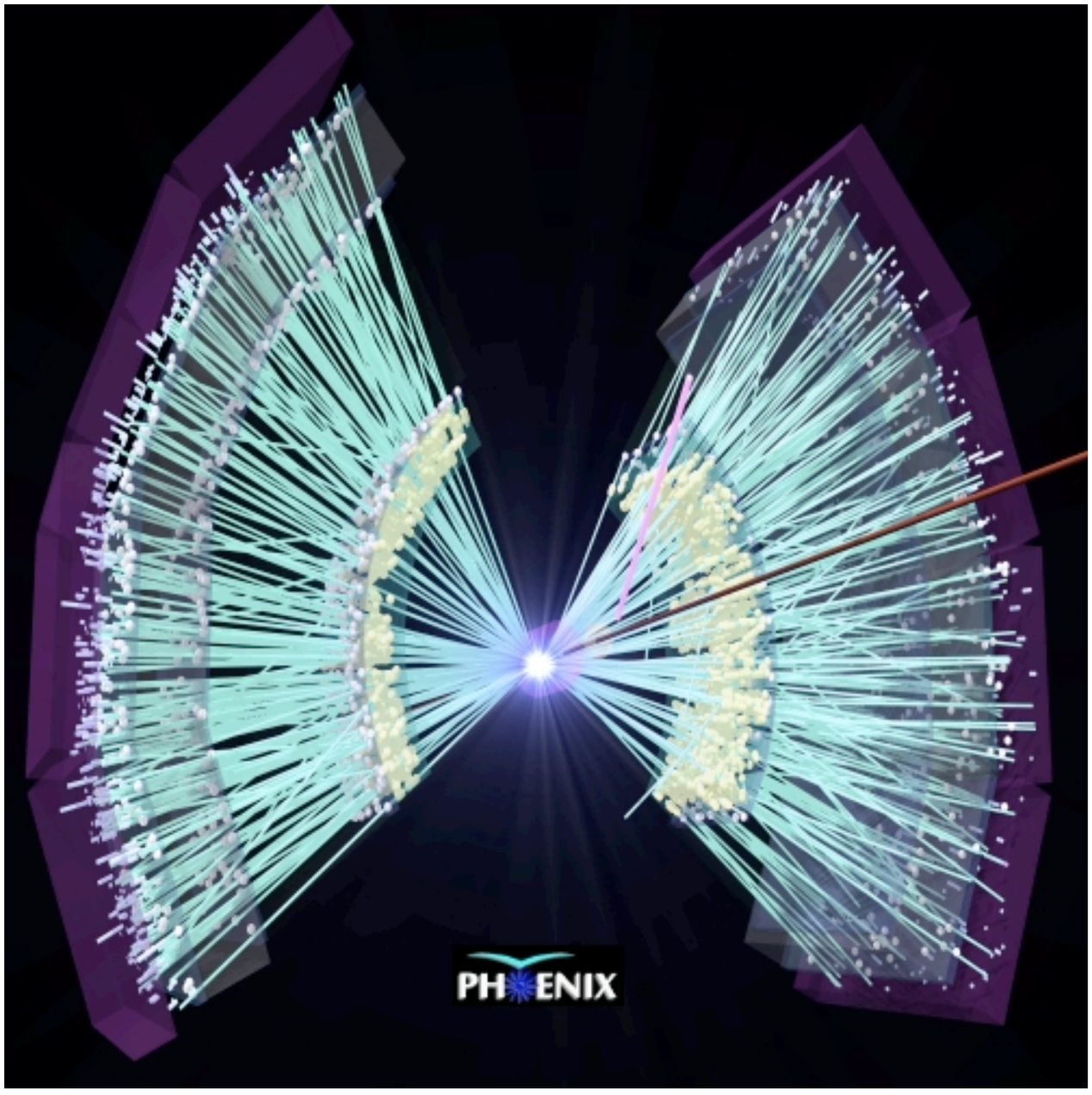
Direct photons from 200 GeV Au+Au



PHENIX
[nucl-ex/0503003]

NPG Journal Club
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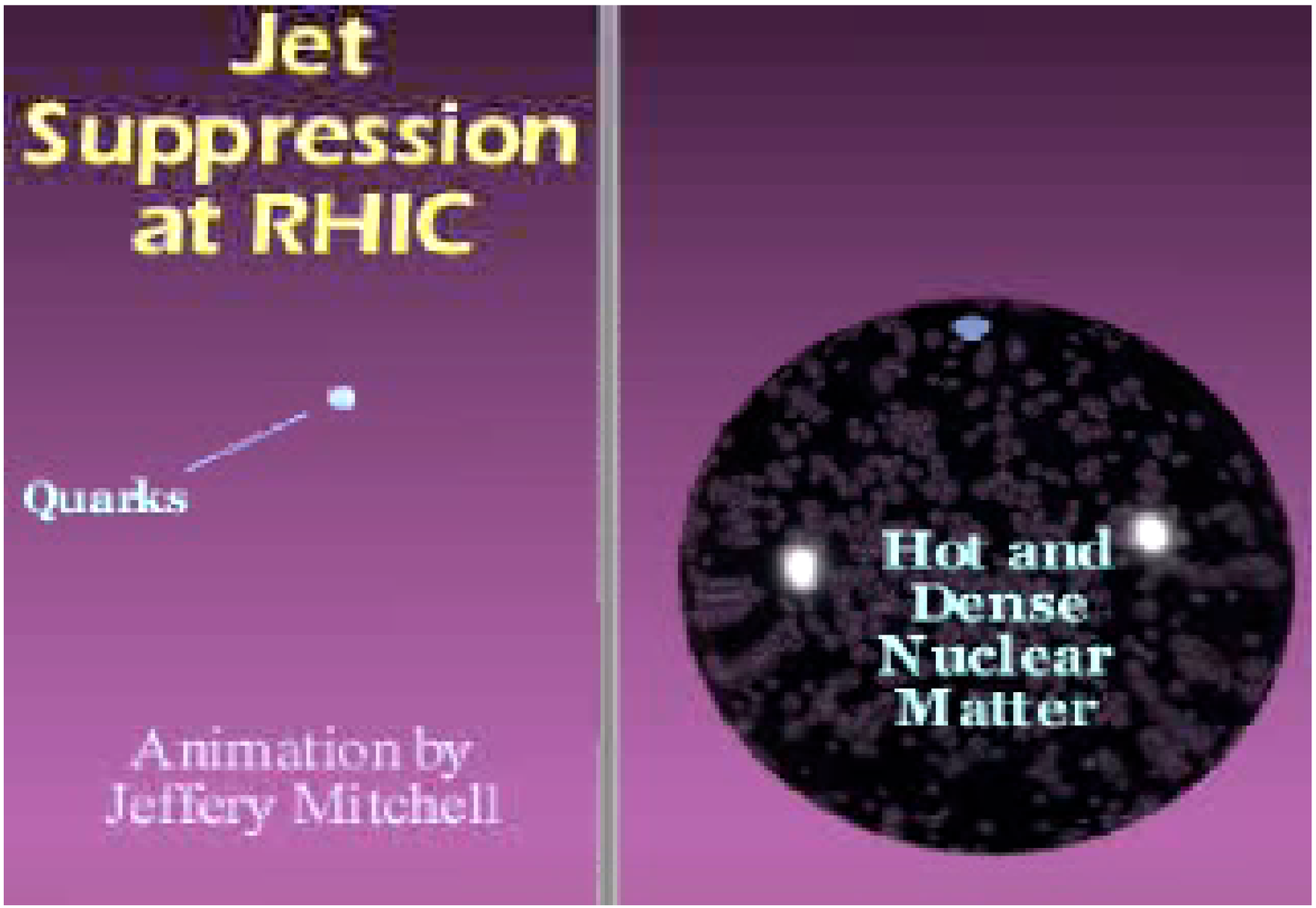
Roppon Picha

intro

- strong quenching of hadron yields at p_T > 2 GeV/c in central Au+Au has been observed
- such suppression was predicted to come from energy loss of hard scattered partons inside final-state dense matter (as opposed to initial-state saturation of partons)
- direct photons do not interact strongly with final-state matter - if quenched then suppression is due to initial-state effects

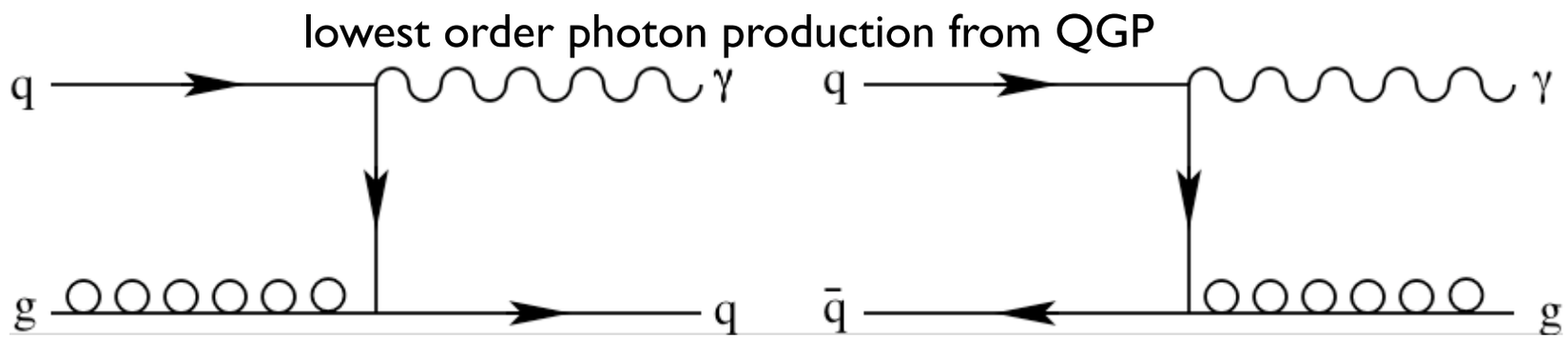
suppression of Jets



http://www.phenix.bnl.gov/WWW/software/luxor/ani/jetSuppress/jetSuppressSmall1.mpg

sources of direct γ

lowest order photon production from QGP

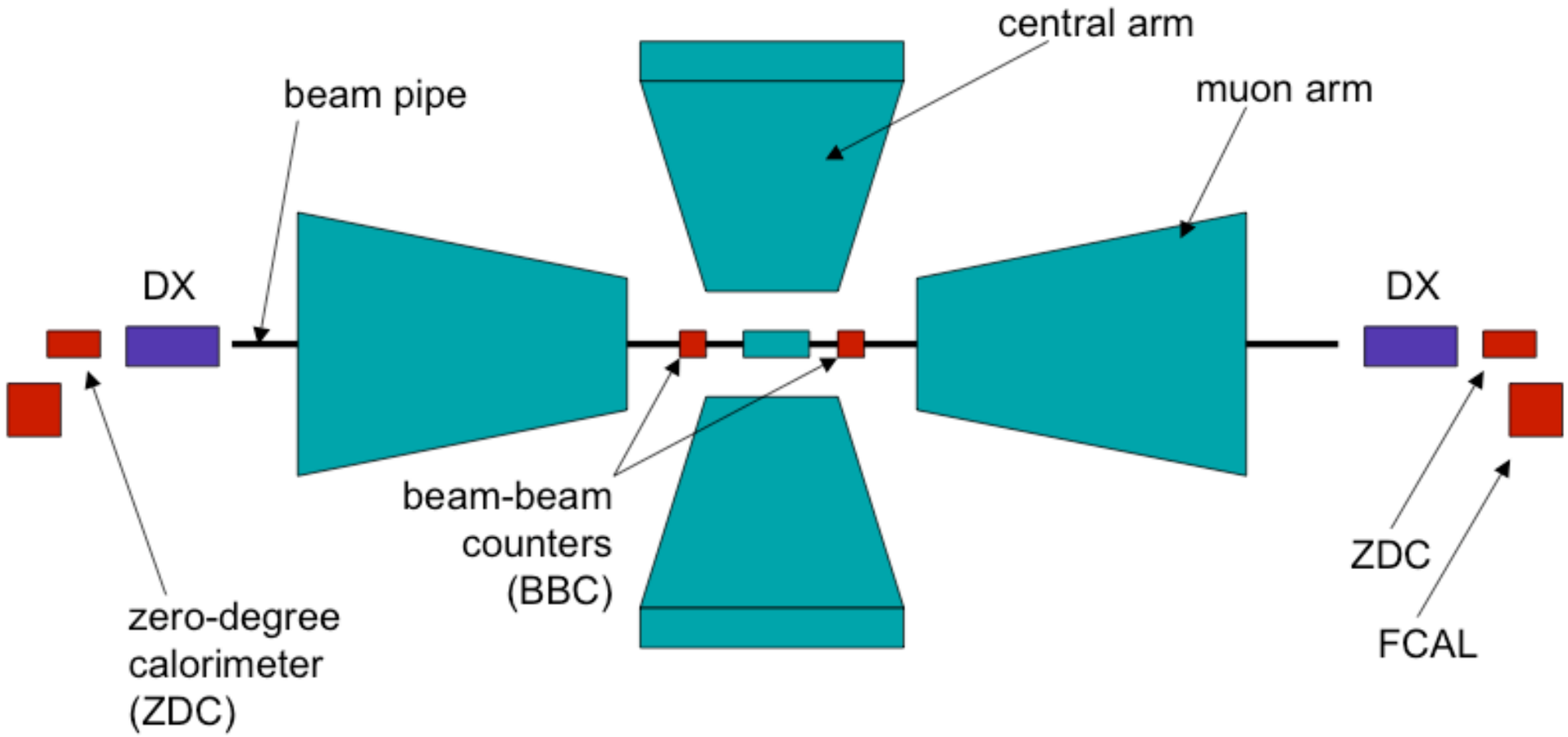


- "hard" photons
  - gluon Compton scattering: q+g -> q+γ (dominant)
  - quark annihilation: q+qbar -> g+γ
  - higher order: Bremsstrahlung: q+q -> q+q+γ (may be modified by medium)
- thermal - "soft" photons

additional direct γ

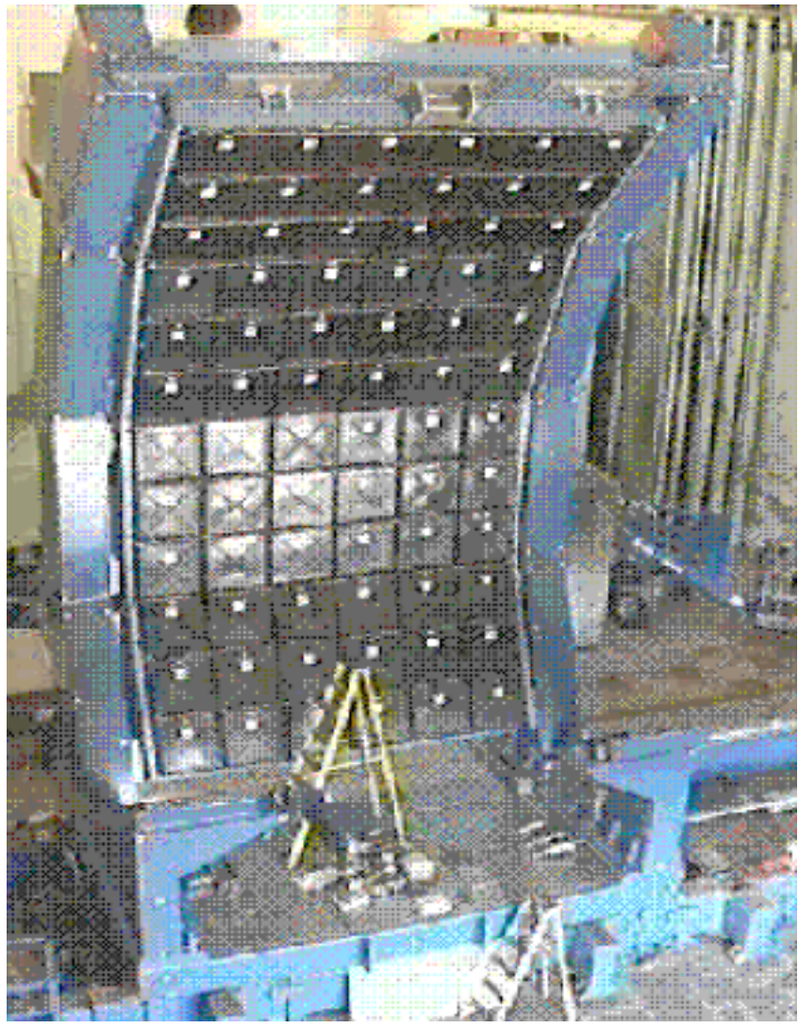
- momentum broadening ("Cronin" effect) of incoming partons
- additional fragmentations (q -> q+γ)
- additional scatterings in final state thermalization

PHENIX measurement



- Au+Au at 200 GeV, RHIC run 2 (2001)
- triggers: BBCs ($3 < |\eta| < 3.9$) and ZDCs
- gamma, π^0, η detection: EMCal ($|\eta| < 0.35$) in 2 central arms

PHENIX EMCal



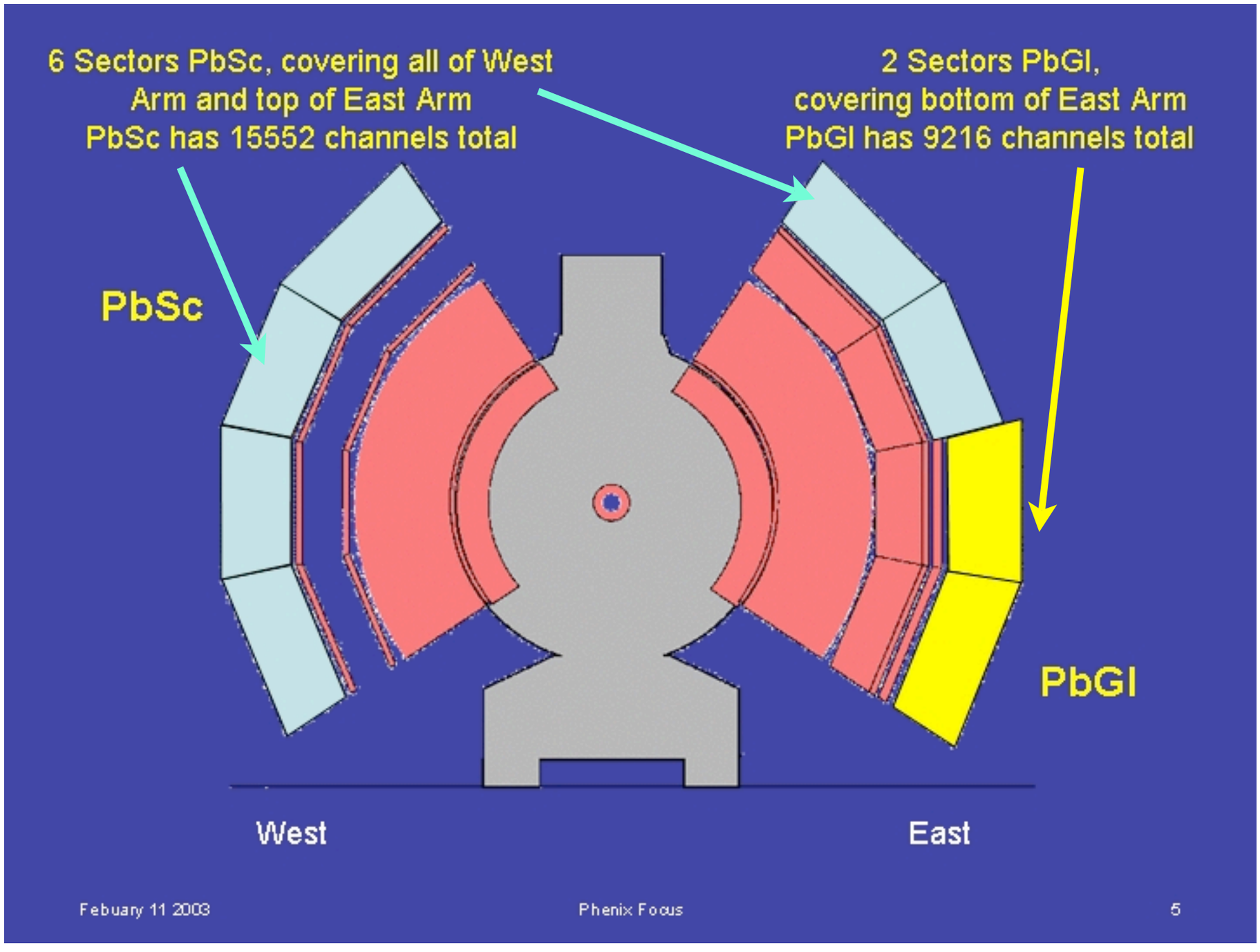
2 arms
4 sectors per arm

- 6 sectors of lead-scintillator (PbSc) sandwich calorimeter (layers)
- 2 sectors of lead-glass (PbGl) cherenkov calorimeter (homogeneous)

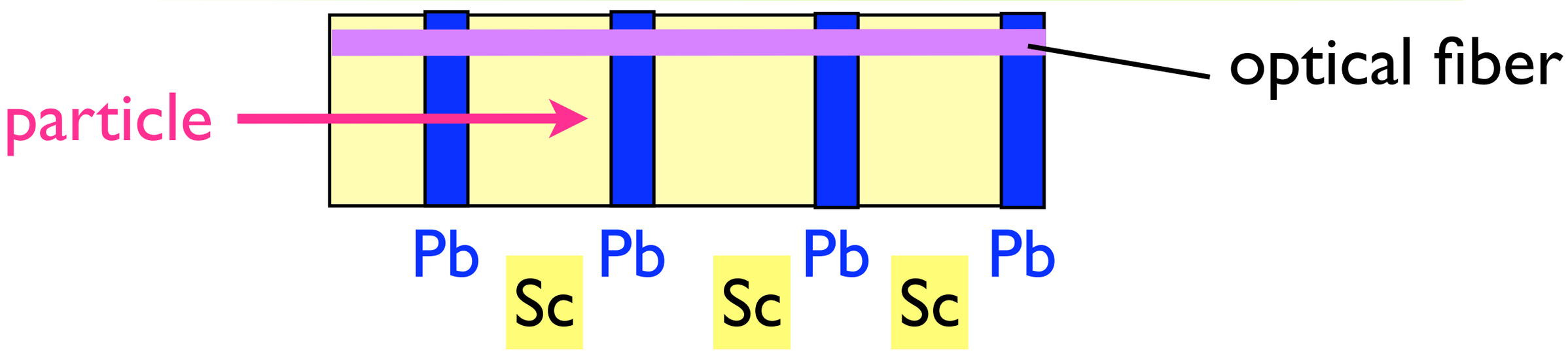
fine segmentation ($\Delta\phi x\Delta\eta \sim 0.01x0.01$)
-> photons from π^0 decay are well resolved up to $p_T \sim$ 15-20 GeV/c

PHENIX EMCal

http://www.phenix.bnl.gov/WWW/run/03/focus/talks/emc/index.html



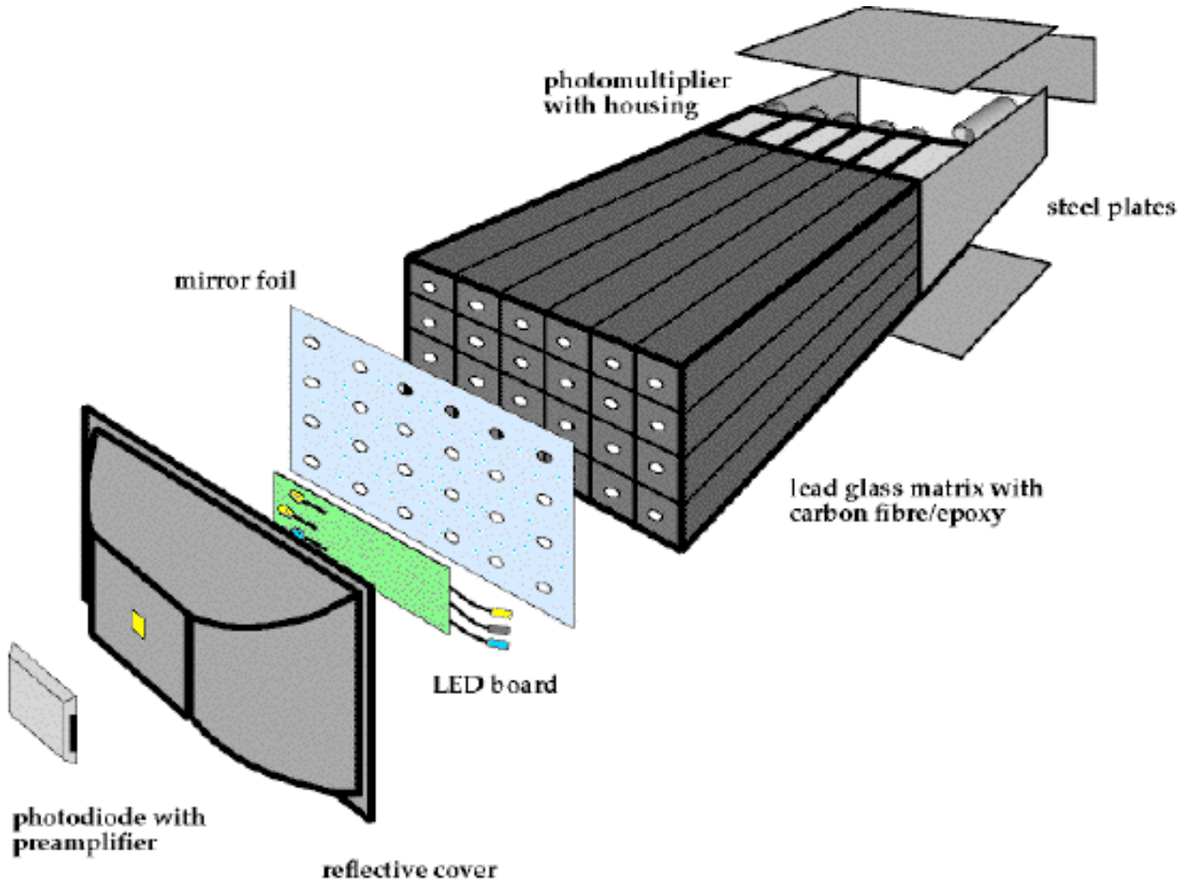
Pb-Scint



- charged particles shower inside lead layers
- photons are collected in optical fiber

Pb-Glass

- charged particles emit Cherenkov light inside medium when they are traveling faster than light
- the Cherenkov photons propagate inside PbGl to PMTs



http://www.phenix.bnl.gov/WWW/emcal/pbglass/pbglass-geometry.html

year-2 data

- 30 million minbias events
- + 55 million Level-2 trigger (selected showers with energy > 3.5 GeV) events
- efficiency plateau = 100% for high p_T:
  - p_T > 5 GeV/c in PbSc
  - p_T > 6.5 GeV/c in PbGl

Photon detection

- photon PID in EMCal: TOF and shower profile
- main background π^0 --> γ + γ
- invariant mass analyses to extract π^0 and η yields of γ pairs:

$$M = \sqrt{(\sum_{i=\gamma_1}^{\gamma_2} E_i)^2 - (\sum_{i=\gamma_1}^{\gamma_2} \vec{p}_i)^2}$$

Contaminations

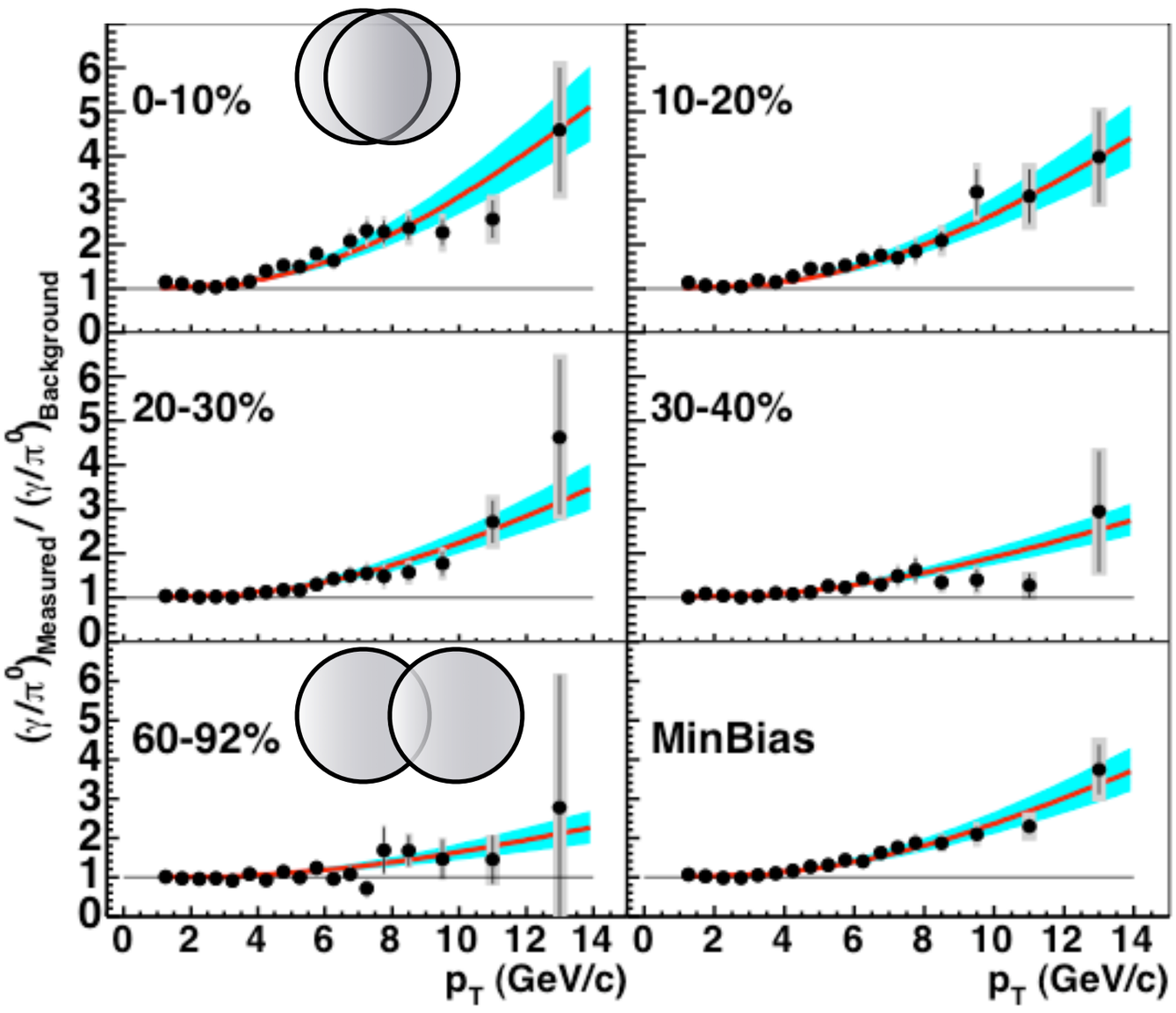
- charged hadrons from EMCal
  - 4% above p_T = 3 GeV/c
- neutral hadrons (mostly nbar) determined with Geant simulation based on p and pbar yield
  - less than 1% above p_T = 5 GeV/c

Corrections

- detector response
- reconstruction efficiency
- occupancy effects

} estimated by simulating γ, η, π^0 in Geant

Double ratio gives excess over background; anything above 1 is a signal of direct photons



excess of high-p_T γ increases with centrality -> due to π^0 suppression in central events

Fig. 1: Double ratio of measured $(\gamma/\pi^0)_{Measured}$ invariant yield ratio to the background decay $(\gamma/\pi^0)_{Background}$ ratio as a function of p_T for minimum bias and for five centralities of Au+Au collisions at sqrt(sNN) = 200~GeV (0-10% is the most central). Statistical and total errors are indicated separately on each data point by the vertical bar and shaded region, respectively. The solid curves are the ratio of pQCD predictions described in the text to the background photon invariant yield based on the measured π^0 yield for each centrality class. The shaded region around the curves indicate the variation of the pQCD calculation for scale changes from $p_T/2$ to $2p_T$, plus the $< N_{coll} >$ uncertainty.

pT spectra

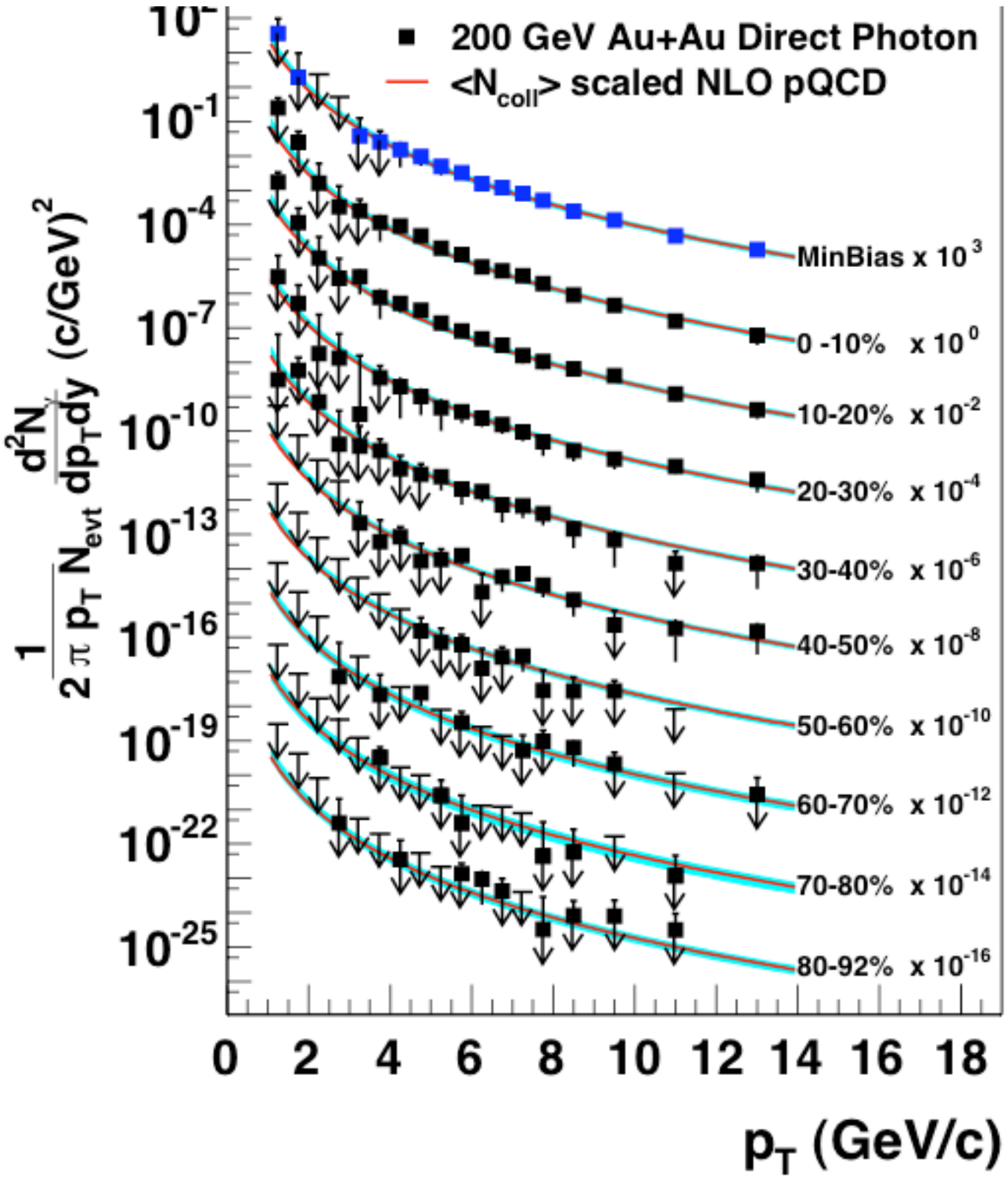
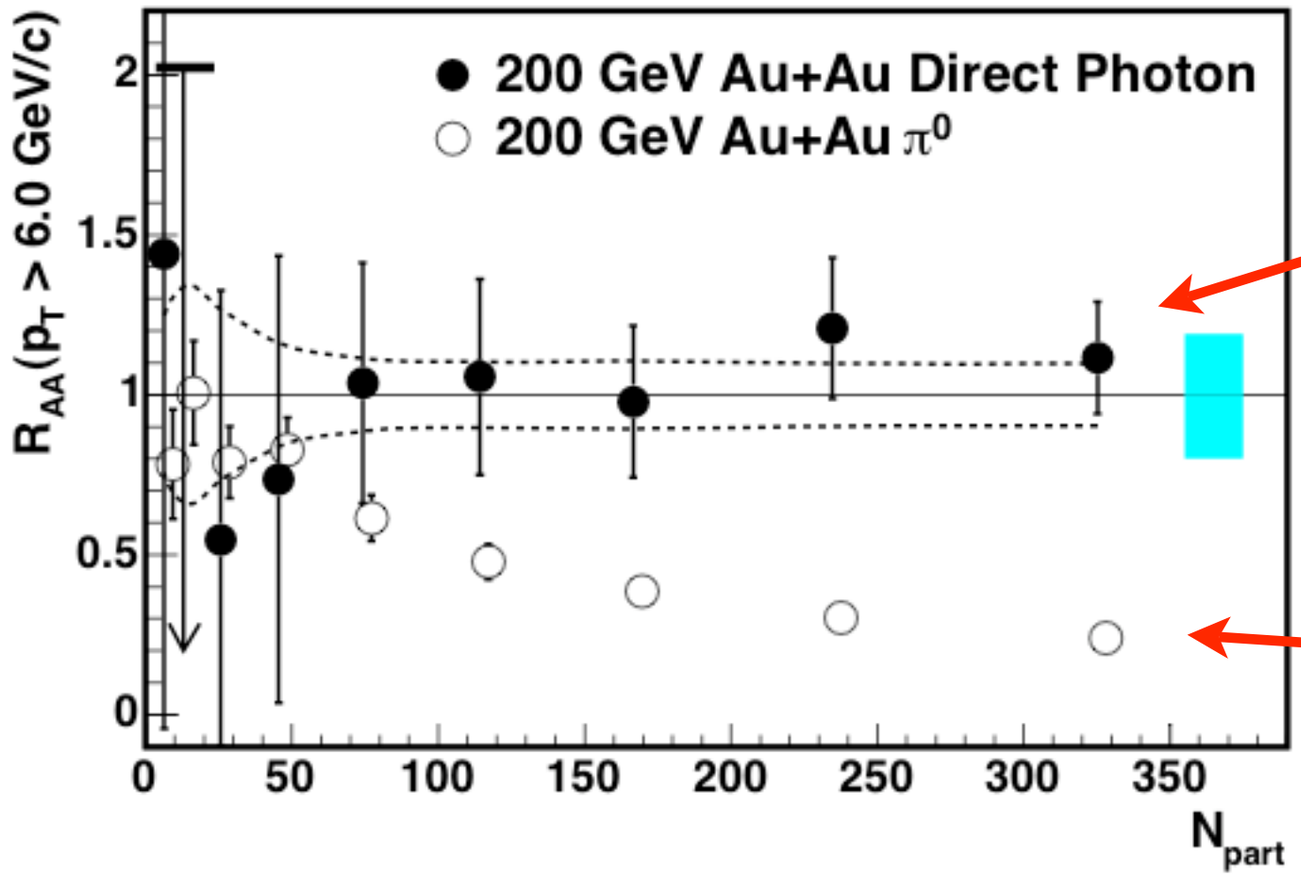


Fig. 2: Direct γ invariant yields as a function of transverse momentum for 9 centrality selections and minimum bias Au+Au collisions at sqrt(sNN) = 200~GeV. The vertical error bar on each point indicates the total error. Arrows indicate measurements consistent with zero yield with the tail of the arrow indicating the 90\% confidence level upper limit. The solid curves are pQCD predictions described in the text.

NLO pQCD can explain γ in Au+Au, p+p and π^0 in p+p

R_{AA}



no medium effect on γ

suppressed π^0

Fig. 3: Ratio of Au+Au yield to p+p yield normalized by the number of binary nucleon collisions as a function of centrality given by N_{part} for direct γ (closed circles) and π^0 (open circles) yields integrated above 6~GeV/c. The p+p direct photon yield is taken as the NLO pQCD prediction described in the text. The error bars indicate the total error excluding the error on $< N_{coll} >$ shown by the dashed lines and the scale uncertainty of the NLO calculation shown by the shaded region at the right.

summary

- PHENIX measured direct photon spectra from Au+Au at 200 GeV up to p_T ~ 13 GeV/c for various centrality bins
- direct photon yield increases with centrality due to π^0 suppression and associated decrease of background photons from hadron decays
- spectral shapes and invariant yields consistent with NLO pQCD predictions for p+p reactions scaled by $\langle N_{inel\ coll} \rangle$
- ***results confirm that high-p_T suppression of hadrons is final-state effect due to parton energy loss in dense medium***