Direct Photon Production in p+p collisions at $\sqrt{s}$=200GeV

RIKEN Lunch Seminar

November 10, 2005

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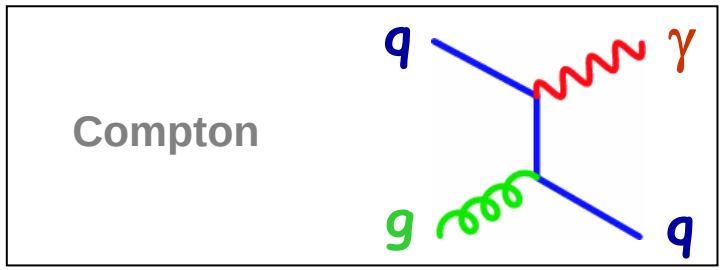
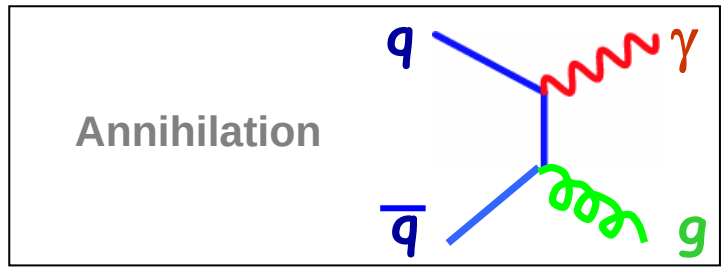
Motivations

—Test of our theoretical understanding based on QCD
—Direct information on gluon distribution in the proton
With polarized beam at RHIC, it is a probe for gluon polarization
—Reference for A+A collisions
A transparent probe brings information of the initial condition.



80~90%

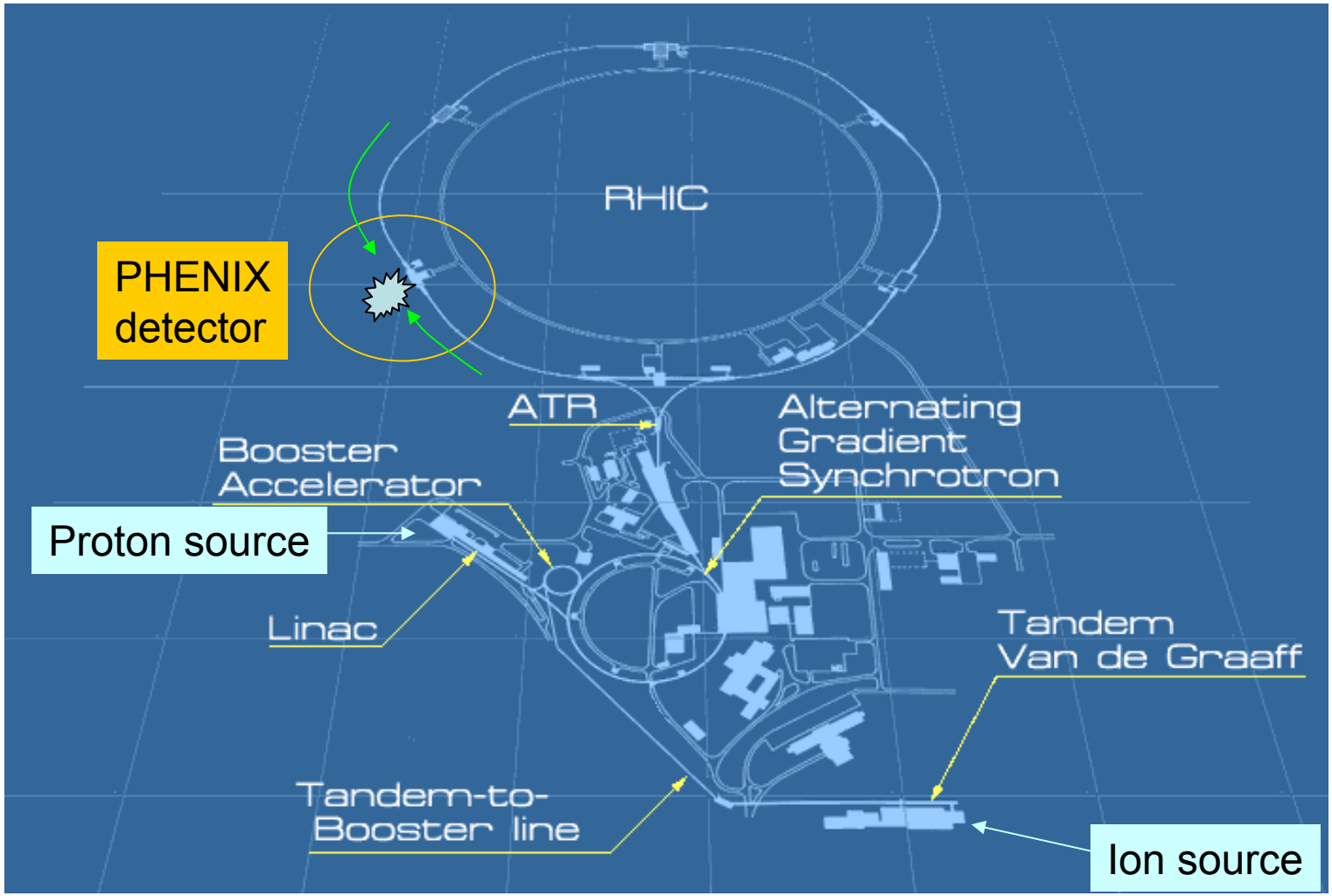
Dominant (at RHIC p+p)



20~10%

RHIC

Relativistic Heavy Ion Collider and
Polarized Proton Collider



Experimental aspect

- It's not so simple

  Backgrounds from hadronic decays (mainly $\pi^0 \rightarrow 2\gamma$).

- Approaches

  —Subtraction

  From π^0 spectra, estimate their contributions.

  ☹ Difficulty in low pT (1~5 GeV/c) region because of low Signal to Noise ratio.

  —Internal conversion (Low mass $e^{\pm}$ pair)

  π^0,η Dalitz decay has a limit at their mass.

  Direct photon component can be extracted from

  $$\underbrace{Y(\text{high } M_{ee})}_{\text{Direct}} \,/\, \underbrace{Y(\text{low } M_{ee})}_{\text{Direct+bg}} \text{ times inclusive photons}$$

  ☹ Limited in low pT (1~5 GeV/c) region because of the necessity of high statistics.

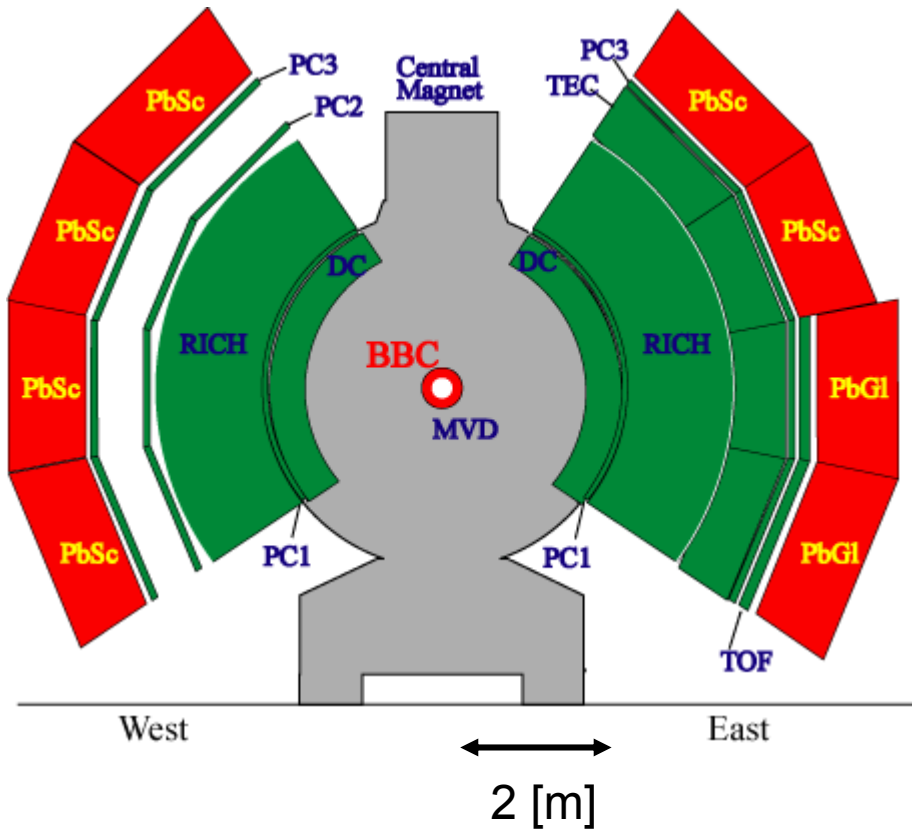
PHENIX Detector

RHIC-PHENIX detector (Central arm)

Central Arm (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
  - Luminosity measurement

BBC and EMCal Trigger for the data taking



For internal conversion analysis

+RICH
electron ID

Run-1 to Run-5 Capsule History

(PHENIX)

Run	Year	Species	$s^{1/2}$ [GeV]	$\int Ldt$
01	2000	Au+Au	130	1 μb^{-1}
02	2001/2002	Au+Au	200	24 μb^{-1}
		p+p	200	0.15 pb^{-1}
03	2002/2003	d+Au	200	2.74 nb^{-1}
		p+p	200	0.35 pb^{-1}
04	2003/2004	Au+Au	200	241 μb^{-1}
		Au+Au	62	9 μb^{-1}
05	2004/2005	Cu+Cu	200	3 nb^{-1}
		Cu+Cu	62	0.19 nb^{-1}
		Cu+Cu	22.5	2.7 μb^{-1}
		p+p	200	3.8 pb^{-1}

Direct photon analysis: Nov. 2005

AuAu subtraction (published)

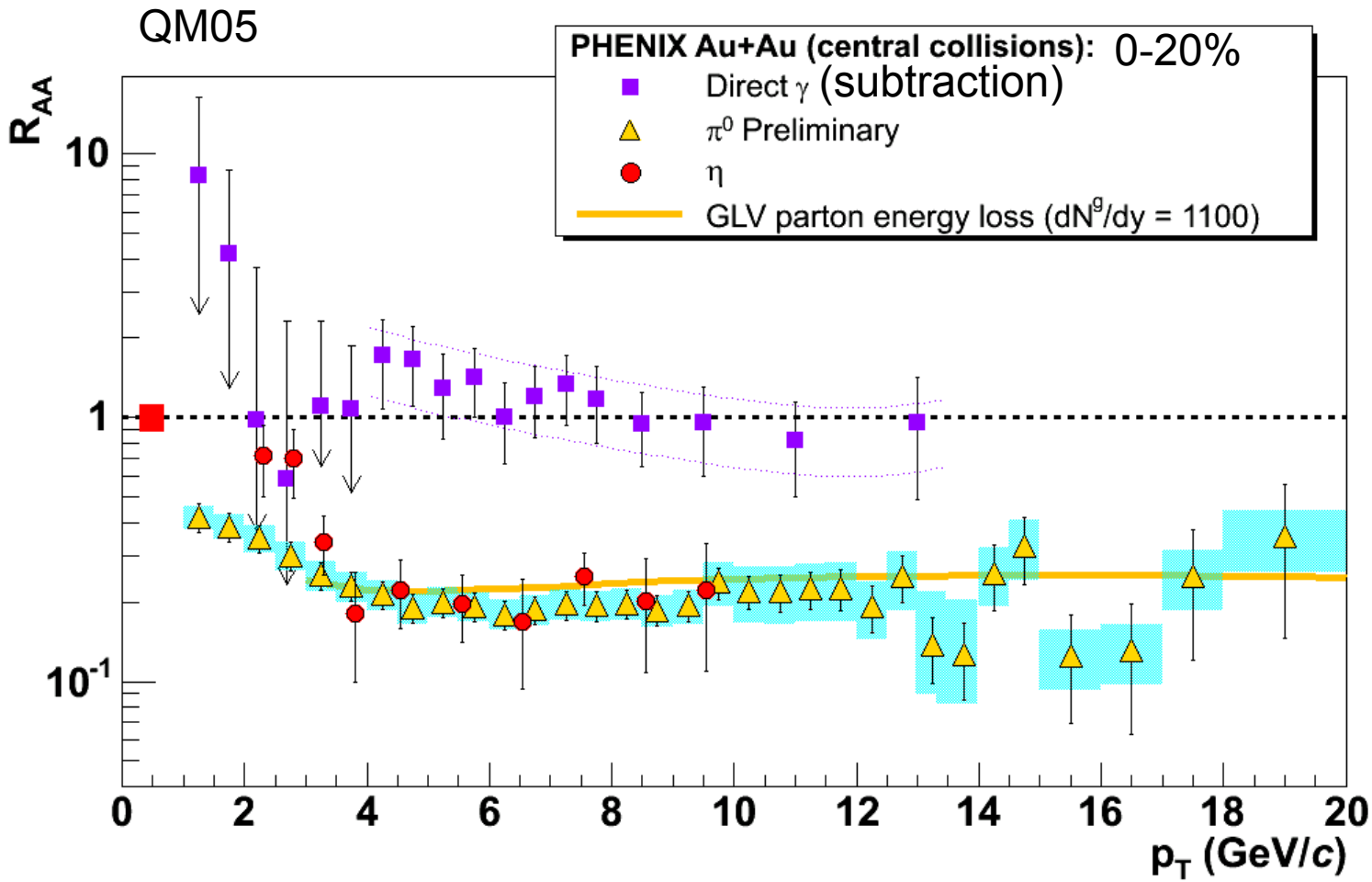
p+p subtraction
(published with 40.3nb^{-1})

dAu subtraction (preliminary)

p+p subtraction
(preliminary with 240nb^{-1})

AuAu subtraction / internal conv.
(preliminary)

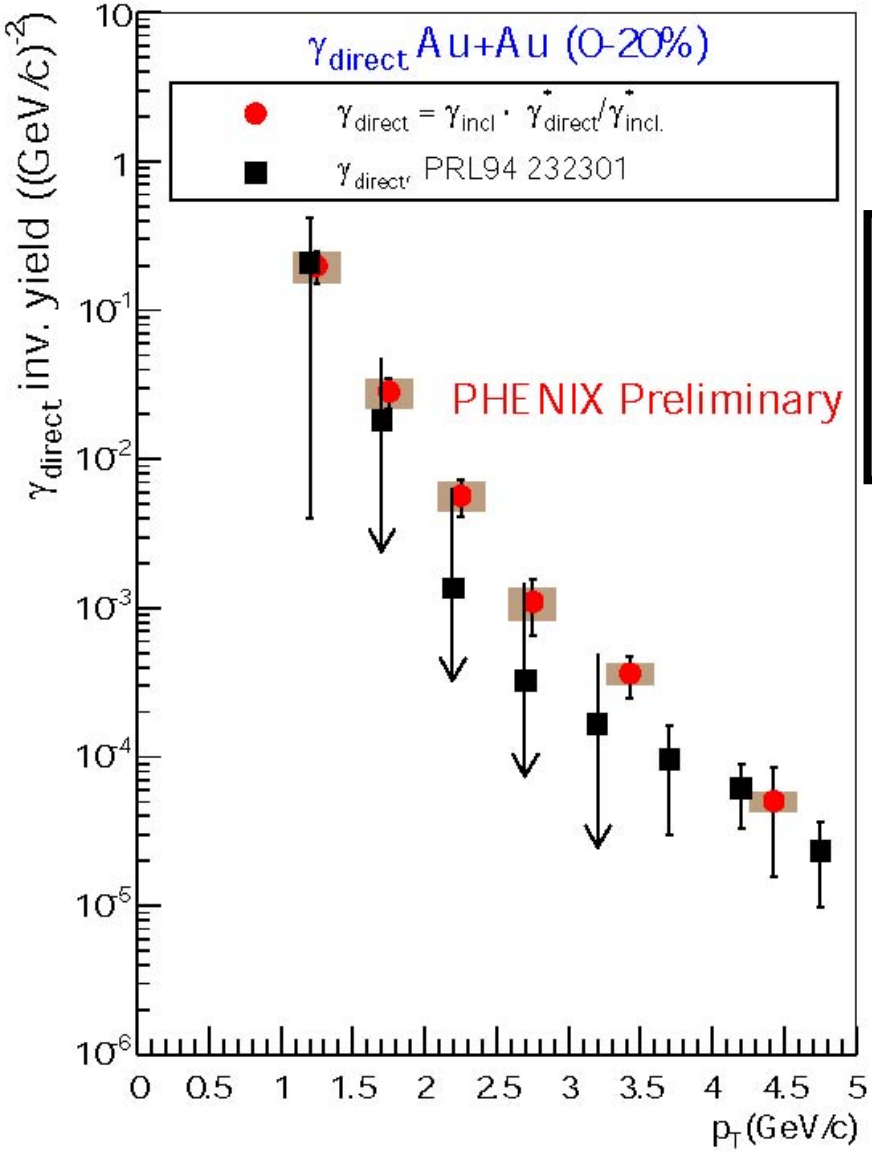
Result in AuAu



Direct photon follows binary scaling.
>> Large suppression of π^0 and η are the final state effect.

Result in AuAu

QM05



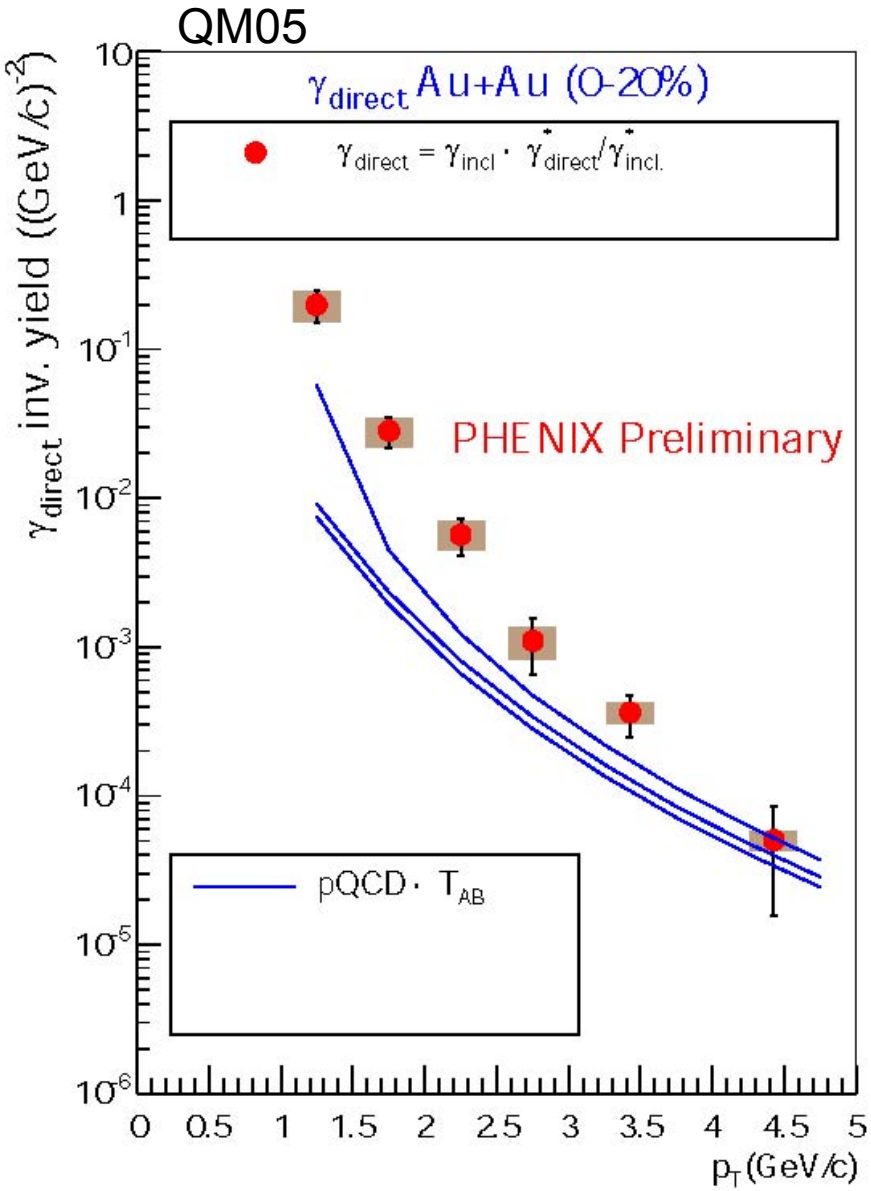
Internal conversion
(Low mass e± pair) method

$$\frac{\gamma^*_{direct}}{\gamma^*_{incl.}} = \frac{R_{data} - R_{\pi^0+\eta}}{R_{direct} - R_{\pi^0+\eta}} = \frac{\gamma_{direct}}{\gamma_{incl.}}$$

Compare to published Run2 result: PRL94 232301

Those are consistent

Result in AuAu



Compare to NLO pQCD

- L.E.Gordon and W. Vogelsang
- Phys. Rev. D48, 3136 (1993)

- excess above pQCD

Analysis in p+p

Low multiplicity

→ Tag photons from π^0

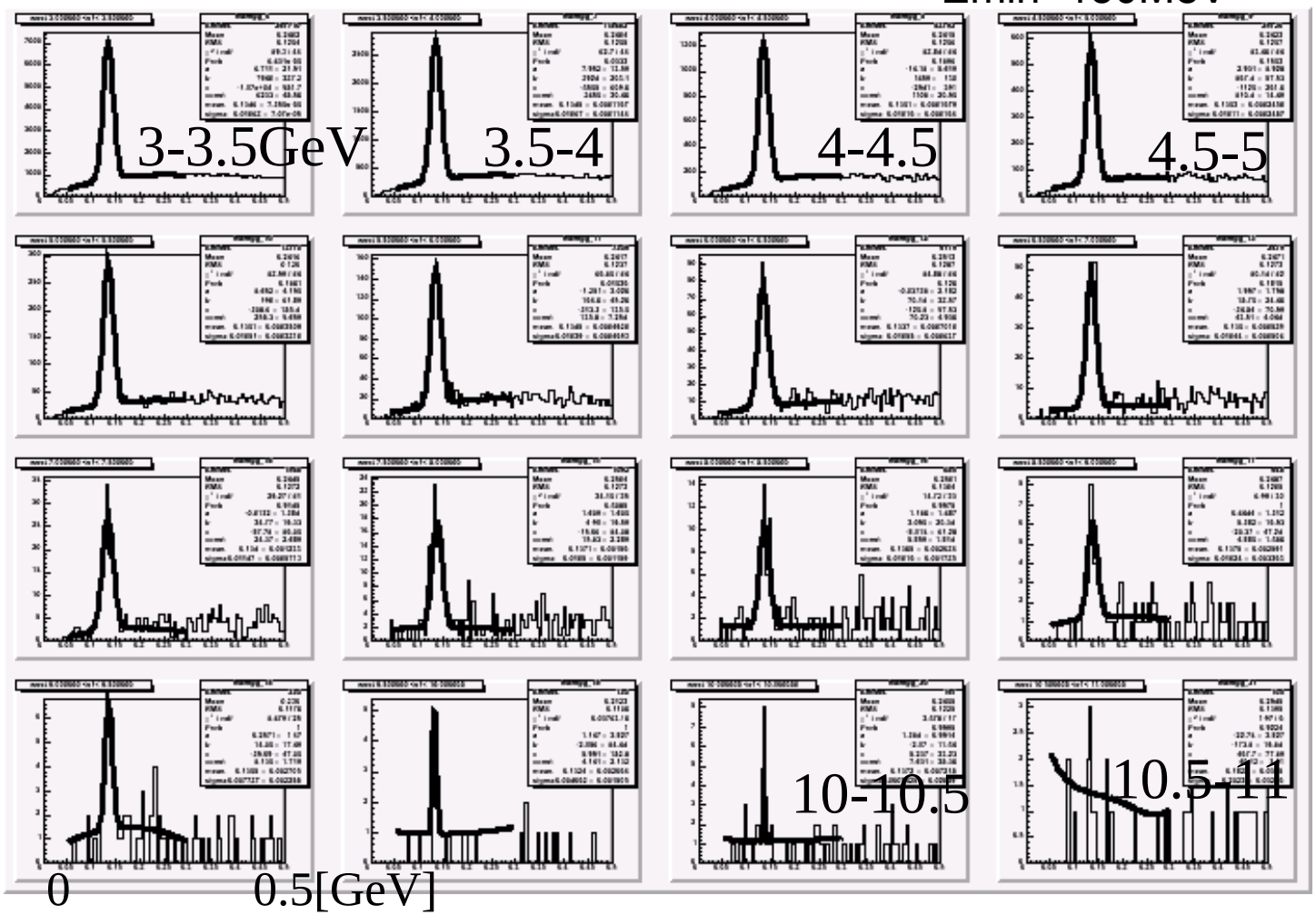
→ Photon isolation cut

Low combinatorial BG

π^0 peaks

Mγγ distributions for each photon pT bin

Emin=150MeV



Analysis Strategy

Photon cluster selection

—Photon shape cut (important to remove merged π^0 clusters)
—Charged veto with DC track
—Timing cut

π^0 photon tag

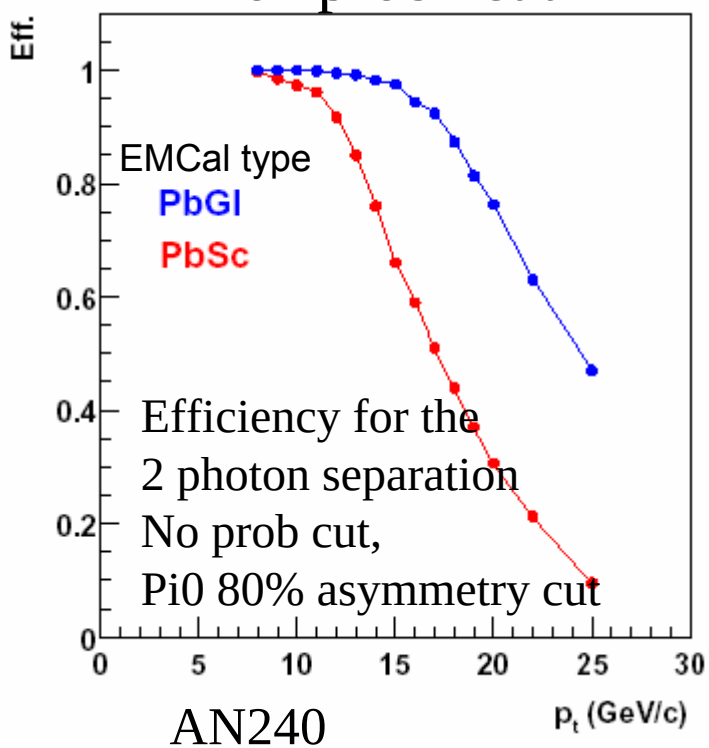
—Count photons with π^0 partner
—Estimate π^0 photons without partner
(it is only kinematics and geometrical issue)

Study of cluster merging in EMCal

Photon separation is 25.4 towers/E_π^0 [GeV]

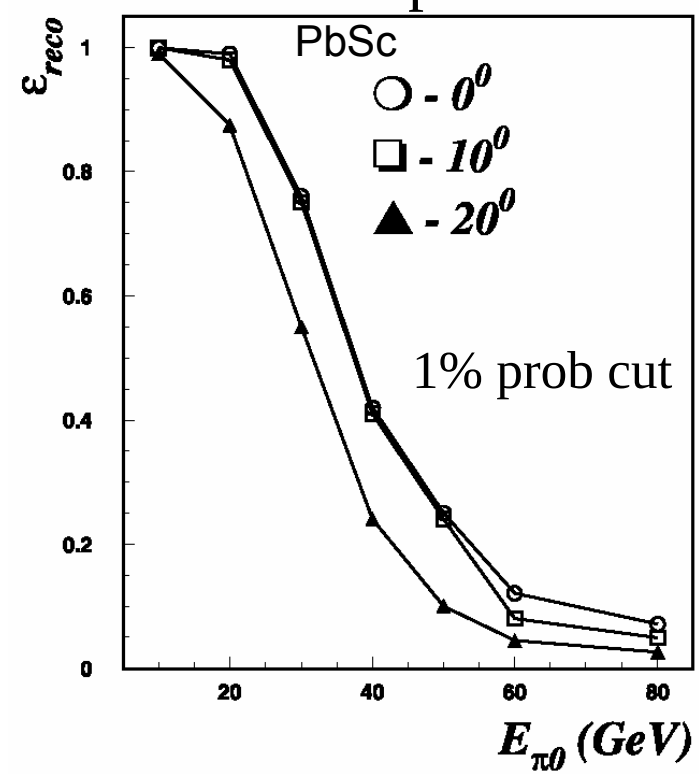
"prob" cut (=photon shape cut) discards all merged photons up to 20 GeV.

No "prob" cut



AN240

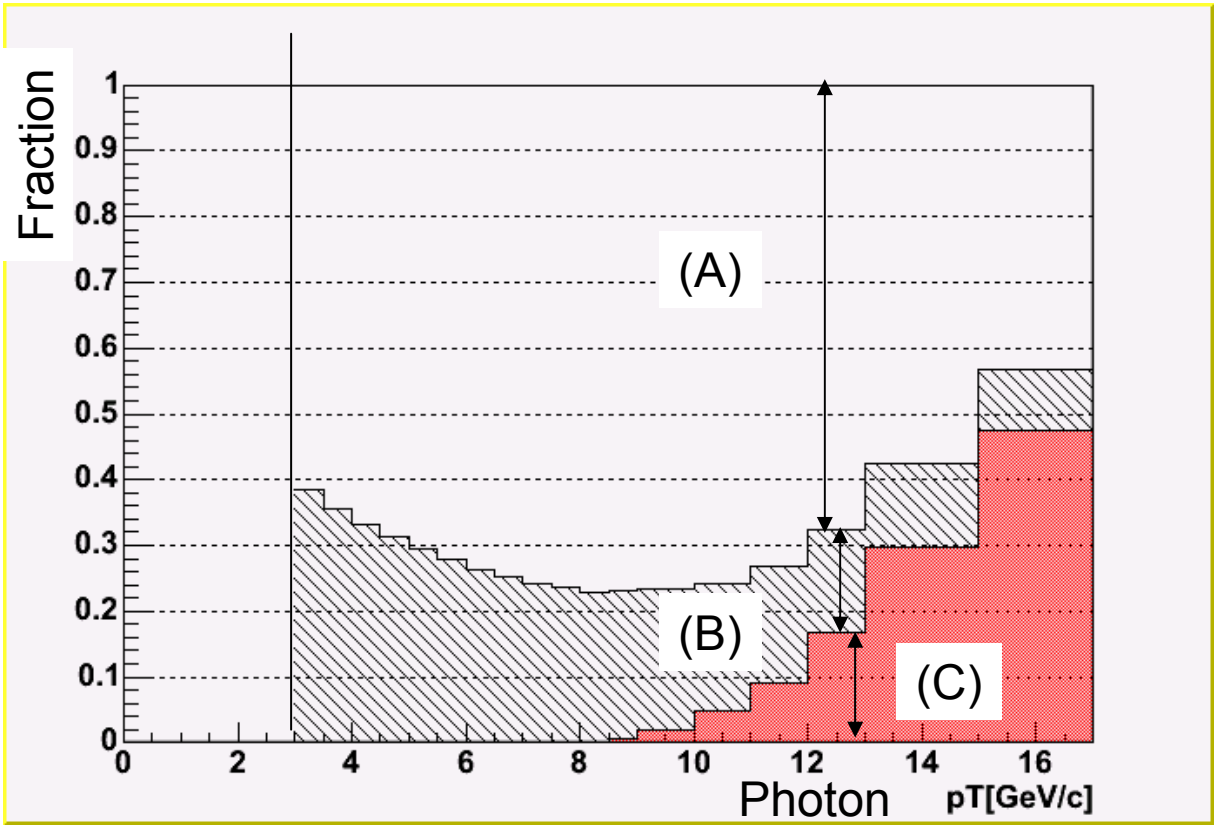
With "prob" cut



RIKEN Review No28 (May2000)

π^0 photons

π^0 spectra → MC (Geometry, kinematics) → categorize



(A) With partner
(B) Missing Partner
(C) Merged cluster

Total π^0 contribution = (with partner) * (A+B) / A
measured

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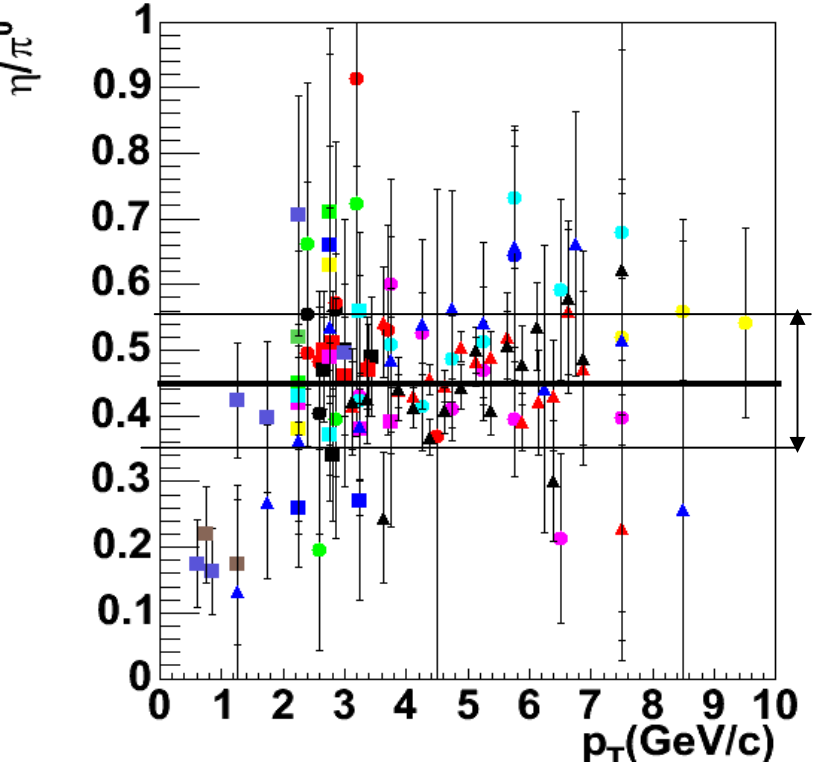
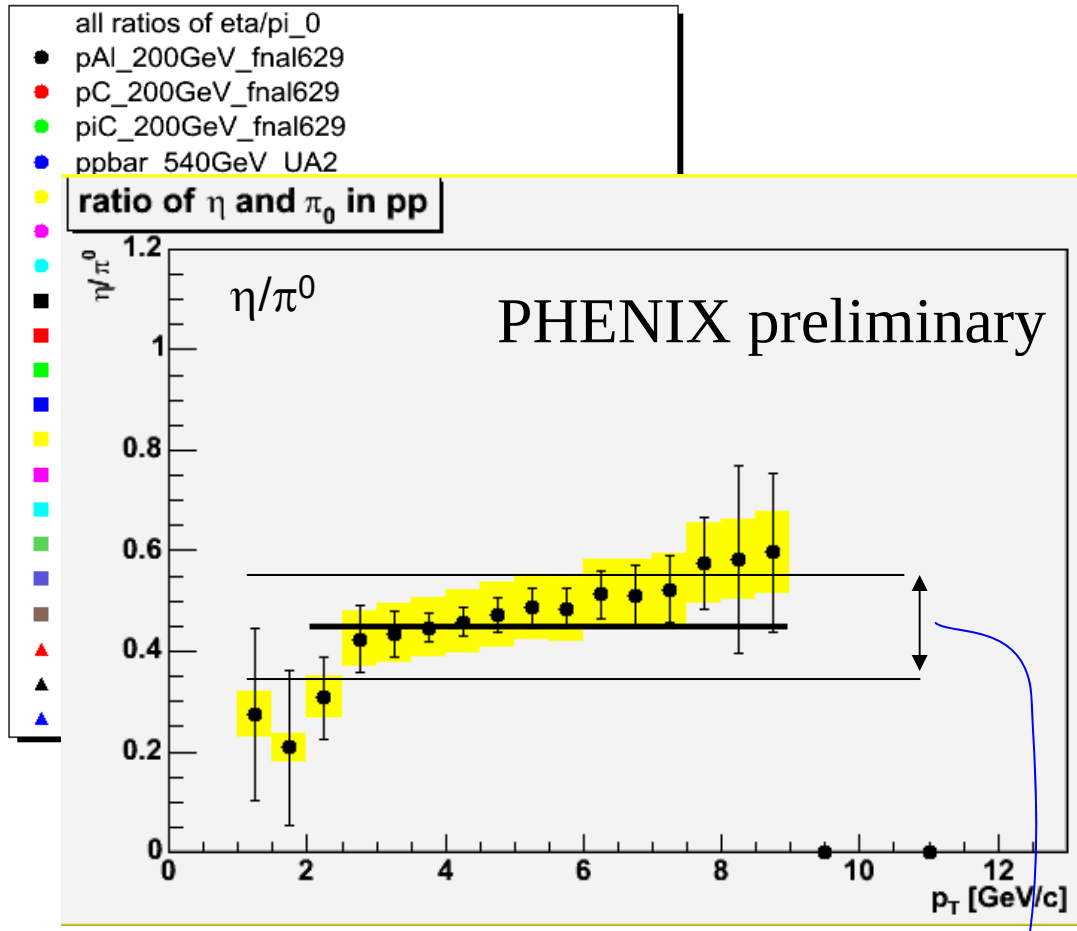
(it is only kinematics and geometrical issue)

Other hadron to photon estimation (η,ω, etc.)

—Scale π^0 photon contribution by their production and branching ratio

η,ω Contribution





Production Br(γ)

Eta/pi0 = 0.45*0.394/0.988=0.18 (assuming no pT dependence)

+ omega, eta',… = 0.23 ± 0.05

Analysis Strategy

Photon cluster selection

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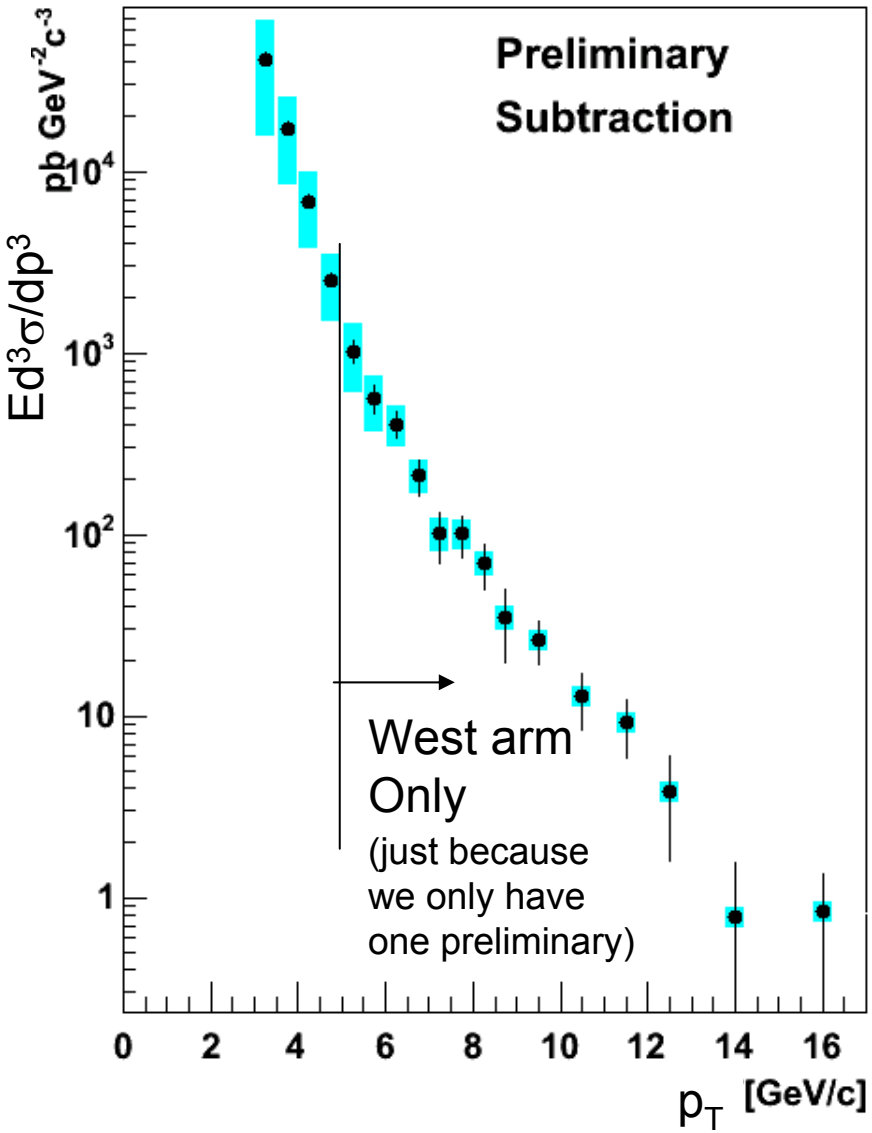
The rest is our direct photon signal !! **(Subtraction method)**

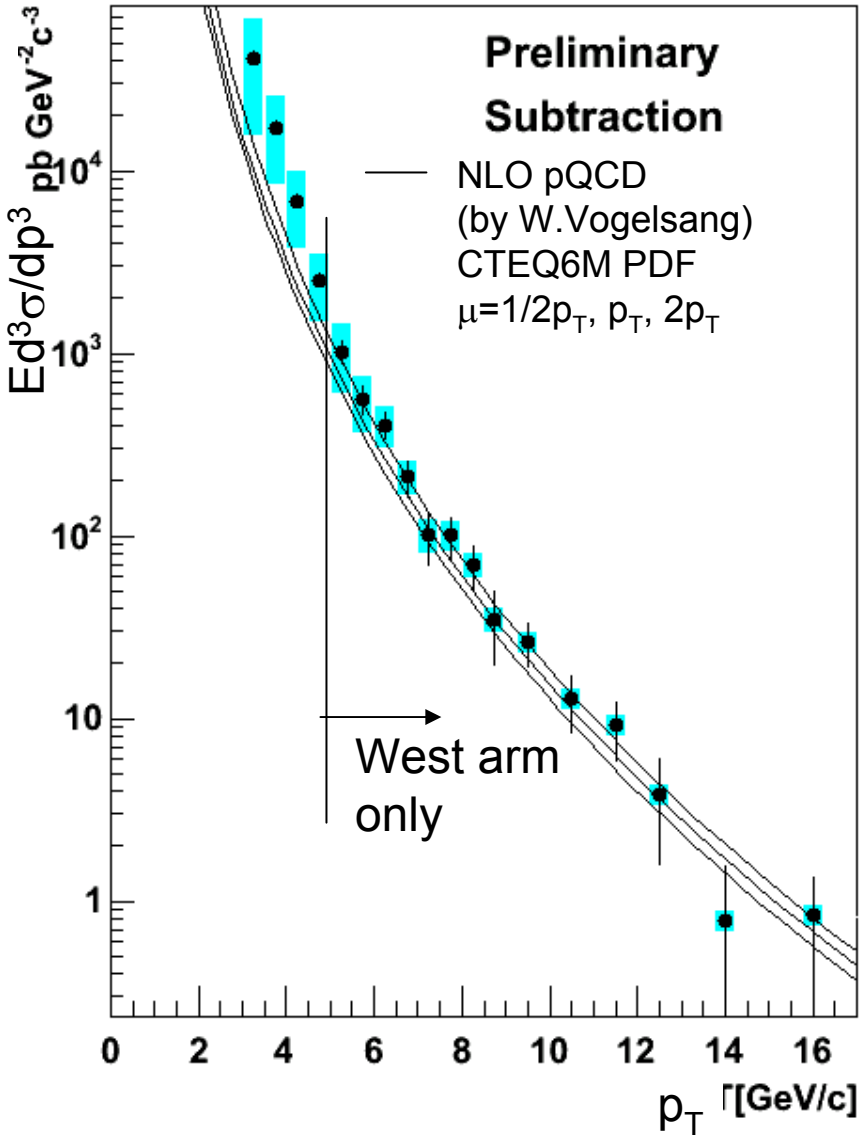
Subtraction method



Systematic error sources ✓ ✓ ✓ ✓

	pT region Low	Mid	High
Luminosity	✓	✓	✓
Energy scale	✓	✓	✓
Non photon BG	✓		
Pi0 tag	✓	✓	
Missing π^0	✓	✓	
Non π^0 photon	✓	✓	

Subtraction method



NLO pQCD calculation explains the data well.

At low pT, the data show an excess.

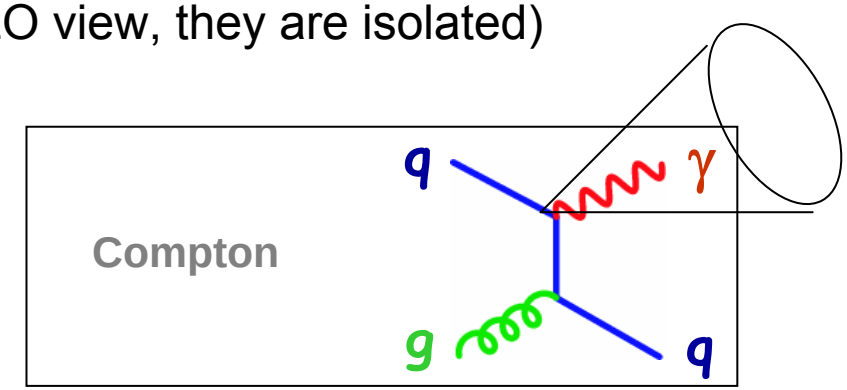
—with large systematic error

—but may be soft physics contributions as well

Isolation cut method : 2 goals

1

— Check if our direct photon signal is isolated.
(with LO view, they are isolated)



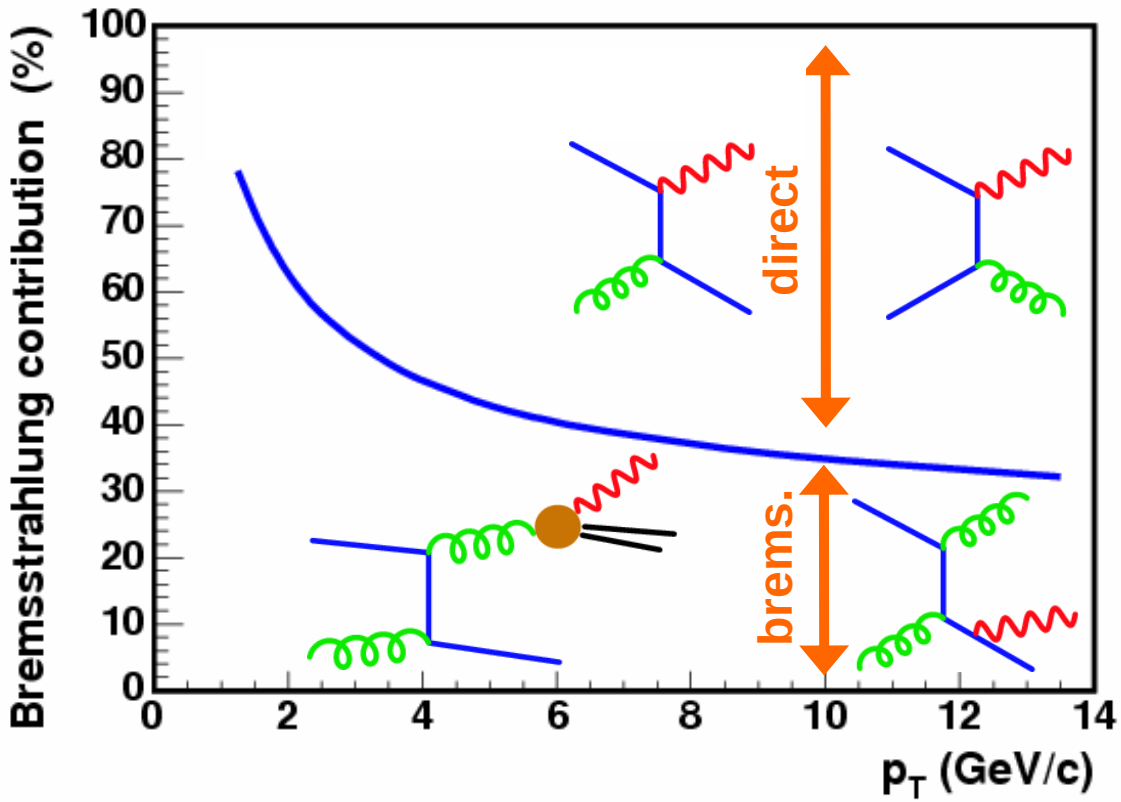
— A confirmation is done by applying the same isolation cut on photons from π^0

Isolation cut method : 2 goals

2

Comparison to a theory calculation

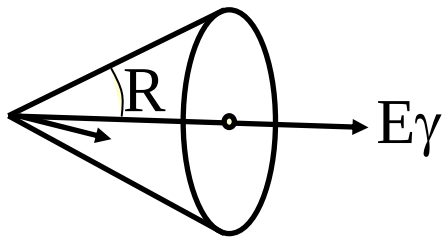
NLO pQCD calculation by W. Vogelsang (p+p at √s=200 GeV)



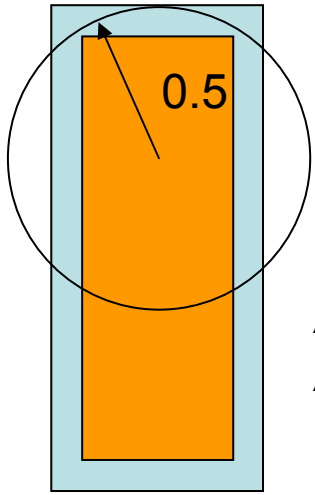
Isolation cut with PHENIX

- Starting from isolated photons

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



E_{cone} : photon energy
+ charged particle momentum

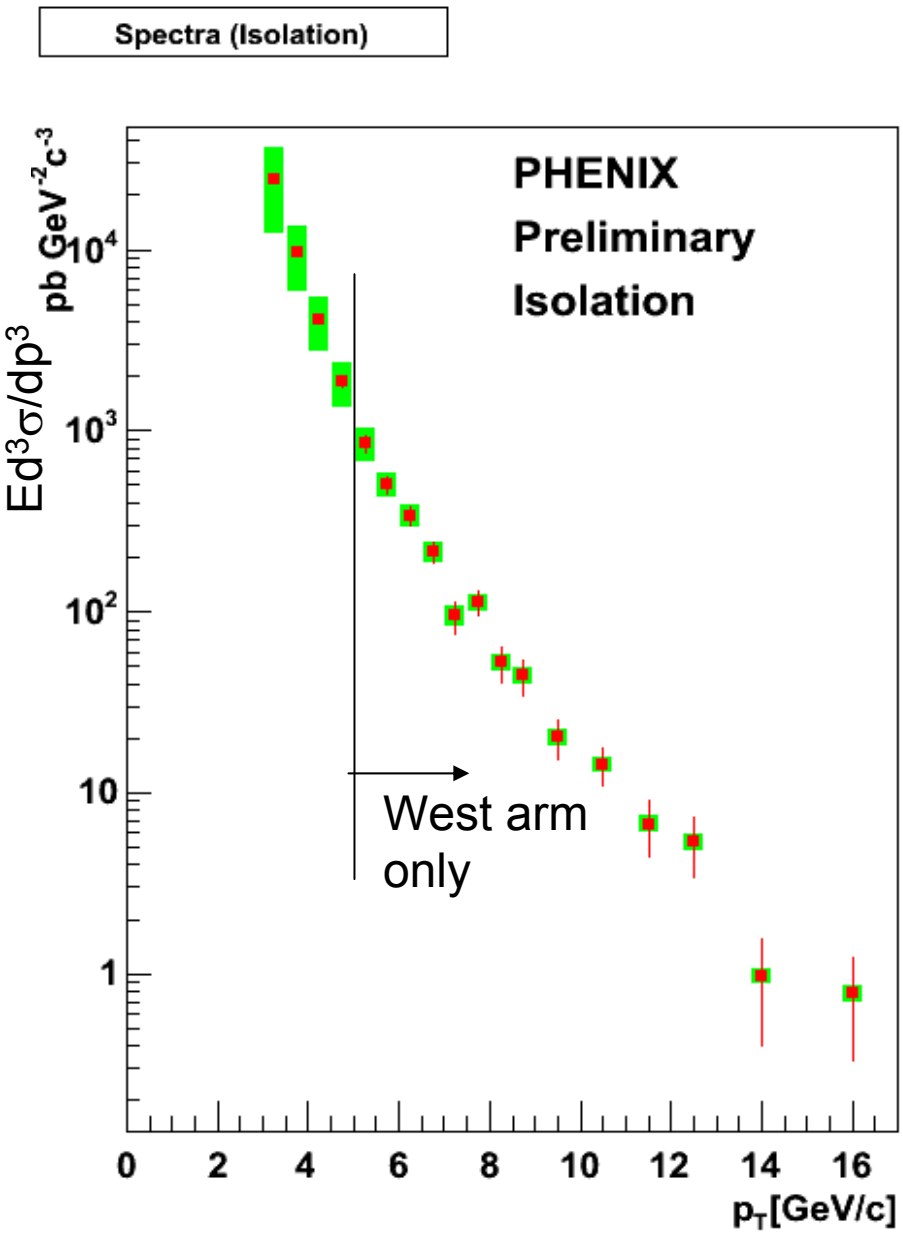


PHENIX arm
$\Delta\eta=0.7$
$\Delta\phi=\pi/2$

- Starting with isolated photons, the same subtraction procedure is applied. For the estimation of hadron contribution,

"π^0 photon in isolated pair" is introduced
They have π^0 partner.
They pass the isolation cut when the partner energy is excluded.

Isolation cut method



Isolation cut

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

No correction for isolation cut efficiency was applied.

Ratio of Isolation/Subtraction

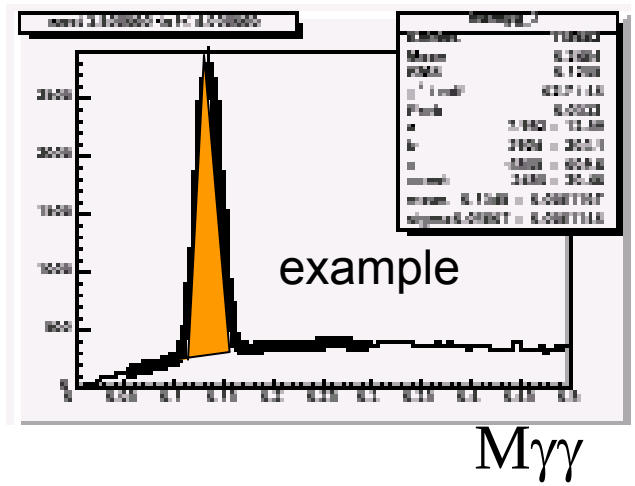
Photons: (Isolation method) / (Subtraction method)

Statistical error : Some of them are canceled out.
Systematic error: The global scale is canceled.

Pi0 photons: (pi0 in isolated pair) / (all pi0)

pi0 in isolated pair : (Mγγ with isolated pair photon)
All pi0: (Mγγ with all photon)

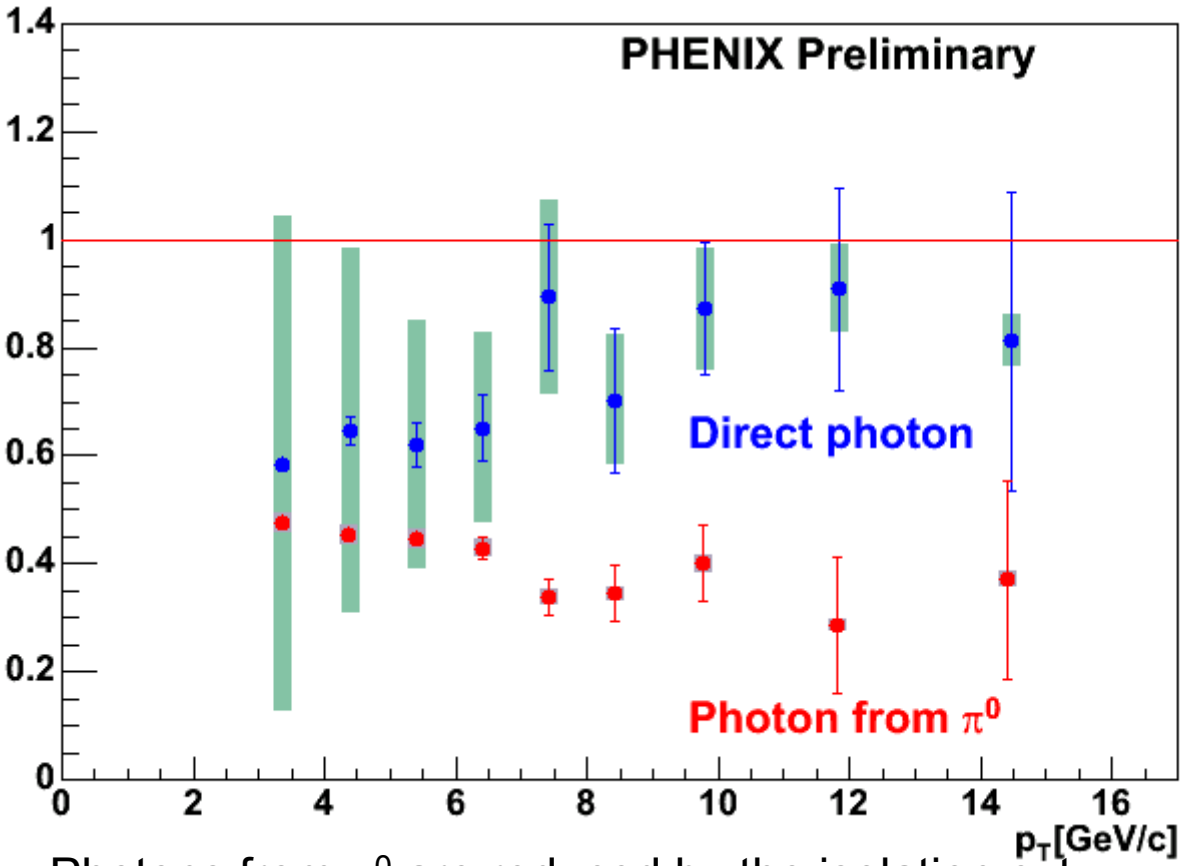
Statistical error : binomial
Systematic error : from combinatorial BG subtraction



Ratios

1

Direct photon : isolation / subtraction
Photon from π^0 : isolated photon / all

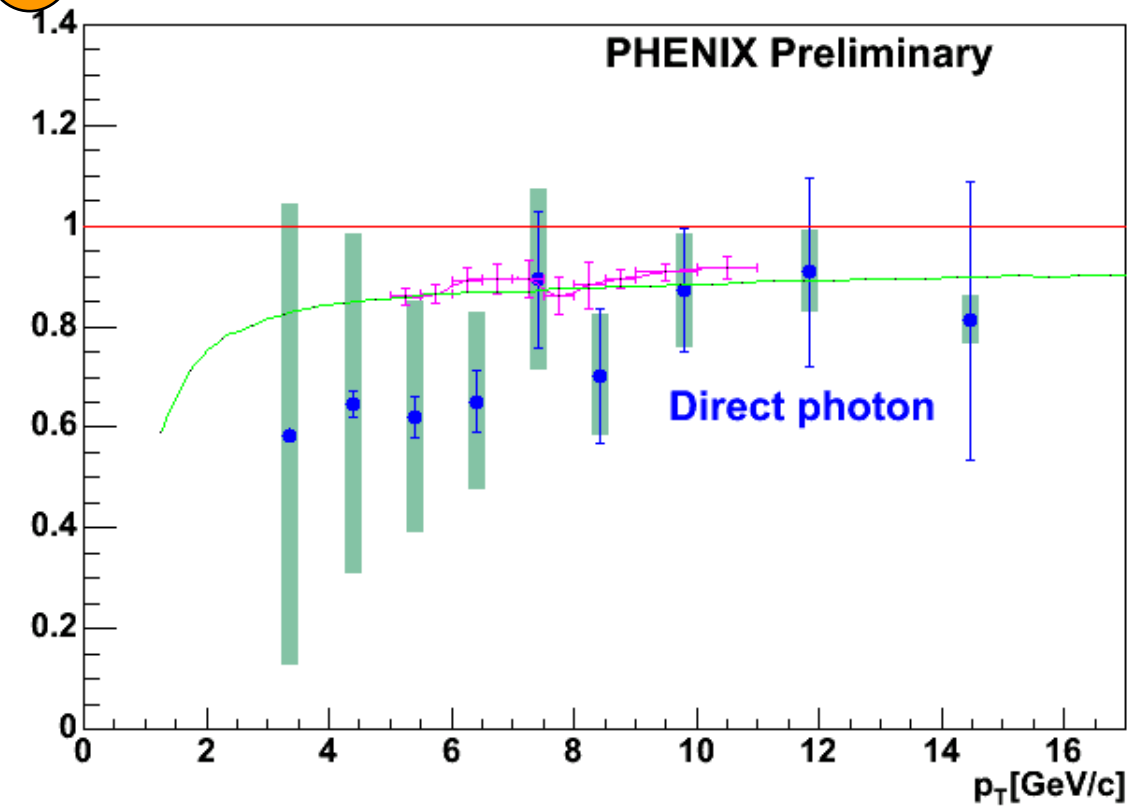


Isolation cut
$0.1*E\gamma > E_{cone(R=0.5rad)}$

Photons from π^0 are reduced by the isolation cut.
Direct photons are isolated at high pT region.

Iso/sub ratio with a theory calculation

2



Isolation cut
$0.1*E_\gamma > E_{cone(R=0.5rad)}$

By M.Werlen, JETPHOX
-.35<y<.35
μ=pT
BFG set2, CTEQ6M

By W.Vogelsang,
R=0.4
μ=pT, CTEQ6M

At high pT, theory predictions are consistent with the data.

Prospects for Δg measurement

Double spin asymmetry : A_{LL}

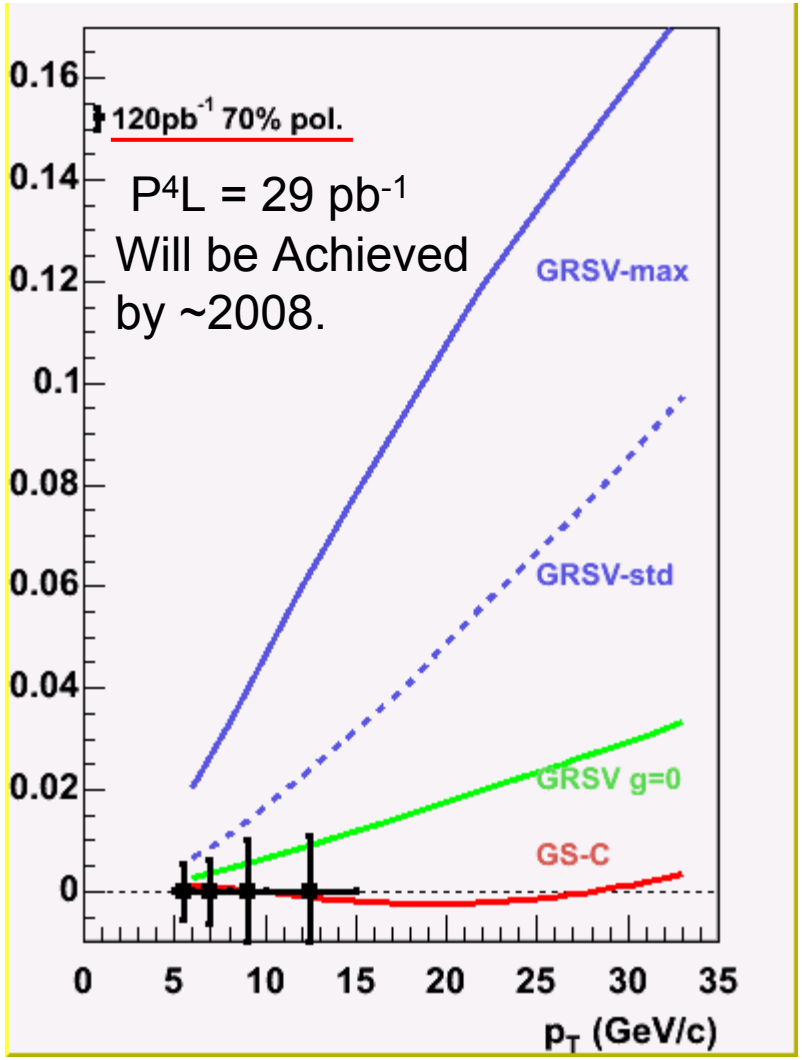
For spin asymmetry measurements, the purity is important.

δA_{LL}_signal= D * δA_{LL}_allphoton
1/D: purity (=signal/all)

With the isolation cut, the purity is about 80% for pT>10GeV/c.
And most direct photons remains.

In Run5, we took ~3.5pb^{-1} with 50% pol.
(The figure of merit (P^4L) = 0.22 pb^{-1})

We need a little more luminosity and polarization for photon A_{LL}.



Summary

—The measurements of the direct photon production in p+p is much improved from the published one.
NLO pQCD calculation describes our data well in overall.

—In AuAu collisions, the preliminary result from internal conversion (low mass $e^{\pm}$ pair) method shows an excess above NLO pQCD calculations in pT less than 3GeV/c region.
However there is also an excess seen in p+p, although they are with large systematic errors.
We need to apply internal conversion (low mass $e^{\pm}$ pair) method on p+p.

—For the gluon spin, an isolation cut helps to increase the purity, which is very important for asymmetry measurements.
We need more luminosity and higher polarization.