The low and intermediate mass dilepton and photon results

Outline:

- Introduction
- New results on dileptons
- New results on thermal photons
- Future measurements
- Summary

Penetrating probe of the hot, dense medium

Low mass dileptons (M_{ll}<1.1 GeV/c^2) (Spectrum and v_n versus M_{ll}, p_T)	vector meson in-medium modifications, link to Chiral Symmetry Restoration
Intermediate mass dileptons (1.1<M_{ll}<3.0 GeV/c^2) (Spectrum and v_n versus M_{ll}, p_T)	QGP thermal radiation, charm correlation modification.
Thermal photons (p_T<4 GeV/c) (p_T spectrum and v_n)	QGP thermal radiation, hadron gas thermal radiation

Energy and centrality dependence → Constrain T_0, t_0, lifetime, and density profile …

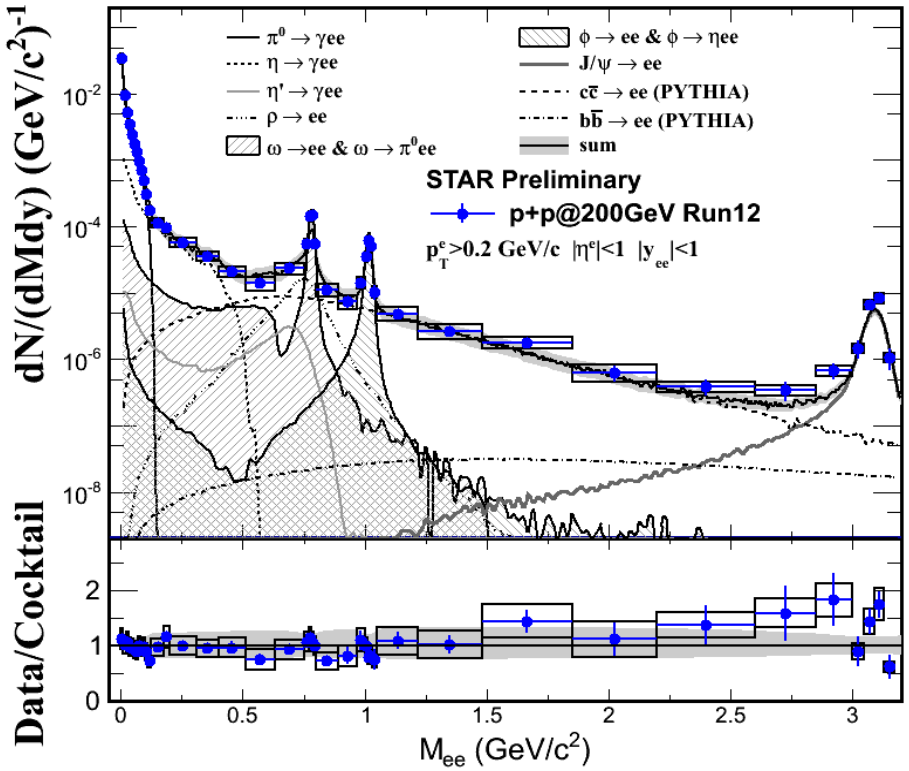
The measurements

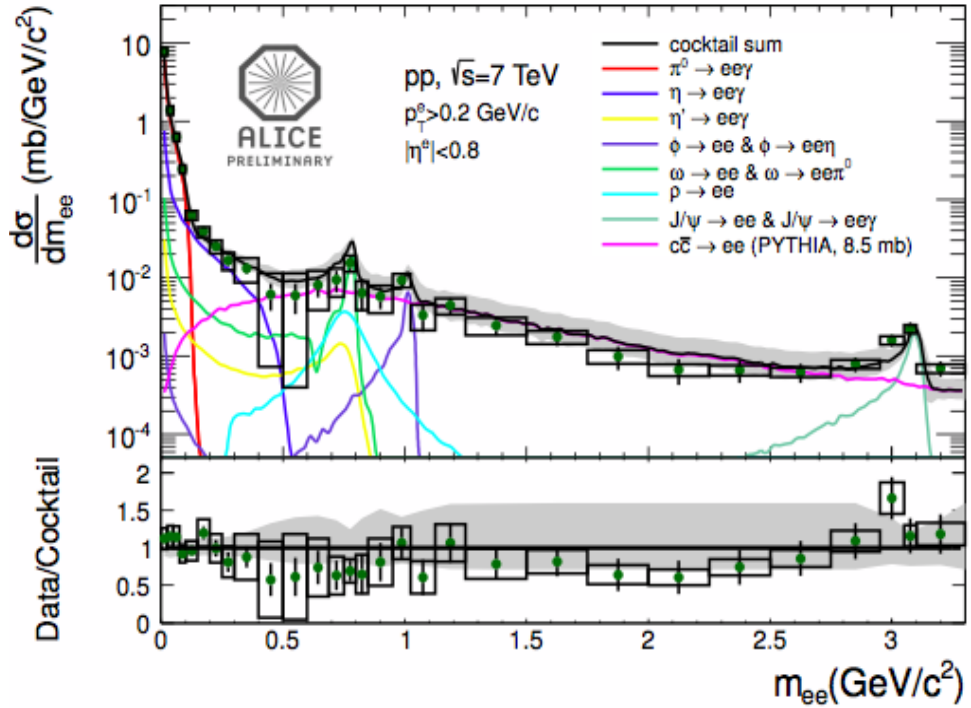
Experiment	dilepton	direct photon	S/B, purity, acceptance*
PHENIX	dielectron	internal and external conversion p_T>0.4 GeV/c	1/300, 70% in central, p_T>0.2 GeV/c, |η|<0.35
STAR	dielectron	internal conversion p_T>1 GeV/c	1/250, 93% in central, p_T>0.2 GeV/c, |η|<1
ALICE	dielectron	external conversion p_T>1 GeV/c	3-4%in p+p, 1.5-2% in p+Pb, 99% in p+p, 93% in Pb+Pb p_T>0.2 GeV/c, |η|<0.8
NA60	dimuon		1/7 for <S/B> in the whole mass region in In+In collisions without centrality cut.

***S/B for inclusive dileptons at M_{ll}=0.5 GeV/c^2, purity and acceptance for electrons.**

For HADES results, see T. Galatyuk for details.

Dielectron measurements in p+p collisions



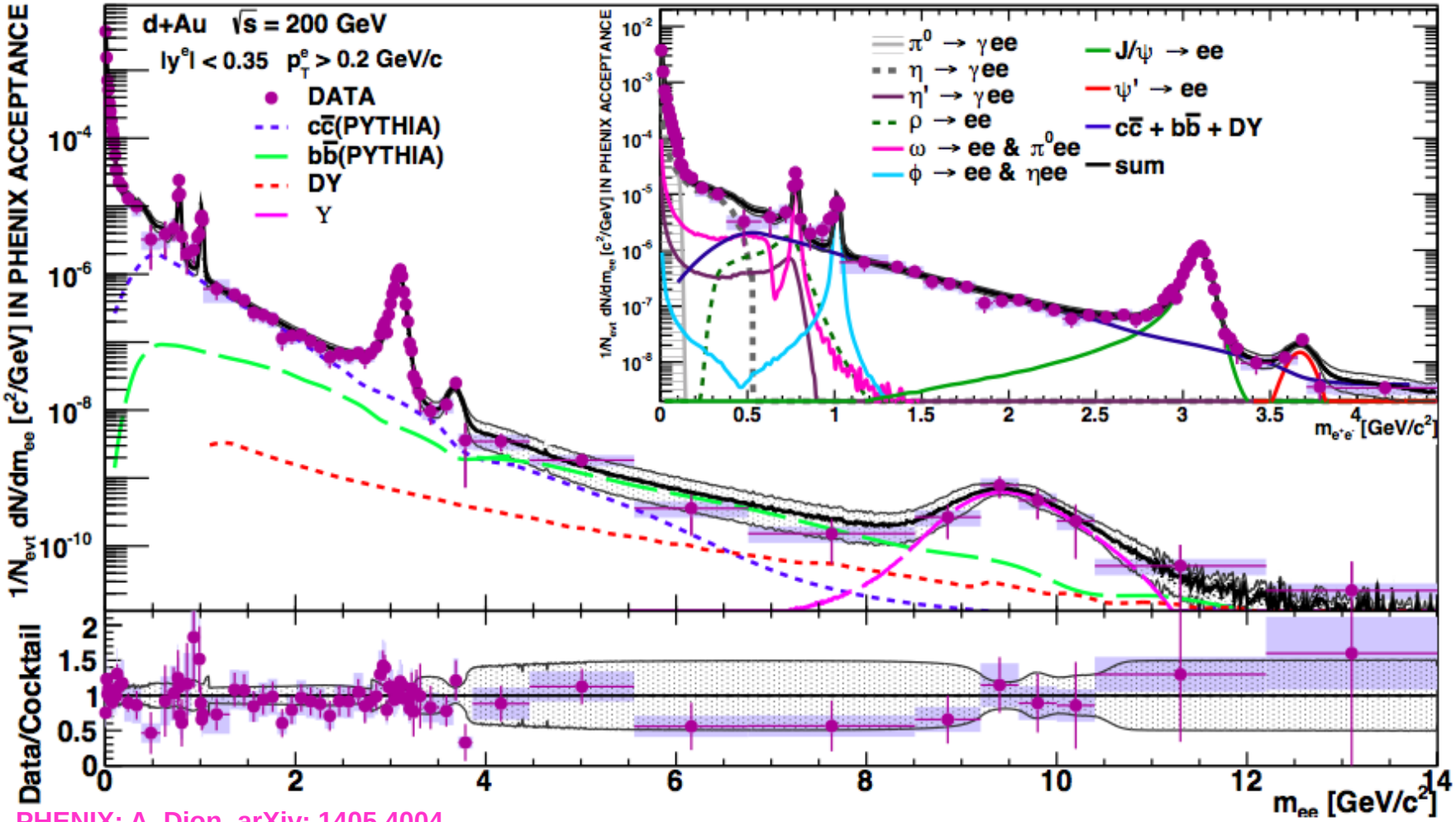


STAR: C. Yang, Y. Guo
ALICE: M. Kohler

Charm correlation contribution increases from RHIC to LHC at $0.4<M_{ee}<0.5$ GeV/c^2.

The cocktail simulation with expected hadronic contributions, is consistent with data in p+p collisions.

Dielectron measurements in d+Au collisions

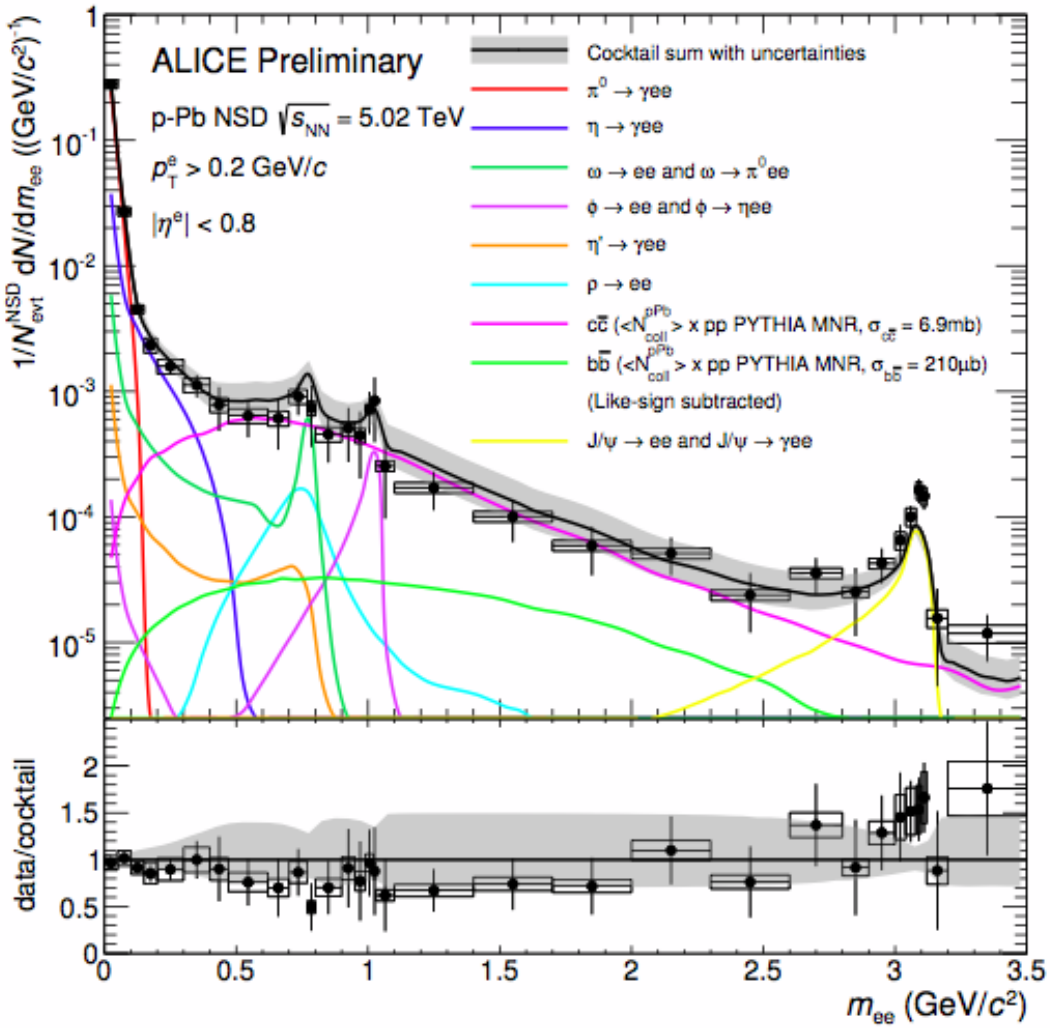


PHENIX: A. Dion, arXiv: 1405.4004

Hadronic cocktail is consistent with data in d+Au collisions.

Obtained bbbar cross section per NN at 200 GeV: σ_{bbbar}= 3.4 ± 0.28 ± 0.46 μb.

Dielectron measurements in p+Pb collisions

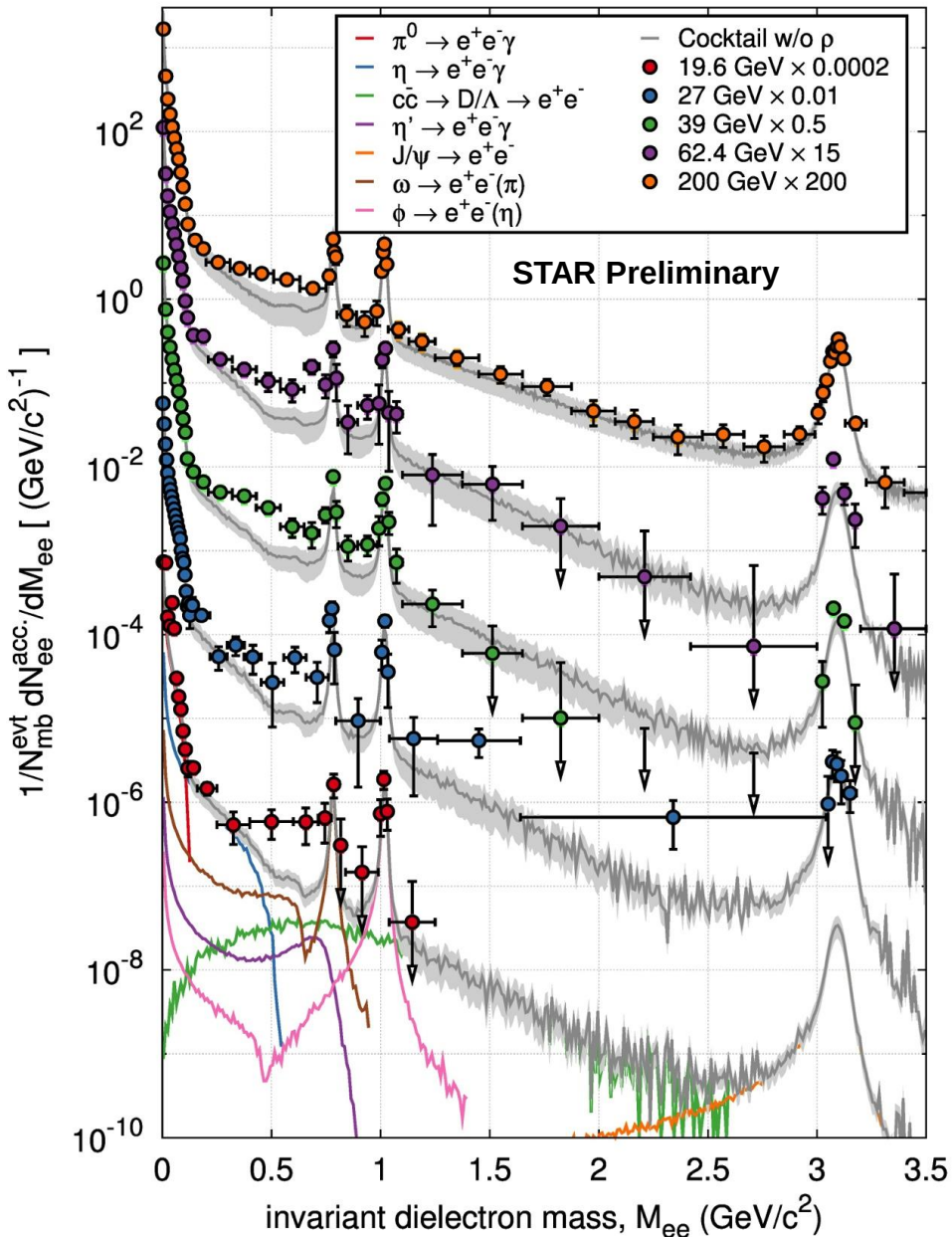


ALICE: M. Kohler

Hadronic cocktail is consistent with data in p+Pb collisions.

There is no medium radiation observed in p(d)+A collisions.

Energy dependence of di-electron spectra

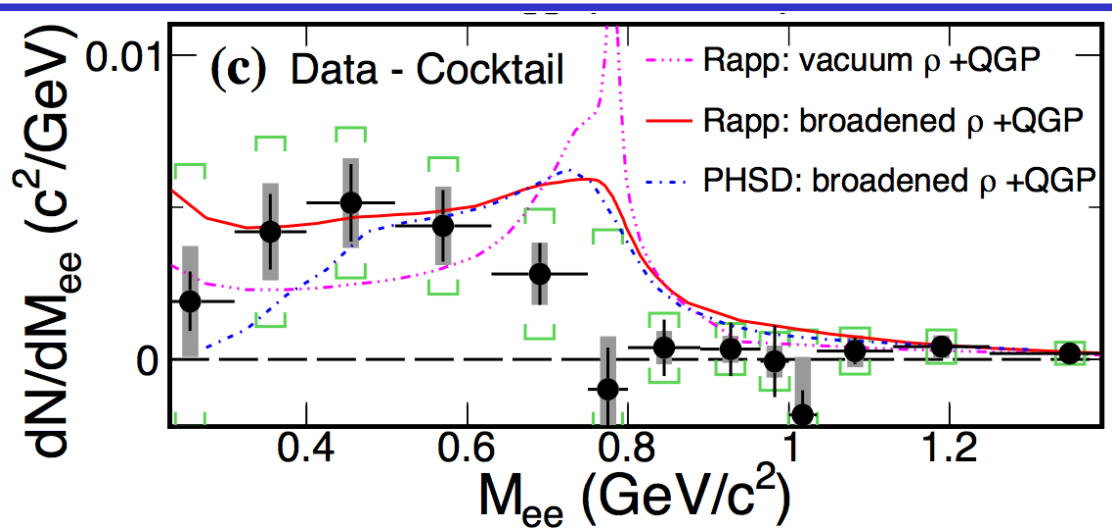


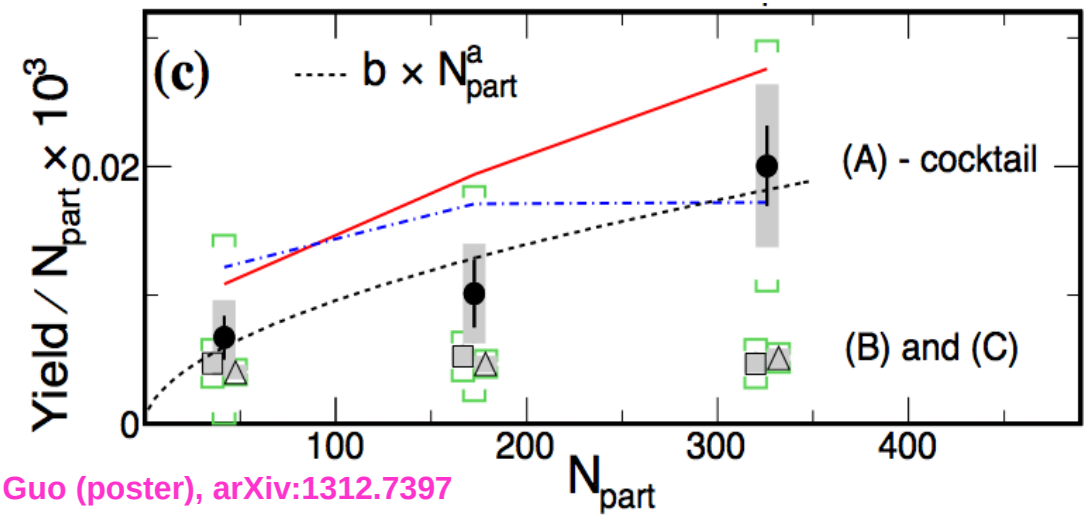
STAR results: systematically study the di-electron continuum from 19.6, 27, 39, 62.4 and 200 GeV.

Low mass excess is observed for all the energies.

STAR: P. Huck, C. Yang, J. Butterworth, Y. Guo

Excess di-electron spectra

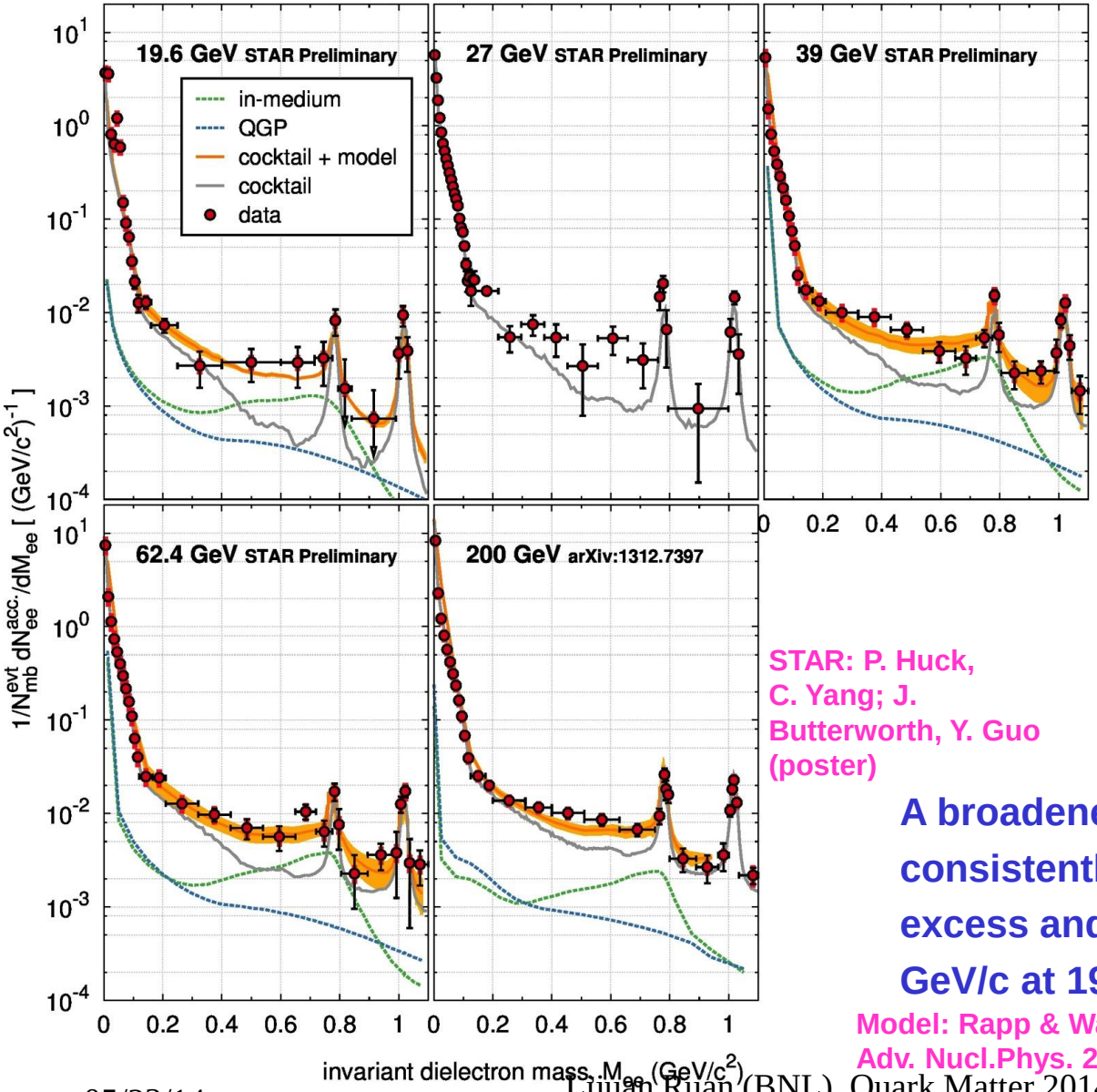


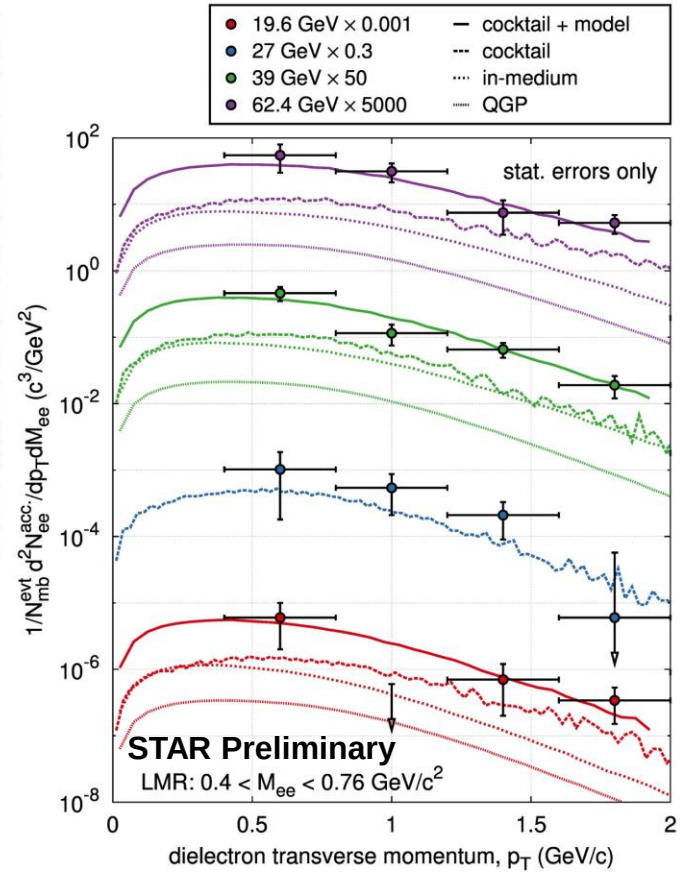


STAR: C. Yang, Y. Guo (poster), arXiv:1312.7397

Excess dielectron mass spectrum in the mass region 0.3-0.76 GeV/c^2 in 200 GeV Au+Au collisions follows Npart$^{1.54\pm0.18}$ dependence.

Energy dependence of di-electron spectra





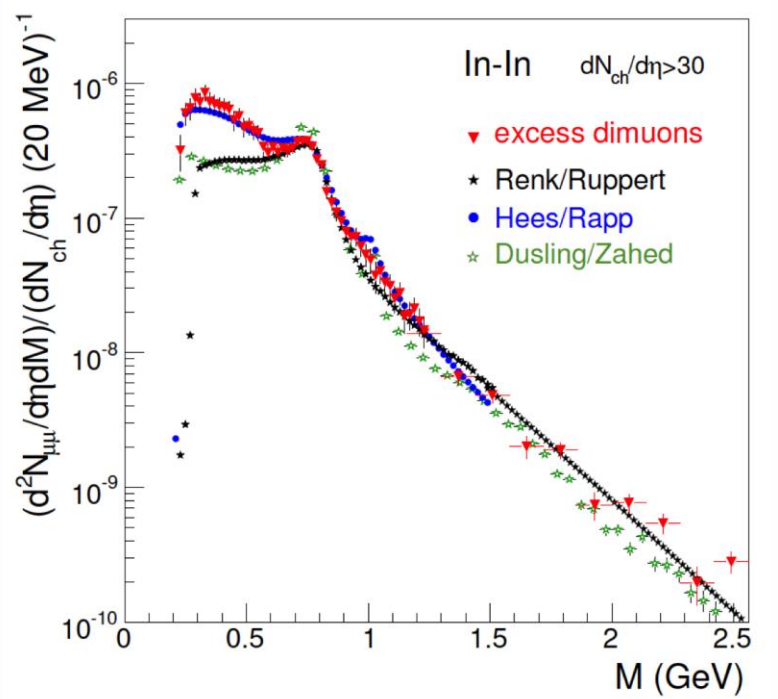
STAR: P. Huck, C. Yang; J. Butterworth, Y. Guo (poster)

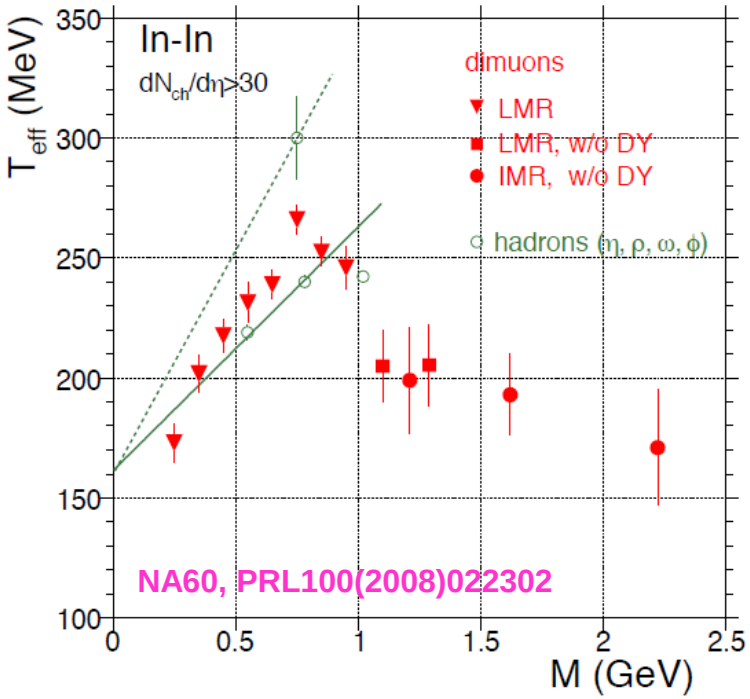
A broadened ρ spectrum function consistently describe the low mass excess and its p_T dependence up to 2 GeV/c at 19.6, 39, 62.4 and 200 GeV.

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

NA60 precise dimuon measurement

NA60, AIP. Conf. Proc. 1322 (2010) 1-10



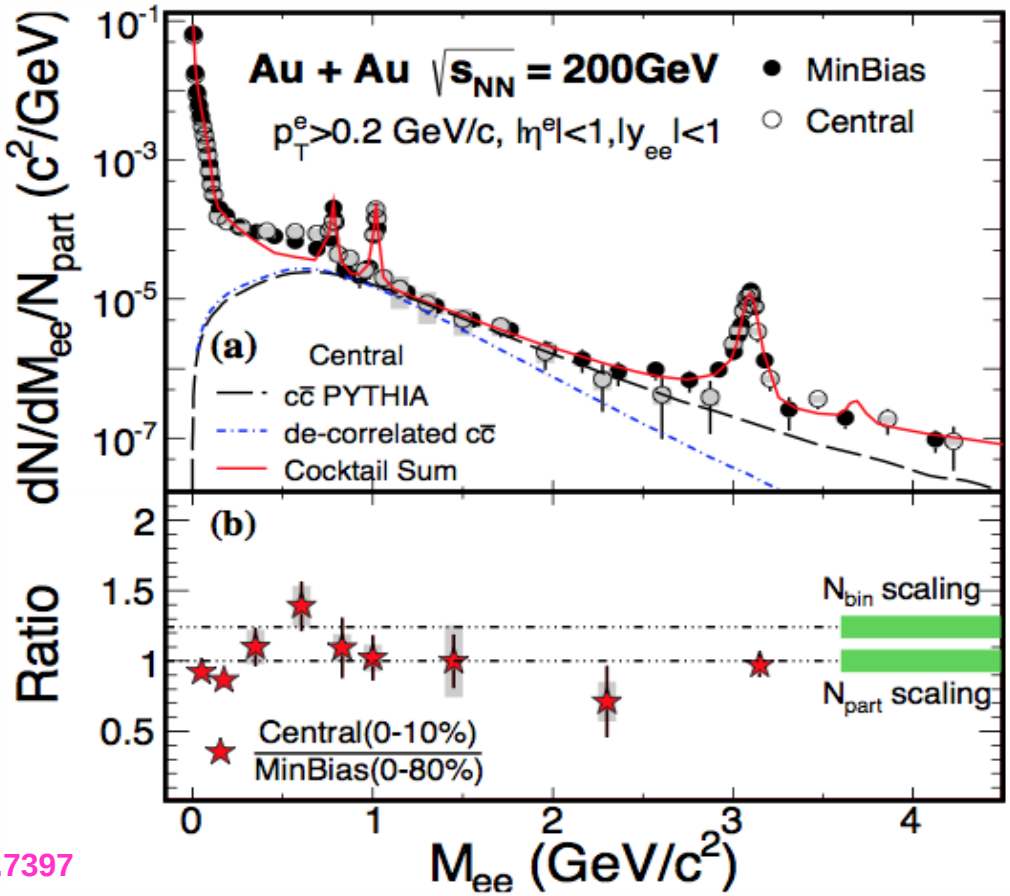


NA60 at 17.3 GeV: small charm correlation contribution, vertex detector to reject the charm background, no muon p_T cut.

Intermediate mass region: measure the temperature of hot, dense medium, determine whether mass spectrum can be smoothly matched with low-mass region. No structure in the mass spectrum would imply Chiral Symmetry Restoration.

RHIC energy scan: charm contribution varies when energy is changed, need measure and subtract charm contribution.

Towards intermediate mass region

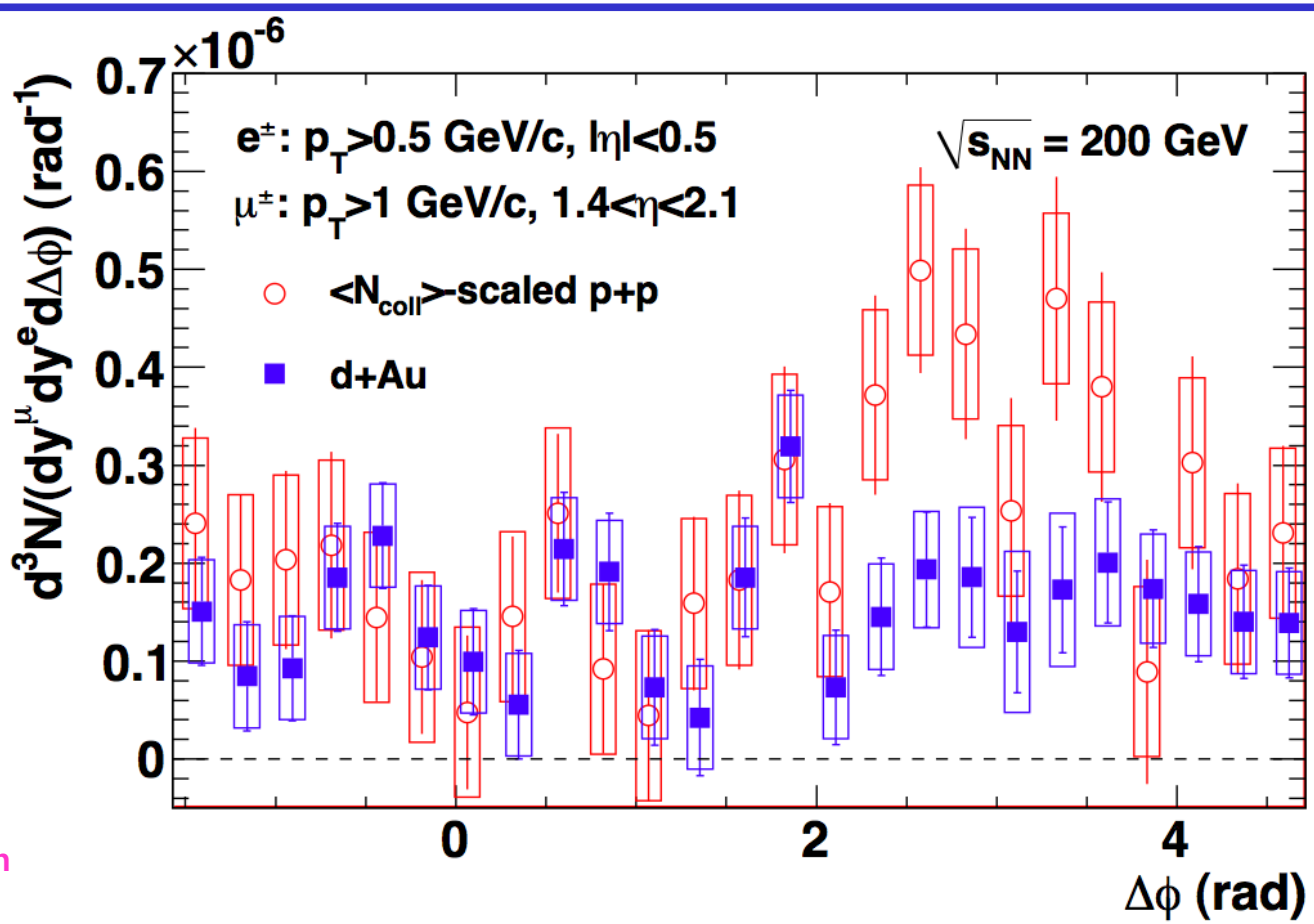


STAR: Y. Guo, arXiv:1312.7397

Need independent measurements (e.g. e-muon) of the charm correlation contribution to dilepton continuum in order to access the possible signature of QGP thermal radiation.

e-muon correlation with the Muon Telescope Detector in 2014.

e-muon correlation

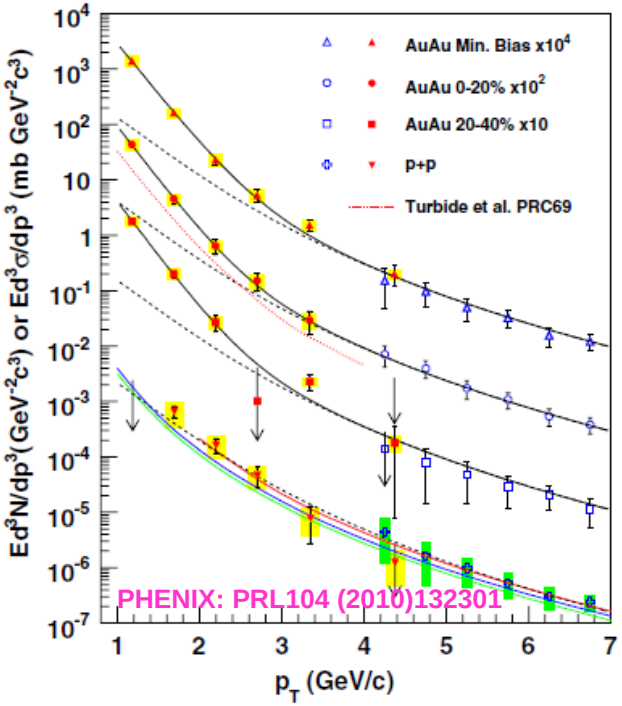


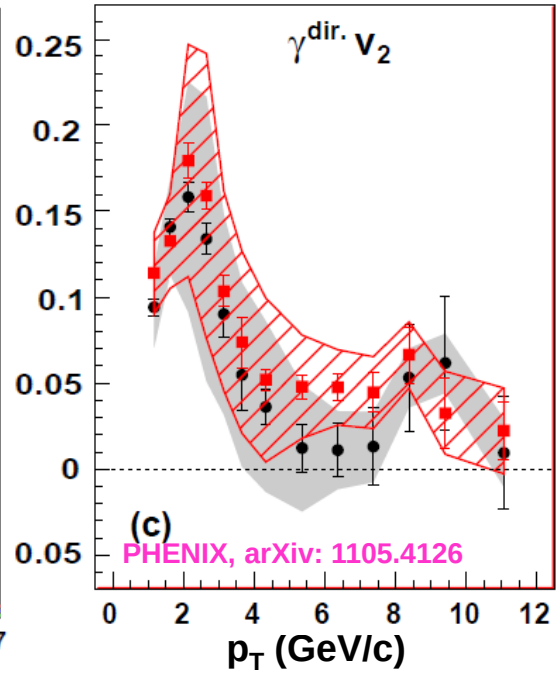
PHENIX: A. Dion

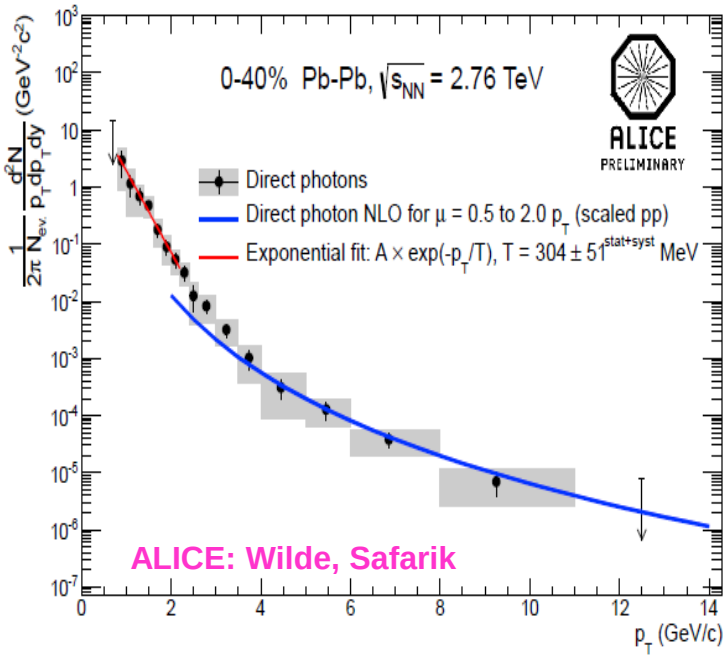
e-muon (mid-forward rapidity) correlations in d+Au and p+p collisions at 200 GeV.

How to connect this mid-forward e-muon correlation to mid-rapidity dilepton physics, need further investigation.

Direct photon spectra and elliptic flow v_2 at QM2012



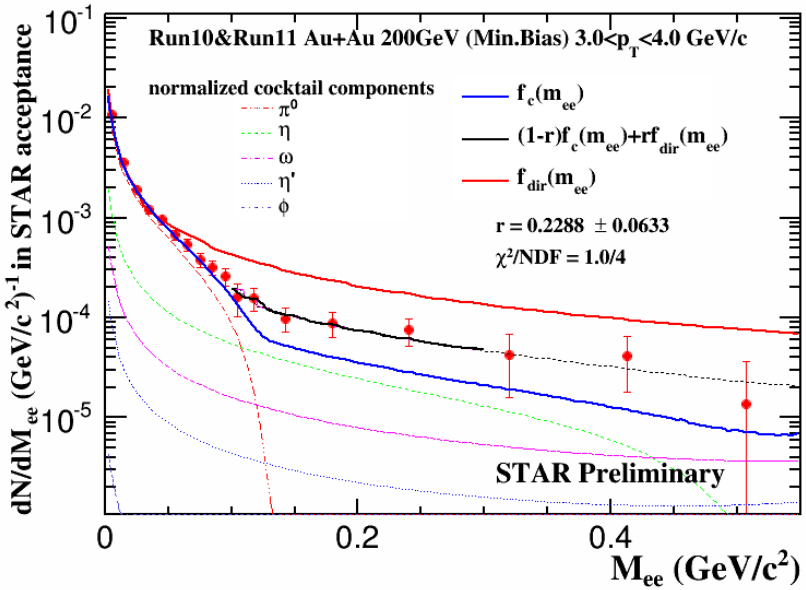


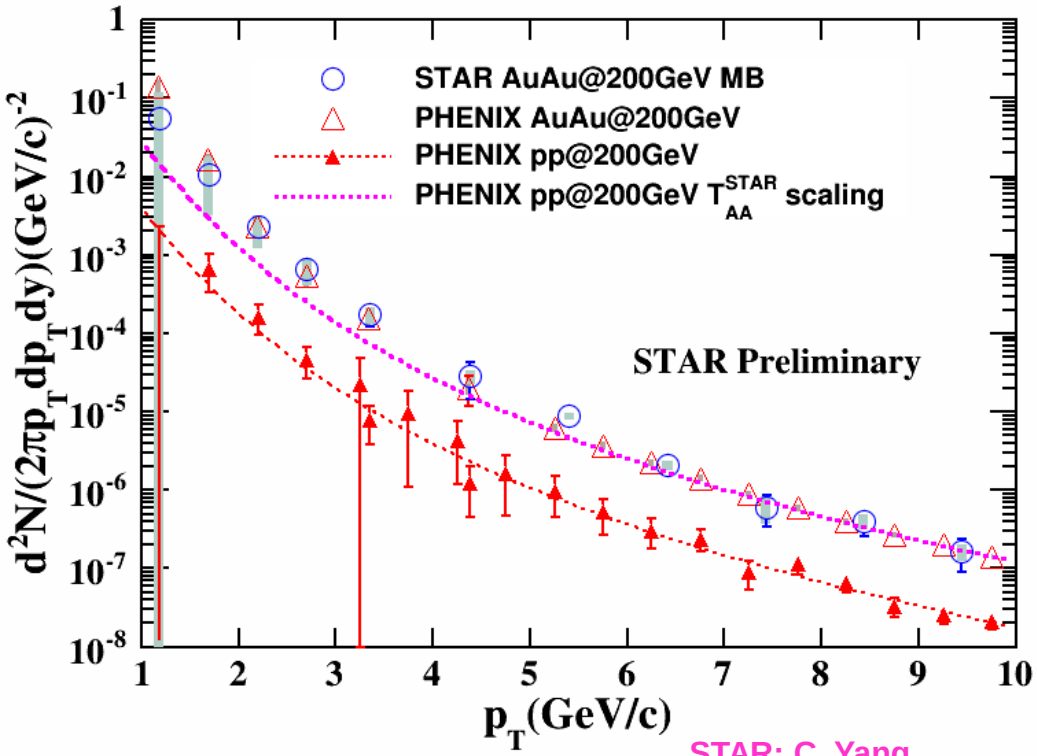


- Low p_T direct photon elliptic flow measurement could provide direct constraints on QGP dynamics (η/s, T, t_0…).
- Excess of direct photon yield over p+p: T_{eff}=221 ± 19 ± 19 MeV in 0-20% Au+Au;

  substantial positive v_2 observed at p_T<4 GeV/c.
- Excess of direct photon yield over p+p at p_T<4 GeV/c: T_{eff}=304 ± 51 MeV in 0-40% Pb+Pb.

Direct virtual photon results from STAR

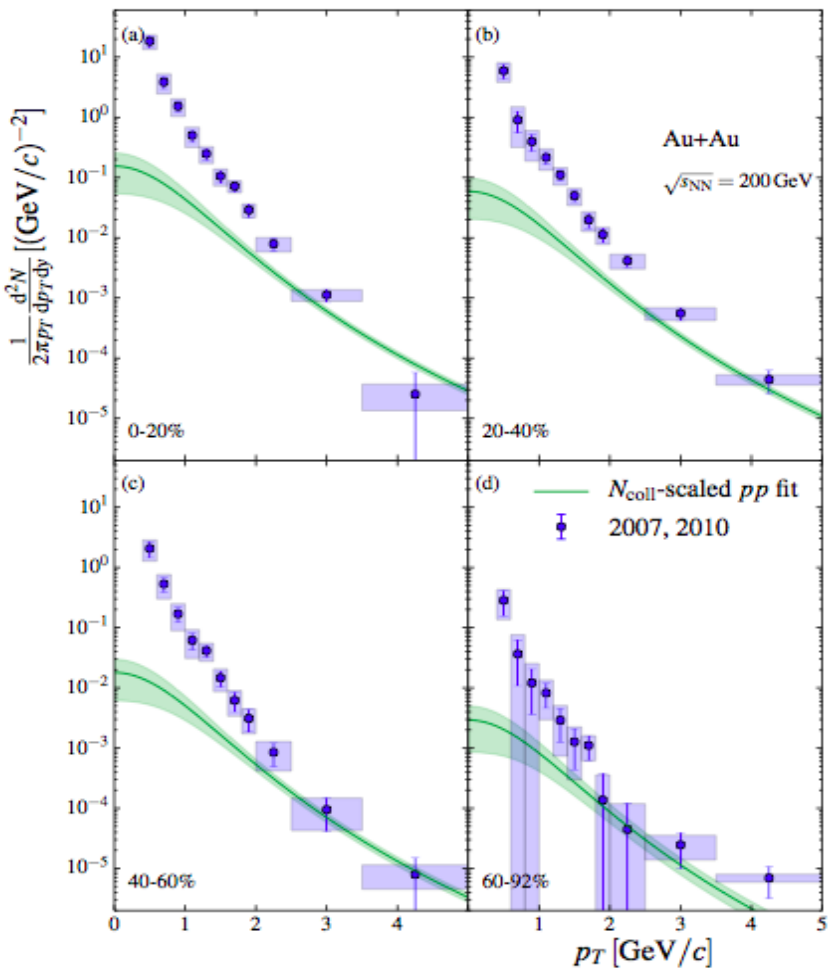


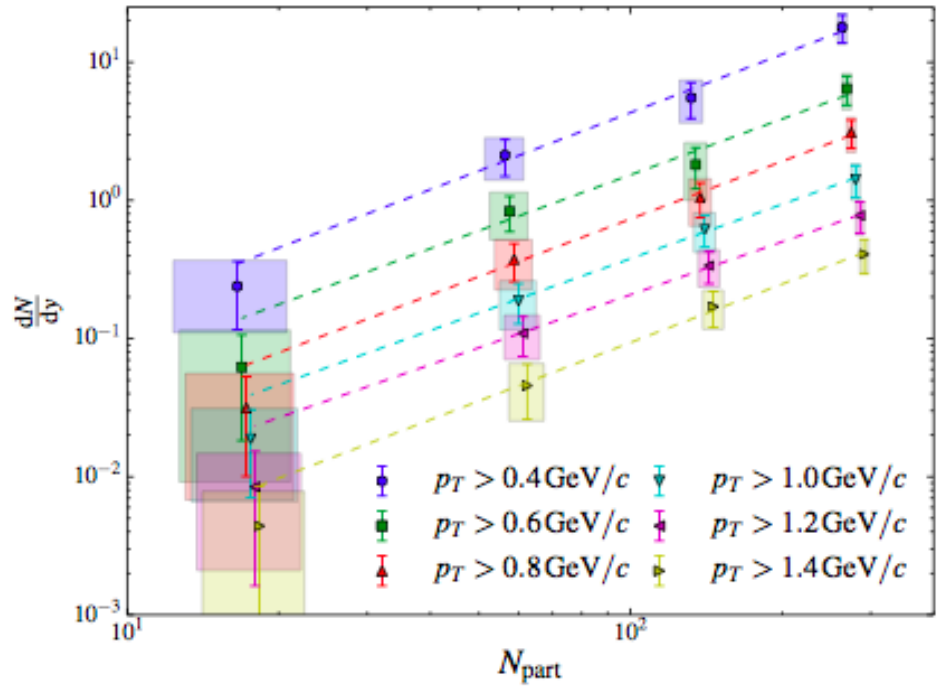


STAR: C. Yang

- Direct virtual photon spectrum up to 10 GeV/c: an excess is observed compared to N_{bin} scaled p+p expectations at 1<pT<4 GeV/c.
- low p_T η measurement is crucial to reduce systematic uncertainties.

Direct soft photon spectra from PHENIX

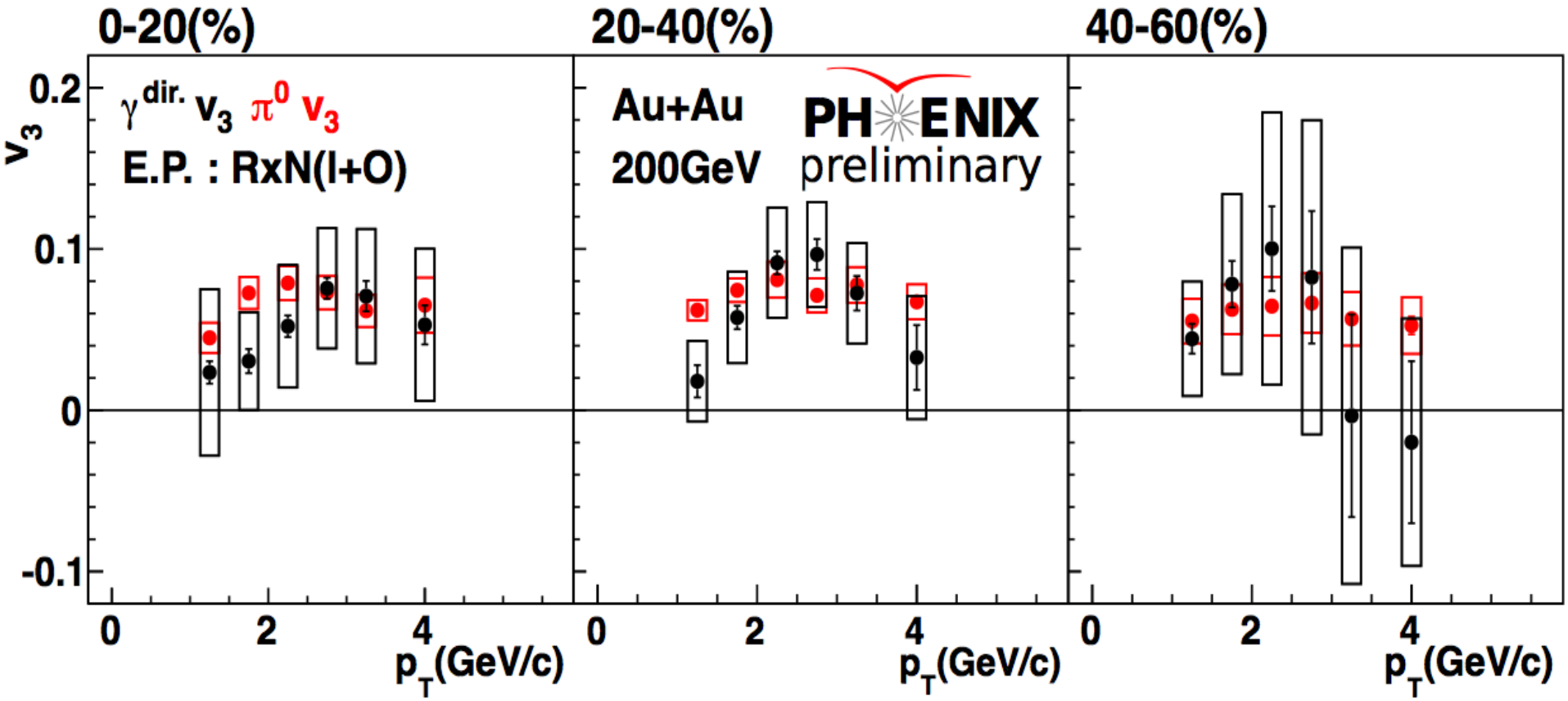




PHENIX, S. Mizuno, arXiv: 1405.3940

- Direct photon spectrum down to 0.4 GeV/c: T_{eff} from the excess p_T spectrum, has no centrality dependence.
- The excess follows $N_{part}^{1.48 \pm 0.08 \pm 0.04}$ dependence.

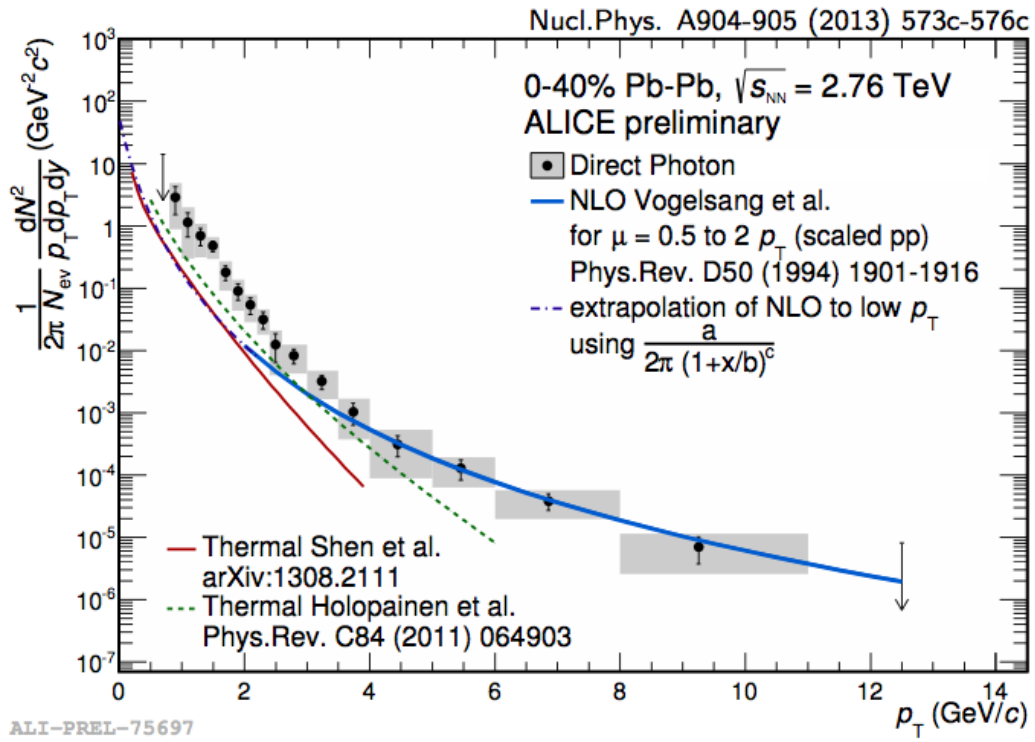
Direct photon v_3

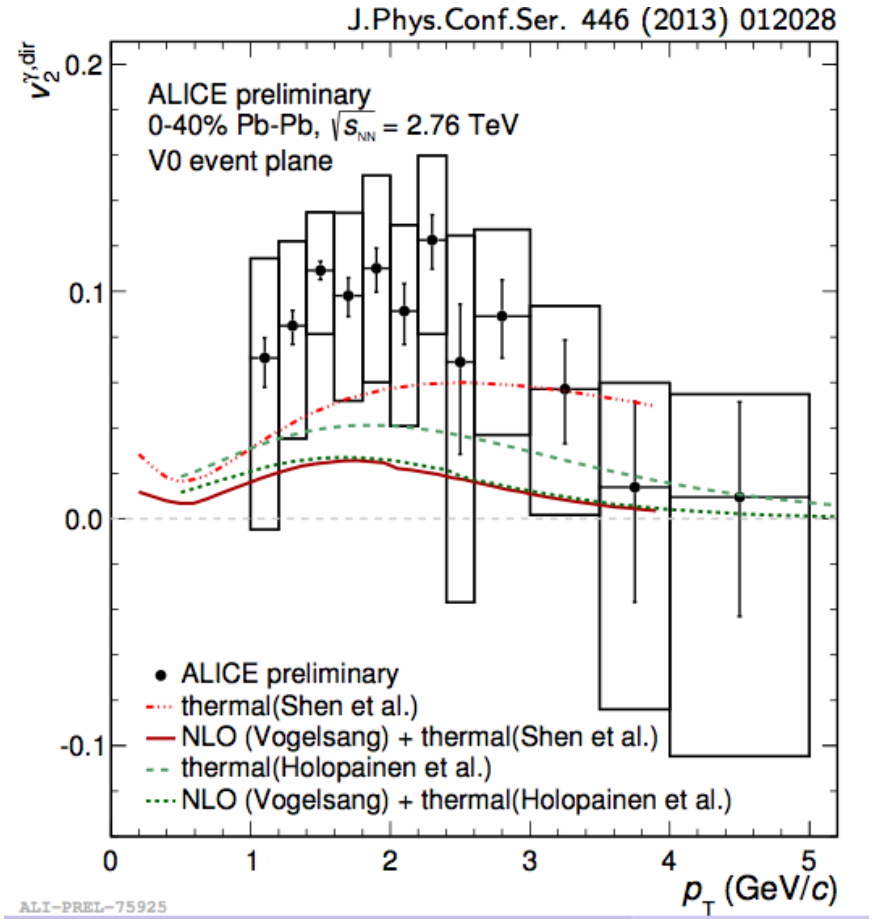


PHENIX: S. Mizuno

- Direct photons have a significant v_3 as pions in 200 GeV Au+Au collisions.

Direct photon in Pb+Pb





ALICE: F. Bock

- The systematic uncertainties under critical assessment for p_T-spectra and v_n.
- Need low p_T p+p reference measurements.

To understand the origin of the excess photons

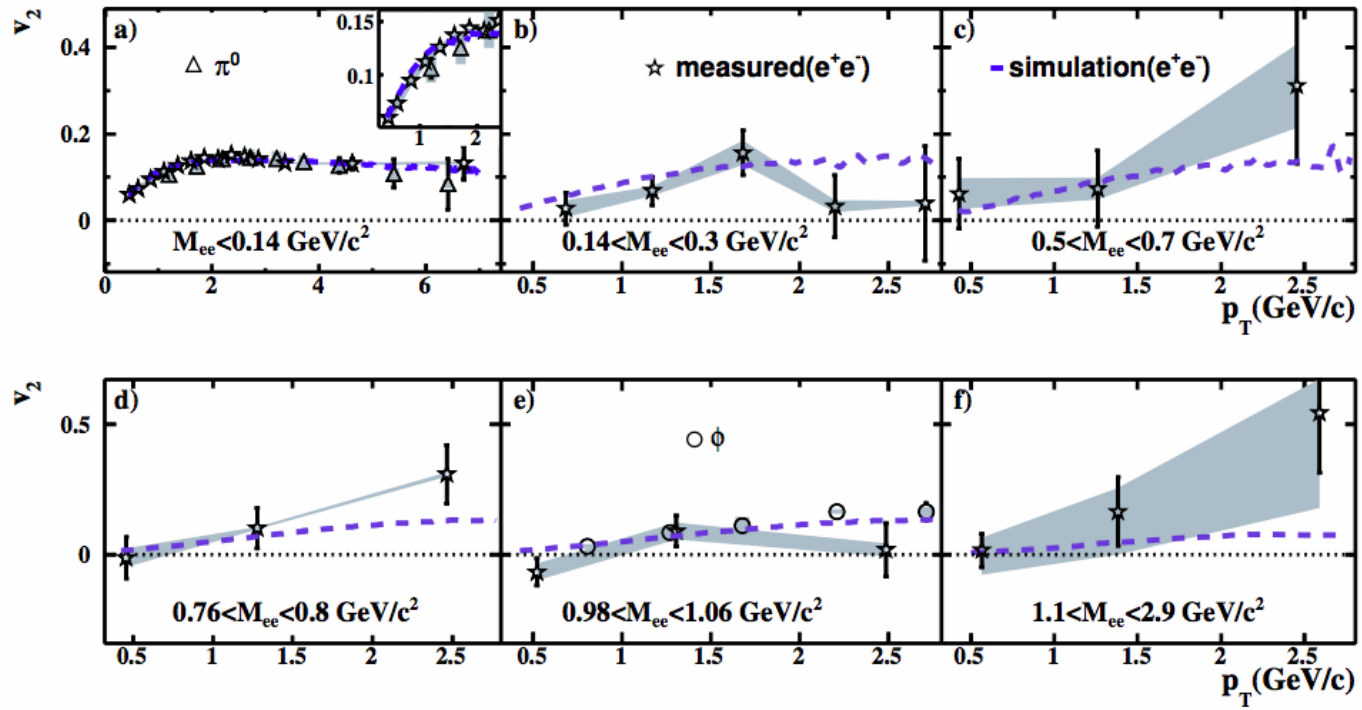
The critical components for the excess photons in A+A are:

- Background subtraction of decayed photons or two-component fit to the dielectron spectrum.
- p+p baseline measurement.

Next steps:

- Measure η p_T-spectrum at p_T<2 GeV/c to constrain the cocktail for the direct virtual photon measurement.
- Improve π^0, η measurements if possible.
- Measure p+p reference for p_T<2 GeV/c.
- Measure dilepton v_2 versus p_T & M_{ll}: probe the properties of the medium from hadron-gas dominated to QGP dominated. (R. Chatterjee, D. K. Srivastava, U. Heinz, C. Gale, PRC75(2007)054909)

Dielectron v_2 at 200 GeV Au+Au

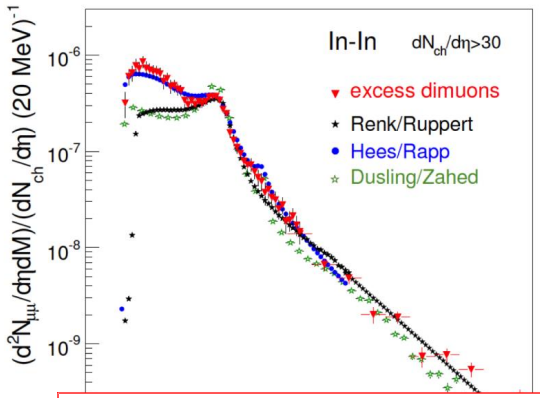


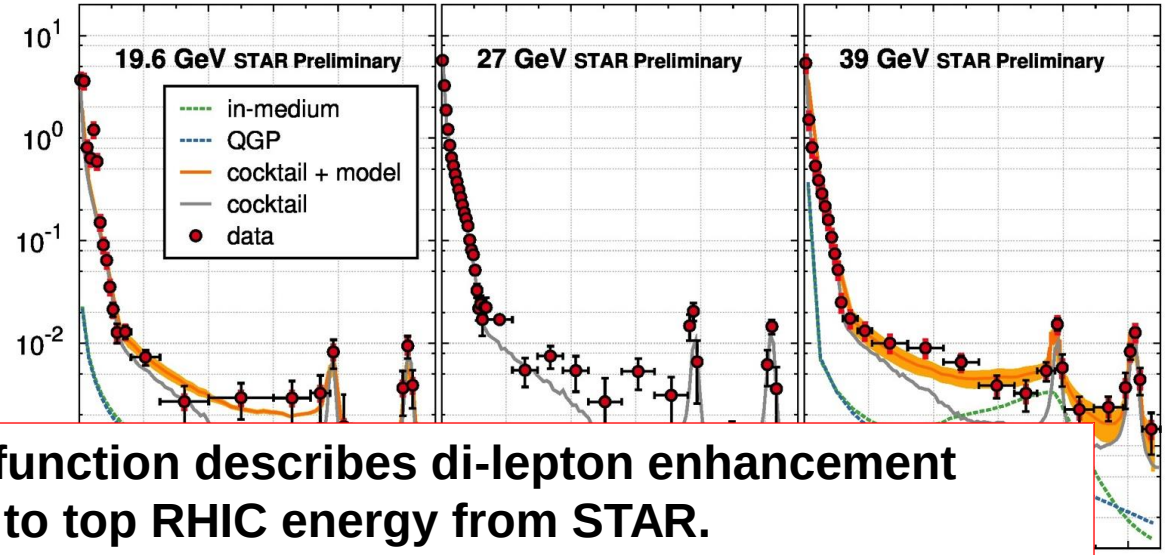
- **Cocktail simulation is consistent with the measured inclusive di-electron v_2 at low and intermediate mass region.**
- **Cocktail need to be subtracted: require much more data and independent measurement of ccbar contribution to dielectron v_2.**
- **Alternative approach: e.g. dimuon channel in the future.**

STAR: arXiv: 1402.1791

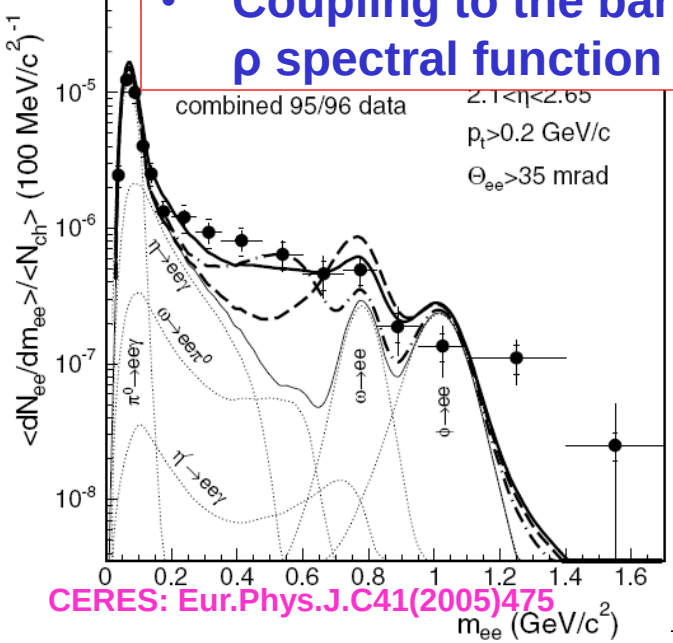
A tool to study Chiral Symmetry Restoration

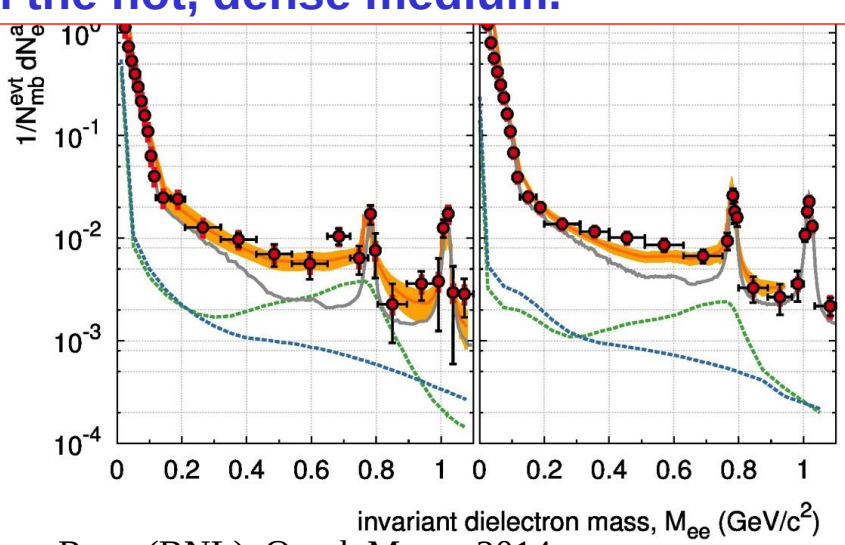
NA60, AIP. Conf. Proc. 1322 (2010) 1-10





- **A broadened spectral function describes di-lepton enhancement from SPS at 17.3 GeV to top RHIC energy from STAR.**
- **Coupling to the baryons plays an essential role to the modification of ρ spectral function in the hot, dense medium.**

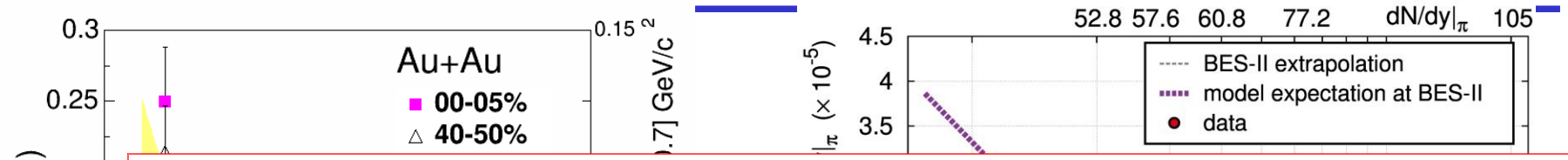




STAR: P. Huck, C. Yang, J. Butterworth, Y. Guo

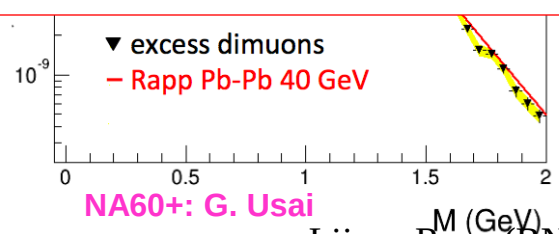
CERES: Eur.Phys.J.C41(2005)475

A tool to study Chiral Symmetry Restoration

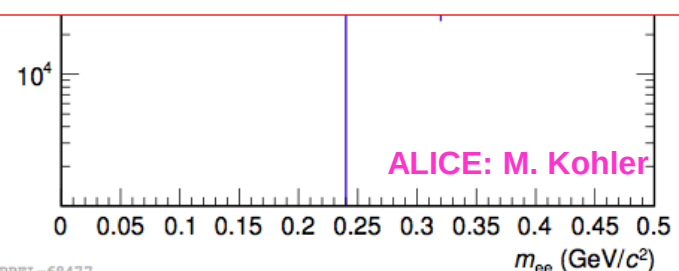


- **17.3 GeV to 200 GeV: examine in-medium modification effect on the temperature and system evolution considering that the total baryon density is nearly constant.**
- **2-20 GeV: to examine total baryon density effect on the modification.**
- **To determine whether the intermediate-mass spectrum can be smoothly matched to low-mass region.**

Precise di-lepton measurements over a broad beam energy scan at FAIR, SPS, RHIC, and LHC provide a unique opportunity to study Chiral Symmetry Restoration.



NA60+: G. Usai



Summary

Dilepton and Photons: a broadened spectra function describes STAR's 19.6, 39, 62, and 200 GeV data and SPS dilepton data consistently. Precise dilepton measurements over a broad beam energy scan at FAIR, SPS, RHIC, and LHC provide a unique opportunity to study Chiral Symmetry Restoration.

- Dielectron excess mass spectrum in the mass region 0.3-0.76 GeV/c^2 in 200 GeV Au+Au collisions follows $N_{part}^{1.54\pm0.18}$ dependence.
- Soft photon excess follows $N_{part}^{1.48\pm0.08\pm0.04}$ dependence at $0.6<p_T<2$ GeV/c in 200 GeV Au+Au collisions.
- Photons show a significant v_2 and v_3 as pions, observed at 200 GeV Au+Au collisions.
- Models have difficulty to describe photon spectrum and v_n simultaneously.