CSD Preventivi - Gruppo 5

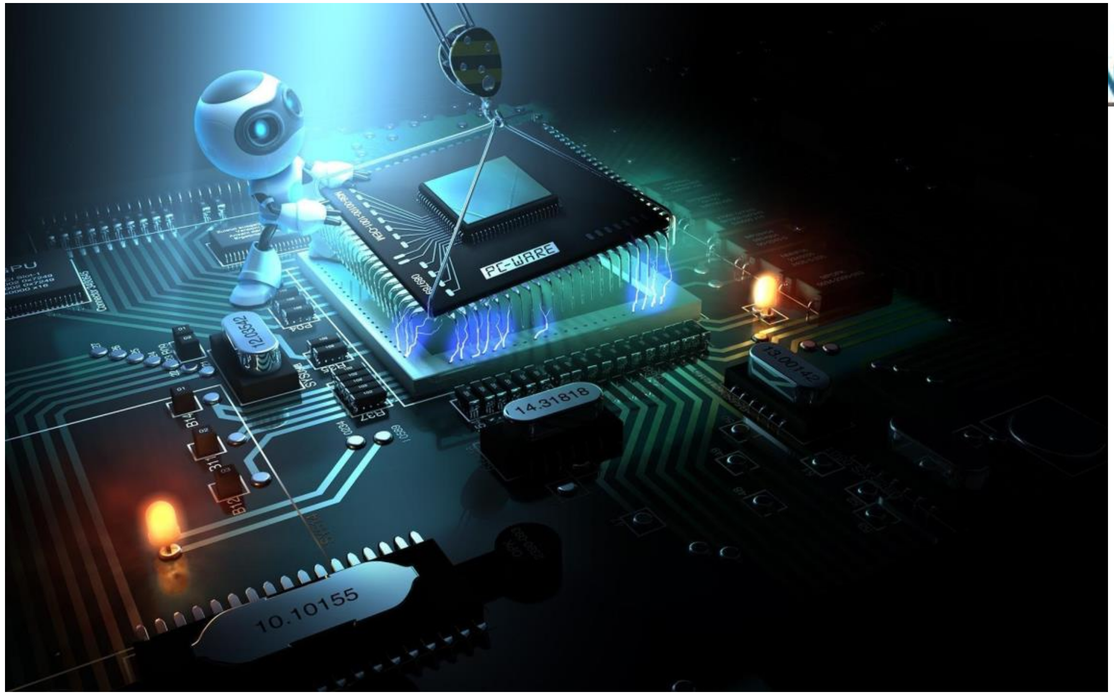
Gabriele Simi – Università di Padova e INFN

02.07.2025

Introduzione: la Commissione e le tipologie di esperimenti

La Commissione 5

- 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
  - Applicazioni mediche
  - Energetica
  - Ambiente
  - Beni culturali

Tipologie di esperimenti

- Sigle Standard: progetti di 2-3 anni a budget medio-basso (∼ 50k€/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 75k€/y) di 2 anni per giovani (PhD ≤ 6y). Viene finanziata l’attività sperimentale e il contratto di ricerca 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 (∼1M€ max su 3y da bando).
  - Supporto alla formazione di network ampi per progetti di frontiera su argomenti strategici.
  - Finanziamento di ~~Assegni di Ricerca~~ incarico post-doc (da definire)
  - Bando a Maggio, valutazione a luglio + settembre

Modalità di presentazione nuove sigle standard/grant giovani

- Nuove sigle
  - Modalità di presentazione progetto per nuova sigla
    - Template progetto disponibile su sito CSN5
    - presentazione progetto entro 5/7 tramite caricamento in database
  - Revisione criteri di valutazione proposte di nuova sigla (dal 2023)
    - Impatto scientifico e sugli interessi dell'Ente
    - Chiarezza degli obiettivi e delle metodologie
    - Congruità economica e delle risorse
  - Primo referaggio/selezione a luglio
  - Referaggio finale a settembre
- Grant Giovani
  - Bando a fine giugno/inizio luglio, valutazione a settembre

Scadenze

- Chiusura del DB per gruppo V per inserimento preventive e progetti nuove sigle
  - 5 luglio
- Bando Grant Giovani
  - Bando a fine giugno, inizio luglio, scadenza dopo un mese
- Riunione CSN5
  - 15-18 luglio @ Frascati
  - Prima discussione dei nuovi proposal

Temi emersi dalle riunioni di commissione 5 di rilievo per la sezione

Regole transitorie per i grant giovani

- Il grant giovani prevede il **contratto di ricerca**, unica posizione attualmente disponibile
- Le regole interne dell’INFN prevedono che **non si possa applicare** per una posizione “**inferiore**” come una borsa post-doc.
- Per non penalizzare i vincitori di grant giovani quest’ultimo **potrà** in seguito avere anche **borse post-doc**, quando saranno istituite.
- **Non** possono applicare al bando Grant Giovani chi ha avuto un contratto TD, un articolo 36 o un RTT/RTDA/RTDB.

Novità sui Consuntivi

- Importante compilare il database per permettere il referaggio entro maggio
  - Compilare I report nel db
- Alla riunione di maggio
  - Presentazione dei consuntivi finali secondo un template che verte sulla presentazione dei **risultati ottenuti** e le **eventuali prospettive**
  - **Novit**à: valutazione ex-post con effetti su finanziamenti futuri

Prolungamenti

- Definita anche per I prolungamenti una sequenza di richieste da seguire [di seguito per referenza]
  - Entro 5 luglio
    - Discussione richiesta di prolungamento con i referees.
    - Riapertura sigla locale
    - Compilazione moduli del db: richieste economiche, report attività pregressa
  - Entro la riunione di luglio
    - E-mail @ presidente e referees per notificare la richiesta
  - Alla riunione di luglio
    - I coordinatori a luglio oltre alle sigle nuove devono presentare ANCHE le richieste di prolungamento.
  - Prima della riunione di settembre
    - Organizzare riunione con refree entro Settembre
  - Alla riunione di settembre
    - Referaggio prolungamenti

Novità sui fondi di missione

- Fondi di missione per conferenze vanno richiesti come in passato tramite richiesta straordinaria nelle riunioni durante l’anno
- **Novità**: nella riunione del 19-21 maggio la Commissione 5 ha stabilito che, durante la prima settimana di settembre, le disponibilità sulla voce economica "Rimborso per viaggio e trasloco" (missioni) dei bilanci delle sigle CSN5 dovranno essere stornate verso la stessa voce delle Dotazioni locali di CSN5 al netto delle esigenze di chiusura delle missioni in corso. Si potranno lasciare 0.5kE per eventuali conguagli.
  - Questa operazione è finalizzata alla **riduzione degli avanzi** di gestione e quindi **all'ottimizzazione delle risorse** finanziarie del bilancio 2025 della Commissione, anche in considerazione dell'avanzo di gestione risultante nel 2024.
- Tutti gli storni relativi alla voce "Rimborso per viaggio e trasloco" dalle sigle CSN5 verso le Dotazioni, inserite dalle amministrazioni locali in occasione della determina del 18 settembre, sono da considerarsi **autorizzati dalla Commissione 5**.
  - I successivi impegni di missione dovranno quindi essere effettuati sulle Dotazioni CSN5 locali.
  - La mail inviata il 27 maggio costituisce autorizzazione ufficiale alle operazioni di trasferimento.

Novità sui fondi di consumo/inventariabile

- Nel caso di **avanzi di spese per materiale** (inventariabile o consumo), i RN sono invitati a restituire per la riunione di settembre quello che non riusciranno a spendere entro l'anno.
- Sempre durante la riunione di settembre prenderemo in considerazione gli avanzi più vistosi e chiederemo garanzie sulla loro spendibilità entro l'anno.
- In mancanza di tali garanzie **ne trasferiremo una quota (stabilita caso per caso) sulle casse della commissione** da utilizzare per gli **anticipi** del 2026.

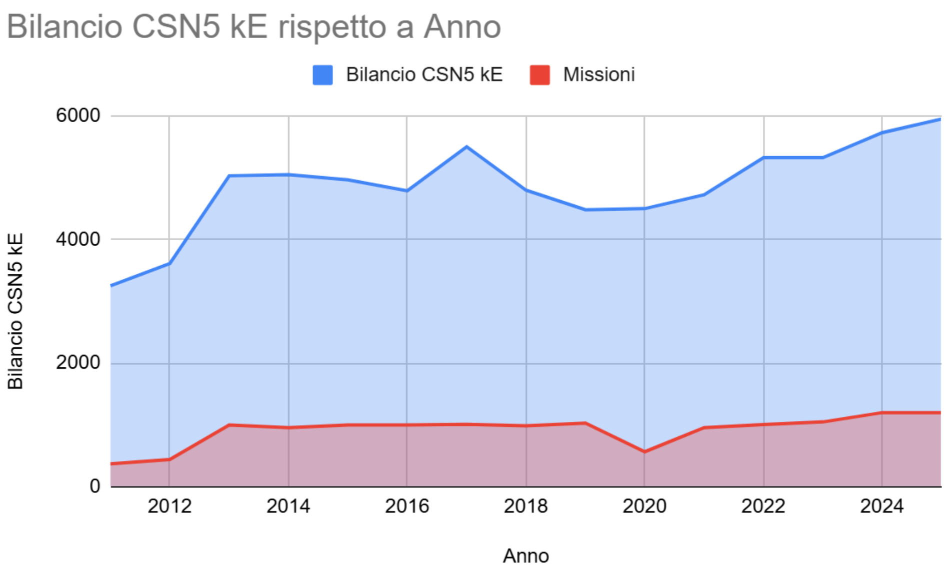
DRD

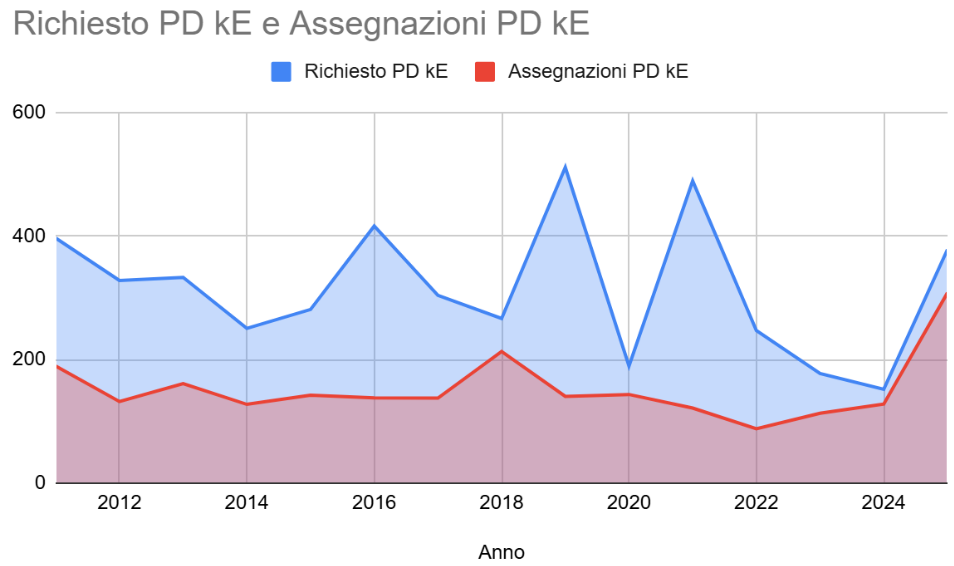
La CSN5 si distingue da CSN1-2-3 perche' le attività vengono valutate e finanziate indipendentemente dalla loro configurazione all'interno dei DRD,

- in base alla loro consistenza, innovatività e fattibilità con le regole in atto
- le proposte possono corrispondere - come gia' in passato - a task deliverables/milestones attualmente inclusi nei programmi DRD
- N.B. Dal bilancio della CSN5 non sono previsti allocazioni o supporti alle attività DRD in quanto tali.
- Non finanzia Common Funds @ CERN

Storico Fondi e anagrafica

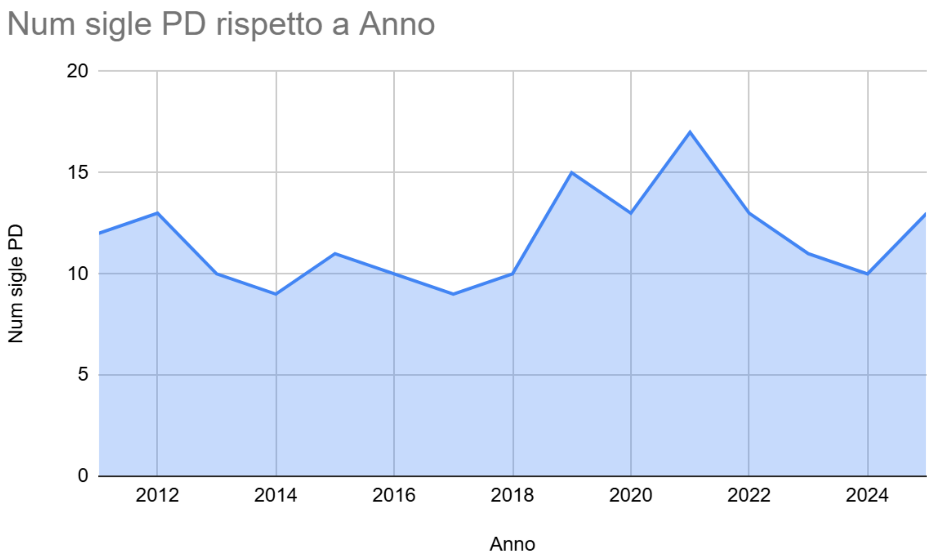
Storico Fondi CSN5 e sigle a Padova

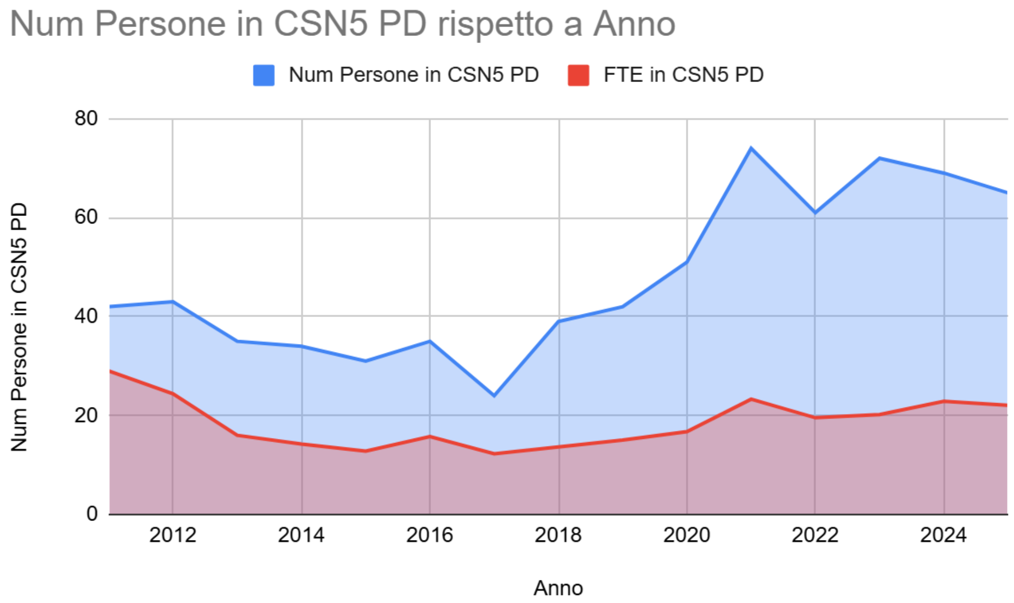




- Negli Ultimi 5 anni
  - Fondi CSN5: 5.4 ME
  - Fondi Padova: 152k
    - Fluttuazione 2025: DOCET 114k, QuteFDS 55k, SQUEEZE 31.5k

Storico Fondi CSN5 e sigle a Padova


Num sigle PD rispetto a Anno


Num Persone in CSN5 PD rispetto a Anno

- Negli Ultimi 5 anni
  - Fondi CSN5: 5.4 ME
  - Fondi Padova: 152k
    - Fluttuazione 2025: DOCET 114k, QuteFDS 55k, SQUEEZE 31.5k
  - Sigle: 13
  - FTE/Persone: 22/68 ~ 32%
  - Tecnologi/Persone: 21/68 ~ 31%
  - FTE/Sigla: 22/13 ~ 1.7

Prospetto Sigle Attive/Nuove

Predecessore	Sigla	Stato	Resp Locale	Anni
REMIX	CUPRUM_TTD	Estensione	L. De Nardo	23,24,25
ASAP	ADA_5D		G. Collazuol	23,24,25
ISOLPHARM_EIRA	ADMIRAL	In Chiusura 2025	Lunardon	23,24,25
	FEROCE	In Chiusura 2025	Triossi	23,24,25
ML_INFN	AI_INFN	Continuazione	M. Verlato	24,25,26
	TIMEPIX4		G. Collazuol	24,25,26
PHYDES	DOCET		G. Carugno	25,26,27
	ASPIDES		G. Collazuol	25,26,27
	SQUEEZE		M.Bazzan	25,26,27
	QuteFDS	Grant giov. 2anni	A. Grimaldi	[25],26,27
	SEGNAR		M. Dettin	25,26,27
	VITA_5		L. Altabella	25,26,27
HISOL	HISOL_NEXT		P. Rebesan	25,26,27
	MAAT	Nuove proposte	P. Rebesan	26,27,28
ADMIRAL	ISOLPHARM_APEX		M. Lunardon	26,27,28
	SLBP		M. Morandin	26,27,28
	INCANTO	Call	D.Zuliani	26,27,28
	DIOMEDES	Call	F. Recchia	26,27,28

Prospetto Sigle Attive/Nuove

- Sigle attive
  - All’ultimo anno
    - ADMIRAL
    - FEROCE
  - Al secondo anno
    - AI_INFN
    - TIMEPIX4.2
  - Al primo anno
    - DOCET [resp. naz]
    - SQUEEZE
    - ASPIDES
    - QuteFDS [Grant, da novembre]
    - SEGNAR
    - VITA_5
    - HISOL_NEXT
  - Prolungamenti
    - CUPRUM
    - ADA_5D
- Nuove proposte
    - MAAT
    - ISOPHARM_APEX
    - SLBP
    - INCANTO [Call]
    - DIOMEDES [Call]

- 13 sigle attive di cui 2 prolungamenti
- 5 nuove proposte con responsabilità locale e 4 in chiusura/prolungamento
- 22 FTE / 65 persone = 34% FTE/pers
- 22 FTE /13 sigle = 1.7 FTE/ sigla

Computer Science

AI_INFN
Infrastructure for Artificial intelligence

Responsabile Locale: Marco Verlato

Obbiettivi del progetto AI_INFN (2024-2026)

- Sigla 2024->2026, resp locale M.Verlato
- Raccogliere **l'eredita` di ML_INFN** in termini di comunita`, hardware e software...
  - ML_INFN nasce nel 2020 con l'obiettivo di sviluppare una visione di sistema dell'applicazione di tecniche di ML alla ricerca scientifica nei vari settori rilevanti per l'INFN
- Costruire un **modello di calcolo** in grado di soddisfare una domanda crescente e scalare agevolmente in vista di una piu` ampia disponibilita` ed **eterogeneita`** di risorse —> vedi ad es. Progetto PNRR Terabit
- Potenziare il **supporto ai molti eventi di livello base** organizzati dall'INFN e dalle Universita`, 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 attivita` di ML, in particolare **FPGA** e processori quantistici
- Quasi tutte le sezioni INFN coinvolte

Attività 2024/2025

- 2024: Sviluppo di un nuovo modello di calcolo per le condividere VM connesse a GPU tra vari progetti
  - Un modello basato sui ‘’container’’
- 2024: Sinergia con attività di INFN DataCloud per sviluppare/testare sistemi che rendono trasparente e agile l’uso di risorse disponibili con diversi backend
- 2024: Integrazione col servizio CaaS (Container-as-a-service) di CloudVeneto che permette di distribuire e gestire facilmente applicazioni containerizzate (Docker, Kubernetes) senza doversi occupare della complessità dell'infrastruttura sottostante
- Fine 2024: organizzazione dell' Advanced Hackathon il 26-28/11/2024
  - con presentazioni di due ricercatori padovani su Quantum ML (D. Jaschke) e Applicazioni di ML in CTA (I. Viale), e una di M. Verlato su CloudVeneto e INFN Cloud.
- 2025: integrazione dell'HPC Bubble padovana nella piattaforma AI_INFN tramite InterLink (A. Troja e F. Fanzago)
- 2025: distribuzione di modelli di ML su immagini di container tramite INFN Cloud Harbor registry e cvmfs/unpacked (M. Verlato)

Terabit – HPC Bubbles

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

M2.1 - Organization of the first Advanced Hackathon Worksho

Proposed status
100%

1st AI-INFN Advanced Hackathon

26–28 Nov 2024
University of Padua, Complesso Paolotti

- Overview
- Timetable
- Registration
- Experts and tutors
- Access to cloud resources
- Groups and servers
- Streaming

Contact

Welcome
Classroom P4C, University of Padua, Complesso Paolotti Via Paolotti 09:00 - 09:15

Coffee break
Lucky bar - The Brick

Generative models to unfold detector effects

Introduction to Quantum Machine Learning
Laura Cappelli et al.

Coffee
Lucky Bar - The Brick

Introduction to Magnetic Resonance Imaging

Machine Learning for Future Colliders — Dr Riccardo Torre
Classroom P2B, University of Padua, Complesso Paolotti 09:00 - 09:40

Applications of machine learning in the event reconstruction of Imaging Atmospheric Cherenkov Telescopes
Classroom P2B, University of Padua, Complesso Paolotti 09:40 - 10:20

What's happening in EU? A gentle introduction to the AI Act — Francesca Lizzi
Classroom P2B, University of Padua, Complesso Paolotti 10:20 - 10:40

An introduction to MLOps — Luca Clissa
Classroom P2B, University of Padua, Complesso Paolotti 10:40 - 11:00

Coffee
Lucky Bar - The Brick 11:00 - 11:20

Experiment Tracking: Hands on — Luca Clissa
Classroom P2B, University of Padua, Complesso Paolotti 11:20 - 12:06

Advanced features of the AI_INFN Platform and presentation of the afternoon activity — Lucio Anderlini
Classroom P2B, University of Padua, Complesso Paolotti 12:06 - 13:00

Customizing the software environment with conda and apptainer — Lucio Anderlini
Classroom P2B, University of Padua, Complesso Paolotti 14:30 - 15:30

Final remarks and closure — Francesca Lizzi
Classroom P2B, University of Padua, Complesso Paolotti 15:30 - 15:50

agenda.infn.it/event/43129/

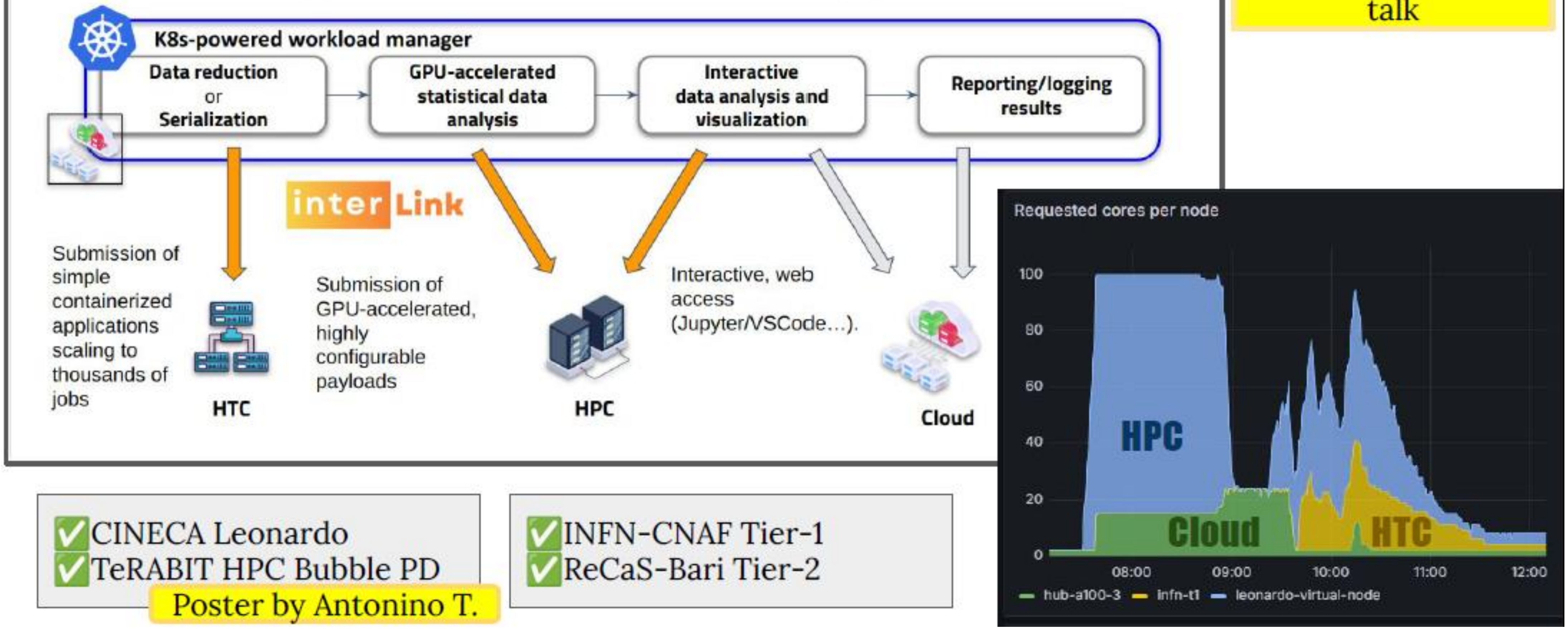
Welcome to the First edition of the Advanced Artificial Intelligence @ INFN (AI_INFN) hackathon, dedicated to INFN affiliates. This edition is hosted at INFN Sezione di Padova.

Notably, it is the third Hackathon to happen in Person, so please apply only if you are planning to come to Padua. The logistics allow for ~ 20 participants.

Scaling out to the distributed INFN infrastructure

Workload Offloading: extending the container orchestration layer (K8s) to support the execution of a user payload to a remote resource instead of a physical node of the cluster

... more in Giulio Bianchini's talk



Submission of simple containerized applications scaling to thousands of jobs

Submission of GPU-accelerated, highly configurable payloads

Interactive, web access (Jupyter/VSCode...).

✅CINECA Leonardo
✅TeRABIT HPC Bubble PD

Poster by Antonino T.

✅INFN-CNAF Tier-1
✅ReCaS-Bari Tier-2

Storage & Data Management

User's homes (software & configuration)

Developing ML requires **interactive tinkering**.

Switching from a GPU model → switch server.

An **responsive network** file system, tuned for intense **metadata activity** is needed:

→ *prototyped* ***bcached Cinder volume via NFSv4***

Talk by Rosa P.

Data Management for Training & Validation

Training data and metadata are often the most precious asset.

Security + privacy + throughput

Several tools & backends explored:
Ceph+RadosGW (CNAF), Invenio RDM (GLOS), MinIO on K8s (Firenze), xNATS (Pisa), OwnCloud (CH-Net)

Artifact management and distribution

Trained models should be versioned, and distributed.

We prototyped a solution based on **ORAS** (OCI Registry As Storage) for using **INFN Cloud harbor** for artifacts (e.g. trained models).

Automatic upload of artifacts to **cvmfs** via unpacked.

Poster by Alessio F.

credits to *Marco Verlato*

Multi-site distributed file system

POSIX access to data **decouples the AuthN/Z from the application layer**.

Apptainer leverages modern features of the **Linux kernel** to enable mounting custom **fuse volumes**, without admin privileges.

→ Successful integration tests with InterLink.

Anagrafica/Richieste

Fanzago	**Federica**	**AI_INFN**	**0,05**
Gianelle	**Alessio**	**AI_INFN**	**0,05**
Jaschke	**Daniel**	**AI_INFN**	**0,05**
Montangero	**Simone**	**AI_INFN**	**0,05**
Verlato	**Marco**	**AI_INFN**	**0,2**
Andreetto	**Paolo**	**AI_INFN**	**0,1**
Sgaravatto	**Massimo**	**AI_INFN**	**0,1**
Traldi	**Sergio**	**AI_INFN**	**0,1**
Pagano	**Alice**	**AI_INFN**	**0,1**
Reini¿	**Nora**	**AI_INFN**	**0,1**

Predecessore	Sigla	Stato	Resp Locale	Anni	missioni	consumo	inventariabile	trasporti	Maintenance
ML_INFN	**AI_INFN**		**M. Verlato**	**24,25,26**	**1**				

Elettronica e rivelatori

FEROCE
Front-End
Rdma Over Converged Ethernet

Area di ricerca: Rivelatori, Elettronica, Calcolo
Periodo:2023-2025
Responsabile nazionale: Andrea Triossi (Unipd – INFN Padova)
Unita partecipanti: INFN sezione di Padova, Laboratori Nazionali di Legnaro

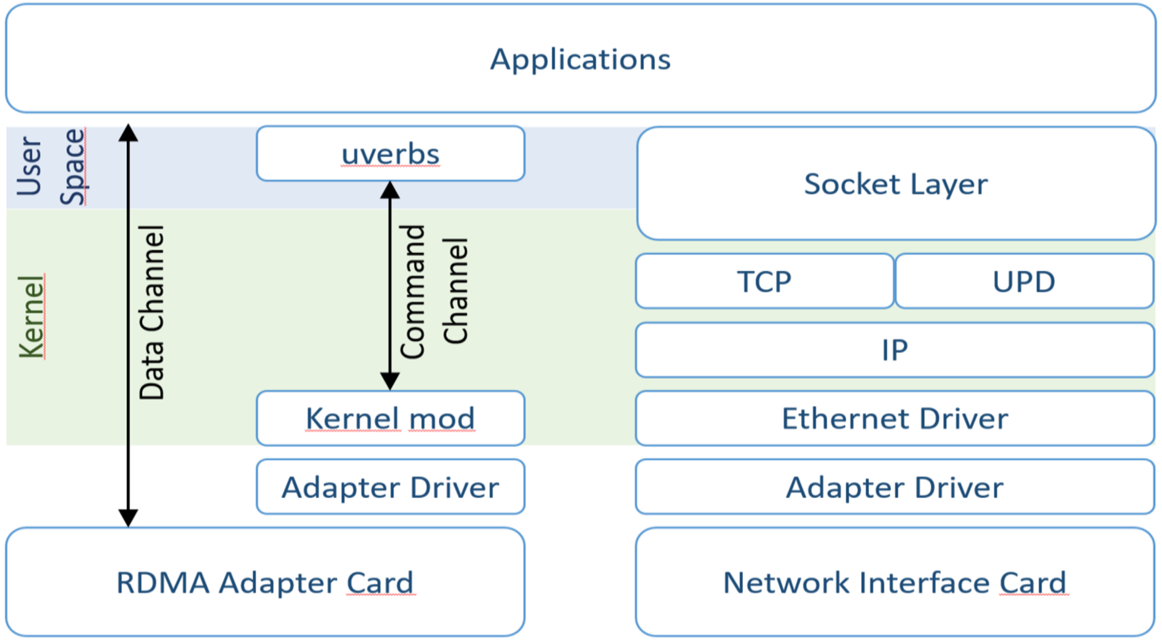
Objectives

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



- **FEROCE 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)

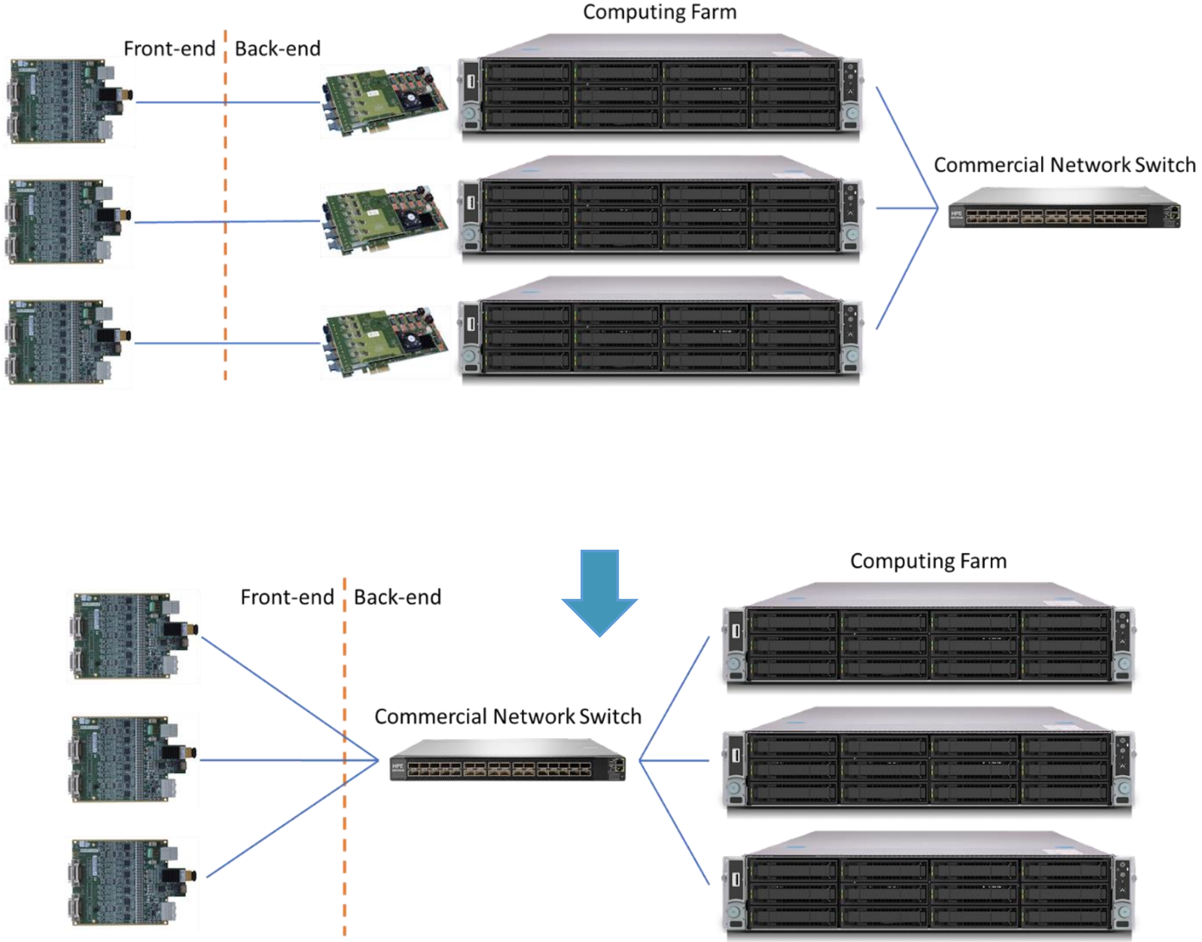
- Based on Ethernet networks
- Industry-standard
- Multi-vendor ecosystem
- RoCE v2 packet switching (layer 2 and 3)

FPGA are already used for implementing network stacks

- Data center
- ATLAS

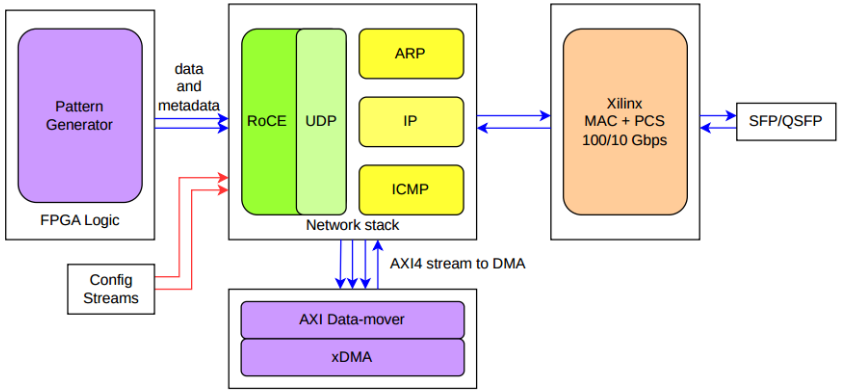
DRD7 WP5:

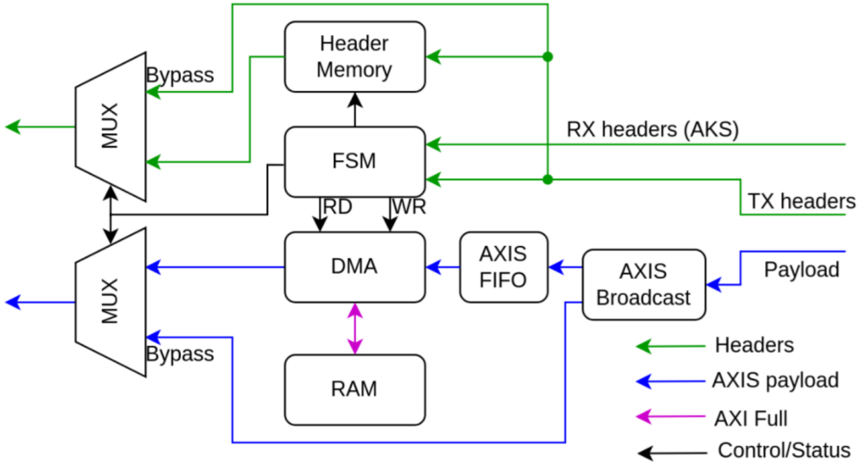
- One of the options for future readout links



Attività

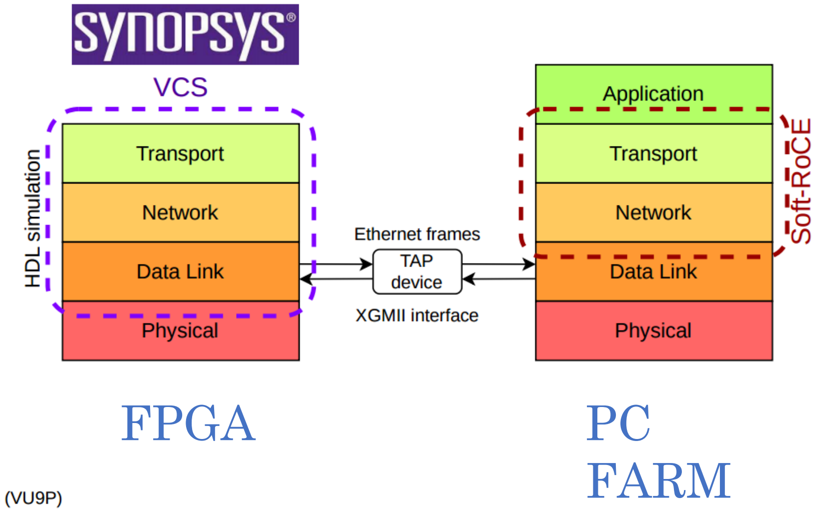
- Studio delle librerie esistenti
    - Librerie Opensource
        - ETH Zurich Network Stack
            - Scritto interamente in HLS
            - 10/100 Gbps via Xilinx 10G and 100G MAC IPs
            - xDMA, DDR4 memory and recently HBM support
        - Lite-RoCEv2 Module
            - Based on Alex Forencich UDP/IP 1G/10G/25G open-source network stack for low level layers, with minor modifications
            - •Completely written at RTL (Verilog)
            - •Only RDMA SEND and WRITE with immediate for completion of the transfer
            - Presentato a ICHEP 2024
            - Errore correction
                - Re-transmission

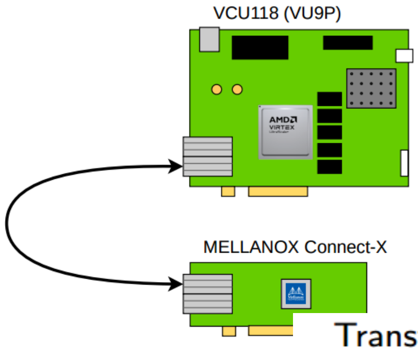




Attività

- Test con simulazione SW della FPGA e del ricevitore (PC FARM)
  - RoCE firmware simulator sends data to Soft-RoCE end-point
  - RDMA WRITE tested successfully with a 10G MAC
  - Results presented at two international conferences TIPP and TWEPP: proceeding here
- Implementazione Hardware
  - UDP and TCP stacks deploymen on VCU118
  - RoCE v2 stacks deployment on VCU118
  - Occupancy nella FPGA
  - Misre di latency e troughput





RoCEv2 (no retrans)			TX only estimate (no retrans)		
LUT [k]	FF [k]	BRAM	LUT [k]	FF [k]	BRAM
38	49	93	~ 15	~ 15	~ 30

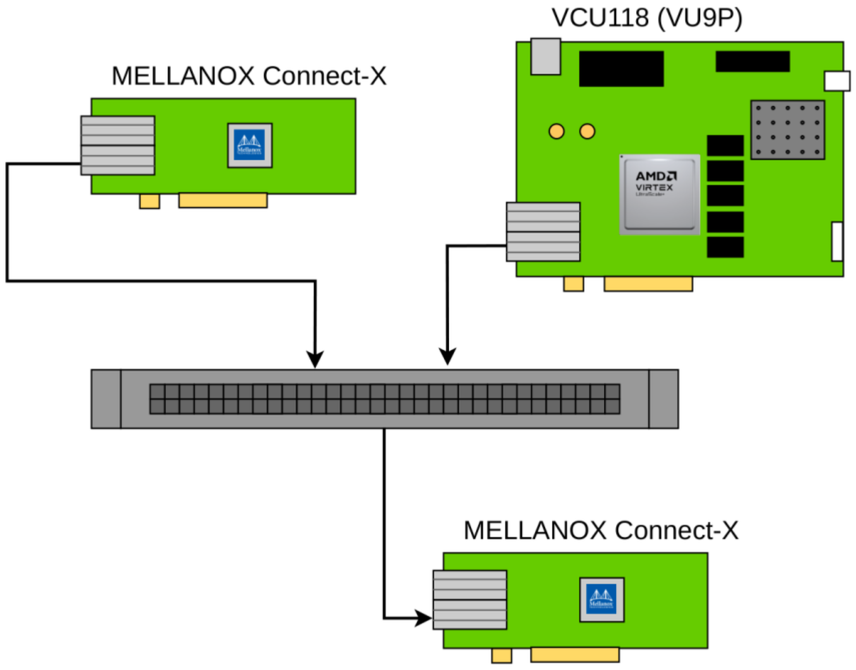
Transfer size	Throughput [Gbps]	Latency [μs]
8 kB	30.7	1.6
32 kB	62.8	2.3
64 kB	73.3	3.1
128 kB	80.5	3.3
512 kB	92.9	12.4
5.12 MB	95.8	12.4
51.2 MB	96.0	12.4
512 MB	96.0	12.4

Attività

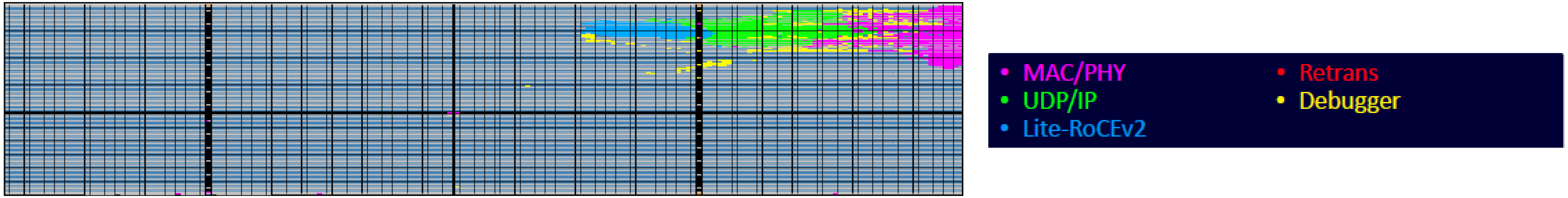
Congestion tests

	Latency	Throughput
10G	15 µs	8.8 Gbps
25G	20 µs	22.2 Gbps
100G	25 µs	96.5 Gbps

Message size of 1 MB



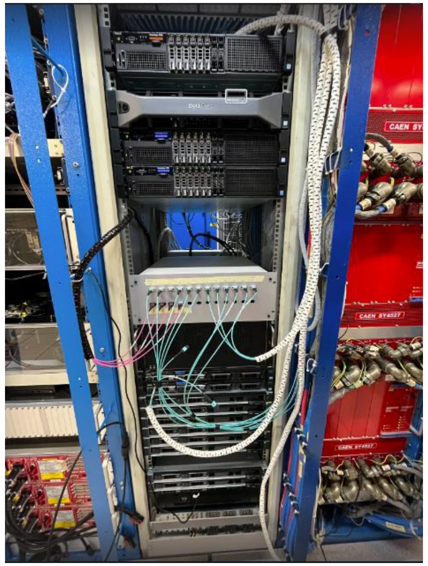
Porting to flash-based FPGA



Prospective developments

CMS (CSN1)L1T

- Scouting is a project aiming at acquiring the L1 primitives at the full bunch crossing rate
- It is meant for HL-LHC but a demonstrator based on commercial electronic is already deployed
- At present as DAQ link it adopts a lite version of the TCP/IP protocol at 100G move to lite-RoCEv2
- Next Generation Trigger is designing new electronics for scaling to 400G



Porting the stack to Versal

RDMA to GPU

- Unburdening CPU by serving data directly to GPU memory

Elettronca e Rivelatori

ADA_5D

Area di ricerca: Rivelatori, Elettronica

Periodo:2023-2025

Responsabile locale: Gianmaria Collazuol (Unipd – INFN Padova)
Unita partecipanti: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)

ADA_5D

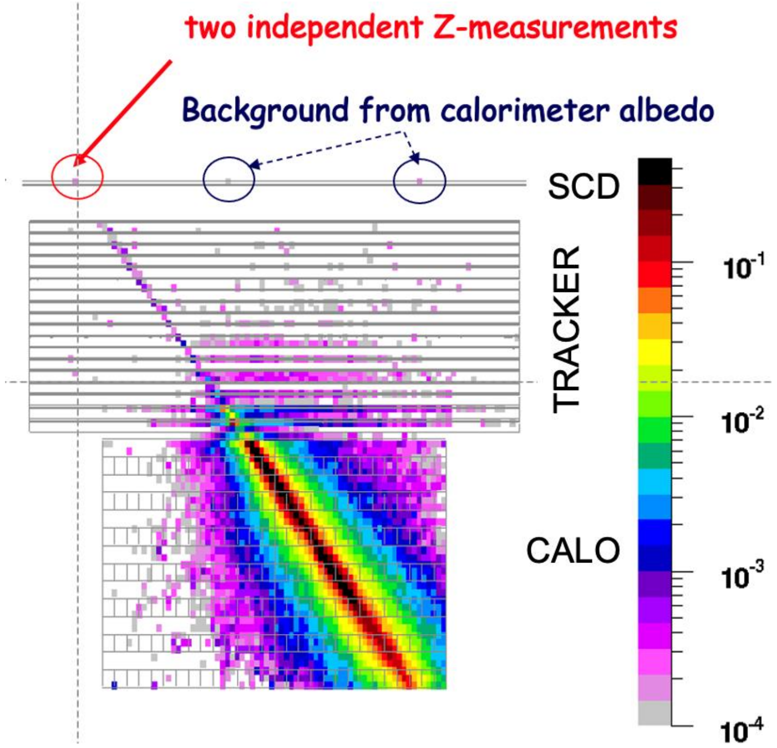
Charge & Timing **5D detector** (x,y,z, charge, time) based on **LGAD sensors** for the next generation of multi-TeV calorimetric experiments in space

CHARGE IDENTIFICATION of cosmic-ray ions with charge $1 \leq Z \leq 30$ via multiple $dE/dx \propto Z^2$ in a pixelated sub-ns **Charge-ToF detector** (SCD)

Backscattering (BSC) from calorimeter generates fake hits in SCD and tracker, degrading charge-ID as energy increases.

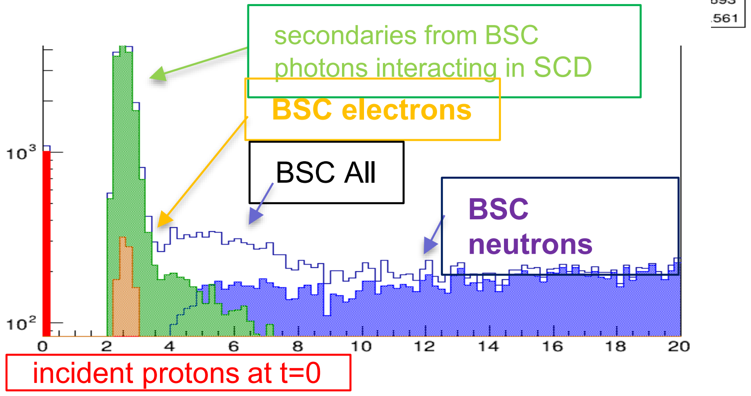
ADA_5D concept: BSC rejection with a high resolution ToF measurement

- large dynamic range > 1000 m.i.p
- 100 ps time resolution (e.g. for 20 cm flight path)
- large pixels (3mm x 3mm) to cover large O(m^2) sensitive area
- indipendent TRACKER for fine track resolution
- challenging power budget < 150 W/m^2
- modest Rad Hardness required in space < 10^{11} 1 MeV neq



simulation of 1 TeV incident carbon nucleus

Arrival time (ns) of BSC from calorimeter on SCD: a GEANT4 simulation with 30cm flight path



Avalanche Diodes Array – ADA-5D

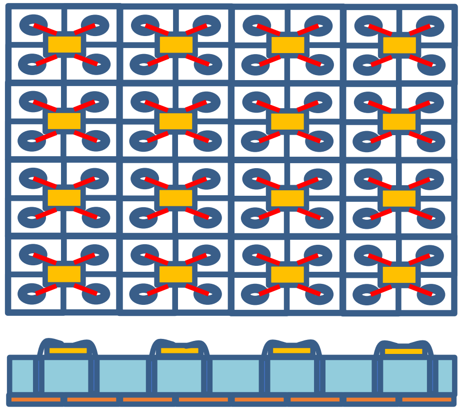
University of Pisa & INFN **Pisa** / University of **Siena** & INFN Pisa
University of Padova & INFN **Padova** / University of **Pavia** & INFN Pavia
University of **Trento** & **TIFPA** / Fondazione Bruno Kessler **FBK** (Trento)

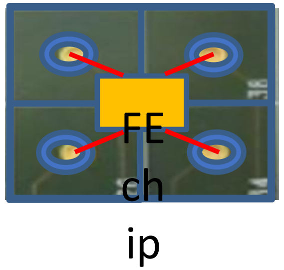
G.Collazuol
INFN Padova
CdS 2025/7/2

Development thick LGADs and related large dynamic range electronics

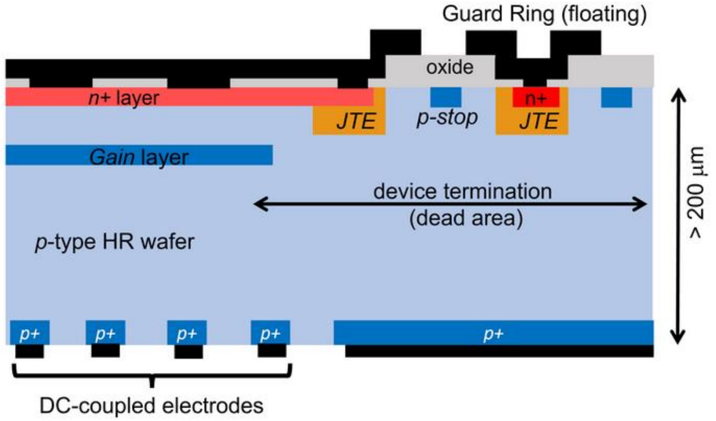
- large pixels (3mm x 3mm)
- sensor thickness 200-300 um

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





Example of thick LGAD implementation

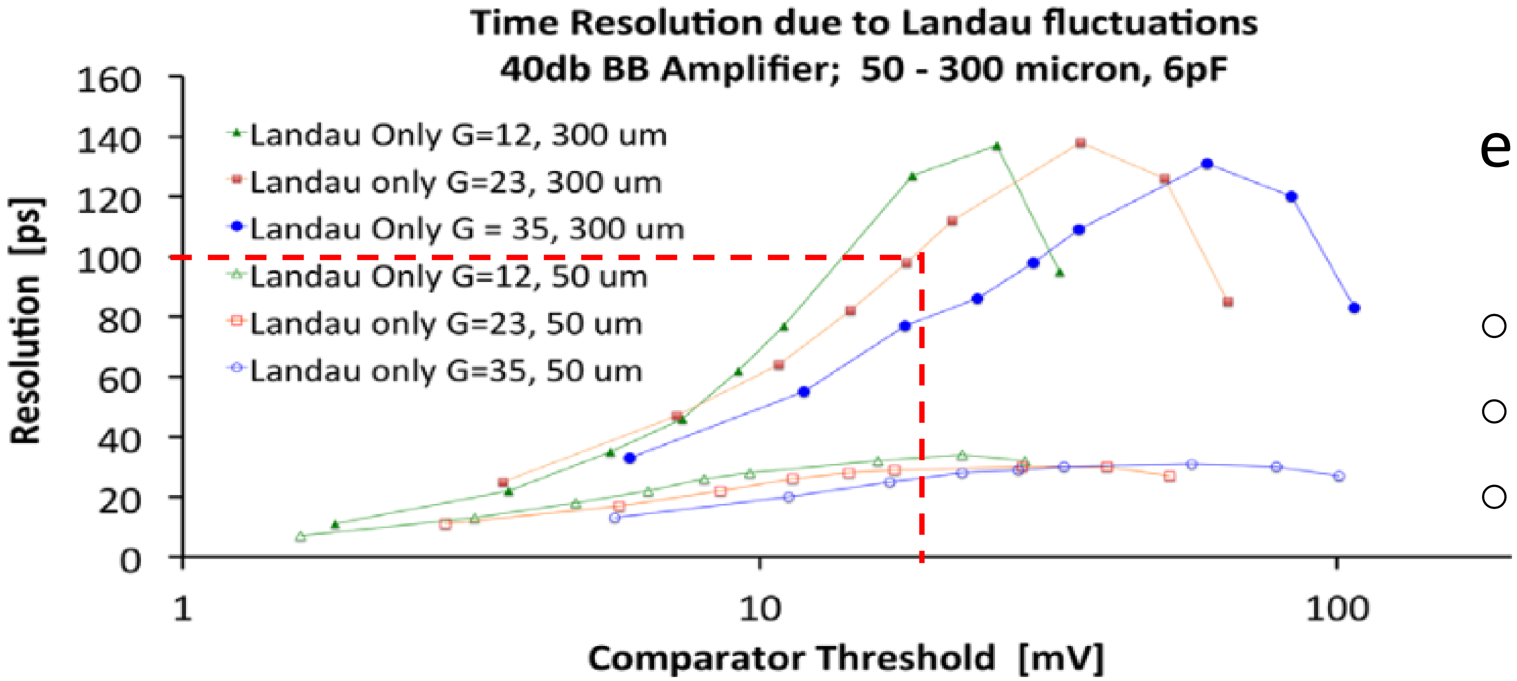


Each FE chip, connected to 4 LGADS, implements:
- double gain linear range to cover > 1000 m.i.p.
- internal ADC
- internal TAC + ADC conversion
- Track & Hold

Gain and Time resolution

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

~ 100ps feasible with a low threshold (ok as S/N>30 for 1 m.i.p)



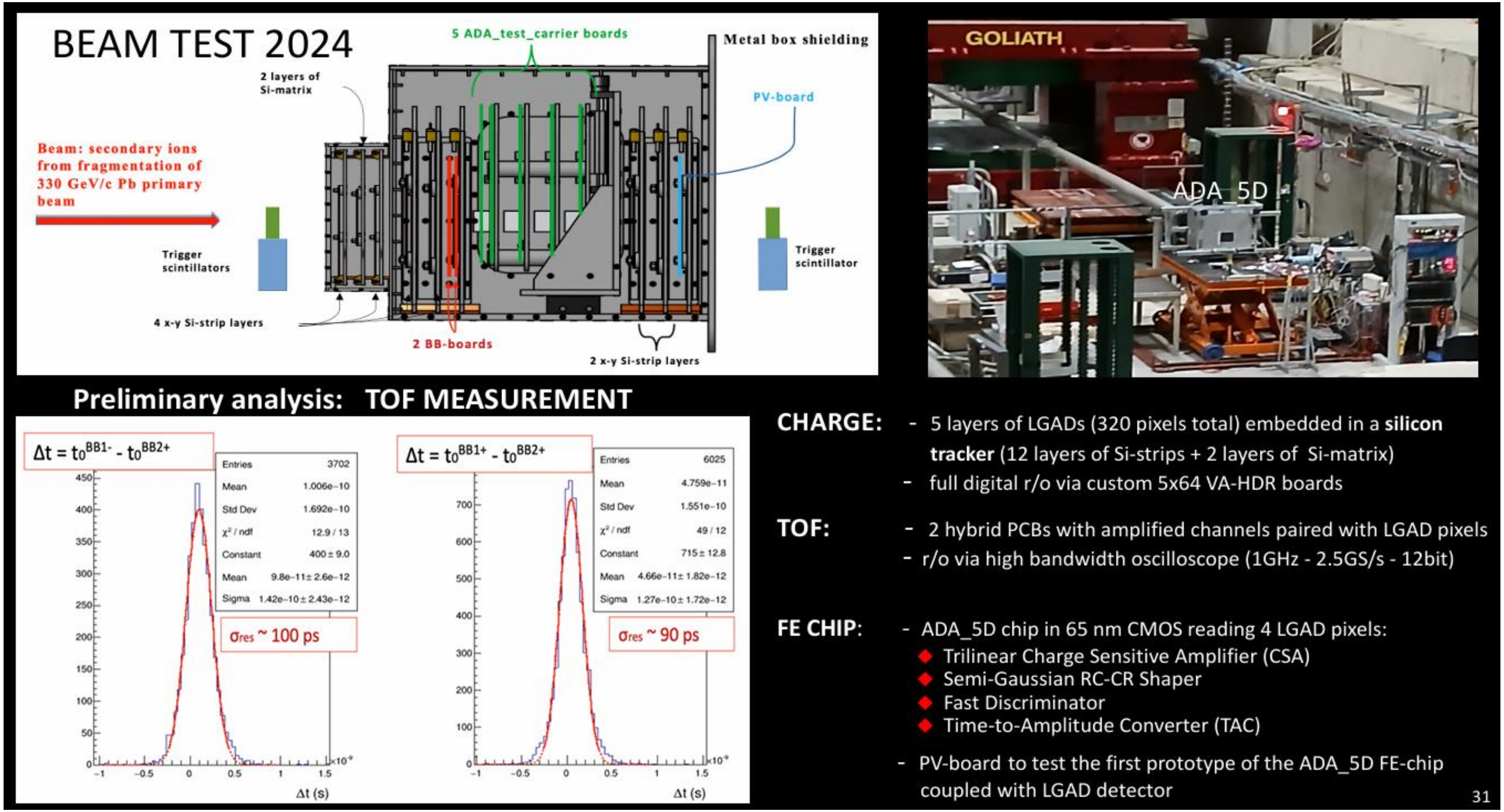
e.g.: 100 ps resolution with:

- 300 um thickness
- G=23
- threshold ~ 20 – 30 mV

Nuclear Instruments and Methods in Physics Research A 845 (2017) 47–51

Attivita`

2024: test sensori



BEAM TEST 2024

Preliminary analysis: TOF MEASUREMENT

$\Delta t = t_0^{BB1-} - t_0^{BB2+}$

Entries	3702
Mean	1.006e−10
Std Dev	1.692e−10
χ^2 / ndf	12.9 / 13
Constant	400 ± 9.0
Mean	9.8e−11 ± 2.6e−12
Sigma	1.42e−10 ± 2.43e−12

σ_{res} ~ 100 ps

$\Delta t = t_0^{BB1+} - t_0^{BB2+}$

Entries	6025
Mean	4.759e−11
Std Dev	1.551e−10
χ^2 / ndf	49 / 12
Constant	715 ± 12.8
Mean	4.66e−11 ± 1.82e−12
Sigma	1.27e−10 ± 1.72e−12

σ_{res} ~ 90 ps

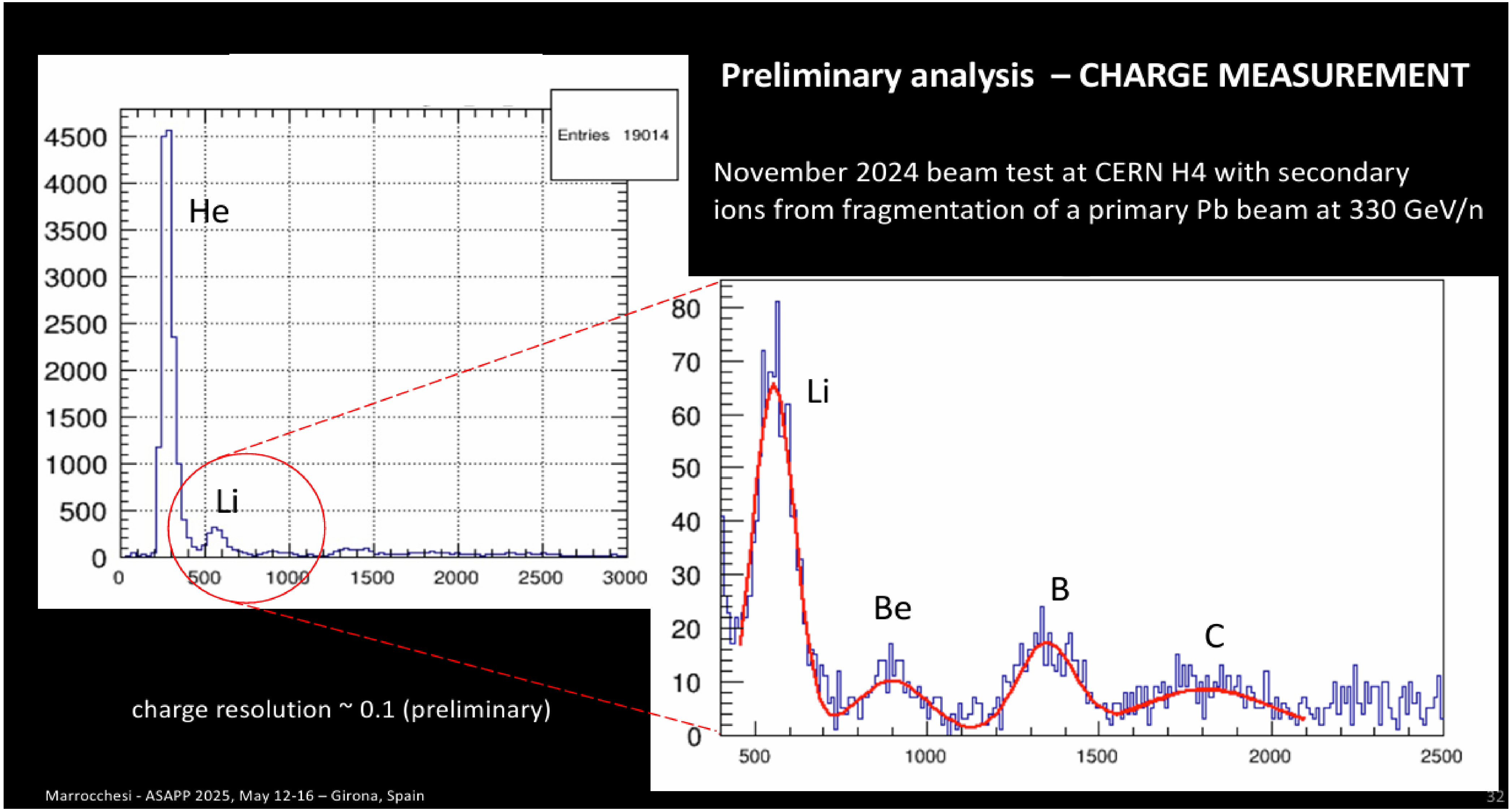
CHARGE:
- 5 layers of LGADs (320 pixels total) embedded in a **silicon tracker** (12 layers of Si-strips + 2 layers of Si-matrix)
- full digital r/o via custom 5x64 VA-HDR boards

TOF:
- 2 hybrid PCBs with amplified channels paired with LGAD pixels
- r/o via high bandwidth oscilloscope (1GHz - 2.5GS/s - 12bit)

FE CHIP:
- ADA_5D chip in 65 nm CMOS reading 4 LGAD pixels:
  - ◆ Trilinear Charge Sensitive Amplifier (CSA)
  - ◆ Semi-Gaussian RC-CR Shaper
  - ◆ Fast Discriminator
  - ◆ Time-to-Amplitude Converter (TAC)
- PV-board to test the first prototype of the ADA_5D FE-chip coupled with LGAD detector

Attivita`

2024: test sensori



Preliminary analysis – CHARGE MEASUREMENT

November 2024 beam test at CERN H4 with secondary ions from fragmentation of a primary Pb beam at 330 GeV/n

charge resolution ~ 0.1 (preliminary)

Activities in 2025

- **TIFPA** - caratterizzazione laser IR di campioni LGAD FBK con spessore 275um
- **Pavia** – nuova versione del ASIC con on-chip ADC e interfaccia digitale per R/O
- **FBK -** secondo batch di LGAD
- **Pisa & Padova**
  - Digital readout system and DAQ integration
  - Charaterization and selection sensors
  - Setup telescope for Test Beam @ SPS ions => November 2025

Request CSN5 for 1 year Extension

Activities in 2026

- Last batch of thick sensors → characterization
- Demonstrator layer
- Digital readout system and DAQ integration
- Setup telescope for Test Beam @ SPS ions => Fall 2026

Resources @ INFN Padova

FTE Padova 2026

- G.Collazuol	10 %
- M.Mattiazzi	60%

Preventivi 2026

- Consumo per circa 10kEuro
- Missioni (CERN) per 5kEuro

Richieste 2026 in Sezione PD

- Servizio Elettronica
  programmazione FPGA TimePix4 + SiPixels (collab. con INFN FE) ~ 3m.p.
- Servizi Tecnici ed Elettronici
  elettronica ancillare TimePix4 ~ 1m.p.
- Servizio Progettazione Meccanica
  disegno setup telescopio (collaborazione con Stefano Levorato) ~ 1m.p.
- Servizio Officina Meccanica
  meccanica telescopio ~ 1m.p.

Rivelatori, elettronica

TIMEPIX4

Area di ricerca: Rivelatori, Elettronica

Periodo:2024-2026

Responsabile locale: Gianmaria Collazuol (Unipd – INFN Padova)

Responsabile nazionale: M Fiorini (FE)
Unita partecipanti: : Ferrara, Laboratori Nazionali del Sud, Napoli, Padova, Pisa, Trieste

TIMEPIX4

G.Collazuol
INFN Padova Gr5 2025/6/25

Acronym: TIMEPIX4
Project duration: 3 years (2025, 2026, 2027)
Research area: Interdisciplinary / Detectors
Principal Investigator: Massimiliano Fiorini (INFN Sezione di Ferrara)
Participating Units: Ferrara, Laboratori Nazionali del Sud, Napoli, Padova, Pisa, Trieste

Ambito: DRD4 - WG1 (Gaseous) / WP2 (Vacuum Based)

Sinergia: HYPER-K (CNS1) per charge & optical readout in gaseous detectors

Aims: exploiting TIMEPIX4 chip => to develop detector systems beyond State-of-the-Art

Applications:

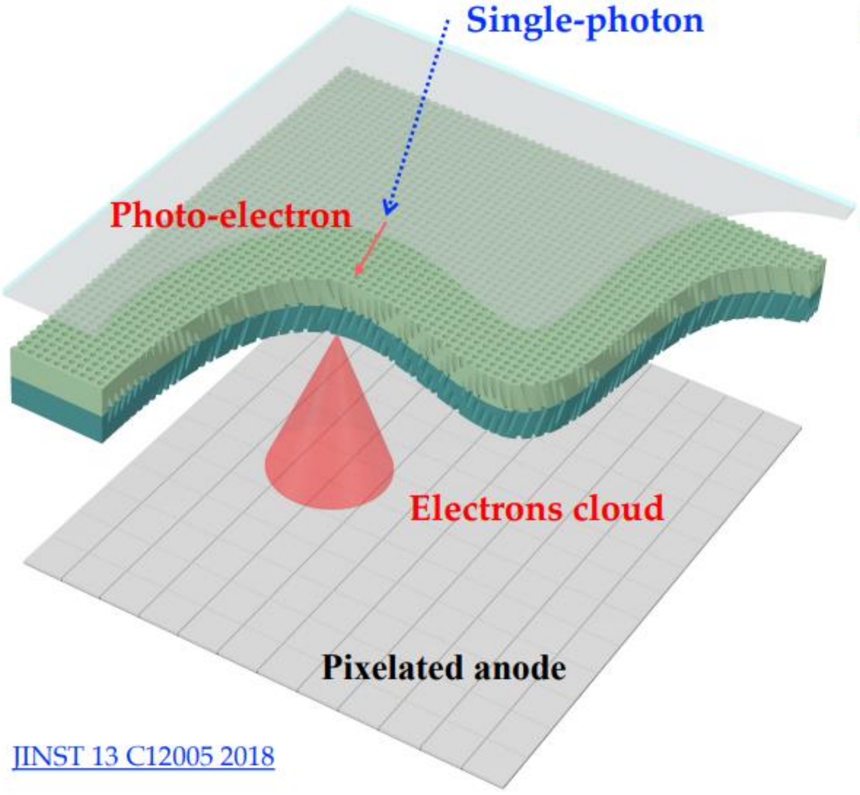
- Ultra-fast, high granularity MCP based photon detector => HEP
- X-ray, gamma ray and particle imaging w/ semiconductors => Medical Physics
- Photons detection and Tracking w/ gas detectors => Padova proposal

Staff: G.Collazuol, S.Levorato
Post-Doc: M.Feltre

Hybrid vacuum photon detector - MCP / TIMEPIX4

- Timepix4 ASIC in 65 nm CMOS (TSMC) **silicon pixel technology**
  - Developed and produced by the Medipix4 Collaboration for hybrid pixel detectors
- Charge sensitive amplifier, single threshold discriminator and TDC based on Voltage Controlled Oscillator
  - 4-side buttable (TSV)
  - Data-driven and frame-based read-out

JINST 17 C01044 2022



JINST 13 C12005 2018

- Entrance window + photocathode
- Microchannel plate stack
- Timepix4 ASIC as pixelated anode
  - Electron cloud (pixels cluster)
  - **55µm × 55µm** pitch
  - **0.23 M pixels** measuring arrival time and duration of input signals
  - **7 cm²** active area
  - Up to **2.5 Ghits/s**
  - Local signal processing

Technology			**CMOS 65 nm**
Pixel Size			55 µm × 55 µm
Pixel arrangement			4-side buttable 512×448 (0.23 Mpixels)
Sensitive area			6.94 cm² (2.82 cm × 2.46 cm)
Read-out Modes	Data driven	Mode	TOT and TOA
		Event Packet	64-bit
		Max rate	358 Mhits / cm² / s
TDC bin size			**195 ps**
Readout bandwidth			≤163.84 Gbps (16× @10.24 Gbps)
Equivalent noise charge			50-70 e⁻
Target global minimum threshold			<500 e⁻

X. Llopart (CERN)

TIMEPIX4

TIMEPIX4 gas detector – WP2 rimodulated

Aim

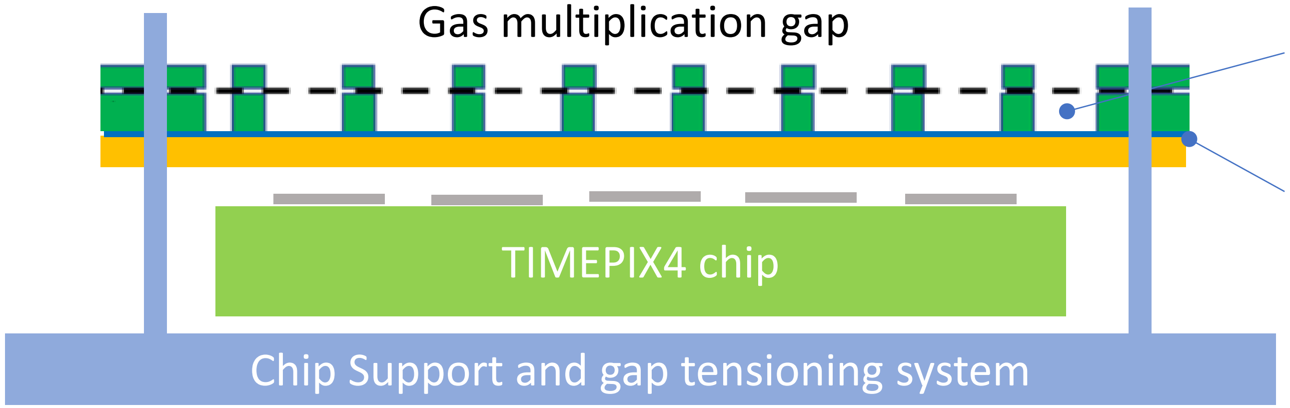
Proof of principle of coupling gas multiplication gap to TIMEPIX4 chip in a simple way

Target applications

high-resolution & low material budget tracking detectors with PID capabilities for charged particles down to very low momenta

Method

building MicroMegas Resistive Embedded Anode gap by standard technique at CERN
(stainless steel mesh supported by pillars on DLC resistive layer on Kapton)
to be tensioned and over-imposed on top of TIMEPIX4



128 um gap with SD45/18 woven stainless steel mesh

DLC resistive layer on 50 um of Kapton

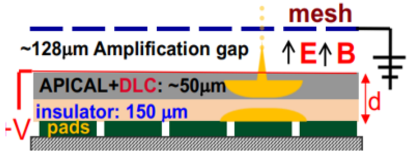
- 1995 Micropatterned Gas Detectors
  - GEM
  - Micromegas
- 2004
  - Micromegas + Medipix2
- Discharges
  - High resistivity quenching and protection layer
- Alignment of chip pad with micromega holes
  - Solved in TIMEPIX3 with aluminum grid obtained with lithographic thechniques
  - Solved for T2K with ERAM
    - Charge spreads on low resistivity foil->resoltion

Apply principle of Resistive Plate Chamber (RPC):
quench discharge before completion
by covering the chip with a high-resistivity protection layer

Resistive layer prevents charge build-up and hides sparks
→ enables operation at higher gain
→ no need for spark protection circuits for ASICs
→ compact FEE → max active volume

Resistive layer encapsulated and properly insulated from GND
→ Mesh at ground and Resistive layer at +HV
→ improved field homogeneity → reduced track distortions
→ better shielding from mesh and DLC → potentially better S/N

ERAM
= Encapsulated Resistive Anode MM

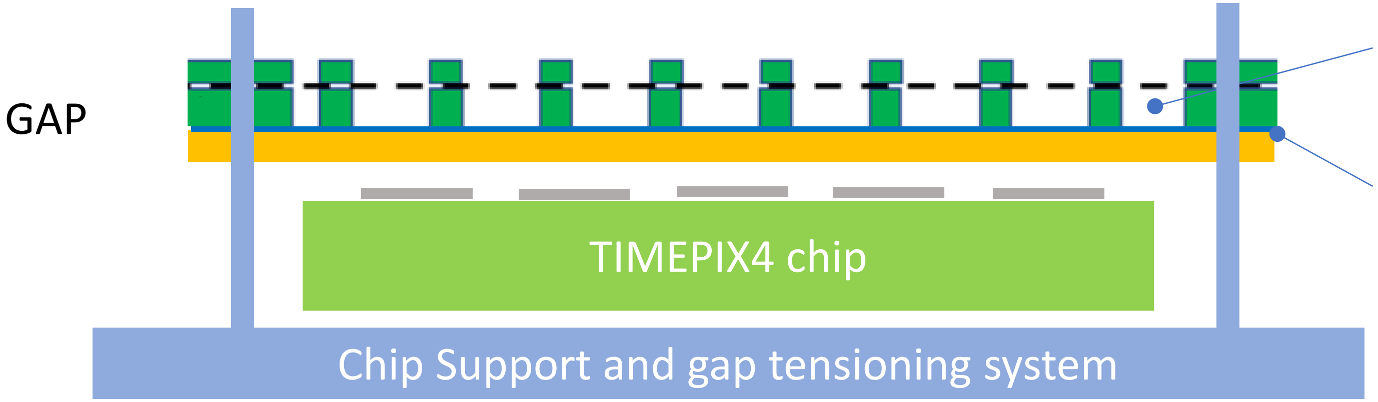


First use of Encapsulated Resistive foil in detector for regular experiment

Coupling ERAM gaps to TIMEPIX4 chip => ERAMPIX

Proof of principle of simple coupling of TIMEPIX4 with ERAM-like multiplication gap

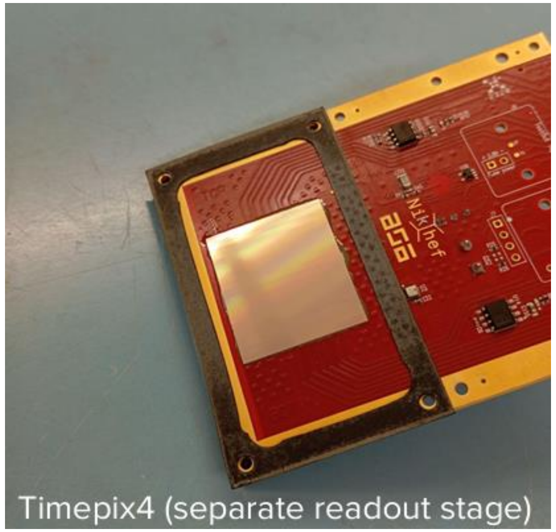
1) DLC (Diamond-like-Carbon) resistive layer = chip protection against discharges
2) DLC layer with low resistivity = charge spread against efficiency non uniformity
3) Micromegas principle allowing low ion feedback

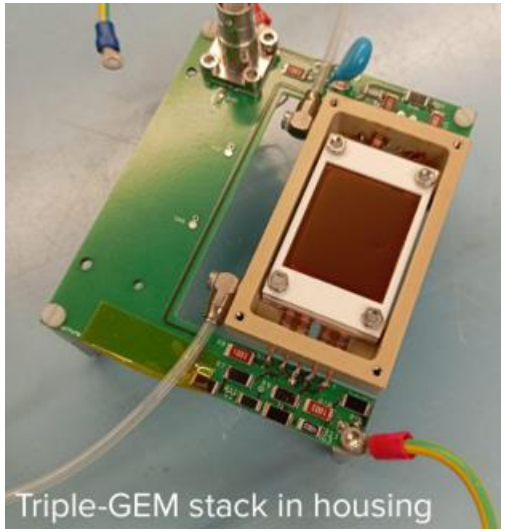


128 um gap with SD45/18
woven stainless steel mesh

DLC resistive layer
on 50 um of Kapton

TIMEPIX4 on
NIKHEF carrier board

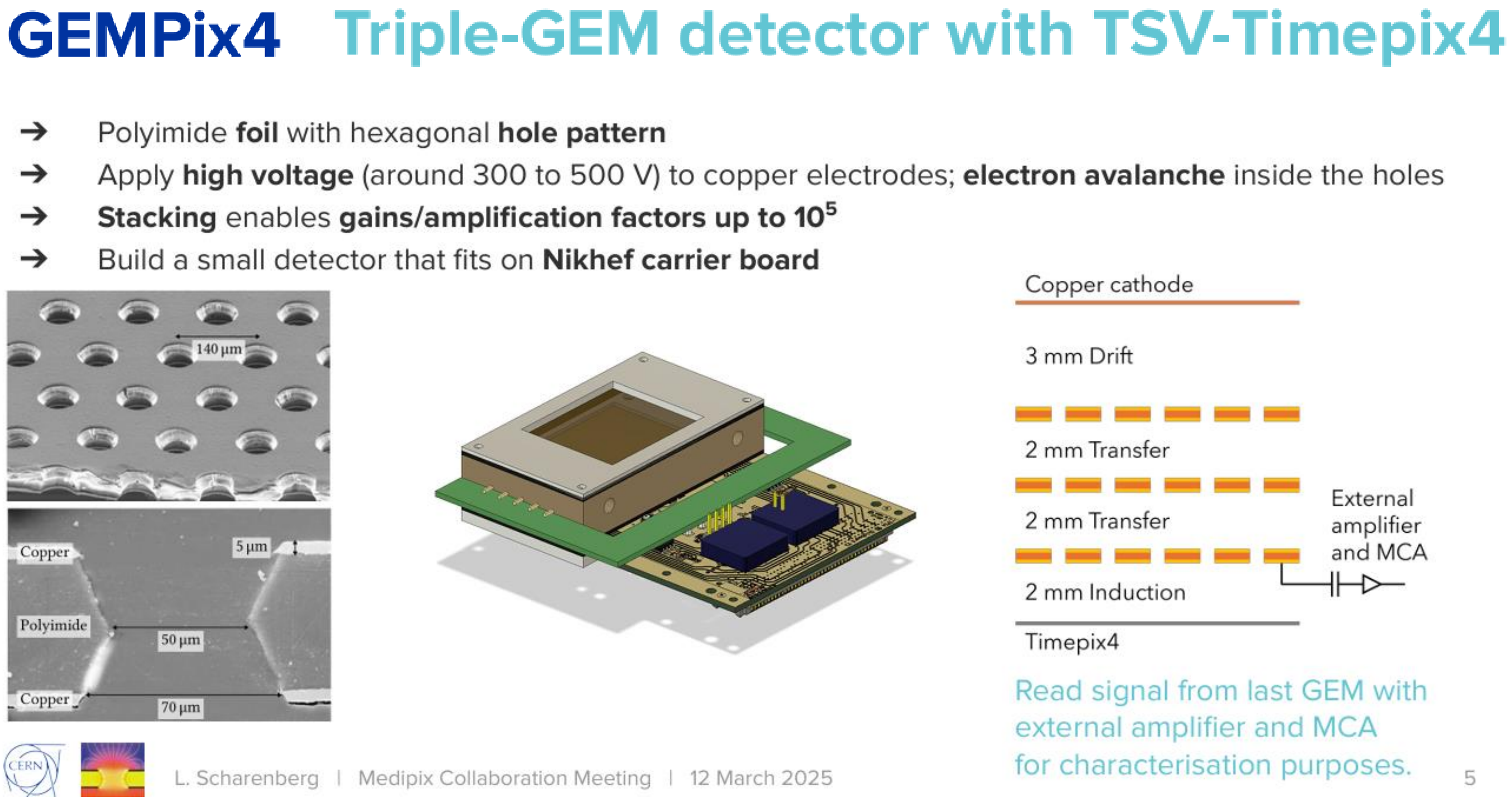

Timepix4 (separate readout stage)


Triple-GEM stack in housing

Readout based on FPGA
Xilinx AMD Kintex
UltraScale KCU105-G

Developments 2024/25 at CERN

TIMEPIX4



GEMPix4 Triple-GEM detector with TSV-Timepix4

- ➔ Polyimide **foil** with hexagonal **hole pattern**
- ➔ Apply **high voltage** (around 300 to 500 V) to copper electrodes; **electron avalanche** inside the holes
- ➔ **Stacking** enables **gains/amplification factors up to 10^5**
- ➔ Build a small detector that fits on **Nikhef carrier board**

Read signal from last GEM with external amplifier and MCA for characterisation purposes.

Activities 2025

TIMEPIX4

Acquired RO system and start development of TIMEPIX4 readout (based on INFN FE FW)

Xilinx AMD Kintex UltraScale FPGA KCU105 thanks to INFN-PD-Dtz1

Production of ERAMPIX structures fror simple coupling with TIMEPIX4

Resistive Micromegas detector
- Panel of 4 detector (2 guaranteed): production Panel P2 (330X254) Thickness 200um
- 77mm x 97 mm (Based on DFS 3192 uRwell layout but adapted to MM)
- 25mm x 41mm active area, 150um gap amplification (Dynamask)
- DLC resistivity from 5 to 10M Ohm - 2 external connexions for Mesh and DLC

Activities 2026

Eager to move our “gas detector” activities from LNL to new Lab. “dell’Universo” in via Luzzatti

Development TIMEPIX4 readout fast links

Production and test of ERAMPIX structure to embed with TIMEPIX4

Development of gas photon-multiplier layer for TPC optical readout

Resources @ INFN Padova

FTE Padova 2025/7 => 40%

- G.Collazuol	10 %
- S.Levorato	10 %
- M.Feltre	20%

Preventivi 2026

- Consumo (new ERAM structures) per circa 10kEuro
- Missioni (CERN) per 4kEuro

Richieste 2026 in Sezione PD

- Servizio Elettronica
  programmazione FPGA TimePix4 (collaborazione con INFN FE) ~ 3m.p.
  (overlap – con richiesta ADA-5D)

- Servizi Tecnici ed Elettronici
- Servizio Progettazione Meccanica
- Servizio Officina Meccanica

Rivelatori, elettronica

ASPIDES
A CMOS SPAD and Digital SiPM Platform for High Energy Physics

Area di ricerca: Rivelatori, Elettronica

Periodo:2025-2027

Responsabile locale: Gianmaria Collazuol (Unipd – INFN Padova)
Responsabile nazionale: **:** Lodovico Ratti (Universita` e INFN Sezione di Pavia)

Participating Units: Pavia(PV), Bari (BA), Bologna (BO), Milano (MI), Napoli (NA), Padova (PD), Torino (TO), Trento (TIFPA)

ASPIDES

Acronym: ASPIDES - A CMOS SPAD and Digital SiPM Platform for High Energy Physics
Project duration: 3 years (2025, 2026, 2027)
Research area: rivelatori ed elettronica
Principal Investigator: Lodovico Ratti (Universita` e INFN Sezione di Pavia)
Participating Units: Pavia(PV), Bari (BA), Bologna (BO), Milano (MI), Napoli (NA), Padova (PD), Torino (TO), Trento (TIFPA)

Ambito: DRD4 - WG1 (dSiPM) / WP1 CMOS SPAD

Aims: development technology platform for the design, production and commissioning of digital silicon photomultipliers (dSiPMs) => detectors with single-photon sensitivity and embedded functionalities

Applications:

- Scintillation and Cherenkov light detection in dual-readout calorimetry
- Scintillation det. (e.g. SciFi / Water Based L.Sci.) and TPC optical RO for Hyper-Kamiokande Near detector => involvement Padova

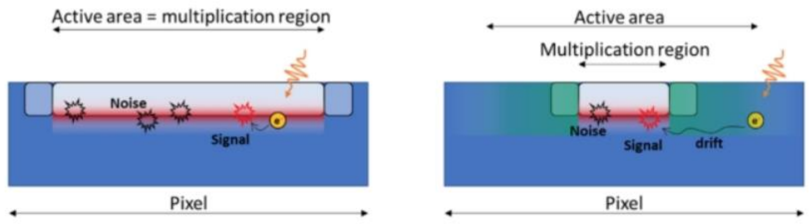
Gruppo Padova
Staff: G.Collazuol, R.Stroili
Post-Doc: M.Feltre
Dottorandi: C.Forza

ASPIDES will deliver 2D CMOS monolithic sensors

ASPIDES

Target technology

- 110 nm CMOS image sensor process



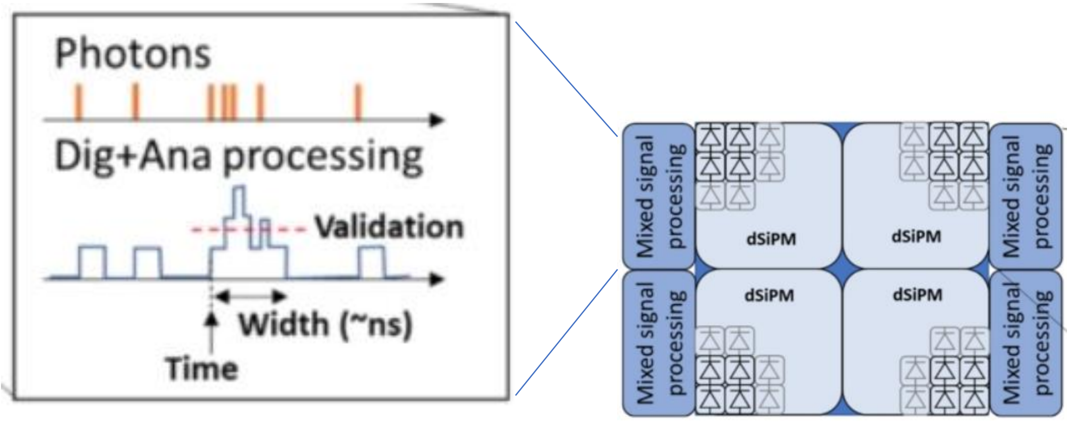
Ultra-low noise SPAD design through field shaping and charge focusing.

Main features

- Noise mitigation
  - Optimization for ultra-low noise spad cell
  - Single SPAD control (on/off)
  - threshold adjustment capabilities for noise rejection (output validation)

- Photons counting
  - fully digital output, obtained through a completely digital processing chain or through analog, Q/V or I/V transformation and final A/D conversion
  - asynchronous counting with wide O(1000) dynamic range of simultaneous photons

- Timing features
  - time of arrival of the first photon
  - photon pulse duration (width) w/ 100ps resolution
  - … additional features available to measure accurately shape of photon pulse evolution)



Possible floorplan and readout architecture

ASPIDES will deliver 2D CMOS monolithic sensors

ASPIDES

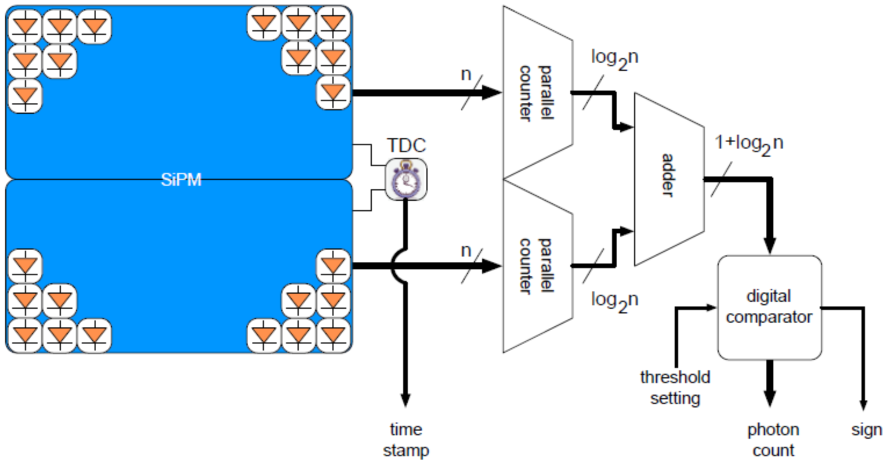


Figure 1. Block diagram of a dSiPM as proposed in the ASPIDES experiment.

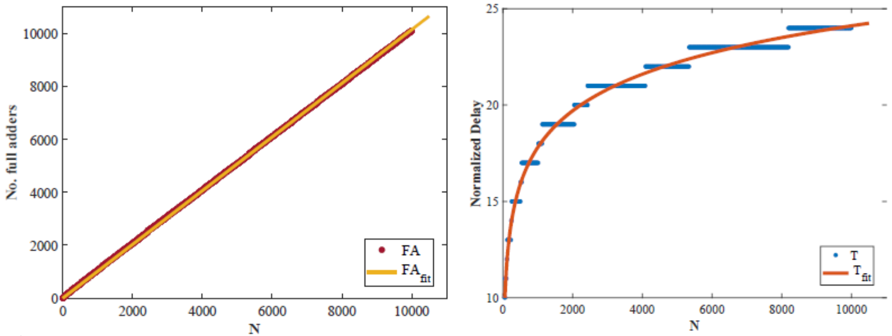


Figure 4. Number of full adders needed for a parallel comparator (left) and normalized delay between the input and the output of a parallel counter (right) bith as a function of the number N of inputs.

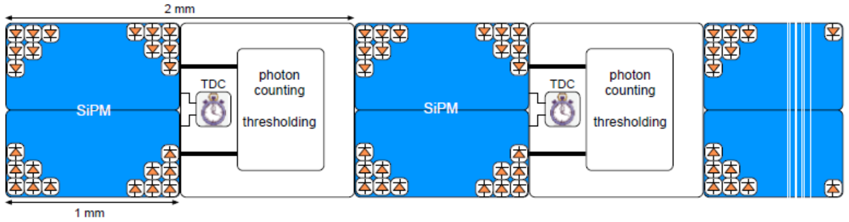
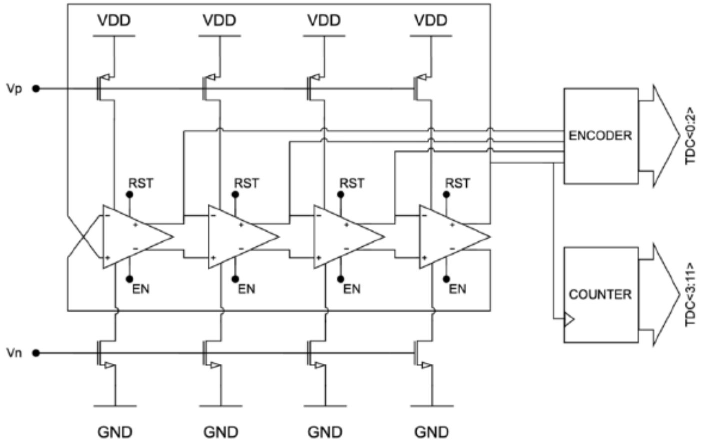


Figure 3. Modular structure for a dSiPM in dual-readout calorimetry.

Photon counting might be performed through a parallel counter based on adder trees, usually employed in digital multipliers to perform the sum of partial products (digital compressors as they reduce n bits into $\lceil log2n \rceil$ bits)

Possible alternative is mixed analog and digital approach based on I/V or Q/V conversion, followed by an ADC (current steering circuit integrated in each individual micro-cell to summing node when the micro-cell is hit and a trans-resistance amplifier or a charge preamplifier provides a measurement of the overall signal)

The time of arrival of the first photon will be measured by means of a time to digital converter (TDC) triggered by the first hit micro-cell through an OR-tree (or by a transition of one of the bits at the parallel counter output).



Block diagram of a 12-bit ring-oscillator-based TDC

ASPIDES Demonstrator – first version

Technology & Architecture:

- **110 nm CMOS image sensor** process.
- **1024 micro-cells** with a **30 µm pitch** and **50% fill factor**.

Key Features:

- **Parallel counter** for real-time digital readout of hit pixels, delivering results within **ns** after the last photon arrival.
- **Fast NAND/NOR tree** with optimized symmetry minimizing **fixed-pattern jitter** achieving **<10 ps timing uncertainty** for the first photon.

Noise Mitigation:

- **Individual micro-cell disablement** to suppress hot pixels.
- **Threshold-based triggering** to reduce false events in timing circuitry

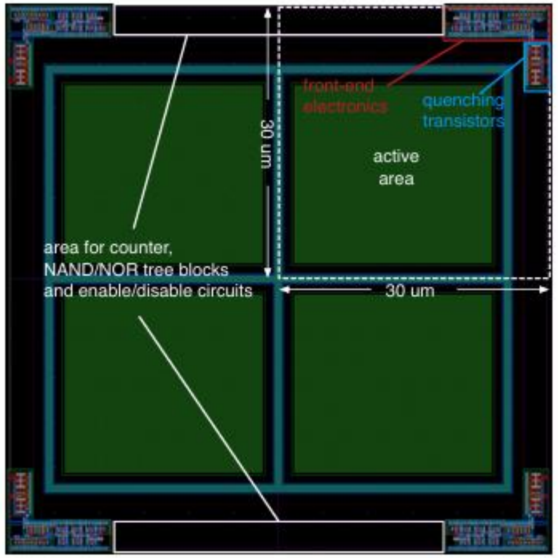
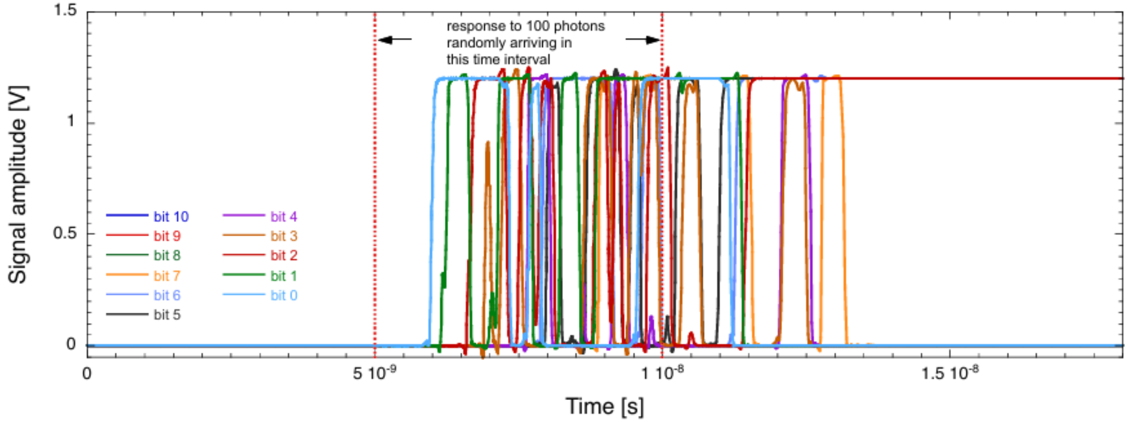


Fig. 1. Layout of the elementary 2×2 SPAD macro-cell.



. 3. Time diagram of parallel counter output as a response to the random arrival of 100 photons in a time window extending from 5 to 10 ns.

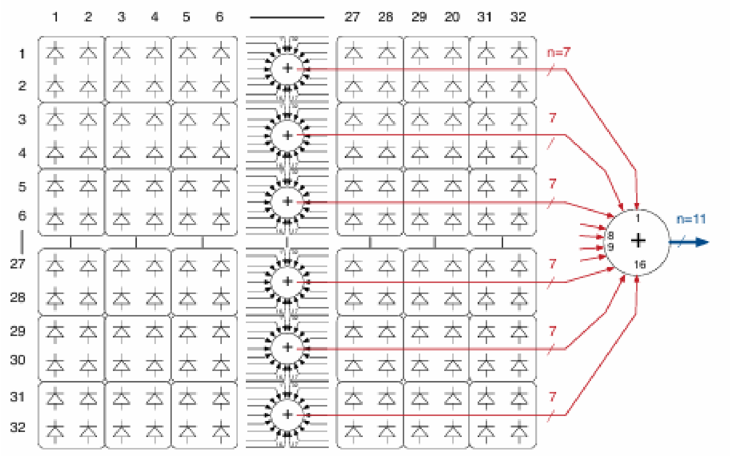


Fig. 2. Schematic diagram of the parallel counter used in the dSiPM.

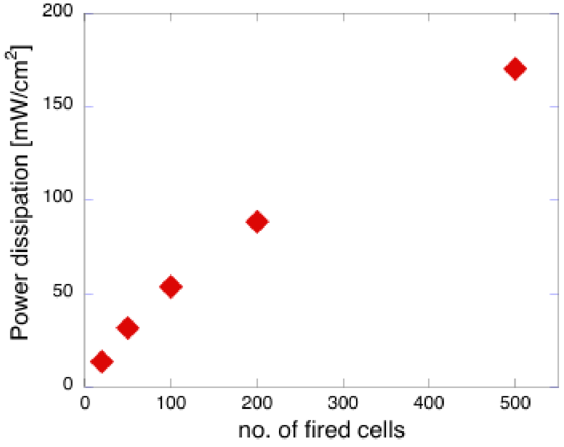


Fig. 4. Specific power dissipation of the parallel counter as a function of the number of fired cell, assuming operation with a duty cycle of 25 ns.

ASPIDES will deliver 2D CMOS monolithic sensors

ASPIDES

Project Deliverables

- A prototype chip, including structures such as mini-SiPMs with O(1000) micro-cells with different pitch and single electronic blocks (e.g., TDC/QTC) for characterization purposes
- A final demonstrator, with full scale SiPMs and optimized fill factor for dual-readout calorimetry

Involvement in Padova 2026

1) Characterization

- Investigation of radiation tolerance both to ionization and displacement damage
- Study device operation in cryogenic conditions or high pressure and different radiators
- PDE to light from 200nm to 1000nm

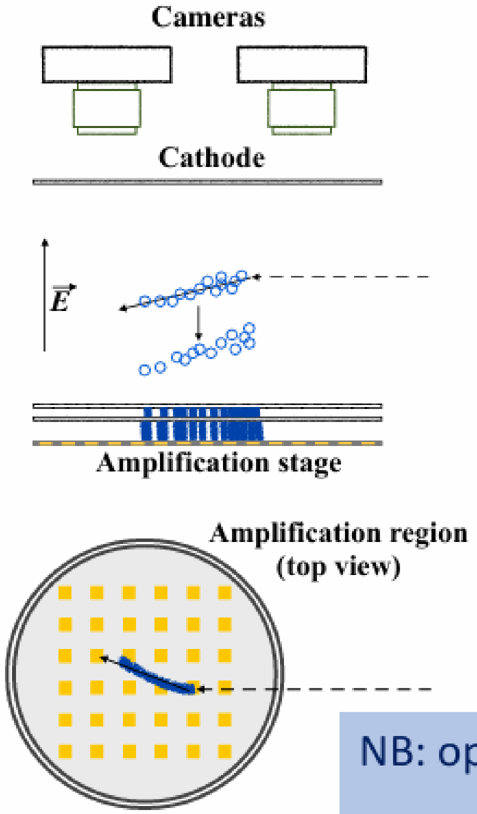
2) Applications

- Scintillation applications (HYPER-K ND)
- Focussed / Imaging
- Optical Readout
  for STP Gas TPC (HYPER-K ND)
  for High Pressure TPC (DRD1 / WP8)

Eager to move our PhotoDet. activities from LNL to new Lab. “dell’Universo” in via Luzzatti

Courtesy
E.Radicioni
G.Catanesi

HPTPC with optical readout (a possible "great" improvement)



- Primary ionisations in the drift region are guided to the amplification region by an electric field
- Amplification produces electrons and photons
- Cameras image the amplification region and record a 2D projection of the electroluminescence photon
- Highly segmented readout (~ 100 × 100 μm^2) at low cost per pixel possible

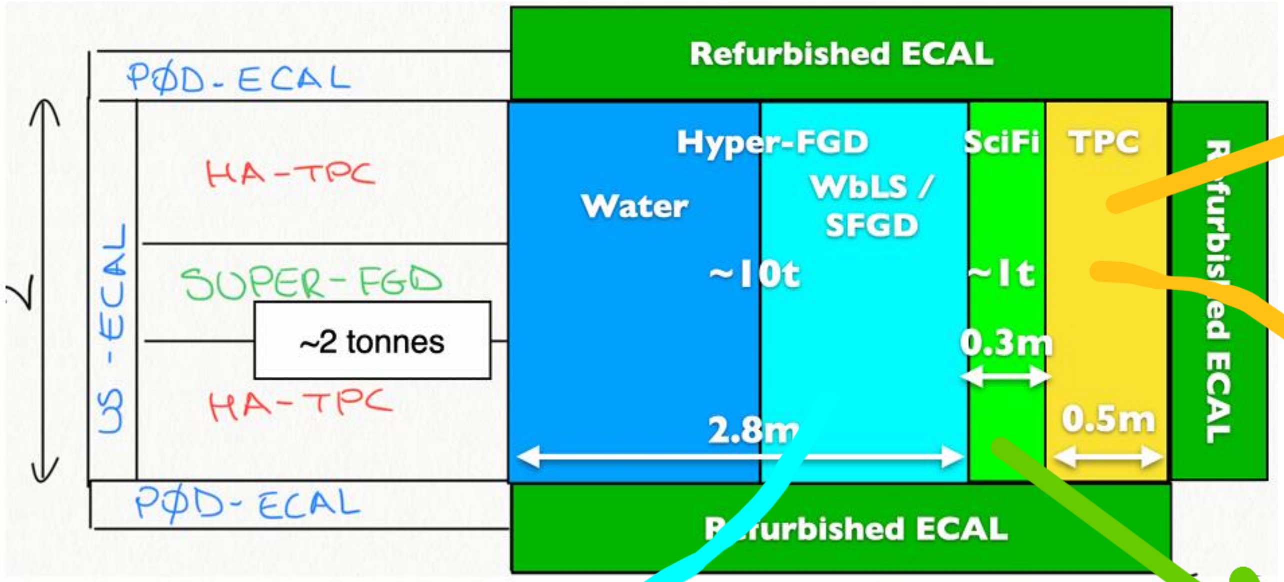
Current CCD cameras do not allow to access the longitudinal coordinate due to their slow readout speed

The goal is to combine optical and charge readout ➔Full 3D tracking information (since the longitudinal coordinate can be reconstructed from charge signals) ➔ (TimePix or SIPM array)

NB: optical readout is also of great interest for for the beam instrumentation case:

1) reduction of the budget material along the beam line
2) readout optimization ➔ low gas amplification factor ➔ high density of tracks

Further upgrade Hyper-Kamiokande Near Detector (2030)



Development **TPC Optical Readout**

Synergy → DRD1/4 / INFN Gr5 TIMEPIX4

1. Downstream TCP under study

- Optical readout of avalanche gas multiplication
- Extended drift regions
- Transparent conductive anodes
- Advanced timing solutions

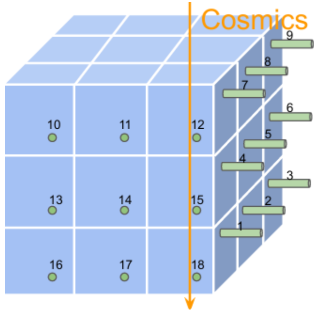
2. “Thin” top and bottom TCPs under evaluation

Development new **Digital-SiPM**

Synergy → DRD4 / INFN Gr5 ASPIDES

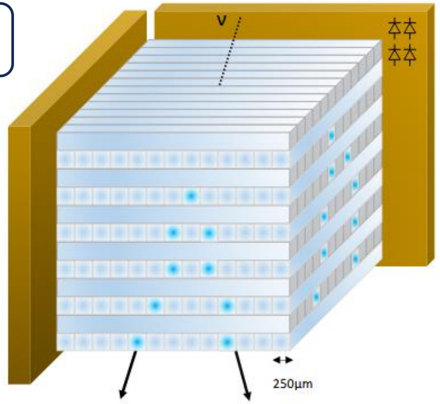
Development new **Back Side illuminated SiPM**

Synergy → DRD4 / INFN Gr5 IBIS-Next (C.Forza - PhD)



Readout of
Water-based liquid scintillator

SiPM => low noise & high PDE



→ Optical Readout of TPC

← Readout of
very fine grained sci-fi detector

Further upgrade HK Near Detector

Requests to ASPIDES: optical instrumentation & parts for Photo-detector characterization

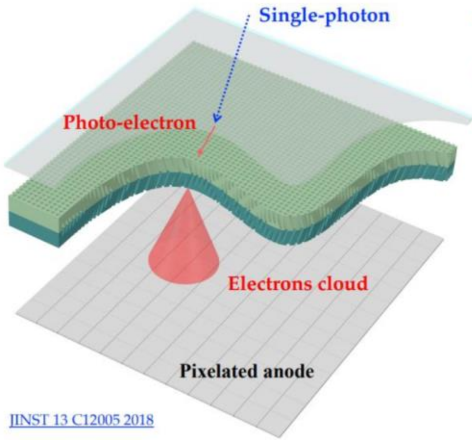
Requests to TIMEPIX4: gas multiplier structures

DTZ-Gr1 Padova: provided FPGAs for Readout systems

Requests to HK for R&D = optical parts for imaging anode (Lenses, Mirrors, Quartz windows …) needed also for TPC laser data taking
Request → O(15kE) including MM structures (prev. slide)

Development **TPC Optical Readout**

Synergy → DRD1/4 / INFN Gr5 TIMEPIX4



JINST 13 C12005 2018

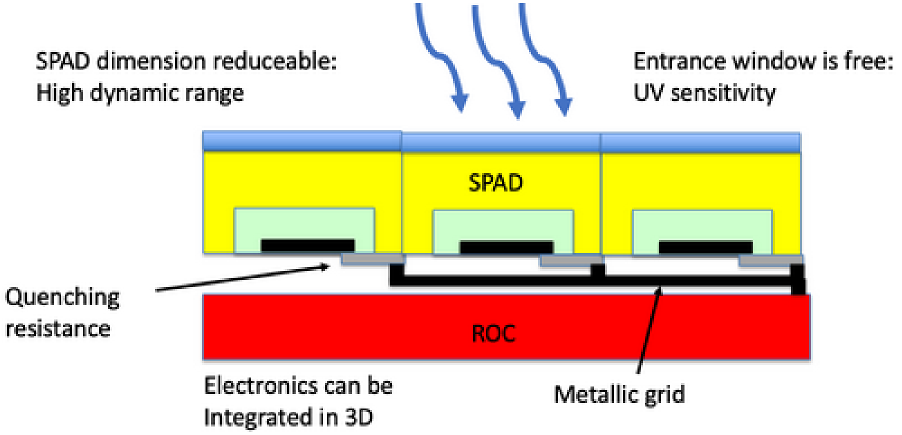
- Entrance window + photocathode
- Microchannel plate stack
- Timepix4 ASIC as pixelated anode
  - Electron cloud (pixels cluster)
  - 55µm × 55µm pitch
  - 0.23 M pixels measuring arrival time and duration of input signals
  - 7 cm² active area
  - Up to 2.5 Ghits/s
  - Local signal processing

Development new **Digital-SiPM**

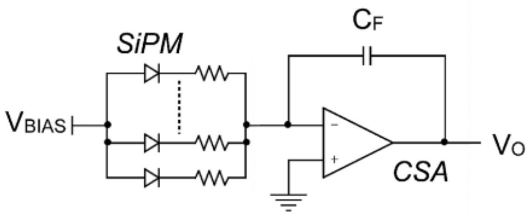
Synergy → DRD4 / INFN Gr5 ASPIDES

Development new **Back Side illuminated SiPM**

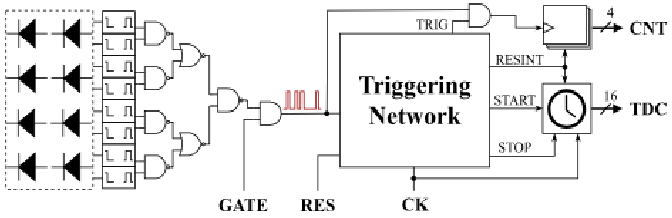
Synergy → DRD4 / INFN Gr5 IBIS-Next (C.Forza - PhD)



SiPMs: analogue signal proportional to number of fired cells, readout performed externally



Digital (CMOS) SiPMs: readout functionalities implemented in the sensor substrate (e.g. binary counters, SPAD masking, TDCs …)



Rivelatori, elettronica

SLBP [Nuova Proposta]

Sapphire detectors for Luminosity and Beam Profile

Area di ricerca: Rivelatori, Elettronica

Periodo:2026-2028

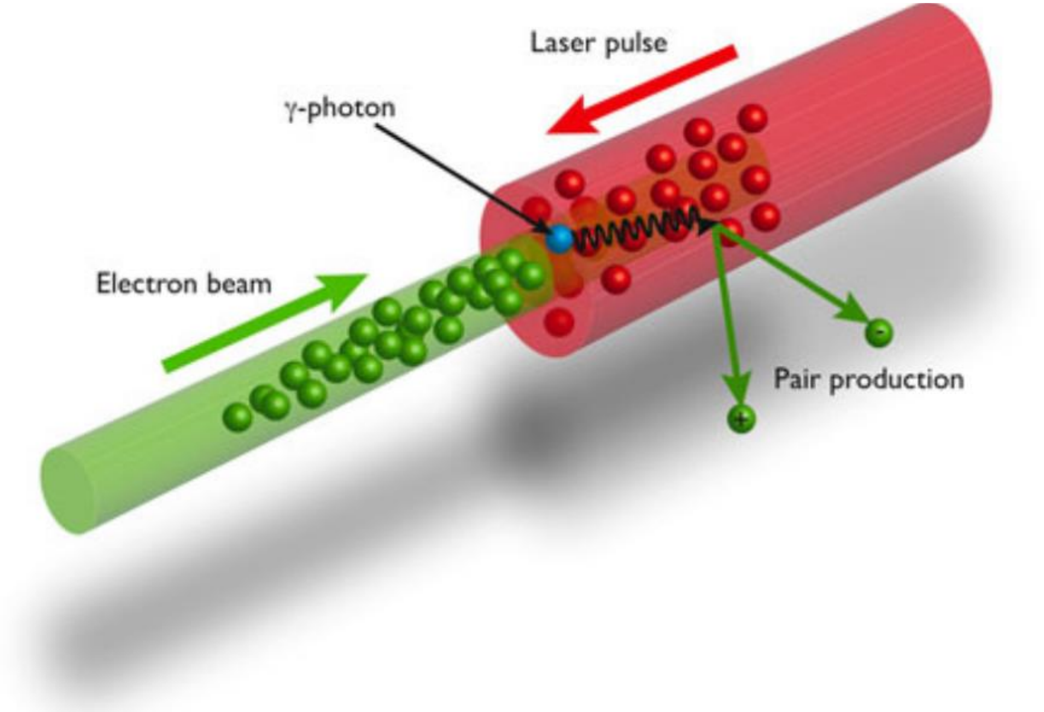
Responsabile locale: P. Grutta
Responsabile nazionale: M. Bruschi (BO)

Participating Units: Padova, Bologna

Motivazione

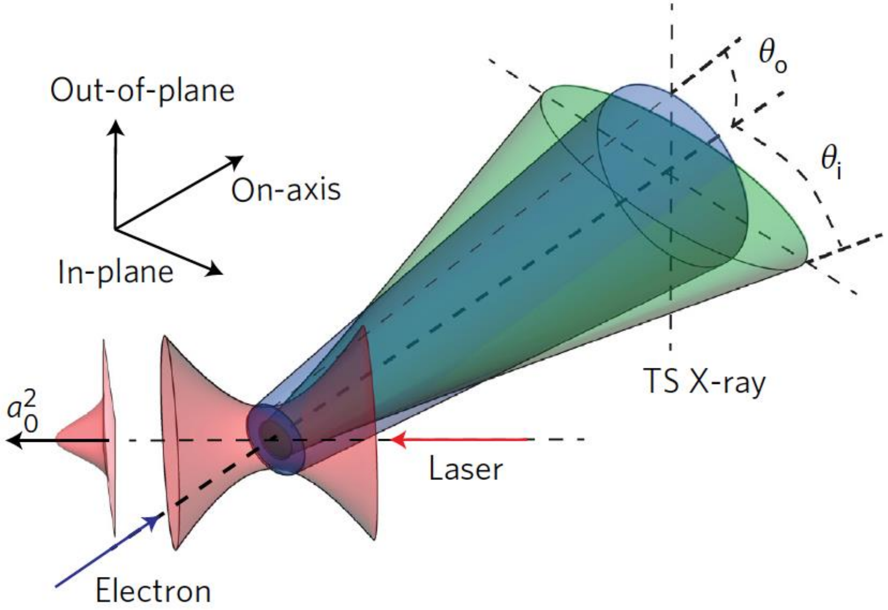
- LUXE (Laser Und XFEL) a DESY
  - Nuovo esperimento HEP proposto a DESY e Eu.XFEL
  - Collisioni inizialmente di fascio di elettroni XFEL e Laser ad alta potenza – in una seconda fase di fascio gamma con Lase, Collaborazione internazionale – ~100 membri (20 istituzioni a Apr. 2024), Gruppi INFN coinvolti: Bologna, Padova

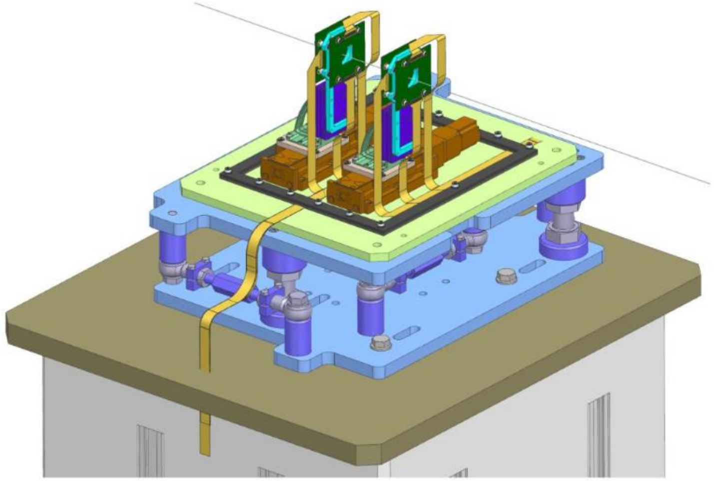
- Obiettivi
  - esplorare le interazioni di fotoni reali con elettroni e positroni in un regime di intensità del campo e.m. dove gli accoppiamenti con le cariche diventano non-lineari a nonperturbativi (Strong Field QED)
  - effettuare misure di precisione di tali interazioni in particolare nella regione di transizione fra il regime perturb. e non perturb. della QED
  - utilizzare i processi di strong-field QED per effettuare una ricerca di nuove particelle BSM

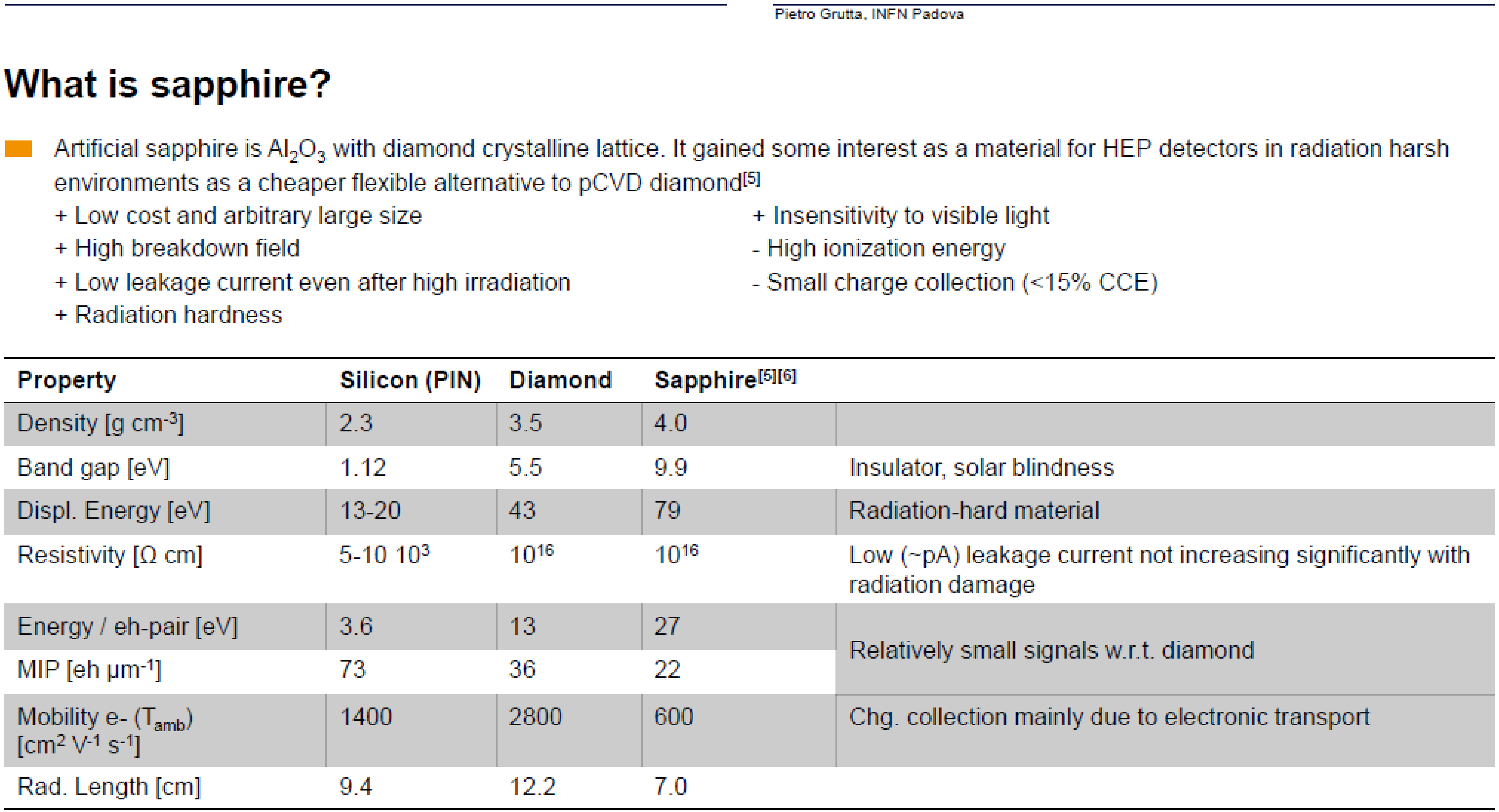


Motivazione

- Per la misura dell'intensity`a del laser e' necessario un monitor del profile del fascio realtime
- Il rivelatore proposto per misurare il profilo del fascio utilizza due sensori a micro-strip di zaffiro con passo 100 um di 2x2 cm2, con le strip ortogonalizaffiro è un buon match per un fascio intenso con fino a 109 fotoni per bunch, data:notevole resistenza alla radiazione
- corrente di leakage che non aumenta con la dose assorbita
- bassa CCE che è compensata dal poter utilizzare di spessori sottili
- L'obiettivo è di arrivare ad una misurare della larghezza del fascio < 10 um







Pietro Grutta, INFN Padova

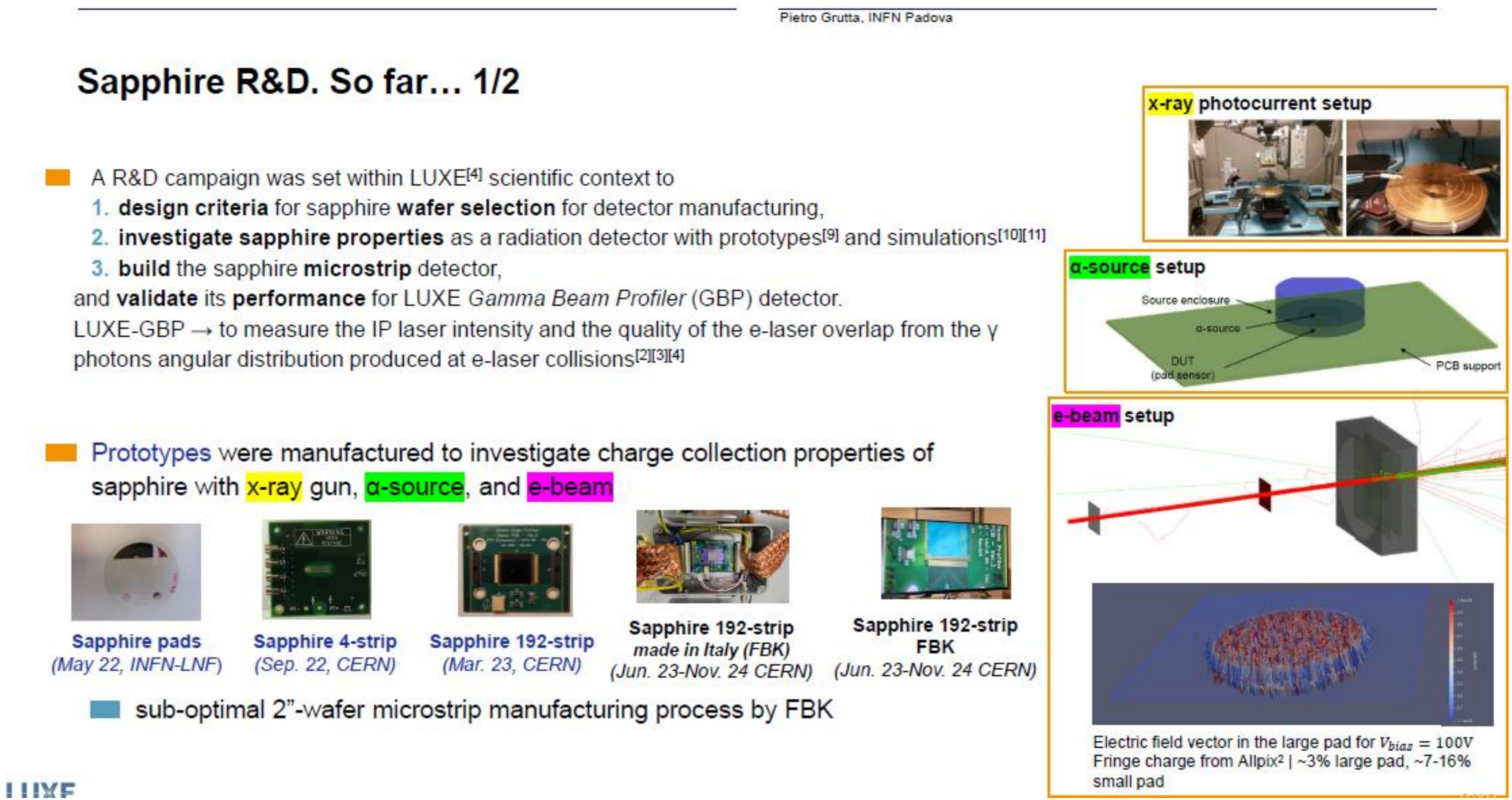
What is sapphire?

- Artificial sapphire is Al_2O_3 with diamond crystalline lattice. It gained some interest as a material for HEP detectors in radiation harsh environments as a cheaper flexible alternative to pCVD diamond[5]

+ Low cost and arbitrary large size
+ High breakdown field
+ Low leakage current even after high irradiation
+ Radiation hardness

+ Insensitivity to visible light
- High ionization energy
- Small charge collection (<15% CCE)

Property	Silicon (PIN)	Diamond	Sapphire[5][6]	
Density [g cm^{-3}]	2.3	3.5	4.0	
Band gap [eV]	1.12	5.5	9.9	Insulator, solar blindness
Displ. Energy [eV]	13-20	43	79	Radiation-hard material
Resistivity [Ω cm]	5-10 10^3	10^{16}	10^{16}	Low (~pA) leakage current not increasing significantly with radiation damage
Energy / eh-pair [eV]	3.6	13	27	Relatively small signals w.r.t. diamond
MIP [eh μm^{-1}]	73	36	22	
Mobility e- (T_{amb}) [cm^2 V^{-1} s^{-1}]	1400	2800	600	Chg. collection mainly due to electronic transport
Rad. Length [cm]	9.4	12.2	7.0	



Sapphire R&D. So far… 1/2

- A R&D campaign was set within LUXE[4] scientific context to
  1. **design criteria** for sapphire **wafer selection** for detector manufacturing,
  2. **investigate sapphire properties** as a radiation detector with prototypes[9] and simulations[10][11]
  3. **build** the sapphire **microstrip** detector,

  and **validate** its **performance** for LUXE *Gamma Beam Profiler* (GBP) detector.

  LUXE-GBP → to measure the IP laser intensity and the quality of the e-laser overlap from the γ photons angular distribution produced at e-laser collisions[2][3][4]

- Prototypes were manufactured to investigate charge collection properties of sapphire with x-ray gun, α-source, and e-beam

Sapphire pads
(May 22, INFN-LNF)

Sapphire 4-strip
(Sep. 22, CERN)

Sapphire 192-strip
(Mar. 23, CERN)

Sapphire 192-strip ***made in Italy (FBK)***
(Jun. 23-Nov. 24 CERN)

Sapphire 192-strip FBK
(Jun. 23-Nov. 24 CERN)

- sub-optimal 2”-wafer microstrip manufacturing process by FBK

x-ray photocurrent setup

α-source setup

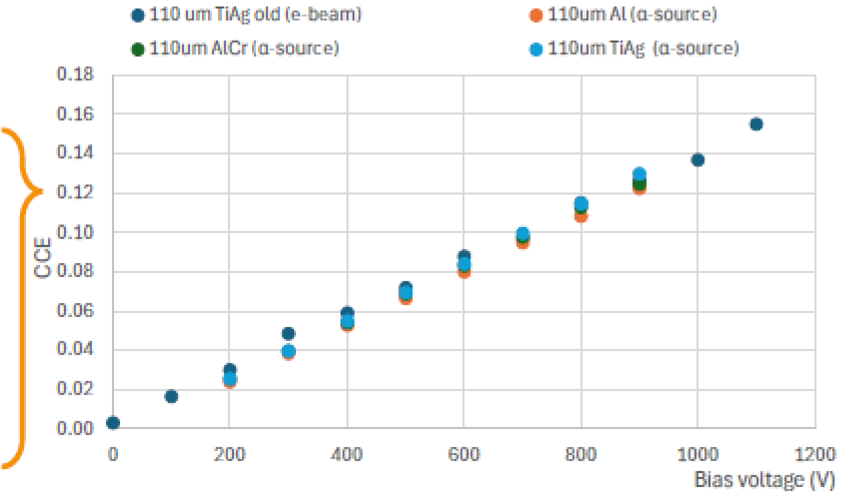
e-beam setup

Electric field vector in the large pad for $V_{bias} = 100V$
Fringe charge from Allpix^2 | ~3% large pad, ~7-16% small pad

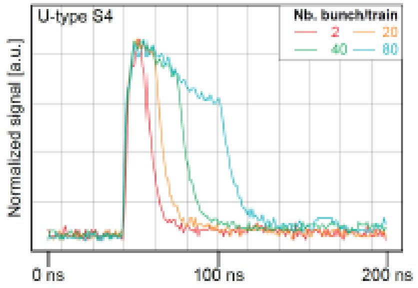
Pietro Grutta, INFN Padova

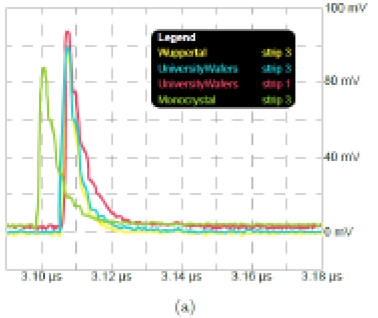
Sapphire R&D. So far… 2/2

- CCE(-V) + α-source → **Negligible hole contribution**
- **Plasma effect** with α-particles could difference w.r.t. e-beam in $\mu\tau$ (lower reduced collection distance in a $d_1 = 6\ \mu\text{m}$ region)
- Small charge collection distance with respect to thickness
  - Typical **CCE 10%** for $110\ \mu\text{m}$ at HV bias **6 V μm^{-1}**
  - Product $(\mu\tau)_e \in [1,\ 3]\ \mu\text{m}^2/\text{V}$

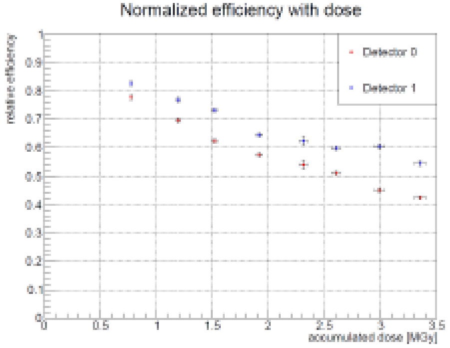


- **Time-resolved** readout of sapphire signal **without** amplification[9]
  - From rise-time **low electron mobility** $\mu_e \lesssim 1.5\ \text{cm}^2(\text{Vs})^{-1}$
  - Pulse decay components hints on **2 types of electron traps**





- **Measured radiation damage** degradation $O\left(\frac{1}{2}\text{CCE}_0\right)$ **at 12 MGy**



Project proposal

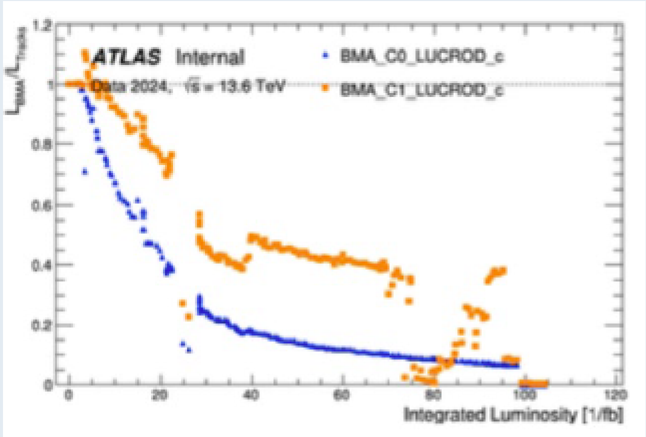
- **Goal:** Develop radiation-hard sapphire-based detectors for luminosity measurement
- **Target applications**
  - Gamma Beam Profiler for LUXE (DESY, 2029/2030)
  - Luminosity measurement in ATLAS (HL-LHC) as LGAD replacement.
- Other possible applications (harsh environments)
  - Long-term neutron/gamma flux monitoring in nuclear reactors (w/ CAEN A1425 readout)
  - Medical application in e/ɣ irradiation processes (sterilization)
  - Dosimetry at high temperatures (i.e., where silicon-based detector have large leakage)
- **Structure**
  1. WP1 – finalization of GBP sensor
     1. WP1.1 – improve current sub-optimal electronics setup
     2. WP1.2 – investigate sapphire non-linearity charge response in LUXE-like (low) intensity regime
     3. WP1.3 – deepen sapphire charge generation (DLTS, TCT, PIXE + simulations)
     4. (2027) WP1.4 – new microstrip sensor manufacturing
  2. WP2 – sapphire-based ATLAS BMA
     1. WP2.1 solution-1 manufacturing and characterization
     2. (2027) WP2.2 solution-2 manufacturing and characterization

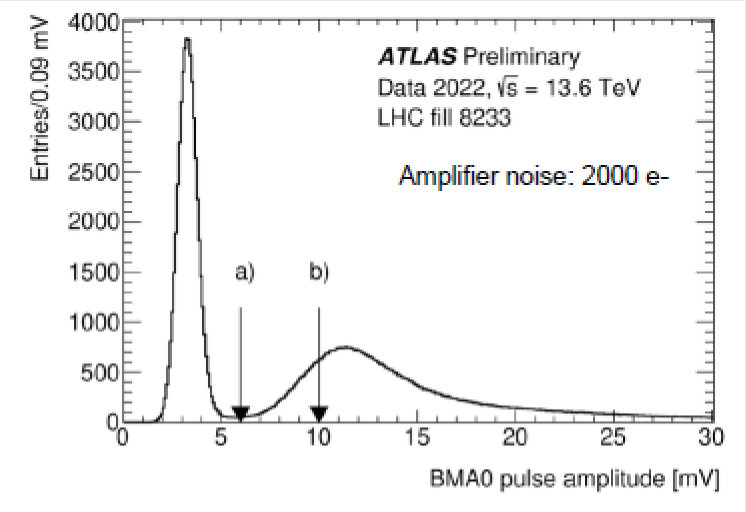
WP2 - Atlas BMA

- Develop radiation-hard sapphire-based detectors for luminosity measurement (as upgrade for ATLAS's BMA)

current ATLAS BMA

- Two C-doped LGAD 1.3x1.3 mm^2 0.7mm-thick pads / C ~ 0.3 pF
- Detector pre-amp. connection over 25m cable
- 80% efficiency loss in 80 fb^{-1} (Run4 300 fb^{-1}/yr)



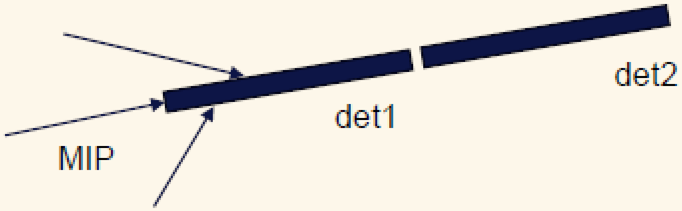


WP2 - Atlas BMA

- Develop radiation-hard sapphire-based detectors for luminosity measurement (as upgrade for ATLAS's BMA)

sapphire-based BMA - type 1 (2026)

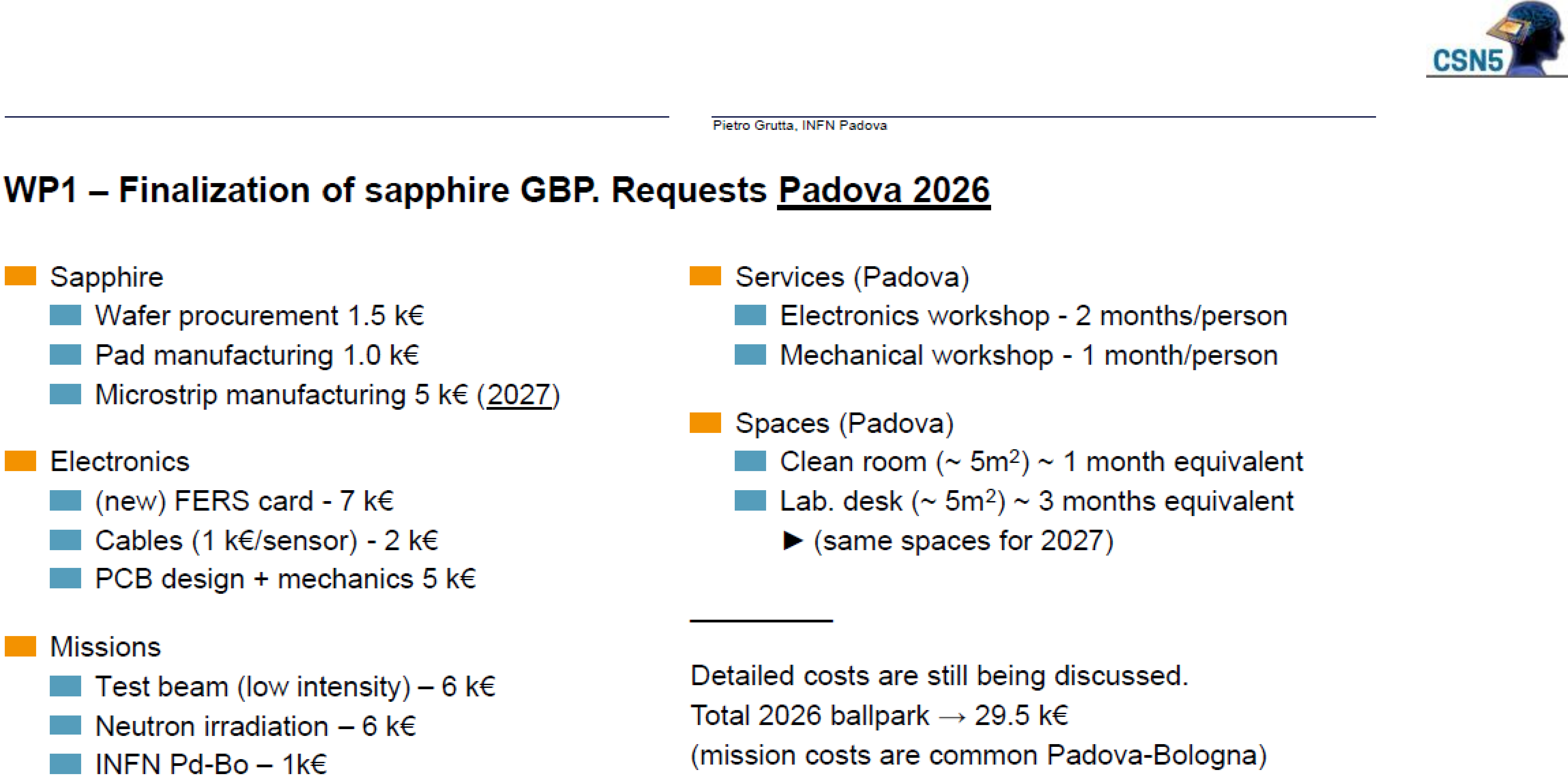
- Sapphire pointing detector
- 1 x 1 mm^2 cross section
  18 mm thickness / C = 1.6 pF



- Signal = 18000e x 22 e/um x 5% CCE
  ~ 20000 e-
  - S/N ~ 10
- MIPs releasing lower signals can be cut away with a 2-channel coincidence

sapphire-based BMA - type 2 (2027)

- 20 ps time resolution with a fully-efficient monolithic silicon pixel detector without internal gain layer
- Sensor geometry with 0.7 mm2 cross section by 0.7mm thickness
  C = ~ 90 fF
- Charge produced 22 eh/um x 700 um ~ 15.4 ke
  - assuming CCE~5% 700e
    → S/N ~ 770/87 ~ 8
- Dose up to 1e16 n/cm2



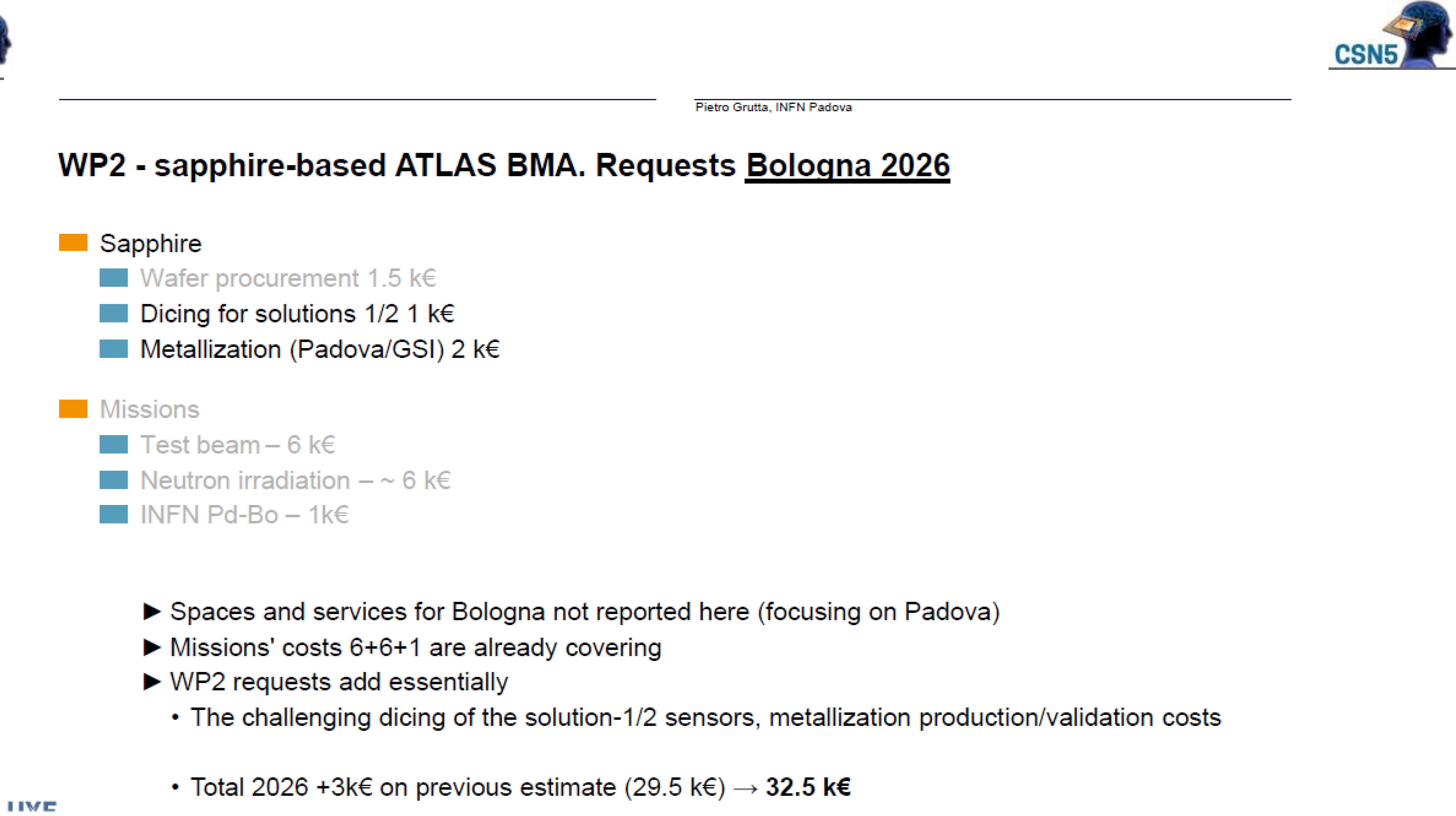
Pietro Grutta, INFN Padova

WP1 – Finalization of sapphire GBP. Requests Padova 2026

- Sapphire
  - Wafer procurement 1.5 k€
  - Pad manufacturing 1.0 k€
  - Microstrip manufacturing 5 k€ (2027)
- Electronics
  - (new) FERS card - 7 k€
  - Cables (1 k€/sensor) - 2 k€
  - PCB design + mechanics 5 k€
- Missions
  - Test beam (low intensity) – 6 k€
  - Neutron irradiation – 6 k€
  - INFN Pd-Bo – 1k€

- Services (Padova)
  - Electronics workshop - 2 months/person
  - Mechanical workshop - 1 month/person
- Spaces (Padova)
  - Clean room (~ 5m^2) ~ 1 month equivalent
  - Lab. desk (~ 5m^2) ~ 3 months equivalent
    - ▶ (same spaces for 2027)

Detailed costs are still being discussed.
Total 2026 ballpark → 29.5 k€
(mission costs are common Padova-Bologna)



WP2 - sapphire-based ATLAS BMA. Requests Bologna 2026

- Sapphire
  - Wafer procurement 1.5 k€
  - Dicing for solutions 1/2 1 k€
  - Metallization (Padova/GSI) 2 k€

- Missions
  - Test beam – 6 k€
  - Neutron irradiation – ~ 6 k€
  - INFN Pd-Bo – 1k€

- ▶ Spaces and services for Bologna not reported here (focusing on Padova)
- ▶ Missions' costs 6+6+1 are already covering
- ▶ WP2 requests add essentially
  - The challenging dicing of the solution-1/2 sensors, metallization production/validation costs

  - Total 2026 +3k€ on previous estimate (29.5 k€) → **32.5 k€**

Person power

Collaboration between INFN Padova and Bologna, plus experts from solid state wide band gap materials and electronics from other institutes.

- INFN Padova ($\sum_{FTE}$ 0.6)
  - M. Morandin (0.4), P. Grutta (0.2)

- INFN Bologna ($\sum_{FTE}$ 0.9)
  - M. Bruschi (0.5), F. Lasagni Manghi (0.4, PI), R. Cardarelli

- Other collaborators
  - M. Angelone (ENEA Frascati), D. Trucchi (CNR Montelibretti), M. Pillon (CNR Milano), CAEN

Rivelatori, elettronica

INCANTO [Call]
InNovative CAlorimeters for New Topologies and Operation

Area di ricerca: Rivelatori, Elettronica

Periodo:2026-2028

Responsabile locale: D. Zuliani [ma discussione in corso]
Responsabile nazionale**:** LNF

Participating Units Bari, Ferrara, Firenze, LNF, MiB, Padova, Roma3

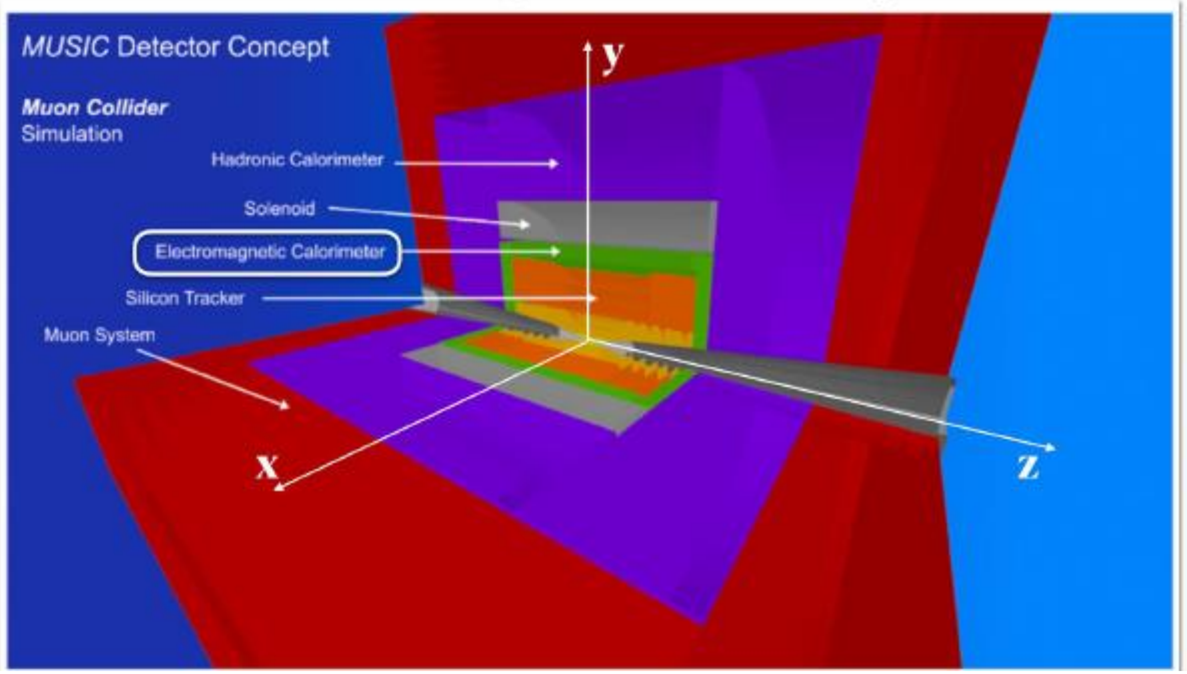
Goals

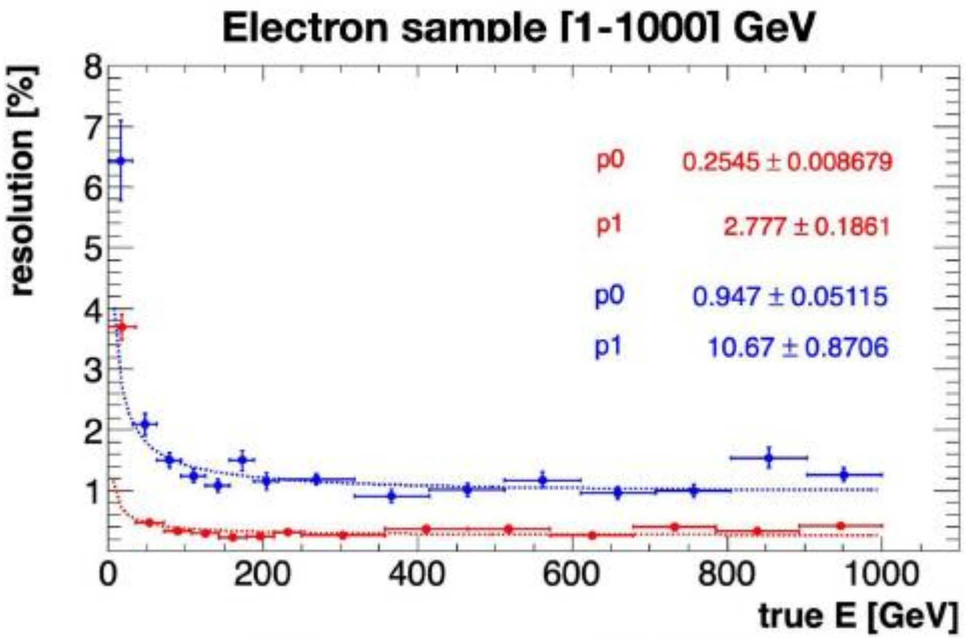
- push calorimeter technology well beyond the current state of the art, addressing the stringent requirements posed by future collider detectors and high-intensity fixed-target experiments
- Construct and test **two longitudinally segmented ECAL prototypes** based on **dense, fast, radiation-hard crystals** (PbF2 and PWO-UF), exploring both **oriented and non-oriented crystal** configurations. One module will feature **SiPM matrices** for compact, low-power readout in magnetic fields, while the other will use **fast PMTs** for high-intensity environments .
- Develop and assemble a **~1.5 λI high-granularity semi-digital HCAL** module based on **MPGD technologies** (MicroMegas and/or µRWELL), capable of achieving fine spatial and temporal resolution, by leveraging sampling layers interleaved with absorber materials. Specifically, we will improve the MPGD design by **optimizing the width of the drift gap to improve the time resolution at the O(1ns)** level.
- **Implement dedicated front-end electronics**, combining both **commercial solutions** (e.g., CAEN) and **custom-developed designs**, with a focus on scalability, fast timing performance (sub-100 ps), and radiation tolerance. For the MPGD-HCAL, the final readout electronics should ensure low noise (ENC ~1000 e^-) and a wide dynamic range (1–100 fC), enabling studies of various semi-digital readout architectures.
- A rigorous validation program is planned, including **extensive test beam campaigns on both individual components and integrated calorimeter modules**. The combined ECAL+HCAL systems will be tested to assess their performance in terms of energy resolution, reconstruction techniques, and particle identification capabilities.
- The project also fosters the creation of a **unified Italian calorimetry community, combining expertise in detector development, electronics, simulations, and data analysis**, thus positioning itself at the forefront of global calorimeter R&D efforts.

@ Padova: simulation

- ➢ The Padova group has always been involved in simulation activities of calorimeters for future colliders
- ➢ In particular, evaluation of ECAL performance for a Muon Collider

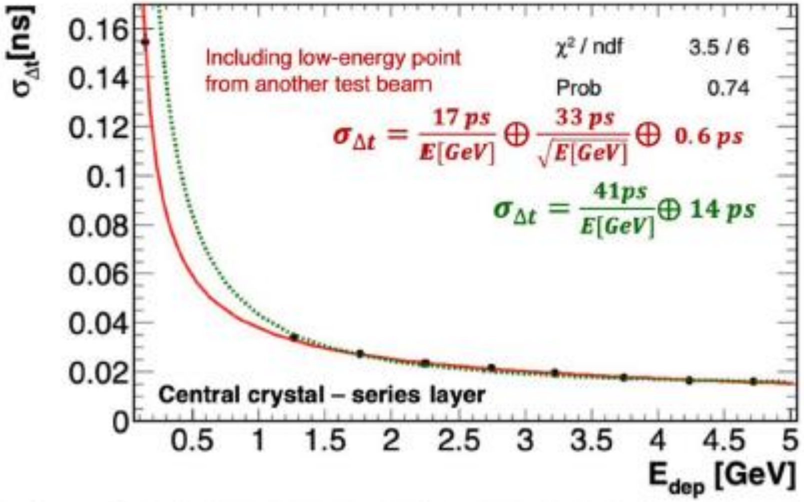
MUSIC: MUon System for Interesting Collisions

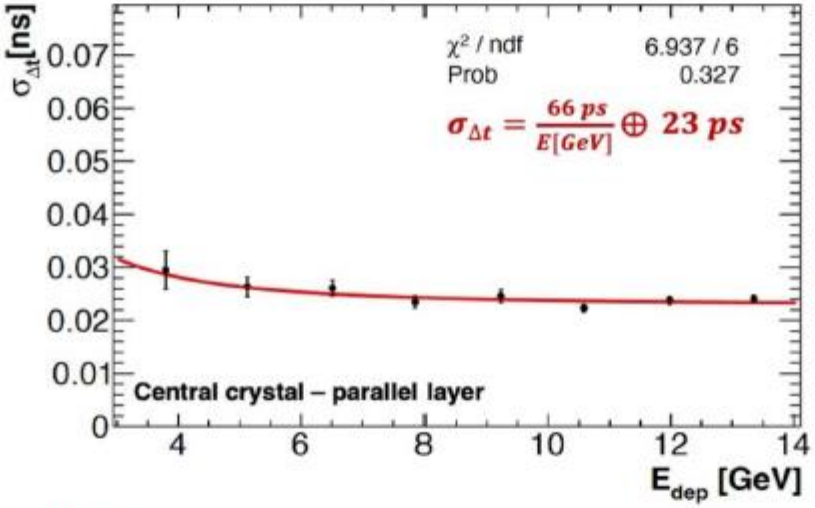


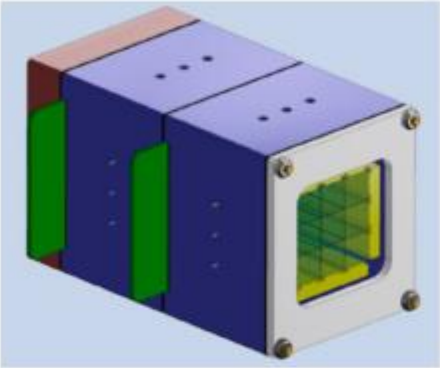


@ Padova: test beams

- The Padova group has also been involved in recent test beam activities for performance evaluation of calorimeter prototypes
- Characterization of energy and time resolution
- Several test beams @ different facilities (SPS, LNF-BTF)



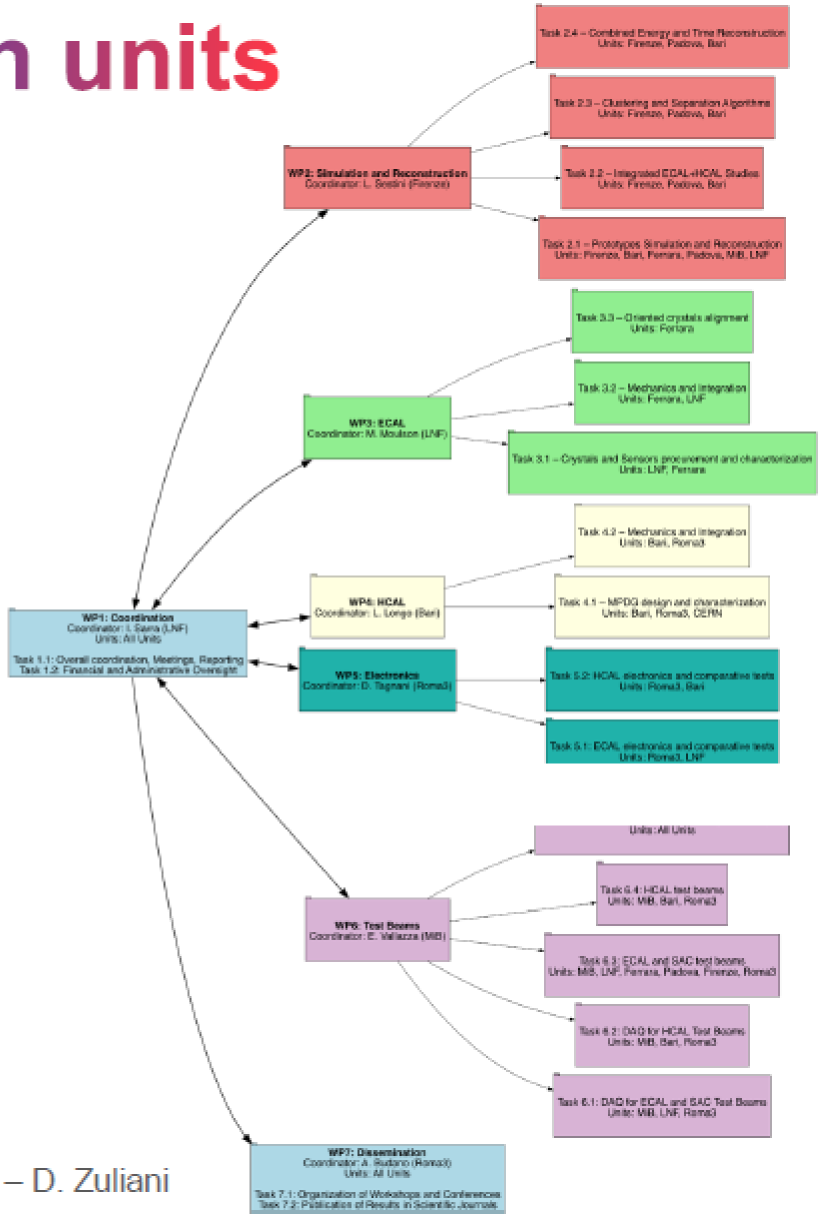




Research units

INCANTO

- The INCANTO project is built on the consolidated expertise of INFN units (Bari, Ferrara, Firenze, LNF, MiB, Padova, Roma3), which have long-standing experience in detector development, supported by technical infrastructures and international collaborations:
  - **47 people – 11 FTE** (2026)
  - **49 people – 14 FTE** (2027-2028)
- The work is organized in **seven Work Packages,** each coordinated by a unit with specific responsibilities.



Task 2.4 – Combined Energy and Time Reconstruction
Units: Firenze, Padova, Bari

Task 2.3 – Clustering and Separation Algorithms
Units: Firenze, Padova, Bari

WP2: Simulation and Reconstruction
Coordinator: L. Sestini (Firenze)

Task 2.2 – Integrated ECAL+HCAL Studies
Units: Firenze, Padova, Bari

Task 2.1 – Prototypes Simulation and Reconstruction
Units: Firenze, Bari, Ferrara, Padova, MiB, LNF

Task 3.3 – Oriented crystals alignment
Units: Ferrara

Task 3.2 – Mechanics and Integration
Units: Ferrara, LNF

WP3: ECAL
Coordinator: M. Moulson (LNF)

Task 3.1 – Crystals and Sensors procurement and characterization
Units : LNF, Ferrara

Task 4.2 – Mechanics and Integration
Units : Bari, Roma3

WP4: HCAL
Coordinator: L. Longo (Bari)

Task 4.1 – MPDG design and characterization
Units: Bari, Roma3, CERN

WP1: Coordination
Coordinator: I. Sarra (LNF)
Units: All Units

Task 1.1: Overall coordination, Meetings, Reporting
Task 1.2: Financial and Administrative Oversight

WP5: Electronics
Coordinator: D. Tagnani (Roma3)

Task 5.2: HCAL electronics and comparative tests
Units : Roma3, Bari

Task 5.1: ECAL electronics and comparative tests
Units : Roma3, LNF

Units : All Units

Task 6.4: HCAL test beams
Units: MiB, Bari, Roma3

WP6: Test Beams
Coordinator : E. Vallazza (MiB)

Task 6.3: ECAL and SAC test beams
Units: MiB, LNF, Ferrara, Padova, Firenze, Roma3

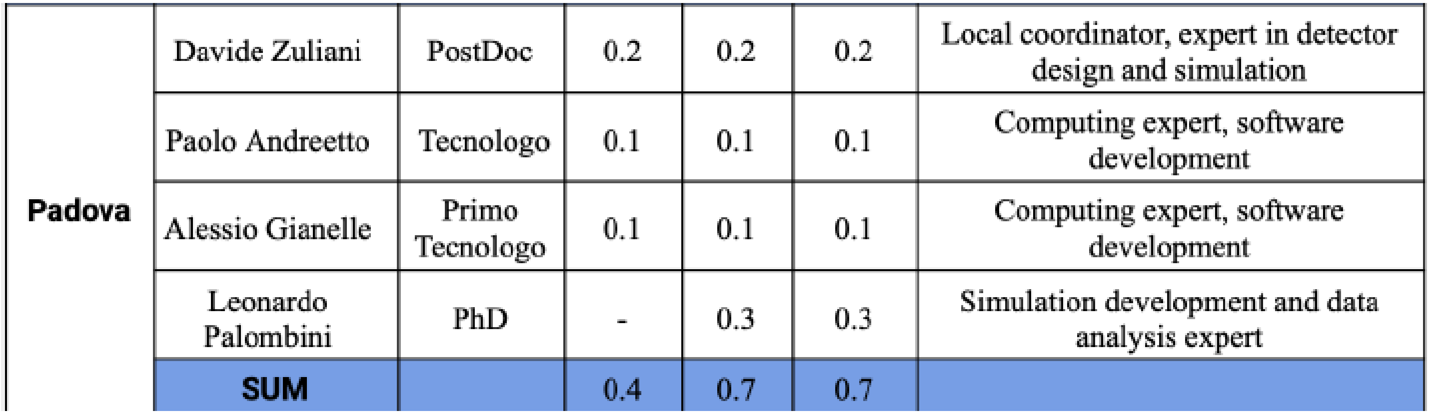
Task 6.2: DAQ for HCAL Test Beams
Units: MiB, Bari, Roma3

Task 6.1: DAQ for ECAL and SAC Test Beams
Units: MiB, LNF, Roma3

WP7: Dissemination
Coordinator: A. Budano (Roma3)
Units: All Units

Task 7.1: Organization of Workshops and Conferences
Task 7.2: Publication of Results in Scientific Journals

PD Research unit and financial request



Padova	Davide Zuliani	PostDoc	0.2	0.2	0.2	Local coordinator, expert in detector design and simulation
	Paolo Andreetto	Tecnologo	0.1	0.1	0.1	Computing expert, software development
	Alessio Gianelle	Primo Tecnologo	0.1	0.1	0.1	Computing expert, software development
	Leonardo Palombini	PhD	-	0.3	0.3	Simulation development and data analysis expert
	SUM		0.4	0.7	0.7	

- **3 people – 0.4 FTE** (2026)
- **4 people – 0.7 FTE** (2027-2028)

Padova	1,2,7	Coordination, meetings, and conferences	2	2	2	Travel
	6	Test beams	-	3	3	Travel
		Totale Padova	**2**	**5**	**5**	**12**

Rivelatori, elettronica

DIOMEDES [Call]
Detector Innovation and custOM Electronics for DEcay Spectroscopy

Area di ricerca: Rivelatori, Elettronica

Periodo:2026-2028

Responsabile locale: F.Recchia
Responsabile nazionale: Milano

Participating Units Mlano, Legnaro, Torino, Padova, Napoli

DIOMEDES call proposal: Detector Innovation and custOM Electronics for DEcay Spectroscopy

<u>S.Capra</u>

Responsabile Nazionale

[1] INFN-Milano
[2] Università degli Studi di Milano

CALL

Durata triennale

Sezione Milano
A. Pullia

Laboratori di Legnaro
D. De Salvador

Sezione Torino
S. D. Tchernij

Sezione Padova
F. Recchia

Sezione Napoli
E. Fasci

Aim

Innovative detector system combining state-of-the-art HPGe and custom electronics for unprecedented performance in decay spectroscopy of exotic nuclei.

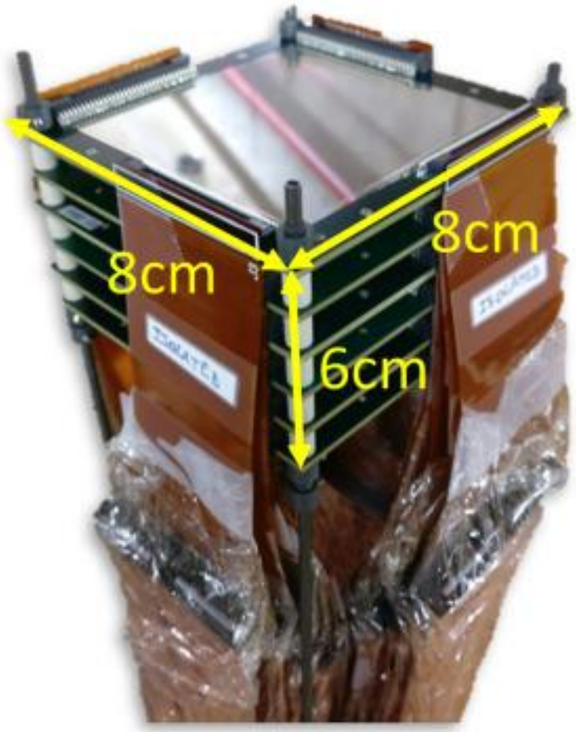
- Design custom integrated readout electronics with high dynamic range and low dead-time
- Develop planar high-purity germanium (HPGe) detectors with exceptional energy resolution, 3D position sensitivity, and radiation-hardness through pulsed laser melting (PLM) technology
- Characterize prototypes through simulations, radioactive sources, and in-beam tests

Final user:

The nuclear physics community studying exotic nuclei through decay spectroscopy with in-flight radioactive ion beams at leading facilities like FAIR.

While primarily targeted for in-flight experiments, the DIOMEDES technology may find future applications at ISOL facilities like SPES for beam characterization or other experiments.

Diomedes strategy:



State of the art: AIDA Silicon double strip detectors absorber.

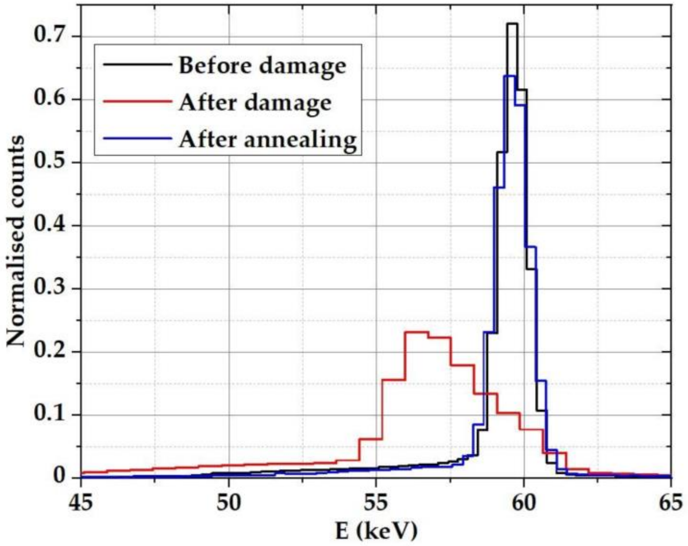
Redefining Readout Capabilities for Decay Spectroscopy:

- High dynamic range: Handling GeV implantations to keV decays
- Ultra-low dead-time: microsecond reset after saturation
- Integrated solution: Compact, high channel density

Diomedes strategy:

Unlocking the Full Potential of HPGe for Decay Spectroscopy

- Planar geometry: Increased thickness for higher detection efficiency
- Submillimeter 3D position sensitivity: Precise implant-decay correlation
- Radiation hardness through PLM technology: Repeated annealing restores performance
- Tailored segmentation: Optimized for energy and position resolution



Technical scientific proposal

WPs	Tasks	Sez.
Integrated Readout Development (Capra,MI)	• Design, simulations and prototyping of key circuit blocks (op-amp, input switch/charge reservoir, current sink, bipolar functionality) on multi-project wafer runs • Characterization and testing of prototypes with silicon detectors • Integration and testing of full readout ASIC with HPGe detector prototypes • Validation using pulsed laser test bench fabricated at INFN Naples	MI NA LNL
Planar HPGe development (De Salvador, LNL)	• Sputtering chamber and B-implantation upgrade (LNL, TO) • Processing of PLM Sb – B implanted double-sided HPGe detector with increasing geometry complexity (LNL, TO) • Cryostat implementation and electrical testing (LNL, MI	LNL TO MI
Detector characterization and in-beam tests (Recchia, PD)	• Use scanning tables to measure reference signals and create database for different interaction positions and adapt signal analysis algorithms from AGATA for planar segmented detectors • Characterize prototypes with collimated radioactive sources at INFN-PD facilities • Perform in-beam tests at FAIR facility	PD MI

Quantum

SQUEEZE
Integrated Squeezed Light Source

Area di ricerca: Rivelatori, Quantum

Periodo:2024-2026

Responsabile locale: M. Bazzan
Responsabile nazionale**:** Padova

Participating Units Padova, TIFPA

Squeezed states of light

- Electric Field Quadratures

Phase noise

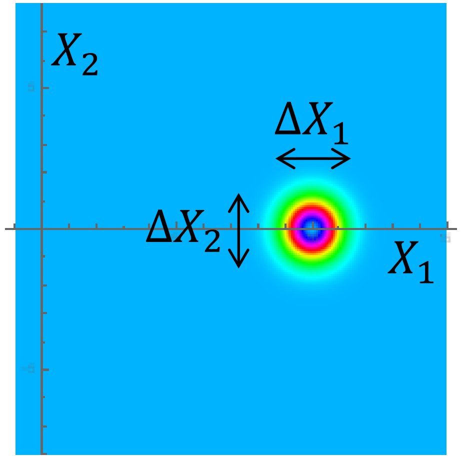
$$\hat{E} = [X_1 + \widehat{\Delta X}_1]Cos(\omega_0 t) + [\widehat{\Delta X}_2]Sin(\omega_0 t) = X_1[1 + \widehat{\Delta X}_1/X_1]Cos(\omega_0 t - \widehat{\Delta X}_2/X_1)$$

Amplitude noise

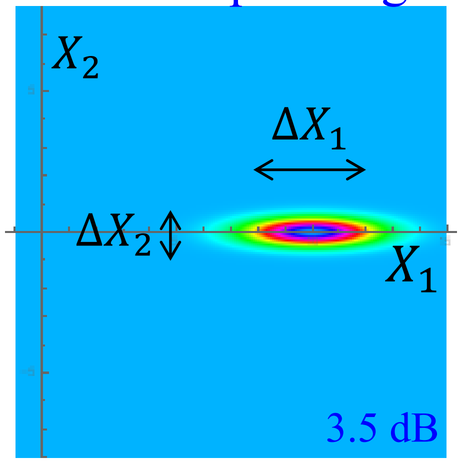
- Minimum Uncertainty States

$$\Delta X_1 \Delta X_2 = 1$$

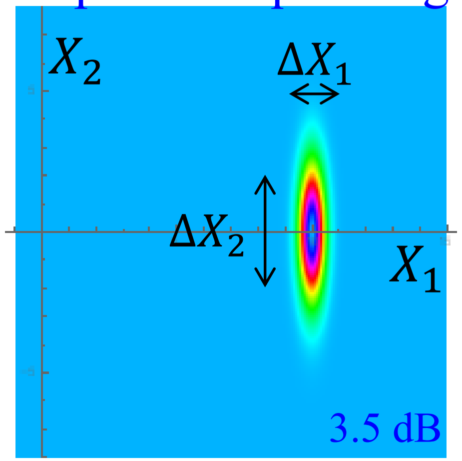
Coherent State



Phase squeezing

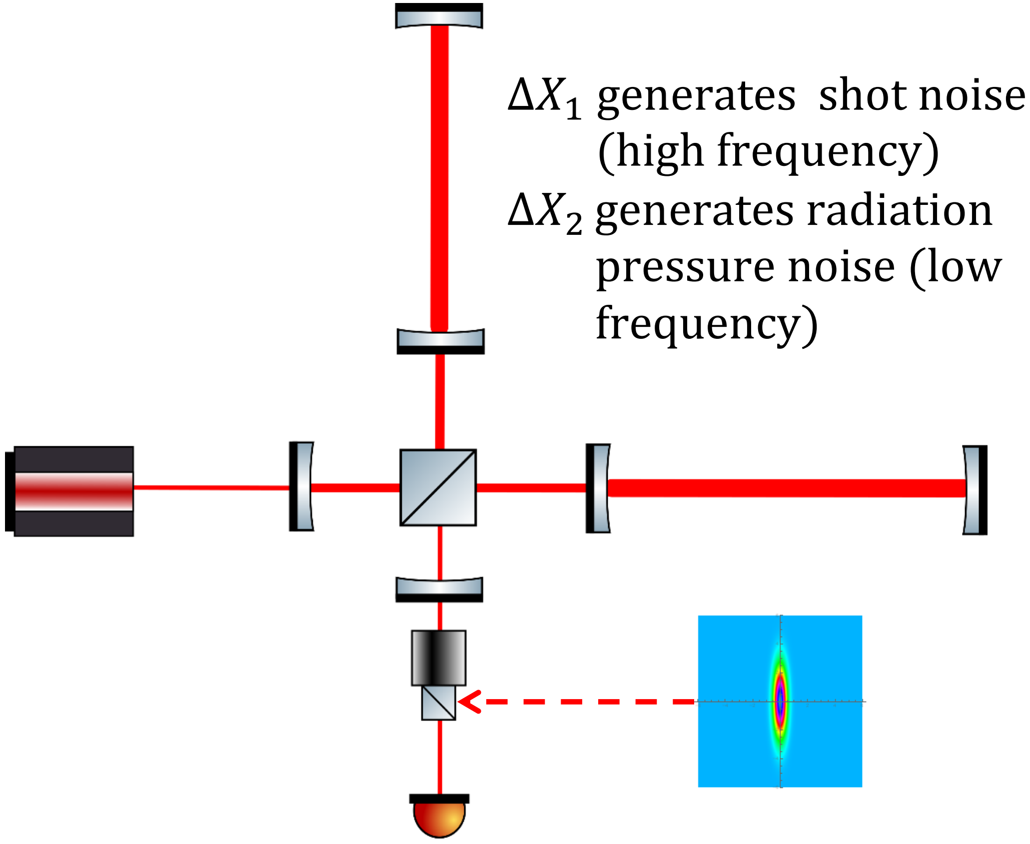


Amplitude squeezing



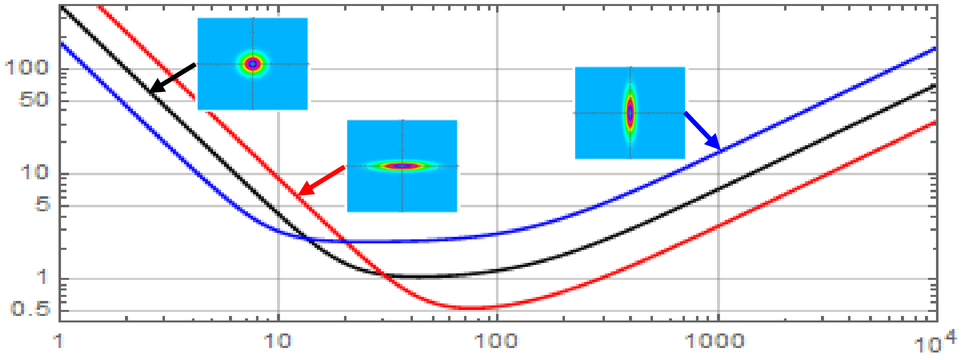
Squeezing and GW detectors

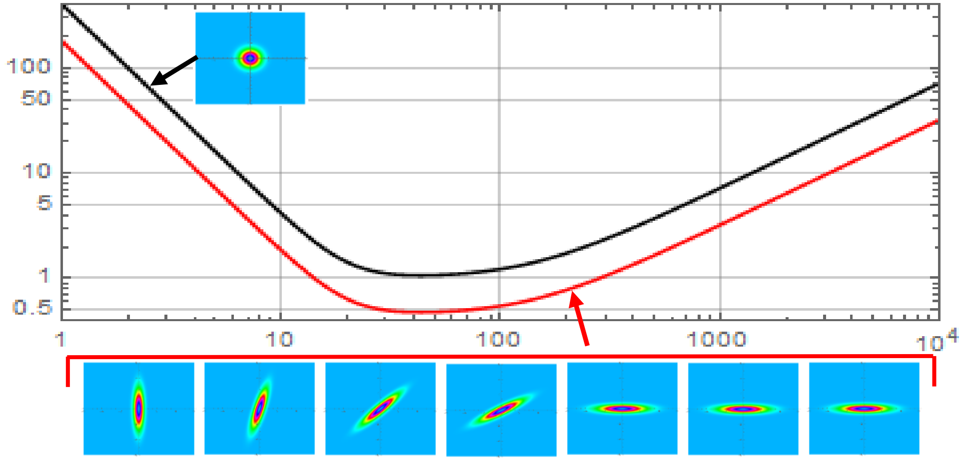
- Quantum noise can be manipulated with squeezed light



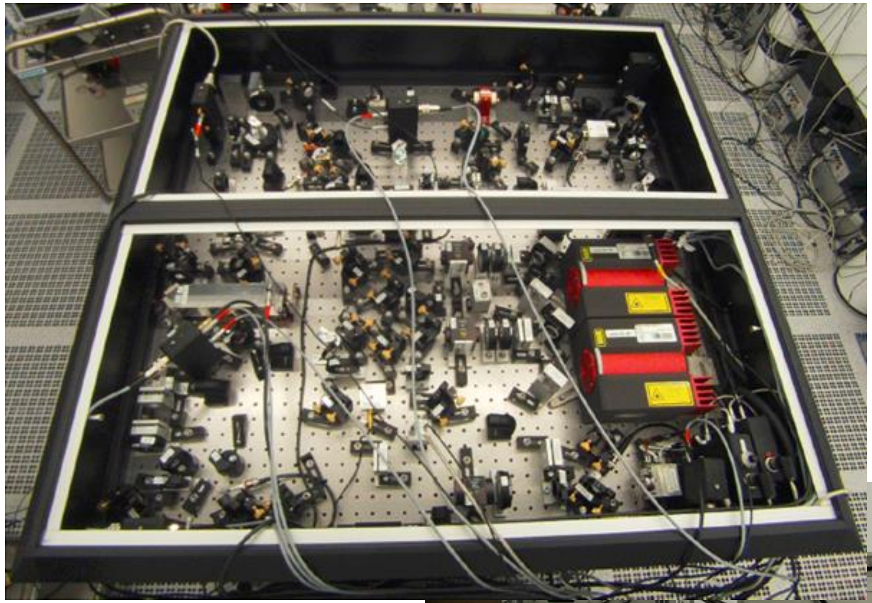
ΔX_1 generates shot noise (high frequency)

ΔX_2 generates radiation pressure noise (low frequency)

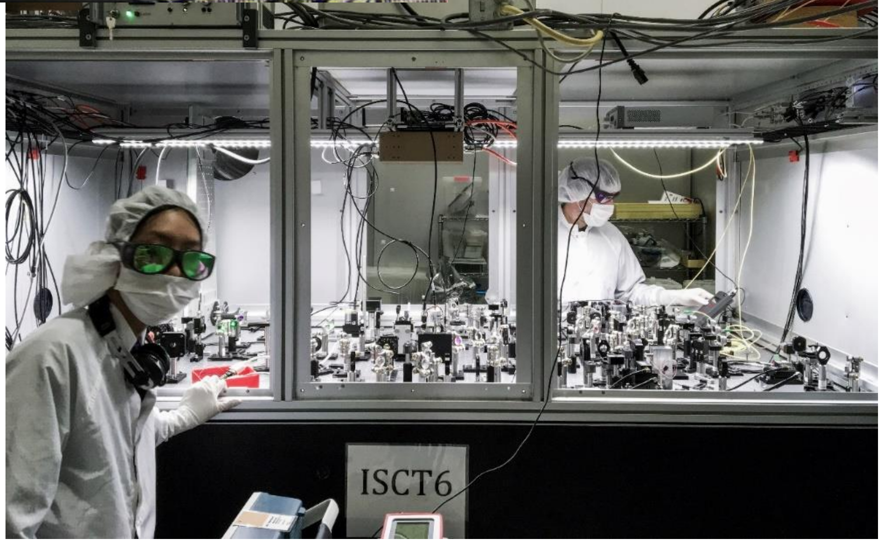




Real squeezer boards



Virgo AEI squeezer



LIGO squeezer

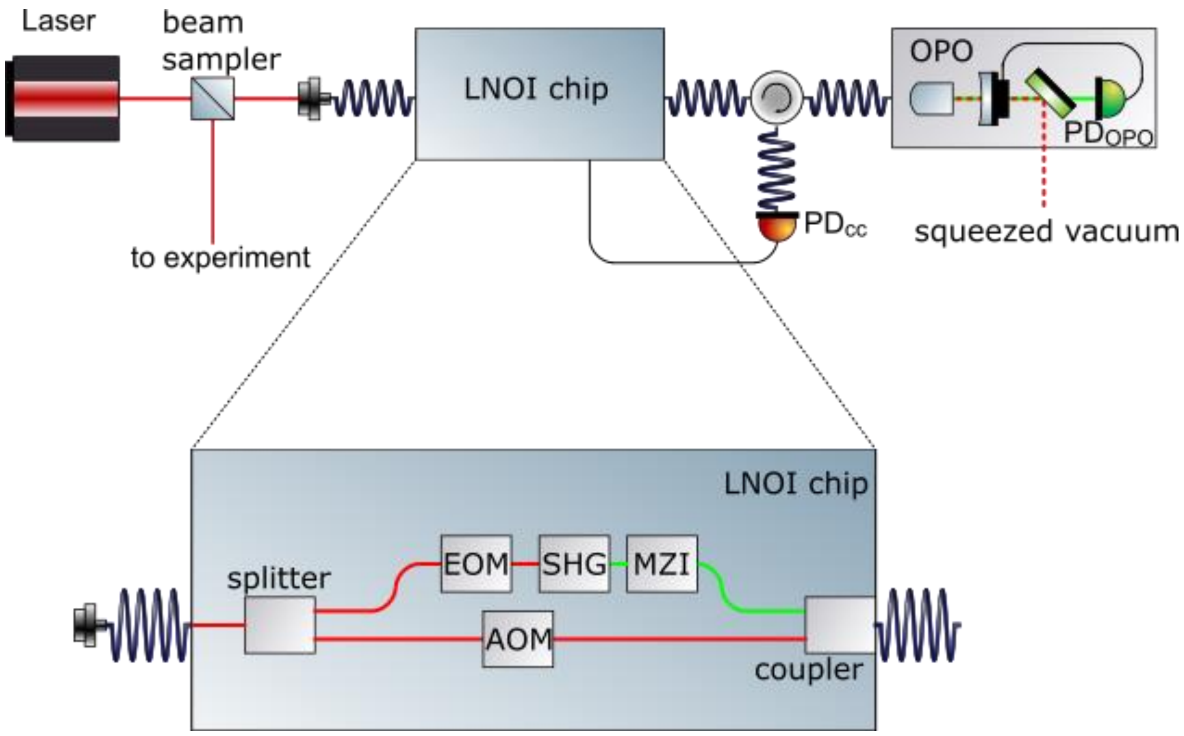
In addition to the OPO a squeezer board includes

- Pump power generator (SHG:Second Harmonic Generator)
- Pump power stabilizer (MZI:Mach Zehnder Interferometer)
- Phase and frequency modulators (EOM, AOM)
- Auxiliary control laser (coherent control laser, Sub Carrier laser..)
- Beam mode cleaners
- Faraday isolators
- Phase Locked Loop optical set-up
- Diagnostic homodyne detector

Most of these components can be integrated in a LNOI chip

LNOI:Lithium Niobate On Isulator

SQUEEZE



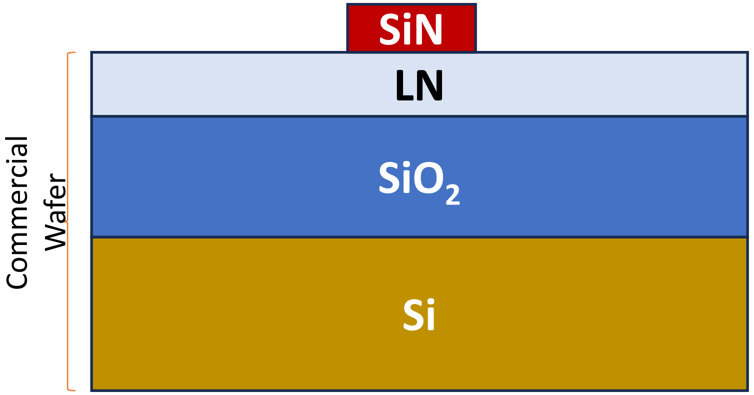
STEPS

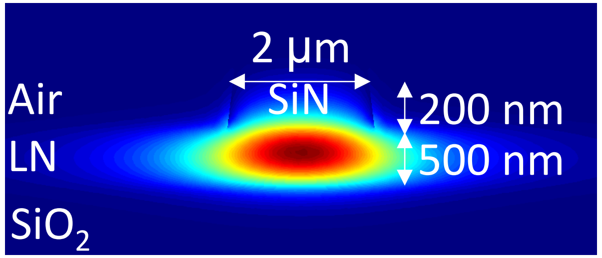
1. Chip design
2. Waveguides
3. Splitter/Couplers
4. Electro-Optic Modulator (EOM)
5. Mach-Zehnder Interferometer (MZI)
6. Second-Harmonic Generation (SHG)
7. Component integration
8. OPO coupling

GOAL: realize an **integrated photonic chip** using **Lithium Niobate on Insulator (LNOI)** technology for the generation of **squeezed light**

Status: Silicon Nitride strip-loaded waveguides

✓ **Waveguide design**





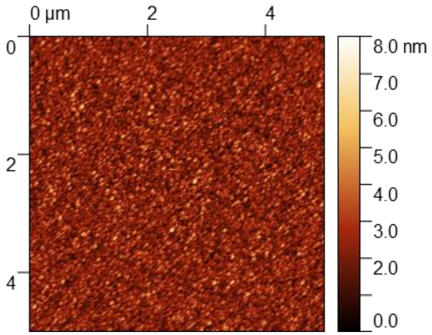
Comsol simulations

✓ **SiN deposition**

RF reactive magnetron sputtering @ INFN-LNL

RBS @ LNL (AN2000)	
N/Si	1.35
Si	53.5%
N	39.6%
O	6.3%
Ar	0.5%

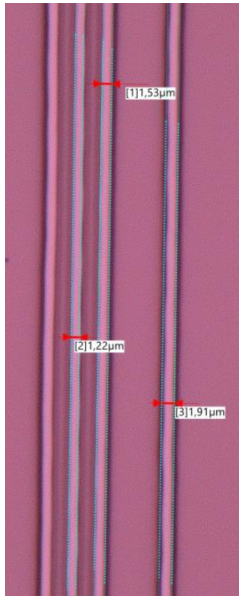
Ellipsometry (1550 nm): n ~ 2.03, k < 10^{-4}

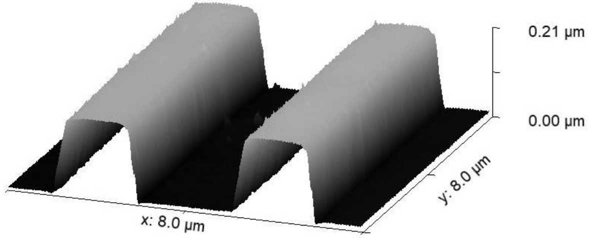


Roughness ~ 0.6 nm

✓ **Waveguide fabrication**

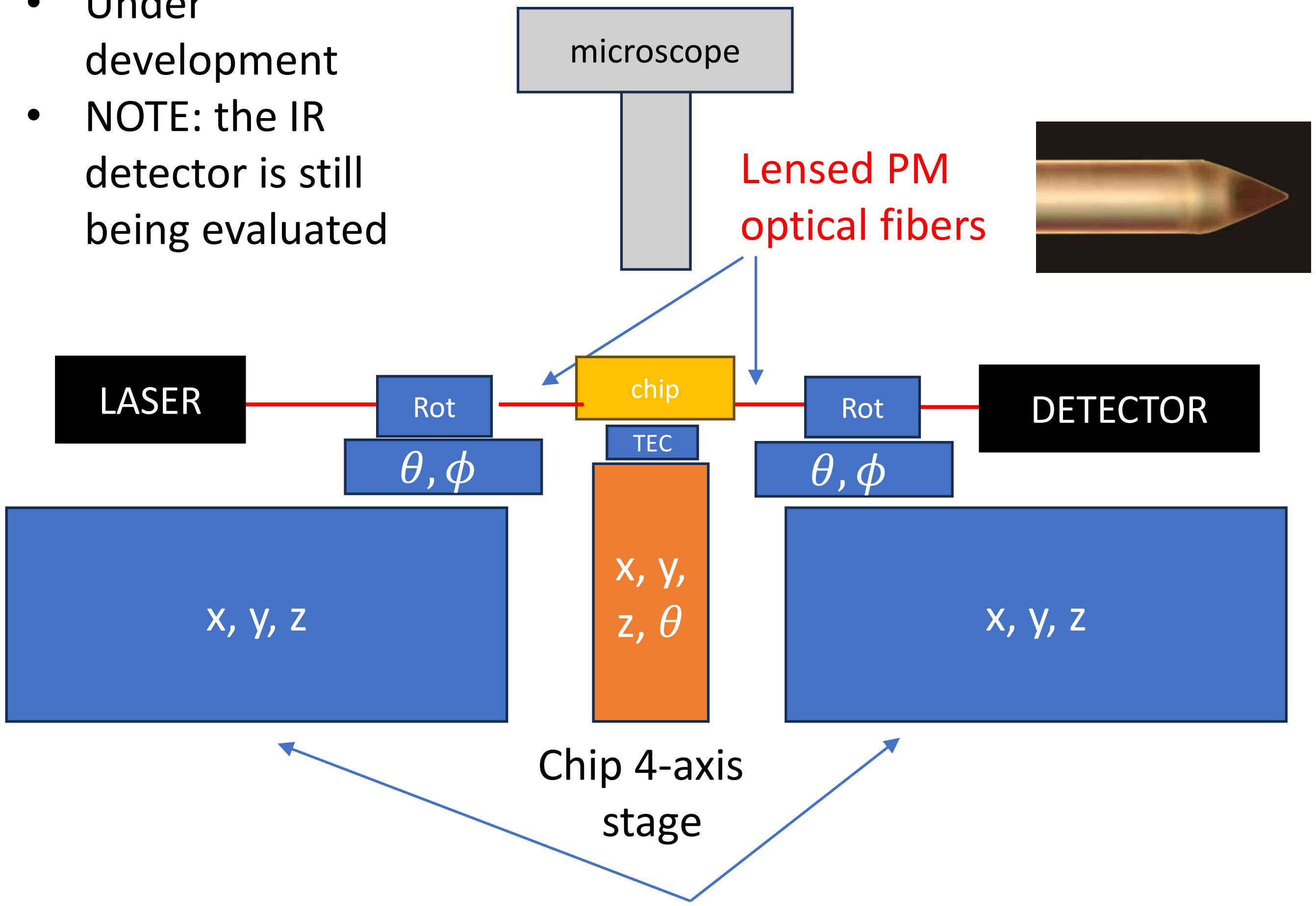
UV maskless lithography @ DFA





Next step: fiber alignment apparatus

- Under development
- NOTE: the IR detector is still being evaluated



Sub-micrometric 5-axis fiber alignement stages
with PM fiber rotation

Description	€	Q.ty	Tot.
Thorlabs MAX313D/M	1.9k	2	3.8k
Thorlabs AMA562/M	0.1k	2	0.2k
Thorlabs APY002/M	0.43k	2	0.86k
Thorlabs HFR007	0.33k	2	0.66k
Thorlabs MVS05/M	0.84k	1	0.84k
Thorlabs LX20/M	0.96k	1	0.96k
Thorlabs PR01/M	0.38k	1	0.38k
Thorlabs miscellanea	1k	1	1k
OzOptics lensed fibers	0.15k	8	1.2k
DinoLite microscope	0.64k	1	0.64k
Total (ex. VAT)			**10.5k**

Assegnazione vs spese

Tipologa	ITEM	Assegnazione (k€)	Sub iudice	Speso (k€)	Note
CONS	2 Substrati LNOI	7.5		9.88	In attesa di consegna
CONS	Micrometro			0.2	
CONS	Utilizzo camera bianca	2.0			
CONS	Sputtering deposition	2.0	3.0		
CONS	Materiali di consumo	4.0		2.0 k€	
INV	Set up per accoppiamento in guida	16		~13.0 k€	Preventivo in corso, manca CCD IR ($\sim 7\ k$€)
TRASPORTI	Spedizione in USA per misure			0.6	Spostamento
	TOTALE	31.5	3.0	25.7	

Possibilità di acquisto CCD IR spostando 6 k€ da CONS + 3 k€ SJ già quest’anno.

Attività 2026

- Fabbricazione guide tramite e-beam lithography a Trieste (collaborazione con Prof. F. Romanato)
- Test di produzione di seconda armonica tramite conversione ottica su chip ottico commerciale, come attività propedeutica alla generazione di luce squeezed.

Richieste 2026

TIPOLOGIA	ITEM	COSTO PREVISTO (k€)	NOTE
CONS	Materiale di consumo e camera bianca	10	
CONS	Substrati LNOI	7,5	erroneamente ascritti a inventariabile, ma in realtà sono CONS
INV	Anticipo per CCD IR	2,5	Se non si può sbloccare SJ dell’anno precedente
INV	SHG in fibra	12	

FTE e utilizzo di servizi

Nome	Affiliazione	Ruolo	FTE
Marco Bazzan	DFA	Responsabile locale	20
Jean Pierre Zendri	INFN – PD	Ottica, elettronica	10
Simone Marchetti	DFA	Microfabbricazione, ottica, elettronica	40
Filippo Romanato	DFA	Microfabbricazione	20
Gianluigi Maggioni	DFA	Deposizione film	

- Officina Meccanica: 1 M.U. Per realizzazione componenti da banco ottico

Quantum

QuteFDS [Grant Giovani]
Quantum Teleportation induced Frequency Dependent Squeezing.

Area di ricerca: Rivelatori, Quantum

Periodo:[2025]-2026,2027

Responsabile locale: A. Grimaldi
Responsabile nazionale**:** Padova

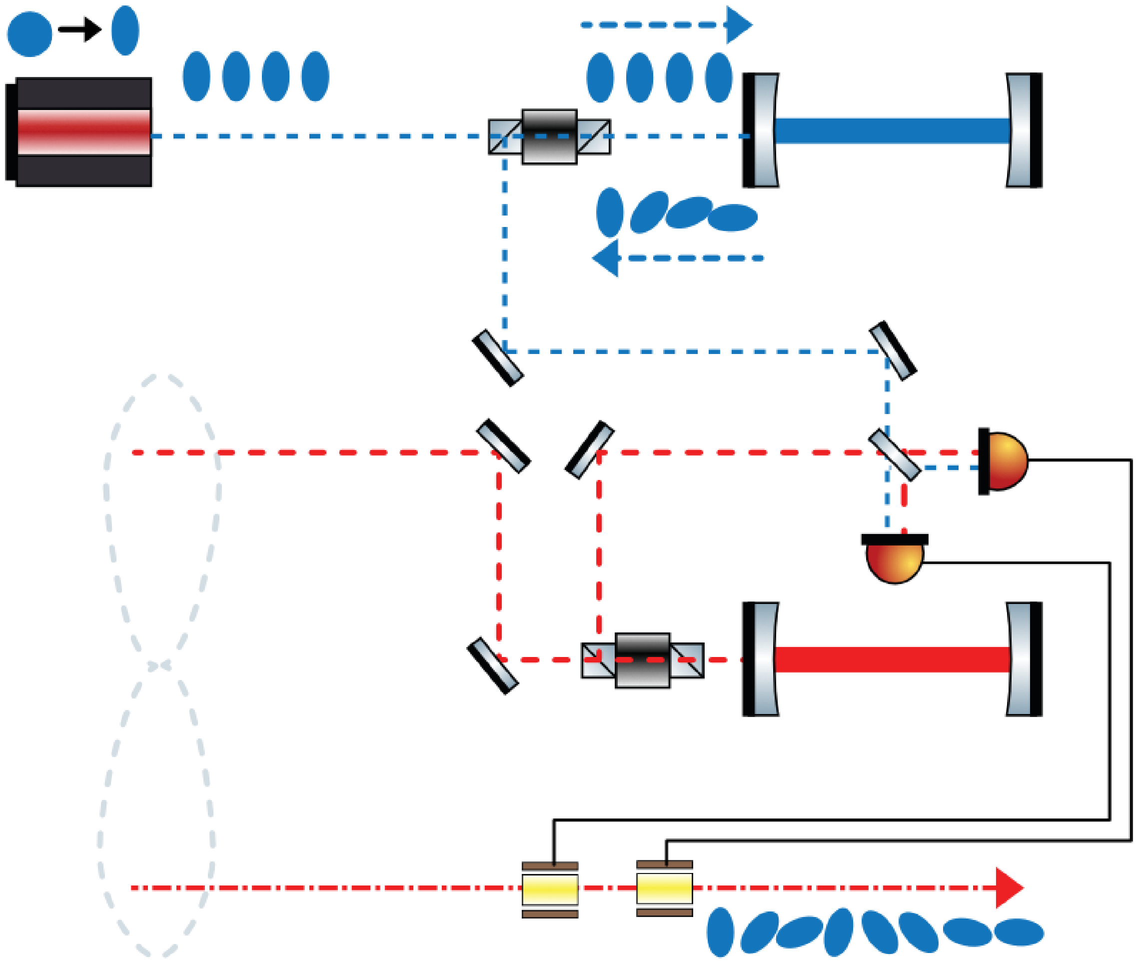
Participating Units Padova

Goal

- The main challenge for the next Gravitational Wave Detectors is achieving broadband quantum noise reduction in detuned signal recycled-Fabry-Pèrot–Michelson interferometers. This configuration introduces a second resonance due to an optical spring, which imposes an additional Filter Cavity to generate Frequency-Dependent Squeezing (FDS), leading to substantial financial costs and technological complexities.
- To overcome this problem, a recent study has proposed a new method for reducing quantum noise based on Quantum Teleportation. As the conditional EPR entanglement, the idea is to prepare the phase rotations by using optical fields frequency shifted from the detector carrier, $\omega 0$, using the interferometer as a detuned cavity.

Breve introduzione

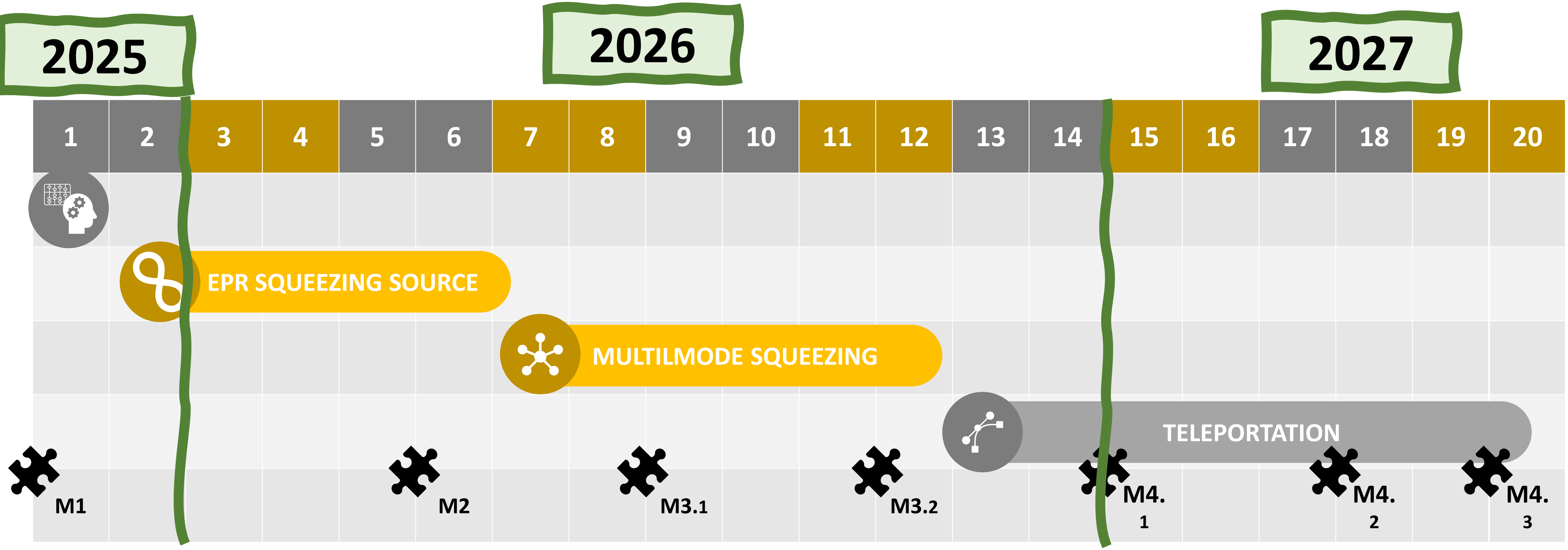
Qute_FDS



Steps

1. Generate **Frequency Dependent Squeezing** at detuned frequency $\omega_0 + \Delta\Omega_b$ by using the **Interferometer as Filter Cavity.**
2. Couple it with **EPR entangled** link and project the joint state with the Bell Measurement
3. **Teleport** the Frequency Dependent Squeezing from the $\omega_0 + \Delta\Omega_b$ to the interferometer frequency ω_0
4. Inject the teleported state into the **Interferometer ITF**

Breve introduzione


2025
2026
2027
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
EPR SQUEEZING SOURCE
MULTILMODE SQUEEZING
TELEPORTATION
M1
M2
M3.1
M3.2
M4.1
M4.2
M4.3

Milestones

M1 Final design of the optical setup and place the order for the custom optics.
M2 Measurement of two-mode squeezing
M3.1 Measurement of single mode squeezing

M3.2 Measurement of the benchmark defined in M2 and M3.1 simultaneously.
M4.x Measurement of Frequency-Dependent Squeezing

Attività previste

Richieste Finanziarie 2026

WP2 Develop an EPR entanglement source.

The WP2 is dedicated to implementing the EPR sources based on a single OPO. :

- **T2.1** Installation of first AOMs for the freq. shift $\Delta\Omega_a$
- **T2.2** Installation of Mode Cleaners and OPO
- **T2.3** Measuring two-mode Squeezing **M2**.

WP2 Conver the EPR entanglement source into a multimode squeezer.

The WP3 is dedicated to realise a multimode squeezer.

- **T3.1** Installation of first AOMs for the freq. shift $\Delta\Omega_v$.
- **T3.2** I measure the single mode Squeezing **M3.1**.
- **T3.3** Run the OPO in multimode configuration **M3.2.**

Name	Task	Inventariabile	Costo Parziale (IVA inclusa)
Piezo actuator	T2.2	No	8.17 k€
FPGA controller	T2.1/T3.1	No	5.12 k€
Temperature Controller	T2.2	Yes	1.34 k€
Cavity mirrors	T2.2	No	25.03 k€
PPKTP crystal	T2.2	No	9.98 k€
Low Losses Optics	T2.2	No	23.06 k€
Faraday Isolators 1550nm	T2.2	Yes	2.65 k€
		Total	75 k€

Attività previste
Richieste Servizi

WP2 Develop an EPR entanglement source.

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- **T2.1** Installation of first AOMs for the freq. shift $\Delta\Omega_a$
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- **T3.3** Run the OPO in multimode configuration **M3.2.**

Servizi	Task	Costo Mesi/Uomo
Electronical Workshop	Photodiode Detectors	3
Mechanical Workshop	Cavity Holders.	4

WHO?
Official Team

Name	Role	FTE
A. Grimaldi	Assegnista	.9
Prof. M. Bazzan	Prof. Associato	.1
Dott. JP. Zendri	Ricercatore INFN	.1
Marco Toffano	PHD	.2
Simone Marchetti	PhD	.2
Total FTE		150%

Contributions

- **A. Grimaldi:** Everything
- **Prof. M. Bazzan:** Design and characterization of non-linear crystal
- **Dott. JP. Zendri:** Opto-Electronics (Balance Detector, Photodetector for cavity lock); RF electronics for phase control
- **Marco Toffano**: design and characterisation of the Balance Detectors
- **Simone Marchetti:** Installation and characterisation of the squeezing source.

Quantum

DOCET

Area di ricerca: Rivelatori, Quantum

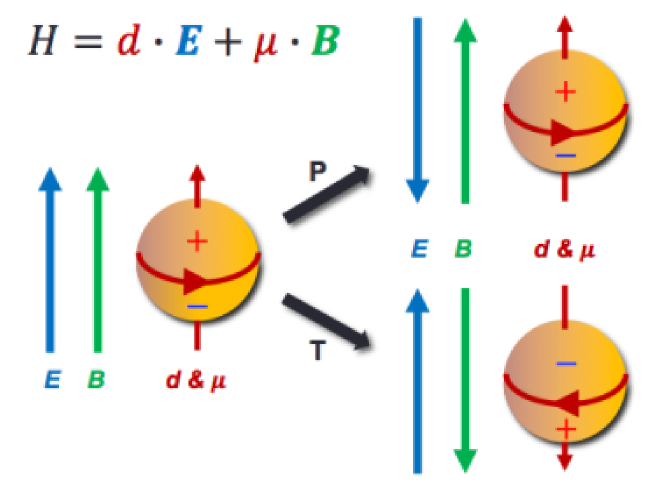
Periodo: 2025,2026,2027

Responsabile locale: G. Carugno
Responsabile nazionale**:** Padova

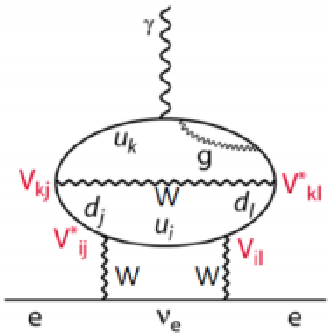
Participating Units Padova, LNL, Ferrara

EDM Searches

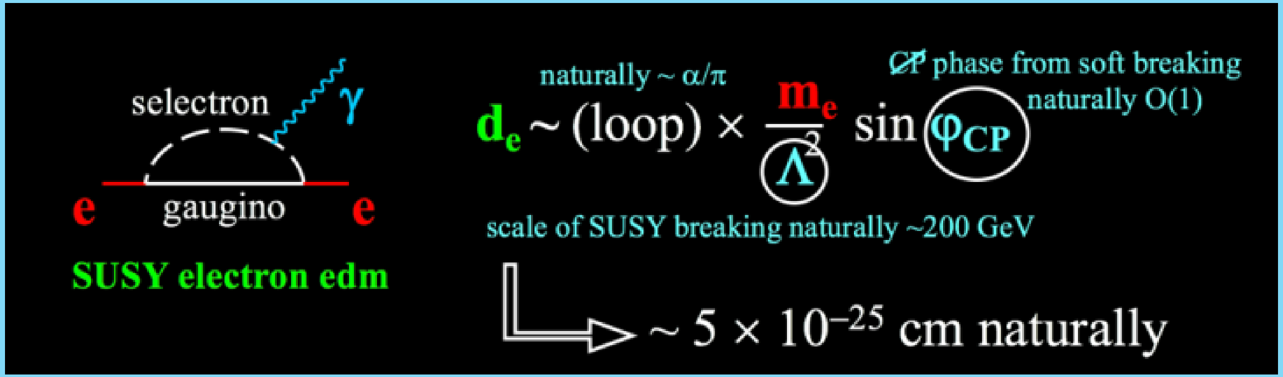
Search for new physics trough Electric Dipole Moments



- 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.

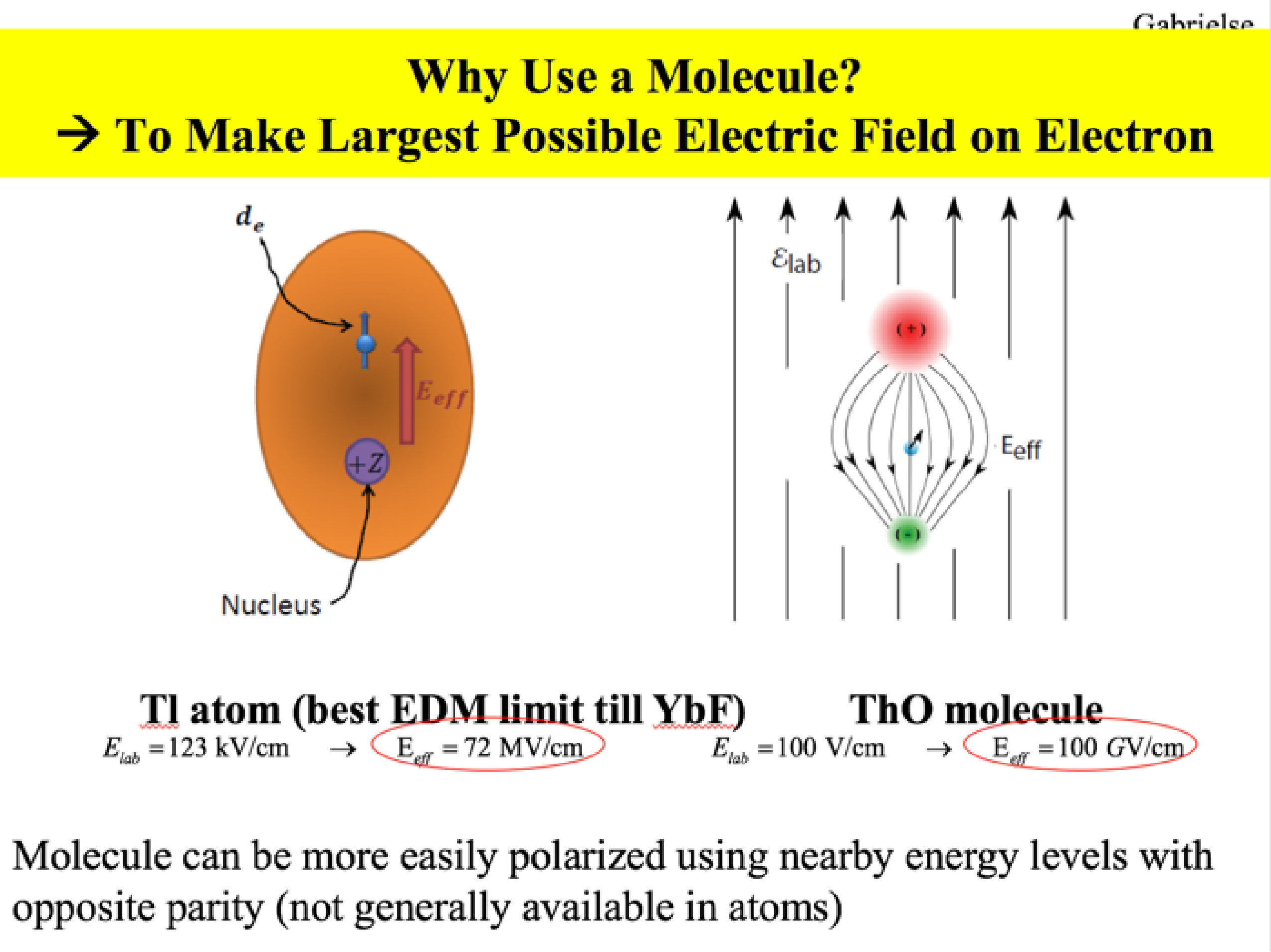


four-loop level in perturbation theory



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

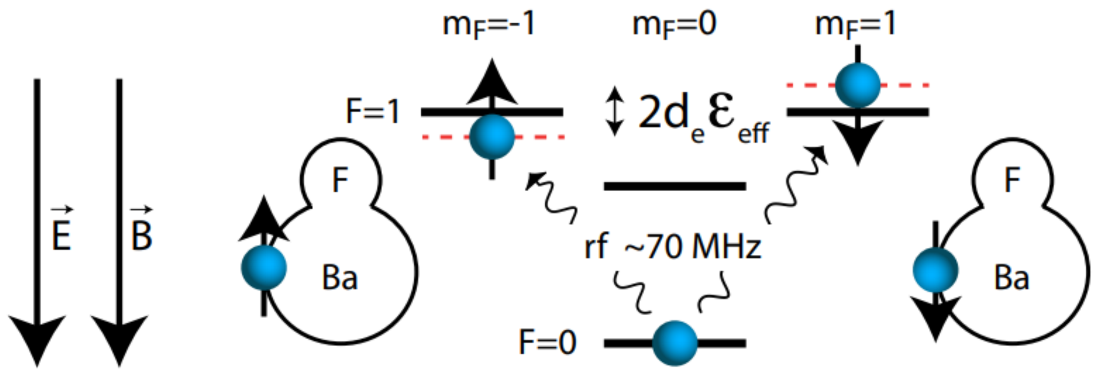
Tl atom (best EDM limit till YbF)

$E_{lab} = 123$ kV/cm → $E_{eff} = 72$ MV/cm

ThO molecule

$E_{lab} = 100$ V/cm → $E_{eff} = 100$ GV/cm

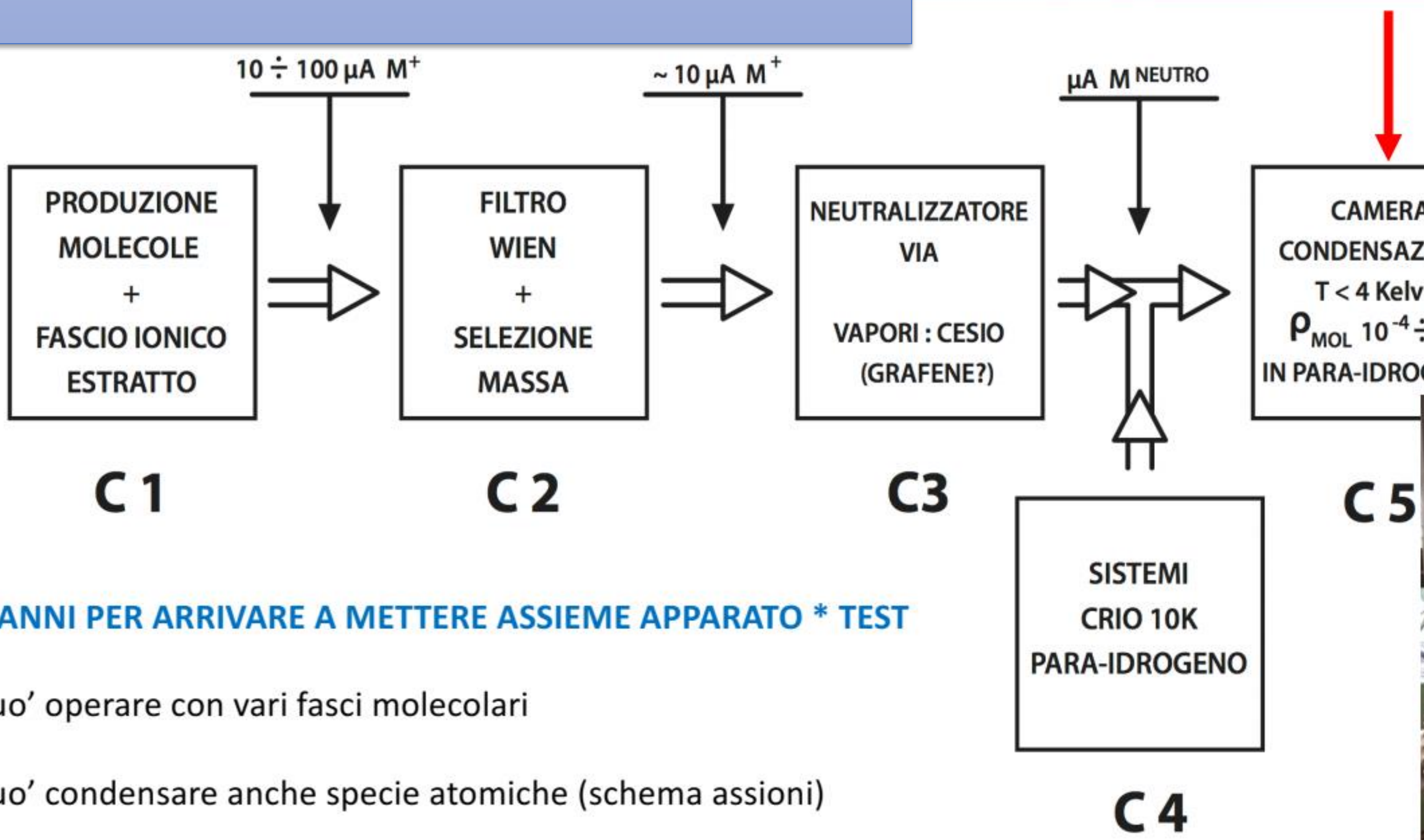
Molecule can be more easily polarized using nearby energy levels with opposite parity (not generally available in atoms)



EXPERIMENTAL COLD & DOPED CRYSTAL SET-UP

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

1 cm³ ParaHydrogen Crystal doped with BaF molecule



$10 \div 100\ \mu A\ M^+$

$\sim 10\ \mu A\ M^+$

$\mu A\ M^{NEUTRO}$

PRODUZIONE MOLECOLE + FASCIO IONICO ESTRATTO

C 1

FILTRO WIEN + SELEZIONE MASSA

C 2

NEUTRALIZZATORE VIA

VAPORI : CESIO (GRAFENE?)

C3

SISTEMI CRIO 10K PARA-IDROGENO

C 4

CAMERA CONDENSAZIONE

T < 4 Kelvin

$\rho_{MOL}\ 10^{-4} \div 10^{-3}$

IN PARA-IDROGENO

C 5

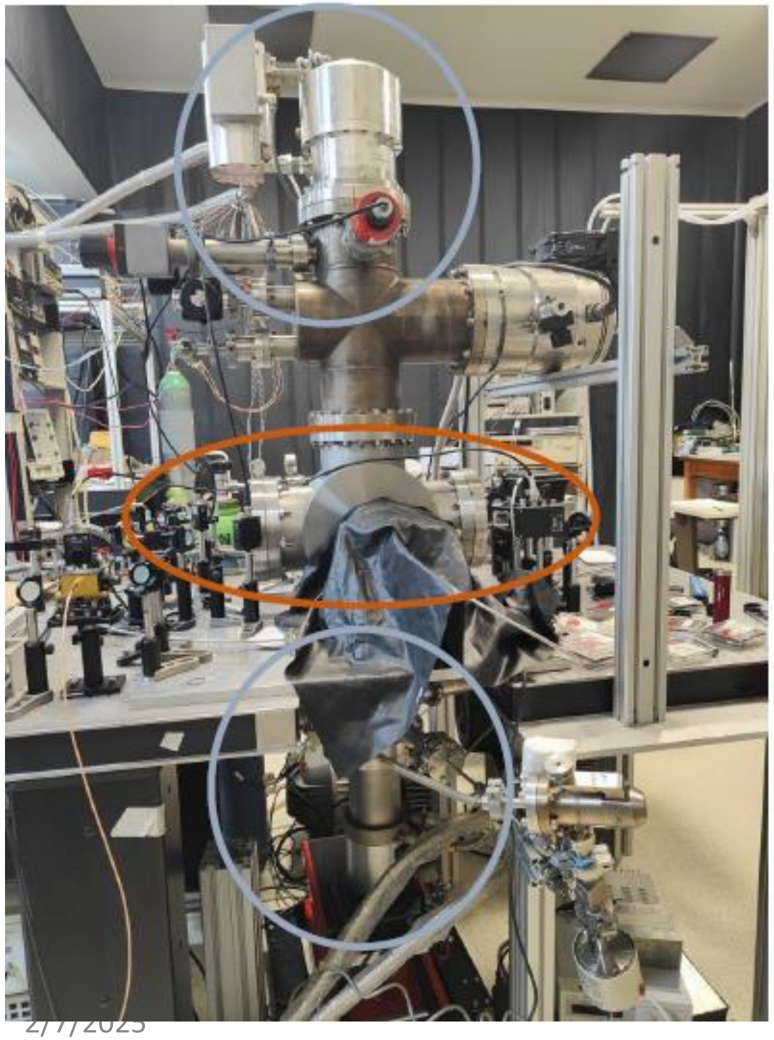
3 ANNI PER ARRIVARE A METTERE ASSIEME APPARATO * TEST

Puo’ operare con vari fasci molecolari

Puo’ condensare anche specie atomiche (schema assioni)

Attività: Spettroscopia del Ba e BaF in neon

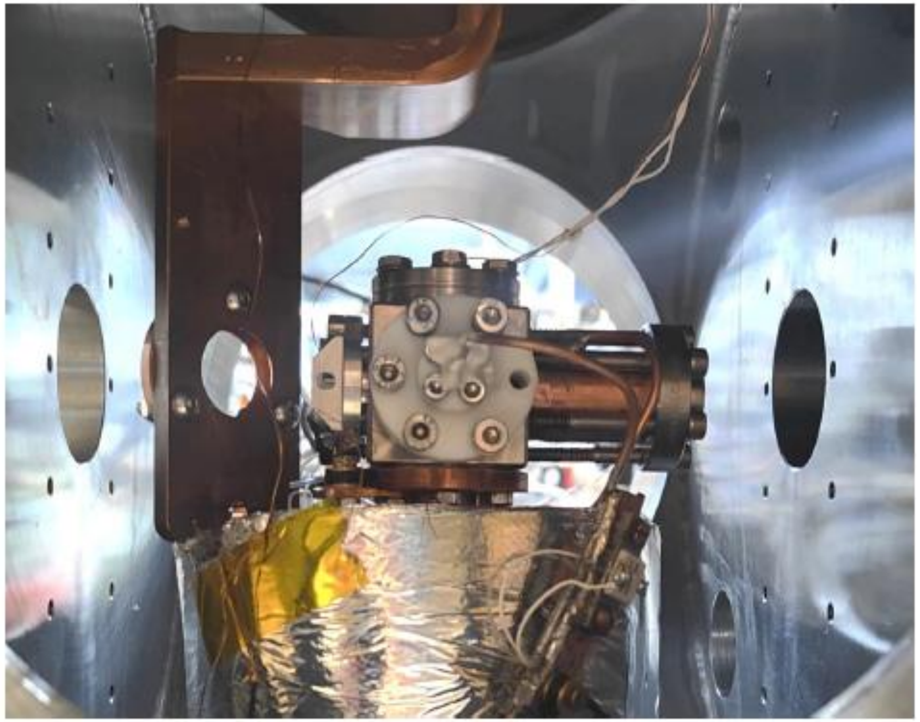
- Setup sperimentale



Sumitomo 3 K Crystal

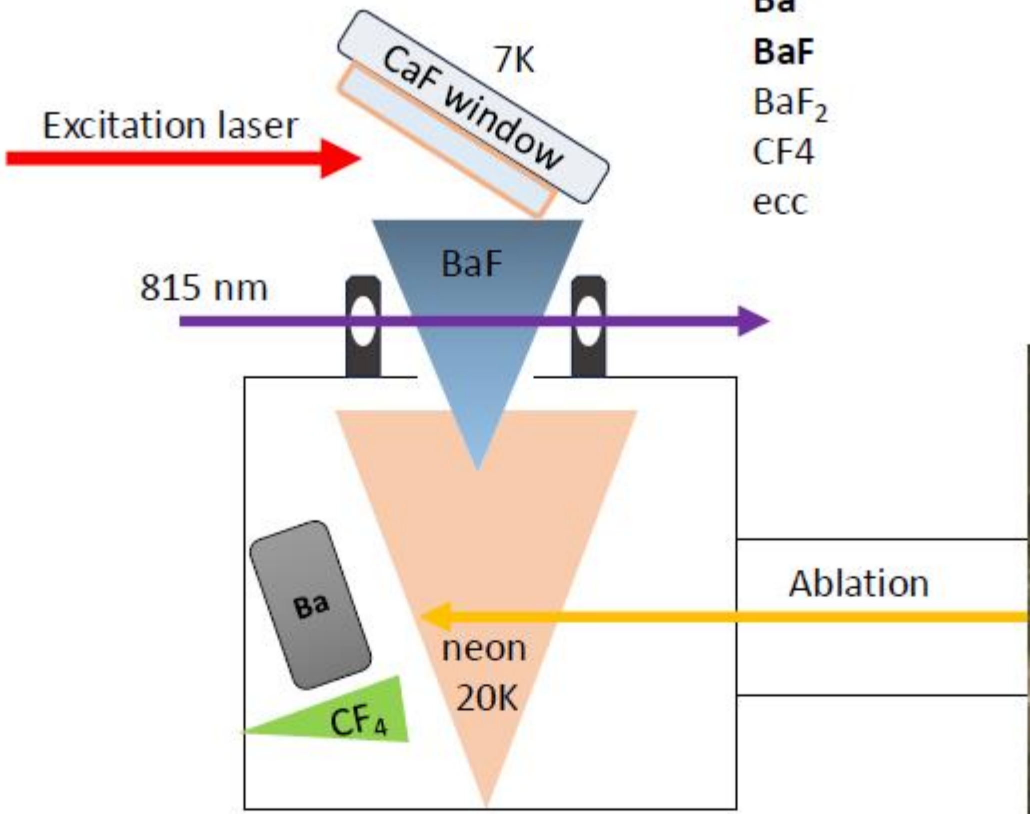
Chamber with cell and sapphire window

Leybold 12 K source



Attività: Spettroscopia del Ba e BaF in neon

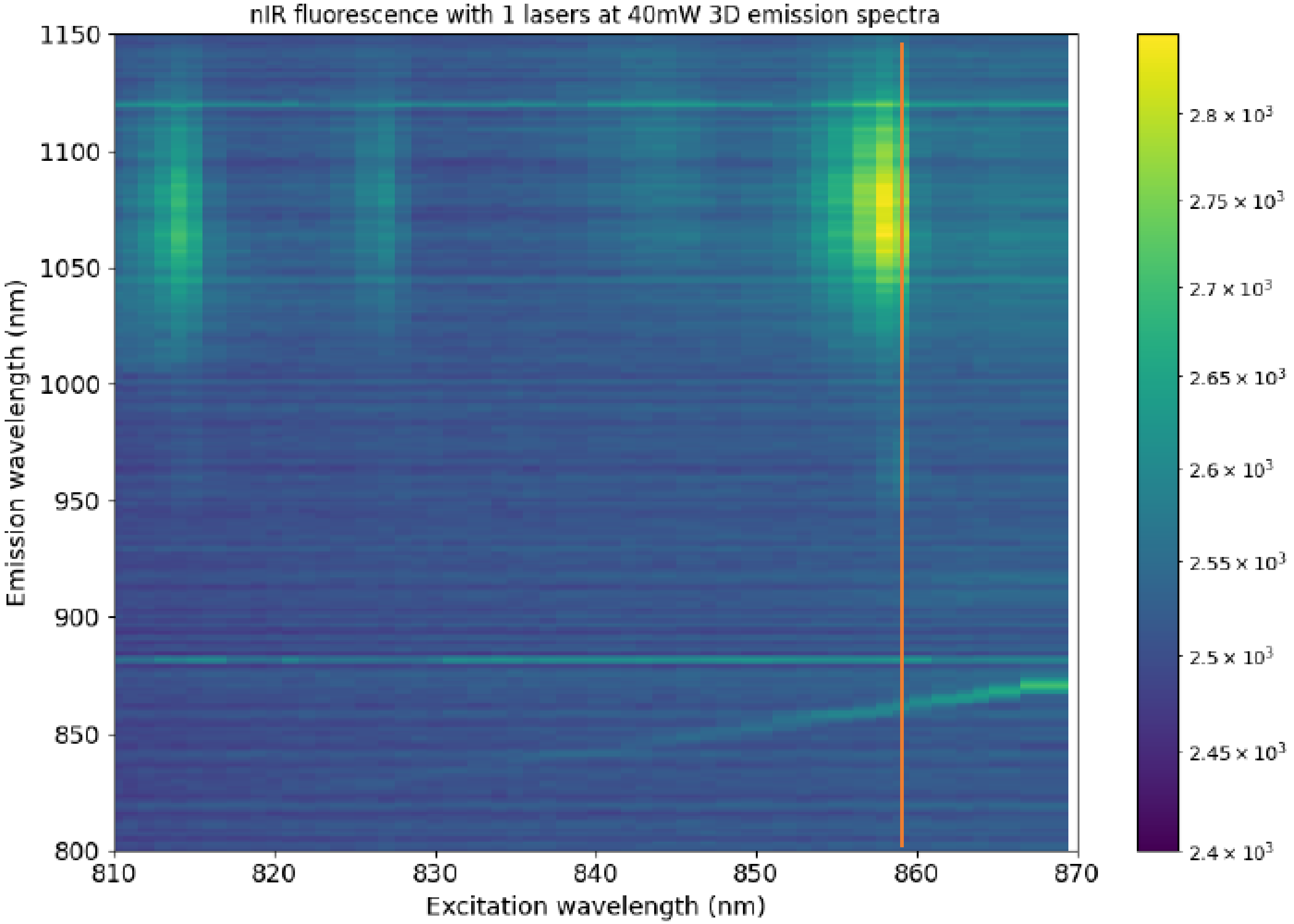
- Misure di assorbimento e fluorescenza

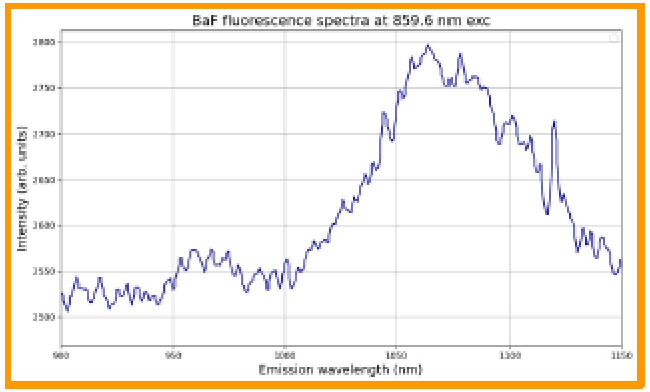


Neon doped with:
Ba
BaF
BaF$_2$
CF4
ecc

Attività: Spettroscopia del Ba e BaF in neon

- Misure di assorbimento e fluorescenza





Attività: Spettroscopia del Ba e BaF in neon

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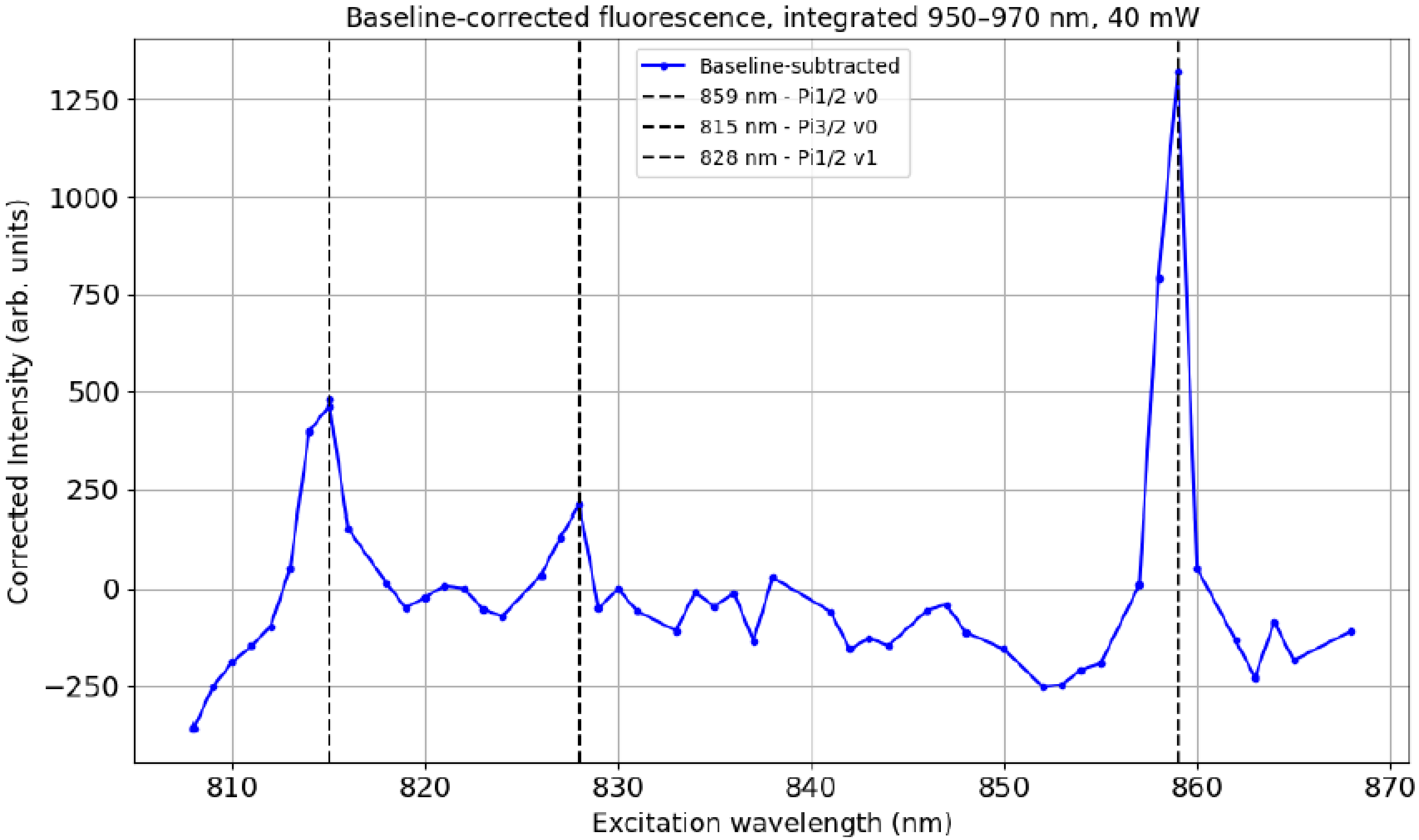


Anagrafica e richieste

Predecessore	Sigla	Stato	Resp Locale	Anni	missioni	consumo	inventariabile
PHYDES	**DOCET**	**Continuazione**	**G. Carugno**	**24,25,26**	**14**	**23**	**23**

Sigla	Prog. Meccanica	Serv. Tech. Avanzate	Off. Meccanica	Prog. Elettronica [Bellato]	Serv. Tecnici ed Elettronica [Nicoletto]
DOCET	**1 m.p.**		**10 m.p.**	**1 m.p.**	**8 m.p.**

Carugno	**Giovanni**	**DOCET**	**0,4**
Borghesani		**DOCET**	**1**
Messineo		**DOCET**	**1**
Gasparini		**DOCET**	**0,2**
Zanetti	**Marco**	**DOCET**	**0,15**
Pazzini	**Jacopo**	**DOCET**	**0,15**
Gonella		**DOCET**	**0,4**
Chiossi		**DOCET**	**1**
Tehrem	**Tariq**	**DOCET**	**1**
Madiha	**Makhdoom**	**DOCET**	**1**
G. Simi		**DOCET**	**0,15**

SPES, Fisica Medica

ISOLPHARM_APEX

Area di ricerca: Fisica Medica, SPES

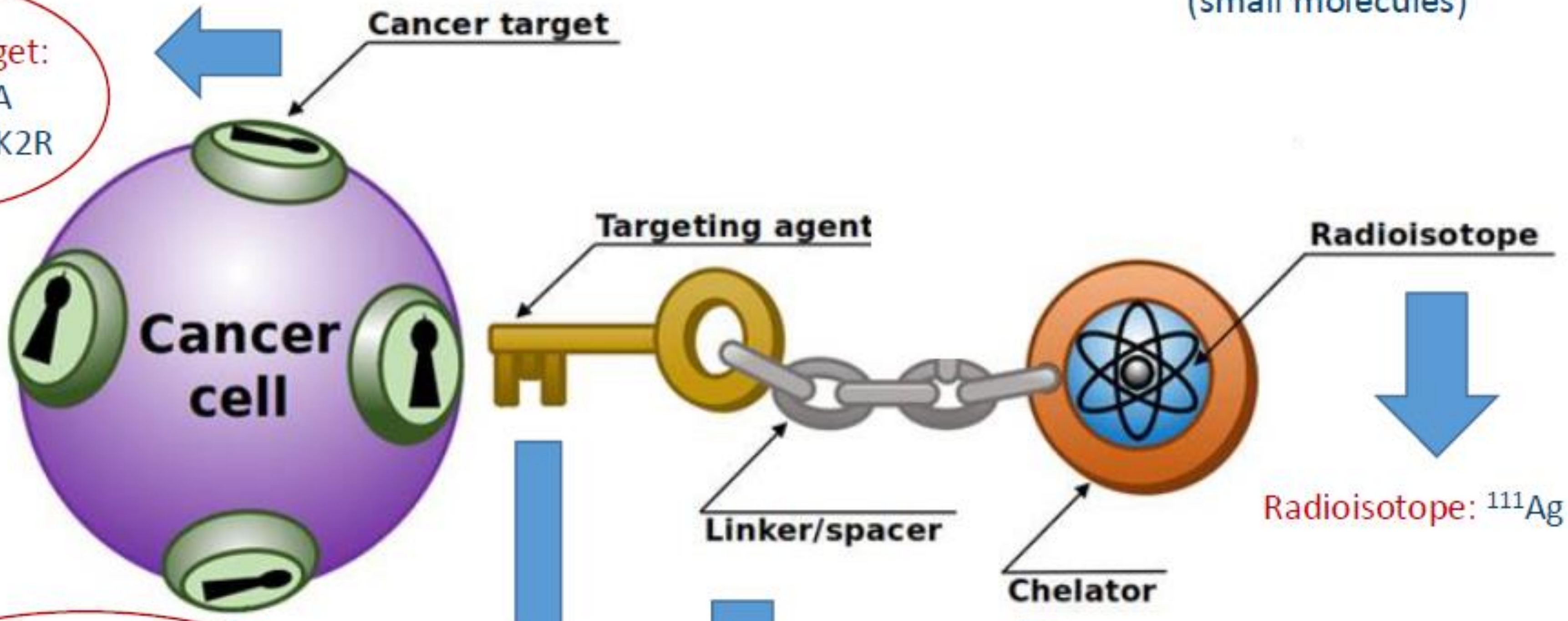
Periodo: 2026,2027, 2028

Responsabile locale: M. Lunardon
Responsabile nazionale: Andrighetto LNL

Participating Units LNL, Padova, Bologna, LNS, Pavia, Pisa, TIFPA

Radiopharmaceutical frame

(small molecules)



Cancer target:
Now: PSMA
Before: CCK2R

Targeting agent:
Now: PSMA-617
Before: Z360 (for CCK2R)

Linker: Bifunctional

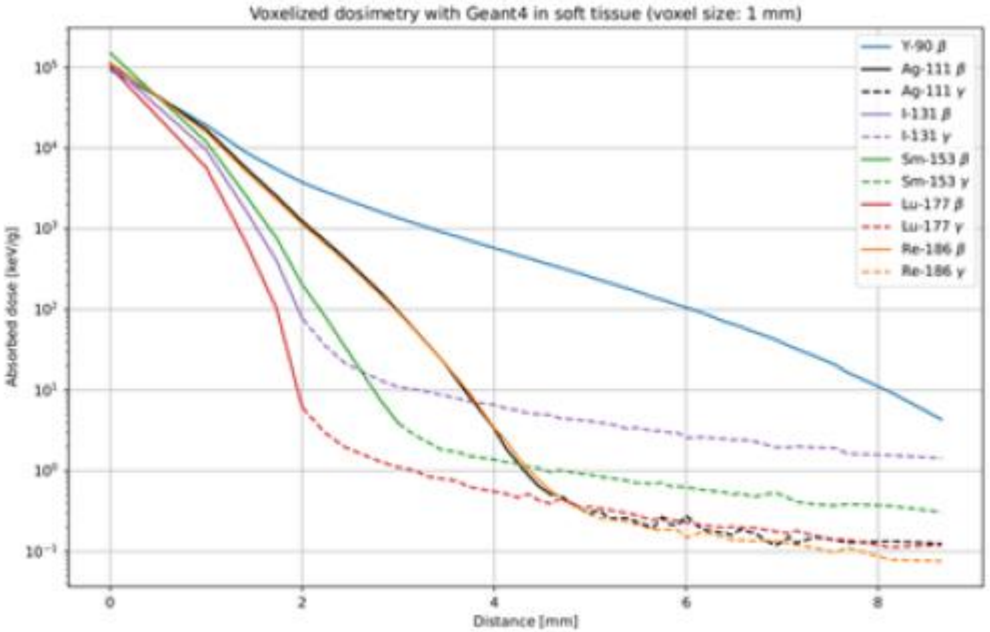
Chelator: DO4S

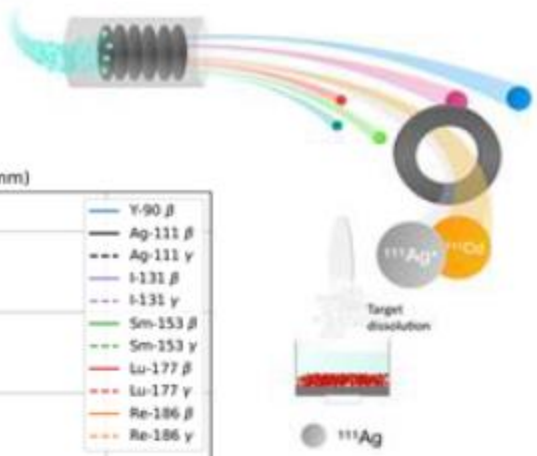
Radioisotope: ^{111}Ag

Experiments: why ^{111}Ag?

^{111}Ag properties

- **β⁻ emitter** (average energy **360 keV**)
- Good half-life (**7.45 days**)
- Average tissue penetration (1.8 mm)
- Medium energy **γ rays** -> SPECT?


Voxelized dosimetry with Geant4 in soft tissue (voxel size: 1 mm)



→ In the market no radiopharmaceuticals radiolabeled with silver-111

→ Silver-111 can be produced @ SPES with high purity & high production rate

→ No isobaric radioactive contamination in the implantation foil (also with LASER off!)

→ ^{111}Ag exhibits theranostic properties similar to ^{177}Lu which was recently approved by FDA

→ ^{111}Ag behaves similarly to ^{186}Re, recently studied in phase I/II clinical trials

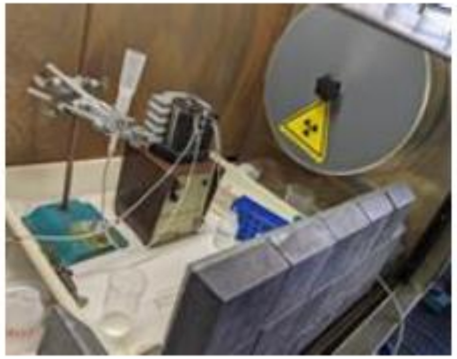
111 Isobaric chain	Half-Life $T_{½}$	Decay	Target Yield
Cadmium-111	Stable		Low yield production
Silver-111	7.45 days	β−	Good yield production
Palladium-111	23.4 min	β−	Bad release, short $T_{1/2}$
Rhodium-111	11 sec.	β−	No release, very short $T_{1/2}$

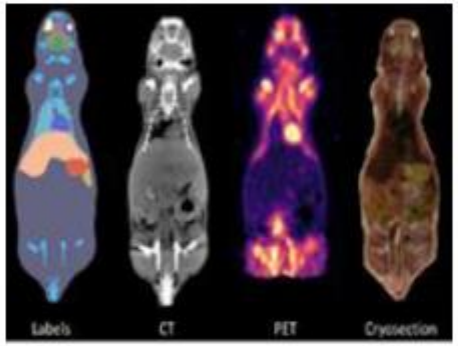
ISOLPHARM
SPES exotic beams for medicine

ISOLPHARM: over 10 years of activity

INFN

	✓	2014 – 2017		Interdisciplinary study group on production of medical radioisotopes at SPES
INFN experiments	✓	2018 – 2019	ISOLPHARM Ag	Simulations and feasibility evaluation of Ag as radiopharmaceutical precursor
	✓	2020 – 2022	ISOLPHARM_EIRA	First production of ^{111}Ag in reactor and beginning of *in-vitro* and *in-vivo* testing
	⚠	2023 – 2025	ADMIRAL ISOLPHARM	Characterizing the 2D/3D *in-vitro* therapeutic effect of ^{111}Ag and its imaging capabilities
	⚠	2025 – 2027	SPES MED	First nuclear measurements of radionuclide production at SPES
PRIN	⚠	2024 – 2025	ISOLPHARM CORE	Technological aspects of radionuclide production (target, ion source, implantation…)





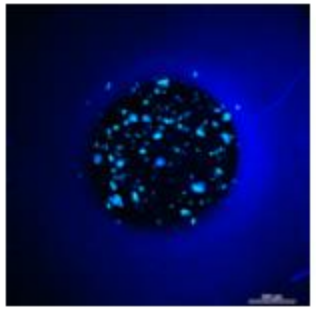
ADMIRAL achievements

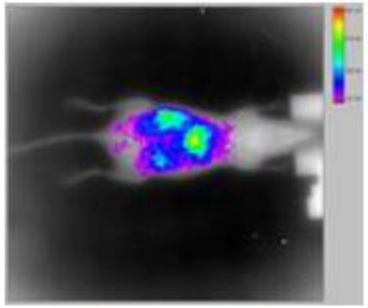
WP1 - Radiopharmaceutical production
- Optimization of chelators for Ag
- Optimization of Ag production and separation
- Development of 3D scaffolds for prostatic cancer cells

WP2 - β imaging
- 2D β imager "DUMBO" construction
- Characterization tests with ^{111}Ag

WP3 - γ imaging
- ^{111}Ag γ camera prototype development
- Characterization tests with ^{111}Ag

WP4 - Targeted radiobiology
- 2D survival of different cell lines treated with free ^{111}Ag
- Protocol for experiments in 3D scaffolds
- Cell dosimetry and DNA damage/repair models





ISOLPHARM_APEX (2026-2028)

^{111}Ag-PSMA-617 EXperiments

Main route / Secondary route

con una password o un
sta le autorizzazioni

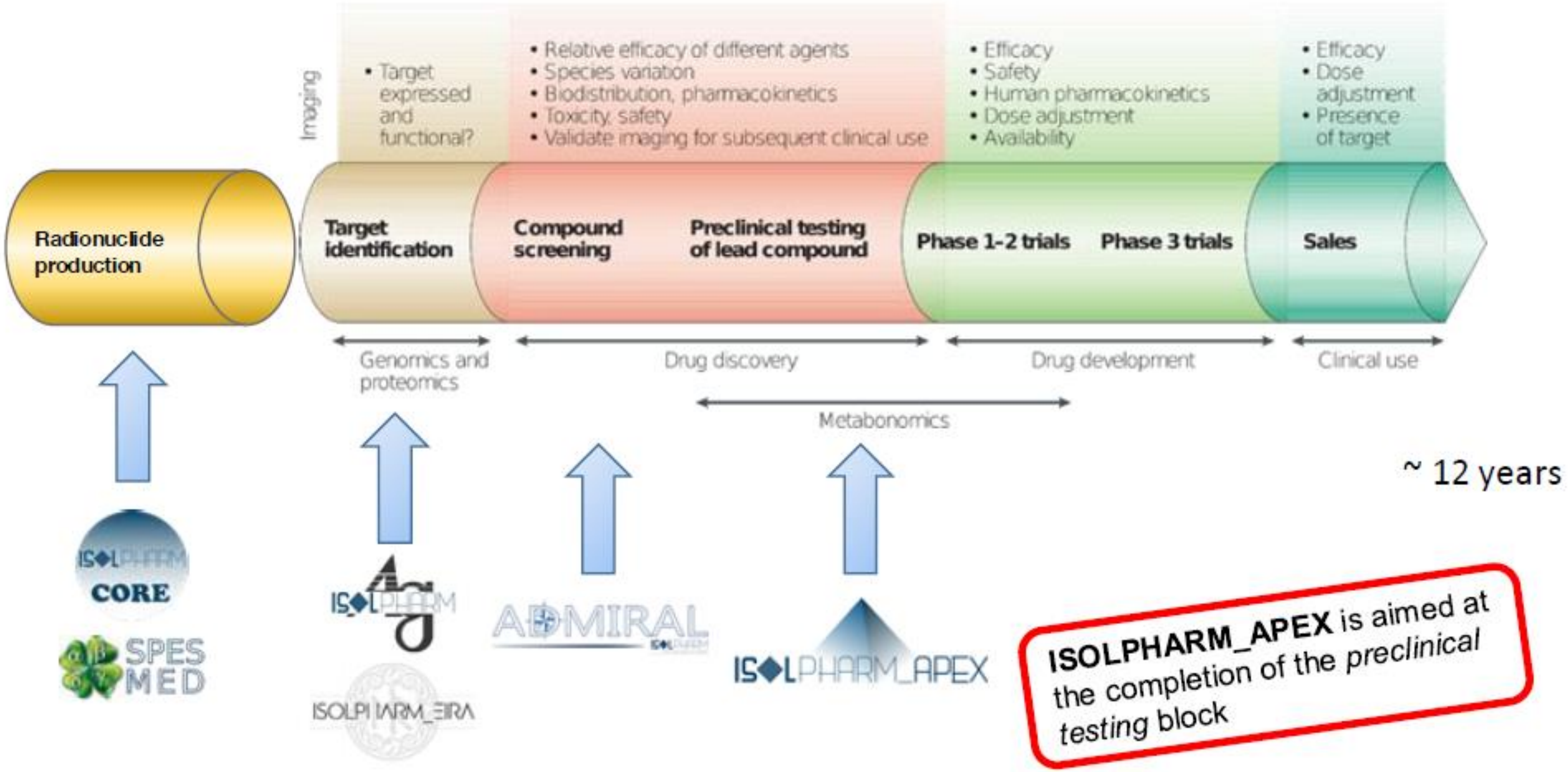
Radionuclide production at LENA and SPES

Main goals

1) Understanding the dosimetry of ^{111}Ag-PSMA-617 in living systems such as cells, small animals and human patients.
2) Studying this radiopharmaceutical in cancer cell cultures in 2D monolayers and in 3D tissue-mimicking scaffolds.
3) Observing the biodistribution and the effects of theranostic ^{111}Ag-PSMA-617 on small animals.
4) Investigating the radiobiological response to low-dose-rate radiation using the first nuclides obtainable at SPES.

The long road to (radio)pharmaceuticals

SPES exotic beams for medicine

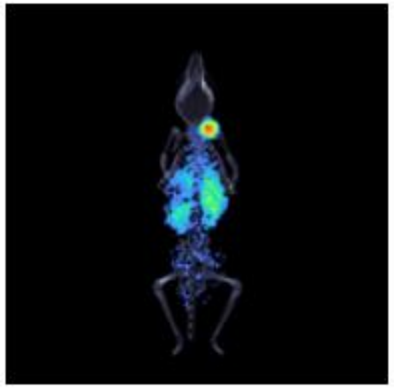


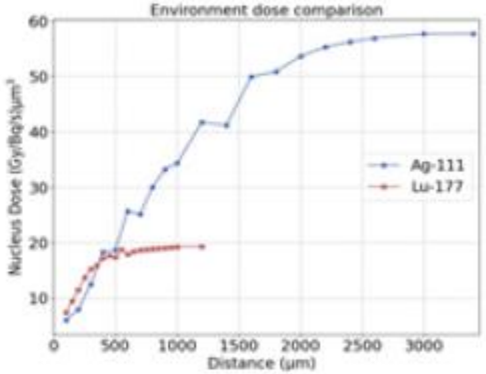
~ 12 years

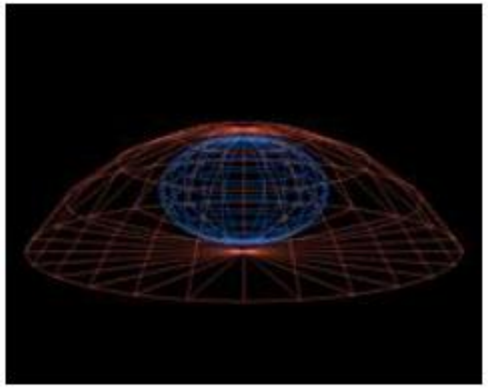
ISOLPHARM_APEX is aimed at the completion of the *preclinical testing* block

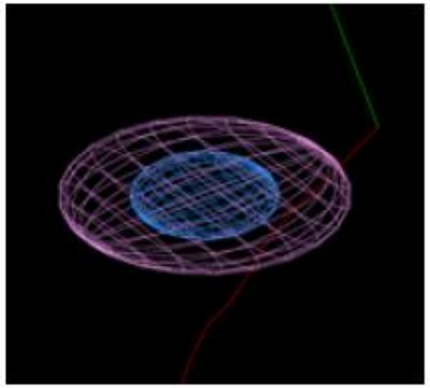
WP1 – SILICO

- Computational dosimetry at cell and organ level
- Survival models and DNA damage study
- Monte Carlo simulations for imaging prototypes



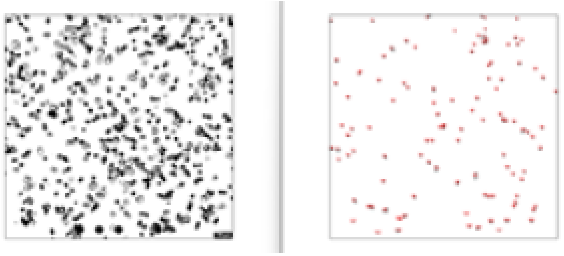




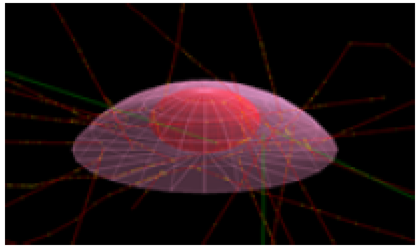


WP1 methodology

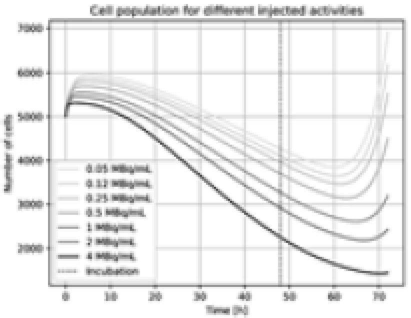
Silico for vitro



Cell shape and dimensions are retrieved from microscopy via image-processing software.

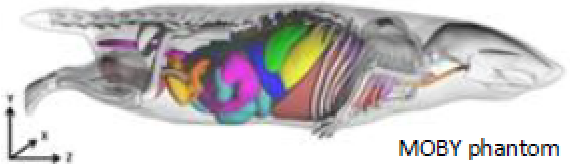


Monte Carlo simulations compute the absorbed dose per activity unit (***S-value***) and the consequent **DNA damage**.

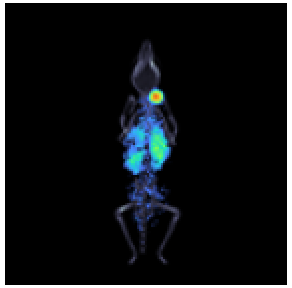


Biophysical models help understanding the **dose-rate curve** and the **DNA repair dynamics** from data.

Silico for vivo

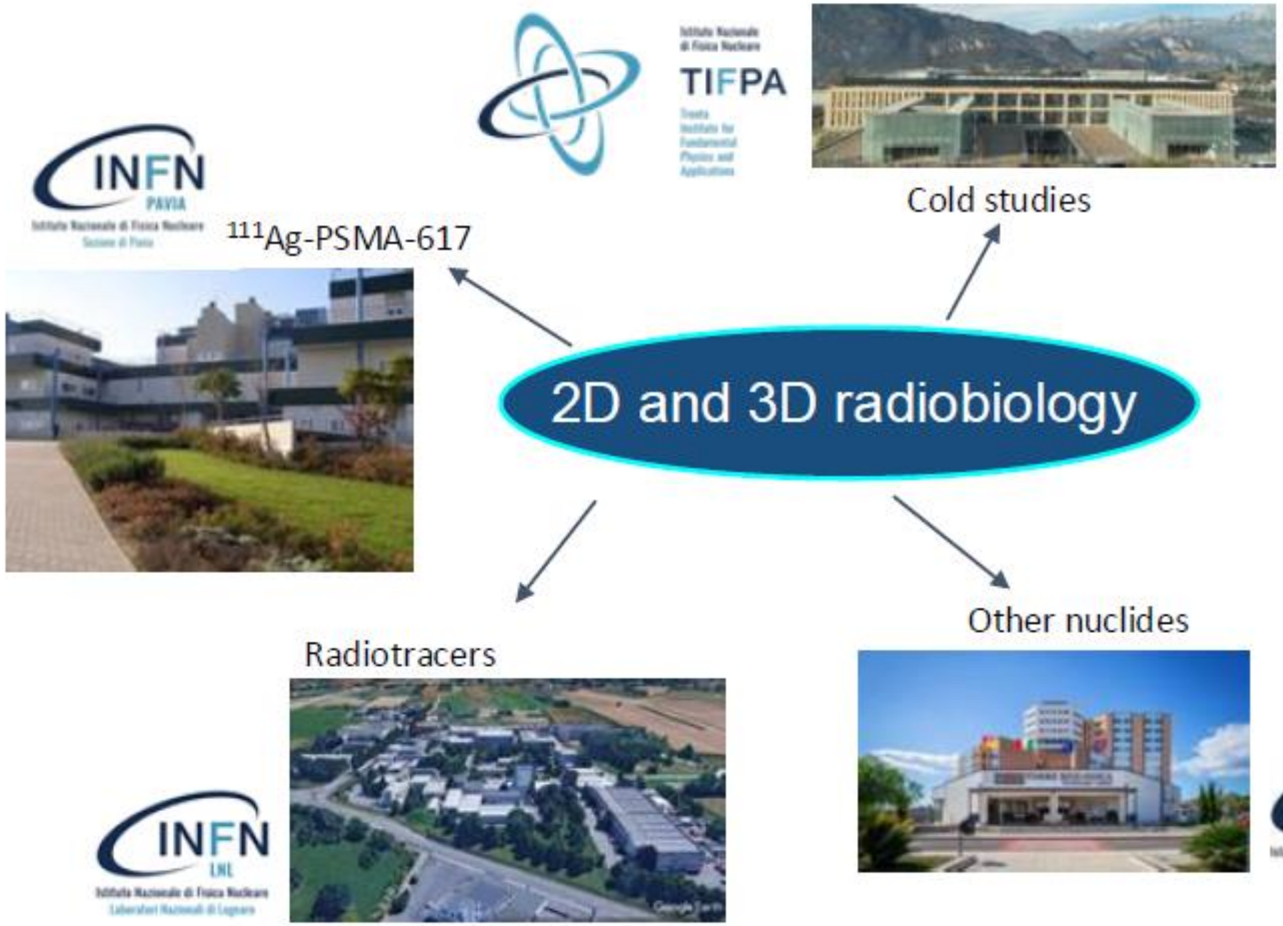


Monte Carlo simulations are performed using commercial **virtual phantoms** or **CT** images; the **input biodistribution** can be measured **ex vivo** or taken from **PET/SPECT** imaging.



Simulations can provide **organ S-values** for treatment plans as well as **imaging previews** to tune the devices.

WP2 – VITRO



- Clonogenic survival assays
- Uptake measurements with β imaging
- *Foci* assays

Endorsement of hospitals

Santa Maria Nuova (Reggio Emilia)

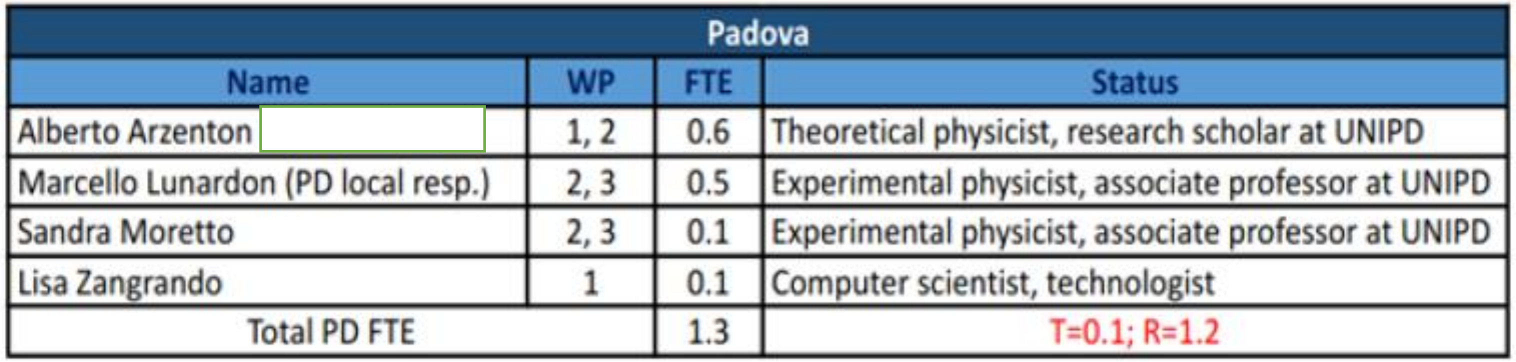
Cannizzaro (Catania)

IRST D. Amadori (Meldola, FC)

[Loading...]

Spedali Civili (Brescia)

Padova prospect



Padova			
Name	WP	FTE	Status
Alberto Arzenton	1, 2	0.6	Theoretical physicist, research scholar at UNIPD
Marcello Lunardon (PD local resp.)	2, 3	0.5	Experimental physicist, associate professor at UNIPD
Sandra Moretto	2, 3	0.1	Experimental physicist, associate professor at UNIPD
Lisa Zangrando	1	0.1	Computer scientist, technologist
Total PD FTE		1.3	T=0.1; R=1.2

Padova							
Type	ID	Item	WP	Year 1 [k€]	Year 2 [k€]	Year 3 [k€]	Total
Consumables	5	New components for β detector	2	1	1	1	3
Shipping	6	Shipping of detectors, etc.	3	1	1	1	3
Travels	7	Travels for research activities	1, 2, 3	3	3	3	9
Total PD				5	5	5	15

SPES, Fisica Medica

CUPRUM.

Area di ricerca: Fisica Medica, SPES

Periodo: 2023,2024, 2025 ->2026

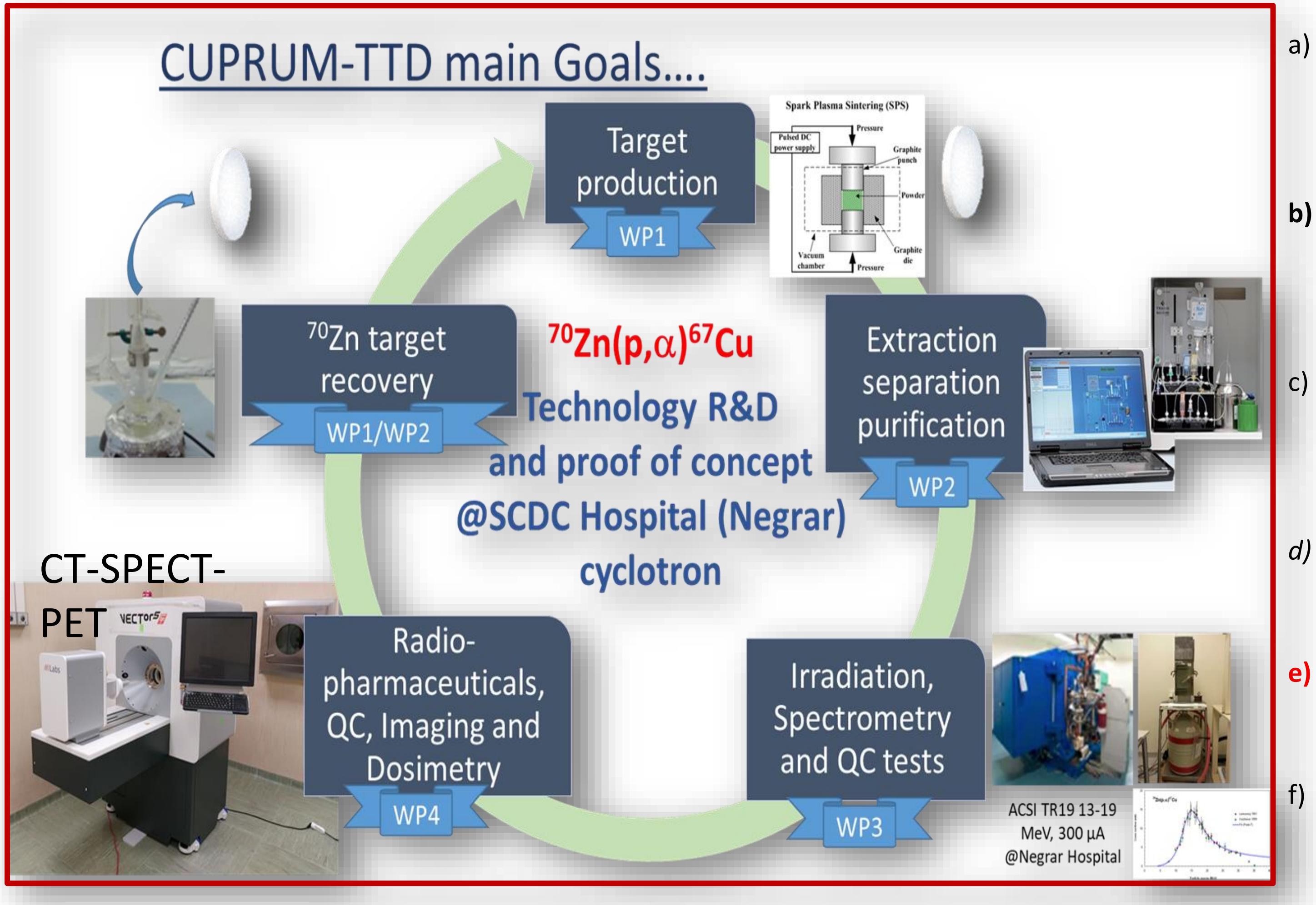
Responsabile locale: L. De Nardo

Responsabile nazionale**:**

Participating Units

CUPRUM-TTD (2023-2025) main project goals

To develop 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 manufacture 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: Zn⍰ Cu** to achieve a clinical-grade **^{67}Cu radionuclide**;

d) *in-vitro* cells studies with **^{67}Cu-labelleded 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.**

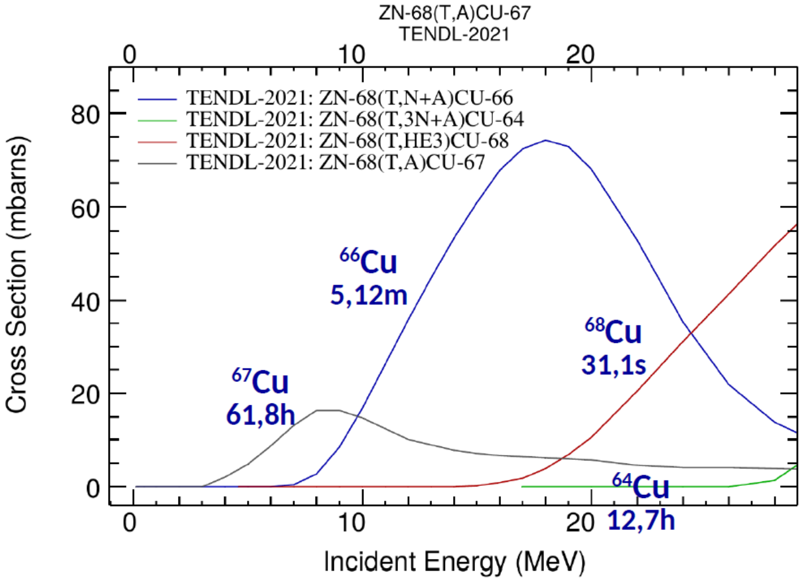
CUPRUM-TTD WP3 (PD): theoretical activities on alternative nuclear reaction routes to yield ^{67}Cu

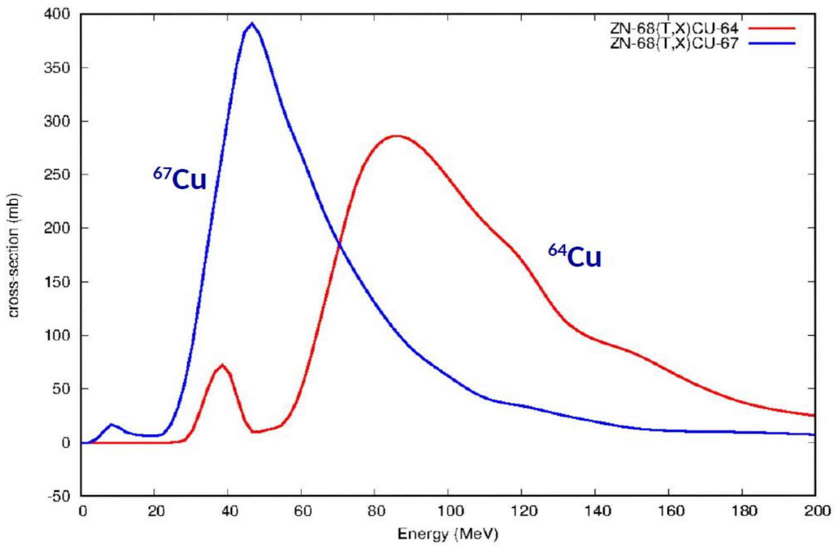
? ^{68}Zn(t,α)^{67}Cu

UniPD/INFN-PD
F. Barbaro
L. Canton
Y. Lashko

- Started investigation of the triton production route: **^{68}Zn(t,α)^{67}Cu**
- Comparison with the “standard” production routes: **^{68}Zn(p,2p)^{67}Cu, ^{70}Zn(p,α)^{67}Cu**
- Bibliography study and data search
- Started simulation analysis with Nuclear Reaction Codes Talys
- Supervision of a master thesis on this topic

Continuazione di REMIX

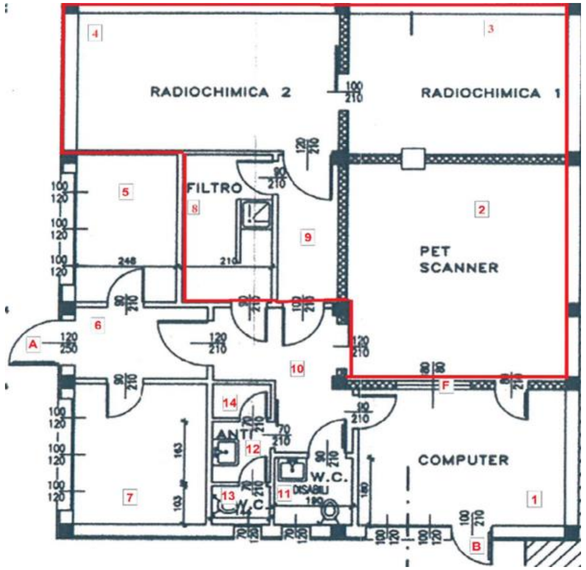




CUPRUM-TTD WP4 (PD-IOV-CNR-UNIFE): RP activities (Synthesis of new Cu conjugates)

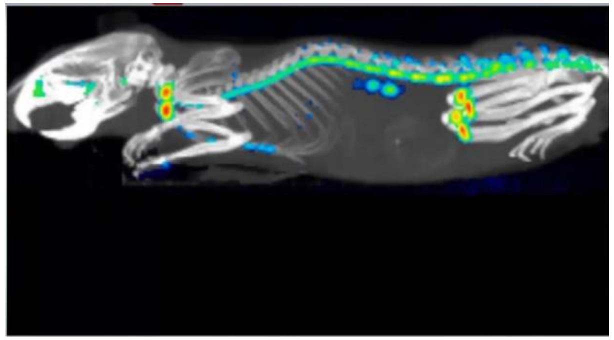
Feasibility of Radiopharmaceutical research studies within LNL LARIM (Padua Univ.)

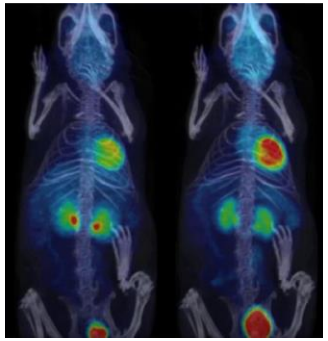
LARIM is located close to SPES building.
Now under renewal of HVAC/Electric/safety plants (Dec. ’23 –July ’24)
Expected to re-start first operations (new instr. included) on Sept/Oct ‘24



Last-generation small animal scanner: MILABS Vector 5 CT

Set of phantoms with different geometries





HPLC instrumentation in the radiochemistry lab

Radiochemical and Biological hoods

Richiesta prolungamento di un anno (3+1)

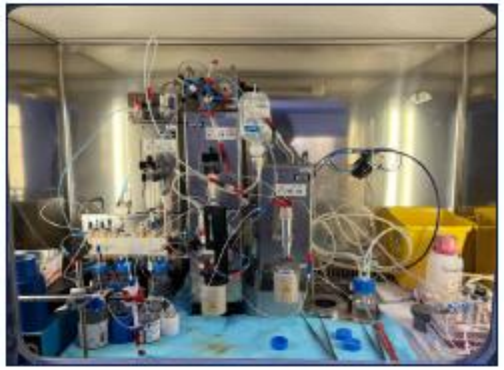
Motivazione: **due aspetti (milestone) chiave per il progetto** molto probabilmente non potranno essere raggiunti entro la fine del 2025.

1) L'esportazione (**trasporto autorizzato fino ai LNL**) del Cu67 che produrremo con i ns. bersagli al ciclotrone del IRCSS Sacro Cuore Don Calabria - SCDC di Negrar (VR)

Irraggiamento

ACSI TR19/300, SCDCH, Negrar

Separazione



Moduli a cassetta per l'automazione del processo di separazione

^{67}Cu

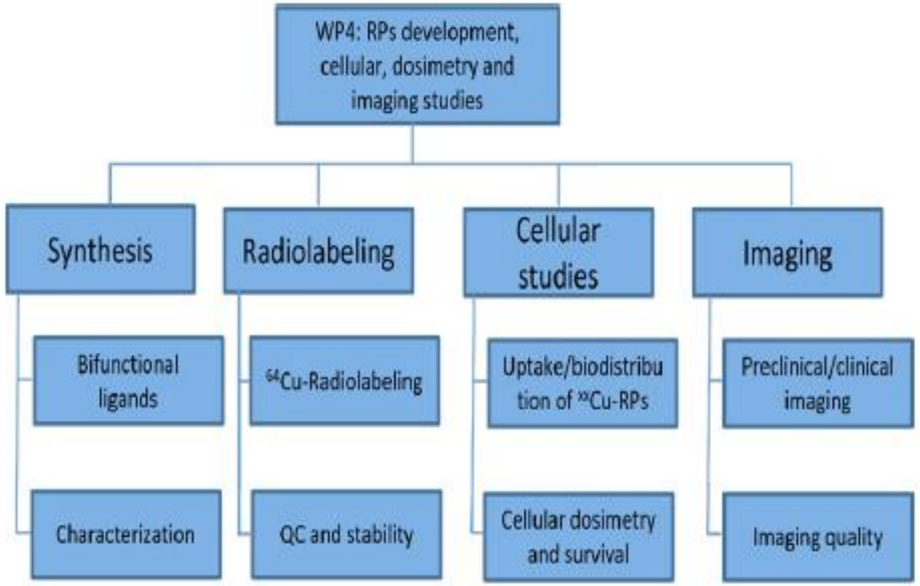
trasporto autorizzato fino ai LNL

laboratorio LARIM ai LNL

- Autorizzazione per <u>ottobre/novembre 2025?</u>

Richiesta prolungamento di un anno (3+1)

2) la possibilità di poter svolgere le attività pianificate al **laboratorio LARIM ai LNL**.



WP4: RPs development, cellular, dosimetry and imaging studies

- Synthesis
  - Bifunctional ligands
  - Characterization
- Radiolabeling
  - ^{64}Cu-Radiolabeling
  - QC and stability
- Cellular studies
  - Uptake/biodistribution of ^{xx}Cu-RPs
  - Cellular dosimetry and survival
- Imaging
  - Preclinical/clinical imaging
  - Imaging quality

Le operazioni di collaudo impiantistico della macchina trattamento aria/depressurizzazione (UTA) del laboratorio LARIM **stanno impiegando molto più tempo del previsto**.
Seguirà poi la fase di verifica da parte dei VVF del comando di Padova per il rilascio del CPI, necessario per poter entrare in esercizio con uso di radioattivo.

CUPRUM-TTD Padova: richieste finanziarie e FTE

INFN-PD	FTE
De Nardo L. (R. Loc)	0.80
Canton L.	0.20
Bolzati C.	0.20
Paiusco M.	0.20
Zorz A.	0.20
Barbaro F.	?

Sezioni / Lab	Missioni	Consumo/ Altri consumo	Tot. per sez/lab	FTE previsto
PD	1.0	5.5**	**6,5**	**1.60**

**richiesta riassegnazione

Consumables: 64Cu to radiolabel the developed Radiopharmaceuticals (2x10mCi) (3 keuro)
Solvents for HPLC analysis, reagents for stability test, buffers and cell culture media, Sep-Pack cartridges for radiopharmaceutical purification (2.5 Keuro).

SPES, Fisica Medica

SEGNAR
Synergic Effects of Gold Nanorods And Radiopharmaceuticals

Area di ricerca: Fisica Medica, SPES

Periodo: 2025,2026,2027

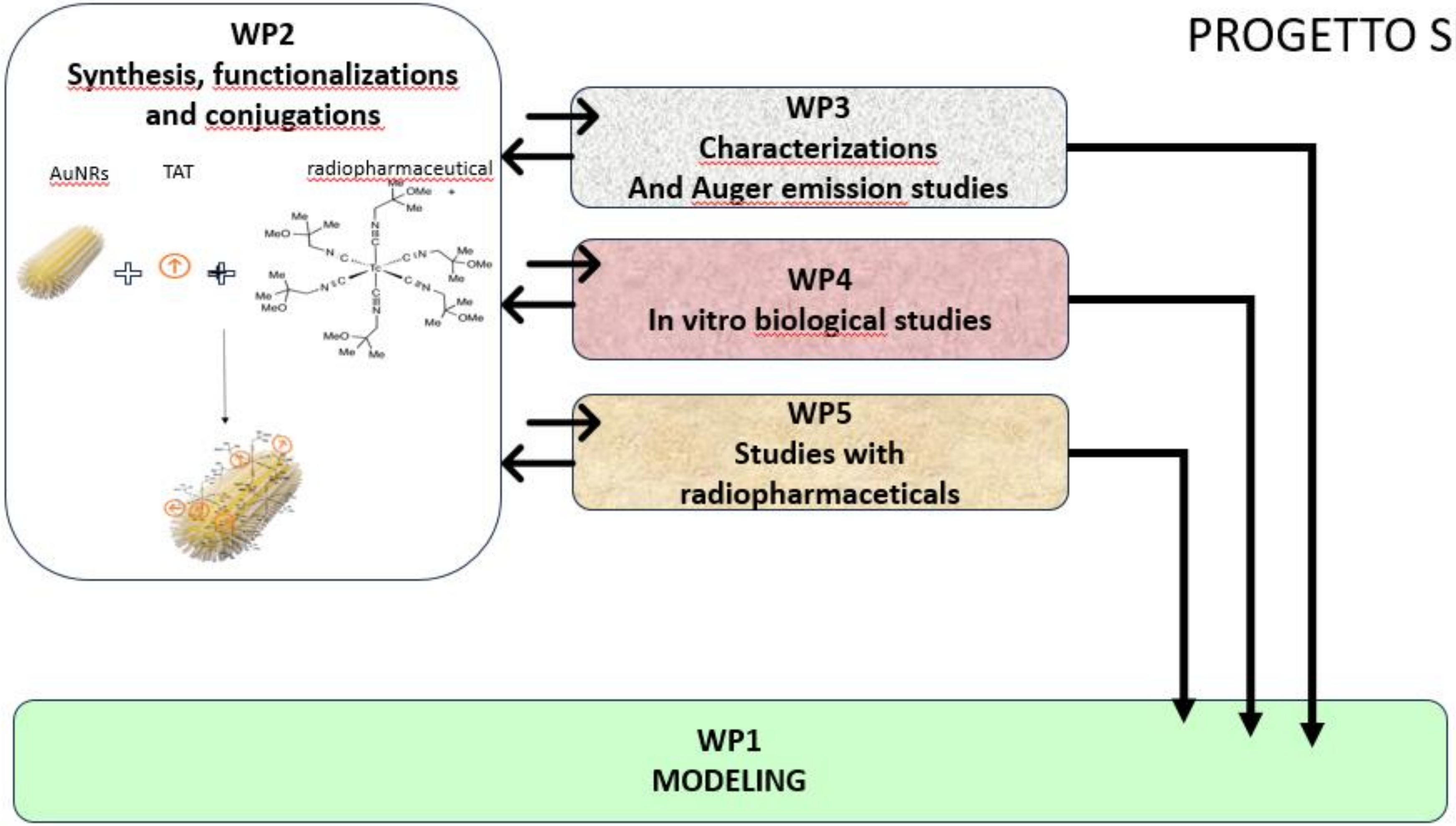
Responsabile locale: M. Dettin)UniPD=
Responsabile nazionale: A. Fabbri Roma3

Participating Units: Padova, Roma3, ….

Goal

- The SEGNAR idea is based on the realization as a proof of concept of a conjugated AuNRs radiopharmaceutical system for diagnosis and therapy. The functionalization of AuNRs for targeting the nucleus of tumor cells, the radiopharmaceutical loading of the functionalized AuNRs and the study of Auger emission from AuNRs subjected to gamma irradiation are some of the first challenges that the project has to solve to achieve this proof of concept. Another main goal of the project is modeling of the AuNR system in the cell environment to predict the radiobiological enhancement following irradiation trying to identify the possible enhancement mechanism and to highlight possible synergistic effects of modified AuNRs-TAT and radiopharmaceutical based on 99mTc-sestaMIBI

PROGETTO SEGNAR



WP2
Synthesis, functionalizations and conjugations

WP3
Characterizations
And Auger emission studies

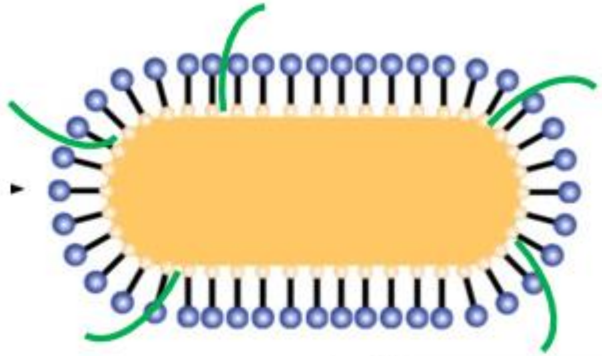
WP4
In vitro biological studies

WP5
Studies with radiopharmaceticals

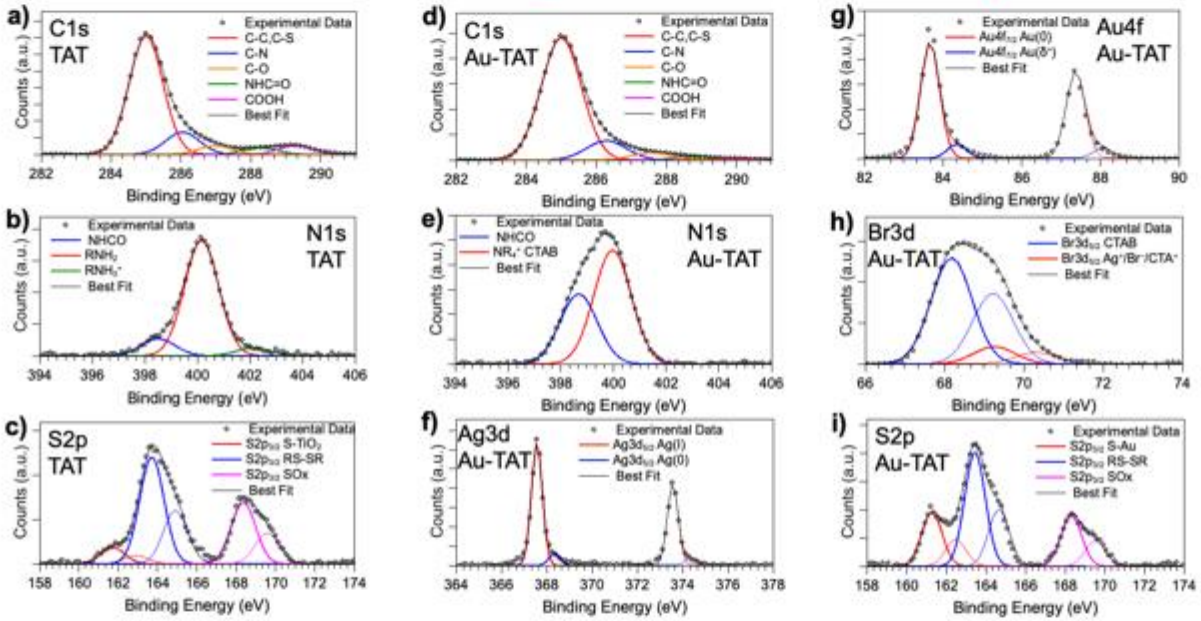
WP1
MODELING

Modified peptide TAT

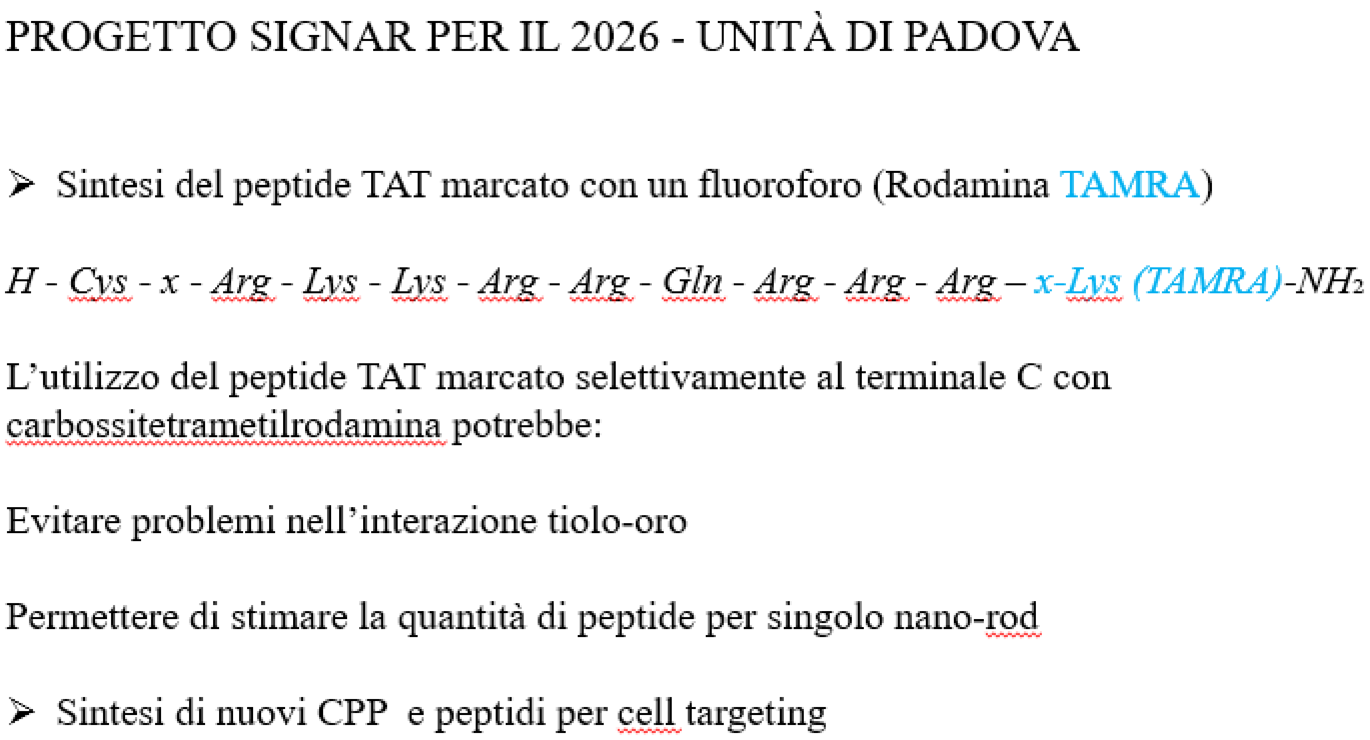
AuNRs FUNCTIONALIZED WITH CTAB AND MODIFIED TAT



SR-XPS data analysis allowed to assess the molecular stability of TAT peptide upon interaction with the AuNRs, as well as to probe the formation of a covalent chemical bond between the thiol moieties of TAT and the gold atom at the AuNRs surface. At the same time, the stability of AuNRs was also assessed by the reproducibility of Au4f, Br3d and Ag3d spectra with respect to previously published data collected on AuNRs stabilized by CTAB and secondary surfactants



SR-XPS spectra collected on sample TAT at a) C1s, b) N1s, c)) S2p core levels, and on sample AuNRs-TAT (namely Au-TAT in figure) at d) C1s, e) N1s, f) Ag3d, g) Au4f, h) Br3d and i) S2p core levels.



PROGETTO SIGNAR PER IL 2026 - UNITÀ DI PADOVA

- Sintesi del peptide TAT marcato con un fluoroforo (Rodamina TAMRA)

H - Cys - x - Arg - Lys - Lys - Arg - Arg - Gln - Arg - Arg - Arg – x-Lys (TAMRA)-NH_2

L'utilizzo del peptide TAT marcato selettivamente al terminale C con carbossitetrametilrodamina potrebbe:

Evitare problemi nell'interazione tiolo-oro

Permettere di stimare la quantità di peptide per singolo nano-rod

- Sintesi di nuovi CPP e peptidi per cell targeting

			FTE
Dettin	**Monica**	**SEGNAR**	**0,2**
Zamuner	**Annj**	**SEGNAR**	**0,2**

SPES, Fisica Medica

VITA
Virtual Imaging Trials in Medicine

Area di ricerca: Fisica Medica, SPES

Periodo: 2025,2026,2027

Responsabile locale: L. Altabella, (CTO Verona)
Responsabile nazionale: G. Mettivier (Napoli)

Participating Units:…

VITA

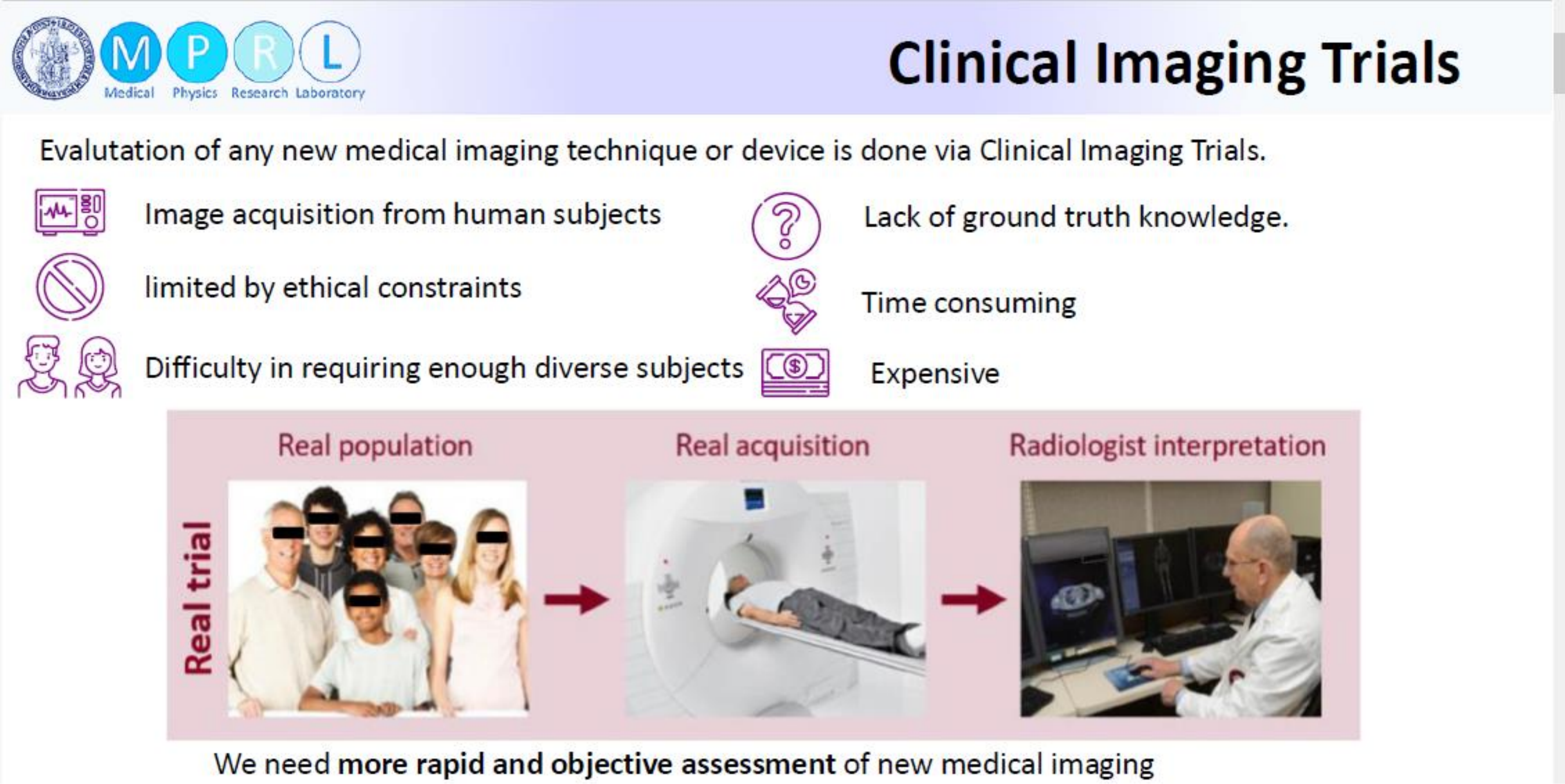
Virtual Imaging TriAls in Medicine

a frontier project of interdisciplinary & technological research of INFN CSN5

Responsabile Nazionale
Giovanni Mettivier

Sezioni Coinvolte
Napoli, Roma1, Padova, Torino, Catania, CNAF, TIFPA, Firenze

40 Ricercatori coinvolti



Clinical Imaging Trials

Evalutation of any new medical imaging technique or device is done via Clinical Imaging Trials.

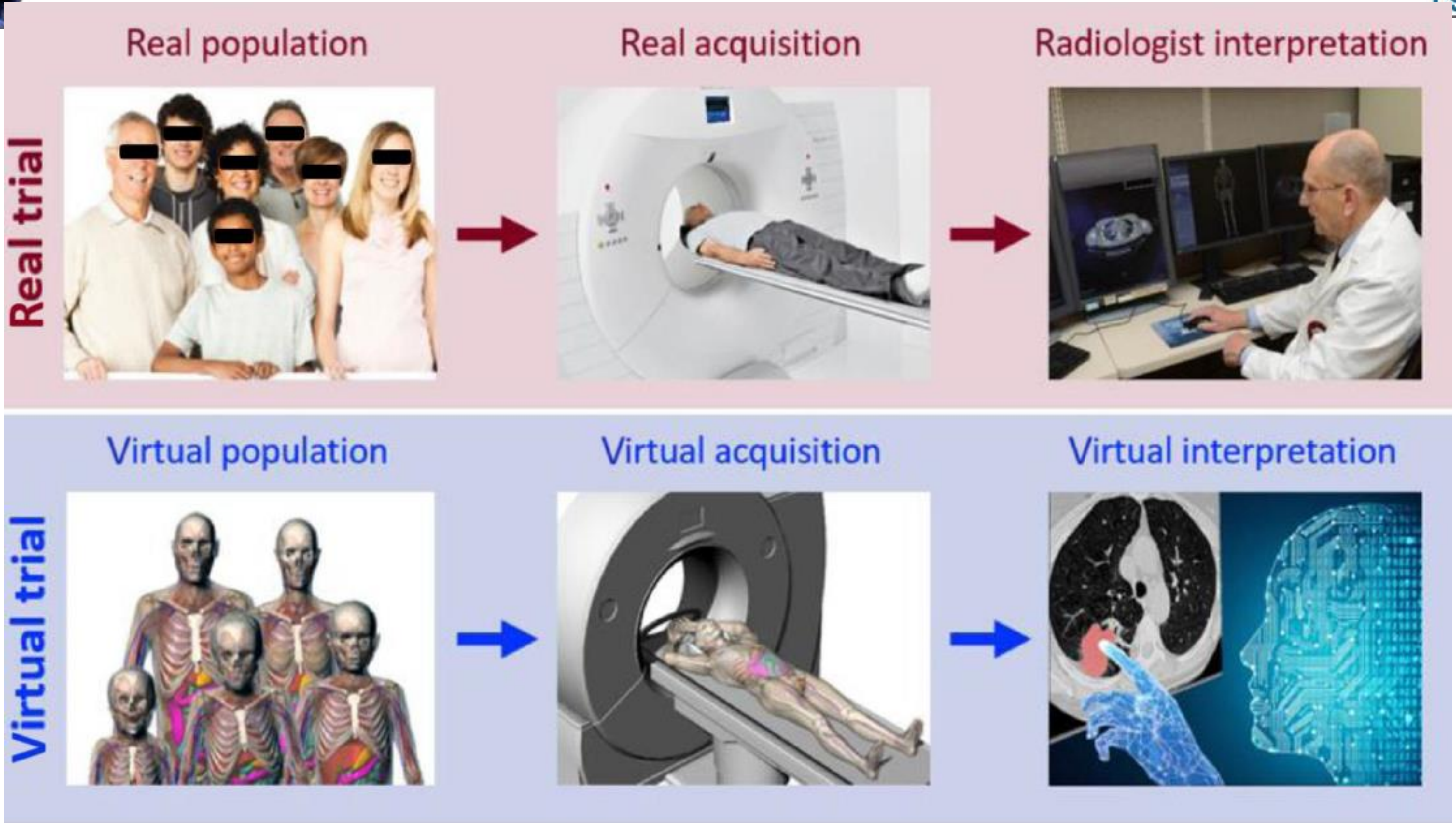
- Image acquisition from human subjects
- limited by ethical constraints
- Difficulty in requiring enough diverse subjects
- Lack of ground truth knowledge.
- Time consuming
- Expensive

Real trial

Real population → Real acquisition → Radiologist interpretation

We need **more rapid and objective assessment** of new medical imaging

➔ In silico trials using computational methos


Real trial
Real population
Real acquisition
Radiologist interpretation
Virtual trial
Virtual population
Virtual acquisition
Virtual interpretation

Essentials for a VIT

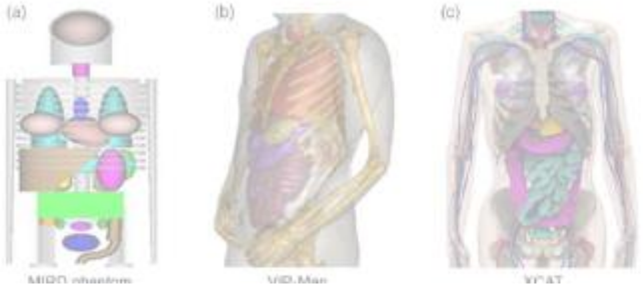
Virtual patient

(digital twin)

Computational anthropomorphic phantoms that model the patient anatomy and physiology.

Provide ground truth for virtual imaging.

Phantom types
(a) Mathematical
(b) Voxelized
(c) Boundary Representation (BREP)



Virtual scanner

(digital twin)

Techniques to replicate the scanner

1. Monte Carlo techniques (X-ray imaging, SPECT, PET)
2. Efficient equation solvers (MRI)
3. Finite-element analysis (Ultrasound)

Virtual reader

Mechanism to retrieve a judgement and interpretation about a virtual imaging case.

AI models to decide whether the lesion is present or not or to localize it (computer-aided detection algorithms)

Metodologia

Infrastruttura di calcolo

- Con i ricercatori dell'INFN si individueranno ed implementeranno le migliori soluzioni per la realizzazione di una infrastruttura capace di fornire uno storage condiviso per i fantocci ed i codici messi a disposizione dai diversi partner, all'uso di questi codici ed alle politiche di accesso a queste risorse

Virtual Patients

- Libreria di fantocci che modellano una vasta gamma di anatomie includendo aspetti patologici in tessuti e organi con caratteristiche note
- Libreria di immagini generate di volta in volta «su misura» tramite IA (GAN)

Virtual Scanner

- Ottimizzazione di due piattaforme di simulazione, una per la Breast CT e una per la brachiterapia oculare già precedentemente sviluppate dall'unità di Napoli e dall'ISS

Virtual Readers

- In clinica, le immagini mediche vengono interpretate dai radiologi La creazione di un equivalente computazionale sotto forma di lettori virtuali che abbracciano tre categorie: modelli di osservatori, radiomica e reti neurali è un ambito di ricerca molto interessante ed attivo.

Richiesta budget 2025

- ✓ Fondi pubblicazione → No
- ✓ Missioni → partecipazione incontro ISS a Novembre (2pp)
- ✓ Consumabili→ Hard disk 5 TB per storage dati

Virtual Clinical Trial: stato dell'arte in Italia e prospettive

data da definire

organizzato da

ISTITUTO SUPERIORE DI SANITÀ
Centro nazionale per la protezione dalle radiazioni e fisica computazionale

In collaborazione con
ISTITUTO NAZIONALE DI FISICA NUCLEARE
e
ASSOCIAZIONE ITALIANA di FISICA MEDICA e SANITARIA

Richiesta budget 2026

- ✓ Fondi pubblicazione → 3000 euro
- ✓ Missioni→ 5000 euro
- ✓ Consumabili→ 2000 euro

FTE

Padova		
Carlo Cavedon	0.4	1
Luisa Altabella	0.3	
Pier Giorgio Esposito	0.3	

← Progetto Iniziale

2026 →

Carlo Cavedon	0.3	1
Luisa Altabella	0.3	
Pier Giorgio Esposito	0.2	
Marina Fedon Vocaturo	0.2	

MAAT

Metal Additive manufacturing for Accelerator Technologies

MAAT

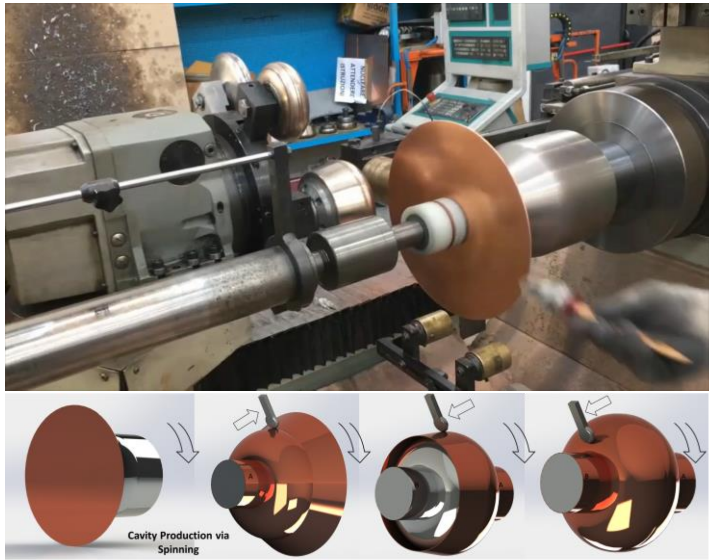
Oscar **Azzolini** INFN LNL **(Resp. Nazionale)**

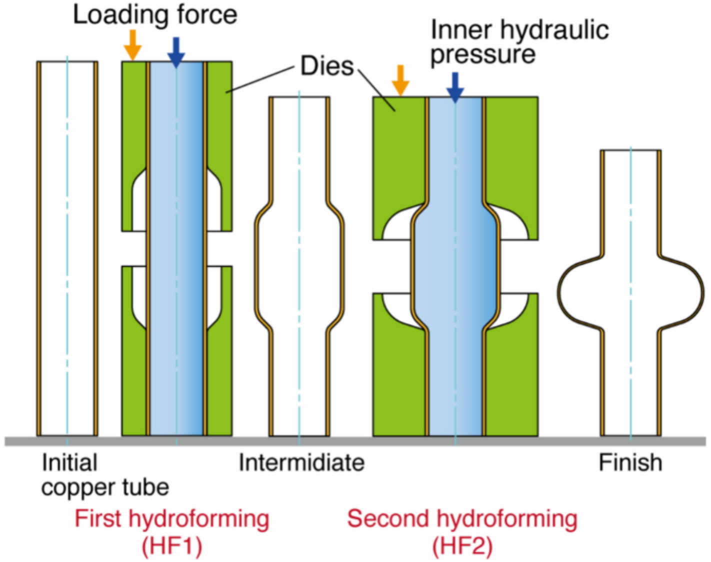
Pietro **Rebesan** INFN PADOVA

Massimiliano **Cannavò** INFN LASA

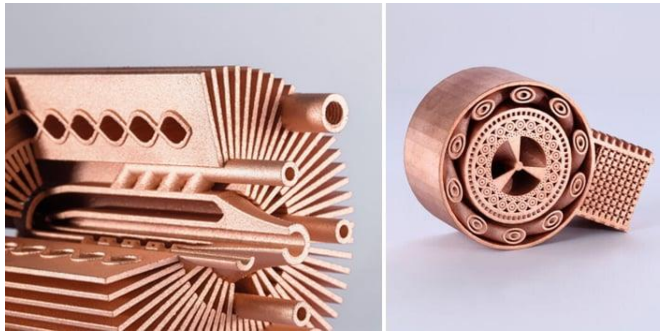
MAAT Motivation 2026-2028

1. Innovative Seamless RF cavity Forming (INFN Patent)





2. Innovative Cooling Concept for Cryogenic Components



MAAT Objectives 2026-2028

1. Materials Research and Development:

A core focus of MAAT is the development and optimization of advanced materials specifically tailored for additive manufacturing (AM) processes, and structural requirements of components needed for the next generation accelerators.

2. Process Engineering and Design for Additive Manufacturing:

MAAT aims to drive innovation in manufacturing process engineering and component design tailored specifically for additive manufacturing, developing two parallel pathways based on Laser Powder Bed Fusion (LPBF) and Wire Laser Additive Manufacturing (WLAM) combined with CNC machining (INFN Patent).

3. Characterizations and post processing treatments of the final component:

MAAT will integrate advanced characterization and post processing techniques into its workflow (i.e. computed tomography). Surface finishing processes (plasma electropolishing) are fundamental for ensuring the final performance of accelerators components.

MAAT WPs 2026-2028

WP1: Materials Research and Development (MI WP Leader)

Objective: tailor and validate advanced materials and novel copper-based alloys for additive manufacturing (AM).

- Task 1.1 - AM powder blend formulation and characterization (PD/LNL)
- Task 1.2 - Optimization of AM processing parameters (MI/PD)
- Task 1.3 - Thermal, mechanical & electrical testing (MI/PD)

WP2: – Process Engineering and Design for Additive Manufacturing (PD WP Leader)

Objective: develop and optimize AM workflows and component architectures with integrated thermal management.

- Task 2.1 - Hybrid process optimization WLAM + CNC (LNL)
- Task 2.2 - LPBF process optimization (PD/MI)
- Task 2.3 - Design of innovative cooling channel architectures (PD/MI)

WP3: Characterizations and post processing treatments of the final component (LNL WP Leader)

Objective: ensure final components meet stringent RF, thermal, vacuum, and quality standards through inspection and finishing.

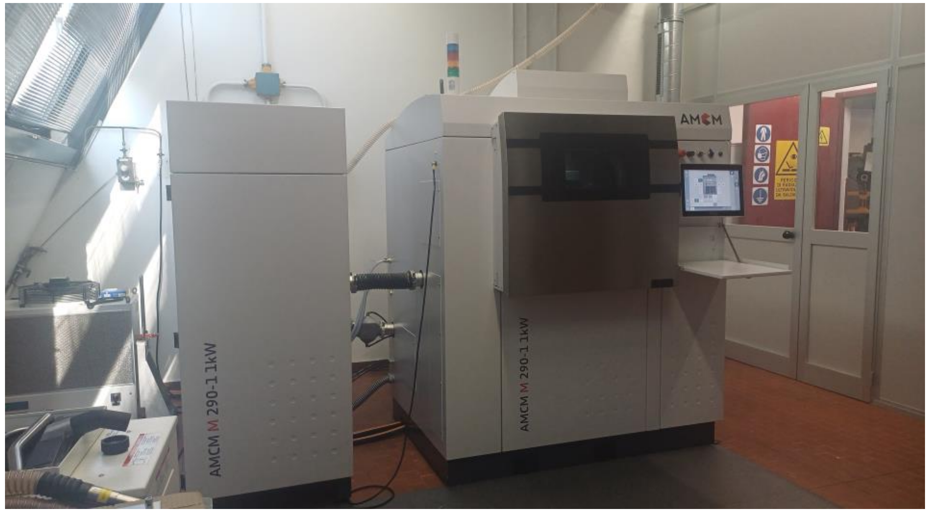
- Task 3.1 - Non-destructive inspection and Surface topography analysis (LNL/PD)
- Task 3.2 - Surface finishing & chemical cleaning (LNL/PD)
- Task 3.3 - Component performance validation (LNL/MI)

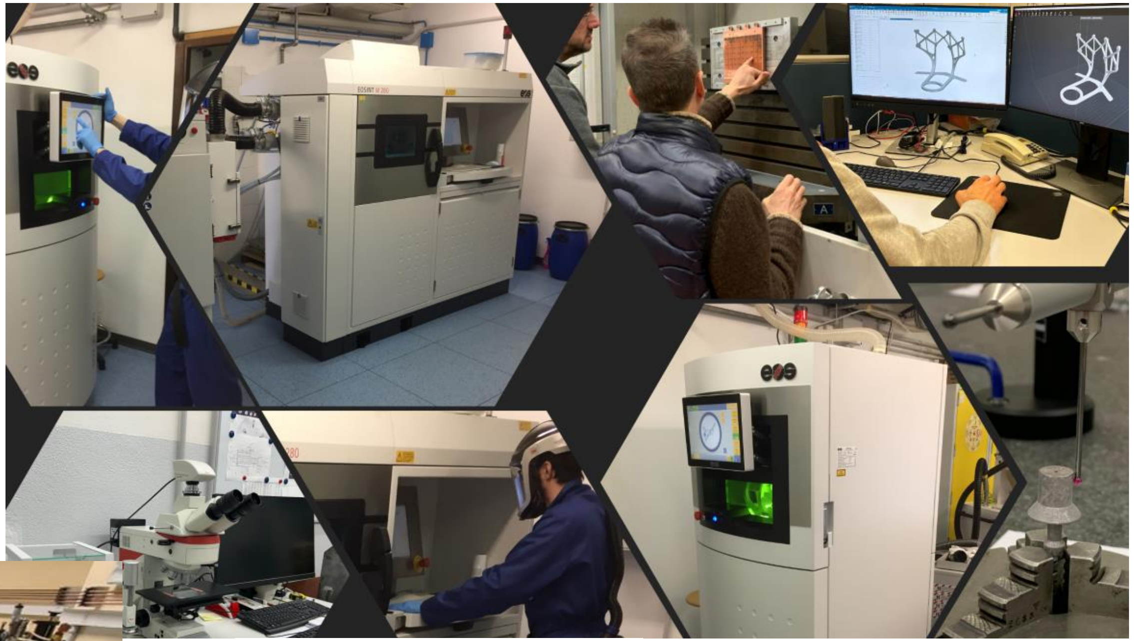
MAAT Infrastructure 2026-2028

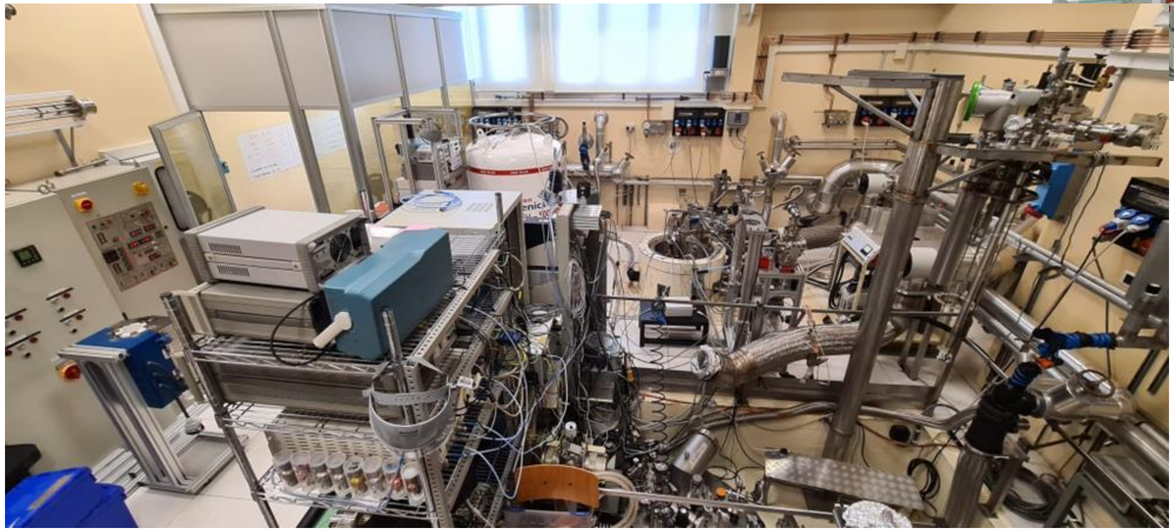
INFN LNL

INFN PADOVA

INFN LASA







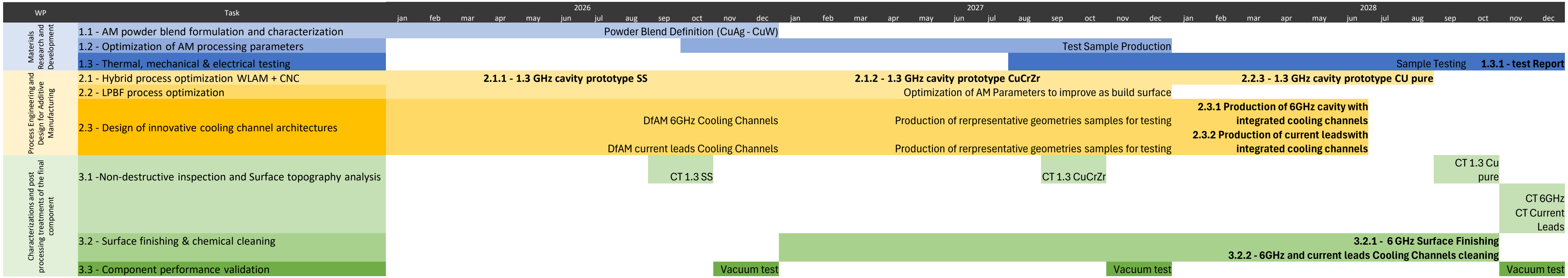
MAAT FTE 2026

Section	Participant	Association	Qualification	Age	FTE
LNL	**Azzolini Oscar (NR/LR)**	Technologist	First Technologist	46	0.6
	Angioletti Lorenzo		fellow	*	1.0
	Emmanuel Ezeaba		PhD	*	0.1
	Matteo Lazzari		fellow	*	0.3
				TOTALE FTE LNL	**2.0**
PD	**Rebesan Pietro (LR)**	Employee	Technologist	*	0.1
	Favero Giacomo	Associated	Tecnologica Ricercatori/Professori università	*	0.25
	Alberto Barci	Associated	Tecnologist PhD	*	0.3
	Davide Cester	Associated	Tecnologist PhD	*	0.3
	Valentini Francesca	Associated	Tecnologist PhD	*	0.3
	Mehrdad Faraji	Associated	Tecnologist PhD	*	0.3
	Technician (under recruitment)	Employee	Technician	*	0.2
	Simone Carmignato	Associated	Tecnologica Ricercatori/Professori università	*	0.2
				TOTALE FTE PD	**1.95**
MI-LASA	**Cannavò Massimiliano (LR)**	Technologist	Technologist	36	0.3
	Enrico Beneduce	Technologist	Technologist	27	0.3
	Nicola Cavaliere	Associated	Technician	36	0.1
	Nicola Ciarchi	Associated	Technician	24	0.1
	Leonardo Carletto	Associated	Technician	23	0.2
				TOTALE FTE MI	**1.0**
		TOTALE FTE MAAT			**4.95**
			95Researcher: - FTE, Technologist: - FTE, Technician: - FTE		

MAAT BUDGET 2026

Section	Chapter	Description	Request (k€)
LNL	MISSIONI	Travels to external mechanical workshop for components manufacturing (SPAIN)	2
		TOTALE MISSIONI 2	
	CONSUMO	Chemicals for SS cleaning and polishing	2
		Chemicals for Cu cleaning and polishing	2
		TOTALE CONSUMO 4	
	SERVIZI	3D Wire Laser Cu sample for mechanical test	1
		3D Wire Laser 1 Cavity Prototype 1.3 GHz Cu	21
		Waste disposal chemical treatments	2
		TOTALE SERVIZI 23	
	INVENTARIO	Shared expense for purchasing a new X-Ray Diffractometry	5
		TOTALE INVENTARIO 5	
		TOTALE LNL REQUESTS	**35**
PD	MISSIONI	Travels to LASA for LPBF production -	4
		TOTALE MISSIONI 4	
	CONSUMO	Powder Cu alloys	8
		Consumables for LPBF machines (filters, sieving, ...)	1.5
		Dispositivi di Protezione Individuale (DPI)	2.5
		Tools for CNC post-processing	1.0
		TOTALE CONSUMO 13	
	INVENTARIO	Conductive probe (Strumento per misura conducibilità elettrica (%IACS) campioni stampati)	9.5
		TOTALE INVENTARIO 9.5	
	SERVIZI	Shared expense for machine maintenance	6
		TOTALE SERVIZI 6	
		TOTALE PD REQUESTS	**32.5**
MI-LASA	MISSIONI	Travels to other labs for measures	2
		TOTALE MISSIONI 2	
	CONSUMO	Powder pure Cu	14
		Consumables for LPBF machines (filters, sieving, ...)	2
		Tools for post processing	1
		Argon	2
		TOTALE CONSUMO 19	
	INVENTARIO	Macchina inglobatrice per analisi metallografica	(5)
		TOTALE INVENTARIO (5)	
		TOTALE MI-LASA REQUESTS	**19 + (5)**
		TOTALE MAAT REQUESTS	**86.5 + (5 SJ)**

MAAT Timeline 2026-2028



WP	Task	2026												2027												2028											
		jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Materials Research and Development	1.1 - AM powder blend formulation and characterization	Powder Blend Definition (CuAg - CuW)																																			
	1.2 - Optimization of AM processing parameters										Test Sample Production																										
	1.3 - Thermal, mechanical & electrical testing																				Sample Testing														**1.3.1 - test Report**		
Process Engineering and Design for Additive Manufacturing	2.1 - Hybrid process optimization WLAM + CNC	**2.1.1 - 1.3 GHz cavity prototype SS**												**2.1.2 - 1.3 GHz cavity prototype CuCrZr**												**2.2.3 - 1.3 GHz cavity prototype CU pure**											
	2.2 - LPBF process optimization	Optimization of AM Parameters to improve as build surface																																			
	2.3 - Design of innovative cooling channel architectures	DfAM 6GHz Cooling Channels DfAM current leads Cooling Channels												Production of rerpresentative geometries samples for testing Production of rerpresentative geometries samples for testing												**2.3.1 Production of 6GHz cavity with integrated cooling channels** **2.3.2 Production of current leadswith integrated cooling channels**											
Characterizations and post processing treatments of the final component	3.1 -Non-destructive inspection and Surface topography analysis									CT 1.3 SS												CT 1.3 CuCrZr												CT 1.3 Cu pure		CT 6GHz CT Current Leads	
	3.2 - Surface finishing & chemical cleaning													**3.2.1 - 6 GHz Surface Finishing** **3.2.2 - 6GHz and current leads Cooling Channels cleaning**																							
	3.3 - Component performance validation											Vacuum test												Vacuum test												Vacuum test	

Conclusioni

Predecessore	Sigla	Stato	Resp Locale	Anni	missioni	consumo	inventariabile	trasporti	Maintenance
REMIX	CUPRUM_TTD	Estensione	L. De Nardo	23,24,25	1	5,5			
ASAP	ADA_5D		G. Collazuol	23,24,25	5	10			
PHYDES	DOCET	Continuazione	G. Carugno	24,25,26	14	23	23		
	ASPIDES		G. Collazuol	25,26,27	4	10			
	TIMEPIX4		G. Collazuol	25,26,27	4	10			
	SQUEEZE		M.Bazzan	24,25,26		17.5	14.5		
ML_INFN	AI_INFN		M. Verlato	24,25,26	1				
	QuteFDS	Grant giov. 2anni	A. Grimaldi	[25],26,27		71.5	4.5		
	SEGNAR		M. Dettin	25,26,27		2.15			
	VITA_5		L. Altabella	25,26,27	5	2			
HISOL	HISOL_NEXT		P. Rebesan	25,26,27	3	19			
	MAAT	Nuove proposte	P. Rebesan	26,27,28	4	13	9,5		6
ADMIRAL	ISOLPHARM_APEX		M. Lunardon	26,27,28	3	1		1	
	SLBP		M. Morandin	26,27,28		24,5			
	INCANTO	Call	D.Zuliani	26,27,28	2	-	-	-	-
	DIOMEDES	Call	F. Recchia	26,27,28	-	-	-	-	-

Conclusioni

Sigla	Prog. Meccanica	Serv. Tech. Avanzate	Off. Meccanica	Serv. Elettronica [Bellato]	Serv. Tecnico Generale [Nicoletto]
CUPRUM_TTD	**-**		**-**	**-**	**-**
ADA_5D	**1 m.p. telescopio**		**1 m.p. telescopio**		
DOCET	**1 m.p.**		**11 m. p.**	**1 m.p.**	**8 m.p.**
ASPIDES	**-**	**-**	**1 m.p. TPC parts**	**-**	**-**
TIMEPIX4				**3 m.p. FPGA x TimePix4**	**1 m.p.**
SQUEEZ	**-**		**1 m.p. banco ottico**	**-**	**-**
AI_INFN	**-**		**-**	**-**	**-**
SEGNAR	**-**	**-**	**-**	**-**	**-**
VITA_5	**-**	**-**	**-**	**-**	**-**
MAAT		**1 m. p.**	**1 m. p.**		
HISOL_NEXT		**1 m. p.**	**1 m. p.**		
ISOLPHARM_APEX					
SLBP			**1 m. p.**		**2 m. p. PCB design**
QuteFDS			**4 m.p. cavity holders**		**3 m.p. photodiodes**
INCANTO	**-**	**-**	**-**	**-**	**-**

Considerazioni finali

- 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
- Limitazioni
  - I giovani che partecipano ai grandi esperimenti hanno problemi a mettere il 90% FTE perché perdono la possibilità di pubblicare
    - Cercare sinergie con gli esperimenti

Esorto chi e’ nelle condizioni di applicare di provarci