The new heavy ion irradiation facility at KVI-CART

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Proton & Heavy ion radiation hardness testing

- For more than ten years we have provided proton beams up to 190 MeV
- We are extending our capabilities to provide heavy ion (HI) beams at energies ranging from 8 to 90 MeV/u either in air or vacuum for scientific and commercial users (table on right gives details of our new HI cocktail)


The AGOR superconducting cyclotron


In-air heavy ion irradiation facility for radiation hardness testing & radiobiological research

Available beams from the heavy ion cocktail

- KVI-CART's Superconducting cyclotron provides protons at 190 MeV and heavy ion beams of 30 MeV/u (up to Xe) or 90 MeV/u (up to O)
- The table below shows details of the 30 MeV/u heavy ion cocktail we provide for commercial and scientific irradiations, including the ion species, maximum flux, energy at DUT, the beam purity and switching times between beams

Ion Species	Maximum Flux ion cm^{-2} s^{-1}	Energy at DUT in air (SRIM 2013) MeV/u	LET at DUT in Air (SRIM 2013) MeV/(mg/cm²)	Max LET (SRIM 2013) Using a degraded beam MeV/(mg/cm2)	Contamination Ions per beam ion	Time to switch ion species				
						O	Ne	Ar	Kr	Xe
$^{16}O^{4+}$	1E6	27.93	1.1	4.5	<1E-5	x	15m	15m	30m	<1h
$^{20}Ne^{5+}$	1E6	26.9	1.8	7.8	<1E-5	15m	x	15m	30m	<1h
$^{40}Ar^{10+}$	1E6	26.3	5.7	16.6	<1E-5	15m	15m	x	30m	<1h
$^{84}Kr^{21+}$	1E6	24.6	20	40	<1E-5	30m	30m	30m	x	<1h
$^{129}Xe^{32+}$	~1E6	25.5	42	65	<1E-5	<1h	<1h	<1h	<1h	x

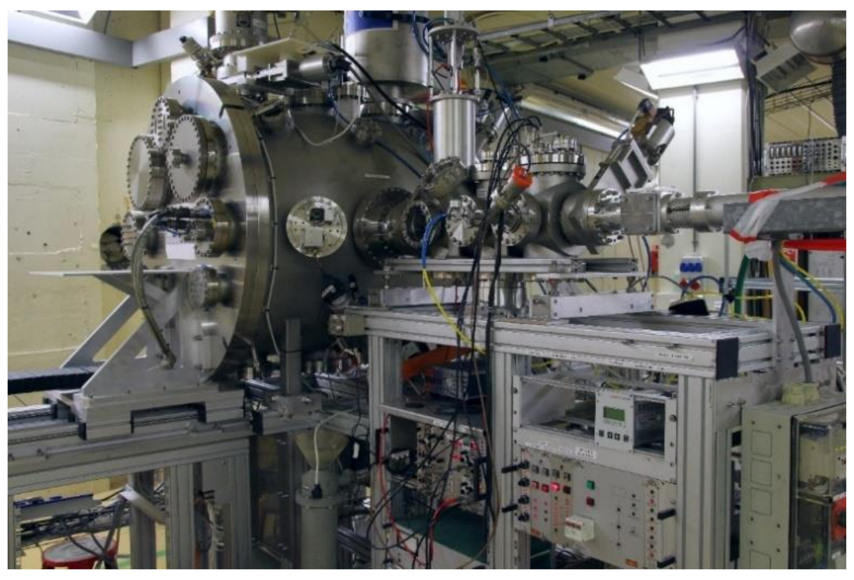
The 30 MeV/u heavy ion cocktail offered by KVI-CART

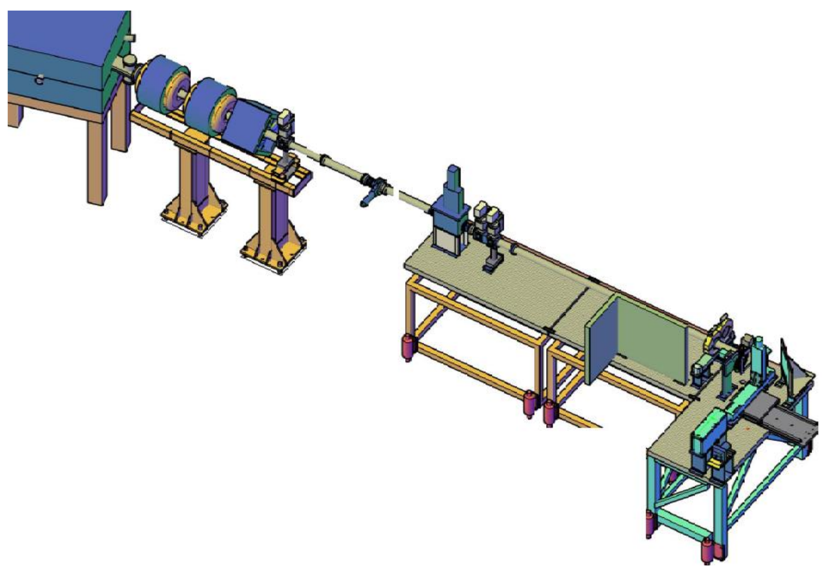
In-air irradiation facility

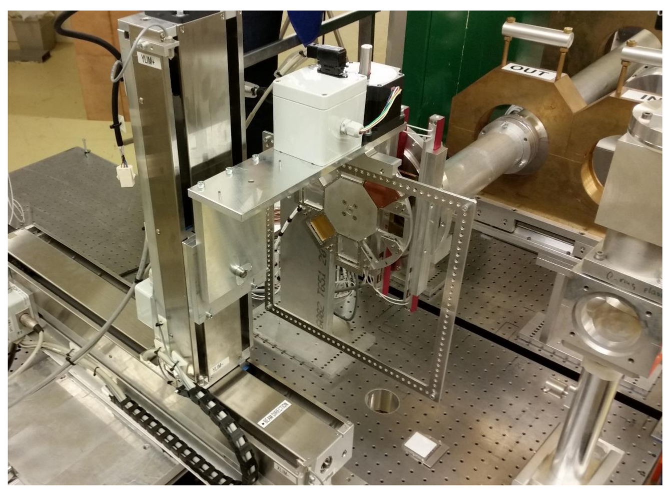
The in-air heavy ion irradiation facility has been upgraded in the following way:

- For light ions (He up to O at 90 MeV/u) AGORFIRM (shown in figure below) is used with minor adaptations to existing proton irradiation facility
- We have extended AGORFIRM for irradiations with heavy ion beams (carbon up to xenon) with a primary beam energy of 30 MeV/u in air (figure to the right with a detailed description in the "Features of the irradiation facility" section)


The in-air proton irradiation facility (AGORFIRM)


The in-vacuum heavy ion irradiation facility




The in-air heavy ion irradiation equipment

In-vacuum irradiation facility

Very high LET irradiations will be delivered in 2019 using the BIBER irradiation set-up (figure to the left):

- A vacuum chamber of volume 1 m^3 is already installed and is being commissioned to deliver 11 MeV/u beams of Pb or Bi to perform irradiations at very high LET
- Beam monitoring will be performed using a residual gas ionization measurement for an absolute determination of the current of the ion beam during the irradiation

Features of the irradiation facility

Field forming system

- Scatter foils and an x-y scan magnet system provide a homogeneous beam
- The magnets scan the heavy ion beam over an area of 30 x 30 mm^2 (protons can be scanned over an area of 10 x 10 cm^2) with a homogeneity of better than10% at a frequency up to 200 Hz (see figures to the right)

Fluence monitoring & measurement

- Flux is monitored using four fast scintillation 'edge detectors' (YAP:Ce crystals readout with a Hamamatsu R12421 photo multiplier) by SCIONIX
- The ratio between upper/lower left and right 'edge detectors' monitors whether or not the field uniformity is changing
- Fluence is measured using a scintillation detector with a known surface area

The degrader system

- A remotely controlled degrader system is used such that degrader material of different thicknesses can be inserted in the beam to vary beam energy on the device under test
- A Si detector is used to guarantee beam purity
- A scintillation foil (Lanex™) is used to check field homogeneity (figure to the right)

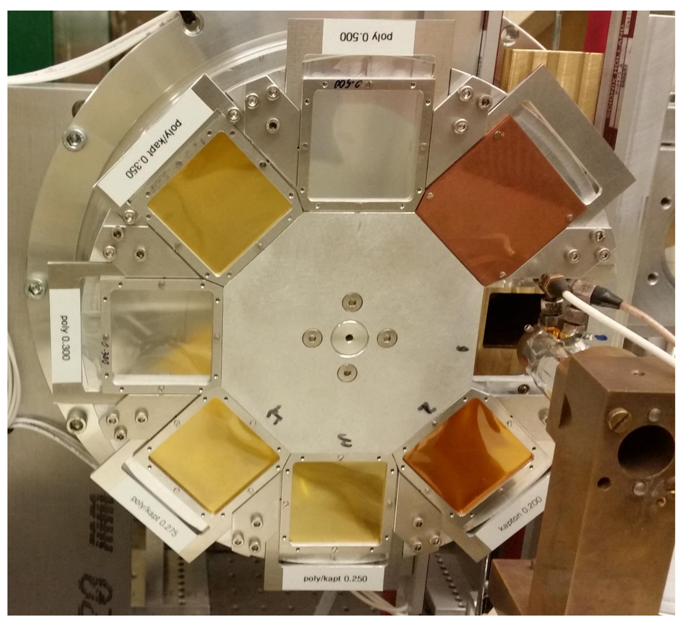
Positioning

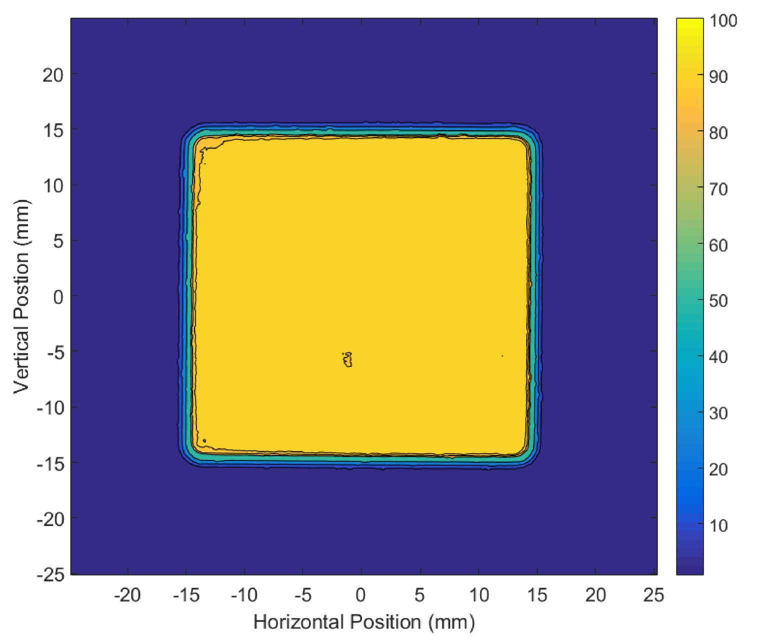
- The xy-table has been extended with a z-direction for tuning the beam energy
- A rotation stage is included to allow the device to be irradiated at any angle

Summary

- High LET with easy access to the device under test
- Heavy ion cocktail offers high beam purity, homogeneity with short switching times (see table above)

- Our facility provides the following:
  - ➢ protons at 190 MeV (in air or vacuum)
  - ➢ lighter ions (helium to oxygen) at 90 MeV/u (in air or vacuum)
  - ➢ carbon to xenon at 30 MeV/u (in air or vacuum)
  - ➢ very high LET heavy ion beam irradiations (Pb or Bi) at 11 MeV/u (only in vacuum and will be made available in 2019)


Degrader wheel with fluence monitoring detectors



Homogeneity of better than 10% (30 MeV/u oxygen with a 30x30 mm² collimator and wobbling with a 3 cm radius)
**larger field size of 50x50 mm² being explored*

For additional Information or to request beam time:

Please contact: Dr Marc-Jan van Goethem (irradiations liaison)
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