Reactivity Measurements in Subcritical Core: RACE-T Experimental Activities

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Layout of the presentation

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- RACE-T generalities
- Fission rates radial traverses
- Subcritical level measurements
- Pre-TRADE experimental benchmark
- Conclusions

Preamble

- The objective of the European Integrated Project EUROTRANS of the EURATOM 6th Framework Program is to bring answers to the high level nuclear waste transmutation in ADS. The EUROTRANS experimental activities have been joined into the ECATS domain, namely Experiment on the Coupling of an Accelerator, a spallation Target and a Subcritical blanket.
- The RACE-T experiment, formerly named TRADE, is part of ECATS. The experimental campaign was held in the period 2004–2006 in the TRIGA RC-1 reactor, operated by ENEA at the Casaccia research center near Rome, in order to propose experimental techniques for absolute reactivity calibration at either startup or shutdown phases.
- RACE-T includes fission rate measurements (performed with a special instrumented fuel element), investigation of different subcritical configurations (with D/T generator in the core center), and development of special devoted instrumentation and acquisition systems.
- The main outcomes of the experimental campaign will converge into an international IAEA benchmark.

Preamble

Synoptic table Experiences-Measures

	PNS α	PNS Area	Source Jerk	Beam Dump/Jump	Power to Current	Noise	MSA/MSM
MUSE				X	X		
RACE-T				X	X	X	
GUINEVERE							
YALINA				?			X

RACE-T generalities

- **Selected RACE-T campaign results**

  - **Characterization of the critical phase performed by fission rate traverses.**
  - **Evaluation of the applicability of various experimental techniques for assessing a subcritical level. Those techniques are based on:**
    - ✓ **The system response to a pulsed neutron source, in particular the Area-ratio method obtained by a D-T generator.**
    - ✓ **The system response to a Source Jerk (SJ), in particular the Inverse Kinetics method applied to a SJ obtained by a D-T generator.**
    - ✓ **The Source Multiplication technique.**
  - **Reactivity estimates were performed at different core locations and for three different "clean" (control rods withdrawn) subcritical core configurations, namely SC0 (~ -500 pcm), SC2 (~ -2500 pcm) and SC3 (~ -5000 pcm).**

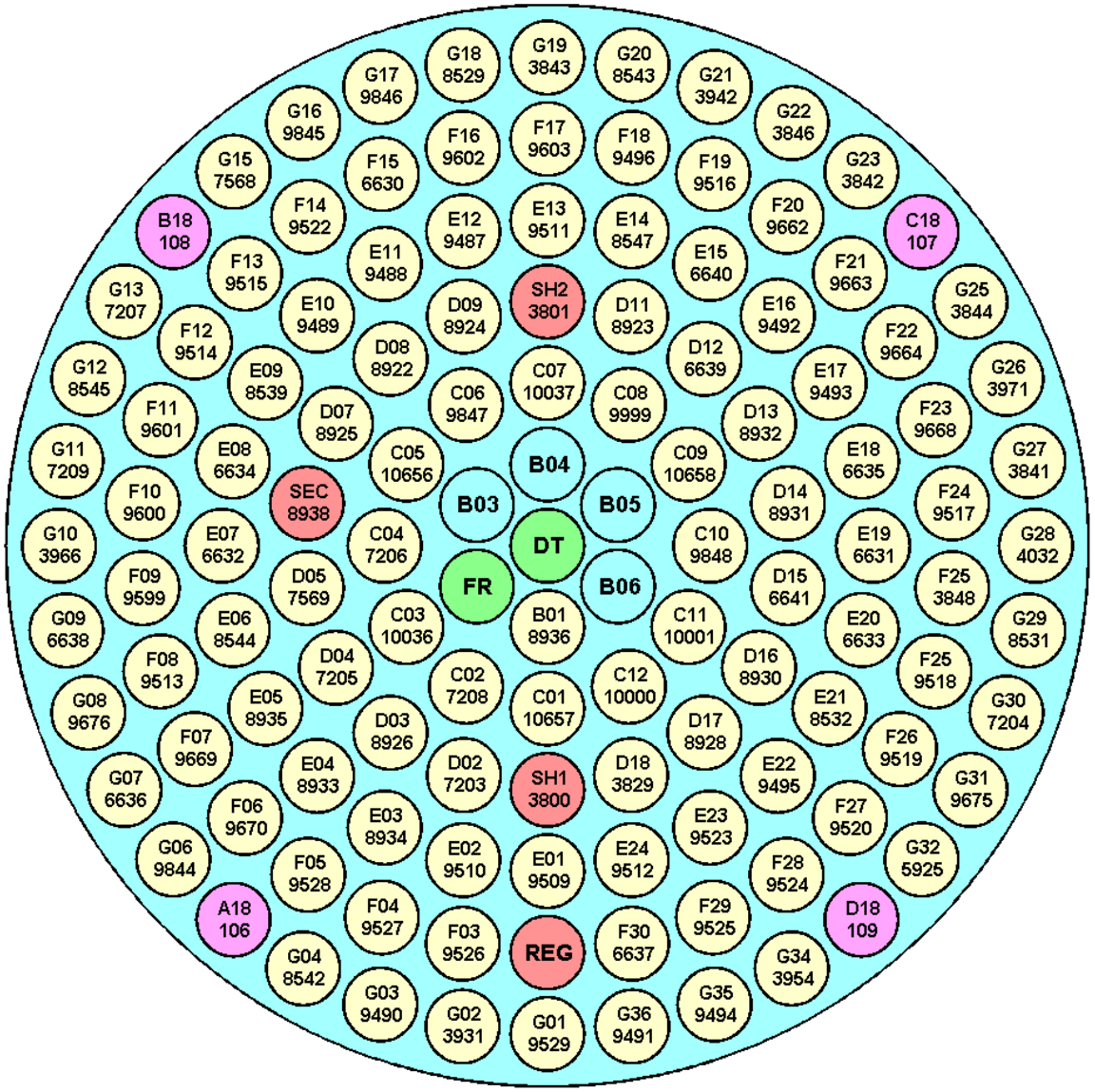
RACE-T generalities: neutron sources

- **For the subcritical configurations, the reactor was coupled with the following neutron sources:**

  - **A pulsed deuterium-tritium neutron generator, accelerating deuterium ions onto a tritium target, and producing 14.1-MeV-neutron bursts with strength of 10^8 n/s at maximal frequency. The frequency range spanned from 1 to 150 Hz. The pulse duration was less than 1 μs. The neutron generator was located at the core center A01.**

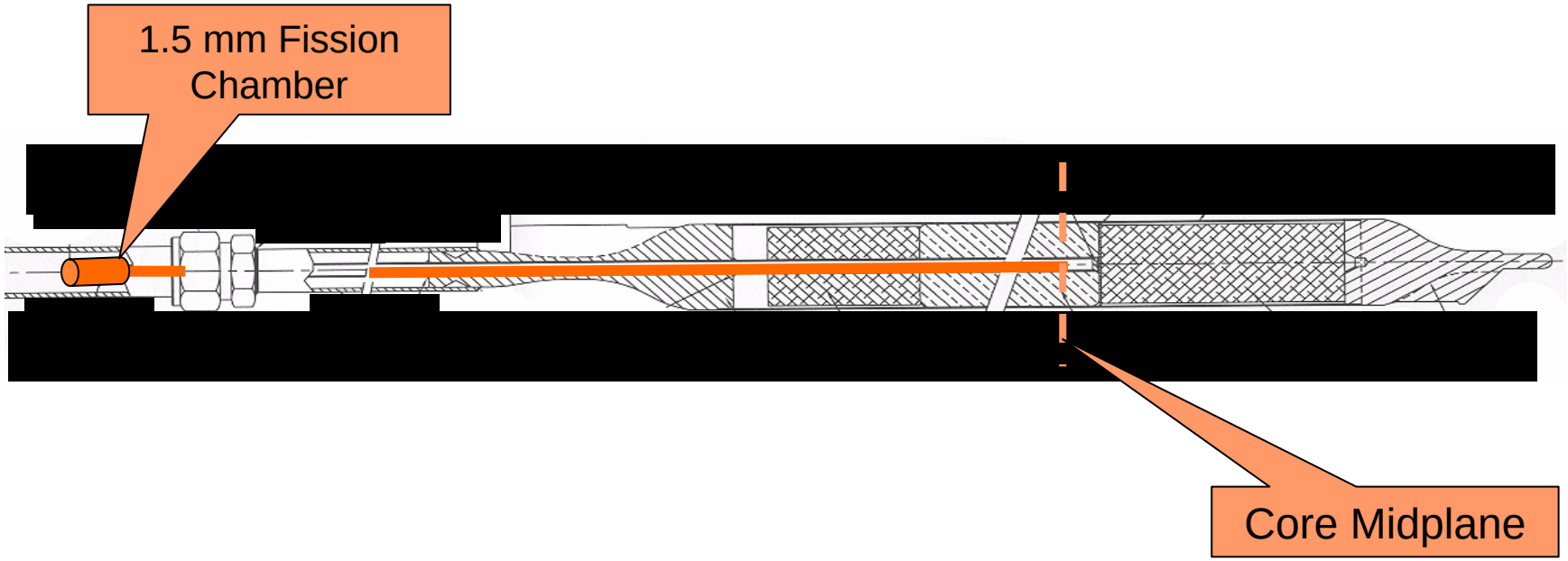
  - **A Cf-252 source, with a strength of 0.4 Ci, was used to perform Source Multiplication experiments using a Fast Rabbit (FR) location in the B02 position in ring B.**

RACE-T generalities: neutron sources



Fission rates radial traverses

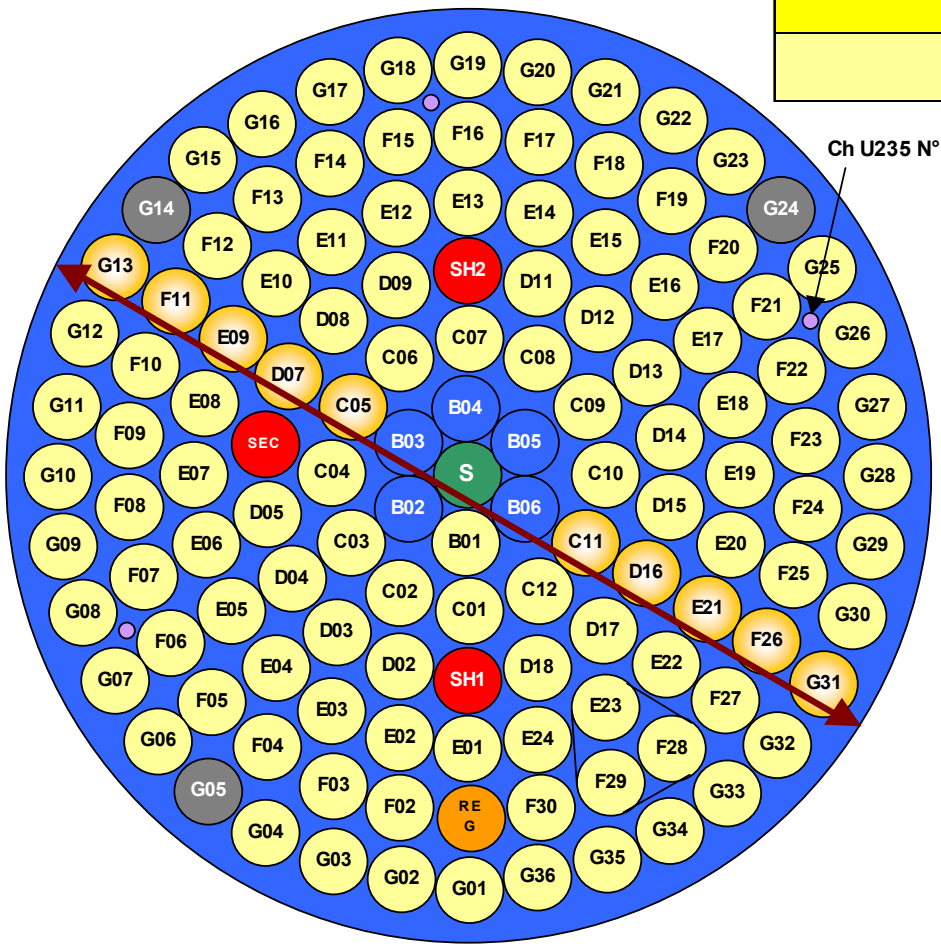
Special Instrumented Fuel Element with central channel of 4 mm internal diameter in order to host a fission chamber and investigate the fission rate inside the fuel.



Fission rates radial traverses

- 3 different loaded fission chambers:
  - ^{235}U for thermal spectrum range
  - ^{237}Np for intermediate spectrum range
  - ^{238}U for fast spectrum range
- 50 measures with SIFE displacement along a core traverse.
- Reactor power: 10÷80 W.

Fission rates radial traverses

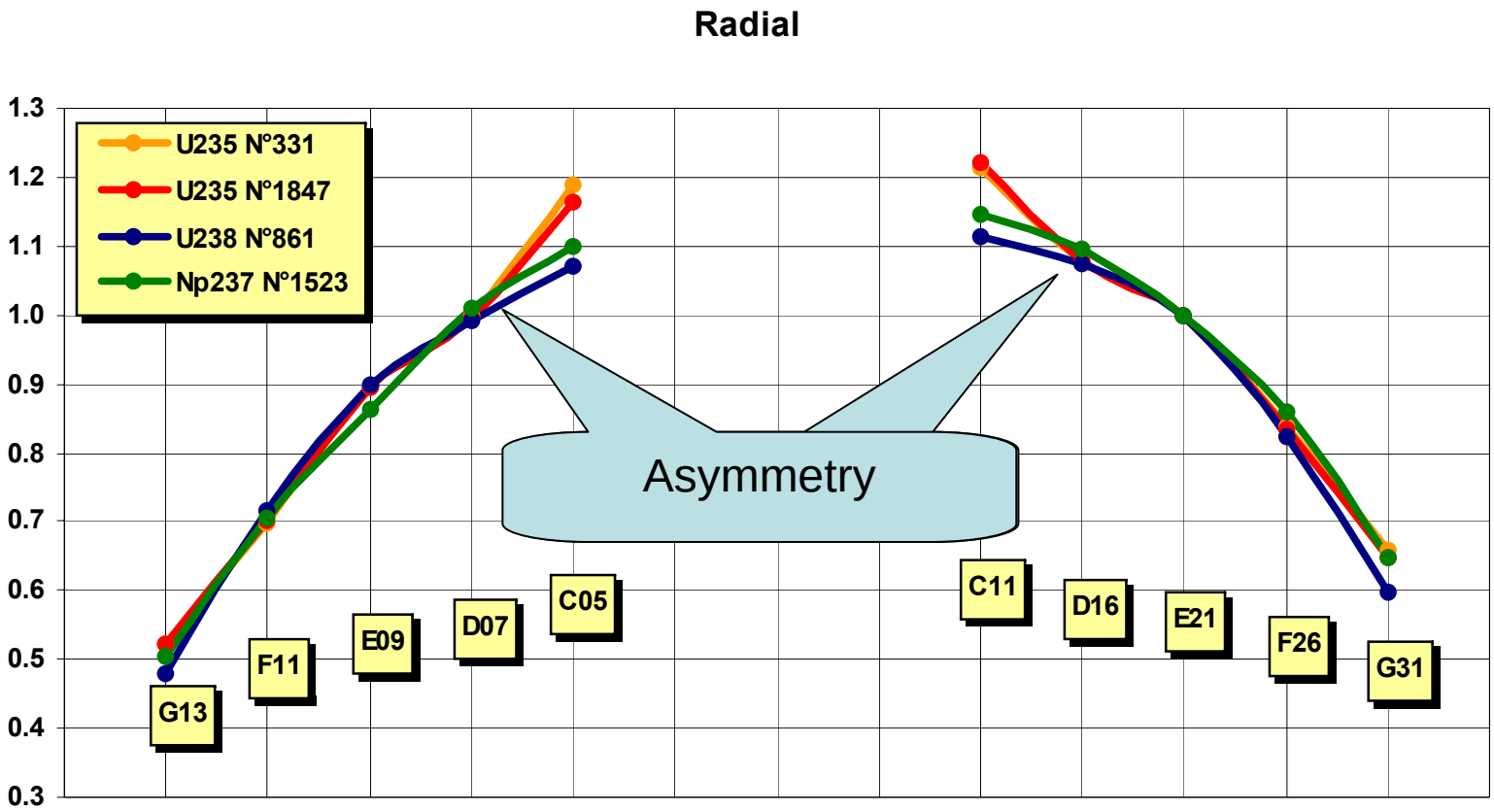


TRADE Exp Week 03-2004

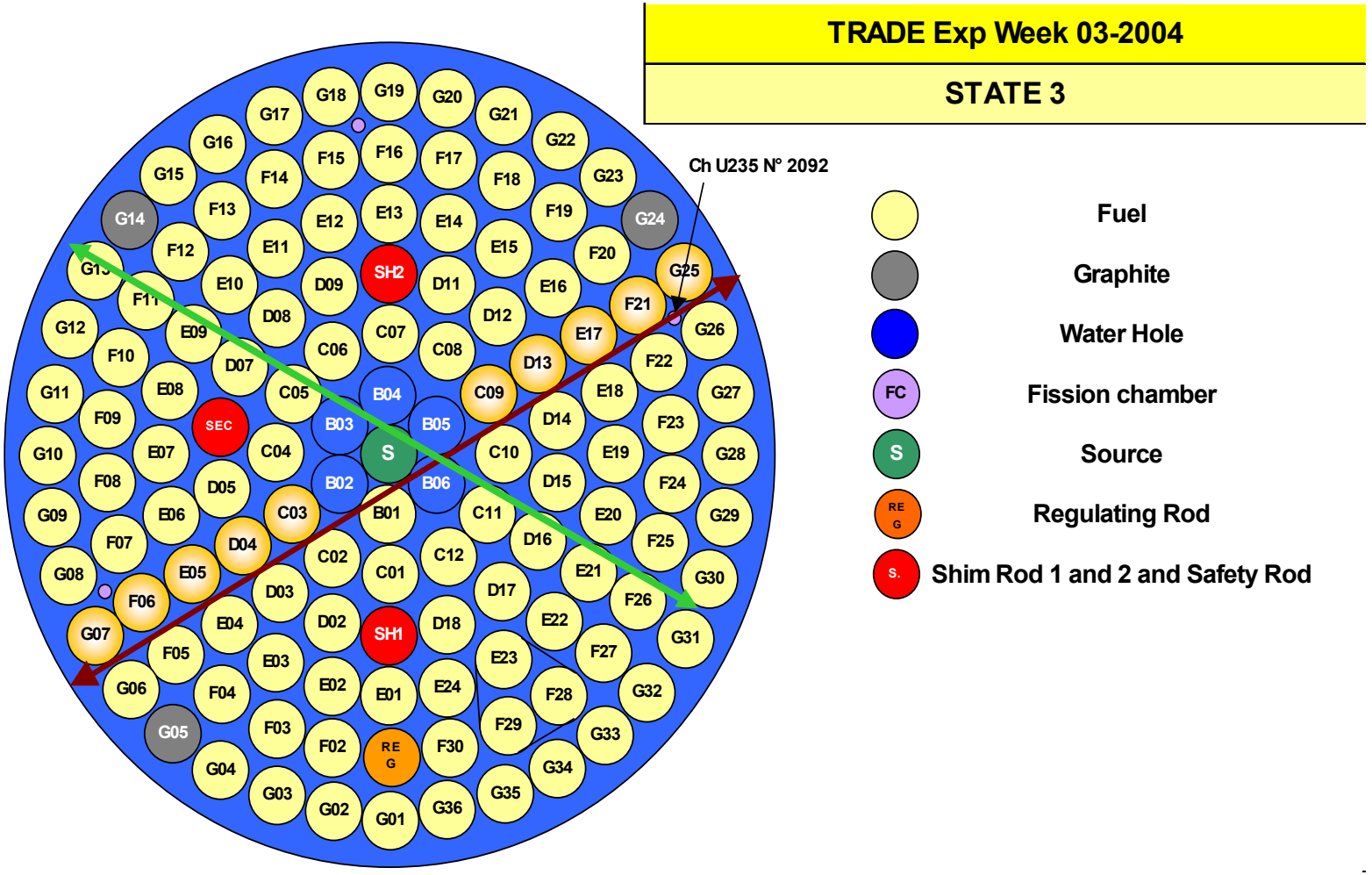
STATE 3

- Fuel
- Graphite
- Water Hole
- FC — Fission chamber
- S — Source
- REG — Regulating Rod
- S. — Shim Rod 1 and 2 and Safety Rod

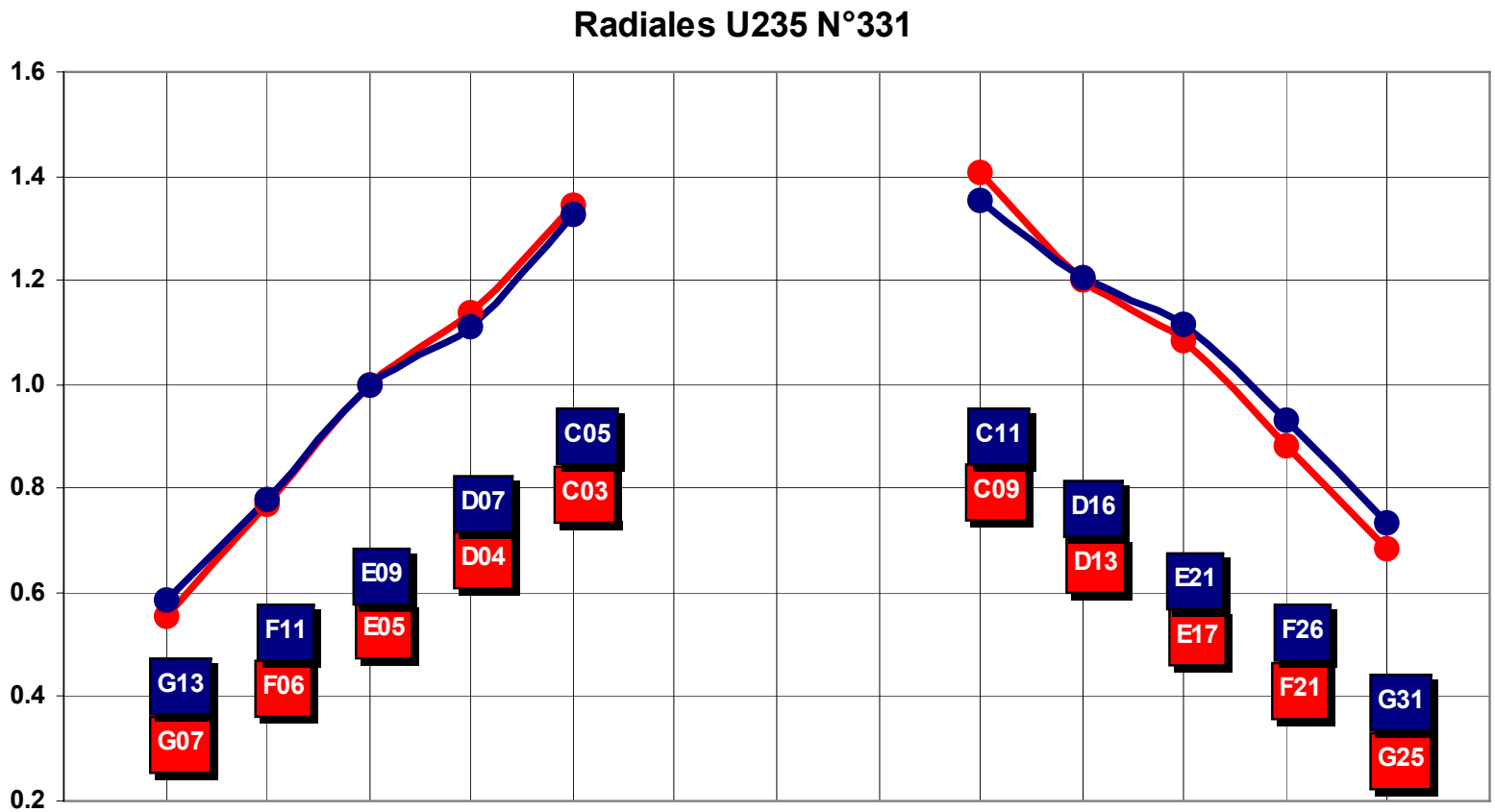
Fission rates radial traverses



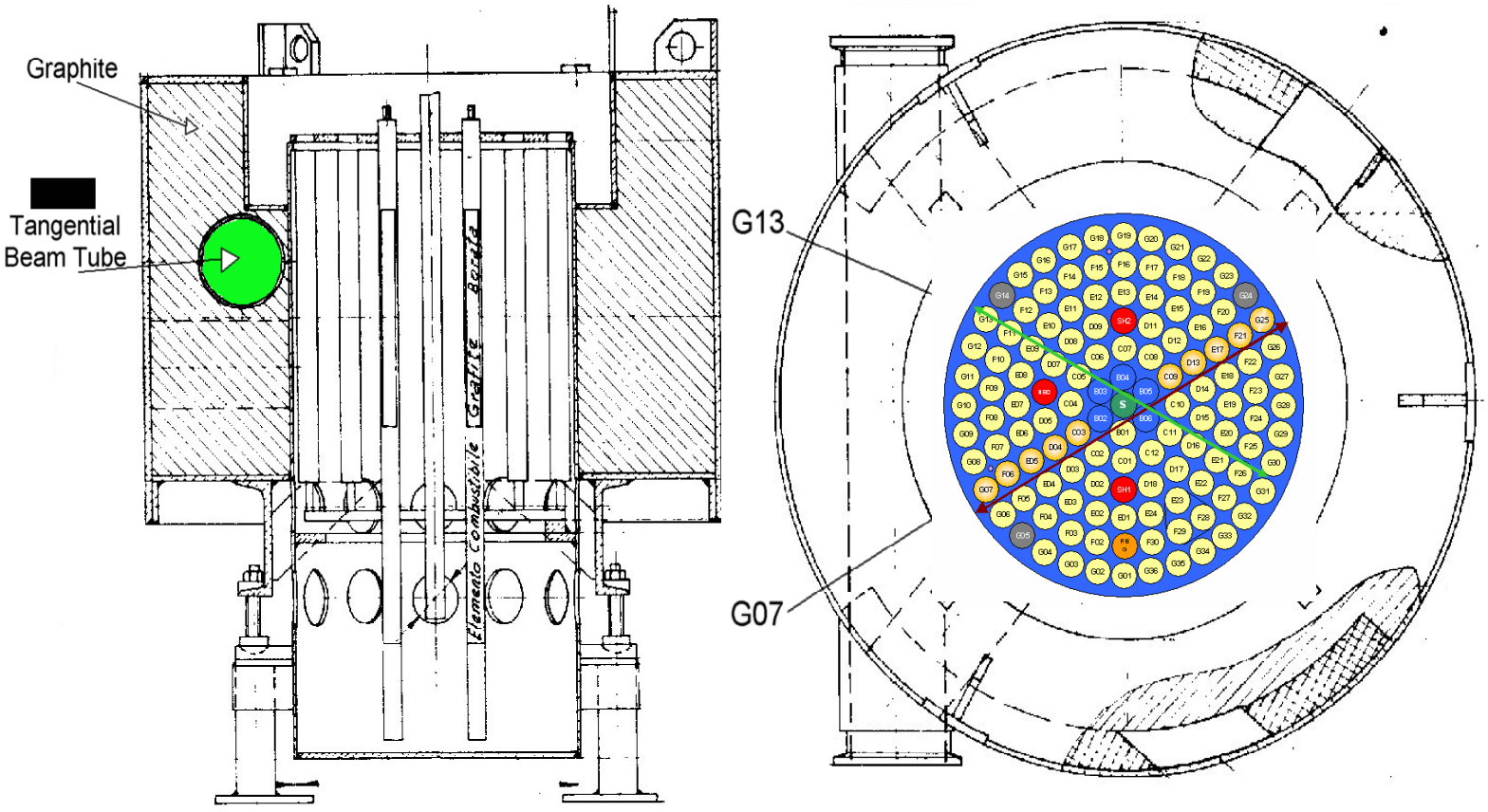
Fission rates radial traverses



Fission rates radial traverses

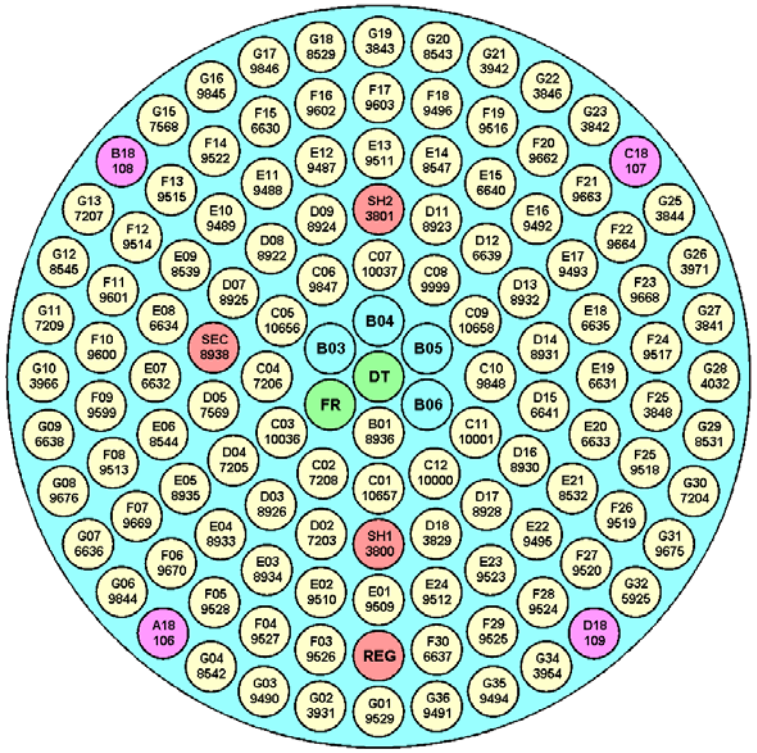


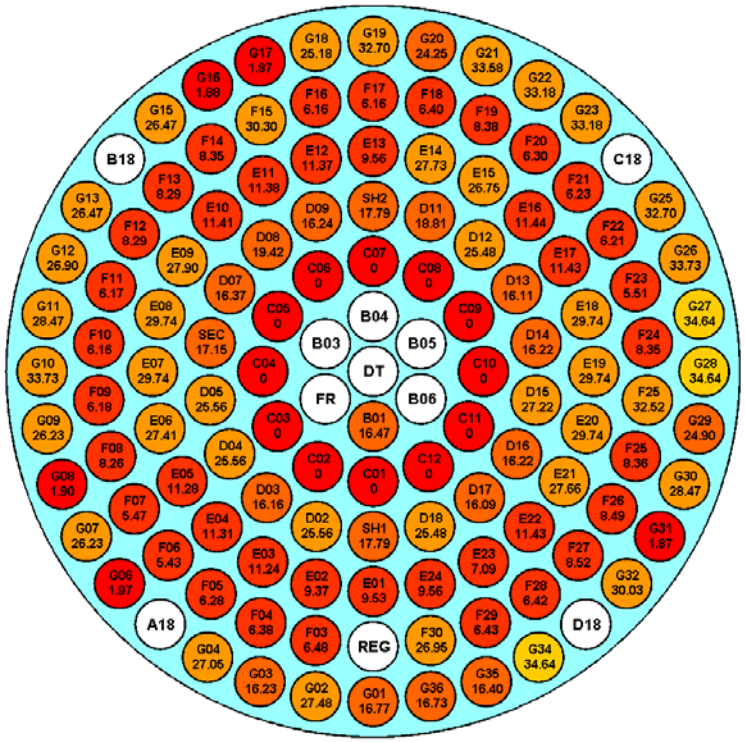
Fission rates radial traverses



Subcritical level measurements: core configurations

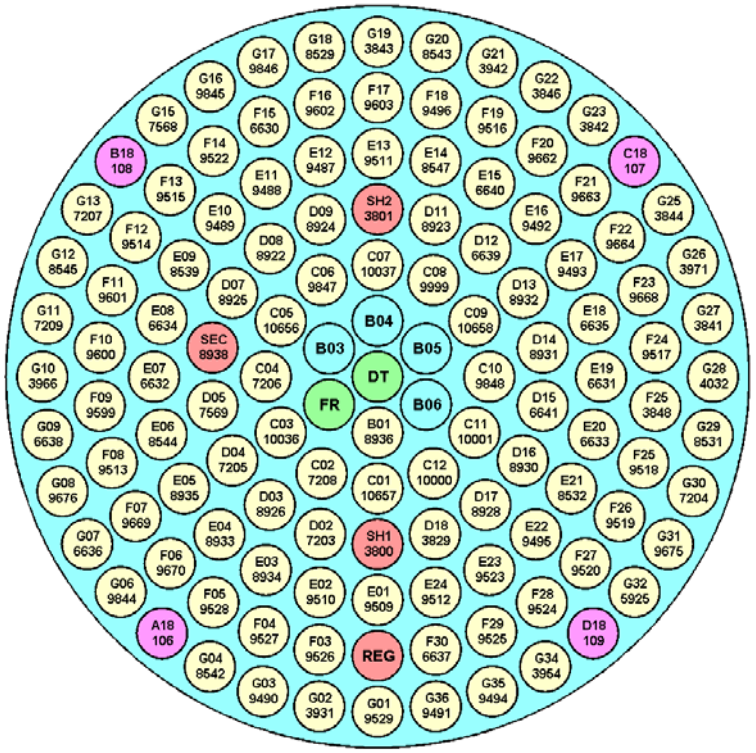
Reference critical (REG rod at 50% insertion)

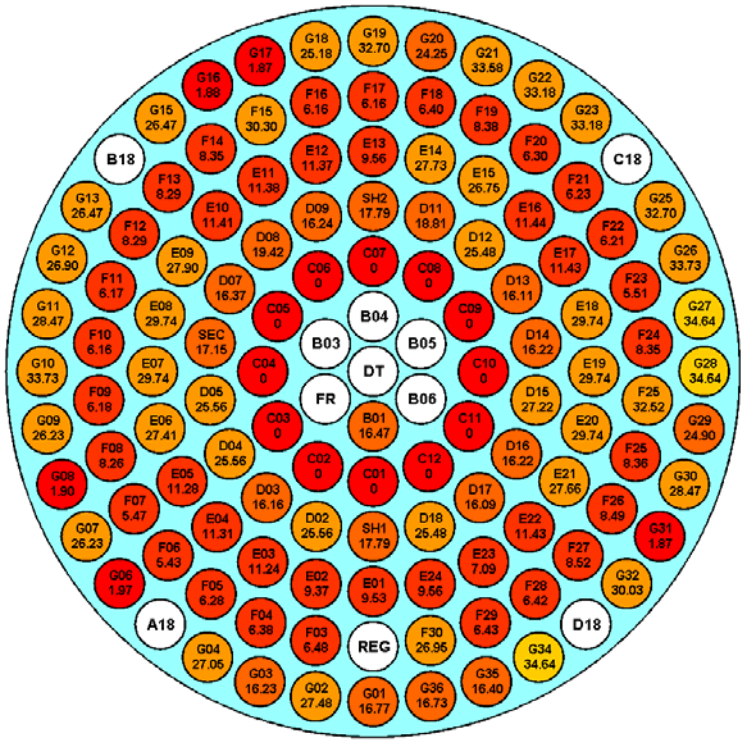




Subcritical level measurements: core configurations

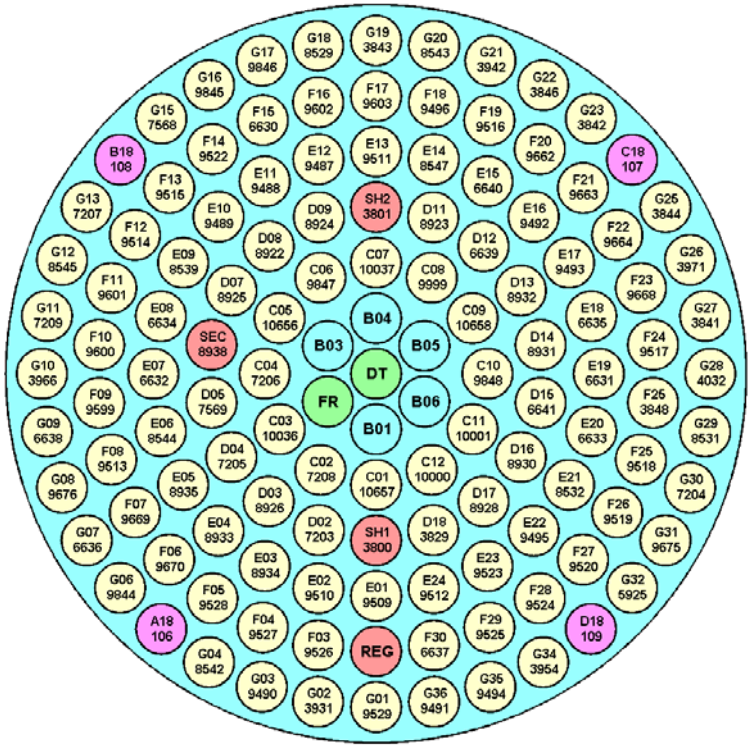
Reference subcritical (REG rod down ~ -300 pcm)

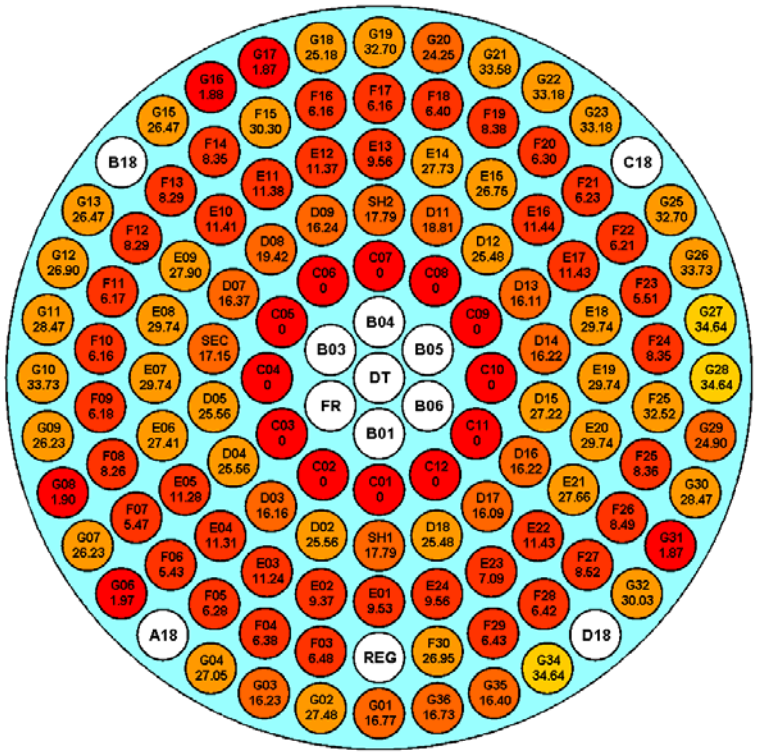


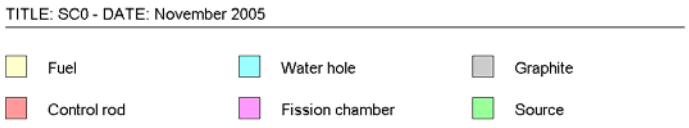


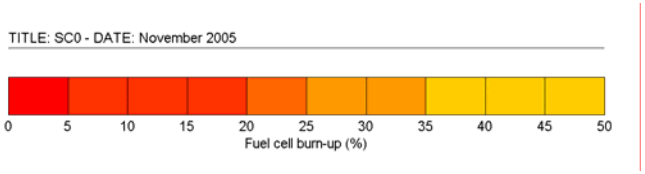
Subcritical level measurements: core configurations

SC0 (~ -500 pcm)



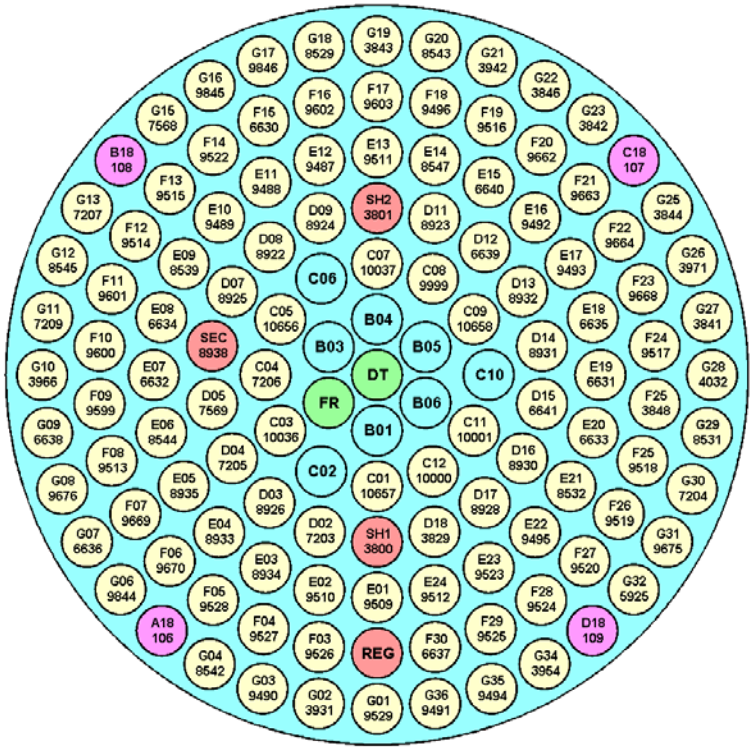


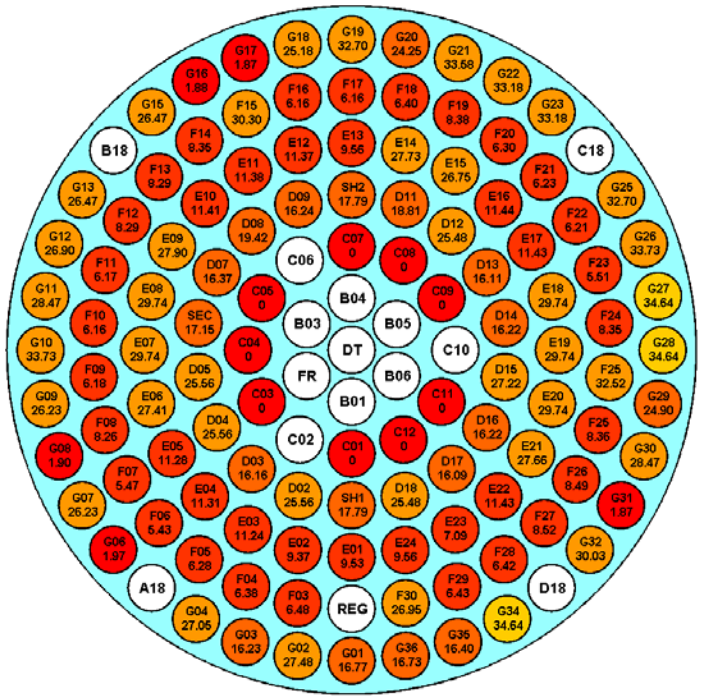


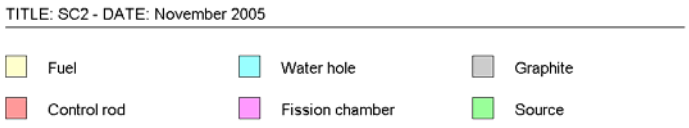


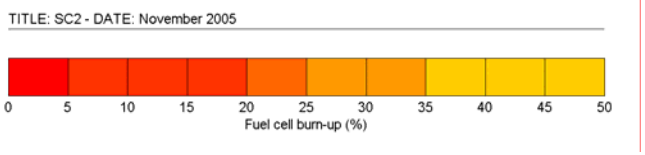
Subcritical level measurements: core configurations

SC2 (~ -2500 pcm)



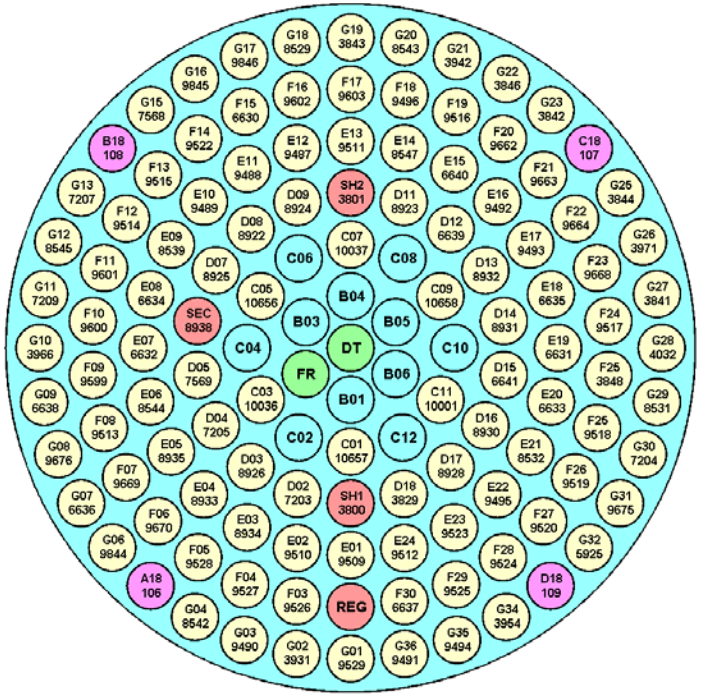


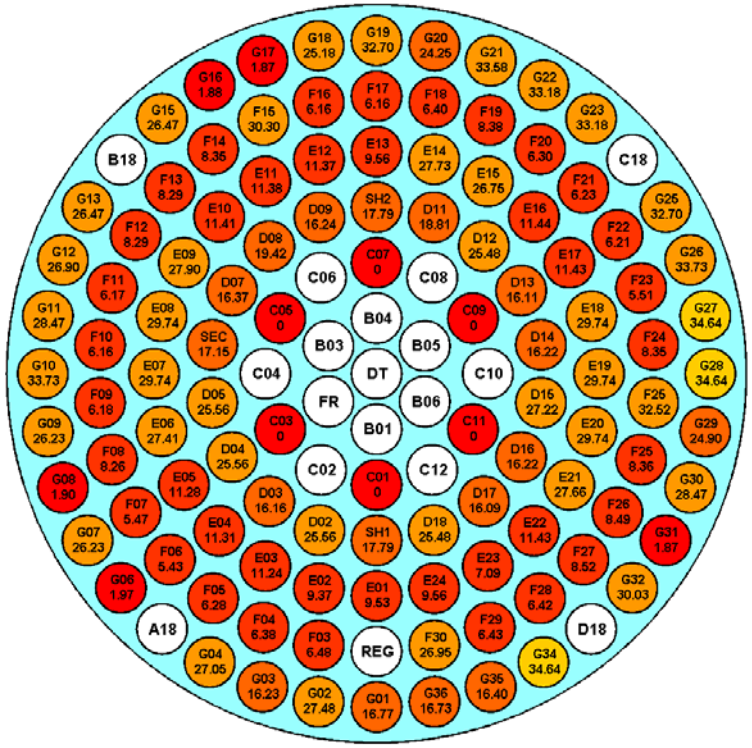


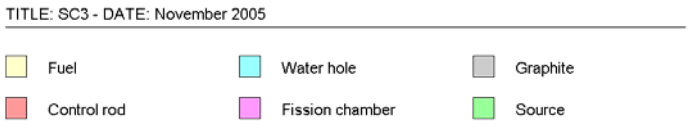


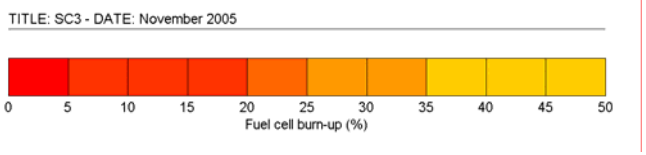
Subcritical level measurements: core configurations

SC3 (~ -5000 pcm)



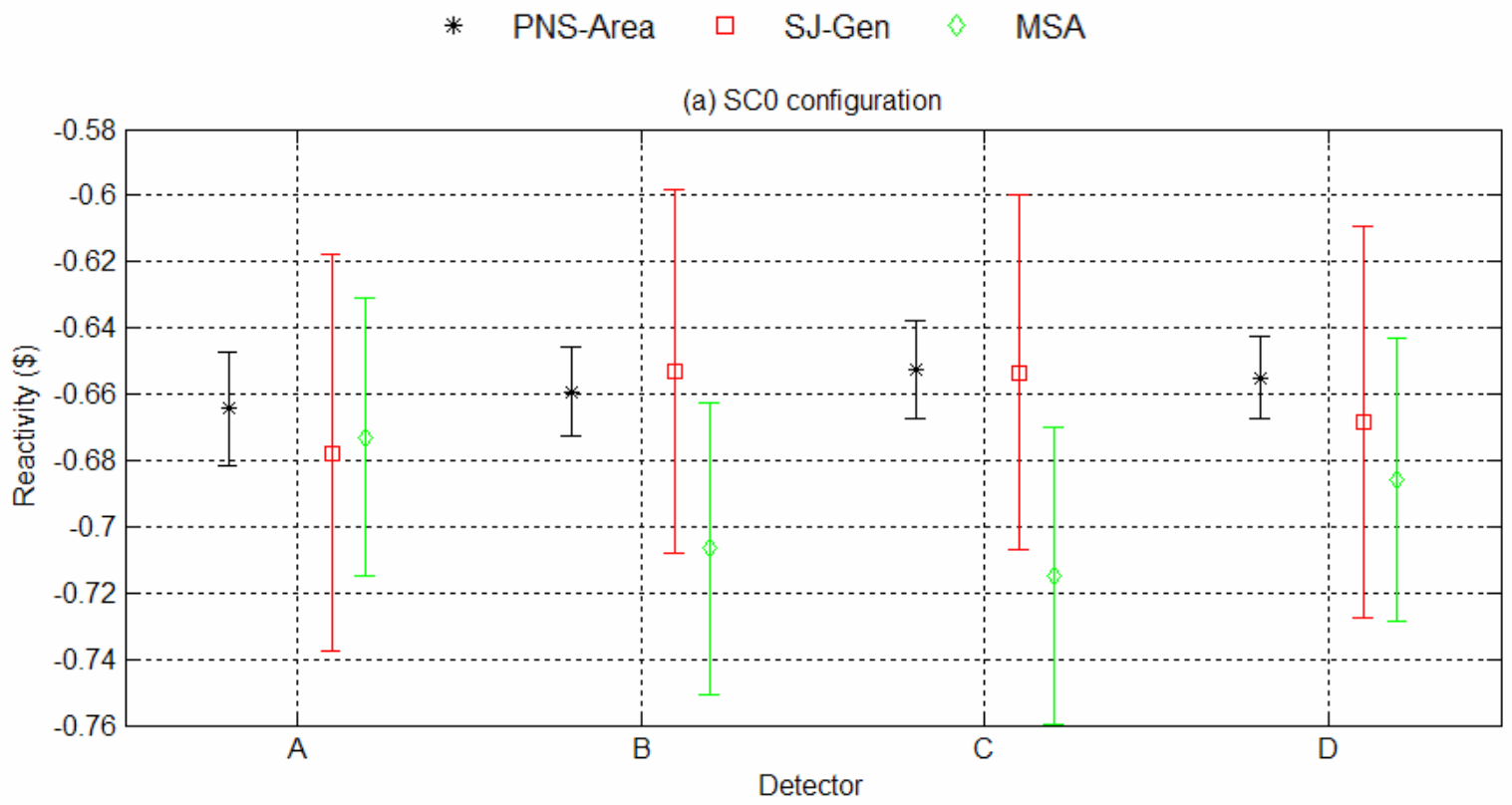






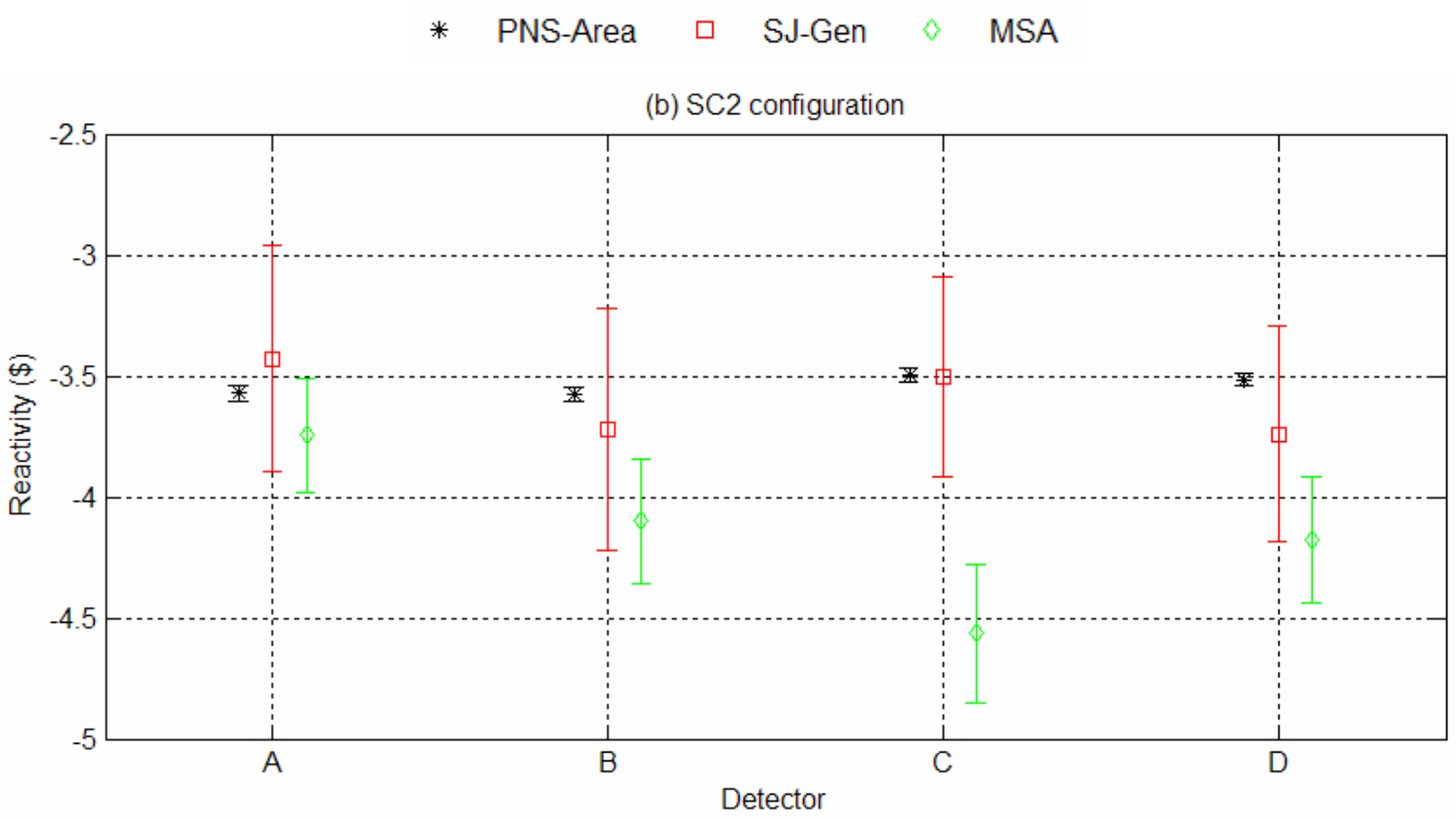
Subcritical level measurements: results

SC0 (~ -500 pcm)



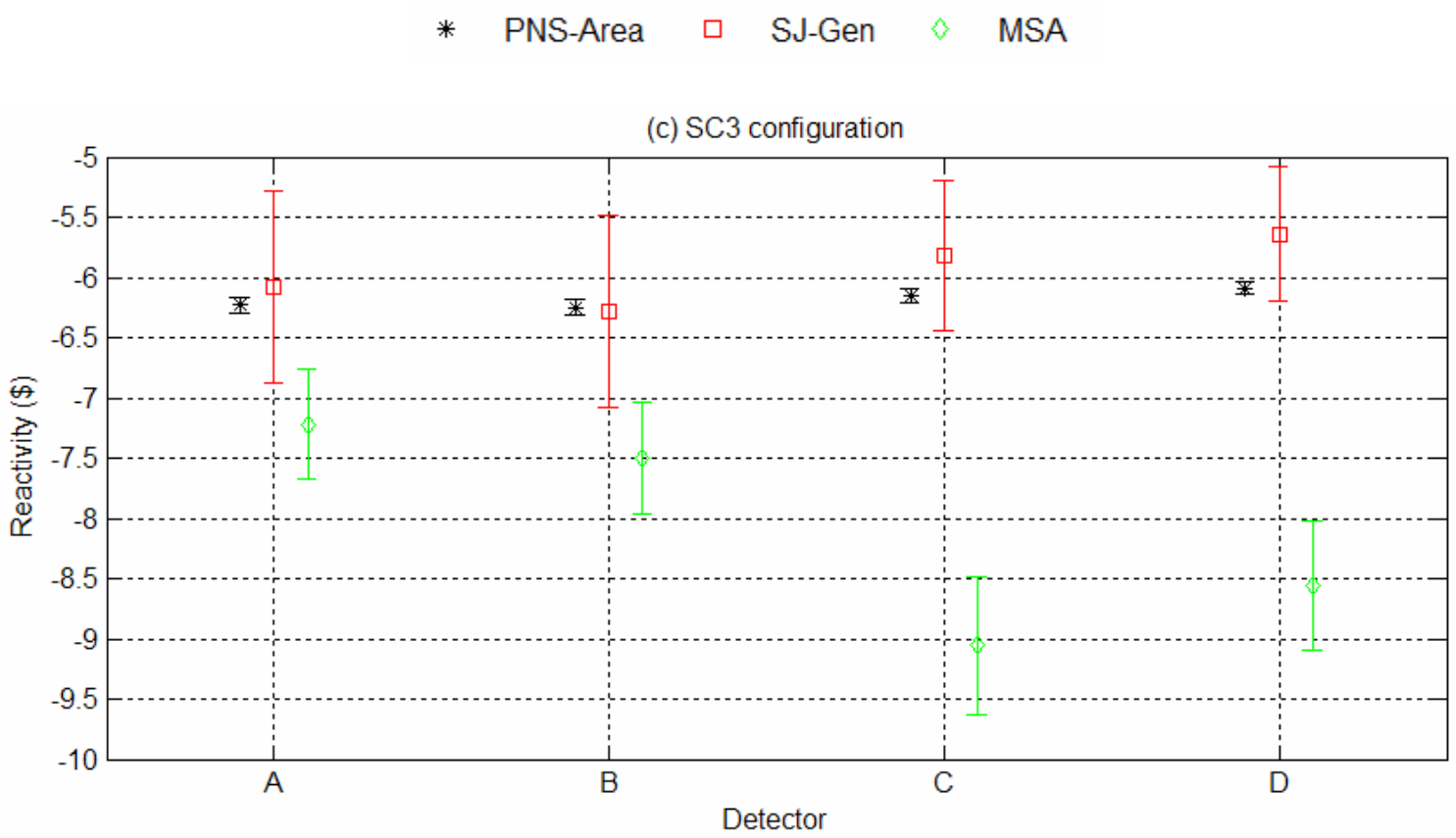
Subcritical level measurements: results

SC2 (~ -2500 pcm)



Subcritical level measurements: results

SC3 (~ -5000 pcm)



Pre-TRADE experimental benchmark: comments about exp. results

•For a given subcritical configuration, PNS-Area/SJ-Gen results exhibit less spread in connection with the detector position in comparison with what happens for MSA results.

•PNS-Area results *stability* was already observed in MUSE, even though such a stability was exhibited in this case with respect to PNS-α fitting results.

•But we are in a (Hamlet-like) dilemma: even if PNS-Area results are in tune between them, are they telling the truth, or they reached an agreement?

•To know it, we have to estimate, by calculation, spatial correction factors for both PNS-Area and MSA methods. This is the aim of the IAEA benchmark.

Pre-TRADE experimental benchmark: burnup issue

•The main problem for the RC-1 Casaccia TRIGA reactor is in relation to the burnup issue (reaching about 35% for some elements loaded in the selected configurations).

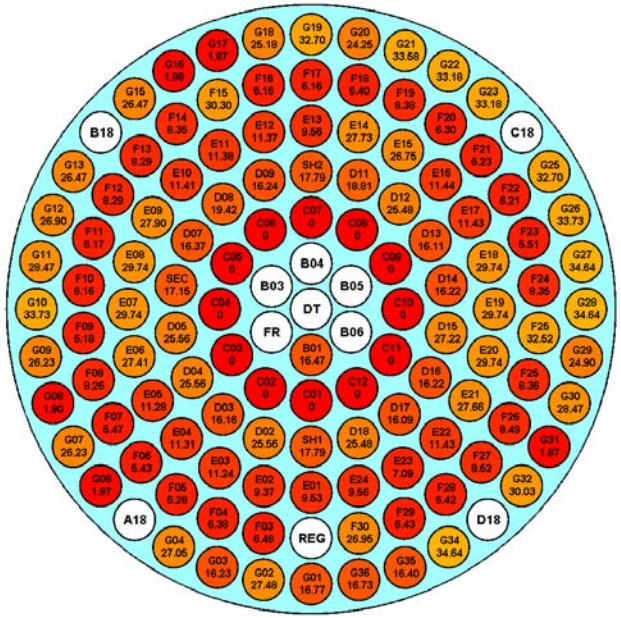
•Burnup values quoted in preceding figures were obtained by TRIGA Casaccia staff by approximated ("Excel") calculations taking into account the detailed in-core history of each fuel element.

•On this subject, RC-1 Casaccia TRIGA reactor staff will perform an experimental estimation of the element-by-element burnup level (taking advantage of the availability of several fresh fuel elements which can be used for calibration purposes).

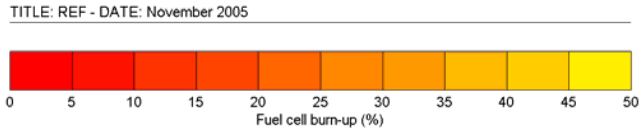
•Nevertheless, a basic question should be asked (not at the end of this speech): at which confidence level we have to know the detailed burnup distribution of the subcritical system in order to correctly *measure* (*not to reproduce* in our calculations) the subcriticality level? Are spatial correction factors very sensitive to burnup distribution? If we consider area results, it doesn't seem so evident. This benchmark will go into this matter.

Pre-TRADE experimental benchmark: burnup issue

REF critical



Evaluation	U-235 consumption (g)	Burnup %
New	554.25	12.73
Old	703.47	16.15
Δ	26.92%	3.43



Conclusions

- **RACE-T experiments have allowed the testing of different techniques to measure the subcritical level in ADS.**

- **Coherently with the outcomes from MUSE, the PNS Area-ratio method seems to be the most stable for what concerns the spatial effects, even if such stability has to be supported by theoretical and numerical confirmations.**

- **Inverse Kinetics/Source Jerk technique provided reactivity estimates always in excellent agreement with those obtained by the Area-ratio technique, although a discrepancy between PNS Area-ratio and Inverse Kinetics/Source Jerk results can be clearly be observed when increasing the subcriticality level.**

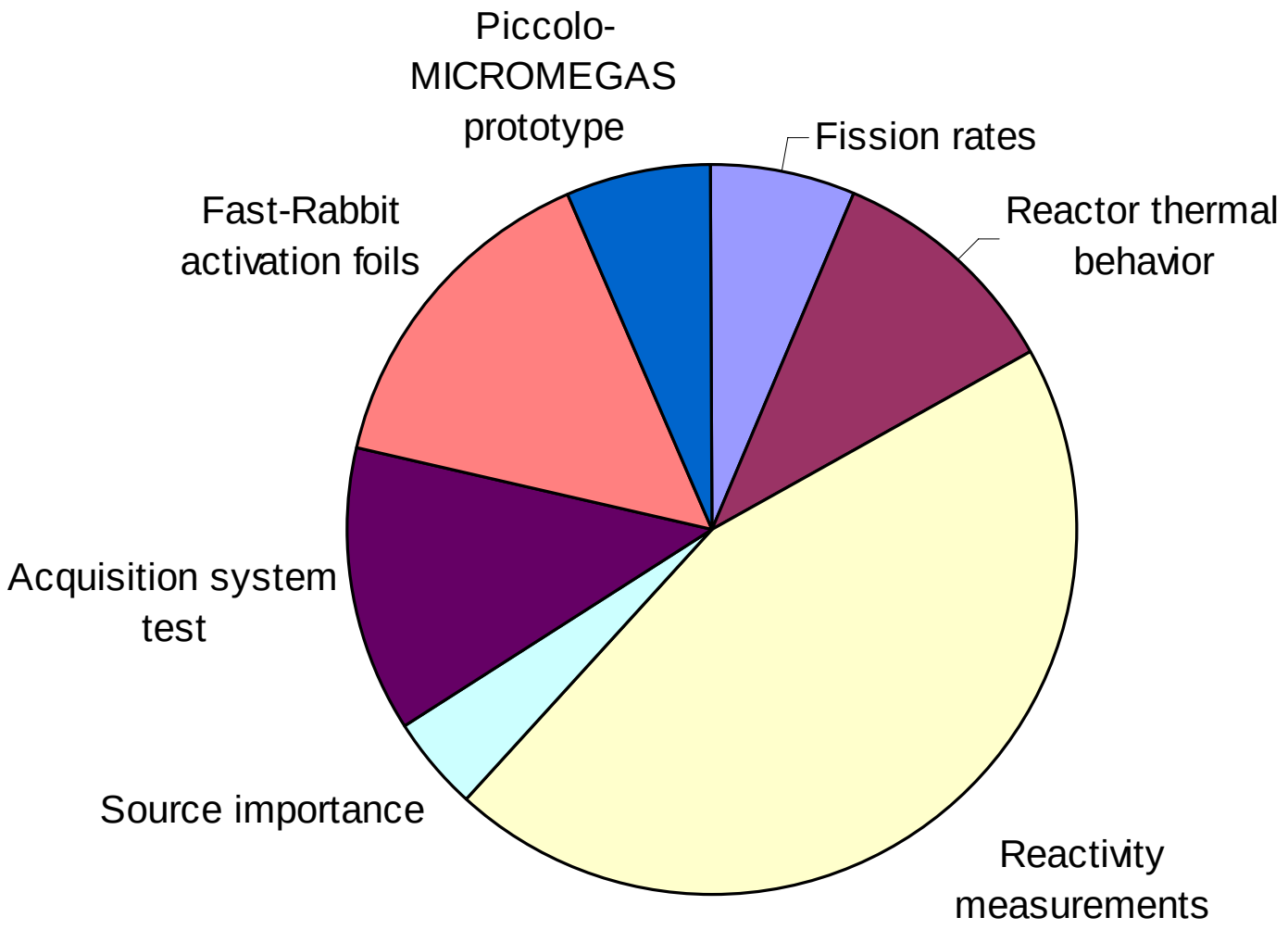
- **The above mentioned theoretical and numerical confirmations will be obtained, hopefully, thanks to a computational benchmark, recently endorsed by IAEA, focused on the evaluation of the correction factors to be applied to the PNS Area-ratio and MSA results.**

Pre-TRADE benchmark site (under preparation)

http://www.triga.enea.it/TRIGA/Eng/IAEA_Benchmark.htm

Main Meeting
Coordinated Research Project "Analytical and Experimental Benchmark Analyses of Accelerator Driven Systems (ADS)"
Embedded Meeting
Collaborative Work "Low Enriched Uranium (LEU) Fuel Utilization in Accelerator Driven Sub-Critical Assembly Systems ADS)"
Date: 12 - 16 November 2007
Meeting Venue
Conference Room
ENEA's Headquarters – Rome – Via Giulio Romano 41

RACE-T experiments



Sharing of 50 Work-Weeks over 2,5 Years Reactor