Low-p_T $\mu^+\mu^-$ pair production in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at STAR

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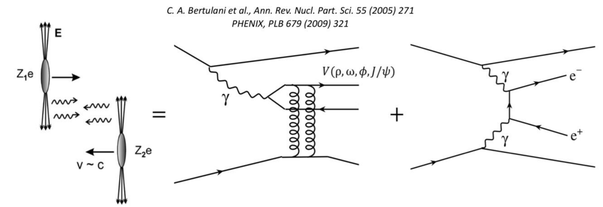
Abstract

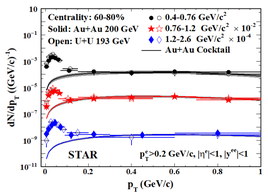
Dileptons are produced in the whole evolution of the system and escape with minimum interaction with the strongly interacting medium. Thus, dilepton measurements play an essential role in the study of hot and dense nuclear matter. Recently, significant enhancements of e^+e^- pair at very low transverse momentum (p_T) were observed by the STAR collaboration in peripheral Au+Au collisions. The excess can be explained by photon-photon interactions induced by the extremely strong electromagnetic field produced by the fast moving heavy ions. The photon interaction was usually studied in ultra-peripheral collisions without any nuclear overlaps. However, the photon interaction in peripheral collisions may provide a novel probe of QGP because the very-low-p_T dileptons are produced in the early stage of the collisions and there could be QGP produced in the nuclear overlapping region in peripheral collisions. In such collisions, the photon-photon interactions could be further used to probe the possible existence of strong magnetic fields trapped in a conducting QGP medium. Measurements with $\mu^+\mu^-$ pairs provide a complementary channel to investigate these phenomena.

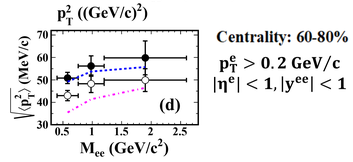
In 2014, the STAR experiment at RHIC recorded large samples of Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. In this talk, we will present invariant mass for $\mu^+\mu^-$ pair production at very-low-p_T. The p_T distribution of the excess yields for these very low p_T $\mu^+\mu^-$ pairs are also shown.

Motivation



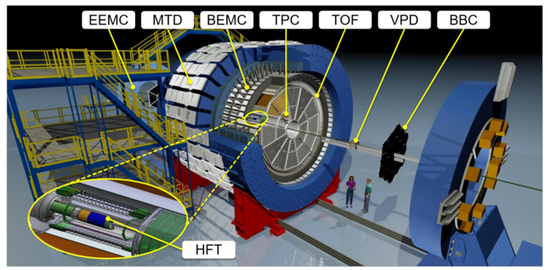
- The strong electromagnetic field, generated by two colliding ions, can be treated as quasi-real photons. The large quasi-real photon flux ($\propto Z^2$) can generate various photon interactions:
  - Photon-nuclear interaction (vector mesons) $\propto Z^2$
  - Photon-photon interaction (dilepton …) $\propto Z^4$
  - Distinctly peaked at low p_T
- Conventionally studied in ultraperipheral collisions (UPCs) -> Can the photon-induced interactions also occur in hadronic heavy-ion collisions, where the nuclei collide and break up?





- Left[1] : Excess e^+e^- pair p_T distribution concentrates below p_T ~ 0.15 GeV/c.
  - ◆ Evidence of photon interactions in hadronic heavy ion collisions.
- Right: The observed p_T^2 broadening[1] is consistent with QED calculations[2] . Possible additional broadening is also proposed as a probe of a trapped magnetic field or of Coulomb scattering in a QGP[3] .
- Low-p_T muon pairs production measurements provide a complementary channel and will help to further improve our understanding of photon-induced processes.

STAR detector

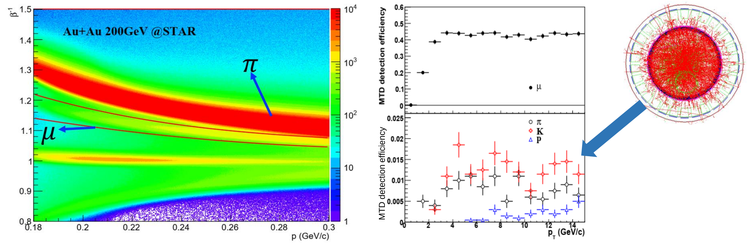


Time **P**rojection **C**hamber
- $|\eta| < 1$,full azimuth
- tracking, momenta.
- PID through dE/dx.

Time **O**f **F**light
- $|\eta| < 0.9$,full azimuth
- PID through velocity.

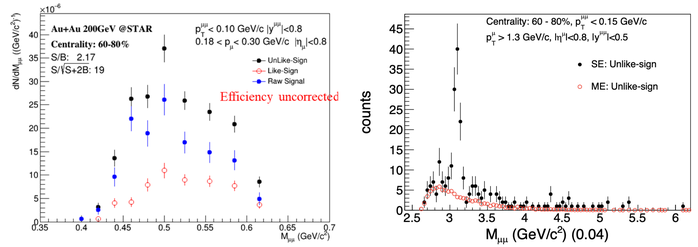
Muon **T**elescope **D**etector
- $|\eta| < 0.5$,~45% in φ
- trigger on and identify muons

Muon identification



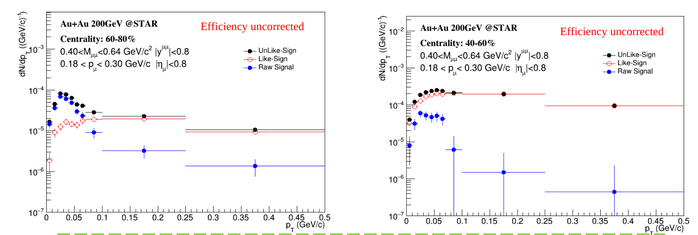
- Left : Muon can be identified at low p_T by using TOF.
- Right[4] : Muon can be identified at high p_T by using MTD.
  - ◘ Significantly suppress pion with MTD

Invariant mass spectrum



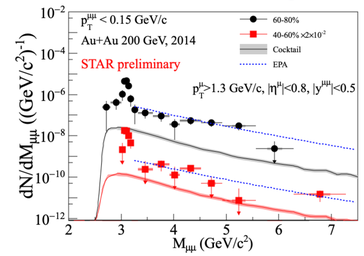
- The $\mu^+\mu^-$ invariant mass distribution at very low p_T in peripheral collisions.
  - ◘ Left: Low mass region ($0.40 < M_{\mu\mu} < 0.64$ GeV/c^2) using TOF.
  - ◘ Right: High mass region ($M_{\mu\mu} > 3.2$ GeV/c^2) using MTD.

Low mass region

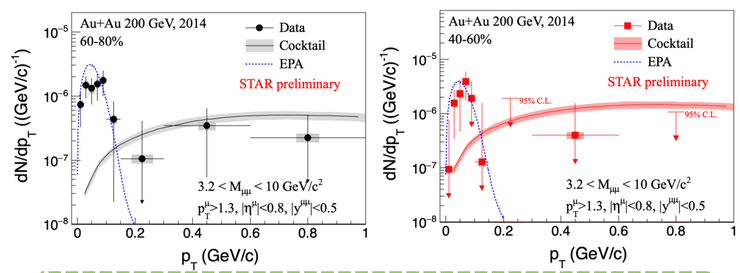


- Similar shape to e^+e^- and high mass $\mu^+\mu^-$ measurements.
- Indication of photon interactions in hadronic heavy ion collisions.

High mass region



- ◆Significant enhancement with respect to the cocktail in 60-80% centrality。
- ◆ Consistent with the Equivalent Photon Approximation (EPA) [2] calculation.



- Excesses concentrate below $p_T \approx 0.15$ GeV/c.
- Data are consistent with hadronic expectation when $p_T > 0.15$ GeV/c.

Conclusions and outlook

- A significant $\mu^+\mu^-$ enhancement is observed at very low p_T in peripheral Au+Au collisions at 200 GeV.
  - **In high mass Region ($M_{\mu\mu} > 3.2$ GeV/c^2)**
  - ◘ Excess was entirely observed below $p_T \approx 0.15$ GeV/c.
  - ◘ Compatible with the EPA theoretical calculation.
  - **In low mass Region ($0.40 < M_{\mu\mu} < 0.64$ GeV/c^2)**
  - ◘ Excess was entirely observed below $p_T \approx 0.15$ GeV/c.
  - ◘ Efficiency correction and cocktail simulation are ongoing.
- Outlook
  - ◘ Search for $\cos 4\Delta\phi$ angular distribution which is related to vacuum birefringence[5].

References

[1] Adam J *et al.* (STAR) 2018 *Phys. Rev. Lett. 121 132301*
[2] W.M. Zha, *et al.* 2020 Phys. Lett. B 800 135089
[3] S. R. Klein, *et. al,* Phys. Rev. Lett. 122, (2019), 132301
[4] Ruan, L., *et al.*(STAR) 2009 J. Phys. G 36095001
[5] Adam J *et al.* (STAR) 2019 arXiv : 1910.12400

The STAR Collaboration
drupal.star.bnl.gov/STAR/presentations