System-size and energy dependence of di-electron excess invariant-mass spectra at STAR

Shuai Yang (for the STAR Collaboration)

University of Science and Technology of China

Brookhaven National Laboratory

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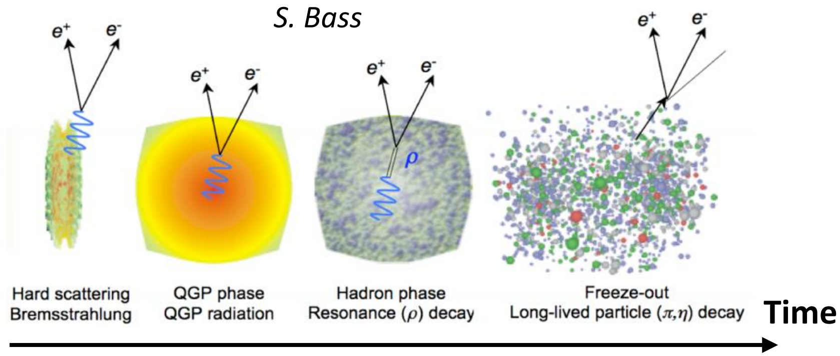
Outline

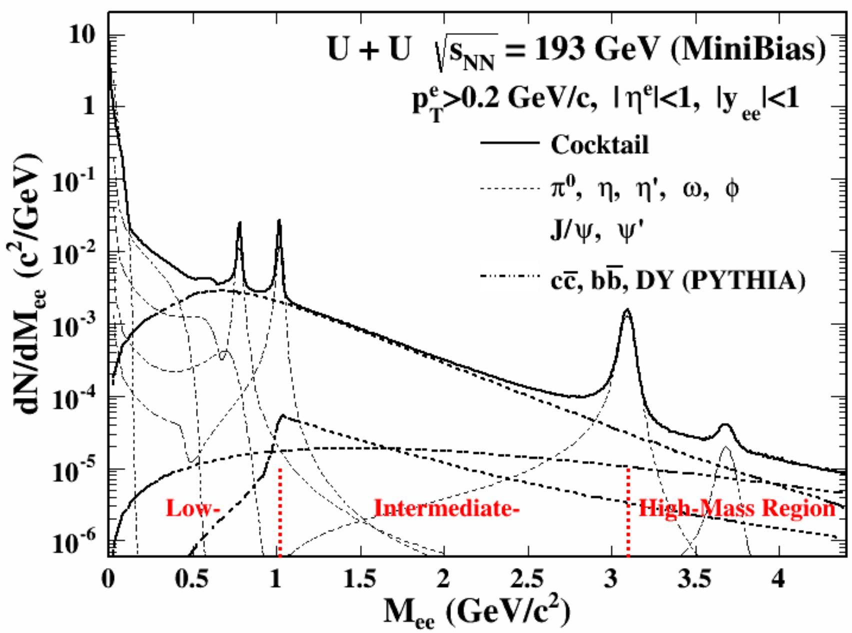
- Motivation
- STAR experiment
- Electron Identification
- Di-electron measurements
  - Di-electron mass spectra within STAR acceptance in U+U@193 GeV
    - Transverse momentum dependence
    - Centrality dependence
  - Energy and system-size dependence of acceptance corrected yield
    - AuAu@19.6, 27, 39, 62.4, 200 GeV
    - UU@193 GeV
- Summary

Di-lepton production



Di-leptons – penetrating probe

- Do not suffer strong interactions
- Bring direct information of the medium created in heavy ion collisions



Different physics of interest

- **Low Mass Region (LMR, $M_{ll} < M_{\phi}$)**
  - In-medium modifications of vector meson
- **Intermediate Mass Region (IMR, $M_{\phi} < M_{ll} < M_{J/\psi}$)**
  - QGP thermal radiation
  - Semi-leptonic decays of correlated charm
- **High Mass Region (HMR, $M_{J/\psi} < M_{ll}$)**
  - Drell-Yan process
  - Heavy quarkonia

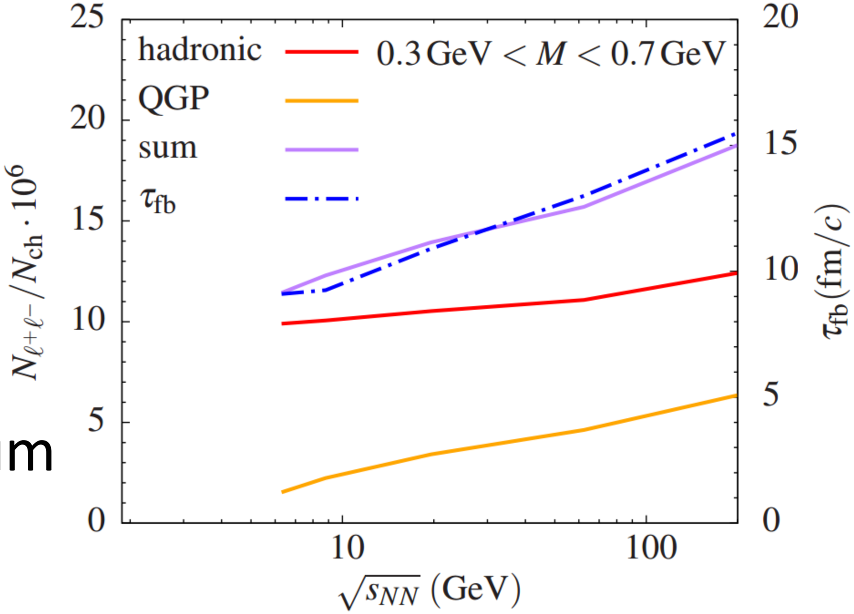
Di-electron physics @ STAR

- UU@193 GeV

D. Kikola, G. Odyniec, and R. Vogt, PRC 84 (2011) 054907

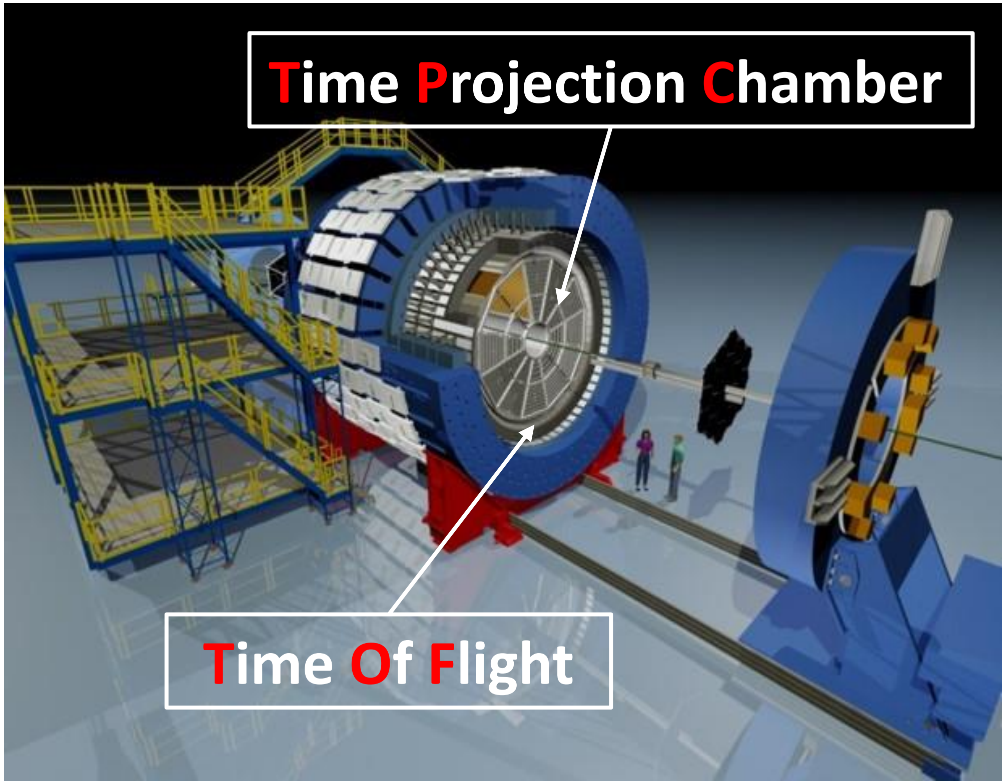
  - Energy density is higher by 20% than that in AuAu@200 GeV.
  - Longer medium life time?
  - Higher excess yield in the low mass region?

- Beam Energy Scan Program
  - Systematically study energy dependence of LMR excess
  - Systematically study the low mass excess yield versus medium life time.



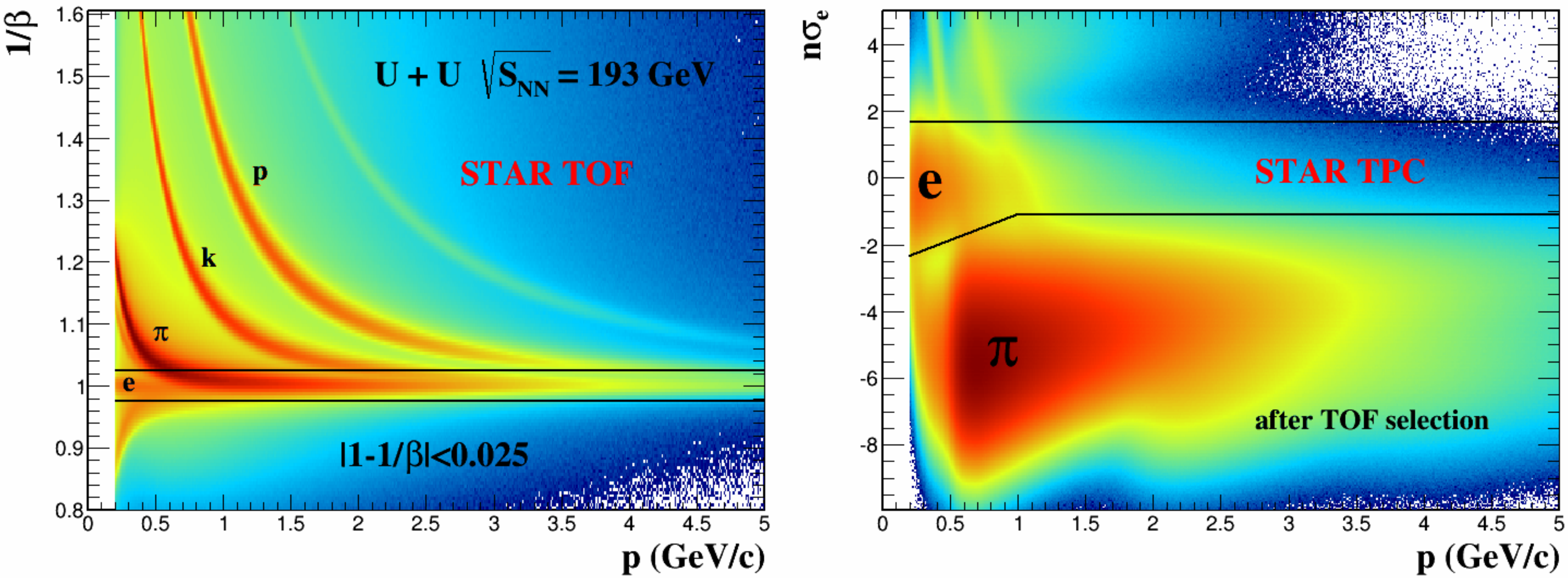
R. Rapp, H. van Hees,arXiv:1411.4612

STAR detector



- Time Projection Chamber
  - $|\eta|<1$, $0<\phi<2\pi$
  - Main detector: tracking, momenta, and energy loss
- Time Of Flight
  - $|\eta|<0.9$, $0<\phi<2\pi$
  - Rejects slow hadrons, enables clean electron identification at $p < 3$ GeV/c

Electron identification

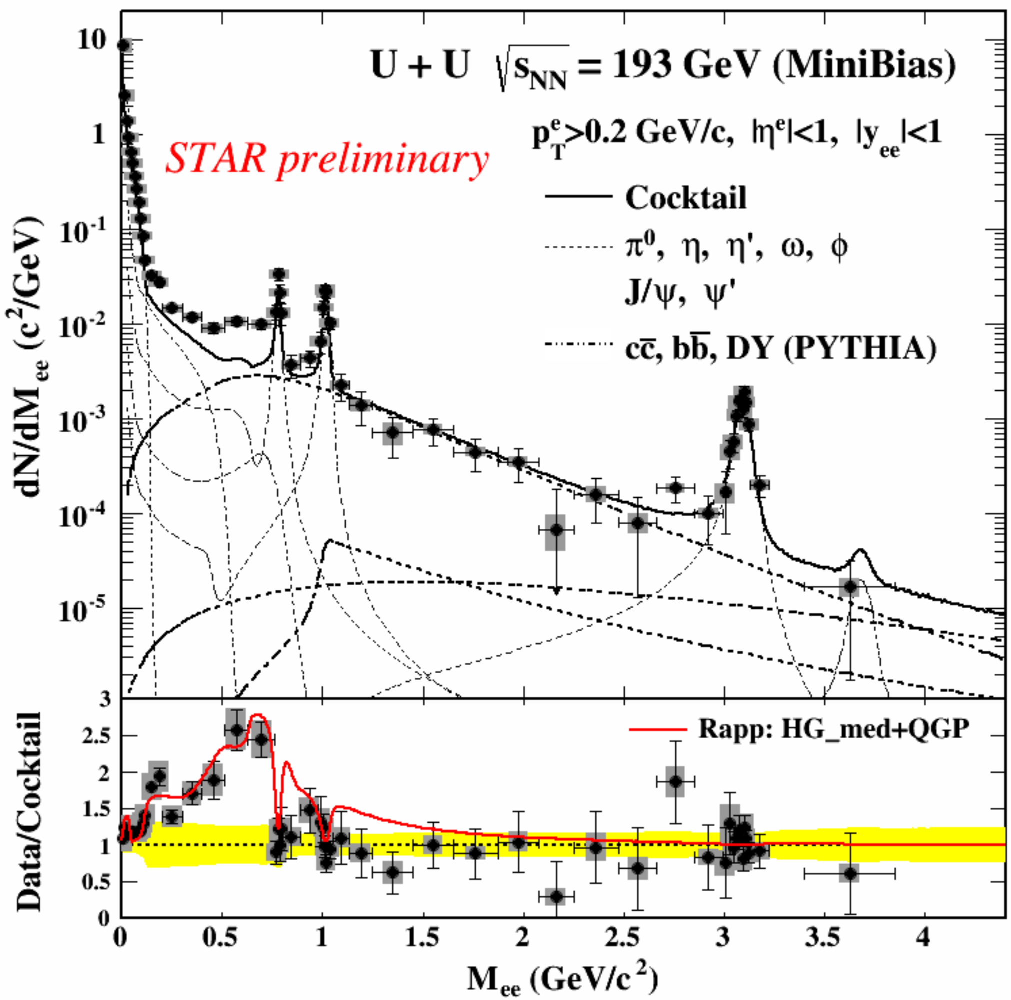


- ➢ Clean electron identification with a combination of TPC and TOF

$$n\sigma_e = \frac{1}{R} \log \frac{(dE/dx)_{measured}}{(dE/dx)_{electron}}$$

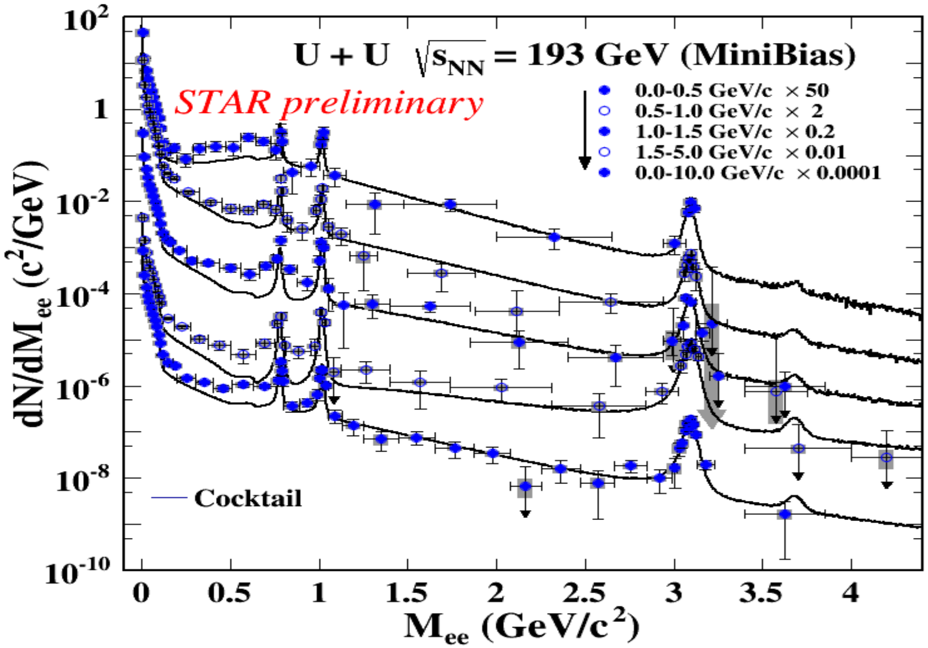
U+U @ 193 GeV results

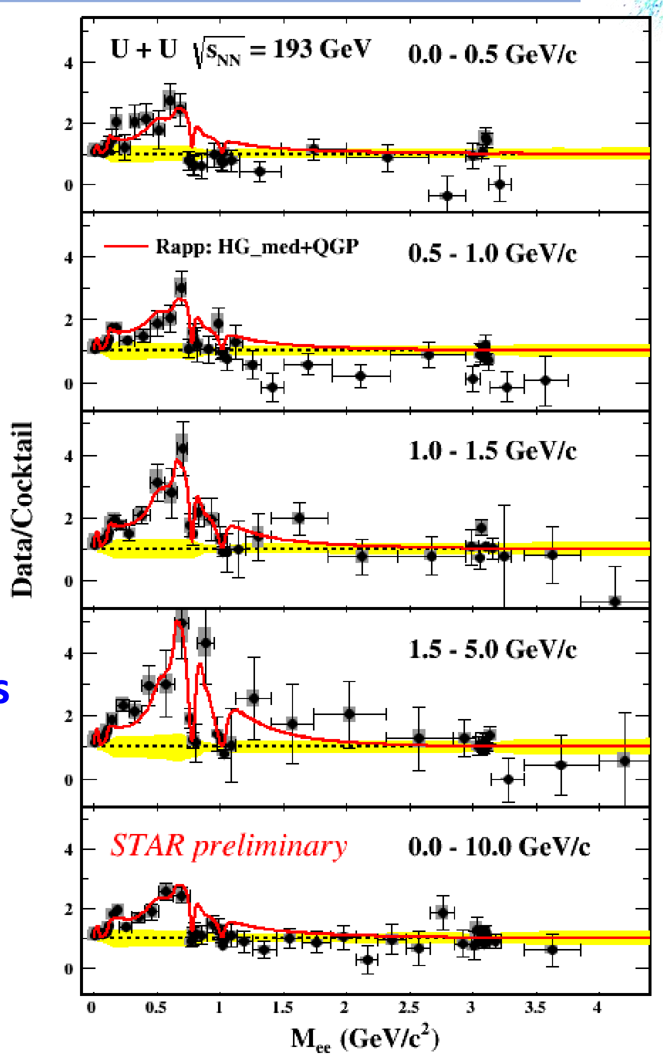
Cocktail simulation: *STAR, PRC 92 (2015) 024912*



- Significant enhancement w.r.t cocktail at ρ-like mass region (0.3-0.76 GeV/c^2)
  2.1±0.1(stat.)±0.2(sys.)±0.3 (cocktail)
- The charm contribution to the total cocktail is significant in the ρ-like mass region (48.5%).
  $\sigma_{c\bar{c}} = 797\ \mu b,\ \sigma_{b\bar{b}} = 3.7\ \mu b,\ \sigma_{DY} = 42\ nb$
- Compared with a theoretical model based on a broadened ρ spectral function [*R. Rapp, Adv. High Energy Phys. 2013 (2013) 148253*]
  Model shows good agreement with data within uncertainty.

p_T dependence



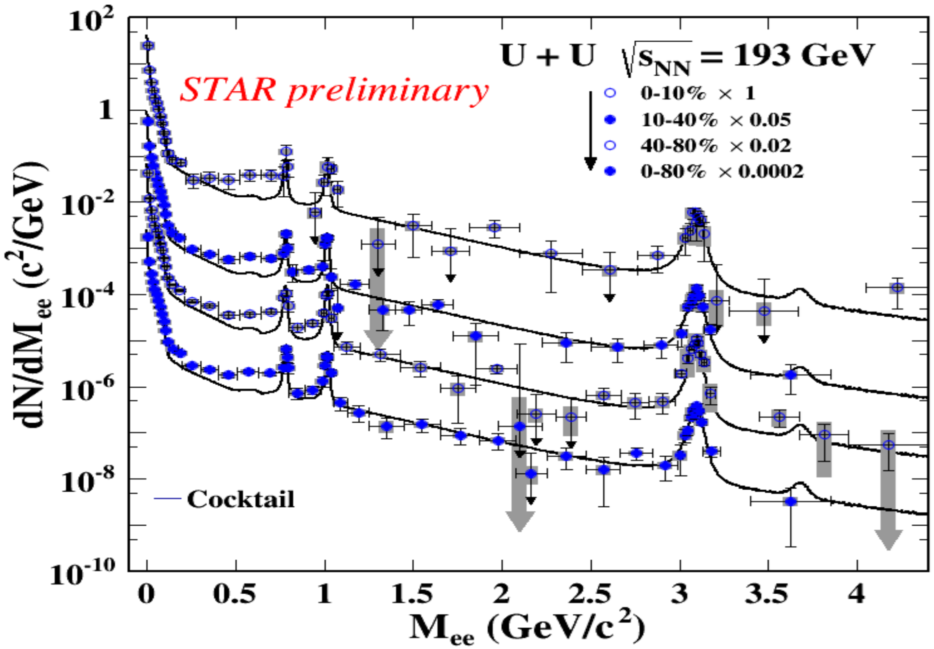


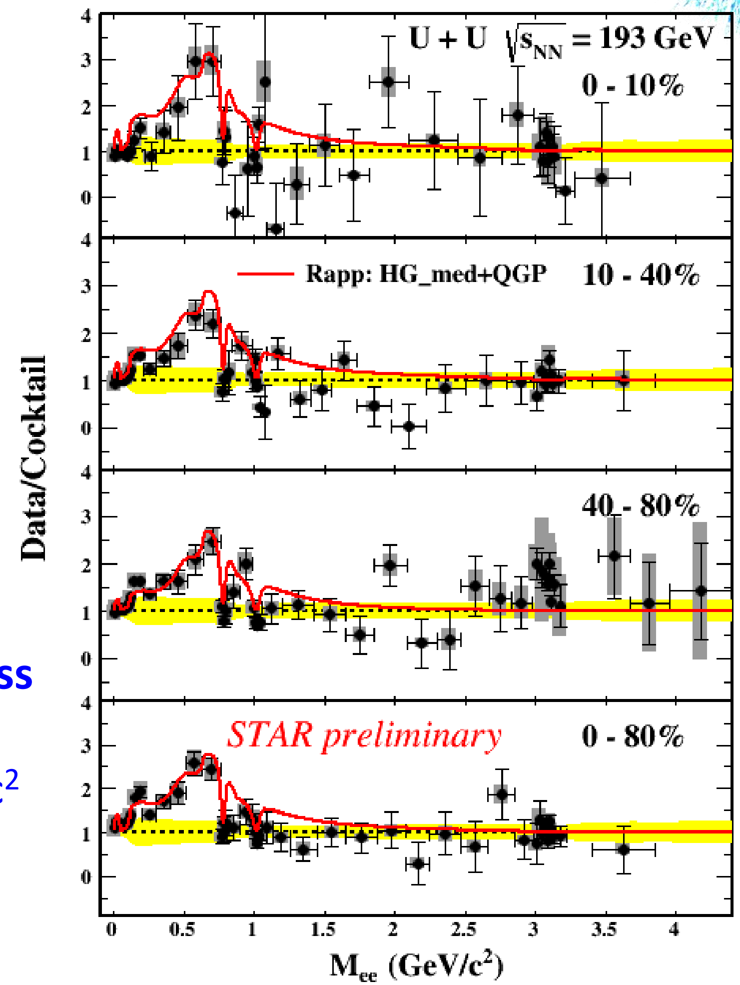
p_T (GeV/c)	Yield/cocktail
0-0.5	2.2±0.2±0.5
0.5-1.0	1.8±0.2±0.3
1.0-1.5	2.7±0.3±0.5
1.5-5.0	3.1±0.4±0.8

Integrated mass region:
0.3-0.76 GeV/c^2

- Model calculation consistently describes the LMR excess in all p_T bins.

Centrality dependence





Centrality(%)	Yield/cocktail
0-10	2.2±0.3±0.3
10-40	1.9±0.1±0.2
40-80	1.9±0.1±0.2
0-80	2.1±0.1±0.2

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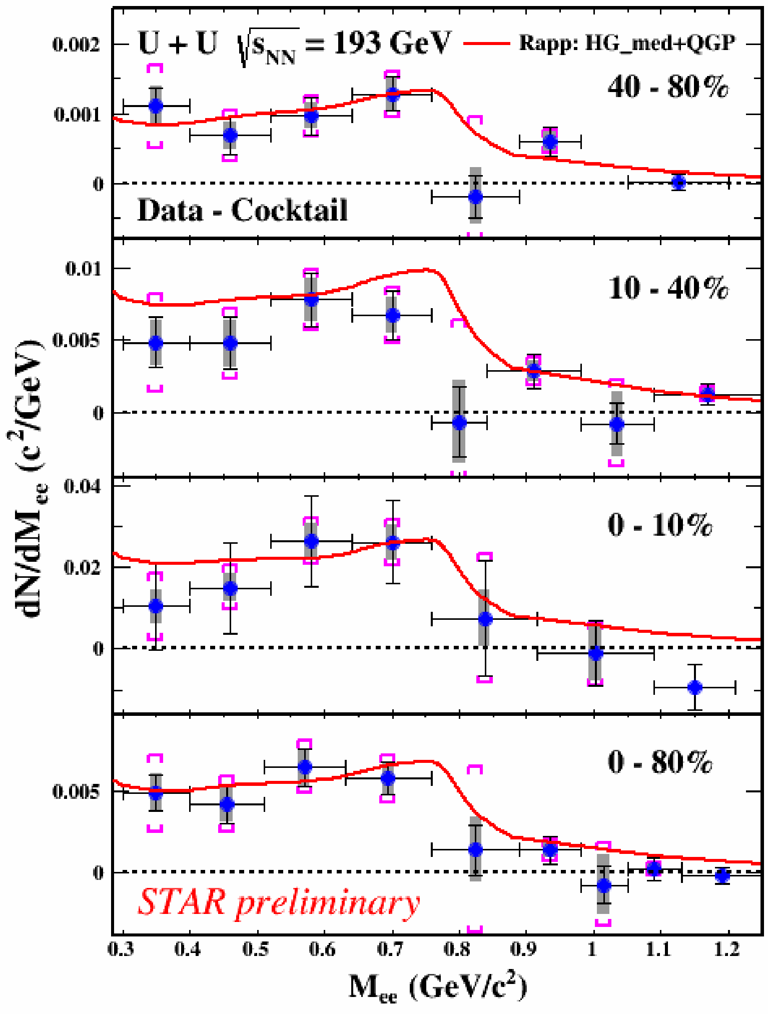
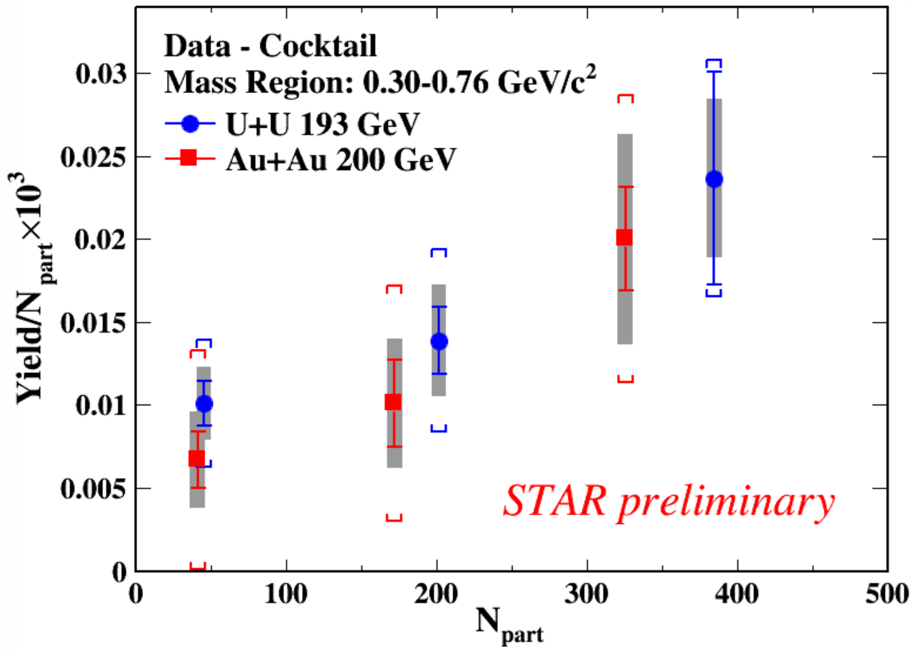
Excess spectrum and yield

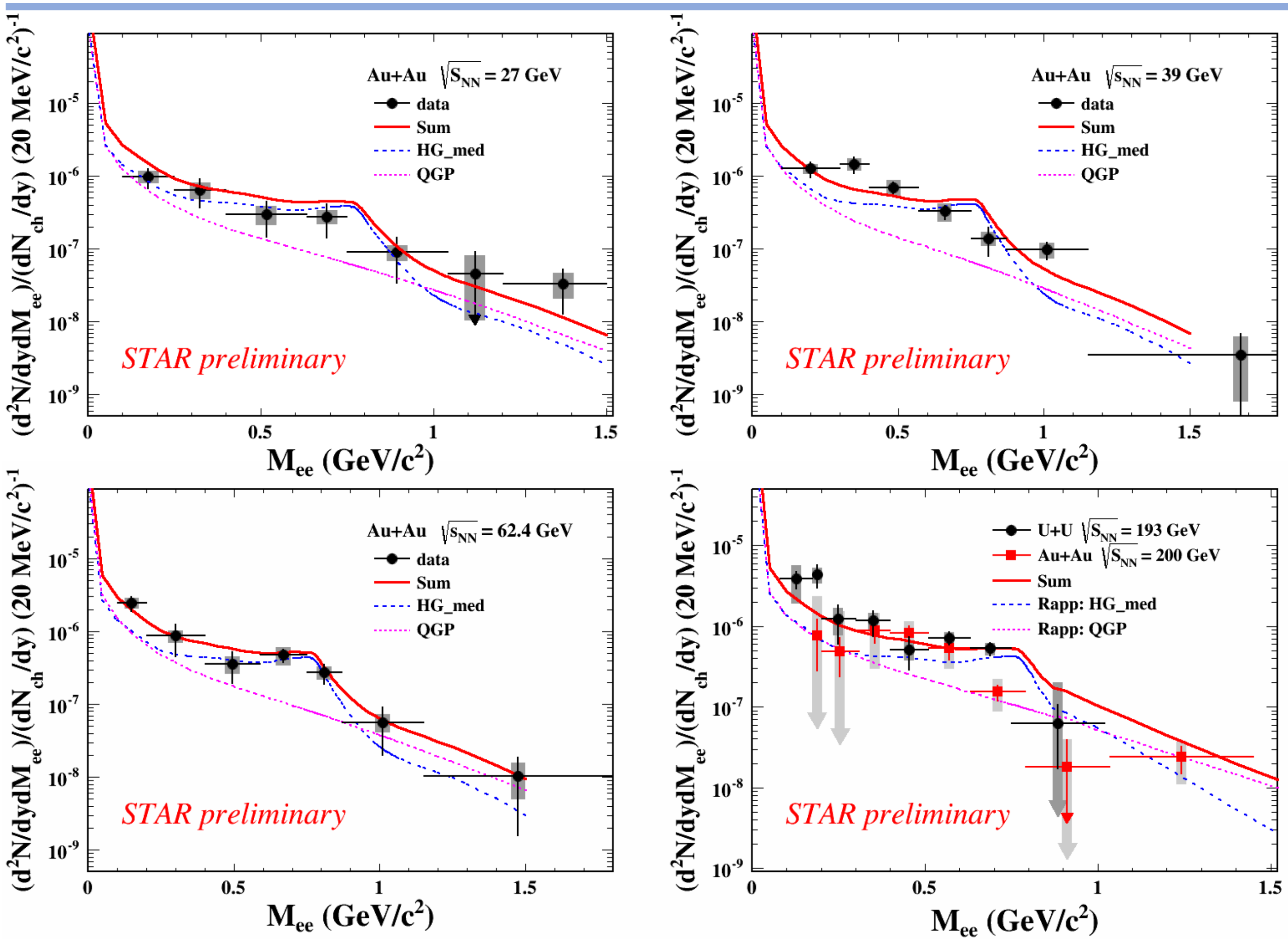




AuAu@200 GeV: *STAR, PRL 113 (2014) 022301*

- Excess yield in ρ-like mass region:
  - Increase faster than N_{part} scaling
  - Sensitive to medium dynamics

Acceptance corrected excess spectra



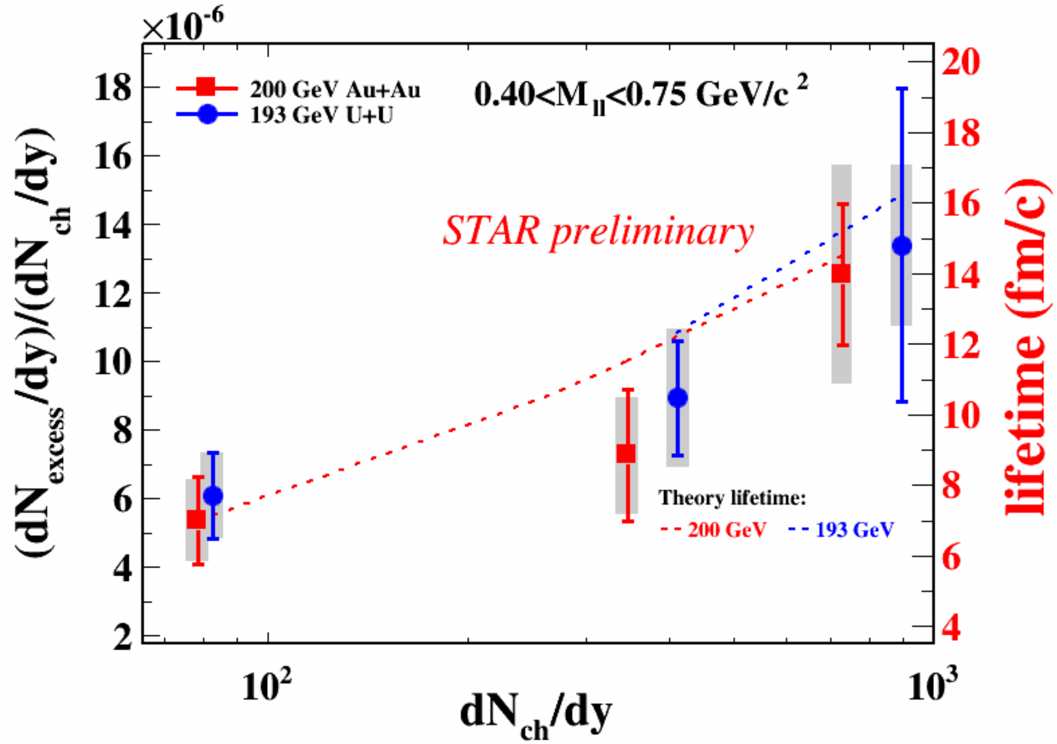
Beam Energy Scan I: 27, 39, 62.4 GeV

AuAu@200 GeV
UU@193 GeV

Theory:
R. Rapp, PRC 63 (2001) 054907
AuAu@200 GeV:
STAR, PLB 750 (2015) 64

➢ Acceptance-corrected excess mass spectra are **well described by a ρ broadened spectral function in various collision systems and energies**.

Energy and system-size dependence of integrated excess yield

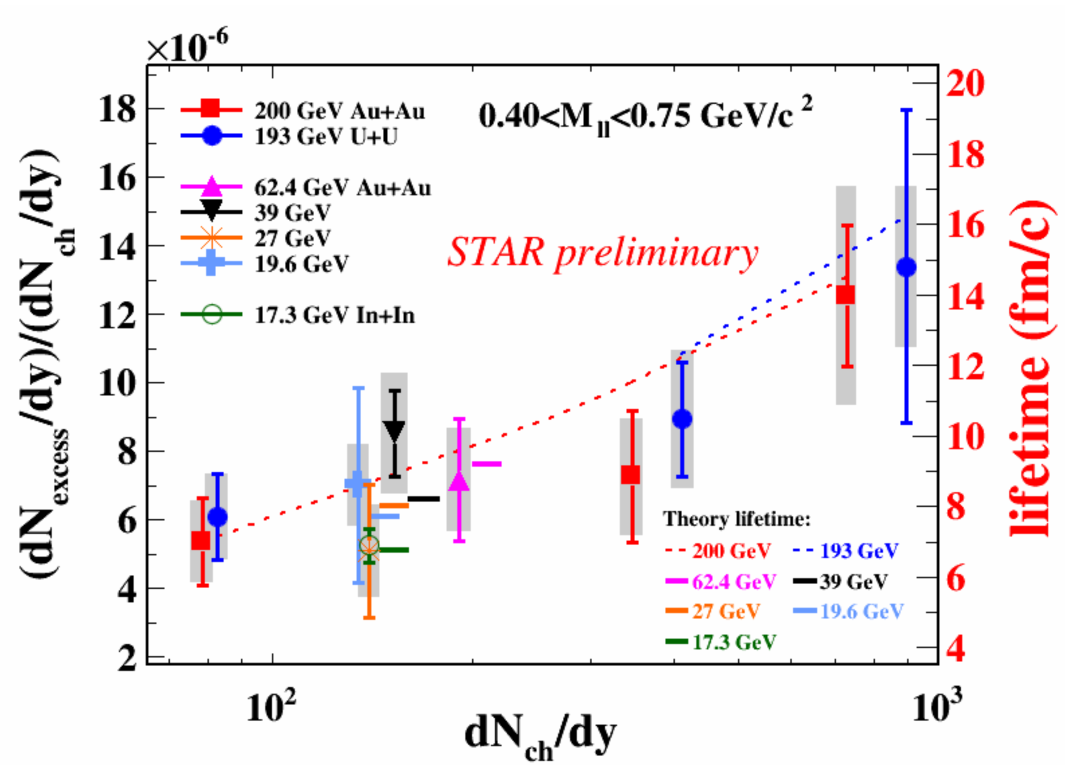


AuAu@200 GeV, 19.6 GeV: *STAR, PLB 750 (2015) 64*
InIn@17.3 GeV: *NA60, Eur. Phys. J. C 59 (2009) 607*

- The normalized excess yield in LMR is proportional to the medium life time (HG + QGP) for $\sqrt{S_{NN}}$ = 17.3-200 GeV
  [*R. Rapp, H. van Hees, arXiv:1411.4612*]
  - Nearly constant total baryon density
  - Emission rate dominated around T_c

- The normalized excess yields of UU@193GeV and AuAu@200GeV
  - Increase from peripheral to central collisions.
  - In central collisions are higher than those at lower energies.
- Indicate longer medium lifetime in central UU@193GeV and AuAu@200GeV collisions.

Energy and system-size dependence of integrated excess yield



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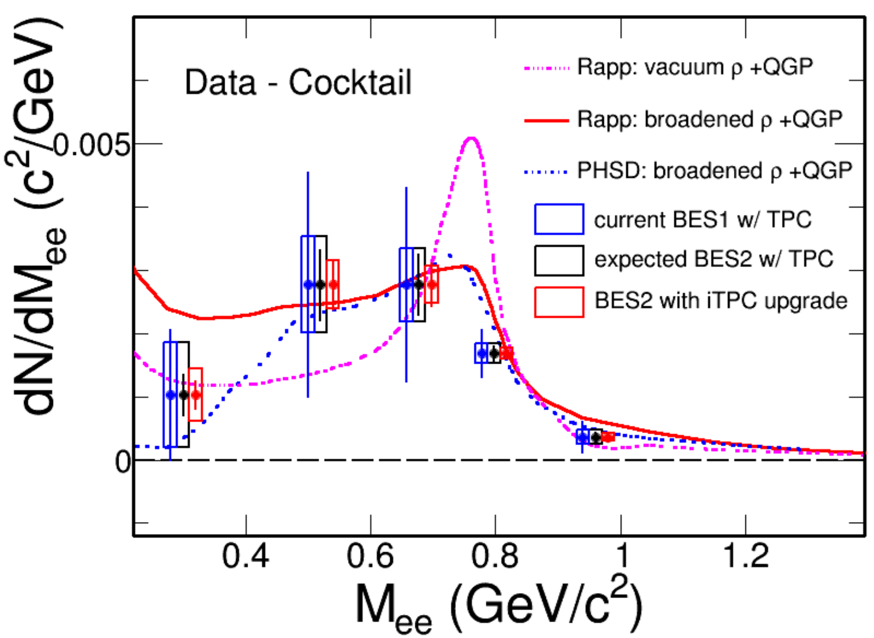
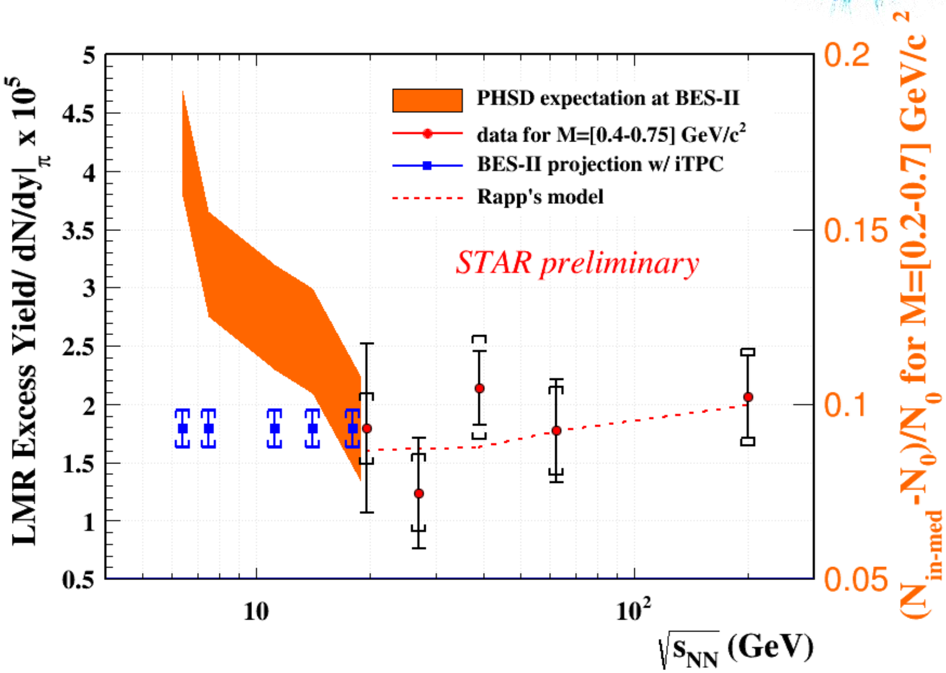
Di-electron measurements in Beam Energy Scan II





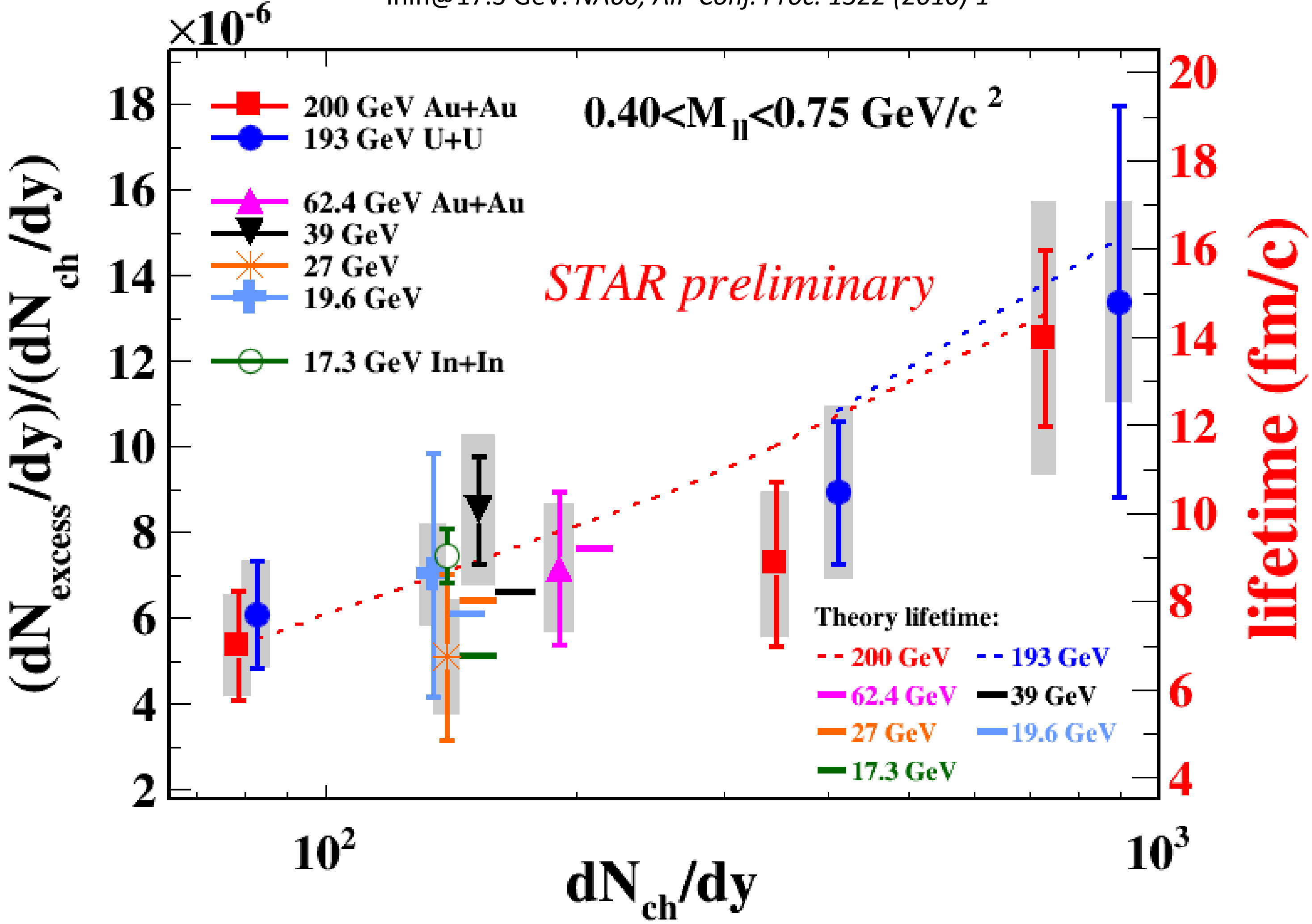
- Systematically study di-electron continuum from $\sqrt{S_{NN}}$ = 7.7 – 19.6 GeV
- Inner Time Projection Chamber (iTPC) upgrade: reduce systematic and statistical uncertainties
- Distinguish models with different ρ-meson broadening mechanisms (Rapp's method vs. PHSD)
- Study the total baryon density effect on LMR excess yield in BESII

Summary

- The di-electron production is systematically studied in UU@193 GeV for the first time.
- The LMR excess at all collision systems can be consistently described by a ρ broadened spectral function scenario.
- The excess yield in ρ-like mass region has a strong centrality dependence and increases faster than N_{part} scaling in UU@193 GeV and AuAu@200GeV.
- The measurements indicate that the lifetime of medium created in central UU@193GeV and AuAu@200GeV collisions is longer than those in peripheral collisions and at lower energies.

Backup

InIn@17.3 GeV: *NA60, AIP Conf. Proc. 1322 (2010) 1*



Theoretical temperature and lifetime

Collision Energy (GeV)	Temperature (MeV)	Lifetime (fm/c)
AuAu@19.6	227	7.7
AuAu@27	230	8.0
AuAu@39	237	8.2
AuAu@62.4	272	9.2
AuAu@200	328	10.5
UU@193 10-40%	357	12.3
UU@193 0-10%	392	16.2

R. Rapp, Adv. High Energy Phys. 2013 (2013) 148253; private communication