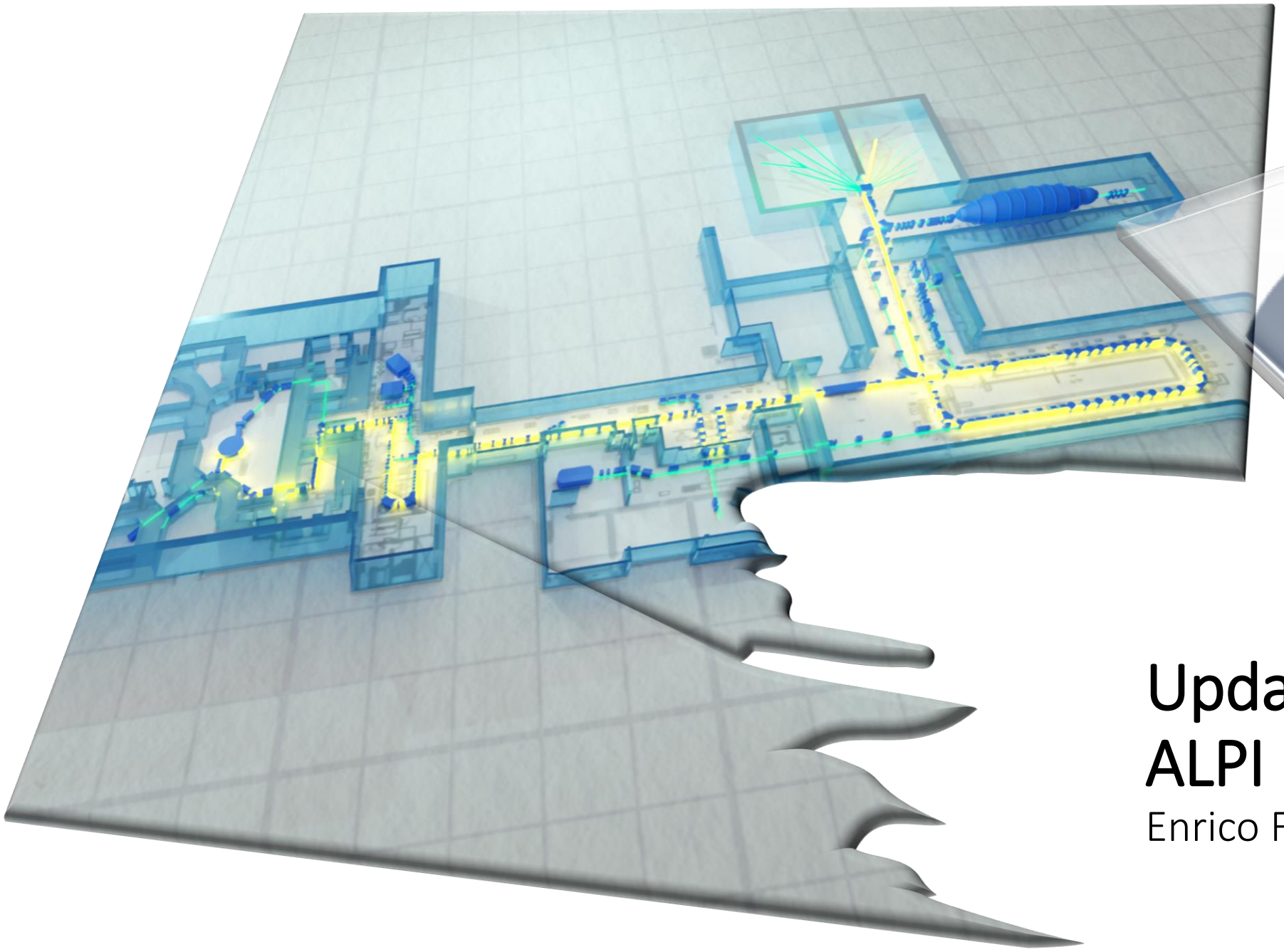


Updates on Tandem ALPI PIAVE 09/09/2024

Enrico Fagotti

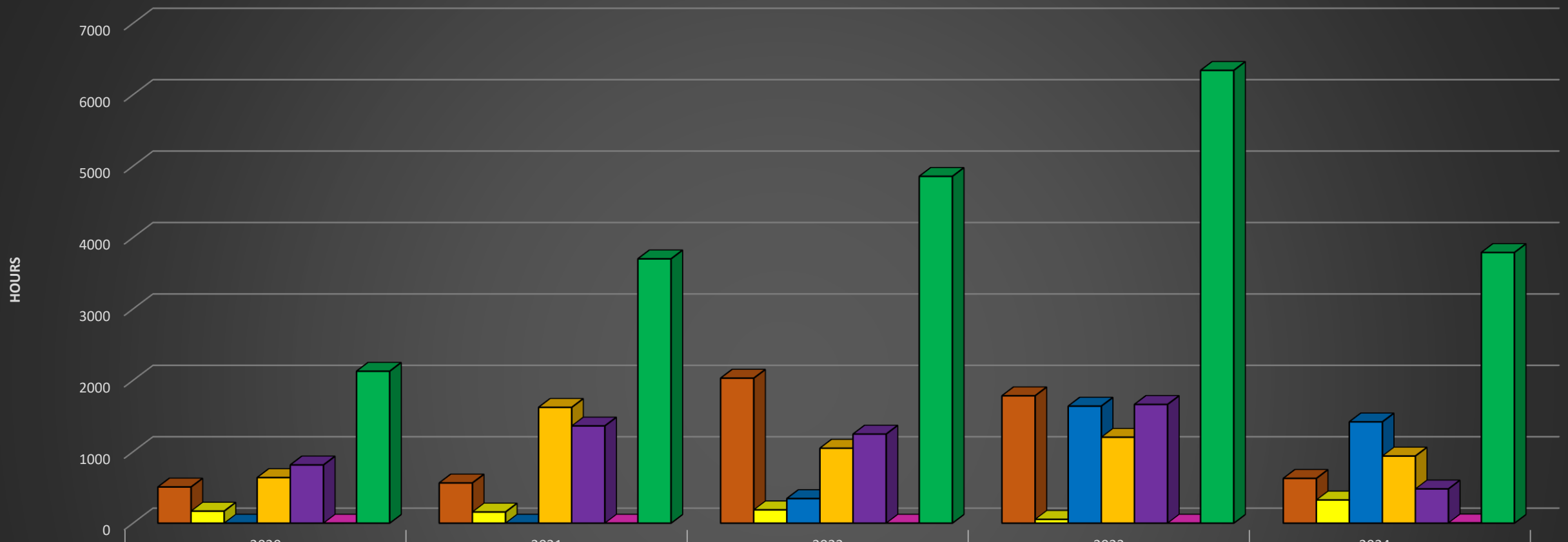
Outline

- General considerations on LNL accelerators
- PIAVE-TANDEM-ALPI complex: current status

Outline

- General considerations on LNL accelerators
- PIAVE-TANDEM-ALPI complex: current status

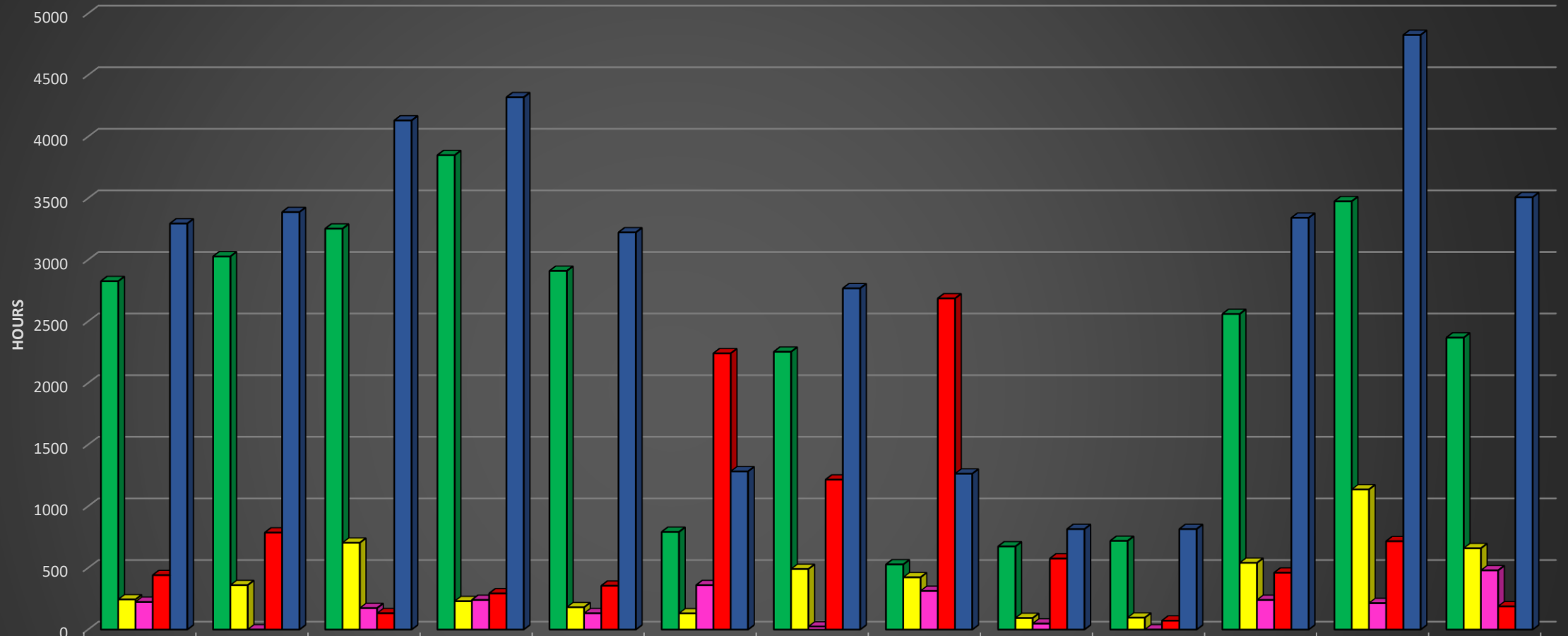
Accelerator complex (2020 - now)



	2020	2021	2022	2023	2024 now
TANDEM	506	563	2030	1784	627
TANDEM-ALPI	168	156	186	53	324
PIAVE-ALPI	0	0	344	1639	1418
AN2000	638	1621	1049	1203	940
CN	815	1361	1247	1662	479
SPES	0	0	0	0	3
LNL BoT	2127	3701	4856	6340	3790

YEAR

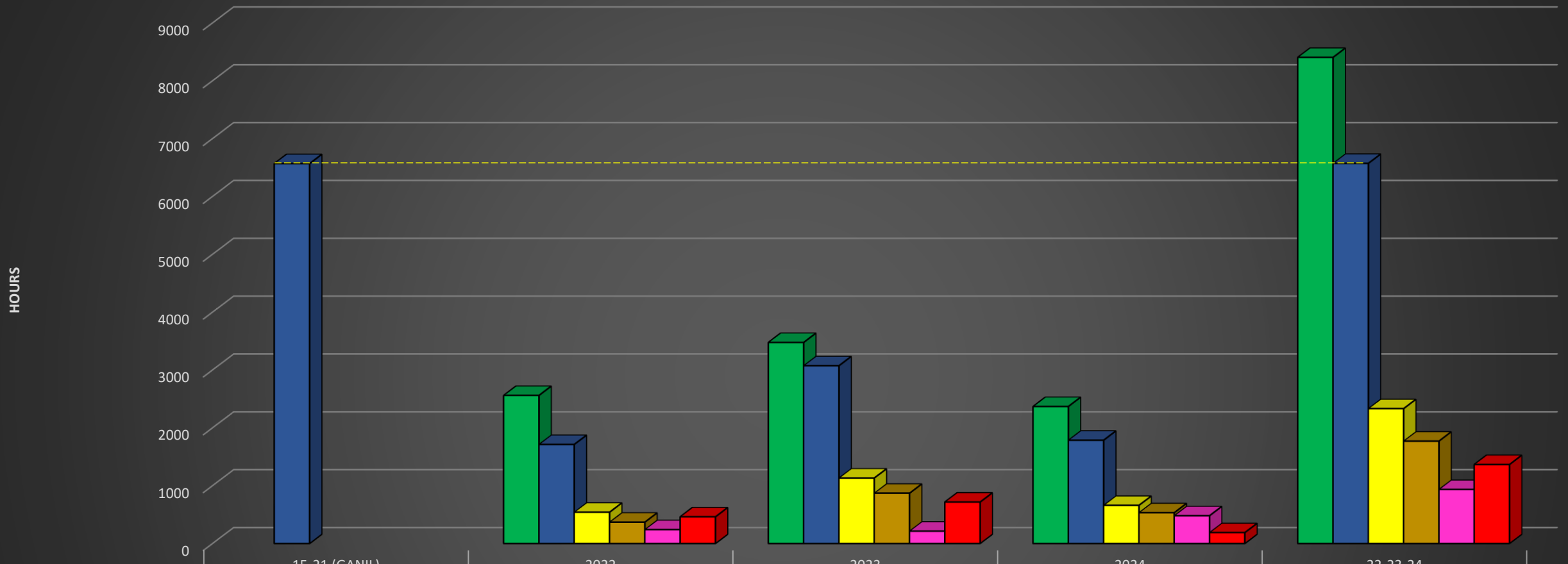
PIAVE Tandem ALPI



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024 now
PTA - Beam on Target	2827	3028	3253	3850	2910	792	2254	528	674	719	2560	3475	2369
PTA - Beam Preparation	244	360	704	230	181	131	491	424	93	96	541	1137	659
PTA - AD Tests	224	0	174	240	132	360	24	313	48	0	240	214	480
PTA - Unscheduled Maintenance	441	787	132	293	355	2241	1216	2687	576	72	461	717	188
PTA - working time	3295	3388	4131	4320	3223	1283	2769	1265	815	815	3341	4826	3508

YEAR

AGATA beam time (2022 - now)



	15-21 (GANIL)	2022	2023	2024	22-23-24
Beam on Target		2560	3476	2369	8405
AGATA Beam on Target	6568	1713	3074	1786	6572
Beam Preparation		541	1132	659	2332
AGATA Beam Preparation		369	869	533	1770
Accelerator Division Tests		240	214	480	934
Unscheduled Maintenance		461	717	188	1366

YEAR

LNL beam on target

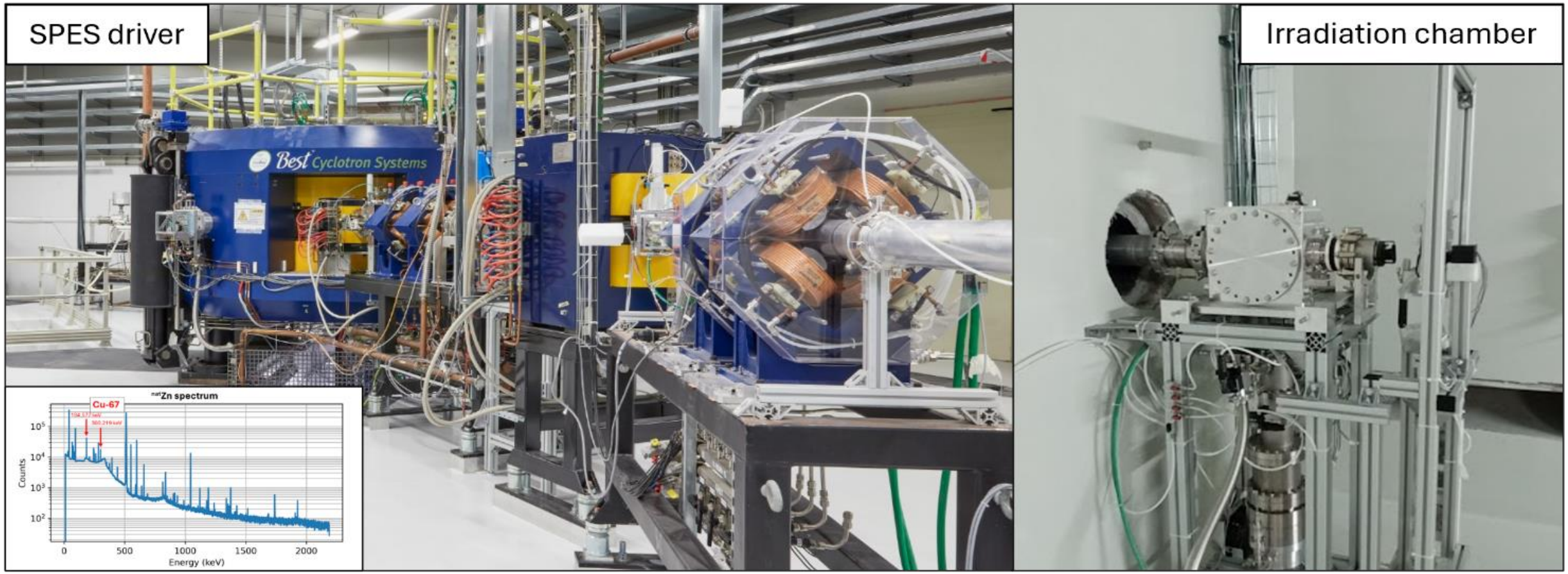
- Until now LNL accelerator complex guaranteed **3790 h** global beam on target:
  - 2369 h with PTA complex (**1786 h** BoT devoted to **AGATA** experiment)
  - 1419 h with AN2000+CN
  - 3 h with SPES

- AGATA experiment at LNL already reached the same BoT hours reached in GANIL

- We are currently operating with TANDEM and we will go on at least till beginning of 2026 with current configuration.

- Last May SPES Phase 1 was completed and the first proton beams were produced and delivered to experimental study of medical radioisotope production.

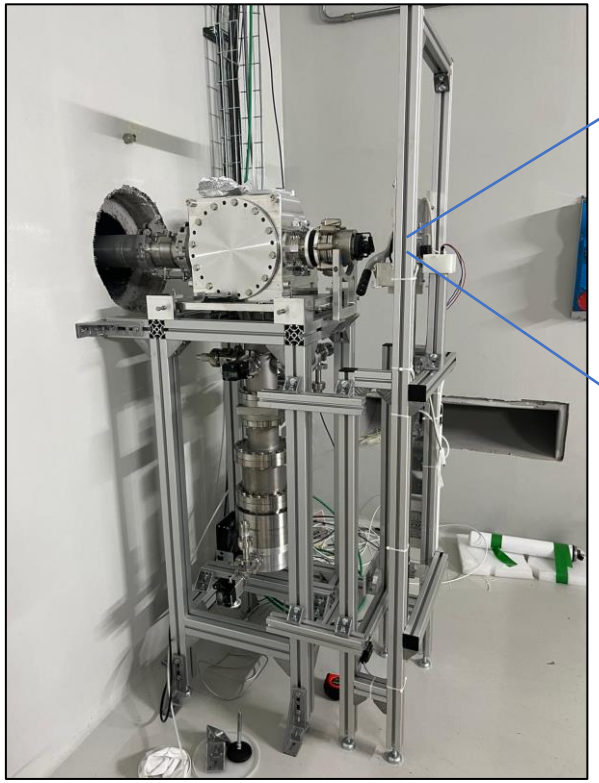
SPES highlight



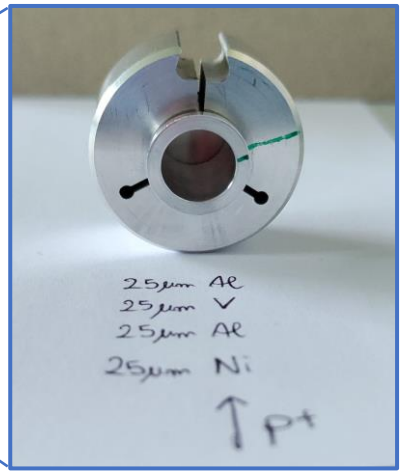
During SPES commissioning, cyclotron was optimized for three different proton energies: 35 MeV, 50 MeV and 70 MeV. After each optimization the proton beam was used to irradiate thin targets of different materials.
Picture shows the gamma spectrum of a natural Zn target irradiated at an energy of 50 MeV, which allowed observation of the gamma-decay of the theranostic radionuclide Cu-67.

Commissioning experiments @ SPES

3 irradiation runs (May-June 2024) to extract info on the beam current at 35-70-50 MeV proton beam energies



Target station



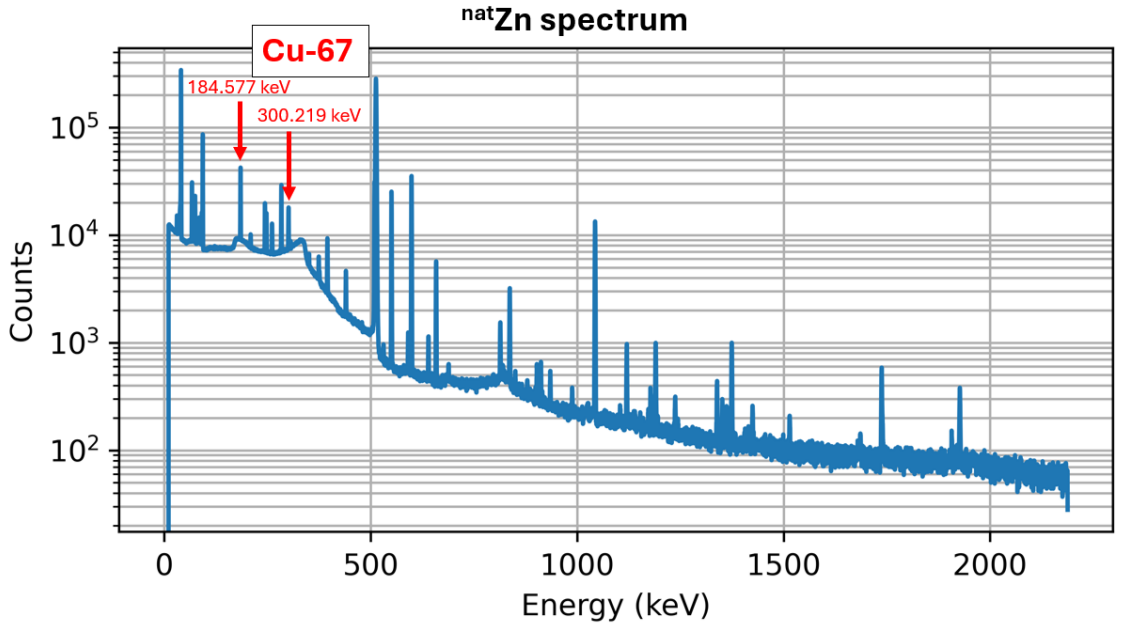
1° and 2° irradiations stacked-foils target compositions

^{nat}Ni (25 μm)	^{nat}Al1 (25 μm)	^{nat}V (25 μm)	^{nat}Al2 (25 μm)	^{nat}Zn (11 μm)	^{nat}Al3 (25 μm)

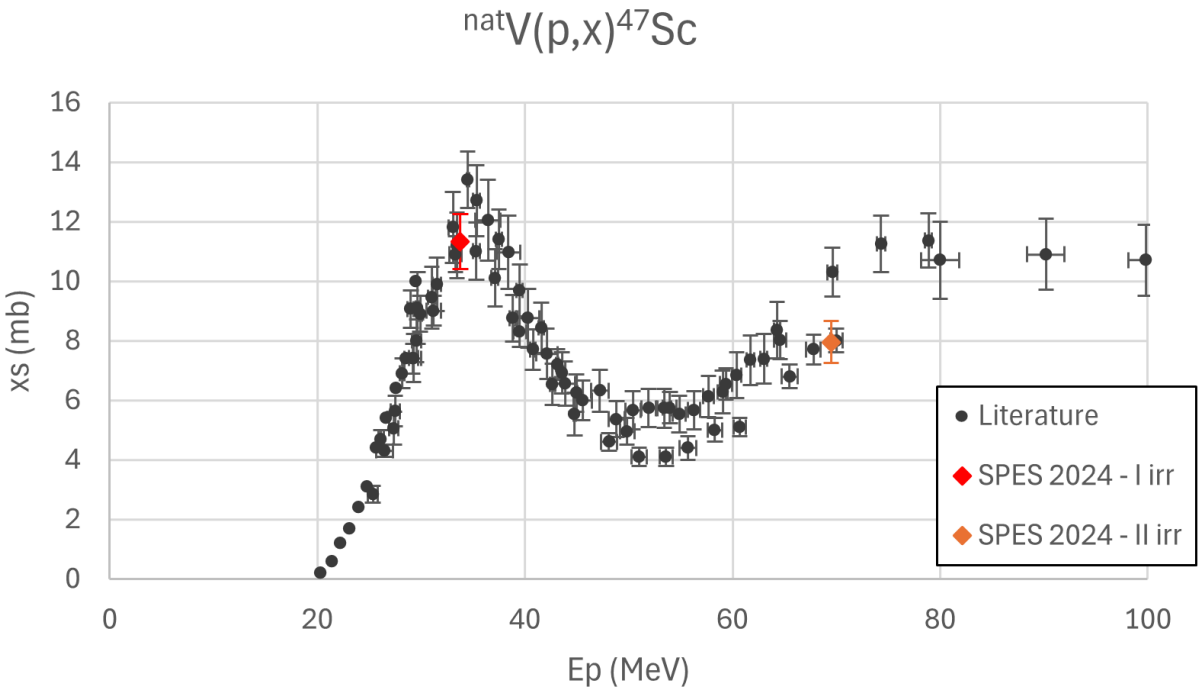
HPGe detectors

3° irradiation stacked-foils target composition: ^{nat}Zn foil added to detect ^{67}Cu

Commissioning experiments @ SPES

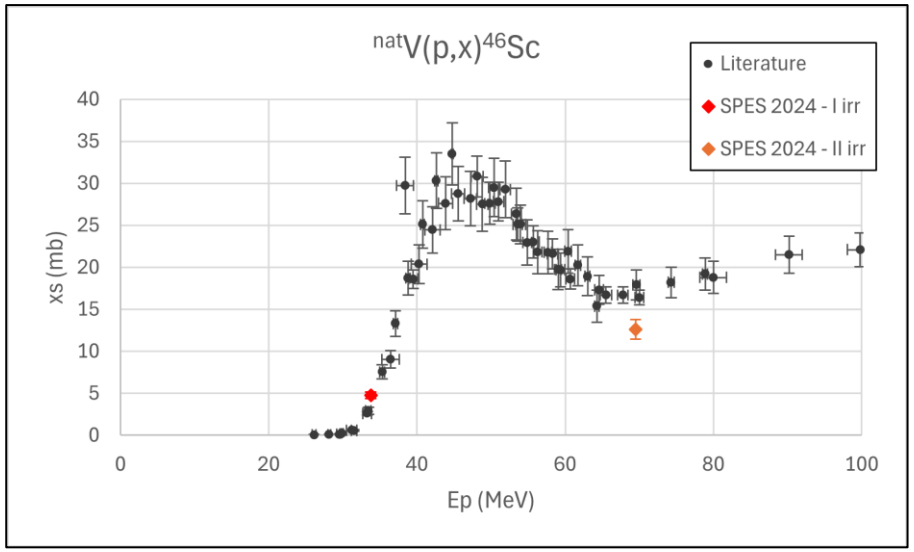


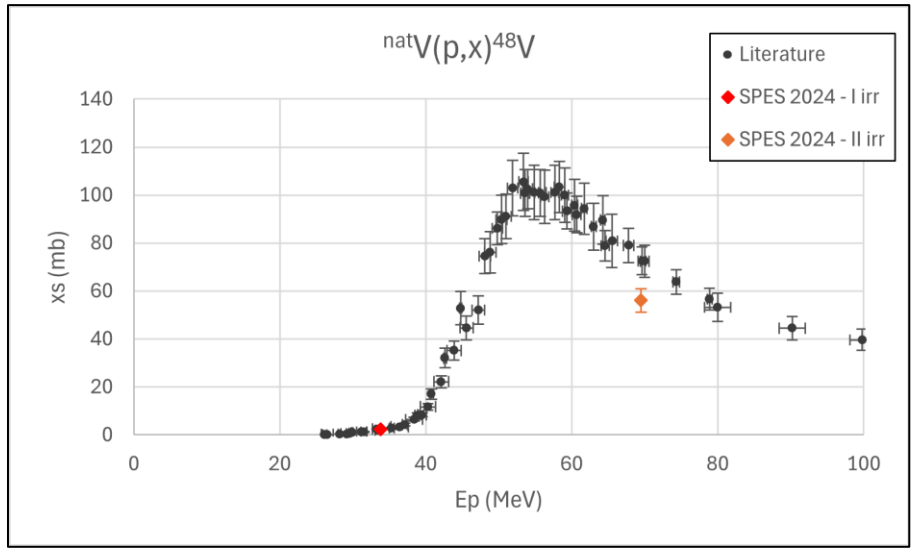
γ spectrum of the ^{nat}Zn foil where the ^{67}Cu γ lines can be observed

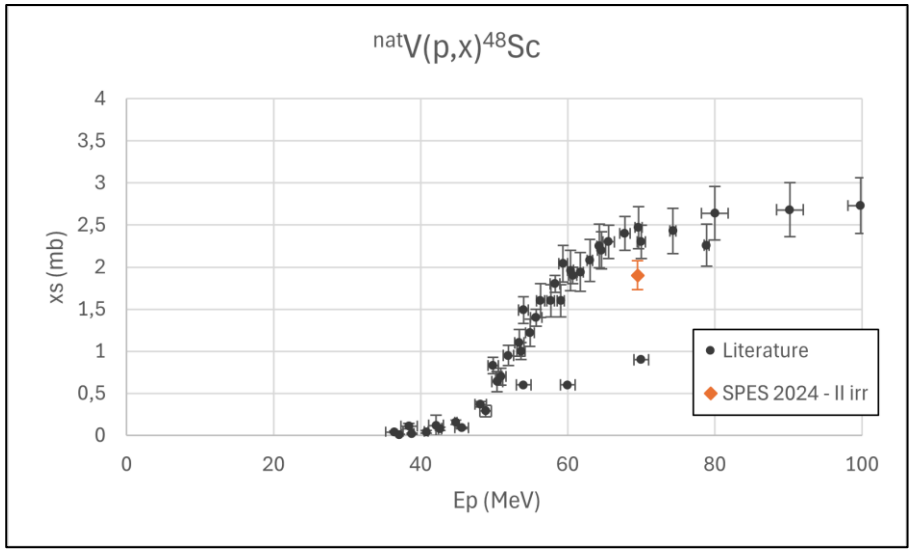


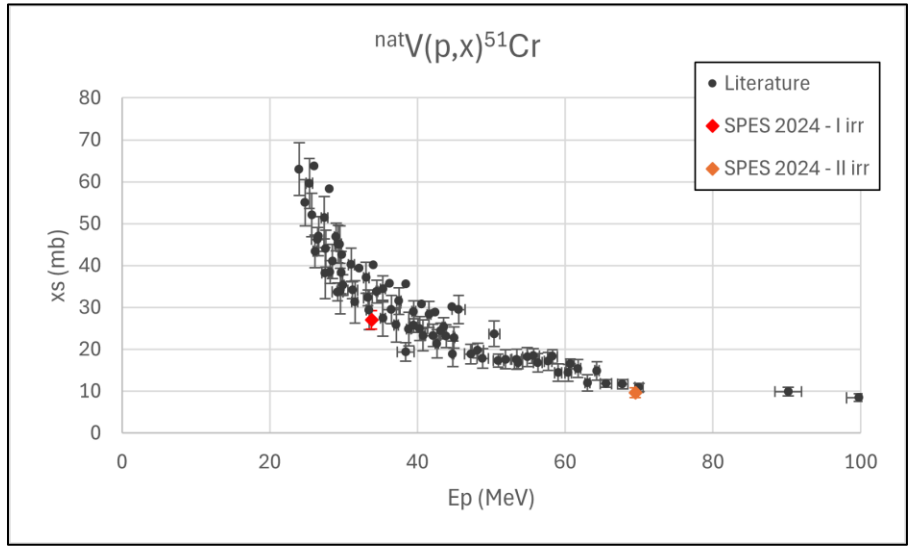
^{47}Sc cross section results from the ^{nat}V target bombarded at 35 MeV (in red) and 70 MeV (in orange) protons at SPES, compared to the previous literature data (in black).

Evaluation of co-produced contaminant





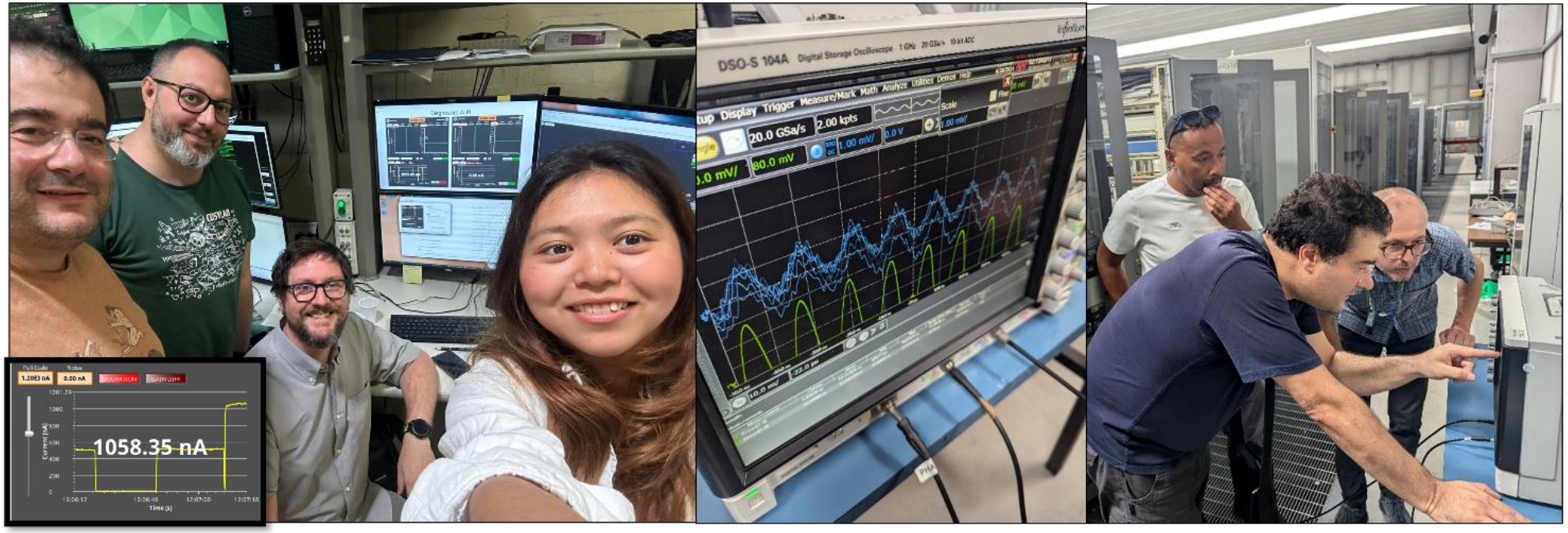




Outline

- General considerations on LNL accelerators
- PIAVE-TANDEM-ALPI complex: current status

PTA highlight



Artificial Intelligence and Machine Learning push PIAVE-ALPI accelerator to record performance in 2024

- In June 2024 PIAVE-ALPI superconductive accelerator reached outstanding performance levels.
- Main points for this achievement were the integration of advanced AI with ML techniques, Bayesian optimization algorithms and particle swarm optimization algorithms.
- These complex algorithms played an essential role in parameters optimization of accelerator configuration resulting in remarkable accelerator performance improvements and a strong improvement of accelerator setting time.
- ALPI overall transmission reached values of 85%, very near to 93% theoretical maximum transmission and significantly higher than 35% reached in the previous decades.

PTA main results

- PIAVE-ALPI (**PA**) 19/02 - 07/06 **1418 h**
- TANDEL-ALPI (**TA**) 15/05 - 19/06 **324 h**
- TANDEM (**T**) 17/05 - now **627 h**
- Accelerator Division shifts:
  - Commercial activities
    - 14/05 129Xe PA (8.6 h);
    - 20/06 - 21/06 T (22.6 h).
  - 21/06-28/06 accelerator machine tests and improvements using new algorithms based on Machine Learning and Artificial Intelligence
    - PIAVE transmission automatic optimization – 64.4% in 32 minutes;
    - ALPI transmission optimization – **35%** → **85%** (93% max theoretical transmission) in 1 hour;
    - PIAVE-ALPI accelerator setting and optimization with ML and AI in 12 hours.
  - Improvements: RF system, LLRF system, alignement, ECR source, control system, cryogenic system, beam diagnostics.
  - New beam current record inside ALPI Linac (**3000 enA**) made it possible to measure beam loading effect.

PIAVE ALPI performances and improvements

- PIAVE performances improved a lot in the last two years. PIAVE SRFQ can no more be considered a fragile element, but its maintenance remains expensive and unpredictable
- Average beam on target increased from 200 h/year in the period 2012-2022 to 1500 h/year in the period 2023-2024
- Ca and Mg beam production issues were completely solved
- Operation confirmed that ECR high voltage transformer special maintenace solved instability issue
- Phase reference is not very stable, but transmission loss can be recovered in manual mode or using AI and ML in less than 20 minutes
- PA beam preparation time can be reduced (96h->54h):
  - Transmission improval will reduce injector current needed → Injector preparation time will decrease accordingly (48h->36h)
  - Automatic tuning + AI&ML will reduce cavities phasing time → Beam delivery time will decrease accordingly (48h->18h)
- Beam loading measurement could be used for automatic cavity phasing (new setting time reduction). Next years studies will be addressed to improve beam loading signal at low beam current

TANDEM performances

- New laddertron chain is working well and we already reached 2433 h
- Ca and Mg beam production issues on TANDEM injector were completely solved
- Injector-TANDEM beam transport was improved recovering best transmissions
- TANDEM injection improval reduced TANDEM low energy section instabilities

Thank you