SIG-WP4

New technologies for dose delivery system

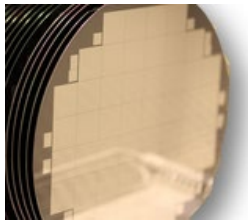
Revisione planning globale e budget

21/12/2021

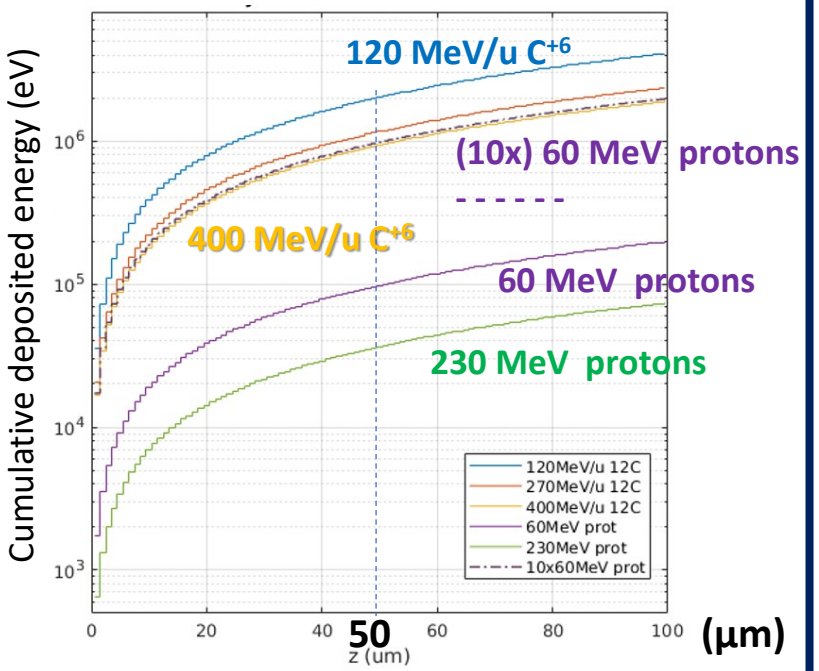
Simona Giordanengo – INFN To

WP4 – New technologies for dose delivery system

T4.1 – Thin planar silicon sensors for Carbon ion counter



? Single ion signal
? Ionization density effects
? Radiation resistance



T4.2 - Single ion crossing time measurement

Starting point: INFN-MoVeIT results with protons

- **Proof of Concept** to provide the time stamps for ions with high efficiency.
- **Start counter** for range verification system.

→ **Exploiting existing ASICs at INFN-To for timing**

12bit 5 GS/s Digitizer + offline analysis

picoTDC readout board

pico-TDC ASIC for precise time-tagging of up to 64 inputs channels

- 3ps or 12ps binning
- very low jitter (<1ps)

T4.3 – GPU-based data analysis for online dose verification

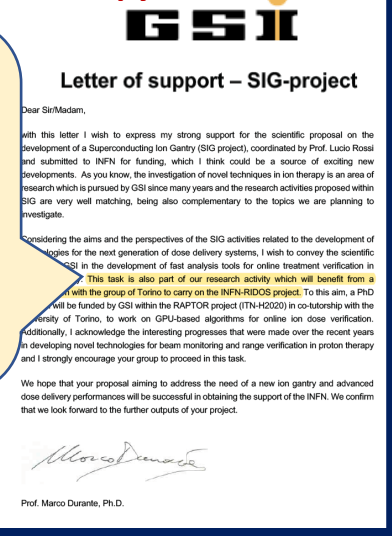
Starting point: INFN-RIDOS results

New GPU-based algorithms to exploit ion treatments (ADAPTIVE PT) with a very fast data analysis for online feedback on the dose delivered.

→ Collaboration with GSI within the **RAPTOR** project (ETN – H2020)

Real-Time Adaptive Particle Therapy Of Cancer

This task is also part of our research activity which will benefit from a collaboration with the group of Torino to carry on the INFN-RIDOS project.



GSI

Letter of support – SIG-project

Dear Sir/Madam,

with this letter I wish to express my strong support for the scientific proposal on the development of a Superconducting Ion Gantry (SIG project), coordinated by Prof. Lucio Rossi and submitted to INFN for funding, which I think could be a source of exciting new developments. As you know, the investigation of novel techniques in ion therapy is an area of research which is pursued by GSI since many years and the research activities proposed within SIG are very well matching, being also complementary to the topics we are planning to investigate.

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We hope that your proposal aiming to address the need of a new ion gantry and advanced dose delivery performances will be successful in obtaining the support of the INFN. We confirm that we look forward to the further outputs of your project.

Prof. Marco Durante, Ph.D.

INFN-CSN5 - RIDOS
2014-2016

WP4 – NEW GANTS

			2022				2023				2024				2025			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP4	task4.1	Existing Si-sensor studies with ions																
		New sensors design&development																
		Ion counter assembly&test																
	task4.2	Test of FAST+picoTDC	X															
		SIG-ASIC develop&test (SJ)					X											
		Test&Integration with RVS																
	task4.3	GPU-based PGT analysis																
		Fast tools integration&test																

WP4 – BUDGET ASSEGNATO

Sigla Loc.	Capitolo	Riunione	Note Alla Richiesta	Rich.	Rich. SJ	Assegn.	Assegn. SJ	Assegn. Dot.	Assegn. Ant.	Assegn. Ant. Dot.	Commento Alla Assegnazione
TO	MISS	Assegnazioni	Missioni WP4 - Turni di misura a CNAO (ioni C) per caratterizzazione di sensori e di misure di tempo con ASIC dedicati. Visita al CERN per consulenza su impiego del picoTDC. Â§	5.0	0.0	2.5					
		Assegnazioni	Missioni WP5 - Misure su fascio a CNAO (ioni C) per studio della produzione di radiazione secondaria, test rivelatori l3PET e rivelatore LaBr3(Ce). Misure di PGT.Â§	5.0	0.0	2.5					Attività limitata ai rivelatori già esistenti (upgrade differito al secondo anno di progetto)
		Totale MISS		10.0	0.0	5.0	0.0	0.0	0.0	0.0	
	CON	Assegnazioni	WP4 (task 2) PicoTDC evaluation boards Â§	2.5	0.0	2.5					
		Assegnazioni	~~WP4 (task 1) Realizzazione due schede di front-endÂ§~~	2.0	0.0	0.0					Attività differita al secondo anno di progetto
		Assegnazioni	WP4 (Task 1 e 2) materiale di consumo per il montaggio e i test su fascio Â§	2.0	0.0	2.0					
		Assegnazioni	~~WP4 (Task 3) Workstation con GPU Qudro RTX 5000 Â§~~	8.0	0.0	0.0					
		Assegnazioni	WP5 (task 1) Acquisto cristalli LaBr3Â§	18.0	0.0	0.0					Attività differita al secondo anno di progetto
		Assegnazioni	WP5 (task 1) Produzione di SIPM c/o FBKÂ§	2.0	0.0	0.0					Attività differita al secondo anno di progetto
		Assegnazioni	WP5 (task 1) FE board per rivelatore LaBr3Â§	1.0	0.0	0.0					Attività differita al secondo anno di progetto
		Assegnazioni	WP5 (task 1) FPGA Xilinx Kintex-7 Evaluation kitÂ§	2.0	0.0	2.0					
		Assegnazioni	WP4 (task 2) FPGA Xilinx Kintex-7 Evaluation kitÂ§	2.5	0.0	0.0					Attività differita al secondo anno di progetto
		Totale CON		40.0	0.0	6.5	0.0	0.0	0.0	0.0	
	INV	Assegnazioni	WP5 (task 1) Digitizer CAEN V1742Â§	9.0	0.0	0.0					
		Assegnazioni	WP5 (task 1) Alimentatore LV da bancoÂ§	1.0	0.0	0.0					
		Totale INV		10.0	0.0	0.0	0.0	0.0	0.0	0.0	
	SPSERVIZI	Assegnazioni	Una annualità AdR per WP5 Â§	31.0	0.0	0.0					Richiesta differita al secondo anno di progetto
		Totale SPSERVIZI		31.0	0.0	0.0	0.0	0.0	0.0	0.0	
Totale TO				91.0	0.0	11.5	0.0	0.0	0.0	0.0	
Totale Generale SIG				91.0	0.0	11.5	0.0	0.0	0.0	0.0	

WP4 – budget 2022

2.5 kE → 2 picoTDC + 2 FanoutBoard

2 kE consumo per misure dei sensori

WP4 – NUOVO BUDGET SU 4 ANNI

Nuovo BUDGET WP4						TOT
WP4 - Dose Delivery System		2022	2023	2024	2025	
Task1	Instruments (sensors)		35			35
	Consumables	2	2	2.5	2	8.5
Task2	Instruments (ASIC)			35		35
	Consumables (picoTDC+FPGA+varie)	2.5	2	2	2	8.5
Task3	Consumables (GPU)	0	8			8
Mission		2.5	3.5	4.5	6.5	17
AdR –II fascia			31	31		62
TOTAL WP4		7	81.5	75	10.5	174

MS # or DLV#	Description WP4	Inputs from	Time (Month from 1/1/22)
MS4.1	Characterization of the available silicon sensors with carbon ions and study of radiation damage.		M24
MS4.2	Design and production of new silicon sensors		M30 **M36**
MS4.3	Ion counter assembly and test with the ESA ABACUS frontend board.		M36 **M42**
MS4.4	Test with carbon ions of available sensors using FAST-ASIC matched with the picoTDC.		M24 **M30-33**
MS4.5	Design, production and test of the SIG-ASIC (sub judice to results of MS4.4)	WP5	M30 **M36**
MS4.6	**Detector able to count the ions up to 10^8 ions/cm^2*s and integrated timing detector and PGT system.**		**M36** **M48**
MS4.7	Optimization of the multi-detector PGT analysis to run on CUDA.	WP5	M30 **M30**
MS4.8	**DDS sub-system for online treatment delivery verification through GPU-based data analysis.**		**M36** **M42**

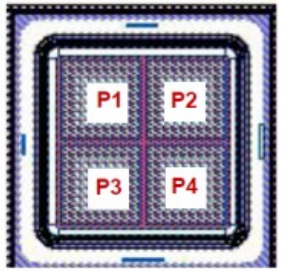
WP4 – MILESTONES 2022

MILESTONES PROPOSTE E CONCORDATE

Milestones Concordate	
Data	**Descrizione**
31-03-2022	Deliverable WP1 : Magnet Demonstrator Main Parameters
31-05-2022	Preliminary magnet design
30-06-2022	Agreement with CERN-CNAO
30-06-2022	Design of SMS
31-08-2022	Report sulle misure con fasci di carbonio presso il CNAO con i sensori per il DDS.
31-08-2022	Report sulle misure con fasci di carbonio presso il CNAO con i rivelatori I3PET per il RVS.

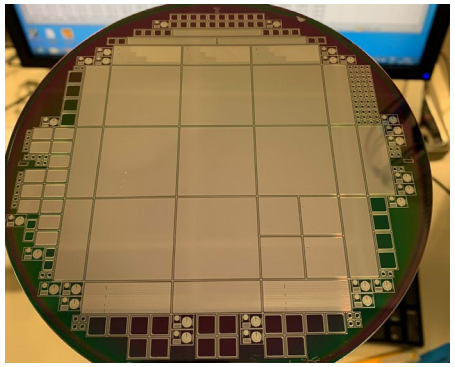
WP4 – Task4.1 : R&D on new planar thin silicon sensors

Thin silicon sensors and readout boards from past experiments



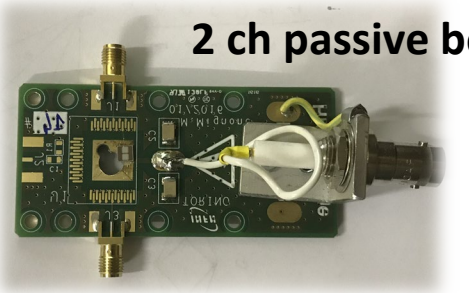
Exflu
W6, 2*x*2, type 10
10-4, PiN
Active thickness: 35 µm
Single Pads (P1, P2, P3, and P4) area: 1.3 *x* 1.3 mm^2

MoVeIT 2020 – 48 strips
W10-B6
Active thickness: 60 µm
Strip Dimensions: 0.114 mm width,
26.214 mm length, 0.180 mm pitch

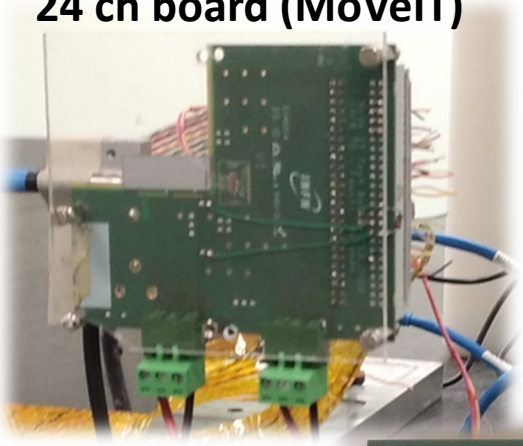


MoVeIT 2020 – 146 strips
W10-A..
Active thickness: 60 µm
Strip Dimension: 0.114 mm width,
26.214 mm length, 0.180 mm pitch

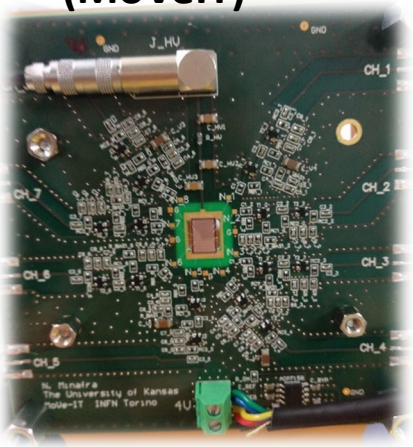
2 ch passive board



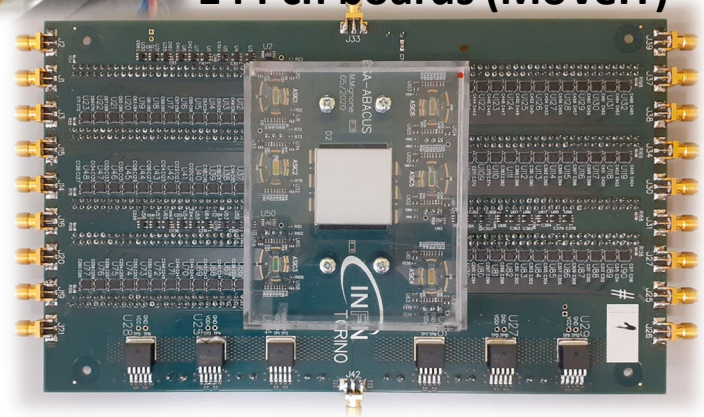
24 ch board (MoVeIT)



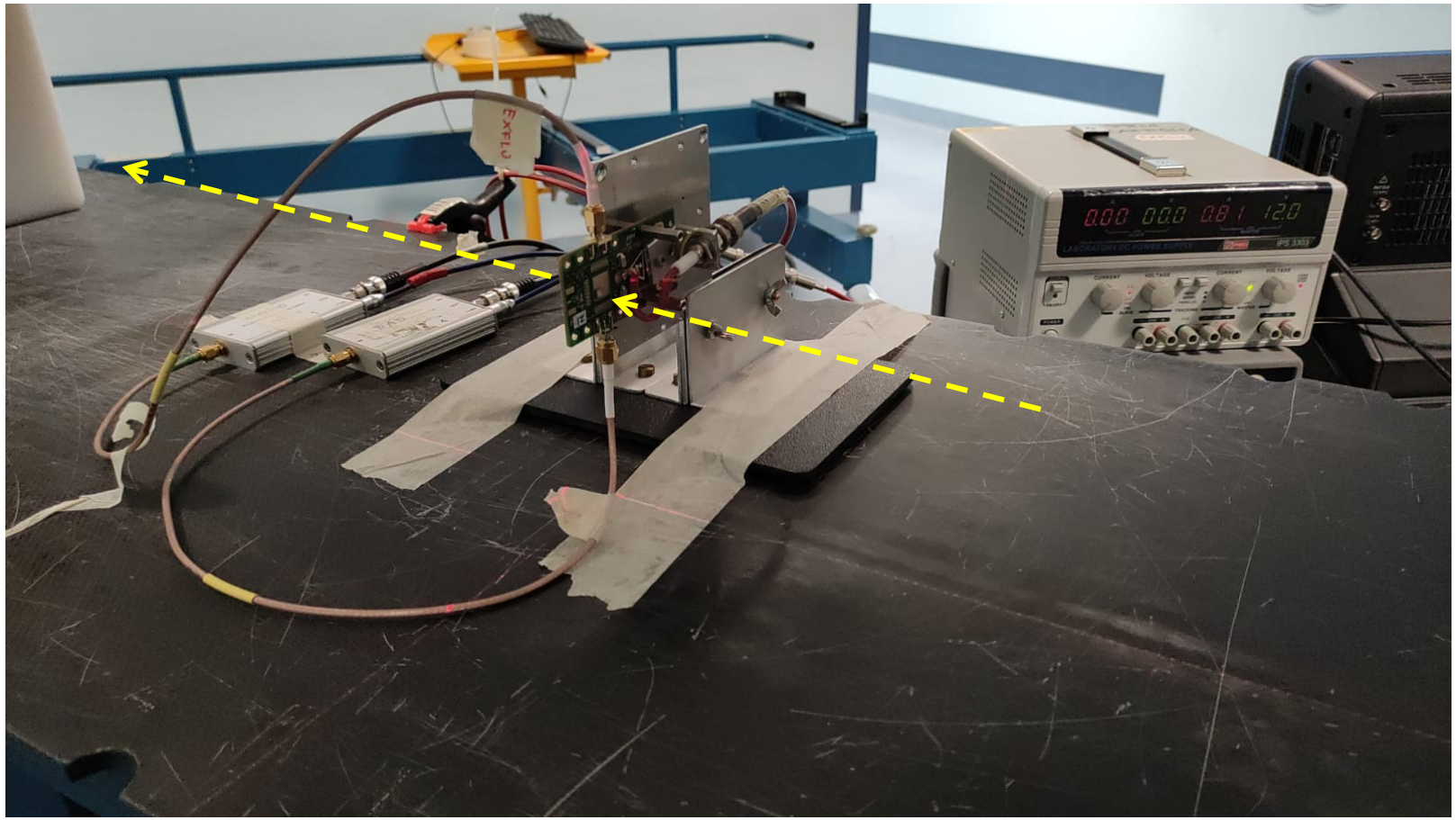
8 ch board (MoVeIT)



144 ch boards (MoVeIT)



12 DICEMBRE 2021
PRIMO TEST CON IONI CARBONIO A CNAO



- Energies used:

398.84 MeV/nucl
271 MeV/nucl
221 MeV/nucl
166.41 MeV/nucl
115.26 MeV/nucl

- HV: 120 V (Both sensors)

SETUP MISURE DEL 12 DICEMBRE A CNAO

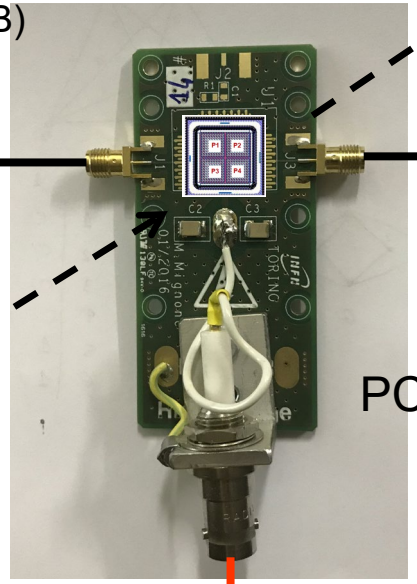
2 signals configuration

offline analysis

CIVIDEC Broadband amplifiers (40 dB)

CIVIDEC Broadband amplifiers (40 dB)

2



3

Beam

PCB board designed by Mignone

Lecroy Oscilloscope
(WAVERUNNER 9254M)
up to 40 GSample/s

2 3

DT1471ET

4 Ch Reversible 5.5 kV/300 µA Desktop HV Power Supply Module (USB/Ethernet/T.screen)

SENSORI USATI NEL TEST DEL 12 DICEMBRE A CNAO

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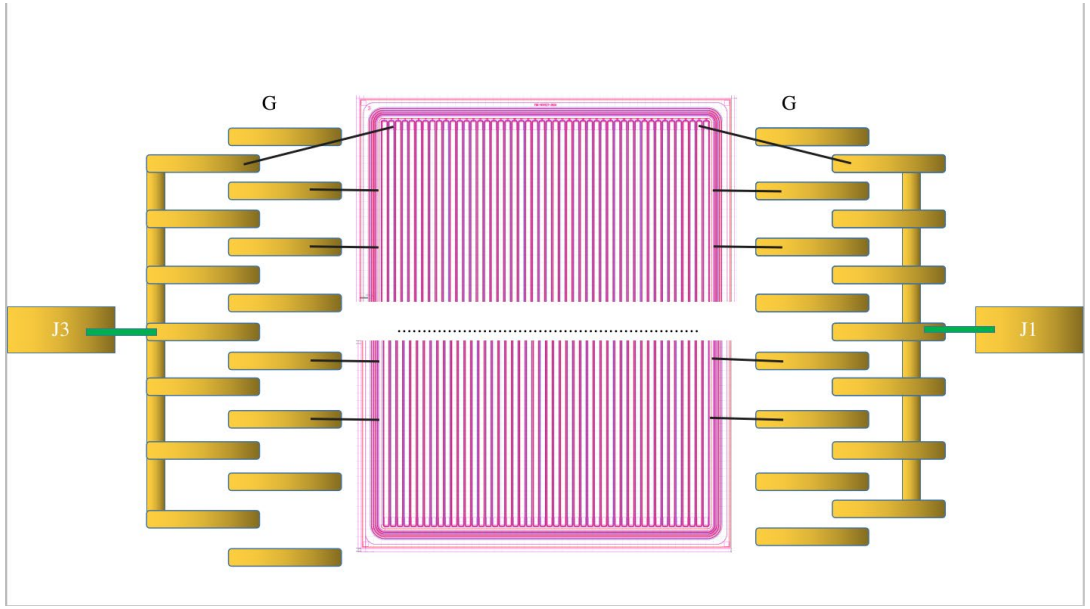

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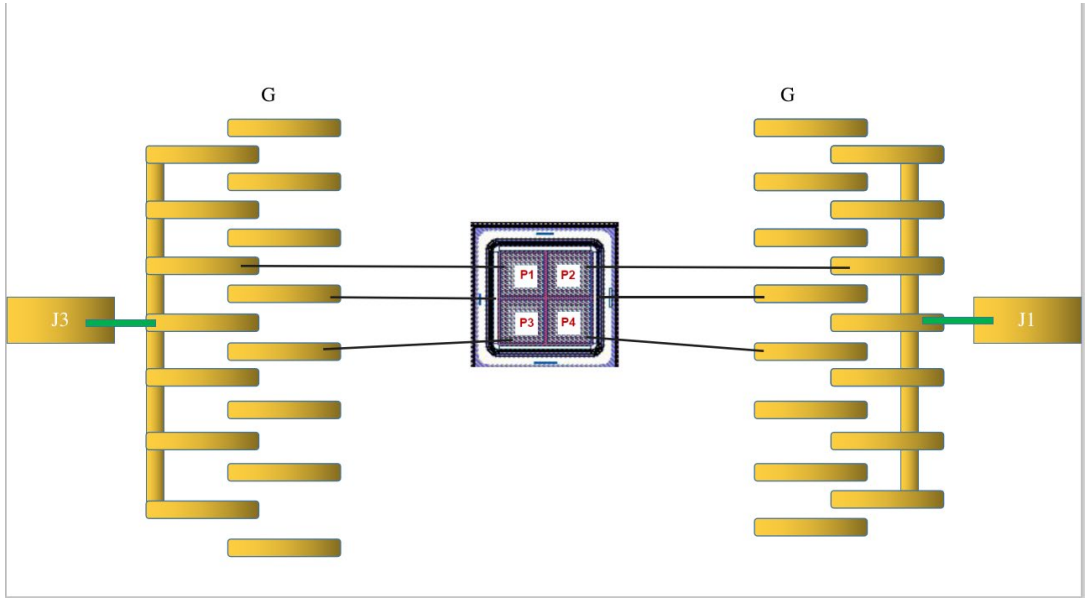
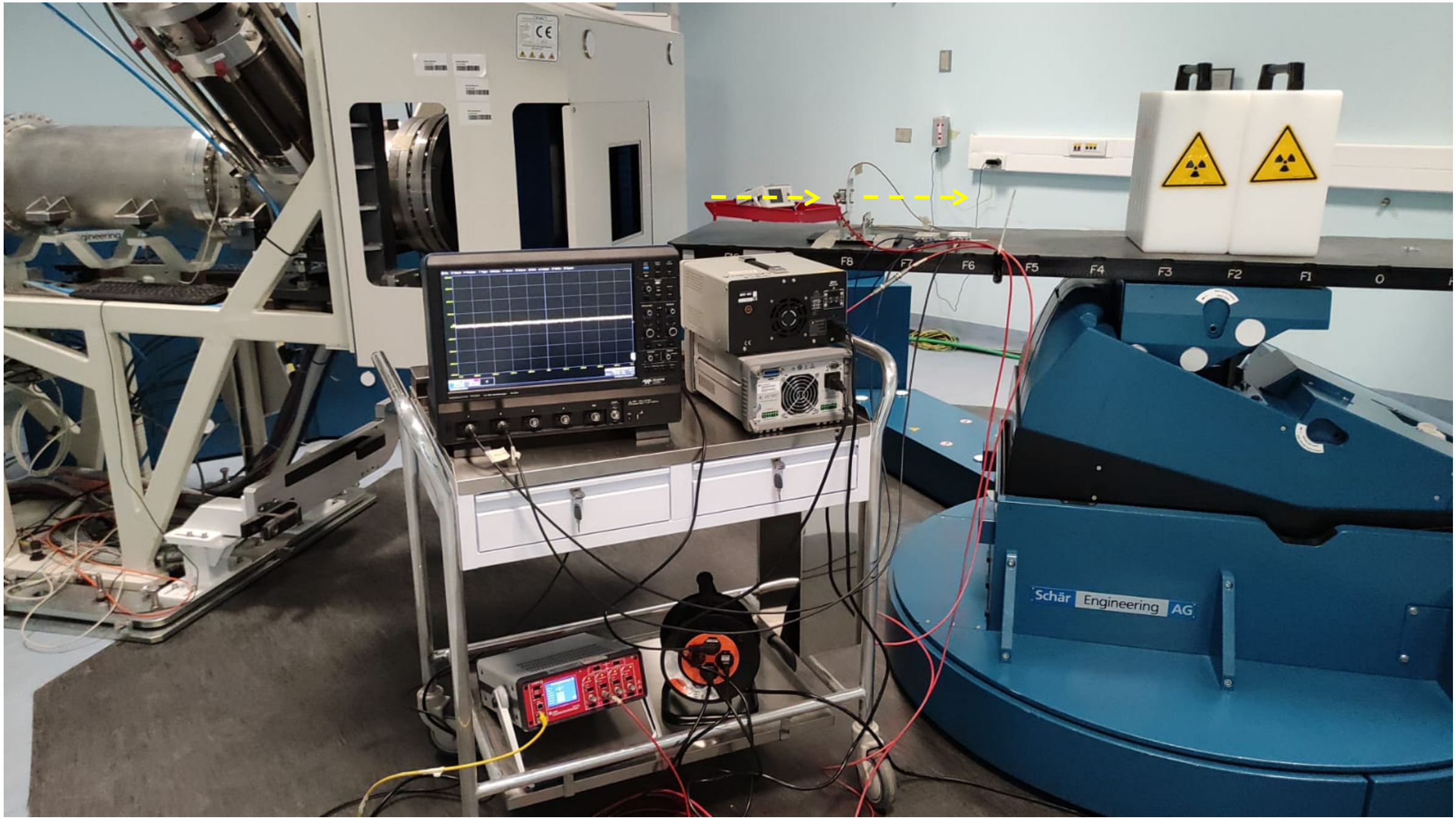
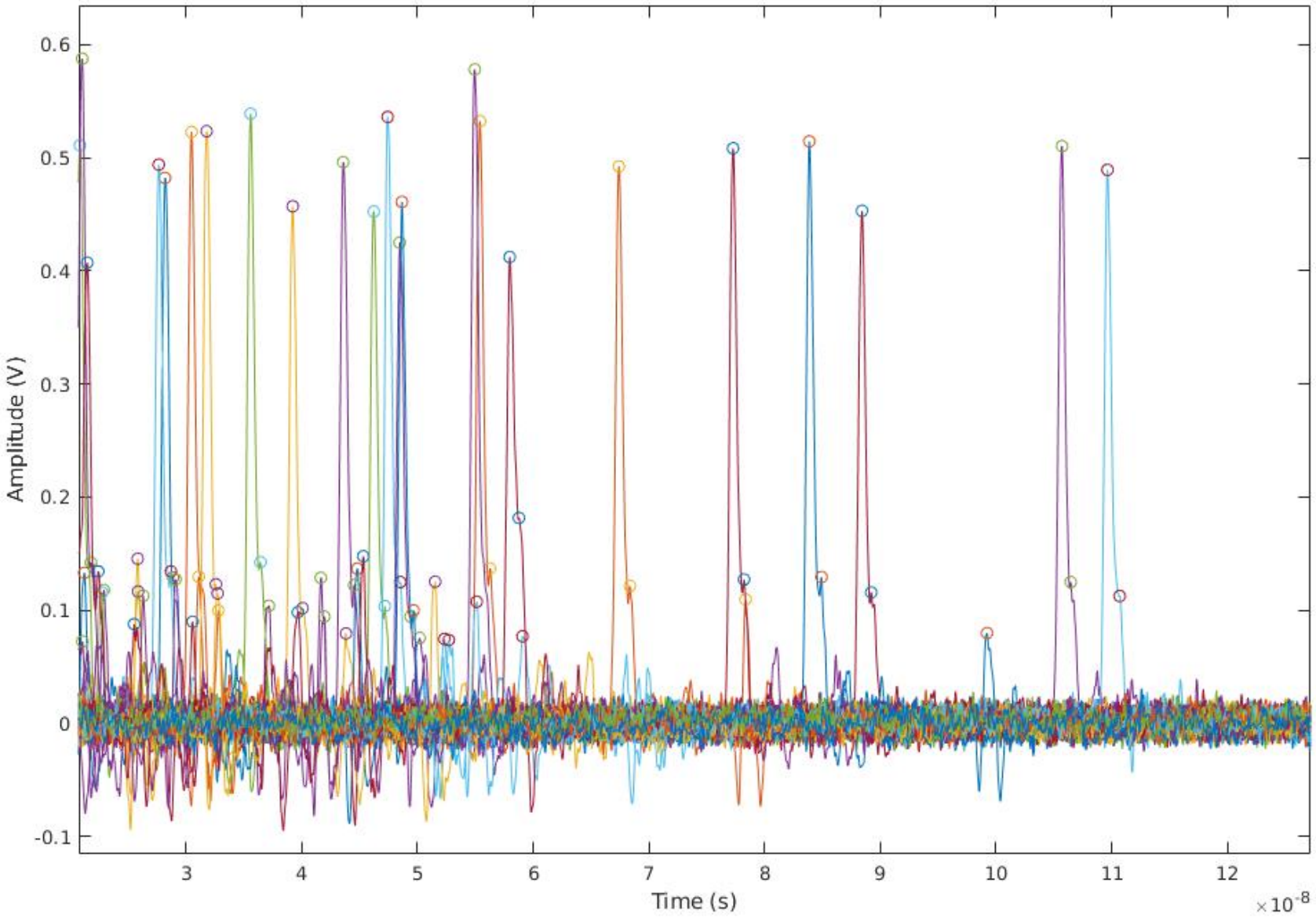
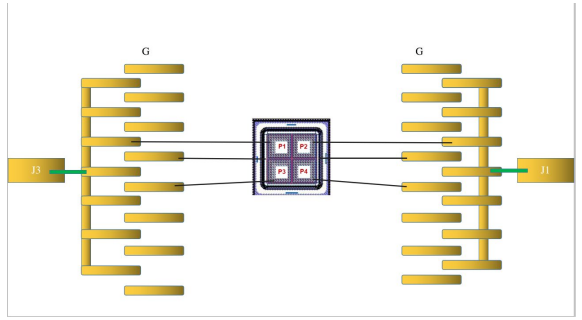



F8
F7
F6
F5
F4
F3
F2
F1
Schär Engineering AG

SEGNALI PRODOTTI DAI SINGOLI IONI NEI PADS

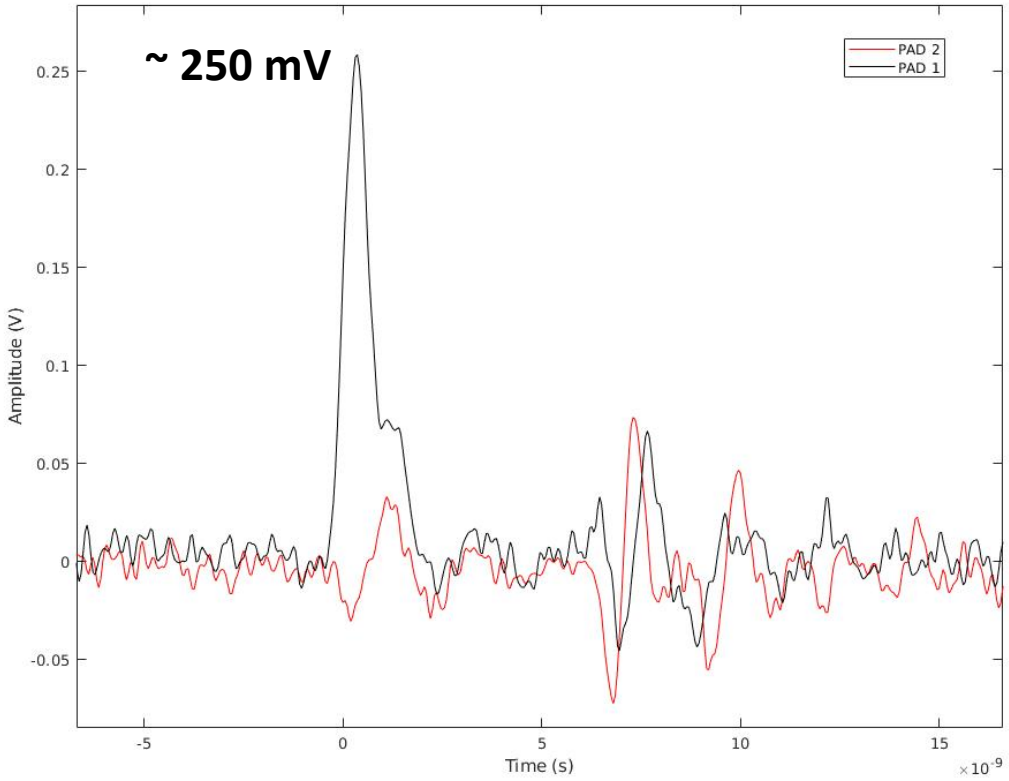


166.41 MeV/nucl
PAD 1
100 Waveforms

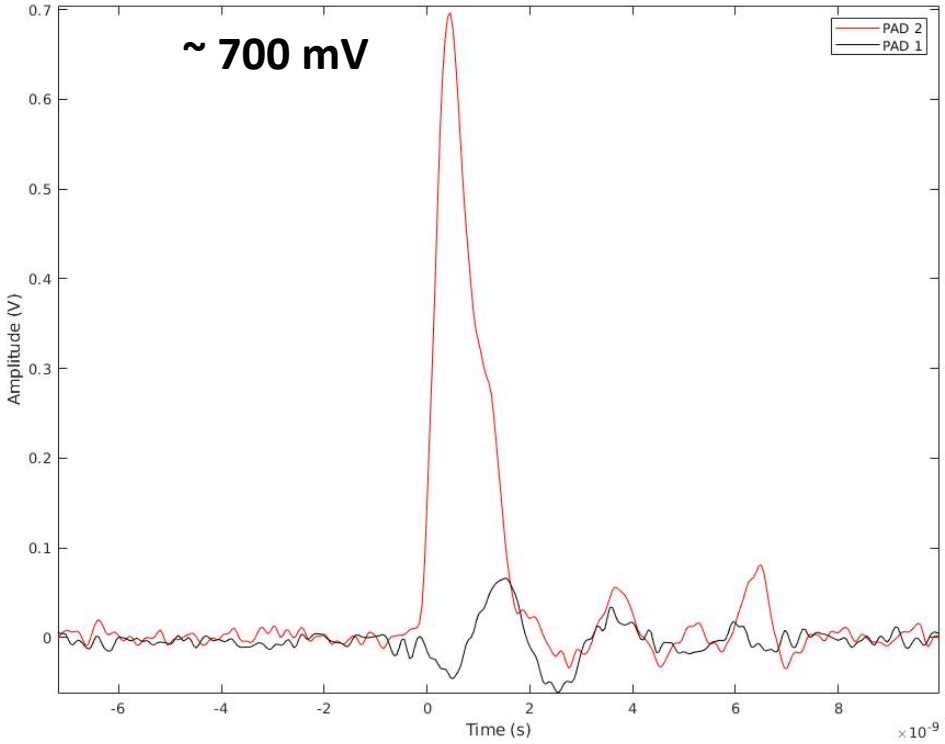


AMPIEZZA SEGNALE A ENERGIE DIFFERENTI

400 MeV/nucl



115 MeV/nucl



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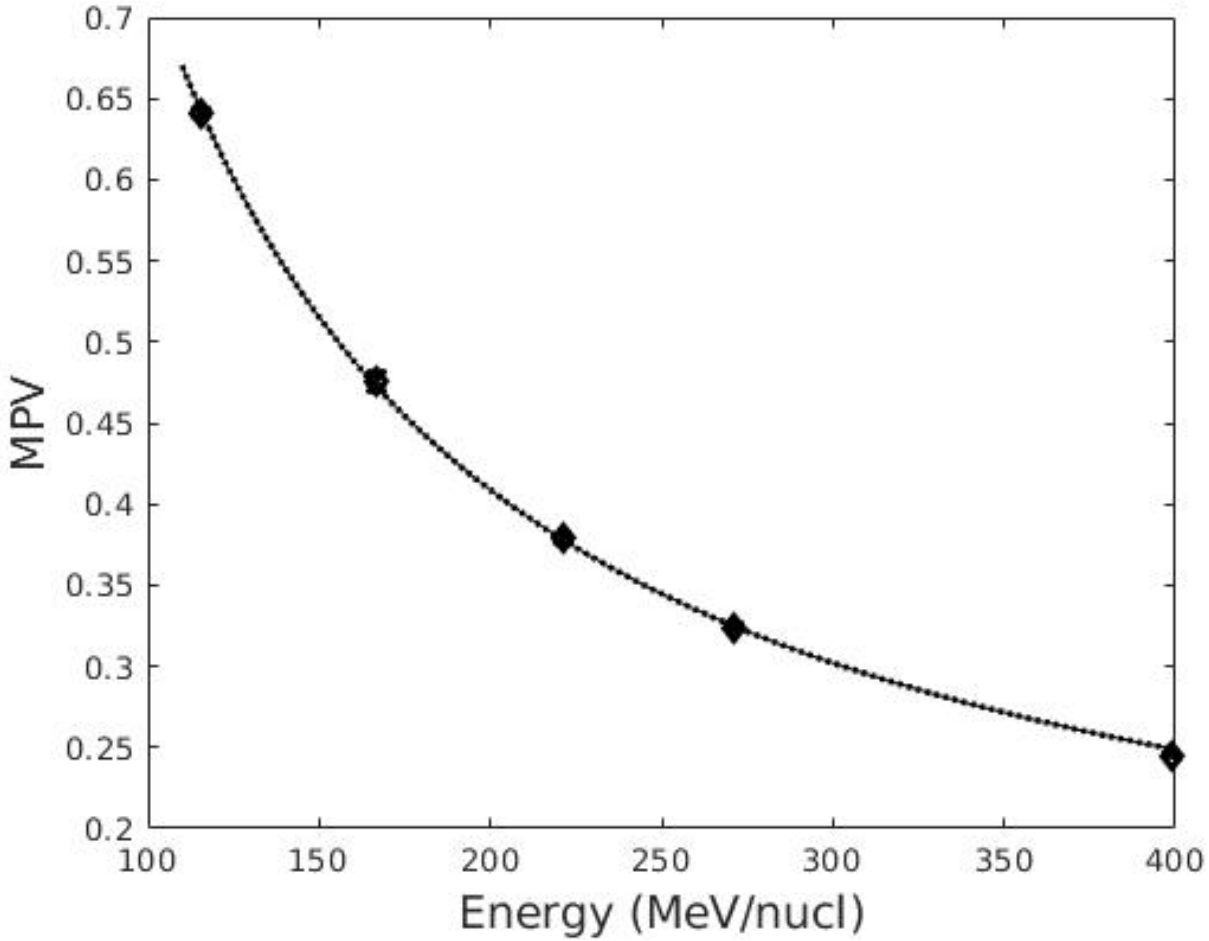


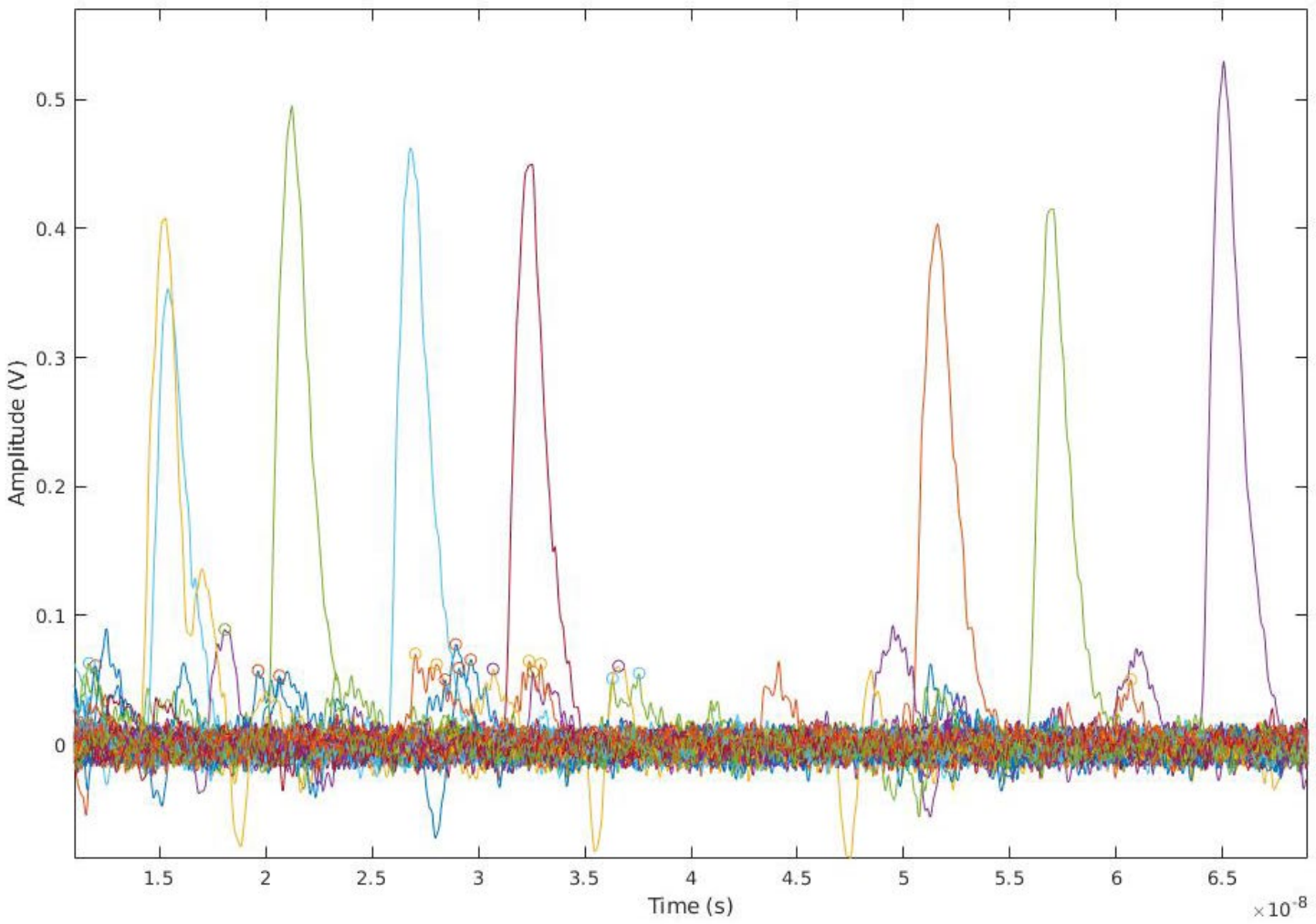
Bethe-Bloch formula

$$\frac{dE}{dx} \propto \frac{1}{v^2} \propto \frac{1}{E}$$

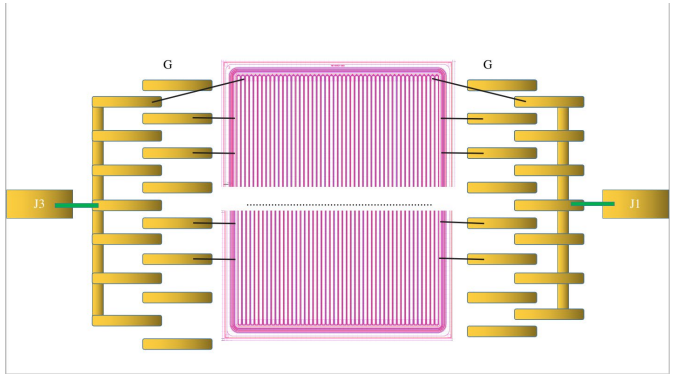
f(E)=a/(E)+b

General model: fitres(x) = a/(x)+b
Coefficients (with 95% confidence bounds):
a = 63.98 (61.8, 66.17)
b = 0.08875 (0.07582, 0.1017)
rsquare: 0.9997

SEGNALI PRODOTTI DAI SINGOLI IONI NELLE STRIPS



166.41 MeV/nucl
100 Waveforms
Strips sensor



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TASK 4.2

Il 15/11/2021 16:31, Jorgen Christiansen ha scritto:

Dear colleagues interested in the PicoTDC

As you know from our last PicoTDC meeting:
https://indico.cern.ch/event/1087968/
We now have working PicoTDCs in final production package.
Manual and package info to be found on our sharepoint: https://espace.cern.ch/PicoTDC
Production testing will be developed over the coming months.
Final production lot of chips will be packaged over the next months. As substrates already produced, we assume/hope that there will not be significant delays on this.

We can in the coming weeks start to deliver samples of PicoTDC in final package, that will pass a basic functional test.

Evaluation/test board prototype (64 differential TDC channels on FMC connector and readout on another FMC connector) works well and small production lot of this will be submitted within the next 2 weeks.
Simple Fanout board getting 64 differential channels from FMC to SMA connectors already exist (but channel mapping will be different).

In case you want to get PicoTDC samples and/or evaluation and/or fanout board please let us know this week (if not already done so).
We will have to charge the following for this (via TID from CERN account):
PicoTDC samples: 200CHF/chip
Evaluation board with PicoTDC: 500CHF
Fanout board (only few channels SMA connectors mounted): 500CHF
We will only produce one lot of evaluation/fanout boards, so can only supply these if ordered now.

Evaluation board with PicoTDC: 500 CHF
Fanout board (only few channels SMA mounted):500 CHF

Oggetto **RE: PicoTDC** 18/11/2021, 14:03

A Me <simona.giordanengo@to.infn.it>

Dear Simona

2 Schede PicoTDC + 2 interfaccia ordinate

I confirm that we have booked you for two of each board.
We expect that they should become available in ~February and will then contact you for payment and delivery.

Best regards

Jorgen

Task4.3 – New technologies for dose delivery system

T4.3 – GPU-based data analysis for online dose verification

Starting point: INFN-RIDOS results

New GPU-based algorithms to exploit ion treatments (ADAPTIVE PT) with a very fast data analysis for online feedback on the dose delivered.

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Real-Time Adaptive Particle Therapy Of Cancer

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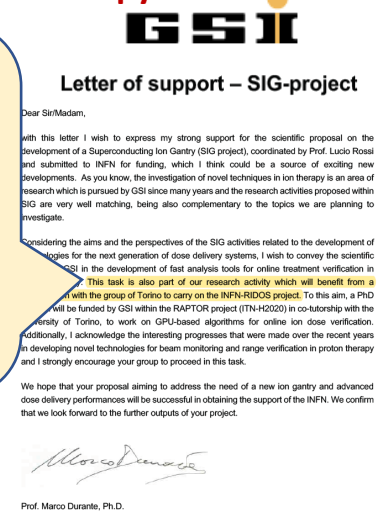
INFN-CSN5 - RIDOS
2014-2016



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We hope that your proposal aiming to address the need of a new ion gantry and advanced dose delivery performances will be successful in obtaining the support of the INFN. We confirm that we look forward to the further outputs of your project.

Prof. Marco Durante, Ph.D.

ESR8: Real-Time 4D-dose calculation to assess the efficacy of motion mitigation strategies

ESR : Cosimo Galeone

Contact info: c.galeone@gsi.de , cosimo.galeone@unito.it

Supervisors : Christian Graeff, GSI Helmholtzzentrum fur Schwerionenforschung (Darmstadt, Germany)
Martin Janson, RaySearch, (Stockholm, Sweden)
Simona Giordanengo, National Institute of Nuclear Physics (INFN), (Torino, Italy)

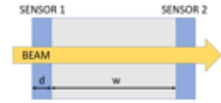
Funded by European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 955956

BIO







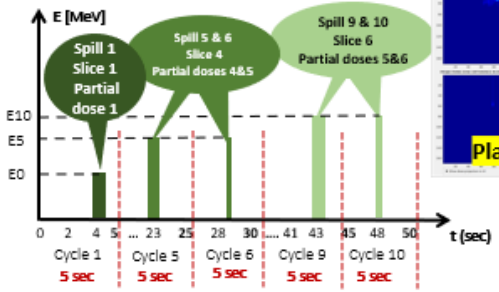
Introduction

Prompt treatment verification represents one of the major aspects of the new workflow proposed by RAPTOR (imaging, intervention and verification).
The FAST estimation of dose errors is a key part of online adaptive therapy because, for example, the daily plan can be adjusted to cope with discrepancies on the delivery of previous fractions.
Moreover, a fast forward planning (FP) can be exploited to verify during treatment the efficacy of motion mitigation strategies like beam tracking, gating and 4D-optimized plan libraries.
Towards this goals, GSI Helmholtzzentrum fur Schwerionenforschung, University of Torino (UniTO) and National Institute of Nuclear Physics (INFN) aim at developing a GPU-based tool to reconstruct in real-time the 4D-dose delivered during treatments, considering regular and irregular motions, and compare online the delivered dose with the planned one.

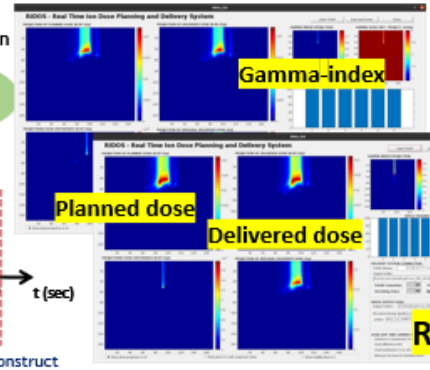
Current System: RIDOS 3D Dose Reconstruction

The project is based on RIDOS (Real-time Ion DOse planning and delivery System), an online dose computation tool developed by INFN and UniTO. This system, designed to be integrated into the Dose Delivery System (DDS) in use at CNAO (Centro Nazionale di Adroterapia Oncologica, Pavia), evaluates during the inter-spill time both the cumulative delivered and prescribed dose distributions and compares them through a fast γ-index algorithm.

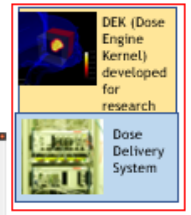
Dose delivery time structure with Synchrotron

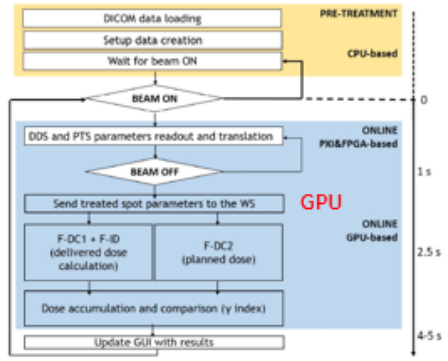


Spill (~1 s) + Inter-spill (~4 s) times are used to reconstruct the partial dose, delivered up to the last spill.



INPUT





RIDOS "per spill" operations

Future System: RAPTOR 4D Dose Reconstruction

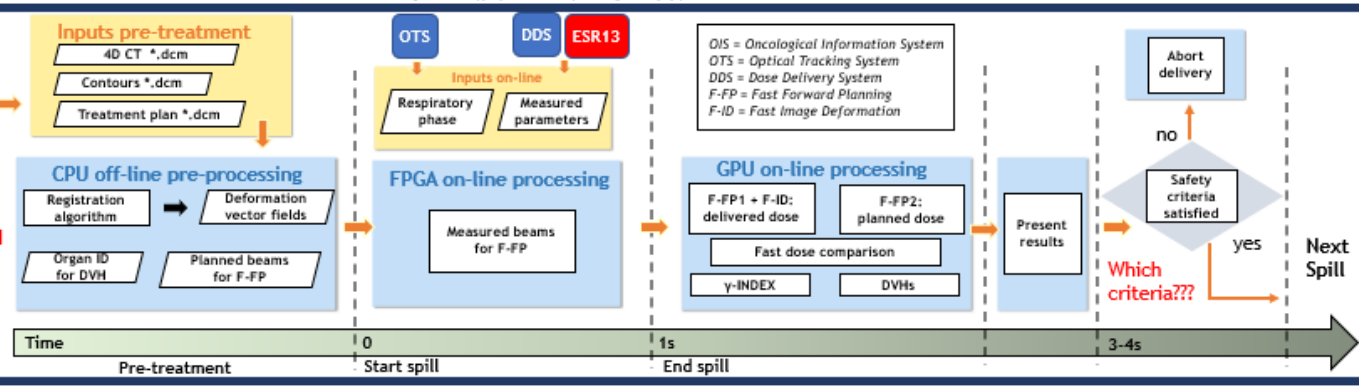
The plan is to develop an adaptable tool to be used during 4D experiments and real treatments.

OIS
ESR5

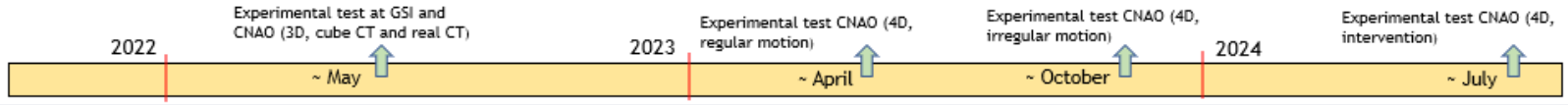
CROSS-COLLABORATIONS:

ESR5: 4D-MRI Imaging and motion modelling techniques for adaptive proton therapy

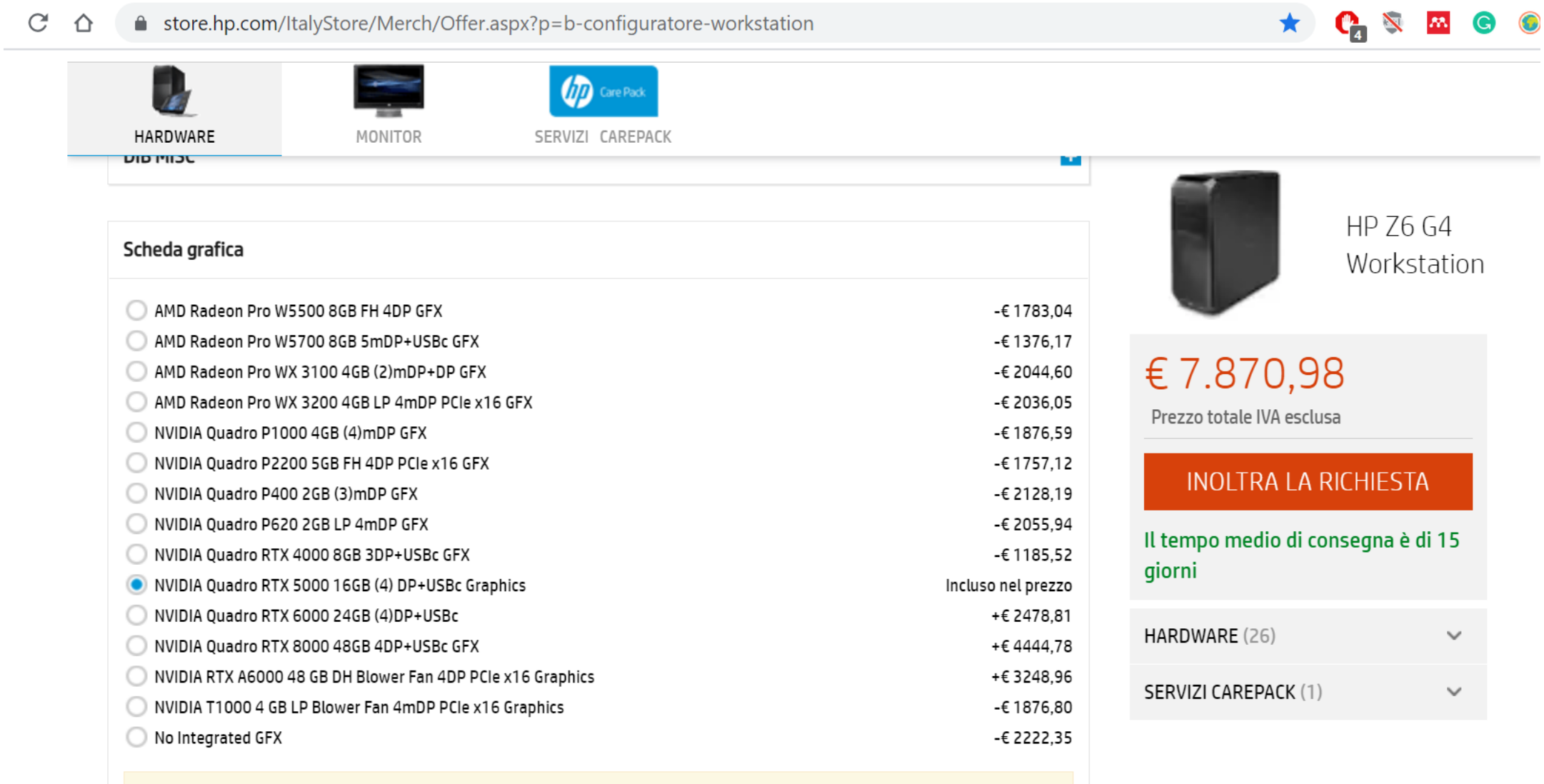
ESR13: Towards automated prompt-gamma treatment verification: identification and classifications of clinically relevant deviations



Timeline



WS per WP4 – con GPU Quadro RTX 5000 acquisto spostato nel 2023



WP4 – NEW GANTS

			2022				2023				2024				2025			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP4	task4.1	Existing Si-sensor studies with ions																
		New sensors design&development																
		Ion counter assembly&test																
	task4.2	Test of FAST+picoTDC	X															
		SIG-ASIC develop&test (SJ)					X											
		Test&Integration with RVS																
	task4.3	GPU-based PGT analysis																
		Fast tools integration&test																