Project 8

A New Generation of Neutrino Mass Experiment

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On behalf of Project 8 collaboration

University of Washington

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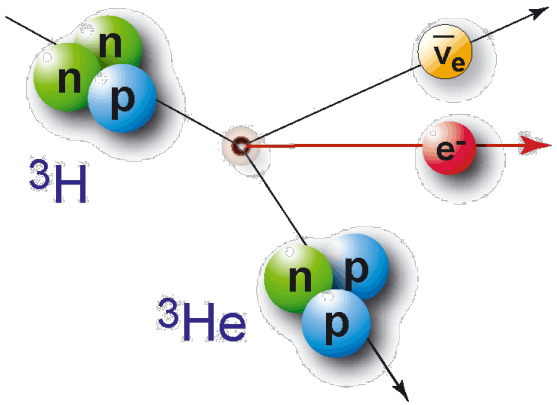
APS | DIVISION OF PARTICLES & FIELDS

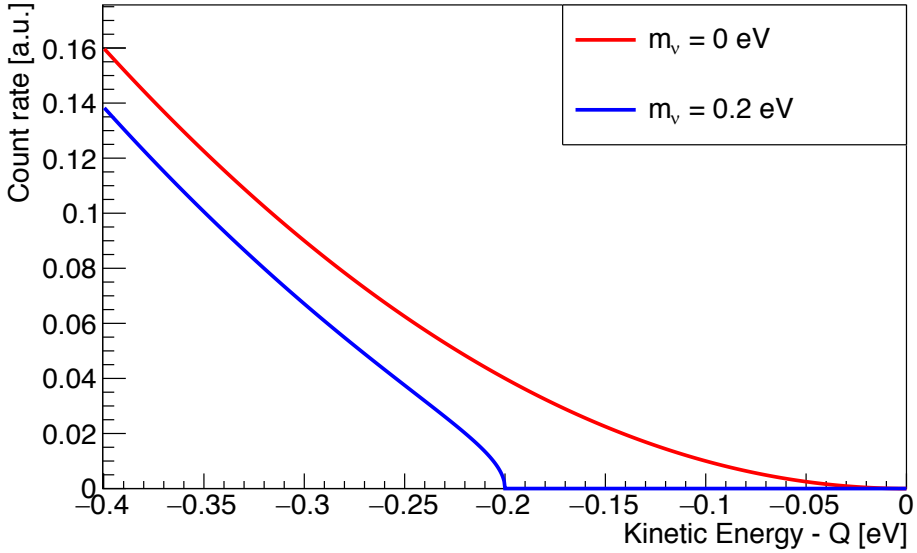
DPF 2017

MEETING OF THE AMERICAN PHYSICAL SOCIETY DIVISION OF PARTICLES AND FIELDS

Neutrino Mass Search

- Neutrino oscillation experiments confirm massive neutrinos
- What is the absolute scale?
- Where to look?
  - Cosmological observation
  - Neutrino-less double beta decay
  - Model independent direct measurement

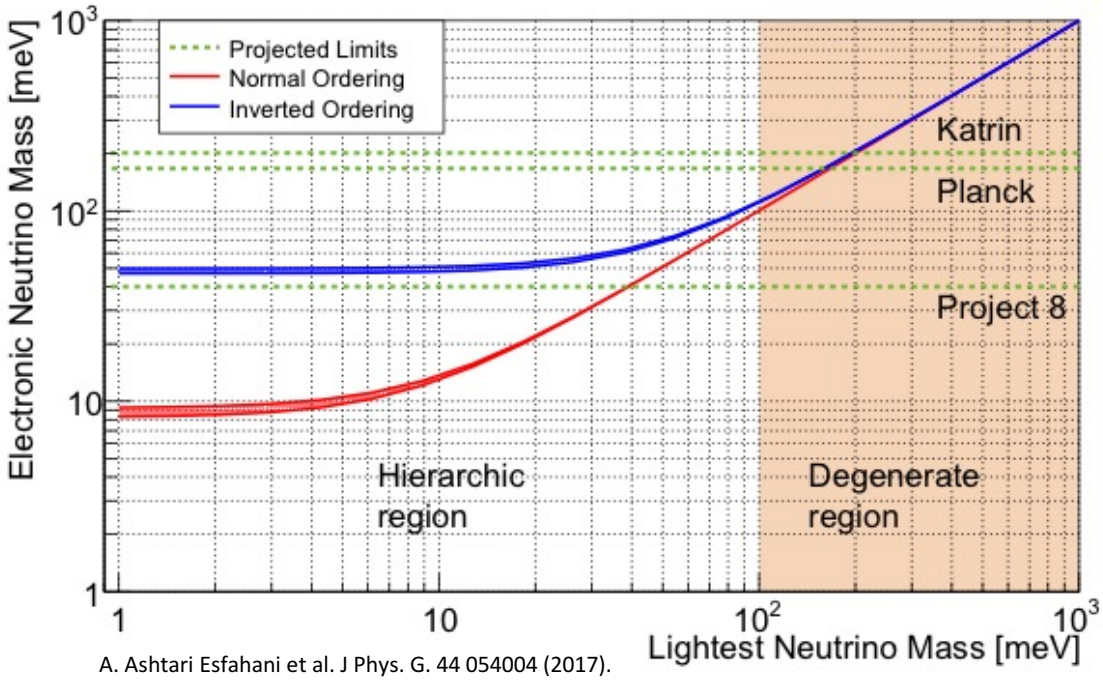




- Why tritium?
  - Endpoint energy of 18.6 keV
  - Half life time of 12.5 y
  - Super allowed transition

Direct Measurement of Neutrino Mass

- The current limit on electron anti-neutrino: 2 eV from Mainz and Troitsk (Eur Phys J C 2005; 4: 447-68, Phys. Rev. D 84 (2011) 112003)
- KATRIN will search the degenerate region of the neutrino phase space
- A new approach is needed to explore the non-degenerate region

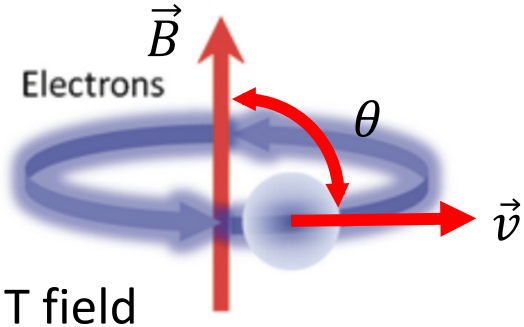


A. Ashtari Esfahani et al. J Phys. G. 44 054004 (2017).

Cyclotron Radiation Emission Spectroscopy (CRES)

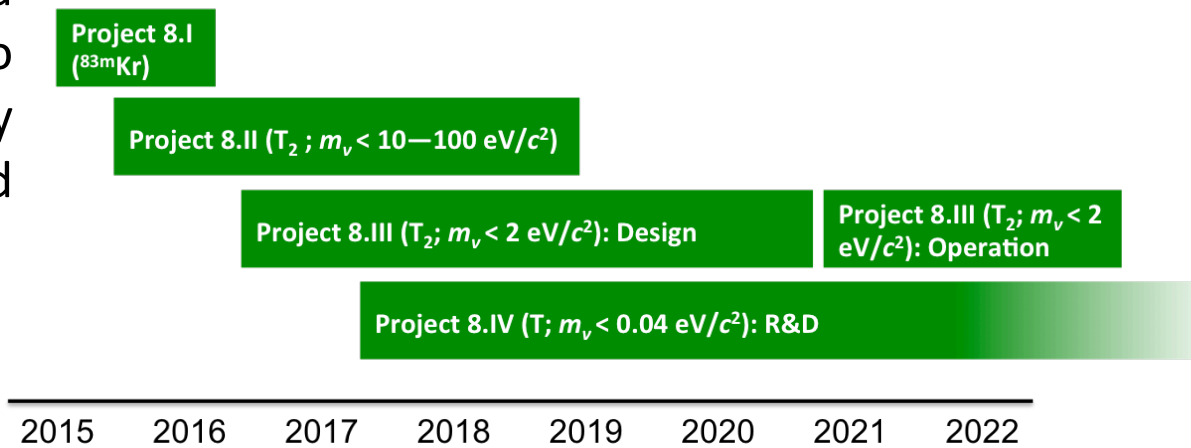
- Project 8 uses a novel technique to measure the electron energy non-destructively by detecting the cyclotron radiation

$$f_c = \frac{1}{2\pi}\frac{eB}{E_{kin} + m}$$



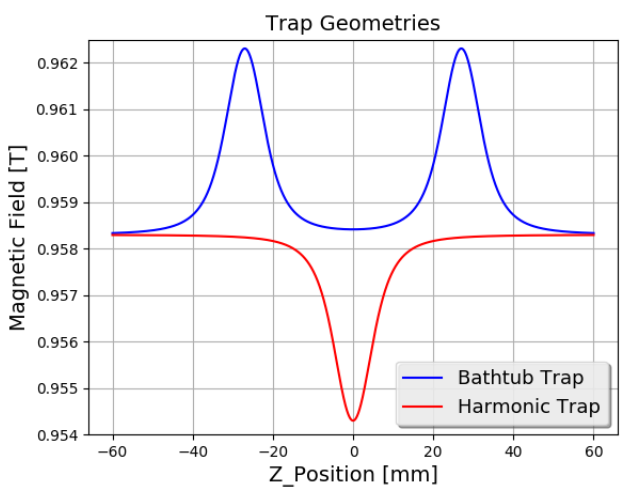
- 18 keV electron will radiate at ~ 26 GHz in a 1 T field

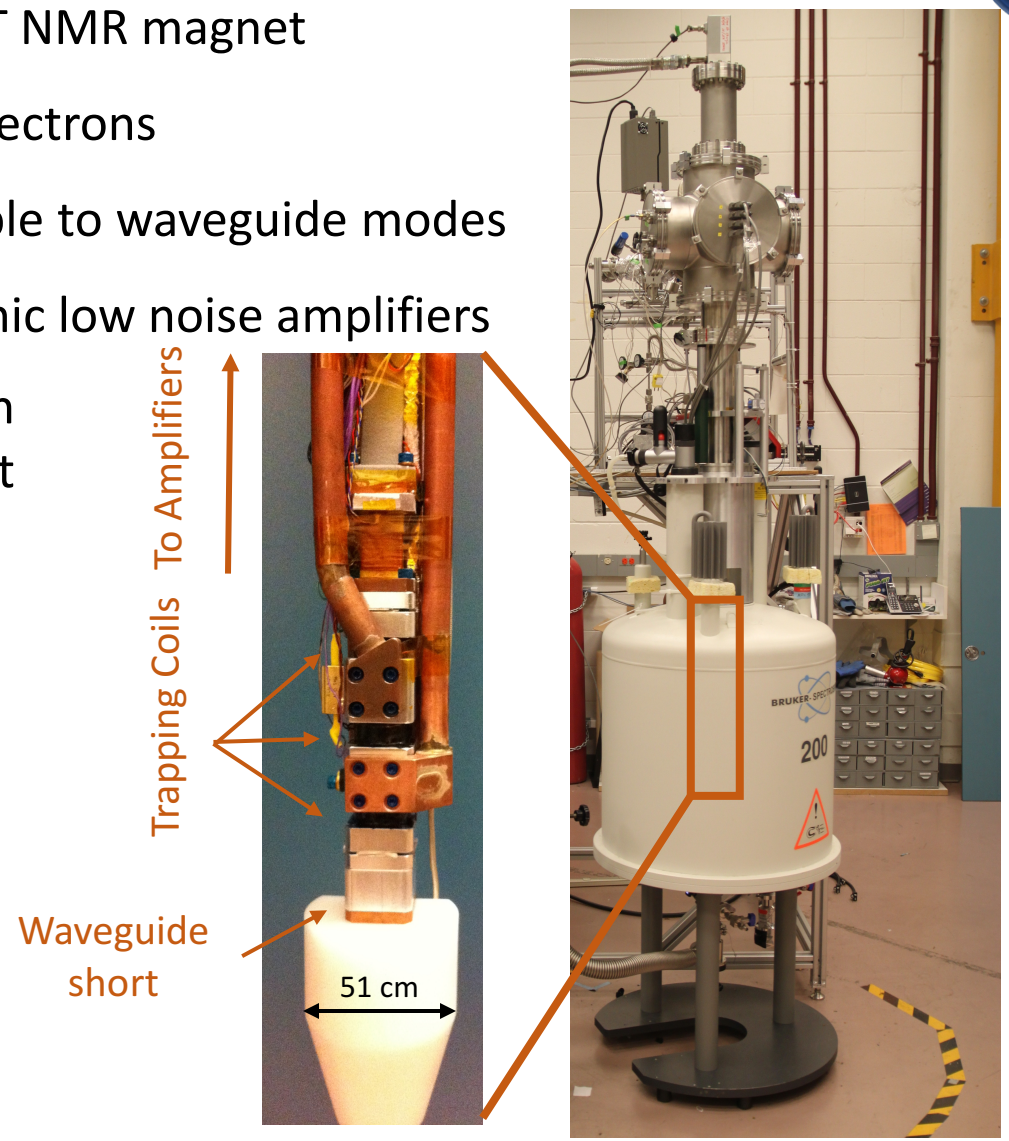
- Project 8 adopted a phased approach to reach the sensitivity below the Inverted hierarchy scale



Phase I Hardware

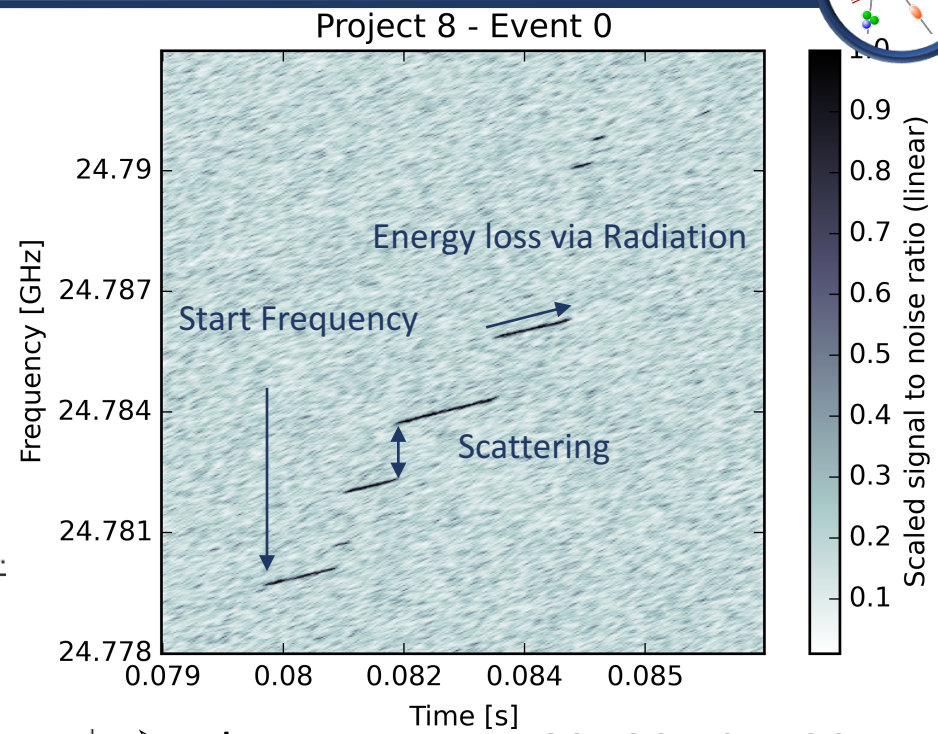
- First two phases use a 1 T NMR magnet
- Using ^{83m}Kr conversion electrons
- Radiated power will couple to waveguide modes and propagate to cryogenic low noise amplifiers
- Three trapping coils can provide two different trap geometries

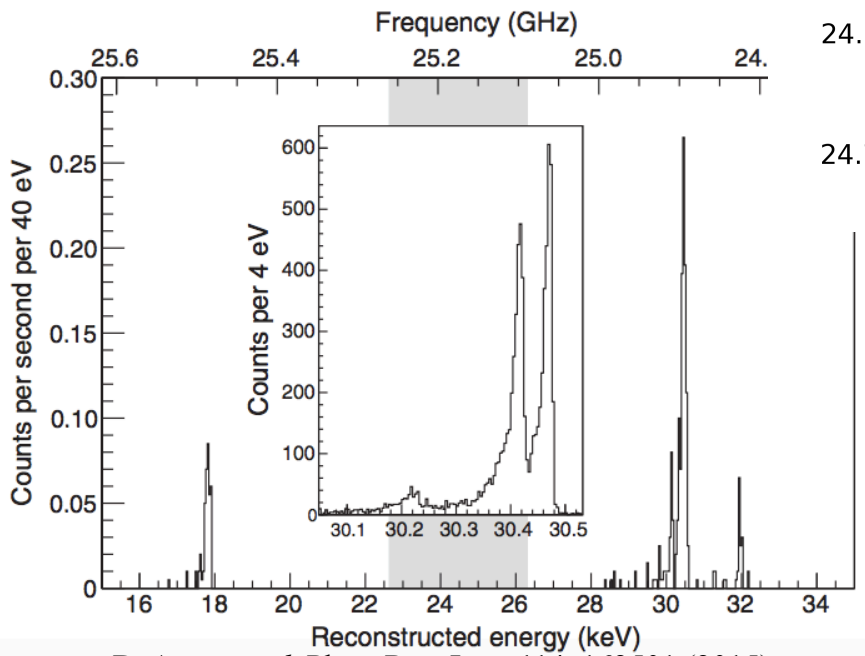




Phase I Result

- First detection of single electron cyclotron radiation
- Energy histogram for ^{83m}Kr conversion electrons





D. Asner *et al*. Phys. Rev. Lett. 114, 162501 (2015)

- Electrons at 17.83, 30.424, 30.477, 31.934 and 31.941 keV
- Electron energy reconstruction with 15 eV of FWHM

Phenomenology of Electron Kinematics in the Magnetic Trap

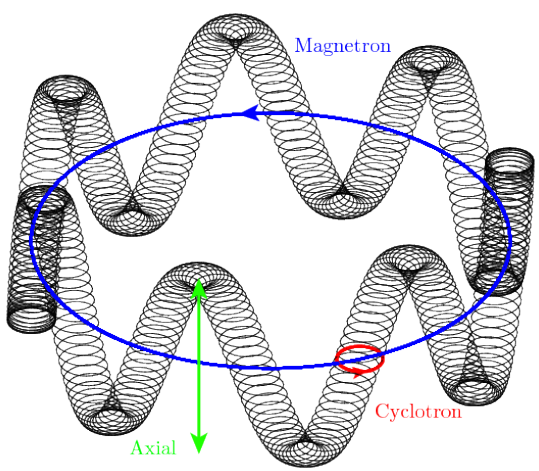
- Biggest systematic in energy reconstruction comes from pitch angle
- Where is it coming from?
- Axial motion:
  - Change of average magnetic field seen by the electron

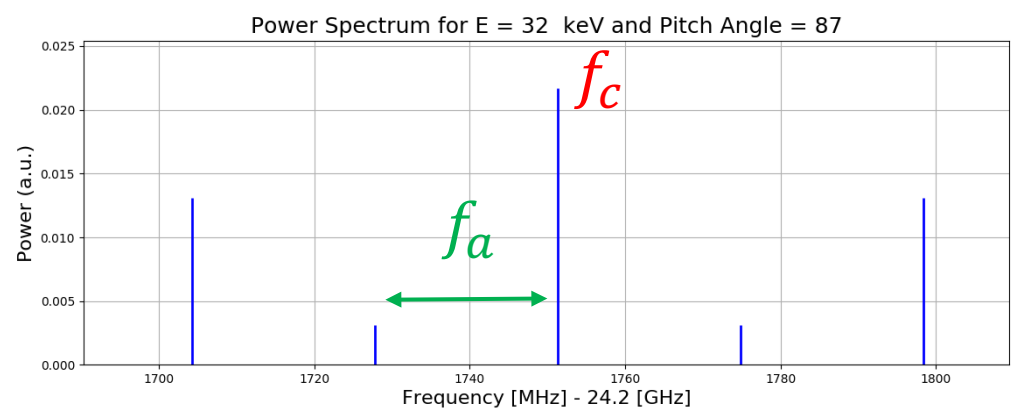
$$f_c = \frac{1}{2\pi} \frac{eB_{average}(\theta)}{E_{kin} + m}$$

  - The Doppler effect

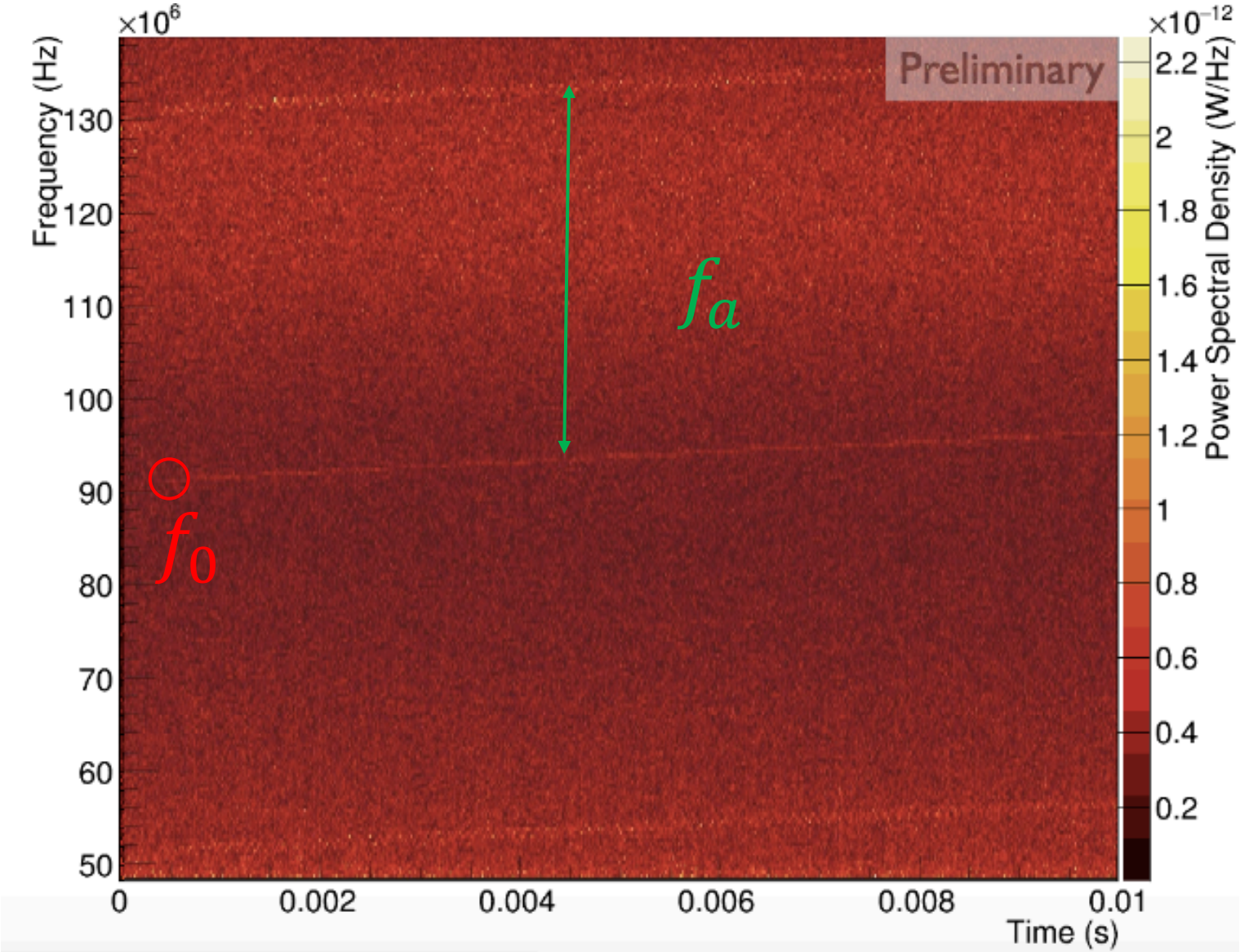
$$f_R \approx f_c \left(1 + \frac{v_z}{v_p}\right) = A + B \sin 2\pi f_a t$$

A 26 GHz FM Radio!





Phenomenology of Electron Kinematics in the Magnetic Trap



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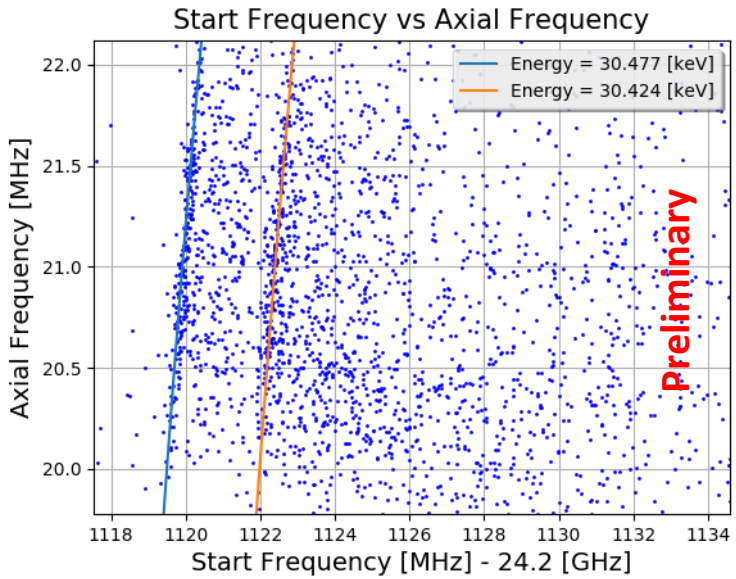
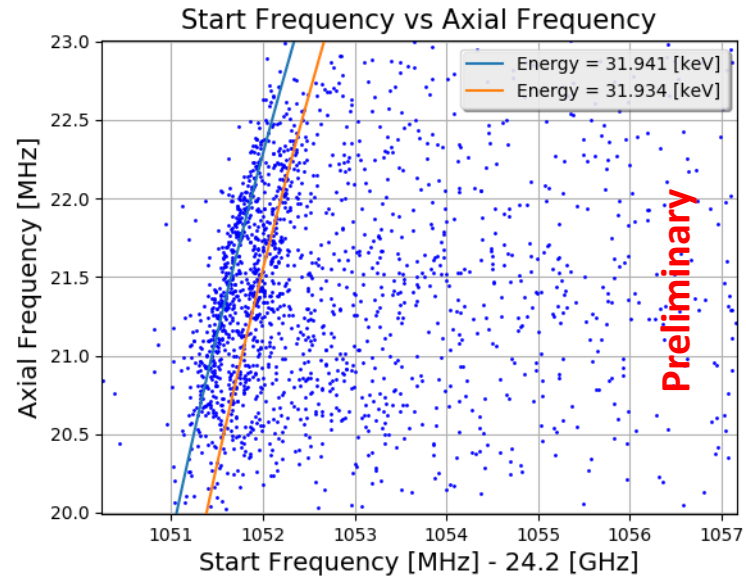
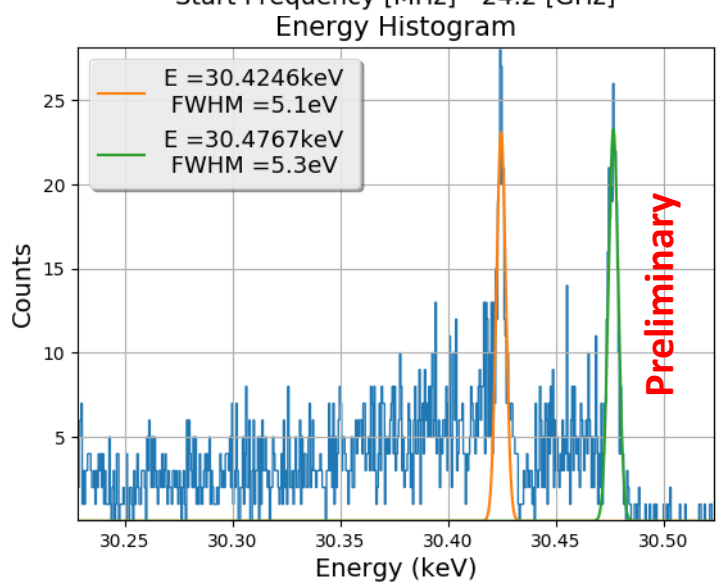
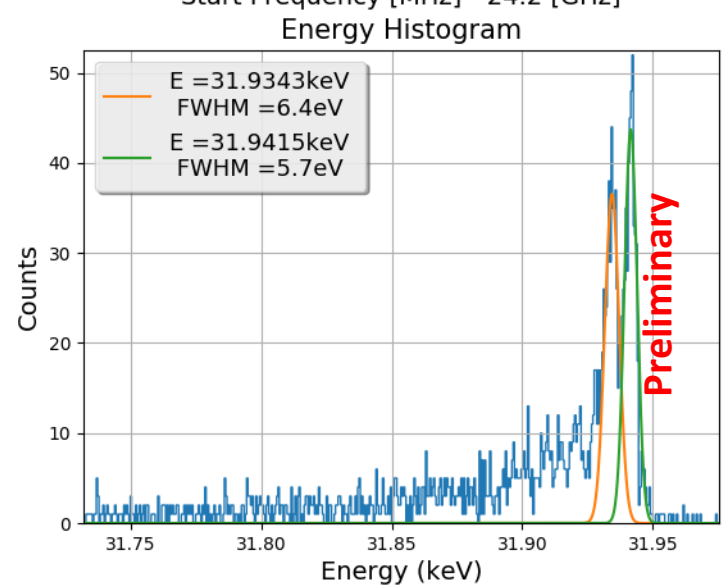


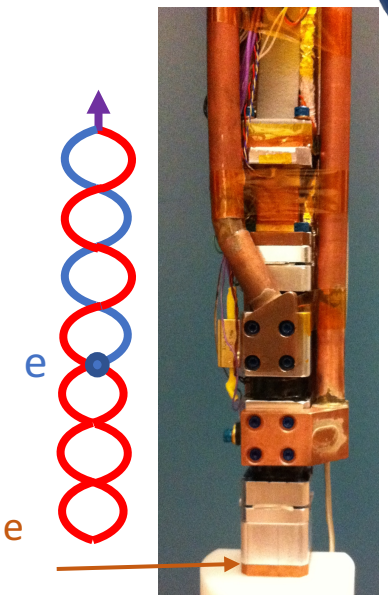


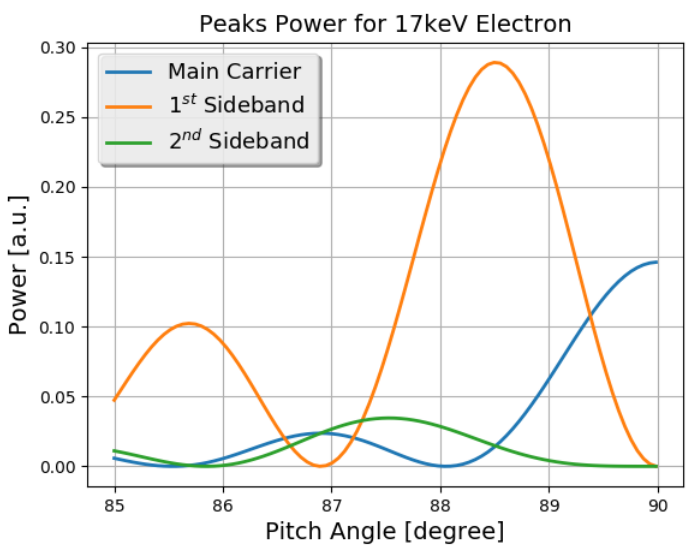


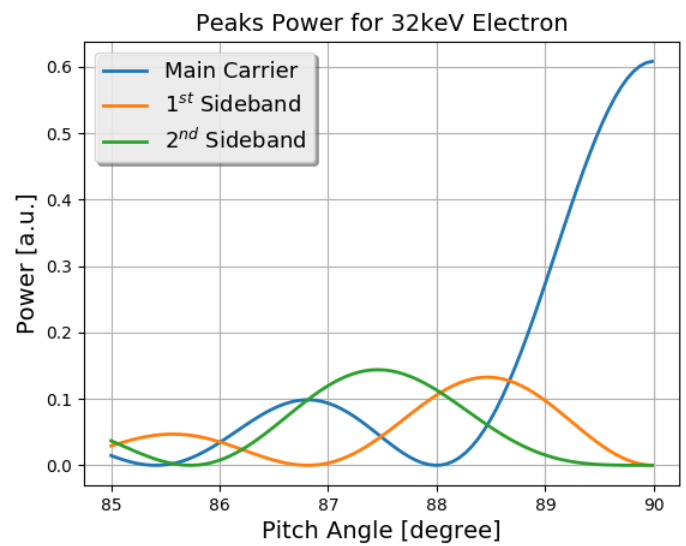


Phenomenology of Electron Kinematics in the Magnetic Trap

- Besides the frequency of the peaks, the knowledge of their power is also beneficial
- Electron's energy and pitch angle will specify its power spectrum
- Waveguide short recovers about half of the radiated power, but causes traveling wave interference

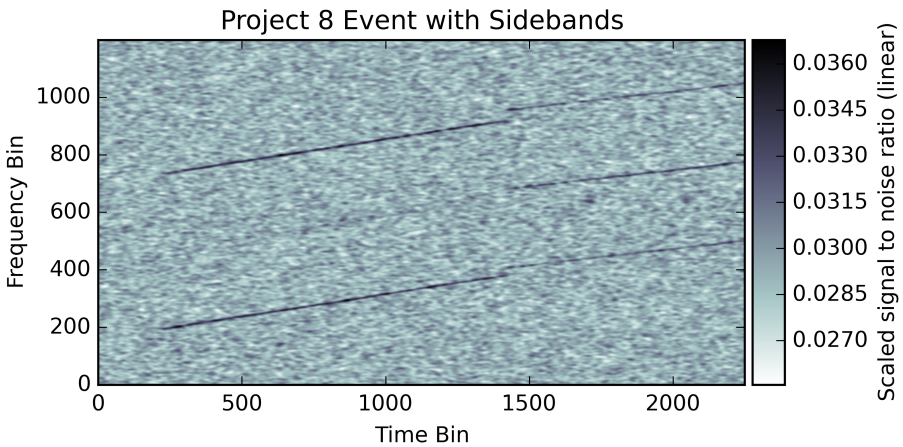


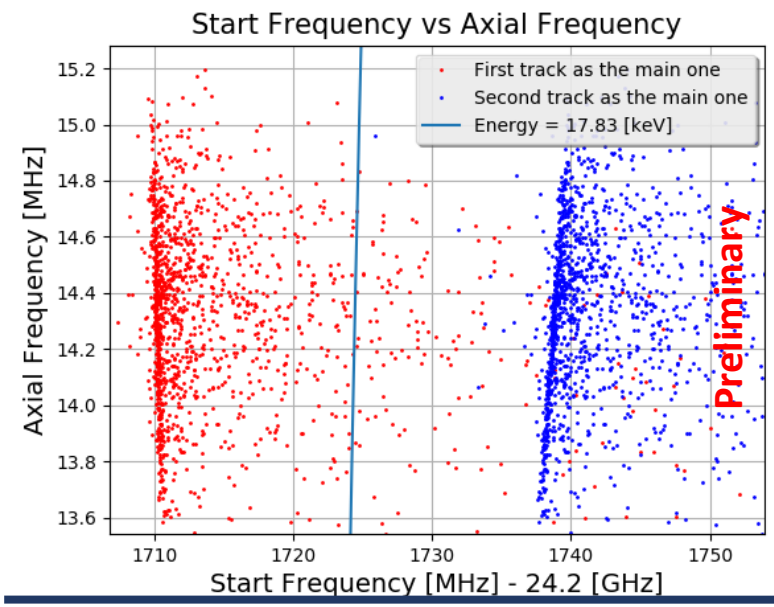


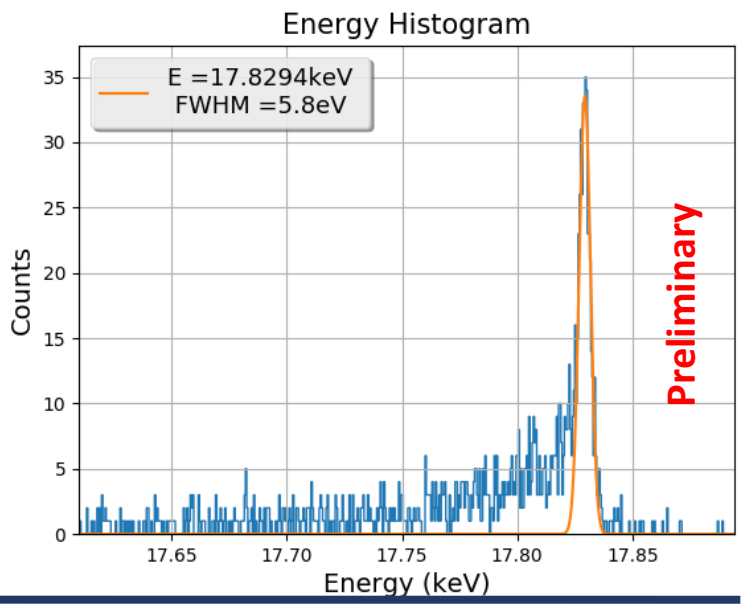


Phenomenology of Electron Kinematics in the Magnetic Trap

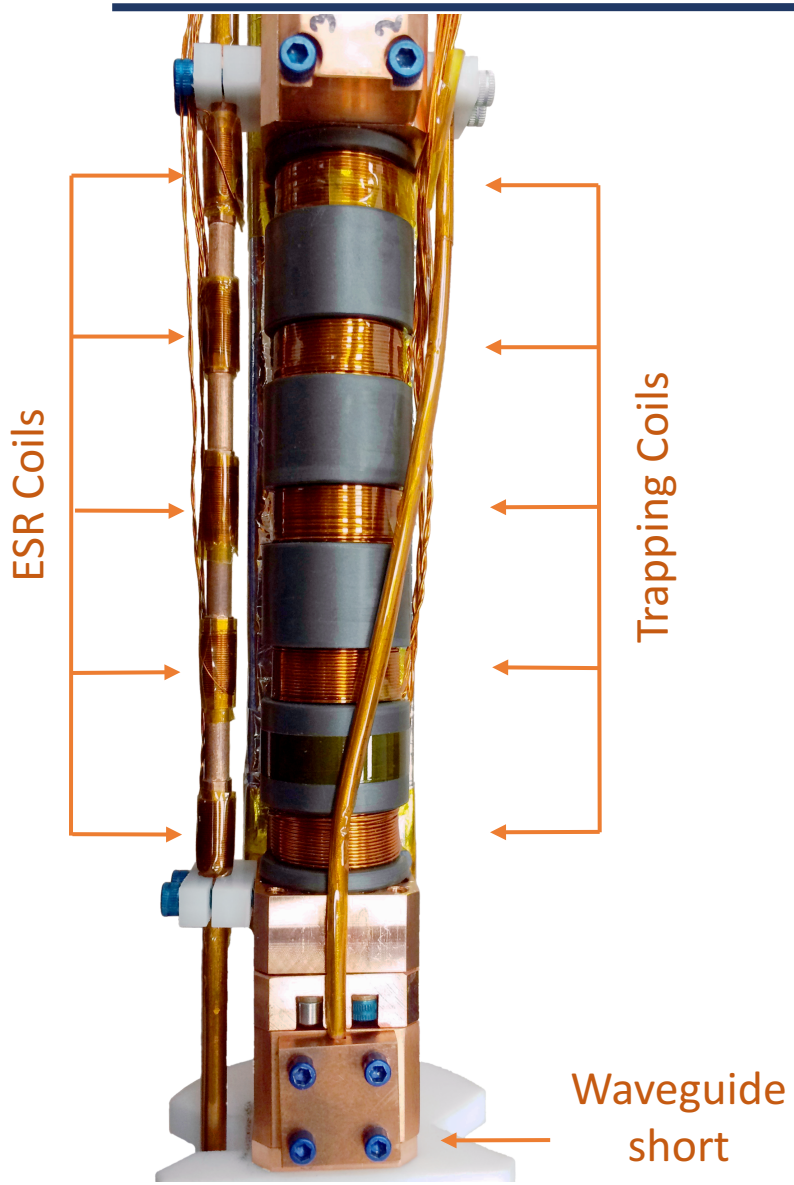
- A change of the electron's pitch angle in a scattering can result in redistribution of power
- Knowledge of power spectrum is crucial for reconstructing the 17.83keV conversion electron line of ^{83m}Kr



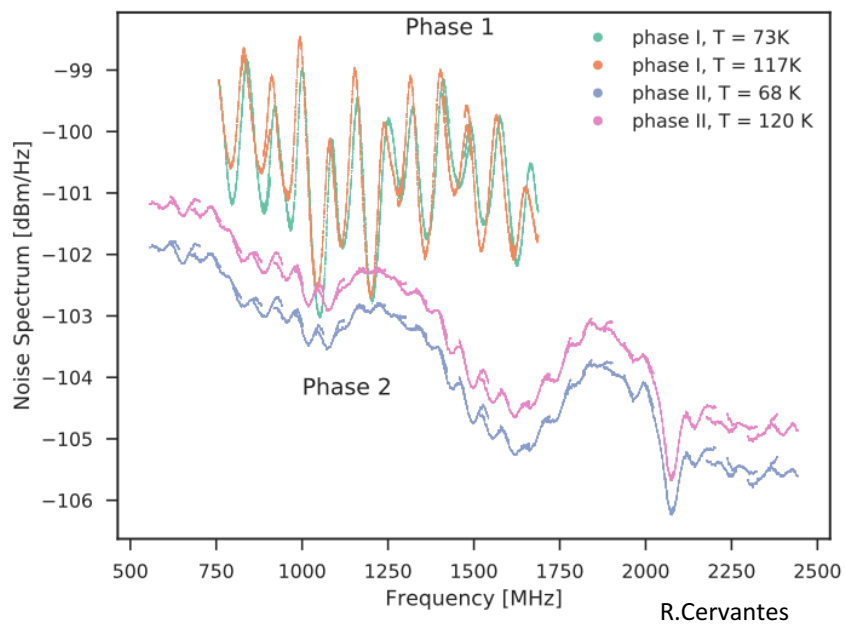




Phase II Hardware



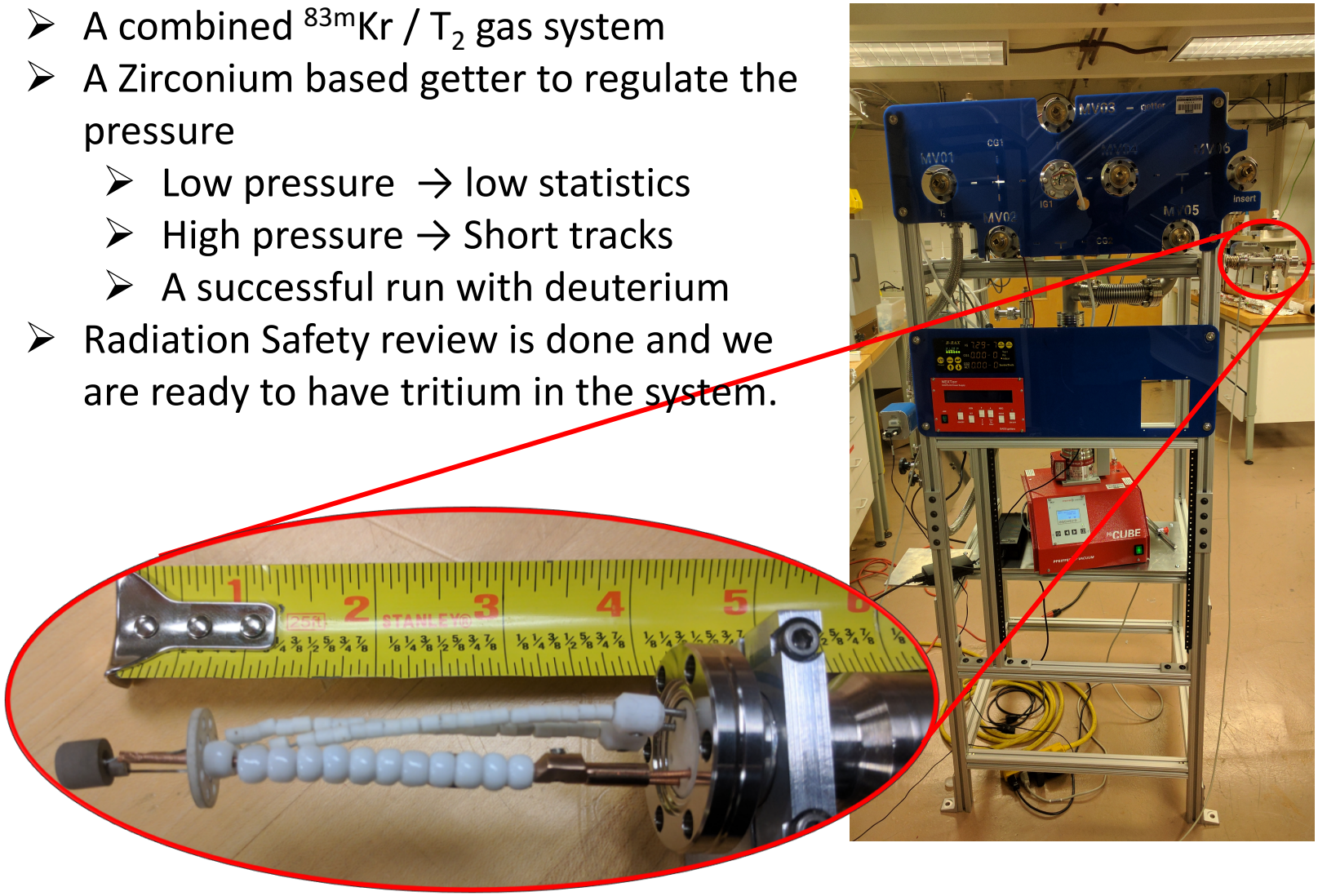
- New cell
  - Circular waveguide
  - 5 trapping coils
  - ESR magnetometer
  - Tritium compatible
- Lower noise level
- New DAQ system



R.Cervantes

Toward the First Tritium Measurement

- A combined ^{83m}Kr / T_2 gas system
- A Zirconium based getter to regulate the pressure
  - Low pressure → low statistics
  - High pressure → Short tracks
  - A successful run with deuterium
- Radiation Safety review is done and we are ready to have tritium in the system.



Conclusion

- The CRES is introduced by Project 8 as a novel technique for measuring the energy of electrons non-destructively in particle and nuclear physics.

- We have developed a detailed model of electron's rich signal structure.

- The new cell is already in the NMR magnet taking ^{83m}Kr data.

- The new gas system is almost ready for introducing tritium into the system.

Project 8 Collaboration

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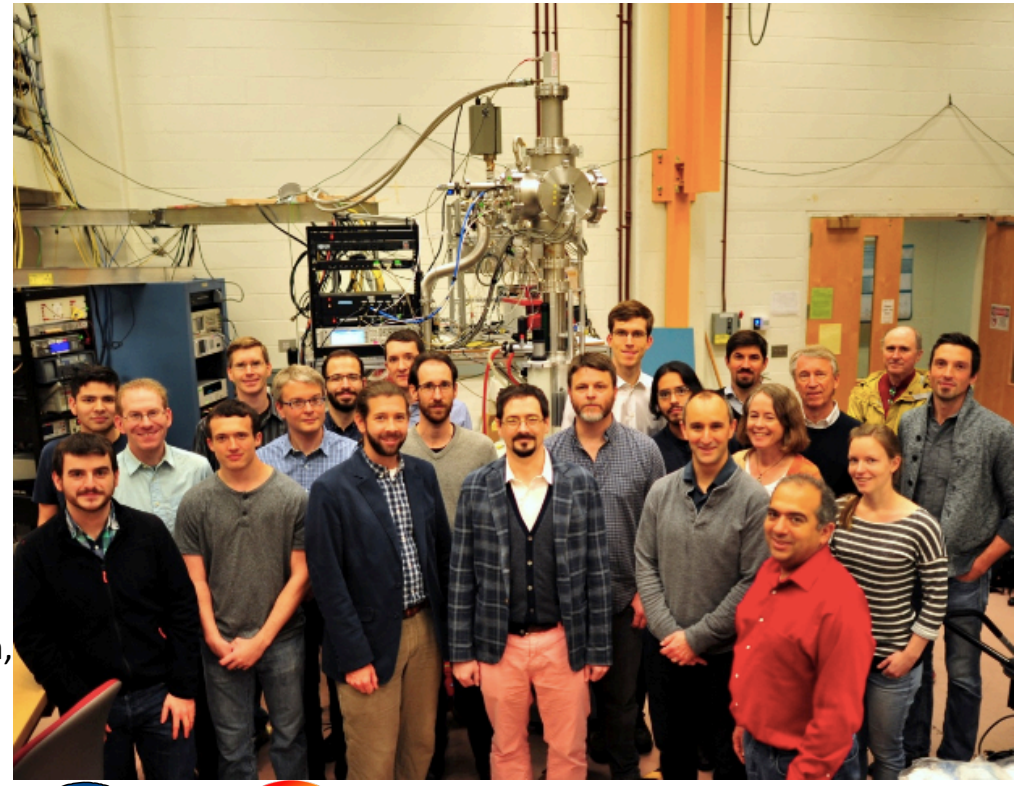
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