The Production of Low-Mass Dielectrons in Au+Au Collisions at $\sqrt{s_{NN}}$ = 27 GeV from STAR

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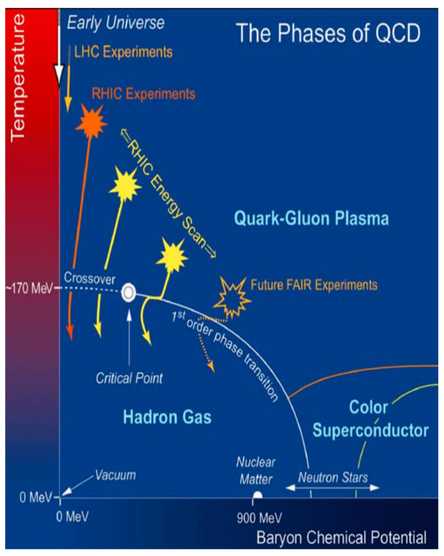
Abstract

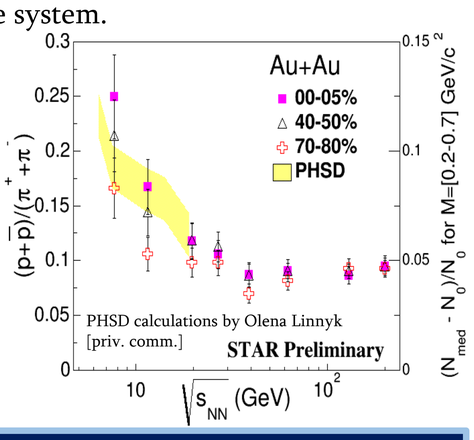
Dileptons in the low-mass region, (M_{ll} <1.1GeVc^{-2}), retain information about vector mesons that originated in the strongly interacting matter created by relativistic heavy-ion collisions. Linking these vector mesons to an in-medium broadening of their spectral functions may suggest chiral symmetry restoration.[1] Measurements at SPS and RHIC energies have been made in the low-mass region that are consistent with in-medium modification of the ρ-meson spectral function. By using RHIC's beam energy scan (BES) program and its high-purity, large-acceptance electron identification, STAR has been systematically studying the production of low-mass dielectrons as a function of collision energy. We present the preliminary results of the low-mass dielectron production in Au+Au collisions at $\sqrt{s_{NN}}$ = 27 GeV. The study is focused on the comparison of the spectra with the expected hadronic contributions without production from the ρ-meson. In addition, the results will be compared with previously presented measurements from other BES energies ($\sqrt{s_{NN}}$ = 19.6, 39, and 62.4 GeV) and projections for future BES II measurements will be presented.

Motivation



- RHIC's BES program explores the phases of QCD by colliding Au+Au at different $\sqrt{s_{NN}}$ [Left Fig.]
- As $\sqrt{s_{NN}}$ increases, the relative lifetime of the system in the partonic phase increases and in the hadronic phase, it decreases.
- Models by various authors [2-6], which describe SPS data and STAR's measurements at $\sqrt{s_{NN}}$ =200 GeV, indicate that the low-mass dielectron production is dominated by vector-meson production in the hadronic phase.
- In the models, these mesons experience a broadening of their spectral function, which depends on the total baryon density of the system.

- [Right Fig.] The total baryon density varies minimally from 19.6-200 GeV; hence, it is expected the medium-induced yield will remain consistent at these energies.
- At lower energies, where the density rises, we expect to see the medium-induced yield to increase. This is corroborated by the PHSD [5] calculations in the shaded region showing an increase in the relative medium-induced yield as the energies drop.

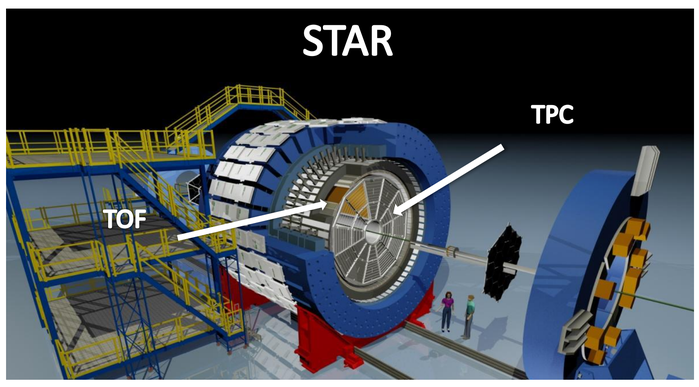


Objective

- To measure the yield and test the spectral function broadening of the vector mesons, STAR finds itself in a unique position to systematically study the dielectron production in the low-mass region with enough data taken at $\sqrt{s_{NN}}$ = 19.6, 27, 39, and 62.4 GeV. **This study focuses on the production at $\sqrt{s_{NN}}$ = 27 GeV.**

Data Set

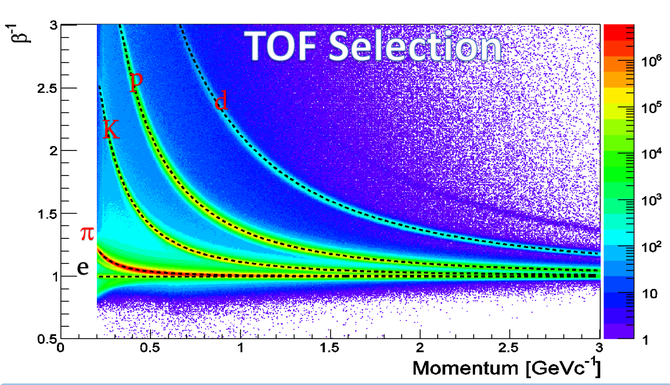
STAR's Time Projection Chamber (TPC) and Time of Flight (TOF) detectors enable the large acceptance and high-purity detection of electrons by using the TOF's precise timing, σ < 100 ps, to remove slower hadrons, which extends and improves the TPC's normalized dE/dx, $n\sigma_e$.

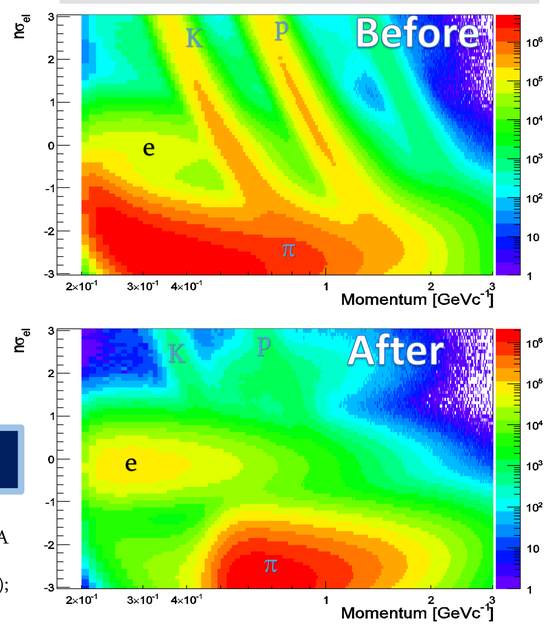


Sample	Event Criteria
Au+Au @ $\sqrt{s_{NN}}$ = 27 GeV	|Vz| < 70 cm
	|Vr| <2 cm
70M events	0-80% Centrality

Track Criteria
Primary track associated to TOF
p_T > 0.2 GeVc^{-1}

Electron/Positron Criteria
|β^{-1}-1| < 0.03
[See before & after TOF selection below]



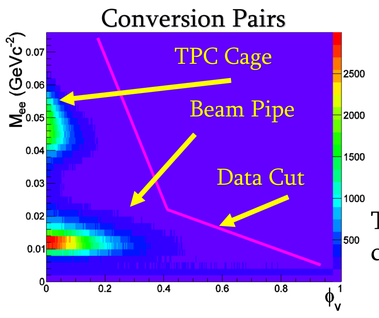


References

[1] R.Rapp and J.Wambach, Advances in Nuclear Physics 25(2000).
[2] H. van Hees & R. Rapp, PRL 97, 102301 (2006); H. van Hees & R. Rapp, NPA 806, 339 (2008)
[3] J. Ruppert, C. Gale, T. Renk, P. Lichard, & J. Kapusta, PRL 100,162301 (2008); T. Renk & J. Ruppert, PRC 77, 024907 (2008)
[4] K. Dusling, D. Teany, & I. Zahed, PRC 75, 024908 (2007)
[5] O. Linnyk et al., PRC 84, 054917 (2011).
[6] STAR Collaboration, arxiv:1312.7397
[7] T. Ullrich, D. Irmscher, GENESIS code parameterized by CERES
[8] Z. Tang et al. Phys. Rev. C 79, 051901 (2009)
[9] Private communication with B.Huang. Based on a FONNL upper-limit curve fitted to previously measured p+p charm cross-sections.

Invariant Mass Spectrum

Dielectron Backgrounds



- Peaks represent pairs from converted photons
- ϕ_v, on y-axis, is the angle between the pair's opening angle orientation and the orientation if the pair was from conversion

Background Sources:
Correlated
Combinatorial
Conversion

This equation estimates correlated & combinatorial backgrounds:

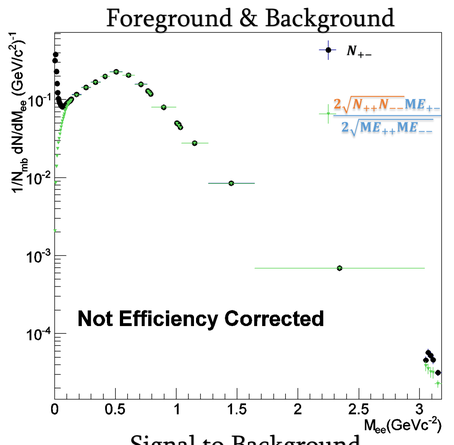
$$\text{Background} = 2\sqrt{N_{++}N_{--}}\,\frac{ME_{+-}}{2\sqrt{ME_{++}ME_{--}}}$$

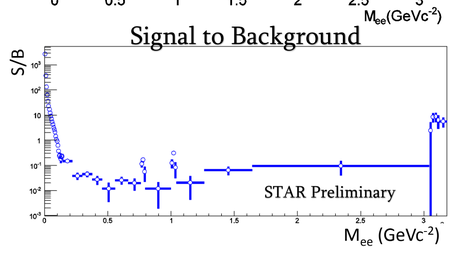
where:

Geometric Mean:
same-event like-sign pairs N_{--}, N_{++}

Acceptance Correction:
mix-event pairs ME_{+-}, ME_{--}, ME_{++}

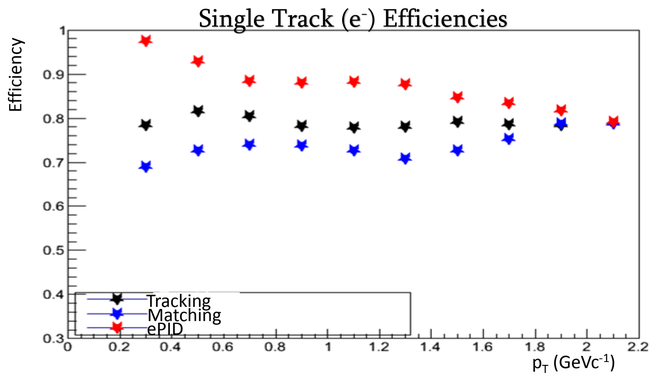
- Similar reference multiplicity, z vertex position, & event plane
- 20 Events/pool

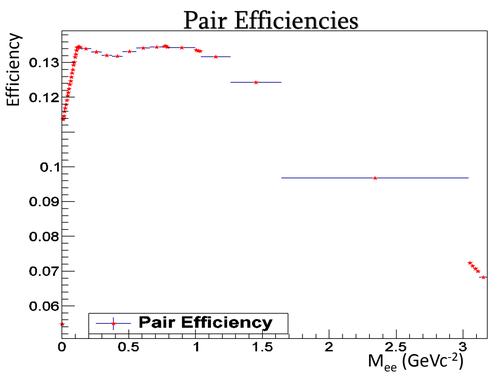




Efficiencies

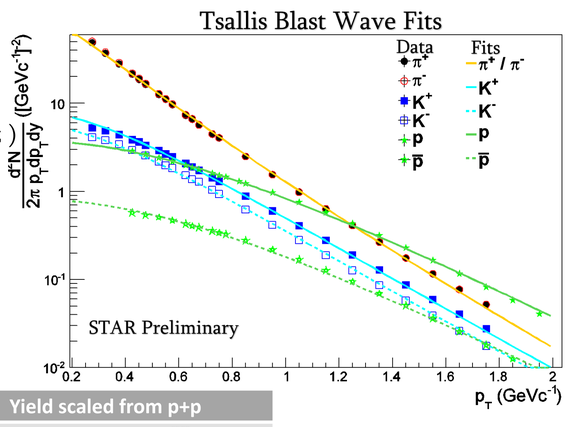
Efficiencies Types:	
Figure 1 (below)	Figure 2 (below)
Single: Tracking (embedding sample)	Pair: Built from single track efficiency
Single: Matching (photonic $e^{+/-}$ sample)	
Single: ePID (photonic $e^{+/-}$ sample)	





Cocktail

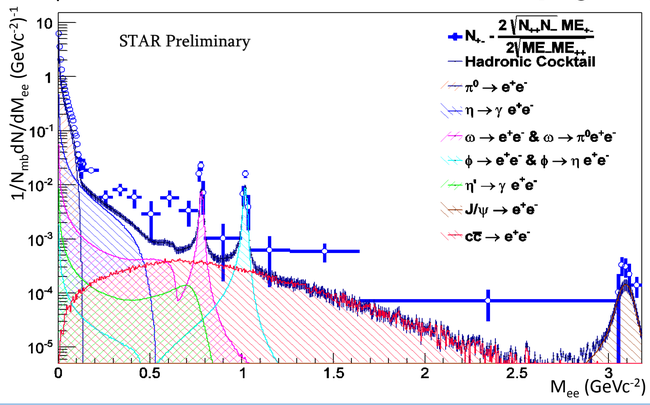
- A combination of hadronic contributions to the mass spectrum
  - $\pi^0 \to \gamma e^+e^-$, $\eta \to \gamma e^+e^-$, $\eta' \to \gamma e^+e^-$, $\omega \to e^+e^-$, $\omega \to \pi^0 e^+e^-$, $\phi \to \eta e^+e^-$, $\phi \to e^+e^-$, $J/\psi \to e^+e^-$, $c\bar{c} \to e^+e^-$ (PYTHIA)
- Parent distribution input:
  - Isotropic azimuthal angle
  - Rapidity follows GENESIS distribution [7]
  - Mass by Breit-Wigner (VMs) or Kroll-Wada (Dalitz)
  - p_T by Tsallis Blast Wave calculations [8]
    - Parameterized to 27 GeV STAR π/K/P
- Dielectrons:
  - Toy Monte Carlo decay
  - Yield scaled by SPS meson to π^0 ratios
  - π^0's $\frac{dN}{dy}$ = 55.8 (Estimated via TBW)

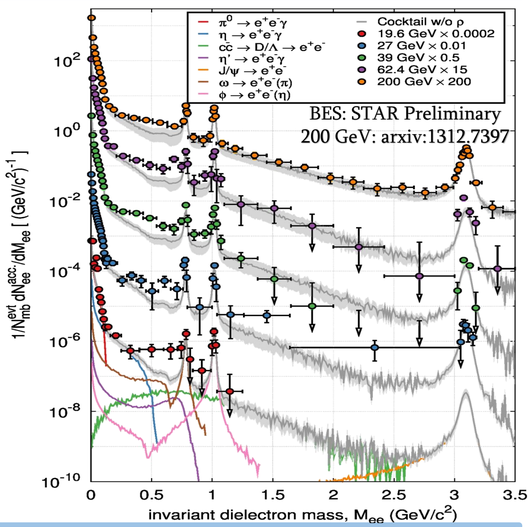


Meson	π^0	η	ω	ϕ	η	J/ψ	$c\bar{c}$ Yield scaled from p+p
Meson/π^0	1	0.085	0.069	0.018	0.078	6.2E-6	$n_{Coll}(230) * \sigma_{c\bar{c}}(18.9\mu b[9]) / \sigma^{pp}_{mb}(33mb)$

Results & Comparisons to Other BES Data

The mass spectra for e^+e^- from Au+Au collisions at:
$\sqrt{s_{NN}}$ = 27 GeV [Left Fig.]
$\sqrt{s_{NN}}$ =19.6, 27, 39, 62.4, and 200 GeV [Right Fig.]





Future Dielectron Measurements

- Proposal to run RHIC BES II
- STAR's aim is to continue the systematic study of dielectron production where the total baryon densities are **higher** as shown in section: Motivation.
- The table below shows STAR's request for BES II. These statistics will allow for a similar statistical significance reached in STAR's study at $\sqrt{s_{NN}}$ = 200 GeV. This is helped by the expected drop in combinatorial and $c\bar{c}$ continuum backgrounds with respect to the signal.

Dielectron Projections for BES II					
Collision Energy [GeV]	7.7	9.1	11.5	14.5	19.6
Time Running [Weeks]	14	9.5	5.0	2.5	4.0+
μ_B [MeV] 0-5% Centrality	420	370	315	260	205
Events [Million]	100	160	230	300	400

Acknowledgements

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