UNIVERSITÄT BERN

Multi-disciplinary research activities and beam diagnostic detector developments at the Bern medical cyclotron

Saverio Braccini

Albert Einstein Center for Fundamental Physics
Laboratory for High Energy Physics
University of Bern

Outline

UNIVERSITÄT BERN

- Medical cyclotrons and their potential for research
- Bern cyclotron laboratory: production and research “under the same roof”
- GMP radiopharmaceutical industrial production (highlights)
- Some on-going research activities:
  - Particle detectors for beam monitoring
  - Methods for accelerator physics
  - Radiation hardness
  - Theragnostic radioisotopes
- Conclusions and outlook

Compact medical cyclotrons

UNIVERSITÄT BERN

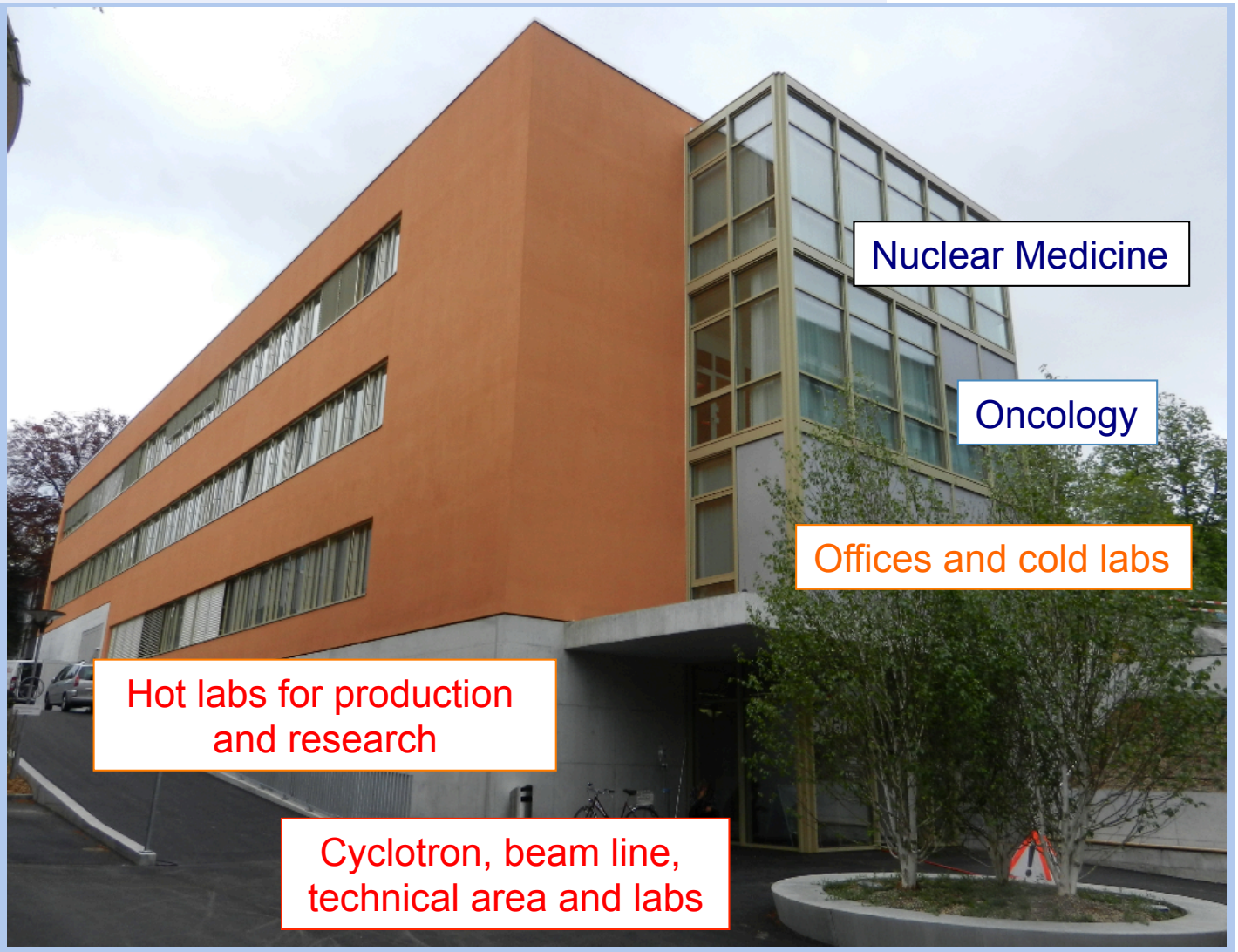
Manufacturer	Model	Particles	Energy (MeV)	Max. Beam Current (μA)	Source	Extracted Beams
ACSI	TR19	H^- (D^-)	14-19 (9)	>300 (100)	Ext. Cusp	2
ACSI	TR24	H^-	15-24	>300	Ext. Cusp	2
Best	15p	H^-	15	400	Ext. Cusp	2
Best	25p	H^-	25	400	Ext. Cusp	2
GE	PETtrace	H^- / D^-	16.5 / 8.4	>80 / 60	Int. PIG	6
IBA	Cyclone 18/9	H^- (D^-)	18 (9)	>100 (65)	Int. PIG	8
IBA	KIUBE	H^-	18	200	Int. PIG adjustable	8
Sumitomo	HM-18	H^- / D^-	18 (10)	>90 / 50	Int. PIG	2

- Commercial accelerators (> 300 in operation)
- PET radioisotope production (almost only) during the night
- Available beam time for research and training
- Complementary with respect to large infrastructures

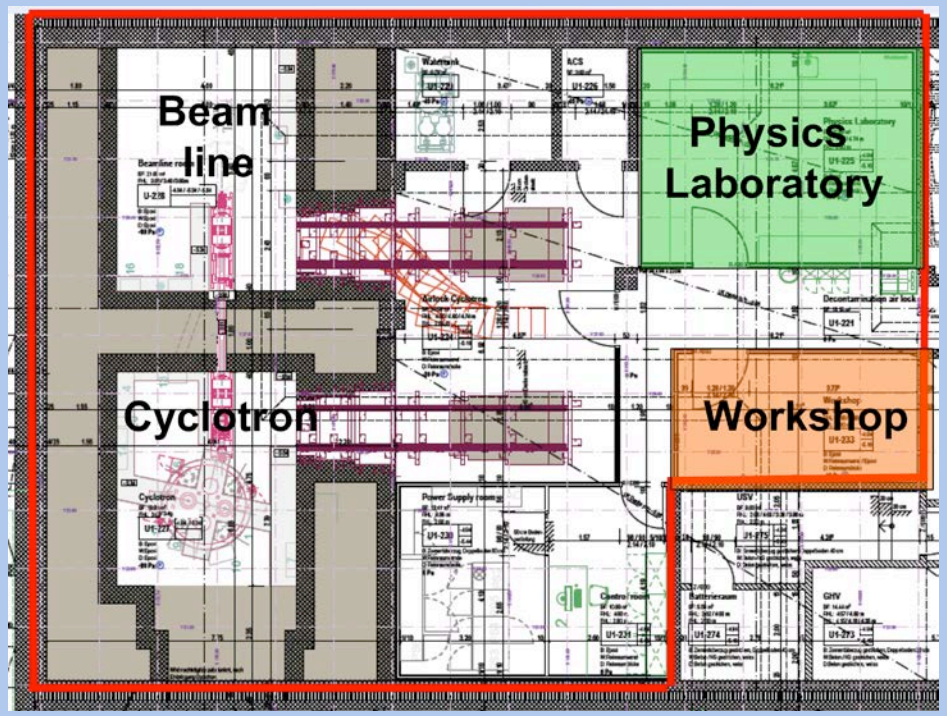
Bern medical cyclotron: operational since may 2013

Construction of the cyclotron bunker
June 2010

Cyclotron rigging
June 2011

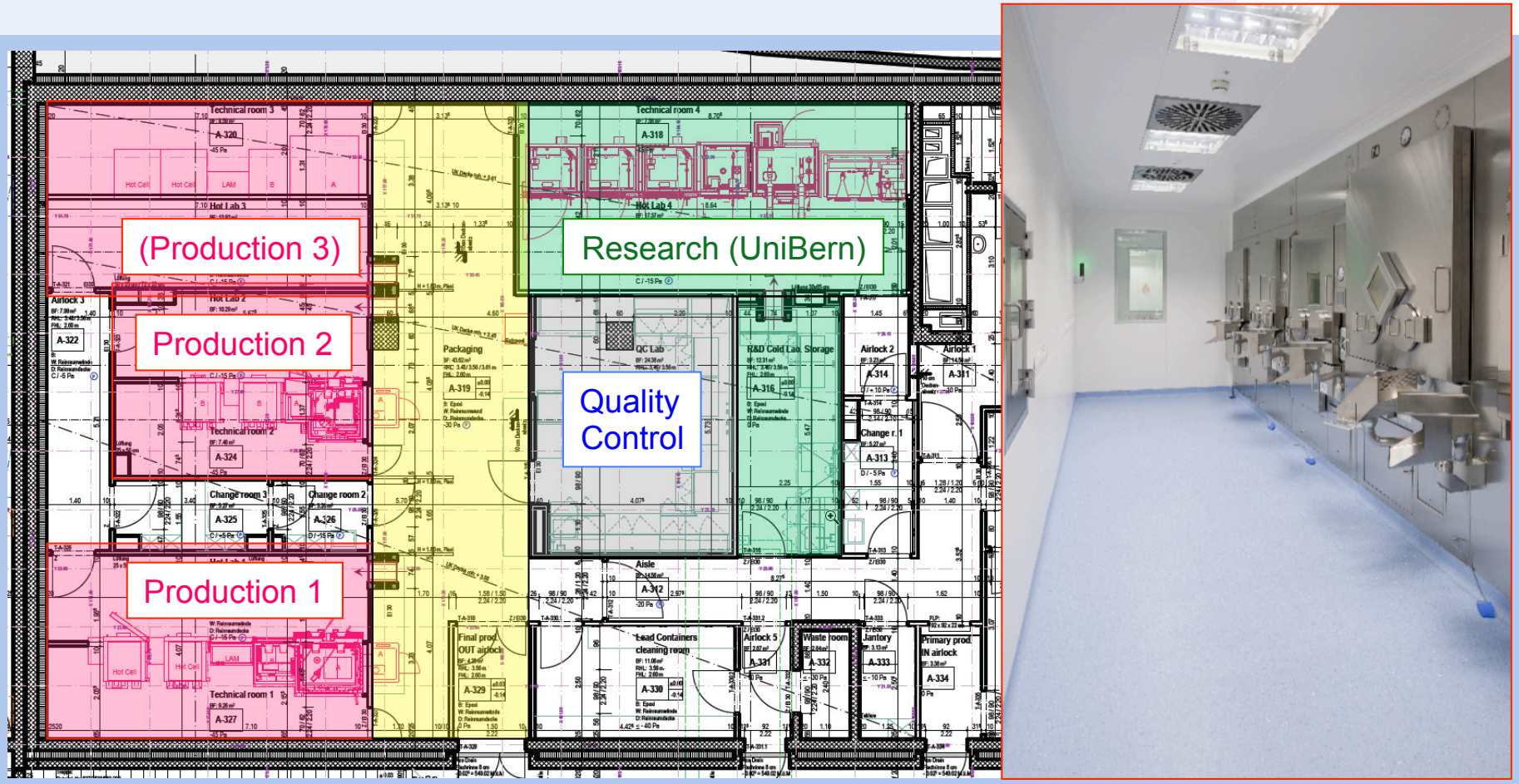


The cyclotron and the Beam Transport Line (BTL)



- IBA 18 MeV “twin” (two H^- ion sources) high current (150 mA) cyclotron
- 8 out ports (4 ^{18}F liquid targets, BTL, solid target, *^{15}O gas target,* 1 spare)
- Beam line + separate bunker (UniBern): production and research in parallel

The hot labs



- 2 GMP production labs (FDG, ^{18}F compounds) + future developments
- 1 multi-function research lab (UniBern)

GMP radiopharmaceutical production

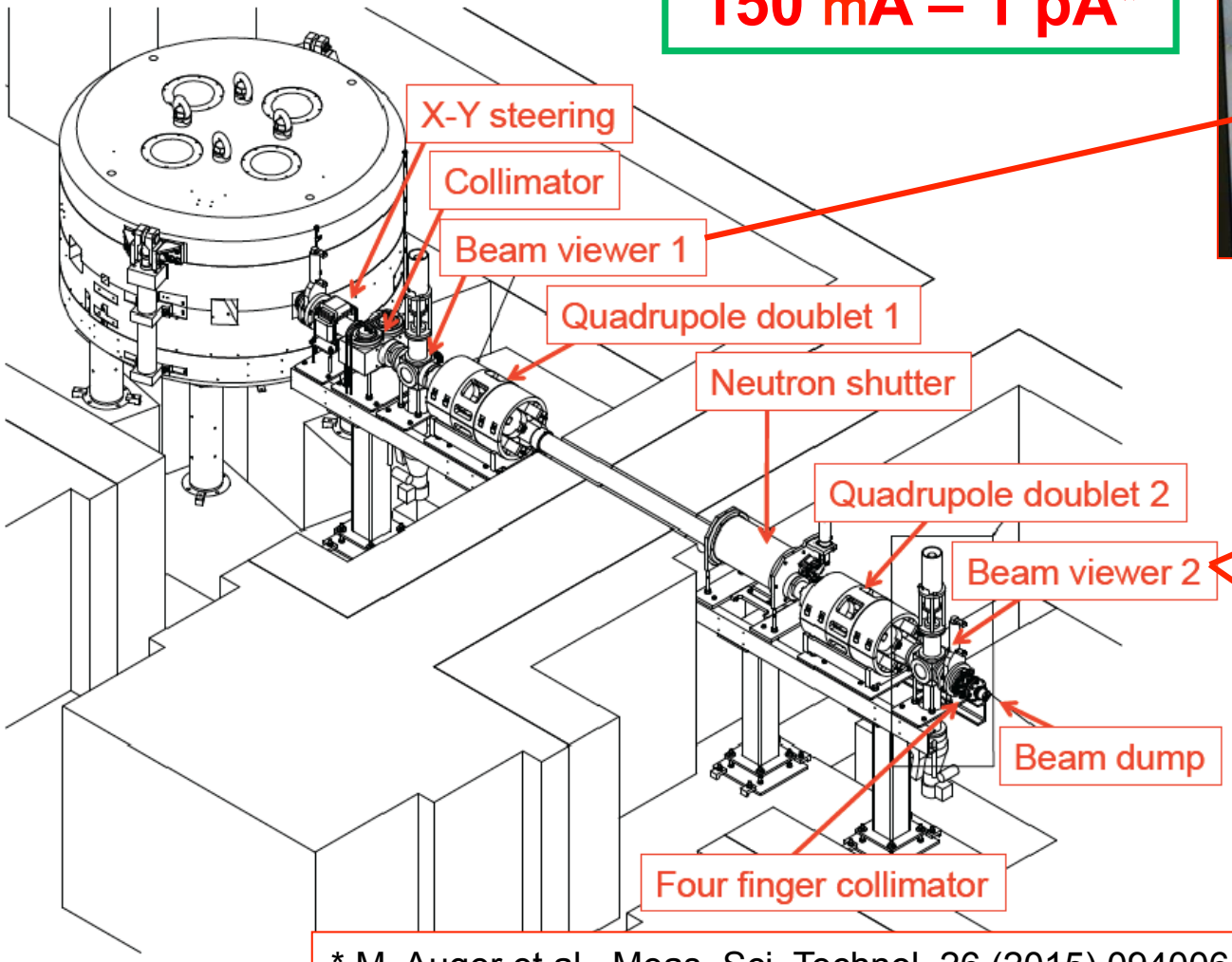
UNIVERSITÄT BERN

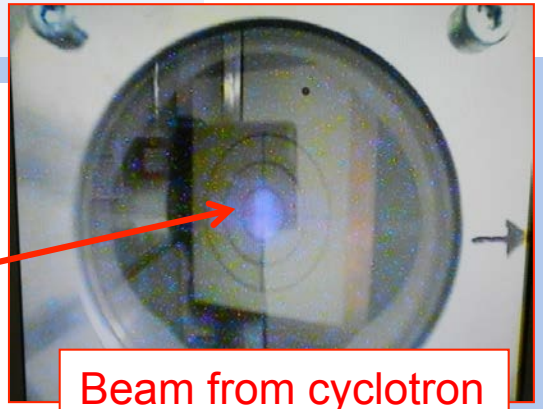
- Industrial production by SWAN Isotopen AG
- FDG: started in May 2013
- F-Choline: started in October 2016

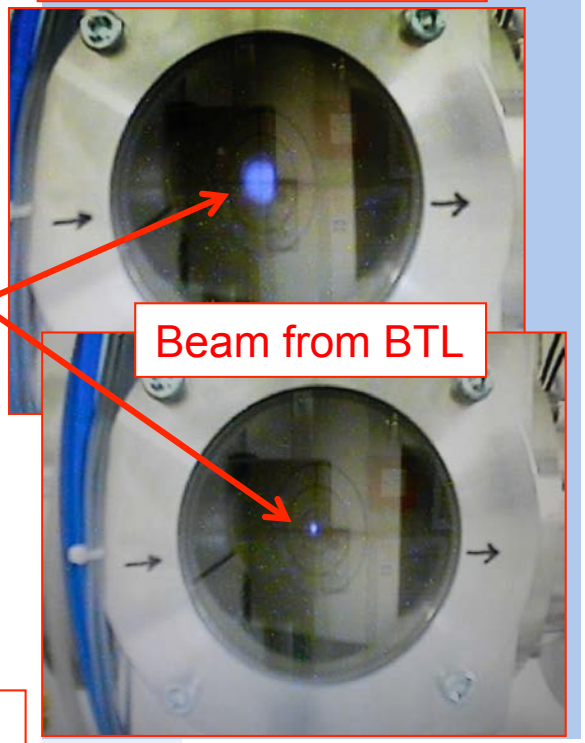
- Summary 2016:
  - 324 cyclotron production runs (single and dual beam)
  - 132 TBq (EOB) of ^{18}F produced
  - Mostly FDG (F-Choline: 1 or 2 runs per week)
  - No major radiation protection or other issues
  - Cyclotron efficiency: >99%

Research activities with the BTL

Intensity range: 150 mA – 1 pA*

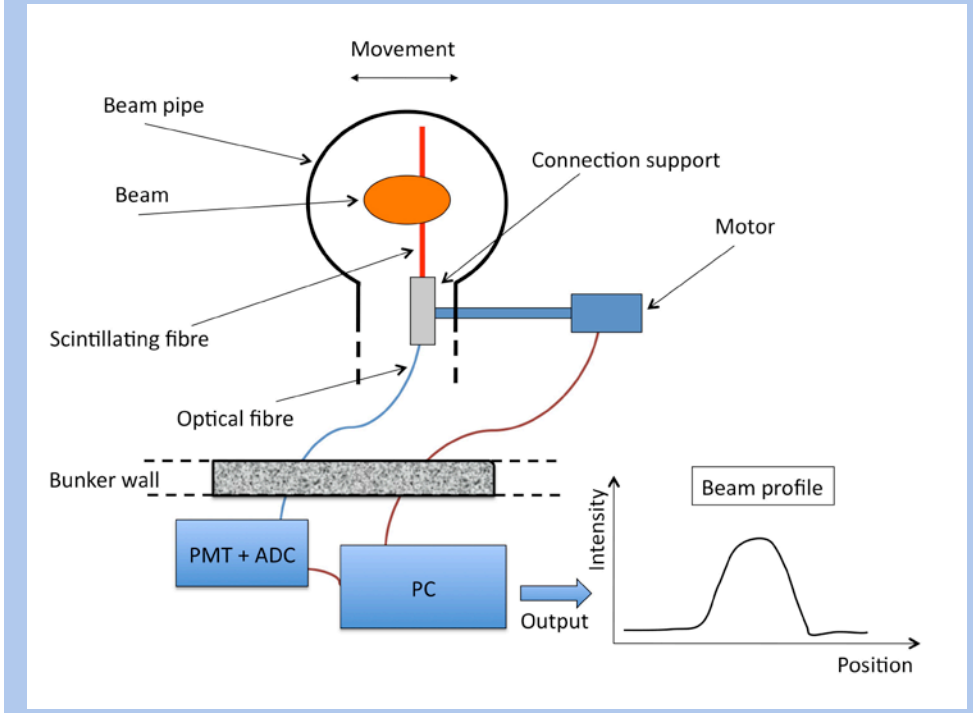


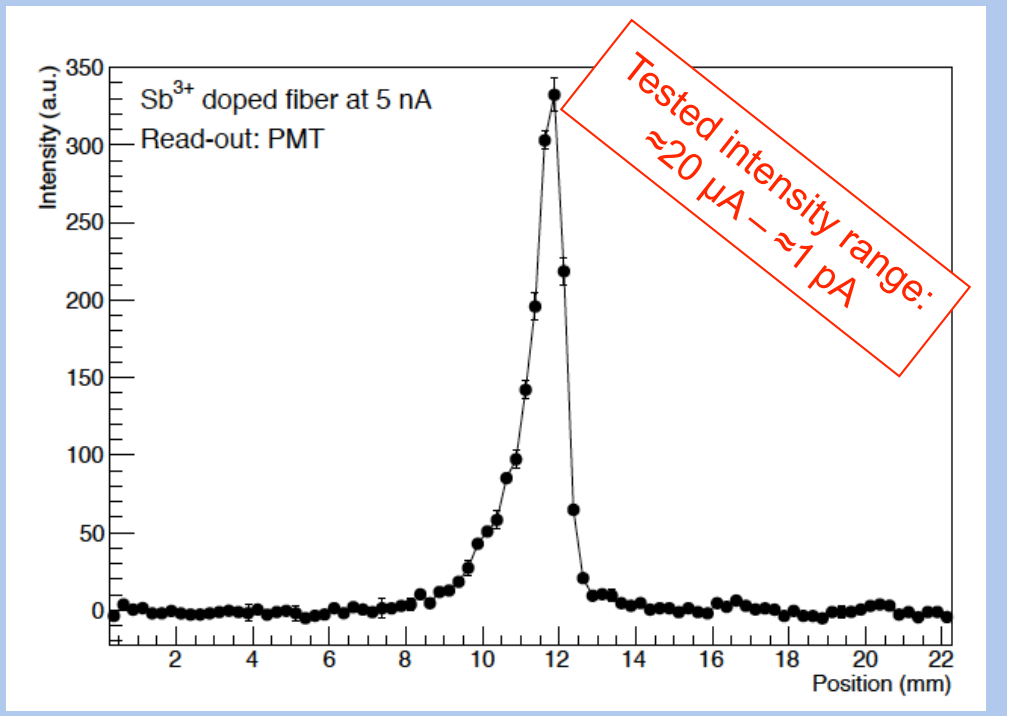




* M. Auger et al., Meas. Sci. Technol. 26 (2015) 094006

UniBEaM



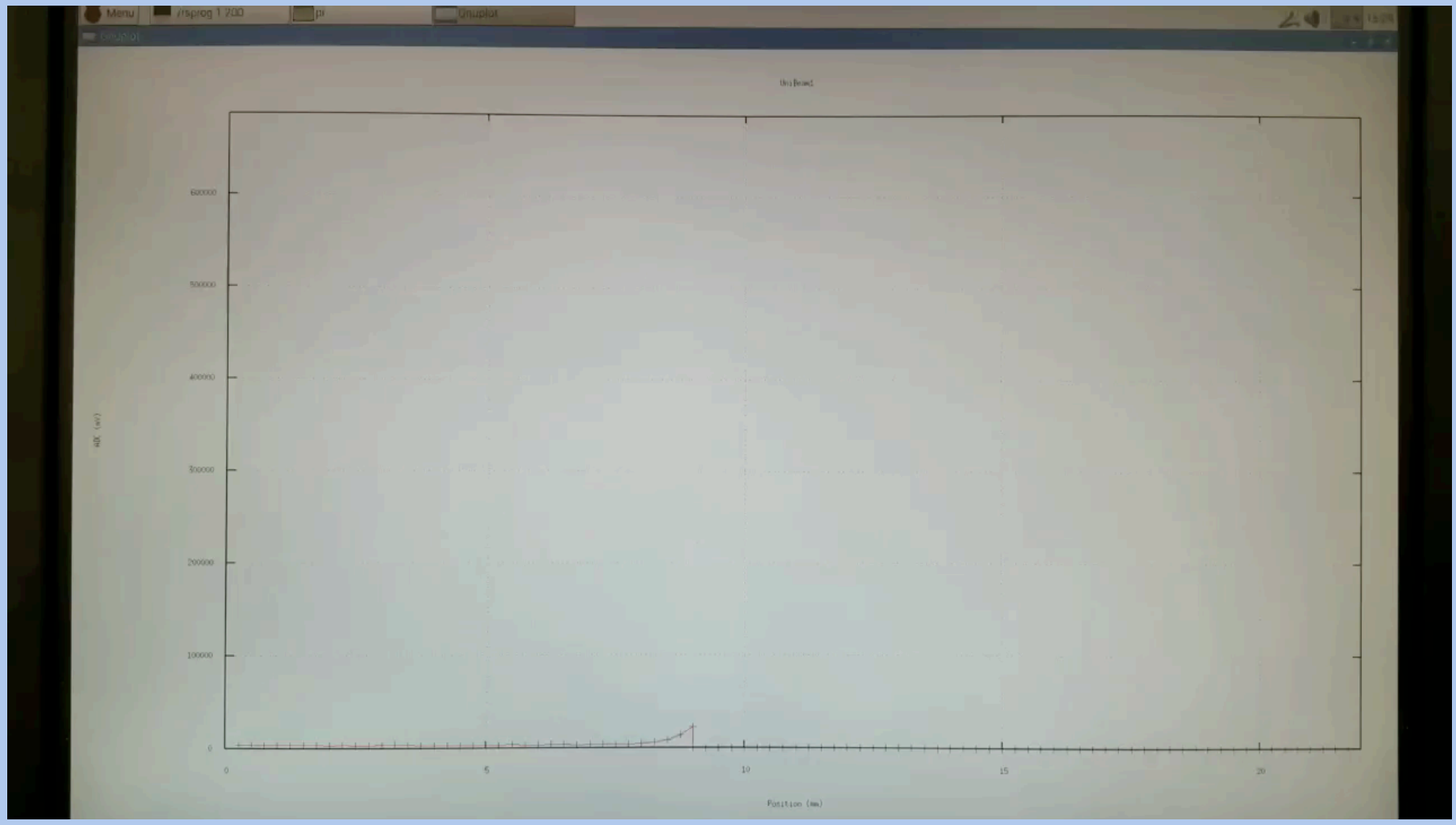


> 1D beam profiler based on (doped) optical fibres passed through the beam

> On-line, minimal interference with the beam

S. Braccini et al., 2012 JINST 7 T02001

On-line monitoring with UniBEaM



UniBEaM commercialized by D-Pace

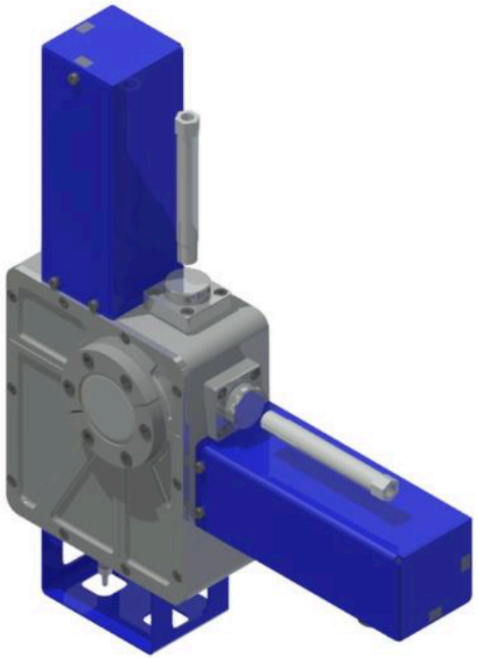
UNIVERSITÄT BERN

D-Pace

UniBEaM25

Ion Beam Profiler using Optical Fiber Sensor
Single and Dual Axis Systems

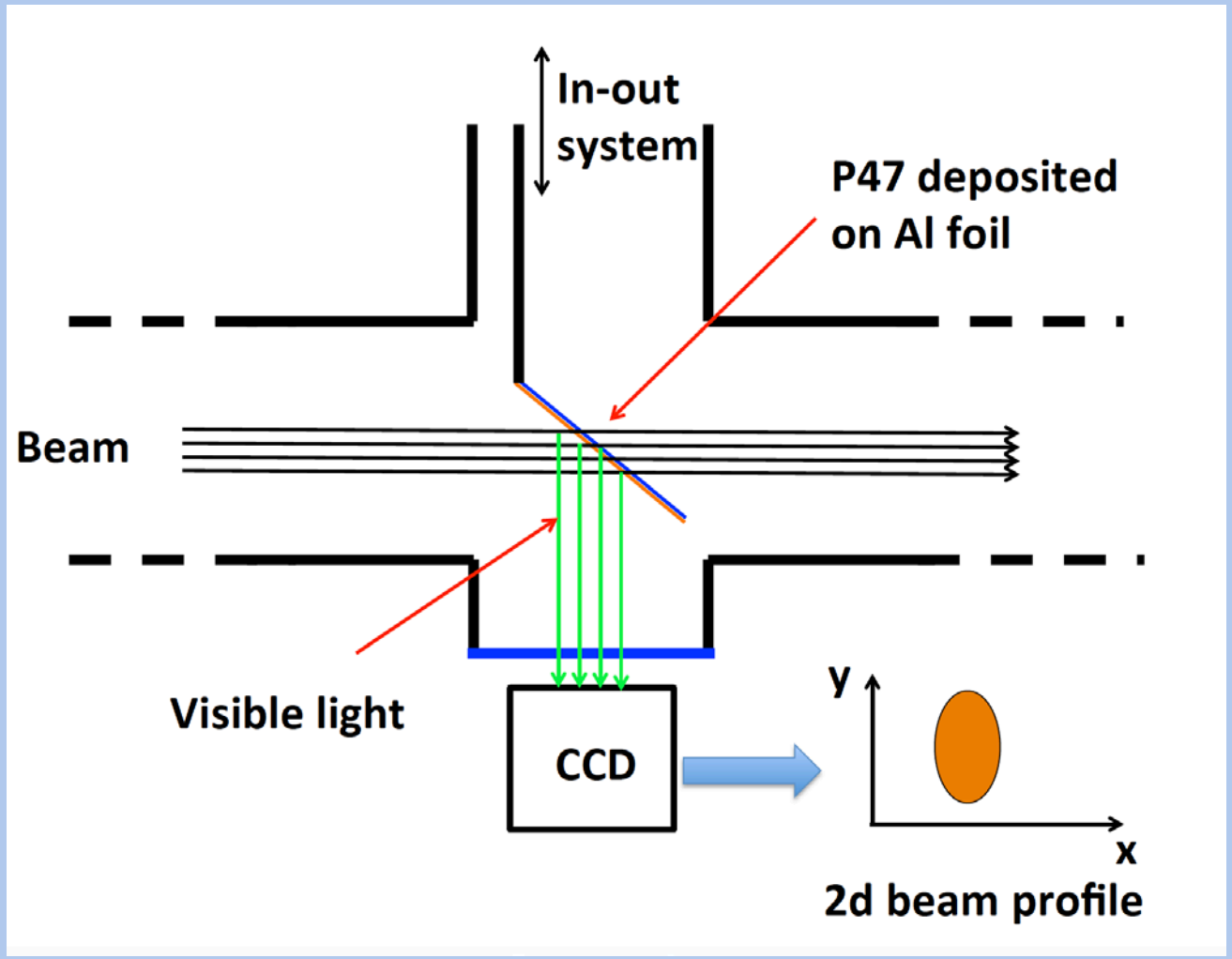
UniBEaM25-S – Single Axis Probe



UniBEaM25-D – Dual Axis Probe

UniBEaM was conceived by the **AEC-LHEP** of the **University of Bern**[1] and commercialized by **D-Pace.**

2D non-destructive beam monitoring: π^2



First preliminary results

UNIVERSITÄT BERN

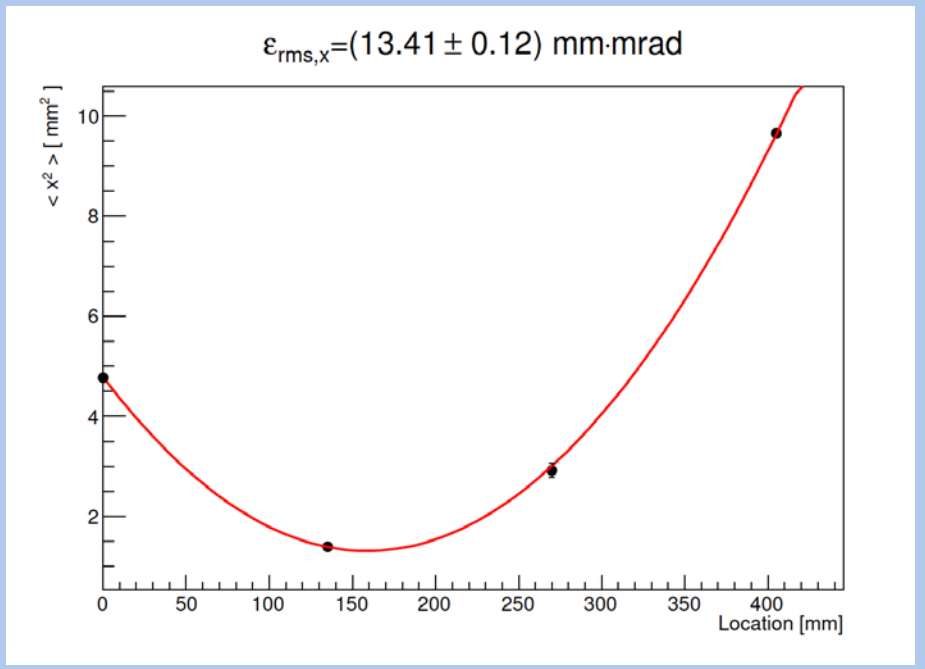
Preliminary

On-line measurement of the transverse beam emittance

4PrOBεaM

UNIVERSITÄT BERN

- Poorly known (or unknown!) for compact medical cyclotrons
- Crucial for reliable simulations (ex. of the BTL)
- Method based on 4 UniBEaM detectors
- Good agreement with quadrupole variation method

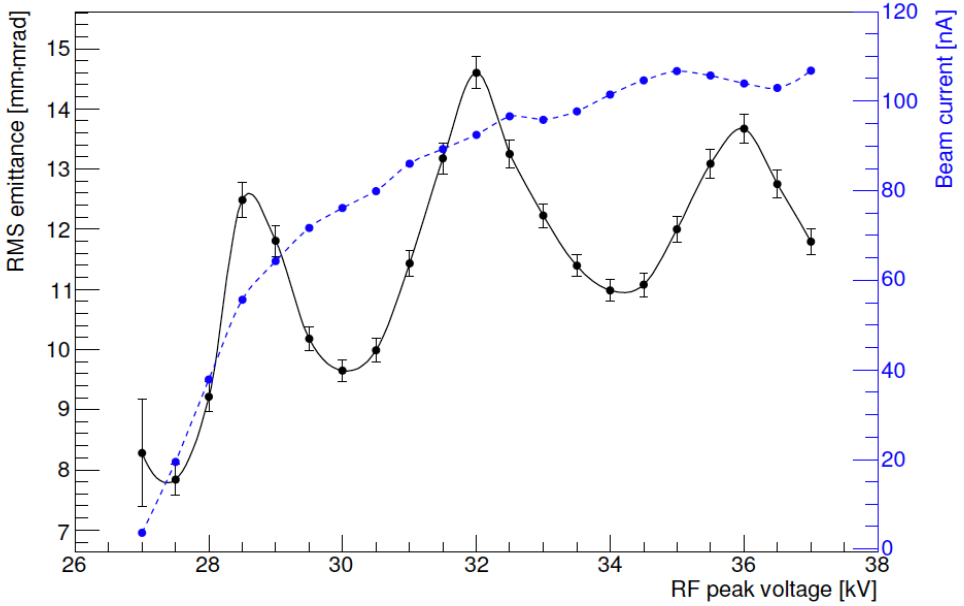


K. Nesteruk , PhD thesis, 2017; K. Nesteruk et al., arXiv:1705.07486, 2017.

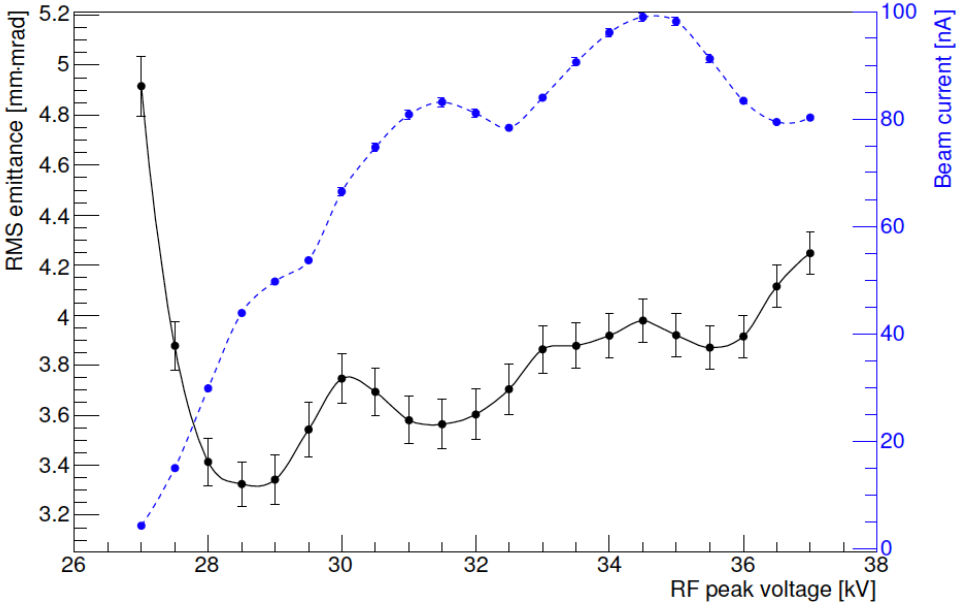
Transverse beam emittance vs cyclotron parameters

UNIVERSITÄT BERN

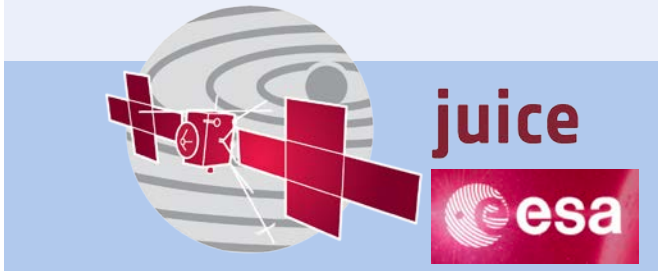
Horizontal plane

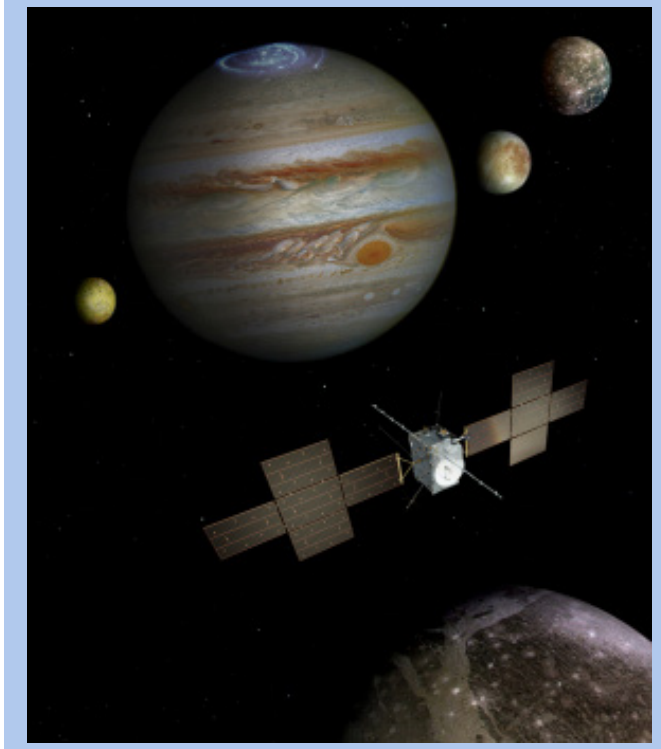


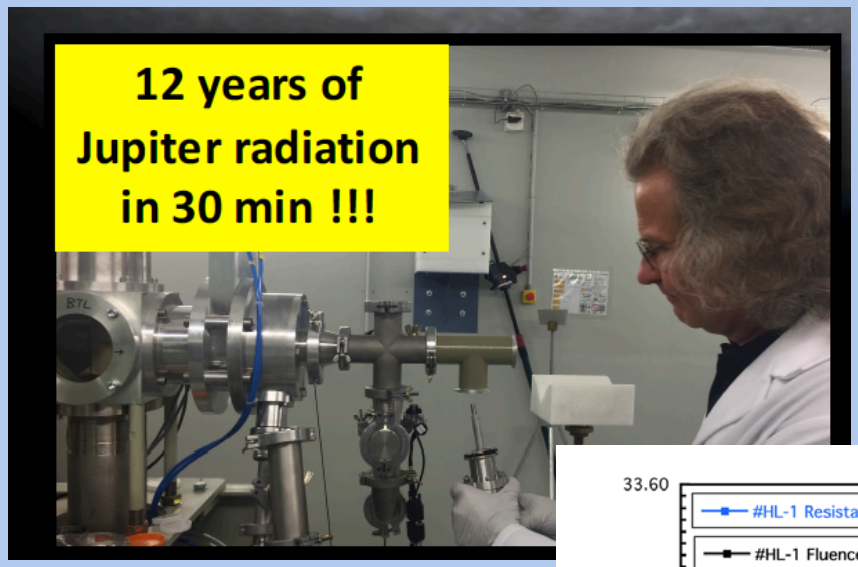
Vertical plane

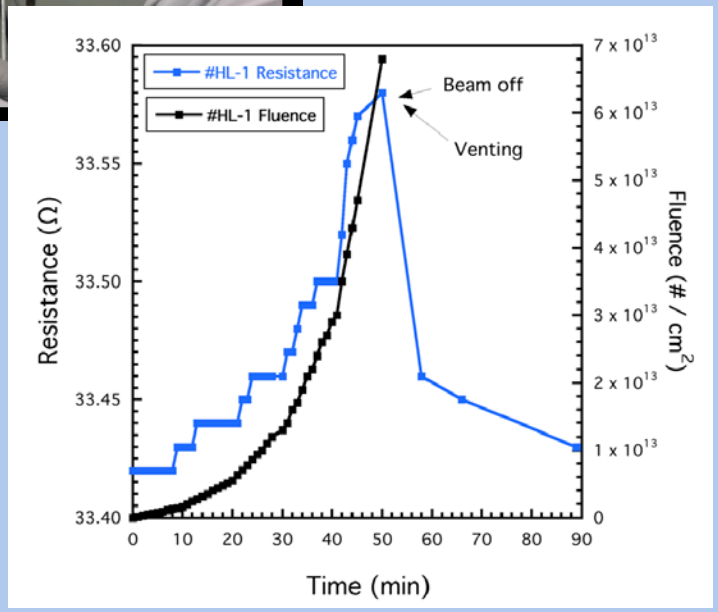


JUpiter ICy moons Explorer (JUICE)





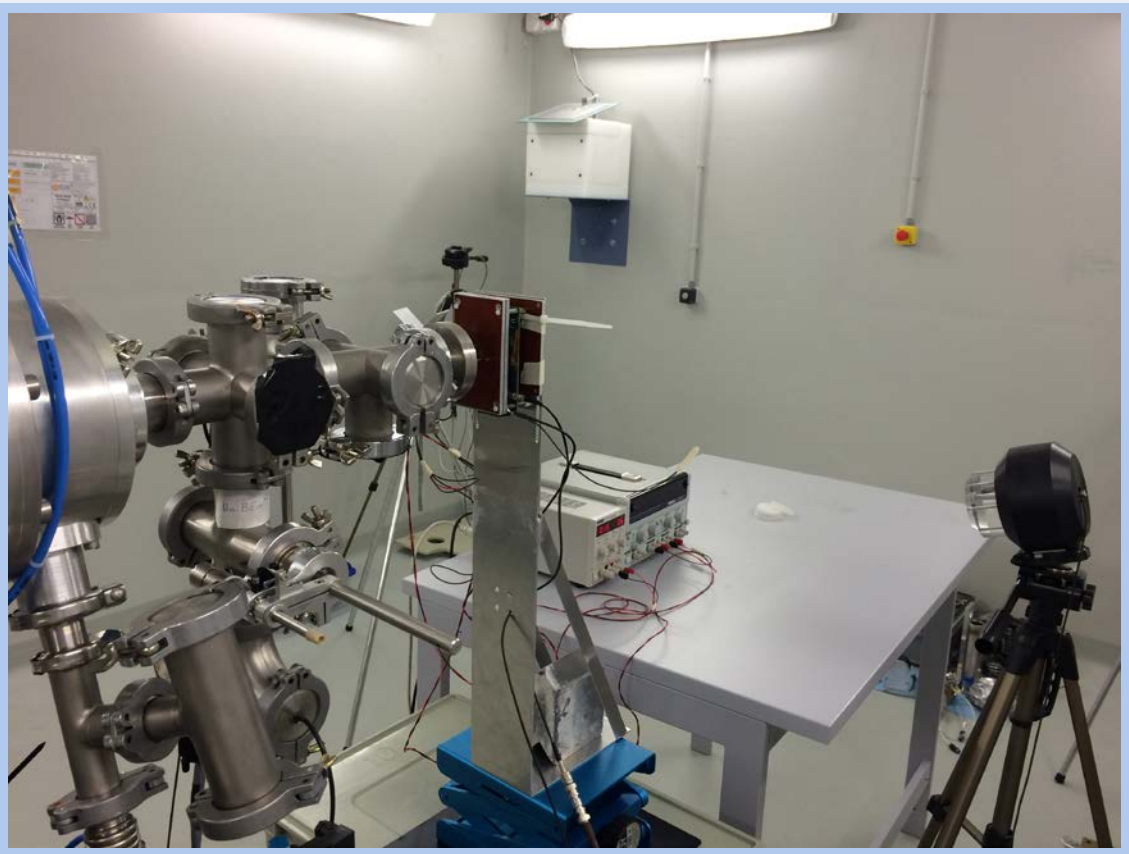


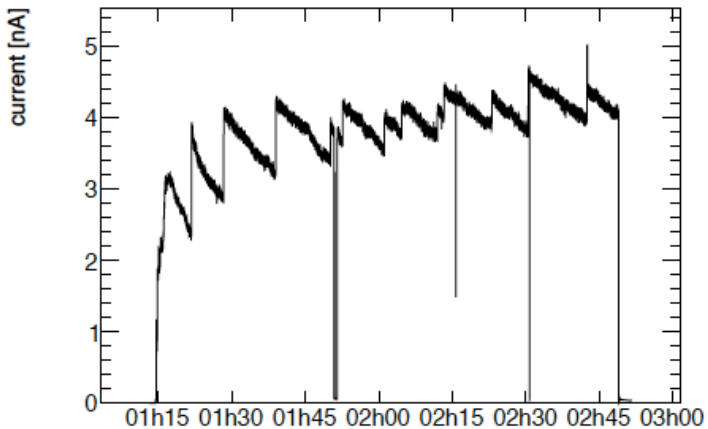


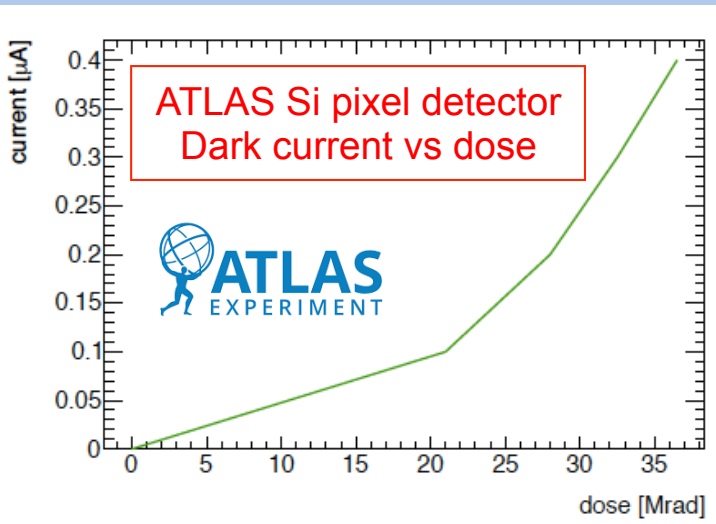
Collab. with WP UniBE
D. Lasi et al., IEEE 2017

Radiation hardness studies for the ATLAS experiment at CERN

UNIVERSITÄT BERN

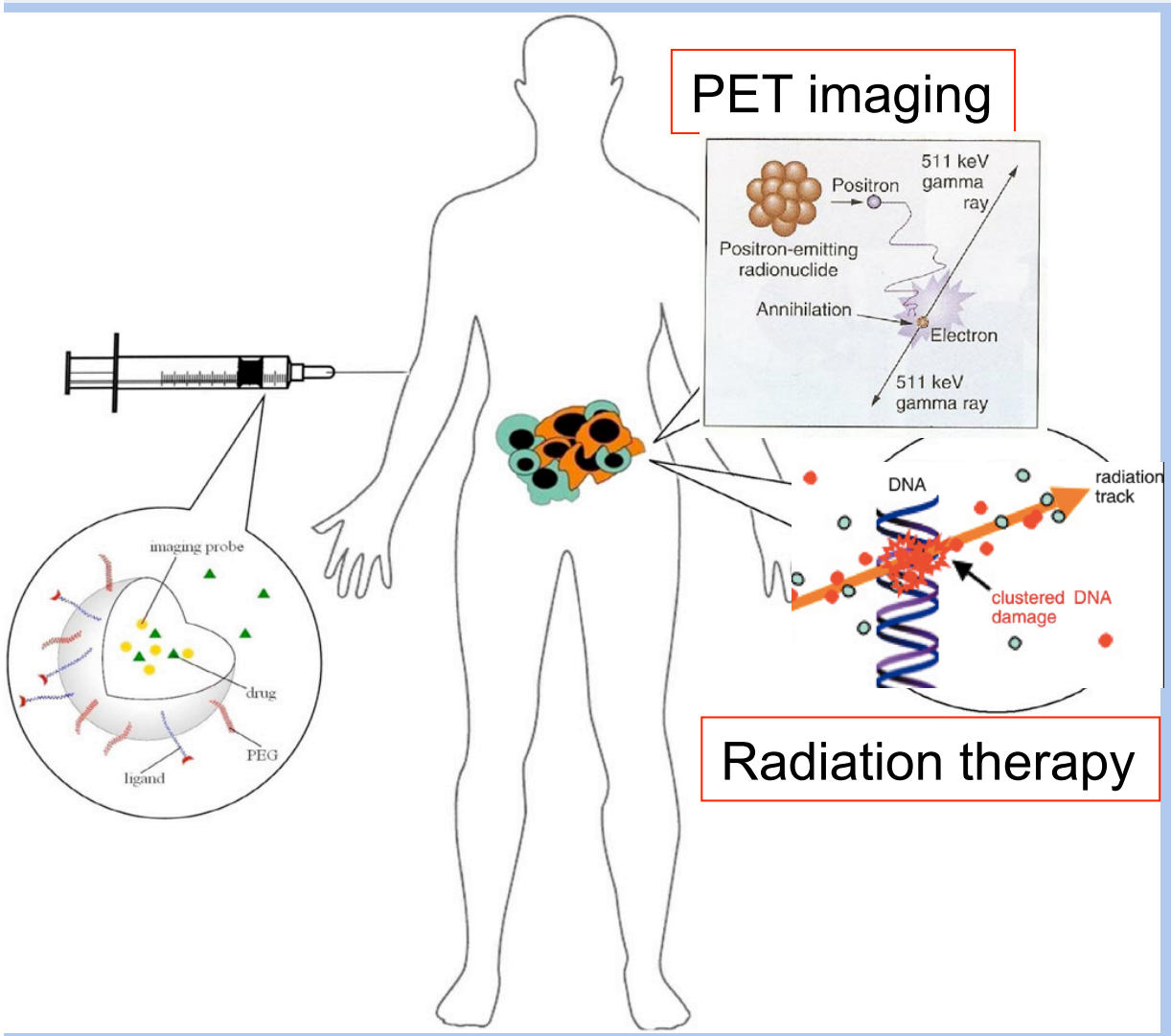






- Beam current in the nA range
- Extraction in air
- Doses in the 1-100 Mrad range (10^3-10^5 Gy)

Theragnostic isotopes



> Promising pairs: $^{64}Cu/^{67}Cu$, $^{44}Sc/^{47}Sc$ and $^{43}Sc/^{47}Sc$

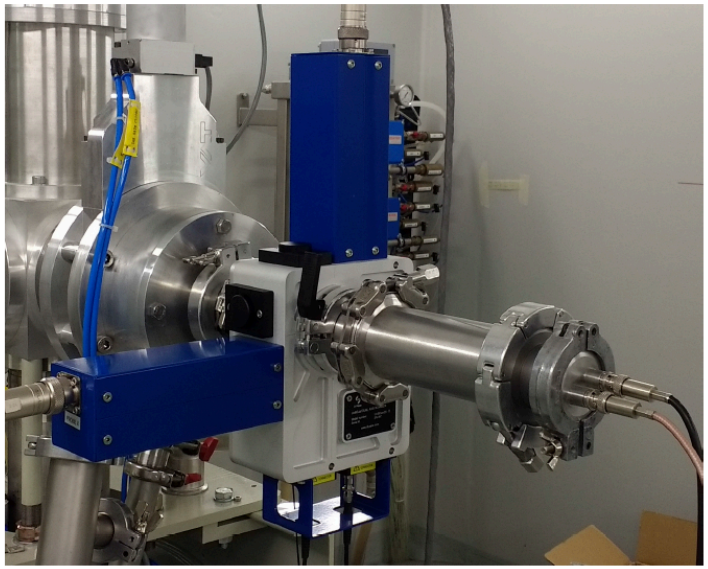
> Sc cyclotron production ?

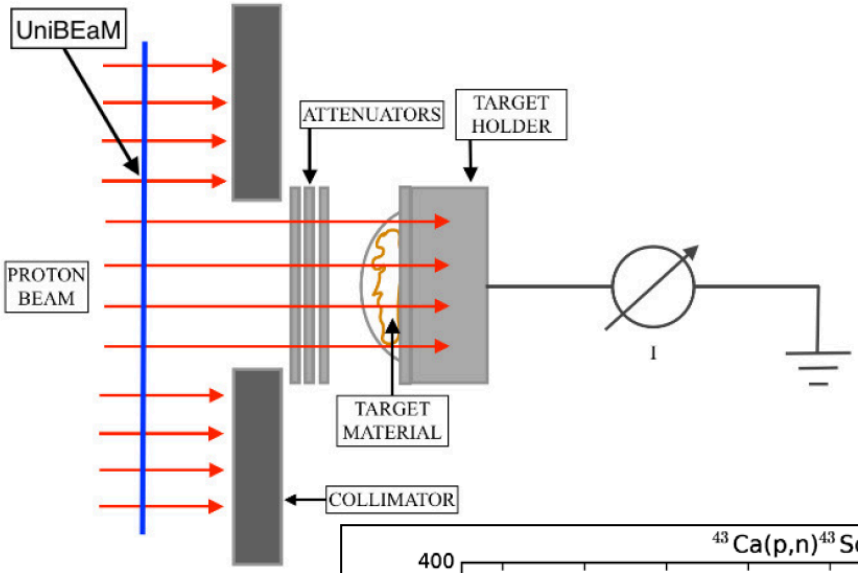
- $^{44}Ca(p,n)^{44}Sc$,
  $^{43}Ca(p,n)^{43}Sc$,
  $^{46}Ti(p,a)^{43}Sc$

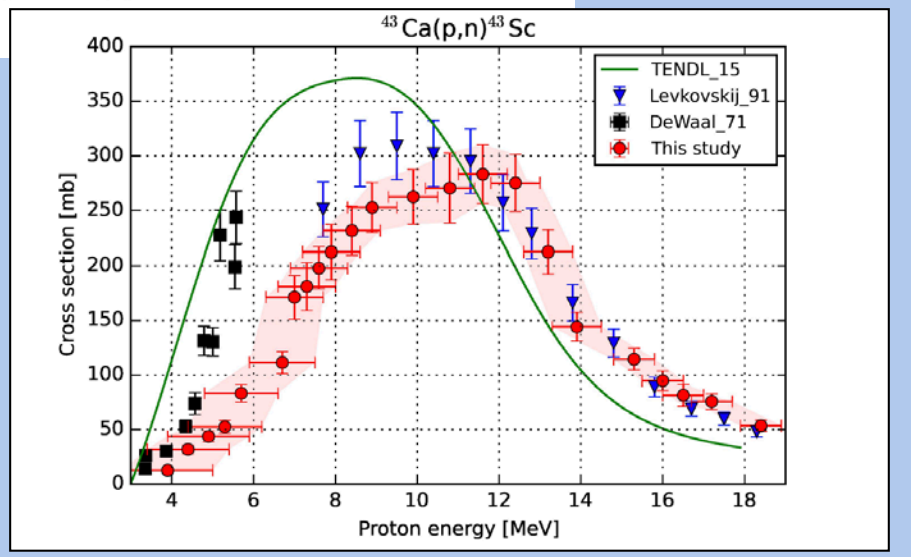
> Solid target station

Collab. with PAUL SCHERRER INSTITUT PSI

New method for production cross section measurement





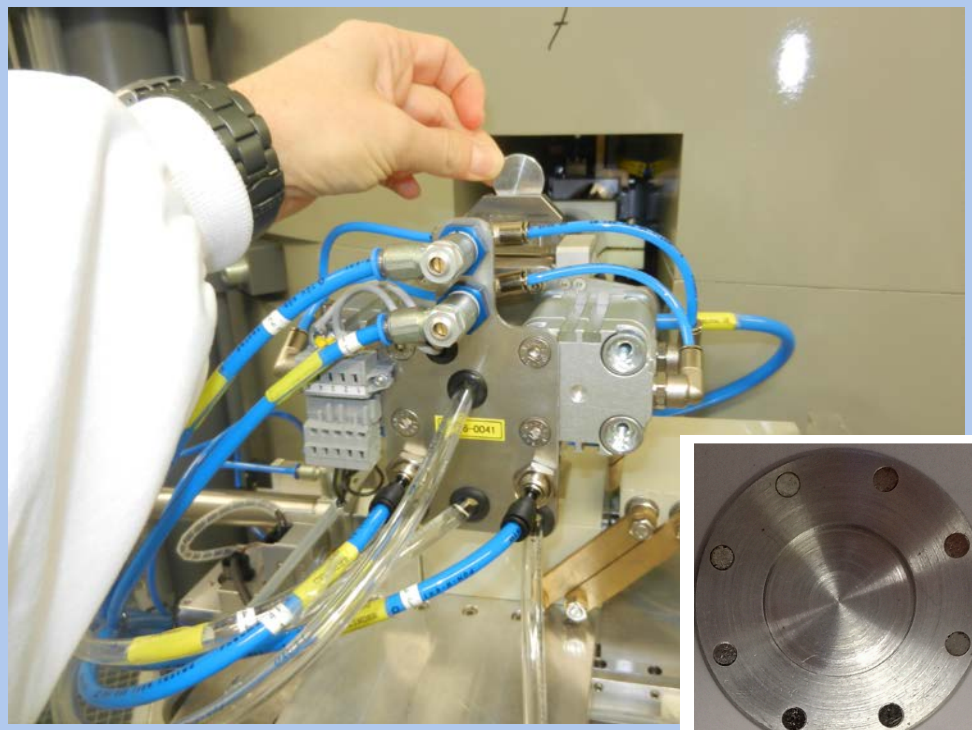


> Yield and purity are critical issues!

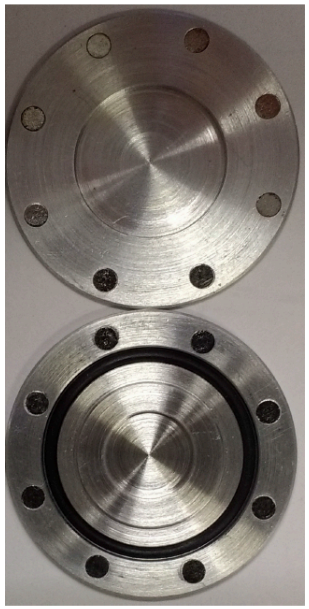
T. Carzaniga et al., Applied Radiation and Isotopes, 129 (2017) 96-102.

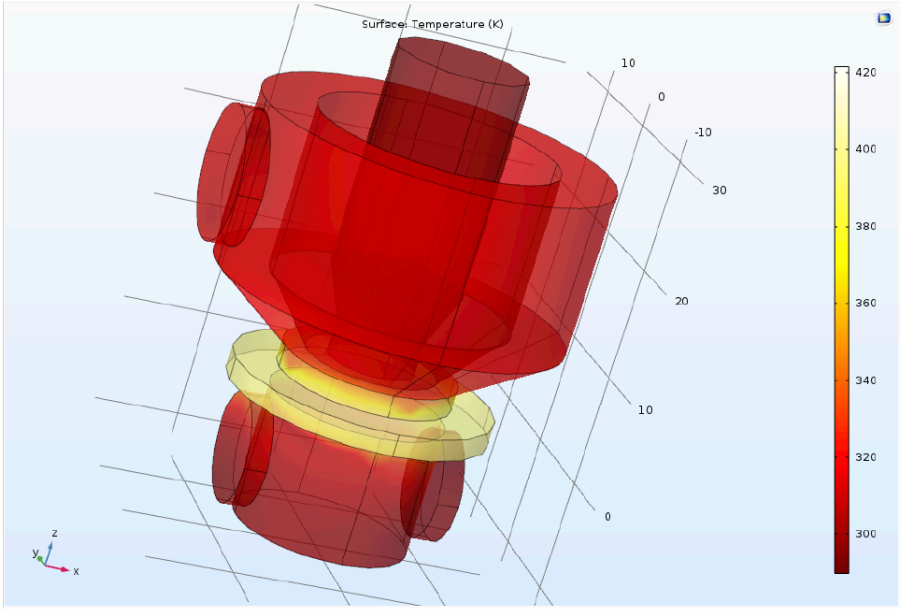
ECPM − Poster session - 35

Solid target station with pneumatic target transfer system

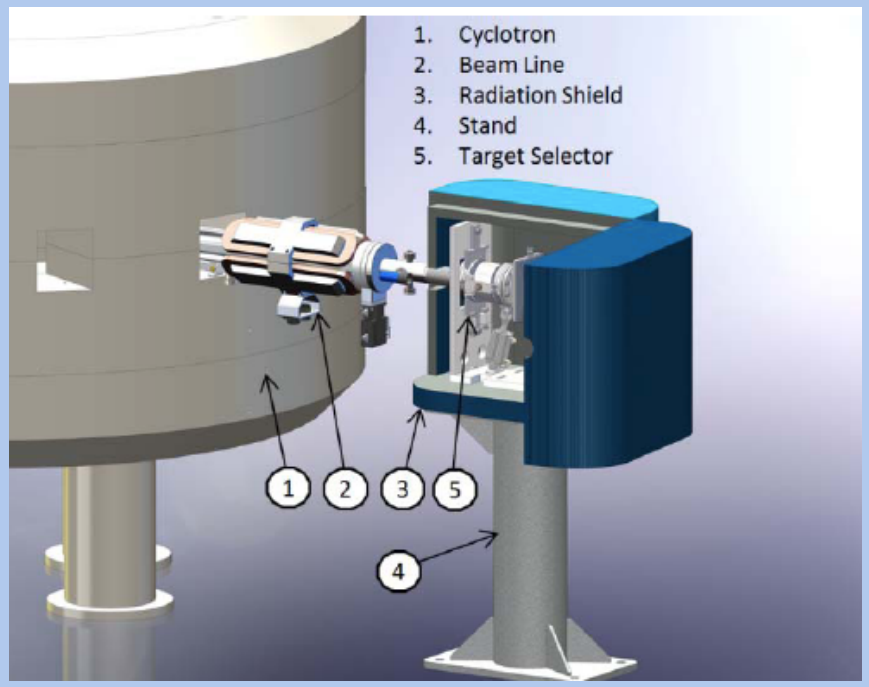


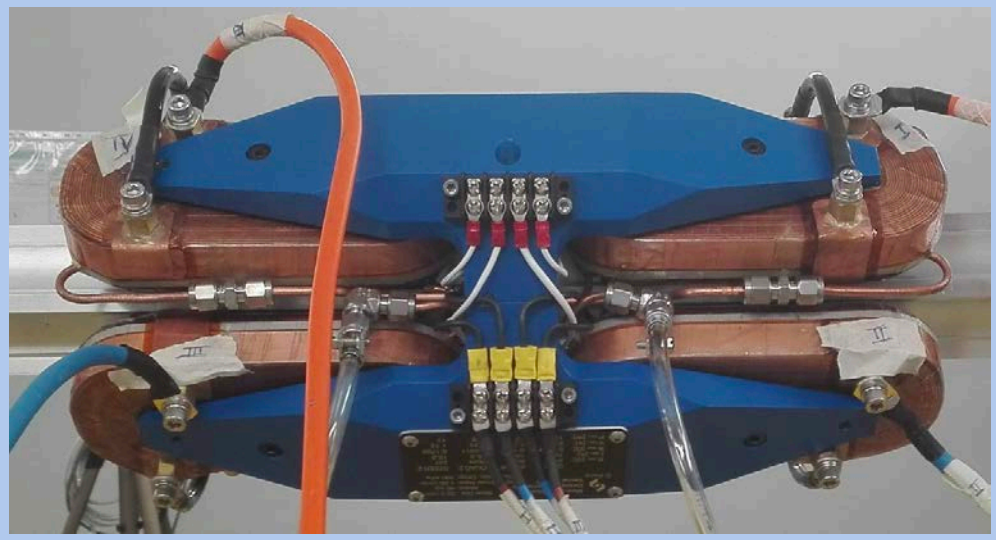
The irradiation of compressed highly enriched materials in powders is difficult!





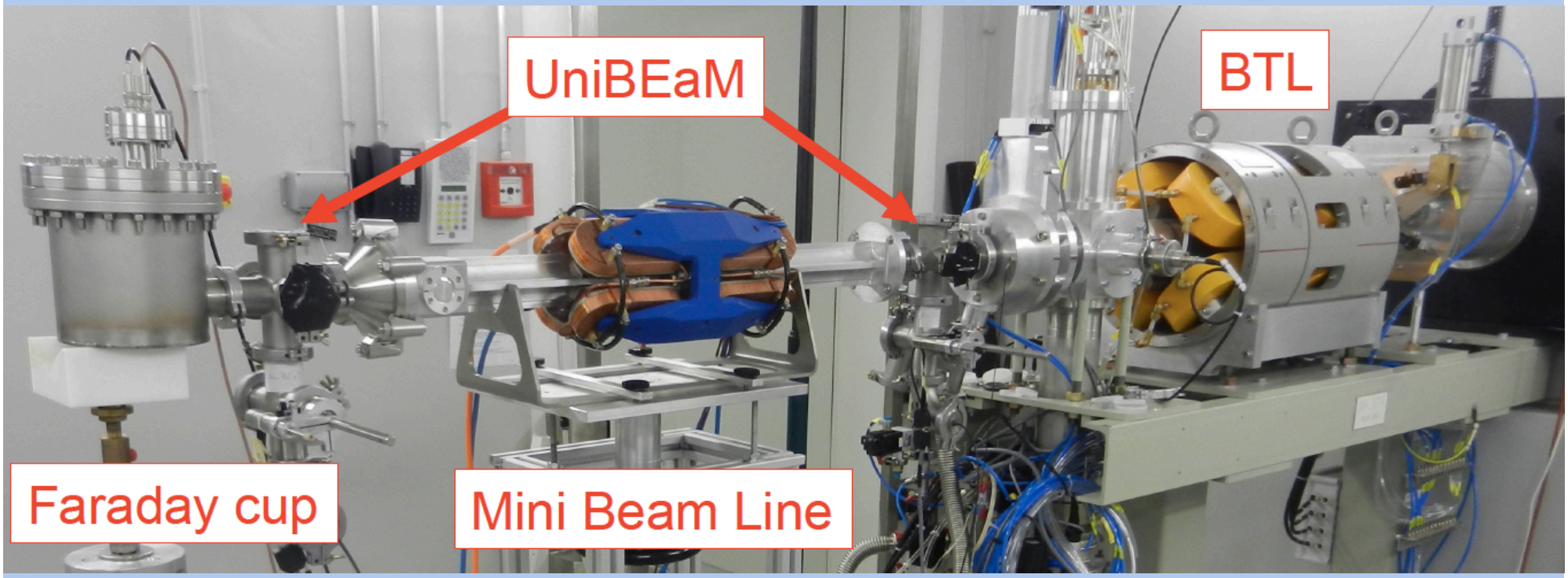
MiniBeamLine





- Quad doublet + XY steering within a single magnet ➔ complex beam optics
- Compact: 40 cm long, 54 kg
- Does not need a second bunker!
- D-Pace, Canada

Characterization of the MiniBeamLine



- Initial beam : ~ 10 mm FWHM (~as extracted from the cyclotron)
- Focused beam down to ~ 3 mm FWHM

M. A. Gilio, Master Thesis, University of Pisa, 2017.

Conclusions and Outlook

UNIVERSITÄT BERN

- Compact medical cyclotrons:
  - "Production and research under the same roof" is an added value!
- The Bern cyclotron is an example:
  - 1d and 2d beam monitoring detectors
  - On-line system for transverse beam emittance measurements
  - Radiation hardness (CERN and ESA)
  - Novel radioisotopes for theranostics
    - Cross-section measurements
    - Compact Mini-Beam-Line + targets for powders
- … we are open to collaborations …

Thank you very much for your attention!

UNIVERSITÄT BERN