IFMIF/ELAMAT

# Accelerator-Based Boron Neutron Capture Therapy

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*Town meting on IFMIF/ELAMAT Rzeszów 14-15 April 2016*

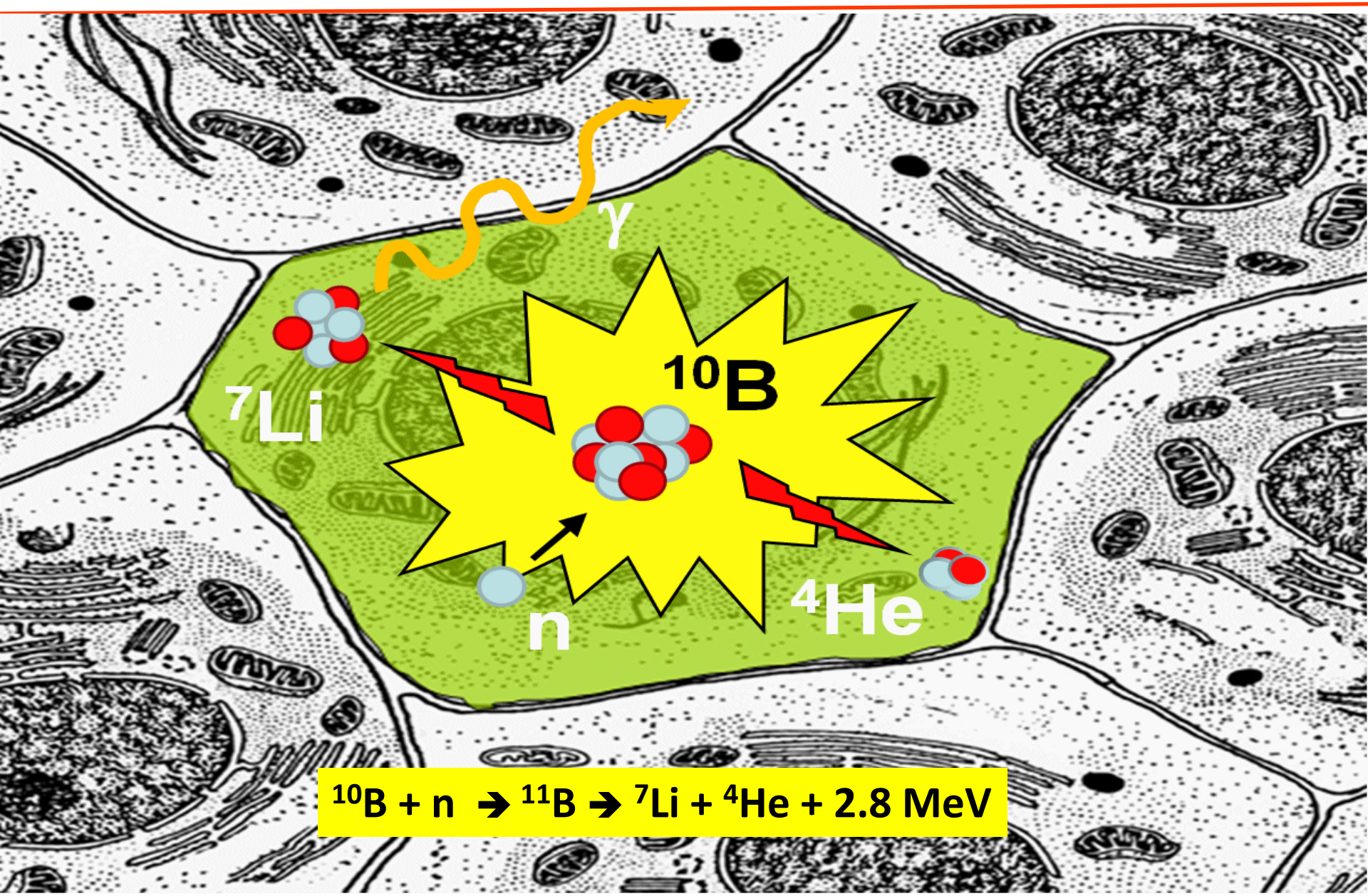
# *Talk Topics*

1. **BNCT rationale.**
2. **BNCT drawbacks.**
3. **BNCT medical results.**

4. **Neutron sources from particle accelerators.**
5. **The Neutron *Beam-Shaping Assembly*.**
6. **Treatable tumours: *the Advantage Depth*.**

7. **The AB-BNCT 4 pillars:**
   1. ***powerful accelerator;***
   2. ***safe target handling;***
   3. ***tracing the Boron carrier;***
   4. ***microdosimetric detector.***

# *Rationale: BNCT is a Cellular Hadronic Therapy*

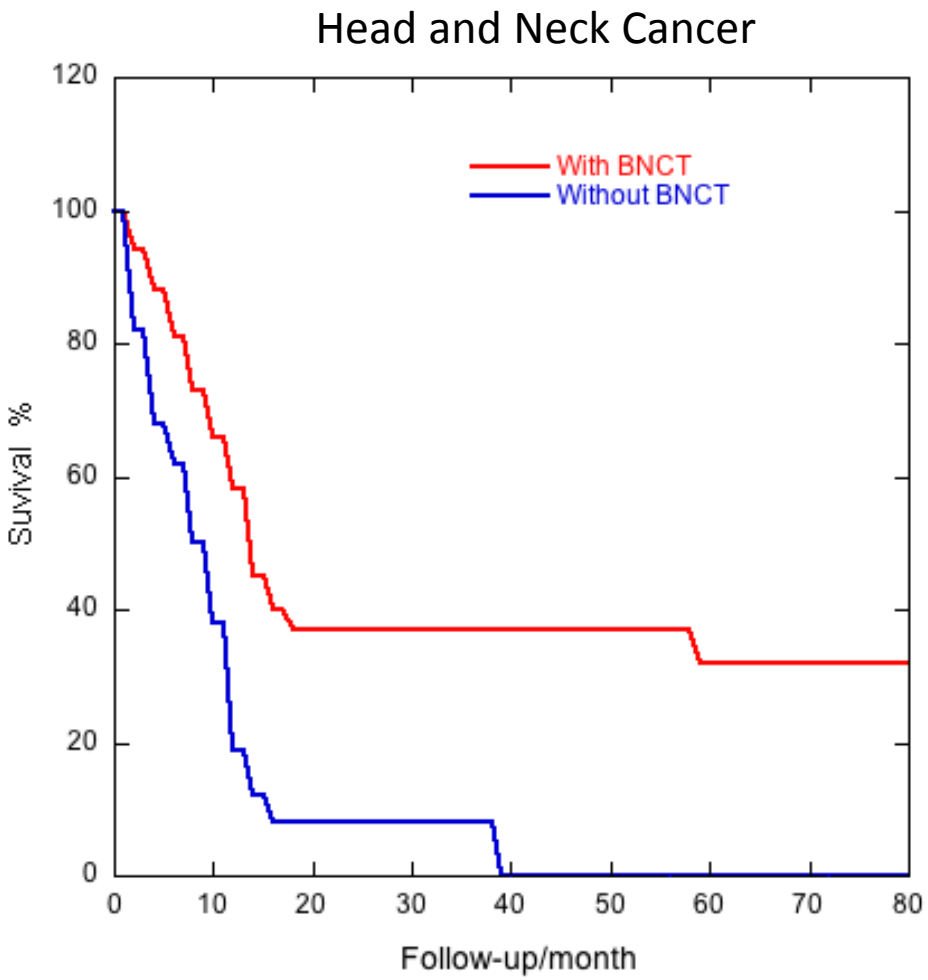


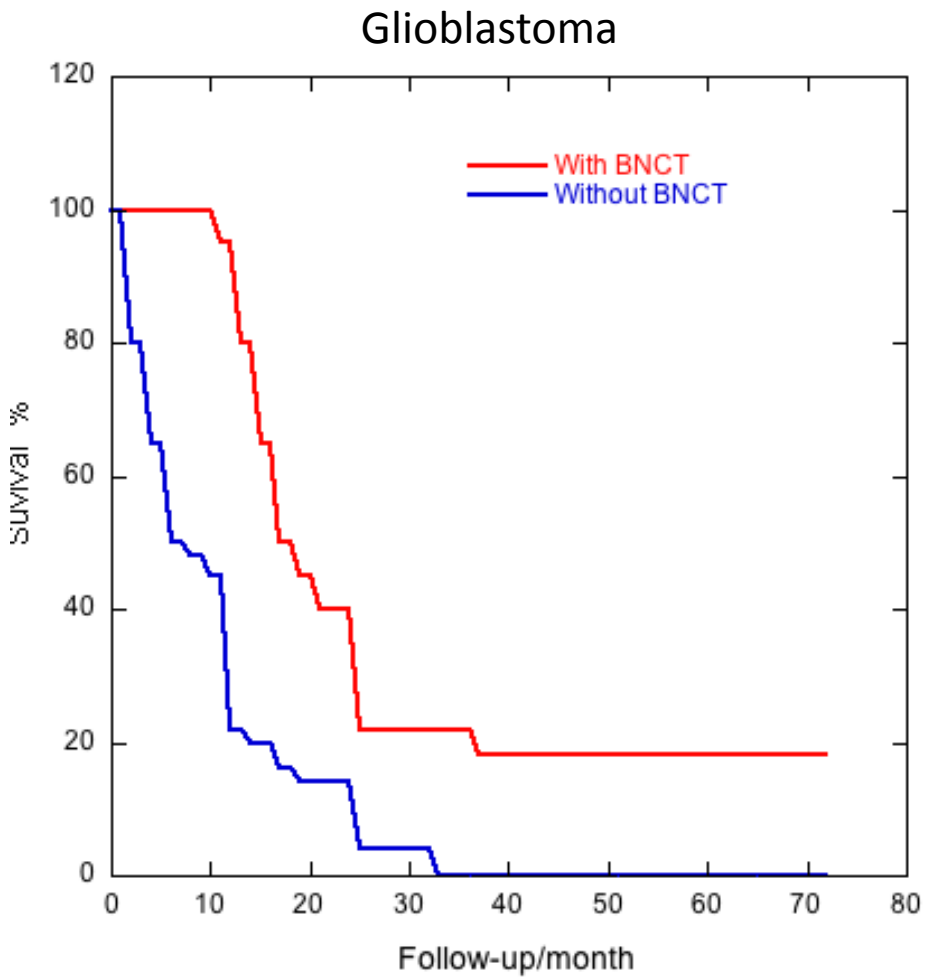

$^{10}B + n \rightarrow {}^{11}B \rightarrow {}^{7}Li + {}^{4}He + 2.8\ MeV$

# BNCT Drawbacks: Nuclear Reactions Which Damage Also Health Cells

| Reaction | Q-Value (MeV) | Cross Section barn | Threshold MeV |
|---|---|---|---|
| $^{1}H(n, \gamma)^{2}H$ | +2.22 | 20.8 | --- |
| $^{14}N(n,p)^{14}C$ | +0.63 | 1.6 | --- |
| $^{14}N(n,\alpha)^{11}B$ | -0.158 | 0.084 | 0.17 |
| $^{40}Ca(n,\alpha)^{37}Ar$ | +1.75 | 0.05 | --- |
| $^{16}O(n,\alpha)^{13}C$ | -2.16 | 0.008 | 2.36 |
| **$^{10}B+n \rightarrow {}^{7}Li+{}^{4}He$** | **2.79** | **3837** | **---** |

# BNCT Medical Results: Kaplan-Meier Plots



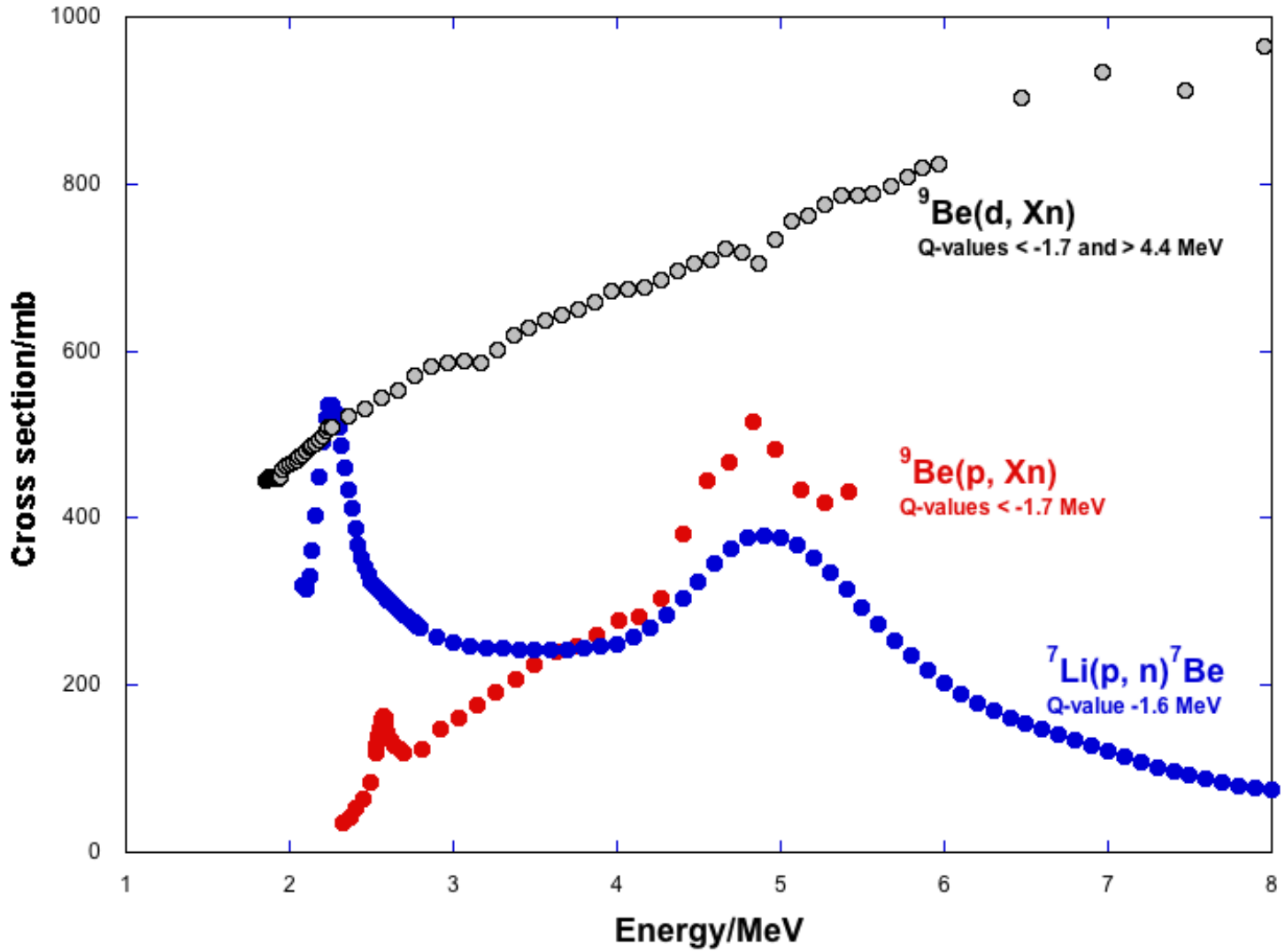

*Nuclear Physics for Medicine*. NuPECC Report, edit A.Bracco et al. 2014, http://www.nupecc.org/npmed/npmed2014_hires.pdf

- **Treatments with thermal neutrons (skin melanomas, explanted liver, brain-glioblastoma intraoperative irradiation) were successful.**

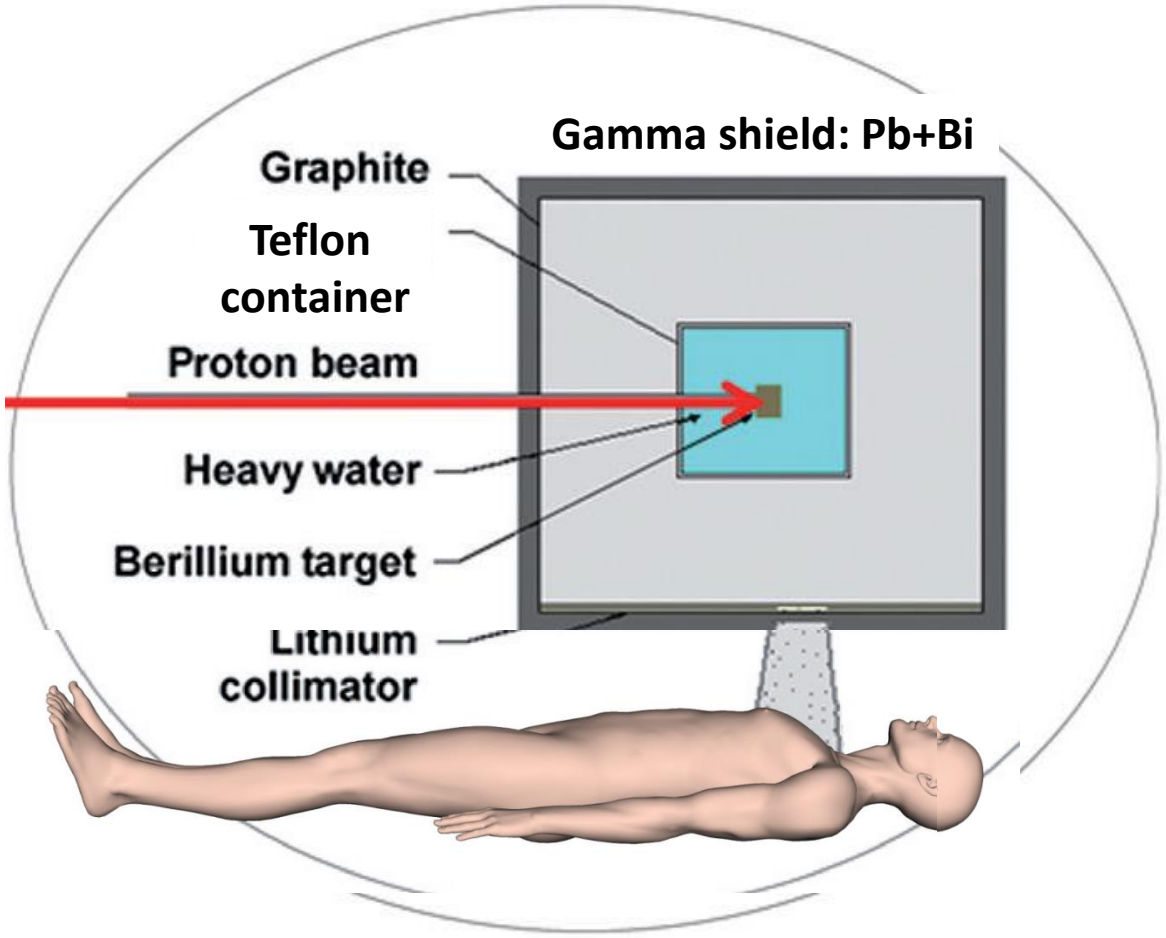
- **Treatments with epithermal neutrons are only partially successful.**

- **So far, all BNCT treatments have used nuclear research reactors.**
- **Unlikely nuclear reactors could be installed inside a hospital.**
- **The use of a dedicated particle accelerator, rather than a research reactor, will implement a real clinical BNCT.**

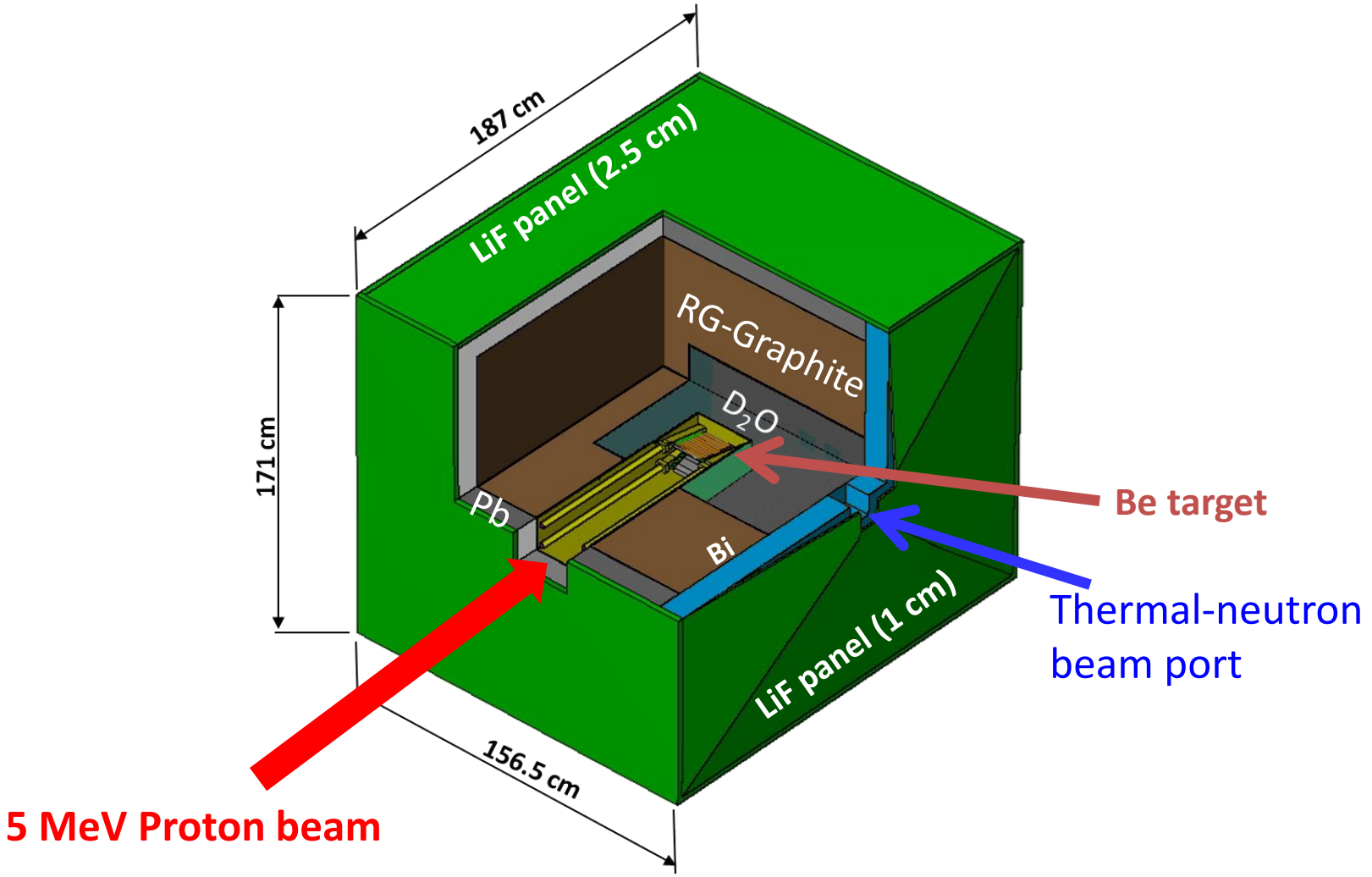
# Neutron Sources Exploitable for AB-BNCT



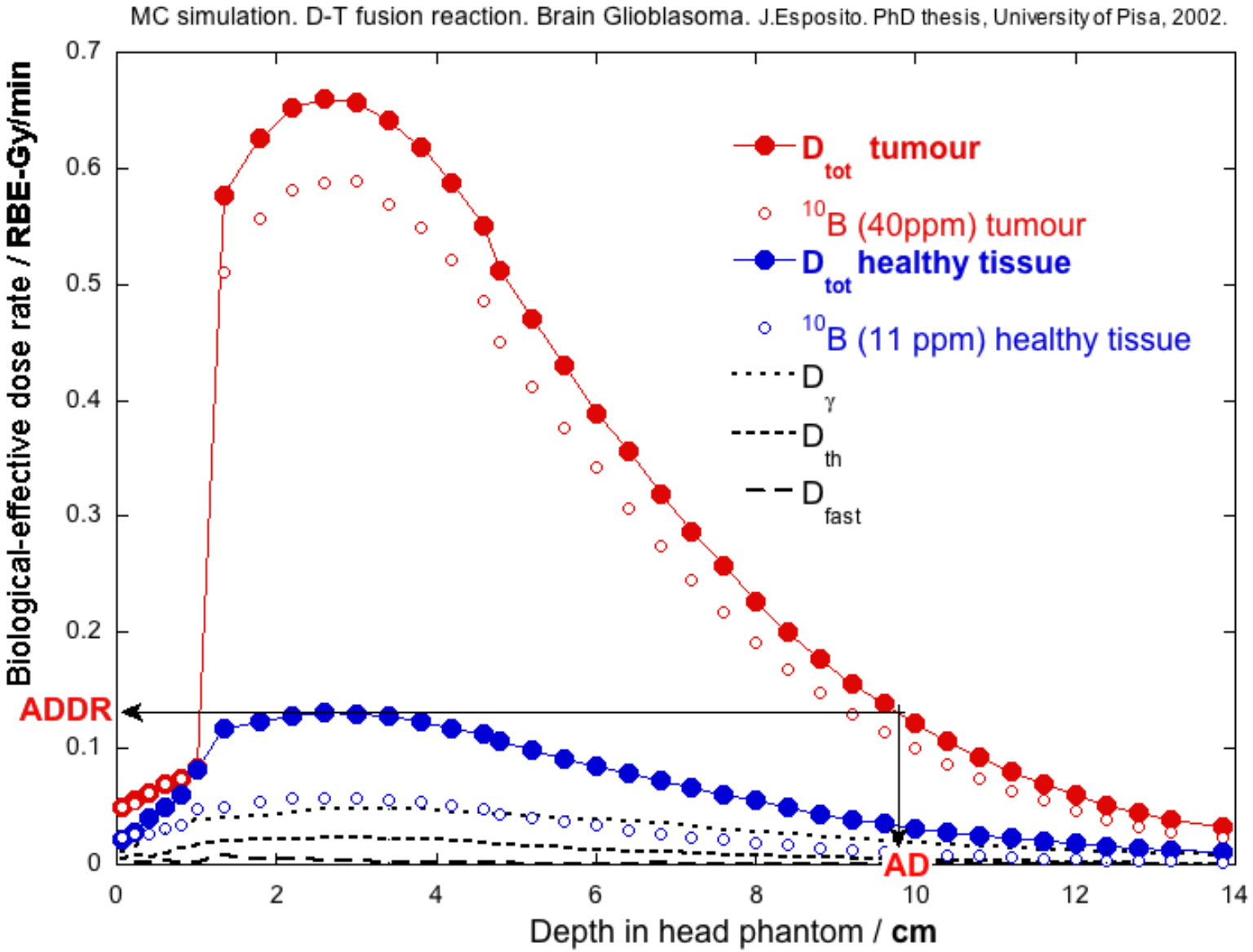
# ***The Beam Shaping Assembly*** *to Slow Down and Shaping the Neutron Beam*



# The LNL Beam-Shaping Assembly

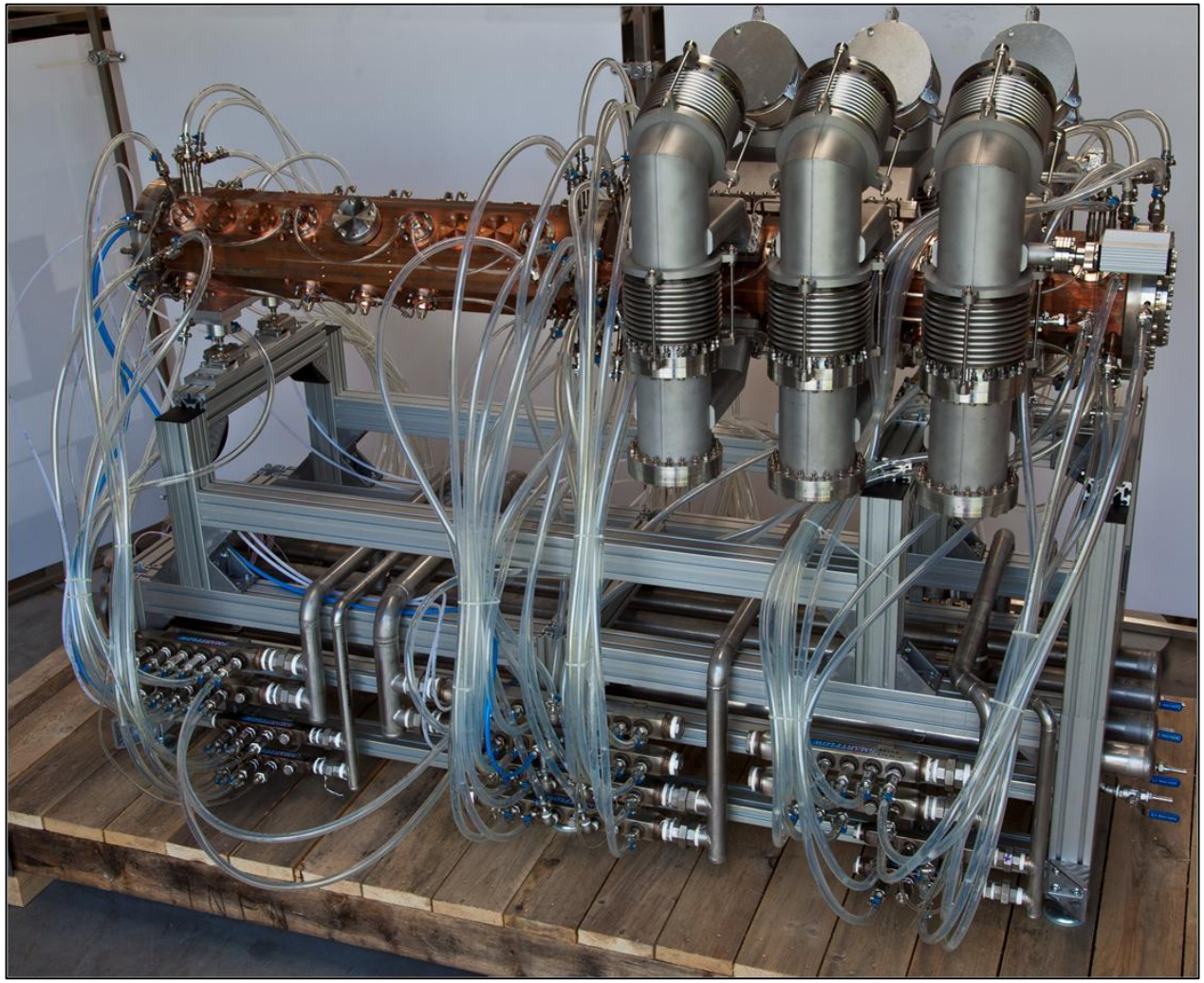


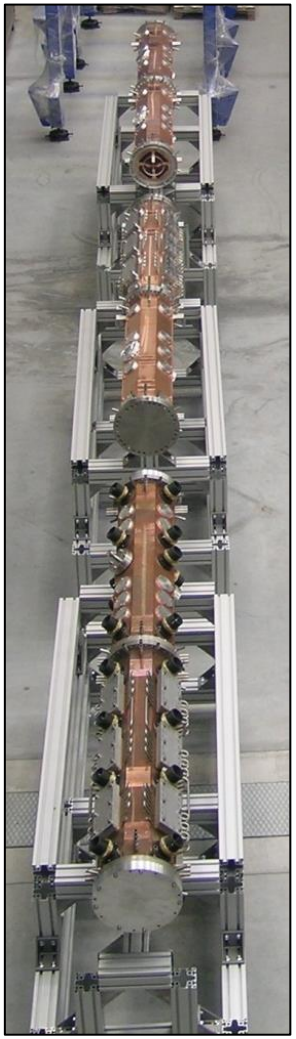
# The Advantage Depth



# The AB-BNCT 4 Pillars

*1. Powerful accelerator, the LNL RFQ accelerator*

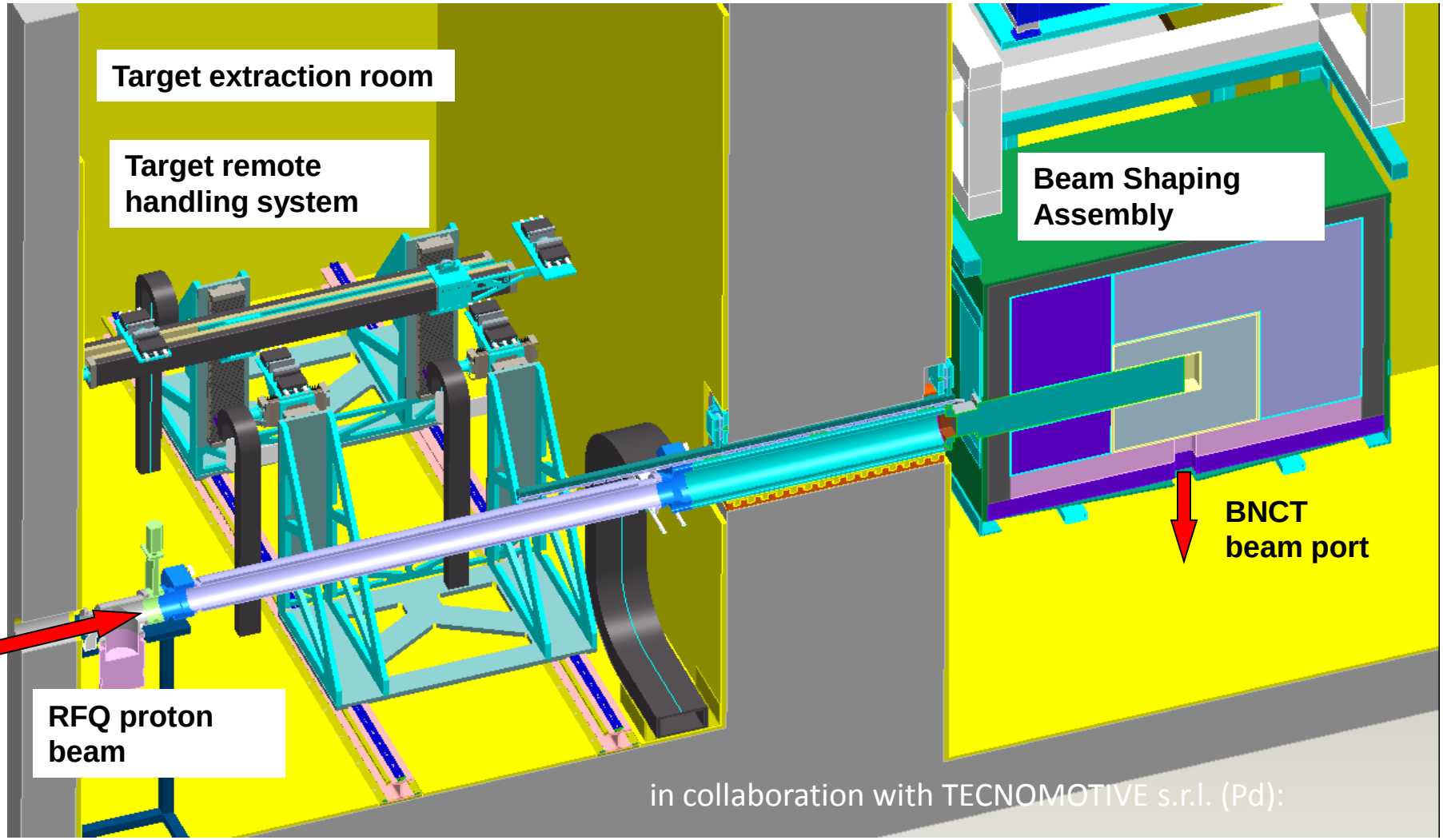




**5 MeV 30 mA proton beam ===> $10^{14}$ $s^{-1}$ neutron production rate**

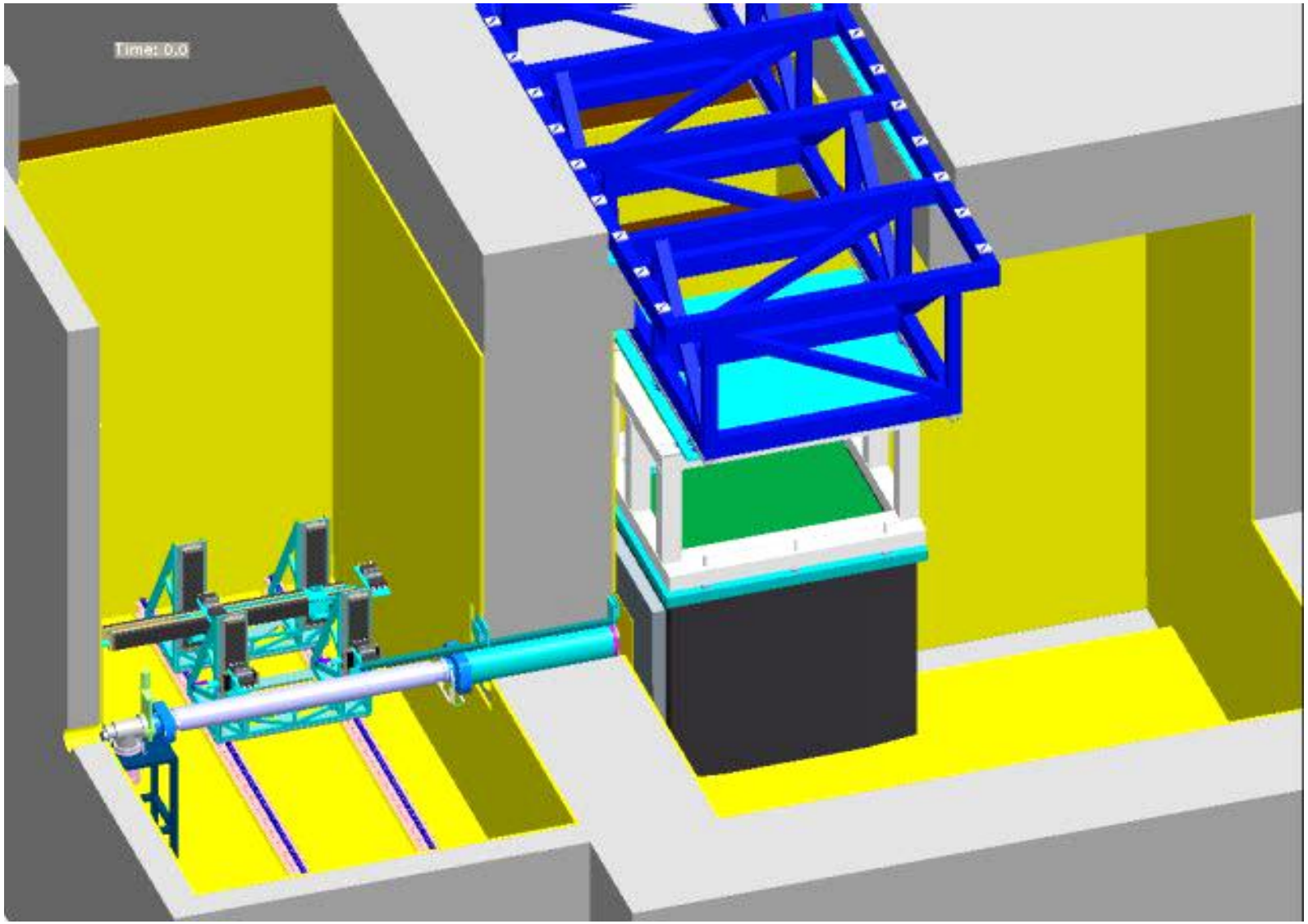
# The AB-BNCT 4 Pillars

*2. Safe target handling, the LNL design*



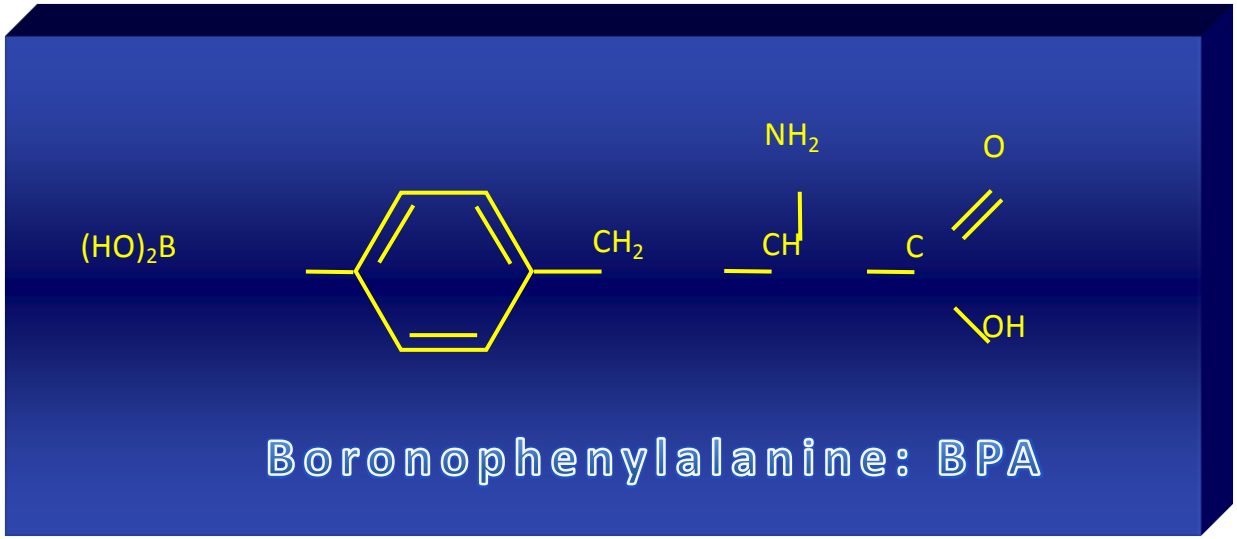
# *The AB-BNCT 4 Pillars*

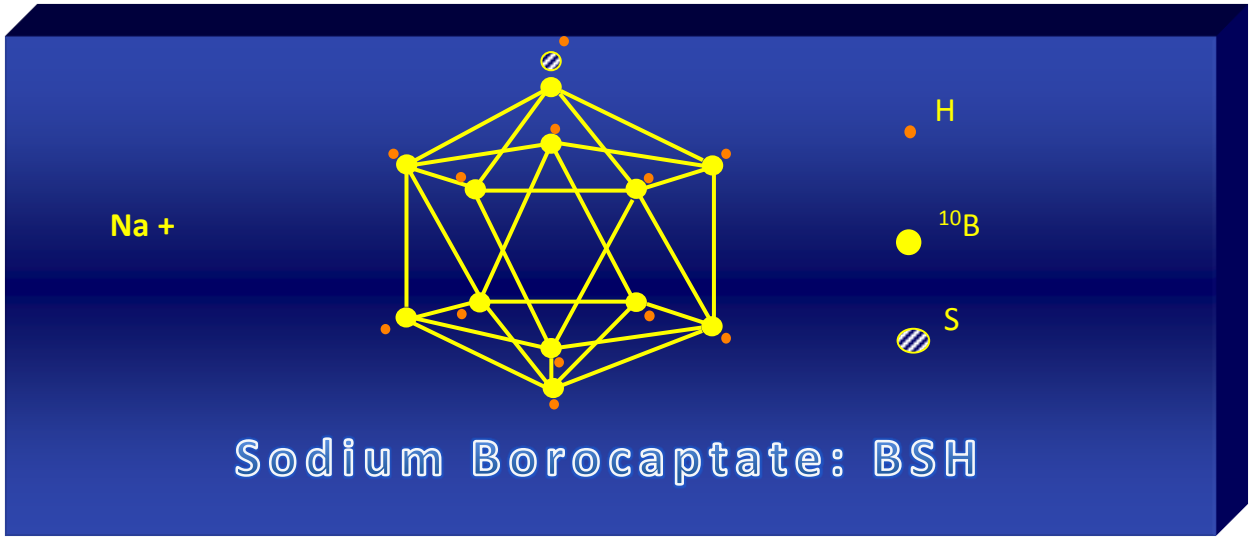
*2. Safe target handling, the LNL design*



# The 4 AB-BNCT Pillars

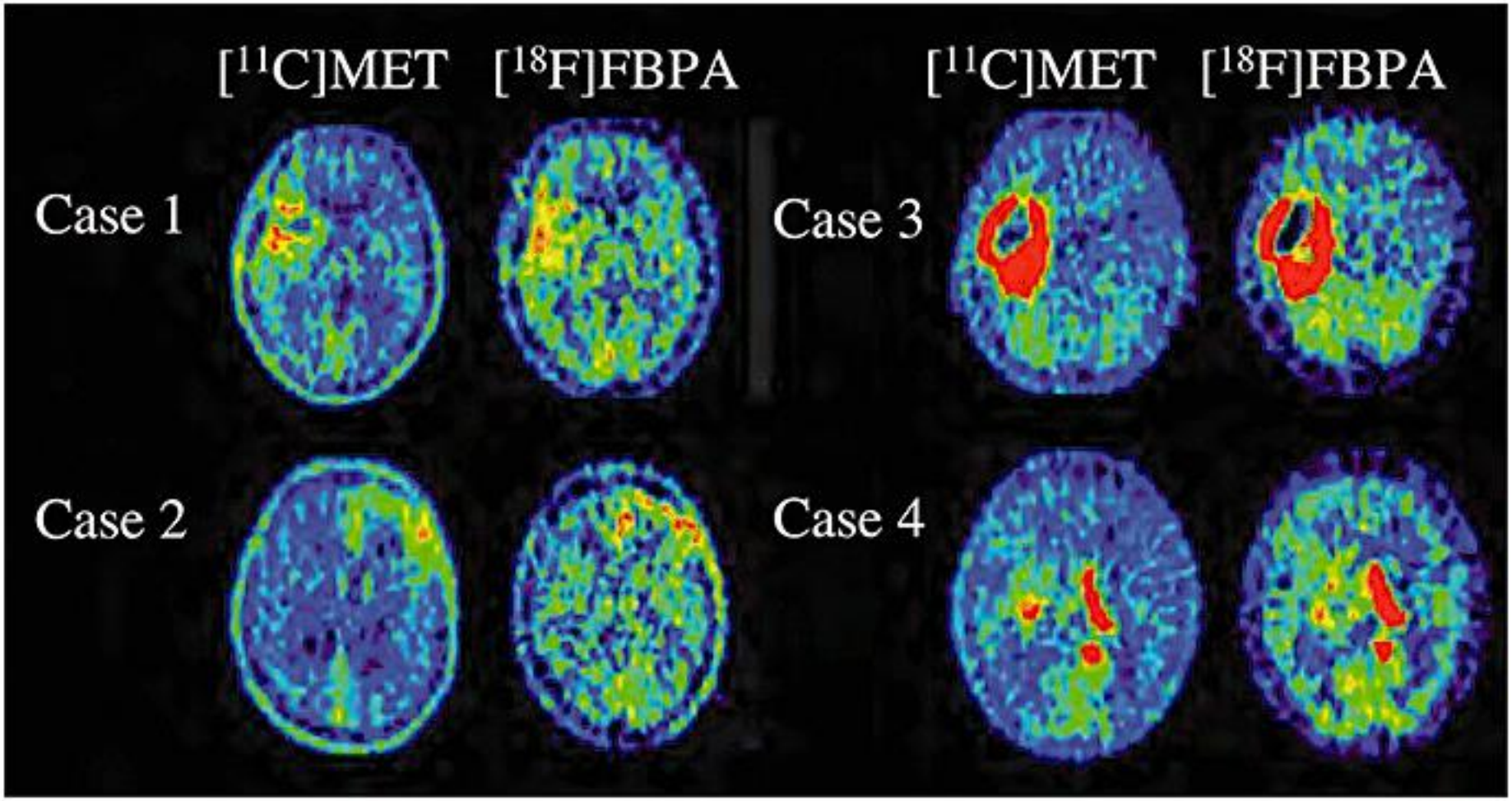
*3. Selective Boron Carrier, Actual Commercial Compounds.*



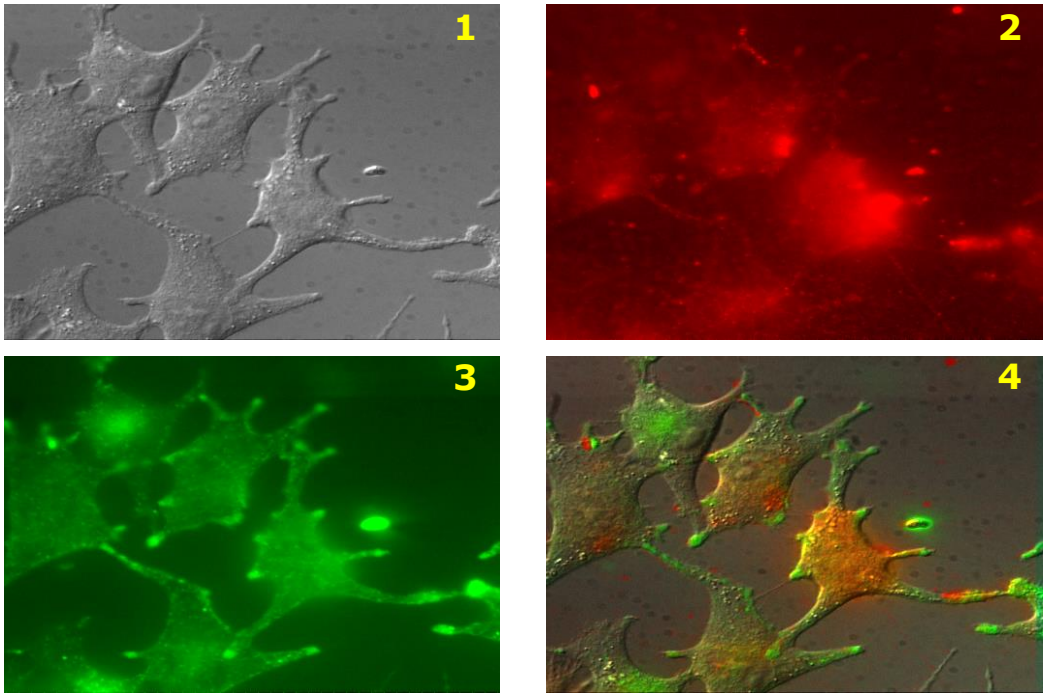



# The 4 AB-BNCT Pillars

*3. Tracing Boron carrier, fluorinated BPA and PET .*



## $B_4Pc$: the selective uptake can be simply traced by fluorescence

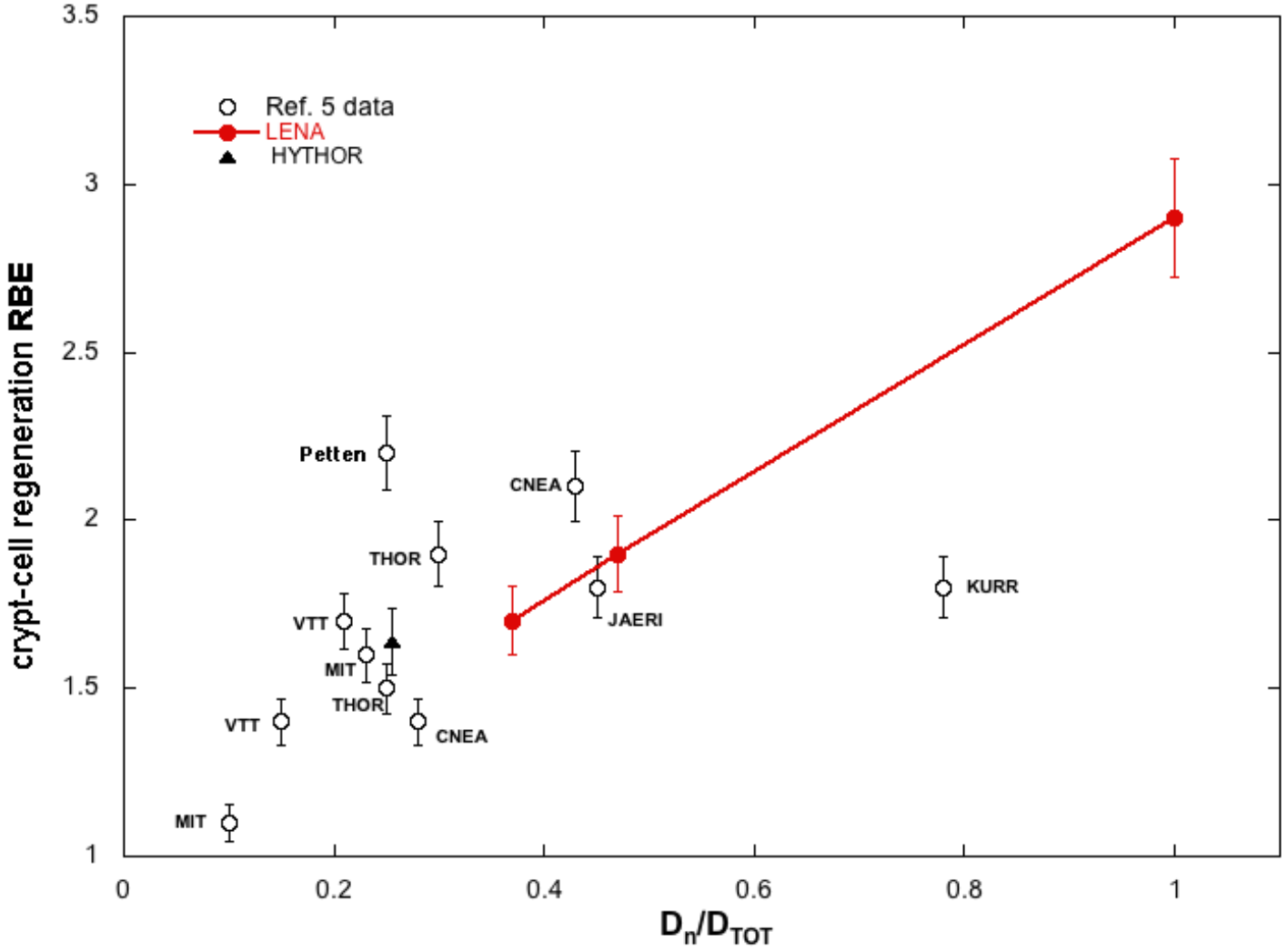



**Fluorescence micrographs of cells after 24 h incubation with 7 μM DOPC liposome-incorporated $B_4Pc$ 1 bright field image, 2 fluorescence of phthalocyanine, 3 fluorescence of endosomal probe Lucifer Yellow, 4 overlay of images 2 and 3**

E.Friso et al., Photochem.Photobiol. Sci. 5, 39-50, 2006.

# The 4 AB-BNCT Pillars

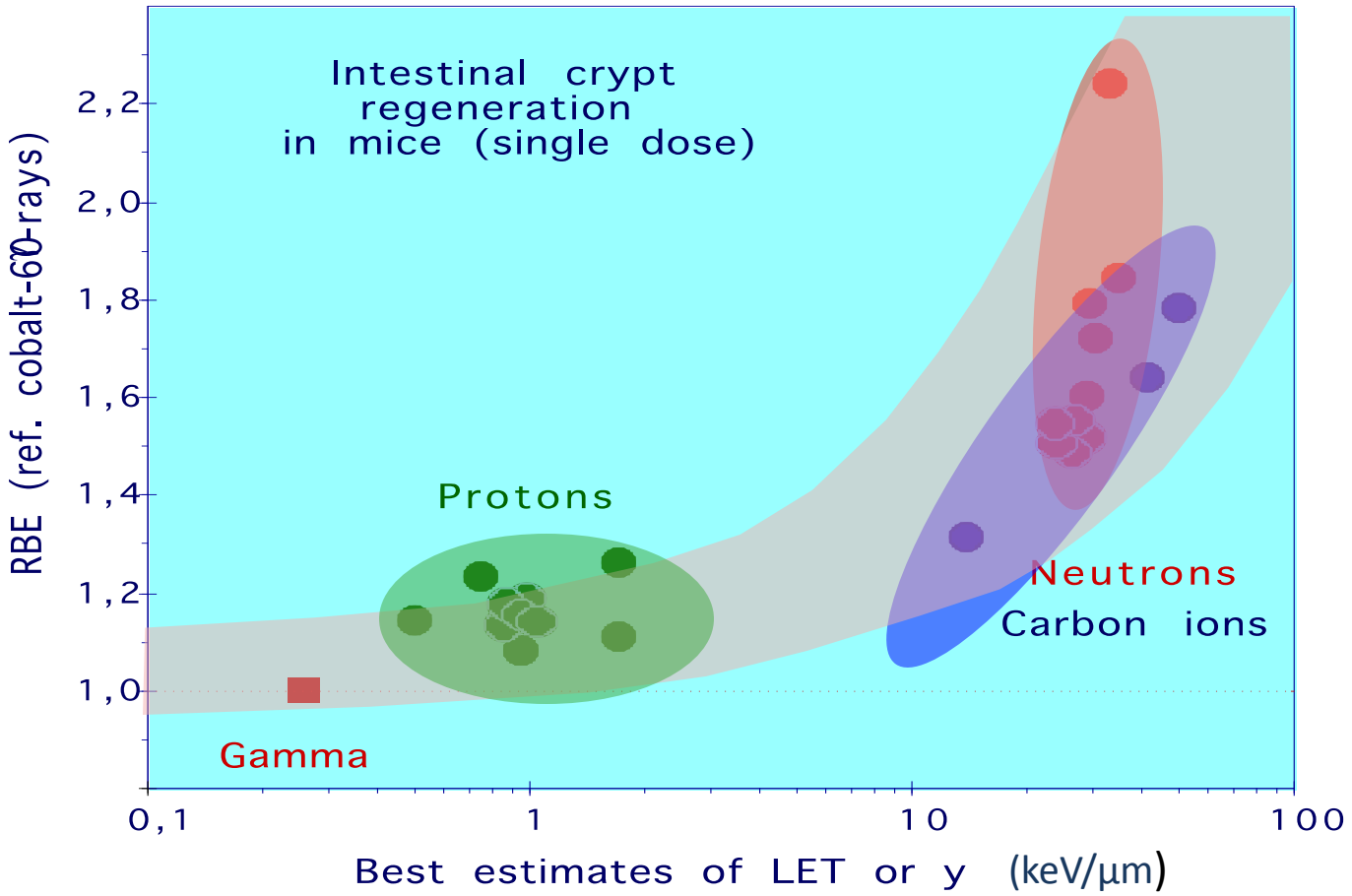
*4. Microdosimetric detector, the RBE case*




J.Guellette et al. Proceedings ICNCT 12,81-84, 2006

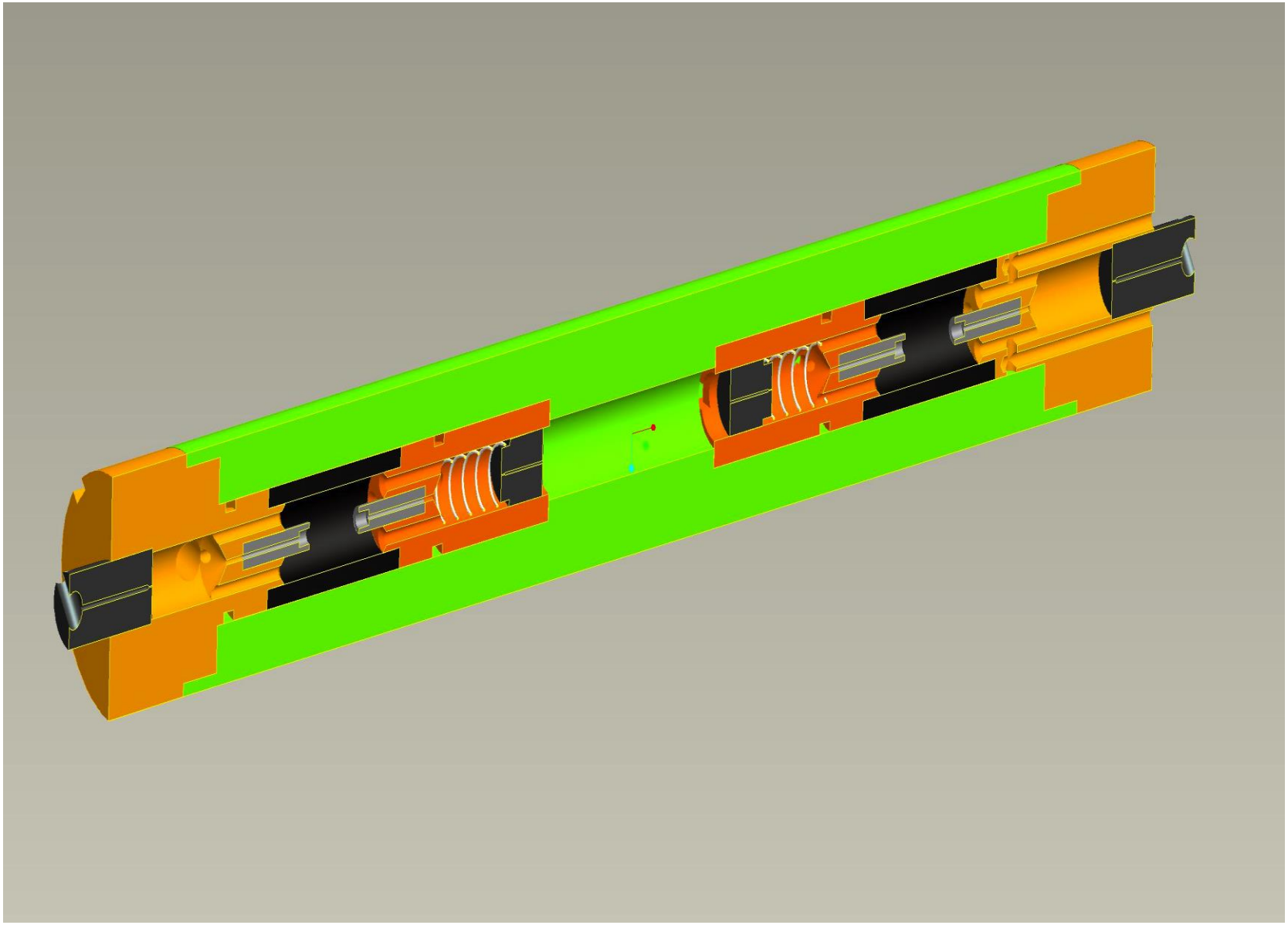
P.Colautti et al., ARI 88, 147-152, 2014

# RBE of BNCT components



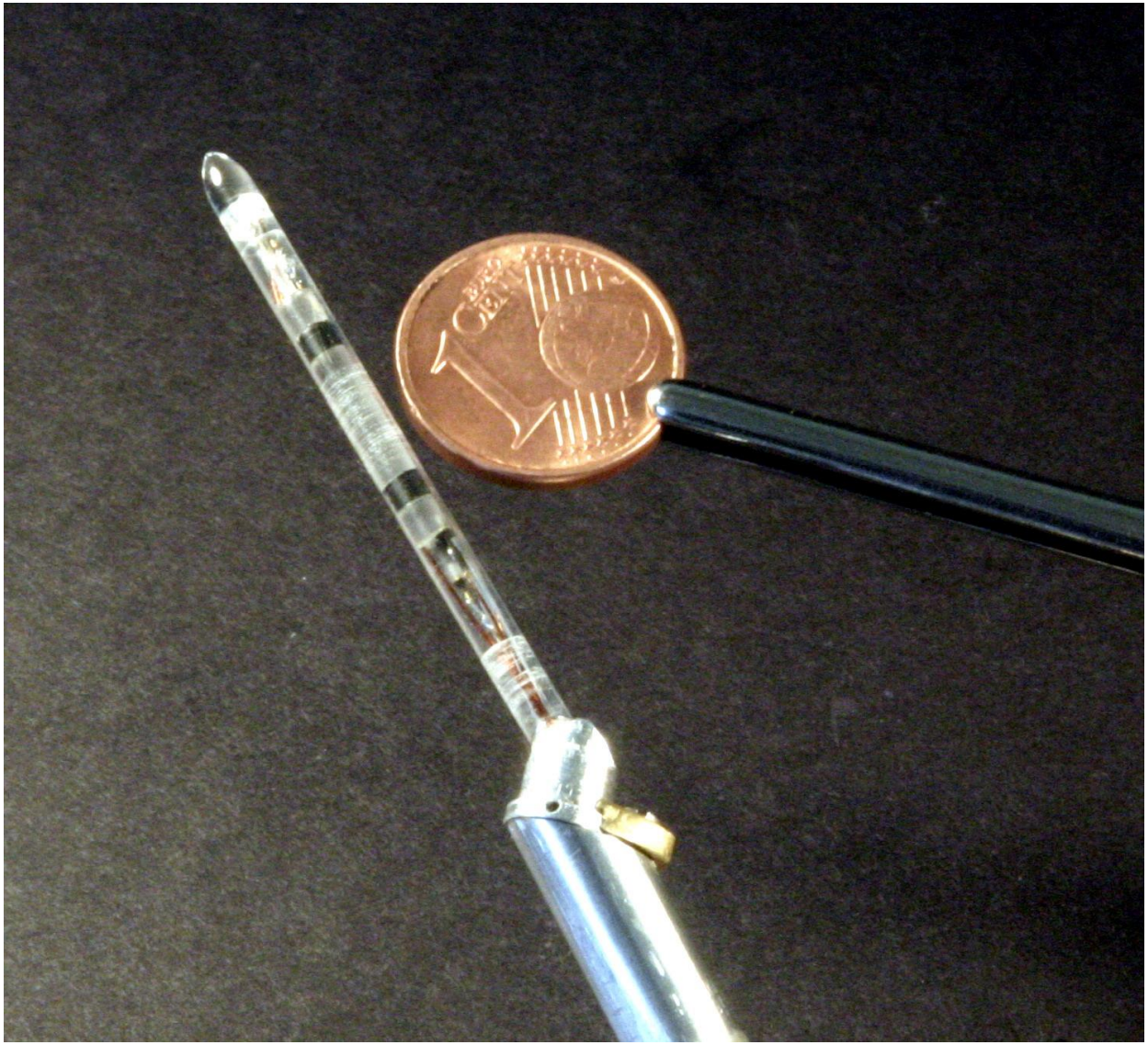
# The 4 AB-BNCT Pillars

*4. Microdosimetric detector, the LNL twin TEPC*



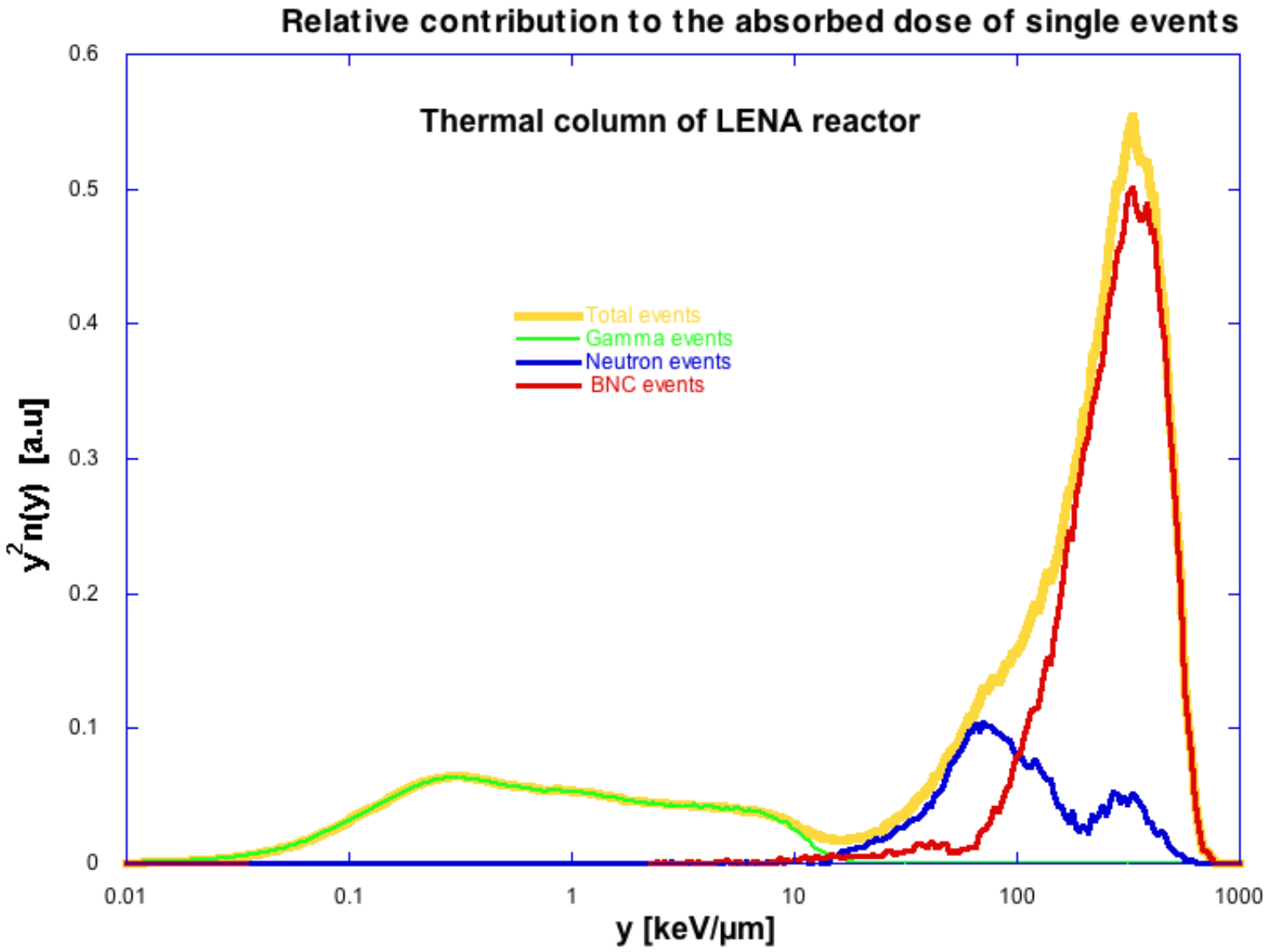
# *The 4 AB-BNCT Pillars*

*4. Microdosimetric detector, the LNL twin TEPC*



# The 4 AB-BNCT Pillars

*4. Microdosimetric detector, the LENA reactor BNCT microdosimetric spectrum*



# CONCLUSIONS

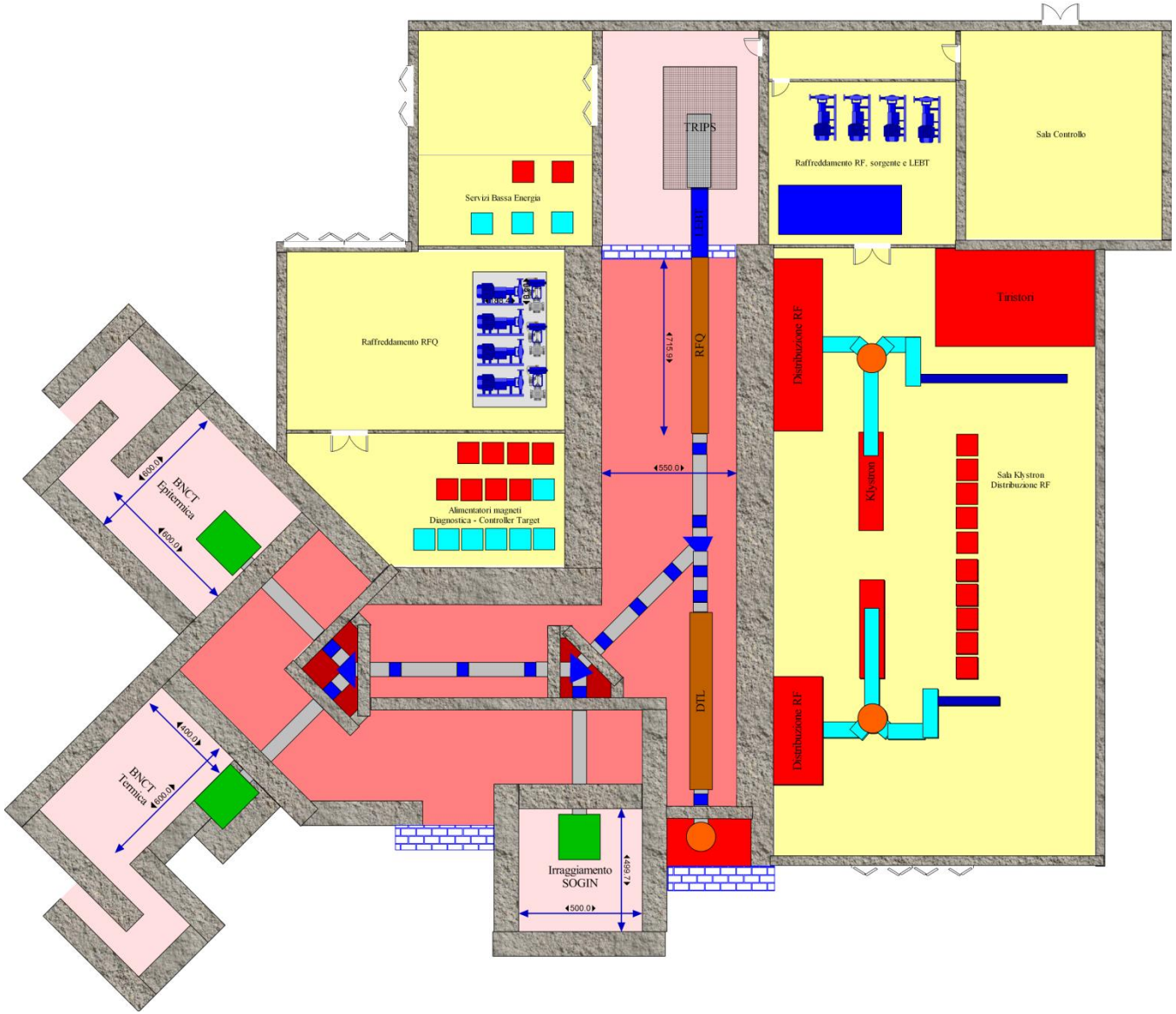
1. BNCT is a tumour radiation therapy useful when a cellular therapy is recommended. It needs high neutron-fluence rates, so far provided only by nuclear research reactors.

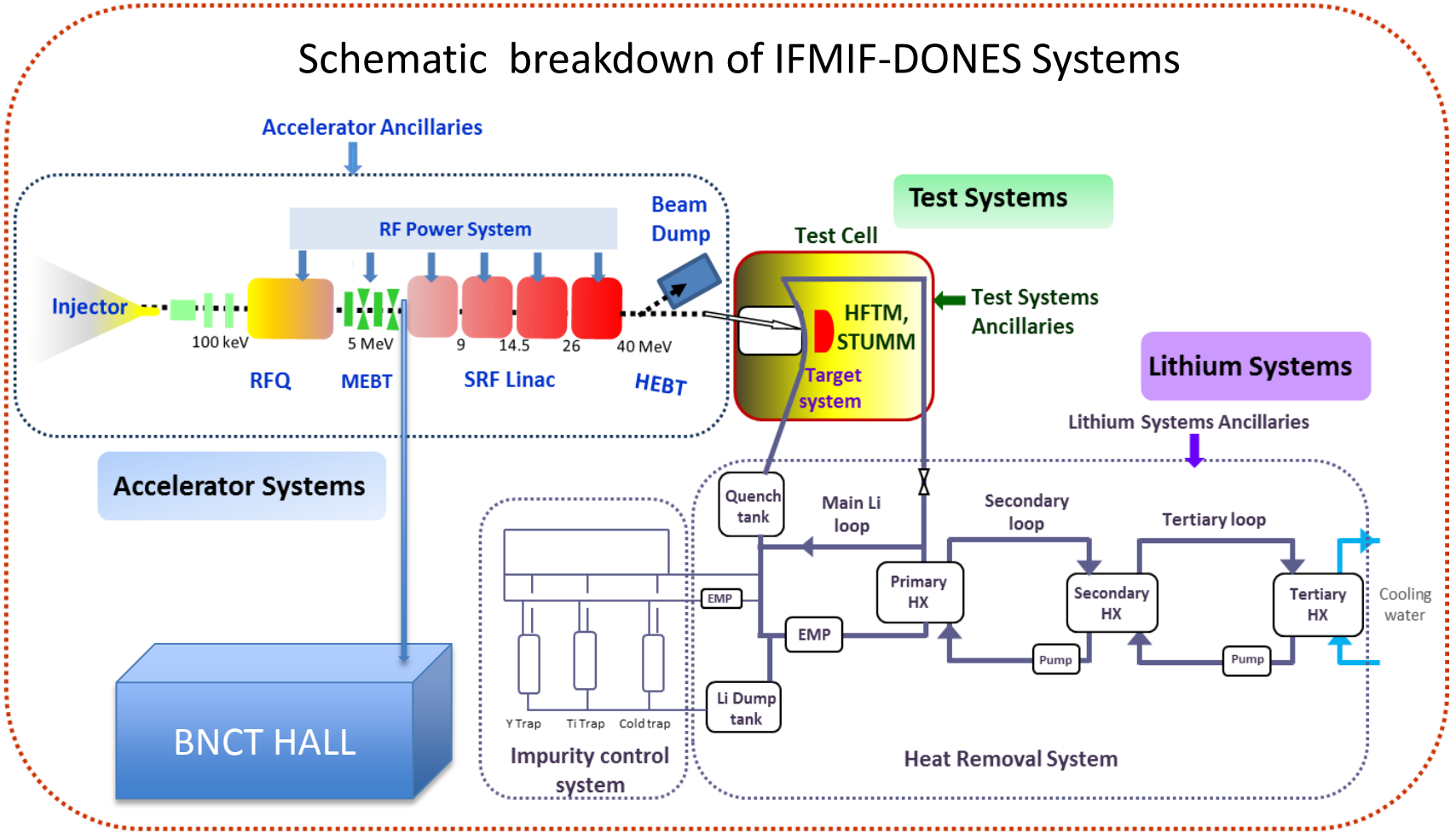
1. New neutron sources based on particle accelerators could give a boost to BNCT studies. Nine AB-BNCT projects are actually running in the world (Italy, Russia, UK, Japan, Israel, Argentina).

2. A poor $^{10}B$ carrier specificity limits the BNCT therapeutic advantage. Knowledge of the $^{10}B$ carrier metabolic distribution in the patient improves the BNCT therapeutic advantage.

3. The radiation field complexity and the poor knowledge of the radiation field RBE limit the BNCT therapeutic advantage. Experimental microdosimetry performed with TEPCs or other microdosimetric detectors could improves the BNCT therapeutic advantage.

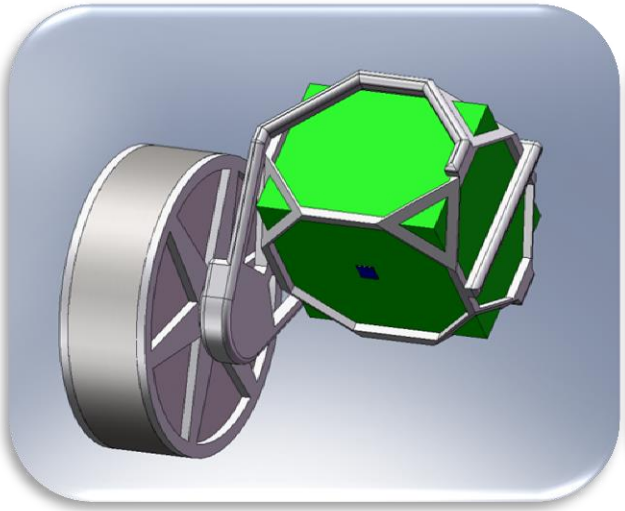
# The LNL AB-BNCT Proposed Centre

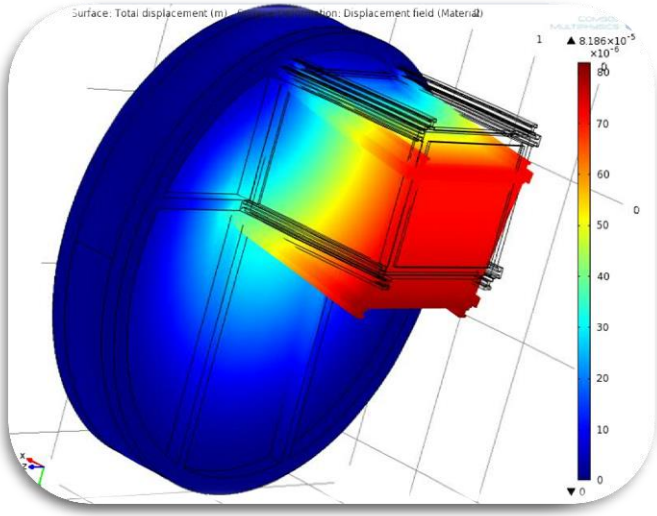


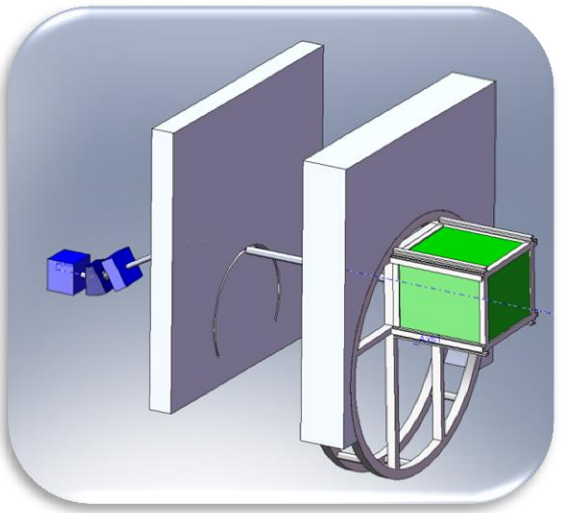

Schematic breakdown of IFMIF-DONES Systems
Accelerator Ancillaries
RF Power System
Beam Dump
Injector
100 keV
5 MeV
9
14.5
26
40 MeV
RFQ
MEBT
SRF Linac
HEBT
Test Systems
Test Cell
HFTM, STUMM
Target system
Test Systems Ancillaries
Lithium Systems
Lithium Systems Ancillaries
Accelerator Systems
BNCT HALL
Quench tank
Main Li loop
Secondary loop
Tertiary loop
Primary HX
Secondary HX
Tertiary HX
Cooling water
EMP
EMP
Pump
Pump
Li Dump tank
Y Trap
Ti Trap
Cold trap
Impurity control system
Heat Removal System
Site, Buildings & Plant Systems
Layout & Site Infrastructures
Buildings
Plant Systems (I and II)
Remote Handling
Central Control Systems and Integrated Instrumentation

# Sviluppo di gantry rotante (2)

- Da simulazioni preliminari, il punto meno critico di ancoraggio del moderatore è la parete di calcestruzzo intorno al tubo di passaggio del fascio.
- L'ancoraggio del moderatore alla parete di calcestruzzo in questo punto impone la rotazione di un cilindro di calcestruzzo di 5.5 m di diametro e 1 m di spessore.
- Il peso di tale ciambella è circa 80 t.





- Il peso complessivo degli elementi da muovere è maggiore di 110 tonnellate.
- Il costo di tale sistema rischia di essere eccessivo > 8 M€

# The third pillar: experimental microdosimetric spectrum