CERN

Target Instrumentation

Beam Dump Facility (BDF)

Targetry Systems Advisory Committee (TSAC) #1

https://indico.cern.ch/event/1488161/

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With contributions from many others

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Summary – Instrumentation for TARGET health

- Beam monitoring for physics and non-target equipment damage are not covered in this talk → **See talk: Beam delivery to target (inc. final focus system: instrumentation and dilution), Laurie Nevay**

Sensor strategy

- Sensors used for:
  1. **Beam Interlocks** (machine protection)
  2. **Alarms** (Operation team, Equipment owner, Piquet team)
  3. **Logging** (Online & Offline monitoring of target health & conditions)

Primary monitoring (direct)	**Secondary monitoring (indirect)**	**Beam monitoring (monitored for multiple hardware)**
Temperature of target. TCs on Target Core Blocks	Helium conditions: 1. Detrimental to target 2. Indicative of target damage	Several beam parameters monitored

- **The design in these slides is preliminary**
- Formal FMEA being performed is foreseen to generate additional monitoring requirements or backups
- In 2025, planned work includes investigating and comparing the approach and sensors to ESS, ISIS-I TS1, ISIS-II, SNS.

Target monitoring requirements Preliminary

Sensors on Target	Sensors on Cooling Station	Sensors detecting Beam

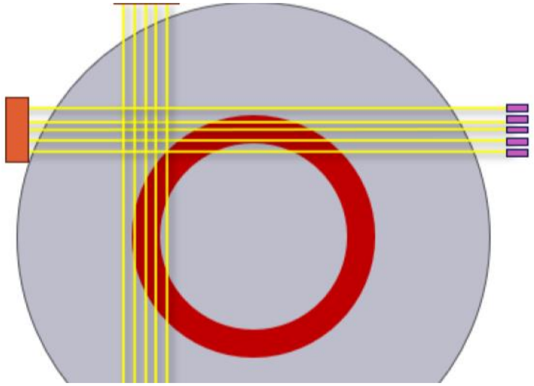
Item num'	State to monitor	Sensor	Monitoring description	Off-normal states to detect	Status	Precision in monitored units	Precision in x,y,z	Precision in time	Inter-lock to beam?
1	**Core blocks temperature**	**Thermocouples (K type, Inconel sheath)**	**2 or 3 per block.** One per block embedded in hole from curved outer face, embedded deep into block. One per outer curved face of block	**High W temperatures.** **Margin on T(°C) dependent stress, strain limits.** **Damage scenarios:** delamination, large cracks, blocked cooling channel. **Target health:** radiation damage, micro cracks, thermal conductivity. Oxidation temperatures.	**Required**	*~ ± 5°C*	*~ ± 1mm*	*~2s*	**Yes**
2	**Neutronic production**	**Self Powered Neutron Detector (SPND)**	**Situated to side of target.** Monitors change in fluence	**Damage scenarios:** delamination, loss of material, large cracks, blocked cooling channel.	**Required**	*1%. Requires study*	*TBD. Requires study*	*TBD. Requires study*	**No**
3	**T distribution in target**	**TPT type device**	**In beam**, upstream & close to target. Continuously in beam.	**Temperature distribution in target** Long timescale	**Optional. Very preliminary**	*TBC Requires study.*	*TBC Requires study.*	*>30s*	**No**

Self Powered Neutron Devices (SPND)

- Measure neutron fluence
- To be placed around the external target vessel
- We have agreement with DONES to develop them with competence to perform data analysis.

SPNDs on n_ToF target

Target position thermometer (TPT) device concept



- TCs on rods
- Long characteristic timescale
- Prototypic and under analysis whether is needed or not

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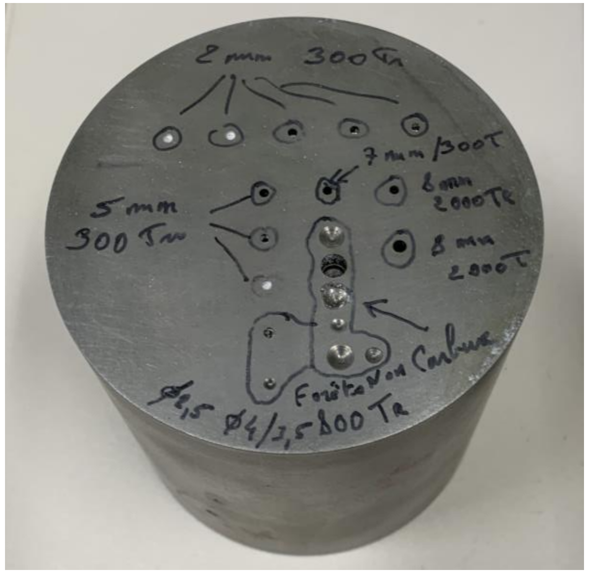
4	**Downstream helium temperature**	**Thermocouple (K type, SS sheath)**	**In downstream helium flow**; in pipework external to vacuum vessel.	**Insufficient target cooling**. Change to heat transfer rates due to **target damage.**	**Required**	*~ ± 2.5°C*	-	*~5s*	**Yes?**
5	**Inlet Helium temperature**	**Thermocouple (K type, SS sheath)**	**In upstream helium flow**; in pipework external to vacuum vessel.	**Insufficient target cooling**.	**Required**				**No?**
6	**ΔP across target**	**Pressure sensors**	**Upstream and downstream of target** helium flow	Changes to pressure drop or elevated pressure drop caused by **target damage**: Channel blockage, delamination.	**Required**	*50 mbar*	-	*5s*	**Yes**
7	**Helium flow rate**	**Mass flow meter, e.g. wire meter.**	**In helium system**. In compressor room.	**Insufficient target cooling**. Large blockage caused by **target damage.**	**Required**	*3g/s*	-	*5s*	**Yes**
8	**Pressure of helium circuit**	**Pressure sensor**	**In helium system**. In compressor room.	**Insufficient target cooling**.	**Required**	*50 mbar*	-	*5s*	**Yes**
9	**Impurities in Helium system.**	**Mass spectrometer in Helium circuit.**	Detect Tungsten Oxides **in helium system.**	**Oxidation/degradation of Tungsten blocks** via presence of WO_x. High W surface temperature.	**Optional (WO_x likely to be gettered by heat exchanger.**	*1appm*	-	*1min*	**No**
10	**Beam size & location**	**Current meters**	Current check on **dilution system magnets**	**Beam spot size** damaging to target. **Beam sweep** accident damaging to target.	**Required**	*Requires study. ± 1mm?*	*±5mm?*	*0.05s? Delay =0.1s?*	**Yes**
11	**Beam size & location**	**Harp / Grid / Emittance monitor TBC**	**In beam**, upstream of target. Continuously in beam.	**Beam spot size** damaging to target. **Beam sweep** accident damaging to target. Information for monitoring **target health** over time.	**US of target Required. DS optional.**	*Requires study. ± 1mm?*	*±5mm?*	*0.05s? Delay =0.1s?*	**No**

R&D of Target Thermocouples

Drilling tests - Prototypes

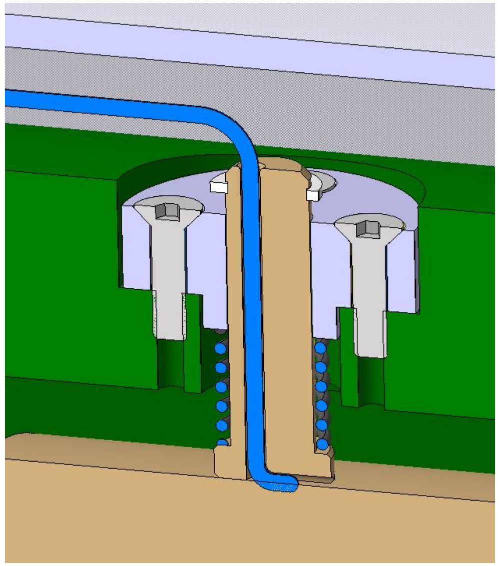


- ❑ Drilling tests performed on prototype blocks
- ❑ Holes: Ø2mm | depth 25mm
- ❑ Drilling unsuccessful > 5mm
- ❑ Die sinking successful
- ❑ Work is ongoing to characterise the profile shape of the holes.

Drilling tests – full target

- ❑ Drilling tests to be performed on full size blocks (die sink)
  - Company contacted
- ❑ Holes: Ø2mm

Fixation design



- ❑ *Sprung fixations for TCs on side of blocks.*
- ❑ *Further work to be done on similar design for TCs at centre of blocks.*
- ❑ For water cooled concept, hole will need to be clad (similar to ISIS)
- ❑ For helium design with or without cladding, hole can potentially be unclad.

Many thanks

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Sensor loss [Backup Slide]

- Sensor loss is part of ongoing FMEA exercise

Item num'	State to monitor	Sensor	Fault	Probability 1=very unlikely 5=highly likely	Effect 1=minor 5=Severe	Severity 1=minor 5=Severe	Intervention	Duration of intervention	Preventative action
1	Core blocks temperature	Thermocouples (K type, Inconel sheath)	Inaccurate reading. Dead TC. TC moved.	3	5	15	Use redundancy from multiple TCs per block. Sensor replacement not possible on highly activated target.	-	3 TCs per block gives redundancy. Test of TC mounting method. Construction by checklist. Test TC readings after construction.
2	Neutronic production	Self Powered Neutron Detector	?	3?	5	15			
3	Beam size & location	TPT type device	Sensor loss	3	2	6			
4	Downstream helium temperature	Thermocouple (K type, SS sheath)	Sensor loss.	1	3	3	Use redundancy from #1,#2,#5. Cross reference to helium circuit readings. Replace TC.	2 hours, wait for access could be weeks?	Use multiple TCs for redundancy. Replace sensors after X years.
5	Inlet Helium temperature	Thermocouple (K type, SS sheath)	Sensor loss	1	4	4	Cross reference to helium circuit readings. Replace TC.		Replace sensors after X years.
6	ΔP across target	Pressure sensors	Inaccurate reading / Sensor loss.	1	2	2	Use redundancy from #1,#3. Cross reference to helium circuit readings. Replace TC.		Replace sensors after X years.
7	Helium flow rate	Mass flow meter, e.g. wire meter.	Inaccurate reading. High flutter. Sensor loss.	2	2	4	Use redundancy from #7. Cross reference to helium circuit readings. Replace TC.	Hours.	Implement both #6 and #7. Replace sensors after X years.
8	Pressure of helium circuit	Pressure sensor	Inaccurate reading. Sensor loss.	1	2	2	Use redundancy from #6, Cross reference to helium circuit readings. Replace TC.	Hours.	Implement both #6 and #7. Replace sensors after X years.
9	Impurities in Helium system.	Mass spectrometer in Helium circuit.	WO_x plates HX, not reaching spectrometer.	2	4	8	-	-	Obtain mass spectrometer sensitive to <1appm.
10	Beam size & location	**Current meters**	Sensor loss.	2	5	10	Stop beam, replace monitor.	1 days?	Replace / test sensor yearly.
11	Beam size & location	**TBC. Harp / Grid / Emittance monitor**	Sensor loss.	2	5	10	Stop beam, replace sensor	2 days?	Replace / test monitor yearly.