Pacific Northwest
NATIONAL LABORATORY
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# Status of the Project 8 Phase II

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Pacific Northwest National Laboratory – Richland, WA

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# Toward a neutrino mass measurement



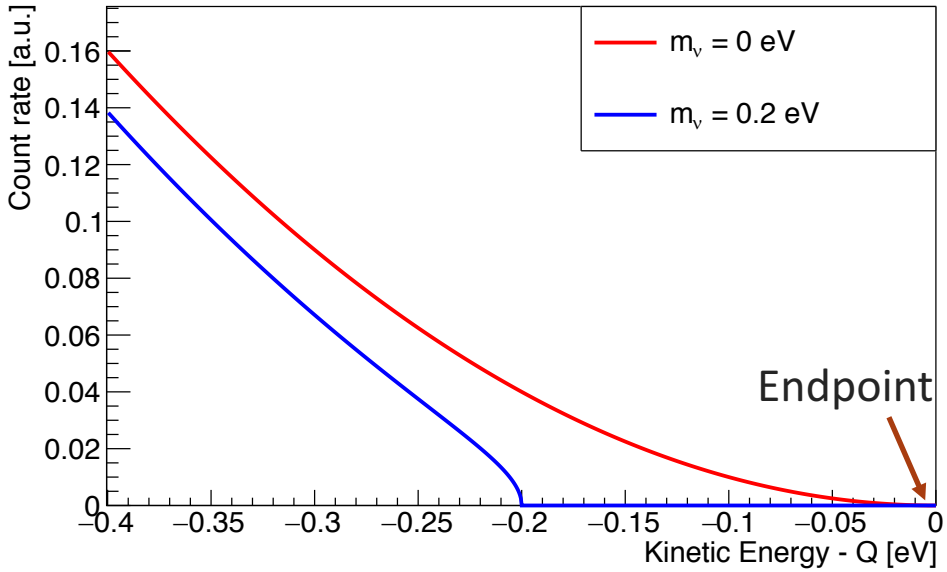
- Tritium beta spectrum ($Q \sim 18.6\ \mathrm{keV}$):

$$\frac{\mathrm{d}N}{\mathrm{d}E_{kin}} = 3rt(E_{kin} - Q)\sqrt{(E_{kin} - Q)^2 - m_\nu^2}$$

- Cyclotron frequency

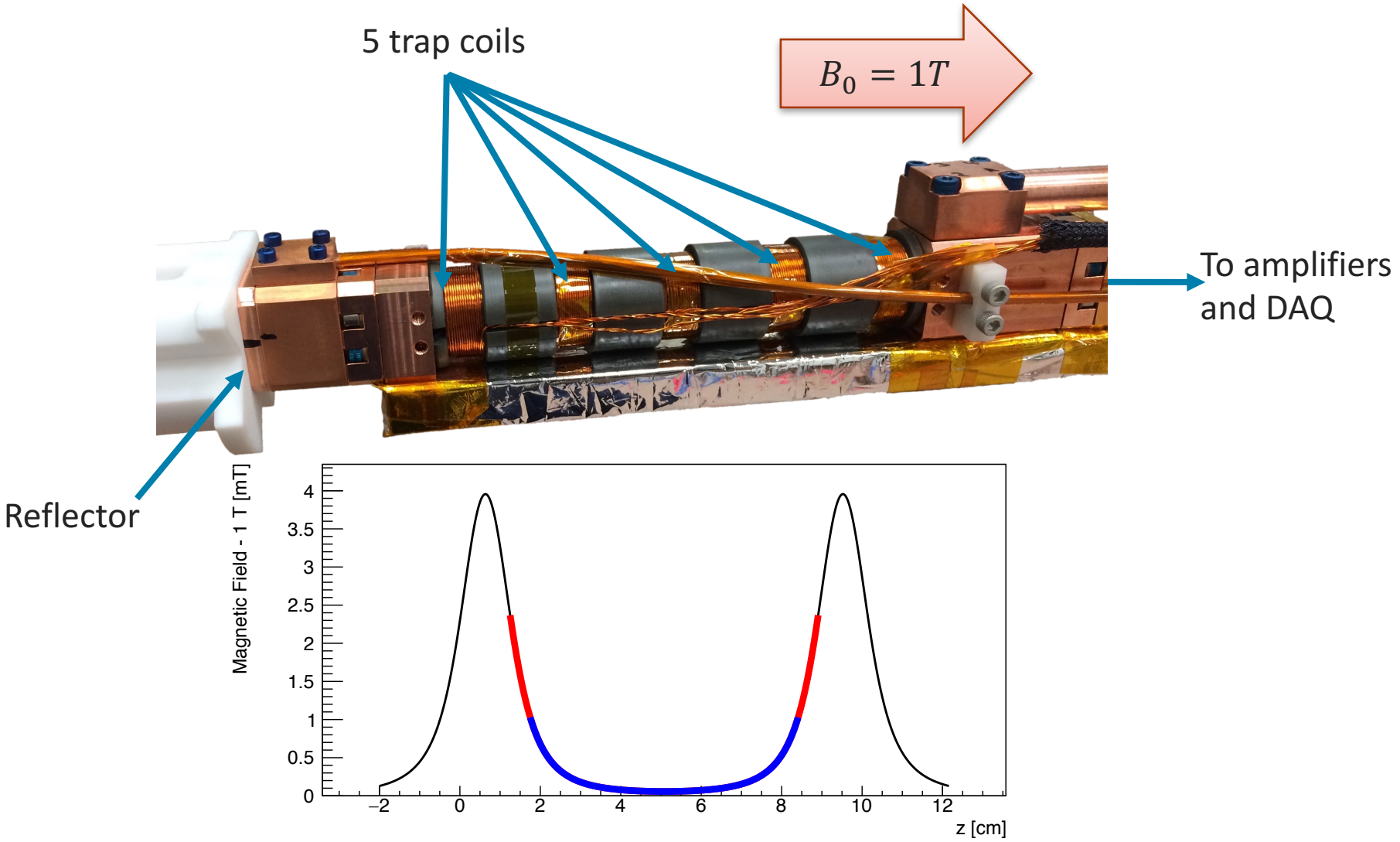
$$f_c = \frac{1}{2\pi}\frac{eB}{m_e + KE/c^2}$$

- Calibration with a source of monoenergetic electrons
  - Conversion electrons from $^{83\mathrm{m}}\mathrm{Kr}$:
    - $17.8\ \mathrm{keV},\ 30.4\ \mathrm{keV},\ 32\ \mathrm{keV}$



# Phase II waveguide

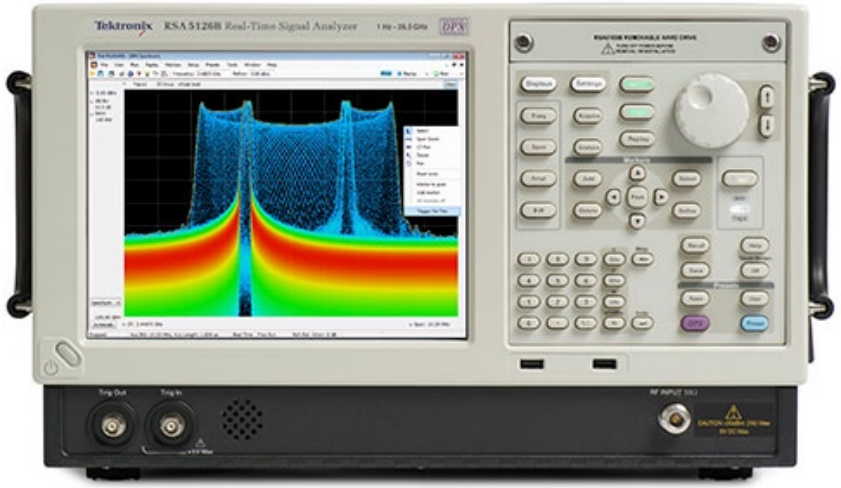


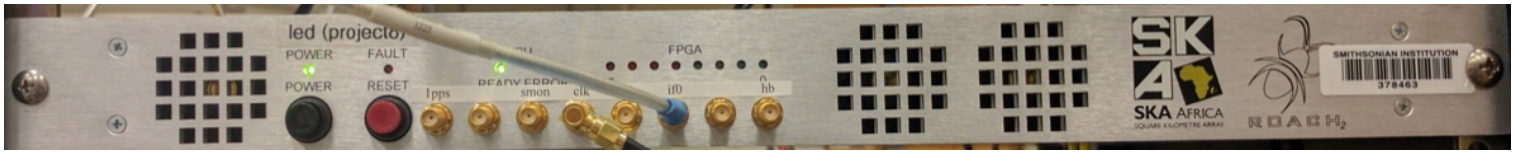


# Phase II DAQs



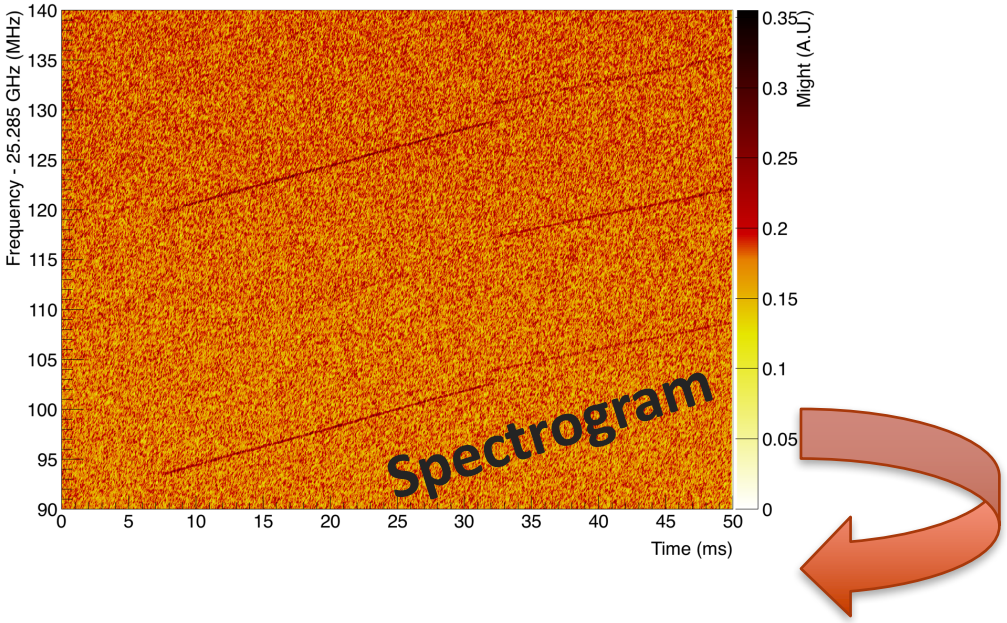
- Amplification of the RF signal
- Down-mixing (25.7 GHz → 1500 MHz)
- 2 DAQ systems
- Real-Time Signal Analyzer
  - Excellent diagnostic tool
  - Triggering digitizer
- ROACH2
  - Large bandwidth digitizer (300MHz+)
  - Currently streaming mode
  - Triggering mode in development




ROACH
Reconfigurable Open Architecture Computing Hardware

# Event reconstruction in a nutshell



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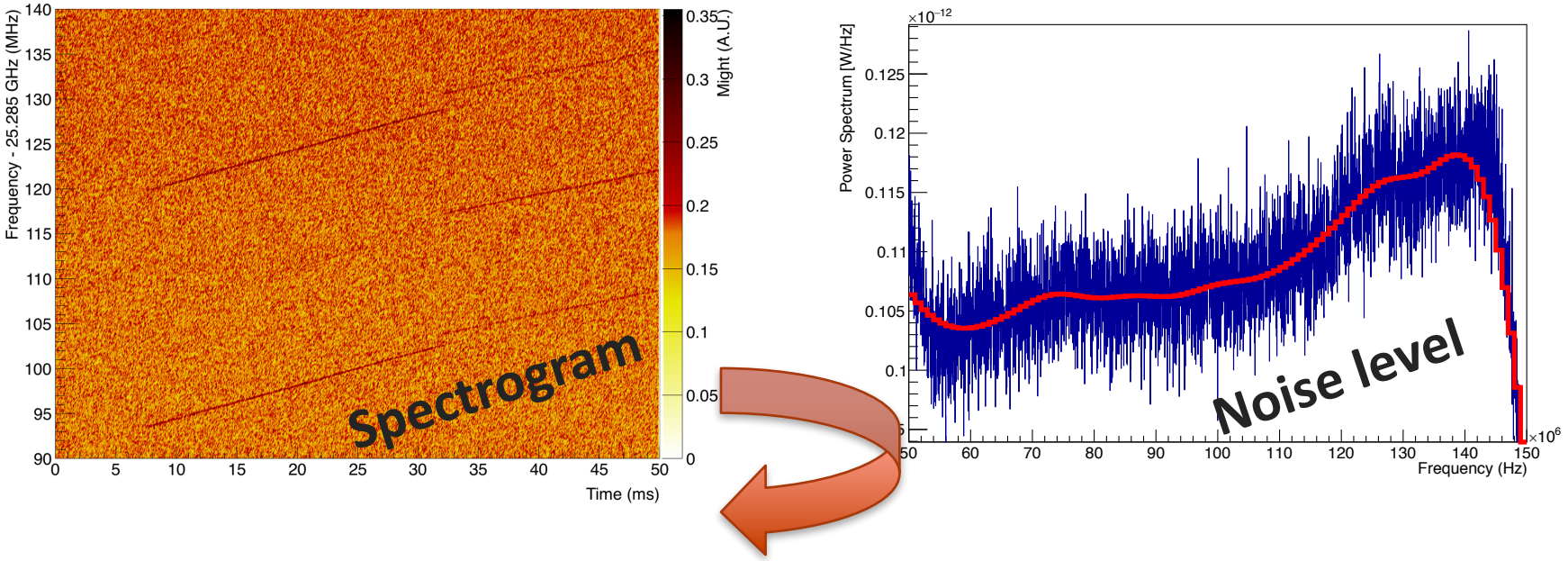

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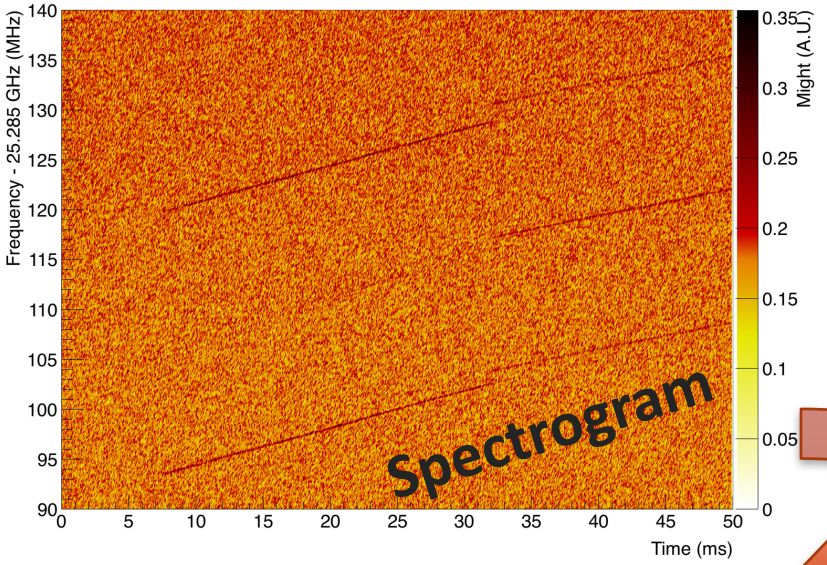


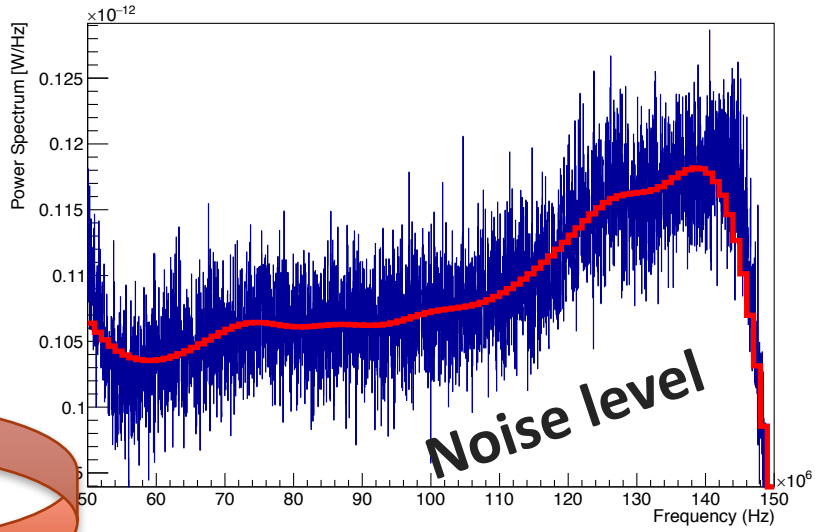


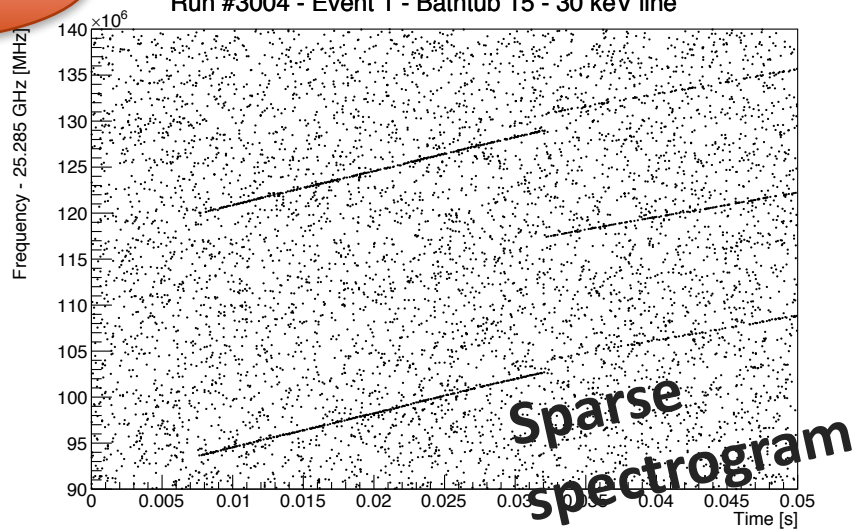

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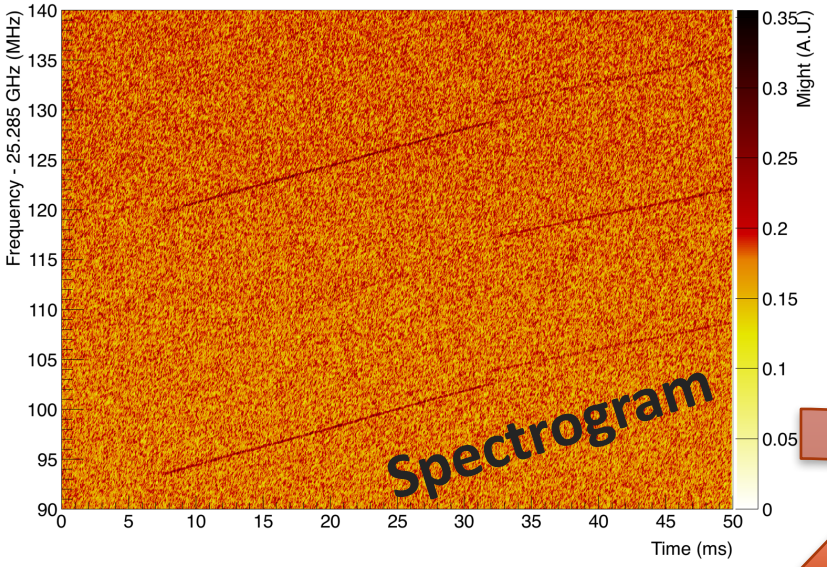
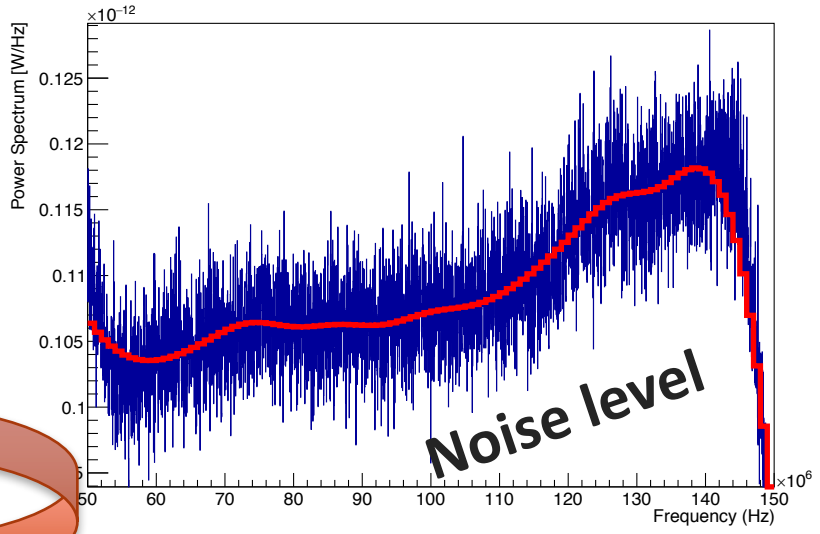
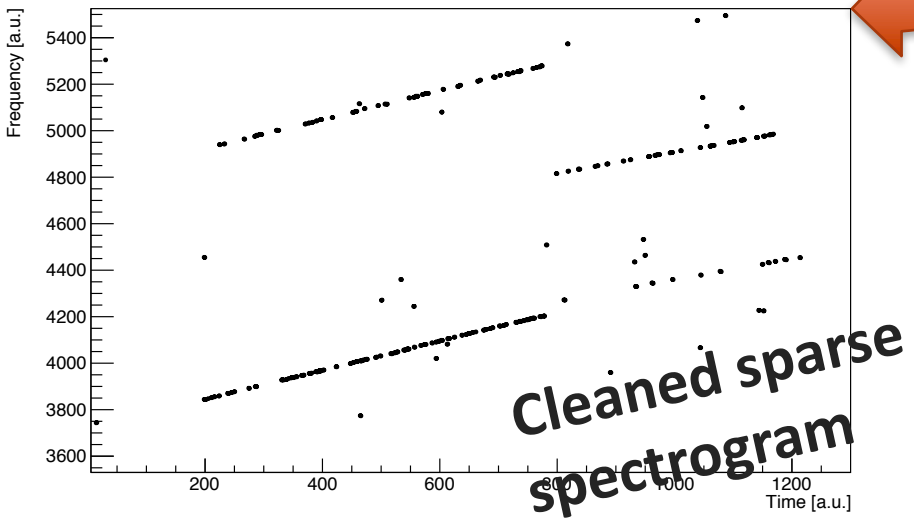
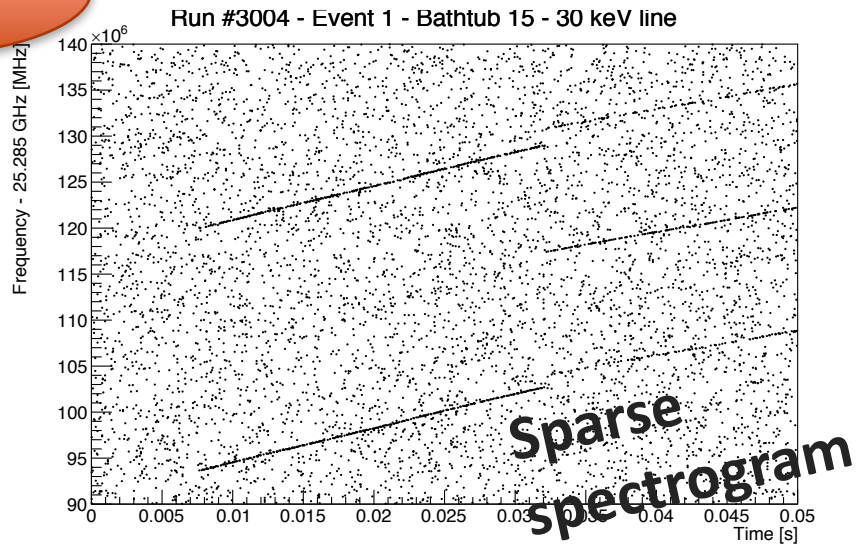


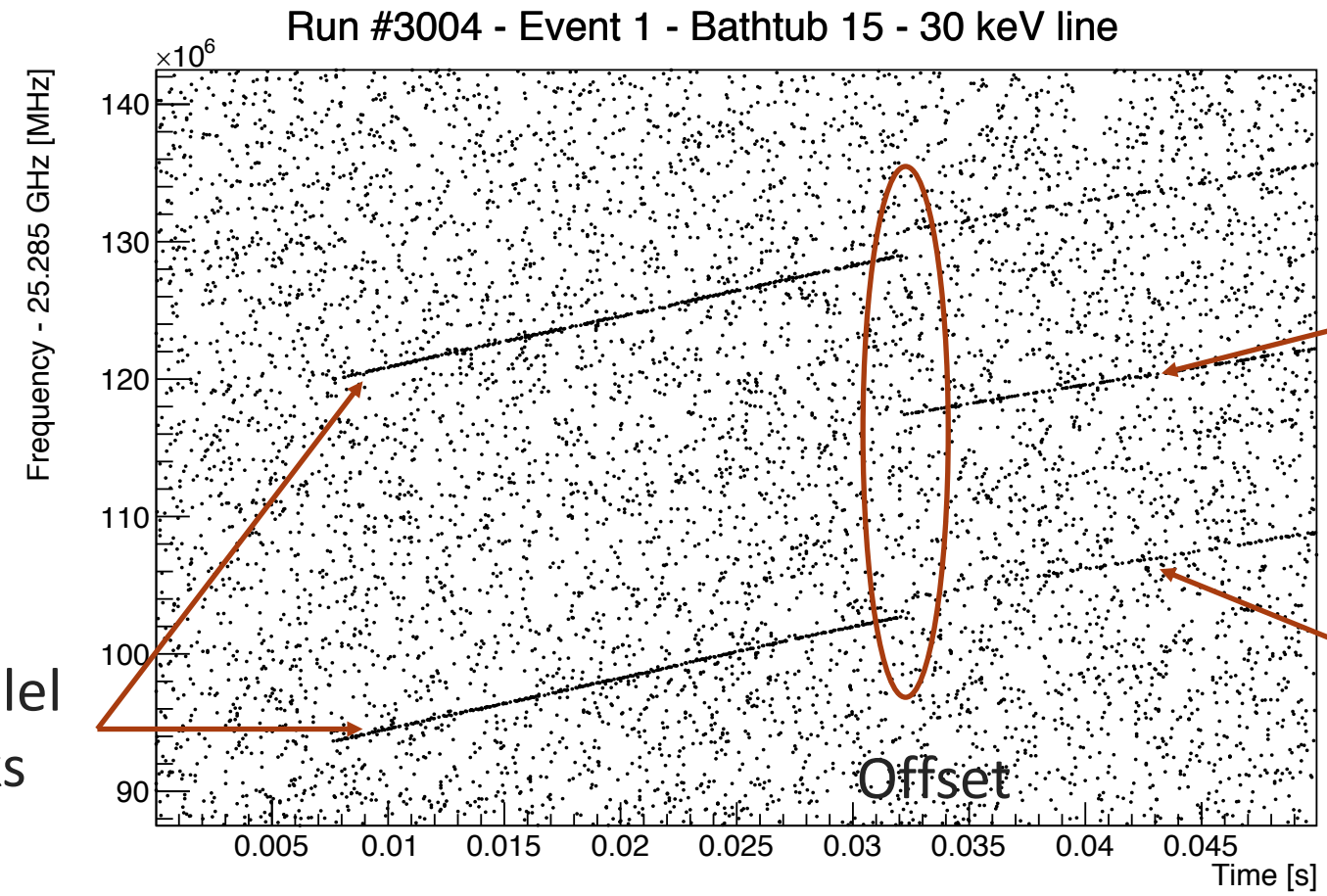



# An interesting event topology






Parallel tracks

Appearance of new track

Change of slope

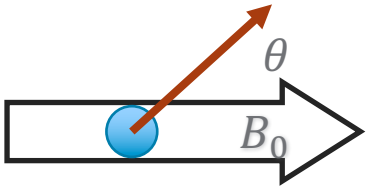
# Line shape distortion

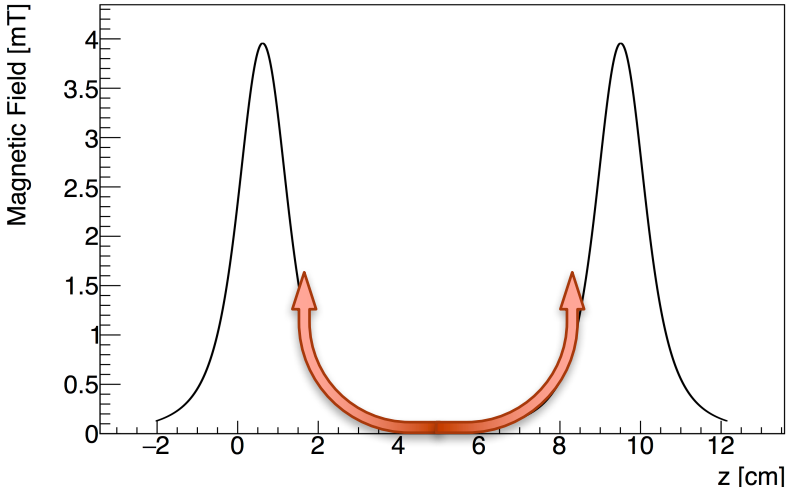


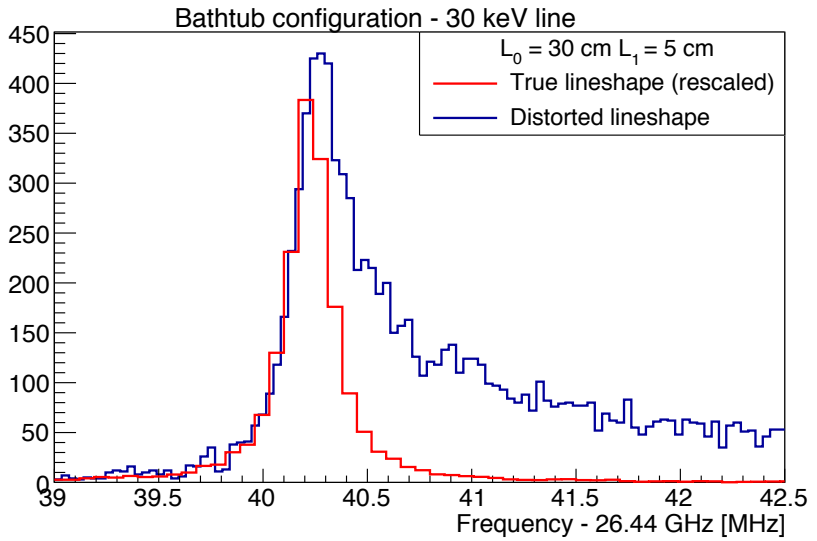
- Electrons explore the lower region of the magnetic trap
- Dependence of the measured start frequency with the pitch angle:

$$f_s = \frac{1}{2\pi}\frac{e(B_0 + b(\theta))}{m_e + KE/c^2}$$

- Line shape distortion and increased width




Pheno.: A. Esfahani

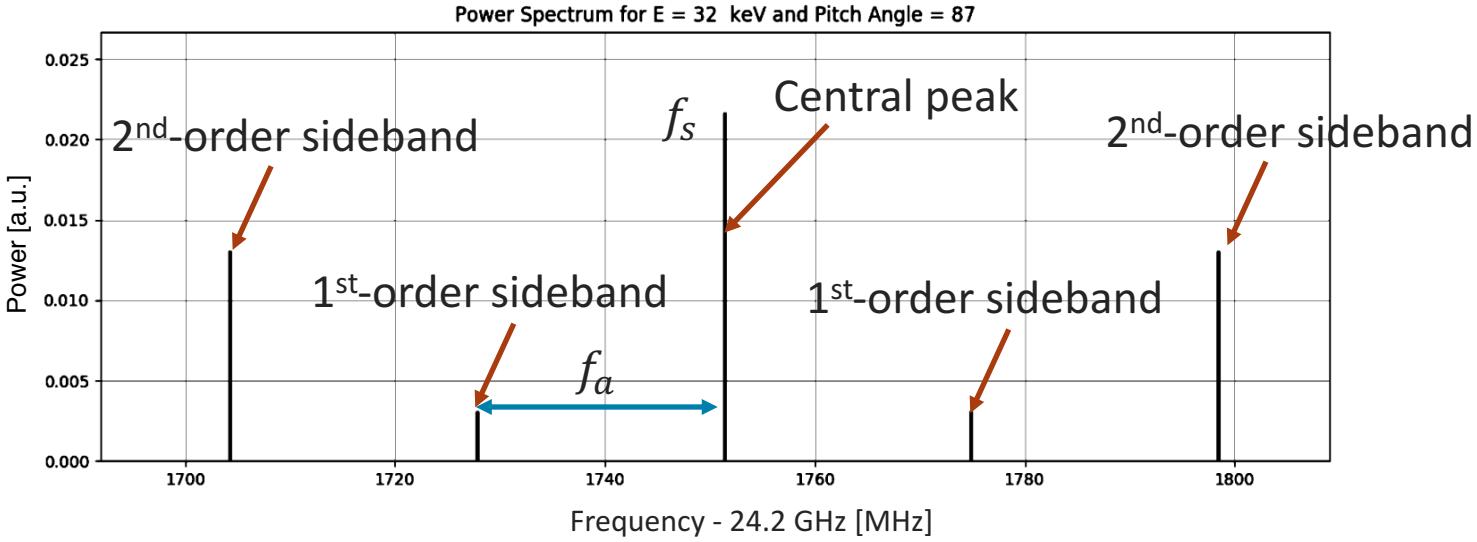
# Sidebands

- Axial frequency:

$$f_a = \frac{1}{2\pi} \frac{\sqrt{\frac{2KE}{m_e}}\, c}{\frac{2\pi L_0}{\sin\theta} + \frac{2L_1}{\cos\theta}}$$

  - $L_1$: curvature of the edges
  - $L_0$: size of the flat region

- Axial motion generates oscillations in the magnetic field seen by the electron at the axial frequency $f_a$
- Harmonics in the power spectrum
  - Comb structure

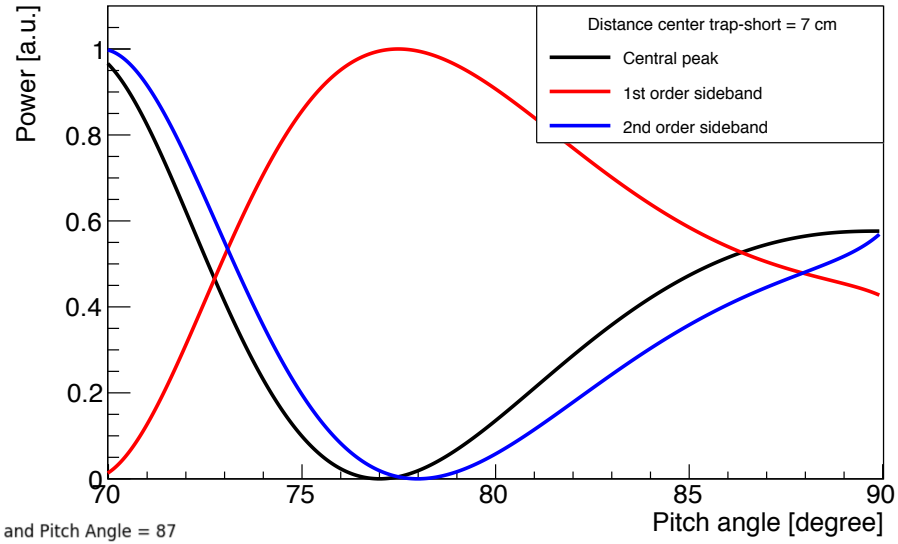


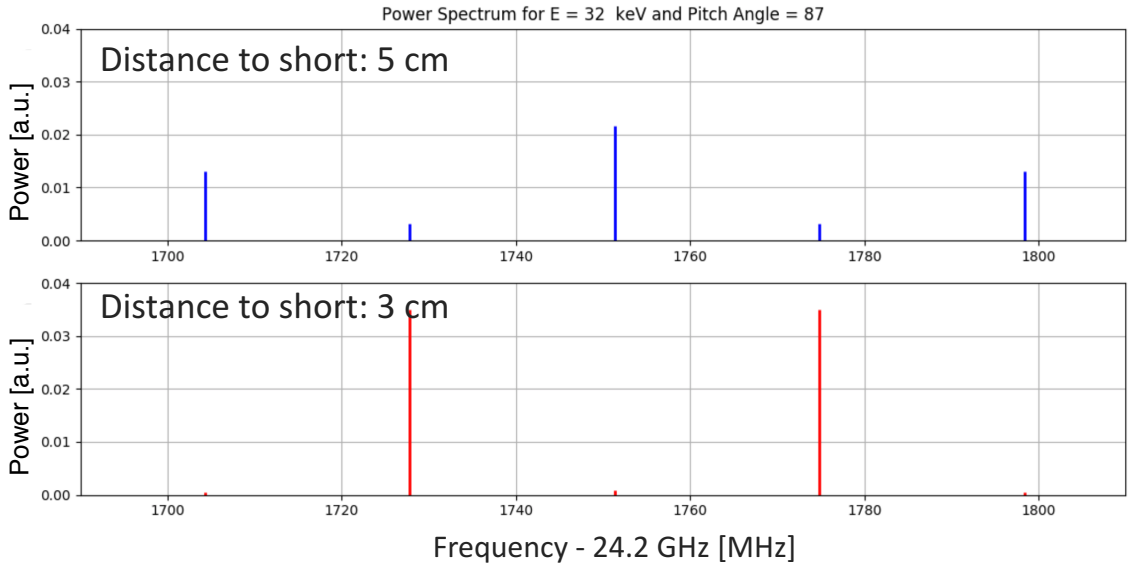

Pheno.: A. Esfahani

# Waveguide short effects



- Short reflects part of the power back to the amplifier
- Received power is superposition, constructive or destructive, of two components:
  - Dependence with the pitch angle and distance to short



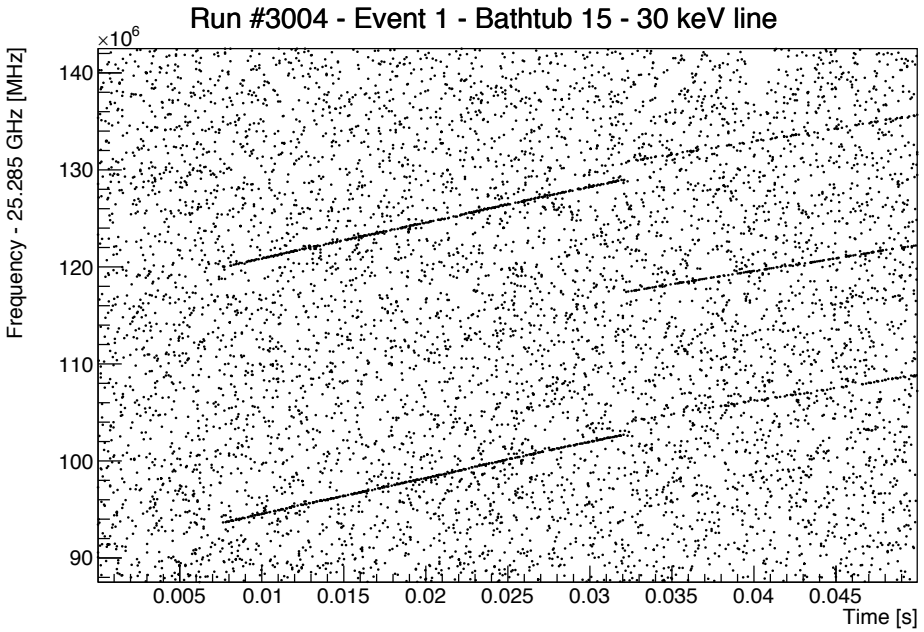




Pheno.: A. Esfahani

# Interpreting the interesting event



- One single electron
- First part: two 1st-order sidebands
- Collision with an atom
  - Change of the electron propagation direction
  - Change of the pitch angle
- Second part: main peak + two 1st-order sidebands
  - Appearance of the central peak
  - Less pronounced sidebands
  - Different total radiated power/slope



# Conclusions and perspectives

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- Project 8 Phase II data taking and analysis is in progress
- New digitizer ROACH2
- Development of a phenomenology explaining the structure of our events

- Implementation of a robust algorithm for correcting the line shape distortion using sidebands and slope and improving the energy resolution
- Finishing the instrument calibration using the Krypton source
- Getting ready for connecting the Tritium source and recording our first differential tritium spectrum

Stay tuned!

# Many thanks!

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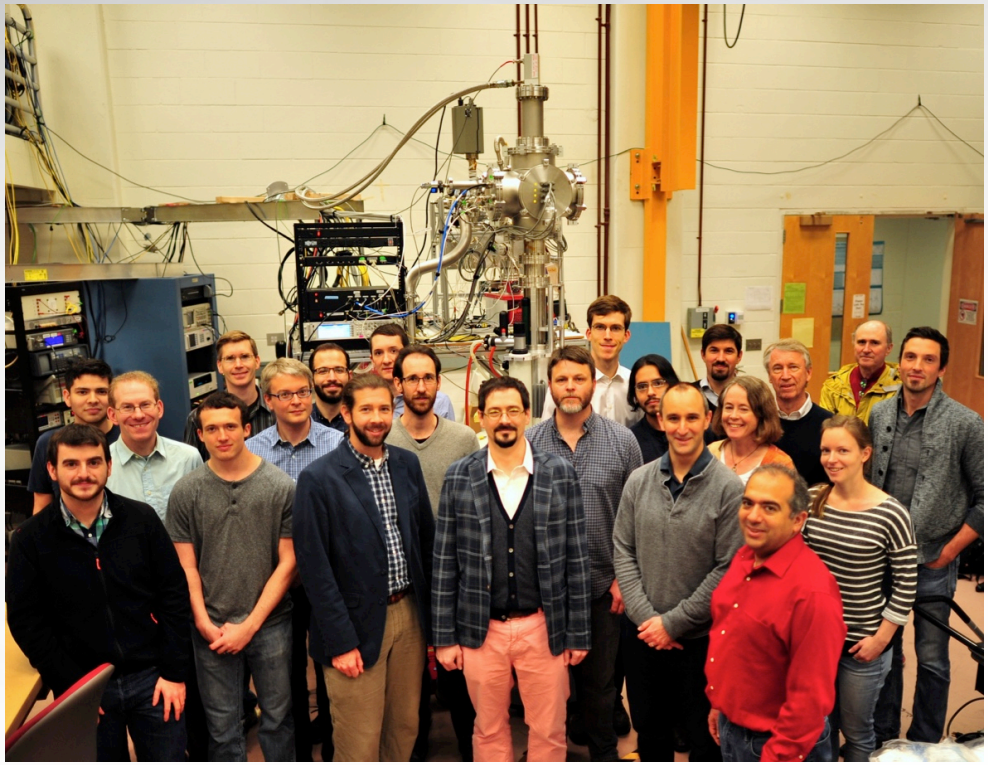

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