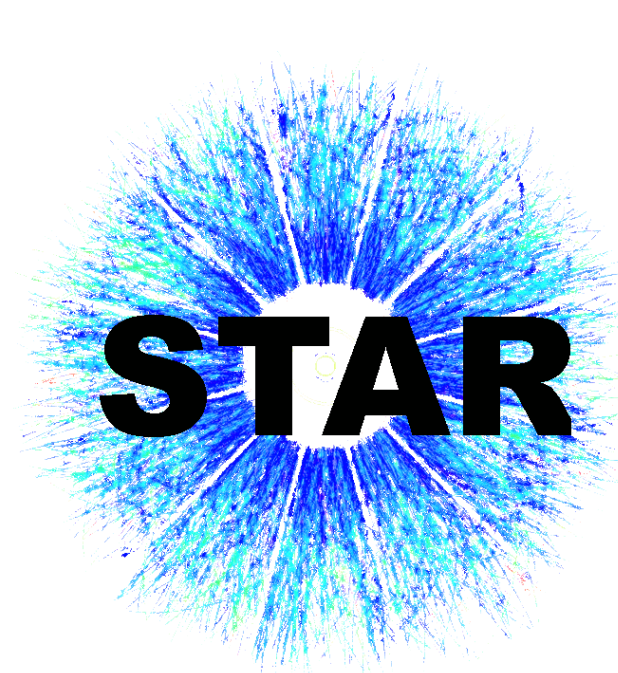


Search for dark photons in π^0/η Dalitz decays with the STAR detector



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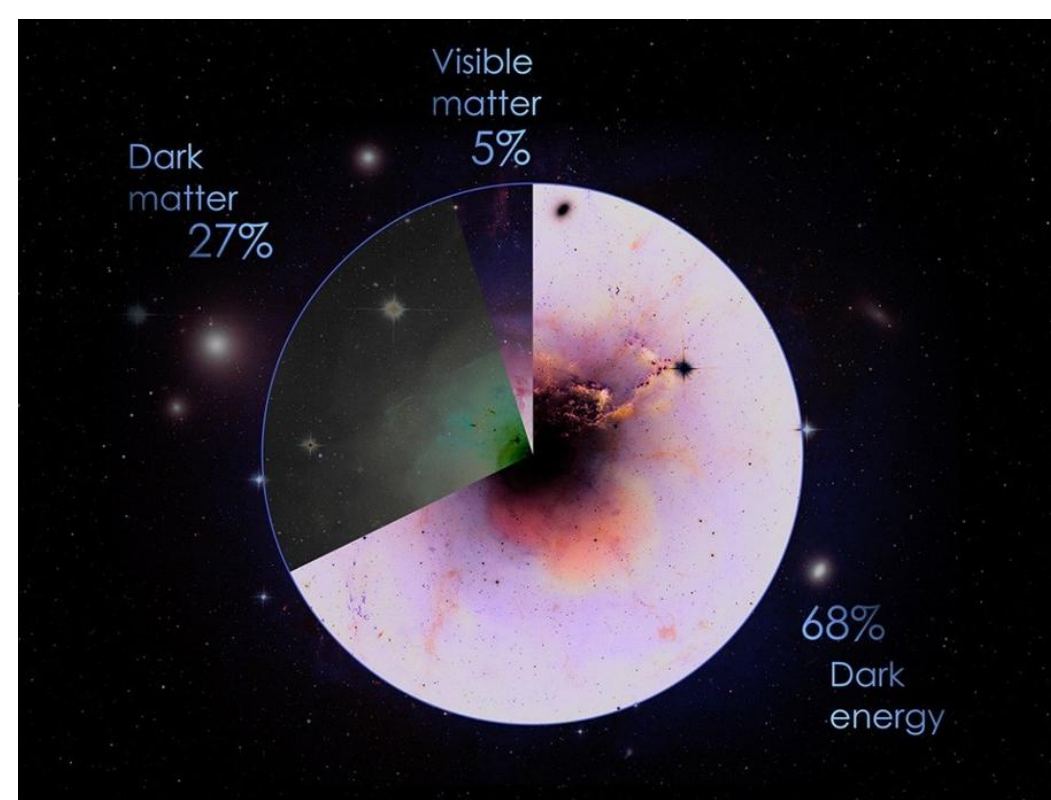
Abstract

As one of the potential candidates for dark matter, the dark photon (A') could act as a mediator between dark matter particles, analogous to the photon (γ) in the Standard Model, which mediates electromagnetic interactions. The dark photon could be detected through its kinetic mixing with the QED photon, with the strength of this coupling suppressed by a factor labeled ϵ . This allows dark photons to be produced in laboratory environments via processes that generate ordinary photons, which can then decay into visible Standard Model final states.

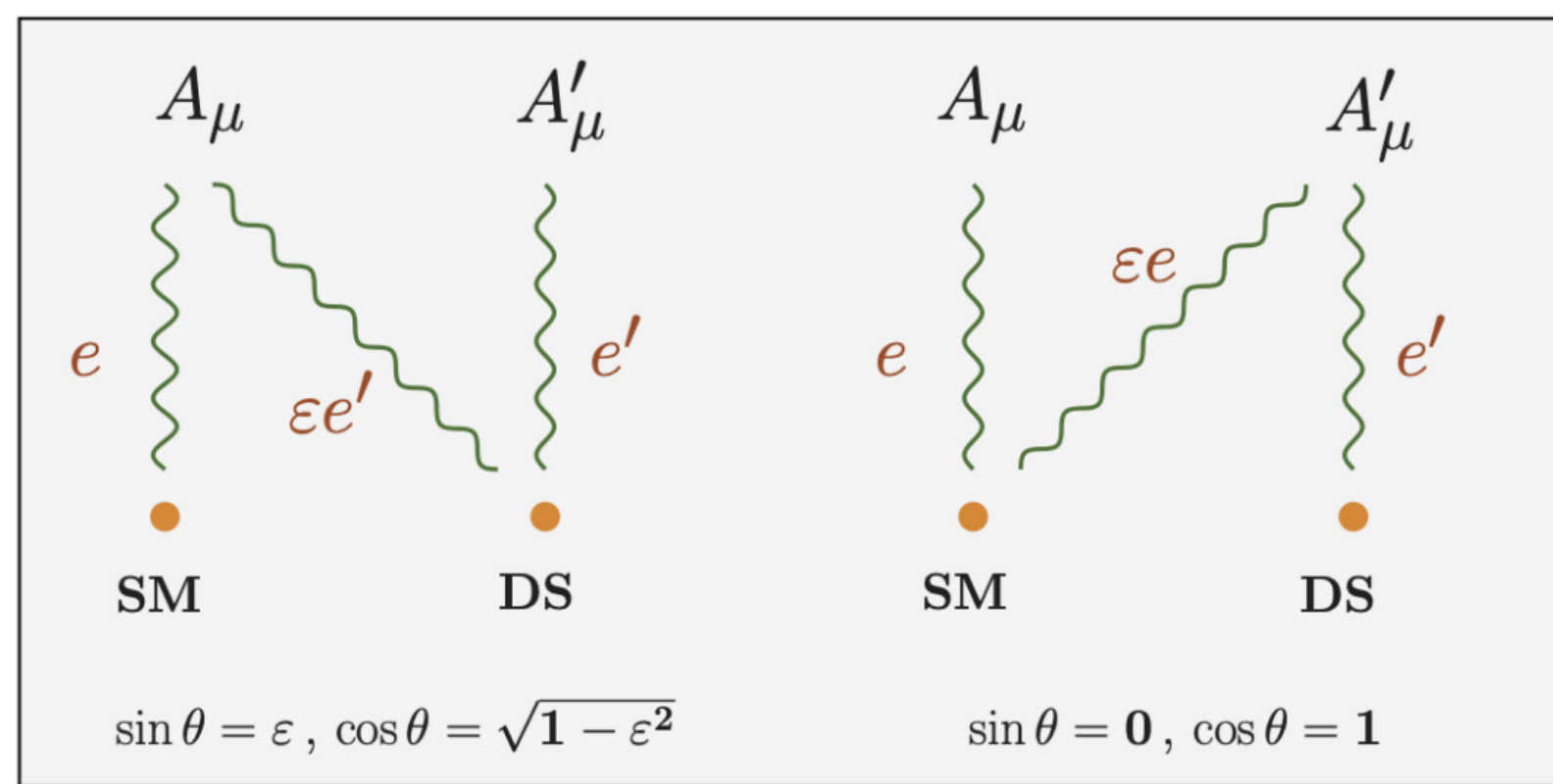
In this poster, we will present the search for prompt-like massive dark photons produced in Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}} = 200$ GeV, using the STAR detector through dielectron decay channel. The search focuses on invariant mass range up to $100 \text{ MeV}/c^2$. The dark photon search is crucial for extending our understanding of new physics beyond the Standard Model

Motivation

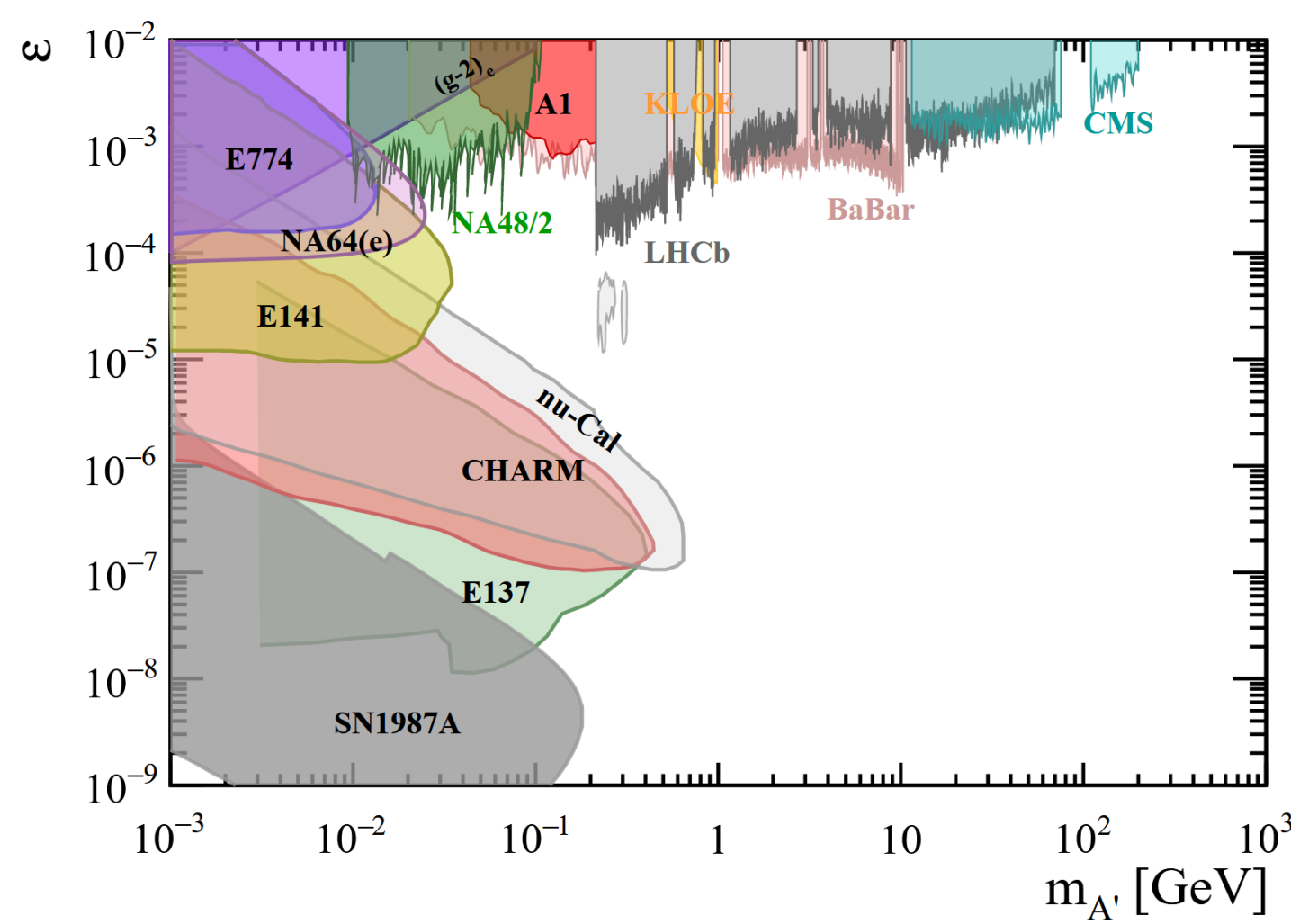
- The universe is believed to be made up of three components: normal or visible matter (5%), dark matter (27%), and dark energy (68%).



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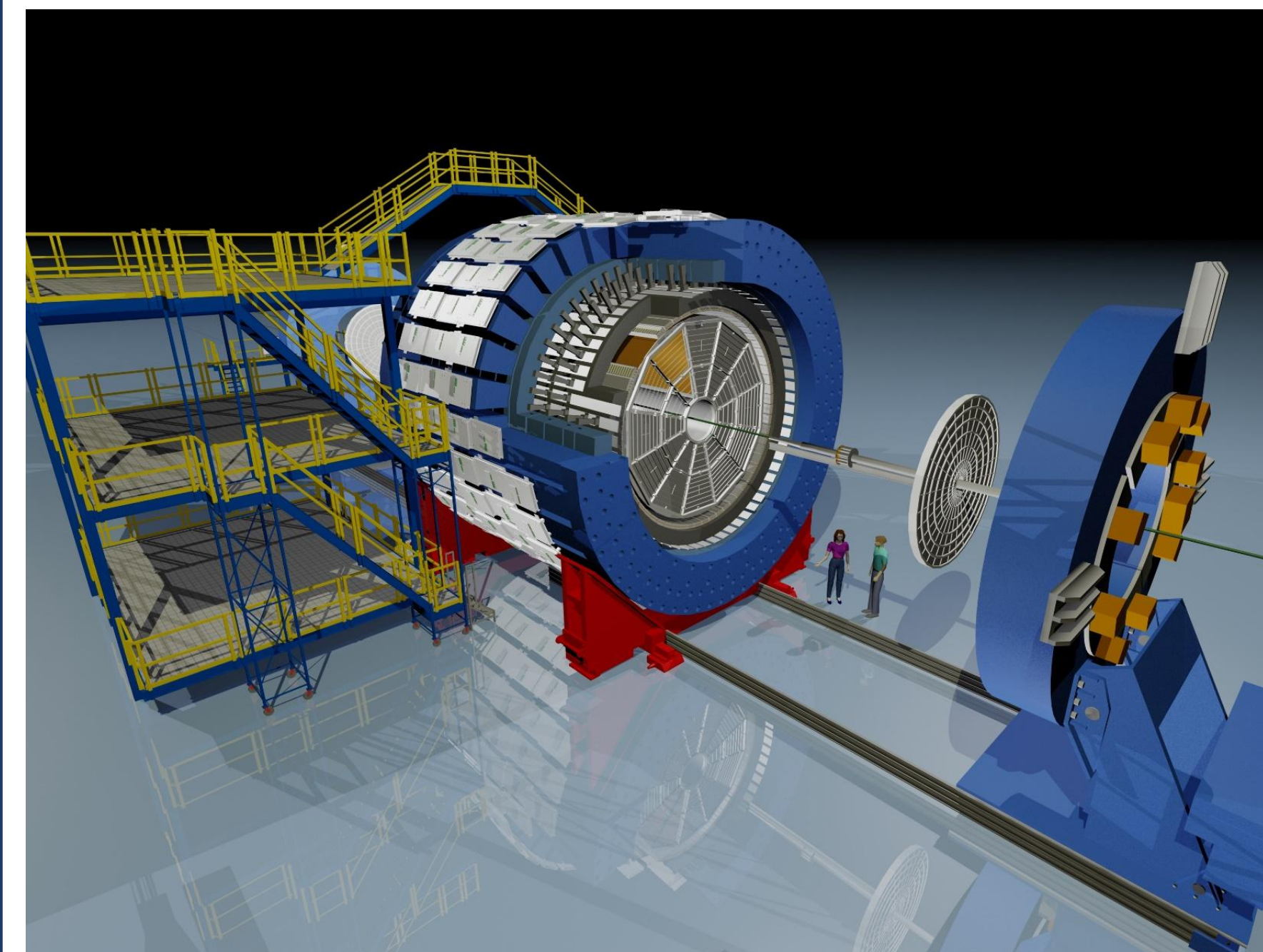
- The dark photon could be the candidate of dark matter or dark force mediator, and interact with the standard model by kinetic mixing with the QED photon.



- The current status of experimental search of massive dark photon have not yet excluded the mixing parameter (ϵ) in the range of 10^{-5} to 10^{-3} for $m_{A'}$ below twice the muon mass.

- At STAR, the Dalitz decays of π^0 and η mesons dominate in this mass range, and the virtual photon produced in these decays can mix with a massive dark photon.

STAR detector



- TPC: Tracking, momentum and dE/dx

- TOF: Time of flight, particle identification

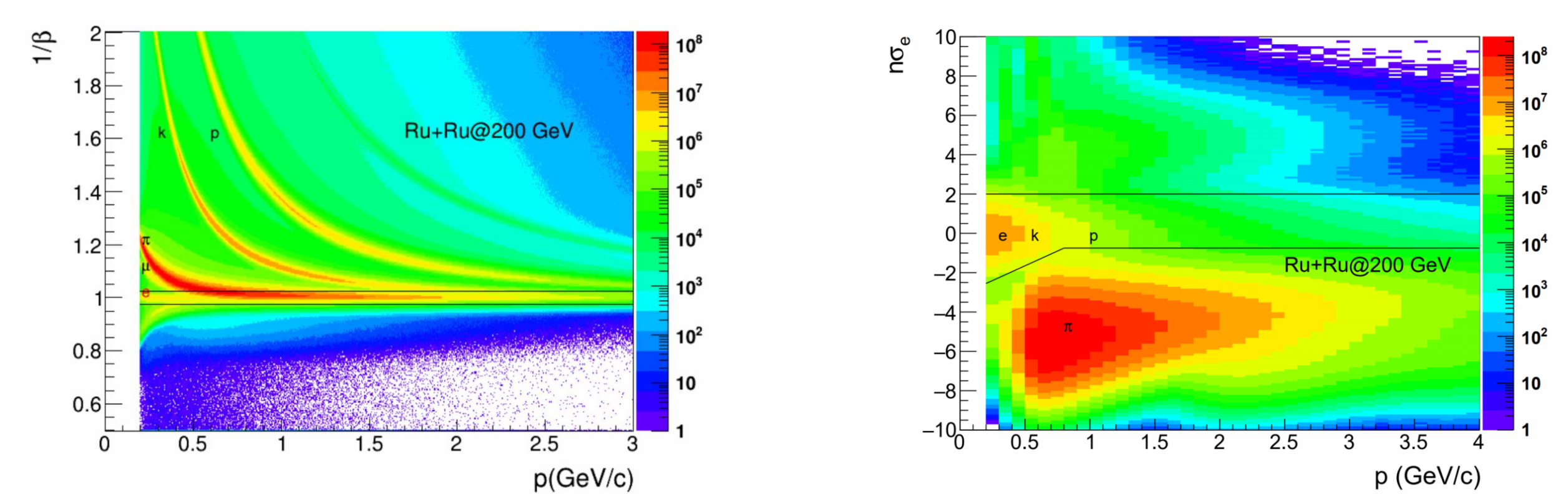
Collision species (taken in 2018)

- $^{96}\text{Ru} + ^{96}\text{Ru}$ (~2B events)
- $^{96}\text{Zr} + ^{96}\text{Zr}$ (~2B events)

Kinematic acceptance:

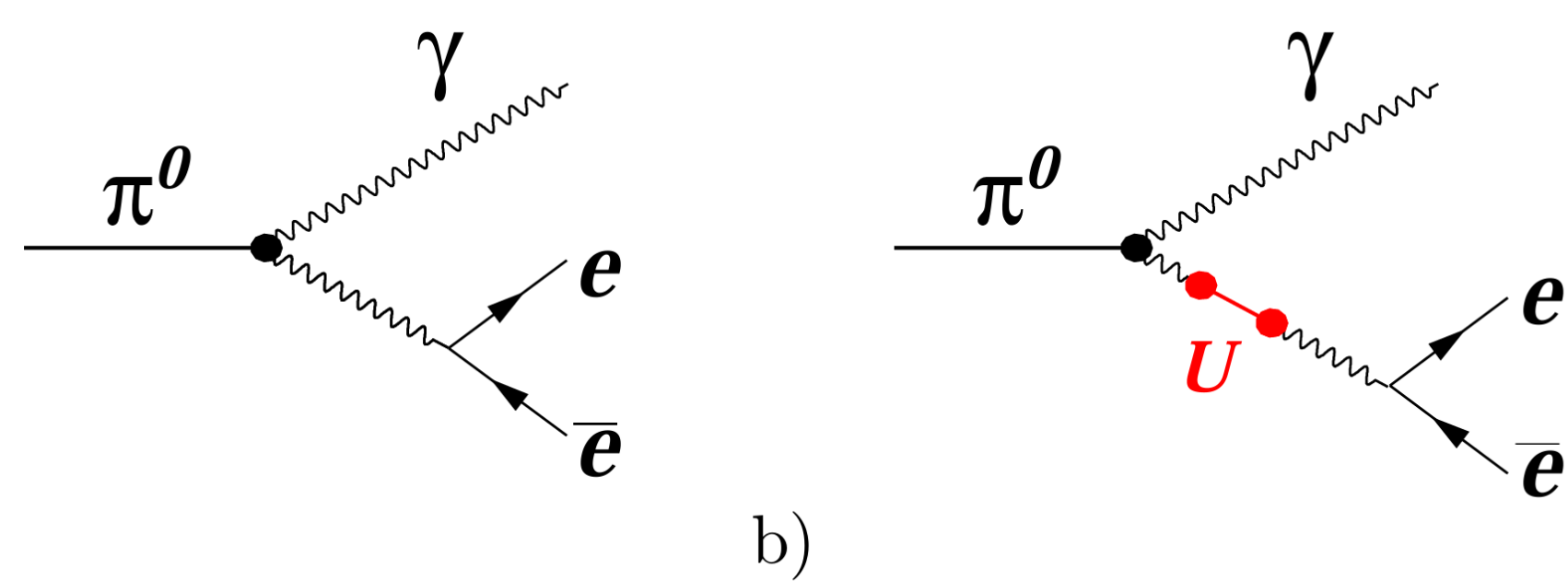
- $p_T^e > 0.2 \text{ GeV}/c$
- $|\eta^e| < 1$
- $|y^{ee}| < 1$

Electron identification



- For e^+e^- pair production: using TPC (dE/dx) and TOF (time of flight) to select electron

The method of dark photon search through light meson decay

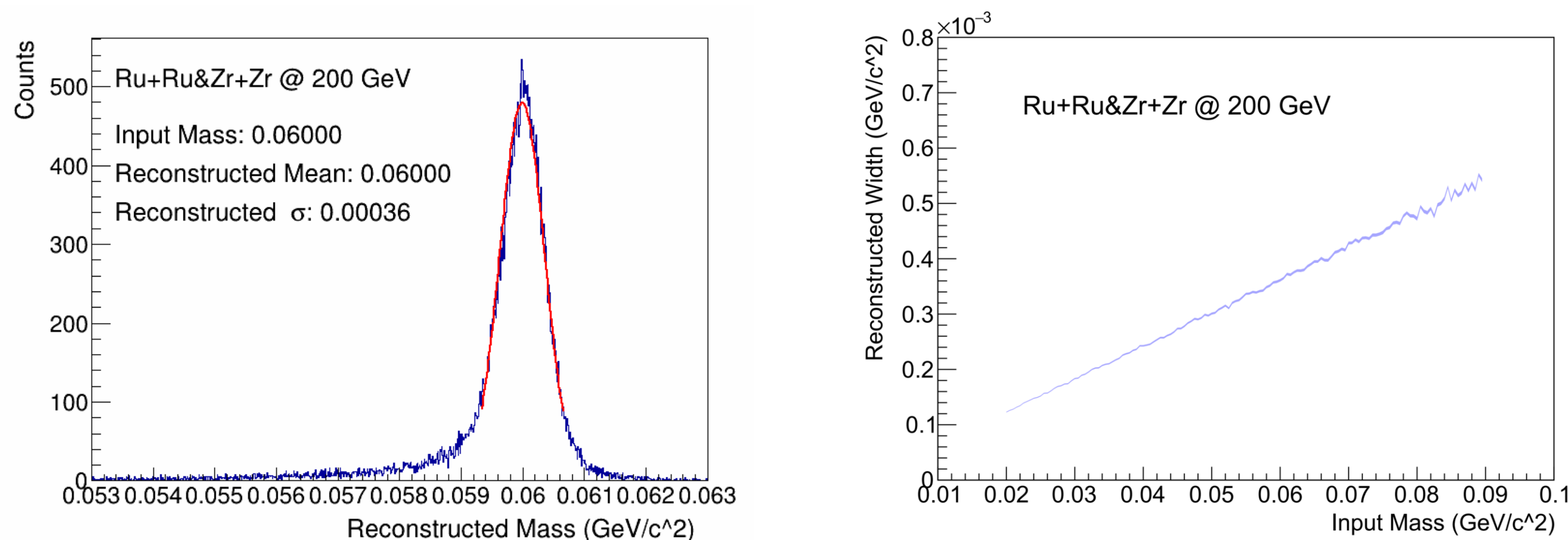


- For π^0 meson, the relevant processes are $\pi^0 \rightarrow \gamma A'$, $A' \rightarrow e^+e^-$, if there are massive dark photons mixed in this process, then a resonance peak can be observed in the e^+e^- invariant mass spectrum

- The mixing parameter ϵ can be calculated by:

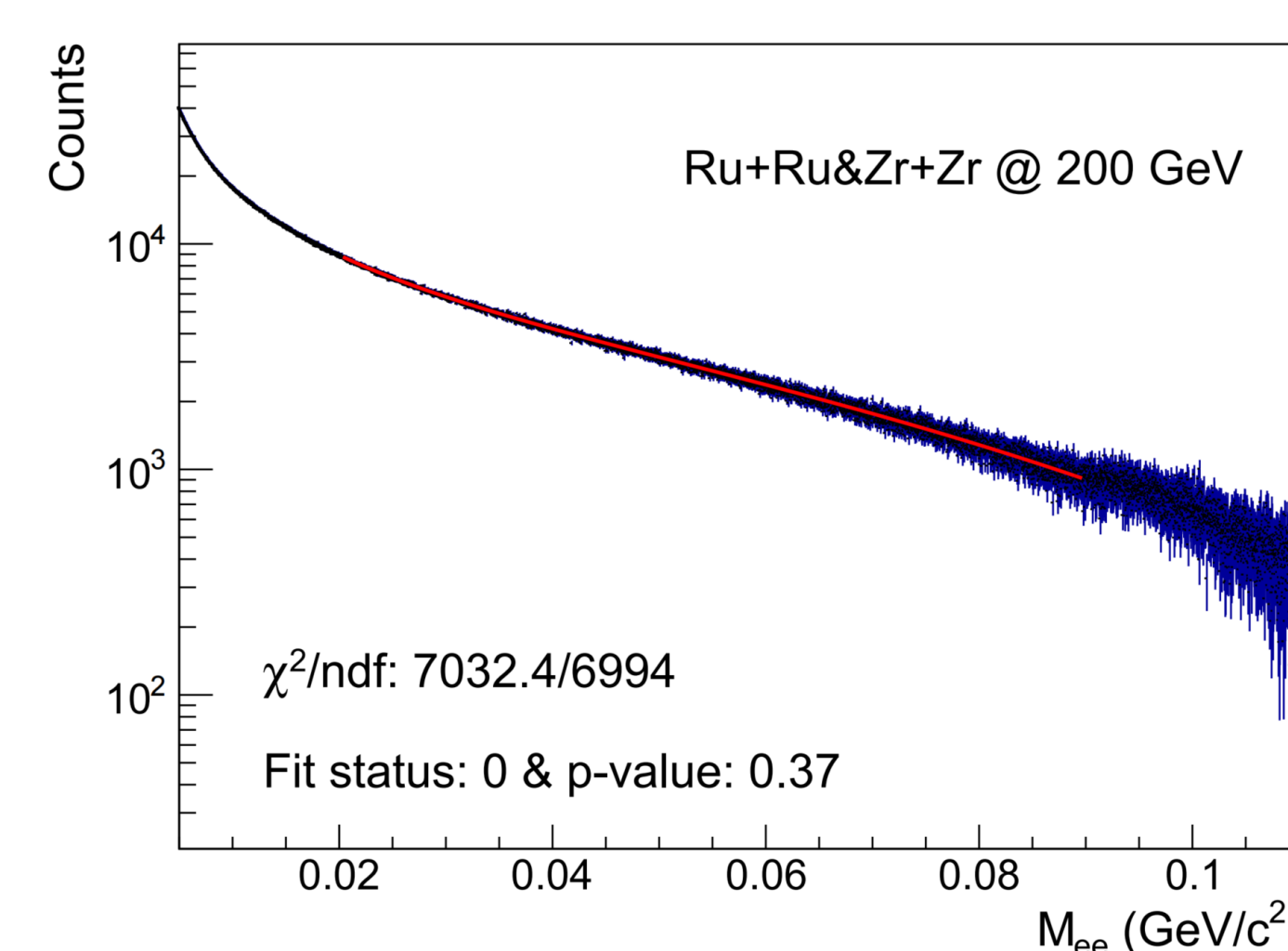
$$\epsilon^2 = \frac{2\alpha_{EM} \sigma}{3\pi m_{A'}} \sqrt{2\pi R(m_{A'})}$$

where α_{EM} is the fine structure constant, σ is the width of the resonance peak which is mainly determined by the detector resolution, and the peak height ratio $R(m_{A'})$ can be obtained by the ratio between $\left(\frac{dN_{ee}}{dm_{ee}}\right)_{\pi^0 \rightarrow \gamma A'}$ and $\left(\frac{dN_{ee}}{dm_{ee}}\right)_{\pi^0 \rightarrow \gamma e^+e^-}$



- The mass dependence of σ is obtained from Monte Carlo simulations embedded into real data with additional momentum smearing

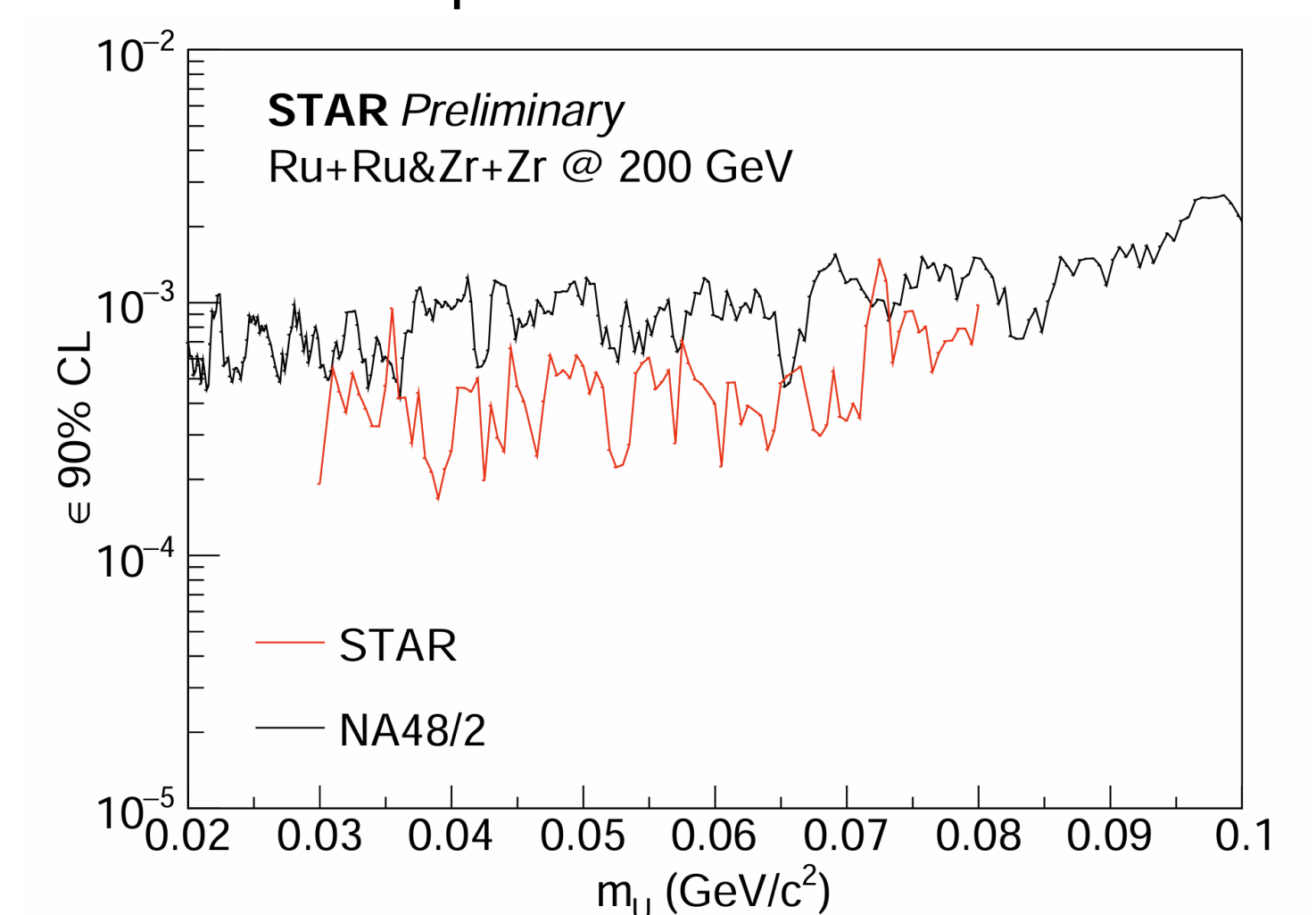
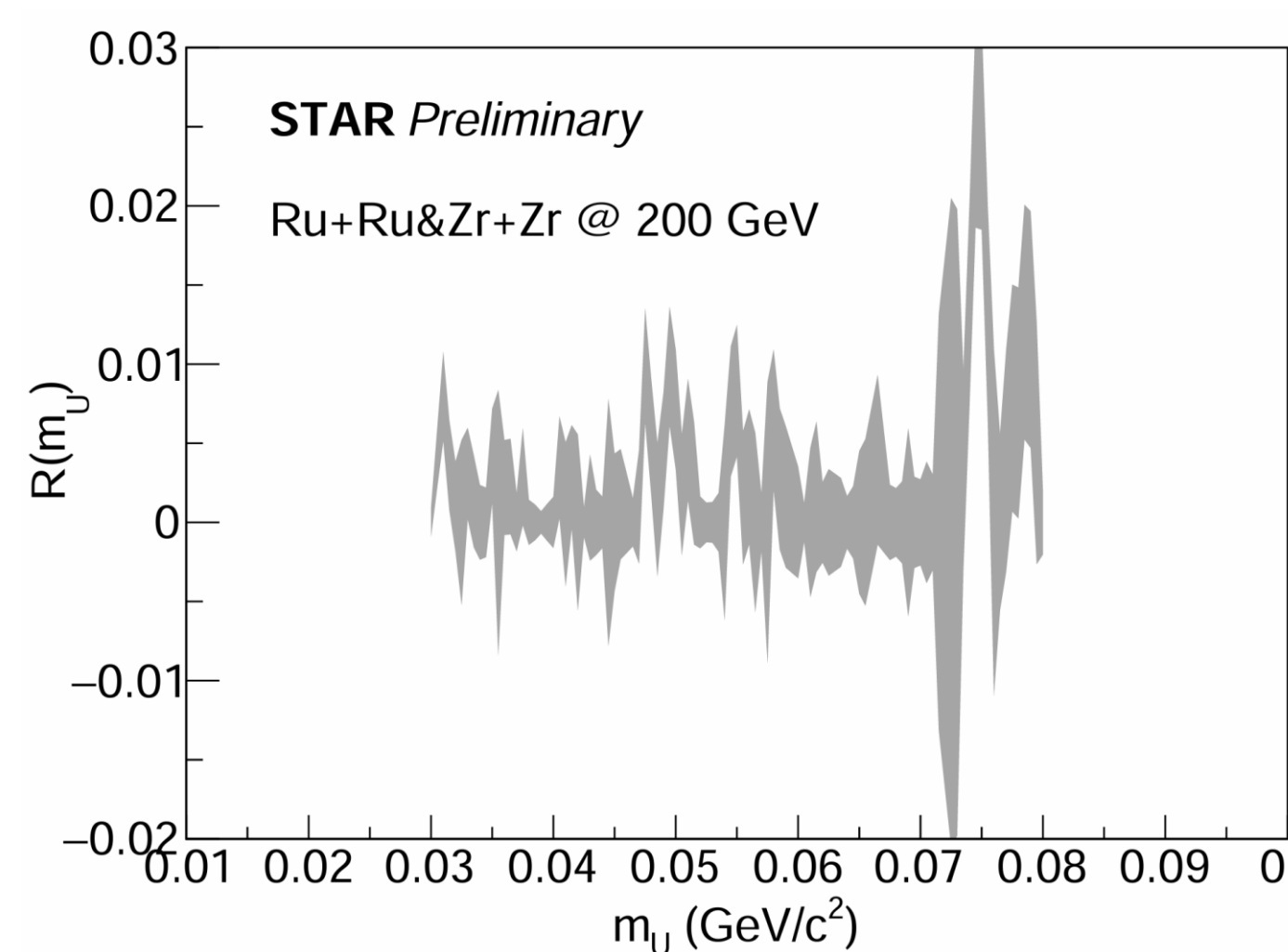
Extract the upper limit of mixing parameter ϵ



- The e^+e^- invariant mass distribution can be described very well by the following function:

$$f(m_{ee}) = \frac{1}{m_{ee}} \times \left[\left(1 - \frac{m_{ee}^2}{m_{\pi^0}^2}\right)^3 + r_{\eta/\pi^0} \times \left(1 - \frac{m_{ee}^2}{m_{\eta}^2}\right)^3 \right] \times T_4(m_{ee})$$

- Refit the e^+e^- mass spectrum with the same background function plus a Gaussian function to model the possible dark photon signal with σ from embedding from $30-80 \text{ MeV}/c^2$ with $0.5 \text{ MeV}/c^2$ as step



- The peak ratio distribution indicates that no significant dark photon signal is observed within uncertainties
- The 90% CL of ϵ is improved by approximately a factor of three compared to existing experimental constraints.

Summary

- The search of massive dark photon has been performed at STAR experiment in $30-80 \text{ MeV}/c^2$ dielectron mass range
- The 90% CL of ϵ obtained by Ru+Ru and Zr+Zr experiment can exclude new space of mixing parameter
- In the future, more datasets already collected by the STAR experiment detector will be used for the dark photon search.

References

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