HITRI plus
Heavy Ion Therapy Research Integration

Project Overview 2RP

Sandro Rossi
Coordinator

7th General Assembly meeting –
Marburg, May 23rd, 2024

Vila Vita Rosenpark Hotel

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

New Project Officer

Due to internal re-shuffling (partly linked to our Project Office retirement likely next year), a new PO has been appointed for HITRI*plus*, **Anna Santoro.**

"…she is well familiar with particle accelerators and linked technology".

Andreas Holtel will still remain available to ensure smooth handover and/or additional assistance as needed.

Anna Santoro

Expert - Reviewer

Alejandro Mazal

HITRI*plus* Consortium (started April 2021)

23 Institutes

(4 CIRT centres, 11 research institutions, 5 universities, 3 SMEs)

14 European Countries

4.5 years Project

(1st April 2021 – 30th September 2025)

Total budget: 5 MEuro

New Entries

iba

NHa NORMANDY HADRONTHERAPY

Tera-Care

dkfz.

Grant Agreement number: 101008548 – HITRIplus

H2020-INFRAIA-2018-2020

Coordination meetings so far …

Technical Project Board meeting:

1) April 9, 2021
2) June 30, 2021
3) July 29, 2021
4) September 29, 2021
5) October 27, 2021
6) November 25, 2021
7) January 18, 2022
8) February 10, 2022
9) March 22, 2022
10) April 27, 2022
11) June 23, 2022
12) July 28, 2022
13) October 25, 2022
14) November 22, 2022
15) January 26, 2023
16) February 28, 2023
17) April 4, 2024
18) May 23, 2023
19) June 26, 2023
20) September 13, 2023
21) November 3, 2023
22) January 26, 2024
23) March 8, 2024

WorkPackage Leaders Meeting:

- June 16, 2021
- December 12, 2022

GA meetings:

- (19 March 2021)
- June 21, 2021
- December 7, 2021
- May 18, 2022
- December 13, 2022
- June 28, 2023
- December 14, 2023

Project meetings:

- April 13, 2021 (Kick off meeting)
- December 7, 2021
- May 17-18, 2022 (CNAO, Pavia)
- June 26-28, 2023 (Riga, Latvia)
- May 22-23, 2024 (Marburg, Germany)

ESAB meeting:

- April 28, 2022
- December 12, 2022
- June 26, 2023
- May 22, 2024

ABELII Meetings:

- November 16, 2021
- May 18, 2022
- December 12, 2022
- April 28, 2023

Deliverables

☑ 8/8 Deliverables completed
(18/18 Deliverables completed)

Deliverables, Ethics, DMP, Other Reports

For the full management of the deliverable submission use the 'Continuous Reporting' page

Show Filters Clear Filters

WP No	Del Rel	Del No	Title	Lead Benef	Nature	Est. Del. Date (annex I)	Status
WP10	D10.2	D31	Data Distribution and Synchrotron Timing Requirements	UKHD	Repor	31 Jan 2023	Submitte
WP5	D5.1	D14	Delivery of specialised training courses	SEEIIST	Websi	30 Sep 2023	Submitte
WP5	D5.4	D17	Organisation of secondments and internships: calendar of events	UM	Websi	30 Sep 2023	Submitte
WP7	D7.1	D21	Linac injector design	BEVA	Repor	30 Sep 2023	Submitte
WP9	D9.2	D28	Particle arc therapy delivery to a small scale demonstrator of a rotational patient positioning system for gantry-free delivery with	GSI	Demo	30 Sep 2023	Submitte
WP4	D4.1	D11	HITRIplus technologies and dissemination plan	CERN	Repor	31 Jan 2024	Submitte
WP4	D4.2	D12	Value propositions	GSI	Repor	31 Jan 2024	Submitte
WP5	D5.3	D16	Provision of e-learning courses	UM	Websi	31 Mar 2024	Submitte

Milestones

☑ 1/1 Milestones completed
(11/11 Milestones completed)

Milestones

Number	Name	Lead Beneficiary	Delivery Date (Annex I)	Achieved	Comments
11	Intermediate report on the state-of-the-art treatment room, acceler	CSL	31 Mar 2022	☑	An internal report providing an overview of th…
7	Linac and Gantry conceptual design, and SC synchrotron main parame	CERN	31 Mar 2022	☑	An internal report describing the basic paramet…
5	Specialised Courses and masterclasses content definition	SEEIIST	30 Sep 2022	☑	The goal of WP5 is to increase the European Poo…
14	Evaluation of web based registry development status	MEDA	30 Sep 2022	☑	A proposal for a web based registry to provide …
1	Mid-term General Assembly Meeting completed	CNAO	30 Sep 2022	☑	The HITRplus mid-term General Assembly meeting …
9	Finished simulation environment for particle arc therapy	GSI	30 Sep 2022	☑	The completion of the simulation setup for part…
8	Magnet Layout decision and Engineering design	INFN	30 Nov 2022	☑	After the design comparison study (deliverable …
10	Real-Time Data Generation Strategy	UKHD	30 Nov 2024	☐	
12	Generation of a standardized dosimetry for collaborative radiobiologi	UMR	31 Jan 2025	☐	
3	Evaluation of impact on European centres OARs constraints	MEDA	31 Mar 2025	☐	

Publications during 2nd reporting period

19 articles, 9 conference proceedings, 9 posters

Scientific Articles 2 RP

- M G Pullia, E Benedetto, L Dassa, E De Matteis, M Donetti, E Felcini, G Frisella, M Karppinen, C Kurfürst, S Mariotto. "Explorative studies of an innovative superconducting gantry". J. Phys.: Conf. Ser. 2420 012099, 2023. DO https://iopscience.iop.org/article/10.1088/1742-6596/24
- A. Mamaras, D. Sampsonidis, L. Bellan, G. Biso Vretenar. J. Phys.: Conf. Ser. 2687 052010, 2024. DOI 10.1 https://iopscience.iop.org/article/10.1088/1742-6596/26
- F Toral, F. D Barna, C Calzolaio, A Carloni, G Ceru Mariotto, J Munilla, D Perini, M Prioli, L Rossi, M Statera Nb-Ti CCT Magnet EU Programs for Hadron Thera Superconductivity, vol. 34, no. 5, pp. 1-5, A 10.1109/TASC.2023.3349252. (https://ieeexplore.ieee.or
- L. Rossi, D. Barna, A. G. Carloni, E. De Matteis, Karppinen, G. Kirby, T. Lecrevisse, R. Musenich, D. Per Tommasini." Magnet Technology and Design of Supercon Hadron Therapy" J. Phys.: Conf. Ser. 2687 092009, 2024. I https://iopscience.iop.org/article/10.1088/1742-6596/26
- E. Benedetto, M. Vretenar, Innovations in the r therapy with ion beams, 2024 J. Phys.: Conf. Se 6596/2687/9/092003. https://iopscience.iop.org/article/
- E. De Matteis *et al.*, "Straight and Curved Canted (Ion Therapy: Comparison Between Various Design C Operation," in *IEEE Transactions on Applied Superconduc* Art no. 4401205, doi: 10.1109/TASC.2023.3259330
- L. Rossi, et al. "Magnet Technology and Design of Gantry for Hadron Therapy." Journal of Physics. Confer 92009-, https://doi.org/10.1088/1742-6596/2687/9/092(
- L. Nikitovic, T. Torims and M. Vretenar "Comparison of 352 MHz linac structures for injection into an ion therapy accelerator". J. Phys.: Conf. Ser. 2687 052011, 2024. DOI 10.1088/1742-6596/2687/5/052011 https://iopscience.iop.org/article/10.1088/1742-6596/2687/5/05
- M. Prioli, E. Bianchi, A.G. Carloni, R. Cereseto, E. De Matte Mariotto, R. Musenich, A. Palmisano, L. Rossi, M. Sorbi, S. Sorti, M M. Pullia, A. Bonasia, T. Boutboul, G. Ceruti, J. Fleiter, J. M. Karp Superconducting Ion Gantry (SIG) Dipole Demonstrator Magnet, Superconductivity, vol. 34, no. 5, pp. 1-5, Aug. 20 10.1109/TASC.2024.3361440. https://ieeexplore.ieee.org/abstract/document/10418987
- Georgieva, P., Dosanjh, M. ENLIGHT (European Network f its role in Hadron therapy. Health Technol. (2024). https://doi.org
- A. Facoetti and S. Rossi. "The Heavy Ions Therapy Res Health Technol., March 2024. https://doi.org/10.1007/s12553-024-00841-y
- B. Vischioni, M. Bonora, S. Ronchi, et al. "Head and neck c results of hadrontherapy of a dual beam facility". Health Technol. https://doi.org/10.1007/s12553-024-00843-w
- P Georgieva and M. Dosanjh. "ENLIGHT (European Netwo and its role in Hadron therapy". Health Technol., 2024. https://doi.org/10.1007/s12553-024-00837-8
- Molinelli, S., Mirandola, A., Magro, G. et al. Treatment Planning: comparing techniques and standards. Health Technol. (2024). https://doi.org/10.1007/s12553-024-00845-8
- S. Sorti *et al.*, "Electromagnetic Losses in Fast-Ramped Canted-Cosine-Theta Magnets," in *IEEE Transactions on Applied Superconductivity*, vol. 34, no. 3, pp. 1-6, May 2024, Art no. 4003506, doi: 10.1109/TASC.2024.3360933.
- De Matteis, E. New technologies: superconducting magnets. *Health Technol.* (2024). https://doi.org/10.1007/s12553-024-00849-4
- Volz, L.; Reidel, C.-A.; Durante, M.; Prezado, Y.; Schuy, C.; Weber, U.; Graeff, C. Investigating Slit-Collimator-Produced Carbon Ion Minibeams with High-Resolution CMOS Sensors. *Instruments* 2023, *7*, 18. https://doi.org/10.3390/instruments7020018
- Volz L, Graeff C, Durante M, Collins-Fekete CA. Focus stacking single-event particle radiography for high spatial resolution images and 3D feature localization. Phys Med Biol. 2024 Jan 10;69(2):024001. doi: 10.1088/1361-6560/ad131a. PMID: 38056016; PMCID: PMC10777170.
- E Benedetto, D Barna, M D'Addazio, R De Maria, E Felcini, G Frisella, L Garolfi, A Latina, H Norman, E Oponowicz. "Strongly curved super-conducting magnets: beam optics modeling and field quality". J. Phys.: Conf. Ser. 2687 062007, 2024. DOI 10.1088/1742-6596/2687/6/062007 https://iopscience.iop.org/article/10.1088/1742-6596/2687/6/062007/meta
- S. Sorti , G. Ceruti, E. De Matteis, S. Mariotto, M. Prioli, L. Rossi, M. Sorbi, R.U. Valente. "Electromagnetic Losses in Fast-Ramped Canted-Cosine-Theta Magnets". IEEE Transactions on Applied Superconductivity, vol. 34, no. 3, pp. 1-6, May 2024, Art no. 4003506, DOI: 10.1109/TASC.2024.3360933. https://ieeexplore.ieee.org/abstract/document/10418266

Summary of scientific contributions

Invited scientific talks

- S. Rossi, CNAO experience and international pe
  Developing Human Resources for Setting Up ar
  Headquarters – Vienna
- S. Rossi, Ion Therapy Ce
  Sofia, 12-13th May 202
- S. Rossi, HITRIplus – He
  Conference, Madrid, 10
- S. Rossi, Practical exper
  Research: consideratio
- S. Rossi, HITRIplus, Onli
- S. Rossi, Introduction t
  CERN, Geneva, Octobe
- S. Rossi, IS CNAO THE R
  Development of a hadr
  BNCT. Workshop CNAC
- A.Facoetti, HITRIplus –
  status and perspective
  existing. Scientific day
- S. Rossi, Health ecosyst
  knowledge exchange &
- S. Rossi, Hadrontherap
  Annual Meeting of Arg
  Aires, Georgetown. No

- Fossati P. Co
  Symposium-
- Fossati P. Ca
  Therapy Sym
- Fossati P. Ca
  Particle Ther
- Ankita Nacha
  Joanna Gora,
  strategy in ca
  2023, Vienna
- Ankita Nacha
  Gora, Gernot
  ion radiother
  2023, Madrid
- Marco Duran
- M. Vretenar,
  HITRIplus ser
- M. Vretenar,
  11-13.10.23
- E. Benedetto
  HEP Projects
- R.Taylor, Slo
- H.Huttunen,

Scientific Talks
(50 speeches)

Public talks
(13 events)

Webinars
(9 events)

Lectures
(18 events)

le

e-to-mass Ratio of 1/2 with a
erence (CBC 2022),
an Ion Therapy Accelerator

gy layer optimization for carbon ion arc therapy"
TCOG) annual meeting, PTCOG60, 1st of July 2022,
ble yet
c therapy" ESTRO Physics workshop 2022: Particle
ality , 7th of October 2022, Lisbon, Portugal;

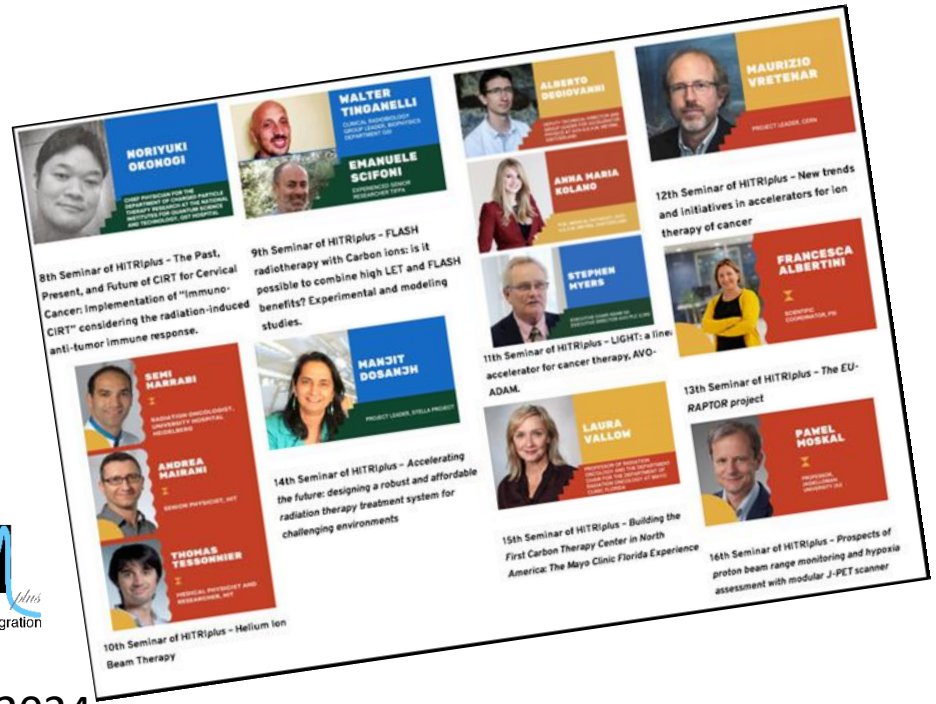
lins-Fekete „Focus stacking particle radiography"
ER, 2022.
, M. Durante, U. Weber, C. Graeff "Characterizing
ams with CMOS sensors " PTCOG 2023 annual

Durante, A. Mairani, X. Ding, C . Graeff, T. Li
tic Radiosurgery of Multiple Brain Metastases"
ouncil symposium recognition, full oral presentation
M. Durante, C. Graeff, C.-A. Collins-Fekete
time image guidance" 4th Ion Imaging workshop

erence 2023, Darmstadt, GER

WP2 – Tasks: Activity Report

- **Newsletters**
- **Social Media**
- **Website Updates**
- **Workshops and Public Events**
- **Conferences and Educational Outreach**
- **Seminars**



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WP2 Deliverables and Milestones

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.1	Dissemination to the community about the possibility of the TA and access to clinical research with patients from EU - through out	WP2	1 - CNAO	Report	Public	3
D2.2	Dissemination and outreach activities developed and regularly updated	WP2	13 - SEEIIST	Report	Public	42
D2.3	Provide an annual activity report for the NA Pillar and final scientific achievements including the use and dissemination of foreground.	WP2	13 - SEEIIST	Report	Public	46

done

done and in progress

done and in progress

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS2	Project website launched	1 - CNAO	2	Realization of Project Website

done

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WP3 - Draft of the protocol is being finalised

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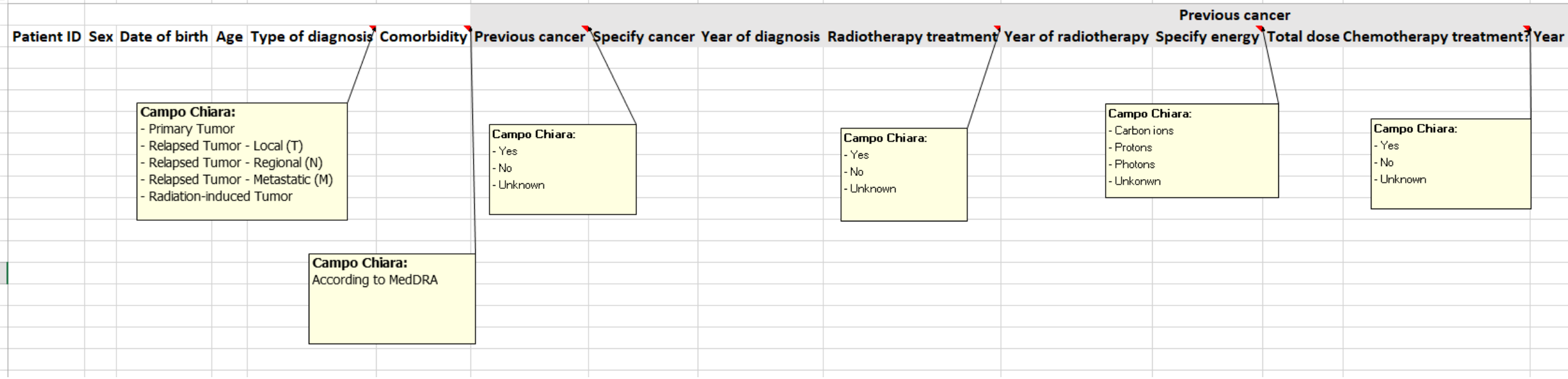
Task 3.2



In the last phase of the project the database will be used to support the activity of task 3.3

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WP4 Deliverables and Milestones

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.1	HITRIplus technologies and dissemination plan	4 - CERN	Report	Confidential, only for members of the consortium (including the Commission Services)	28
D4.2	Value propositions	7 - GSI	Report	Public	28
D4.3	Technology matching event	9 - INFN	Report	Public	36

January 2024 ✓ Done

September 2024 ✓ In Progress

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	First meeting of the Technology Overview committee	4 - CERN	8	Meeting of the Technology Overview committee, dedicated to the definition of the workplan.

November 2021 ✓ Done

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D4.2: Value Propostions - Targeted at companies

Deadline: January 2023

HITRIplus Technology in the Report

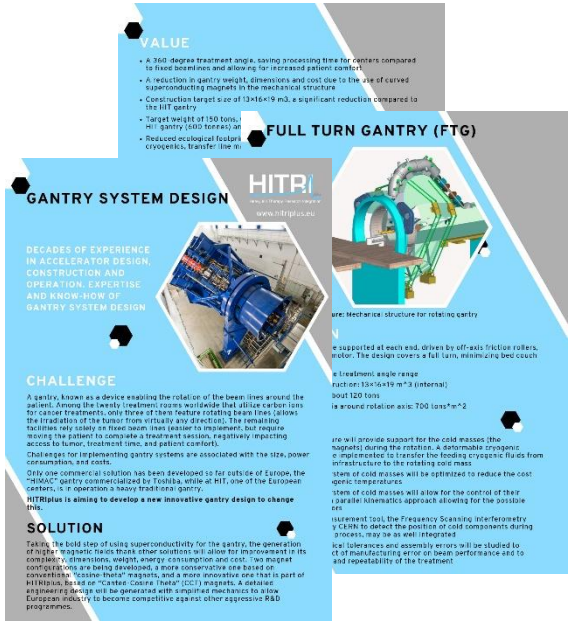
- Description
- Challenge
- Solution
- Value
- Dissemination Route
- IP Protection
- Companies of Interest
- Action Plan
- Publications and Results

PowerPoint Versions

Value propositions for every technical WP:

- Available for presentations from the coordinator/technical WPs
- Available for display on TV screens at conferences

Brochure Versions



One brochure with 7 appendixes:

- Available for hand-out at conferences
- Available on project website
- Available for stream-out on social-media

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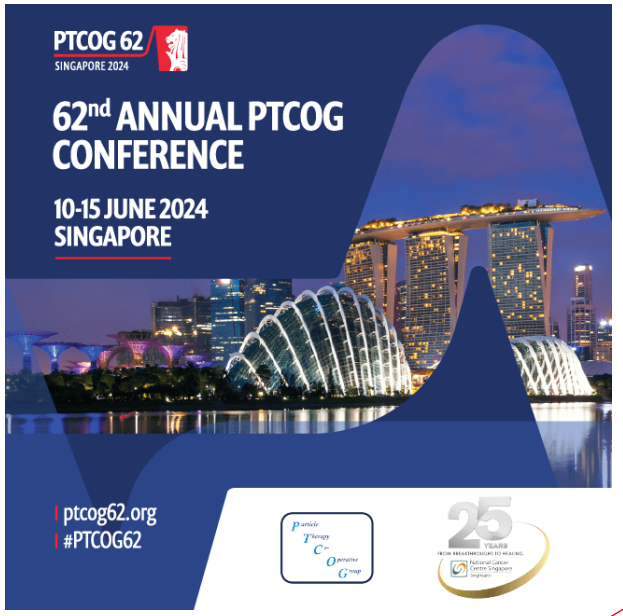
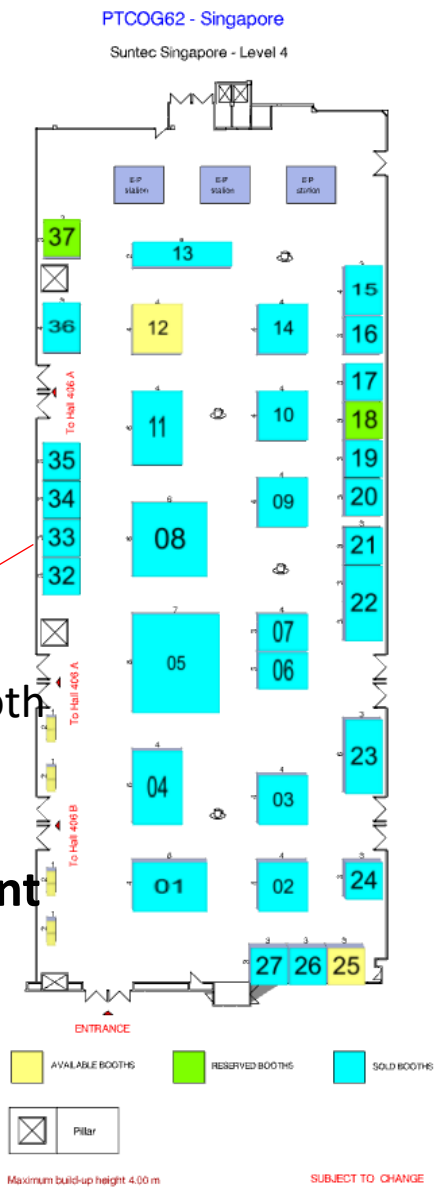
WP 4 - Innovation, technology transfer, industry relation





The HITRIplus booth

D4.3: Technology Matching Event

D4.1: HITRIplus Technologies and dissemination plan

HITRIplus — Heavy Ion Therapy Research Integration

Ref. H2020-INFRAIA-2020-1- RIA GA - 101008548

Horizon 2020 - INFRAIA-2020-1

HITRIplus — Heavy Ion Therapy Research Integration

Project: 101008548– HITRI*plus*

Heavy Ion Therapy Research Integration *plus*

https://www.hitriplus.eu

Deliverable 4.1 HITRIplus technologies and dissemination plan

Date:	16/01/2024
Due Date	31/01/2024
Type:	Report
Dissemination Level:	Confidential
Work Package:	WP4
Lead Beneficiary:	CERN
Author(s):	S.Muhr
Contributing Beneficiaries:	GSI, INFN

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- 12 HITRIplus Technologie
- 3 Companies have signed the Memorandum of Understanding with the coordinator
- 19 Companies have expressed industrial interest
- 7 Value Propositions and one brochure for WP7-12 technologies have been produced targeting companies

WP5 Education and Training

Task	Deliverable	Lead	Due Date	% Completed	Status
5.1	Delivery of Specialised Training Courses	SEEIIST	M30	100%	Completed Deliverable submitted
5.2	Delivery of Masterclasses and train-the-trainer masterclasses	GSI	M47	95%	Completed Report in Progress
5.3	Provision of e-learning courses	UM	M30	100%	Completed Deliverable submitted
5.4	Organisation of secondments and internships: calendar of events	UM	M24	100%	Completed Deliverable submitted
M5.1	Specialised Courses and Masterclass Definition	SEEIIST	M18	100%	Completed Deliverable Submitted

WP5 Education and Training

- 1st course - led by SEEIIST
    - held online limited to 60 participants to maximise student interaction
    - targeting advanced masters, Ph.D., postdocs and researchers from close fields
    - 36 faculty members, 35 hours of material
    - accelerators, magnet tech, biophysics, clinical aspects, radiobiology, treatment planning, simulations, dosimetry, moving targets, arc delivery, imaging, gantry design, beam dynamics, business development, entrepreneurship, certification
    - 44 students obtained attendance certificate
    - included train the trainer session
- students from 30 countries + 8 through nationality (44 EU, 11 third countries, 4 Balkan, 1 Ukraine)
- 2nd course - clinical aspects - SEEIIST in collaboration with GSI
    - held online 3rd to 7th July:
    - 557 students registered with 150 to 180 students logged in at any one time
    - targeting medical students, clinicians, oncologists
    - 39 hours of lectures, 39 faculty members
    - head and neck, sarcoma, prostate, liver, pancreas, organ motion, treatment planning, re-irradiation, gynae and rare indications, innovative methods, present and future clinical trials and radiobiology
    - included train the trainer session
    - 67 countries world wide; 36% from EU, 17% from SEE, 56% third countries
    - 77 students awarded certificate of attendance (80% attendance, 80% of polls); 27 train the trainer mention
    - network data (students, specialists, contact institutions used in marketing) inputted into WP2

WP5 Education and Training

Task 5.3 – e-learning Material

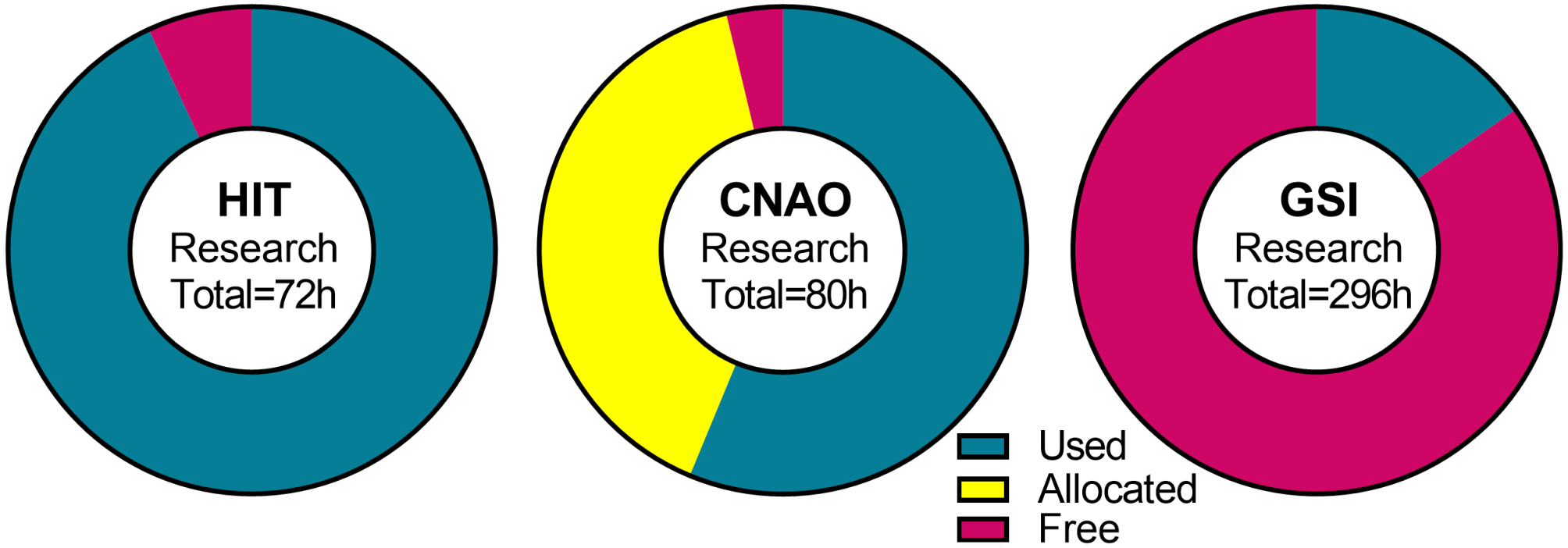
- Task 5.1 1st specialised school recorded and made available online (**3,216 views** to date)
- Task 5.1 2nd specialised school recorded and made available online (**14,434 views** to date)
- Task 5.2 masterclass school recorded and made available online (**2,936 views** to date)

- **1,177 hours** watched by students;
- estimated **319 full course views**

Task 5.4 – Secondments & Internships

- 56 applications (40 form EU or Balkan states)
- 25 eligible applications
- 2 internships offered ; Microdosimetry, Accelerator Physics
- 3 secondments offered; Radiation Oncology, Medical Physics, Radiotherapy
- 59 weeks in total
- countries represented: Italy/Palestine, Turkey, Albania, Romania
- All internships and secondments are complete

Research beamtime provided by facilities



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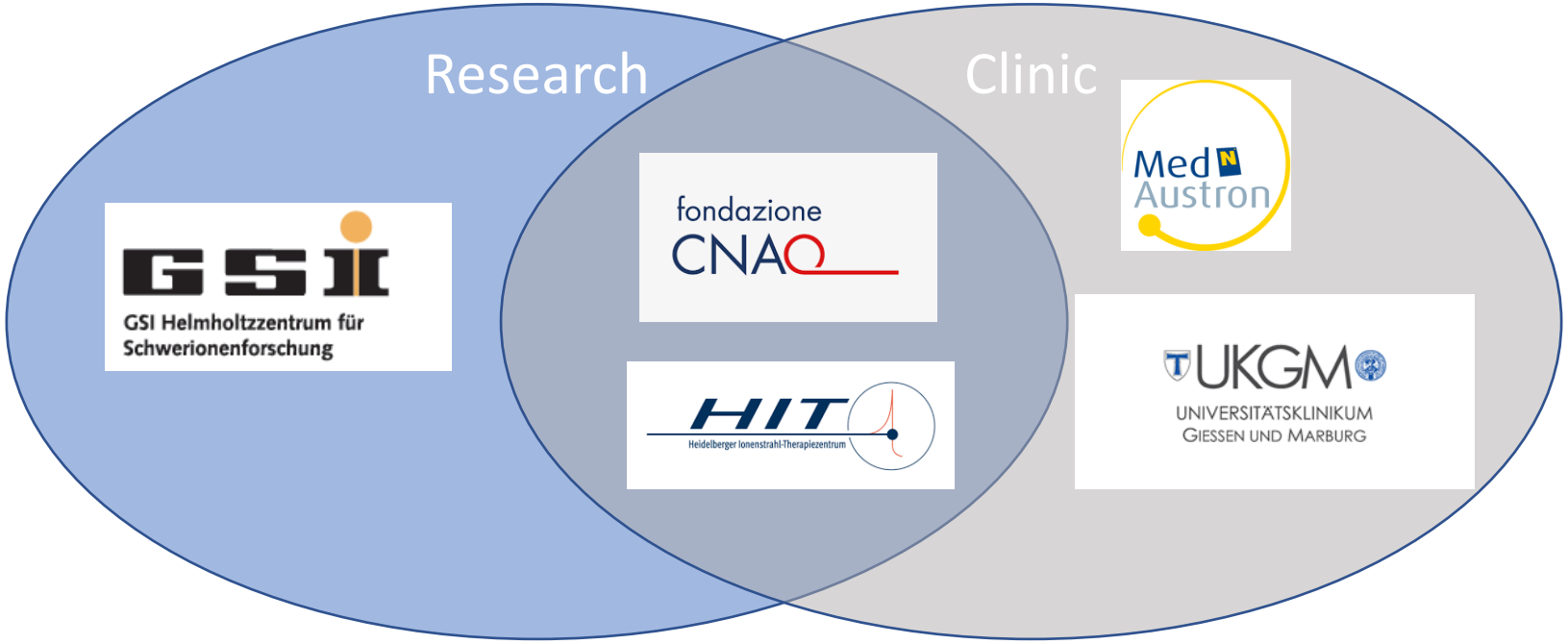
WP6 - TNA



	Res. [h]	Clin. [P]	Total
CNAO	80	12	92
GSI	296	-	296
UKHD/HIT	72	10	82
MEDA	-	12	12
MIT	-	16	16
	448	**50**	**498**

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Beamtime situation at GSI

- High energy prizes led to complete cancelling of beamtime in 2023.
- Ongoing construction of FAIR centre drains available means and interferes with accelerator availability.
- => shortage in beam time; only few days / year
- reassignment of TNA hours to HIT and CNAO is being discussed

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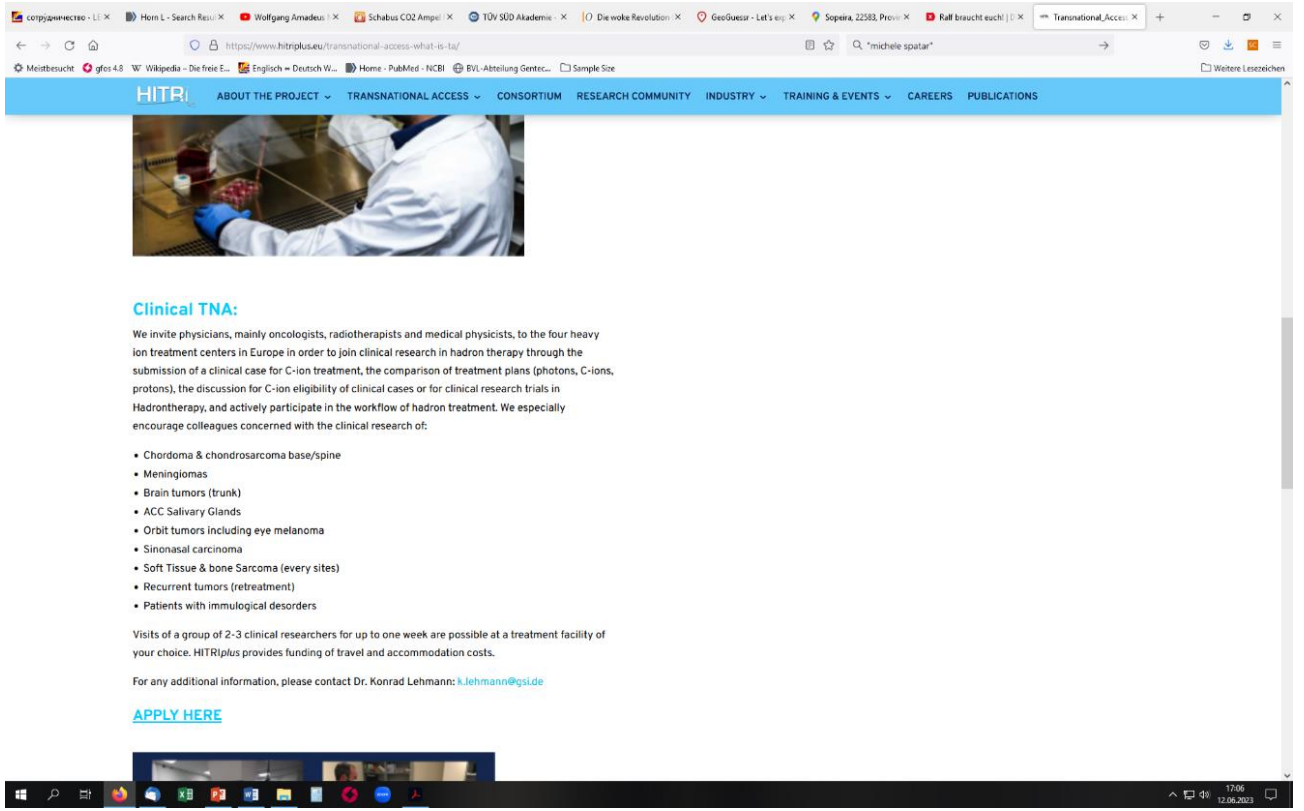
New modality of clinical research TNA

- Following the suggestions of the advisory committee, as of February 2023:
- Call for applications by radiotherapists / oncologists
- Visits to radiotherapy facilities by teams of physicians
- Getting acquainted with treatment planning, work flow, potential of hadron therapy
- No patient required, only submission of clinical case for discussion



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Clinical research TNA applications

Applicant	Affiliation	Country	Host	Approved	# visitors
Ioannis Boukovinas	Thessaloniki	Greece		no	patient
Rogelio Robaina Escobar	AEPROT	Spain	CNAO	yes	1
Erika Korobeinikova	Hospital of Lithuanian University of Health Sciences	Lithuania	CNAO	yes	3
Renata Zahu	Amethyst Radiotherapy	Romania	CNAO	yes	2
Maria Topalidou	Papageorgiou General Hospital	Greece	CNAO	yes	3
Ghizela Ana Maria Salagean	University of Babes Bolyai Cluj Napoca	Romania	CNAO	yes	2
Juliette Thariat	Centre Baclesse	France	CNAO	yes	1
Zsolt Cselik	Veszprém County Hospital	Hungary	MedAustron	yes	1
Alexandra Kolenova	National Institute of Children's Diseases	Slovakia	MedAustron	yes	1
Ana Perpar	Institute of Oncology Ljubljana	Slovenia	MedAustron	yes	2
Katalin Hideghety	University Szeged, Department Oncotherapy	Hungary	MedAustron	yes	1
Daniel Koffler	Mayo Clinic Florida	USA	MedAustron	yes	1
Roy Holland	Rambam Health Care Campus	Israel	MedAustron	yes	2
Remi Nout	Erasmus MC, University Medical Center Rotterdam	Netherlands	CNAO	yes	3
Linh Tran	Wollongong University	Australia	MedAustron	yes	1

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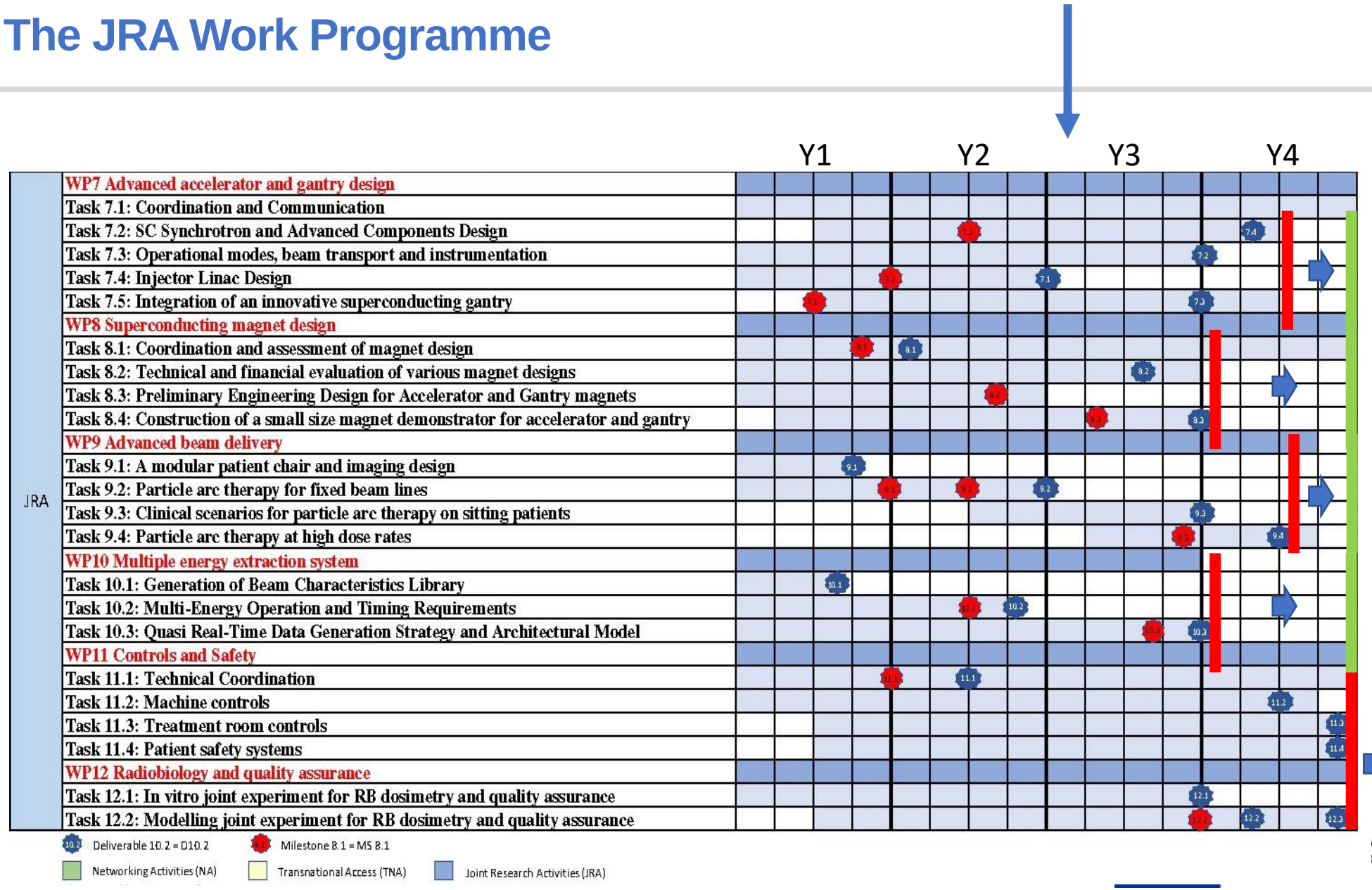
The JRA Work Programme



The 6 month project extension has moved all Deliverables and WP end dates by 6 months or more. Activity to be completed in:

- 4 years for WP7, WP8, WP9, WP10
- 4.5 years for WP11, WP12

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Summary of HITRI*plus* JRA status at end of P2

WP7: helium synchrotron design progress, completed injector linac design, definition gantry design – **D7.1**

WP8: decision of the technical design aspects of the final demonstrator (Curved Canted Cosine Theta based on NbTi superconductor): a) conductor; b) impregnation; c) manufacturing procedure; d) assembly procedure; e) iron yoke. Evaluation and test of procedures – **MS8**

WP9: Conceptual Design Report completed for chair (vertical axis rotation + vertical imaging), demonstrator and studies for arc therapy – **D9.2, D9.3**

WP10: Design of an accelerator control system capable of executing multi-energy operation (control of real-time data) – **D10.2**

WP11: Advanced study of control system needs (Del. next period).

WP12: associations between various physical doses and their effects induced on cellular level, comparison of data from clinical centres, finalizing radiobiological experiments at partners (Del. next period).

HITRI*plus*
Heavy Ion Therapy Research Integration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

WP7 contractual obligations and status

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS7	Linac and Gantry conceptual design, and SC synchrotron main parameters	4 - CERN	12	Choice of conceptual design and basic parameters of the innovative superconducting gantry and Selection of basic linac design: frequency, layout. Definition of key parameters for the superconducting synchrotron

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.1	Linac injector design	2 - BEVA	Report	Confidential, only for members of the consortium (including the Commission Services)	24
D7.2	Gantry design	1 - CNAO	Report	Confidential, only for members of the consortium (including the Commission Services)	36
D7.3	SC synchrotron design	13 - SEEIIST	Report	Public	40

MS7: achieved on schedule (basic design choices)
D7.1 achieved (September 2023)
D7.2 on schedule for M42 (September 2024)
D7.3 ongoing, for M46 (February 2025).

Regular meetings, all partners contributing with some readjustments of work between partners, integration of a new partner TERA-CARE.

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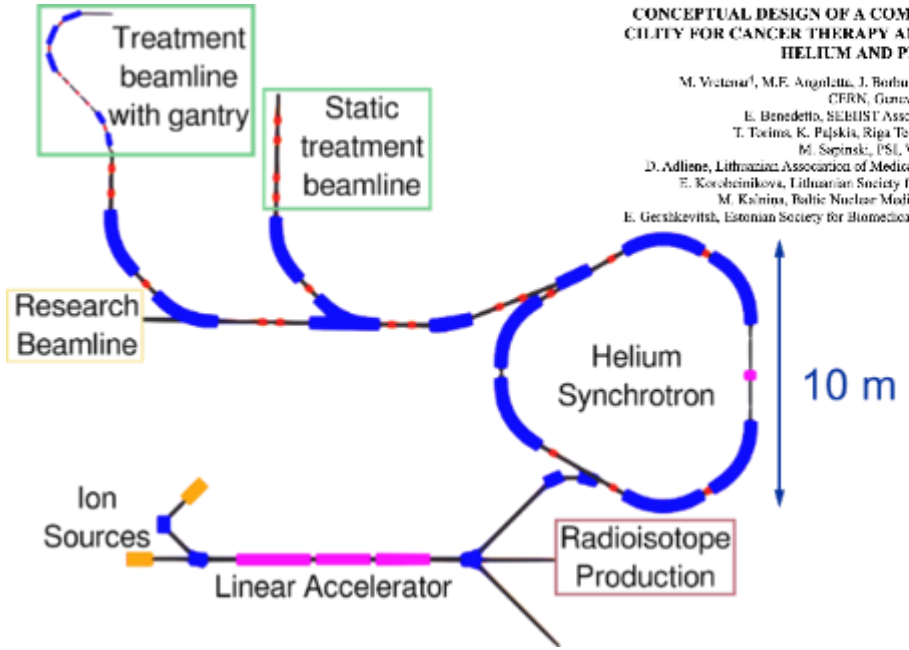
Task 7.2 Synchrotron and advanced components design (SEEIIST, CERN, CNAO, MEDA)

- The initial design of a triangle-shaped compact superconducting synchrotron led to the idea of using the same layout with normal-conducting magnets to accelerate protons and helium ions (4He2+) in a compact facility.



CONCEPTUAL DESIGN OF A COMPACT SYNCHROTRON-BASED FACILITY FOR CANCER THERAPY AND BIOMEDICAL RESEARCH WITH HELIUM AND PROTON BEAMS*

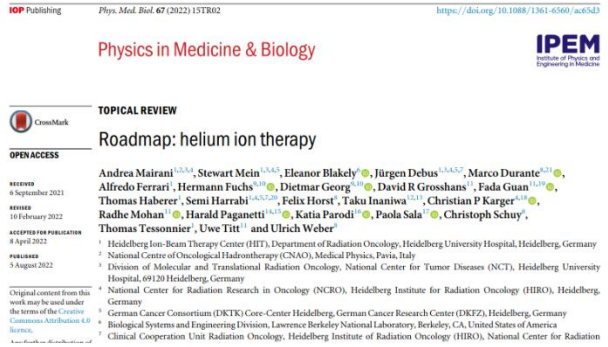
M. Vretenar[†], M.E. Angoletta, J. Borburgh, L. Bottura, R. Taylor, G. Tranquille, CERN, Geneva, Switzerland
E. Benedetto, SEEIIST Association, Geneva, Switzerland
T. Torims, K. Pajskis, Riga Technical University, Riga, Latvia
M. Seidel, PSI, Villigen, Switzerland
D. Adliene, Lithuanian Association of Medical Physicists and Engineers, Vilnius, Lithuania
E. Korobeinikova, Lithuanian Society for Radiation Therapy, Vilnius, Lithuania
M. Kalnins, Baltic Nuclear Medicine Association, Tallinn, Estonia
E. Gerstakevitsh, Estonian Society for Biomedical Engineering and Medical Physics, Tallinn, Esto-

- 2 beamlines treatment
- 1 beamline research.
- Surface ~2,000 m2

Main features:

- ❑ rigidity 4.6 T/m: 4He2+ at 220 MeV/u (33 cm pen.).
- ❑ 4 x 10^{10} ions, to irradiate 1 litre tumour with 2 Gy.
- ❑ RF/KO slow extraction, multiple energies, FLASH extraction (100-200 ms) with phase displacement.

Renewed interest in He treatment (superior conformality) led by the Heidelberg team


IOP Publishing Phys. Med. Biol. 67 (2022) 15TR02 https://doi.org/10.1088/1361-6560/ac65d3

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

TOPICAL REVIEW

Roadmap: helium ion therapy

Andrea Mairani, Stewart Mein, Eleanor Blakely, Jürgen Debus, Marco Durante, Alfredo Ferrari, Hermann Fuchs, Dietmar Georg, David R Grosshans, Fada Guan, Thomas Haberer, Semi Harrabi, Felix Horst, Taku Inaniwa, Christian P Karger, Radhe Mohan, Harald Paganetti, Katia Parodi, Paola Sala, Christoph Schuy, Thomas Tessonnier, Uwe Titt and Ulrich Weber

OPEN ACCESS
RECEIVED 6 September 2021
REVISED 10 February 2022
ACCEPTED FOR PUBLICATION 8 April 2022
PUBLISHED 5 August 2022

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HITRI Heavy Ion Therapy Research Integration

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HITRI*plus* WP8 – Superconducting magnet design

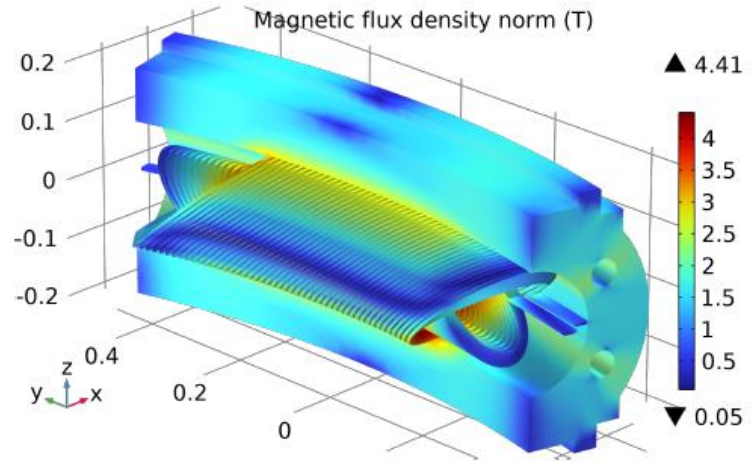
First technical and financial assessment of various magnet designs: Canted cosine theta and Cosine theta layouts with several superconductors (NbTi, Nb3Sn and HTS);

Preliminary engineering design for the new concept of accelerator magnets and innovative gantry magnet;

Construction and test of a small demonstrator for feedback useful for accelerator as well as gantry final magnet design.

Program based CCT layout led by S. Prestemon

The decision[1] to explore a **curved CCT layout magnet based on NbTi** (Low losses strand) and conductor (rope 6+1 strands);

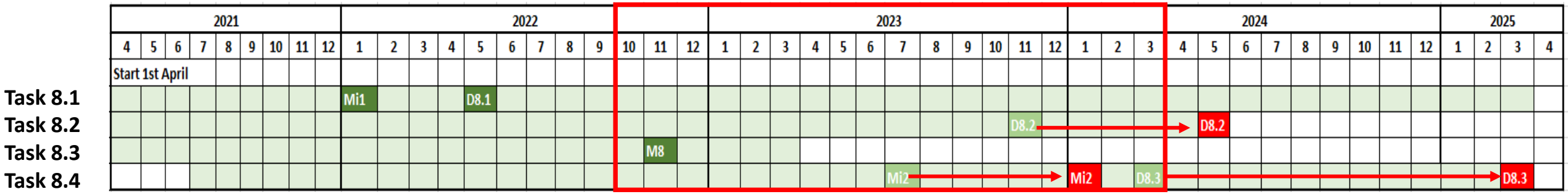


[1]E. De Matteis, S. Mariotto, T. Lecrevisse, M. Prioli, S. Sorti, M. Statera, L. Rossi, **"Magnet Assessment for SC accelerator and gantry",** HITRIplus WP8 - Deliverable 8.1, Zenodo. https://doi.org/10.5281/zenodo.7875298

WP8 Timeline – MLS and DLVs

HITRI+ WP8: Superconducting Magnet Design
Task 8.1 - Coordination and Assessment of magnet design
Task 8.2 - Technical and Financial evalaution of various magnet designs
Task 8.3 - Preliminary engineering design for accelerator and gantry magnets
Task 8.4 - Construction of a small size magnet demonstrator for accelerator and gantry

19 – 36 months activities



Deliverables

- D8.1 (05/2022): Magnet Assessment for SC accelerator and gantry (**ACHIEVED**);
- D8.2 (05/2024): TDR (Technical Design Report) (writing);
- D8.3 (03/2025): Magnet Demonstrator (postponed of 12 months);
  - **The postponement of the deliverables was necessary due to the difficulty to find companies able to machine the curved formers.**

Milestones:

- Mi1 – Internal (01/2022): Decision on layout of demonstrator magnet (**ACHIEVED**);
- M8 (11/2022): Magnet Layout decision and Engineering design (**ACHIEVED**);
- Mi2 – Internal (01/2024): Manufacturing readiness of demonstrator(almost **ACHIEVED**):
  - **Conductor, curved formers and part of the tooling are defined – iron yoke and assembly under study.**

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HITRIplus WP8 – activities of last 18 months

- Task 8.1: Coordination and assessment of magnet design
  - From the 4th of October 2022 we had n. 9 general meetings and more than 25 dedicated weekly meetings about the demonstrator (every Monday);
  - **Survey** for machining of the **curved formers** and related tests;
  - Collaboration with the other WPs (WP4 and WP7);
- Task 8.2: Technical and financial evaluation of various magnet designs for synchrotron and gantry
  - Magnet designs concerning electromagnetic losses, field quality optimization and mechanical simulations;
  - Preparation of the **Technical Design Report (TDR)** – Deliverable D8.2;
- Task 8.3: Preliminary Engineering Design for Accelerator and Gantry magnets
  - Submission of the **Milestone 8(MLS 8)**: "Magnet Layout decision and Engineering design of the synchrotron-gantry dipole magnet";
  - Engineering design: Various materials for formers were considered, with Aluminium-Bronze chosen for its machinability and conductivity. Successful winding and impregnation tests led to using wax as a baseline filler and an Aluminium-Bronze external shell for conductor protection during impregnation.
- Task 8.4: Construction of a small size magnet demonstrator for accelerator and gantry
  - Definition of the final conductor rope (6 NbTi +1 copper core strands), and of the curved formers construction;
  - Assembly procedure and tooling for the impregnation;
  - First wax- impregnated magnet (SUSHI magnet – Wigner RCP).

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WP 8 - Conclusions and next steps

- Milestone 8: Magnet Layout decision and Engineering design (achieved)(Task 8.3 – Wigner RCP, INFN, CIEMAT, CERN, CNAO):
  - Former material tests (Al-Bronze could be the final one), Conductor (qualification of the rope), Winding parameterization (dedicated algorithm), Winding and Impregnation procedure and setup, Magnetic and mechanical design, and Magnet Assembly.
- Finalized the rope conductor by Ic meas., HV tests and splice tests (INFN and Wigner RCP) :
  - Launched the order for the final production at Texcavi company;
- Finalized the construction procedure for the curved Al-Br former in collaboration with Tosti srl;
  - Constructing curved subsections from straight tubes, machining the grooves and joining them with slotted pins.
- Defined the tooling for the winding and the impregnation (INFN, CIEMAT and Wigner RCP);
  - Winding machine is in order from CIEMAT, and impregnation tooling drawings are ready (INFN-LASA);
- Technical Design Report (TDR) – Deliverable D8.2 (05/2024) is in preparation:
  - Report on the last design updates and construction readiness of the final demonstrator.

Open points and next steps:

- Complete the magnet assembly tools and iron yoke construction (INFN and CERN).
- Final test of the demonstrator will be done at Uppsala (Deadline for the demonstrator is March 2025):
  Magnetic measurements (in synergy with EuroSIG project + involvement of Senis for warm measurements).

WP9: Advanced beam delivery

- **Task 9.1:** A modular patient chair and imaging design
- **Task 9.2:** Particle arc therapy for fixed beam lines
- **Task 9.3:** Clinical scenarios for particle arc therapy on sitting patients
- **Task 9.4:** Particle arc therapy at high dose rates

Milestones/deliverables:

- **Deliverable 9.1 (M9):** Conceptual design report for a modular patient chair and vertical imaging
- **Deliverable 9.2 (M30):** Particle arc therapy delivery to a small scale demonstrator of a rotational patient positioning system for gantry-free delivery with a position feedback integrated to the DDS
- **Deliverable 9.3 (M48):** Patient identification and Experimental validation of arc therapy treatment plans through patient QA-like procedures
- **Milestone 9 (M18):** Finished simulation environment for particle arc therapy

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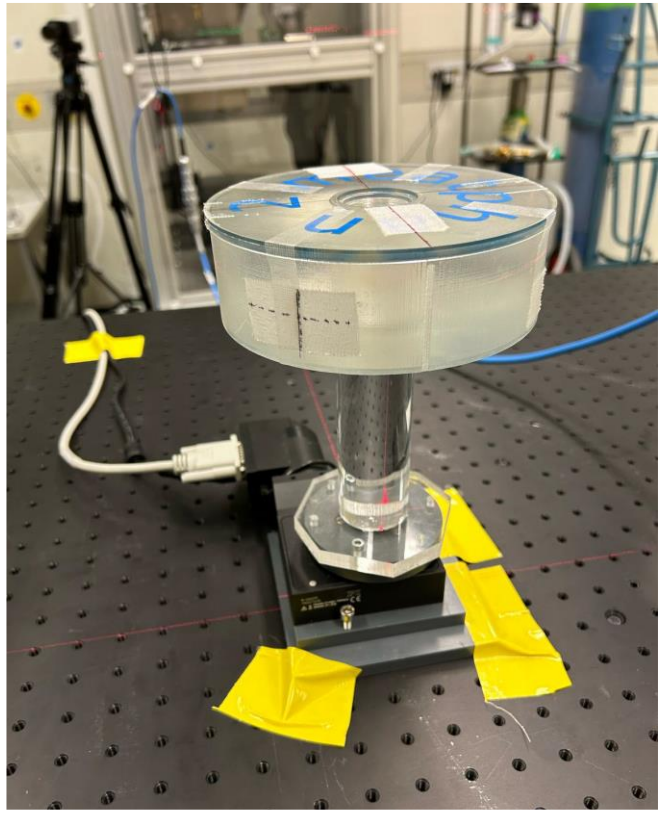
Task 9.2: First experiments at GSI

- Arc simulator running at GSI
- Rotation controlled by (our research version of) the CNAO dose delivery system
  - Step & shoot with multiple angles per spill – synchroniziation of delivery and rotation by gating
  - 180 control points with single energies to small targets



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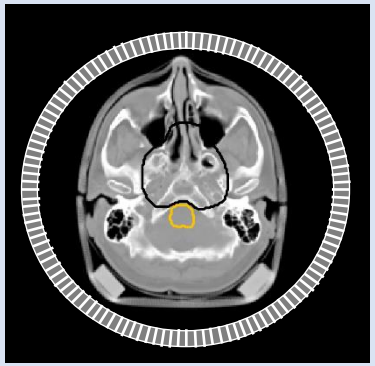
Task 9.2: Particle arc therapy for fixed beam line

Carbon arc TPS:



Field setup

Pre-selection of energy band and spot positions

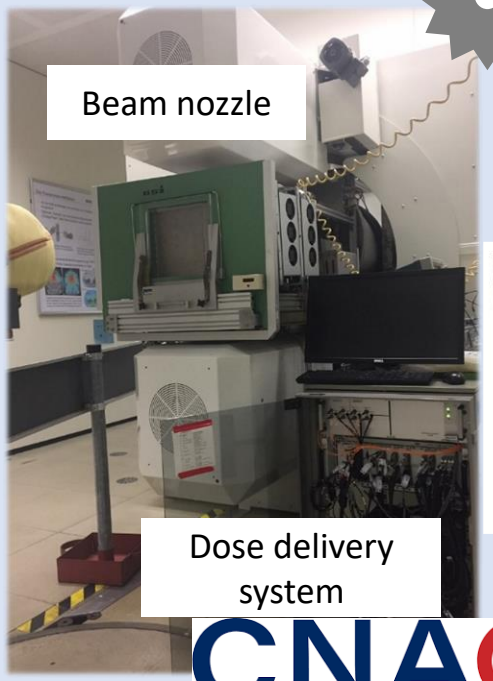
A-priori energy selection

Raster point setup

Iterative energy optimization

Rob. bio. optimization and plan refinement

Small scale demonstrator:



Beam nozzle

Dose delivery system

Rotating stage

CNAO
Centro Nazionale di Adroterapia Oncologica

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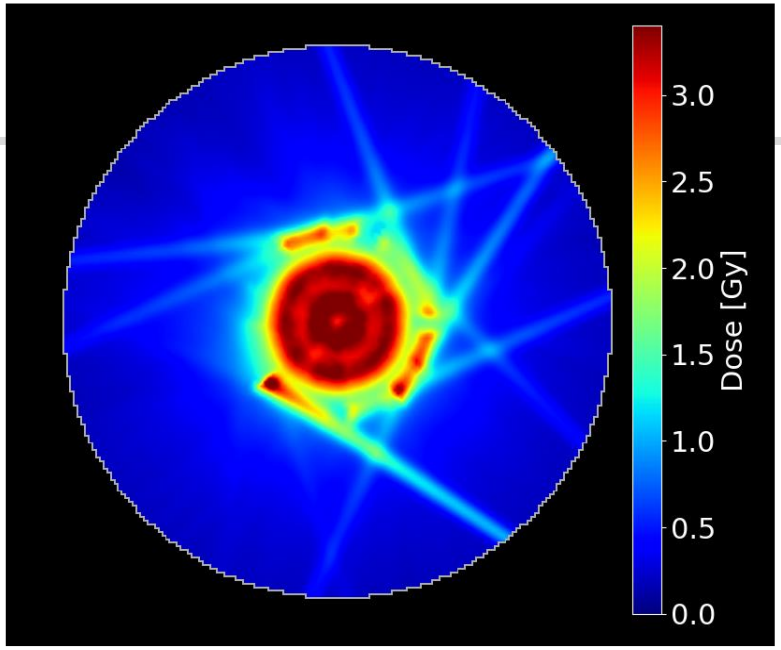
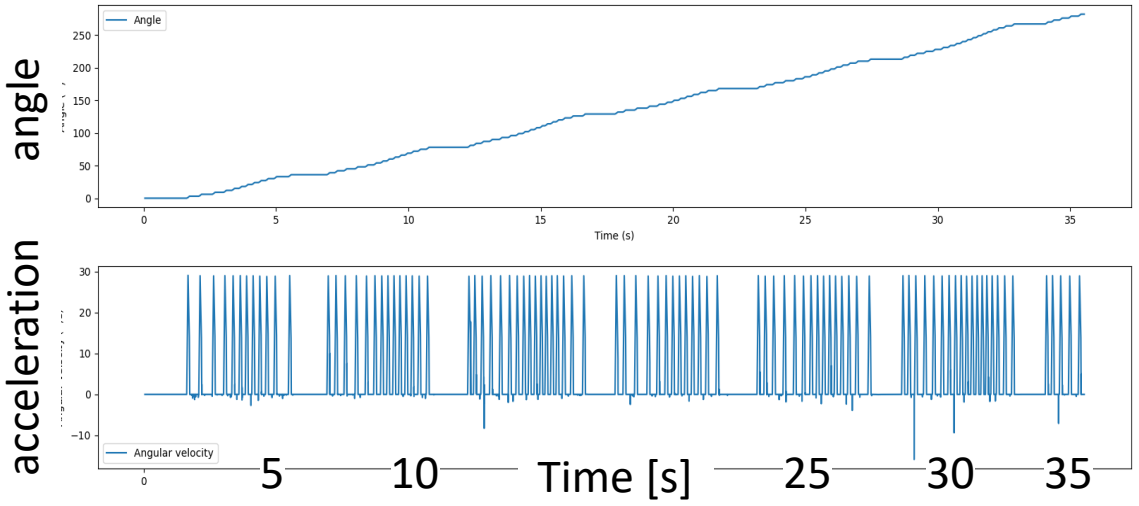
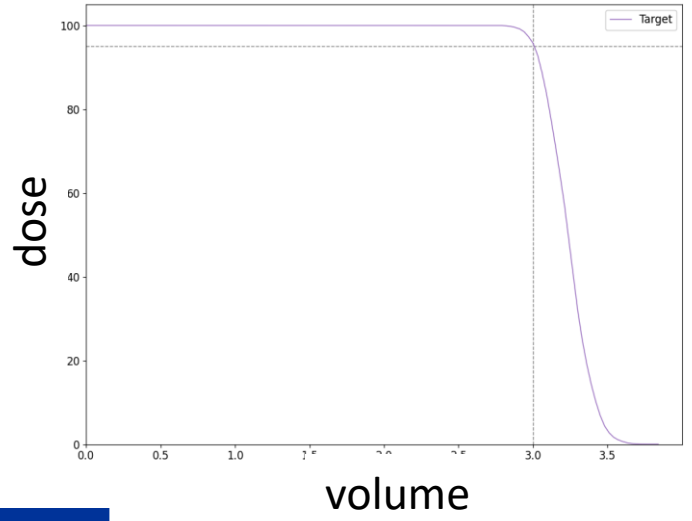
Task 9.2: First experiments at GSI - results

- Several issues identified, a.o. gating system at GSI is not sufficient, upcoming beam time in 2025 will use one spill per angle –
  delivery still within 5-10 min
- Outcome: synchronization was successful; ready for next experiments







Laila El Ouali

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Summary and contributions

- Research platform for particle arc established & exploited for new approaches
- Continuation funding secured
- Upright therapy project developed into a large international collaboration
  - Lennart Volz co-organizer of Upright Research Consortium
- Publications & Talks:
  - 2 Talks (Volz, Li) on arc therapy at ESTRO2024, upcoming proffered posters at PTCOG
  - PT review including WP9 topics (Graeff et al, PPNP 2023); arc strategy (Volz et al, Health & Technology 2024)
  - Particle arc review (Mein et al, Green Journal) in revision
  - Manuscripts ready to be submitted for upright therapy strategies & arc boost therapy.

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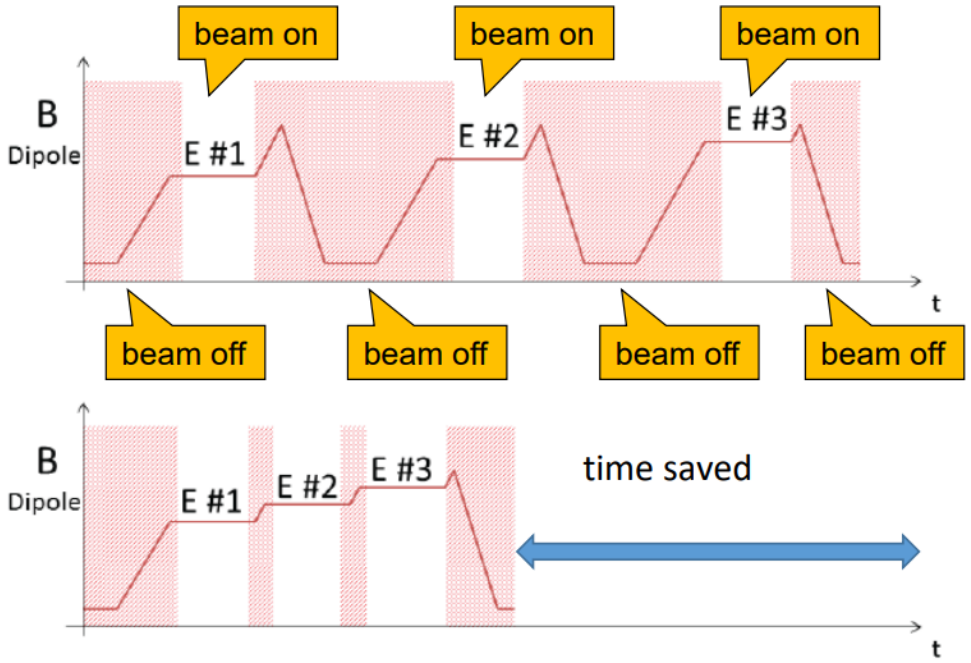
WP 10 - Multiple energy extraction system

- **Motivation**:
  Ion extractions at different energies within one synchrotron cycle
  → shorten treatment times
- **Goal:**
  Development of architectural model for accelerator control system



Challenges for accelerator control system

- Number and values of beam energy steps not known at the start of the synchrotron cycle → cycle cannot be pre-calculated
- Re-acceleration phase depends on initial and final beam energy
  → Huge number of possible combinations

Solution:

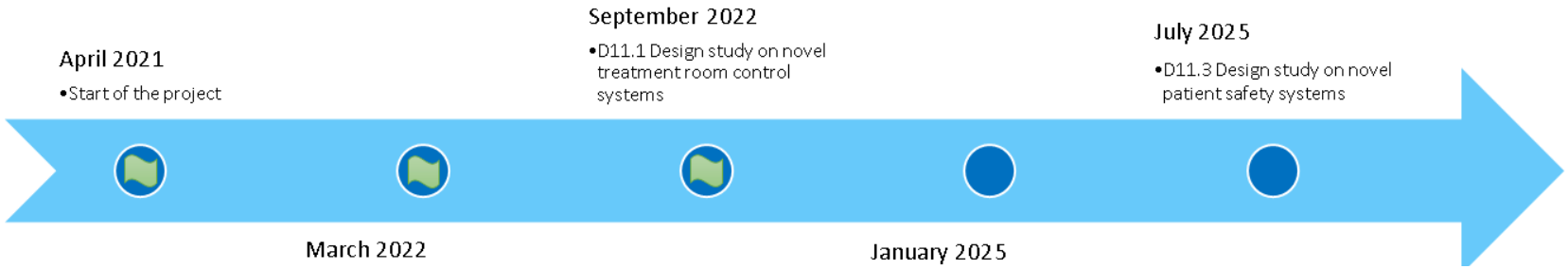
- Calculate control data on the fly!
- Perform calculations on the device controllers to avoid network delays

WP 10 - Multiple energy extraction system

- Task 10.2 finished
  - Report D10.2 delivered
  - Control data computing speed sufficient for multi-energy operation
- Task 10.3 ongoing:
  - Tool developed to resolve dependencies for single device calculation
  - Applied to HIT data supply module
- Upcoming:
  - Perform calculations on prototype of new HIT device controller
  - Merge all parts into the description of the architectural model

    → Report D10.3

WP 11 - Controls and Safety



- Delivered and accepted Milestone 11.1 report ☑
- Delivered and accepted for D11.1 ☑
- Collaboration with impact and dissemination

- As planned, large gap between D11.1 (Sep 2022) and D11.2 (Jan 2025)
  - RP2 quiet period for WP11 – work will ramp up now in RP3
  - WP11 Leader: Mariano Cecowski → Dominik Peruško
  - Planning and drafting for D11.2 (ACS Study, M46 / Jan 2025) and D11.3 (Safety System Study, July M52)

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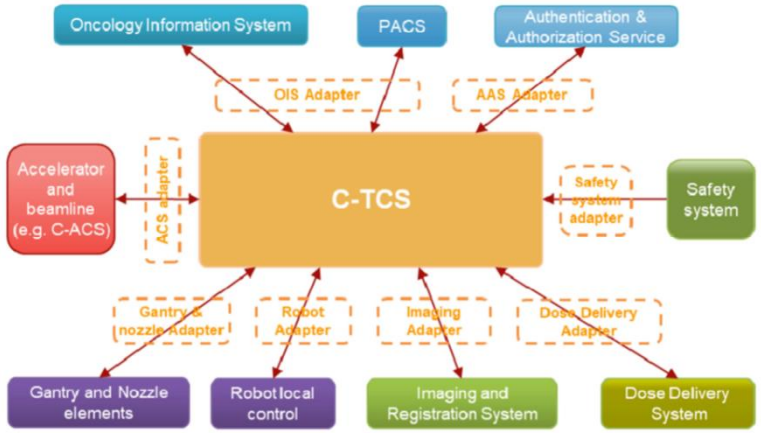
D11.1 (TCS Design Study) Overview



- Functional and non-functional requirements based on:
  - State-of-the-art systems such as MedAustron and experience by Cosylab
  - Requirements gathering workshops
    - Open to HITRIplus members
    - Go through clinical and non-clinical workflows, focusing on a single session
- Design solutions, addressing requirements:
  - Distributed systems favored over monolithic solutions, decoupling of components
  - Adaptability and flexibility (to support varying equipment/workflows between TRs/centers)
  - Technology stack

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WP12 - Radiobiological Dosimetry and QA

Protocols and experimental setup:

- Radiobiological experiments
  - are finished at CNAO, GSI, UMR
  - MedAustron experiments were performed by UMR
  - HIT experiments are still awaited
- Characterization of mixed radiation field using silicon detectors, TEPC
  - Protocol was provided by MedAustron
  - Performed at the partner sites in UMR, MedAustron
  - HIT due in July, CNAO follows
  - Radiobiological experiments for validation were performed at UMR
  - Evaluation is still ongoing

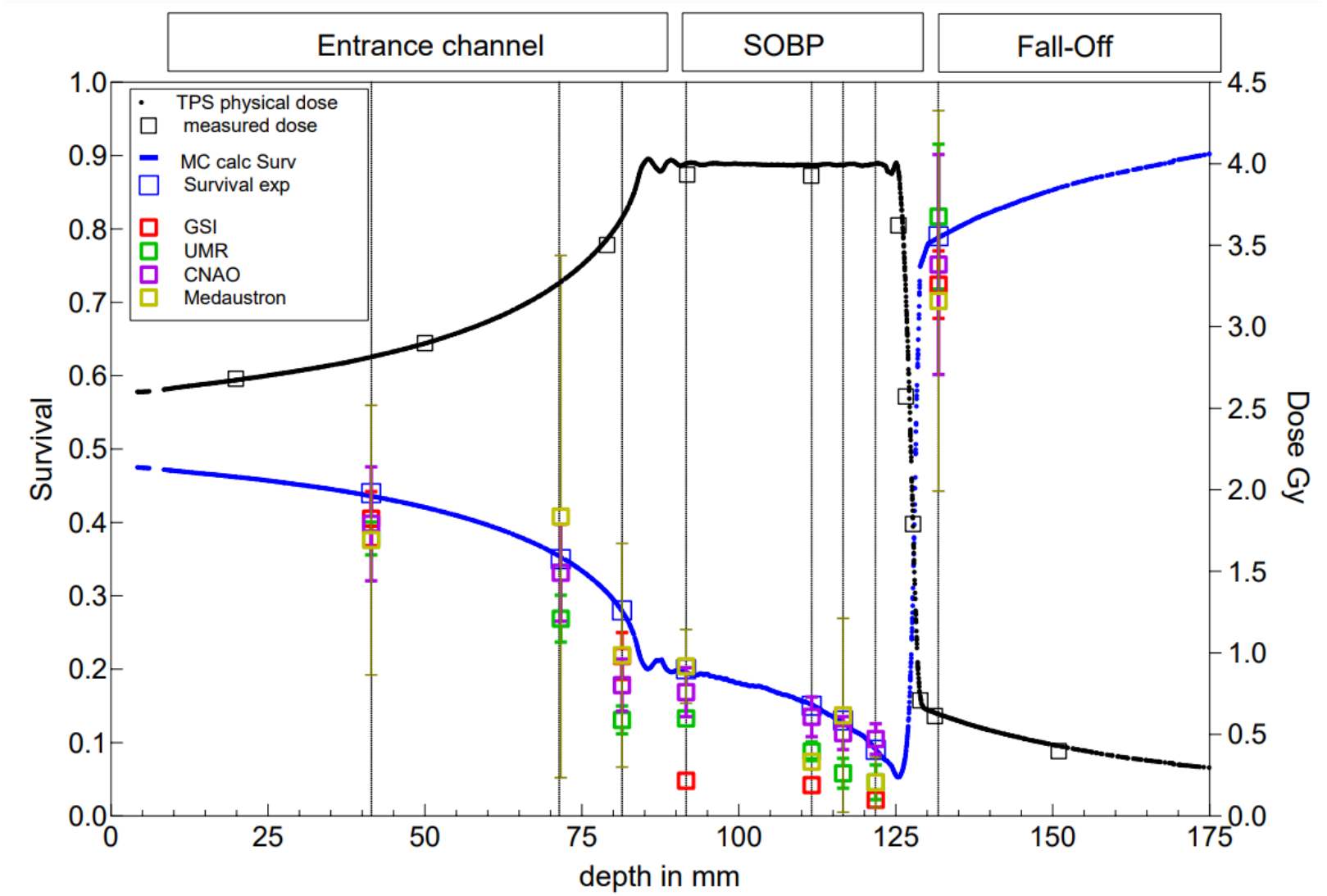
Radiobiological results
- Awaiting results Xray from GSI
- Xray and 12C HIT

Modelling of the joint results
- Data is transferred to HIT

Microdosimetry
- Data is evaluated by MedAustron

D12.3
- Final report and summary
- Due: Summer 2025

WP 12 – Results Radiobiology



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HITRI*plus* – 7th General Assembly meeting

Thursday 23 May 2024
VILA VITA ROSENPARK Congress Center, Marburg (Germany) and On line

14:30 → 14:40 Welcome, verification of the quorum and approval of the Agenda
Speaker: Sanja Damjanovic

14:40 → 15:10 Report of the Coordinator including the summary of the Review meeting
Speaker: Sandro Rossi

15:10 → 15:25 Second Technical Reporting
Speaker: Angelica Facoetti

15:25 → 15:40 Second Financial Reporting
Speaker: Chiara Marazzi

15:40 → 16:10 Open discussion on future evolutions of HITRIplus
Plenary

16:10 → 16:20 Date for the next meeting - AOB