Reactor Neutrino Anomalies and Possible Solutions

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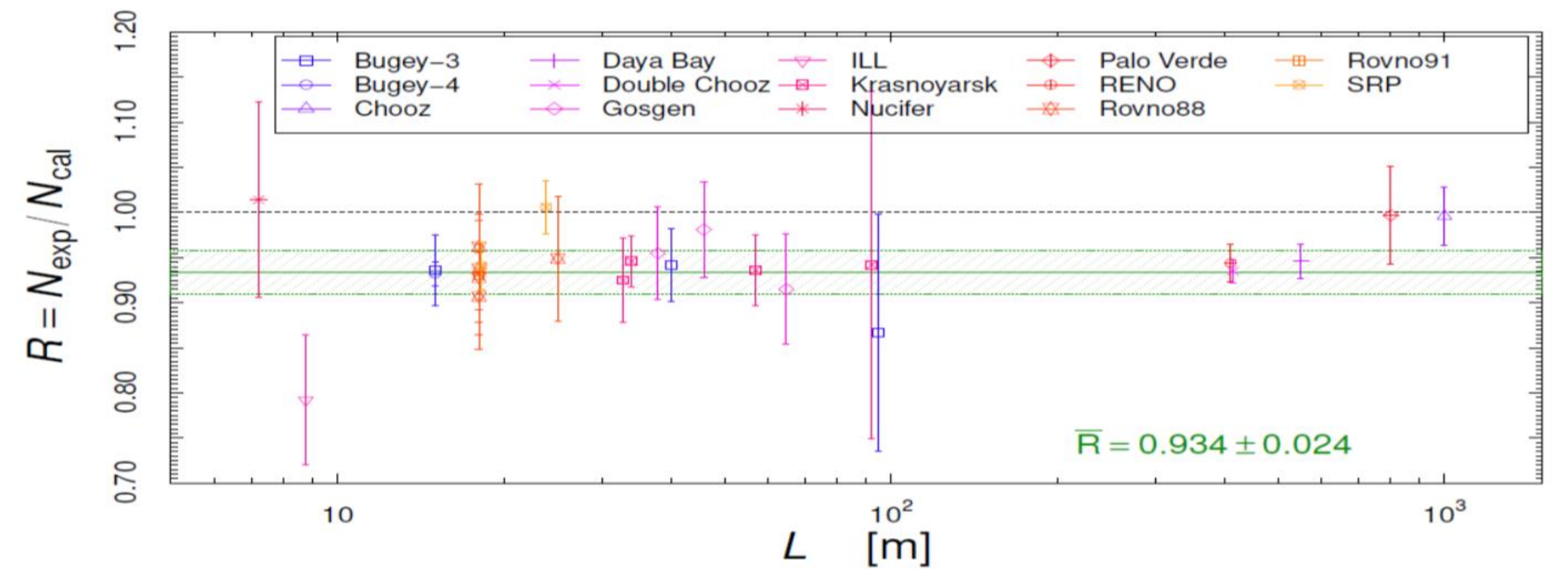
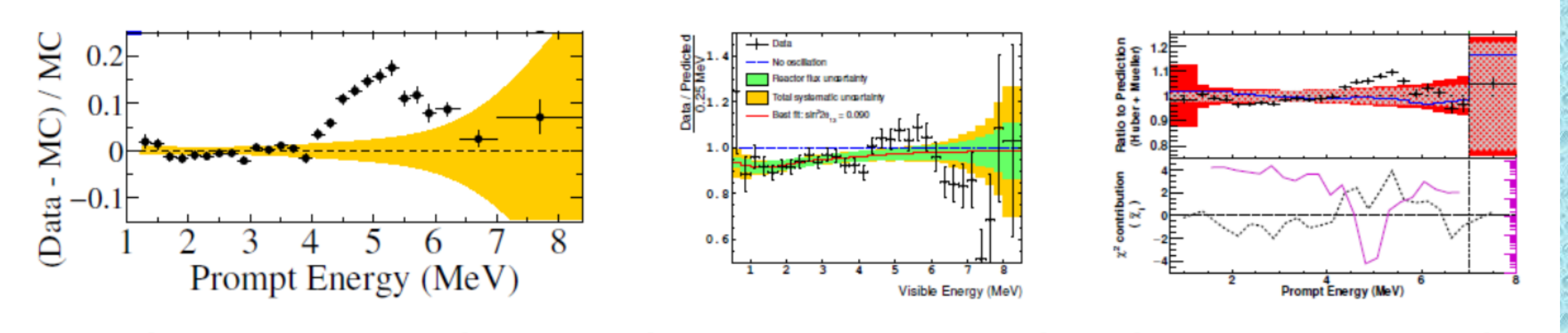
1. Reactor neutrino anomalies

- **Reactor neutrinos (electron antineutrinos) are produced from beta decays of the neutron-rich fission products, and are detected via the inverse beta decay (IBD) process.**
- **Reactor experiments have shown anomalous results for both IBD rate (left plot) and spectrum (right plot) measurements**



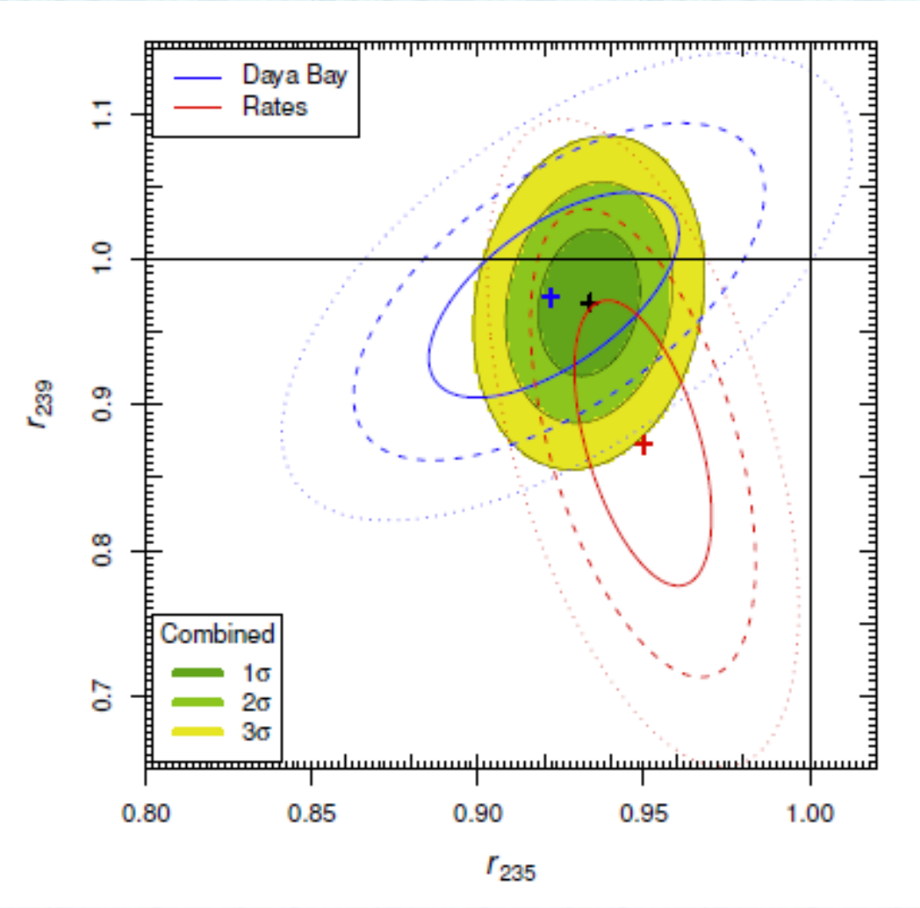


[RENO, arXiv:1511.05849] [Double Chooz, arXiv:1406.7763] [Daya Bay, arXiv:1508.04233]

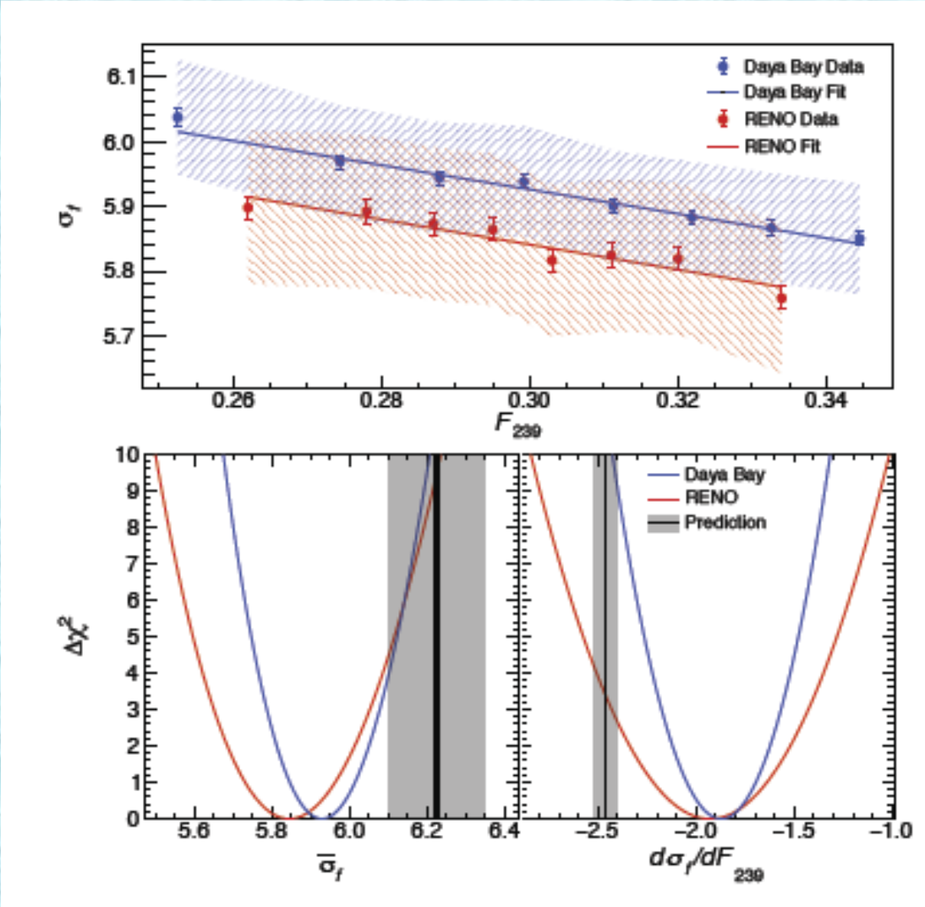
- **Reactor rate anomaly: measured IBD yields are smaller than model predictions by around 6%.**
- **Reactor spectrum anomaly: there is a bump at around 5 MeV when comparing the measured and predicted spectra.**
- **How to solve these reactor anomalies is an intensively discussed topic in nuclear and particle physics community.**

2. Data-driven method

- **Using the reactor rates data and fuel evolution data:**



Giunti et al., JHEP 10 (2017) 143



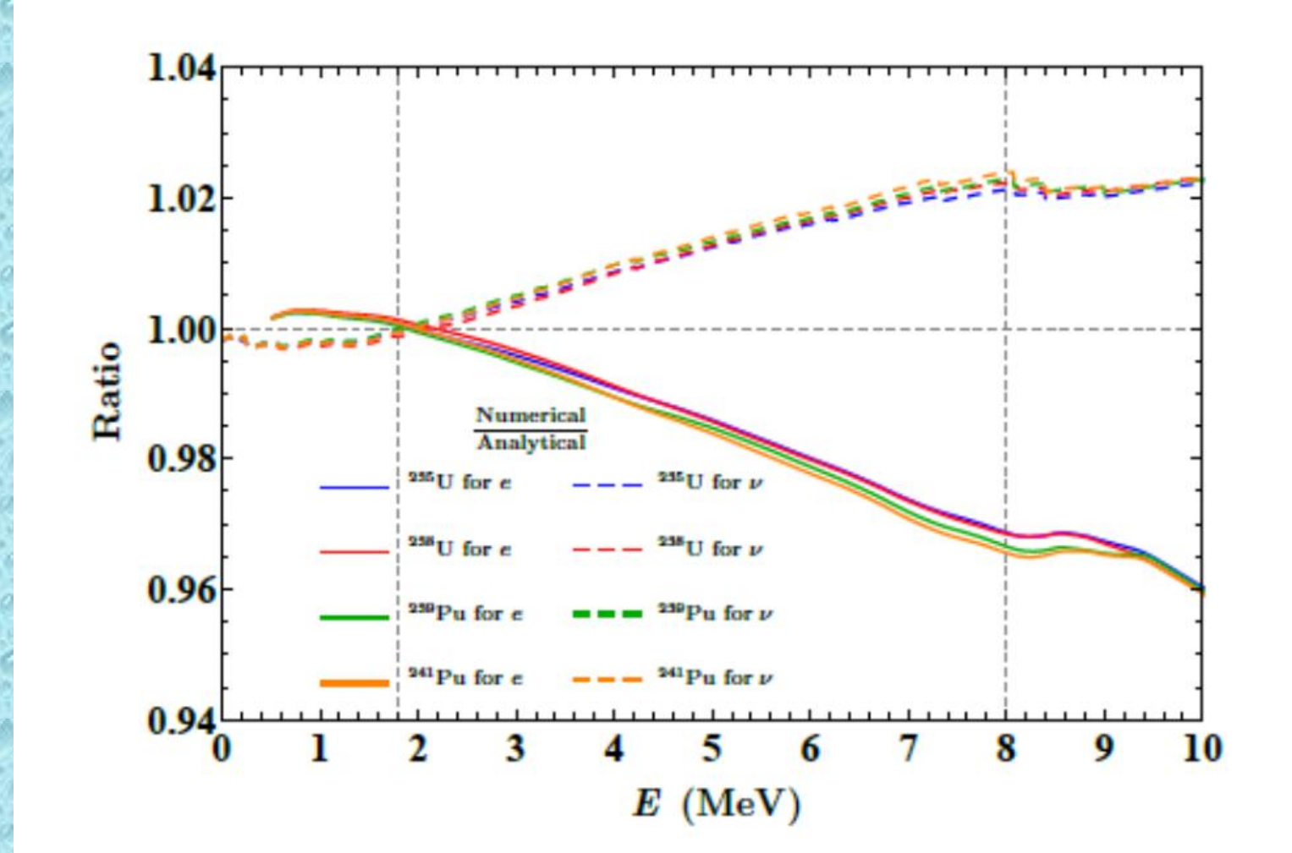
Giunti et al., Phys. Rev.D 99 (2019) 073005

- **Reactor rates tend to favor equal suppression of the ^{235}U and ^{239}Pu fluxes (oscillation), while (DYB & RENO) fuel evolution data favor the suppression of ^{235}U.**
- **Regarding all hybrid hypotheses: a) a deficit for the ^{235}U flux is always obtained; b) oscillation-including hypothesis is favored over the oscillation-excluding one: moderately at 1-2σ**

3. Ab initial method

- ***Ab initial* model for the reactor neutrino flux: summation of each beta decay branches using the nuclear database for the fission and decay information**
- **Possible problems: the nuclear database (e.g., pandemonium effect), fission yield, single beta decay spectrum, etc.**
- **We discuss the effects of the single beta decay spectrum by using a fully numerical calculation of lepton wave functions, compared to previous ones using the famous Fermi function.**

Fang, et al., arXiv: 2001.01689



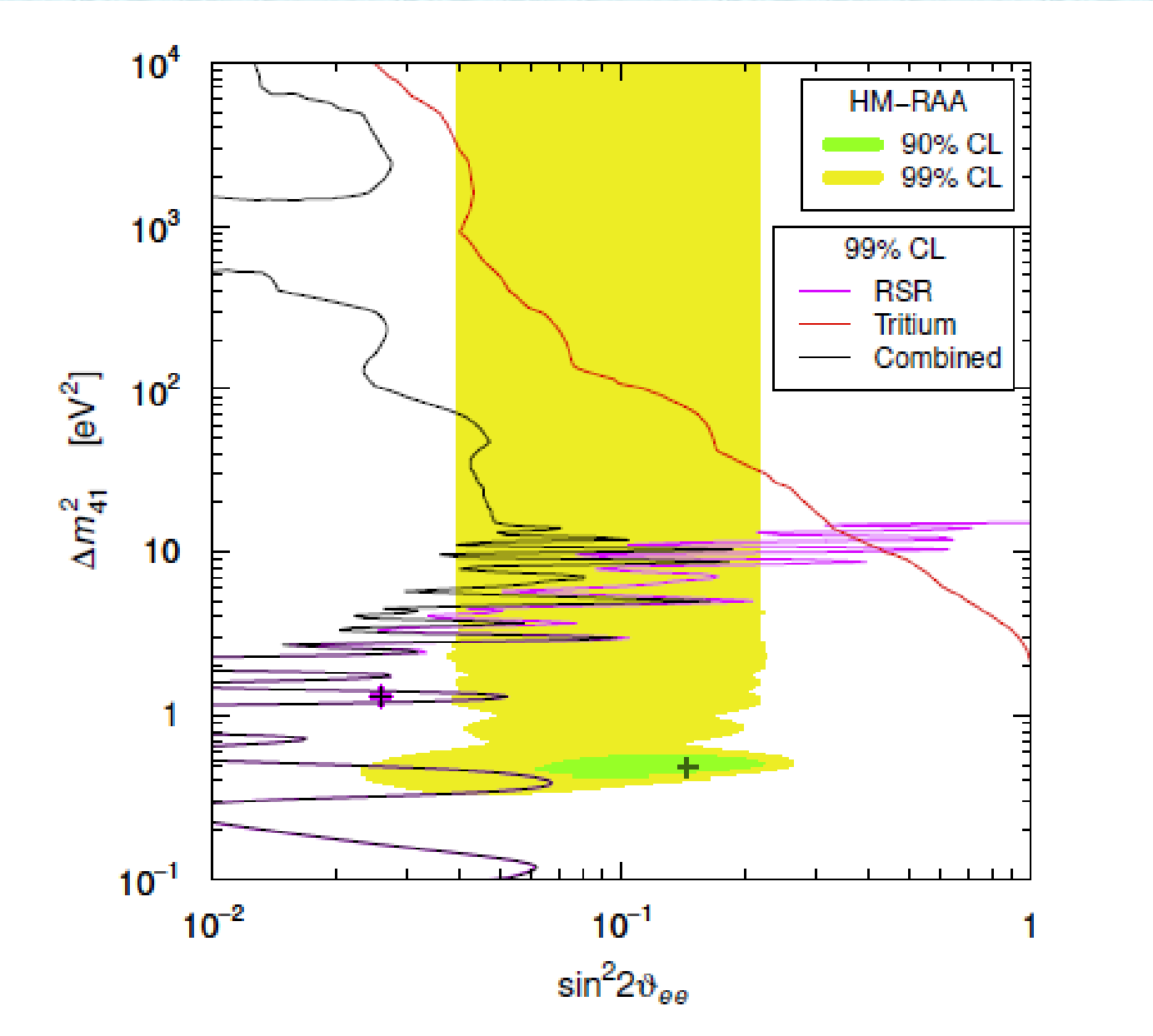
- **ENDF VIII.0, for fission yield data, and ENSDF for the decay data.**
- **2% and 4% deviations for the neutrino and electron spectra.**

4. Beta decay at KATRIN

- **Beta decay is a model-independent way to probe the absolute neutrino masses.**
- **KATRIN published its first data in 2019, with a limit on the effective neutrino mass as m_ν< 1.1 eV (95% C.L.).**
- **We test the reactor rate anomaly using the beta decay data at KATRIN by assuming the 3+1 active-sterile mixing.**
- **KATRIN improves the exclusion of the large-Δm^2_{41} solution of the Huber-Muller reactor rate anomaly.**

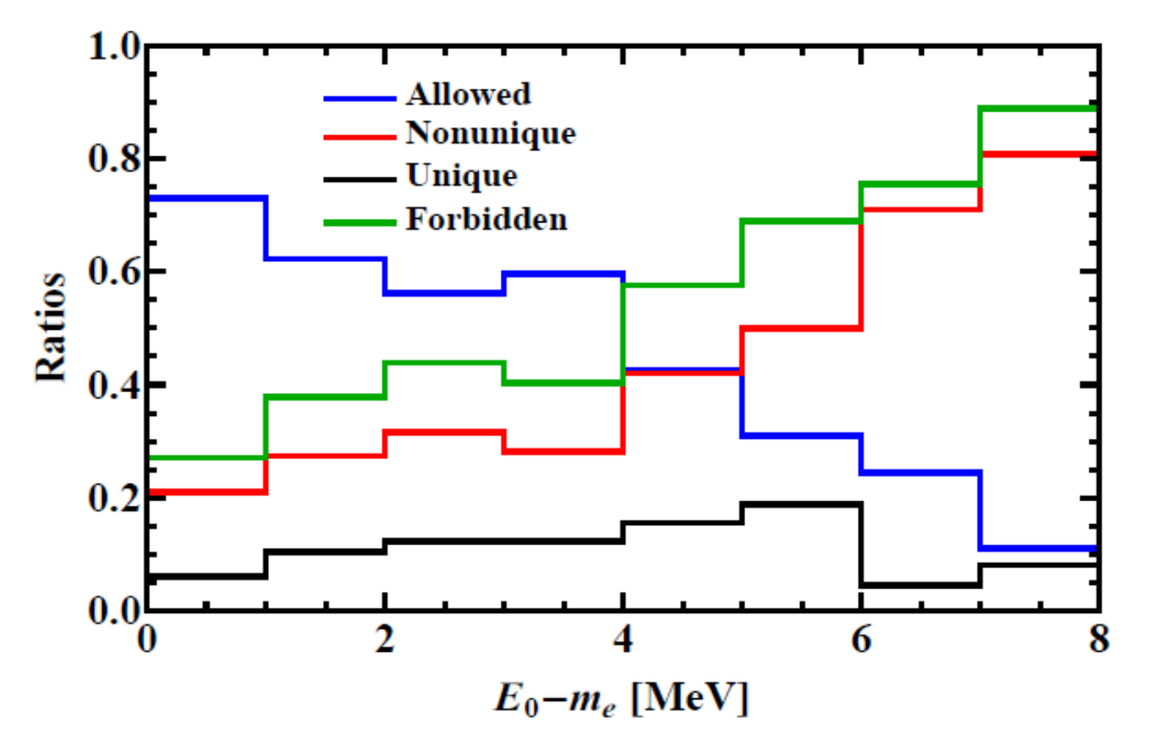
Giunti et al., JHEP 05 (2020) 061

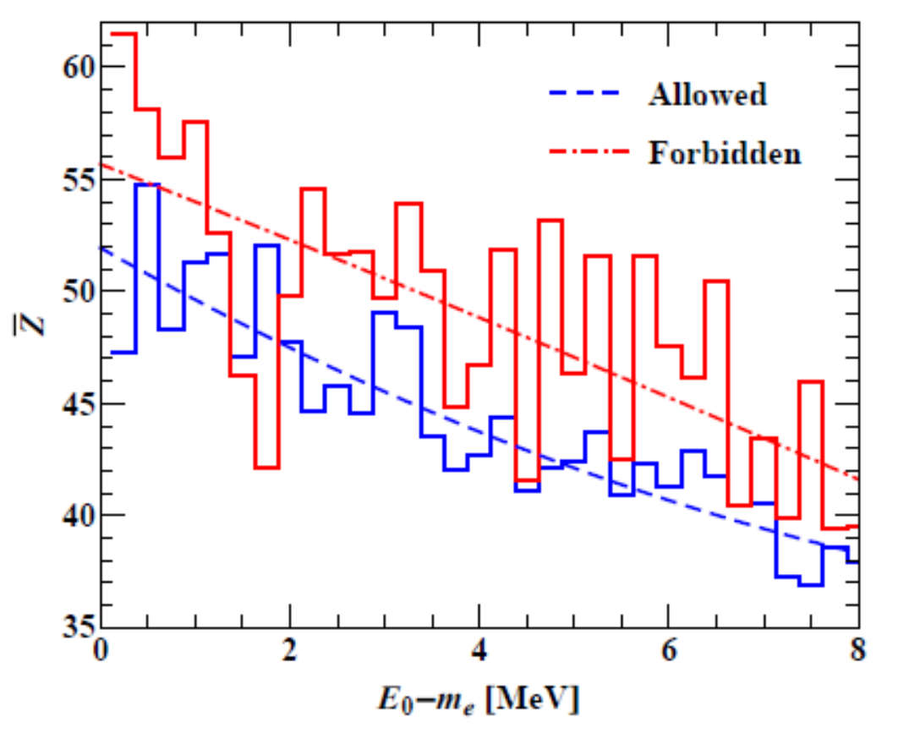
- **RSR: the reactor spectra ratio data test a large part of the small-Δm^2_{41} region.**
- **Tritium:**
  KATRIN + Mainz + Troitsk
- **RSR and Tritium limits are complementary, and rule out most of the parameter space.**

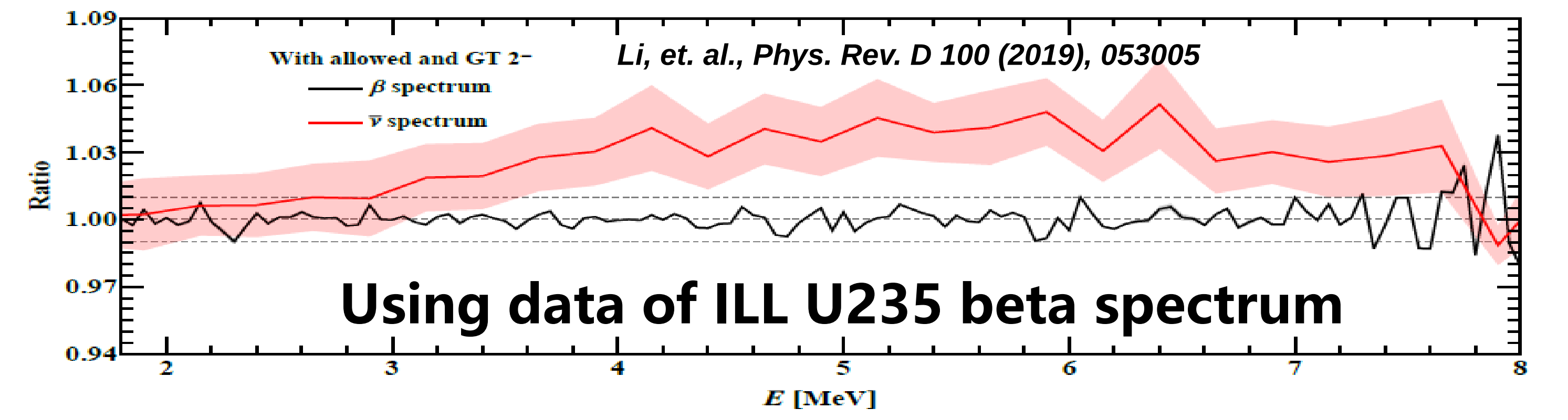


5. Conversion method

- ***Conversion* model for the reactor neutrino flux: using dozens of virtual beta decay branches to fit the aggregate electron spectra of ^{235}U, ^{239}Pu, and ^{241}Pu at ILL.**
- **We propose a new realization of the conversion calculation by including the contribution of forbidden decay branches.**







Li, et. al., Phys. Rev. D 100 (2019), 053005

Using data of ILL U235 beta spectrum

6. Conclusion

- **Reactor rate/spectrum anomalies are interesting topics in particle and nuclear physics, and awaiting satisfactory solutions.**
- **Data-driven method always favors a suppression of the ^{235}U flux, while KATRIN can provide independent tests.**
- **Both the ab initial and conversion calculations need to be improved in many aspects (database, fission yield and single spectrum, etc.).**
- **Accurate reactor rate and spectrum predictions are important for future reactor experiments (i.e., JUNO).**

7. Reference

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[7] D.L. Fang et al., arXiv: 2001.01689.
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