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

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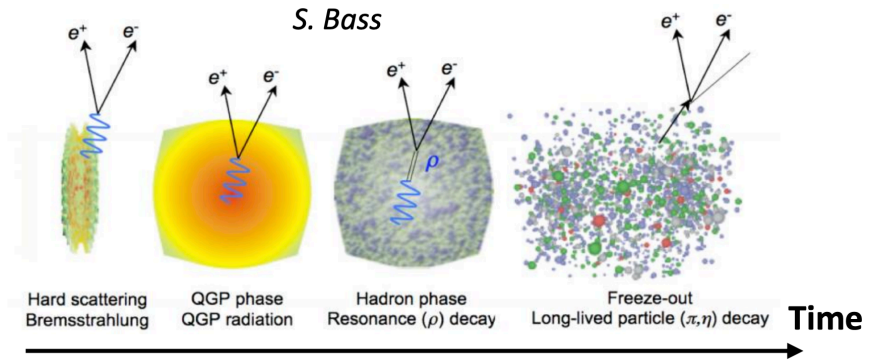
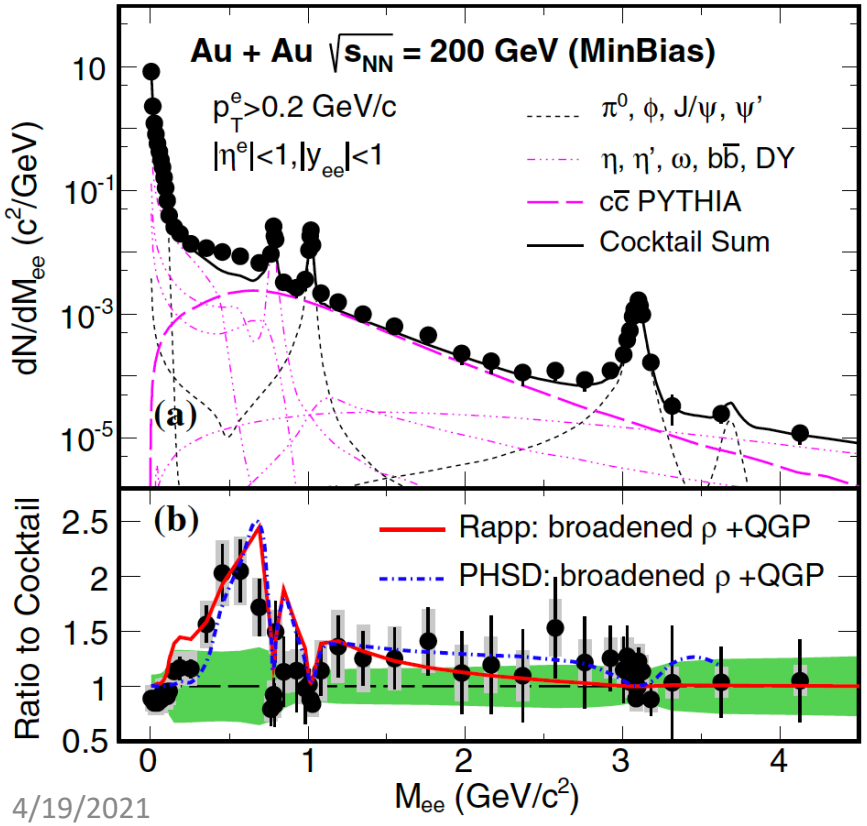
Dielectron production



STAR, PRL. 113 (2014) 22301



Dielectron – an excellent probe

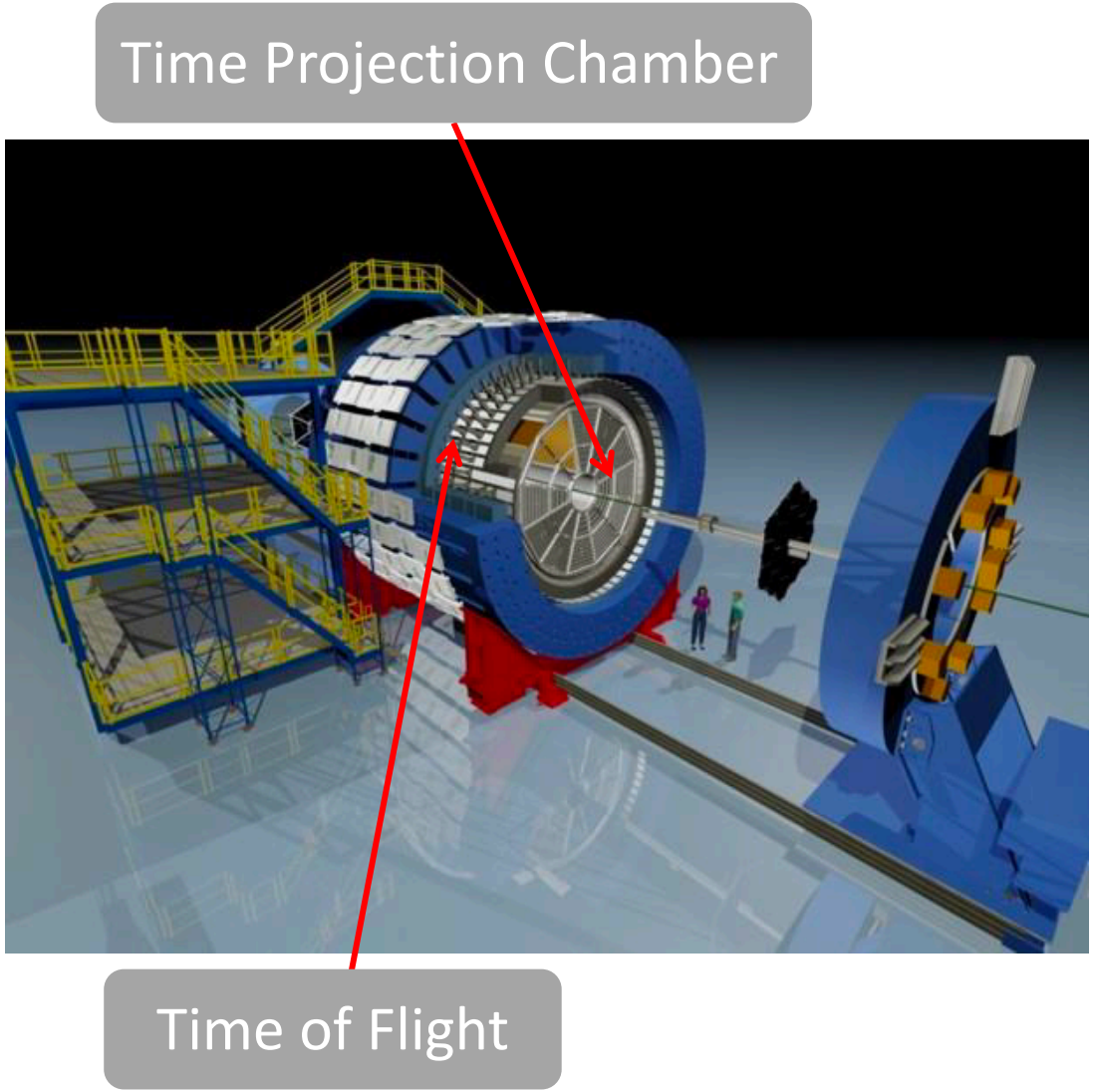
- Minimal interaction with the medium
- Carries information from the initial stage to the final stage of a collision

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 : $|\eta| < 1$, $0 \le \phi \le 2\pi$
- Tracking, particle momenta, electron identification

Time of Flight

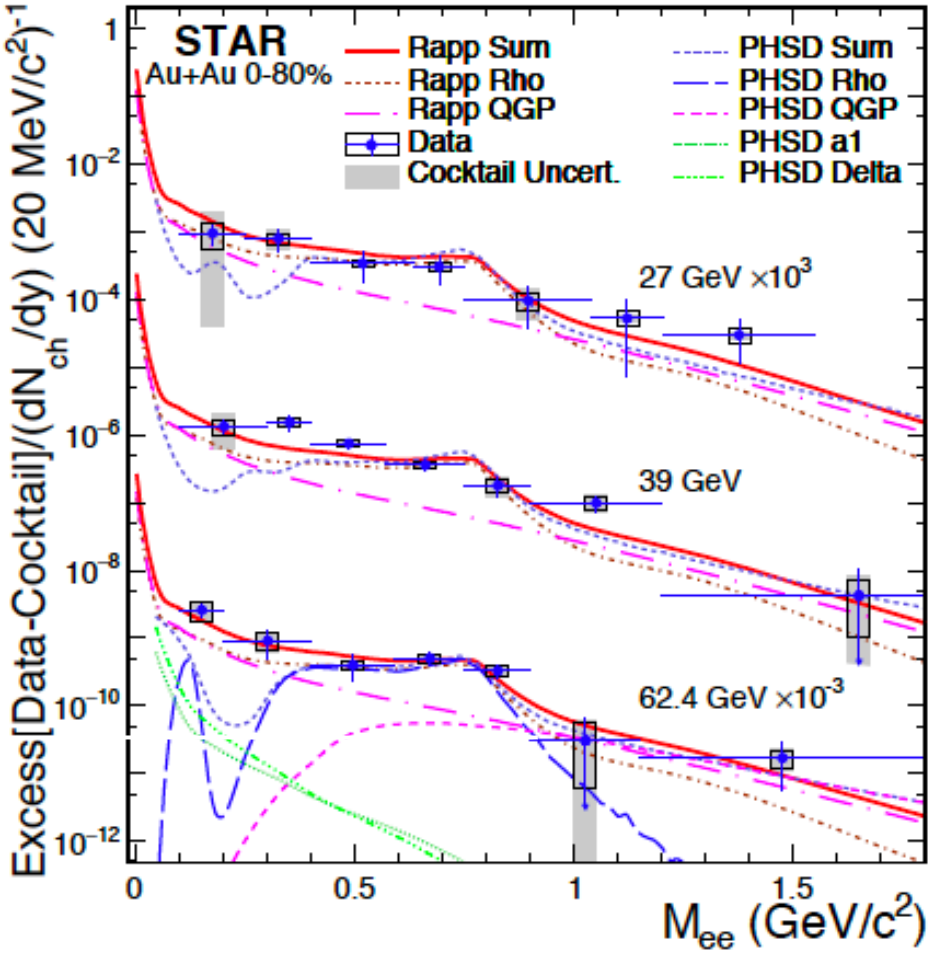
- Acceptance : $|\eta| < 0.9$, $0 \le \phi \le 2\pi$
- Rejection of slow hadrons
- Improve electron purity

Dataset

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

Year	Energy	Used events
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

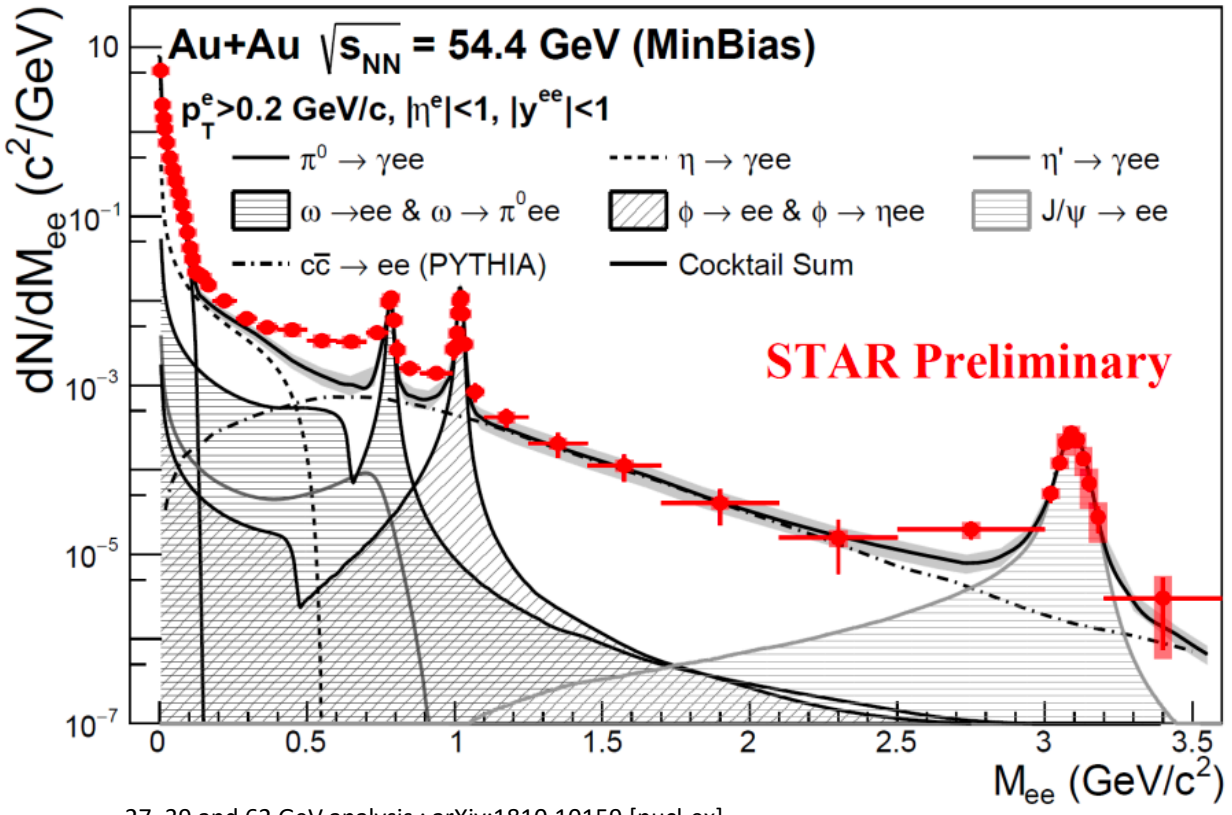


- Excess yield (data - cocktail) with acceptance correction
- Theory calculations including in-medium broadened ρ and thermal radiation are compared with data
- Within uncertainties, the model calculations are found to reproduce the acceptance-corrected excess yield in Au+Au collisions at each of the collision energies.

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

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

Cocktail in 54.4 GeV analysis

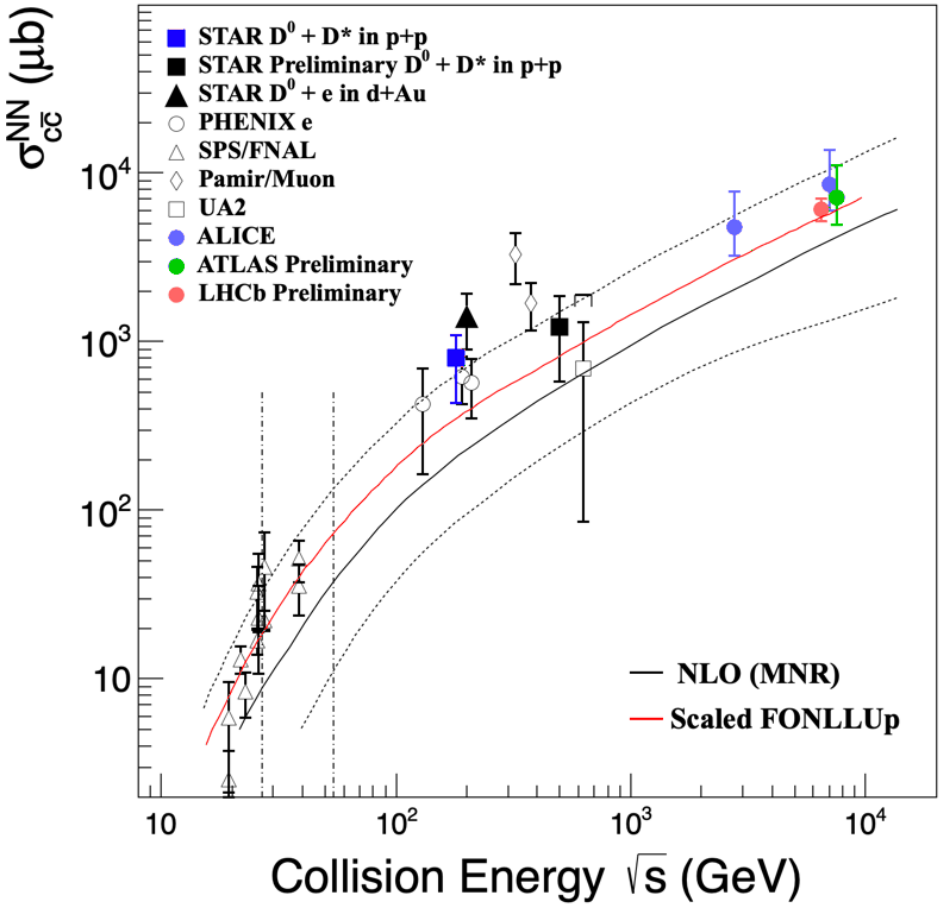


27, 39 and 62 GeV analysis : arXiv:1810.10159 [nucl-ex]

Cocktails in QM 2019

- $\sqrt{s_{NN}}$ = 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 $\sqrt{s_{NN}}$ = 54.4 GeV QM19 cocktails

Charm component



[1] Fermilab E769 Collaboration : Phys. Rev. Lett. 77, 2388 (1996).
[2] S P K Tavernier : Rep. Prog. Phys. 50, 1439 (1987).
[3] STAR : Phys. Rev. D 86, 072013 (2012).
[4] PHENIX : Phys. Rev. Lett. 97, 252002 (2006).
[5] ATLAS : JHEP 01 (2012) 128
[6] LHCb : JHEP 03 (2016) 159

Charm yield scale method

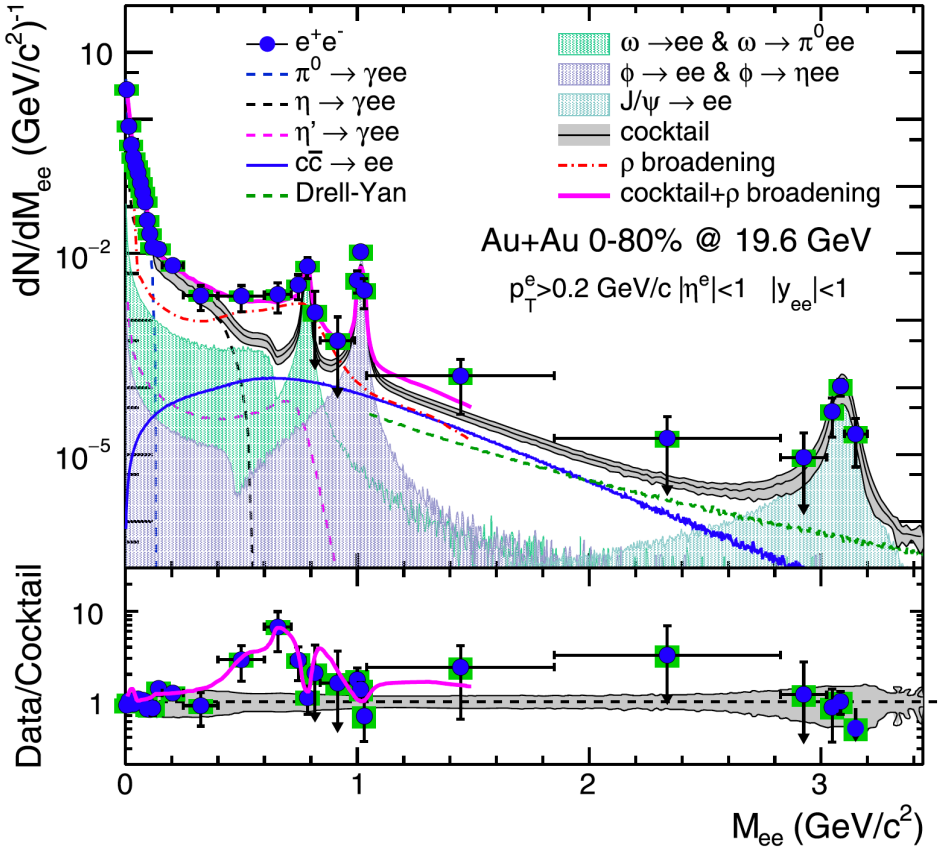
- Charm semi-leptonic decay in p+p collisions is scaled by following equation to match the Au+Au collisions.

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

Charm cross section

- The charm cross sections at $\sqrt{s_{NN}}$ = 54.4 GeV are extrapolated from worldwide data[1][2][3][4][5][6].
- 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 cross section.

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

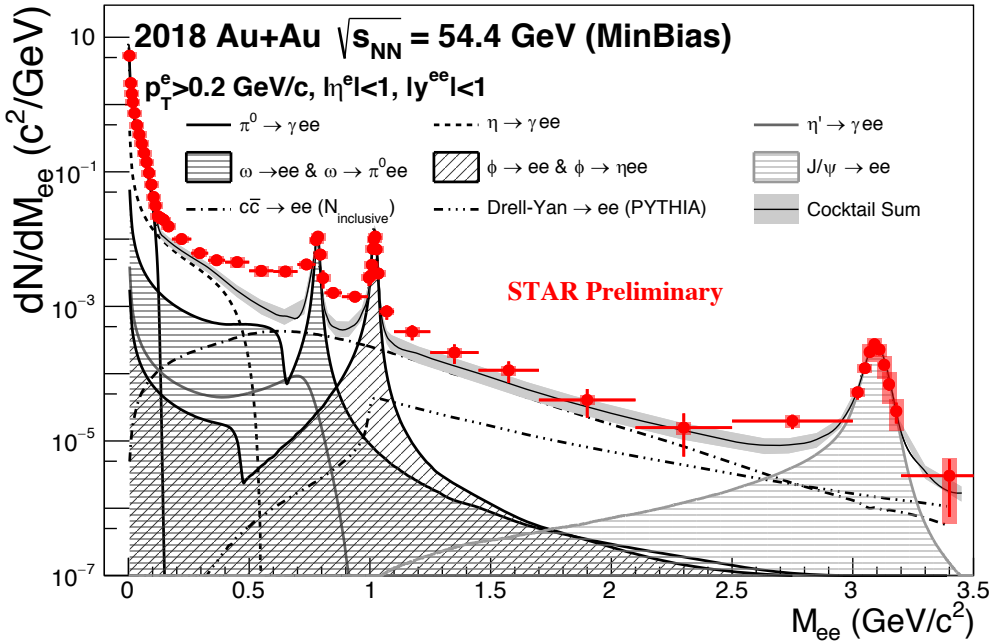
- Drell-Yan component becomes similar order of magnitude with charm component at lower energy in the intermediate mass region
- σ_{DY} was taken from PYTHIA and was corrected by the ratio of the cross-section used in STAR 19.6 GeV dielectron measurement to the corresponding PYTHIA cross-section at 19.6 GeV

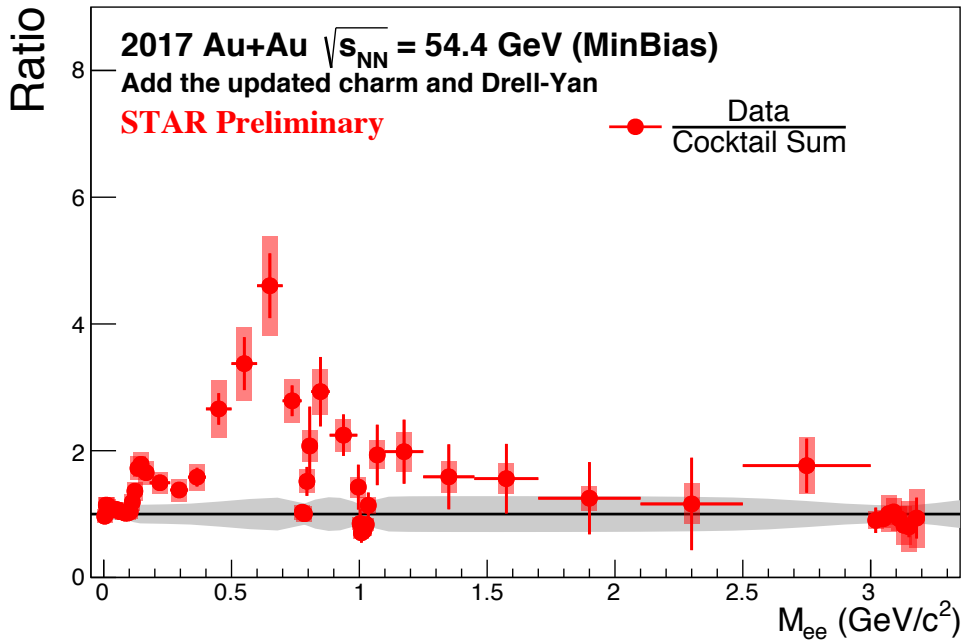
$$\sigma_{DY} = \sigma^{PYTHIA}_{DY\ 54.4\ GeV} * \frac{\sigma^{Paper}_{DY\ 19.6\ GeV}}{\sigma^{PYTHIA}_{DY\ 19.6\ GeV}} = 19.25\ nb$$

$$\sigma^{PYTHIA}_{DY\ 54.4\ GeV} = 26.19\ nb$$

54.4 GeV efficiency corrected spectra

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

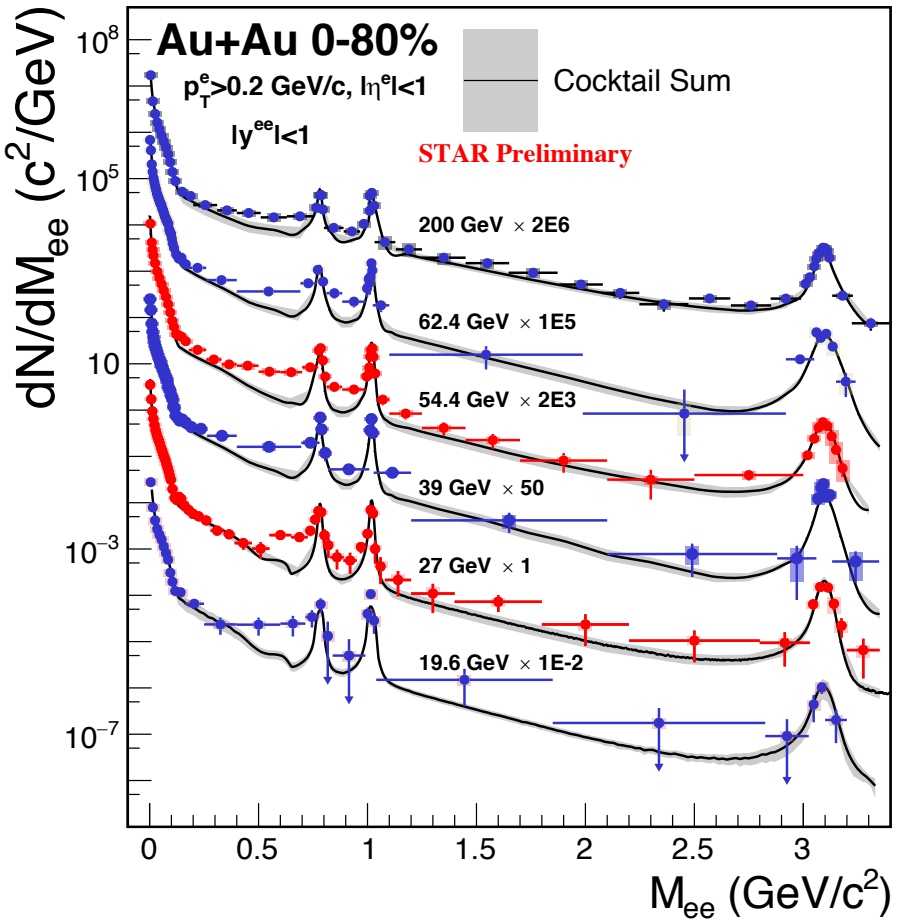




$\sqrt{s_{NN}}$ = 54.4 GeV : first dielectron measurement at this energy, cocktail updated

- A hint of excess in the intermediate mass region at 1.8σ level
- p_T and centrality differential analysis is ongoing
- Working on having a better background removal. For example, photonic electron

Summary and outlook



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

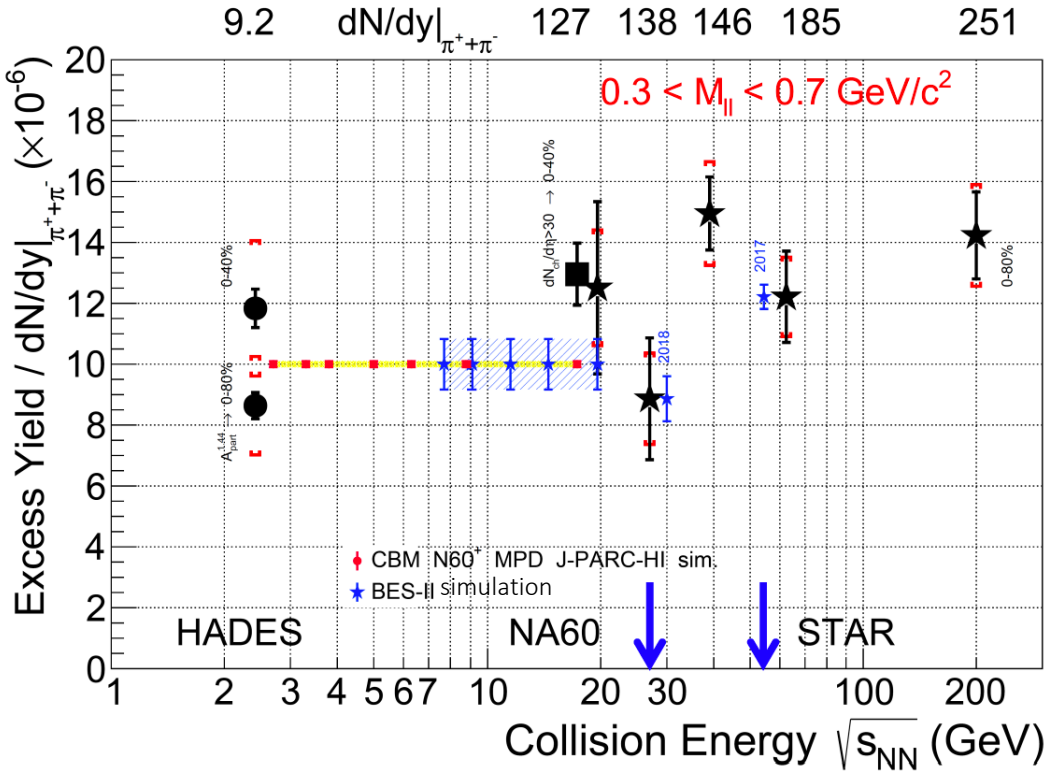
New measurements at $\sqrt{s_{NN}}$ = 54.4 GeV :

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

BES-II Program:

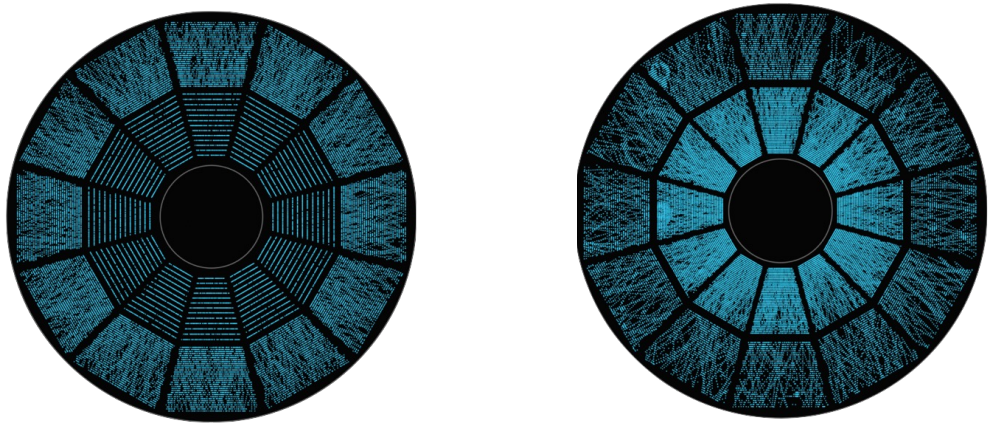
- Measurement of dielectron spectra for $\sqrt{s_{NN}}$ = 7.7, 9.1, 11.5, 14.5, 19.6 GeV will be possible with STAR BES-II data
- Reduced charm cross section enhances sensitivity to thermal radiation in the intermediate mass region
- Detector upgrade will reduce the uncertainties of dielectron analysis

Dielectron measurement with STAR BES-II program



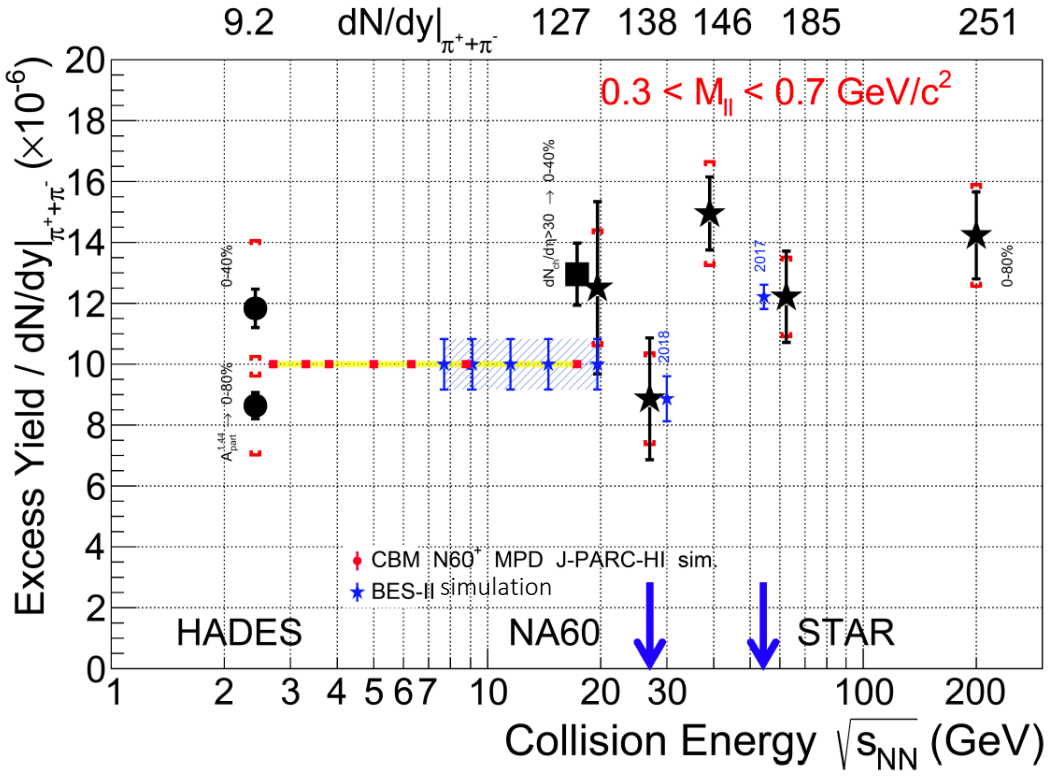
Plot : STAR, F.Seck, QM 2019
NA60: Chiral 2010, AIP Conf.Proc. 1322 (2010) 1
STAR: PLB 750 (2015) 64, arXiv:1810.10159 [nucl-ex]
HADES: Nature Phys. 15 (2019) 1040

- Systematically study energy dependence of low mass region excess between $\sqrt{s_{NN}}$ = 7.7 and 19.6 GeV
- Enhanced tracking and particle identification capabilities with iTPC and eTOF upgrades
  - Extend η acceptance from $|\eta| < 1.0$ to $|\eta| < 1.5$
  - Extend the lower limit of p_T from 0.2 to 0.1 GeV/c



Events display: without iTPC with iTPC

Dielectron measurement with STAR BES-II program



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Thanks for your attention!

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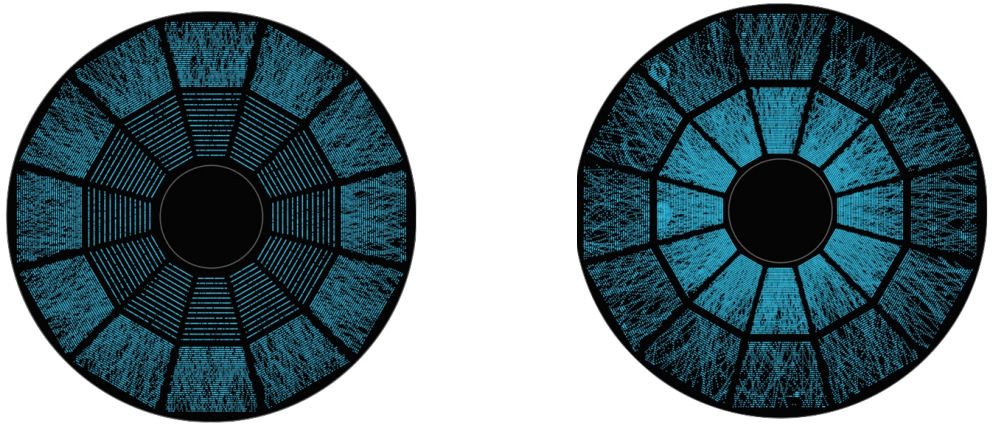


Events display: without iTPC with iTPC

Backup

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

Eur. Phys. J. C (2009) 61: 711–720

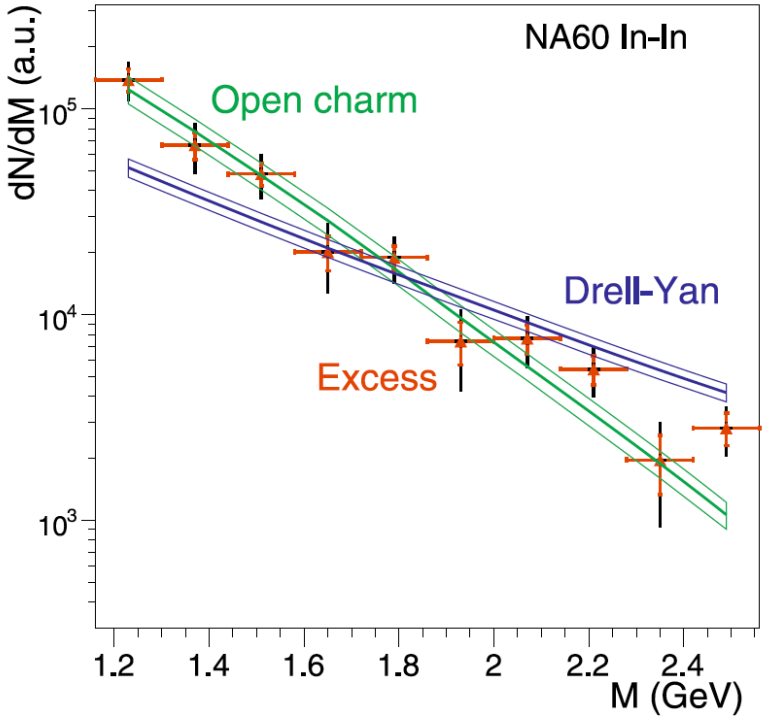


Fig. 4.3 Acceptance-corrected mass spectra of all three contributions to the IMR spectrum: Drell–Yan, *open charm* and the excess (*triangles*). The data are integrated over centrality

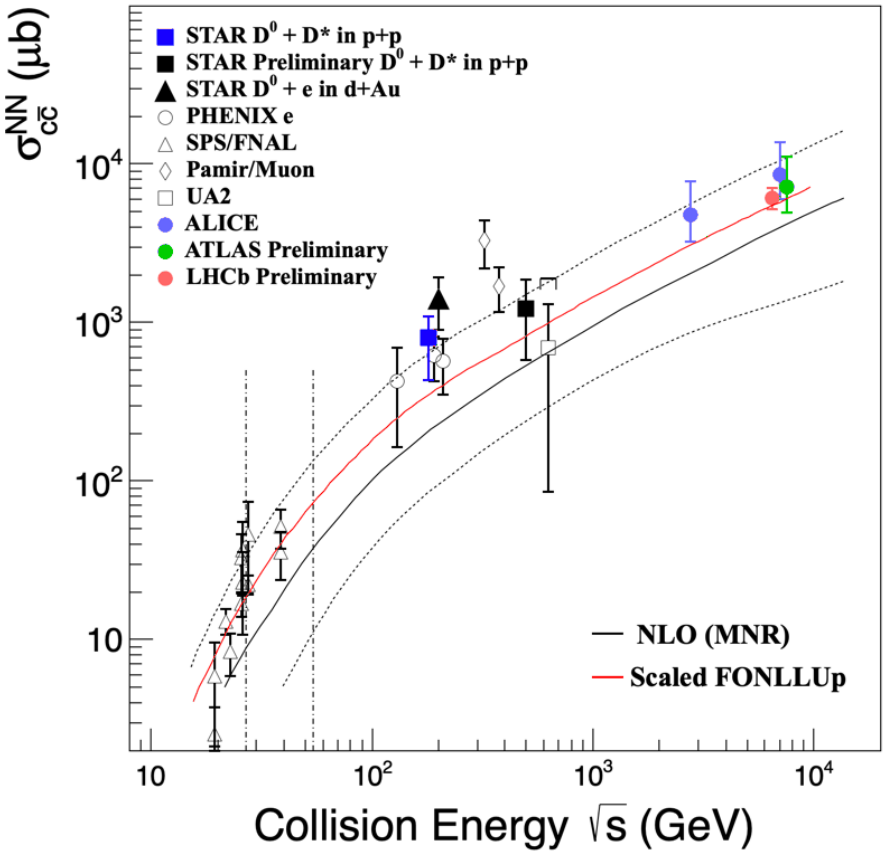
Drell-Yan cross-section scale factor

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

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

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

Charm cross-section and scale method



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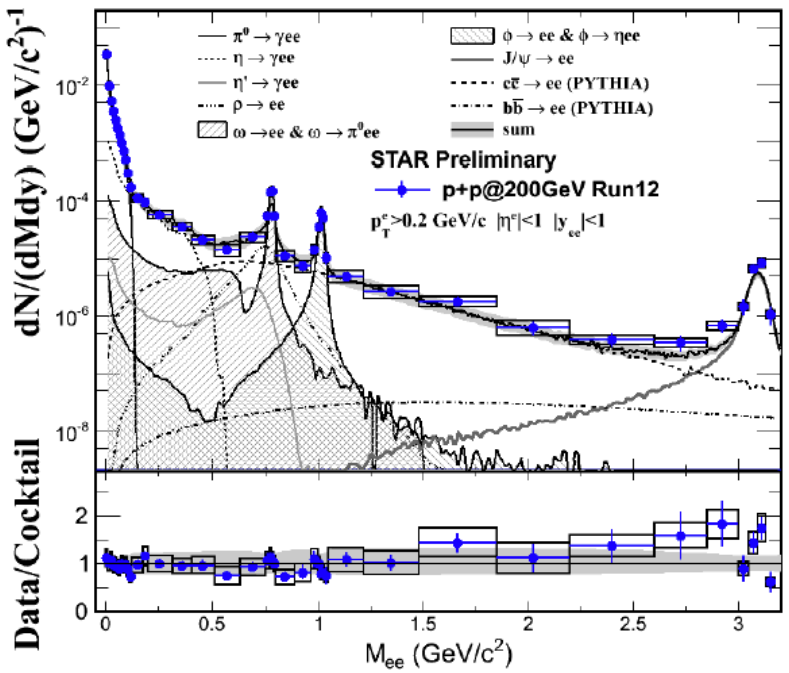
$$\frac{1}{N}\frac{dN}{dM} = \frac{1}{nCharm}\left(\frac{dN}{dM}\right)_{pp}\frac{\sigma_{c\bar{c}}}{\sigma_{mb}} N_{bin} BR_{(c\to e^+)} BR_{(c\to e^-)} \quad (1)$$

- 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

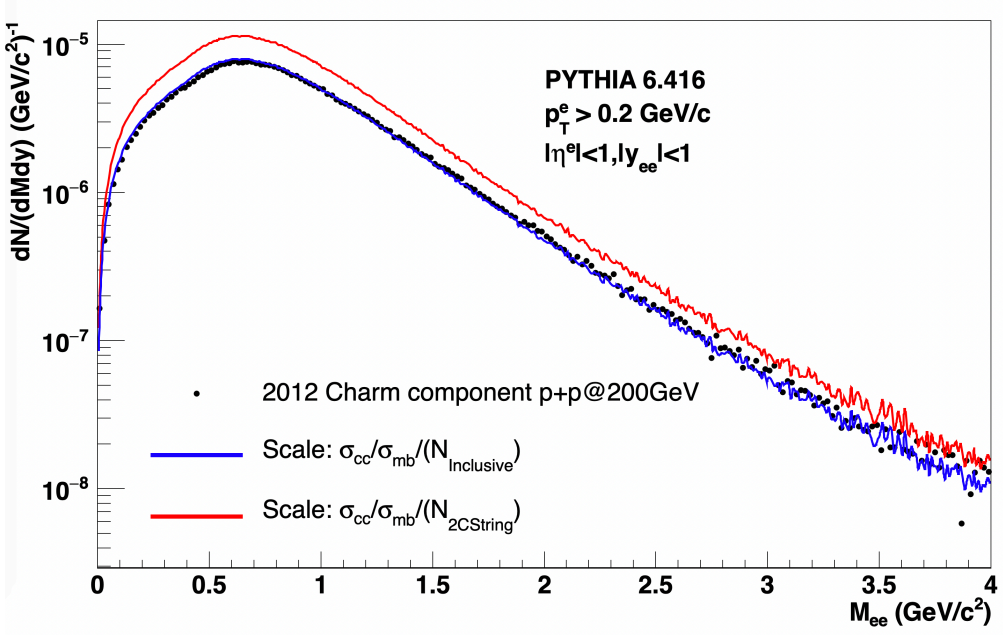
Journal of Physics: Conference Series, 535:012006, sep 2014

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



$\sqrt{s_{NN}}$ = 200GeV $\sigma_{NSD} = 30 \pm 3.5$ 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 $\sqrt{s_{NN}}$ = 54.4 will be scaled by $N_{inclusive}$ method