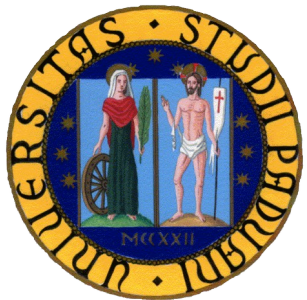


Stato e preventivi di spesa esperimenti gruppo 5



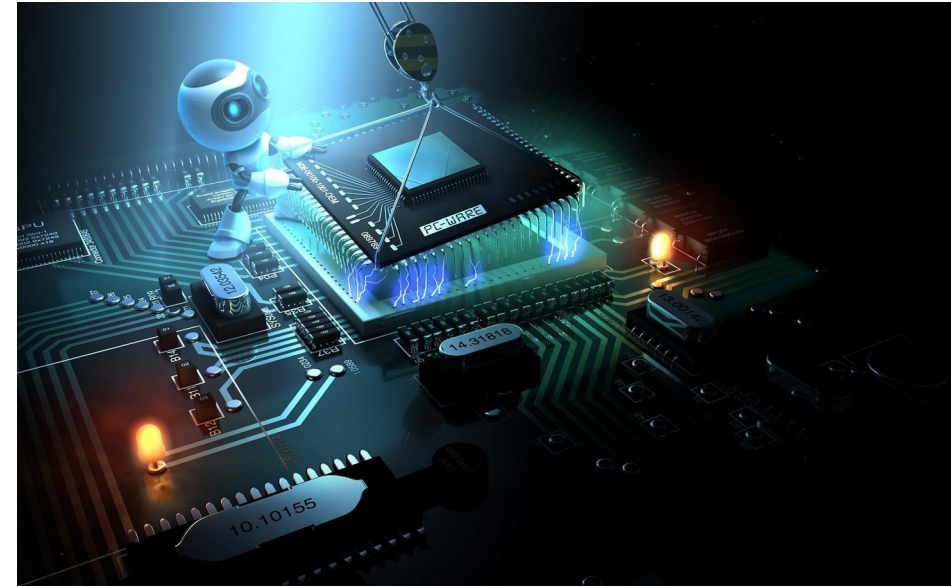
Gabriele Simi – Università di Padova e INFN

05.07.2023



- Tipologia esperimenti, presentazione proposte, missioni
- Storico Fondi e anagrafica
- Esperimenti già conclusi
- Esperimenti in continuazione
- Nuove proposte

La CSN5 coordina le ricerche tecnologiche e lo sviluppo di applicazioni e promuove l'utilizzo, In altri settori, di strumenti, metodi e tecnologie della fisica fondamentale. L'INFN è un solido riferimento a livello nazionale e internazionale per lo sviluppo dei futuri prototipi e la realizzazione degli odierni acceleratori di particelle. Questi sono utilizzati, oltre che nelle ricerche di fisica fondamentale, in altri campi di ricerca e della vita economica e sociale.



- **Acceleratori di particelle**
- **Rivelatori di particelle**
- **Elettronica e software**
- **Applicazioni interdisciplinari della tecnologia INFN**
 1. Applicazioni mediche
 2. Energetica
 3. Ambiente
 4. Beni culturali

Tipologie di esperimenti

Presentazione proposte

Missioni

- Sigle Standard: progetti di 2-3 anni a budget medio-basso ($\sim 50\text{k€}/\text{y}$).
 - Incubatori di attività e idee promettenti e interessanti per l'Ente.
 - Supporto ad attività di più ampio respiro di altre commissioni.
 - Possono avere livelli di rischio elevati.
- Grant Giovani: Esperimenti (max $75\text{k€}/\text{y}$) di 2 anni per giovani ($\text{PhD} \leq 6\text{y}$). Viene finanziata l'attività sperimentale e l'AdR del PI.
 - Supporto per giovani ricercatori che presentino idee originali.
 - Supporto all'autonomia scientifica e alle capacità direzionali.
- Call: Progetti ad alto budget e ampio network ($\sim 1\text{M€}$ max su 3y da bando).
 - Supporto alla formazione di network ampi per progetti di frontiera su argomenti strategici.
 - Finanziamento di Assegni di Ricerca.

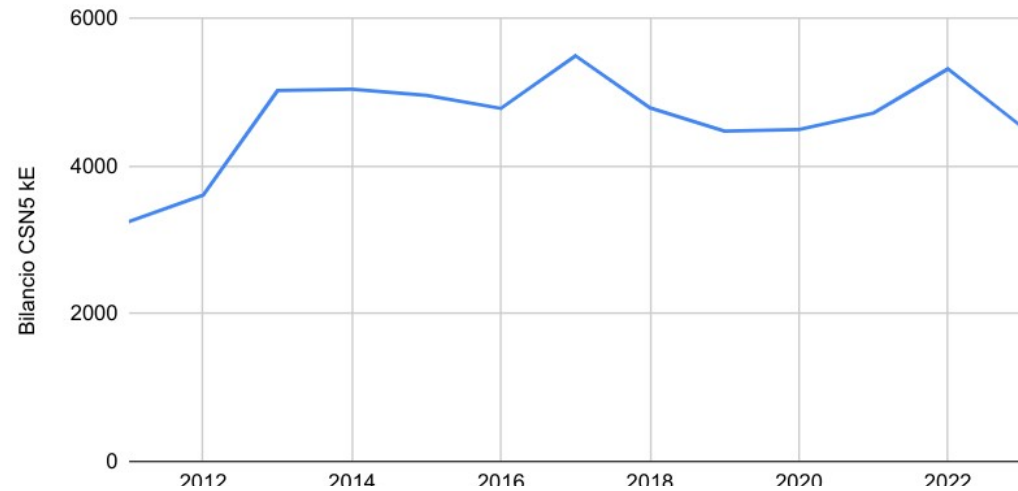
- Modalità di presentazione progetto
 - Template progetto disponibile su sito CSN5
 - presentazione progetto entro 14/7 tramite caricamento in database
- Revisione criteri di valutazione proposte (dal 2023)
 - Valutazione nella riunione di luglio
 - Presentazione da parte del coordinatore di 5 slides (titolo e proponenti, introduzione, obiettivi, metodi, numeri - soldi e FTE)
 - Criteri di valutazione da parte della sottocommissione:
 - Impatto scientifico e sugli interessi dell'Ente
 - Chiarezza degli obiettivi e delle metodologie
 - Congruità economica e delle risorse
 - Punteggio
 - ogni voce 10pt, max 30.
 - Sufficienza
 - minimo 5pt per ogni voce, altrimenti cassato

- Referaggio a settembre
 - Due o tre referee di cui uno della commissione
 - Obbligatoria riunione con i referee prima della riunione della CSN5 per discutere criticità e rimodulazione finanziaria
 - Presentazione plenaria da parte dei proponenti con richieste finanziarie finali
- Criteri di valutazione referaggio
 - Stessi criteri/punteggio/sufficienza della slide precedente
 - Approvazione in base alla classifica/budget suddivisi per aree (Rivelatori, Acceleratori, Interdisciplinare)

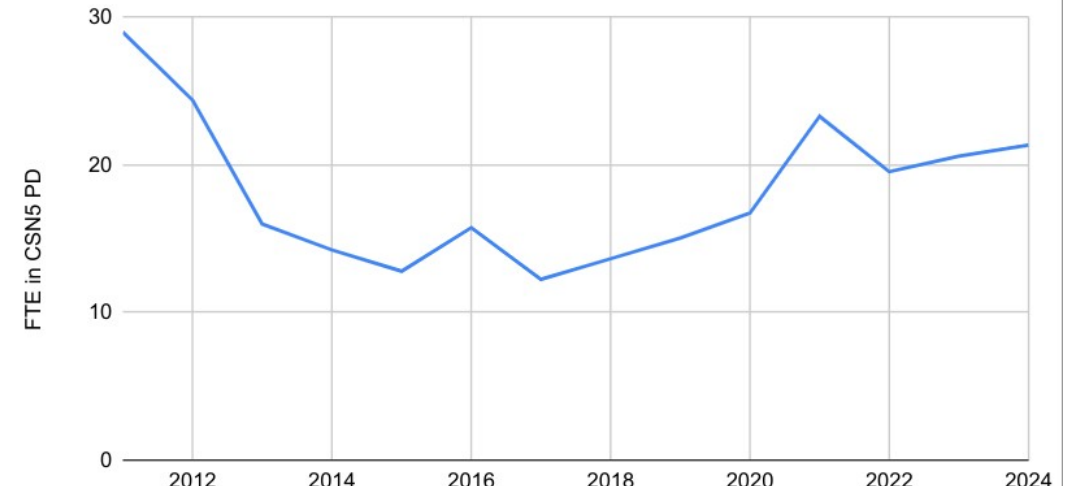
- Storicamente i fondi di missione per conferenze venivano assegnati a seguito di richieste straordinarie in corso d'anno dopo innumerevoli discussioni
- Tenendo conto che
 - La partecipazione a conferenze internazionali di alto livello fa parte integrante dell'attività di molti gruppi afferenti alla CSN5.
 - La partecipazione è indice di visibilità anche per le attività promosse dall'Ente.
 - L'inserimento delle richieste per la partecipazione a conferenze nel fondo indiviso ha creato un dissesto causa l'aumento complessivo dei costi di missione.
- Dal 2024 verrà prevista (nei preventivi) un'assegnazione dedicata alle missioni per conferenze internazionali: modalità ancora da discutere.
- Nei preventivi 2024 si chiede di inserire le richieste di fondi per conferenze

Storico Fondi e Anagrafica

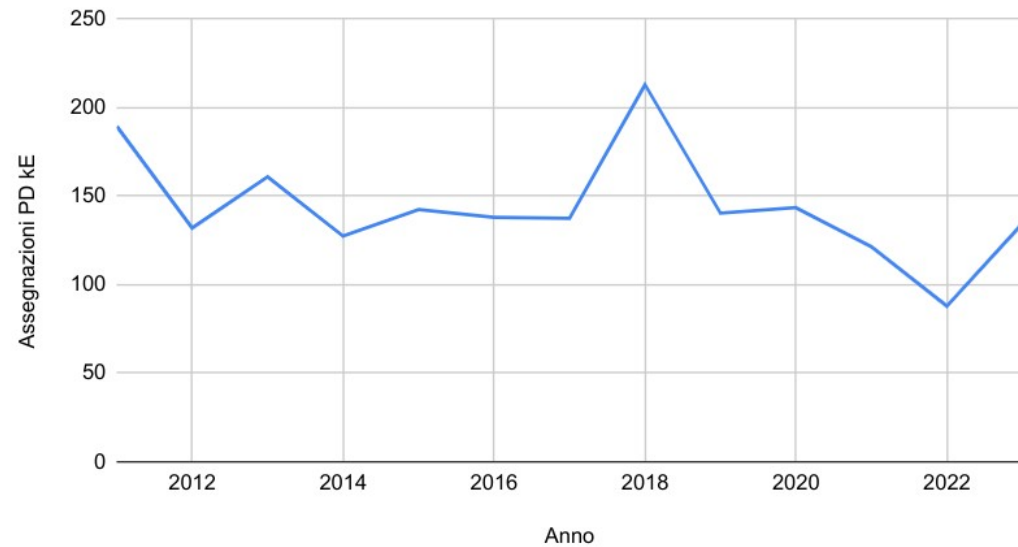
Bilancio kE rispetto a Anno



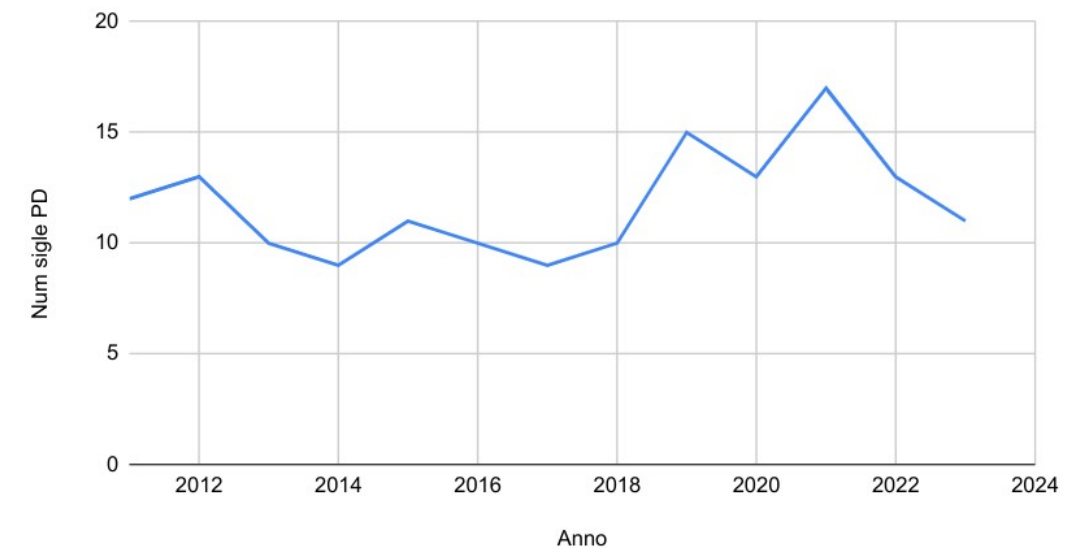
FTE in CSN5 PD rispetto a Anno



Assegnazioni PD kE rispetto a Anno



Num sigle PD rispetto a Anno



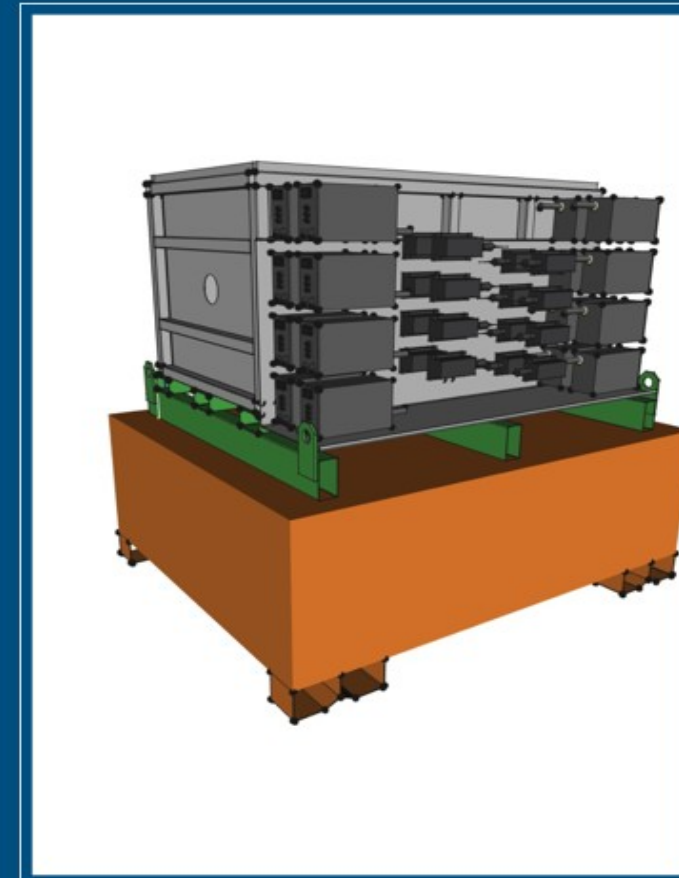
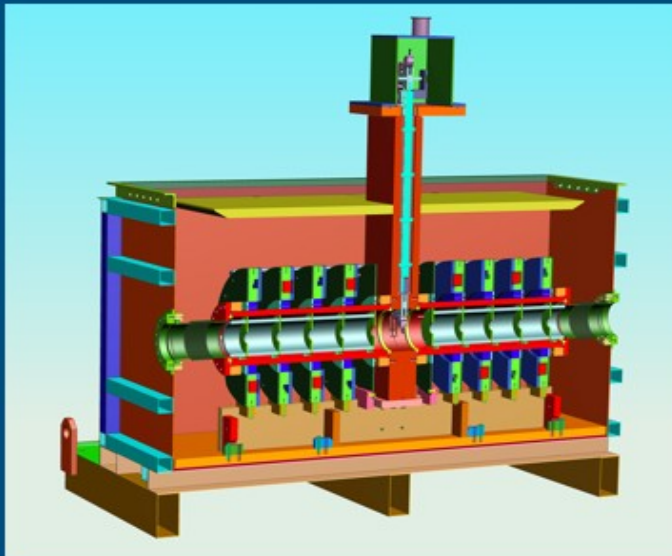
Esperimenti già conclusi



Realizzazione di un Acceleratore Elettrostatico di Nuova Concezione



Acceleratore elettrostatico in versione tandem da 800 keV
HV sugli elettrodi ottenuta per somma in serie di moduli invece che per divisione resistiva
Isolamento elettrico realizzato con liquido invece che con gas ad alta pressione



Utilizzo di generatori di tensioni alimentati otticamente per costruire e testare un acceleratore elettrostatico modulare

- Modularità
- Upgradabilità
- Facilità di maintenance, controllo, diagnosi

Sigla 2019-2021, estesa al 2022, nel 2023 passa sotto dotazioni

Sezioni coinvolte:

Padova [Fanin, Zotto (RN), Dal Corso, Montecassiano, Pegoraro]
LNL

Situazione nel 2023

- Dopo la lettera di support dai laboratori LNL ottenuto un finanziamento ad hoc 10kE per il completamento del progetto (impianti sicurezza e idraulici)
- Primi test a Legnaro effettuati con successo a bassa tensione
- Realizzazione Locale schermato (bunker) in progress (mancano ancora i preventivi)
- Certificazione REI 120 ottenuta (necessaria per realizzare impianti)
- Impianti di sicurezza ancora da realizzare. Fondi SJ si potrebbero impegnare una volta ottenuti i preventivi

Elettronica [per rivelatori]

FALAPHEL Call 2022->2024

(**F**ast **L**inks and **R**ad**H**ard Front End with Integrated **P**hotonics
and **E**lectronics for Physics)

Serena Mattiazzo

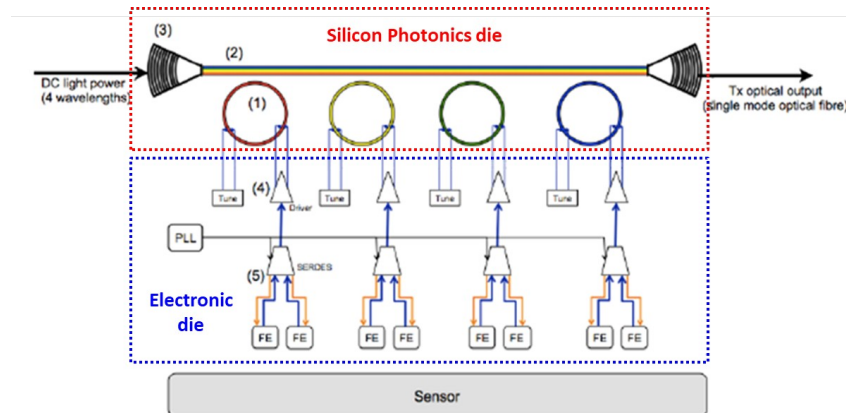
Responsabile Nazionale F. Palla (Pisa)

INFN Units: Padova, Pavia, Pisa

External Units: Scuola Superiore S. Anna di Pisa, Dip. Ingegneria
Informazione UniPisa, Dip. Fisica UniMilano

Goal

- This project will investigate innovative circuit and system solutions for the **integration of SiPh optical devices and subsystems and high-speed electronics** for high rate data transmission, designed to be **radiation hard** for HEP applications.
- Design and production of two chips:
 - **PIC (Photonic Integrated Circuit)**: Silicon Photonics modulators.
 - **EIC (Electronics Integrated Circuit)**: high speed radiation hard (≥ 1 GRad) electronics in 28 nm (both digital electronics for high speed data transmission and analog front-end electronics)
- The final goal is the design and fabrication of a demonstrator integrating (hybrid or 3D integration) the two chips





- Call APERTA di Gr V (elettronica): 2021-2023 (2023 è l'ultimo anno)
 - Estensione da discutere coi referee (già accennata ad Alberto Quaranta)
- Sezioni coinvolte:
 - INFN Pisa (Responsabile Nazionale: Fabrizio Palla)
 - INFN Pavia (Responsabile Locale: Luigi Gaioni)
 - INFN Padova (Responsabile Locale: Serena Mattiazzo)
- Unità esterne
 - Scuola Superiore S. Anna (SSSA) – Pisa
 - Dipartimento di Ingegneria dell'Informazione (DII) – Università di Pisa (UNIFI)
 - Dipartimento di Fisica, Università di Milano (UNIMI)



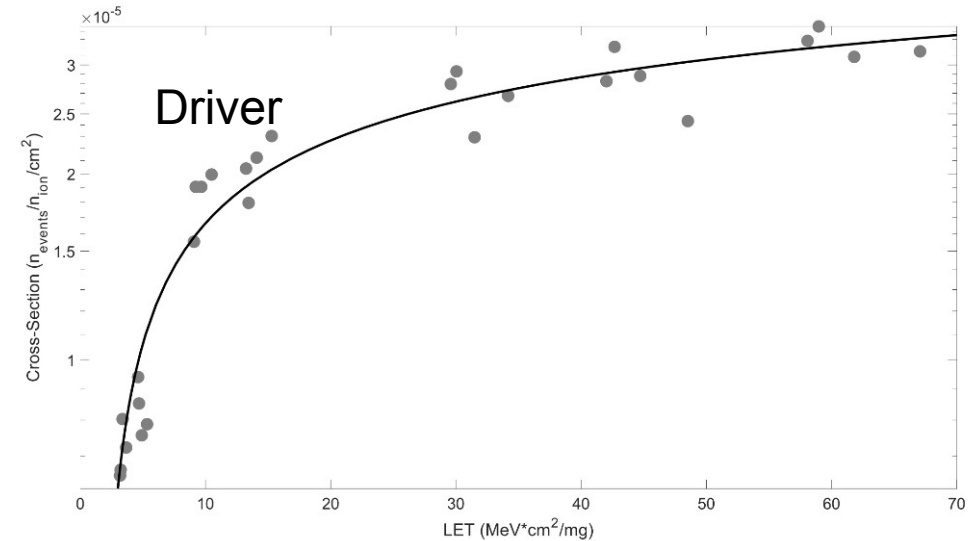
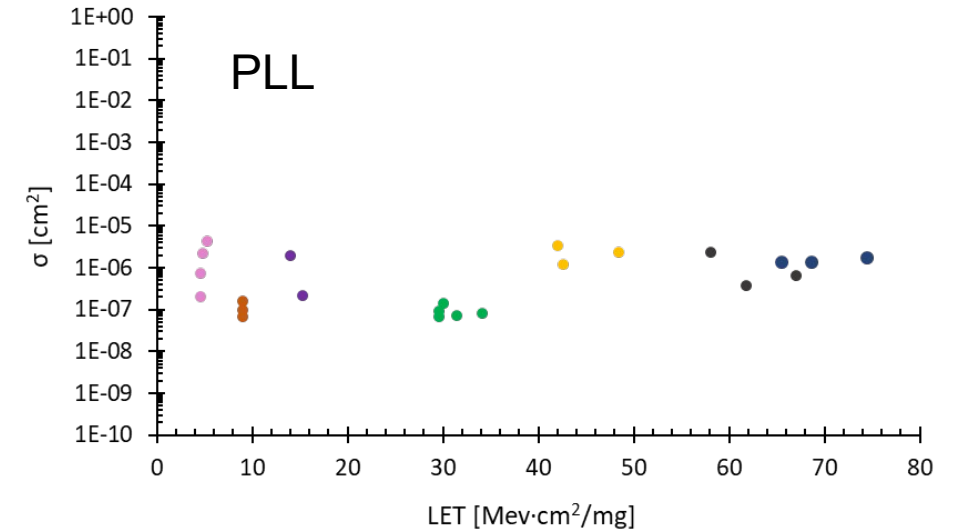
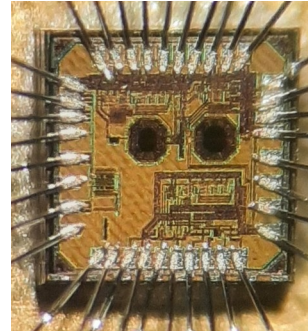
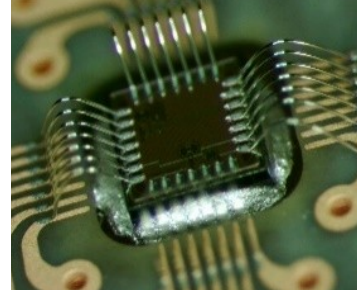
Contributo della Sezione

- WP3: Electronics
 - Contributo (DEI) al disegno della parte digitale dell'EIC
- WP4: EIC-PIC integration:
 - Discussione avviata fra designer e gruppo DIAM di Padova per valutare la possibilità di usare la facility per il raffreddamento dei dispositivi nella fase finale di integrazione
- WP5: Radiation hardness:
 - Total Ionizing Dose (TID):
 - Single Event Effect (SEE)

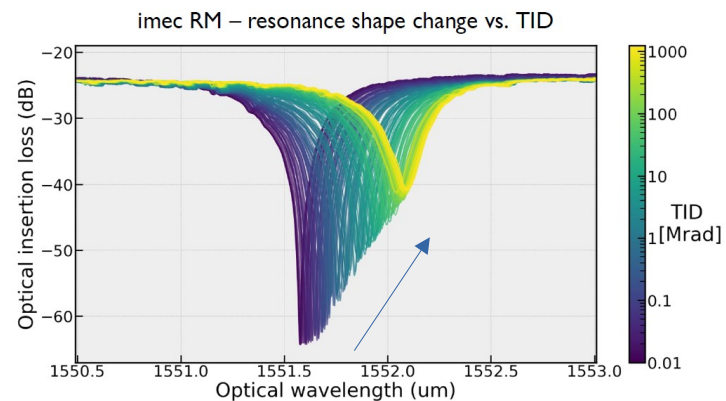
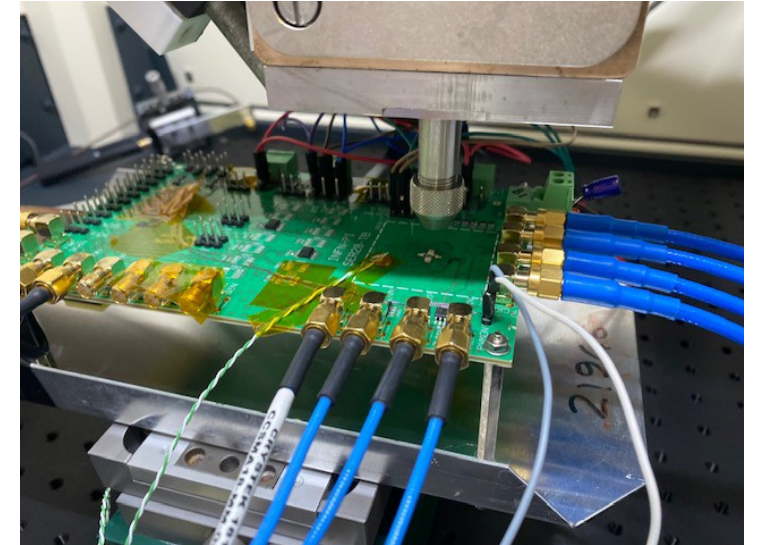
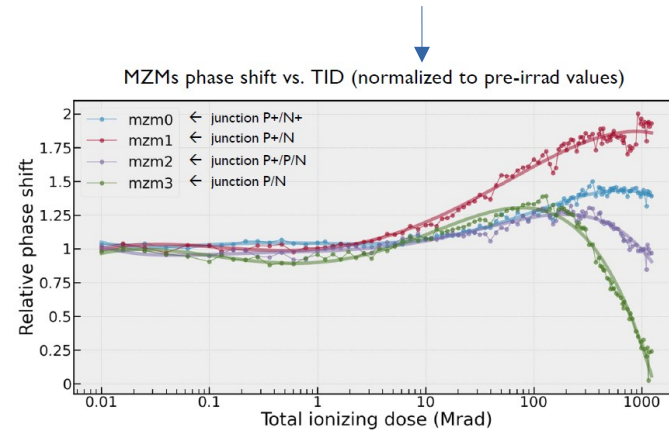
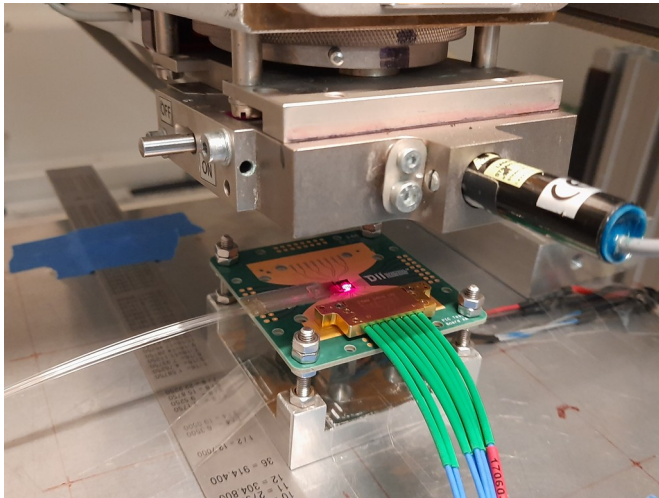


Attività 2021-2023

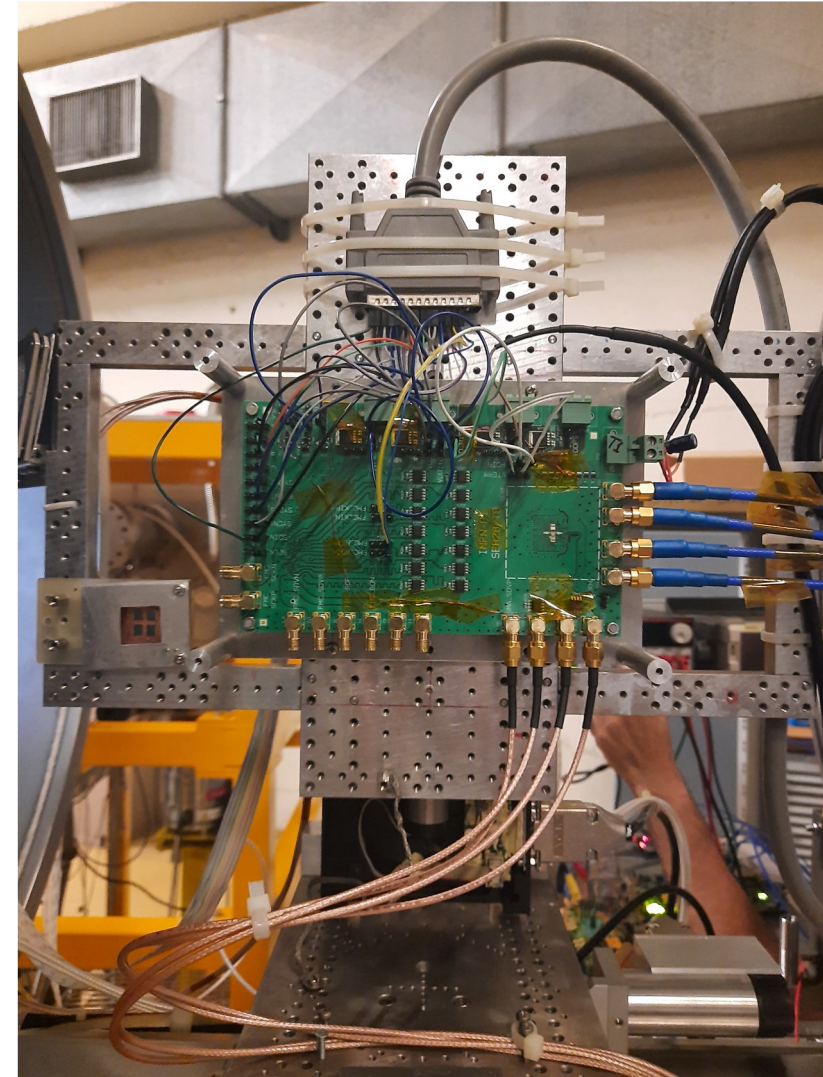
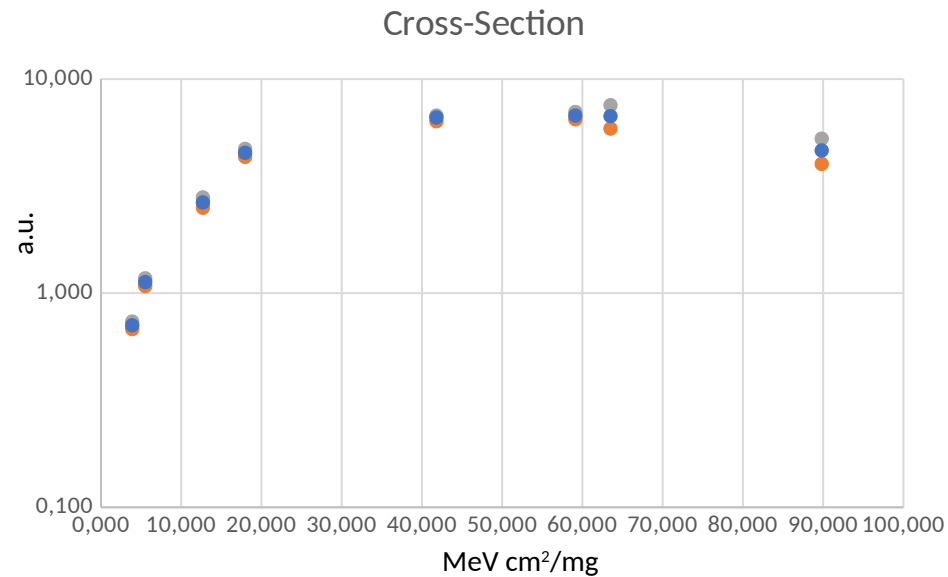
- Attività **2021**
 - ///
- Attività **2022**:
 - Total Ionizing Dose
 - Long shutdown of X-ray facility (end 2021-beginning 2022) for TID
 - April: calibration of INFN Pisa X-ray irradiation machine
 - Single Event Effect
 - SEE test @ LNL (2 days @ July)
 - PLL (Phase-locked loop) in 65 nm, driver in 28 nm



- Attività **2023**:
 - TID
 - Test up to 1 Grad on band gap circuit, Modulators, Serializer



- Attività **2023**:
 - SEE
 - Test @ LNL (29-30/6/2023)



- FALAPHEL finisce nel 2023 ... ma ancora sottomissioni, chip da testare e fare il dimostratore

- Analog Front-End (Pavia)**

- Test FLASH ADC in corso
- TOT based da sottomettere

- Serializzatore (Pisa)**

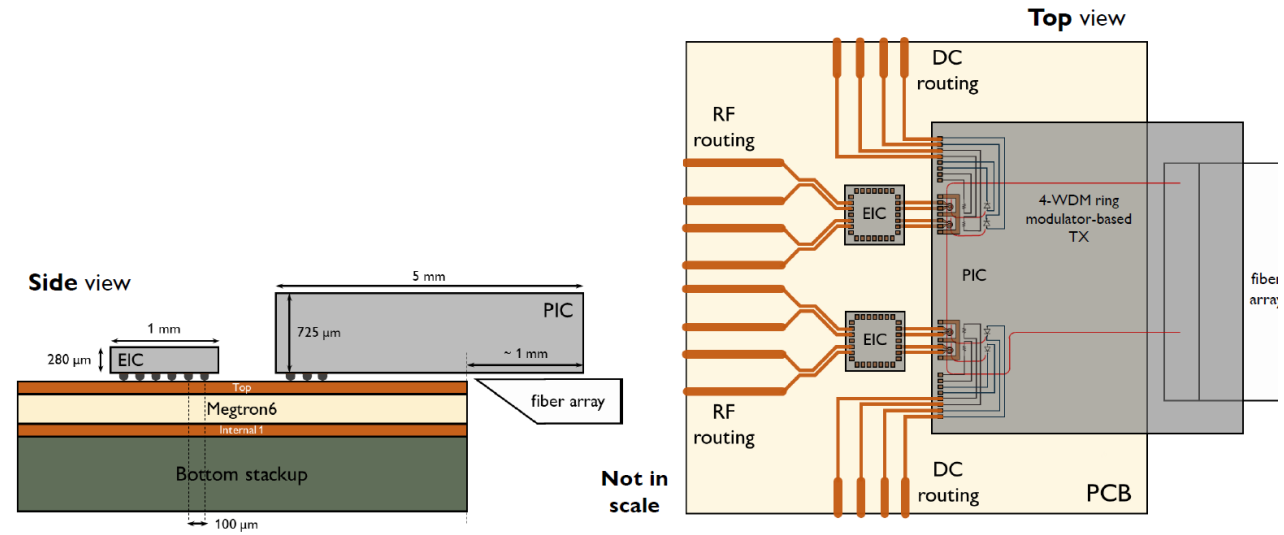
- CML irraggiamenti in corso (TID, SEU)
- CML DDR sottomesso
- Disegno CMOS in corso – da sottomettere

- Driver (Pisa)**

- CML da irraggiare
- CMOS da progettare

- Chip fotonico (Pisa)**

- Risultati irraggiamenti fatti a Padova
- Progettazione chip finale
- Bonding PIC+EIC (Pisa/Camgraphic)
 - da definire
- Caratterizzazioni TID e SEE (Padova e Pisa)





Anagrafica + richieste ai servizi

Cognome	Nome	Ruolo	% in FALAPHEL	WP
Bagatin	Marta	Prof. Associato	0.15	WP5
Bonaldo	Stefano	Assegnista	0.10	WP5
Candelori	Andrea	Docente	0.20	WP5
Gerardin	Simone	Prof. Associato	0.15	WP5
Mattiazzo	Serena	RTDb	0.10	WP5
Paccagnella	Alessandro	Prof. Ordinario	0.15	WP5
Vogrig	Daniele	Prof. Associato	0.20	WP3
Wyss	Jeffery	Prof. Associato	0.50	WP5
			TOT 1.35	

- Supporto eventuali attività di irraggiamento al Tandem nel 2024
 - La call per la richiesta di fascio non è stata ancora aperta.
- Supporto per la manutenzione della facility a raggi X (tubo, chiller, etc)
- **2 s.u. al laboratorio di elettronica**

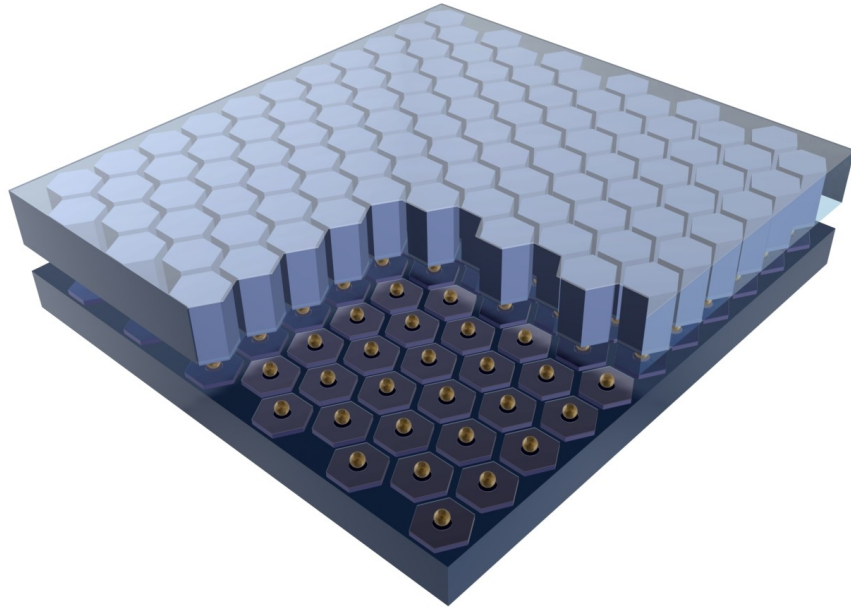
ASIX Analog Spectral Imager for X-rays

Nuova Proposta



Trento Institute for
Fundamental Physics
and Applications

ASIX Analog Spectral Imager for X-rays



ASIX will deliver a new class of large area ($\geq 3 \text{ cm}^2$), high channel density ($\sim 50 \text{ kpixels/cm}^2$), buttable, hybrid silicon and CdTe pixel detectors with fast, event-driven read-out and single-photon sensitivity for X-ray spectral imaging of celestial sources through satellite observations and for X-ray diffraction, fluorescence and microtomography of industrial, chemical and biological samples.

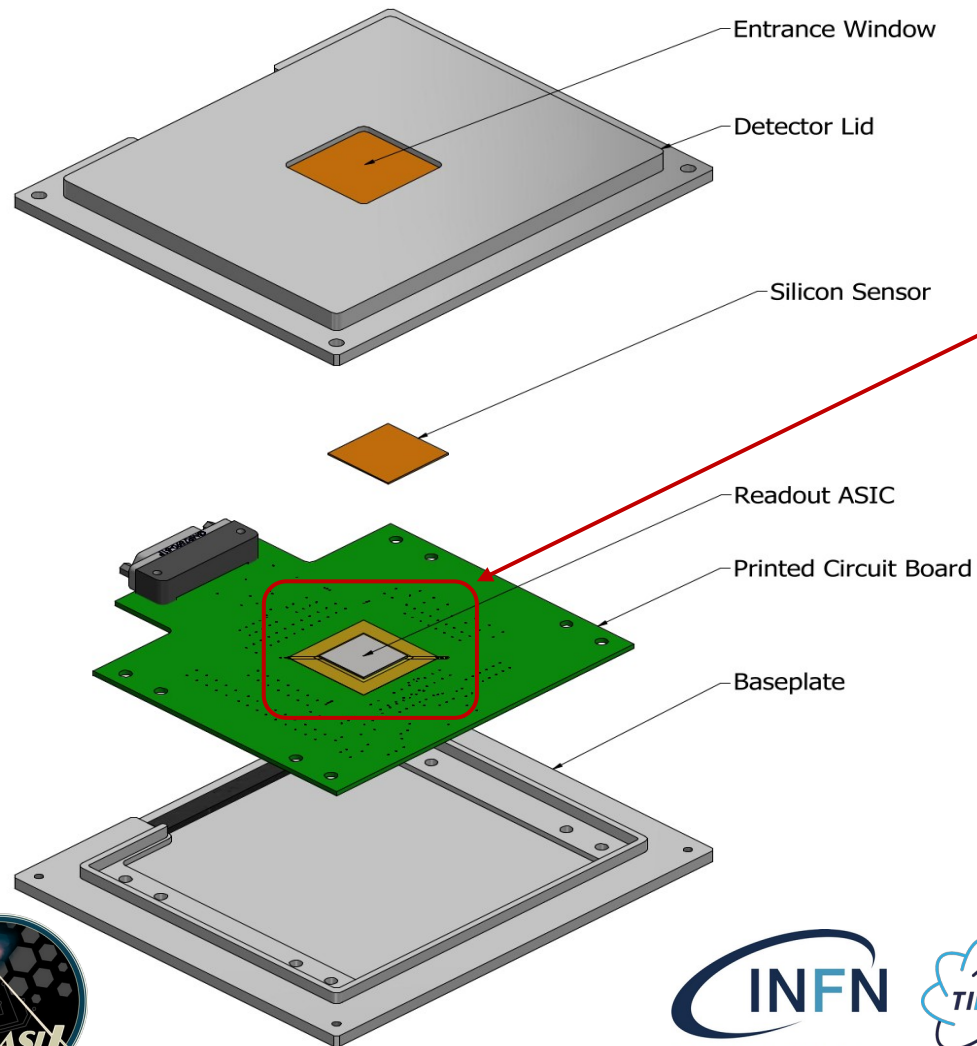
Main Goals

- 1) high spatial ($\sim 10 \text{ }\mu\text{m}$) and spectral ($\sim 300 \text{ eV}$ at 8 keV) resolution
- 2) extended Energy range ($1\text{-}50 \text{ keV}$)
- 3) low readout noise ($\leq 30 \text{ e- ENC}$)
- 4) large Area ($\geq 3 \text{ cm}^2$)
- 5) edgeless layout
- 6) High Speed event-driven Analog readout



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ASIX Analog Spectral Imager for X-rays



Topics

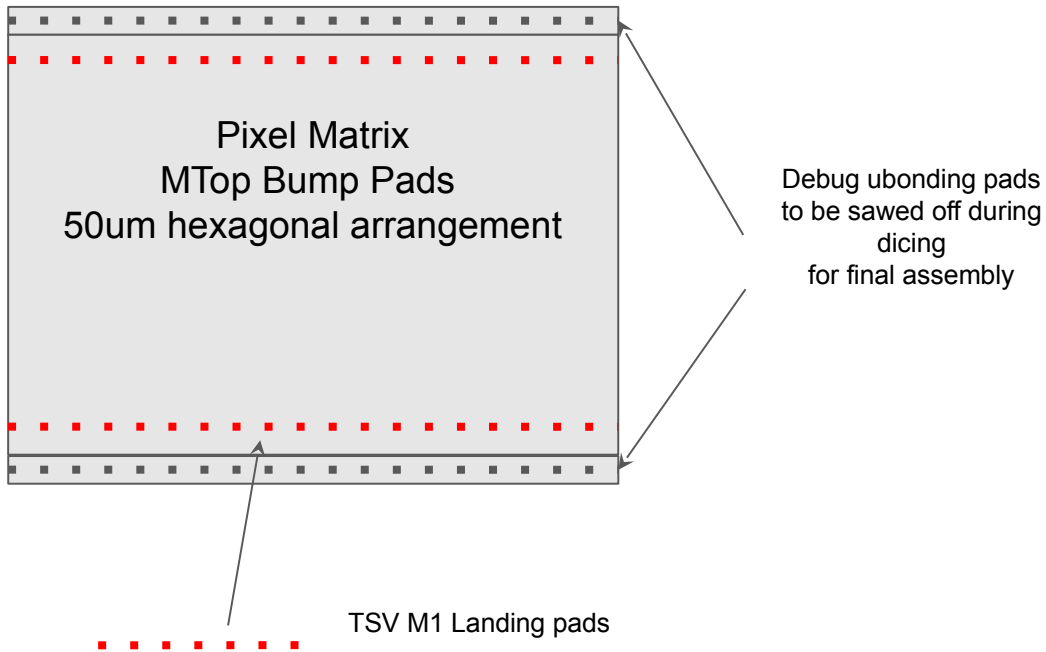
- 1) **a core front-end, TSV ready, large area Full-Custom CMOS ASIC with 50 μ m pitch pixels featuring signal triggering and smart processing logic [Padova & Torino];**
- 2) **a customized edgeless silicon sensor** for optimized performance at low energy (<15keV), and best geometry for matching with the ASIC pixels layout;
- 3) **a customized High-Z sensor(CdTe)** for optimized performance at high energy (>15keV), and best geometry for matching with the ASIC pixels layout;
- 4) **a simple, robust and scalable electro-mechanical integrated assembly** (4-Sides buttable hybrid sensor module).



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ASIX New Readout ASIC

Padova e Torino



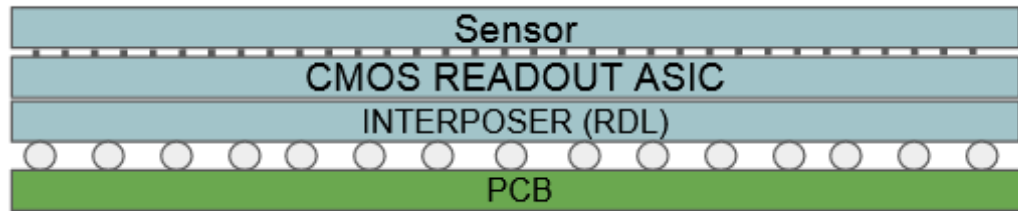
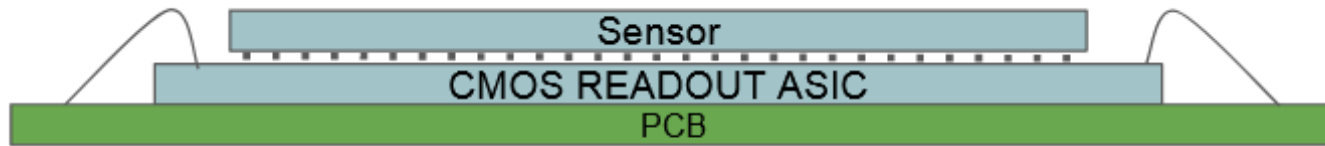
Keeping XPOL-III as a reference. A new readout full custom ASIC will be developed. It will have **more flexible triggering and readout scheme, more on-pixel functionalities, larger active area ($\geq 3 \text{ cm}^2$), and a four-side, buttable-ready, TSV-compatible** design will be developed and become the baseline for the final generation of ASIX detectors. The baseline technology for the readout ASIC will be a standard CMOS 110nm technology, compromise of the request for higher integration density for on-pixel digital processing, in respect to the XPOL-III ASIC(180nm), and a mature, high-yield and low-cost platform that allows for a reduction of the risk of a full-reticle size single-project chip design.



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ASIX 4-side buttable

Old configuration



New configuration

Debug pad connection can be used during preliminary tests

Ultimate level of 4-side buttability will be accomplished with TSV processing on the new readout ASIC (ASIX_ROC).

TSV processing will require thinning of the readout ASIC down to ~100um, TSV will be “drilled” and contacted from the backside reaching the M1.

A redistribution layer (RDL) will be built on the ASIC backside and connection with the PCB will be done via fine pitch BGA. We will provide external foundries with RDL design and ASIC build up information.



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ASIX Contributions

25+ Researchers and Technologists
from:
INFN Pisa
INFN Torino
INFN Padova
TIFPA, FBK

Nome	Struttura	WP	2024	2025	2026
L.Baldini	PI	1-10	0.3	0.3	0.3
R.Bellazzini	PI	1-10	0	0	0
M.Minuti	PI	1-10	0.5	0.5	0.5
F.Morsani	PI	2,6,7,9	0.3	0.3	0.3
L.Orsini	PI	8,9	0.2	0.2	0.2
M.Pesce-Rollins	PI	1-10	0.2	0.2	0.2
C.Sgrò	PI	1-10	0.25	0.25	0.25
G.Spandre	PI	1-10	0.1	0.1	0.1
M.Boscardin	TIFPA	1,3,10	0.3	0.3	0.3
M.Centis Vignali	TIFPA	1,3,10	0.2	0.2	0.2
G.Paternoster	TIFPA	1,3,10	0.3	0.3	0.3
L.Parellada Monreal	TIFPA	1,3,10	0.5	0.5	0.5
G.Pepponi	TIFPA	1,3,10	0.5	0.5	0.5
S.Ronchin	TIFPA	1,3,10	0.4	0.4	0.4
A.Boughedda	TIFPA	1,3,10	0.5	0.5	0.5
L.Latronico	TO	1-10	0.25	0.25	0.25
A. Di Salvo	TO	2	0.25	0.25	0.25
F. Cossio	TO	2	0.25	0.25	0.25
M. Rolo	TO	2	0	0.15	0.15
M. Aglietta	TO	9	0.25	0.25	0.25
S. Maldera	TO	9	0.25	0.25	0.25
D. Chiappara	PD	2	0.1	0.1	0.1
G. Meng	PD	2	0.25	0.25	0.25
D. Pantano	PD	2,6	0.2	0.2	0.2
P. Giubilato	PD	2	0.15	0.15	0.15
J. Wyss	PD	2,6	0.3	0.3	0.3



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ASIX WP Break Out

Main WPs(2,3,5) are respectively conducted by Torino, TIFPA, **Padova** and Pisa.

WP	Name	Responsible	Contributors
WP 1	Project Office	Minuti(PI)	PI,TO
WP 2	Front-End ASIC	Andrea Di Salvo (TO)	TO,PI, PD
WP 3	Silicon sensors	Boscardin(TIFPA)	TIFPA,PI
WP 4	High Energy Sensor	Sgrò(PI)	PI
WP 5	Packaging and Interconnections	Minuti(PI)	PI,TO
WP 6	Electronics and DAQ	Minuti(PI)	PI,TO, PD
WP 7	Detector Control Software	Baldini(PI)	PI
WP 8	Mechanics and integration	Sgrò(PI)	PI
WP 9	Assembly Integration Verification and Test	Sgrò(PI)	PI, TO, PD
WP 10	Technical Documentation and papers	Latronico(TO)	PI, TO, TIFPA



Trento Institute for
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and Applications



Istituto Nazionale di Fisica Nucleare
Sezione di Padova



Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

FEROCE

Front-End Rdma Over Converged Ethernet

Durata: 3 anni

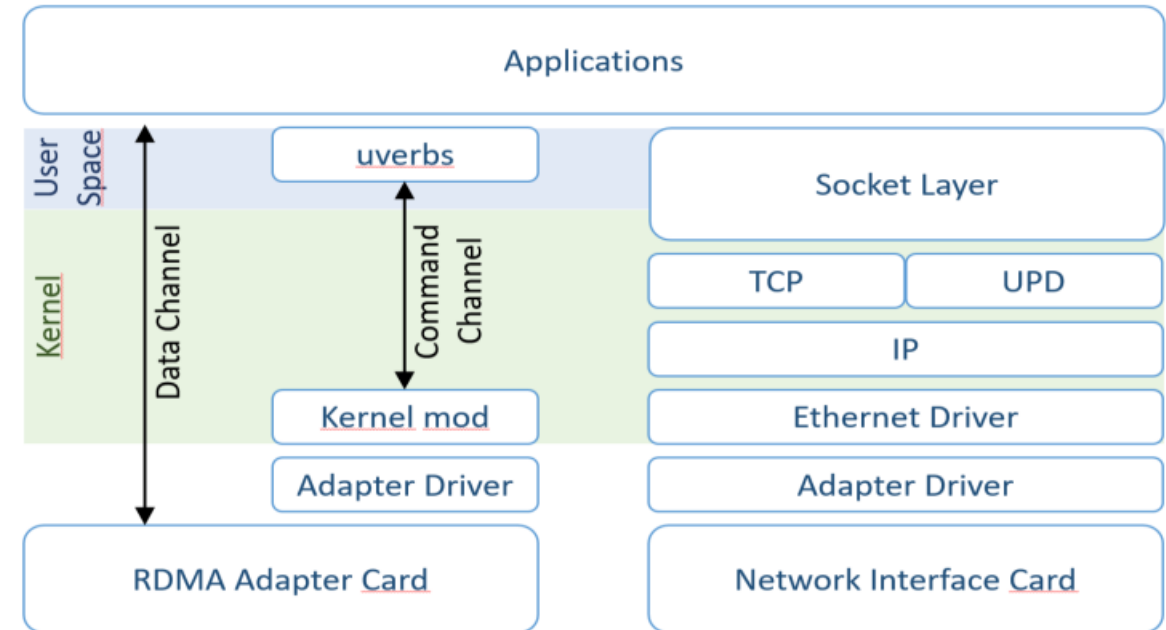
Area di ricerca: Rivelatori, Elettronica, Calcolo

Responsabile nazionale: Andrea Triossi (Unipd – INFN Padova)

Unità partecipanti: INFN sezione di Padova
Laboratori Nazionali di Legnaro

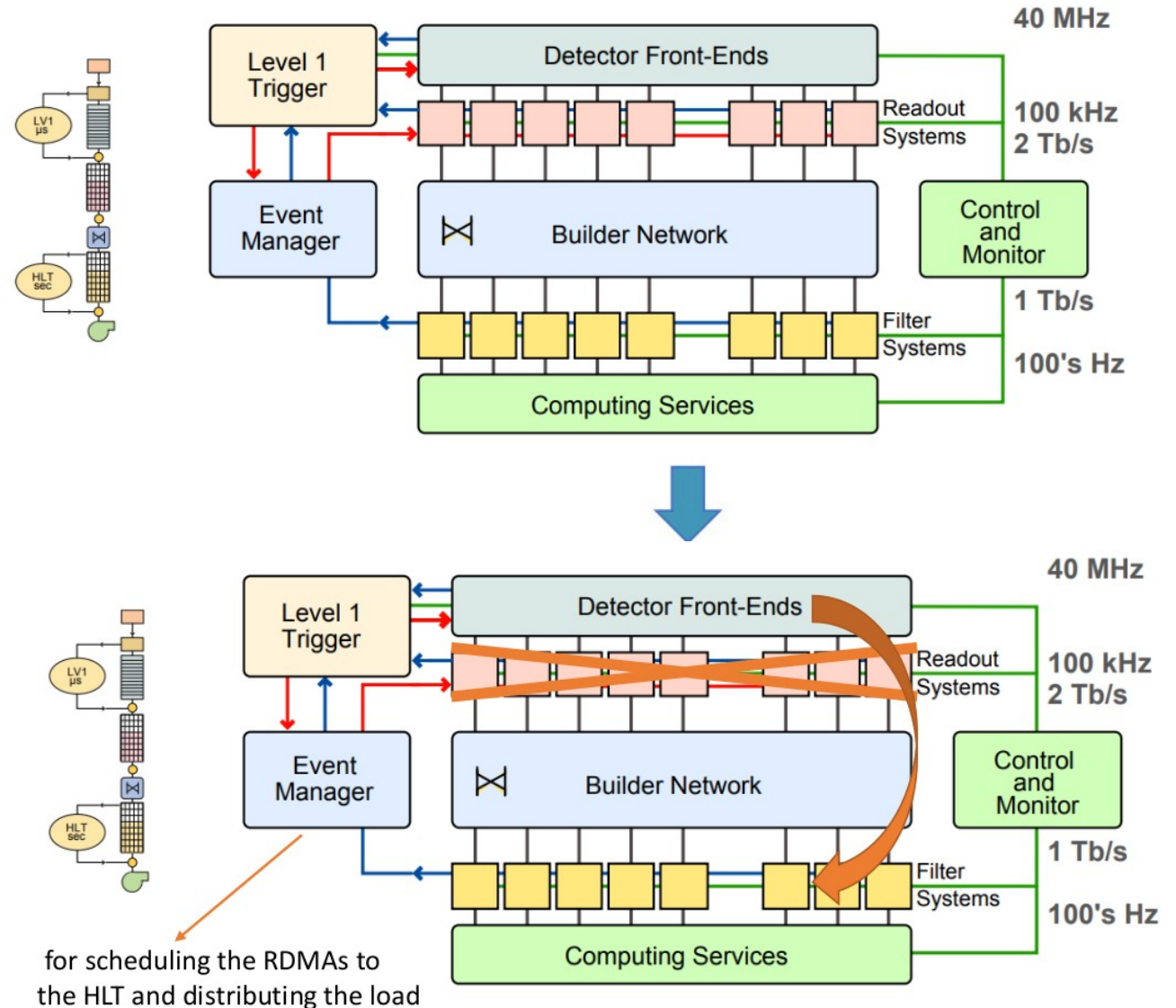
Objectives

- Processing power is important as an efficient data movement
- In a DAQ system a large fraction of CPU is engaged in networking
 - Data manipulation (several copies)
 - Latency increase and throughput reduction
- Zero-copy is obtained by adding RDMA layer to the network stack
- FEROCCE wants to move the adoption of the network protocol to the data producer
 - Front-end initiates the RDMA transfer
 - No point-to-point connection between front-end and back-end
 - Dynamical switching routing according to node availability



Methodology

- Several network stacks implementing RDMA
 - InfiniBand, RoCE, iWARP...
- RoCE (RDMA over Converged Ethernet)
 - Based on Ethernet networks
 - Industry-standard
 - Multi-vendor ecosystem
 - RoCE v2 packet switching (layer 2 and 3)
- FPGA are already used for implementing network stacks
 - Data center
 - ATLAS

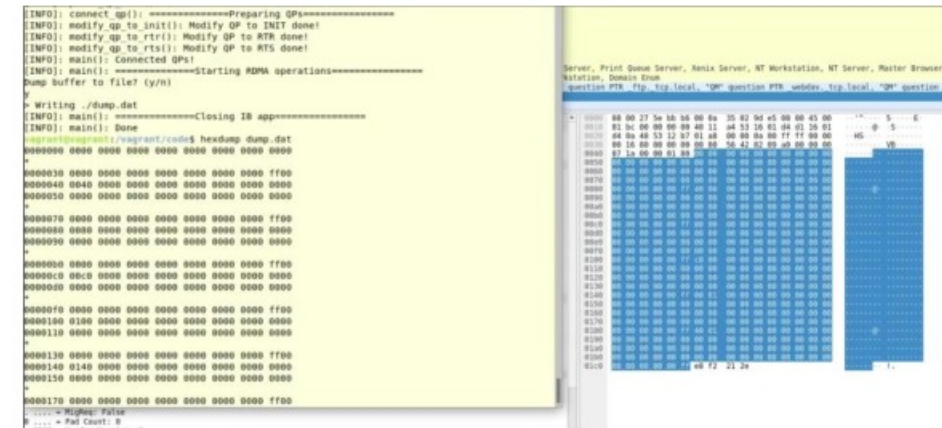
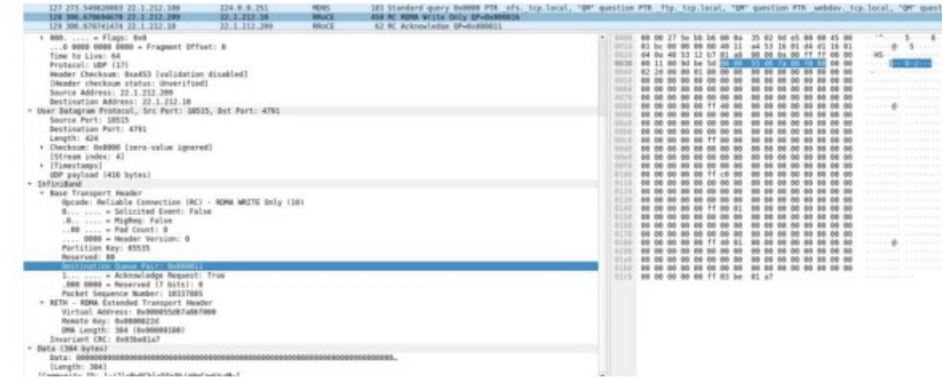


WP1 Activities: Front-end firmware core

- Study of the exiting libraries
 - Open-source libraries for UDP/IP, TCP/IP and RoCEv2, at 10-100Gbit/s
 - ETH Zurich Network Stack
- Testing of UDP and TCP
 - Dynamic VCS simulation
 - TUN/TAP
 - Modifications in MAC and in DDR interface
 - Tested UDP and TCP loopback
 - Deployed in VCU118
 - Tested for UDP and TCP stacks
 - Good bandwidth results for TCP (> 60Gbps with two connections)
 - Hard to close the timing (even in HLS doesn't close)
 - Porting to Vivado 22.2 was needed (intelligent runs)

WP1 Activities: Front-end firmware core

- Next steps (second half 2023)
 - Dynamic VCS simulation of RoCE v2
 - Modification of the existing library
 - Based on block memory transfer (from memory to memory)
 - We need a stream-based approach where a continuous stream of data is encapsulated in RoCE payload
 - Pruning of the unused RoCE features
 - Accepted talk at TIPP 2023
- 2024 Activities
 - Possibly, rewriting library at lower level (RTL)
 - Deployed in FPGA evaluation board
 - Test on real network (commercial switch)
 - Implementing different datapath (1G/10G/100G)



Research group

- Padova
 - Marco Bellato (0.3)
 - Antonio Bergnoli (0.2)
 - **Gabriele Bortolato (0.3)**
 - Daniele Mengoni (0.15)
 - Matteo Migliorini (0.3)
 - Fabio Montecassiano (0.2)
 - Jacopo Pazzini (0.15)
 - Andrea Triossi (0.3)
 - Marco Zanetti (0.15)
- LNL
 - Damiano Bortolato (0.15)

Total FTE: 2.2

Richiesta finanziaria

Anno	Missioni	Inventariabile	Consumo	Totale
2024	1	21		22
2025	1	10		11
Totali	2	31		33

La parte di apparati è dettagliata come segue:

2024	1x scheda di valutazione FPGA Xilinx	8kE
	1x scheda di valutazione FPGA Microchip	1kE
	1x 100GbE switch 8 porte	12kE
2025	1x GPU NVIDIA	10kE

Rivelatori

Avalanche Diodes Array – ADA-5D

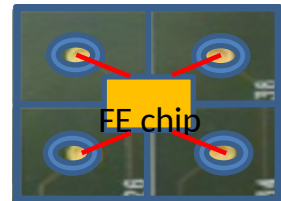
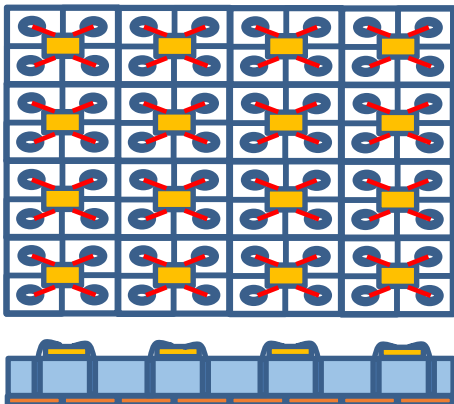
University of Pisa & INFN **Pisa** / University of **Siena** & INFN Pisa
University of Padova & INFN **Padova** / University of **Pavia** & INFN Pavia
University of **Trento** & **TIFPA** / Fondazione Bruno Kessler **FBK** (Trento)

G.Collazuol
INFN Padova
CdS 2023/7/4

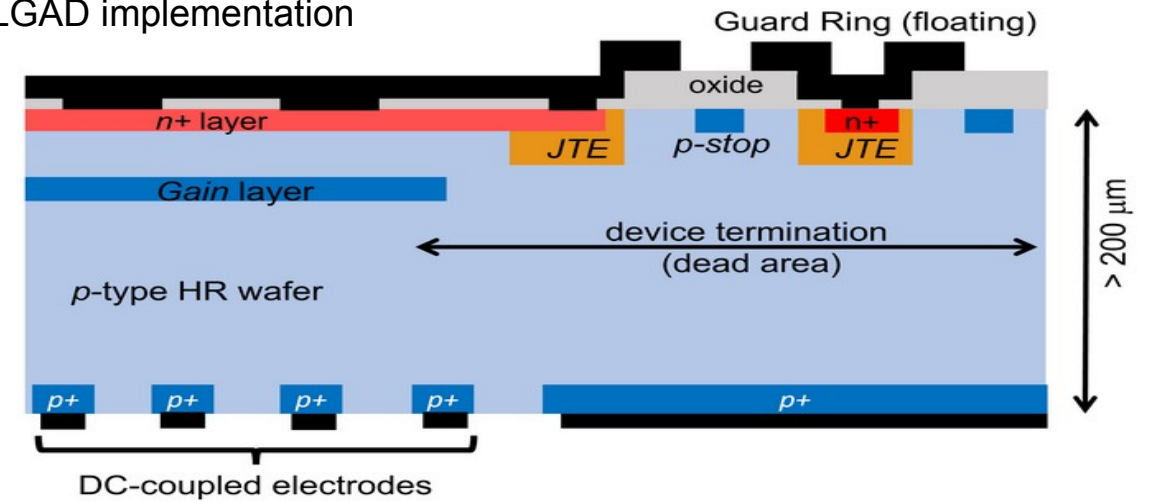
Development thick LGADs and related large dynamic range electronics

- large pixels (3mm x 3mm)
- sensor thickness 200-300 μm

mini-TILE (2.4cm x 2.4 cm):
16 FE = 8 x 8 LGADs



Example of thick LGAD implementation



Each FE chip, connected to 4 LGADS, implements:

- double gain linear range to cover > 1000 m.i.p.
- internal ADC
- internal TAC + ADC conversion
- Track & Hold

CHARGE IDENTIFICATION of cosmic-ray (CR) ions with charge $1 \leq Z \leq 30$ with $dE/dx \propto Z^2$ measurements in a **charge detector** (SCD) at the top of the instrument

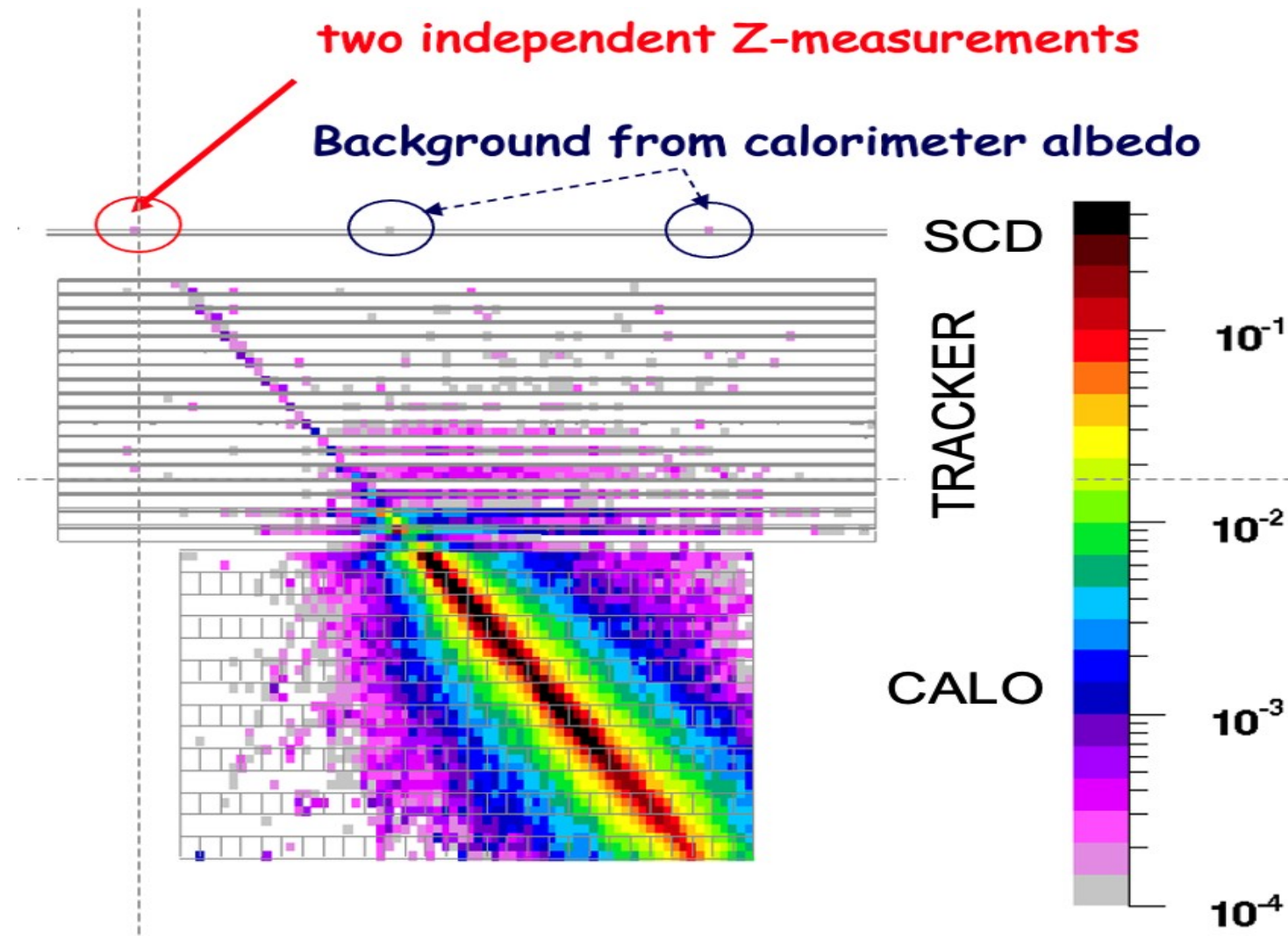
Example of a typical space-borne CR experiment with a generic charge detector (silicon pixels, scintillator paddles/tiles, etc.)

Backscattering (BS) from the calorimeter generates fake hits in the charge detectors and in the tracker.

The tracker back extrapolates to the SCD with an impact point IP resolution $\sim 150 - 200 \mu\text{m}$

BS increases with energy and deteriorates the charge ID of individual CR elements.

ADA-5D concept: reject BS with a high resolution ToF measurement



FLUKA simulation of 1 TeV incident carbon nucleus

TARGET = space experiments ... VERY tight requirements

Charge & Timing 5D detector: x,y,z, charge, time (5D)

Charge measurement:

- large dynamic range > 1000 m.i.p.
- charge resolution for proton < 0.1 => 200-300 μm sensors for primary ionization

Timing measurement:

- sub-ns resolution (e.g., for 10 – 20 cm flight path -> 100 ps)

Space resolution and granularity:

- modest granularity (3mm x 3mm pixels) to cover large $\text{O}(\text{m}^2)$ sensitive area
- an independent TRACKER is in charge of the fine spatial resolution

Power budget:

- VERY challenging < 150 W/m²

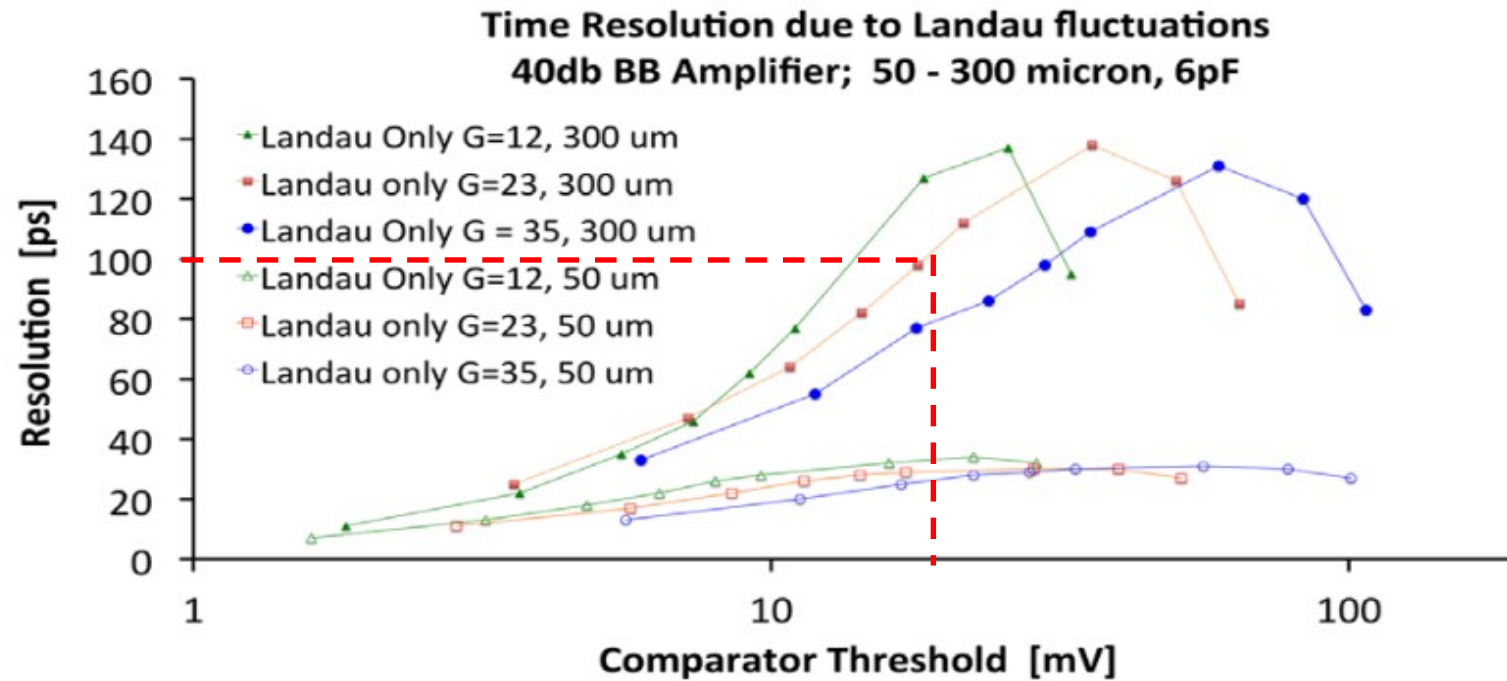
Radiation hardness:

- modest problem for space experiments < 10^{11} 1 MeV neq (TID ~100 krad)

Gain and Time resolution

with $G \sim 10-20$ dominant term in time resol. is the Landau tails jitter

$\sim 100\text{ps}$ feasible with a low threshold (ok as $S/N > 30$ for 1 m.i.p)



e.g.: 100 ps resolution with:

- 300 um thickness
- $G=23$
- threshold $\sim 20 - 30$ mV

Activities in 2023

- FBK/Trento - sensor design & simulation at FBK
- Pavia - chip design and simulation in Pavia
- Padova/Pisa - Flex circuit design (at CERN)
- Padova/Pisa - Digital Readout

Activities in 2024

- FBK/Trento - **First sensors** produced & testes at FBK ready by June 2024
- Pavia - **First chips delivered** at Pavia for tests by September 2024
- Padova - **Development of RF amplifier** for reading out single sensors
w/o standard FE chip &
- Pisa / Padova - **Telescope based on TimePix3 (Pisa) and TimePix4 (Padova)**
- **Test Beam at CERN SPS with ions in Fall 2024**

Resources @ INFN Padova

- G.Collazuol - 10 %
- Matteo Feltre (PhD) - 20%
- Marco Mattiazzi (PhD) - 80%
- Daniele D'Ago (Post-Doc) - 20%

Preventivi 2024

- Consumo per circa 10kEuro
- Missioni (CERN) per circa 4kEuro

Richieste in Sezione PD

- **Servizi Tecnici ed Elettronici**
progettazione scheda Amplificatore RF ~ 3m.p.
- **Servizio Elettronica**
programmazione FPGA TimePix4 ~ 3m.p.
- **Servizio Progettazione Meccanica**
setup telescopio ~ 1m.p.
- **Servizio Officina Meccanica**
meccanica telescopio ~ 1m.p.

N3G : Next Generation Germanium Gamma Detectors

D. De Salvador^{1,2}

Responsabile Nazionale

¹ INFN-LNL

² Università di Padova

CALL 2021-2023

Laboratori di Legnaro
W. Raniero

Sezione Milano
S. Capra

Sezione Ferrara
A. Mazzolari

Sezione Padova
F. Recchia

Aim:

The proposal aims to implement **Pulsed Laser Melting technology to produce complex HPGe coaxial detectors** and test their potential for the challenge of nuclear spectroscopy experimentation in conditions of high flux and high damage.

Besides the innovatively processed crystals, the implementation of complete prototypes with optimized electronics and DAQs and their **testing under damage and annealing will be developed.**

All this will lead to two further possible benefits:

- INFN will have the technology to repair existing detectors
- INFN will have the technology to be able to build detector prototypes with innovative geometries, for research in various fields.

Final user:

International Community of Nuclear Gamma Spectroscopy. The core business regards CSN III INFN with possible future implications in space and medical applications.

WP e Tasks

WP	Task	Sez.
1 -Fabbricazione (De Salvador,LNL)	• Depositi dei precursori droganti su superfici non planari (LNL) • Realizzazione e caratterizzazione giunzioni su superfici non planari.(LNL) • Litografia per la segmentazione di superfici non planari. Segmentazione esterna.(FE)	LNL FE
2- Elettronica e implementazione (S.Capra, MI)	• Raccolta e amplificazione del segnale elettronico. (MI) • Criostati per test (LNL) • Meccanica alloggiamento del rivelatore (MI)	MI PD LNL
3- Simulazioni e Test (Recchia, PD)	• Simulazione segnali in funzione della geometria, definizione geometria (PD) • Preparazione sistema di scansione segmenti e DAQ (PD,LNL) • Test performance, rad-hardness (PD,LNL)	PD LNL

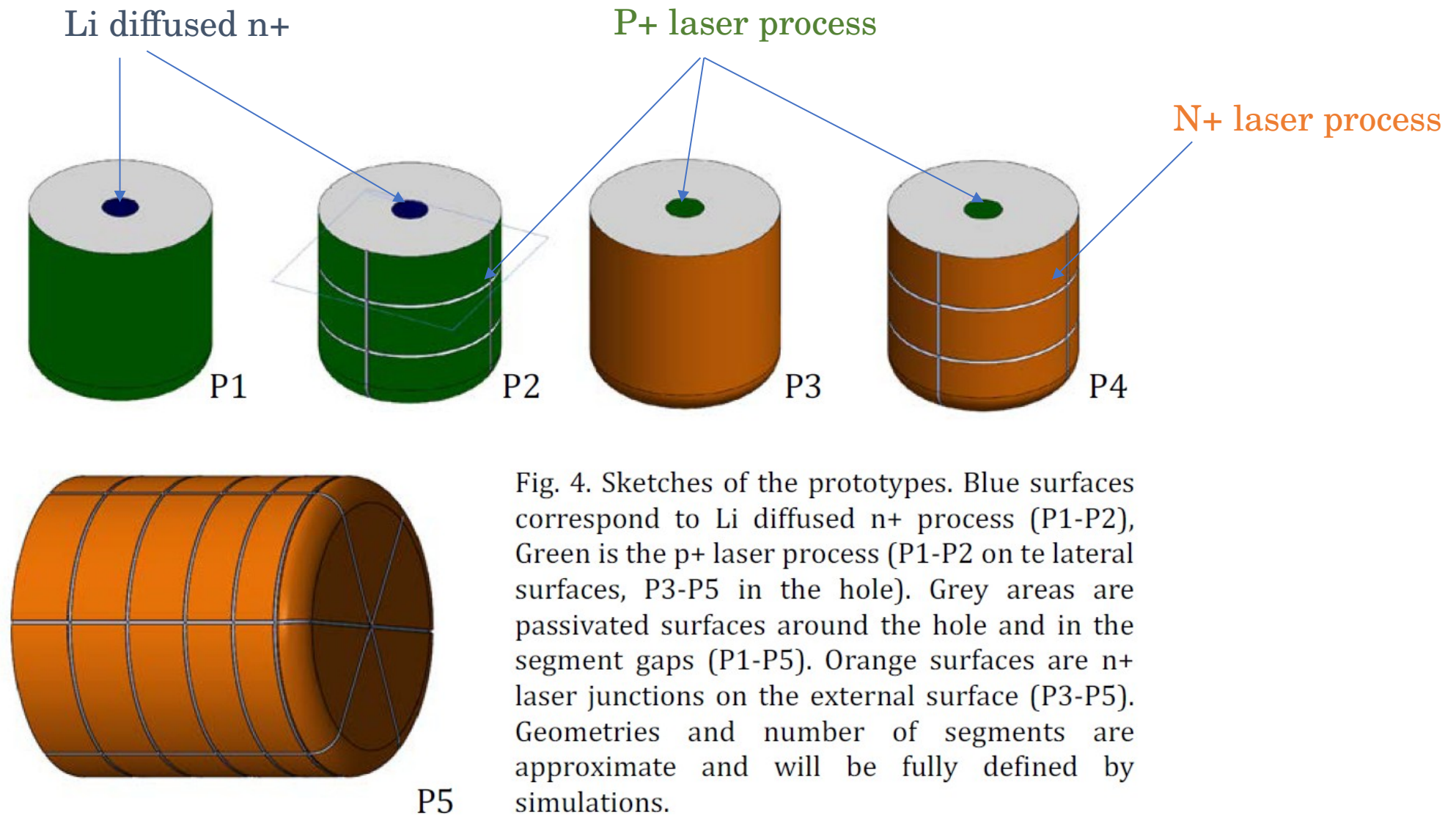


Fig. 4. Sketches of the prototypes. Blue surfaces correspond to Li diffused n+ process (P1-P2), Green is the p+ laser process (P1-P2 on the lateral surfaces, P3-P5 in the hole). Grey areas are passivated surfaces around the hole and in the segment gaps (P1-P5). Orange surfaces are n+ laser junctions on the external surface (P3-P5). Geometries and number of segments are approximate and will be fully defined by simulations.

WP1 :

- Realizzato cristallo di germanio con deposito d'oro segmentato (privo di contatto esterno)
- Problemi di disallineamento delle segmentazione nella parte superiore del campione
- Soluzione ricostruire 3D detector coassiale e ricavare le sue coordinate rispetto al sistema di coordinate del robot con una accuratezza minore di 0.1mm

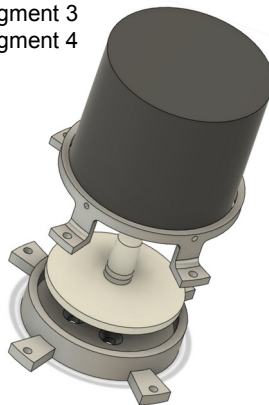
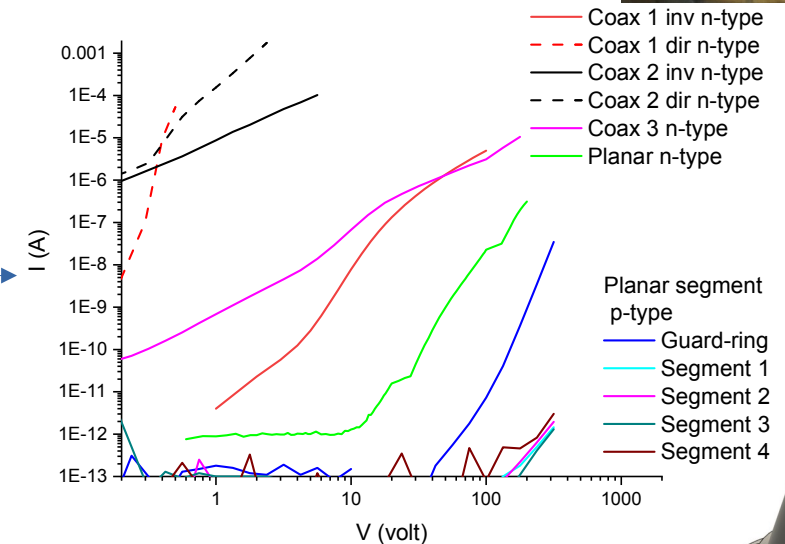
WP1 – I-V tests : Eccessiva corrente di fuga per coax →

WP2

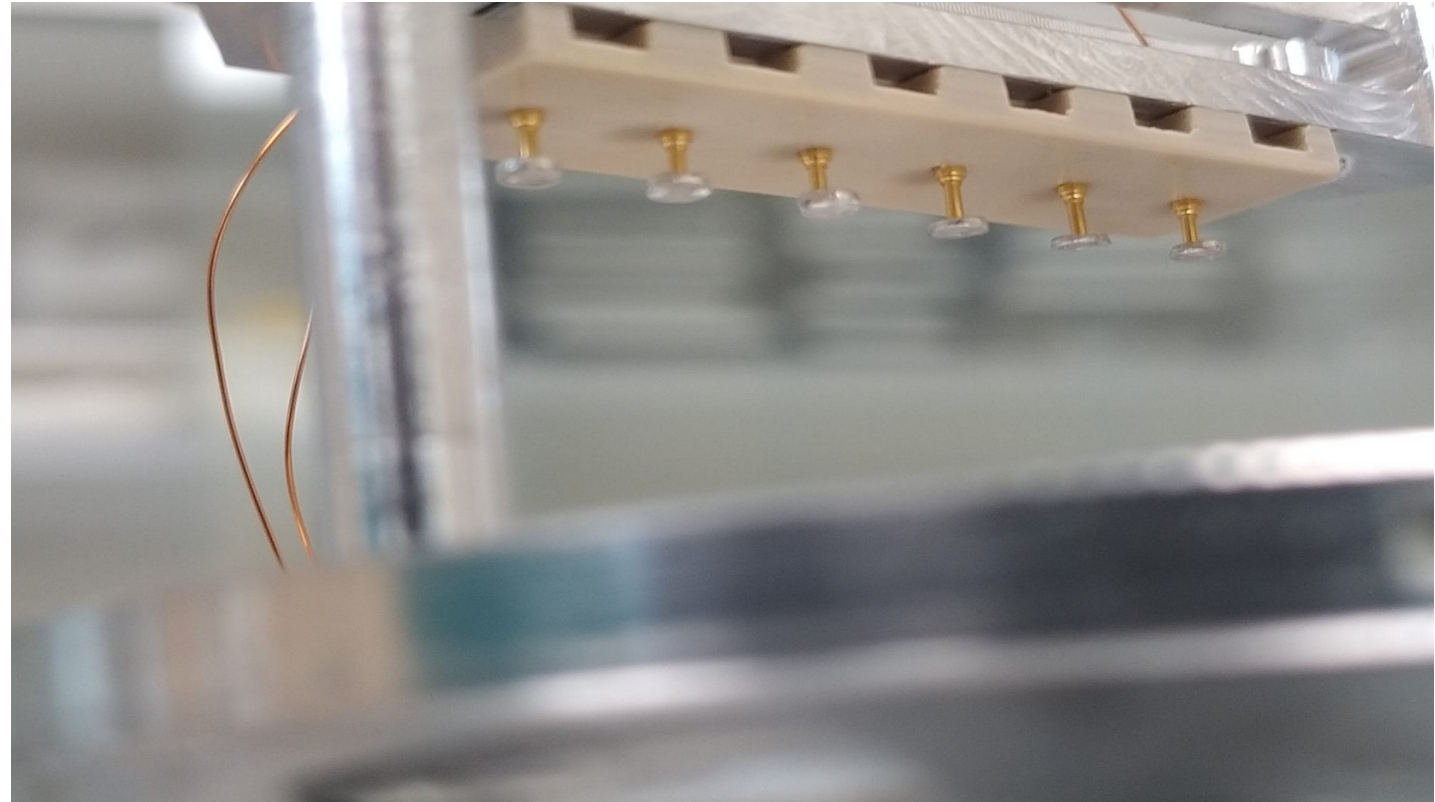
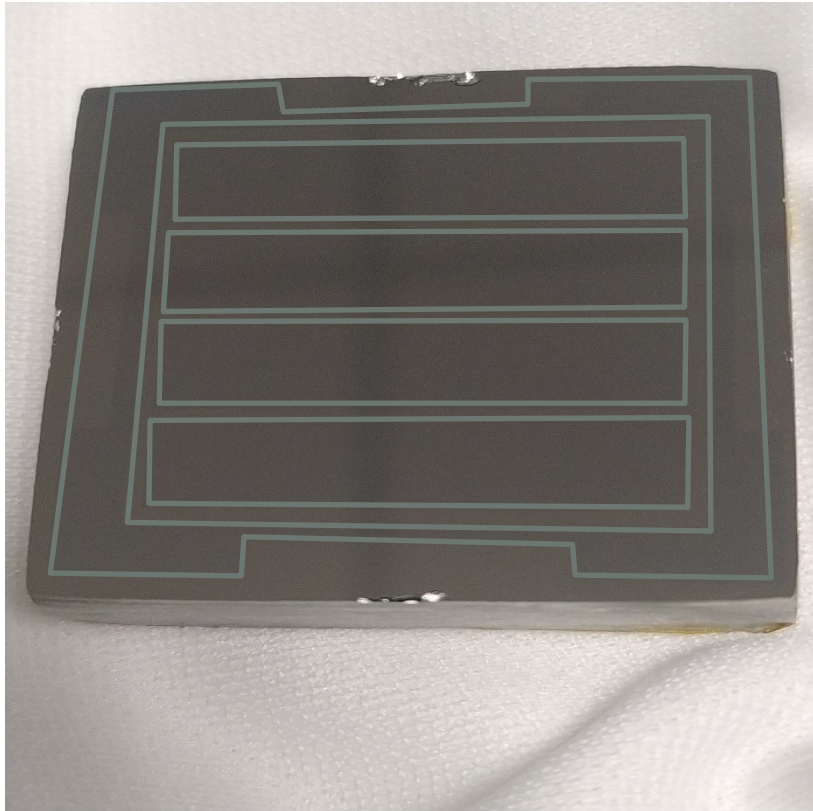
Misure resistenza alla temperature criogenica dell'**azoto liquido**. La conducibilità del germanio crolla. Si dimostra un'alta resistenza tra i segmenti >100MΩ!!!!

Next step: segmentazione e test detector coassiale tipo p commerciale

WP2 – Lavoro in corso per montaggio detector con polarizzazione nella capsula

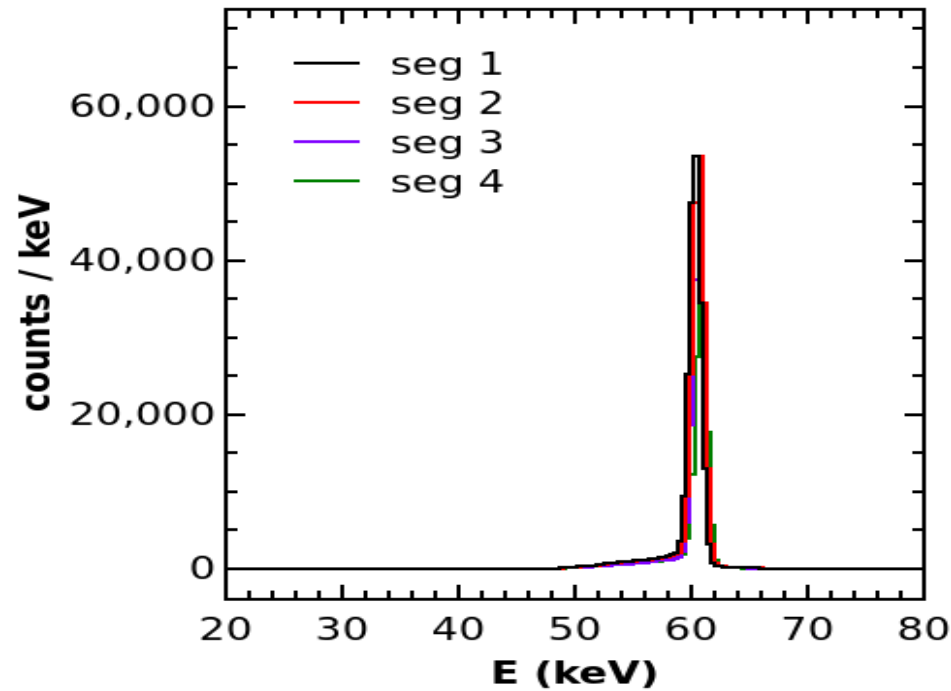
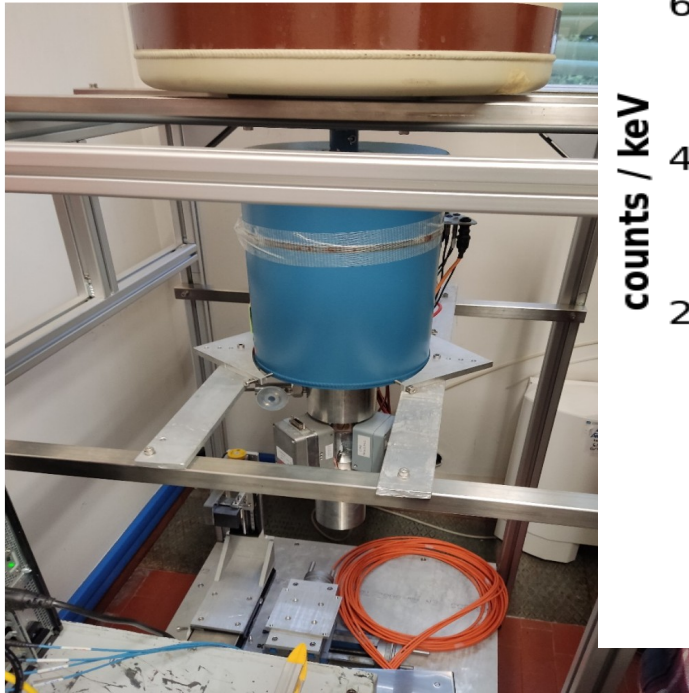


Possibili cause corrente di fuga nel planare tipo p segmentato: pressione meccanica dei contatti sugli elettrodi di Cromo

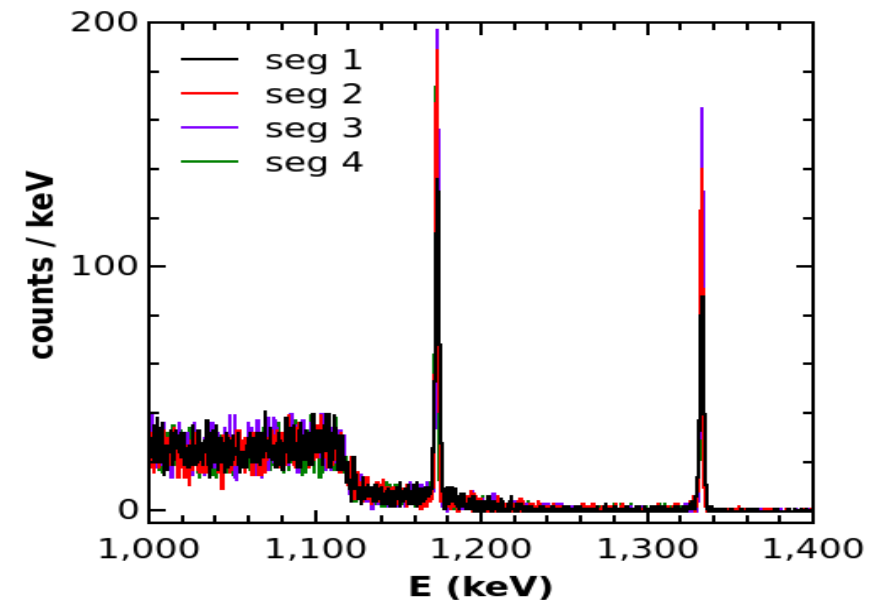


Misure su detector planare p-type segmentato n+ laser core p+ laser (WP3)

FWHM (59.50KeV) < 1.1 KeV

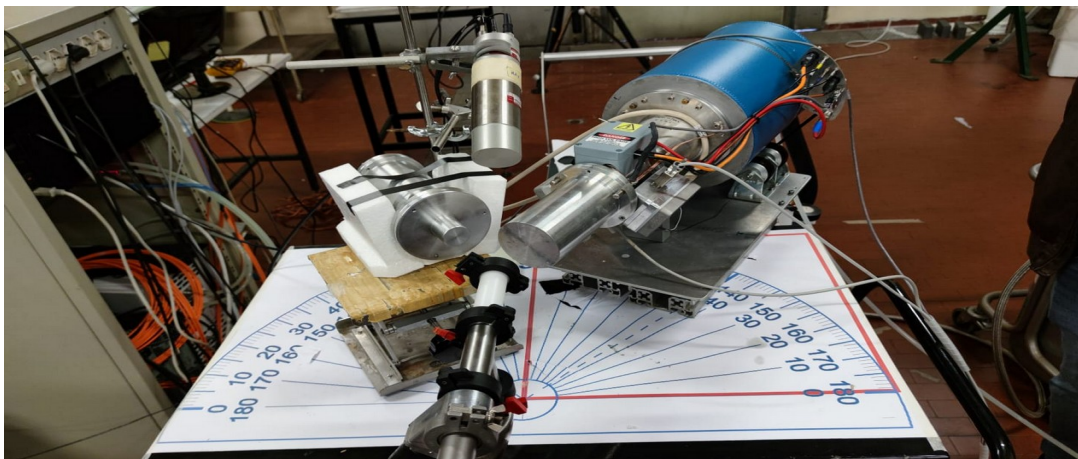


FWHM (1332.50KeV) < 1.8 KeV



Irraggiamento neutronico CN (WP3)

FWHM (59.50KeV) = 3.2 – 4.3 KeV



Prima misura di danno neutronico di detector p segmentato n+.

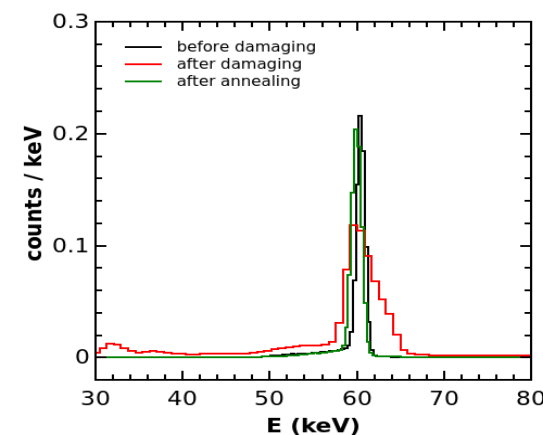
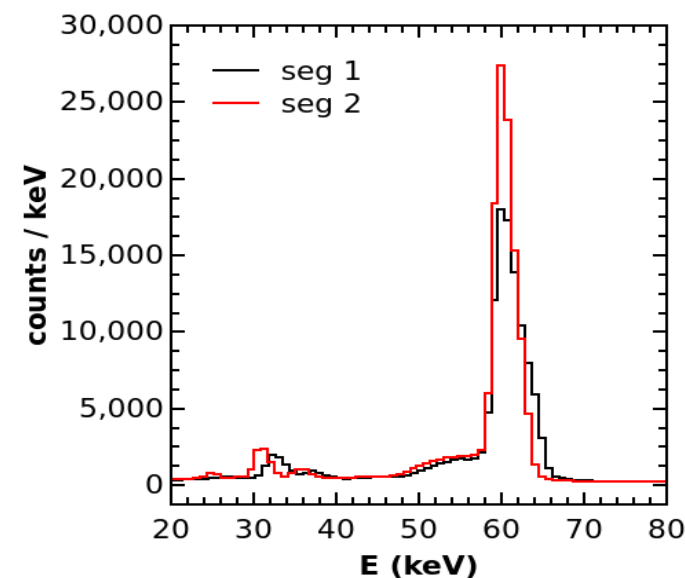
Turni CN assegnati 21-22 Aprile, 11-12 Luglio

Design set-up irraggiamento:

Target Litio $7\text{Li}(p,n)7\text{Be}$ (P. Mastinu)

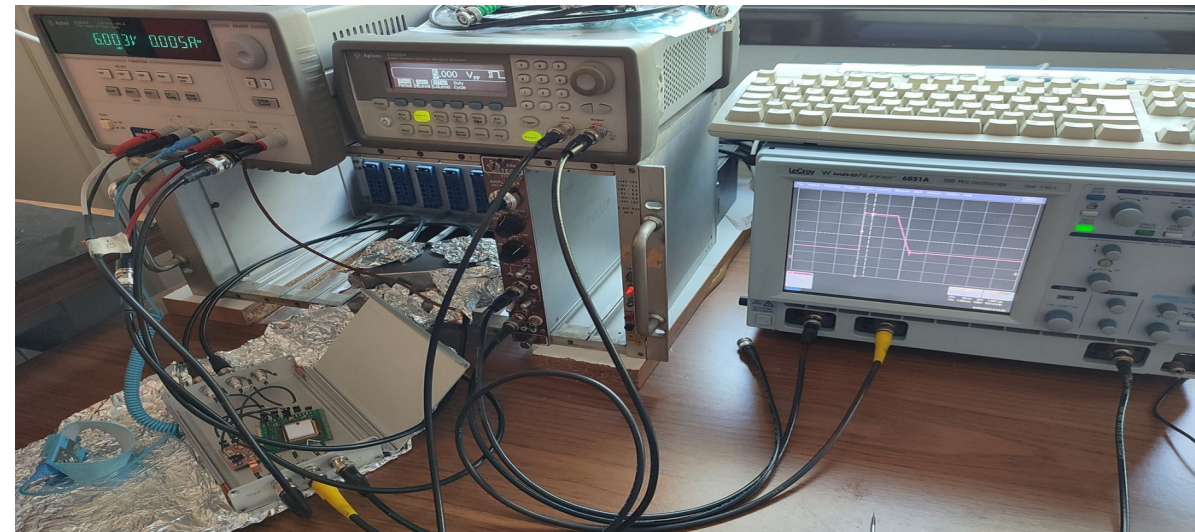
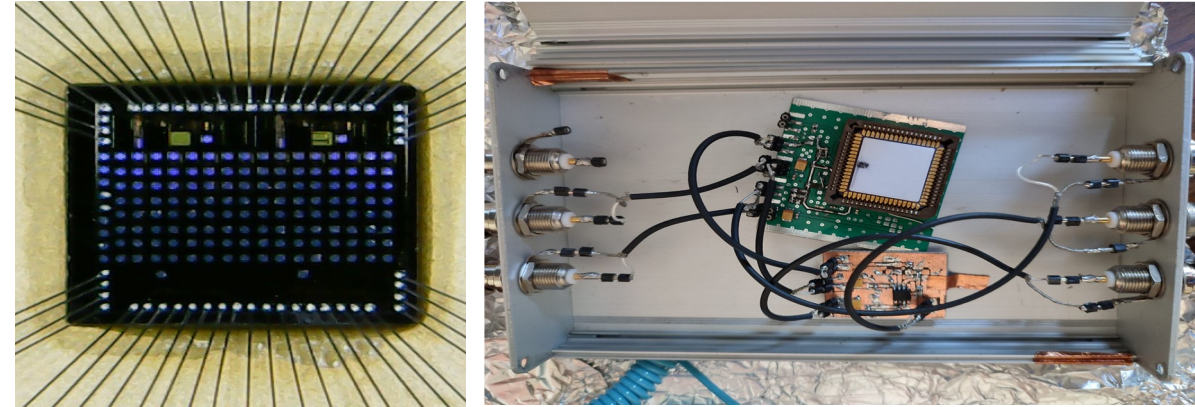
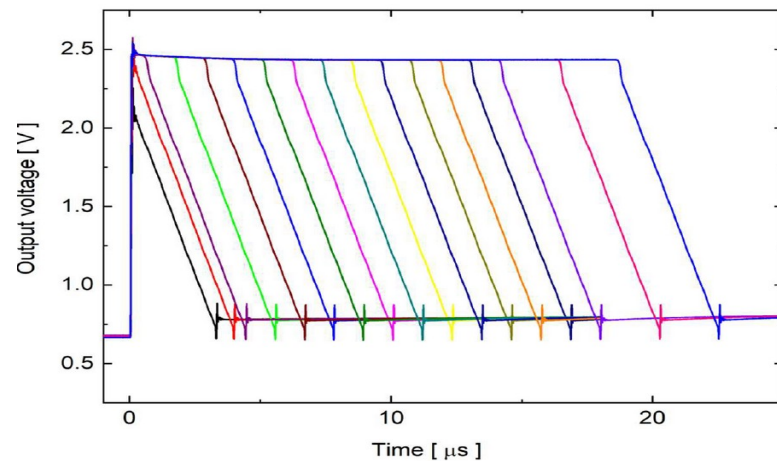
Misura dose: in progress

Recupero del danno da radiazione dopo annealing



Elettronica ASIC (WP2)

- Bonding dell' ASIC (Application Specific Integrated Circuit) su carrier e realizzazione della PCB per effettuarne il test.
- Implementazione dell'innovativo circuito di **fast-reset** a potenza nulla. Test di linearità del circuito e validazione della tecnica Time Over Threshold, simulando interazioni di energia compresa tra 30 e 190 MeV.
- L'errore statico risulta compreso entro il $\pm 0.5\%$ del valore della misura.



Attività TT

- INFN-TT ha finanziato richiesta **l'estensione internazionale (USA e Europa) del brevetto** inerente al processo: WO2021/214028 A1 dal titolo: "P+ or N+ doping process for semiconductors". LNL-INFN. Inventori : G. Maggioni, D. De Salvador, D.R. Napoli, E. Napolitani. PCT/EP2021/060183 per le estensioni EPO (09/11/2022) e USA (19/10/22).
- **Accordo di collaborazione con Mirion France** per la produzione congiunta di un prototipo coassiale PLM a livello pre-industriale. Importanti discussioni riguardo alla corrente di fuga.
- **Depositata domanda di brevetto** 102023000009687, «Contenitore per rivelatore di radiazioni e apparato rivelatore». INFN-MI. Inventori: L. Manara, S. Coelli, G. Secci, S. Capra.
- Presentata domanda R4I, Call TT, per finanziare attività LNL-MIRION

Richiesta di estensione

- Permettere di finalizzare obiettivi **WP1-LNL** (detector coassiale tramite PLM) anche grazie alla collaborazione **LNL - MIRION**, fine 2023 inizio 2024.
- Finalizzare test e R&D delle altre unità in modo più approfondito:
 - segmentazione detector completo (FE-LNL),
 - test irraggiamento sia su tipo p che tipo n (PD-LNL) ,
 - elettronica asic su detector completo (MI-LNL).

Richieste

Le richieste di **servizi PD**

- Officina meccanica
Mesi/persona

0.5

Personale

- Recchia 30%
- Bazzan 20% (TBC)
- Escudiero 50%

Unità/Voce	CSN3 GAMMA	CSN5 N3G	FTE N3G
LNL			~3.5
Consumo (collaborazione Mirion - N3G)	11		
Inventariabile capacimetro		6.5	
Missioni (collaborazione Mirion - N3G)	3.5		
Adr 6 mesi prolungamento			
Spedizioni		1.5	~2
MI			
Consumo (connessioni criogeniche interne al canister - nuova versione)		2.5	
Consumo (schede per rivelatori segmentate – N3G)	7		
Missioni		3	1.2
FE			
Consumo		5	1.2
PD			
Missioni		3	

Electric Dipole Moment: Search for New Physics

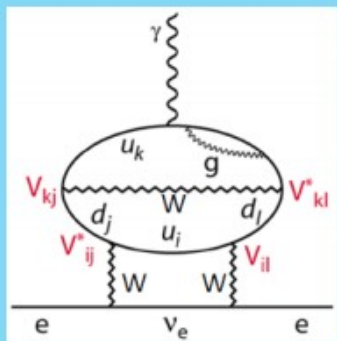
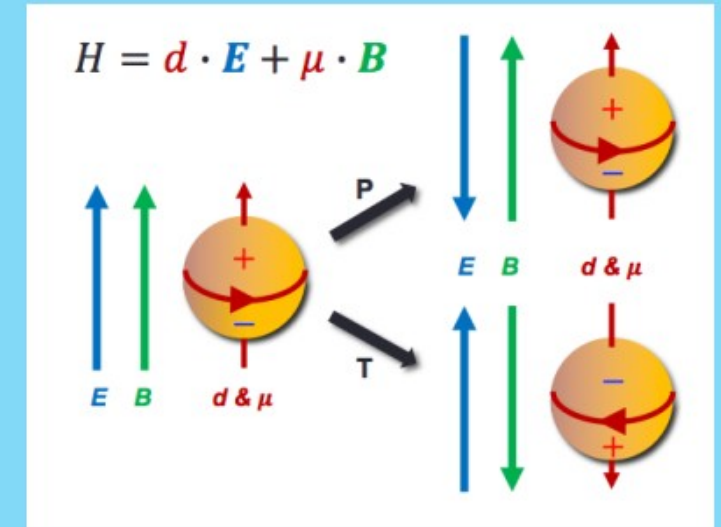
OUTLINE:

- 1) Probing Physics Beyond Standard Model & Fundamental Symmetries
- 2) Electron EDM measurements
- 3) Reactive Molecules in Para-Hydrogen @ Low Temperature
- 4) Set-up for Isotopic Molecular Beam Production and Crystal Formation & Characterization
- 5) Conclusions

EDM Searches

Search for new physics through Electric Dipole Moments

- The EDM is an asymmetric charge distribution along the particle spin
- The EDM violates time reversal symmetry through CPT conservation – CP violation
- CP violation is required to generate a cosmological matter-antimatter asymmetry.
- It is present in the SM, through the complex phase in CKM matrix, however many order of magnitude below what is necessary
- EDM's in SM are tiny ($d_e < 10^{-38}$ ecm), but most SM extensions include new CP violating phases that contribute to EDM's.



four-loop level in
perturbation theory

$$\mathbf{d}_e \sim (\text{loop}) \times \frac{m_e}{\Lambda^2} \sin(\Phi_{CP})$$

naturally $\sim \alpha/\pi$ Φ_{CP} phase from soft breaking naturally $O(1)$

scale of SUSY breaking naturally ~ 200 GeV

$\sim 5 \times 10^{-25}$ cm naturally

SUSY electron edm

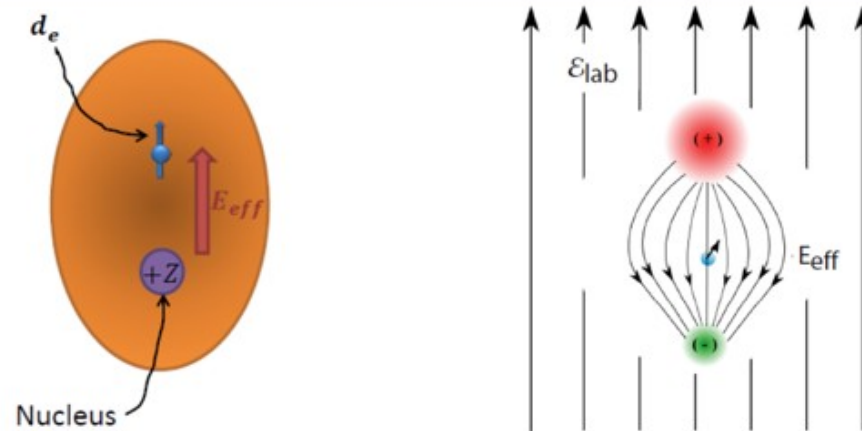
THIS MAKES EDM's an ideal probe for detecting NEW PHYSICS associated with CP violation and a powerful window on energy scales much larger than those that can be probed directly at LHC

Misurare lo sfasamento della precessione dell'elettrone in campo esterno dovuto all'interazione del momento di dipolo elettrico con il campo di una molecola

Gabrielse

Why Use a Molecule?

→ To Make Largest Possible Electric Field on Electron



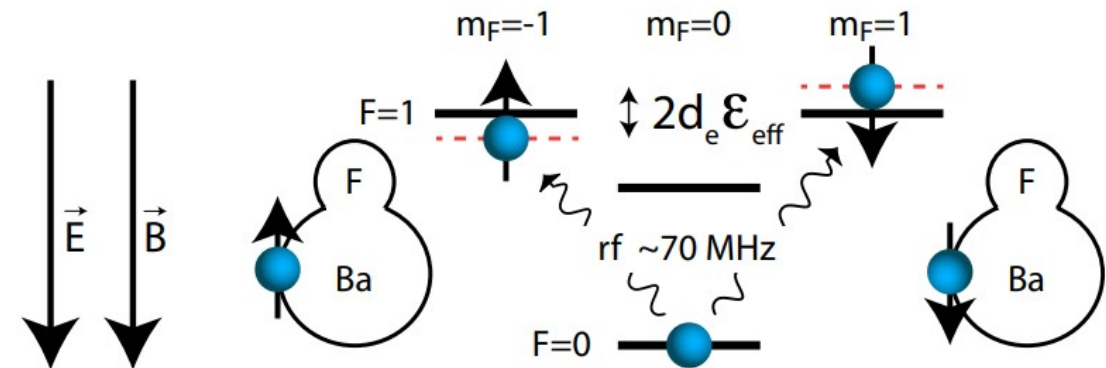
Tl atom (best EDM limit till YbF)

$E_{lab} = 123 \text{ kV/cm} \rightarrow E_{eff} = 72 \text{ MV/cm}$

ThO molecule

$E_{lab} = 100 \text{ V/cm} \rightarrow E_{eff} = 100 \text{ GV/cm}$

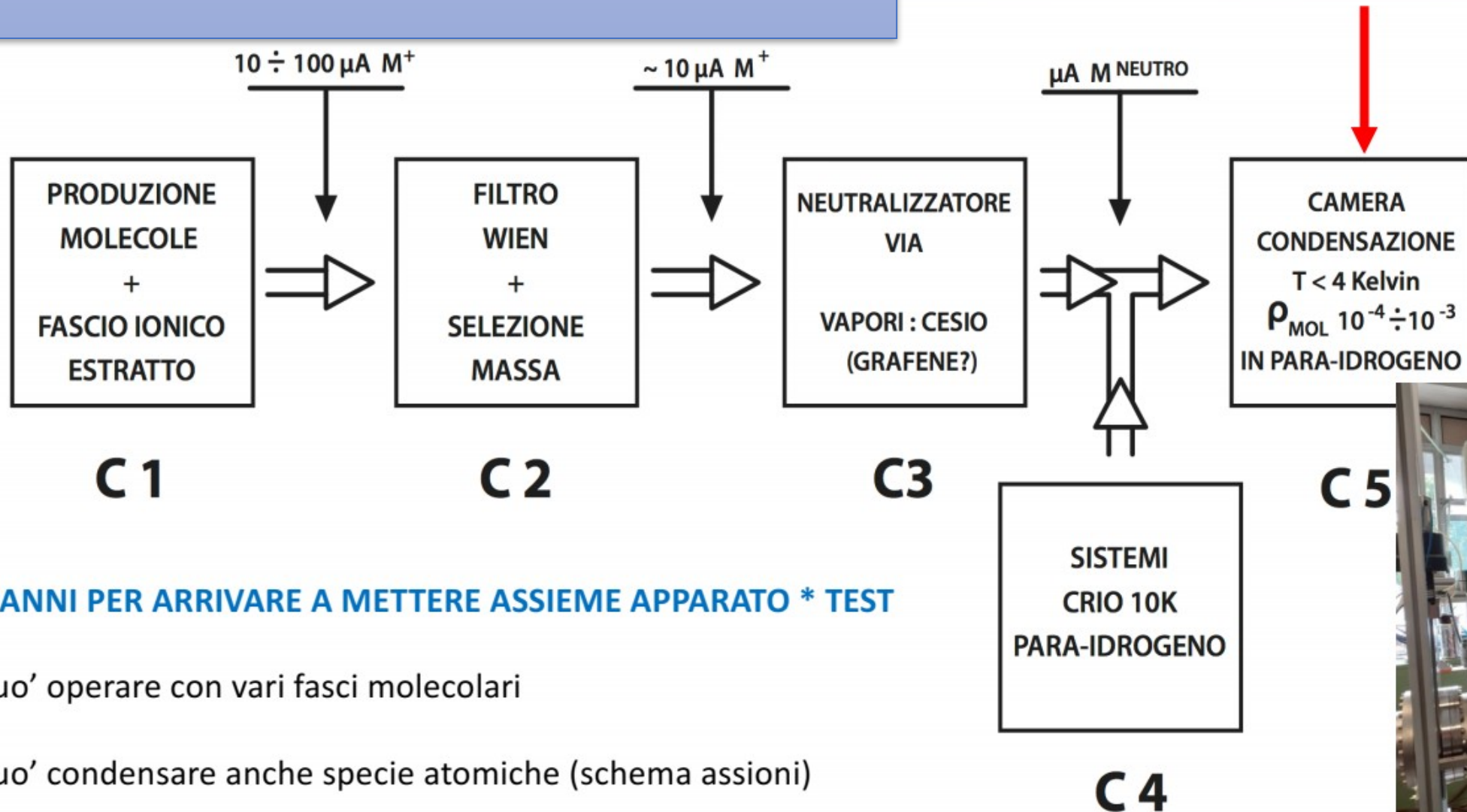
Molecule can be more easily polarized using nearby energy levels with opposite parity (not generally available in atoms)



EXPERIMENTAL COLD & DOPED CRYSTAL SET-UP

Per studiare l'edm è necessario produrre un cristallo di para idrogeno e drogarlo con la molecola di interesse

1 cm³ ParaHydrogen Crystal doped with BaF molecule



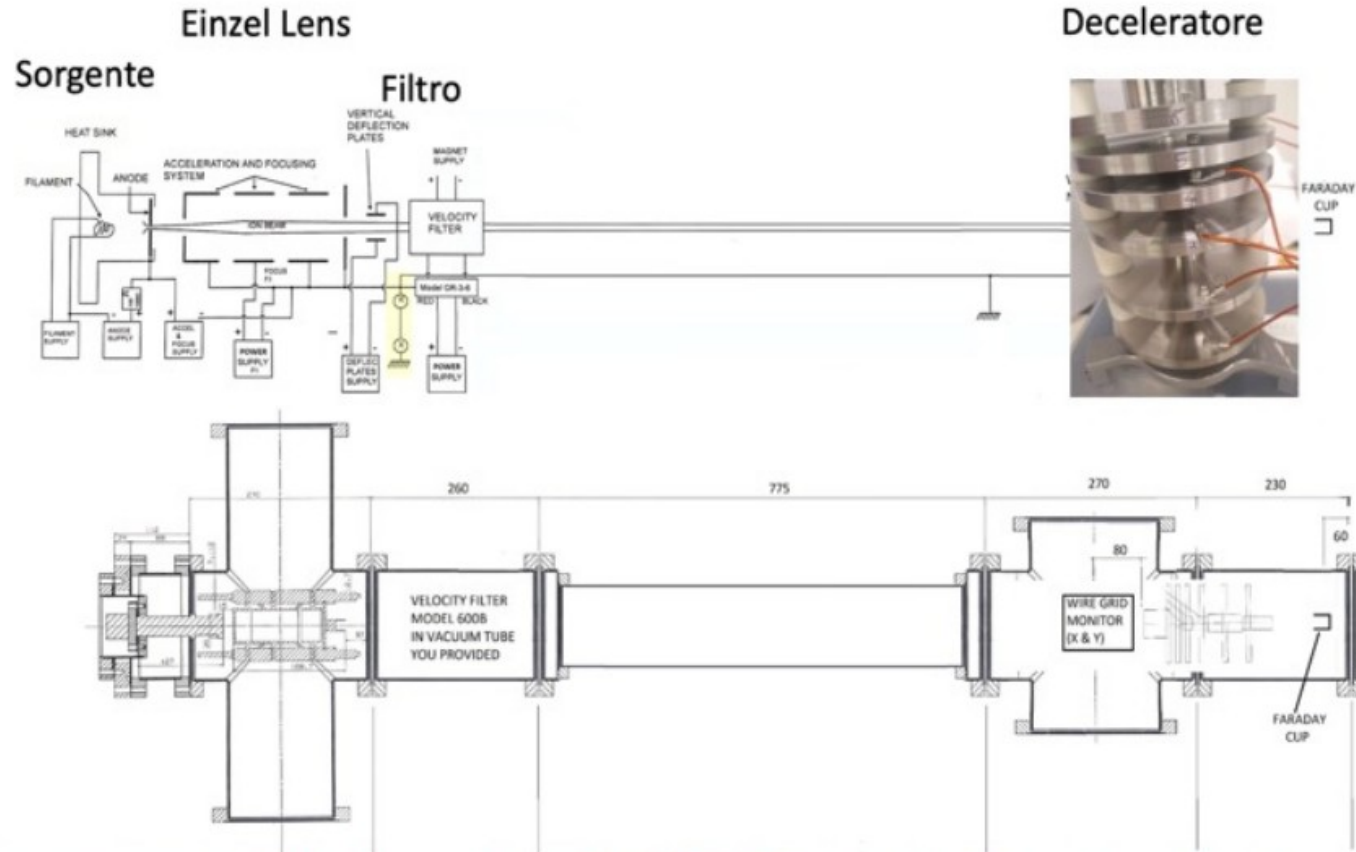
3 ANNI PER ARRIVARE A METTERE ASSIEME APPARATO * TEST

Puo' operare con vari fasci molecolari

Puo' condensare anche specie atomiche (schema assioni)



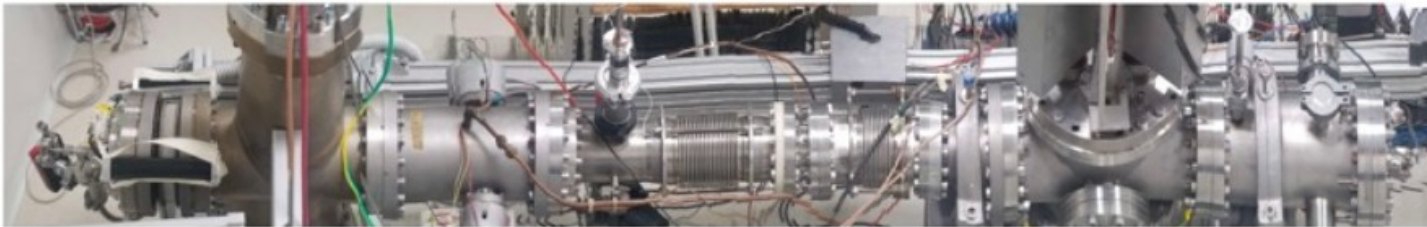
C1+C2: Camera Produzione Fasci Ionici



Fascio di Xe^+

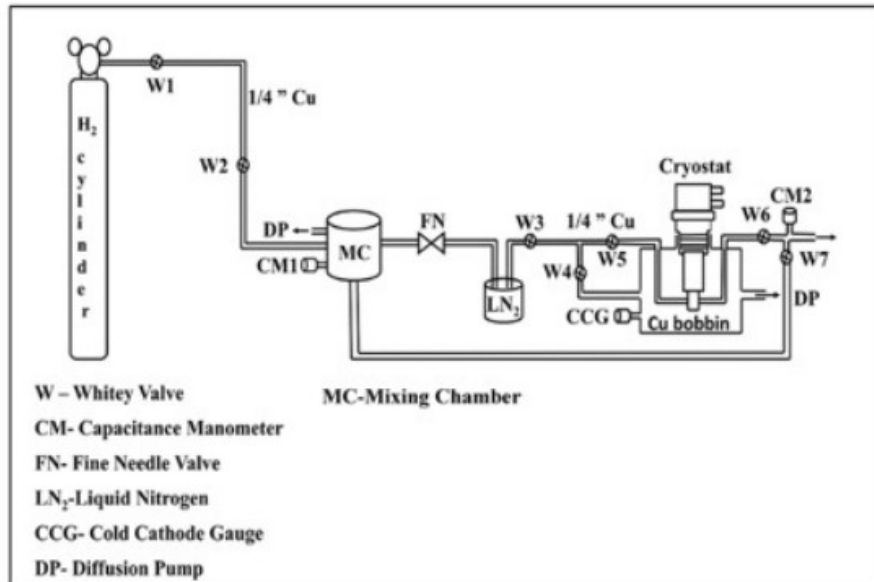


- Fascio di Xe^+ estratto con corrente 100 nA
- ^{132}Xe ha massa simile a BaF ma è più economico, per i test è la soluzione migliore
- Energia finale fascio Xe^+ : 5 eV
- Questi parametri usando BaF si possono ottenere 100 ppm di $[\text{BaF}^+]$ in cristallo
- Crescita cristallo circa 2 – 3 ore



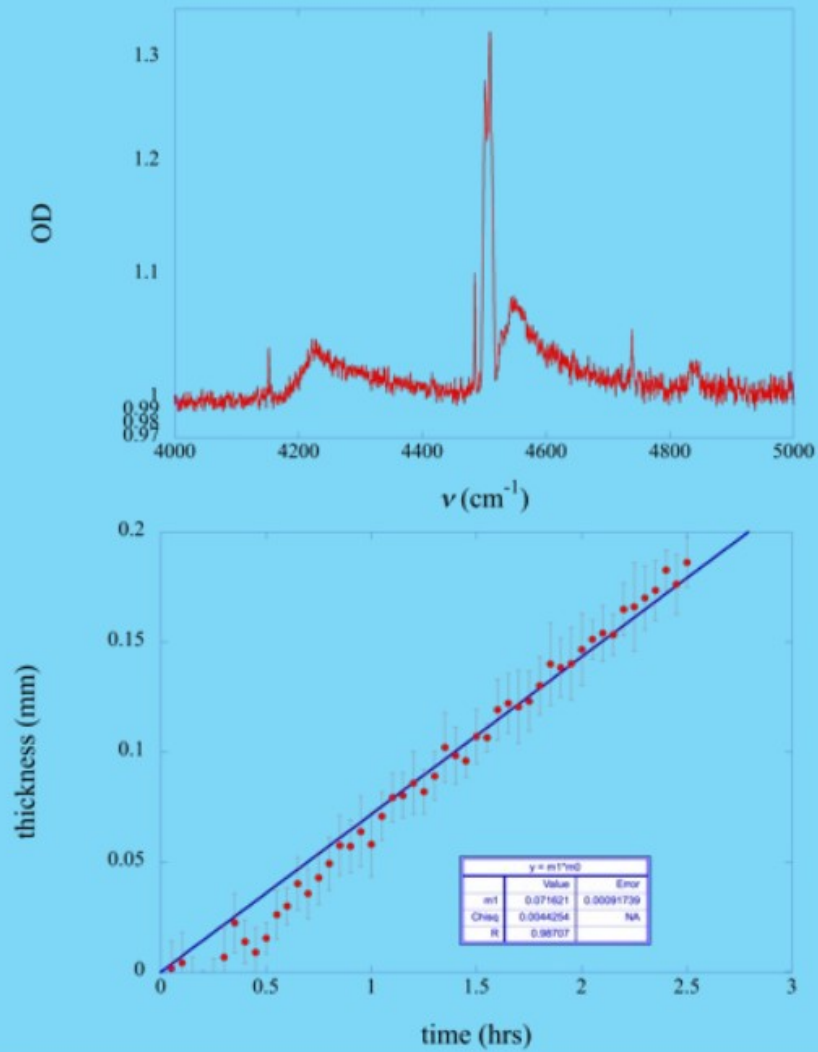
PARAHYDROGEN PRODUCTION-CONDENSATION-SPECTROSCOPY SET-UP @ 3 KELVIN

- Hydrogen is flux into a ferrous oxide powder @ 20 KELVIN Inducing an Ortho to Parahydrogen Transition
- Transparent Cryo p_{H2} crystals with good production yield obtained



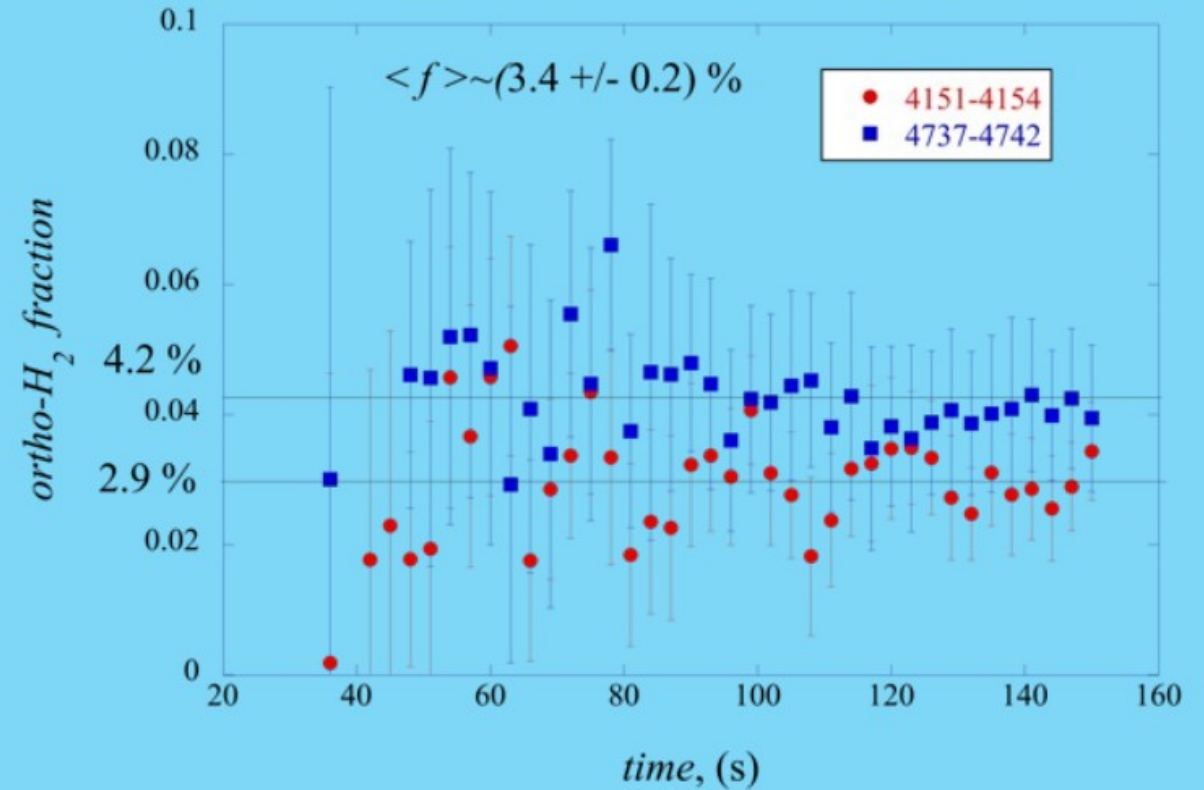
Spectroscopic Determination of pH₂ film thickness: o-H₂ fraction

Para-Hydrogen Absorption IR Line + Thickness



Ortho-Hydrogen concentration

O-H₂ @ 3% level to be reduced



Temperature of the Cold Head Converter has to be reduced to 16 Kelvin to reduce O-H₂ concentration

TIME-LINE vs MILESTONES :

- 1^o Anno **2022**:

- a) Camera Sorgente Produzione Fasci Molecolari (Corrente Ionica = 10 microAmpere @ few KeV) **OK**
- b) Camera Produzione Paraidrogeno @ 10 kelvin. **½ OK (Problemi con FTIR)**

- 2^o Anno **2023**:

- ✓ a) Camera di Selezione Isotopica Ba₁₃₈ F₁₉ (Wien Filter) e Neutralizzazione (Vapori di Cesio o Grafene)
- ✓ b) Camera di Condensazione a 4 Kelvin

- 3^o Anno:

- ~✓ a) Test crescita Cristalli
- ~✓ b) Caratterizzazione: assorbimento spettrale e larghezze di linea e polarizzazione sotto Campo Elettrico

- **We need to be the first to check this ROUTE to open such Approach to EDM measurement**

PHYDES 2024

Sezioni INFN partecipanti all'esperimento: **Padova, LNL, LNS (Palermo), Ferrara**

- Resp. Naz.: **Giovanni Carugno**

- **COSTRUZIONE E PRESA DATI ESPERIMENTO @ LNL**

- **FTE-PD-2024 = 3,4 FTE**

(Carugno 40%, Borghesani 100%, Messineo 100%, Gasparini 20%, Zanetti 15% , Pazzini 15%, Gonella 40%, Benettoni 10%)

- **GOOD NEWS:**

- 1) PNRR NQST e Bando Eccellenza Dipartimento Approvati**

- 2) Vinto PRIN su fasci molecolari e fisica fondamentale**

- 3) INFN-NSF (USA) opportunity to have common EDM physics program**

- **Richiesta Denari PD INFN : 30 Keuro (5 Keuro missioni , 15 Keuro consumo , 5 keuro manutenzioni , 5 Keuro Diodo laser)**

- **Richiesta Servizi : 10 M.U. OM , 8 M.U. STGE , 2 M.U. OE, 1 M.U. Uff.Tec.**

Fisica interdisciplinare - Medicina



Conclusa

REMⁱX



Research on Emerging Medical radionuclides from the X-sections

Gaia Pupillo, resp. nazionale e locale LNL (2021-2023)

SEZIONI INFN: LNL, PADOVA (L. Canton), PAVIA (A. Fontana), MILANO (F. Groppi), FERRARA (P. Martini)



Collaborazioni esterne:

ARRONAX (Saint-Herblain, France), Ospedale Sacro Cuore Don Calabria (Negrar, VR, Italy), IOV (Padova, Italy)



Aim: Studio della produzione di ^{47}Sc e ^{xx}Tb per teranostica



- Misura di XS nucleari inesplorate e confronto con modelli teorici
- Ottimizzazione produzione, considerando anche l'impatto dosimetrico dei contaminanti
- Misura di Thick Target Yield (TTY) per ^{155}Tb , sfruttando la reazione $^{155}\text{Gd}(p,n)^{155}\text{Tb}$ ($E < 20$ MeV)

Isotope	Half-life	IMAGING		THERAPY		
		β^+ E_{average} [keV] (I)	x and γ with $I > 10\%$ E [keV] (I)	β^- E_{average} [keV] (I)	Conv. & Auger electrons (>1 keV) E_{average} [keV] (I)	α E [keV] (I)
^{43}Sc	3.9 h	476 (88%)	372 (23%)	–	–	–
^{44}Sc	4.0 h	632 (94%)	1157 (100%)	–	–	–
^{47}Sc	3.35 d	–	159 (68%)	162 (100%)	–	–
^{149}Tb	4.1 h	730 (7%)	42–50 (69%), 165 (26%), 352 (29%), etc.	–	32 (85%)	3967 (17%)
^{152}Tb	17.5 h	1140 (20%)	42–50 (65%), 344 (64%)	–	36 (69%)	–
^{155}Tb	5.32 d	–	42–50 (108%), 87 (32%), 105 (25%)	–	19 (204%)	–
^{161}Tb	6.89 d	–	45–53 (39%), 75 (10%)	154 (100%)	19 (227%)	–

THERANOSTICS AND PRECISION MEDICINE SPECIAL FEATURE: Scandium and terbium radionuclides for
 REVIEW ARTICLE
 [2018] radiotheranostics: current state of development
 towards clinical application



WP1. Production & target characterization
Sara Cisternino (INFN-LNL & UniPD)



WP7. Devices for INFN-LNL beam-line
Gabriele Sciacca (INFN-LNL & UniPD)



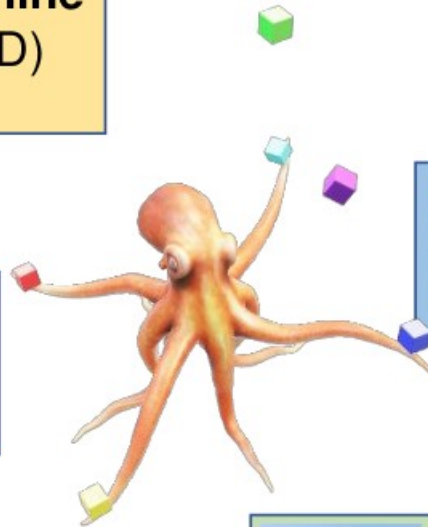
WP2. XS measurements $^{49}\text{Ti}, ^{50}\text{Ti}$
Liliana Mou (INFN-LNL)



WP3. XS measurements $^{\text{nat}}\text{Dy}, ^{159}\text{Tb}, ^{\text{nat}}\text{Eu}$
Simone Manenti (UniMI & INFN-MI)



**WP6. ^{155}Tb TTY production
@ SCDC hospital**
Petra Martini (UniFE & INFN-FE)



WP5. Dosimetric calculations
Laura De Nardo (UniPD & INFN-PD)
Laura Melendez-Alafort (IOV)



WP4. Nuclear codes (TALYS, EMPIRE, FLUKA)
Luciano Canton (INFN-Padova)
Andrea Fontana (INFN-Pavia)

* Calcoli di modellistica nucleare [energy ranges, irraggiam.

* Dosimetria computazionale,

Conclusioni



- Ottima collaborazione!
- Risultati scientifici di interesse internazionale: presentazioni oral e su invito a varie conferenze
2021: SIF, etc
2022: GICR, INPC, Workshop Trento, WTTC, etc
2023: NRM Varenna, 11th ICI, ARCEBS, IAEA ISTR, Workshop Fisica medica Trento, etc
- Importante collaborazione con gli Enti esterni (ARRONAX ha ospitato 2 dottorandi, per circa 3 mesi ciascuno nel 2023)
- Recentemente, sono stati approvati 2 AdR (uno sperimentale/dosimetrico ed uno sulla modellizzazione nucleare) presso l'Università di Padova in continuità con le attività di REMIX
- ☐ Unica difficoltà: approvvigionamento del $^{155}\text{Gd}_2\text{O}_3$ nel 2022, che ha causato un ritardo nelle attività sperimentali anche nel 2023 (ma stiamo facendo del nostro meglio per recuperare!)



CSN5 INFN new research project proposal (2023-2025)

CUPRUM-TTD

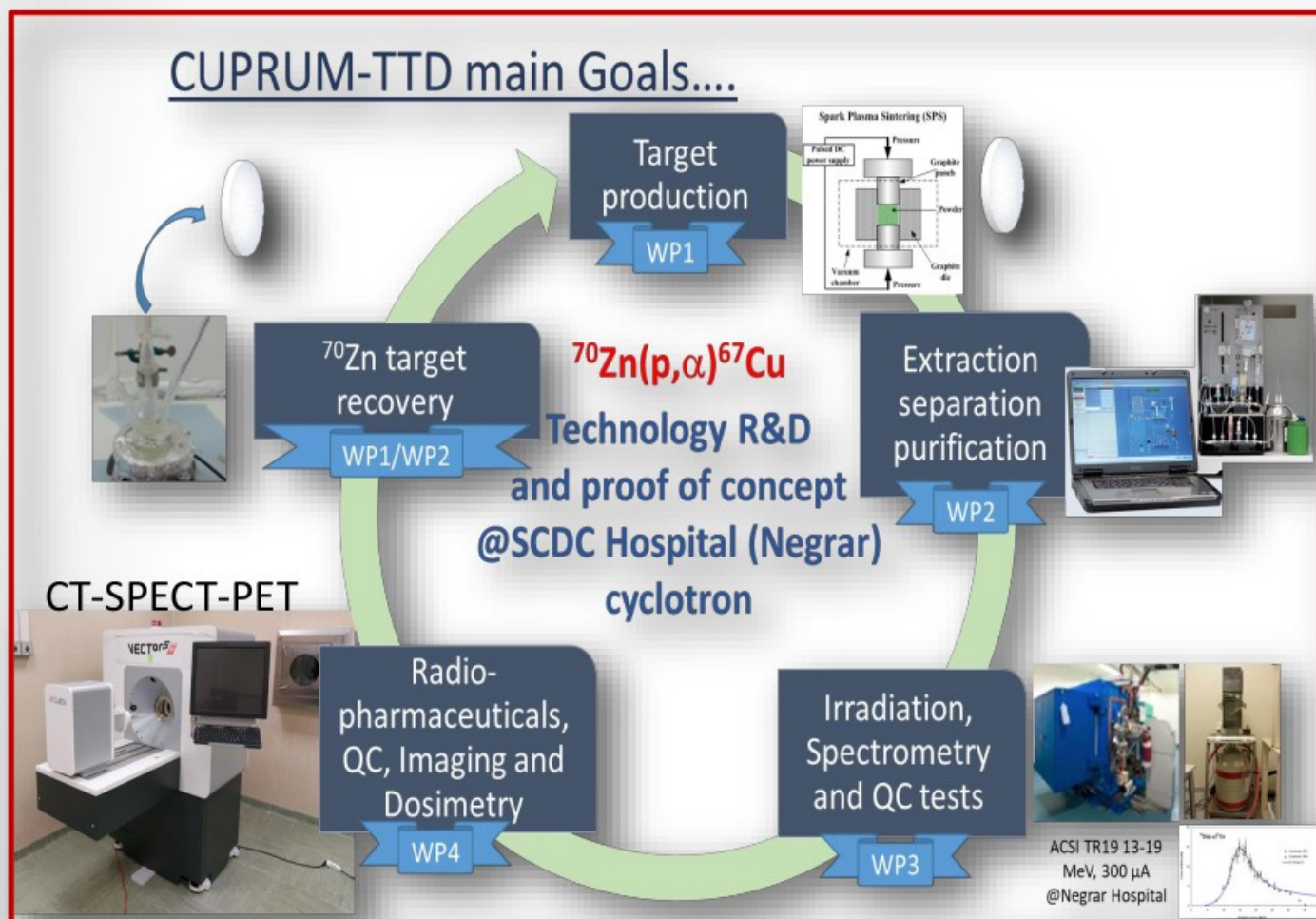
Planned activities and Budget Requests 2024

$^{67/64}\text{Cu}$ PROduction and Use in Medicine – Target Technology Development

INFN/ UNIPD / UNIFE /UNIMI/ SCDC Hospital (Negrar, VR) /IOV/ Padua Univ. Hospital /ICMATE CNR Padua

CUPRUM-TTD (2023-2025) main project goals

In view of the next preclinical/clinical applications the goal of the current research proposal is therefore to develop beforehand a reliable technology aimed at **producing clinical-grade batches of ^{67}Cu - ^{64}Cu , by small medical cyclotrons on a routine basis.**



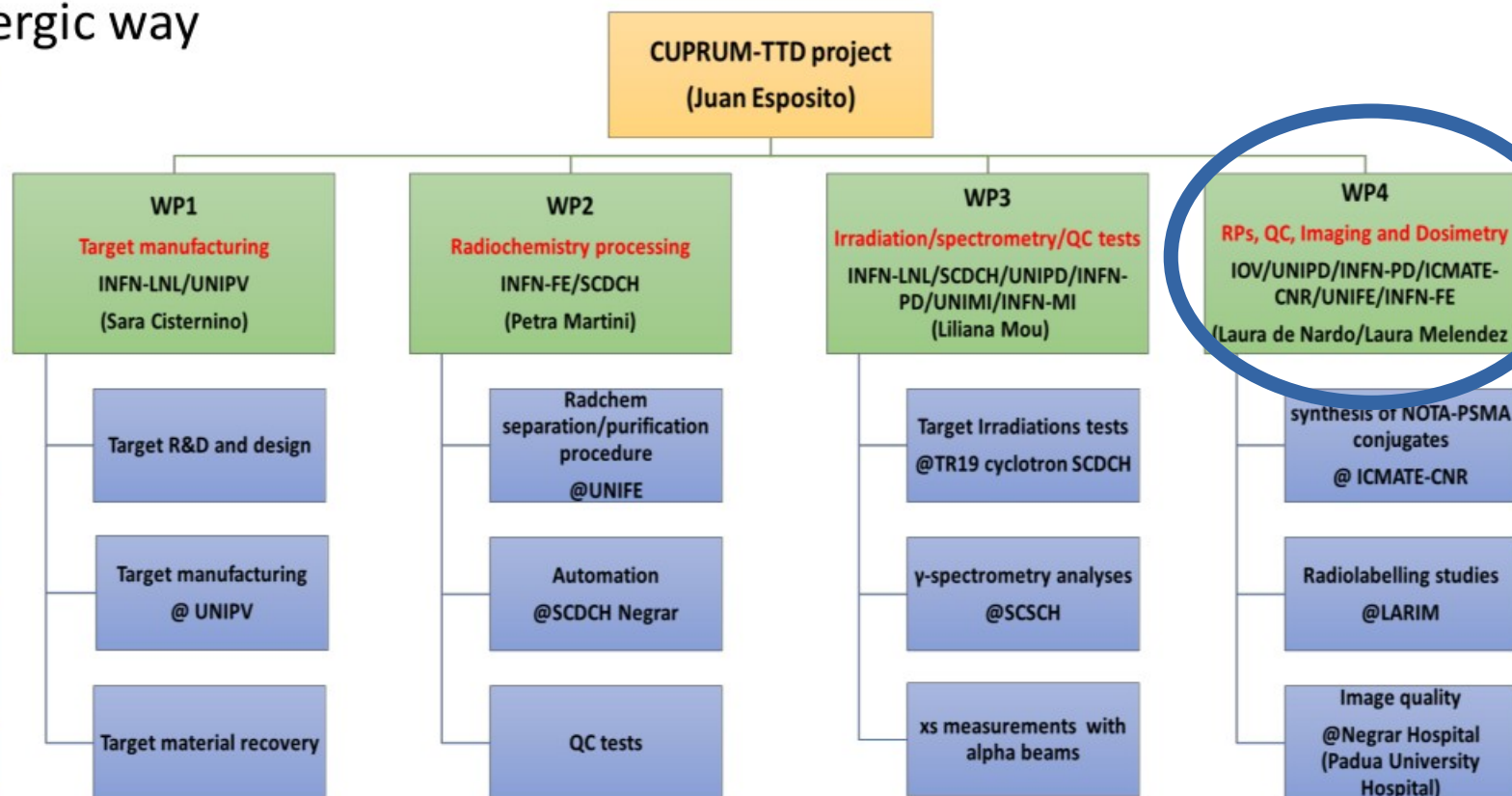
- a) to acquire a **robust and reliable target manufacturing technology** to produce ^{70}ZnO target
- b) To assess targets able to sustain **beam power levels from medical cyclotrons** (i.e. 18-20 MeV, 2/3 kW max);
- c) to develop/optimize the **radiochemistry separation/purification methods**: $\text{Zn} \rightarrow \text{Cu}$ to achieve a clinical-grade ^{67}Cu radionuclide;
- d) *in-vitro* cells studies with **^{67}Cu -labelled RPs using NOTA derivate as chelating agent**;
- e) **Phantom imaging studies of produced ^{67}Cu with pre-clinical and clinical SPECT**;
- f) to develop/optimize technology for the **costly ^{70}Zn -enriched target material recovery**.

CUPRUM-TTD project organization

CUPRUM-TTD project is organized in Work Packages (WP), interacting each other in a synergic way

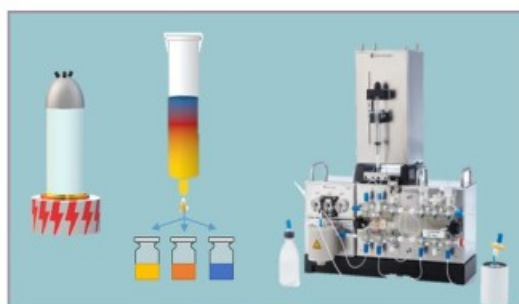
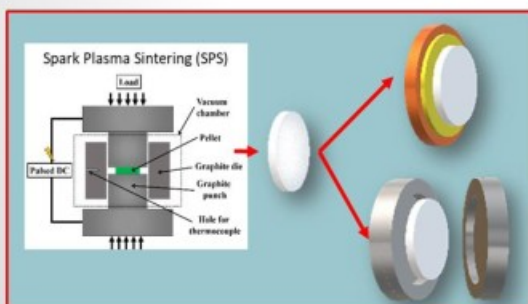
WP1	
Sara Cisternino	LNL
Juan Esposito	
Alisa Kotliarenko	
Giorgio Keppel	
Umberto A. Tamburini	
	UNIPV

WP2	
Petra Martini	INFN-FE UNIFE
Alessandra Boschi	
Francesca Porto	
Teresa Ghirardi	
Licia Uccelli	
Lorenza Marvelli	HSCDC
Emiliano Cazzola	
Giancarlo Gorgoni	



WP3	
Liliana Mou	LNL
Gaia Pupillo	
Juan Esposito	
Emiliano Cazzola	HSCDC
Giancarlo Gorgoni	
Luciano Canton	UNIPD INFN-PD
Francesca Barbaro	
Licia De Dominicis	UNIMI INFN-MI
Silviane Manenti	
Flavia Groppi	
Francesca Cagnetta	
Michele Colucci	

WP4	
Laura De Nardo/ Laura Melendez-A.	INFN-PD IOV
Alessandra Zorz	IOV
Marta Paiusco	UNIPD INFN-PD
Michele Bello	
Diego Cecchin	ICMATE CNR
Cristina Bolzati	UNIFE INFN-Fe
Giov. Di Domenico	
Angelo Taibi	



J. Esposito on behalf of collaborating network for CUPRUM-TTD (2023-2025) project proposal CSN5 INFN

29.06.2023

CUPRUM-TTD WP1 (LNL+FE): Target technology R&D (manufacturing and recovery)

	1st year 2023				2nd year 2024				3rd year 2025			
	1°	2°	3°	4°	1°	2°	3°	4°	1°	2°	3°	4°
WP1	Target manufacturing, characterization, and material recovery											
M1												
M2												
M3												

D1: no. 2-3 ZnO targets for surface analyses investigations (WP2);
D2: no. 5 ZnO targets for cold test chemical processing optimization (WP2);
D3: 3 ^{70}ZnO targets for production test;
D4: recovered $^{\text{nat}}\text{ZnO}$ powders.

M1: SPS technique development for $^{\text{nat}}\text{ZnO}$ target manufacturing (Nb/Au/ZnO kind)
M2: recovery process development for $^{\text{nat}}\text{ZnO}$, and material powders characterization (SEM, EDS, profilometer)
M3: target production with SPS technique starting from recovered $^{\text{nat}}\text{ZnO}$;

Final Target material

- 1.5 g [^{70}Zn]ZnO-enriched material purchase (~ 30\$/mg) –
1 target 500 mg → 3 targets manufacturing

WP1	
Sara Cisternino	LNL
Juan Esposito	UNIPV
U. Anselmi-Tamburini	
Alisa Kotliarenko	LNL
Oscar Azzolini	
Giorgio Keppel	
Teresa Ghirardi	UNIFE
Petra Martini	
Alessandra Boschi	
Teresa Ghirardi	
Francesca Porto	
Lorenza Marvelli	

Main activities

Target manufacturing:



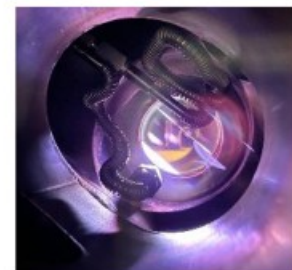
SPS technique

- Sintering of ZnO powder → pellet in a holder for irradiation
- Sintering of ZnO powder and target system investigation (ZnO/Au/Nb)

@ Pavia

- March:** pellets for recovery tests and chemistry (WP2)
- Planned in July:** pellets for WP2 and irradiation tests (in September WP3)

@ LNL: SEM, XRD analysis and heat treatments for carbon evaporation



Magnetron Sputtering technique

- Investigation of thick ZnO deposition onto different substrates (Au/Nb – DLC)
- A. Kotliarenko et al., First Results on Zinc Oxide Thick Film Deposition by Inverted Magnetron Sputtering for Cyclotron Solid Targets Production. Materials, 16, 10, 3810, 2023. DOI: 10.3390/ma16103810

First results from TOTEM project



IN PROGRESS



IN PROGRESS



IN PROGRESS

Target recovery and recycling in collaboration with WP2

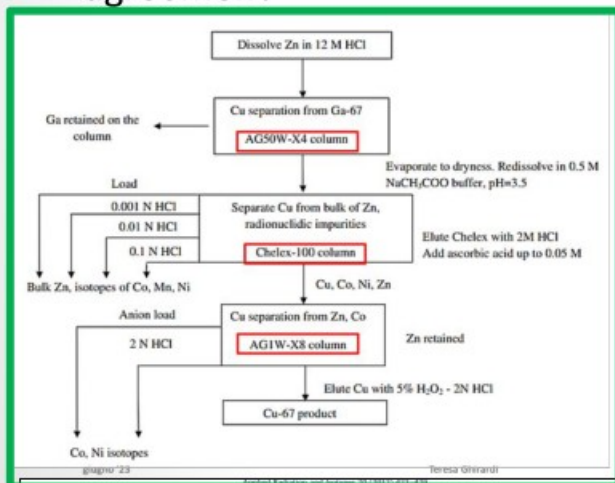
Activities shared with WP2

CUPRUM-TTD WP2 (FE): Target radiochemistry processing

	1st year 2023				2nd year 2024				3rd year 2025				
	1°	2°	3°	4°	1°	2°	3°	4°	1°	2°	3°	4°	
WP2	Target radiochemistry processing												
M4													D5: Zn/Cu separation and purification procedure D6: semi-automatic module for the separation and purification of ^{67}Cu from ZnO target D7: ^{67}Cu radiochemistry product quality assessment M4: development of separation and purification procedure using cold targets of natural ZnO M5: development of a solid target dissolution reactor and optimization of automation of ^{67}Cu separation, M6: development of an automatic system for the separation and purification of Cu-67 from the target of ZnO and other contaminants, M7: production tests of Cu-67 using enriched target and determination of the extraction yield and purity of the final product. M8: Quality controls analysis on Cu-67 produced and isolated for pharmaceutical studies
M5													
M6													
M7													
M8													

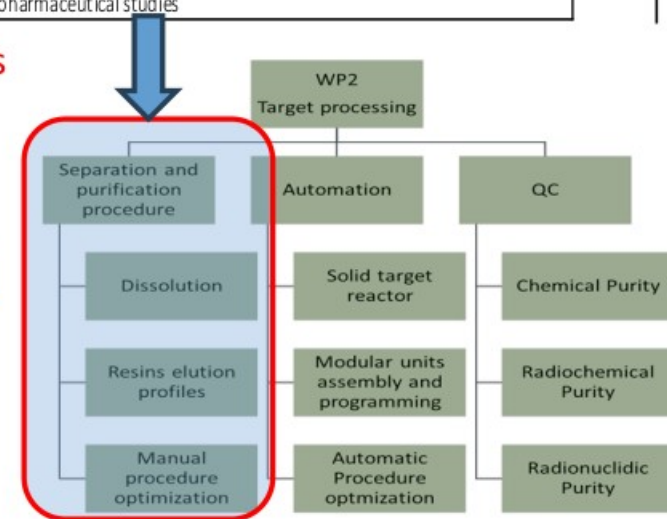
IN PROGRESS

- Literature analysis on **separation and purification studies** (below shown only one of works published, as an example)
- Purchase of resins and accessories for separation studies
- Identification of new laboratory for ICP(MS) characterization @UNIFE and collaboration agreement



Radiochemical separation procedure (main steps)

- Target dissolution in HCl 12M
- Load: **AG50W-X4** (cation exchange) → **Cu/Ga** separation (Ga hold)
- Load: **Chelex-100** (faint cation exchange) → **Cu/Zn** separation (Zn eluted) and other products
- Load (after 5 min): **AG1-X8** (anion exchange) → **Cu/Co** separation



Material Purchase to set up first experiments (may 2023- Products to be delivered)

standard Ga (1000 mg/l) in HNO₃
 standard Zn (1000 mg/l) in HNO₃
 standard Cu (1000 mg/l) in HNO₃
 (AG)1-X8 (100-200 mesh, chloride form) 500g
 (AG)50W-X8 (100-200 mesh, hydrogen form) 500g

TK400 Cartridge (100-150 um)
 TK201 Cartridge (100-150 um)
 TK200 Cartridge (50-100 um)

WP2

Petra Martini

Alessandra Boschi

Francesca Porto

Licia Uccelli

Lorenza Marvelli

Teresa Ghirardi

Emiliano Cazzola

INFN-FE UNIFE

INFN-LNL

HSCDC

CUPRUM-TTD WP2 → support to WP1: Target recovery

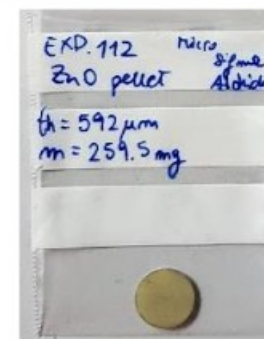
	1st year 2023				2nd year 2024				3rd year 2025				
	1°	2°	3°	4°	1°	2°	3°	4°	1°	2°	3°	4°	
WP2	Target radiochemistry processing												
M4		★											D5: Zn/Cu separation and purification procedure D6: semi-automatic module for the separation and purification of ^{67}Cu from ZnO target D7: ^{67}Cu radiochemistry product quality assessment M4: development of separation and purification procedure using cold targets of natural ZnO M5: development of a solid target dissolution reactor and optimization of automation of ^{67}Cu separation, M6: development of an automatic system for the separation and purification of Cu-67 from the target of ZnO and other contaminants, M7: productions tests of Cu-67 using enriched target and determination of the extraction yield and purity of the final product. M8: Quality controls analysis on Cu-67 produced and isolated for pharmaceutical studies IN PROGRESS
M5													
M6													
M7													
M8													

➤ Chemical processing aimed at ZnO recovery

- From ZnO powder
- From ZnO pellet (SPS) contaminated with carbon

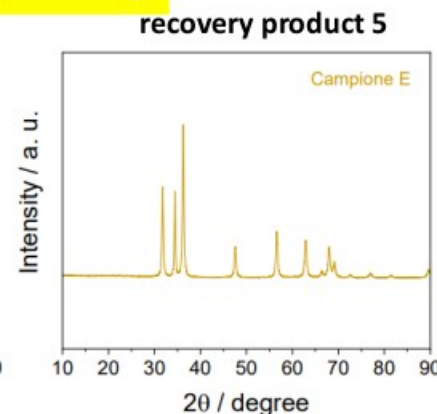
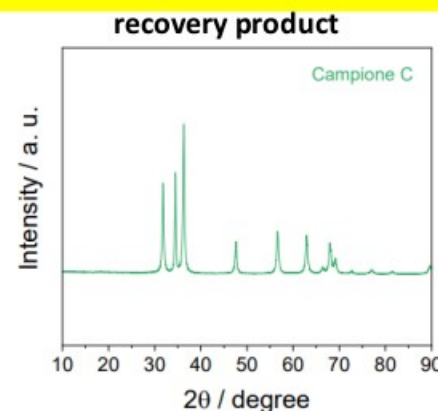
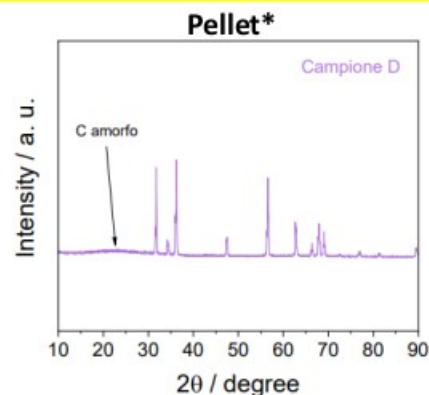
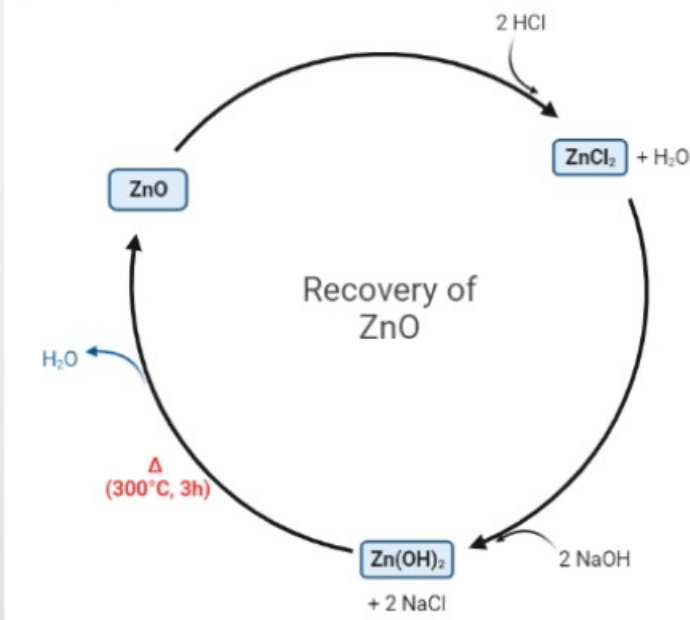
IN PROGRESS

➤ XRD and TGA analysis for carbon determination before and after chemical process for ZnO recovery



Preliminary results:

- **Recovery yield up to 95%**
- C detected in the pellet by XRD
- No C has been detected in the final recovery product
- C mass in a partial sample of the pellet by TGA < 0,001 mg



CUPRUM-TTD WP3: Irradiation, γ -spectrometry and QC test

	1st year 2023				2nd year 2024				3rd year 2025			
	1°	2°	3°	4°	1°	2°	3°	4°	1°	2°	3°	4°
WP3	Cyclotron Irradiation, Spectrometry and QC test											
M9												
M10												
M11												
M12												
M13												
M14												

D8: RNP determination of the produced ^{67}Cu

D9: xs measurements determination with alpha beams for alternative ^{67}Cu productions

IN PROGRESS

M9: ^{nat}ZnO targets irradiation for thermomechanical stability tests

M10: ^{nat}ZnO targets irradiations for radiochemical separation optimization

M11: perform γ -spectrometry measurements to estimate the efficiency of the radiochemical procedure (natZn targets)

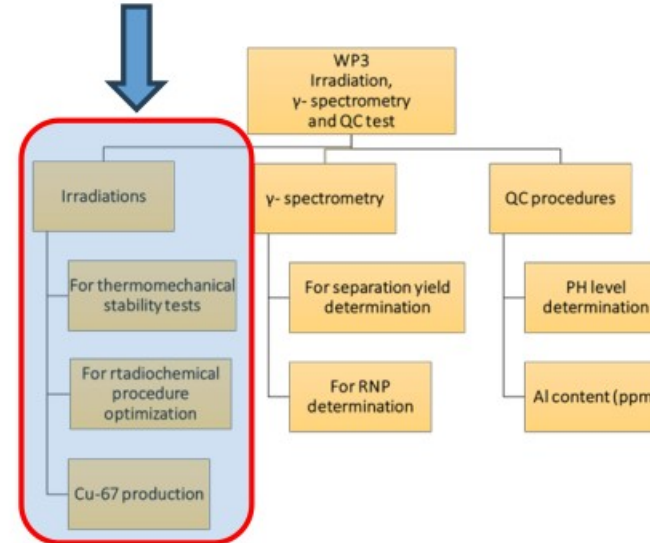
M12: three long irradiations for Cu-67 production on enriched ^{70}ZnO targets.

M13: perform γ -spectrometry measurements to estimate the activity and RNP of the ^{67}Cu produced by irradiation of ^{70}Zn targets

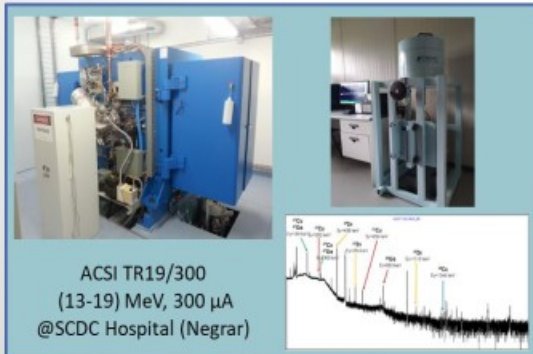
M14: xs measurements for alternative $^{67-61}\text{Cu}$ nuclear reaction routes $^{64}\text{Ni}(\alpha, p)^{67}\text{Cu}$ and $^{59}\text{Co}(\alpha, 2n)^{61}\text{Cu}$

Irradiation runs on $^{nat}\text{ZnO}/^{nat}\text{Ni}$ for targets and related spectrometry measurements

- selection of beam parameters suitable to yield small batches of $^{67}\text{Cu}/^{64}\text{Cu}$ based on theoretical calculations;
- $^{nat}\text{-ZnO}$ target irradiations for thermomechanical stability tests
- 3 irradiation runs on ^{70}ZnO for first batches of ^{67}Cu ;
- 2-3 irradiations runs on ^{nat}Ni and ^{59}Co with alpha beams for $^{61,64,67}\text{Cu}$ optimization production (xs meas. @ARRONAX) UNIMI+INFN-Mi
- 2 irradiations runs on thick target of ^{64}Ni for TTY, RNP, SA det.
- γ -spectrometry analysis for yield and RNP determination



WP3	
Liliana Mou	LNL
Gaia Pupillo	
Carlos Rossi Alvarez	
Juan Esposito	HSCDC
Emiliano Cazzola	
Giancarlo Gorgoni	
Luciano Canton	UNIPD
Francesca Barbaro	
Simone Manenti	UNIMI
Flavia Groppi	
Fiorella M. Cagnetta	
Michele Colucci	INFN-MI
Francesco Broggi	

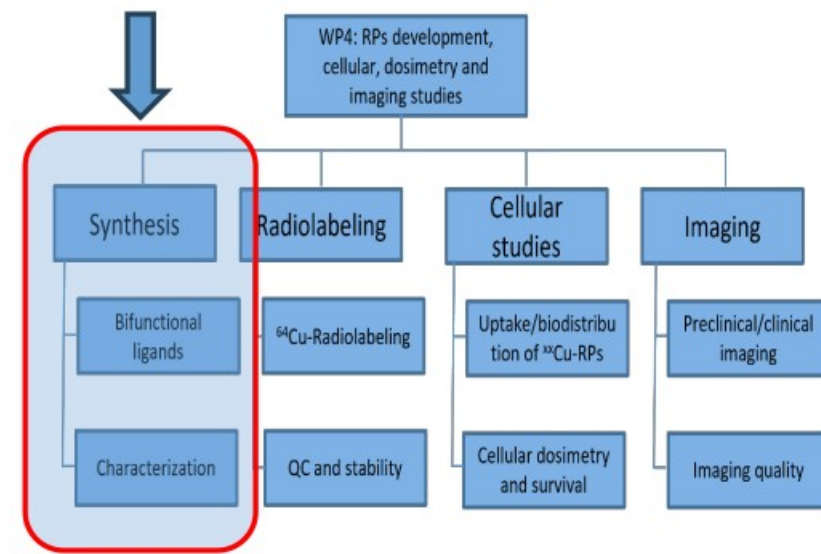


- The first irradiation tests @SCDC hospital for thermomechanical stability of the ^{nat}ZnO targets (M9) will be scheduled starting from September 2023
- From October 2023 starting of theoretical activities on alternative nuclear reaction routes by Padua group

Production Route	Reaction	Natural Abundance (%)	Threshold ^{67}Cu (MeV)	Threshold ^{64}Cu (MeV)
ACCELERATOR	$^{64}\text{Ni}(\alpha, p)^{67}\text{Cu}$	0.925	4.93	23.49
	$^{70}\text{Zn}(p, \alpha)^{67}\text{Cu}$	0.61	0	23.83
	$^{70}\text{Zn}(p, X)^{67}\text{Cu}$	0.61	0	23.83
	$^{70}\text{Zn}(d, \alpha n)^{67}\text{Cu}$	0.61	0	26.42
	$^{68}\text{Zn}(p, 2p)^{67}\text{Cu}$	18.45	10.12	7.9
	$^{68}\text{Zn}(\gamma, p)^{67}\text{Cu}$	18.45	0	0
	$^{68}\text{Zn}(d, ^3\text{He})^{67}\text{Cu}$	18.45	4.61	10.3
	$^{67}\text{Zn}(d, 2p)^{67}\text{Cu}$	4.04	2.06	17.91
REACTOR	$^{71}\text{Ga}(p, \alpha p)^{67}\text{Cu}$	39.89	5.32	23.19
	$^{67}\text{Zn}(n, p)^{67}\text{Cu}$	4.04	0	17.66

es INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

IN PROGRESS



WP4	
Laura De Nardo/ Laura Melendez-A.	INFN-PD IOV
Alessandra Zorz	IOV
Marta Paiusco	
Michele Bello	UNIPD
Diego Cecchin	INFN-PD
Cristina Bolzati	ICMATE CNR
Giov. Di Domenico	UNIFE
Angelo Taibi	INFN-Fer

- (10)

CUPRUM-TTD WP4: Cellular dosimetry calculations

	1st year 2023				2nd year 2024				3rd year 2025			
	1°	2°	3°	4°	1°	2°	3°	4°	1°	2°	3°	4°
WP4	RP's development, cellular, dosimetric and Imaging studies											
M15												
M16												
M17												
M18												
M19												

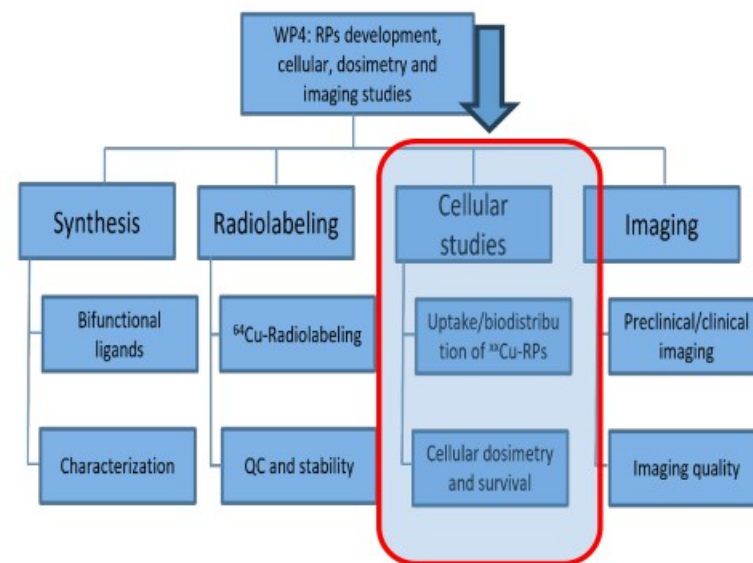
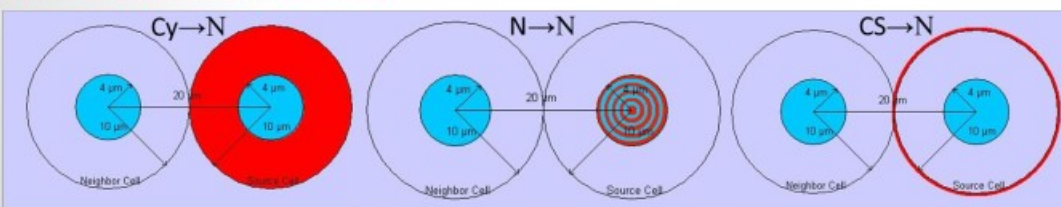
D10: NOTA-PSMA conjugates
D11 A reproducible method to obtain Cu-PSMA RPs with high radiochemical yield
D12: Minimum activity and dimension of the tumour to obtain good imaging

IN PROGRESS

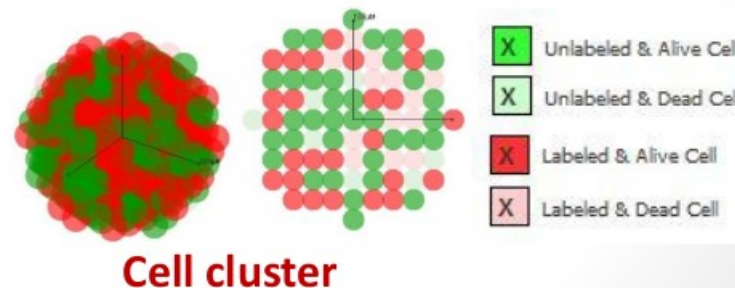
M15 : synthesis and characterization of NOTA-PSMA conjugates
M16 : Radiolabeling and stability studies of synthesized conjugates
M17 : Determination of specific binding of Cu-PSMA RPs to PSMA receptors naturally expressed by PCa tumor cells, uptake % and internalization
M18 : Determination of cell absorbed dose and the surviving fraction after the treatment with ^{64}Cu -NOTA RPs
M19 : Determination of contrast, sensitivity, and spatial resolution of the SPECT/PET imaging of the produced $^{64-67}\text{Cu}$

- Cellular Dosimetry calculations **are foreseen during the 3rd year**, after evaluation of specific uptake and internalization in both PSMA-positive and -negative PCa cells.
- However, preliminary calculations with **both ^{67}Cu and ^{64}Cu have been performed with the MIRDCell software in tumor models** represented as **isolated spheres** of water density with a uniform distribution of radioactivity or as **spherical clusters of cells** by assuming different:
 - subcellular distribution of radionuclides** (100% in Cytoplasm, Nucleus or Cell Surface)
 - cluster cell dimension** ($r_{\text{cluster}} = 50, 150, 290, 625, 1350 \mu\text{m}$)
 - percentage of labeled cells** (10, 30, 50, 80, 100%)

Source- Target configurations:



WP4	
Laura De Nardo/ Laura Melendez-A.	INFN-PD IOV
Alessandra Zorz	IOV
Marta Paiusco	UNIPD
Michele Bello	INFN-PD
Diego Cecchin	ICMATE CNR
Cristina Bolzati	UNIFE
Giov. Di Domenico	INFN-Fe
Angelo Taibi	



CUPRUM-TTD project 2024 FTE (subject to further refinement)

Personnel and FTE distribution expected among units taking part

LNL	FTE	INFN-Fe	FTE	INFN-Mi	FTE
Esposito J. (R.Naz.-Loc.)	0.6	Martini P. (R. Loc)	1.0	Groppi F. (Res. Loc)	0.7
Pupillo G.	0.1	Taibi A.	0.1	Manenti S.	0.7
Mou L.	0.3	Boschi A.	1.0	Cagnetta F.M.	0.5
Cisternino S.	0.5	Uccelli L.	1.0	Colucci M.****	1.0
Melendez-Alafort L.**	1.0	Marvelli L.	1.0	Broggi F.	0.2
Bello M.	0.8	Porto F.*	1.0		3.1
Kotliarenko A.	0.5	Ghirardi T.*	1.0		
Keppel G.	0.1		6.1		
Anselmi-Tamburini U.	0.2	INFN-Pd	FTE		
Cazzola E. #	1.0	De Nardo L. (R. Loc)	0.8		
Gorgoni G.#	1.0	Canton L.	0.2		
	6.1	Barbaro F.	0.6	TOTALE FTE	17.8
		Paiusco M.**	0.2		
		Zorz A.**	0.2		
		Cecchin D.§	0.2		
		Bolzati C.***	0.2		
		Lashko Y.	0.1		
			2.5		

- * studenti PhD associate INFN-Fe (da nov 2023)
- ** personale IOV associato PD or LNL
- *** personale CNR associato INFN-Pd
- **** studente PhD associato INFN-MI
- § personale UNIPD associato INFN-Pd
- # personale SCDCH associato INFN-LNL

CUPRUM-TTD project

INFN-Padua

PLANNED ACTIVITIES for 2024 and budget quotation

Item	What is needed	Estimated cost K€
In vitro studies to determine the percent of specific uptake and internalization in cells	Refrigerated shaker for incubating biological cultures*	6.5
	^{64}Cu to radiolabel the developed Radiopharmaceuticals (2x10mCi)*	3.0
	Consumables for cellular studies*	1.0
Travels	Domestic travels Padua-Legnaro and Padova-Pavia	1.5
TOTAL		12.0



* Richieste del 2023 da ridiscutere al secondo anno, secondo planning rimodulato

Nessuna richiesta di servizi in sezione



Advanced Dosimetry Methods and In-vitro Radiobiology of Ag-111 Labeled radiopharmaceuticals

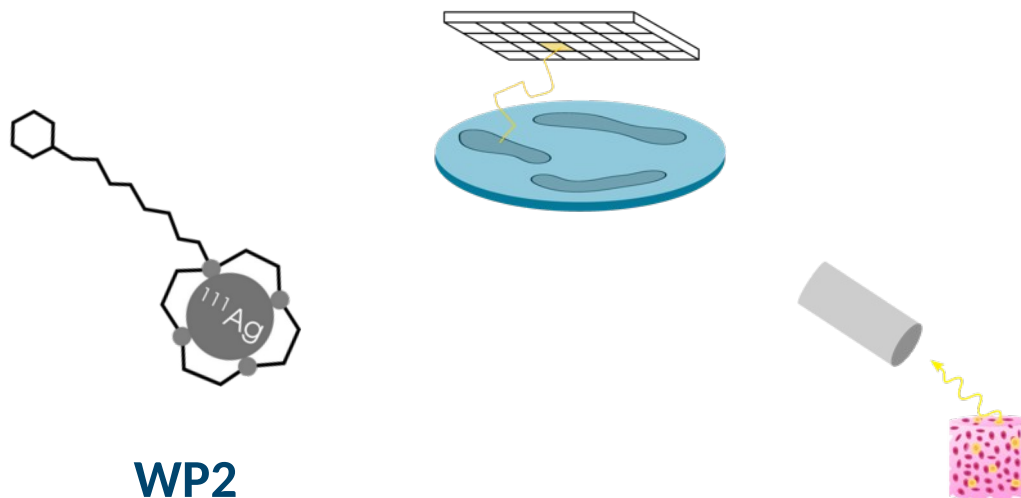
- **Principal Investigator**
Alberto Andrichetto, INFN-LNL.
- **INFN Research Units**
LNL, Padova, TIFPA, LNS, Pavia, Bologna.
- **Research Fields**
Medical Physics, Radiation Detectors, Radiobiology.
- **Duration**
3 years.



WP3



Development of a β -imaging system based on solid-state detector

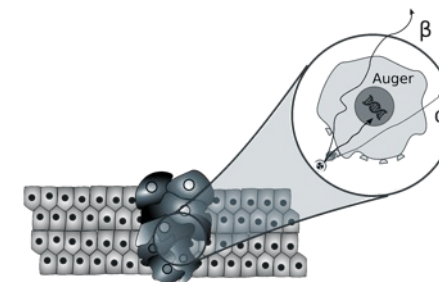


WP2

Development of a γ -imaging scintigraphic system for ^{111}Ag

WP4

Radiobiological characterization of ^{111}Ag radiopharmaceutical



WP1

Radiopharmaceutical production



POLICLINICO DI SANT'ORSOLA



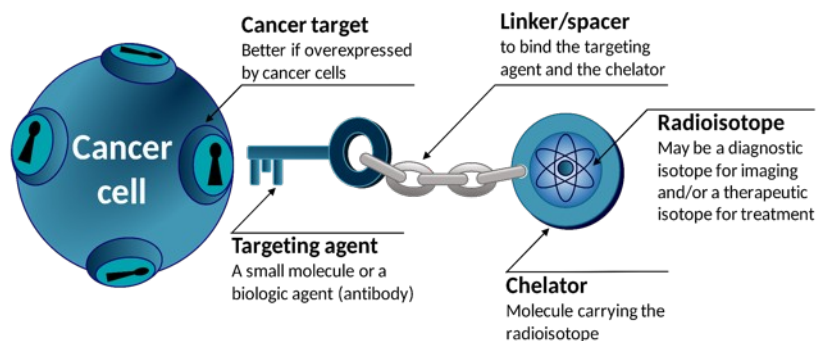
WP1

WP Leader: V. Di Marco (UNIPD) and D. Meniglio (UNITN)



Work Package Aim

WP1 will sum up all the preexisting activities leading to the **development of the radiopharmaceutical itself**, with the addition of the **tissue-mimicking scaffold production** to generate **more realistic 3D cell cultures** to be employed in the other work packages.



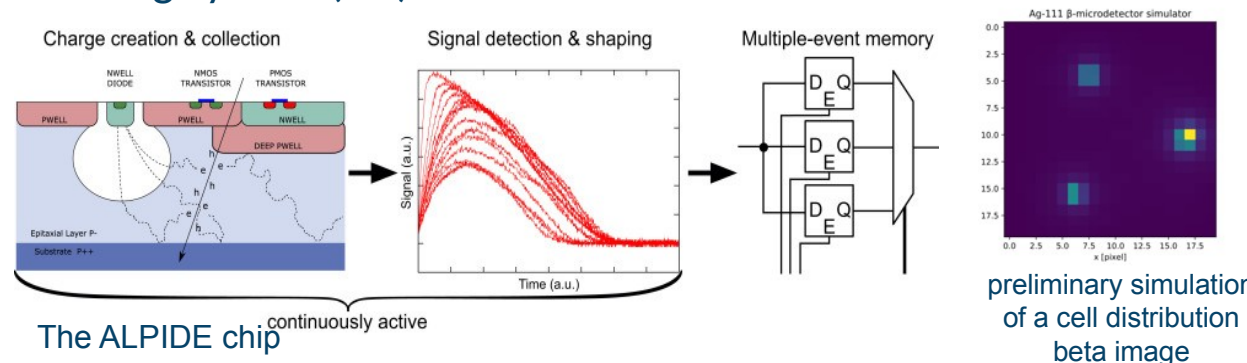
WP2

WP Leader: M. Lunardon (UNIPD)



Work Package Aim

This WP will be devoted to the **design, construction** and **characterization** of a new large-area detector for 2D β -imaging at high resolution. This new device will take advantage of the monolithic silicon pixel technology developed recently for the ALICE experiment, namely the **ALPIDE**, the Monolithic Active Pixel Sensor of the new Inner Tracking System (ITS).



WP3

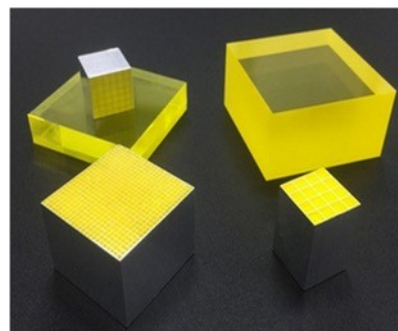
WP Leader: C. Sbarra (UNIBO)



Work Package Aim

This WP is aimed at the **design and development** of a planar scintigraphic system optimized for the incoming **γ emission** from the de-excitation of ^{111}Cd after the radioactive decay of ^{111}Ag . The design and construction of the imaging device will begin considering **all its components**, from **detectors** to **data acquisition software**.

GAGG scintillators in slab and matrix produced by EPIC-Crystals



WP4

WP Leader: S. Bortolussi (UNIPV)



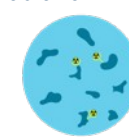
Work Package Aim

The whole set of experimental activities concerning **radiobiology**. In particular cell survival in 2D and 3D scaffolds will be evaluated. The acquired **radiobiological data** will be related to the absorbed **dose at cell level**, which will be calculated using Monte Carlo method, exploiting the available data about ^{111}Ag **uptake in vitro** and transporting the emitted radiation in simulated geometries that reproduce the monolayer or the **3D scaffold**.

Step 1:
Culture Preparation



Step 2:
Irradiation



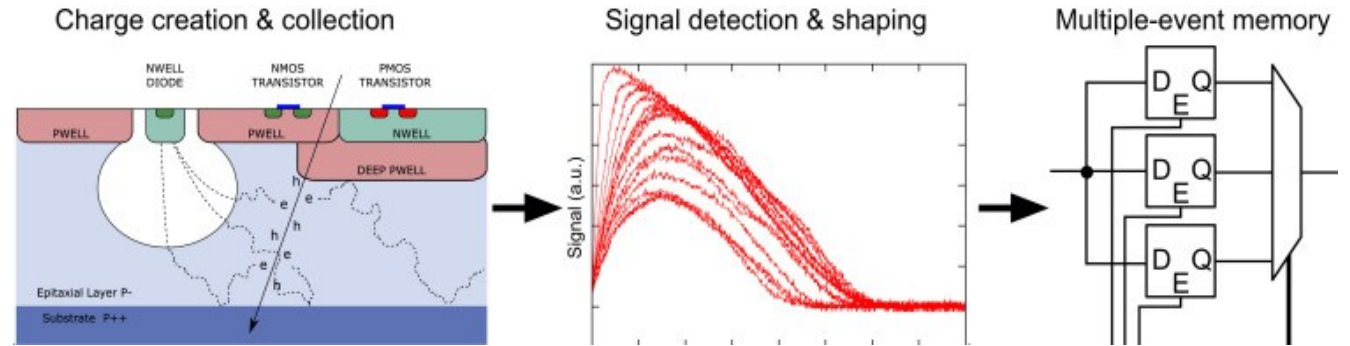
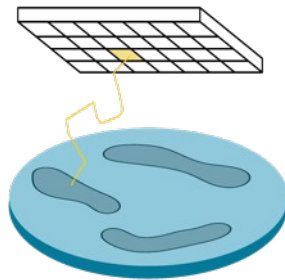
Step 3:
Growth Stimulation



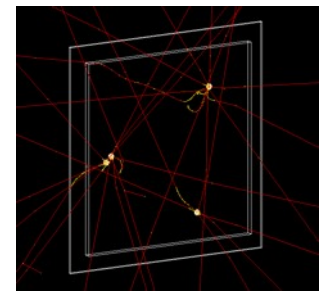
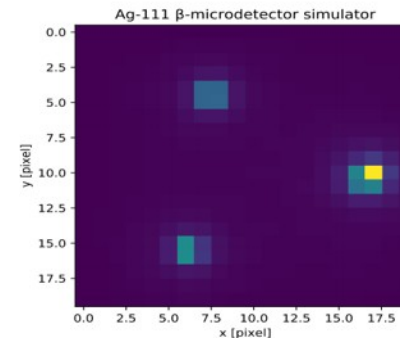
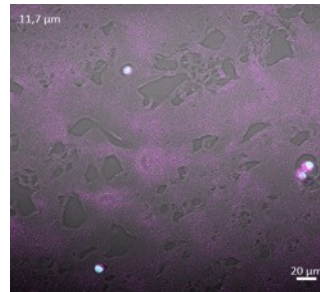
Step 4:
Colonies Counts



- **ALPIDE chips:** technology from HEP
- 15 mm x 30 mm active area with 512 x 1024 pixels (typical size about 25 μm)
- low-cost readout electronics using commercial FPGA + custom PCB + dedicated Firmware
- modular system, scalable size, compact, easy to use. With 8 chips an active plate of **60 mm x 60 mm** can be easily assembled.



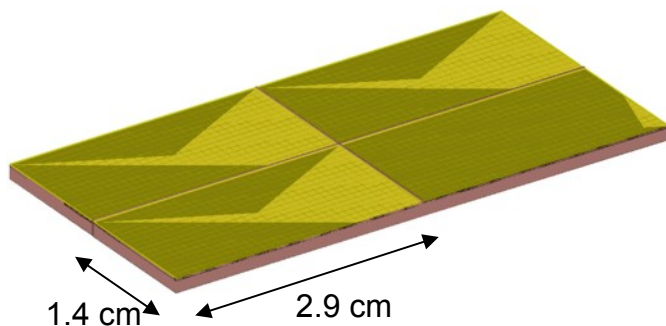
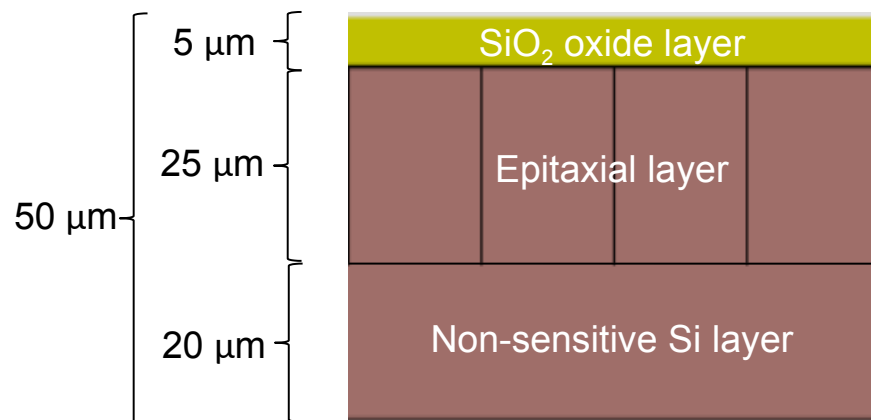
Schematic concept of a bivalent fluorescent radiopharmaceutical.



Cell culture in 3D scaffold slice administered with a pharmaceutical: fluorescence confocal microscopy (unlabeled) vs β -microdetector simulation using Geant4 (labeled with ^{111}Ag ; pixel size 20 μm , noise 12%, 10^6 CCK2 receptors [26], detector distance 10 μm).

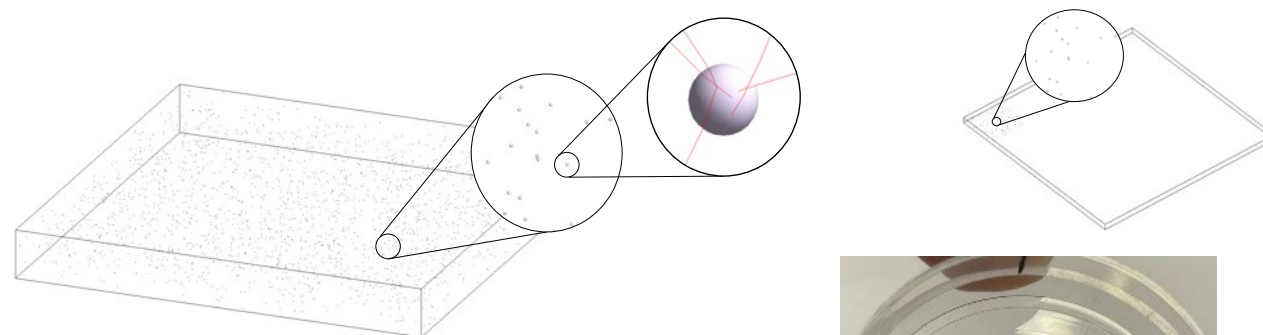
ALPIDE Modelling

ALPIDE: silicon detector developed for **particle tracking** in ALICE (CERN). It is made of 1024x512 sensitive pixels of size $(28 \times 28) \mu\text{m}^2$.

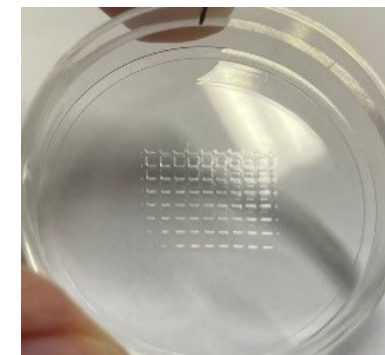


Source Modelling

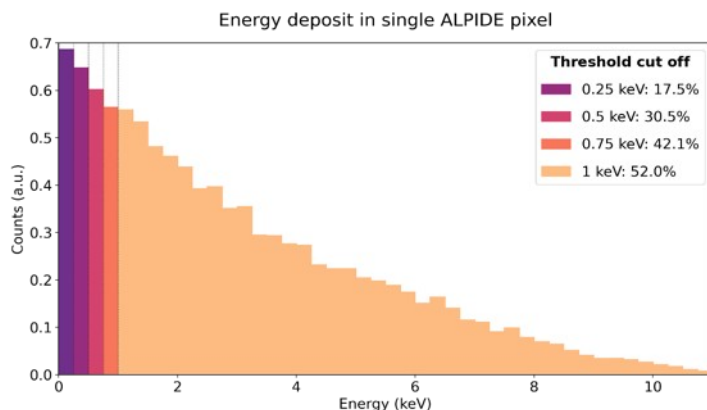
Radiation source: Scaffold → **Aqueous spherical cells** ($10 \mu\text{m}$ radius) dispersed in hydrogel matrix. Inside the cell volume, ^{111}Ag undergoes β decay.



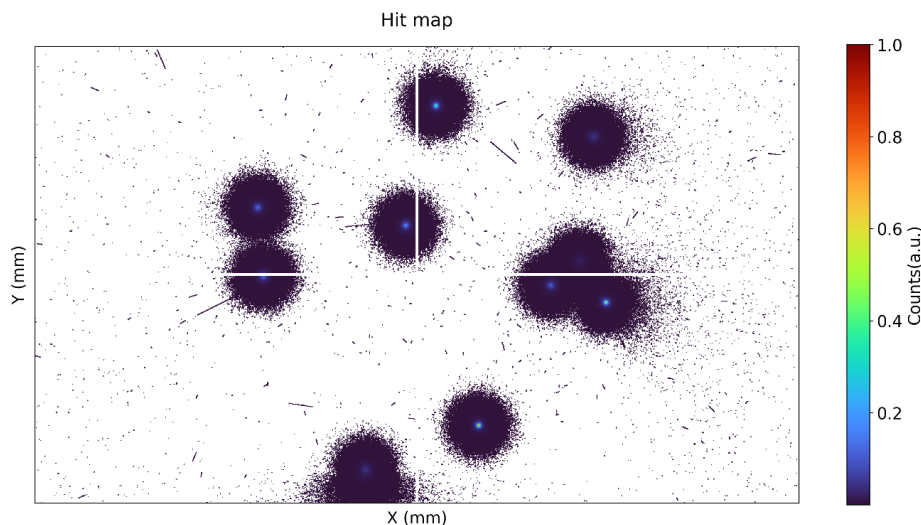
- **Scaffold**
- different geometries
 - different substrates



- **Traditional cell culture**
- Petri dish
 - Mylar (or other materials) substrate

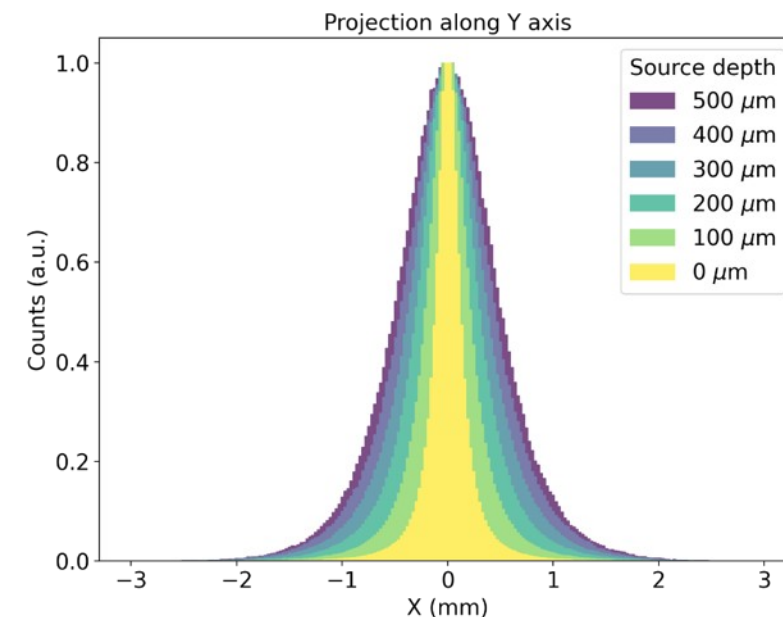


Energy deposit and threshold effect



Sample image obtained with GEANT4 Monte Carlo simulations. 10 cells dispersed in hydrogel matrix serve as radiation source.

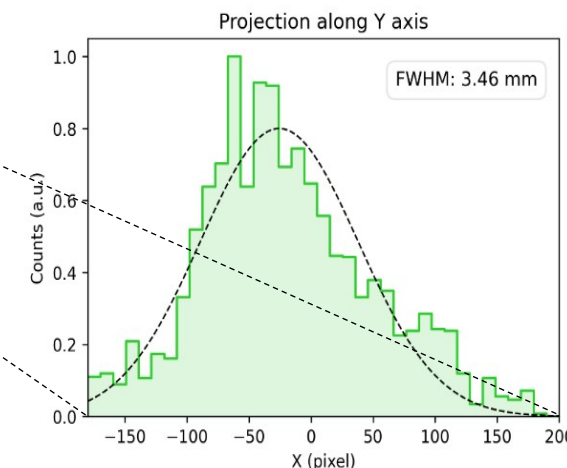
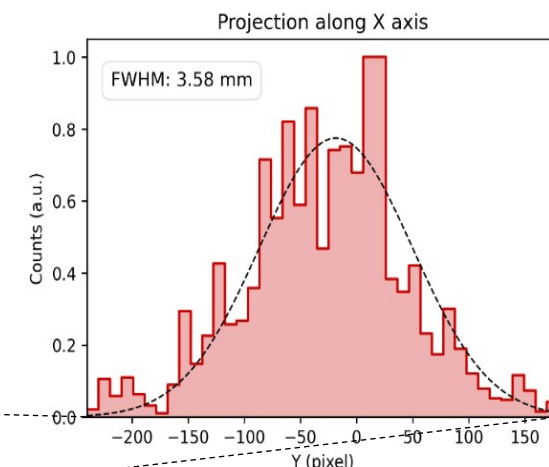
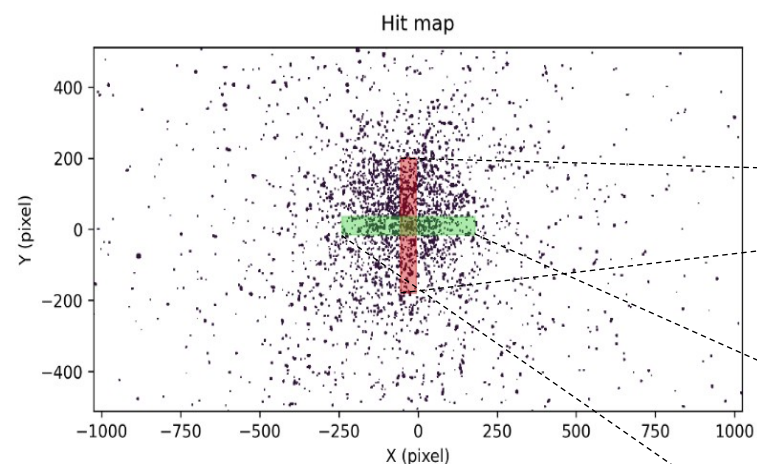
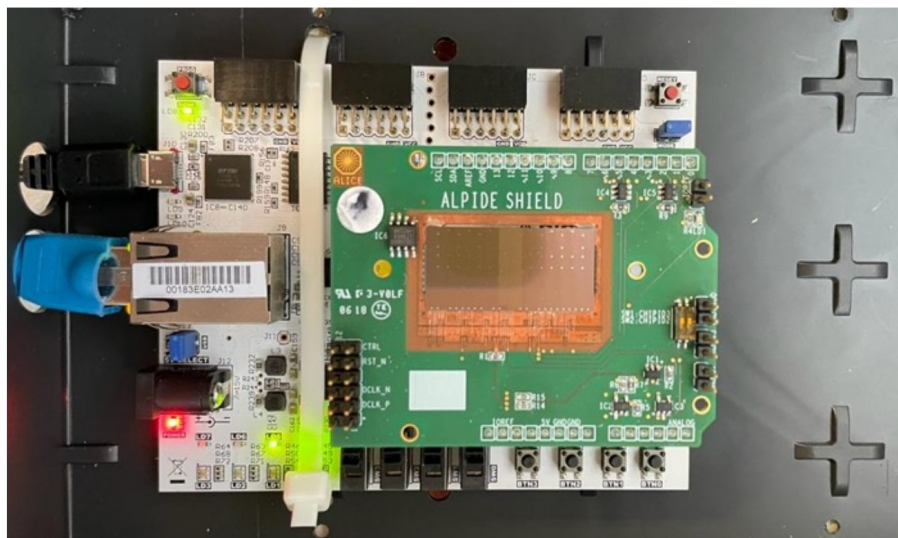
Depth (μm)	FWHM (mm)
0	0.22
100	0.39
200	0.56
300	0.73
400	0.99
500	1.01



Detector resolution capability for *single cell* source placed at different depths inside the hydrogel matrix (from 0 = surface in contact with the detector to 500 = opposite surface).

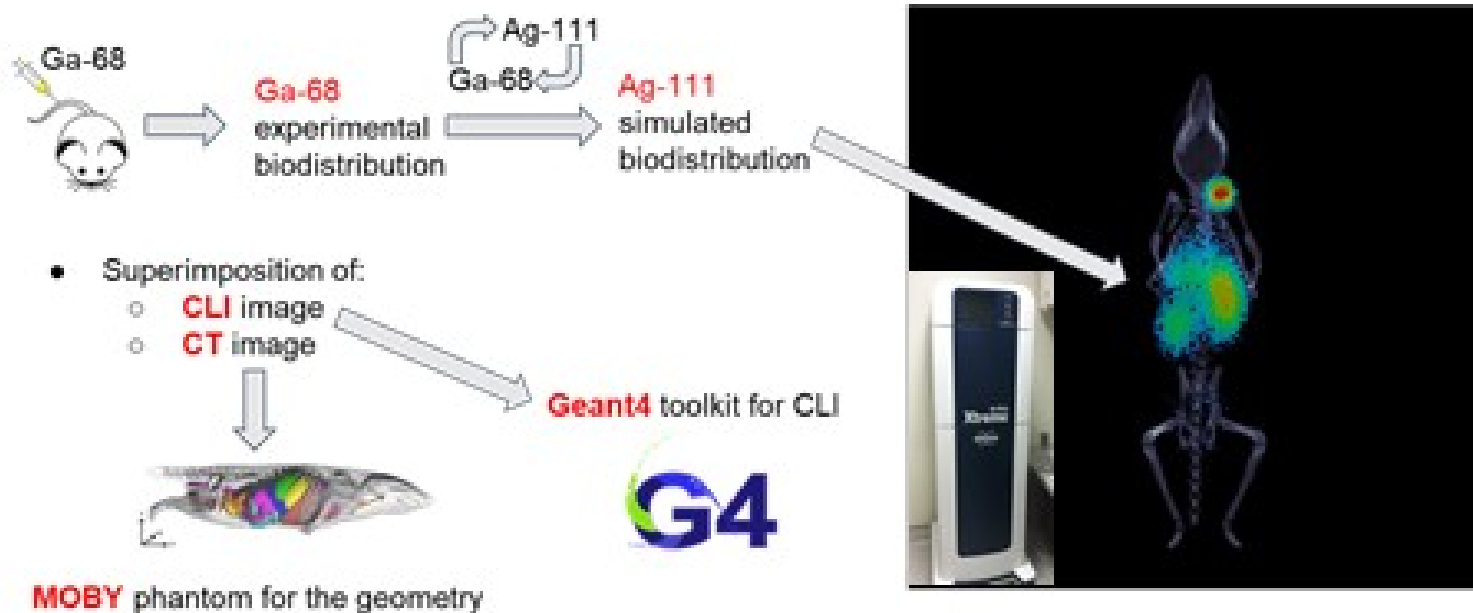
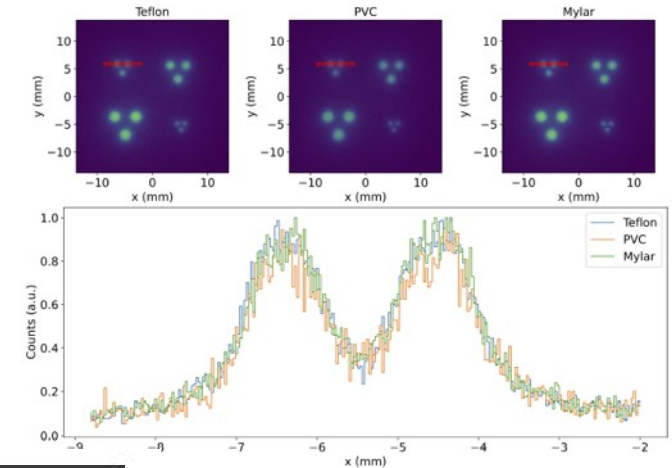
first measurements with ALPIDE

First measurements conducted with ALPIDE: dedicated **firmware** mounted on the detector and carried out preliminary **data acquisition** with ^{90}Sr source (roughly collimated).



New more precise assembly under construction. New better images with standard sources available soon

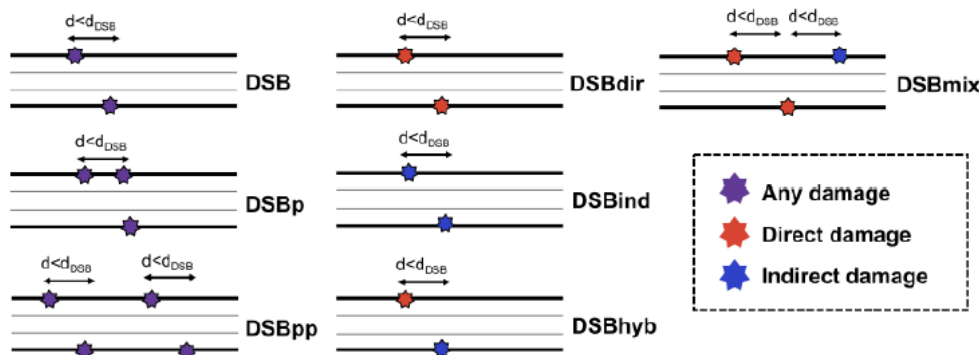
- ➔ Simulations can be used to assess various information before data taking
- ➔ Phantom placed upside down, need for **closing film**
- ➔ Simulation to study if image is perturbed by presence of layer
- ➔ **Refractive index** might influence: simulate materials with different n and thickness $[10-100] \mu\text{m}$



by Aurora Leso (LM Physics)

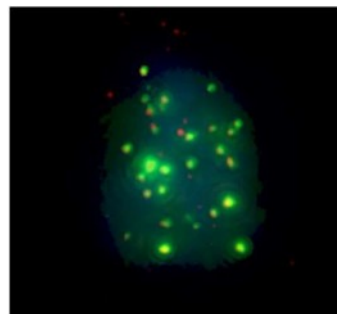
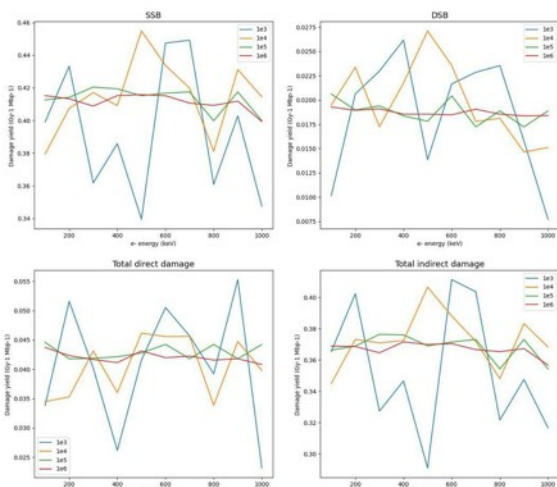
by Emma Reniero (LM Physics)

Dose - DNA damage studies using **GEANT4-DNA**



direct and indirect radiation damage on the DNA

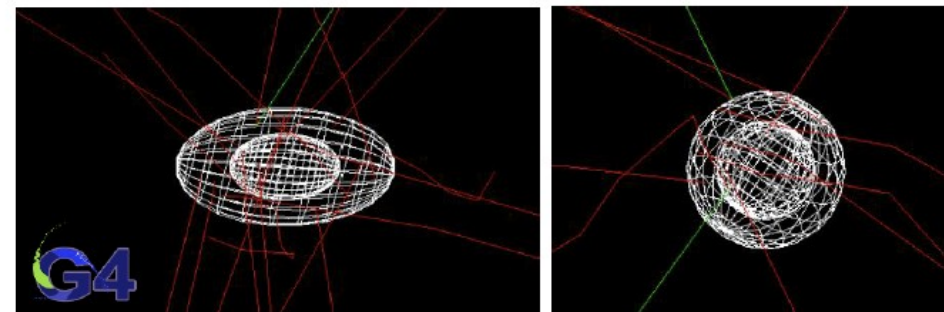
Damage with increasing events, superficial distribution



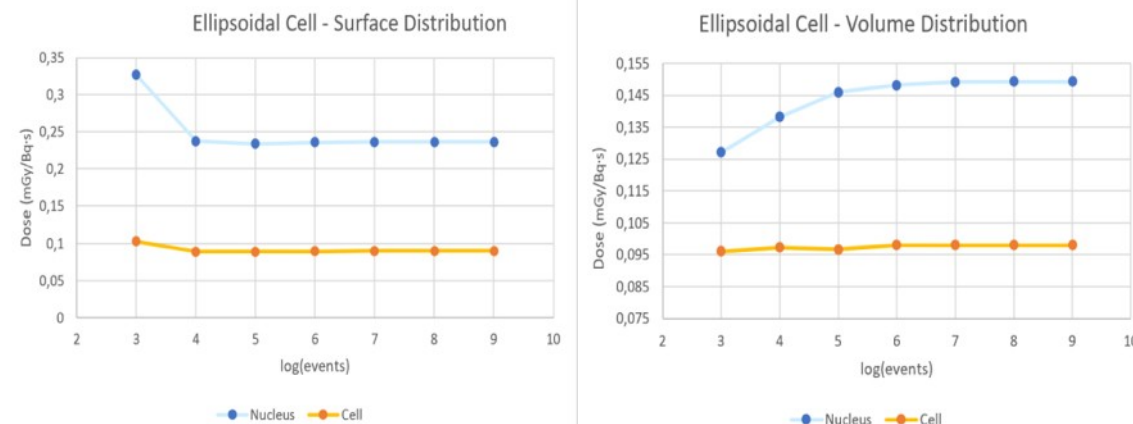
foci assay will be used to validate the calculations

single (SSB) and double (DSB) strand break evaluated

Dose release at cellular level with GEANT4



Different Ag-111 distribution models used (membrane, cytoplasm, whole cell)

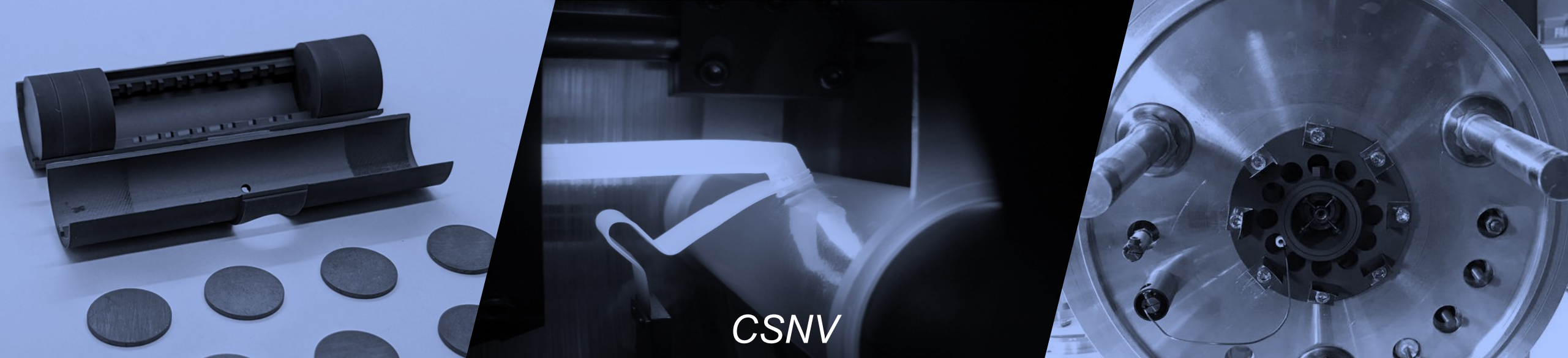


Dose in ellipsoidal cells: better release from Ag-111 on membrane

		Year 2
		[k€]
Consumables	Mechanical and Ancillary components: - Thorlabs precision XY movements (or equivalent) - other components	5
	Electronics - Xilinx FPGA development kit (or equivalent) - PCB production - other components	3 1 1
Shipping	Shipping of detectors from PD to test sites in Italy	2
Travels	Travels for experimental activity	4
TOTAL INFN-PD		16

Anagrafica: M. Lunardon **0.3**, S. Moretto **0.1** , P.Lotti **0.3**, L. Zangrando **0.2**, Chiara Bonini (PhD) **0.5**, **Daiyuan Chen (PhD) 1.0**, **Jessica Delgado Alvarez (Assegno) 1.0**
TOT = 3.4 FTE

Richieste servizi: 1 M.U. officina elettronica per chip bonding e altre operazioni di assemblaggio



HISOL

High performance **ISOL** systems for the production of radioactive ion beams

Principal Investigator: Mattia Manzolaro

Work Package 1: Development of High Performance ISOL Targets – WP1 leader: Stefano Corradetti

Work Package 2: Development of High Performance ISOL Ion Sources – WP2 leader: Alberto Monetti

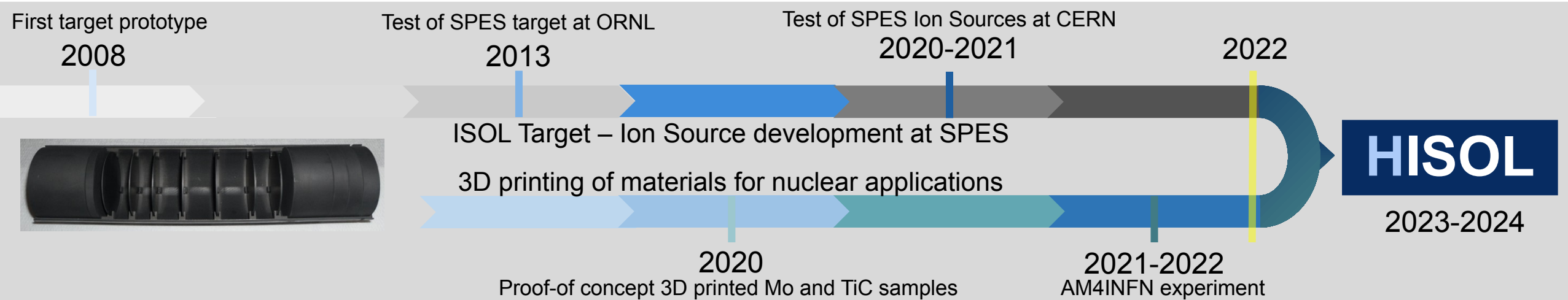
Work Package 3: Materials Characterization and Multiphysics Simulation – WP3 leader: Michele Ballan

Introduction

High intensity and pure Radioactive Ion Beams (RIBs): fundamental for research in various fields (for basic research in nuclear physics, high-level applications such as nuclear medicine)

Improving **ISOL Targets** and **Ion Sources** can increase the **intensity** and the **purity** of **RIBs**.

INFN-SPES project: the LNL ISOL group developed a considerable amount of **know-how** (on targets, ion sources, molecular beams, ...) benefitting of prestigious **international collaborations** (ISOLDE-CERN, ORNL, ...).



AM4INFN (supported by INFN_E): 3D printing of high temperature materials such as **SiC**, **TiC**, **Ta**, **W**, and **Mo** (for ISOL systems).

A dedicated **INFN-CSN_5 Experiment** could be great opportunity to define a **New Generation of High Performance ISOL Targets and Ion Sources**.

Project Objectives and organization

Production of TiC/SiC samples with regular structures



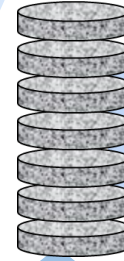
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DEGLI STUDI
DI PADOVA



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DI PADOVA



DIPARTIMENTO
DI INGEGNERIA
INDUSTRIALE



Development of High Performance ISOL Targets

Microstructural, thermal and structural characterization



Multiphysics simulations

Thermal, electric and structural characterization



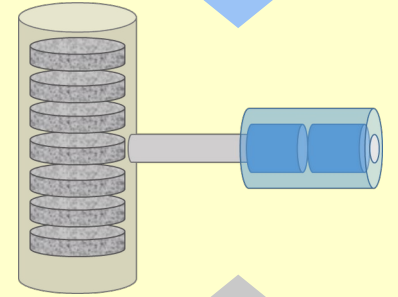
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Development of High Performance ISOL Ion Sources

R&D of complex shape Ion Source components

**Development and test
of High performance
ISOL Target – Ion
Source systems**



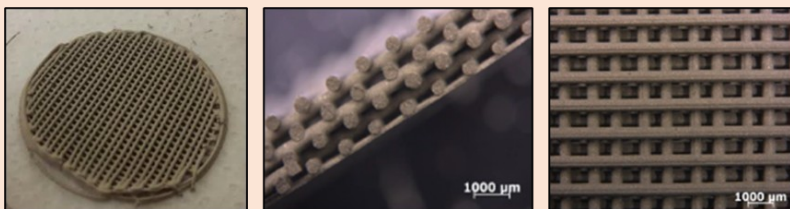
Research Metodology

Work package 1: Development of High Performance ISOL Targets

Production of **TiC/SiC** samples with **regular structures** for **characterization** activities



Development of **TiC/SiC** disks with regular structures for **ISOL Targets**



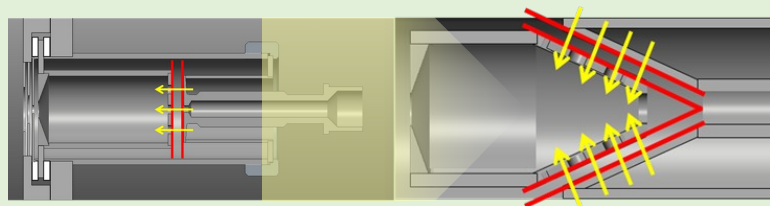
Long term **high temperature** test of a **TiC/SiC** ISOL Target prototype

Aim: maximize heat transfer and release

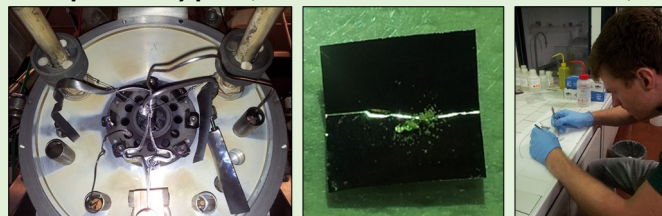
Work package 2: Development of High Performance ISOL Ion Sources

Production and test of **W, Ta and Mo** Ion Source components with **complex shapes**

Alternative anode-cathode interfaces



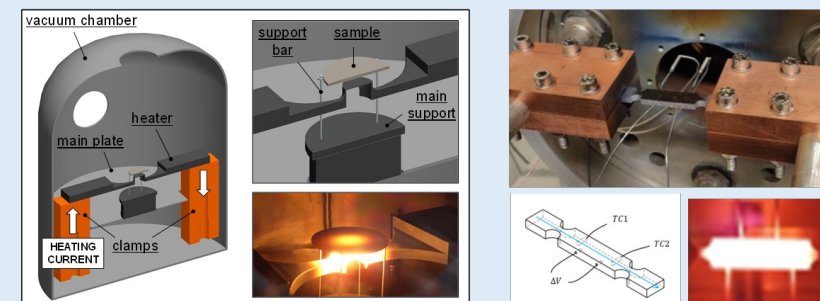
Production of ion beams with the Ion Source prototype (also **molecular beams**)



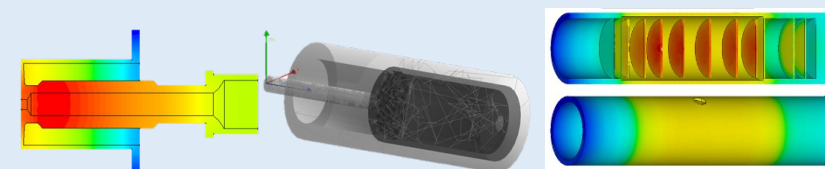
Aim: improve the ionization efficiency, the source stability and reproducibility

Work package 3: Materials Characterization and Multiphysics Simulation

Microstructural, thermal, electrical and structural **characterization**



Multiphysics Simulation of High Performance ISOL Targets and Ion Sources



Aim: component characterization

Personnel and budget

INFN-LNL			INFN-PD		
Name	WP	FTE	Name	WP	FTE
Mattia Manzolaro (National resp.)	1,2,3	0.3	Adriano Pepato (PD local resp.)	2,3	0.1
Stefano Corradetti (LNL local resp.)	1,3	0.1	Pietro Rebesan	2,3	0.1
Alberto Monetti	1,2,3	0.1	Massimiliano Bonesso (fino giugno '23)	2,3	0.1
Alberto Andrichetto	1	0.1	Razvan Dima	1,2	0.1
Michele Ballan	1,2,3	0.1	Simone Mancin	2,3	0.5
Lisa Centofante	1,2,3	0.1	Lisa Biasetto	2,3	0.5
Sara Carturan	1,3	0.1	Paolo Gregori	2,3	0.5
Giovanni Meneghetti	1,3	0.5	Matteo Perini	2,3	0.5
Alberto Campagnolo	1,3	0.5	Total PD FTE		2.4
Paolo Colombo	1,3	0.5	INFN-PV		
Giorgia Franchin	1,3	0.4	Name	WP	FTE
Alice Zanini	1,3	0.5	Valerio Villa (PV local resp.)	2	0.1
Irene Calliari	3	0.5	Antonietta Donzella	3	0.1
Claudio Gennari	3	0.5	Ileana Bodini	2	0.1
Total LNL FTE		4.3	Diego Paderno	2	0.1
			Alberto Girotto	2	1
			Total PV FTE		1.4
Total project FTE				8.1	

BUDGET REQUESTS year 1 [k€]	
INFN-LNL	
equipment (workstation), DII - Mech. Eng.	3
consumables, DII - Mech. Eng.	7
consumables, DII - Mat. Eng.	7
consumables, DII - Metall.	4
consumables, LNL	3
travel, LNL	1
travel, DII - Mech. Eng.	1
travel, DII - Mat. Eng.	1
travel, DII - Metall.	1
TOTAL	28
INFN-PD	
consumables, PD	9
consumables, PROM	3
consumables, DTG	3
travel, PD	4
TOTAL	19
INFN-PV	
equipment (workstation), UNIBS	3
consumables, UNIBS	4
travel, UNIBS	3
TOTAL	10
TOTAL YEAR 1	57

next_AIM

Responsabile locale: Zucchetta Alberto
Responsabile nazionale: Alessandra Retico
Durata: 3 anni (2022-2024)

Istituto Nazionale di Fisica Nucleare - Sezione di Padova

July 4, 2023



Istituto Nazionale di Fisica Nucleare
Sezione di Padova

Introduction to AIM and next_AIM

- ▶ AIM (Artificial Intelligence in Medicine) is an INFN CSN5 project that aims to:
 - exploit the expertise of INFN and associated researchers on medical data processing and enhancement
 - turn it in the development of advanced and effective analysis instruments
 - results to be eventually clinically validated and translated into products
- ▶ **AIM** was a research project funded by INFN-CSN5 in 2019-2021
- ▶ **next_AIM** funded by INFN-CSN5 for the tree-year period **2022-2024**
- ▶ Resoponsabile Nazionale: Alessandra Retico (PI)
- ▶ Other Sezioni involved: Pisa (PI), Bari (BA), Bologna (BO), Cagliari (CA), Catania (CT), Ferrara (FE), Firenze (FI), Genova (GE), Laboratori Nazionali del Sud (LNS), Milano (MI), Napoli (NA), Pavia (PV)
- ▶ Official website: [link](#)

People involved

		position	institution	FTE
Federico	Agostini	Dottorato Nazionale Intelligenza Artificiale	UNIPD	1.00
Manlio	De Domenico ^a	Prof. Associato	UNIPD	0.30
Marco	Zanetti	Prof. Associato	UNIPD	0.15
Alberto	Zucchetta ^b	Ricercatore	INFN	0.30
				1.75

^aAlso Head of the Complex Multilayer Networks (CoMuNe) Lab at the DFA

^bResponsabile Locale next_AIM

- Our work has been presented during the **next_AIM General Meeting** in Milan (February 13-15, 2023): [link](#) to the presentation



next AIM: research topics, challenges and implementation

WP1

Challenge I: no-so-big data

Strategies for efficient learning with limited data samples.

Evaluation of robustness and reliability of trained models.

WP2

Challenge II: explainable AI (XAI)

Make AI results understandable to humans.

Which image/data features were relevant to make a decision?

WP3

Applications to real-world data samples

Practical medical data analysis use cases on available samples (public data, private collections, integration of both), where the analysis approaches a, b or both are implemented, and the challenges I, II or both are encountered.

Implementation, test and validation in collaboration with colleagues working in Clinical context

WP4

Computing resources and SW repository organization

(ReCaS, IBiSCo, INFN-Cloud
+ risorse HW locali)

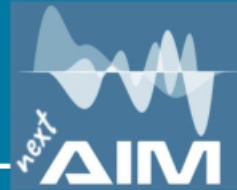
WP5

Exploitation of research results and communication

(connection with AIFM,
conferences, publications)

WP3 tasks: Real-world study cases (updated 2023)

WP conveners:
P. Oliva (CA), A. Lascialfari (PV),
M. Marrale (CT)



Sedi partecipanti										Task	Topic		
				FE		LNS		NA		PI		T1	Radiomics in Digital Breast Tomosynthesis (DBT)
	BO			FE				NA				T2	Super-Resolution in DBT
	BO		CT									T3	Radiomics in prostate cancer
	BO		CT									T4	Radiomics and DL in tcMRgFUS
	BO					GE	LNS					T5	Nuclear Neuro Imaging Quantification and Radiomics
BA		CA	CT						PD	PI		T6	Connectivity in functional MRI and EEG
		CA	CT	FE	FI	GE		MI		PI	PV	T7	Radiomics and Deep Learning analysis of CT and patients' data in COVID-19
								MI		PI	PV	T8	Radiomics and ML-segmentation on Facio-Scapulo-Humeral dystrophy (FSHD), lung and liver tumor
BA?											PV	T9	ML on Imaging data of 10B uptake tracks and dose monitoring by Compton cameras
					FI					PI		T10	Artificial intelligence for monitoring RT response in soft-tissue sarcomas
				FE					PD			T11	Machine Learning techniques for cardiological applications
					FI				PD	PI		T12	Application of NLP techniques to clinical notes towards the automated reading of instrumental data

Next_AIM activities in Padova

- ▶ next_AIM is structured like a network among different Sezioni INFN
- ▶ Synergies with other activities on AI, ML, HPC, AIFM (Associazione Italiana di Fisica Medica)

Current activities in Padova

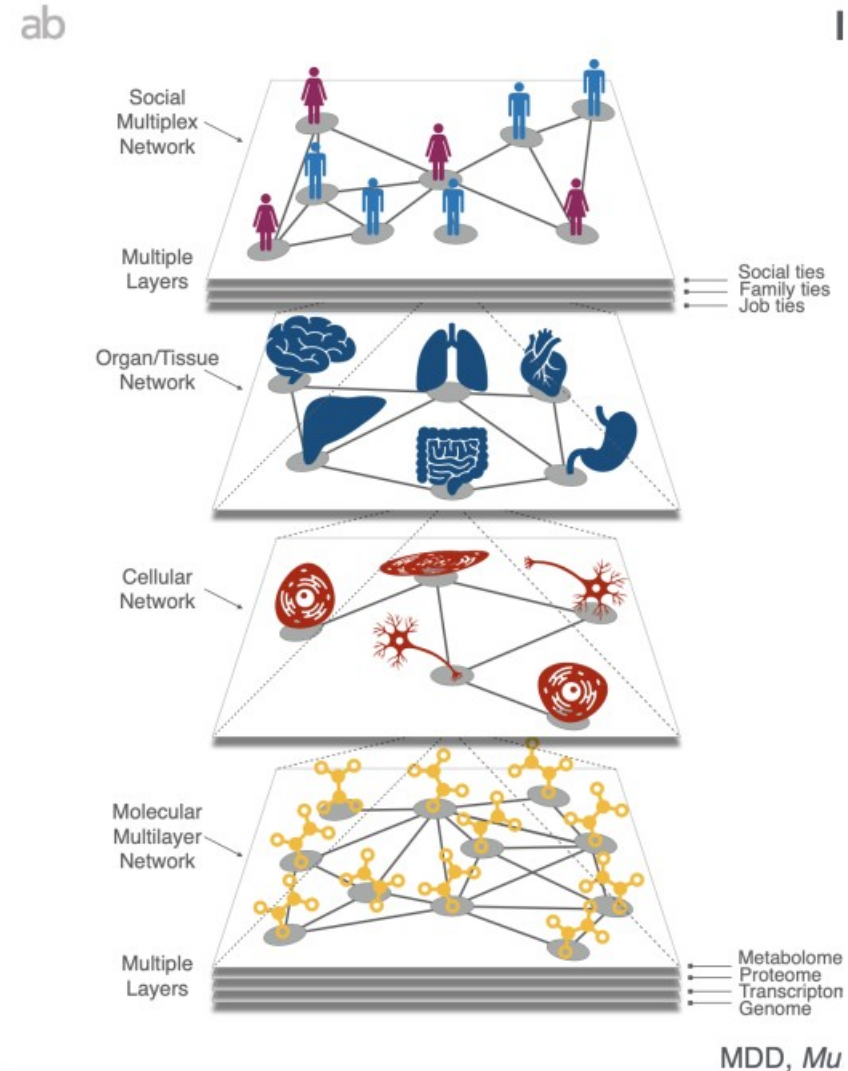
- ▶ We are currently working on several projects, which correspond to different Tasks:
 - Network and Systems Medicine (WP1)
 - Plethysimograph data analysis (WP3 Taks 11) [NEW 2023]
 - Anomalies detection in Holter analysis (WP3 Taks 11)
 - Identification of Myocardial fibrosis in MRI (WP3 Taks 6)
- ▶ Consolidated collaboration and involvement of the UNIPD Cardiology Department
 - and specifically, with dott. Alberto Cipriani and his collaborators

Network and Systems Medicine

Work Package 1

- ▶ Development of novel techniques based on the consolidated theoretical and computational framework known as Network Medicine
- ▶ The field aims to reconnect the microscopic scale (biomolecular interactions), with the macroscopic scale (the phenotype characterizing complex diseases)
 - by using the tools from network science and the methodologies typical of statistical physics

link to [Manlio's webpage](#)

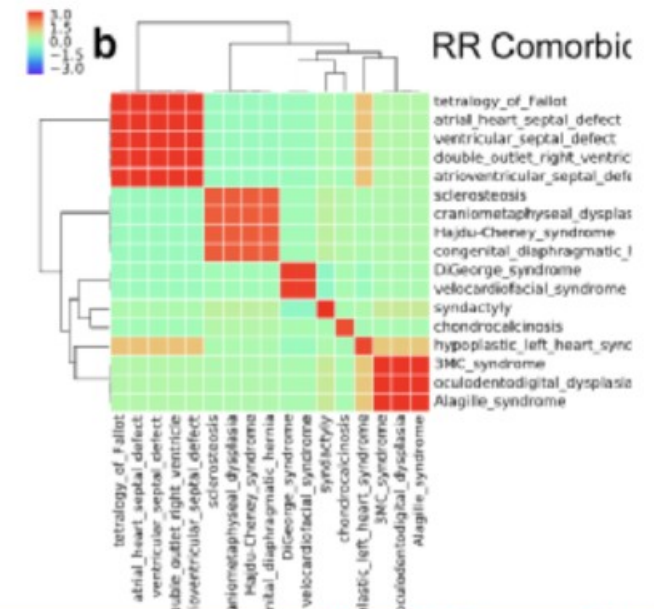
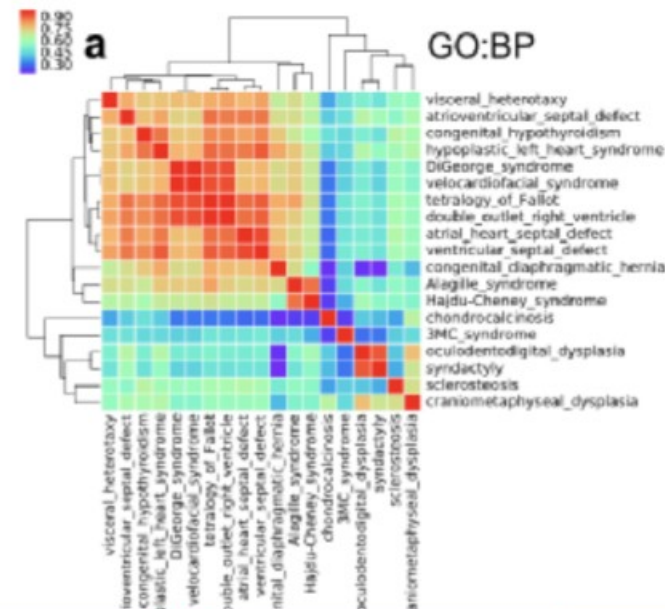
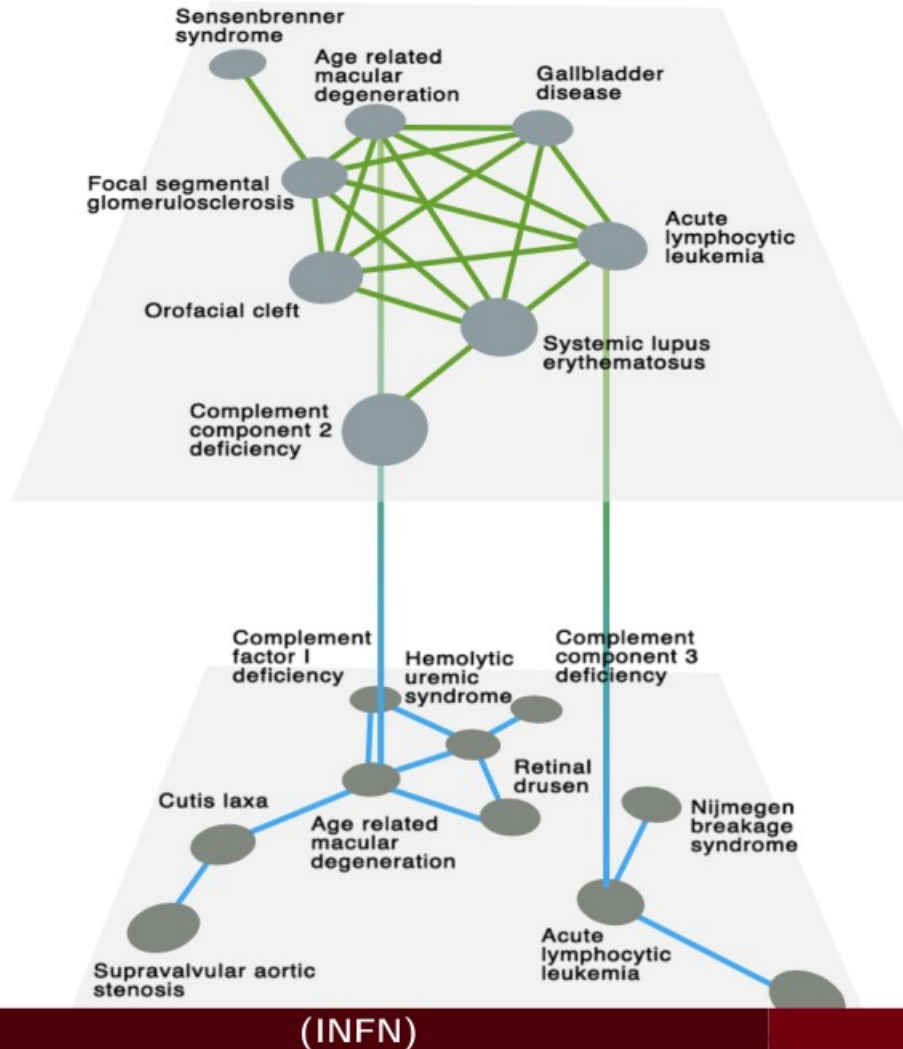


Network and Systems Medicine

Work Package 1

► Ultimate goals:

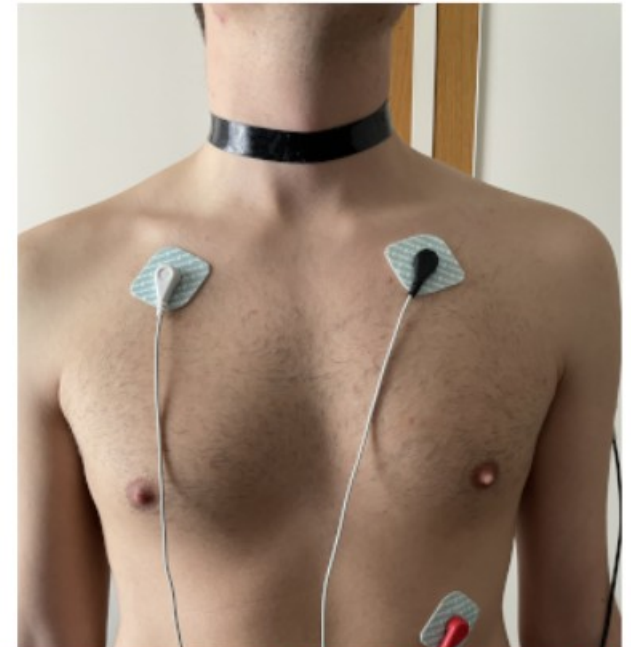
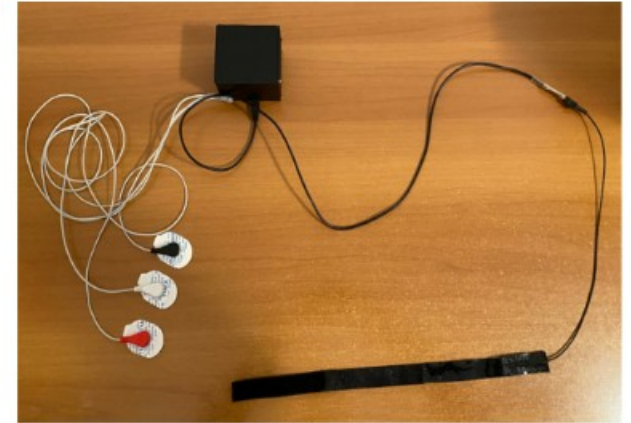
- gain novel insights about pathogenesis
- model interdependent systems across distinct biological scales
- drug repurposing
- identification of novel disease-disease associations



Plethysmography

Work Package 3, Task 11

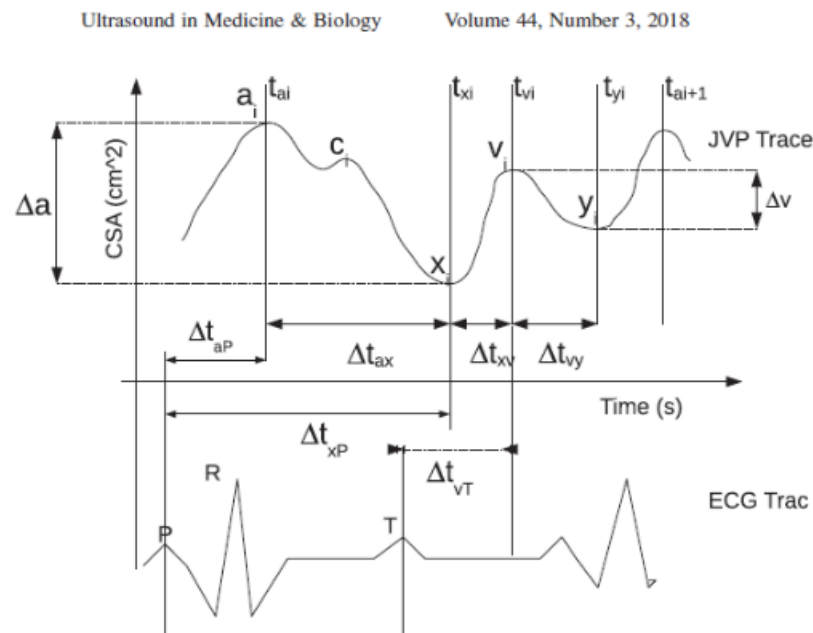
- ▶ New project, begun in January 2023 with a new collaboration with the Ferrara next_AIM group
- ▶ A Plethysmograph is a device that measures changes of volume in different parts of the body, such as to arms, legs or other extremities to determine circulatory capacity
- ▶ Long time expertise in the Ferrara group [1], [2], [3]
 - Gianfranco Paternò, Antonino Proto, Daniele Conti, Erica Menegatti, Angelo Taibi, Giacomo Gadda
- ▶ *Drain Brain project*: monitor the cerebral venous outflow of a crew member during an experiment on the International Space Station (ISS)
- ▶ *Wise project*: develop a portable, non-invasive, and non-operator dependent device to measure venous blood volume on Earth



Plethysmography

Work Package 3, Task 11

- ▶ Plethysmography is used to investigate the jugular venous pulse (JVP) as an indicator of the vein cross-sectional area
- ▶ The JVP is commonly extrapolated via the ultrasound technique, but it requires a qualified healthcare operator to perform the real-time examination
- ▶ Instead, the device can perform a continuous, non-invasive measurement of the JVP

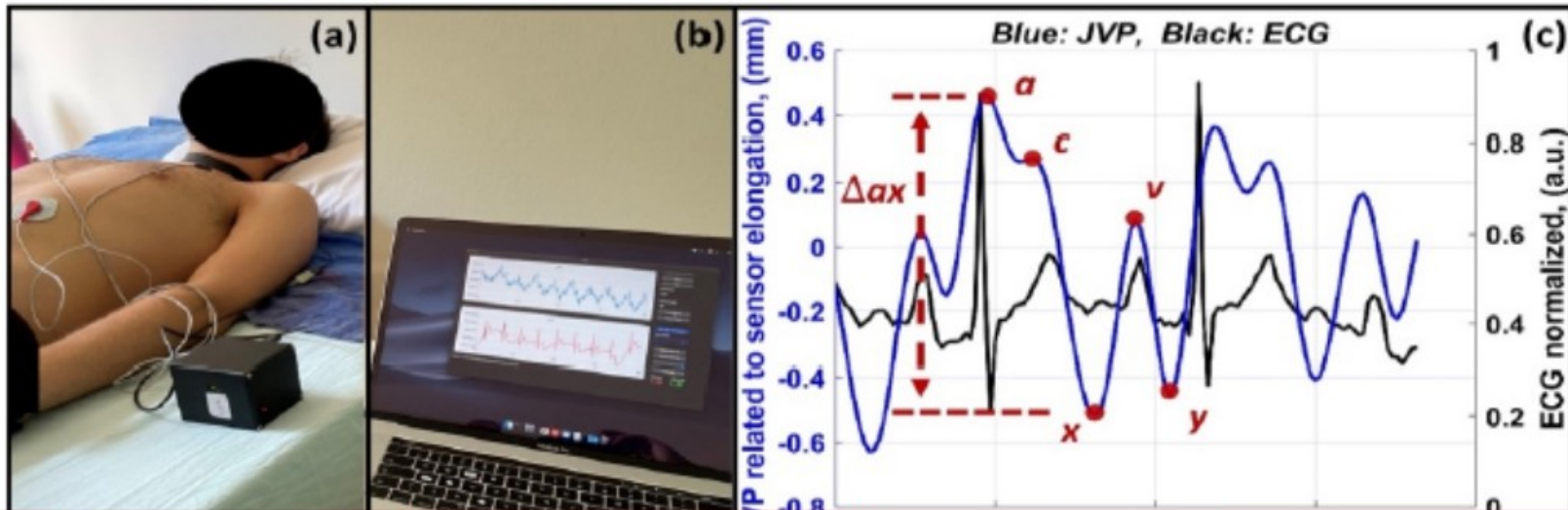


- ▶ The analysis of the signal aims to identify peaks a and x , which correspond to the atrial and ventricular contraction, respectively
- ▶ The pressure gradient between these two phases is correlated to Δax
- ▶ We also want to correlate Δax with the physical exercise of the patient: at rest (supine or sitting), or during walking or leg-pressing

Plethysmography data analysis

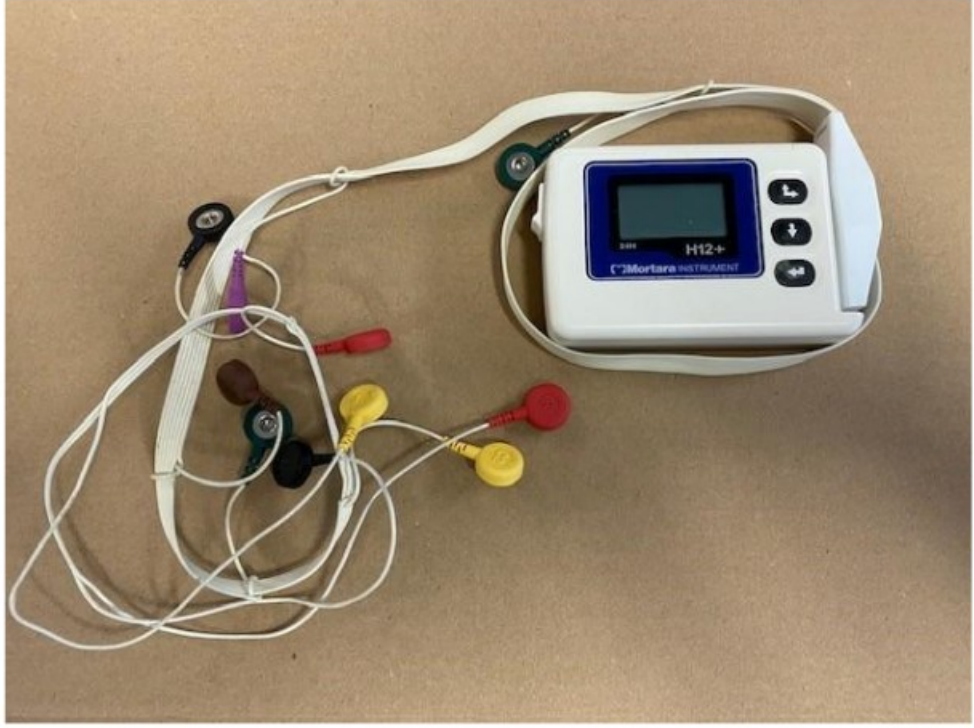
Work Package 3, Task 11

- ▶ Dataset consists of a 30-second plethysmography + ECG measurements for 20 patients
- ▶ Analysis consists in artifact removal + signal filtering + labeling of the relevant features
- ▶ We are working to apply ML techniques to automate the analysis to:
 - 1 correlation with the ECG signal
 - 2 determination of the features of the signal (a , x , but possibly also c , v and y)
 - 3 automatically locate and remove artifacts (large difference between prediction and signal) from neck muscles, external causes
 - 4 classification of the type of measurement (supine, sitting, moving)



Holter analysis

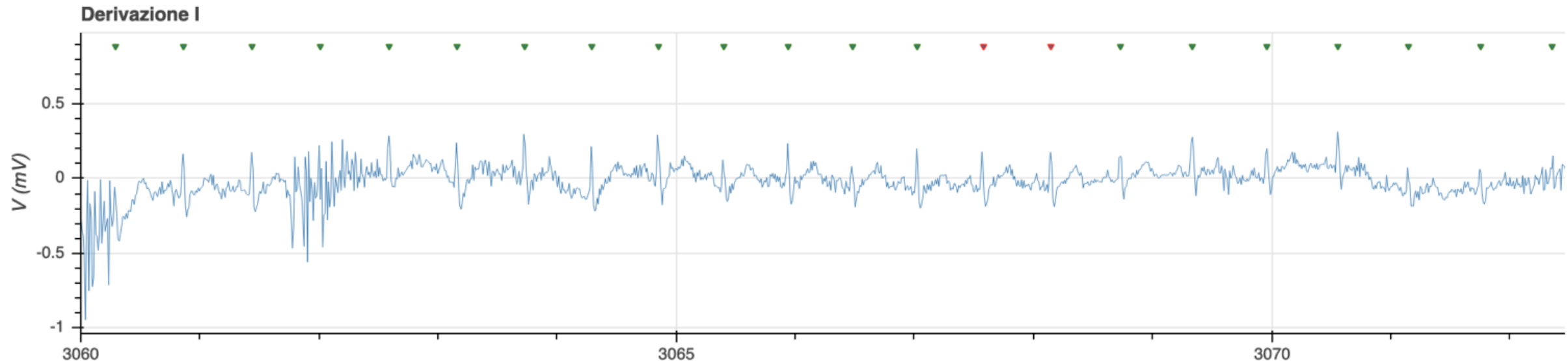
Work Package 3, Task 11

- ▶ Assist cardiologists scrutinize the large amount of data (24 hours of continuous recording)
 - ▶ Use ML to isolate potentially anomalous and dangerous heartbeats, discriminating against normal beats and artifacts due to noise and patient movements
- 
- ▶ The dataset available to the University of Padova consists of approximately 450 Holter ECGs (anonymized) collected in the past decade by the Cardiology Department
 - ▶ Data and metadata extraction, in progress, is complicated by poorly documented (if any) proprietary formats and softwares

Holter analysis

Work Package 3, Task 11

- ▶ Data extraction is possible thanks to an experimental (proprietary) software, but metadata (the cardiologist's annotations) are lost in the process
 - without annotations, supervised learning training is impossible
- ▶ A workaround we are working on is to train the network on open-access data, provided by the PhysioNet network and publicly accessible
- ▶ This is a segmentation (separation of individual heartbeats) and classification task
- ▶ First results are promising, work is in progress



Myocardial Fibrosis

Work Package 3, Task 6

- ▶ Myocardial Fibrosis can lead to Heart Failure
- ▶ ≈ 650 Cardiac Magnetic Resonance Images (MRI) from Padova Hospital (Dott. Cipriani)



(INFN)

Dataset

- ▶ After reading the raw image, train ML algorithm to:
 - 1 identify the presence of fibrosis (binary label per subject)
 - 2 determine its position (segmentation)
- ▶ 3 different methods tested:
 - 1 2.5D Convolutional Neural Network
 - 2 Principal Component Analysis + Support Vector Machine
 - 3 Principal Component Analysis + Multiple Kernel Learning
- ▶ Computational Resources: 2xV100 GPUs from HPC-Physics in CloudVeneto

Myocardial Fibrosis

Work Package 3, Task 6

2.5D CNN

		True LGE		Predicted LGE	
		YES	NO		
True LGE	YES	61%	39%	Predicted LGE	
	NO	45%	55%		
		YES	NO		

- ▶ MobileNetV2
- ▶ 58% Accuracy
- ▶ 58% Sensitivity

PCA + SVM

		True LGE		Predicted LGE	
		YES	NO		
True LGE	YES	77%	23%	Predicted LGE	
	NO	40%	60%		
		YES	NO		

- ▶ Gaussian Kernel
- ▶ 68% Accuracy
- ▶ 60% Sensitivity

PCA + MKL

		True LGE		Predicted LGE	
		YES	NO		
	YES	70%	30%		
	NO	28%	72%		
		YES	NO		

- ▶ Multiple Gaussian Kernels
- ▶ 71% Accuracy
- ▶ 72% Sensitivity

Presented during EACVI/SCMR Joint Summit on AI in CMR (London, May 2022)

Summary

- ▶ 4 people involved in next_AIM, total **1.75 FTE**
- ▶ We are already actively working on the following topics:
 - Network and Systems Medicine (WP1)
 - Plethysimograph data analysis (WP3 Taks 11) [**NEW 2023**]
 - Anomalies detection in Holter analysis (WP3 Taks 11)
 - Identification of Myocardial fibrosis in MRI (WP3 Taks 6)

Requests for the Padova group

	richieste (kEuro)
missioni	2.0
consumo	1.5

- ▶ Missioni: 0.5 kE for collaboration with Ferrara group (WP3 T11) - 1.5 kE to attend the wrap-up workshop “AI in medicine: the right to explanation”

Computer science

ML_INFN in breve

Lowering The potential barriers with ML_INFN

Employing machine learning techniques often requires:

- specialized hardware and software setup
WP1: provide a centrally maintained cloud-based infrastructure for interactive and batch ML fast prototyping, with access to modern GPU hardware and systems tuned for ML performance



- specific training to identify tools and learning resources

*WP2: organize national training events for INFN users
(Machine Learning hackathons)*



- a community of experts providing support to research use cases

WP3: provide and organize example applications in a knowledge base



ML_INFN in numeri

- **11** strutture INFN coinvolte nella preparazione della knowledge base
BA BO CNAF FI GE NA PD PG PI ROMA1 TO
- **79** ricercatori che dedicano una frazione del loro tempo per promuovere le tecniche ML per la ricerca
- **14** GPU professionali a disposizione accessibili attraverso l'interfaccia di INFN-Cloud
- **110** partecipanti agli hackathon, tra studenti e ricercatori di ruolo

Obbiettivi del nuovo progetto AI_INFN

- Raccogliere l'eredità di ML_INFN in termini di comunità, hardware e software...
- ... per costruire un modello di calcolo in grado di soddisfare maggiore domanda e scalare agevolmente in vista di una più ampia disponibilità ed eterogeneità di risorse —> vedi ad es. **Progetto PNRR Terabit**
- Potenziare il supporto ai molti eventi di livello base organizzati dall'INFN e dalle Università, concentrando la propria azione sullo sviluppo di materiale audiovisivo (webinar) ed eventi di aggiornamento di tipo **Advanced Hackaton**
- Formare un nuovo WP dedicato allo studio di futuri acceleratori per le attività di ML, in particolare **FPGA** e **processori quantistici**

Progetti PNRR: principali aree di intervento



Progetto ICSC → Risorse IT + infrastrutture

CPU “standard” per HTC

Storage sia a blocchi con controller che a brick per CEPH

Nuova libreria + Nastri al T1



DARE → Risorse IT per zone ISO Certified

slides from D. Cesini



Terabit → risorse tipo HPC, CPU+Acceleratori+Storage, → “HPC Bubbles”



Evoluzione infrastruttura di base

Spazi

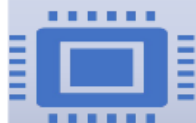
Elettricità

Raffreddamento

Grazie a questo sosteniamo i datacenter per i prossimi 10 anni senza gravare sul FOE

Terabit – HPC Bubbles

Gara bandita – scade il
03/08/2023



Nodo CPU

Min 112 core fisici (max 192)
RAM > 8GB/core DDR5
IB NDR 400G
20TBL + dischi di sistema



Nodo GPU

Come CPU + 4x NVIDIA H100 SXM5 con minimo 80GB e memoria HBM2e



Nodo FPGA

Min 32core
RAM > 512GB DDR4 o DDR5
IB NDR 440G
4 x XILINX U55C o 4 x TerasicP0701



Nodo Storage (CEPH Bricks)

Min 48core fisici
RAM > 512GB DDR4 o DDR5
Almeno 360 TBL HDD + 12TBL SSD



Accessori

Switch IB, Switch ETH
Cavi IB, Cavi ETH
Transceiver vari
Assistenza 3+2

Quantità stimate –
non definitive

L'intera
infrastruttura INFN
per l'HPC fornirà
~ 5 - 10 PFlops
(FP64)



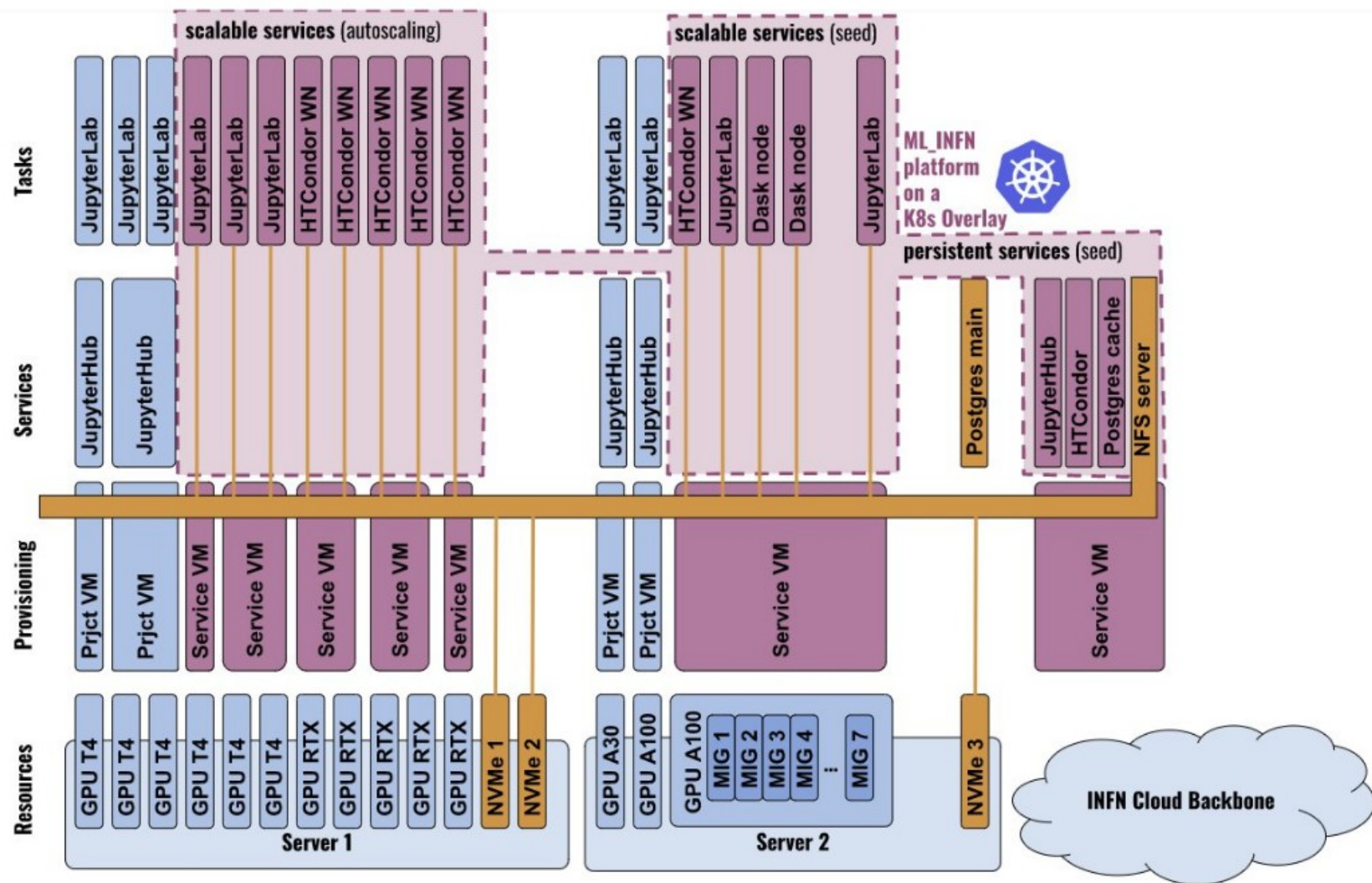
Sito	Nodi CPU	Nodi GPU	Nodi FPGA	Storage (PBN EC)
CNAF	16	14	2	4
CNAF-ISO27001	8	8	0	2
BA	7	3	0	3
MI-BI	0	0	4	0
PI	8	0	0	0
TO	6	4	0	0
LNGS	0	4	0	0
NA	8	0	2	0
RM1	8	0	0	0
PD/LNL	6	6	0	0
TOTAL	60	35	6	9

In particolare per WP1: Infrastruttura

- Necessita` di superare i limiti del modello basato sull'assegnazione di VM connesse a GPU in modo esclusivo a determinati progetti
- Un nuovo modello basato sui container e` allo studio per:
 - ✓ abilitare il “resizing” delle risorse assegnate ad un progetto
 - ✓ riassegnare GPU altrimenti inutilizzate per lunghi periodi
 - ✓ abilitare un tuning piu` dinamico del n. di CPU core per GPU
 - ✓ abilitare l'uso opportunistico di risorse da parte di code batch
 - ✓ implementare soluzioni di autoscaling (dispiegamento automatico di VM)
 - ✓ ridurre il numero di utenti forzati ad amministrare la propria VM

Scalable and replicable Kubernetes platform for ML_INFN

Nel corso dei tre anni di progetto, faremo evolvere il **dimostratore** aggiungendo le funzionalita' discusse, fino a convergere verso un prototipo agevolmente integrabile come servizio gestito offerto da **DataCloud** per il calcolo scientifico, anche contando sulla stretta collaborazione con il “**WP6: Ricerca e Sviluppo, Testbeds, Usecases**” di DataCloud.



Milestones proposte per AI_INFN

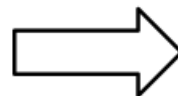
Milestone	
M1.1	<i>Kubernetes overlay scalabile su più VMs in beta test</i>
M1.2	<i>Monitoring e accounting implementati e documentati</i>
M1.3	<i>Batch System per uso opportunistico in beta test</i>
M1.4	<i>Prototipo integrabile tra i servizi gestiti di DataCloud</i>
M2.1	<i>Advanced Hackathon Workshop di apertura</i>
M2.2	<i>Corso e-learning disponibile su moodle</i>
M2.3	<i>Advanced Hackathon Workshop intermedio</i>
M2.4	<i>Advanced Hackathon Workshop di chiusura</i>
M3.1	<i>Organizzazione di 30 seminari tematici</i>
M3.2	<i>Soluzione tecnologica per User Self-Support identificata</i>
M3.3	<i>Piattaforma User-Self Support configurata e operativa</i>
M3.4	<i>Report consuntivo sul modello di provisioning</i>
M4.1	<i>Report sull'utilizzo di FPGA in Cloud come acceleratori rilasciato</i>
M4.2	<i>Simulatori di Quantum Computing interfacciati alla piattaforma</i>
M4.3	<i>Pipeline di compression modelli di Deep Learning per FPGA sviluppate e documentate</i>
M4.4	<i>Algoritmi RL per la simulazione rumore e il transpiling di circuiti quantistici, sviluppati e documentati</i>
M4.5	<i>Report sull'offloading a Computer Quantistici dalla piattaforma</i>

WP4: Future accelerators: FPGAs and Quantum processors

- Dimostratore operativo di acceleratori FPGA fruiti tramite Cloud
- Sviluppo e documentazione nella Knowledge Base, di tecniche di compressione e ottimizzazione di modelli classici di Machine Learning e Deep Learning per utilizzo su acceleratori FPGA commerciali
- Esempio di Quantum Machine Learning documentato nella Knowledge Base
- Dimostratore operativo di interfaccia tra INFN Cloud e le risorse di quantum computing da fornitori esterni (per esempio IBM, o risorse ICSC)

- Interesse a Padova da parte del gruppo di S. Montangero (**Quantum Computing and Simulation Center**):

- ✓ S. Montangero 5%
- ✓ A. Pagano 10%
- ✓ M. Ballarin 10%
- ✓ N. Reinic 10%
- ✓ L. Zangrando 20%



- emulazione di circuiti quantistici per sviluppare e testare algoritmi di quantum ML con un elevato numero di qubit

e del gruppo di L. Sestini (**LHCb**):

- ✓ A. Gianelle 5%
- ✓ L. Sestini 5% (sinergico con LHCb)

- Inferenza/training su hardware quantistico
- Quantum GAN for fast simulation of LHCb detector

Sommario personale PD e piano finanziario

Andreetto	10%
Fanzago	5%
Sgaravatto	10%
Traldi	10%
Verlato	20%
Zangrando	20%
Dorigo	0%
Gianelle	5%
Sestini	5%
Montangero	5%
Pagano	10%
Ballarin	10%
Reinic	10%
Totale FTE	1.20

- Manutenzione e aggiornamento hardware PC farm: **120 k€** (40 k€/anno) al CNAF
 - ✓ nuovo server, comprensivo del disco veloce NVMe + 2 FPGA di modello Xilinx Alveo V70 nel primo anno
 - ✓ da definire negli anni successivi, sulla base dell'evoluzione dell'offerta e delle interazioni con il progetto Terabit. Stima basata sul costo di server e 2 GPU di modello nVidia A100
- Missioni per finanziamento hackathon: **51 k€** (17 k€/anno), di cui:
 - ✓ **1 k€ / anno per ciascuna Struttura partecipante**
 - ✓ 4 k€ / anno da redistribuire tra le Strutture per contingenza

Conclusioni

Sigle in chiusura

- MOPEA [acceleratori]
 - già chiusa , su dotazioni
- FALAPHEL [elettronica]
 - S. Mattiazzo, call, Resp Naz. Pisa, in conclusione, prolungamento?]
- N3G [rivelatori]
 - F. Recchia, call , resp. Naz. LNL, in chiusura -> prolungamento]
- ML_INFN [software]
 - M. Verlato, in chiusura -> nuova]
- REMIX [interdisciplinare -medica]
 - L. Canton, in chiusura, continua con CUPRUM-TTD']

Nuove proposte

- ASIX [rivelatori]
 - P. Giubilato – Resp Naz Pisa
- AI_INFN [software]
 - M. Verlato – Resp Naz Firenze

Sigle in continuazione

- ADA_5D [rivelatori]
 - G. Collazuol (Resp Nazionale Pisa)
- PHYDES [rivelatori]
 - Resp. Naz. G. Carugno
- FEROCCE [rivelatori – software]
 - A. Triossi Resp. Naz
- NEXT_AIM [interdisciplinare - software]
 - A. Zucchetta (Resp Nazionlale Pisa)
- ADMIRAL [interdisciplinare – medica]
 - M. Lunardon (Resp Nazionale LNL)
- CUPRUM_TTD [interdisciplinare – medica]
 - L. De Nardo (Resp Nazionale LNL)
- HISOL [interdisciplinare – medica]
 - A. Pepato (Resp Nazionale LNL)

Riassunto delle richieste ai servizi

Sigla	Prog. Meccanica	Off. Meccanica	Prog. Elettronica [Bellato]	Serv. Tecnici ed Elettronica [Nicoletto]
FALAPHEL	-	-	-	2 sett. p.
N3G	-	0.5 m.p.	-	-
ML_INFN	-	-	-	-
ADA_5D	setup telescopio ~ 1m.p.	meccanica telescopio ~ 1m.p.	programmazione FPGA TimePix4 ~ 3 m.p.	progettazione scheda Amplificatore RF 3 m.p.
FEROCE	-	-	-	-
PHYDES	1 m.p.	10 m.p.	2 m.p.	8 m.p. [TBC]
NEXT_AIM	-	-	-	-
ADMIRAL	-	-	-	1 m.p. chip bonding e altre operazioni di assemblaggio
CUPRUM_TTD	-	-	-	-
HISOL	1 m.p. supporto progetti disegnatori	0.5 m.p. lavorazioni meccaniche catodo ed anodo		
Tot	1 m.p.	10.5 m.p.	5 m.p.	

- Link alla [tabella riassuntiva](#) delle percentuali previste per il 2024

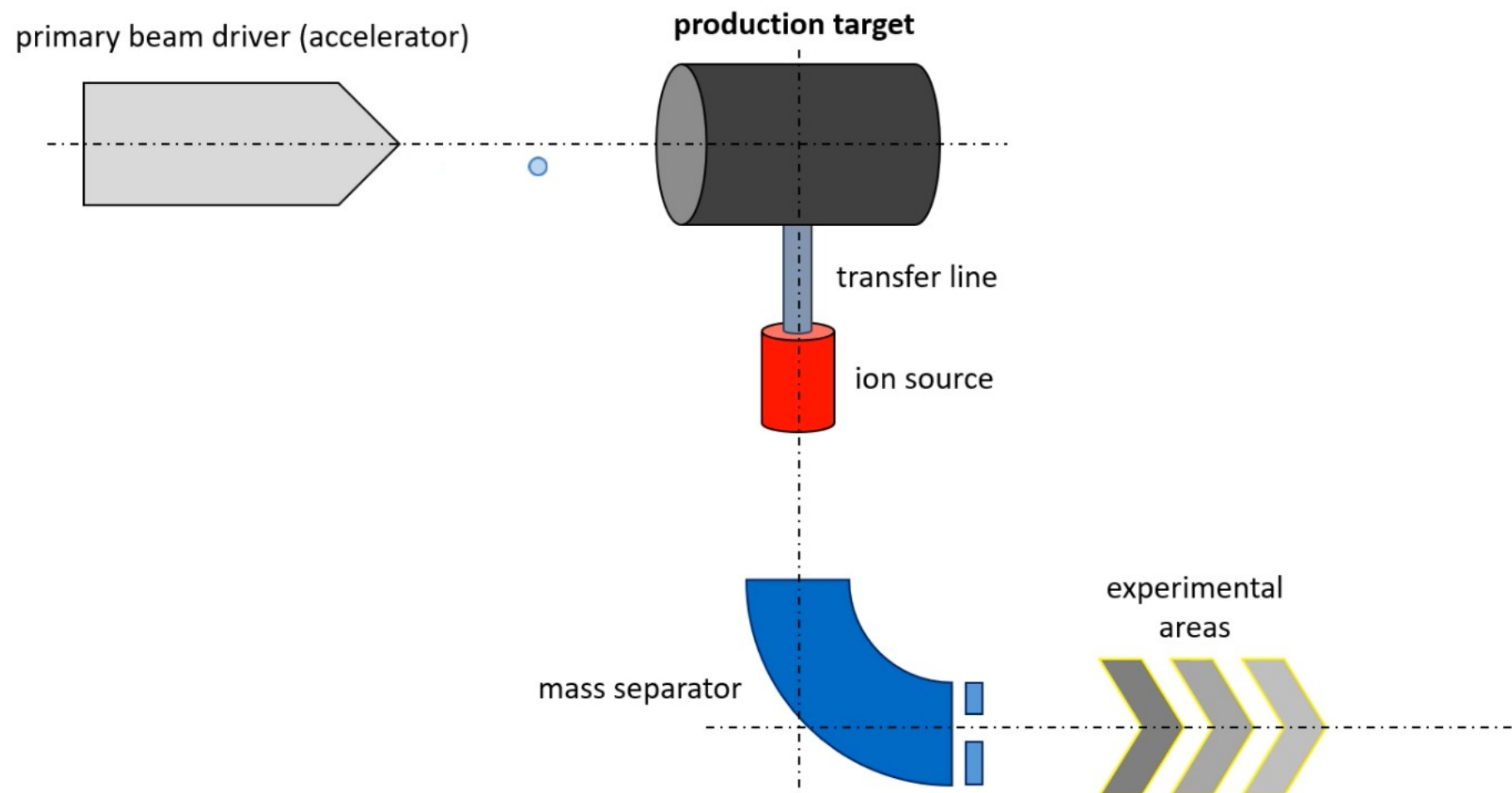
- I grant giovani della CSN5 sono un'opportunità molto attraente per giovani ricercatori
 - ~ Possibilità di essere assunti con un assegno di ricerca
 - ~ Possibilità di fare esperienza diretta di gestione di un finanziamento
 - ~ Permettono di sviluppare idee nuove che sono potenziali volani di ulteriori sviluppi

Esorto chi e' nelle condizioni di applicare di provarci

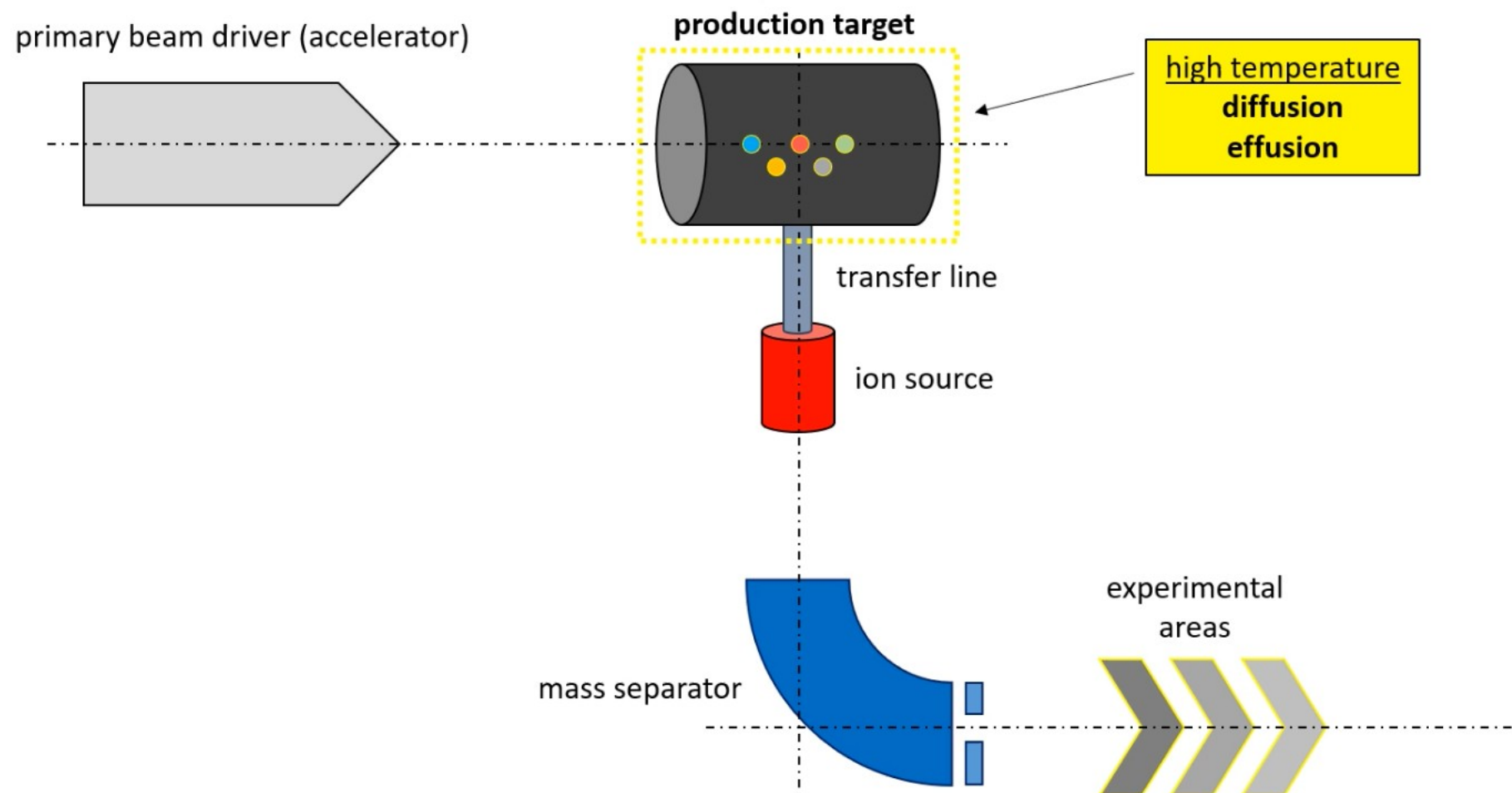
- Ci sono alcune attività che trattano argomenti simili (per esempio studio dei radionuclidi) che potrebbero beneficiare di una collaborazione sinergica

BACKUP

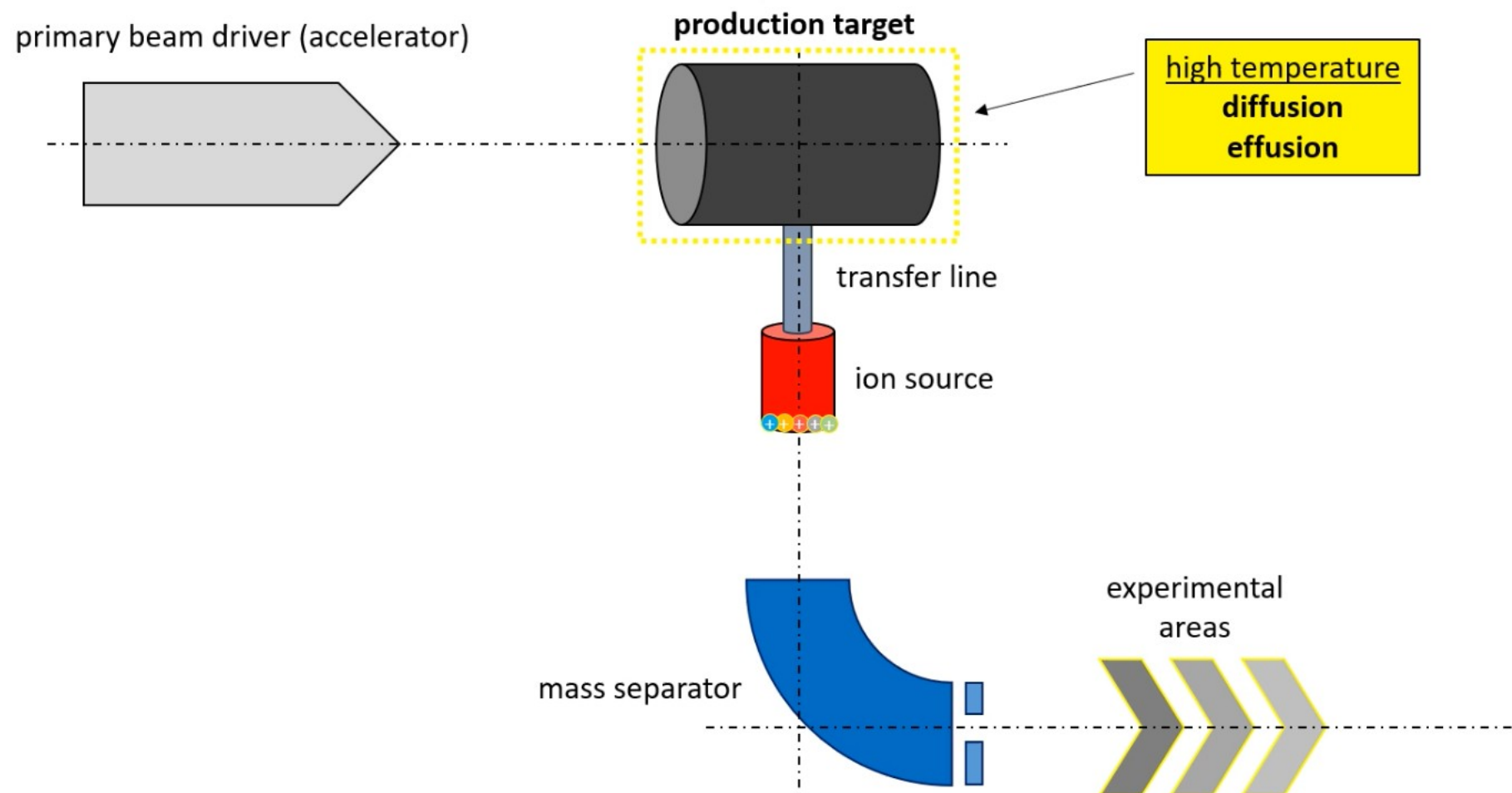
2- Mass Separation Techniques: ISOL (Isotope Separation On Line)



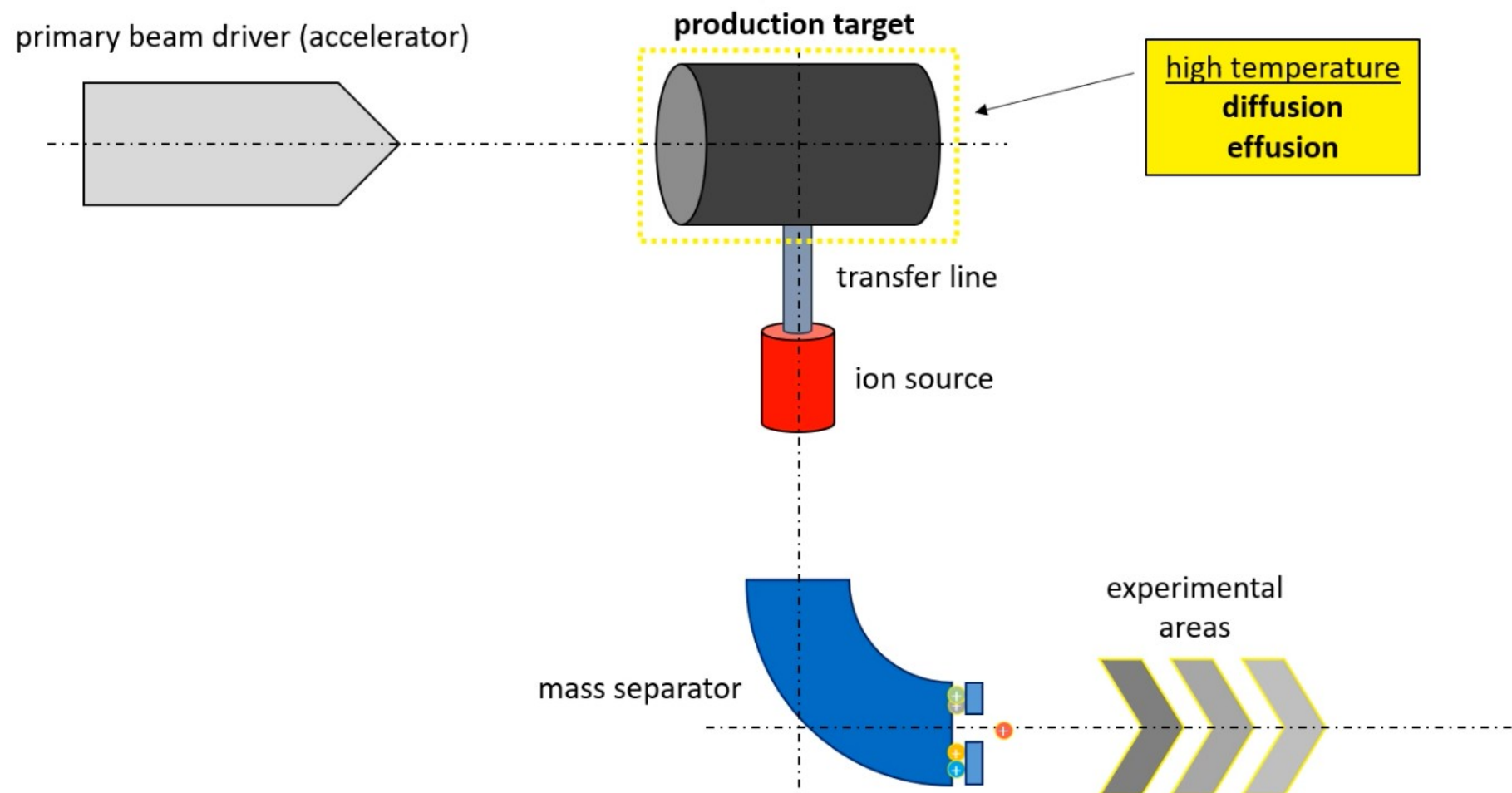
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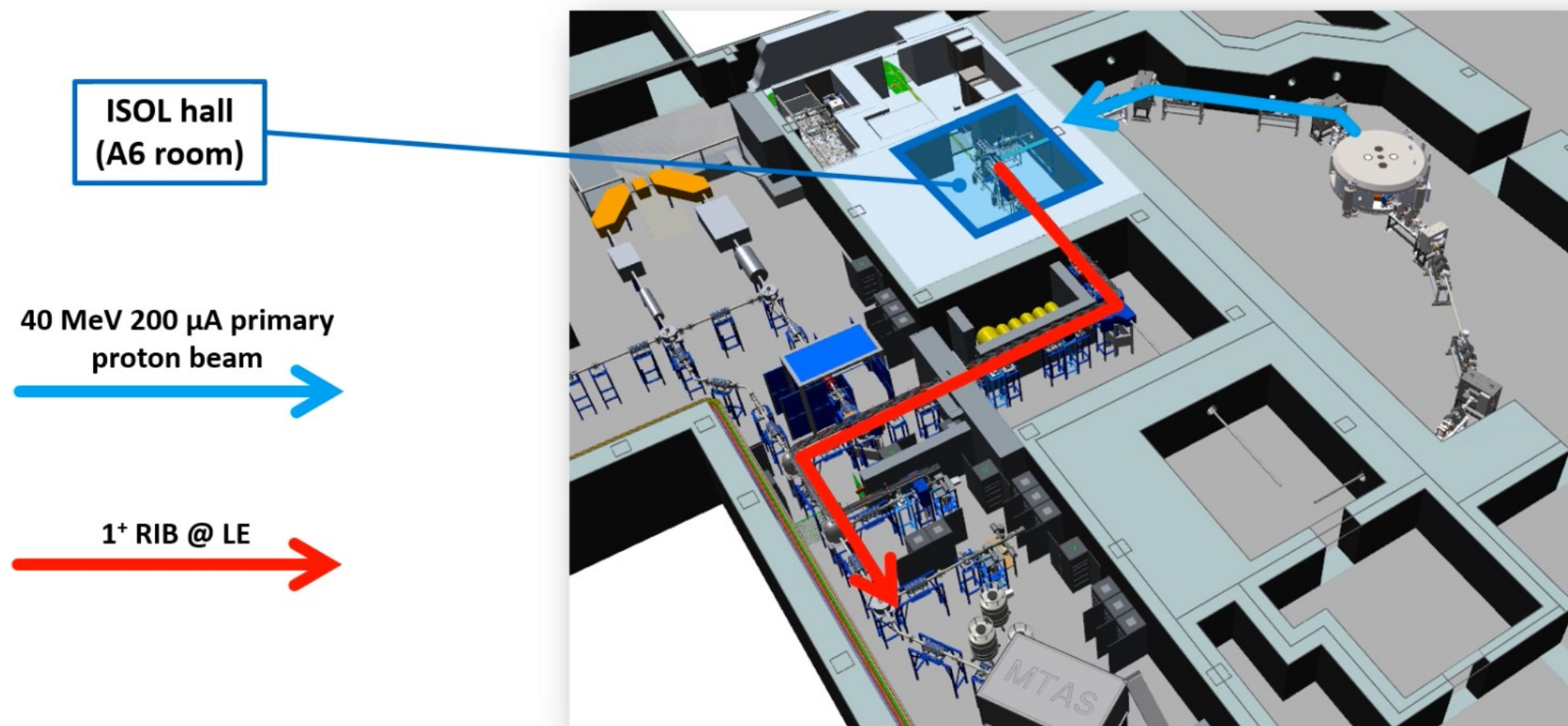
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2- Mass Separation Techniques: ISOL (Isotope Separation On Line)



3- Implementation of the ISOL Technique @ LNL: the SPES Facility

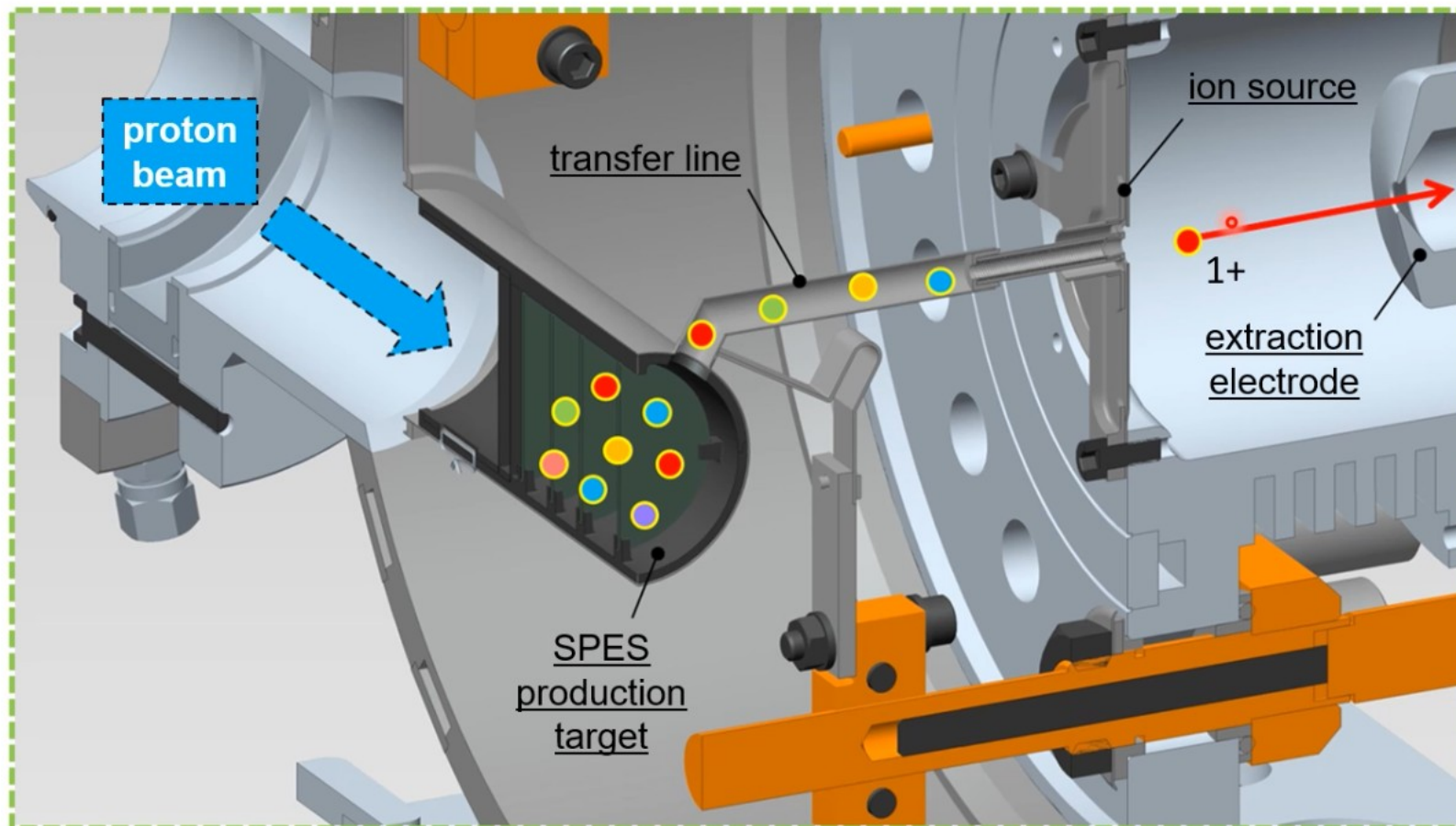
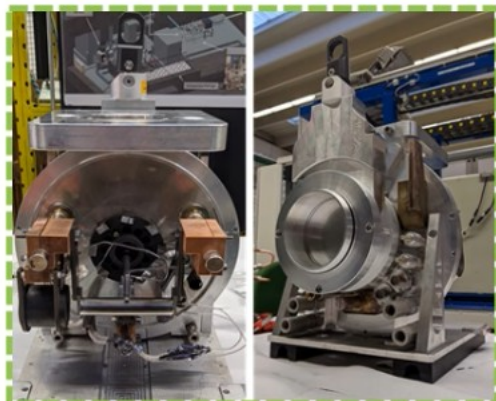


3- Implementation of the ISOL Technique @ LNL: the SPES Facility

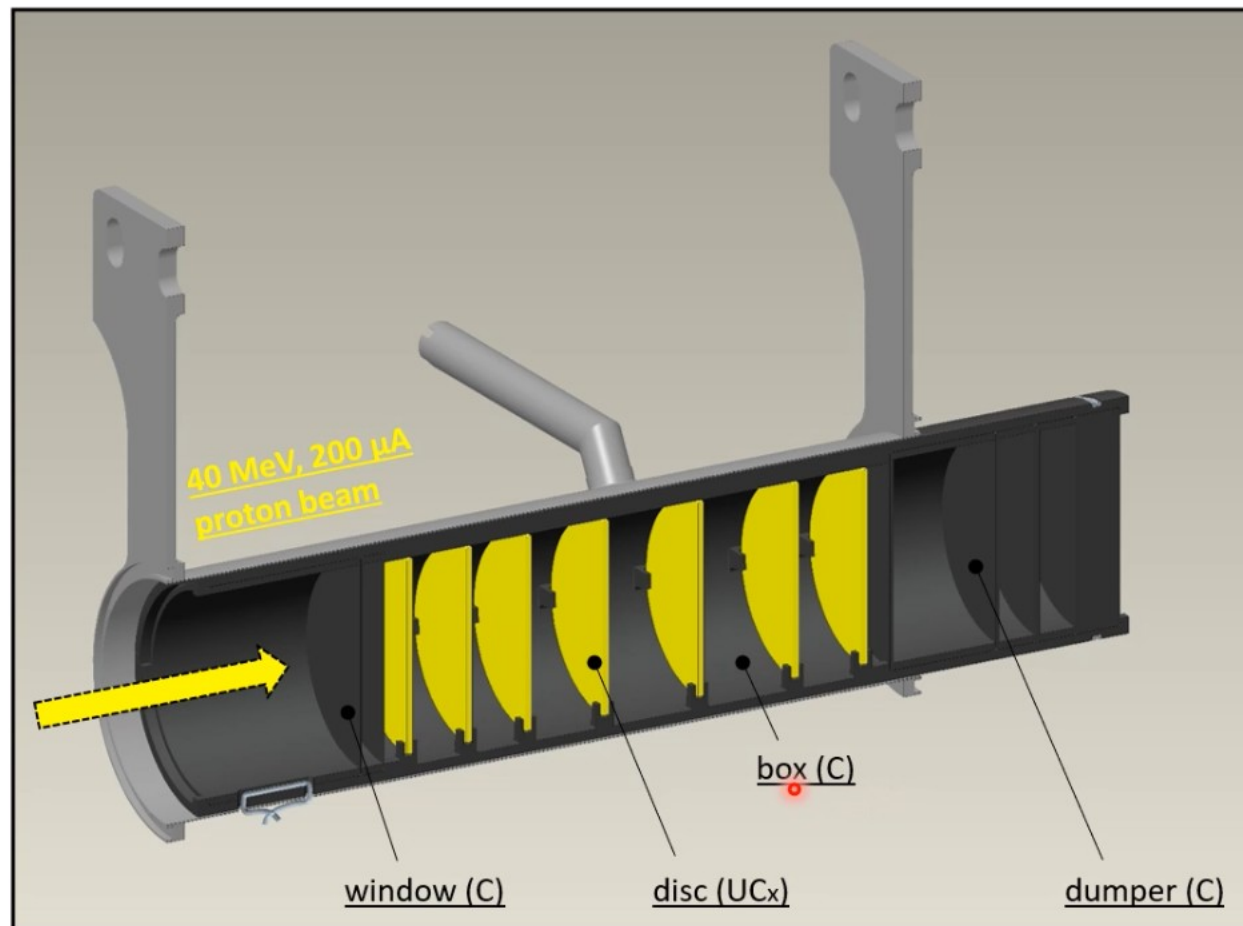
TIS unit:

the Vacuum Chamber containing:

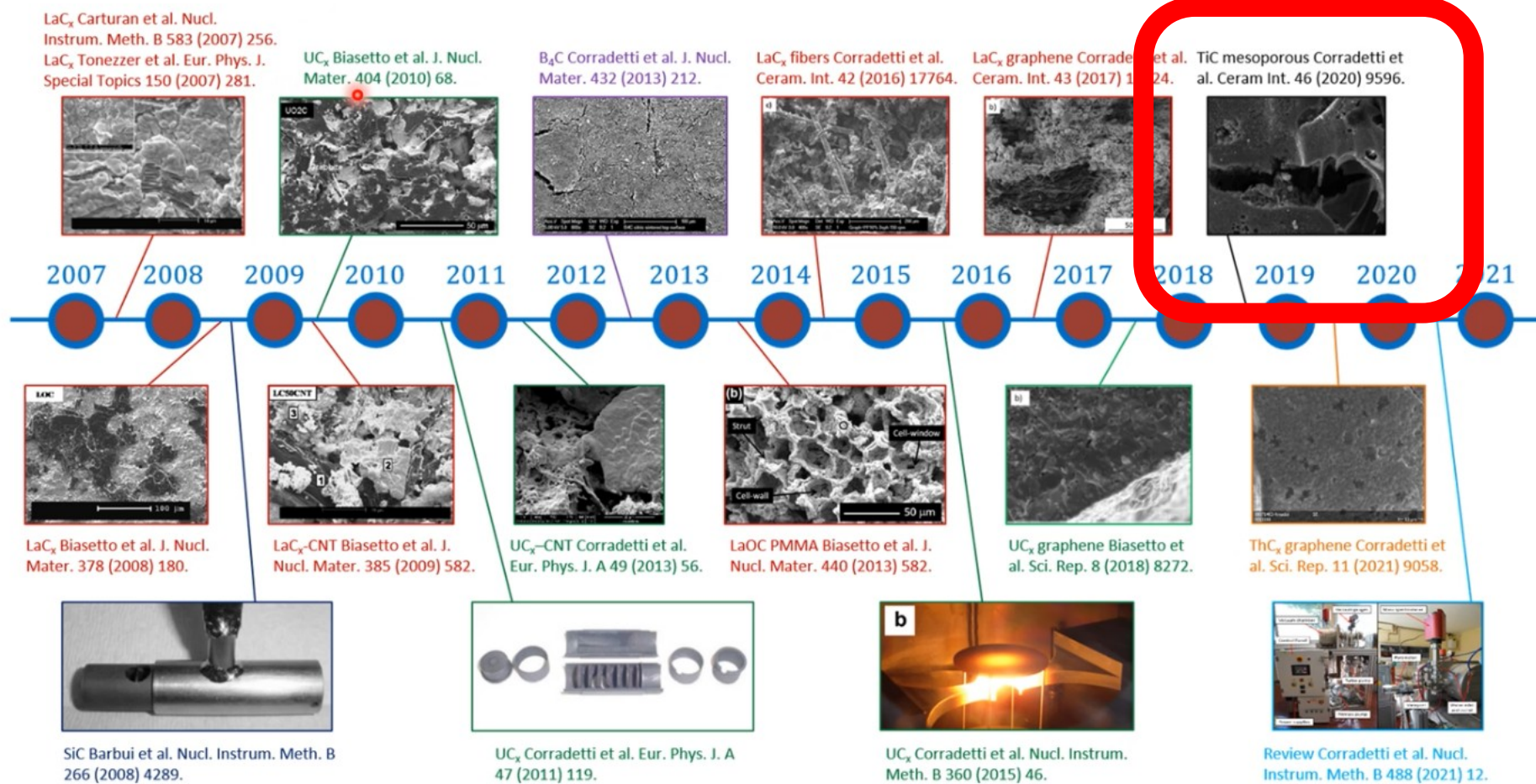
- Target
- Ion Source



4- Targets



4- Targets



5- Ion Sources

																		surface ionization mechanism																			
																		laser ionization mechanism																			
																		electron impact ionization mechanism																			
																		not extracted																			
																		</																			

