The GUINEVERE facility and associated experimental programs and outputs

Peter Baeten

on behalf of the VENUS team

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

MYRRHA in the 2014 BE Gov. Declaration

De regering zal het behoud van excellentie in het onderzoek naar de nucleaire veiligheid en informatie voor de burger, de omgeving en nucleaire infrastructuren op Belgisch grondgebied nastreven.

Ze zal het MYRRHA-project of evenwaardige projecten van het SCK progressief ondersteunen om het noodzakelijke onderzoek naar innovatieve oplossingen voor hoogradioactief afval, naar de kwalificatie van fusiereactormaterialen, naar het behoud van de medische radio-isotopenproductie in ons land en naar fundamenteel kernfysisch onderzoek optimaal verder te zetten in een internationale context, in samenwerking met universiteiten, onderzoekscentra en zusterorganisaties van het SCK.

Le gouvernement visera le maintien de l'excellence dans la recherche dans les domaines de la sûreté nucléaire et de l'information du citoyen, de l'environnement et des infrastructures nucléaires sur le territoire belge.

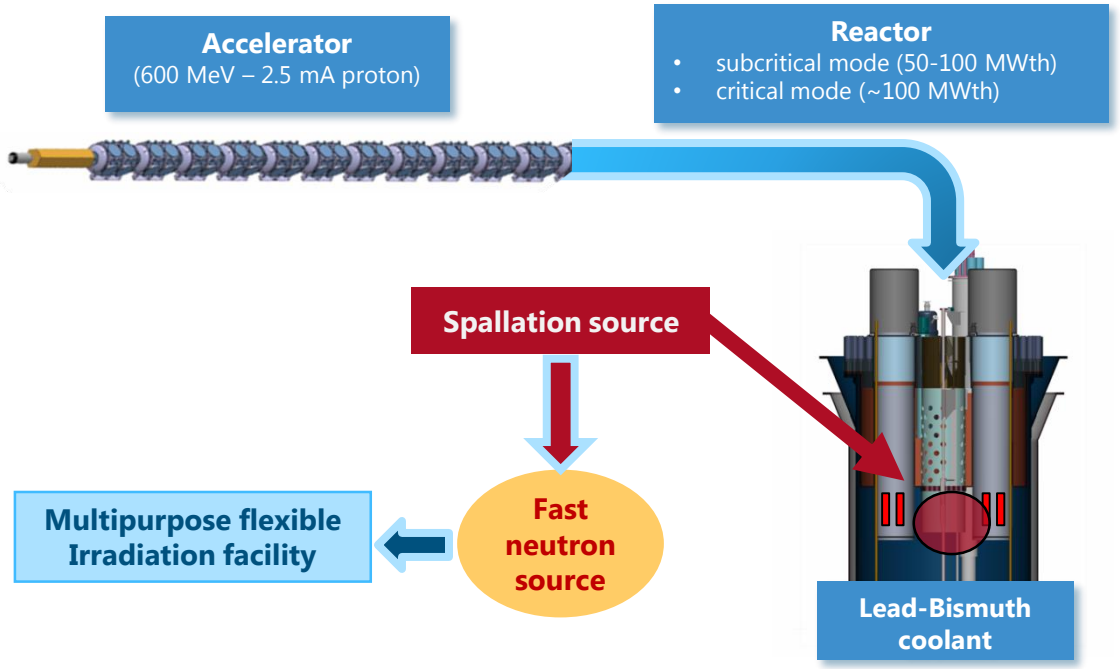
Il soutiendra progressivement le projet MYRRHA ou des projets équivalents du CEN en vue de poursuivre de manière optimale, dans un contexte international, les recherches nécessaires concernant des solutions innovantes pour les déchets hautement radioactifs, la qualification des matériaux des réacteurs à fusion, le maintien de la production de radio-isotopes médicaux dans notre pays et de recherche nucléaire fondamentale, en collaboration avec les universités, les centres de recherche et les organisations sœurs du CEN.

The Belgian Government will support in a progressive way the MYRRHA project or any equivalent project at SCK•CEN aiming to continue the needed research for innovative solutions for High level waste, qualification of materials for fusion, the production of radioisotopes for medical applications in our country and fundamental nuclear research in collaboration with the universities and sister organisation of SCK•CEN

Key objective of the MYRRHA-programme

Construction of an Accelerator-Driven System (ADS) as a Large Research Facility consisting of

- A 600 MeV – 2,5 mA proton linear accelerator
- A spallation target/source
- A lead-Bismuth Eutectic (LBE) cooled reactor able to operate in subcritical & critical mode



Elements of the Pre-Licensing Phase

- There are two main elements that form part of the pre-licensing phase process
  - Focus Points
  - The Design Options and Provisions File (DOPF)

- Focus Points address specific issues/topics that are considered important to be addressed in the pre-licensing phase. These are the fundamental important points that can influence the licensability of the project

- The DOPF works on a slightly higher level, though it will finally incorporate many of the aspects of the focus points. The document outlines the safety approach of the facility as well as the options and provisions taken to meet the safety objectives.

Focus Points Overview

- Focus Points address specific topics of importance that meet the three following conditions:
  - New or not mature enough
  - Specific to MYRRHA
  - Has an impact on the safety of the facility
- Focus Points are defined by FANC/Bel V
- Focus Points may be added or removed as the project progresses, however this has to be done with approval from FANC
- Focus Points are grouped into Focus Point Themes, each theme can have several specific Focus Points associated with it

Focus Point Themes

- External Hazards
- LBE Issues
- **Criticality**
- Fuel Qualification Program
- Decay Heat Removal
- Confinement
- I&C
- Management of gases
- In-Vessel Fuel Storage
- In-Vessel fuel manipulation and recovery
- Radiological safety
- Licensing of codes, standards and methodologies
- Accident analysis
- Severe accidents
- Experimental devices
- Accelerator

Focuss Point: KE1

KE1: Sub-criticality Monitoring and Control in ADS mode

1. FP presentation and description

The control and the monitoring of the sub-criticality level ($k_{eff}<1$ or $\rho<0$) of an ADS is recognized as a focus point since:

a) Despite the existence of sub-critical facilities (as nuclear fuel stockages or repositories), few operating experiences are available concerning the monitoring and control of sub-critical facilities characterized by a high neutron flux driven by an intense and potentially time-dependent external neutron source.

b) It is crucial for the design strategy of an ADS that the system remains sub-critical in both normal operation and postulated accident conditions including some design extended conditions. This sub-criticality margin is mandatory especially when large quantity of minor actinides, characterized by more challenging neutronic characteristics (e.g. a lower β_{eff}), is loaded in the fast-spectrum core.

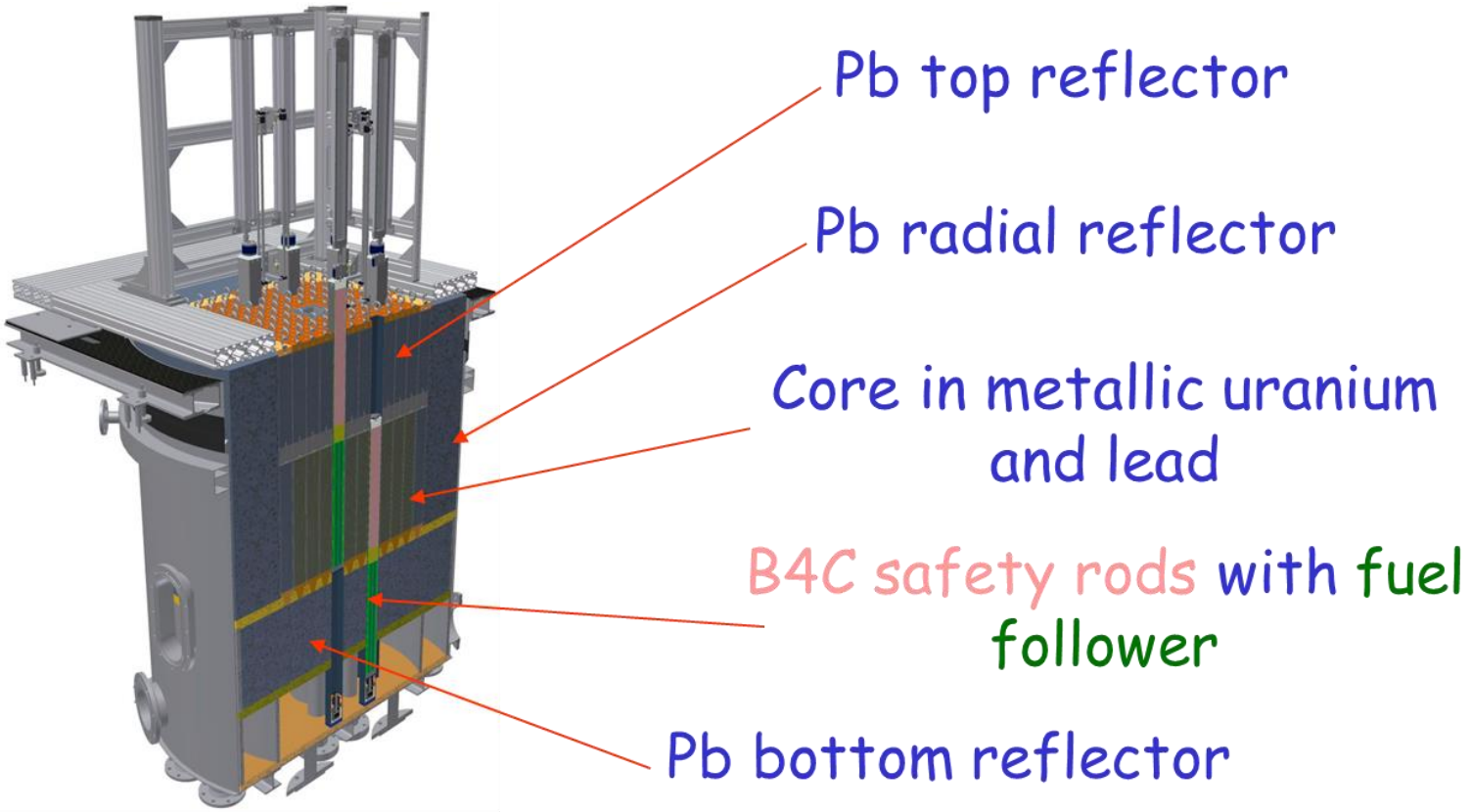
GUINEVERE and FREYA programs

- GUINEVERE: Generator of Uninterrupted Intense NEutrons at the lead VEnus REactor (2007-2011)
- FREYA: Fast Reactor Experiments for hYbrid Applications (2011-2016)

  → projects using VENUS-F reactor and GENEPI-3C accelerator at SCK•CEN
- For the investigation of licensing and design tasks for MYRRHA:
  - validation of methodology for online reactivity monitoring of an Accelerator Driven System (ADS)
  - validation of nuclear data and neutronic codes

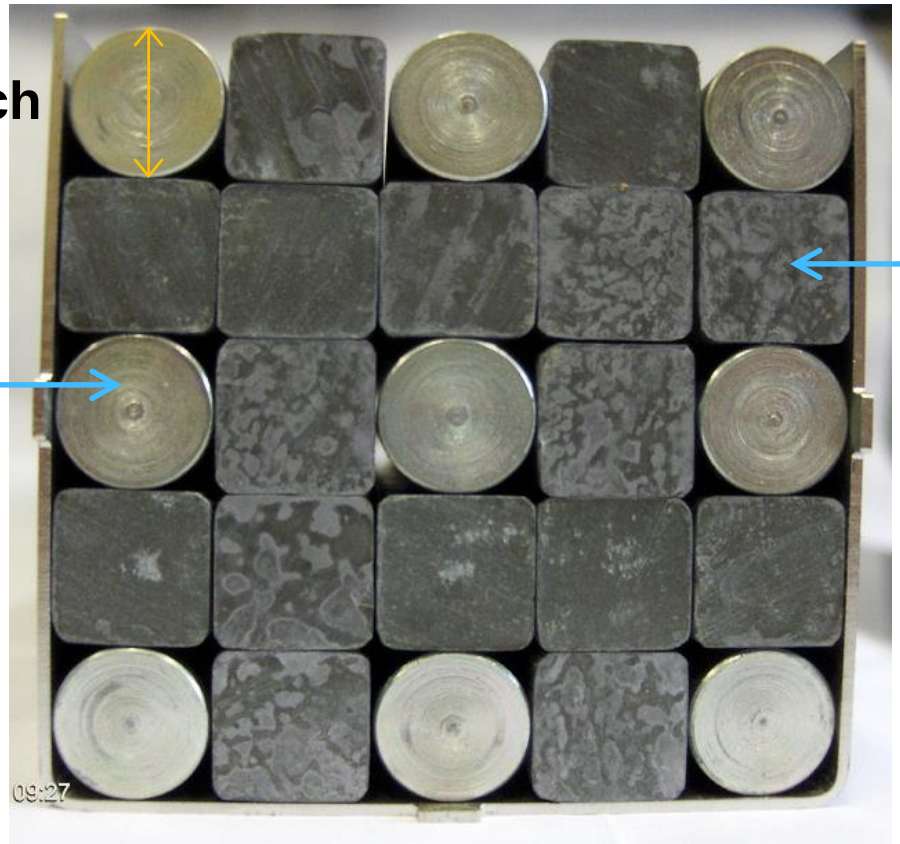
VENUS-F reactor

- fast version of the VENUS reactor (since 2011)
- no moderator



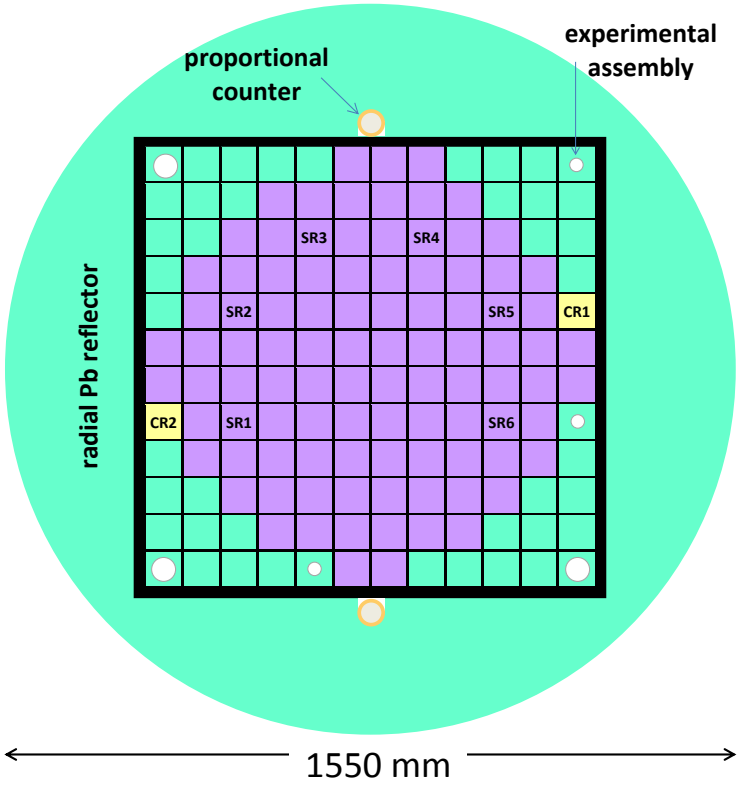
VENUS-F reactor

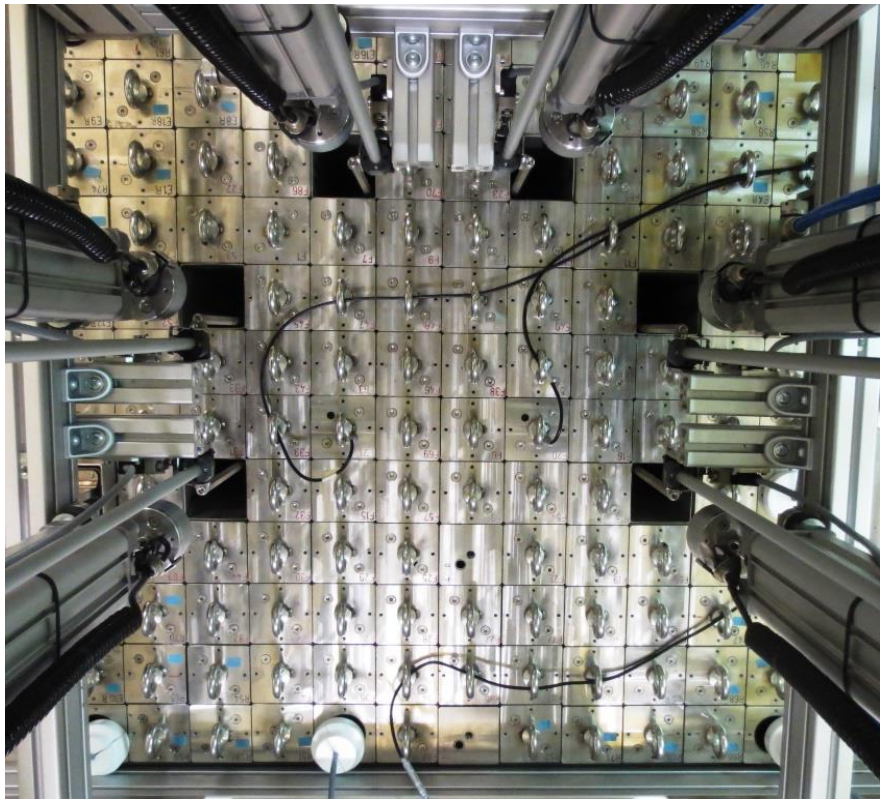
- fuel+coolant are combined in fuel assemblies



First critical core (02/2011)

- fuel assemblies and reflector assemblies are combined in a 12×12 lattice



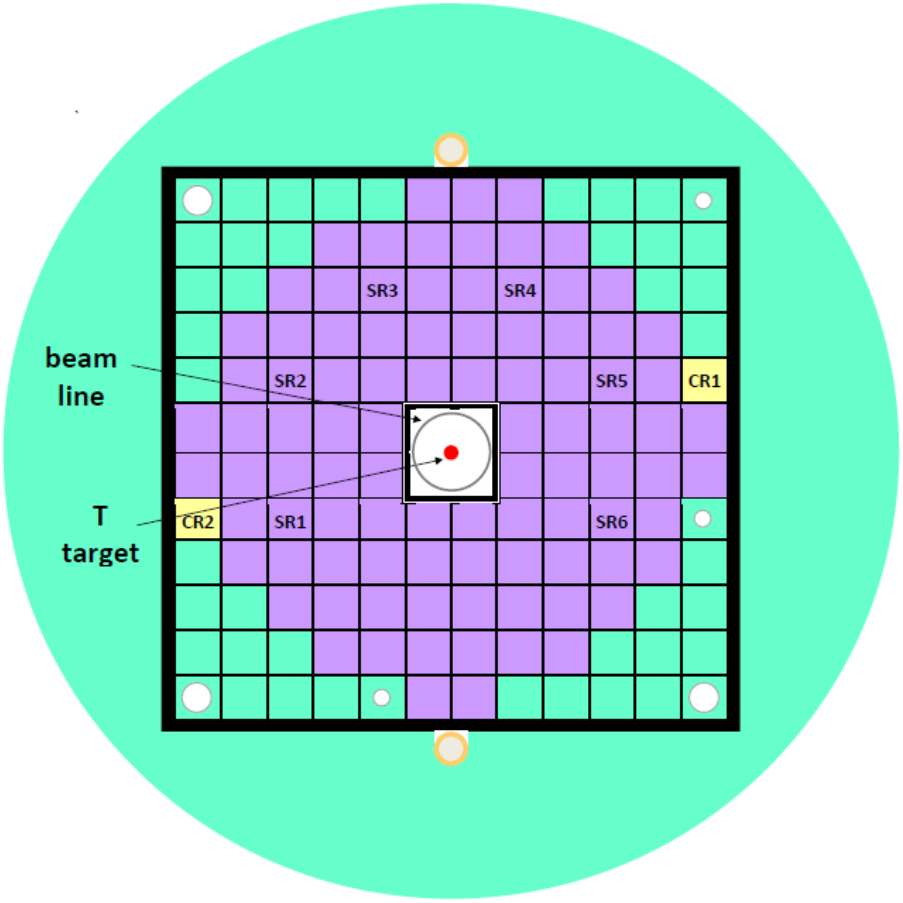


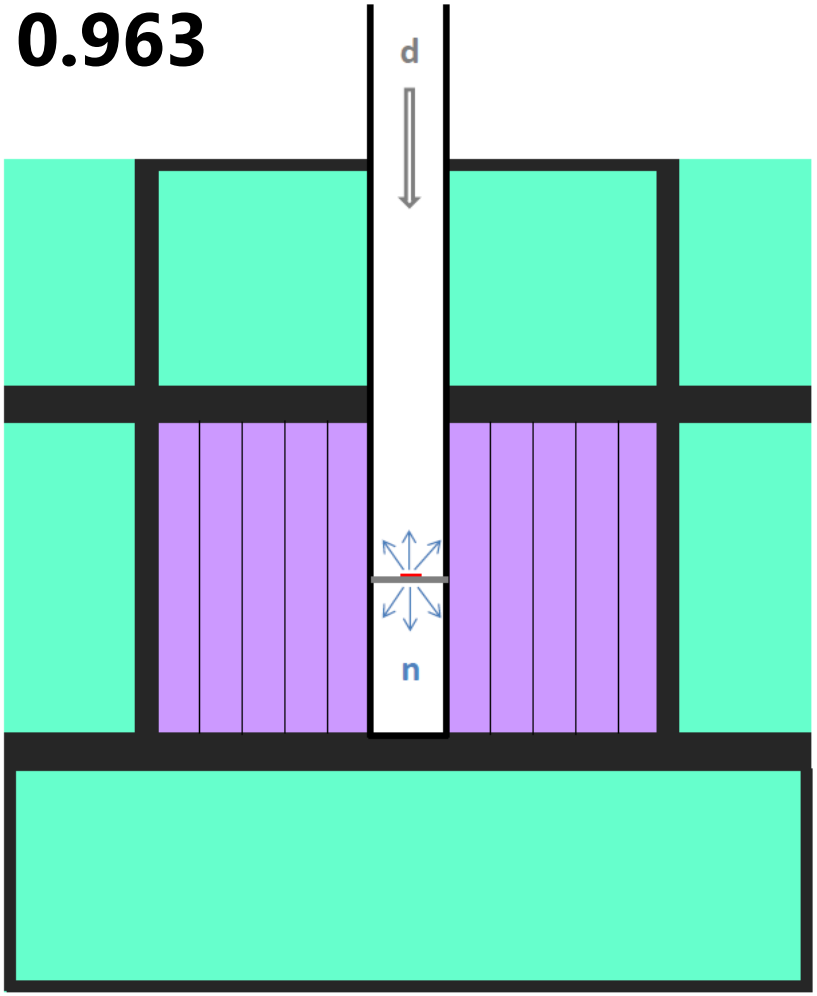
Reactor – accelerator coupling (11/2011)

- coupling VENUS-F reactor to a particle accelerator **GENEPI-3C**

Subcritical core (2011)

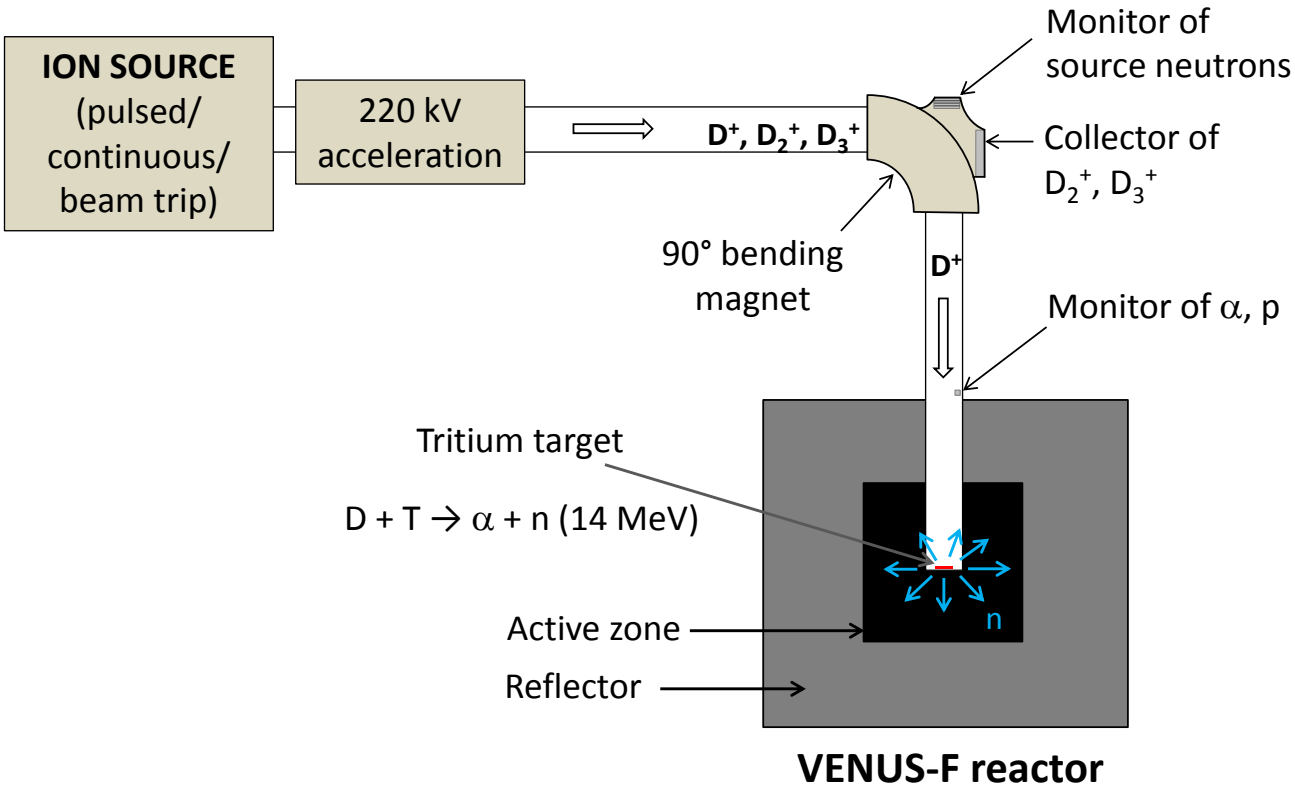
- inner 4 fuel assemblies are replaced by beamline with tritium target → k_{eff} = **0.963**

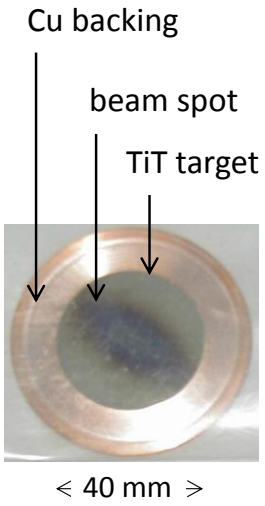




VENUS-F + GENEPI-3C coupling

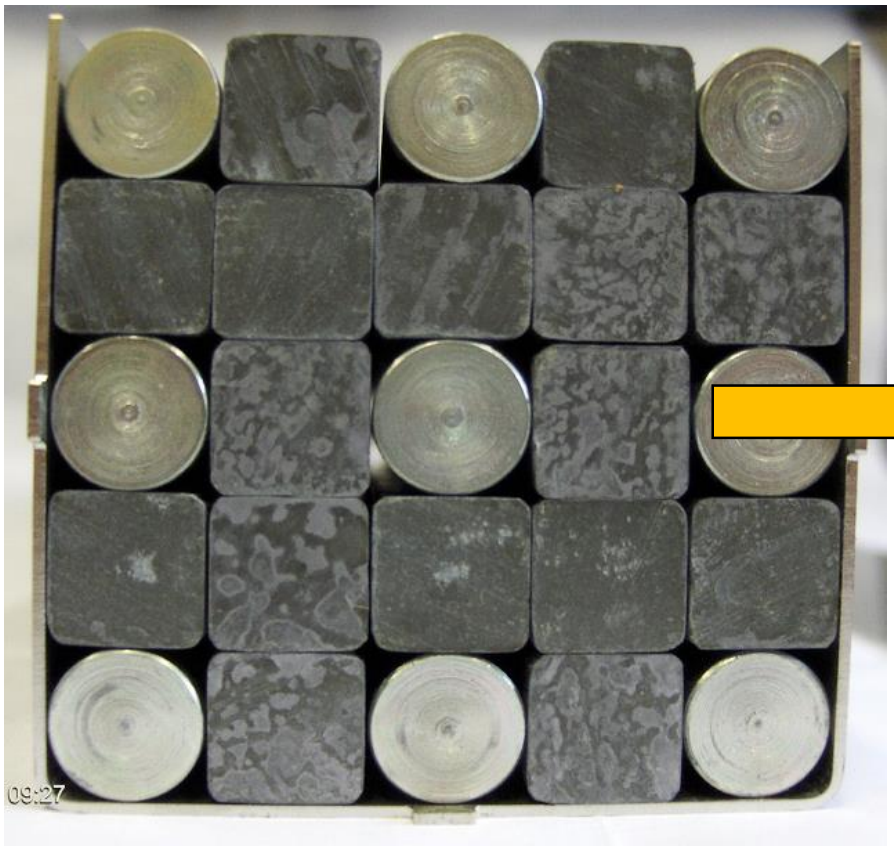
GENEPI-3C accelerator

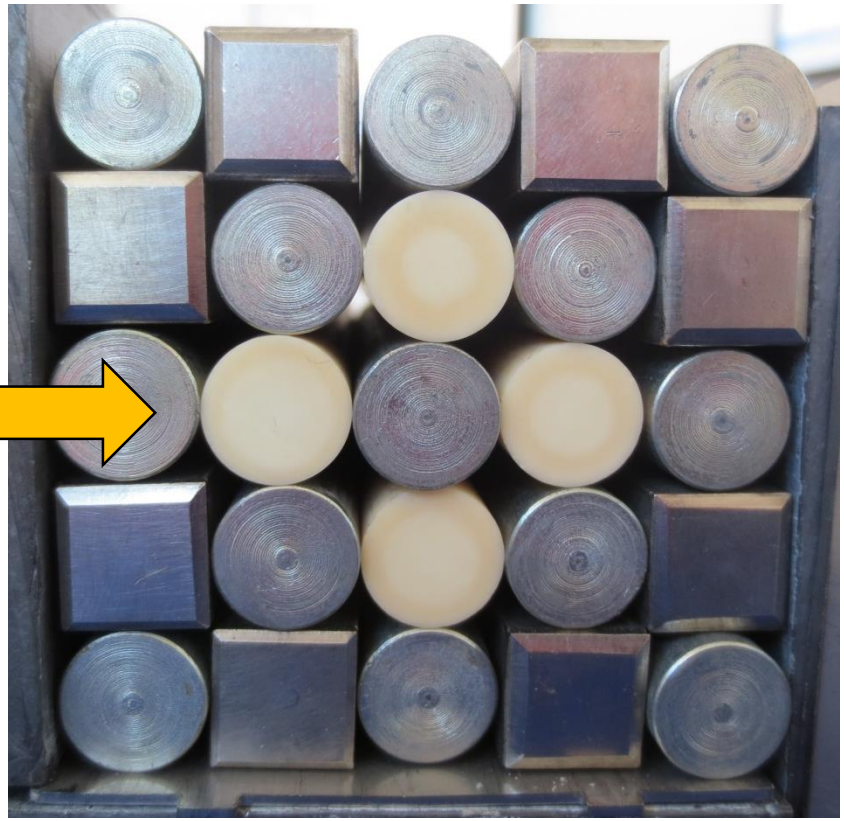




New MYRRHA-like fuel assembly

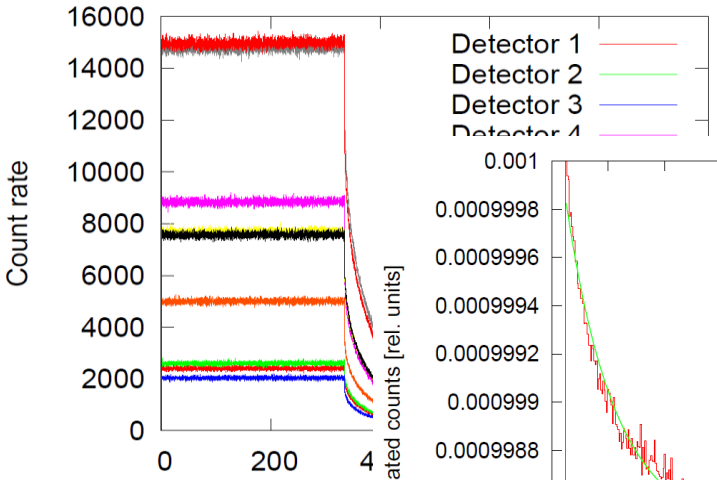
	heavy metal	O_2	SS	coolant	gas	Al
MYRRHA	27.1%	3.6%	22.1%	44.3% LBE	2.9% He	-
VENUS-F	24.7%	3.7%	15.4%	38.9% Pb	13.2% air	4.1%

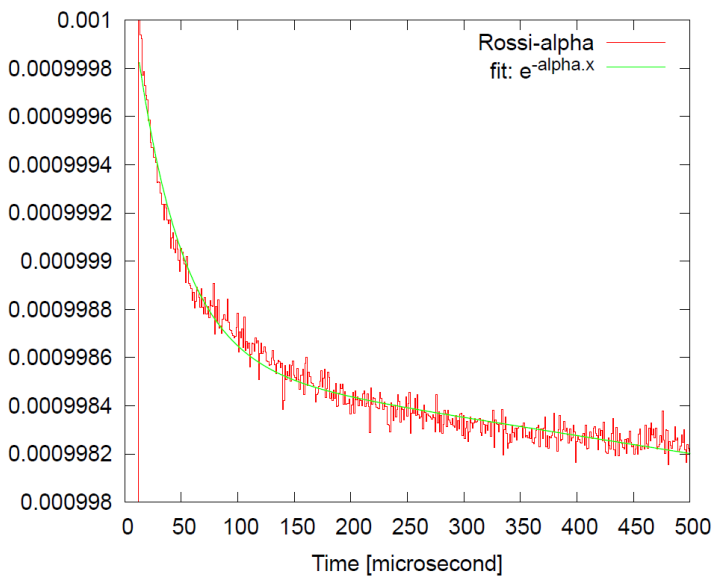


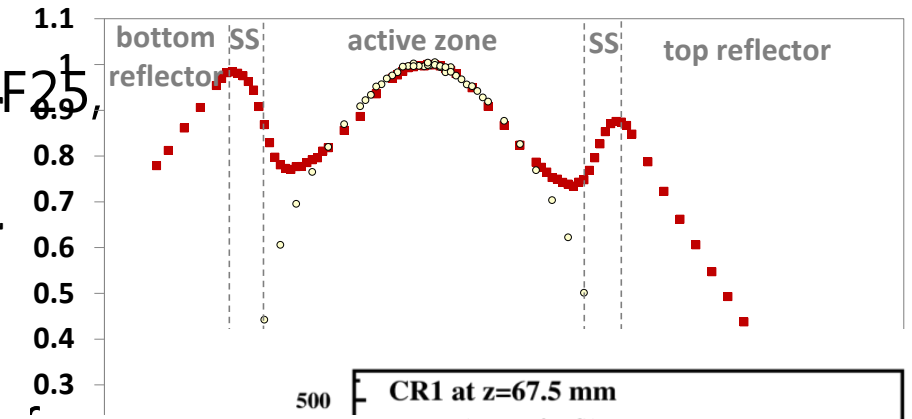


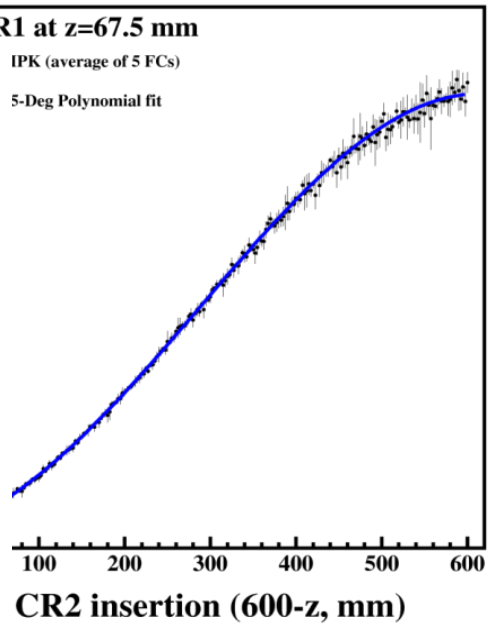
Experiments in critical cores

- axial and radial traverses with fission chambers and activation foils (fissile and threshold)
- spectral indices (F28/F25, F49/F25,
- rod drop (for MSM method)
- control and safety rod worth
- kii
- re



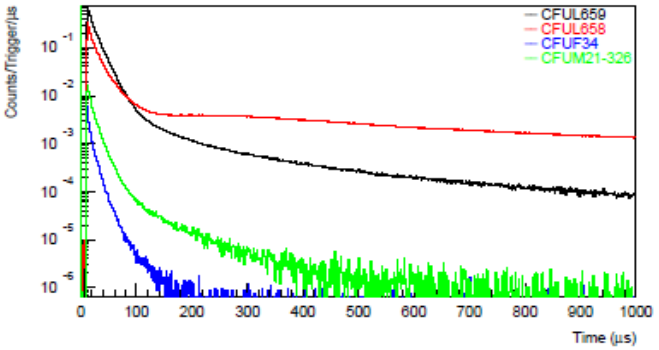


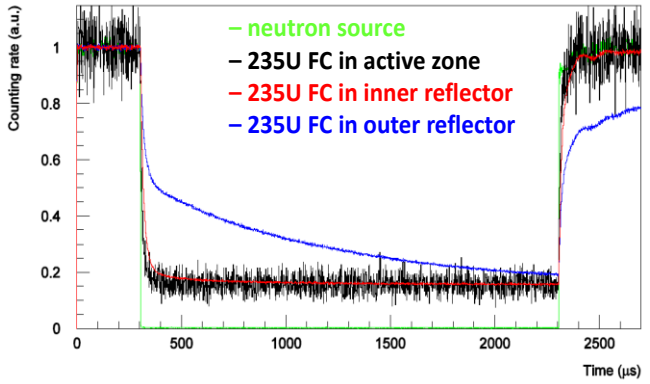




Experiments in subcritical cores

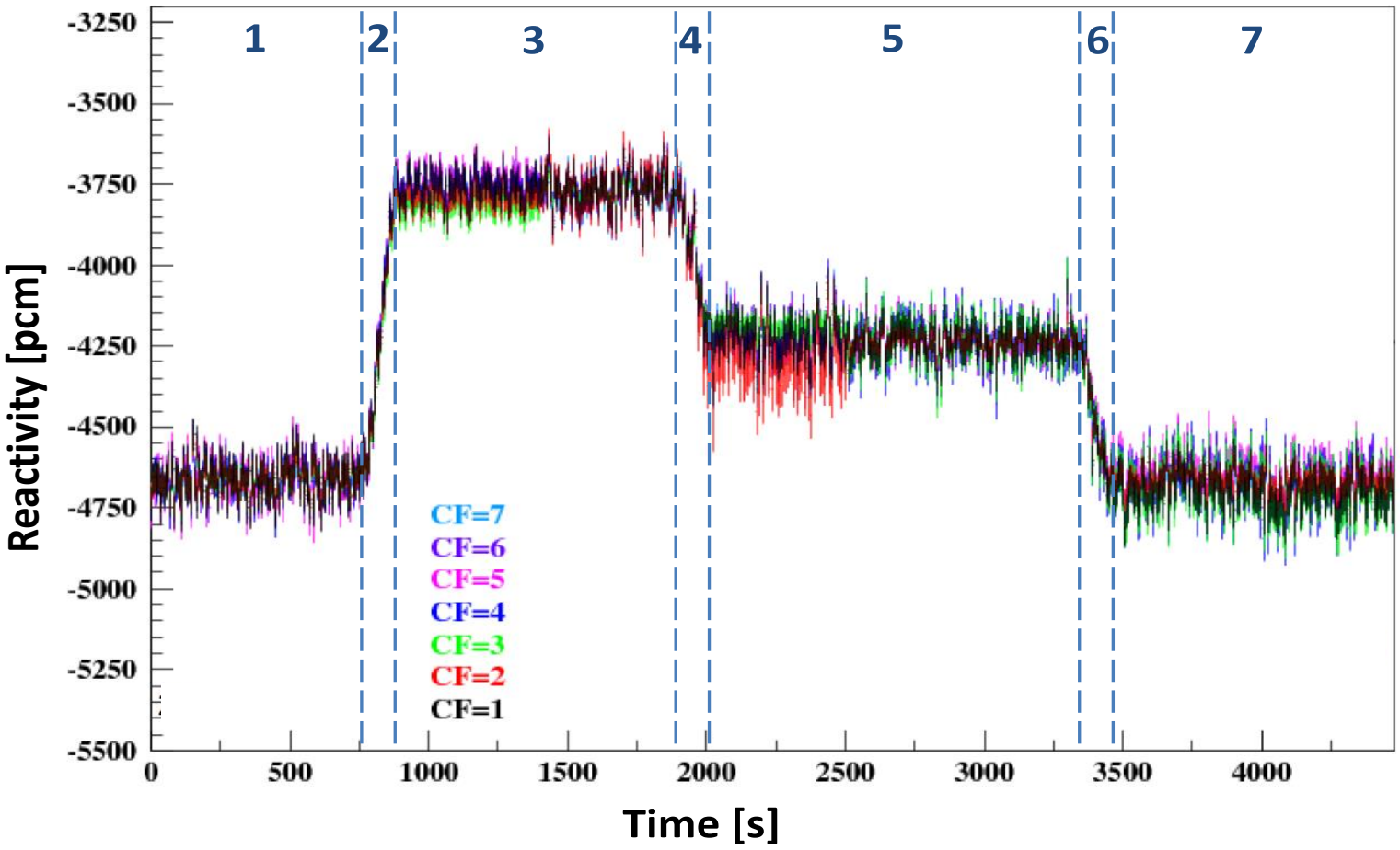
- Experiments for validation of the methodology for on-line reactivity monitoring of ADS:
  - Pulsed Neutron Source technique
  - Beam Trip measurements
  - Current-to-Flux measurements



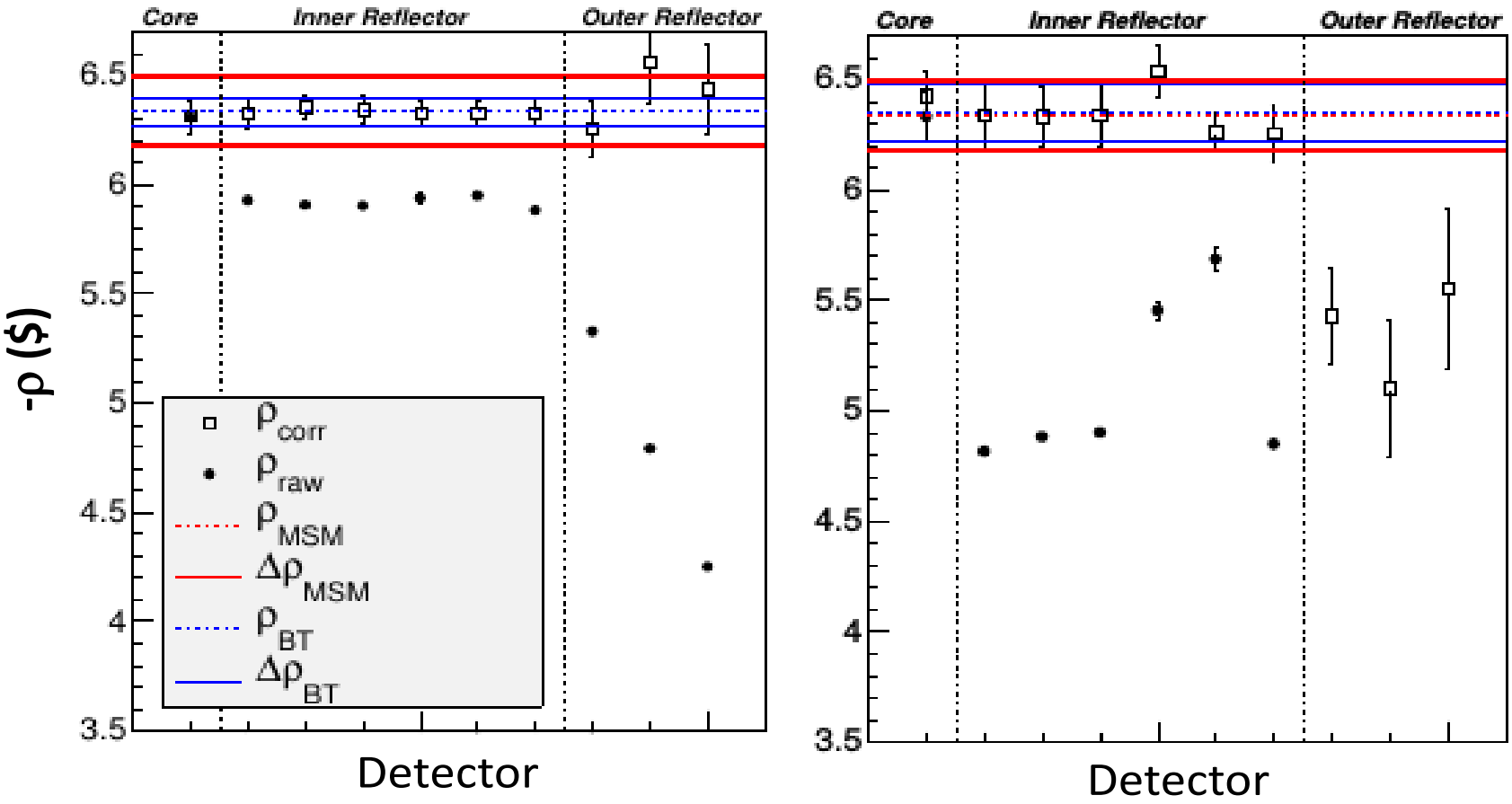


- Various:
  - k_{eff}: 0.89-0.97
  - reflectors: Pb, SS, graphite
  - in-pile sections: PE+Cd, PE+U+Cd
  - neutron source positions: middle or periphery of the core

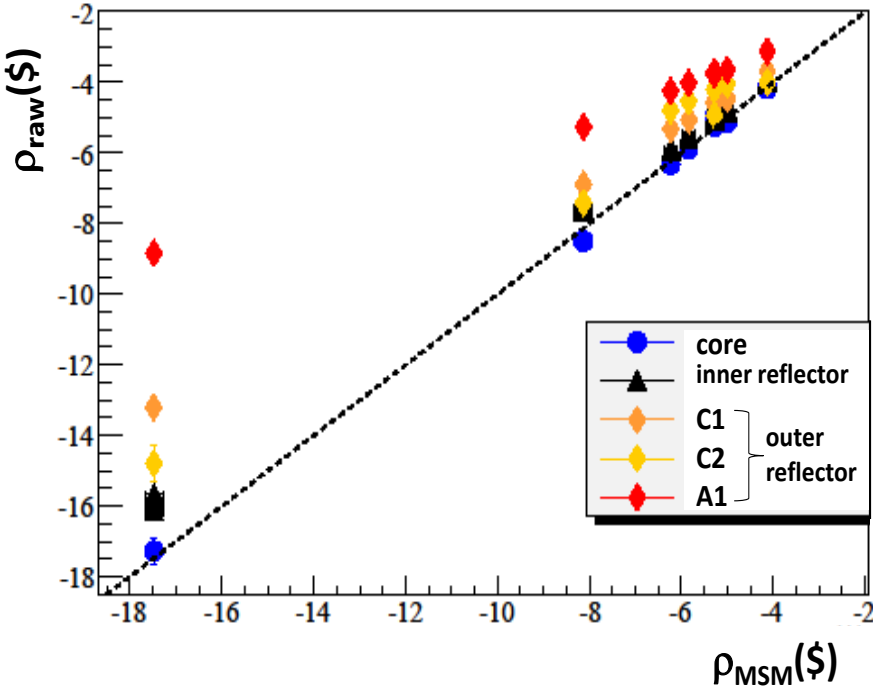
Current-to-flux measurements

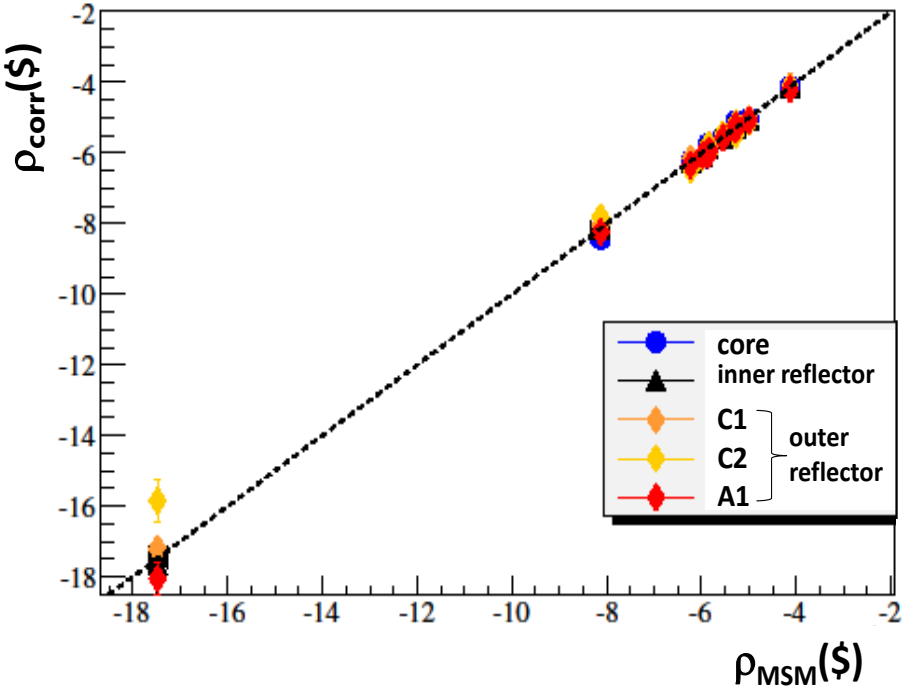


Beam trip measurement results



Beam trip measurement results





Conclusions

- MYRRHA is a first ADS demonstrator to contribute to the demonstration of P&T at European scale
- The MYRRHA pre-licensing phase foresees a dedicated focuss point on subcriticality monitoring
- With VENUS-F and GENEPI-C, we have a unique installation to provide the necessary data for the validation of codes and of the methodology of subcriticality monitoring through different experimental programmes GUINEVERE, FREYA and MYRTE
- Current-to-flux and beam-trip measurements were validated in representative conditions in VENUS-F coupled to GENEPI-C