Differential measurements of dielectron and direct virtual photon productions at STAR

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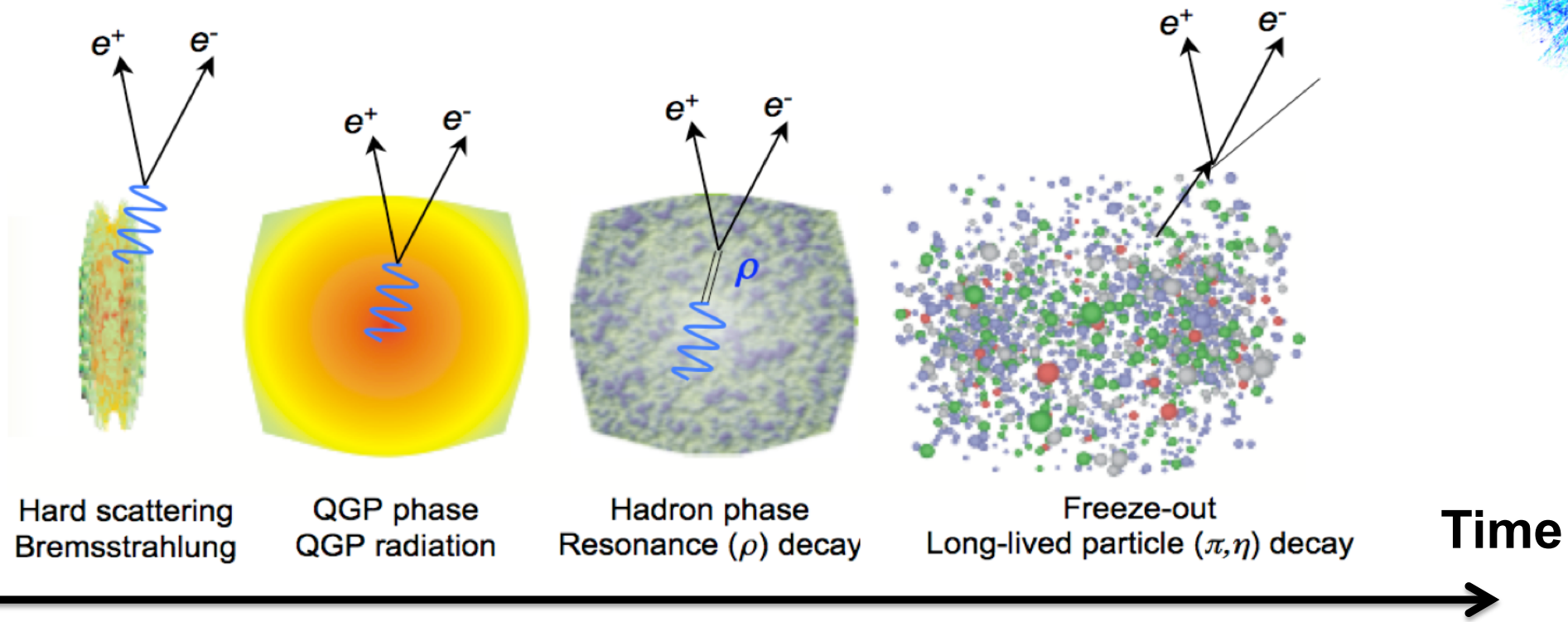
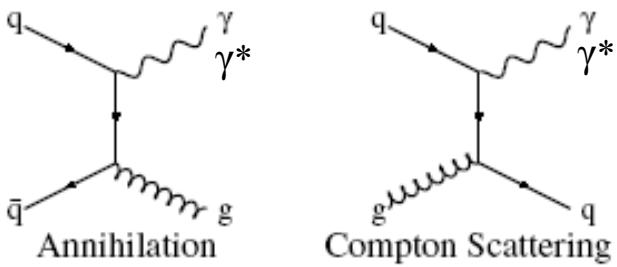
Di-leptons and photons





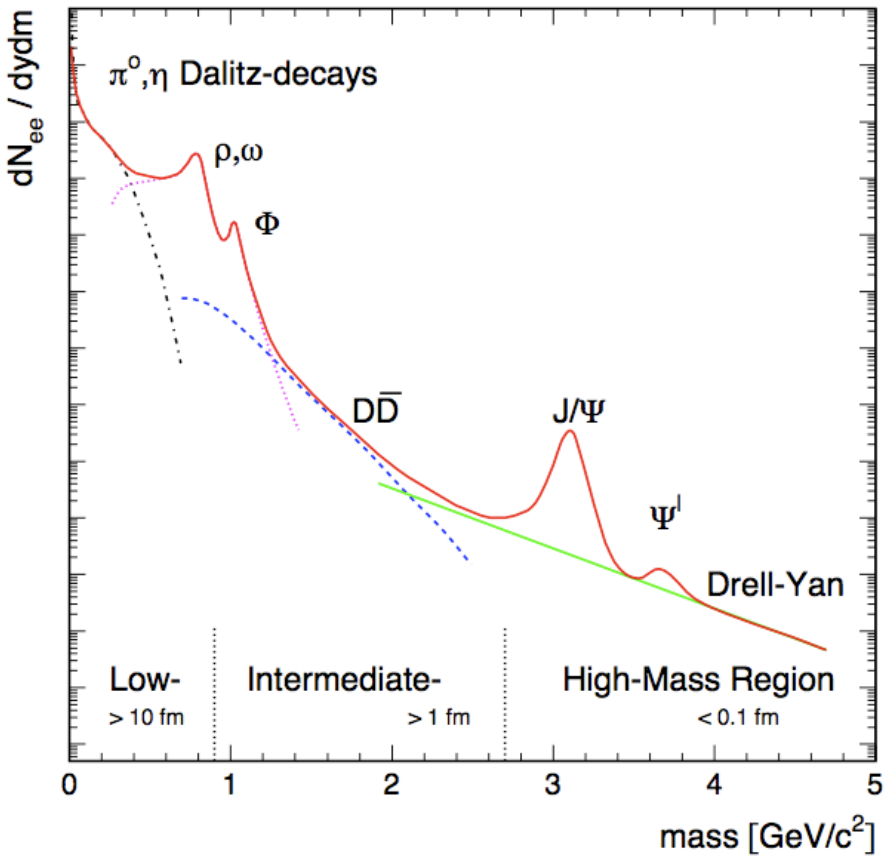
Excellent penetrating probe:

- Created throughout evolution of system.
- Minimum interactions with QCD medium.

Direct photon:

- Kinematic range links to different sources
  - High p_T (>5 GeV/*c*) --- initial hard scattering.
  - Low p_T (1-5 GeV/*c*) --- QGP.

Dielectron physics

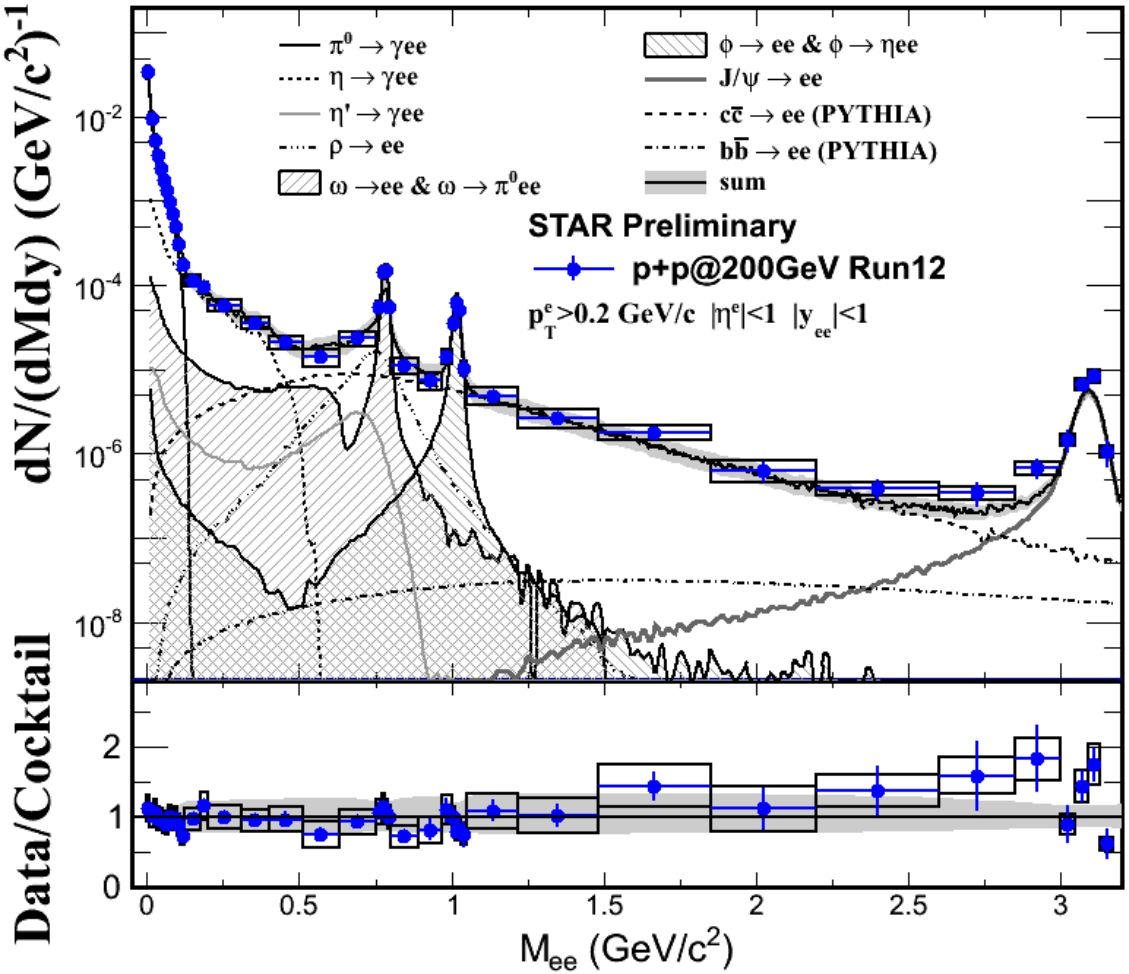


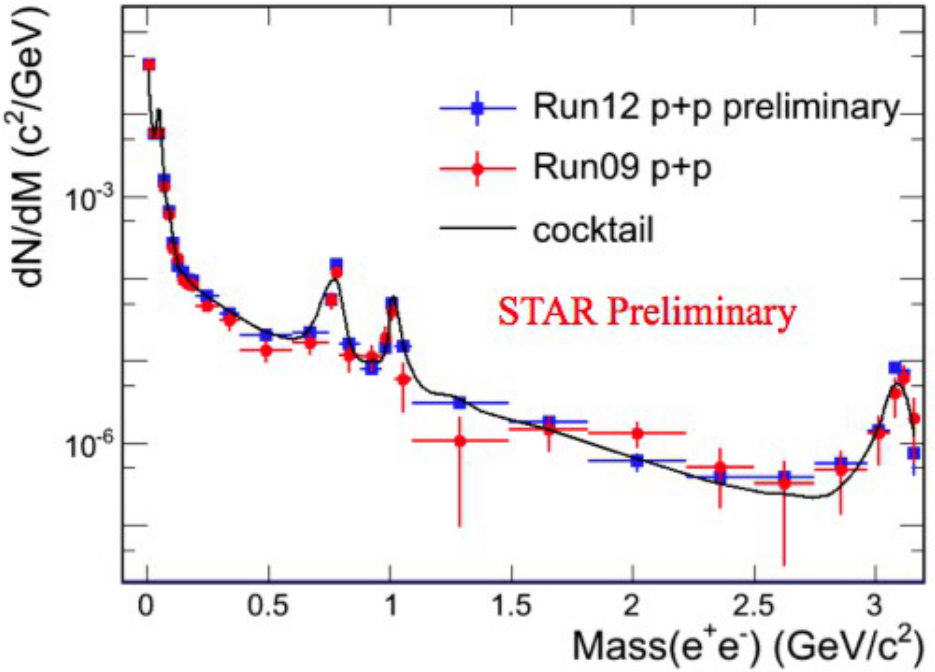
- **Low Mass Range (LMR < 1 GeV/c^2)**
  in-medium modification of vector mesons.
  possible link to chiral symmetry restoration.

- **Intermediate Mass Range (IMR 1.1-2.9 GeV/c^2)**
  QGP thermal radiation.
  Heavy-flavor modification.

- **Very Low Mass Range (0-0.3 GeV/c^2)**
  Link to direct photon via internal conversion.
  Low p_T (1-5 GeV/c) production is related to thermal radiation.
  High p_T (>5 GeV/c) production is from initial hard scattering, test of pQCD and PDF.

Dielectron in p+p at 200 GeV

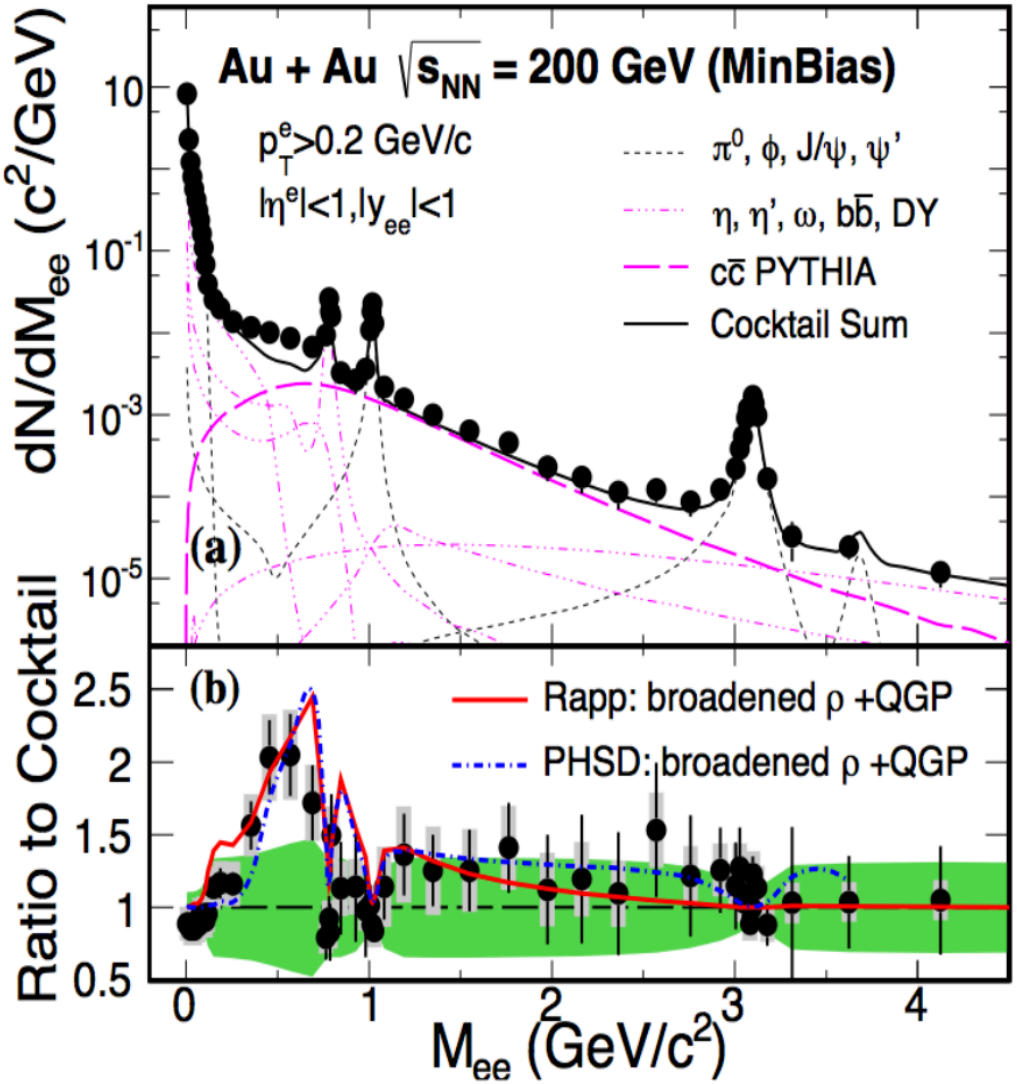




Cocktail [STAR, Phys. Rev. C 86, 024906 (2012)] with updated charm cross section 0.797+0.3/- 0.36mb [STAR, Phys. Rev. D. 86, 072013(2012)]
Run9 p+p: [STAR, Phys.Rev.C. 86, 24906 (2012)]

p+p results has been improved significantly with ~7 times more statistics.
More precise baseline for Au+Au studies.

Au+Au 200 GeV results

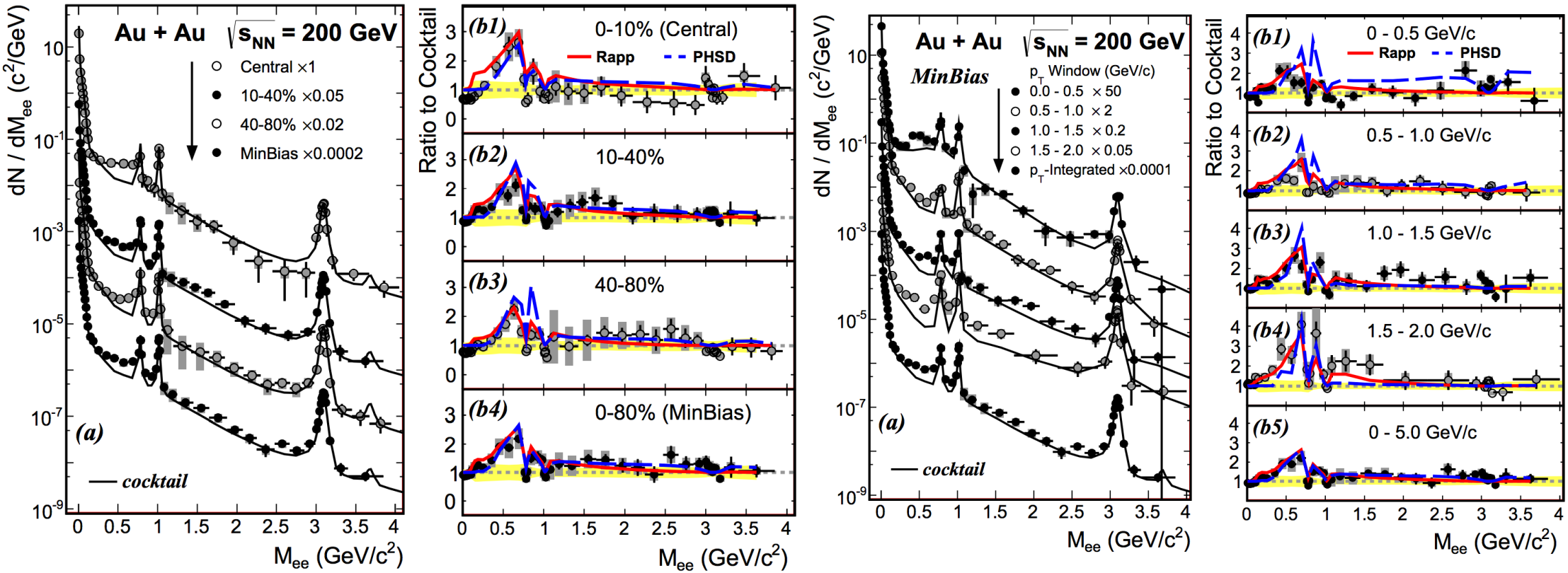


STAR, PRL. 113 (2014) 22301

Enhancement w.r.t cocktail at ρ like region(0.30-0.76 GeV/c^2):
1.77±0.11(stat.)±0.24(sys.)±0.41(cocktail) in MinBias.

Data is compared with two models both based on a ρ broadening scenario:
1) Model I by Rapp et al. is an effective many-body model.[R. Rapp, PoS CPOD2013, 008 (2013)]
2) Model II is a microscopic transport model – Parton-Hadron String Dynamics (PHSD). [O. Linnyk et al., Phys. Rev. C 85, 024910 (2012)]
Both models show good agreement with data within uncertainty.

Centrality and p_T dependence



STAR, PRL. 113 (2014) 22301, arXiv:1504.01317

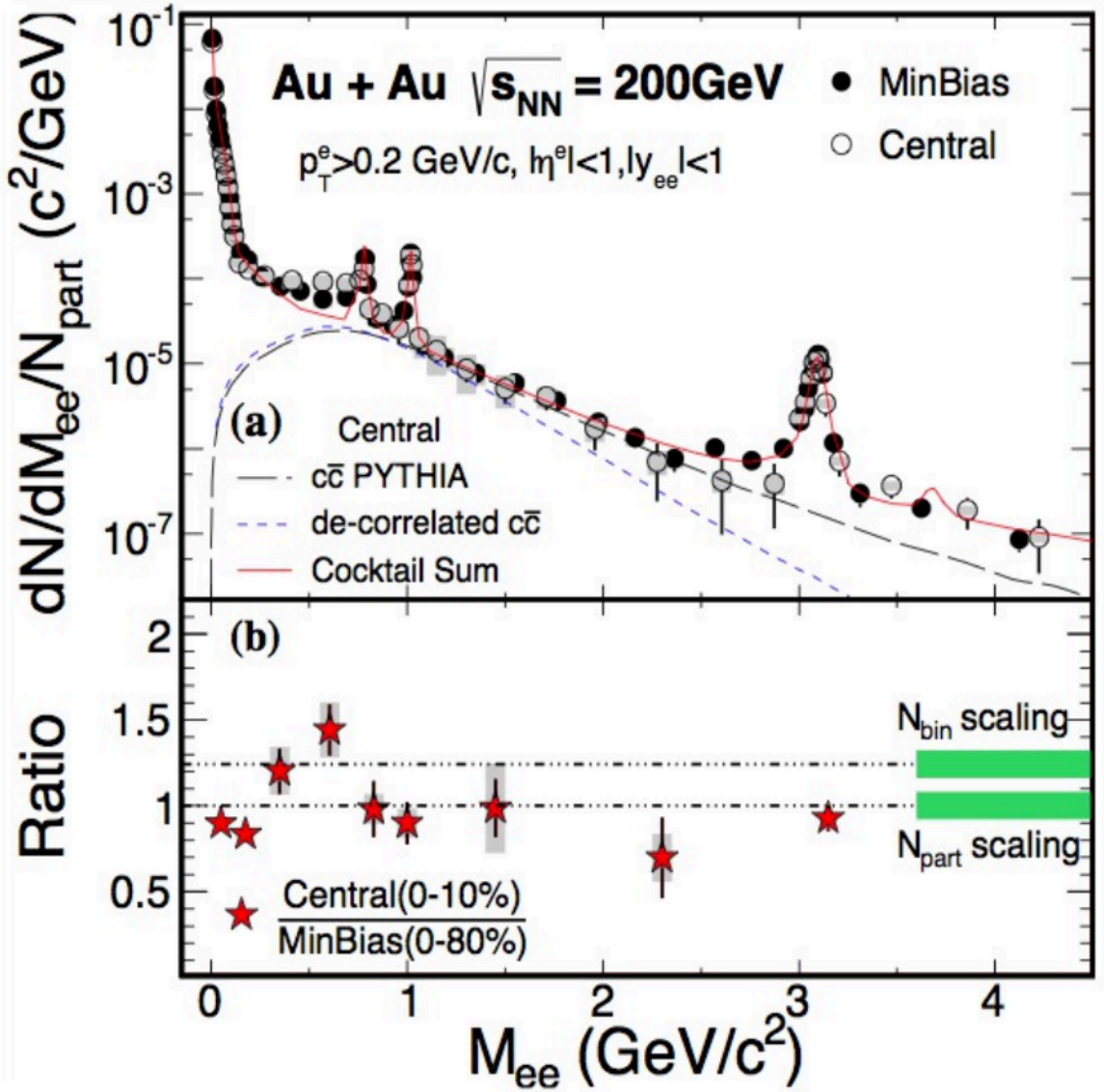
Increasing from peripheral to central and from low to high p_T.
Consistent with model calculations.

centrality	yield ($\times 10^{-3}$)	yield/cocktail
0 - 10%	$13.63 \pm 1.01 \pm 2.06$	$2.03 \pm 0.15 \pm 0.31$
10 - 40%	$4.81 \pm 0.22 \pm 0.71$	$1.63 \pm 0.08 \pm 0.24$
40 - 80%	$0.85 \pm 0.03 \pm 0.12$	$1.51 \pm 0.06 \pm 0.22$
0 - 80%	$3.87 \pm 0.13 \pm 0.57$	$1.76 \pm 0.06 \pm 0.26$

Yield in 0.3-0.76 GeV/c^2

p_T (GeV/c)	yield ($\times 10^{-3}$)	yield/cocktail
0 -0.5	$115 \pm 0.09 \pm 0.20$	$1.71 \pm 0.12 \pm 0.29$
0.5-1.0	$158 \pm 0.07 \pm 0.27$	$1.56 \pm 0.07 \pm 0.27$
1.0-1.5	$066 \pm 0.03 \pm 0.11$	$1.81 \pm 0.09 \pm 0.29$
1.5-2.0	$024 \pm 0.02 \pm 0.04$	$2.65 \pm 0.16 \pm 0.44$

Possible charm de-correlation



Ratio(Central/MinBias) shows 2.0σ deviation from the N_{bin} scaling in $1.8<M_{ee}<2.8$ GeV/c^2.

Possible charm de-correlation in Au+Au collision or other source from thermal radiation?

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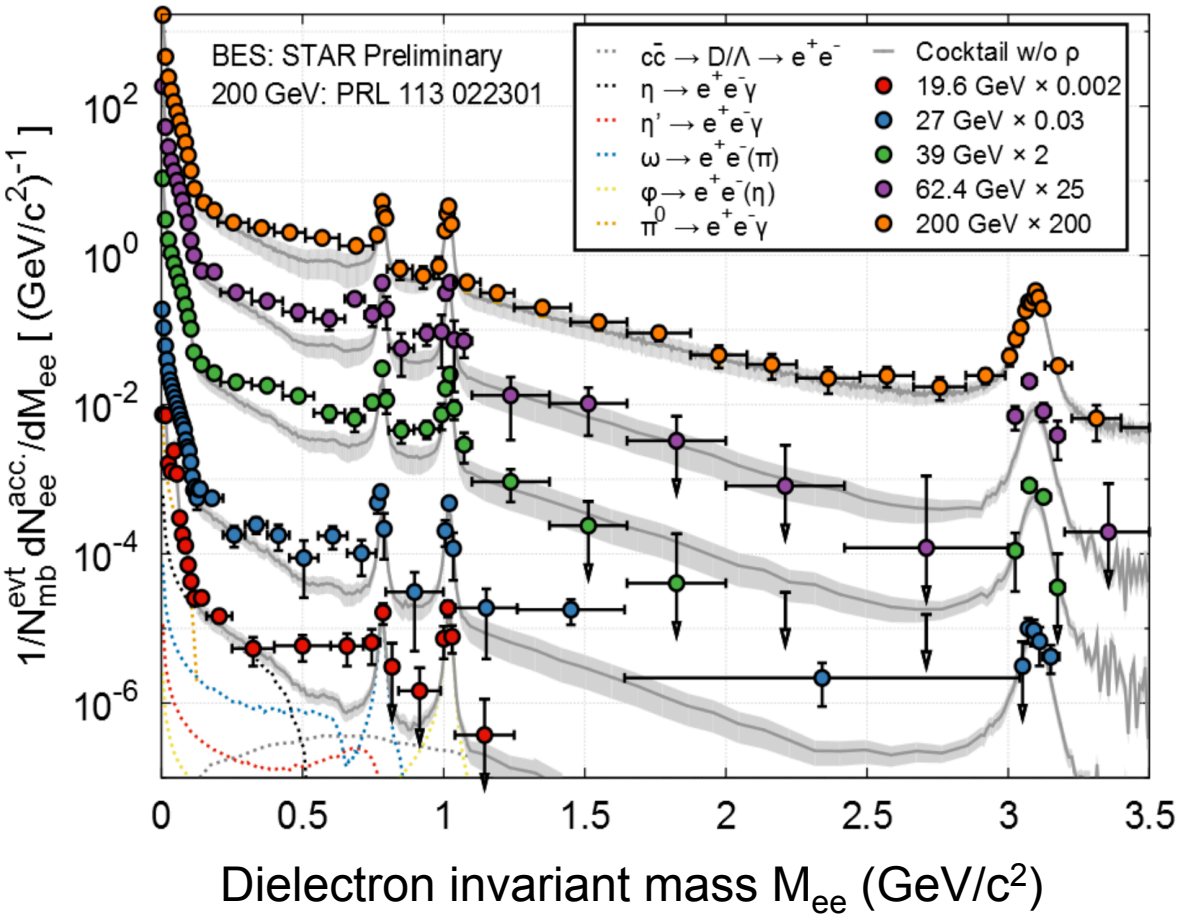
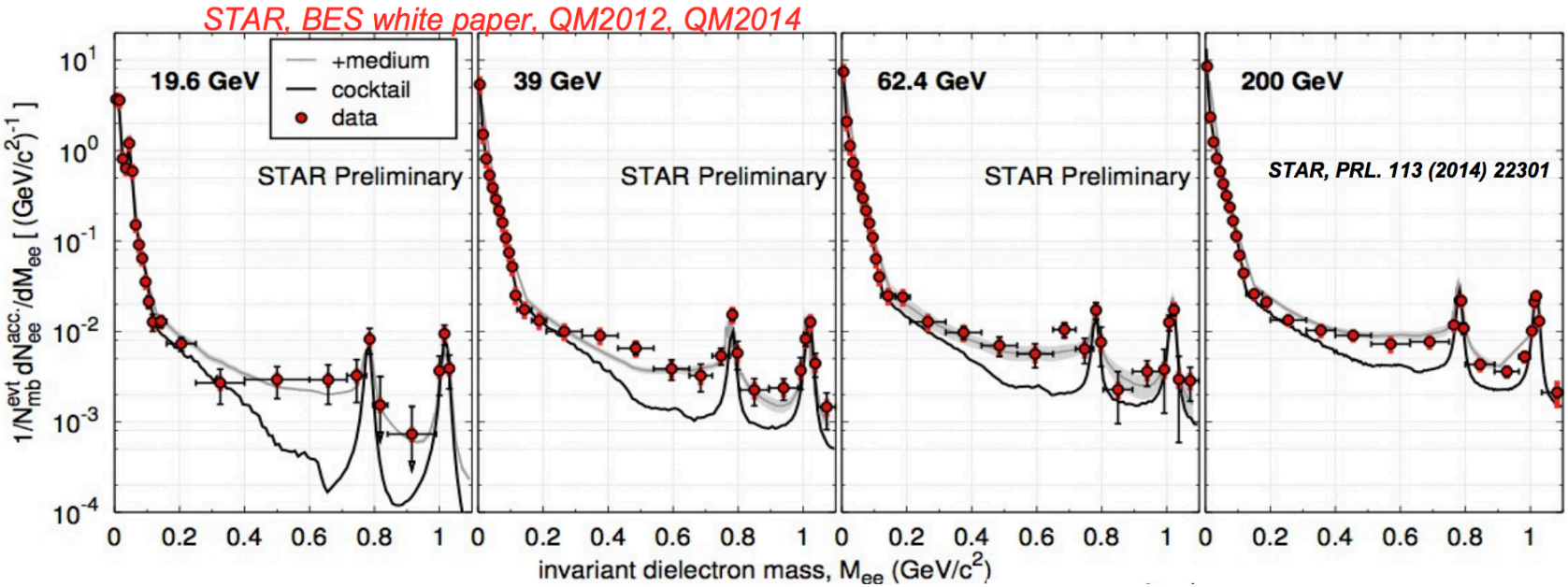
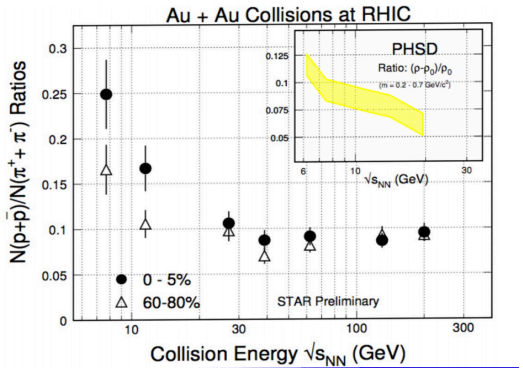
Dielectron in BES



- LMR excesses over cocktail observed from 200 down to 19.6 GeV.

Dielectron from RHIC BES-I





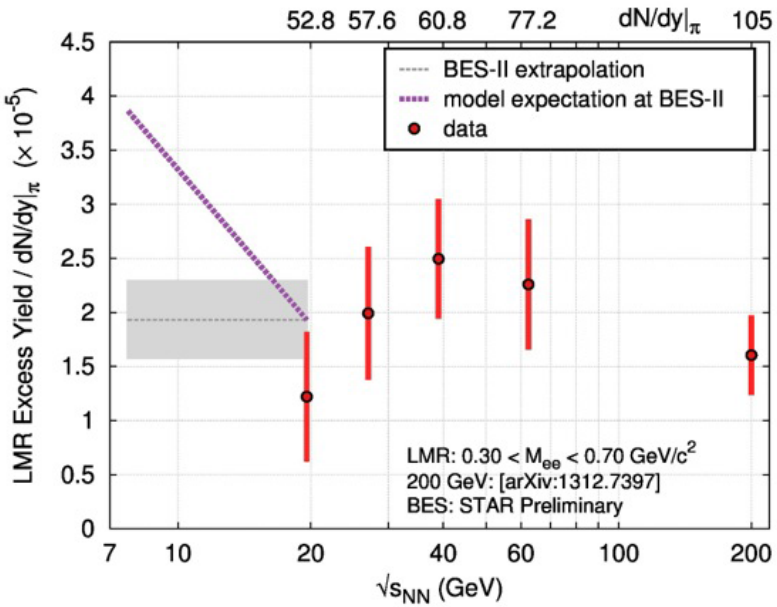
Model calculations† robustly describe the data from 200GeV to 19.6 GeV:

– model calculations by Rapp, based on in-media broadening of ρ spectra function, expected to depend on total baryon density.

– almost constant baryon density from 20-200GeV.

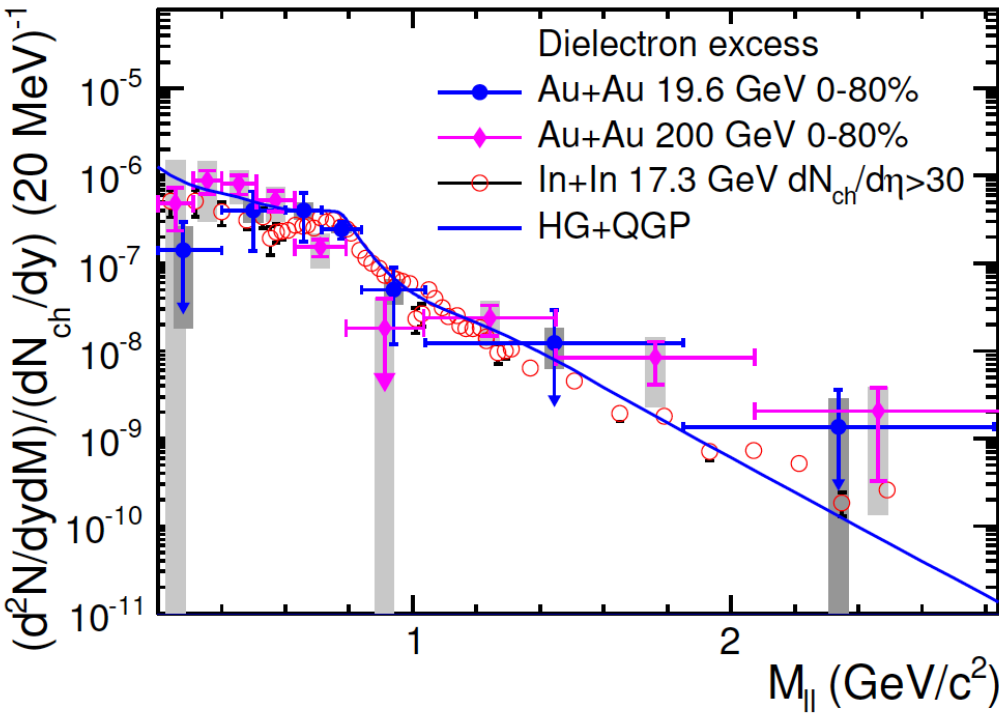
– PHSD model predicts enhanced contributions at lower energies (<19.6 GeV).

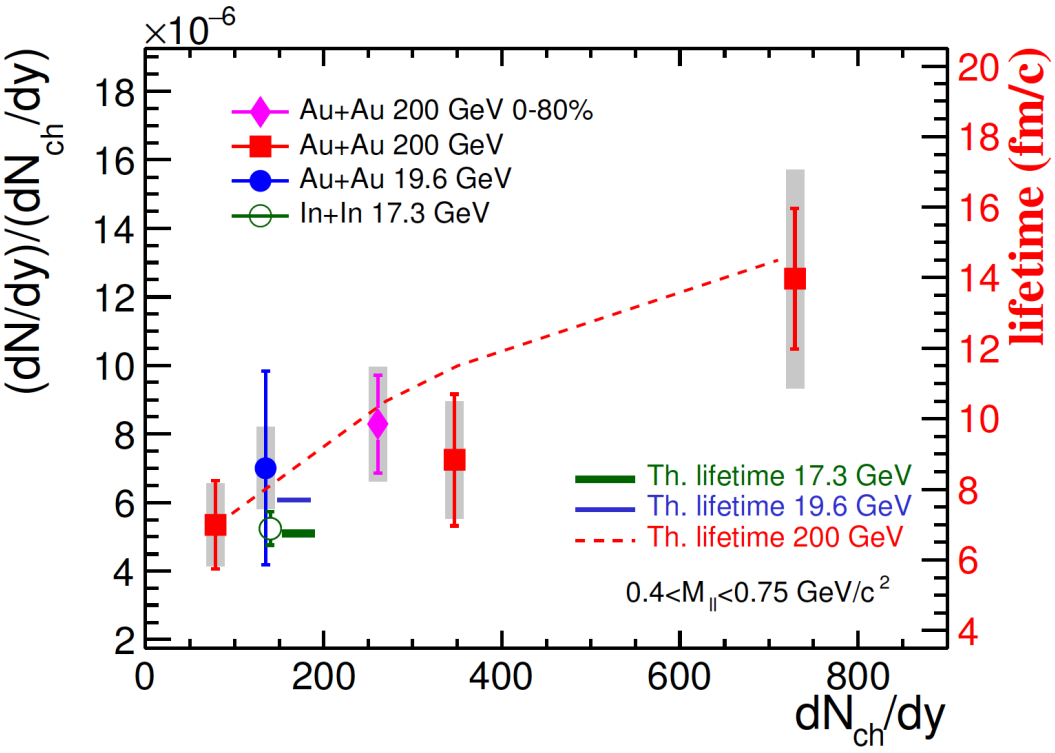
†Model: Rapp & Wambach, priv. communication;
Adv. Nucl.Phys. 25, 1 (2000) Phys. Rept. 363, 85 (2002)



Energy dependence of dilepton excess

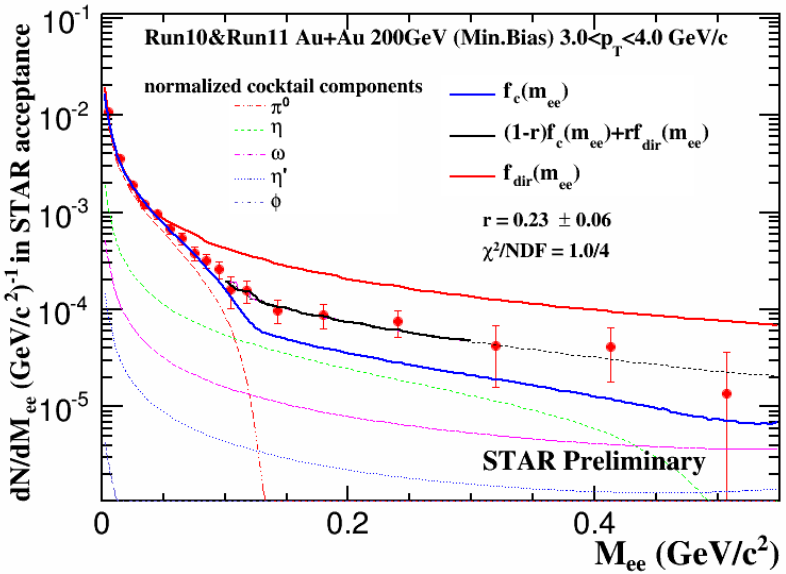
arXiv:1501.05341





- 19.6 GeV consistent with SPS results.
- Excess shape at low mass well described by rho in-medium broadening.
- Excess yields (after detector acceptance correction) are sensitive to early system lifetime: integrated over duration at the high temperature.

Direct virtual photon

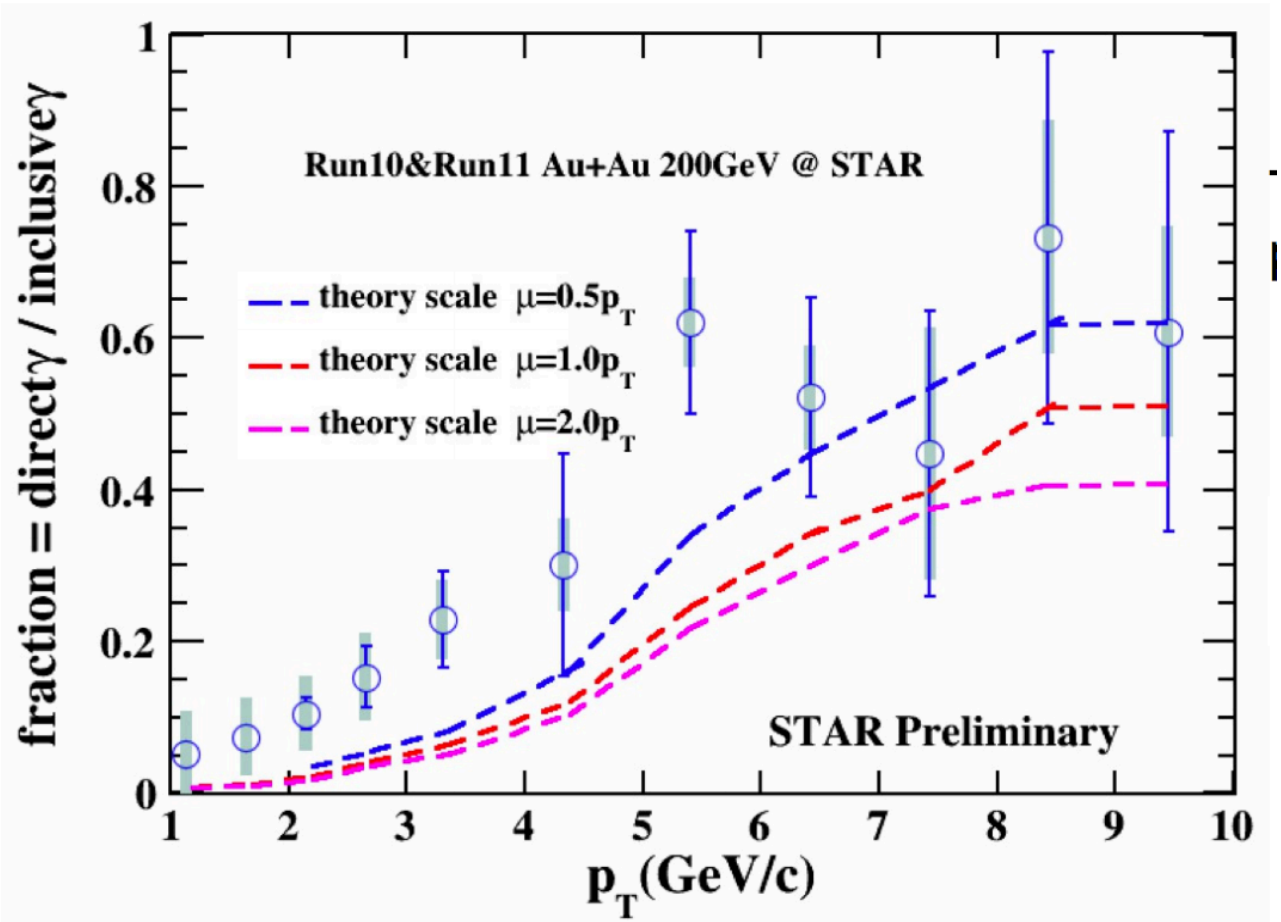


The curves represent NLO pQCD prediction:

$$\frac{T_{AA} d\sigma_{\gamma}^{NLO}(p_T)}{dN_{\gamma}^{inclusive}(p_T)}$$

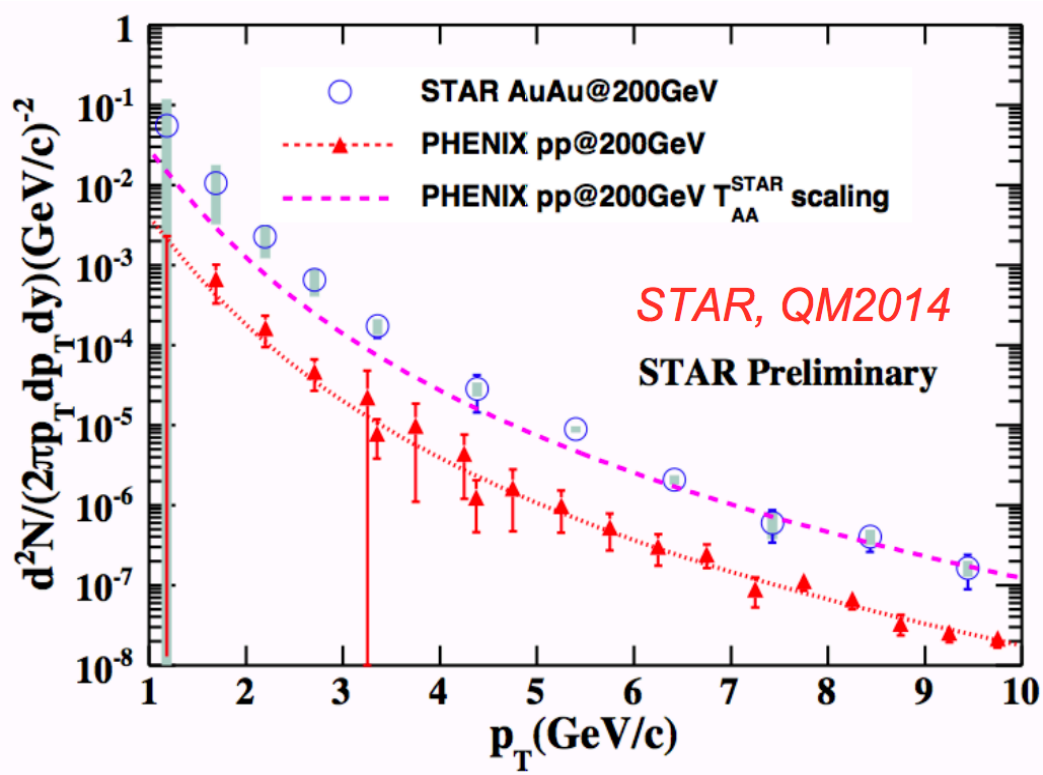
L. E. Gordon and W. Vogelsang, Phys. Rev. D 48, 3136 (1993).
PHENIX Collaboration, Phys.Rev.L 98, 012002 (2007).
PHENIX Collaboration, Phys.Rev.L 104,132301(2010).

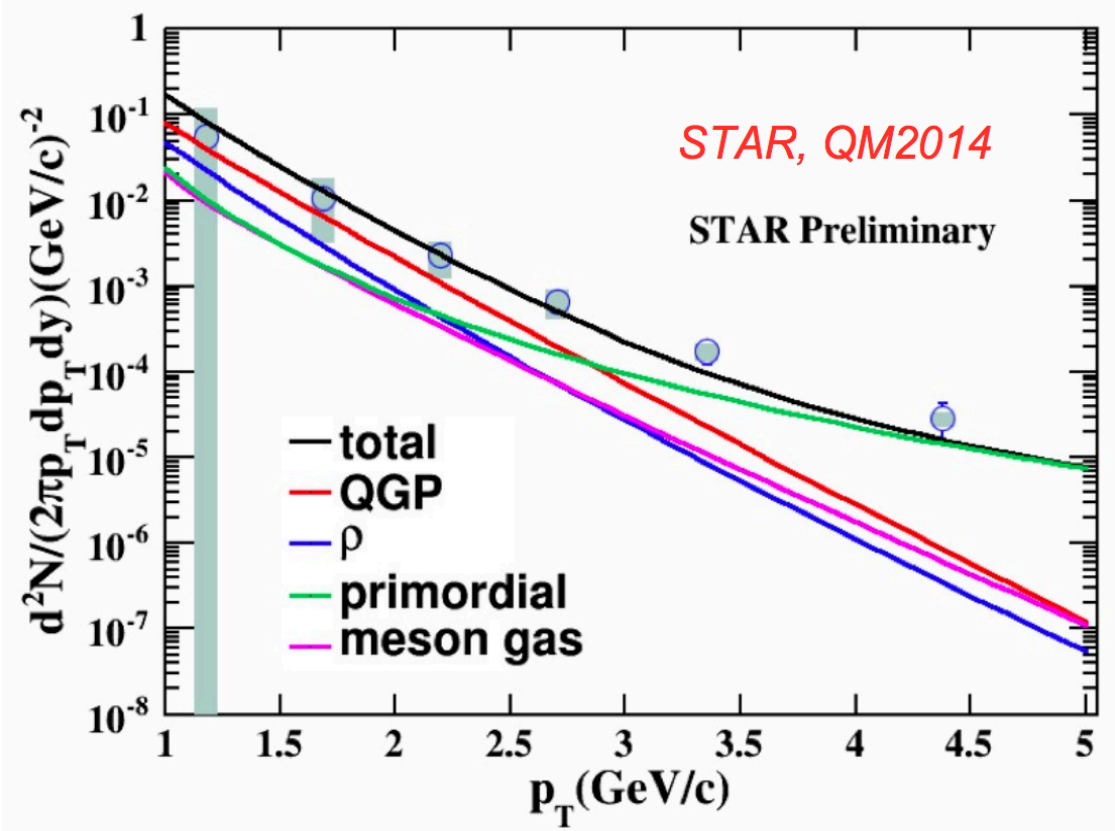
STAR, QM2014



Compare to the p+p reference, an excess is observed up to 4 GeV/c.

Direct virtual photon yield





In high p_T region (5~10 GeV/c):
– consistent with T_{AA} scaled function fit to PHENIX p+p data.
In low p_T region:
– an excess is observed in p_T range 2~4 GeV/c.

Rapp's model prediction:
➔ Including QGP, ρ, meson gas, and primordial production contributions.
➔ Well describing the low p_T excess in our data within uncertainty.

Summary

- Dielectron productions measured in p+p 200 GeV and Au+Au from 19.6 to 200 GeV.
  - Dependences of LMR excess on kinematics, baryon densities, and energies have been studied.
  - Provide insights into vector meson in-medium modifications by comparing with model calculations.
  - Possible charm decorrelation in central Au+Au 200 GeV.

- Direct virtual photon measured in Au+Au at 200 GeV
  - High p_T yield consistent with T_{AA} scaled pQCD expectation.
  - Low p_T excess indicates thermal contribution from hot medium.

Backup

- Relation between real photon yield and the associated e^+e^- pairs:

$$\frac{d^2N_{ee}}{dM} = \frac{2\alpha}{3\pi}\frac{L(M)}{M}S(M,q)dN_\gamma$$

✓ pass STAR acceptance
✓ normalize to 0-30MeV/c^2

cocktail normalized to 0-30MeV/c^2

$$(1-r)\,f_c + r\,f_{dir}$$

cocktail component

direct virtual photon component

$$L(M) = \sqrt{1-\frac{4m_e^2}{M^2}}\left(1+\frac{2m_e^2}{M^2}\right)$$

$$S(M,q) = \frac{dN_{\gamma^*}}{dN_\gamma}$$

Direct photons can be measured by the associated dielectron production.

S = 1 => direct virtual photon ($p_T \gg M$, $M \gg m_e$)

: two-component fit to dielectron continuum.

$$r = \frac{yield\ of\ direct\ virtual\ photon}{yield\ of\ inclusive\ photon}$$