2nd ANNUAL ARDENT WORKSHOP

Quality assessment of hadrontherapy fields with TEPCs

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The radiation quality concept

The radiation field quality is meant as a physical measurable quantity, which is significant for primary effects on a biological system

We define the measured y-spectrum in 1-2 µm sites as the radiation-field microdosimetric quality

Some detectors measure only $\bar{y}_D$, which is used as quality mark of the radiation field.

The couple of values $\bar{y}_D$ and $\bar{y}_F$ is a better quality mark of the radiation field.

RBE_μ, the microdosimetric assessment of RBE, can be an accurate quality mark for a given biological end-point.

Therapeutic beam constrains

Fluence rates

Proton continuos beam $\frac{10^7 \div 10^8 \, \text{particles}}{cm^2 \times s}$

BNCT facility $\approx \frac{10^9 \, \textit{neutrons}}{cm^2 \times s}$

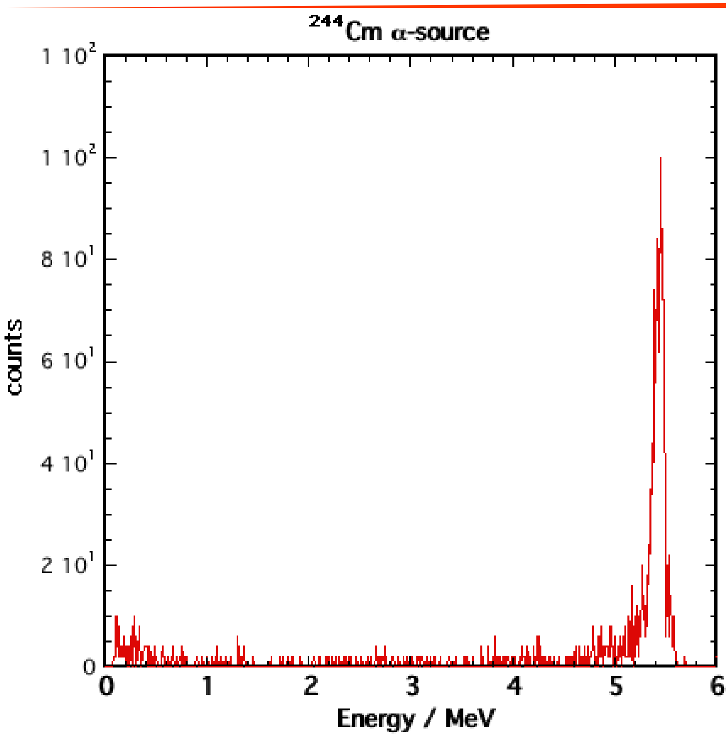
CNAO protons per spill $\frac{10^8 \div 10^{10} \, \text{particles}}{cm^2 \times s}$

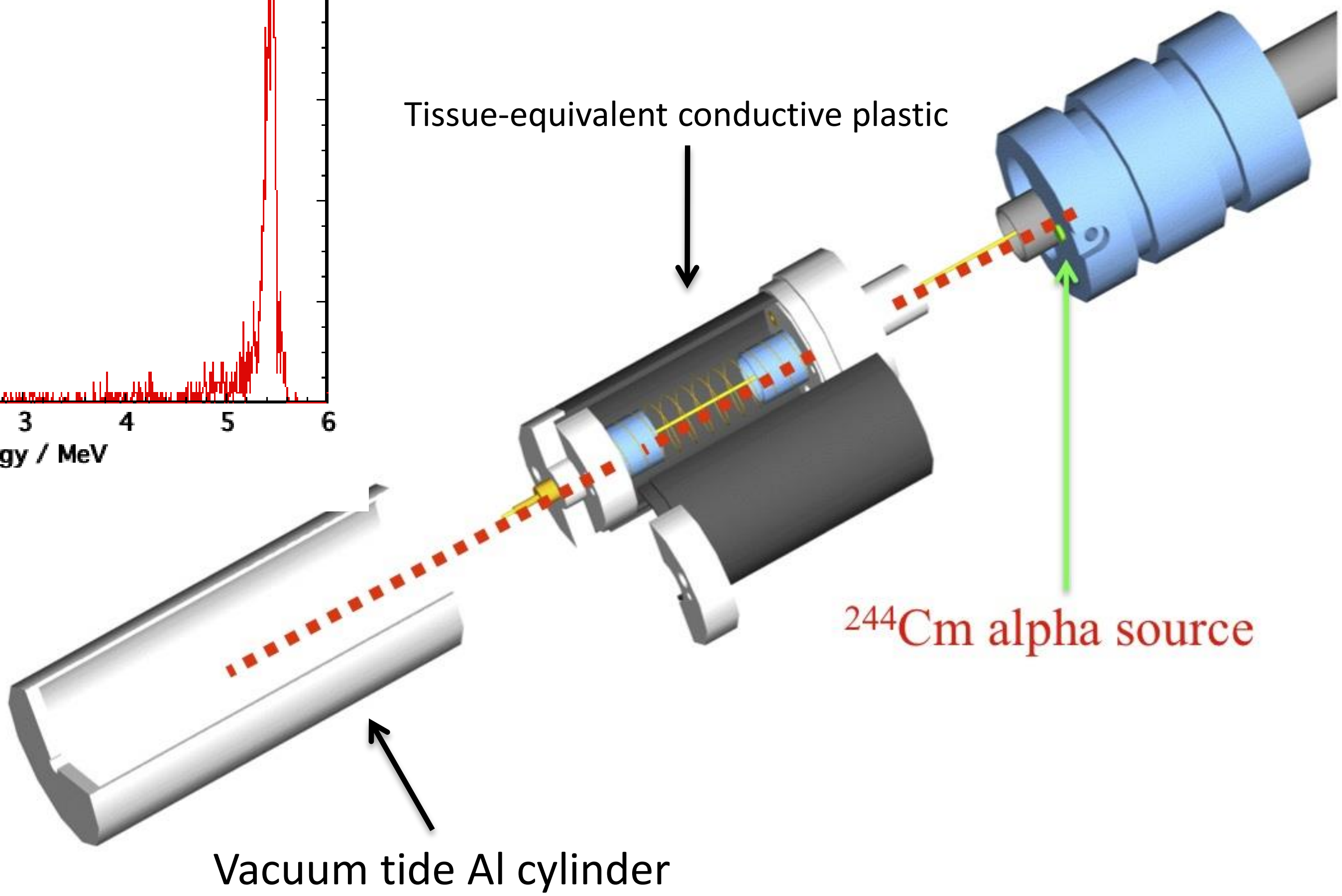
CNAO carbon ions per spill $\frac{10^6 \div 10^8 \, \text{particles}}{cm^2 \times s}$

1 cm TEPC ought to measure at counting rates bigger than 10^6 s^{-1}

1 mm TEPC will measure at counting rates bigger than 10^4 s^{-1}

Energy calibration technique in Φ ~ 1cm cylindrical TEPCs





Energy calibration technique in $\Phi \sim 1$mm cylindrical TEPCs

Cathode H.V.

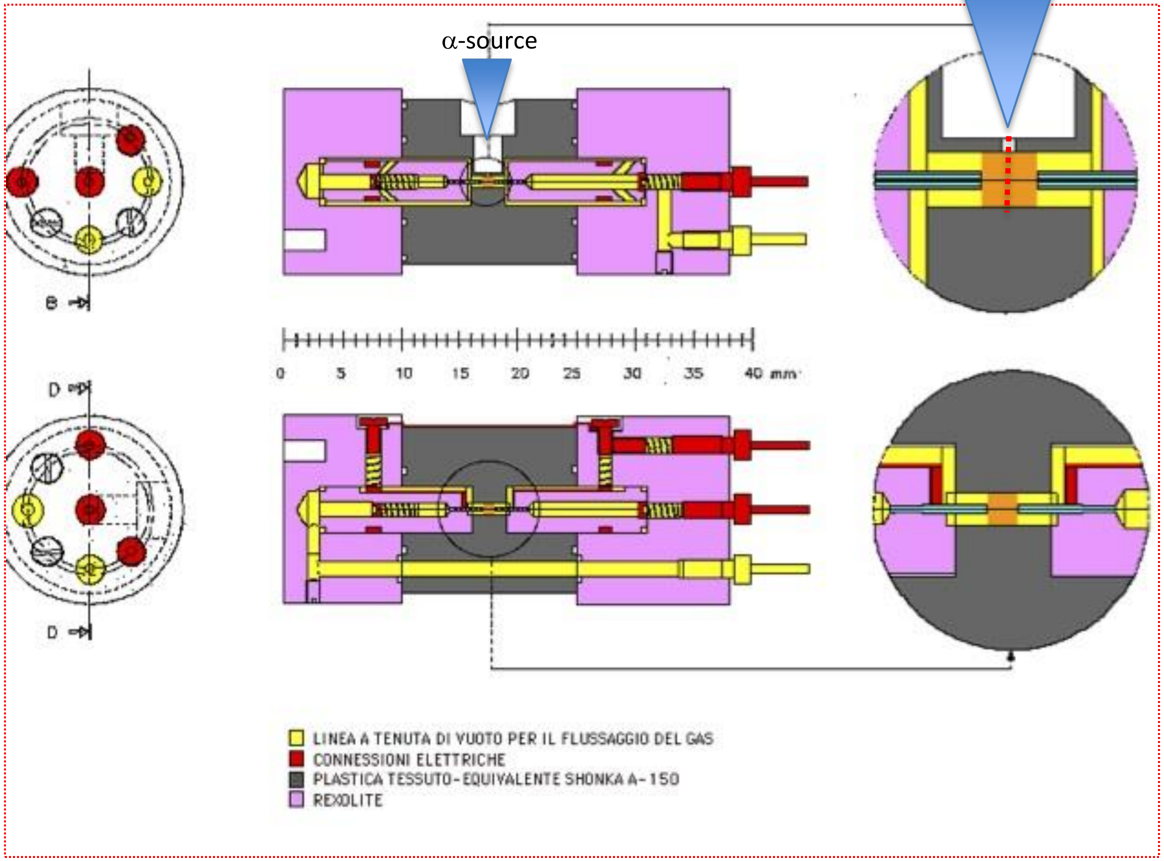
Gas OUT

Guard tubes H.V.

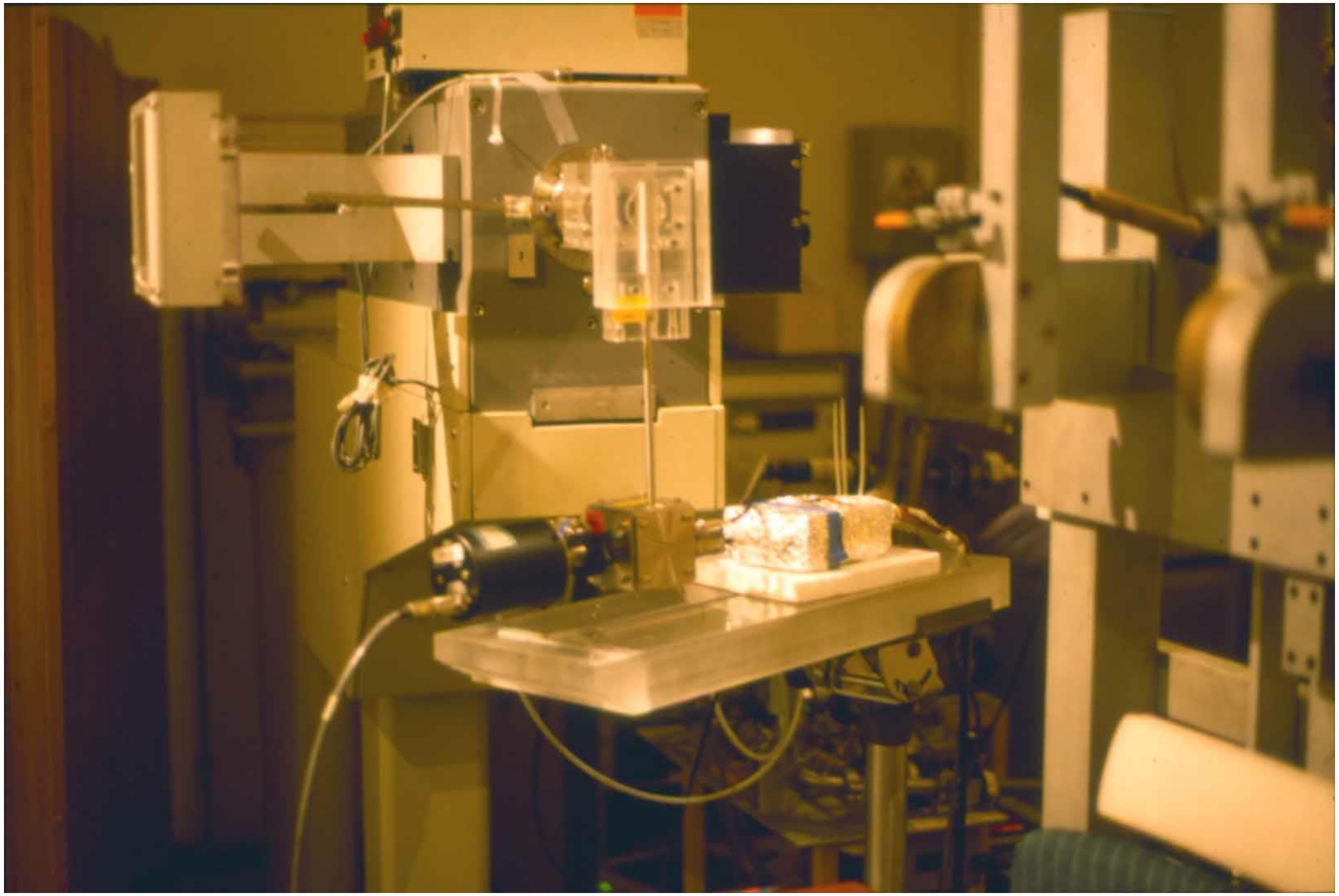
Gas IN

Anode pulse

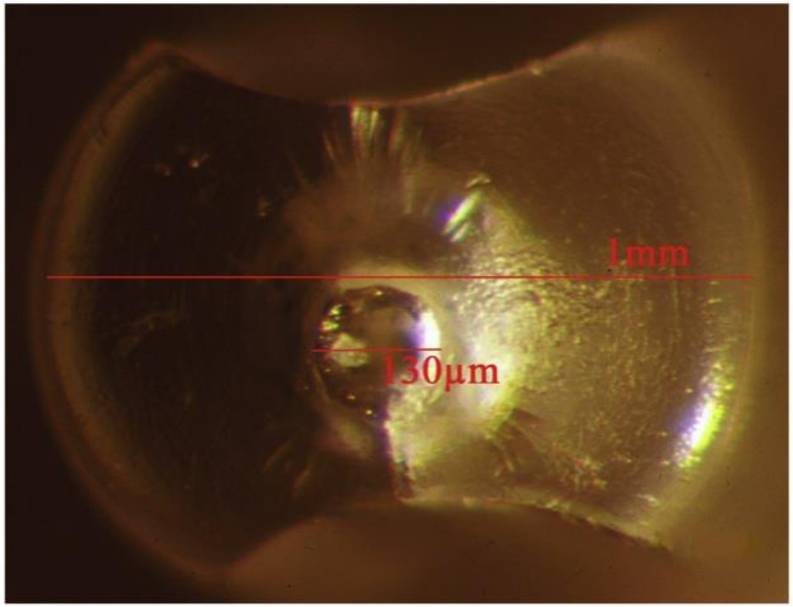
α-source

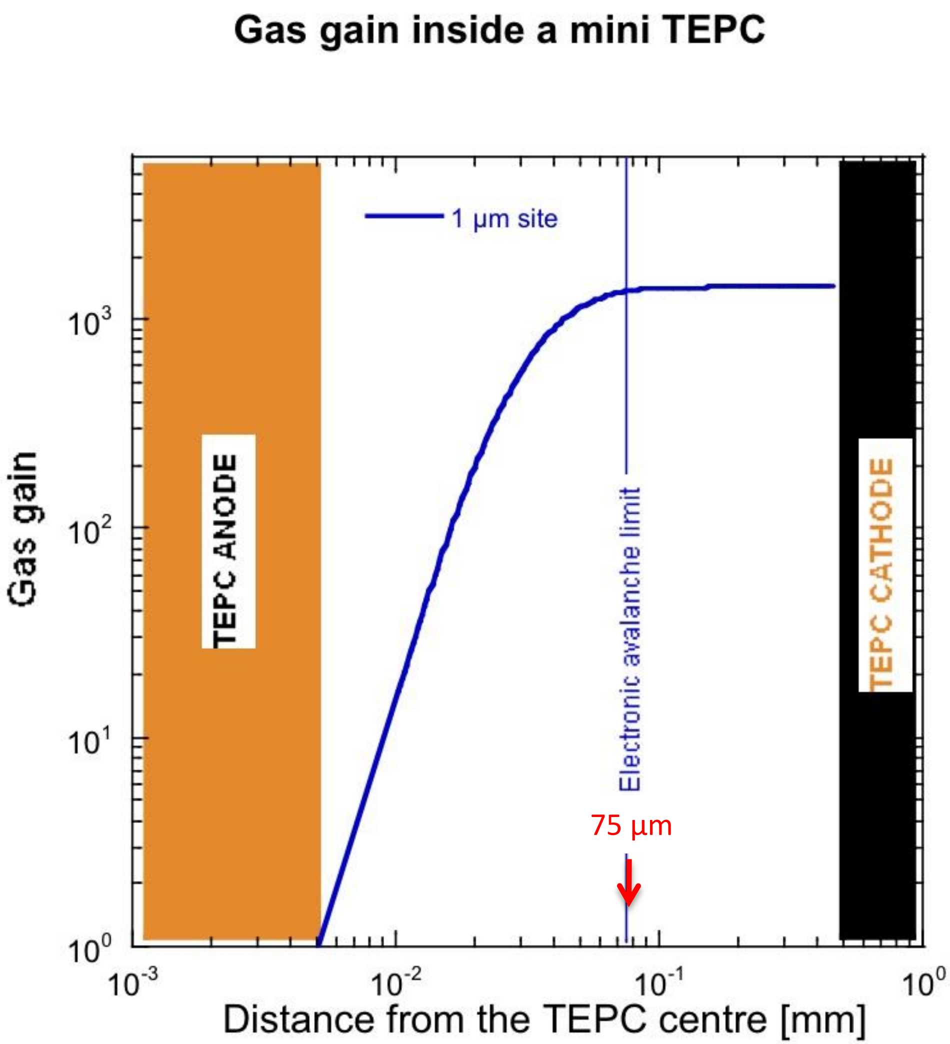


Measurements at the Nice therapeutic proton beam

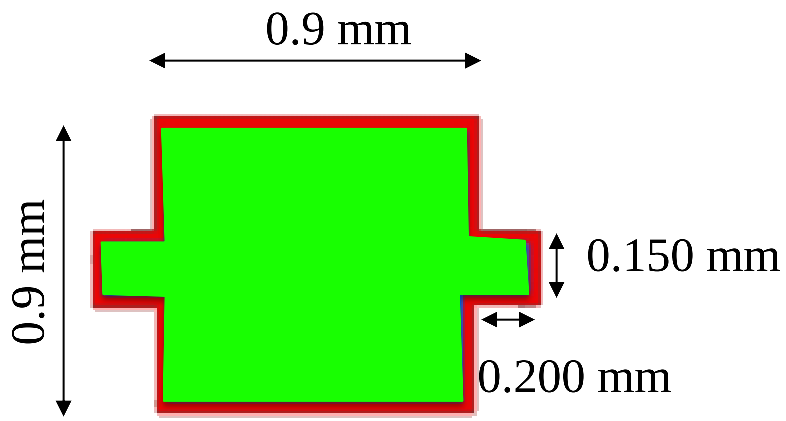


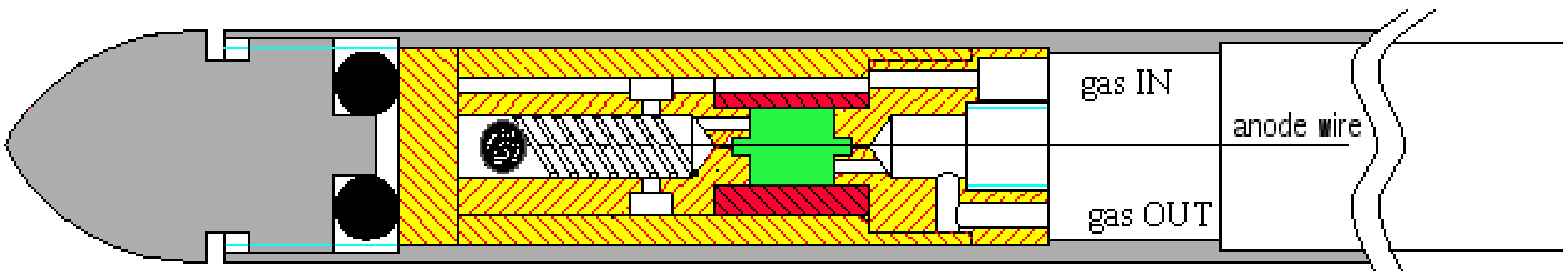
Insulator surfaces damage without electric-field tubes



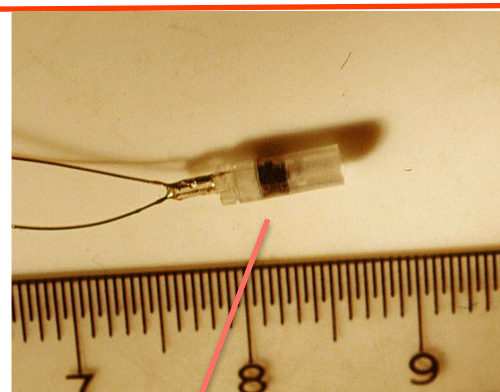


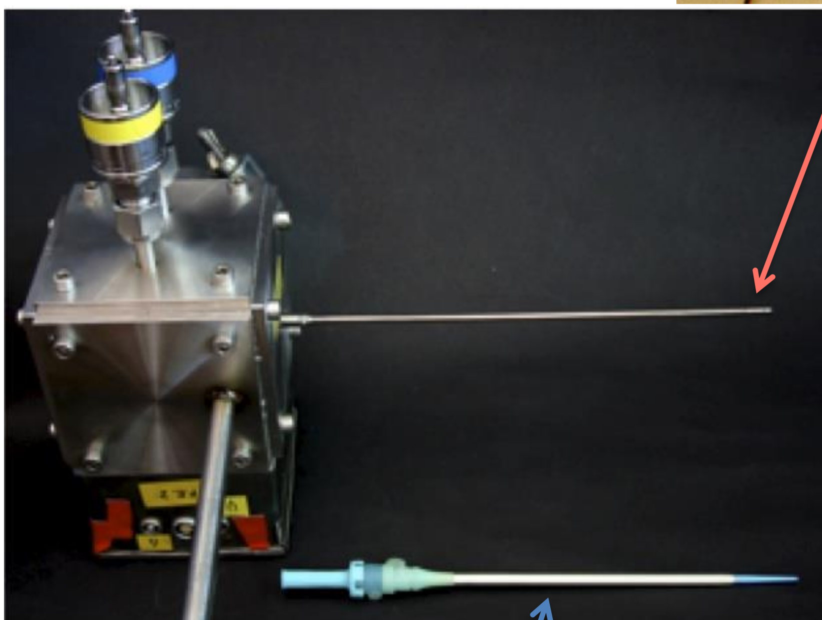
Solution: a cavity inside the insulator to switch off the the electronic avalanche

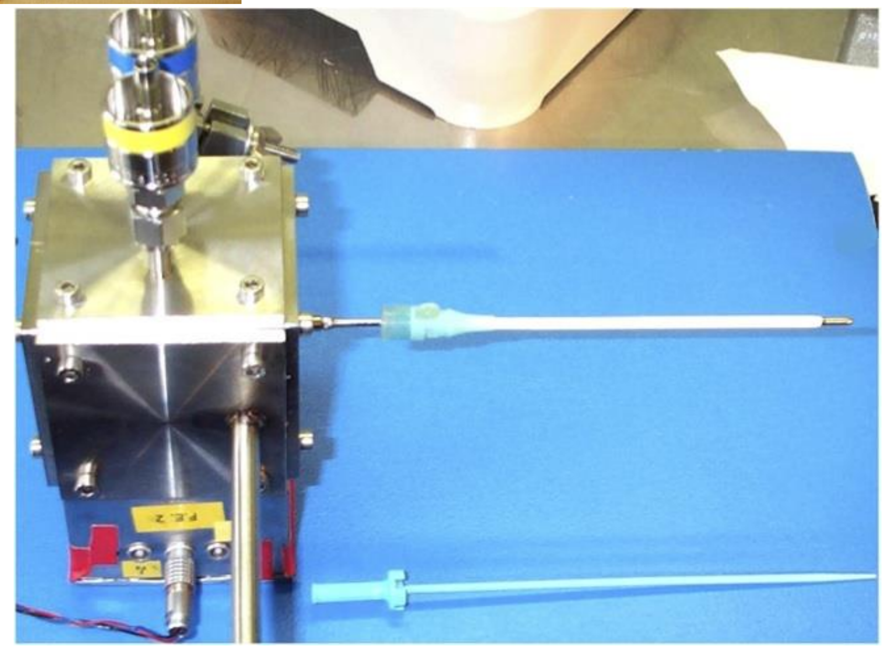




Mini TEPC of 2.7 mm of external diameter

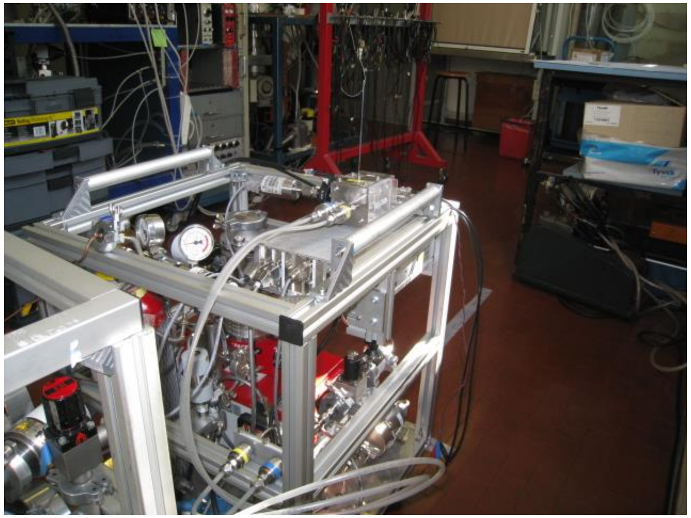


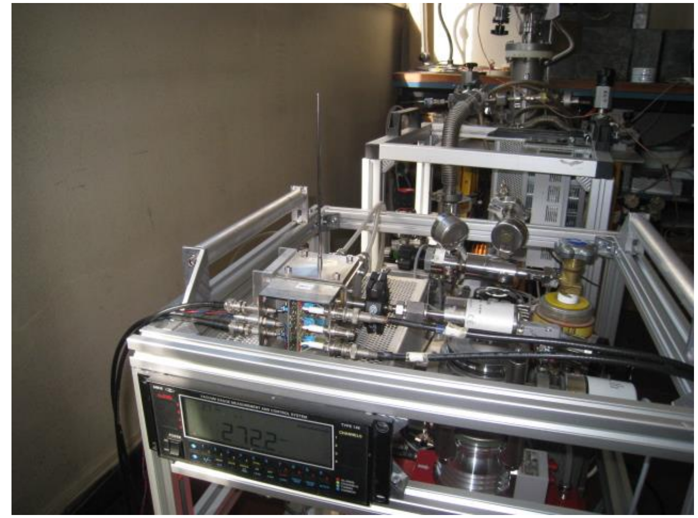


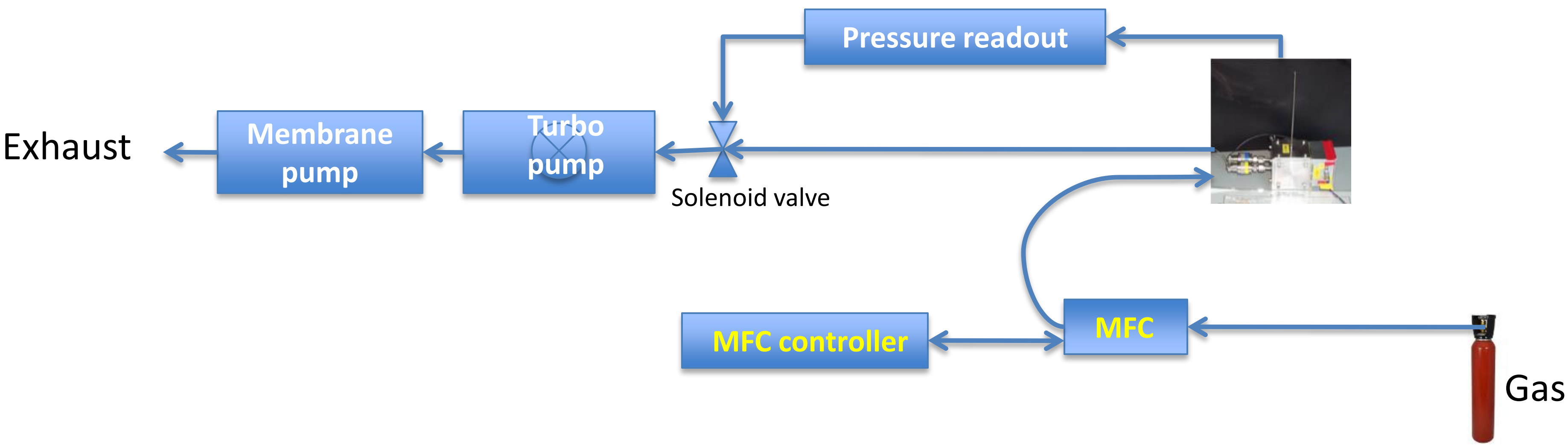


8 FRENCH CANNULA

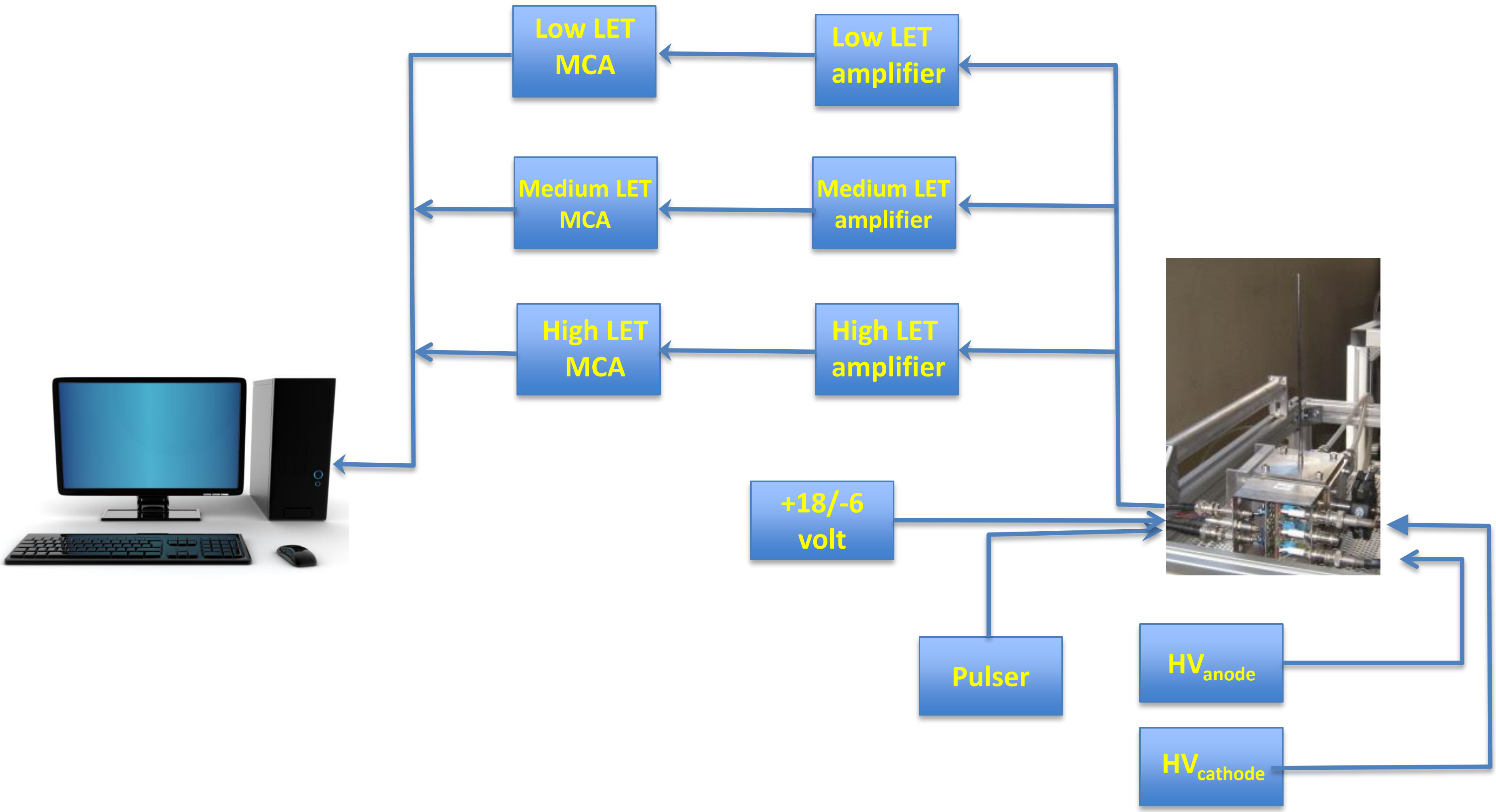
Vacuum and gas flow apparatus



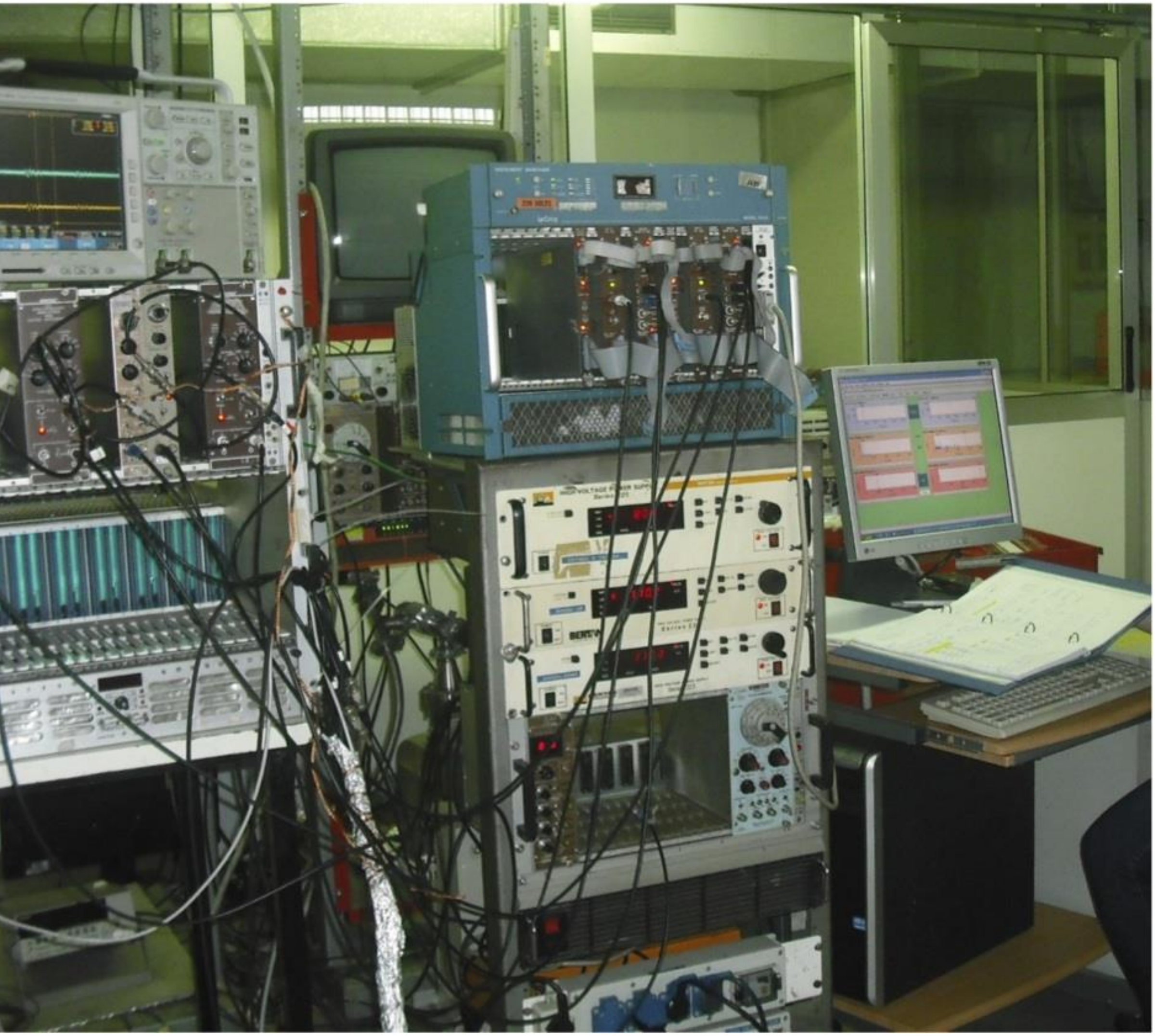




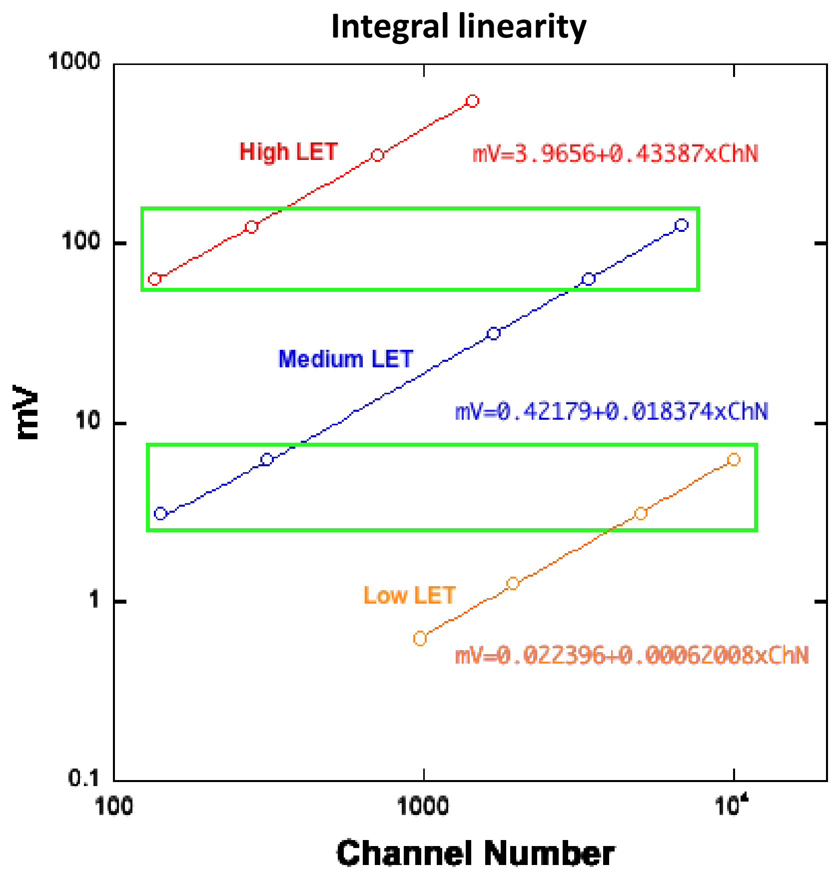
Electronic chain

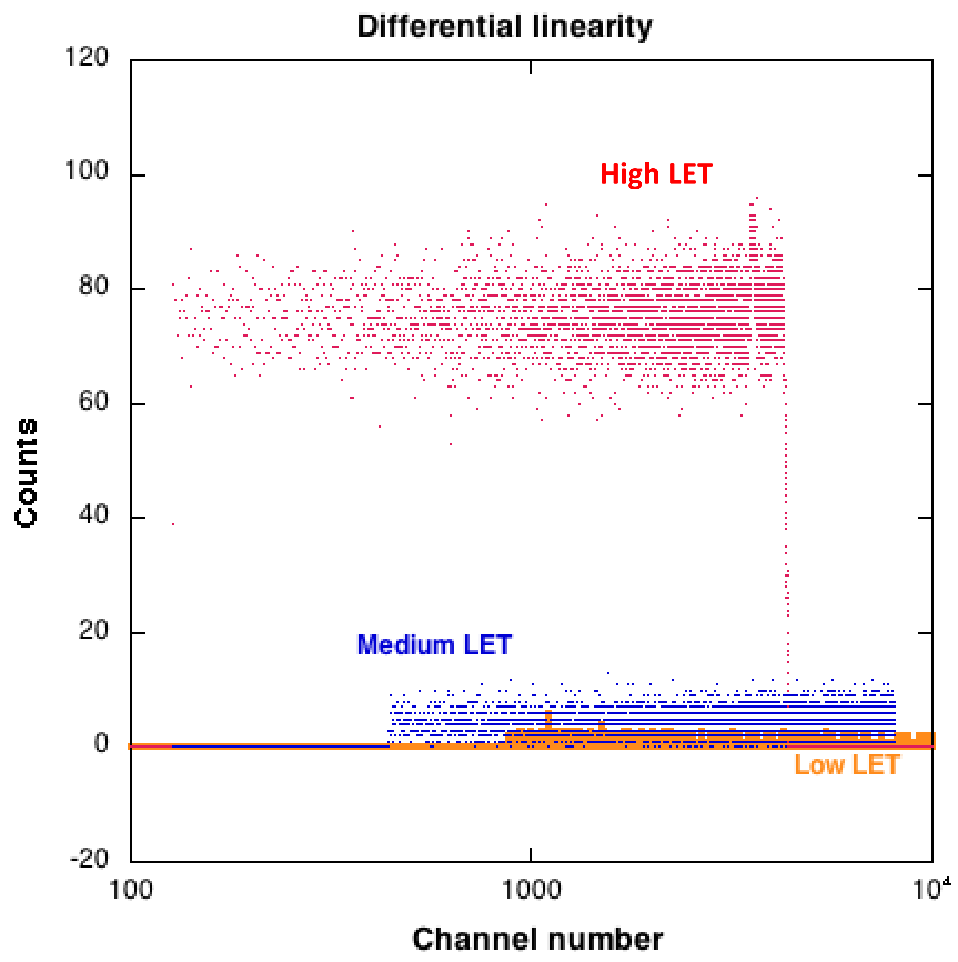


Electronic chain

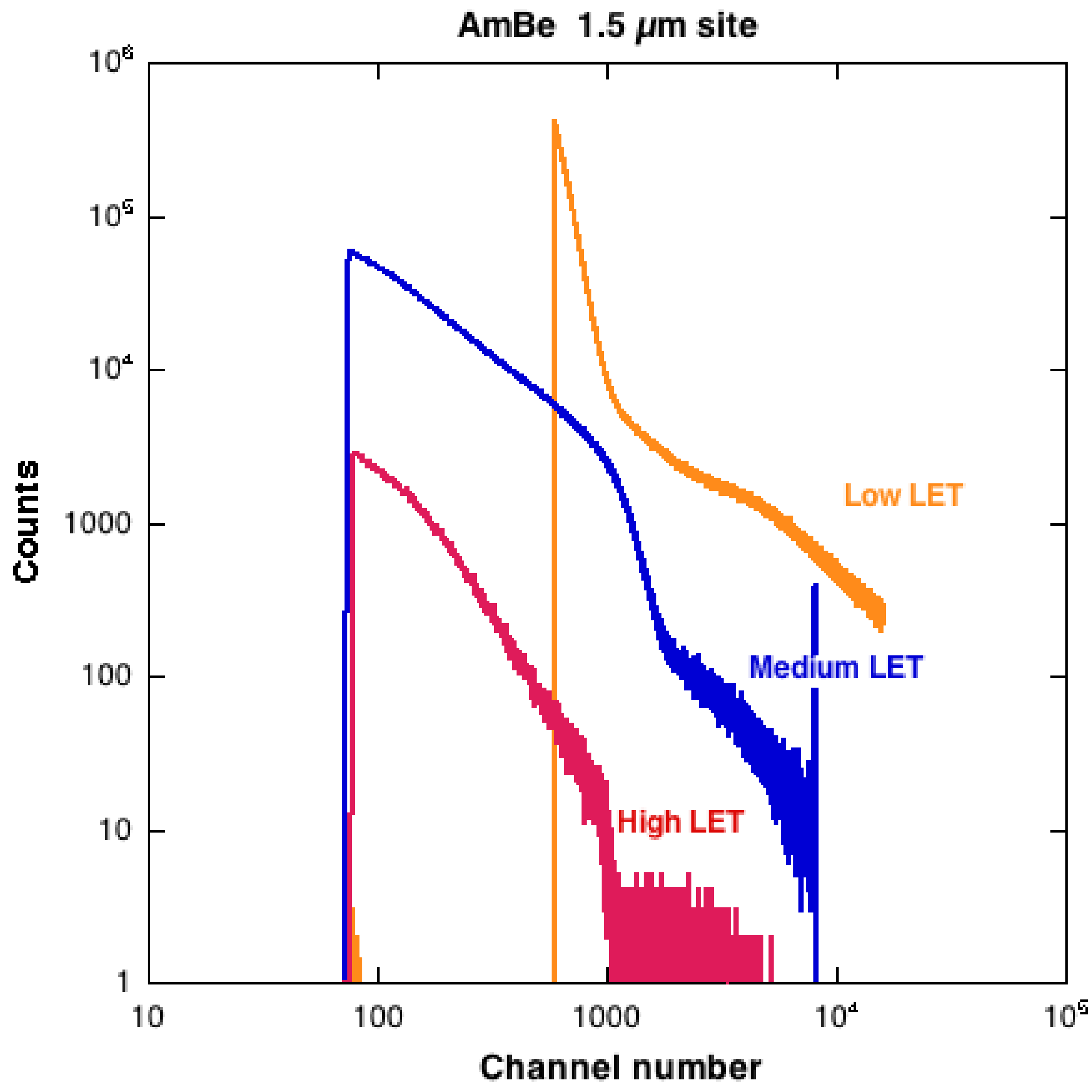


Before measuring: linearity checks

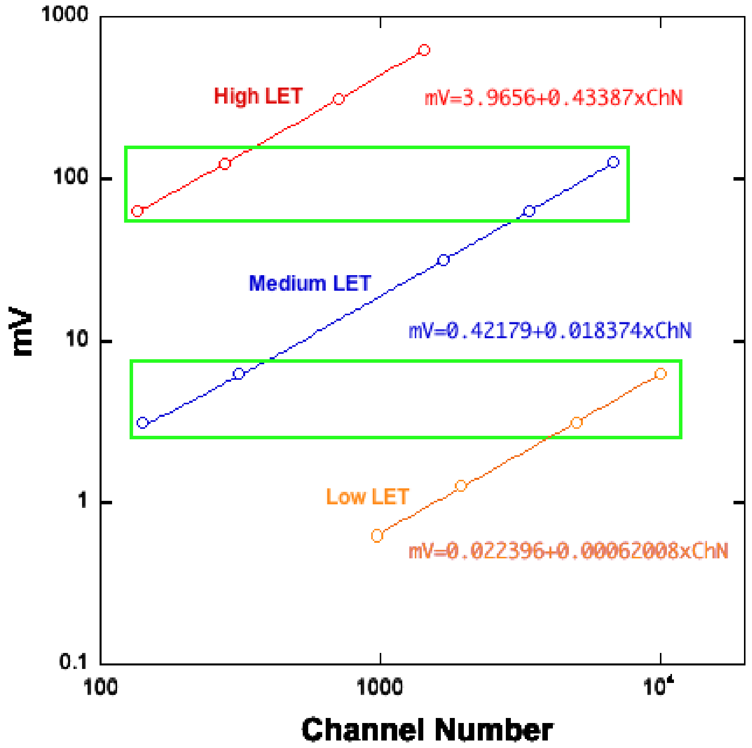


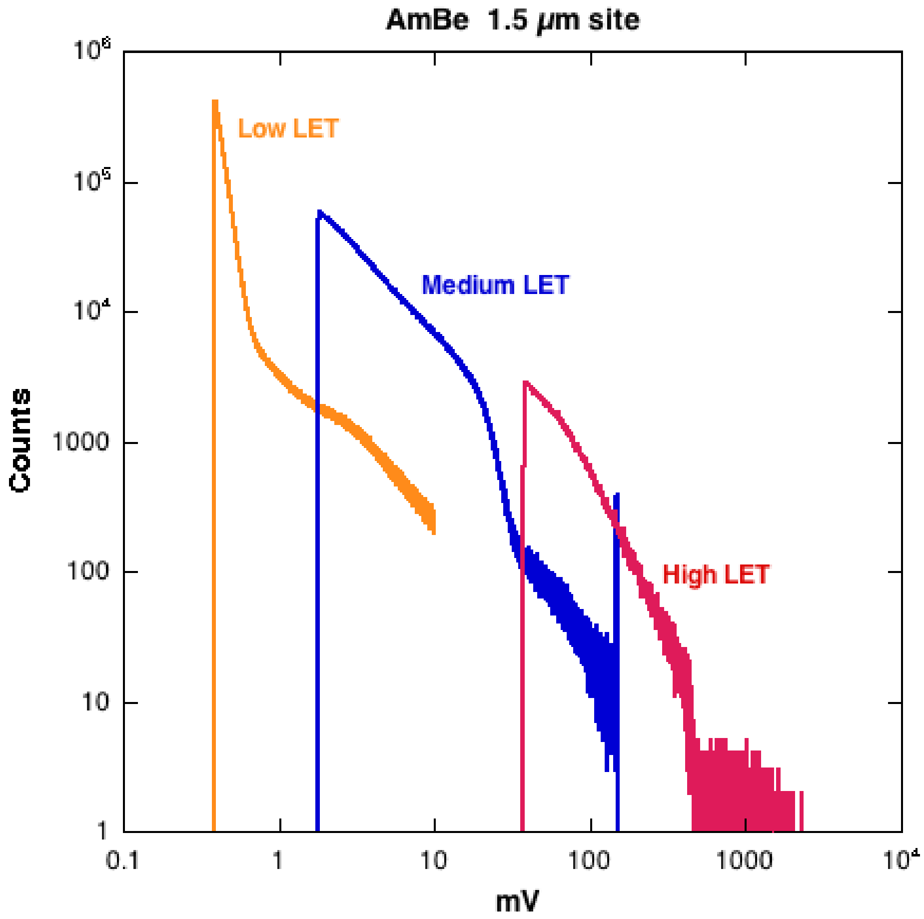


Initial data from the 3 MCA



Volt calibration

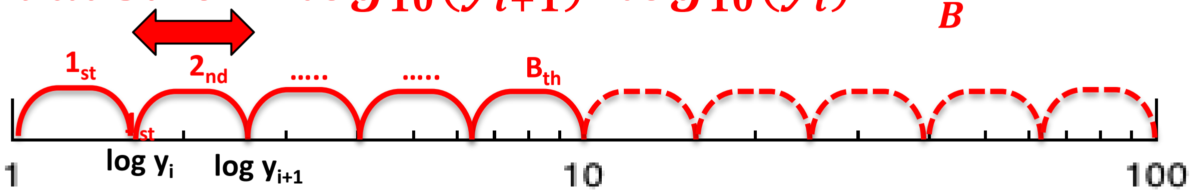




Logaritmic compaction

$$\textit{interval size} \stackrel{\text{def}}{=} \log_{10}(y_{i+1}) - \log_{10}(y_i) = \frac{1}{B}$$

Equal log intervals



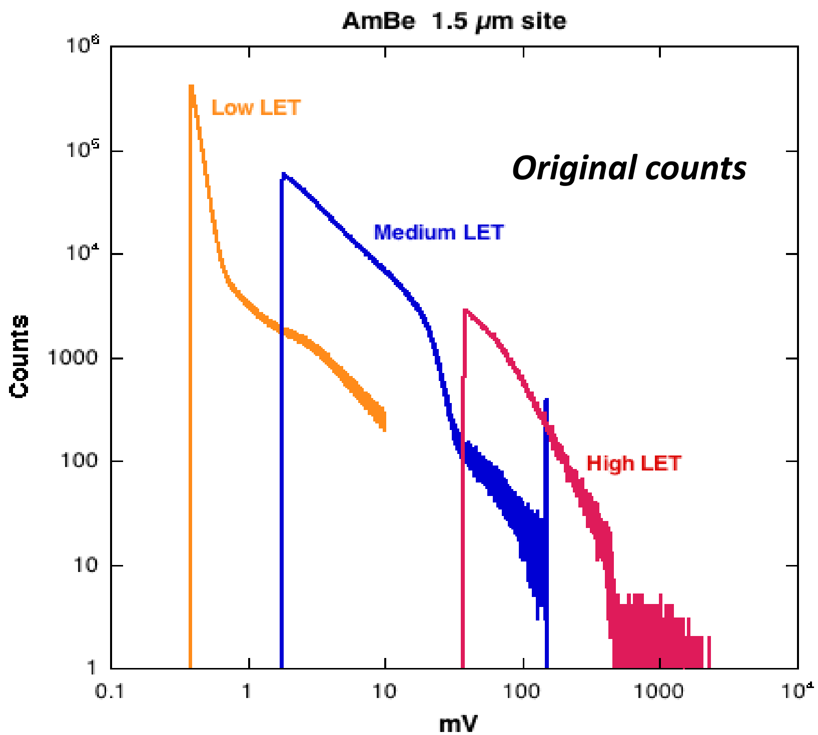
Example: ***B = 60***

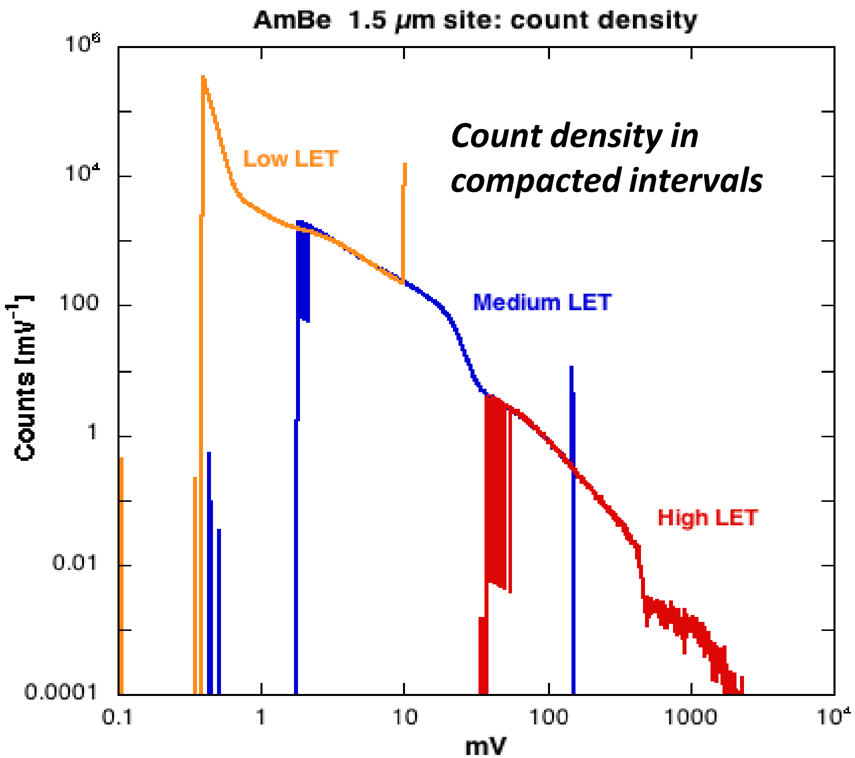
$$y_{i+1} = y_i \times 10^{1/60}$$

First decade $y_1 = 1.0391$, $y_2 = 1.0798$, y_3 .... **Δ_1 = 0.04065**

$$\Delta y_i = y_{i+1} - y_i = y_i \cdot \left(10^{1/60} - 1\right)$$

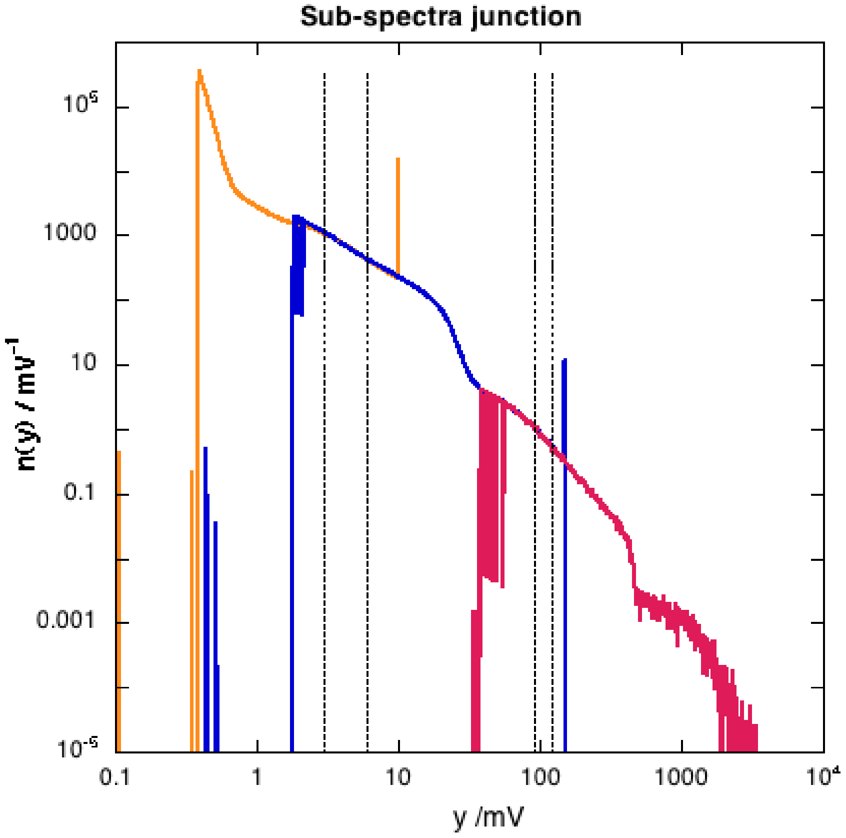
Second decade $y_1 = 10.0391$, $y_2 = 10.0798$, y_3 .... **Δ_1 = 0.4065**

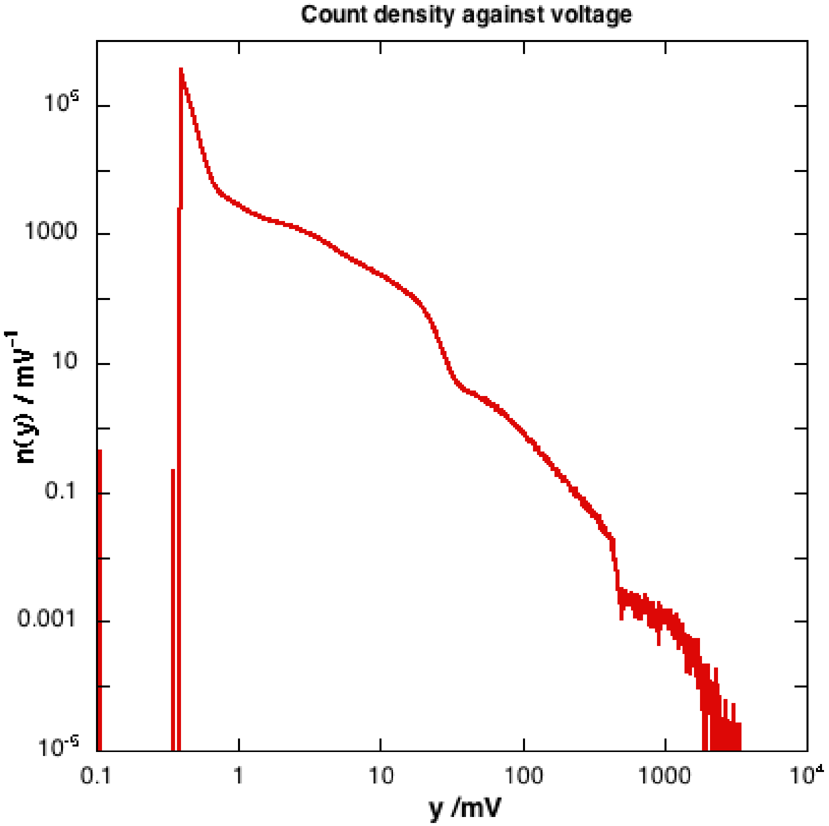




kshop.

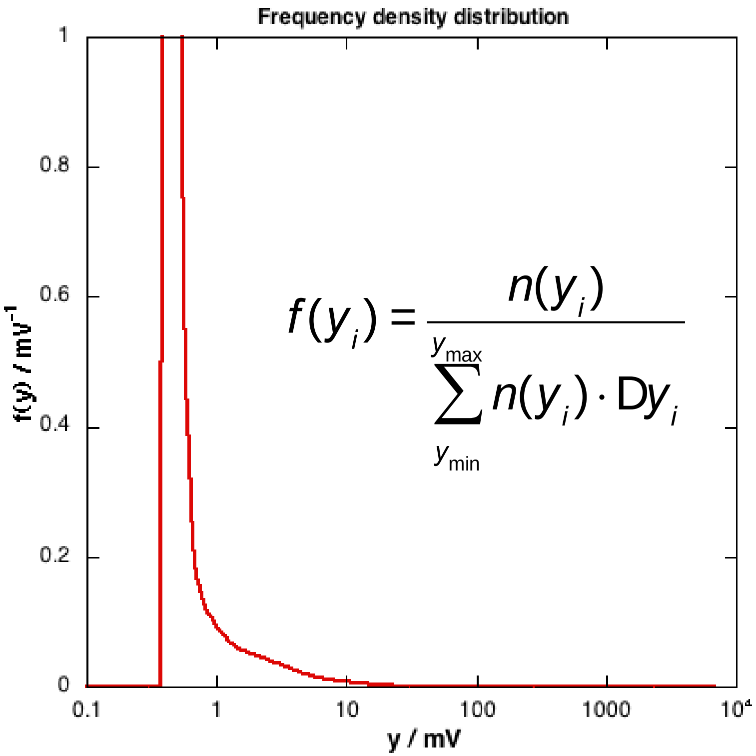
Sub-spectra junction





Sub-spectra junction is not feasible if they do not superimpose

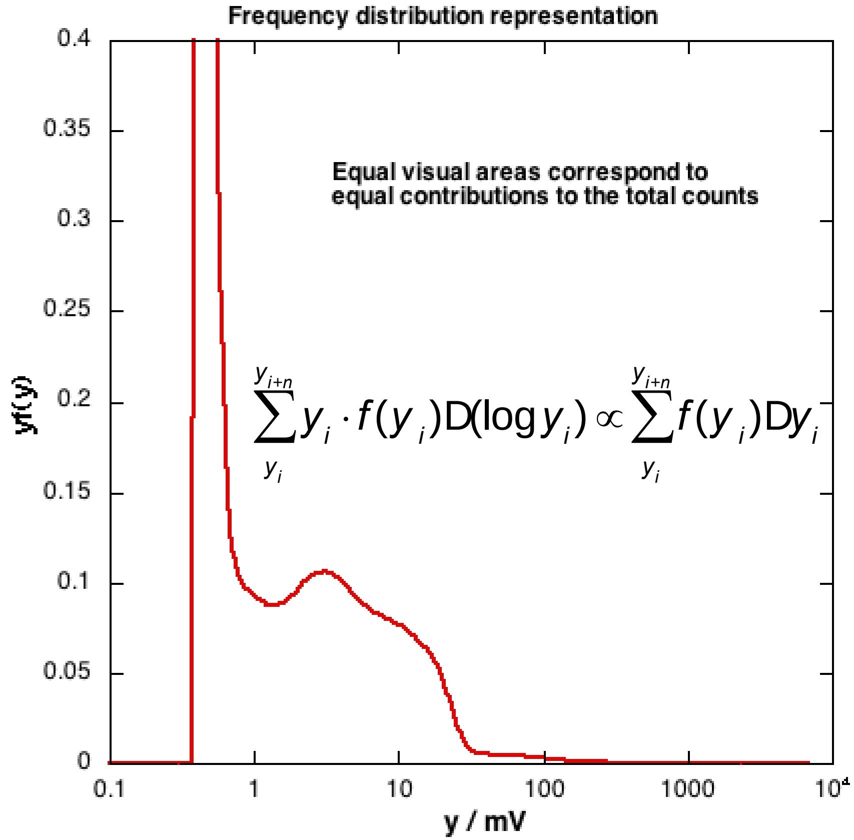
The pulse-height frequency distribution



$$f(y_i) = \frac{n(y_i)}{\sum_{y_{min}}^{y_{max}} n(y_i) \cdot \Delta y_i}$$

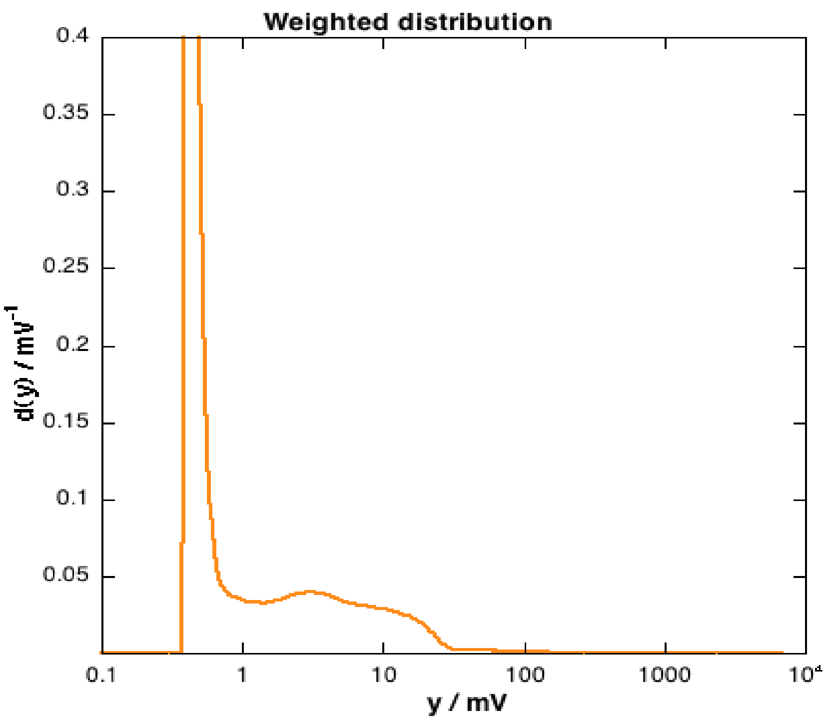
$$\sum_{y_{min}}^{y_{max}} f(y_i) \cdot \Delta y_i = 1$$

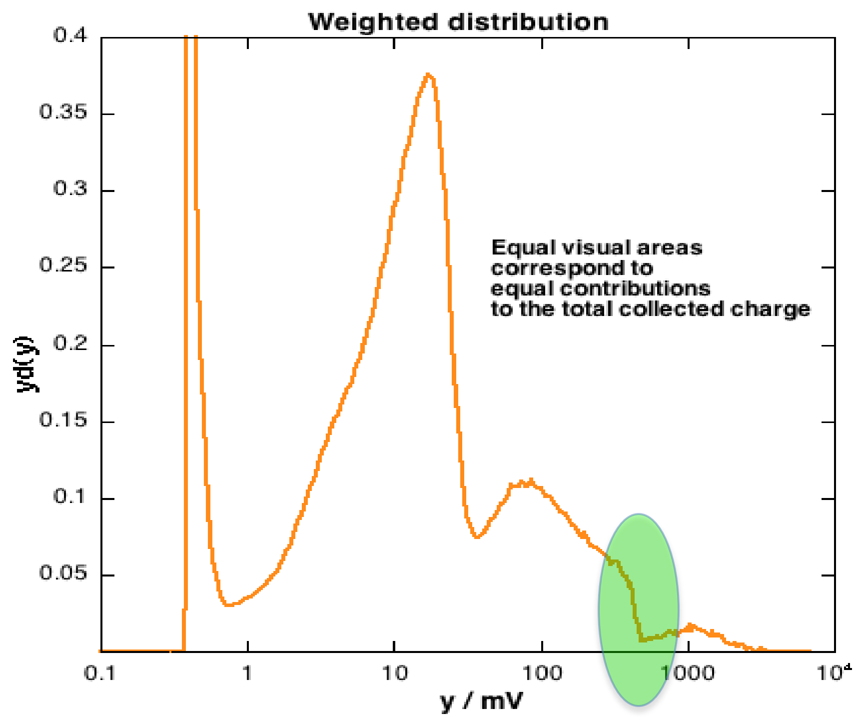
$$d(\log y) = \frac{dy}{y} \times \log e$$



$$\sum_{y_i}^{y_{i+n}} y_i \cdot f(y_i)\Delta(\log y_i) \propto \sum_{y_i}^{y_{i+n}} f(y_i)\Delta y_i$$

The pulse-height weighted distribution

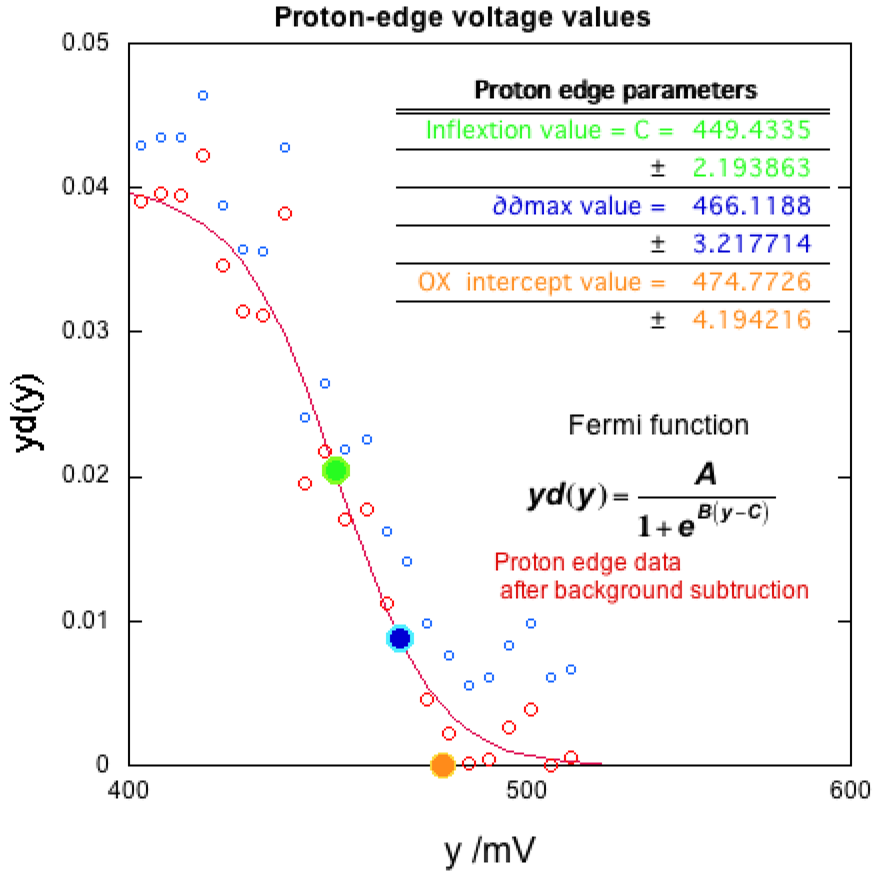


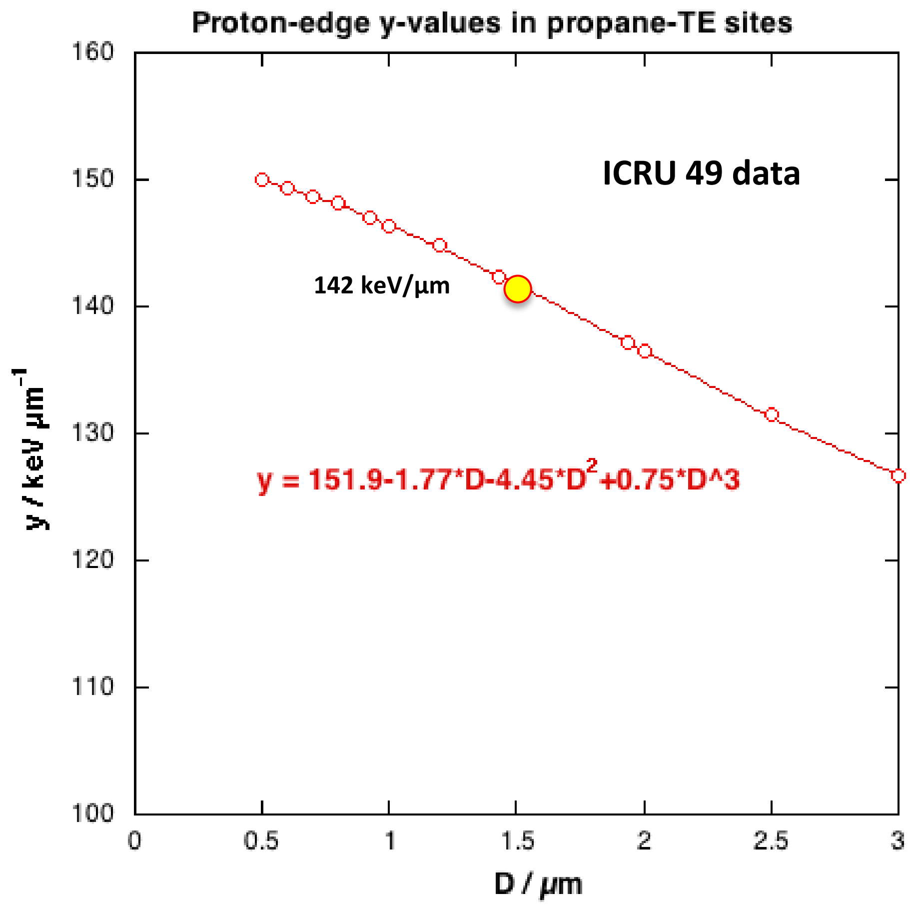


$$d(y_i) = \frac{y_i \cdot f(y_i)}{\sum_{y_{min}}^{y_{max}} y_i \cdot f(y_i) \cdot \Delta y_i} = \frac{y_i \cdot f(y_i)}{\bar{y}_F}$$

$$\sum_{y_i}^{y_{i+n}} y_i \cdot d(y_i) \Delta(\log y_i) \propto \sum_{y_i}^{y_{i+n}} d(y_i) \Delta y_i = 1$$

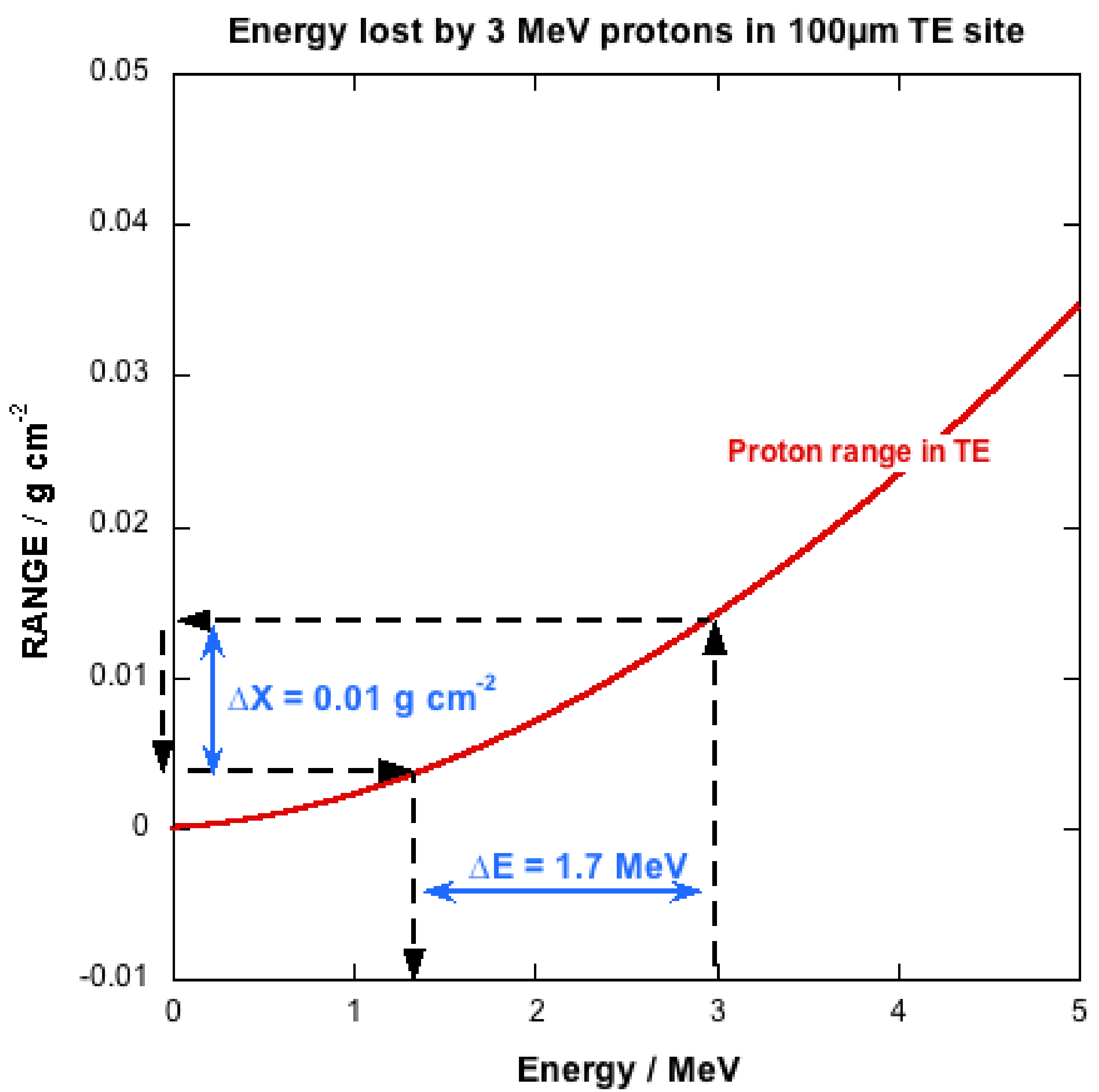
Lineal energy calibration



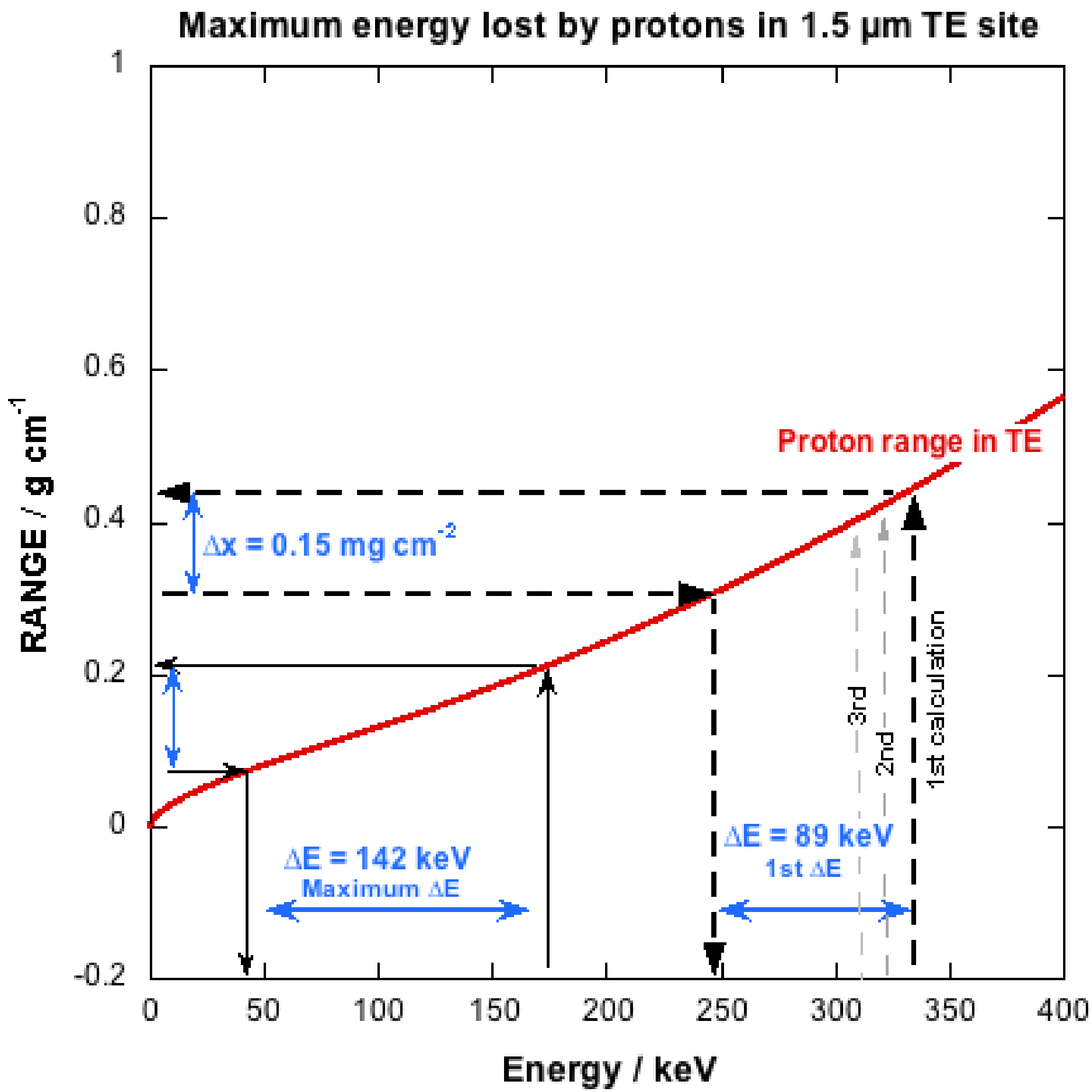


Calibration factor: 142/475 = 0.299

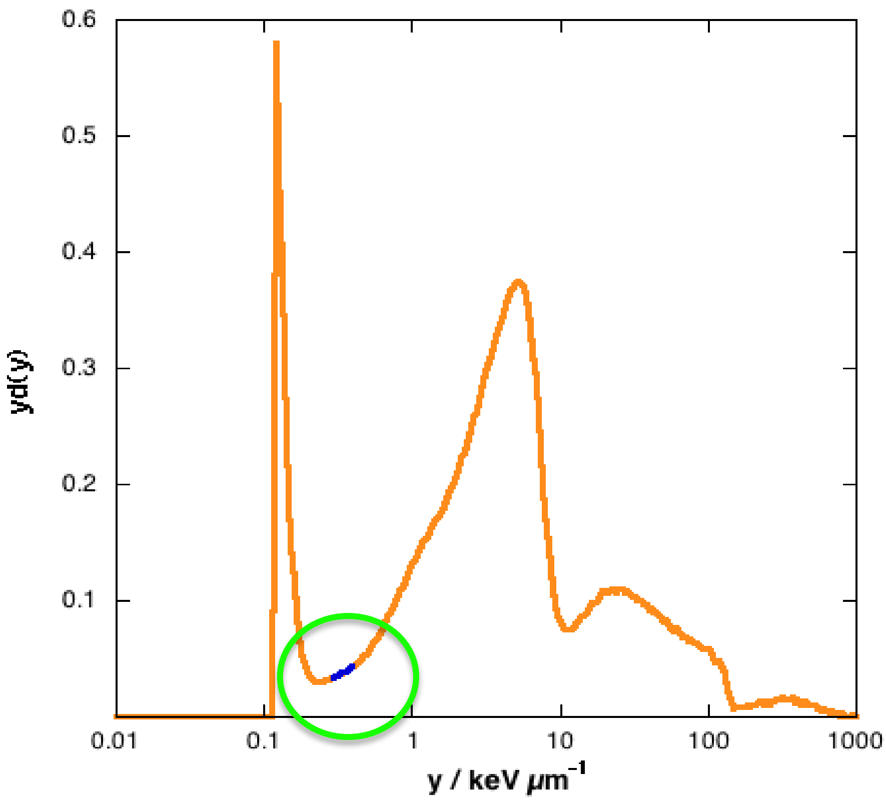
ΔE calculation in CSDA

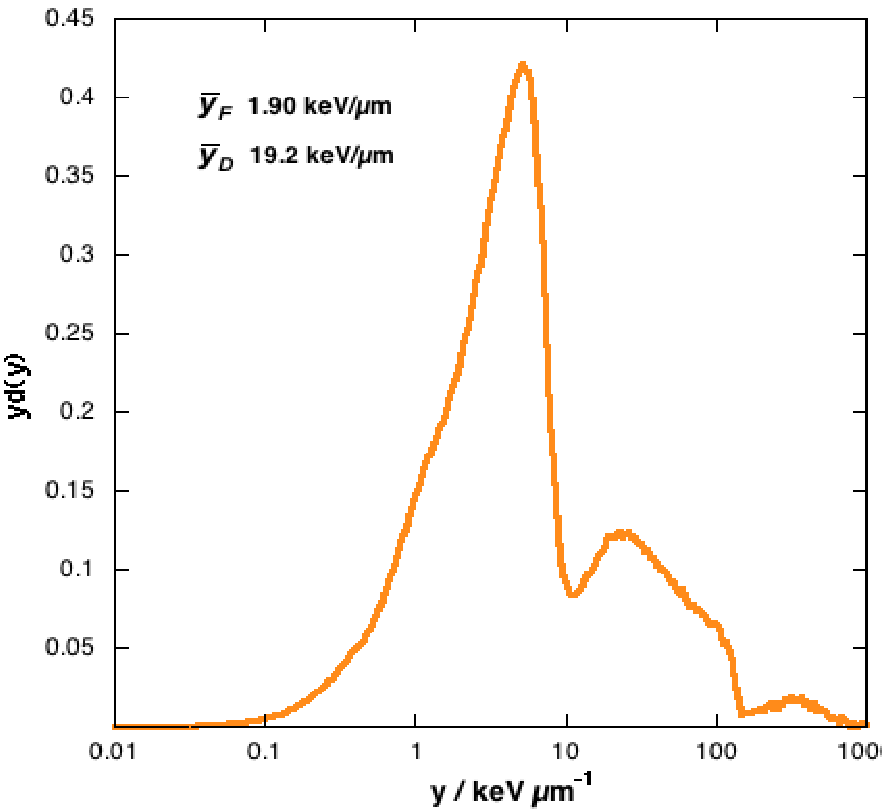


Maximum ΔE-lost calculation in CSDA



Lineal-energy dose distribution

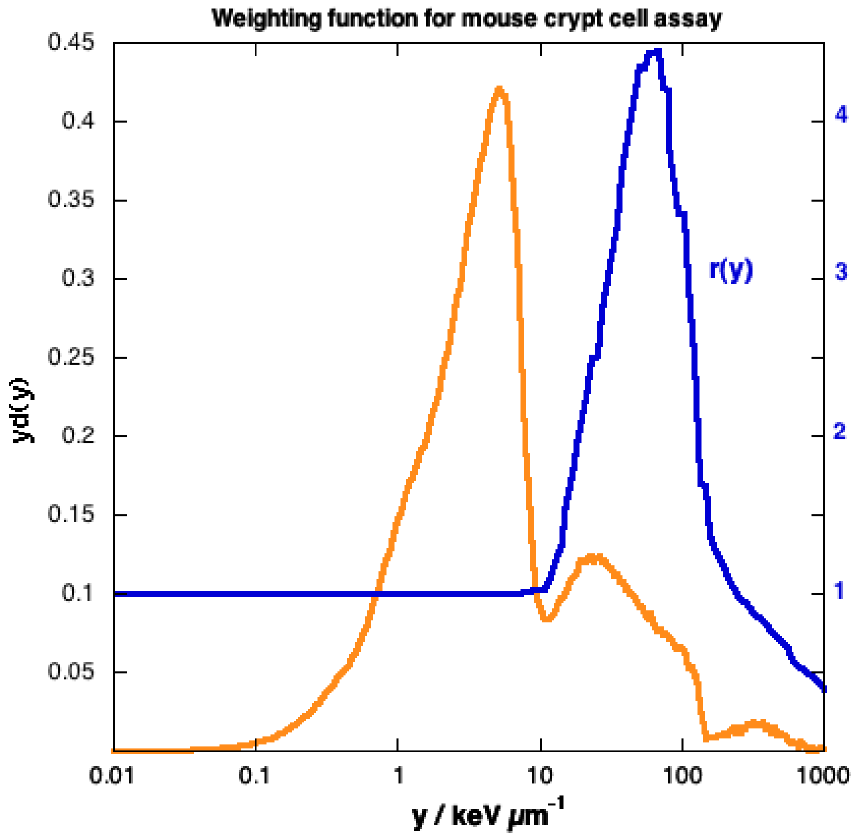


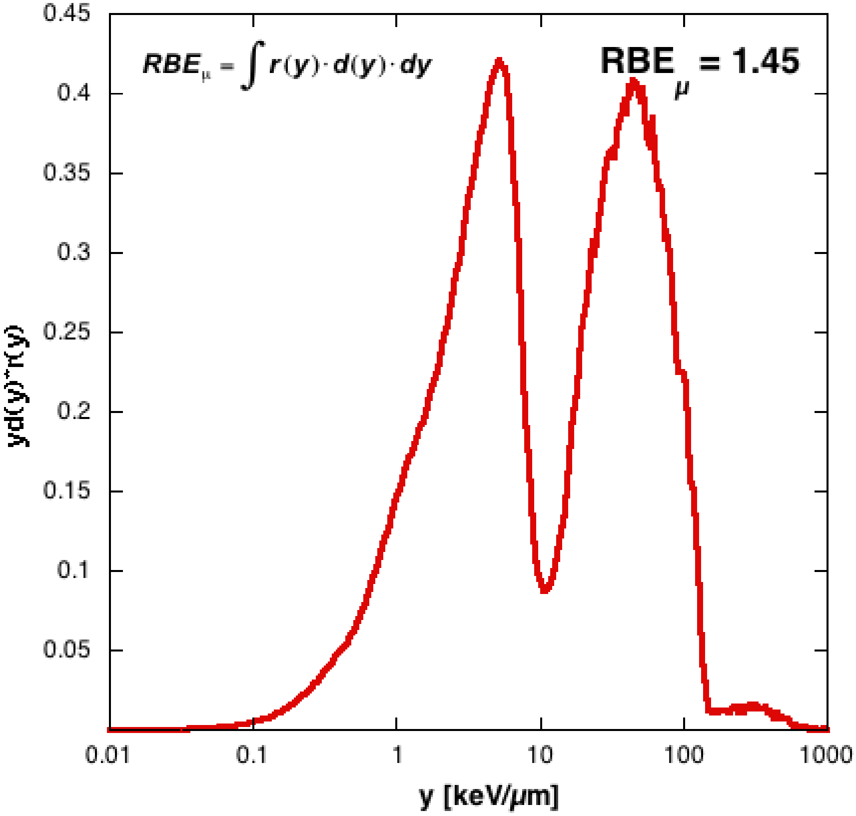


Blue points are used to linearly extrapolate the frequency y-values down to 0.01 keV/μm

Fractional part of the visual area is the fractional contribution to the the absorbed dose by the corresponding y-events

Weighting the dose distribution with a biological-significant function

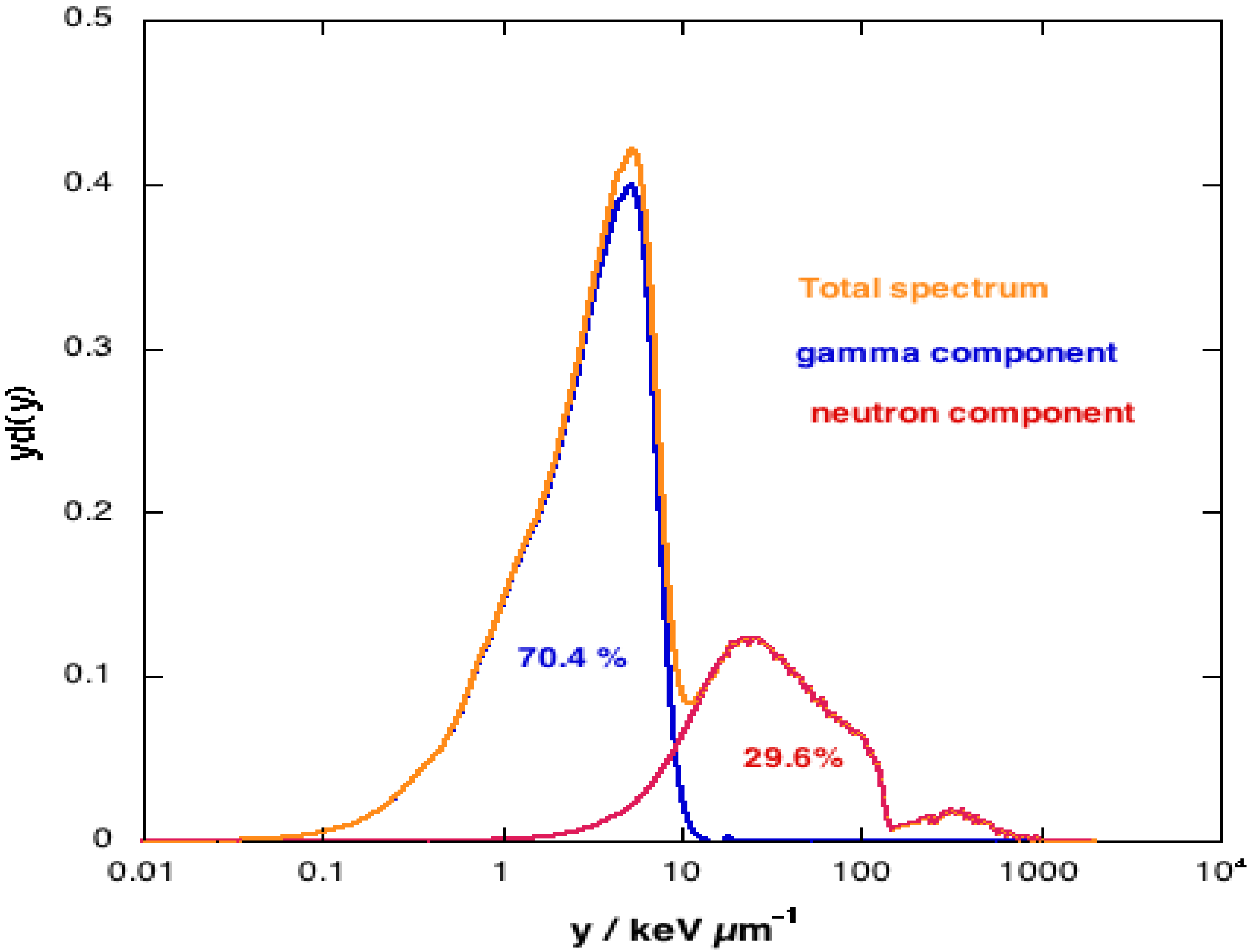




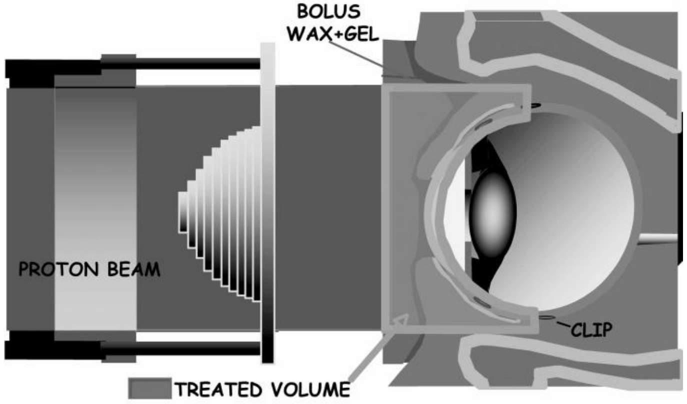
The weight is **1** for y-values < 10 keV/μm
The weight is **< 1** for y-values ≈> 200 keV/μm

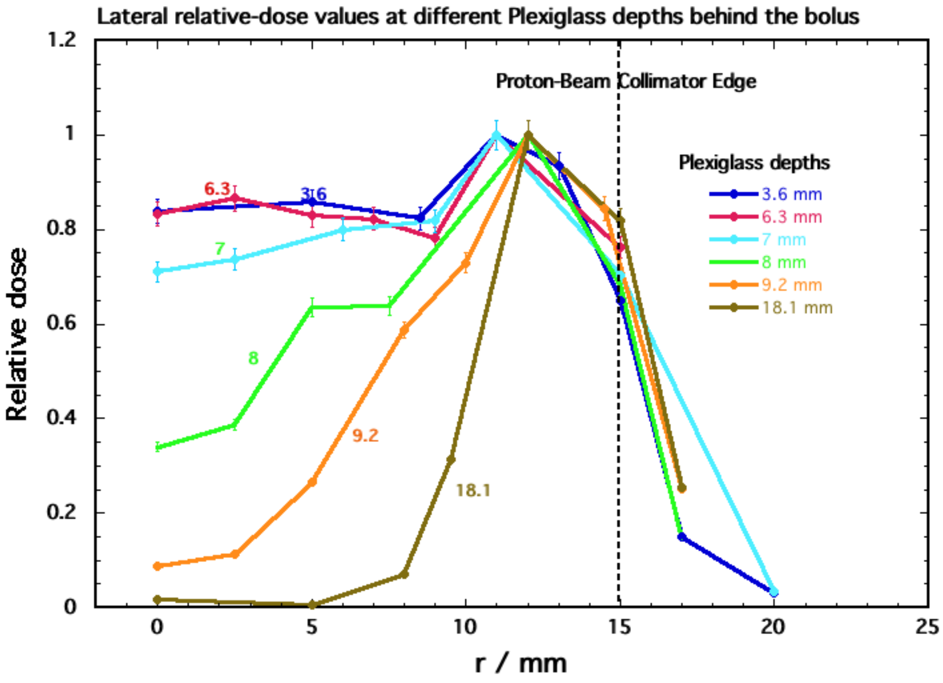
Fractional part of the visual area is the fractional contribution to the effective-dose of corresponding y-events

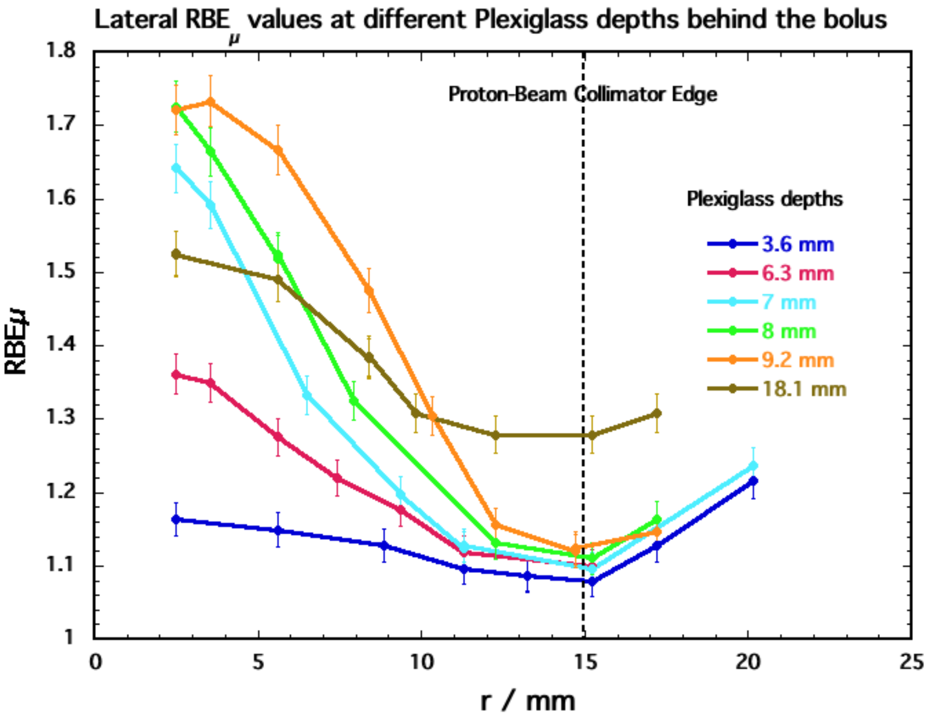
Splitting the dose spectrum in its neutron and gamma components



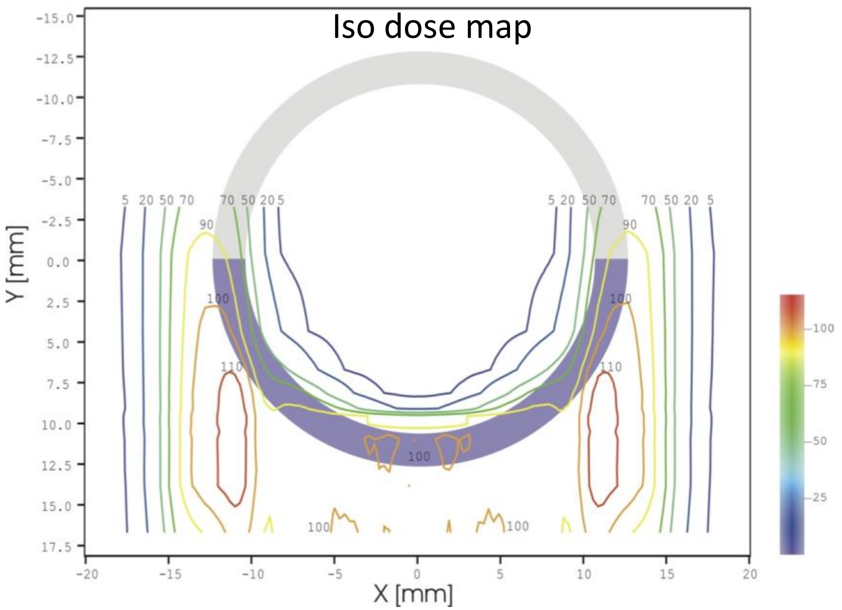
Quality of the conjunctive-melanoma proton-therapeutic beam

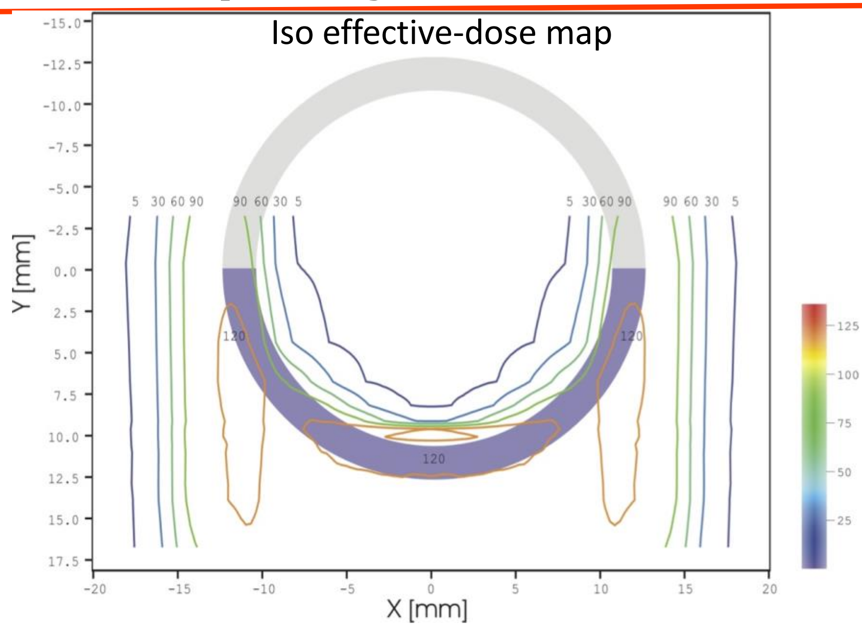


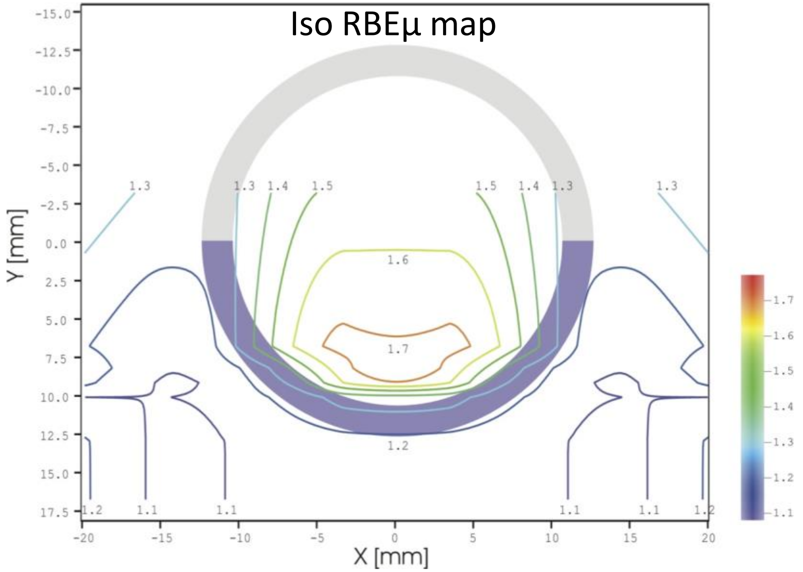




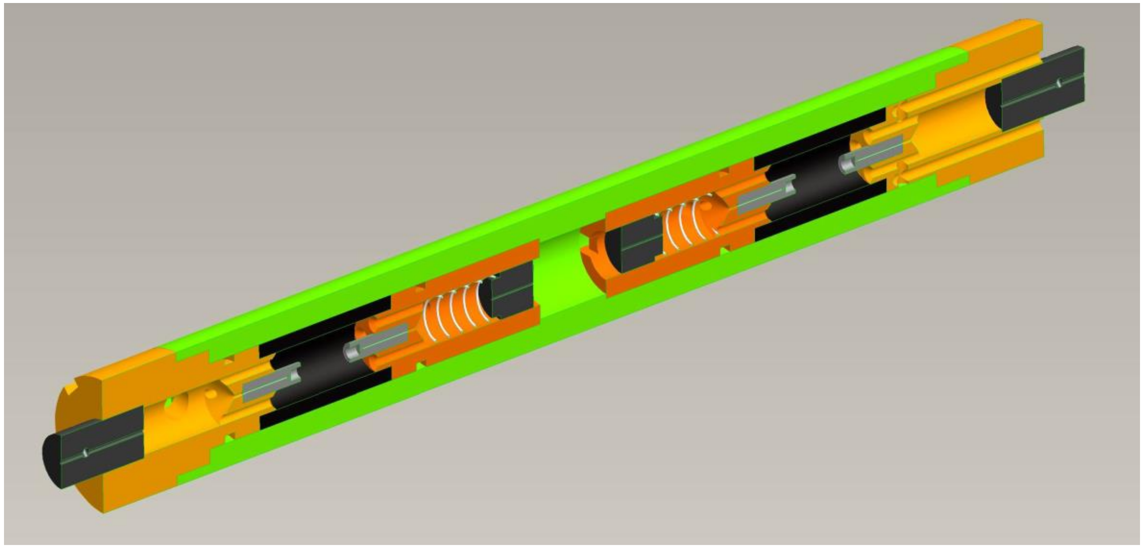
The therapeutic beam quality

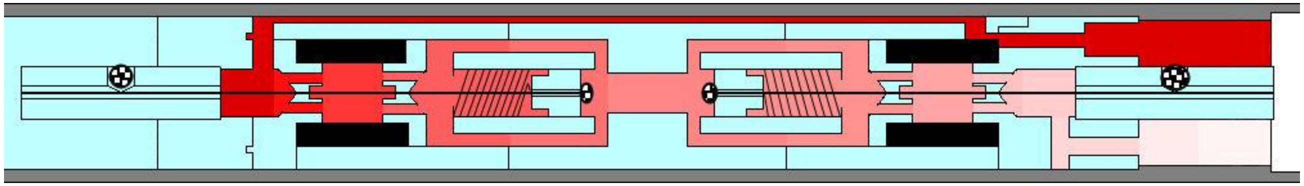




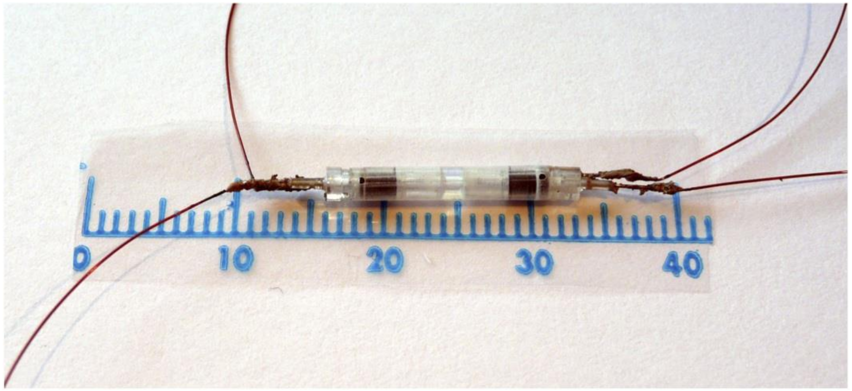


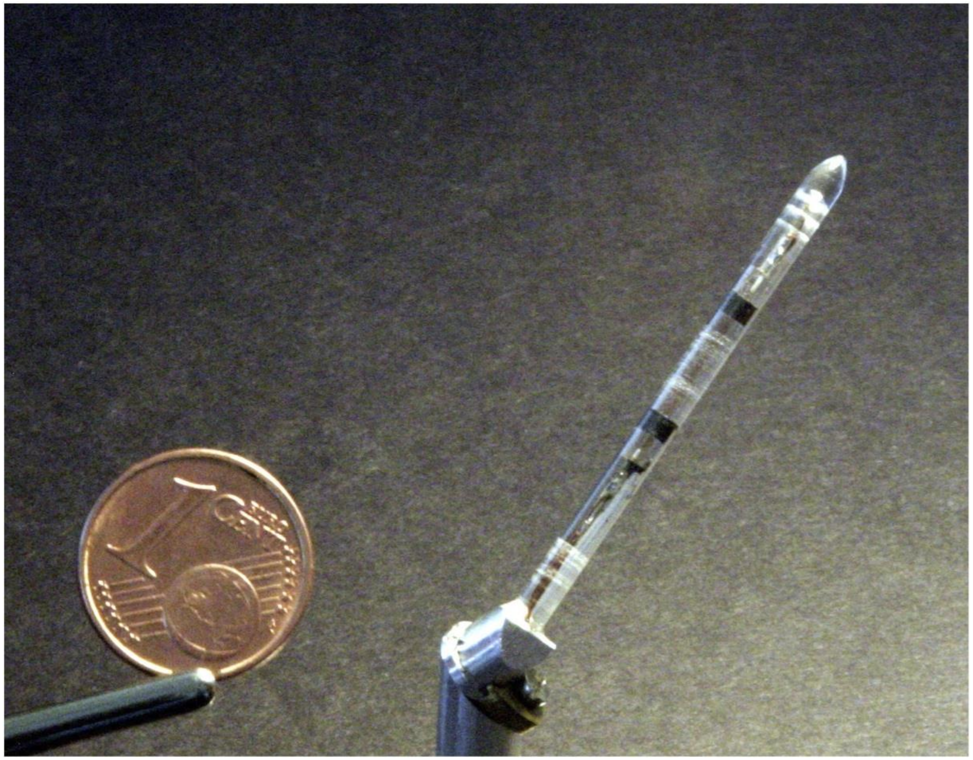
Two mini TEPCs for quality measurements of BNCT radiation fields





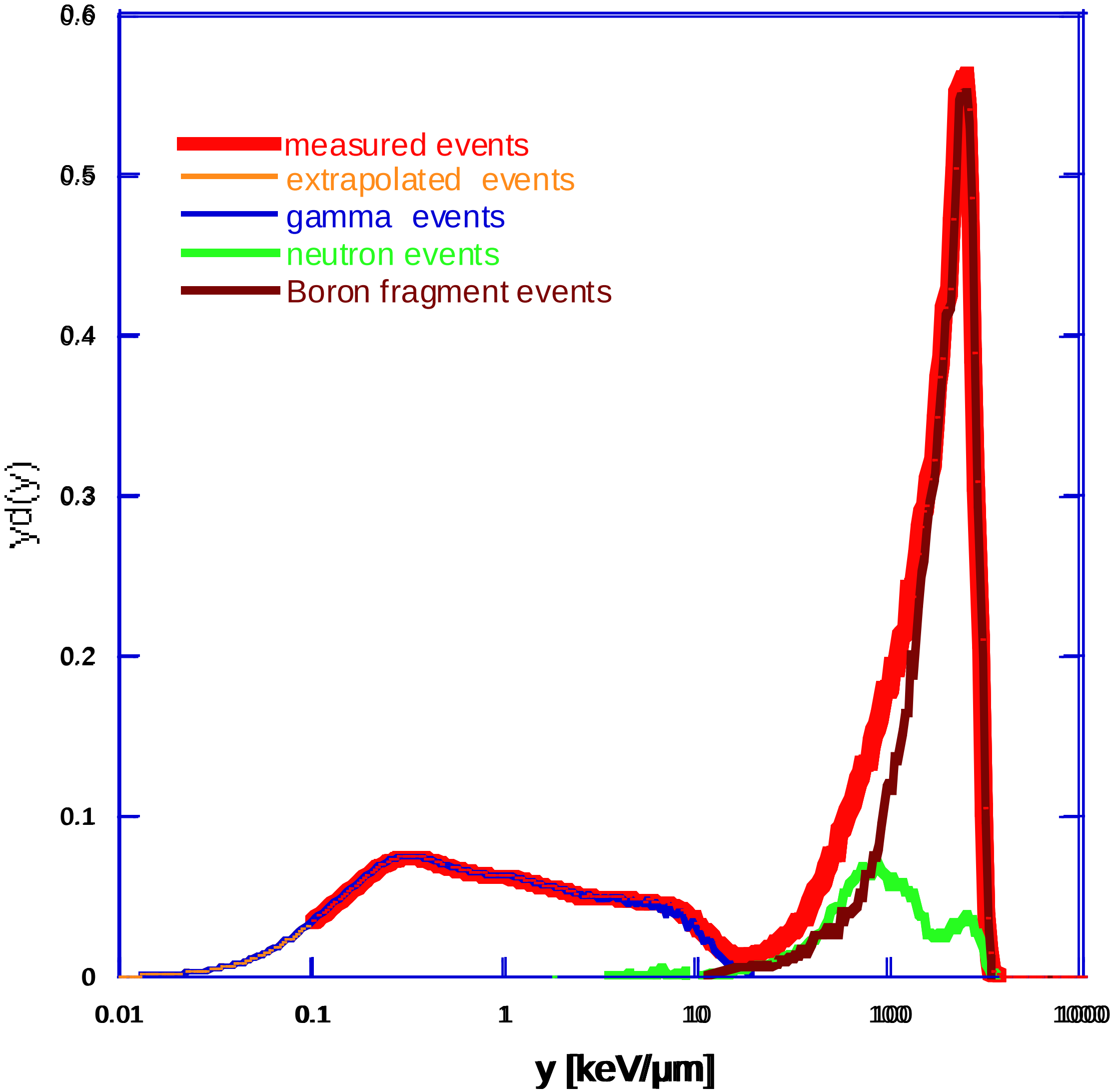
The twin TEPC for BNCT





BNCT dose components

twin TEPC measurements



Suggested lectures

- Glenn F.Knoll. *Radiation Detection and Measurements*. John Wiley & Sons, NY, 1979

- ICRU Report 36. *Microdosimetry*. 1983