HITRI plus
Heavy Ion Therapy Research Integration

WP9: Advanced beam delivery

C. GRAEFF

GSI HELMHOLTZ CENTER FOR HEAVY ION RESEARCH

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

Overview

- **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: Particle arc therapy for fixed beam line

Carbon arc TPS:

Field setup

Pre-selection of energy band and spot positions

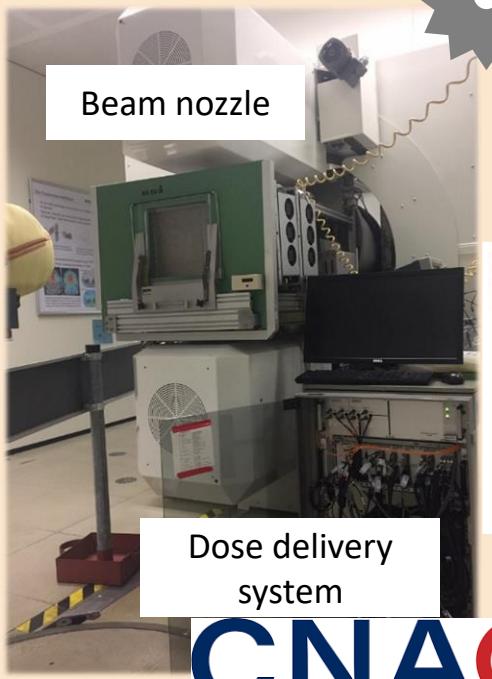
A-priori energy selection

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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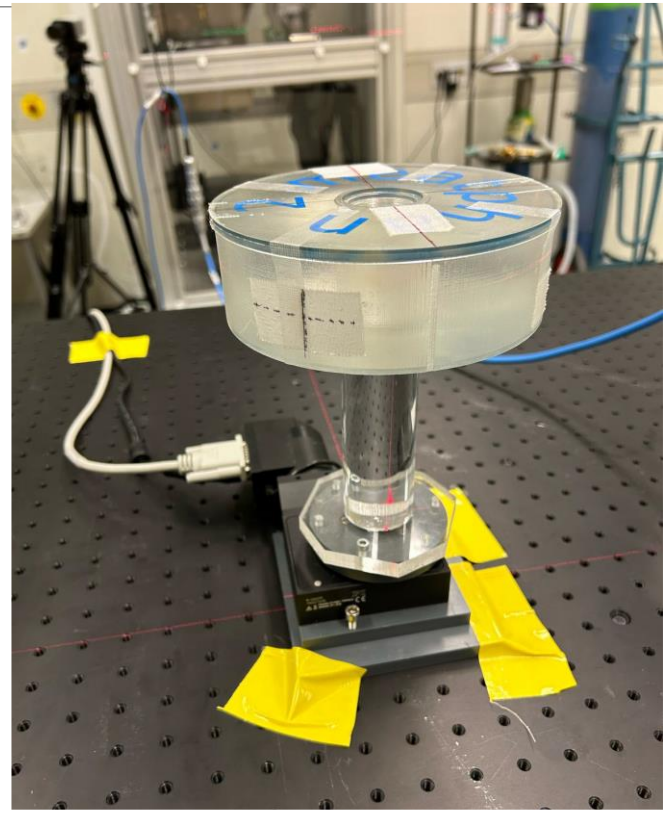
Task 9.2: First experiments at GSI

- 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



Laila El Ouali

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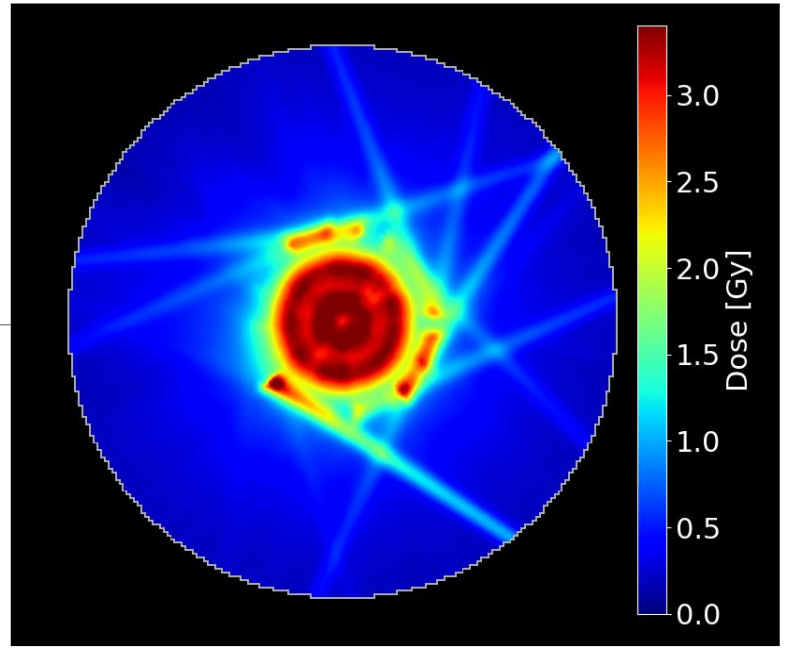
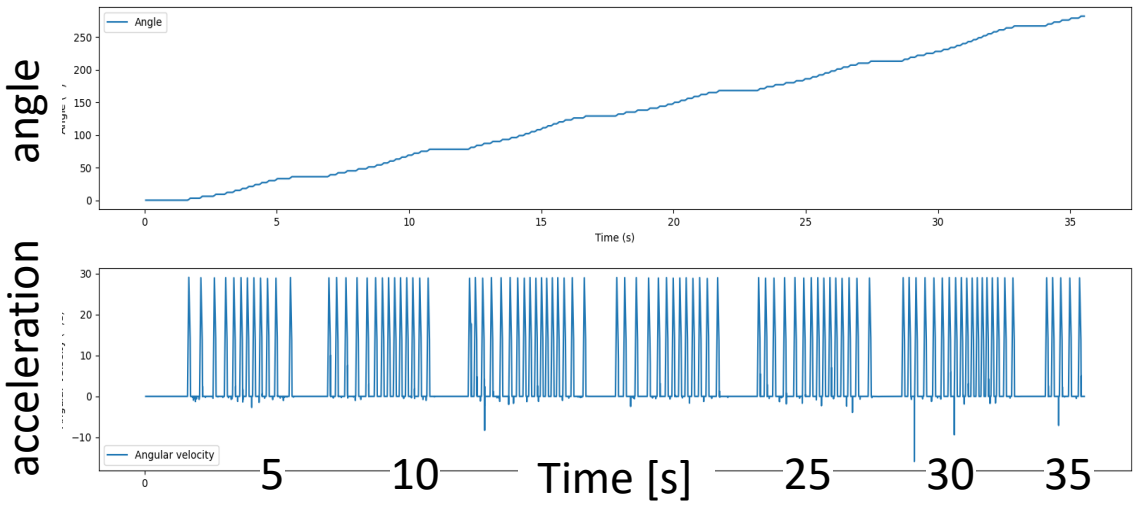
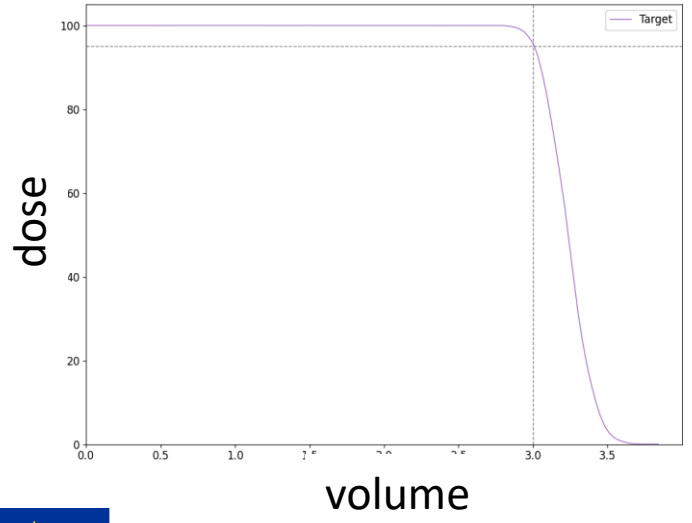
Task 9.2: First experiments at GSI - results

- 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







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Task 9.3:
Clinical scenarios for particle arc therapy on sitting patients

- Datasets of upright patient treatment
  - arc simulations on energy selection in 6 patients from SPHIC (presented last year, now published)
    Volz et al, Health and Technology 2024, https://doi.org/10.1007/s12553-024-00877-0)
  - 6 lung patients scanned upright and supine:
    - developed method for co-registration (ready for submission)
    - investigated dosimetric differences, will be extended to 14 pax
  - dataset on multiple metastases in the brain: comparison of photon hyper arcs, proton and carbon ion arc therapy

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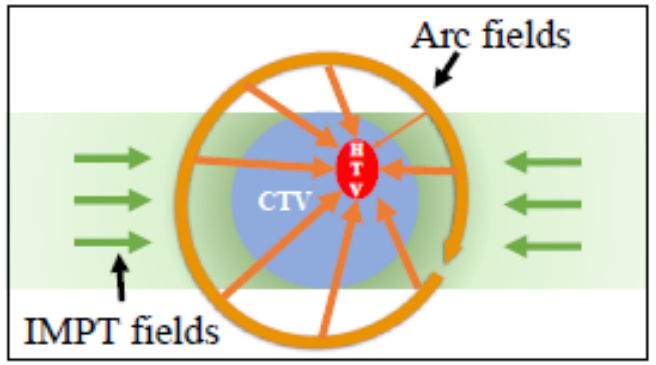
Ion-based LET boost by particle arc irradiation (LEOPARD)

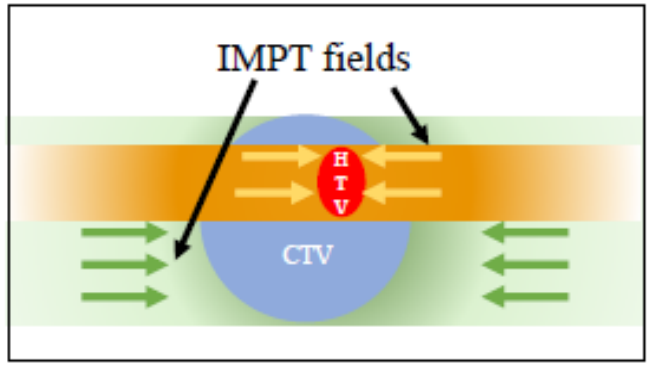
Idea: boost hypoxic core with dose and LET

Boost delivered by arc vs. by conventional SIB

and because we can: multi-ion combinations
to further concentrate LET where it matters



tested in H&N patient cases,
with hypoxic target volume (HTV) defined as GTV minus 1…5 mm



courtesy of
Guangru Li

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LEOPARD simulations in TRiP98

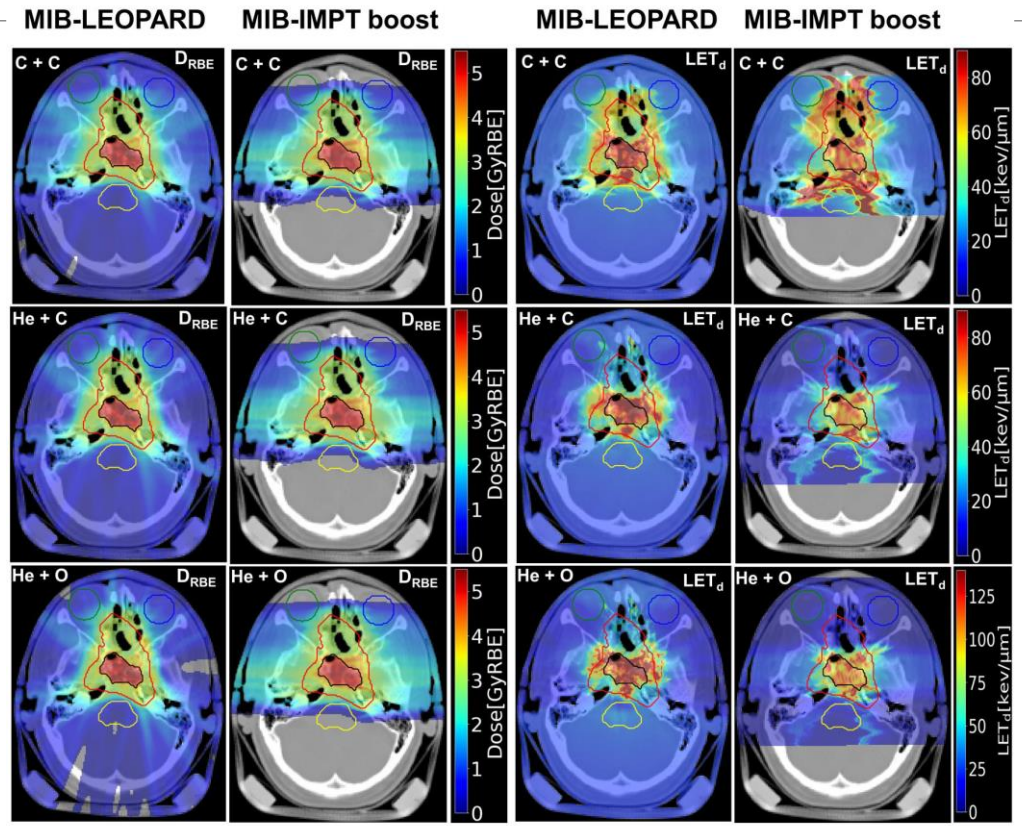

Figure 2. D_{RBE} and LET_d maps, depicted VOIs: CTV (red), HTV (black), brainstem(yellow),right eye (green),left eye(blue).

courtesy of Guangru Li

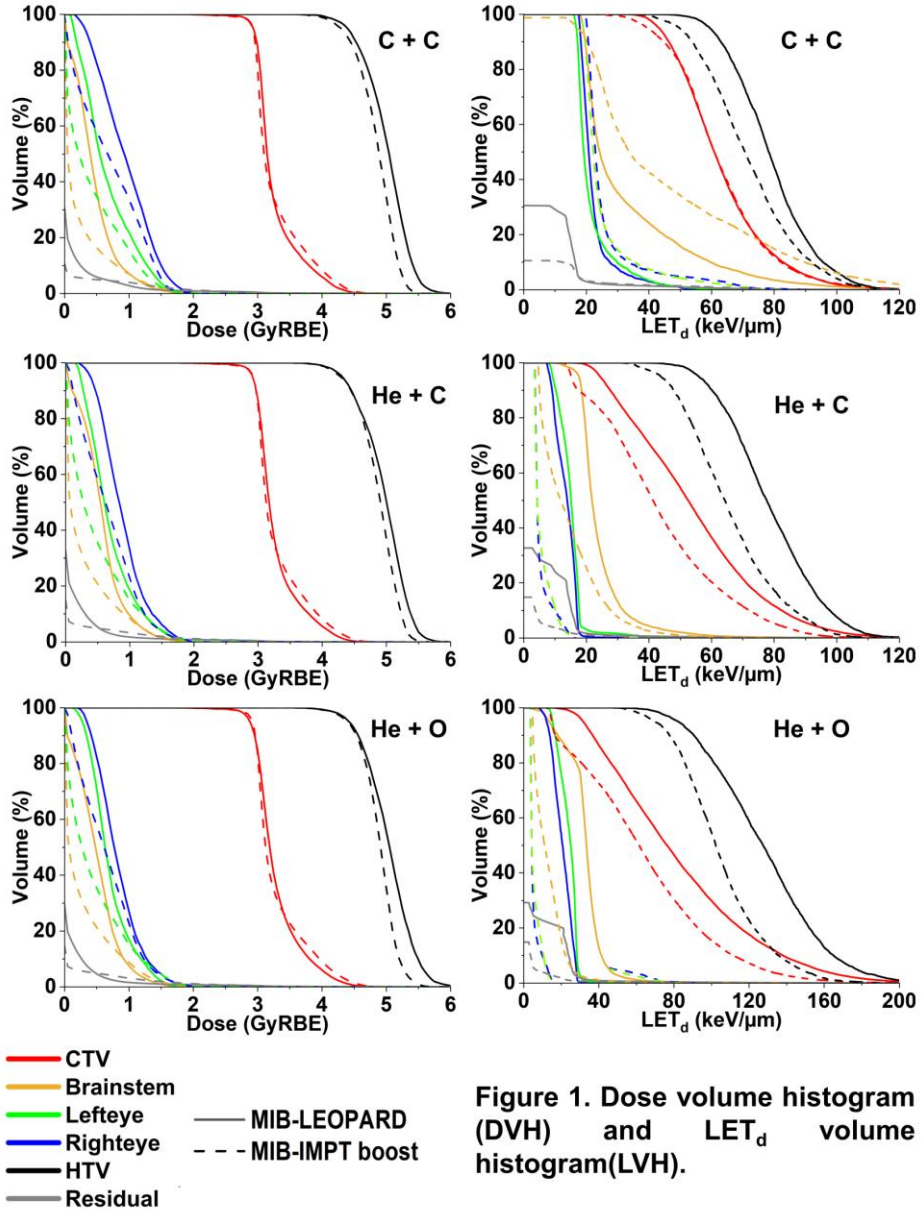

Figure 1. Dose volume histogram (DVH) and LET_d volume histogram(LVH).

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Spot-scanning hadron arc (SHArc) for stereotactic radiosurgery of multiple brain metastases

L. Volz[1], P. Liu[2], T. Tessonnier[3], M. Durante[1], A. Mairani[3], X. Ding[2], T. Li[4] and S. Mein[3,4]

oral presentation at ESTRO 2024

use case: recurring metastases in the brain

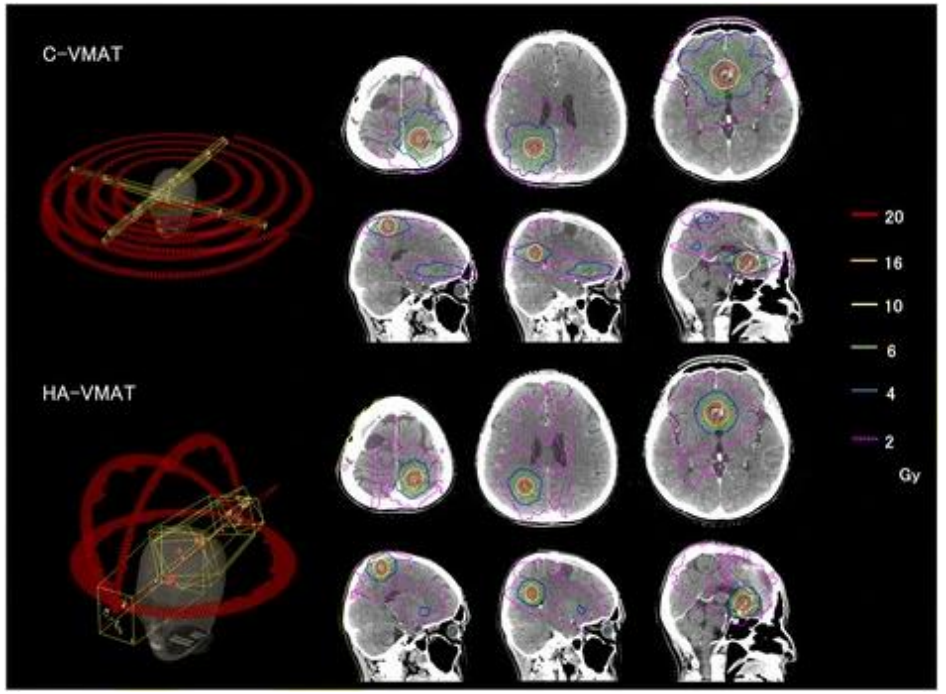
Stereotactic radiosurgery (SRS),
esp. Hyper-Arc VMAT (HA-VMAT)[1]

Single dose SRS effective[2]

Recurrences are common, re-irradiation leads to challenging brain exposure

protons (non-coplanar SPArc, RayStation) or carbon (SHArc, FROG, TRiP98) for lower dose volume

- robust optimization to 1mm / 2.5%



Ohira et al. (2018) Radiat. Oncol.

[1]Palmer et al (2020) Neurooncol. Adv.; [2]Zelefsky (2021) IJROBP.; [3]Milano et al. (2021) IJROBP; [4]Atkins et al. (2018) IJROBP

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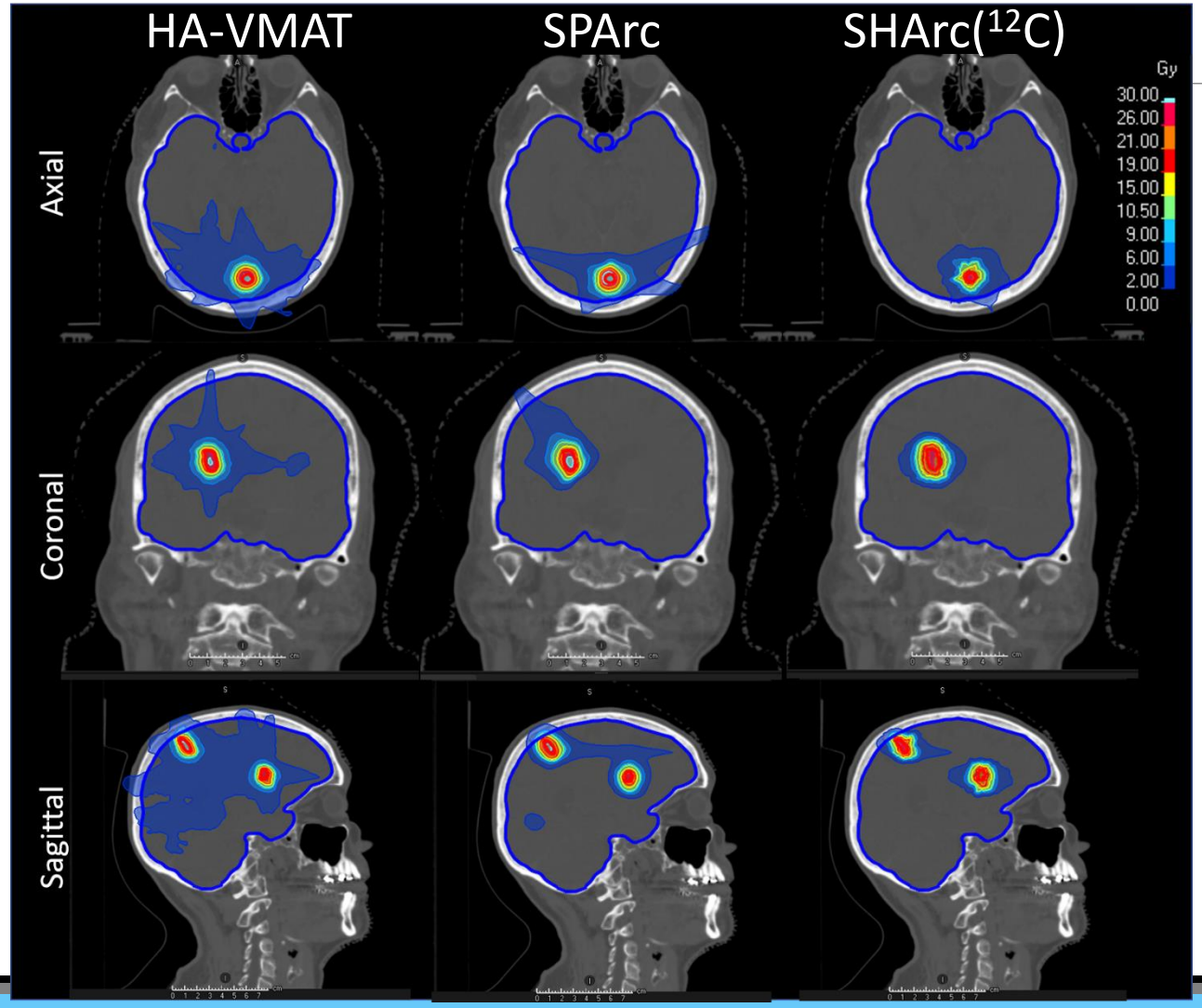
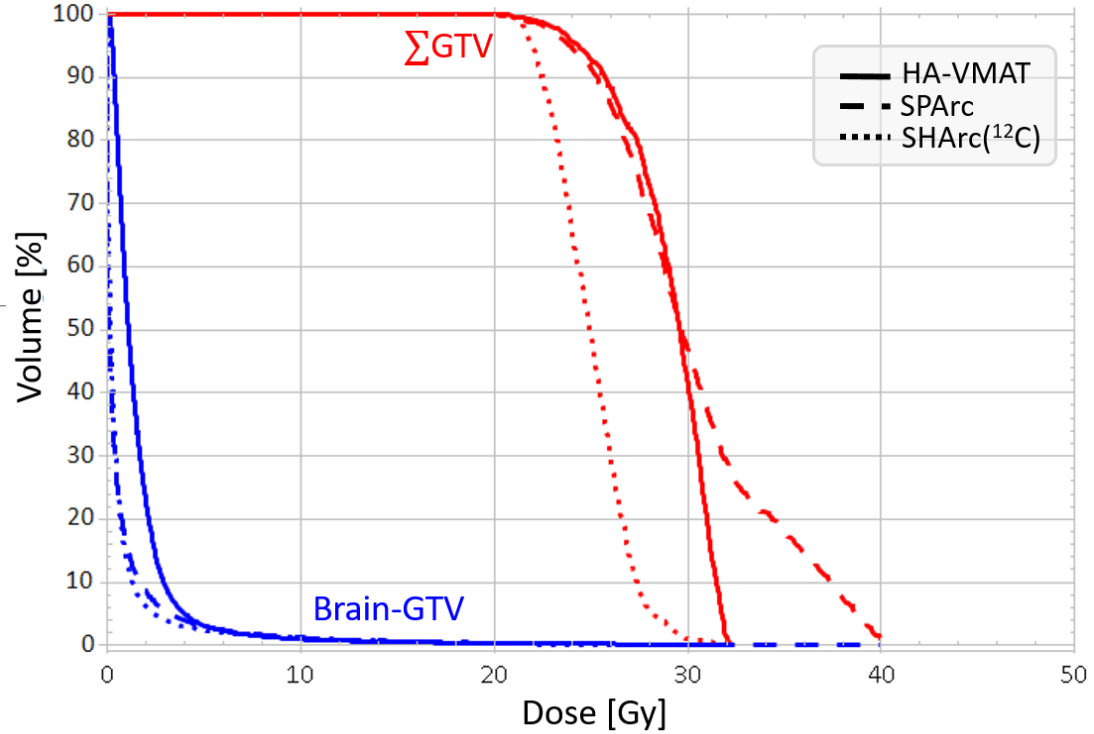
Patient case with 3 metastases





Modality	D99%	D1%	V2Gy	V12Gy
HA-VMAT	25 Gy	32 Gy	342 cc	9 cc
SPArc	25 Gy	35 Gy	123 cc	12 cc
SHArc^{12}C	21 Gy	29 Gy	89 cc	11 cc

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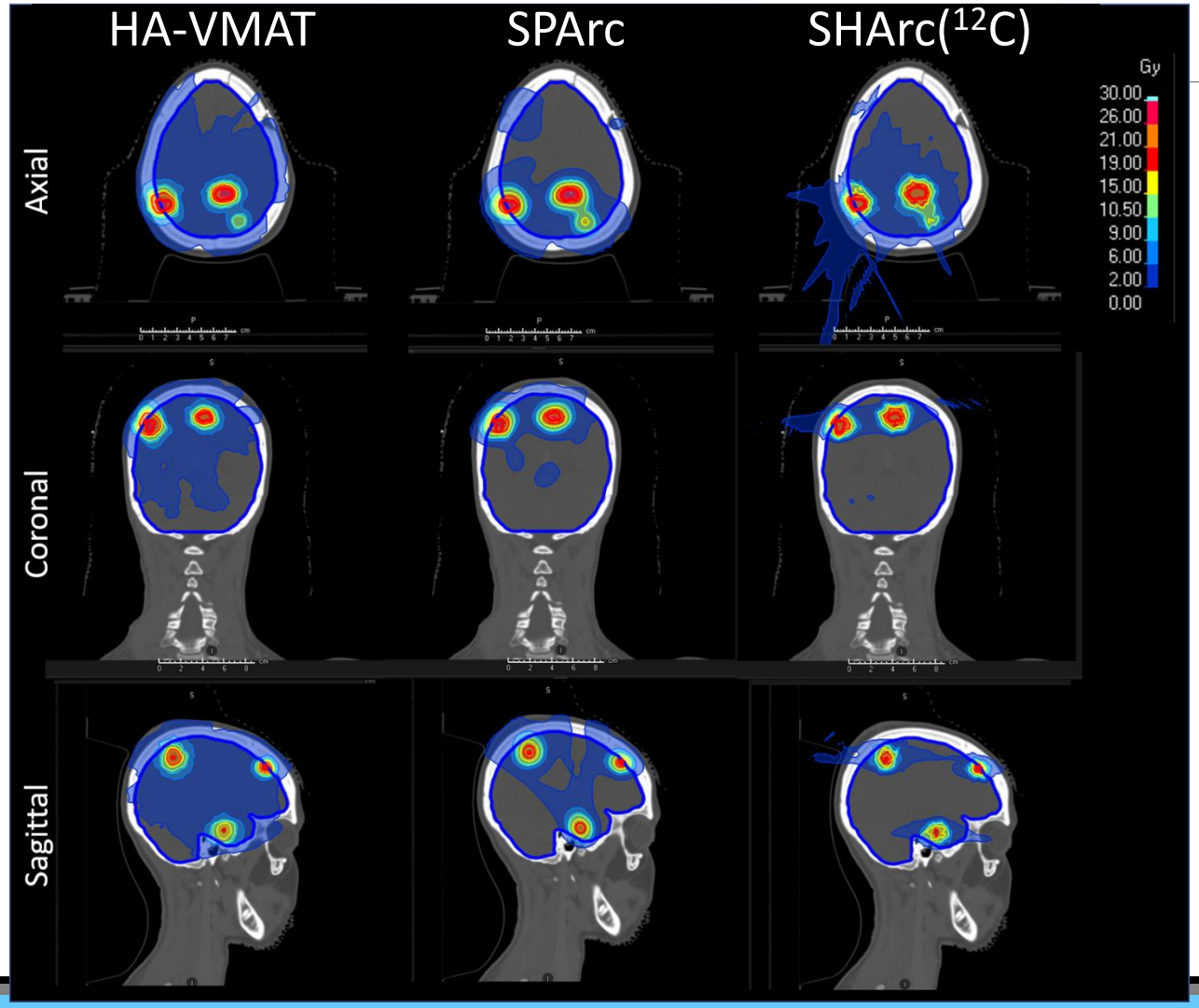
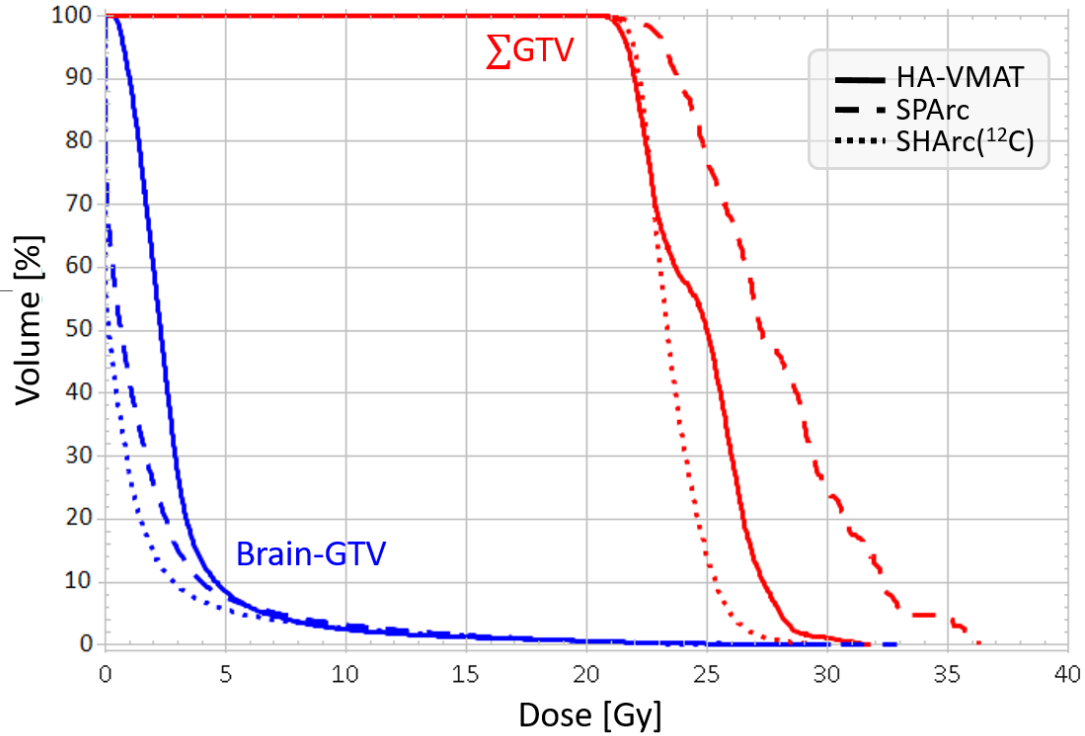
Patient case with 5 metastases





Modality	D99%	D1%	V2Gy	V12Gy
HA-VMAT	25 Gy	28 Gy	776 cc	12 cc
SPArc	22 Gy	31 Gy	331 cc	15 cc
SHArc^{12}C	22 Gy	27 Gy	190 cc	14 cc

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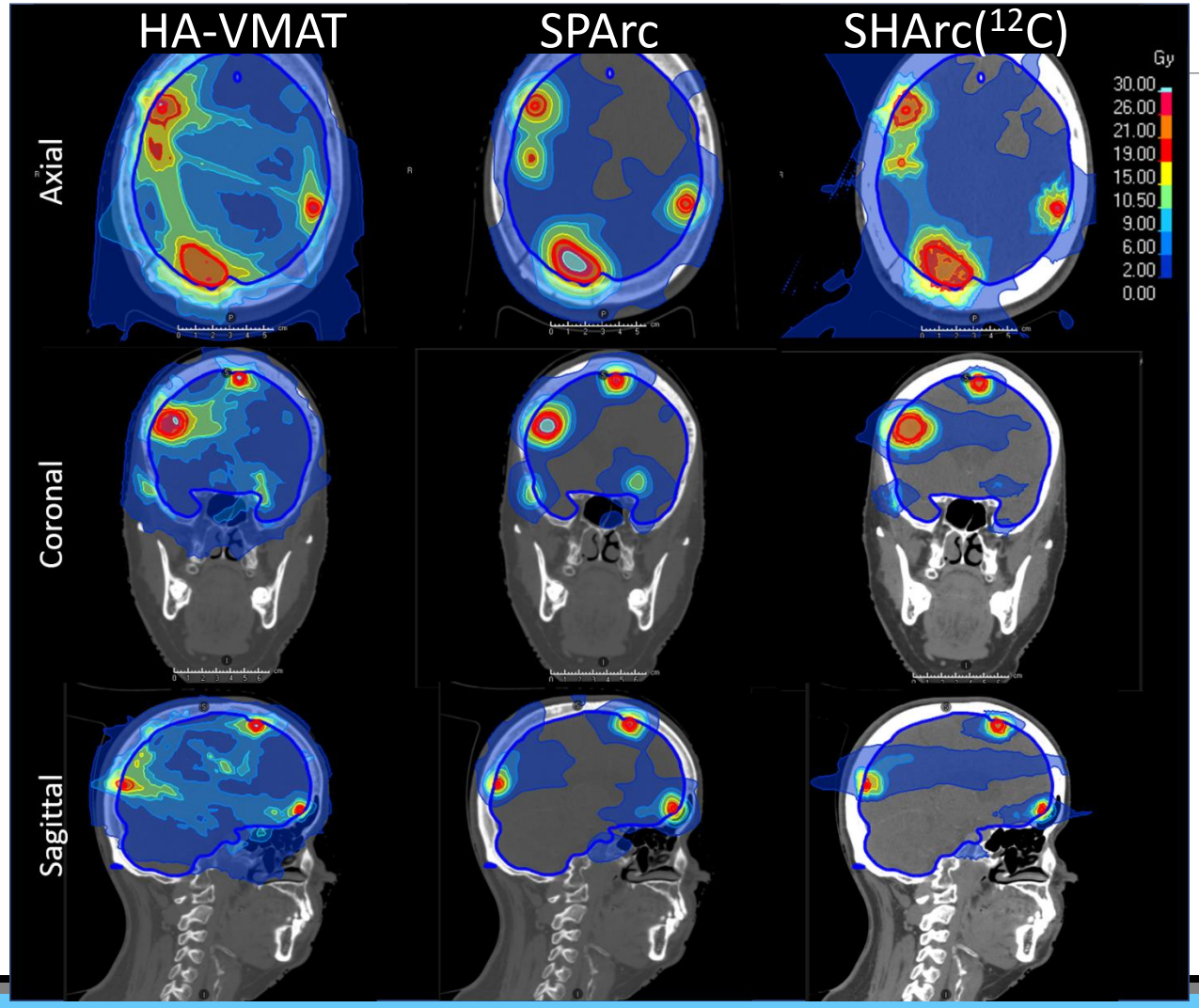
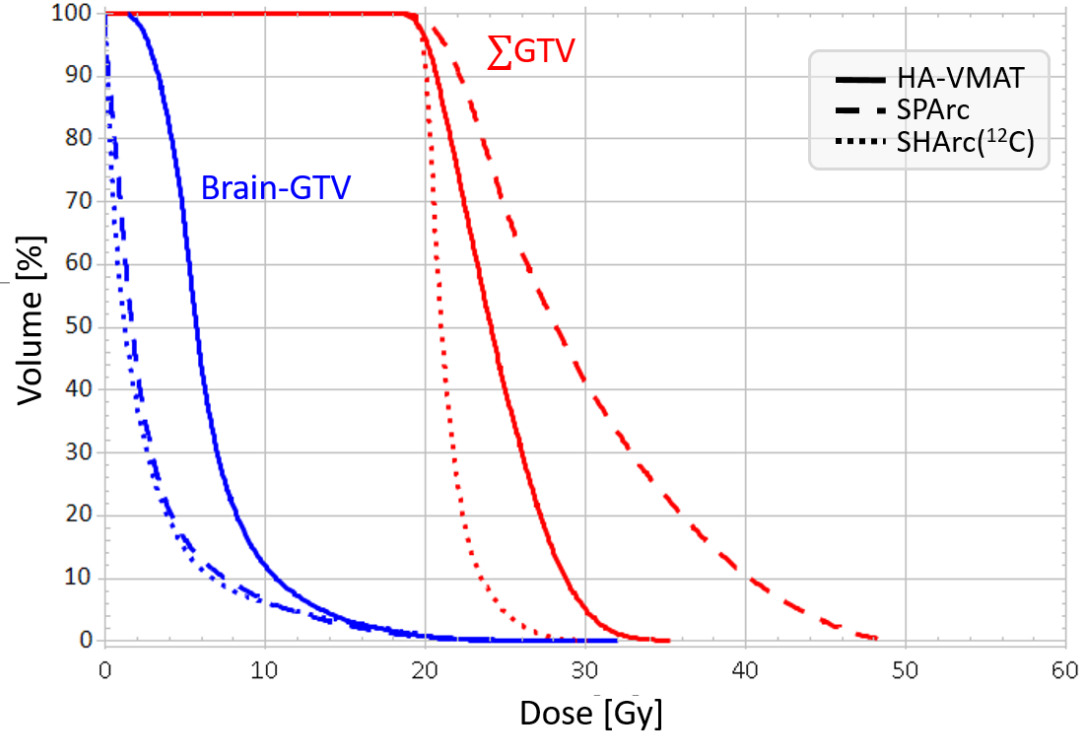
Patient case with 10 metastases and resection cavity





Modality	D99%	D1%	V2Gy	V12Gy
HA-VMAT	23 Gy	28 Gy	1278 cc	93 cc
SPArc	22 Gy	29 Gy	565 cc	58 cc
SHArc^{12}C	21 Gy	28 Gy	488 cc	60 cc

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UPLIFT Doctoral Network coordinated by GSI

Strong interest in upright particle therapy enabled us to assemble DN consortium

- 14 institutes across Europe to host 19 ESR (15 EU, 2 CH, 2 UK) ~ 5 M€
- spanning industry, particle and photon centers
- from clinical & technical to health economics and patient empowerment

Funding granted in April 2024, project start is Oct 1, 2024:
we need excellent students – please send us yours!

GA awaits signature, details still in embargo

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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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THANK YOU

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