ID: 864

FUSION DEVICES AS NEUTRON SOURCES FOR FFH(FUSION FISSION HYBRID REACTORS):ANALYSIS OF TOKAMAK PARAMETERS , READINESS LEVEL AND DESIGN OF VALIDATION EXPERIMENTS

F. P. ORSITTO[1], M. SALVATORES[4] , M. CARTA[2], M CIOTTI[1],N BURGIO[2], V FABRIZIO[2], L FALCONI[2], F PANZA [2,3]
[1]ENEA Fusion and Nuclear Safety Department, C R Frascati
00044Frascati (Roma) Italy
[2]ENEA Fusion and Nuclear Safety Department, C R Casaccia
00123 S.Maria di Galeria (Roma), Italy
[3]Istituto Nazionale di Fisica Nucleare Sezione di Genova , Via Dodecaneso
16146 Genova, Italy
[4]Senior Scientific Advisor
Email: francesco.orsitto@enea.it; fporsitto@gmail.com

ABSTRACT

- Plasma parameters of Fusion Fission Hybrid Reactors (FFH) neutron sources based on tokamaks can be obtained from a new derivation of the scaling laws for fusion reactors. The basic properties of tokamak neutron source useful for FFH and the related Technology Readiness Levels (TRL) are then reviewed.
- The study of the FFH reactor based on the tokamak neutron source surrounded by a subcritical fission blanket and by a lithium blanket is carried out showing one of the main property: tritium production.
- The proof of principle of the FFH can be demonstrated using a DD or DT neutron source at low power and a fission reactor operated in subcritical mode. The scheme of validation of the FFH can be extrapolated from that already developed for the pre-TRADE experiments using the TRIGA fission reactor.

BACKGROUND

- The fusion neutron sources needed for FFH (Fusion-Fission Hybrid) devices are not available so far, and the blankets integrating the fusion and fission characteristics need to be projected and validated. The concrete validation of the FFH concept is needed. The present paper presents results of a study related to these arguments.
- Fusion Fission Hybrid reactors are studied as devices capable of producing energy and for the incineration of nuclear waste .
- The present study makes clear that FFH reactors can produce TRITIUM for fusion reactors.
- The challenges are : I) to build a tokamak as neutron source with low Fusion Gain , high reliability, long pulse- steady state; ii) coupling of the neutron source with a two blankets : fission blanket which includes nuclear waste and fusion blanket which contains Lithium for producing TRITIUM.

A.Tokamak based Neutron source

Using a novel scaling law for fusion reactor which extends the Kadomtsev similarity methodology a set of plasma parameters for the tokamak neutron source. The scaling law is the following : S_{FR} =scaling parameter for fusion reactors = $R\ B^{4/3}\ A^{-1}\ Q0^{1/3}$. Where R is the major radius, B magnetic field, A aspect ratio, Q0 fusion gain factor. Fusion reactors are classified by the value of the S_{FR} value.

R(m)	1,5
A	2,5
B(T)	8,5
Ip(MA)	10
nG(10^{20} m-3)	6,28
n (10^{20} m-3)	5
Beta(%)	3,7
betaN(%)	2,1
Pfus (MW)	44
Pinput(MW)	22
T0(keV)	7,3
fi(dilution)	0,8
Neutron(n/s)1.E20	0,158

Table I .Q=2 tokamak neutron source parameters

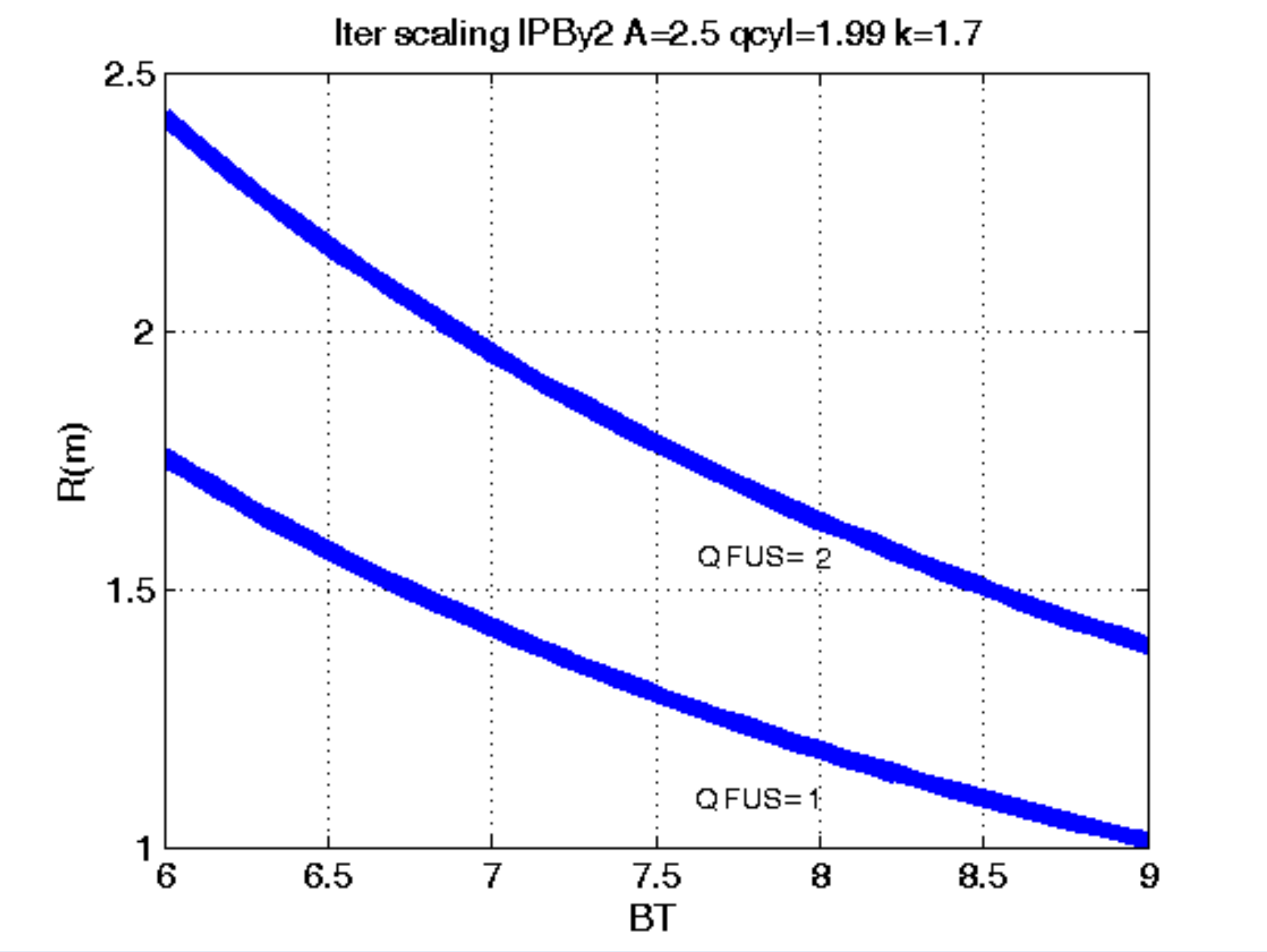

Fig.1. Major radius vs magnetic field of devices at QFus=1and 2 aspect ratio A=2.5, qcyl=1.99, elongation k=1.7

B.FFH reactor Model analysis focused on TRITIUM production : blankets composition

Fission Blanket : Fuel Fresh MOX (Natural U + 5 % 239Pu oxides, density 7.91 g/cm3) , 24 fuel rods (Height=400 cm, Radius=19 cm)

Coolant: Helium

Fusion Blanket : Fusion Breeder γ lithium aluminate

Neutron yield of neutron source (n/s) 7.60E+19 (DT) ; 7.60E+17 (DD)

RESULT : Comparing the Tritium yields obtained in the fuel rods presence with the one obtained without them, we found a significant increase in tritium production, a factor 5.66 gain for the DT gas mix, and a factor of 4.33 DD mix. This gain is due to the reaction of ^{6}Li with neutrons producing Tritium .

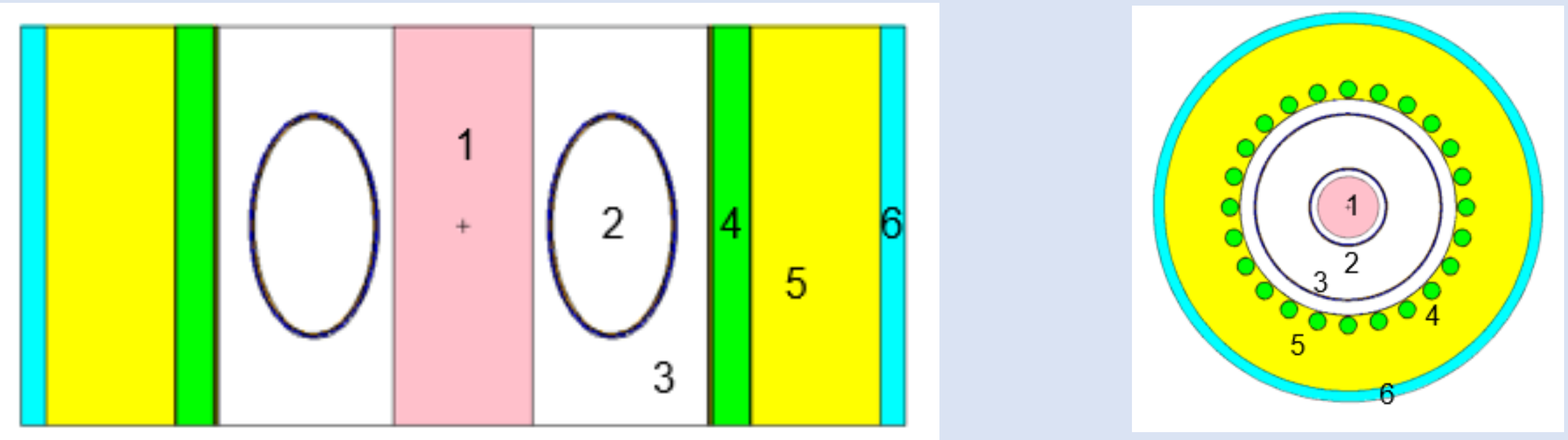

Fig.2. MCNP model for FFH conceptual design. The poloidal (left) and toroidal (right) views of the tokamak and blankets : 1-central solenoid;2-plasma chamber; 3-torus first wall;4-. fission fuel ;5-fusion blanket;6-reflector.

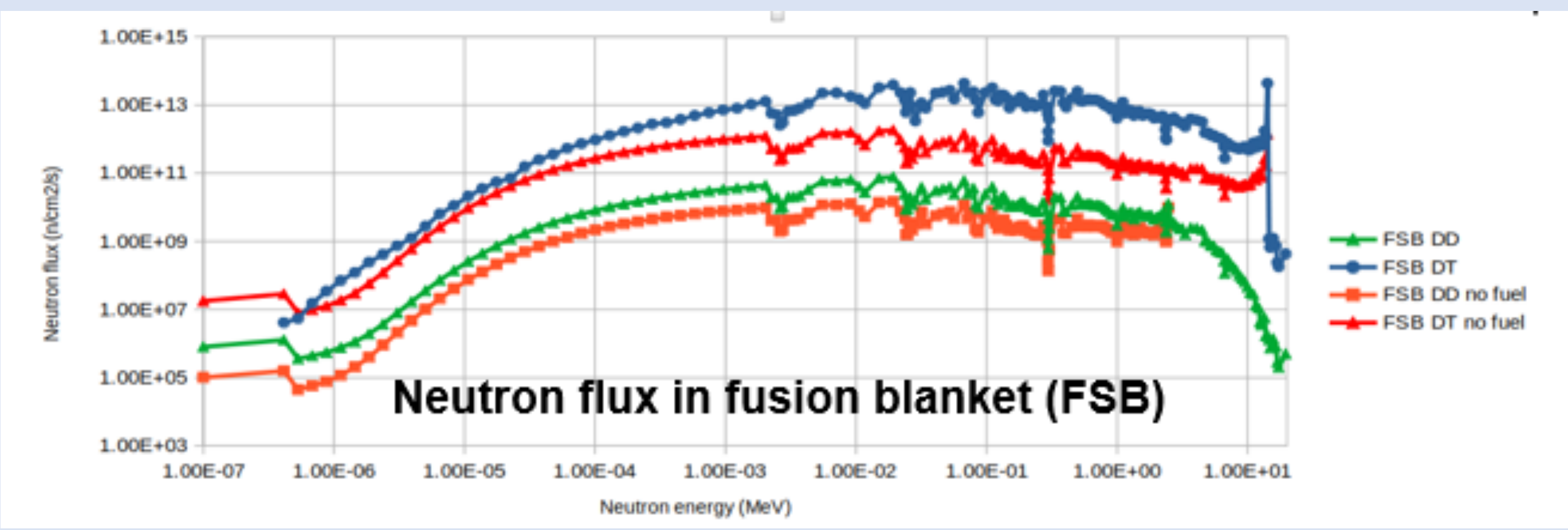

Fig.3.Neutron spectrum generated inside the fusion blanket for both DD and DT gas mix used in the main fusion plasma chamber.

C.Validation of a FFH reactor using TRIGA RC-1 as sub-critical blanket

A research reactor, the TRIGA-RC1 configured in a sub-critical mode, coupled with a neutron generator, could offer some measurements possibilities (sub-criticality, neutron fluxes and neutron energy distributions in the fission core) to study in a detailed way the hybrid in the frame of a pilot experimental proposal.

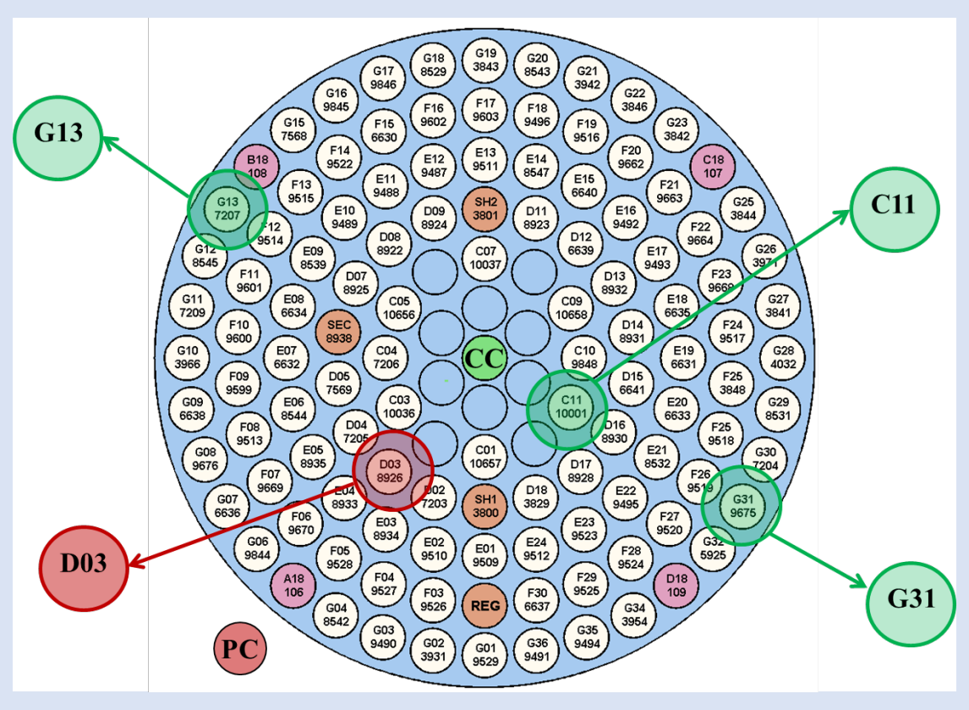

Fig. 4. TRIGA RC-1 subcritical configuration coupled with DD (2.5 MeV) or DT (14.1 MeV) external sources.

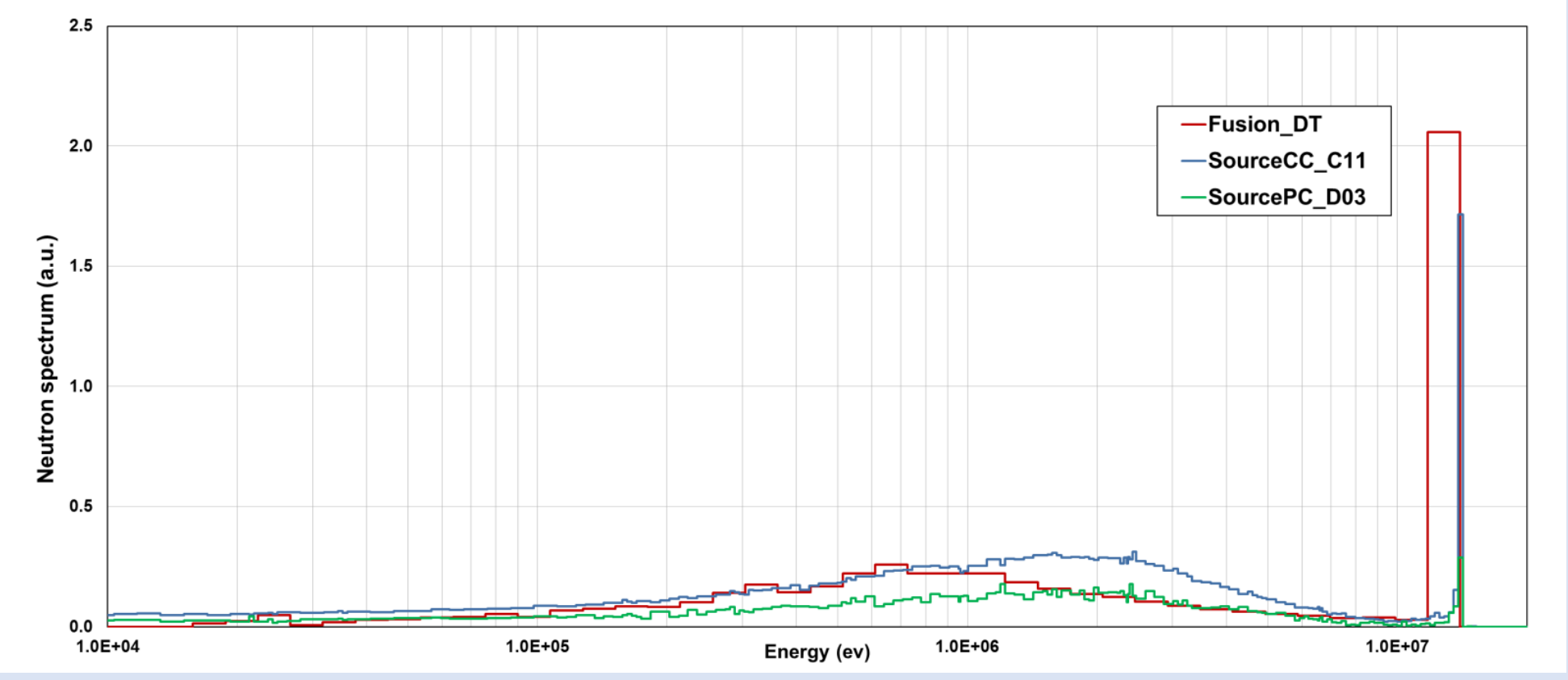

Fig. 5. Neutron spectra comparison between fusion blanket and TRIGA RC-1 reactor in subcritical configuration driven by an external DT source.

CONCLUSIONS

- A compact tokamak Q=2 neutron source with major radius R=1.5m and magnetic field B=8.5T , with aspect ratio A=2.5 can be deduced from a Fusion Reactor scaling law. The neutron yield is in the range of 7E19n/s.
- The tokamak neutron source is included in a FFH model focused on TRITIUM production. The fusion breeder is lithium aluminate and the nuclear fuel is a MOX . Increase of tritium production by a factor 6 in the fusion blanket when the fuel is present in the fission blanket(see sec.B)
- The experimental validation of FFH concept is proposed using a DT neutron source injecting 14.1MeV neutrons in the subcritical core of TRIGA RC-1

ACKNOWLEDGEMENTS / REFERENCES

- F P Orsitto et al Nuclear Fusion 56(2016) 020009
- M Salvatores , F P Orsitto , M Carta et al , Annals of Nuclear Energy 2021