An Introduction to Total Absorption Spectroscopy

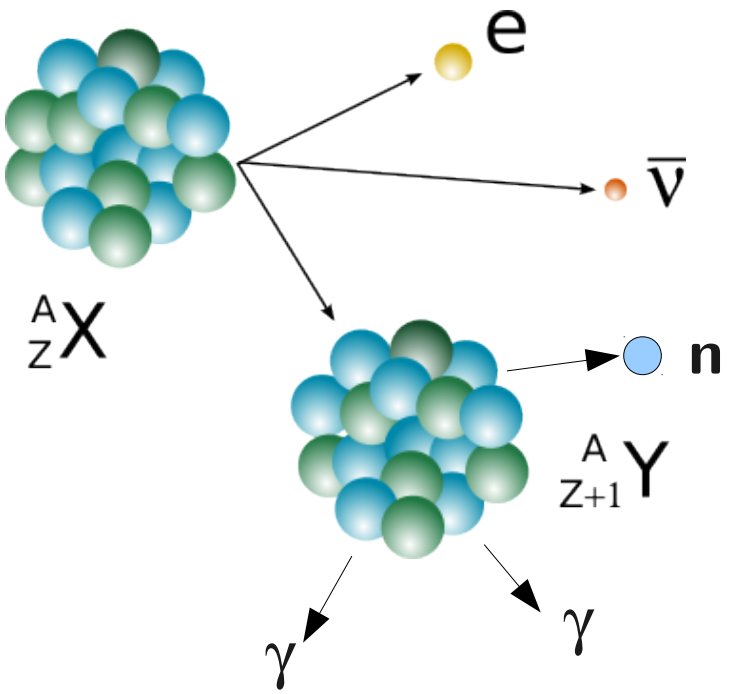
in beta decay

Exotic Beams Summer School

Oak Ridge 2014

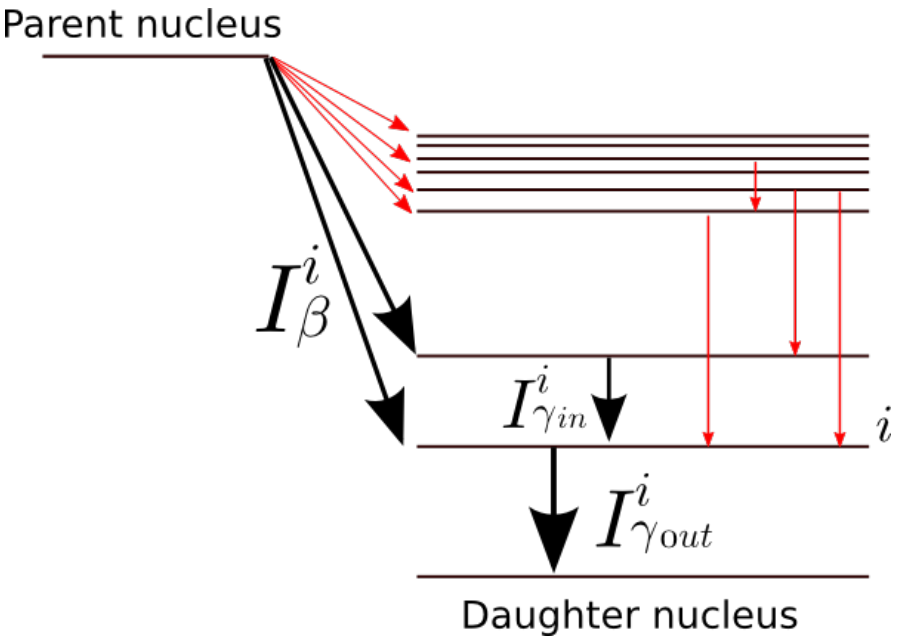
M. Karny, A.Fijałkowska

Beta decay spectroscopy



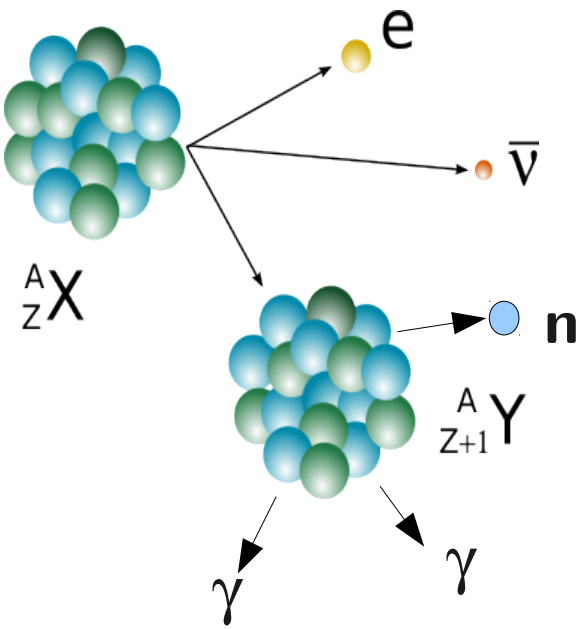
Total Absorption -

capture "everything" with high efficiency



$$I^i_\beta = I^i_{\gamma out} - I^i_{\gamma in}$$

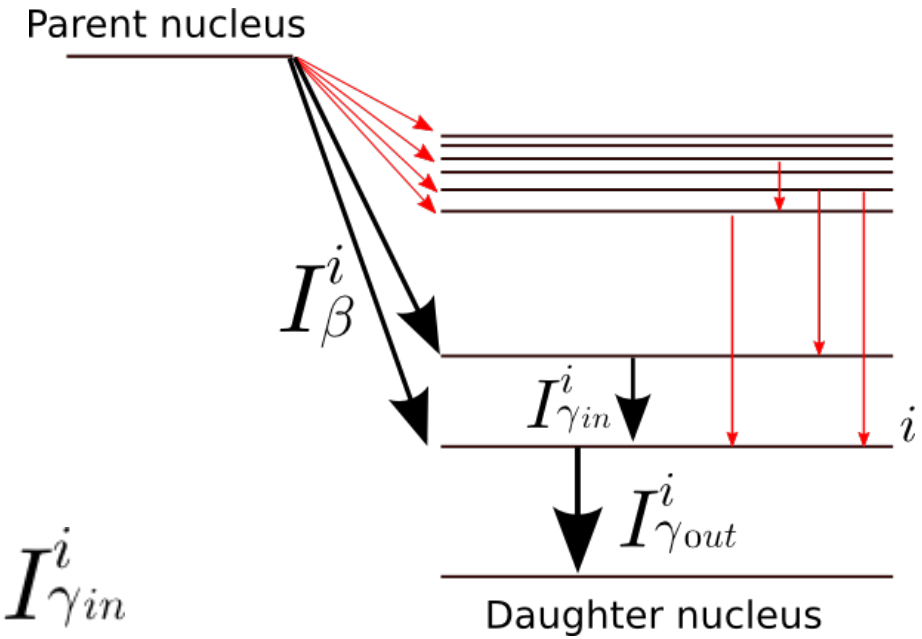
Why bother?



nuclear structure - nuclear physicists

ant-neutrino study - particle physicists

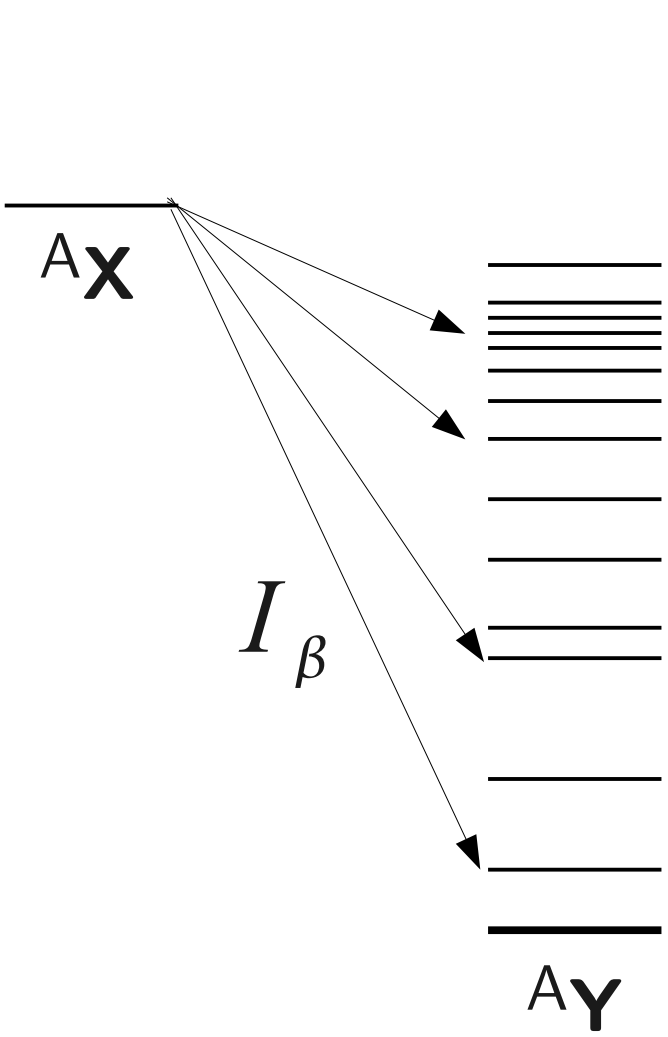
post fission processes - nuclear engineers



$$I^i_\beta = I^i_{\gamma out} - I^i_{\gamma in}$$

Nuclear structure - Beta decay strength

$$|M_{if}|^2 \cdot \frac{1}{const} = \frac{1}{T_{1/2}} \cdot \frac{I_\beta}{f(Z, Q_\beta - E_f)}$$

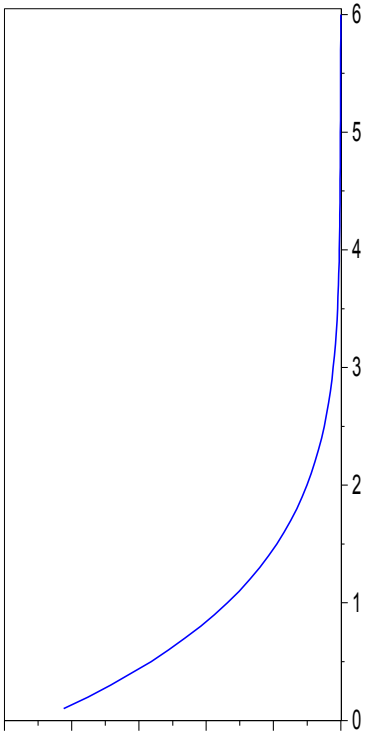


I_β

small

LARGE

$f(Z, Q_\beta - E_f)$

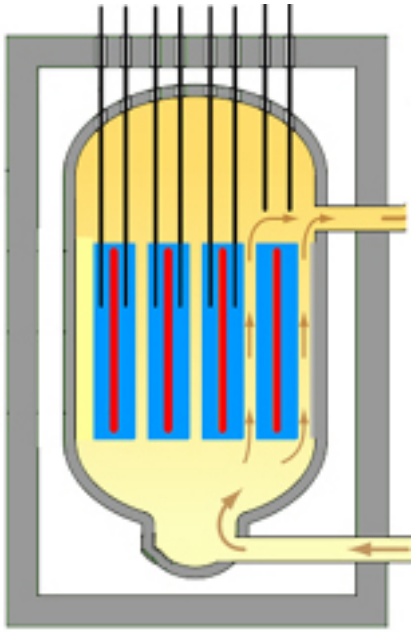


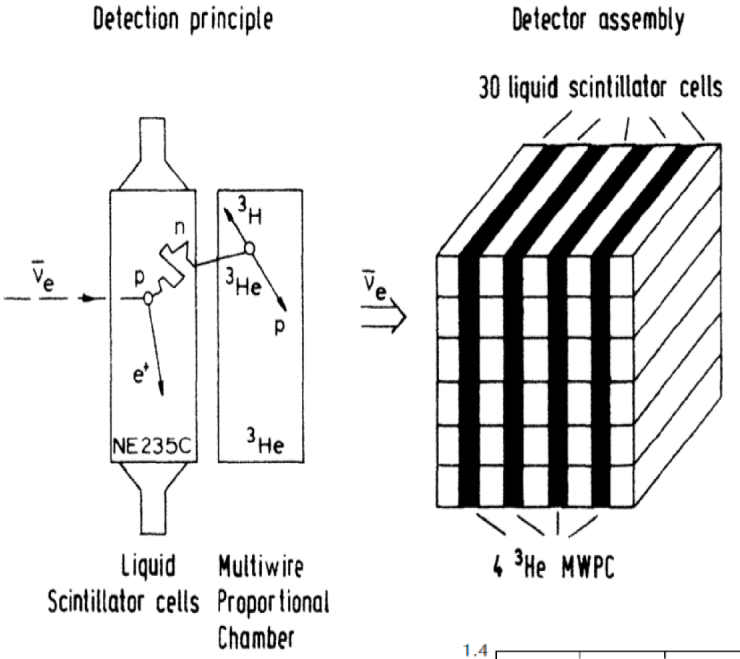
$$\frac{I_\beta}{f(Z, Q_\beta - E_f)}$$

not that small

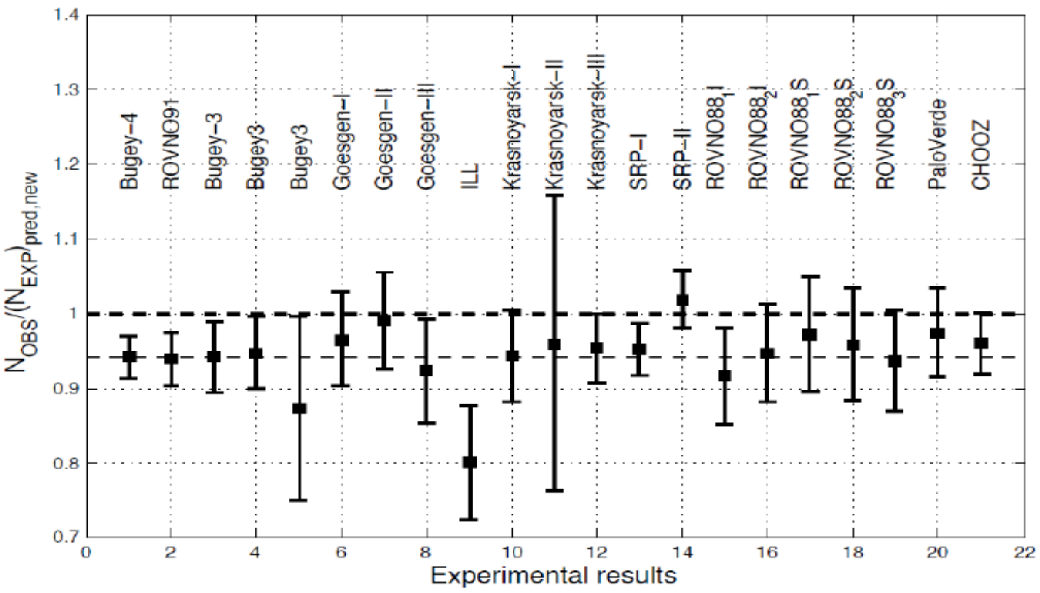
not so LARGE

Anti-neutrino study - reactor anti-neutrino anomaly



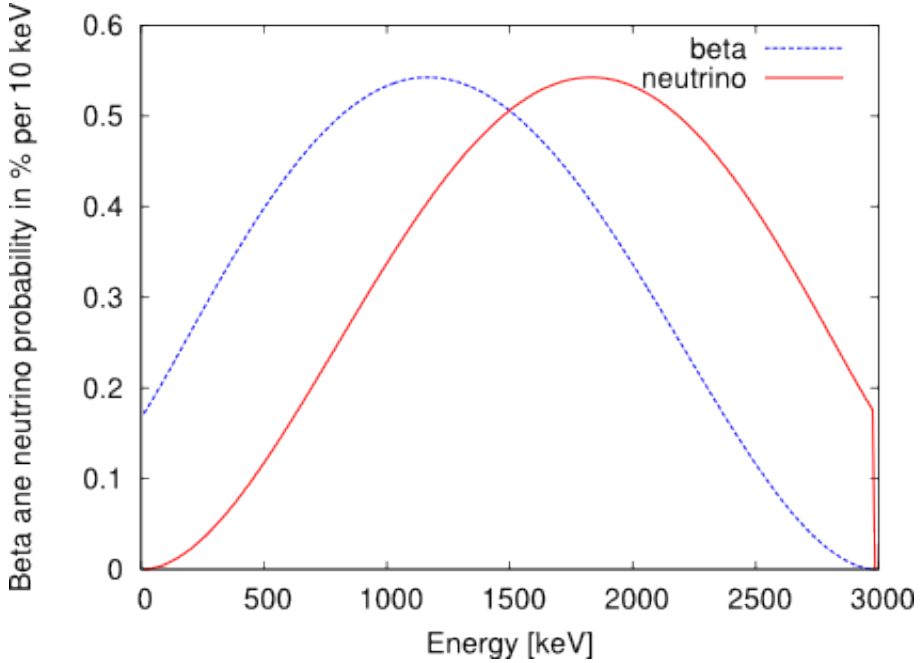


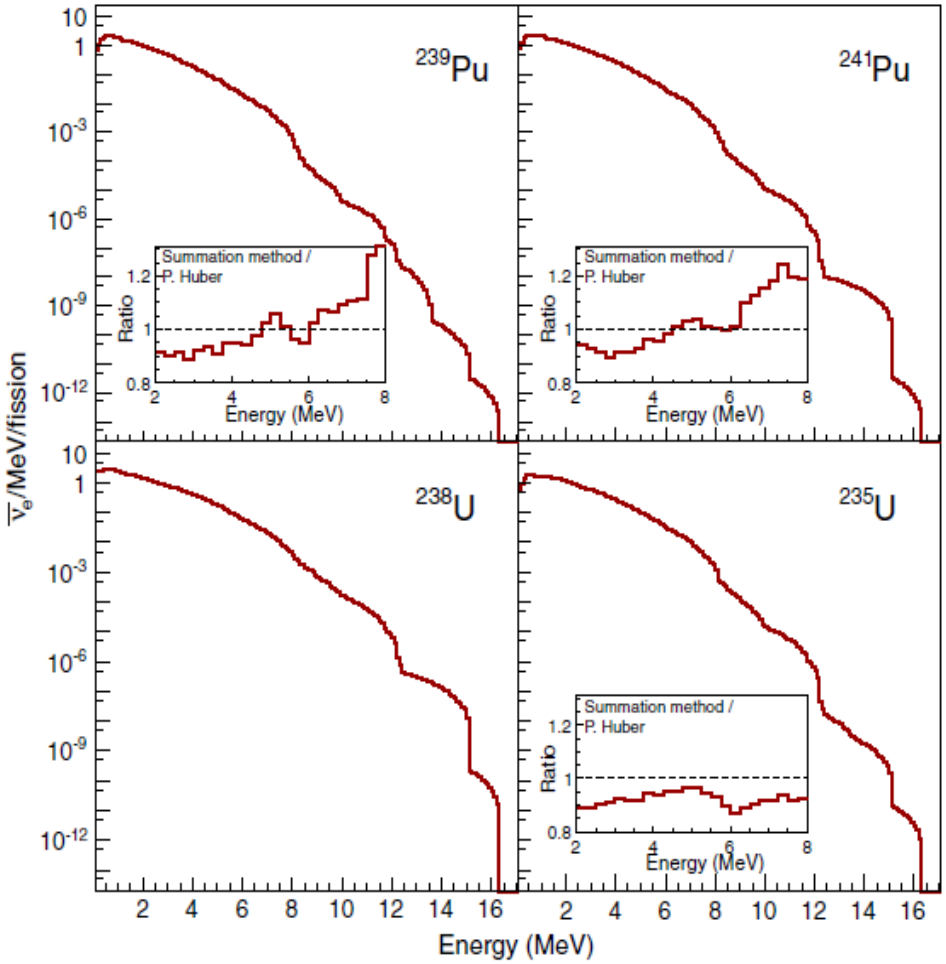
$N_{obs} / N_{cal} \approx 95\%$



Anti-neutrino study - reactor anti-neutrino anomaly

β and anti-neutrino energy spectrum for single beta transition





Overestimating β feeding to laying excited levels means overestimating the number of high energy anti-neutrinos

M. Fallot et al., PRL 109, 202504 (2012)

Post fission processes - Decay heat

Beta and gamma energy released by the decay of fission products amounts to approx. 10% of total energy released during the fission process - main source of energy after reactor shut-down

$$f(t) = \Sigma_i (E_{\gamma,i} + E_{\beta,i}) \lambda_i N_i(t)$$

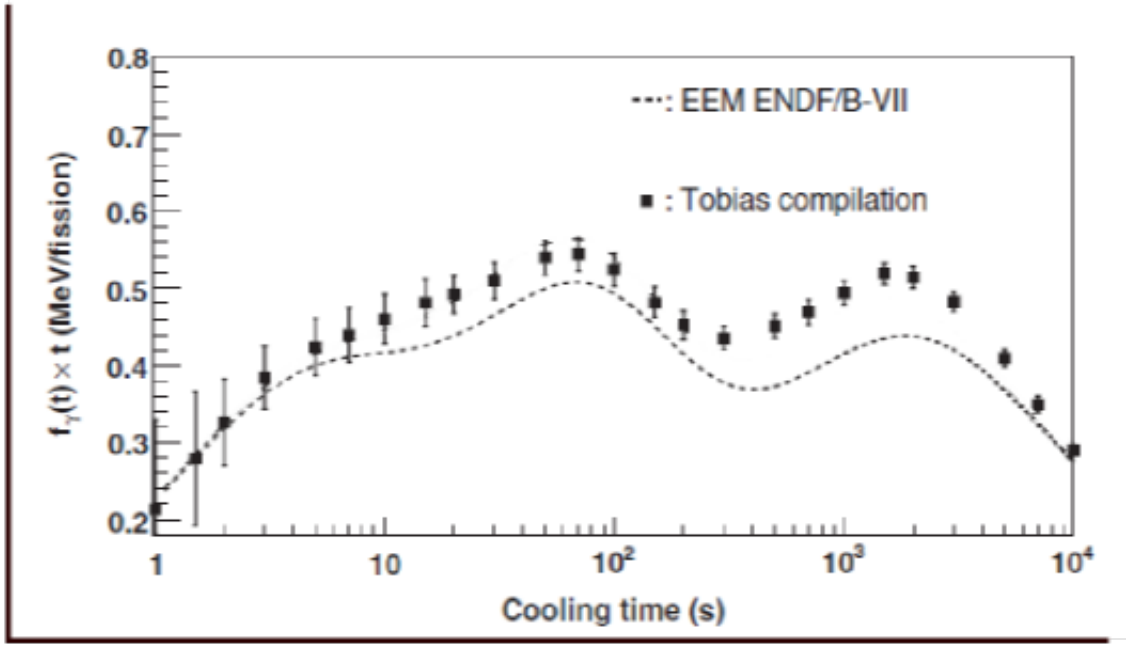
Mean gamma and beta energy are calculated based on the beta decay scheme

$$E_\gamma \approx \Sigma E^i \cdot I^i_\beta$$

E_i - mean decay energy of nucleus i (β and γ)
λ_i - decay constant
$N_i(t)$ - number of nuclei i at time t

Post fission processes - Decay heat

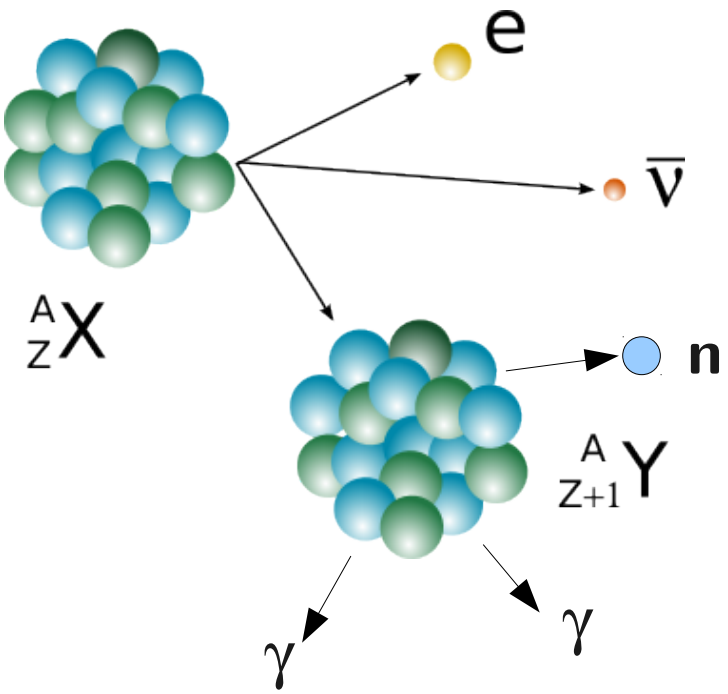
Gamma component of ^{239}Pu decay heat

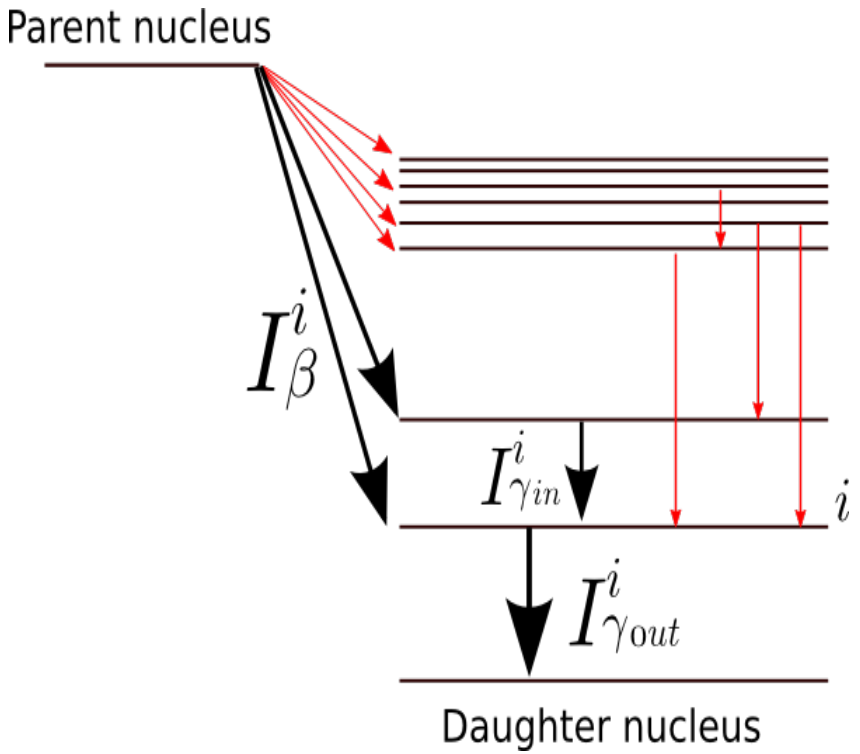


A. Algora et al., PRL 105, 202501 (2010)
A. Tobias, CEGB Report No. RD/B/6210/R89, 1989

$$f(t) = \Sigma_i (E_{\gamma,i} + E_{\beta,i}) \lambda_i N_i(t)$$

Beta decay

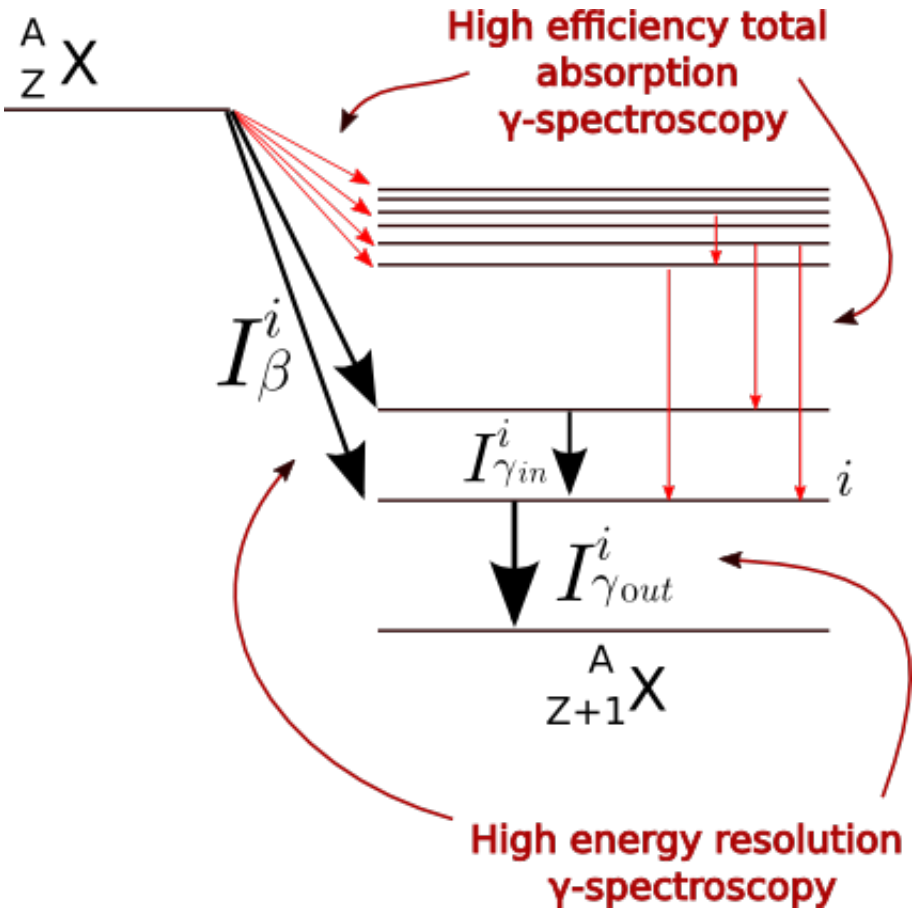




$$I^i_\beta = I^i_{\gamma out} - I^i_{\gamma in}$$

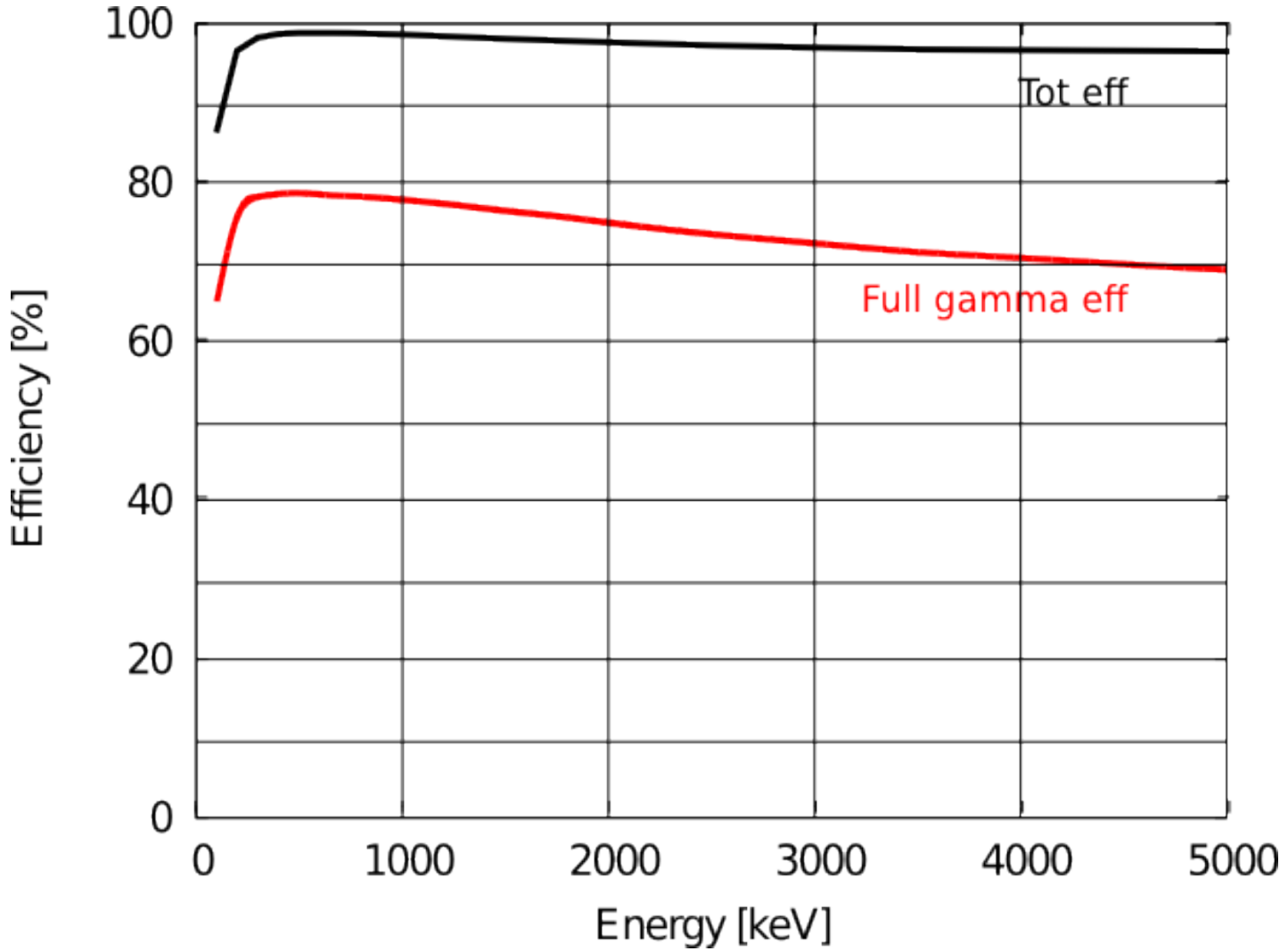
We need ...

Efficiency

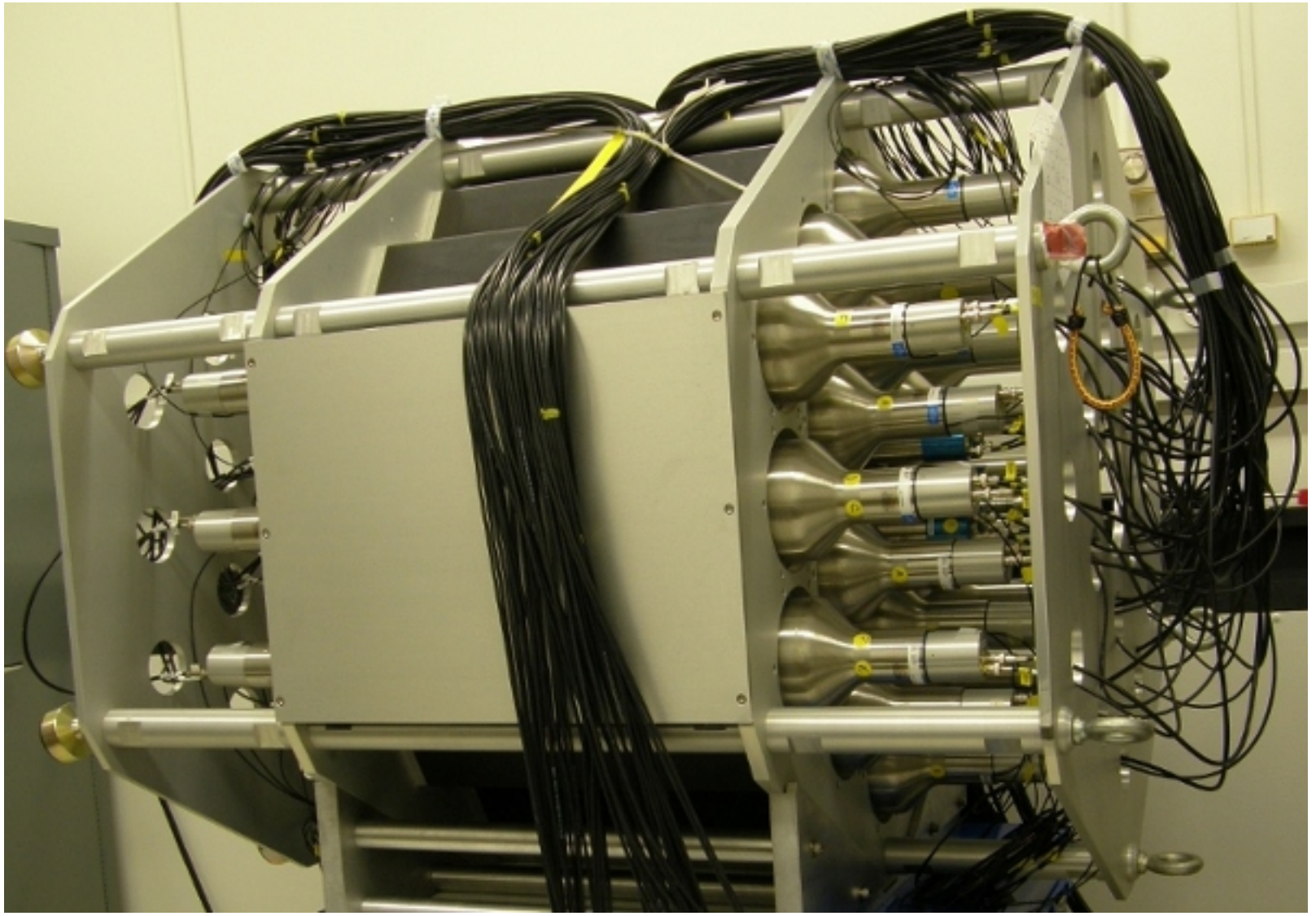


Modular Total Absorption Spectrometer -

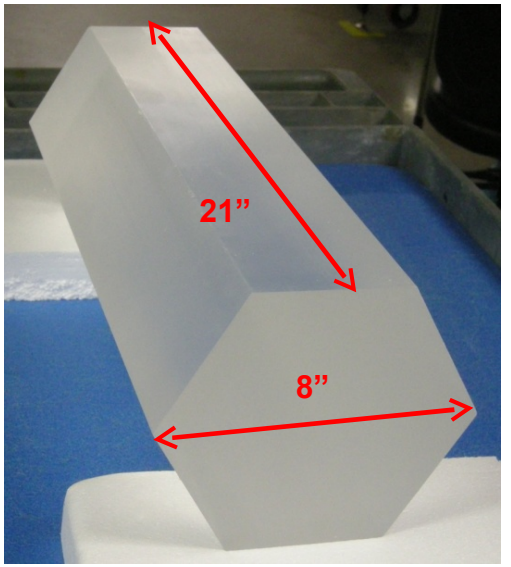
Efficiency

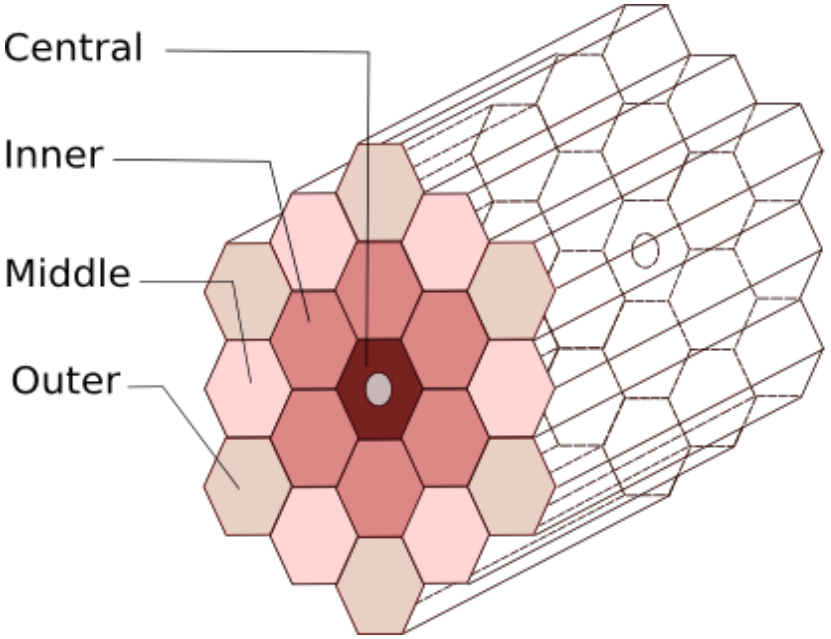


MTAS detector

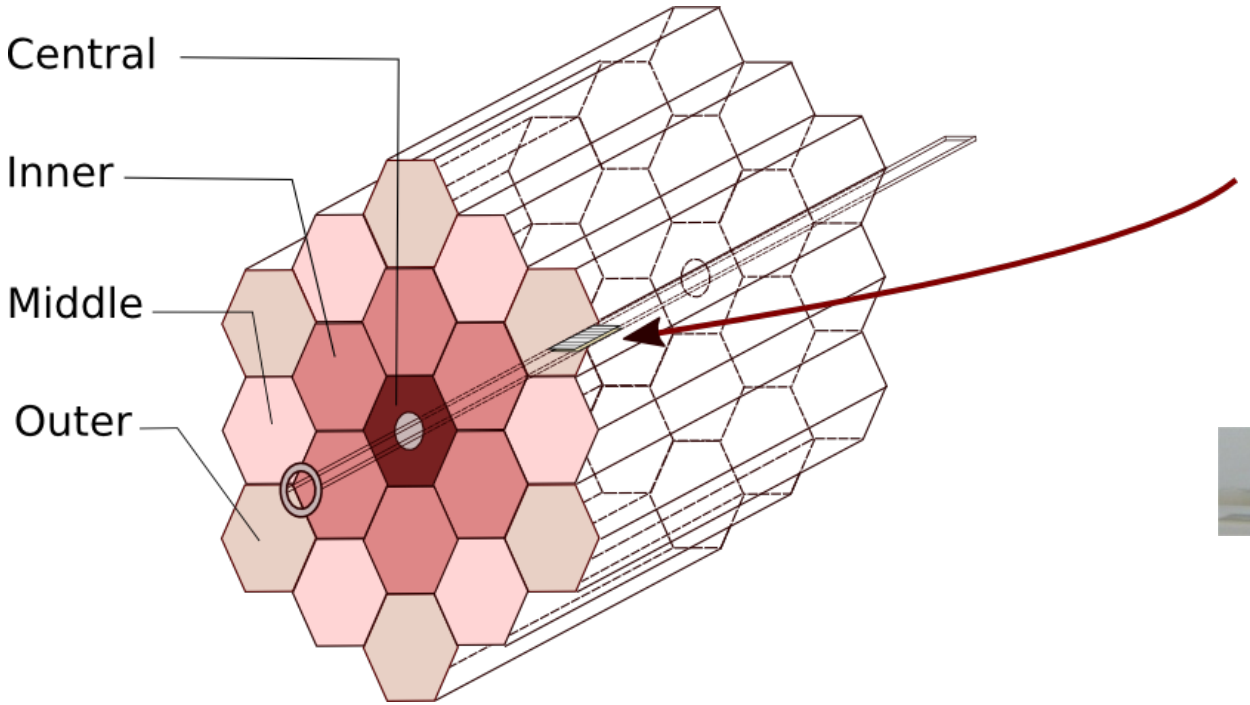


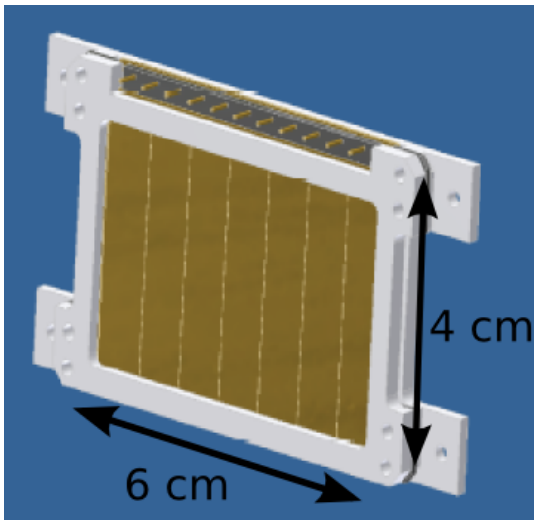
MTAS detector

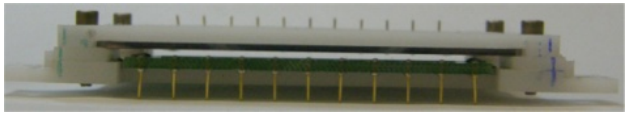




Auxiliary detectors



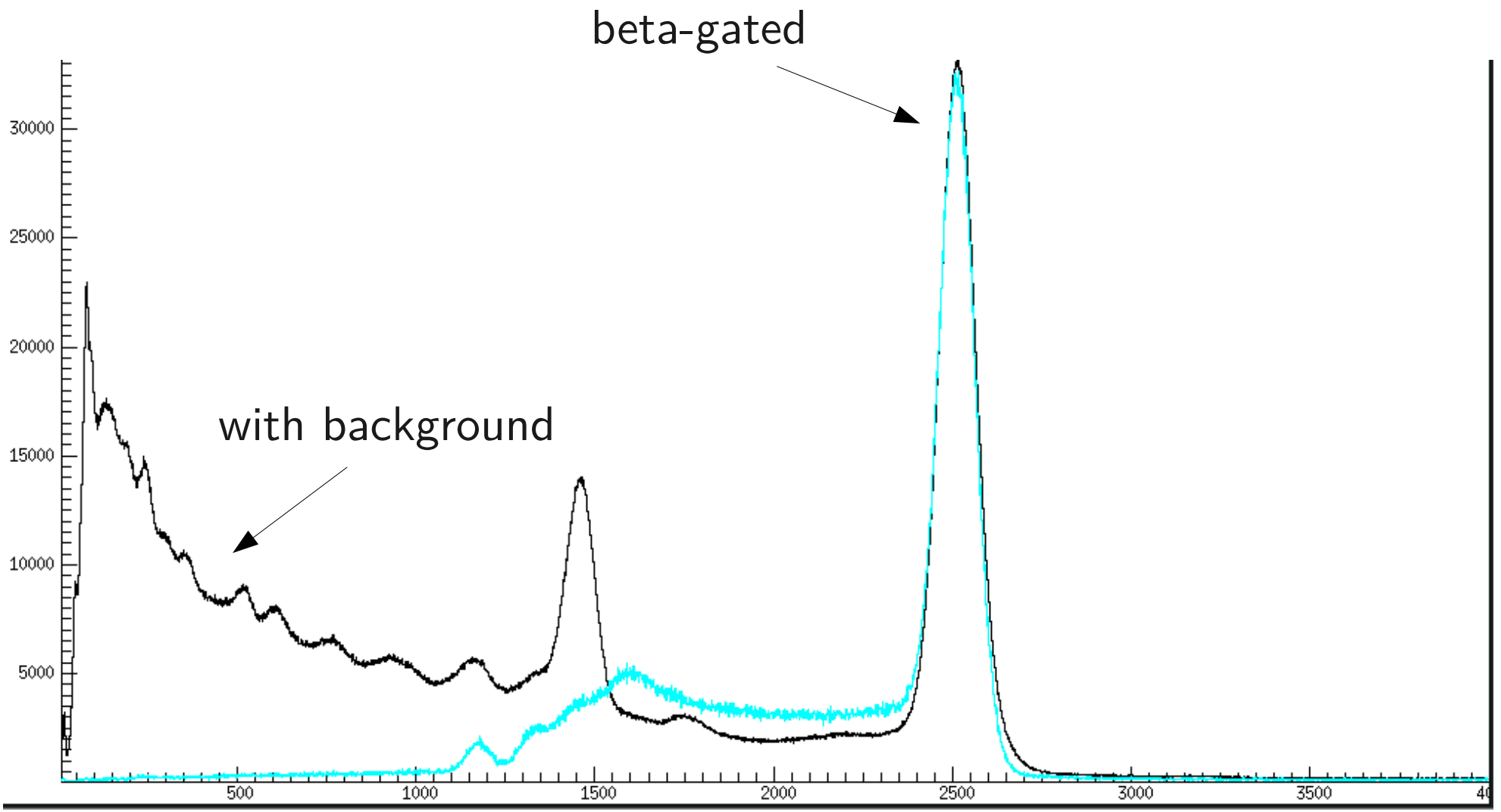


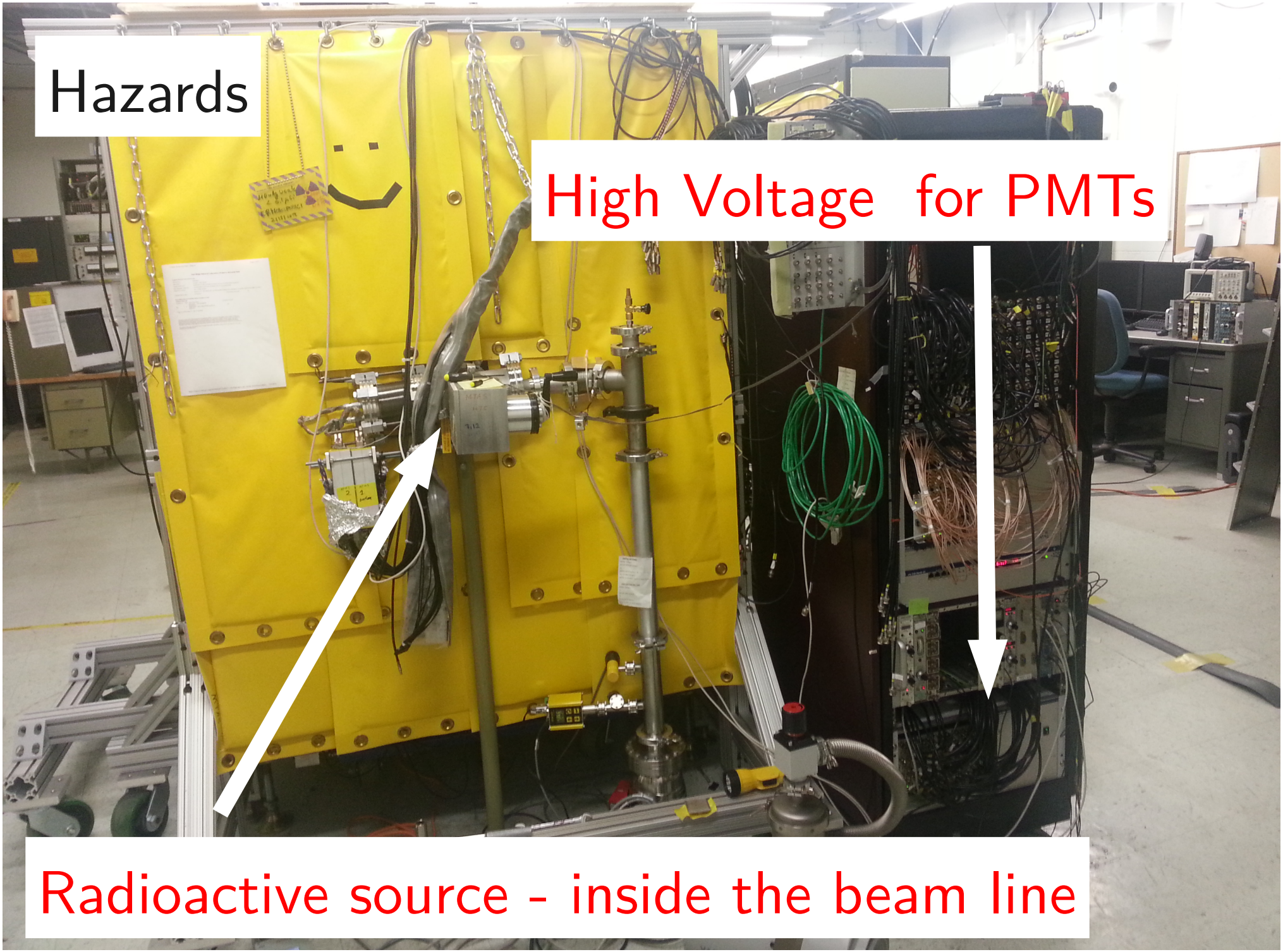


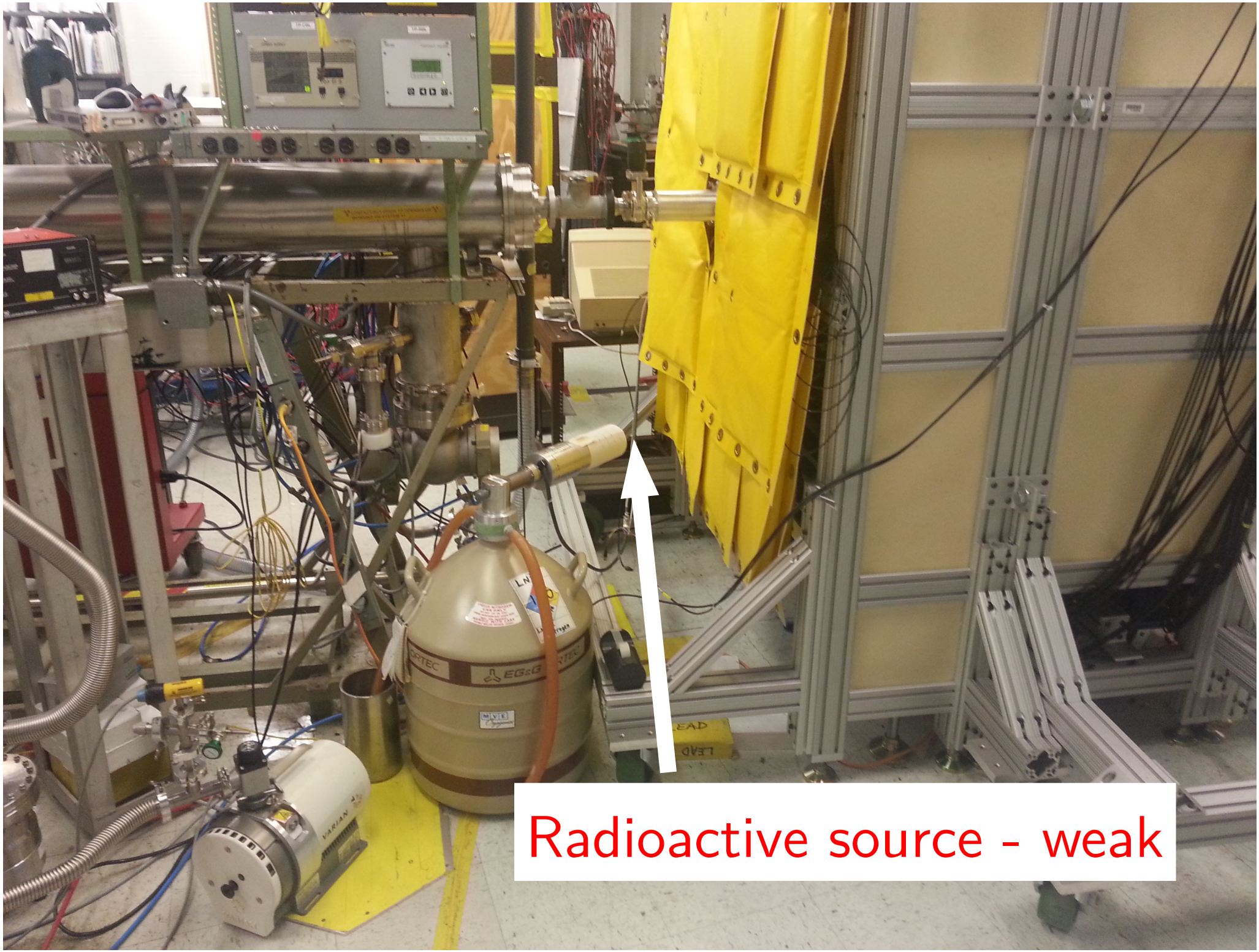
Auxiliary detectors include two 1 mm thick silicon strip detectors placed in the center of MTAS around the tape.

MTAS detector - read to measure at ORNL

^{60}Co


beta-gated
with background
30000
25000
20000
15000
10000
5000
500
1000
1500
2000
2500
3000
3500


Hazards
High Voltage for PMTs
Radioactive source - inside the beam line


Radioactive source - weak