

# A COMPACT ACCELERATOR DRIVEN NEUTRON SOURCE

AT THE APPLIED NUCLEAR PHYSICS LABORATORY,  
LUND UNIVERSITY

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INTERNATIONAL CONFERENCE ON

## ACCELERATORS FOR RESEARCH AND SUSTAINABLE DEVELOPMENT

From good practices towards socioeconomic impact



**23–27 May 2022**

IAEA Headquarters, Vienna, Austria



# CONTENT

## The Nuclear Applications Laboratory

- Laboratory and infrastructure
- Research outputs



**K.E. Stenström**



**K. Fissum**



**M. Elfman**

## Compact Neutron Source Development

- Motivation
- Integration into laboratory
- Beamline components
- Ion-source upgrade
- Target, shielding and moderator
- Predictions from simulation



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**G. Pedehontaa-Hiaa**



**R.J.W. Frost**



**N. Mauritzson**

## Towards a European CANS Network

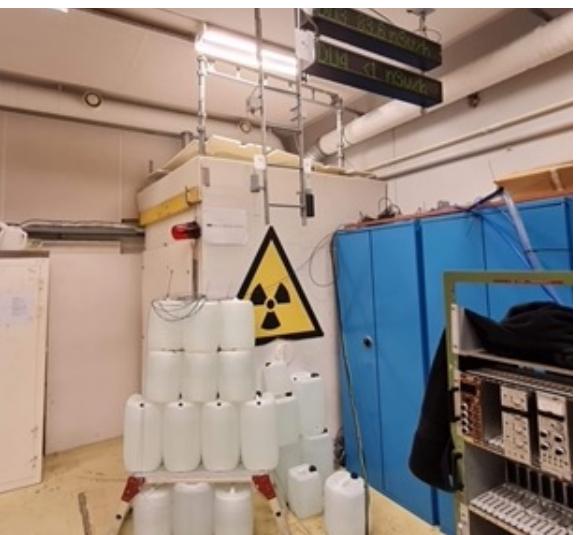
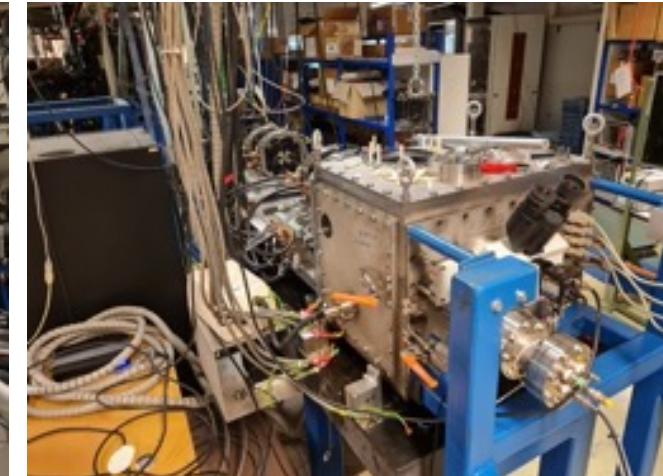


**P. Kristiansson**



**J. Pallon**

# LABORATORY AND INFRASTRUCTURE



## 3 MV Pelletron with three IBA chambers:

- Macro PIXE chamber (1 cm beam)
- TIBA chamber (10  $\mu\text{m}$  beam)
- Nano PIXE chamber (1  $\mu\text{m}$  beam)

Dedicated neutron production beamline nearing completion

## Gamma-ray and neutron sources including:

- AmBe, PuBe, 252-Cf (approx. 1e6 n/s)
- SODERN Geni-16 neutron generator ( up to 4.7e8 n/s)

# RESEARCH OUTPUTS – ION-BEAM ANALYSIS

**Deuterium/hydrogen microscopy in astrogeological material using an elastic recoil approach**

L. Ros, P. Kristiansson, M. Borysiuk, N. Abdel, M. Elfman, E.J.C. Nilsson, J. Pallon  
Nucl. Instrum. Methods Phys. Res. B 348 (2015) 273-277

**Cellular nutrient content measured with the nuclear microprobe and toxins produced by *Dinophysis norvegica* (Dinophyceae) from the Trondheim fjord (Norway)**

E.P. Blanco, C. Karlsson, J. Pallon, T. Yasumoto, E. Granéli  
Aquat. Microb. Ecol. 75 (2015) 259-269

**Ion beam evaluation of silicon carbide membrane structures intended for particle detectors**

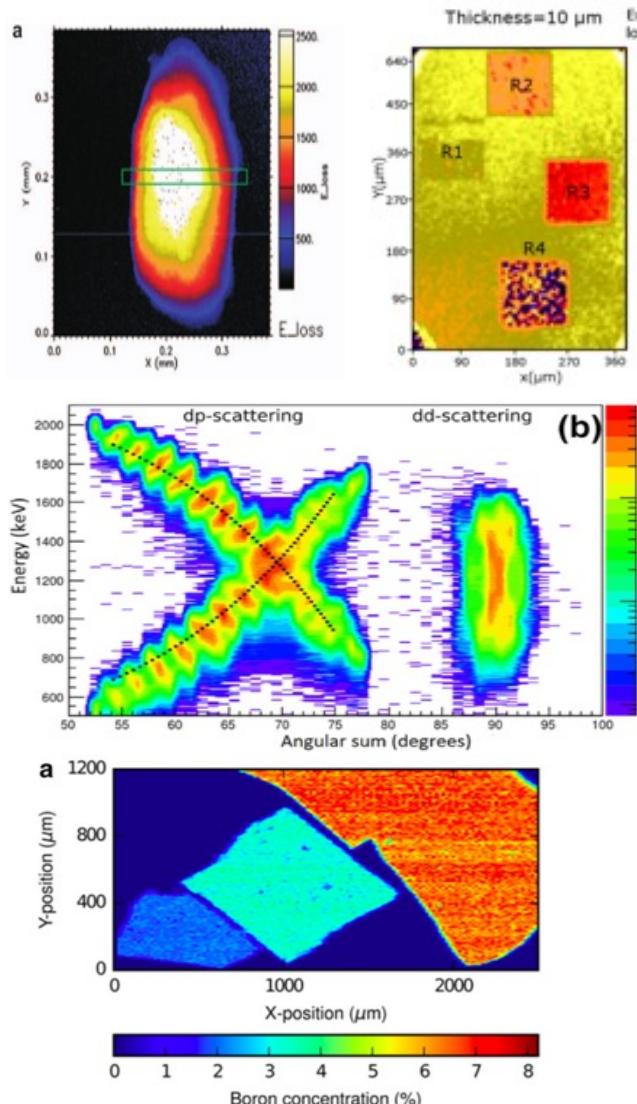
J. Pallon, M. Syväjärvi, Q. Wang, R. Yakimova, T. Iakimov, M. Elfman, P. Kristiansson, E.J.C. Nilsson, L. Ros  
Nucl. Instrum. Methods Phys. Res. B 371 (2016) 132–136

**Insights from two-dimensional mapping of otolith chemistry**

K.E. Limburg, M. Elfman  
Journal of Fish Biology 90 (2017) 480-491

**Late magmatic controls on the origin of schorlitic and foititic tourmalines from late-Variscan peraluminous granites of the Arbus pluton (SW Sardinia, Italy): Crystal-chemical study and petrological constraints**

F. Bosi, S. Naitza, H. Skogby, F. Secchi, A.M. Conte, S. Cuccuru, U. Hålenius, N. De La Rosa, P. Kristiansson , E.J.C. Nilsson, L. Ros, G.B. Andreozzi  
Lithos 308-309 (2018) 395-411



**PIXE analysis as a tool for dating of ice cores from the Greenland ice sheet**  
H.-C. Hansson, E. Swietlicki, N.P.-O. Larsson  
Nucl. Instrum. Methods Phys. Res. B 75 (1993) 428-434

**The use of PIXE and complementary ion beam analytical techniques for studies of atmospheric aerosols**

E. Swietlicki, B.G. Martinsson, E Kristiansson  
Nucl. Instrum. Methods Phys. Res. B 109/110 (1996) 385-394

**Scanning probe microscopy characterisation of masked low energy implanted nanometer structures**

T. Winzell, S. Anand, I. Maximov, E.-L. Sarwe, M. Graczyk, L. Montelius, H. J. Whitlow  
Nucl. Instrum. Methods Phys. Res. B 173 (2001) 447-454

**Tolerance to proton irradiation in the eutardigrade *Richtersius coronifer* – a nuclear microprobe study**

E.J.C. Nilsson, K.I. Jönsson, J. Pallon  
International Journal of Radiation Biology 86:5 (2010) 420-427

**Radiation tolerance of ultra-thin PIN silicon detectors evaluated with a MeV proton microbeam**

N.S. Abdel, J. Pallon, M. Elfman, P. Kristiansson, E.J.C. Nilsson, L. Ros  
Nucl. Instrum. Methods Phys. Res. B 356-357 (2015) 17-21

# RESEARCH OUTPUTS – NEUTRONICS AND ENVIRONMENTAL

## GEANT4-based calibration of an organic liquid scintillator

Mauritzson, N., Fissum, KG., Perrey, H., Annand, J., Frost, R., Hall-Wilton, R., Jebali, R., Kanaki, K., Mauerova-Subert, V., Messi, F. & Rofors, E., 2022 Jan 21, In: Nucl. Instrum. Methods Phys. Res. B 1023, 8 p., 165962.

## Modern Neutron Detectors with Fast Timing Resolution

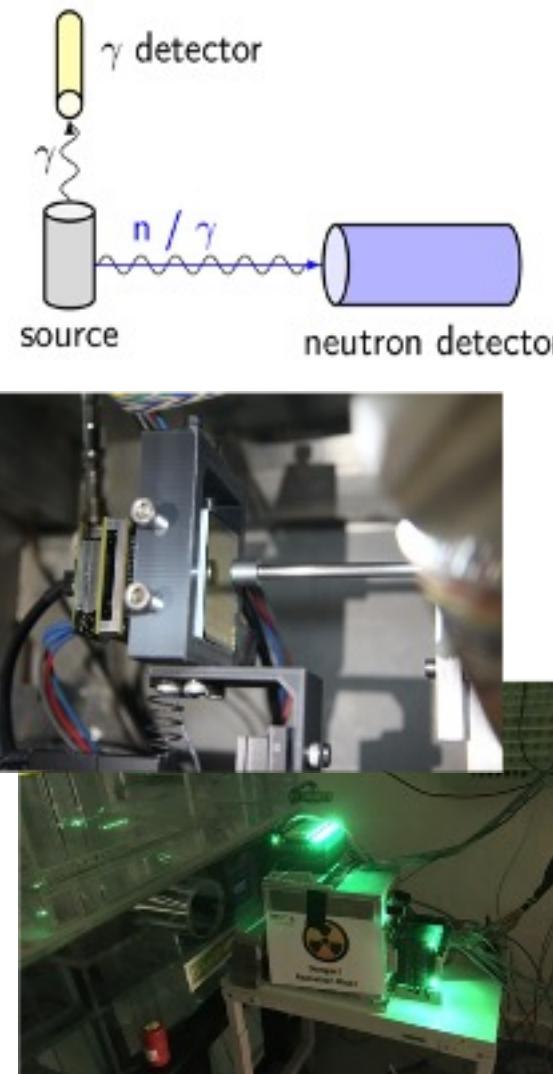
Seitz, B., Annand, J. R. M., Boyd, L. & Fissum, K., 2020, Modern Neutron Detection: Proceedings of a Technical Meeting. Vienna, p. 273-277 5 p. (IAEA-TECDOC Series; no. 1935).

## Response of a Li-glass/multi-anode photomultiplier detector to focused proton and deuteron beams

Rofors, E., Pallon, J., Al Jebali, R., Annand, J. R. M., Boyd, L., Christensen, M. J., Clemens, U., Desert, S., Elfman, M., Engels, R., Fissum, K. G., Frielinghaus, H., Frost, R., Gardner, S., Gheorghe, C., Hall-Wilton, R., Jaksch, S., Kanaki, K., Kemmerling, G., Kristiansson, P. & 9 others, , 2020, In: Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 984, 164604.

## A polyethylene-B4C based concrete for enhanced neutron shielding at neutron research facilities

DiJulio, D. D., Cooper-Jensen, C. P., Perrey, H., Fissum, K., Rofors, E., Scherzinger, J. & Bentley, P. M., 2017 Jul 1, In: Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 859, p. 41-46 6 p.



## Environmental levels of radiocarbon in Lund, Sweden, prior to the start of the European Spallation Source

Eriksson Stenström, K., Skog, G., Bernhardsson, C., Mattsson, S., Nielsen, A. B., Rundgren, M., Muscheler, R., Linderson, H., Pédehontaa-Hiaa, G. & Rääf, C., 2022, In: Radiocarbon. 64, 1, p. 51-56 17 p.

## Evaluation of the region-specific risks of accidental radioactive releases from the European Spallation Source

Pédehontaa-Hiaa, G., Bernhardsson, C., Barkauskas, V., Puzas, A., Eriksson Stenström, K., Rääf, C. & Mattsson, S., 2021, Medical Physics in the Baltic States: Proceedings of the 15th International Conference on Medical Physics. Adliené, D. (ed.). Kaunas University Of Technology Press, p. 142-146

## Identifying radiologically important ESS-specific radionuclides and relevant detection methods

Eriksson Stenström, K., Barkauskas, V., Pédehontaa-Hiaa, G., Nilsson, C., Rääf, C., Holstein, H., Mattsson, S., Martinsson, J., Jönsson, M. & Bernhardsson, C., 2020 Jun, Strålsäkerhetsmyndigheten. 180 p.

## Prediction of the radionuclide inventory in the European Spallation Source target using FLUKA

Barkauskas, V. & Stenström, K., 2020 May 15, In: Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms. 471, p. 24-32 9 p.

# RESEARCH OUTPUTS – NUCLEAR SAFEGUARDS



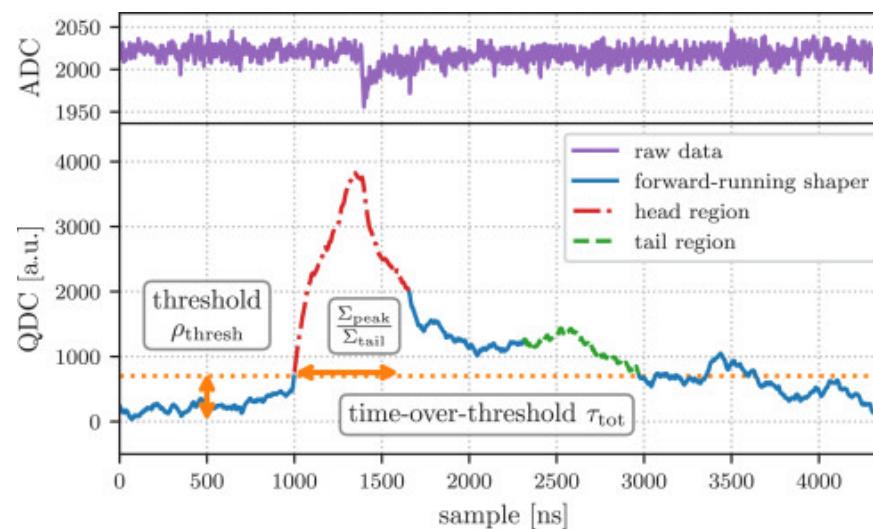
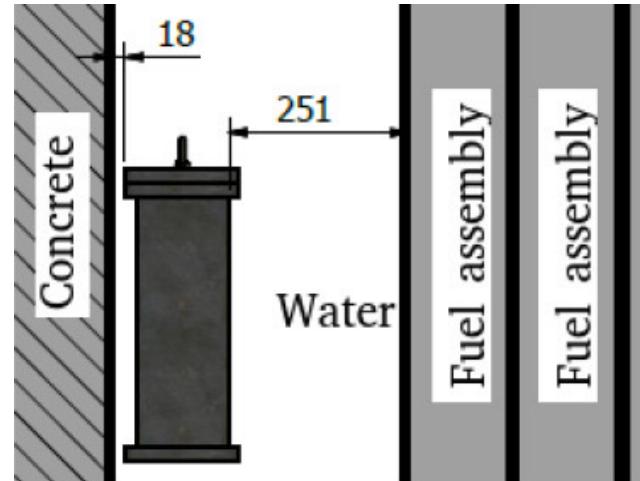
Nuclear Instruments and Methods in Physics  
Research Section A: Accelerators, Spectrometers,  
Detectors and Associated Equipment  
Volume 1020, 21 December 2021, 165886



Evaluation of the *in-situ* performance of neutron detectors based on EJ-426 scintillator screens for spent fuel characterization

Hanno Perrey <sup>a</sup>, R. <sup>b</sup>, Linus Ros <sup>b</sup>, Mikael Elfman <sup>b</sup>, Ulrika Bäckström <sup>d</sup>, Per Kristiansson <sup>a</sup>, Anders Sjöland <sup>a,c</sup>

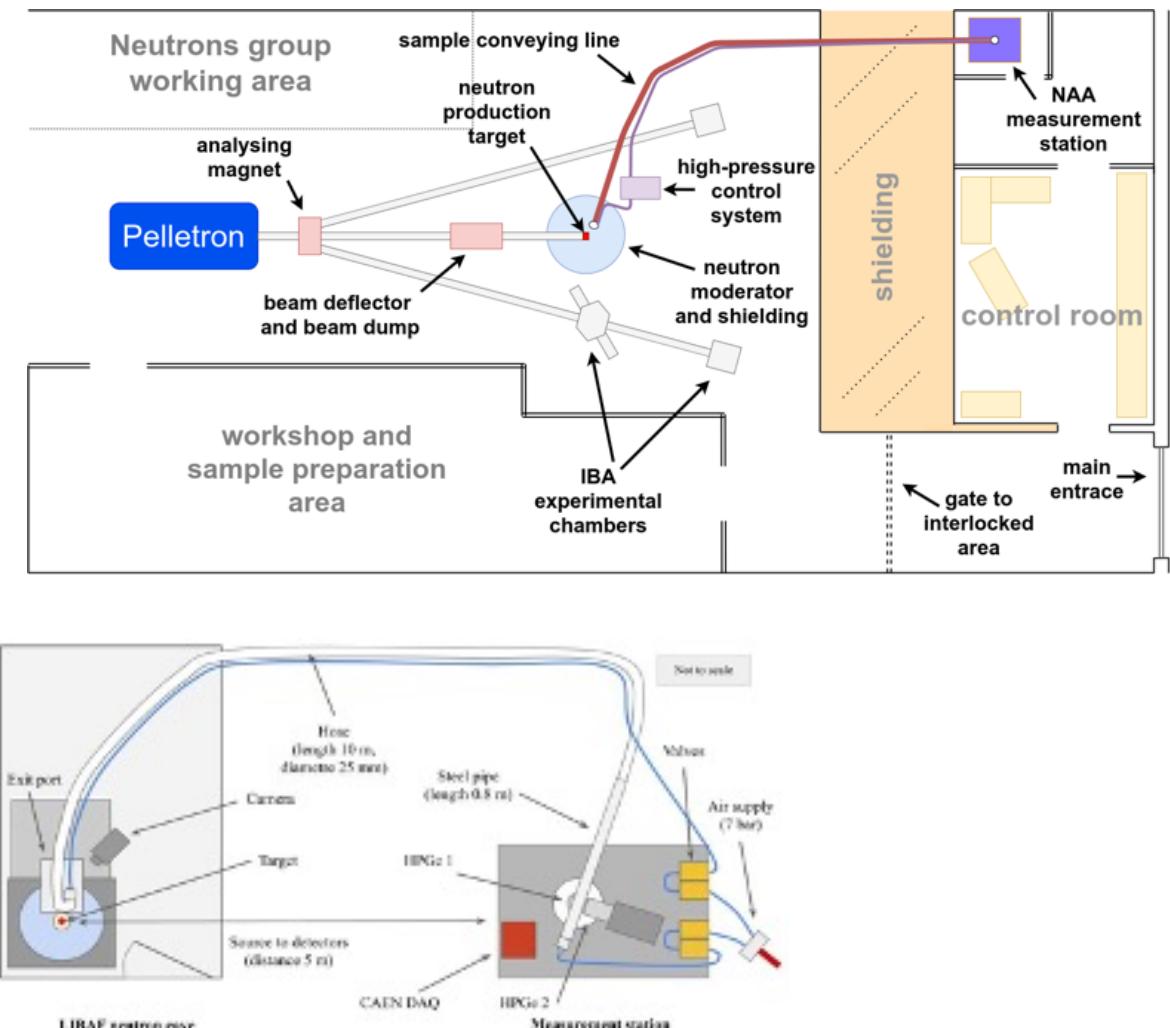
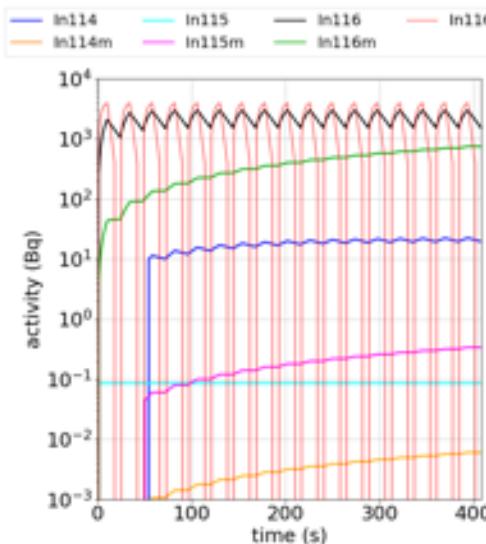
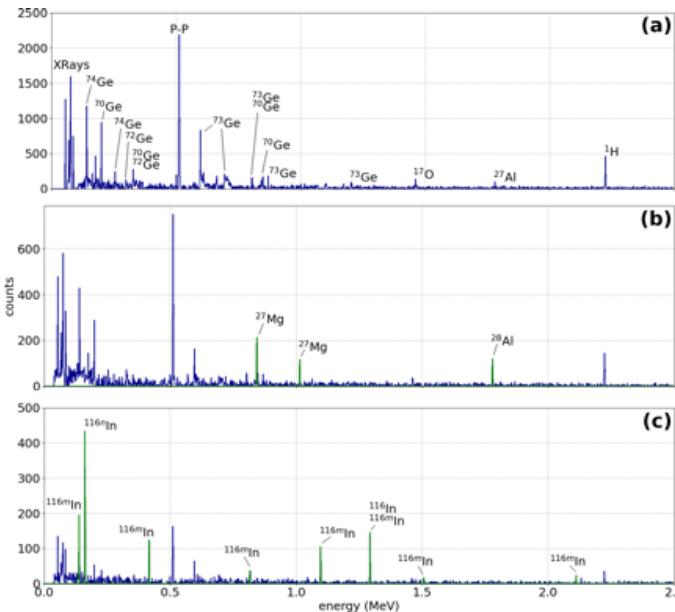
- Non-destructive methods for the characterisation of spent nuclear fuel
- Detection of neutrons in a harsh gamma-ray environment.
- Detector system development.
- Extended in-situ monitoring of detector system.
- 280 n/s/cm<sup>2</sup> and 6 Sv/h gamma.



# MOTIVATIONS FOR CANS DEVELOPMENT

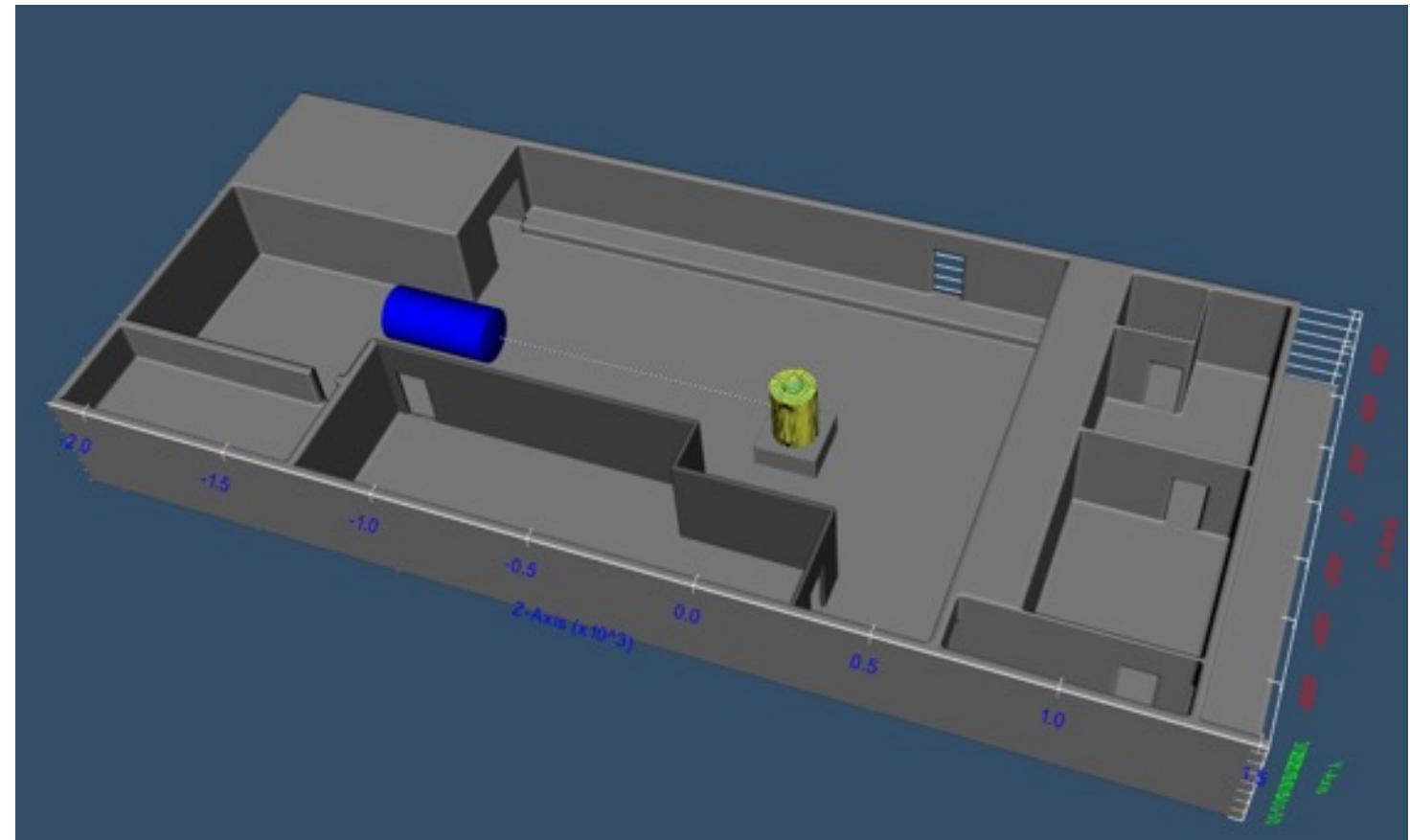
Will enhance all neutron related activities, but with an initial focus on the in-lab cyclic-NAA system

- Can measure activation products with  $h\tau < 1$  s
- Prototyping with DT neutron generator
- Will be implemented with the CANS once finished

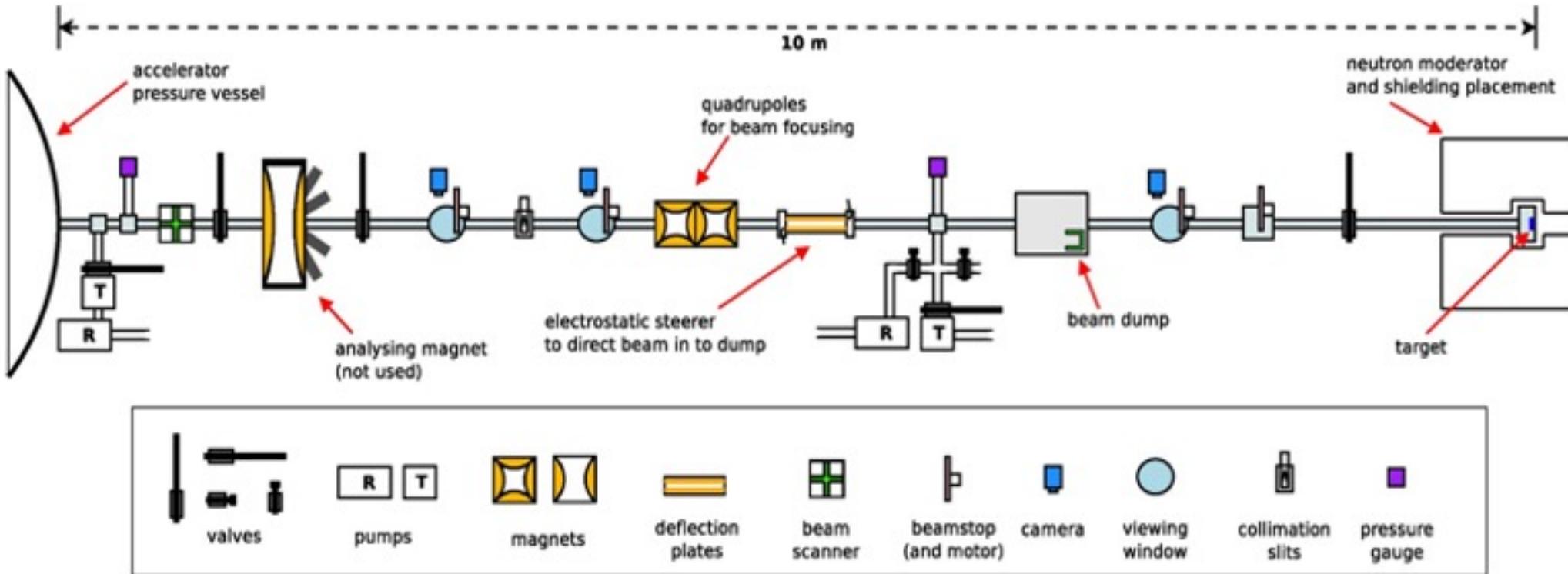


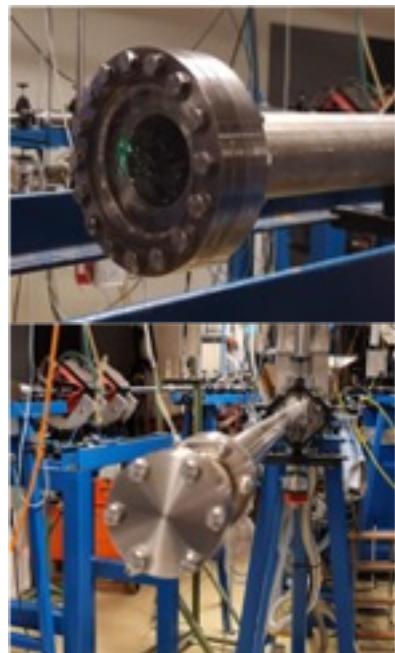
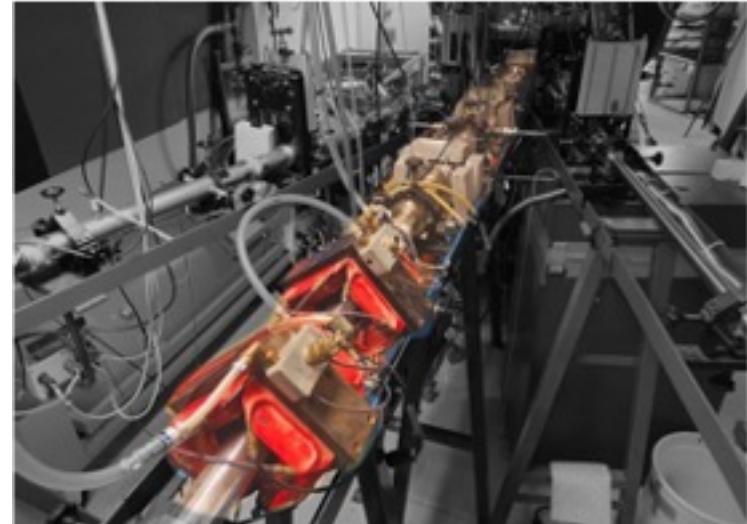
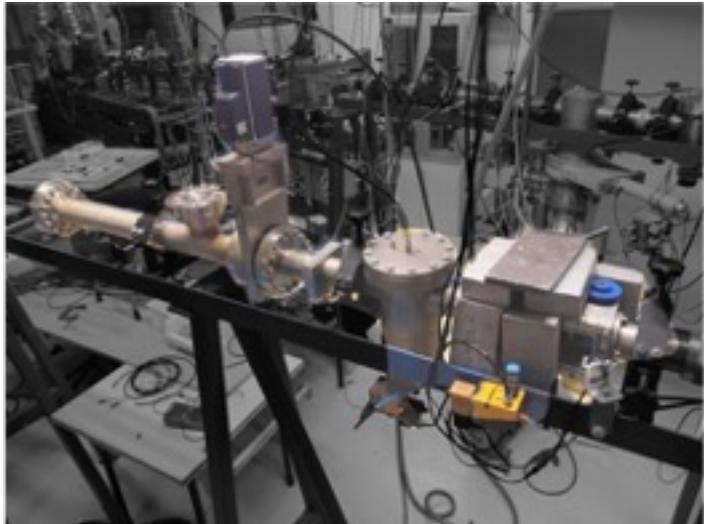
# INTEGRATION INTO CURRENT LABORATORY ENVIRONMENT

- Former synchrotron laboratory with heavy shielding of control room.
- ‘busy’ environment: beamlines experimental stations, surrounding laboratories and office space.
- CANS is constructed with the exception of the shielding and moderator.
- At this stage the CANS concept is very flexible with regards to moderator design and end-station(s).



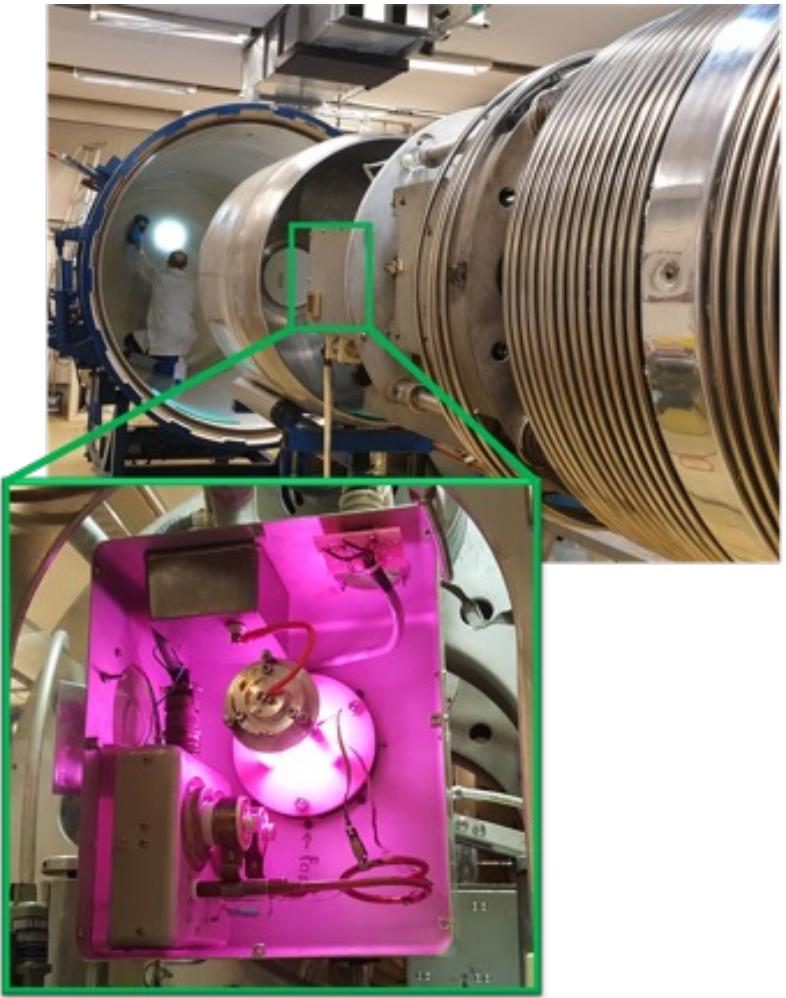
# BEAMLINE COMPONENT OVERVIEW





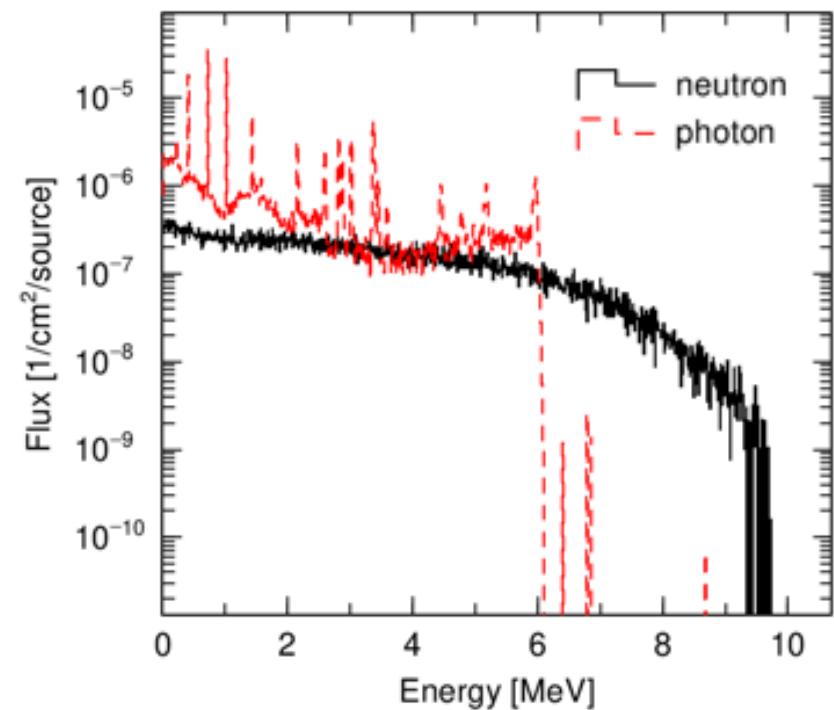
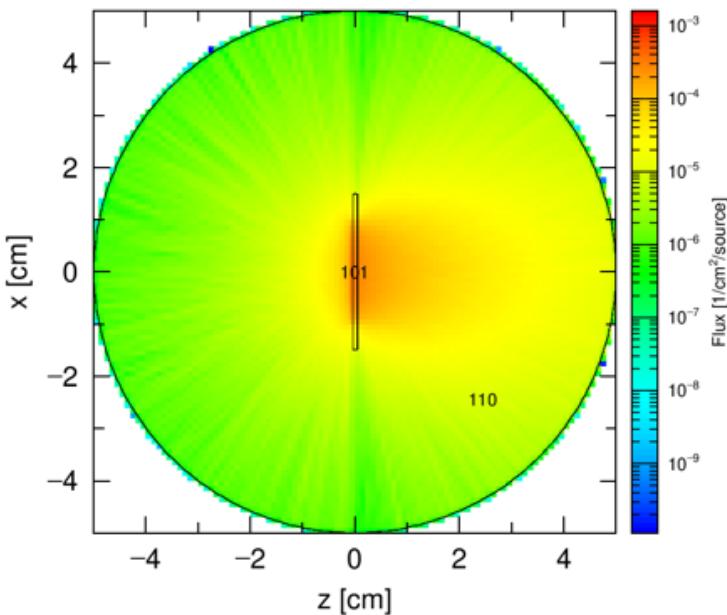
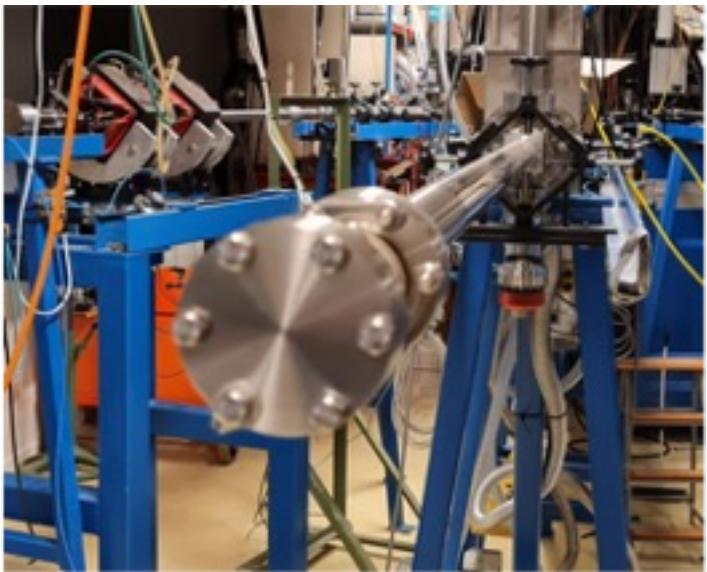
- Electrostatic deflection and tantalum beam dump.
- Focusing magnets.
- Beam viewers and current monitors.
- All under vacuum
- PLC system currently being installed.

# ION-SOURCE UPGRADE



- 3 MV single ended Pelletron from NEC - Commissioned January 1990
- Radio frequency ion source - H, D and He
- Continuous beam up to 10  $\mu\text{A}$
- Upgrade of ion source planned
- Factor of 10 increasing in beam current
- 100  $\mu\text{A}$
- Will increase cooling requirements on target

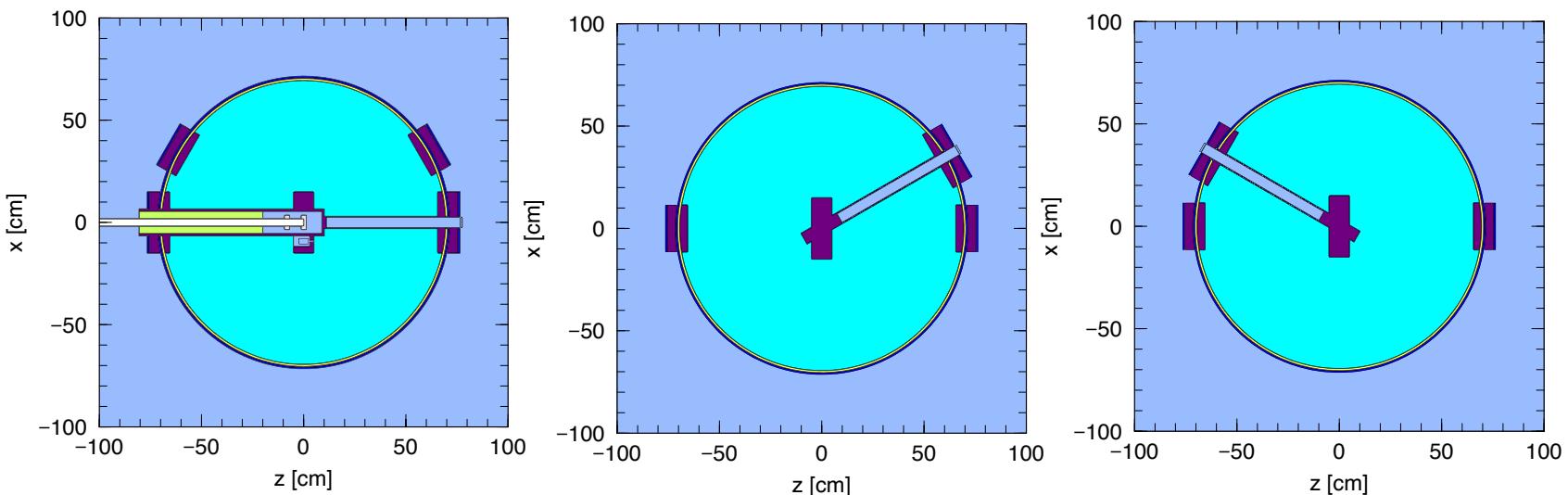
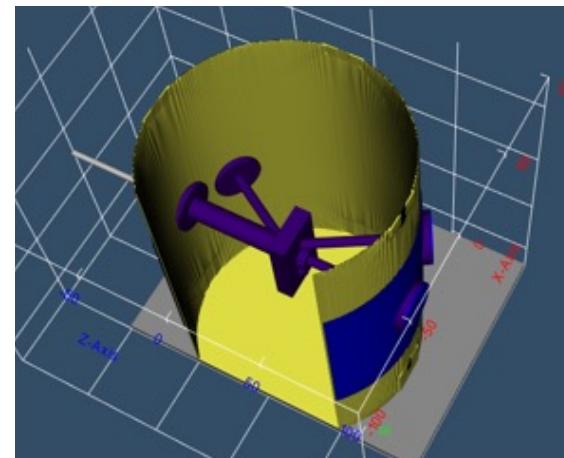
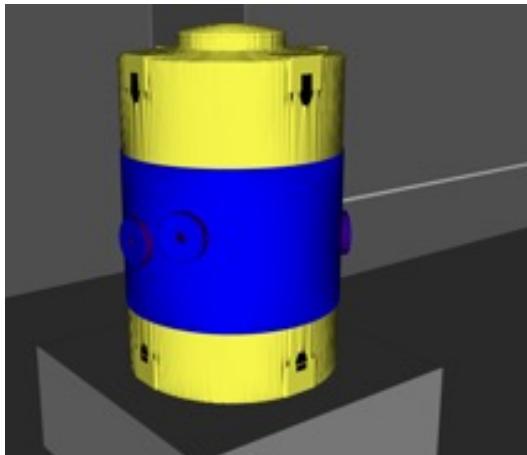
# TARGET



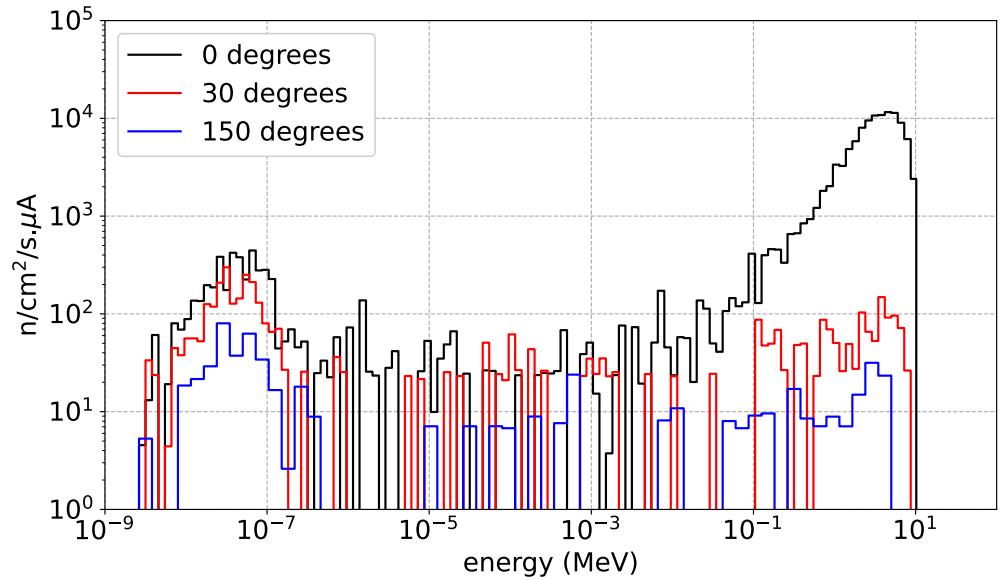
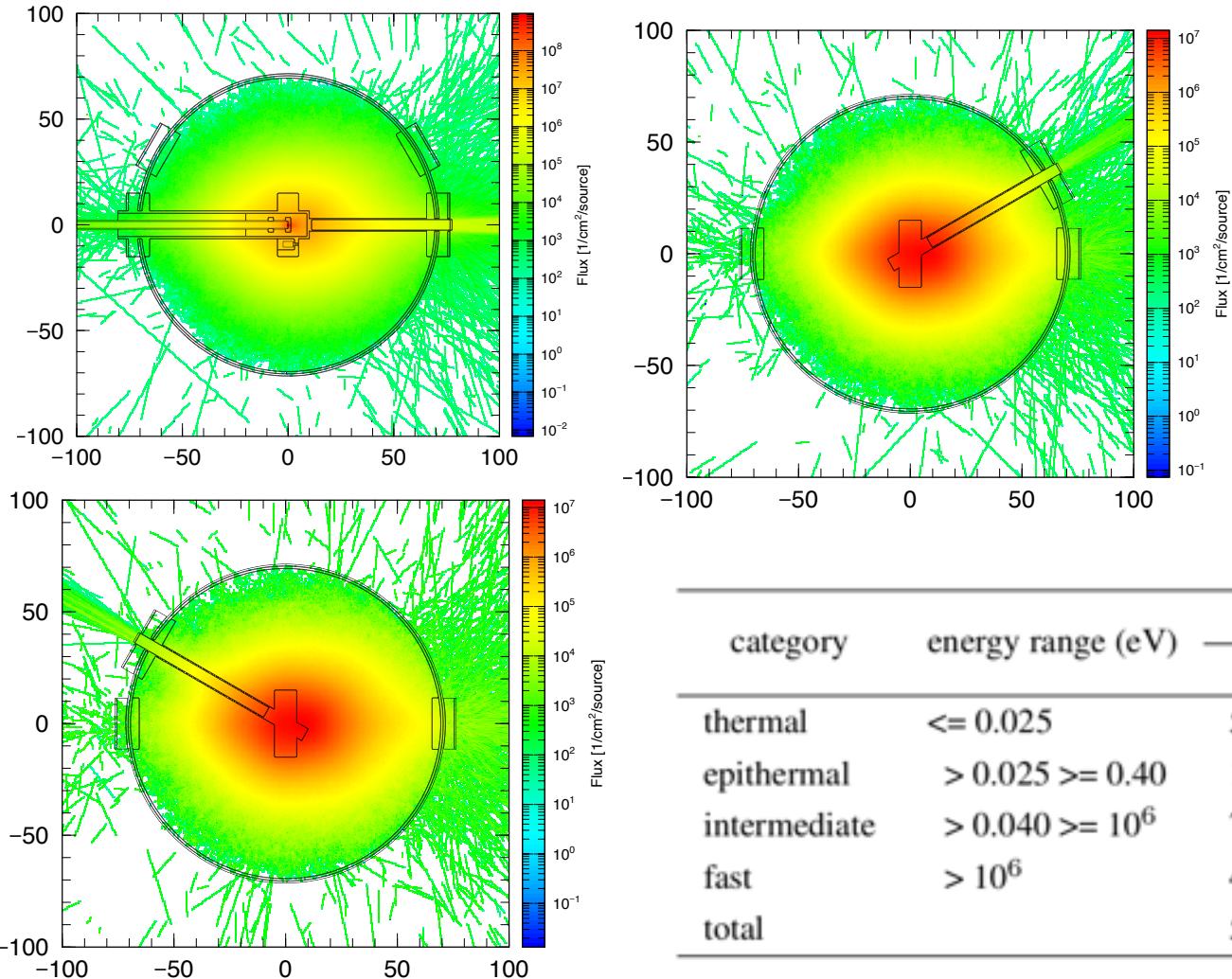
- Neutrons produced by deuterium (2.8 MeV) on 1 mm Be.
- Flux largely produced in the forward direction.
- Anticipated flux of  $1\text{e}10$  n/s in  $4\pi$  (for 10 uA beam).
- Water-cooling to be added to external face of end-flange.
- Electrically isolated for current measurement.

# SHIELDING AND MODERATOR

- Preliminary simulation of neutron and gamma-ray fluxes performed in PHITS.
- Based on 6000 l tank of deionised water.
- Neutrons extracted on axis with deuteron-beam and at two additional ports.



# PREDICTED NEUTRON FLUXES



category	energy range (eV)	flux (n/cm <sup>2</sup> /s)		
		0° port	30° port	150° port
thermal	<= 0.025	5.2x10 <sup>4</sup>	2.9x10 <sup>4</sup>	1.0x10 <sup>4</sup>
epithermal	> 0.025 >= 0.40	1.6x10 <sup>5</sup>	8.6x10 <sup>4</sup>	3.9x10 <sup>4</sup>
intermediate	> 0.040 >= 10 <sup>6</sup>	7.2x10 <sup>5</sup>	6.3x10 <sup>4</sup>	2.4x10 <sup>4</sup>
fast	> 10 <sup>6</sup>	4.9x10 <sup>6</sup>	4.2x10 <sup>4</sup>	1.3x10 <sup>4</sup>
total		5.9x10 <sup>6</sup>	2.2x10 <sup>5</sup>	8.9x10 <sup>4</sup>

# POTENTIAL UPGRADES TO MODERATOR DESIGN

- Layered moderator and shielding.
- Cavity or convoluted moderator.
- Concepts explored in GEANT4
- Separation of fast/slow neutrons possible by pulsing the deuteron beam using an electrostatic deflector.

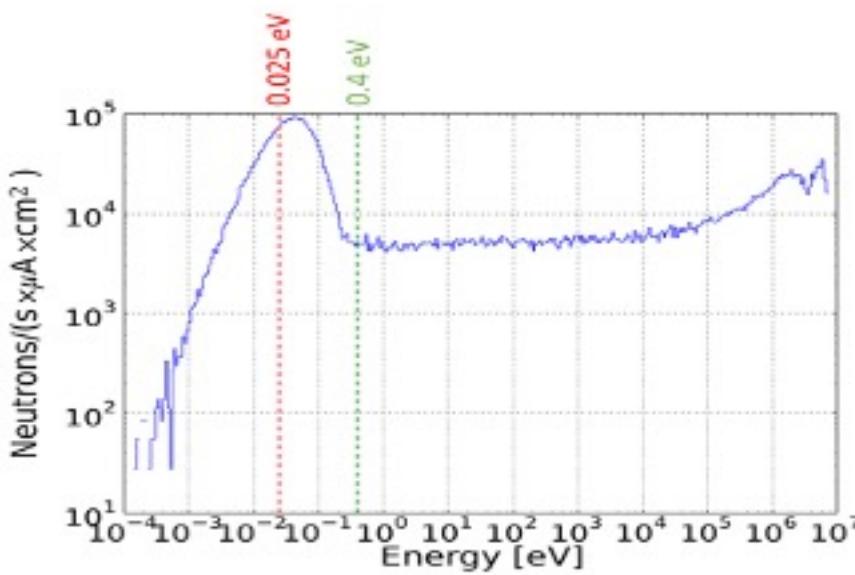
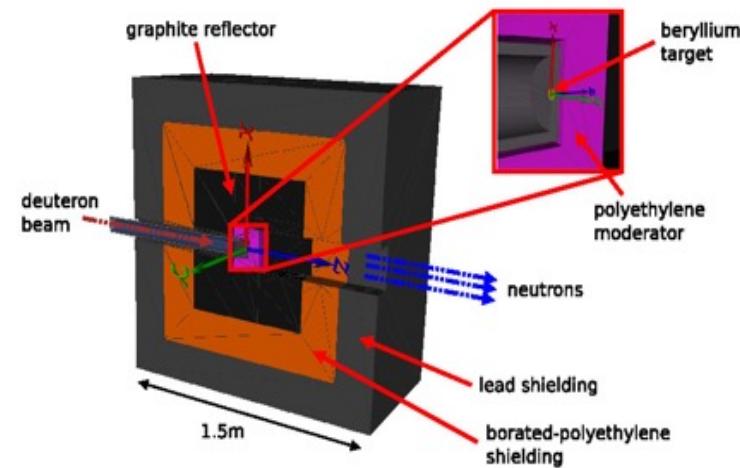
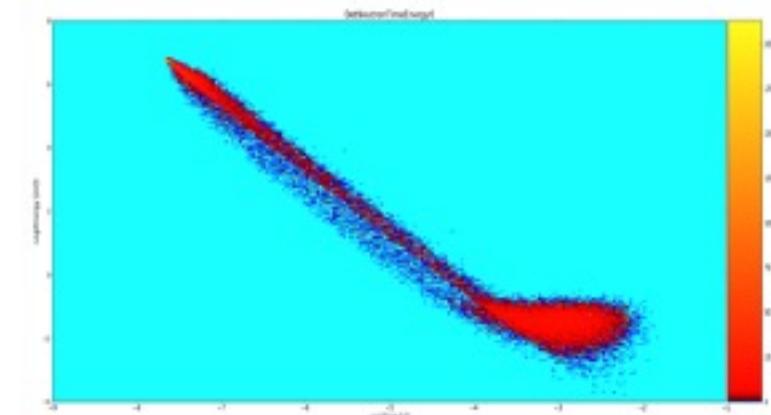


Fig: Neutron spectrum at end of exit hole of the TMRS.



Tab: Simulated flux at end of exit hole of TMRS.

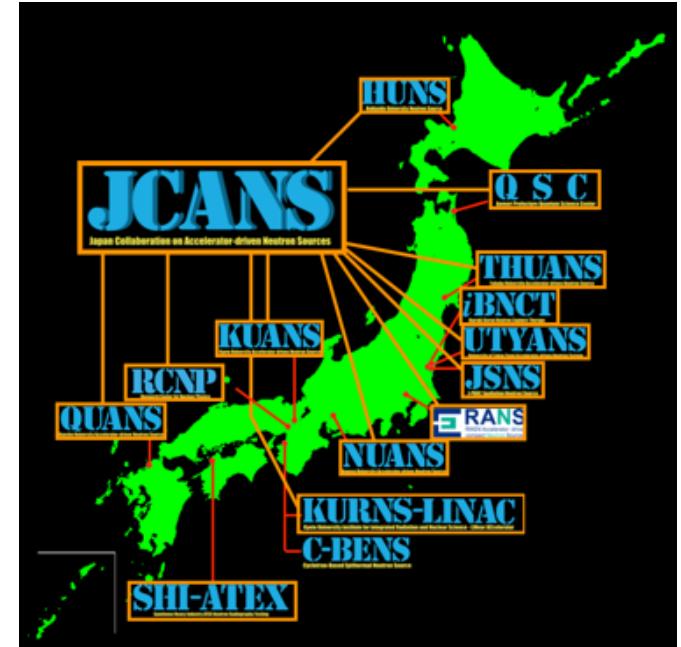
Neutron Group	Flux [N/s/10μA/cm <sup>2</sup> ]
Thermalised ( $E \leq 0.025$ eV)	1.2e5
Epithermal ( $0.025 < E \leq 0.4$ eV)	2.3e5
Fast ( $E > 0.4$ eV)	2.5e5



# TOWARDS A EUROPEAN NETWORK OF CANS



- The map should not be empty!
- Geographically spread.
- Specialisation at each facility.
- Integrated with each other.
- Integrated with the wider scientific community.



# Thank you

## Acknowledgements:

Thanks goes to The Swedish Radiation Safety Authority and The Walter Gyllenberg Foundation for funding provided towards the CANS project.

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**ACCELERATORS FOR RESEARCH  
AND SUSTAINABLE DEVELOPMENT**  
From good practices towards socioeconomic impact

