Measurement of direct photon in ¥sqrt{s_NN}=200GeV Au+Au collisions at RHIC-PHENIX

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for the PHENIX Collaboration

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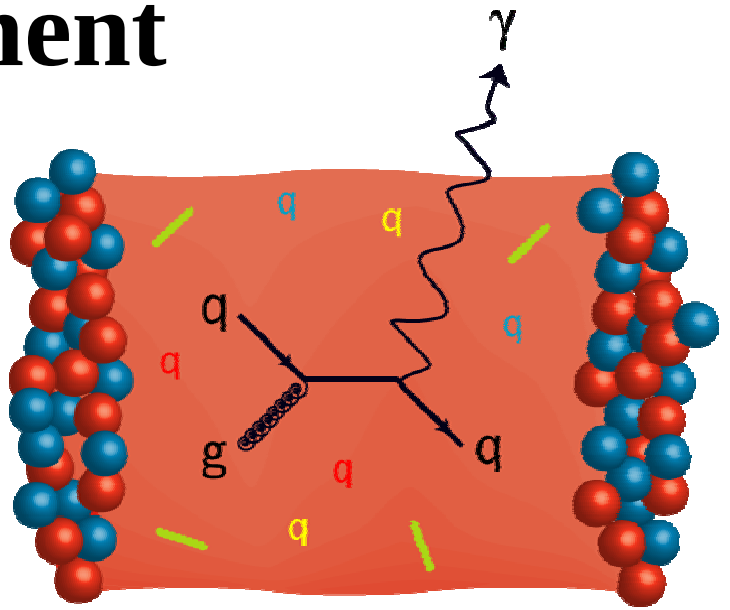
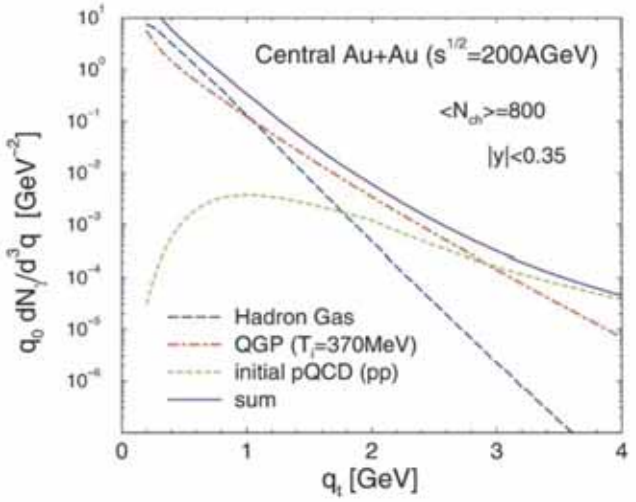
Motivation of direct photon measurement

- **For study of the hot and dense matter created in relativistic HIC**
- Direct photon: non-hadronic photon
- Strong probe for the bulk matter produced by Au+Au collision
  - Doesn't interact strongly
- **Thermal radiation from QGP**
  - 1GeV/c<pT<4GeV/c
  - Strong signature of the existence of QGP
  - Carry information on Thermo-dynamical state of medium (temp., degree of freedom)
- Hadron gas interaction
  - pT<1GeV/c

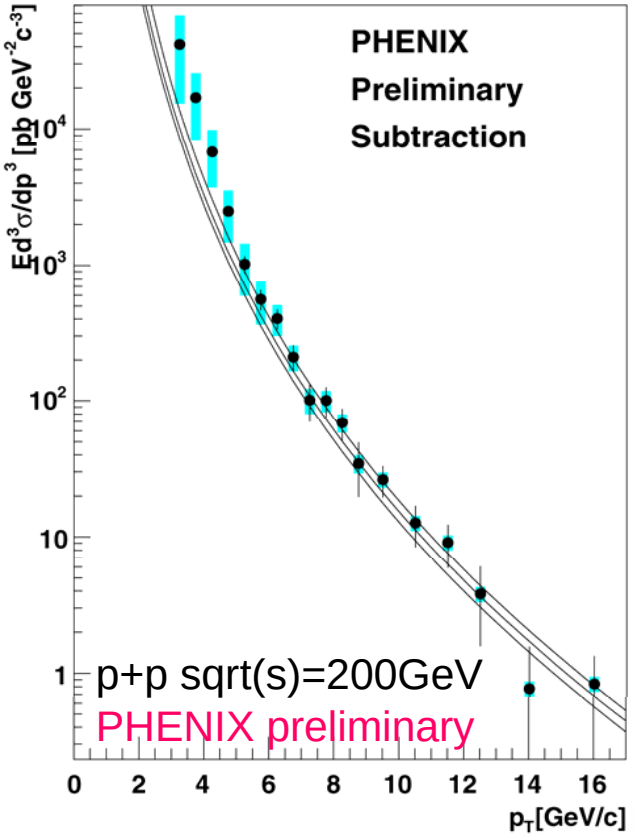


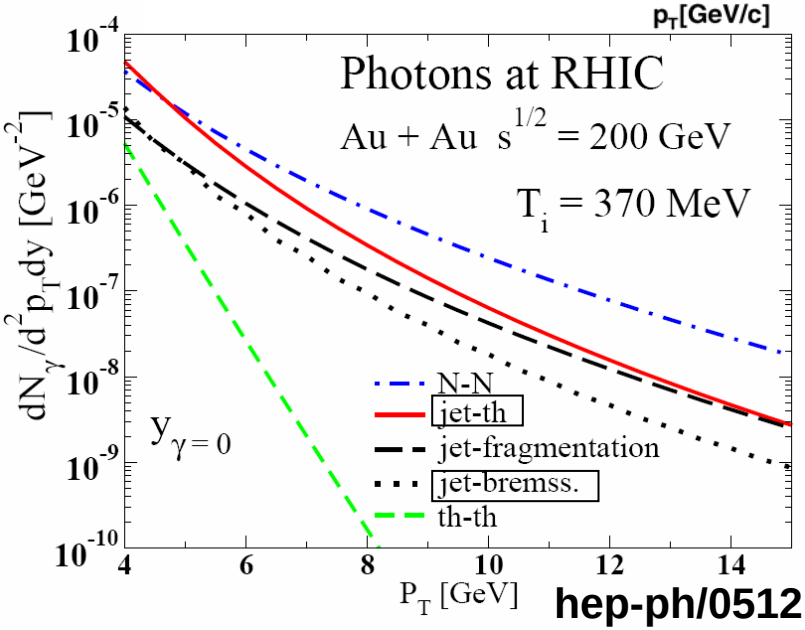


PRC 69(2004)014903

Motivation 2

- **High-pT direct photon as hard probe of dense matter**
- **pQCD** (hard scattering)
  - 4GeV/c<pT
  - p+p data agree with pQCD at high-pT
  - 70% prompt photon + 30% jet fragmentation at high-pT(pT>8-10GeV)
    - Fragmentation photon will be suppressed by jet-quenching effect in HIC?
- **Interaction of hard-scattered parton with dense matter**
  - 6GeV/c<pT
  - Compton scattering (jet-photon conv.)
  - Bremsstrahlung
  - possible to be usable as hard probe of bulk matter

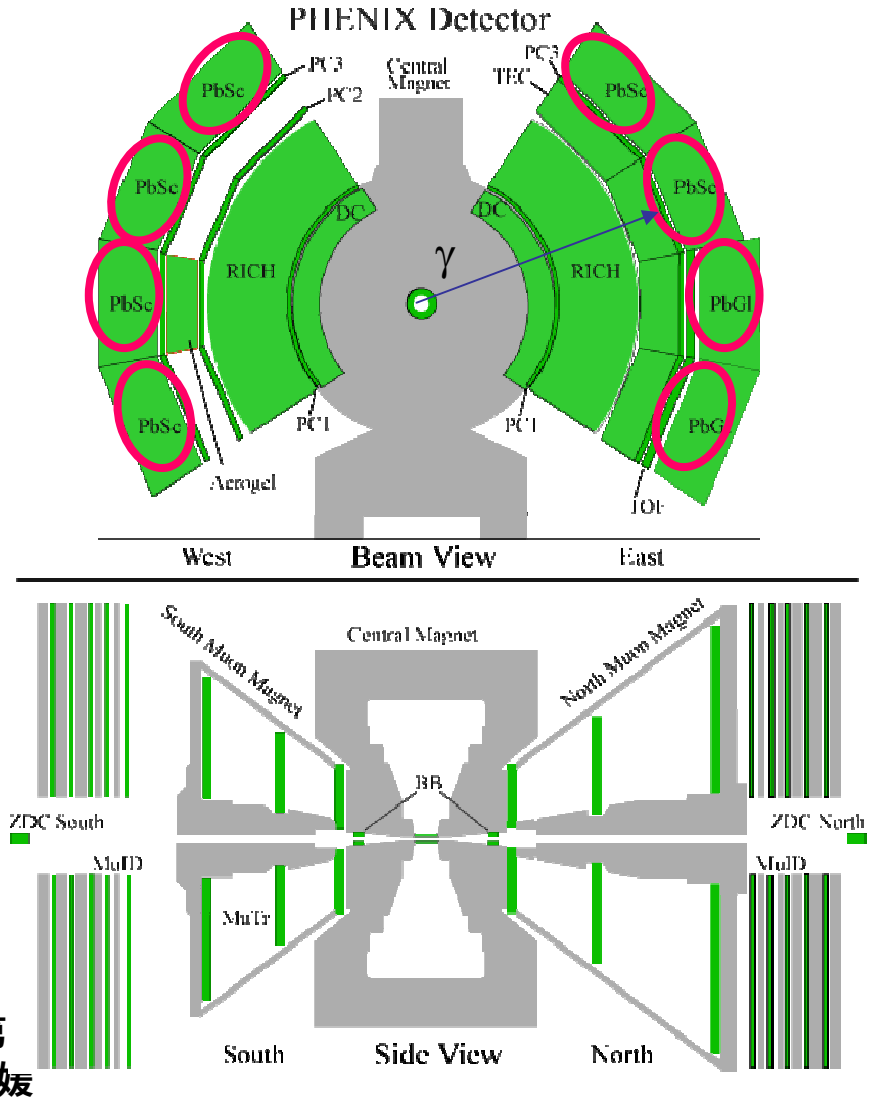




hep-ph/0512109

Direct photon measurement at RHIC-PHENIX

- RHIC-PHENIX Au+Au 200 GeV Run at Year-4
  - Sampled Luminosity 241μb-1
    - 1.5B events
- **<u>Photon measurement using PHENIX- Electromagnetic Calorimeter (EMCal)</u>**
  - Lead Scintillator Type (PbSc, $18X_0$)
  - Lead Glass Type (PbGl, $16X_0$)
- **Min. Bias trigger from BBC-ZDC coincidence**
  - Also used for Centrality determination
    - 0%: central, 100%: peripheral collision

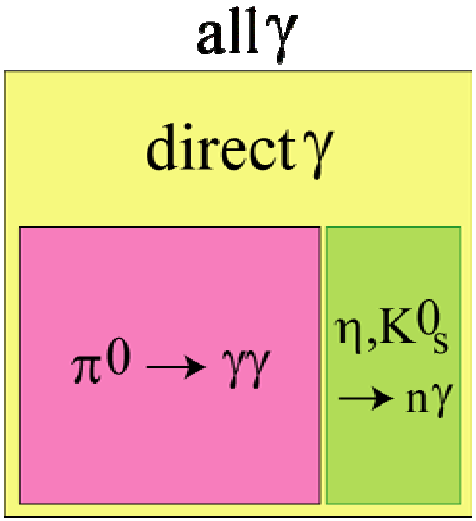


Method for direct photon measurement

- **Cocktail method**

$$N^{\gamma}_{all} = N^{\gamma}_{decay} + N^{\gamma}_{direct}$$

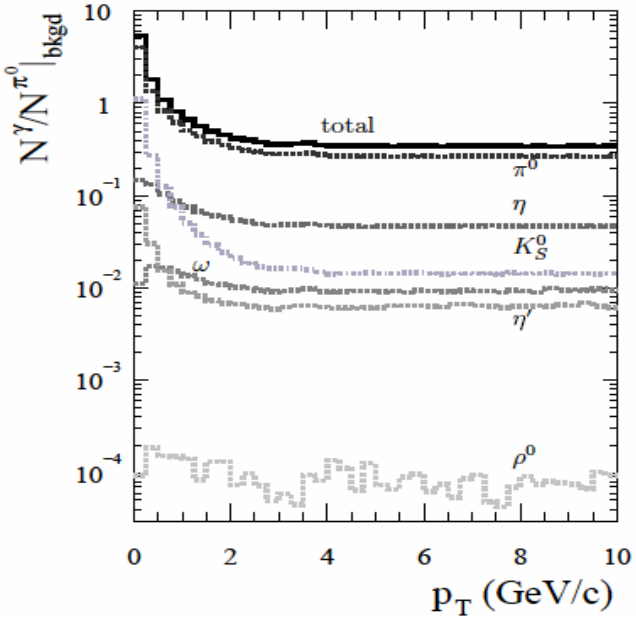
  - Pi0-> 2gamma
  - Eta, K0s, omega..
    - Reconstruct the slope with mT scaling and for eta using the eta/pi0 ratio measured in PHENIX
  - Precise estimation of pi0 merging for high-pT direct γ
    - 70% of pi0 clusters merge at 20GeV/c



- **Direct photon excess ratio**

$$\frac{N^{\gamma}{}_{all}}{N^{\gamma}{}_{bg}} = \frac{(N^{\gamma}{}_{all} / N^{\pi^0})_{measured}}{(N^{\gamma}{}_{bg} / N^{\pi^0})_{MC}}$$

  - Part of systematic errors cancel



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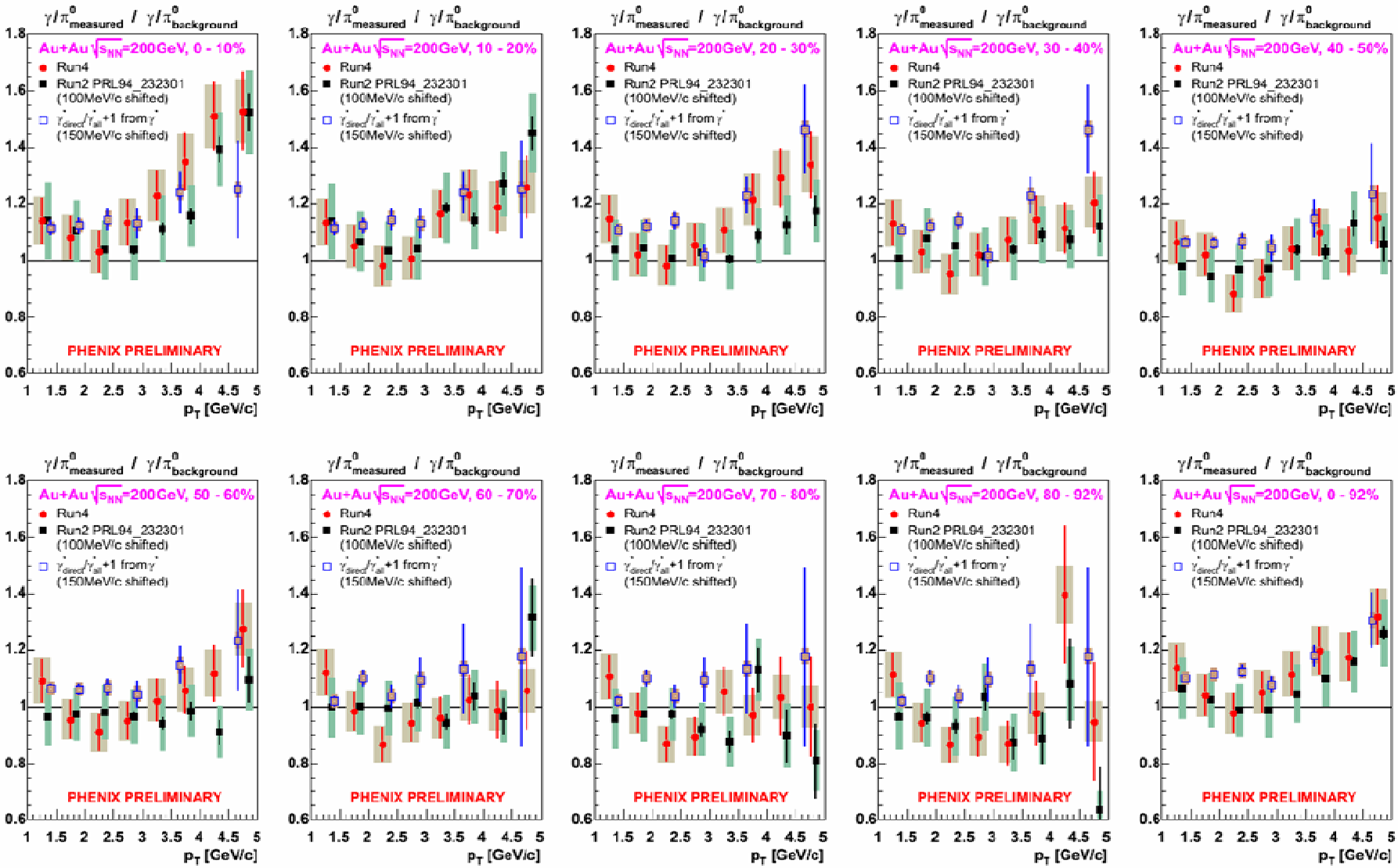
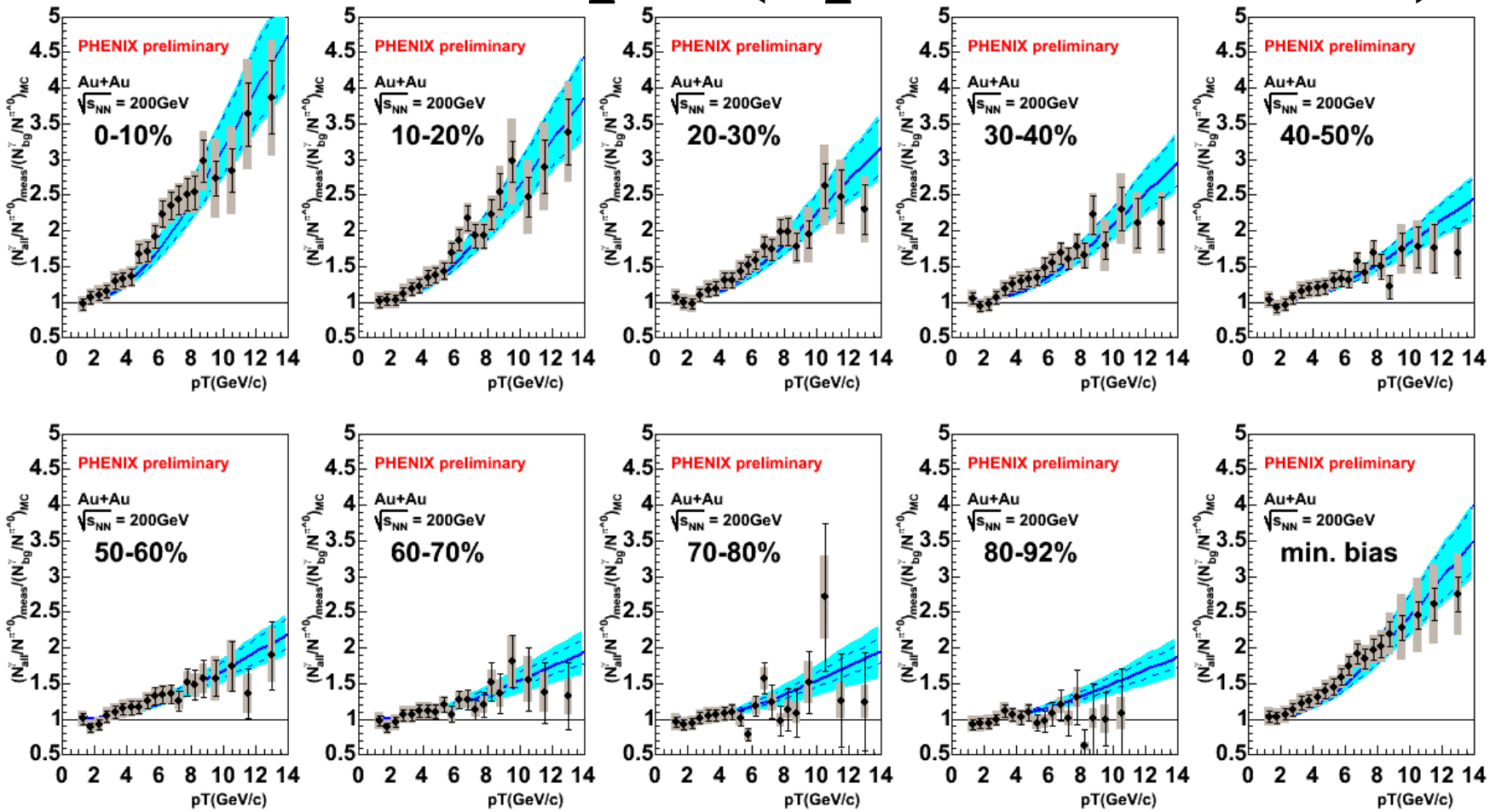
Result in mid. pT region (1-5GeV/c)



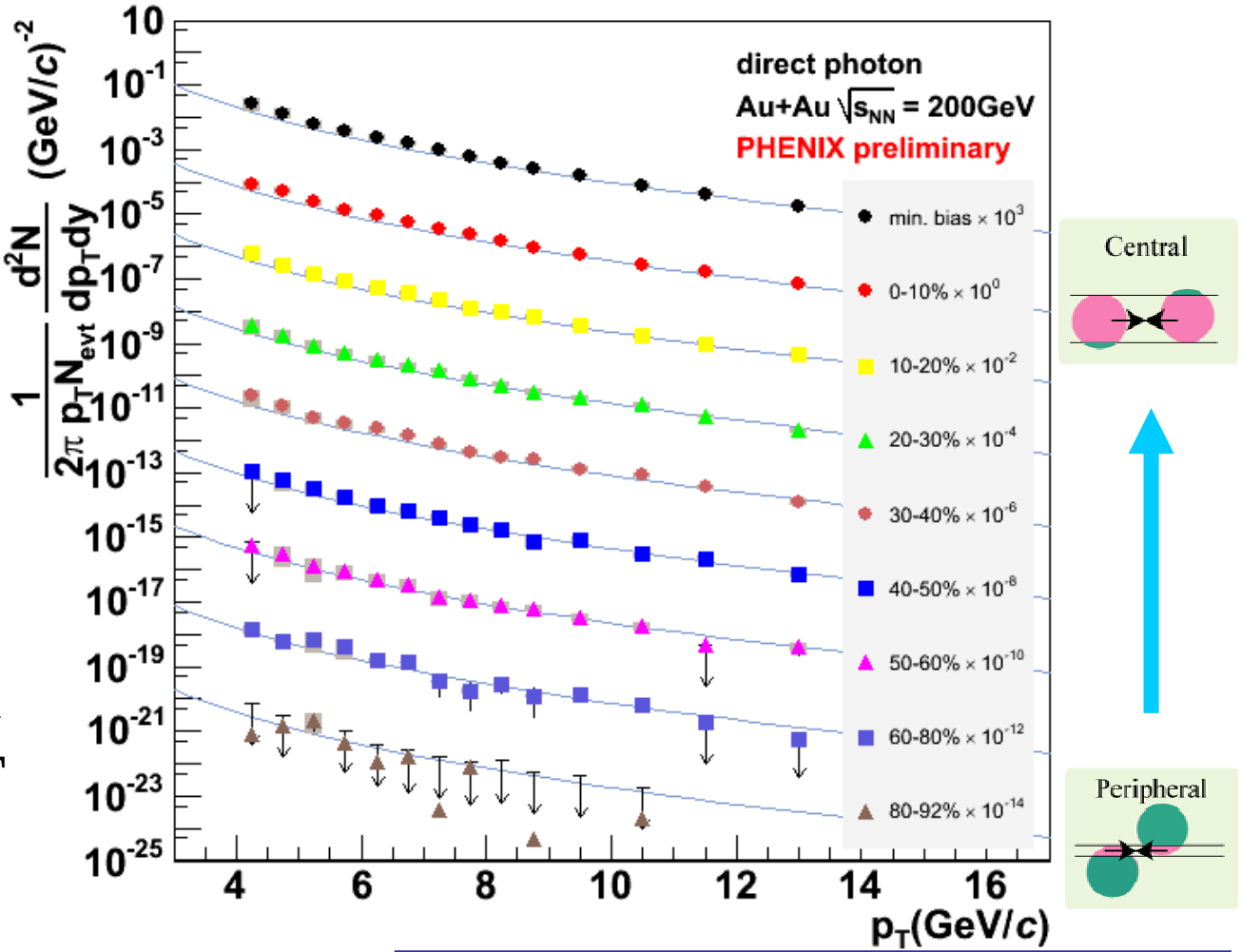
Extension of pT (up to 14GeV/c!)



- **Work in progress for pT<5GeV/c**
- **Compared with pQCD calculation**
  - **(theoretical uncertainty: dashed lines, blue bands: dashed+Ncoll error)**
- **Direct γ: hadronic γ = 3:1** (@pT=12GeV/c 0-10%Central)

Direct photon spectra

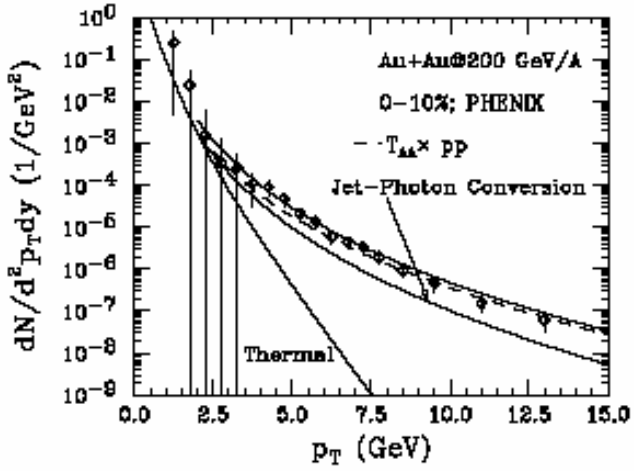
- PbSc/PbGl combined result
  - Run4 new result
- Measured up to 14GeV/c
- Good agreement with Ncoll scaled pQCD at high-pT

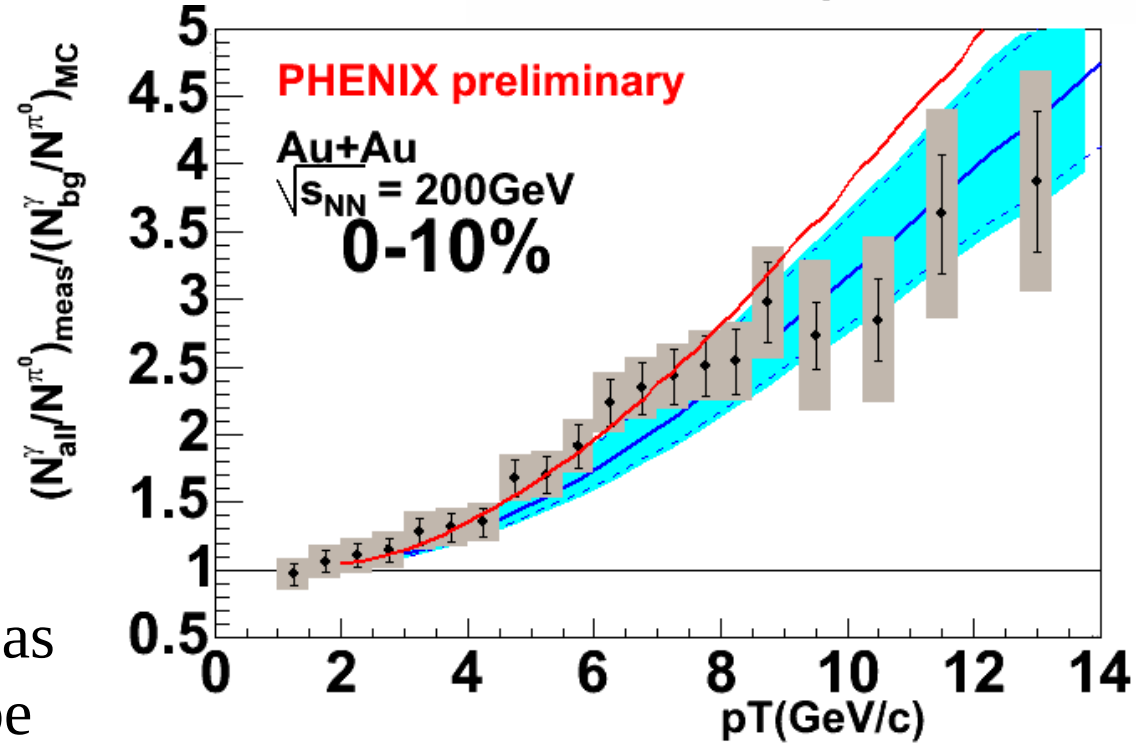


Blue line: Ncoll scaled pQCD prediction

Discussion

- Agree with pQCD calculation within error.
  - Small enhancement around 6GeV?
- Comparison with jet-photon conversion
  - Agreement around 6GeV/c
  - Discrepancy for pT>9GeV/c
  - Additional effect, such as jet-quenching, should be taken into account?





Blue line: pQCD only
Red line: pQCD and Jet-photon
Fries et al., nucl-th/0507018

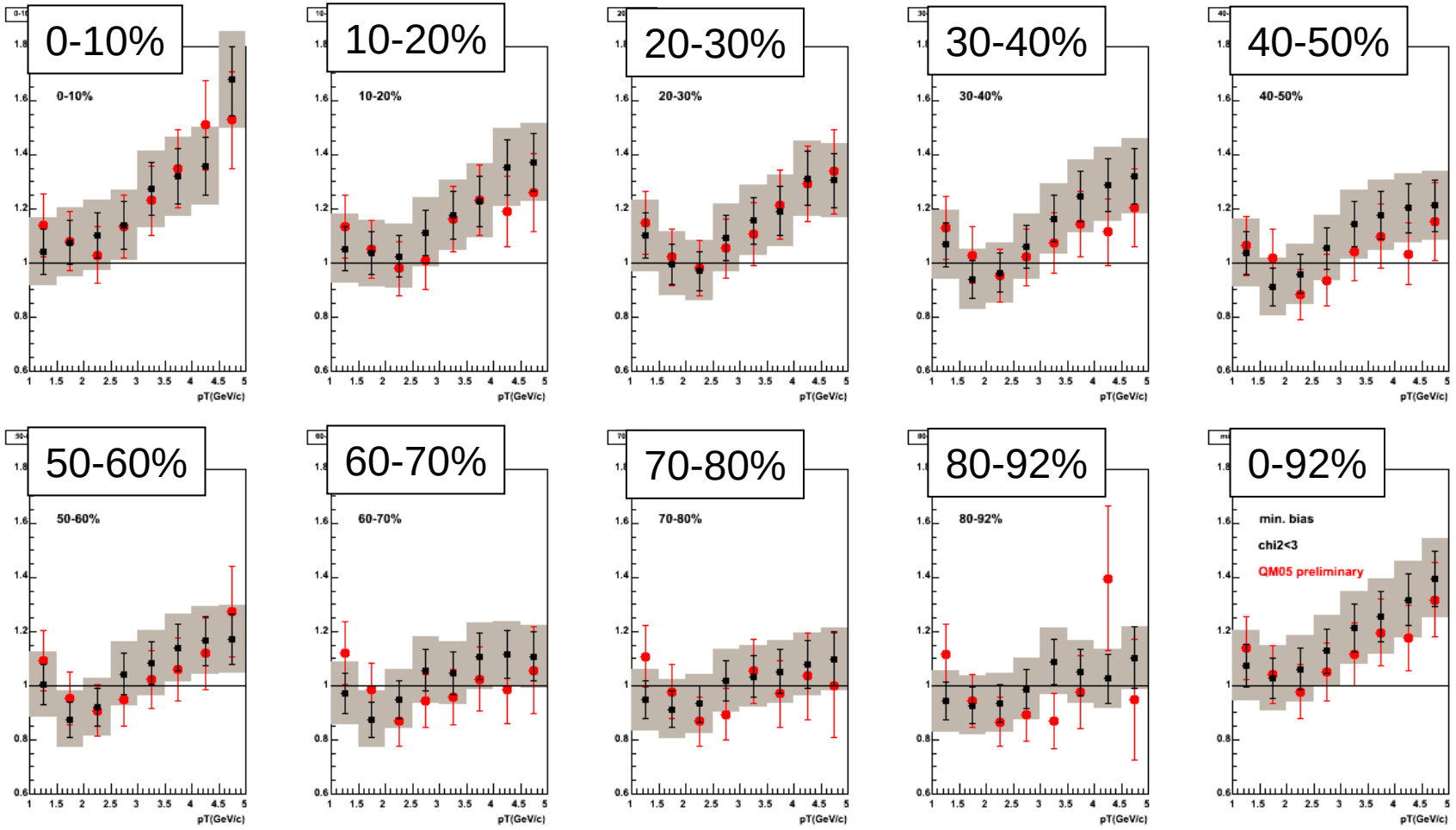
Summary and Outlook

- Measurement of direct photon using PbSc/PbGl
  - Clear signal of direct photon at high-pT due to the strong suppression of neutral hadrons
  - Extend up to 14GeV/c
  - 75% photon is direct photon @ pT=12GeV/c, 0-10%
  - Good agreement with pQCD expectation at high-pT

- Azimuthal anisotropy of direct γ (Next Talk)
  - Anisotropy from jet-conv. or bremss.? (v2<0)
- Use direct photon for jet-tagging (γ-jet correlation)
  - Measure momentum information of a jet directly

backup

New PbSc result (Work In Progress)

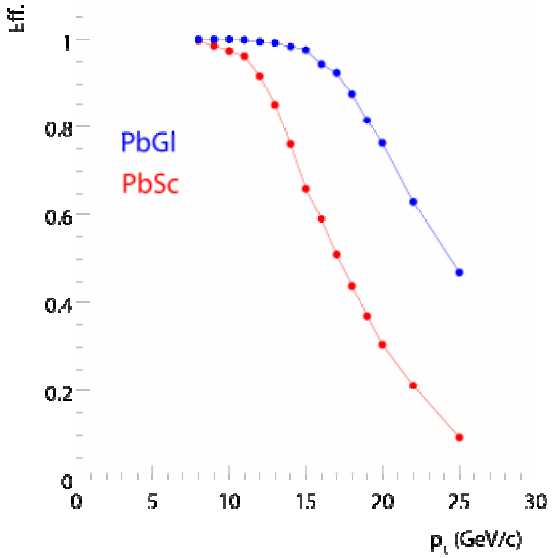


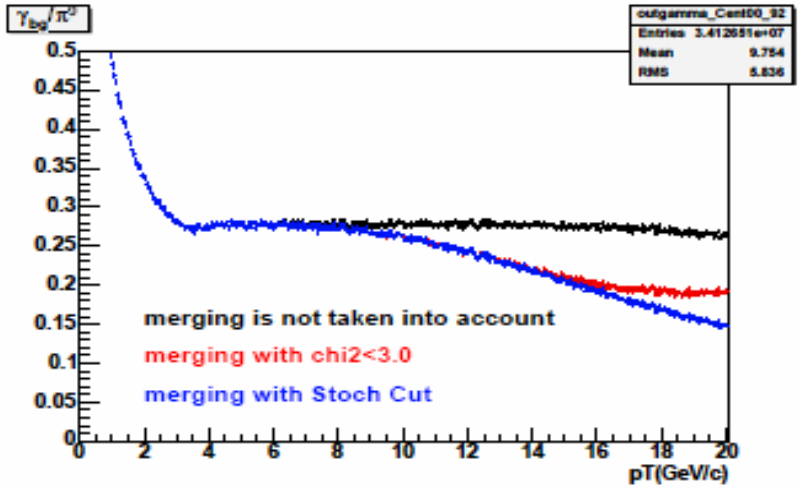
- Good agreement with preliminary result
- Partial systematic error is canceled out

Black: New Analysis
Red: preliminary

Pi0 merging effect

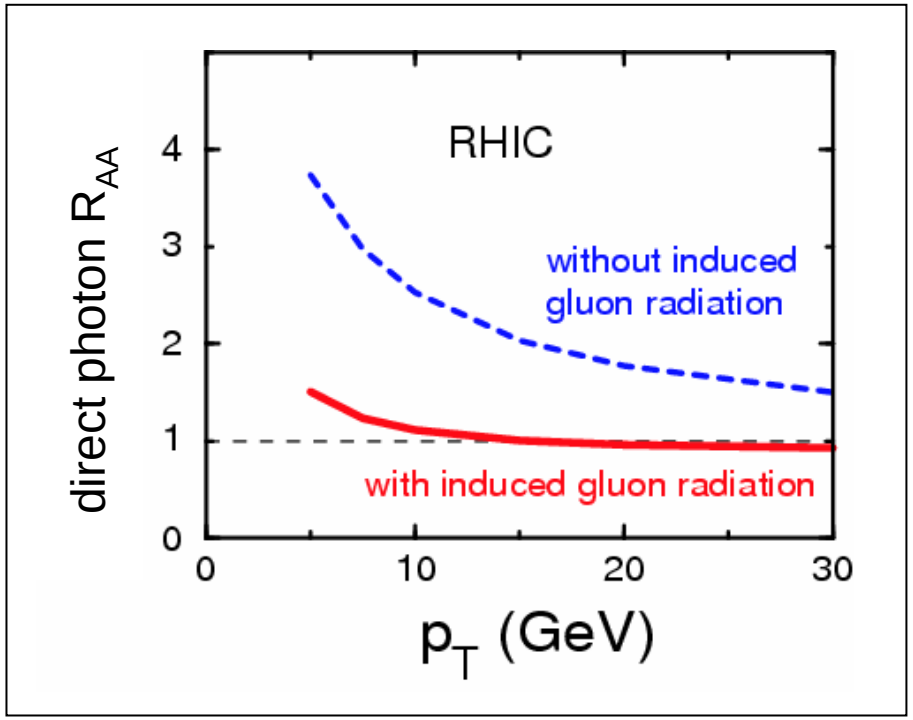
pi0 merging efficiency



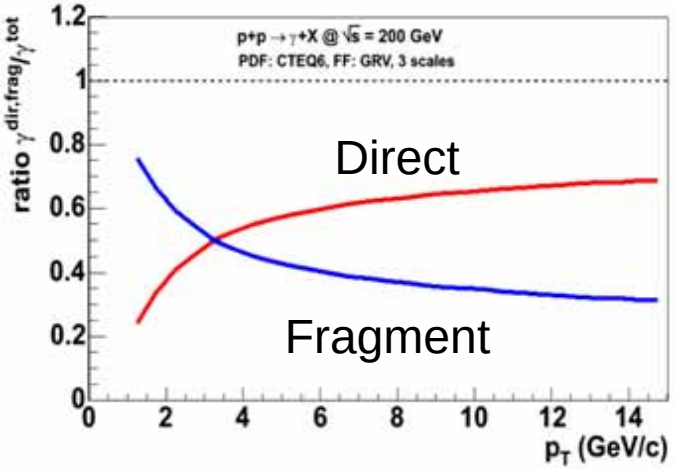


Direct photon source

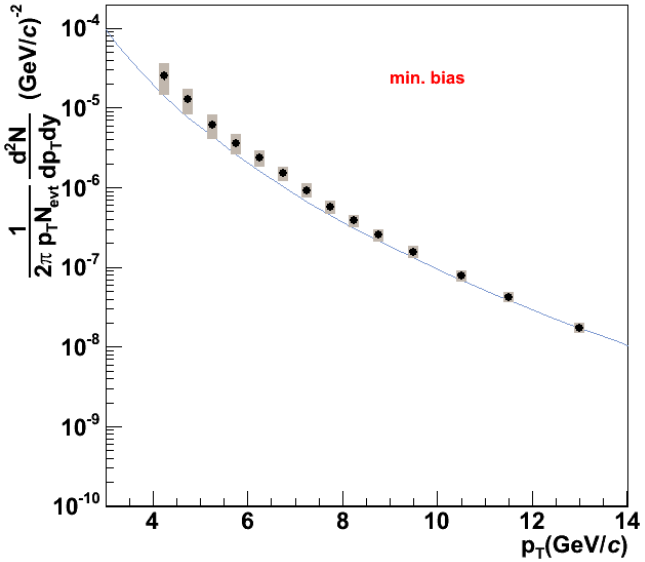
Zakharov, hep-ph/0405101

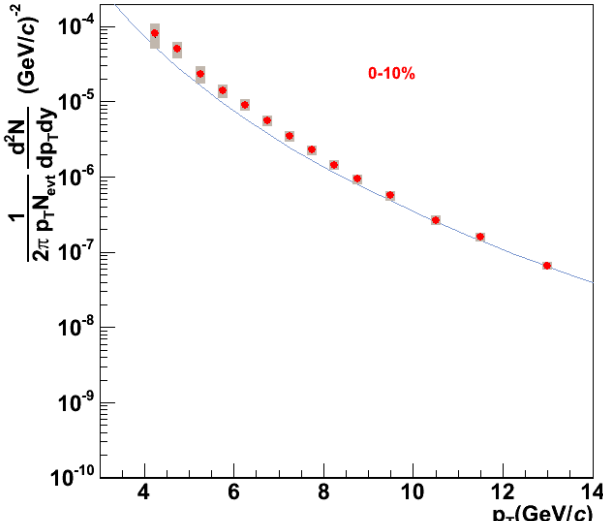


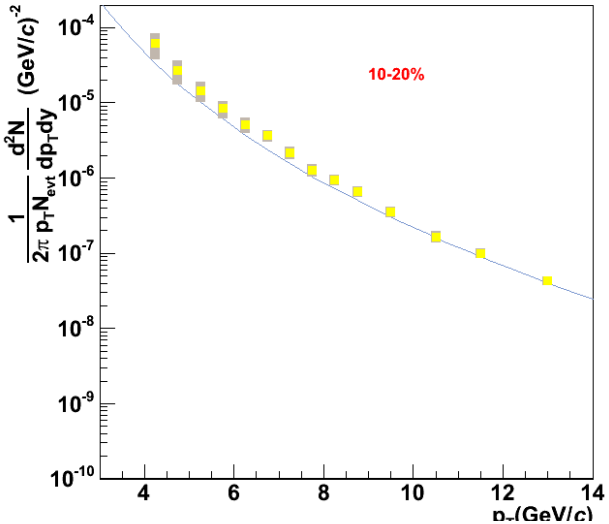
Bremss.

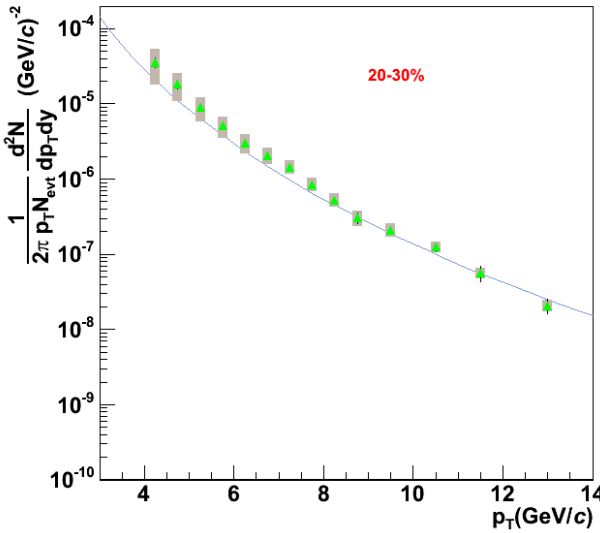


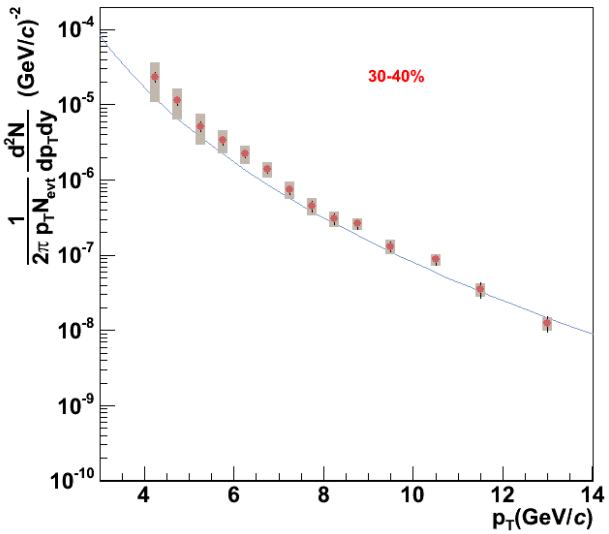
Each spectrum (Combined 1)





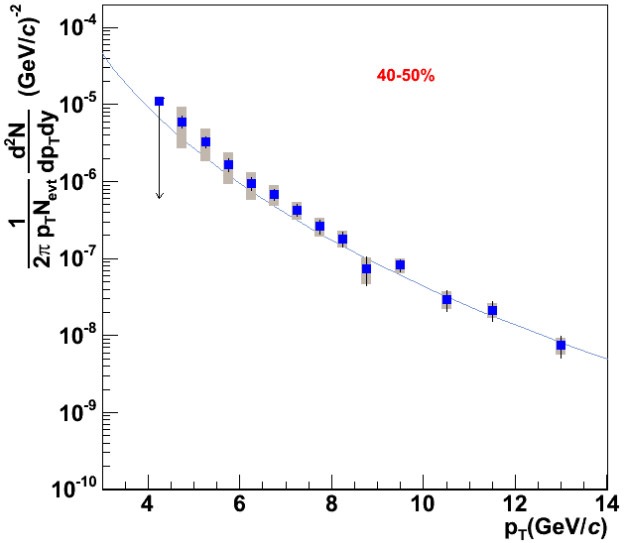


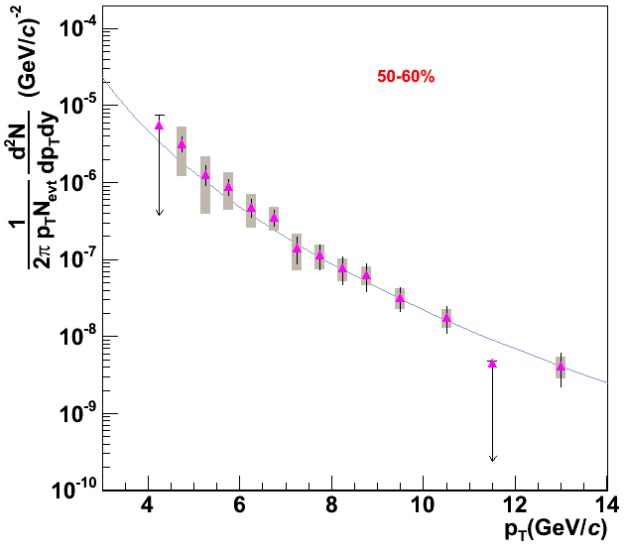


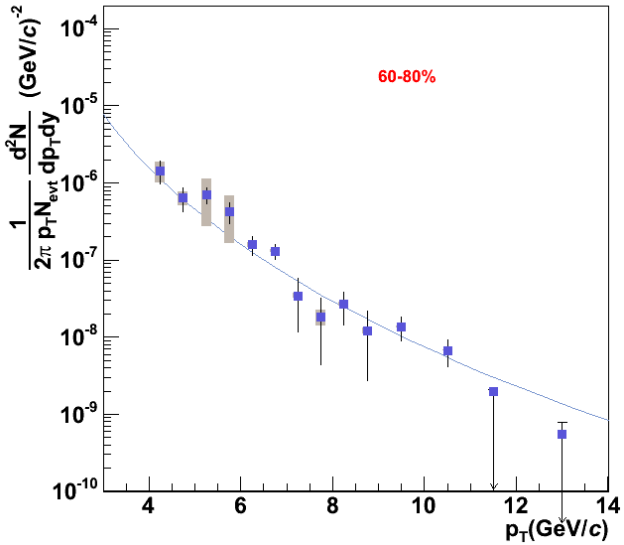


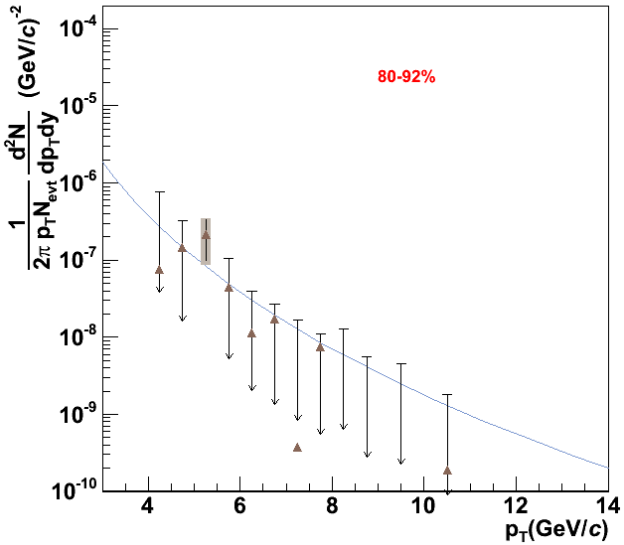
2006/03/27

Each spectrum (Combined 2)

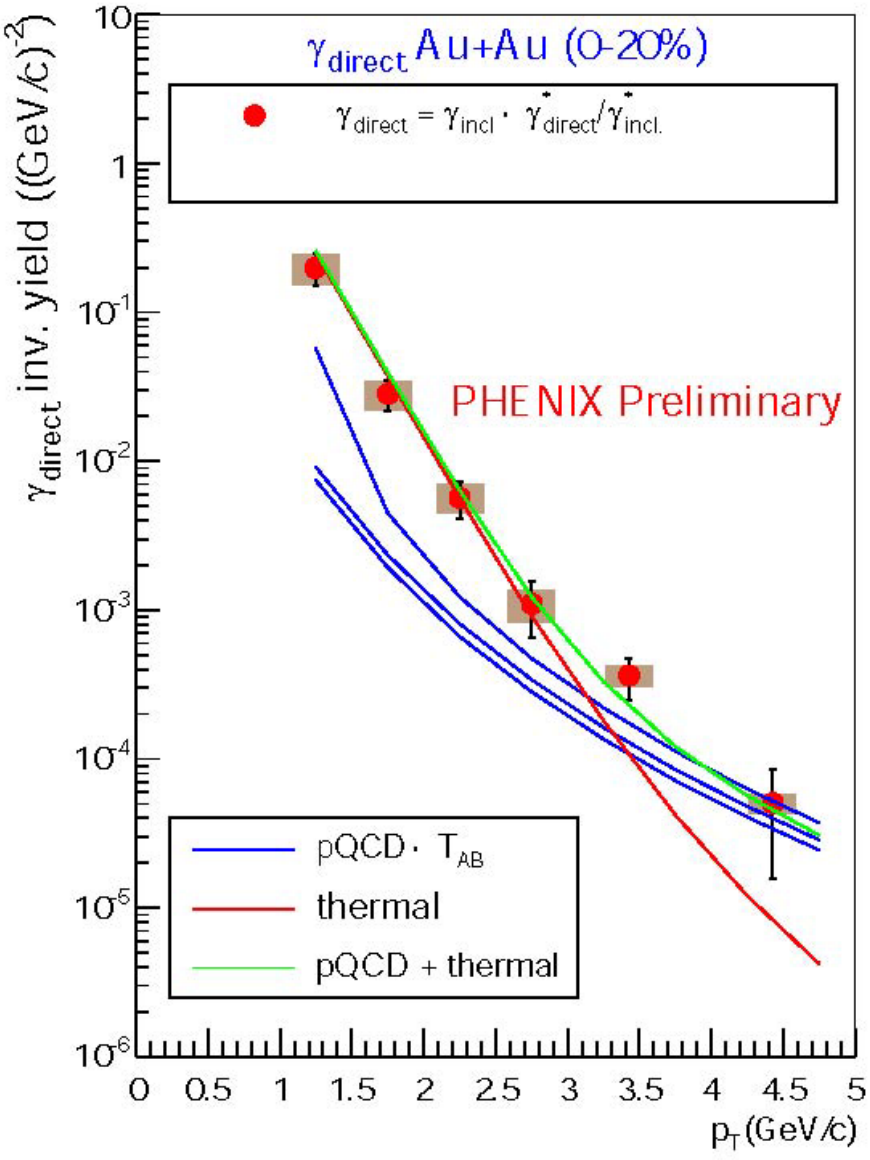








The Direct-Photon Spectrum



- NLO pQCD

  Phys. Rev. D48, 3136 (1993)

  L.E. Gordon, W. Vogelsang

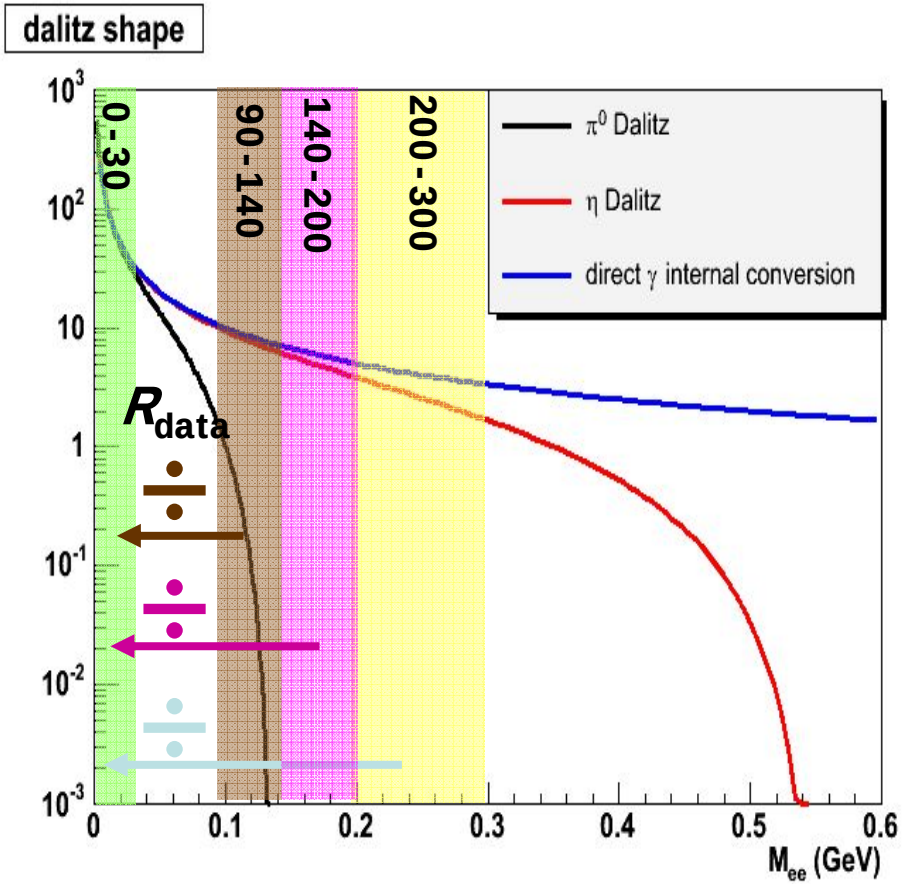
  nucl-th/0503054

  D. d'Enterria, D. Perresounko
- Thermal Model
  - 2+1 hydro
  - T_0^{ave}=360 MeV(T_0^{max}=570 MeV)
  - τ_0=0.15 fm/c
- The data are consistent with thermal + pQCD

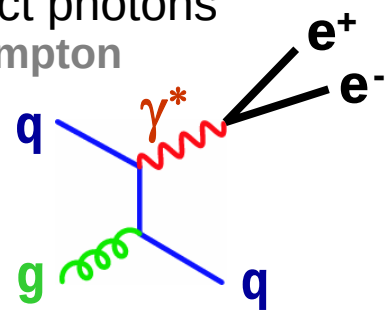
Analysis ~Very low-mass dilepton~

$$\frac{1}{N_\gamma}\frac{dN_{ee}}{dm_{ee}} = \frac{2\alpha}{3\pi}\sqrt{1-\frac{4m_e^2}{m_{ee}^2}}\left(1+\frac{2m_e^2}{m_{ee}^2}\right)\frac{1}{m_{ee}}\left|F(m_{ee}^2)\right|^2\left(1-\frac{m_{ee}^2}{M^2}\right)^3$$

Kroll-Wada Formula



phase space factor 1 for high p_T γ

- Ratios of M_{inv} bins to lowest one (R_{data})
- If no direct photons: the ratios become exactly what can be calculated from Dalitz decay formulae above
- If excess over calculation: direct photons

Compton