PROCEEDINGS OF SCIENCE

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

**Zhen Wang for the STAR Collaboration** [a,b,*]

[a] *Shandong University,*
*72 Binhai Road, Jimo District, Qingdao, China*
[b] *Key Laboratory of Particle Physics and Particle Irradiation (MOE), Shandong University,*
*Qingdao 266237, China*

*E-mail:* wangzhen@rcf.rhic.bnl.gov

Dielectron production is suggested as an excellent probe of the hot and dense medium created in relativistic heavy-ion collisions due to their minimal interactions with the partonic and hadronic medium. They can carry the information from the initial to the final stage of a collision. The study of the dielectron mass spectrum could help to disentangle various contributions. In the low mass region (LMR, $\mathrm{M_{ee}} < \mathrm{M}_{\phi}$), the mass spectra of vector mesons are modified due to their interaction with the medium which could provide an access to the chiral symmetry restoration. In the intermediate mass region (IMR, $\mathrm{M}_{\phi} < \mathrm{M_{ee}} < \mathrm{M_{J/\Psi}}$), dielectrons from thermal radiation are predicted as a QGP thermometer, meanwhile the contributions from heavy quark semi-leptonic decays make the extraction of the thermal radiation contribution very challenging.

In this proceedings, we present the latest dielectron spectra measurements in Au+Au collisions at $\sqrt{s_{\rm NN}} = 27$ and 54.4 GeV with the STAR experiment. The 1.5 B (1.3 B) minimum-bias events of Au+Au collisions at $\sqrt{s_{\rm NN}} = 27$ (54.4) GeV taken in 2018 (2017) significantly enhance the precision of the in-medium $\rho$ modification measurement compared to the STAR BES-I results. Lower heavy quark semi-leptonic decay contributions compared to those at top RHIC energies and the large data samples may allow the first extraction of the medium temperature with IMR dielectrons at RHIC. The physics implications of these measurements will be discussed and put into context of previous results.

*HardProbes2020*
*1-6 June 2020*
*Austin, Texas*

[*] Speaker





PoS(HardProbes2020)045

## 1. Introduction

Dielectrons play an important role in the study of the quark-gluon plasma. Because electrons do not interact via strong interactions and are emitted throughout the entire evolution of a heavy-ion collision, they can provide information about all states of the system evolution [1].

The dielectron invariant mass spectrum is divided into different mass regions according to different physics interests. In the low mass region (LMR, $M_{ee} < M_\phi$), the vector meson spectra modification is the major physics interest. This modification may serve as the tool to study the chiral symmetry restoration. The production of dielectrons in the intermediate mass region (IMR, $M_\phi < M_{ee} < M_{J/\psi}$) is closely linked to the QGP thermal radiation[2]. This measurement can be used to determine the temperature of the QGP medium. However, the heavy flavor semi-leptonic decay contributions are the major source of dileptons in this mass region. To measure the dielectrons from QGP thermal radiation, this contribution should be measured and subtracted.

In this proceedings, we will present the STAR dielectron measurement results at $\sqrt{s_{NN}} = 27$ and 54.4 GeV Au+Au minimum bias collisions.

## 2. Analysis

The data reported in this proceedings are collected with the Solenoidal Tracker At RHIC (STAR) detector in 2018 (2017) in Au+Au collisions at $\sqrt{s_{NN}} = 27$ (54.4) GeV respectively. These two new data samples are roughly 10 times larger statistics, compared to previous STAR data at $\sqrt{s_{NN}} = 27$ and 62.4 GeV taken in years 2011 and 2010 [3]. The two key subdetectors used in these two analysis are Time Projection Chamber (TPC) [4] and the Time of Flight (TOF) [5].

The TPC is the primary charged-particle tracking detector at STAR. It provides tracking and momentum information of charged particles. The ionization energy loss (dE/dx) information can be used to identify the particle species. By combining the dE/dx from the TPC and the velocity measured by the TOF, the particle identification capabilities can be improved.

The unlike-sign technique is used to reconstruct the foreground signal by combining all electrons and positrons from the same event. The background is estimated by the like-sign technique, including correlated and combinatorial background, and corrected by a pair sign acceptance correction factor. The difference in the acceptance between the mixed-event unlike-sign and like-sign pairs is used to get the pair sign acceptance correct factor [6]. The contributions of the dielectron from hadronic decays, which called the hadronic cocktail, can be simulated once hadron yields and $p_T$ spectra are measured.

## 3. Results and discussion

For the results presented in Quark Matter 2019, the charm contribution was taken from the STAR previous result and the Drell-Yan contribution was not included, because of the lack of charm and Drell-Yan yield measurements at $\sqrt{s_{NN}} = 27$ and 54.4 GeV [3]. Figure 1 shows the dielectron invariant mass spectra and the hadronic cocktail (without the $\rho^0$ contribution) at the respective energy. The charm yields are extrapolated from the worldwide data [7–9], and the Drell-Yan yields are estimated by using the same method in [10]. The enhancement of LMR comes from the $\rho$

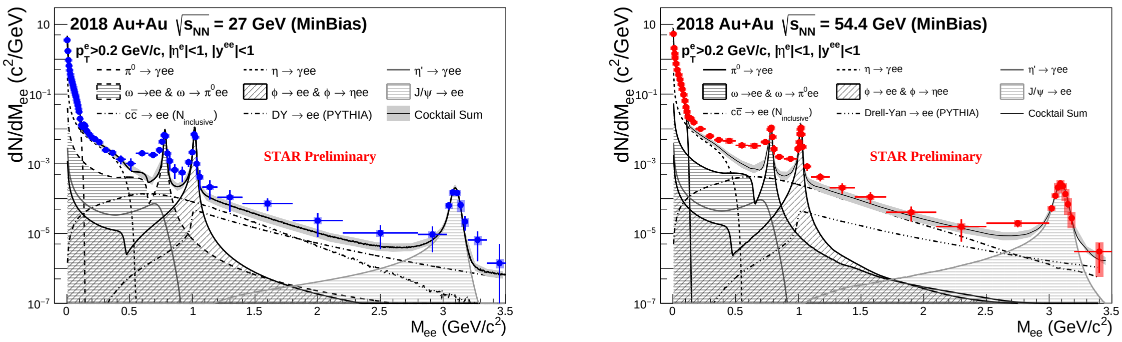


**Figure 1:** Left panel shows dielectron invariant mass spectrum within STAR acceptance ($p_T^e > 0.2$ GeV, $|\eta^e > 1|$ and $|y_{ee} < 1|$) in minimum bias(MinBias) Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV. The dashed and solid lines shows the contributions from the hadronic decays. Right panel shows the dielectron spectrum with same acceptance in Au+Au collisions at $\sqrt{s_{NN}} =$ 54.4 GeV compared the hadronic cocktail. The veritcal error bars and boxes around the data points indicate the statistic and systematic uncertainties. The gray band present the uncertainty of the cocktail simulation

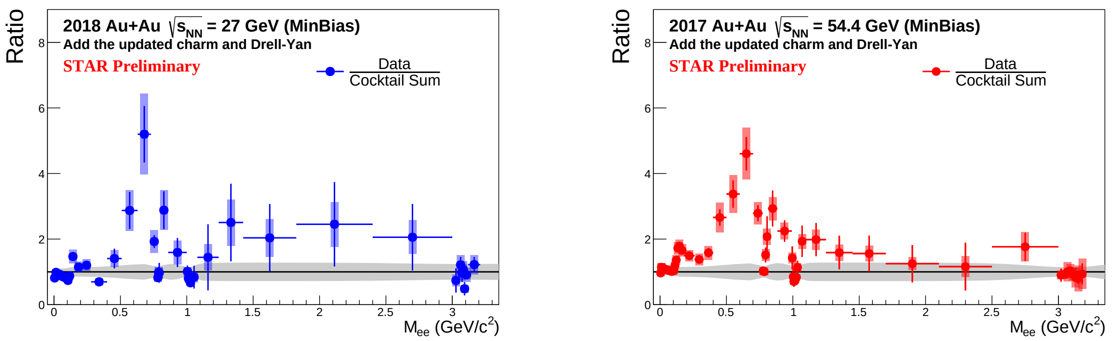


**Figure 2:** Ratio of the data to respective hadronic cocktail at $\sqrt{s_{NN}} =$ 27 (left panel) and 54.4 (right panel) GeV.

meson, whose mass spectrum is modified by the hot and dense medium. The J/Ψ yields from their two-body decay are used to tune the parameters of the hadronic cocktail and reduce their uncertainty.

The ratio of data to the hadronic cocktail shows in Figure 2. A slight enhancement can be observed in the intermediate mass region at $\sqrt{s_{NN}} =$ 27 GeV. That enhancement might provide a chance to measure the QGP thermal radiation with the lower charm cross at lower collision energy.

The left panel of Figure 3 shows the dielectron spectra in Au+Au minimum bias collisions measured by STAR at different energies. STAR is collecting the high statistic datasets between $\sqrt{s_{NN}} =$ 7.7 and 19.6 GeV and upgrades the detector during the second phase of the Beam Energy Scan (BES-II) program. The detector upgrades will extend the rapidity acceptance and enhance the tracking and particle identification capabilities [11]. The right panel of Figure 3 shows the predicted precision of excess yield of the $\sqrt{s_{NN}} =$ 27 GeV, 54.4 GeV, and upcoming BES-II datasets. To get

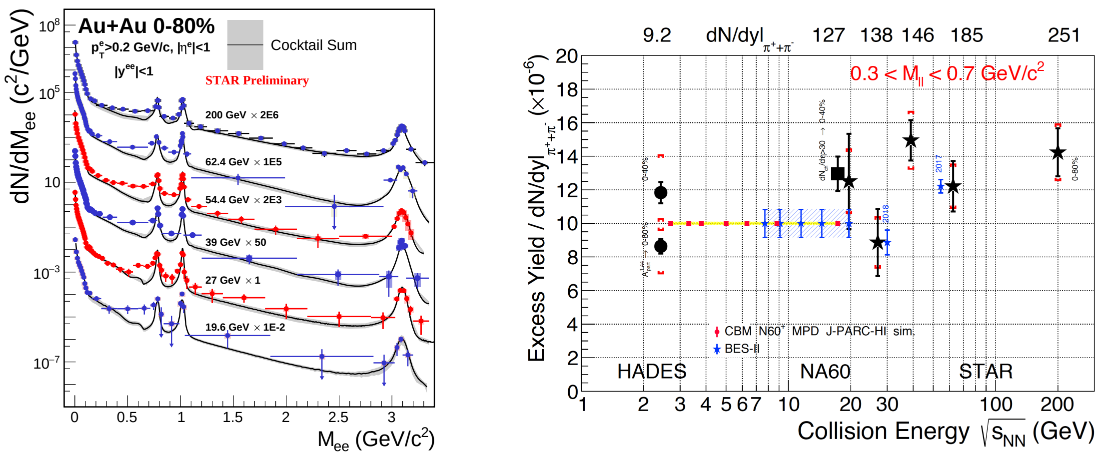


**Figure 3:** Left panel show the dielectron spectra measured by STAR experiment at different energies. The two new measurements are highlighted in red points. The excitation function of dielectron excess yields measured by different experiments in the mass region $0.3 < M_{ee} < 0.7$ GeV/$c^2$ is shown in the right panel [12–14]. The blue error bars represent the predicted precision of excess yield of the $\sqrt{s_{NN}} =$ 27 GeV, 54.4 GeV and upcoming BES-II datasets

the excess yield, the dielectron spectra with cocktail subtraction is integrated in the mass region of 0.3 - 0.7 GeV and normalized by the charged pion yield.

With BES-II high statistic datasets and upgraded detector, the total baryon density dependence of dielectron production can be studied. The BES-II program also provides an excellent opportunity to check the model descriptions and fill the excitation function of dielectron production between $\sqrt{s_{NN}} =$ 7.7 and 19.6 GeV.

## 4. Summary

We report the dielectron invariant mass spectra from high statistic datasets of Au+Au collisions at $\sqrt{s_{NN}} =$ 27 and 54.4 GeV collected by the STAR experiment at RHIC. In the low mass region, a significant enhancement of dielectron yields is observed with respect to the hadronic cocktail simulation without $\rho$ contribution. In the intermediate mass region, a hint of excess can be observed at $\sqrt{s_{NN}} =$ 27 GeV. There might have a potential temperature measurement from the thermal radiation.

With these two high statistic datasets, the $p_T$ and centrality differential analysis will be allowed. That is the first time to do the differential measurements at this energy range. BES-II program will provide a chance to verify model calculations and a potential measurement of QGP thermal radiation in low energy range.

## 5. Acknowledgments

The work is partly supported by the Shandong Provincial Natural Science Foundation, China (No. ZR2019MA005) and the Program of Qilu Young Scholars of Shandong University.

## References


[1] E.V. Shuryak, *Quark-Gluon Plasma and Hadronic Production of Leptons, Photons and Psions*, *Sov. J. Nucl. Phys.* **28** (1978) 408.

[2] R. Rapp and J. Wambach, *Chiral symmetry restoration and dileptons in relativistic heavy ion collisions*, *Adv. Nucl. Phys.* **25** (2000) 1 [hep-ph/9909229].

[3] STAR collaboration, *Measurements of Dielectron Production in Au+Au Collisions at* $\sqrt{s_{NN}}$*= 27, 39, and 62.4 GeV from the STAR Experiment*, 1810.10159.

[4] M. Anderson et al., *The Star time projection chamber: A Unique tool for studying high multiplicity events at RHIC*, *Nucl. Instrum. Meth. A* **499** (2003) 659 [nucl-ex/0301015].

[5] STAR collaboration, *Multigap RPCs in the STAR experiment at RHIC*, *Nucl. Instrum. Meth. A* **661** (2012) S110.

[6] STAR collaboration, *Measurements of Dielectron Production in Au+Au Collisions at* $\sqrt{s_{\rm NN}}$ *= 200 GeV from the STAR Experiment*, *Phys. Rev. C* **92** (2015) 024912 [1504.01317].

[7] E769 collaboration, *Forward cross-sections for production of D+, D0, D(s), D*+ and Lambda(c) in 250-GeV pi+-, K+-, and p - nucleon interactions*, *Phys. Rev. Lett.* **77** (1996) 2388.

[8] STAR collaboration, *Measurements of* $D^0$ *and* $D^*$ *Production in* $p + p$ *Collisions at* $\sqrt{s} = 200$ *GeV*, *Phys. Rev. D* **86** (2012) 072013 [1204.4244].

[9] PHENIX collaboration, *Measurement of high-*$p_T$ *single electrons from heavy-flavor decays in* $p + p$ *collisions at* $\sqrt{s} = 200$ *GeV*, *Phys. Rev. Lett.* **97** (2006) 252002 [hep-ex/0609010].

[10] STAR collaboration, *Energy dependence of acceptance-corrected dielectron excess mass spectrum at mid-rapidity in Au+Au collisions at* $\sqrt{s_{NN}}$ *= 19.6 and 200 GeV*, *Phys. Lett. B* **750** (2015) 64 [1501.05341].

[11] STAR collaboration, *The STAR BES-II and Forward Rapidity Physics and Upgrades*, *Nucl. Phys. A* **982** (2019) 951.

[12] NA60 collaboration, *First measurement of the rho spectral function in high-energy nuclear collisions*, *Phys. Rev. Lett.* **96** (2006) 162302 [nucl-ex/0605007].

[13] HADES collaboration, *Probing dense baryon-rich matter with virtual photons*, *Nature Phys.* **15** (2019) 1040.

[14] T. Galatyuk, *Recent Results from HADES*, *JPS Conf. Proc.* **32** (2020) 010079.