

# Radionuclide Production with Cyclotrons

## Proposal for a CHERNE Summer School

12th CHERNE Workshop

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2. Facility Layout – Radiation Protection (Planning, Routine)
3. Target Design
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## Motivation

The demand of **radiopharmaceuticals** is increasing steadily

This is presently caused by new imaging technologies combining two imaging modalities: e.g. **SPECT/CT, PET/CT, MRI/PET**

The combination of high resolution anatomical imaging combined with functional imaging has great diagnostic advantages.

Usage of these technologies requires radiopharmaceuticals labelled with short-lived radionuclides which have to be produced locally briefly before consumption.



## Motivation 2

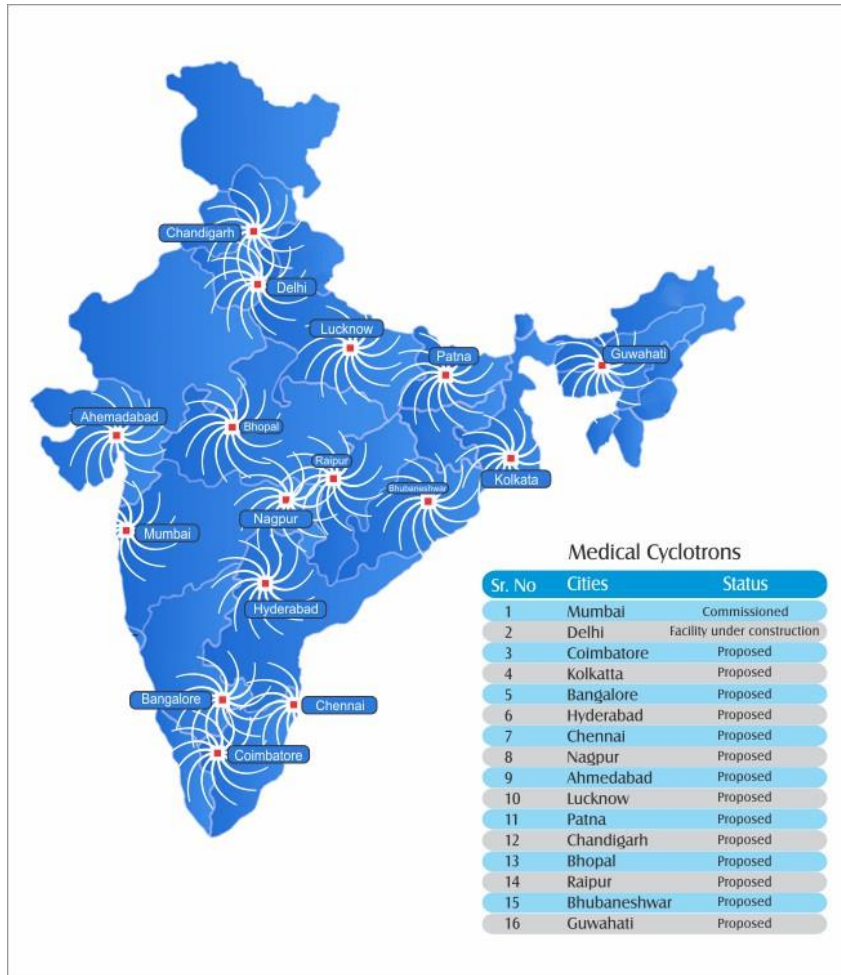
Besides of the classical „**organic isotopes**“ i.e.  $^{11}\text{C}$ ,  $^{13}\text{N}$ ,  $^{15}\text{O}$ ,  $^{18}\text{F}$  other **metallic radionuclides** e.g.  $^{64}\text{Cu}$ ,  $^{89}\text{Zr}$ ,  $^{177}\text{Lu}$ ,  $^{213}\text{Bi}$ ,  $^{225}\text{Ac}$  are of increased interest but are **not produced in most countries on a regular scale.**

Some radionuclides e.g.  $^{68}\text{Ga}$  can be produced from **radionuclide generators** which are commercially available.

This development lead to an **increased number of radiopharmacists educated** in radiolabelling techniques, handling of automated synthesizers and the pharmaceutical production conditions.



## Medical Cyclotrons planned in India



The number of medical cyclotrons keeps increasing steadily, even in countries like India.



## Motivation 3

**There is a lack in graduates educated for cyclotron operations or radionuclide production.**

Targets for the standard radionuclides can be obtained commercially but some of them are not easily operated and maintained in a daily production routine.

Moreover, targets for non-standard radionuclides need to be constructed and tested.

**Hence, there is the need of educating engineering and science students for these applications.**

**We propose a CHERNE summer school covering relevant topics.**



## Curriculum 1

### Facility Layout – Radiation Protection Planning

Most of the facilities are planned from scratch in new buildings erected for that purpose.

Radiation Protection issues should be integrated in the planning stages, e.g. the layout of the cyclotron and target vault(s).

There are technical norms e.g.

- DIN 6871-1: Zyklotron-Anlagen für die Positronen-Emissions-Tomographie. Teil 1: Anforderungen an den baulichen Strahlenschutz
  - DIN 6871-2: Zyklotron-Anlagen für die Positronen-Emissions-Tomographie. Teil 2: Strahlenschutzlabyrinth und Wanddurchführungen
- or similar regulations.

MC calculations provide additional planning data.





## Curriculum 2

### Facility Layout – Radiation Protection Routines

In the phase of operations Radiation Protection Routines have to be established and maintained.

Best practice rules should be implemented in education covering e.g.

- access controls and interlocks
- survey measurements during scheduled operations and extraordinary situations
- control of the gaseous effluents
- protection during scheduled and emergency maintenance
- procedures for handling leakages of targets and pipelines to radiochemistry laboratories
- ....





## Curriculum 3

### Target Design

The module starts with lecture and calculated problems on radionuclide production (theory of nuclear reactions to target design and operations, as well as radiochemistry and hot-atom chemistry)

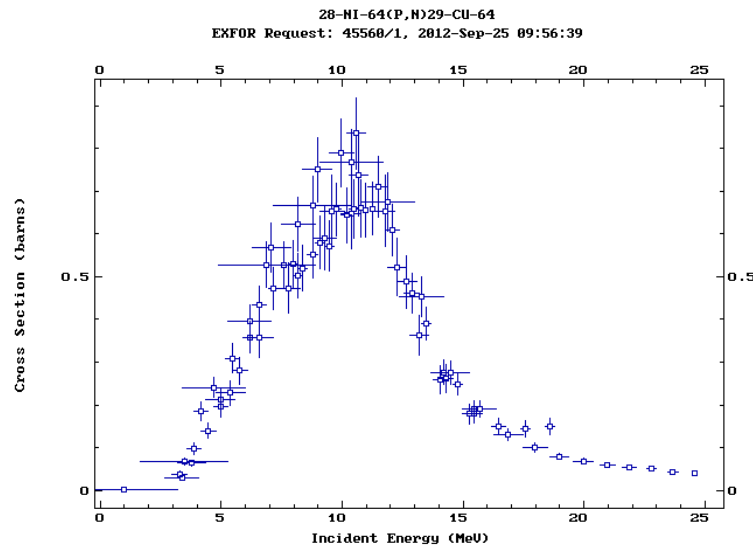
The design principles of targets for the production of standard and non-standard are instructed by analysing target designs for existing targets and having the students doing design studies using model calculations (e.g. SRIM, COMSOL, MC...)

”



# Development of a Cyclotron Target $^{64}\text{Ni}(p,n)^{64}\text{Cu}$

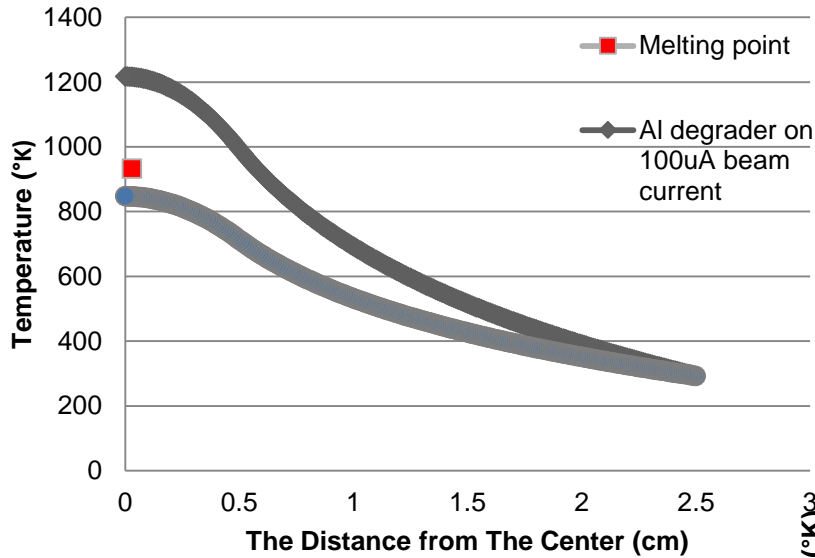
Starting from the known excitation function



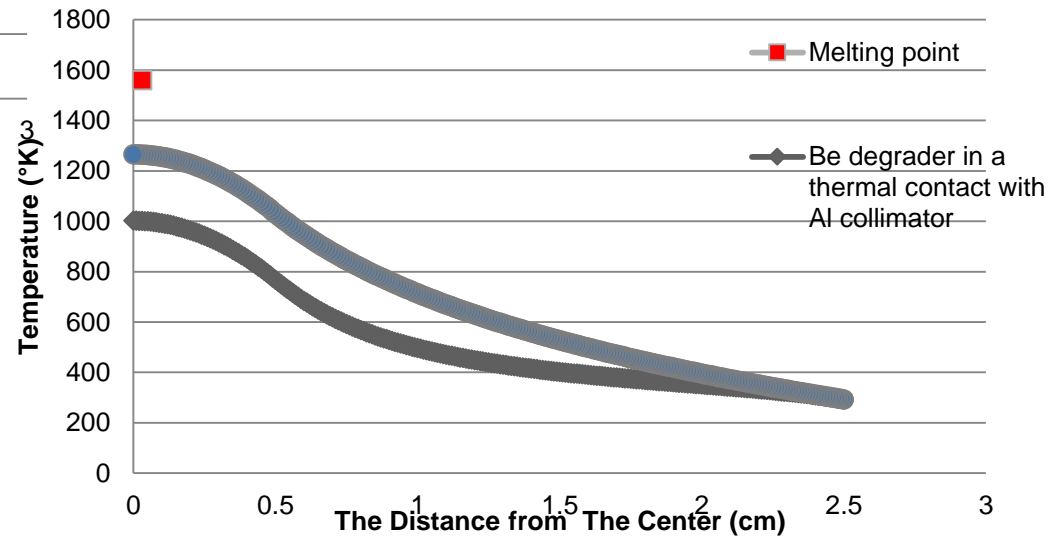
or measuring the data with a foil stack target.



## Heat Deposition in Degradar Foil



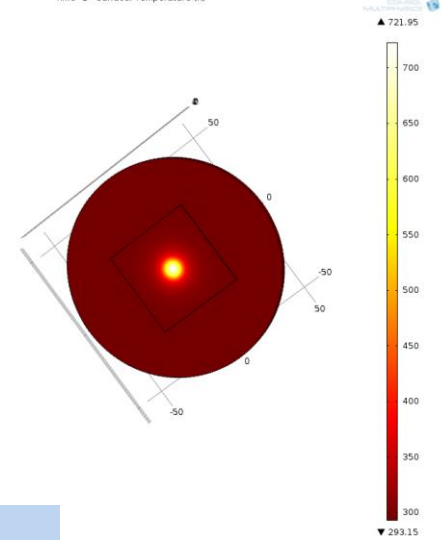
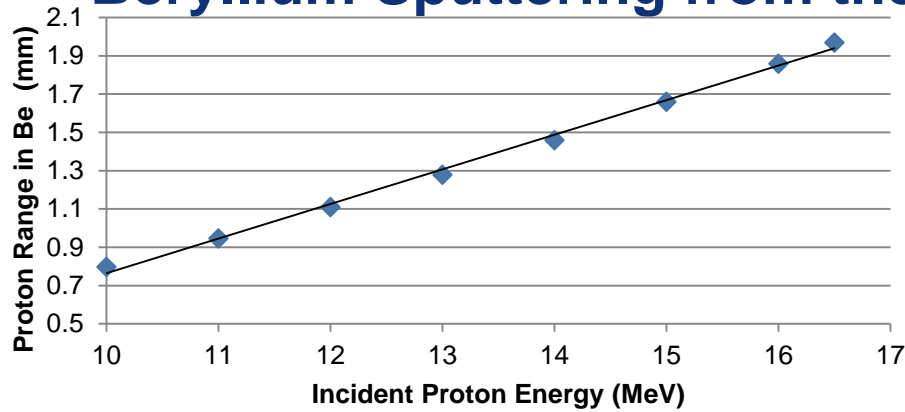
**5 MV \* 100μA = 500 W**



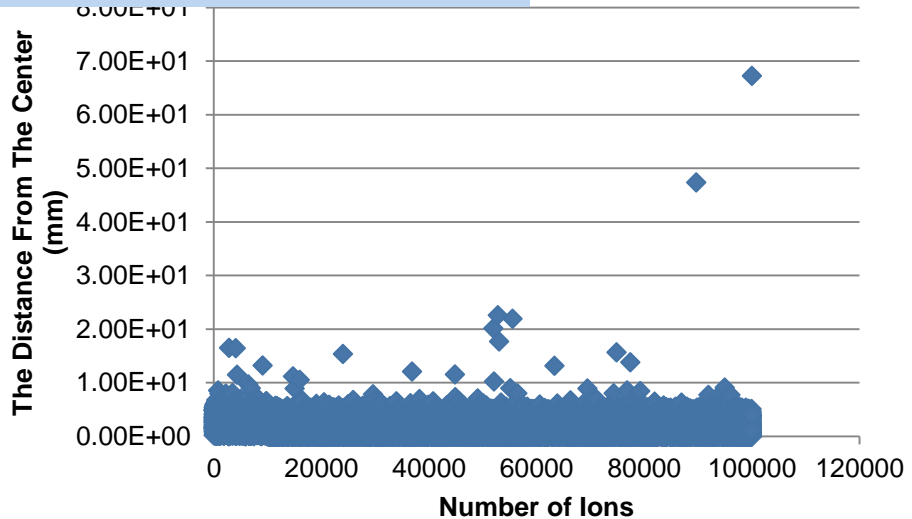
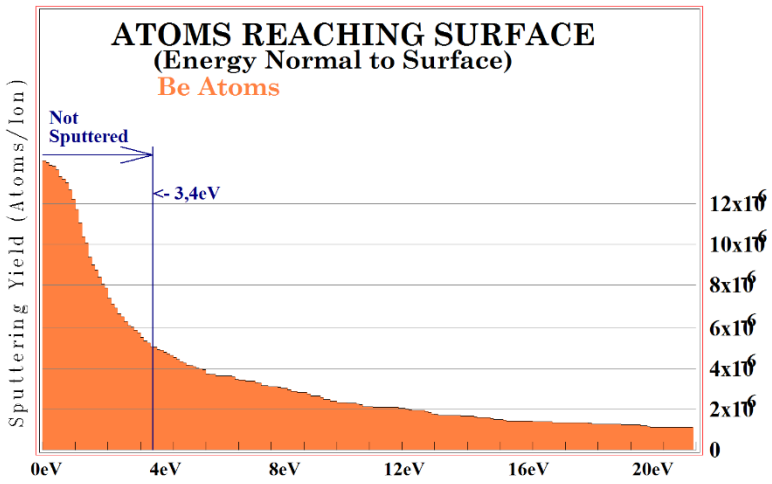


Time=1 Surface: Temperature (K)

# Beryllium Sputtering from the Degradator

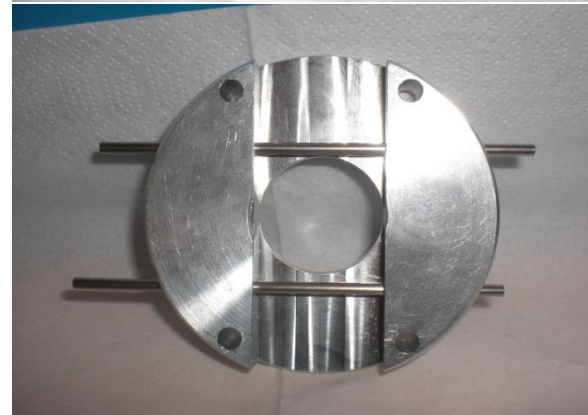
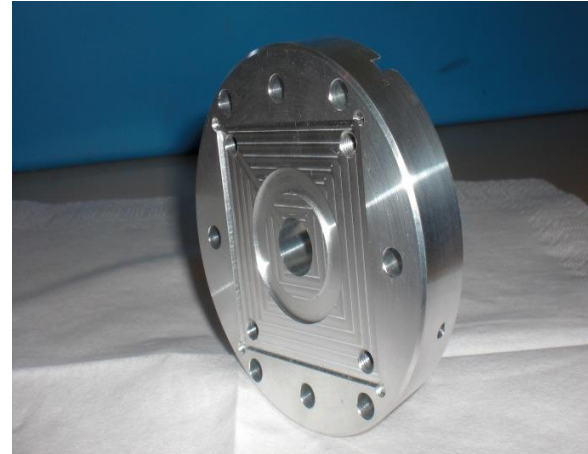


Loss during 1 h at 100μA : ~0,25 ng Be





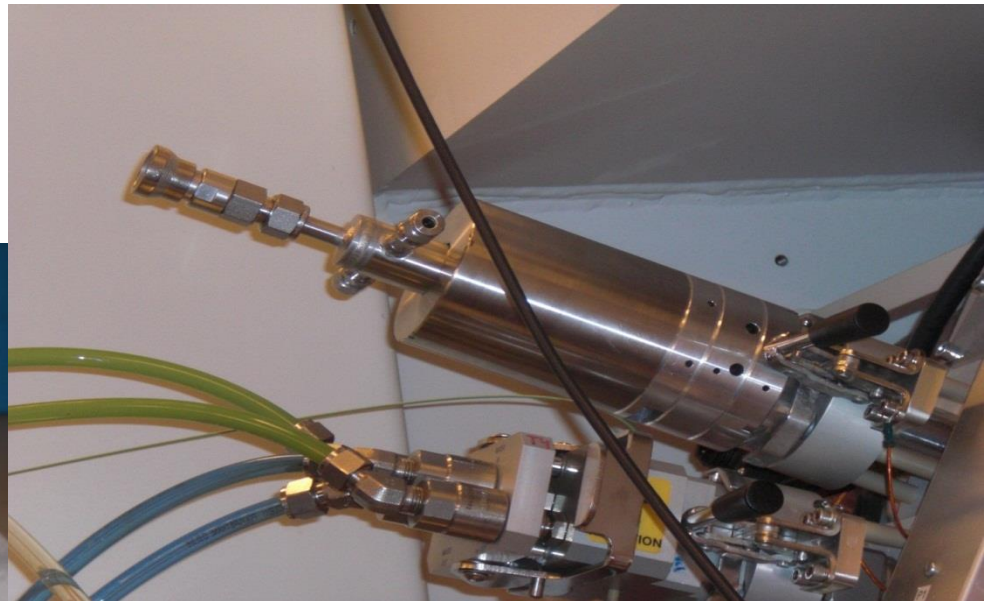
## Technical Realisation 1







## Cooling System for 1100W on the Backing





## Testing with High Proton Fluxes (100 – 150 $\mu\text{A}$ )







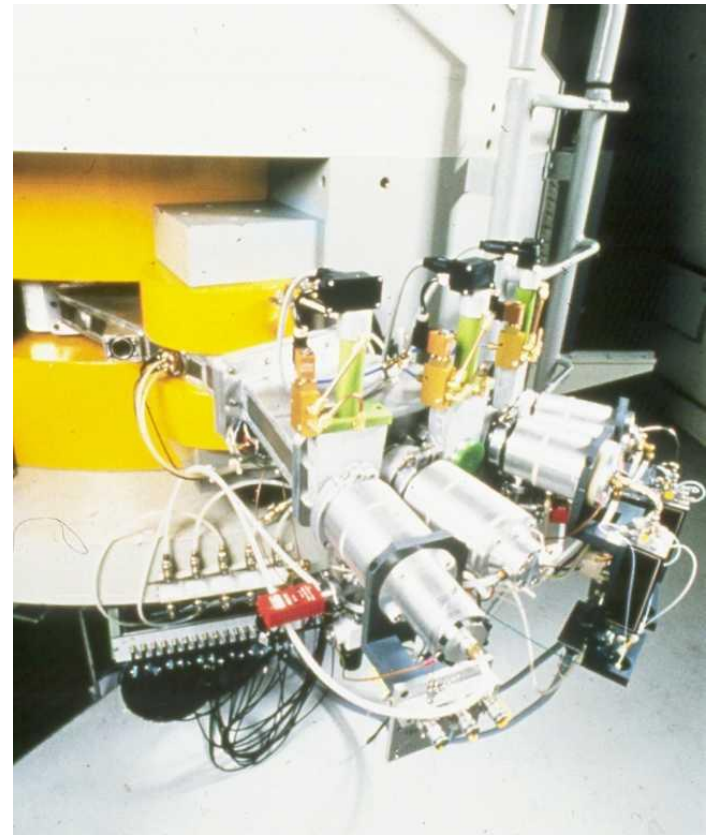
## Curriculum 4 Operations

After theoretical introductions on design and operating principles of cyclotrons calculated and practical exercises to different aspects of cyclotron operations and radionuclide production are performed including the formal aspects.

Radiation Protection is a permanent topic in all modules.

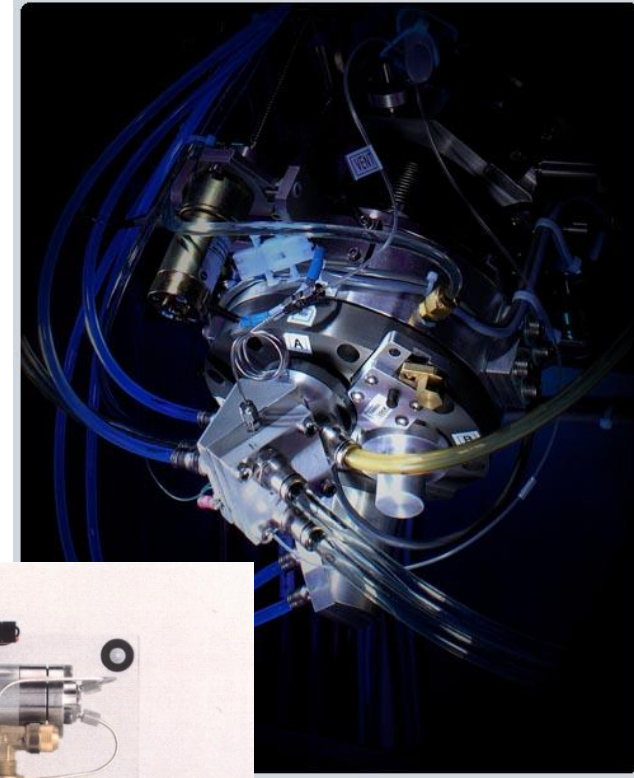


## Peripheral Target Stations

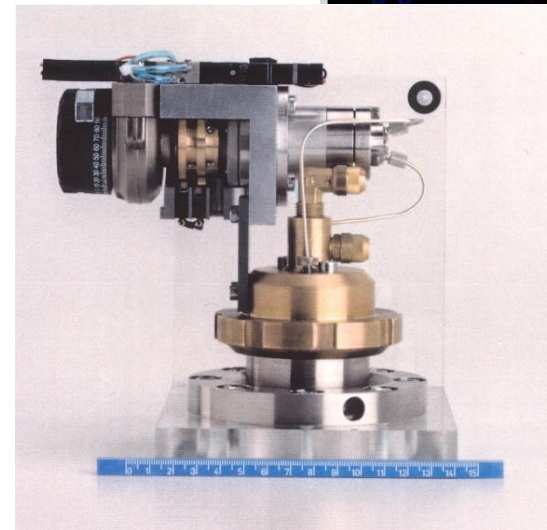




## External Cyclotron Targets



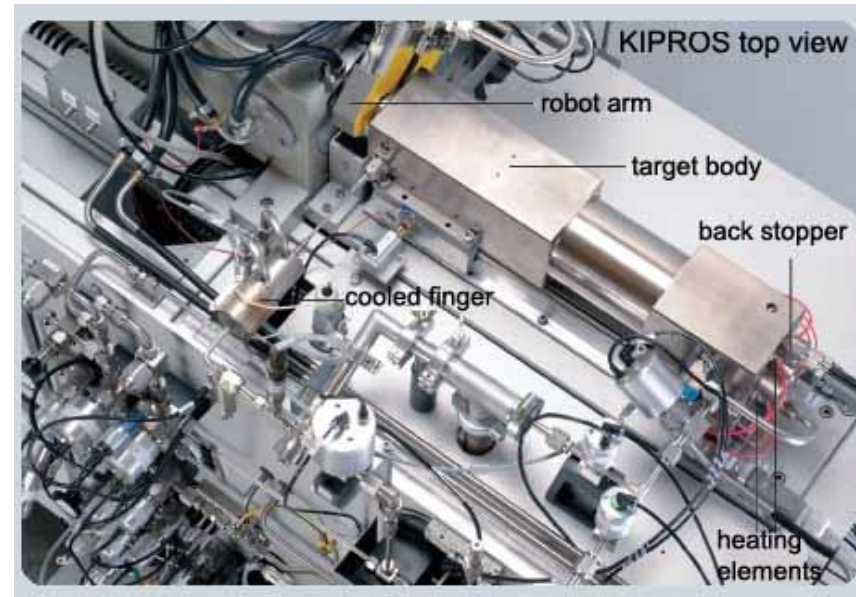
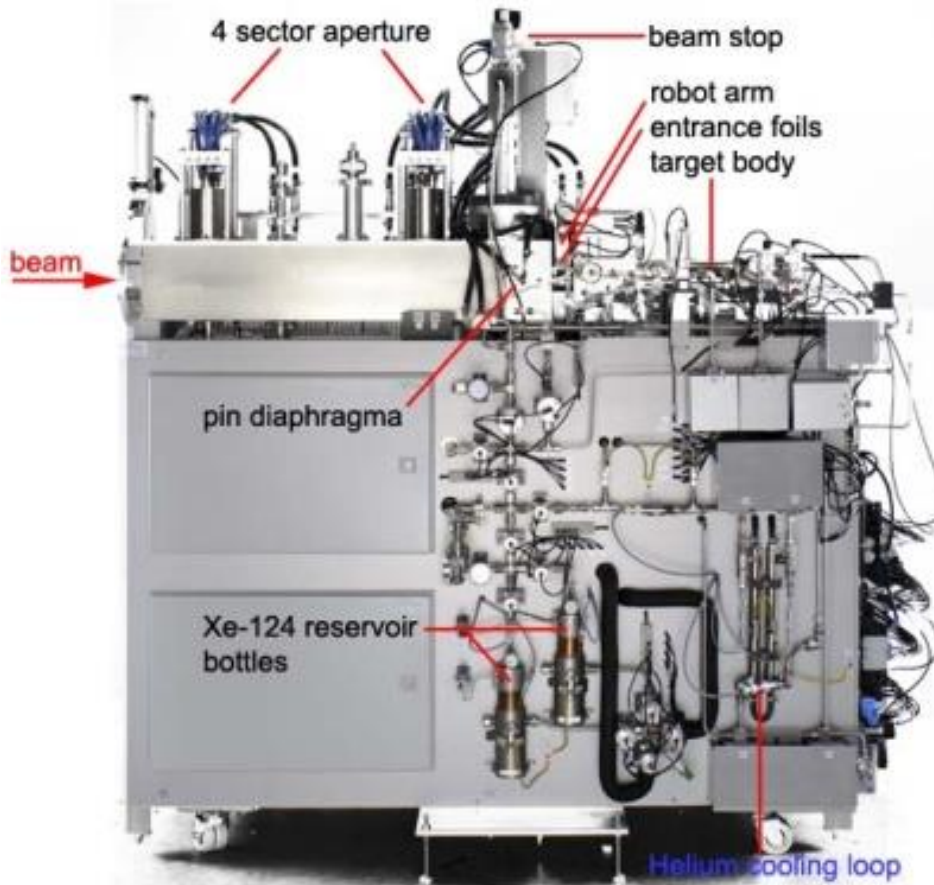
Typically designed for high beam intensities  
<250  $\mu\text{A}$  protons or  
<100  $\mu\text{A}$  deuterons







# KIPROS-Target





## Extra-curricular Activities



Mannheim is located in the center of the Rhein-Neckar Metropolitan Area which is not only well-known for its excellent educational institutions and industries but also for its rich cultural heritage and life.





## Summary

Intensive course for 14 participants from the CHERNE network

1 week duration in co-operation with local cyclotron facilities

Planned for September 2017



# Thank you for your attention !

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# Mannheim University of Applied Sciences







# State of Baden-Württemberg

## Facts and Figures



Area: 35.752 km<sup>2</sup>

(~ 10 % of Germany)

One of the most innovative regions in Europe

(ref: Innovation-index on research, invest and patents)

Inhabitants: 10.8 million

(~ 13.5% of Germany)

Low unemployment rate of 4 % (2013)

30 % of GDP by industry



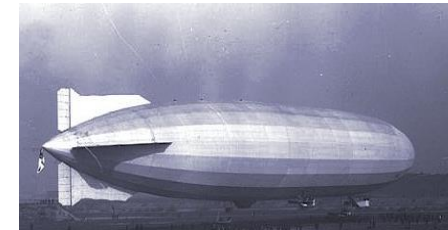
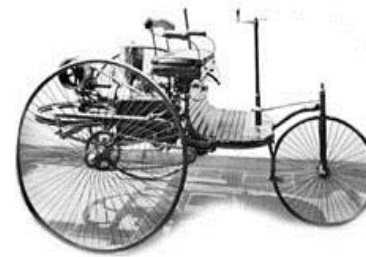






## Mannheim

- City of
  - Inventions
  - Sciences
  - Art and culture
  - Business
- 328.000 inhabitants/71.000 foreign
- 177.000 employees/125.000 services sector
- 9 institutions of higher education with 36.000 students
- Significant global companies
- 12,6 entrepreneurs/1000 inhabitants





## Mannheim University of Applied Sciences

- 5400 students
- 900 international students
- 182 professors
- Staff           179 academic staff  
                    119 non-academic staff
- 9 faculties
- 34 Bachelor and Master programmes
- Budget 42 Mio. €/a (without buildings)



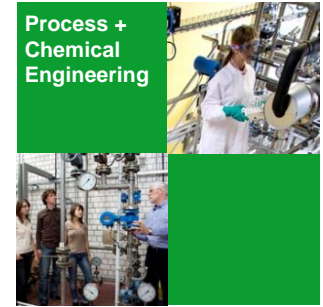
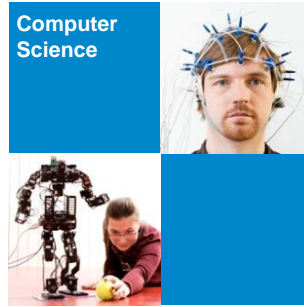








# Faculties





# Study programs

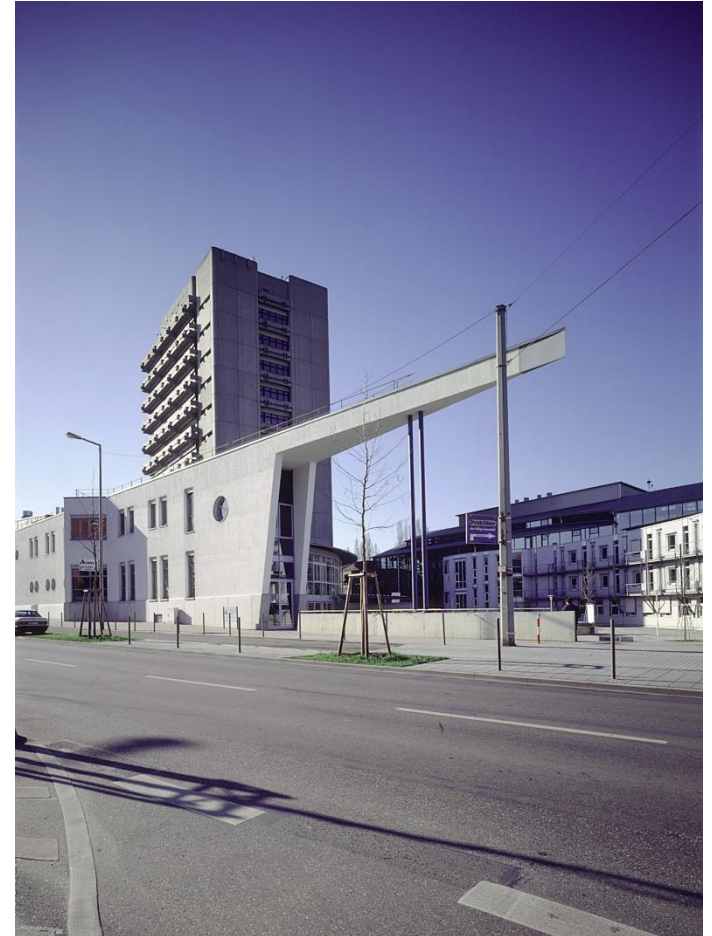
	<p><b>Information Technology</b></p> <p>Electronics (Bachelor)</p> <p>Computer Engineering (Bachelor)</p> <p>Medical Technology (Bachelor)</p> <p>Information Technology (Master)</p>		<p><b>Electrical Engineering</b></p> <p>Automation Technology (Bachelor)</p> <p>Power Engineering and Renewable Energies (Bachelor)</p> <p>Mechatronics (Bachelor)</p> <p>Translation Studies for Information Technologies (Bachelor)</p> <p>Teaching in Professional Schools (Bachelor, Master)</p> <p>Automation and Energy Systems (Master)</p>		<p><b>Biotechnology</b></p> <p>Biotechnology (Bachelor)</p> <p>Biological Chemistry (Bachelor)</p> <p>Biotechnology (Master)</p>
<p><b>Process + Chemical Engineering</b></p> <p>Chemical Technology (Bachelor)</p> <p>Process Engineering (Bachelor)</p> <p>Chemical Engineering (Master)</p> <p>Franco-German course Process Engineering</p>		<p><b>Social Work</b></p> <p>Social Work (Bachelor)</p> <p>Social Work (Master)</p>		<p><b>Computer Science</b></p> <p>Computer Science (Bachelor)</p> <p>Medical Informatics (Bachelor)</p> <p>Enterprise Computing (Bachelor)</p> <p>Computer Science (Master)</p>	
	<p><b>Design</b></p> <p>Communication Design (Bachelor)</p> <p>Communication Design (Master)</p>		<p><b>Engineering Management</b></p> <p>Engineering Management (Bachelor)</p> <p>Engineering Management (Master)</p>		<p><b>Mechanical Engineering</b></p> <p>Mechanical Engineering/ Design (Bachelor)</p> <p>Mechanical Engineering/ Production (Bachelor)</p> <p>Mechanical Engineering (Master)</p> <p>Franco-German course Mechanical Engineering</p>



## R&D Centers

- Modern Production Systems
- Power Plant Service and Energy Efficiency
- Institute for Medical Technology
- Virtual Engineering
- TurboAcademy
- Tribology



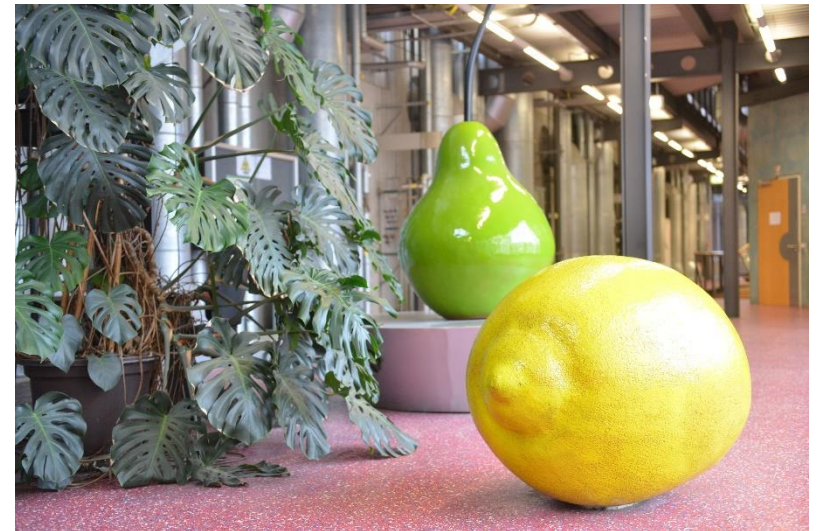






## Business partners













Thanks for your attention