



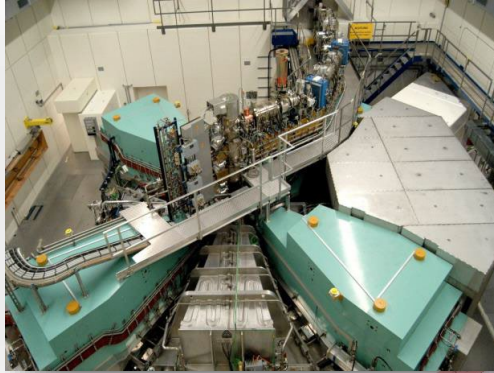
R. Eichler, C. Baumgartner, D. Kiselev, A. Ivanov, S. Jollet, N. van der Meulen,  
D. Reggiani, J. Snuverink, H. Zhang, D. Laube

## IMPACT-TATTOOS AS PART OF THE “INFRASTRUCTURE ROADMAP SWITZERLAND” INITIATIVE: CHALLENGES OF THE DESIGN CONCEPTS

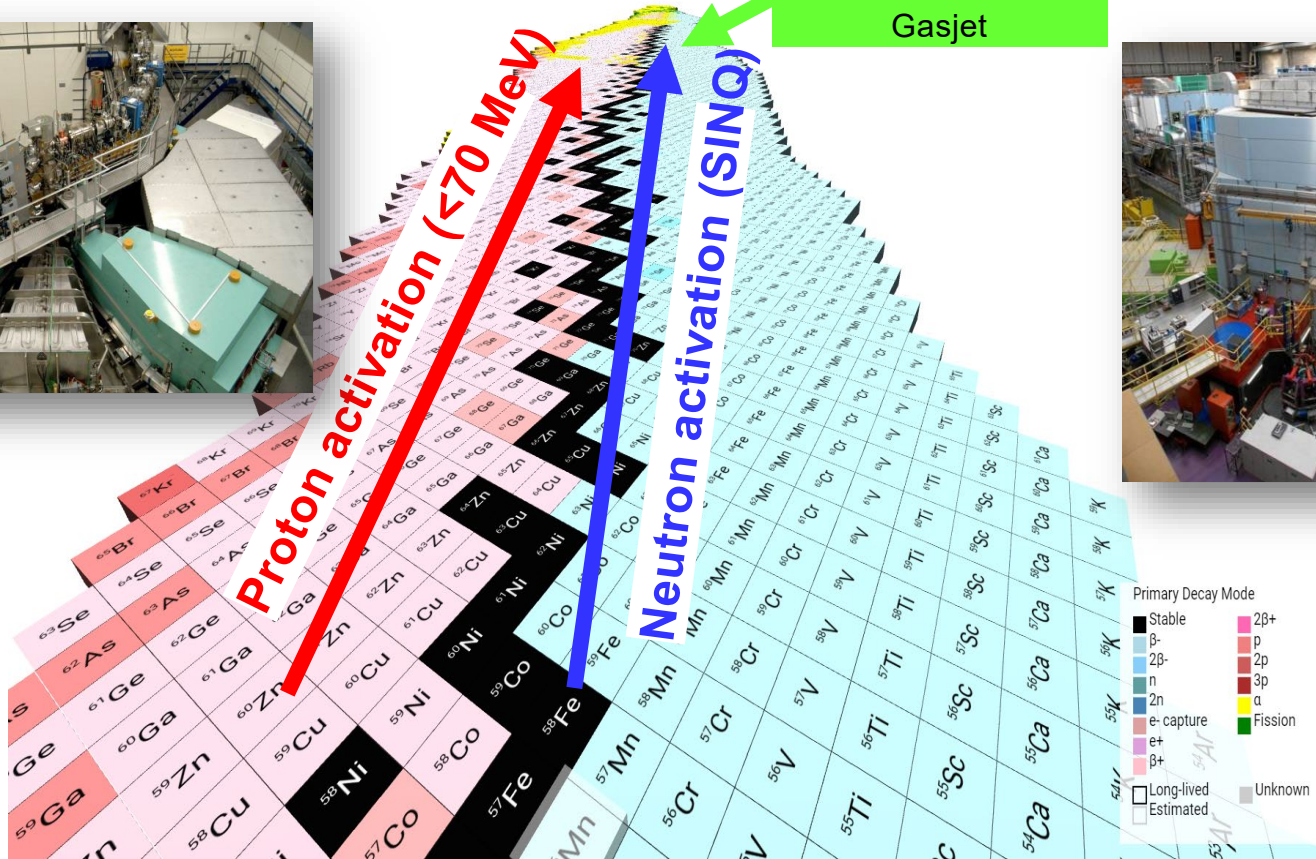
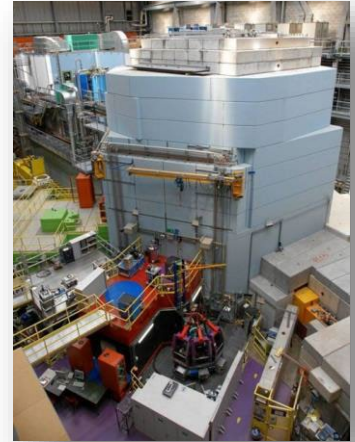
TATTOOS: Targeted Alpha Tumor Therapy and Other Oncological Solutions



# Current Isotope Production at PSI



SINQ Fission product  
 Gasjet

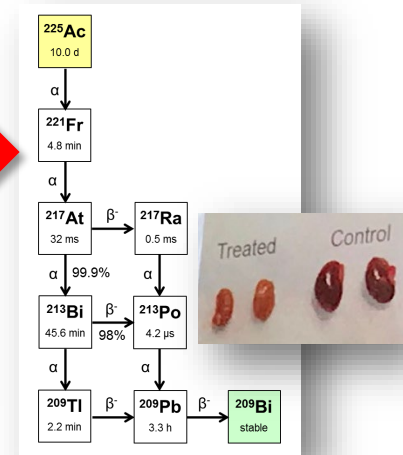
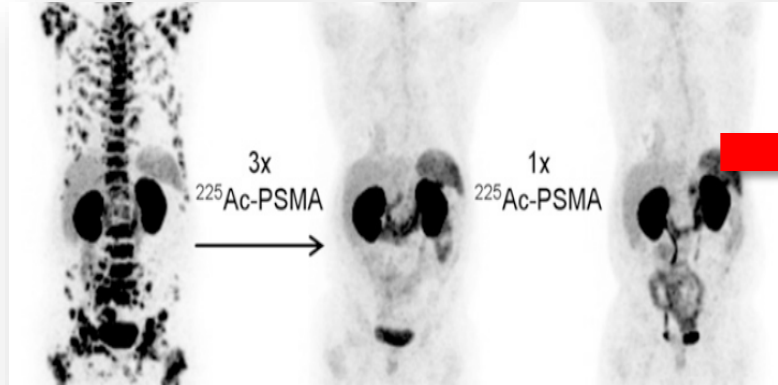


# “Matched Pair” Radionuclides for Teragnostics

$\alpha$ -Therapy	Auger-e Therapy	$\beta$ -Therapy	PET ( $\beta^+$ )	SPECT ( $\gamma$ )
		Lu 177 6.71 d $\beta^-$ 0.2... $\alpha$ 3.97 $\gamma$ 208; 316(122); 113... $\epsilon$ 3.2 $\sigma$ 1000	Ga 68 67.63 m $\beta^+$ 19... $\gamma$ 1077(1833...)	
<i>The “Terbium Sisters”</i>				
Tb 149 4.2 m 4.1 h $\alpha$ 3.97 $\beta^+$ 1.8 $\gamma$ 796; 352; 165... 165...	Tb 161 6.90 d $\beta^-$ 0.5, 0.6... $\gamma$ 20, 48, 75...		Tb 152 4.2 m 17.5 h $\beta^-$ 283; 160... $\beta^+$ 2.8... $\gamma$ 344; 586; 671... 271...	Tb 155 5.32 d $\gamma$ 87; 105... 160, 262
		Sc 47 3.35 d $\beta^-$ 0.4; 0.6 $\gamma$ 159	Sc 43 3.89 h $\beta^+$ 12... $\gamma$ 373... Sc 44 2.44 d 3.92 h $\beta^-$ 271 $\gamma$ 1100; 1261; 1157 $\beta^+$ 1.5... $\gamma$ 115...	
		Cu 67 2.58 d $\beta^-$ 0.4; 0.6... $\gamma$ 185, 93, 91...	Cu 64 12.7 h $\beta^-$ 0.6 $\beta^+$ 0.7... $\gamma$ (1346) $\epsilon$ -270	
	Er 165 10.3 h $\alpha$ 20.7	Er 169 9.40 d $\beta^-$ 0.3... $\gamma$ (110...) $\epsilon$		



# Targeted Alpha Therapy is a Hot Topic!

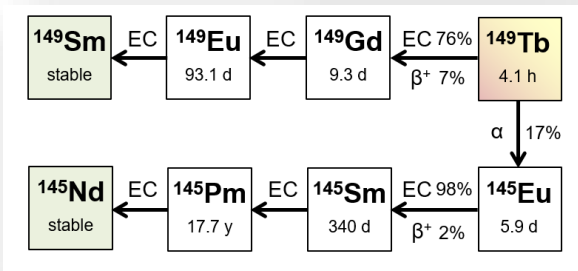


Multiple  $\alpha/\beta^-$ -decaying daughter nuclides can cause much damage, Resulting in side effects!

4h Half-life / alpha & beta+ decay

Tb 149	
4.2 m	4.1 h
$\epsilon$	$\epsilon$
$\beta^+$ 3.99	$\alpha$ 3.97...
$\gamma$ 796	$\beta^+$ 1.6...
165...	$\gamma$ 352
	165...

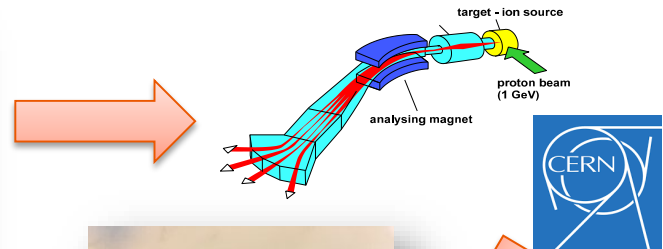
$^{149}\text{Tb}$  has NO  $\alpha$ -daughters!



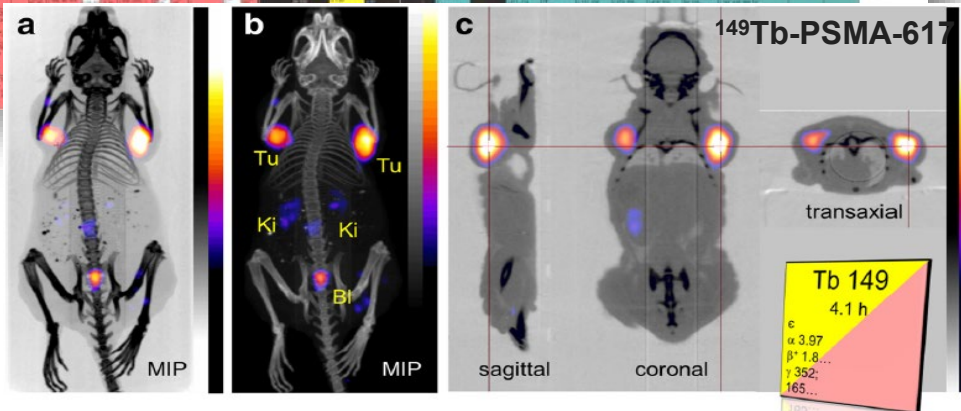
# $^{149}\text{Tb}$ : Progress So Far



## Isotope Separation Online (ISOLDE)



Chemical Separation and Processing @ PSI



Umbricht et al. , Scientific Reports, 2019

# TATTOOS the initiative of...

- TATTOOS: Targeted Alpha Tumor Therapy and Other Oncological Solutions

## Laboratory of Radiochemistry

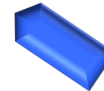
(PSI-NES, ETHZ, University Bern)

Expertise in Radionuclide production,  
Chemical separation and Radionuclide application

## Center for Radiopharmaceutical Sciences

(PSI-BIO, ETHZ)

Expertise in Radiolabeling chemistry,  
Preclinical assessment  
and Radionuclide therapy development, GMP

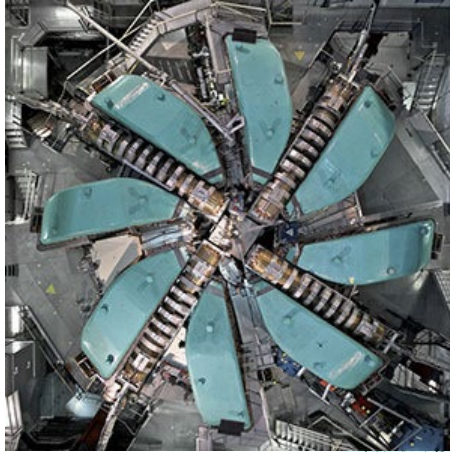


*Radionuclide Development  
Group*

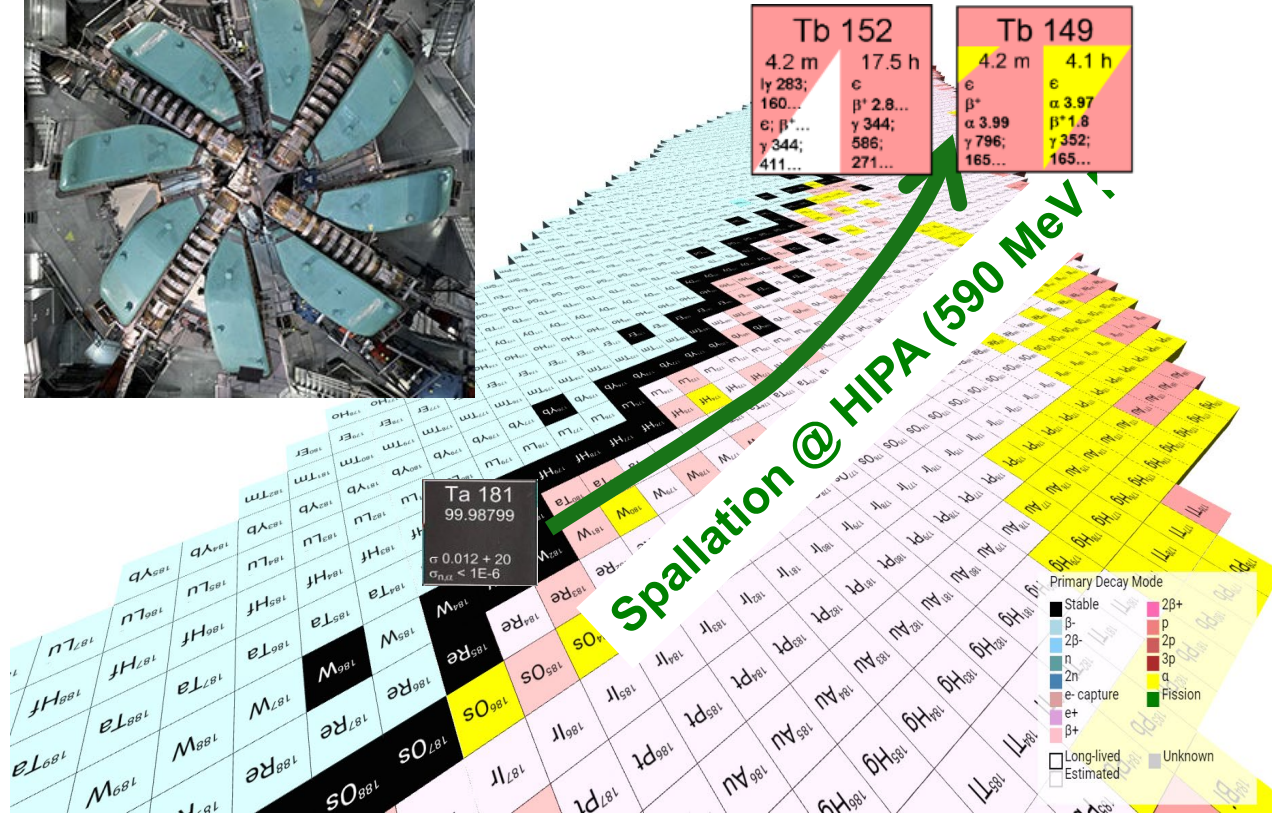


# $^{149}\text{Tb}$ Production @ PSI-HIPA (50 fold beam dose (100 $\mu\text{A}$ ))

$^{181}\text{Ta}(p, 10p \text{ \& } 20/23 n)^{149,152}\text{Tb}$



Tb 152		Tb 149	
4.2 m	17.5 h	4.2 m	4.1 h
$\gamma$ 283;	$\epsilon$	$\epsilon$	$\epsilon$
160...	$\beta^+$ 2.8...	$\beta^+$	$\alpha$ 3.97
$\epsilon$ ; $\beta^+$ ...	$\gamma$ 344;	$\alpha$ 3.99	$\beta^+$ 1.8
$\gamma$ 344;	586;	$\gamma$ 796;	$\gamma$ 352;
411...	271...	165...	165...



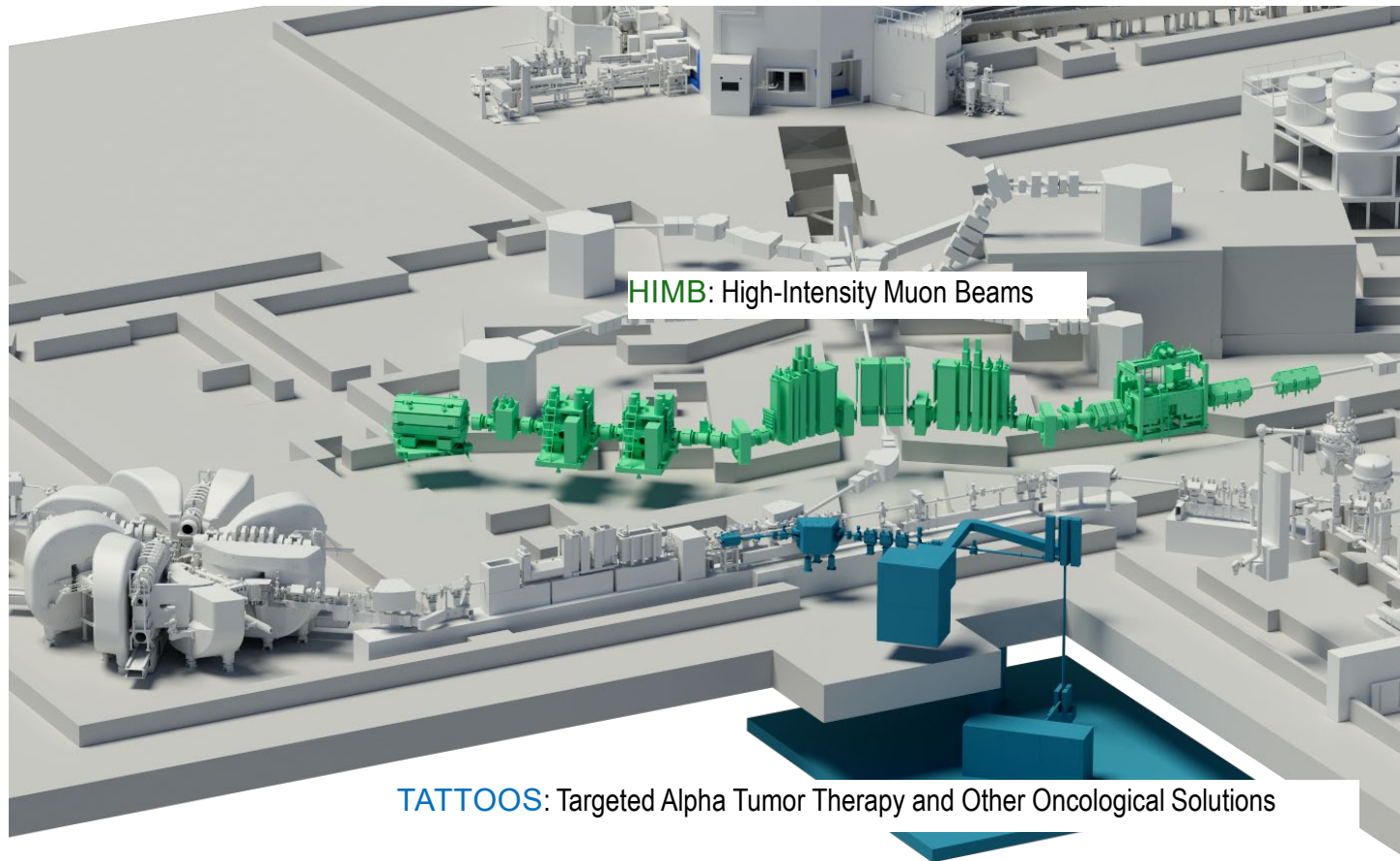
Ta 181
99.98799
$\sigma_{p,10p} = 0.012 + 20$
$\sigma_{p,20/23n} < 1E-6$

Primary Decay Mode

■ Stable	■ 2 $\beta^+$
■ $\beta^-$	■ p
■ 2 $\beta^-$	■ 2p
■ n	■ 3p
■ 2n	■ $\alpha$
■ e-capture	■ Fission
■ e+	
■ $\beta^+$	
□ Long-lived	■ Unknown
□ Estimated	



# The IMPACT Project



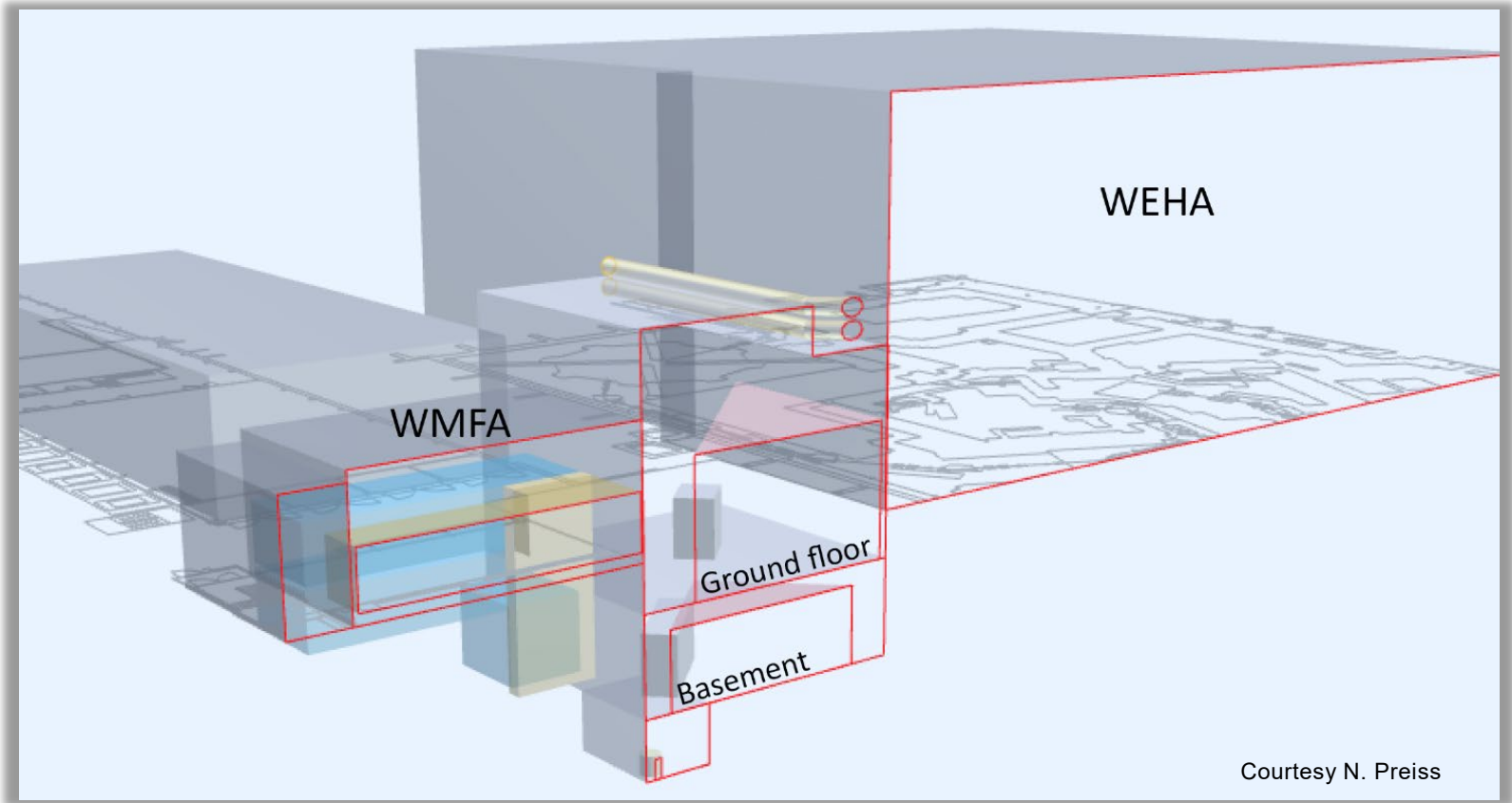
HIMB: High-Intensity Muon Beams

TATTOOS: Targeted Alpha Tumor Therapy and Other Oncological Solutions





# New TATTOOS Building

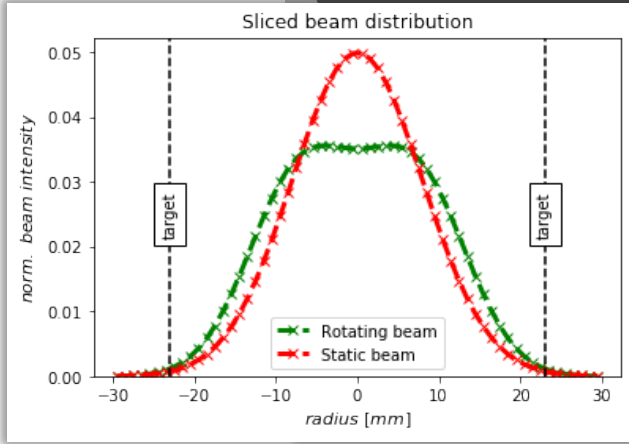
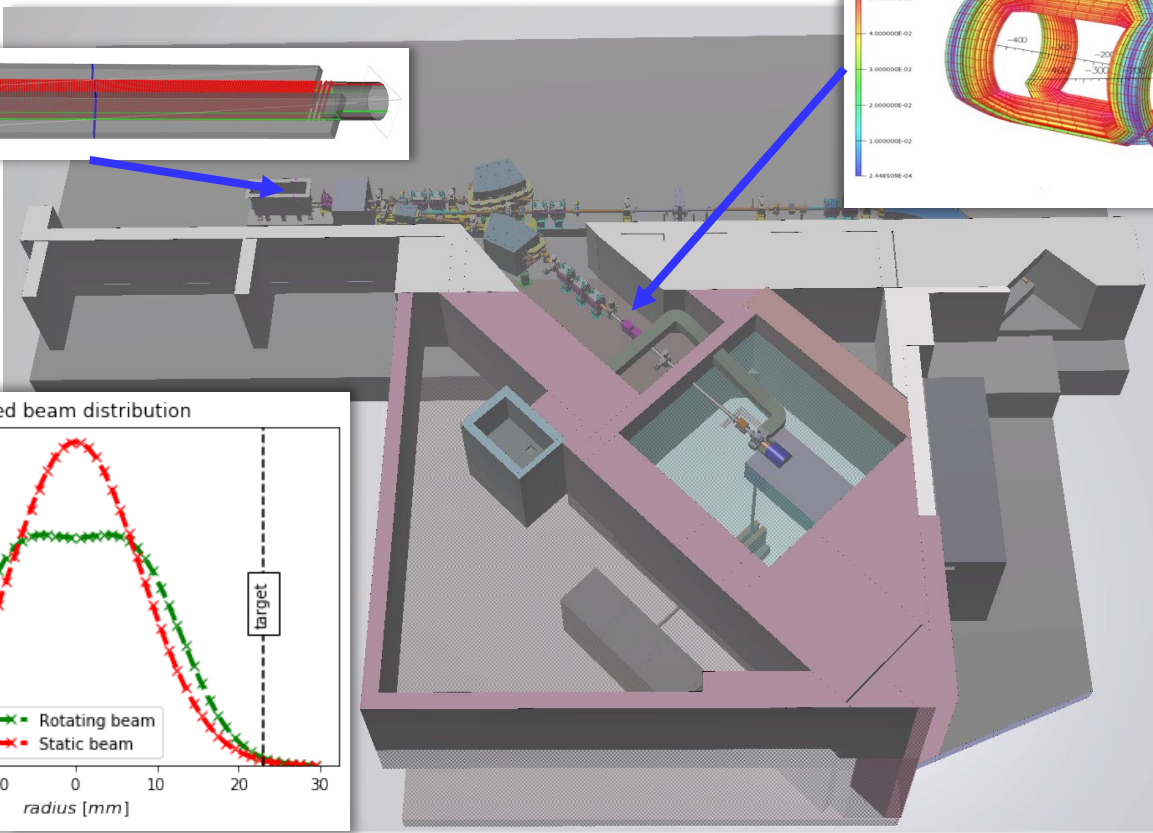
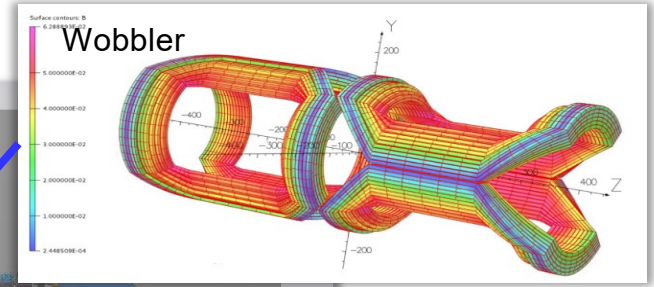
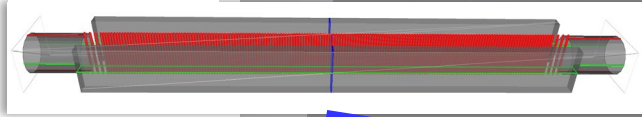


Courtesy N. Preiss



# Beam

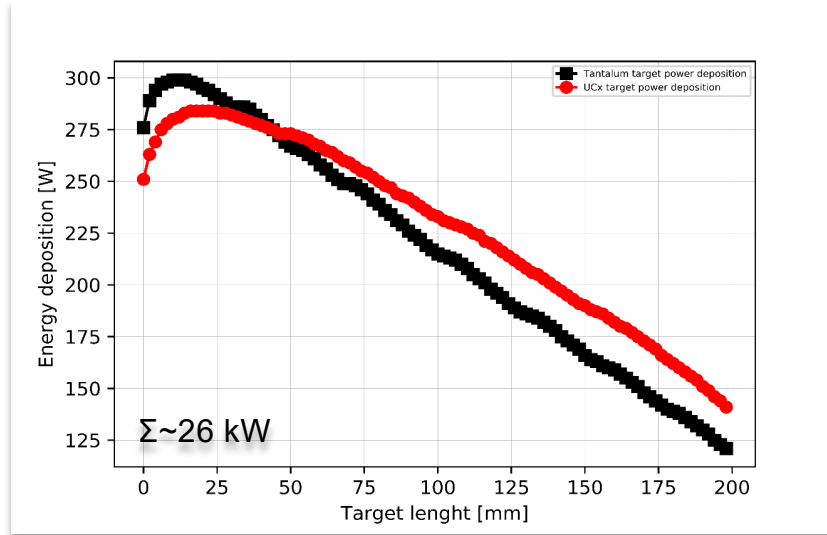
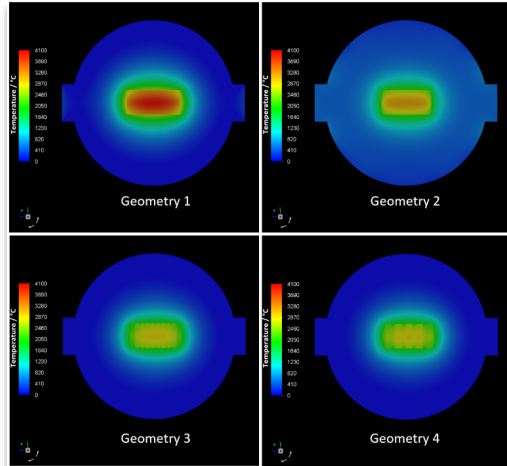
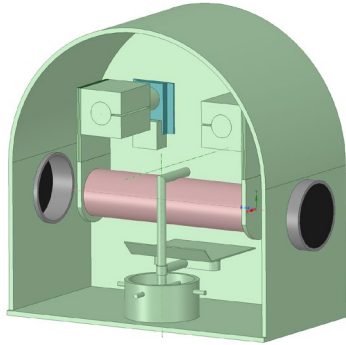
Beam Splitter



Courtesy C Sattler, D.Reggiani,  
J. Snuverink et al.

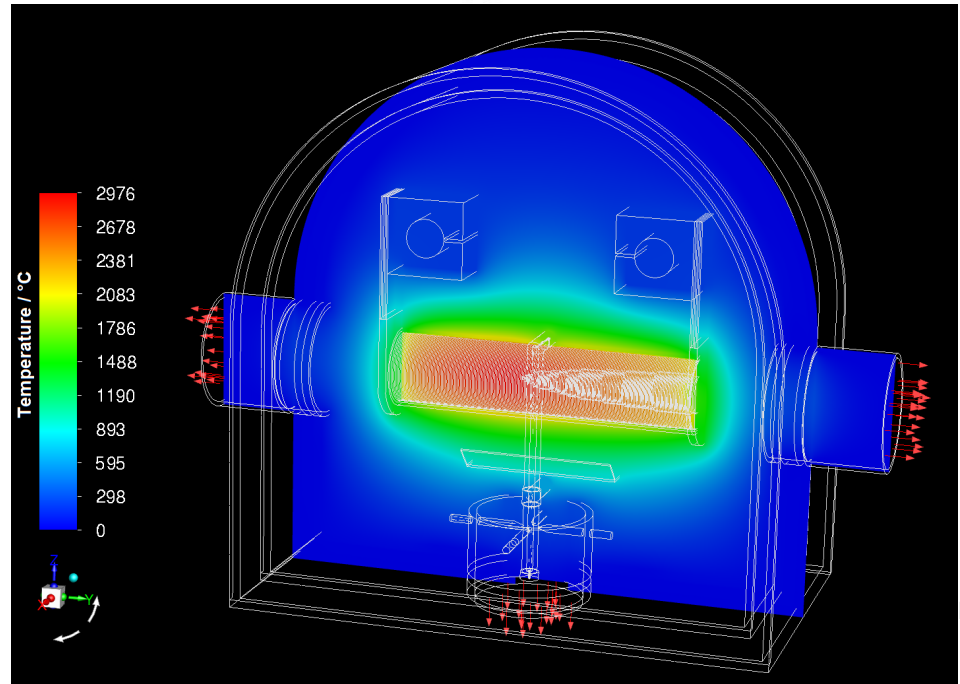
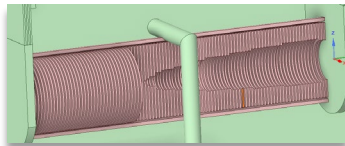
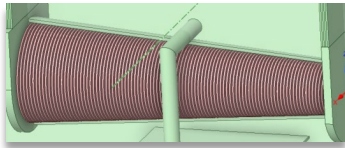
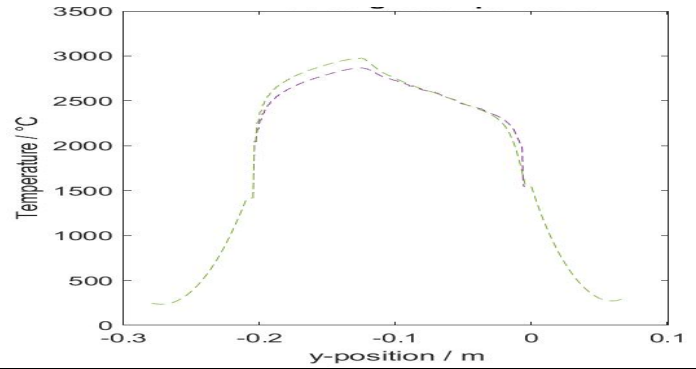
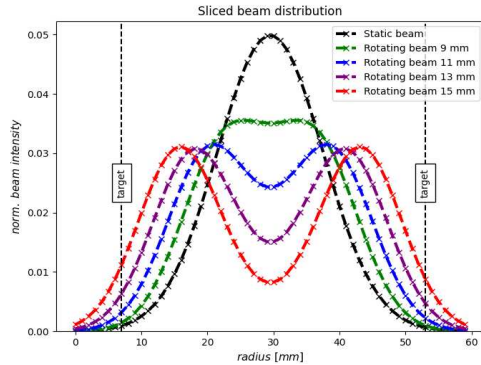


# High power Target

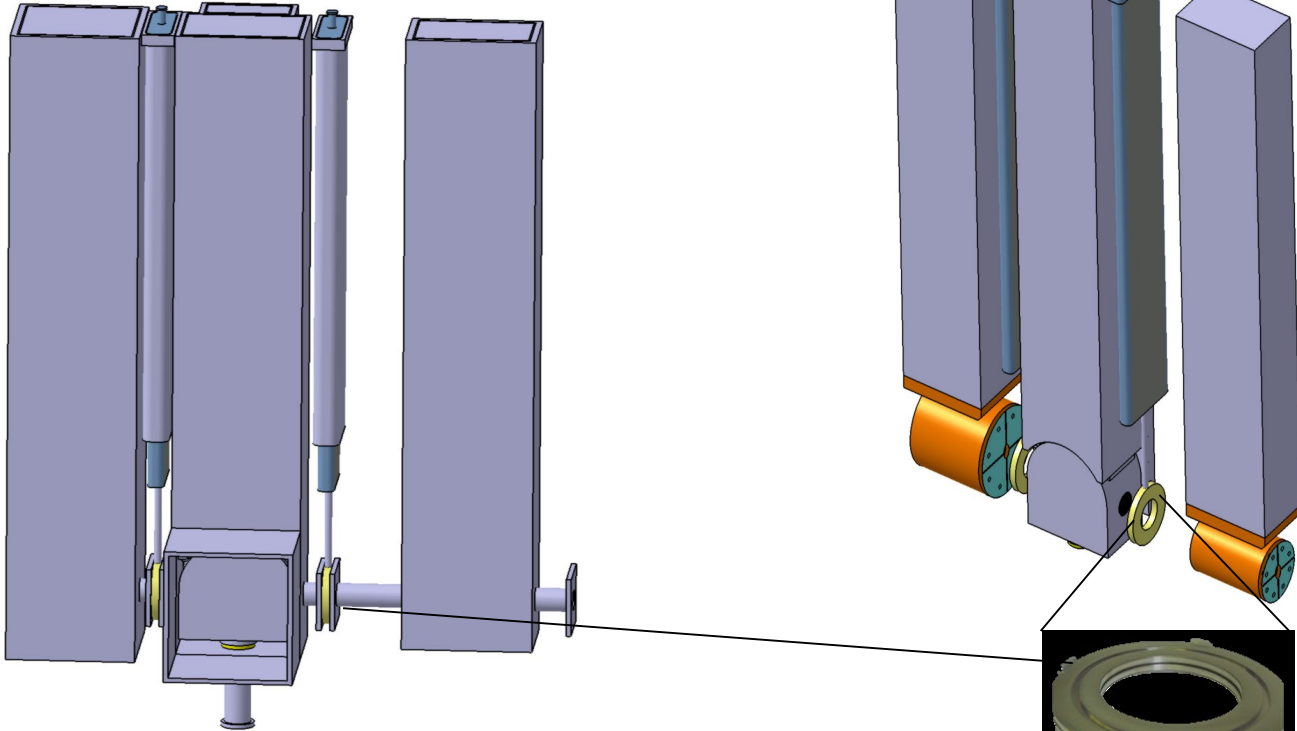


Courtesy S. Jollet, J. Snuverink et al.

# High power Target



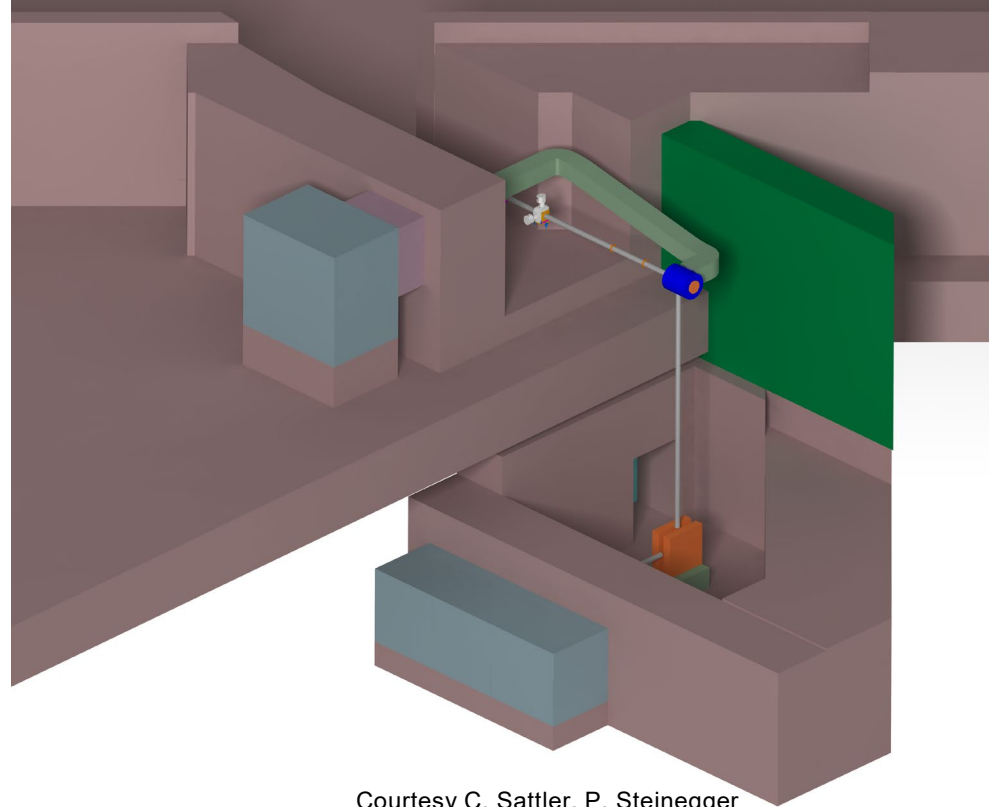
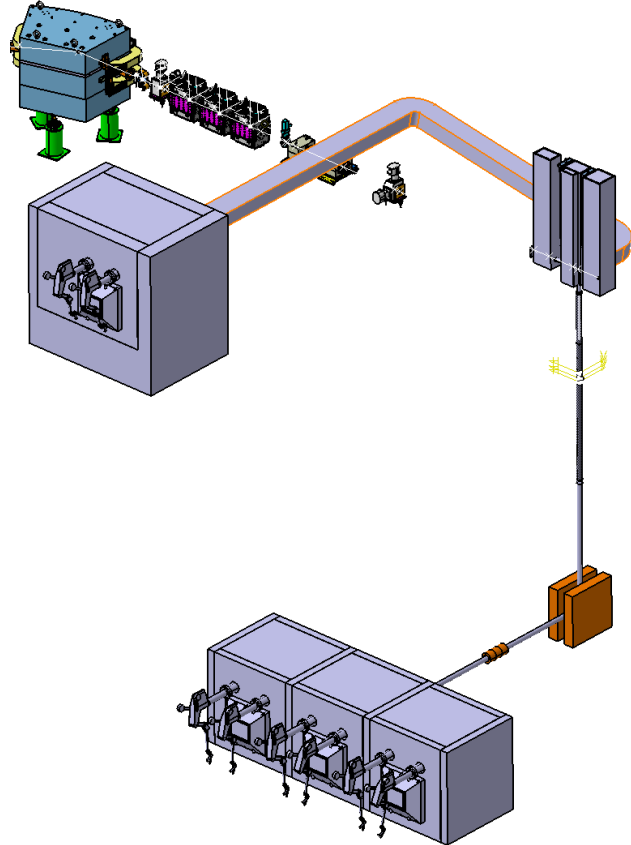
# Target exchange



metallic  
cushion  
seals



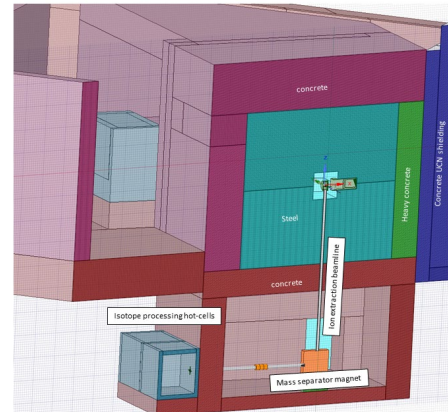
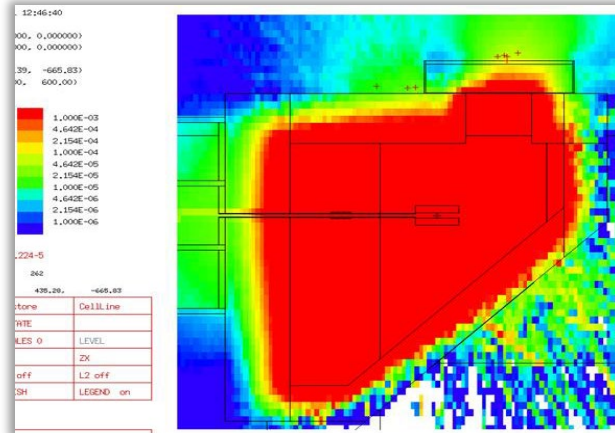
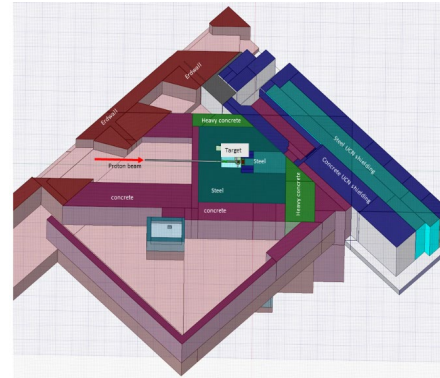
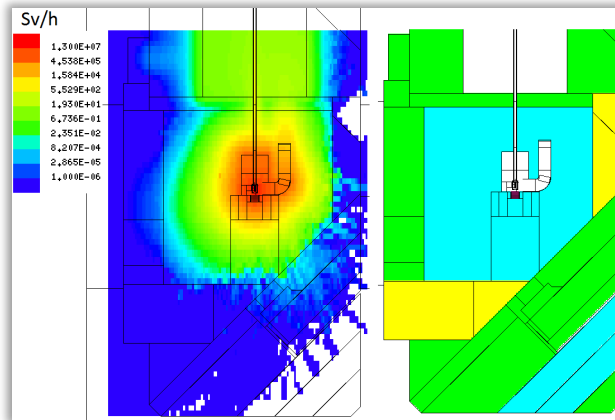
# Overall view TATTOOS Target exchange



Courtesy C. Sattler, P. Steinegger

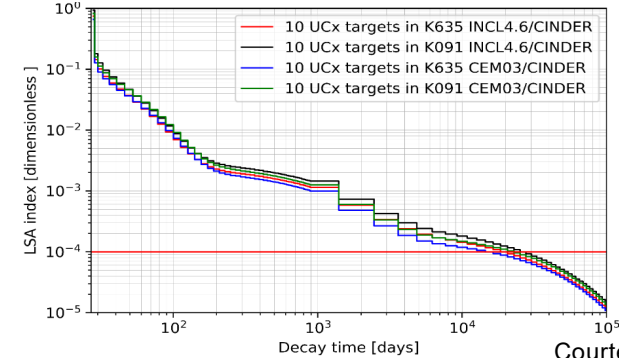
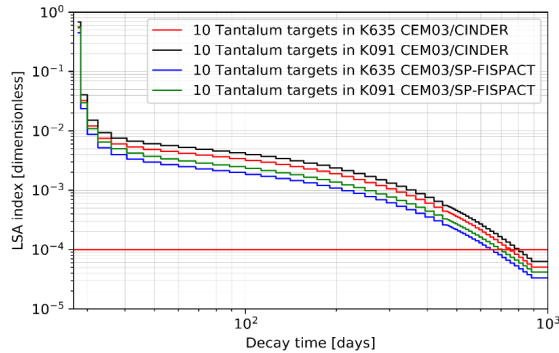
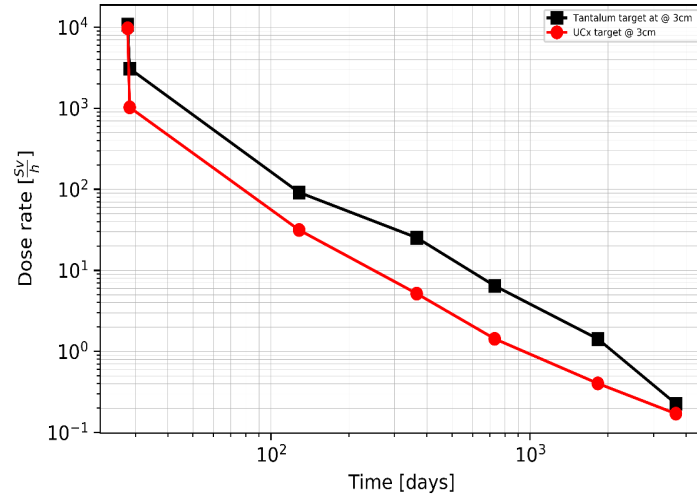


# In-situ Dose & Shielding



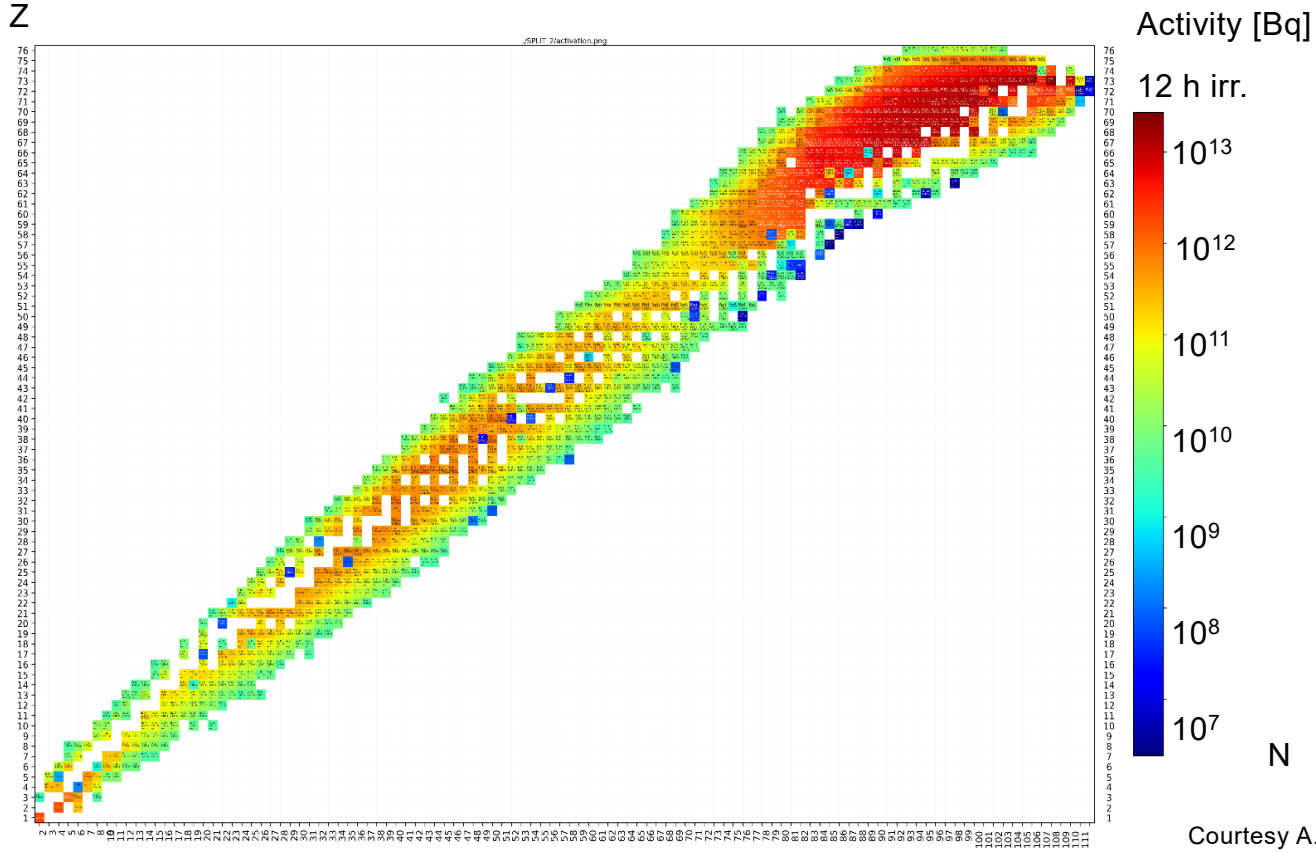
Courtesy A. Ivanov

# Storage and Disposal TATTOOS





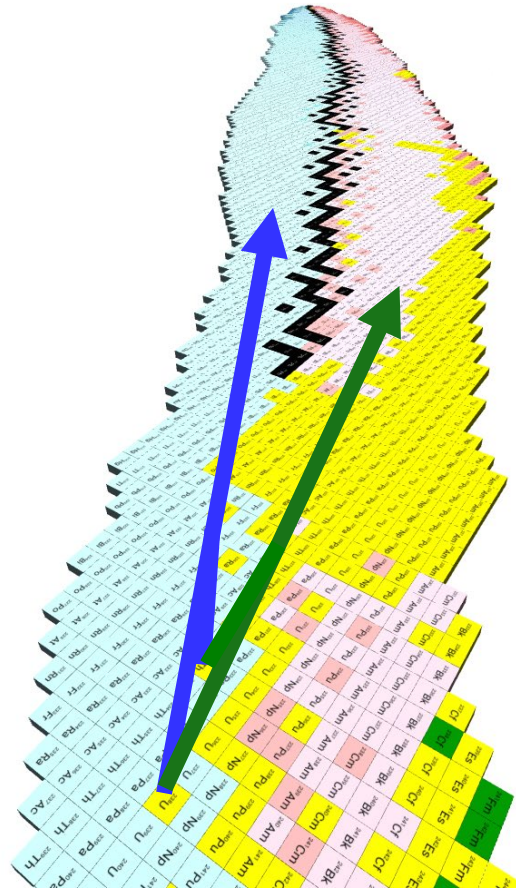
# Production of Radionuclides in Spallation of Ta



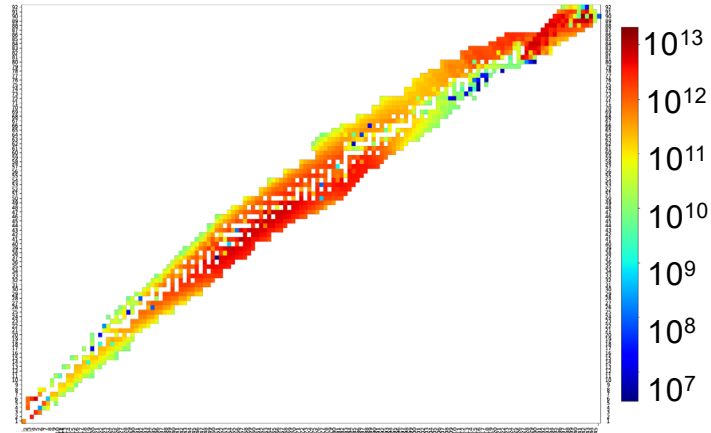
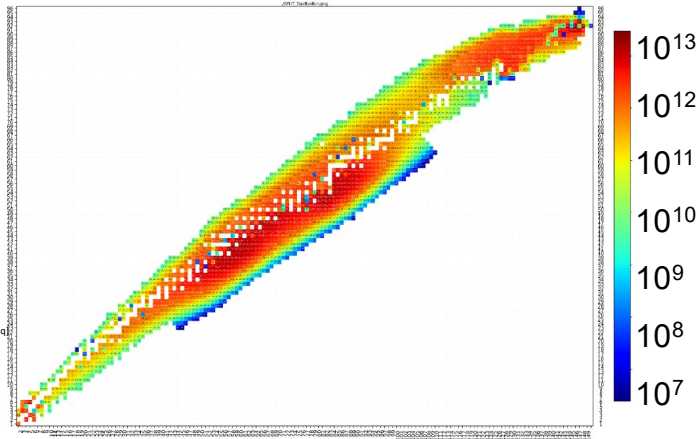
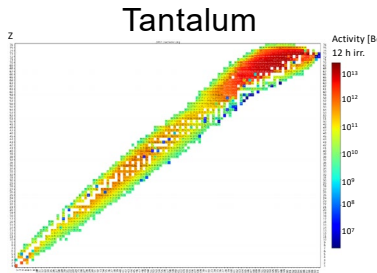
Courtesy A. Ivanov



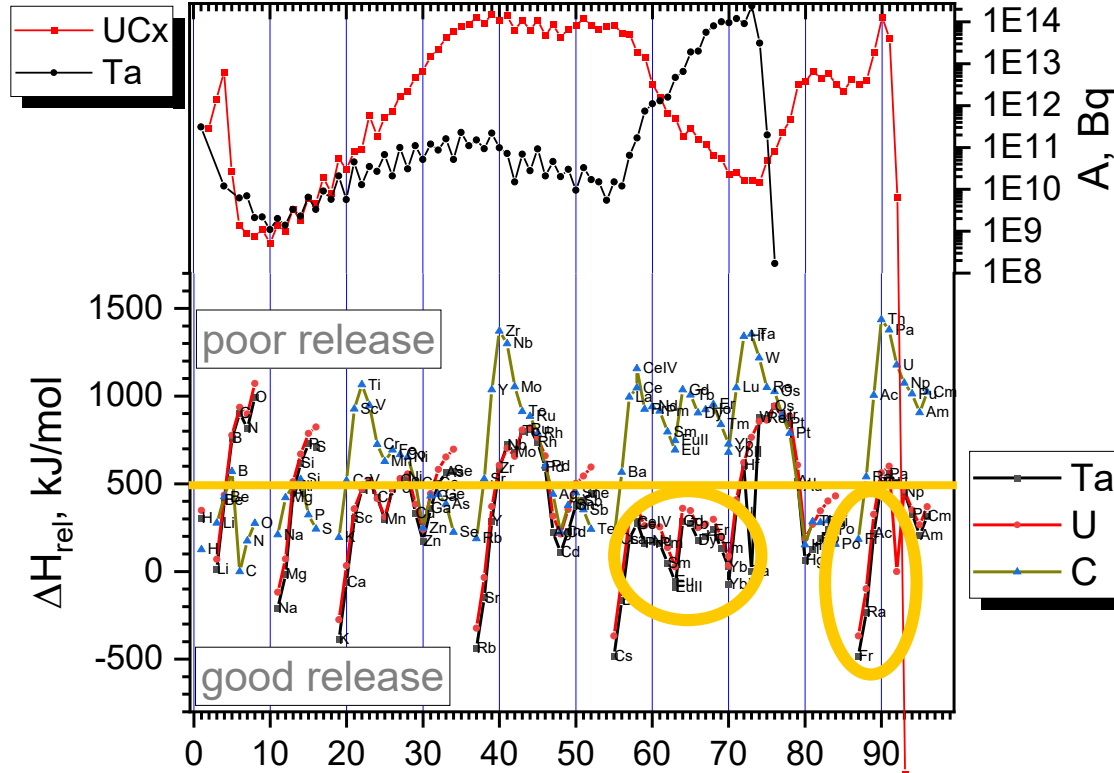
# Production of Radionuclides in Spallation of U/Th



# Production of Radionuclides in Spallation of U/Th



# Production & Atomic Release from Target



MIEDEMA calculations

Z Adsorption data of lanthanides on Ta  
work in progress JAEA/PSI.



# Ionization

Non-specific:

Surface Ionization

(Saha-Langmuir)  $I_p < 6eV$

Specific: RILIS-like

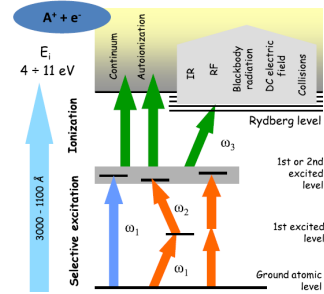
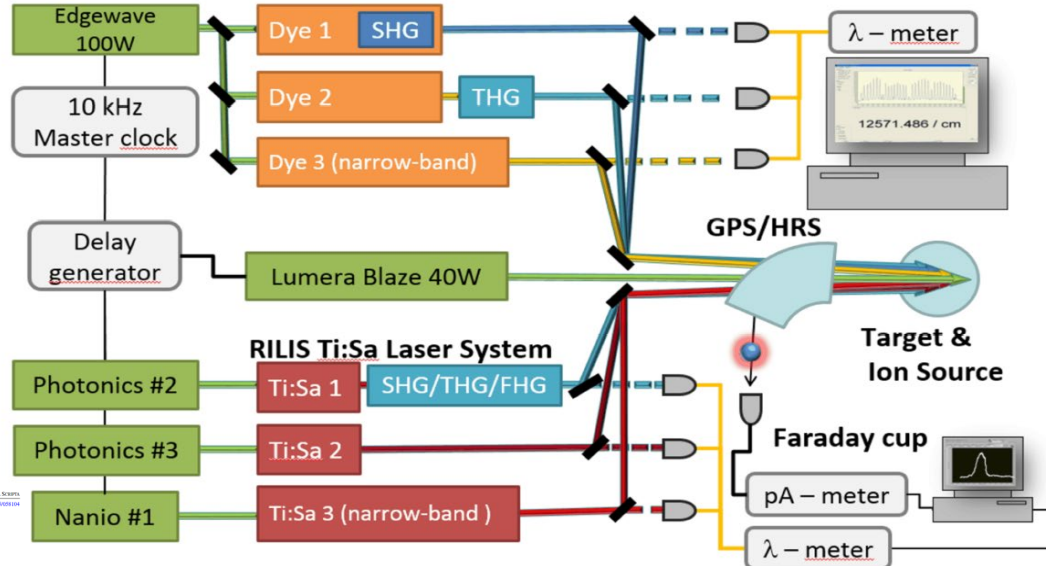
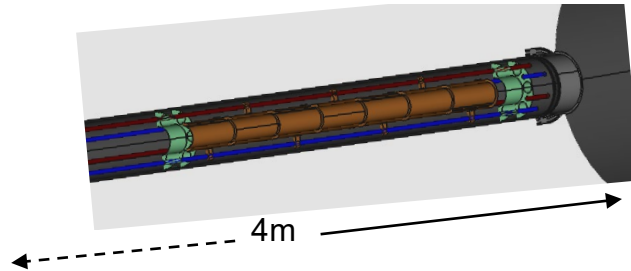
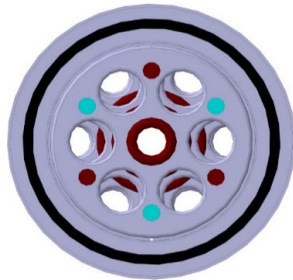
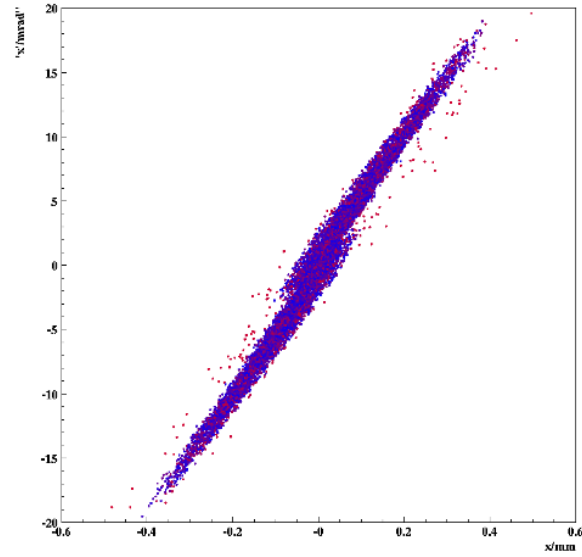
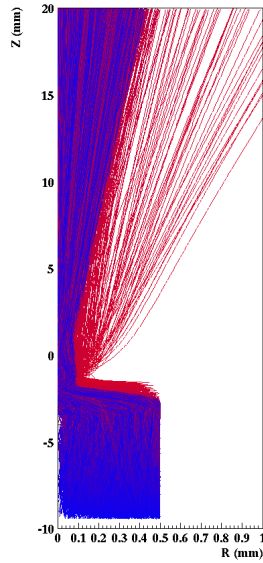
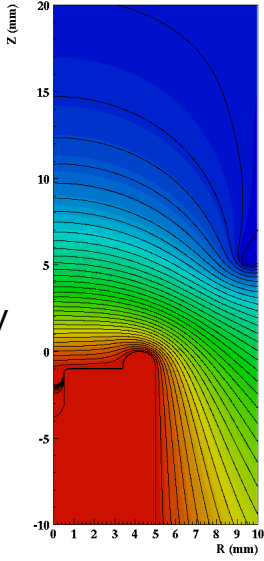


Figure 1. Schemes of resonance ionization.



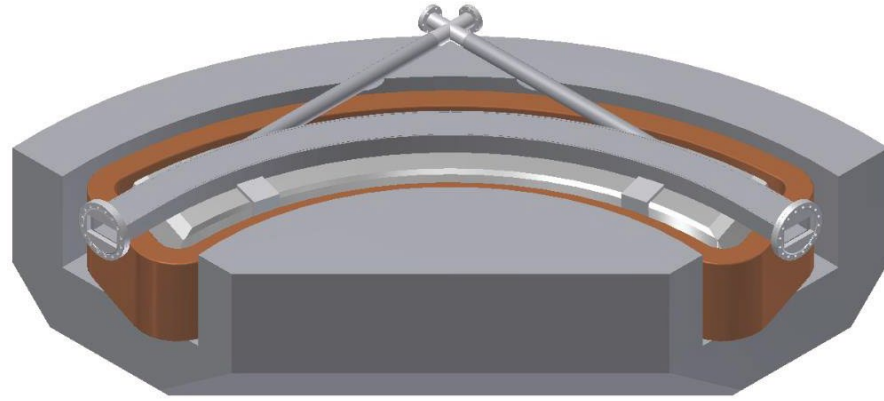
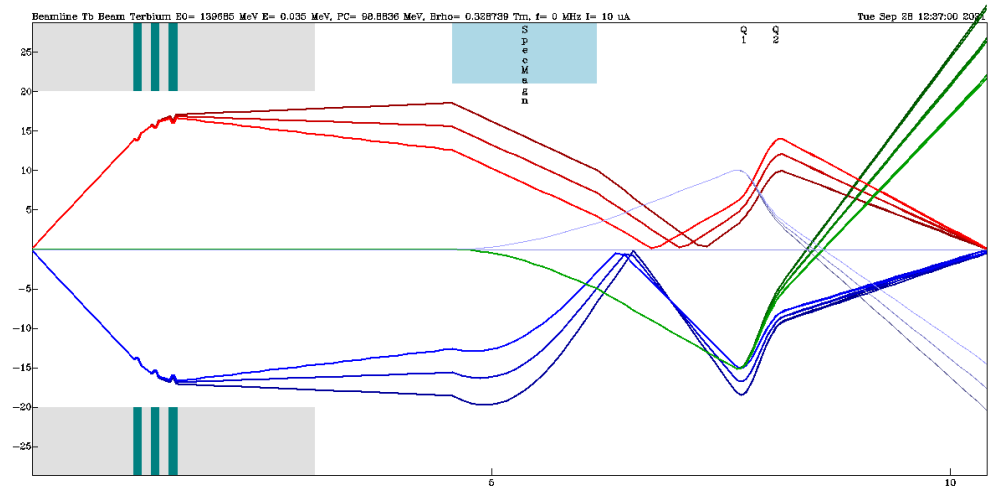
# Extraction of Ions

35 kV

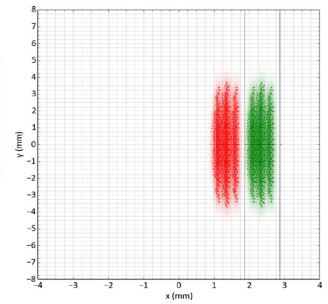


Einzellenses (6kV) and HV steerer

# Mass separation under design



D-Pace:  $M/\delta M$ : 1500



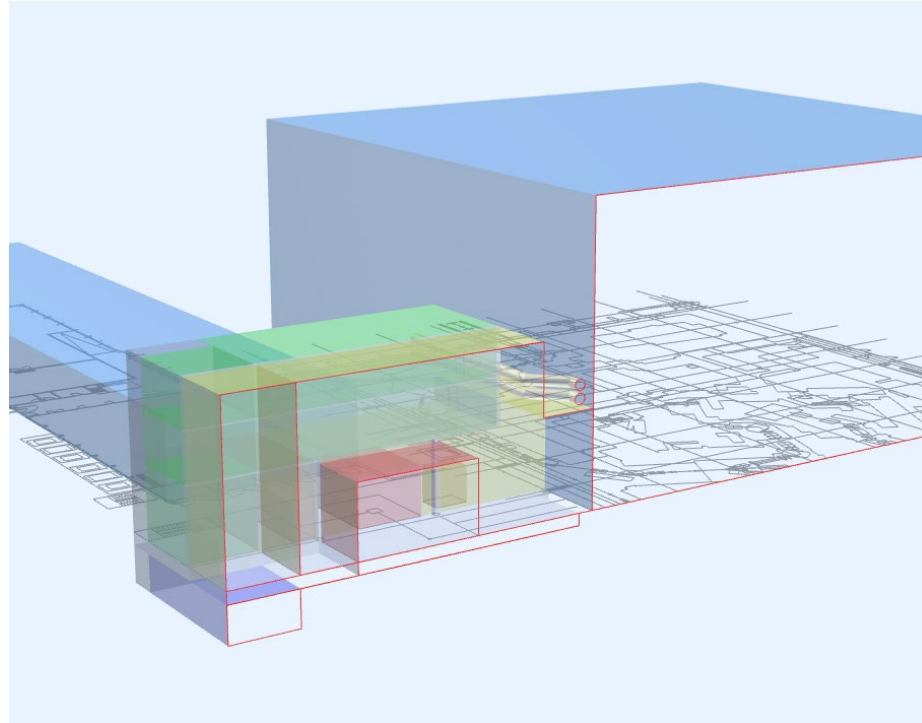
Courtesy D-Pace

# Collection & Radiochemistry





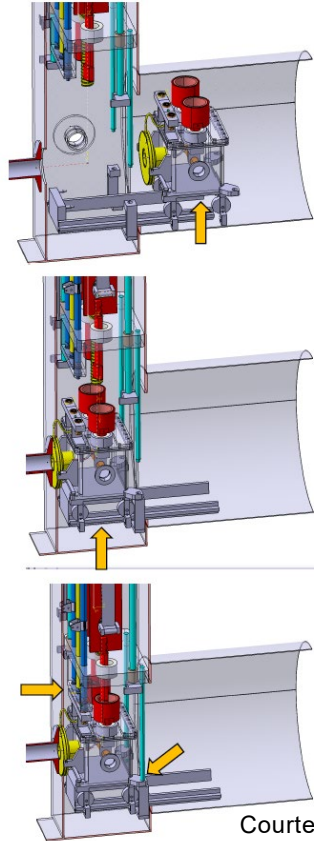
# Ground floor option



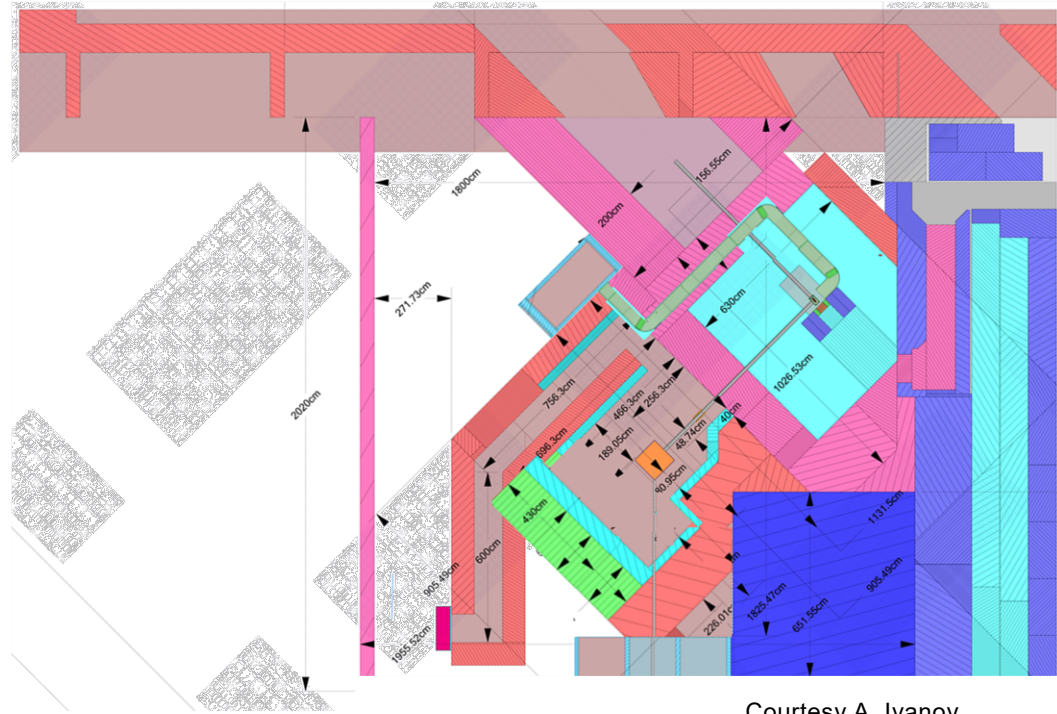
Courtesy N. Preiss



# Ground floor option



Courtesy U. Wellenkamp



Courtesy A. Ivanov



# 60 MCHF-IMPACT Proposal submitted & SNF grading obtained 08/22 (AAA)!



TATTOOS

u<sup>b</sup>  
UNIVERSITÄT  
BERN

ETH zürich

PAUL SCHERRER INSTITUT  
PSI



**Nuclear Medical Practitioners + Say... YES**

in and abroad

<https://www.psi.ch/en/impact>