New irradiation facility for biomedical applications at the RA-3 reactor thermal column

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Introduction

Typical BNCT treatments: patient´s tumors irradiated in-situ with external near collimated neutron beams.

New concept of BNCT: (University of Pavia, 2001) resection of the zone to be treated, its irradiation with thermal neutrons inside a nuclear reactor thermal column and finally its re-implantation.

Introduction

- Immersion of the tissue in a near isotropic neutron radiation field providing a reasonable uniformity in all the volume (specially for small samples).
- Uniformity is an important requirement for diffused and multifocal tumors.

Introduction

- University of Pavia applied this idea to an entire liver with multifocal unresectable metastasis. (non uniformity along the organ: treatment included irradiations in two positions rotated 180º).

- Results were promising.

- An alternative technique was proposed by a liver surgeon of the Roffo Institute: partial liver autograft (Advantages: absence of an anhepatic phase and better uniformity during neutron irradiation due to a smaller liver volume)

Introduction

- To carry out this new proposal in the frame of the Argentine BNCT project: construction of a new irradiation facility in the thermal column of the RA-3 reactor of Ezeiza Atomic Center.

- Specifications:

✔ Highly thermalized neutron spectrum
✔ Thermal flux of around 10^{10} n/cm^{2}s (10 min)
✔ Neutron flux as isotropic and uniform as possible
✔ Gamma flux as low as possible

- Facility also adequate to treat other organs ex-situ and to perform experiments with biological samples (cells and small animals).

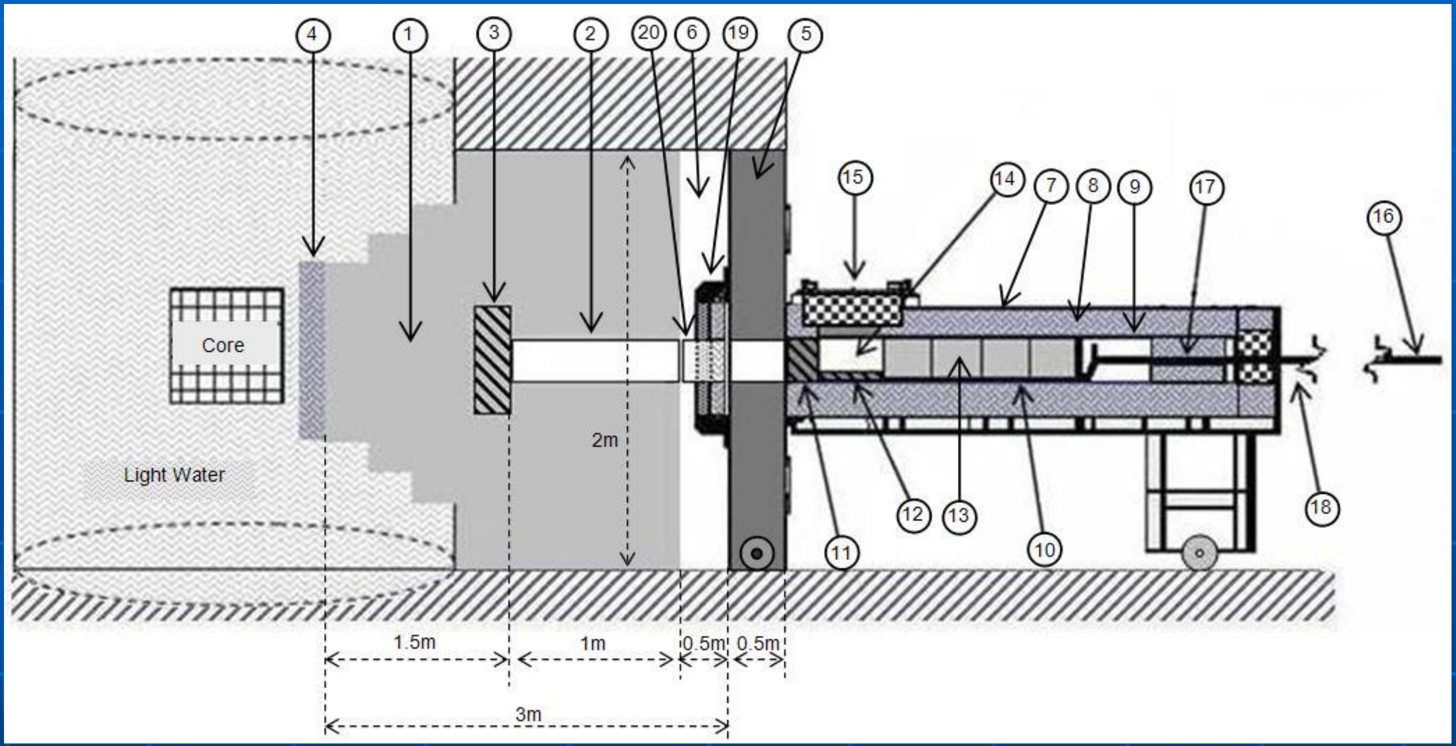
Description of the new facility

RA-3:

- Open pool reactor, up to 10 MW power.
- Radioisotopes production.
- Operates continuously five days a week.
- Lateral graphite thermal column (access into the column during reactor operation was not possible).

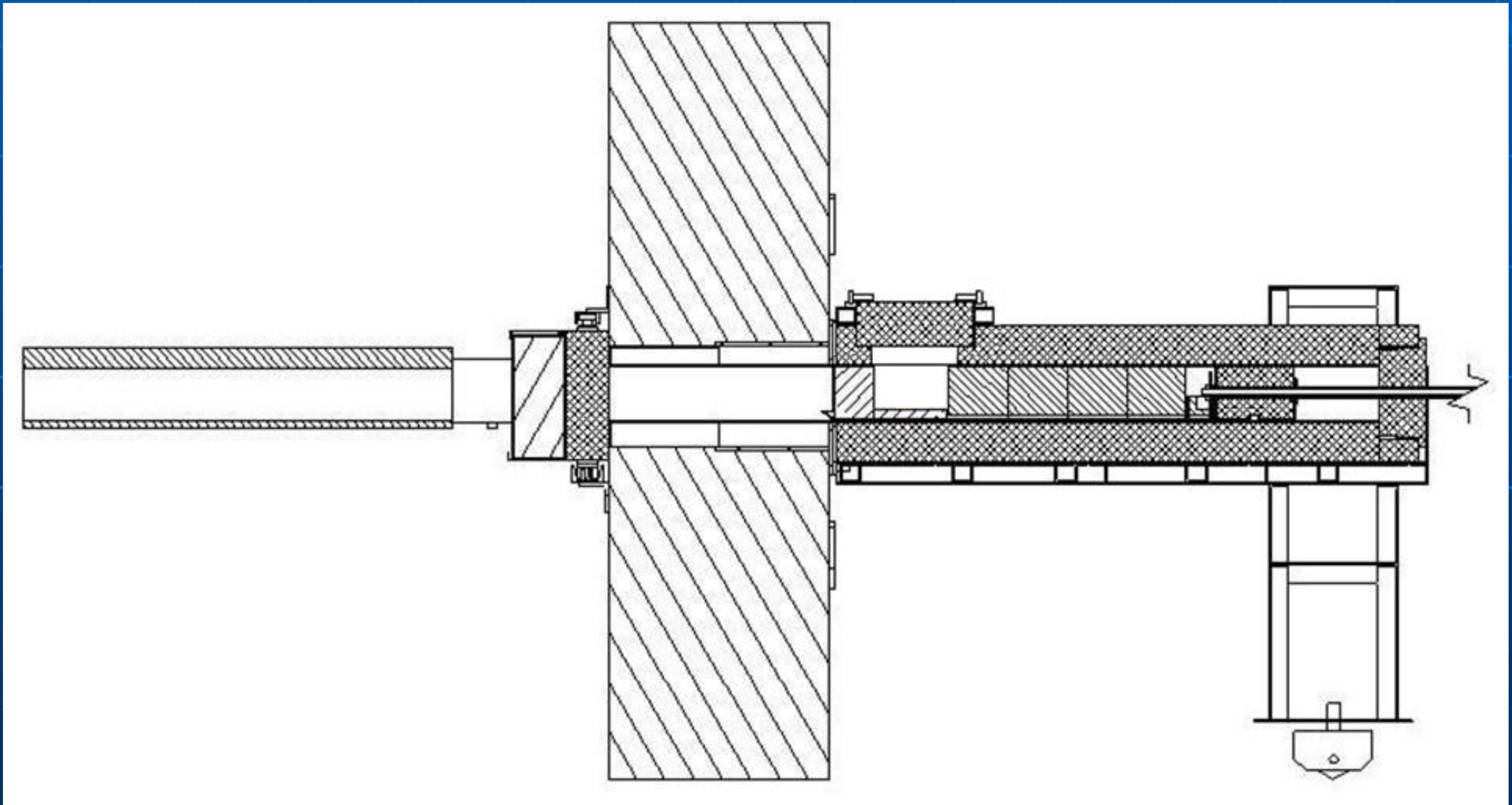
- **New facility: additional shields (fix and movable) to allow for sample introduction with the reactor operating (great availability).**

Diagram of the new facility

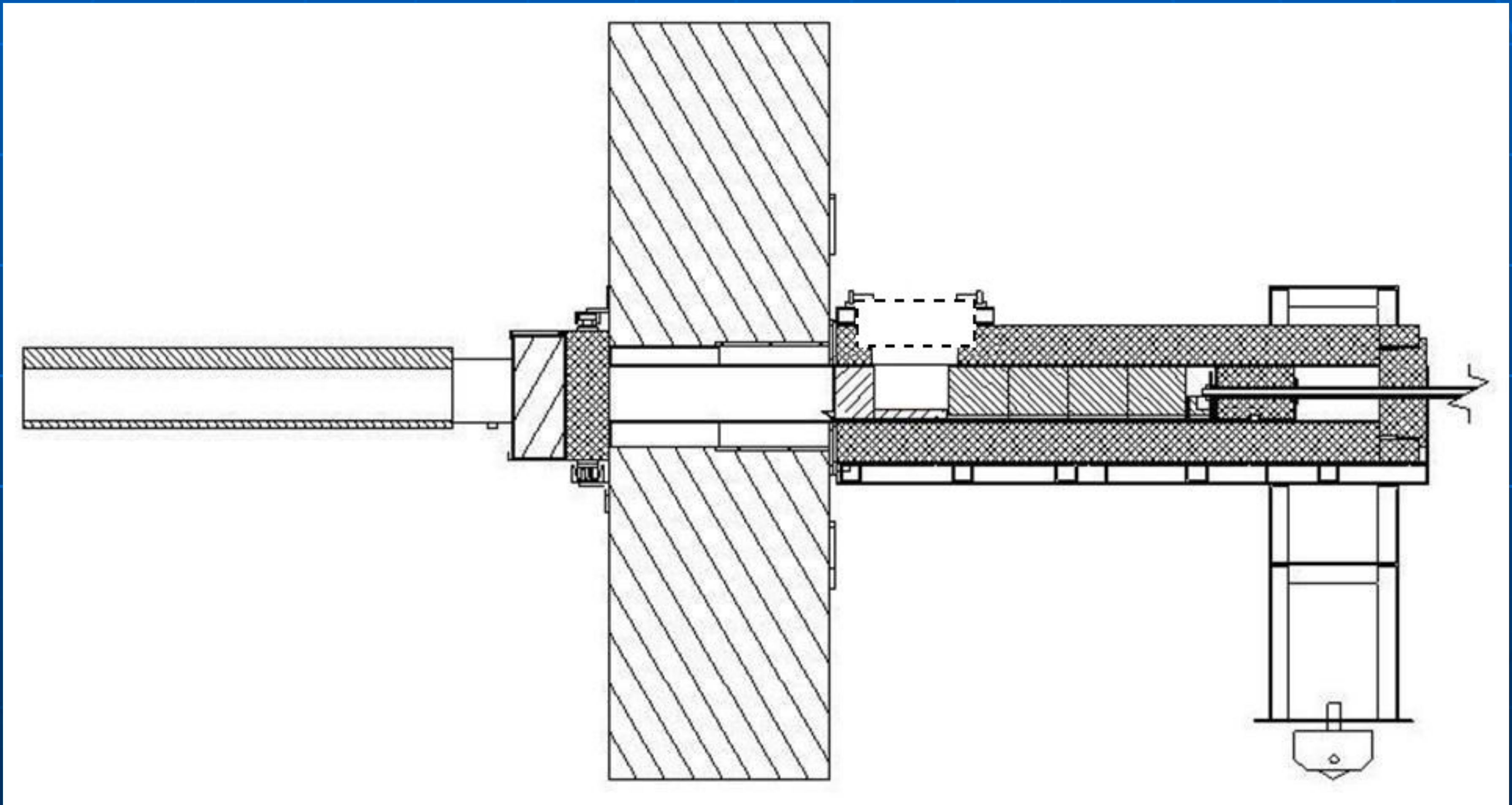


1- Thermal column with graphite as main material
2- Air tunnel (square section ~ 15cm x15cm).
3- Bismuth gamma shield (20x20x10cm).
4- Lead gamma shield (end of the column).
5- External door for column shielding (air tunnel with square section ~ 15cm x15cm).
6- Air
7- External shield for sample insertion
8- Surrounding lead shield (~ 10 cm thickness).
9- Air tunnel (square section ~ 15cmx15cm, 110cm length).
10- Movable Zy-4 carrier sample tray (11- Bismuth block ~ 15x15x10 cm, 12- Bismuth base ~ 15x2x18 cm, 13- Graphite blocks for neutron reflection, 14- Space for samples ~ 15x11x18 cm).
15- Upper door with lateral movement for insertion of samples in the corresponding space.
16- Tube to push the movable carrier sample tray into the column.
17- Movable cadmium and lead block for neutron and gamma shield during sample irradiation.
18- Tube to push the movable shield.
19- Movable gamma and neutron shield (shutter), (lateral movement with external control, square section 20cmx20cm, lead, cadmium and paraffin wax).
20- Movable bridge (lateral movement accompanying the shutter).

Steps for irradiation of samples



Steps for irradiation of samples



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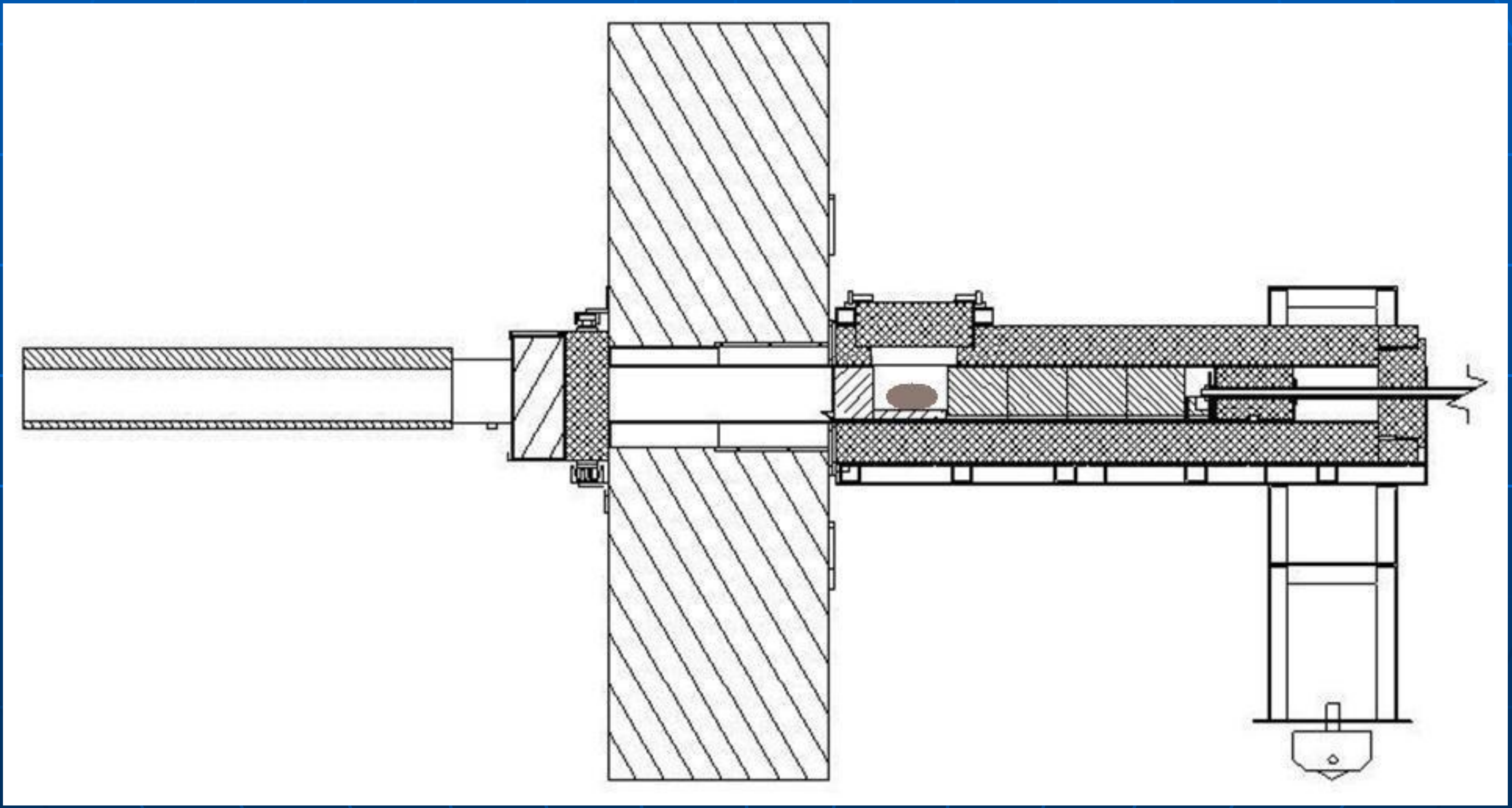

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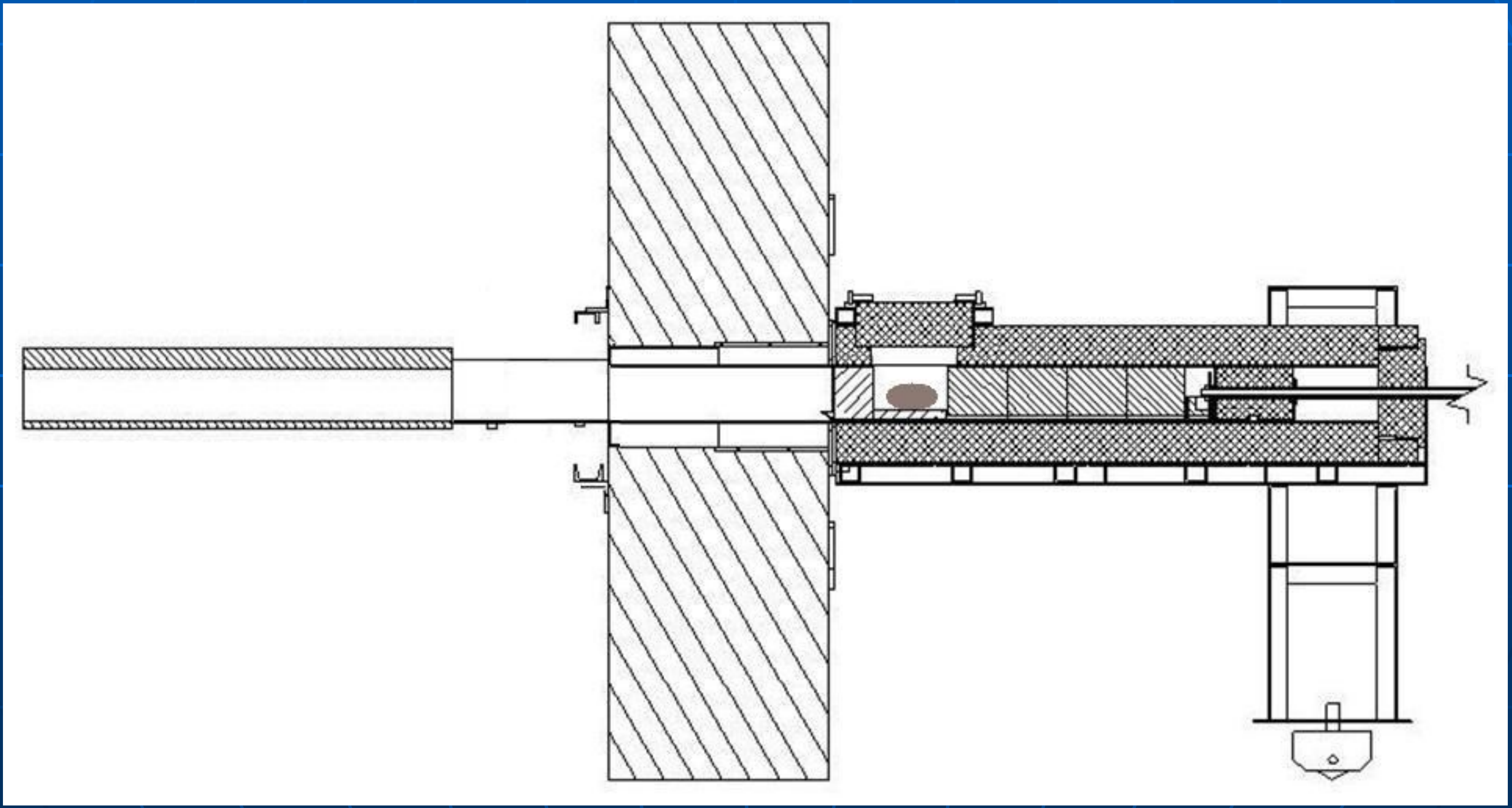
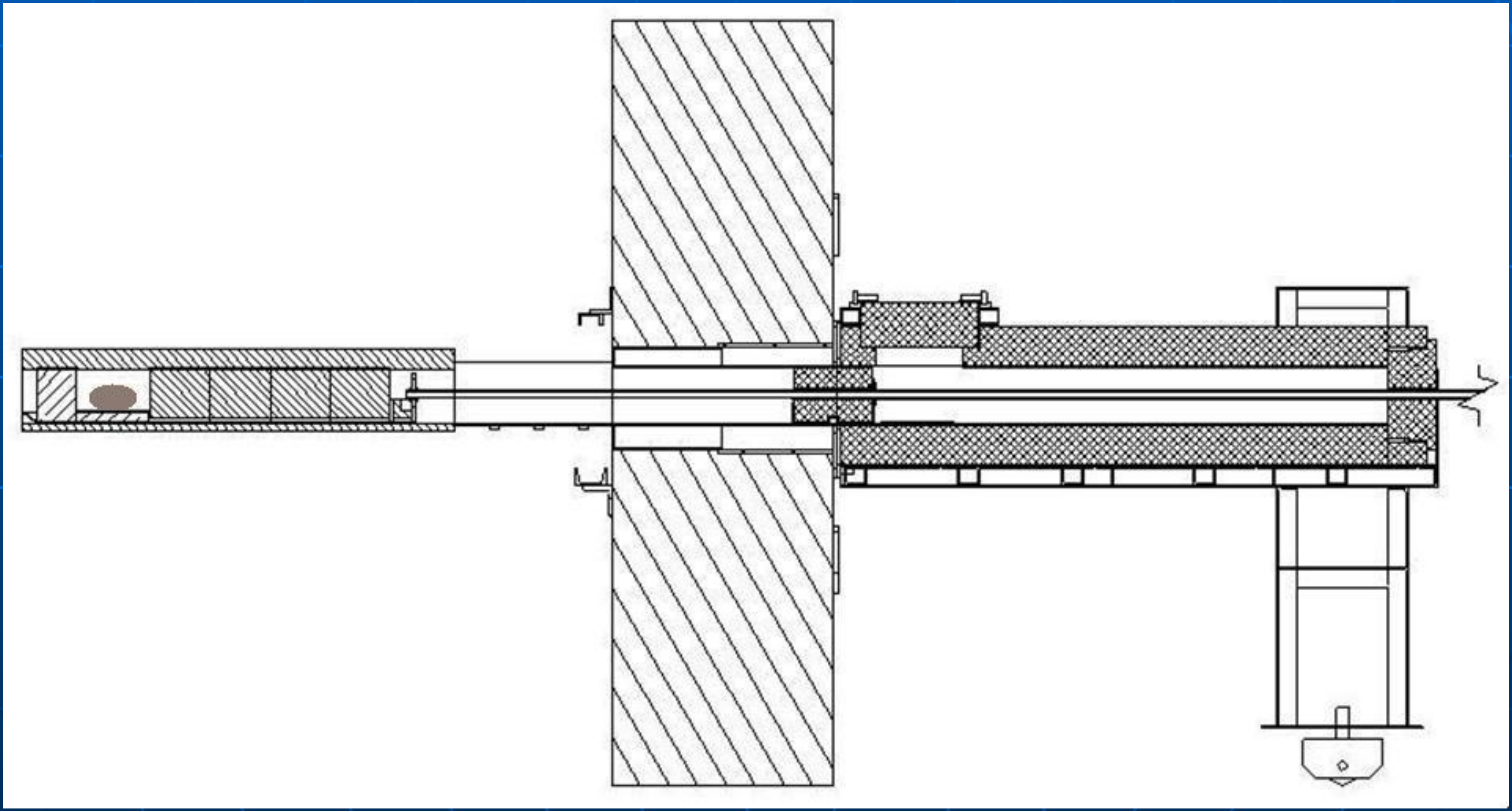
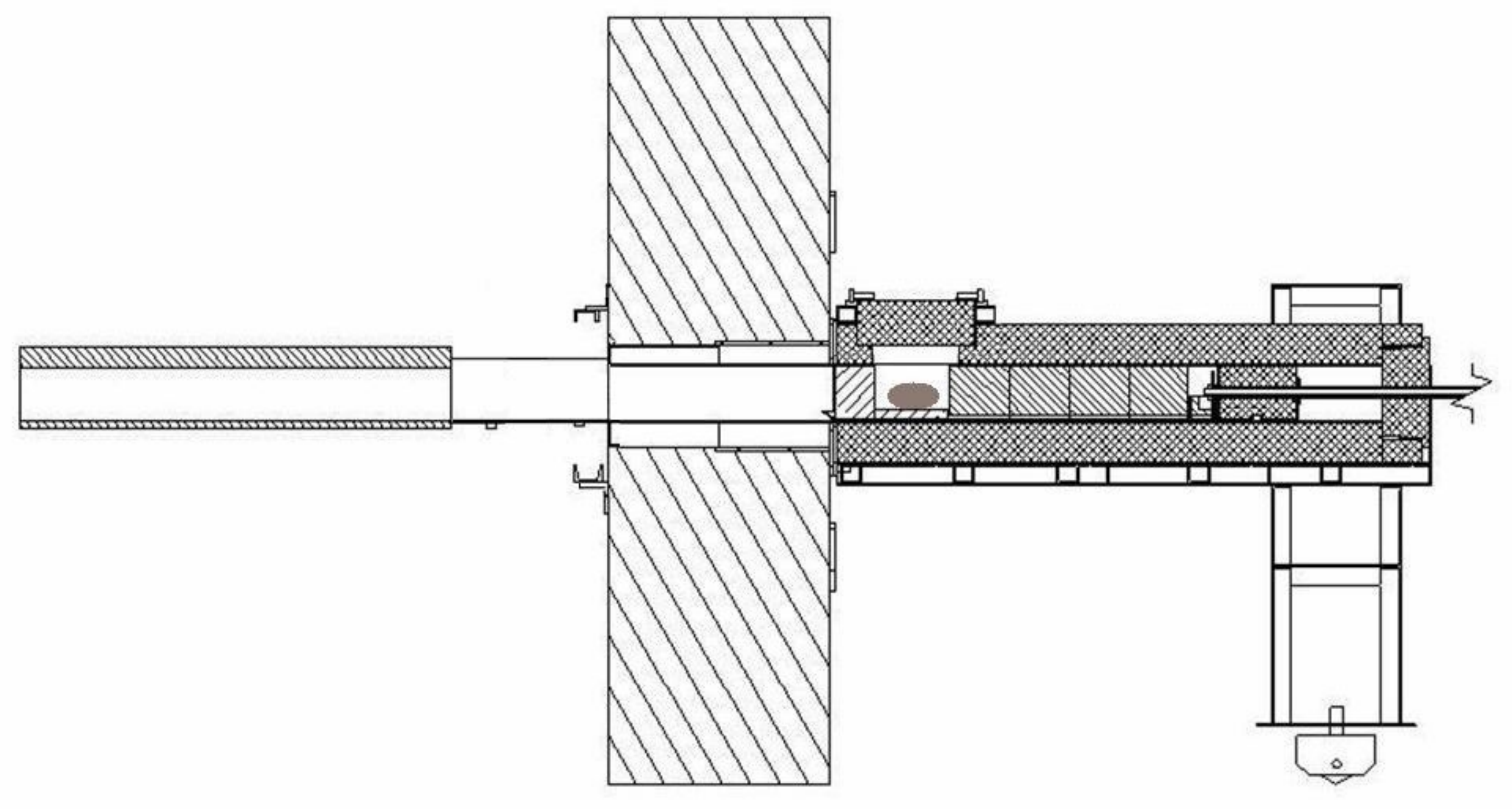


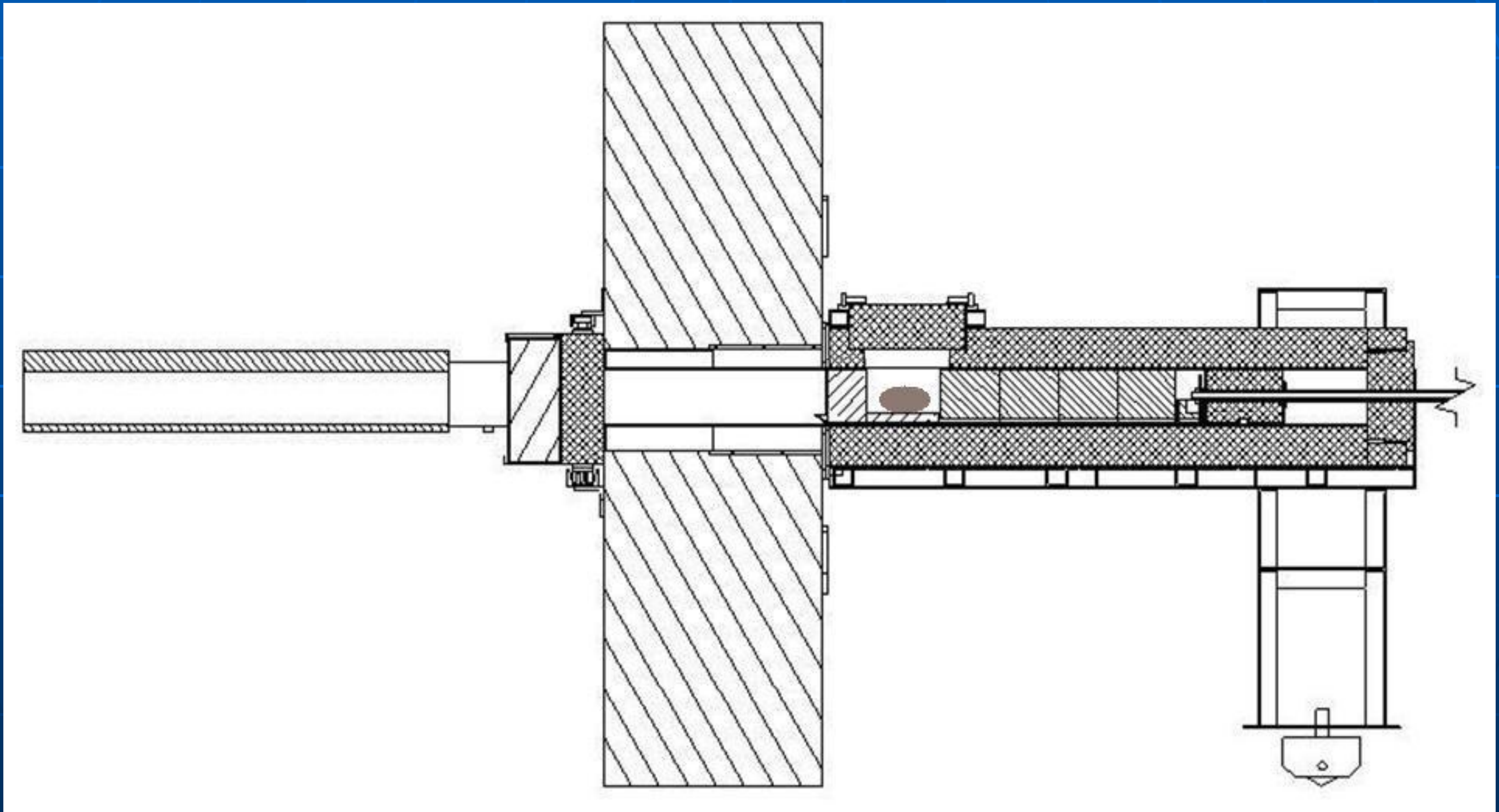
Steps for irradiation of samples



Steps for irradiation of samples



Steps for irradiation of samples



External views of the facility

1- Left view

2- Right view (instrumentation cables and external control of internal shutter)

3- Detail of the upper door (closed)

4- Detail of the upper door (opened) and space for samples.

Physical characterization of the space for samples

General conditions: a) free-in-air
b) power reactor: 8 MW
c) irradiation position nearest to the core

1. Thermal to fast neutron ratio: bare and under Cadmium cover Gold foils were used.
2. Thermal flux: bare Cobalt and Gold foils and calibrated SPNDs.
3. Uniformity: ratio between neutron flux in both extremes (nearest and farthest from the core)
4. Structural gamma dose rate: Far West graphite ionization chamber covered with a neutron shield of ^{6}LiF

Results and discussion

1. Cadmium ratio: 4100
   % Epicadmium/thermal neutron flux ~ 0.03 %
   (Pozzi et al., 2007)

Highly thermalized spectrum was obtained

2. Thermal neutron flux nearest to the core = (9±1) 10^9 n cm^{-2} s^{-1}

3. Difference between maximum and minimum thermal flux ~ 20%

4. Gamma-ray dose rate (free-in-air): (5.6±0.5) Gy h^{-1}

Gamma dose per thermal neutron fluence unit: 1.7 10^{-13} Gy/ncm^{-2}

Results and discussion

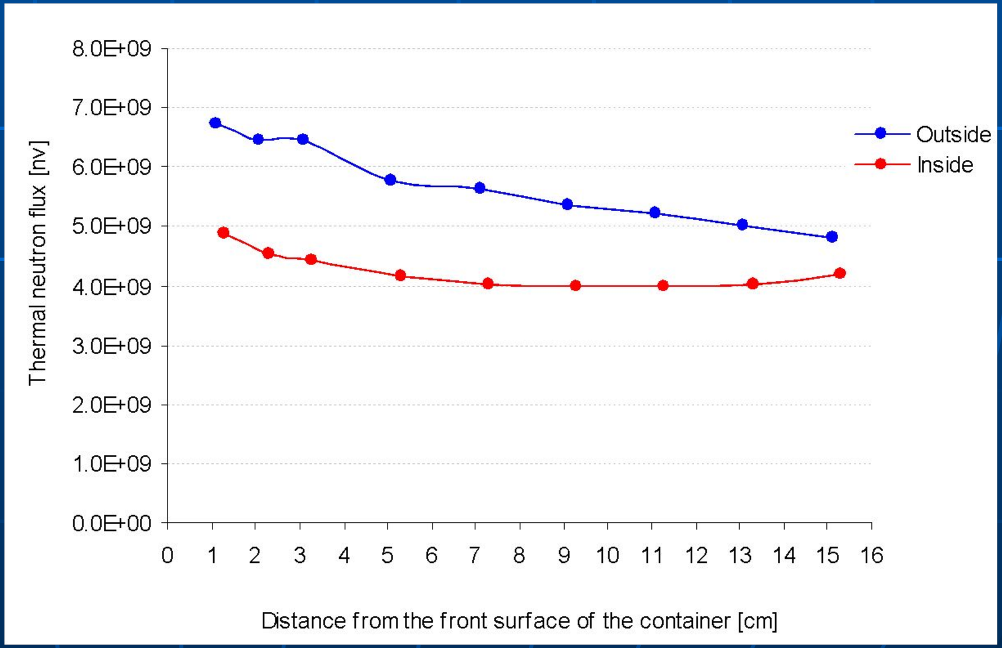
- The use of the facility started in 2006.

- Due to its final characteristics and high availability, several biological experiments have been able to be performed: irradiation of small animals (hamsters and rats), different tumoral cells (thyroid and melanoma), and, in particular our group has performed a preliminary liver dose estimation using portions of cow and pig livers simulating human liver left lobe (poster of Gadan et al.)

Results and discussion

Detectors:

- Two implantable Self Powered Neutron Detectors (0.2cm diameter and 20cm length).
- Sensitive material (Rhodium) length: 1cm.



Conclusions

- As a consequence of the very well thermalized spectrum available in the new facility the contribution from fast neutron to overall dose can be considered as negligible for typical BNCT assays.
- Structural gamma dose rate also resulted low enough to assume that its importance in total dose will not be a limiting factor.
- First uses of the facility to test neutron profiles in portions of livers, showed that an acceptable uniformity can be obtained, without rotating or moving the sample during its irradiation.

Cámara de Ionización para medición de tasa gamma Far West