Status and outlook of nuclear-data activities at n TOF

Eric Berthoumieux, Emmeric Dupont, Frank Gunsing
CEA Irfu, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France

Outline

- **Introduction**
  - Neutron-induced reactions
  - The n_TOF facility

- **Overview achievements 2018 - 2026**
  - capture and fission on ^{233}U
  - level densities and strength functions of ^{234,236,238}U
  - simultaneous capture and fission of ^{241}Pu (APRENDE)
  - neutron capture of ^{87}Sr
  - ξ-Megas (ANR project)
  - optical-fiber based neutron detector (APRENDE)

- **Outlook for the coming years**

Introduction: Nuclear Data

- Nuclear Data are at the intersection of
  - **low-energy nuclear physics and**
  - **applied nuclear science and technology**

- Physical quantities related to properties of atomic nuclei and their interactions with other particles.
  Includes: • cross sections, • angular distributions, • particle multiplicities, • fission yields, • decay data, • nuclear level densities, • photon strength functions, • others

- Experimental data feed **experimental databases** for reactions (**EXFOR**) and structure (**XUNDL**)

- In combination with **theoretical models**, they are used as input for **evaluated** nuclear data,
  reactions: **JEFF** (Europe), **ENDF/B** (USA), **JENDL** (Japan), others
  structure: **ENSDF**

Nuclear Data

Producers

Measurements

Evaluation
Validation

Models
Theory

Benchmarks

General purpose

Evaluated Nuclear Data Library

for example:
JEFF
JENDL
ENDF/B
BROND
CENDL

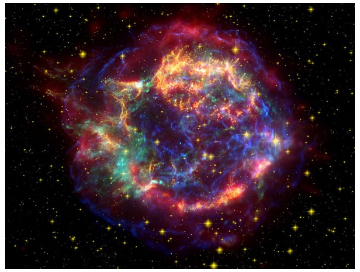
HPRL

Users

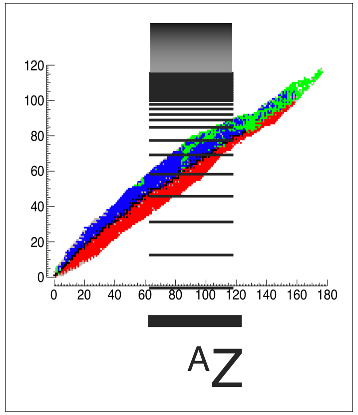
Applications

- reactors, GEN IV
- safety
- criticality
- fuel cycles
- design
- transmutation
- ADS
- dosimetry
- health
- fusion
- nuclear structure
- astrophysics

nuclear technology

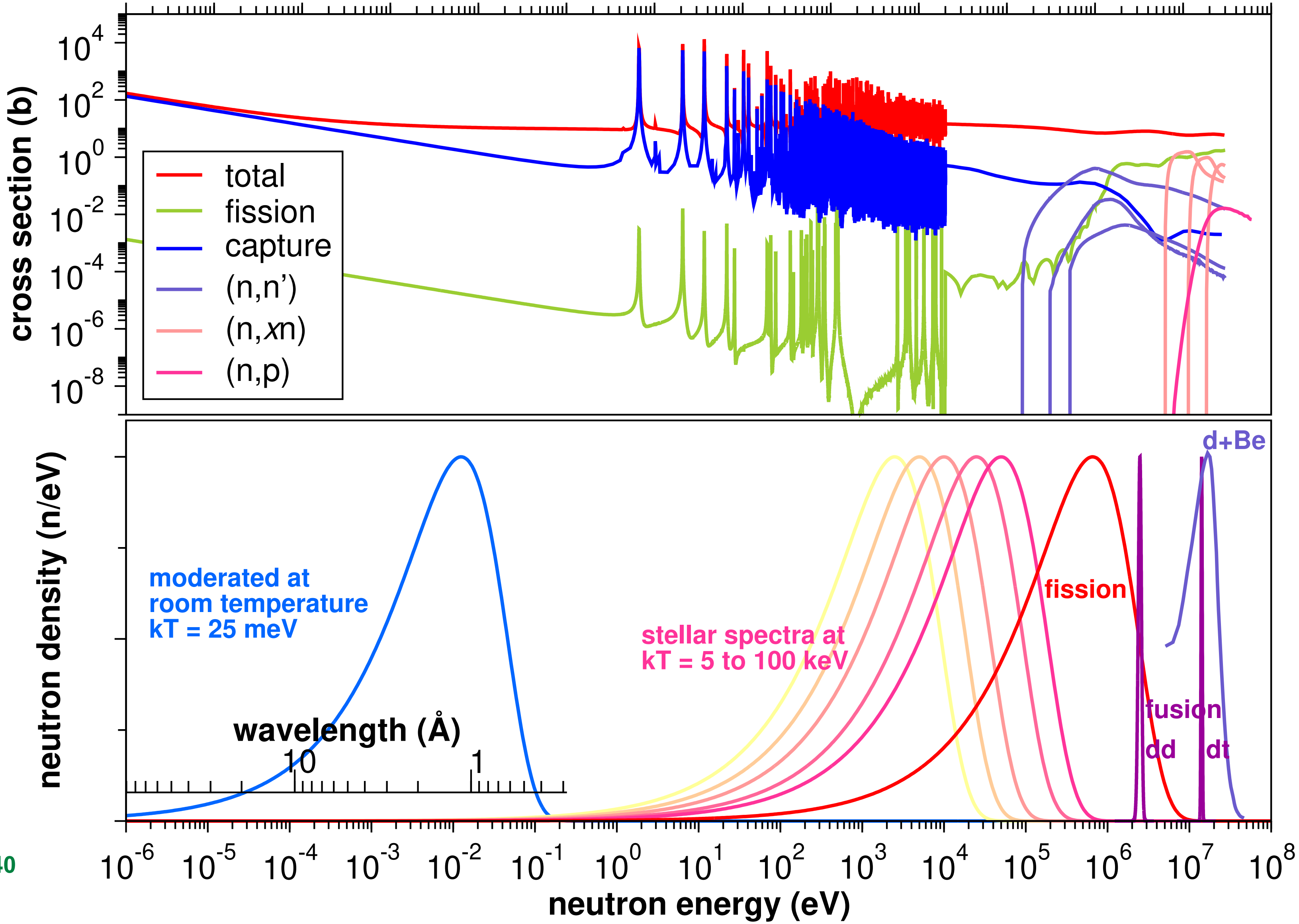


astrophysics



nuclear science

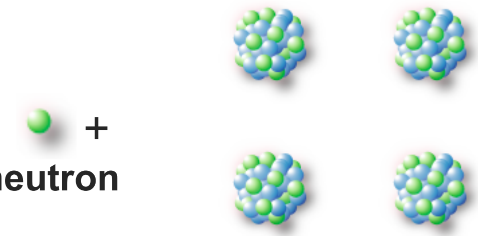
Neutron-induced reactions, nuclear data



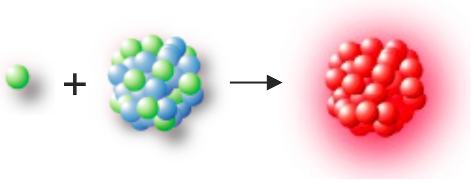
- Eur. Phys. J. Plus 133 (2018) 440
- NuPECC LRP2024

Neutron induced nuclear reactions

solid state,
Bragg scattering

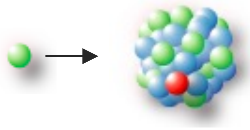


nuclear, compound
nucleus reactions

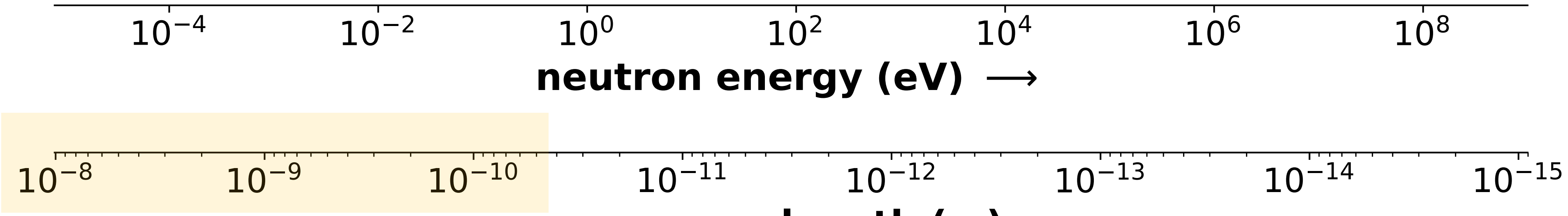


$\tau \sim 10^{-16}$ s
$E_n < 10$ MeV

nuclear,
direct reactions



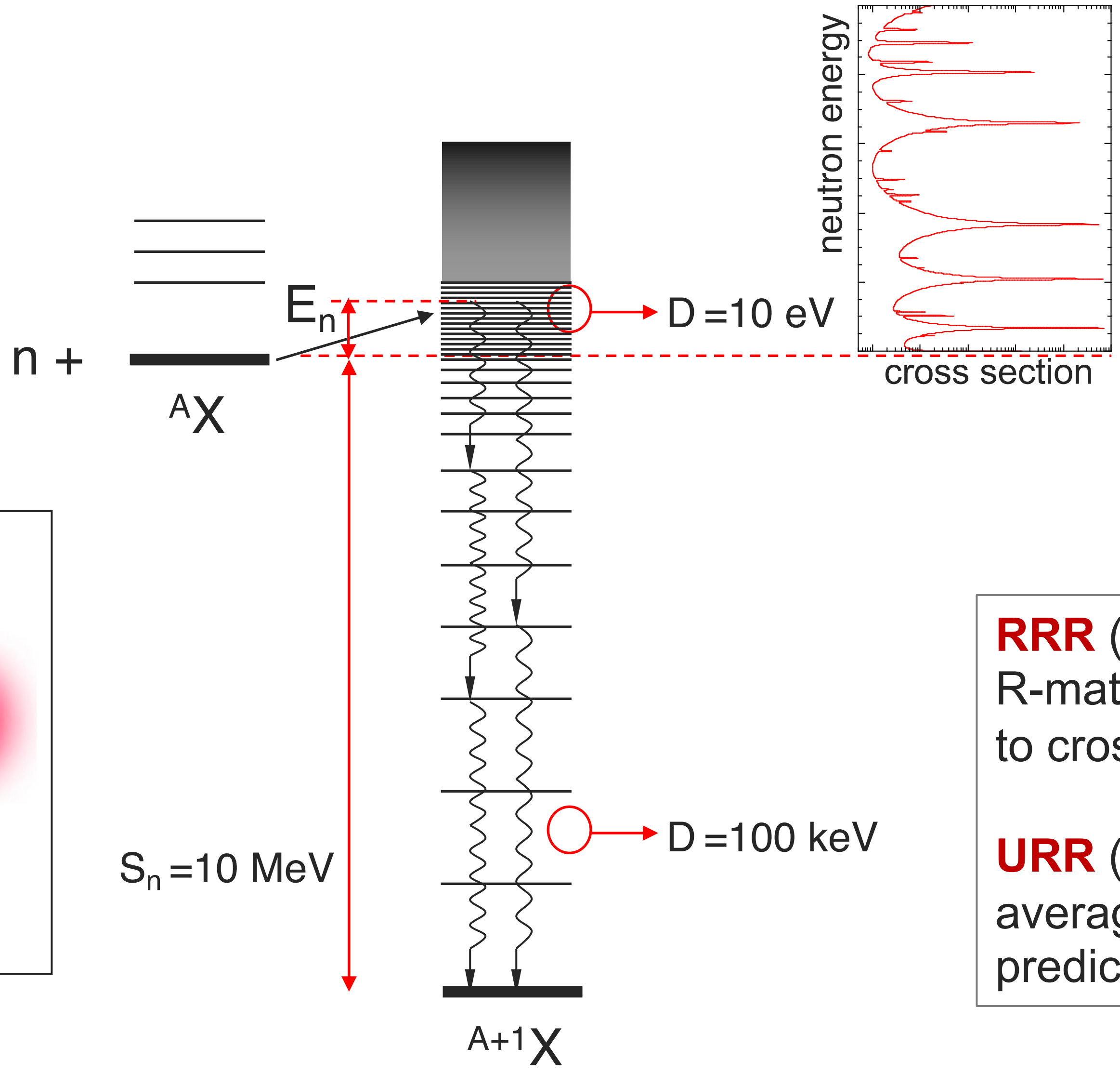
$\tau \sim 10^{-22}$ s
$E_n > 10$ MeV



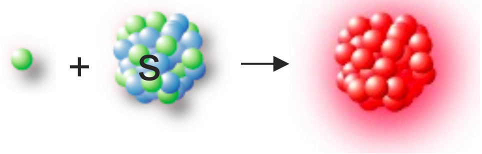
1 Å = 10^{-10} m

de Broglie wavelength: $\lambda = \dfrac{h}{\sqrt{2mE_k}}$

Compound neutron-nucleus reactions



compound
nucleus reaction

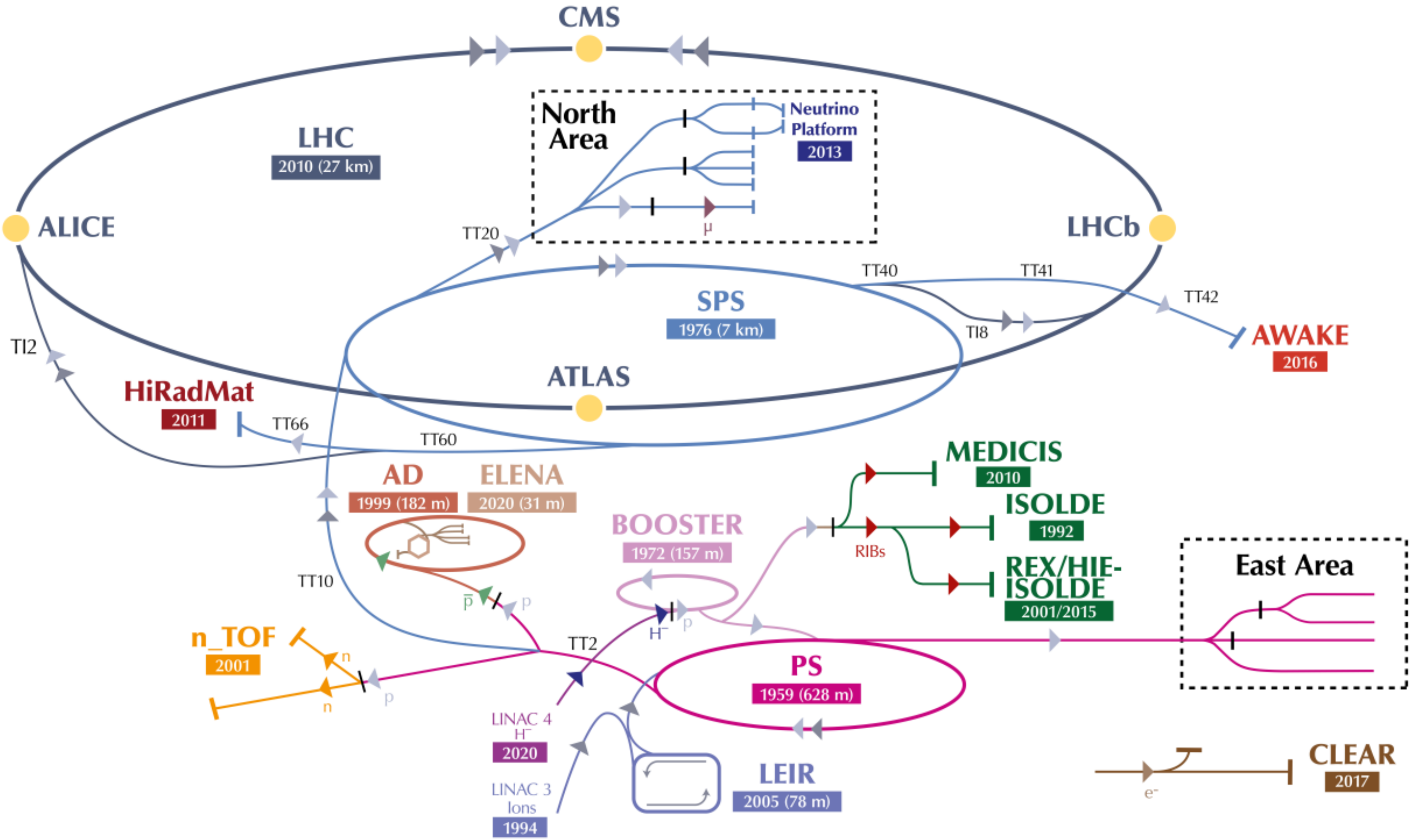


$\tau \sim 10^{-16}$
$E_n < 10$ MeV

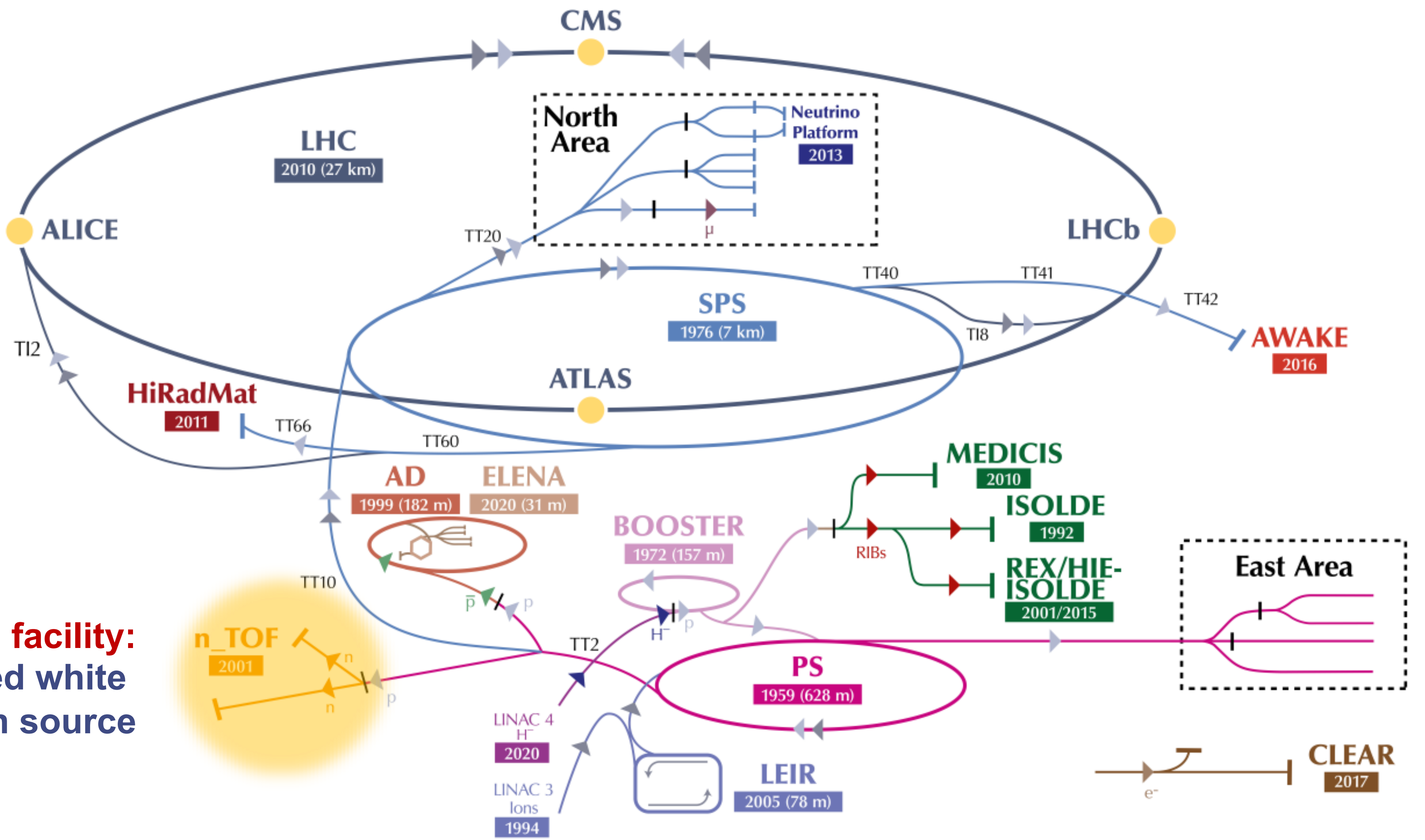
RRR (resolved resonance region)
R-matrix links resonance parameters
to cross section, no predictive models

URR (unresolved resonance region)
average cross sections, average parameters
predictive/prescriptive models

CERN accelerator complex

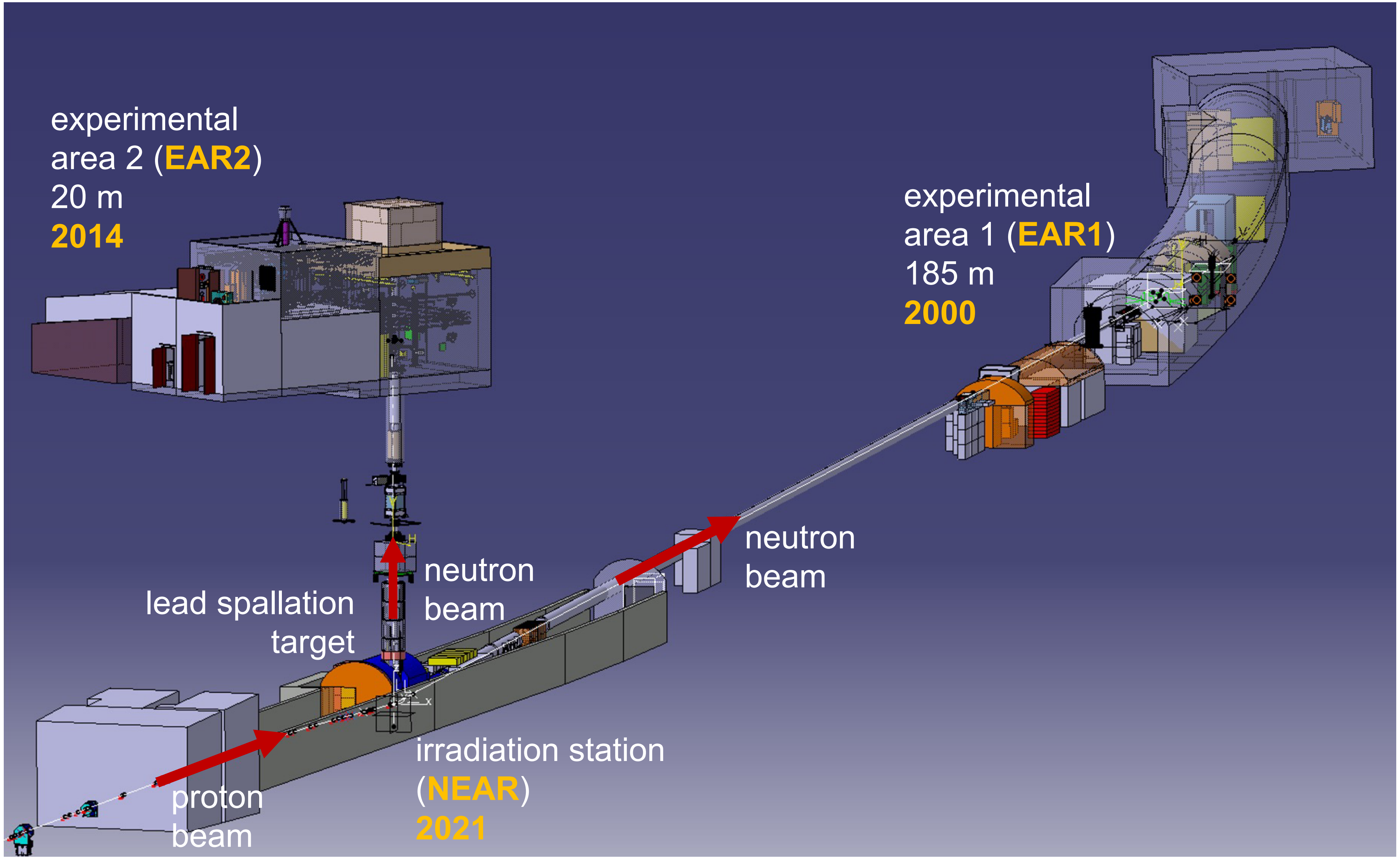


CERN accelerator complex



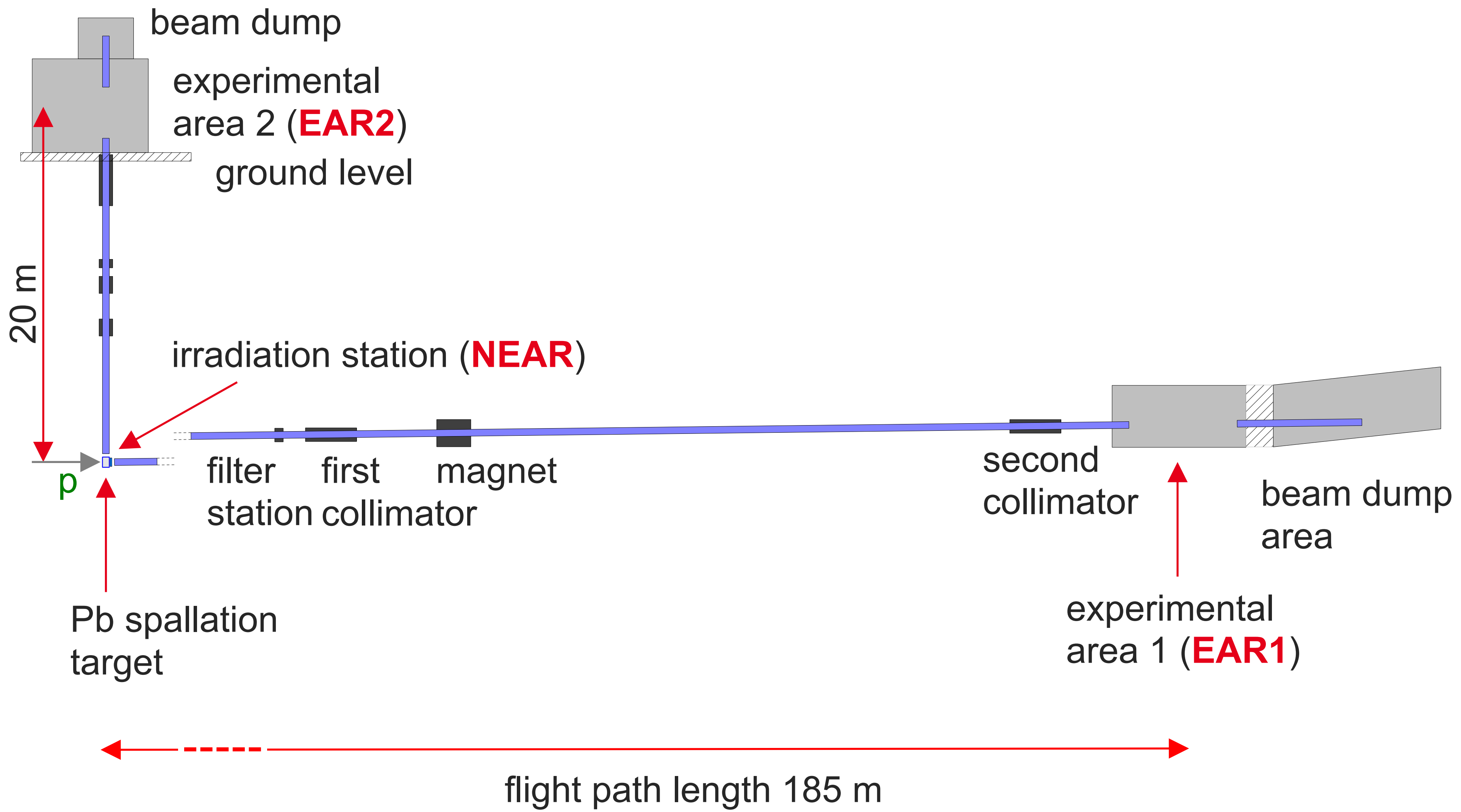
n_TOF facility:
a pulsed white neutron source

n_TOF at CERN



experimental
area 2 (EAR2)
20 m
2014
experimental
area 1 (EAR1)
185 m
2000
neutron
beam
lead spallation
target
neutron
beam
irradiation station
(NEAR)
2021
proton
beam

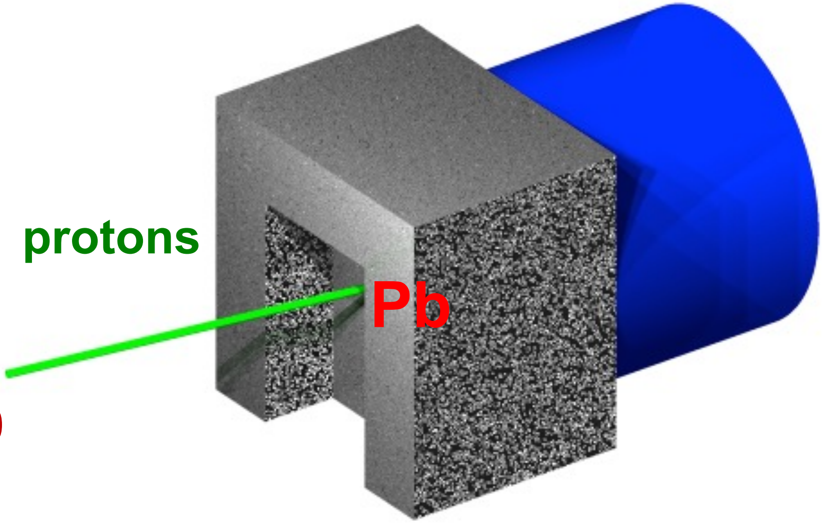
n_TOF at CERN



Eur. Phys. J. Plus 131 (2016) 371

Spallation target n_TOF at CERN

Pulsed white neutron source:
- **20 GeV/c** protons
- neutrons from spallation
- **7 ns** rms pulse width
- frequency **1 pulse/2.4** seconds
- separate cooling and moderation
- flight path length EAR1: **185 m, since 2000**
-
- @source: 7×10^{12} protons/pulse
- @source: 2×10^{15} neutrons/pulse
- @EAR1: $5 \cdot 10^{5}$(capture) – $5 \cdot 10^{7}$(fission) neutrons/pulse



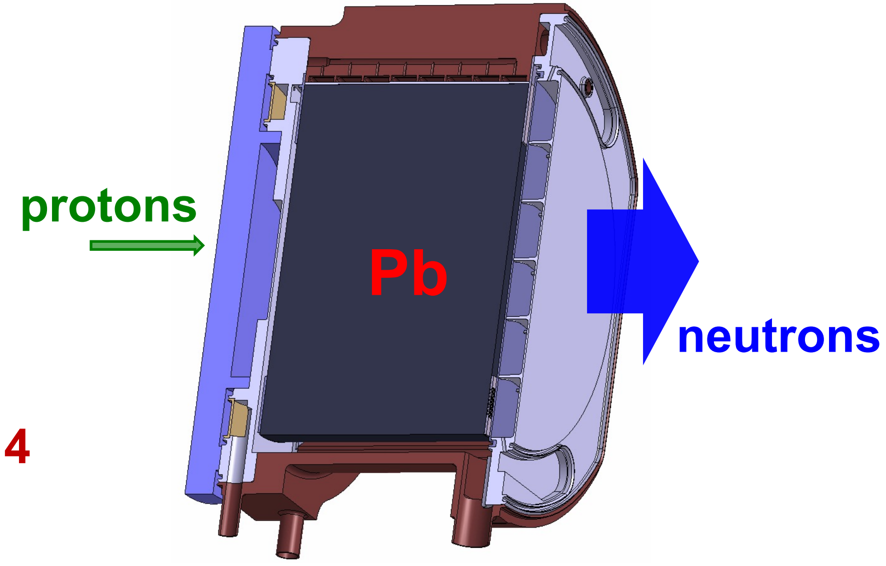
phase I target
2001-2004

Single water volume
coolant and moderator

Main features:
- Large energy range available (0.01 eV – 1 GeV)
- Favorable signal to noise ratio for capture on radioactive isotopes (actinides, fission products)

Spallation target n_TOF at CERN

Pulsed white neutron source:
- **20 GeV/c** protons
- neutrons from spallation
- **7 ns** rms pulse width
- frequency **1 pulse/2.4** seconds
- separate cooling and moderation
- flight path length EAR1: **185 m, since 2000**
- **flight path length EAR2: 20 m, since 2014**
- @source: 7×10^{12} protons/pulse
- @source: 2×10^{15} neutrons/pulse
- @EAR1: $5 \cdot 10^{5}$(capture) – $5 \cdot 10^{7}$(fission) neutrons/pulse



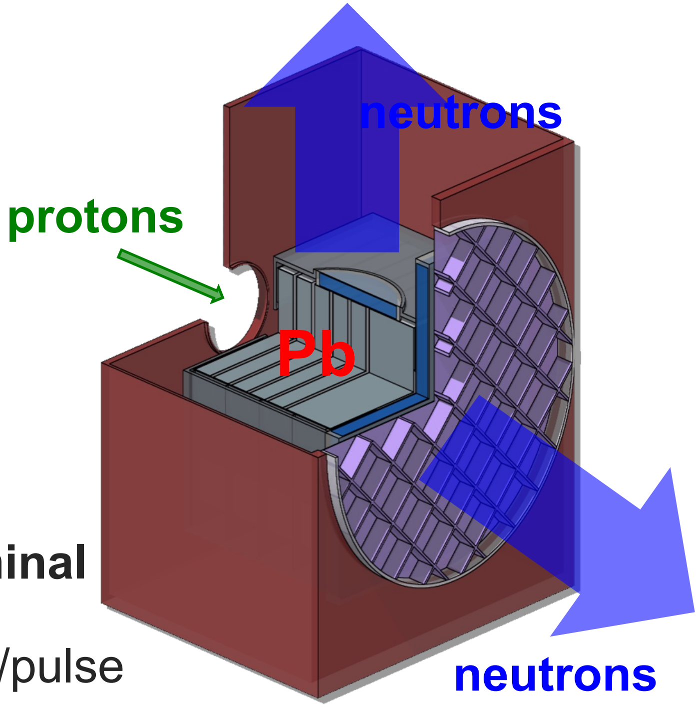
phase II-III target 2009-2018

Main features:
- Large energy range available (0.01 eV – 1 GeV)
- Favorable signal to noise ratio for capture on radioactive isotopes (actinides, fission products)

Moderator separated from water coolant

Spallation target n_TOF at CERN

Pulsed white neutron source:
- **20 GeV/c** protons
- neutrons from spallation
- **7 ns** rms pulse width
- frequency **1 pulse/1.2** seconds
- separate cooling and moderation
- flight path length EAR1: **185 m, since 2000**
- **flight path length EAR2: 20 m, since 2014**
- @source: 7×10^{12} (--> **8×10^{12}**) protons/pulse **nominal**
- @source: 2×10^{15} neutrons/pulse **nominal**
- @EAR1: $5 \cdot 10^5$(capture) – $5 \cdot 10^7$(fission) neutrons/pulse

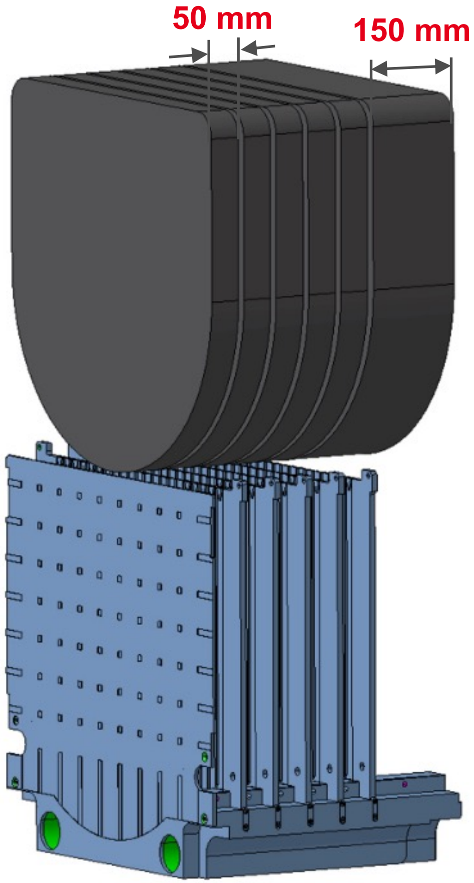


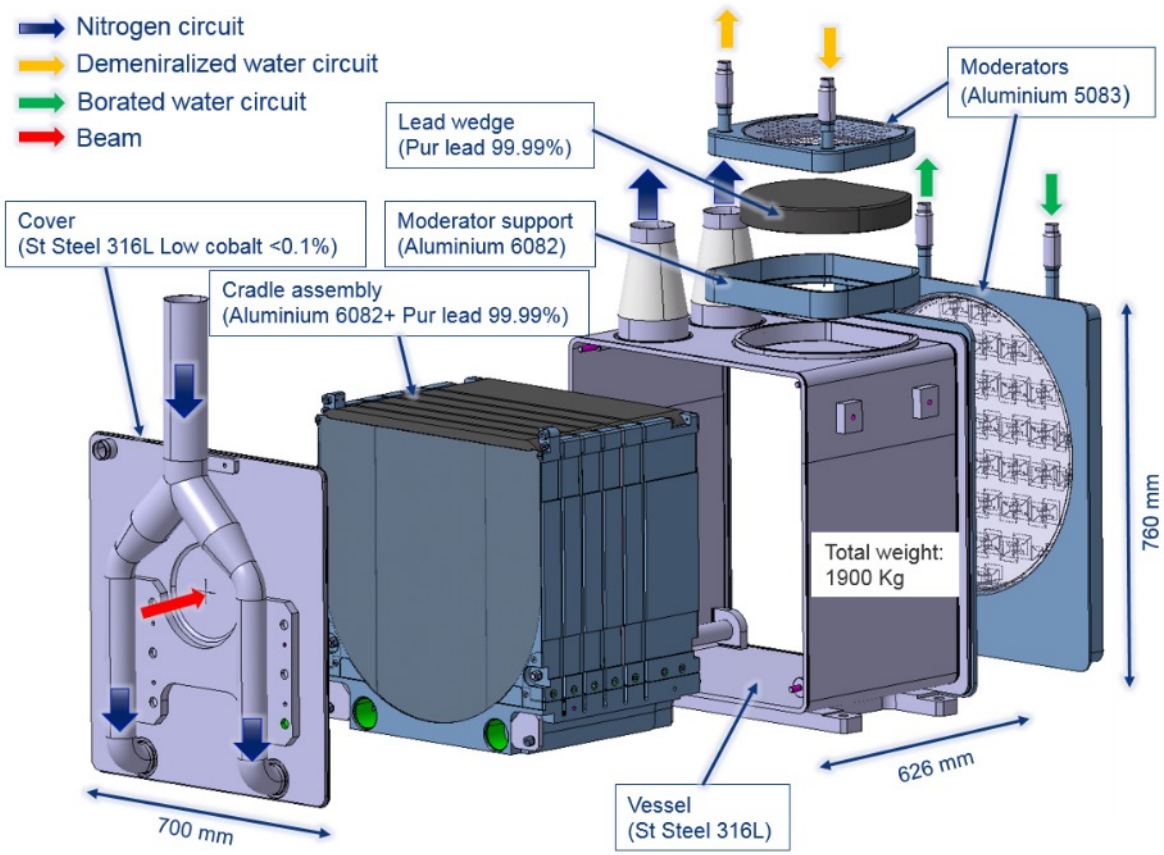
phase IV target, N_2-cooled since 2021

Only moderator contains water

Main features:
- Large energy range available (0.01 eV – 1 GeV)
- Favorable signal to noise ratio for capture on radioactive isotopes (actinides, fission products)

Spallation target n_TOF at CERN



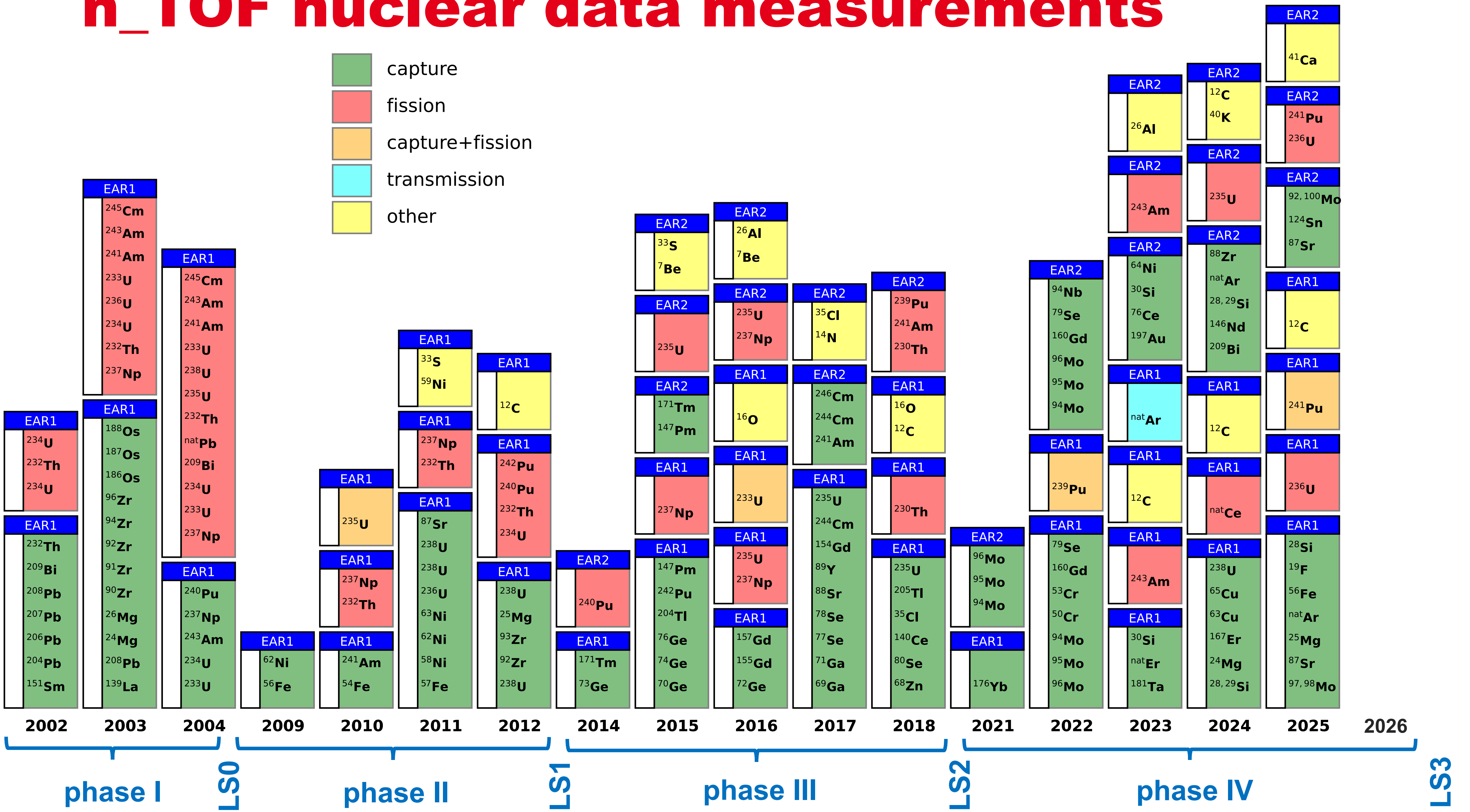


Al-6082-T6 supporting structure
(anti-creep and N_2 cooling channels)

5.4 kW (average)

ref: EDMS 2378651

n_TOF nuclear data measurements



Irfu-DPhN at n_TOF CERN, 2018-2026

- LS2 (**2019-2020**)
  - installation new Pb spallation target
  - commissioning

- Finishing PhD theses
  - **2019** M. Bacak, *Capture and fission of* ^{233}U
  - **2020** J. Moreno Soto, *Photon strength functions of n +* ^{234}U, ^{236}U, *and* ^{238}U

- Phase IV data taking (**2021-2026**)
  - neutron capture and fission of ^{241}Pu,   PhD A. Cahuzac (since 2023)
  - neutron capture of ^{87}Sr

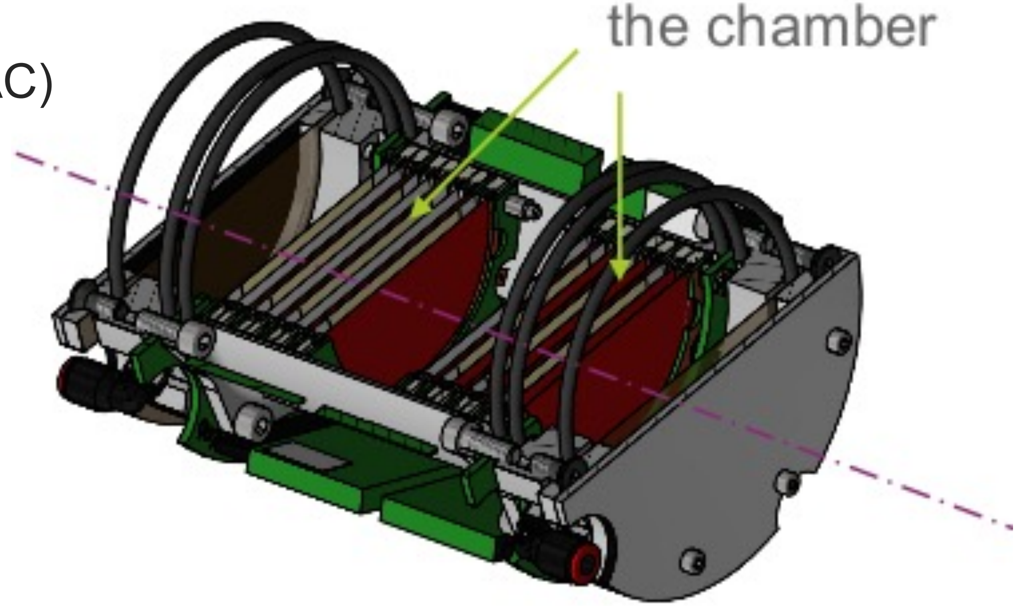
- ANR project (together with JRC-Geel) 2021-2026
  - XY Micromegas

^{233}U(n,γ) and (n,f) with TAC

- Simultaneous capture and fission measurement of ^{233}U (fission tagging)
- Development compact fission chamber ø9 cm
- Dedicated fast electronics developed at CEA-DAM/DIF
- Samples produced at JRC-Geel, total mass 46.5 mg
  14 samples mounted in 4π total absorption calorimeter (TAC)

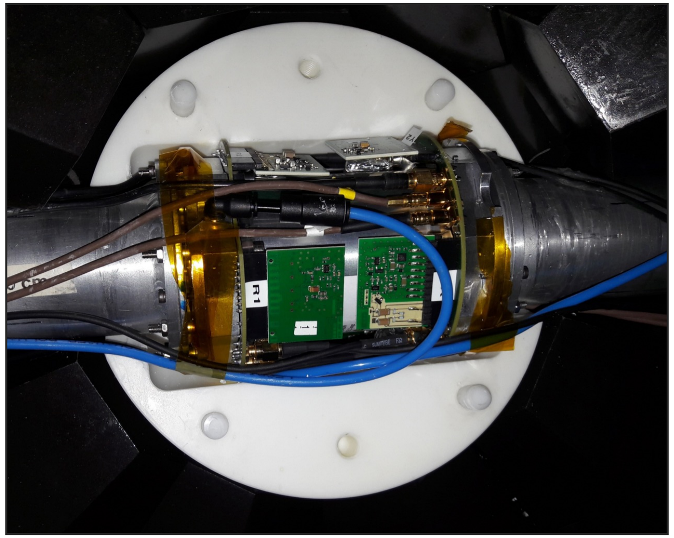
Isotopic composition (mass fraction %)

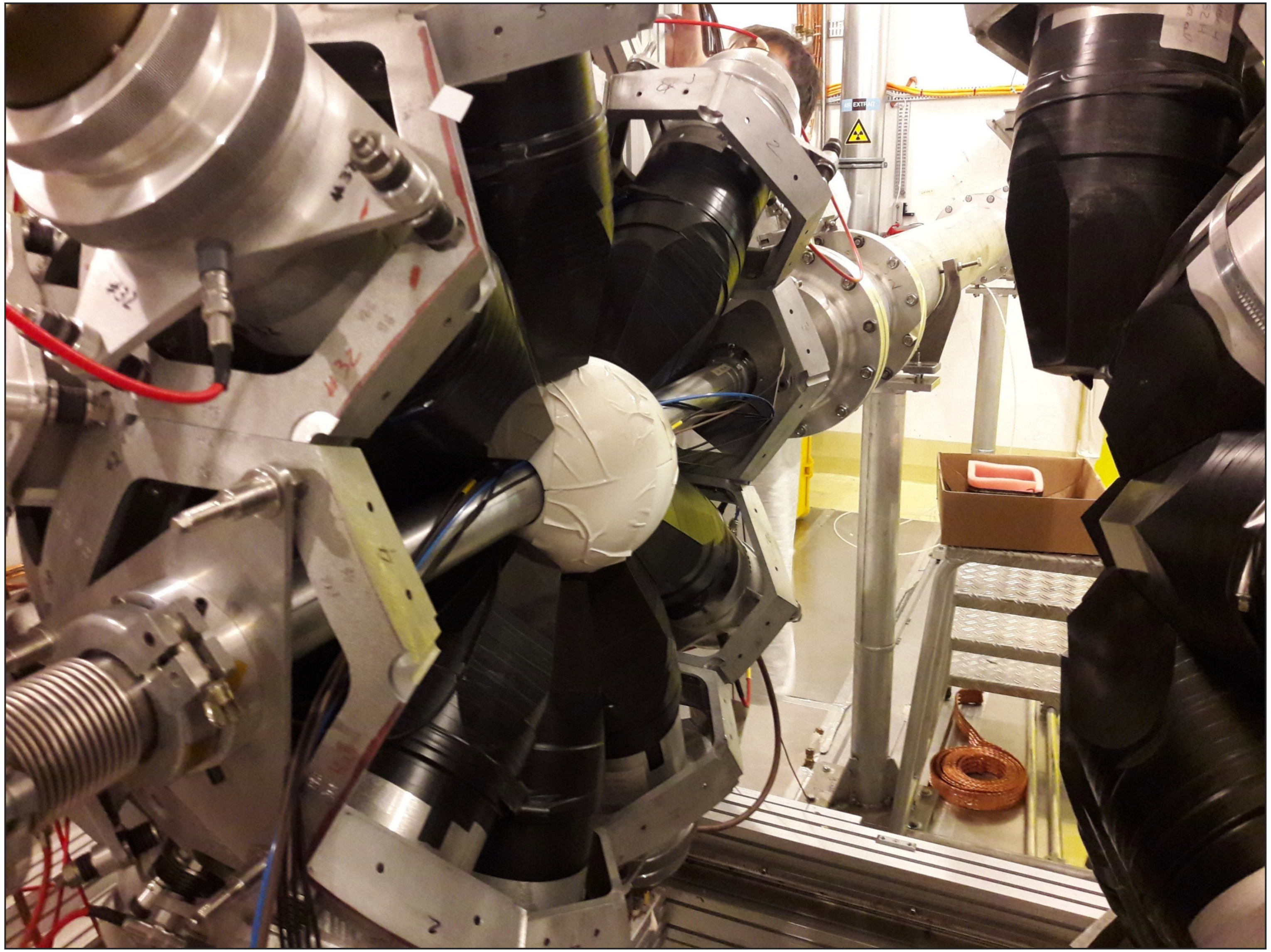
^{233}U	^{234}U	^{235}U	^{236}U	^{238}U
99.9361	0.04965	0.00124	0.00025	0.0128



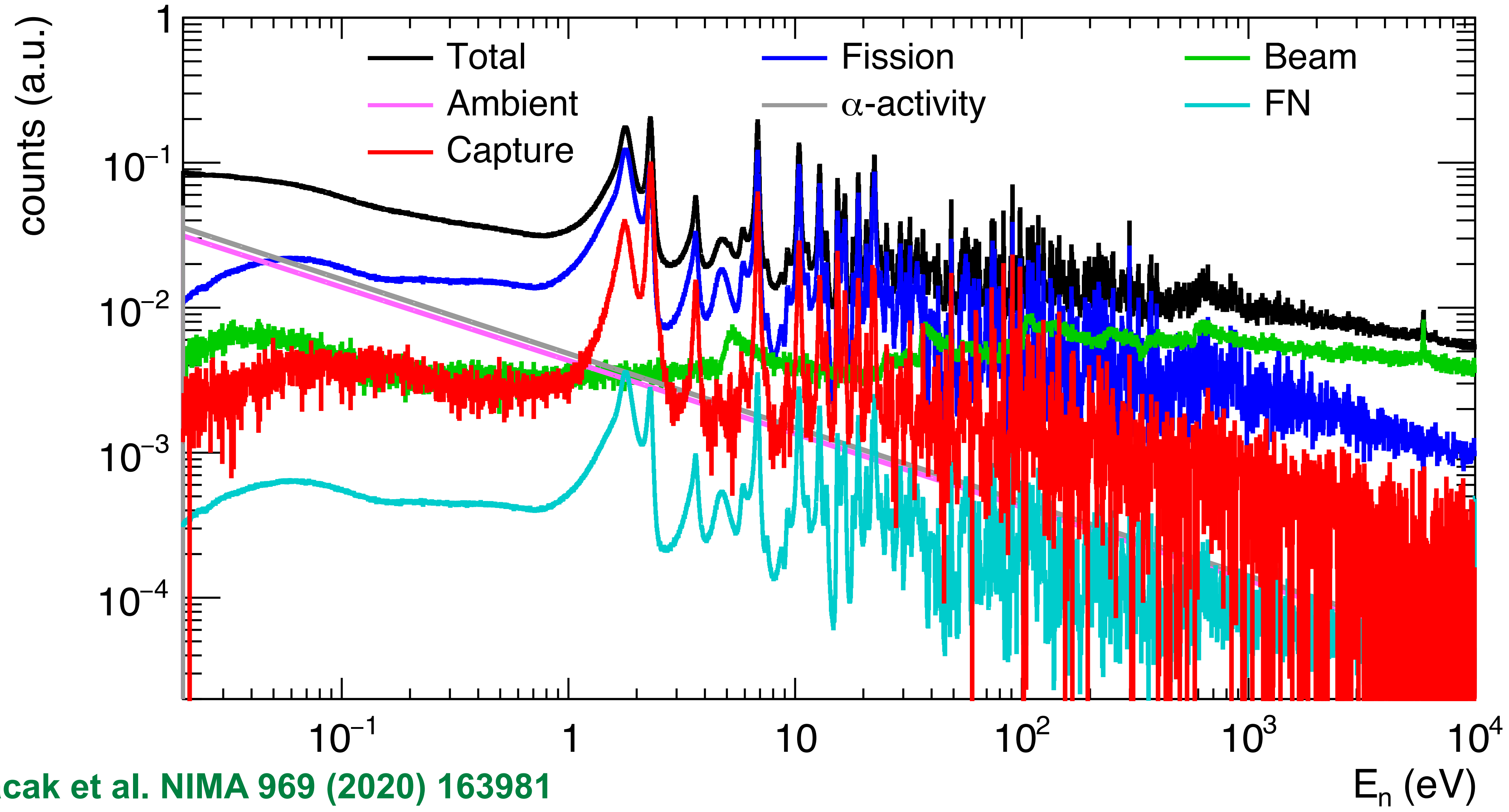
PhD M. Bacak 2019
co-tutelle TU-Wien

^{233}U(n,γ) and (n,f) with TAC



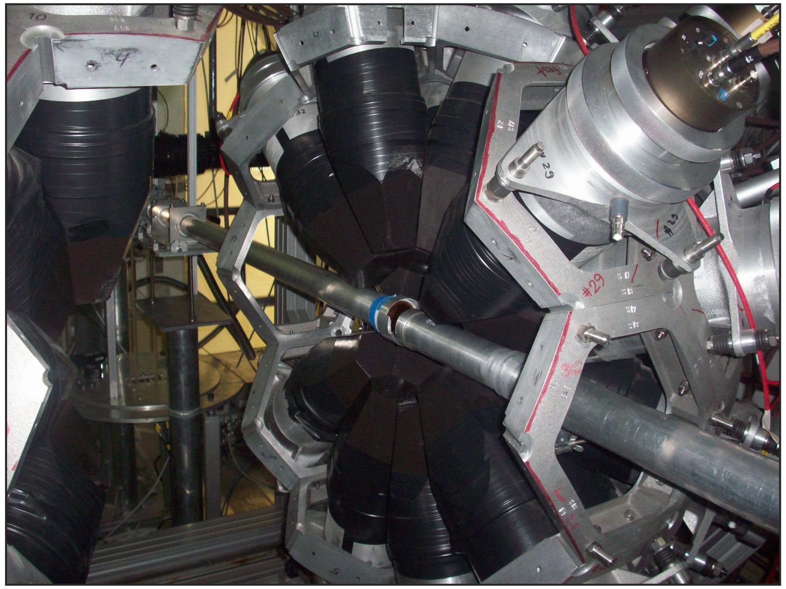


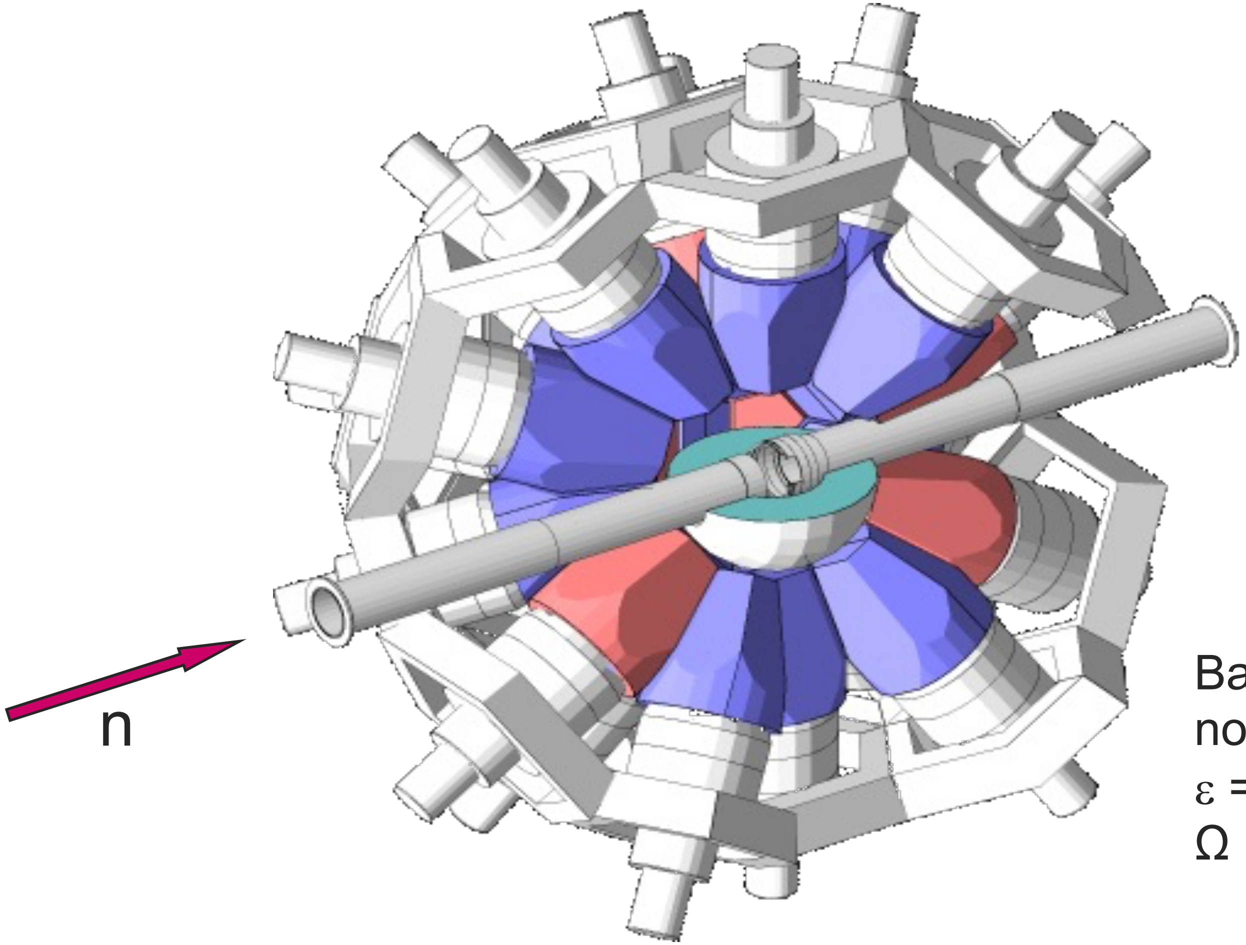
$^{233}U(n,\gamma)$ and (n,f) with TAC



- M. Bacak et al. NIMA 969 (2020) 163981
- M. Bacak et al. in progress

^{234}U, ^{236}U, $^{238}U(n,\gamma)$ with TAC data: re-analyzed for photon strength functions and level densities





BaF$_2$ crystals
nominal:
ε = 100%
$\Omega = 4\pi$

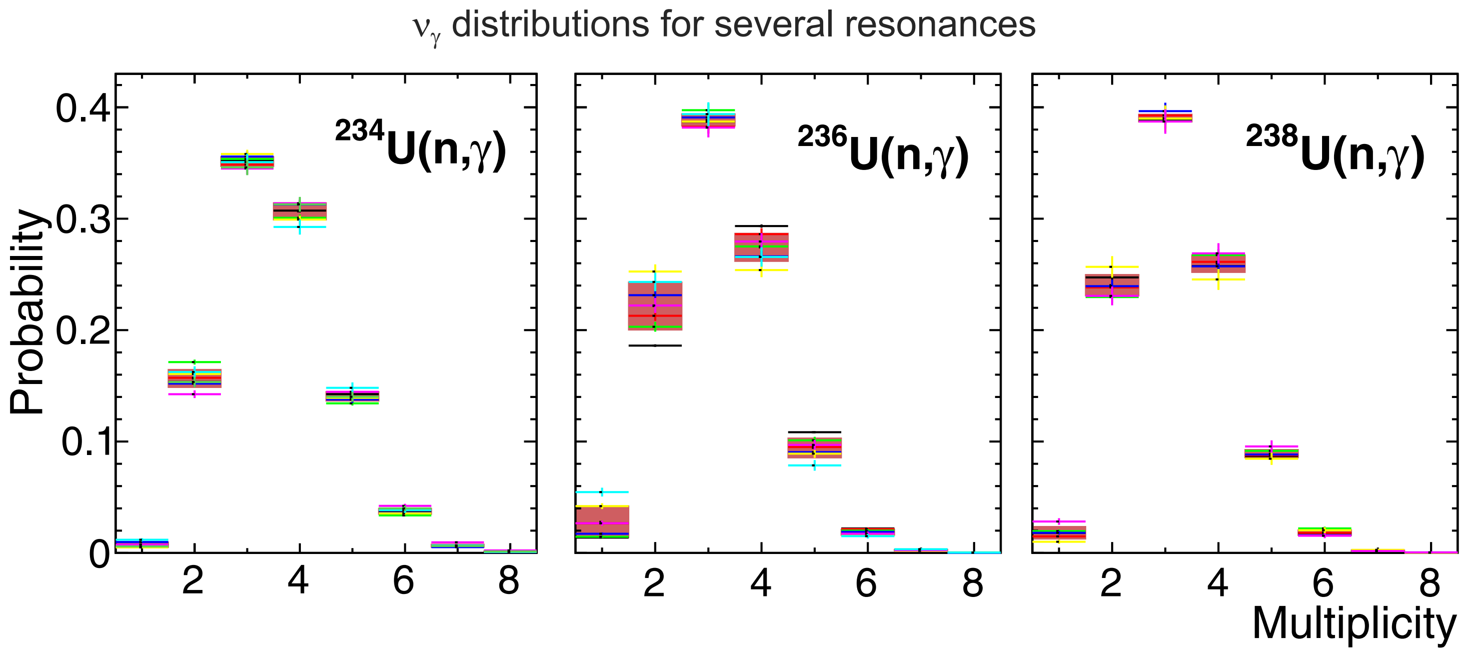
- simulate gamma decay cascades with code DICEBOX(C)
- key ingredients:
  - **level densities**
  - **photon strength functions**
- simulate detector response (GEANT4)
- compare simulations with experiment

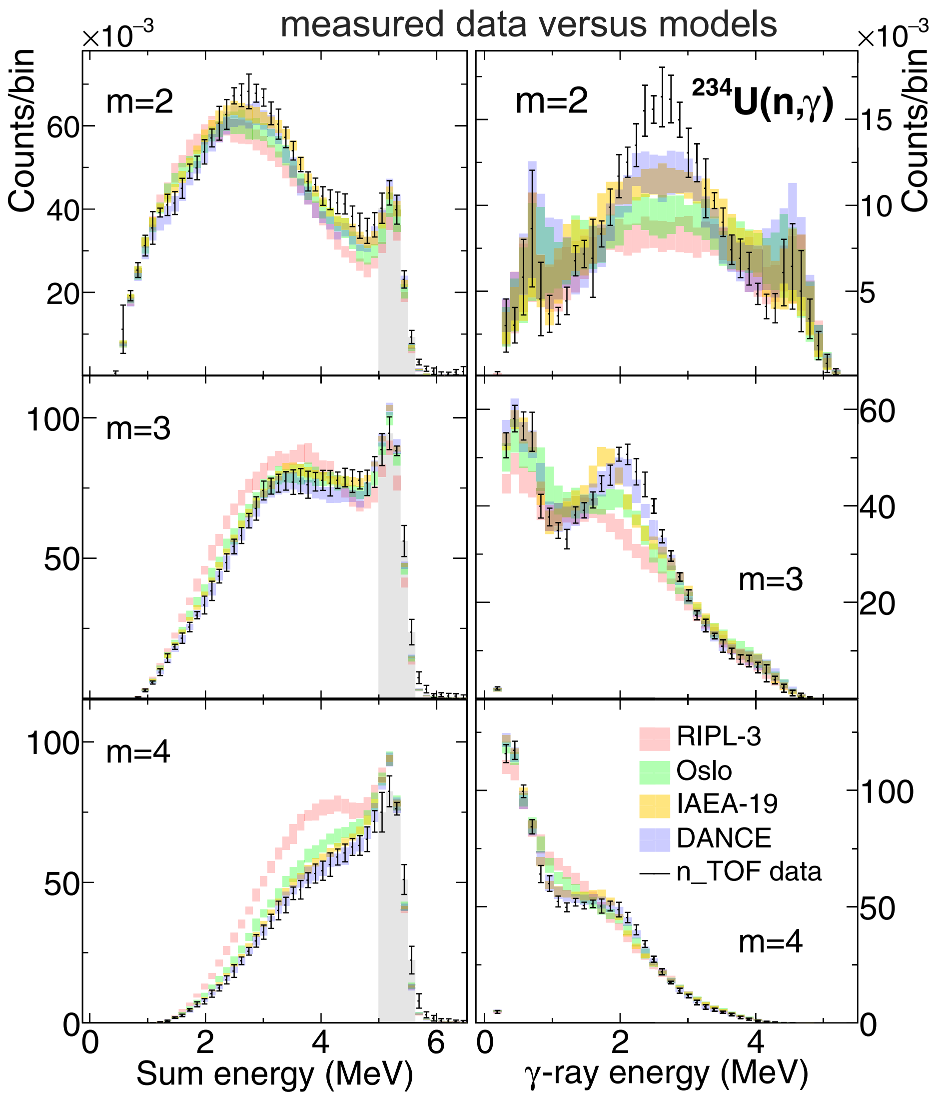
PhD J. Moreno Soto 2020
DRF and DES

^{234}U, ^{236}U, ^{238}U(n,γ) photon strength functions and level densities

Observables from TAC data:
- gamma multiplicity
- gamma-ray spectra (singles)
- sum energy spectra

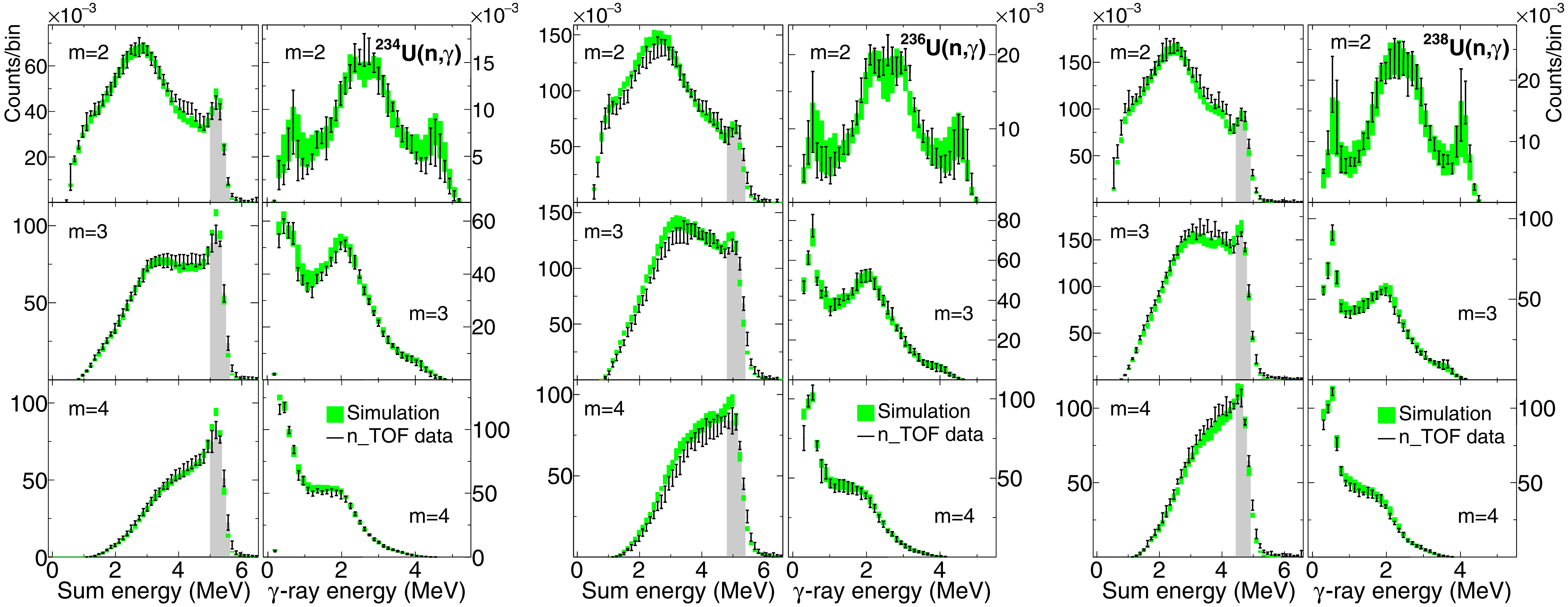
as function of neutron energy





J. Moreno Soto *et al.* Phys. Rev. C 105.2 (2022)

^{234}U, ^{236}U, ^{238}U(n,γ)
photon strength functions and level densities



- Many model combinations tried for best match experimental data:
  LD → ~CT **PSF** → strong M1 component, scissors mode

J. Moreno Soto *et al.* Phys. Rev. C 105.2 (2022)

^{241}Pu capture and fission

- Initial contours of this project started in 2021

- Main motivations
  - Fissile isotope produced in nuclear reactors
  - Impact on the loss of reactivity with burnup
  - Only one existing capture measurement (Weston and Todd 1978)

- Challenges
  - Production and characterization of ^{241}Pu samples (β^-, $T_{1/2}$ = 14 y)
  - Development of compact fission tagging detectors for high count rates
  - Measurements both at n_TOF (EAR1 and EAR2), and at JRC-GELINA in short time span (build-up to ^{241}Am)

^{241}Pu capture and fission

- Search for suitable sample material, including sample preparation, lead to JRC-Geel. Raw legacy material from the 1970s available.

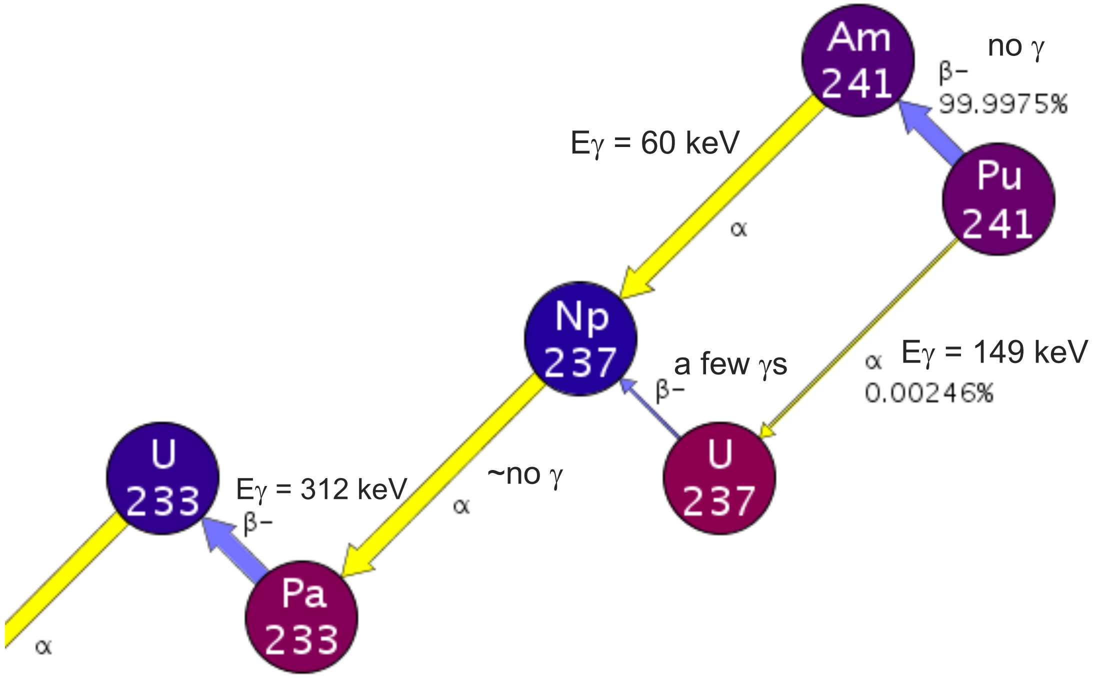
- A complex chemical sequence of purification to remove ^{241}Am, then ^{237}Np, and then residual uranium, was performed at JRC-Geel in collaboration with CEA DAM/DIF.

- Design of new compact fission chamber, using fast electronics developed at DAM/DIF

- New PhD student: A. Cahuzac (on leave from DGA) since 2023

^{241}Pu capture and fission: samples

- Sample production, starting once the decades-old raw material was identified
  - **2022**: assessing the condition of the material
  - **2023**: initial **Pu-Am** separation and characterization
  - **2024**: **Pu-Np** separation and characterization (in collaboration with CEA/DAM)
  - **2025**: **Pu-U** separation and characterization
- Just before the experiment mid **2025**:
  - final **Pu-Am** separation and characterization
  - sample production by molecular plating
  - sample mounting in fission chamber
  - detector transport from JRC to CERN

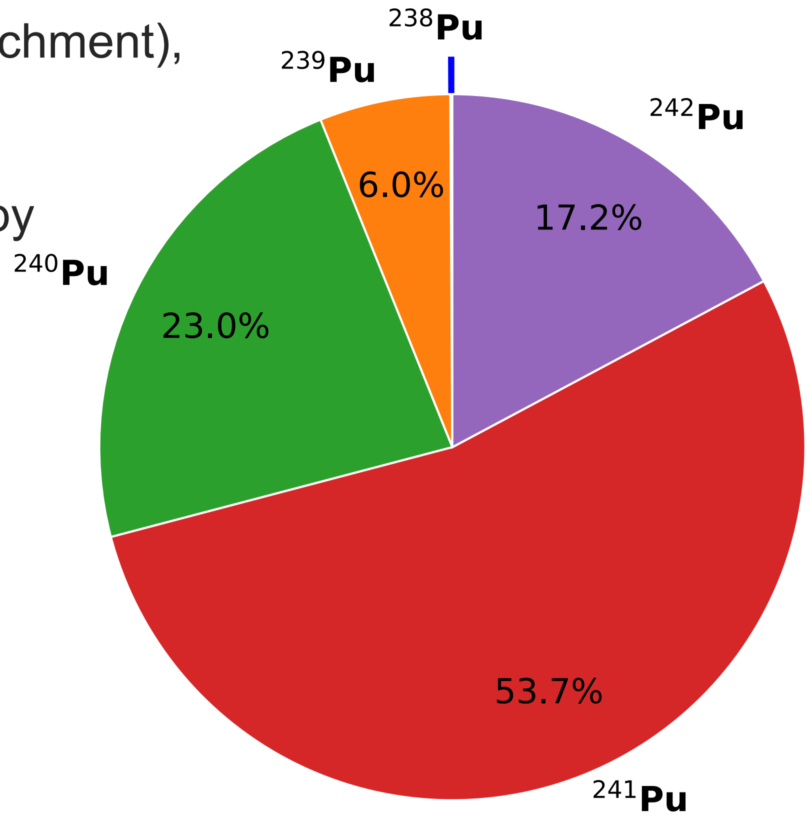


^{241}Pu capture and fission: samples

- Final Pu samples: 8 deposits of 30 mm diameter of ^{241}Pu (54% enrichment), total mass **^{241}Pu 5.9 mg**, (total Pu 10.9 mg)

- Isotopic composition (mass fraction %) from JRC mass spectroscopy

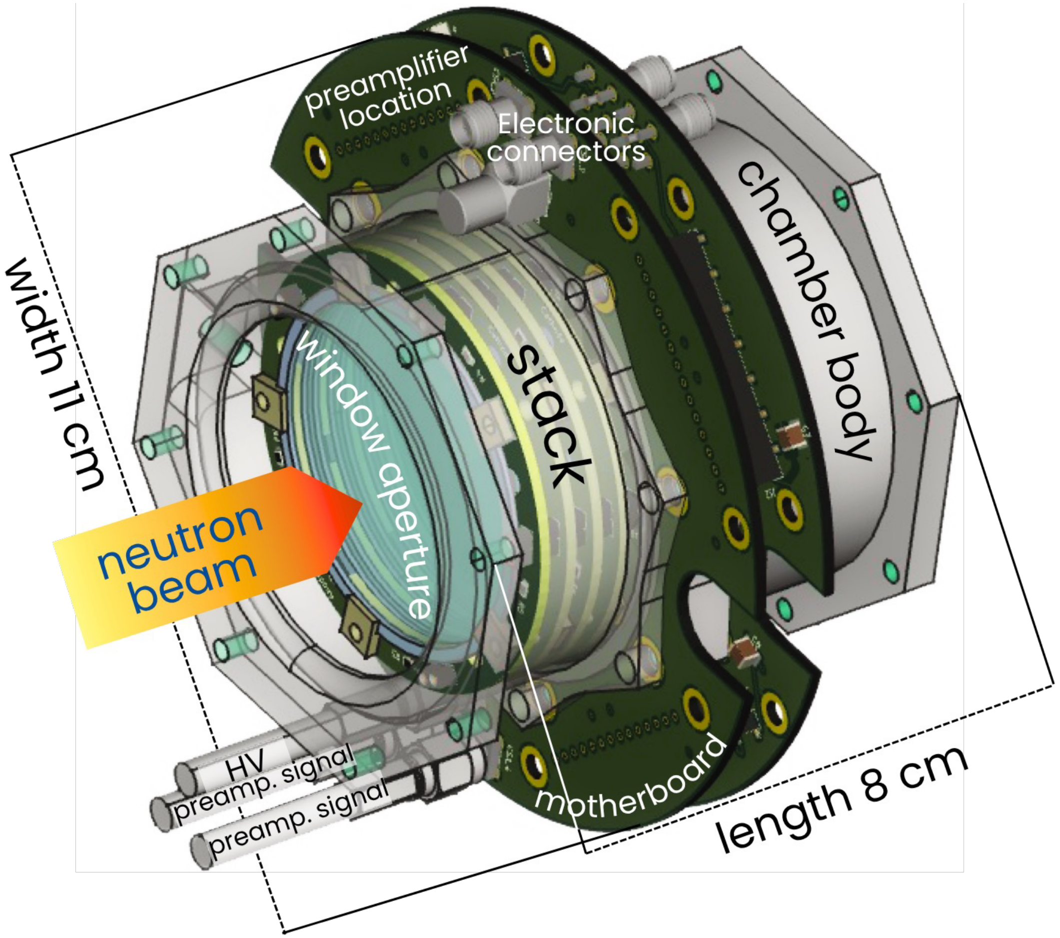
^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu
0.09	6.0	23.0	53.7	17.2

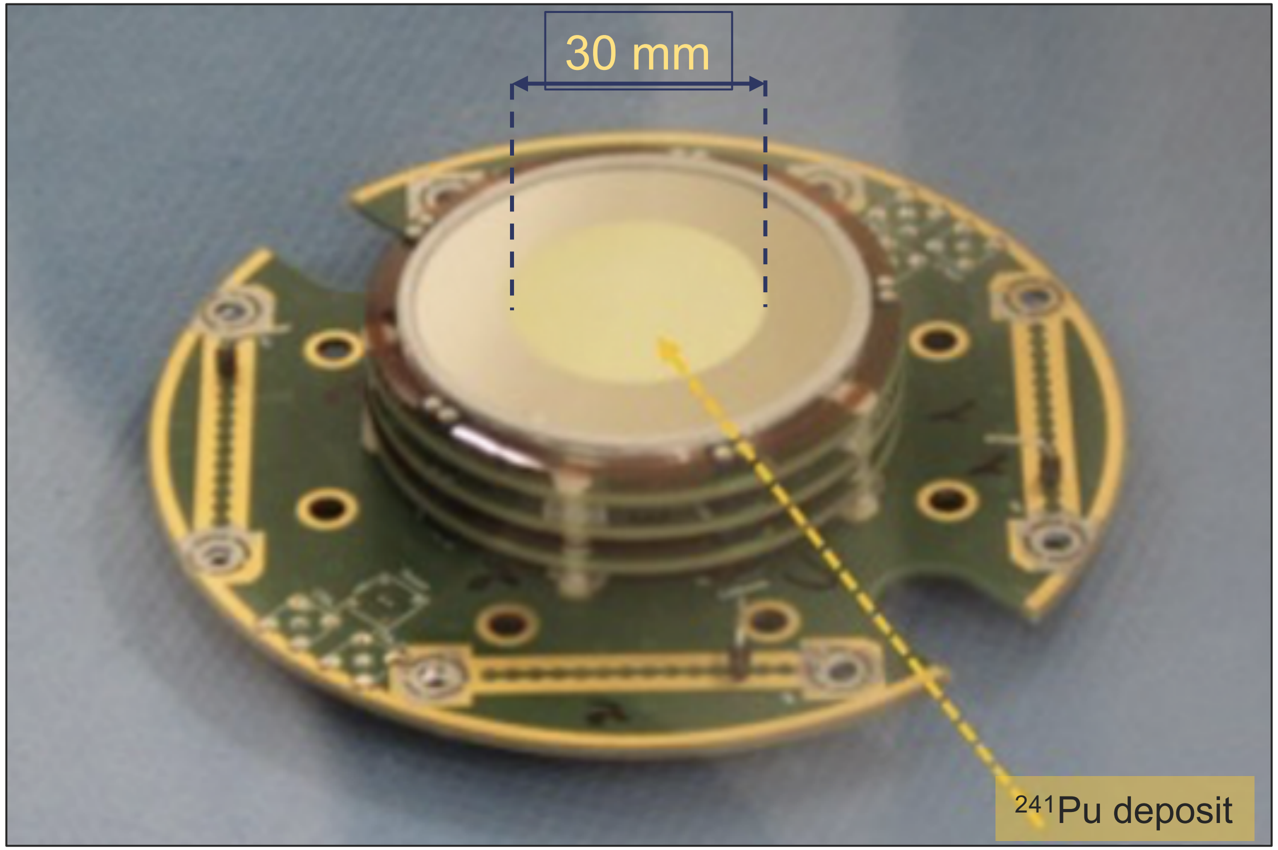


- Activity
  - **23 GBq** from β^- decay to ^{241}Am
  - **33 MBq** from α decay mainly from ^{238}Pu, ^{240}Pu and ^{241}Am
  - **5 MBq** increase per month from ingrow ^{241}Am

- In addition, 2 highly enriched reference **^{235}U samples** (7.8 mg), produced and characterized at JRC-Geel (on loan from PTB-Braunschweig)

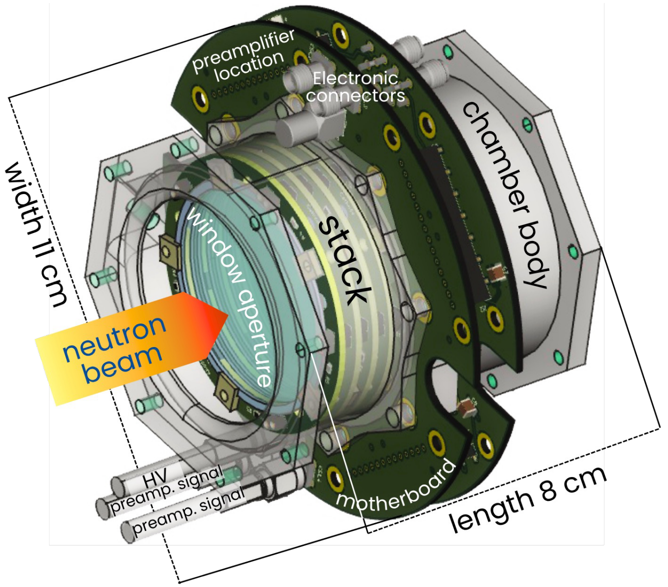
^{241}Pu fission chamber





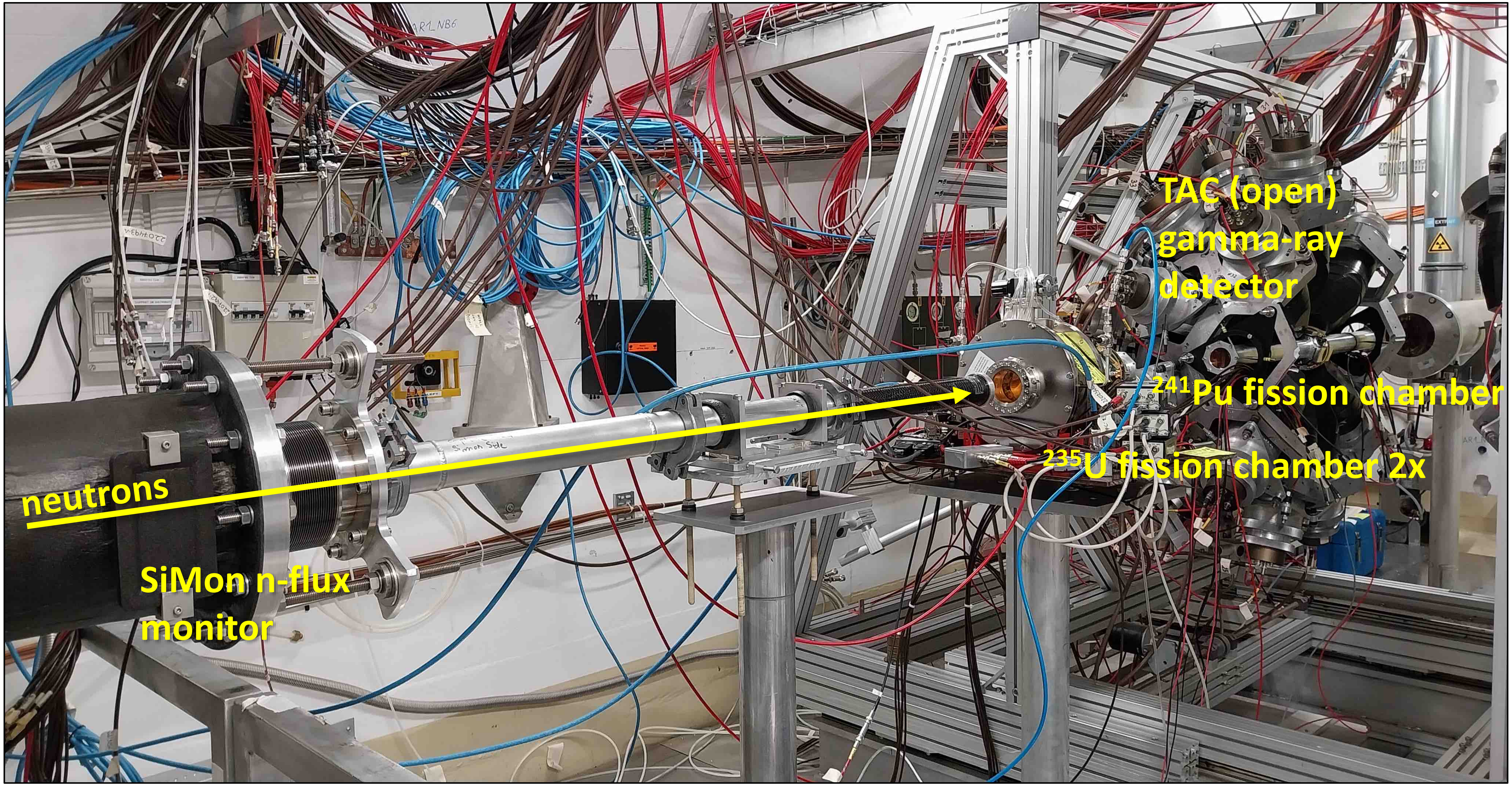
^{241}Pu experiments

- New in-house design compact fission chamber
  - Transparent to neutrons and gammas, fission tagging inside TAC 4π calorimeter
  - Fast pre-amps, developed at CEA/DAM, can handle high count rate
  - Good (enough) energy resolution for α–fission fragment separation
  - Two identical stacks of 4 ionization chambers, gap 3 mm low pressure (300 mb)
  - 8 ^{241}Pu samples and 8 independent acquisition channels
  - Fission chamber tested
    - Off-beam with ^{252}Cf source at CEA-DAM/DIF
    - In-beam at JRC-Geel (^{235}U)

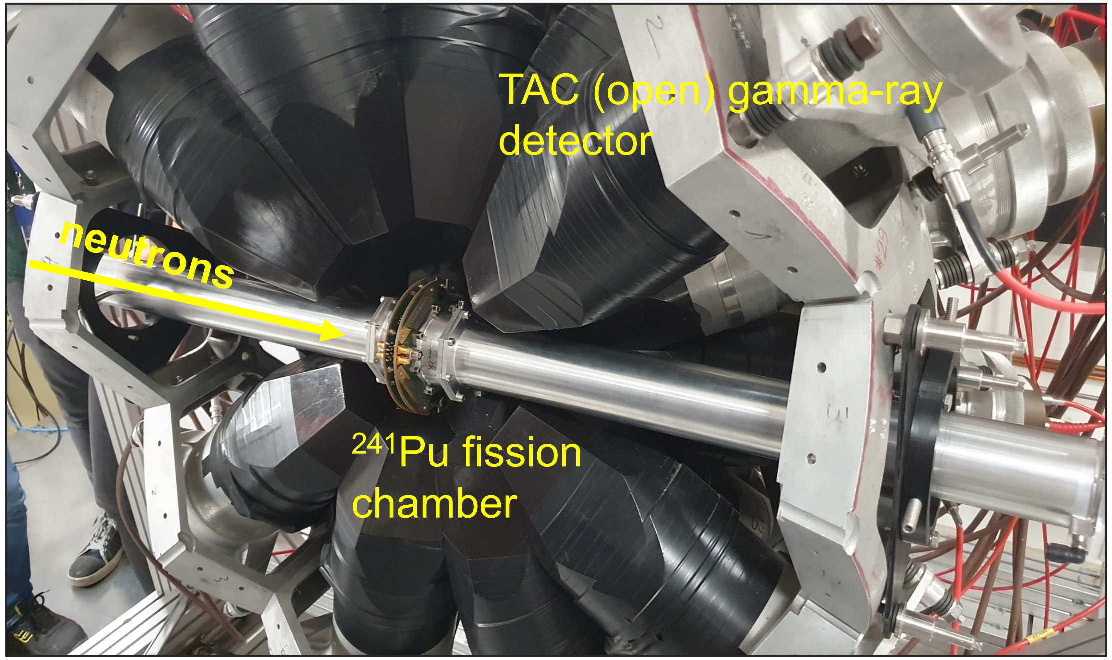


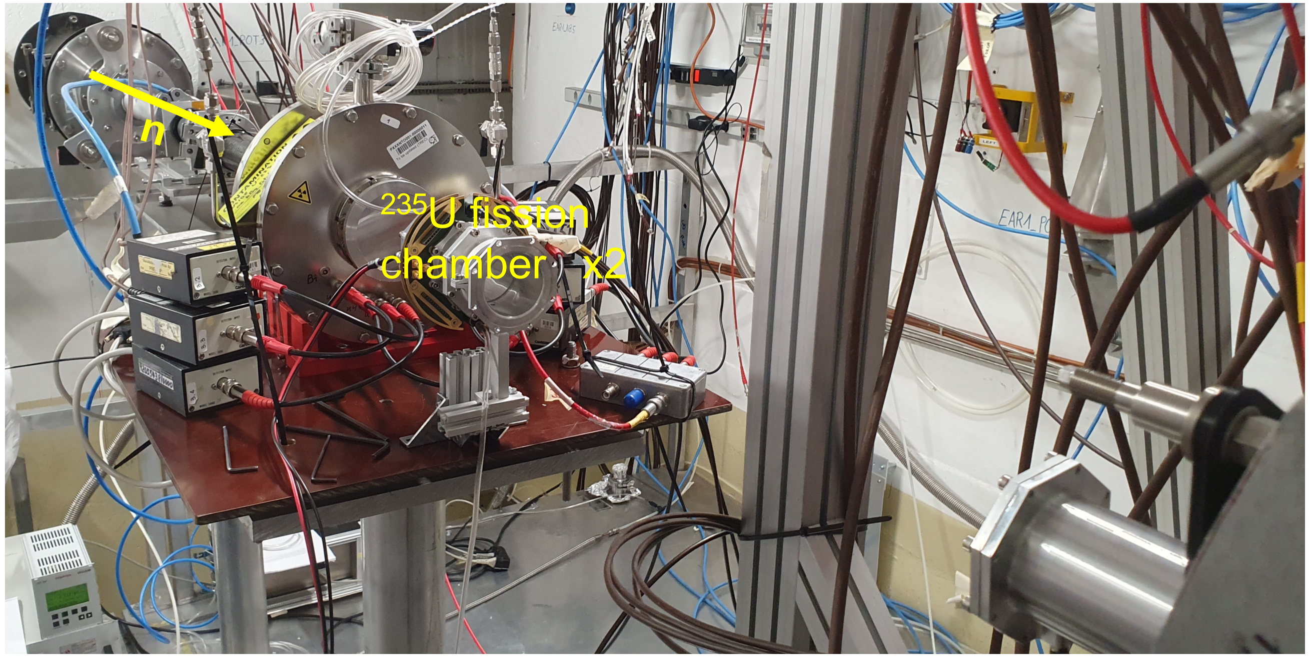
- Three real experiments performed, including auxiliary measurements
  - **n_TOF EAR1** (L=185 m) in 2025 (>0.1 eV) **2 PB raw data**
  - **n_TOF EAR2** (L=20 m) in 2025 (thermal region)
  - **JRC-Geel** (L=10 m) early 2026 (RRR)

^{241}Pu experiment at n_TOF EAR1



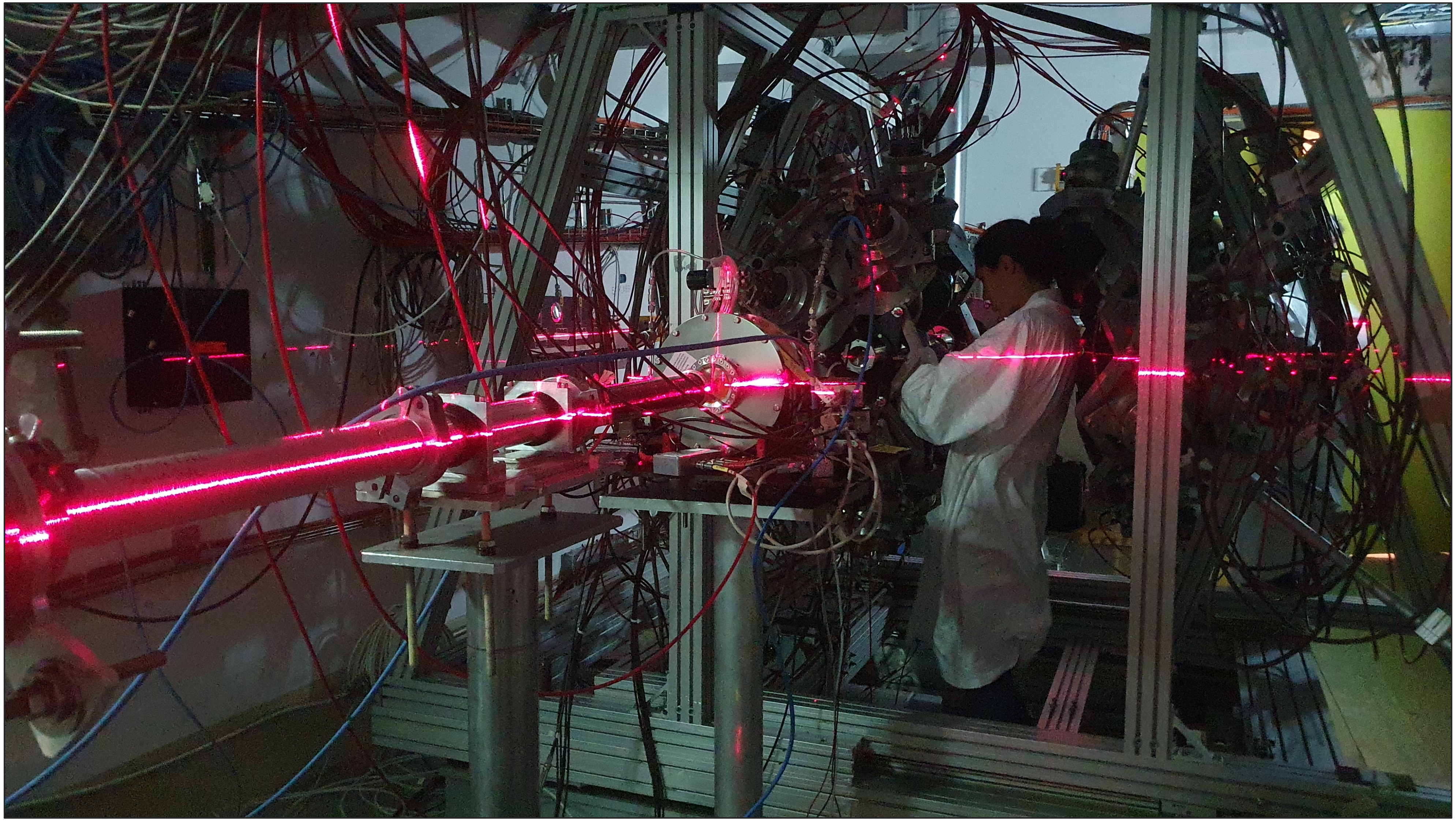
^{241}Pu experiment at n_TOF EAR1





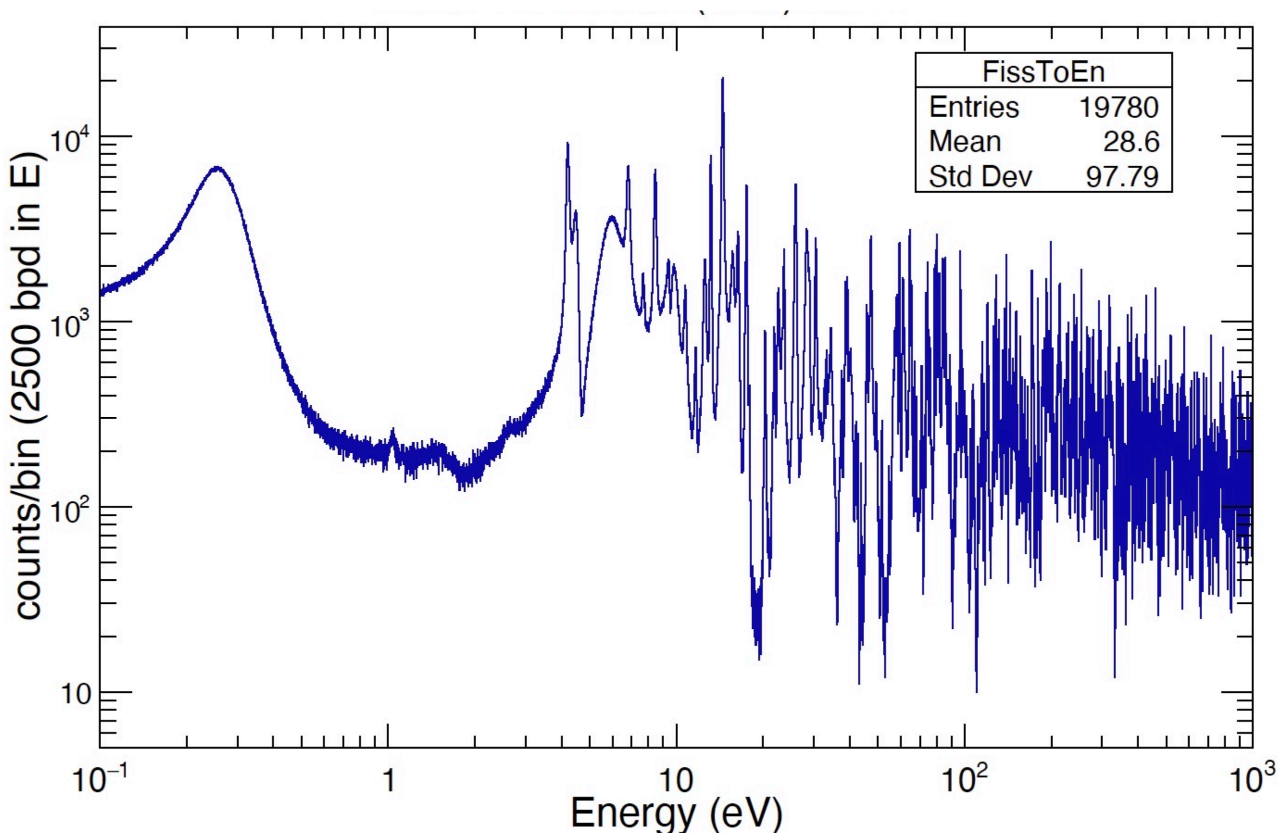
^{241}Pu experiment at n_TOF EAR1

^{241}Pu experiment at n_TOF EAR1

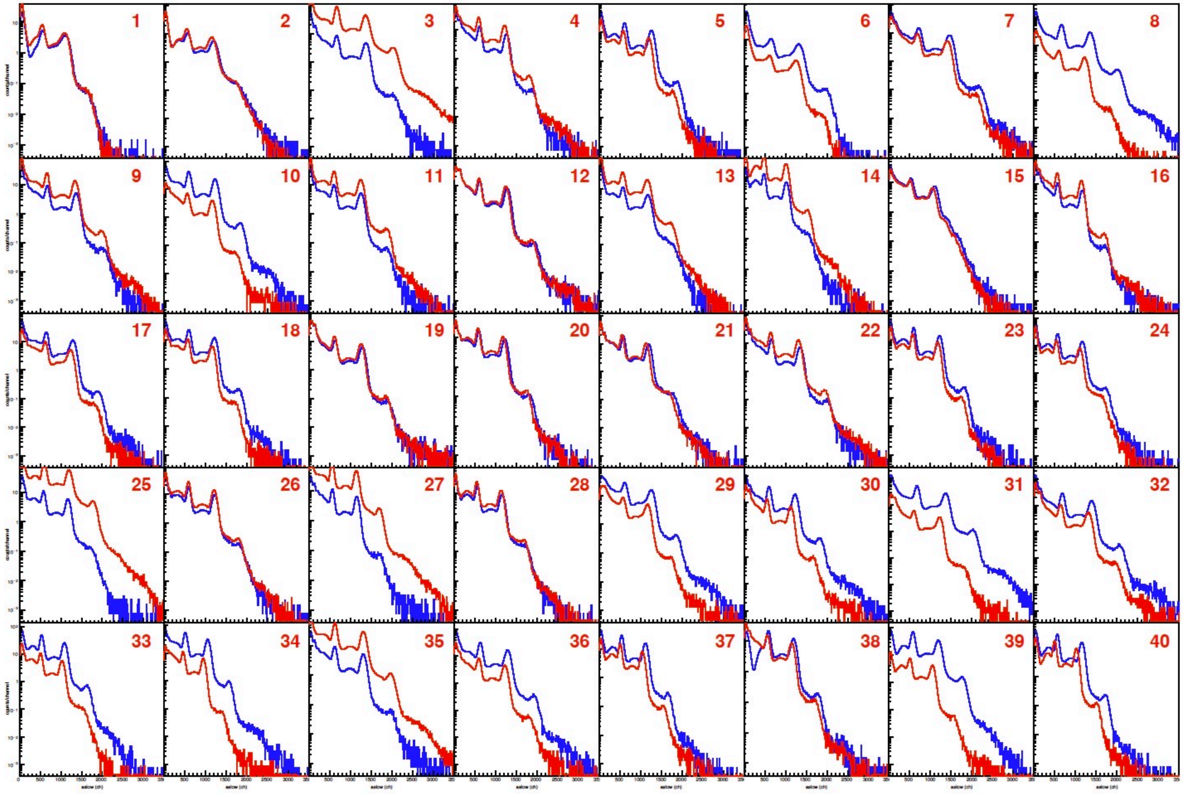


^{241}Pu experiment at n_TOF EAR1

fission chamber respons to neutrons

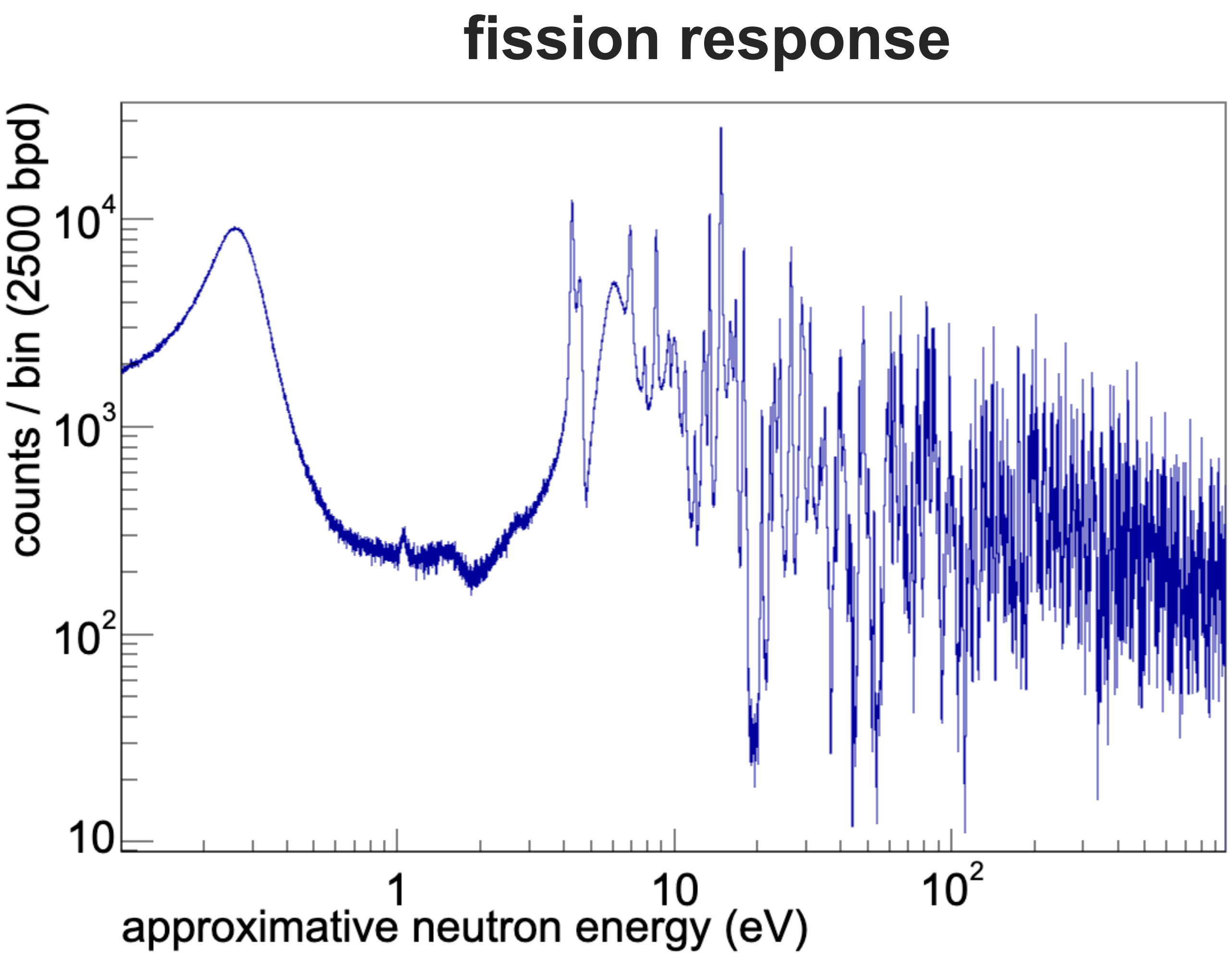


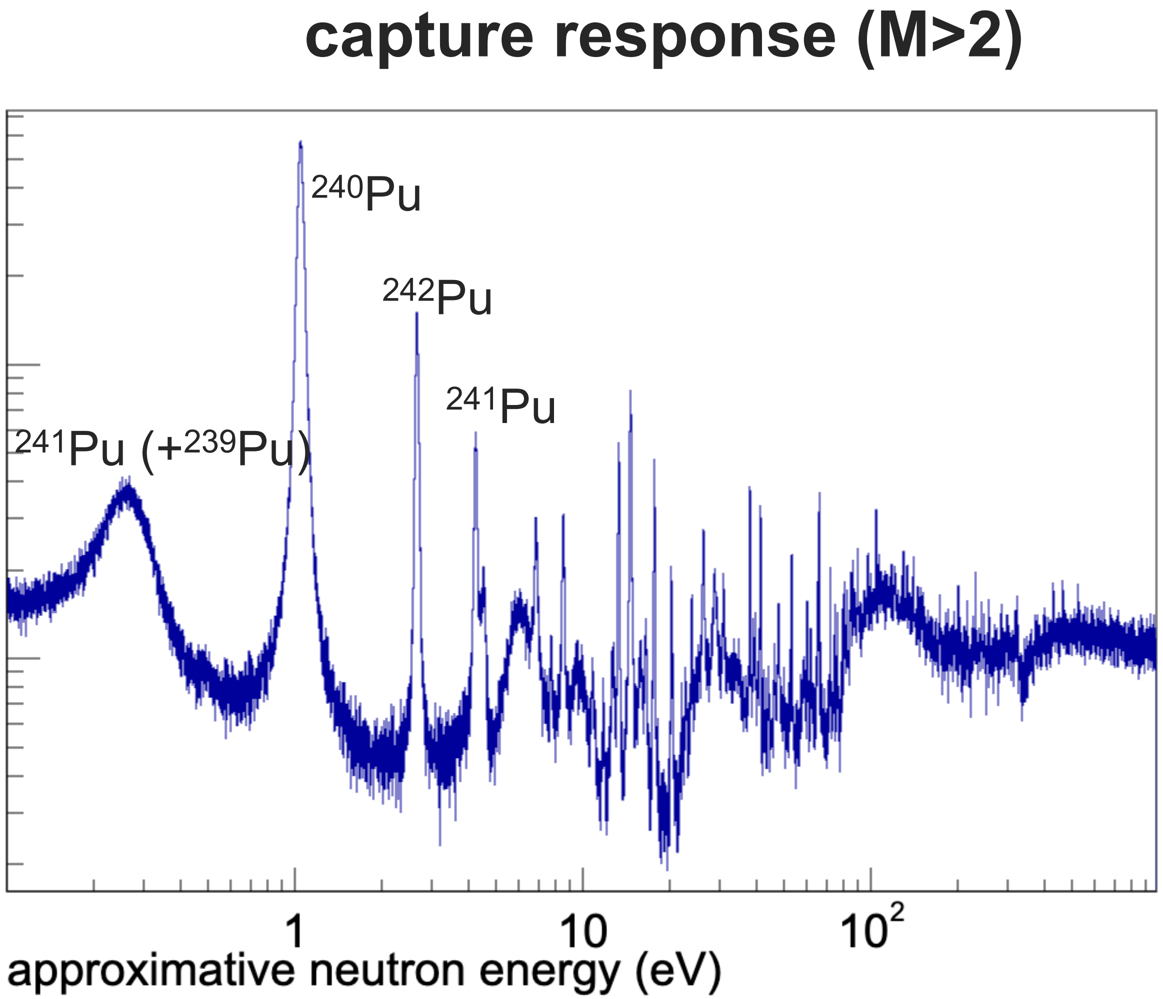
TAC response to ^{88}Y calibration source



PhD A. Cahuzac

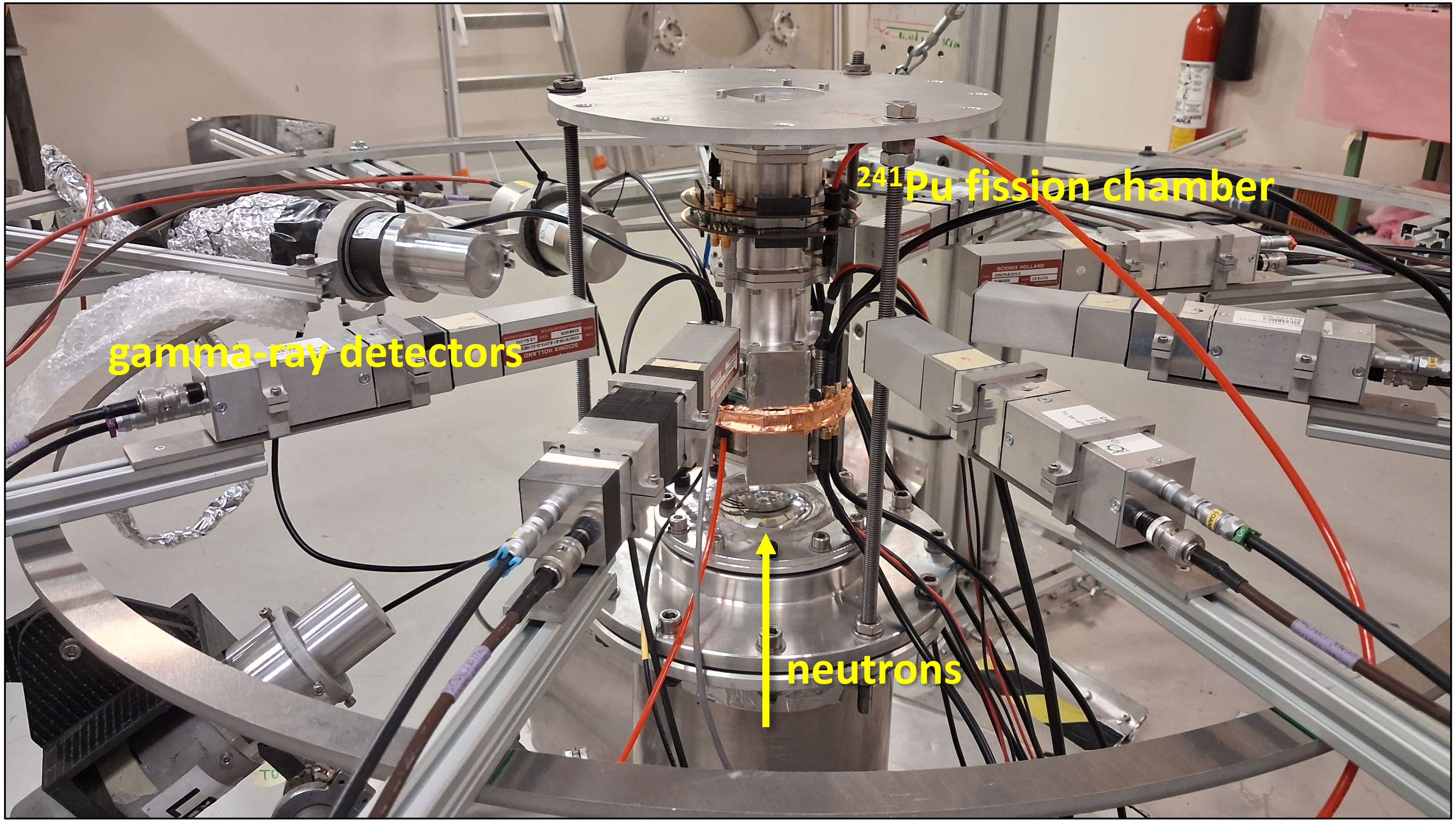
^{241}Pu experiment at n_TOF EAR1





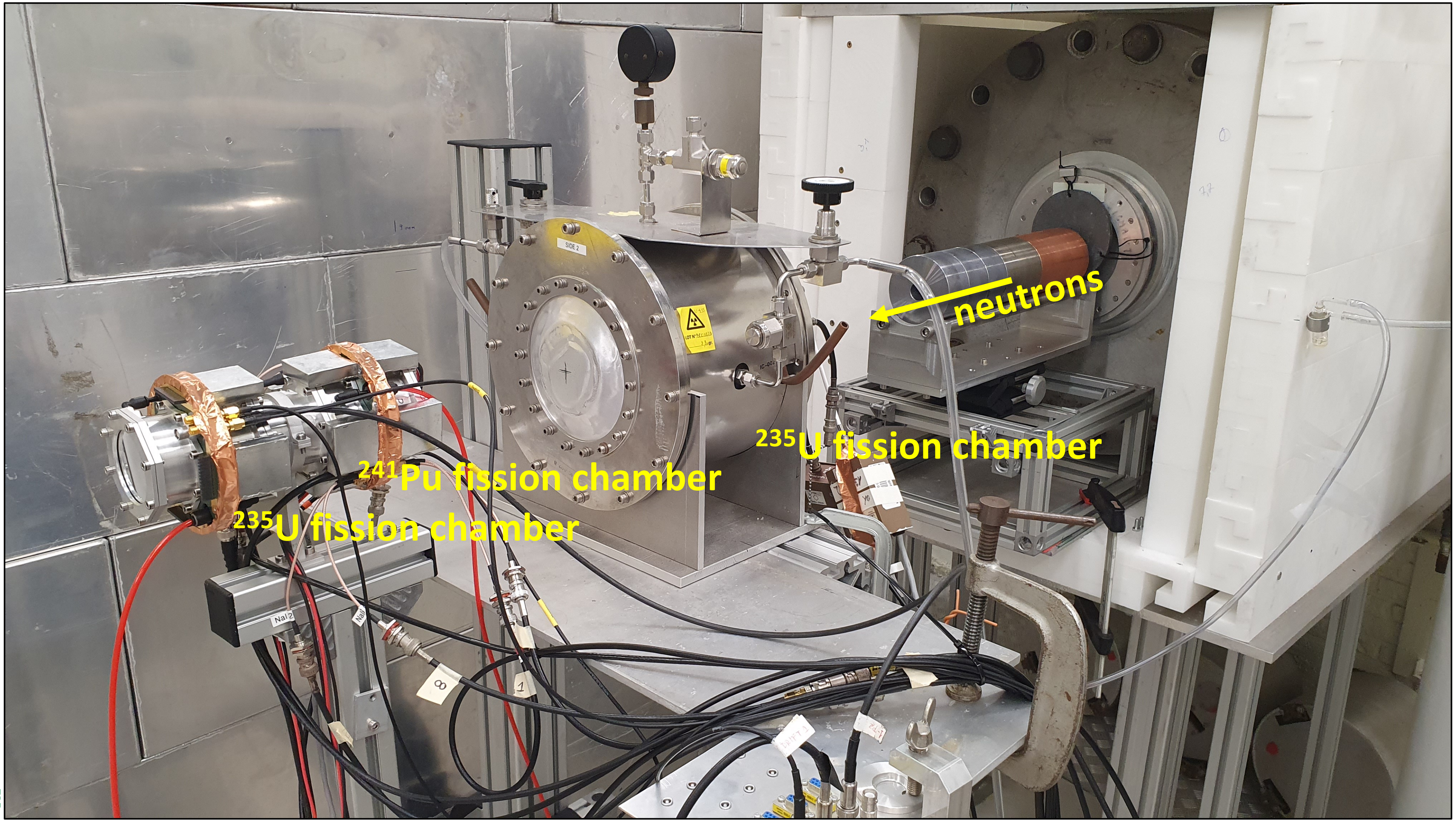
A. Cahuzac *et al.* proc. ND2025

^{241}Pu experiment at n_TOF EAR2



A. Cahuzac *et al.*
proc. ND2025

^{241}Pu experiment at JRC-Geel



A. Cahuzac e
proc. ND2025

Measurement of $^{87}Sr(n,\gamma)$

- Neutron capture cross section for:

  - astrophysical *s*-process

  - $^{87}Rb/^{87}Sr$ cosmochronometer
    $T_{1/2}$ ^{87}Rb is 49 Gy

- Both need accurate capture cross sections

- Standard n_TOF cross section measurement with C_6D_6 detectors.

- Allocated: **$2.4 \cdot 10^{18}$** protons in **EAR1** for the cross section

- Allocated: **$1 \cdot 10^{18}$** protons in **EAR2** for test γ-spectroscopy

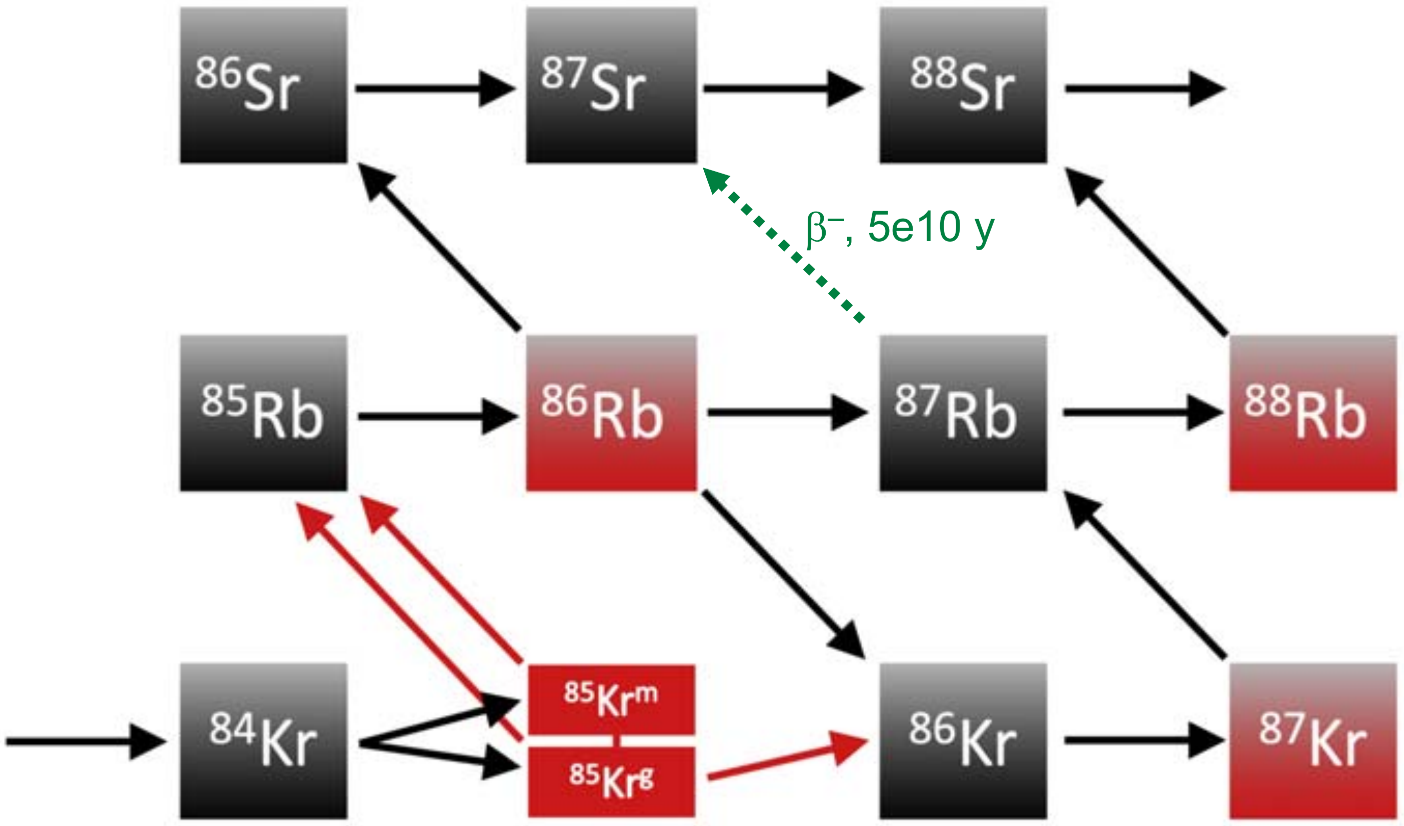
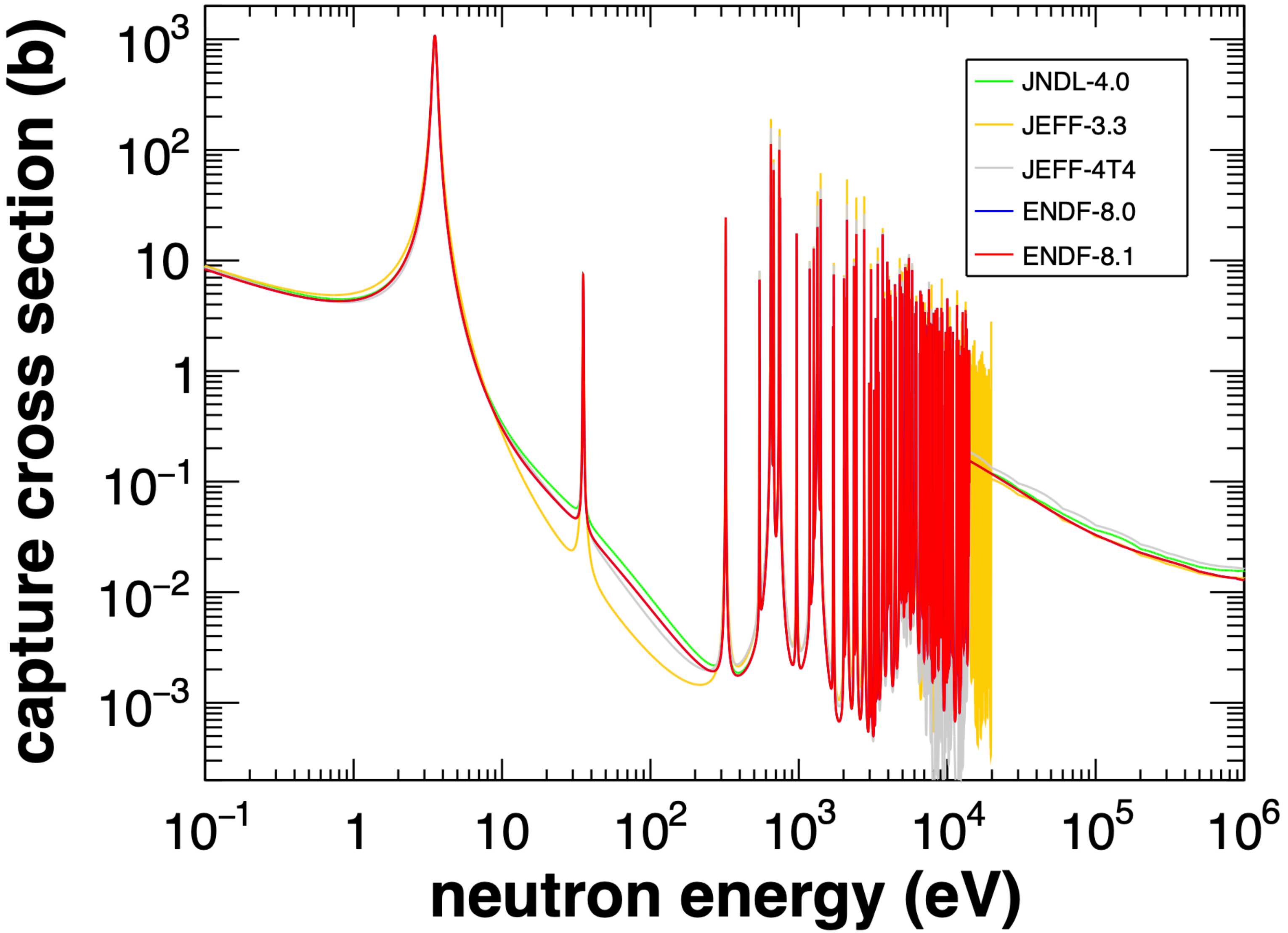


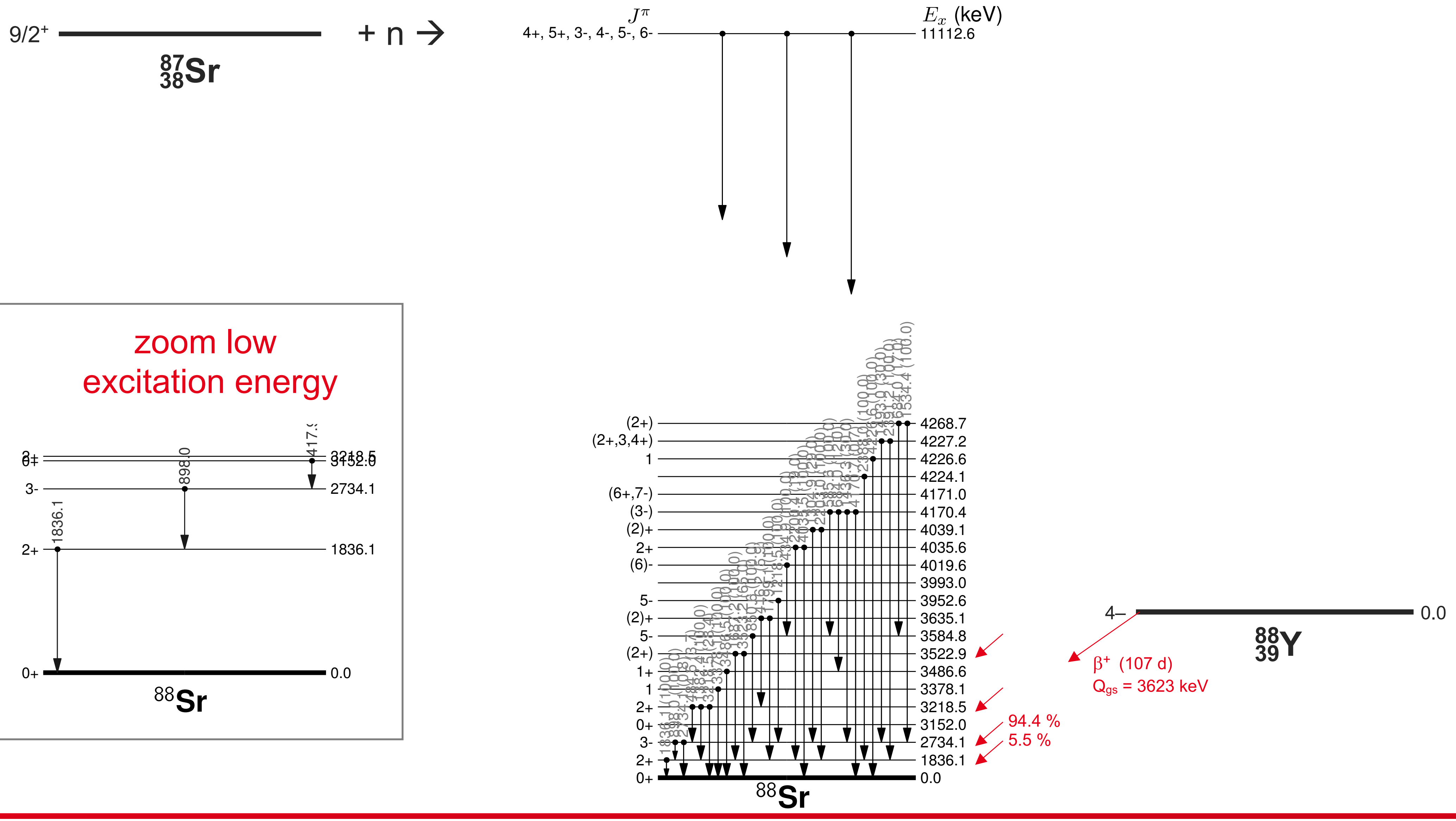
figure from Palmerini et al.
doi.org/doi:10.3847/1538-4357/ac1786

Measurement of $^{87}Sr(n,\gamma)$

- evaluations based on scarcely available measurements as reported in EXFOR, mostly:
  - -- Macklin (1967, 3 pts)
  - -- Hicks (1982, 15 pts)
  - -- Walter (1985, 390 pts)
  - -- Bauer (2011, only MACS)

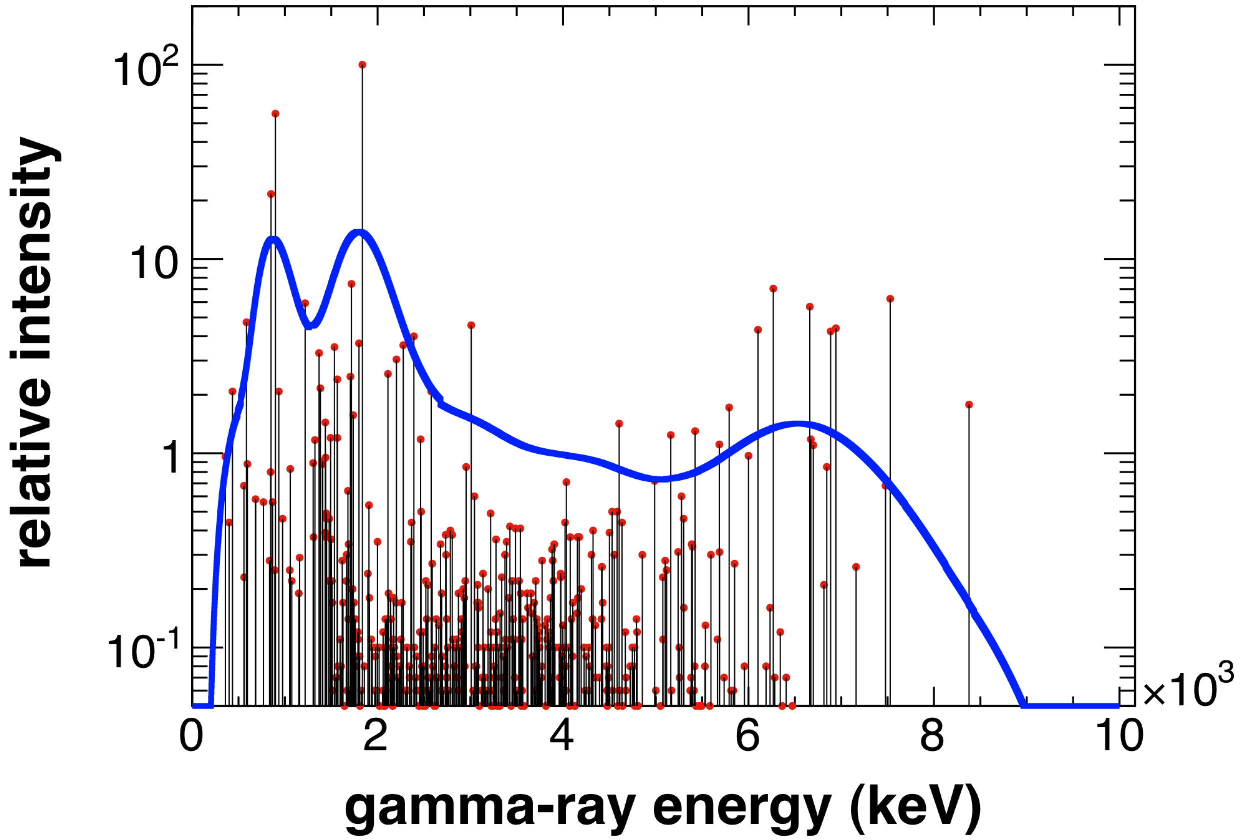


Simplified level scheme ^{87}Sr + n

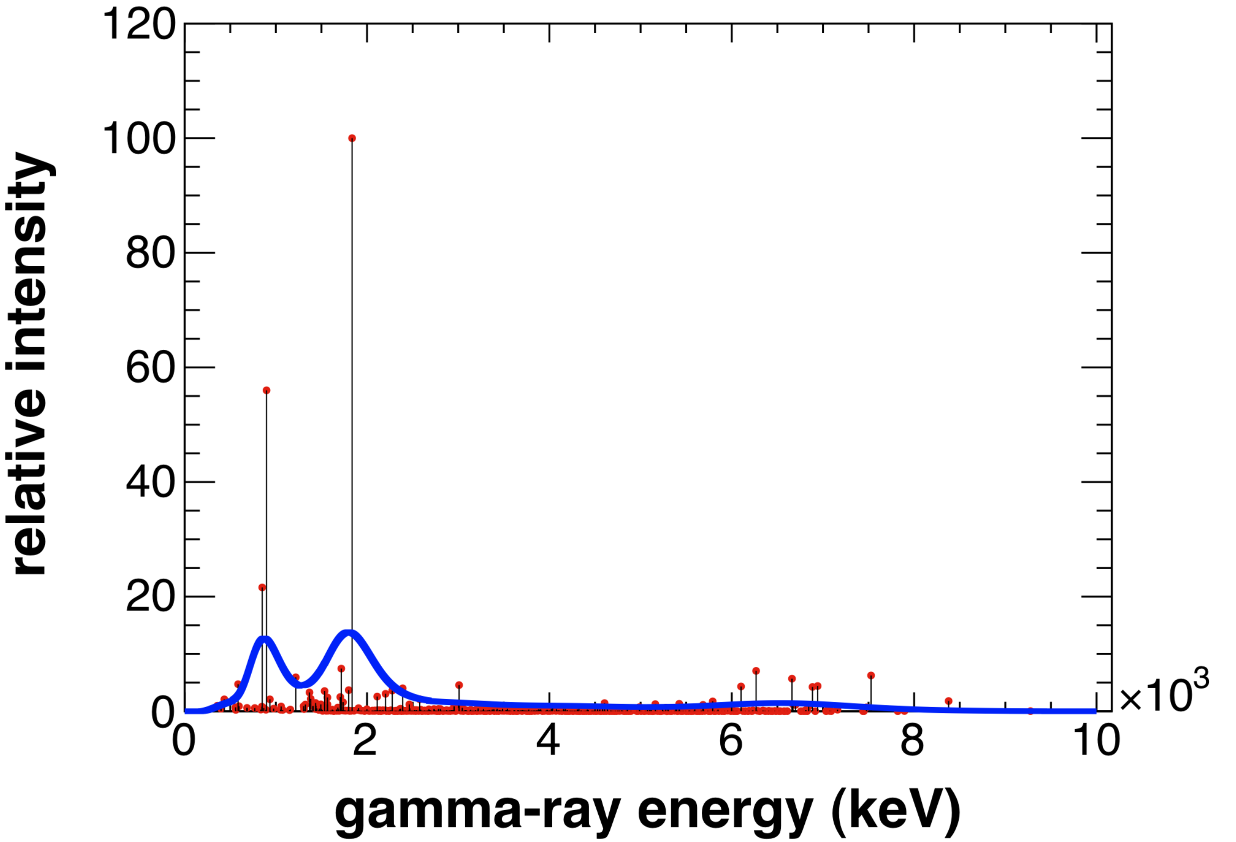


^{87}Sr TAC gamma-ray spectroscopy

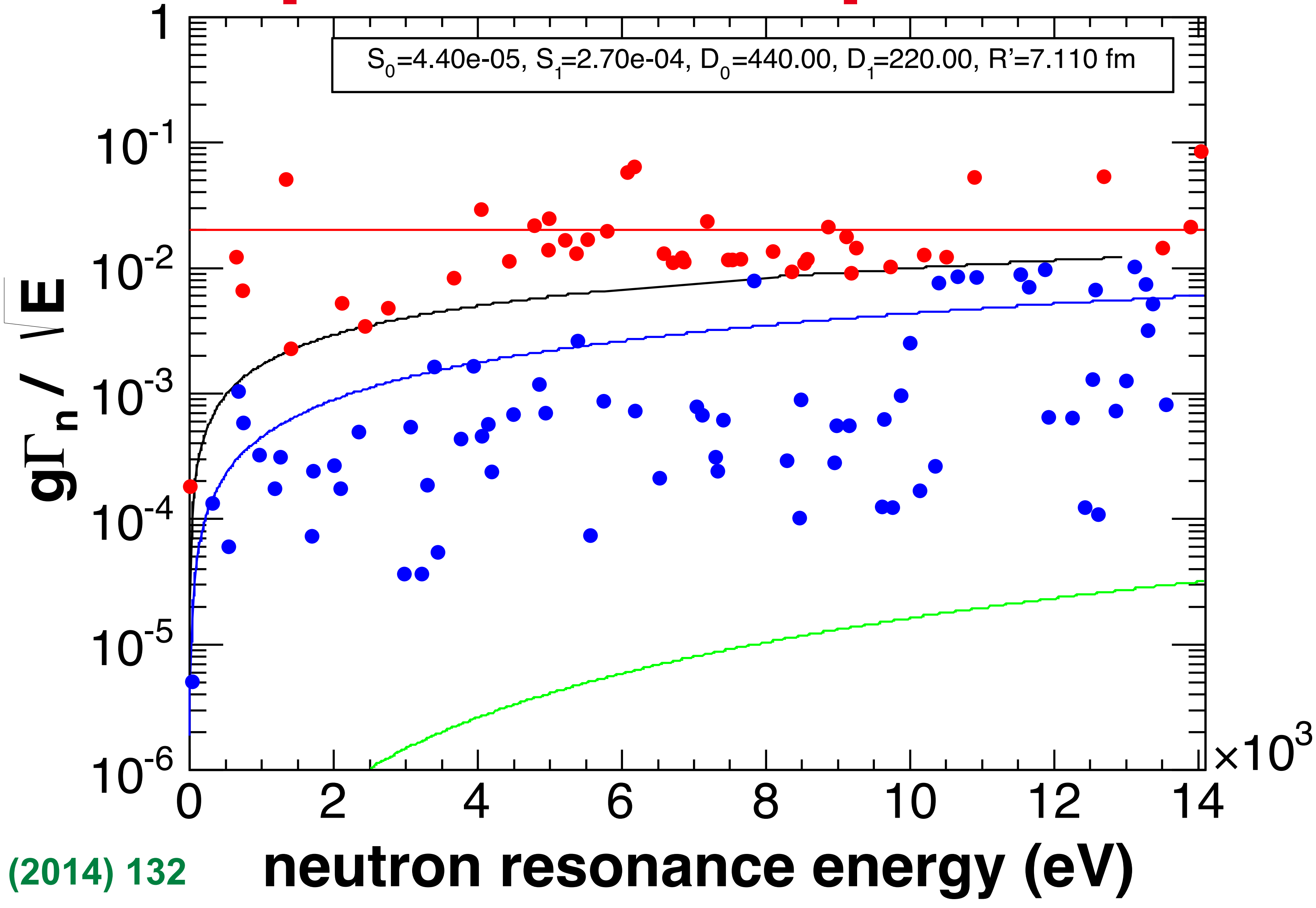
logarithmic scale



linear scale

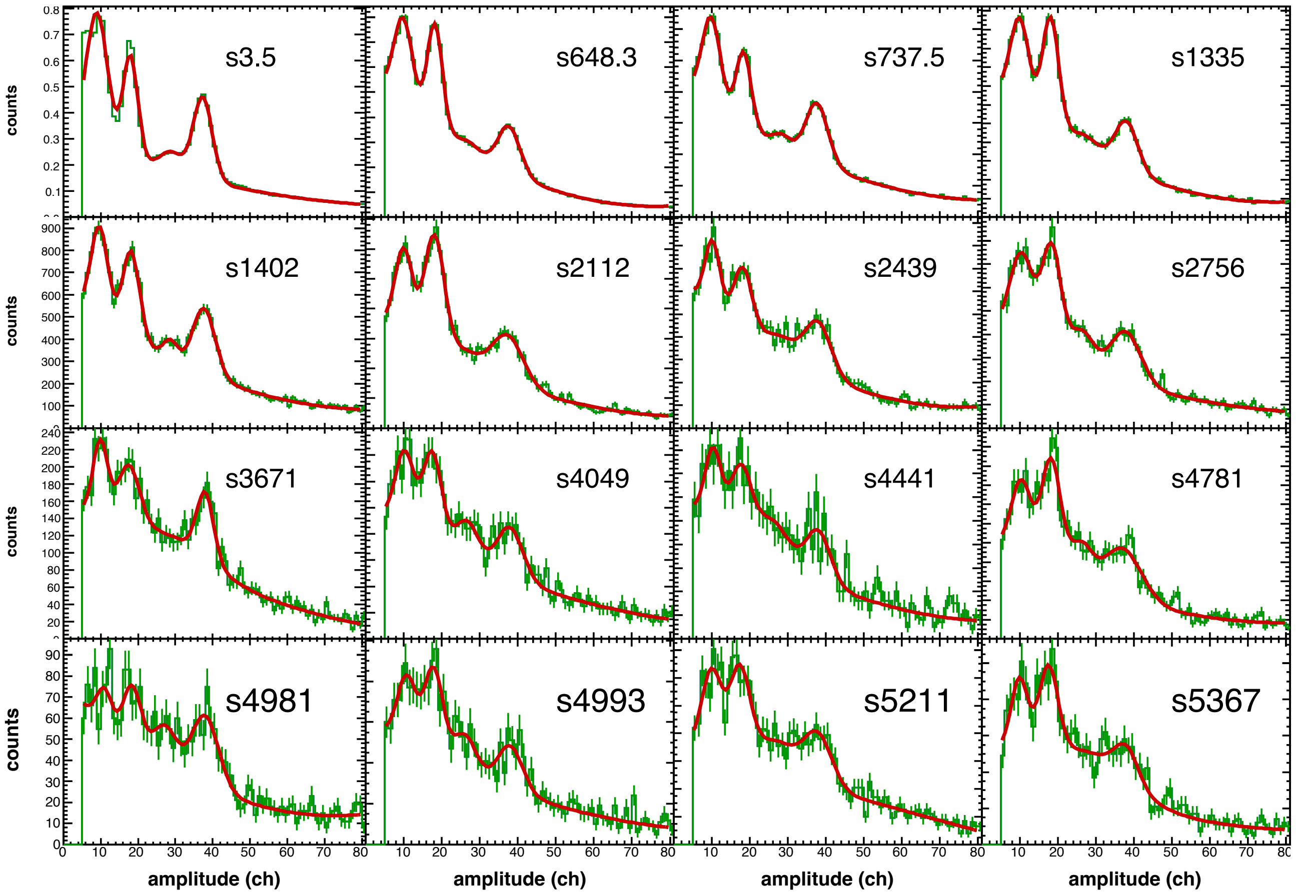


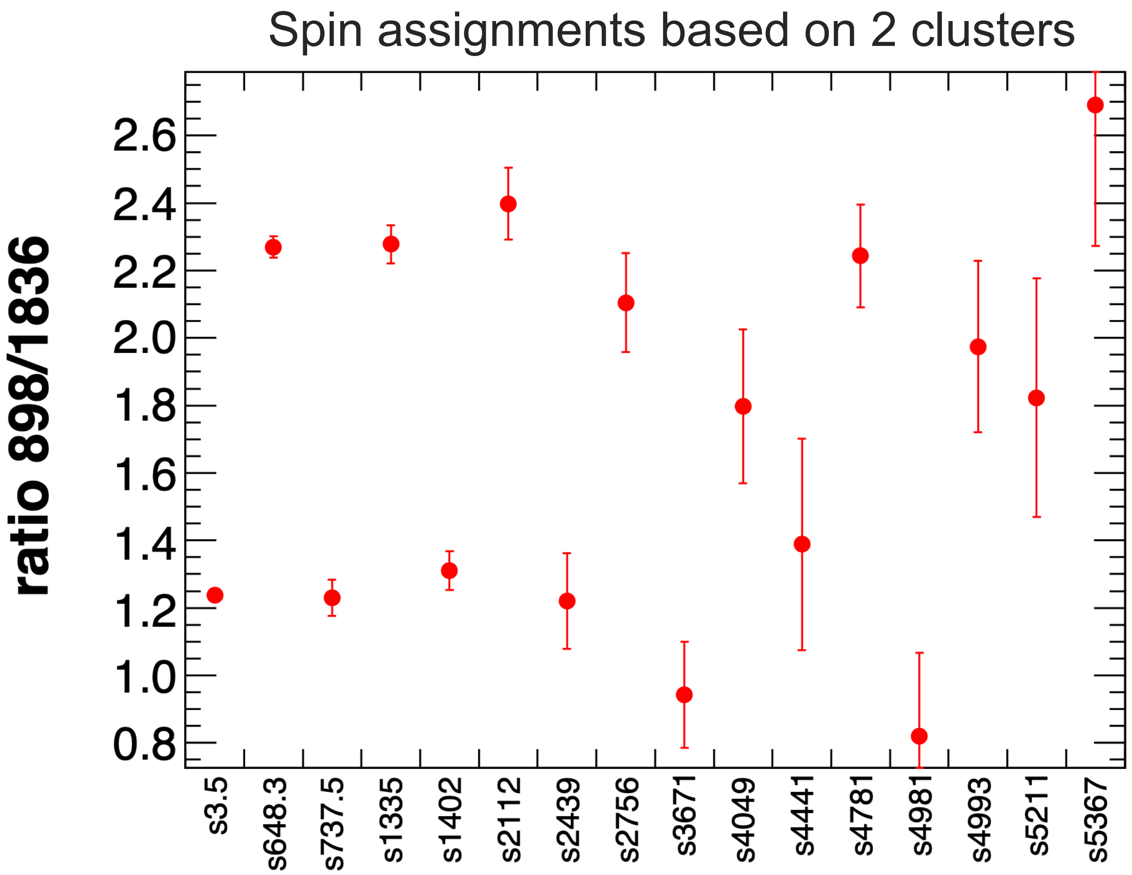
^{87}Sr separation s- and p-waves



Nucl. Data Sheets 119 (2014) 132

^{87}Sr TAC gamma-ray spectroscopy

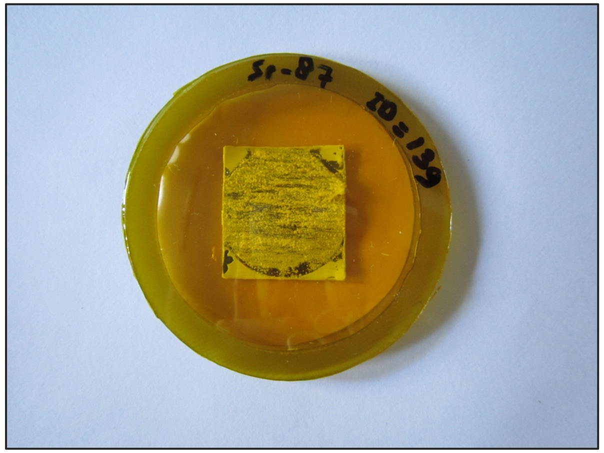




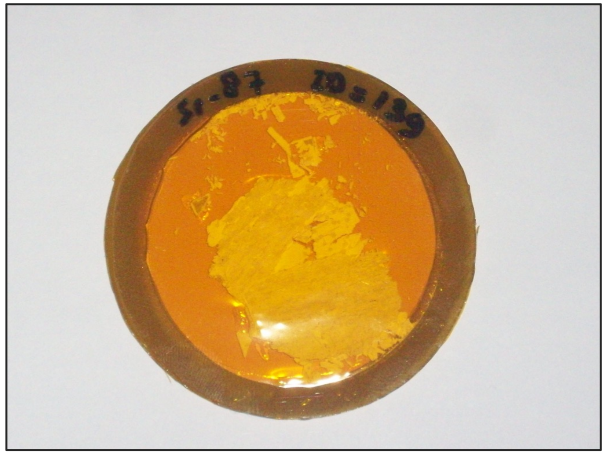
Nucl. Data Sheets 119 (2014) 132

^{87}Sr sample

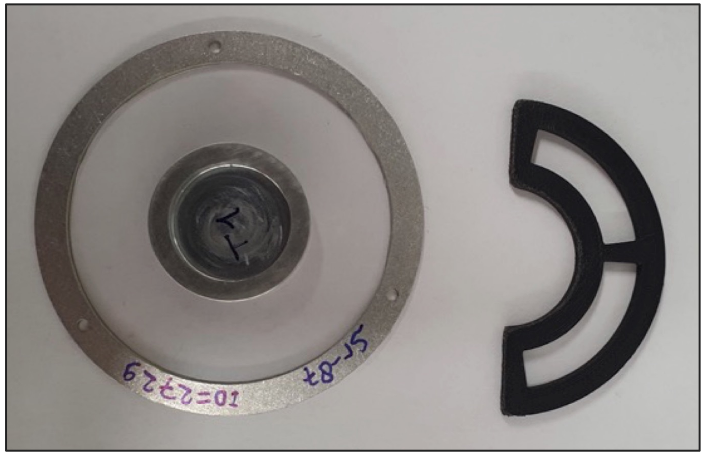
metallic sample on arrival at Saclay in 2010



sample before TAC experiment in 2011



sample after TAC experiment in 2011

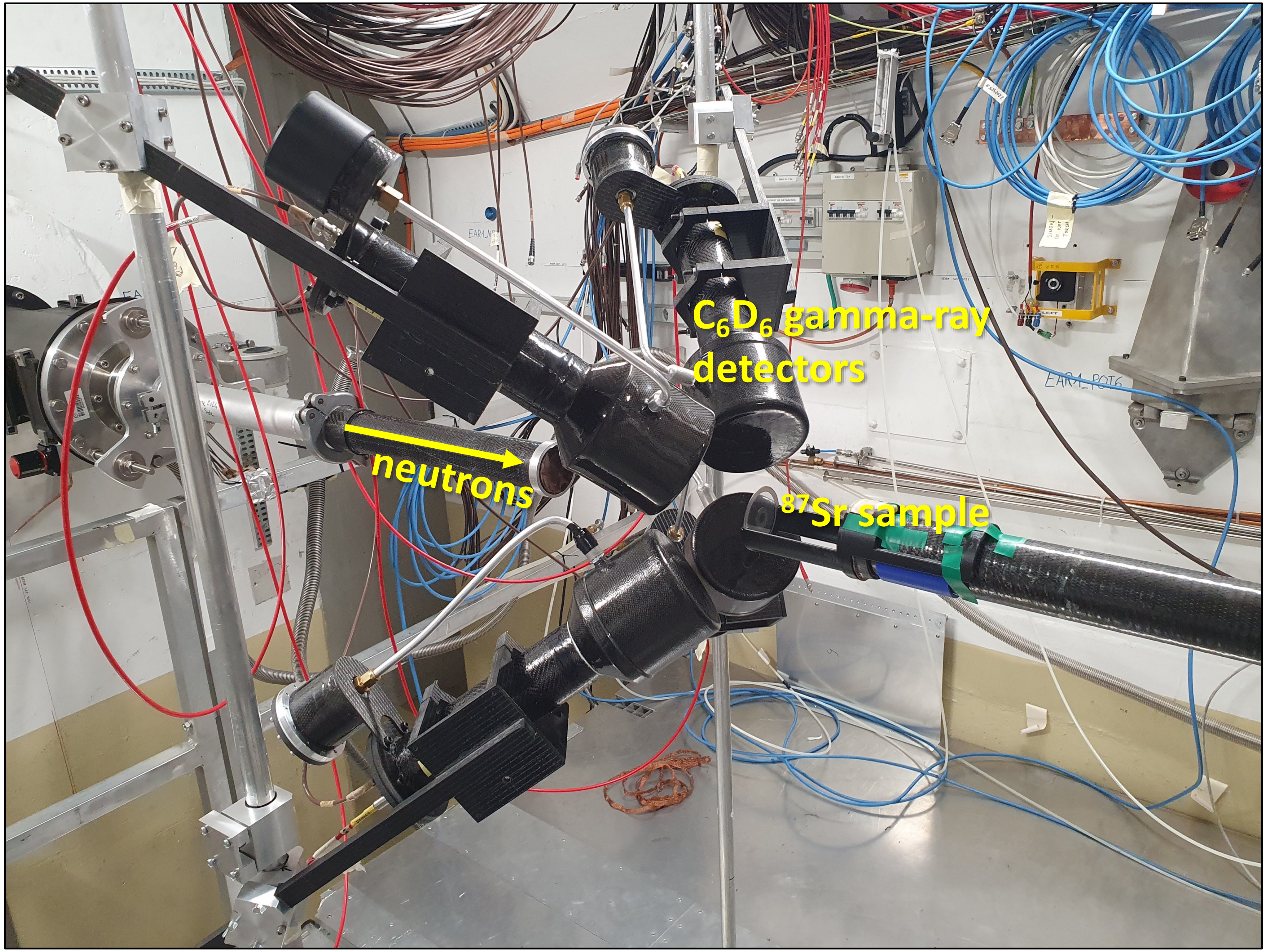


sample repackaged for EAR1 and EAR2 experiment in 2025

- original sample, enriched (87.73%) metallic ^{87}Sr on loan from Los Alamos
- sample reprocessed and transformed into ^{87}SrO
  oxidation 1100 °C, pressed 5 tons, done at PSI-Villigen
- sample put in sealed Al container (produced by JRC)

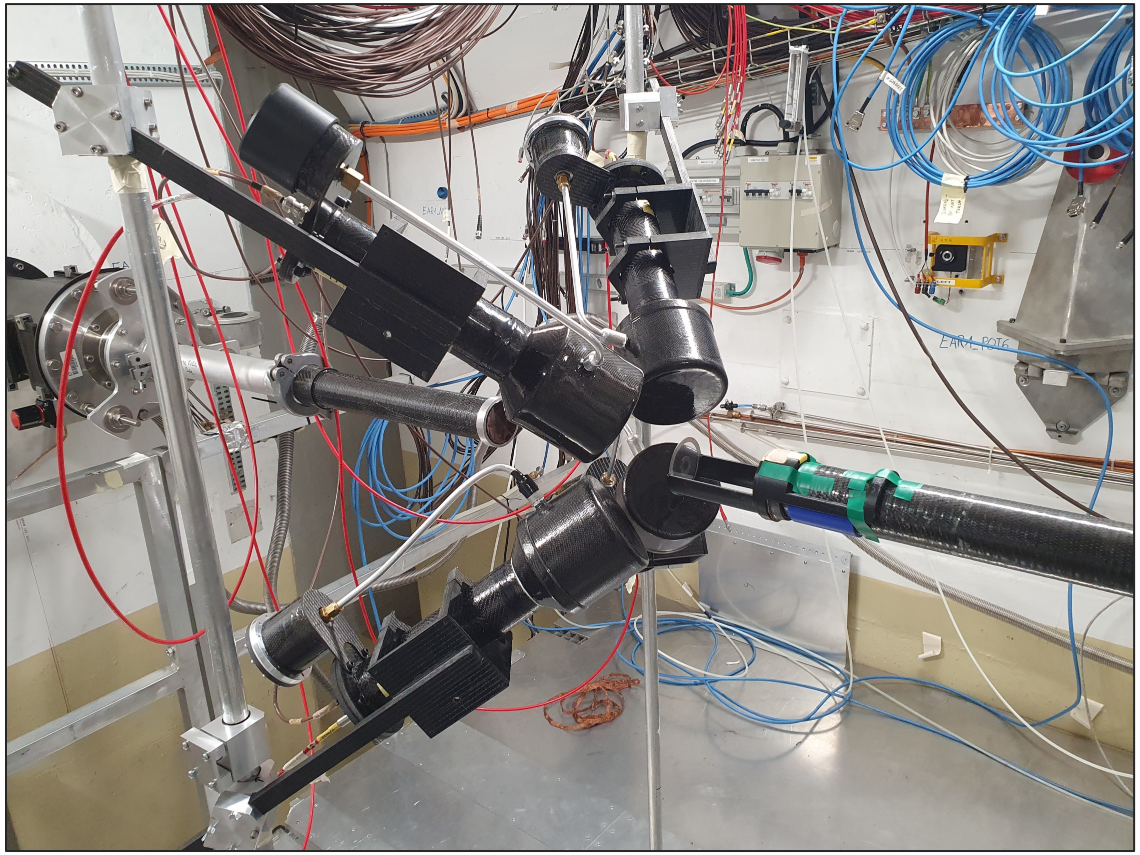
	^{84}Sr	^{86}Sr	^{87}Sr	^{88}Sr
natural	0.56	9.86	7.00	82.58
enriched	0.015	1.39	87.73	10.87

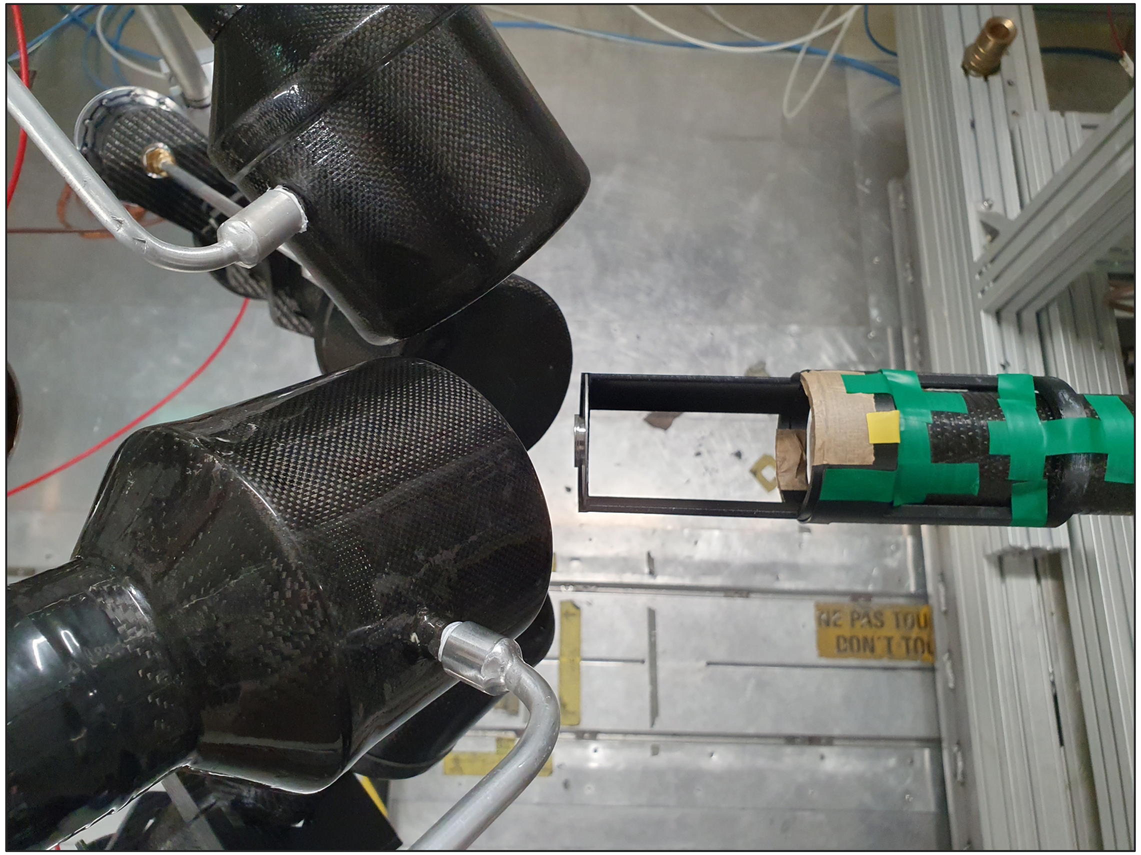
$^{87}Sr(n,\gamma)$ in EAR1



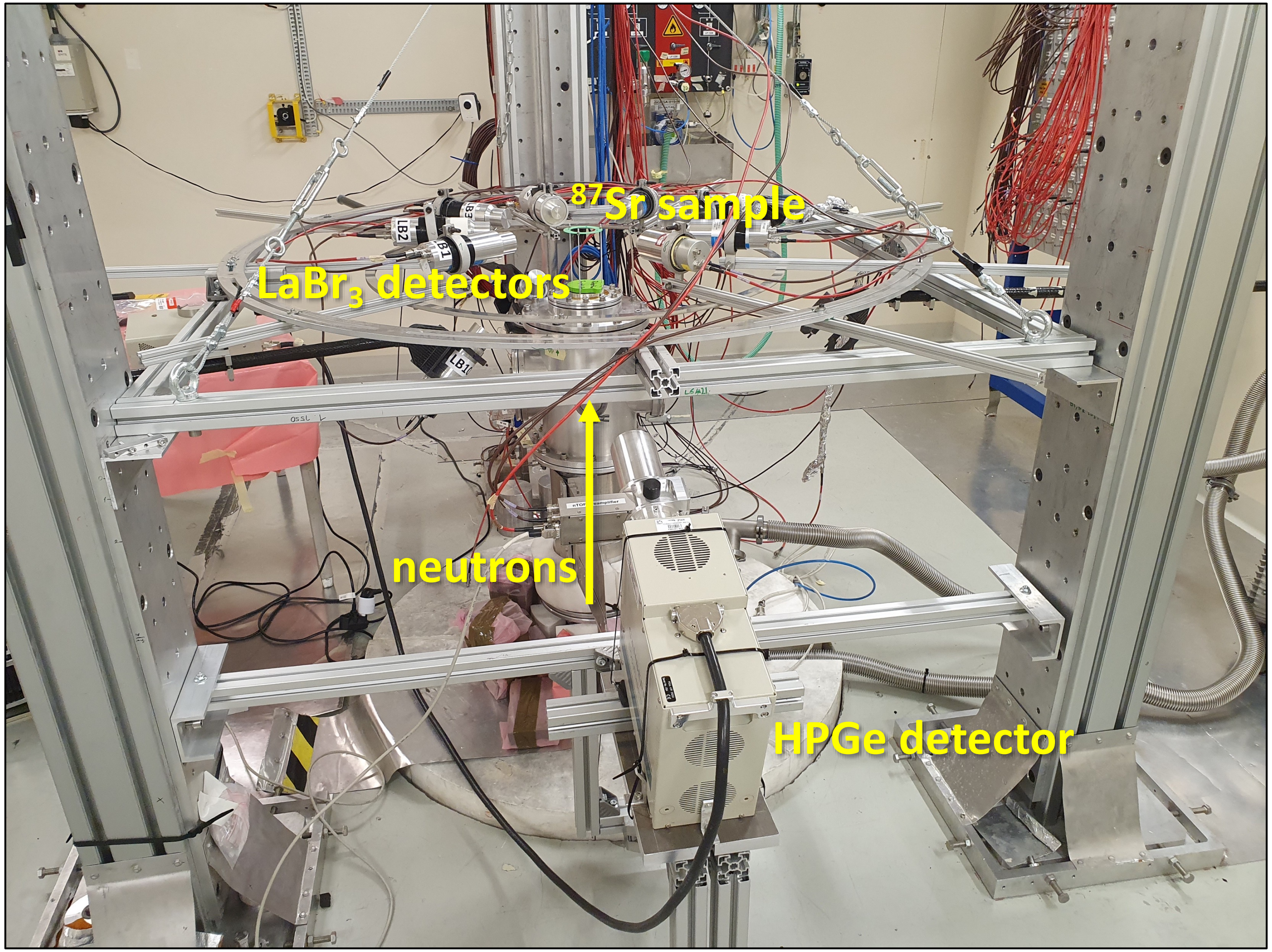
$^{87}Sr(n,\gamma)$ in EAR1

- setup with 4 C_6D_6 gamma-ray detectors



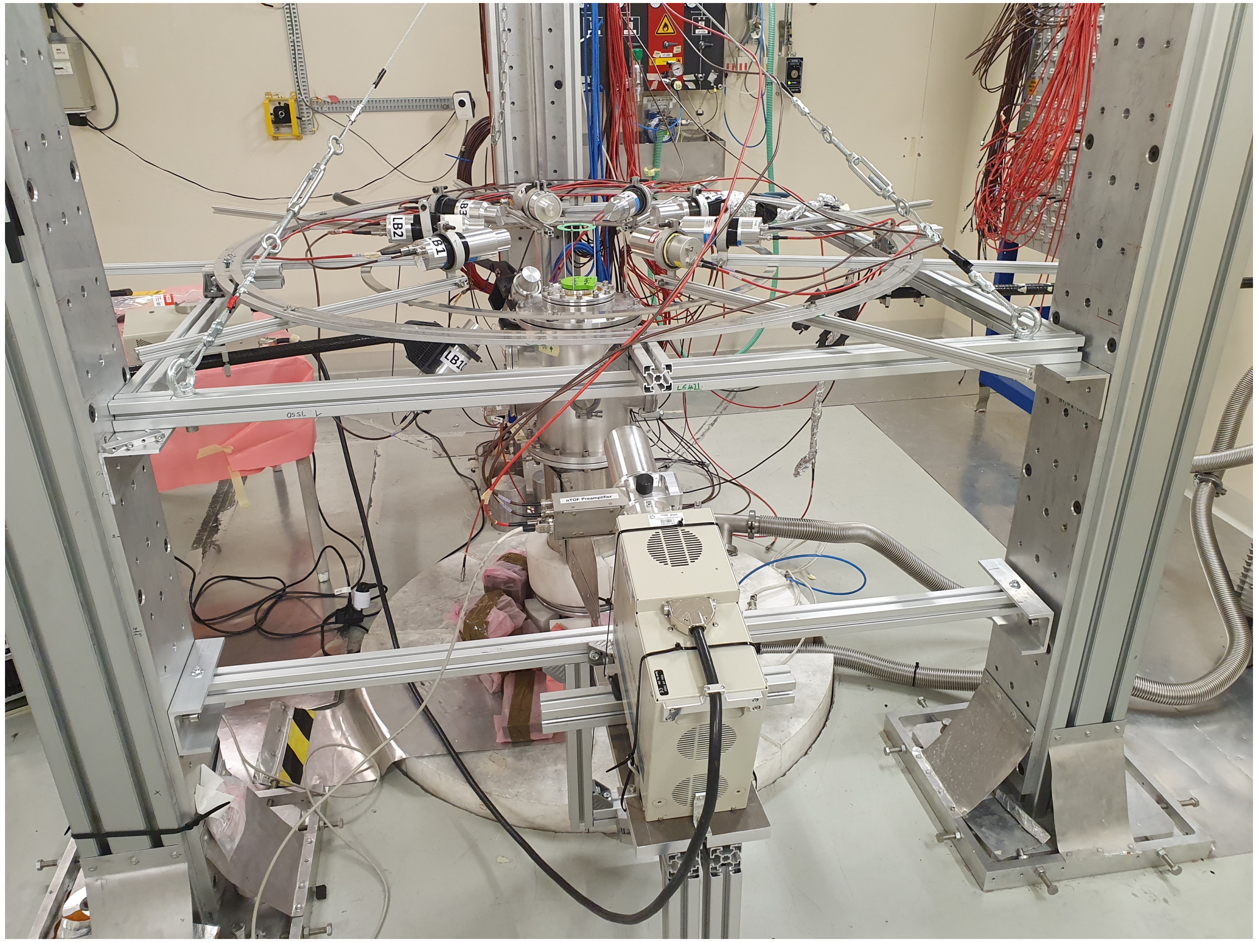


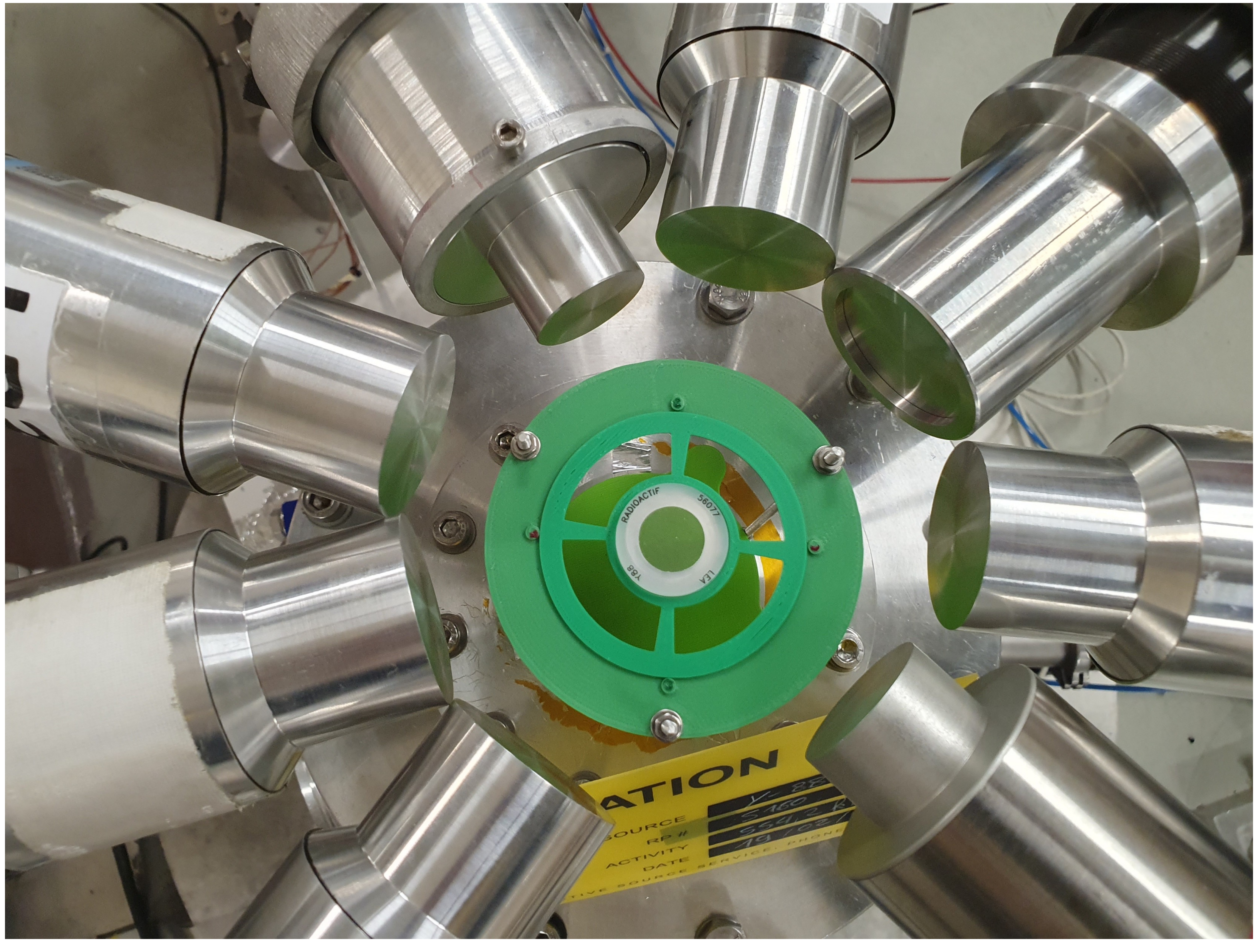
$^{87}Sr(n,\gamma)$ in EAR2



$^{87}Sr(n,\gamma)$ in EAR2

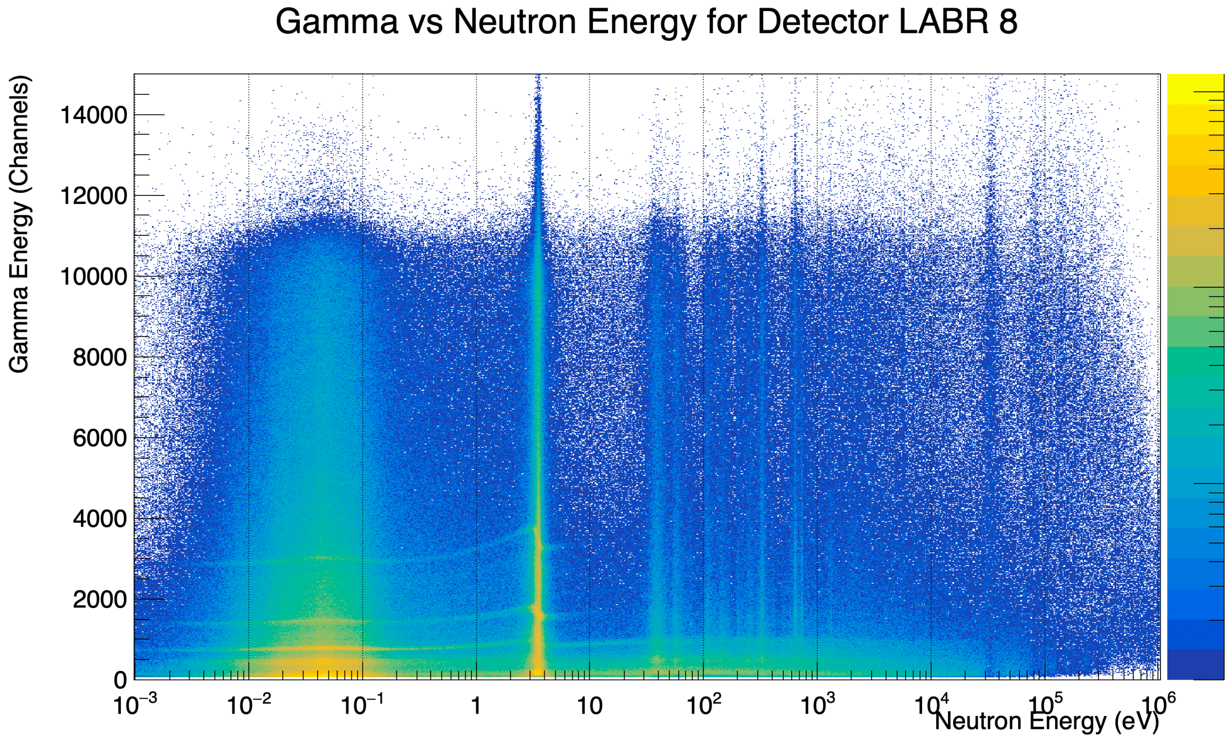
- setup with 8 $LaBr_3$ - $LaCl_3$ gamma-ray detectors



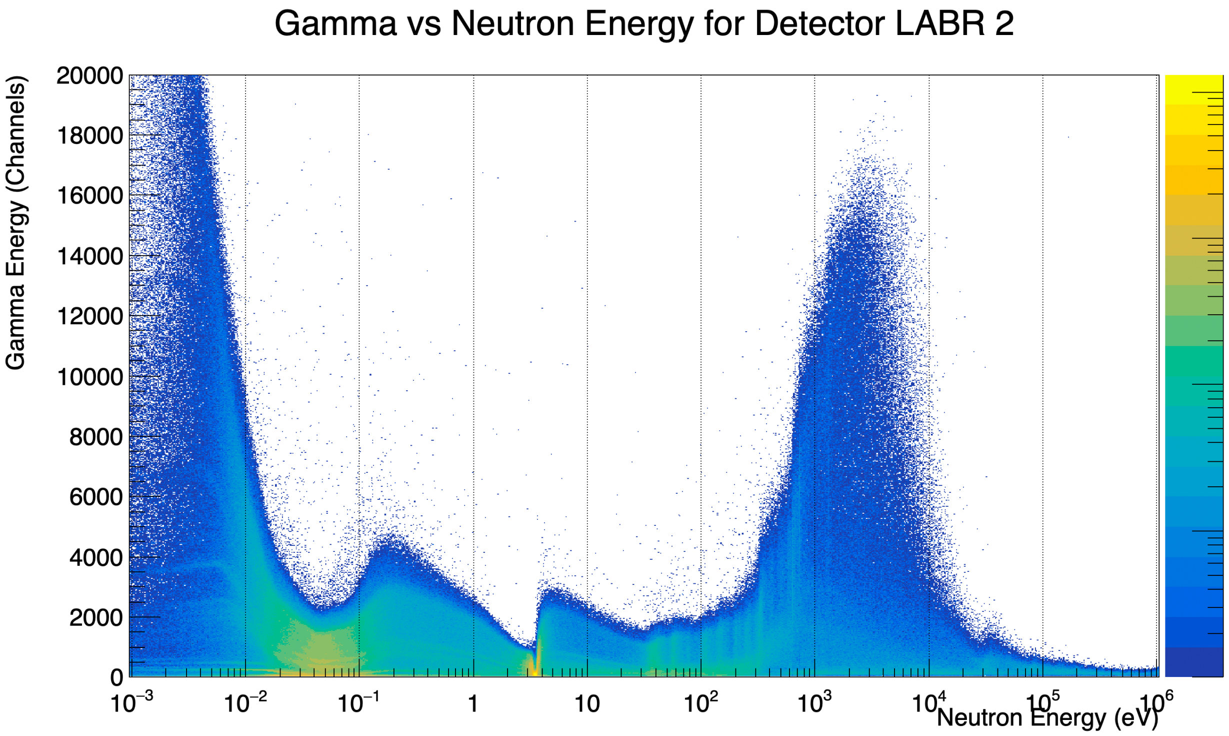


$^{87}Sr(n,\gamma)$ in EAR2

detector response EAR2, **close configuration**

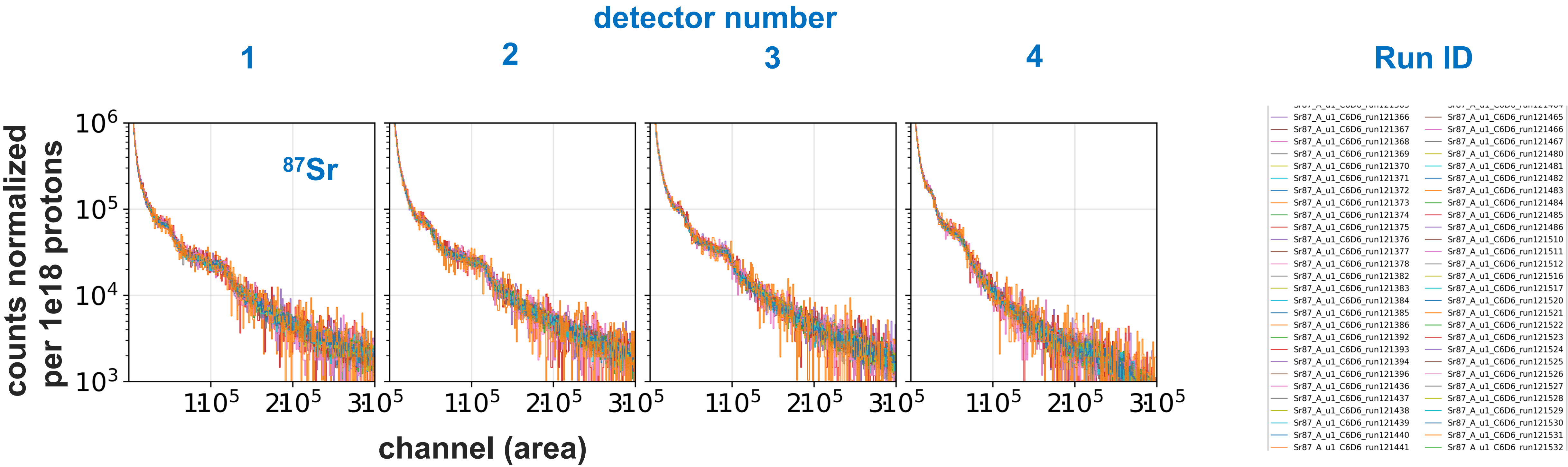


detector with **active** voltage divider



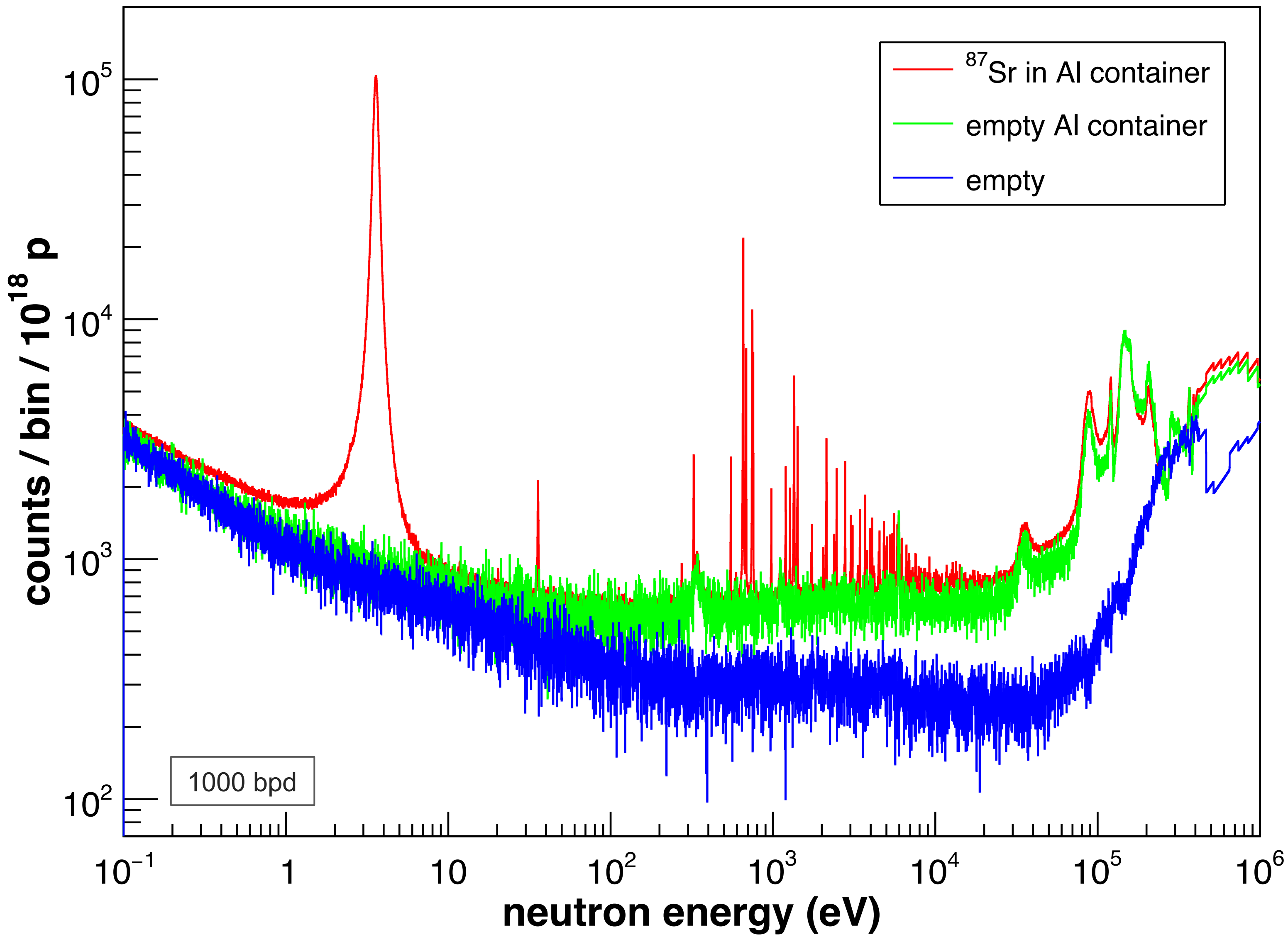
detector with **passive** voltage divider

$^{87}Sr(n,\gamma)$ in EAR1



- data integrity checks for all data, including calibrations and auxiliary data

Final statistics for ^{87}Sr



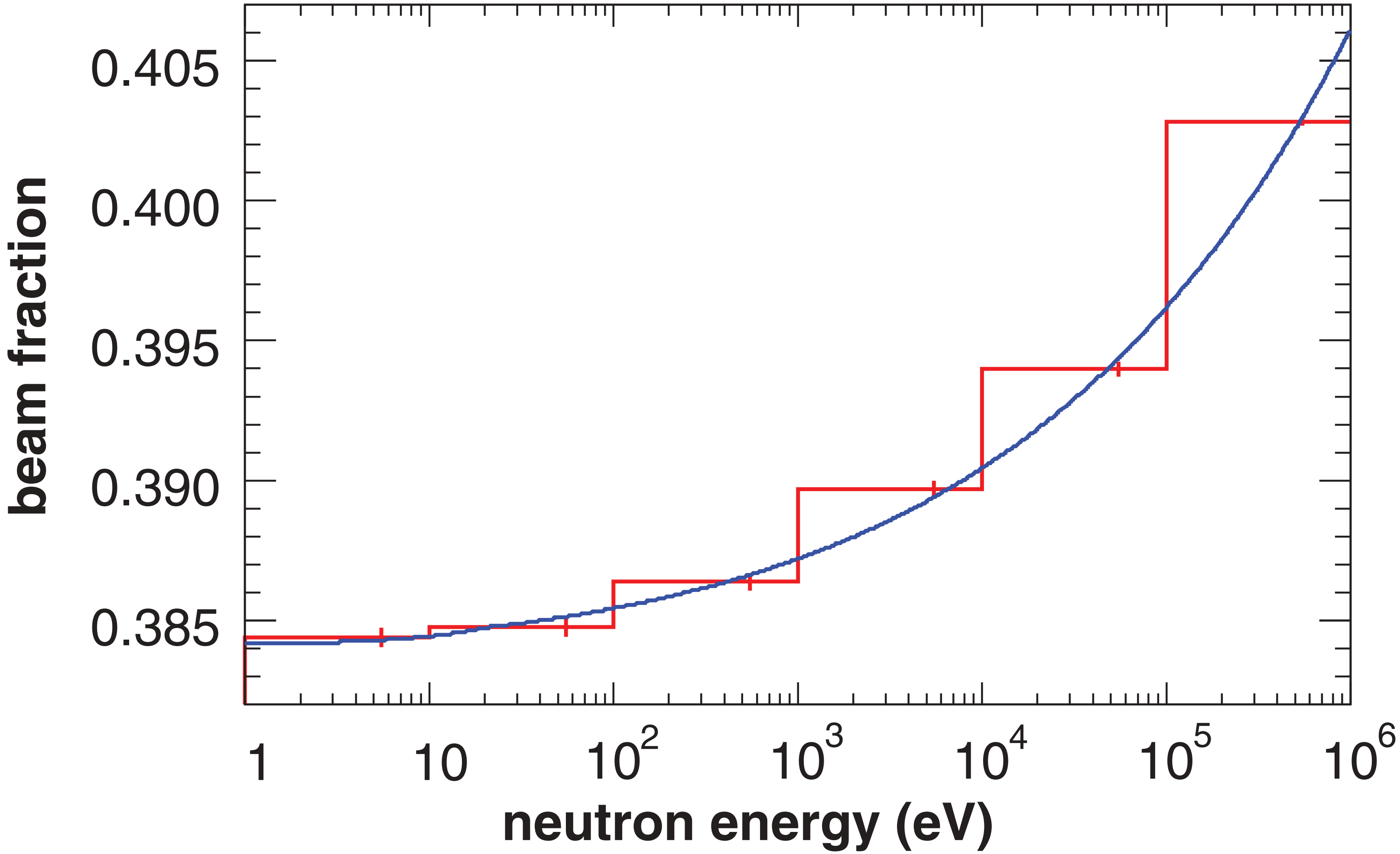
XyMegas (ξ-Megas): ANR project

- French national **ANR** project (type: PRC) partnered with JRC-Geel

- **Objectives:** Development of a multipurpose, portable detector for measurements of
  - neutron beam imaging, in particular for corrections normalization capture (**BIF**)
  - energy-dependent neutron flux monitoring
  - neutron-induced reaction cross sections
  - angular distributions of (n,f) and (n,lcp) reactions

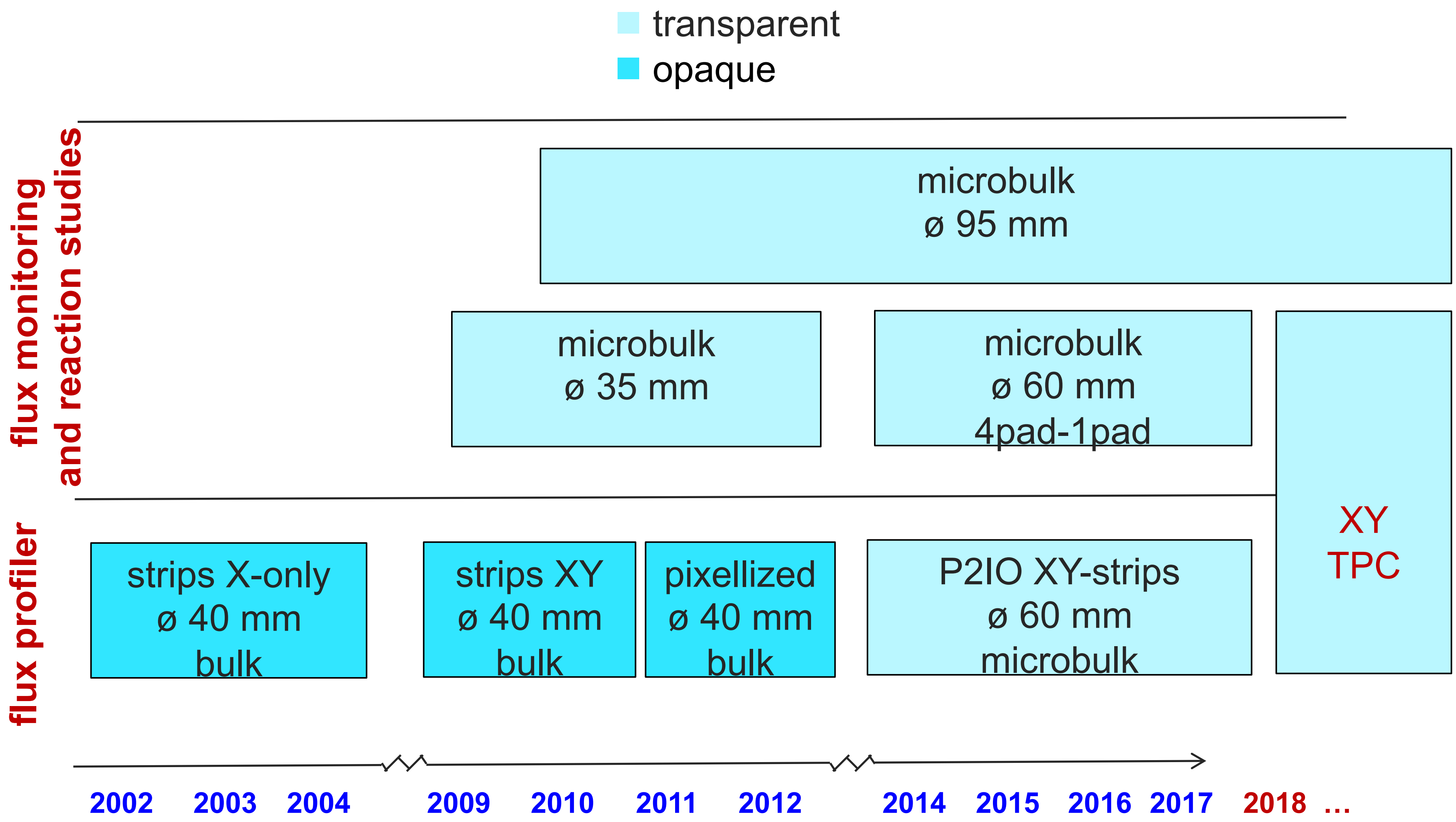
- **Challenge**
  - Combine existing techniques to a new, ”transparent” neutron detector with orthogonal strip read-out, using a state-of-the-art multi-channel acquisition.
  - Transparent detector (Microbulk technology) to keep possibility to stack detectors (combine reactions)

Beam interception factor (simulation)



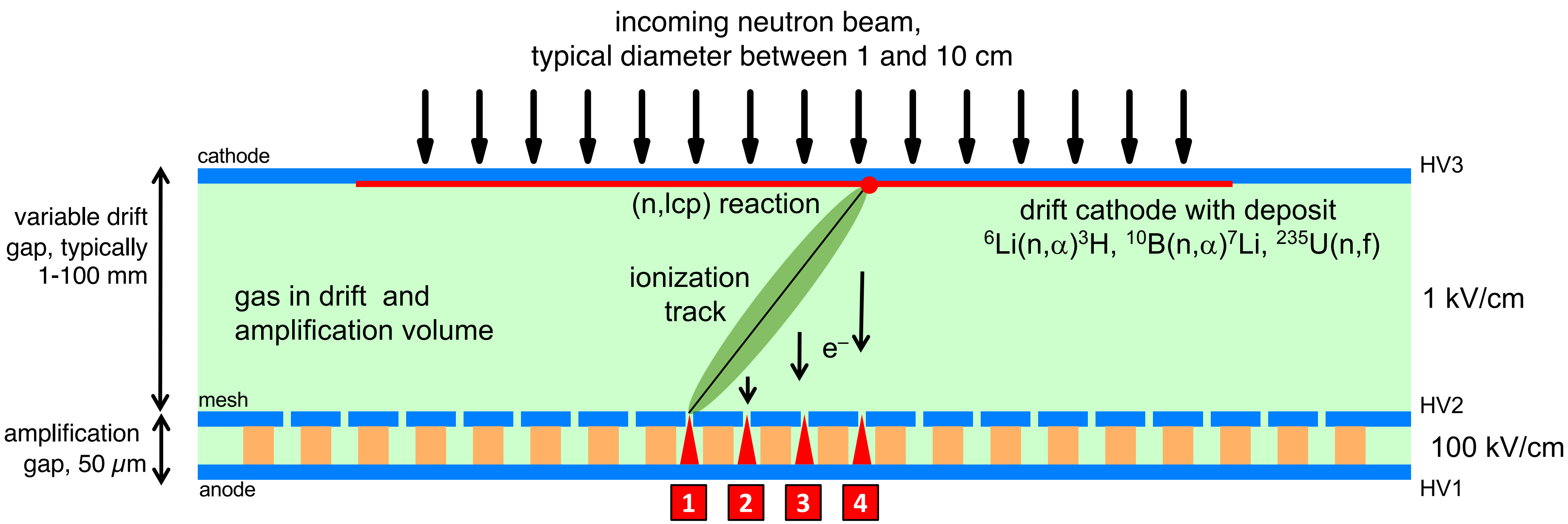
Phys. Rev. C 85 (2012) 064601

Micromegas at n_TOF

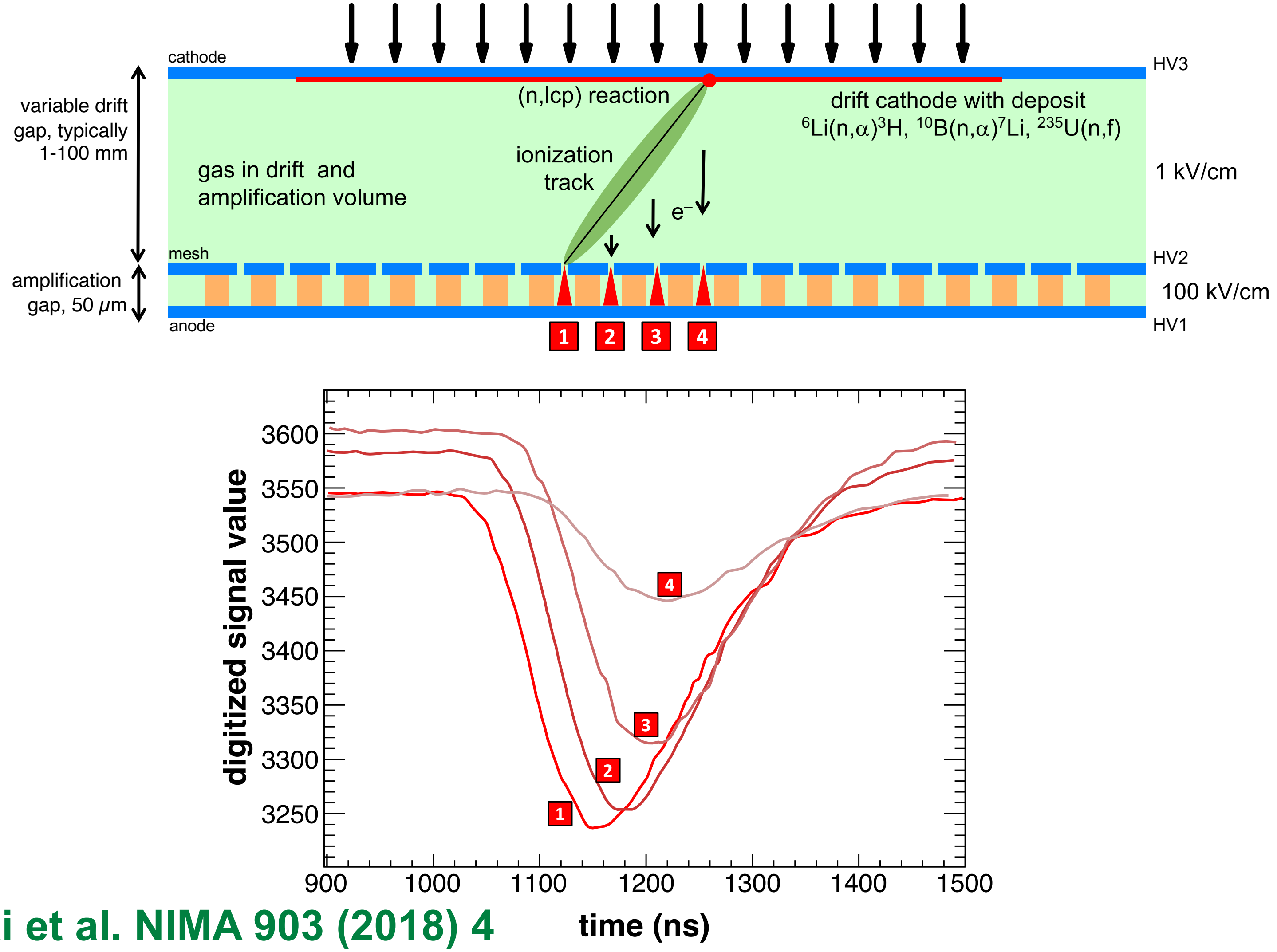


full MM history: Scintillations 99 (2022)

XyMegas: Micromegas detector



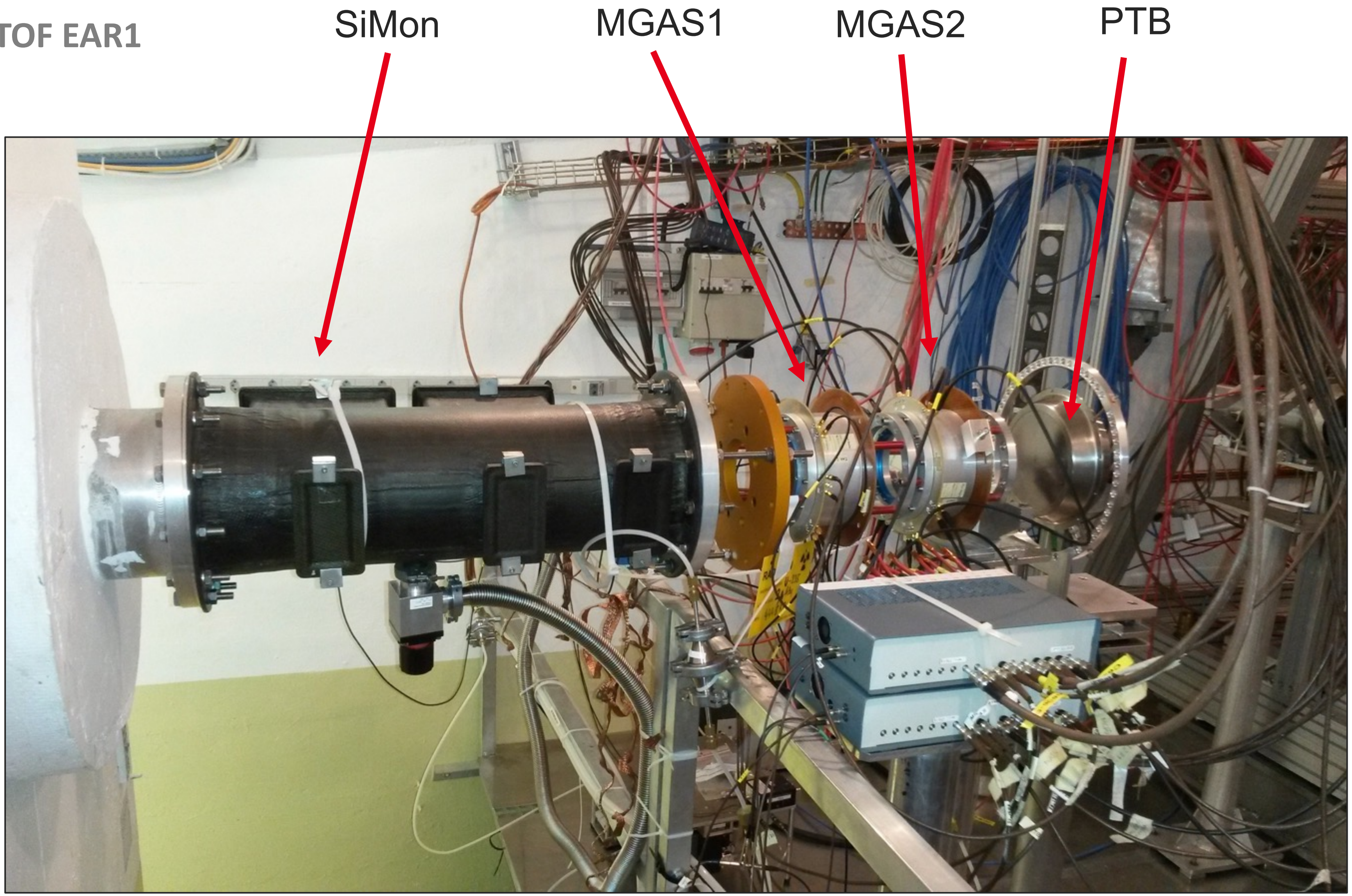
XyMegas: Micromegas detector



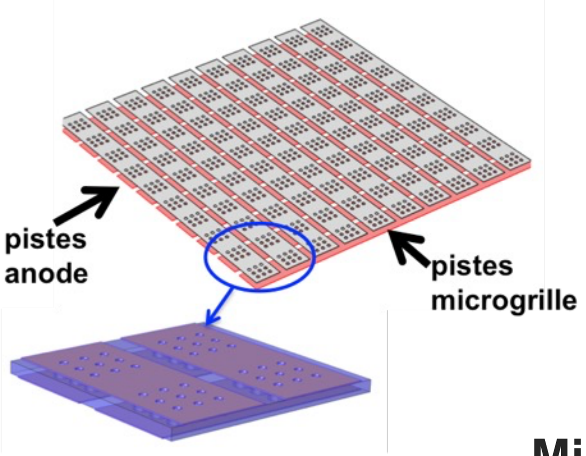
M. Diakaki et al. NIMA 903 (2018) 4

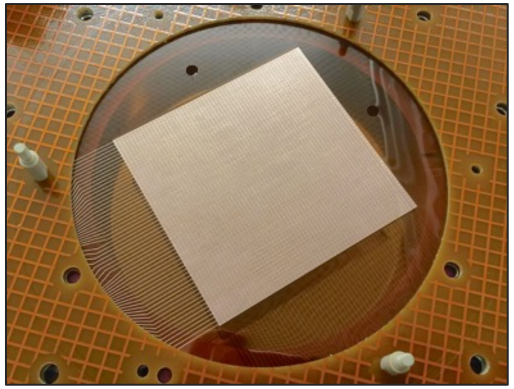
Previous Micromegas detectors at n_TOF EAR1

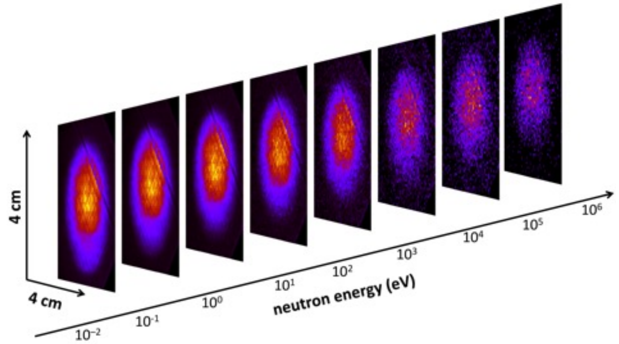
n_TOF EAR1



Previous XY-Micromegas detector

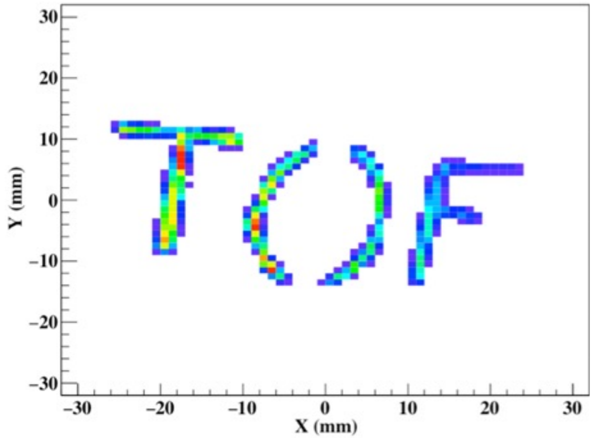




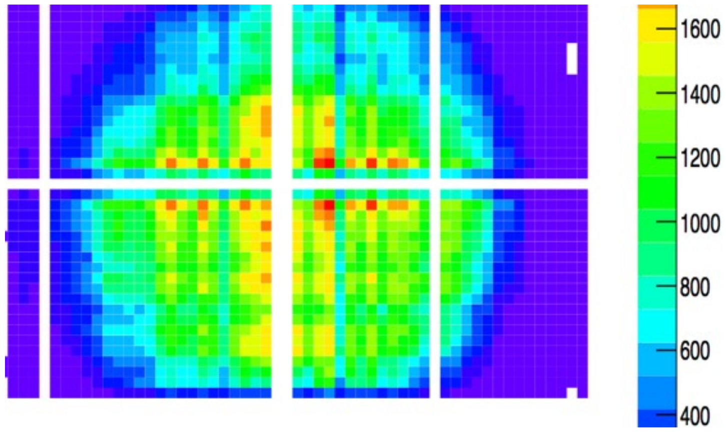


MicroBulk + GET electronics

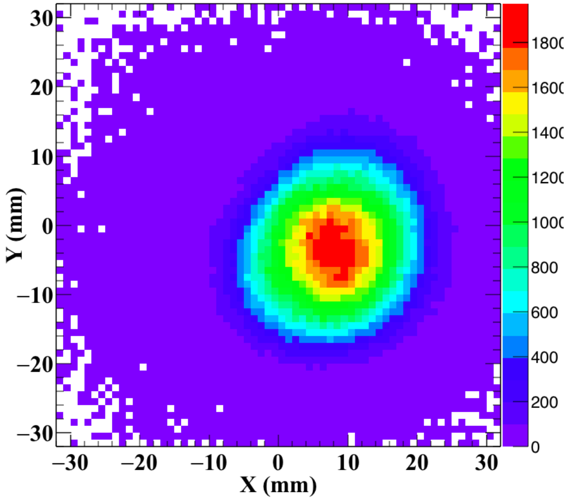
@Lab. Saclay



@GELINA



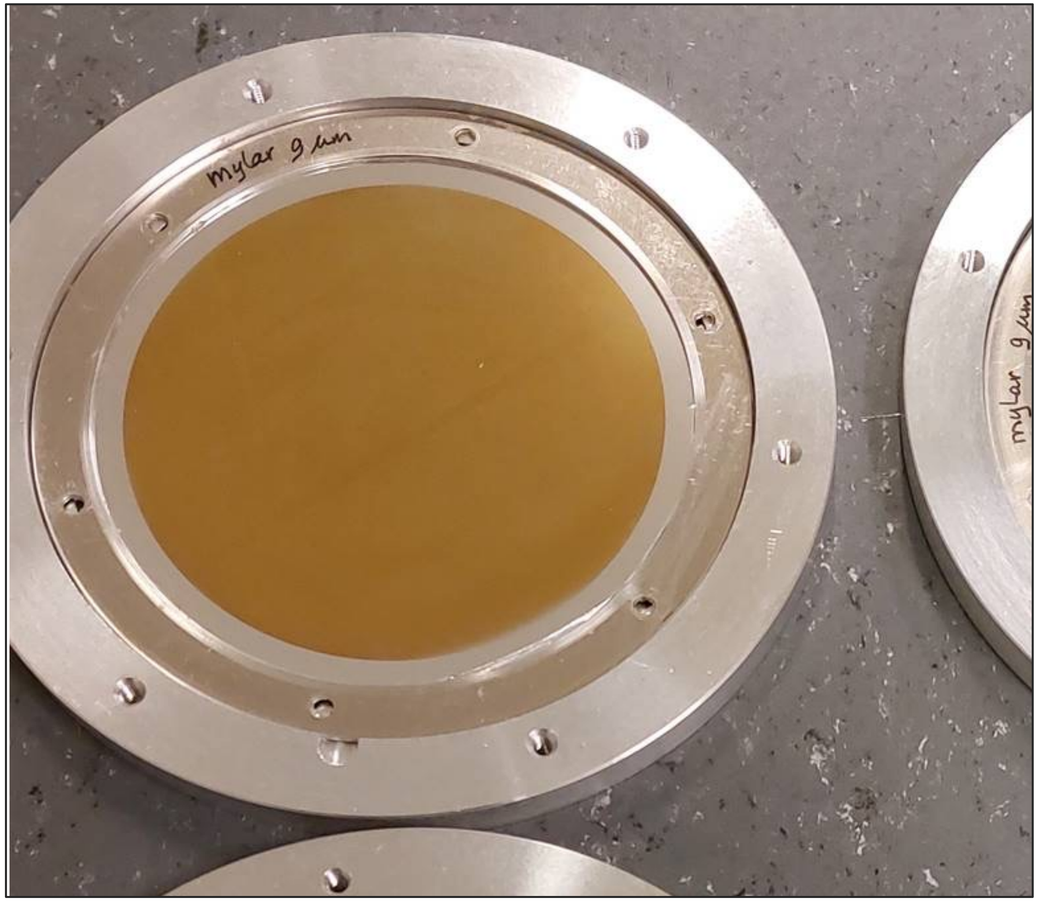
@ n_TOF EAR2

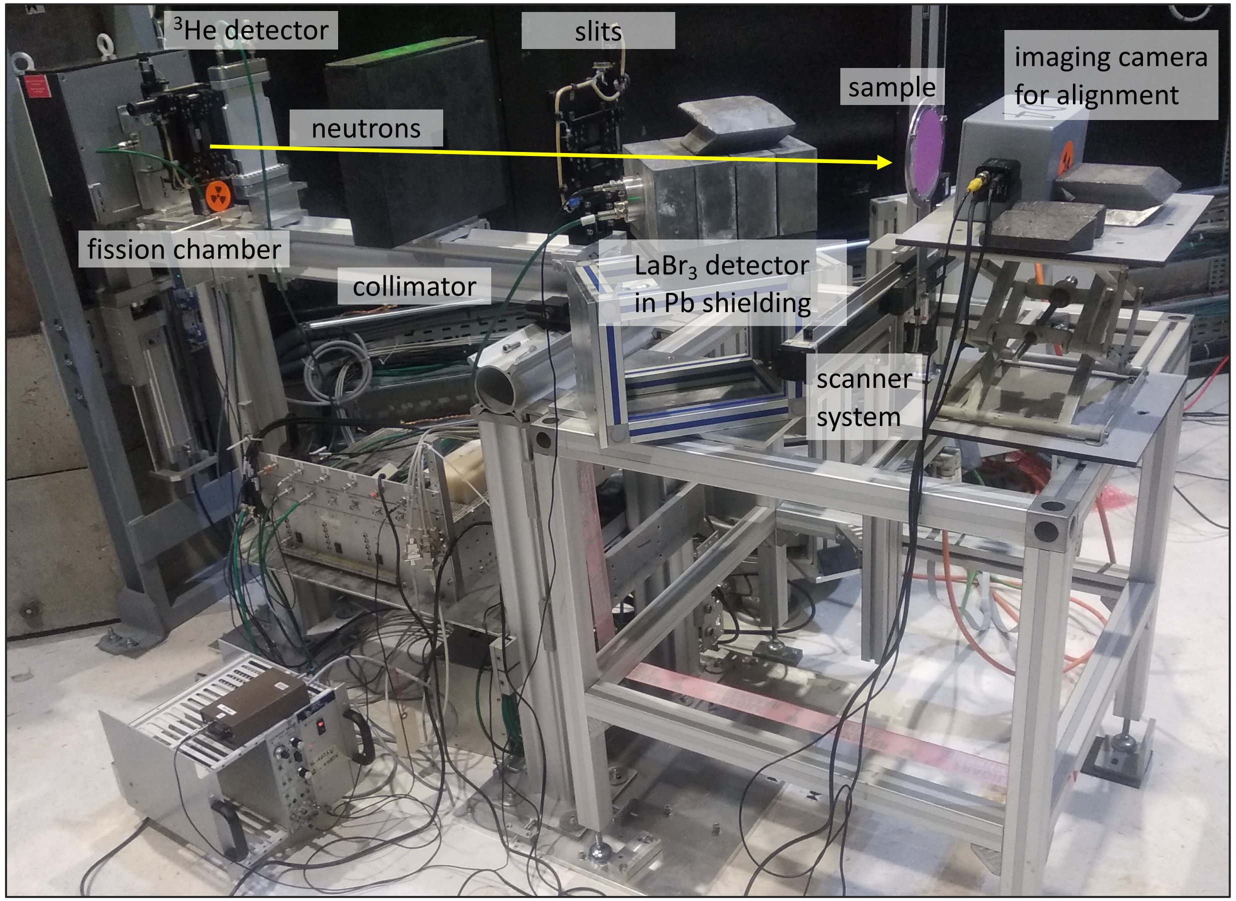


M. Diakaki et al. NIMA 903 (2018) 4

^{10}B samples from JRC-Geel at ILL

- Preparation ^{10}B samples at JRC for neutron to charged-particle converter
- Measurement of sample characteristics using thermal neutrons at ILL



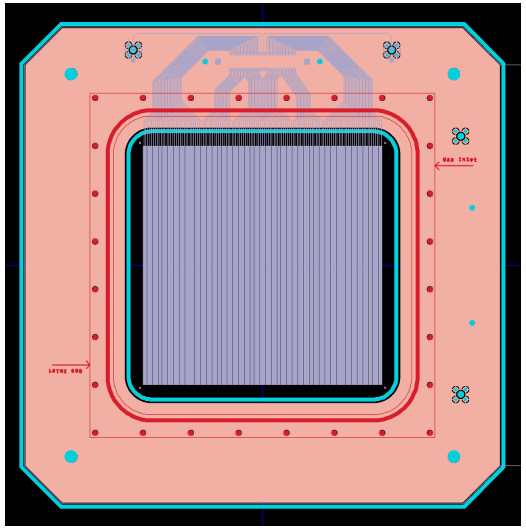


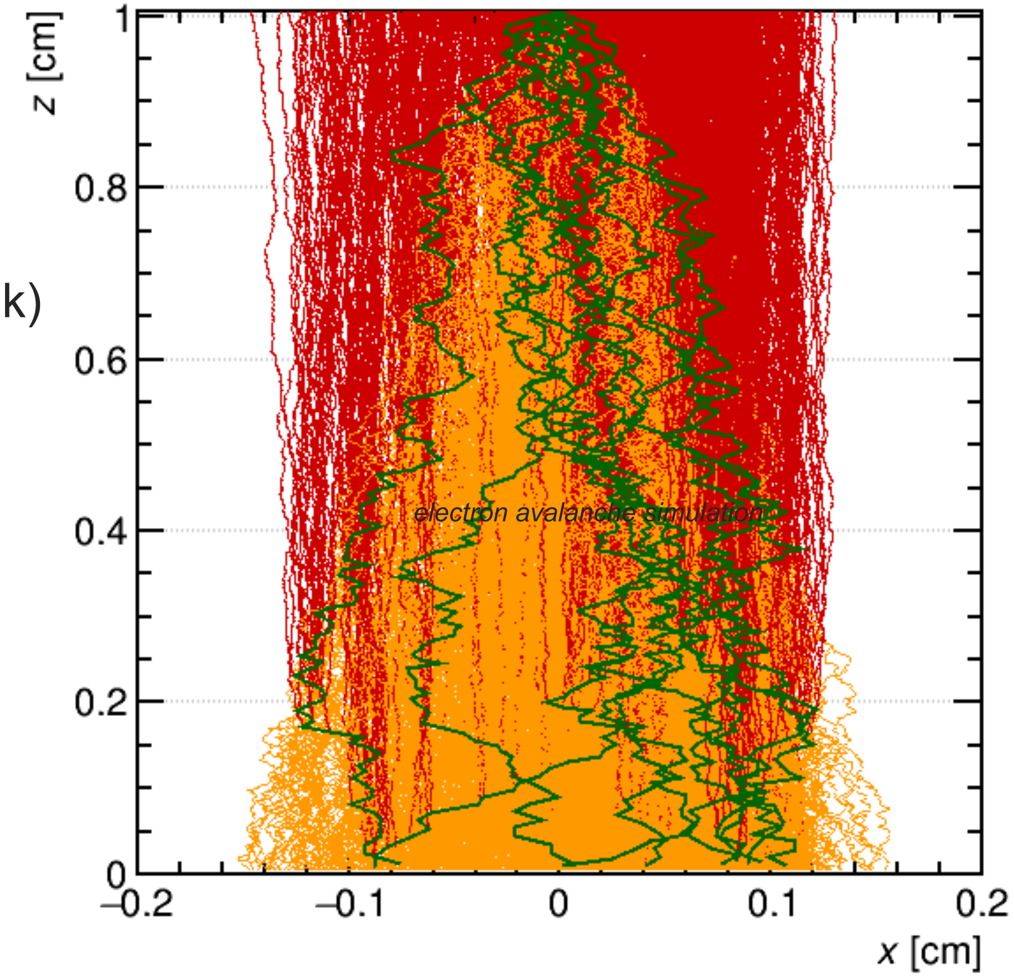
Technical Report IRFU-24-02

XyMegas detector

- Extensive detector simulations of response, gain and tracks
- Full SRS-VMM3 system with two hybrids (2 x 128 channels
- Design final detector finalized and ordered from CERN (microbulk)

SRS-VMM3 system at Saclay


part of the final detector design (2D gerber view)



XyMegas, data acquisition

- VMM3 hybrids produce a data stream over ethernet, captured by the receiving acquisition computer. Files in **pcapng** format, very compact

- Existing VMM3 software available but without time-of-flight implementation. After discussion with authors, we implemented time of flight ourselves using the NIM input for T_0 triggers.

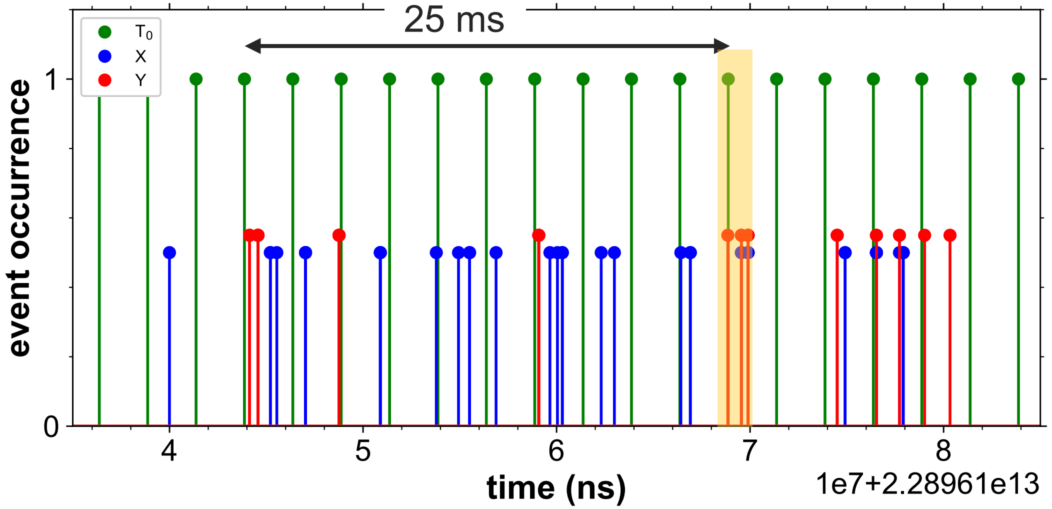
- We keep all raw data in **pcapng** without intermediate ROOT trees, then only processed data in form of histograms in ROOT files

- time scales for TOF measurements:
  1 ns sampling time during 100 ms time window (10^8 bins)

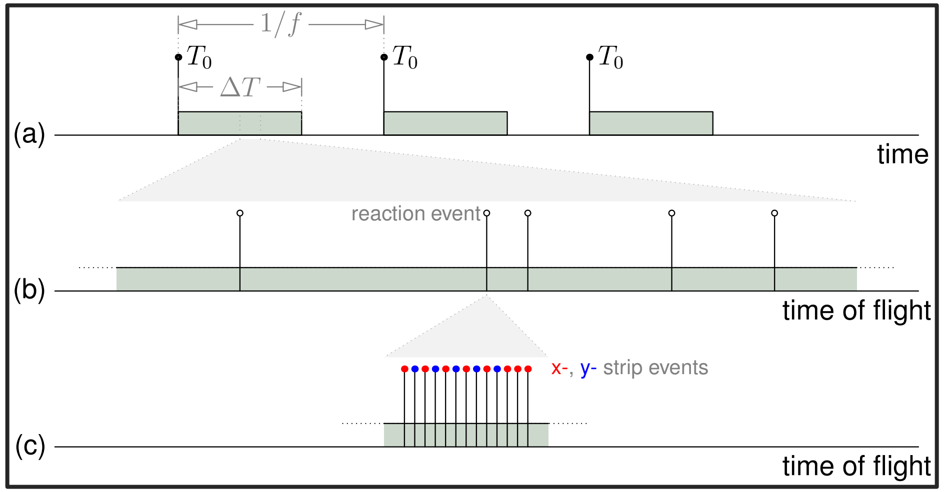
- Use specific MicroMegas readout and acquisition chip VMM3, developed for ATLAS-NSW (I. Iakovidis) --> P2

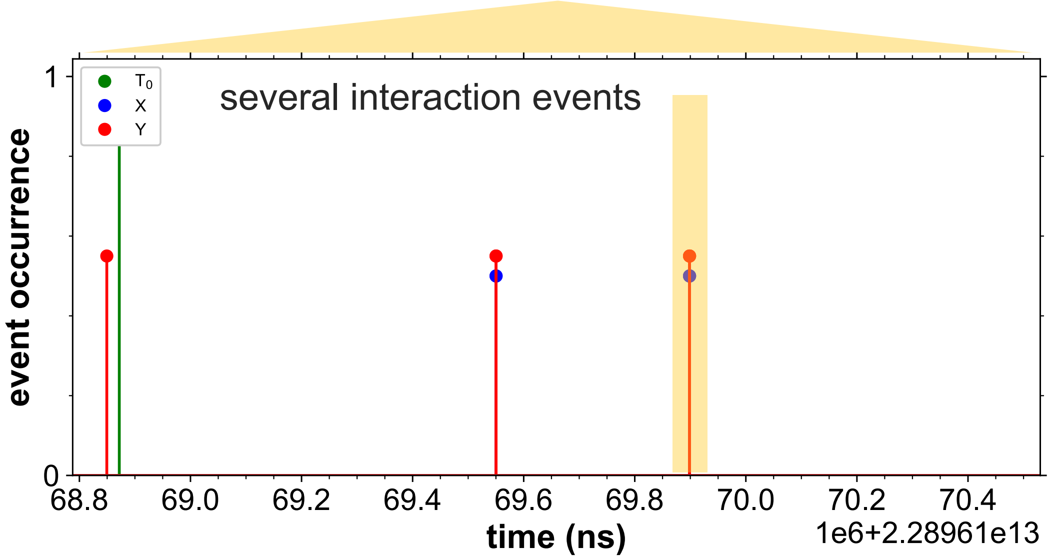
Event time structure, X, Y, T_0

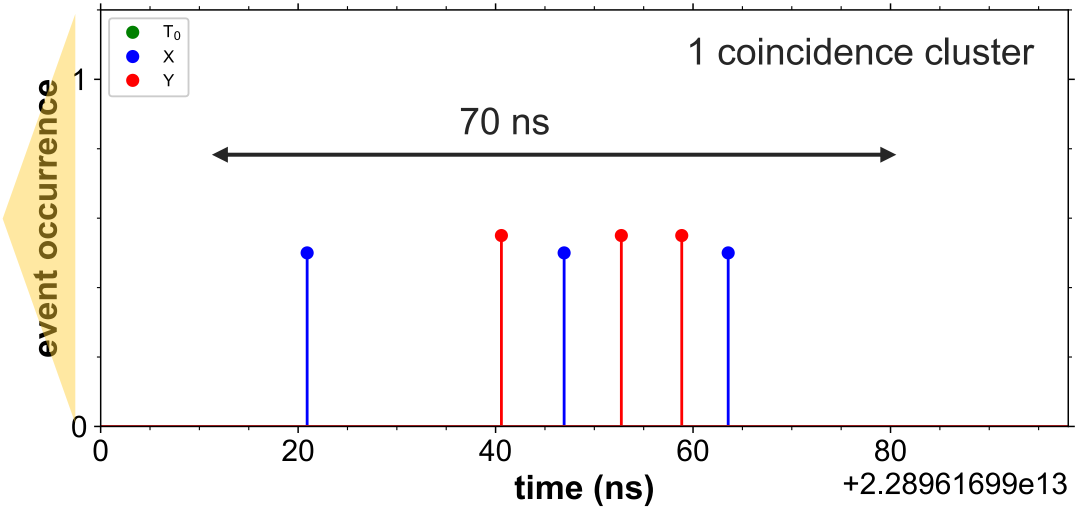
real data



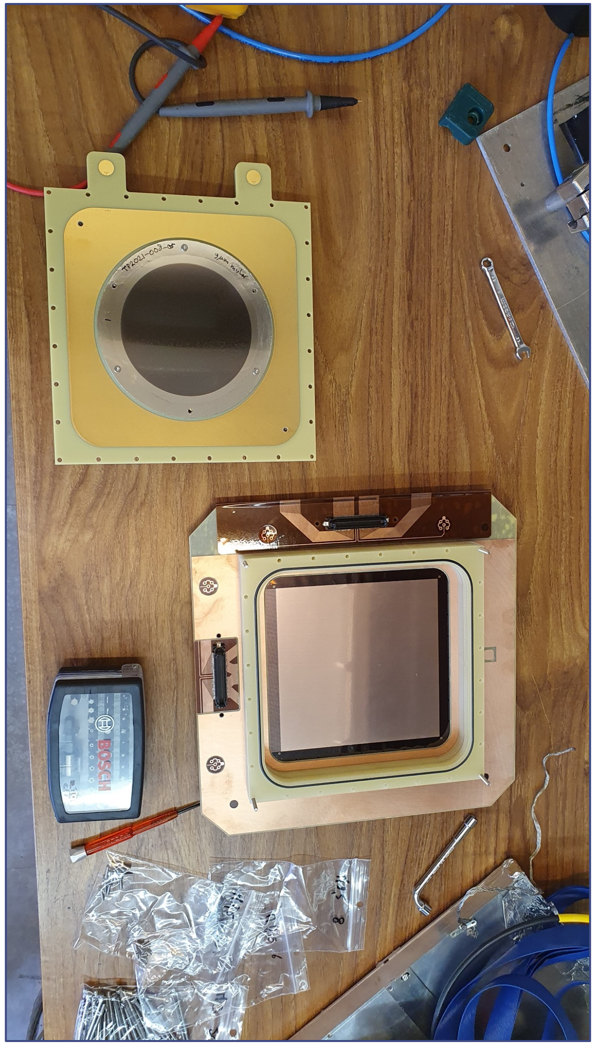
schematic view

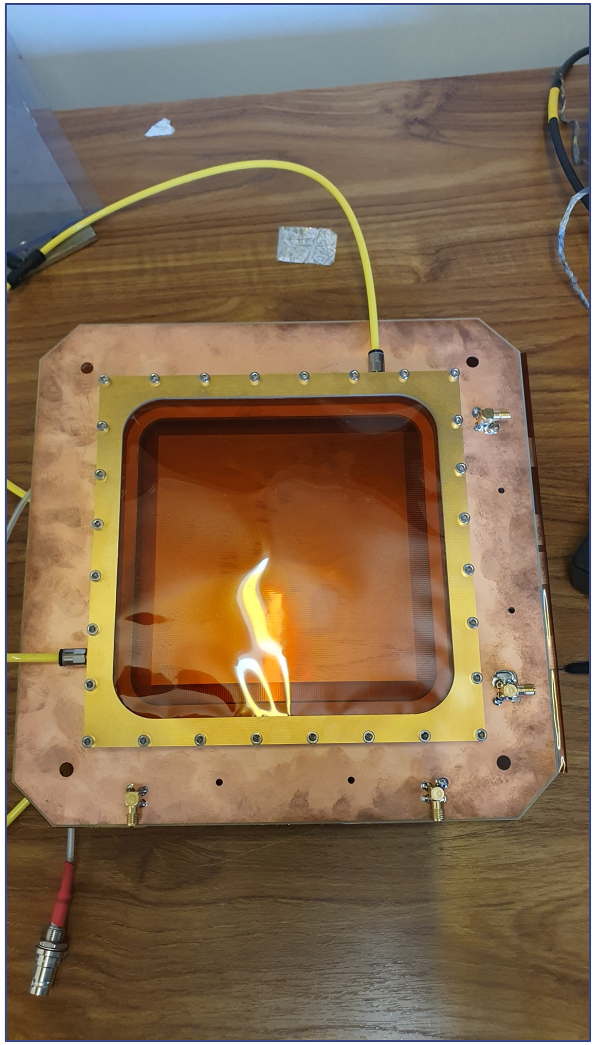


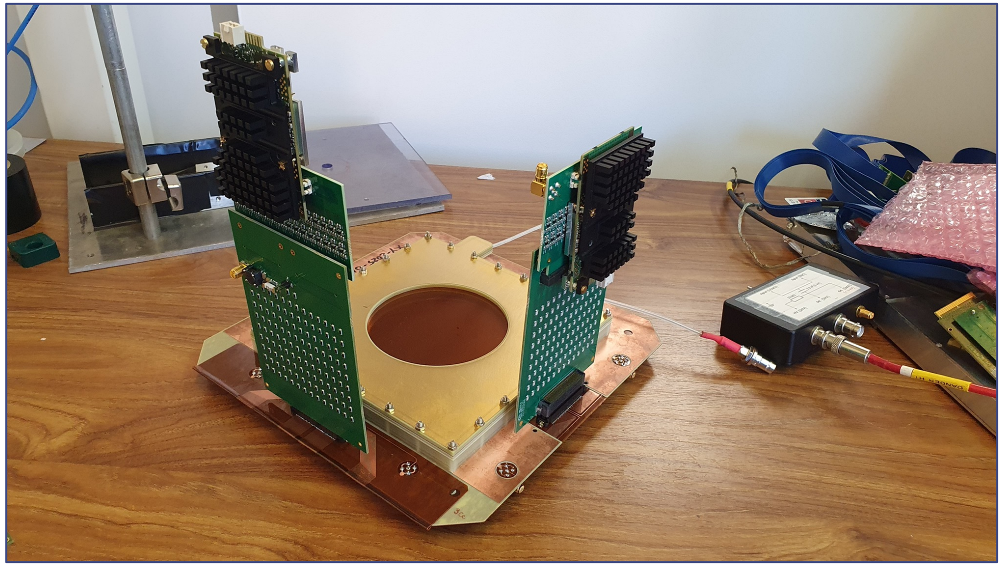


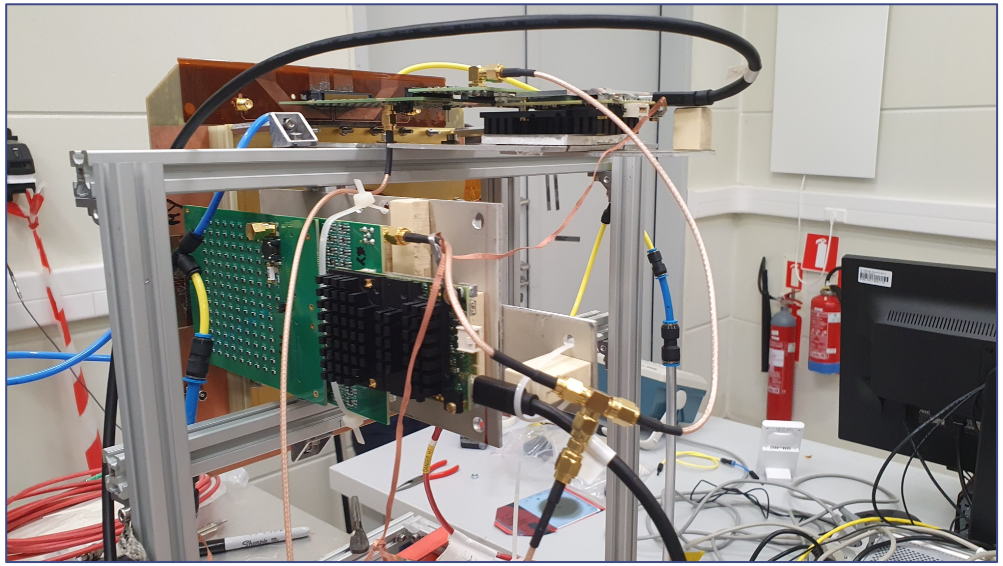


New XyMegas detector

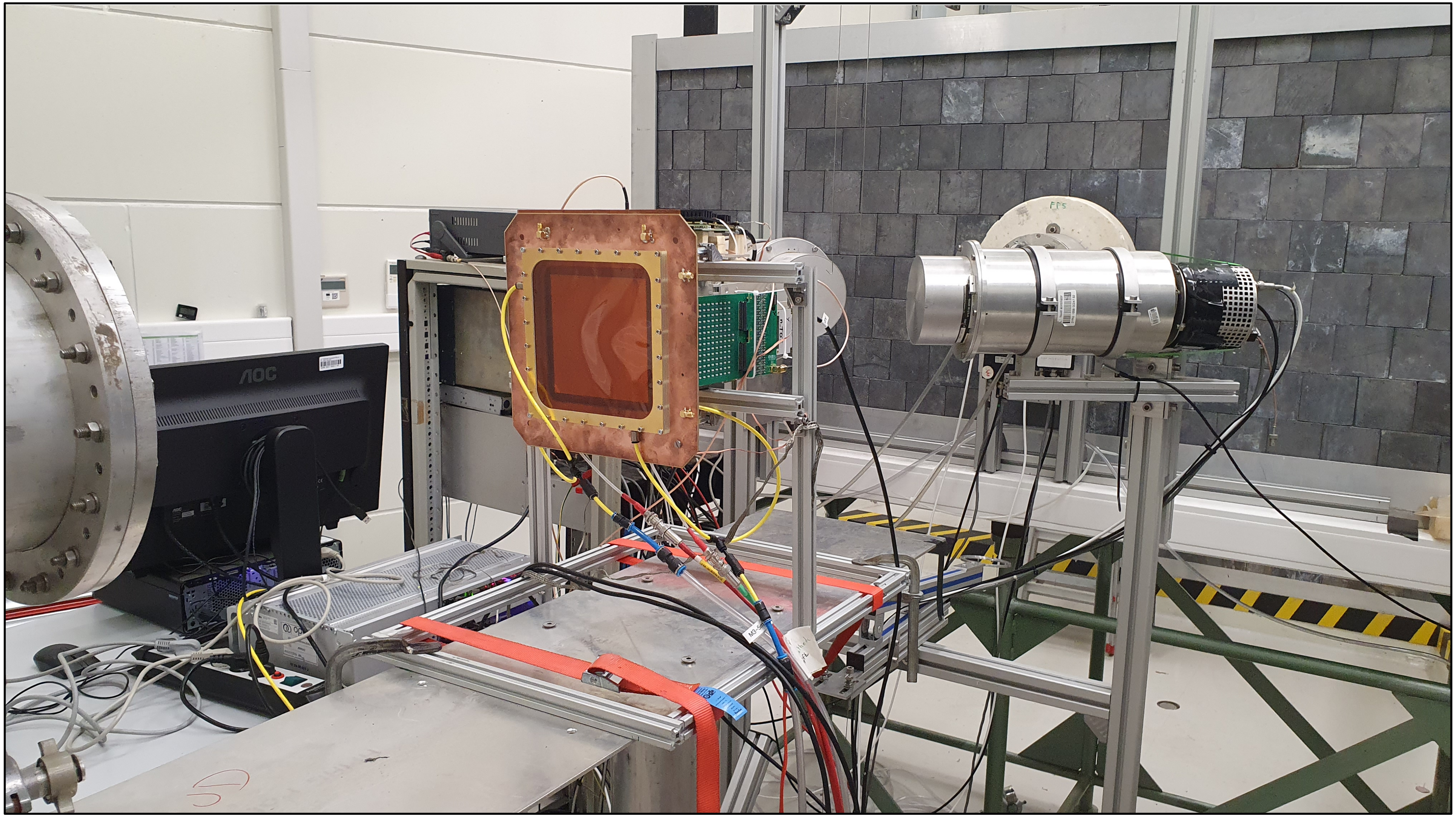




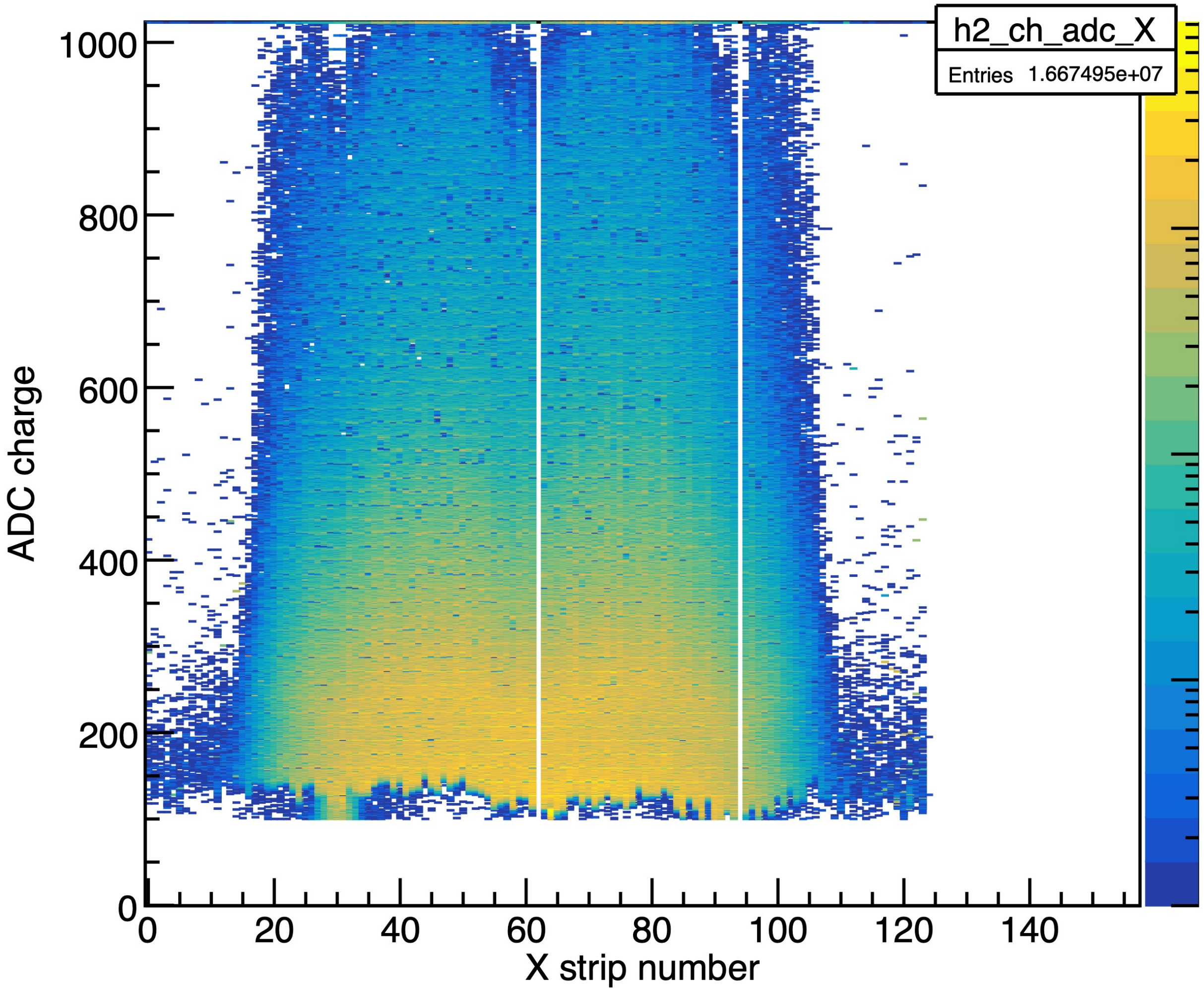


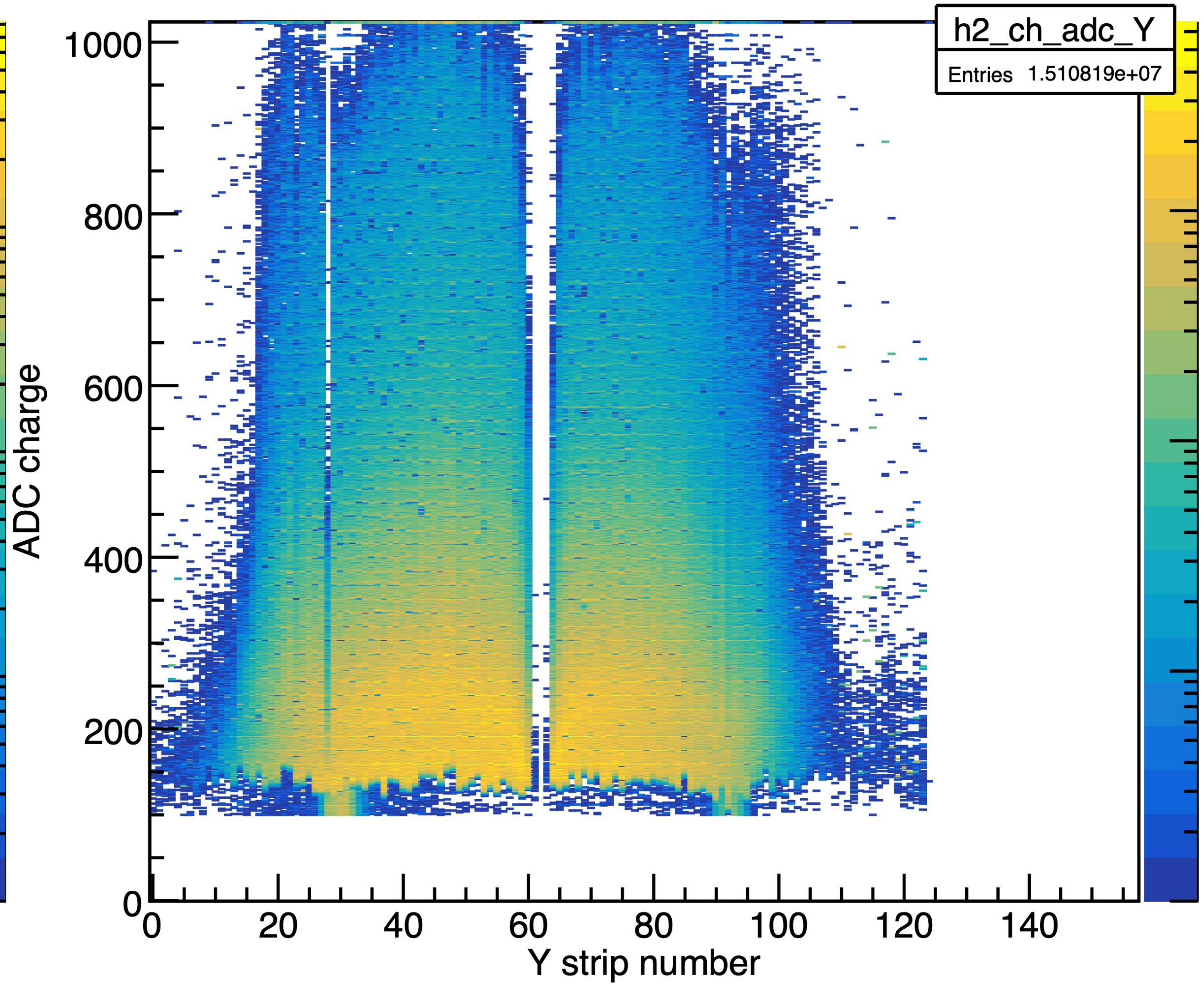


XyMegas setup at JRC-Geel



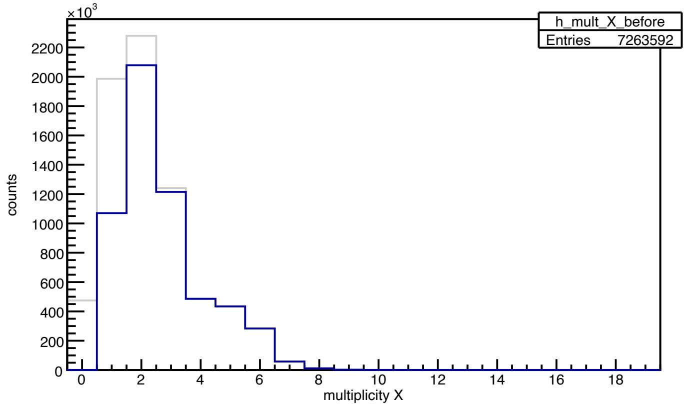
Charge distribution per strip

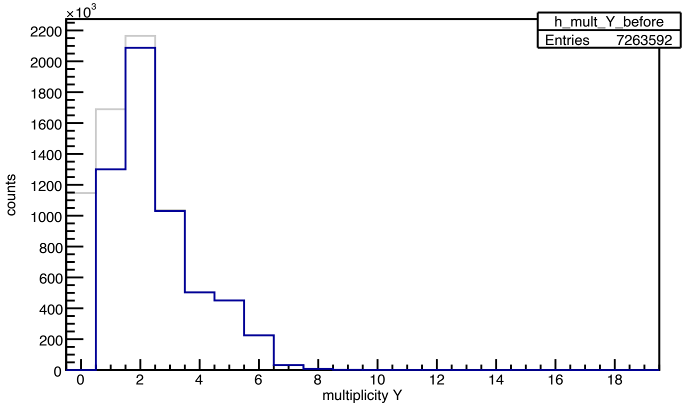


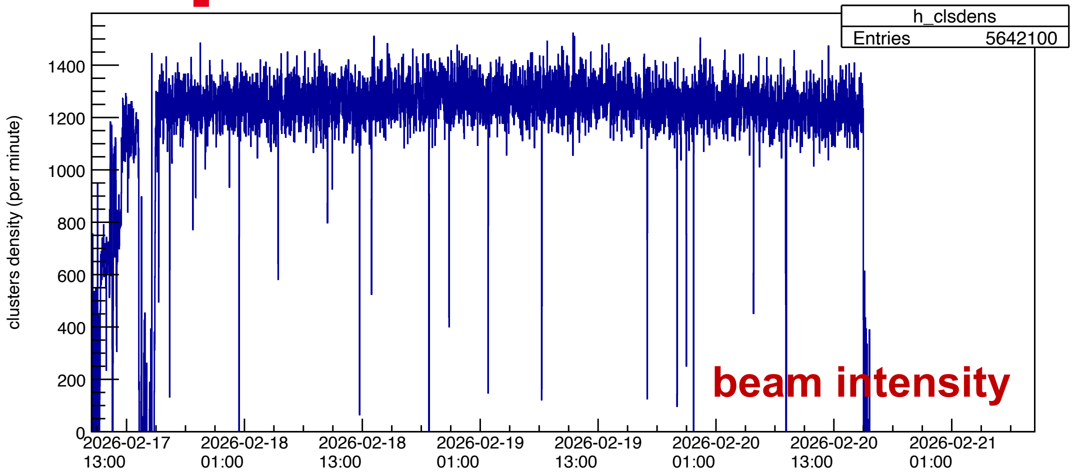


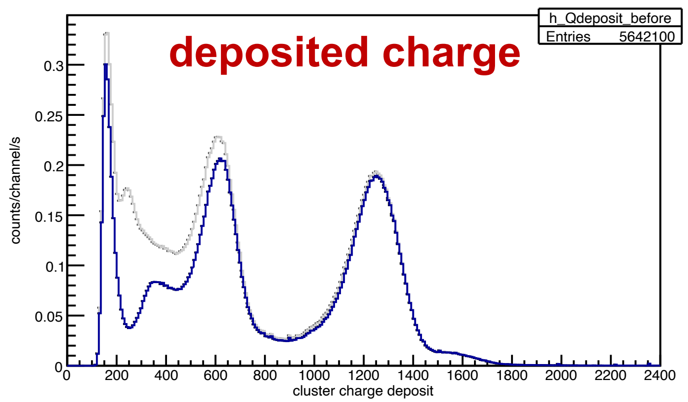
Total charge deposition, charge, ratio, multiplicity beam intensity, neutron spectrum

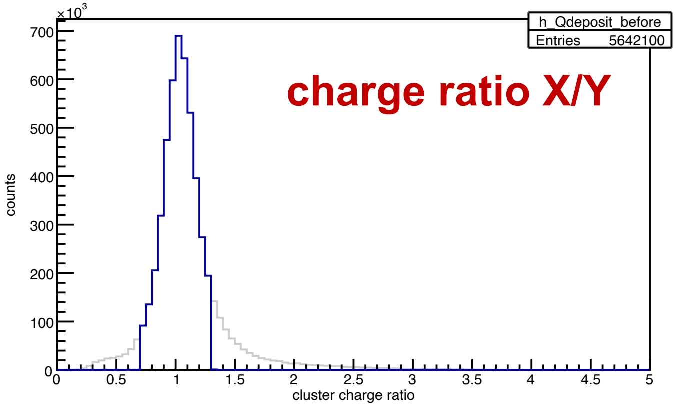
hit multiplicity in X, Y

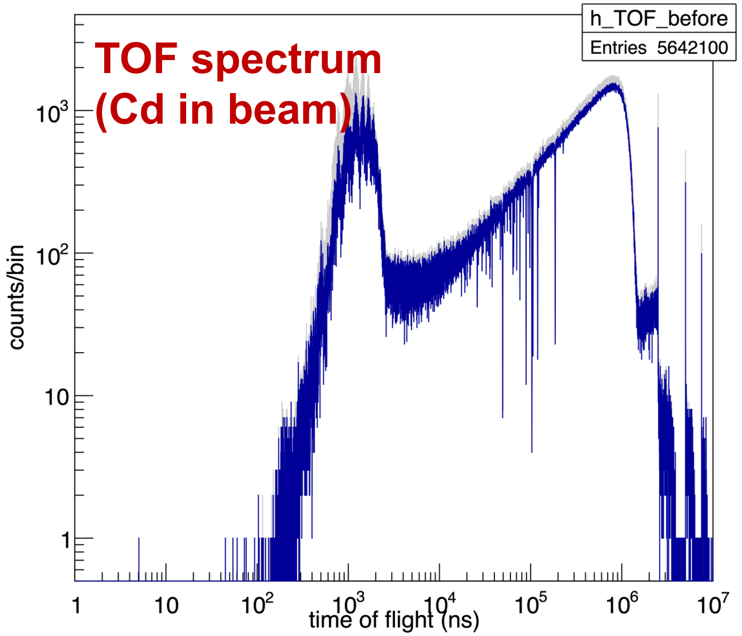




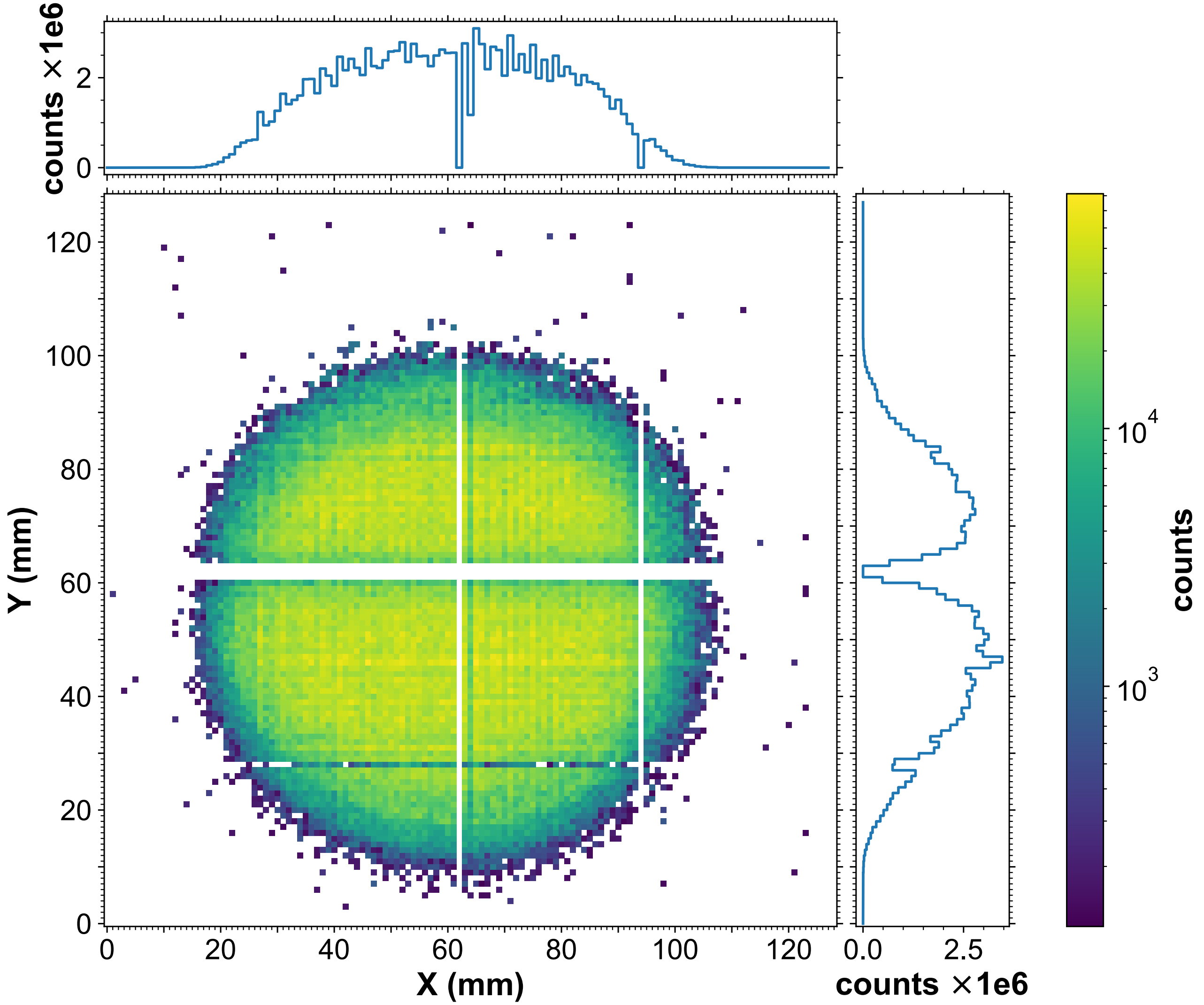




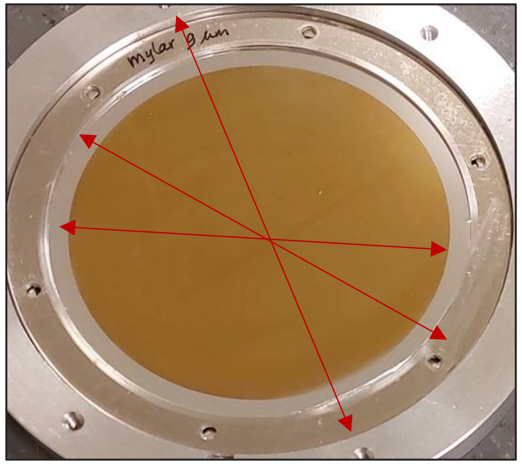




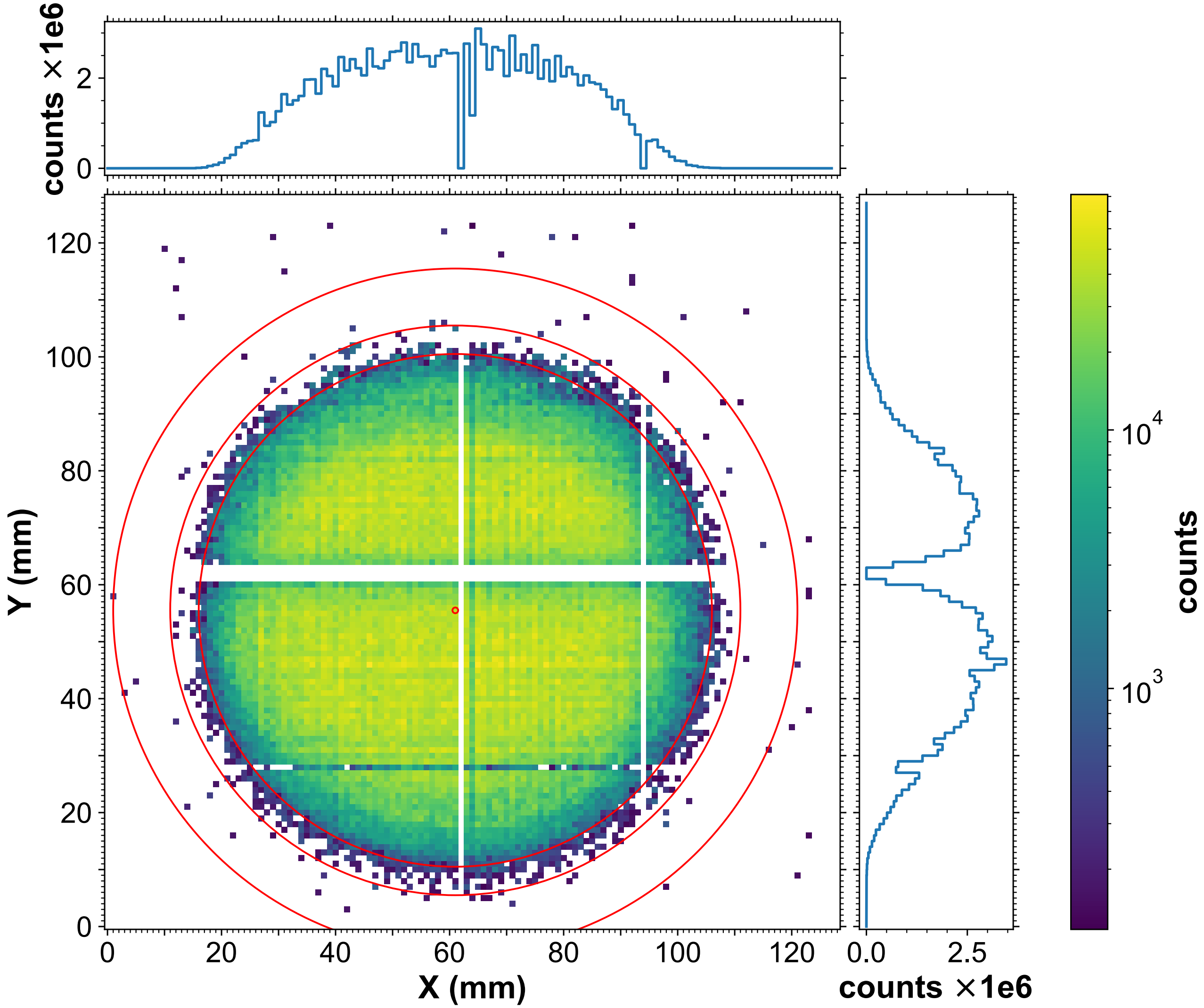
Beam image from coindicent events



Beam image from coindicent events

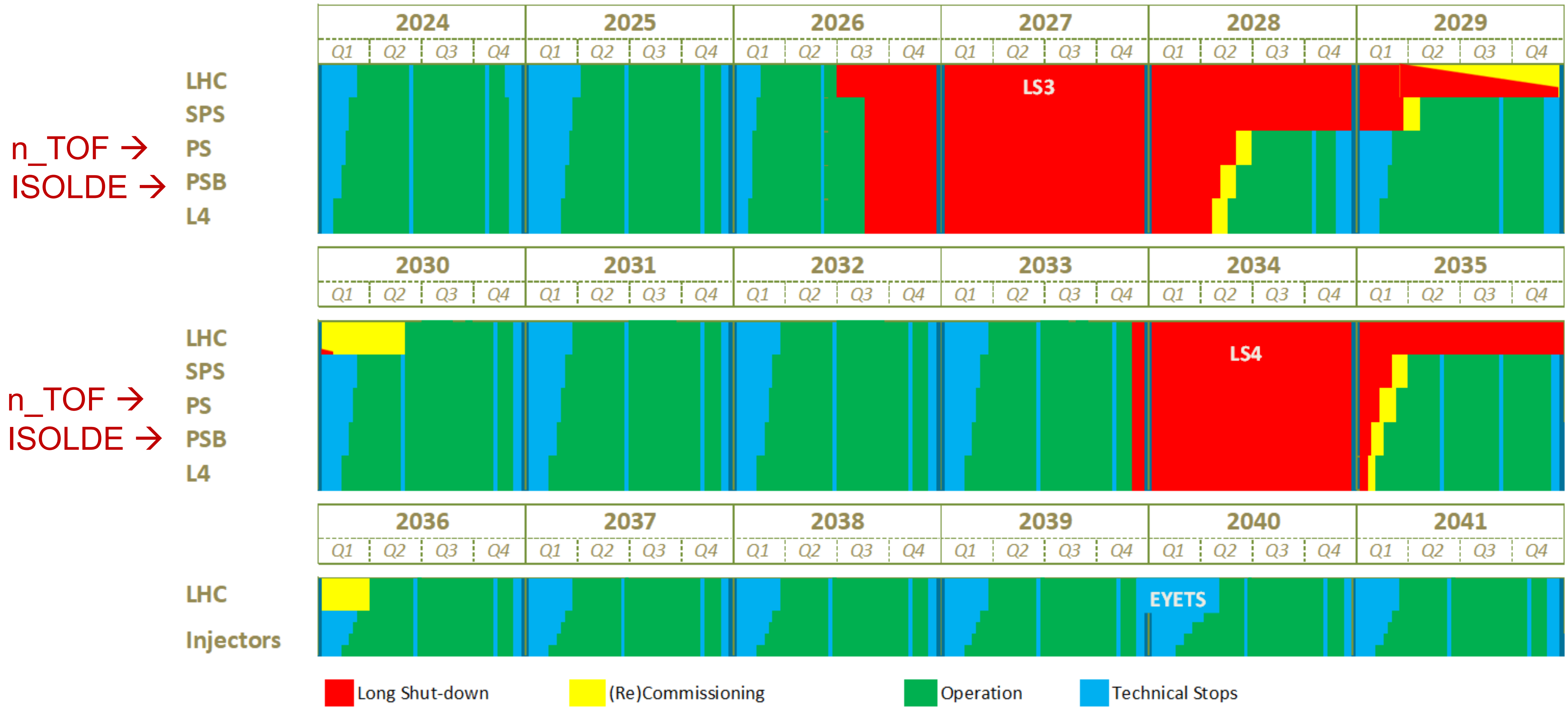


90-100-120 mm



DPhN at n_TOF, the future

Future of n_TOF: CERN's accelerator schedule



from: https://edms.cern.ch/document/2311633/5.0 (2025-02-19)

DPhN at n_TOF synthesis discussion latest JEFF meeting

In order to improve the predictions of the simulation codes, the capture cross section of the following isotopes should be investigated further in the resonance ranges.

- Cesium: ^{133}Cs (stable), ^{134}Cs (2 y), ^{135}Cs (2x10^{6} y), ^{137}Cs (30 y)
- Neodymium: ^{143}Nd (stable), ^{145}Nd (stable), ^{147}Nd (11 days…)
- Promethium: ^{147}Pm (3 y), there is no stable isotopes
- Samarium: ^{147}Sm (stable), ^{149}Sm (stable), ^{150}Sm (stable), ^{151}Sm (90 y), ^{152}Sm (stable)
- Europium: ^{151}Eu (stable), ^{153}Eu (stable), ^{154}Eu (9 y), ^{155}Eu (5 y)
- Gadolinium: ^{154}Gd (stable), ^{155}Gd (stable)

DPhN at n_TOF

- Demands not only from HPRL, also from evaluators (JEFF meetings)
  - challenges in accuracy and / or difficulty
  - improvements nuclear reaction models (LD, PSF)

- Feedback from irradiation experiments (burn-up, post-irradiation analyses)

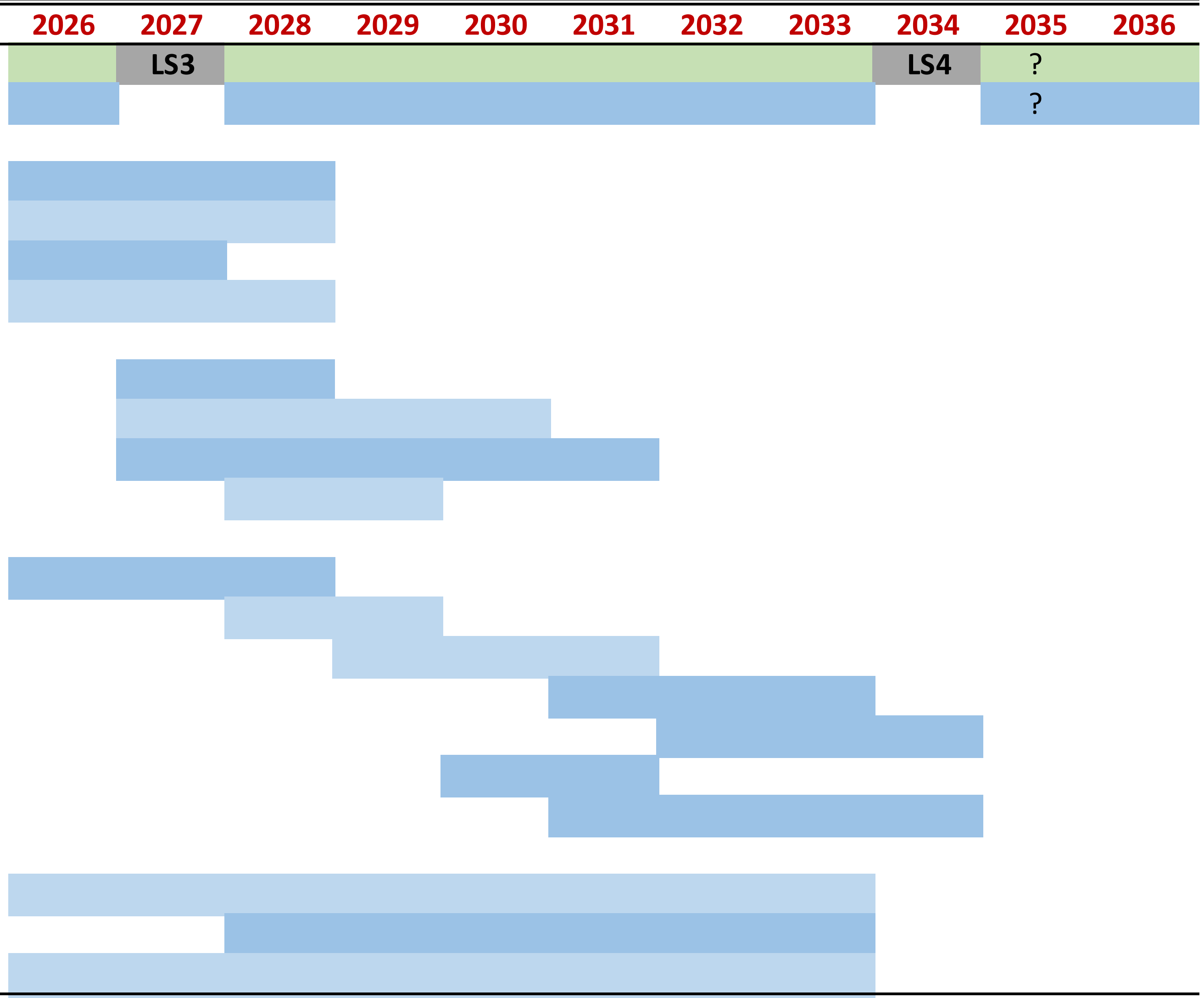
- Improvements on (absorbing) fission product capture cross sections
  - ^{103}Rh(n,γ), ^{151,153}Eu(n,γ) (stable)
  - feasibility production ^{154,155}Eu(n,γ) (8.6 / 4.7 y)

- Cross sections for new applications (eutectic neutron production targets)
  - ^{113,115}In(n,γ) (stable)

- Opportunities
  - ^{238}Pu(n,f) (samples JRC for DAM)

One possible roadmap for DPhN at n_TOF

priority	
	CERN n_TOF operation
● high	n_TOF experimental programme
● ongoing	data analysis and publication Pu241 (APRENDE)
● ongoing	data analysis and publication Sr87(n,γ)
● ongoing	data analysis and publication XyMegas
● ongoing	development neutron detector for transmission (APRENDE)
● medium	Additional data taking XyMegas, JRC
● low	Detector development XyMegas dΩ
● low	Detector development MMegas (n,lcp)
● low	Neutron detector in-beam transmission n_TOF EAR1
● high	Exploration thermal region n_TOF EAR2
● medium	Possible measurement Rh103(n,γ) stable
● medium	Analysis Rh103(n,g)
● high	Possible measurement Eu(151),153(n,γ) stable
● high	Analysis Eu153(n,g)
● medium	Possible measurement In113,115(n,γ) stable
● medium	Analysis In113,115(n,g)
● medium	Feasibility Eu154,155(n,γ) 8.6 / 4.7 y
● high	Possible measurement Pu238(n,f) 88 y
● medium	Any unstable nucleus in sufficient purity and quantity (n,γ)



DPhN at n_TOF

- Team DPhN, current and recent members:
  - **staff** Eric Berthoumieux, Emmeric Dupont, Frank Gunsing
  - **post-docs** Michele Spelta, Georgios Tsiledakis, Gurpreet Kaur
  - **PhDs** Aline Cahuzac, Michael Bacak, Javier Moreno Soto

- Regular help from DEDIP: David Baudin, Thomas Papaevangelou, Esther Ribas-Ferrer, many others

- Not sufficient manpower for full roadmap. Priority always to high-quality measurements

- Continued fund seeking for PhD and post-docs

- Securing the future involvement of DPhN in n_TOF or similar activities needs attention

- Request to DEDIP
  - keep lab space in 534/37
  - maintain occasional support (electronics, workshop)
  - technical support for optical fibre / SiPM project
    (help with assembly or with purchase off-the-shelf material)

Conclusion (1/2)

- Long-standing involvement of DPhN in nuclear data, in particular neutron-induced cross section measurements| and related quantities.

- Mainly at the two high-resolution white pulsed neutron sources in Europe
    - GELINA (JRC-Geel)
    - n_TOF (CERN-Geneva)

  and occasionally at other facilities, like NFS at Ganil-Caen)

- At n_TOF, several responsibilities within the collaboration. In addition, regularly SP for experiments.

- Recurrent issue is sample (target) availability (orders of magnitude **μg – mg – g** depending on type of xs)

- External funding (2018-2026)
    - European programs (CHANDA, SANDA, EURO-LABS, APRENDE)
    - National funding (ANR, NEEDS-NACRE)
    - Institutional funding (P2IO, CFR)

Conclusions (2/2)

- Short term plans
  - **2026:** running from 5-2-2026 to 31-8-2026
  - all experiments already approved by the INTC

- LS3 for n_TOF (2027)
  - several technical improvements/updates (including FIRIA) and DAQ upgrades
  - considerable amount of data to be analyzed
  - preparing an outline of possible experiments for phase V (2028-2033)

- Between LS3 and LS4, and post-LS4
  - experimental program with focus on nuclear astrophysics, advanced nuclear technologies and basic nuclear science and applications
  - plan construction of next generation spallation target
  - planning of the post-LS4 experimental program

- Possible future initiative at CERN **n_ACT@BDF** (**SPS**, note: n_TOF depends on **PS**)
  Irradiation facility, similar to n_TOF-NEAR, for flux-integrated cross sections $\int\sigma(E)\phi(E)dE$

- Main focus DPhN on high resolution time-of-flight measurements $\sigma(E_n)$

The n_TOF Collaboration in 2026

O. Aberle[1], V. Alcayne[2], S. Amaducci[3], V. Babiano-Suarez[4], M. Bacak[5], J. Balibrea-Correa[4], J. Bartolomé[6], A. Basavaraja-Allannavar[7], A. P. Bernardes[1], E. Berthoumieux[8], R. Beyer[9], M. Birch[10], S. E. Birincioglu[11], M. Boromiza[12], D. Bosnar[13], B. Brusasco[7], M. Caamaño[14], A. Cahuzac[8], F. Calviño[7], M. Calviani[1], D. Cano-Ott[2], A. Casanovas[7], D. M. Castelluccio[15,16], F. Cerutti[1], G. Cescutti[17,18], E. Chiaveri[1,10], G. Claps[19], P. Colombetti[20,21], N. Colonna[22], P. Console Camprini[15,16], G. Cortés[7], M. A. Cortés-Giraldo[6], L. Cosentino[3], S. Cristallo[23,24], A. D'Ottavi[10], G. de la Fuente Rosales[4], M. Diakaki[25], M. Di Castro[1], A. Di Chicco[26], M. Dietz[26], C. Domingo-Pardo[4], E. Dupont[8], I. Durán[14], Z. Eleme[27], S. Fargier[1], M. Farkas[1], B. Fernández-Domínguez[14], P. Finocchiaro[3], W. Flanagan[28], V. Foteinou[27], V. Furman[29], B. Gameiro[4], A. Gandhi[12], F. García-Infantes[11], A. Gawlik-Ramięga [30], G. Gervino[20,21], S. Gilardoni[1], E. González-Romero[2], S. Goula[27,1], E. Griesmayer[5], C. Guerrero[6], F. Gunsing[8], C. Gustavino[31], J. Heyse[32], W. Hillman[10], E. Jacoby[28], D. G. Jenkins[33], E. Jericha[5], A. Junghans[9], U. Köster[34], Y. Kadi[1], N. Kalantar-Nayestanaki[35], K. Kaperoni[25], M. Kavatsyuk[35], M. Kokkoris[25], S. A. Kopanos[25], Y. Kopatch[29], M. Krtička[36], N. Kyritsis[25], C. Lederer-Woods[11], J. Lerendegui-Marco[4], G. Lorusso[37], A. Manna[1], T. Martínez[2], M. Martínez-Cañada[38], A. Masi[1], C. Massimi[16,39], P. Mastinu[40], M. Mastromarco[22,41], E. A. Maugeri[42], A. Mazzone[22,43], E. Mendoza[2], A. Mengoni[15,16], V. Michalopoulou[25], P. M. Milazzo[17], J. Moldenhauer[28], R. Mucciola[22], E. Musacchio González[40], A. Musumarra[44,45], A. Negret[12], E. Odusina[11], D. Papanikolaou[44], C. Paradela[32], A. Parmenter[28], N. Patronis[27], J. A. Pavón[6], M. G. Pellegriti[44], P. Pérez-Maroto[7], A. Pérez de Rada Fiol[2], G. Perfetto[22], J. Perkowski[30], C. Petrone[12], N. Pieretti[16,39], L. Piersanti[23,24], E. Pirovano[26], I. Porras[38], J. Praena[38], J. M. Quesada[6], R. Reifarth[46], A. Reina[6], D. Rochman[42], Y. Romanets[47], A. Rooney[11], G. Rovira[48], C. Rubbia[1], A. Sánchez-Caballero[2], N. Sánchez-Vázquez[14], R. N. Sahoo[16], U. Salma[22], D. Scarpa[40], A. G. Smith[10], N. V. Sosnin[10], M. Spelta[17,18], K. Stasiak[30], G. Tagliente[22], A. Tamburrino[19], A. Tarifeño-Saldivia[4], D. Tarrío[49], P. Torres-Sánchez[4], G. Tsiledakis[8], S. Valenta[36], P. Vaz[47], G. Vecchio[3], D. Vescovi[23,24], V. Vlachoudis[1], R. Vlastou[25], A. Wallner[9], C. Weiss[5], T. Wright[10], R. Wu[33], R. Zarrella[16], P. Žugec[13]

2026: 153 members from 43 institutes