ADS (Accelerator driven systems for research on nuclear technology)

Project Leader: ***Giovanni Ricco***

Project Coordinator: ***Marco Ripani***

Work Institution & Collaborations:

Centro Fermi, INFN Sezione di Genova, University of Genova (GENERG-DIME/TEC), Ansaldo Nucleare Spa, ENEA Casaccia, ENEA CR Frascati

EU project CHANDA (EURATOM)

ADS (Accelerator driven systems for research on nuclear technology)

Research Group:

ADS studies and Fusion-Driven device studies

- Michail Osipenko, INFN, ricercatore
- Fabio Panza, INFN, assegnista (fondi UE) *scad. 1 Giugno 2017*
- Giovanni Ricco, associato Centro Fermi e INFN
- Marco Ripani, INFN, primo ricercatore – associato Centro Fermi

ADS studies

- Walter Borreani, GENERG-DIME/TEC Scuola Politecnica Unige, PhD student and INFN, assegnista *(active on project until mid 2017)*
- Guglielmo Lomonaco, GENERG-DIME/TEC Scuola Politecnica Unige, ricercatore
- Paolo Saracco, INFN, ricercatore
- Gabriele Firpo, Ansaldo Nucleare
- Carlo Maria Viberti, Ansaldo Nucleare

Fusion-Driven device studies

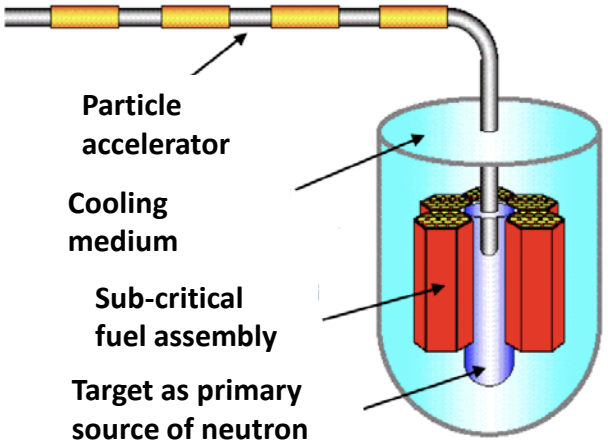
- Marco Ciotti, ENEA Casaccia, ricercatore
- Jorge Manzano, ENEA CR Frascati, ricercatore
- Aldo Pizzuto, ENEA CR Frascati, dirigente
- Francesco Paolo Orsitto, Consorzio CREATE Università di Napoli Federico II

ADS (Accelerator driven systems for research on nuclear technology)

Motivations and previous work

- ADS is based on subcritical reactor core → per each fission, less than one neutron starts another fission → chain reaction not self-sustained → safety margin
- The proportionality of the reactor power to the accelerator beam current allows an easier reactor control
- In any anomalous instance, the accelerator can be shut down and so the chain reaction instantaneously
- The fuel composition, in particular the fraction of transuranic elements, is less constrained than in case of critical reactors

A project for a low-power ADS was first proposed for the INFN Legnaro National Laboratory → LEADS: Legnaro ADS



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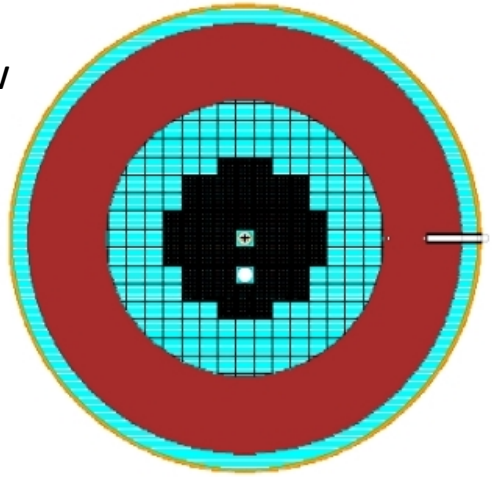
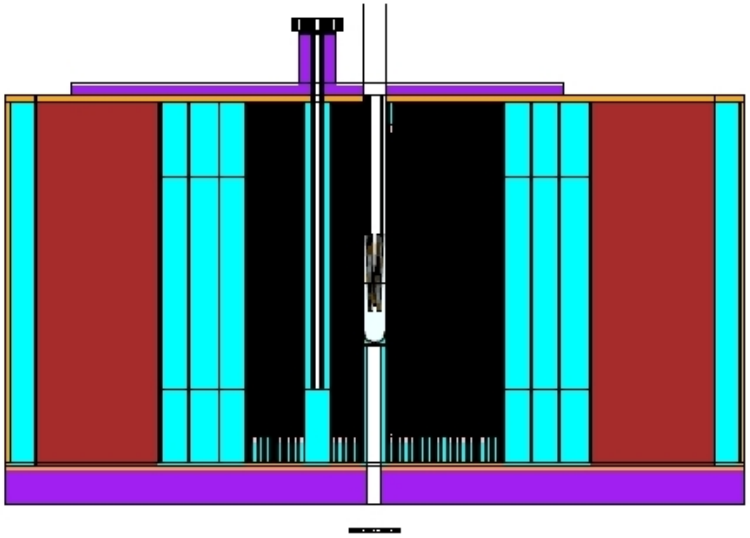
Plan of activity 2016-2018: new hybrid designs

An ADS irradiation facility for fast and slow neutrons

Top view





Side view

- **Fast core** based on MOX (U-Pu) fuel and solid Lead matrix
- **Cooling** of core through **water** pipes
- **Reflector** surrounding the core made by **composite lead-graphite-lead** structure

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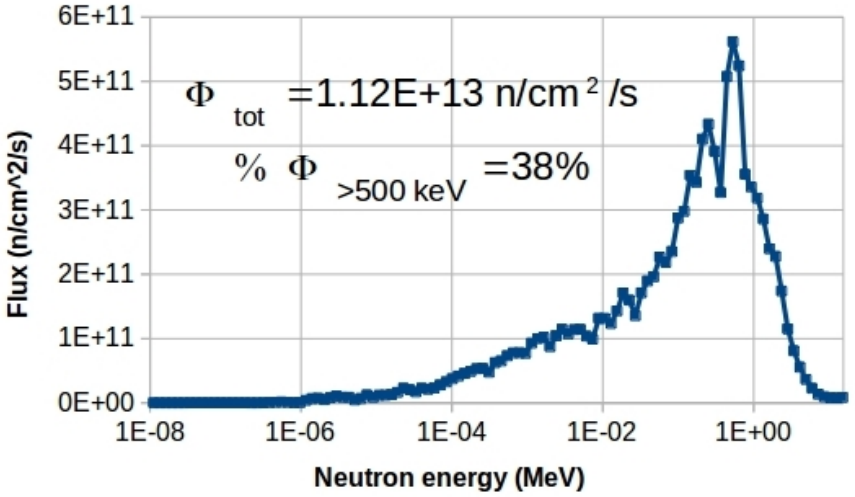
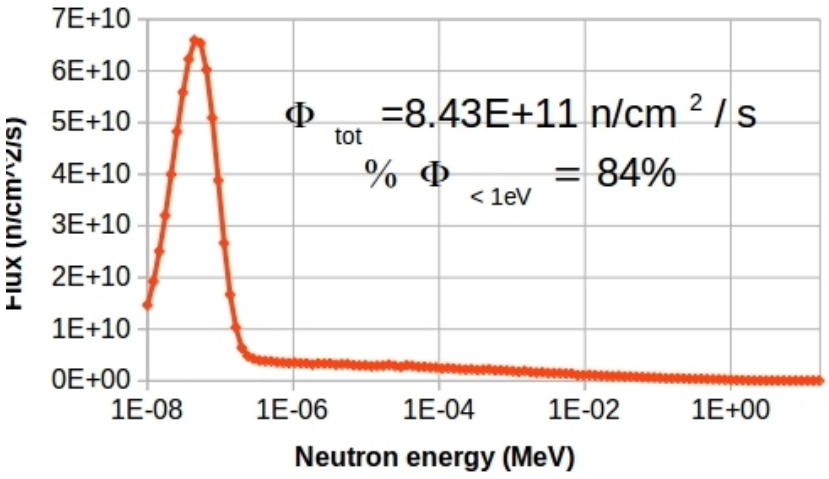
- Graphite moderates neutrons out of the core
- Water increases power

→ Core still fast, while reflector nearly to fully thermal



Neutron spectrum in innermost core position

Neutron spectrum in intermediate graphite position



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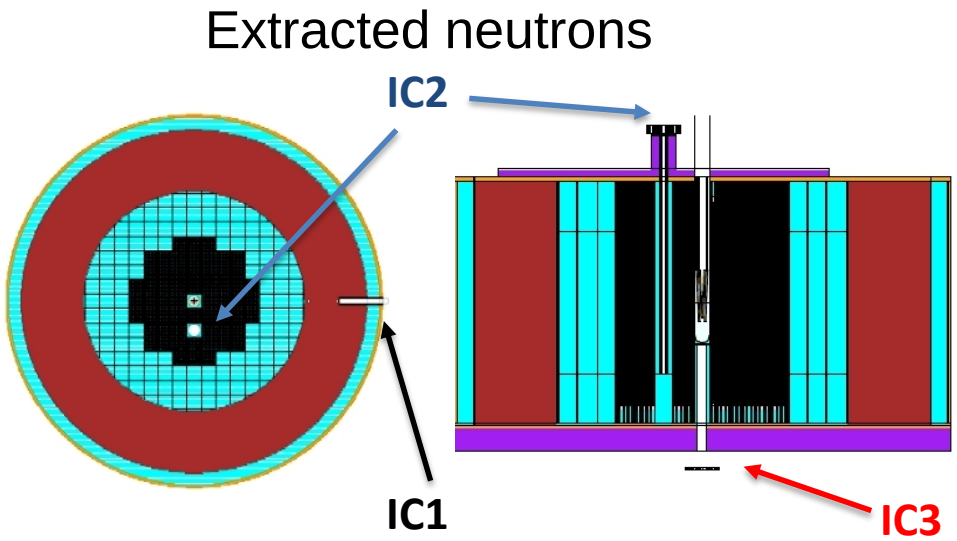

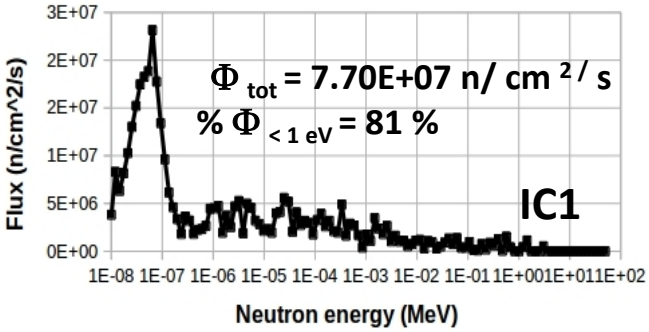

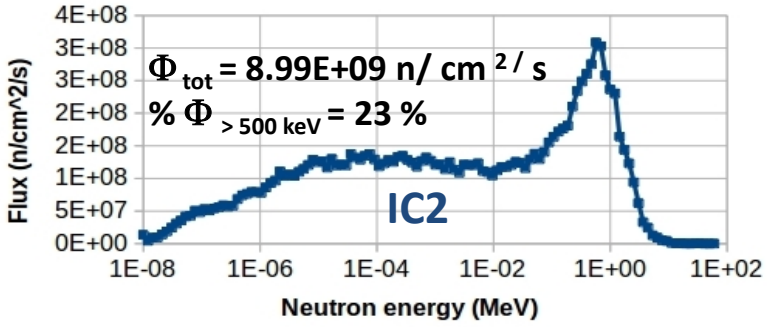

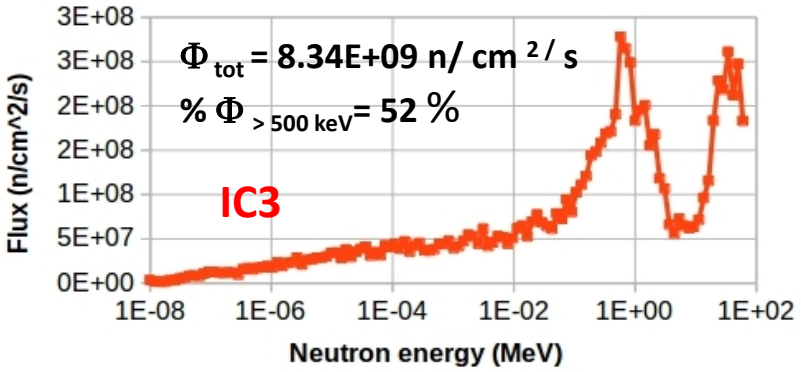

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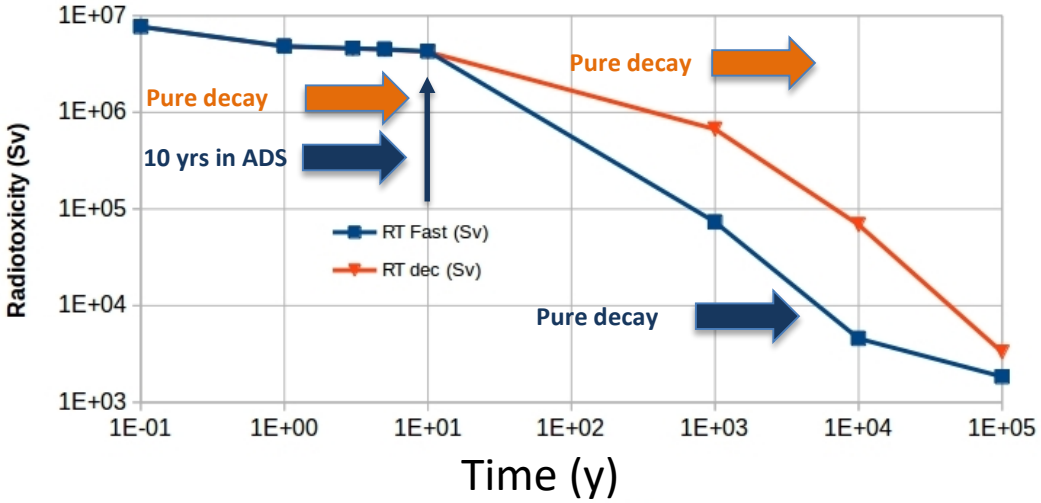
Plan of activity 2016-2018: new hybrid designs

Applications

Specific irradiations can be performed:
- in-core
- in-reflector
- in-beam

In-core applications: waste and fission products transmutations

Example: test of fuel pin irradiation (mixture Pu-Minor Actinides) for waste burner



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In-reflector applications: production of isotopes for nuclear medicine
Example: ^{99m}Tc production

Natural Mo sample (m=12 g, ~24% ^{98}Mo) 1 day irradiation in reflector graphite layer
^{99}Mo mass: 3.5E-8 g → 7 x 10^9 Bq ^{99m}Tc (after 1 d of decay period)

If we consider 30 mCi of ^{99m}Tc for a single medical treatment → production of 7 specimens

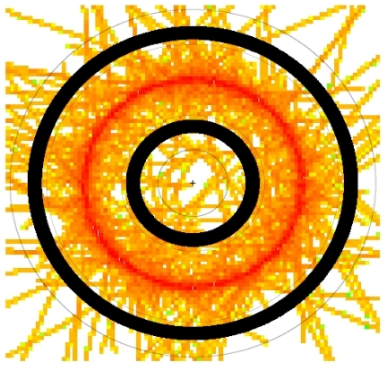
In-beam applications: cross section and particle production measurements
Example: transmutation and gamma production in the reaction ^{99}Tc (n,γ) ^{100}Tc

Irradiation of ^{99}Tc sample,($t_{1/2}$ = 2 x 10^5 y), m= 1 mg using the fast irradiation channel (IC2) prompt gamma detected ~ 80 sec^{-1}

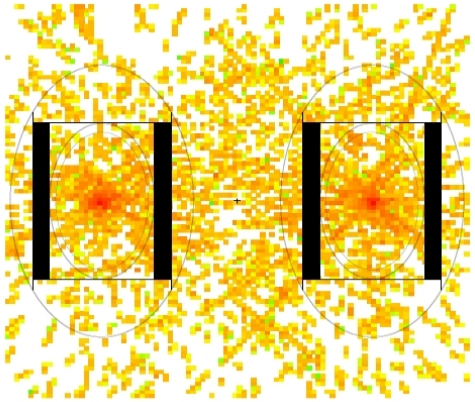
Plan of activity 2016-2018: new hybrid designs

A Fusion Driven System (FDS) for power amplification and transmutation

- Base option is tokamak with 160 MW fusion power
- Tokamak may be evolution from current working designs (e.g. Jet) in reasonable time scale
- MOX fuel, core cooling by liquid Pb, core surrounded by liquid Pb-Li for Tritium breeding
- Fission thermal power achieved 2.5 GW

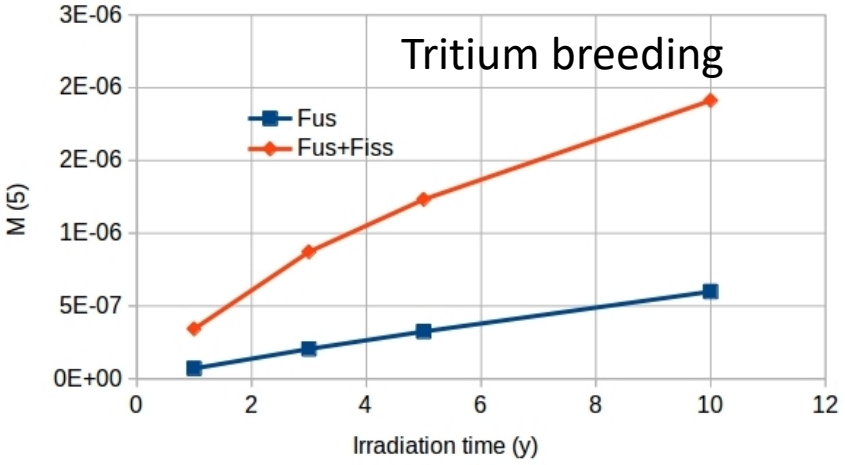


Top view



Side view

Red: plasma in a toroid
Black: fission core



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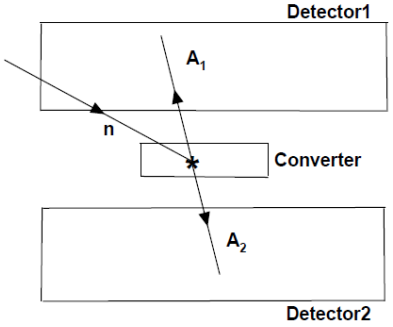
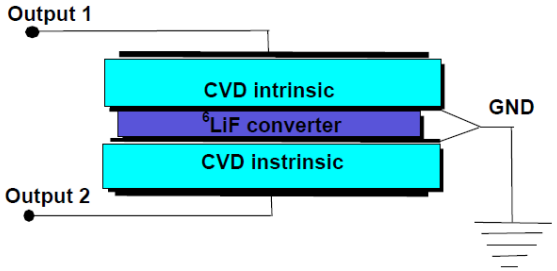
Plan of activity 2016-2018: new hybrid designs

Neutron spectrometer based on diamond detectors for fast reactors

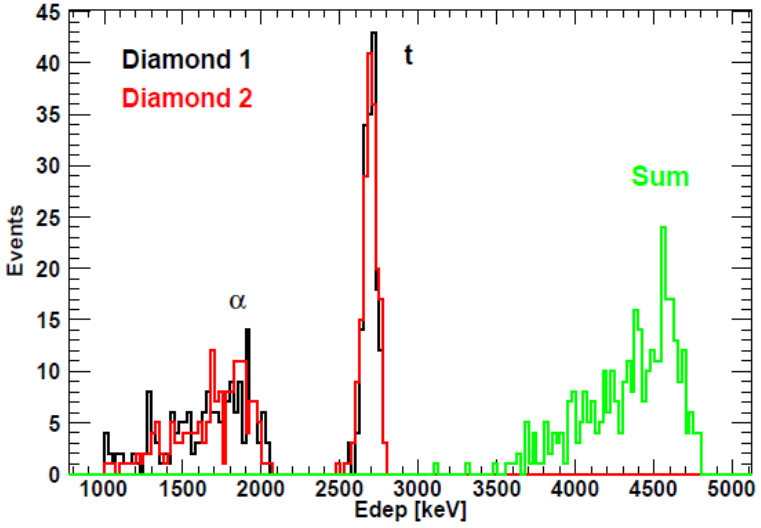
Fission spectrum < ~ 6 MeV, exothermic reaction (Q = 4.7 MeV):

$n + {}^{6}Li \rightarrow t\,(2.73MeV) + \alpha\,(2.06MeV)$





n therm.



- Signals to fast preamp after 3-5 m cable
- Set-up with electronics far from neutron source so as to avoid radiation damage
- Small active area and conversion efficiency + fast signals (~ 10 ns) allow working in high neutron flux (likely up to ~ 10^{12} n/cm^2/s)
- Energy resolution moderate (~ 300 keV FWHM) but sufficient to give indication on neutron spectrum

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Publications and Talks

1. D. Chersola, G. Ricco, M. Ripani, P. Saracco, An alternative observable to estimate keff in fast ADS, Annals of Nuclear Energy 95 (2016) 42

2. F. Panza, M. Osipenko, G. ricco, M. Ripani, P. Saracco, "Influence of reflector materials and core coolant on the characteristics of accelerator driven systems" submitted to Annals of Nuclear Energy, https://arxiv.org/submit/1758324

3. F. Panza, G. Firpo, G. Lomonaco, M. Osipenko, G. Ricco, M. Ripani, P. Saracco and C. M. Viberti, New infrastructure for studies of transmutation and fast systems concepts, submitted to EPJ Nuclear Sciences & Technologies

4. P. Saracco, W. Borreani, D. Chersola, G. Lomonaco, G. Ricco, and M. Ripani, A useful observable for estimating keff in fast subcritical systems, in Proceedings of the 13th International Conference on Radiation Shielding (ICRS-13) & 19th Topical Meeting of the Radiation Protection & Shielding Division of the American Nuclear Society 2016 (RPSD-2016), Paris, France, 3-6 October 2016, to be published in European Physical Journal - Web of Conferences

5. F. Panza, G. Firpo, G. Lomonaco, M. Osipenko, G. Ricco, M. Ripani, P. Saracco and C. M. Viberti, New infrastructure for studies of transmutation and fast systems concepts, in Proceedings of the 13th International Conference on Radiation Shielding (ICRS-13) & 19th Topical Meeting of the Radiation Protection & Shielding Division of the American Nuclear Society 2016 (RPSD-2016), Paris, France, 3-6 October 2016, to be published in European Physical Journal - Web of Conferences

6. F. Panza, G. Firpo, G. Lomonaco, M. Osipenko, G. Ricco, M. Ripani, P. Saracco and C. M. Viberti, An ADS irradiation facility for fast and slow neutrons, Communication at the 16th Congress of the Italian Physical Society, Padova, Italy, 26-30 September 2016

7. F. Panza, G. Firpo, G. Lomonaco, M. Osipenko, G. Ricco, M. Ripani, P. Saracco and C. M. Viberti, A new hybrid fast-slow ADS for research and applications, in Proceedings of the Third International Workshop on Technology and Components of Accelerator-Driven Systems, Mito, Japan, 6-9 September 2016, to be published by OECD-NEA

8, F. Panza, M. Ciotti, F. P. Orsitto, M. Osipenko, J. Manzano, A. Pizzuto, G. Ricco, M. Ripani, Application of a new fast reactor for fission-fusion hybrid systems, in Proceedings of the 2nd International Conference on Fusion for neutrons and sub-critical nuclear fission for waste management and safety, Frascati, Italy, 26-28 October 2016, to be published by ENEA

9. F. Panza, Guglielmo Lomonaco, Walter Borreani (GeNERG/DIMETEC University of Genova + INFN), Giovanni Ricco, Marco Ripani (INFN+Centro Fermi), Mikhail Osipenko, Paolo Saracco (INFN), Gabriele Firpo, Carlo Maria Viberti (Ansaldo Nucleare), An ADS irradiation facility for fast and slow neutrons, invited talk at Workshop "Status of Accelerator Driven Systems Research and Technology Development", CERN, 7-9 February 2017

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Plan of activity 2017 - 2019

(Max 3 slides - indicare per punti gli highlights e inserire eventuali figure con le relative didascalie)

- Complete the simulations and evaluations performed until now
- Complete the basic study of both physics and engineering aspects of the system like burn-up and transmutation capability, target and core cooling, shielding
- Continue study on integral measurements of nuclear cross sections of interest for fission, fusion and radioisotope production; examine practical radioisotope applications
- Explore possibilities to continue study on fusion-fission hybrid
- Continue work on new instrumentation for neutron monitoring
- Make comprehensive publication on results of project and explore possible interest within the EU for this facility

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Possible links to other Projects (internal or external to Centro Fermi):

Activity carried on within strategic project INFN_E (“INFN Energy”)

Link with EU projects

- CHANDA (challenges in nuclear data)
- Preparation of knowledge base that can allow for participation in future Euratom projects about ADS and/or Generation IV activities

ADS (Accelerator driven systems for research on nuclear technology)

Expected funding in the 3-year period:

- **Request of funding by Centro Fermi**

80 k€, including a **two-year post-doc fellowship starting in 2017** (essential to complete the project)

10 k€ for travels, consumables, small capital investments in 2017

- **Co-funding**

INFN →INFN_E project, about 20 k€

EU → CHANDA project about 18.5 k€, including 2-year post-doc 2015-2017

- **Potential external funding**

Possible participation in future Euratom projects about ADS and/or Generation IV activities

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Expected Products

Internal reports

Communications at workshops/conferences

Publications on peer-reviewed journals

Impact of the research and outreach initiatives

- Maintenance of knowledge base on ADS and Generation IV general topics
- Collaboration with industry involved in Generation IV projects, aimed at increasing the sustainability of nuclear power through enhanced safety and reduced production of long-lived radioactive nuclides