Measurements of dielectron production in Au+Au collisions at $\sqrt{s_{NN}}$ = 27 and 54.4 GeV with the STAR experiment

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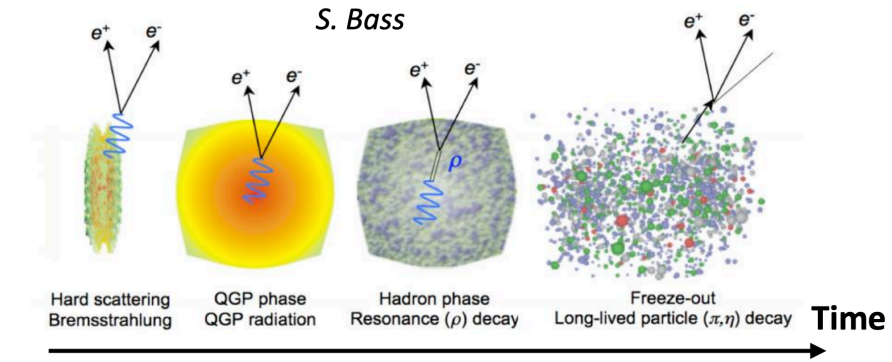
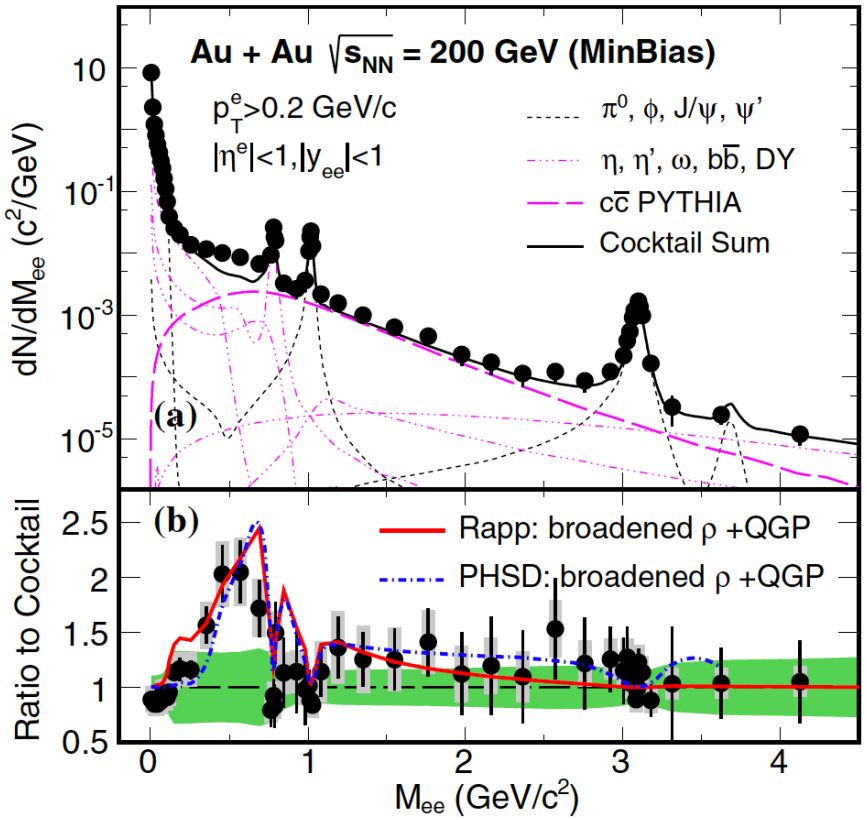
Dielectron production



STAR, PRL. 113 (2014) 22301



Dielectrons – an excellent probe

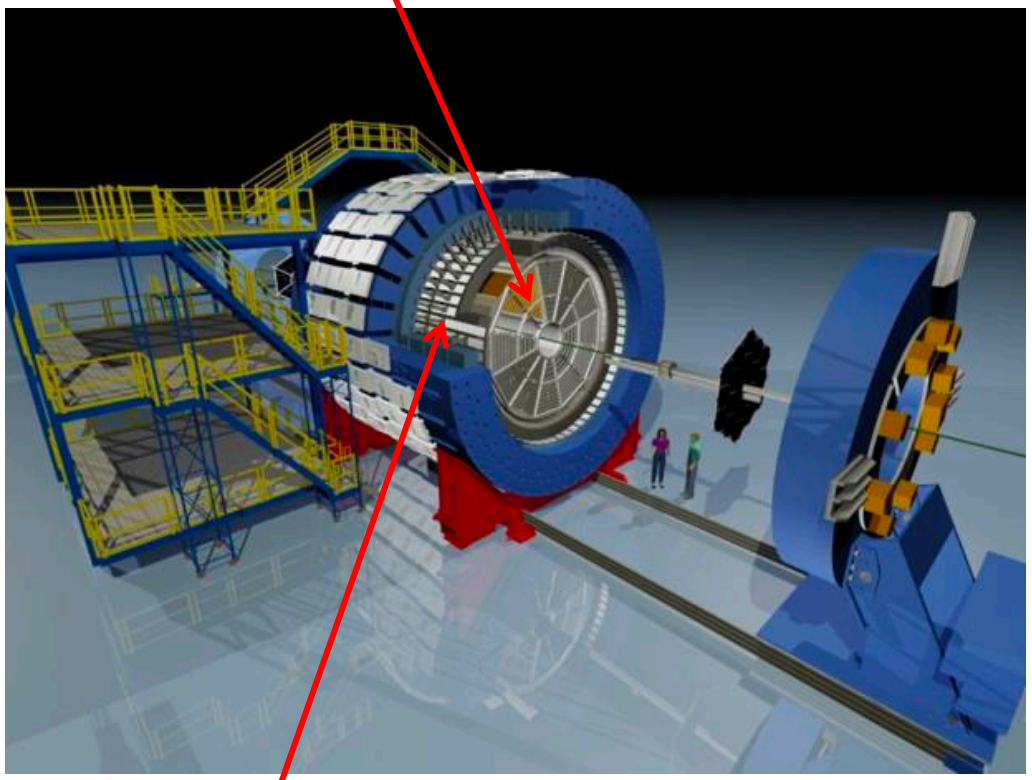
- Minimal interaction with the medium
- Carries information from the initial stage to the final stage of a collision

Different physics of interest

- Low Mass Region (LMR, $M_{ee} < M_{\phi}$)
  - Vector meson in-medium modifications
  - Possible link to chiral symmetry restoration
- Intermediate mass region (IMR, $M_{\phi} < M_{ee} < M_{J/\psi}$)
  - QGP thermal radiation is predicted as a QGP thermometer

Physics interest : Adv. Nucl. Phys. 25 (2000) 1
Rapp: PoS CPOD2013, 008 (2013)
PHSD: Phys. Rev. C 85, 024910 (2012);

The STAR experiment



Key detectors used in this analysis

Time Projection Chamber

- Acceptance : $|\eta| < 1, 0 < \phi < 2\pi$
- Tracking, particle momenta, eID

Time of Flight

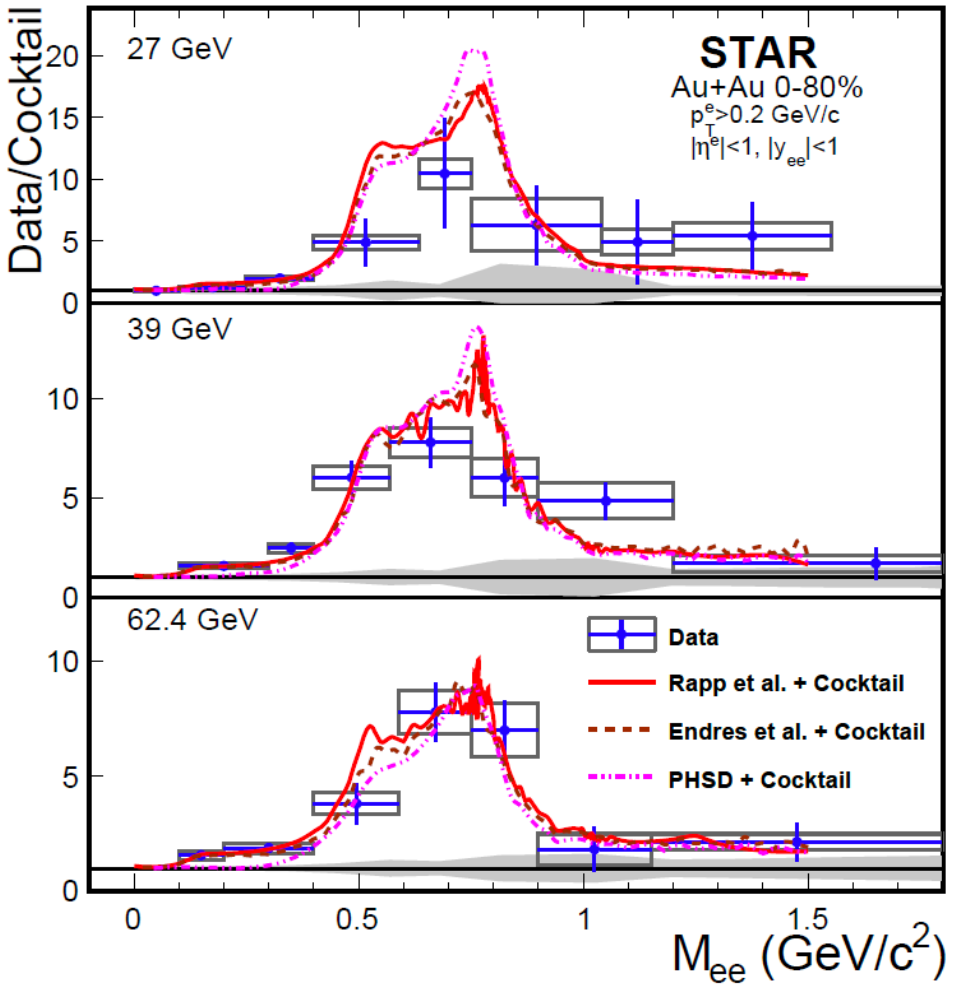
- Acceptance : $|\eta| < 0.9, 0 < \phi < 2\pi$
- Rejection of slow hadrons
- Improve electron purity

Dataset

- New datasets are ~10 times larger than that in the $\sqrt{s_{NN}}$ = 27,39 and 62.4 GeV

Year	Energy	Used events
2018	27 GeV	500M
2017	54.4 GeV	875M
2011	27 GeV	68M
2010	39 GeV	132M
2010	62.4 GeV	62M

$\sqrt{s_{NN}}$ = 27, 39 and 62.4 GeV dielectron result



STAR: arXiv:1810.10159 [nucl-ex]
Rapp et al.: PRC 63 (2001) 054907, PRL 97 (2006) 102301
Endres et al.: PRC 91 (2015) 054911, PRC 94 (2016) 024912
PHSD: Nucl. Phys. A831 (2009) 215, Prog. Part. Nucl. Phys. 87 (2016) 50

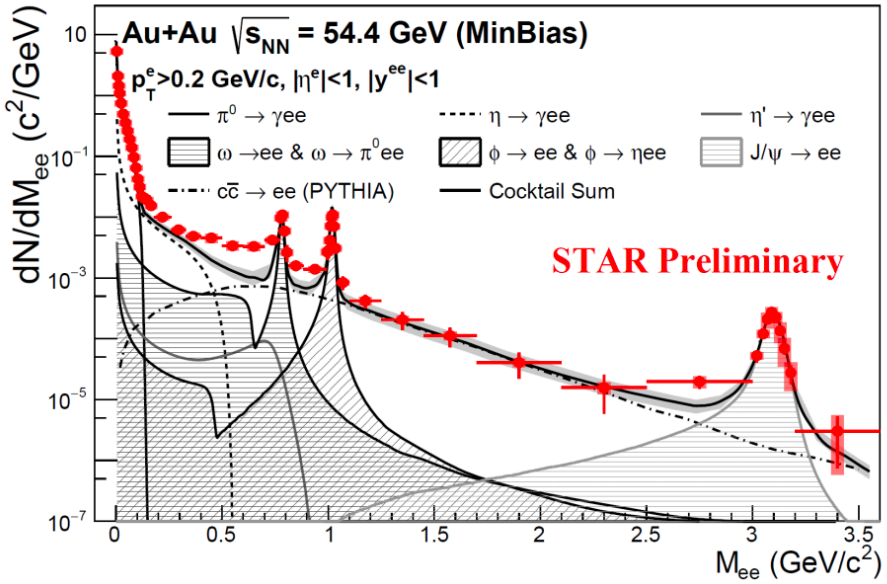
Data / Cocktail ratio in STAR acceptance

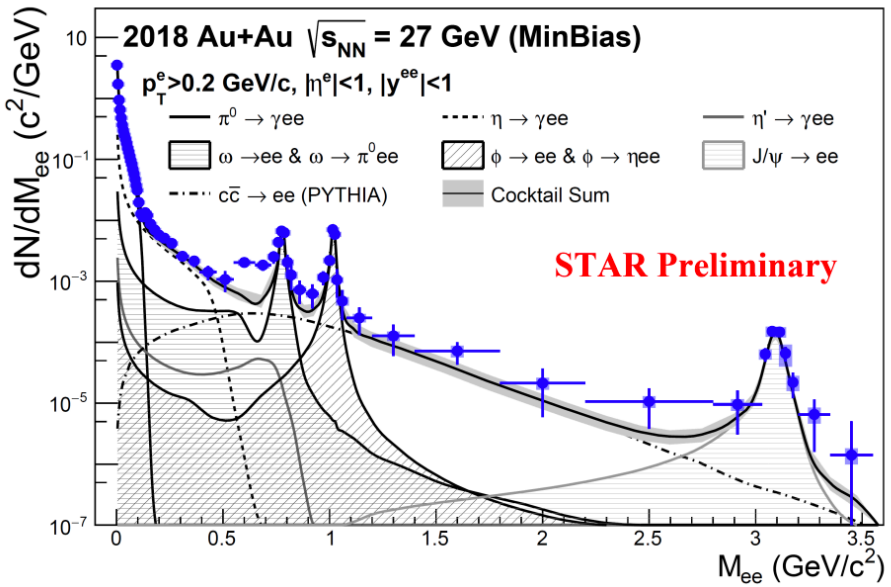
- ω and ϕ are subtracted from the data and the cocktail
- Theory calculations including in-medium broadened ρ and thermal radiation are compared with data
- The model by Rapp et al. is an effective many-body calculation for vector mesons where the ρ spectral function is modified (broadened)
- The model by Endres et al. is a coarse-grained transport approach that includes the ρ spectral function
- PHSD is a microscopic transport model which includes the collisional broadening of the ρ.

Higher precision measurements now possible with new datasets at $\sqrt{s_{NN}}$ = 27 and 54.4 GeV

- Factor ~10 more data compared to $\sqrt{s_{NN}}$ = 27,39 and 62.4 GeV measurement

Cocktail in 27 and 54.4 GeV analysis



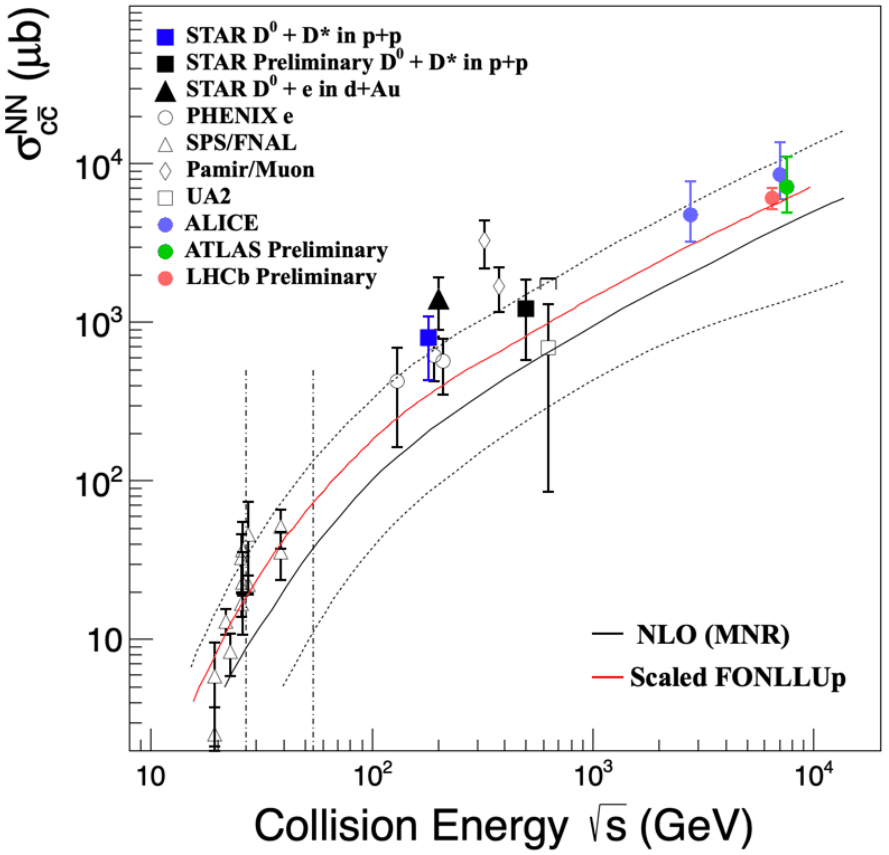


Cocktails in QM 2019

- $\sqrt{s_{NN}}$ = 27 GeV cocktail is taken from the analysis of 2011 $\sqrt{s_{NN}}$ = 27 GeV data
- $\sqrt{s_{NN}}$ = 54.4 GeV charm component is taken from analysis of 2010 $\sqrt{s_{NN}}$ = 62.4 GeV data charm component and scaled by the ratio of charm cross section and N_{bin} at $\sqrt{s_{NN}}$ = 54.4 GeV to 62.4 GeV
- Drell-Yan contribution was not included in $\sqrt{s_{NN}}$ = 27 and 54.4 GeV QM19 cocktails

BES-I analysis : arXiv:1810.10159 [nucl-ex]

Charm cross-section and scale method



Phys. Rev. Lett. 77, 2388 (1996).
Rep. Prog. Phys. 50, 1439 (1987).
Phys. Rev. D 86, 072013 (2012).
Phys. Rev. Lett. 97, 252002 (2006).

Charm cross section

- The charm cross sections at $\sqrt{s_{NN}}$ = 27 and 54.4 GeV are extrapolated from worldwide data.
- The perturbative QCD leading-order plus next-to-leading logarithms upper-limit was used to fit the world-wide measurements of $\sigma_{c\bar{c}}^{NN}$ in order to determine the input charm production cross section.

Charm scale method

- Charm semi-leptonic decay in p+p collisions is scaled by equation (1) to match the Au+Au collisions.

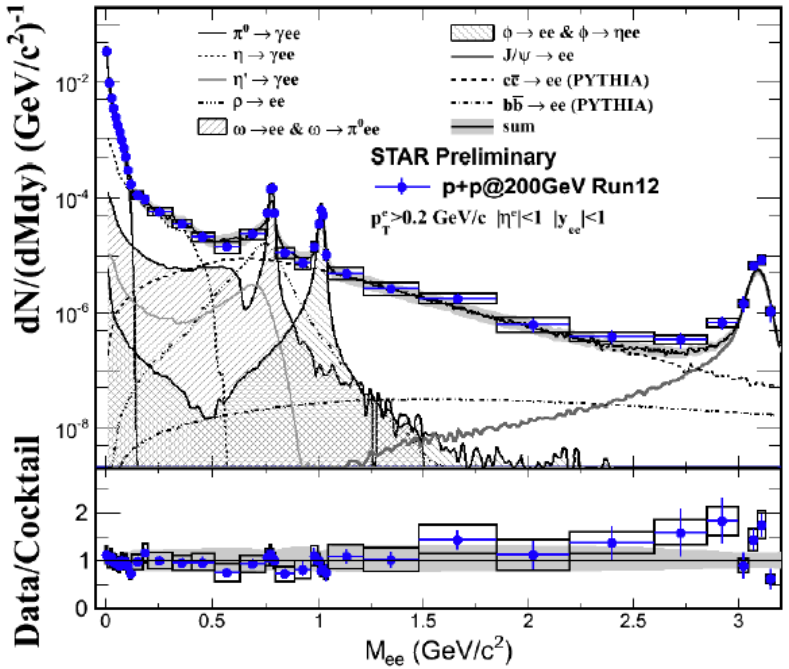
$$\frac{1}{N}\frac{dN}{dM} = \frac{1}{nCharm}\left(\frac{dN}{dM}\right)_{pp}\frac{\sigma_{c\bar{c}}}{\sigma_{mb}} N_{bin} BR_{(c\to e^+)} BR_{(c\to e^-)} \quad (1)$$

- In STAR $\sqrt{s_{NN}}$ = 27,39 and 62.4 GeV analyses, the number of PYTHIA events with 1 c string and 1 $\bar{c}$ string events is used as the number of charm ($N_{2CString}$ method)
- In STAR $\sqrt{s_{NN}}$ = 200 GeV paper, the number of PYTHIA events with at least 1 c or $\bar{c}$ is used as the number of charm ($N_{inclusive}$ method)

Comparison of two scale method

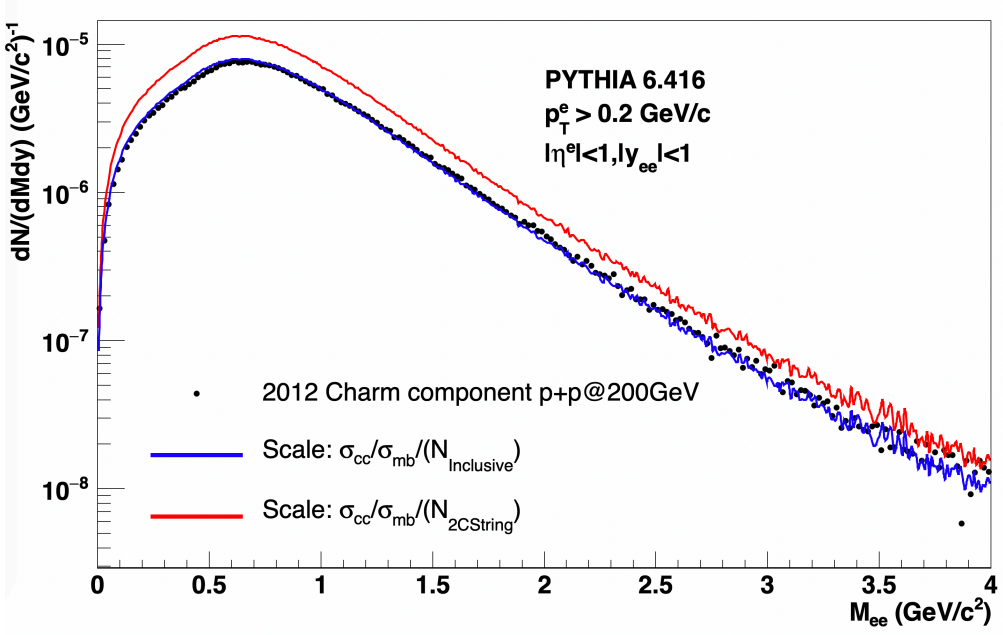
Journal of Physics: Conference Series, 535:012006, sep 2014

σ_{NSD}: PHYSICAL REVIEW C 86, 024906 (2012)



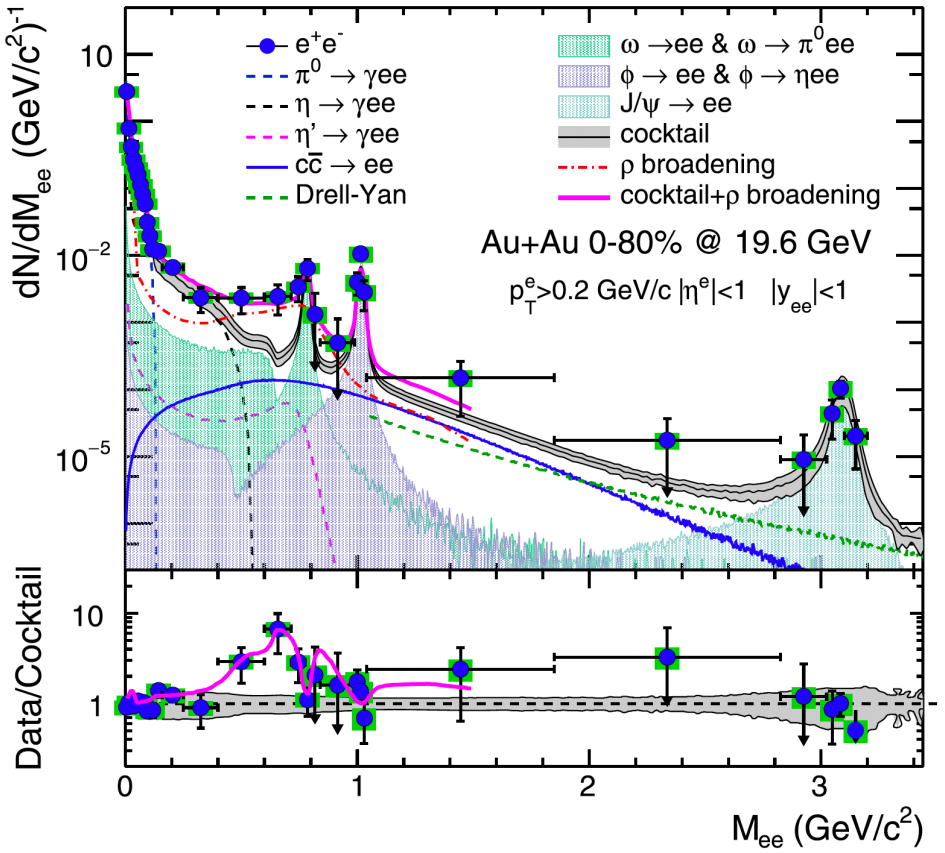
$\sqrt{s_{NN}}$ = 200GeV $\sigma_{\mathrm{NSD}} = 30 \pm 3.5$ mb

$\sqrt{s_{NN}}$ = 200GeV $\sigma_{cc}^{pp} = 797 \pm 210(stat.)^{+208}_{-295}(sys.)$ nb



- STAR p+p at √s = 200 GeV was used to see if the cross-section from PYTHIA is consistent with experimental data
- Charm component scaled with $N_{inclusive}$ method is consistent with charm component measured in pp collisions (STAR Run12)
- Charm component scaled with $N_{2CString}$ method is ~1.4 factor higher than charm component measured in pp collisions (STAR Run12)
- $N_{inclusive}$ method is the correct way to scale charm component
- The charm component in both $\sqrt{s_{NN}}$ = 54.4 and 27 GeV will be scaled by $N_{inclusive}$ method

Drell-Yan component



STAR 19.6 GeV : Physics Letters B 750 (2015) 64–71
NA50 17.3 GeV: Physics Letters B 410 (1997) 327

Drell-Yan component

- Drell-Yan component becomes similar order of magnitude with charm component at lower energy in the intermediate mass region
- Drell-Yan cross-section has been measured at $\sqrt{s_{NN}}$ = 17.3 GeV in Pb+Pb collisions by NA50 experiment. This cross section is used as an approximation of $\sqrt{s_{NN}}$ = 19.6 GeV Drell-Yan cross section
- σ_{DY} was taken from PYTHIA and was corrected by the ratio of the cross-section used in STAR 19.6 GeV dielectron measurement to the corresponding PYTHIA cross-section at 19.6 GeV

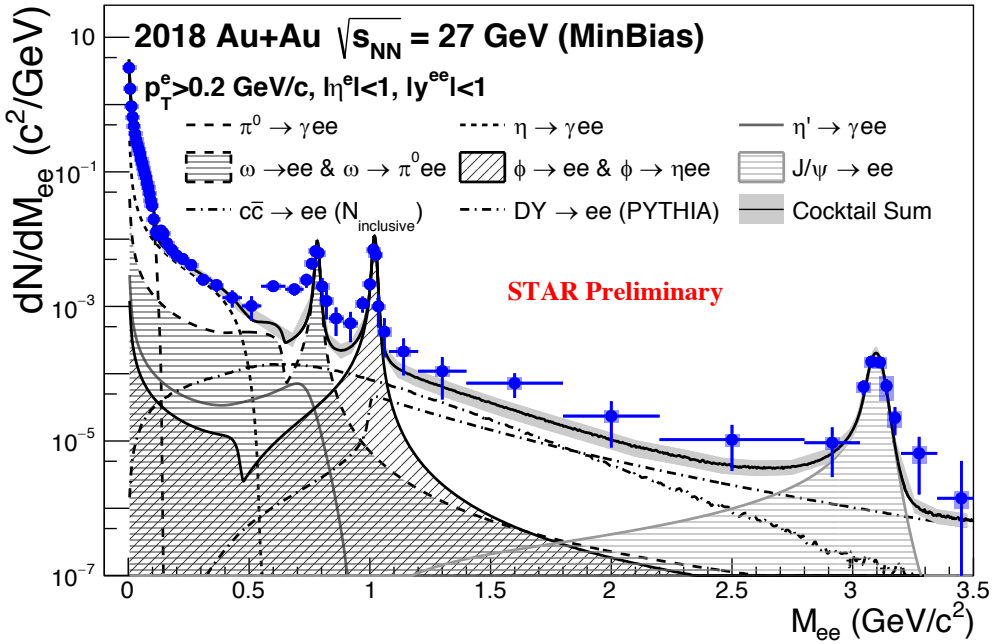
$\sqrt{s_{NN}}$ = 54.4 GeV $\sigma_{DY} = \sigma_{DY\ 54.4\ GeV}^{PYTHIA} * \frac{\sigma_{DY\ 19.6\ GeV}^{Paper}}{\sigma_{DY\ 19.6\ GeV}^{PYTHIA}} = 19.25\ nb$

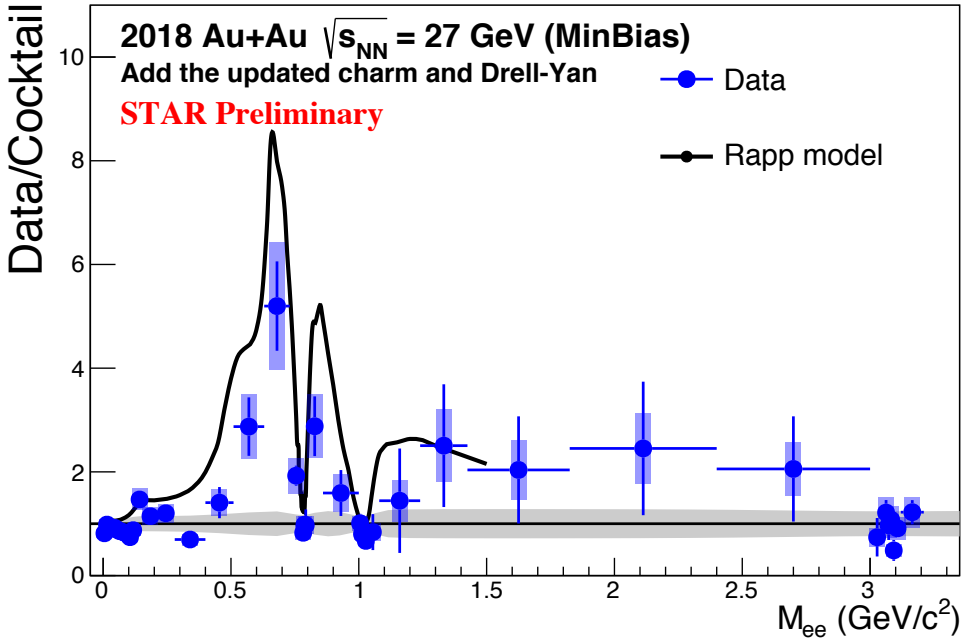
$\sqrt{s_{NN}}$ = 27 GeV $\sigma_{DY} = \sigma_{DY\ 27\ GeV}^{PYTHIA} * \frac{\sigma_{DY\ 19.6\ GeV}^{Paper}}{\sigma_{DY\ 19.6\ GeV}^{PYTHIA}} = 12.7\ nb$

$\sigma_{DY\ 54.4\ GeV}^{PYTHIA} = 26.19\ nb$
$\sigma_{DY\ 27\ GeV}^{PYTHIA} = 17.27 nb$

27 GeV efficiency corrected spectra

Charm component with $N_{inclusive}$ scale method and Drell-Yan component added in cocktail



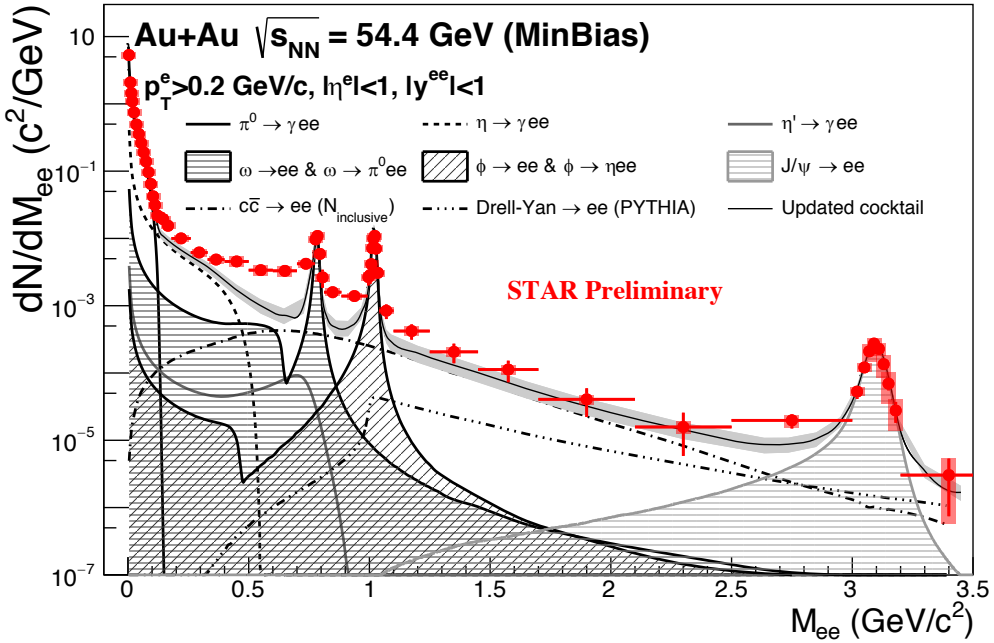


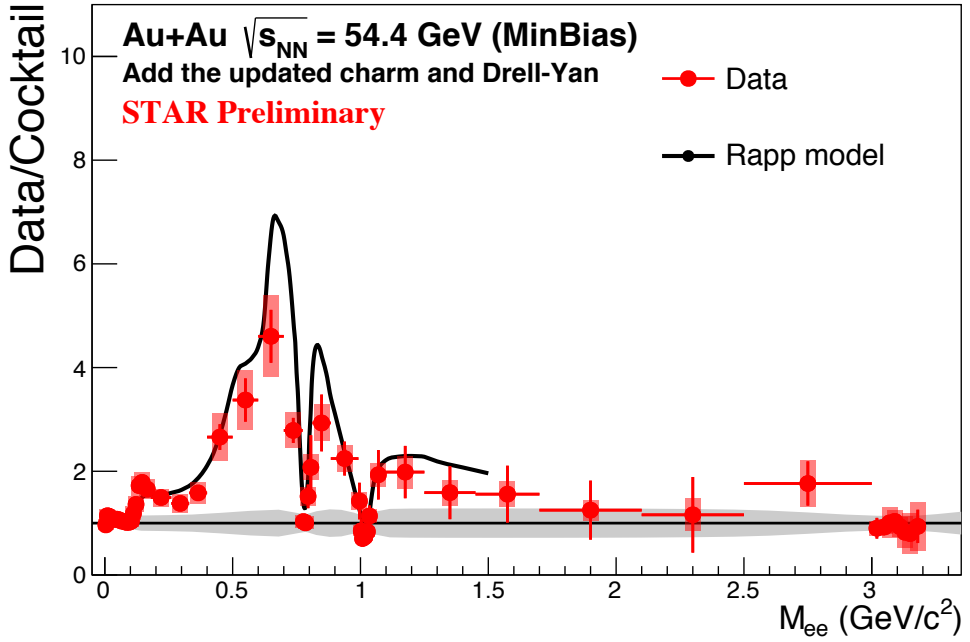
2018 $\sqrt{s_{NN}}$ = 27 GeV : ~ 10x improved statistics compared to 2011 $\sqrt{s_{NN}}$ = 27 GeV data

- New result is consistent with result from 2011 $\sqrt{s_{NN}}$ = 27 GeV data within uncertainties
- A hint of excess in the intermediate mass region at 1.6σ level
- The Rapp model overestimates the data
- p_T and centrality differential analysis is ongoing

54.4 GeV efficiency corrected spectra

Charm component with $N_{inclusive}$ scale method and Drell-Yan component added in cocktail

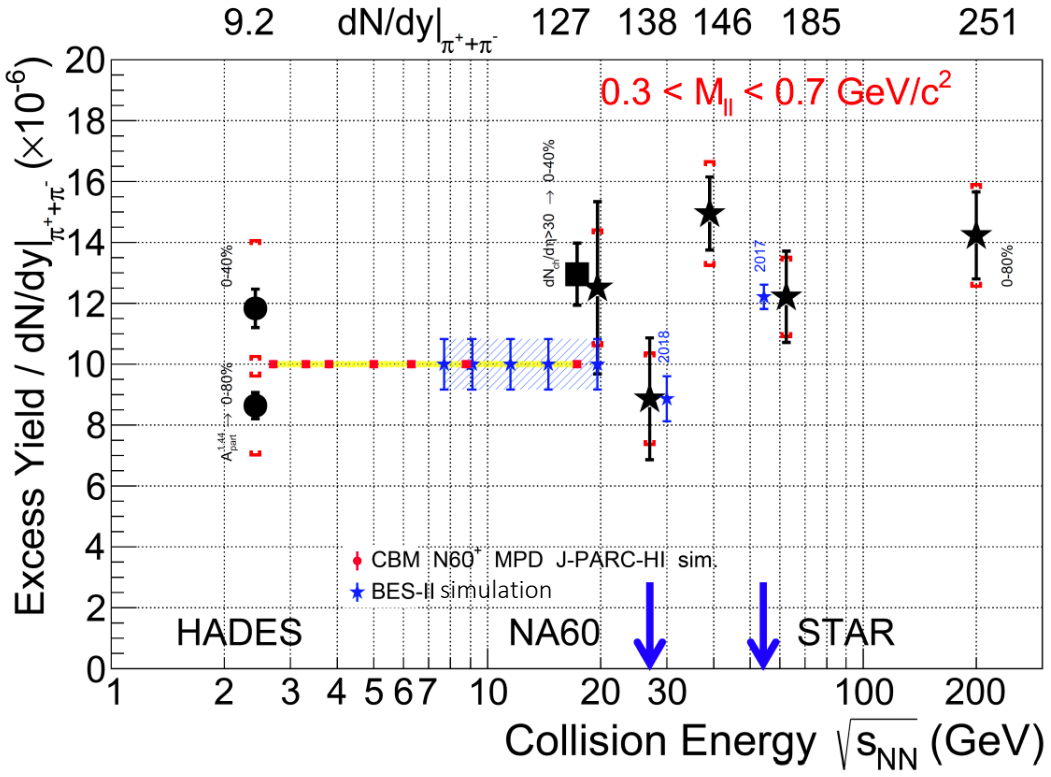




$\sqrt{s_{NN}}$ = 54.4 GeV : first dielectron measurement at this energy, cocktail updated

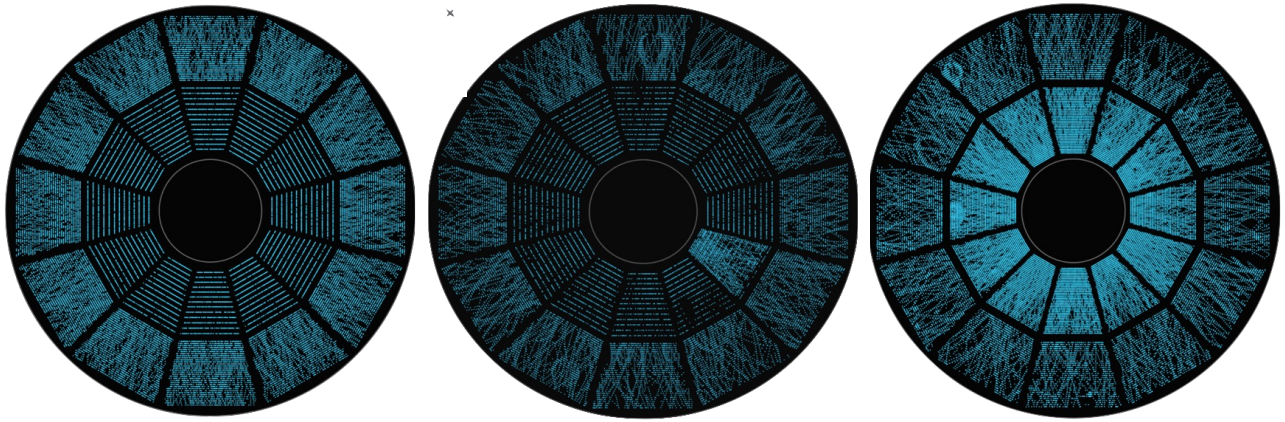
- A hint of excess in the intermediate mass region 1.8σ level
- The Rapp model overestimates the data
- p_T and centrality differential analysis is ongoing

Dielectron measurement with STAR BES-II program



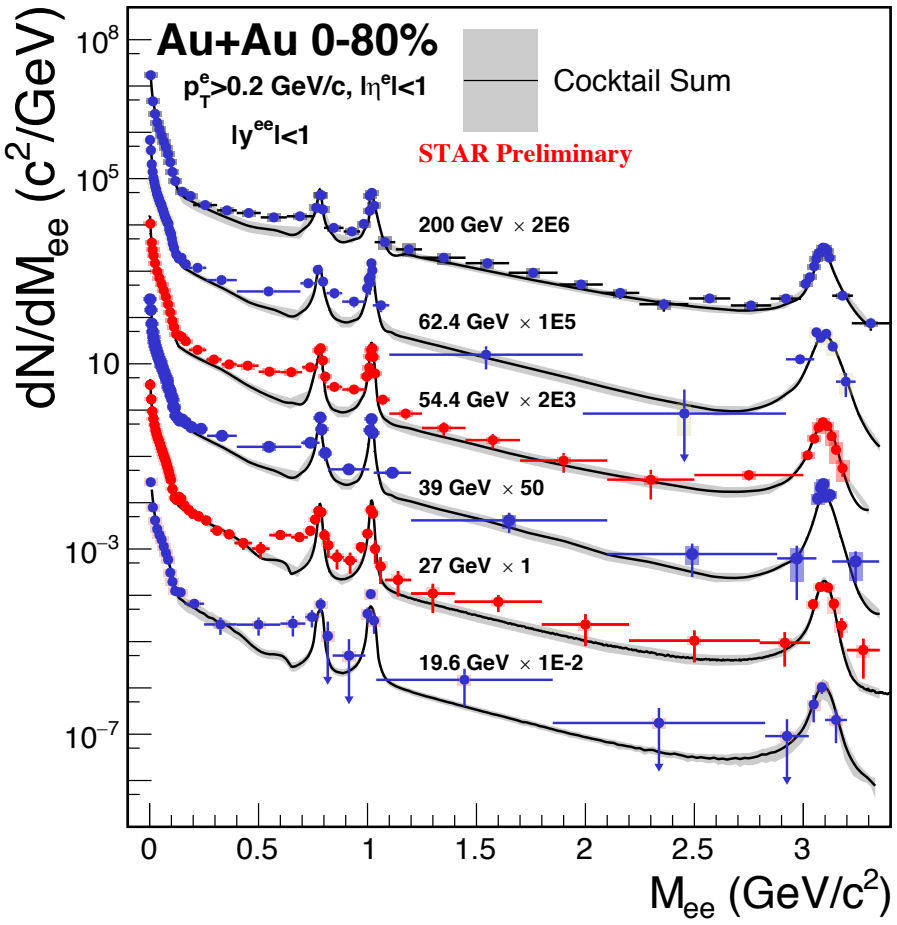
Plot : STAR, F.Seck, QM 2019
NA60: Chiral 2010, AIP Conf.Proc. 1322 (2010) 1
STAR: PLB 750 (2015) 64, arXiv:1810.10159 [nucl-ex]
HADES: Nature Phys. 15 (2019) 1040

- Measurement of dielectron spectra between $\sqrt{s_{NN}}$ = 7.7 GeV and 19.6 GeV will be possible with STAR BES-II data
- Enhanced tracking and particle identification capabilities with iTPC and eTOF upgrades
  - Extend η acceptance from 1.0 to 1.5



Events display: without iTPC with one iTPC sector with iTPC

Summary and outlook



200GeV: PRC 92 (2015) 024912
19.6 GeV: PLB 750 (2015) 64
62.4 & 39 GeV: arXiv:1810.10159 [nucl-ex]

New measurements at $\sqrt{s_{NN}}$ = 27 and 54.4 GeV :

- Enough statistics for differential measurements vs p_T, centrality, etc.
- Rapp theory calculation overestimates in low mass region
- A hint of excess in the intermediate mass region can be observed in both $\sqrt{s_{NN}}$ = 27 and 54.4 GeV measurements

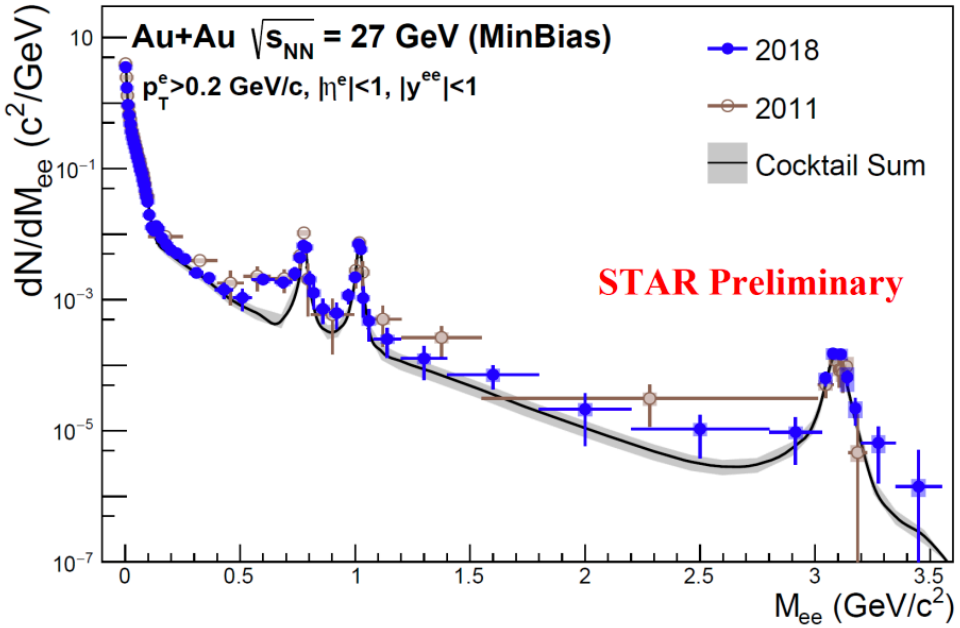
BES-II Program:

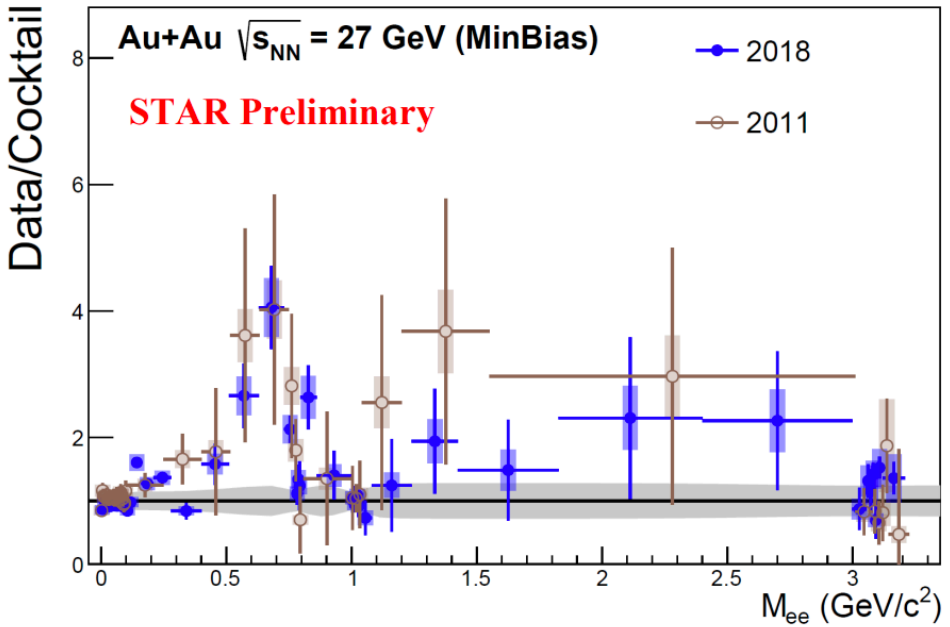
- Systematically study energy dependence of low mass region excess $\sqrt{s_{NN}}$ = 7.7 and 19.6 GeV
- Reduced charm cross section enhances sensitivity to thermal radiation in the intermediate mass region

Thanks for your attention!

Backup

Comparison Run11 and Run18 27 GeV result





Backup

Open charm and Drell-Yan contributions at 17.3 GeV In–In collisions.

Eur. Phys. J. C (2009) 61: 711–720

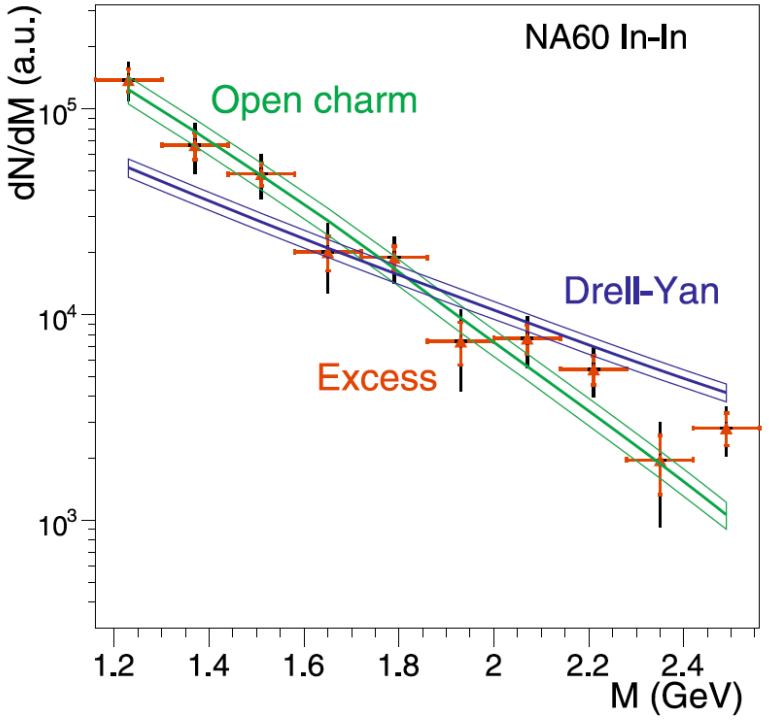


Fig. 4.3 Acceptance-corrected mass spectra of all three contributions to the IMR spectrum: Drell–Yan, *open charm* and the excess (*triangles*). The data are integrated over centrality

Drell-Yan cross-section scale factor

$\sqrt{s_{NN}}$ = 17.3 GeV σ_{DY}^{NA50} = 9.88nb

$\sqrt{s_{NN}}$ = 19.6 GeV σ_{DY}^{Pythia} = 13.44nb

Correct factor : $\frac{\sigma_{DY}^{NA50}}{\sigma_{DY}^{Pythia}}$