Results on Photon Production in Au+Au Collisions at RHIC

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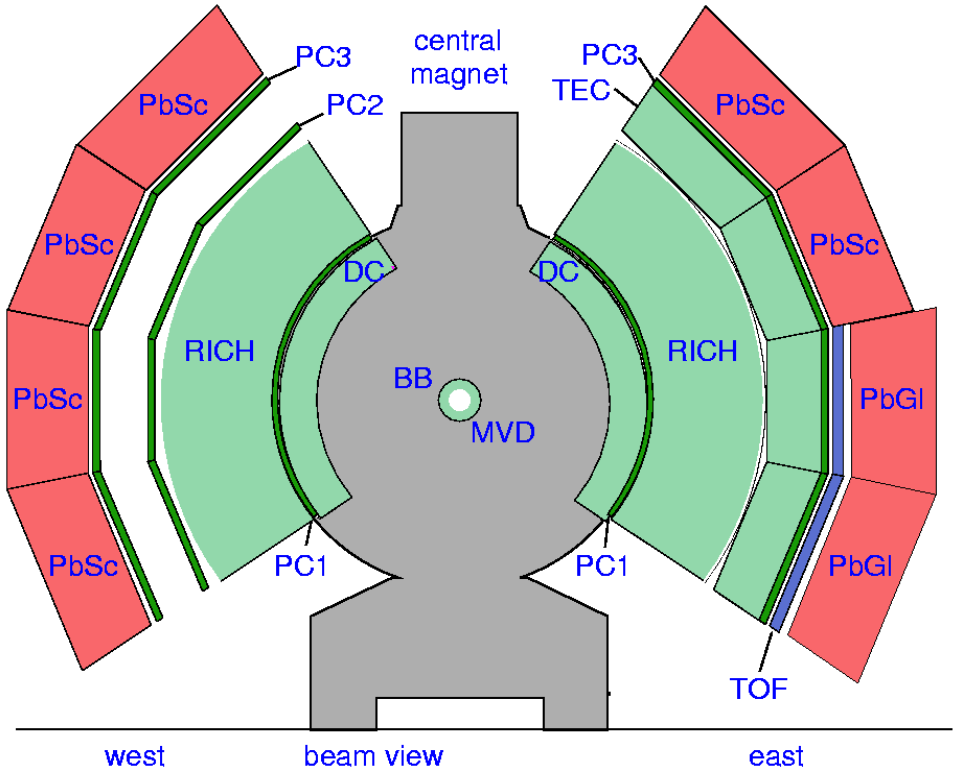
Direct Photons in Heavy Ion Reactions

- Prompt photons
  - Produced in initial hard scatterings, before a possible QGP has formed
  - Help to constrain models
    - Intrinsic k_T
    - Gluon structure function
- Thermal Photons
  - Produced in all stages of the reaction (possible QGP, hadron gas)
  - Strongest contribution from hottest phase
  - Measurement constrains
    - Initial temperature
    - Degrees of freedom

- Measurement of direct photons notoriously difficult
- But: PHENIX offers the possibility to measure photons with different methods
  - e.m. calorimeters (focus of this talk)
  - Photon conversion method

PHENIX Electromagnetic Calorimeter



- **PbSc**
  - Highly segmented lead **scintillator** sampling Calorimeter
  - Module size: 5.5 cm x 5.5 cm x 37 cm
- **PbGl**
  - Highly segmented lead glass **Cherenkov** Calorimeter
  - Module size: 4 cm x 4 cm x 40 cm
- Differences
  - Different response to hadrons
  - Different corrections to get linear energy response
  - Different shower overlap corrections

See Christian Klein-Bösing's poster for further details

⇒ **Measurement of the same quantities (photons, π^0's) with different systematics**

Direct Photon Search

- Measure inclusive photon p_T -spectrum

  (hadron decay γ + direct γ)

  - Identify photon-like showers based on
    - Shower shape
    - Time of flight
  - Correct for remaining background of
    - Charged hits
    - Neutron and anti-neutron hits
    - Non-vertex particles
  - Apply photon reconstruction efficiency correction

- Measure π^0 p_T -spectrum

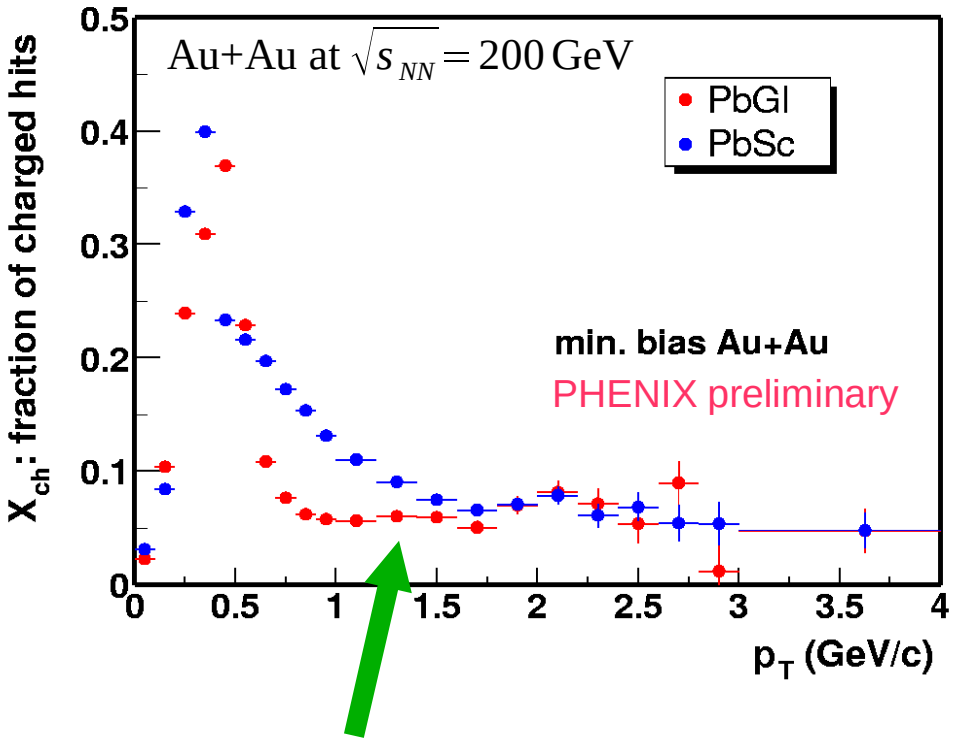
- Use fit to π^0 p_T -spectrum as input for decay photon simulation

- Compare measured photons with expected photons from hadron decays

$$R_\gamma := \frac{N_\gamma^{incl} / N_{\pi^0}^{meas}}{N_\gamma^{decay,sim} / N_{\pi^0}^{fit}}$$

See poster by Justin Frantz for an alternative method to search for direct photons

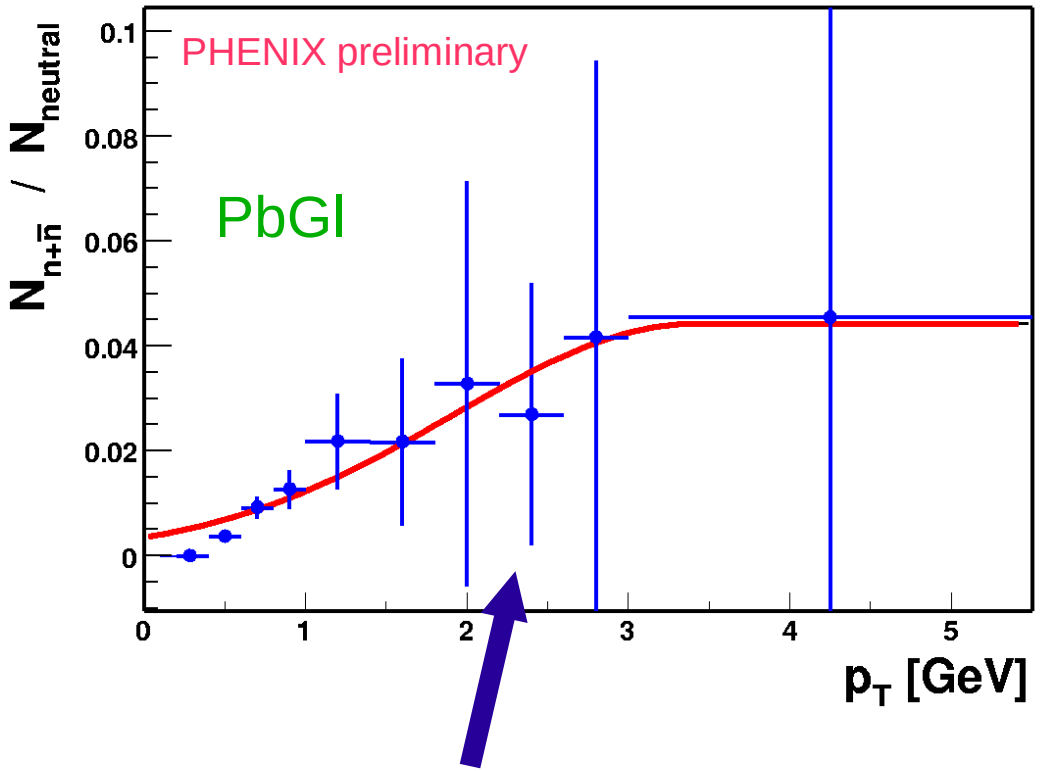
Charged Particle Background



Result after photon identification cuts
(time-of-flight and shower shape cut)

- X_{ch}: ratio of charged to all EmCal hits
- Identified tracks used to veto charged EmCal hits
- random vetos corrected by event mixing
- Charged background < 10% above $p_T \approx 1.5$ GeV

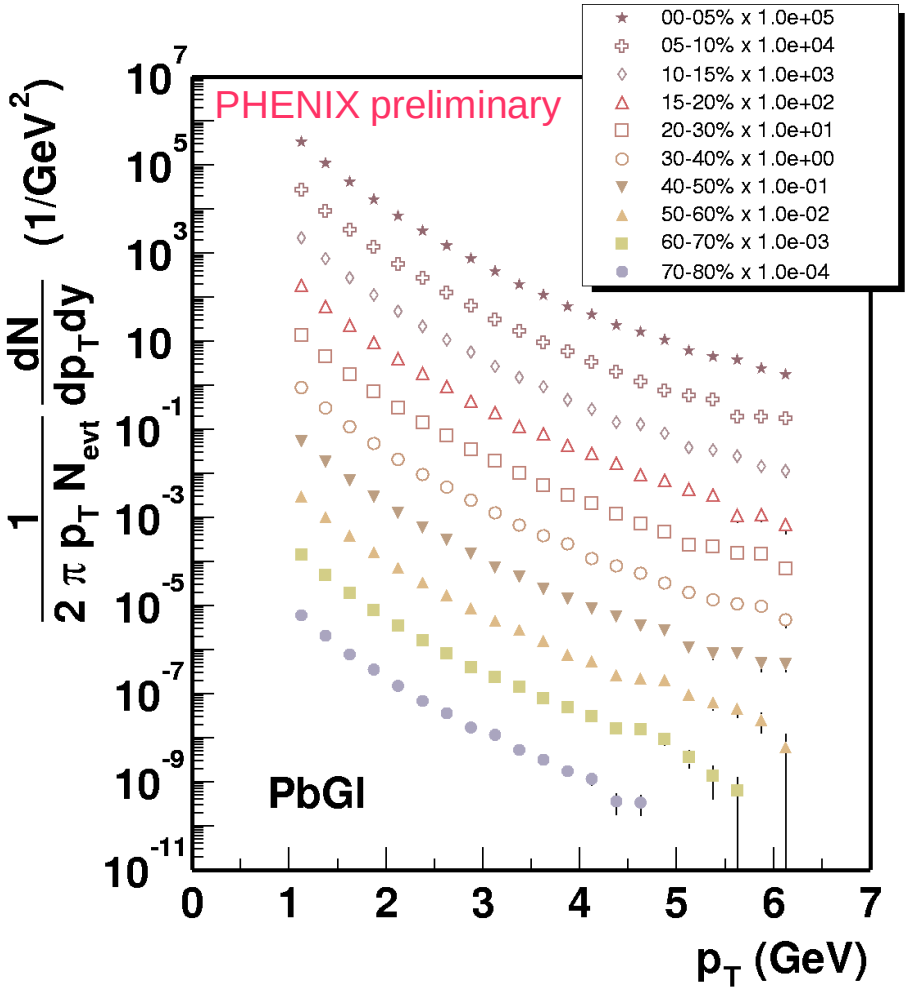
Background from Neutrons and Anti-Neutrons

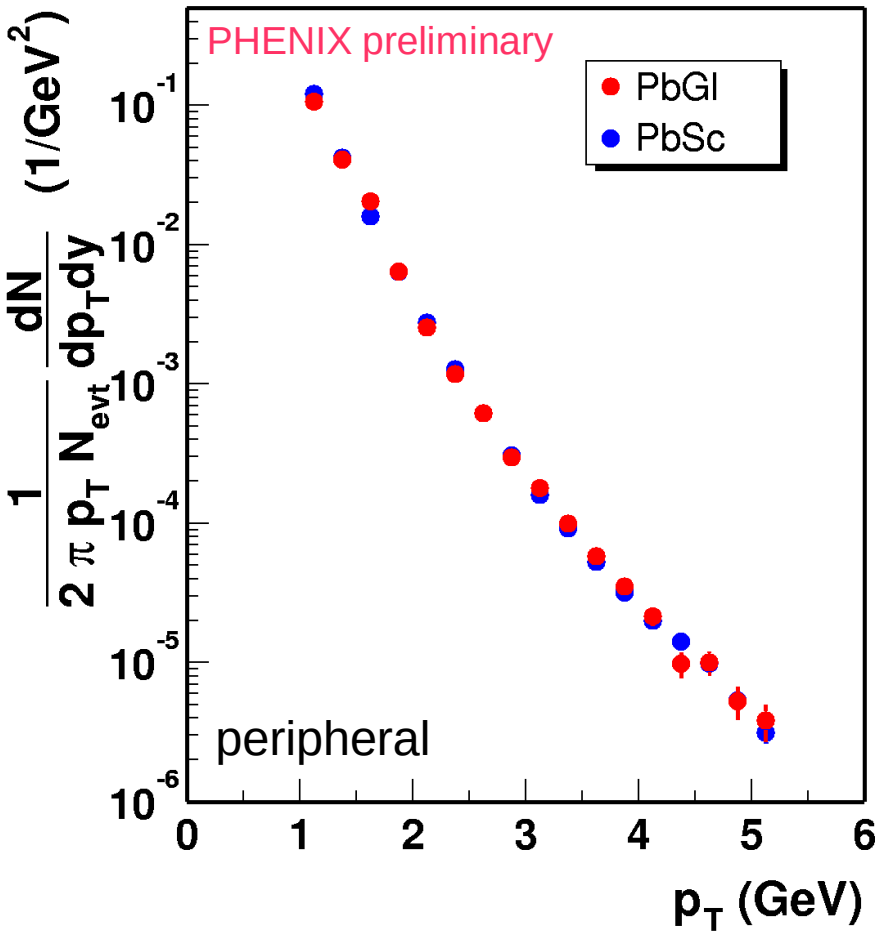


PbGl hadron response hard to parameterize: time consuming simulation with full tracking of Cherenkov photons necessary

- Can only be determined from simulation
- Input n and $\bar{n}$ spectrum estimated based on measured p and $\bar{p}$ spectrum
- Neutron, anti-neutron background to all neutral EmCal hits < 6%

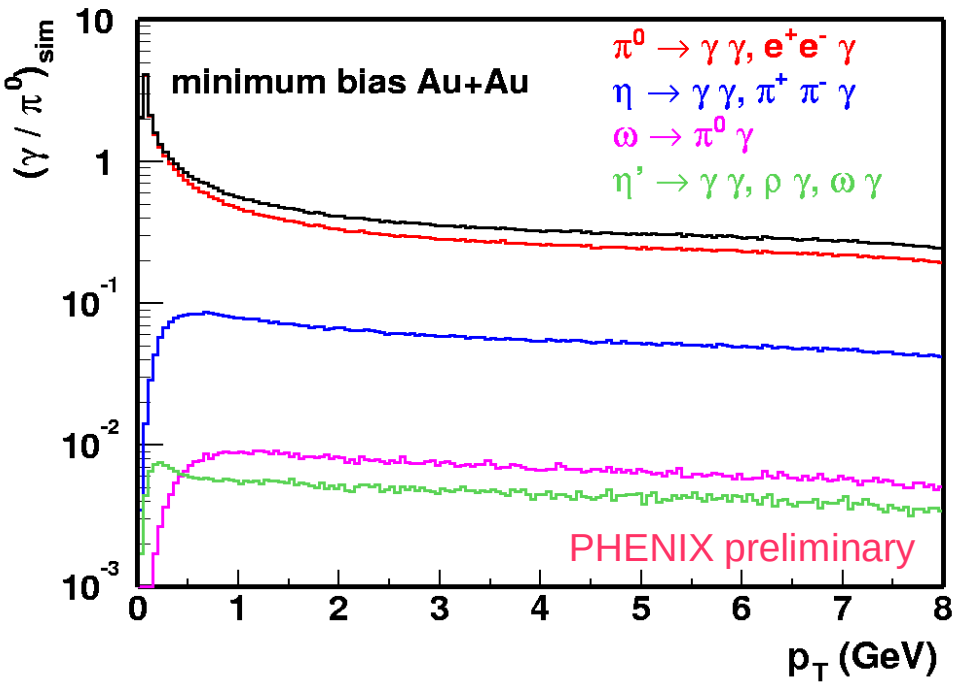
Inclusive Photon Spectra for Different Centralities at $\sqrt{s_{NN}}$ = 200 GeV





Error bars reflect only statistical errors

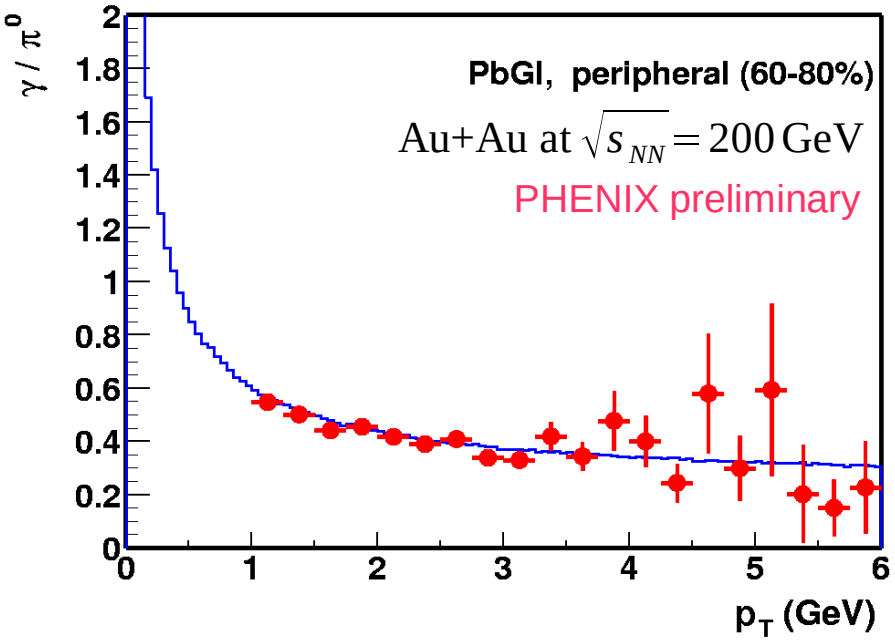
Background Photon Simulation

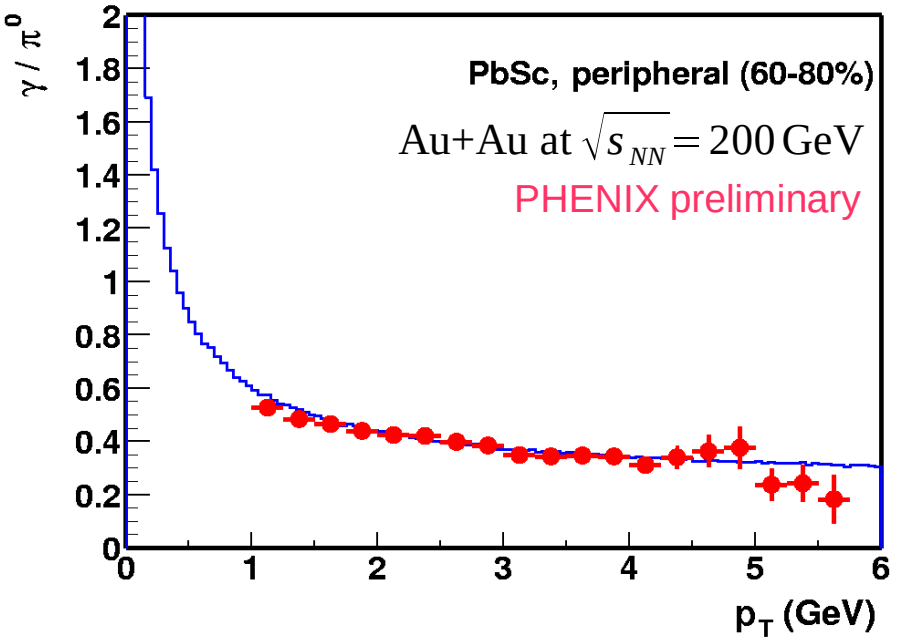


- Input: Parameterization of measured π^0 -spectrum
- Assume m_T-scaling for η and other hadrons with photon decay branches
- η-spectrum not (yet) measured,taking η/π^0-literature value:

$$(dN_\eta/dm_T)/(dN_{\pi^0}/dm_T) = 0.55$$

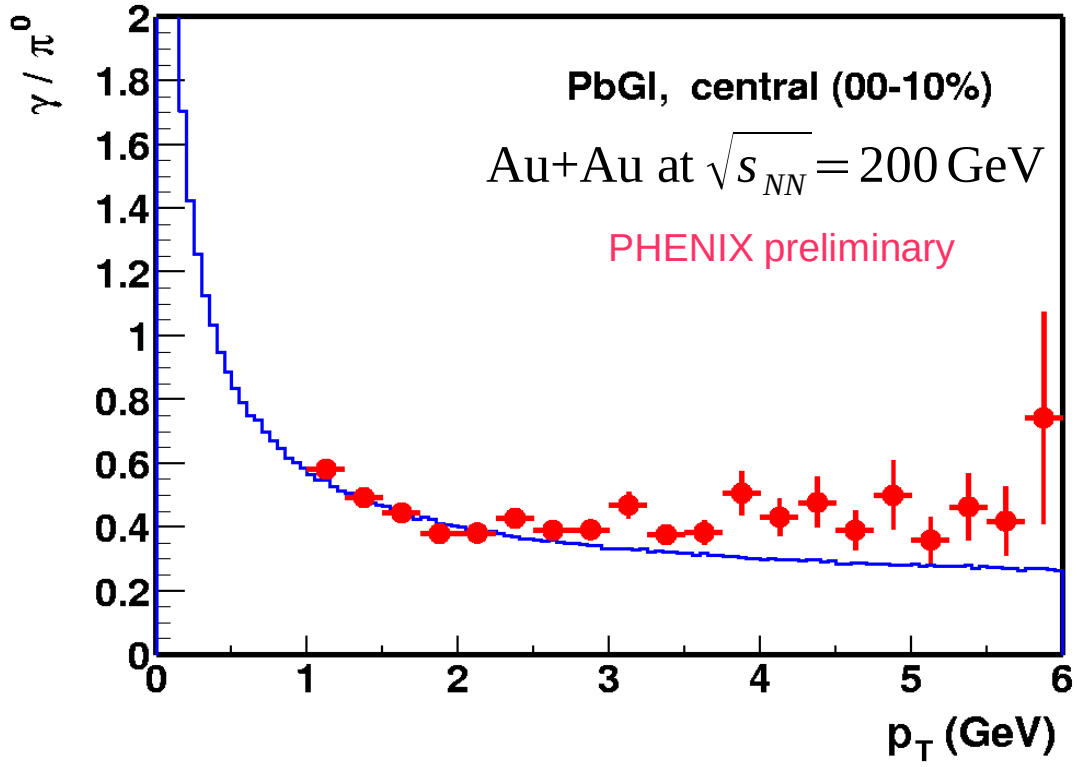
Measured and Simulated γ/π^0 ratio: Peripheral Events





Warning: Error bars reflect only statistical errors

Measured and Simulated γ/π^0 ratio: Central Events



Warning: Error bars reflect only statistical errors

⇒ **Thorough evaluation of systematic errors is of paramount importance for direct photon search ...**

Current Estimate of Systematic Errors

	pT = 1 GeV	pT= 3 GeV
photon yield: charged particle background	2,7%	4,1%
photon yield: gamma conversion	2,1%	2,1%
photon yield: neutron background	3,5%	4,3%
photon yield: efficiency	14,0%	15,0%
Neutral pion yield: gamma conversion	2,1%	2,1%
Neutral pion yield: yield extraction sys. error	10,0%	10,0%
Neutral pion yield: efficiency	16,0%	18,0%
non-vertex background	2,8%	2,8%
energy scale calibration	3,0%	6,0%
acceptance	1,0%	1,0%
eta/pi0 ratio, mT-scaling	4,0%	4,0%
other radiative decays	1,0%	1,0%
Neutral pion spectrum fit	5,0%	5,0%
quadratic sum	25,3%	27,9%

Systematic error is quoted for

$$R_\gamma := \frac{N_\gamma^{incl} / N_{\pi^0}^{meas}}{N_\gamma^{decay,sim} / N_{\pi^0}^{fit}}$$

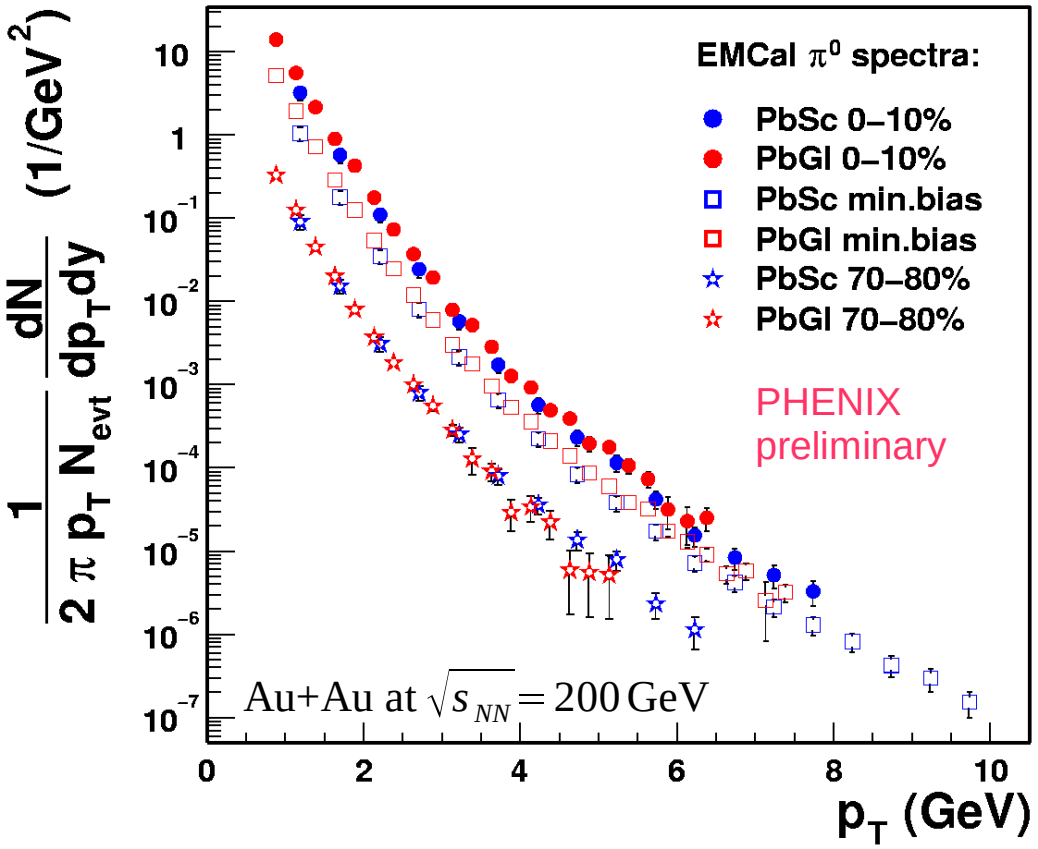
γ and π^0 reconstruction efficiencies are currently the biggest uncertainties

Same total systematic error on π^0 yields as in an independent analysis:
see David d'Enterria's talk on neutral pions

See Gabor David's poster for further details on systematic error evaluation

$\Rightarrow$ Hope to significantly reduce uncertainties in the future with refined efficiency calculation methods

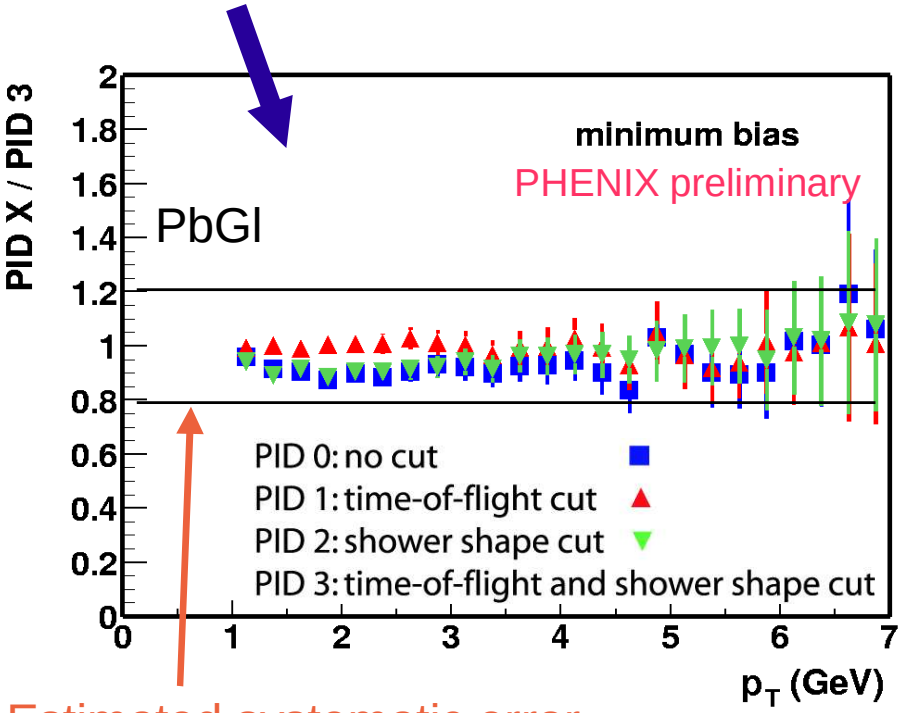
Are the Systematic Errors Reasonable? (I)



- Neutral pion spectra from PbGl and PbSc available, analyzed independently by two different teams
- Results agree within the quoted systematic errors

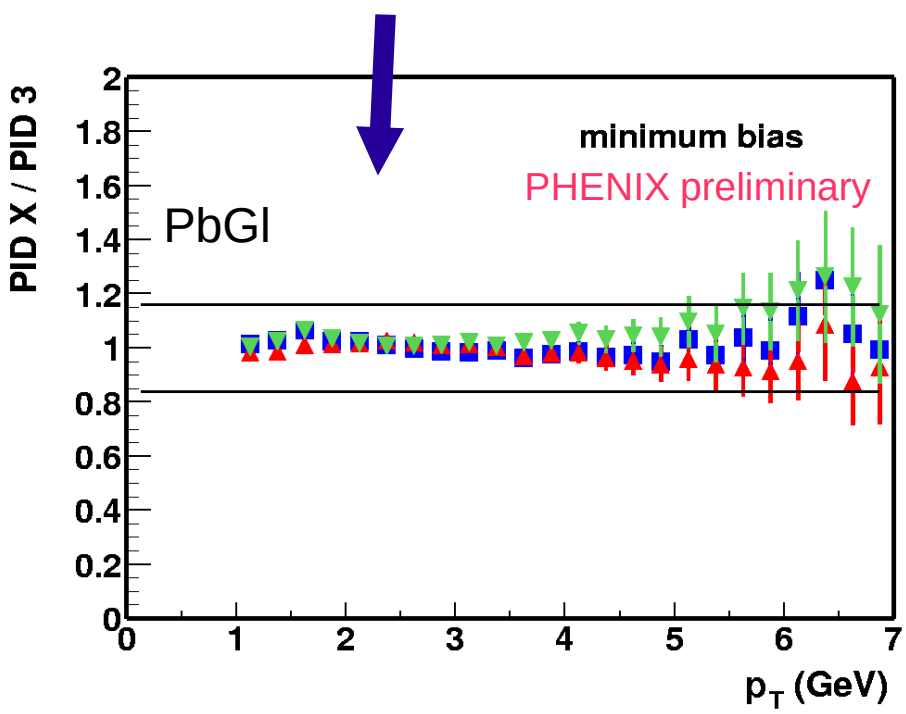
Are the Systematic Errors Reasonable? (II)

Ratio of π^0 spectra for different photon identification cuts



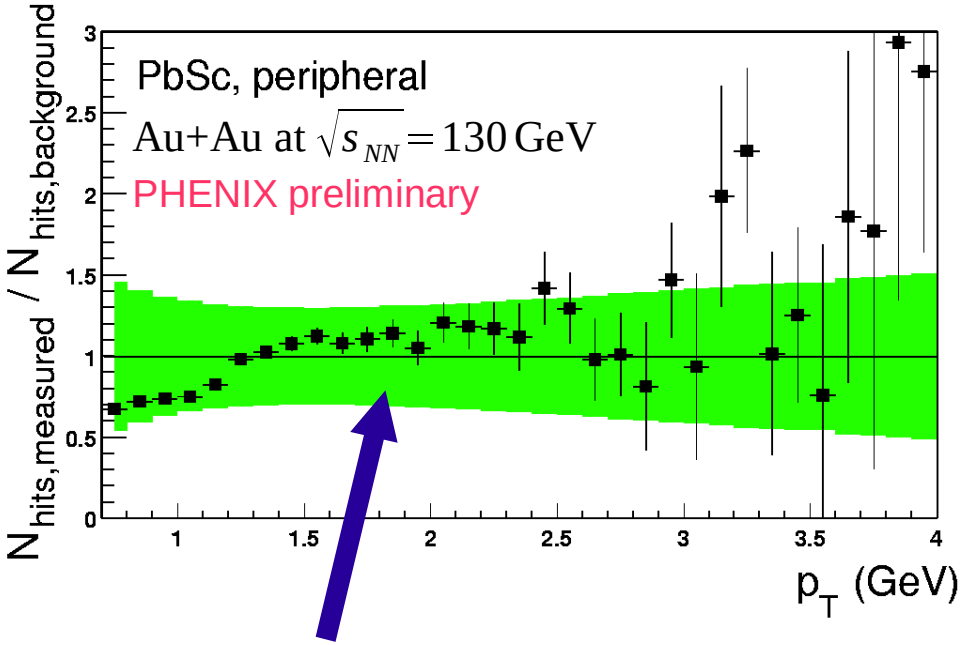
Estimated systematic error

Ratio of photon spectra for different photon identification cuts

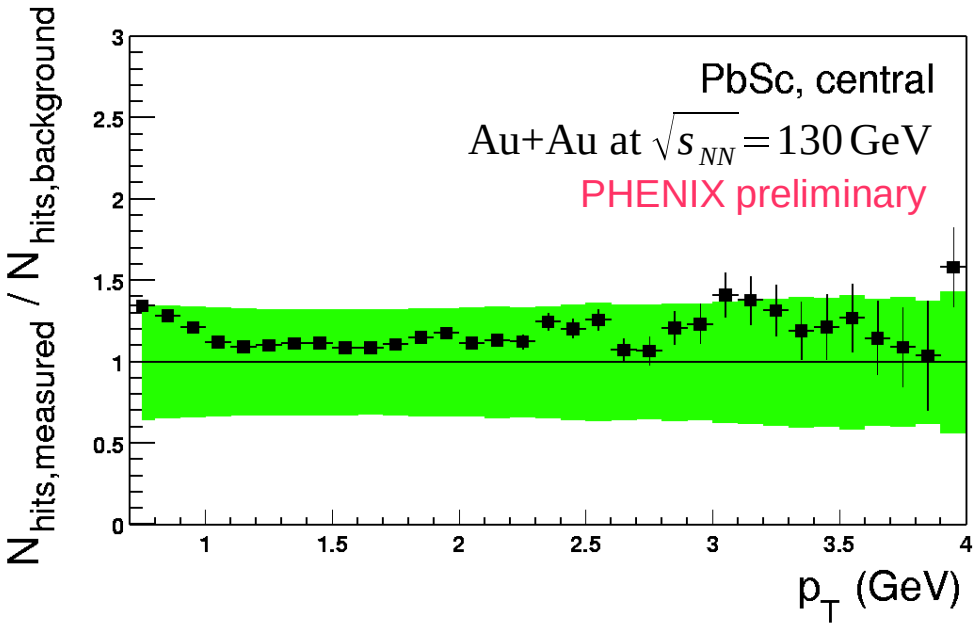


$\Rightarrow$ Spectra determined with different systematics agree within errors

Results for Au+Au at $\sqrt{s_{nn}}$ = 130 GeV

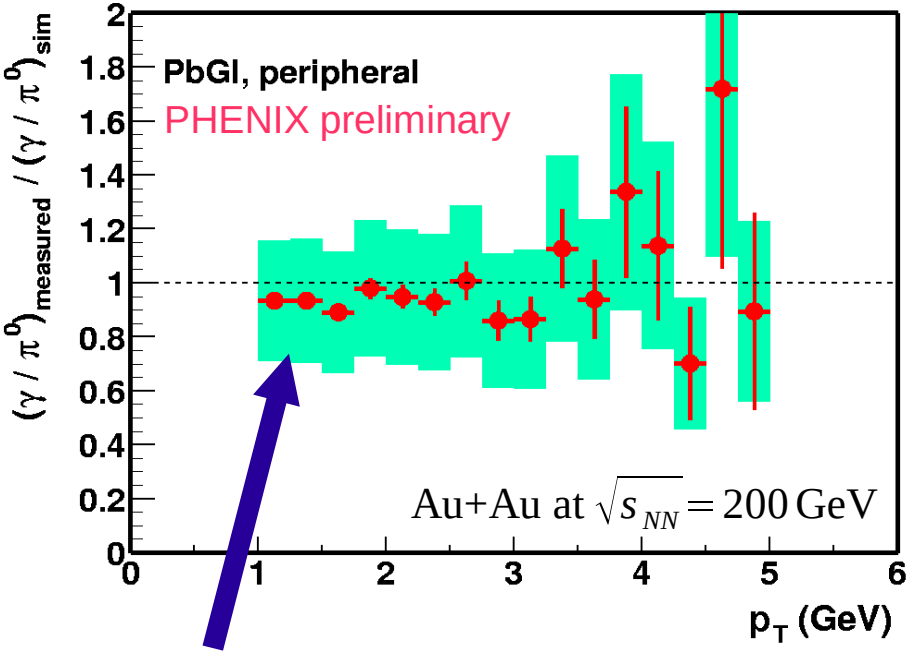


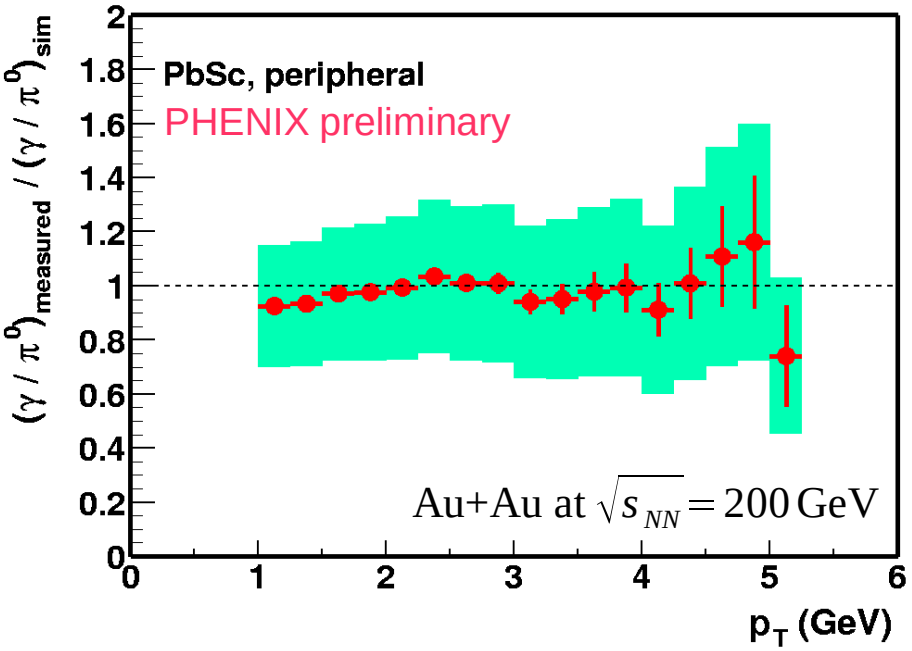
Band indicates systematic error



No photon excess seen within errrors

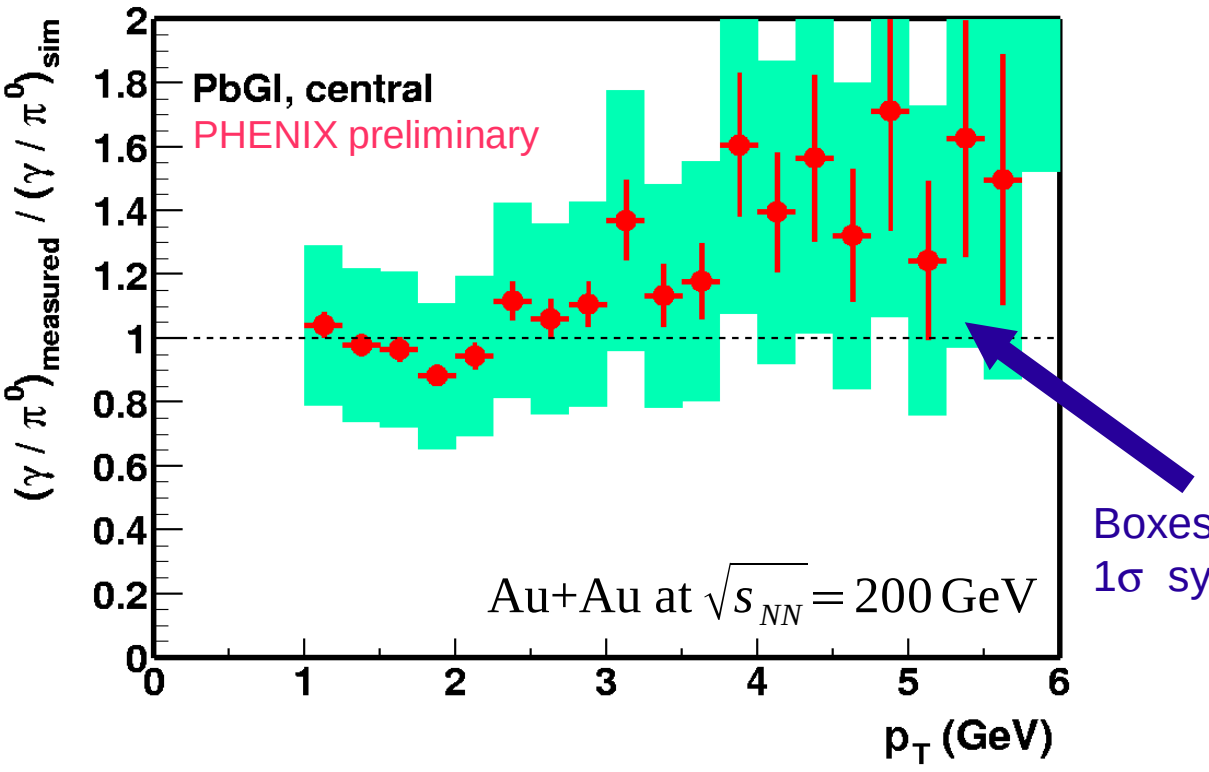
$(\gamma/\pi^0)_{measured}$ / $(\gamma/\pi^0)_{simulated}$: Peripheral





Boxes: 1σ systematic error

$(\gamma/\pi^0)_{measured}$ / $(\gamma/\pi^0)_{simulated}$: Central



Boxes:
1σ systematic errors

- No photon excess seen within errors
- Working on better understanding of systematics

Summary

- First try of direct photon measurement in Au+Au at RHIC
- No photon excess found within errors in central and peripheral Au+Au reactions at $\sqrt{s_{NN}}$ = 130 and 200 GeV
- There's legitimate hope to significantly reduces systematic uncertainties in the future