THPP033

(listed as TUPP100 in booklet)

Operation of the versatile accelerator driving the low power ADS GUINEVERE at SCK•CEN

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Genesis and goals

- Experimental studies of Accelerator Driven Systems (ADS) in Europe
  - FP5 : MUSE-4 experimental program run at CEA-Cadarache
  - FP6 IP-EUROTRANS, ECATS domain (Experiments to Coupling an Accelerator, a Target and a Subcritical blanket): driving and monitoring a subcritical reactor

    ➔ GUINEVERE project launched

- GUINEVERE : Generator of Uninterrupted Intense NEutrons at the lead VEnus REactor

- Provide a system representing an ADS demonstrator to investigate
  - on-line reactivity monitoring
  - sub-criticality determination
  - operational procedures of an ADS (core loading, system startups and shutdowns)

- Low(zero)- power coupling of
  - a fast lead core reactor, VENUS-F
  - a versatile neutron source, GENEPI-3C

GUINEVERE

- GUINEVERE program:
  - ❖ modification of the existing VENUS reactor into a fast reactor with a lead moderator
    - ➔ VENUS-F by SCK•CEN (Mol, Belgium)
  - ❖ construction of a new accelerator to provide pulsed & continuous neutron source
    - ➔ GENEPI-3C by CNRS/IN2P3 (France)
  - ❖ experimental program on the monitoring of a subcritical reactor
    - ➔ European collaboration : IN2P3, CEA, SCK•CEN and EC

- Provides a unique facility in Europe for experimental studies of ADS feasibility
  - ❖ Design, construction and accelerator commissioning (2007-2010)
  - ❖ Critical mode commissioning, nuclear safety authorizations (autumn 2011)
  - ❖ First coupling achieved in October, 2011
  - ❖ Coupled operation for the experimental program since April, 2012

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The GENEPI-3C accelerator specifications

- GEnerator of NEutrons Pulsed & Intense-3C
  - ❖ Electrostatic Deuteron accelerator (250 keV)
  - ❖ Neutron (14 MeV) production via $T(d,n)^4He$
- Accelerator capable of producing alternatively
  - ❖ Intense pulsed mode

    I_{peak} ~ 25 mA

    FWHM < 1 µs

    repetition rate : 10-5000 Hz

DC interrupted mode

Mean current	~50 µA to 1 mA
Beam trip rate	0.1 to 200 Hz
Beam trip duration	~ 20 µs to 10 ms
Transition edge	~ 1 µs

  - ❖ Continuous mode (DC), possibly chopped

    DC beam up to 1 mA

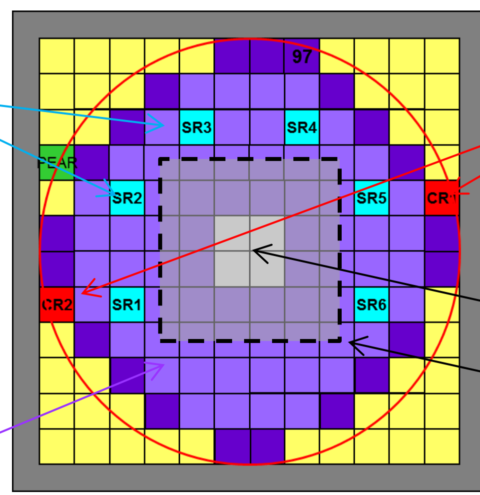
    programmable beam interruptions: short and fast transition time ON/OFF
- Designed & built by CNRS/IN2P3 (France) collaboration (2007-2009)
  - LPSC Grenoble, LPC Caen, IPHC/DRS Strasbourg & IPN Orsay
- Largely based on technology of the previous machines developped by LPSC
  - GENEPI-1 to drive MASURCA reactor (MUSE-4), GENEPI-2 at LPSC for cross section measurments

Reactor core

- VENUS-F reactor, designed and operated by SCK•CEN (Belgium)
  - Previous core, VENUS, modified into fast lead core
  - Fuel provided by CEA
  - Operation in critical or sub-critical mode

- Sub-critical operation
  - 93 fuel assemblies or FA (SC1)
  - FA : ^{235}U enriched to 30% and solid lead
  - Axial and radial lead reflectors
  - Compact core (Φ= 800 mm, H=600 mm)

Reactor top view in subcritical configuration (SC1)



Accelerator facility

- **Duoplasmatron ion source**

- Beam intensities and time structures
- Source and electrodes within platform at 250 kV

- **Beam transport line**

- Horizontal and vertical sections
- 12 electrostatic quadrupoles, 4 magnetic steerers

- **Dipole magnet**

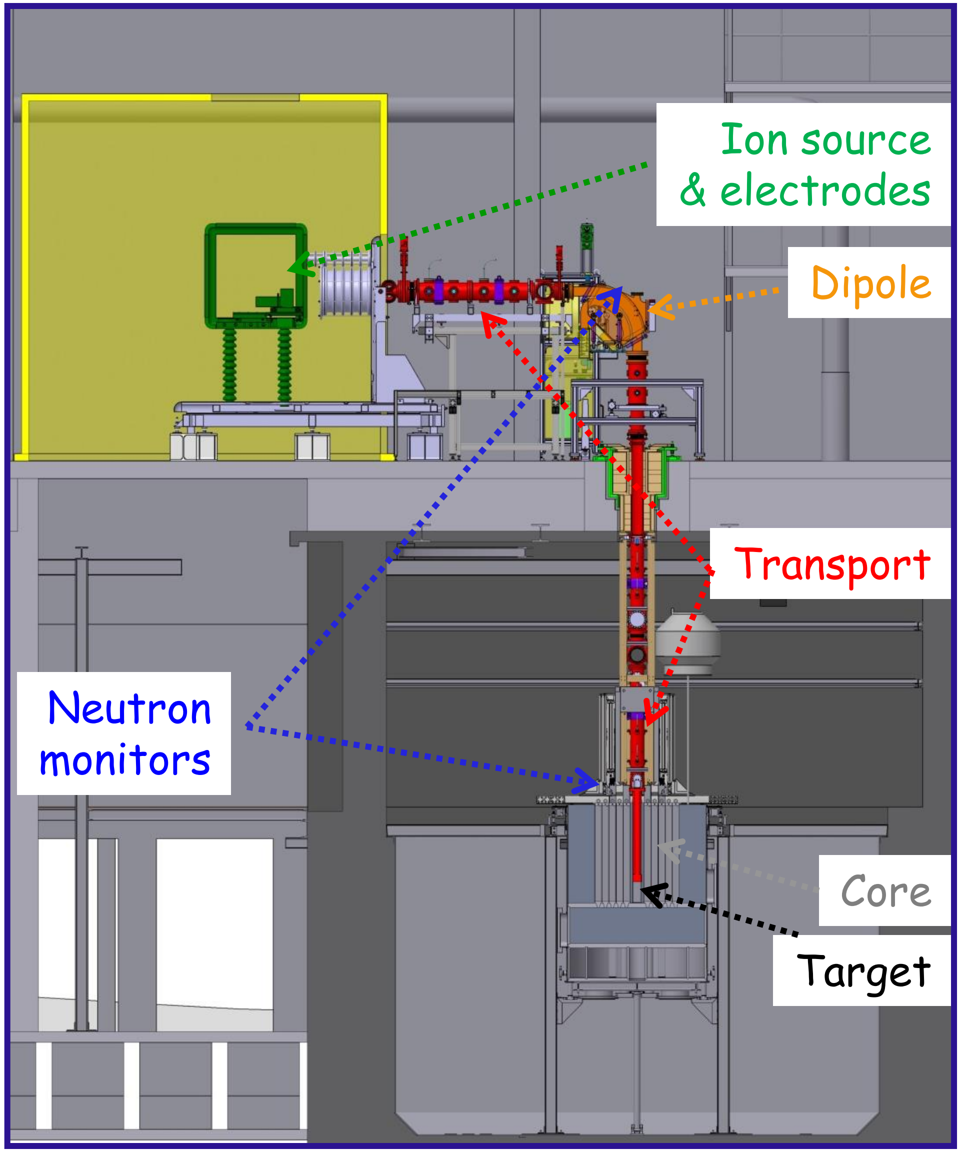
- Magnetic selection of species
- Bends D^+ down towards the core
- On a mobile frame for access to V beam line
(V line to be craned out for maintenance)

- **Tritium target**

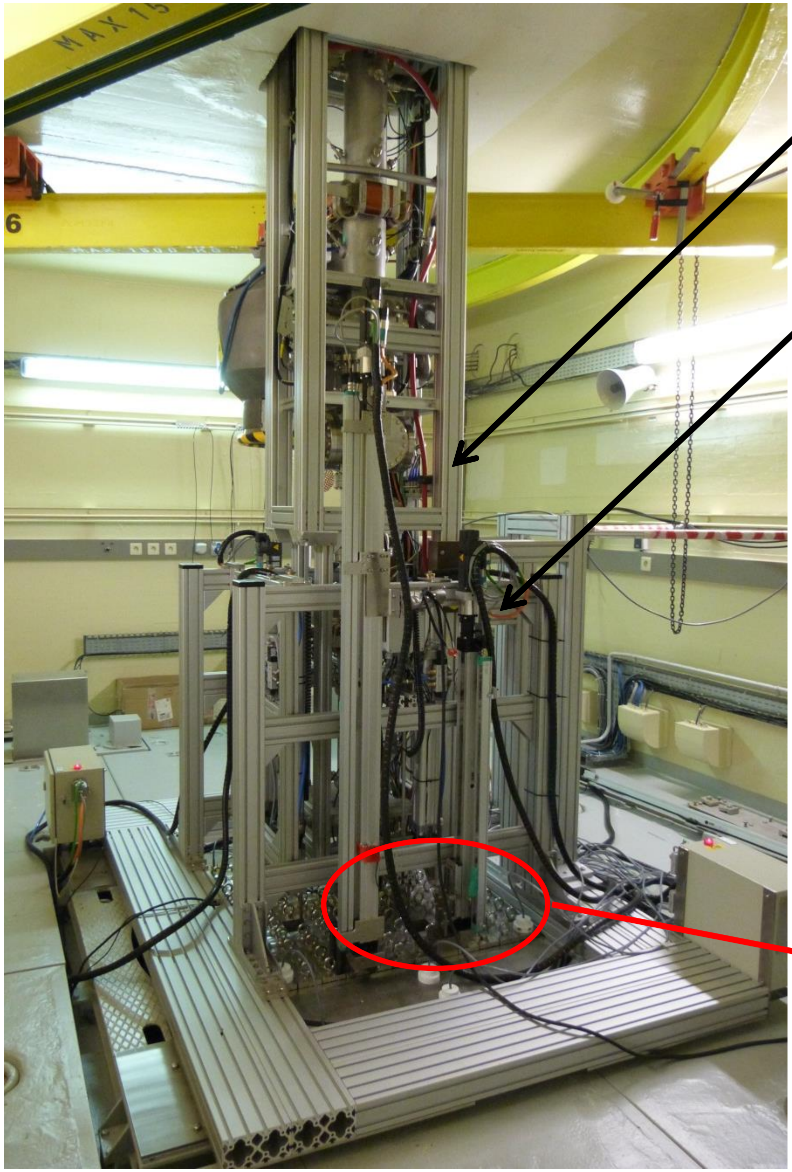
- Thin layer of deposition of TiT (12 Ci)
- Air cooled to dissipate beam power up to 250 W

- **Neutron monitors**

- 2 silicon detectors to measure neutron production
- Located atop the reactor and on top of the dipole



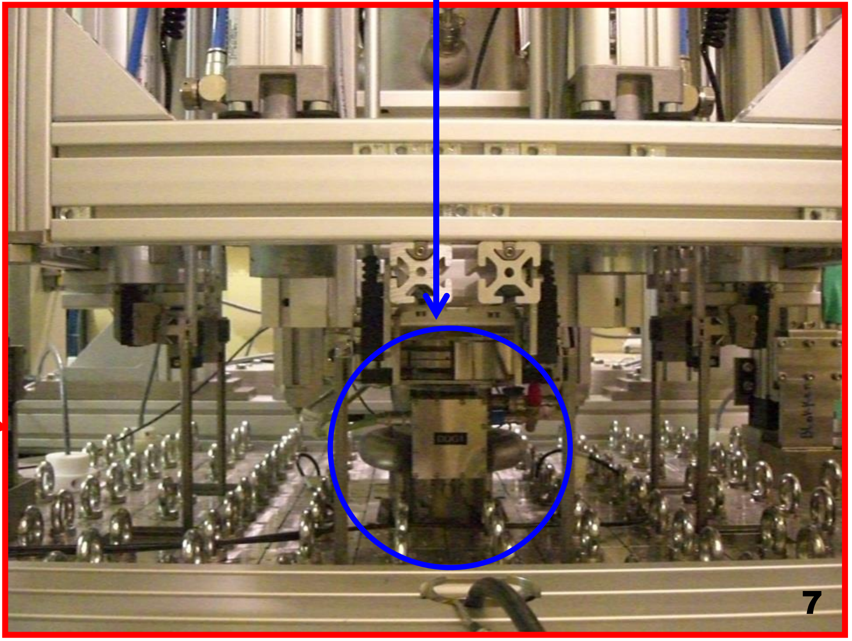
Beam line inserted in the loaded core



Vertical beam line & support structure

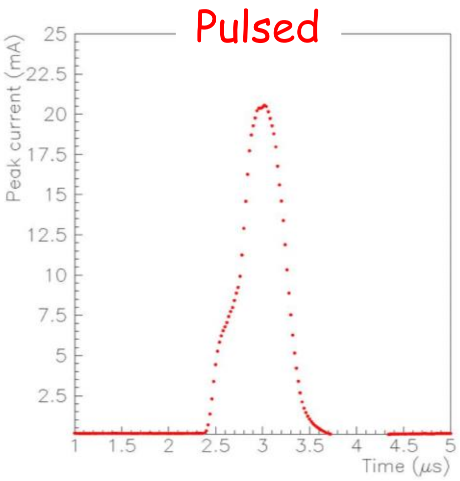
Reactor rods & mechanism

Beam line (current & temperature meas., target cooling)

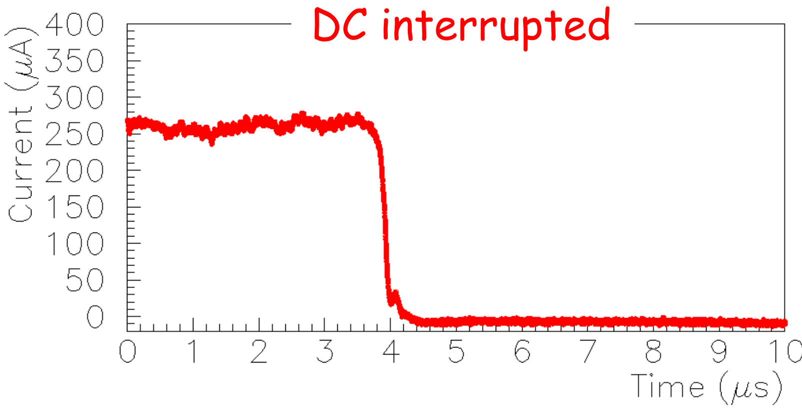


Accelerator performances

- PULSED MODE
  - ❖ Beam current : I_{peak} ~ 20-25 mA
  - ❖ Pulse width: T_{pulse} ~ 550 ns (FWHM)
  - ❖ Pulse stability: $\sigma(T_{pulse}) / T_{pulse} < 1\%$



- DC MODE WITH SHORT INTERRUPTIONS
  - ❖ Beam current : $I_{average}$ up to 1 mA
  - ❖ Interruption transition duration < 1 μs
  - ❖ Interruption tuning range
    T_{OFF} / T_{ON} as low as 6%
  - ❖ Some remaining issues, mainly HV discharges



- NEUTRON PRODUCTION
  - ❖ Measured rate of 10^{11} $n.s^{-1}.mA^{-1}$ from a fresh tritium target (DC mode)
  - ❖ Excellent agreement with expectations

Feedback on the coupled operation

- Pulse mode (low average current) : no operational difficulty, excellent availability

- DC interrupted mode (higher average current): tricky
  - ❖ Severe HV discharges cause beam trips (~s)
  - ❖ Restoring beam after a trip can generate reactor emergency shutdown
    - ➔ All rods drop: reactor SCRAM

- Reactor startup required to recover from every SCRAM
  - ❖ Rod liftup sequence requires ~30 minutes, over 8 hours of daily running

- Reactor SCRAMs : Major cause of facility downtime
  - ❖ Some bad running periods: up to 6 SCRAMs per week
  - ❖ After the last machine optimizations: no SCRAM for the last 2 weeks of running

- VENUS-F safety rules (SCRAM upon beam loss) designed for a critical reactor
  - ❖ Penalizing conditions unnecessary for ADS (reactor remains sub-critical)
  - ❖ Most likely, this stringent constraint to be loosened in the future

Summary and outlook

- Low power ADS in operation for more than 2 years
- Unique ion source
  - quick changes between beam modes (~15 minutes), but limits on machine performances
- Machine specifications mostly met, some remaining improvements required (stability)
- Main operational limitation
  - downtime caused by severe HV discharges inducing reactors SCRAMs
- Expectation of enhanced availability for future operation
  - improvements minimized discharges and reactor safety rules to be optimized for ADS operation
- Experimental program in progress and producing first physics results
  - despite limited availability, the accelerator performances are excellent
  - an extensive experimental campaign is scheduled for the coming years
- *Analysis of GUINEVERE operation: feedback for ADS demonstrator project MYRRHA*

Poster THPP033 (listed as TUPP100 in booklet)