

# How to standardize experiments within HEARTS?

The GSI perspective – now including the feedback

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Online, 12.04.2023

related to:

WP4 Task 4.4 and D4.4

WP6 Task 6.1 and D6.1

WP8 Task 8.1 and D8.1



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GSI Biophysics

- The goal of this presentation is start a discussion. All ideas/proposed solutions are up for discussion.
- The discussion is tailored for the GSI part of the project but significant parts can be directly used for CERN as well.
- NSRL is our internal benchmark, but it is important to understand that there are significant differences e.g.
  - NSRL is a pure user facility. Everybody working at NSRL is either doing beamline development or user service
  - GSI is rather a science facility.
    - ➔ The level of direct support we can offer will most likely be smaller
- Beam time is very limited and must be used very efficiently, thus universal, simple and practical interfaces are needed
- The “standard” we try to find doesn’t need to fit all possible experiments, only most. Non-standard experiments will, of course, still be possible if necessary.

### Part 1

#### Technical parameters

- Beam parameters
- Variable shielding / range shifter
- Target station

Points added due to the feedback (via the discussion afterwards or via email by TAS) are added in green to the following slides.

### Part 2

#### Proposed workflow

- first contact point of users via webpage
  - user guide
  - FAQ
  - contact/beam request
- assignment of liaison scientist
- experiment scheduling / planning
- on-site dry-run
- beam exposure
- test report

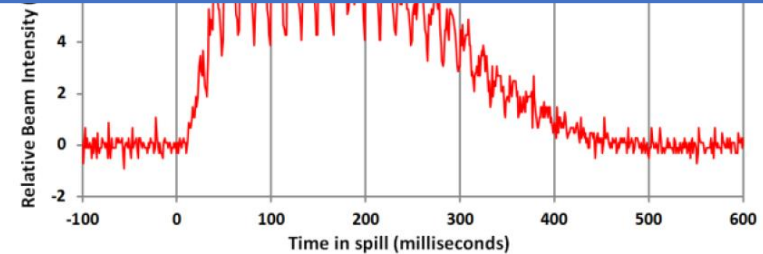
# Part 1

## Beam parameters

	GSI	comments
Energies	80-1000 MeV/u	Typically 2-3 energies
Ions	H to U	typically C, Fe, U *
Intensity range	500 – 10 <sup>9</sup> per spill	Depends (a bit) on the ion species
Extraction	Slow 1-10 s (quadrupole resonance)	Optional slow RF-KO (1 – 10 s), Fast kick out extraction (<1μs)
Spill length	0.2 – 10s	
Spill pause	< 2s	Variable duty cycle
Delivery	Scanning	Arbitrary shapes
Max area	Up to 20 x 20 cm <sup>2</sup>	< 5 x 5 cm <sup>2</sup> for uranium
Uniformity	Better than +-5%	
Beam microstructure	Important?	Can be improved with RF-KO

**Note:**  
 Every change to the accelerator settings during beamtime take at least 30 min and can take up to hours  
 Ions are not offered at the same time

- beam  
beam
- Proposal:**
- One high energy → Shoot through/Bio
  - One low → BP scanning
  - One high intensity > 10<sup>6</sup> per spill
  - One low intensity ≈ 5000 per spill



\* additional ions like protons, helium might be available



# Part 1

## Beam parameters

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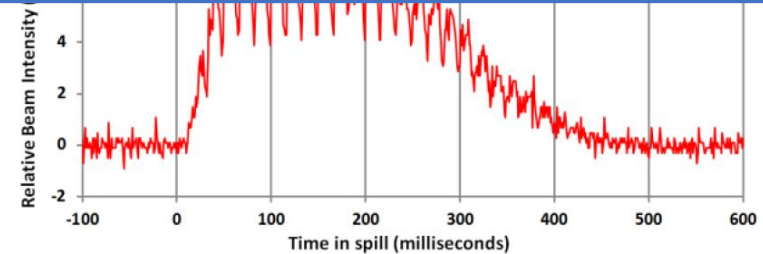
**Note:**  
 Every change to the accelerator settings during beamtime take at least 30 min and can take up to hours  
 Ions are not offered at the same time

### TAS:

- Crucial to deliver defined LET values between 1 to 60 MeV/cm<sup>2</sup>/mg  
 → Pick 5 critical LET values (to be discussed and agreed upon)
- 5x5cm<sup>2</sup> spot (Uranium) is small for board level testing  
 → The board can also be moved to cover a larger area, just not at the same time.
- Defined time for change of ions is important.  
 → **There is no offer of multiple ions at the same time.** Different ions are only available in different slots (possibly weeks apart). Different LET values can be achieved with different energies of the same ion.

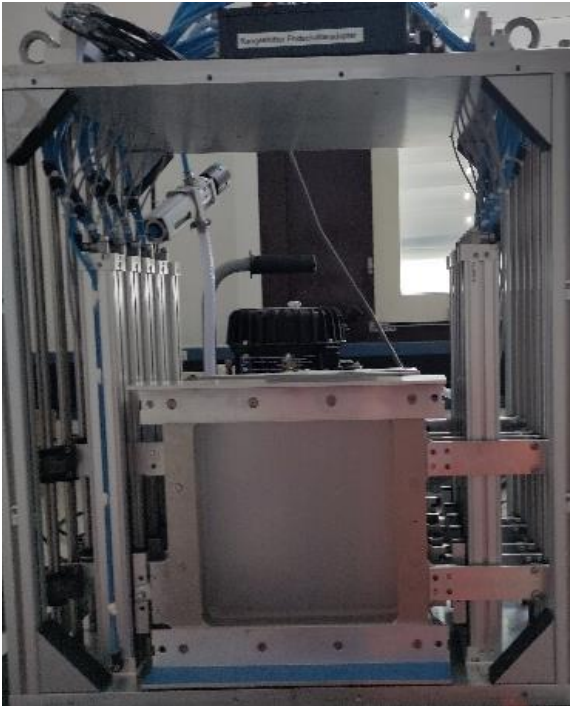
### Proposal:

- One high energy → Shoot through/Bio
- One low → BP scanning
- One high intensity > 10<sup>6</sup> per spill
- One low intensity ≈ 5000 per spill



## Part 1

### Variable shielding handler/ Variable depth Bragg Peak Range shifter



“Old” binary Range shifter

- modular version of the cave A binary range shifter
- 4 modules → 8 plates
  - module
    - 2 plates, two sets of pneumatic linear motors
    - max size 20 x 20 cm<sup>2</sup>
    - max weight ≈ 10 kg
- modules can be used individually or combined
- standardized frames for “fast” plate exchange
  - CAD available for users in case of non-standard configuration
- Standard plate-sets for
  - shielding (aluminum, PE) → thicker
  - peak finding for electronics → binary, thinner



**Note:**  
NSRL uses 2 target wheels which offers some geometrical benefits but is far less flexible/useful for different settings

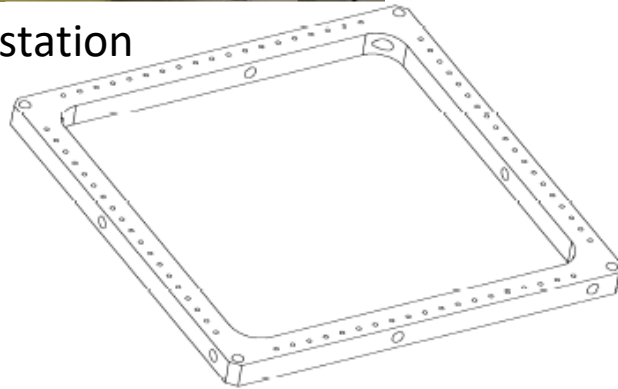
PE and PMMA are okay materials for electronics irradiation as a degrader, as light fragments do not influence measurements much. **Awaiting further feedback from industry.**

## Part 1

### Target station / Target station interface



CERN target station  
and holder



- Based on linear axes with hybrid steppers
  - every point within the frame reachable via scanner and/or motor
- Distortion corrected and calibrated target camera (OpenCV)
  - Front or back
- Distortion corrected Target laser
- Remote movement (z → beam direction)
  - x / y → standard
  - + 1D-Rotation **to be incorporated optional**
- One frame per “experiment”
- Frame design based on CERN holder
  - Inner opening > 20 x 20 cm<sup>2</sup> (RADEF and GANIL allow for up to 25 x 25cm<sup>2</sup> boards)
  - Laser markers (back and/or front)
  - Material: aluminum or reinforced plastic
- **Common frame between CERN and GSI**

Note: Entering the  
cave takes a minimum  
of ≈ 10 min



## Part 1

### Target station / Target station interface Bio

- Biology irradiations typically use:
  - T25 or T12.5 Flasks in sets of three or six per dose
  - Well plates
- Cells inside the flasks prefer to stay inside the medium
  - a. Fill the flasks completely
  - b. Only position them upright for a short time (<20min, depends on the experiment)

#### Proposal:

- Utilize a system, which flips flasks into an upright position only for irradiation and positions them horizontally otherwise (based on the GSI flask exchanger).
- System should accept at least three, better six, T25 flasks at the same time and also be compatible with well plates



T25 Flask

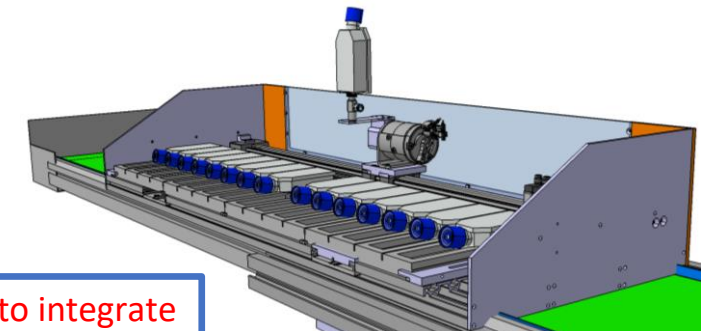


Well plate



Possible to integrate into a target station

NSRL remote sample flipper



More complicated to integrate into a target station, prototype exists at GSI already

GSI Flask exchanger



# Part 2

## HEARTS website – facility user guide

Similar to the NSRL user guide (<https://www.bnl.gov/nsrl/userguide/>)

Brookhaven National Laboratory NASA Space Radiation Laboratory

Home User Guide StackUp Tool About Apply for Beam Time Run Information Related Facilities PETRA

### NSRL User Guide

#### Frequently Asked Questions

##### First-time User Information

1. You MUST complete a dry run of your experiment before conducting your first NSRL run.
2. When planning an exposure, the time you need for each sample exposure should include time to change samples. If RHIC is running, the sample changing time is approximately 4 minutes. If RHIC is not running, time to change samples is only about 2 minutes.
3. The size of the radiation field that can uniformly expose a set of samples can be as large as 20 x 20 cm<sup>2</sup> for most ions and energies. By special request, the NSRL beam can operate in Large Beam mode with a 60 x 60 cm<sup>2</sup> usable beam size.
4. If you have further questions, please check other pages in the user guide and then contact NSRL personnel at 631.344.3072 or 631.344.3930.

##### Electronics & Physics Experiments

1. A rotation table allows experiments to be mounted centered on the beam and rotated to any angle with an accuracy of approximately 1 degree.
2. A translation table allows many samples to be mounted on a table that can be remotely controlled to move samples into or out of the beam without any access required.
3. A variety of sample holders are available at the facility to assist in mounting devices under test. Please see the [Sample Holder page](#) for more information.
4. The data acquisition equipment at NSRL consists of VME crates with a variety of ADCs, TDCs, and scalars that can be used to accommodate most physics experiments. Data rates in excess of 2048 (600 events per spill) are practicable, with data recording in the format of ASCII files or images. Contact the NSRL Liaison Physicist at [nsrl@bnl.gov](mailto:nsrl@bnl.gov) for more information.
5. Beam signals to indicate when beam is possible to occur or when beam is incident on the target are able to be generated at any point of the facility. These signals can be provided as TTL (with voltage of your specification, base 2.5V) or NIM (fast-negative logic). The signals generated for experiments have 50Ω impedance through BNC coaxial cables.
6. Heat guns and compressed air lines are available to experimenters if requested. Contact the liaison physicist to discuss specifications.
7. An [Electronics testing presentation](#) (pdf, 5 MB) has been produced to inform users of the NSRL facility and use of heavy ion beams.

##### Biology Experiments

1. For users preparing cell exposures, incubators are available to keep cell samples at constant temperature and humidity during the length of an exposure. Incubators are available for 15 x 15 cm<sup>2</sup> and 60 x 60 cm<sup>2</sup> exposure areas. Contact NSRL personnel for more information.
2. Standard sample holders are available for cells at NSRL. Holders for various types of T75, T25, and test tube sizes have already been made up. If the sample holders do not fit your needs, custom sample holders can be prepared with a few hours advance notice. If you are bringing your own sample holders, make yourself familiar with the information regarding beam fragmentation and the documentation on [saxtilo stability](#).
3. A [saxtilo filter](#) is available that allows flasks to remain horizontal until the time of exposure, keeping the cells in the medium as long as possible.
4. There are [multiple sample holders](#) that allow up to 10 samples to be placed in the beam per exposure. In most cases, the time taken to load the samples into the sample holders is longer than the exposure itself, and so there is no benefit in planning to expose a large number of samples in a single entry. At the request of users, custom sample holders can be fabricated at NSRL, with only a few hours notice.
5. For exposures to only part of a sample, collimators can be arranged that shield all parts of a sample except for the region to be exposed.

#### User Guide Contents

- User Guide Home
- I. Beamline Hardware
  - Sample Holders
  - Collimators
  - Remote Sample Floorer
  - Remote Translation Table
  - Remote Rotation Table
  - Rail System
  - Incubators
  - Data Acquisition System
  - Mini Pixel and Large Pixel Chamber
  - Patch Panels
  - Cables and Cable Tray
- II. Technical Data
  - Beam ions and energies
  - Beam characterization studies
  - Beam uniformity and profile
  - Beam fragmentation
  - Time structure in beam
  - Dosimetry Calibration
  - Straps, curves, peaks
  - LE Trance plots
  - Material in the Beam
- III. Operations
  - Galactic Cosmic Ray Simulation (GCR)
  - Simulated Galactic Cosmic Ray Simulation (SimGCRSim)
  - Solar Particle Event Simulation (SPESim)
  - Stacking Samples
  - Target Room Exposure Levels
  - Calculating Target Room access time
  - Activation decay times
- IV. Life in the Beam
  - A Cell Phone's Life in the Beam
  - A Microscope's Life in the Beam

Tech Notes

- Short explanation of basic physics with relevant examples
  - Scattering/fragmentation/etc.
  - Shared GSI/CERN
- Explanation of irradiation room + CAD
  - Space, cables, etc.
- Explanation of beamline + CAD
- Explanation of dosimetry/beam monitoring
- Explanation of Shielding exchanger + interface CAD
- Explanation of target station + interface CAD
  - In case of bio → standardized flasks/etc.
- Explanation of preparation/dry run
- Resource/tools (Lise++, etc.)
  - Shared GSI/CERN

Generally liked by everyone  
Started with information collection  
and writing a first draft.

How much support is necessary/wanted by industry?

Possibilities for support

- Regulatory requirements (e.g. radiation protection, biological lab safety, required GSI instructions, etc.)
- Experimental planning?
- MC simulations or other forms of calculations

**Discussion Result:** Provide LET Spectra at the top of the package of the DUT. Inside the package is the users responsibility.

**TAS Feedback:** MC simulations for beam transport and LET determination through a large and complex amount of shielding

→ **Both points agree with each other**

- Non-standard holders etc.
- Fully perform the testing (no industry partner) on-site
- Use of GSI/FAIR experimental equipment e.g. power supplies

Note: Beam exposure, etc. will always be performed by GSI/FAIR staff

Generally no extra equipment is needed. Only in case of failures it would be good to have.

## Part 2

### Requirements to access GSI

#### Workflow for onsite access for experimenters

- Apply for guest status at GSI
  - Fill online registration forms
    - Sign Home institute declaration
  - Perform general GSI safety instructions online
- If access to the cave is needed:
  - Further online safety instructions
  - Medical certificate
  - Apply for TLD dosimeter (or Barcode if neutron sensitive dosimeter is available)
  - Safety instructions on site
- Possibly apply for access to the Internet\* or even to the GSI network / clusters

The application for a guest status process is required for everyone coming to GSI

The rules for getting access to the cave follow German radiation protection laws and cannot be changed.

Guides for all registration processes are available on the GSI webpages

## Part 2 Experiment scheduling / planning

APR	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	
2022-v036	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
IS N	238-U																				238-U			
IS S	56-Fe																				40-Ar			
ECR	48-Ca																							
UNILAC	U321 Raeder; 48-Ca; Y7										Operator Training										U000			
UNILAC	UMAT; 48-Ca; M1-3										U326 Michel; 48-Ca; M3													
UNILAC	U327 Yakushev; 48-Ca; X8																							
UNILAC																								
SIS	ESA; 56-Fe; HTA/M	S BIO; 56-Fe; HTA/M	ESA; 56-Fe + 238-U; HTM/HTA	SMAT; 238-U; HTA							Operator Training										S000			
SIS	S489 Bagnoud; 238-U; HHT																							
SIS																								
ESR	E142 Brandau, 238-U; ESR										Operator Training										E000			
CRY											Operator Training										C000			

(1) only if parallel operation possible /// (2) only block mode

Available at

[https://www.gsi.de/fileadmin/beamtime/2022/BTS\\_2022\\_v042.pdf](https://www.gsi.de/fileadmin/beamtime/2022/BTS_2022_v042.pdf)

- Influencing when a specific beamtime block is scheduled is really difficult
- Specific user wishes for dates are essentially impossible
- Scheduling within a specific beamtime block is up to us → degree of flexibility

The beam time block is fixed and the time slots must be accepted by the users



example

### Goal: time optimization

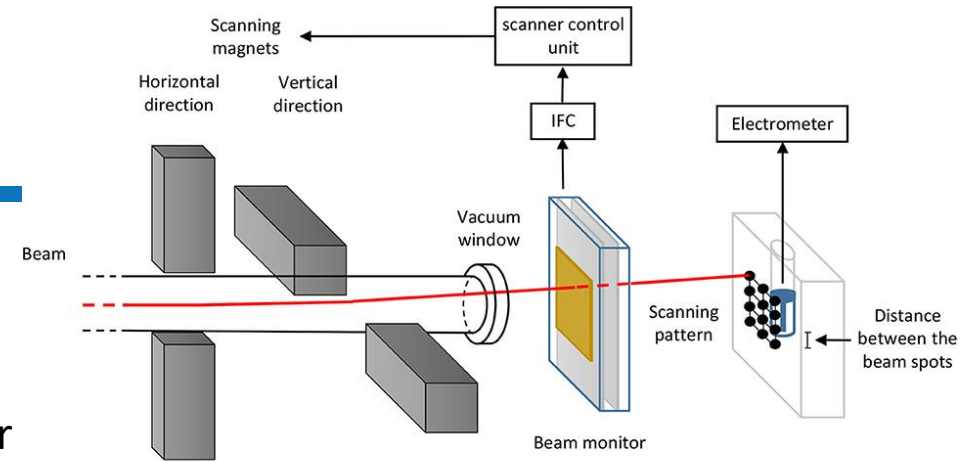
- Minimizing the setup time (likely, there are other experiments right before and afterwards)
- Every experiment gets one cart to place electronics
  - For larger equipment tables with wheels are an option\*
- If possible, every experiment should perform a dry run outside of the cave
- Proposed process
  - Prepare experiment on cart
  - Test outside of cave
  - Move fully tested experiment to cave
  - Irradiate
  - Bulk remove

\*Maximal size needs to be investigated for the maneuverability through the labyrinth and cave.

## Part 2 Beam exposure

Information, which has to be supplied for the irradiation process

- Desired beam intensity
  - Can also be adjusted during the experiment, but takes time (larger steps take more time)
- Irradiation areas (positions on the DUT and sizes)
  - Used for setting up the scanning system
  - Easily adjustable during the experiment in case more or less are needed
- Desired total number of ions / cm<sup>2</sup> (for each irradiation area)
  - Easily adjustable during the experiment in case more or less are needed

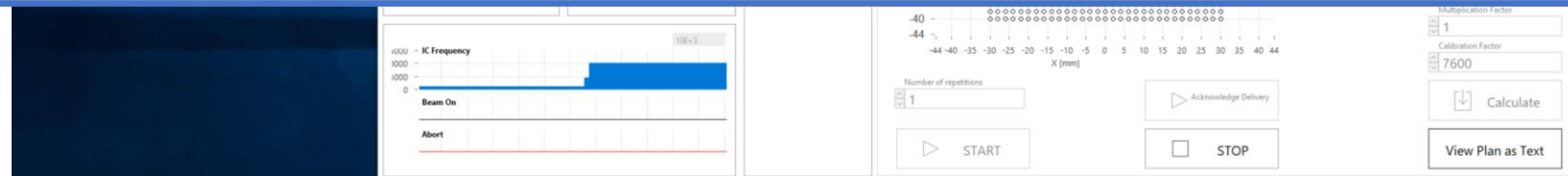


Cave A Scanning system

Beam scanning is different to a standard beam spot  
→ Influence needs to be investigated

Request to start and stop the beam with user provided signals (e.g. standard TTL)  
→ Needs to be checked with the GSI safety department

**Note:** The signal can only be a request to start the beam at the next possible time slot and not an immediate start due to the multi-user operation at GSI (and CERN).



Cave A Scanning system GUI

## Part 2

### Online information for users

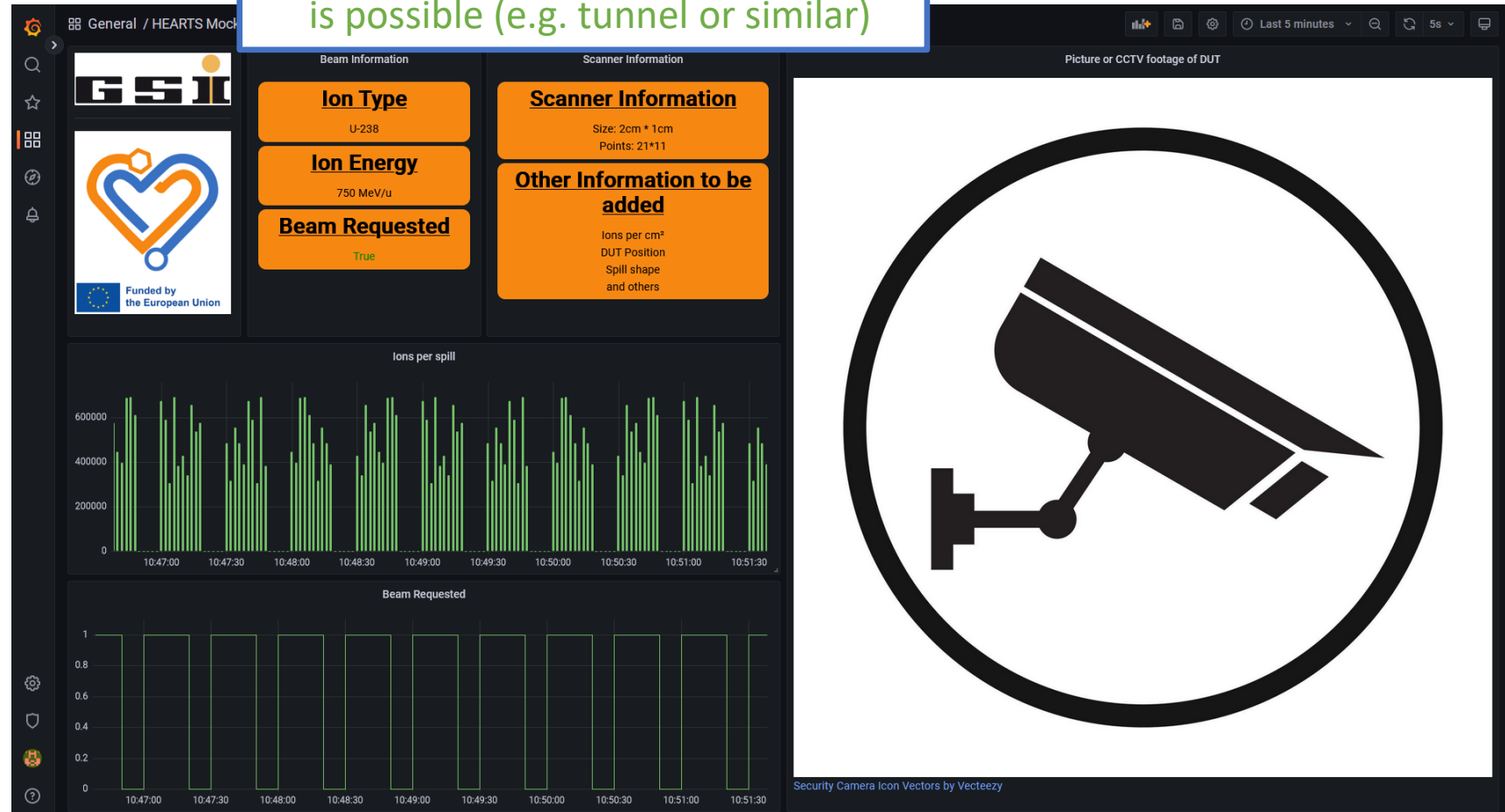
Goal: Supply information to users

Show live data about the irradiation

- Beam type & energy
- Status / Progress of the beam application via scanning
- Ions / spill, avg. # ions for last N spills, ions / cm<sup>2</sup> / s, etc.
- DUT positioning picture
- Target station data (X & Y position, etc.)
- Information about other instrumentation (e.g. shielding)

What other kind of data would be needed here?

- Not connected to the internet (data protection concerns)
- To be investigated if remote access is possible (e.g. tunnel or similar)





## Part 2

### Beam exposure – additional signals for users during exposure

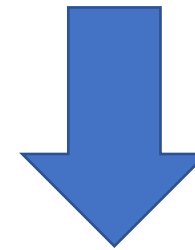
E.g. time resolved pulses of the beam monitoring detectors

- What standard? NIM/TTL 5V/24V

Will these signals recorded by the user or by us and we only provide a timestamp or a synchronization pulse?

- Beam start and stop signals for DAQ synchronization
- User triggered logging:
  - Is a good idea to allow a synchronization with the user DAQ.
  - One needs to decide on a common logging format (e.g. xml) and the information content (which signals and/or other data).

Note: The amount of recorded information in different systems of the irradiation room/accelerator is extremely high



Define a set of information of interest for most experiments

# Part 2 Test/Summary sheet/Logbook

		<b>INSPECTION CERTIFICATE</b> CERTIFICADO DE INSPECCION ABWÄHRBEREITIGUNG according to / de acuerdo con / nach EN ISO 9001-1		Original number / Número original / Originalnummer <b>0000363416 /</b> Page / Pagina / Seite <b>1 / 2</b>																																																			
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Terms of delivery / Condiciones de entrega / Lieferbedingungen ASTM A240/A240M-17, ASME SA-240 Sec. II part A 6.6.2017 ASTM A480/A480M-17, ASME SA-480 Sec. II part A 6.6.2017 ASTM A886-18 SAE AMS 8616 P SAE AMS 8613 J		Manufacturer's serial number / P.º de Fabricación / Hersteller-Nr. <b>00156520 / 201</b> Product / Producto / Erzeugnis <b>COIL ROOM/RAHAM</b>																																																					
Quantity / Cantidad / Menge 1.58 mtr x 1.219,20 mm 0.0020 inch x 48.0000 inch		Heat treatment / Tratamiento térmico / Wärmebehandlung <b>AOD</b>		Substrate / Substrato / Unterlage <b>Blc / 2B</b>																																																			
<table border="1"> <thead> <tr> <th>Part No. / No. de pieza / Teil-Nr.</th> <th>Material / Material / Material</th> <th>Amount / Cantidad / Menge</th> <th>Actual weight / Peso real / Eigengewicht</th> <th>Cal. No. / Número / Nummer</th> <th>Serial No. / Número / Nummer</th> <th>Sample No. / Muestra / Probe</th> </tr> </thead> <tbody> <tr> <td>1127311</td> <td>1</td> <td>12,200 lb / 5,570 kg</td> <td>1,194 lb / 564 kg</td> <td>879796</td> <td>871987</td> <td>1000666866</td> </tr> <tr> <td>1127326</td> <td>1</td> <td>12,200 lb / 5,570 kg</td> <td>1,194 lb / 564 kg</td> <td>879796</td> <td>871987</td> <td>1000666866</td> </tr> <tr> <td>1127345</td> <td>1</td> <td>12,200 lb / 5,570 kg</td> <td>1,194 lb / 564 kg</td> <td>879796</td> <td>871987</td> <td>1000666866</td> </tr> </tbody> </table>	Part No. / No. de pieza / Teil-Nr.	Material / Material / Material	Amount / Cantidad / Menge	Actual weight / Peso real / Eigengewicht	Cal. No. / Número / Nummer	Serial No. / Número / Nummer	Sample No. / Muestra / Probe	1127311	1	12,200 lb / 5,570 kg	1,194 lb / 564 kg	879796	871987	1000666866	1127326	1	12,200 lb / 5,570 kg	1,194 lb / 564 kg	879796	871987	1000666866	1127345	1	12,200 lb / 5,570 kg	1,194 lb / 564 kg	879796	871987	1000666866	<table border="1"> <thead> <tr> <th>Part No. / No. de pieza / Teil-Nr.</th> <th>Material / Material / Material</th> <th>Amount / Cantidad / Menge</th> <th>Actual weight / Peso real / Eigengewicht</th> <th>Cal. No. / Número / Nummer</th> <th>Serial No. / Número / Nummer</th> <th>Sample No. / Muestra / Probe</th> </tr> </thead> <tbody> <tr> <td>3</td> <td>37,000 lb / 16,810 kg</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Part No. / No. de pieza / Teil-Nr.	Material / Material / Material	Amount / Cantidad / Menge	Actual weight / Peso real / Eigengewicht	Cal. No. / Número / Nummer	Serial No. / Número / Nummer	Sample No. / Muestra / Probe	3	37,000 lb / 16,810 kg																	
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Element	% C		% Mn		% P		% S		% Cr		% Ni		% Mo		% Cu																																								
	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min																																							
USA	0.028	0.33	1.34	0.031	0.0010	18.18	0.28	0.04	0.082	0.41																																													
Mechanical testing per ASTM A 270-17 <table border="1"> <thead> <tr> <th rowspan="2">Direction</th> <th colspan="2">Yield Strength</th> <th colspan="2">Tensile Strength</th> <th colspan="2">Elongation</th> </tr> <tr> <th>min</th> <th>max</th> <th>min</th> <th>max</th> <th>min</th> <th>max</th> </tr> </thead> <tbody> <tr> <td>TRANSVERSE</td> <td>40,444 / 279</td> <td>88,324 / 609</td> <td>40,000 / 276</td> <td>88,760 / 612</td> <td>57.3</td> <td>80</td> </tr> </tbody> </table>						Direction	Yield Strength		Tensile Strength		Elongation		min	max	min	max	min	max	TRANSVERSE	40,444 / 279	88,324 / 609	40,000 / 276	88,760 / 612	57.3	80																														
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Heat Treatment: Solution anneal 2900°F/1540°C. Min. Air and water quench. No welding or weld repairs were performed on this material. No intentional additions of Mercury compounds were made or used. Free of radioactive contamination. FTI Health Directive 2011/US/UK Compliant.																																																							
Outokumpu Stainless USA, LLC An ISO 9001:2015 certified company An ISO 14001:2015 certified lab EU PED 2014/68/EU, Annex 1, 4.3 certified				Date of issue and validity 08/13/2018 This document is valid for the period of 12 months from the date of issue.																																																			

## Possible options:

- Standardized test report per sample
- Scan of Logbook
- E-Log
- Possible information
  - Beamspot
  - Field
  - Planned exposure
  - ...

Note: The amount of recorded information in different systems of the irradiation room/accelerator is extremely high



Define a set of information of interest for most experiments



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Did we miss any crucial points?