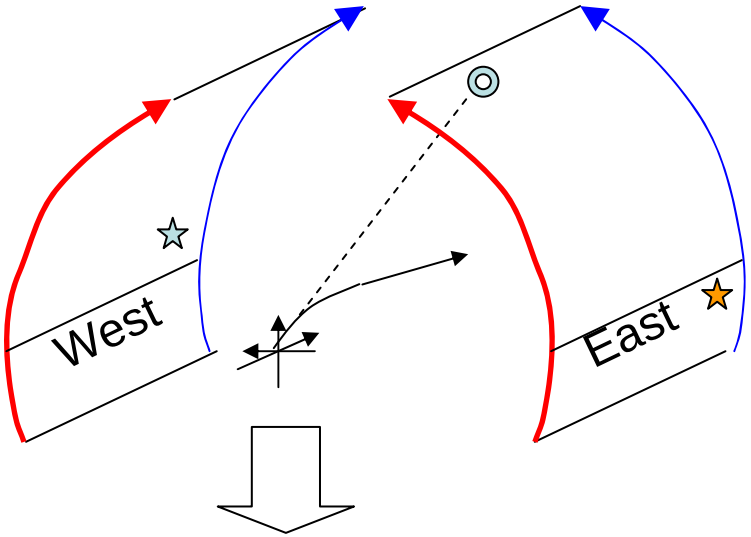


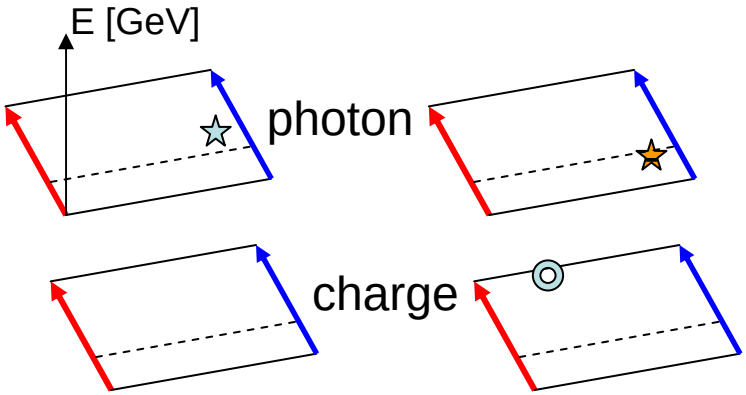
PHENIX arm
$\Delta\eta$=0.7
$\Delta\phi=\pi/2$

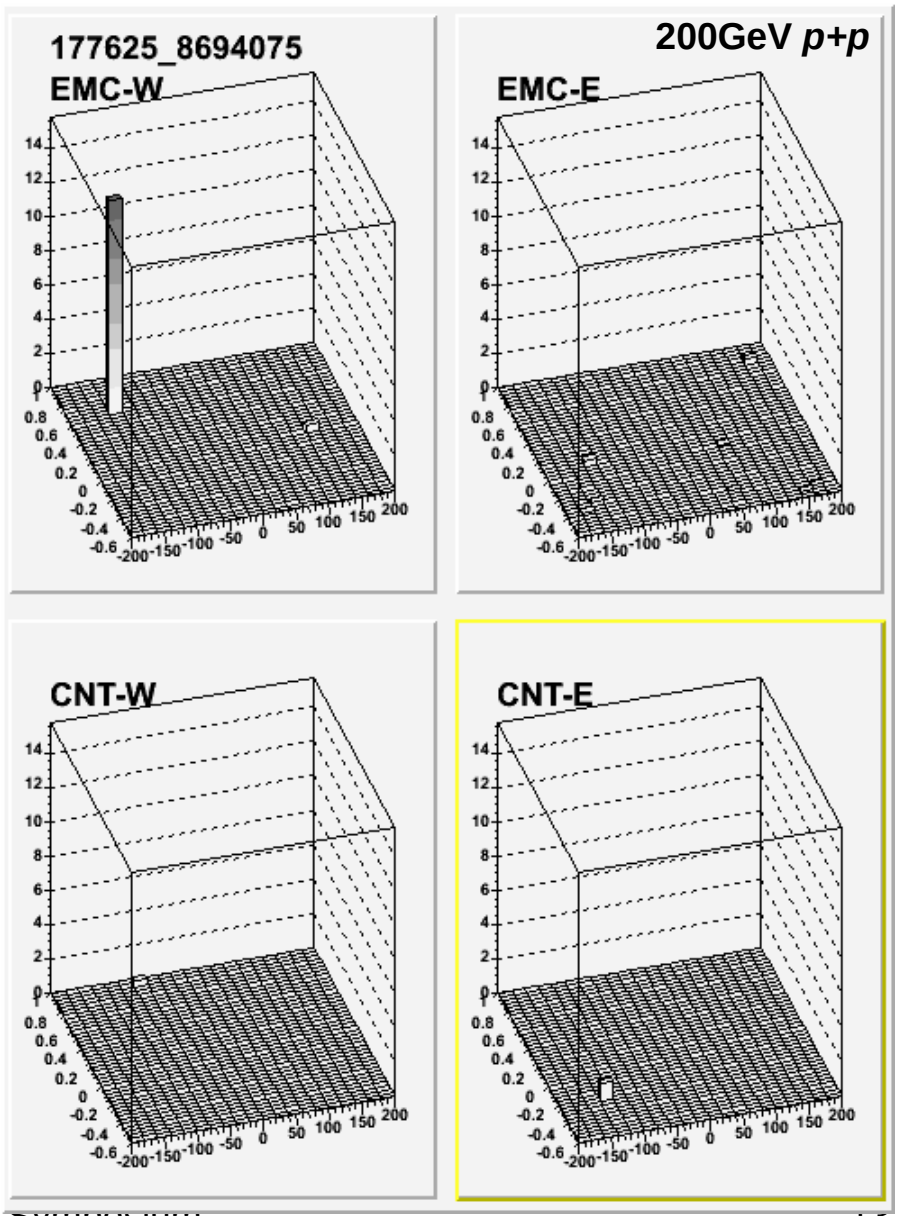
- **Background estimation with <u>isolated photon pairs</u>**

(Apply the isolation cut with ignoring the partner energy)

Event examples (1/4)

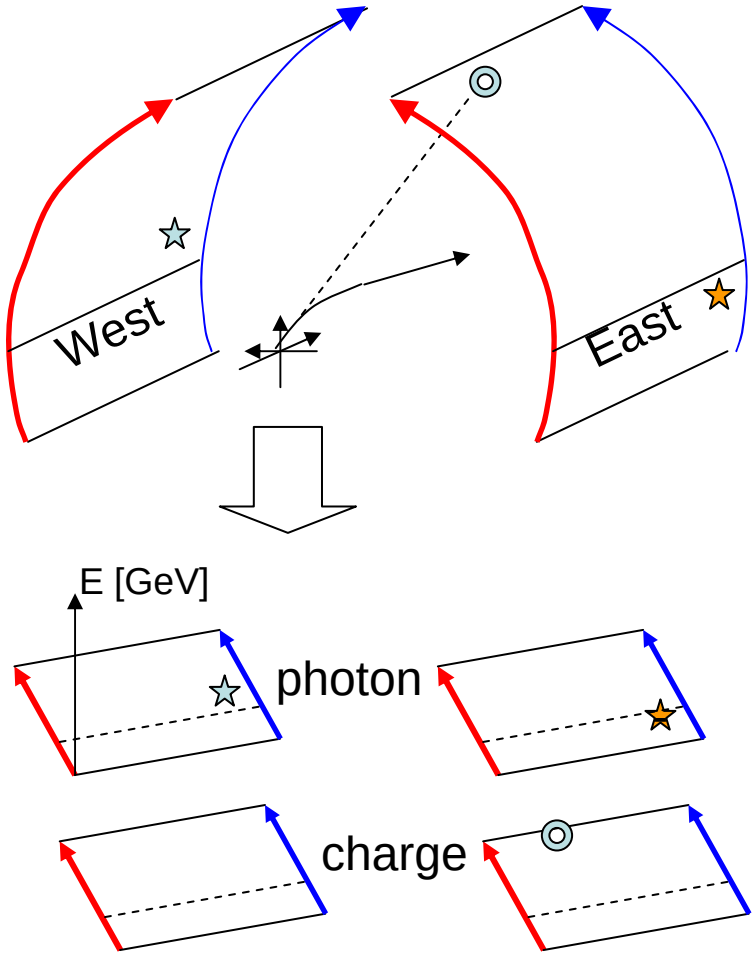


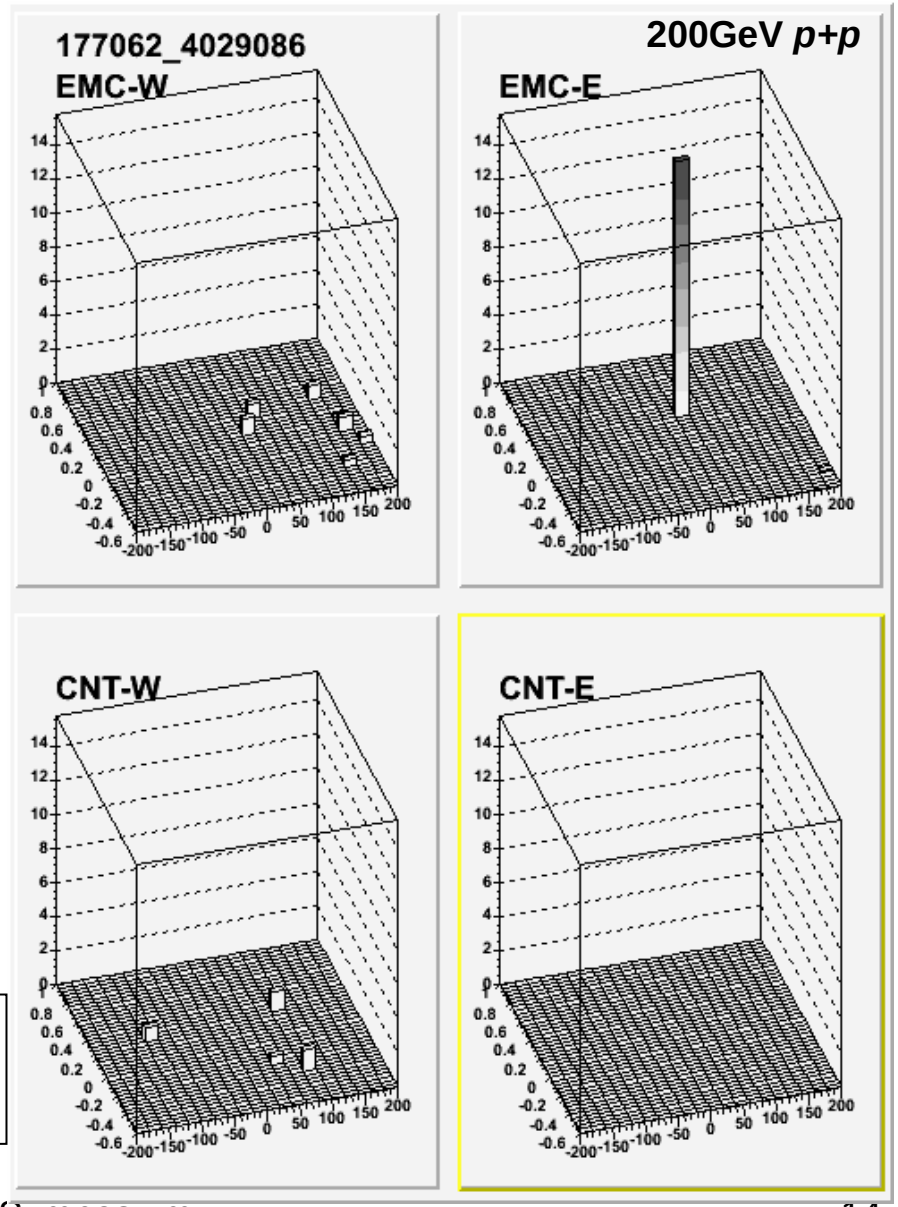




This is from *p*+*p* collisions, most of events are quiet.

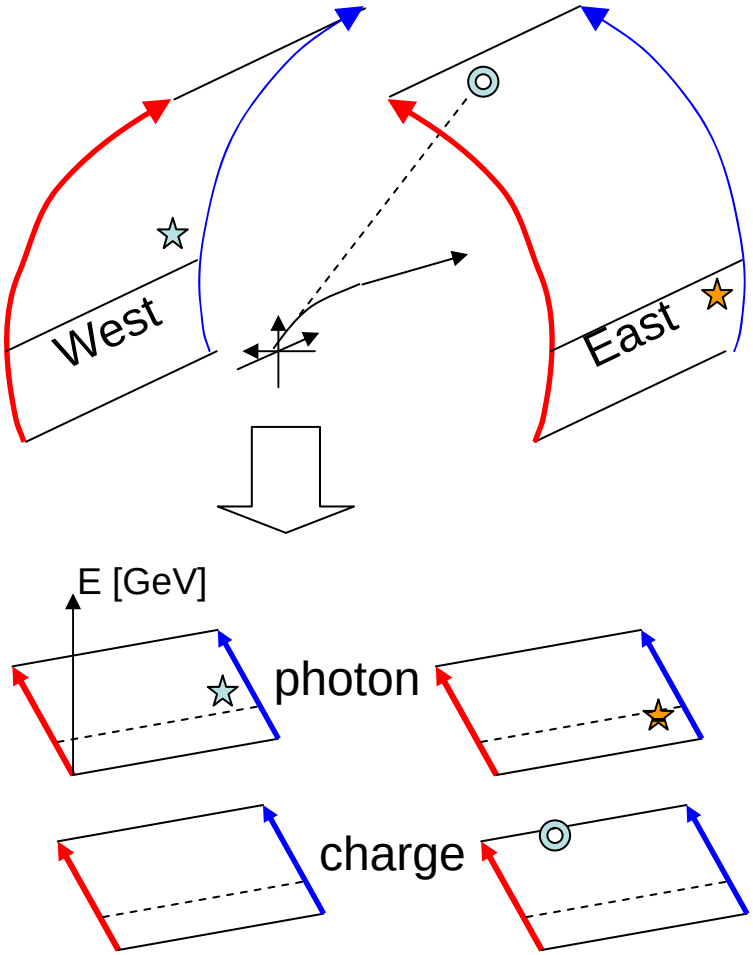
Event examples (2/4)

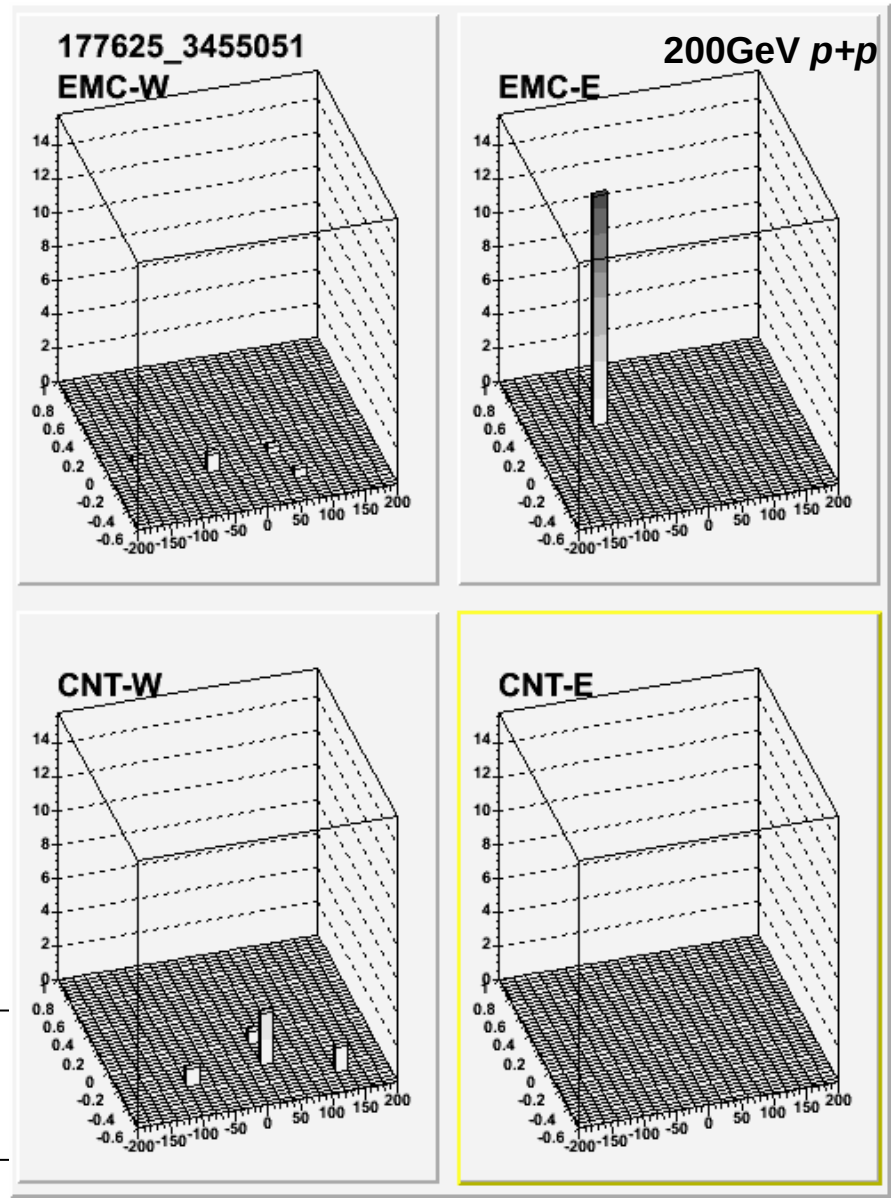




Some events have activities in the opposite side. (1)

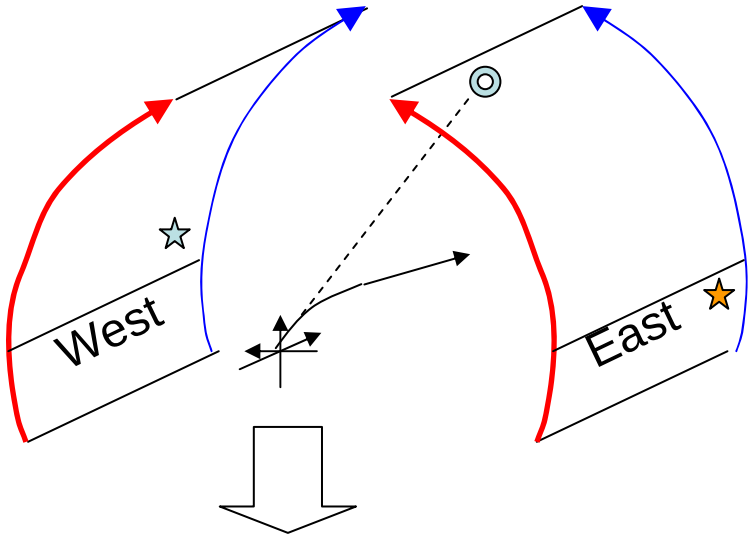
Event examples (3/4)

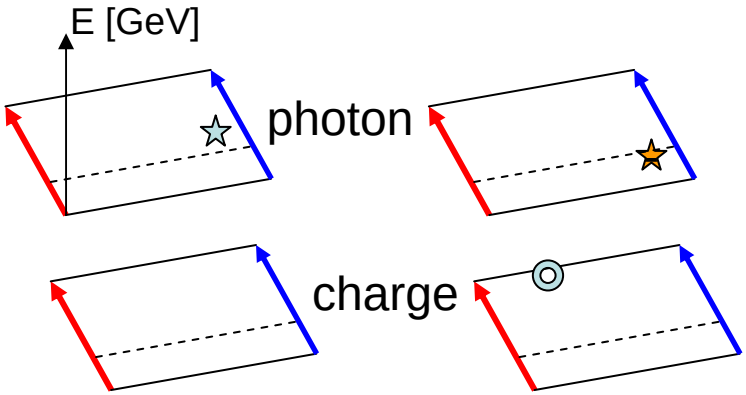




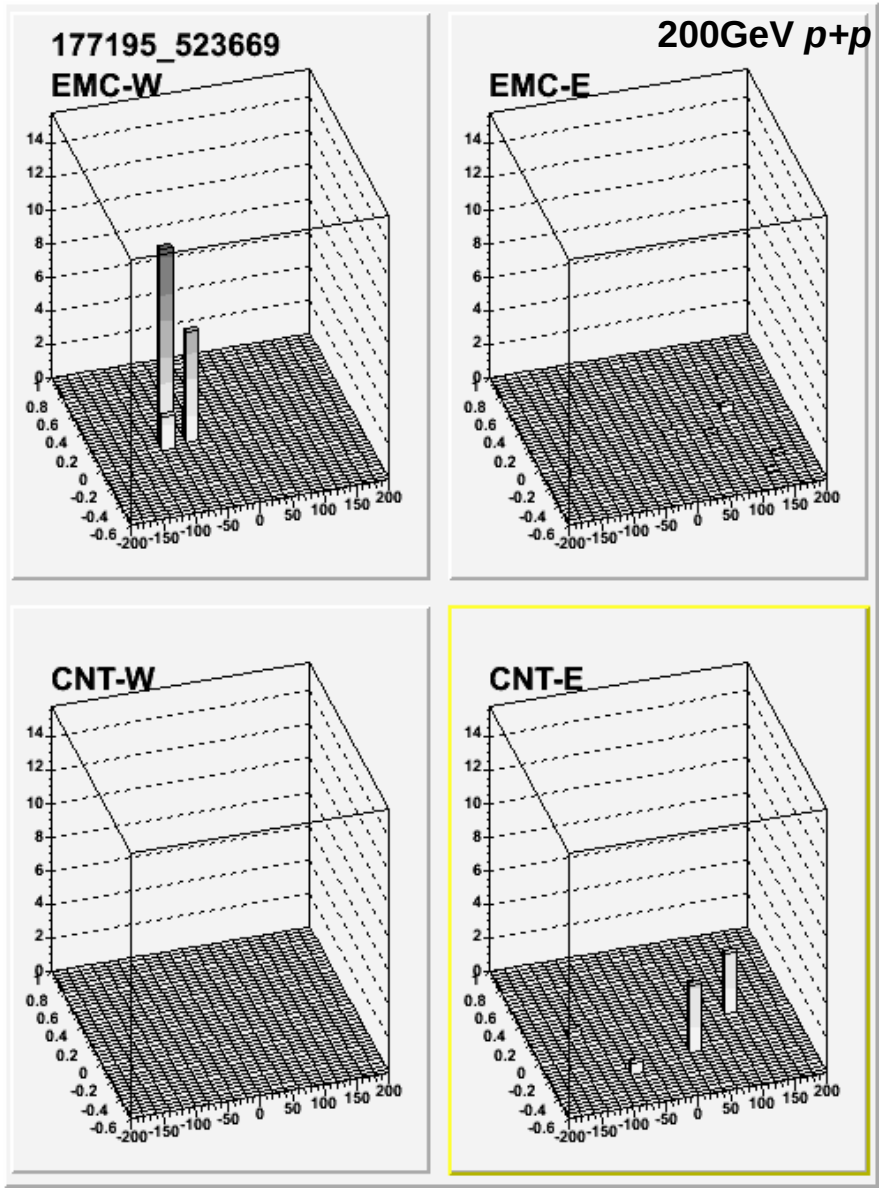
Some events have activities in the opposite side. (2)

Event examples (4/4)





A event not pass the isolation cut

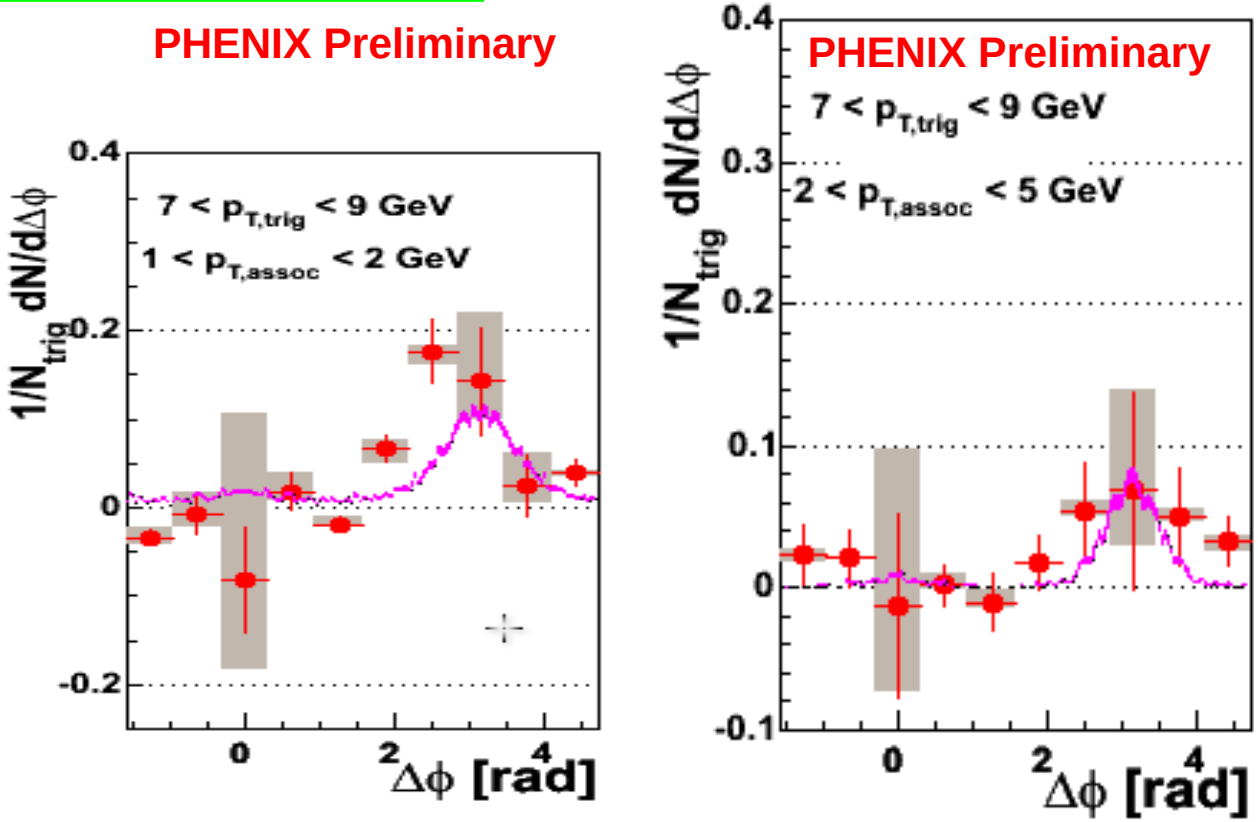


Direct γ-h yield in *p*+*p*

2 particle correlation
(inclusive gamma) – (decay gamma)

- data
— PYTHIA

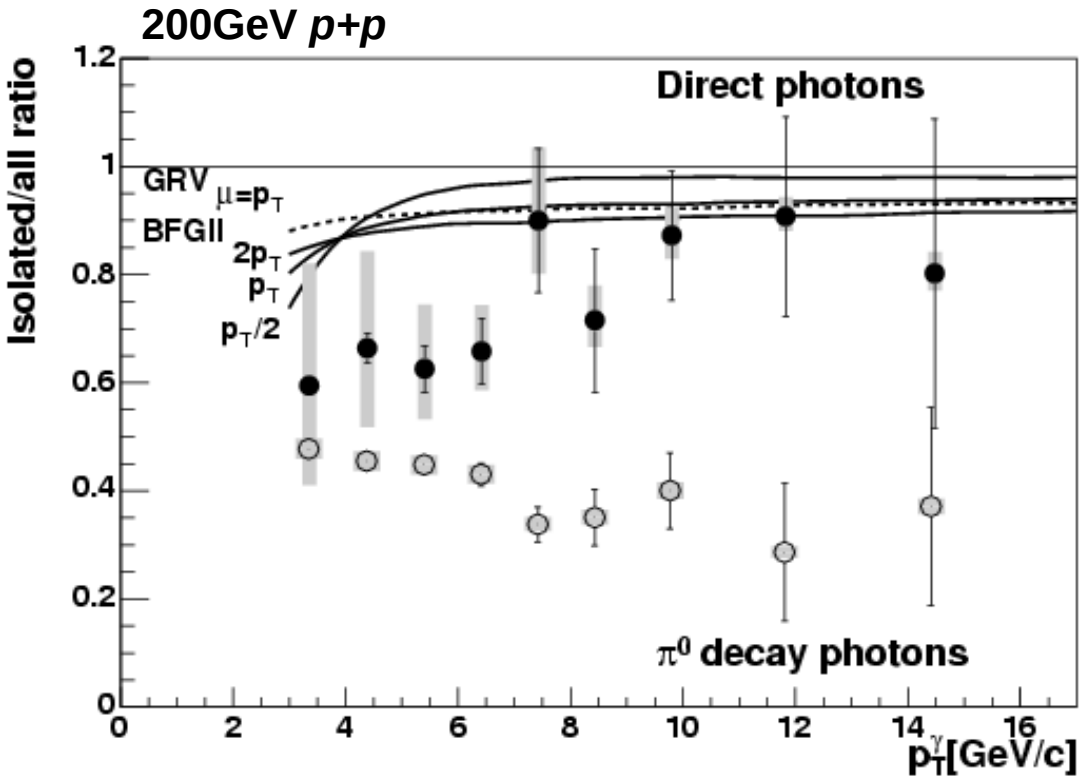
PYTHIA 6.1
k_T = 2.5 GeV



Near side: consistent to 0
Away side: peak structure

It is consistent to the feature of direct photon event.

Fraction of Isolated to All



Included:

PHENIX isolation cut
(0.5rad cone,
0.1Eγ threshold
0.1rad fringe)

Not included:

Effect of Underlying event
Larger in lower p_T

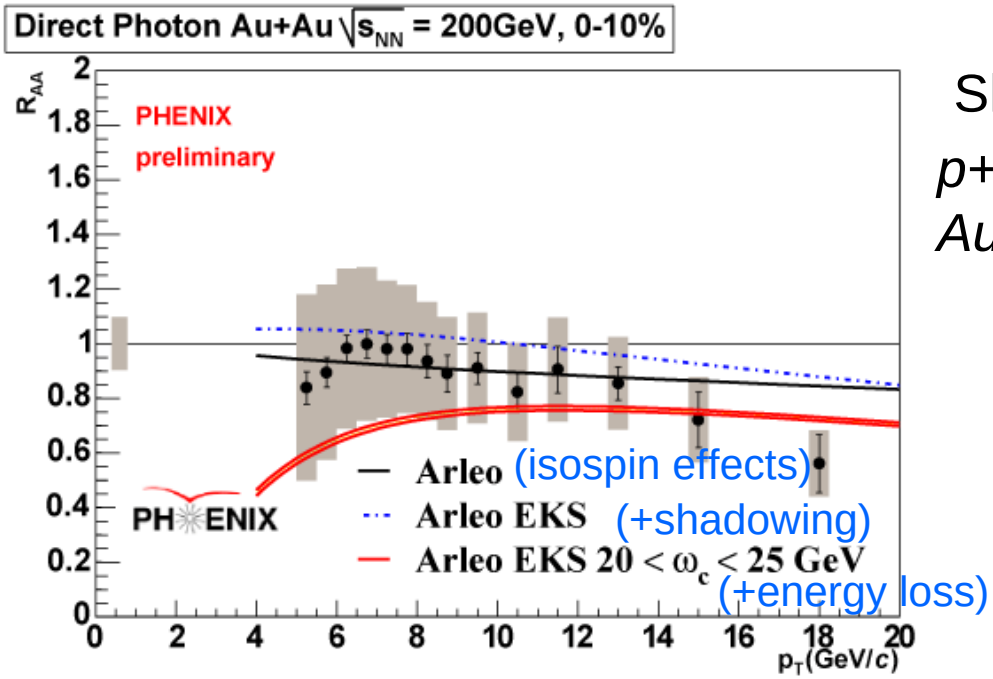
- In contrast to π^0 decay photons, direct photons are mostly isolated.
- Theory calculations agree well to the measurement at high p_T region (p_T >~7GeV/c)

Nuclear modification factor

Direct photon R_{AA}

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA}\, d^2\sigma^{NN}/dp_T d\eta}$$

$$T_{AA} = N_{coll}/\sigma_{NN}$$



Shown at QM06

p+p baseline : fit with p+p data (Run5)

Au+Au : new measurement from Run4

Some model calculation reproduce the high p_T suppression.

F.Arleo JHEP 0609(2006) 015

Summary

- Measurement of direct photon production in *p*+*p* collisions at $\sqrt{s}$=200GeV is done with the PHENIX detector.

- The NLO pQCD calculation describes our result well.
  It gets clear also the shape of direct photon events agree with our understanding.

- The nuclear modification factor (R_{AA}) of direct photon is obtained by data for the first time. Is the suppression at high p_T?

- For the measurement of double spin asymmetry, the isolation cut is essential to increase the signal purity.
  But from the recent results of π^0's asymmetry, it became clear we need more luminosity to catch the gluon spin component in proton with this channel.