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The heavy ion irradiation facility at KVI-CART

Brian N. Jones[1], Marc-Jan van Goethem[1,2], Rob Kremers[1], Harry Kiewiet[1], Emiel van der Graaf[1], Sytze Brandenburg[1]

[1] University of Groningen, KVI-Center for Advanced Radiation Technology

[2] University of Groningen, University Medical Center Groningen, Radiotherapy Department

40th European Cyclotron Progress Meeting

INFN Laboratori Nazionali di Legnaro, Italy

20-23 September 2017

Outline

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– Status: KVI-CART & AGOR Cyclotron

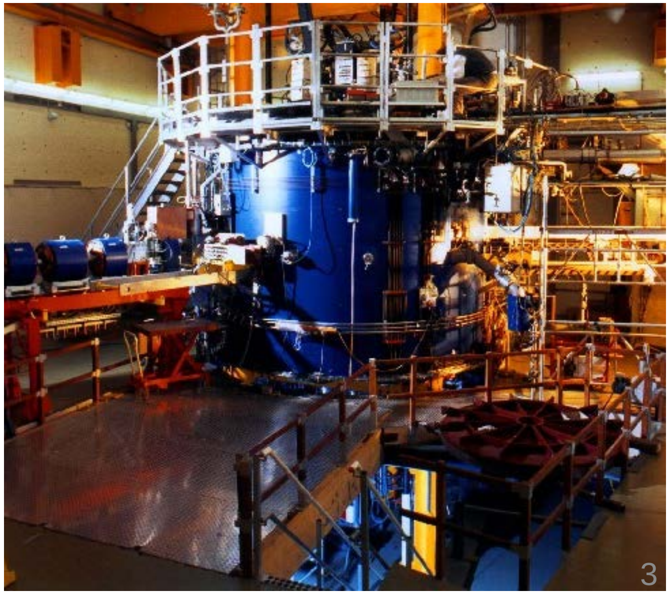
– New Installations

– Strategies

KVI-CART

The KVI-Center for Advanced Radiation Technology (KVI-CART):

- Superconducting AGOR (Accelerator Groningen Orsay) cyclotron
- Originally used for nuclear research
- Irradiation facility for radiobiological research (since 1998)
- Radiation hardness testing (since 2005)
  - mainly for space and aviation industry
  - recently also ground-bound electronics
- Detector Development (proton therapy)



KVI-CART

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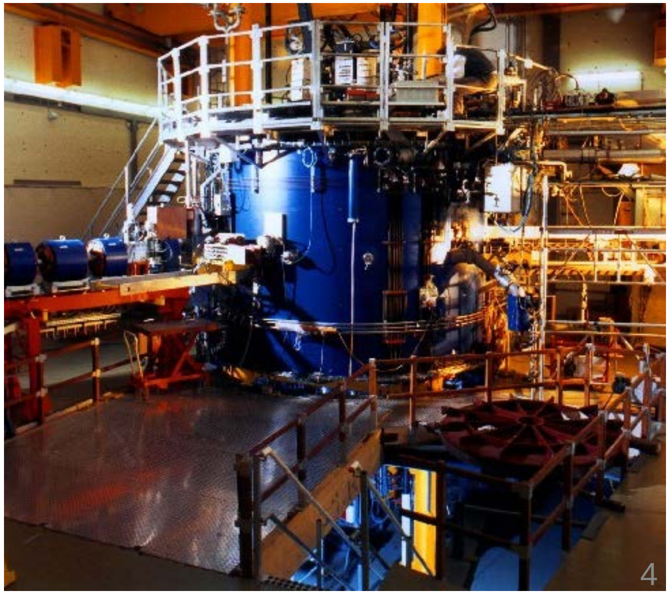
The KVI-Center for Advanced Radiation Technology (KVI-CART):

- There have been rumours about AGOR’s future... our facility will remain operational for the next ten years (at least!)
- ESA Ground Based Unit for Radiation Biology
- ENSAR2 Horizon 2020 (TNA)
  INSPIRE (TNA)
- We are extending our capabilities!



radiation hardness assessment

“consultancy” activities

- accelerator R&D
- radiation protection

AGOR Cyclotron & Irradiation Facility

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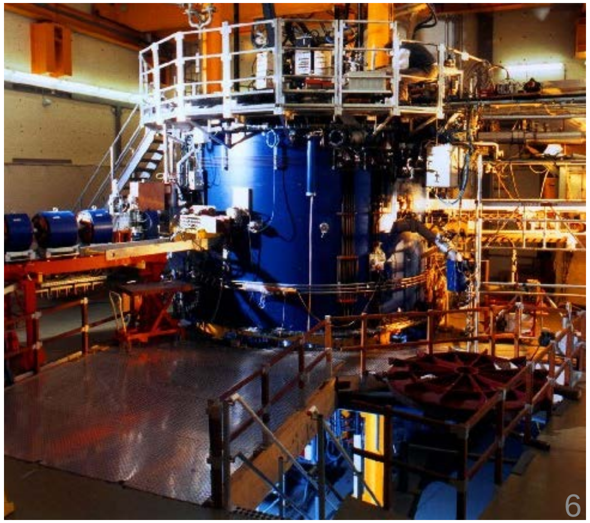
Status of AGOR:

- We are extending the radiation hardness test capabilities to provide heavy ion beams at several energies ranging from about 8 to 90 MeV/u
- Expanding capabilities for radiobiology research (want to build an advanced facility, including imaging capabilities, dose delivery modalities from protons to carbon, scattered beams, scanning (wobble, line scanning, spot scanning)



The AGOR ion sources

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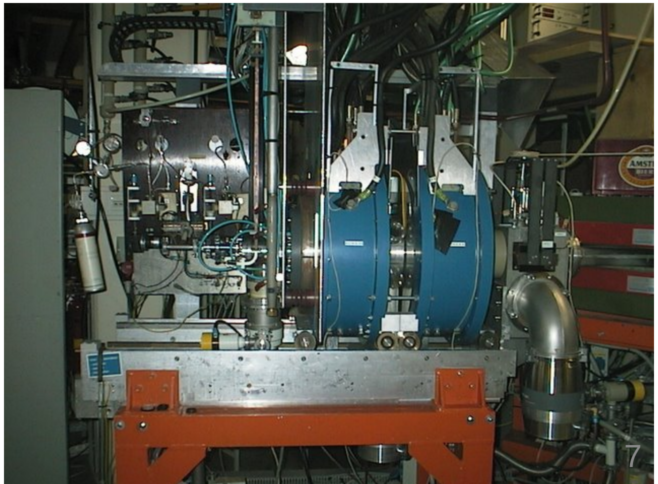
- multicusp ion source: hydrogen, helium
- ECR sources
  - 14 GHz KVI-AECR
    production of highly-charged metal ions (e.g. Pb^{27+})
  - 14 GHz SUPERNANOGAN
    gaseous elements (e.g. Ne^{7+})

- We seem to have a reproducibility problem in the injection line (low energy beam transport) related to higher-order aberrations

- We also need to improve performance of the AECR



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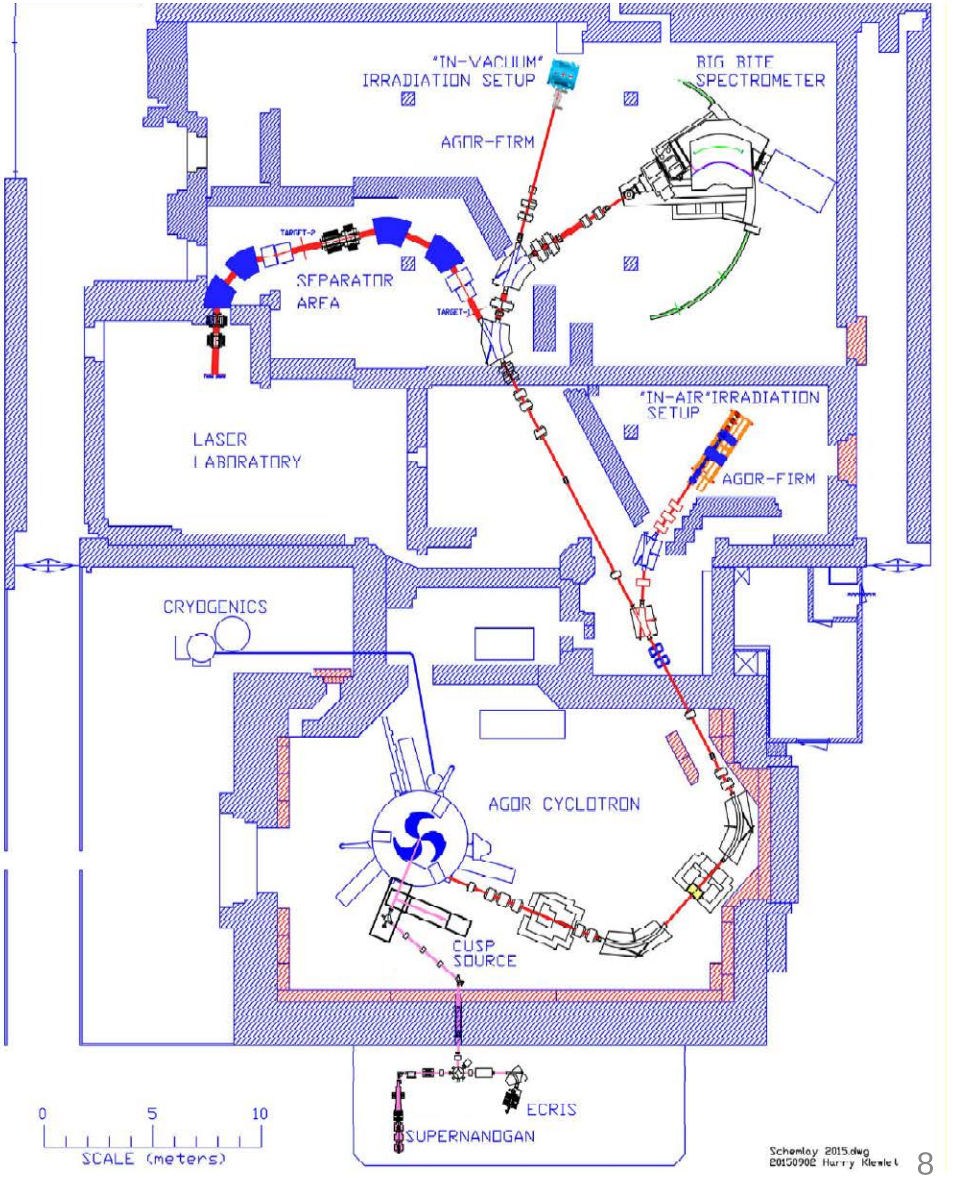
What's new?

- Newly refurbished in-air irradiation facility used for radiation hardness testing & radiobiology
- In-vacuum irradiation



Installation for heavy ions: air

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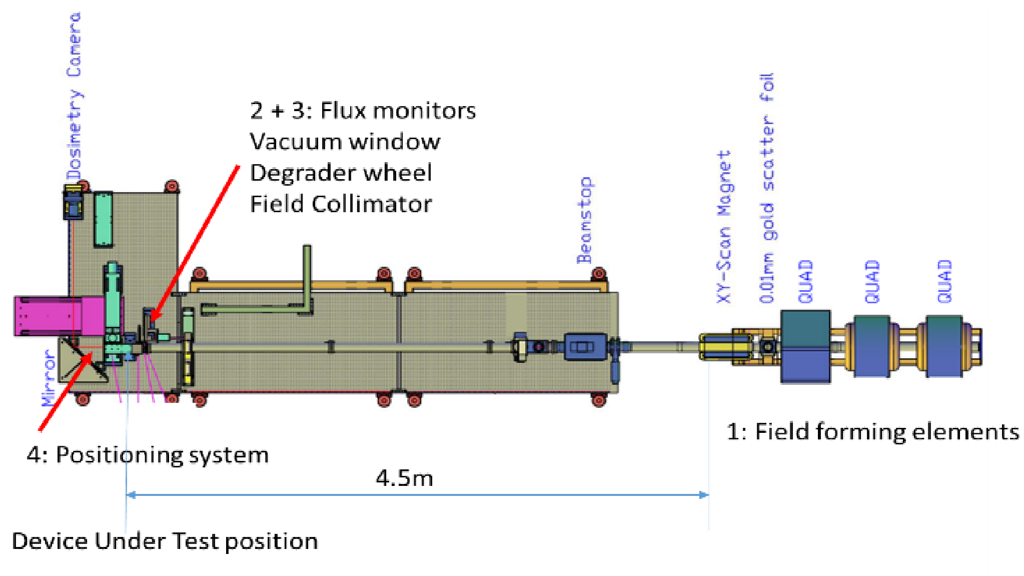
- For irradiations with light ions (He up to O at 90 MeV/u) proton set-up is being used with minor adaptations
- For irradiations with heavy ions of 30 MeV/u (carbon to xenon) more extensive adaptations are necessary



Installation for heavy ions: air

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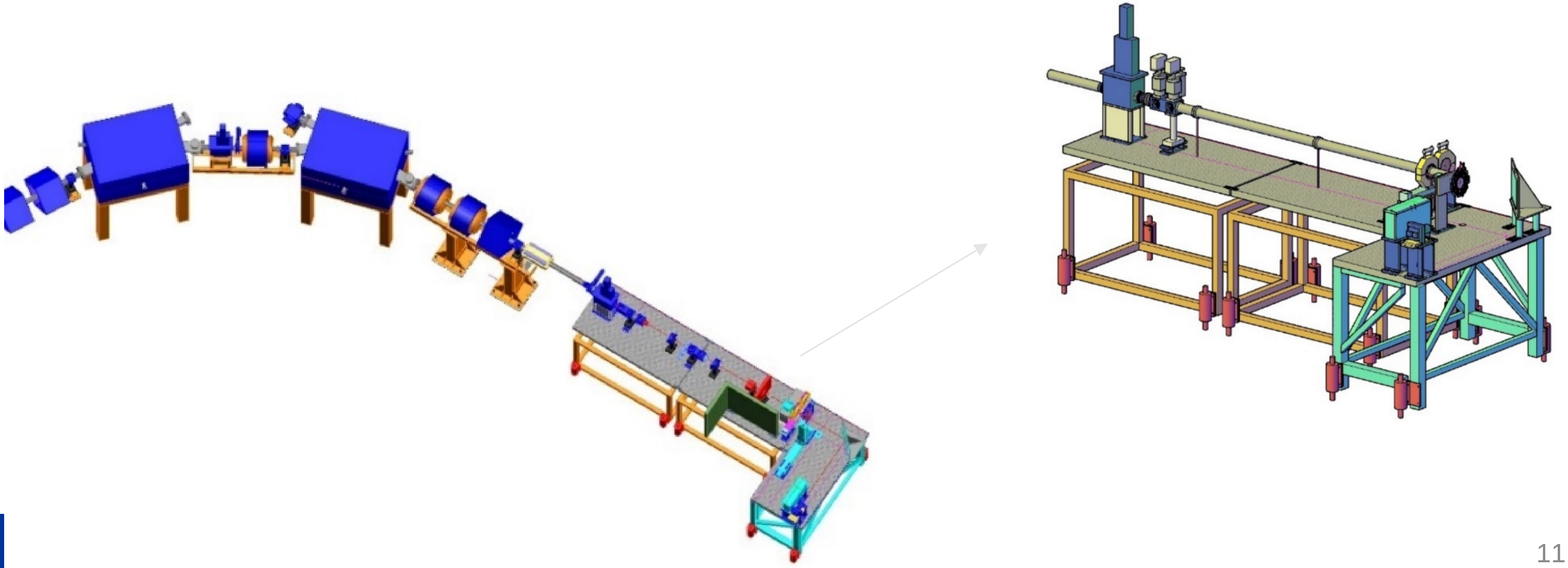
- New in-air heavy ion irradiation facility:

  1) xy-scanning system
  2) flux monitoring system
  3) collimator and degrader system
  4) positioning system

Installation for heavy ions: air

1) Field forming system

- Irradiation field created using a combination of a 10 µm thick gold scatter foil and a new x-y scan magnet system located just after the quads
- Scan magnets scan the beam over an area of 30 x 30 mm^2 (protons 10 x 10 cm^2) with a homogeneity of 10% (or better) at up to 200 Hz



Installation for heavy ions: air

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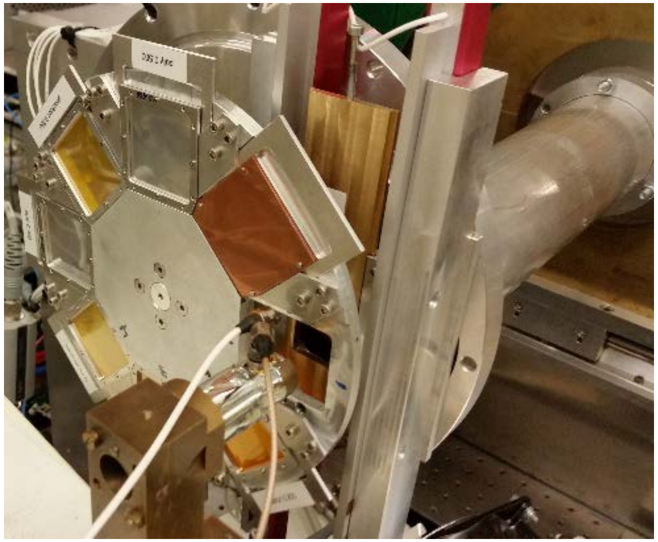
2) Fluence monitoring & measurement

- Flux <u>monitored</u> 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’ will allow for monitoring of whether the field uniformity is changing
- Flux is <u>measured</u> using a detector with a known surface area placed in the center of the field



Installation for heavy ions: air

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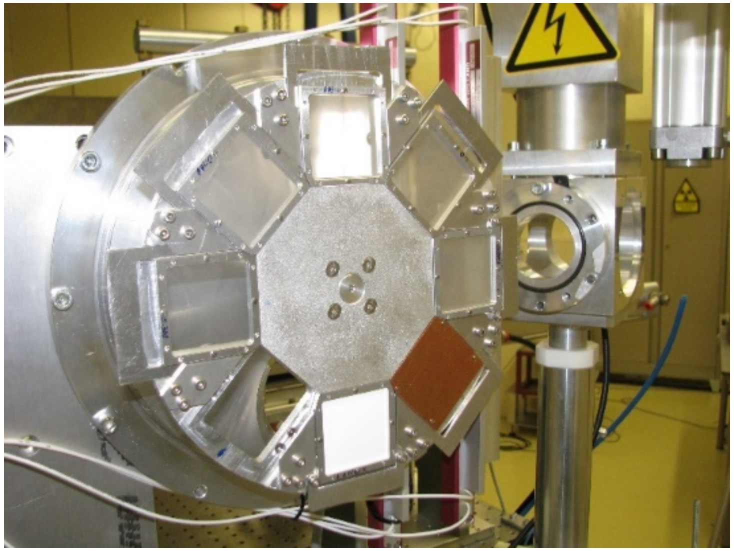
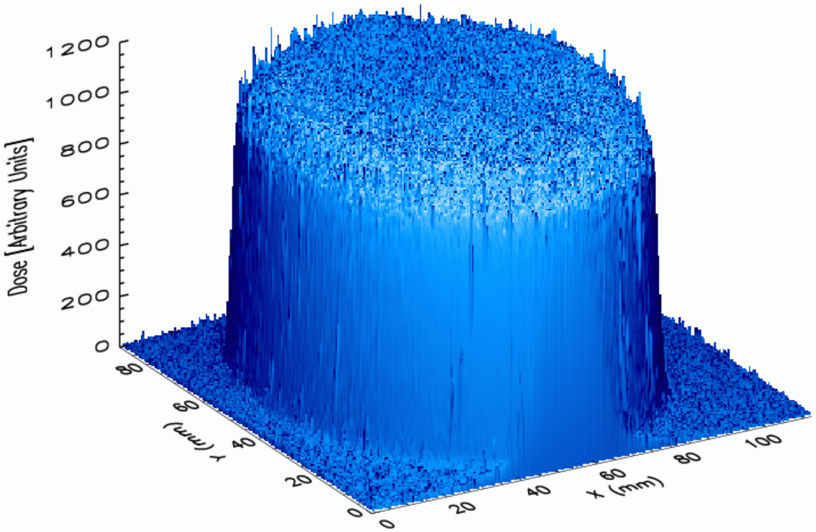
3) The degrader system

- A remotely controlled degrader system is implemented such that degrader material of different thicknesses can be inserted in the beam (vary the beam energy (LET))
- Ion species identification with Si detectors (scan Si detector)
- This system contains a scintillation foil (Lanex^{TM}), which can be used to check the field homogeneity





Installation for heavy ions: air

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4) Positioning

- XY-table has been extended with a Z direction allowing for fine-tuning of the beam energy
- Rotation stage is included allowing the device to be irradiated at any angle between 0 (perpendicular) to 45 degrees.

Installation for heavy ions: vacuum

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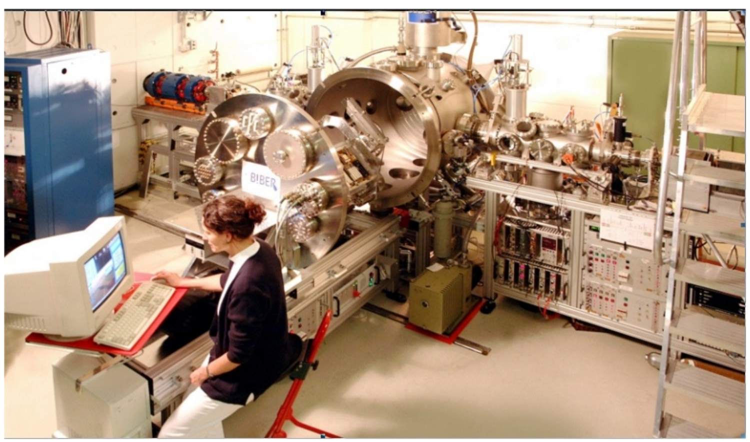
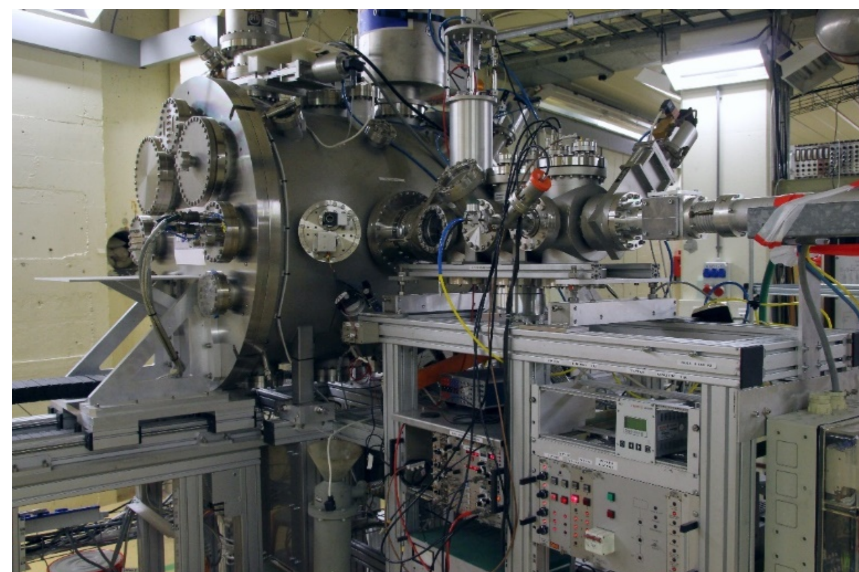
- For heavy ion beam irradiations with energies in the range of 8-15 MeV/u (up to Pb or Bi), the irradiations have to be performed in vacuum
- The “BIBER” irradiation set-up (donated by HZB Berlin) has been installed and will be used to perform in-vacuum irradiations
- vacuum chamber ~1 m^3
- high accuracy positioning (X, Y, Z, q)
- used for: radiation damage, material modification
- future development: ion beam analysis





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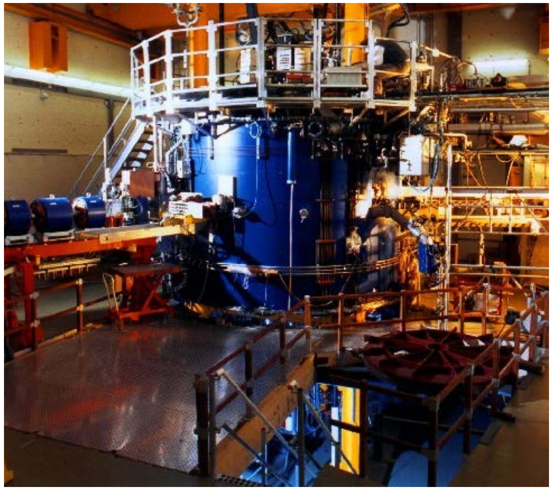
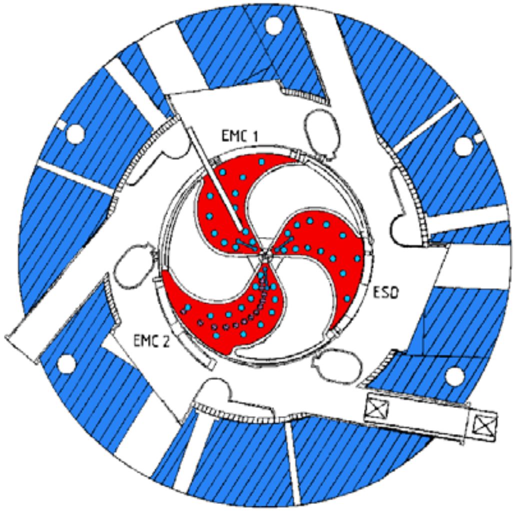
AGOR Specifications:

- Superconducting magnet
- The magnetic field can be operated in the range 1.75 < B < 4.05 T
- The accelerating frequency ranges from 24 to 62 MHz, harmonic modes are h = 2, 3, 4
- The maximum dee voltage is 100 kV
- Ion source maximum injection voltage of 35 kV





Operating diagram / available beams

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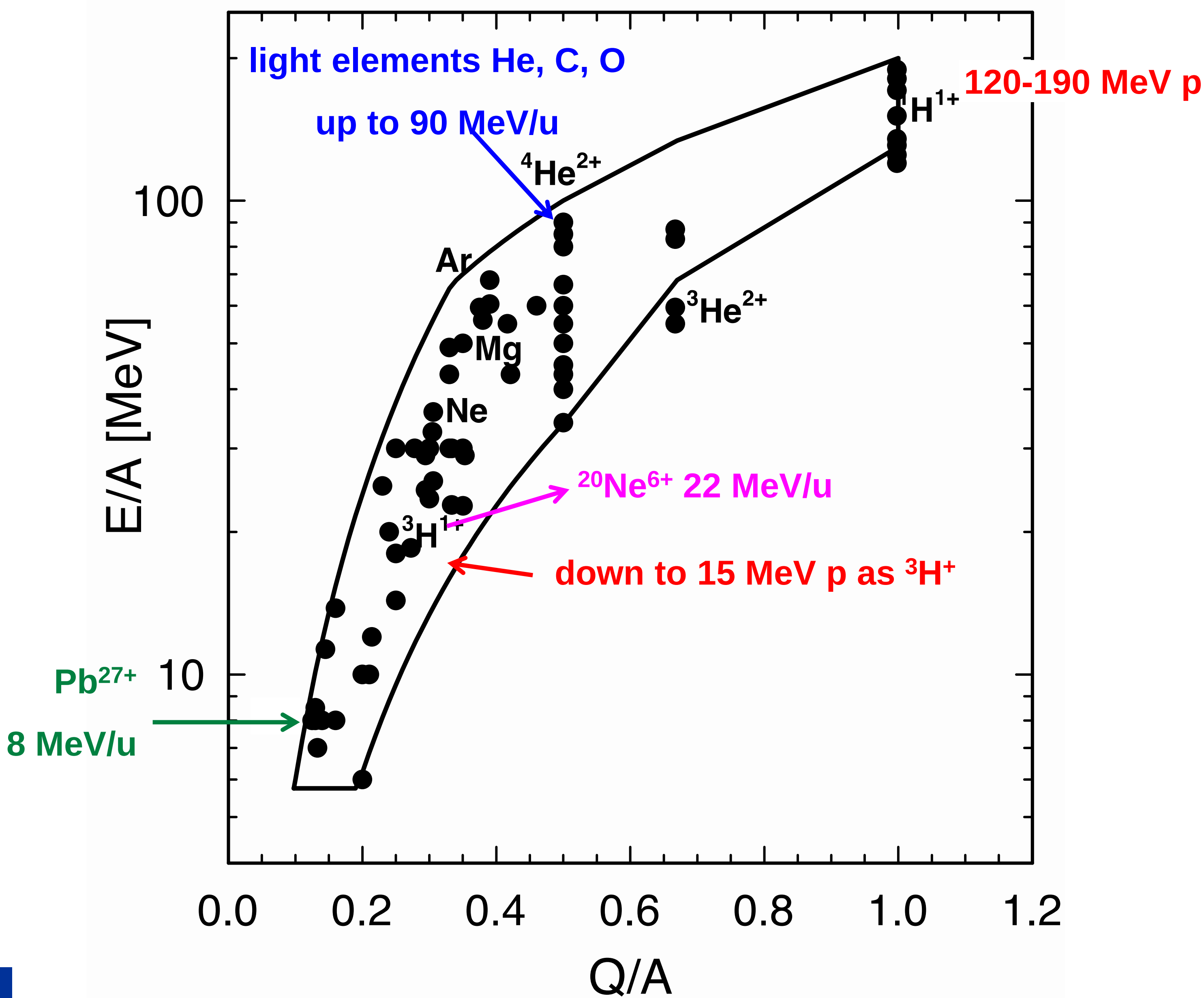
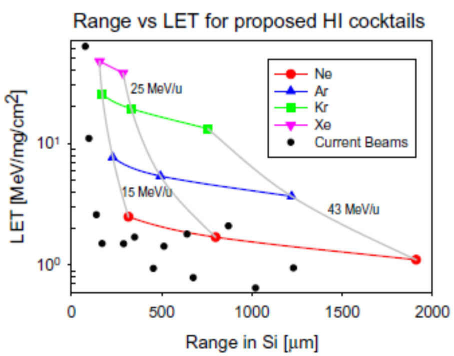


AGOR Cyclotron

Requirements

- Want a wide variety of pure beams with short waiting times
- Looking at various options (based on experience)



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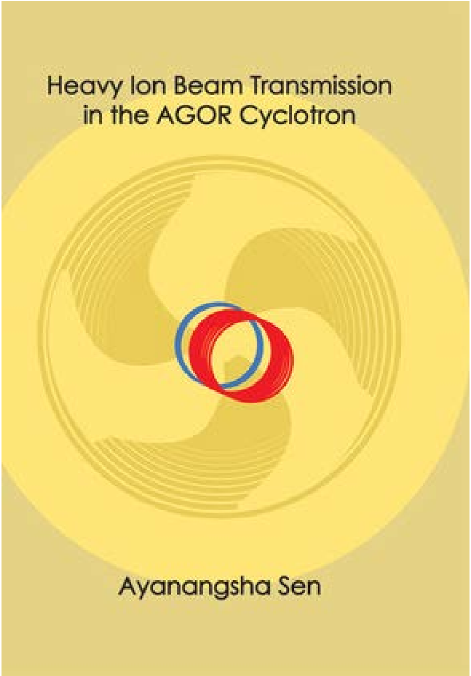
The irradiation facility at the AGOR cyclotron

Sytze Brandenburg, Reint Ostendorf, Mariet Hofstee *, Harry Kiewiet, Hans Beijers

Kernfysisch Versneller Instituut, University of Groningen, Zernikelaan 25, 9747 AA Groningen, The Netherlands

Available online 22 May 2007



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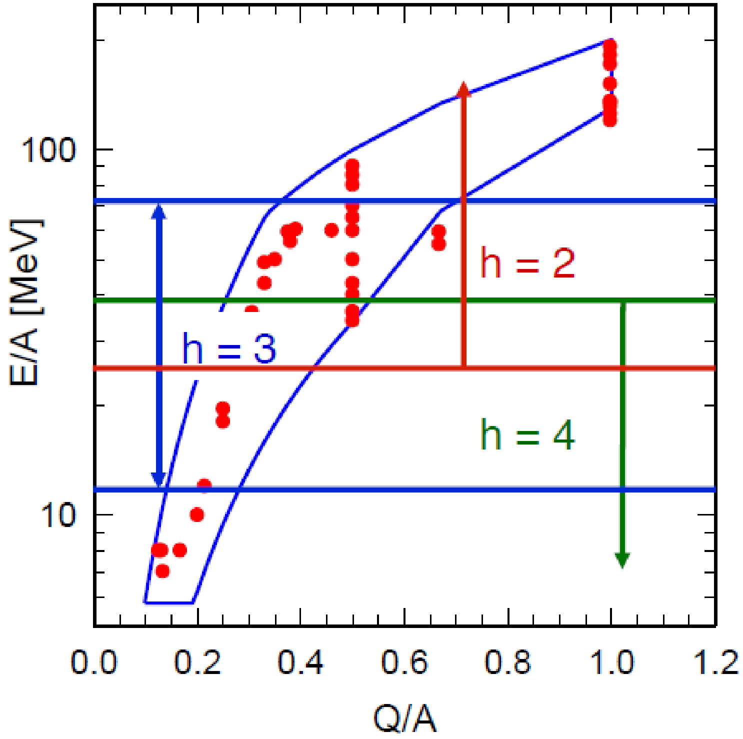
Strategies

- Use a set of ions (O, Ne, Ar, Kr, Xe) from the AECR source each with Q/A ≈ 0.25 to achieve 30 MeV/u
- 30 minute challenge
- Also determining if the inflector needs to be switched every time the cyclotron tuned to different harmonic
- Tune the RF to find the other harmonic (saves time)



Outlook

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By 2008 AGOR will…

- Continue to provide proton irradiation in air (190 MeV)
- Provide in-air irradiation (C to Xe at 30 MeV/u)
- Provide in-vacuum irradiation (C or heavier at 8 to 10 MeV/u, Pb or Bi at 15 MeV/u)

AGOR: the next 20 years!

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Friday 20 October 2017

During this festive event, we present the future of our research facility built around the AGOR particle accelerator. Short presentations, exhibitions and a guided tour will inform you on our focus and possibilities, such as: physics and technology-based research for e.g. proton therapy, radiobiological research and irradiations for industry. Please register before September 8.

We present here the detailed programme and some practical information.

Sincerely,
Peter Dendooven
chairperson organising committee "AGOR: the next 20 years!"

Programme "AGOR: the next 20 years!"

at the Energy Barn

10:30	Registration/coffee & tea
11:00	Welcome *Prof. Dr. Ad van den Berg, Director KVI-CART*
11:15	Precision, precision, where physics meets biology in radiotherapy *Prof. Dr. Rob Coppes, University Medical Center Groningen*
11:50	Hitting the bull's-eye in proton therapy *Dr. Peter Dendooven, KVI-CART*
12:15	Lunch
13.30	KVI-CART: an asset to the University of Groningen *Prof. Dr. Sibrand Poppema, President University of Groningen*
13.45	20 years a space-driven AGOR user: from supernovae to the international space station *Dr. Sven Rakers, Ariane Group GmbH*
14:20	Presentation of the movie "People make the machine"
14:30	Introduction to the interactive get to know each other at KVI-CART

at KVI-CART

14:45	An interactive get to know each other Demonstrations Guided tour of the AGOR facility
16.00	Reception

www.rug.nl/kvi-cart/

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Practical Information

location: KVI-CART and the Energy Barn
Zernikelaan 25 and 17, 9747 AA Groningen

Free parking is available at both KVI-CART and the Energy Barn.
Bus line 15 travels between the Groningen Main Railway Station and the Zernike Campus (bus stop Zernike Noord) every 5-10 minutes.

contact: http://www.rug.nl/kvi-cart/agor20/
agor20-kvicart@rug.nl
+31 50 363 7522

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