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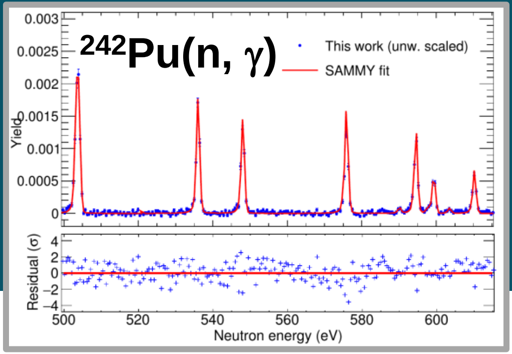

Nuclear Data activities in EURATOM FP7

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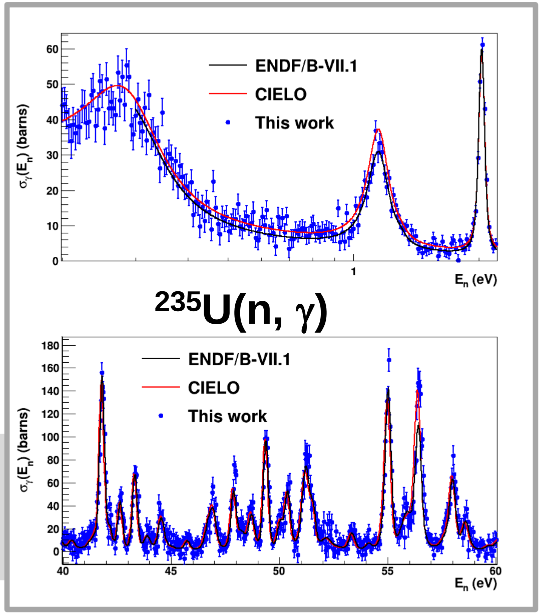


Projects: CHANDA , ERINDA, EUFRAT

Introduction to Nuclear Data R&D- ND needs

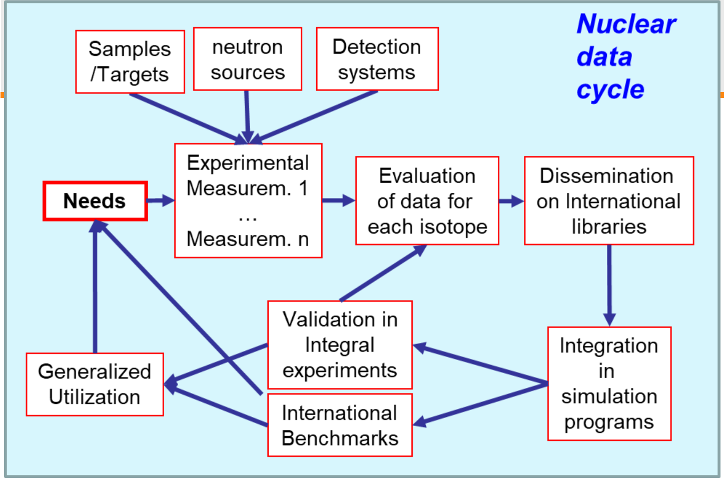
- Nuclear data and associated tools are a critical element of the nuclear energy industry and research. They play an essential role in the **simulation** of nuclear systems or devices for nuclear energy and non-energy applications, for the **calculation of safety and performance parameters** of existing and future reactors and other nuclear facilities, for the **innovation of the design** of those nuclear facilities and the innovation on radioactive devices and use of radioactive materials in non-energy applications, and for the **interpretation of measurements** in these facilities.

- Nuclear Data, ND, is often not visible for applications that rely on the huge data sets of nuclear cross sections, branching ratios, fission yields,… .

- However, in many cases they are the limiting factor for the accuracy of the codes in those applications.

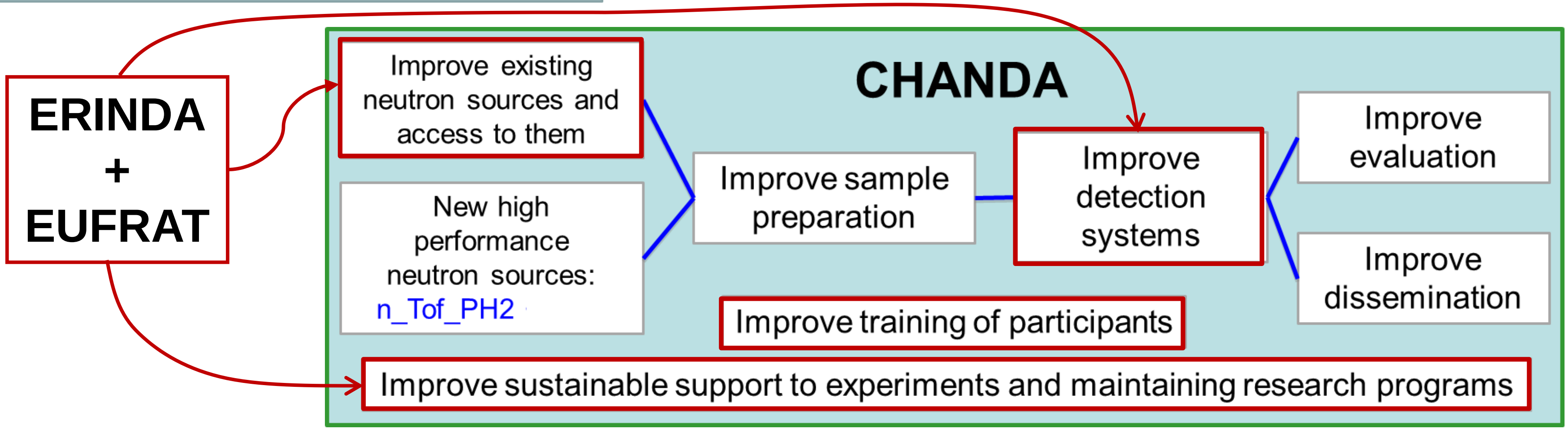
- So, there are continuous requests of new or better nuclear data, coming from:
  - new levels of safety, new safety criteria and scenarios,
  - new reactor designs or new applications or new modes of operations of present reactors,
  - innovative solutions for waste management and
  - from pending requests, not feasible in the past, that can be addressed with the present R&D on nuclear data and tools.

- These requests are regularly evaluated and maintained in high priority request lists IAEA and NEA/OECD.



Introduction to Nuclear Data R&D

In order to have nuclear data available to applications several steps are needed in what is known as the nuclear data cycle



Introduction to Nuclear Data R&D- ND needs

- Producing high quality data requires a combination of many different know-hows (target production, detectors, neutron sources, analysis, evaluation, nuclear theory, nuclear reactors, simulation codes, …).
- In Europe, the necessary expert know-how is widely distributed within many research teams, and most of these teams specialize only on one or few components of the nuclear data cycle.
- So, to provide the nuclear data needed, a very well structured wide and well synchronized collaboration between the key EU expert institutions is needed.
- The EURATOM framework program has been instrumental during the FP7 and before, to nucleate large pan-European collaborations of laboratories like CHANDA.
- It has also facilitated the setup of frameworks for easy and efficient transnational access to experimental facilities needed for those activities, like the competitive proposal ERINDA and the direct JRC action EUFRAT

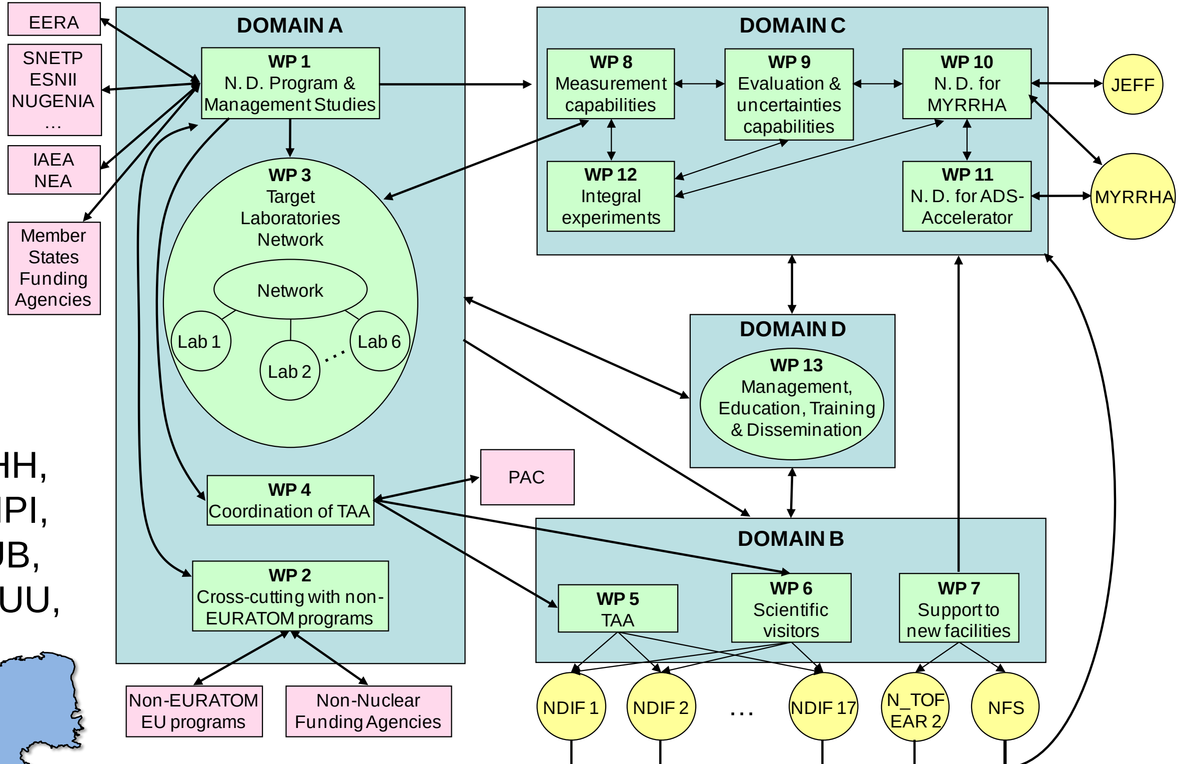
The projects: CHANDA

http://www.chanda-nd.eu/

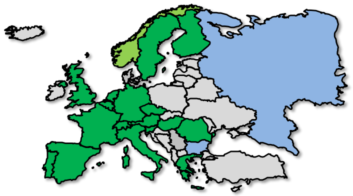
SOLVING <u>CHA</u>LLENGES IN <u>N</u>UCLEAR <u>DA</u>TA FOR THE SAFETY OF EUROPEAN NUCLEAR FACILITIES

Start: 1 Dec. 2013,
Duration proposed: 54 months.
EU funding: 5.4 MEuro.

<u>Participants:</u>
<u>CIEMAT</u>, ANSALDO, CCFE, CEA, CERN, CNRS, CSIC, ENEA, GANIL, HZDR, IFIN-HH, INFN, IST-ID, JRC, JSI, JYU, KFKI, NNL, NPI, NPL, NRG, NTUA, PSI, PTB, SCK, TUW, UB, UFrank, UMainz, UMan, UPC, UPM, USC, UU, UOslo. +*U.Seville*



NDIF = Nuclear Data Infrastructure & Facility



CHANDA: 36 participants (18 countries)

The projects: ERINDA

http://www.erinda.org/

- The ERINDA project (European Research Infrastructures for Nuclear Data Applications) has coordinated the EU efforts to exploit up-to-date neutron beams for novel research on advanced concepts for nuclear fission reactors and the transmutation of radioactive waste.
- ERINDA offered the nuclear data research infrastructures of 13 partners (HZDR, JRC-GEEL, CERN, CENBG, IPNO, UU-TSL, PTB, NPI, IKI, IFIN-HH, NPL, FRANZ and CEA).
- The ERINDA facilities included different neutron sources and methods for nuclear data measurement, in particular:
  1. **Time of flight facilities for fast neutrons**: nELBE (HZDR); n_TOF (CERN); GELINA (JRC);
  2. **Charged-particle accelerators**: electrostatic accelerators in Bordeaux, Orsay, Bucharest and Dresden, neutron reference fields at PTB and NPL, cyclotrons in Řež , Jyväskylä, Oslo and Uppsala with neutron energy range up to 180 MeV, and pulsed proton linear accelerator in Frankfurt;
  3. **Research reactors:** Budapest and Řež cold neutron beam, Prompt Gamma Activation Analysis.
- 3015 hours of beam time, 26 experiments, 16 short term visits (106 weeks)
- Pool of facilities open to user proposals to be selected by independent PAC.
- Four European scientific meetings in Dresden, Prague, Jyväskylä and Geneva.

The projects: EUFRAT

https://ec.europa.eu/jrc/en/eufrat

- Since 2005 JRC-Geel offers access to its nuclear research infrastructure for external users.
- Since the beginning of 2014 as an institutional project entitled "European Facilities for Nuclear Reaction and Decay Data Measurements (EUFRAT).
- The nuclear infrastructure at JRC-Geel includes:

1. **the GELINA** research infrastructure, which combines a white neutron source produced by a 150 MeV linear electron accelerator with a high-resolution neutron time-of-flight facility;
2. **the MONNET** research infrastructure for the production of continuous and pulsed proton-, deuteron- and helium ion beams is based on a 3.5 MV Tandem accelerator and serves for the production of well-characterised quasi mono-energetic neutrons;
3. **the RADMET** radionuclide metrology laboratories, which are used for radioactivity measurements;
4. **an ultra low-level radioactivity laboratory**, which is hosted in the deep-underground facility HADES of the SCK•CEN; and
5. **a laboratory for the preparation and characterisation of samples and targets** needed for nuclear data measurements.

Nuclear Data R&D-Technical Achievements

- Improving the facilities: nELBE, IGISOL, JRC-Geel, n_TOF EAR2, LICORNE and PTB PIAF.
- Integrating and developing target fabrication capabilities: PSI, U.Mainz and JRC-Geel labs.
- New methods for cross section measurements: new detectors (micromegas, DELCO, SCONE, DTAS, BELEN, BRIKEN, FALSTAFF, STEFF), facilities (n_TOF EAR2, AFIRA, GAINS and GRAPhEME).
- Comprehensive developments for concurring reactions:capture, fission, inelastic, (n,xn), (n,chp).
- New and improved evaluation models and tools:TALYS-1.9 EXFOR and ND for FF, and CONRAD.
- Systematic and comprehensive uncertainties and correlation libraries in the evaluation: ^{181}Ta.
- Validation and improvement of data using integral experiments: different uncertainty propagation methods, integral data assimilation methodologies between the "all deterministic" and the "Full MC".
- Fast and comprehensive dissemination of results: contacts with IAEA, NEA, JEFF, CIELO.
- Comprehensive tools for transport problems including high energy particles: better INCL-ABLA.
- Publication of results for specialized users and training young scientists: 125 peer reviewed publications, 30 PhD theses and 18 Master theses from CHANDA + 77 publications from ERINDA.
- Transnational access to experimental facilities to perform measurements and training.

Differential nuclear data measurements at CHANDA

(n,f) cross sections	(n,n), (n,xn) and (n,n'γ) cross sections
^{240,242}Pu(n,f)	^{nat}Fe(n,n)
^{237}Np(n,f)	^{nat}C(n,n)
^{235,238}U(n,f)	^{238}U(n,n'e^{-})
(n,γ) cross sections	^{48}Ti(n,n'γ)
^{235}U(n,γ)	^{7}Li(n,n'γ)
^{242}Pu(n, γ)	^{233}U(n,n'γ)
^{238}U(^{3}He,^{4}He)^{237}U, ^{238}U(^{3}He,t)^{238}Np, ^{238}U(^{3}He,d)^{239}Np	

Example of the huge set of results and activities covered by these projects a table with the differential nuclear data measurements carried out within CHANDA

Decay data	
^{95}Rb, ^{95}Sr, ^{96}Y, ^{96m}Y, ^{98}Nb, ^{98m}Nb, ^{99}Y, ^{100}Nb,^{100m}Nb, ^{102}Nb,^{102m}Nb, ^{103}Mo, ^{103}Tc, ^{108}Mo, ^{137}I, ^{138}I, ^{140}Cs, ^{142}Cs	γ ray and β decay emission probabilities with TAGS at JYFL
^{98,98m,99}Y, ^{135}Sb, ^{138}Te, ^{138,139,140}I	Neutron emission probabilities with the BELEN detector at JYFL

Fission yields	
^{238}U(n,f)	Penning trap at JYFL
^{233,235}U(n,f)	Isobaric beams at ILL
^{239,241}Pu(n,f)	Isobaric beams at ILL
^{235}U(n,f)	STEFF spectrometer at n_TOF/EAR2
^{235}U(n,f)	Orphee reactor at CEA/Saclay
^{238}U, ^{239}Np, ^{240}Pu, ^{244}Cm, ^{250}Cf	VAMOS spectrometer at GANIL
^{234,235,236,236}U(g,γ)	FRS spectrometer at GSI
^{238}U(n,f)	LICORNE + MINIBALL at IPN/Orsay

Nuclear Data R&D- Strategic perspectives

- Inclusive approach including: EU countries (18), institutions with relevant know-how (36), , and opening the pooling system for transnational access to all laboratories (18).
- Synchronizing the priorities of the different teams to the EURATOM calls, is an efficient way to address significant challenges. The visibility and impact of the European ND research has improved significantly during the last decade and can compete with USA, Russia or Japan.
- The pan-European collaborations also guarantee the survival of the ND research teams, maintaining Nuclear Data know-how in EU, and are more flexible to respond efficiently to evolving problems or programs with a large variety of different topics.
- Efficient collaboration of teams with well identified capacities allows mobilizing the national resources and replaces unnecessary competition with complementarity.
- Internal competition both during the preparation of the proposals, by the pooling of the access to facilities and by selection of special actions defined within the project duration had been used to maintain high standards of quality and relevance.
- Collaboration with international bodies (NEA/OECD & IAEA) and with TNA projects.

Nuclear Data R&D- Success stories

- Measuring the same isotope and reaction in 2 different facilities to reduce systematic effects: Capture on ^{238}U and ^{241}Am measured at GELINA and n_TOF with C_6D_6 and total absorption calorimeter.
- Within EUFRAT, studies of (n,n'γ) reactions in support to fast reactor developments are carried out at GELINA using the GRAPhEME and GAINS γ-ray spectrometers.
- With support from ERINDA, CHANDA and NEA the GEF code was developed to be a state of the art phenomenological model to give a general description of all fission observables.
- Joint experiments in integral and differential facilities using same samples of isotopes of interest for the safety of nuclear systems or difficult to fabricate targets.
- Complementarily, of the transmission and capture cross section measurement stations of GELINA are used to determine neutron induced interaction cross section data in the resonance region in support to criticality safety analysis in out-of-reactor applications.
- The organization of a network of radioactive samples/target producers/users. The list of targets produced included isotopes as ^{7}Be, ^{10}Be, ^{10}B, ^{13}C, ^{44}Ti, $^{70,72,73,74,76}Ge$, ^{91}Nb, ^{147}Pm, ^{171}Tm, ^{204}Tl, ^{230}Th, ^{233}U, ^{235}U, ^{237}Np, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{242}Pu and ^{252}Cf (45 targets).

Nuclear Data R&D- Lessons learnt

- There is a continuous request of new or improved nuclear data that will require supporting R&D on ND still for many years.
- To be effective the R&D program on ND has to cover many aspects in a holistic inclusive and comprehensive way.
- Large, widely distributed collaborations, well-coordinated inside inclusive projects, allow performing the required R&D in an efficient way, maintaining the know-how in Europe by aggregation of many, widely distributed, small and medium research teams.
- The EURATOM financial support allows aggregating these collaborations focusing the research each time around the topics identified on the EURATOM calls, normally well aligned with the high priority request list for nuclear data of the international organizations.
- The EURATOM projects have been very successful to produce the expected results, a large number of publications and PhD theses and to enhance the relevance and visibility of the European nuclear data R&D at global level

Nuclear Data R&D- Remaining challenges

- Use of the tools developed within CHANDA, ERINDA, EUFRAT and previous projects to deliver more ND needed for safety, industry and society.
- Widen the existing tools to produce data needed for medical and other non-energy applications of Nuclear Data.
- Reply to new ND needs and continue improving the uncertainty and correlation libraries.
- Validation and verification towards a generic purpose ND library, not as criticality oriented as the present library verification tools.
- Further development and integration of ND know-how in research and final user tools.
- Continue maintaining the know-how in Europe by aggregation of many and widely distributed small and medium research teams.
- Continue supporting the ND facilities and neutron sources.

Nuclear Data R&D- Impact and possible follow-up actions

- The results of the nuclear data projects, CHANDA, ERINDA and EUFRAT have contributed to the improvement of ND for major isotopes and minor but critical isotopes (for safety, waste management and future concepts) covering the most critical reactions and data needs.
- These better data enable more reliable simulation and evaluation capabilities that contribute to improve safety and efficiency of the present European reactors. In addition, making available more complete nuclear data and uncertainty libraries help to progress towards BEPU calculation, to become available for safety assessment, design and operation.
- All this elements will help to support science based decision for the energy policies.
- Two new ND proposals submitted & selected for negotiation in the EURATOM WP2018:
- SANDA, with 35 partners, focused on delivering new data to the end users and to cover energy and non-energy applications, and
- ARIEL, with 23 partners, to provide transnational access for nuclear data experiments that can be used for training and education in the nuclear field.