



# Magnetic electron spectrometer for characterising anti-neutrino anomaly

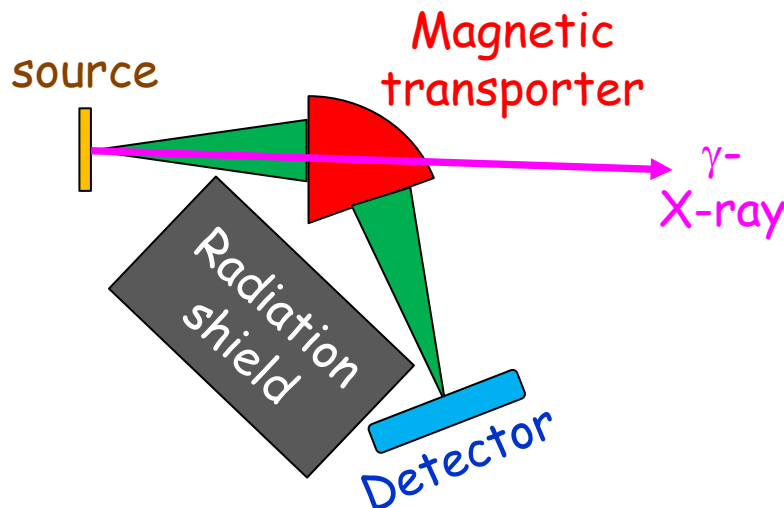
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- ❑ Measure continuous  $\beta$ -spectra up to 10 MeV
- ❑ **Supress**  $\gamma$ - and X-rays, room and neutron beam **backgrounds**
- ❑ Better than **25 keV** (0.025 MeV) **energy resolution**; resolve discrete energy conversion electrons and  $\beta$ -rays
- ❑ **High efficiency** to determine  $\beta$ -spectrum with better than **1% accuracy** up to 8 MeV - critical to observe and characterise oscillations

## Ideal tool:

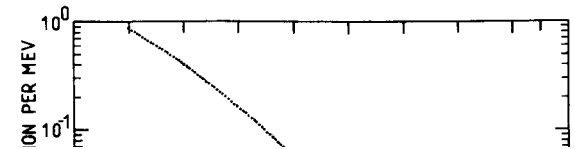


## $\beta$ -spectrum of $^{235}\text{U}$ fission products

Volume 160B, number 4,5

PHYSIC

respect to the well-known intensities of  $^{14}\text{N}(n, \gamma)^{15}\text{N}$  [11] and  $^{12}\text{C}(n, \gamma)^{13}\text{C}$  [12]. Essentially this calibration resulted in a value of 1.074(49) for the ratio of the BILL spectrometer efficiency in the range 5.5 to 9 MeV relative to that in the range 1.2 to 2.5 MeV. This value is consistent with the ratio of 1.093(48) from the In-Pb calibration. Assuming a monotonically increasing efficiency of the spectrometer with energy the final errors were evaluated from the independent In, Pb and Cd measurements, resulting in total uncertainties of 2.8% and 3.1% for the absolute rates at 1.3 and 7.4 MeV, respectively.

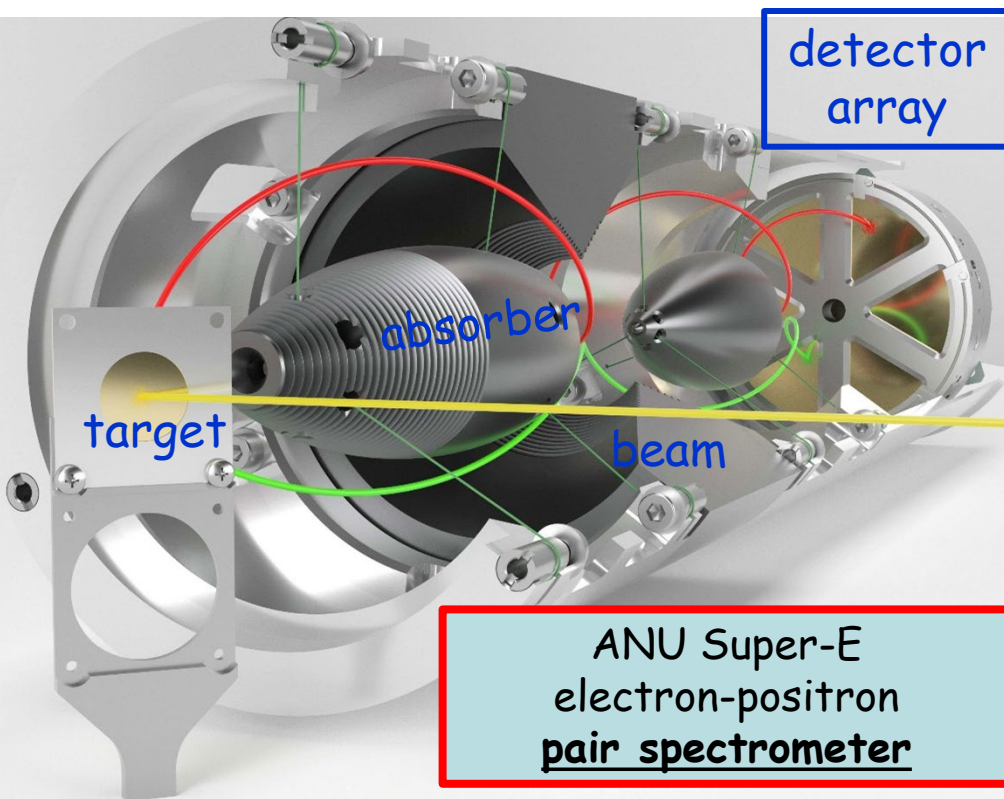


K. Schreckenbach et al.,  
Phys. Lett. B 160 (1985) 325



# Super-E

- ❑ Super-E: 2.1 tesla solenoid to transport up to 15 MeV  $\beta$ -rays
- ❑ Operational since 1991
- ❑ 2 loops absorber system: complete suppression of  $\gamma$ - and X-rays
- ❑ Si(Li) array in sum-coincidences: FWHM < 10 keV energy resolution at 7.65 MeV
- ❑ Well defined electron transport: high accuracy in intensity measurements



## Recent highlights

- ❑ **Carbon production in the universe**  
PRL 125 (2020) 182701  
PRC 102 (2020) 024320
- ❑ **Searching for EO in  $^{24}\text{Mg}$ ,  $^{40}\text{Ca}$ ,  $^{50,52}\text{Cr}$ ,  $^{54,56}\text{Fe}$ ,  $^{58,60,62}\text{Ni}$**   
PLB 779 (2018) 396  
PRC 99 (2019) 024306  
EPJ Web of Conf. 232 (2020) 04004



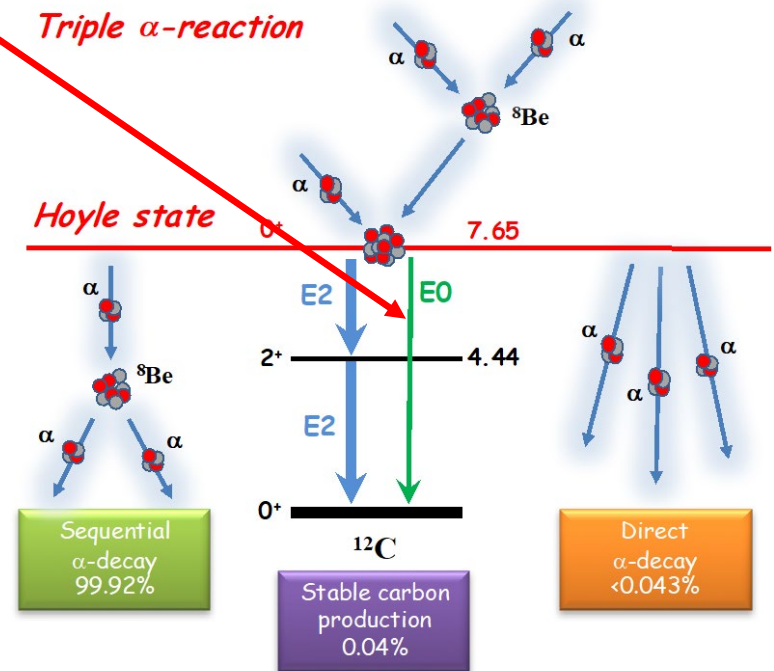
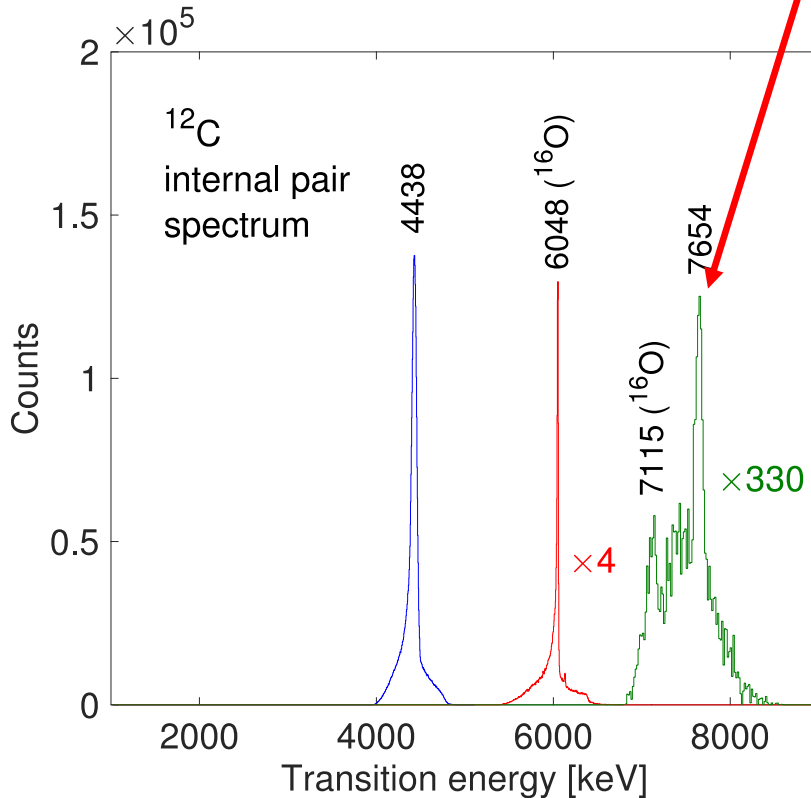
# Super-E - searching for weak decays

**Carbon production in the universe:**  
34% increase in  $3\alpha$  reaction rate

PRL 125 (2020) 182701

PRC 102 (2020) 024320

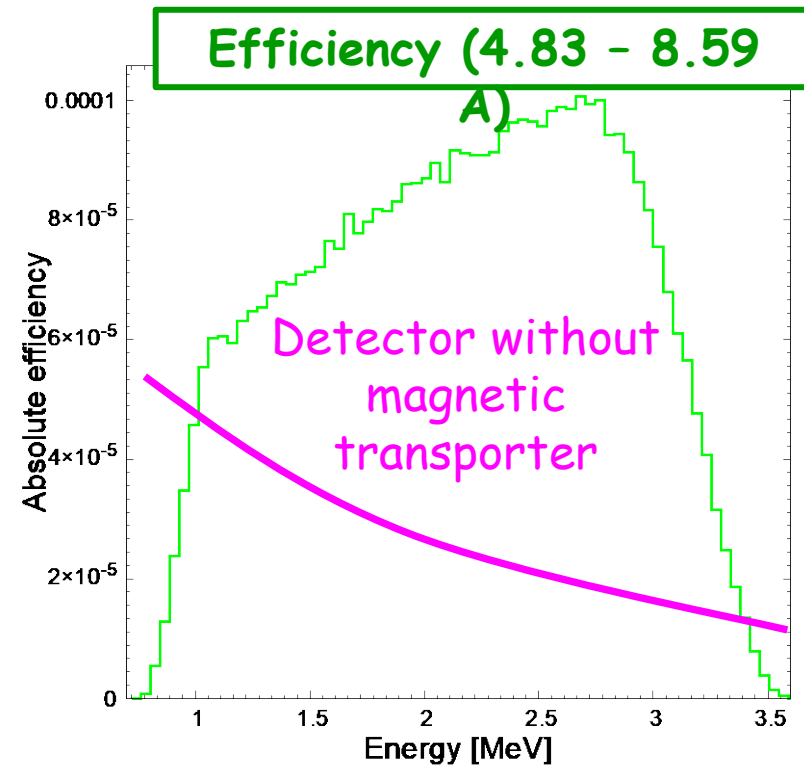
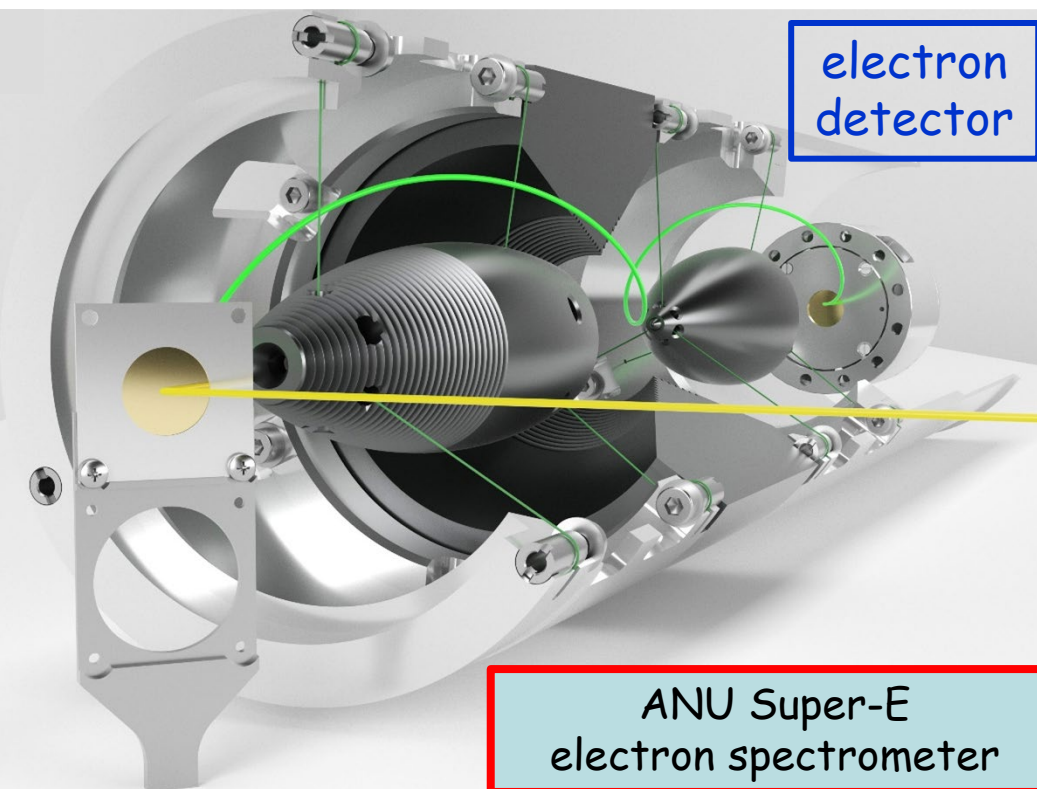
$$7654 \text{ E0: } \Gamma_{\pi}(E0)/\Gamma = 8.2(5) \cdot 10^{-6}$$





# From Super-E to Super-E2

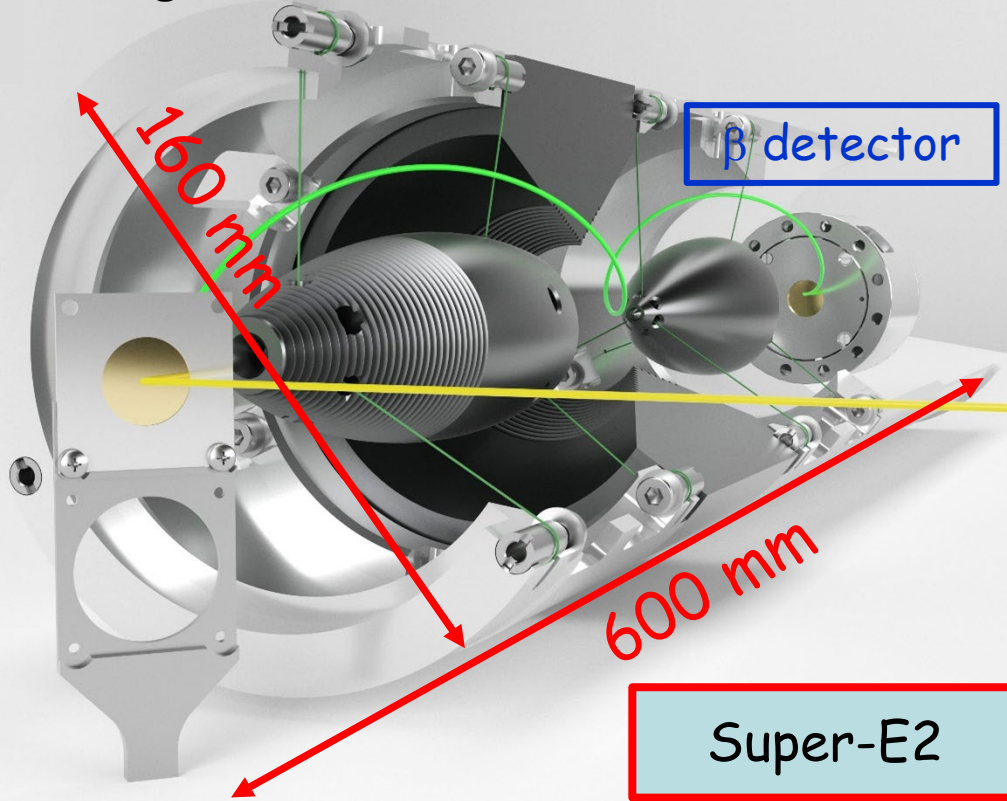
- ❑ Singles electron measurements: Si(Li) detector, FWHM= 2.5 keV at 1.6 MeV
- ❑ Well defined electron transport: high accuracy in intensity measurements





# Super-E2 for integral electron measurements

- ❑ **1 tesla solenoid**; ~160 mm bore; ~600 mm length
- ❑ **2 loops lens**; **32 cm of HeavyMet shield**; **3% solid angle**; ILL Grenoble:  $3 \times 10^{-4}\%$
- ❑ **Compatible with 39 mm diameter neutron beam from HFIR**
- ❑ **hpGe detector**: FWHM < 15 keV; DE-E hpGe telescope
- ❑ **Target, solenoid bore and detector in high vacuum**

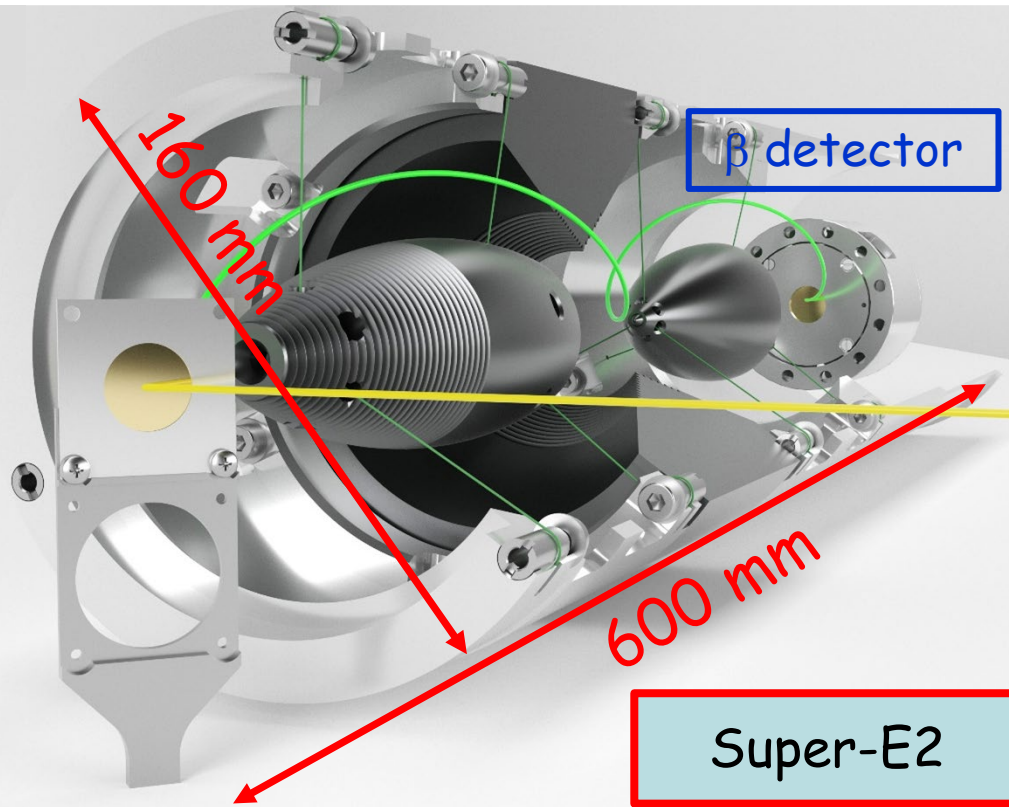


Neutron beam  
Not affected by  
magnetic field

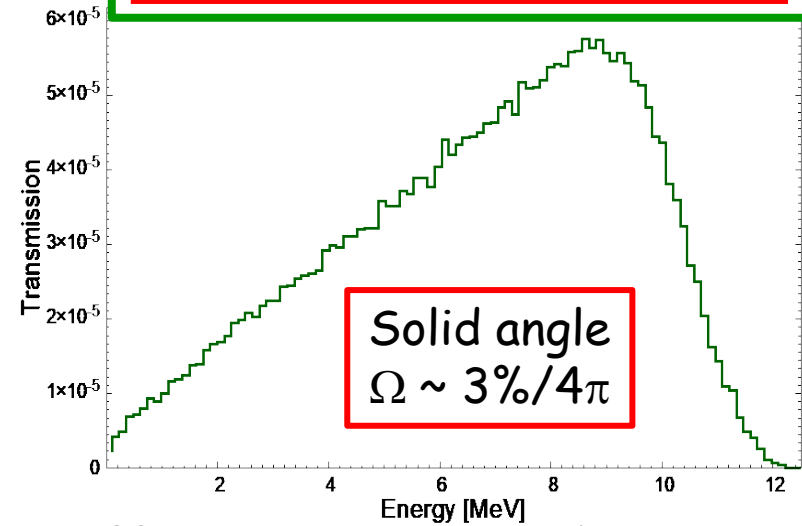


# Super-E2 for integral electron measurements

- Efficiency: **smooth function** of  $\beta$ -energy
- **Swept magnetic field** to cover broader energy range
- Compact, easy to operate, versatile instrument



0 - 10 MeV  
0 - 0.7 tesla  
Ramp up /down  $\sim 30$  m  
2<sup>nd</sup> solenoid for normalisation



Efficiency & energy calibration:

$^{207}\text{Bi}$  EC (up to 1.7 MeV)

$^{170}\text{Lu}$  EC (up to 3.3 MeV)

$^{197}\text{Au}(n,e)$  E1 lines up to 6.5 MeV

$^{115}\text{In}(n,g)$ ,  $Q_{\beta}=3.3$  MeV

$^{11}\text{B}+n$   $^{12}\text{B}$   $Q_{\beta}=13.3$  MeV

Capital cost: USD 1 M



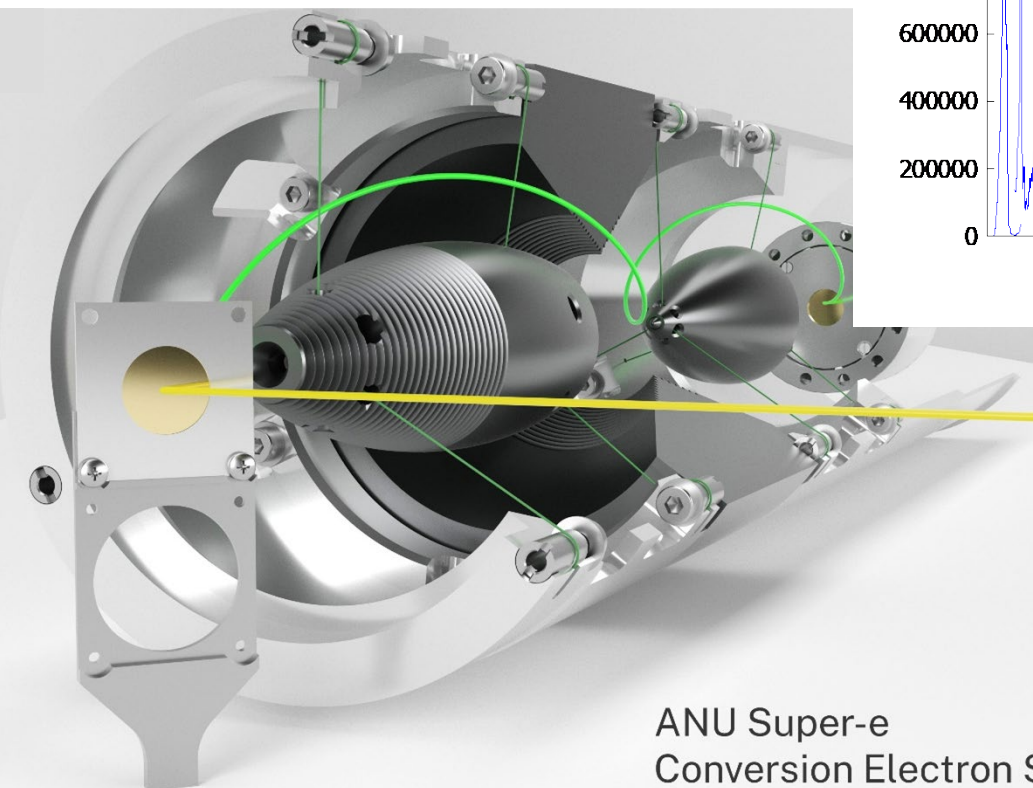
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Thanks

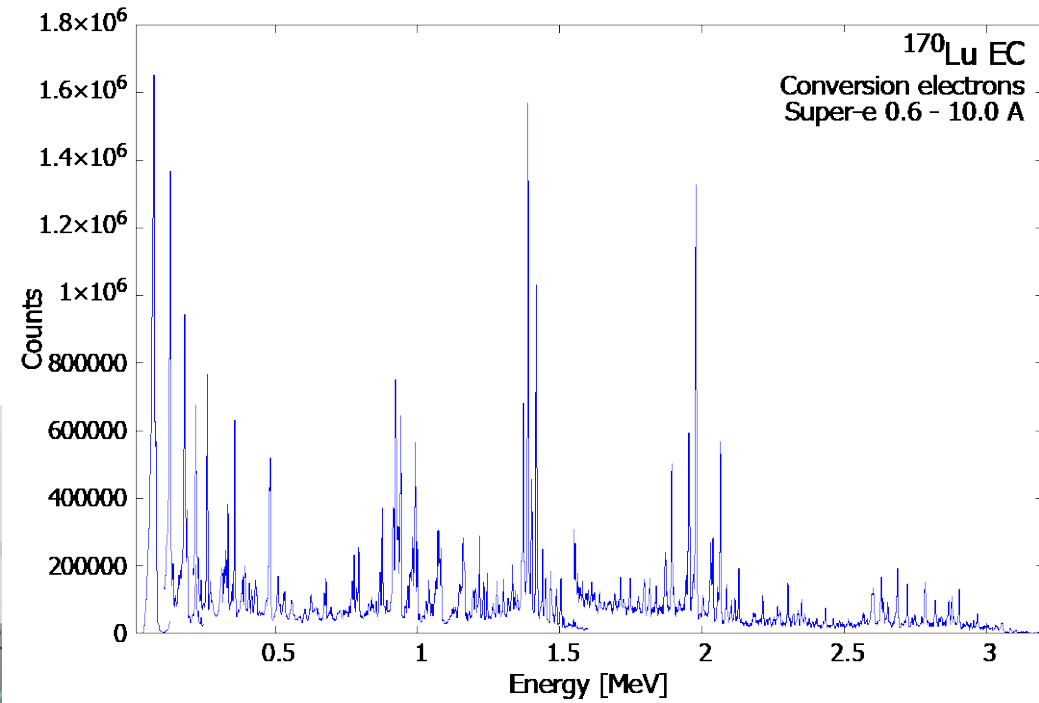




## ANU Super-e



ANU Super-e  
Conversion Electron S



$^{170}\text{Lu}$  EC  
Over 200 CE lines  
FWHM=2.5 - 3.6 keV  
0.6-10.0 A