WP3: Target Preparation for Improvement of Nuclear Data Measurements

Dr. Dorothea Schumann – Dr. Zeynep Talip

SANDA final collaboration meeting, 4-6.7.2024

Outline

Target Preparation for Improvement of Nuclear Data Measurements – Status report

Overview and status of target requests and fostering the network of target makers	G. Sibbens (JRC)
WP3 – overview	Z. Talip (PSI)
Report on user-producer interactions	Z. Talip (PSI)
Development of an isotope separator	D. Studer (UMainz)

Objectives and focus of WP3

Task 3.1: Intensification of the "producer – user – interaction"
Task coordinator: PSI, partners: JRC

Task 3.2: Fostering the network of target makers
Task coordinator: JRC, partners: PSI

Task 3.3: Target production
Task coordinator: JRC, partners: PSI

Task 3.4: Development of an isotope separator
Task coordinator: PSI, partners: UMAINZ, ILL

Partner number and short name	WP3 effort
13 - JRC	15.20
21 - PSI	27.00
28 - UMAINZ	24.00
Total	66.20

Task 3.1: Intensification of the “producer – user – interaction”

Workshops
Inviting potential target users to discuss the boundary conditions for their specific experiments

Teaching potential users that:

- The success of their experiment depends on the quality of the target
- The preparation of high-quality targets takes time
- A budget for target preparation should be foreseen in any proposal
- Radioactive targets require special care and additional money concerning transport, storage and waste disposal

Former events: ERAWAST I (2006), ERAWAST II (2011) as well as the CHANDA workshop (2015)

Next workshop tentatively planned for spring 2020; second one in 2022

Bilateral meetings producer - user
Detailed discussions on specific experiments
User contacts producer; parts of the travel costs will be covered

21 PSI	Cost (€)	Justification
Travel	22500	Support for the travel of participants in the meetings for the targets producer coordination in WP3, 20 person*trips at 1000 euros each plus 5 person*trips at 500 euros each.
Equipment		
Other goods and services	2500	For certificate of financial statement
Total	25000	

Task 3.2: Fostering the network of target makers

- Main collaborators at present: Jyväskylä, GSI, GANIL, Uni Warshaw, IPNO, IFIN-HH, Uni Mainz;
  look for new partners in Europe
- Extend the network to facilities outside Europe (Oakridge; Argonne, Capetown)
- Use synergies with existing platforms (INTDS):
  Establish a joint database of target preparation facilities and enriched isotope suppliers
- Support education of young researchers (short and longer-term visits)
  Equipment sharing
- Knowledge exchange (workshops, meetings)

13 JRC	Cost (€)	Justification
Travel	29000	4000 for travels to meetings, 4 person*trips at 1000 euros each, of the project plus 25000 to support for the travel of participants in the meetings for the targets producer-user interaction in WP3, 25 person*trips at 1000 euros each.
Equipment		
Other goods and services	27000	2000 for the organization of a workshop and 25000 for the support to the E&T course
Total	56000	

Task 3.3: Target production

A limited number of targets can be produced according to requests from collaboration members.
Both PSI and JRC will be responsible for the manufacturing of the final target. The target manufacturer will be in close contact concerning the special requirements of the envisaged experiment using the possibilities of user-producer interaction provided in the frame of task 3.1.

Resources will be allocated according to the effort. Target requests can be submitted to the TP task leader. Both requests related to energy (minor actinides, ^{233}U, ^{239}Pu or fission products like ^{79}Se) and non-energy applications (^{179}Ta, ^{94}Nb) will be considered. Each target request will be evaluated on the basis of the relevance of the target and the possibilities of the TP facilities.

During the first 12 months of the project, target requests from collaborators will be collected and evaluated. As an essential milestone, the decision on which targets can be manufactured will be made after this time span.

Total budget 150 k€ (75 k€ JRC, 75 k€ PSI)

Task 3.4: Development of an isotope separator

Production of isotopically pure targets by dedicated mass separation

Exploration of innovative efficient and selective ionization procedures

Applications: cross section measurements for

- **Nuclear-energy related isotopes**
- **Nuclear astrophysics**

2 subtasks:

Site preparation in Hotlab of PSI - **PSI**

Design development of the machinery for specific applications - **UMAINZ**

Total budget: 245 k€ (160 k€ UMAINZ, 65 k€ PSI, 20 k€ ILL - subcontract)

Deliverables and Milestones – original plan

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	Report on the meetings performed in the frame of ("Producer – user – interaction")	21 - PSI	Report	Public	36
D3.2	Report on the meetings performed in the frame of "Network of target producers"	13 - JRC	Report	Public	42
D3.3	Report on produced targets	13 - JRC	Report	Public	30
D3.4	Documentation of the design of a mass separation tool for target preparation	28 - UMAINZ	Report	Public	48
D3.5	Documentation of the site specification for installation of a mass separator in the Hotlab of PSI	21 - PSI	Report	Public	36

Milestones:

MS27 Scheduling regular user – producer meetings	PSI	February 2020
MS28 Scheduling regular target - maker meetings	JRC	February 2020
MS29 Decision on targets to be manufactured	JRC	February 2021

User – Producer interaction – SANDA I

PAUL SCHERRER INSTITUT PSI

10 contributions on isotope and target production / characterization

8 contributions on applications and target requests

30.3. – 3.4.2020 at Paul Scherrer Institut Villigen
Due to Corona postponed to 6.-8.7.2020, then cancelled

1st SANDA – user – producer – interaction meeting

Paul Scherrer Institut :: 5232 Villigen PSI :: Switzerland :: Tel. +41 56 310 21 11 :: Fax +41 56 310 21 99 :: www.psi.ch

Workshop SANDA II (18.8.2021)

Session 1 Target production and characterisation

JRC-Geel target preparation laboratory	G. Sibbens (JRC)
Isotope production and targetry at PSI	E. Maugeri (PSI)
Isotopic thin films preparation laboratory for nuclear physics; IFIN-HH, Bucharest, Romania	N. M. Florea (IFIN-HH)

Session 2 Applications (SANDA I)

243-Americium targets for the study of neutron induced fission cross section at the n_TOF facility of CERN	Eleme (Univ. Ioannina)
Need in radioactive targets for fission studies at NFS	D. Tarrio (UU)

Session 3 Applications (SANDA II)

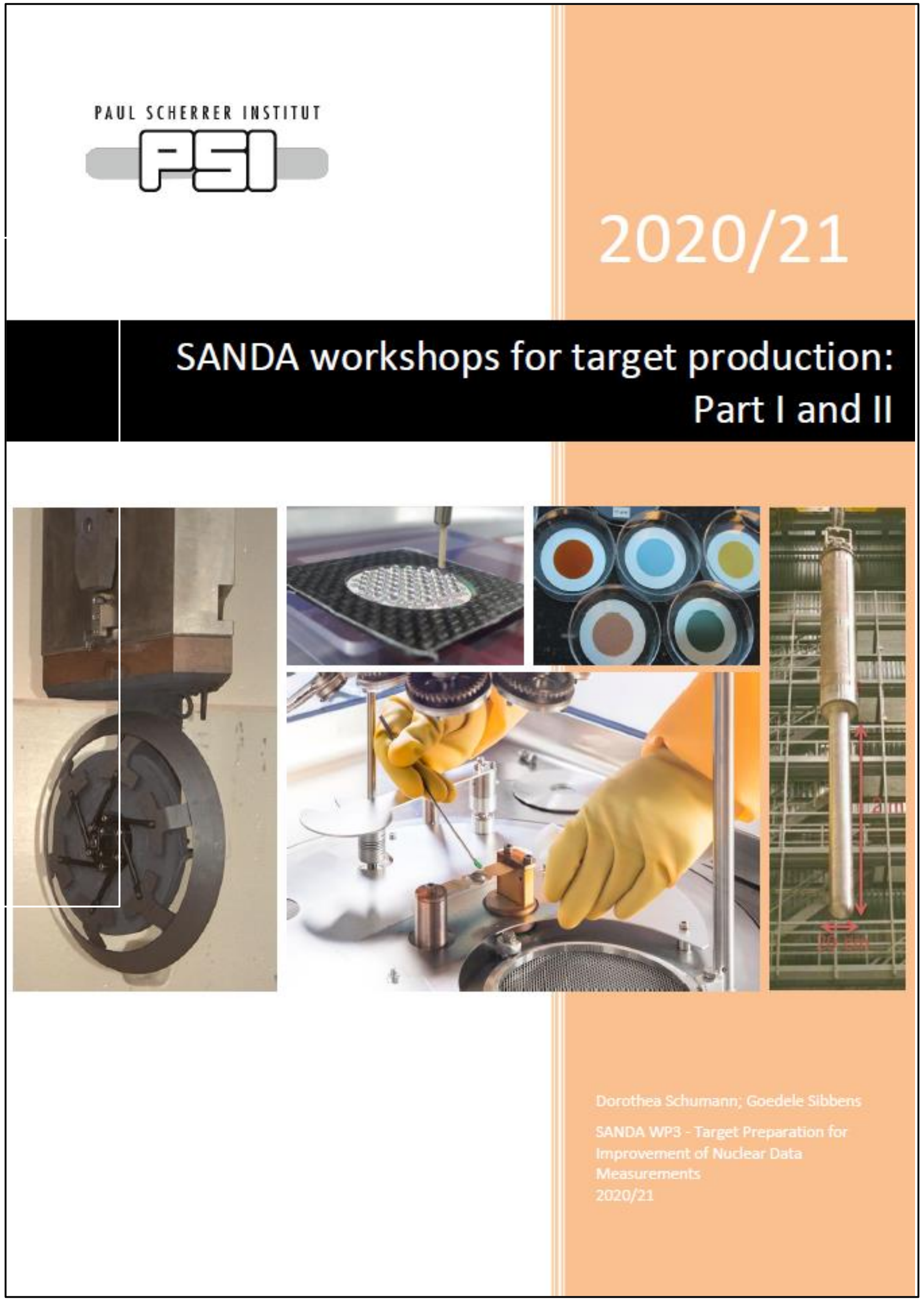
Test of a novel Frisch-Grid chamber, and measurement of the $^{236}U(n,g)$ cross section	G. Lorusso (NPL)
A ^{59}Ni target for neutron-induced gamma-ray spectroscopy	C. Michelagnoli (ILL)
A ^{179}Ta target for (n,gamma) spectroscopy relevant for the astrophysical origin of ^{180}Ta	C. Michelagnoli (ILL)
Production of a ^{10}Be target for nuclear structure Experiments	L. Tetley (Uni York)
^{10}B targets for the production of ^{11}C in deuteron induced reactions	J. Benlliure (Uni Santiago)
Preparation of ^{50}Cr and ^{53}Cr targets for neutron capture and transmission experiments for criticality safety	C. Guerrero (CNA)
Radiative capture measurement on ^{79}Se at n_TOF:sample preparation and future perspectives	C. Domingo-Pardo (IFIC)
First measurement of ^{94}Nb neutron cross section at n_TOF: Sample preparation and future perspectives	C. Domingo-Pardo (IFIC)

SANDA Workshops for target production

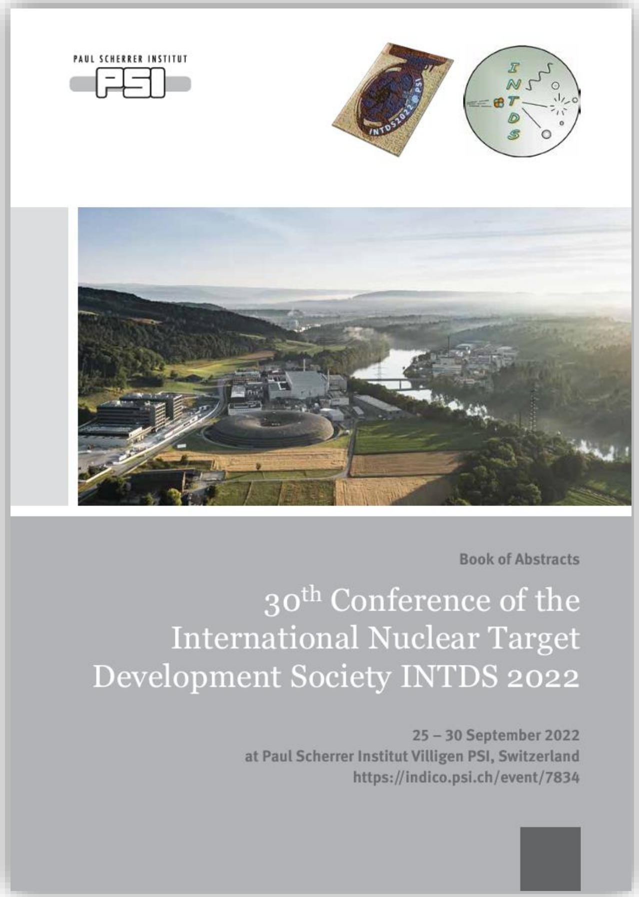
Integration of all contributions
(SANDA I and II)

Talks and abstracts available on the webpage:
https://indico.cern.ch/event/1064846/

The basis for the decision on targets, which can be produced



INTDS 2022 (International Nuclear Target Development Society)



Task 3.4: Development of an isotope separator

Site preparation in Hotlab of PSI

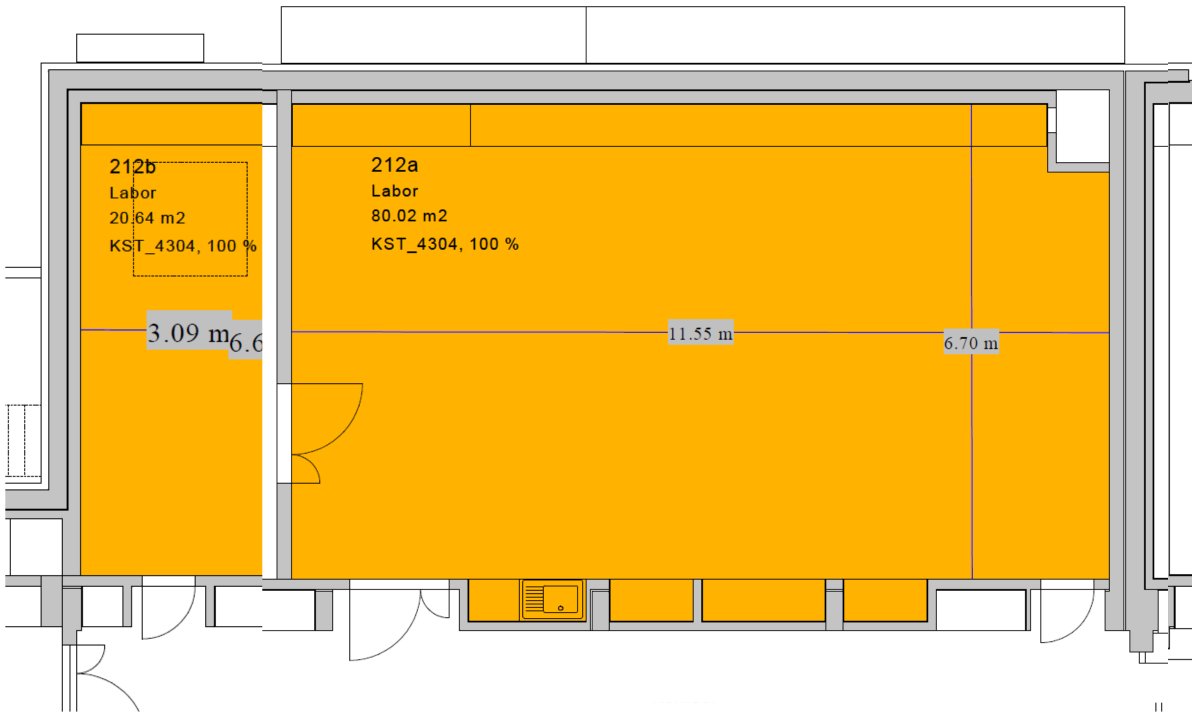
- 1 room for sample preparation and target production
    - Permission for working with α-emitters obtained, equipped with fumehoods, measurement technique, radiochemical devices etc.
      glovebox installation ongoing
- 1 + 1 side room for separation facility
    - Former Pu-zone, former users' remainings must be measured for clearance, conditioned, and disposed of.
    - Problems with supply chains and waste disposal capacities
- Application for funding in APRENDE (accepted)
- Application for funding at SNSF (under evaluation)

Design development of the machinery for specific applications (UMAINZ)

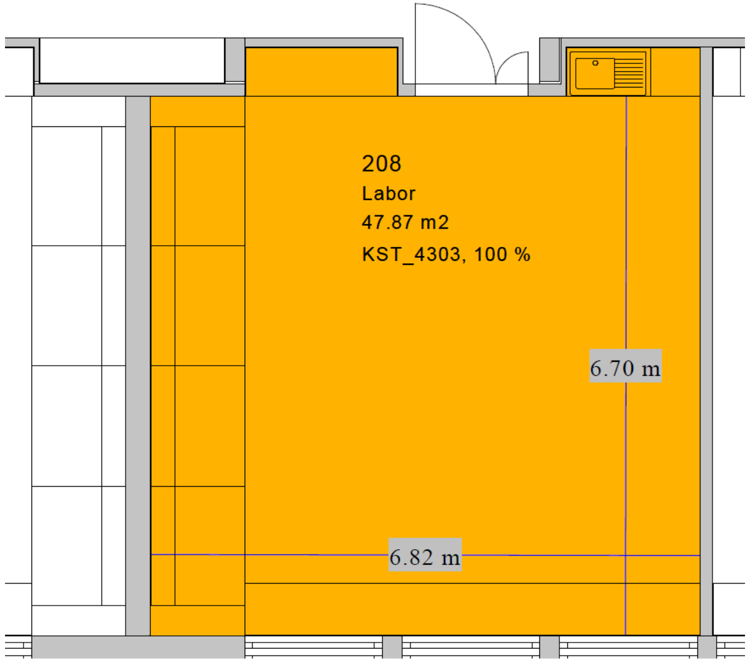
- Finished, report delivered in time

Site preparation at the PSI Hot-lab

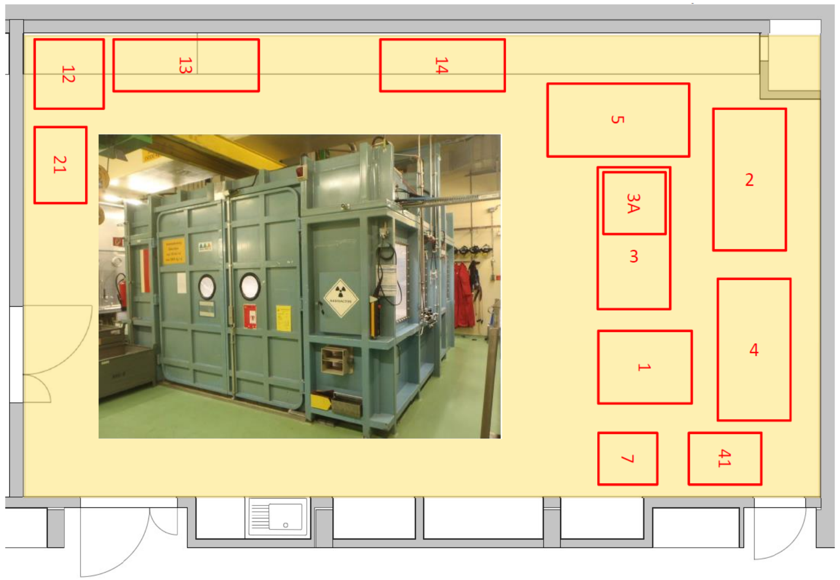
Mass separator

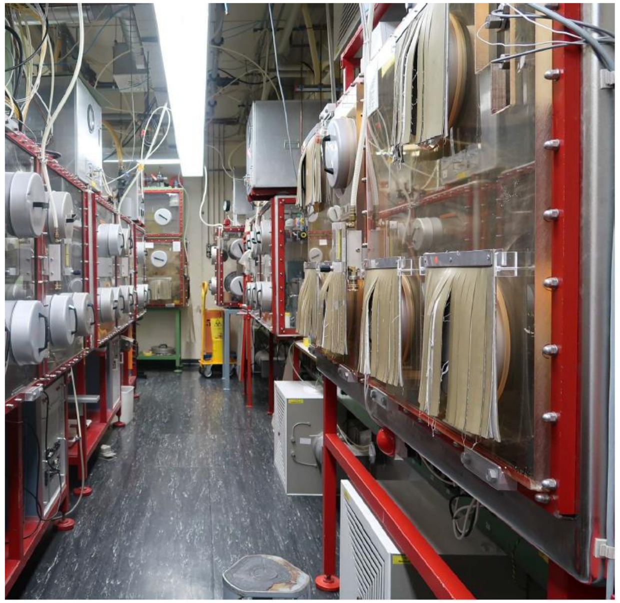


Target preparation

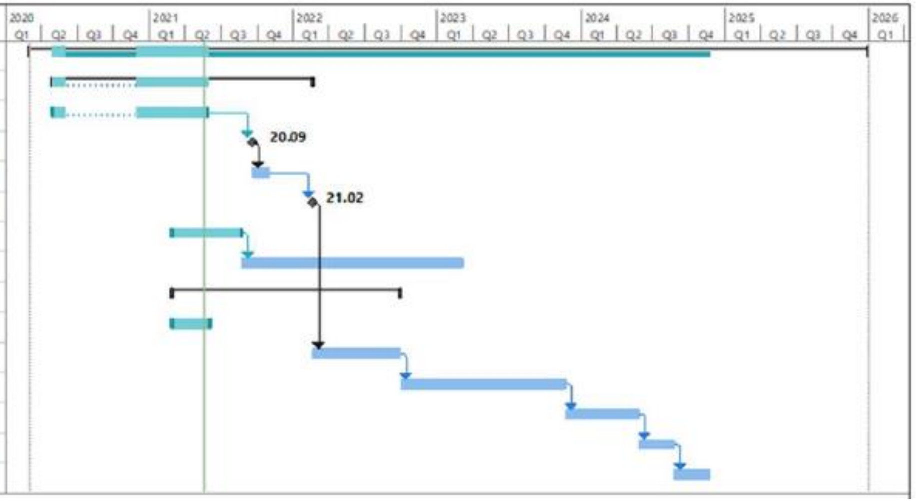


Site preparation at the PSI Hot-lab





Nr.	Vorgangsname	Anfang	Ende
1	**Rückbau Pu-Zone**	**Mon 02.03.20**	**Mit 31.12.25**
2	**Freigabeverfahren mit ENSI**	**Fre 01.05.20**	**Mon 21.02.22**
3	Freigabeantrag H1 erstellen	Fre 01.05.20	Mon 31.05.21
4	Freigabe H1 erteilt	Mon 20.09.21	Mon 20.09.21
5	Freigabeantrag H2-3	Die 21.09.21	Mon 01.11.21
6	Freigabe H2-3 erteilt	Mon 21.02.22	Mon 21.02.22
7	Rückbau inaktive Gerätschaften	Mon 01.03.21	Mit 25.08.21
8	Vorbereiten der Boxen	Don 26.08.21	Mit 08.03.23
9	**Beschaffung Dekont-Container**	**Mon 01.03.21**	**Fre 30.09.22**
10	Evaluation	Mon 01.03.21	Fre 04.06.21
11	Beschaffung u. Installation	Die 22.02.22	Fre 30.09.22
12	Demontage der Handschuhboxen	Mon 03.10.22	Fre 24.11.23
13	Rückbau der Installationen	Mon 27.11.23	Die 28.05.24
14	Freimessen der Räume	Mit 29.05.24	Mon 26.08.24
15	Freigabe H4	Die 27.08.24	Mon 25.11.24



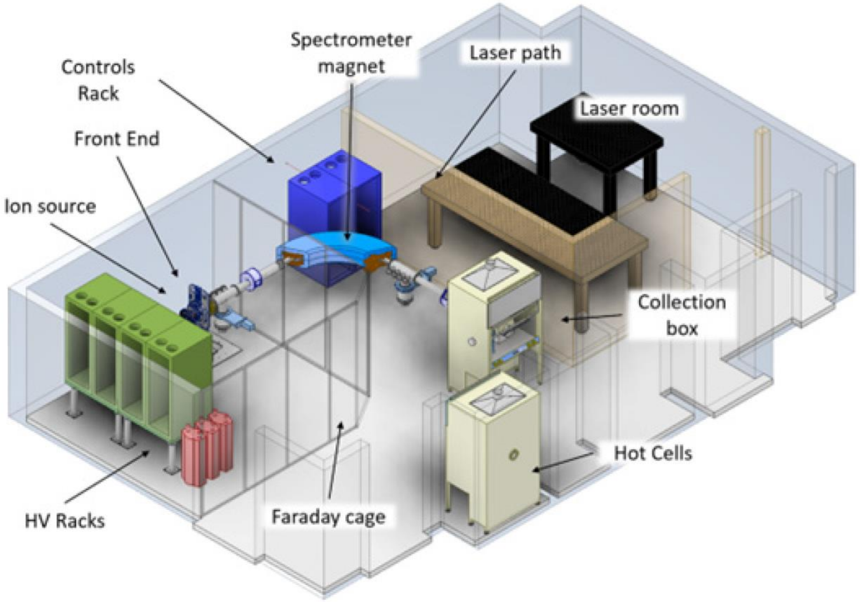
PROMAS Project
PReparative Offline MAss Separation

Project was submitted in May 2024.

Project starts: 01.12.2024

Project ends: 30.11.2025

Project Budget: 2.250 kCHF



Swiss National Science Foundation
1 M CHF

PSI Directorate
500 kCHF

PSI NES
250 kCHF

PSI BIO
250 kCHF

APRENDE
250 kCHF

Total budget: 2.250 kCHF

PROMAS Project

Phase I

- Develop and improve versatile ion source schemes
- A high-resolution mass separator (mass resolution > 1000)
- Suitable ion collector
- Ion optical elements
- Dedicated vacuum system (10^{-6}-10^{-7} mbar)

Phase II

- Installation in the radioactive zone (interim)

Site preparation in the hotlab (Pu-zone) is in progress (Swiss Decommissioning Fund), and it is expected to be ready in 2028.

- Test experiments

The infrastructure will be accessible to national and international academic research scientist.

PROMAS Project

PROMAS

- I Mass-separated radionuclides for fundamental nuclear sciences → APRENDE
- II Mass separated medically relevant radionuclides
- III RILIS Development
- VI Auger-electron emitters: thin targets and spectroscopy
- V Low-energy ion beams for superheavy element research
- VI Sources for Mössbauer spectroscopy

Design of the mass separator

Requirements:

Flexibility: Production actinide targets, e.g. $^{238/236}U$, $^{239/240/242}Pu$, as well as fission products

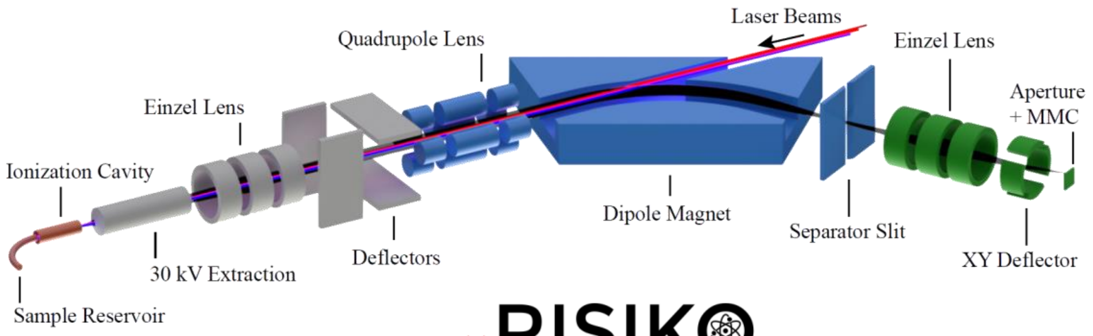
Target purity: Suppression of neighboring isotopes

Efficiency: Minimum waste of valuable sample material

Results:

- RISIKO mass separator was used as starting point for planned SANDA separator
- Slot ion source shows promising performance in simulation
- High-power laser system for larger laser ion sources
- Design report, including:
  - RISIKO description, specifications, drawings, vacuum scheme
  - Characterization and efficiency measurements at different ion currents
  - IBsimu simulations: results and discussion of different ion sources; source code
  - High-power laser design and supporting measurements

Starting point: RISIKO setup at Mainz



RISIKO

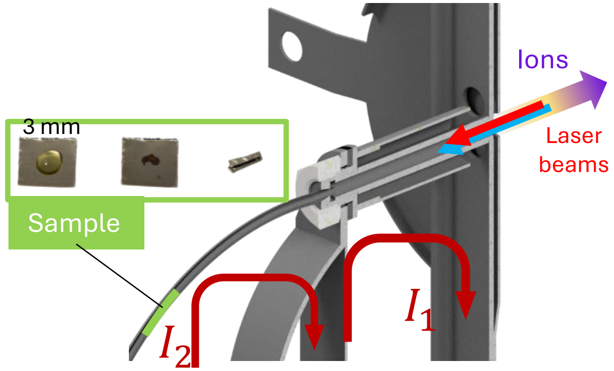
[1]

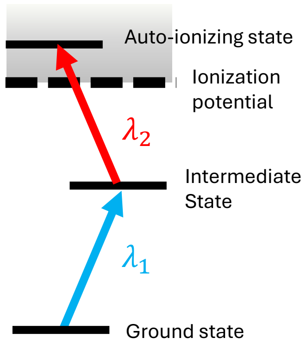
- Resonance ionization laser ion source
- 30 kV beam energy
- Mass separation in 0.6T dipole magnet
- Post-focalization for ion implantation

RISIKO was successfully used for isotope separation & implantation:

- ^{163}Ho for ECHo ($\approx 10^{12}$ atoms/MMC) [1]
- ^{53}Mn for PSI ($\approx 5 \times 10^{17}$ atoms total) [2]
- ^{226}Ra for PTB ($\approx 4 \times 10^{14}$ atoms total) [3]

RISIKO implements most requirements for the planned SANDA separator, but **throughput needs to be improved**





[1] T. Kieck et al., NIM A **945**, 162602 (2019)
[2] N. Kneip et al., Eur. Phys. J. Appl. Phys. **97**, 19 (2022)
[3] F. Mertes et al., Appl. Radiat. Isot. **181**, 110093 (2022)

Limits of RISIKO & Optimization of transmission

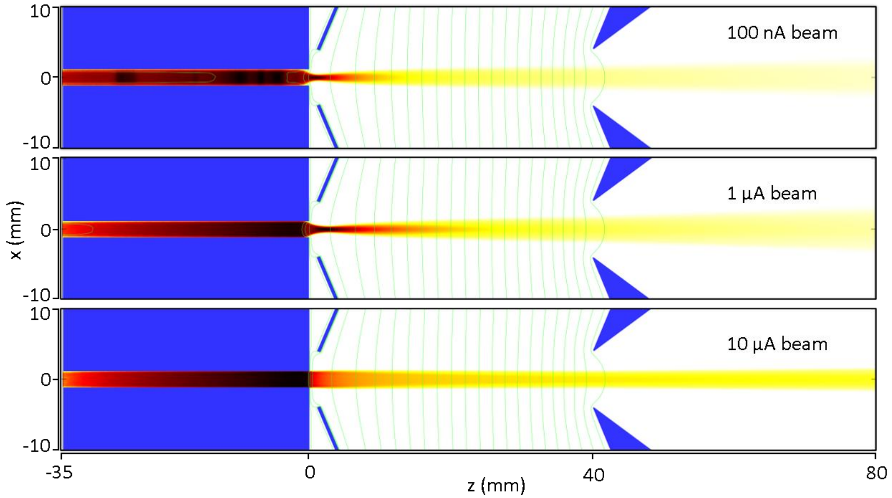
RISIKO mass separator performance was assessed using IBsimu [1]

Deterioration of efficiency/mass resolution at high ion currents

- At ~10 μA steady-state current (simulation)
- At ~2 μA steady-state current (experiment)

A larger ion source is expected to reduce the effects of space-charge limitations; but increases beam emittance

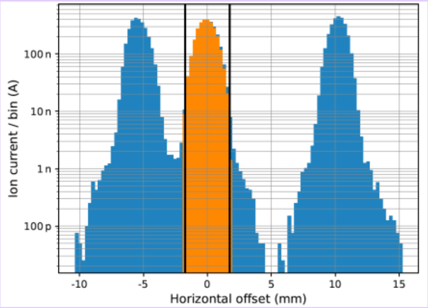
Simulated cross section of the ion source with space-charge-induced focusing at different ion currents.



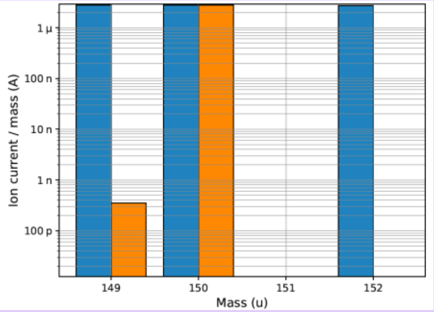
*[1] T. Kalvas et al., Rev. Sci. Instrum. **81**, 02B703 (2010)*

Optimized ion source geometry

Tube ion source
2 mm diameter
10 µA beam

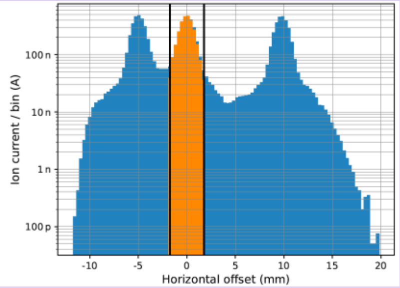


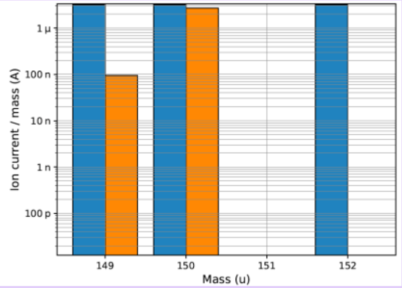
Beam current
in front/after
separation slit



Mass comp.
in front/after
separation slit

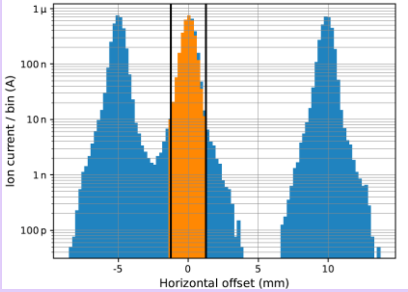
4.5 mm

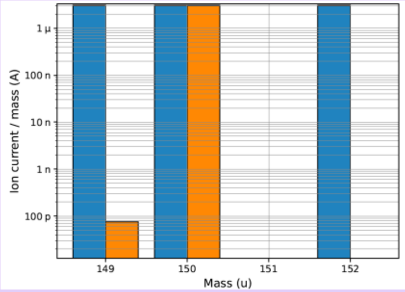




Bad ion source performance by simply increasing orifice diameter

2 mm
x 6.5 mm





Slot ion source shows good transmission & resolution at 4x increased orifice area

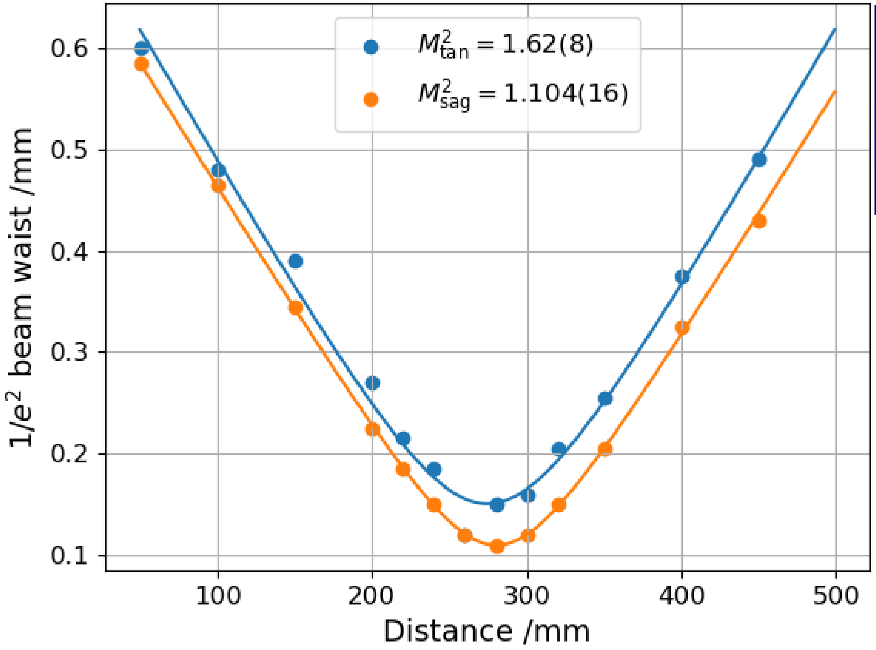
New laser design

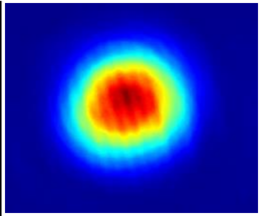
A new laser design was implemented, taking into account thermal lensing effects

Double output power compared to previously used design

Saturation of atomic transitions in larger ion sources

- 10 kHz pulse repetition rate
- 32 W pump power at 532 nm
- 10 W output power near 800 nm
- 700 - 1000 nm tuning range
- Near-TEM_{00} operation ($M^2<2$)





Summary: Deliverables and Milestones

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]	
D3.1	Report on the meetings performed in the frame of (“Producer – user – interaction”)	21 - PSI	Report	Public	36	delivered Oct. 22
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D3.5	Documentation of the site specification for installation of a mass separator in the Hotlab of PSI	21 - PSI	Report	Public	36	planned for Aug. 24

Milestones:

MS27 Scheduling regular user – producer meetings PSI February 2020 delivered Oct. 22

MS28 Scheduling regular target - maker meetings JRC February 2020 delivered Oct. 22

MS29 Decision on targets to be manufactured JRC February 2021 delivered Oct. 22

Thank you for your attention!