Low Momentum Direct Photons in Au+Au collisions at 39 GeV and 62.4 GeV measured by the PHENIX Experiment at RHIC

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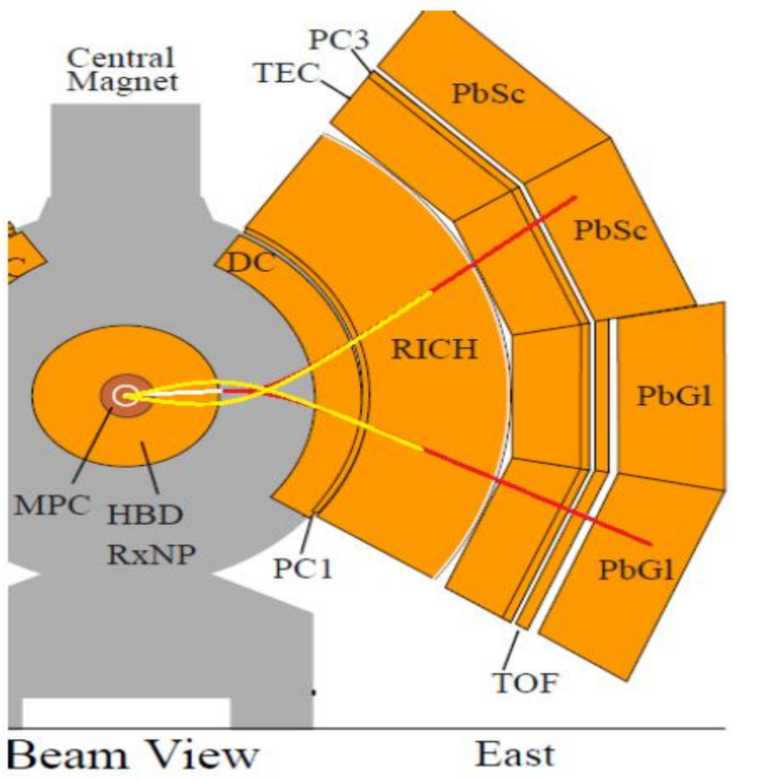
Abstract 1

Direct photons, which are produced during all stages of a heavy-ion collision, directly probe the conditions of their production environment. The large yield and large anisotropy of low momentum direct photons observed in 200 GeV Au+Au collisions poses a significant challenge to theoretical models. Measurements at a lower collision energy may provide new insight on the origin of the low momentum direct photons. PHENIX has already measured the direct photons at 200 GeV via their external conversion on detector material to di-electron pairs. The advantage of this method is a very good purity in photon identification. This method is also used in our current analysis of the direct photons at two lower energies. In this poster we present the results of the measurements of the low momentum direct photons at 39 GeV and 62.4 GeV.

Measurement details of Low Momentum Direct Photons by the PHENIX Experiment in Au+Au at 39 GeV and 62.4 GeV 2

The raw inclusive photon yield N_γ^{incl} is measured through photon conversions to e^+e^- pairs.

The identification of the converted photons is very accurate if the conversions took place in a *relatively thick* detector material, which has a large distance from the true event vertex.



A cartoon illustrating the effect of the assumption of the e^+e^- pair track origin.

The focus is on conversions that occurred in the readout boards (backplane) of Hadron Blind Detector (HBD). It sits at a radius of about 60 cm from the event vertex.

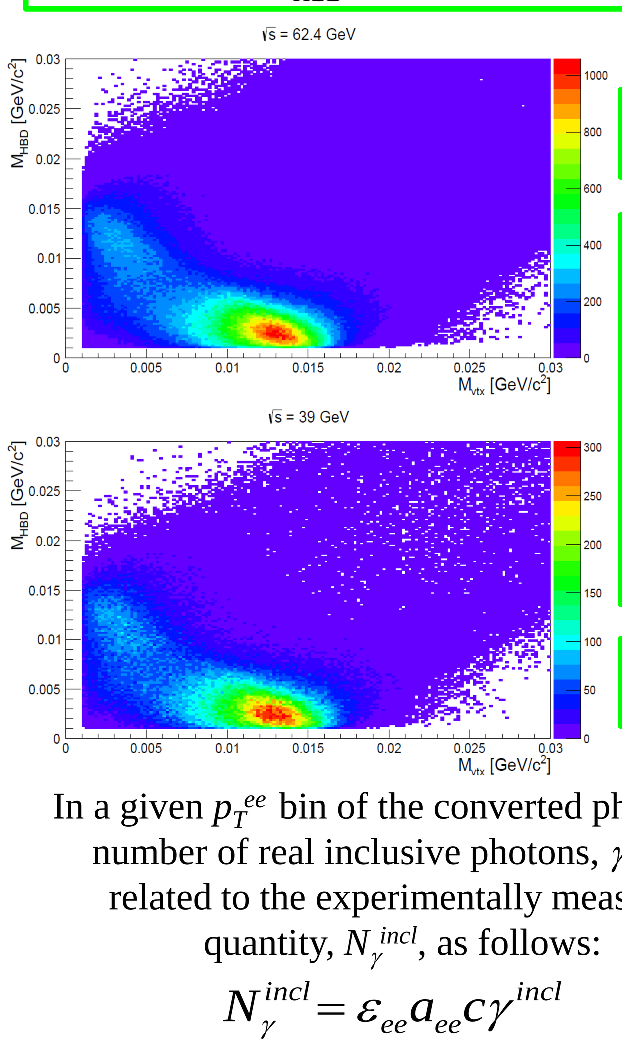
In the **Standard PHENIX Momentum Reconstruction Algorithm** and **Alternate Track Model**

→ the charged tracks originate from the event vertex leading to mis-measured momenta. The result is *large opening angle* and *fake invariant mass* (M_{vtx});

→ the momenta of the conversion pairs are recalculated under the assumption that a conversion takes place at the HBD backplane. The result is the *true invariant mass* (M_{HBD}) of the conversion photons.

Some results from the analysis 3

A view of the cut space in 2D mass plot, used for the conversion photon identification at the two energies.
Use the same mass cuts for both energies:
$10\ MeV/c^2 < M_{vtx} < 15\ MeV/c^2$,
$M_{HBD} < 4.5\ MeV/c^2$



$N_\gamma^{incl} = 3.28\cdot10^5$

The reddish blobs in two figures are the places where the best photon conversion candidates "live".

$N_\gamma^{incl} = 9.42\cdot10^4$

In a given p_T^{ee} bin of the converted photon the number of real inclusive photons, γ^{incl}, is related to the experimentally measured quantity, N_γ^{incl}, as follows:

$$N_\gamma^{incl} = \varepsilon_{ee} a_{ee} c \gamma^{incl}$$

The factor ε_{ee} is the conversion pair reconstruction efficiency; a_{ee} – the pair geometrical acceptance; c – probability for a photon to undergo a conversion in the HBD backplane.

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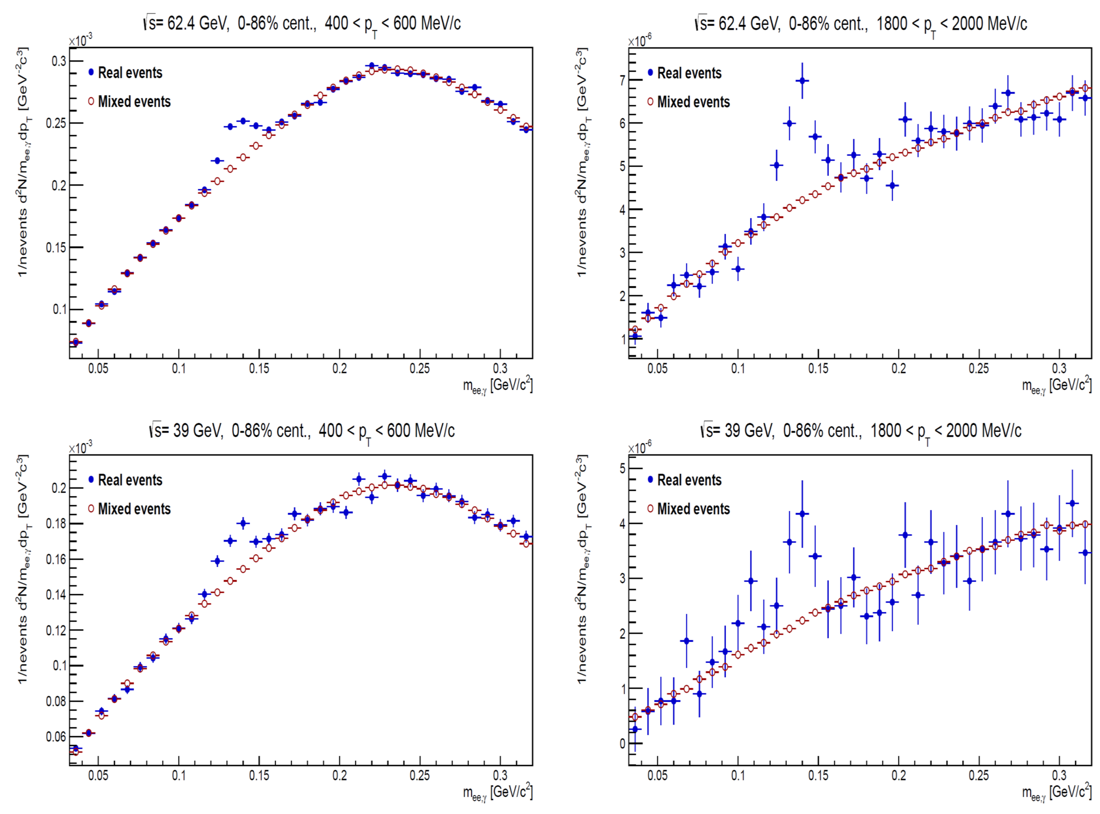
A subset of the inclusive conversion photon sample, N_γ^{incl}, is tagged as photons from π^0 decays if they reconstruct the π^0 mass with the second photon shower from the PHENIX electromagnetic calorimeter (EMCal).

In each p_T^{ee} bin of the converted photon the number of π^0 tagged photons, $N_\gamma^{\pi0,tag}$, is specified by integrating the $e^+e^-\gamma$ mass distribution.

Histograms of the $e^+e^-\gamma$ invariant mass distribution for two different p_T^{ee} bins at 62.4 GeV and 39 GeV in minbias (0-86% centrality class).

The diphoton foreground distribution is in blue, and the normalized background distribution from mixed events is in red.



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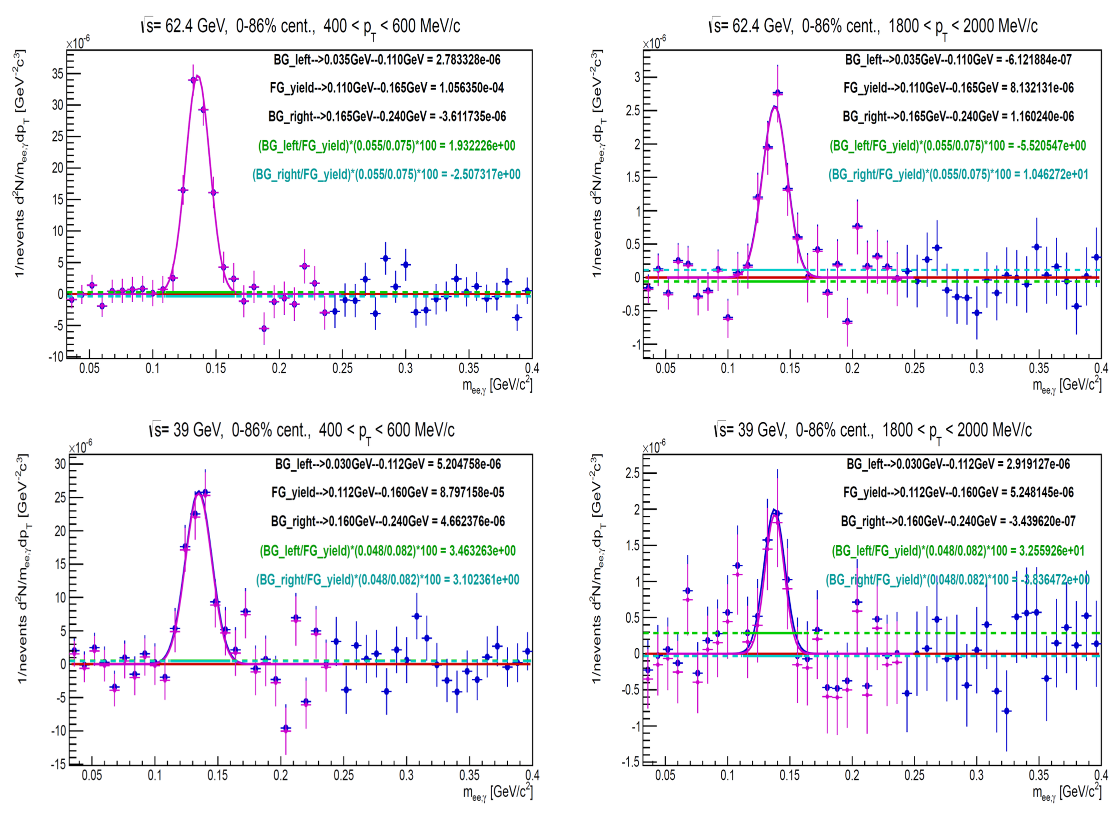
The four plots below show the isolated pion peak after subtraction of the normalized mixed event background from the diphoton foreground at 62.4 GeV and 39 GeV in minbias.

The blue curve is a Gaussian fit to the subtraction. The residual background is assumed to be described by averaging the sum of the green and cyan colored lines. Then it is used to correct the original blue colored subtraction. It results in shifting the blue points up or down, described by the purple points and fitted by a purple Gaussian.



In a given p_T^{ee} bin the number of real π^0 decay photons, $\gamma^{\pi0}$, is related to the experimentally measured quantity, $N_\gamma^{\pi0,tag}$, as follows:

$$N_\gamma^{\pi^0,tag} = \langle \varepsilon_\gamma f \rangle N_\gamma^{\pi^0} = \varepsilon_{ee} a_{ee} c \langle \varepsilon_\gamma f \rangle \gamma^{\pi^0}$$

Measuring R_γ with the Double Ratio 4

By having the raw inclusive and π^0-tagged photon yields, one can address to a more straightforward interpretation of direct photons in terms of R_γ:

$$R_\gamma = \frac{\gamma^{incl}(p_T)}{\gamma^{had}(p_T)} = \frac{\langle \varepsilon_\gamma(p_T) f(p_T) \rangle \cdot \left(\frac{N_\gamma^{incl}(p_T)}{N_\gamma^{\pi^0,tag}(p_T)} \right)_{Data}}{\left(\frac{N_\gamma^{had}(p_T)}{N_\gamma^{\pi^0}(p_T)} \right)_{Sim}}$$

e+e- pair efficiency

e+e- pair acceptance

From DATA

$$N_\gamma^{incl}(p_T) = \varepsilon_{ee} a_{ee} c \gamma^{incl}(p_T)$$
$$N_\gamma^{\pi^0,tag}(p_T) = \varepsilon_{ee} a_{ee} c \langle \varepsilon_\gamma f \rangle \gamma^{\pi^0}(p_T)$$

Probability (conversion) factor

Photon efficiency

Conditional acceptance

From SIMULATION

$$N_\gamma^{had}(p_T) = a_{ee} \gamma^{had}(p_T)$$
$$N_\gamma^{\pi^0,tag}(p_T) = f N_\gamma^{\pi^0} = a_{ee} f \gamma^{\pi^0}(p_T)$$

From SIMULATION

$$\langle \varepsilon_\gamma(p_T) f(p_T) \rangle$$

In the factor $\langle \varepsilon_\gamma f \rangle$, f is the *conditional acceptance* of having the second photon from a π^0 decay in the EMCal acceptance, given that the converted photon is already reconstructed. The probability of the second photon's reconstruction is ε_γ. And the product $\varepsilon_\gamma f$ is averaged over all possible p_T values of the second photon.

In the experimentally measured ratio of $N_\gamma^{incl}/N_\gamma^{\pi0,tag}$ the p_T-dependent factors c, ε_{ee} and a_{ee} cancel explicitly at each p_T^{ee} bin, except for the conditional acceptance $\langle \varepsilon_\gamma f \rangle$.

The ratio in the denominator of the R_γ formula is called *cockfail ratio*, and it is the ratio of hadronic decay photons to those from π^0 decays.

$R_\gamma > 1$ if the direct photons are present in data sample.
$R_\gamma = 1$ if all the photons originate from hadronic decays.

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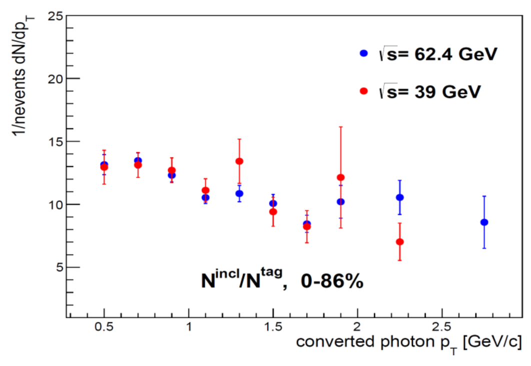
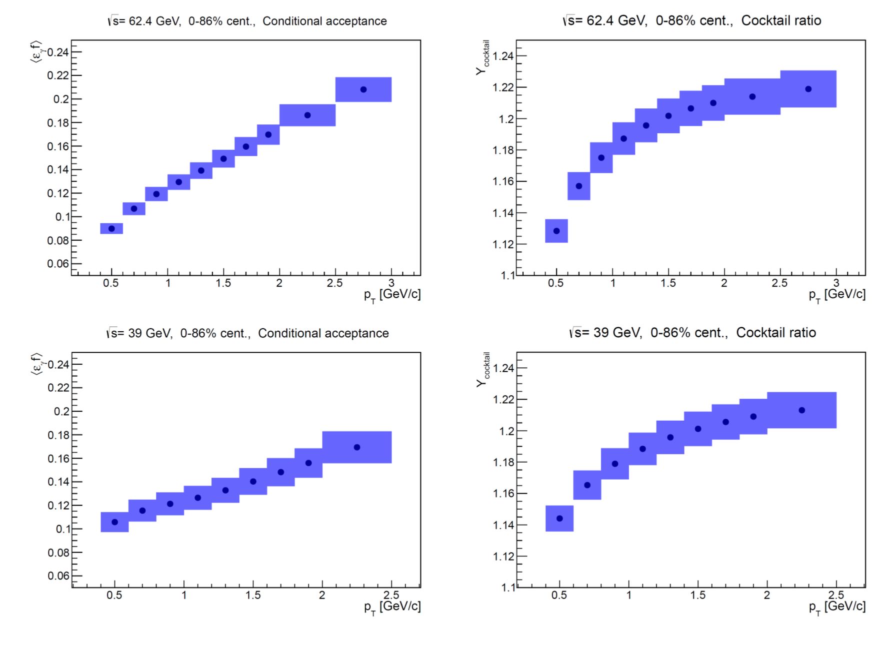
$N_\gamma^{incl}/N_\gamma^{\pi0,tag}$ ratio (with only statistical errors shown),

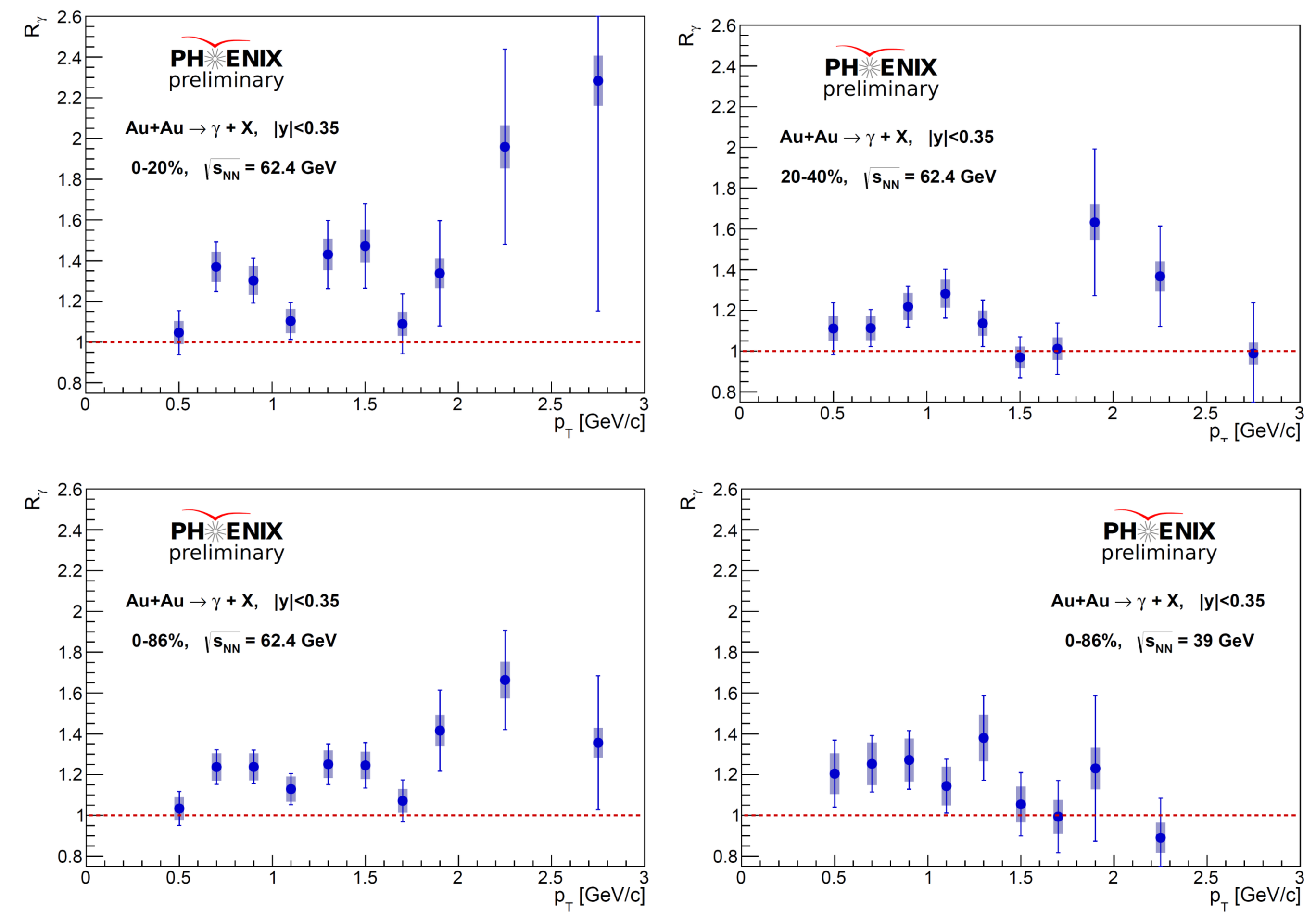
conditional acceptance and cocktail ratio

of direct photons in minbias at 62.4 GeV and 39 GeV.

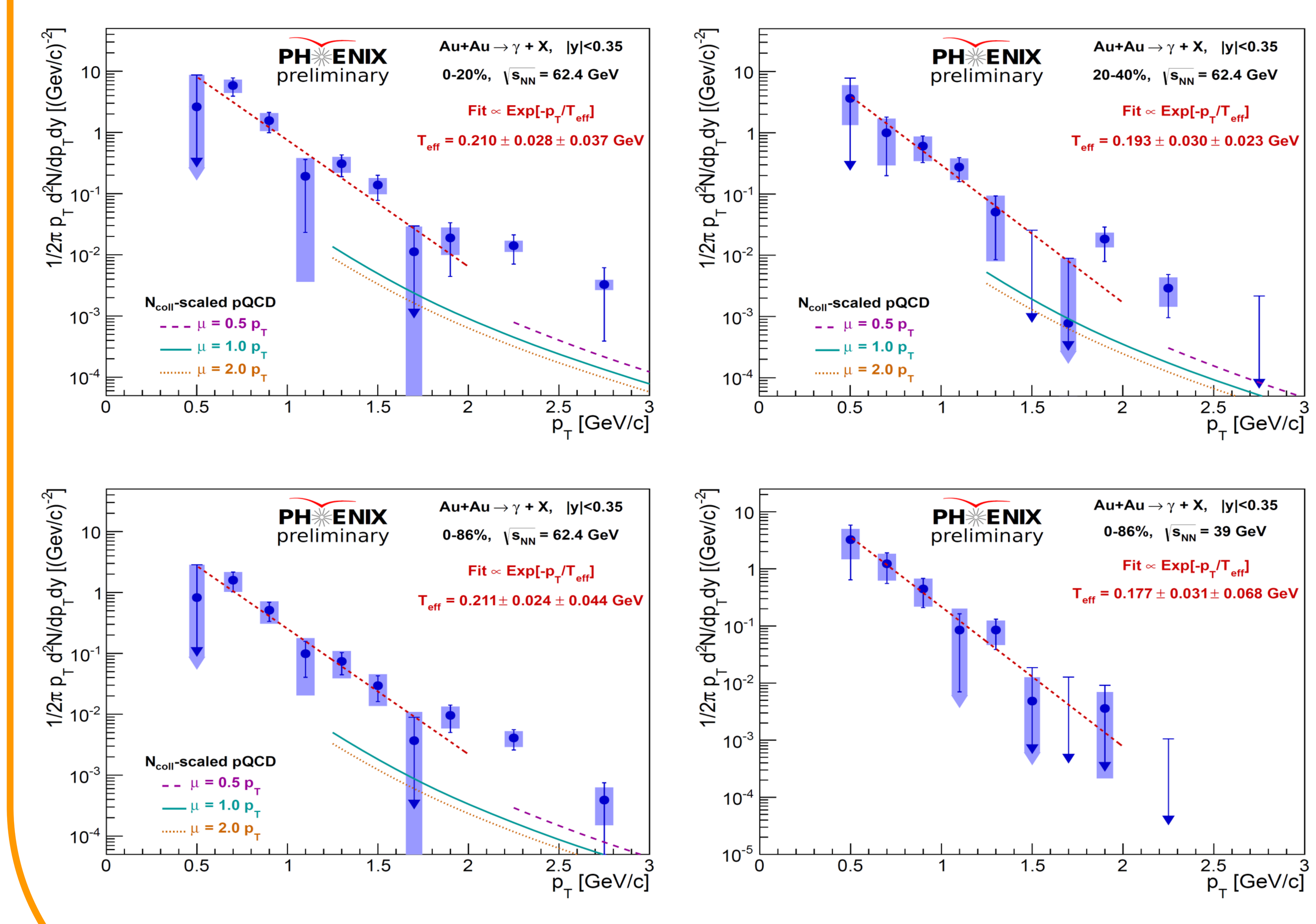




R_γ and invariant yield of direct photons in 0-20%, 20-40% centrality classes and in minbias at 62.4 GeV and at 39 GeV 5



Invariant Yield = $(R_\gamma - 1) \cdot \gamma^{had}$
The pQCD yield is calculated by Werner Vogelsang.



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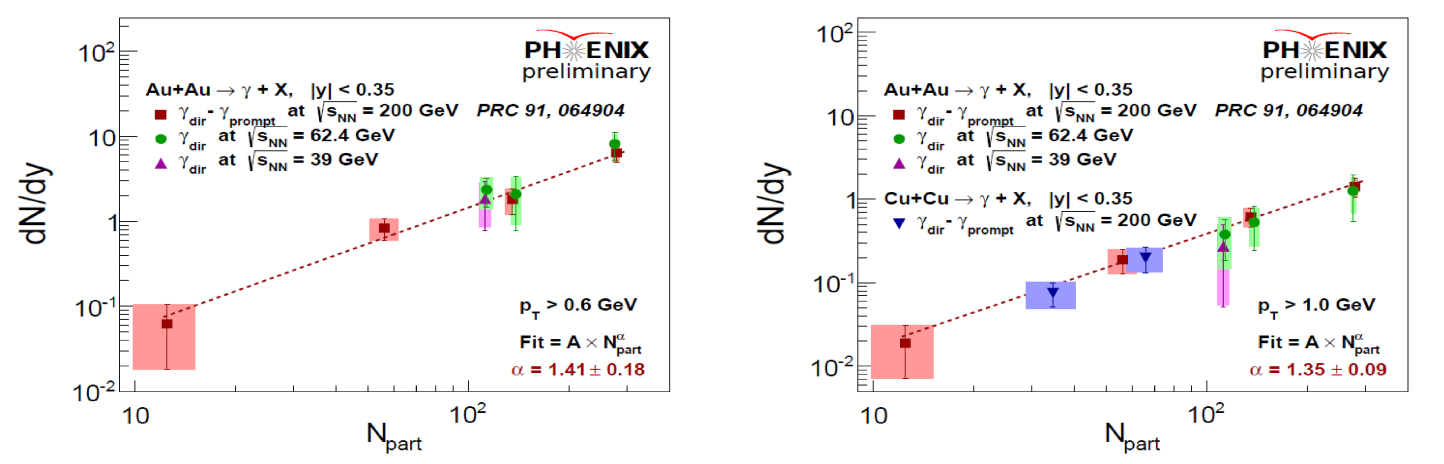
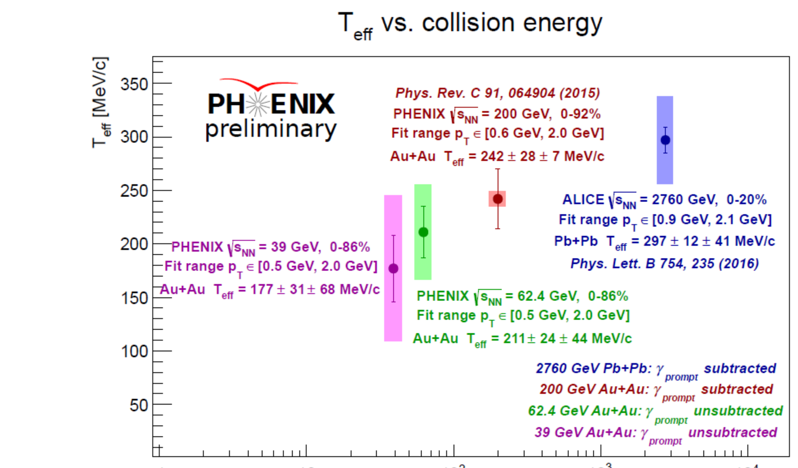
The direct photon p_T-integrated yield vs N_{part}, from 0.6 GeV/c for three systems (on the left) and from 1.0 GeV/c for four systems (on the right).





T_{eff} (inverse slope), extracted from the invariant yield of direct photons, for four systems.

Summary 6

- We have measured R_γ and p_T spectra for real photons at 62.4 GeV and 39 GeV.
- The measurements at 62.4 GeV show the presence of direct photons and significant excess yield at least for the most central collisions and minbias.
- The measurements at 39 GeV show the presence of direct photons at least in the low p_T region of minbias.

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