STRATEGIC ENGAGEMENT WITH EMERGING INFRASTRUCTURES

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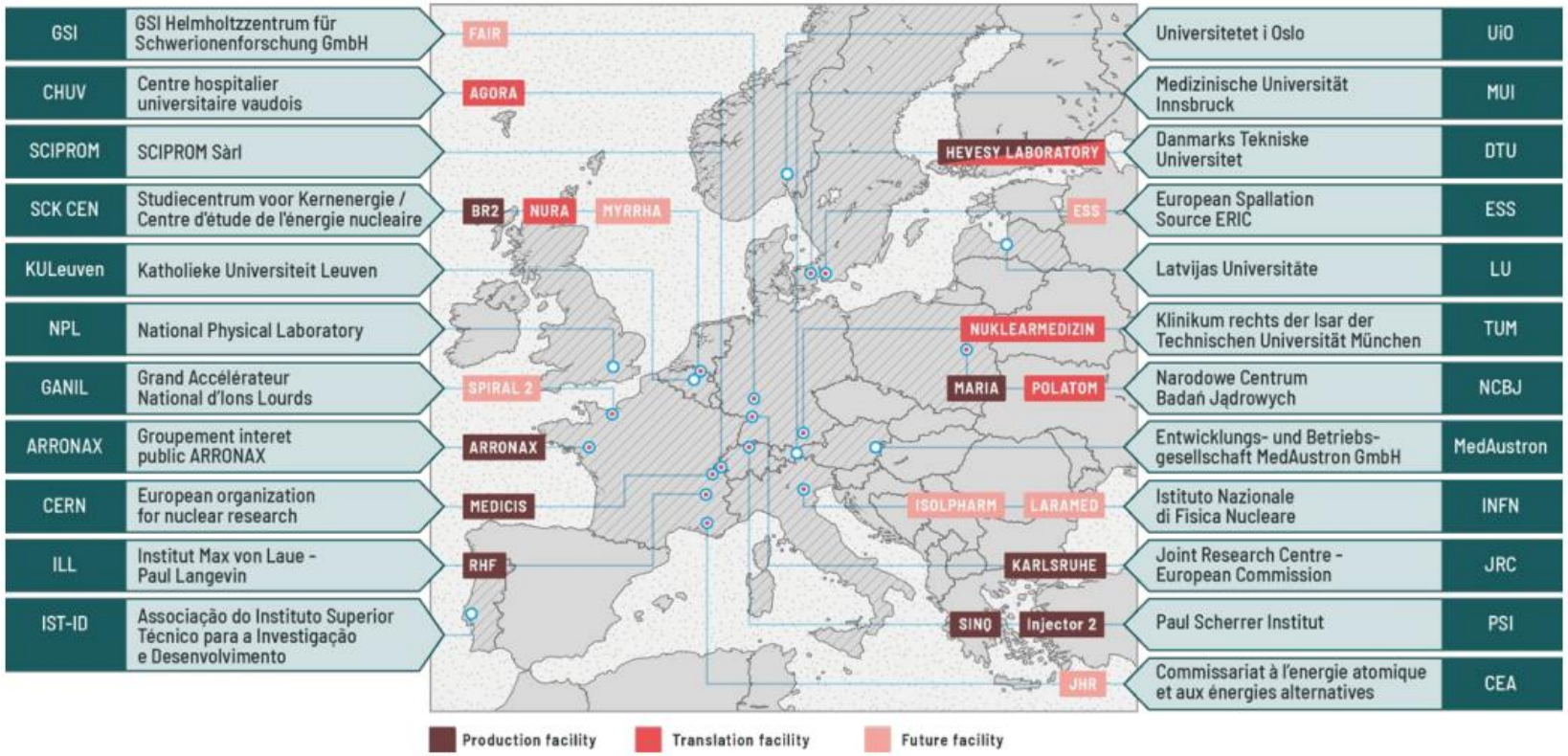
WP 8: Involvement of emerging infrastructures

CERN, PSI, CEA, DTU, CHUV, GANIL, **SCK CEN**, ARRONAX, ESS, MUI, ILL, NCBJ, GSI, INFN

PRISMAP Consortium Meeting CM9
Warsaw, 18 - 21 November 2025

Emerging (production) infrastructures in PRISMAP

Charged-particle irradiation (+ mass separation)	CERAD – NCBJ (Poland) SPES – INFN-LNL (Italy) ISOL@MYRRHA – SCK CEN (Belgium) TATTOOS – PSI (Switzerland)	Neutron-irradiation	ESS (Sweden) JHR – CEA Cadarache (France) SPIRAL2 – GANIL (France)



+ SMILES

+ CERAD

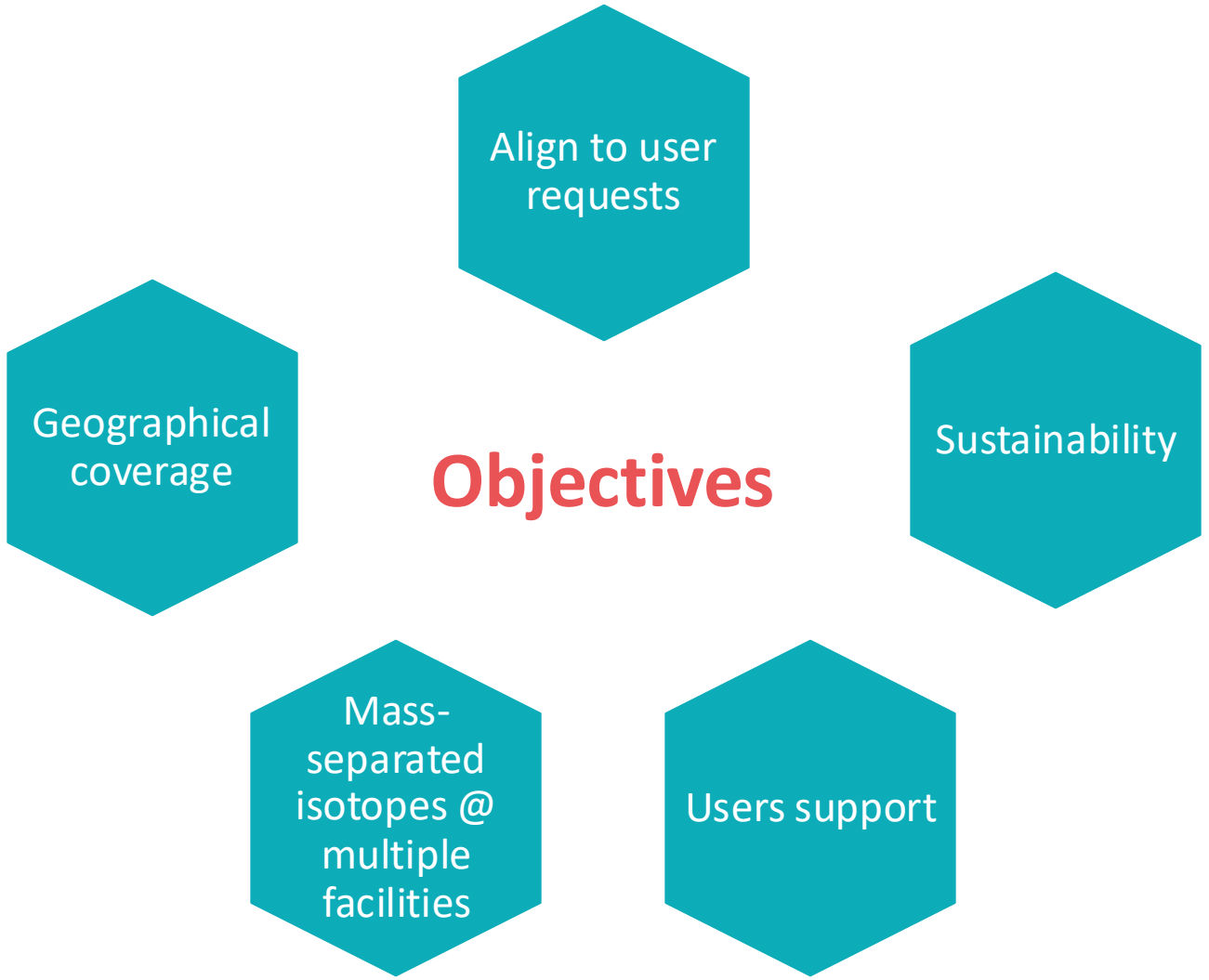
+ TATTOOS

- Strategic role: Complement conventional production, enable novel routes

Strategic Engagement

- Technology Development
  - E.g. WP10 – JRA: Target ion source and mass separation developments
- REX & feedback from operational facilities
  - E.g. mass-separation (for increased purity) at MEDICIS
- Knowledge Sharing
  - Consortium meetings
  - Workshops
  - Schools

WP8: Involvement of Emerging Infrastructures



Tasks of WP8-NA5

- T8.1 - Workshops and facility visits
- T8.2 - Guidance and support of the PRISMAP operating and emerging infrastructures

Deliverables

Deliverables		Date
D8.1	Proceedings of the first workshop organised at INFN in 2022	M24
D8.2	Proceedings of the second workshop organised at SCK CEN in 2024	M44
D8.3	White paper summarising the letters of interest from the user community	M48

T8.1 – Workshops and facility visits

- **First Workshop** on Emerging Infrastructures and Technical Developments
  - November 2023, organized by INFN LNL
  - 76 registered participants
    - 39 in person
    - 37 remotely
  - 21/11: 16 talks dedicated to infrastructures and radionuclides programmes
  - 22/11: 9 technical talks covering the major activities performed within WP10: on targets, ion sources and isotopes purification.
  - The second day was open to the public and advertised via several channels => ~30 on-line participants
  - 9 posters presented during CB & poster sessions
  - Visit of the SPES facility

Proceedings Book (D8.1)

T8.1 – Workshops and facility visits

- **Second Workshop** on Emerging Infrastructures and Technical Topics
  - 31st March – 2nd April 2025, organized by SCK CEN
  - 45 registered participants
    - 35 in person
    - 10 remotely
  - Talks dedicated to infrastructures for radionuclides production in PRISMAP
  - Topical sessions dedicated to 6 selected isotopes (Sc-47; Cu-67; Tb-152,155; Pt-195m; Ac-255)
  - Session dedicated to isotope enrichment and isotope production at external labs
  - Session dedicated to D8.3 White Paper
  - Posters presented during poster session & coffee breaks
  - Visit of the BR2, CRF and MYRRHA facilities at SCK CEN

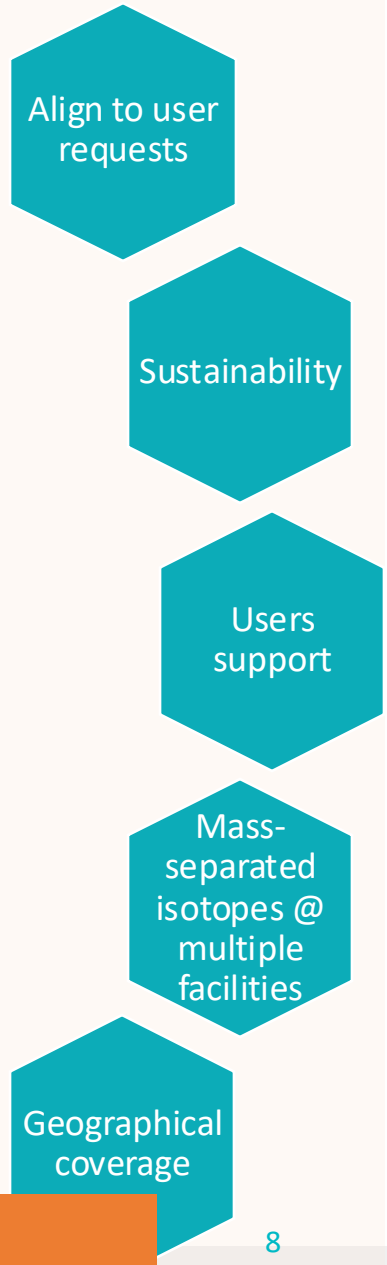
No Proceedings Book (D8.2) – large overlap with the White Paper (D8.3)

T8.2 – Guidance and support of the PRISMAP operating and emerging infrastructures

- "Promising radionuclides" presented at the workshop in November 2022
  - Contribution to D8.1 further reflects ideas formulated in the round-up discussion
- Draft of a roadmap for PRISMAP continuation beyond the H2020-funded period
- Contribution to the realization of the NuPECC Long Range Plan 2024
  - TWG7: Applications and Societal Benefits & TWG6: Research Infrastructures
- New infrastructure initiatives have been identified in Europe
  e.g. TATTOOS (CH), SMILES (FR), IFMIF-DONES (ES)…
- New operational facilities identified to extend geographical coverage
  e.g. at IFIN-HH in Bucharest (Romania)
- Extensive study assessing production of key isotopes was performed in collaboration of 12 partners and external collaborators (e.g. IFMIF-DONES) plus invited guests (ANL, TRIUMF, UNIBE)

  => White paper ~~summarising the letters of~~ assessing the answer to the interest from user community

WP8 Objectives



White Paper (D8.3)

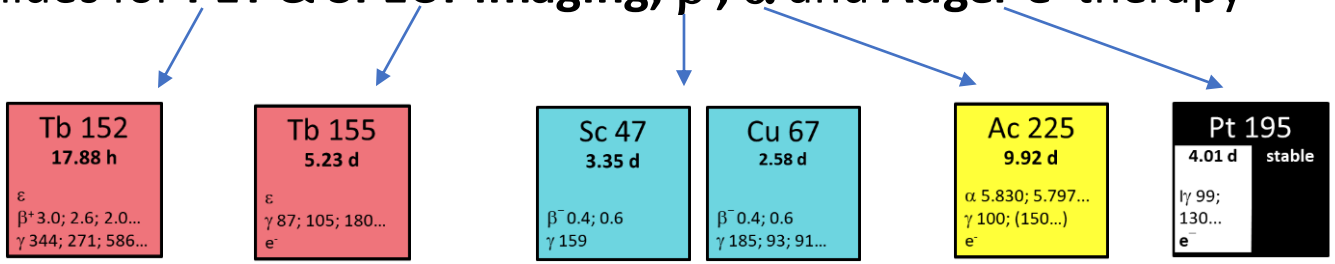
D8.3: White Paper – User Interest

- Interest from user community captured through
  - Online survey on public webpage (addressed to industry, research or clinic)
  - Helpdesk interactions and proposals
  - >60 proposals asking for >80 radionuclides

Slide based on material from Ulli Köster (ILL)

D8.3: White Paper – Radionuclide-Production Study

- Radionuclides selection for the study
  - Cases where **several different production routes may compete**
  - Representative radionuclides for **PET & SPECT imaging, β^-, α** and **Auger e^-** therapy



- What was not selected for the study:
  - Cases with unique or dominant production routes
  - Accelerator-produced radionuclides: ^{43,44}Sc, ^{52}Mn, ^{64}Cu, nca ^{103}Pd, ^{135}La, ^{203}Pb, ^{211}At
  - Reactor-produced radionuclides: ca ^{103}Pd, ^{111}Ag, ^{161}Tb, ^{169}Er, ^{175}Yb
  - Detailed investigation by WP12: ^{165}Er
  - Similarity to other cases: ^{223,224}Ra and ^{227}Th

Slide based on material from Ulli Köster (ILL)

Facilities addressed in the study

- Cyclotron-based:
  - ARRONAX (FR)
  - SPES -LARAMED (IT)
  - CERAD (PL)
- Mass-separator facilities:
  - MEDICIS (CERN)
  - SPES - ISOLPHARM (IT)
  - ISOL@MYRRHA (BE)
  - TATTOOS (CH)
  - SMILES (FR)
- Fast-neutron & reactor-based:
  - ESS (SE)
  - JHR (FR)
  - MYRRHA (BE)
  - GANIL-NFS (FR)
  - IFMIF-DONES (ES) (new)

Selected radionuclides, production routes and candidate facilities

Isotope	Production method	Facility
Sc-47	Ti(p,X)+ mass separation	SPES, ISOL@MYRRHA, ARRONAX*+SMILES
	V(p,X) (+ mass separation)	SPES, ISOL@MYRRHA, ARRONAX*+SMILES
	Ti-47(n,p) with fast neutrons	GANIL, IFMIF-DONES, ESS, MYRRHA, JHR
	V-51(γ, α)	Bremsstrahlung facility
	Ca-44(α,p)	ARRONAX*, CERAD, GANIL
Cu-67	Zn-68(p,2p)	ARRONAX, LARAMED
	Zn-68(γ,p)	Bremsstrahlung facility
	Zn-67(n,p) with fast neutrons	GANIL, IFMIF-DONES, ESS, MYRRHA, JHR
	Zn-68(n,np) with fast neutrons	GANIL, IFMIF-DONES
	Ni-64(α,p)	ARRONAX, CERAD, GANIL
Tb-152, Tb-155	Gd(p,X) + mass separation	SPES, ISOL@MYRRHA, ARRONAX*+SMILES
	Gd(p,X) or Tb(p,X)	ARRONAX, LARAMED
	Ta-181(p,X)+mass separation	TATTOOS, ISOLDE, ISAC, MEDICIS
	Eu(α,X)	ARRONAX*, CERAD, GANIL

Isotope	Production method	Facility
Pt-195m	Off-line mass separation of Pt	MEDICIS*, SPES, ISOL@MYRRHA, ARRONAX*+SMILES
	Ir-193(n,γ)(n,γ)β^- with thermal n	ILL*
	Pt-196(n,2n) with fast neutrons	GANIL, IFMIF-DONES, ESS, MYRRHA, JHR
	Pt-195(n,n') with fast neutrons	GANIL, IFMIF-DONES, ESS, MYRRHA, JHR
	Pt-194(n,γ) with epithermal neutrons	ESS, MYRRHA, JHR
	Pt-195(γ, γ')	Bremsstrahlung facility
	Au-197(γ,np)	Bremsstrahlung facility
	Pt-194(d,p)	GANIL, IFMIF-DONES
	Os-192(α,n)	ARRONAX, CERAD, GANIL
Ac-225	Ra-226(n,2n) with fast neutrons	GANIL, IFMIF-DONES, ESS, MYRRHA, JHR
	Ra-226(γ,n)	Bremsstrahlung facility
	Th-232(p,X)+mass separation	ISOL@MYRRHA, TATTOOS, MEDICIS*

- **E.g.** Ac-225 production at ISOL@MYRRHA: (investigated scenarios)
  - On-line extraction & mass separation of Ac-225
  - Chemical separation of Ac + off-line mass separation of Ac-225
  - Off-line extraction & mass separation of Ac-225
  - On-line extraction & mass separation of Ra-225 -> chemical separation of Ac-225

Extended computational analysis

- Assessments for all selected isotopes:
  - Various reaction channels
  - Various production routes & various processing techniques

- Work coordinated within 3 working groups

- WG1: **irradiation with charged particles**
  - Coordinator: Gilles Defrance (GANIL)
  - Participants: GANIL, ARRONAX, SPES, CERAD, IFMIF-DONES
- WG2: **irradiation with fast neutrons**
  - Coordinator: Luca Zanini (ESS)
  - Participants: GANIL, IFMIF-DONES, ESS, MYRRHA, JHR, CERN, NCBJ
- WG3: **fast protons and mass separation**
  - Coordinator: Lucia Popescu (SCK CEN)
  - Participants: ISOL@MYRRHA, TATTOOS, CERN, SPES

+ invited guests

- *ANL*
- *TRIUMF*
- *UNIBE*
- *CNL*

Extended computational studies

- Computational studies defined and discussed within several meetings of the WGs
  - Consistent/coherent studies
  - Common input parameters for the computational studies
    - Investigation and selection of nuclear data
    - Target composition
    - Timing: irradiation, cool-down, chemical processing or mass separation & collection
    - Efficiencies: isotope release and mass separation, chemical separation
    - Acceptable outcomes (purities, specific activities,…)
  - Well-defined scenarios (production routes and processes…)

Feedback and guidance from operational infrastructures was crucial!

Isotope	Production method	Facility	Target	A	Enrichment	Details of isotopic composition	Chemical form	Backing	rho (g/cm3)	Target area A (cm2)	Target thickness (mg/cm2)	Target mass (mg)	Target moles (mmol)	Target volume (cm3)	Beam	E_in (MeV)	E_out (MeV)	E_loss (MeV)	I (elec. uA)	Thermal neutron flux (10^{14} cm^{-2}s^{-1})	Epithermal neutron flux (10^{14} cm^{-2}s^{-1})	Fast (fission) neutron flux (10^{14} cm^{-2}s^{-1})	Gamma flux (10^{14} cm^{-2}s^{-1})	p (W)	Angle of incidence on target (°)	pA (W/cm2)	pV (kW/cm3)	A1 (MBq/(uAh))	Saturation activity A2 (MBq/uA)	Irradiation time (h)	Saturation factor	Activity EOI (MBq)	Decay time (h)	Chemical yield	Activity EOP (MBq)	Molar activity of product (MBq 47Sc/nmol Sc)	Fraction of theoretical	Specific activity of product (GBq 47Sc/mg Sc)	Apparent molar activity (MBq 47Sc/nmol interfering metals)	Details impurities	Target residues in Sc fraction (nmol)	Separation factor target/Sc	46Sc / 47Sc (Bq/Bq)	48Sc / 47Sc (Bq/Bq)	Radionuclidic purity (%)	Radionuclidic impurities in recycled target XX / 47Sc (Bq/Bq)	Radionuclidic impurity in recycled target XX (Bq/g)	List other notable impurities in residu
47Sc	Ti(p,X) Ca(n,X) + mass separation	MEDICIS																																															
		SPES																																																
		ISOL@MYRRHA																																															
		ARRONAX+SMILES																																															
	50Ti(p,a)	LNL																																															
	natV(p,X)	LNL																																															
		MEDICIS: release																																															
	47Ti(n,p) with fast neutrons	CEA																																															
		ESS																																															
		GANIL																																															
		SCK CEN																																															
	natV(g,a)	ANL/BernTRIUMF																																															
	48Ca(g,n)	ANL																																															
	44Ca(a,p)	ARRONAX																																															
		CERAD																																															

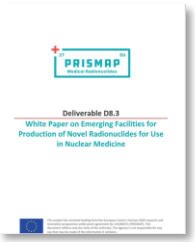
- Studies performed by the various partners and reviewed within the WGs

PRISMAP on Emerging Facilities for Production of Novel Radionuclides for Use in Nuclear Medicine

- Results of the computational studies presented and discussed at PRISMAP Workshop on Emerging Infrastructures, 31st March – 2nd April 2025, Belgium
- Dedicated sessions for infrastructures and the different isotopes investigated

Session -> Chapter	Convener
Facilities	Lucia Popescu (SCK CEN)
Production of Cu-67	Férid Haddad (ARRONAX) & Mikael Jensen (DTU)
Production of Sc-47	Renata Mikołajczak (POLATOM)
Production of Tb-152 and Tb-155	João Pedro Ramos (SCK CEN)
Production of Pt-195m	Ulli Köster (ILL)
Production of Ac-225	Thierry Stora (CERN)

- Conveners in charge with the preparation of the corresponding chapters in the White Paper
- Editor: Luca Zanini (ESS)
- Published on the PRISMAP web tool and Zenodo (https://doi.org/10.5281/zenodo.17553316)



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- Renata Mikolajczak (NCBJ)
- Robert Eichler (PSI)
- Thierry Stora (CERN)
- Ulli Köster (ILL)
- Xavier Ledoux (GANIL)

Conclusions

- **Emerging infrastructures play a strategic role** in complementing conventional radionuclide production and enabling novel routes, ensuring broader geographical coverage and sustainability for PRISMAP activities
- **Workshops and collaborative studies** have successfully engaged a wide community
- **Studies performed in coordinated working groups have established coherent production scenarios**, integrating feedback from operational facilities
- **The White Paper consolidates technical feasibility to answer user needs**, serving as a roadmap for future developments and supporting PRISMAP's continuation beyond the H2020 funding period
- New infrastructure initiatives and partnerships expand PRISMAP's capabilities, **reinforcing Europe's capabilities** in innovative radionuclide production for nuclear medicine

LOOKING BACK WITH PROUDNESS
&
LOOKING FORWARD WITH EXCITEMENT

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PRISMAP PROJECT

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