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The most powerful, versatile commercial cyclotrons in the world

HIGH CURRENT OPERATION OF THE ACSI TR30 CYCLOTRON

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CANADA

Introduction

ACSI manufactures high current commercial cyclotrons based on two magnet platforms designed for maximum extraction energy of 30MeV and 19MeV.

The TR30 and TR19 cyclotrons design first originated in TRIUMF and has been further developed at ACSI.

We are presenting the progress that has been made in increasing the intensity of the beam current extracted from the TR30 Cyclotron:

•30MeV, 1200• A of proton beam through complex acceptance and uptime testing.

•30MeV, 1600• A of stable proton beam.

TR30 Cyclotron Projects

1. TR30 MDS/Nordion commissioned at 500• A in 1990, upgraded by TRIUMF to 1mA in 1996.
2. TR30/15 Institute of Nuclear Energy Research (INER) Taiwan, upgraded to 1mA at 1MeV (T. Kuo) and tested at 800• A, 24MeV (T. Kuo, ACSI).
3. TR30 Nordion 2 commissioned at 750• A in 2003, operates at 1mA.
4. TR30/1 COVIDIEN/Mallinckrodt commissioned at 1mA in 2005, tested for uptime performance in 2005.
5. TR30 GE Healthcare/Amersham commissioned at 1mA in 2005.
6. TR30/2 COVIDIEN/Mallinckrodt commissioned at 1.2mA in 2007, tested for uptime performance at 1.0mA and 1.2mA in 2007.

Cyclotron Upgrades

Main *concepts implemented* in TR30 manufacturing:

•All cyclotron subsystems must be *upgradeable to 2mA* of proton beam.

•Part of the cyclotron subsystems have been fully upgraded and ready to sustain 2mA of proton beam operation.

•*Maximum reliability* achieved through experienced design and GMP

•Each cyclotron is commissioned and tested through a complex and detailed set of *performance testing* on customer site.

Ion Source and Injection Line (ISIS)

The ISIS performance of today has been ensured by:

- The original ISIS design from TRIUMF
- ISIS development by T. Kuo et. al. [2] [3].
- ACSI ongoing improvement and fine tuning of the ion source.

Improvements implemented:

- Four half ring filaments
- The cusp confinement and virtual filter arrangement
- Extraction electrodes
- Addition of an Einzel lens

ISIS Characteristics

- 10mA of beam extracted at 28kV, ion source operating at an arc of 20A &100Volts
- Normalized 4rms emittance of 0.43• -mm-mr
- Emittance-normalized brightness of 5 mA/mm^2-mr^2
- Beam transmission to 1MeV of 18% at 1.2mA operation

Cyclotron operation:

- Routine operation at 1.2mA with an ion source arc current of 12 to 13A at 100V.
- Performance operation at 1.6mA tuned at 35A of arc current.
- Excess capacity makes the 1.2mA operation very reliable and easy to maintain

RF System and Extraction Probe Upgrade

- 100kW, 74MHz RF amplifier suitable for 2mA beam operation
- 6 1/8” transmission line
- Coupler improved design with the addition of cooling water
- Extraction probe improved driving mechanism (existing five foil carrousel)
- Water cooled design added to extraction probe.

Beam Line

Custom designed high current low losses beam lines using 4” lines and modular components.

Extensive diagnosis throughout the beam line.

Typical tuning characteristics and beam line losses:

•1.2mA beam current distribution of 90% on target faces (uniform distributed on a 11mm x 35mm vertical window), 8 to 9% on target collimators and 1 to 2 % beam line losses

•1.6mA beam current distribution of 80% on target faces, 18.4% on target collimators and 1.6% beam line losses

•Beam spot tuning for gas target applications

Solid Target Station

Fully automated and built using radiation resistant materials.

Significantly upgraded to increase current capability and reliability.

Trouble free operation at 600• A per target station.

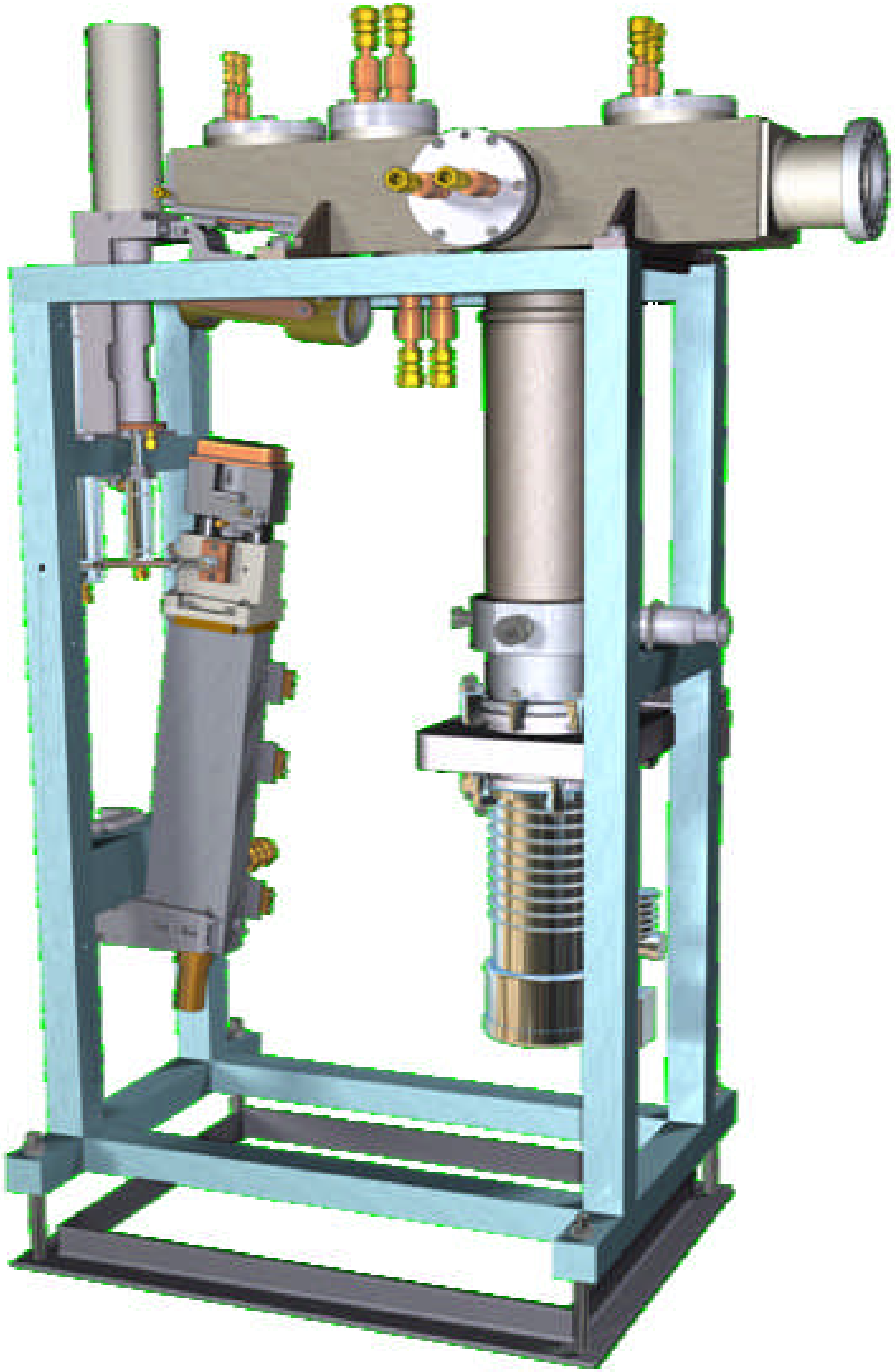
Typical measurements at 600• A routine operation:

- 500• A beam current on target face, uniformly distributed on a 90mm x 35 mm surface area.
- 70• A to 90• A on four target collimators and 20• A to 30• A on target station entrance mask
- tests performed on blank copper targets for a typical 12 hour run between target changes. Target changes take an average of 15 to 20 minutes.

Solid Target Stations (cont'd)

Beam performance at 1600• A of extracted proton current equally split down two beam lines:

- •675• A beam current on target face, uniformly distributed on a 90mm x 35 mm surface area.
- •120• A to 150• A beam current on target station collimators and entrance mask.
- •The test has been performed on blank copper targets for over four hours. There were no significant limitations that precluded continuing. For safety and radiation exposure reasons we elected to limit the beam current and testing time.



Cyclotron Systems Stability Performance

The beam current stability measured on injection line beam stop and 1MeV probe is in the 10^{-4} range.

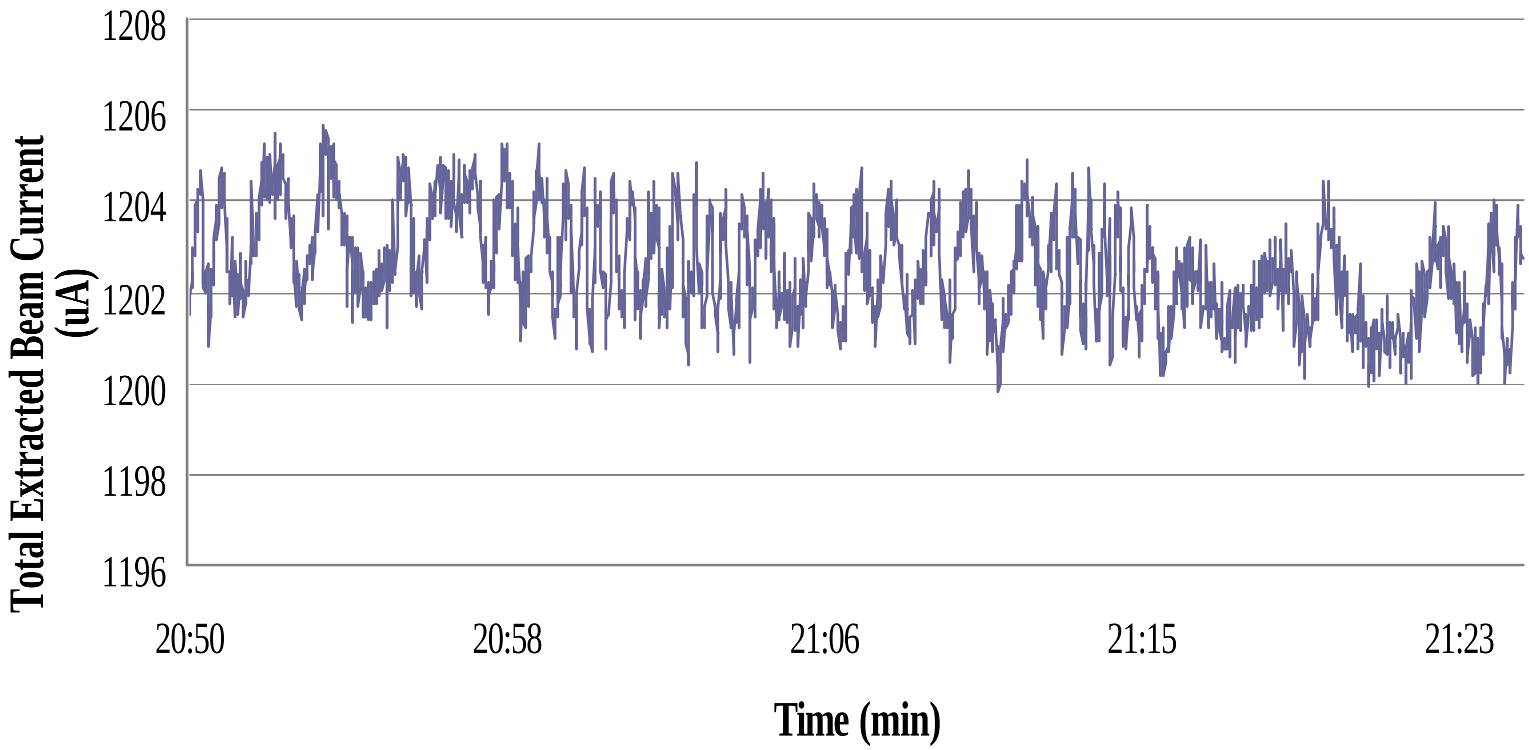
Main magnet stability of 10^{-5} (18 bits digitally controlled power supply).

Dee Voltage stability of 10^{-4} .

Beam Line power supplies stability of 10^{-4} .

Cooling water temperature stability of ±0.25°C.

Total Extracted Beam Stability



Total extracted beam current stability of 0.5%

Beam split ratio stability of 1% of the extracted current.

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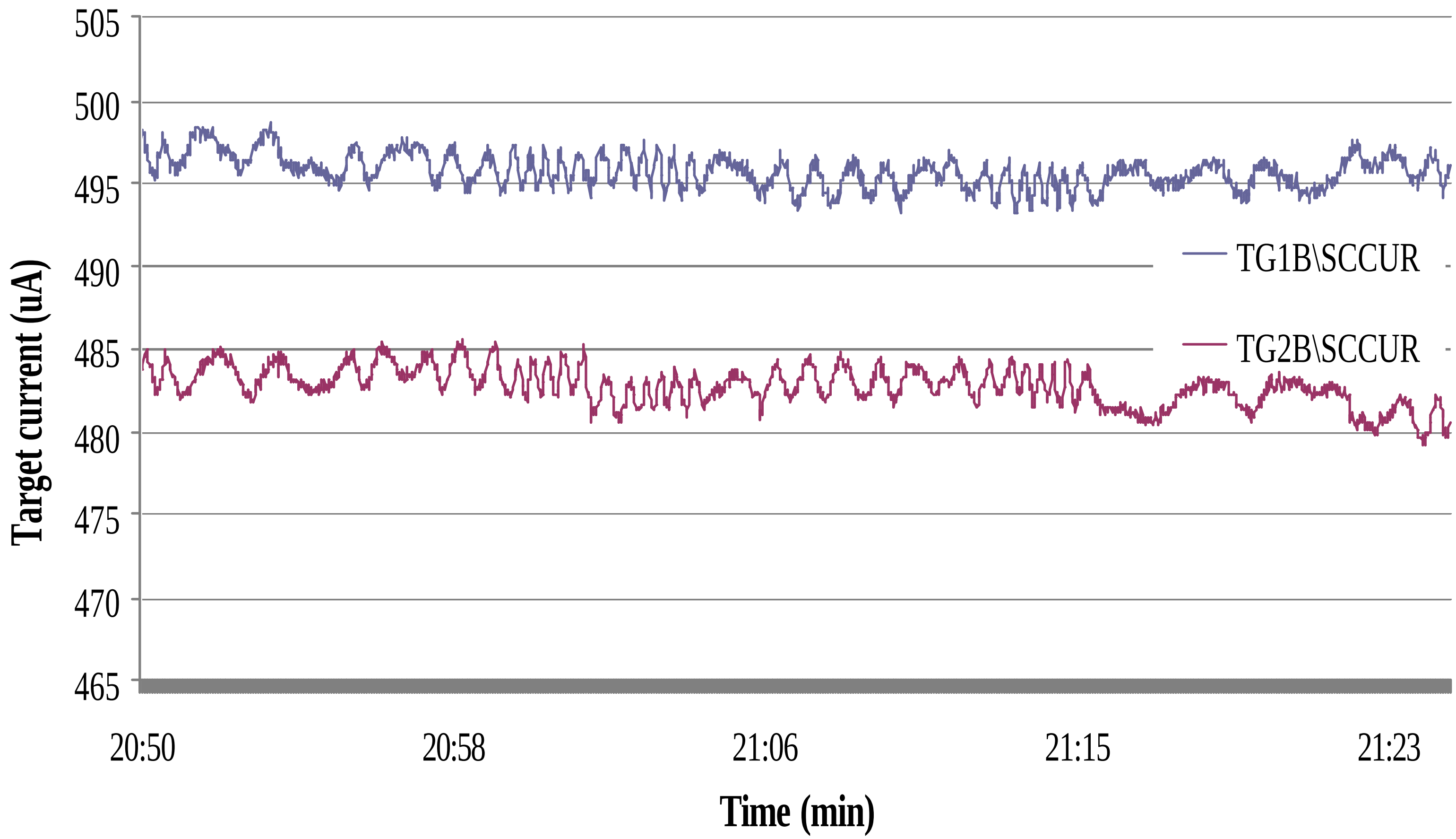
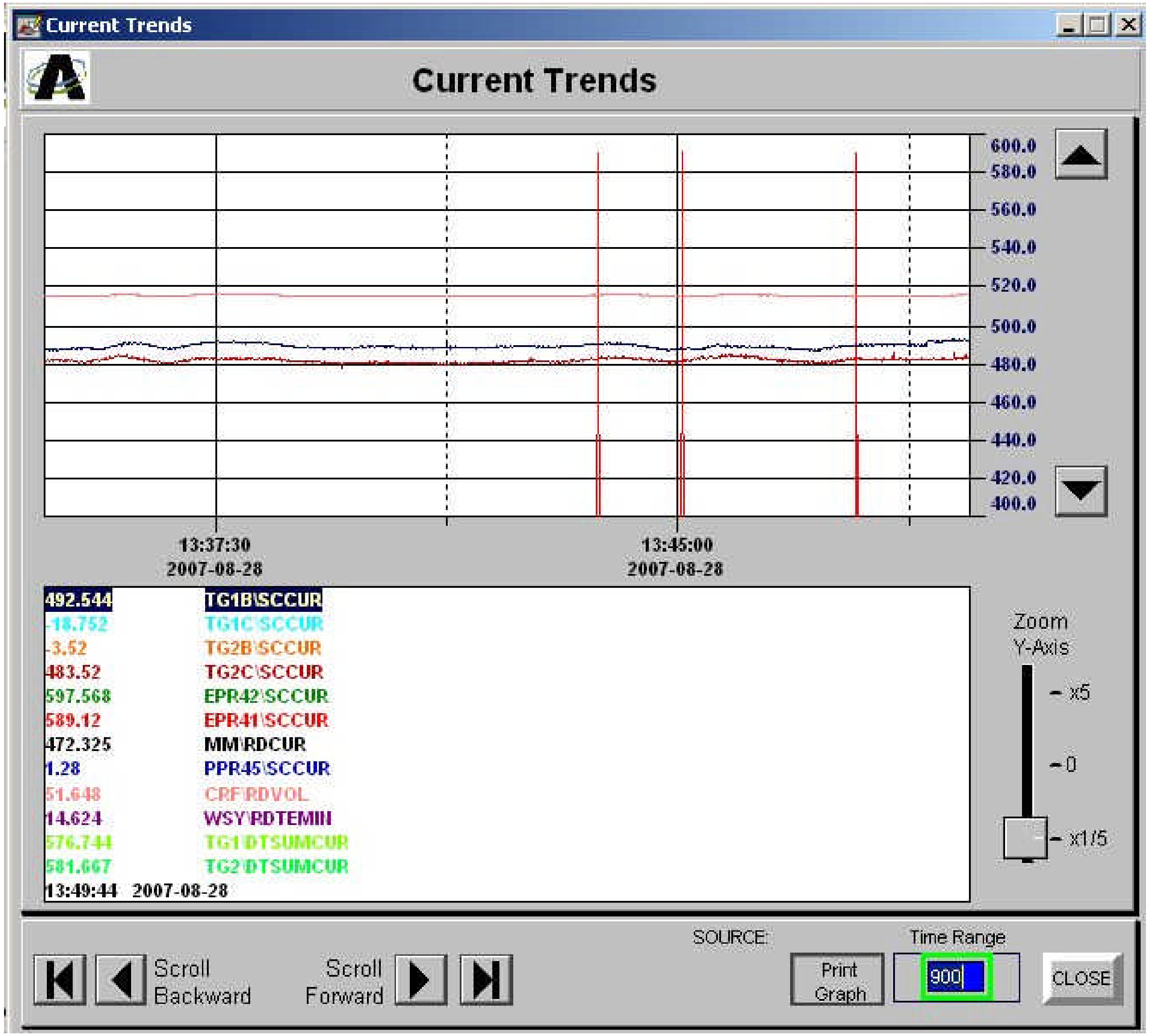
Target Current Stability

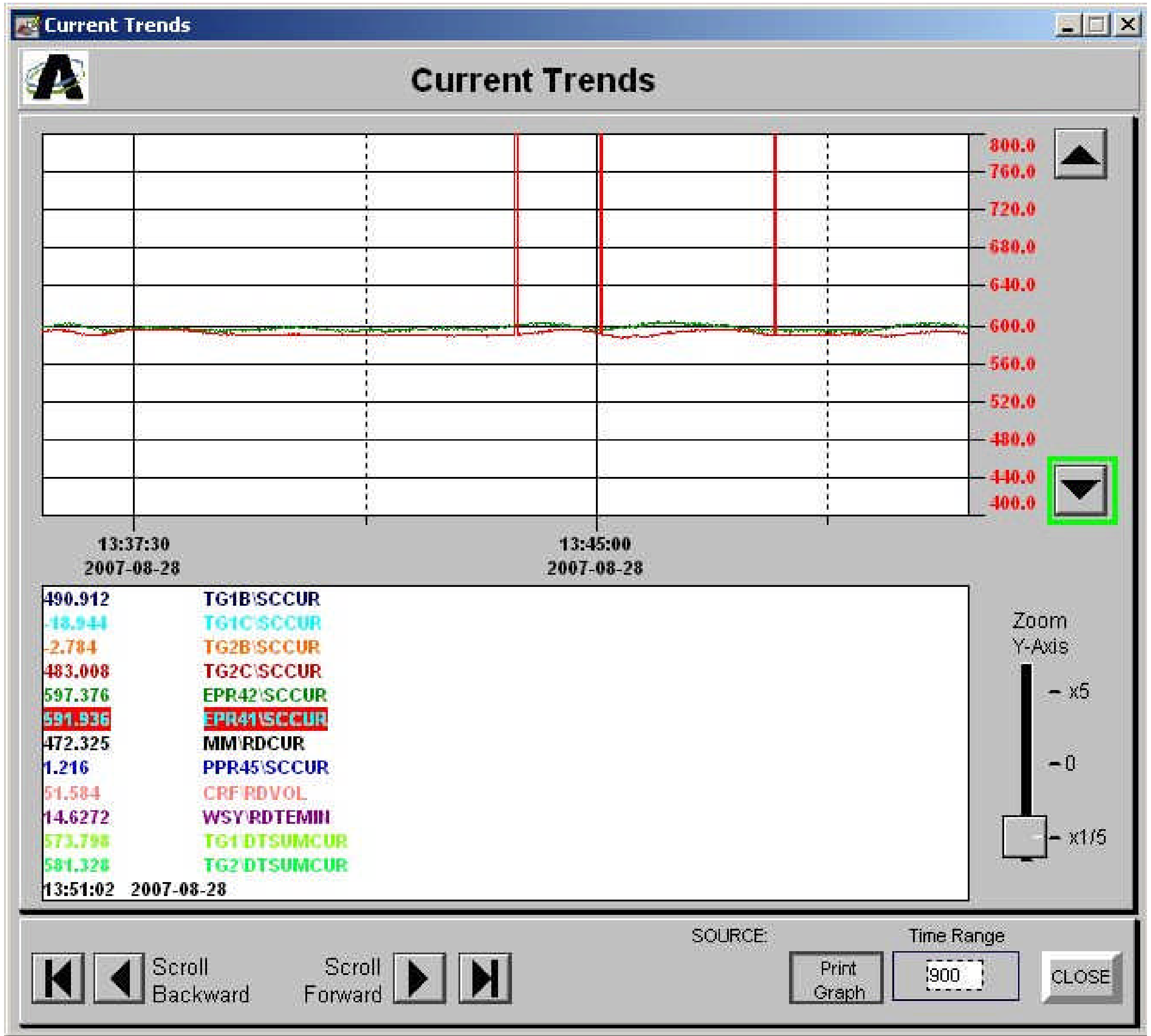


Target current stability of 1.1 to 1.3%

Target station current TG1B



Extraction current EPR41



Uptime Performance

The uptime performance of the TR30 cyclotron systems was thoroughly tested at a total extracted beam current of 1mA and 1.2mA.

A total of three tests have been performed over two TR30 cyclotrons (TR30/1 and TR30/2), each test for a consecutive period of 13 weeks.

During the testing time the machines have been continuously operated at maximum beam current as specified.

The uptime has been defined as the ratio between the time the beam current was at an average value of 1mA or 1.2mA and the time scheduled, 24 hours per day, seven days a week, excluding the target transfer time and scheduled maintenance time.

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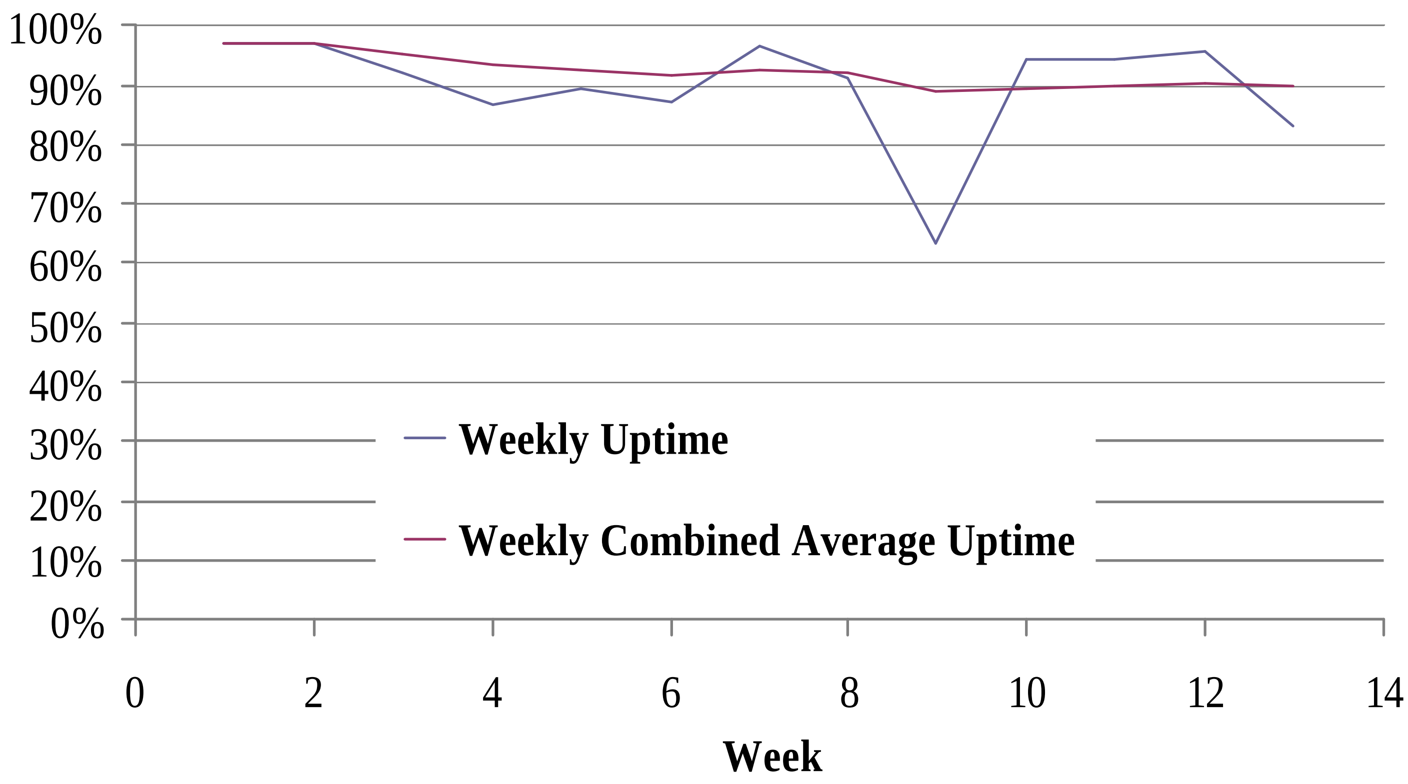
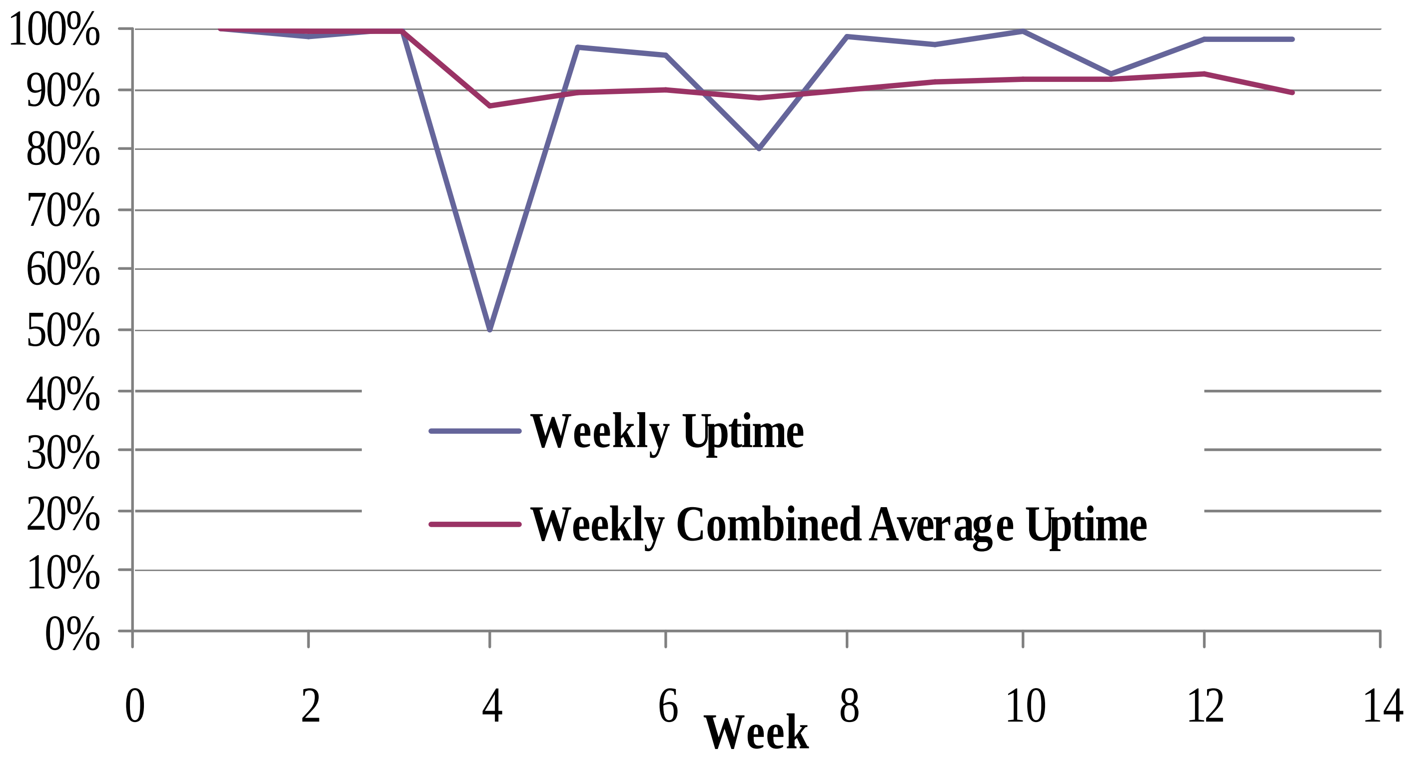
TR30/1, 1.0mA Uptime Test



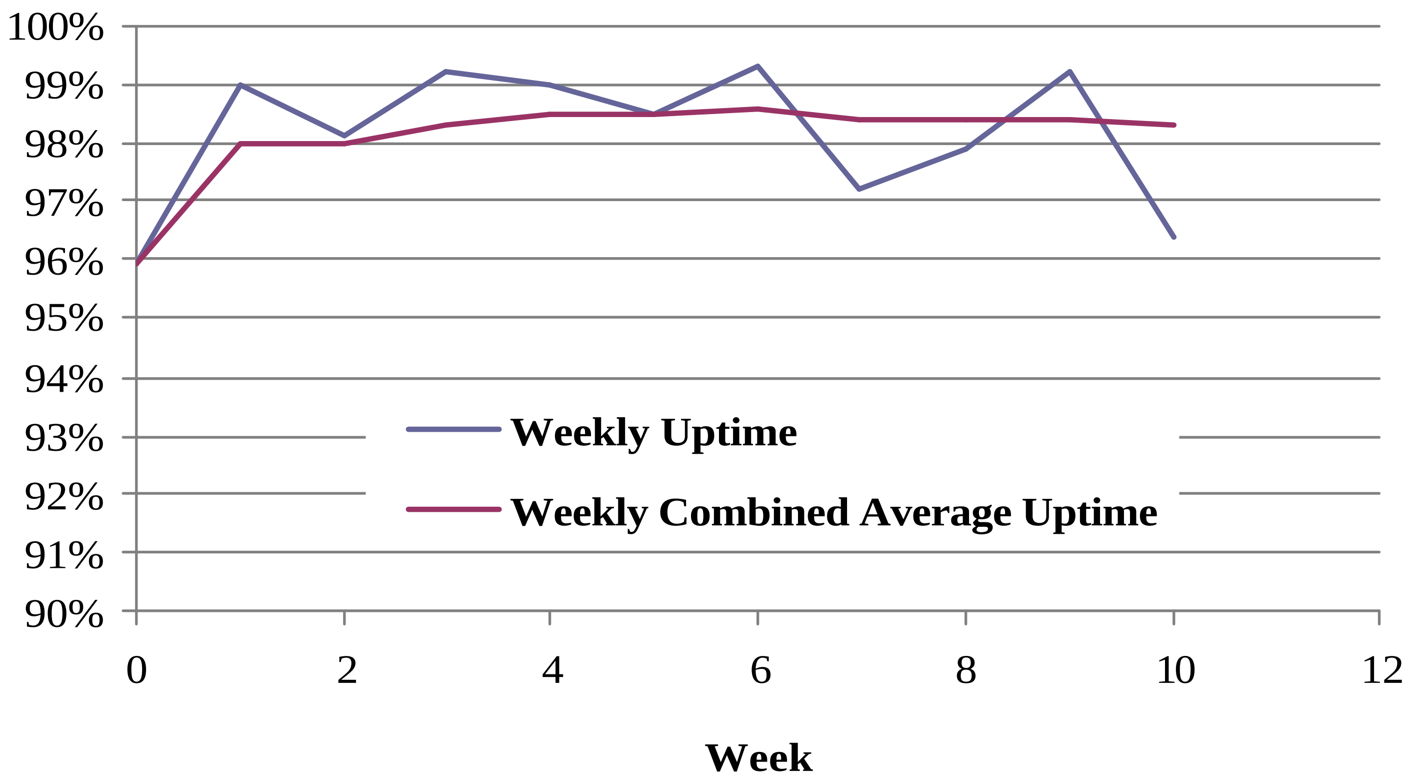
Average uptime of 90%.

TR30/2, 1.0mA Uptime Test



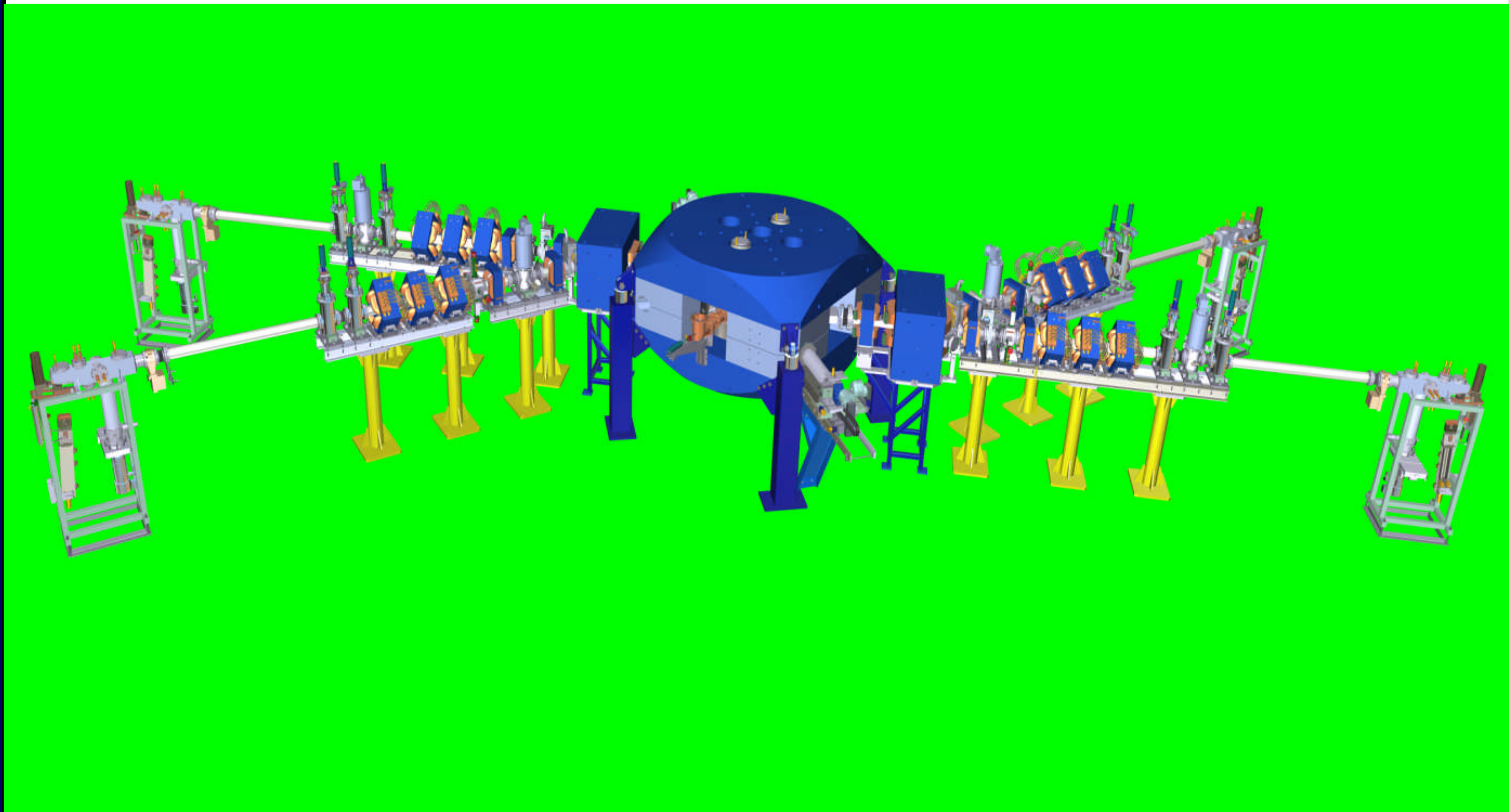
Average uptime of 89.3%.

TR30/2, 1.2mA Uptime Test



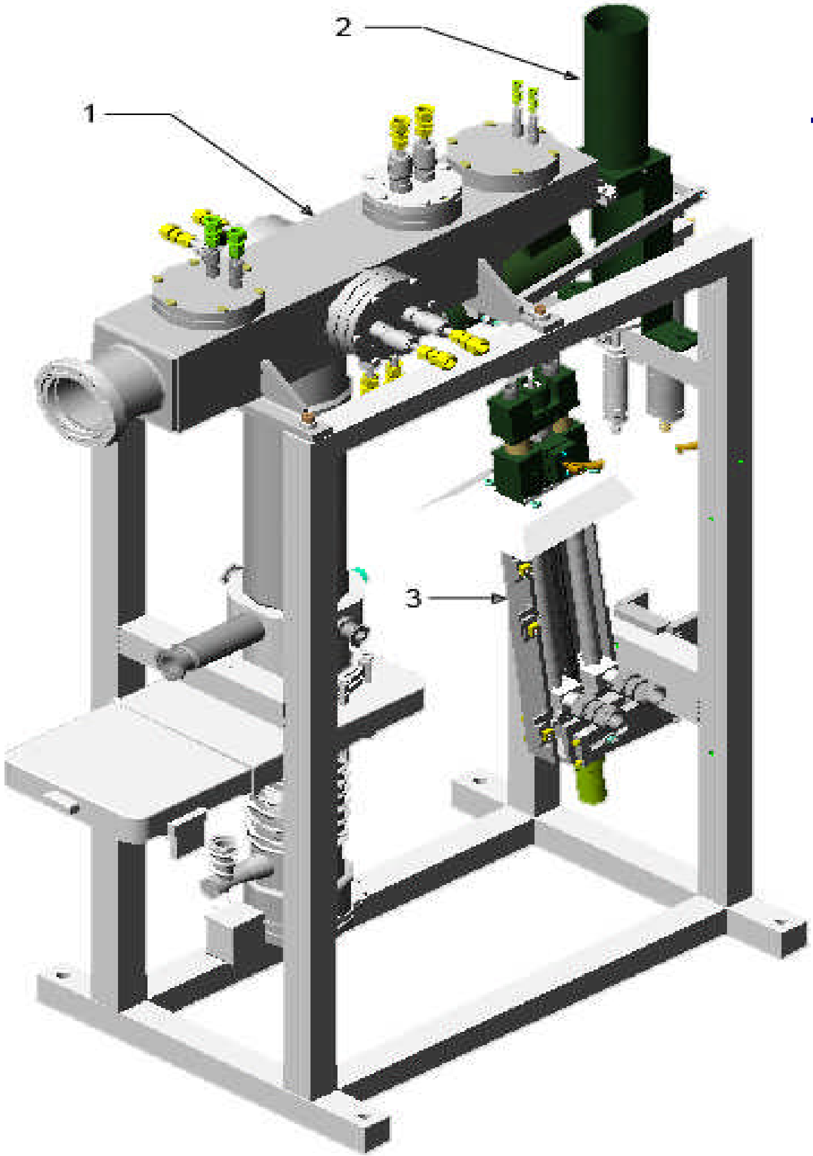
Average uptime of 98.3% for 10 weeks (test to be completed October 5).

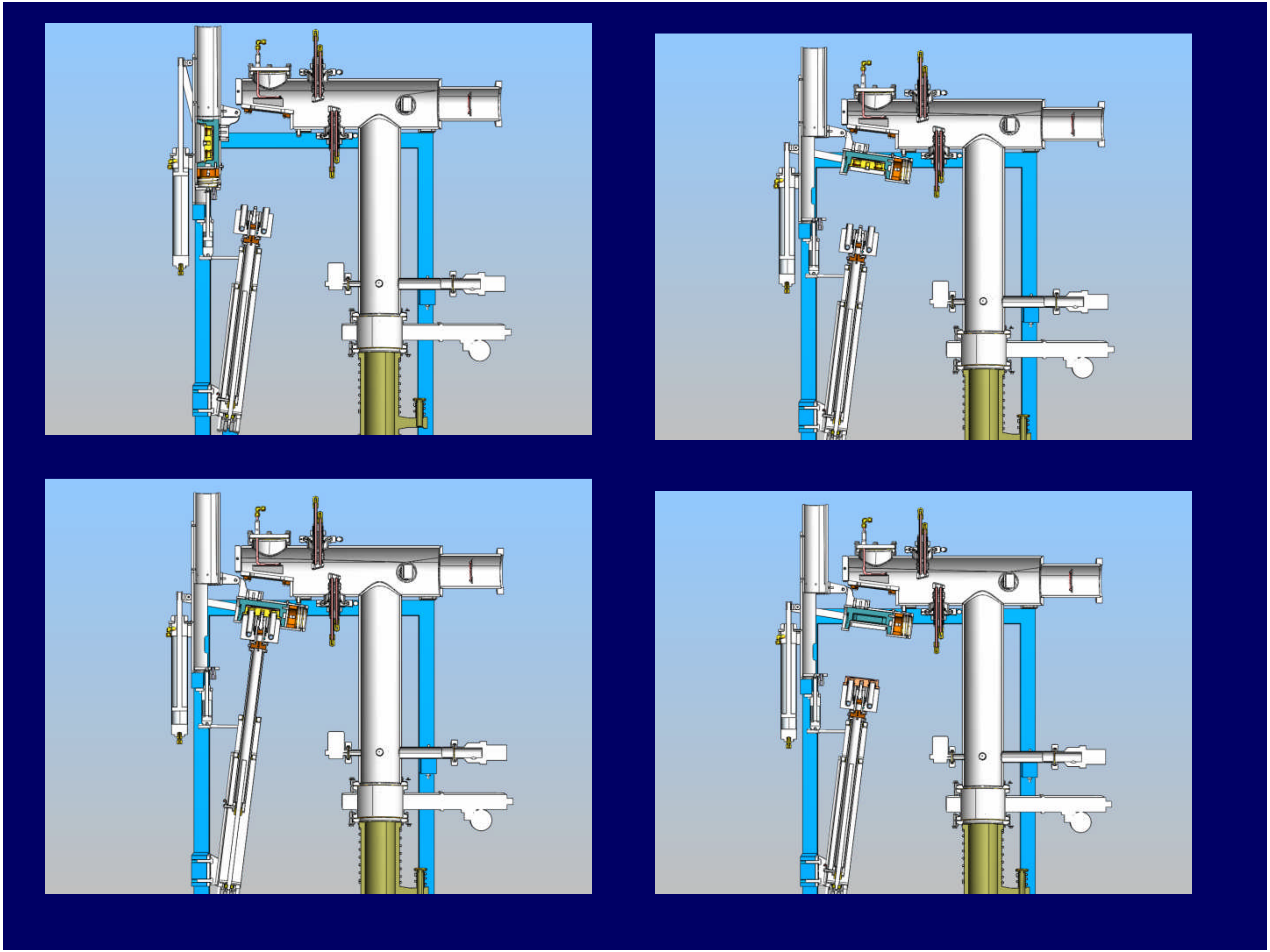
Cyclotron Layout

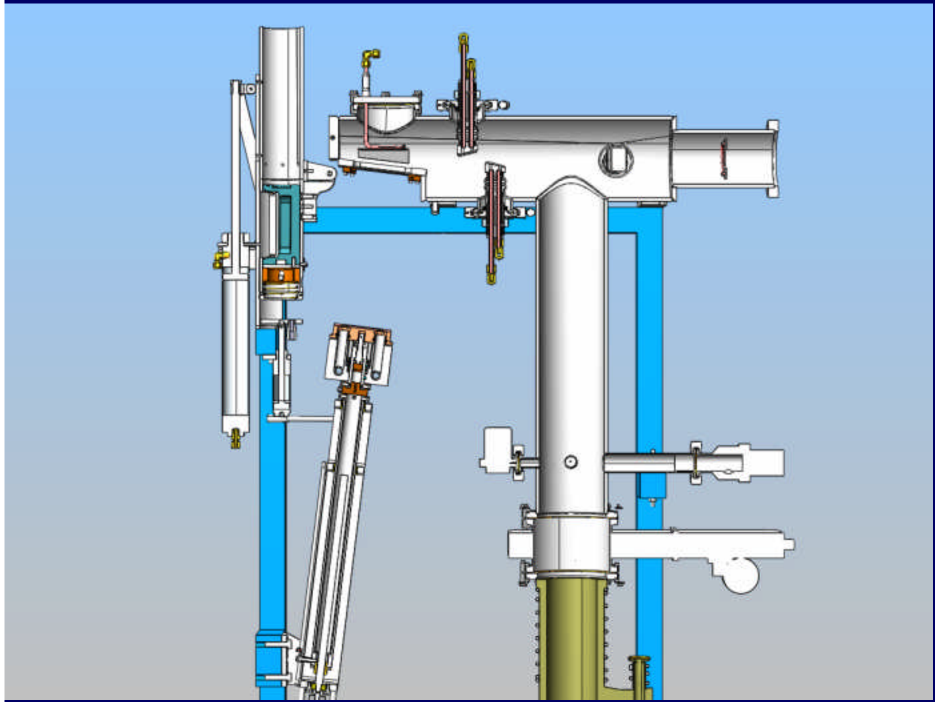


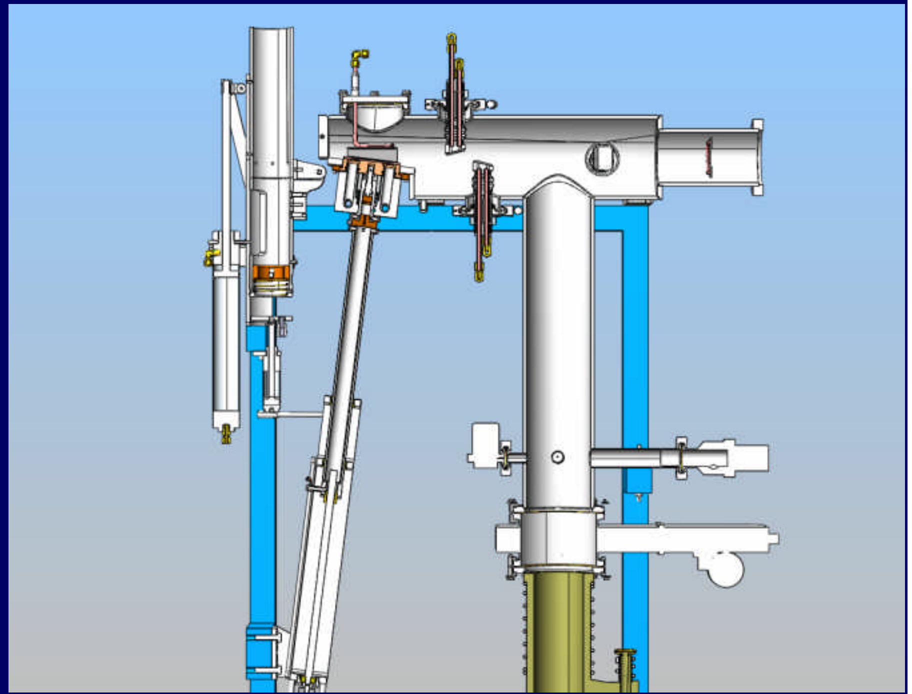
Target Station

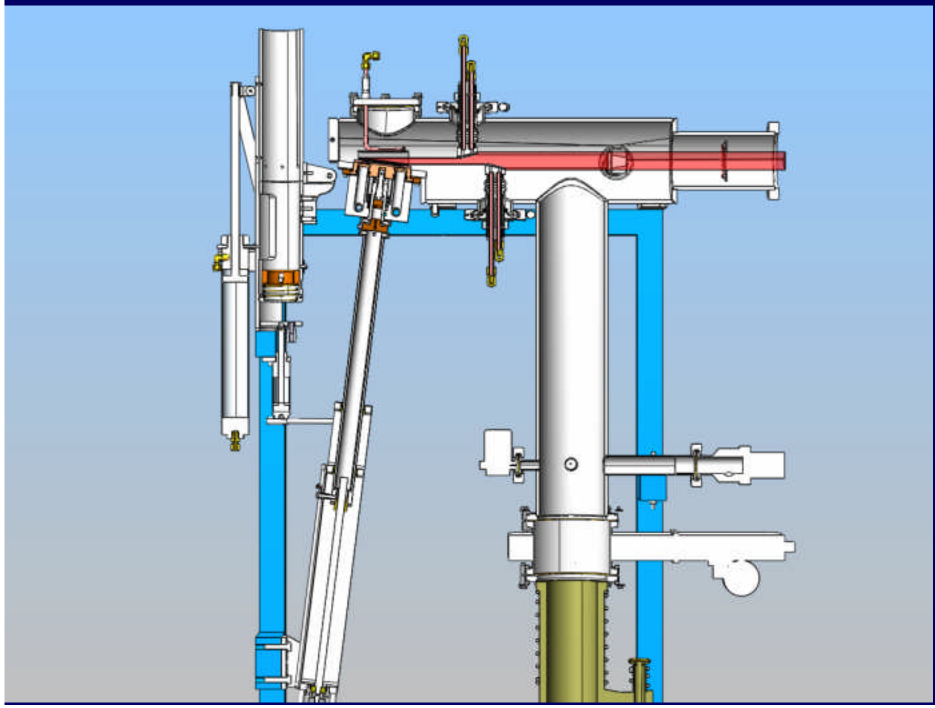
1. Vacuum Chamber
2. Landing Terminal
3. Manipulator

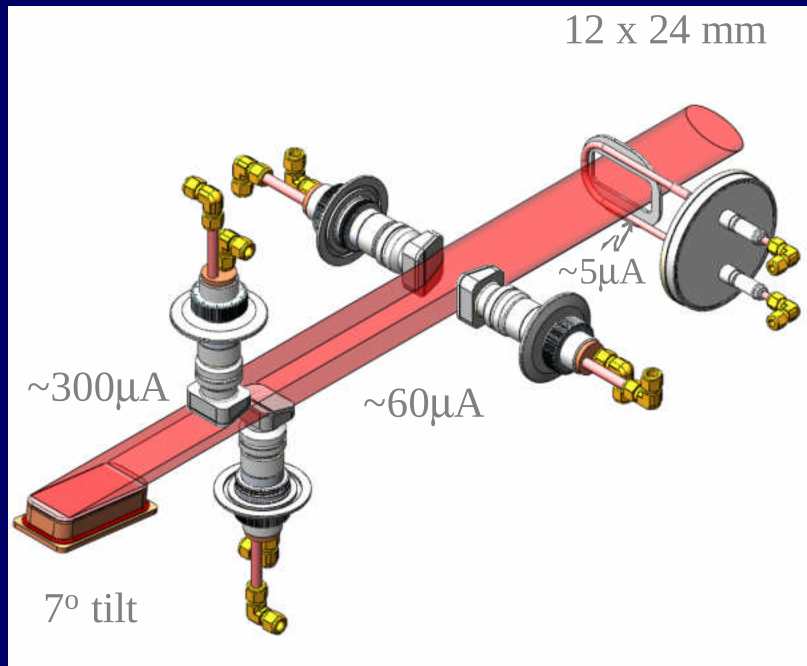




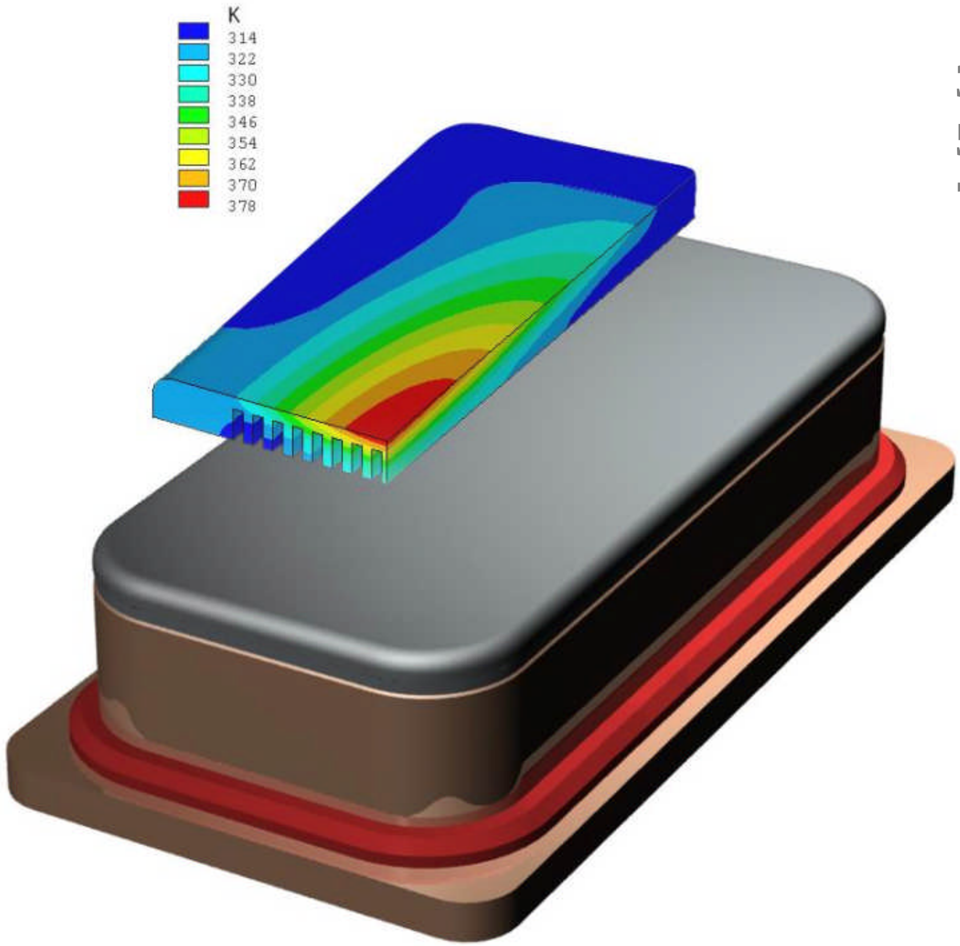







12 x 24 mm
~5μA
~300μA
~60μA
7o tilt

Target Thermal Simulation



30 MeV
500 mA
750 mA upgrade

Beam Radiograph

Beam on Target for 200 uA

Beam on Target for 400 uA

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References

[1] B.F. Milton et. al., “Commissioning and First Operation of a 500• A, 30 MeV, Cyclotron”, Proc. IEEE PAC 1991, p65.

[2] T. Kuo et. al., “On the development of 2mA RF H- Beam for Compact Cyclotrons”, Proceedings of 14th ICC, Cape Town, S. A. 1995.

[3] T. Kuo et. al., “Development of a 15mA DC H- Multicusp Source for Cyclotron”, Proceedings of 14th ICC, Cape Town, S. A. 1995.

[4] T.S. Duh et al., “The Current Status and Future Prospects of the TR30/15 H-/D- Cyclotron Facility at INER Taiwan”, Proceedings of 17th ICC, Tokyo 2004.

[5] R.R. Johnson et. al., “Advances in intense beams, beam delivery, targetry and radiochemistry at Advanced Cyclotron Systems”, NIM B **261** (2007), 803.