Critical assessment of physical data to calibrate microdosimetric spectra

Sabina Chiriotti

D. Moro[3], V. Conte[3], P. Colautti[3], B. Grosswendt[4], E. Sterpin[2] and S. Vynckier[2,5]

[1]Belgian Nuclear Research Centre, SCK•CEN, Mol, Belgium
[2] MIRO, Université catholique de Louvain, UCL, Brussels Belgium
[3] Laboratori Nazionali di Legnaro, LNL-INFN, Legnaro, Italy
[4] Guest at Laboratori Nazionali di Legnaro, LNL-INFN, Legnaro, Italy
[5]Cliniques universitaires St-Luc, Université catholique de Louvain, Brussels, Belgium

Challenges in micro-and nanodosimetry for ion beam cancer therapy (MiND-IBCT)
Wiener Neustadt 07-09 May 2014

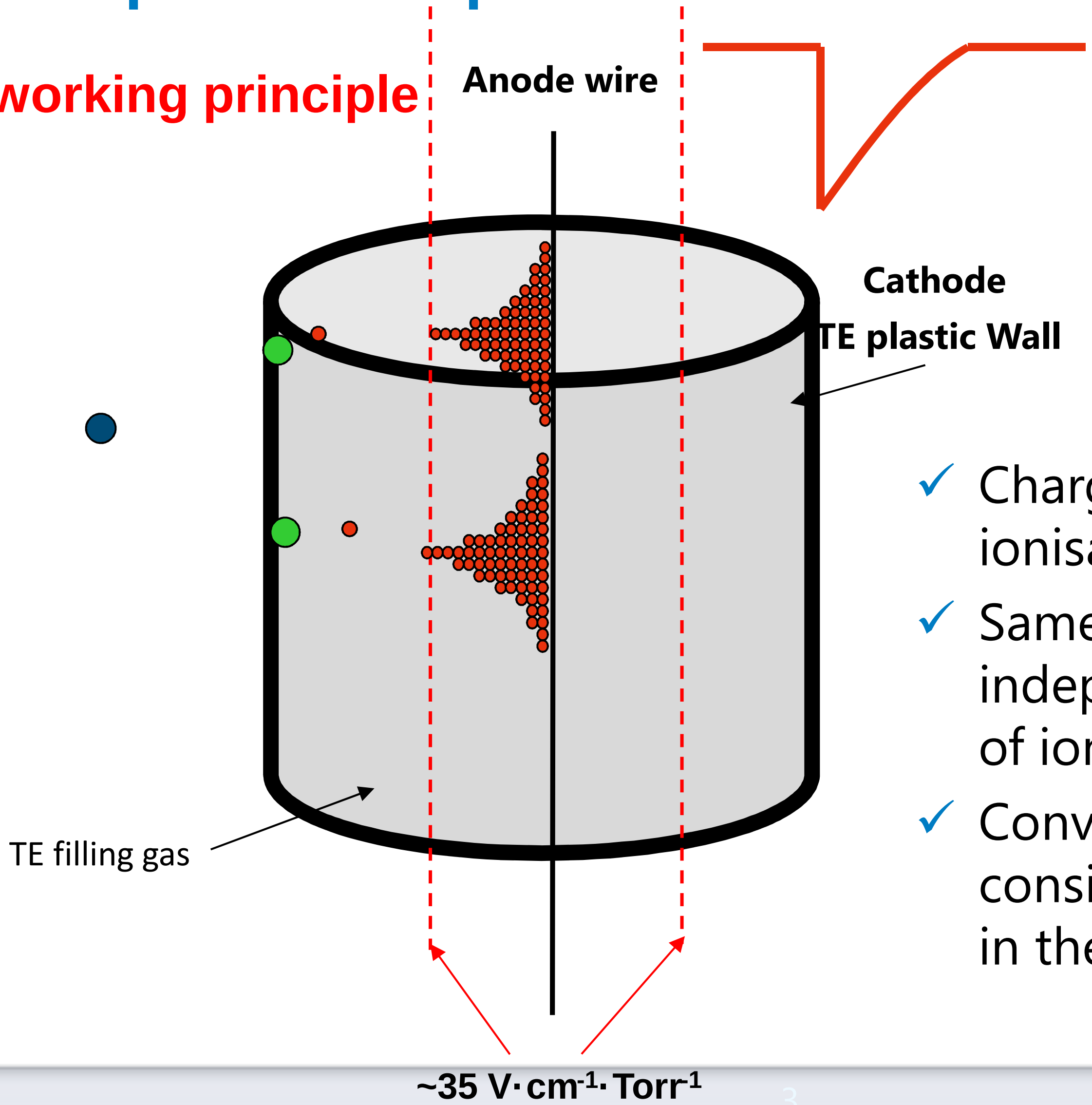
Outline

1. Introduction & motivation
2. Calibration TEPC
3. Electron / Proton / carbon edges
4. Physical data
5. Discussion

1. Introduction

Tissue Equivalent Proportional Counter = TEPC

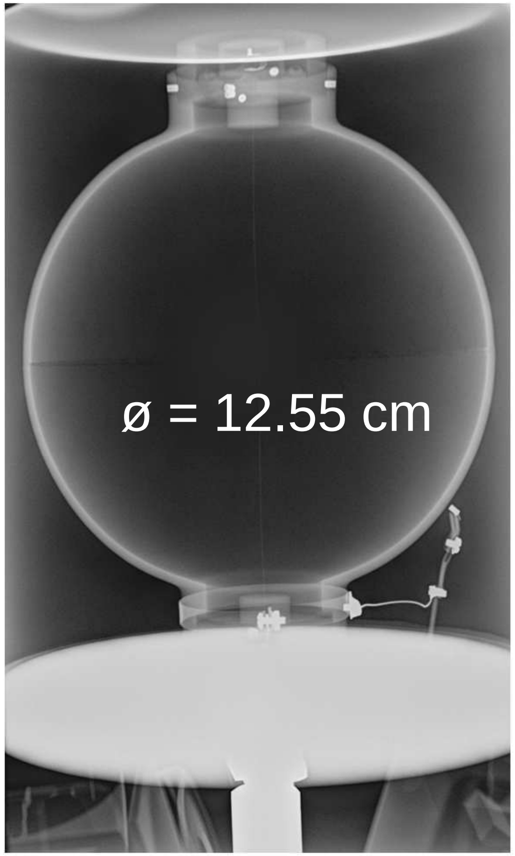
the working principle

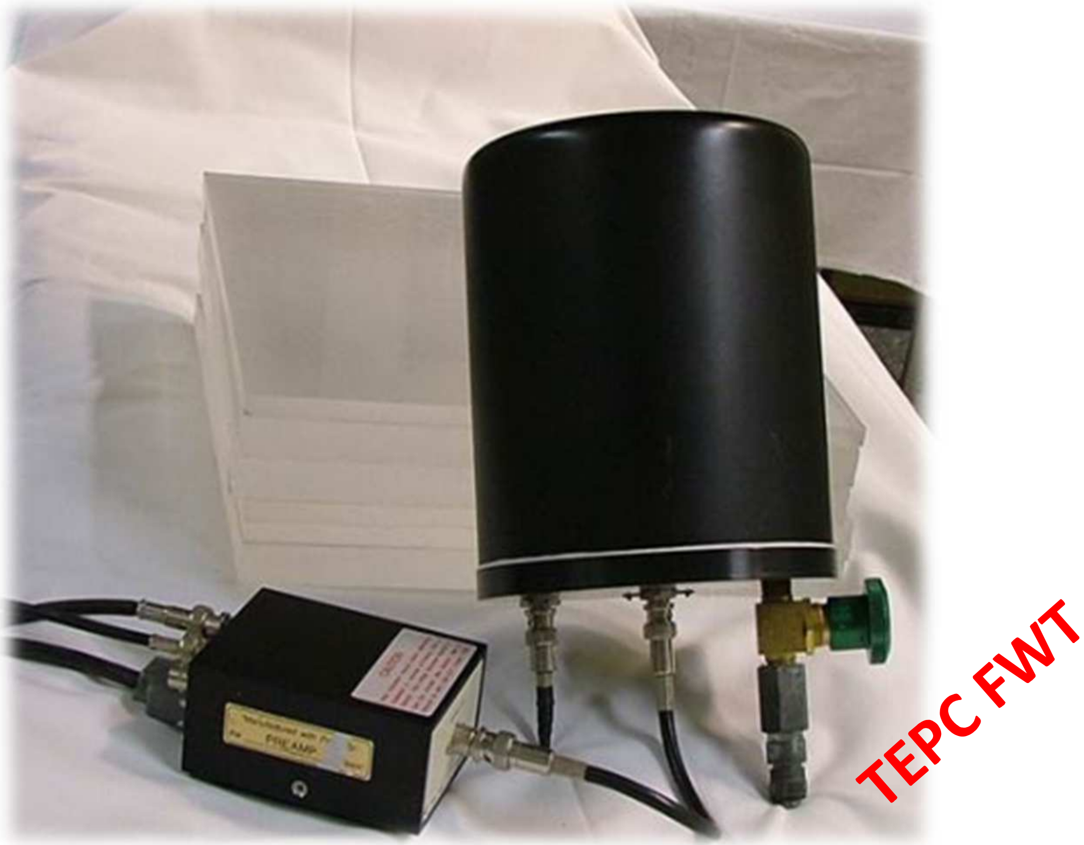


- ✓ Charged collected ~ initial ionisation
- ✓ Same gas multiplication independently of the location of ionisation
- ✓ Conversion to lineal energy considering constant W-value in the ranged measured

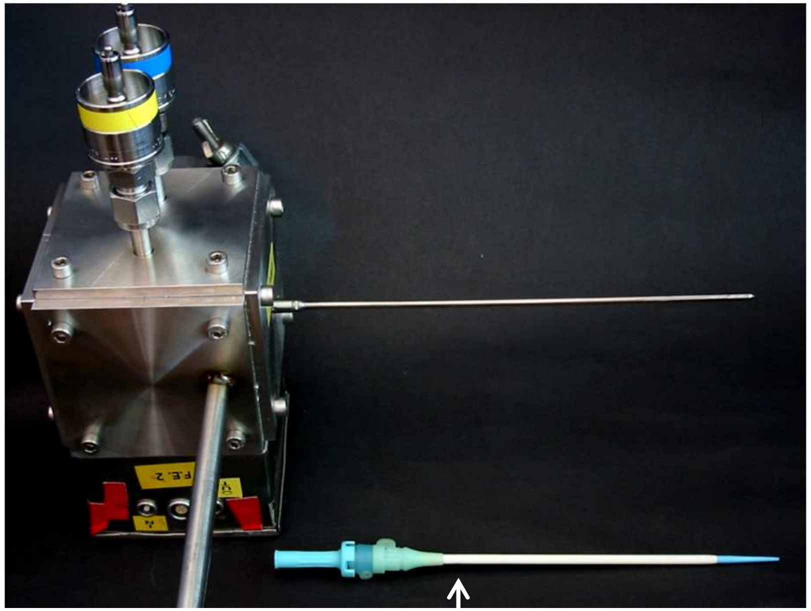
2. Devices:

-Internal alpha sources (Cm-244)



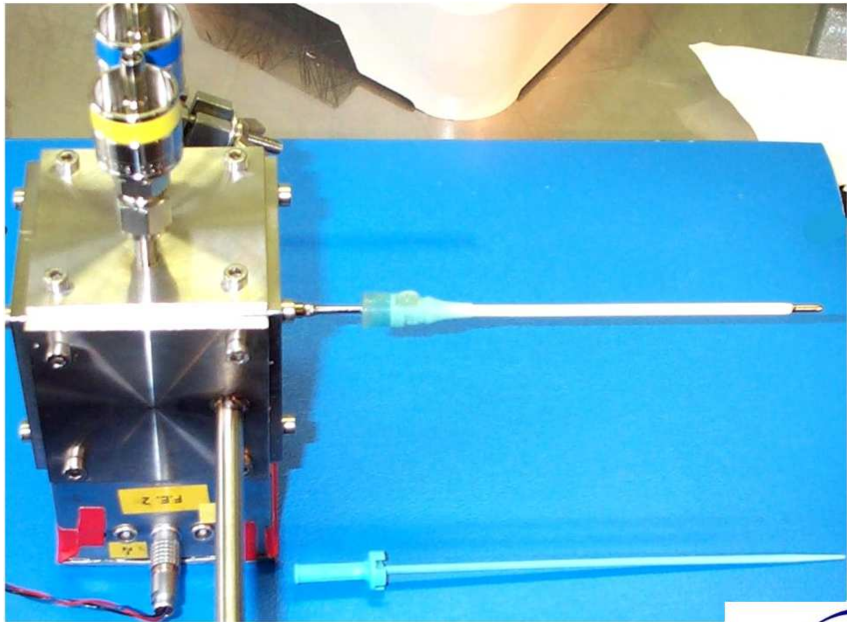


Mini TEPCs with small external dimensions can be used for inside-the-body microdosimetry

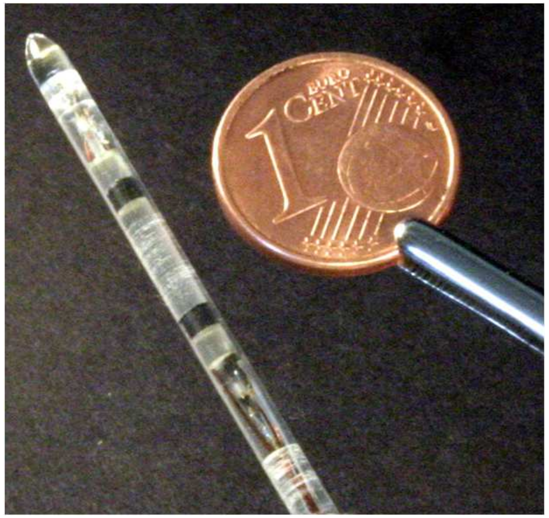


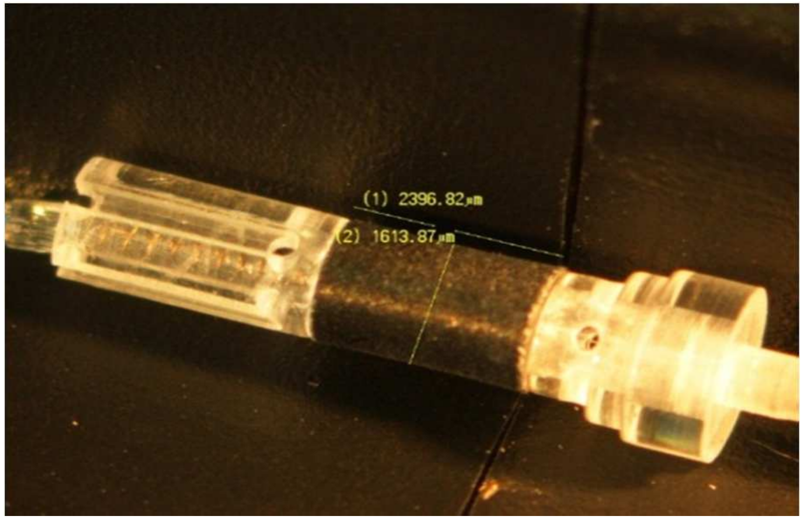
8 French cannula
for mini invasive surgery

External dimensions:
diameter of 2.7 mm
(to fit 8 French cannula



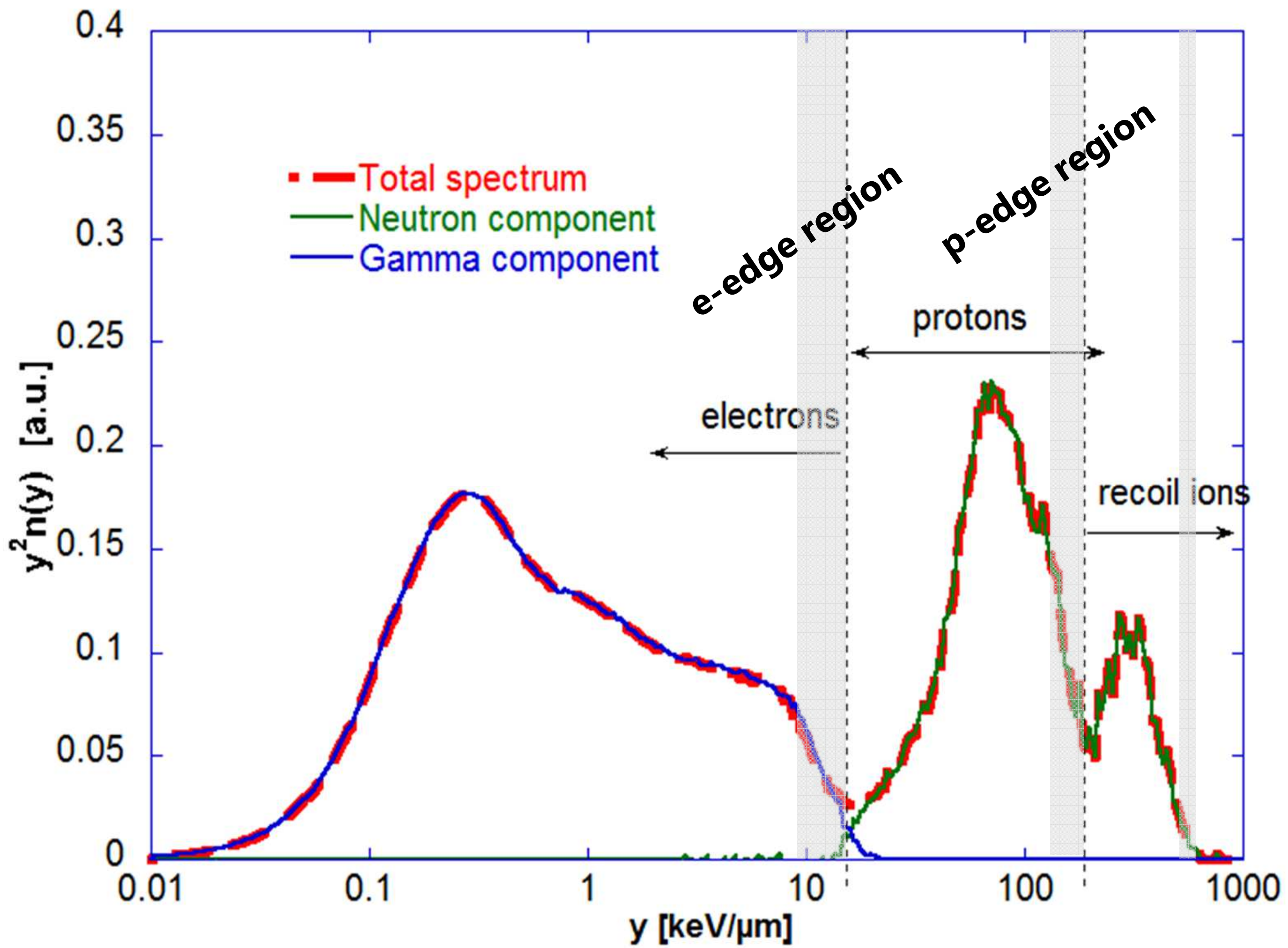
Mini TEPCs internal dimensions





Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

2. Calibration of TEPCs: "edge analysis"



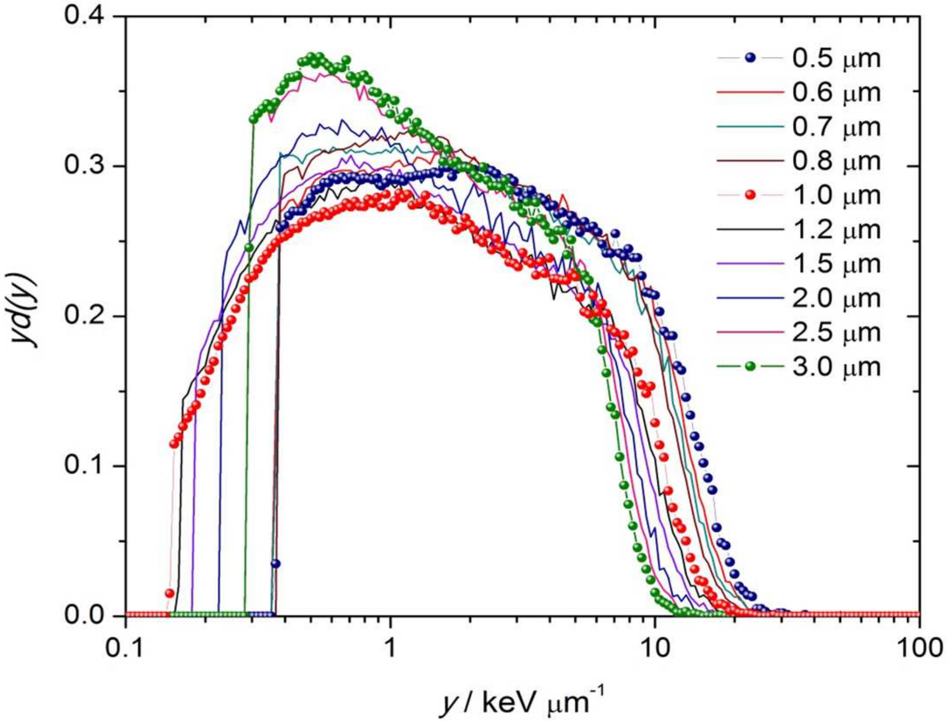
- Identification of special features in the microdosimetric spectra:

2. Calibration of TEPCs

- **Calibration Factor** depends on :

$$k(d)_{\mathrm{cal}} = \frac{y_{\mathrm{p-edge}}(d)}{h_{\mathrm{p-edge}}}$$

  - Marker point of the edge used
  - Simulated diameter
  - Gas composition
  - Counter geometry
  - Stopping power data



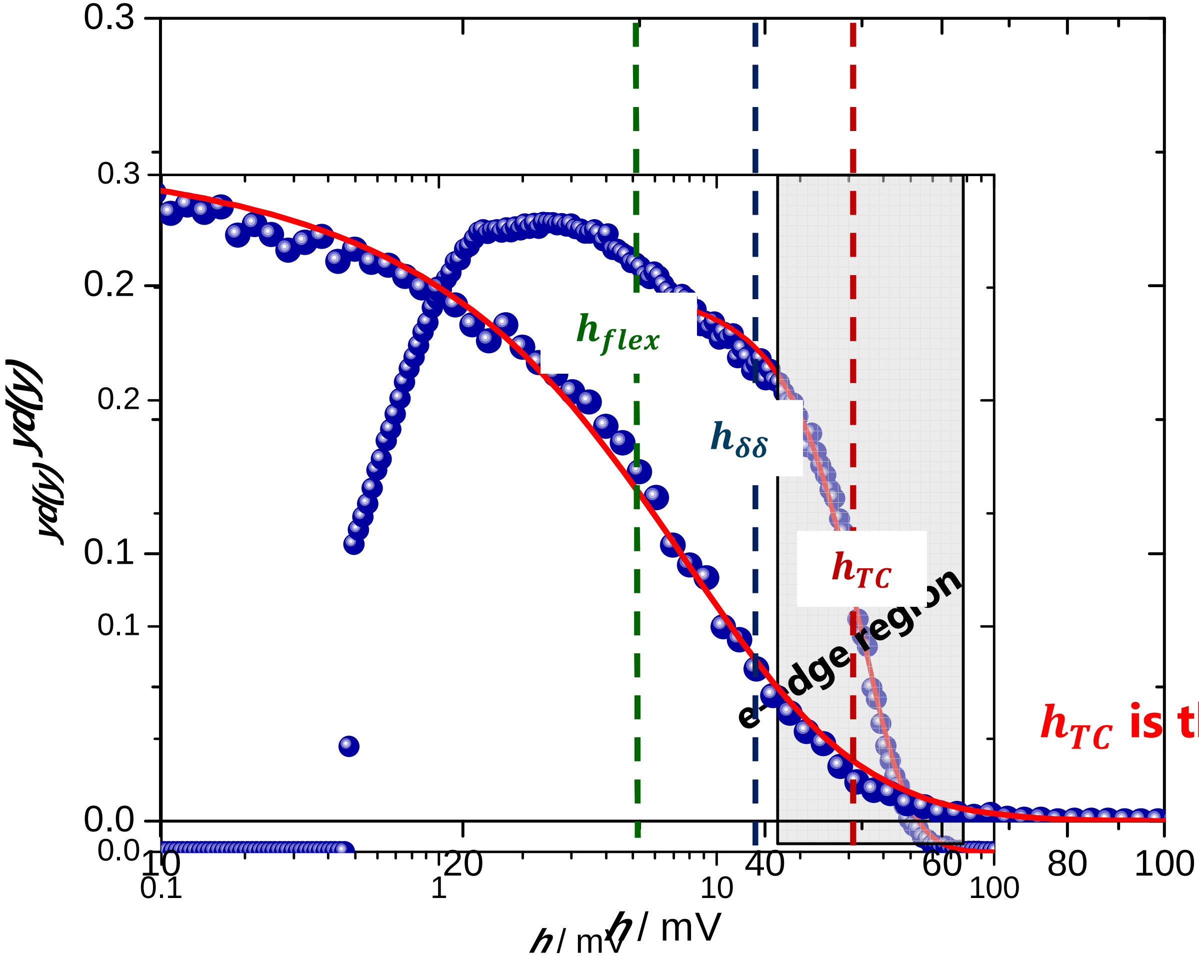
Calibration → Highest source of uncertainty

Objective with mini TEPCs → can measure radiation quality < 5% uncertainty

D. Moro, S. Chiriotti, V. Conte, P. Colautti, B.Grosswend. *Calibration of TEPCs with a 137Cs gamma source.* Rad. Prot. Dosim 2013 submitted.

2. Calibration of TEPCs: Precision

Identification of the "marker point" to calibrate spectra:



Fermi-like function

$$h \cdot d(h) = \frac{A}{1 + e^{B \cdot (h - C)}}$$

$$h_{flex} = C$$

$$h_{\delta\delta} = \frac{\ln(2+\sqrt{3})}{B} + C$$

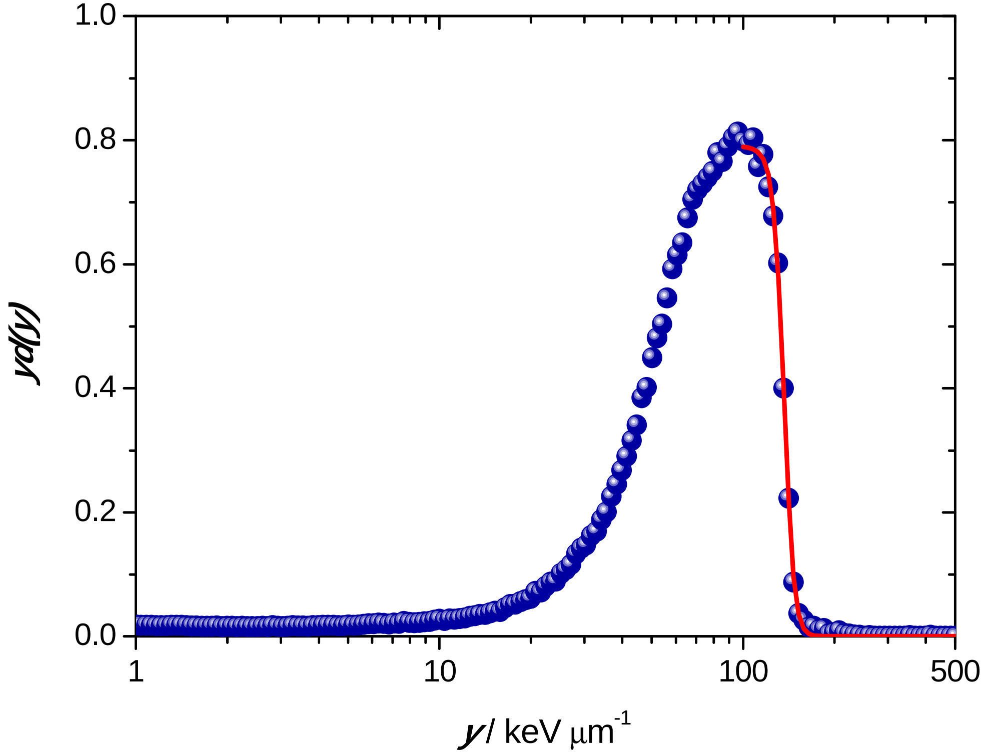
$$h_{TC} = \frac{2}{B} + C$$

h_{TC} is the one with highest precision

V. Conte, D. Moro, P. Colautti, B. Grosswend. *Lineal Energy Calibration Of Mini Tissue Equivalent Gas-Proportional Counters* (TEPC). Multidisciplinary applications of nuclear physics with ion beams. 2012.

2. Calibration of TEPCs

Precision	Accuracy



$$h \cdot d(h) = \frac{A}{1 + e^{B\cdot(h-C)}}$$

- stopping power and W data
- Determination of $y_{\text{p-edge}}(d)$
  - CSDA approximation
  - Monte Carlo simulations
  - Refer to water, tissue or propane-TE ?

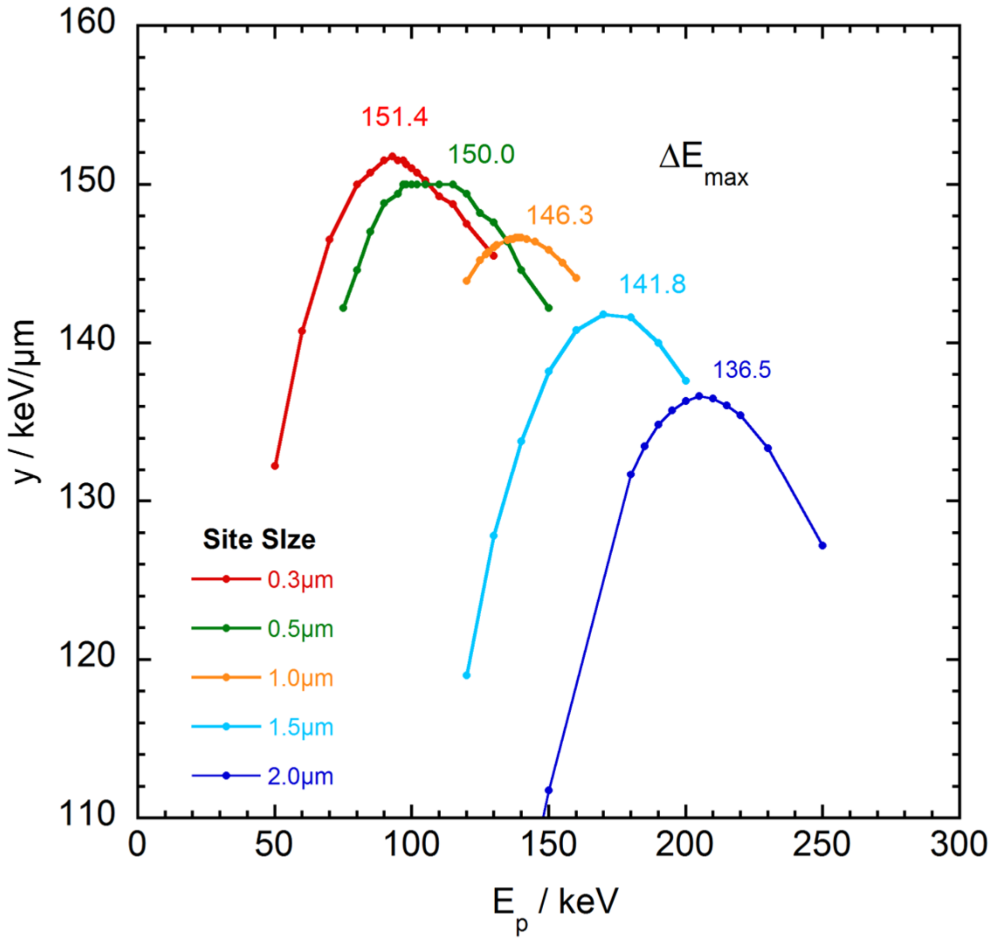
4. Proton edge

- CSDA approximation

$$\Delta E = E_{in}(R_{in}) - E_{out}(R_{in} - d\rho);$$

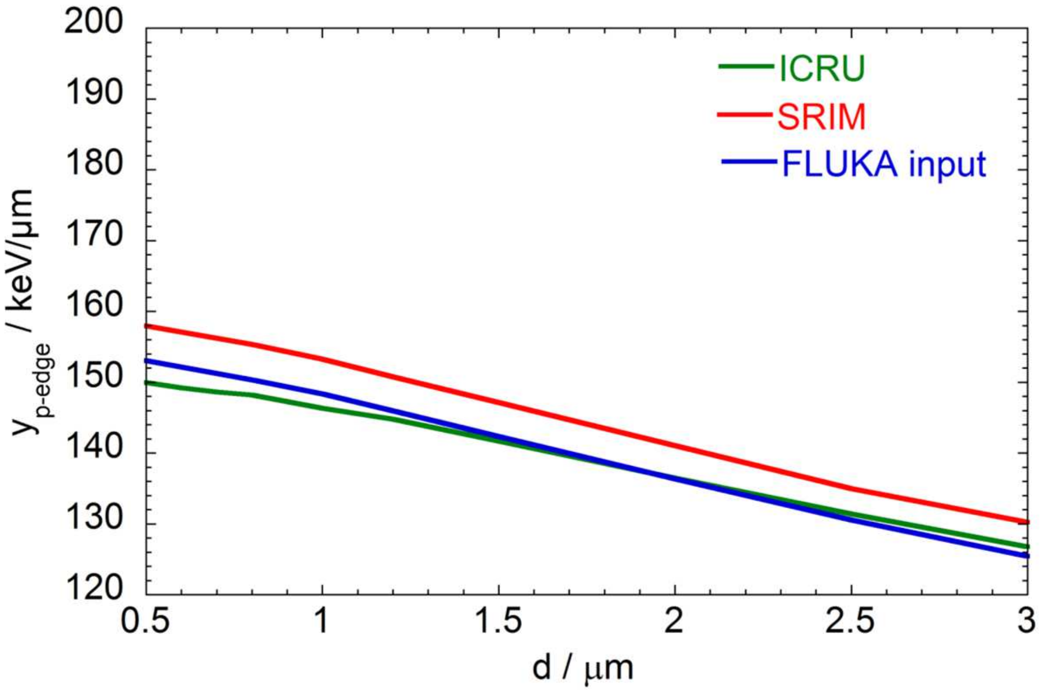
$$y_{p-edge} = \frac{\Delta E_{max}}{\bar{l}}$$

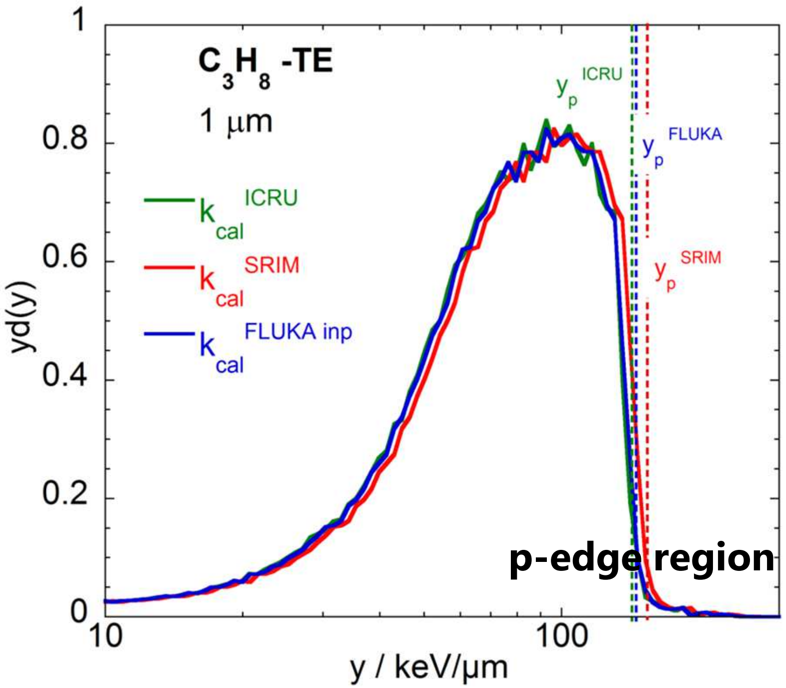
$\bar{l}$ = mean chord length



4. Proton edge: different calibrations

PROPANE-TE



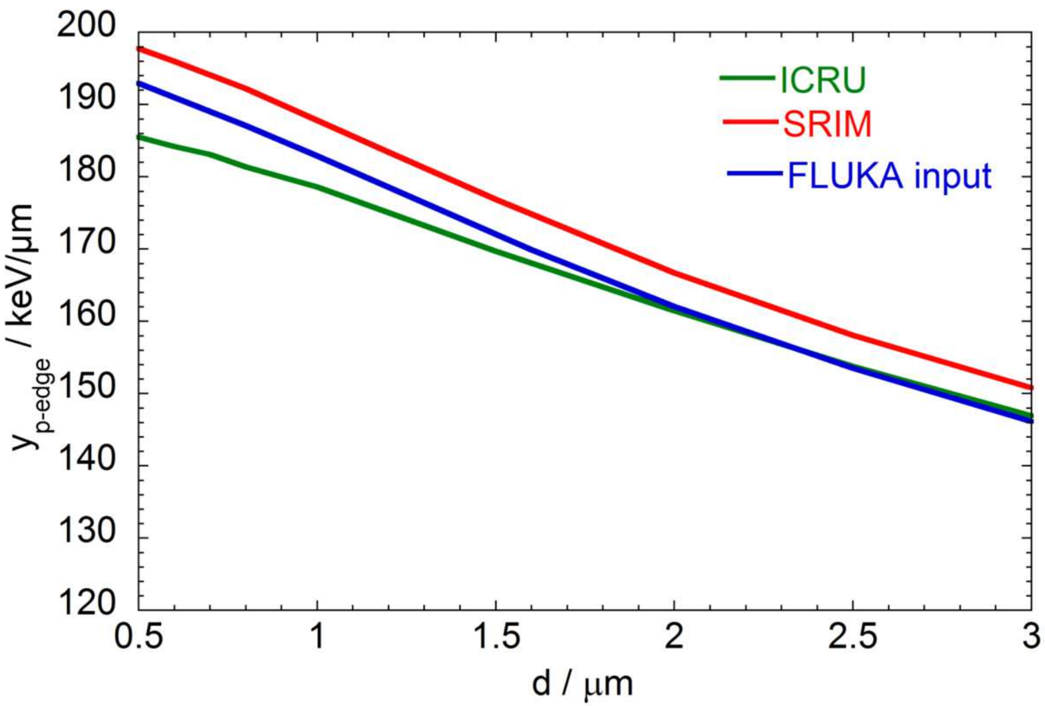


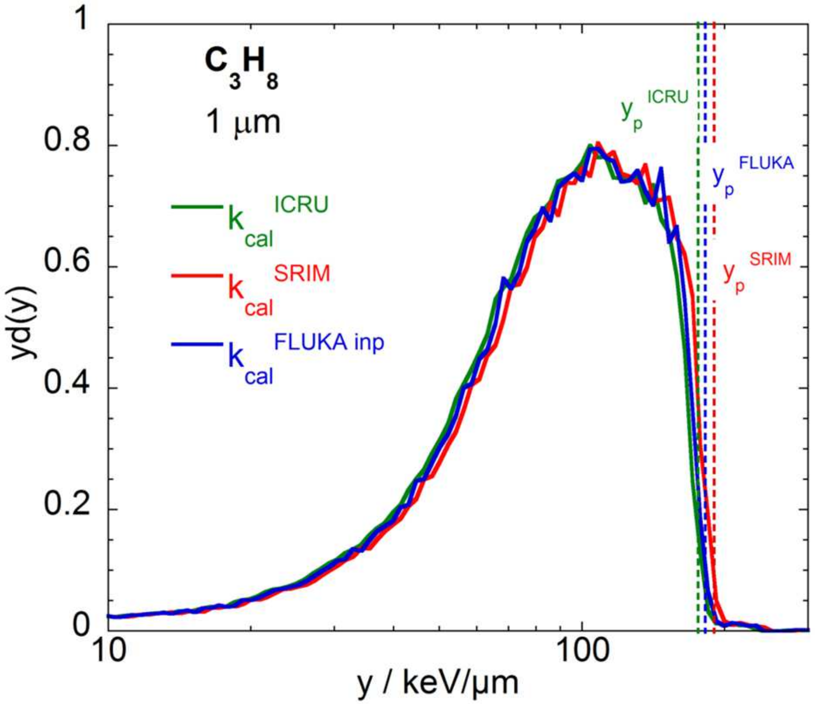
The discrepancies increase for decreasing site size *d* ~ 0.5 µm

S. Chiriotti, D. Moro, P. Colautti, V. Conte, B. Grosswendt, E. Sterpin, S. Vynckier. *Influence of the physical data to calibrate TEPCs*. Rad. Prot. Dosim 2013 submitted.

4. Proton edge: different calibrations

PROPANE





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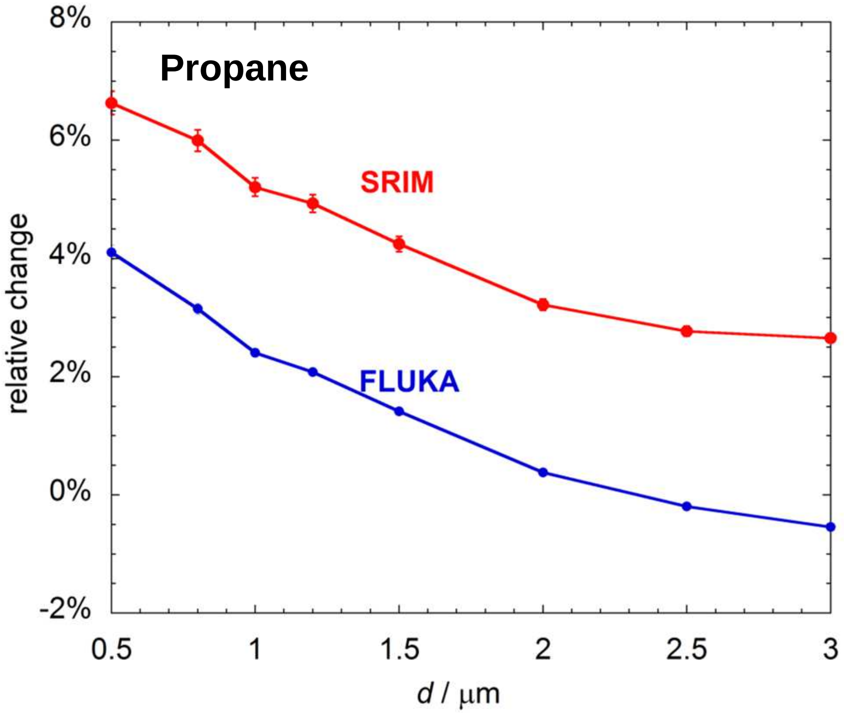
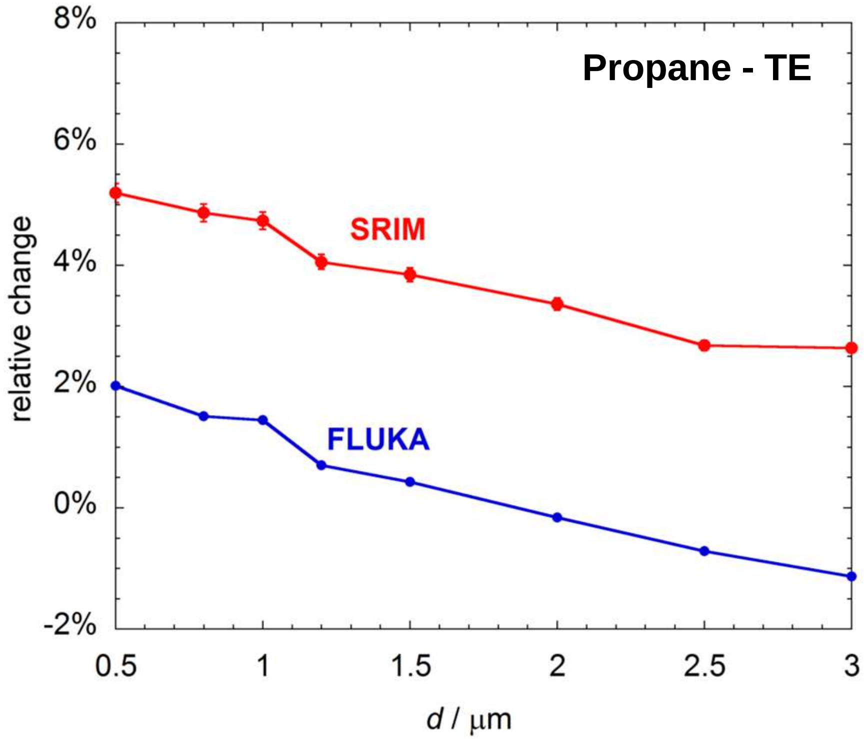
4. Proton edge: microdosimetric values

- Differences in microdosimetric values: $\overline{y}_F, \overline{y}_D$



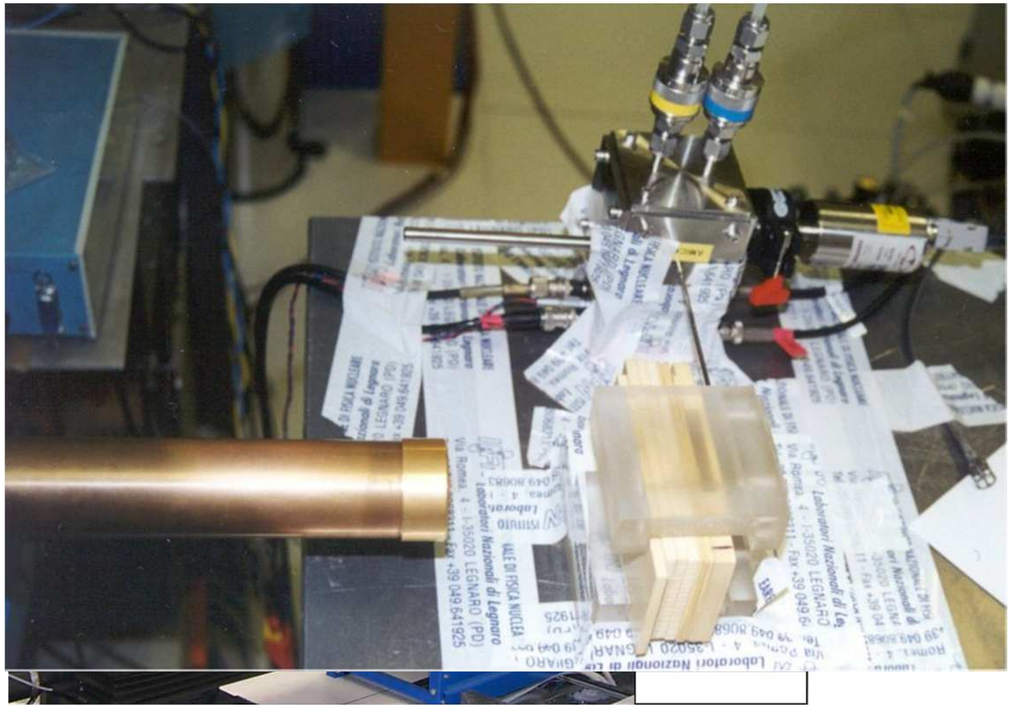


diff ICRU-FLUKA < 2%,

diff SRIM – FLUKA ~6% at 0.5 µm

4. Proton experimental data

Irradiations with 62 MeV modulated proton beam at CATANA facility (LNS-INFN, Catania)



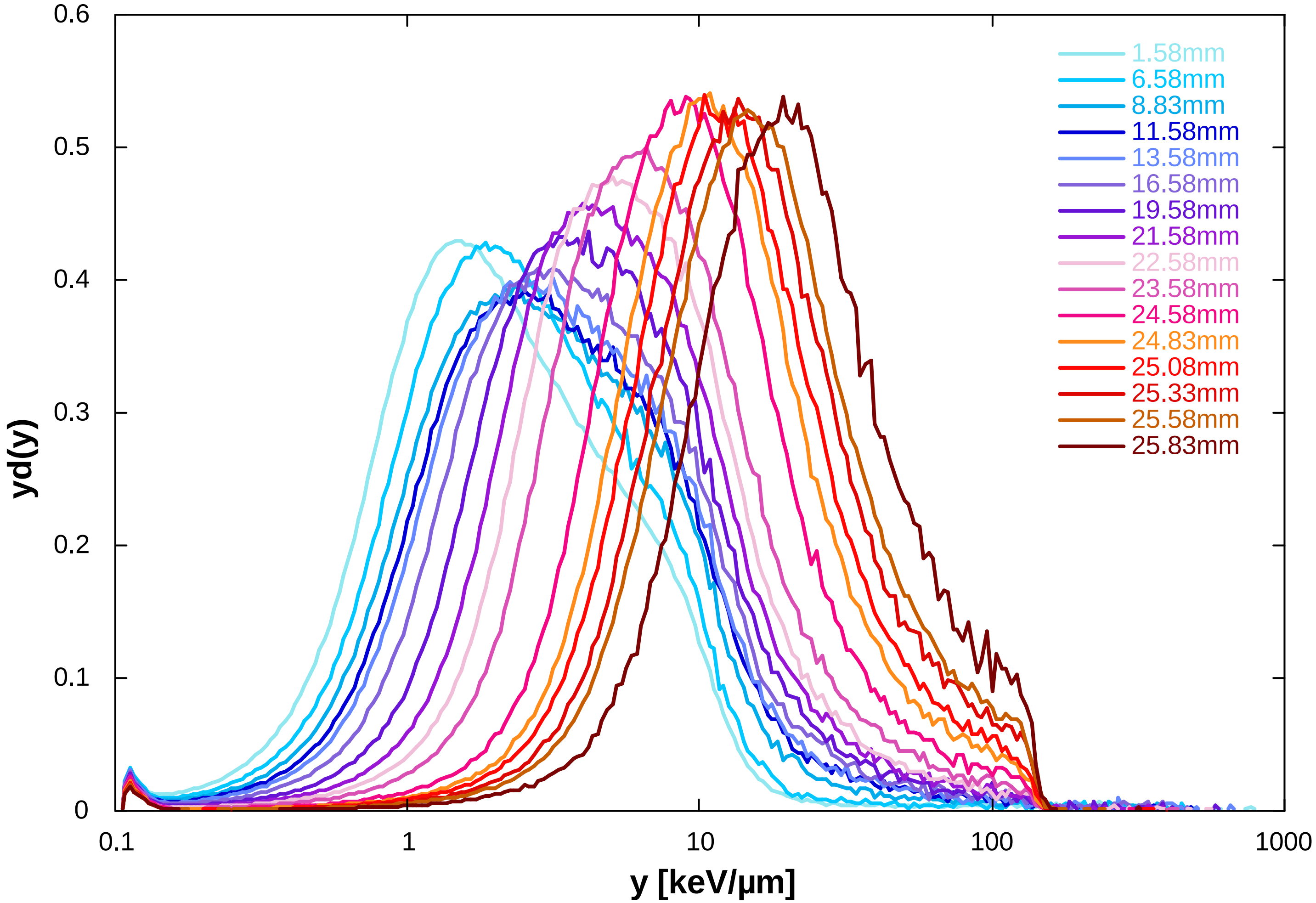
- Equivalent thickness 0.166 g/cm^2
- Accurate measurements
- Calibration uncertainty ~ 3.6%

P=625 mbar , filled with propane-TE

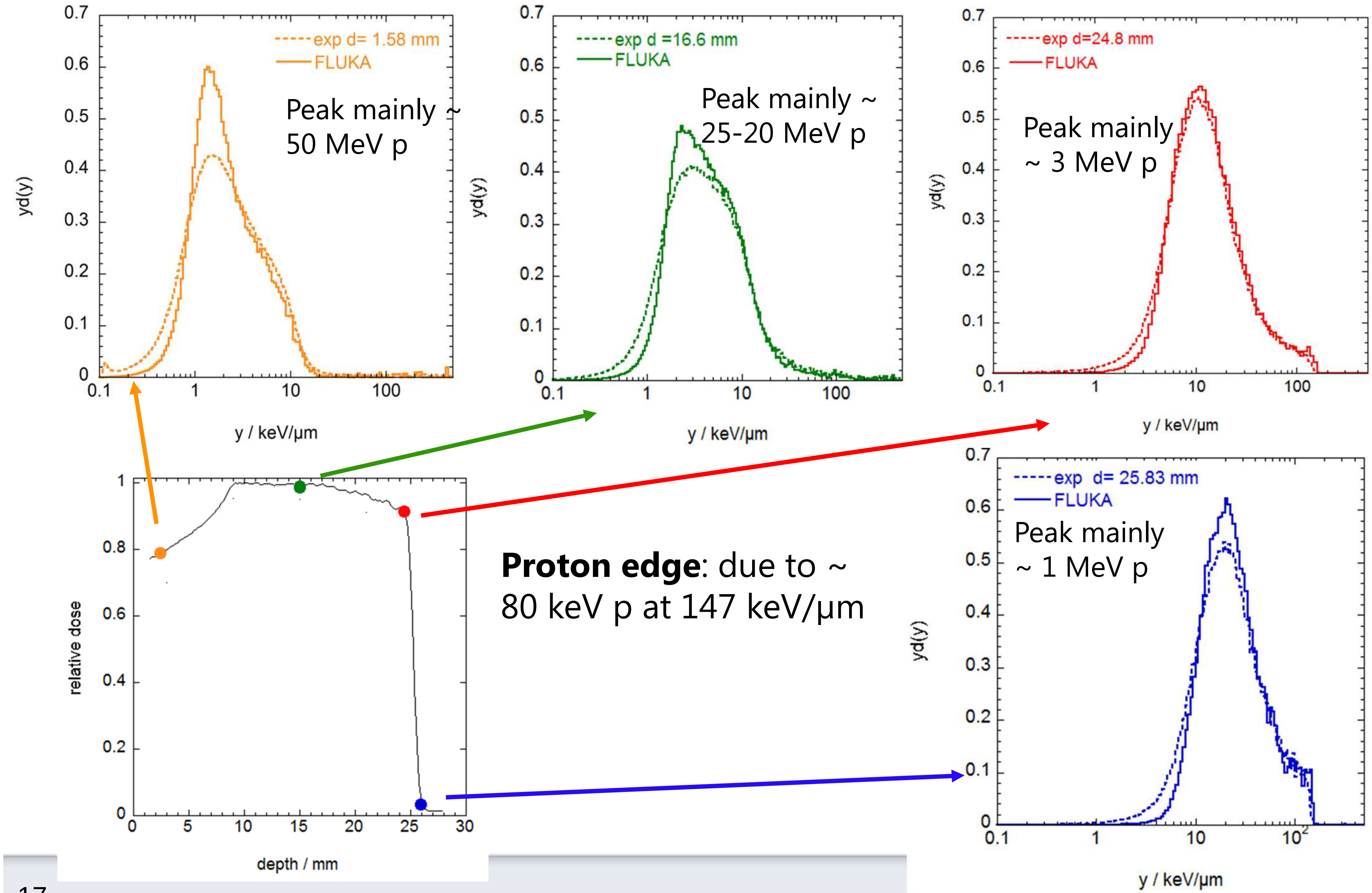
simulated site size 1 μm

L. De Nardo et al., Rad. Prot .Dosim 108, 345-352, 2004.

Microdosimetric spectra at 16 different depth

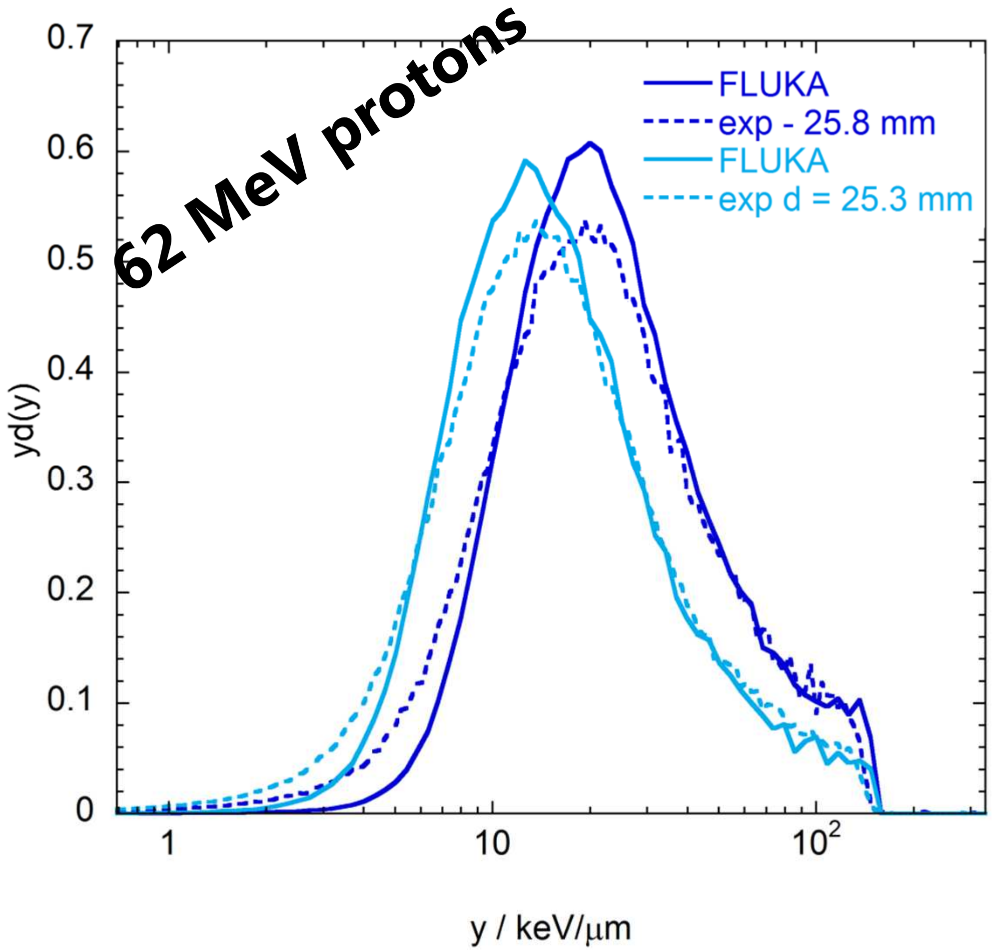


4. Proton μdosimetric data as a function of depth



4. Proton edge: MC & experimental

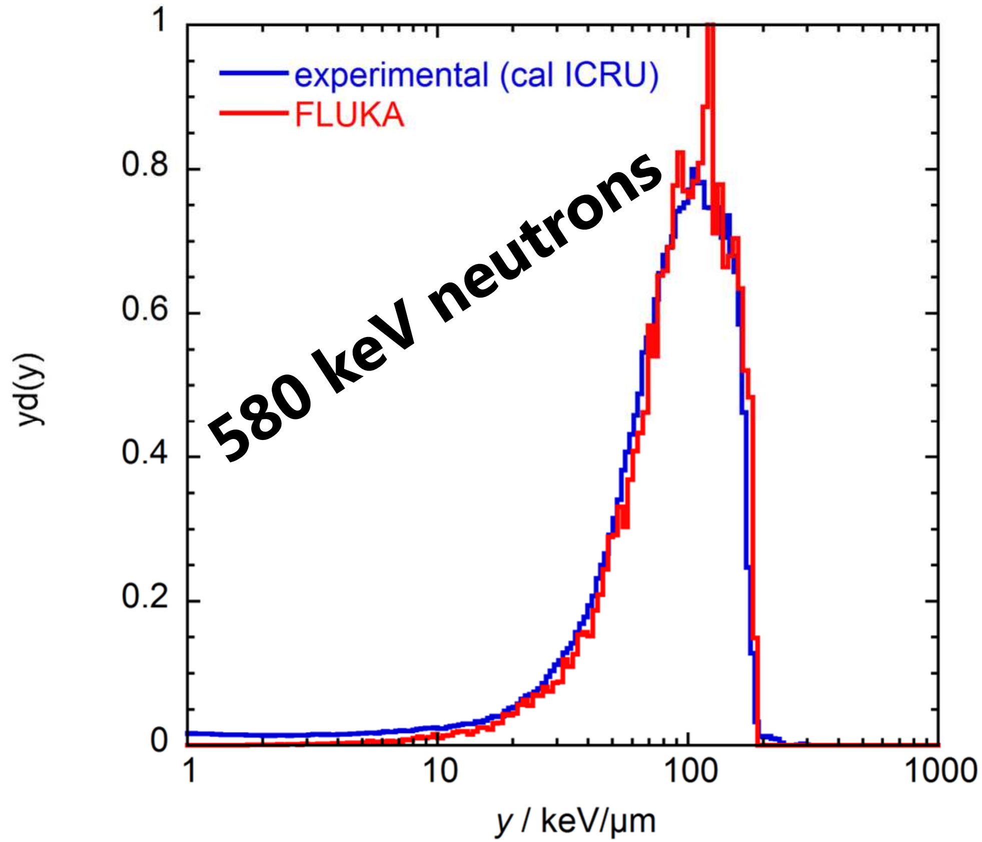
Some discrepancies on the p-edge region:

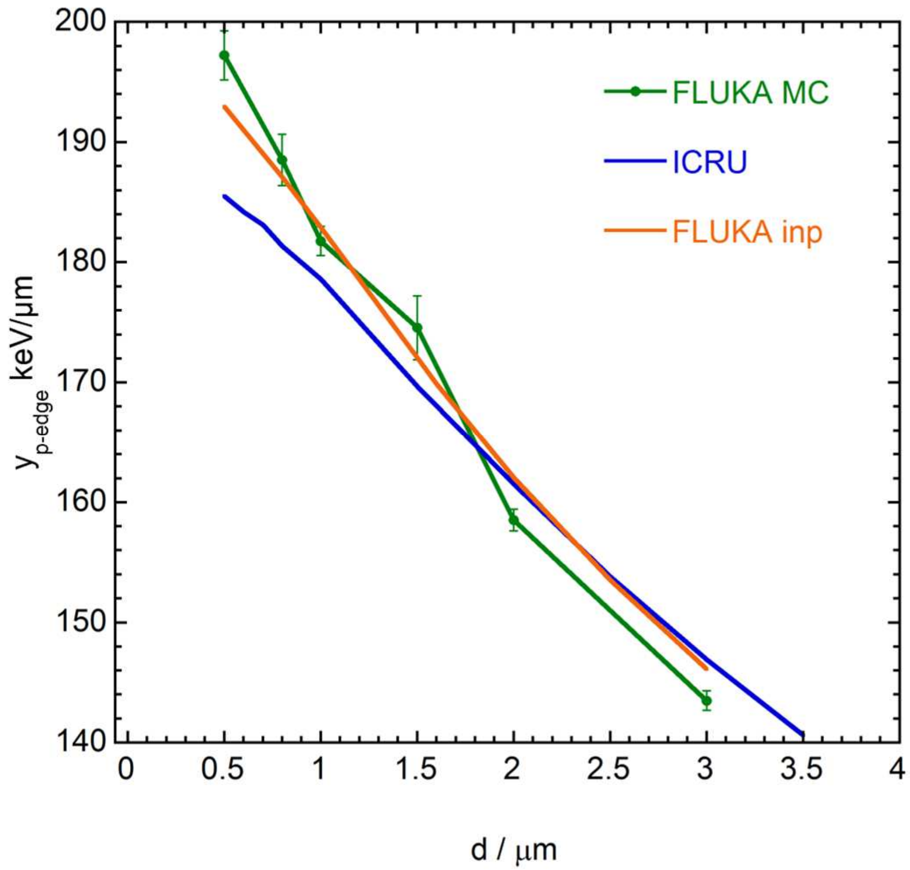


4. Proton edge: MC & experimental

Some discrepancies on the p-edge region:

- Differences on the algorithm to calculate the energy deposition with CSDA and MC

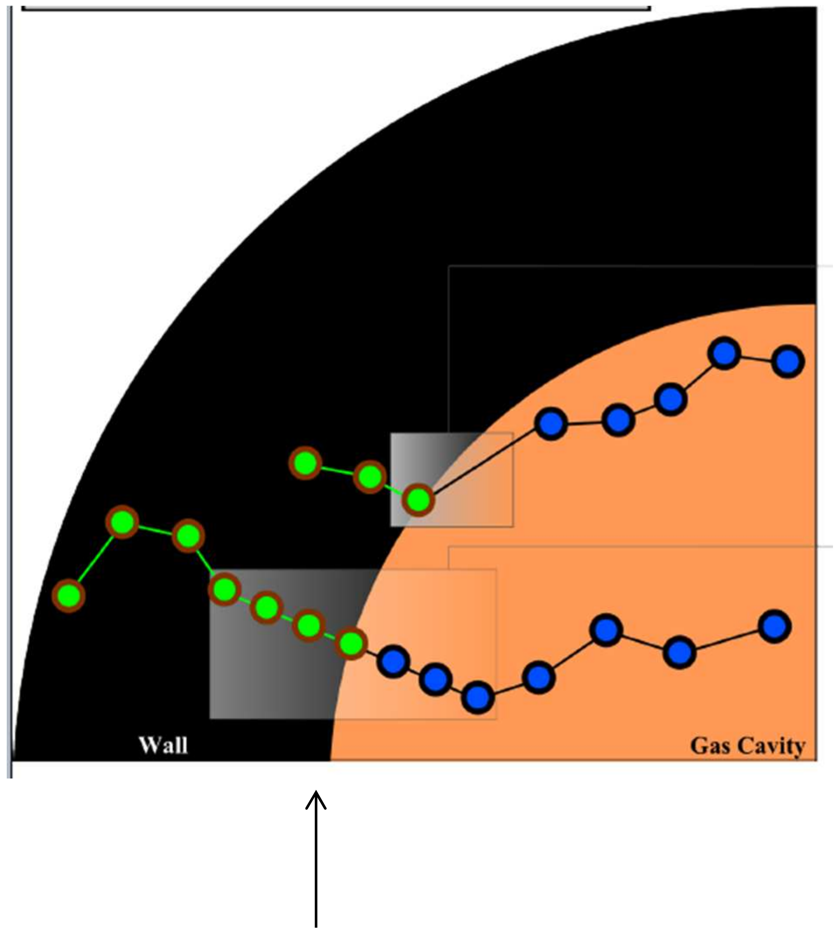




4. MC code: correction of “artifacts”

- With MC – the energy deposited in the gas cavity by every secondary charged particle that traverses is recorded – not ionization

- FLUKA – employs path length correction and drift technique to transport secondary charged particles between two material zones

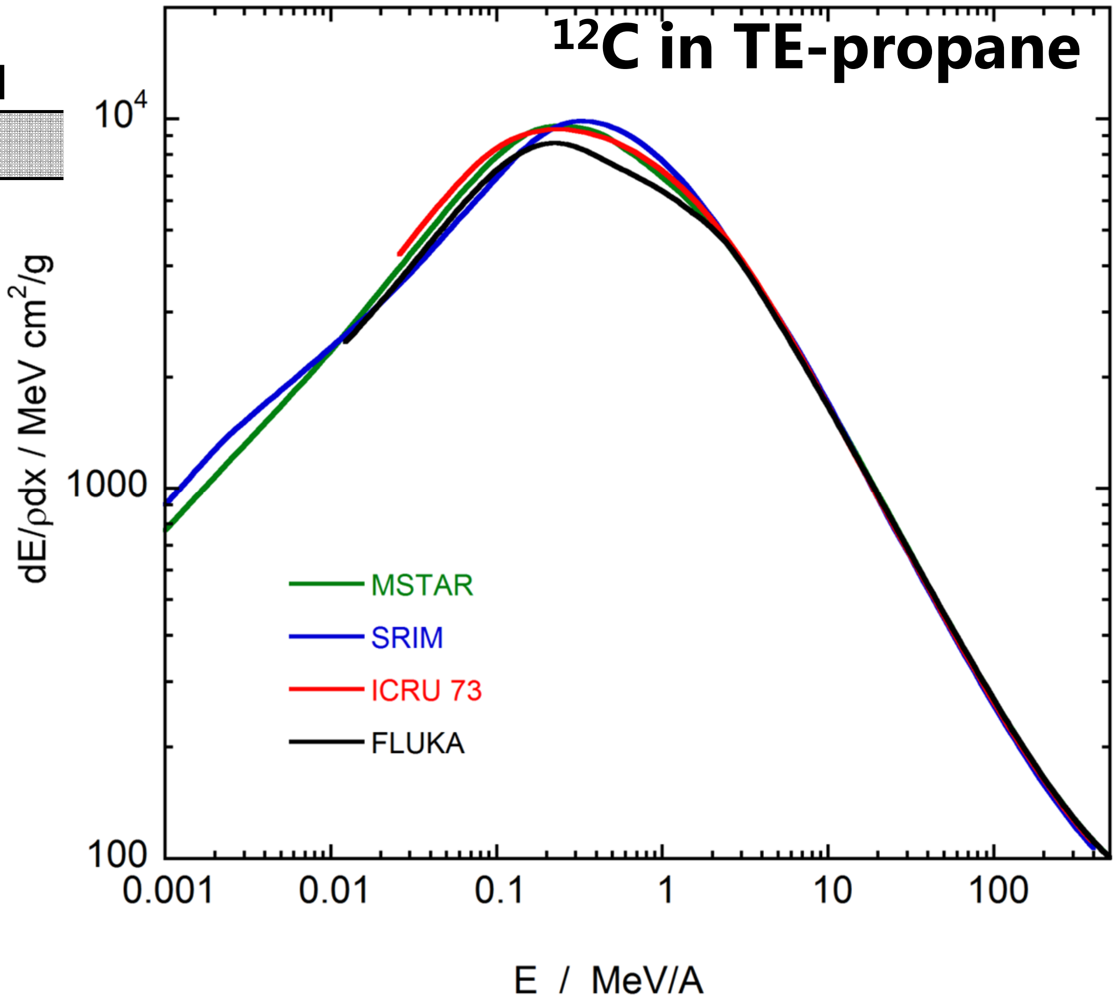


Correction: Vicinity of the boundary smaller angular deflection

5. Carbon edge

FLUKA [keV/µm]	ICRU [keV/µm]	SRIM [keV/µm]
1290.7	1407	1483

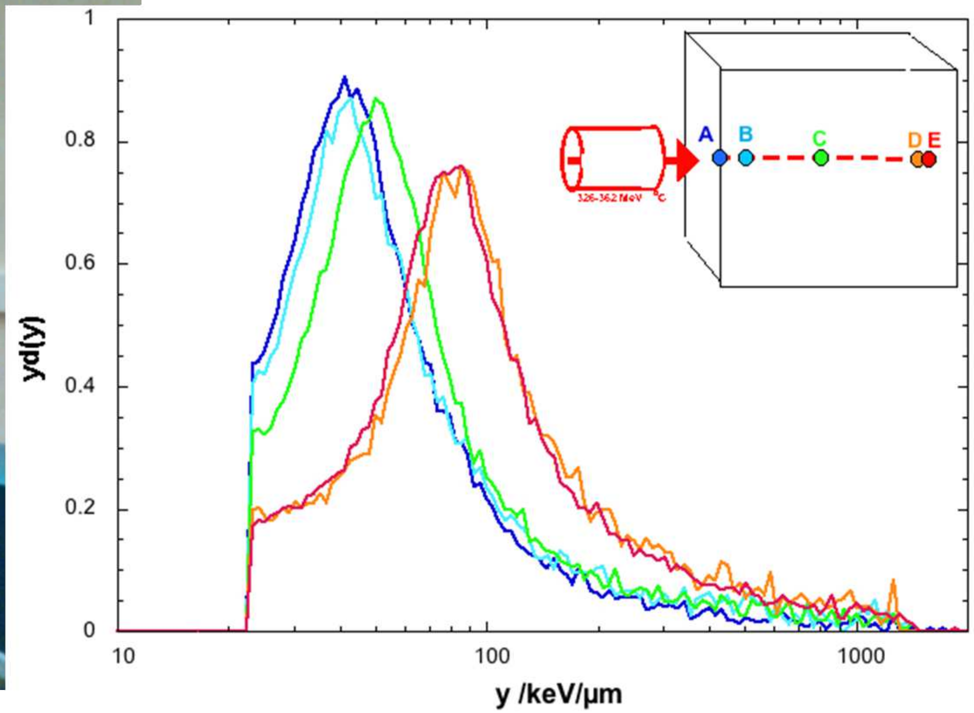
- Close to the Bragg region need accurate calculations including nuclear fragmentation effects
- **Need of microdosimetric carbon data**



5. Mini TEPC response in carbon ions

First measurements in a ^{12}C therapeutic beam

- Irradiations with 362 MeV/u SOBP ^{12}C beam (@ CNAO)



Outlook

- To avoid systematic errors in inter-comparisons:
  - (i) which marker point is used in the p-edge
  - (ii) which database is used
- "Standardization" of data for calibration
- Comparison of experimental and MC data for proton microdosimetric data of the depth and energy specially at the end of the proton range
- Carbon data comparison is on-going → need experimental data

Thank you for your attention

Acknowledgments

LNL micro- and nanodosimetry research group

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