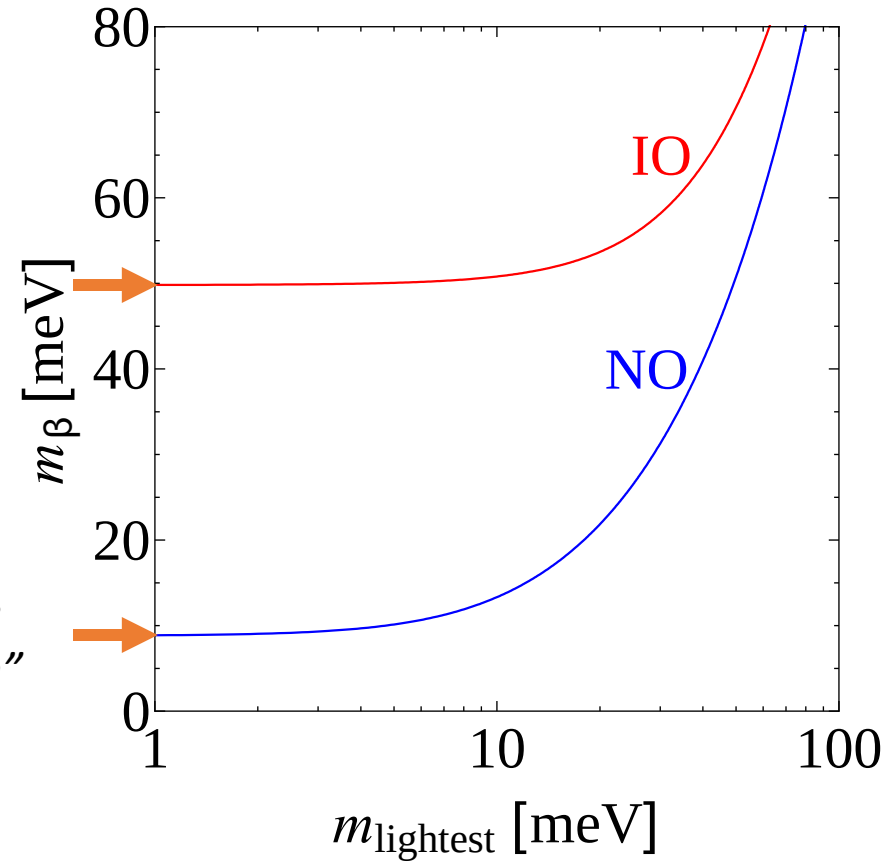
Quantum Technologies for Neutrino Mass

QTNM Quantum Technologies for Neutrino Mass

Physics Objective

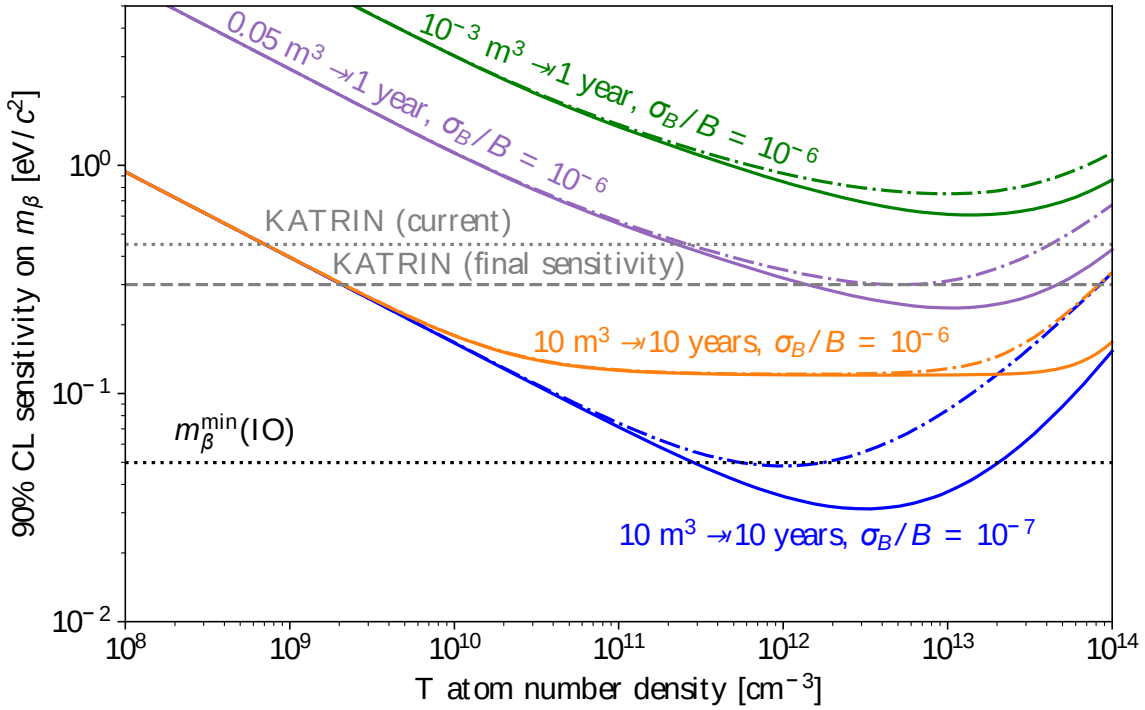
Neutrino mass measurement from atomic ^{3}H β-decay via Cyclotron Radiation Emission Spectroscopy using latest advances in quantum technologies.

Clear sensitivity goals



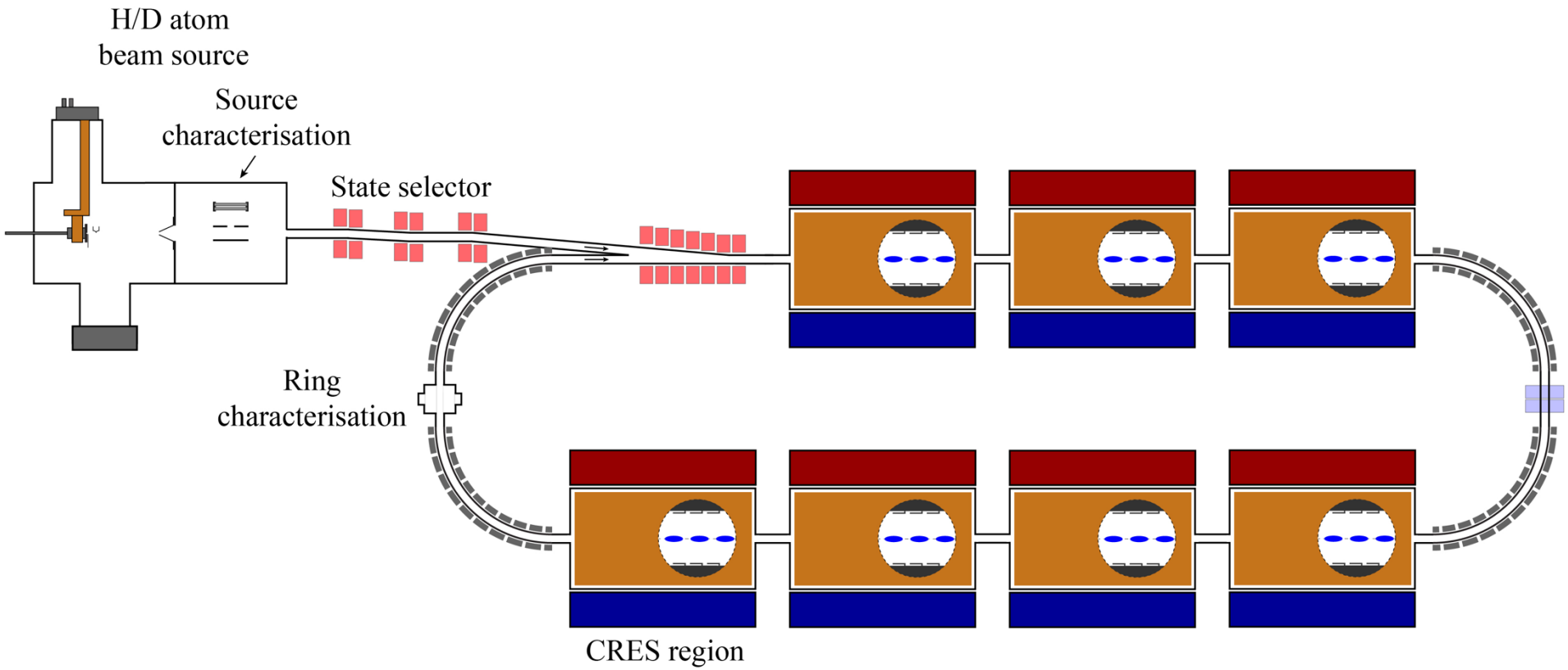
"No lose theorem"

Exposures and sensitivity



- **Eventually targeting lower bound of N.O. ~10 meV**
- BSM physics using full spectrum

QTNM Schematics and Exposure Scalability

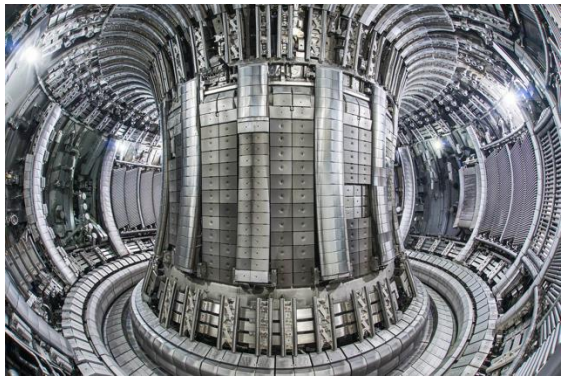


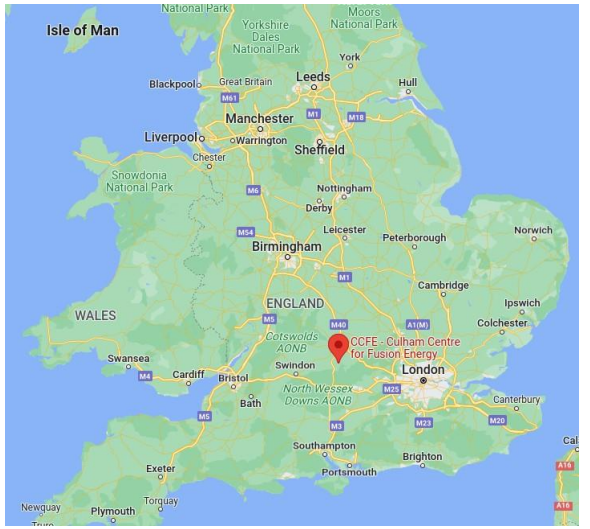
Technology Demonstration (2021-2025):
CRESDA-0 = CRES Demonstration Apparatus

- **Quantum** noise limited microwave **sensors** at TRL7/8 for CRES at ~18GHz (corresponding to 0.7T field)
- 3D B-field mapping with $\lesssim 1\ \mu$T precision, using H-atoms as **quantum sensors** (Rydberg Magnetometry)
- Production and confinement of H-atoms, $\geq 10^{12}$ cm^{-3}
- Modelling tools for CRES and neutrino mass

Preferred Location:

Culham **C**entre for **F**usion **E**nergy





Project Phases

<u>CRESDA0</u> → CRESDA-Tritium → 100 meV → 50 meV → 10 meV

Current (2021-2025) → 2026-2030 → 2030……..2040

Ultimate experiment by joint international collaboration

- Cost of ultimate experiment to be estimated in next phase. *O*(£100M) expected
- UK to lead across all major activities with biggest contributions using its strengths in quantum tech:

quantum noise limited SC-electronics, Magnetometry, Cold atom source

Competition and Partnership

- Project-8 first proposed CRES, demonstrated feasibility and produced 1st T_2 spectrum measurement
- Project-8 and QTNM pursue different avenues for atomic source and CRES detection
- QTNM has competitive edge in quantum tech aspects: Rydberg magnetometry and quantum amplifiers. Competitive results in producing and controlling atomic H.
- Project-8 and QTNM signed Consortium Agreement outlining vision for a joint ultimate experiment taking best developments from both projects
  - QTNM, Project-8 and KATRIN++ established Joint Atomic Tritium Working Group
- PTOLEMY (aim: Cosmic Neutrino Background)
- Calorimeter experiments with ^{163}Ho, ECHo, HOLMES. Complementary to ^{3}H experiments but sensitivity is still far off

Key Challenges

- Scaling up technology to large volumes/exposures – mitigated by phased approach
- Uniformity of B-field in large volumes – QTNM holds a competitive edge in magnetometry