GENEPI-3C, A VERSATILE NEUTRON GENERATOR FOR THE GUINEVERE ADS FEASIBILITY STUDIES

Jean-Marie De Conto, Maud Baylac, Annick Billebaud, Patrick Boge, Dominique Bondoux, Joel Bouvier, Thierry Cabanel, Yves Carcagno, Guillaume Dargaud, Emmanuel Froidefond, Yolanda Gómez Martínez, Muriel Heusch, Denis Marchand, Roger Micoud, Eric Perbet, Michel Planet, Damien Tourres, LPSC, UJF, CNRS/IN2P3, INPG, Grenoble, FRANCE
Gilbert Granget, Frederic Mellier, CEA, Cadarache, FRANCE
Gerard Gaudiot, Guy Heitz, Pascal Poussot, Christophe Ruescas, IPHC/DRS, ULP, CNRS/IN2P3, Strasbourg, FRANCE
Bernard Laune, Denis Reynet, IPNO, CNRS/IN2P3, UPS, Orsay, FRANCE
Jean-Marc Gautier, Yvan Merrer, LPC Caen, ENSICAEN, Université de Caen, CNRS/IN2P3, Caen, FRANCE
Peter Beaten, Guido Vittiglio, SCK-CEN, Mol, BELGIUM.

Abstract

GENEPI-3C is a neutron generator for ADS purposes. It will be installed at Mol (Belgium) after commissioning at Grenoble (FRANCE). We present the general characteristics of the machine, the status of construction and we focus on the deuteron source experimental results.

INTRODUCTION

The GENEPI machines are a family of electrostatic neutron generators dedicated to Accelerator Driven Systems (ADS) studies. They are motivated by the necessity to extend the validation of calculation and measurement methods already made for critical fast reactors to ADS and/or to new reactor concepts using new fuels.

Two GENEPIs have already been built. The first GENEPI machine, working in pulsed mode, was installed at the Cadarache MASURCA [1] reactor. It was dedicated to MUSE-4 experiments. A second machine GENEPI-2, very similar, is still under operation to measure nuclear cross sections for generation IV reactor concepts. In the framework of FP6 "IP-EUROTRANS", the GUINEVERE [2] project proposes to extend the MUSE-4 [3] experimental program.

GUINEVERE intends to use the VENUS reactor from SCK-CEN, serving as a lead fast critical facility, coupled to a continuous beam accelerator. In order to achieve this goal, GENEPI-3C, has to be designed [4] and constructed. Unlike the two previous GENEPI machines, this new accelerator shall provide both pulsed and continuous mode operation with possible beam interruptions at the millisecond level. Besides, GENEPI-3C [5] must accommodate the VENUS topology including a vertical coupling to the reactor. This accelerator is going to be fully designed, assembled, tested and commissioned at the "Laboratoire de Physique de Subatomique et de Cosmologie" (LPSC) in Grenoble.

GENEPI 3-C

The deuteron electrostatic accelerator is made of a 240 keV platform (including a duoplasmatron source) followed by an 3m long horizontal beam line, a magnetic dipole and a 6.5 m long vertical line, ended by a tritiated target in the reactor core. The dipole is also used as a mass separator to suppress molecular ions. Table 1 summarizes the main machine specifications.

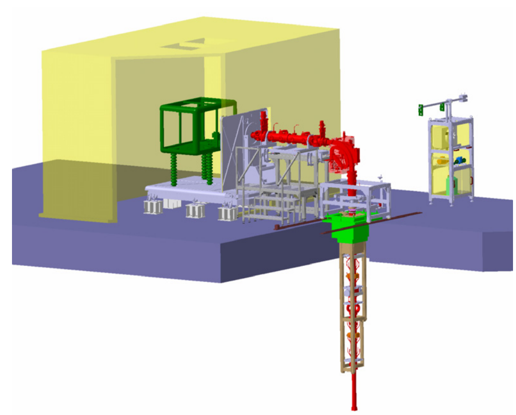

Figure 1: General layout of the GENEPI-3C machine.

Table 1: Characteristics in pulsed and continuous mode.

Parameters	Values
Energy	140 up to 240 keV (deuterons)
Pulsed mode	Peak current: 40 mA on target pulse duration (FWHM) < 1µs Repetition rate up to 5 kHz
Continuous mode	DC current: 1 mA on target Beam interruptions: 20 µs to 10 ms Beam trip rate: 0.1 to 100 Hz Rise/drop times: ~ 1 µs
Beam diameter	~ 20 mm on target
Stability	~ 1%
Beam power	240 W on target (continuous mode)

THE ION SOURCE

GENEPI-3C must have a unique source both for pulsed and continuous mode. For pulsed mode, a duoplasmatron is an ideal solution as shown for GENEPI1 and 2 and has been chosen for GENEPI-3C. As displayed on figure 2, the source consists mainly of:

- An impregnated cathode ("filament") heated by about a 100 A current.
- An anode
- Magnetic coils, providing plasma confinement
- A command electrode ("cone") used as a beam starter.

In pulsed mode, the duoplasmatron is run like a classical hydrogen thyratron, with a charged delay line on the anode. Several developpements are done at LPSC to improve the source in continuous mode with beam trips.

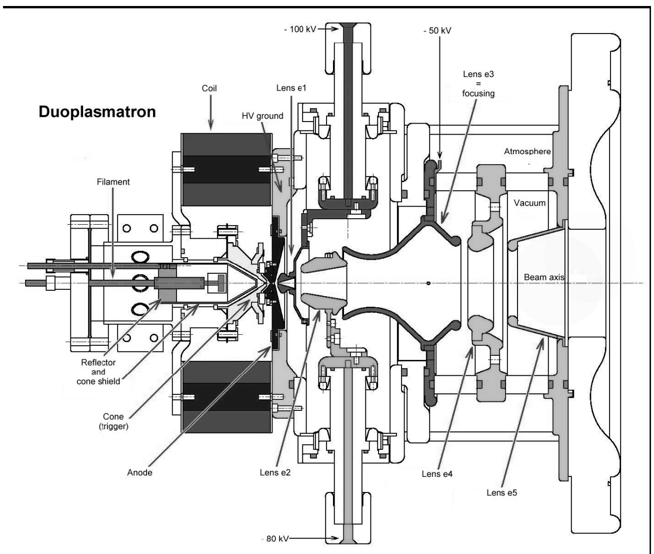

Figure 2: Duoplasmatron source, extraction and focusing electrodes.

SOURCE IN CONTINUOUS MODE

A test bench has been set up at LPSC, made of a duoplasmatron held a 40 kV, followed by a beam profiler, a magnetic separator and a Faraday cup.

Preliminary measurements

In continuous mode, for pulsed mode running conditions, the D+/D3+ ratio is rather bad (10 % typ.). Preliminary studies (figure 3) have shown the necessity to increase simultaneously the electron intensity ("arc current") and the magnetic field. In order to minimize beam losses on the extraction electrode, the extraction hole has been reduced from 3 to 1.5 mm

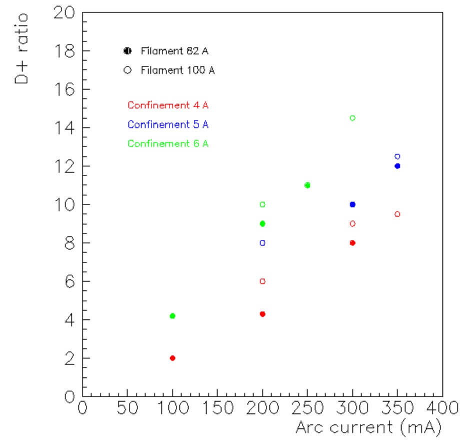

Figure 3: Influence of some source parameters on the D+ ratio (%)

Final Results for Beam Spectrum

Figure 4 shows the spectra for the new configuration. The best working point is found for 1A electron intensity, 2.5 mbar deuterium, 9 A in the coils and 25 kV extraction voltage. The D+ amount is about 35-40%, hence the source delivers 2.5 mA to get 1 mA, and about 400 W will be deposited in the 90 degree dipole which requires cooling.

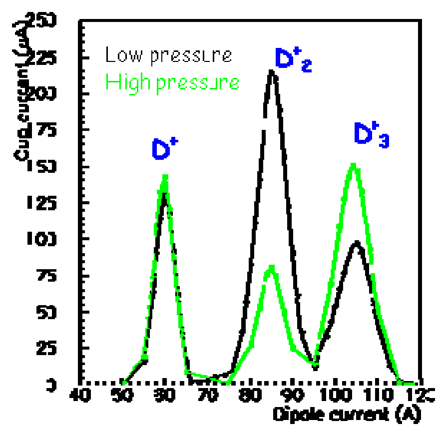

Figure 4: Beam composition for 2 different deuterium pressures.

Emittance Measurements

A pepper-pot has been set up at source exit. It consists of several 1.5 mm holes along the diametral/vertical axis and spaced by 6.5 mm. The pepper-pot is followed 52 mm downstream by a movable 0.1 mm slit in front of a Faraday cup. The vertical RMS emittance has been reconstructed for the continuous mode. The design value (with some safety margins) is 0.6 π mm.mrad (normalized emittance, 95% of the beam) and the measured value is only 0.4 π mm.mrad. This very positive result shows that the beam size remains small at the source exit, well below the pulsed mode, for which space charge is very high, and which dominates the beam lines design constraints (and who is known from GENEPI1 and 2 experiences).

Beam Interruptions

Beam interruptions are required to study reactivity ADS monitoring, with short rise/drop times and variable repetition rates. A new duoplasmatron command system has been developed to generate these interruptions. The drop time (a few µs, figure 5) is achieved easily (it is similar to the pulsed mode), while the rise time shows some instabilities that must be fixed

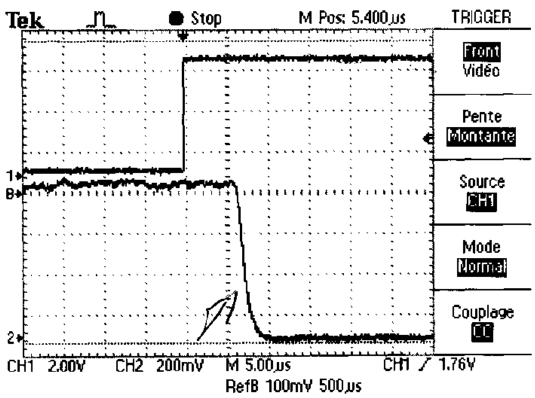

Figure 5: Curve above: duoplasmatron command. Curve below: beam current (drop).

SOURCE IN PULSED MODE

GENEPI1 and 2 were run with the same pulsed mode specification than GENEPI-3C. The only source modification has been the extraction hole size reduction. Due to the high intensity (40 mA) and space charge, tests cannot be done on the source bench (15 keV only) and are undertaken on GENEPI-3C at 240 keV.

CONSTRUCTION OF THE ACCELERATOR

The construction will be done in two phases: construction and commissioning in Grenoble, dismantling and reconstruction in Mol (Belgium) on Venus. Due to the vertical coupling to the reactor, the GENEPI geometry and, hence, its construction, is very constraining (several meters above the floor, with the target in the cellar). The reactor environment leads to some specific and heavy constraints. For example, the vertical line has to be removed completely from the upper floor to allow target change.

The construction of the HV platform, the Faraday cage and the horizontal line have been completed at LPSC in March 2009 (see figure 6). Several ECM tests as well as the safety check of no interference between GENEPI and the reactor command/control system have been made successfully.

The vertical line is under construction and a preliminary beam has been obtained at the dipole exit.

Figure 6: Accelerator GENEPI-3C assembled at LPSC (March 09).

CONCLUSION

GENEPI-3C will use the same duoplasmatron source for both beam modes. Experiments have shown that all the specifications (intensity, time structure, emittance) are achievable. The commissioning of GENEPI-3C is expected for June 2009 at Grenoble. It is planned to be in operation at Mol during winter 2009.

ACKNOWLEDGMENTS

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REFERENCES

[1] C.DESTOUCHES et al, "The GENEPI accelerator operation feedback at the MASURCA reactor facility", Nucl. Instrum. A., 562, 2, 601 (2006).

[2] P.BAETEN, "The GUINEVERE project at the VENUS facility", proceedings to the 5th International Workshop on Utilization and Reliability of High Power Proton Accelerators (HPPA), May 6-9 2007, Mol (Belgium), to be published by NEA.

[3] Collaboration MUSE, 5th EURATOM FP-Contract #FIKW-CT-2000-00063. Deliverable #8: Final Report (2005).

[4] JM.DE CONTO, "The GENEPI neutron sources at Grenoble, prospective for the GUINEVERE program", proceedings to the 5th International Workshop on Utilization and Reliability of High Power Proton Accelerators (HPPA), May 6-9 2007, Mol (Belgium), to be published by NEA.

[5] M. Baylac et all, "The GENEPI-3C accelerator for the GUINEVERE projet" AccApp'07, USA.