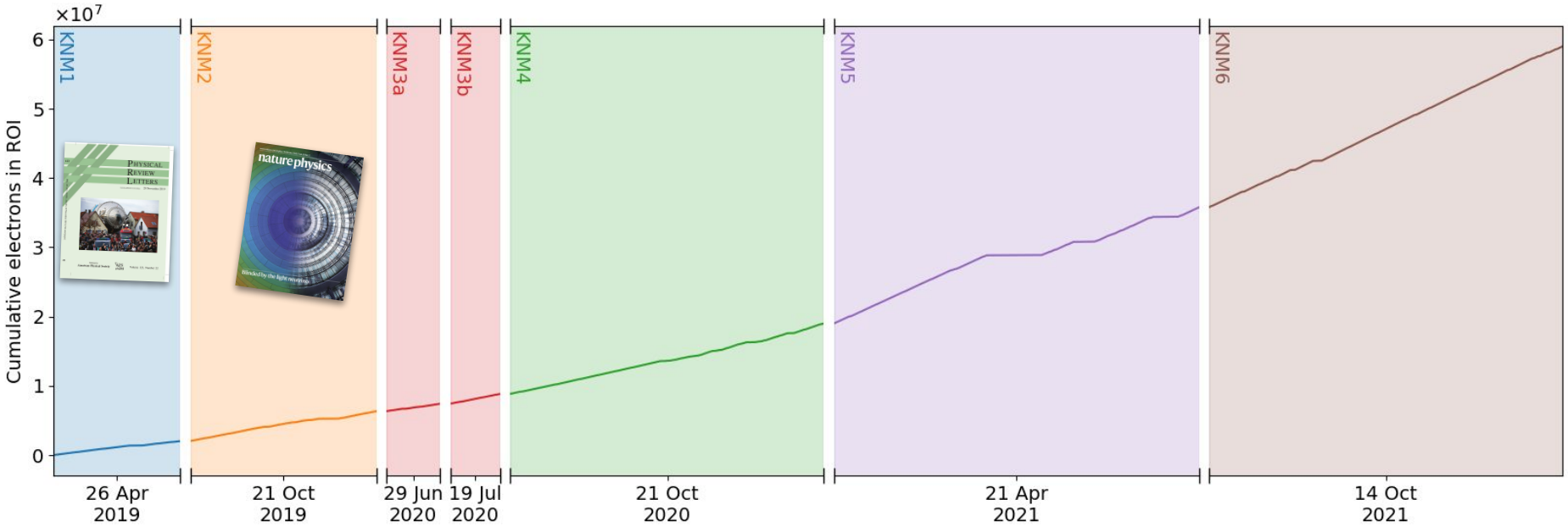
Status of the KATRIN neutrino mass analysis using Monte Carlo propagation and a novel neural network approach

Christian Karl, Susanne Mertens, Alessandro Schwemmer, and Christoph Wiesinger for the KATRIN collaboration

MAX-PLANCK-INSTITUT
FÜR PHYSIK

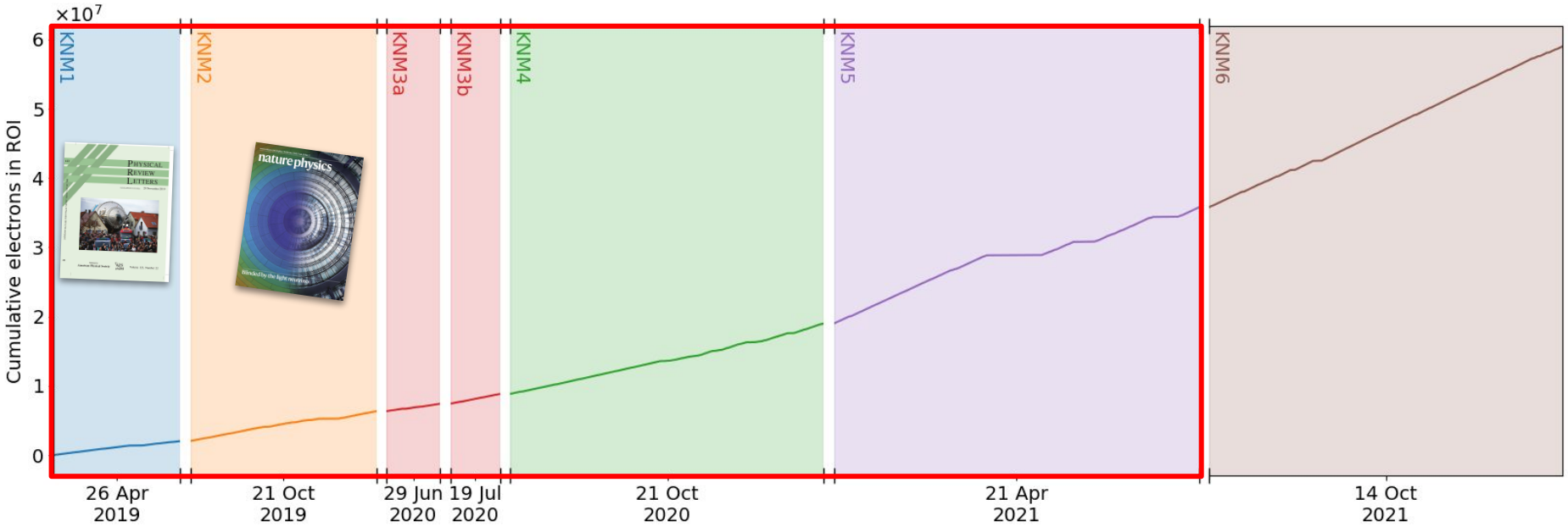
Where we stand

Where we stand



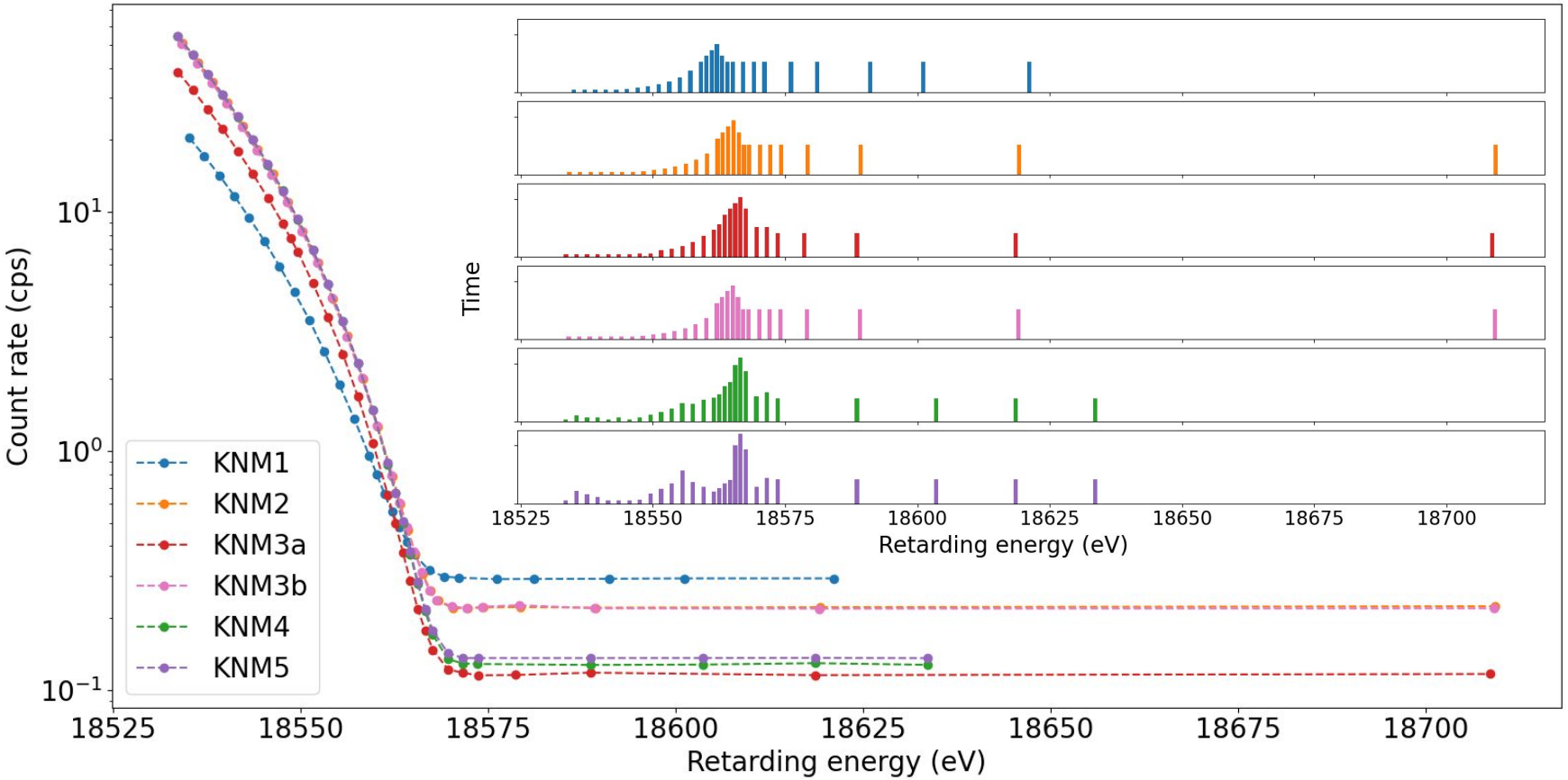
[Aker et al., Phys. Rev. Lett. 123, 221802 (2019)]
[Aker et al., Nat. Phys. 18, 160–166 (2022)]

Where we stand



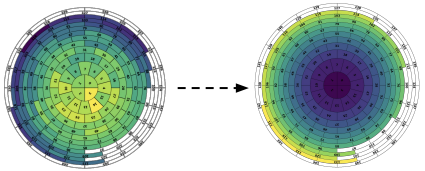
[Aker et al., Phys. Rev. Lett. 123, 221802 (2019)]
[Aker et al., Nat. Phys. 18, 160–166 (2022)]

Where we stand



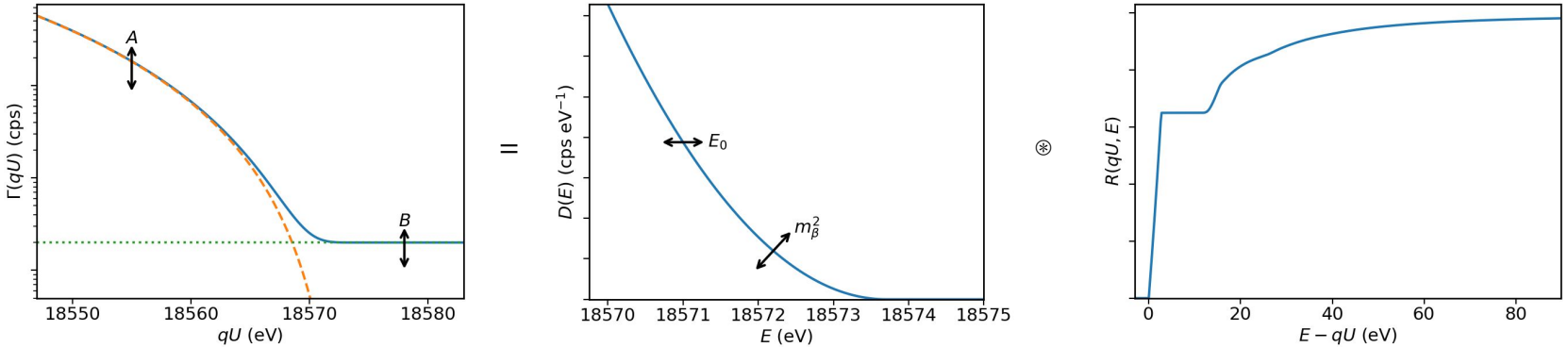
Analysis

Analysis strategy



- **combine pixels** patch-/ring-wise, use average response *R*
- maximum likelihood fit of **model**

$$\Gamma(qU) \propto A \int_{qU}^{E_0} D(E; m_\beta^2, E_0)\, R(qU, E)\, \mathrm{d}E + B$$



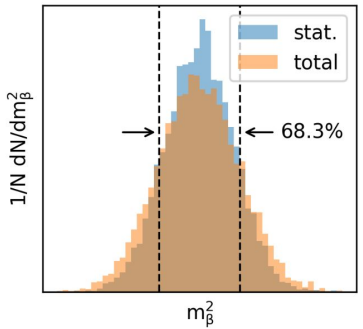
with free **amplitude** *A*, **squared neutrino mass** m_β^2, **endpoint** E_0 and **background** *B*

- **theoretical** (Fermi theory, molecular excitations) and **experimental** inputs (calibration measurements)

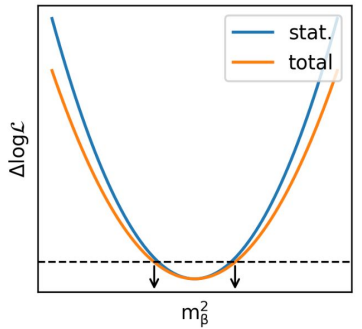
Treatment of systematics

- **Monte Carlo propagation**
- Fit data multiple times, varying systematic(s) parameter in model

➔ Distribution of m_β^2, width quantifies uncertainty



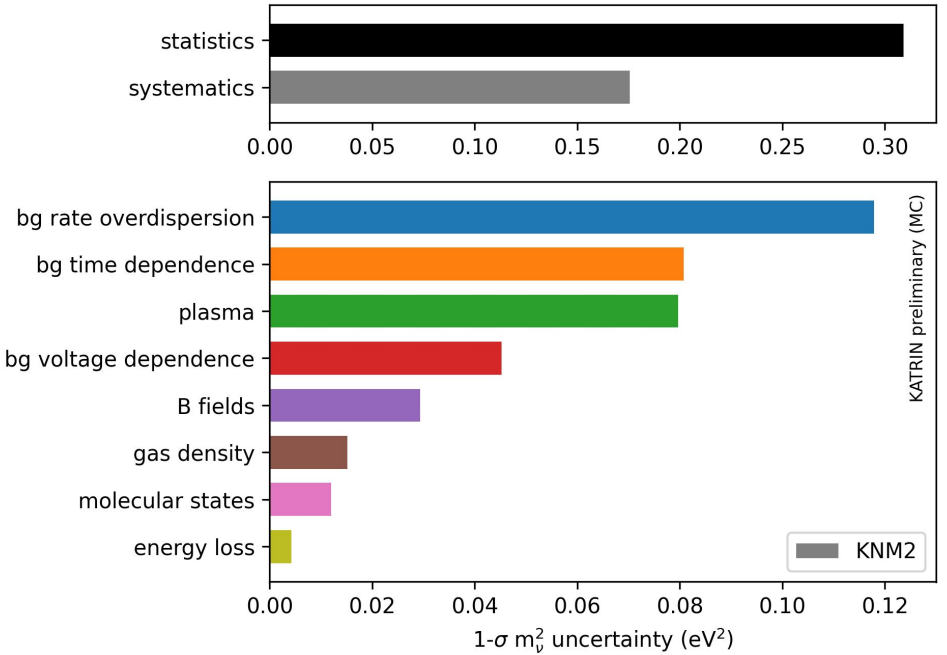
- **Nuisance parameter**
- Fit data once, systematic(s) parameter free in the fit but constrained via pull-term
- Broadening of likelihood quantifies uncertainty



Analysis of latest KATRIN data

- Statistics dominated, systematics non-negligible
- Background related systematics could be mitigated
- Significant plasma uncertainty, to be improved

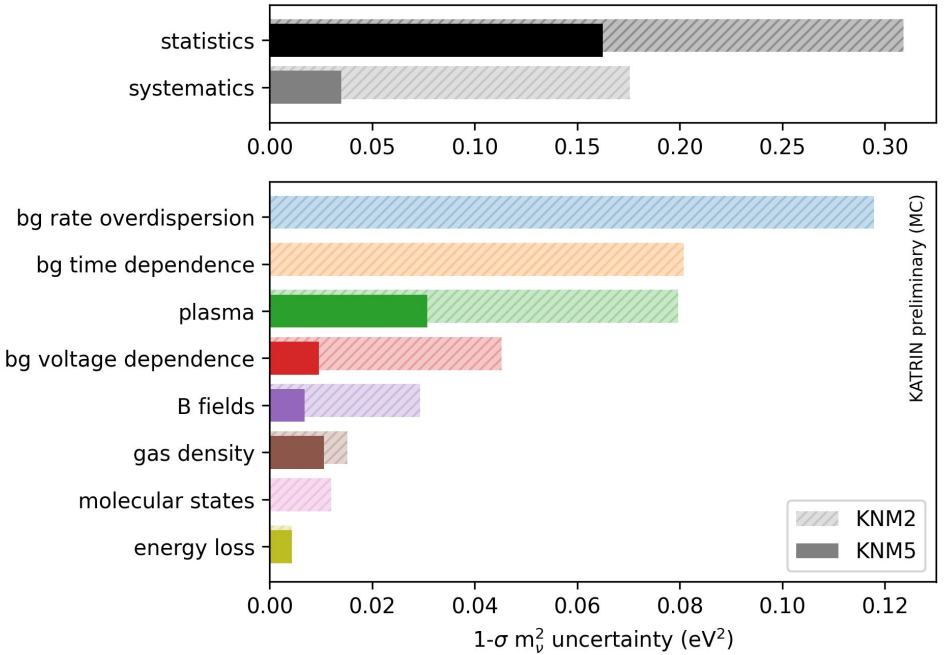
➔ KATRIN well on track to reach its sensitivity goal



Analysis of latest KATRIN data

- Statistics dominated, systematics non-negligible
- Background related systematics could be mitigated
- Significant plasma uncertainty, to be improved

➔ KATRIN well on track to reach its sensitivity goal



Data combination

- Multiple datasets in different settings (magnetic fields, …)

➔ Each dataset needs its own model

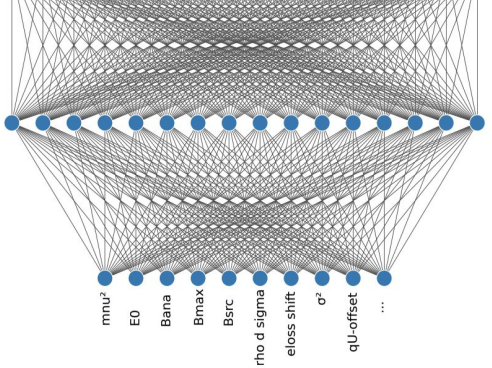
- Simultaneous fit with common m_β^2 (correlated systematic uncertainties)

➔ Large number of fit parameters: > 200

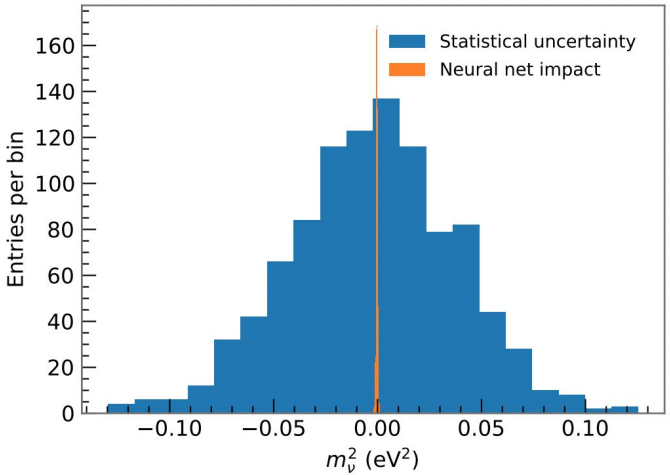
➔ Computationally challenging

- Fast and precise model calculation using a neural net

➔ Speed improvement (x 1000), high accuracy



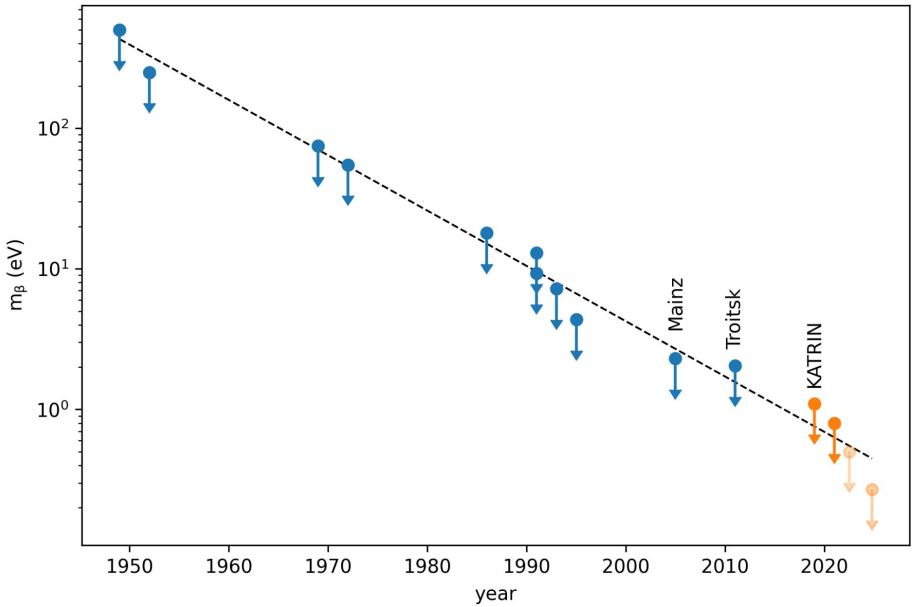
[Karl et al., arXiv:2201.04523]



Data combination

- Blinding scheme: Perform analysis on MC Asimov date ($m_\beta^2 = 0$) first
- Sensitivity already below $m_\beta^2 < 0.25\ eV^2$ (**$m_\beta < 0.5$ eV**) at 90% CL

- Target sensitivity: **$m_\beta < 0.2$ eV** at 90% CL



Conclusion

- Analysis framework ready for data combination
- Sensitivity projection
  $m_\beta < 0.5$ eV at 90% CL
- First direct sub-eV neutrino mass limit

  $m_\beta < 0.8$ eV at 90% CL

  [Aker et al., Nat. Phys. 18, 160–166 (2022)]
- 7th data taking campaign (KNM7) about to start