WP4 : Beam instrumentation, characterization and dosimetry

CERN, 20.01.2023

HEARTS Kick-off Meeting

https://indico.cern.ch/event/1216205/

Tim Wagner / Uli Weber
GSI Biophysics

This project has received funding from the European Union's Horizon Europe Research and Innovation programme under GA No 101082402.

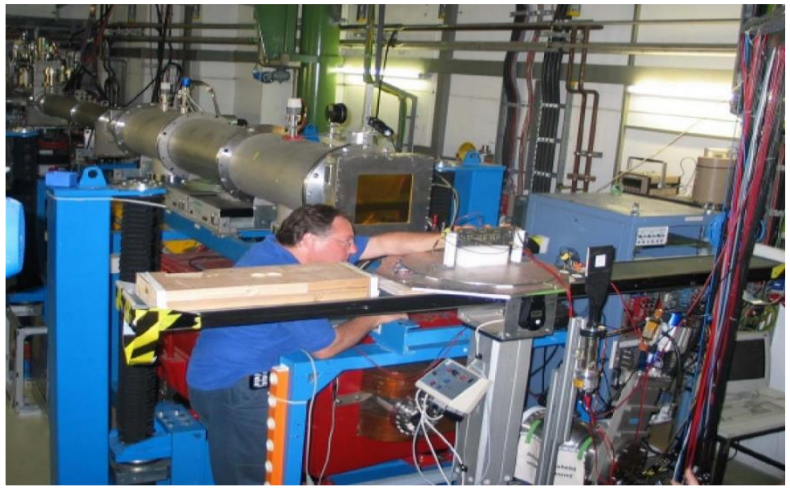
GSI Biophysics: Long history of beam application by raster scanning, precise dosimetry and beam characterisation

- Raster Scanning beam application
- Precise 3D dose application for ion beam therapy
- Dedicated beam monitoring detectors

➔ Good infrastructure for radio biology and radiation hardness experiments

Setup: Preclinical irradiations (mice) for carbon FLASH experiments (2022)

Setup and patient positioned on a treatment table for Carbon Ion Therapy (Photo from late 90s)



Setup:
Radiation tests for the AMS spectrometer (ISS) at GSI, CaveA

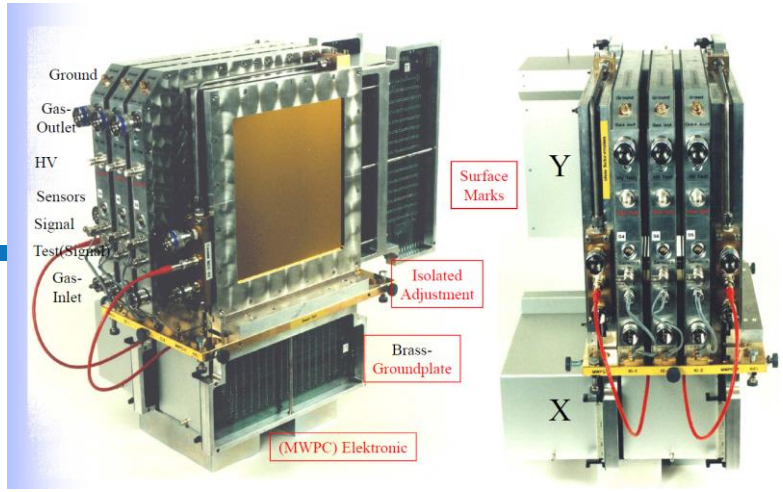
Task 4.1
Knowledge transfer between CERN and GSI (CERN, GSI, M1-12)

GSI-CERN Workshop for discussing concepts and instrumentation for ….

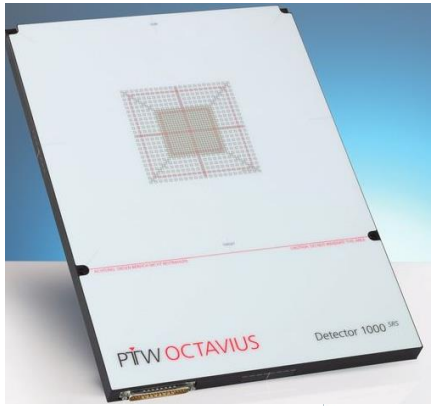
- Beam monitoring
- Dosimetry
- Fluence measurements
- Beam characterization
  - Pencil Beam profile
  - lateral field characterization
  - Energy spectra

Definition of specifications and terms (find a common language, Medical Physics vs Nuclear Physics)

→ **Workshop March or April 2023 ?**



GSI beam monitoring system for ion beam therapy,
2 x MWPC and 3 x Parallel-plate IC



Ionization chamber array
(PTW-Freiburg)

Farmer chamber, standard dosimetry
(PTW-Freiburg)

Micro dosimetry (TE-PC, *FarWest*)

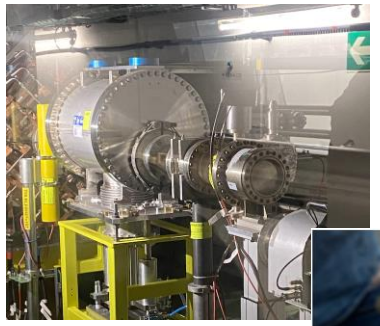
ΔE-E telescope (energy spectra)

Task 4.2

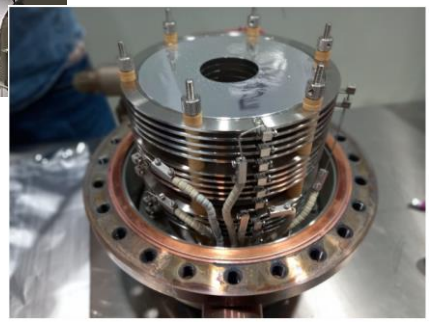
Calibration of beam instrumentation for VHE ion beam extraction (CERN, M1-24)

- Calibration and exploitation of existing beam instrumentation in the PS East Area beam line for characterization and dosimetry of VHE ion beams.
  - Existing beam instrumentation (Ionization chambers, gas scintillator + multi-wire proportional chamber) is calibrated for proton operation only
  - Focus on measuring **key beam parameters** for VHE ion testing:
    - energy variability
    - beam flux/intensity tunability
    - beam size manipulation through optics

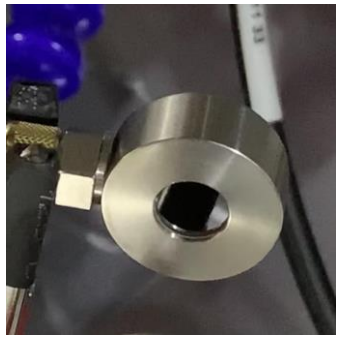
    → Task 7.2



Existing beam instrumentation in East Area beam line



- Identification and installation of new devices (collimator, degraders) and detectors suited for VHE ion applications
  - Simulation work (Task 3.1) to identify materials and material budget, investigate feasibility of using collimator for further beam shaping
  - Identify dedicated diode for beam characterization (energy, LET, fragmentation)

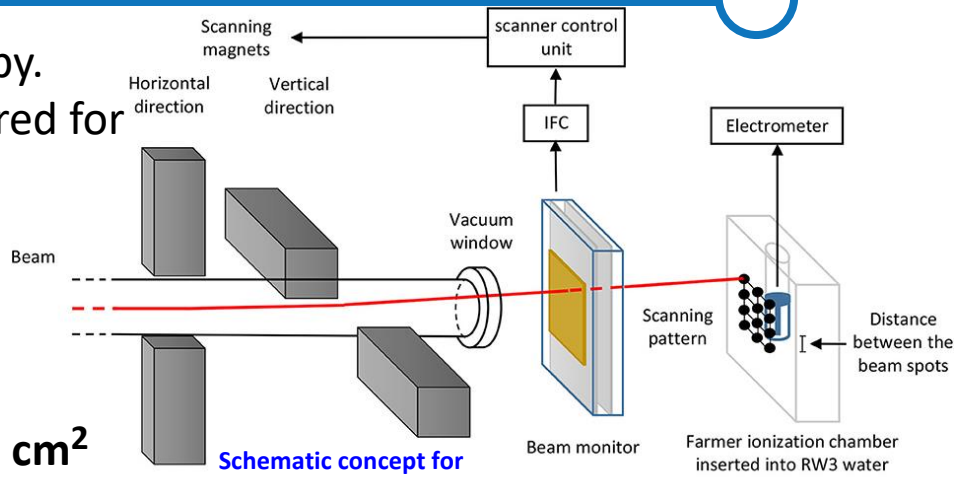


PIN diode

NSRL collimator system

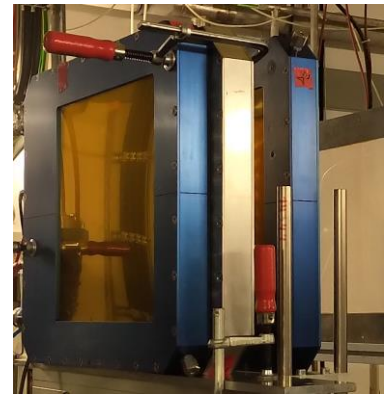
Task 4.3
Beam delivery monitoring (GSI, M12-M36)

- We mainly use the **dose-based** monitor calibration, as usual in particle therapy. Recently we published a work, where show how this concept can be transferred for HZE particles: Luoni et.al https://doi.org/10.3389/fphy.2020.568145
- This concept is successfully used since many years at GSI (CaveA/CaveM) for the beam application with the raster scanner
- Basically, we can use raster scanning for all species (Z=1..92) and all available intensities (**10^3 – 10^9 ions/s**, depends a bit on the species) within an area of **20 x 20 cm^2**
- For high intensities (>10^4 ions/s , depends on the species):
  - Parallel plate ionization chambers as beam intensity monitors, possibly with a Helium mixture (for ultra-high intensities)
  - 2D Dose verification with an ionisations chamber array
- For low intensities (< 10^4)
  - Large area plastic scintillators, discriminator, counting single particle



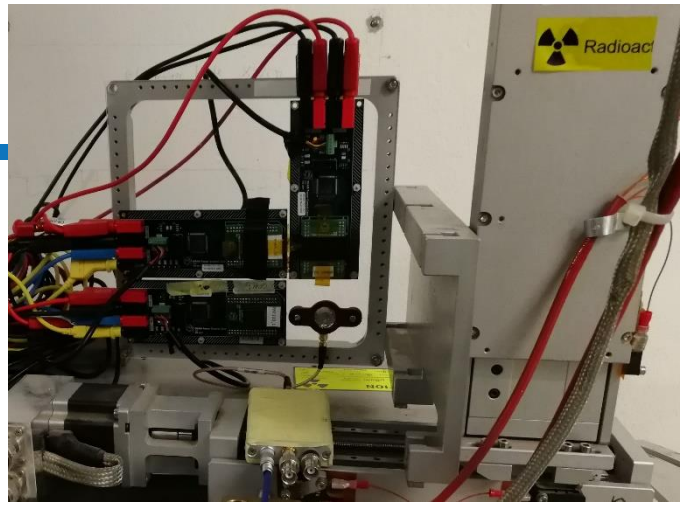
Schematic concept for dose-based monitor calibration


ΔE-E telescope (plastic and BaF scintillators) for cross section and energy spectra measurements


Three parallel-plate ionization chambers (filled with different gases) for particle monitoring

Task 4.4
Target station (GSI, M12-36)

- Goal: Increase technology readiness level (TRL) of GSI
- Build a remotely controlled **target station** for microelectronics
  - Utilize input and suggestions from industrial partners
  - Aim for standardization of the device-under-test (DUT) holder between GSI and CERN
- Remote variation of the **shielding** to degrade the beam
  - Automatic arm to add and remove slabs of material of different thicknesses
  - Enables the measurement of Bragg curves without any vault access



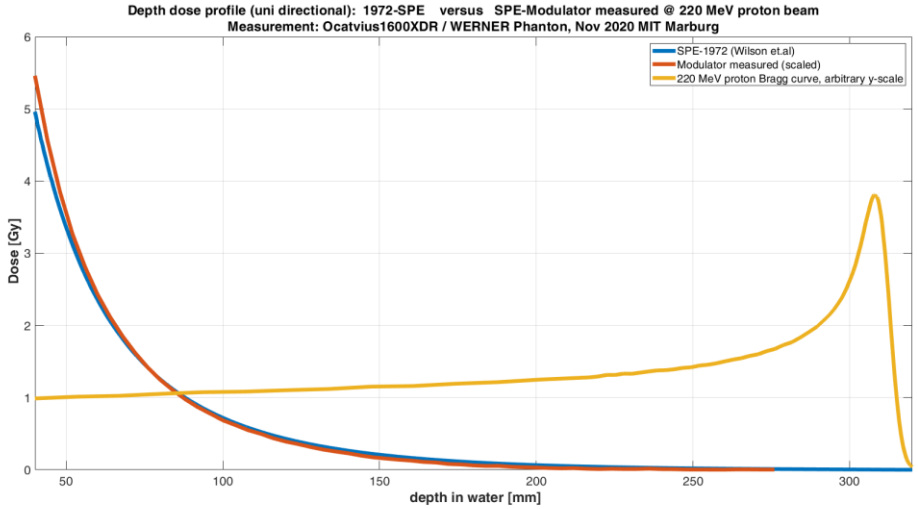
DUT holder at the CHARM facility at CERN


Range shifter in Cave A at GSI

Task 4.5
GCR/SPE simulator dosimetry (GSI, M24-36)

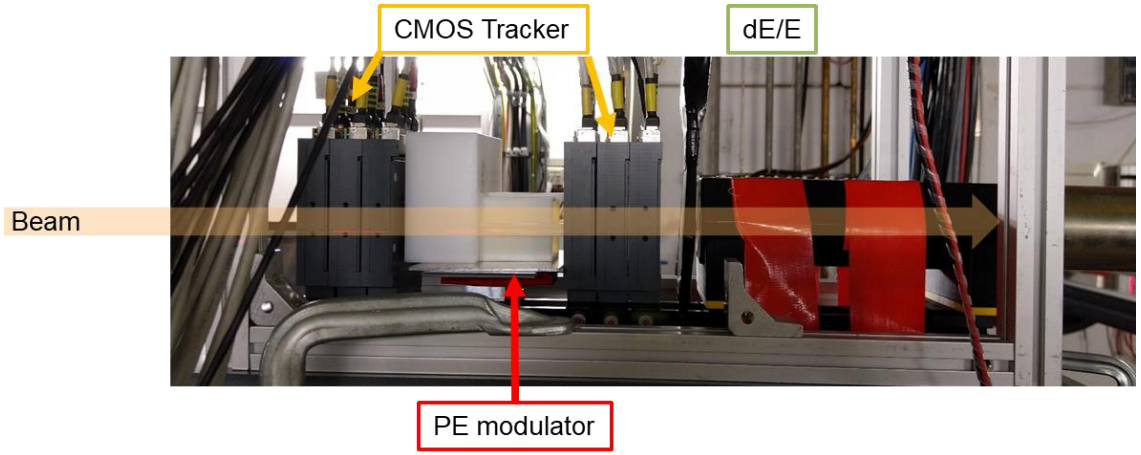
- Define standards and interfaces for on-target dosimetry
- Strongly correlated to Task 6.2

Quality assurance and dosimetry



➔ based on integrated values

Field characterization



➔ based on single particle values

Task 4.6

Intercomparison between CERN and GSI (CERN, GSI, M24-48)

The experience gathered at CERN and GSI will be transferred to one another and dedicated intercomparison measurements

To be defined during the project:

- **Selection of 1 or 2 certain irradiation cases** (e.g. Fe-56 1 GeV/u squared field , 10x10 cm^2)
- **Selection of the dosimetry detector setup (must be applicable at both facilities)**

➔ **Conduction of the test at both facilities (CERN & GSI)**

relatively late at the end of the project period (year 4)

WP4 – personnel allocation

Name	Task	% of the time in HEARTS
Uli Weber	4.1	10%
Andreas Waets (CERN)	4.2	20% (?)
Uli Weber	4.3	50%
HEARTS engineer	4.3	20%
Tim Wagner	4.4	20%
HEARTS engineer	4.4	30%
Christoph Schuy	4.5	20%
Uli Weber	4.5	10%
Tim Wagner	4.5	10%
Uli Weber	4.6	10%
Tim Wagner	4.6	10%

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HEARTS

Backup

WP4 – Work package definition (from the proposal)

Work package number	**4.**	**Lead beneficiary**	GSI	
Work package title	**Beam instrumentation, characterization and dosimetry**			
Short name of participant	1	2		
Short name of participant	CERN	GSI		
Person-months per participant	3	36		
Start month	M1	**End month**	M48	

Objectives:
Streamlined and efficient access to the accelerator facility, especially for industrial partners, requires a precise standardisation of the beam instrumentation in terms of beam delivery, online monitoring, target station remote controlling and dosimetry. In this WP we will define and calibrate the beam delivery sensors at GSI and CERN for both material shielding and microelectronics. Dosimetry activity will include both monoenergetic ions and the full GCR spectrum characterisation.

Description of work:
Task 4.1: Knowledge transfer between CERN and GSI (CERN, GSI, M1-12)
Exchange on beam instrumentation and characterization methods to aid in the upgrade of both infrastructures. This task includes a visit of CERN colleagues to GSI to actually see the current beam instrumentation in Cave A and discuss with the related experts.
Task 4.2: Calibration of beam instrumentation for VHE ion beam extraction (CERN, M1-24)
Calibration and exploitation of existing beam instrumentation in the PS East Area beam line for characterization and dosimetry of VHE ion beams. Identification and installation of new beam instruments (e.g., collimator, degrader) and detectors suited for VHE ion applications. This task is closely linked to Task 3.1 and feeds into Task 7.2.
Task 4.3: Beam delivery monitoring (GSI, M12-M36)
This task will define the necessary beamline instrumentation for beam monitoring during space radiation testing. The monitoring platform will be able to handle both the high intensities (10^8-10^{10} ions/s), required for the assessment of shielding materials and the low intensities (10^2-10^5 ions/s), necessary for SEE cross-section measurements. A dedicated set of dosimeters, including thin gas ionisation chambers and plastic scintillators, will be designed and calibrated.
Task 4.4: Target station (GSI, M12-36)
This task will focus on the optimization of the GSI target station to increase the TRL of the facility. A remotely controlled holder for microelectronics chips will be built and tested following suggestions of the industrial partners. For shielding, we will build an automatic arm to add and remove slabs of different thickness to measure Bragg curves without any vault access. We will aim for standardization between the GSI and CERN device-under-test holder.
Task 4.5: GCR/SPE simulator dosimetry (GSI, M24-36)
Dosimetry-on-target will be defined and standardised for the different applications. We will also explore the possibility of using microdosimetry downstream of the shielding to characterise the quality factor Q of the mixed field generated by the shield. Special attention will be dedicated to the measurements necessary for the GCR/SPE simulator. Here we will be able to produce both the LET spectrum and the charge composition of the mixed field.
Task 4.6: Intercomparison between CERN and GSI (CERN, GSI, M24-48) The experience gathered at CERN and GSI will be transferred to one another and dedicated intercomparison measurements (i.e., testing the same beam instruments and reference electronic devices in both facilities) will be performed.

Deliverables:
D4.1 (M12): Beam instrumentation for high-energy low intensity heavy ion beam characterization
D4.2 (M24): Calibrated CERN beam instrumentation documented and installed in the accelerator
D4.3 (M36): Experimental measurements on GSI beam instrumentation and dosimetry
D4.4 (M36): Documentation on the target station construction and use
D4.5 (M36): Report on microdosimetry for GCR/SPE simulator calibration
D4.6 (M48): Intercomparison between CERN and GSI instrumentation and standardisation