The Energy Resolutions of Current Neutrino Mass Measurement Experiments

Kim, Hanbeom

Introduction

- Probing Low Energy Neutrino Backgrounds with Neutrino Capture on Beta Decaying Nuclei, Cocco A, Magnano G and Messina M 2007

- High resolution of energy measurement is required for reasonable rejection of background in relic neutrino detection

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- KArlsruhe TRItium Neutrino experiment

- $^3\mathrm{H}$ β decay: $^3\mathrm{H} \rightarrow {}^3\mathrm{He}^+ + \mathrm{e}^- + \bar{\nu}$

- Expectation:
  1. Improve the upper limit of the mass down to:
     2.3 eV/c^2 (Mainz and Troitsk) → ~0.2 eV/c^2
  2. Or discover the actual mass if it is larger than 0.35 eV/c^2

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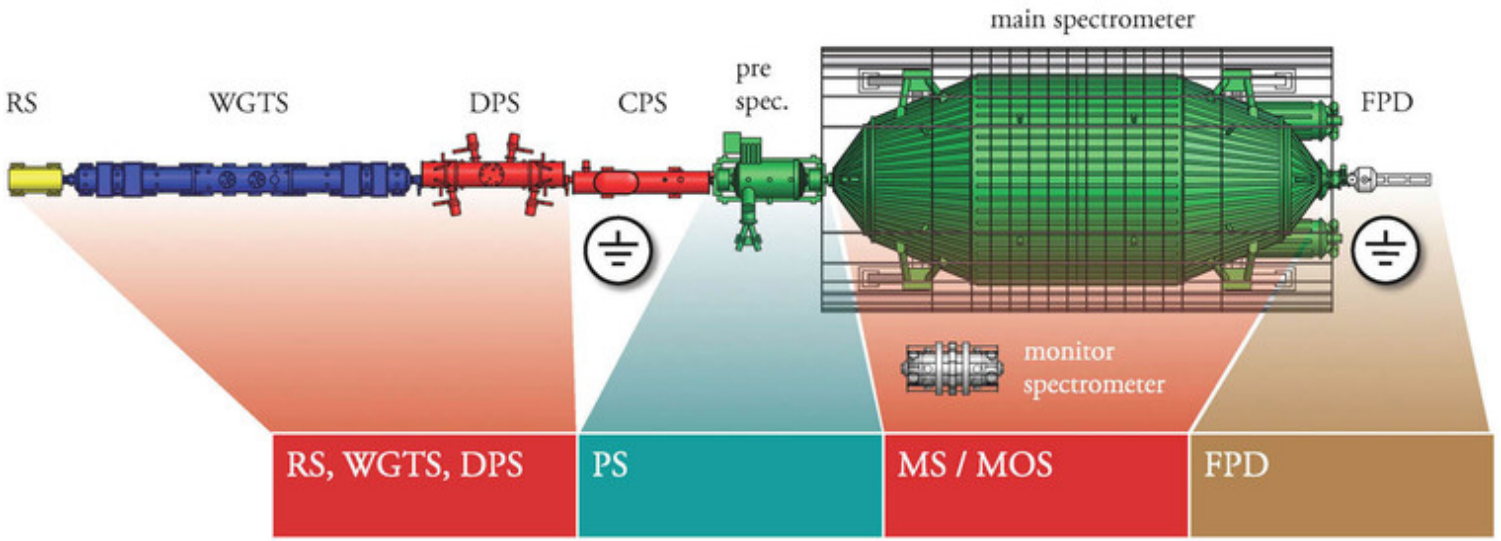
main spectrometer
RS
WGTS
DPS
CPS
pre spec.
FPD
monitor spectrometer
RS, WGTS, DPS
PS
MS / MOS
FPD

70 m

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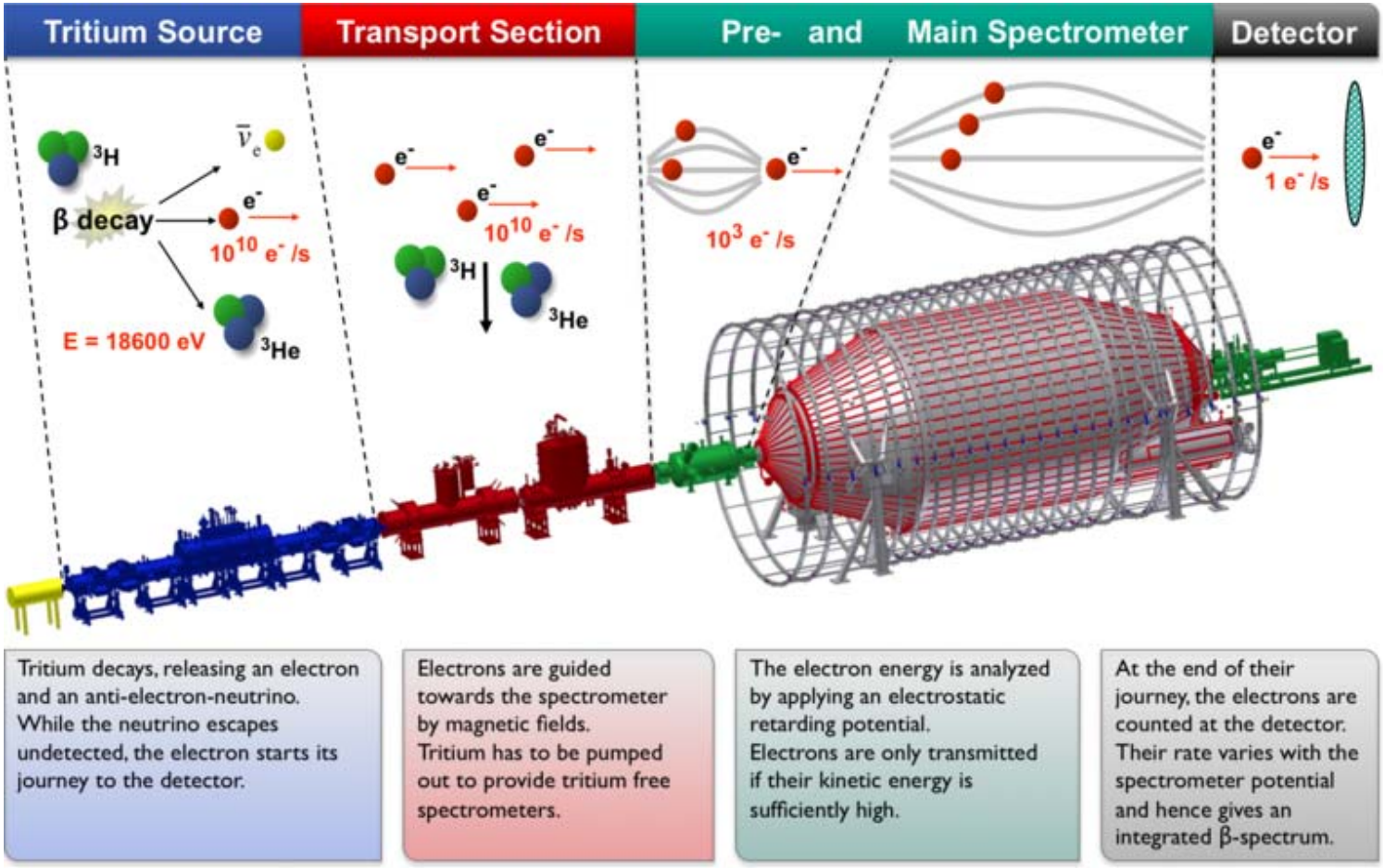
Tritium Source
Transport Section
Pre- and Main Spectrometer
Detector
^{3}H
$\bar{\nu}_e$
β decay
e$^-$
10^{10} e$^-$ /s
E = 18600 eV
^{3}He
e$^-$
10^{10} e$^-$ /s
^{3}H
^{3}He
e$^-$
10^3 e$^-$ /s
e$^-$
1 e$^-$ /s
Tritium decays, releasing an electron and an anti-electron-neutrino. While the neutrino escapes undetected, the electron starts its journey to the detector.
Electrons are guided towards the spectrometer by magnetic fields. Tritium has to be pumped out to provide tritium free spectrometers.
The electron energy is analyzed by applying an electrostatic retarding potential. Electrons are only transmitted if their kinetic energy is sufficiently high.
At the end of their journey, the electrons are counted at the detector. Their rate varies with the spectrometer potential and hence gives an integrated β-spectrum.

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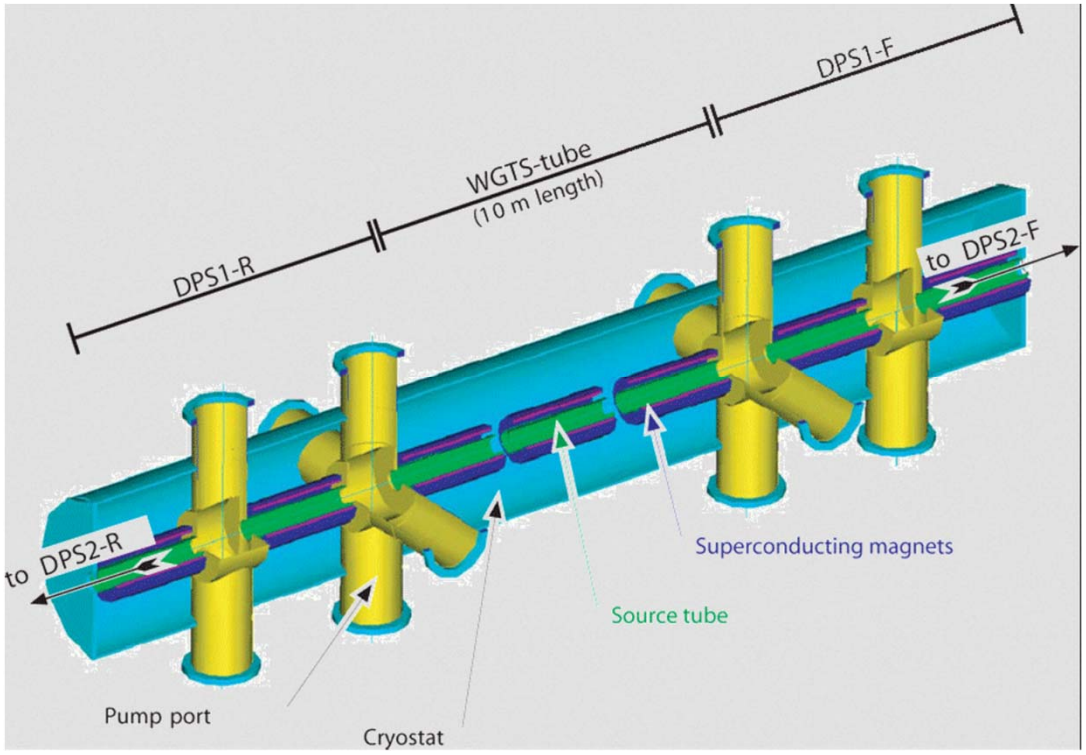
- Windowless Gaseous Tritium Source (WGTS)



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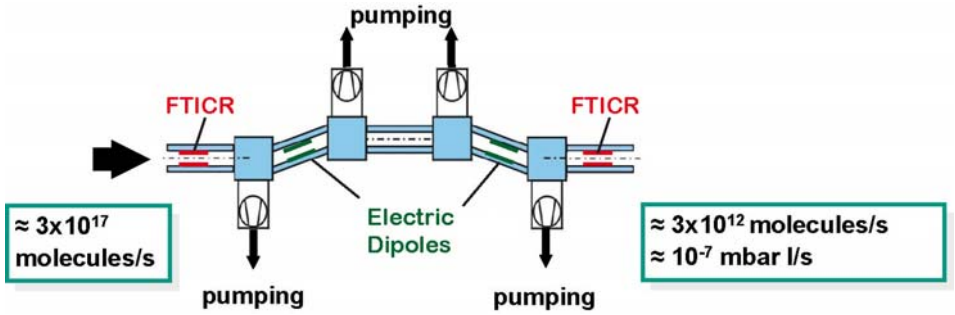
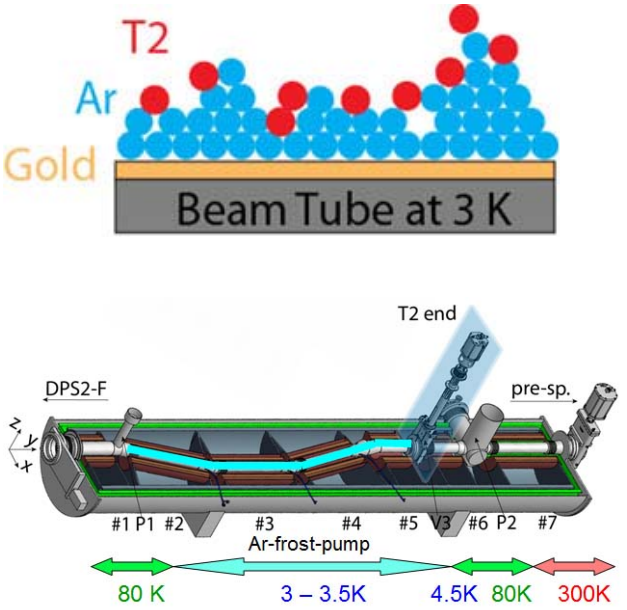
- Transport section



The Differential Pumping Section



The Cryogenic Pumping Section

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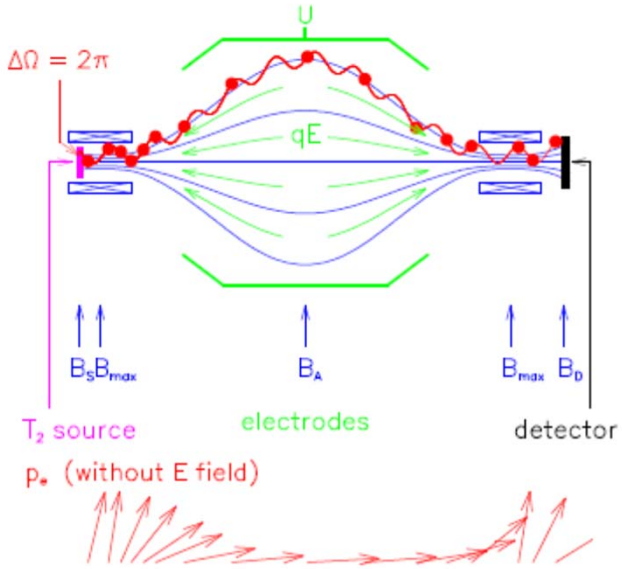
- Spectrometers
- MAC-E filter (Magnetic Adiabatic Collimation combined with an Electrostatic Filter)
- a special type of spectrometers that guarantee high spectroscopy



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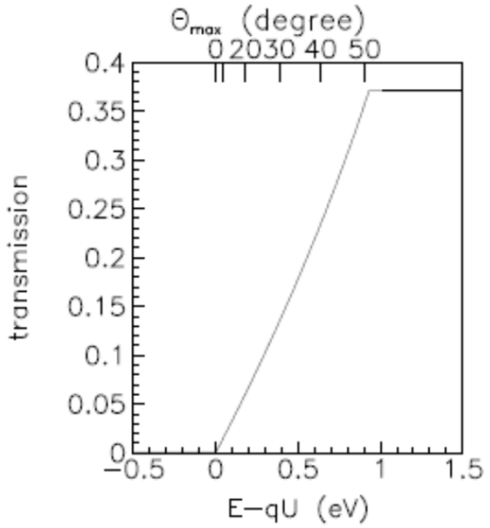
- Spectrometers
- MAC-E filter (Magnetic Adiabatic Collimation combined with an Electrostatic Filter)
- Relative sharpness: $\frac{\Delta E}{E} = \frac{B_{\min}}{B_{\max}}$

$$T(E,U) = \begin{cases} 0 & \text{for } E \le qU \\ 1 - \sqrt{1 - \frac{E-qU}{E} \cdot \frac{B_S}{B_{\min}}} & \text{for } qU < E < qU + \Delta E \\ 1 - \sqrt{1 - \frac{B_S}{B_{\max}}} & \text{for } E \ge qU + \Delta E \end{cases}$$



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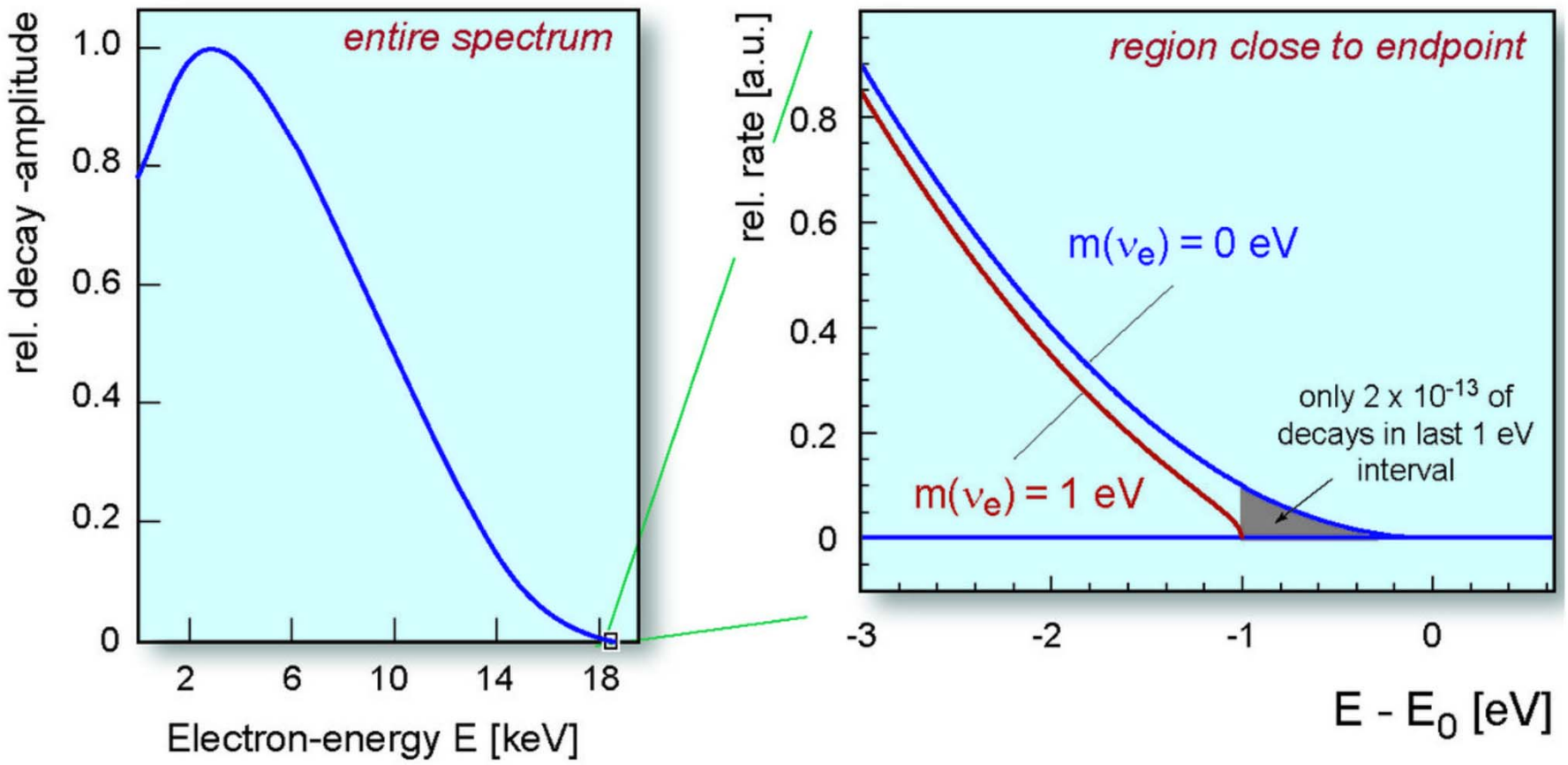
entire spectrum
rel. decay -amplitude
1.0
0.8
0.6
0.4
0.2
0
2
6
10
14
18
Electron-energy E [keV]
region close to endpoint
rel. rate [a.u.]
0.8
0.6
0.4
0.2
0
m(νe) = 0 eV
m(νe) = 1 eV
only 2 x 10-13 of
decays in last 1 eV
interval
-3
-2
-1
0
E - E0 [eV]

Reference

- Current Direct Neutrino Mass Experiments, G. Drexlina, V. Hannenb, S. Mertensa and C. Weinheimerb, 2013
- Direct neutrino mass measurements after PLANCK, J.A. Formaggio, 2014
- Direct Determination of Neutrino Mass, R.G. Hamish Robertson, 2008
- https://www.katrin.kit.edu/