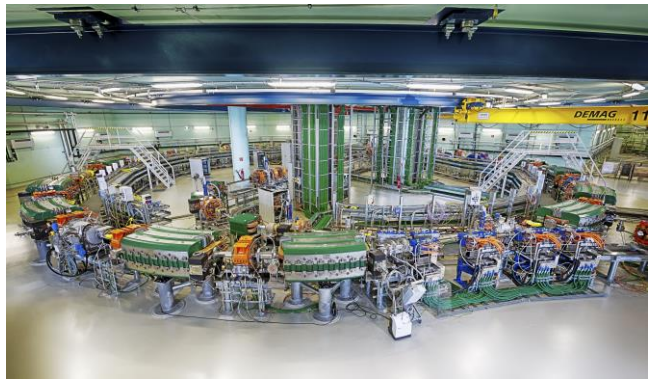

SATIF-16

16th Workshop on Shielding aspects of Accelerators, Targets and Irradiation Facilities

MONTE CARLO APPLICATIONS @ MEDAUSTRON

The use of Monte Carlo Computation Tools in the Hadron Therapy Facility MedAustron

Lukas Jägerhofer, Claudia Lenauer, Marta Mumot, Michael Deutsch, Ivan Strasik, Mauro Pivi, Andreas F. Resch, Yihan Jia

Photos / Graphics: MedAustron, Thomas Kästenbauer, Freepik/MedAustron, Kästenbauer/Ettl

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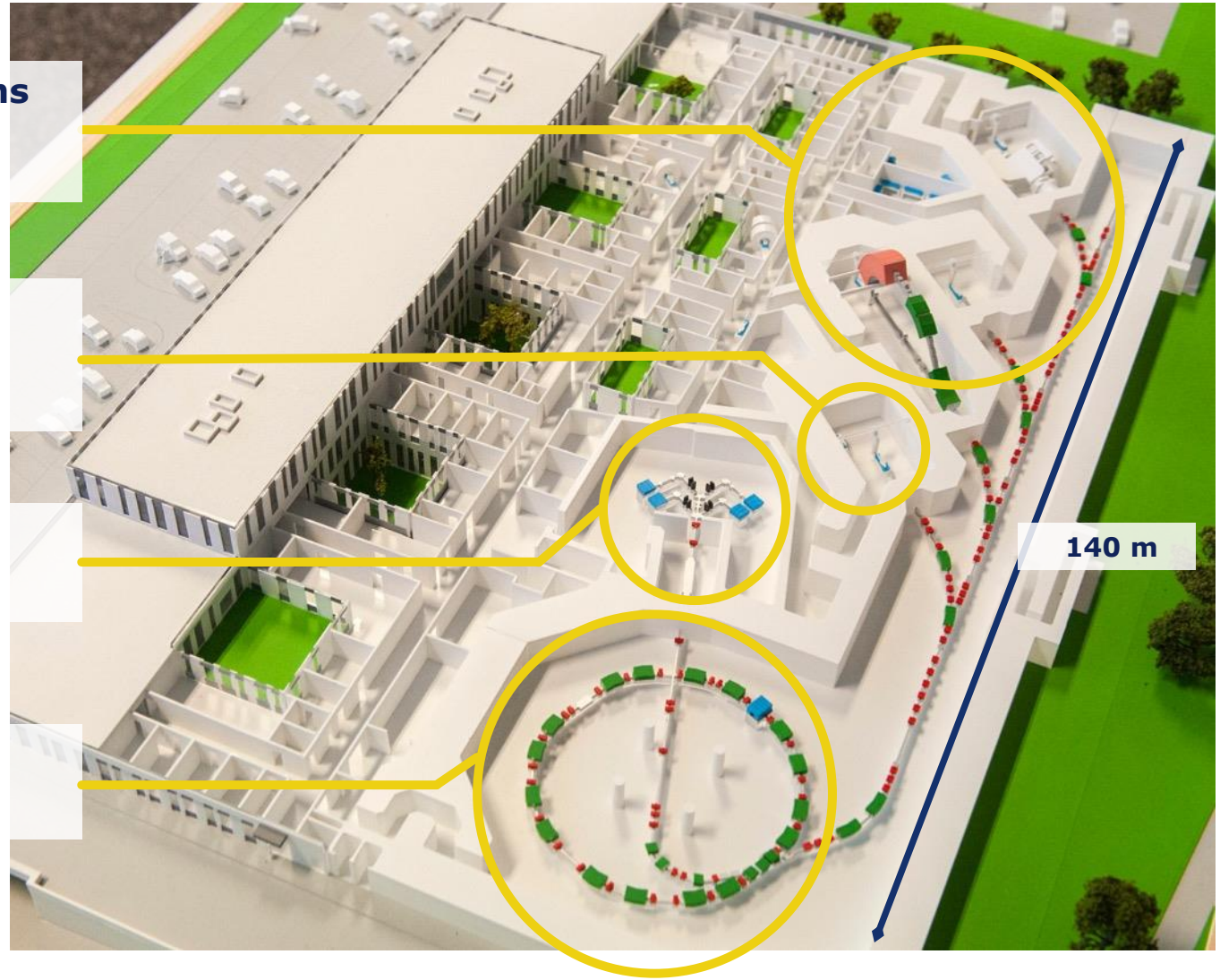
FACILITY OVERVIEW

Clinical Irradiation Rooms
Three rooms for patient treatments

Research
Irradiation room for non-clinical use

Ion Sources
and linear accelerator

Synchrotron



INTERNATIONALITY

TEAM

~300 employees from
20 different countries

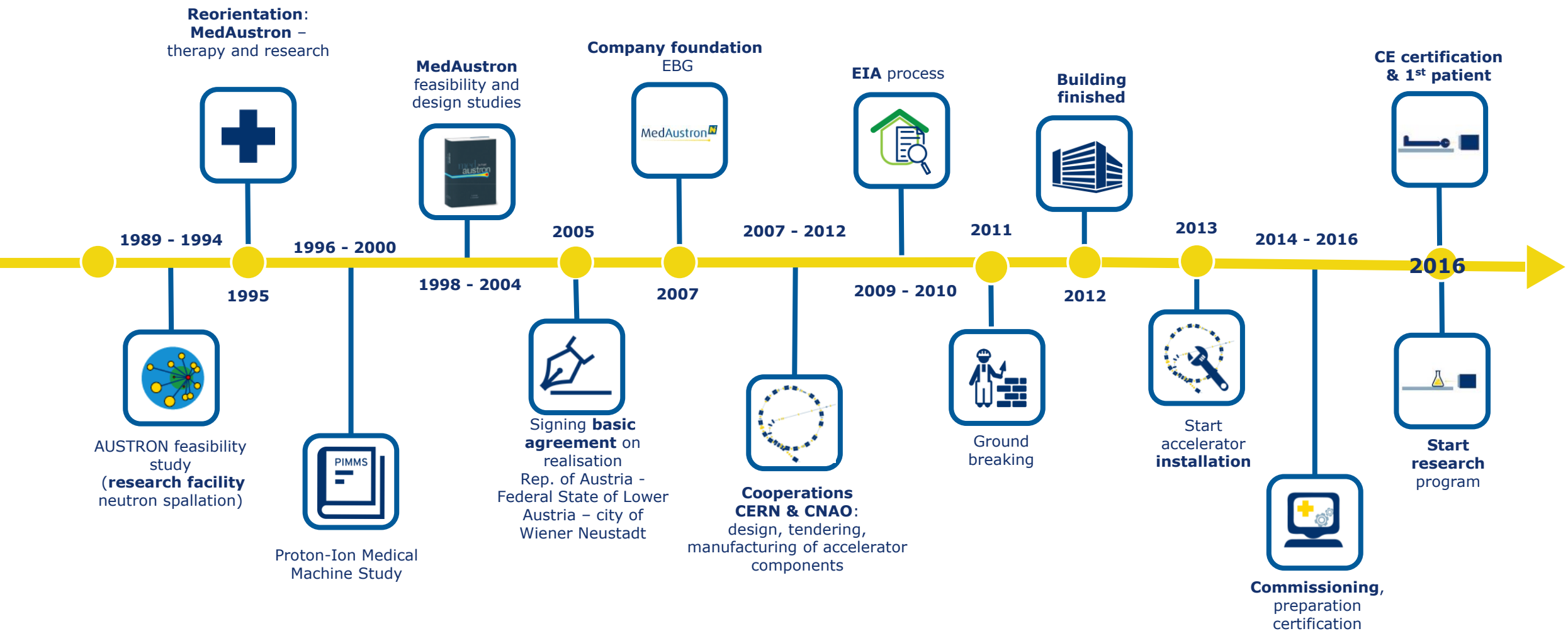
CLINIC

Patients from all over
Austria and abroad

COOPERATIONS

With institutes,
companies,
professional societies
worldwide

COMPANY HISTORY TO FIRST PATIENT

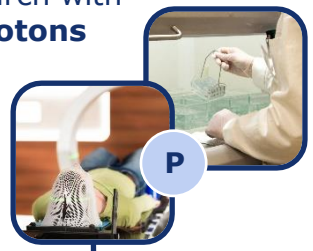


MedAustron Ionentherapiezentrum

MILESTONES SINCE FIRST PATIENT

2016

Start of patient treatments & research with **protons**



2017

Start of **pediatric treatments** & 2nd treatment room

2018

Additional treatment option: **vertical** beamline

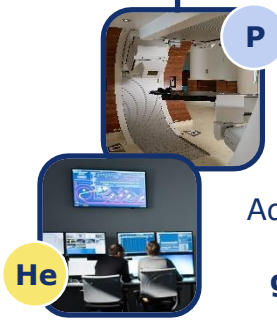
2019

Start of patient treatments & research with **carbon ions**

2020

Additional treatment option: **carbon ions** for **vertical** beamline

2022



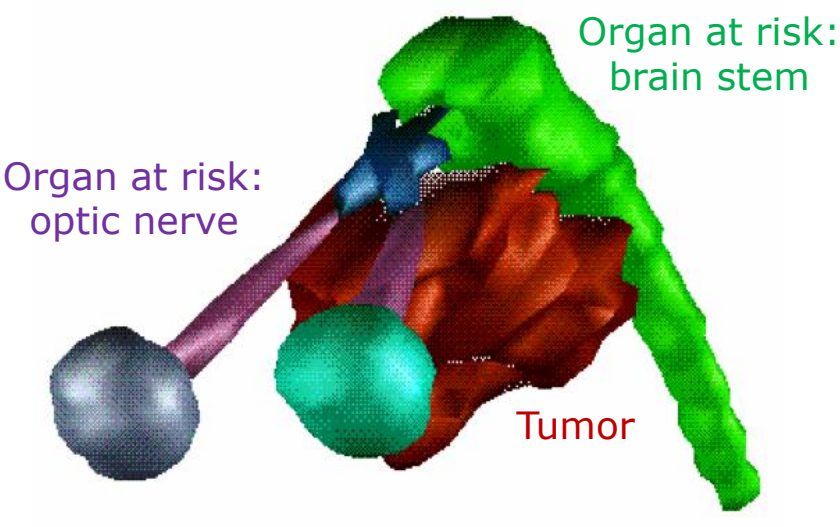
Additional treatment option: **proton gantry** & start of helium commissioning

2023

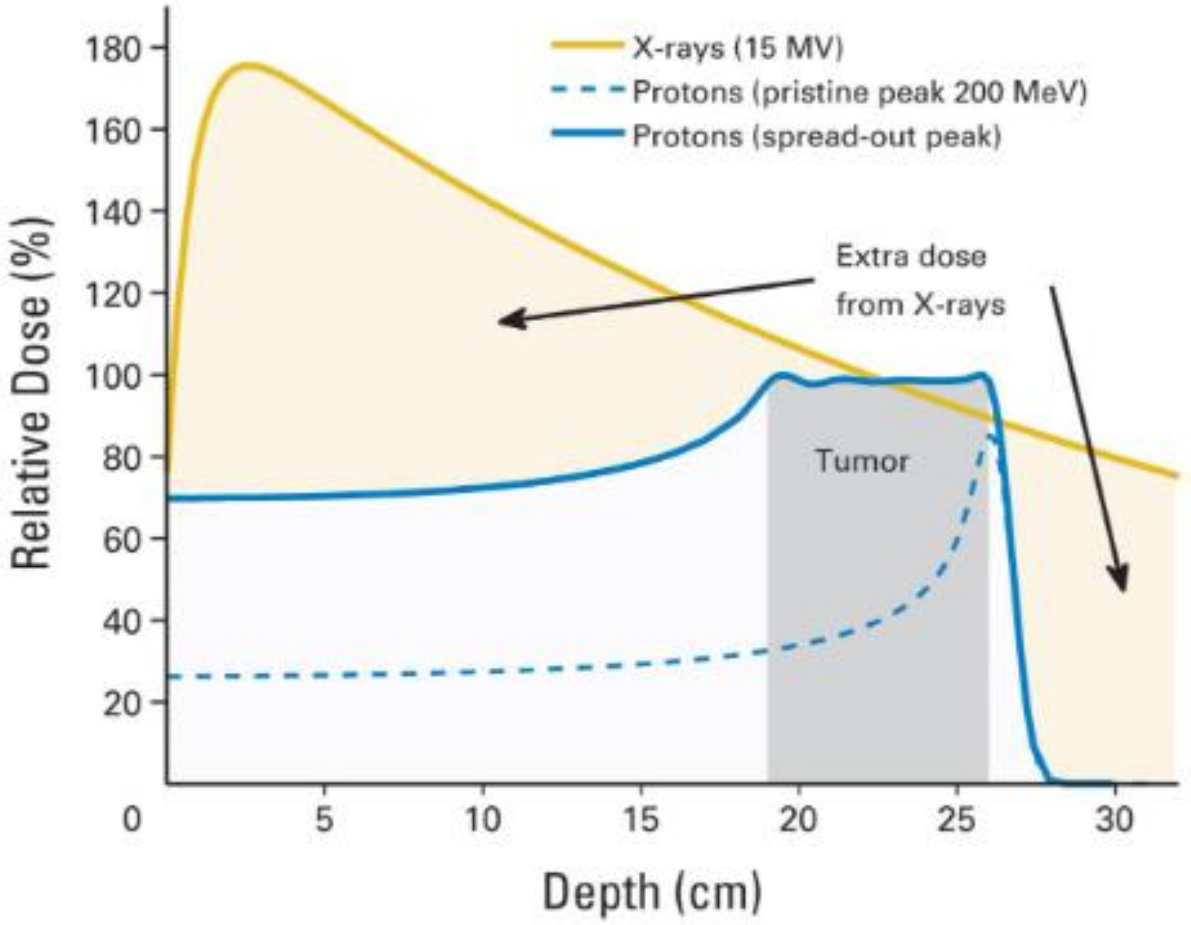
Additional treatment option: **carbon ions** for **2nd treatment room**

RADIOTHERAPY IN GENERAL

- The aim is to **prevent further proliferation** of the tumor cells
- This requires a **high radiation dose** in the tumor cells
- **Organs at risk** tolerate only a low radiation dose



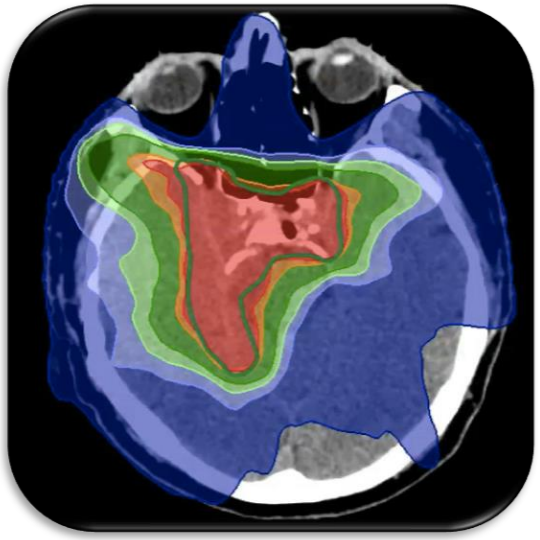
THE PRINCIPLE OF PARTICLE THERAPY



TREATMENT PLANNING - COMPARISON

PHOTONS

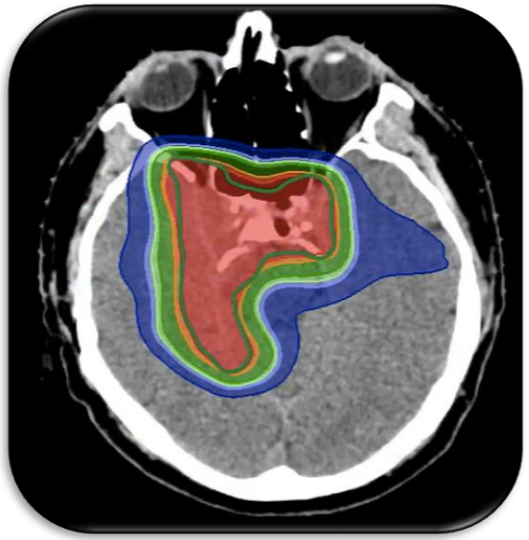
IMRT, VMAT, SBRT



Several fields, entry and exit dose

PROTONS

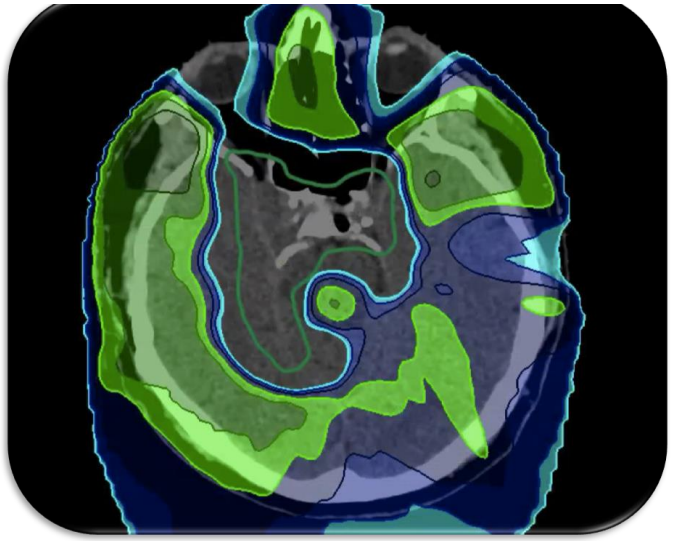
IMPT



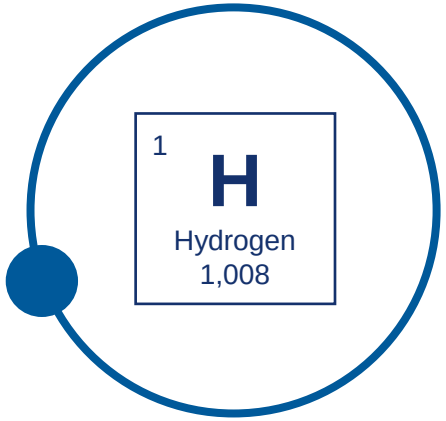
Fewer fields, reduced entry dose, no exit dose

DOSE DIFFERENTIAL

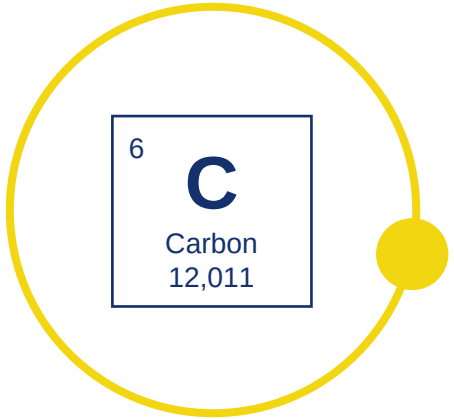
Photons minus Protons



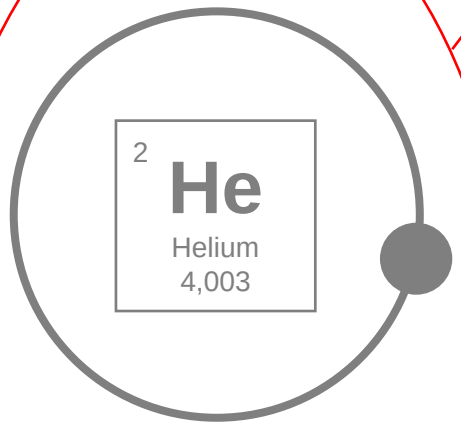
PARTICLE TYPES AT MEDAUSTRON



PROTONS



CARBON IONS



HELIUM IONS

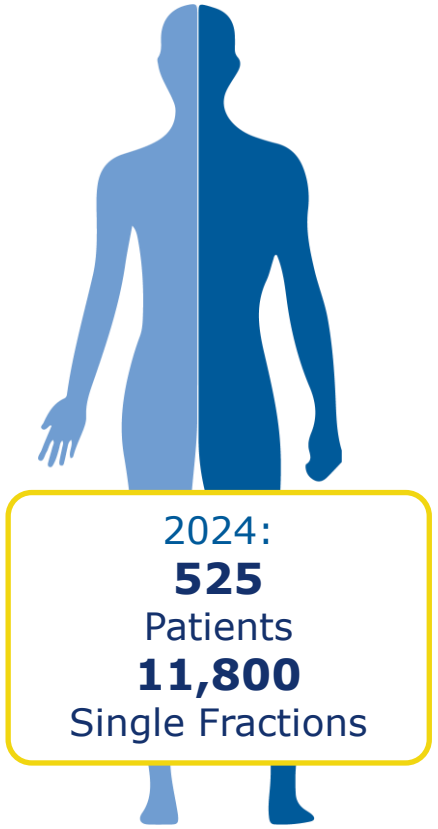
Possible future canditate – currently **subject of research**

Update in the upcoming presentation by C. Lenauer

Sparing of organs at risk and healthy tissue

Higher dose in the tumor / application in **radioresistant tumors**

INDICATIONS TREATED AT MEDAUSTRON



2024:
525
Patients
11,800
Single Fractions

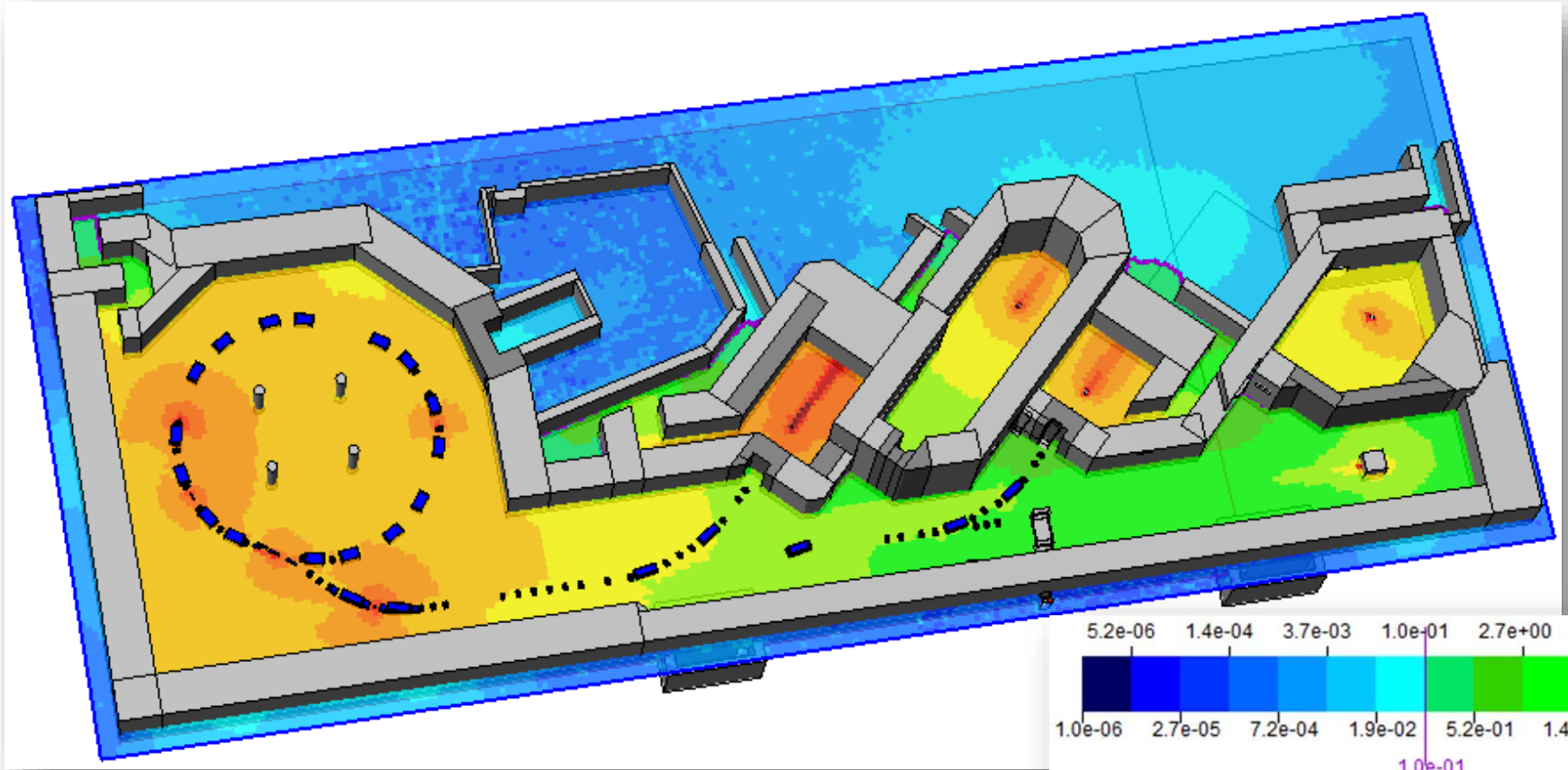
CNS	25%
Head & Neck	20%
Re-Irradiation	16%
Pediatrics	16%
Sarcoma	12%
Skull Base	5%
Prostate	3%
Gastrointestinal (upper)	2%
Thorax	1%
Gastrointestinal (lower)	<1%
Urogenital Tumors	<1%
Breast/Mamma-Ca	<1%
Gynecological Tumors	<1%

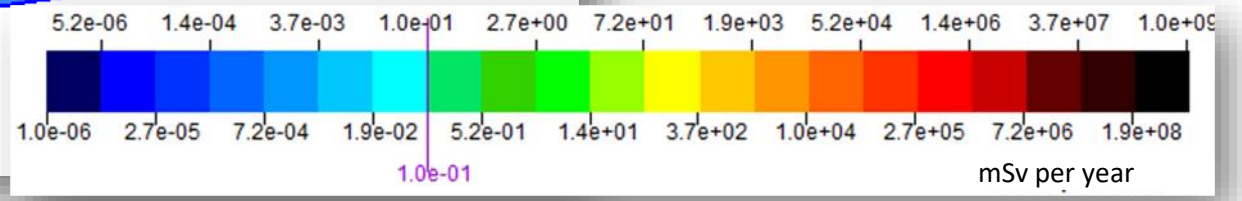
Values (rounded) as of April 2024

Radiation Protection Project

INITIAL AUTHORITY APPROVAL FOR THE FACILITY

SHIELDING CONCEPT IS PART OF AN ENVIRONMENTAL IMPACT ASSESSMENT

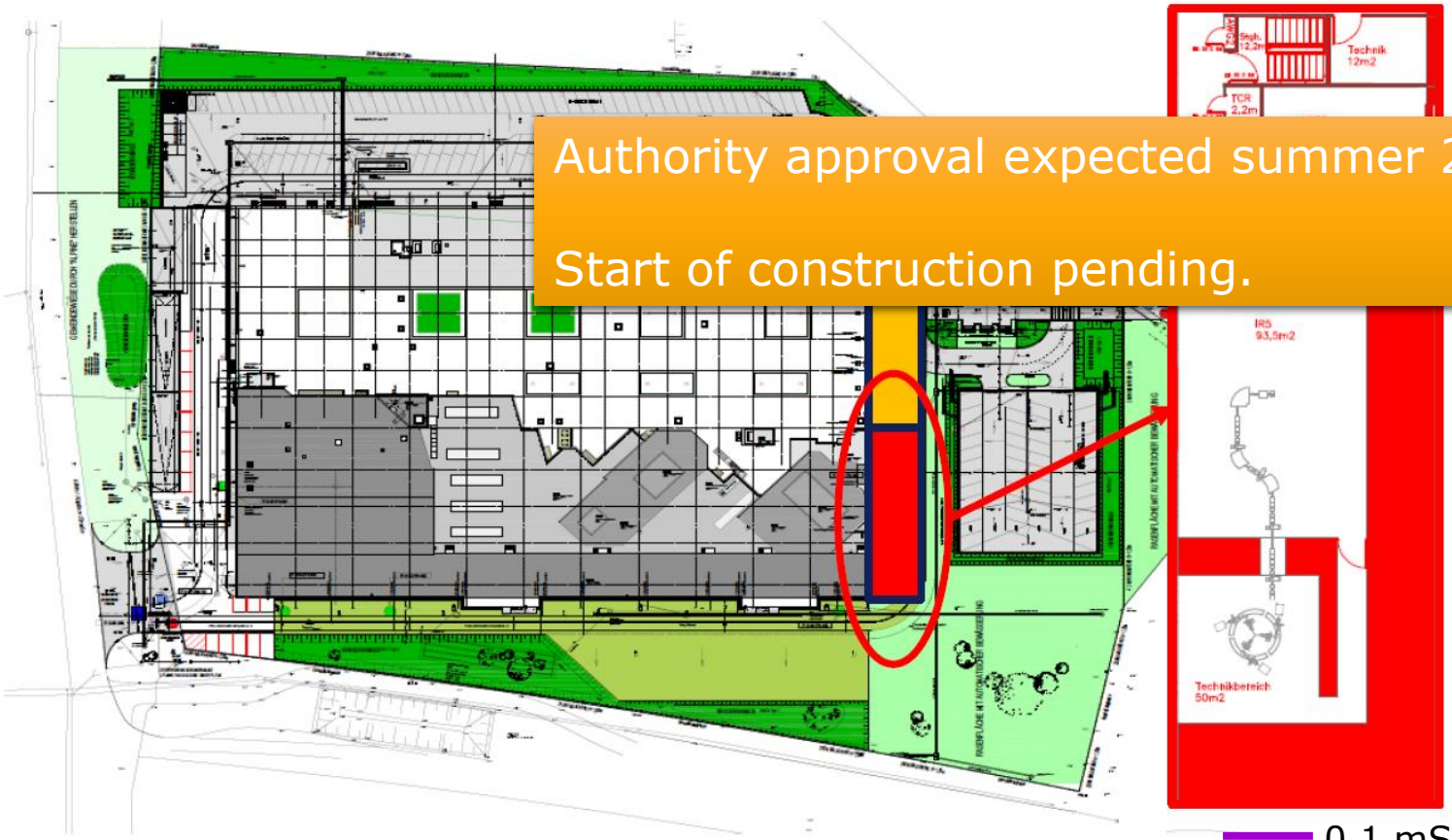




Radiation Protection Project

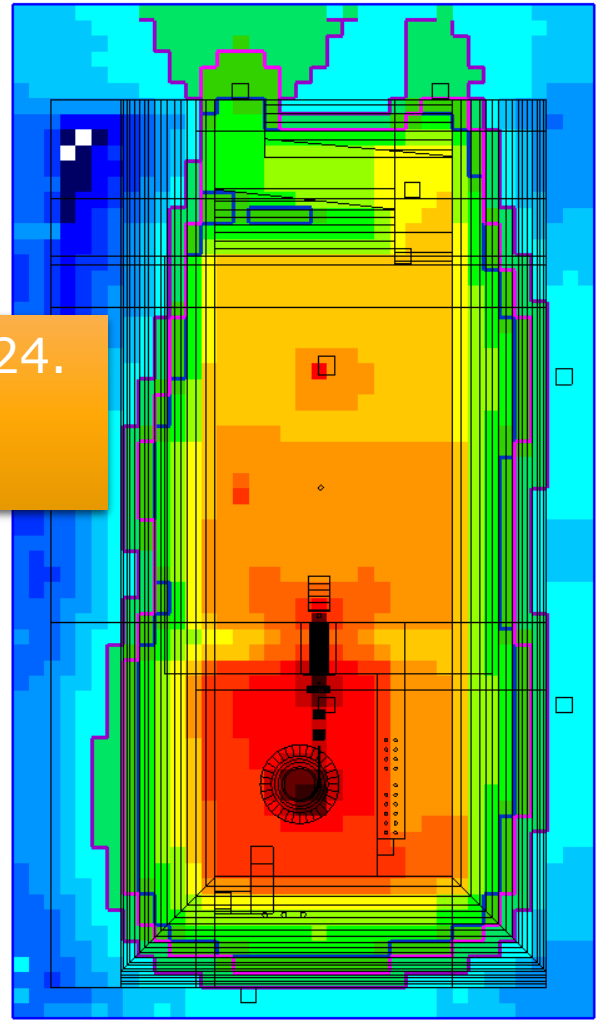
AUTHORITY APPROVAL FOR AN ADDITIONAL IRRADIATION ROOM

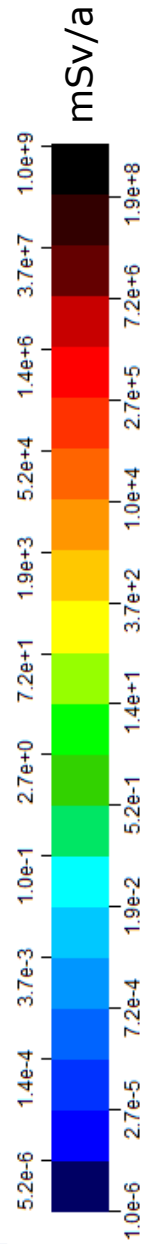
A COMMERCIAL SYNCHRO CYCLOTRON FOR PROTON THERAPY



Authority approval expected summer 2024.

Start of construction pending.

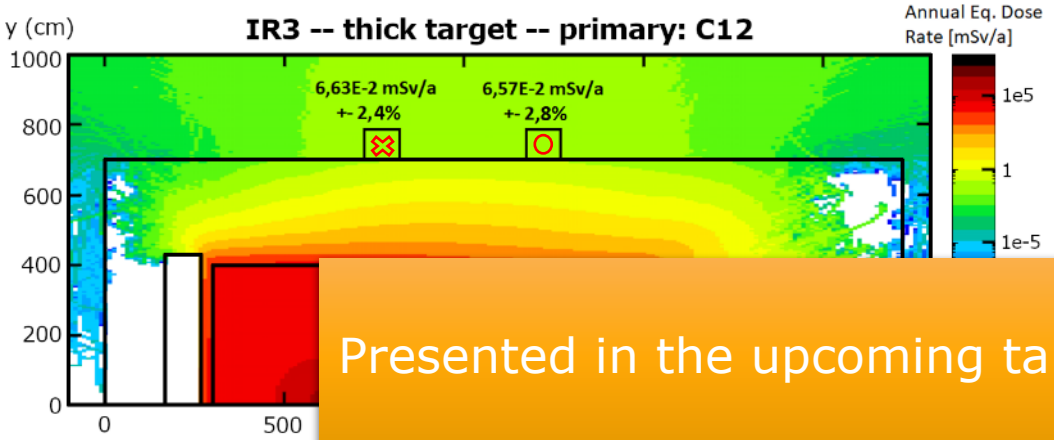




0.1 mSv/a 0.6 mSv/a 2.0 mSv/a

EXTENSION OF APPROVED ION SPECIES

EFFECTS ON THE SHIELDING



Nr of primary particles of ion species A

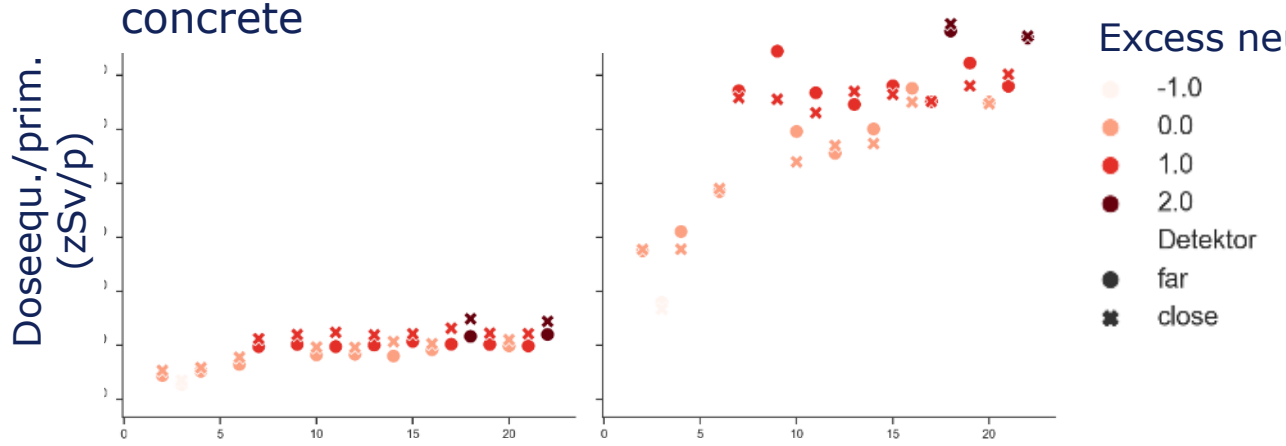
$$D_{ges} = \sum_{A=1}^{A_{max}} N_A \cdot D_A$$

cles of ion species A

Presented in the upcoming talk by C. Lenauer

Room with heavy concrete

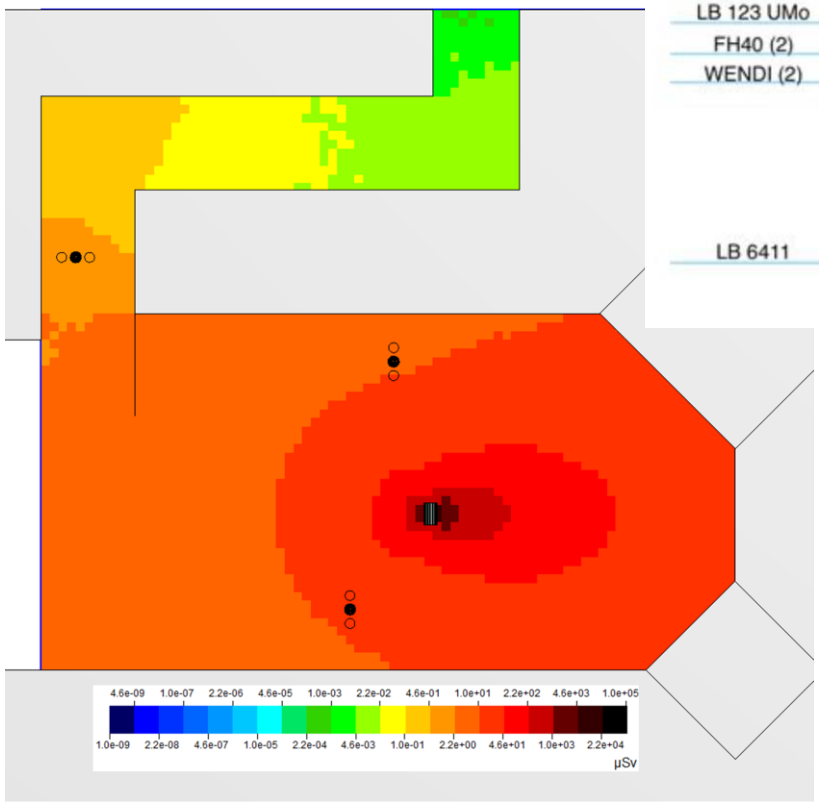
Room with normal concrete



Radiation Protection Project

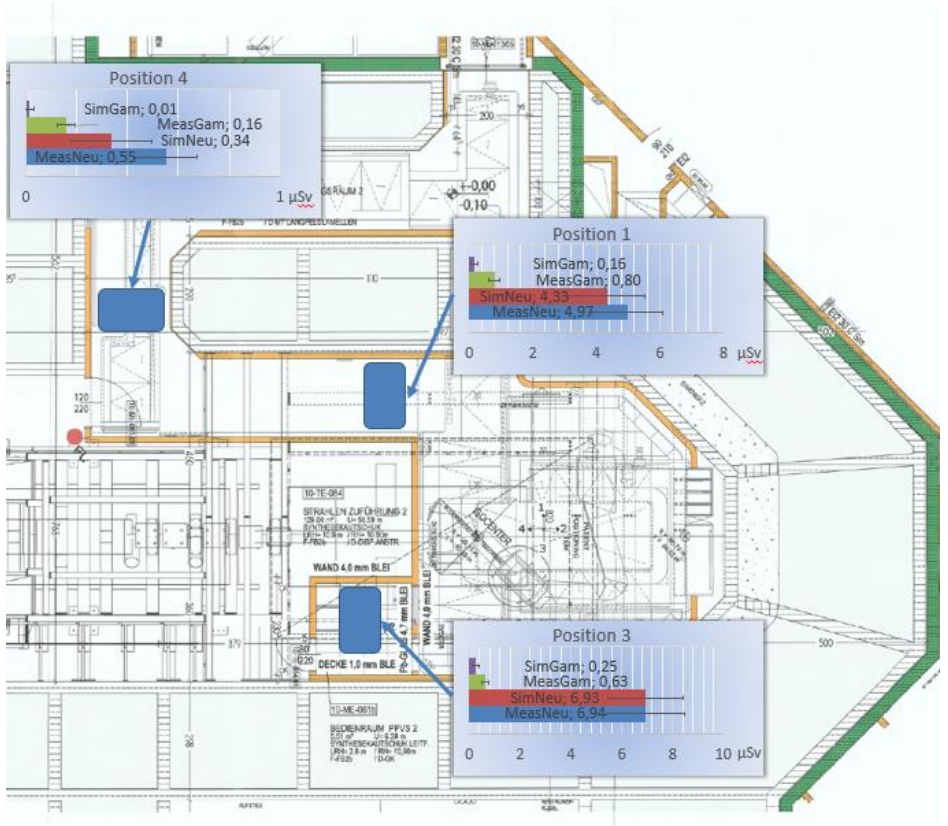
MEASURMENTS AND SIMULATIONS IN IR DURING PATIENT TREATMENT

CAN FLUKA BE USED TO ASSESS DOSE TO PERSON IN THE ROOM IN CASE OF THIS INCIDENT?



Reasonable agreement btw measurements and simulations

-> Method might be valid to assess personal dose

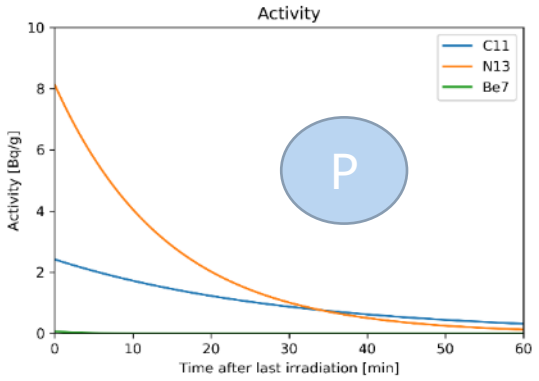


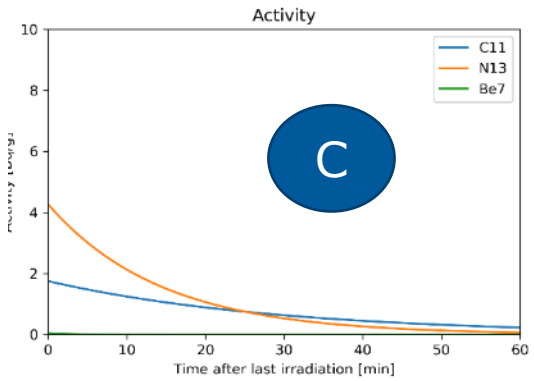
Radiation Protection Project

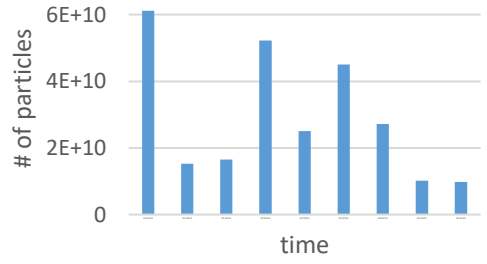
ACTIVATION OF WATER

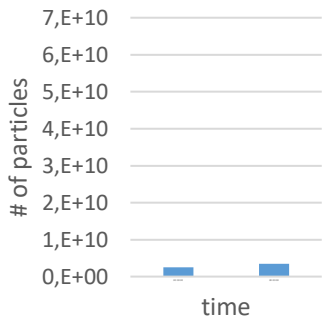
ARE CARBON IONS MORE DANGEROUS THAN PROTONS?

(Bq/g)	After protons			After carbon		
Nuclide	Activity	σ	MDA	Activity	σ	MDA
Be-7	0.07	0.01	0.0066	0.04	0.03	0.0099
C-11*	2.42	0.31	0.0138	1.75	0.22	0.0102
N-13*	8.14	1.04	0.0465	4.27	0.55	0.0248



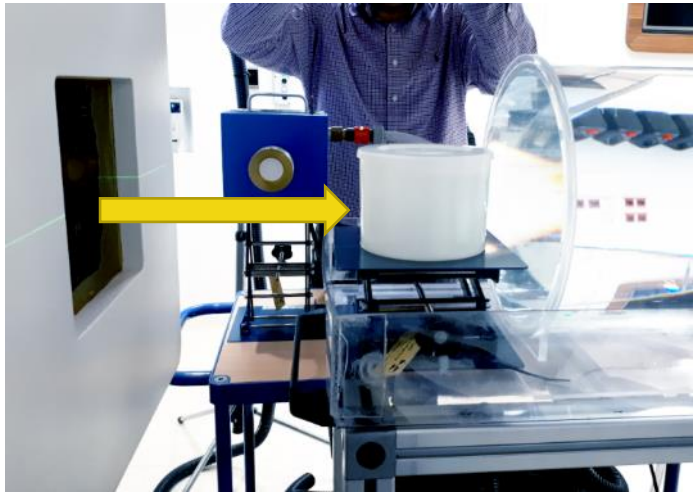






Typical treatment plans:

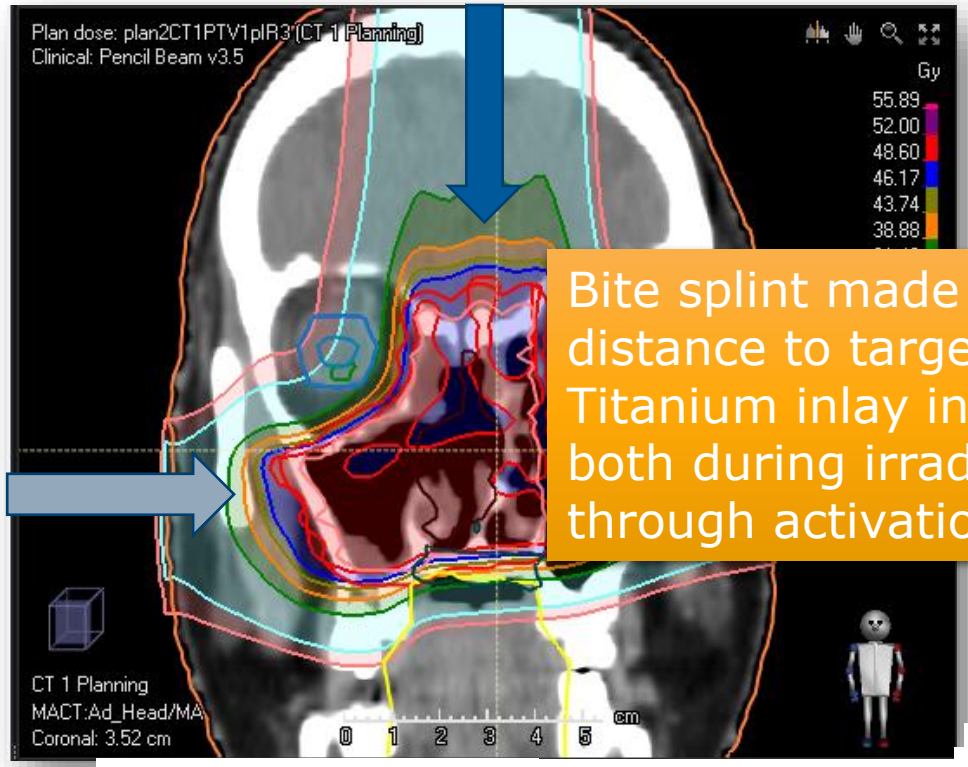
- Less Particles
- Less Activation of phantoms (or immobilization equipment, etc.)



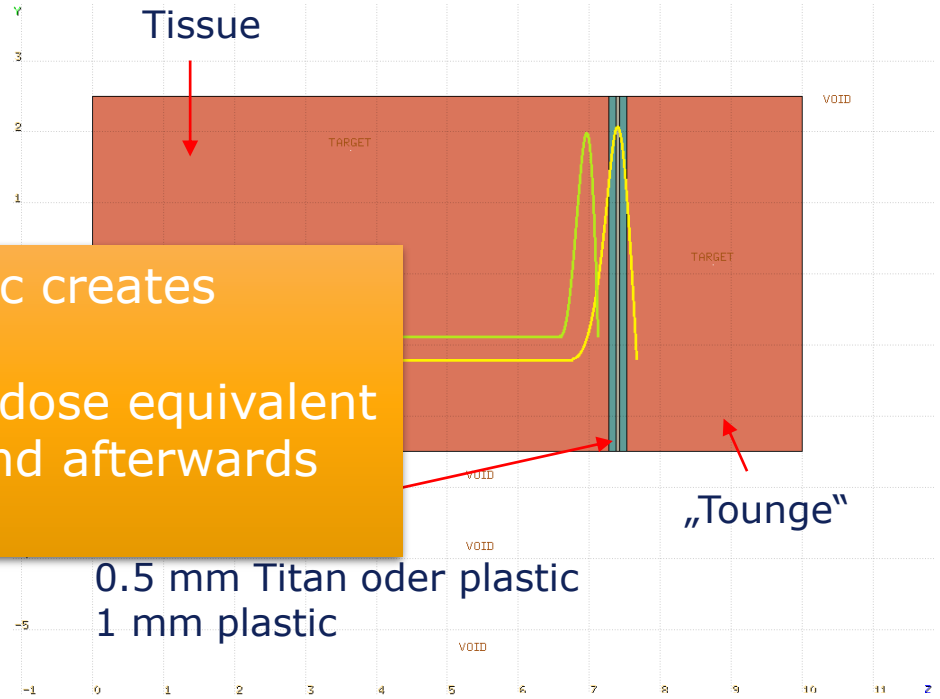
Radiation Protection Project

OPTIMIZATIONS FOR SINUS IRRADIATION

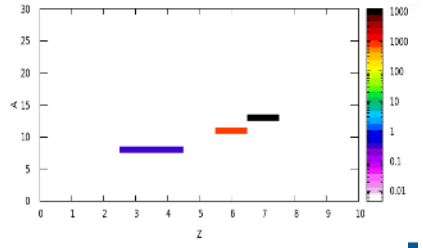
IS A TITANIUM LAYER IN THE BITE SPLINT USEFUL TO REDUCE DOSE EQUIVALENT TO THE PATIENT?



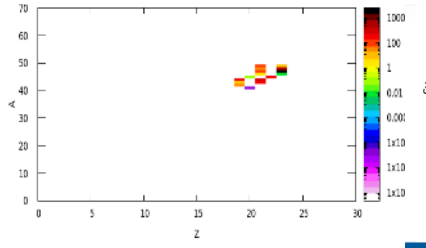
Bite splint made of plastic creates distance to target area -
Titanium inlay increases dose equivalent both during irradiation and afterwards through activation



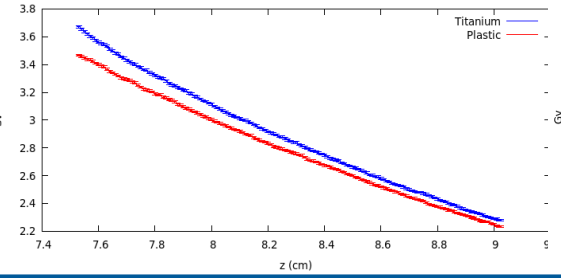
Activation without Ti



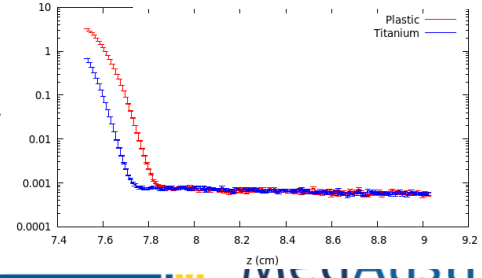
Activation with Ti



Dose Equivalent in beam direction



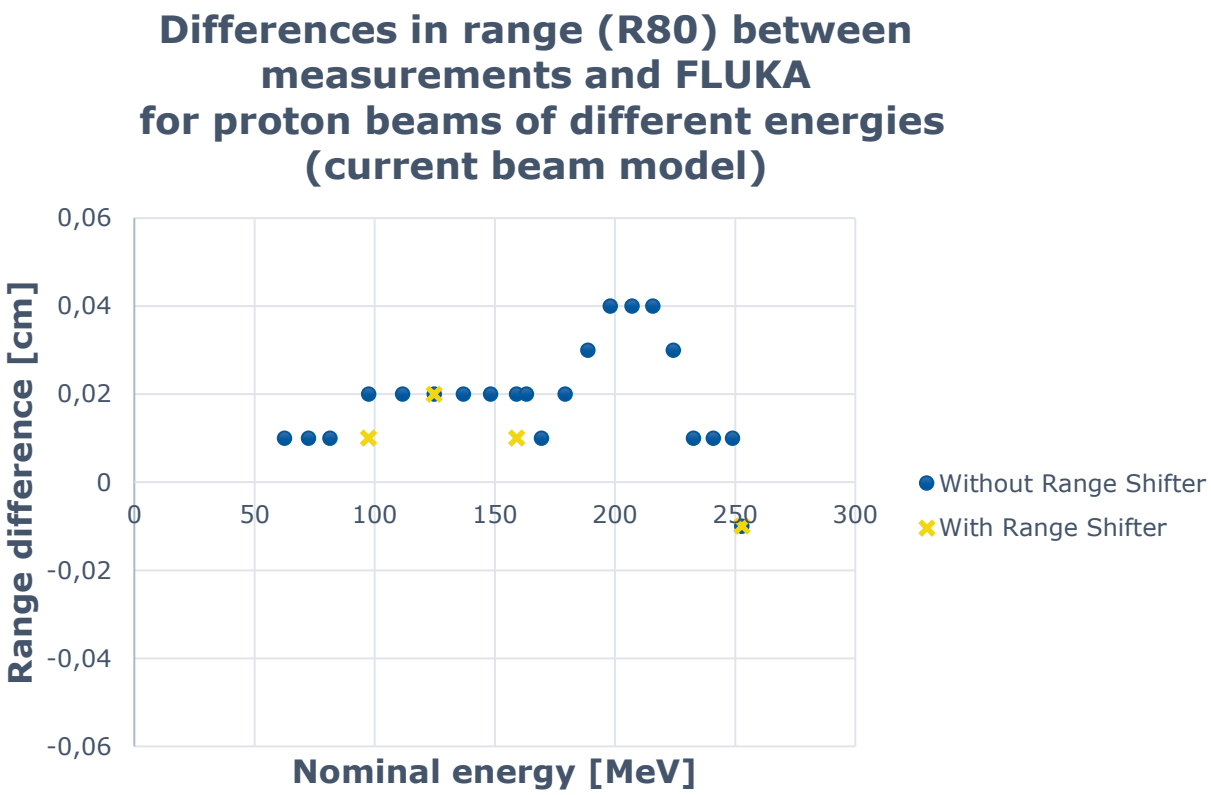
Energy dose in beam direction

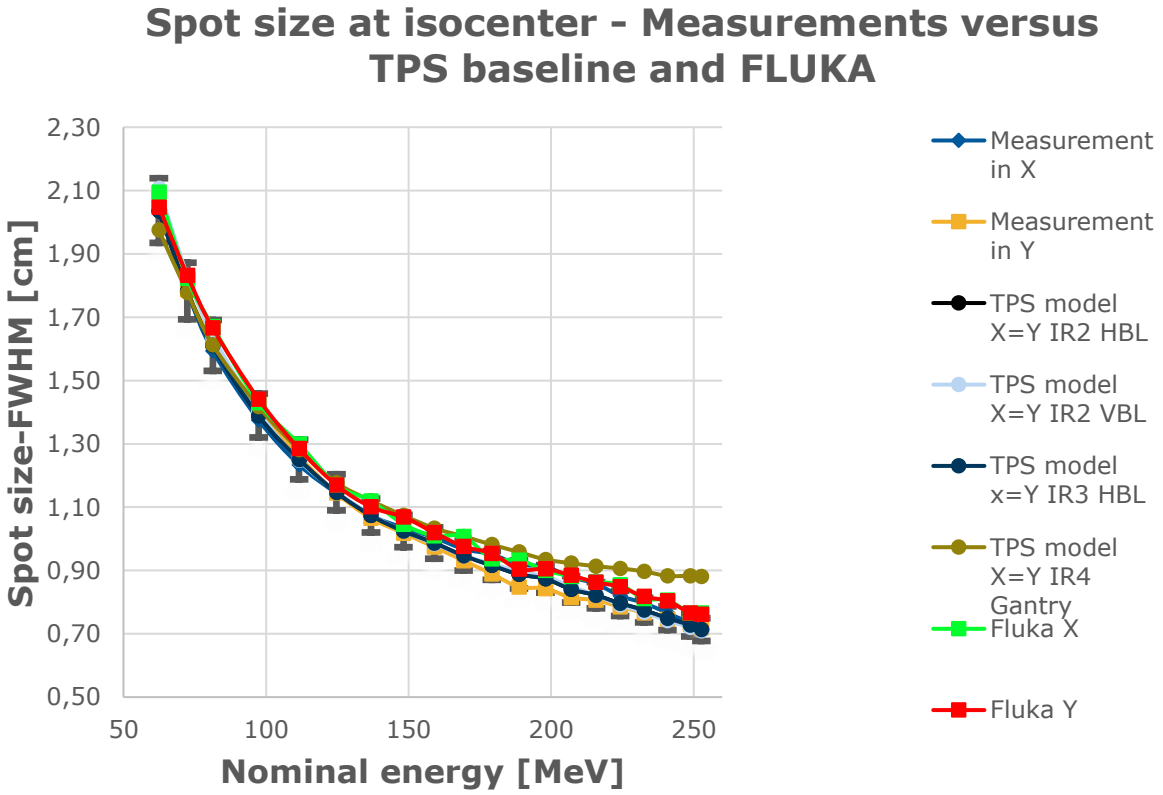


Radiation Protection Project

COMMISSIONING OF THE PROTON BEAM MODEL IN FLUKA

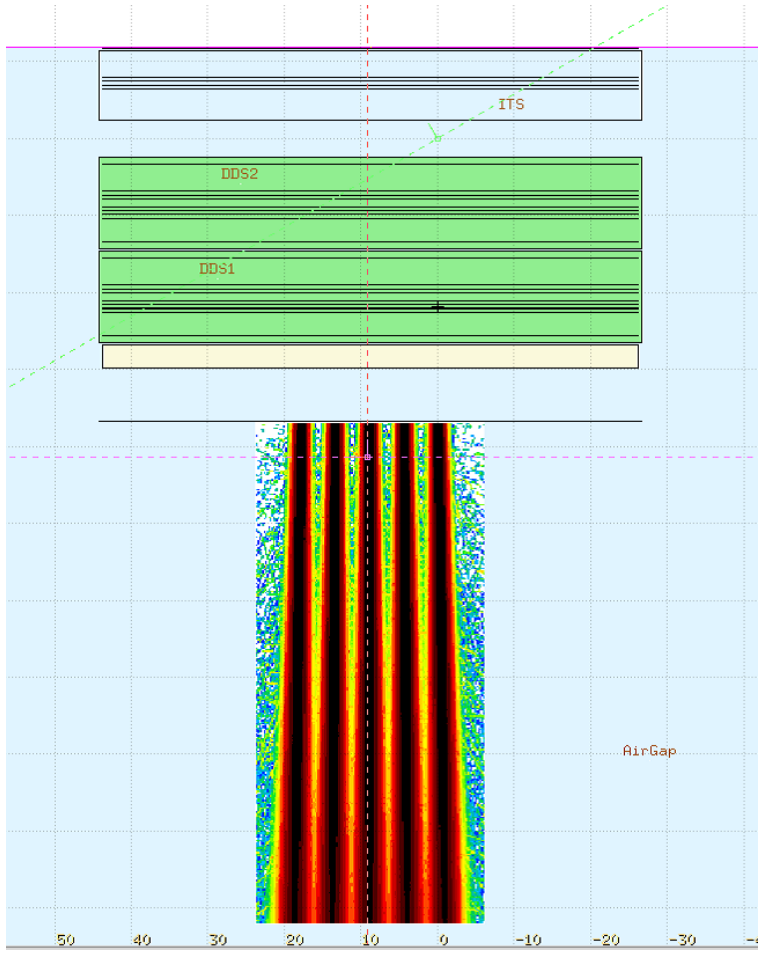
FOR ADDITIONAL EVALUATION OF SPECIAL TREATMENT SITUATIONS (E.G. IMPLANTS)

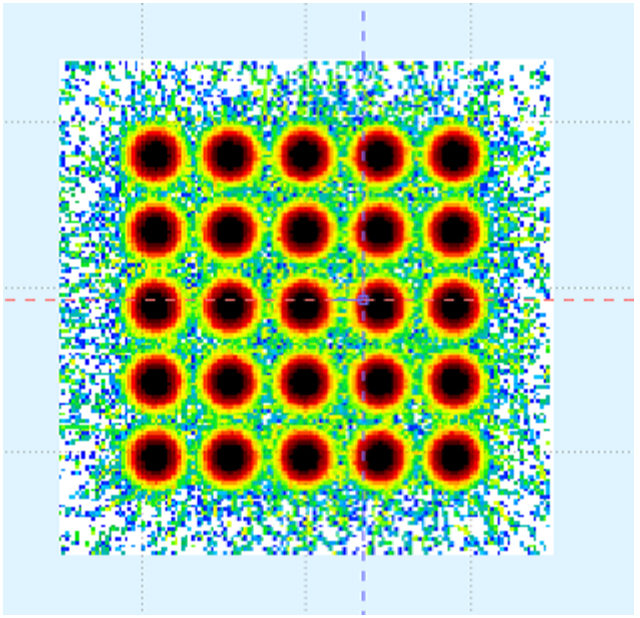




EVALUATION OF PROFILES IN AIR – 5X5 SPOTS PLAN

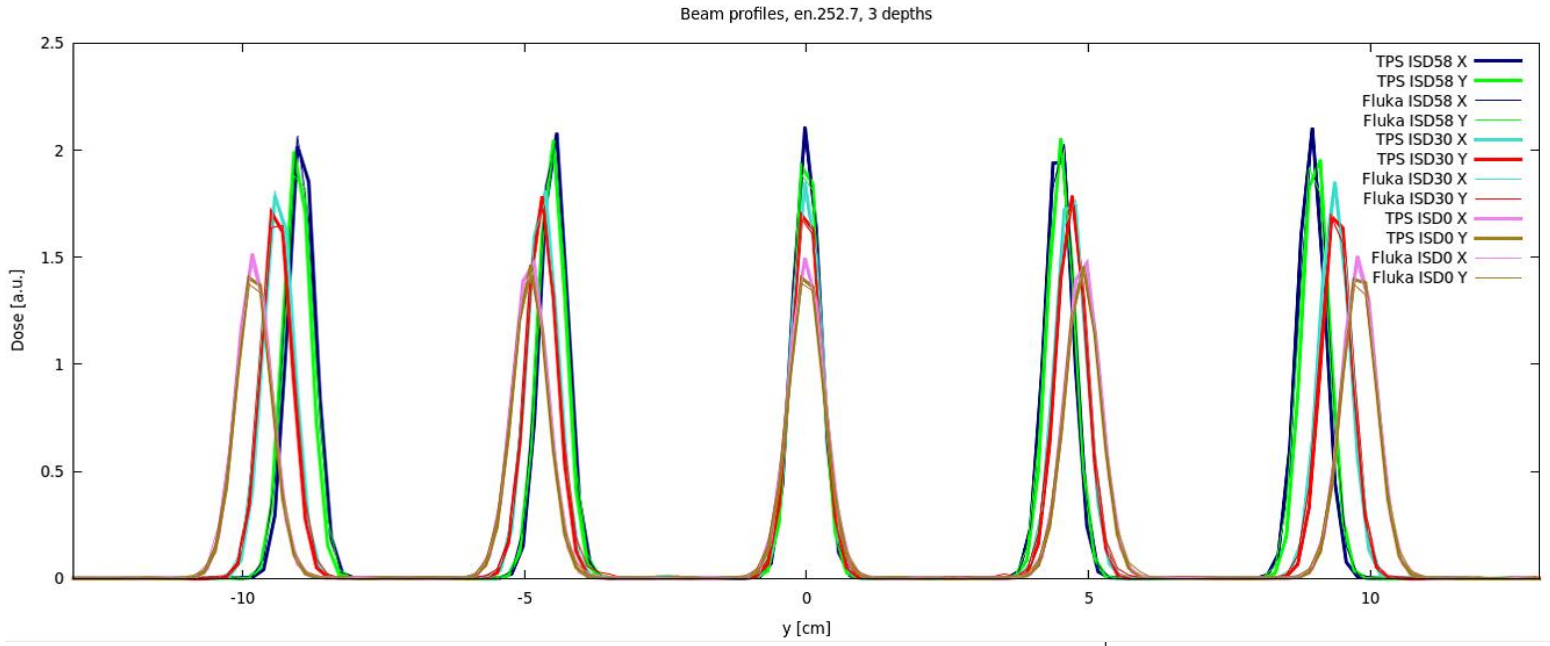
BEST RESULT IF VACUUM WINDOW IS NOT IMPLEMENTED



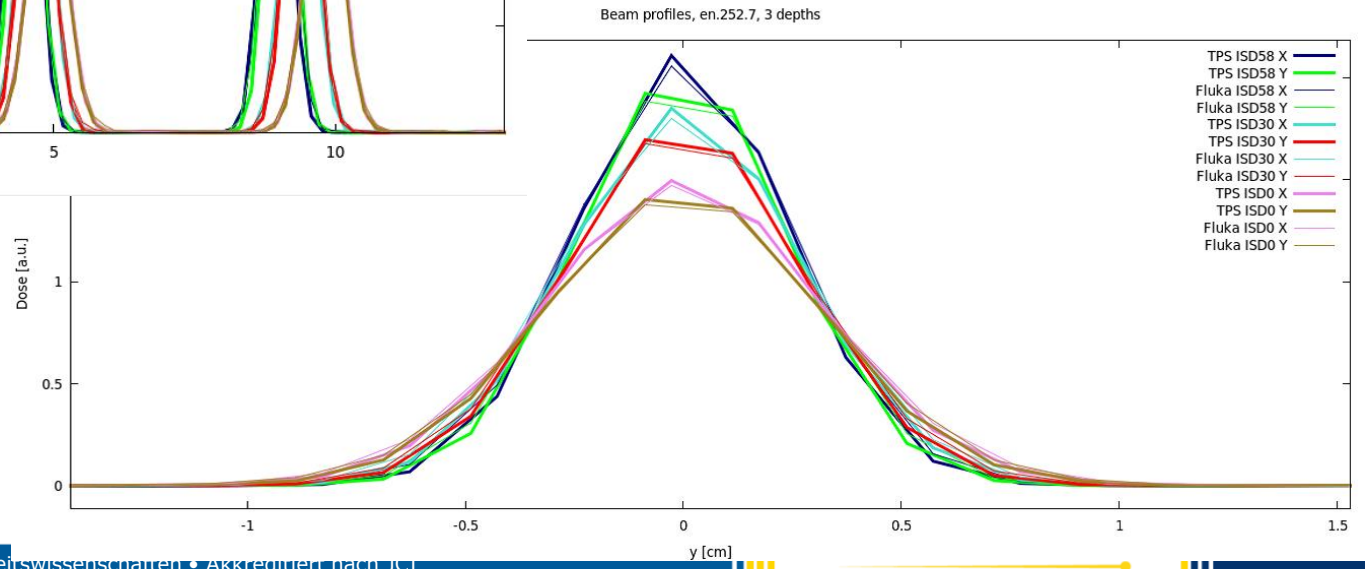


EVALUATION OF PROFILES IN AIR – 5X5 SPOTS PLAN

SHOWN FOR 252,7 MEV PROTON BEAM



For ISD58, ISD30 and ISD0 (at isocenter) FWHMs in agreement (inside 0.6 mm difference from measurements)

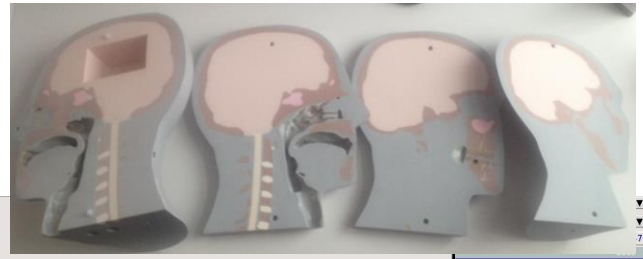


Radiation Protection Project

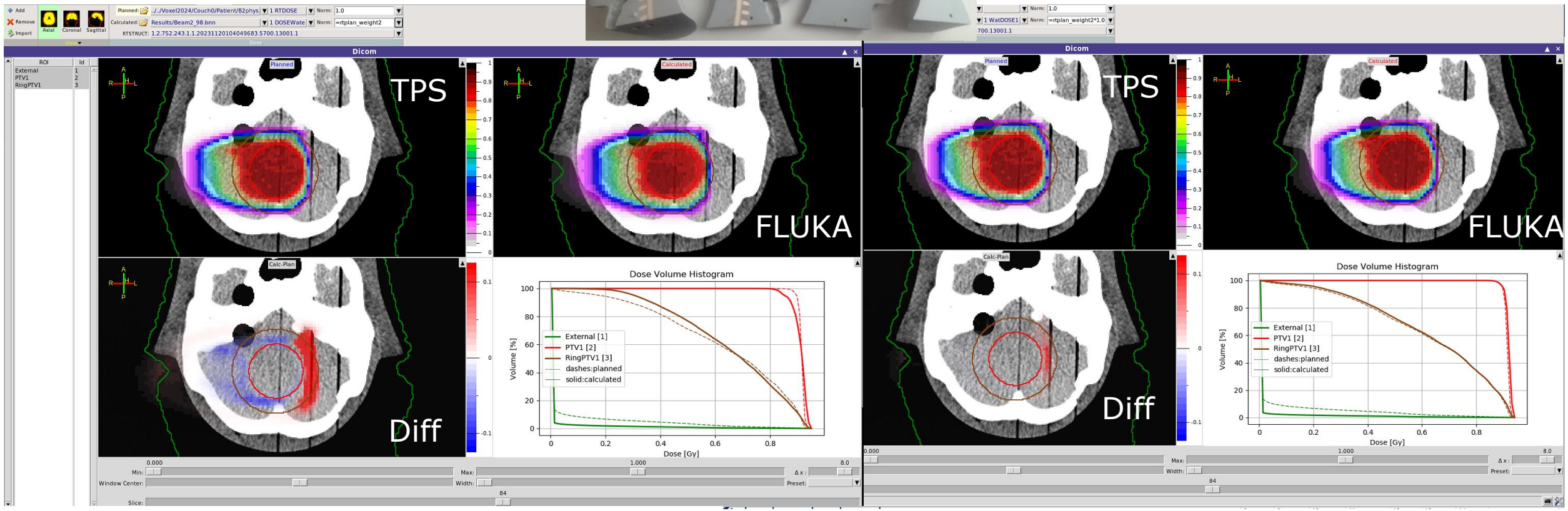
APPLICATION OF BEAM MODEL IN A TREATMENT PLAN

LEFT WITHOUT BEAM MODEL IMPLEMENTED, RIGHT WITH OPTIMIZED BEAM MODEL FOR PROTONS

Without beam model



With beam model



Radiation Protection Project

APPLICATION O MENT PLAN

LEFT WITHOUT BEAM MODE M MODEL FOR PROTONS

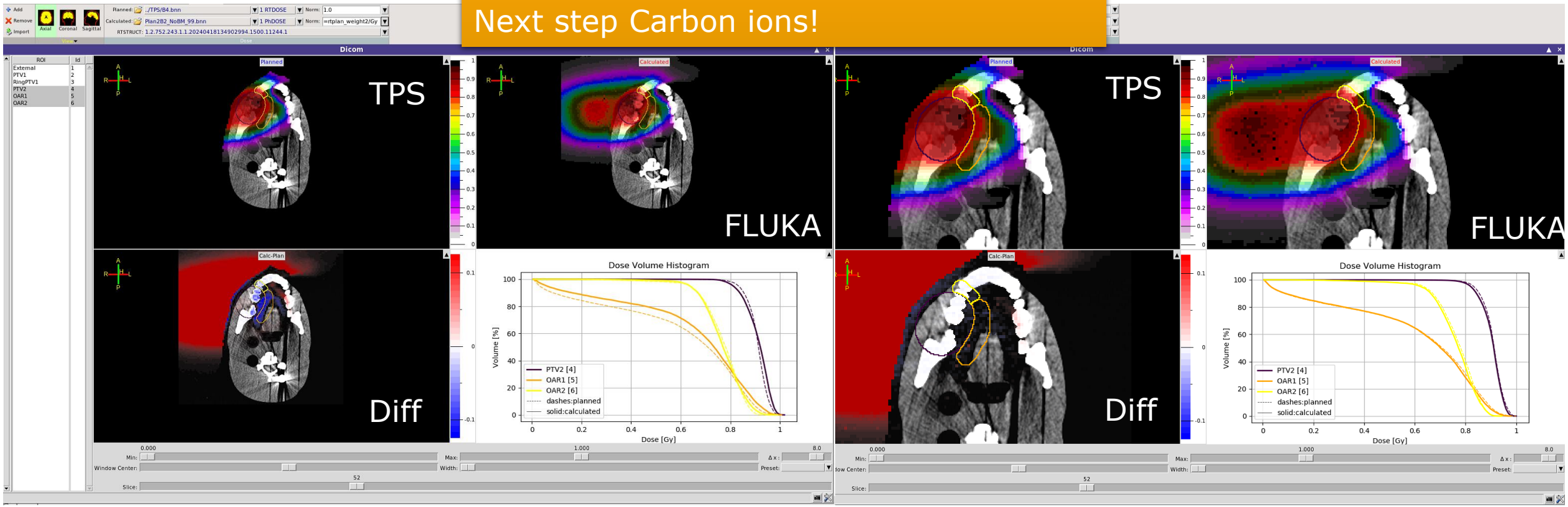
Good agreement between FLUKA and commercial TPS for proton beams.

Beam model still needs optimization concerning effective energy in iso center.

Next step Carbon ions!

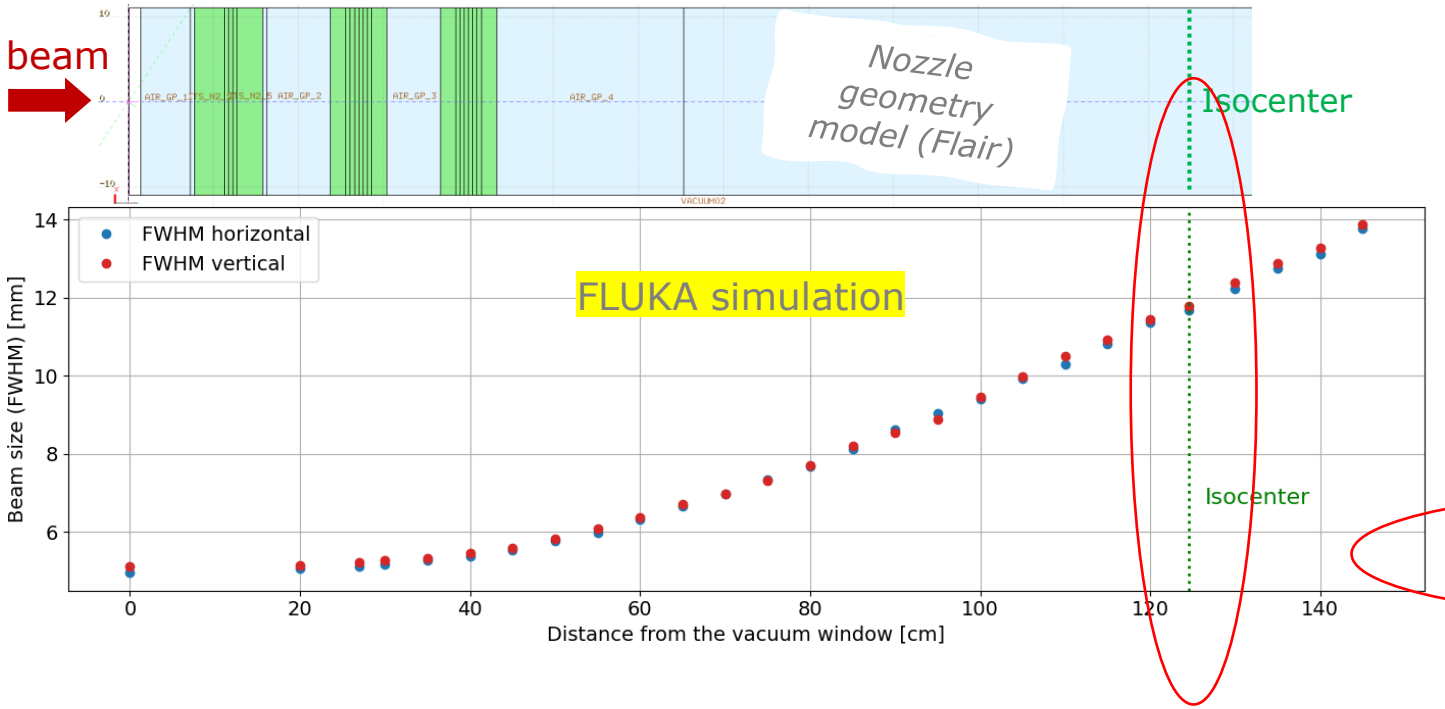
Without beam model

With beam model



FLUKA SIMULATION OF BEAM SCATTERING IN THE NOZZLE

- MAD-X/PTC particle tracking in the accelerator beam line → recorded particle coordinates.
- Output of MAD-X/PTC at the vacuum window → FLUKA input via the SOURCE sub-routine.
- Beam delivery monitors consist of thin metal and plastic foils with gaps filled by gasses.
- Detailed nozzle model was built using Flair to simulate the beam scattering using FLUKA.
- MULSOPT card included → MCS optimization & single scattering activated.
- Below → FLUKA simulation of the 136.8 MeV proton beam passing through the nozzle.



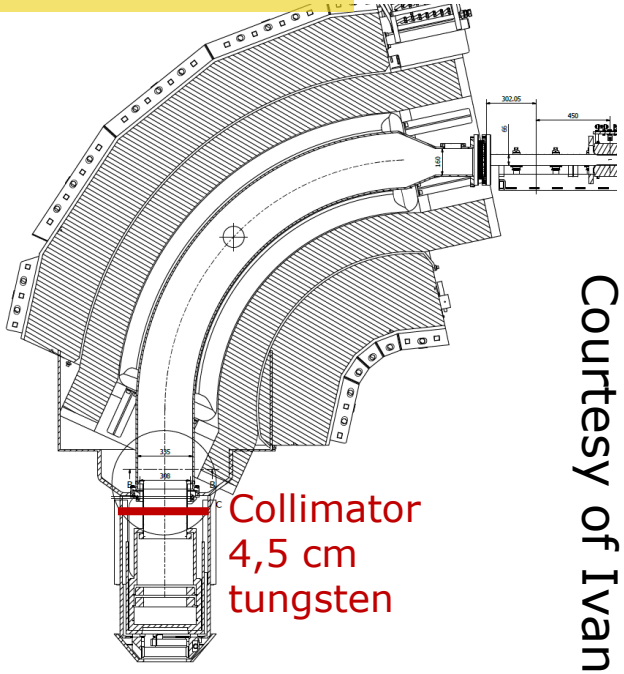
location	longitud. position (cm)	FWHM horizontal (mm)	FWHM vertical (mm)
Vacuum window	0.0	4.94	5.11
BDS2	27	5.11	5.21
BDS1	40	5.36	5.44
Isocenter	124.5	11.69	11.79

Measured FWHM at the isocenter = 11.7 mm (average)

Courtesy of Ivan Strasik & Mauro Pivi

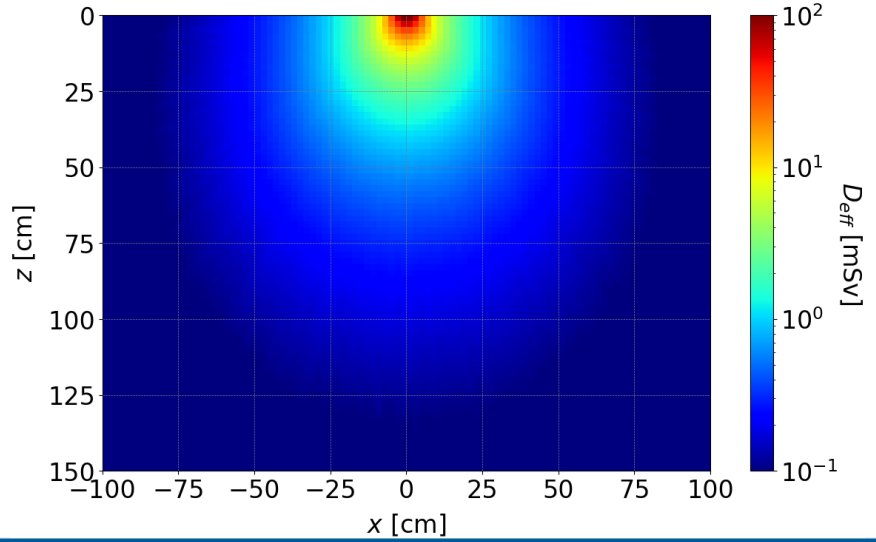
COLLIMATOR DESIGN USING FLUKA

- FLUKA was used to design a protective collimator in the gantry irradiation room.
- The collimator shall protect the patients in case of a failure of the last dipole magnet -> IEC 60601-2-64 clause 201.10.2.101.4.6. – non primary radiation under fault condiditon
- FLUKA simulations were used to determine the collimator parameters (dimensions, material, …).
- Secondary particles generated by the beam which accidentally hits the collimator, are also evaluated.
- Below are presented FLUKA simulations of the 252.7 MeV proton beam impacting on the collimator.

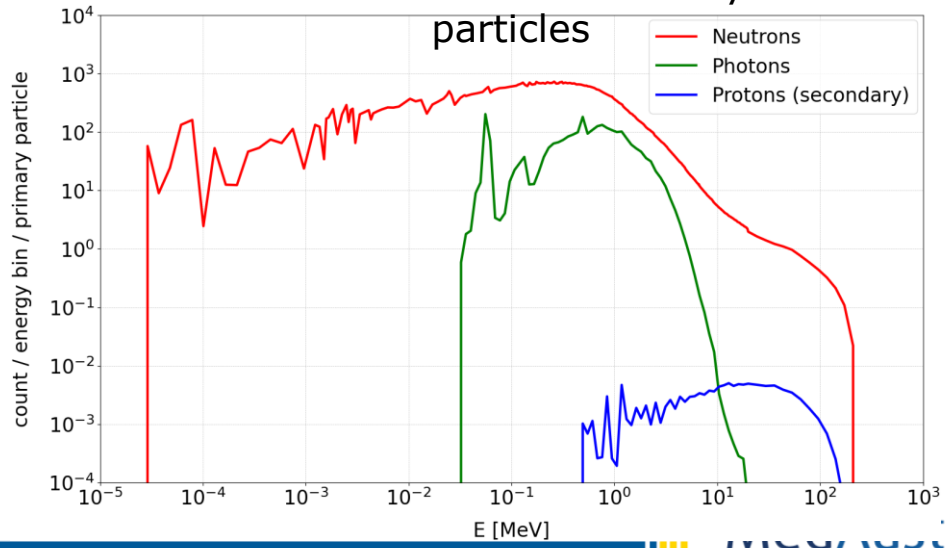


Courtesy of Ivan Strasik & Mauro Pivi

Effective dose rate



Fluence of the secondary particles



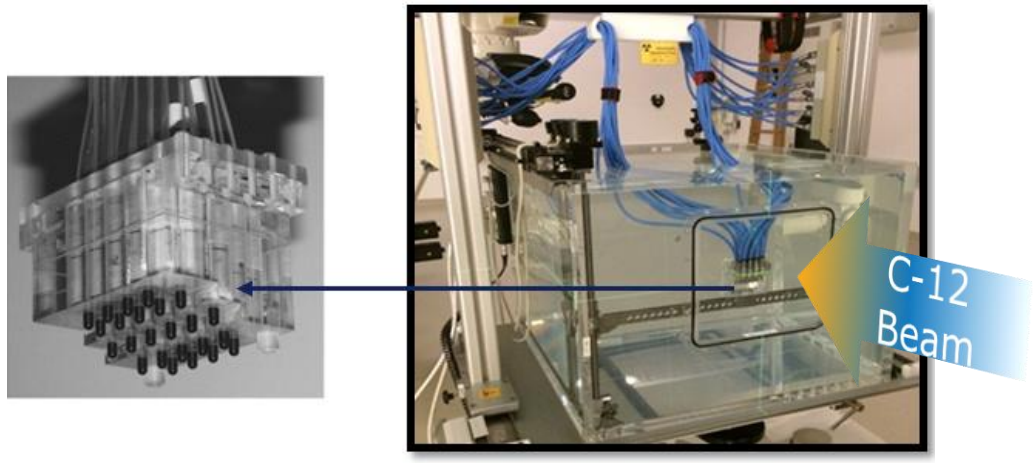
MOTIVATION

SAVING BEAM TIME!

- Experimental **patient-specific quality assurance (PSQA)**

  To verify dose calculation in clinical treatment planning system (**TPS**)

  - **Non-human** standardized geometry and material
  - Limited **sensitivity** to errors in planned/delivered dose
  - **Time consuming**



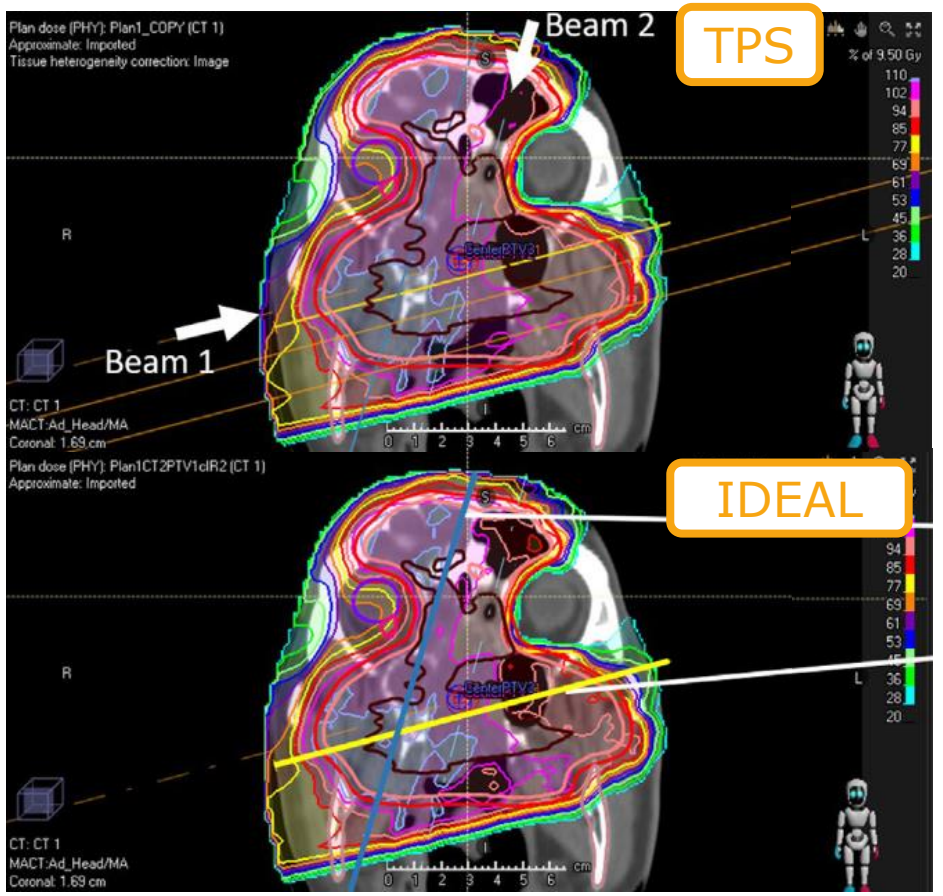
24 PinPoint ICs fixed to the PTW 3D detector block holder in a PTW MP3-P water phantom

Independent system to recalculate dose in patient geometry

Courtesy of Andreas F. Resch & Yihan Jia

IDEAL

- **Independent** DosE cAlculation system for **Light ion beam therapy**
- Wrapper for GATE-RTion v1.0/Geant4.10.3.p3
  - GATE-RTion: well validated release of GATE for clinical usage, release cycle ~ 5 years
- Designed for **daily clinical usage**
  → automatic workflow
- Integration of IDEAL into myQA iON
  - Collaboration with IBA Dosimetry
- First step
  - Absorbed dose validation
- Next step
  - RBE weighted dose validation



Grevillot et al. 2021

Courtesy of Andreas F. Resch & Yihan Jia

THANK YOU FOR YOUR INTEREST!