EFFDOC-987

TASK TTMN-002

Status of TBM neutronics experiments

Paola Batistoni

ENEA – Fusion and Nuclear Technology Dept. – Frascati

JEFF/EFF Meeting, Paris, 20-21 November 2006

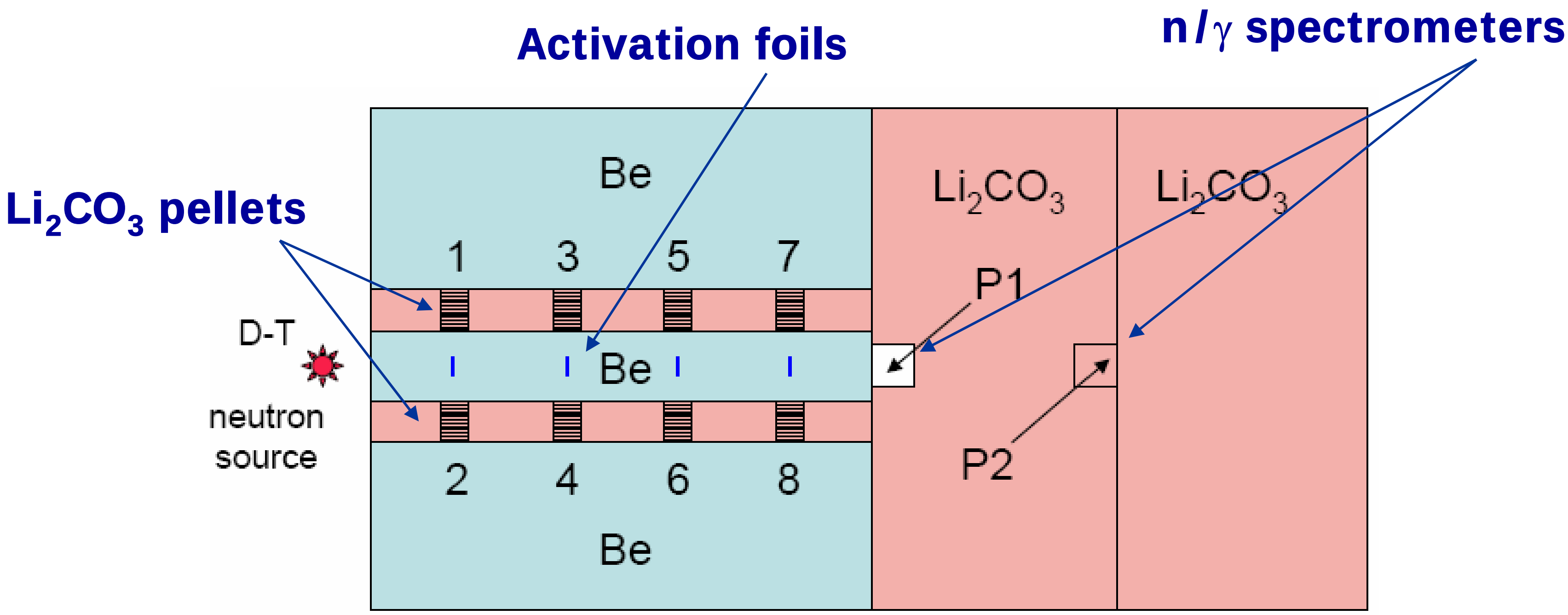
Validation of Tritium production rate calculations for EU breeder blanket concepts

- **Helium Cooled Pebble Bed (HCPB)**
  just completed → **conclusions**
  - ✓ Be as neutron multiplier
  - ✓ Li_4SiO_4 as breeder material

- **Helium Cooled Lithium Lead (HCLL)**
  new benchmark experiment sarted → **design**
  - ✓ LiPb eutectic alloy as breeder/multiplier

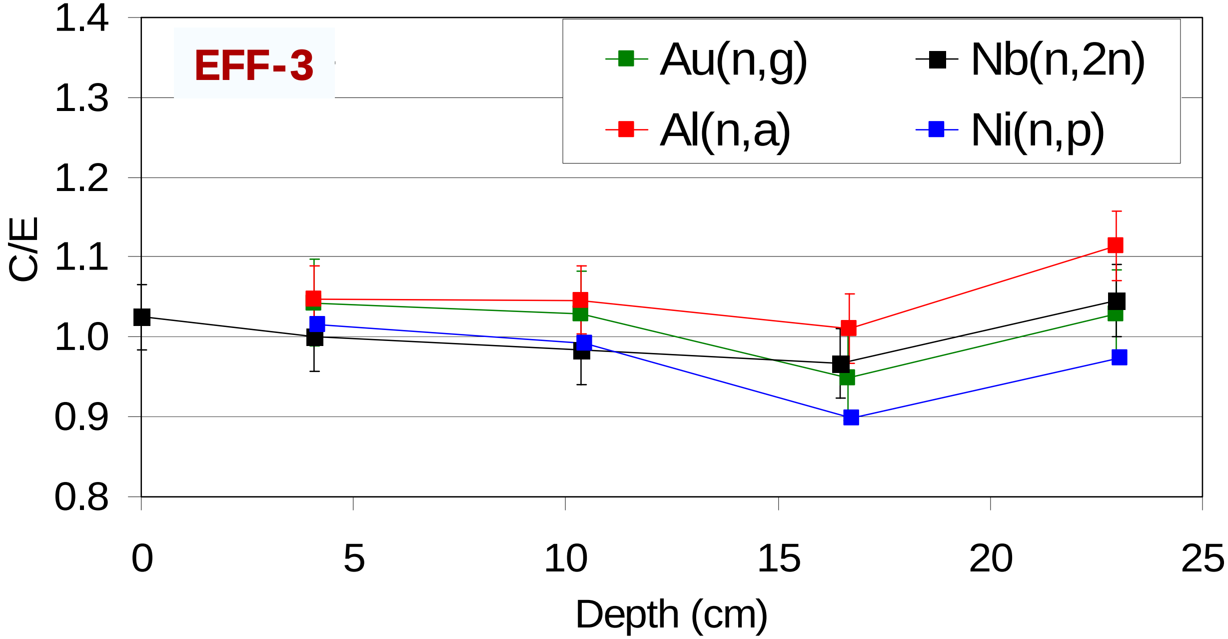
Measurements

- **Tritium production by Li_2CO_3 pellets** (ENEA, TUD, (JAEA))
- **Neutron flux in the central Be layer** (ENEA)
- **Neutron & γ-ray spectra behind the breeder unit** (TUD/VKTA)



- **Neutron flux in the central Be layer** by activation foils

E_n > 10 MeV: Nb-93(n,2n)
E_n > 1 MeV: Al-27(n,α),Ni-58(n,p)
E_n ~ 5 eV: Au-197(n,γ)

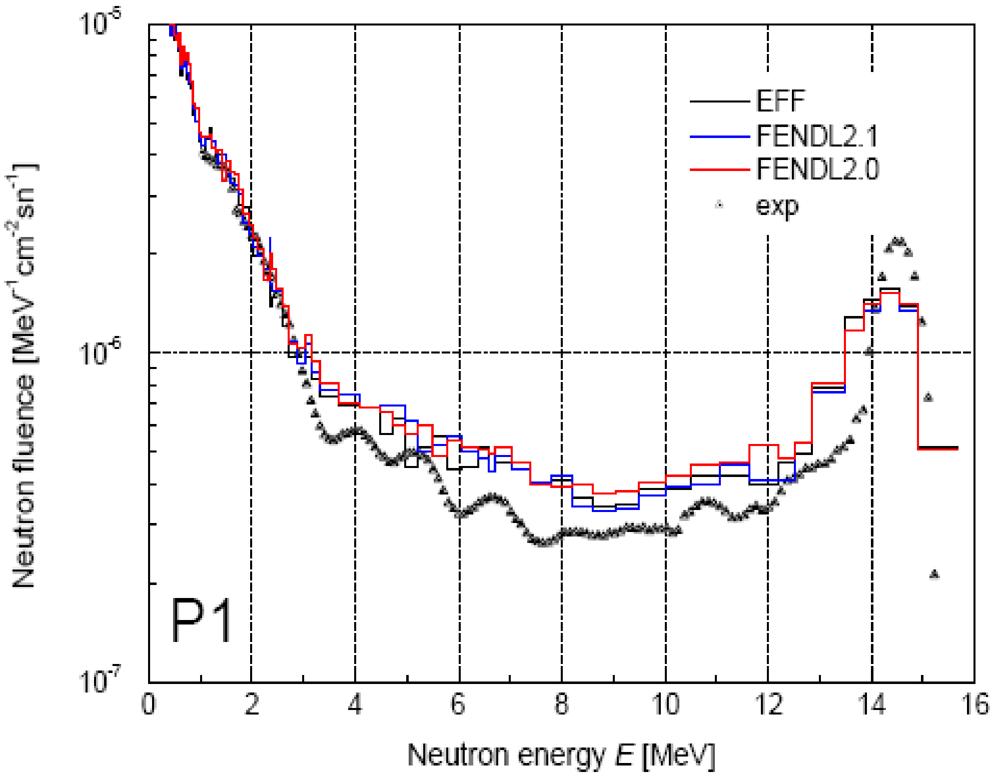


Activation measurements: the neutron flux attenuation is well predicted by EFF-3.05 & FENDL-2.1

Neutron & γ-ray spectra behind the breeder unit

K. Seidel et al. (EFFDOC-972), U. Fischer, D. Leichtle (EFFDOC-976)

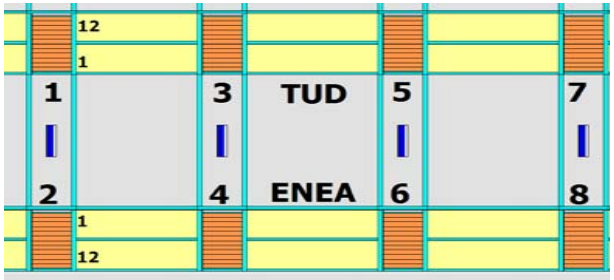
EFF-3.05, FENDL-2.0/1 overestimate fast neut. flux by 10…20% and underestimate γ and slow neutron flux (<1keV) by 10…20%

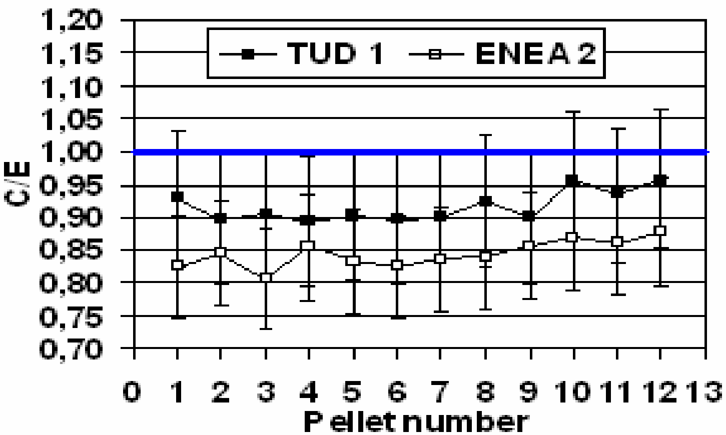


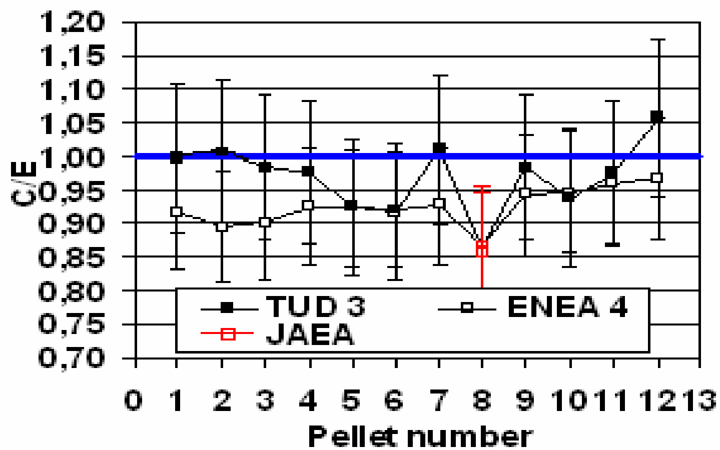
Pos 1	C/E EFF	C/E FENDL2.1	C/E FENDL2
Neutron [MeV]			
1-5	1.07	1.11	1.13
5-10	1.31	1.34	1.40
>10	1.14	1.11	1.17
>1	1.13	1.14	1.18
Gamma [MeV]			
0.4—2	0.81	0.78	0.82
2-4	0.89	0.91	0.90
>4	0.82	0.88	0.91
>0.4	0.82	0.83	0.85
TOA [μs]			
50-100	0.96	0.82	0.92
100-200	0.78	0.72	0.89
200-300	0.88	0.92	0.90
>50	0.91	0.80	0.91

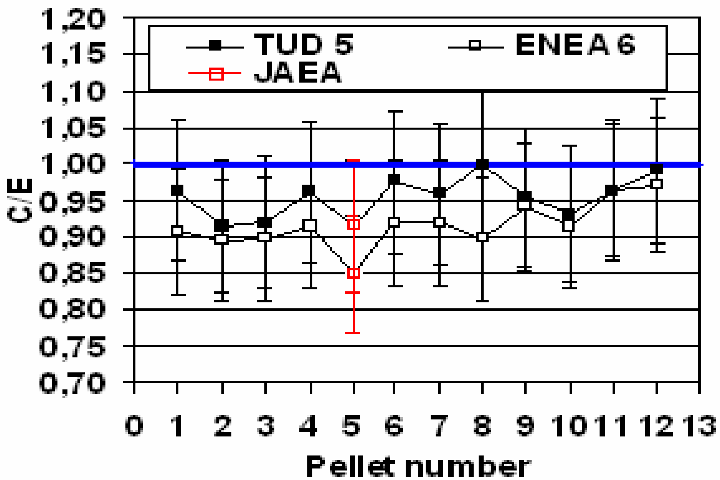
▪ Tritium production measurements

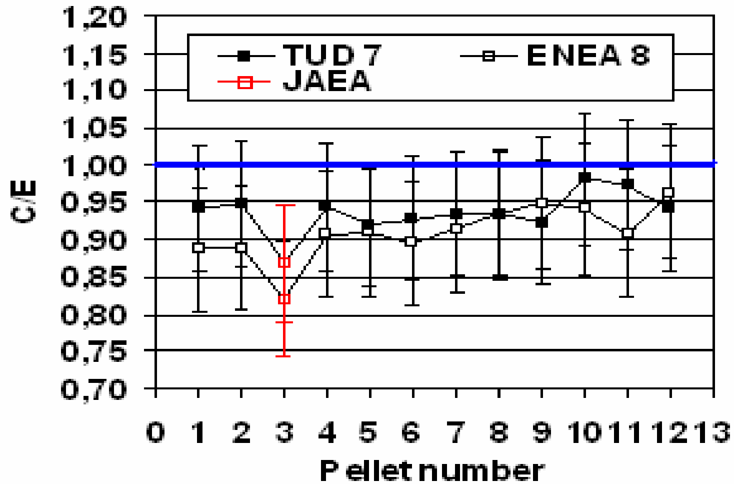
12 Li_2CO_3 pellets (2mm thick) in each position to measure gradient across the ceramic breeder layer











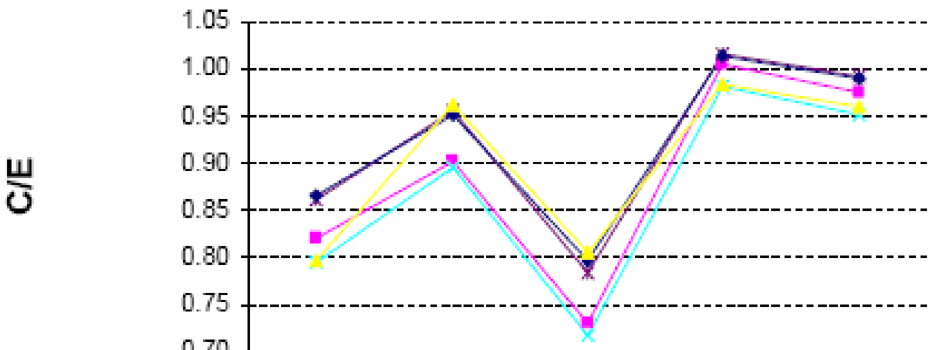
EFF-3 (and also JEFF-3.1, FENDL-2.1) underestimate tritium production by 5 – 10 %

Benchmark calculations with FNS-TOF Be Experiment

Be slab 15.24 cm thick

Processing and Benchmarking of 9Be JEFF-3.1T Data (D. Leichtle EFFDOC-932)

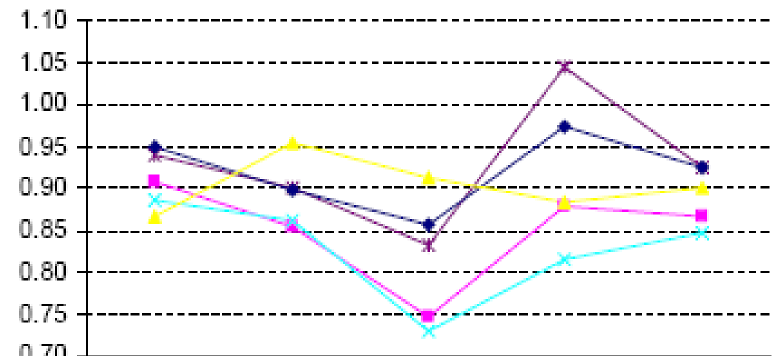
Neutron angular fluxes at 0 deg



	0,052-1 MeV	1-5 MeV	5-10 MeV	>10 MeV	>0,052 MeV
JEFF3.1 orig.	8.21E-01	9.03E-01	7.29E-01	1.01E+00	9.74E-01
JEFF3.1 NRG	7.94E-01	8.96E-01	7.18E-01	9.81E-01	9.51E-01
JEFF3.1 FZK	8.60E-01	9.56E-01	7.83E-01	1.02E+00	9.91E-01
EFF3.05	8.66E-01	9.52E-01	7.96E-01	1.01E+00	9.90E-01
FENDL2.1	7.97E-01	9.62E-01	8.05E-01	9.83E-01	9.60E-01

Energy Interval

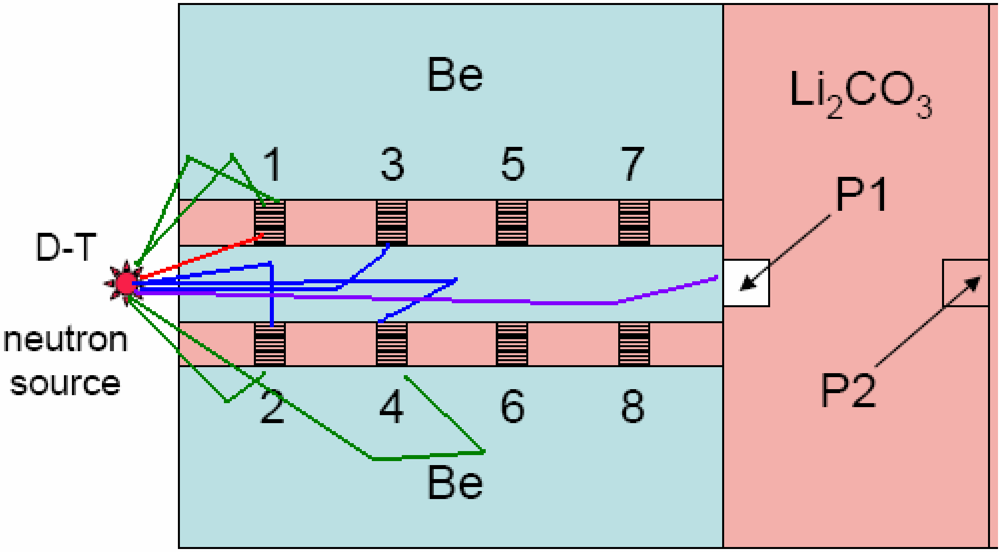
Neutron angular fluxes at 66.8 deg



	0,052-1 MeV	1-5 MeV	5-10 MeV	>10 MeV	>0,052 MeV
JEFF3.1 orig.	9.07E-01	8.55E-01	7.47E-01	8.78E-01	8.65E-01
JEFF3.1 NRG	8.84E-01	8.62E-01	7.29E-01	8.14E-01	8.46E-01
JEFF3.1 FZK	9.39E-01	9.01E-01	8.31E-01	1.04E+00	9.24E-01
EFF3.05	9.49E-01	8.97E-01	8.55E-01	9.73E-01	9.23E-01
FENDL2.1	8.65E-01	9.53E-01	9.13E-01	8.83E-01	9.00E-01

Energy Interval

All libraries underestimate angular fast neut. flux by 10…20% at 66.8 deg.



Experimental configuration very sensitive to angular distribution of elastic cross section (~2 % / % sensitivity to <u>integral</u> elastic cross section)

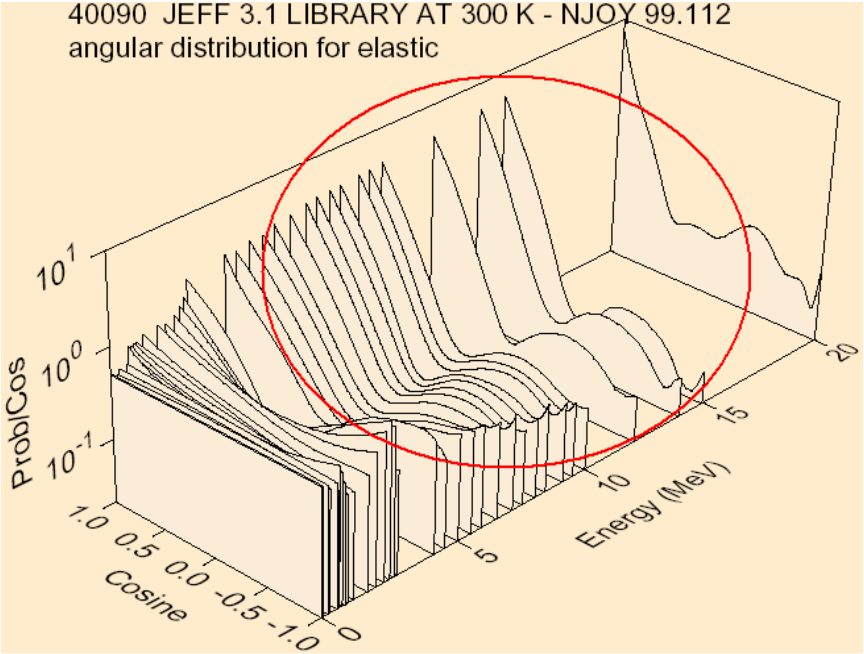
Conclusions from the experiment:

1.T-production in reactor is OK (conservative)

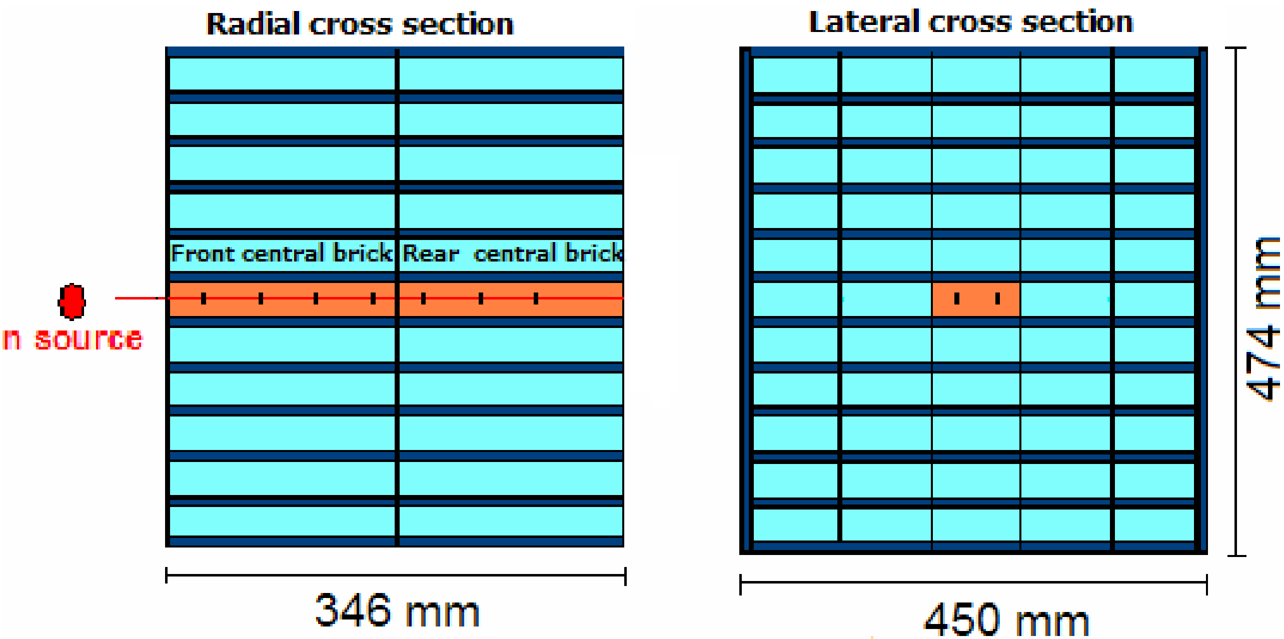
but

2. angle distribution of scatterd neutrons not fully satisfactory yet

→ *sensitivity to angular distribution*



Design of the TBM - HCLL mock-up based on the reference EU design (LiPb, 15.7 at% nat-Li)



Measurements in the two central bricks (up to ~28 cm)

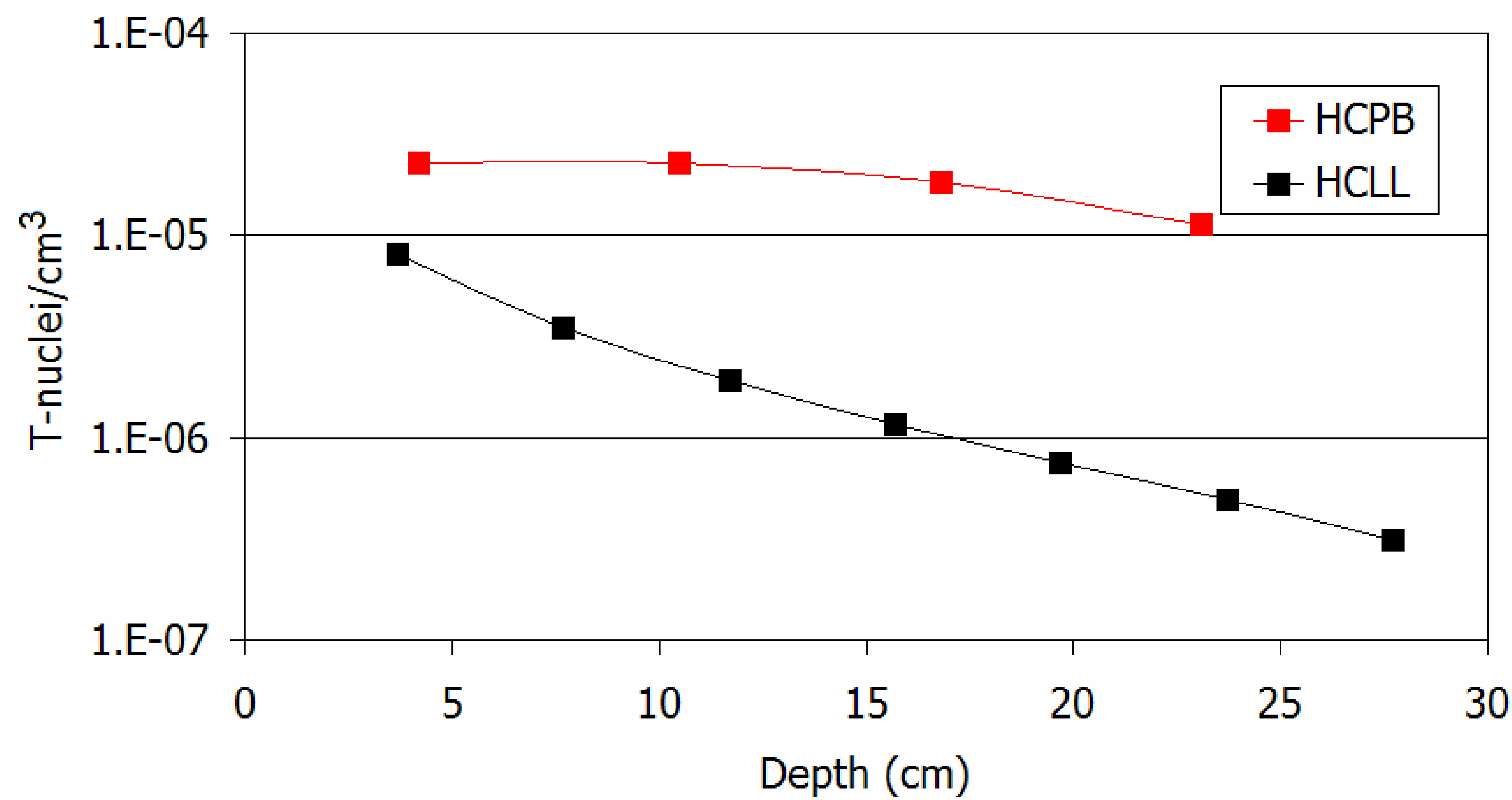
- **T - production**
- **Neutron flux by activation foils**
- **Neutron & γ-ray spectra**

Stainless steel (N.12 cooling plates, thickness 6.5 mm)

LiPb - Li content 15.7±0.5 at%, i.e. 0.62±0.03 wt%

N. of bricks: 2 (radial) x 11 (poloidal) x 5 (toroidal) = 110
Size of bricks: 173 mm (rad) x 36 mm (pol) x 90 mm (tor)
Weight of 1 brick = 5.74 Kg /Total weight = 630 Kg

Tritium production per unit volume vs depth:
Comparison between HCPB (only ceramic cassettes) and HCLL



The following T-measurement techniques have been proposed:

1. Li_2CO_3 pellets (ENEA TUD (JAEA)) (∅ =13 mm, **few pellets, nat.Li & 90% enriched Li-6**)

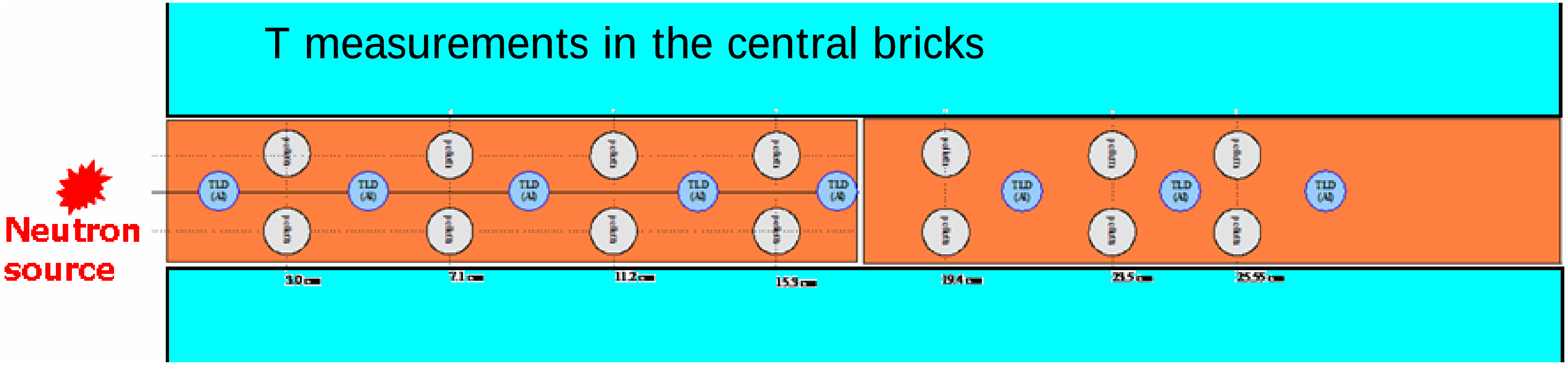
T-activity ~ 30 – 50 Bq/g for Y_{FNG} ~ $5x10^{15}$ n

• LiF probes (**TLD-100,600,700**) + CR-39, BeO (TUD, AGH)

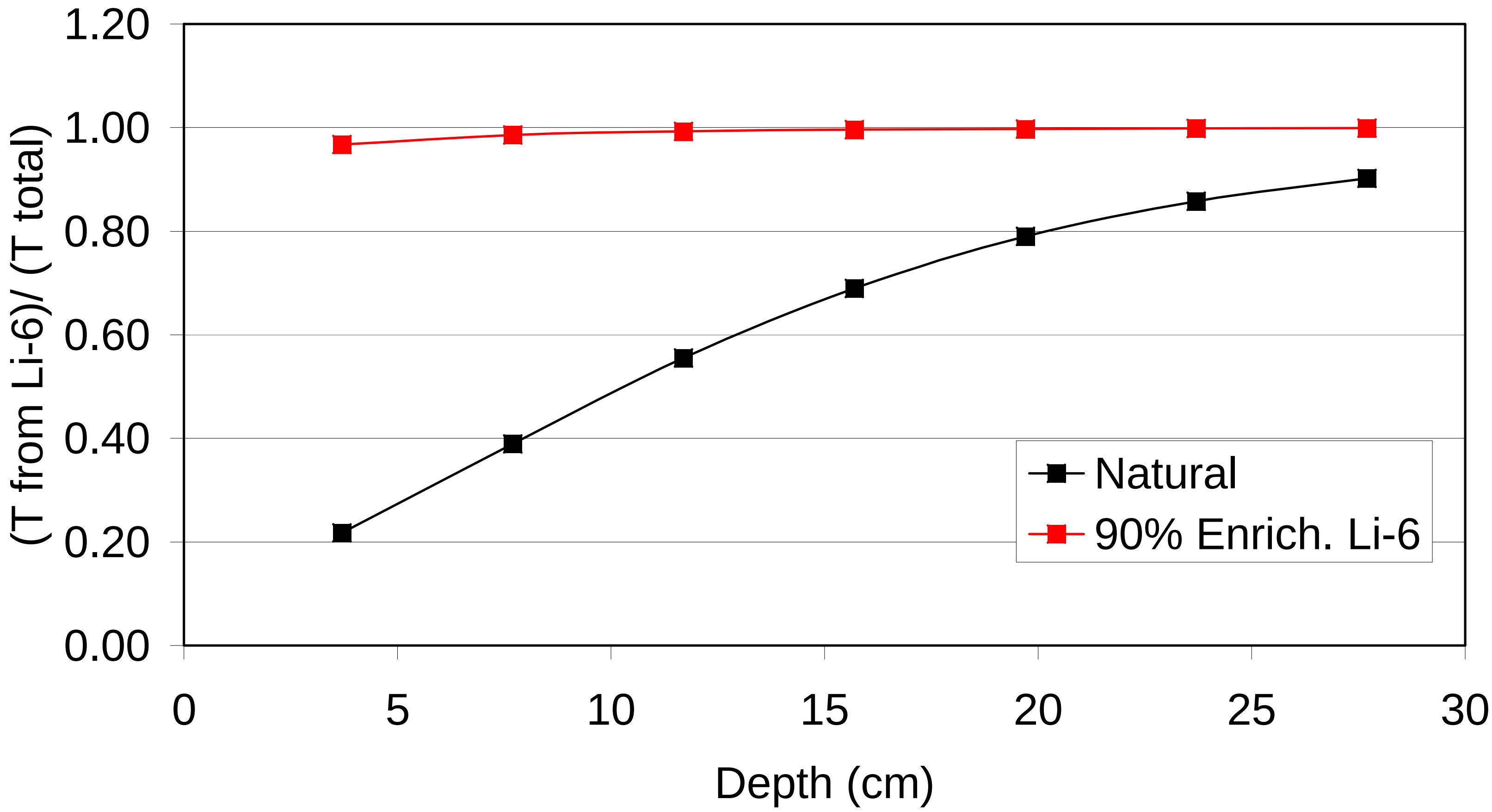
TLD-600: ~10 Gy @5 cm, ~1 Gy @29 cm
TLD-100: ~3 Bq @3 cm, ~0.2 Bq @25 cm

3. Diamond detector covered with 6-LiF

(to be assessed by ENEA)



Tritium produced in Li_2CO_3 from n+Li-6, n+Li-7 reactions



Use of different probes at each depth, with different Li-6 enrichment to discriminate Li-7 from Li-6 contributions

- The LiPB material has already been ordered by EFDA
- Due to a delay in the bid process, the material will be delivered to ENEA Frascati in 2007 (instead of Sept.2006)
- ENEA is preparing the additional materials and the detectors
- The design of measurements is in progress
- The experiment will be performed in 2007