PHENIX photons and dileptons

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Preface

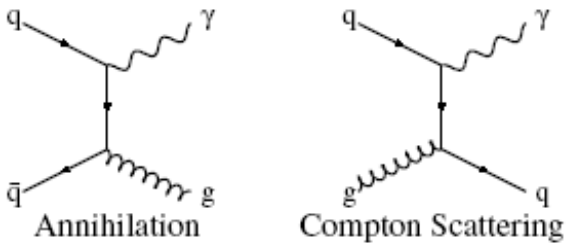
- Photons and dileptons we are going to talk about *may* or *may not* be hard probes

- We will discuss photons and dileptons that are *hard* to measure

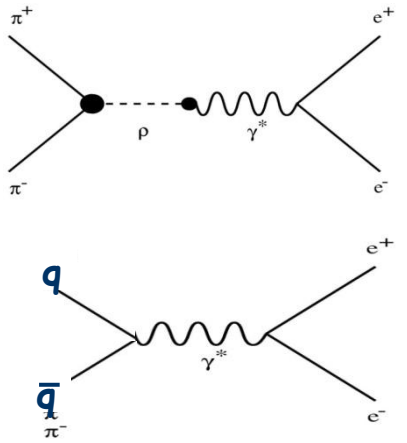
Photons and dileptons basics

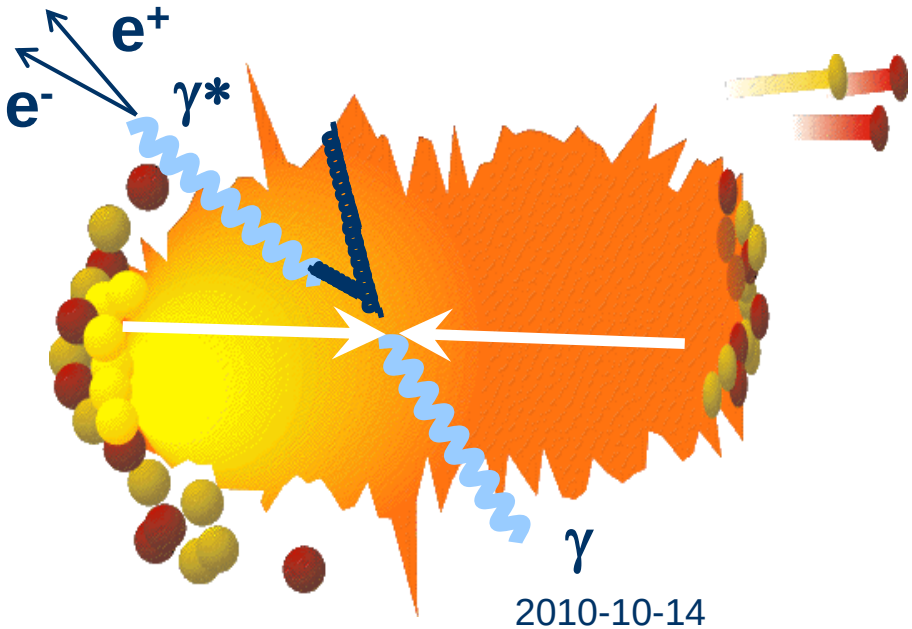
- Production Process
  - Compton and annihilation (LO, direct)
  - Fragmentation (NLO)
  - Escape the system unscathed
- Carry thermodynamical information of the early state
  - Temperature, Degrees of freedom

Photon Production: **Yield $\propto \alpha\alpha_s$**



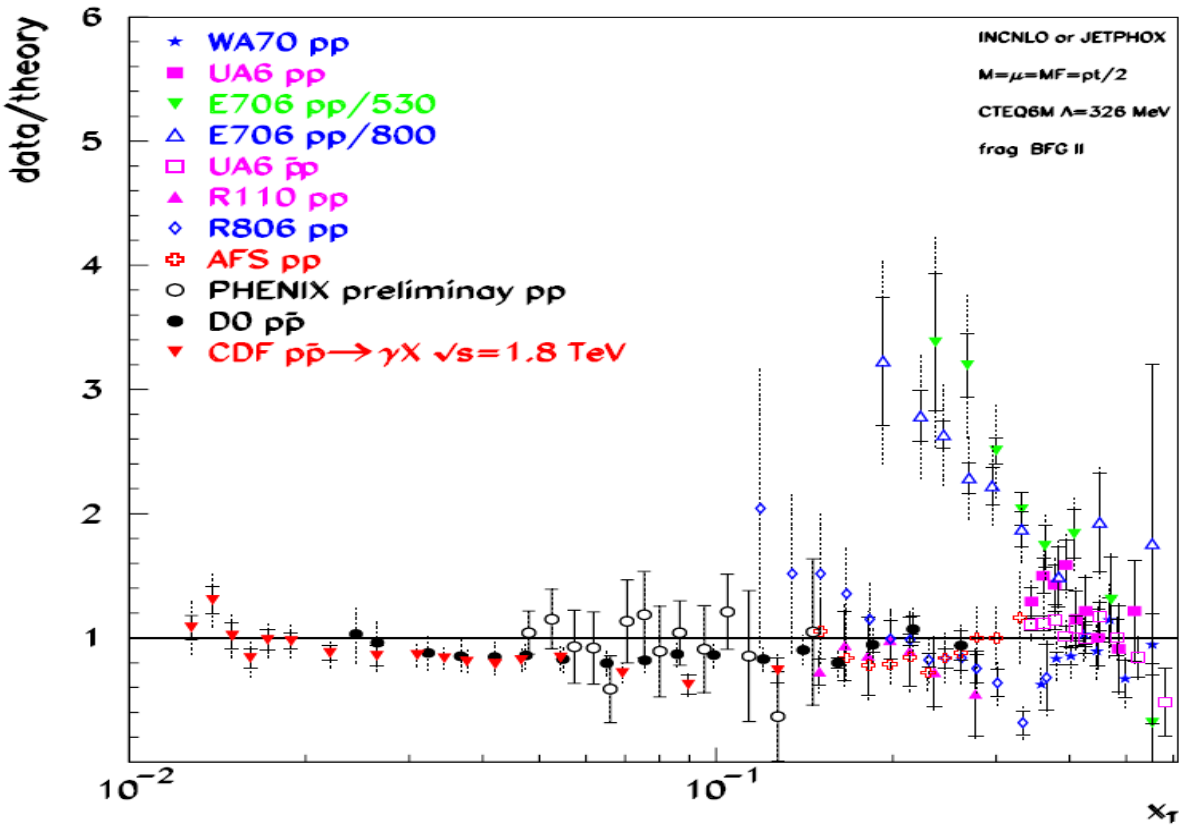
Dilepton Production: **Yield $\propto \alpha^2$**





High pT γ_{dir} in p+p – (p)QCD test

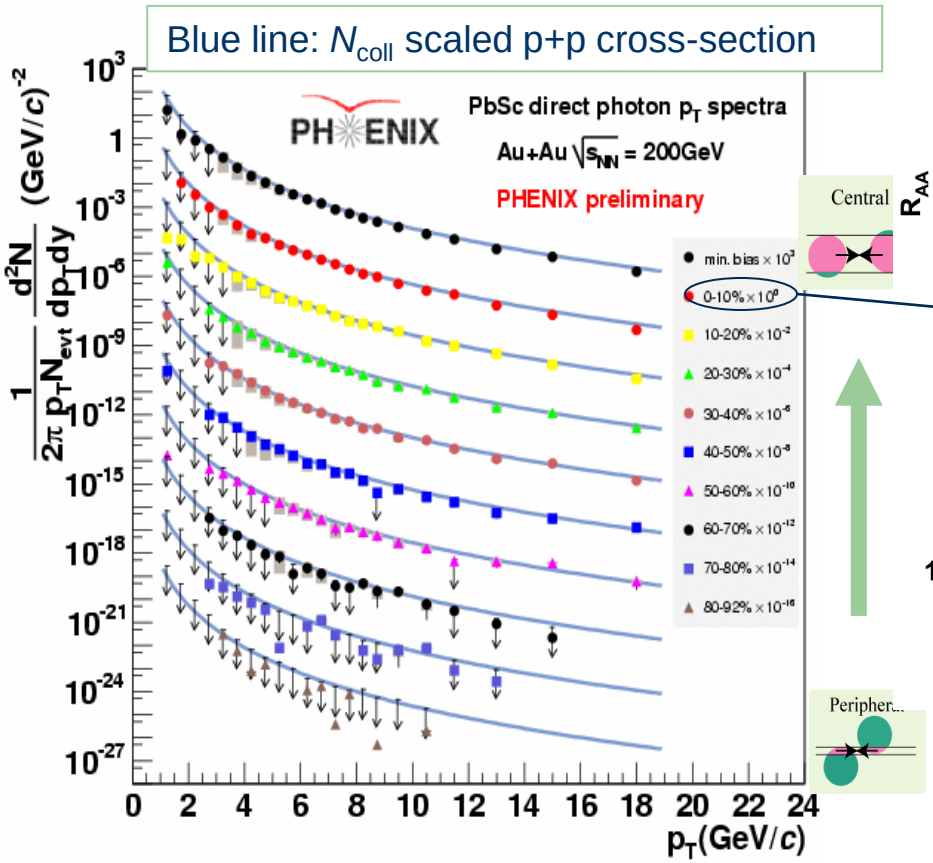
- NLO pQCD calculation of γ_{dir} yield is tested with p+p collisions
- The calculation works very well

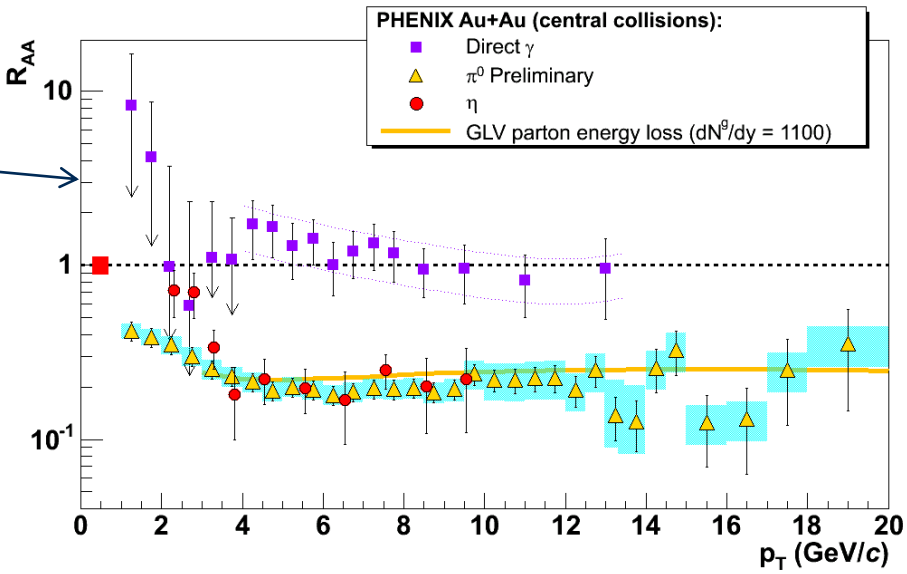


Aurenche et al., PRD73, 094007(2007)

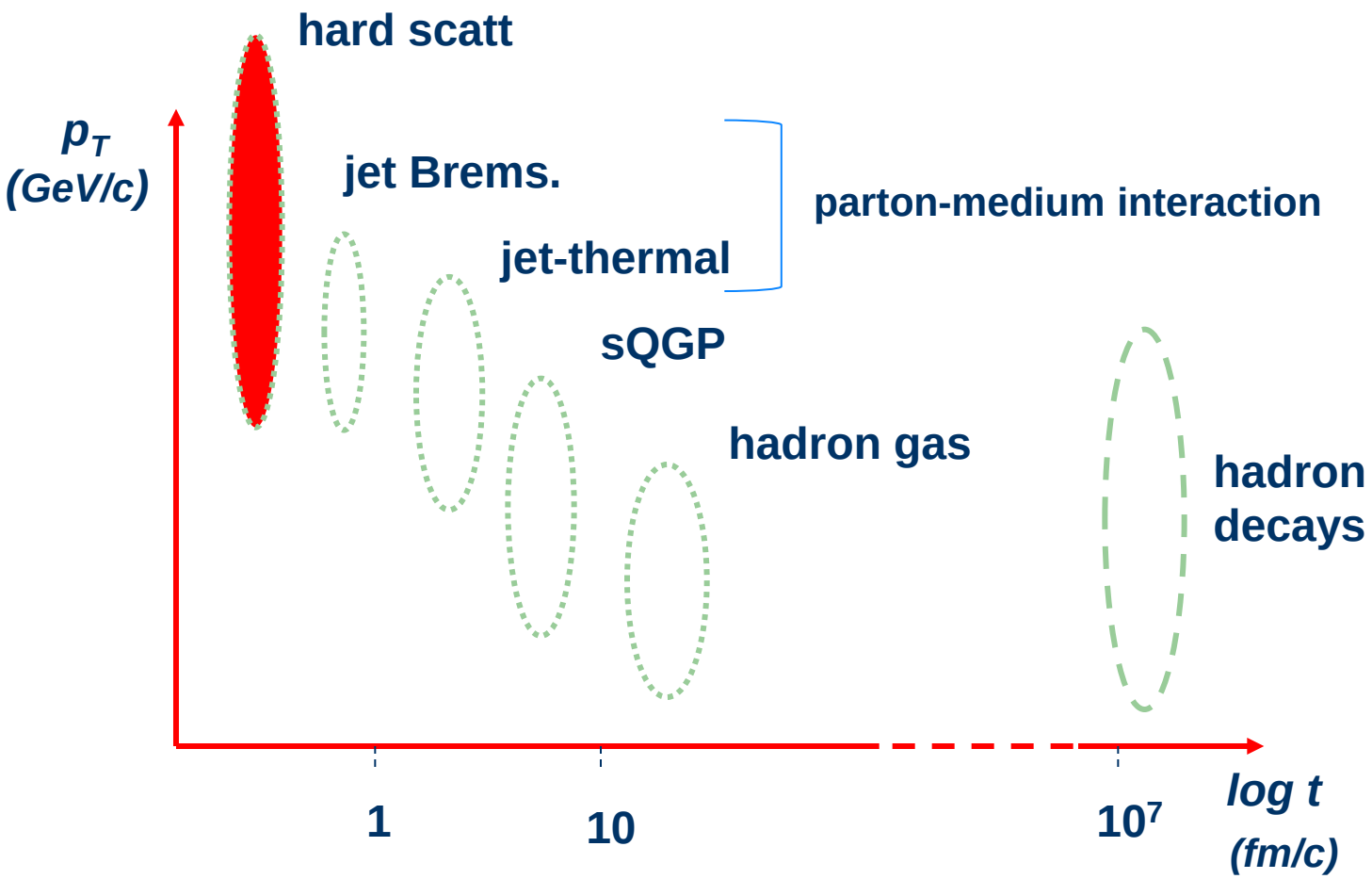
High pT γ_{dir} in Au+Au

- Au+Au = p+p x T_{AB} holds – pQCD factorization works
- NLO pQCD works. Non-pert. QCD may work in Au+Au system





Sources of electro-magnetic probes



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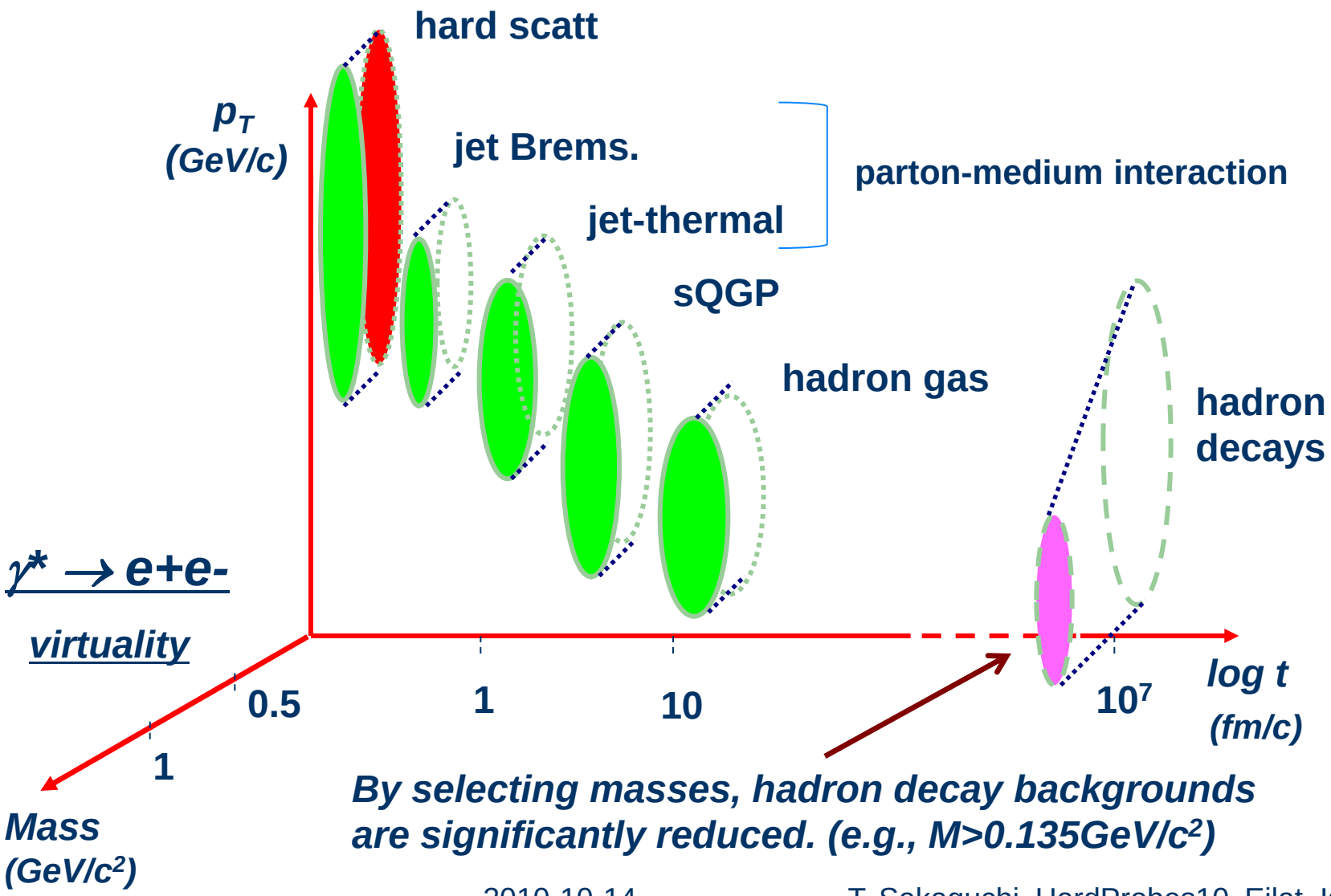
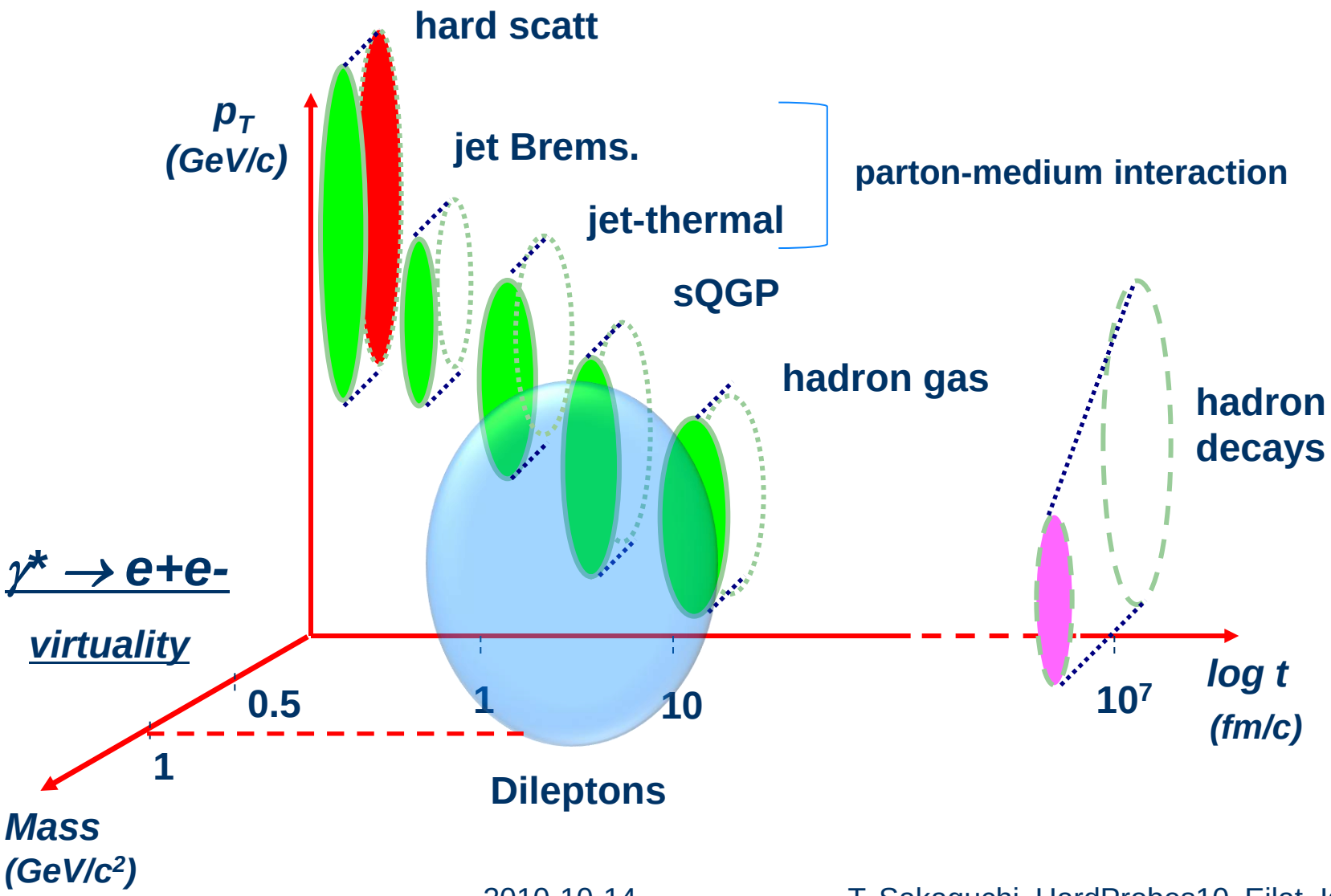


By selecting masses, hadron decay backgrounds are significantly reduced. (e.g., M>0.135GeV/c^2)

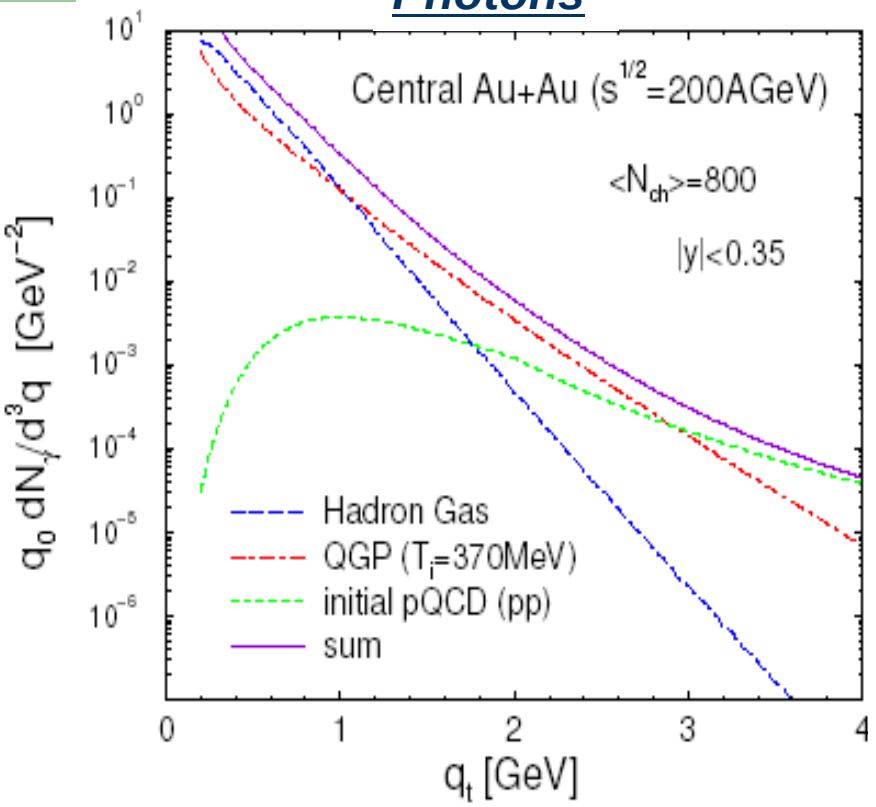
Sources of electro-magnetic probes



Theory prediction on dilepton/photons

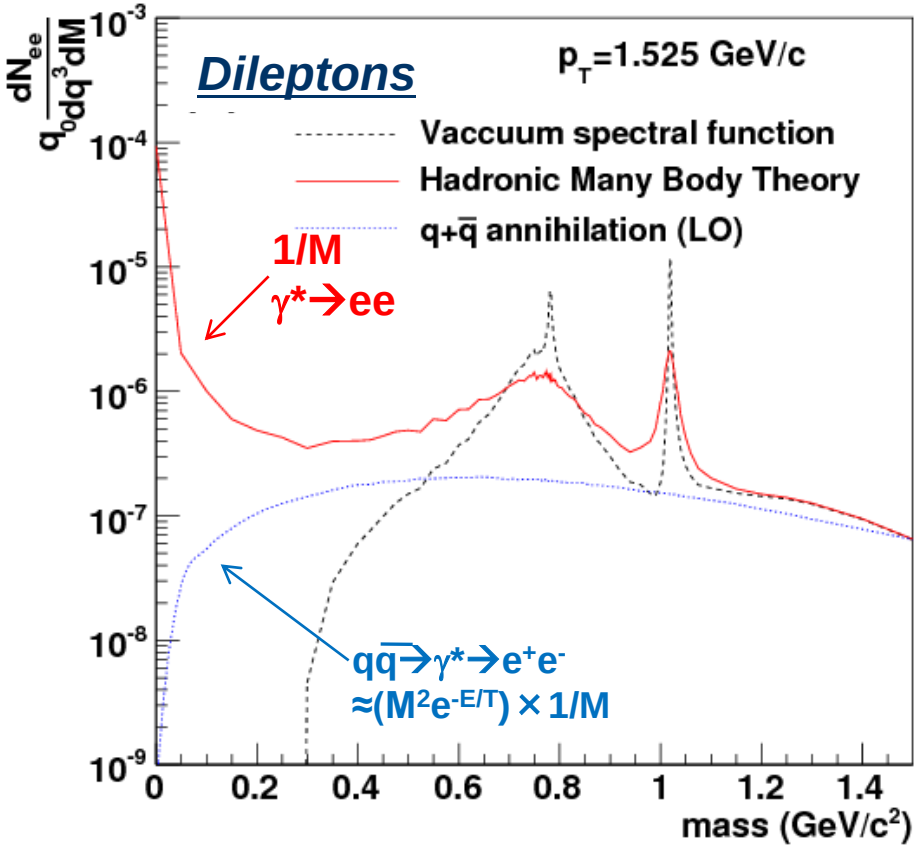
- Similar source are seen in both dileptons and photons
- Internal conversion of photons is not shown in dilepton calculation

Photons



PRC 69(2004)014903

Dileptons



Ralf Rapp, priv. comm.

Dilepton measurement in PHENIX

Designed to measure rare probes:

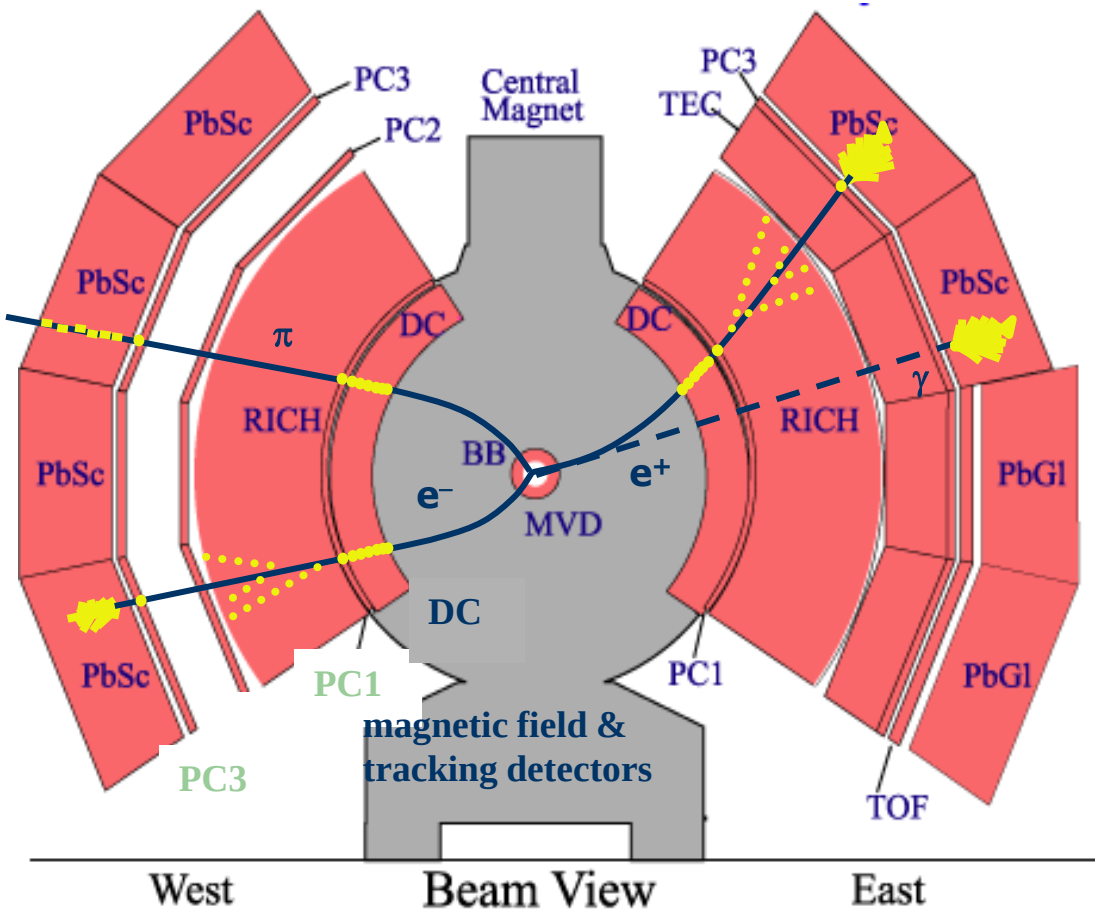
Au-Au & p-p spin

+ high rate capability & granularity
+ good mass resolution and particle ID
- limited acceptance

- 2 central arms:

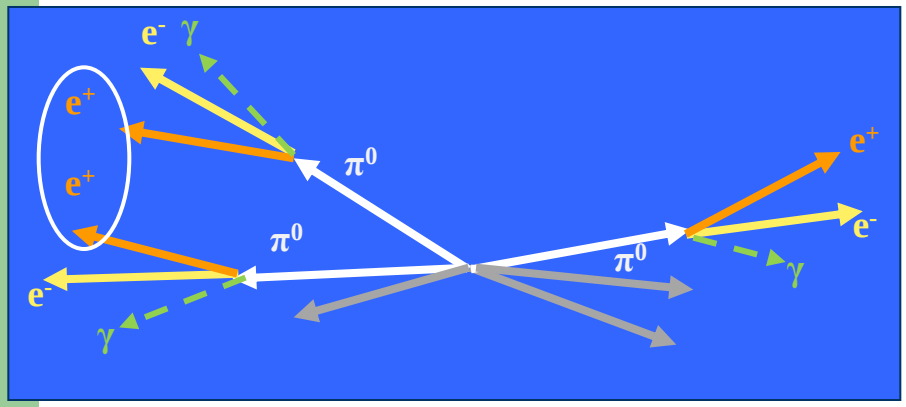
electrons, photons, hadrons

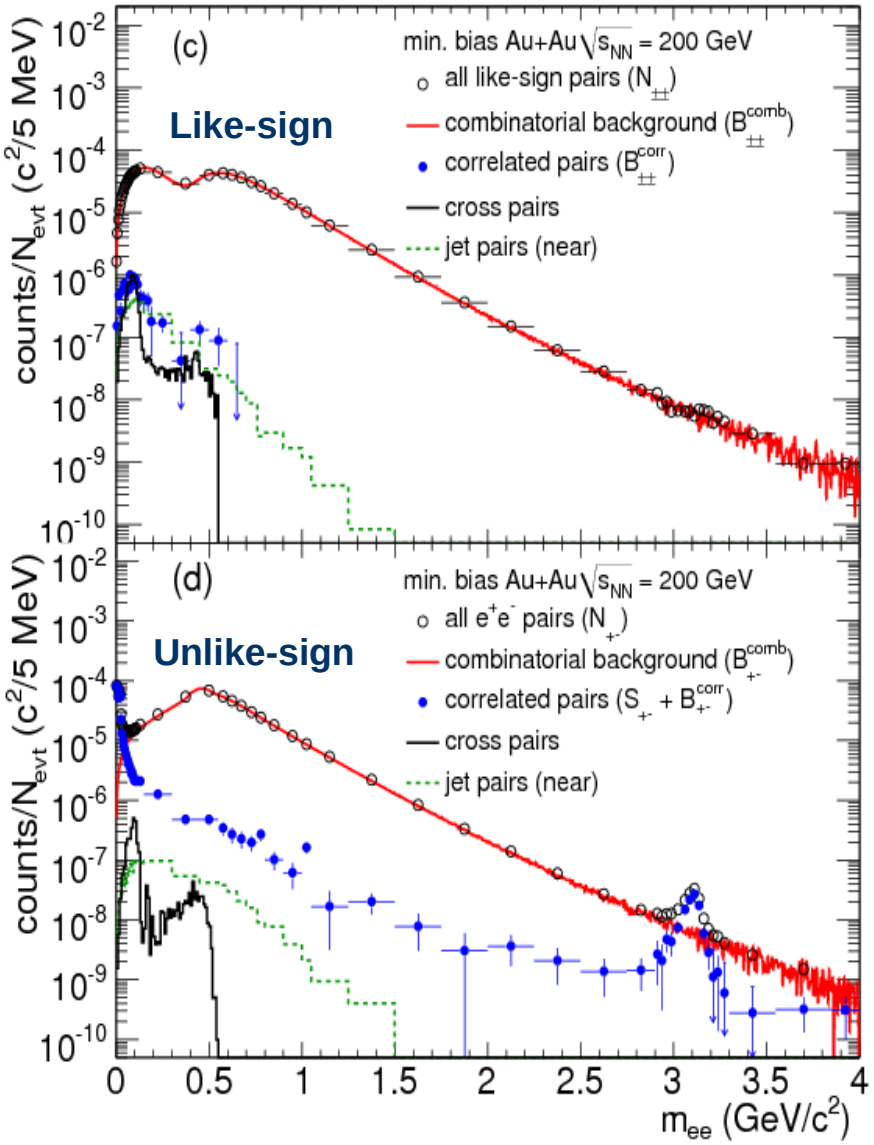
- charmonium J/ψ, ψ' -> e^+e^-
- vector meson r, w, ϕ -> e^+e^-
- high p_T p^o, p^+, p^-
- direct photons
- open charm
- hadron physics



Analysis

- Reconstruct Mass and pT of e+e-
  - Identify and reject conversion photons in beam pipe, using angular correlation of electron pairs
- Subtract combinatorial background
  - Background checked by like-sign dist.
- Apply efficiency correction
- Subtract additional correlated background:
  - Back-to-back jet contribution
  - Determine amount in like-sign dist, and apply to unlike-sign dist.
- Compare with known hadronic sources

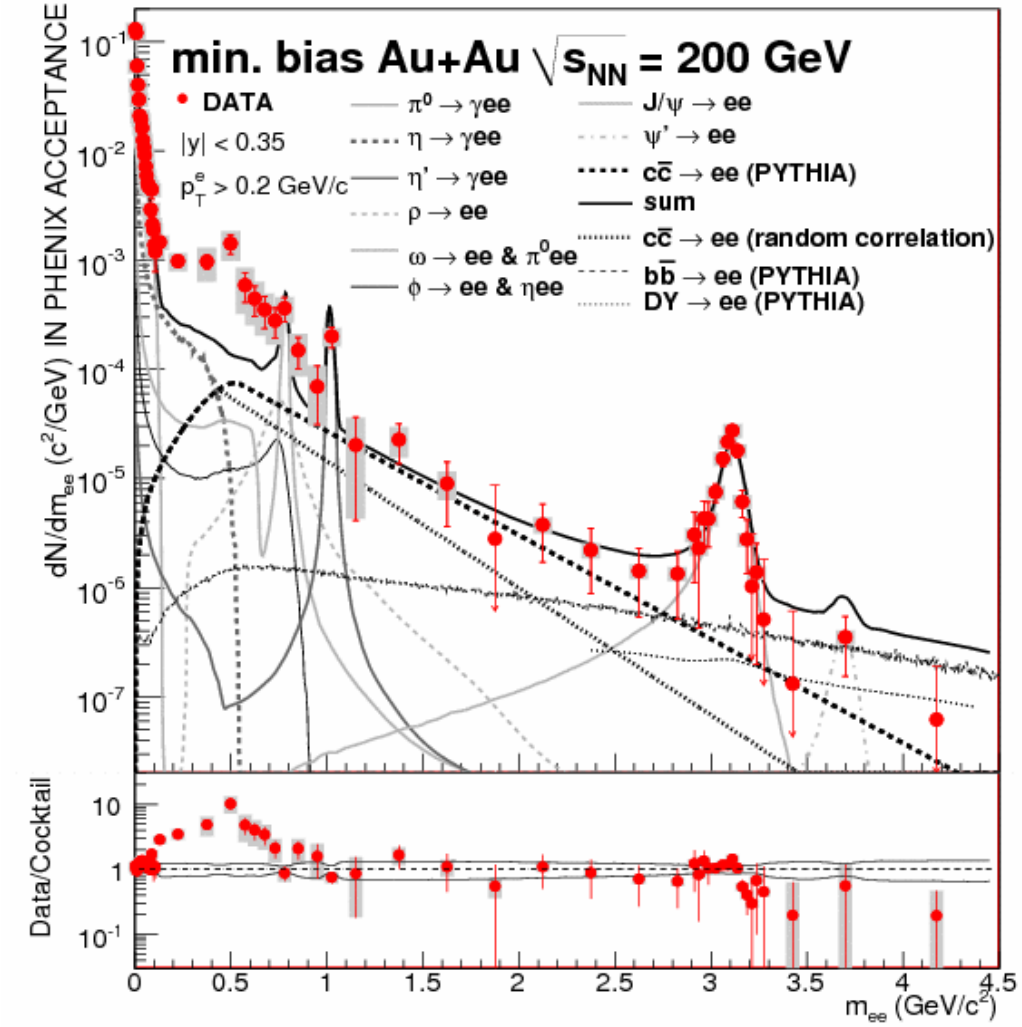




PRC**81**, 034911(2010), arXiv:0912.0244

Outcome from Au+Au collisions

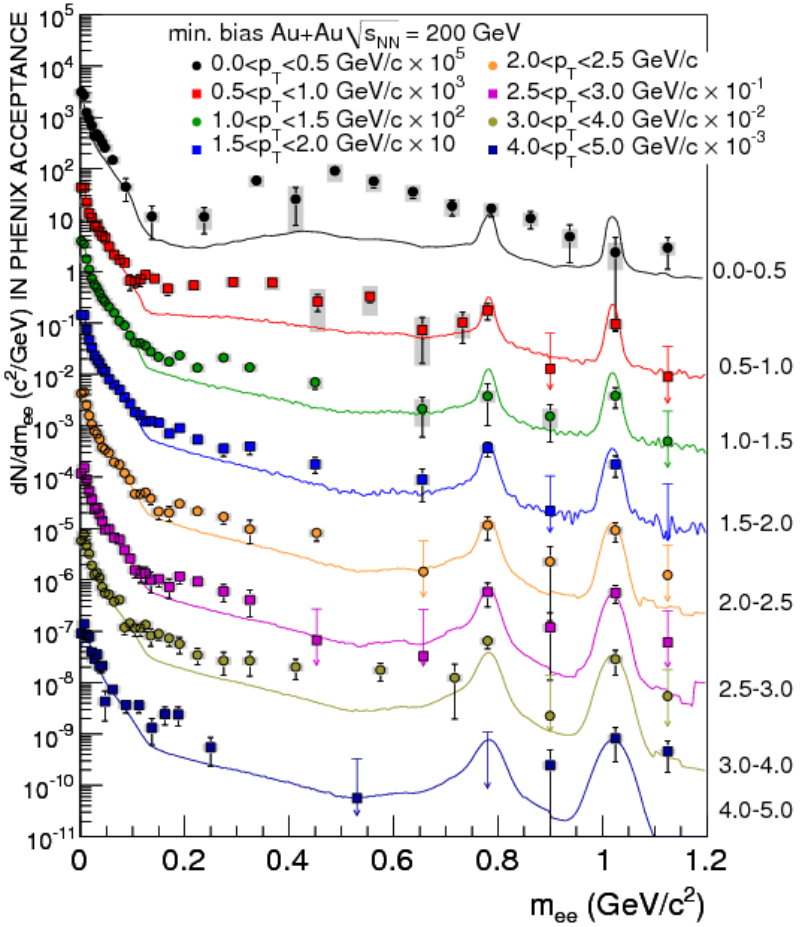
- Comparing with various sources of electron pairs
- Cocktail of the sources are calculated based on π^0/η spectra measured in PHENIX
- Huge excess over cocktail calculation is seen in 0.2-0.8GeV/c^2



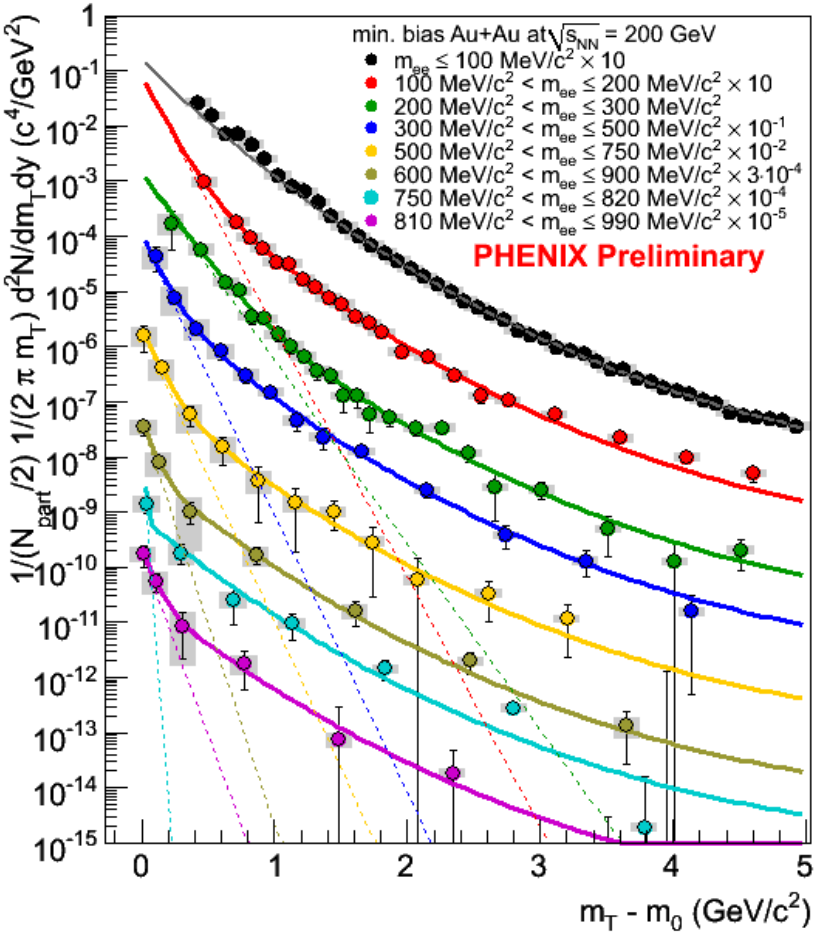
PRC**81**, 034911(2010), arXiv:0912.0244

Enough data to slice into various pT bins (Min Bias)

Mass dists. in various pT ranges



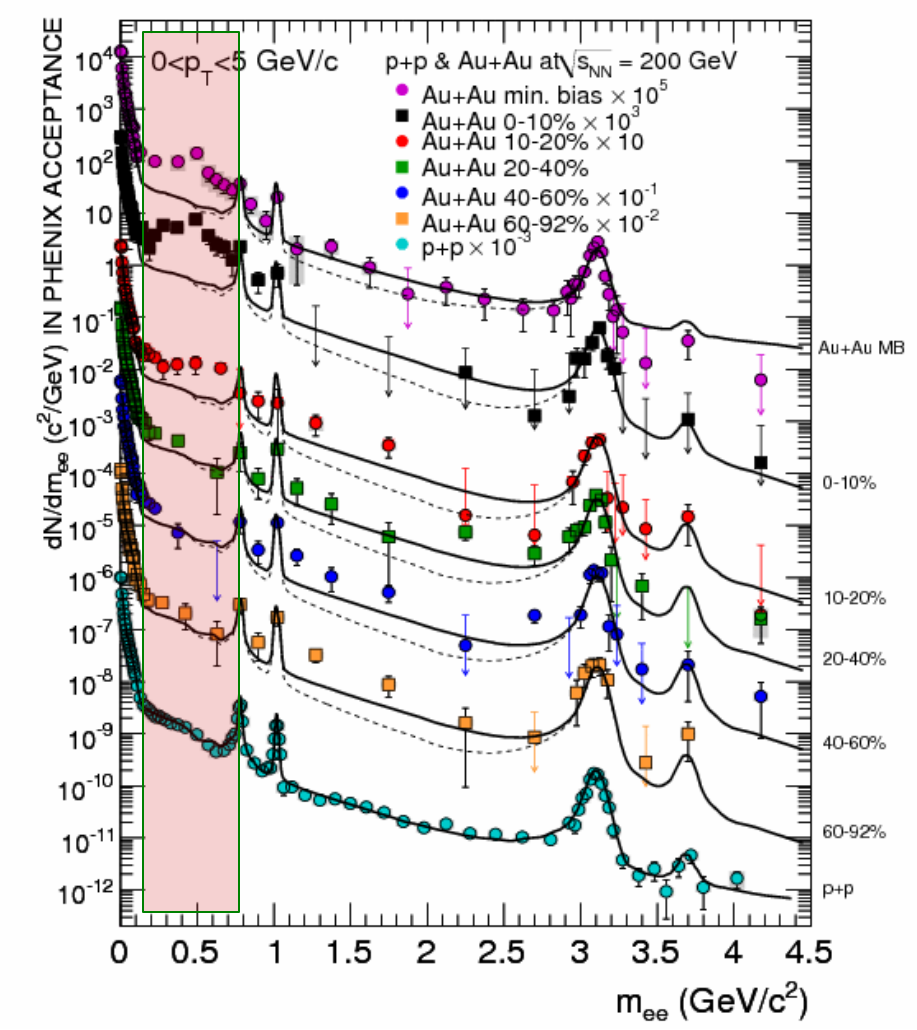
pT dists. in various mass ranges



PRC**81**, 034911(2010), arXiv:0912.0244

Into various centrality bins

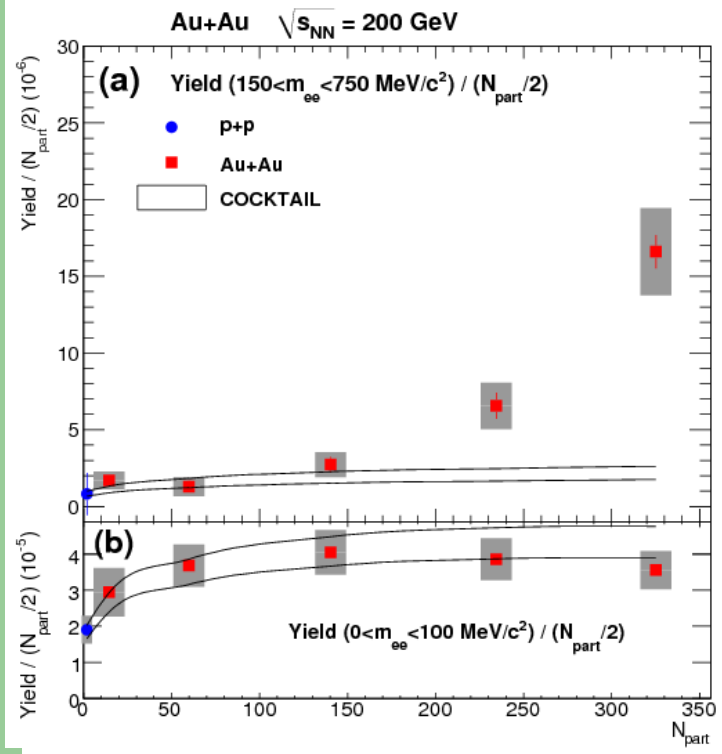
- Au+Au MB, Au+Au most central to peripheral, and p+p
- Excess decreased as we go to peripheral collisions

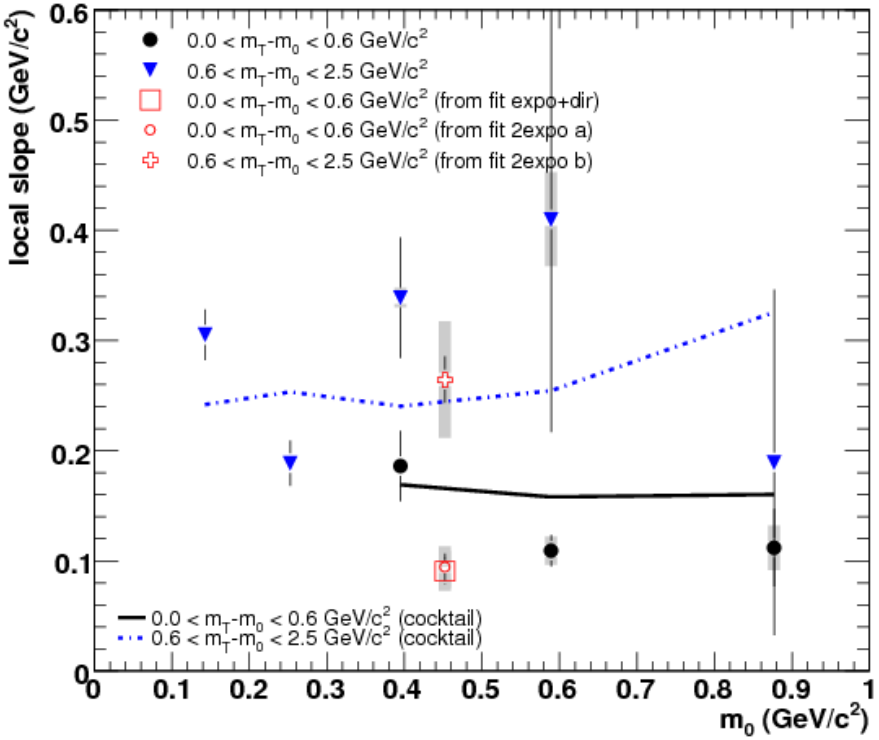


PRC**81**, 034911(2010), arXiv:0912.0244

Summary of low mass dilepton results

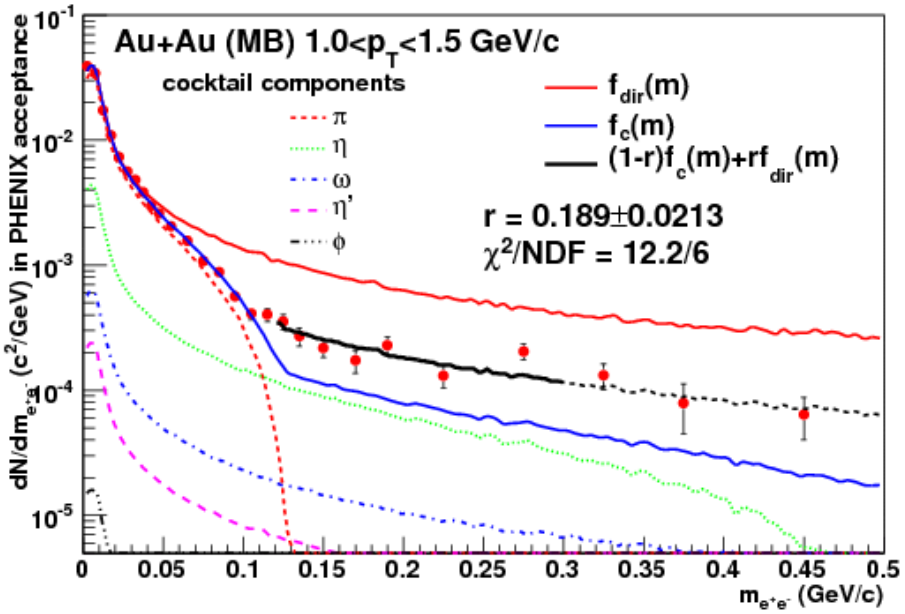
- Increase of the excess as a function of centrality is clearly seen
- Local slopes as a function of mass region
  - Truncated mean shown in solid
  - Slope is low for low m_T-m_0, high for high m_T-m_0





PRC**81**, 034911(2010), arXiv:0912.0244

Going to higher pT and lower mass

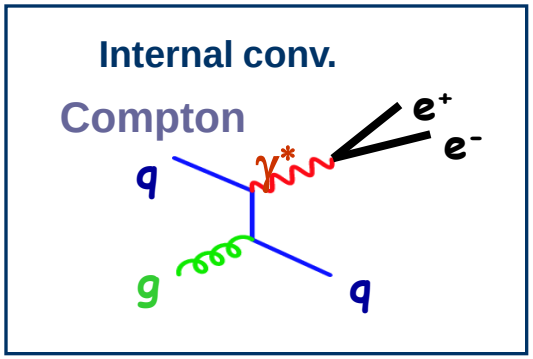


- Focus on the mass region where π^0 contribution dies out
- For $M \ll p_T$ and $M < 300\,MeV/c^2$
  - $q\bar{q} \rightarrow \gamma^*$ contribution is small
  - Mainly from internal conversion of photons
- Can be converted to real photon yield using Kroll-Wada formula
  - Known as the formula for Dalitz decay spectra

One parameter fit: $(1-r)f_c + r\,f_d$
f_c: cocktail calc., f_d: direct photon calc.

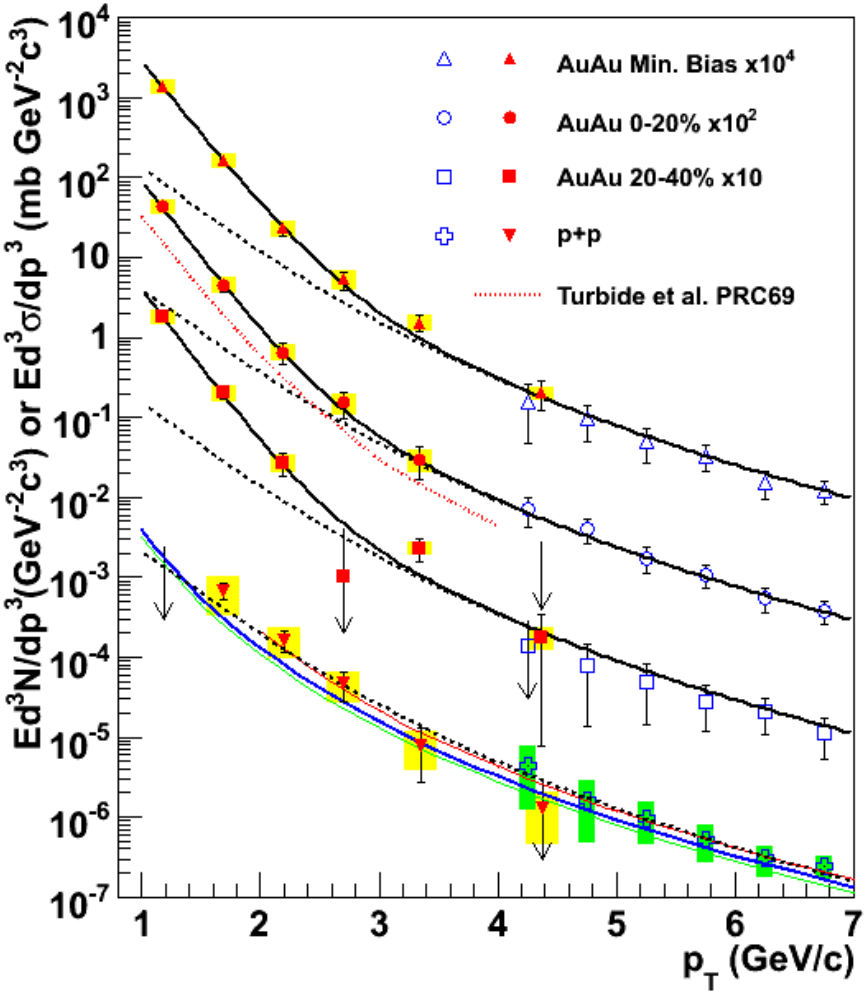
$$\frac{1}{N_\gamma}\frac{dN_{ee}}{dm_{ee}} = \frac{2\alpha}{3\pi}\sqrt{1-\frac{4m_e^2}{m_{ee}^2}}\left(1+\frac{2m_e^2}{m_{ee}^2}\right)\frac{1}{m_{ee}}\left|F(m_{ee}^2)\right|^2\left(1-\frac{m_{ee}^2}{M^2}\right)^3$$

$$r = \frac{\gamma^*_{dir}(m>0.15)}{\gamma^*_{inc}(m>0.15)} \propto \frac{\gamma^*_{dir}(m\approx 0)}{\gamma^*_{inc}(m\approx 0)} = \frac{\gamma_{dir}}{\gamma_{inc}}$$



PRL**104**,132301(2010), arXiv:0804.4168

Direct photons through dileptons

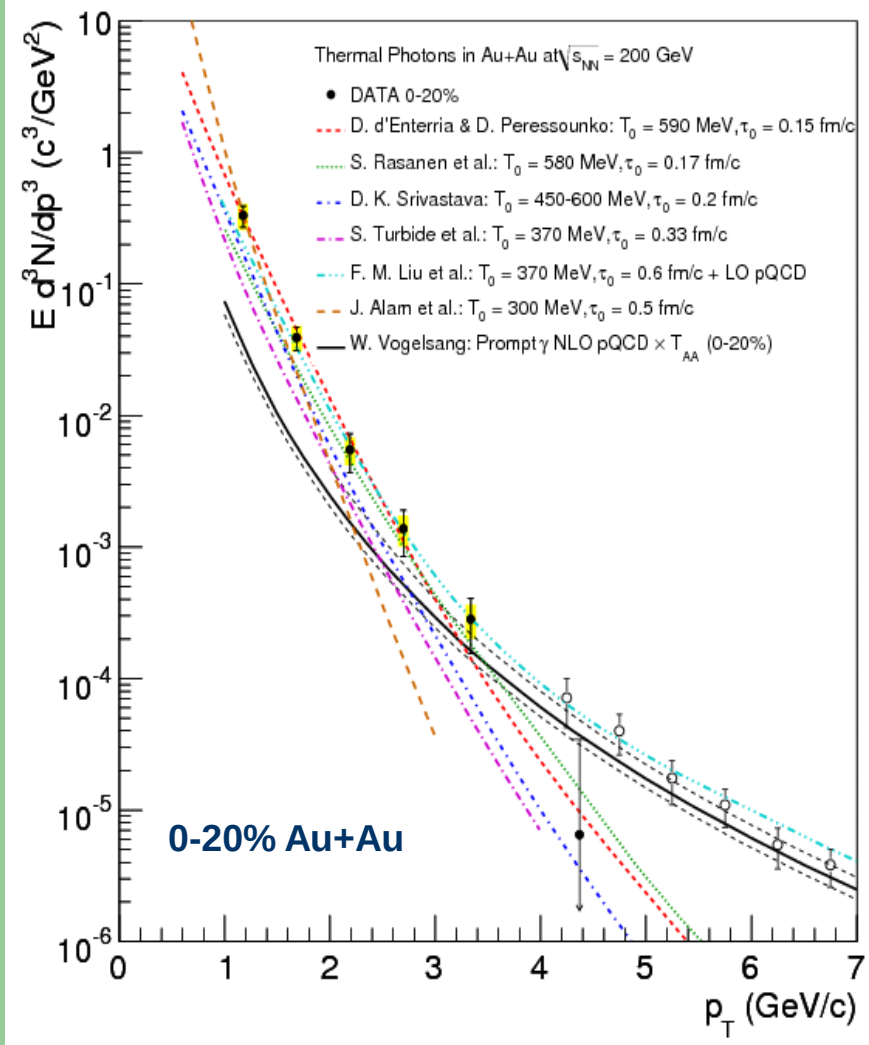


- Inclusive photon × $\gamma_{dir}/\gamma_{inc}$
- Fitted the spectra with p+p fit + exponential function
- Barely dependent of centrality

Cent	dN/dy (pT>1GeV)	Slope (MeV)	χ^2/DOF
0-20%	1.50±0.23 ±0.35	221±19 ±19	4.7/4
20-40%	0.65±0.08 ±0.15	217±18 ±16	5.0/3
MinBias	0.49±0.05 ±0.11	233±14 ±19	3.2/4

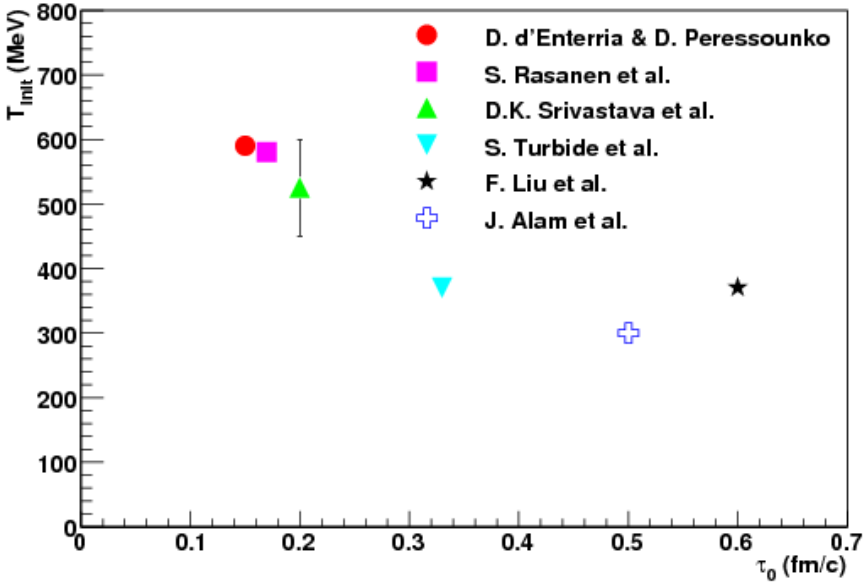
PRL**104**,132301(2010), arXiv:0804.4168

Calculations reasonably agree with data



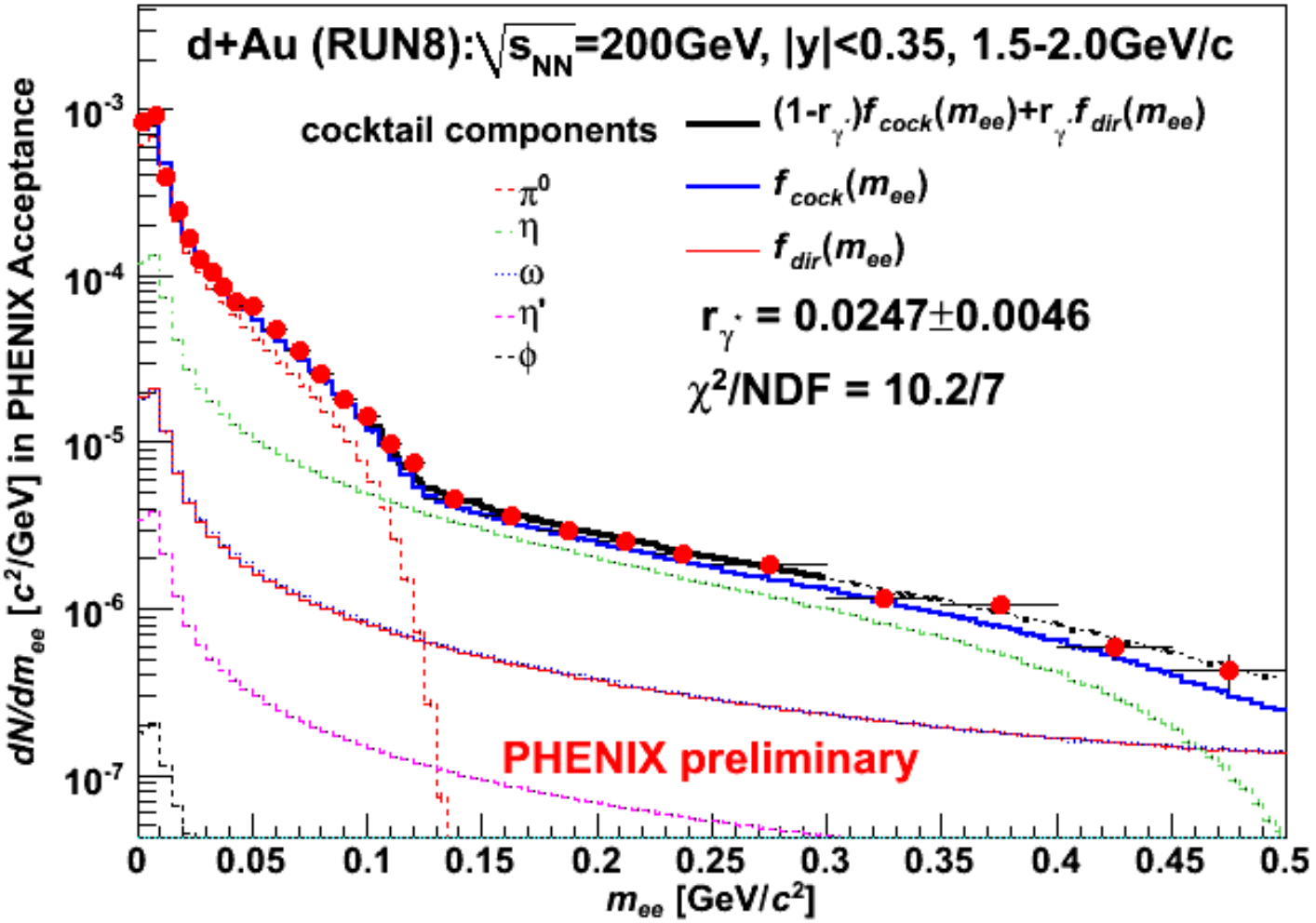
PRL**104**,132301(2010), arXiv:0804.4168

- Factors of two to be worked on ..
- Correlation between T and τ_0



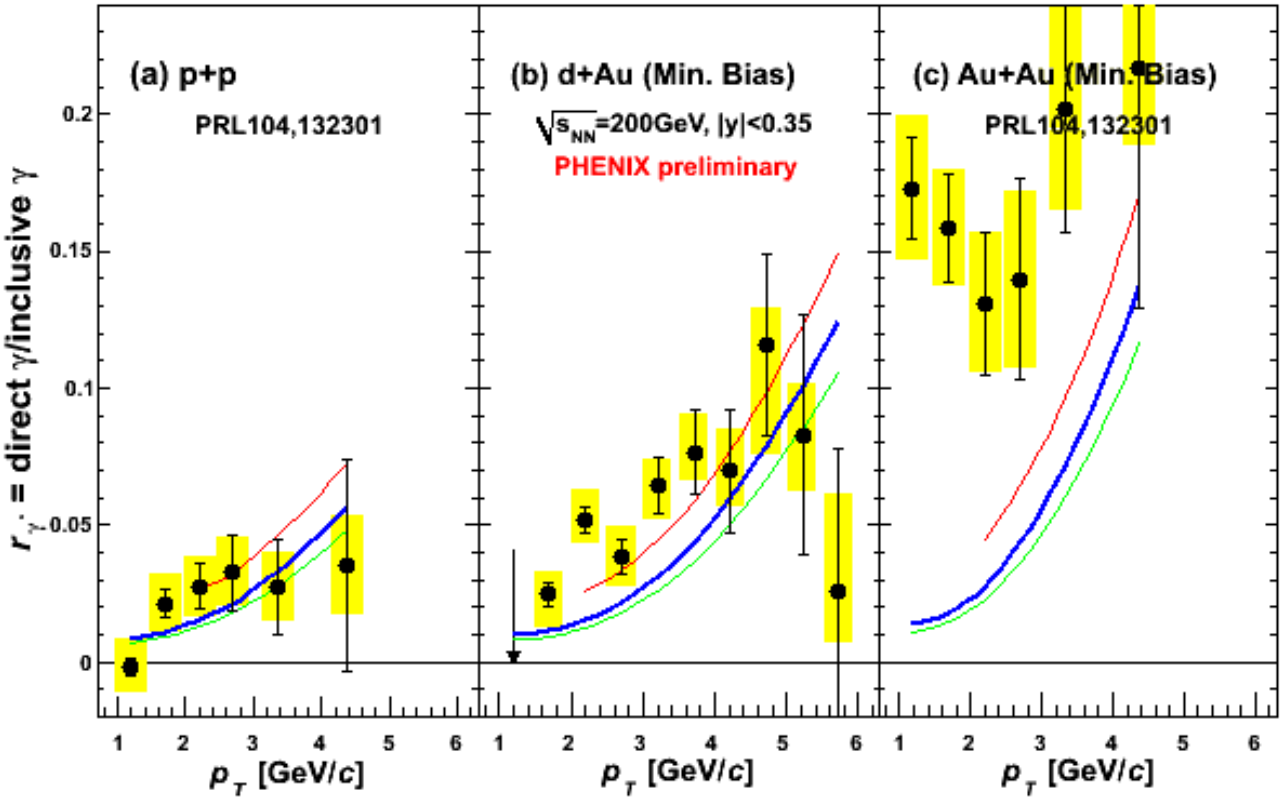
T_{ini} = 300 to 600 MeV
τ_0 = 0.15 to 0.5 fm/c

New results: d+Au virtual photon



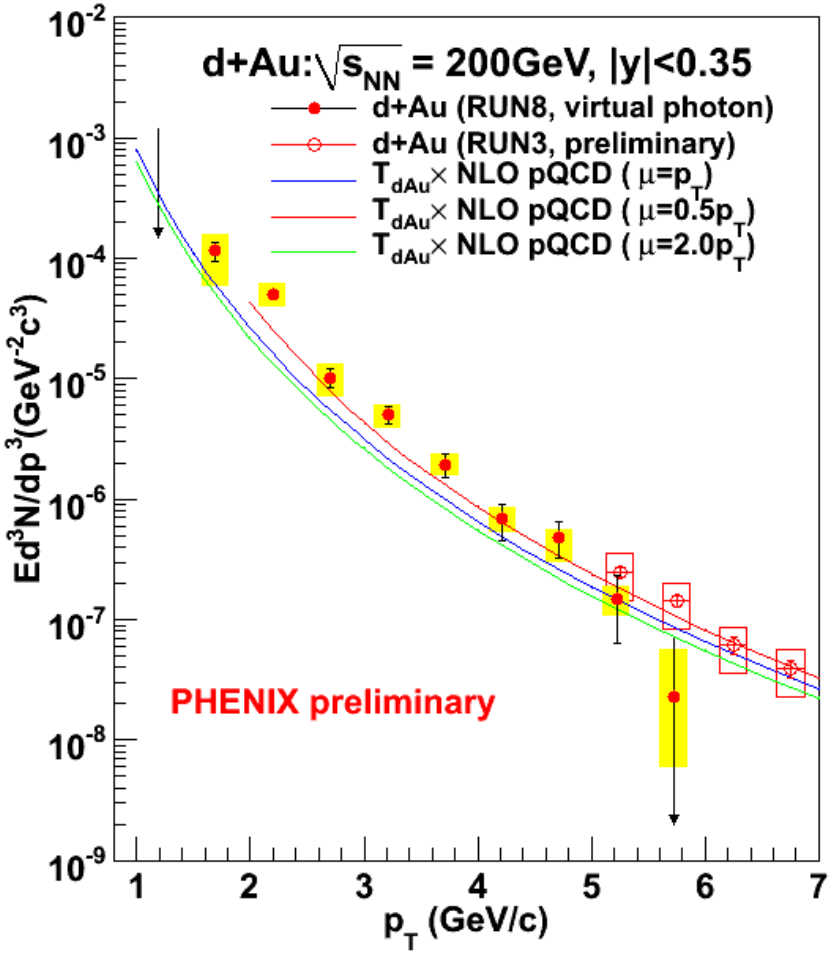
Direct γ to inclusive γ ratios

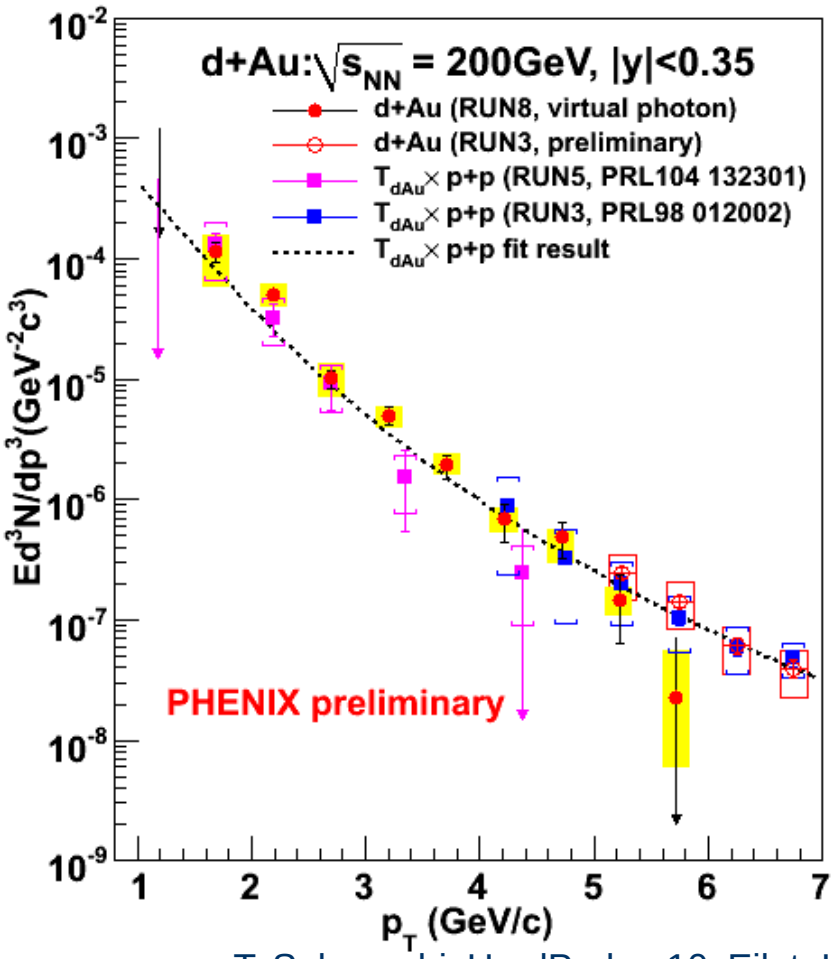
- Shown are in p+p, d+Au and Au+Au collisions at $\sqrt{s_{NN}}$=200GeV
- Lines are NLO pQCD calculation with mass scales (pT=0.5, 1.0, 2.0)
- Excess in min. bias Au+Au is much higher than that in d+Au



Direct photon pT spectra

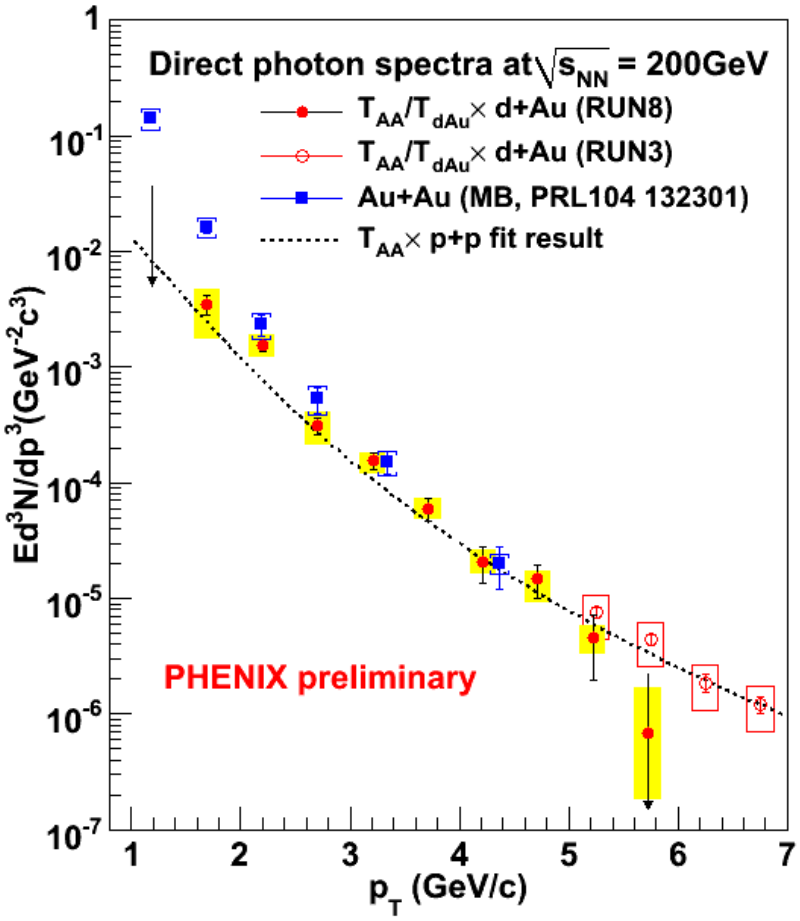
- Compared with NLO pQCD calculation, TAB scaled p+p data fit
- Hint of an enhancement, probably due to a nuclear effect

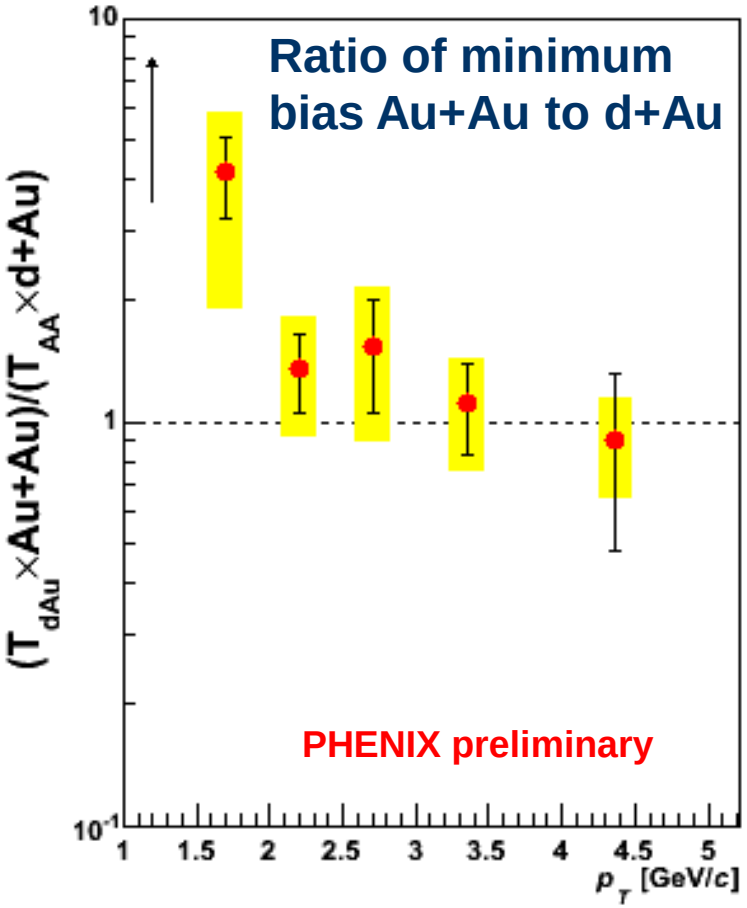




Comparing Au+Au with d+Au

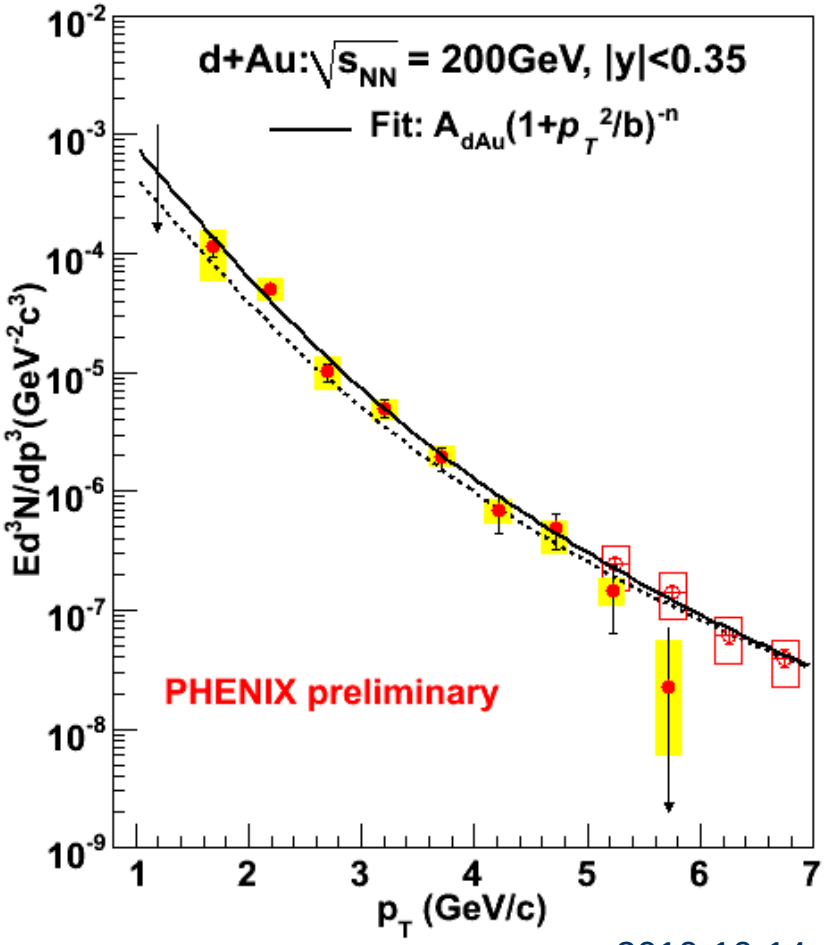
- d+Au is scaled by Ncoll, in order to compare with min. bias Au+Au
  - Nuclear effect seen in d+Au should scale with Ncoll, also.
- Took ratio of Au+Au to d+Au scaled by Ncoll

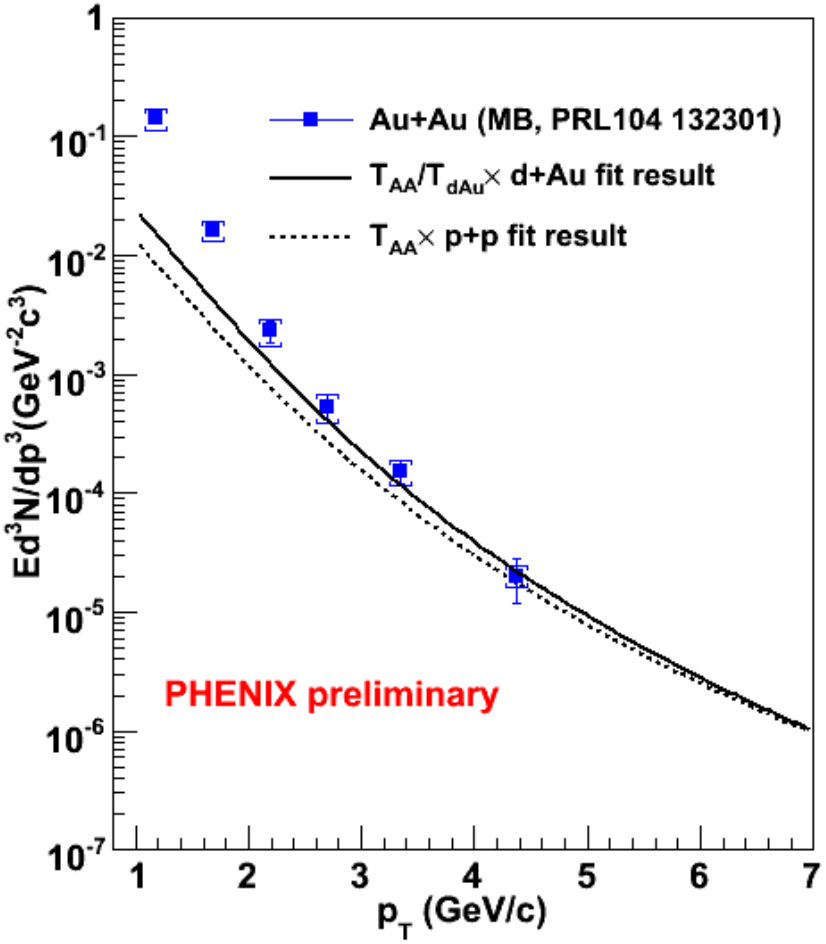




Au+Au together with d+Au fit

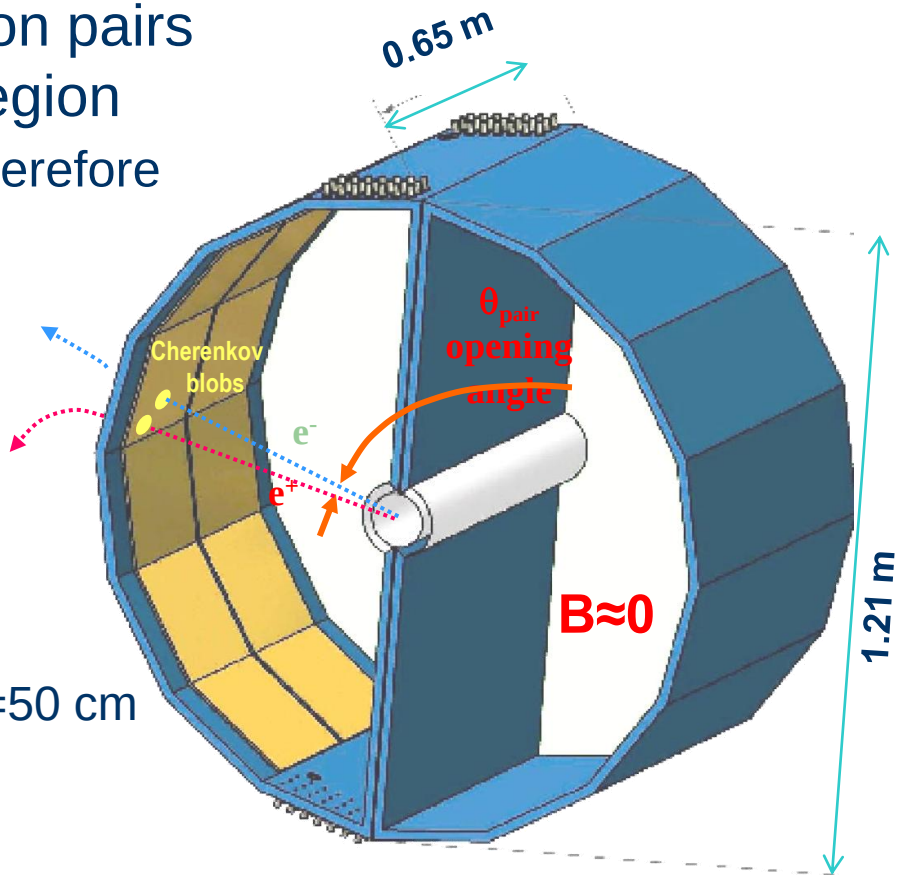
- Fitted d+Au data with power-law function
- Comparing Ncoll scaled d+Au data with min. bias Au+Au





A device to improve measurement -HBD

- Removes Dalitz and conversion pairs by tagging them in field free region
  - Reduce background γ^*, and therefore combinatoric background
- Separate single and double electrons by looking at the charge of a cluster



- ✓ Windowless Cherenkov detector
- ✓ CF_4 radiator gas and active gas. L_{rad}=50 cm
- ✓ triple GEMs for signal multiplication
- ✓ CsI photocathode
- ✓ proximity focus configuration
- ✓ hexagonal pad readout (pad size a = 1.55 cm)
- ✓ total radiation length: ~4.4%

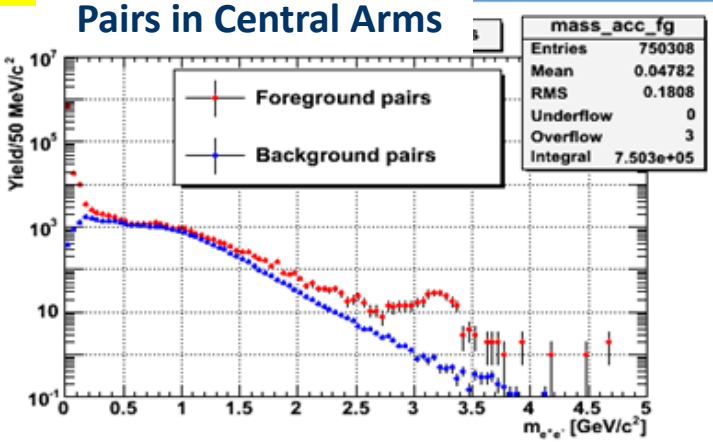
NIM A 546 (2005) 466-480, NIM A 523 (2004) 345-354

HBD news

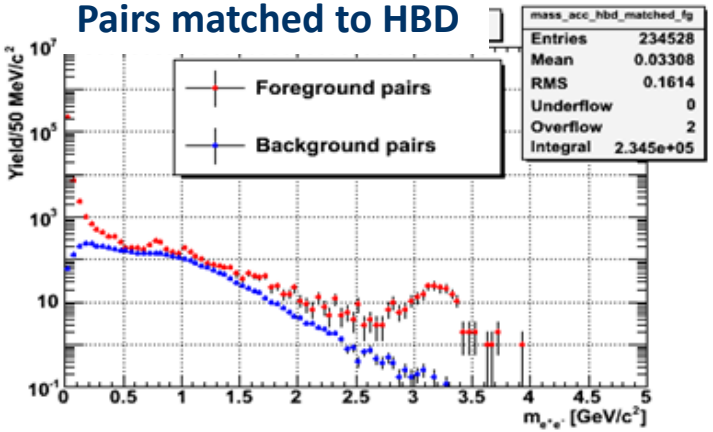
Estimate from Run-9 p+p:

	Step	Bckg. reduction factor
1	matching to HBD	2.2
2	double hit cut close hit cut	6.5
3	single pad cluster cut	2

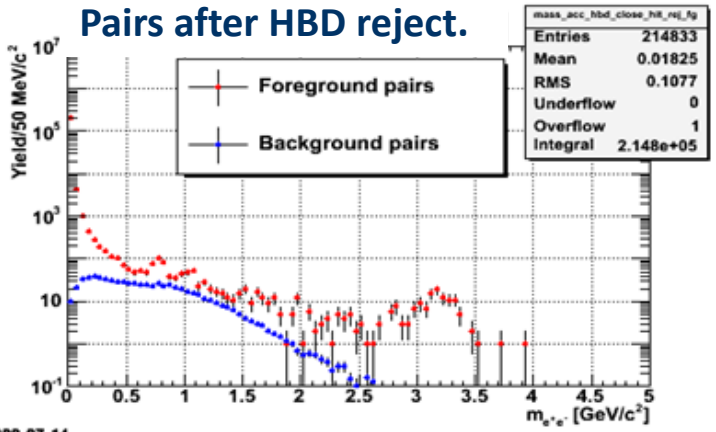
Pairs in Central Arms



Pairs matched to HBD



Pairs after HBD reject.

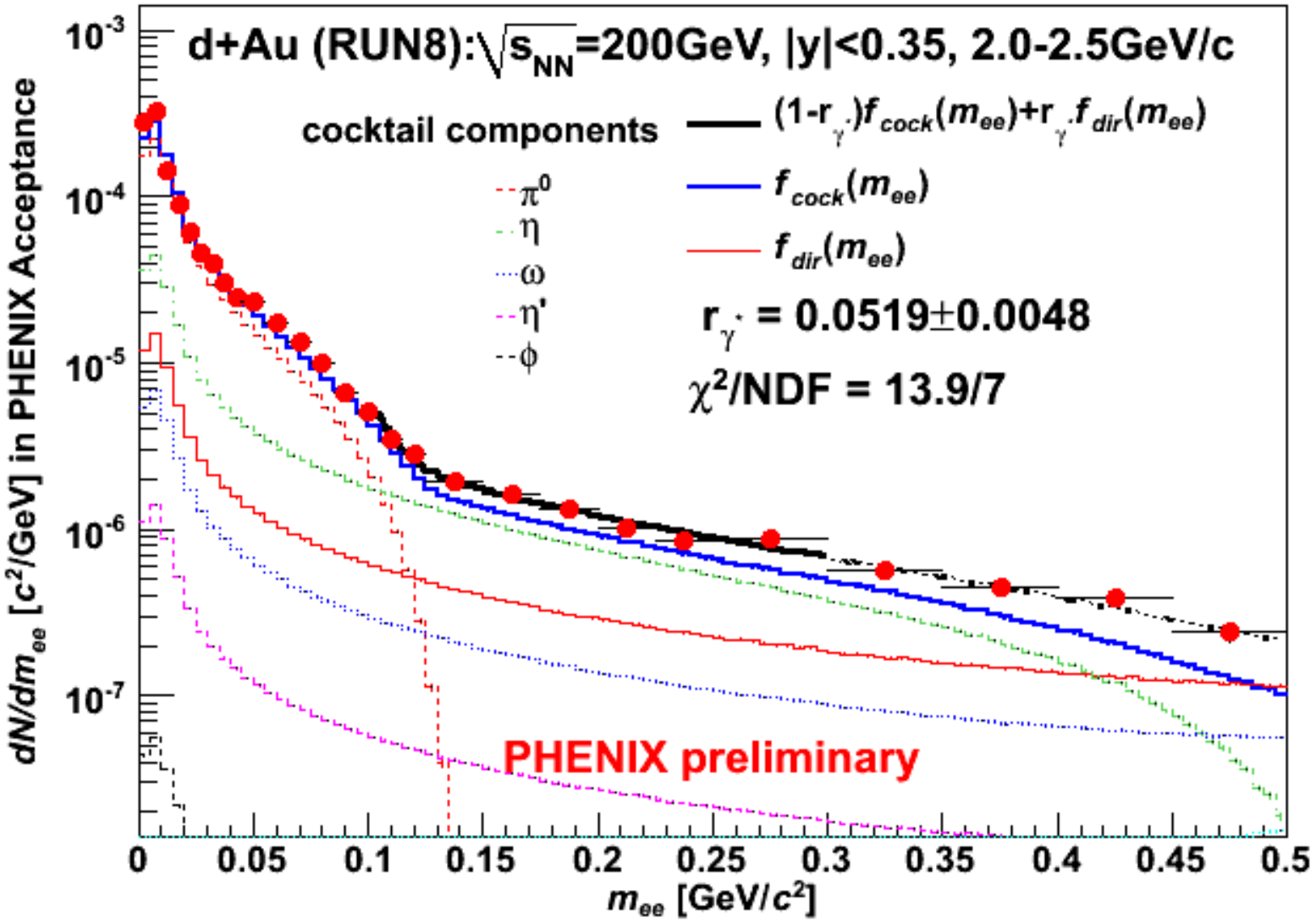


Summary

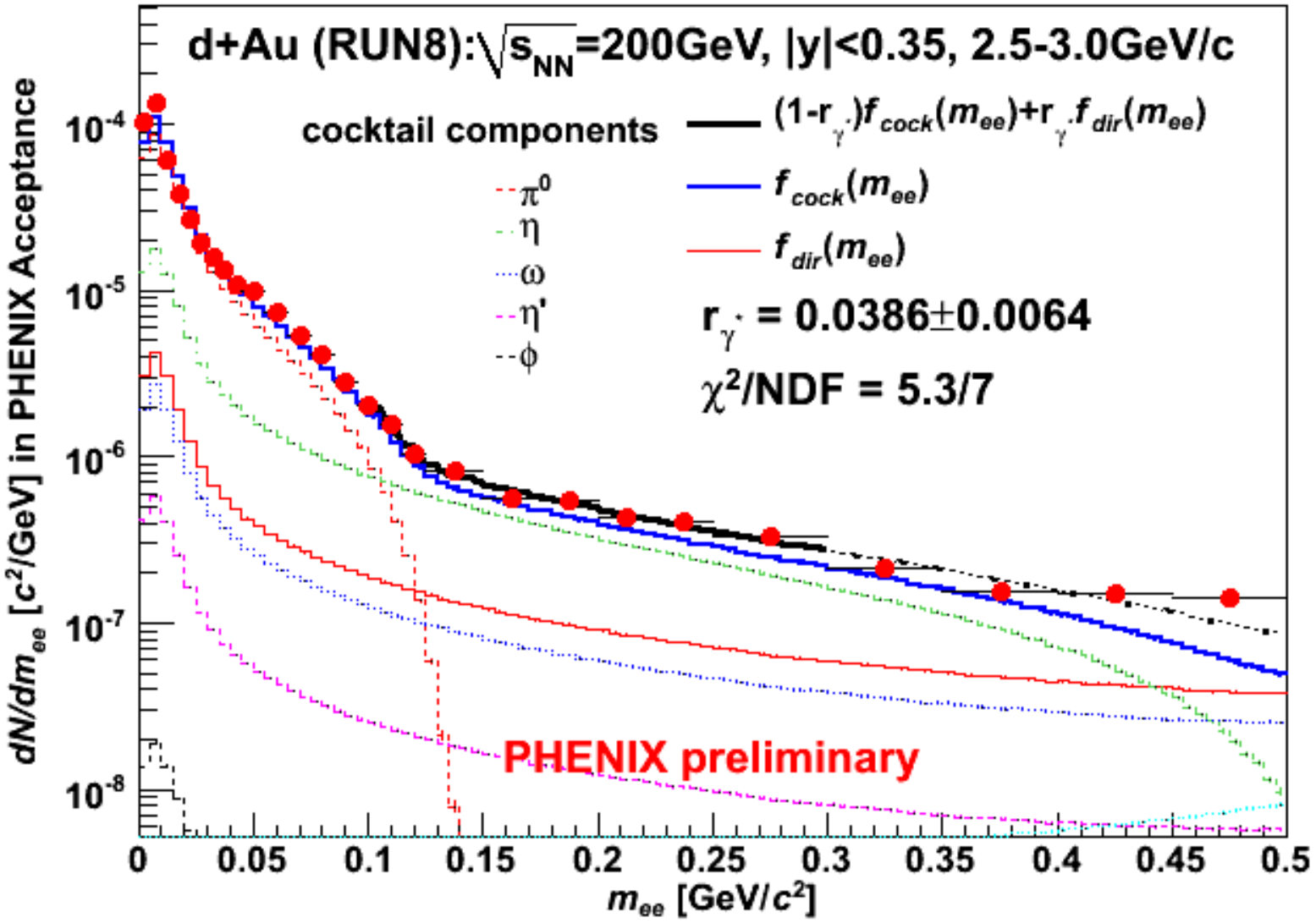
- Photons and Dileptons are strong tool to obtain thermodynamical information of the early state.
  - Both can be measured through dileptons.
- PHENIX has measured dileptons in Au+Au and p+p collisions at $\sqrt{s_{NN}}$=200GeV.
- Detail investigation of dilepton mass spectra has shown that the excess of the yield in low mass region increases with increasing centrality.
  - Inverse slope is higher for high m_T-m_0, lower for low m_T-m_0
- Very low mass and high pT dileptons become a measure of single photons (virtual photons).
- PHENIX has observed an excess of low pT single photons that are not explainable by nuclear effects quantified by the d+Au data.

Backup

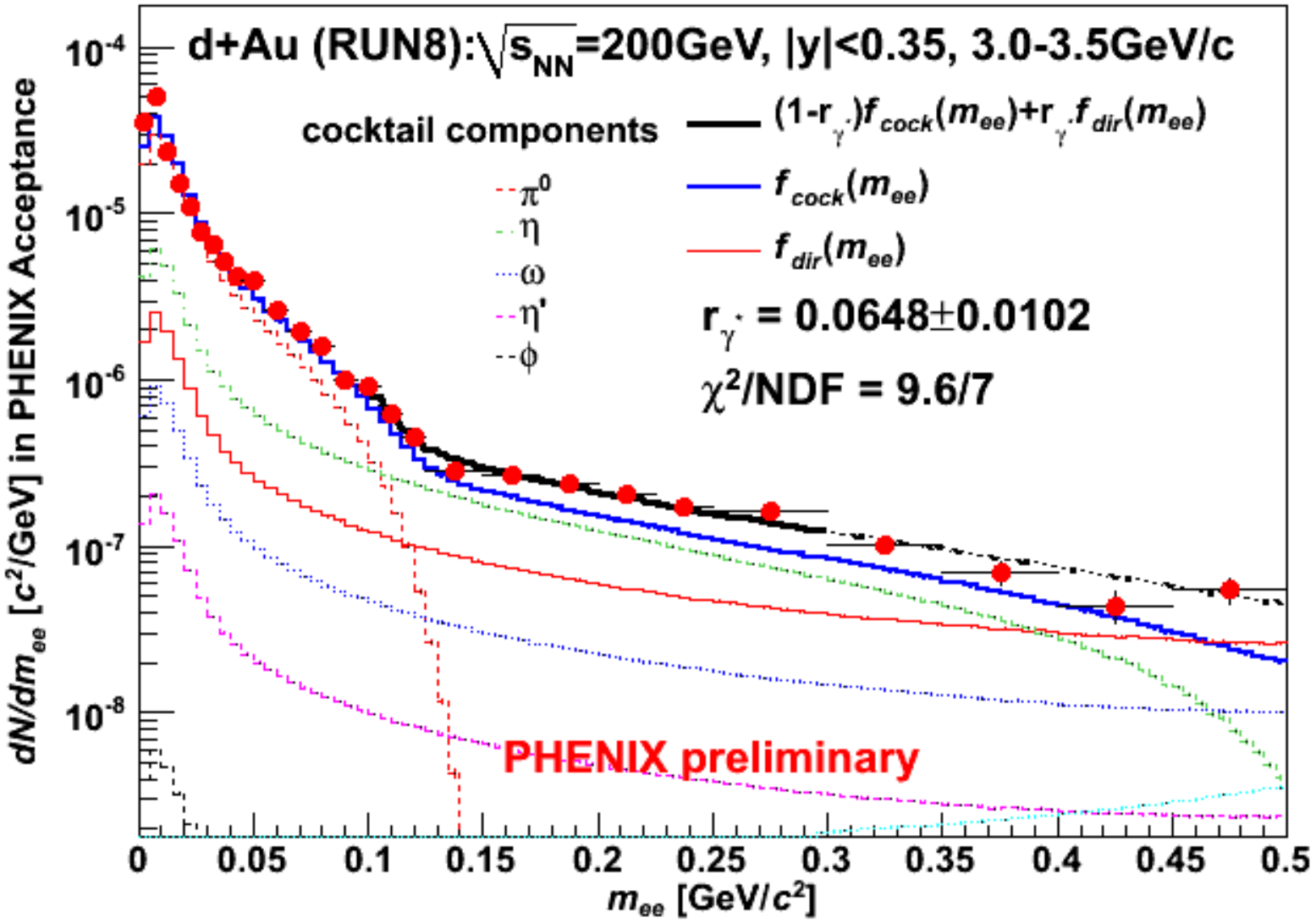
pT sliced mass spectra compared to the cocktail (pT:2.0-2.5GeV/



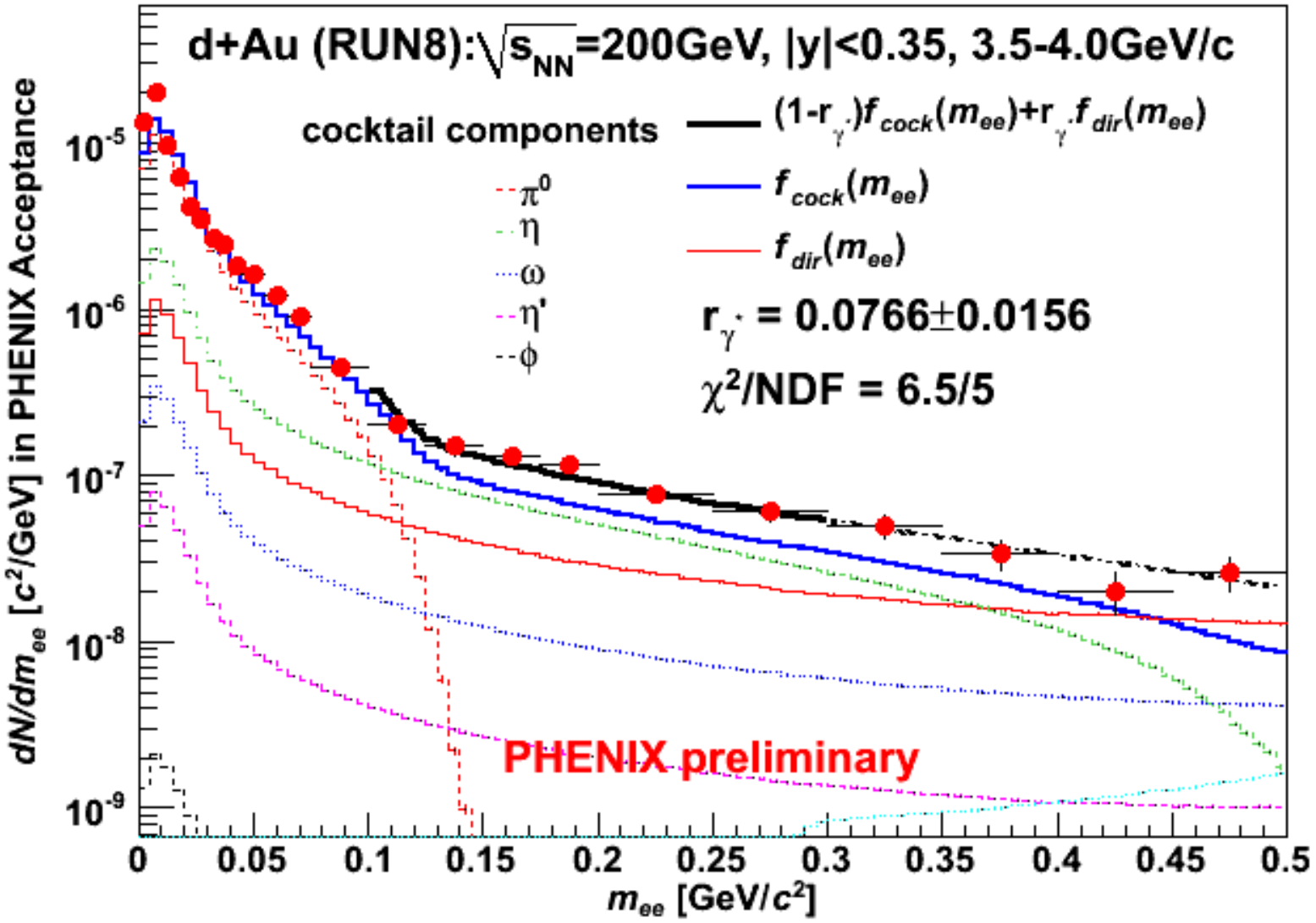
pT sliced mass spectra compared to the cocktail (pT:2.5-3.0GeV/



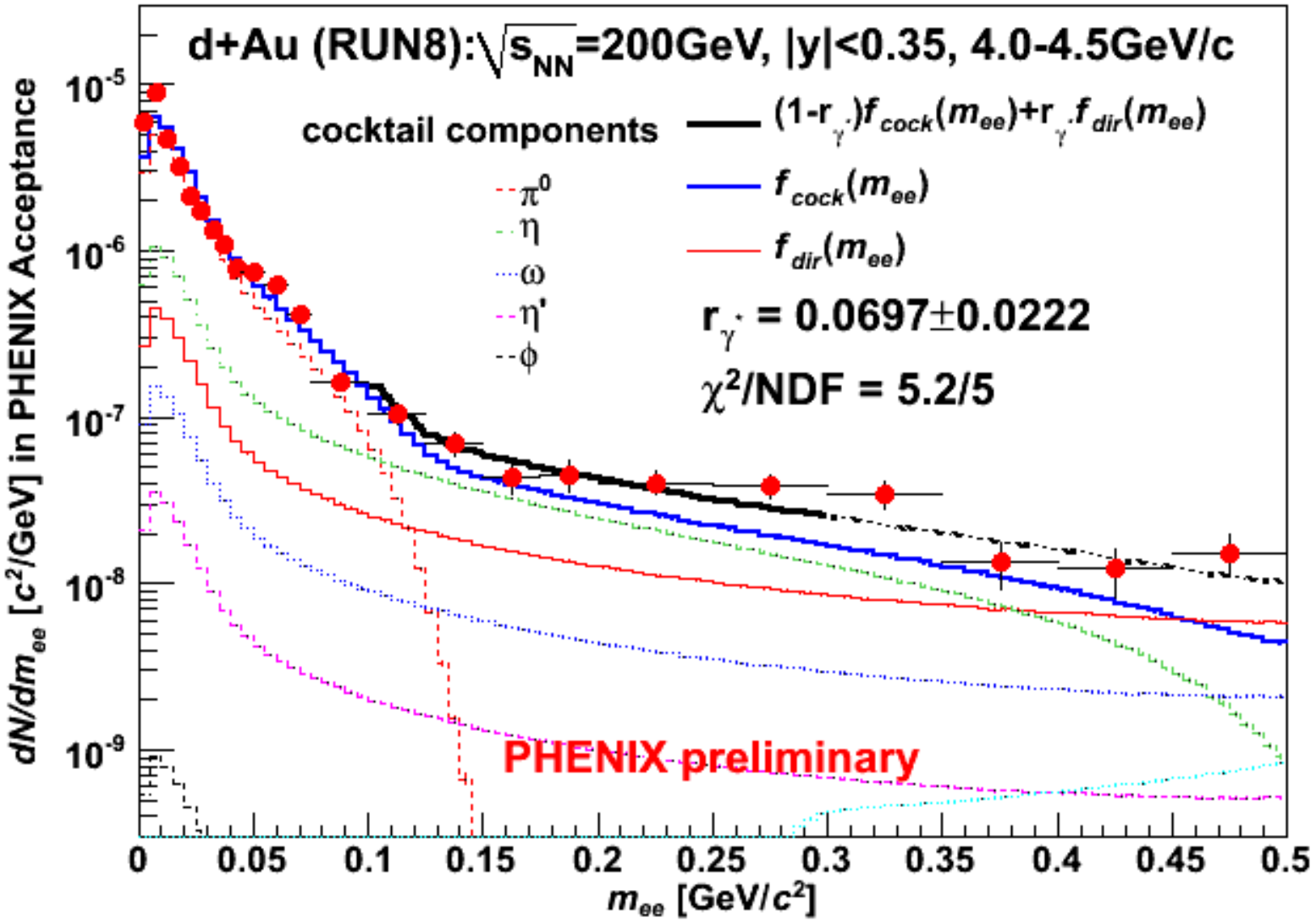
pT sliced mass spectra compared to the cocktail (pT:3.0-3.5GeV/



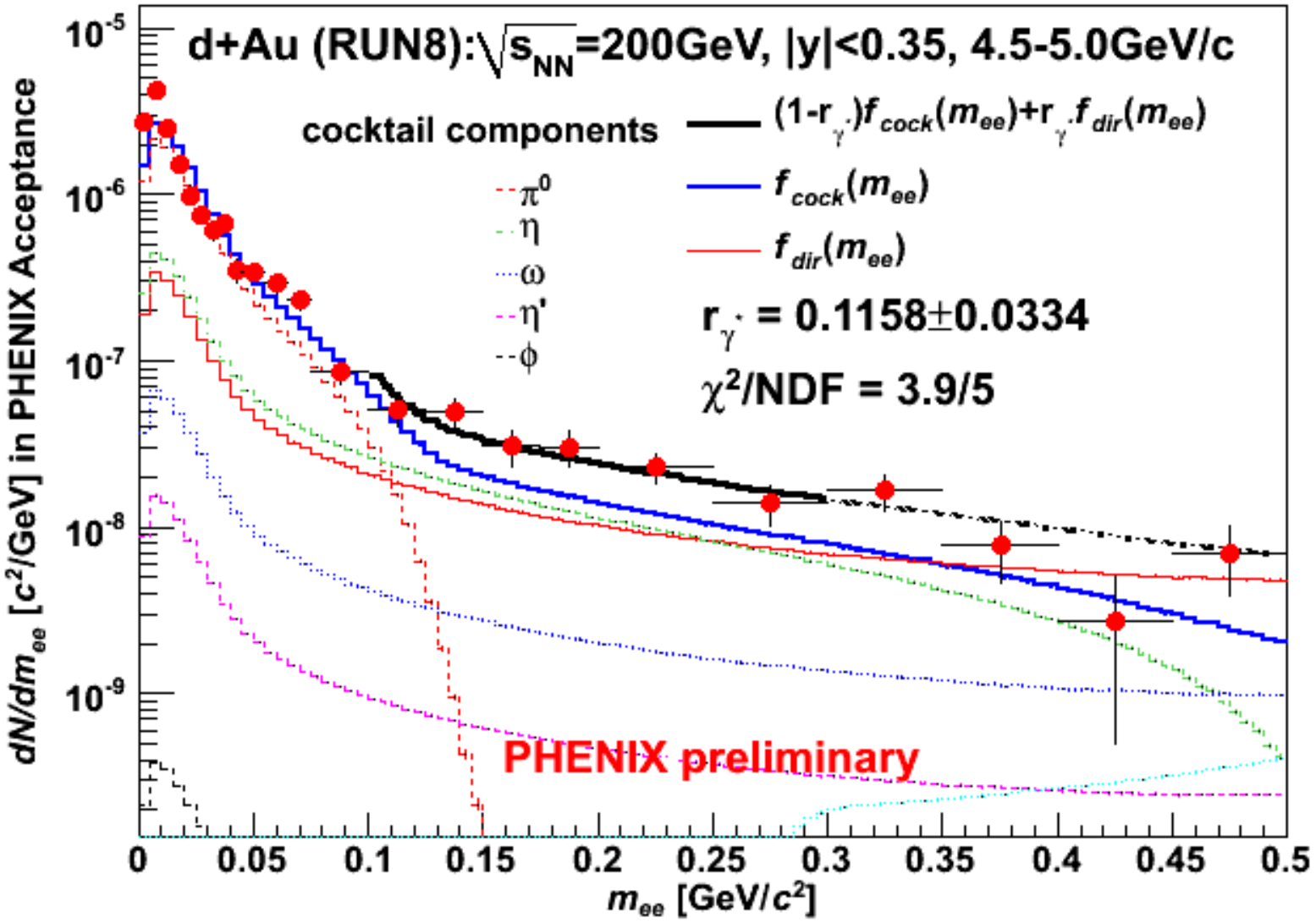
pT sliced mass spectra compared to the cocktail (pT:3.5-4.0GeV/



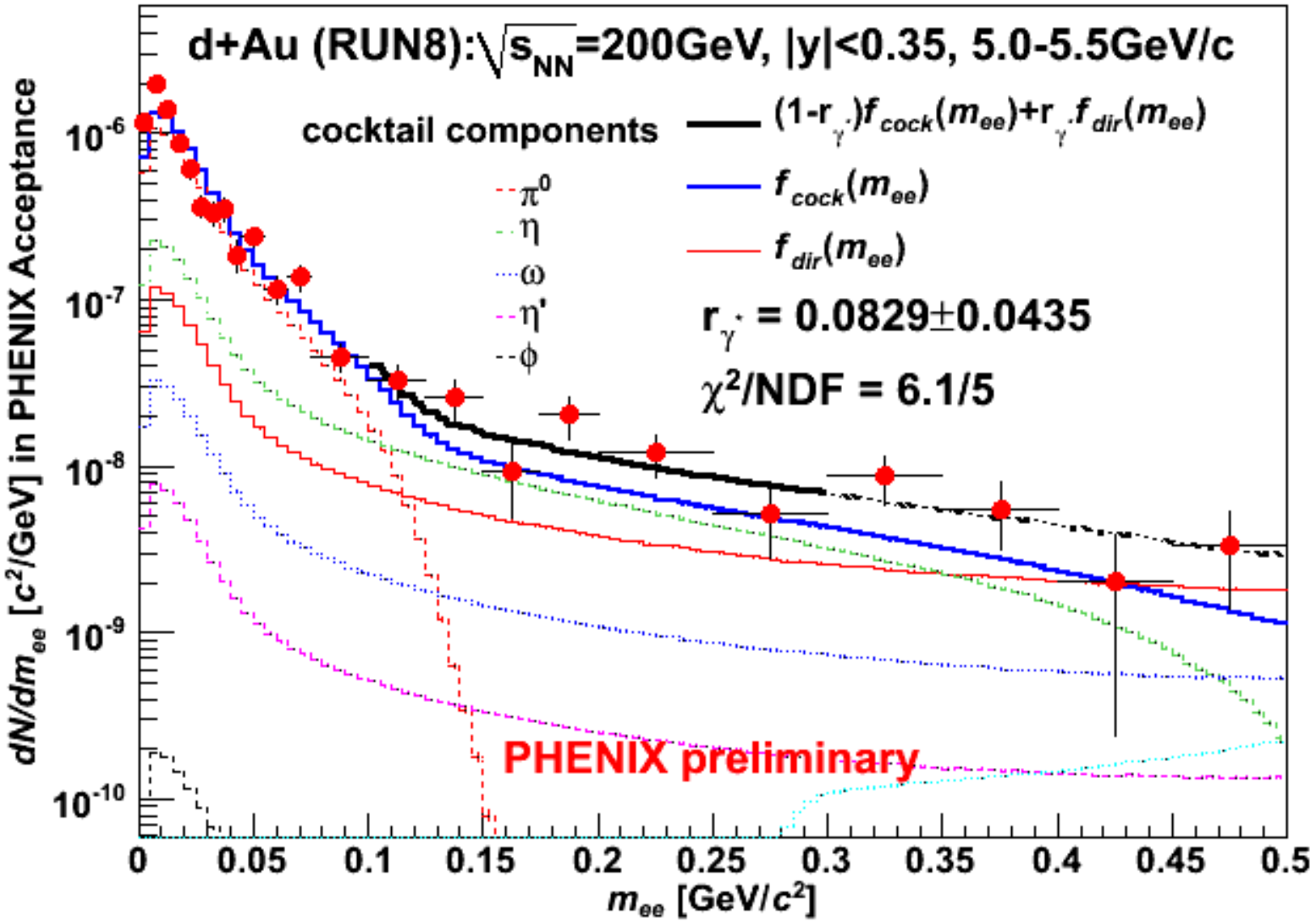
pT sliced mass spectra compared to the cocktail (pT:4.0-4.5GeV/



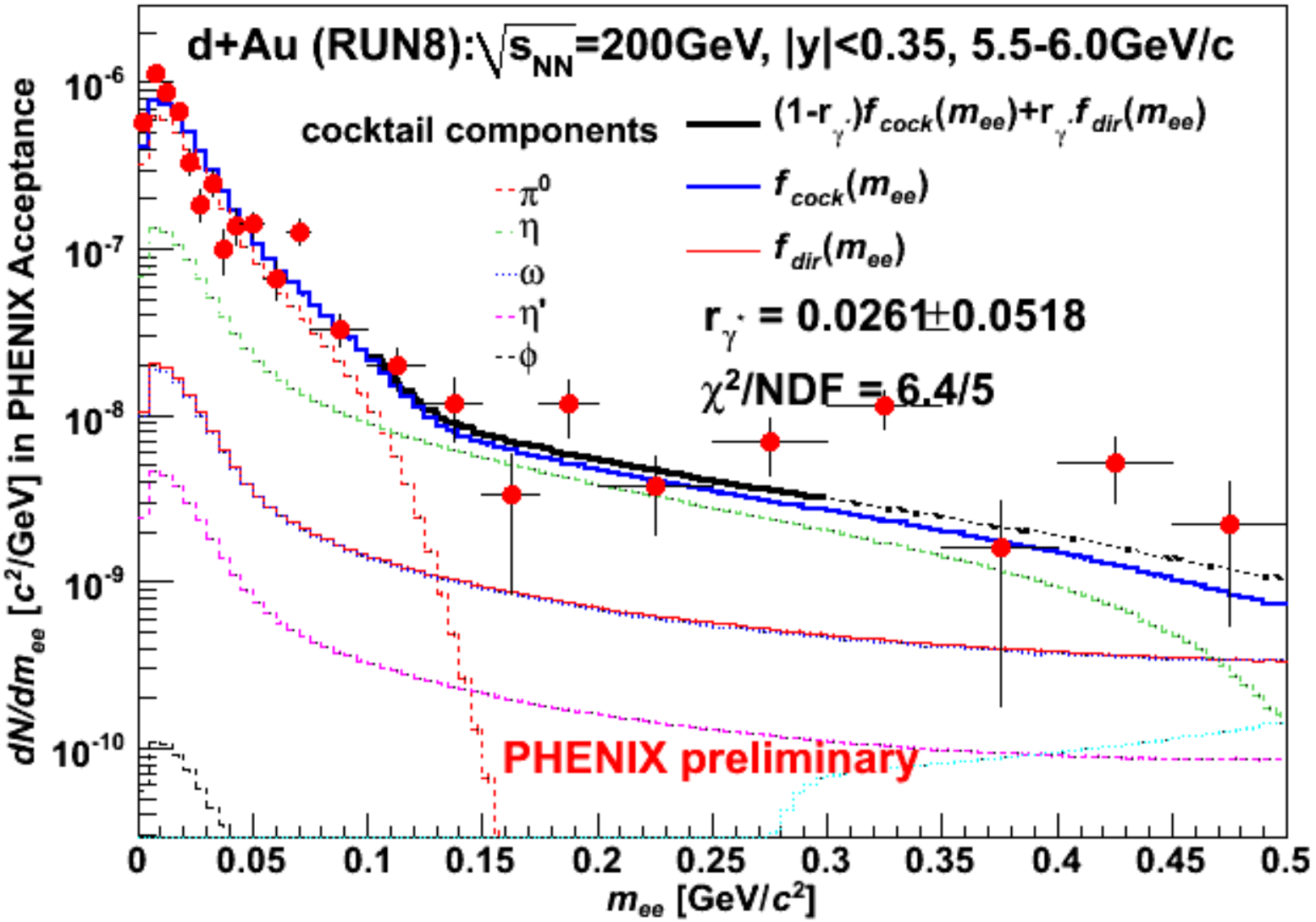
pT sliced mass spectra compared to the cocktail (pT:4.5-5.0GeV/



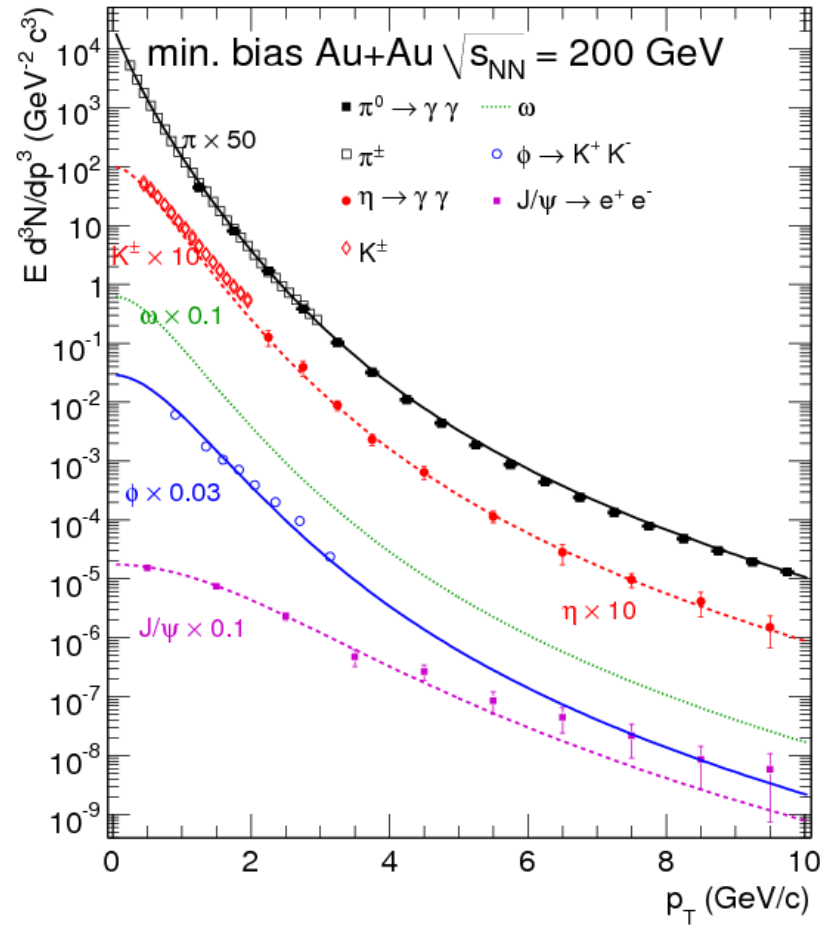
pT sliced mass spectra compared to the cocktail (pT:5.0-5.5GeV/

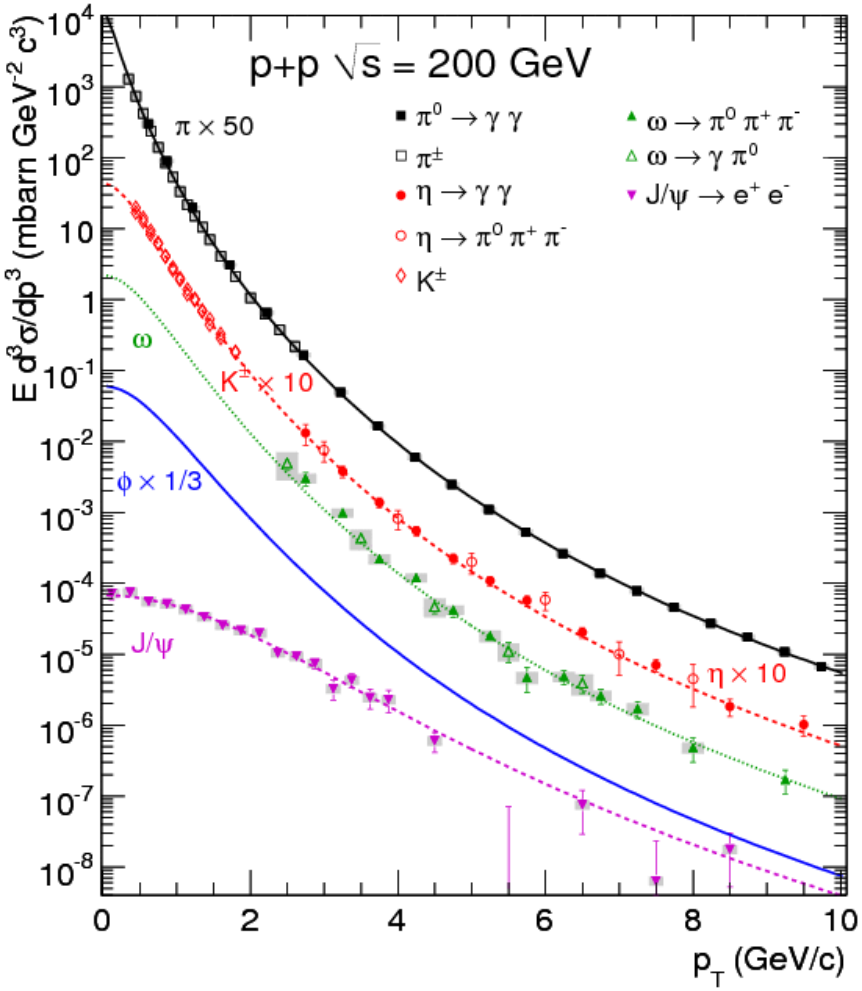


pT sliced mass spectra compared to the cocktail (pT:5.5-6.0GeV/



mT scaling


min. bias Au+Au $\sqrt{s_{NN}}$ = 200 GeV
$E\,d^3N/dp^3$ (GeV^{-2} c^3)
$\pi^0 \to \gamma\,\gamma$
ω
$\pi^\pm$
$\phi \to K^+ K^-$
$\eta \to \gamma\,\gamma$
$J/\psi \to e^+ e^-$
$K^\pm$
$\pi \times 50$
$K^\pm \times 10$
$\omega \times 0.1$
$\phi \times 0.03$
$\eta \times 10$
$J/\psi \times 0.1$
p_T (GeV/c)


p+p $\sqrt{s}$ = 200 GeV
$E\,d^3\sigma/dp^3$ (mbarn GeV^{-2} c^3)
$\pi^0 \to \gamma\,\gamma$
$\pi^\pm$
$\eta \to \gamma\,\gamma$
$\eta \to \pi^0\,\pi^+\,\pi^-$
$K^\pm$
$\omega \to \pi^0\,\pi^+\,\pi^-$
$\omega \to \gamma\,\pi^0$
$J/\psi \to e^+ e^-$
$\pi \times 50$
ω
$K^\pm \times 10$
$\phi \times 1/3$
J/ψ
$\eta \times 10$
p_T (GeV/c)