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University Medical Center Groningen

ESTABLISHMENT OF THE NEW PARTICLE THERAPY RESEARCH CENTER (PARTREC) AT UMC-GRONINGEN

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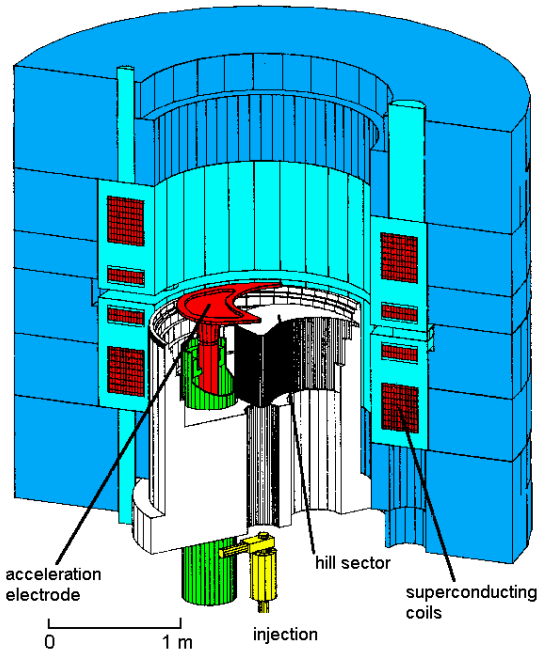

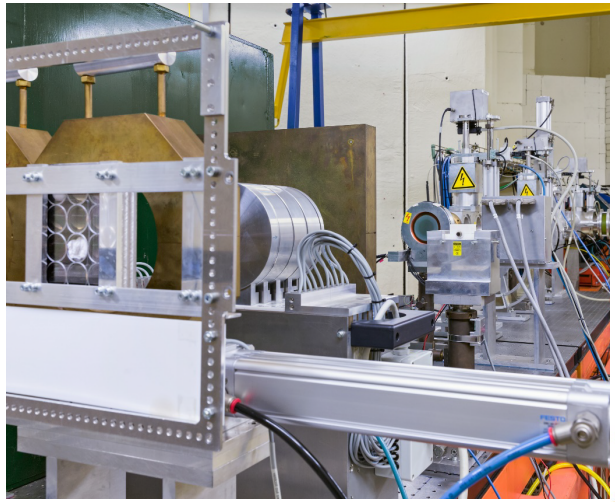

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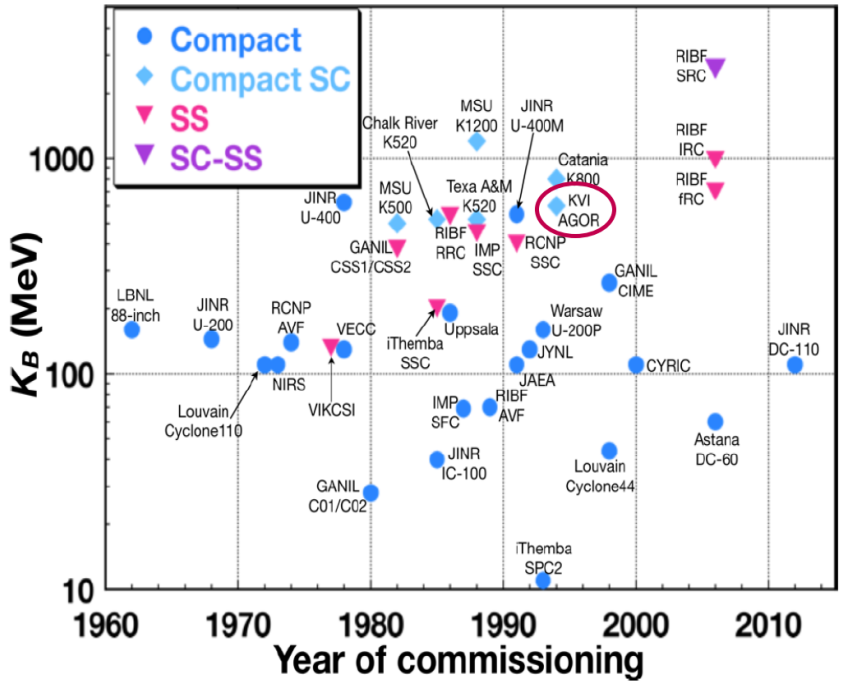
Our Facility

- We operate a large superconducting cyclotron for experimental research

- From our cyclotron's inception, beams were mainly used for research in nuclear physics (light ions) and on fundamental symmetries (heavy ions)

- Emphasis shifted towards detector development and radiation hardness testing (mainly commercial with some funded experimental research) and biomedical research

- Reorganization (September 2020): KVI's accelerator facility, staff and medical physics group was integrated into UMCG and became PARTREC



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REVIEW OF HEAVY-ION CYCLOTRONS

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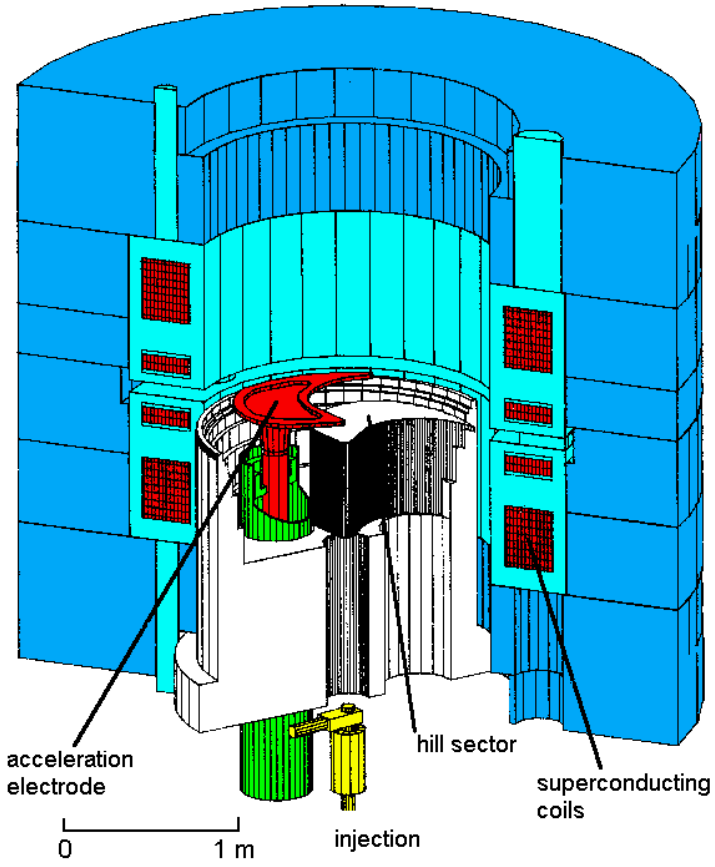
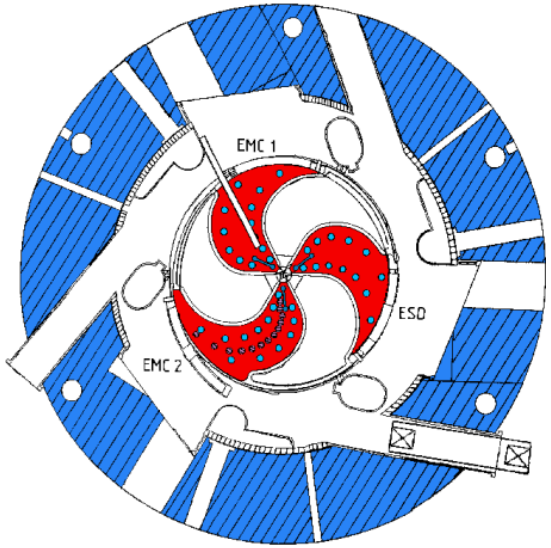
AGOR Cyclotron

- Superconducting AGOR cyclotron is a multi-particle, variable energy AVF-cyclotron
- French-Dutch collaboration built 1987 – 1994
- Operational since 1996
- Magnetic field (1.7 to 4.1 T) produced by
  - two superconducting main coils
  - fifteen trim coils
  - three iron hill sectors for focussing

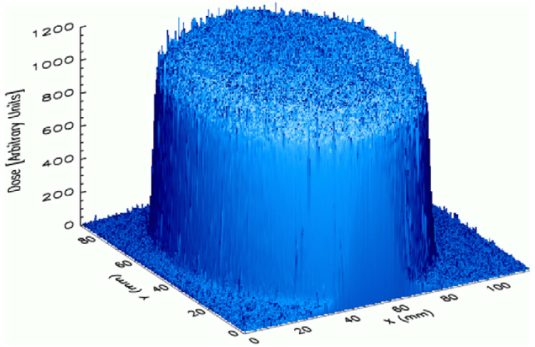
- 3 halfwave RF cavities, 24 - 62 MHz; h = 2, 3 or 4
- Three external ion sources (two ECR sources for heavy ions, multi-cusp source for light ions) are axially injected
- Extraction
  - 300 - 500 turns depending on harmonic mode
  - extraction radius 870 - 890 mm depending on E/A
  - turn separation at extraction 2 - 3 mm ~ beamwidth

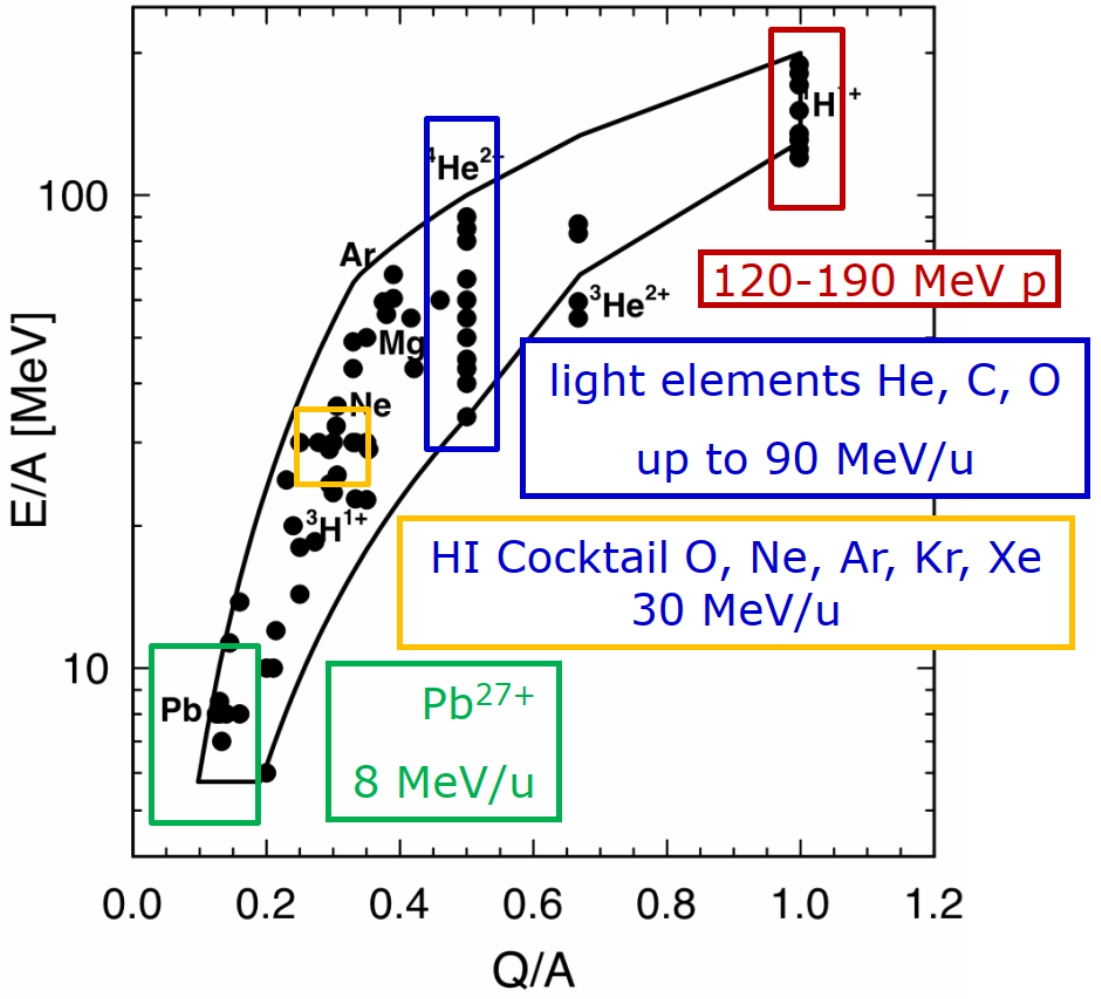




Beam Parameters

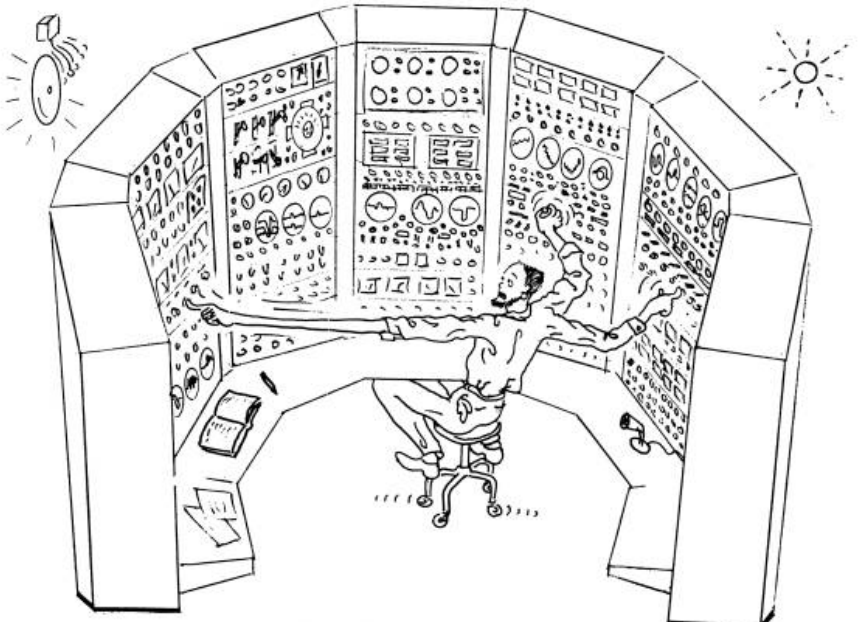
	Protons	Heavy Ions
Kinetic energy (MeV/amu)	≤ 190	≤ 90 for C and O ≤ 30 for all up to Xe
Attainable flux (particles per s)	> 10^{13}	≤ 10^{13} for Ne ≤ 10^{11} for heavier ions
Field size (cm^2)	≤ 10 x 10 (scanned beam) ≤ 8 x 8 (scattered beam)	≤ 7 x 7 for light ions (scanned beam) ≤ 3 x 3 for heavy ions (scanned beam)
Field homogeneity	± 1 % (scanned beam) ± 2 % (scattered beam)	± 1 % (scanned beam) ± 2 % (scattered beam)





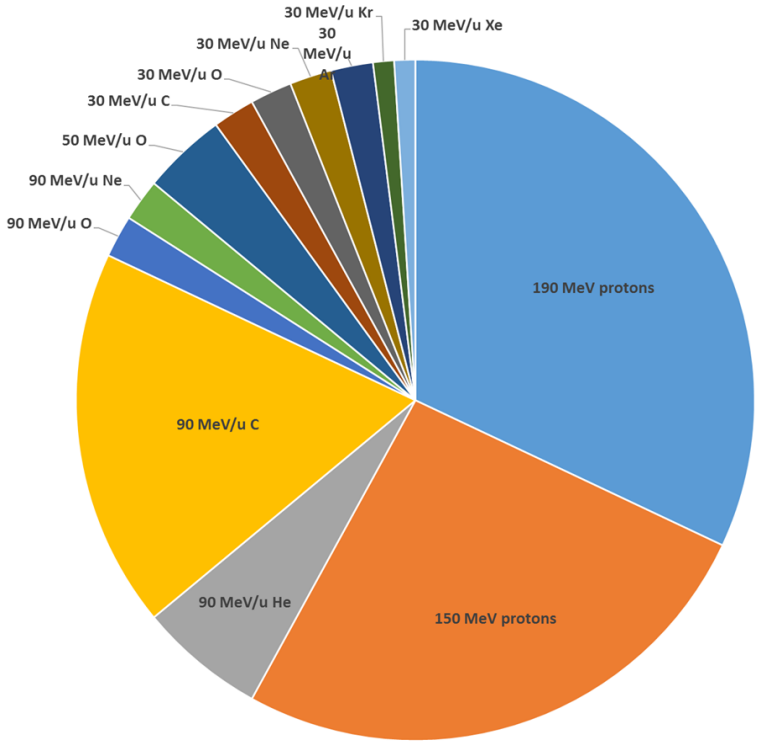
Our Team

- Technical staff (24)
  - Operators to operate and maintain the accelerator (5)
  - Cryogenics, cooling, compressed air and vacuum (2)
  - Design/Mechanical: mechanical repairs, design and construct mechanical components that have become obsolete and contribute to scientific and infrastructure projects (5)
  - Electronics: maintenance of the magnet power supplies, RF-amplifiers, low level RF-electronics, PLC-systems and interfaces of all these systems to the central control system of the accelerator (5)
  - IT Support needed for operation, maintenance and upgrading of the accelerator control system as well as the irradiation control system (3)
  - Experimental and project support provided to internal/external scientists as well as companies, ECR sources (4)
- Faculty (4)
- Post-docs (2)
- PhD-students (5)

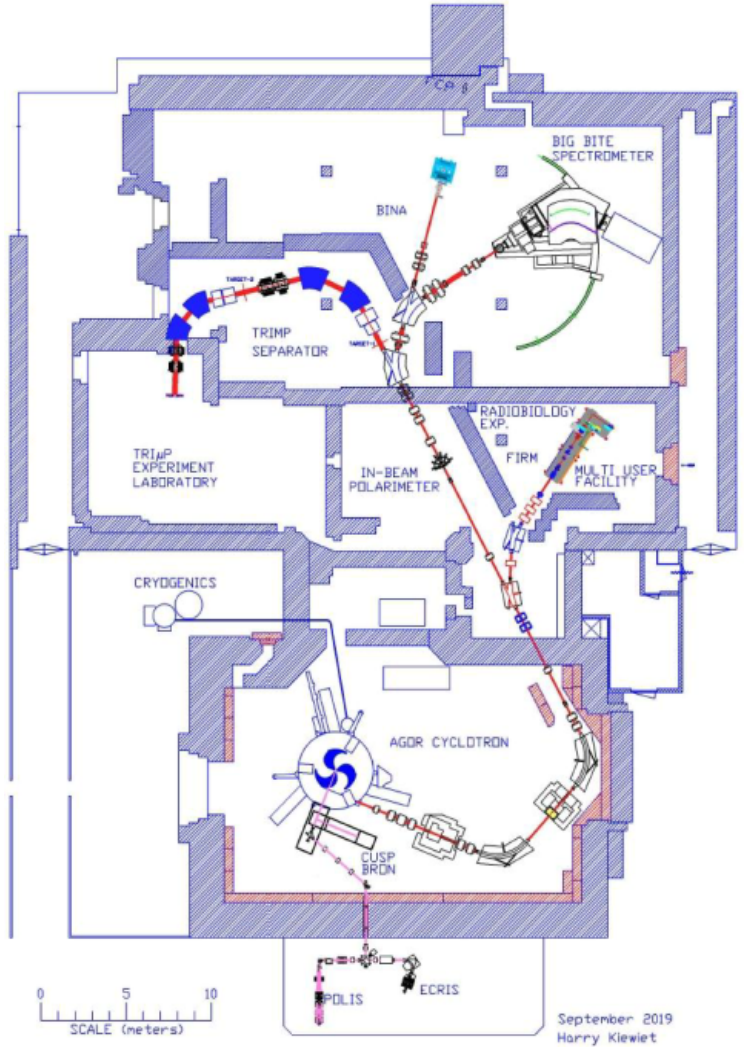


PARTEC Accelerator Operation

- We strive to provide a reliable and reproducible ion beam to satisfy the needs of the user
- Operational 120 hours/week, 26 weeks/year
- Beam requests: irradiations.partrec@umcg.nl
- Proton beams requested for 59% of beam time



KVI facility layout before PARTREC upgrades

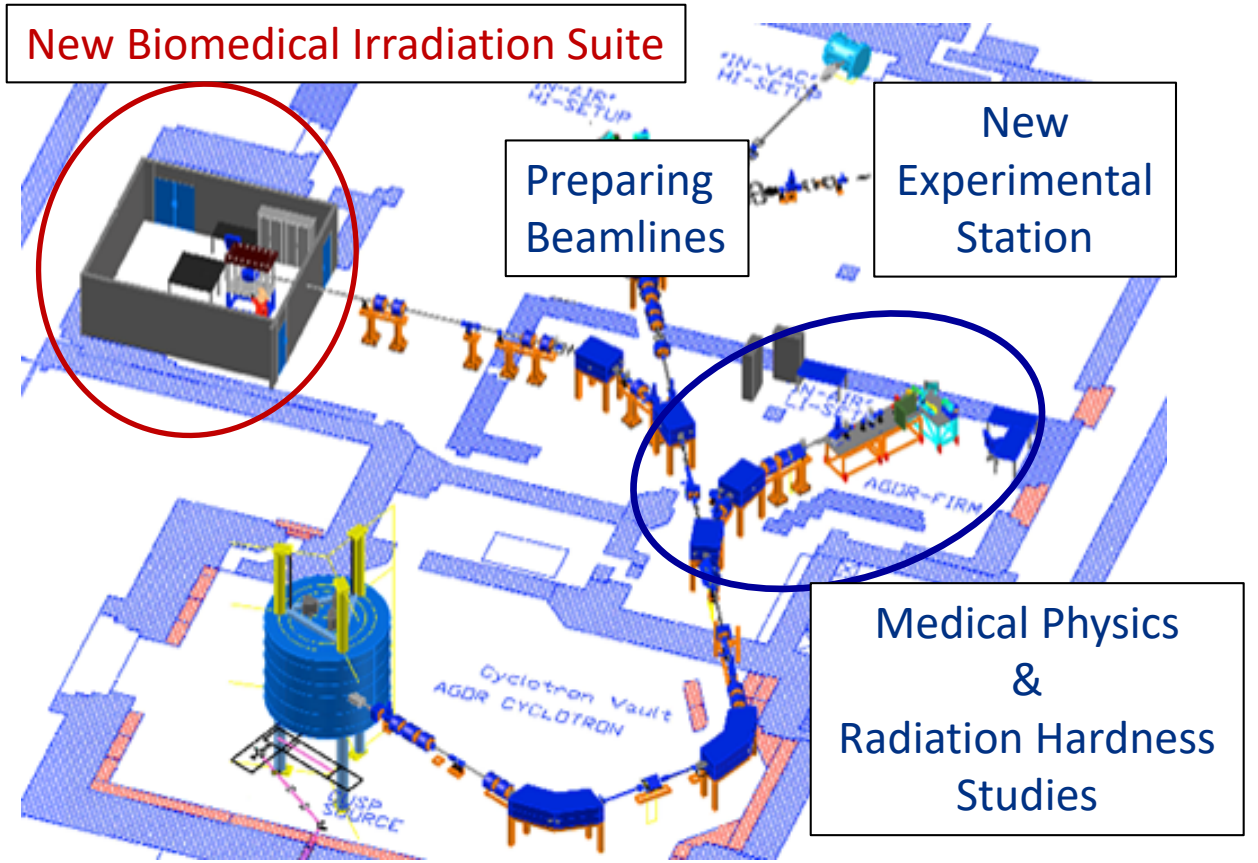


Our Users and Funding

- Recognized by ESA as Ground-Based Facility (CORA-IBER, Investigating biological effects of space radiation)
- Supported by EU as Large-Scale Facility (IAs RADNEXT, INSPIRE)
- Commercial Funding:
  - Mainly proton in-air irradiations
  - Expanding heavy ions
  - Mostly non-domestic aerospace
- Local and national funding (RUG, UMCG, KWF, NWO)

Research Plans For New Infrastructure

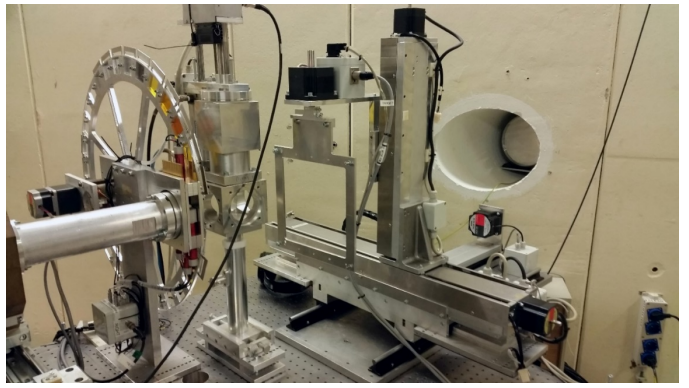
- To extend PARTREC's research capabilities, new infrastructure under development
- Includes the design, installation and commissioning of a new beam line for biomedical research
- New dose delivery modalities that include scattering and pencil beam scanning, shoot-through with high energy protons as well as SOBP for protons and helium
- Adaptation of the facility for the delivery of spatial fractionation and high dose rates in excess of 300 Gy/s (FLASH)



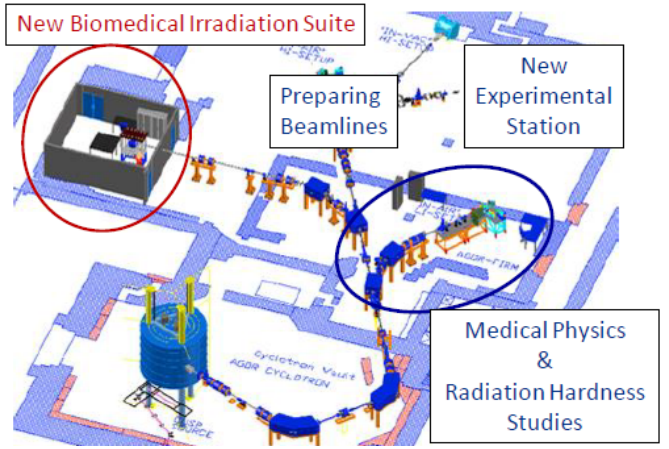
Research Ambitions of New Infrastructure

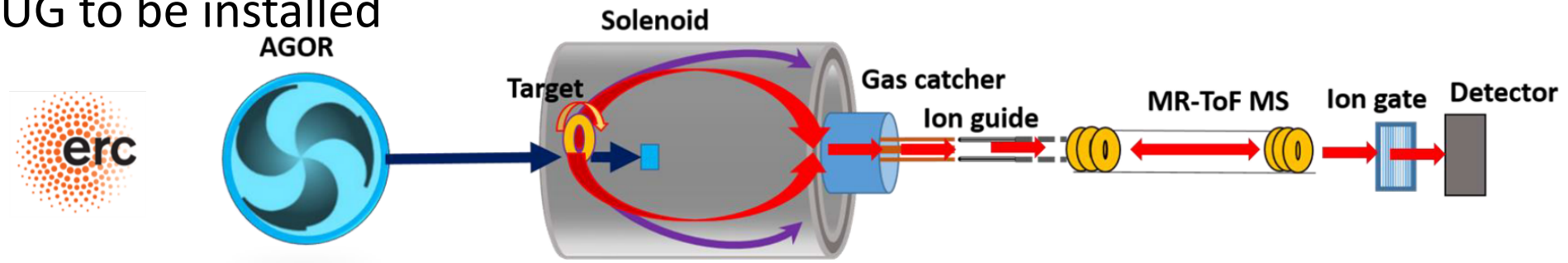
- Studies of Radiation Sensitivity Variations Within Normal Tissue and Tumour
- Biological and Physical Radiation Effects in Space
- LET and RBE Studies for Biological Treatment Planning
- Advanced Radiotherapy Dose Delivery Techniques, such as GRID or FLASH
- Therapeutic Window Optimization and Translation to the Clinic
- Radiation Effects on Electronics
- Testing Particle Detectors

Heavy Ion Beams



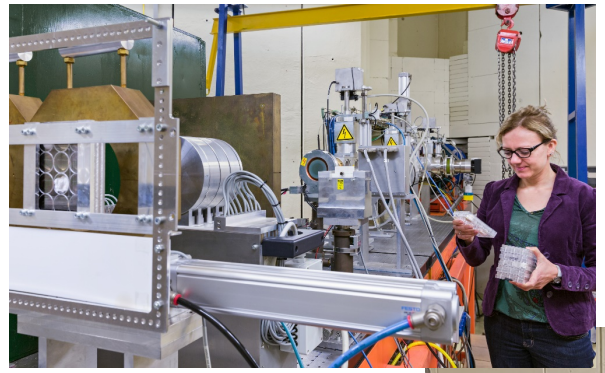
- Main research areas for heavy ion beams: Detector Tests and Development, Radiation Hardness, and Radiobiology
- ERC-funded experimental research on the production of neutron-rich heavy nuclei using multi-nucleon transfer reactions between heavy nuclei (e.g. ^{136}Xe, ^{209}Bi) is an ongoing project
- Requires ECR ion source development to improve transmission from ion source to cyclotron extraction
- A new experimental setup consisting of a 3 T superconducting solenoid fragment separator and MR-ToF mass spectrometer is developed with RUG to be installed

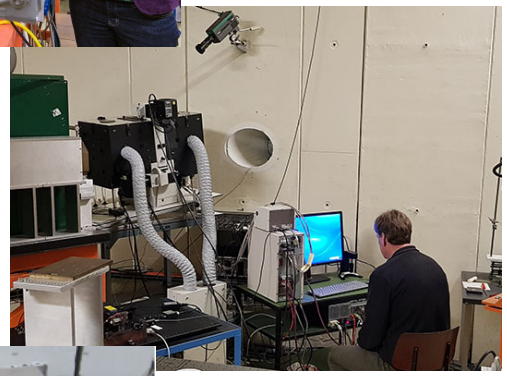


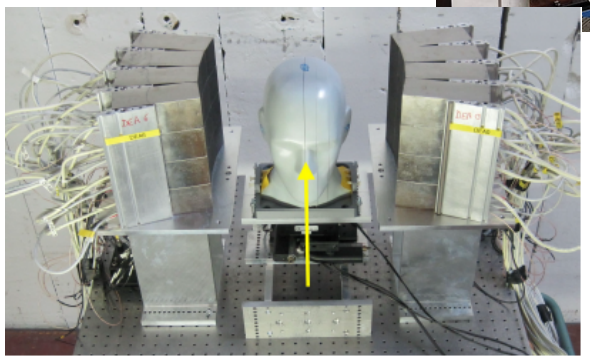


Biomedical Research For New Infrastructure

- Currently: animal (rats) experiments (protons, helium), cell cultures and organoids (protons to neon), detector characterization & dosimetry studies (protons to carbon)
- A new beam line with 3D X-ray and bioluminescence imagining at the irradiation position (individually optimized small animal irradiations) will be built
- Active proton radiography program in collaboration with the GPTC exists and advanced detector technologies, such as PET scanner panels around a head-shaped phantom for the optimization of margins for head-and-neck tumour treatment are under development

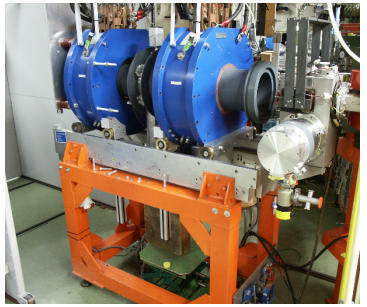


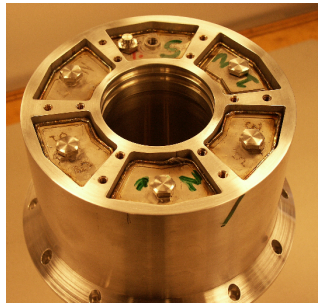




FLASH Irradiations Research

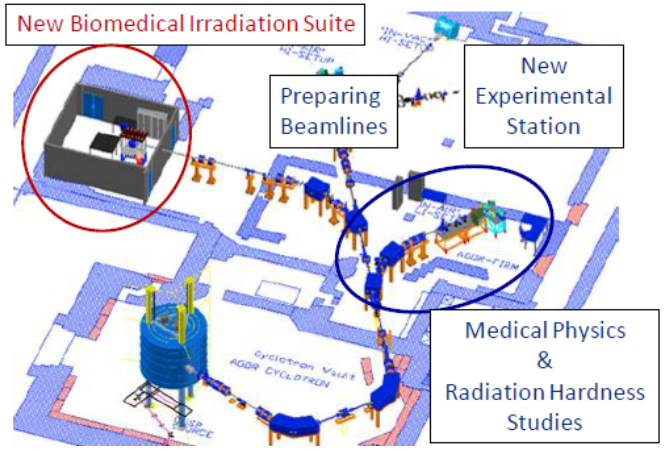
- FLASH effect occurs at high irradiation rates (100 Gy/s)
- FLASH radiation damages healthy tissue less, while delivering full damage to the tumour tissue -> increases therapeutic window
- Beam intensity already provided:
  - proton, helium dose rate 10^2 - 10^4 Gy/s, dependent on field size
  - 90 MeV/A carbon SOBP dose rate up to 200 Gy/min
- Further increase under development (improvement of the source performance and transmission into the cyclotron)
- Establish beam parameters, dose delivery and control methods in conformity with ones clinically achievable for FLASH beam irradiations at GPTC and at other facilities.





One-Stop-Shop

- It is envisaged for PARTREC to provide users a one-stop-shop facility
- PARTREC will support users during the complete process of experiment development, ethics authorisation process, irradiation + follow-up, animal procurement logistics
- On-site animal accommodation with IVCs
  - capacity 200 rats or mice
  - two additional accommodations planned
- Laboratory for animal handling prior and post irradiation
- GronSAI center (Optical, Molecular, CT, MRI)



Summary

- UMCG has unique combination of treatment facility (GPTC)
  and research center accelerator facility (PARTREC)
- PARTREC routinely delivers protons (<190 MeV) and ions up to Xe for:
  - Commercial and institutional irradiation tests
  - Radiobiology and medicine
  - Nuclear physics research
- Ongoing upgrades include:
  - Very heavy ions acceleration (up to ^{209}Bi)
  - Higher dose rates for FLASH
  - New infrastructure for animal, organoid and cell irradiation
- Acknowledgements:

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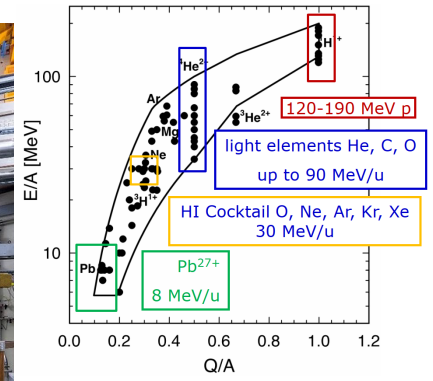

DUTCH CANCER SOCIETY

esa European Space Agency

NWO Netherlands Organisation for Scientific Research

ZonMw

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Thank you!

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