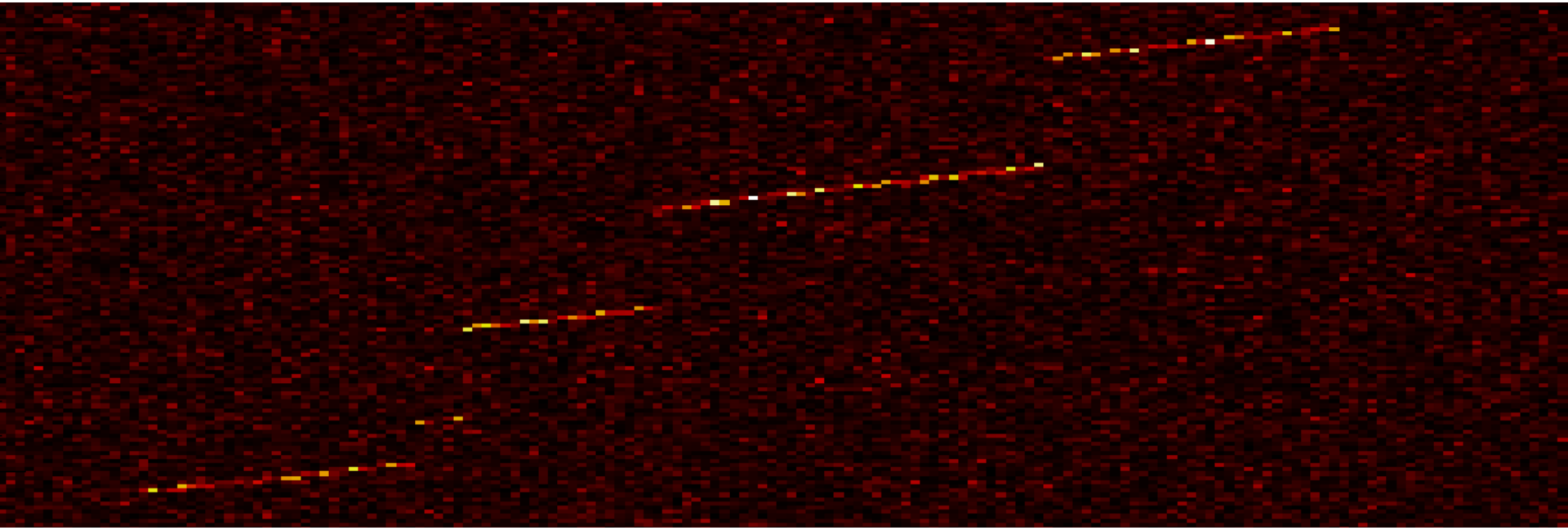
PROJECT 8

Massachusetts Institute of Technology

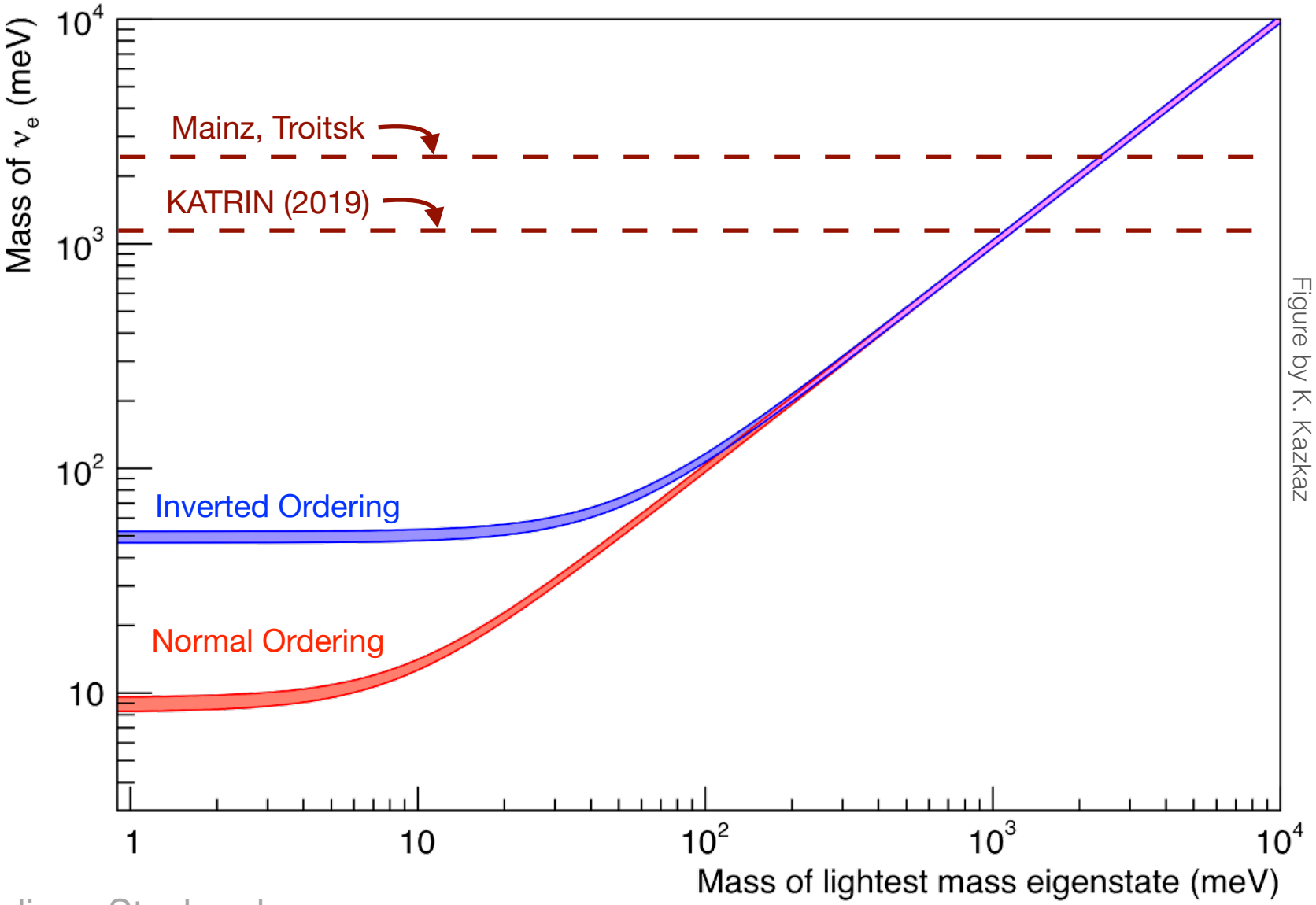
Developing the next neutrino mass experiment: Project 8 Phase III



XIX International Workshop on Neutrino Telescopes

Juliana Stachurska

Project 8 Goal



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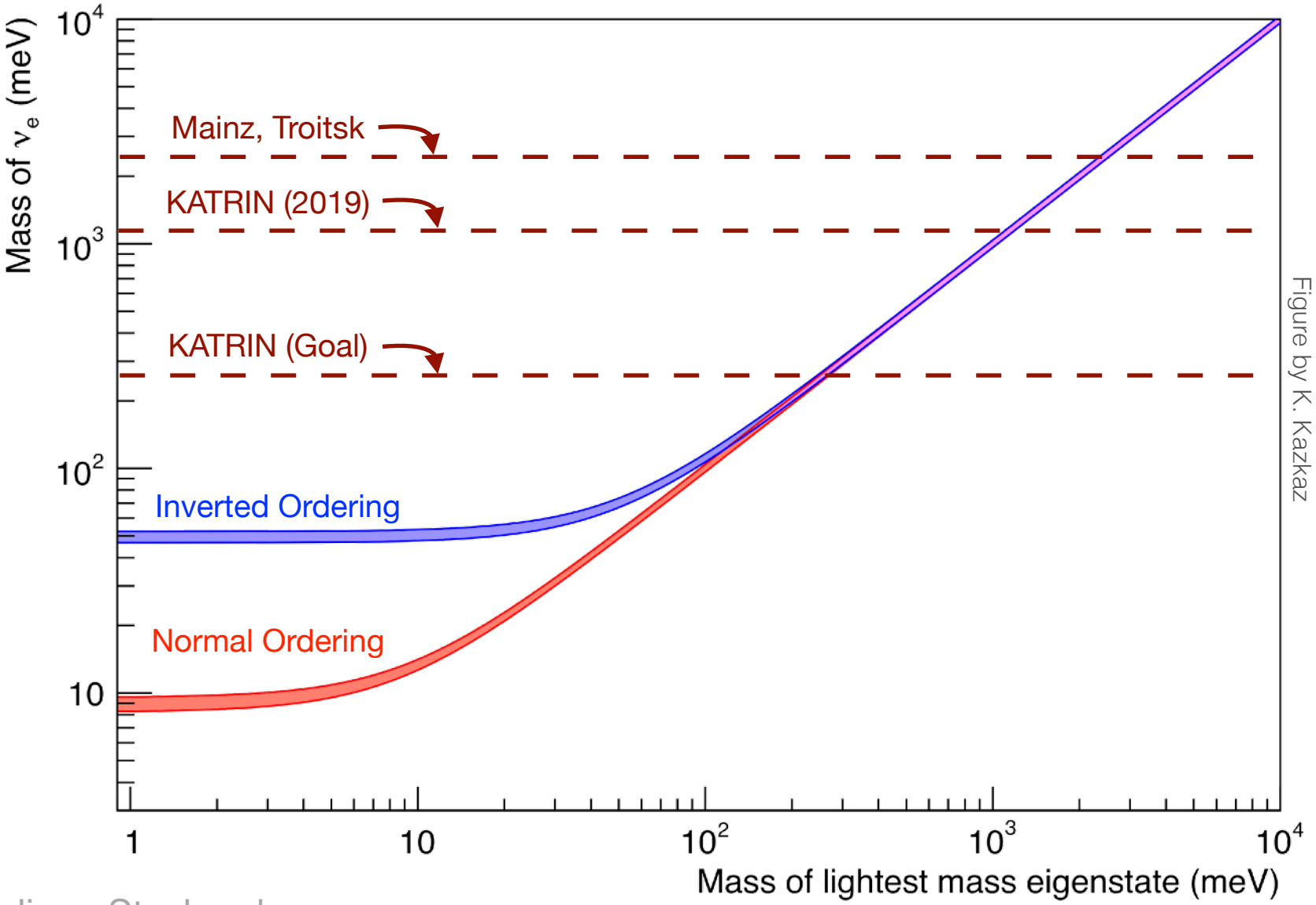

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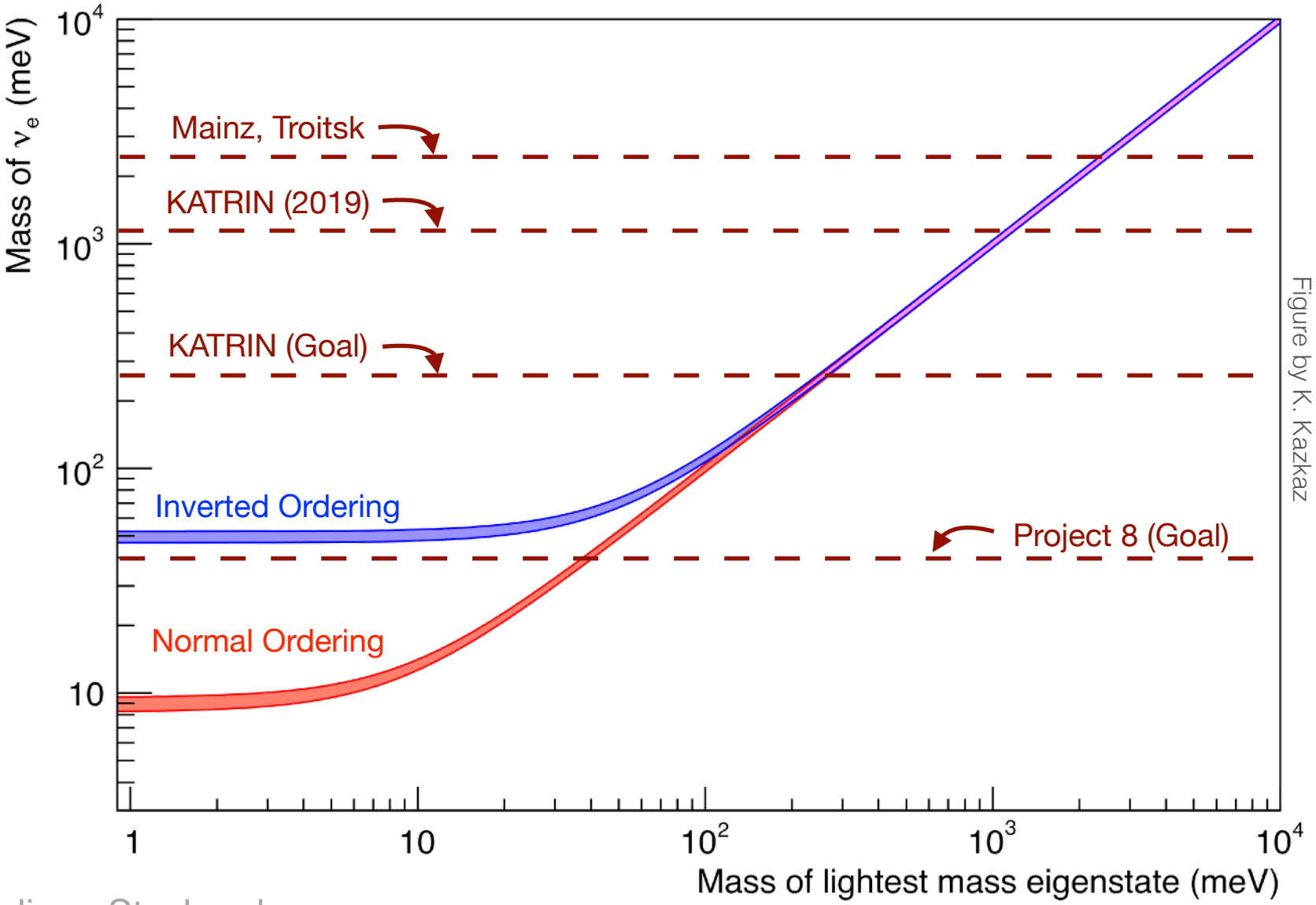

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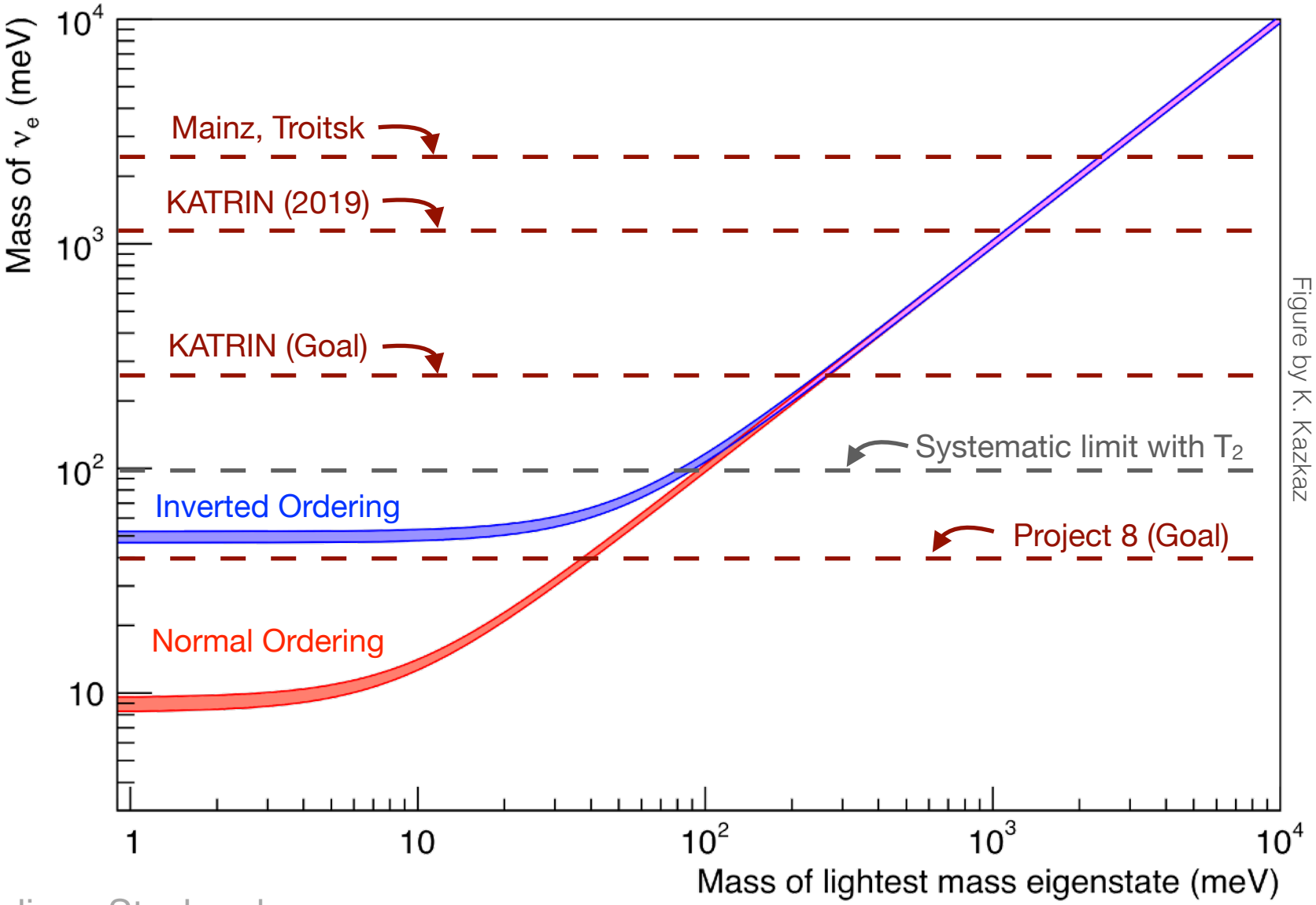


CRES

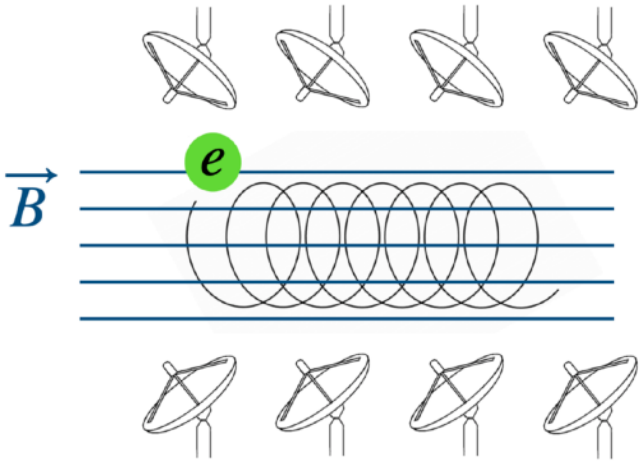
- Cyclotron Radiation Emission Spectroscopy
- Electron in B-field: cyclotron motion & radiation:

$$2\pi f = \frac{eB}{m_e + K_e/c^2} = \frac{eB}{\gamma m_e}$$

- Energy resolution:

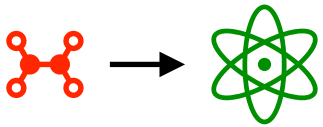
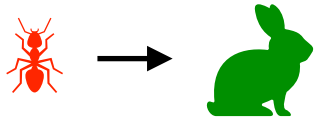
$$\frac{\Delta E}{m_e} = \frac{\Delta f}{f}$$

See Walter's talk later today



PROJECT 8

Phase III

- Phase I — demonstrate CRES technique
- Phase II — first Tritium spectrum with CRES
- **Phase III**
  - Go atomic!  demonstrate atomic tritium trapping
  - Go bigger!  demonstrate CRES in free space
- Phase IV — full apparatus, reaching 0.04 eV sensitivity

Phase III

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- Phase II — first Tritium spectrum

See Walter's talk later today

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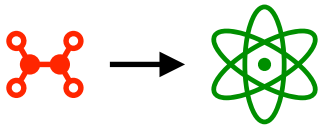
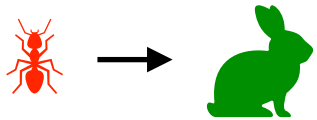
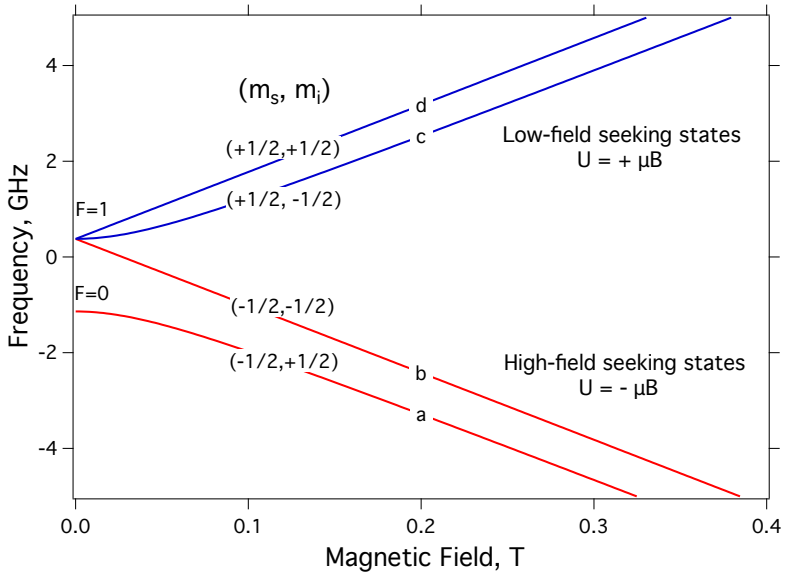
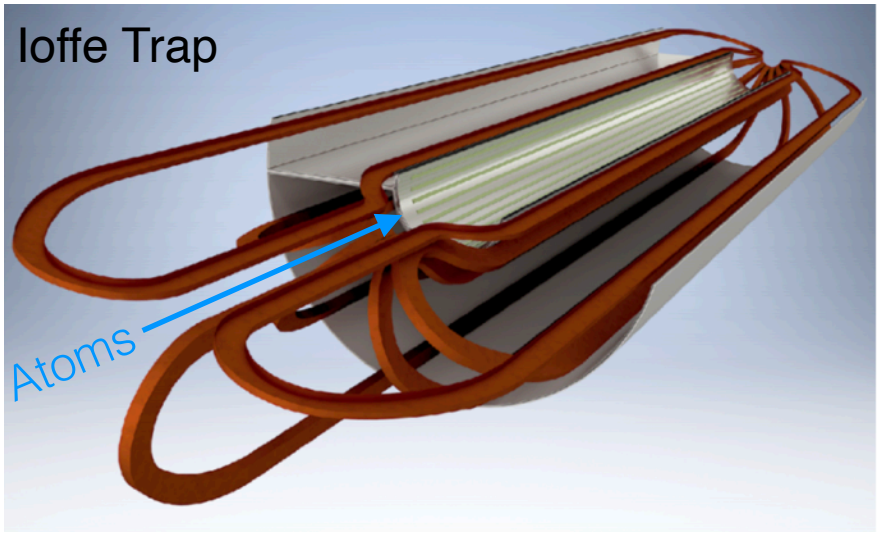
- **Phase III**
  - Go atomic!  demonstrate atomic tritium trapping
  - Go bigger!  demonstrate CRES in free space
- Phase IV — full apparatus, reaching 0.04 eV sensitivity

See Walter's talk later today

Atomic Tritium Demonstrator

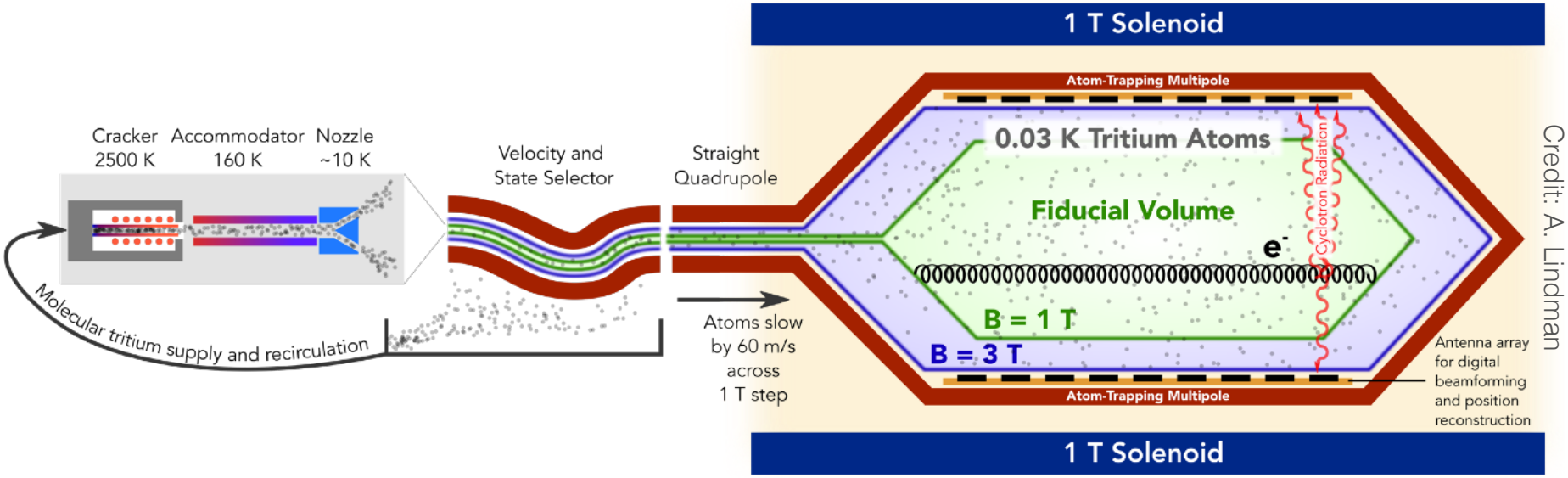




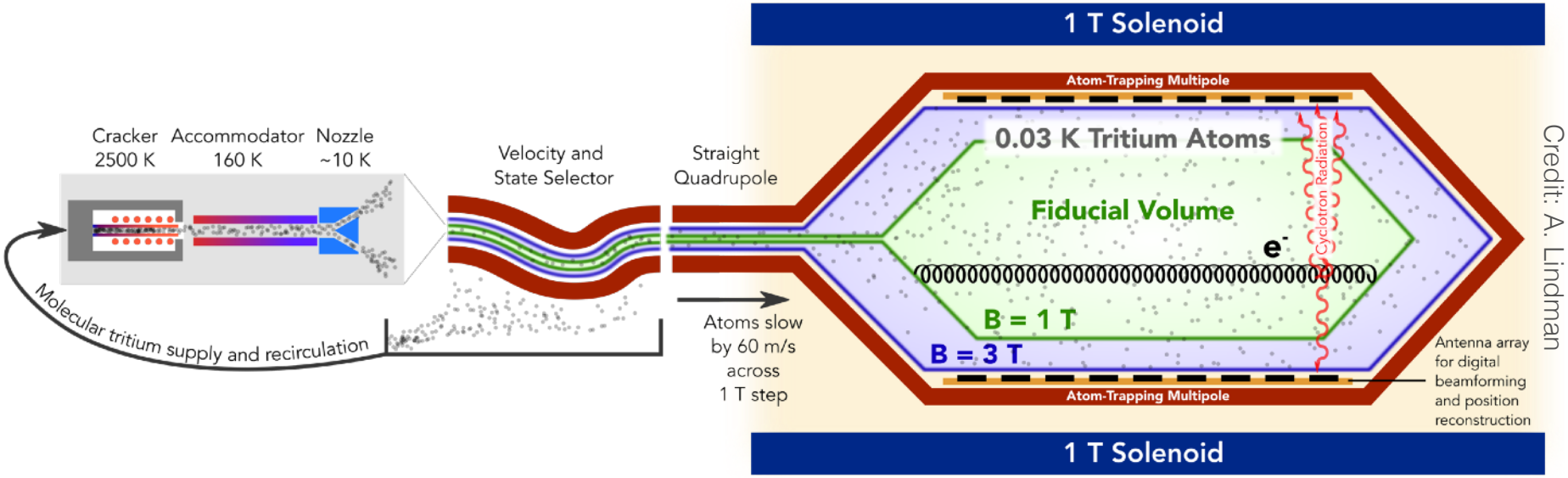
Credit: A. Lindman

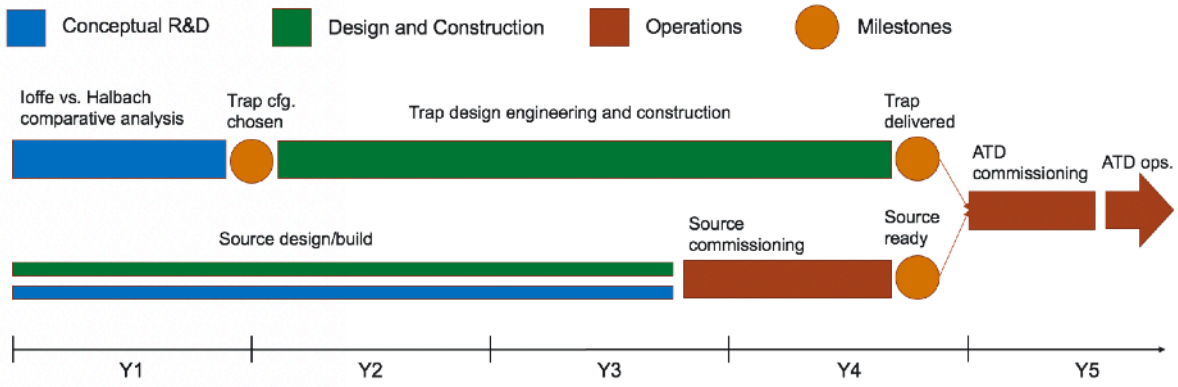
- Ioffe trap: mature design, superconducting coils
- Alternative: Halbach array: permanent magnets

Atomic Tritium Demonstrator



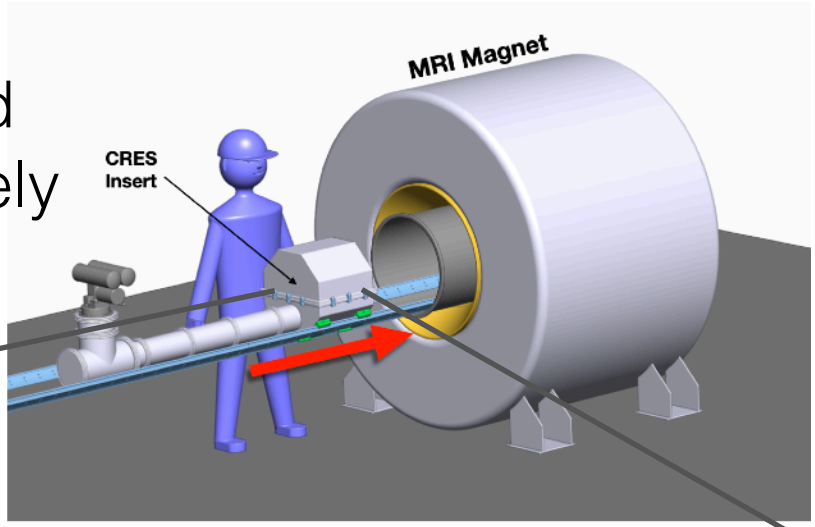
Atomic Tritium Demonstrator

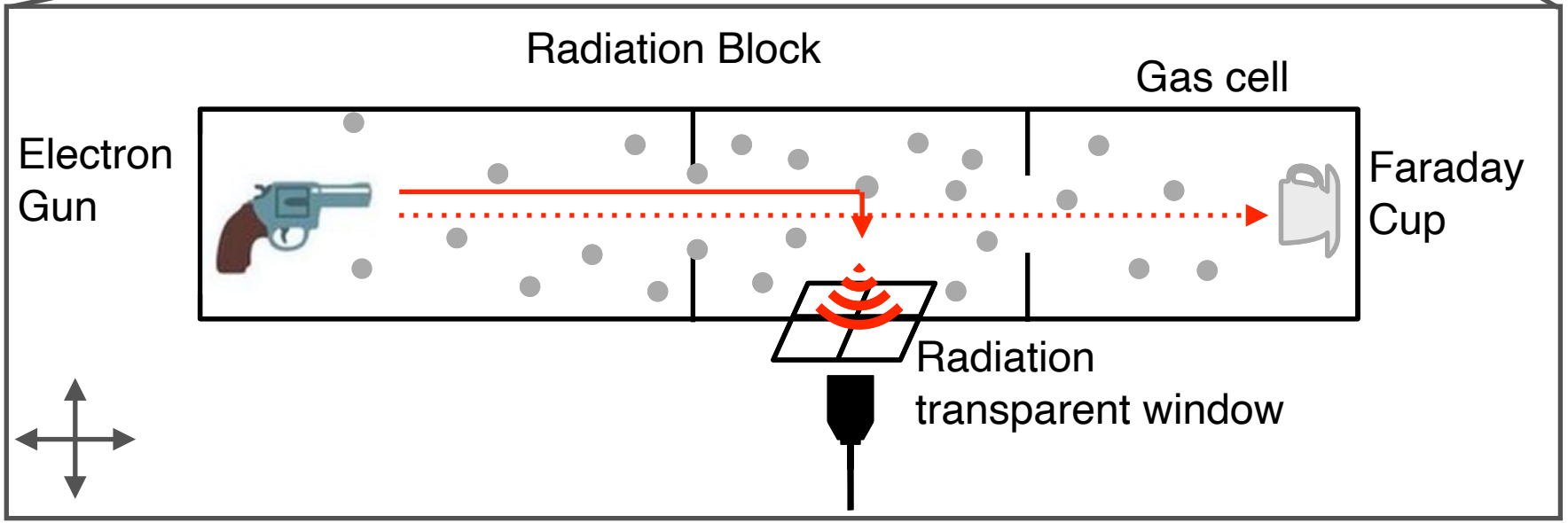




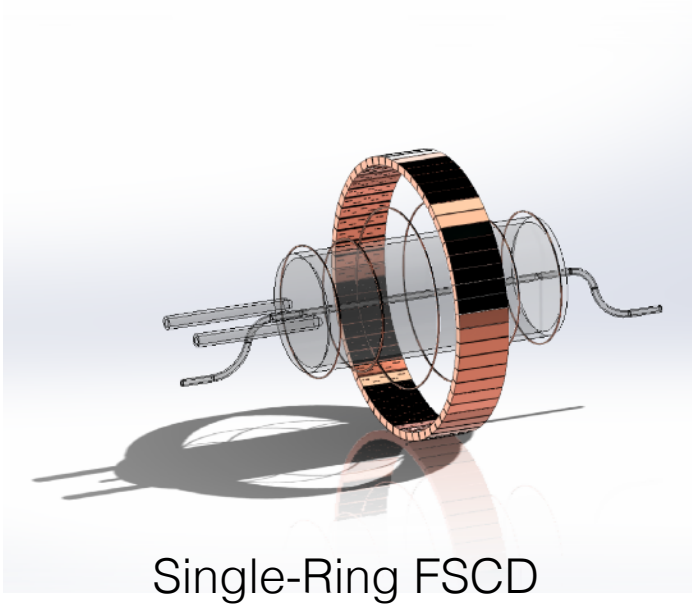
Free-space CRES demonstrator

- Need to know the magnetic field and electron trajectories precisely
- Insert electron gun into MRI
- Map field in center

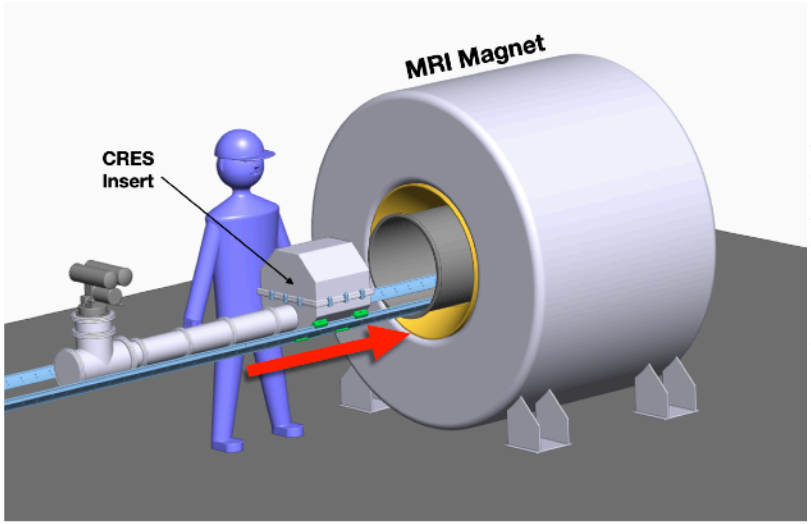




Free-space CRES demonstrator

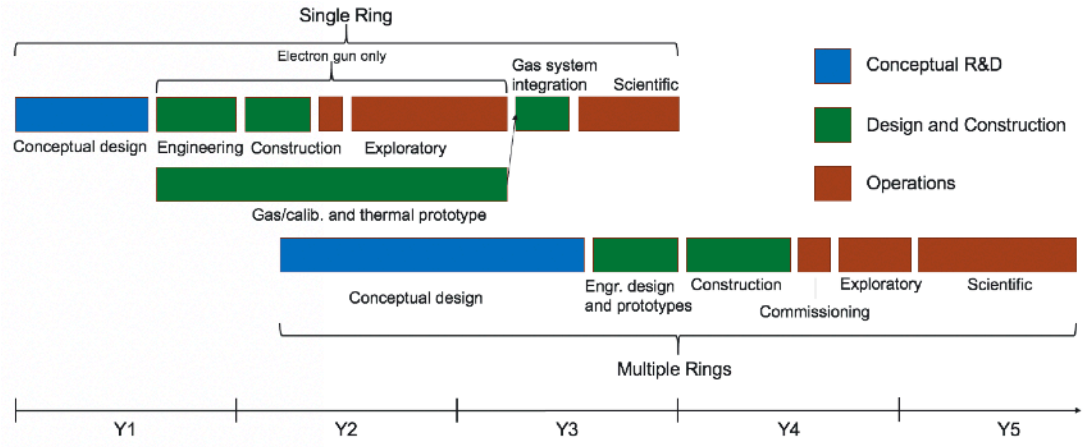


Single-Ring FSCD



Credit: J. Nikkel

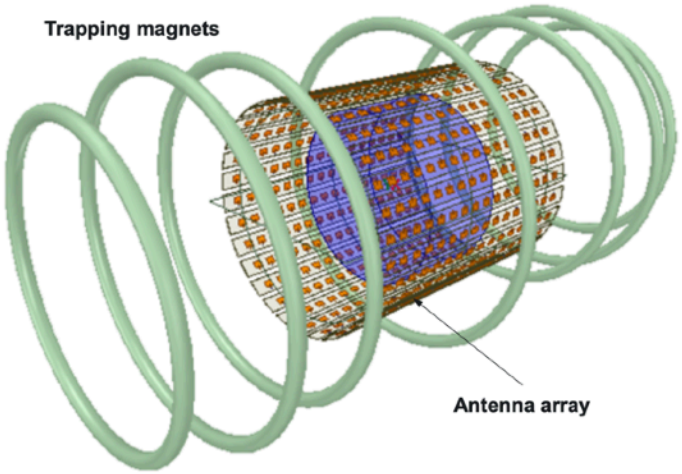
Insert: electron gun + Helium gas cell / Tritium gas cell, antennas



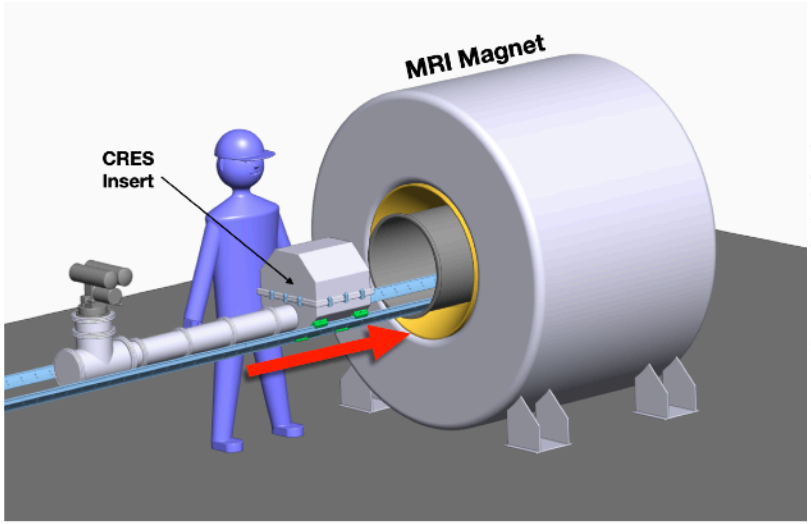
J.Phys.G 44 (2017) 5, 054004

Neutrino 2020: http://doi.org/10.5281/zenodo.4134024

Free-space CRES demonstrator



Multi-Ring FSCD



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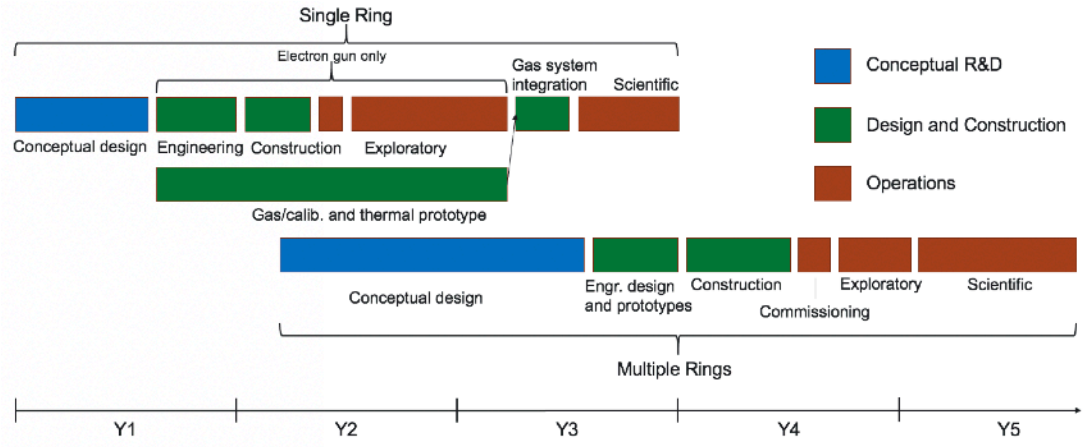
Insert: electron gun + Helium gas cell / Tritium gas cell, antennas



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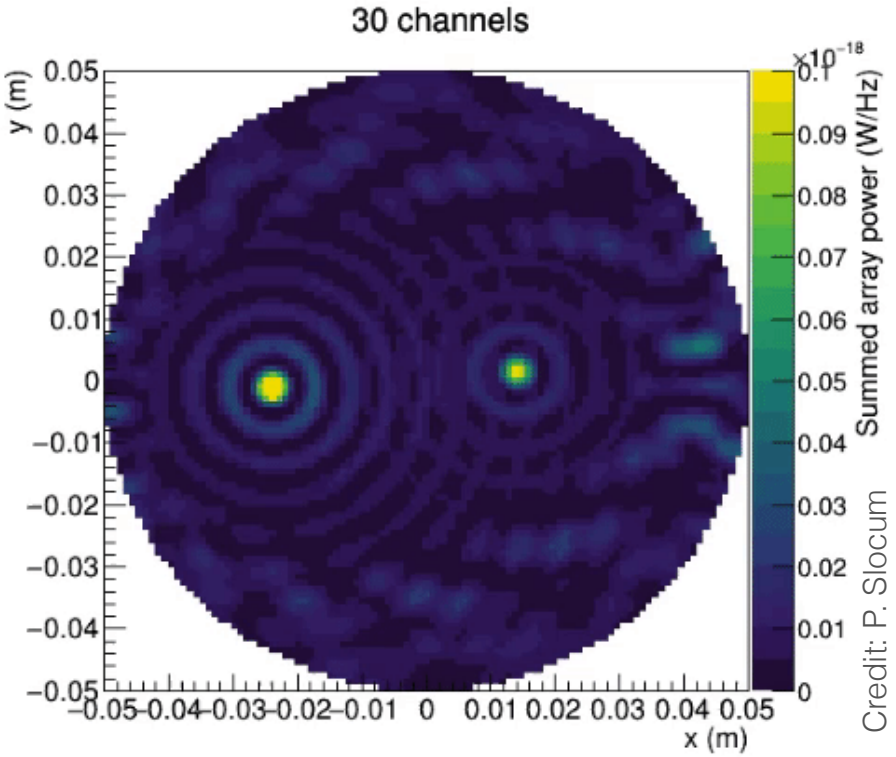
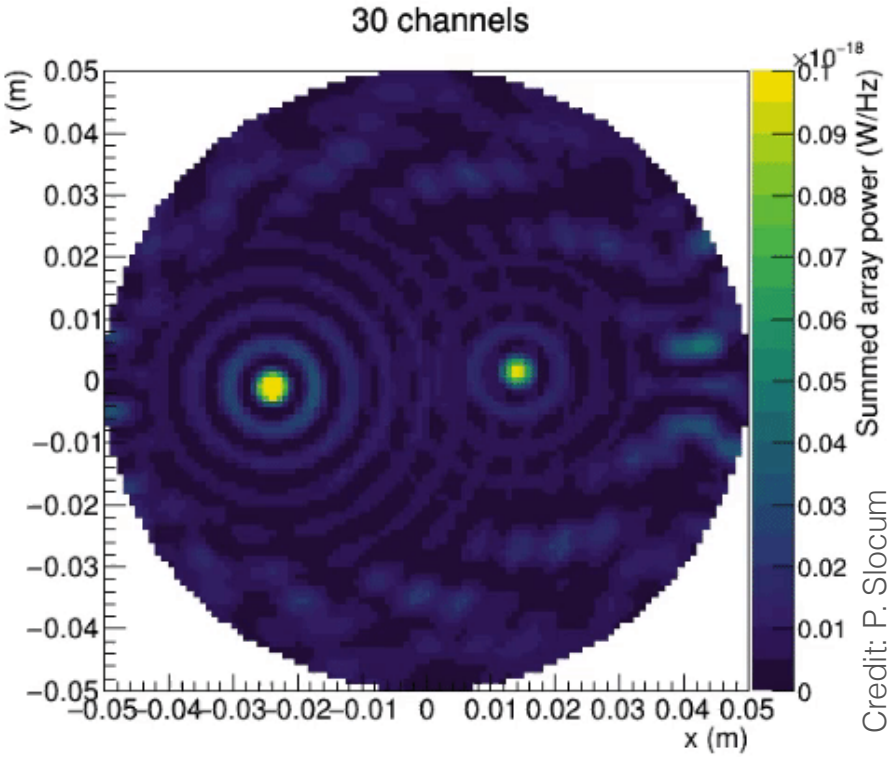


- Every antenna sees part of signal
  → sum coherently (beamforming)
- Challenges: Doppler shift, $\nabla \vec{B}$-motion
  → antennas see slightly different frequency

- Position reconstruction → multiple events in one trigger window

Free-space CRES demonstrator



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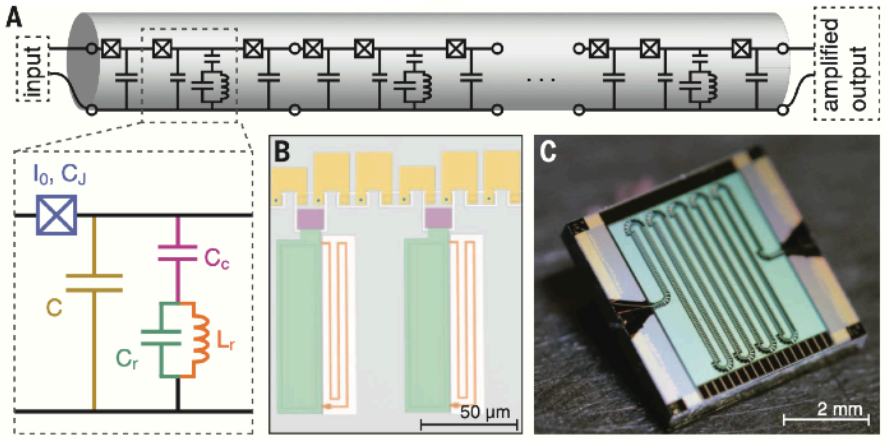
New Amplifiers: JTWPAs

- Josephson Traveling Wave Parametric Amplifier
  - Superconducting
  - Near quantum-noise limited
- High gain over broad frequency range (~20 dB over ~2 GHz)

- Develop JTWPA for Project 8 with MIT Lincoln Laboratory
- Challenges:
  - Performance of 26 GHz JTWPA unknown
  - Multiplexing (not validated >10 GHz)
  - Magnetic fields
  - Operating temperatures



Science 350,6258(2015)

Summary

- To cover entire inverted neutrino mass ordering range, Project 8 needs significant technological development
- Phase III will inform the final design by demonstrating:
  - Free-space application of CRES
  - Atomic tritium trapping & handling
- Complementary developments in readout, digitization, analysis, signal amplification
- Please see Walter Pettus' talk later today (last session) for complete overview and recent results!

The Collaboration

Case Western Reserve University: R. Mohiuddin, B. Monreal, Y.-H. Sun

Harvard-Smithsonian Center for Astrophysics: S. Doeleman, J. Weintroub

Indiana University: W. Pettus

Johannes Gutenberg Universitat, Mainz: S. Böser, C. Claessens, M. Fertl, A. Lindman, C. Matthé, R. Reimann, F. Thomas

Karlsruhe Institute of Technology: T. Thümmler

Lawrence Livermore National Laboratory: K. Kazkaz

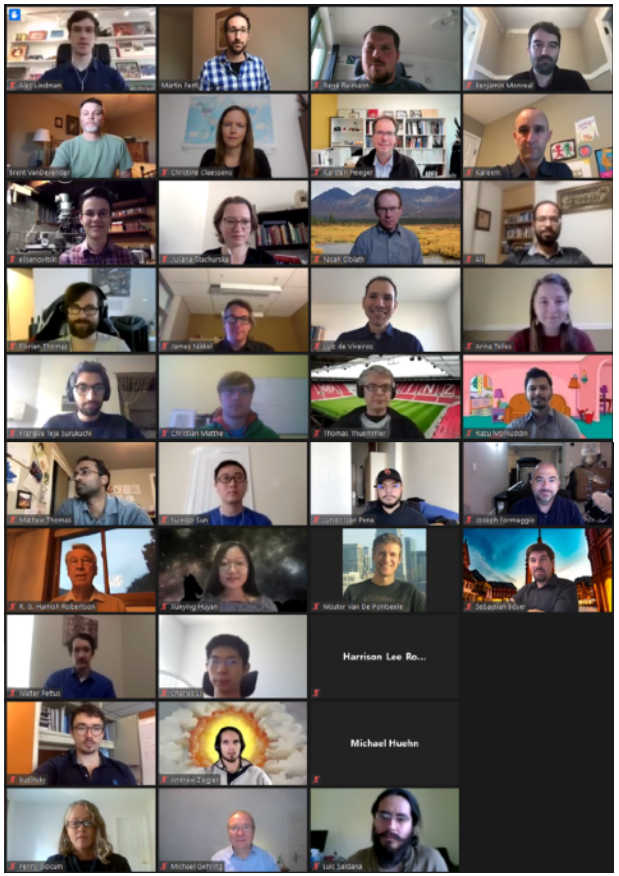
Massachusetts Institute of Technology: N. Buzinsky, J. Formaggio, M. Li, J. Pena, J. Stachurska, W. Van de Pontseele

Pacific Northwest National Laboratory: M. Grando, X. Huyan, M. Jones, N. Oblath, M. Schram, J. Tedeschi, M. Thomas, B. VanDevender

Pennsylvania State University: L. de Viveiros, A. Ziegler

University of Washington: A. Ashtari Esfahani, P. Doe, E. Novitski, H. Robertson, L. Rosenberg, G. Rybka, D. Sweigart

Yale University: K. Heeger, J. Nikkel, L. Saldaña, P. Slocum, P. Surukuchi, A. Telles, T. Weiss



This work was supported by the US DOE Office of Nuclear Physics, the US NSF, the PRISMA+ Cluster of Excellence at the University of Mainz, and internal investments at all collaborating institutions.