GUINEVERE: construction of a zero-power Pb fast ADS at Mol

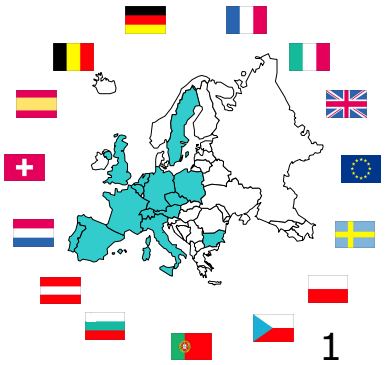
A.Billebaud (CNRS/LPSC)

P.Baeten, H.Aït Abderrahim, G.Ban, M.Baylac, G.Bergmans, D.Bondoux, J.Bouvier, S.Chabod, JM.De Conto, P.Dessagne, G.Gaudiot, JM.Gautier†, G.Granget, G.Heitz, M.Kerveno, A. Kochetkov, B.Laune, F.R.Lecolley, J.L.Lecouey, N.Marie, F.Mellier, Y.Merrer, A.Nuttin, D.Reynet, J.C.Steckmeyer, D. Vandeplassche, F.Vermeersch, G.Vittiglio.

SCK·CEN, Belgium **CNRS/IN2P3, France** **CEA/DEN, France**

SIXTH FRAMEWORK PROGRAMME

On behalf of EUROTRANS-IP, EURATOM FP6 and WP2.3 GUINEVERE collaboration



Motivations…

- **Extend and complete the MUSE-experiments** (pulsed GENEPI at sodium fast reactor MASURCA @CEA-Cadarache, F, 2000-2004 FP5) **on sub-critical system reactivity monitoring**
- Need for a **reactor mock-up** with a core representative of **a fast ADS** (MASURCA reactor unavailable until 2013) **to follow up investigations in support to the design of Fast Transmutation Experimental Facility**
- Need for a coupling with a **neutron source that can be operated in various modes: pulsed, continuous, interrupted**
- **Need for an easily available facility in Europe**

…and Objectives

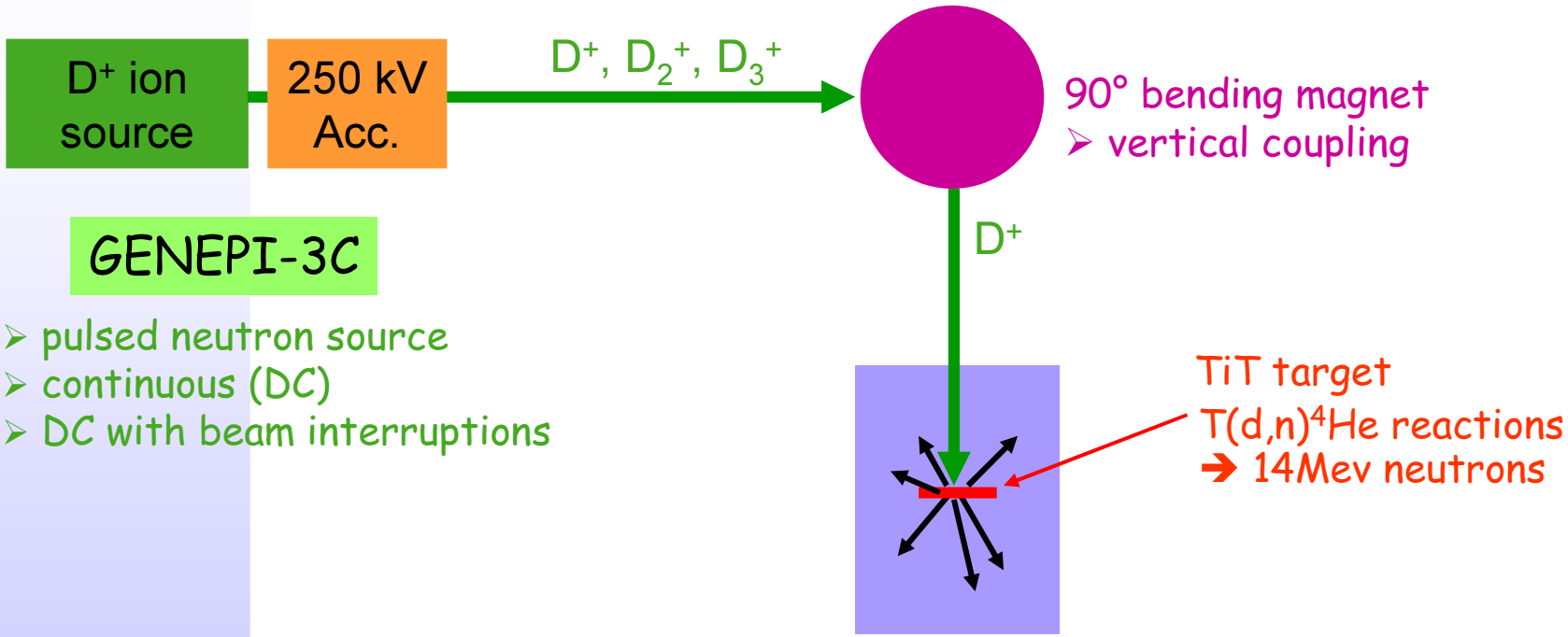
➔ **SCK•CEN initiated the GUINEVERE project** (Generator of Uninterrupted Intense NEutron at the lead VEnus REactor) **in collaboration with CNRS and CEA**

➔ **GUINEVERE project was proposed to the EUROTRANS Integrated Project (FP6) partners in 2006** (accepted in December 2006) to **fulfill the objectives of Domain 2 "ECATS"** dedicated to "coupling experiments" (except issues related to power like thermal feedback effects):

- Qualification of sub-criticality level monitoring, Validation of the core power / beam current relationship,
- Start-up and shut-down procedures, instrumentation validation and specific dedicated experimentation,
- Interpretation and validation of experimental data, benchmarking and code validation activities etc.,
- Safety and licensing issues of different component parts as well as that of the integrated system as a whole.

The ADS mock-up principle

➔ Coupling of VENUS reactor (SCK•CEN, Mol) to a new GENEPI neutron source



GENEPI-3C

- ➢ pulsed neutron source
- ➢ continuous (DC)
- ➢ DC with beam interruptions

VENUS-F

- ➢ fast subcritical reactor (k_{eff}= 0.97)
- ➢ solid lead moderator

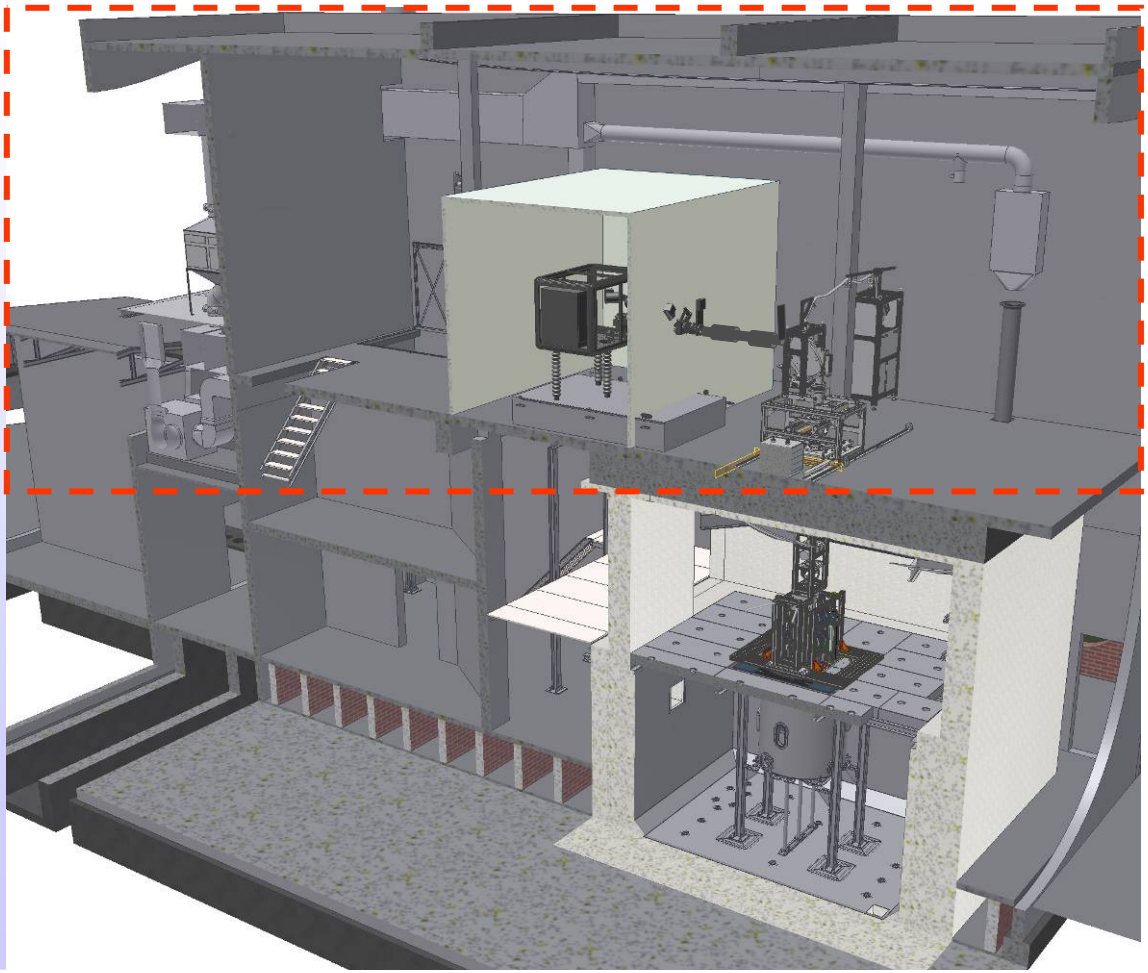
GUINEVERE : a collaborative work

- SCK•CEN is providing the VENUS facility, modifying it to get a Pb-based fast facility able to operate in both critical and sub-critical modes, and is taking the licensing responsability
- CNRS/IN2P3 is in charge of the design and construction of the GENEPI-3C accelerator and of its installation at SCK Mol
- CEA/DEN is providing the needed fuel for the core and part of the lead rodlets
- Other partners of EUROTRANS-IP are supporting the design and the licensing of the facility
- All partners will be deeply involved in the execution of the DM2 experimental programme and analysis

➔ **By the end of EUROTRANS on March 31, 2010**

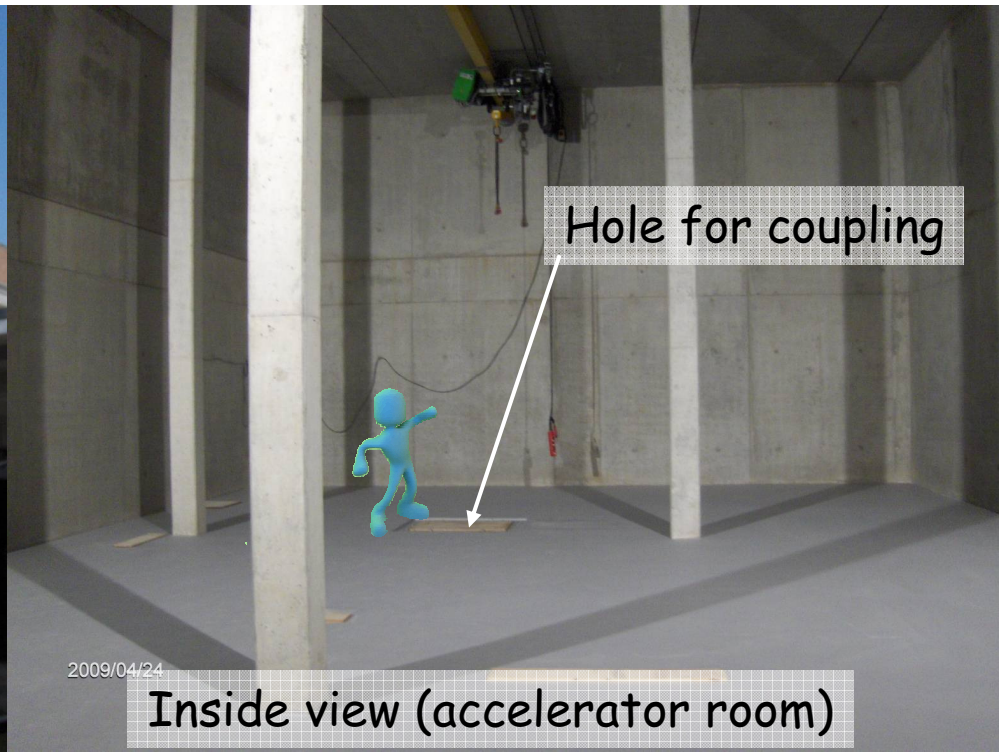
The construction phase (2007-2009)

- **Construction of an additional floor** above the VENUS bunker to host the GENEPI-3C accelerator **for a vertical coupling**



- Civil engineering studies started at the beginning of 2007
- Beginning of the construction on September 1, 2008

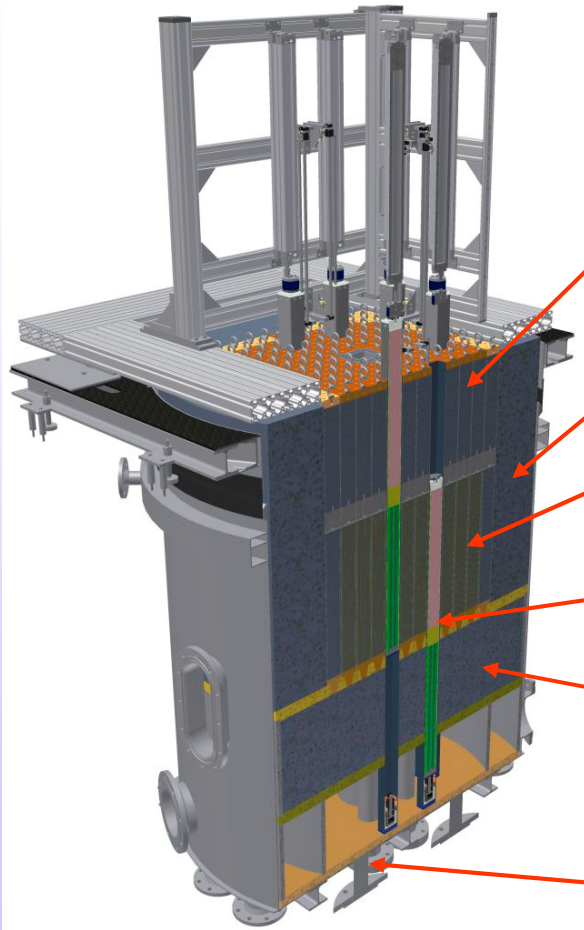
➔ **Civil construction completed since April 24, 2009 !**



➔ Ongoing: technical installation (heating, ventilation, electrical power, strairs…)

- **Modifying VENUS core**

- the core, water moderated, is **changed to a fast lead core**



Pb top reflector

Pb radial reflector

Core in metallic uranium and lead

B_4C safety rods with fuel follower

Pb bottom reflector

Vessel reinforcement

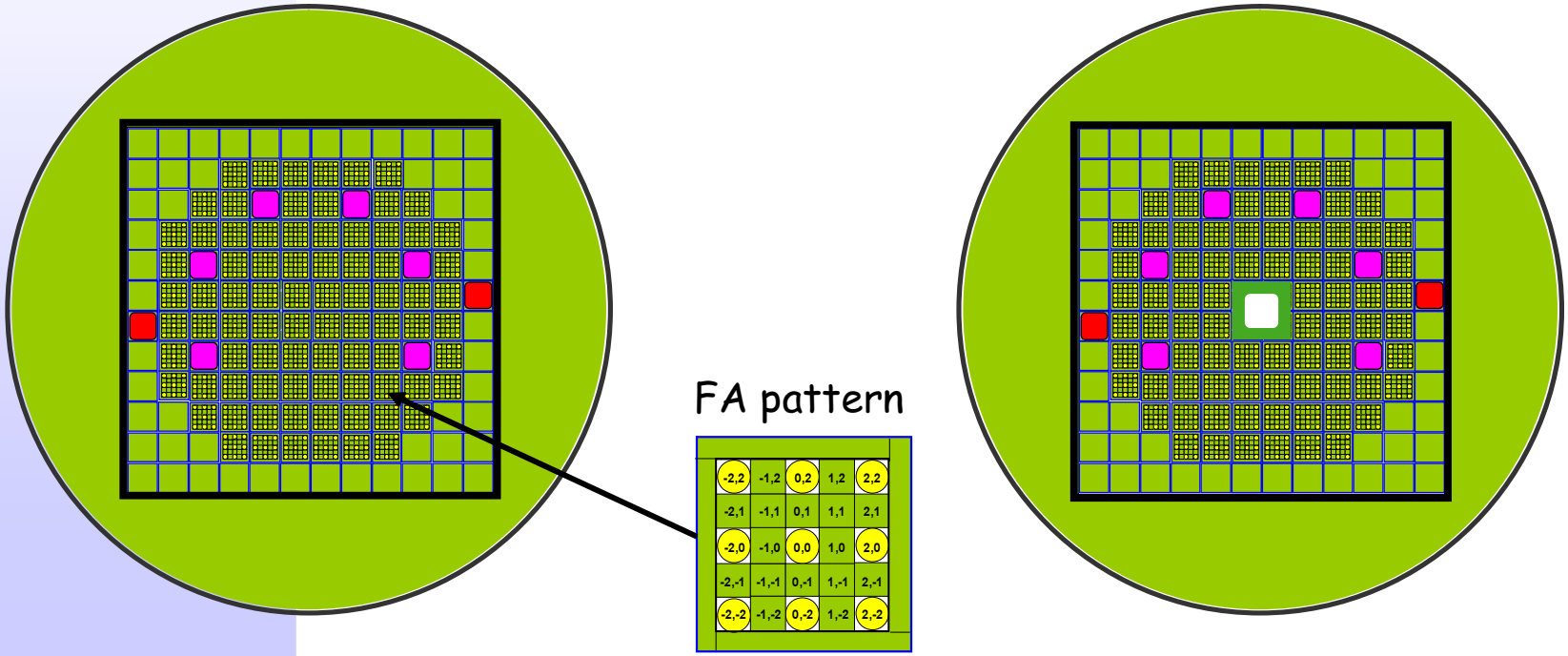
- **GUINEVERE cores**
  - ➤ Critical configuration (CR):

88 Fuel Assemblies
6 safety rods (~14 $)
2 control rods (~1.1 $)
Λ= 0.39 μs
βeff= 748 pcm
Peripheral assemblies ~230 pcm

➤ Sub-Critical configurations:

84 Fuel Assemblies
- **SC1 with k_{eff}= 0.97**
- SC2 with k_{eff}= 0.95
- SC3 with $k_{eff} \geq 0.99$
- SCL with k_{eff} = 0.85-0.95

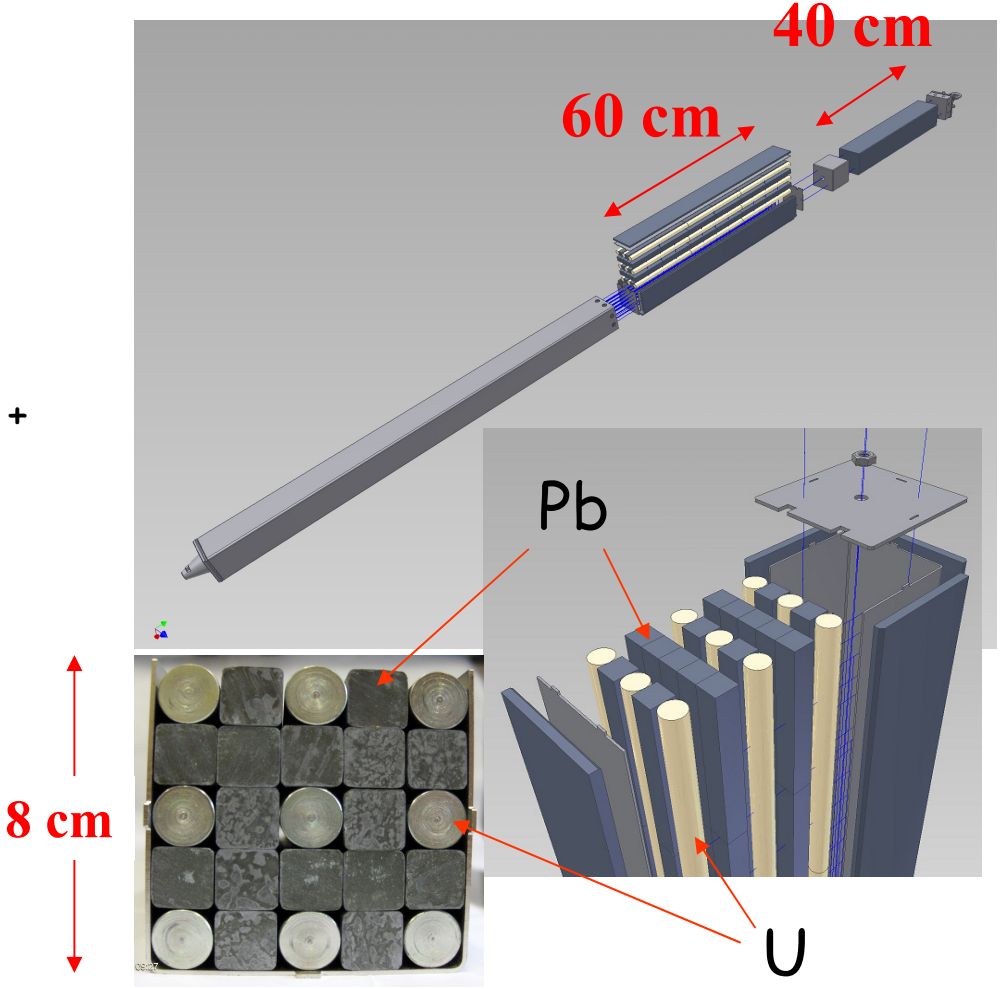
(loading conditions)
- SCR with different reflectors



- Fuel Assemblies

- **CEA fuel rodlets**
  - U-metal
  - Enrichment 30 %
  - Diameter= 1,27 cm
  - Length= 20 cm

- **Fuel assembly**
  - 60 cm active length in height + 40 cm lead reflector
  - 8 cm in lateral dimension



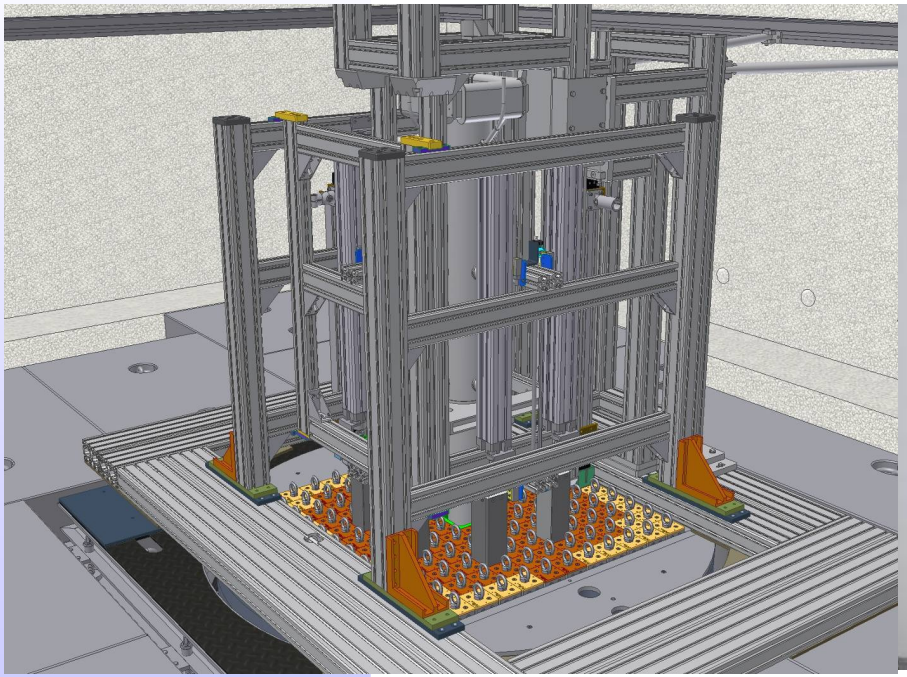
➔ FA structure manufacturing completed

- Safety and control rods

Safety rod structure ➔ manufactured, under pre-assembling

6 Safety Rods ➔ manufactured

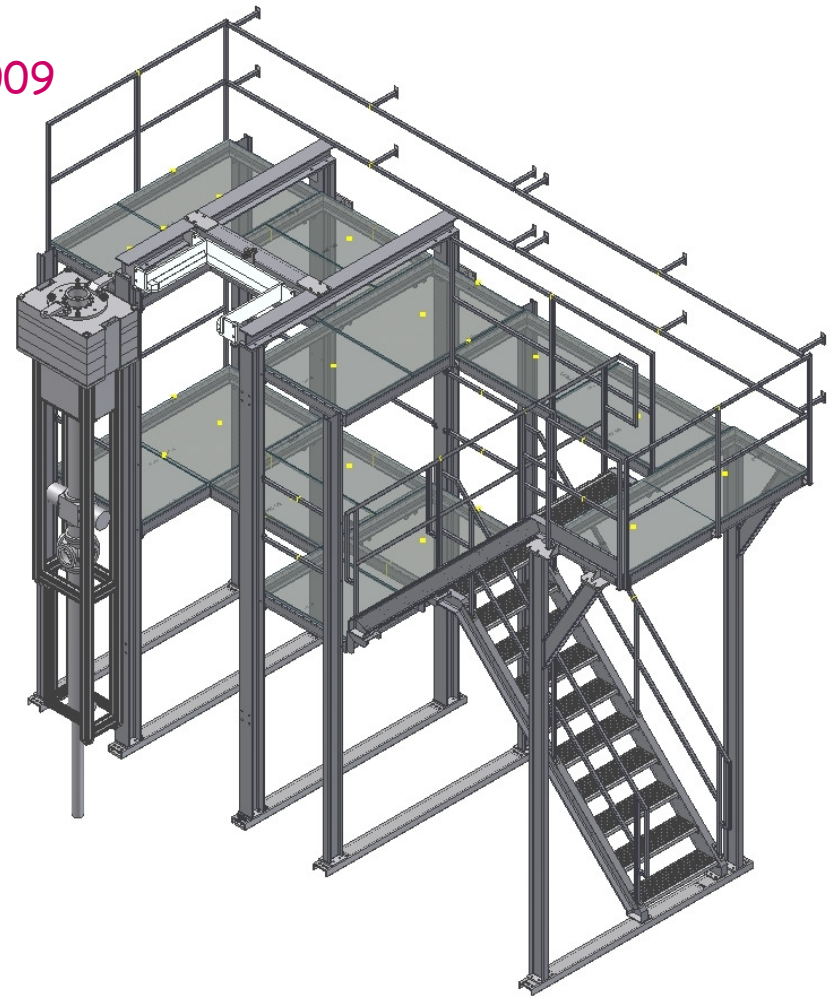
2 Control Rods (stand-alone units)➔ *under manufacturing*



- Accelerator Vertical Beam Line Stand & Working platforms ("the deck")

Structure manufacturing ordered in April 2009

➔ Installation in the accelerator room by July 10, 2009



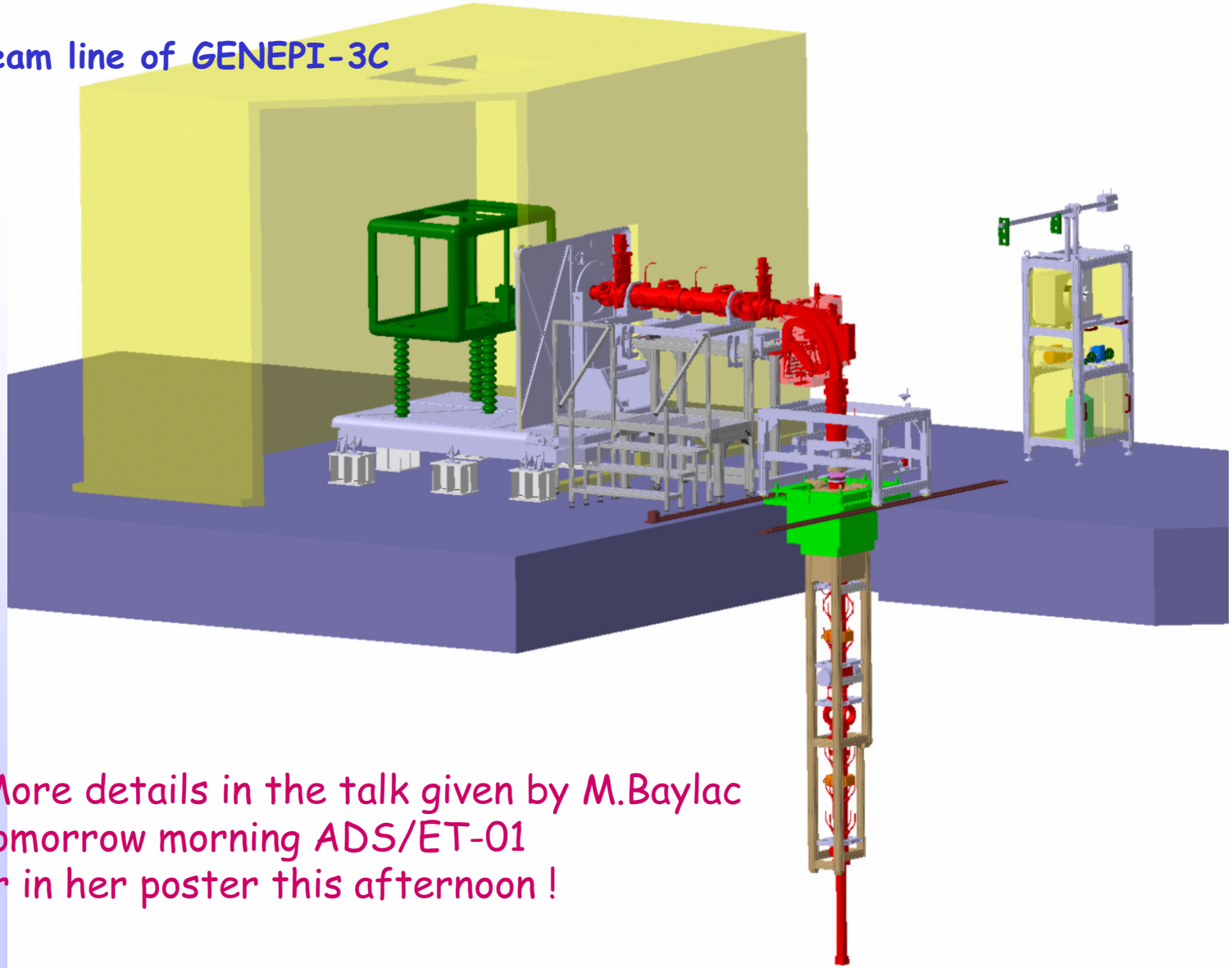
- **The new GENEPI-3C accelerator**

- The validation of the reactivity monitoring methodology requires to operate the neutron source in **both pulsed and continuous modes ➔ GENEPI-3C**

- The GENEPI-3C accelerator is an evolution of the GENEPI-1 (**GE**nérateur de **NE**utrons **P**ulsé **I**ntense) built by CNRS for the MUSE FP5 project: **it combines the GENEPI-1 pulsed characteristics and new specifications:**

Mean current	160 μA to 1 mA
Beam trip rate	0.1 to 100 Hz
Beam trip duration	~ 20 μs to 10 ms
Transition (ON/OFF)	~ 1 μs
Beam spot size	20 to 40 mm in diameter
Neutron production	2×10^{9} - 10^{11} n/s
Pulse stability	~1%

➔ Beam line of GENEPI-3C



➔ More details in the talk given by M.Baylac tomorrow morning ADS/ET-01 or in her poster this afternoon !

➔ Construction status at CNRS/LPSC Grenoble (April 20, 2009):

➔ *Vertical beam line under assembling*

The construction phase: intermediate conclusion !

➔ Really **huge work performed during these 2 years** regarding to:

- civil engineering of VENUS building
- transformation of the reactor core
- safety and licensing procedures
- accelerator R&D,
- ....

➔ **Strong (human) effort of all partners** involved in the construction phase

➔ **Thank you and Bravo !!!**

The experimental phase (2010-2013)

- **EUROTRANS programme** (by March 31, 2010)
  - ➔ reduced to CR and SC1 configurations
  - ➔ contingency plan

- **After the end of EUROTRANS** ➔ full development of the initial reactivity monitoring programme (methodology validation)…
  - ➔ several sub-criticality levels, SC2, SC3
  - ➔ deep sub-criticality level

…and beyond for sub-critical (ADS) and critical (GEN IV) lead reactors
  - ➔ studies of different reflectors
  - ➔ variation of source importance
  - ➔ full characterization of lead core
  - ➔ void effect
  - ➔ reactivity effect of insrumentatio
  - …….

➢ EUROTRANS and reactivity monitoring :

- Critical configuration (CR) for:
  - ➢ Core characterization
    - Radial and axial traverses
    - Calibration of control rod worth
    - Rod drop measurements
    - Spectral indices such as U8/U5, P9/C8
  - ➢ Reference measurements necessary for the **sub-critical measurement techniques validation**

- Reactivity measurements in sub-critical configurations:
  - ➢ Characterisation of Sub-critical levels
    - Pulsed Neutron Source area method for reactivity determination
  - ➢ "Current-to-flux" measurements = "neutron source-to-flux"
    - Static measurements (use of different detectors and currents)
    - Kinetic measurements (variations of the current and/of reactivity)
  - ➢ Reactivity calibration techniques
    - Mainly Pulsed Neutron Source techniques, + Cf source driven method

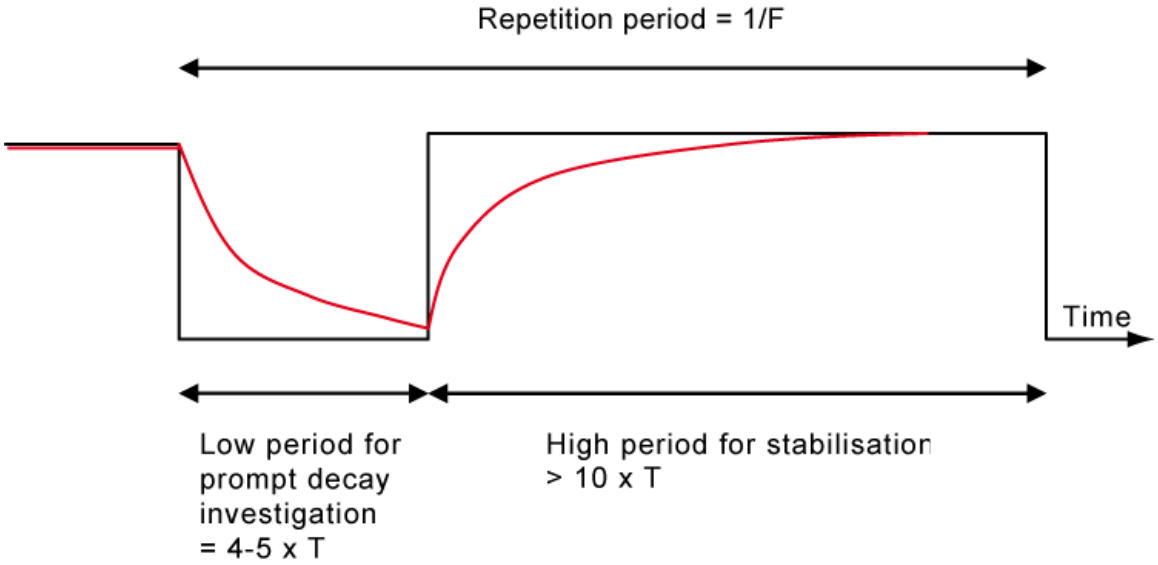
- **Interim cross-checking techniques at beam interruptions**

➔ continuous mode with repetition of short and prompt beam interruptions

➔ 2 techniques planned to be applied (separately):

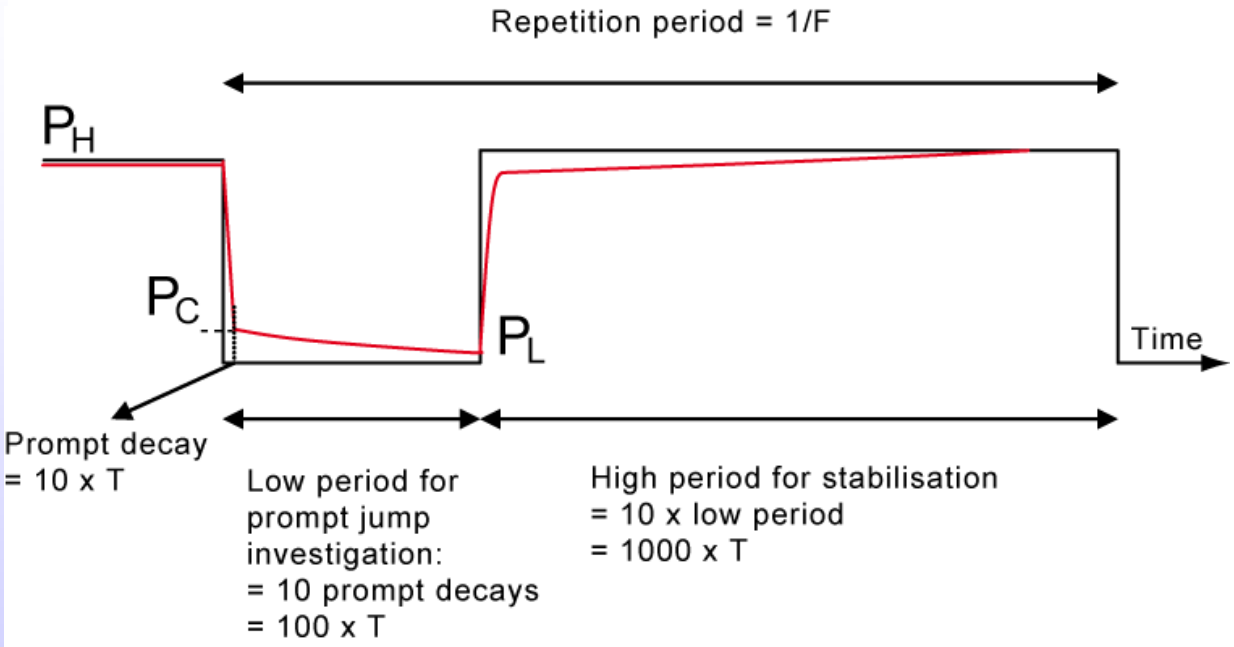
1/ Prompt decay fitting techniques

- **fitting of the prompt population decay** (expo) **or its decrease rate** (kp) after the source interruption
- Highly depends on the spectrum conditions of the core → fast core is needed



2/ Prompt Jump Techniques

- Reactivity determination based on the measurement of P_H, P_C and P_L



$$-\rho(\$) = \frac{P_H - P_C}{P_C - P_L}$$

Status and key dates of the project

- *Stop of VENUS reactor: 1-4-2007 ☺*
- *Design of fuel assembly: 1-4-2007 ☺*
- *Removal of internal parts of VENUS: 1-7-2007 ☺*
- *Conceptual design of core: 1-7-2007 ☺*
- *Transport of fuel from CEA to SCK-CEN: 1-1-2008 ☺*
- *Fuel assembly construction: completed*
- ***Accelerator room construction: started 1-9-2008, completed in 24-04-2009***

➤ Installation new components in VENUS: ➔ 1-7-2009

➤ Commissioning of critical installation: 1-6-2009→15-9-2009

- **Building GENEPI at LPSC Grenoble: 2nd section completed, end in June 2009**

➤ Commissioning of GENEPI at LPSC Grenoble: June-July 2009

➤ De-assembling of GENEPI at LPSC: August 2009

➤ Transfer of GENEPI from Grenoble to Mol : August 24-28, 2009

➤ Re-assembling and commissioning in Mol: September-October 2009

➤ Licensing of the facility: November 2009

➤ Start of experiments: 15-12-2009

Conclusions

- The GUINEVERE-project represents a close collaboration between SCK-CEN, CNRS & CEA (consequence of fruitful collaboration during MUSE FP5 experiment !) and other European partners in 6FP "IP-EUROTRANS" in the framework of P&T

  ➔ Good relationship and efficiency !

- The GUINEVERE-project will provide a unique experiment with a continuous beam coupled to a fast (sub)critical assembly allowing full validation of the methodology of reactivity monitoring for XT-ADS and EFIT

  and brings a valuable experience in licensing procedure

- It is providing by the way a zero power experimental facility (critical as well) for fast lead system studies and related further developments

- In particular it can act as a zero-power facility for the further design of the MYRRHA/XT-ADS