n_TOF Physics Report

72nd INTC meeting, CERN, 08/2/2023

Oliver Aberle, Ana - Paula Bernardes & Nikolas Patronis
for the n_TOF Collaboration

2023 n_TOF planning (already approved)

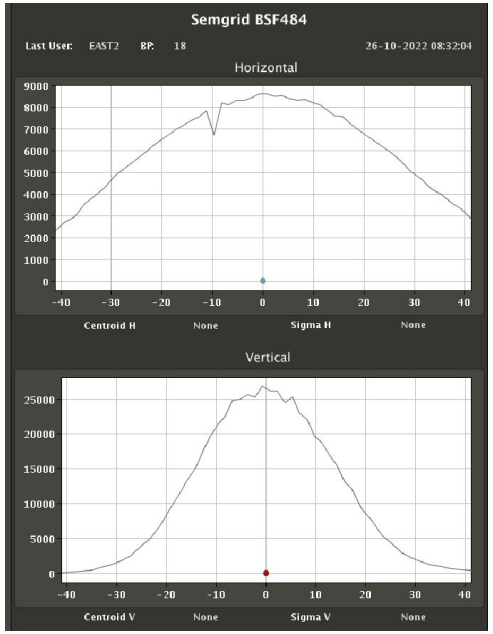
reaction/activity	motivation	setup	experimental area	INTC proposal
^{243}Am(n,f)	Nuclear Technology	uMegas	EAR1 & EAR2	INTC-P566
Ta(n,γ)	Nuclear Technology	C6D6 & sTED	EAR1	INTC-P640
^{40}K(n,p/a)	Nuclear Astrophysics	Si telescopes	EAR2	INTC-P641
^{7}Li(n,n') & ^{56}Fe(n,n')	Detector development	HPGe	EAR1	INTC-I-230
^{12}C(n,p)^{12}B & ^{16}O(n,α)^{13}C	Detector development	Si segmented annular nTD detector	EAR1 & EAR2	INTC-P629
^{64}Ni(n,g)	Nuclear Astrophysics	C6D6 & sTED	EAR2	INTC-P208-ADD-2

2023 n_TOF planning (already approved)

reaction/activity	motivation	setup	experimental area	INTC proposal
^{88}Y(n,γ)	Nuclear Astrophysics/ proof of principle	B4C filter & GEAR	NEAR	INTC-P623
neutron flux	commissioning	Diamond	NEAR	INTC-P631
capture setup optimization	commissioning	C_6D_6 sTED	EAR2	INTC-P587
RF & el noise study	commissioning	Si detector	EAR1	INTC-P587

2023 n_TOF proton request & operation

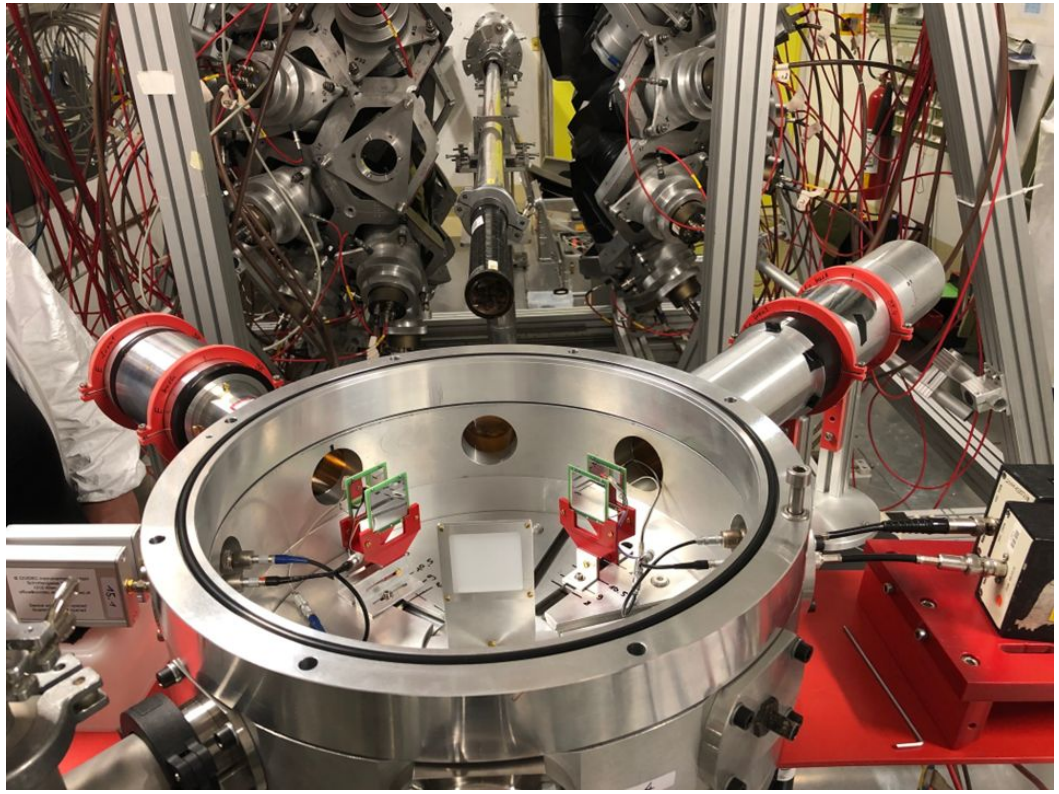
- **2023 Beam for n_TOF (our request: 210E17 or 1E17 protons/day)**
  - 03.04.2023 - for hardware commissioning (7days)
  - 10.04.2023 - Physics Start
  - 30.10.2023 - beam off (203 days of physics)
- **Pulses of different intensities**
  - High intensity (dedicated): 8.5E12 ppp
  - Low intensity (parasitic): 4.5E12 ppp
- **“Fixed” impact point on the lead target for both pulses**
  - ± 5 mm horizontal (centroid)
  - ± 3 mm vertical (centroid)
- **Same (as 2022) spatial profile dimensions of the beam. Thanks to the excellent work done by ABT, OP, BI and RP (+STI), large beam spot on target (and its continuous monitoring via SEM grid) is now available**
- **Proton beam intensity: Raise interlock for avg. intensity from 167e10 p/s to 200-220e10 p/s is technically possible (“homologation” with Tripartite Authority (ASN/OFSP) in the pipeline (TOF-L-SF-0005)**
- **Pulse time length: back to 28 ns (σ ~ 7ns) without “tails” and pre-pulses**



New n_TOF experimental setups: DDX

Neutron induced emission of light charged particles at 100 - 200 MeV is of special interest for medical applications:

- In hadron therapy secondary neutrons are produced with energies up to 200/400 MeV for proton/carbon beams
- Dose calculations require DDX data for (n,p), (n,d), (n,a), …
- Very scarce experimental data even for the most important isotopes: C, N, O



Experimental setup:

- ΔE1 + ΔE2 + E = 51 μm + 1043 μm + 150 mm plastic
- ΔE1 + ΔE2 + E = 49 μm + 507 μm + 3 inch CeBr3
- Target 1 mm and 2.3 mm PE

Test is done: INTC-I-221
First measurement to be discussed within this INTC meeting: INTC-P-651

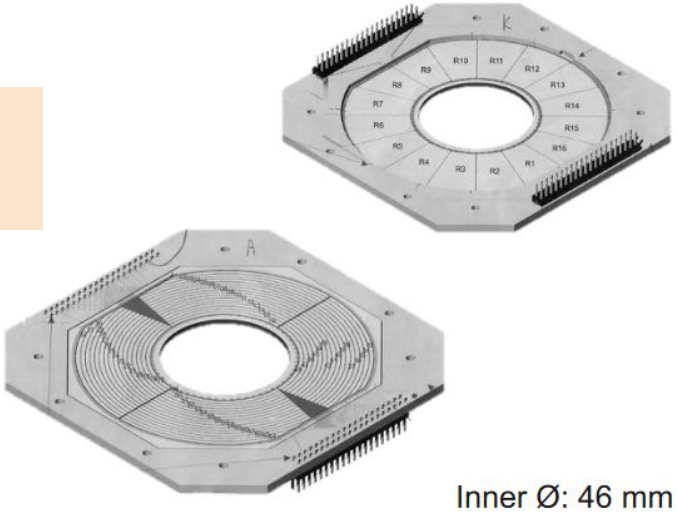
Thanks to M. Dietz, E. Pirovano, R. Nolte, R. Beyer, A. Junghans

New n_TOF experimental setups: SADR

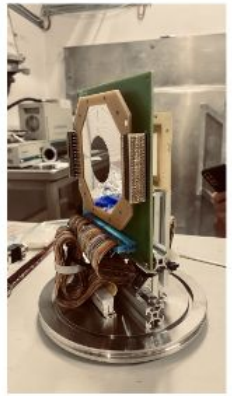
Study of (n,cp) reactions for Nuclear Astrophysics and Nuclear Technology:

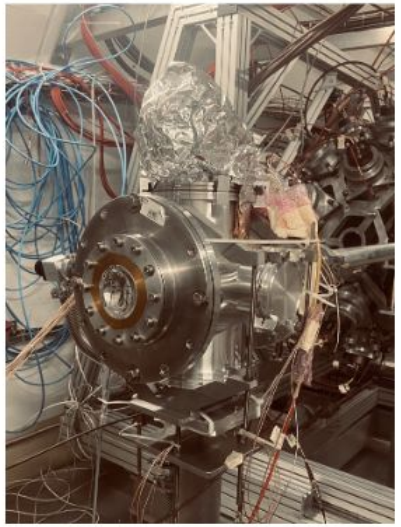
- Lack of experimental data of (n,cp) reaction in low neutron energies
- Long list of “urgently” needed reaction studies (more than 30 isotopes!)
- Go beyond the limitations of the ΔE-E technique using the PSA particle identification technique (applicable between to 2-3 MeV up to tens of MeV neutron energies)
- Determination of the double differential cross section (highly segmented nTD Si detector)

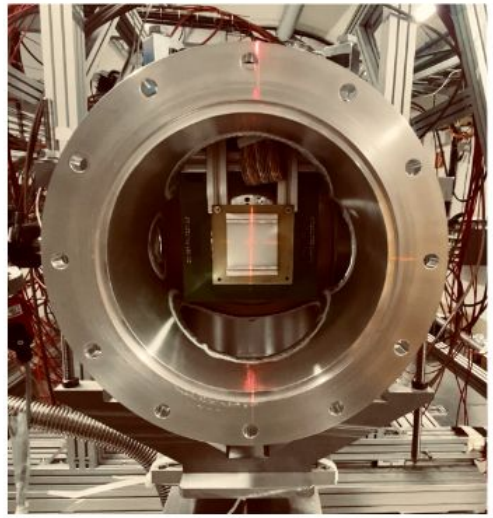
First test and measurement during 2023:
INTC-P-629

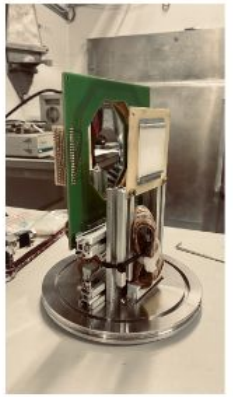


Inner Ø: 46 mm
Outer Ø: 96 mm
Thickness: 305 μm
16 sectors – Rear part
16 strips – Front part





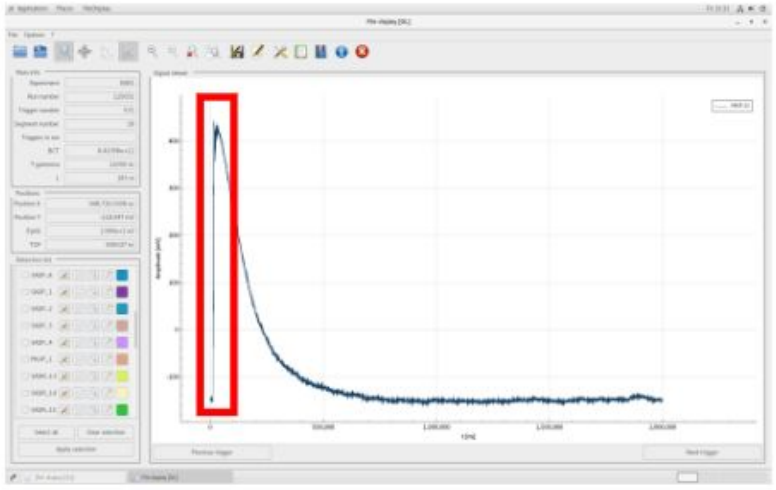


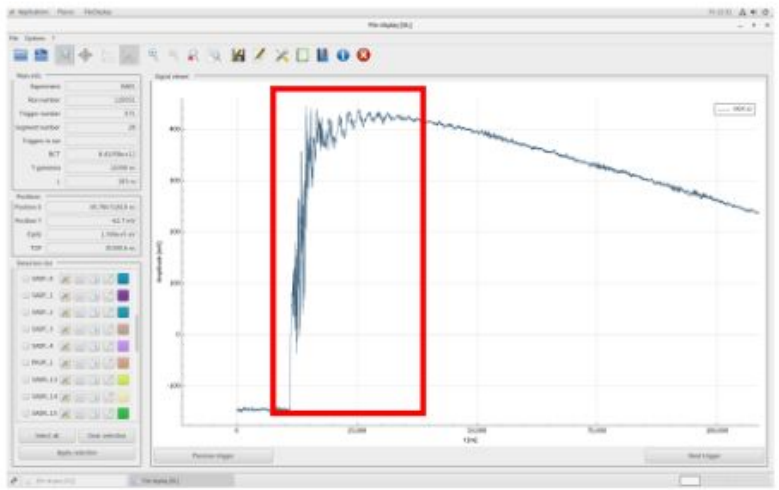


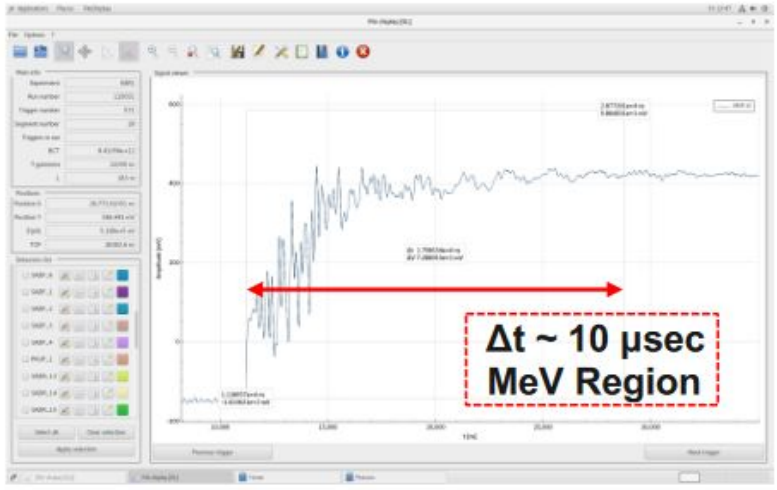
Thanks to S. Amaducci, S. Goula, L. Cosentino, G.Vecchio, …

New n_TOF experimental setups: SADR

Some work is needed to solve the problem with the RF noise present in EAR1







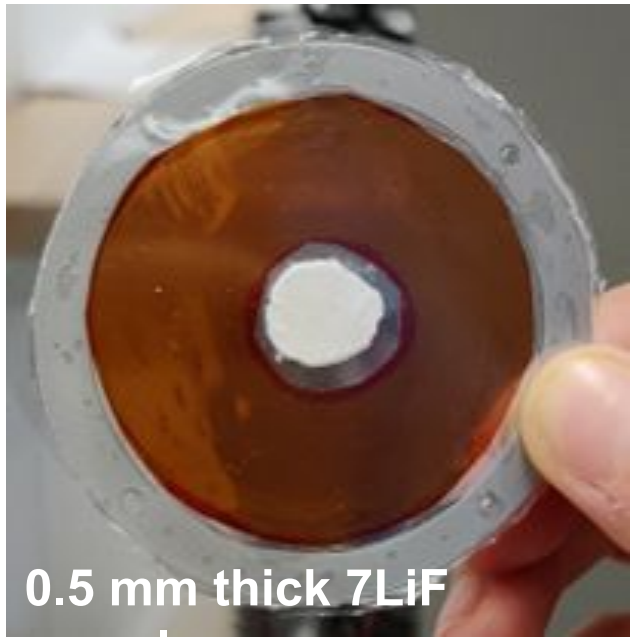
Thanks to S. Amaducci, S. Goula, L. Cosentino, G.Vecchio, …

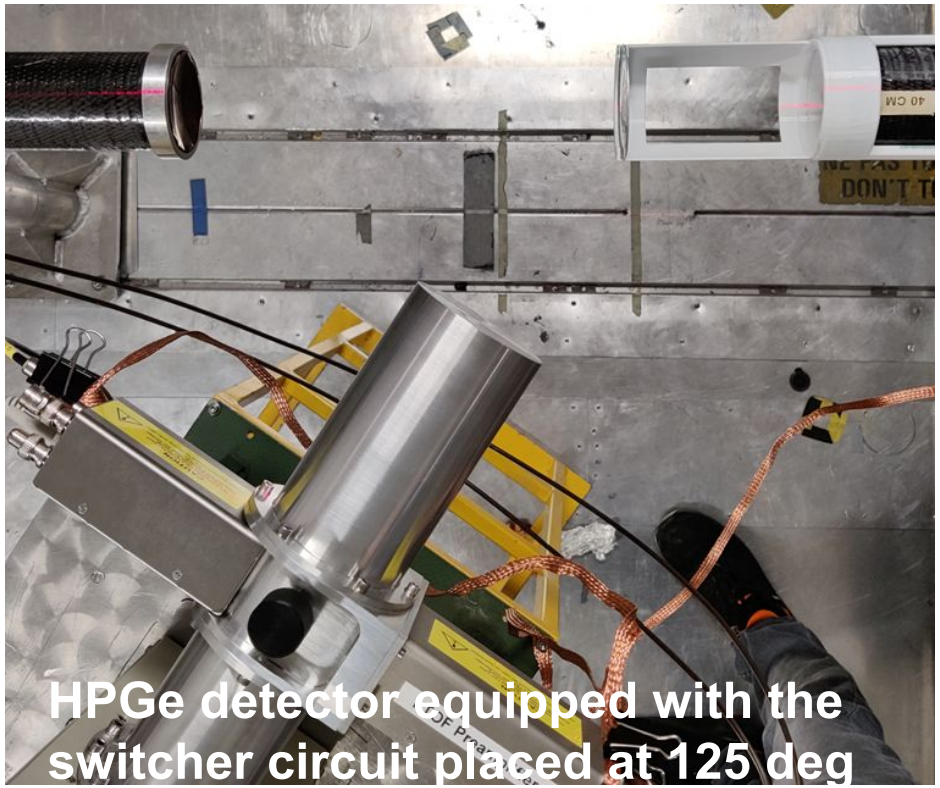
New n_TOF experimental setups: HPGe

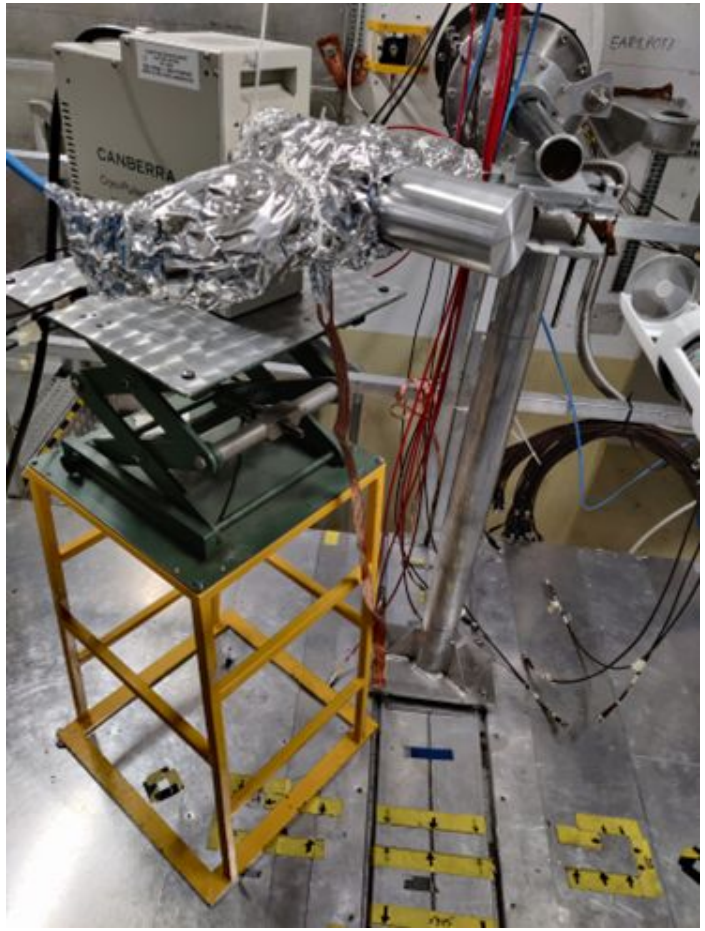
Motivation:

- Study of (n,n') & (n,xn) reactions for basic research and Nuclear Technology
- Fission fragment γ-ray spectroscopy
- n,γ reaction studies

First test and measurement during 2023: INTC-I-230

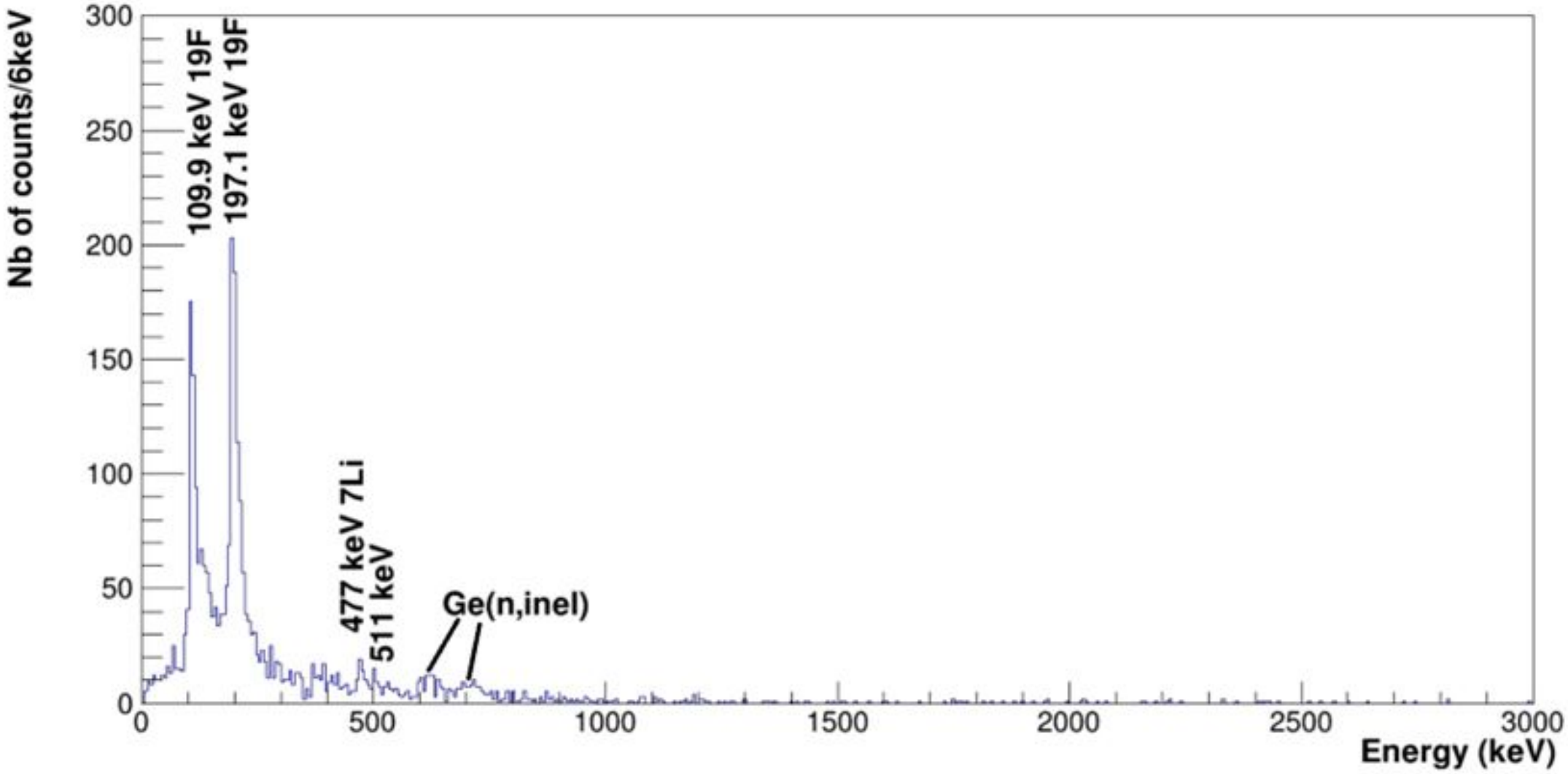






Thanks to M. Bacak, C. Petrone, A. Negret, M. Diakaki, …

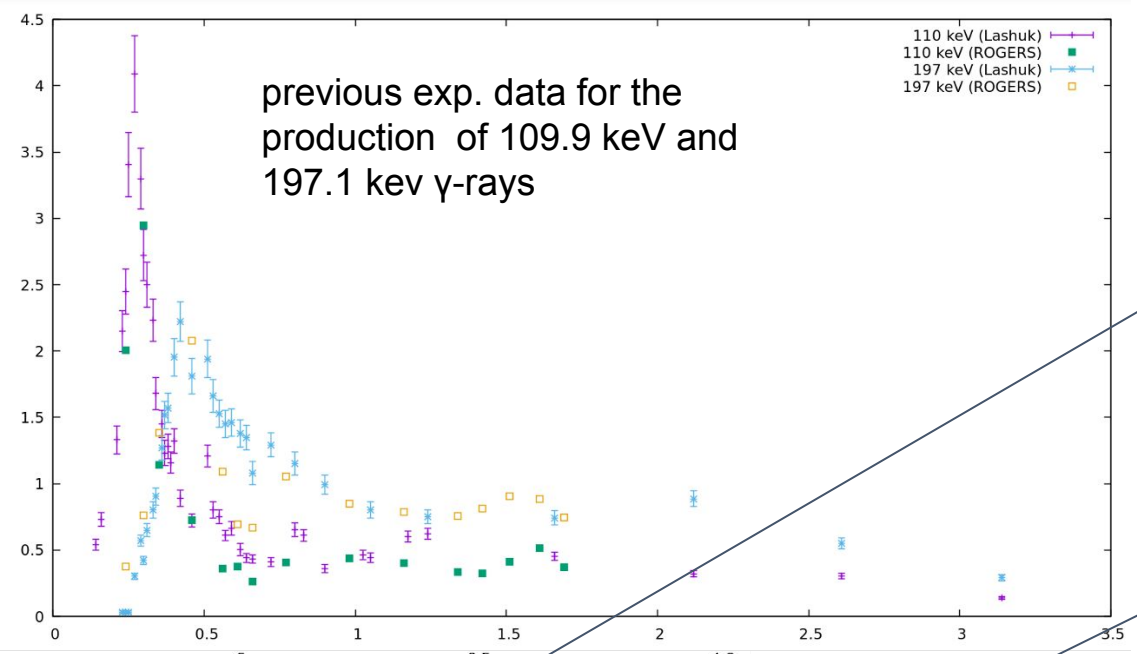
New n_TOF experimental setups: HPGe

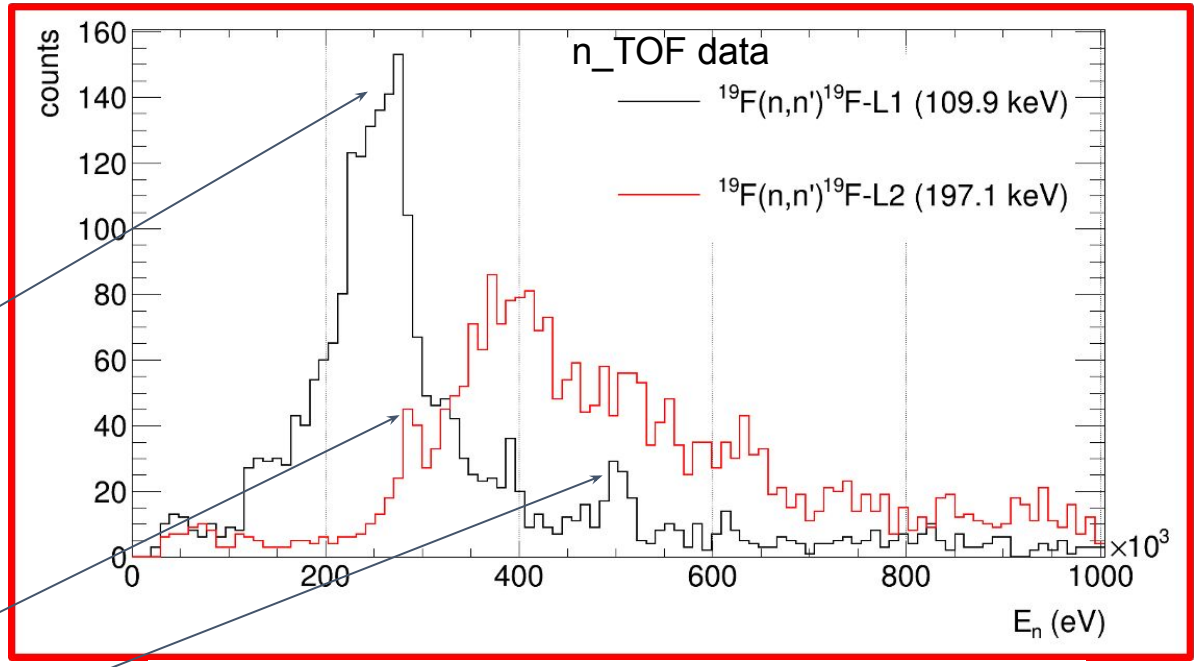


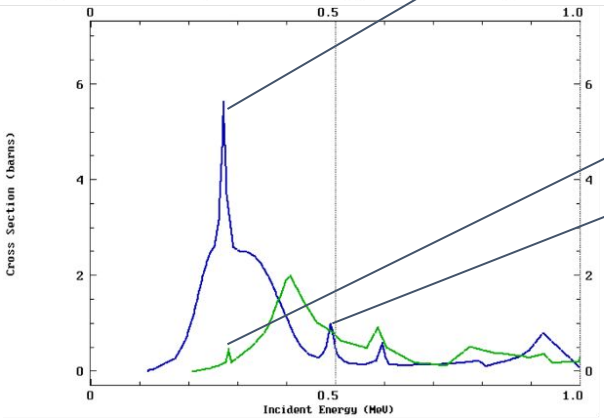
Thanks to M. Bacak, C. Petrone, A. Negret, M. Diakaki, …

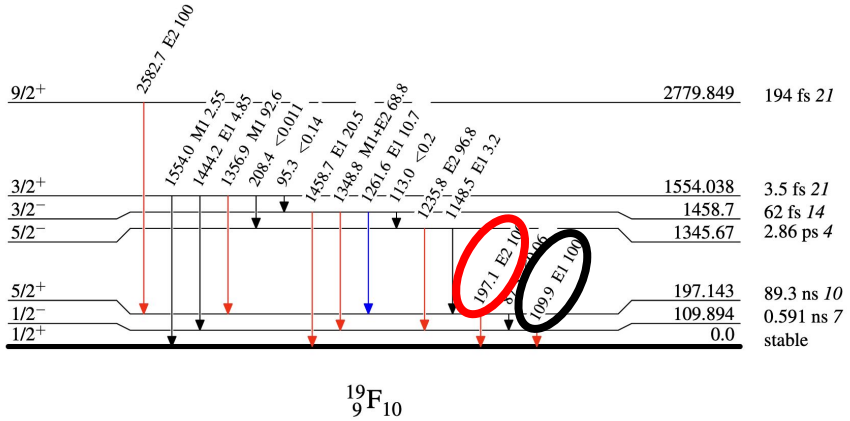
New n_TOF experimental setups: HPGe

The ^{19}F(n,n') γ-ray yield after a **few shots at EAR1**!

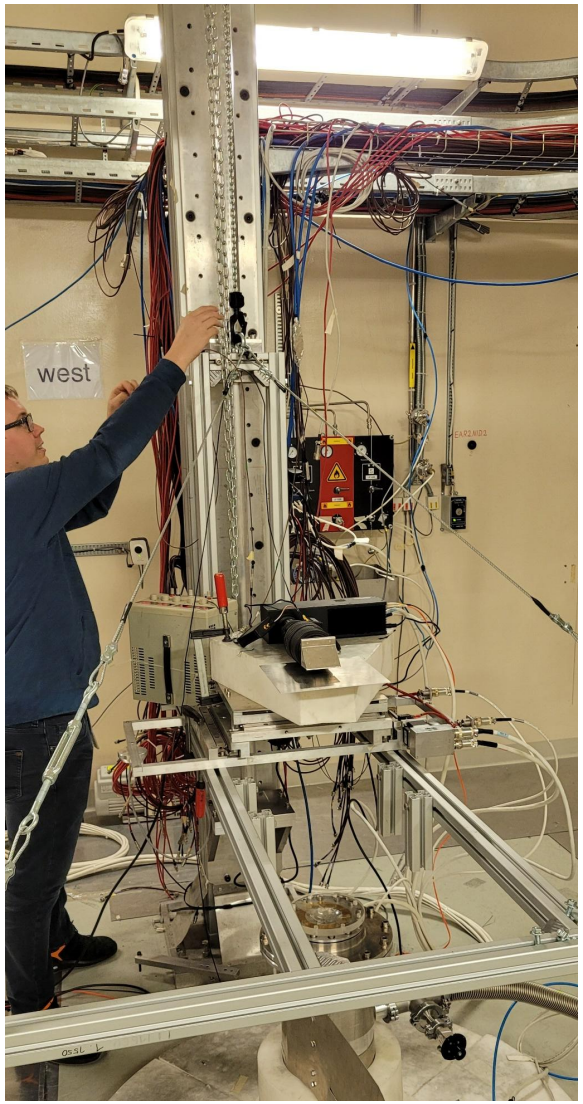








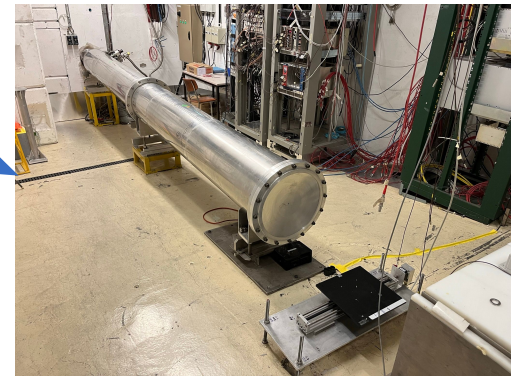
Few facility actions to be addressed during the YETS:



- Revision of grounding and screening in EAR1 Measurement of RF noise
- Develop new low mass detector supports for sTED and/or also for L-C_6D_6

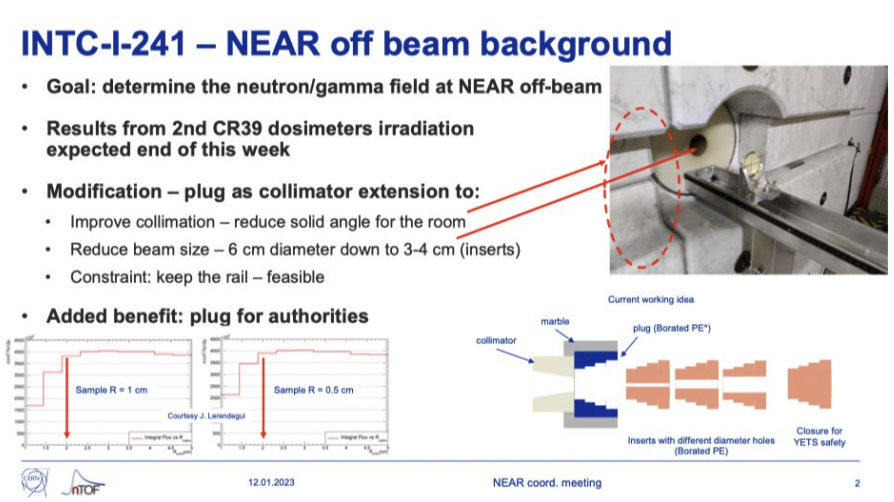
Few facility actions to be addressed during the YETS:

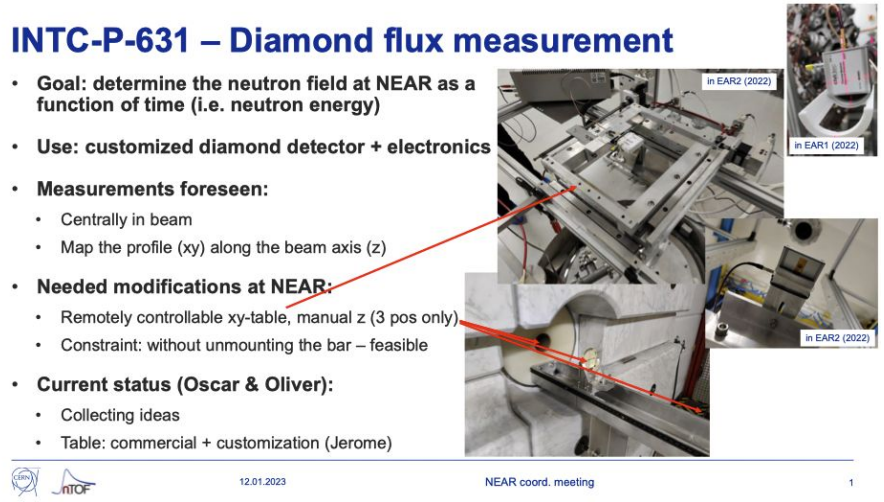
- Prepare SP-Lab (Sample Preparation Laboratory)
- Sample exchanger/holder
- Shielded door EAR 2 revision **Done**
- Revision of UPS
- Ventilation system (EAR1) upgrade, T.H.A. filter exchange (EAR 1 + 2, TT2A)
- Preparation of spare SEM grid
- Neutron Escape Line modification
- …



a-NEAR – n_TOF activities (2023)

INTC-P-623 Neutron capture cross section measurements by the activation method at the n_TOF NEAR station (E.Stamati, A.Manna and Gianpiero Gervino)



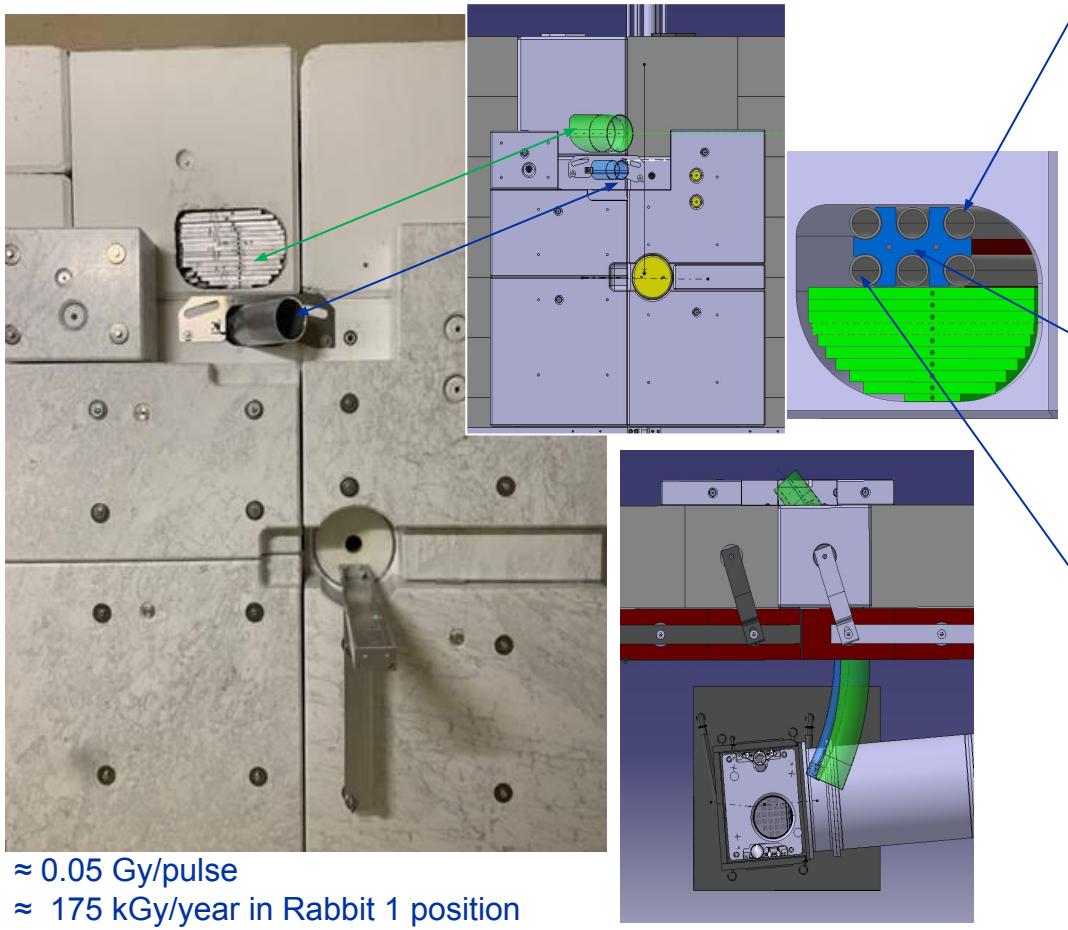


Two n_TOF experiments under preparation

Acknowledgments: O.Aberle, O.Fjord, M.Bacak, M.Diakaki, J.Lerendegui-Marco

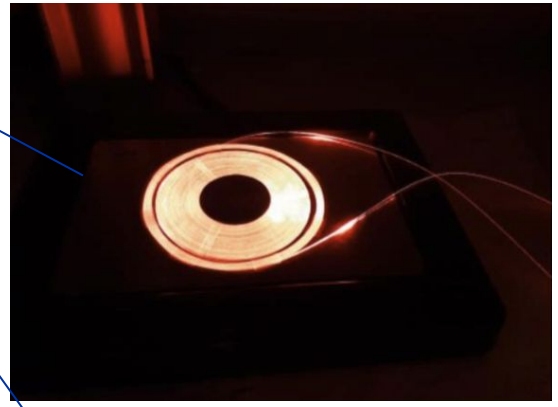
i-NEAR – R2M activities (2023)

Rabbit 1 installation during YETS 22-23



≈ 0.05 Gy/pulse
≈ 175 kGy/year in Rabbit 1 position

SPND detector with mineral cable
INTC-I-247 *Acknowledgement: S.Fiore EP-UNT*

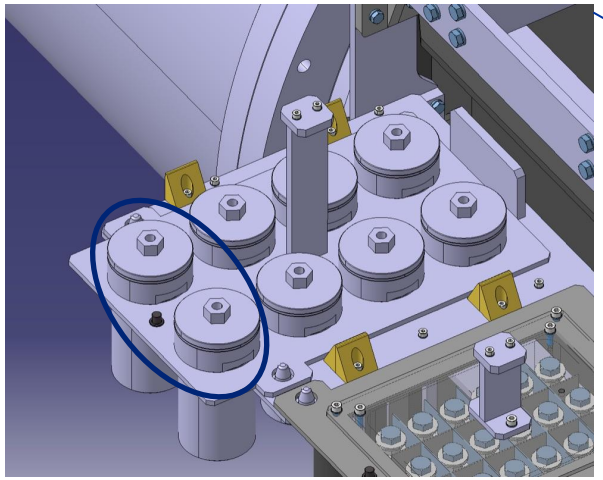


Radioluminiscent fibers
UJM Saint-Etienne MOPERE (**M**aterials for **O**ptics and **P**hotonics in **E**xtreme **R**adiation **E**nvironments) – Agreement under preparation

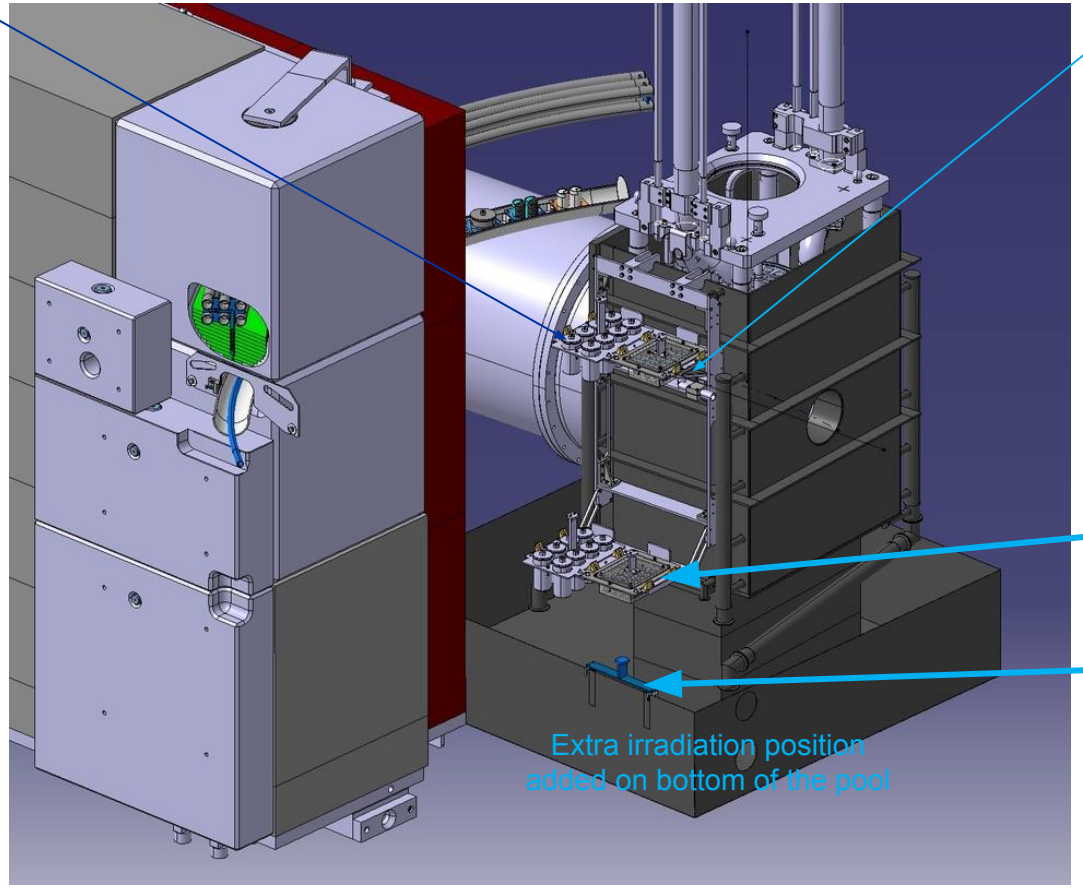
Cable irradiation – CERN CARE program

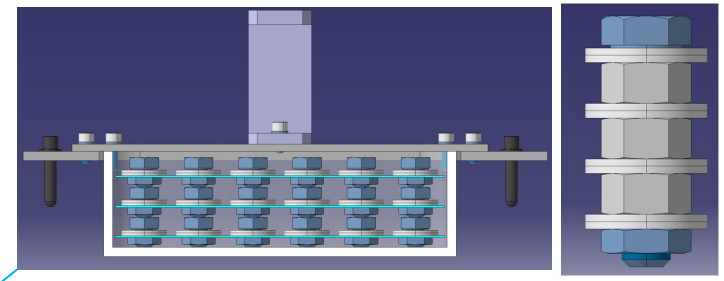
i-NEAR – R2M activities (2023)

Increase shelves capacity & versatility



Increase shelve capability
with 2 extra containers
Acknowledgement : C.Mucher, L.Buonocore, D.Senajova, S.Allegretti SY-STI





Replace 2 samples holders by with square boxes (allow different samples shapes)
Acknowledgement : C.Mucher, L.Buonocore and M.Macha SY-STI

Geometry changes tested with the robot team:
C.Veiga Almagro, E.Romagnoli, L.Buonocore BE-CEM

Conclusions - Physics

- 2022 was a nice year for n_TOF
  - 20 actions were successfully accomplished
  - 2 neutron capture reaction were experimentally studied for the first time
  - 4 new setups were applied for the first time
- New experimental setups have been developed and we are ready to launch new type of measurements
  - (n,cp) reactions in low (SADR) and high energies (DDX)
  - n,n' reactions using HPGe
- A long list of YETS actions is in front of us
  - RF noise study in EAR1
  - uMegas detector preparation and characterization
  - Refurbishment of the HPGe
  - Experimental setups preparation/optimization
  - …

Conclusions - Facility

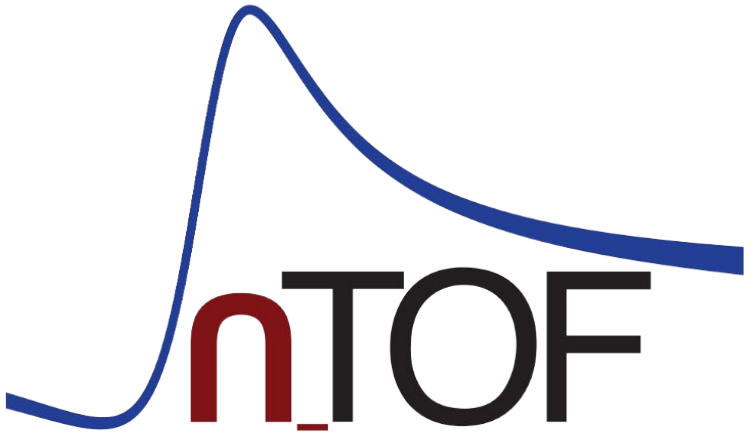
- Target performance excellent, FTN beam line modifications successful, aiming for intensity increase for 2023.
- Implementation of the ASN-OFSP safety recommendations in EAR2 – visit 10/12/2021
- New safety file includes modifications implemented during LS2 “EMDS 2604713 - n_TOF Target Facility Safety Overview”
- New safety file for EAR 1 circulating
- Other activities are also progressing (or done):
  - Revision of the UPS
  - Ventilation system upgrade - THA filter exchange (EAR1, EAR2, TT2A)
  - spare SEM grid production
  - …

Conclusions - NEAR

- a-NEAR
  - Continuation of the neutron capture studies (INTC-P-623)
  - Diamond detector flux measurement (INTC-I-241, under preparation)
  - Off-beam background measurement (INTC-P-631, under preparation)
- i-NEAR
  - Rabbit 1 installation during YETS
  - Extension and optimization of samples holders
  - Robot compatibility checked

Many thanks to …

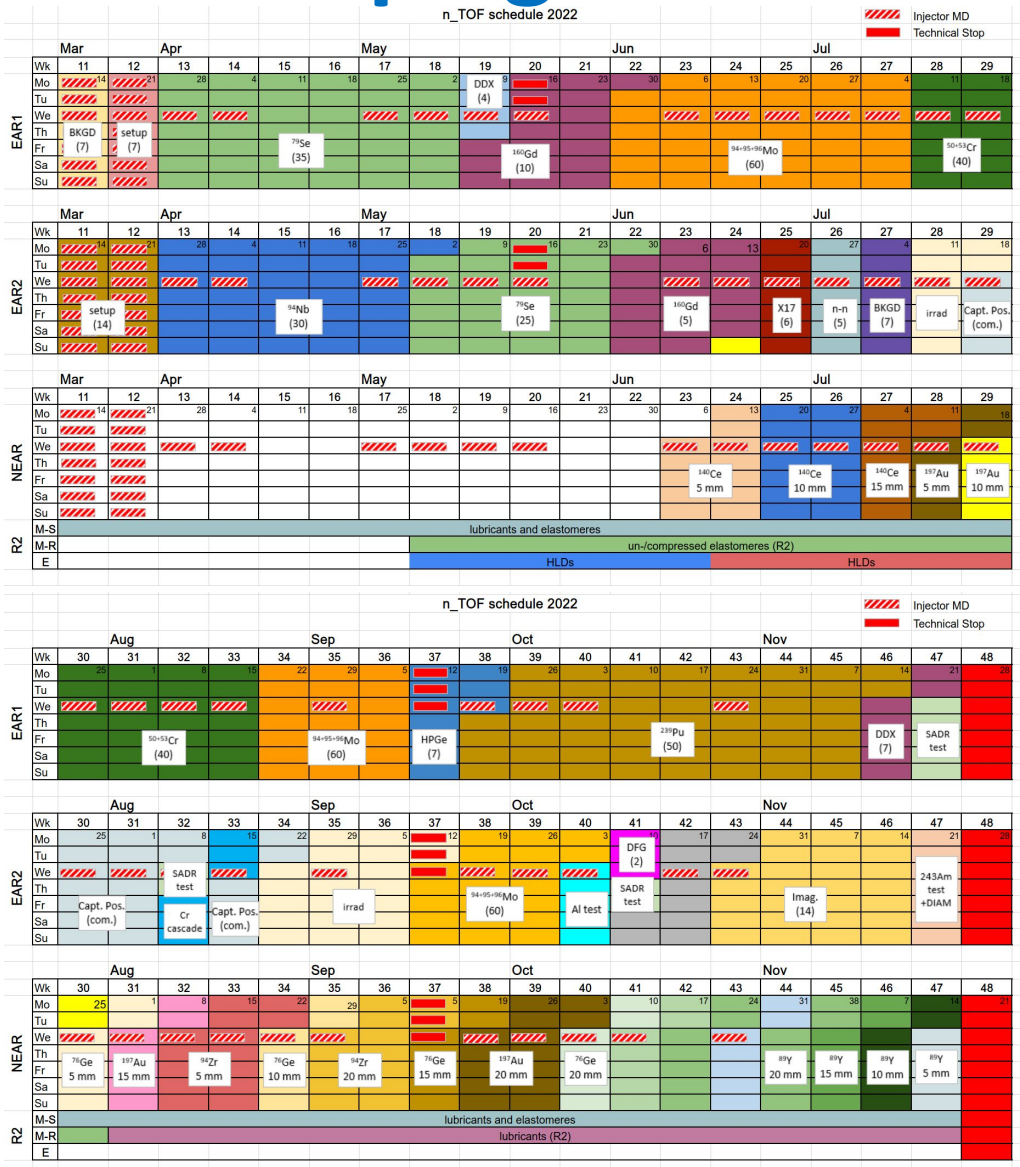
- SY-STI teams (Ana, Oliver, Oscar, …)
- Local team (Michi, Alice, Simone, Adria, …)
- Visiting teams
- …to the n_TOF collaboration



Thank you so much for your attention!

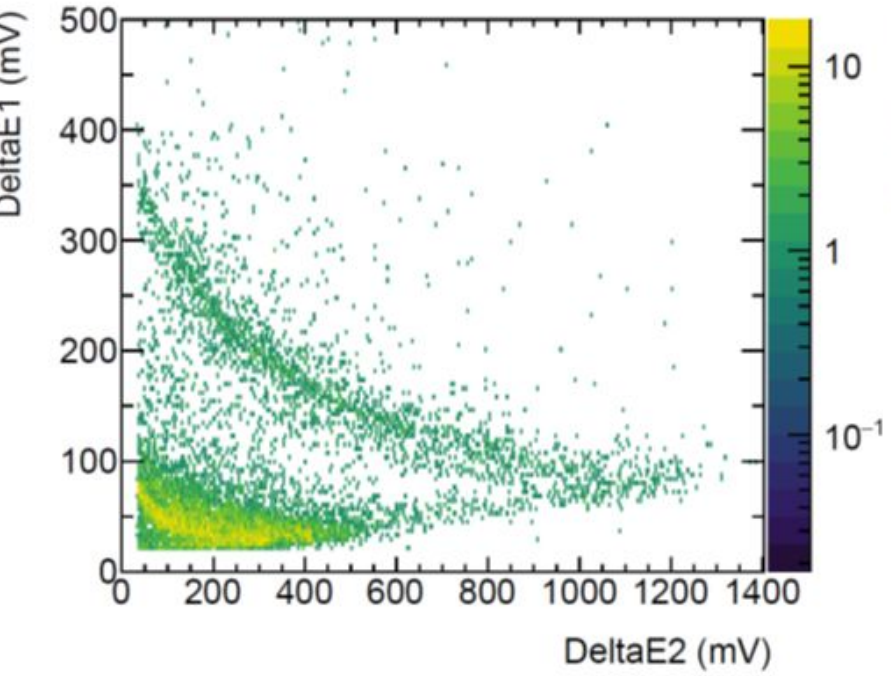
Highlights of the 2022 n_TOF campaign

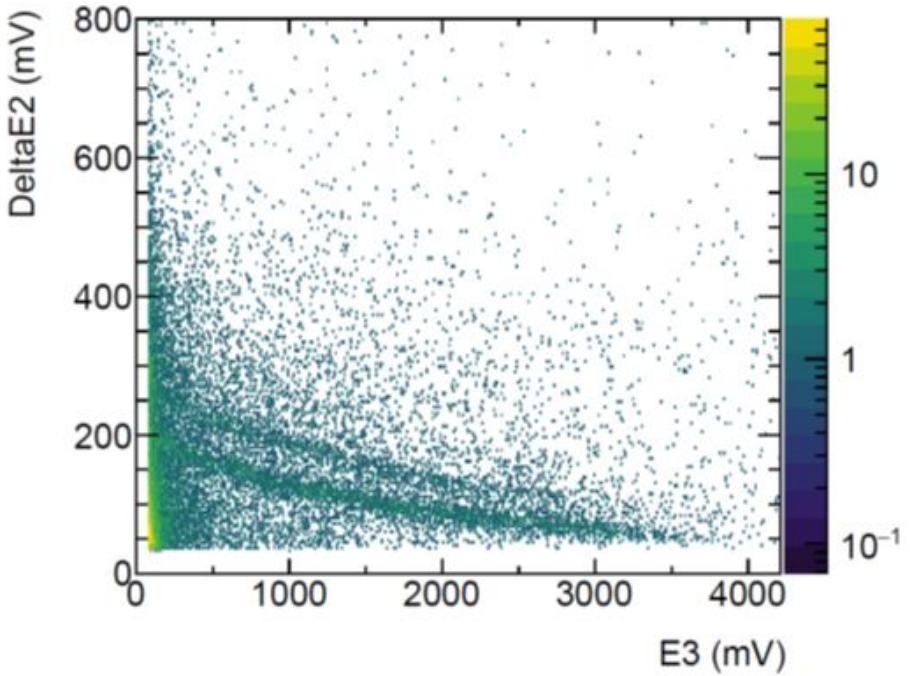
EAR1	EAR2	NEAR
• ^{79}Se(n,γ) • ^{160}Gd(n,γ) • ^{94,95,96}Mo(n,γ) • ^{50,53}Cr(n,γ) • ^{239}Pu(n,γ)(n,f)(a-ratio) • DDX det. dev. • HPGe test (postponed)	• ^{79}Se(n,γ) • ^{94}Nb(n,γ) • ^{160}Gd(n,γ) • ^{94,95,96}Mo(n,γ) • X17 detector test • nn scattering det. test • neutron imaging • diamond det. test (pending) • BKG and other commissioning actions	• ^{197}Au(n,γ) • ^{140}Ce(n,γ) • ^{76}Ge(n,γ) • ^{94}Zr(n,γ) • ^{89}Y(n,γ)

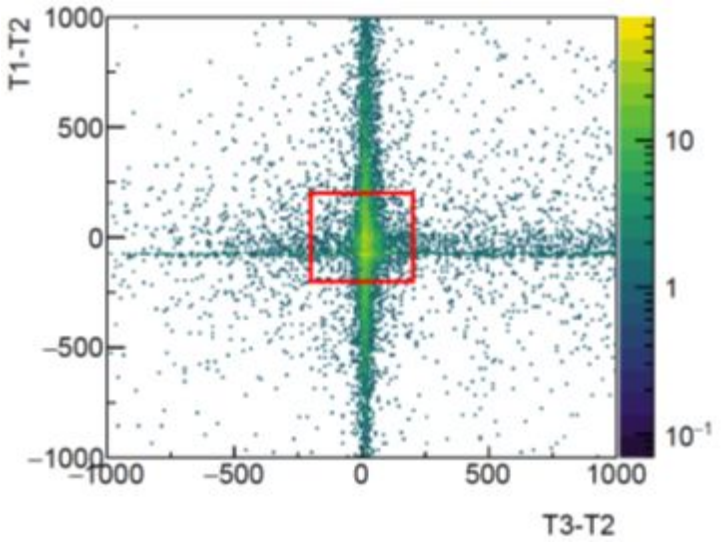


- 9 neutron capture reactions have been studied (2 of the for the first time)
- ^{239}Pu fission tagging measurement successfully accomplished (had to be extended in time) - EAR1
- 5 neutron capture reactions have been studied at NEAR with different B4C filter configurations; Activation technique; MACS for different stellar temperatures; Some irradiations will continue on 2023
- 4 detector development projects have been accomplished successfully (X17, DDX, neutron imaging, diamond detector)
- 4 new detector setups have been successfully applied for the first time (iTED, sTED, GEAR HPGe, beta-detection for NEAR)
- stilbene capture detector setup is progressing well

New n_TOF experimental setups: DDX



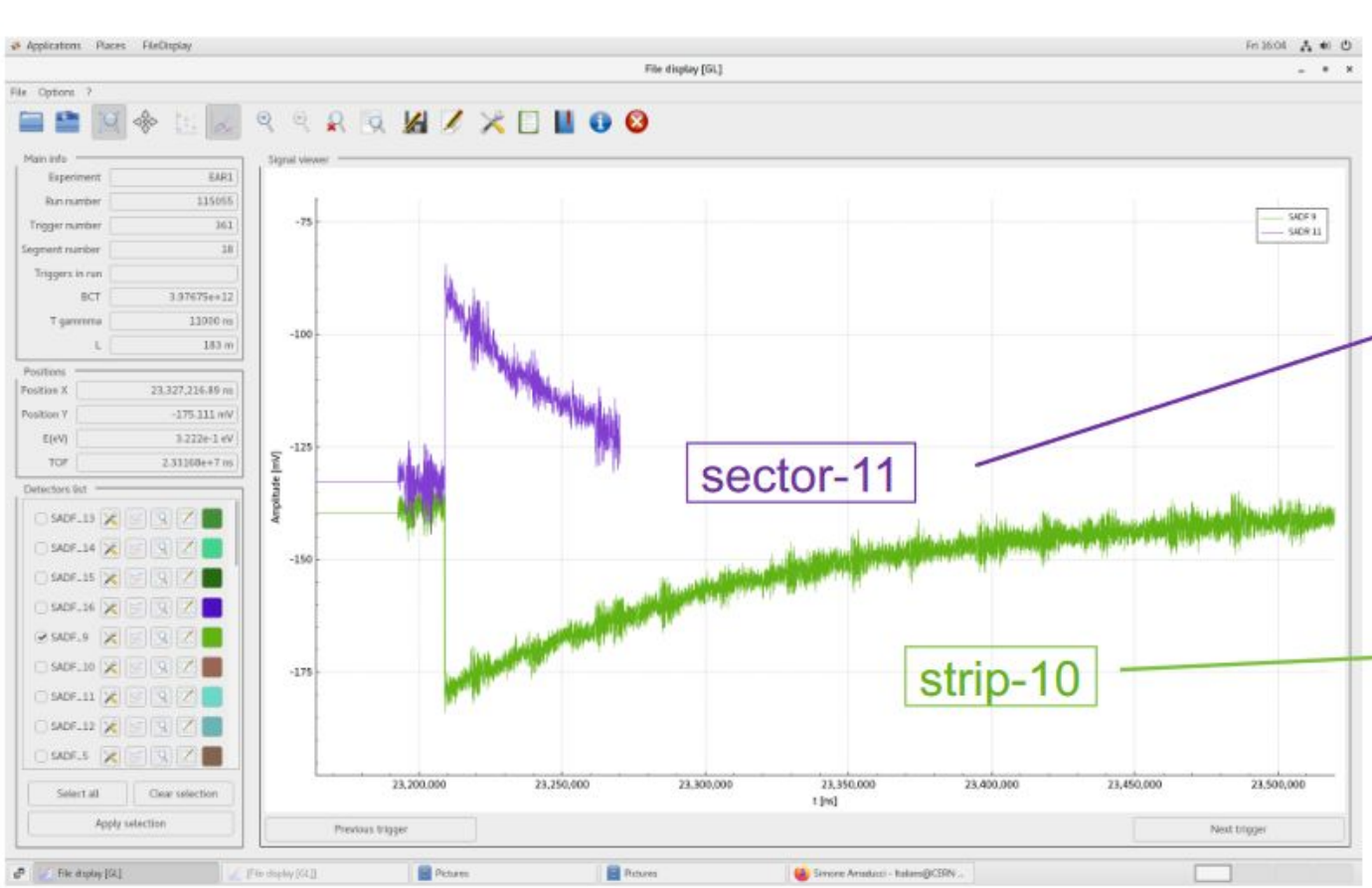


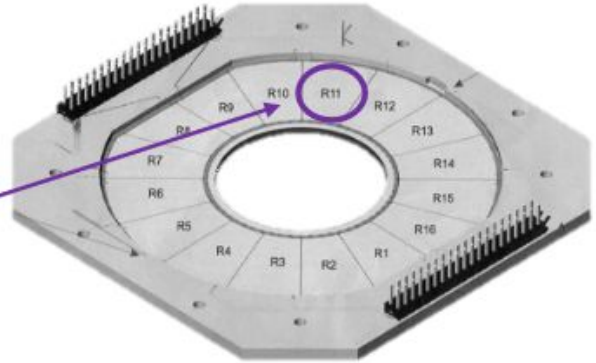


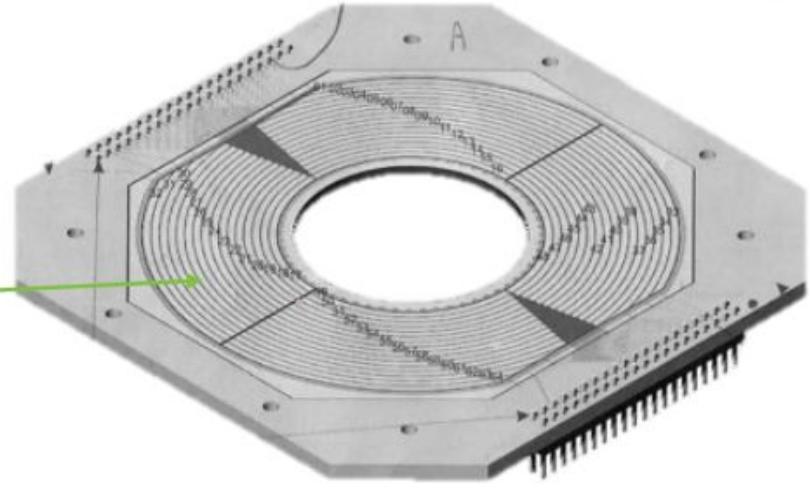
- Clear coincidence pattern
- Nice particle identification (H/He, p/d)
- Target 1 mm and 2.3 mm PE

Thanks to M. Dietz, E. Pirovano, R. Nolte, R. Beyer, A. Junghans

New n_TOF experimental setups: SADR





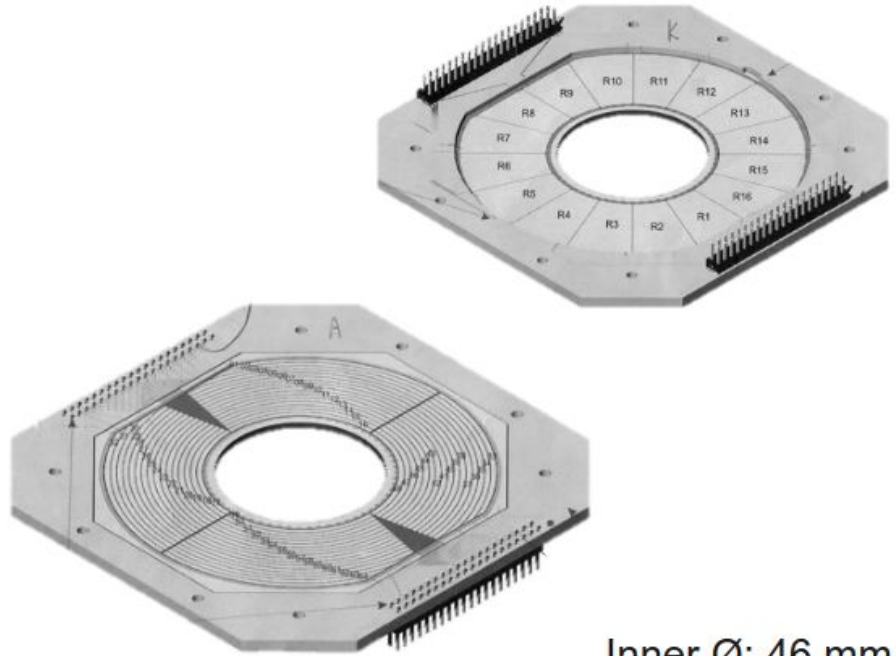


Thanks to S. Amaducci, S. Goula, L. Cosentino, G.Vecchio, …

New detection apparatus **devoted** to particle discrimination

Chance to overcome the ΔE/E technique limitations

- Neutron Transmutation-Doped (**NTD**)
- **Segmentation**: θ & φ angles
  - Angular distribution & Good position-angular resolution
- **Digital-LNS** Pulse Shape Analysis based on signal shapes
  - Readout directly from preamplifiers
- Neutron energies thresholds for PSA:
  - ~ **2-3 MeV** till **tens of MeV**



Inner Ø: 46 mm
Outer Ø: 96 mm
Thickness: 305 µm
16 sectors – Rear part
16 strips – Front part

The full list of YETS 2022-2023 activities

EAR	Task
1	CLEAN THE AREA
1	Vac. pump el. noise (power on/off solved the problem)
1	PC's check what is working what is not; get switches to avoid recabling
1	fiber data connection
1	El. noise in EAR1 (pictures from SADR test) ? IF there is aproblem?
1	Sample changer - make it move
1	Sample changer - integrate it to the DAQ (if possible)
1	Sample changer - Carbon fiber arms
1	Cleanup & ordering new material (tools, gloves, cable binders, tape, pipe elements, ...)
1	Laser Allignement
1	Configurate new CAEN1081 module
2	CLEAN THE AREA
2	El. noise in EAR2 (pictures from SADR test)
2	fiber data connection
2	Check Laser alignement
2	Evaluate what goes in which storage room (material room, storage upstairs of EAR2)
2	Low mas sample holder & protection for pipe
2	Cleanup & ordering new material (tools, gloves, cable binders, tape, pipe elements, ...)
2	PC's check what is working what is not; get switches to avoid recabling
2	Lemo cable storage space is blocked by shelves --> move cables somewhere else
2	Change broken light in the bunker
2	Change collimator from fission to capture
2	Fix the opening of the concrete wall (it gets stuck if opened to much!)
NEAR	Diamond table
NEAR	Collimator reduction

The full list of YETS 2022-2023 activities

GEAR	Optimization of the plastic setup
GEAR	storage place, carbidge bin, cleaning, ...
LAB	Re-arrange the PCs
LAB	CLEAN LAB
LAB	missing tools & material
CR	Re arranegment of the screens
CR	room separation in the CR
CR	Cleaning concept of the CR, i.e. the keyboards (can the CERN cleaning take care of that?)
CR	New office supplies needed? Screens, keyboards, cables, envelopes, pens, ...
SPEAR	Target preparation Experimental ARea (pressing, scaler, encapsulation, lights, teflon foils, teflon thermal sealing, storage

The full list of YETS 2022-2023 activities

Detectors	
HPGe	HPGe and Beta spectrometer coupling (hardware mechanics + DAQ)
HPGe	fine-tuning at MIRION tecnologies -> the removal of the 2nd pre-amp
C6D6	extra holders for EAR1
C6D6	preparation, characterisation
SiMon	Check (and fix?) internal soldering
DAQ	SPD-02918 (problem validating triggers)
	SPD-02920 (strange baseline behaviour)
	m4 machine check at EAR2 after power failure
	Data processing issue
	Test of DAQ (especially in EAR2)
	Time machine migration from public network to technical network
Other	
	taking over the timepix detector; them work in all EARs and install all the necessary software;make them plug and play"
	NEL modification
	Update shifter manual
	Create shift leader manual
	RP sources
	Permanent UPS for GEAR (HPGe's)
	Document for the transport
	CLEAN the old CR
	Return not needed equipment back to EL POOL