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Beam Monitors

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Detector Group

www.europeanspallationsource.se

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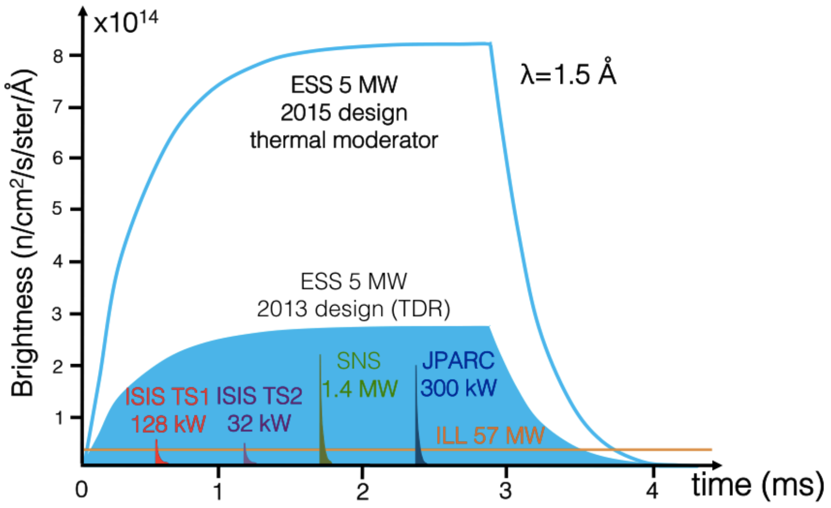
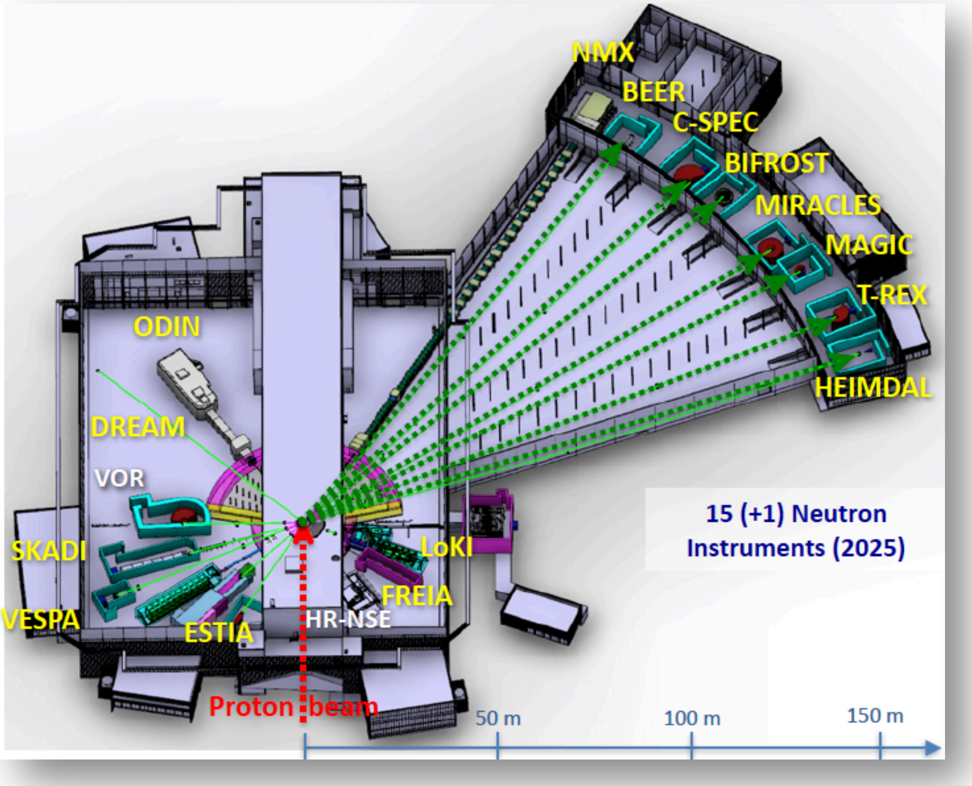
Outline

- Why Beam monitors?
- Types and specifications of the used Beam monitors
- Results:
  - ✧ Efficiency, attenuation, scattering, Position resolution
  - ✧Gamma sensitivity
- Mechanical integration (BM on chopper)
- Parasitic methods (monitoring using gamma detector)
- BM requirement survey
- Outlook

ESS instruments





15 (+1) Neutron Instruments (2025)

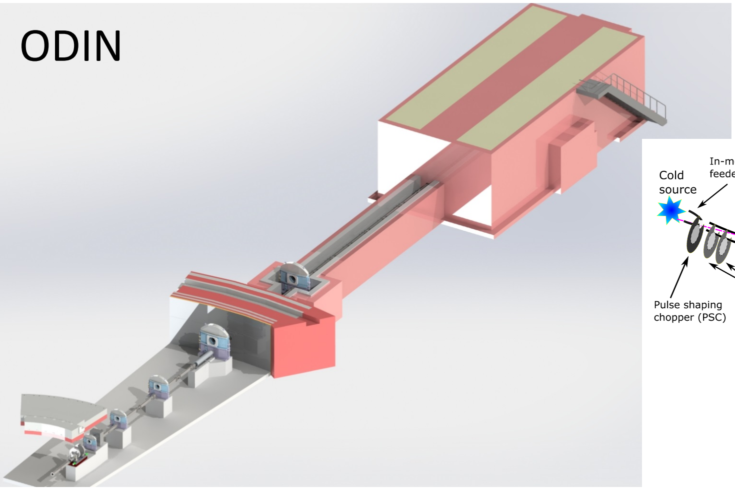
long-pulse and high neutron flux at ESS

Many advancements in the instrument performance

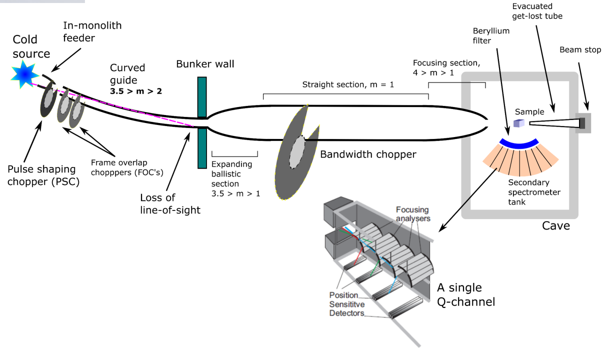
longer neutron guides, complex neutron optics and complex chopper systems

ESS instruments

ODIN



BIFROST



LOKI

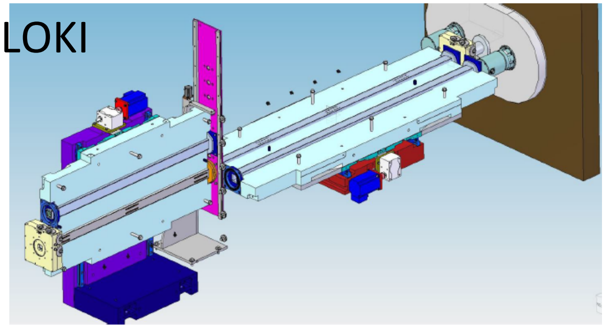
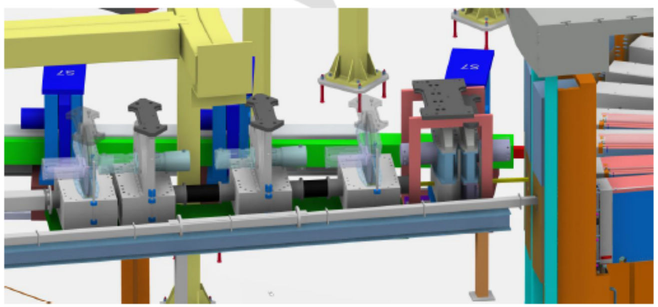


Figure 14 A cutaway view of the selectable guide sections



At ESS: longer neutron guides, complex neutron optics and complex chopper systems

C-SPEC

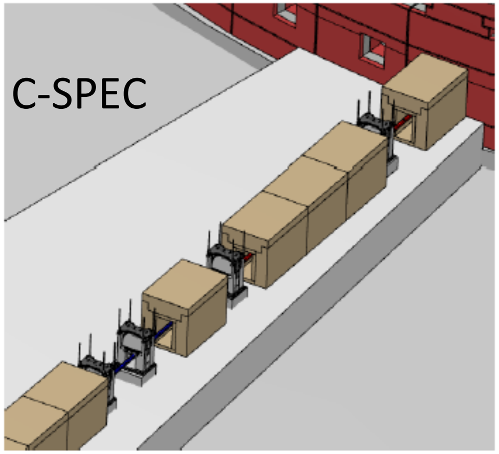
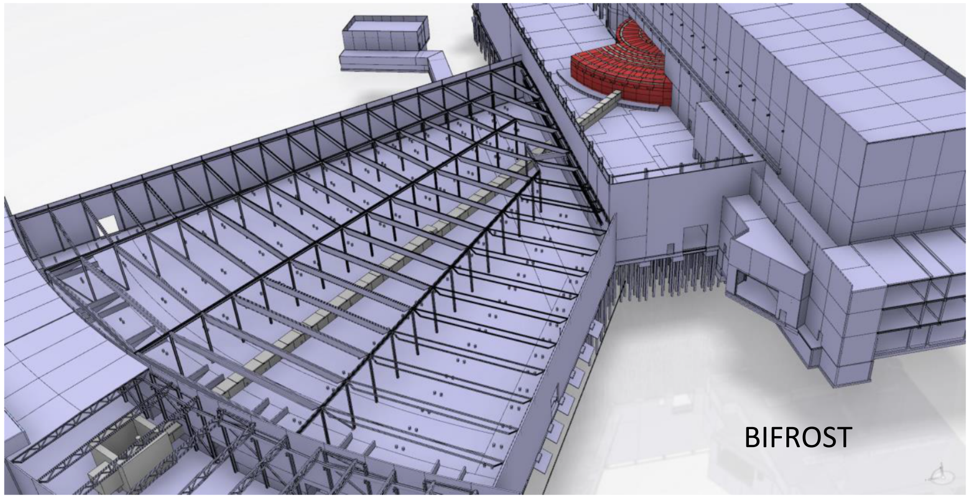
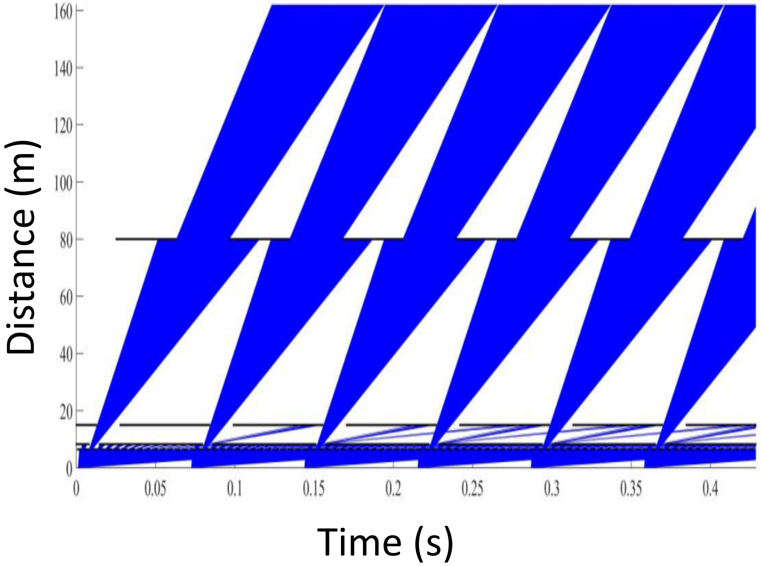


Figure 10: The BW chopper positioned after the bunker shielding. Shielding around choppers is not shown.

For commissioning, diagnostics, normalization → Beam monitors are required

ESS instruments





Pulse duration and neutron flux vary along the beam line

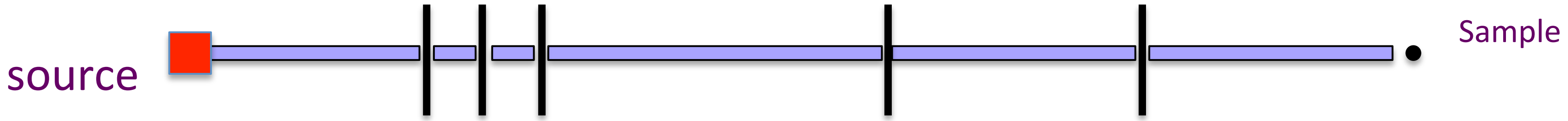
The requirements for the monitors vary greatly with respect to their location and purpose

→

Beam monitors with different specifications are needed

A Little detailed analysis about BM performance is available

Beam Monitor



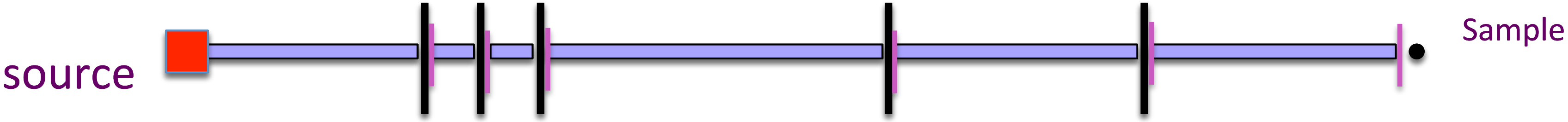
source

Sample

▭ neutron guide

▬ chopper

Beam Monitor



source

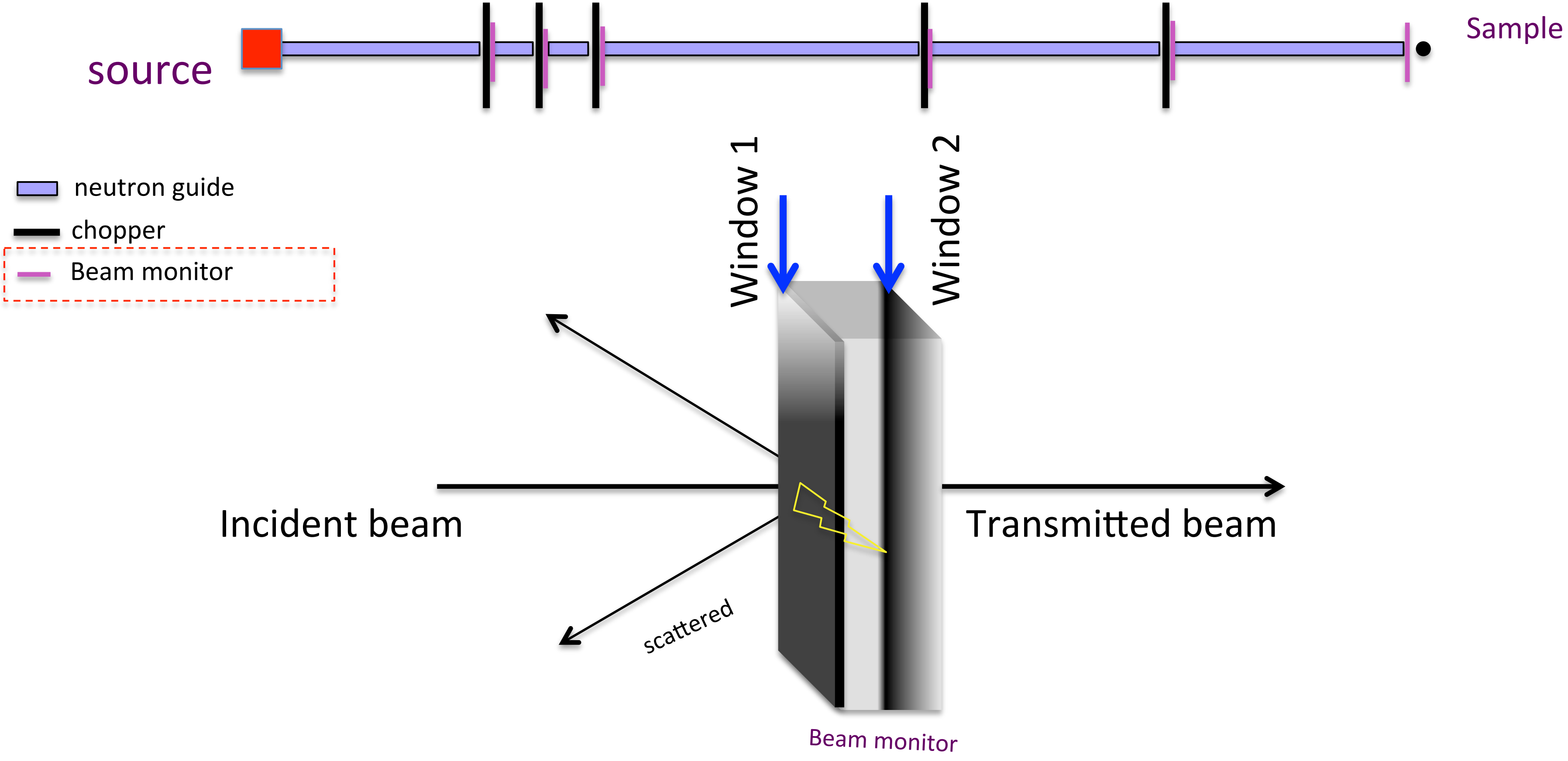
Sample

▭ neutron guide

▬ chopper

▬ Beam monitor

Beam Monitor



Beam monitor with low attenuation and high transmission factor

Beam Monitor

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Nuclear reactions used for thermal neutron detection

Reaction	Isotope abundance (%)	Cross section (barn) at 1.8 Å	Q-value (MeV)
$^{3}He(n,p)^{3}H$	0.014	5330	0.76
$^{10}B(n,\alpha)^{7}Li$	19.9	3838	2.31 (94%) 2.79 (6%)
$^{6}Li(n,\alpha)^{3}H$	7.6	947	4.78
$^{14}N(n,p)^{14}C$	99.63	1.91	0.62
$^{235}U(n,3n)ff$	0.72	680.9	≈200

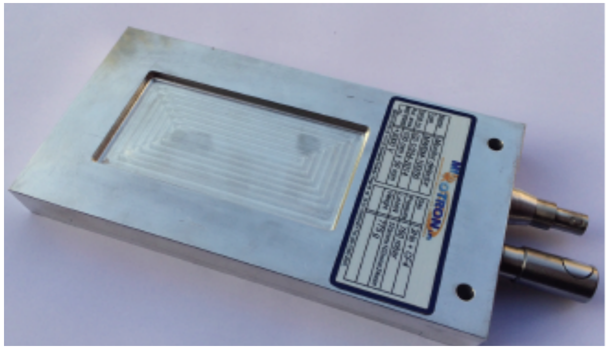
Beam monitors are thermal neutron detectors with relatively low efficiency which can vary from
10^{-6} to 10^{-1} depending on the instrument requirements

Types of Beam Monitor

Multi-wire proportional chamber (MWPC)

MWPC can be filled with either ^{3}He or ^{14}N gas

From Mirrotron



From ORDELA

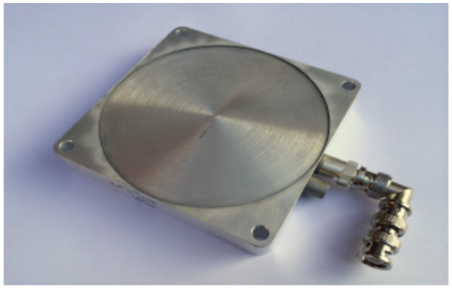
Monitor Manufacturer	MWPC ORDELA	MWPC ORDELA	MWPC Mirrotron	2D-MWPC Mirrotron
Active element	^{3}He	^{14}N	^{3}He	^{3}He
Partial pressure mbar	6.07	81.06	6.5	0.4
Filled gas	$^{3}He+^{4}H+CF_{4}$	$^{14}N+CF_{4}$	$^{3}He+CF_{4}$	$^{3}He+CF_{4}$
Bias voltage (V)	850	850	1300	Anode:-3500 Drift: 1500
Active area (mm)	114x51	114x51	100x50	100x50
Window thickness (mm)	2	2	1	1

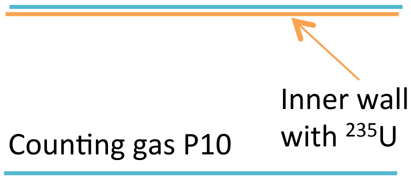
https://indico.esss.lu.se/event/870/
https://indico.esss.lu.se/event/781/

Types of Beam Monitor

Fission Chamber

From LND



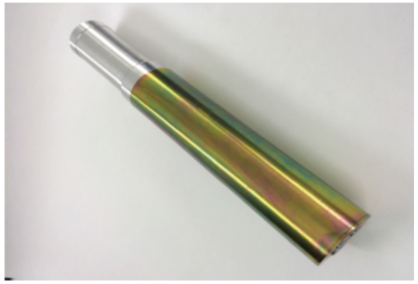


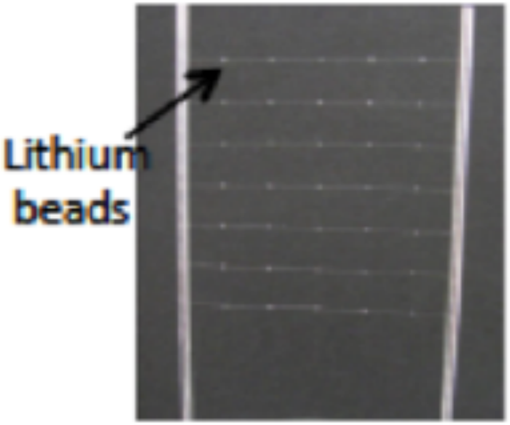
Inner wall coated with ^{235}U

Counting gas P10

Scintillator

From Quantum detector





Monitor Manufacturer	Scintillator QD	Fission chamber LND
Active element	^{6}Li	^{235}U
Total pressure mbar	---	1013.2
Filled gas	---	P10
Bias voltage (V)	650	300
Active area (mm)	28x42	100x100
Window thickness (mm)	0.1	1

Types of Beam Monitor

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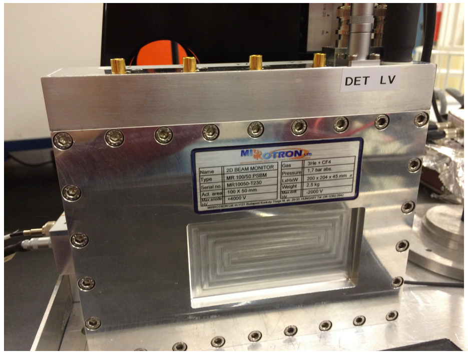
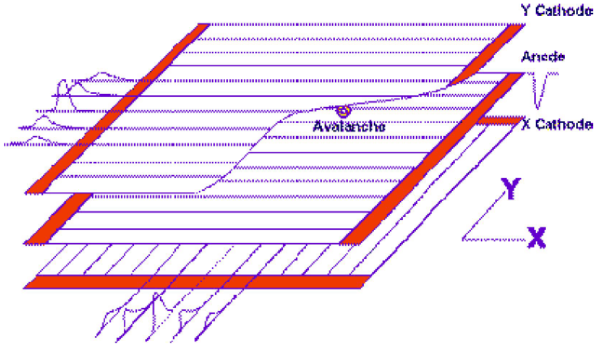
Multi-wire proportional chamber (2D-MWPC)

From Mirrotron

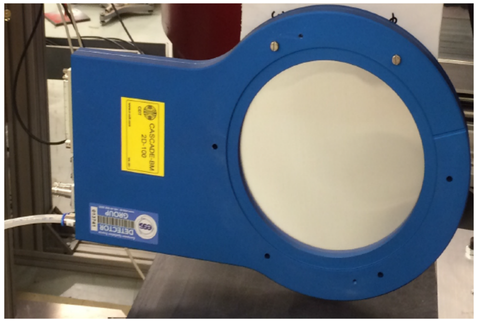


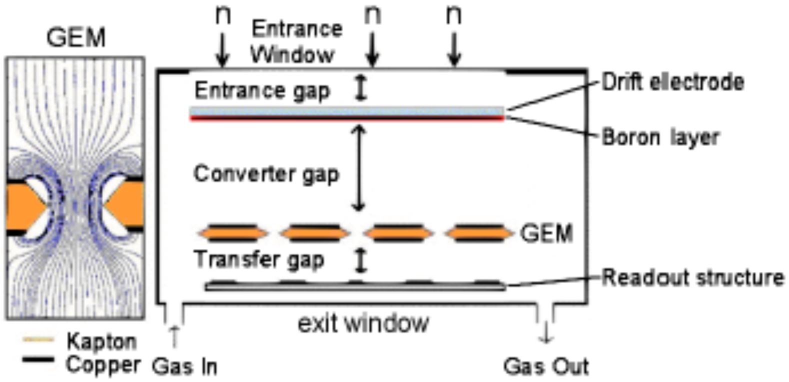


Monitor Manufacturer	2D-MWPC Mirrotron	2D-GEM CDT
Active element	^{3}He	^{10}B
Total pressure bar	1.65	1
Filled gas	^{3}He+CF$_4$	Ar+CO$_2$
Bias voltage (V)	Anode:-3500 Drift: 1500	-1000
Active area (mm)	100x50	100x100
Window thickness (mm)	1	0.1

Gas Electron Multiplier (2D-GEM)

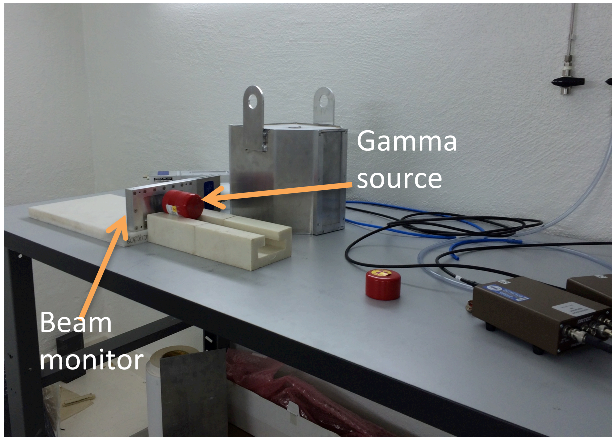
From CDT

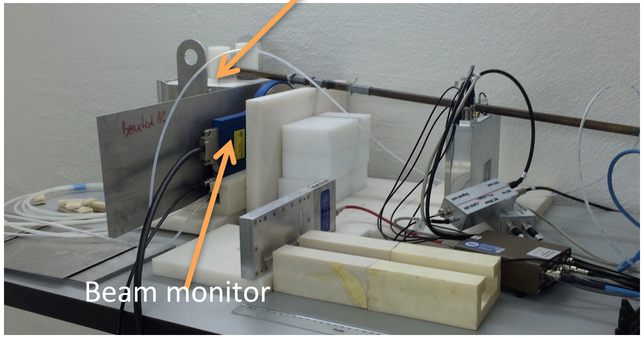


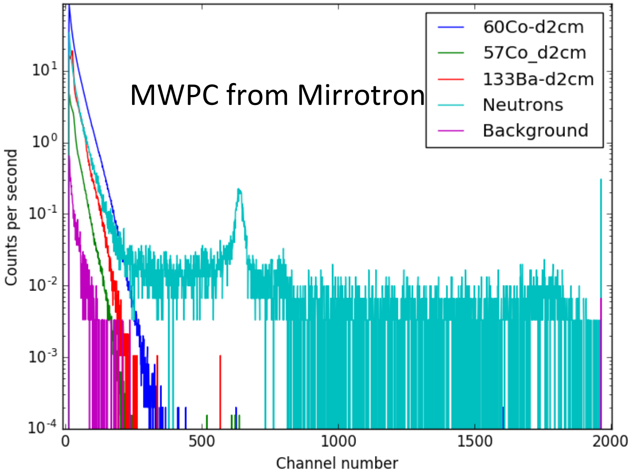


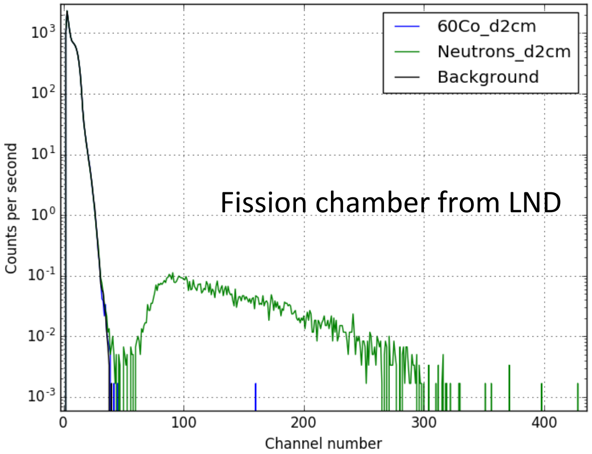
0.8 μm boron layer was selected for the sake of the measurement. Thinner layer will be selected for full implementation.

Beam Monitors-Gamma sensitivity measurement





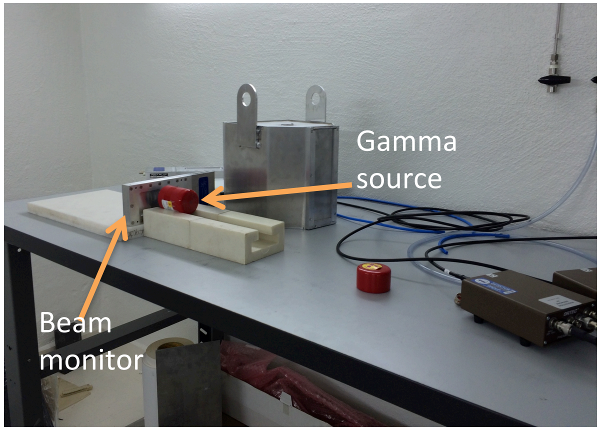


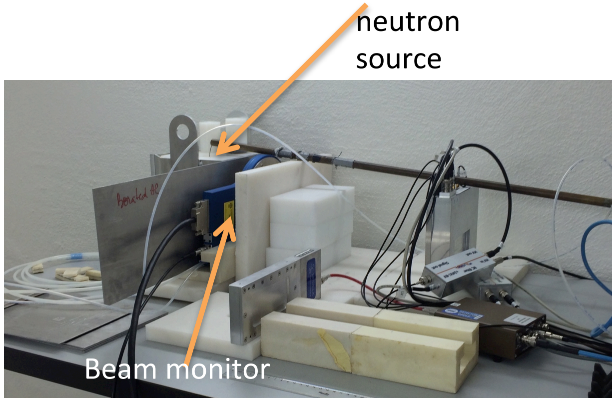


source	Gamma energy KeV	Gamma intensity %
^{57}Co	122	85.6
	136	10.7
^{133}Ba	30-35	117
	80	36
	276	7
	303	18
	356	62
	384	9
^{60}Co	1173	100
	1332	100

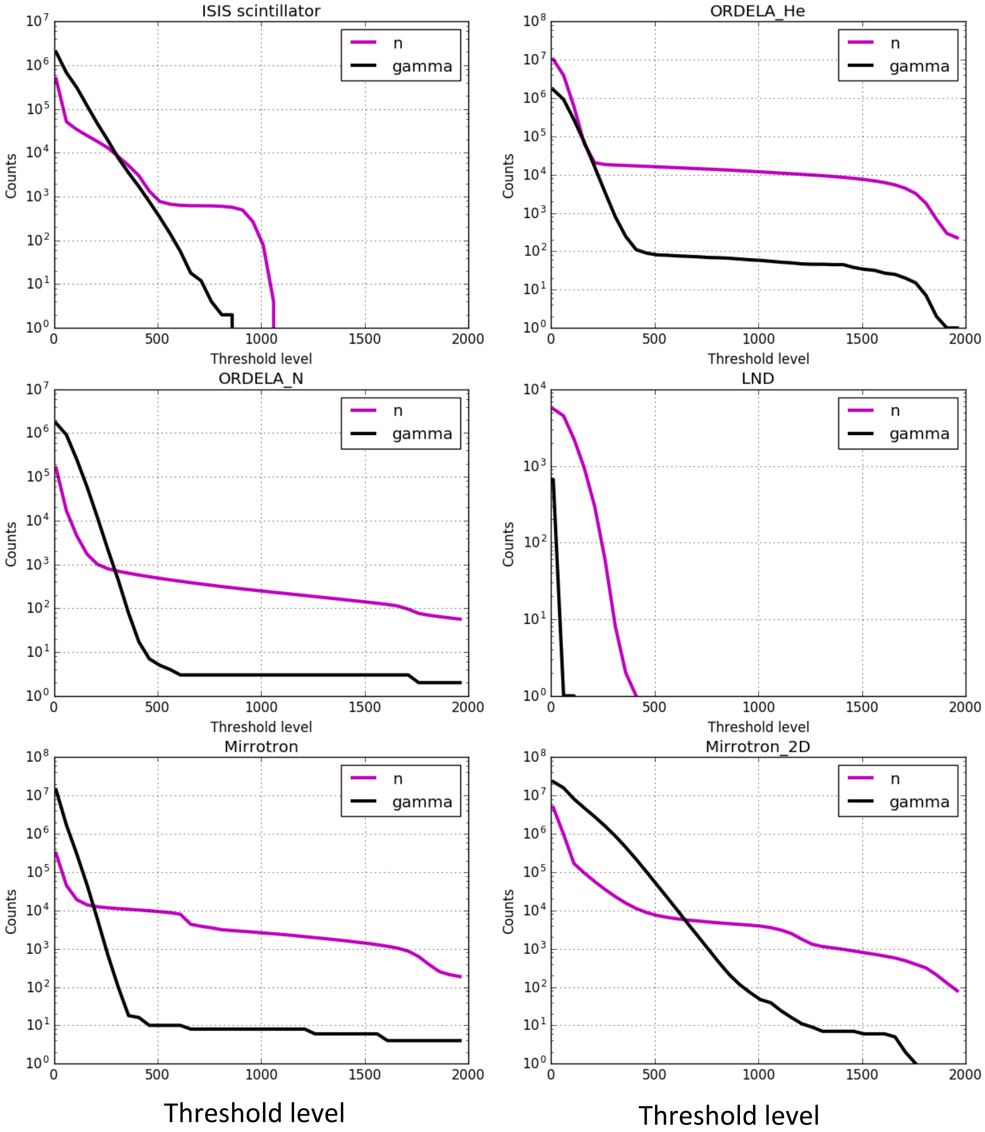
Gamma sensitivity studied with three gamma sources with low, medium, and high energy

Beam Monitors-Gamma sensitivity measurement

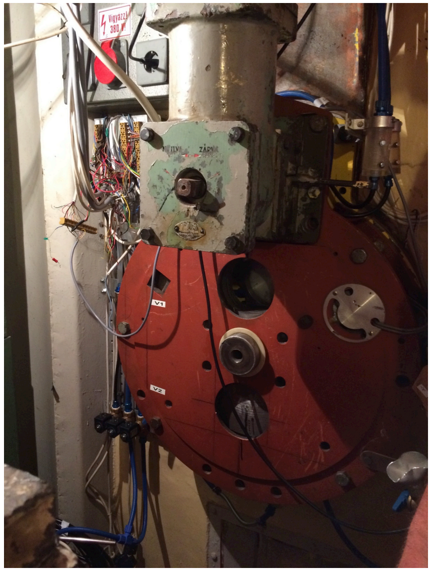


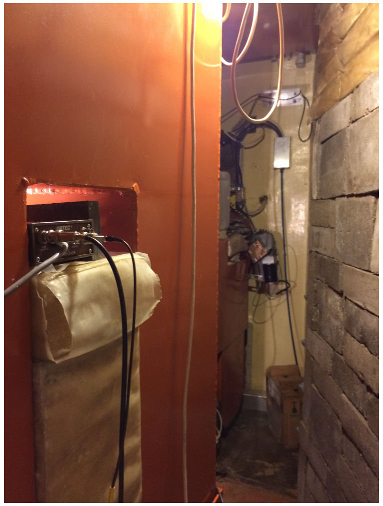


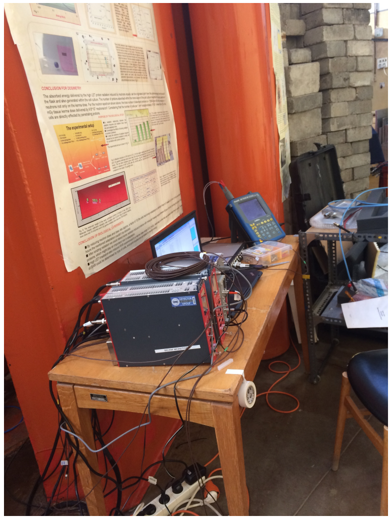
Gamma sensitivity depends on the set threshold. The fission chamber showed the lowest gamma sensitivity



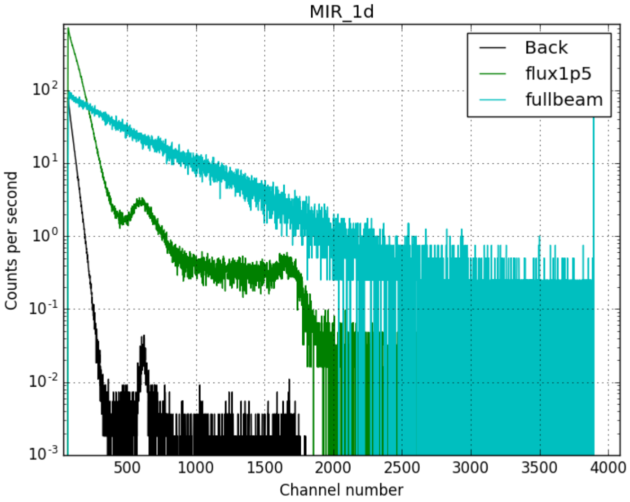
Beam Monitors at BNC







The test experiments have been performed at the Biological Irradiation Channel (BIO) at the Budapest Research Reactor (BRR) belonging to the Budapest Neutron Centre (BNC).

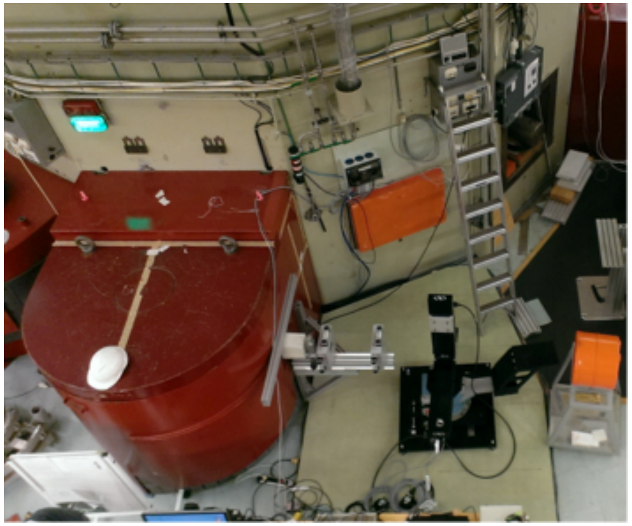


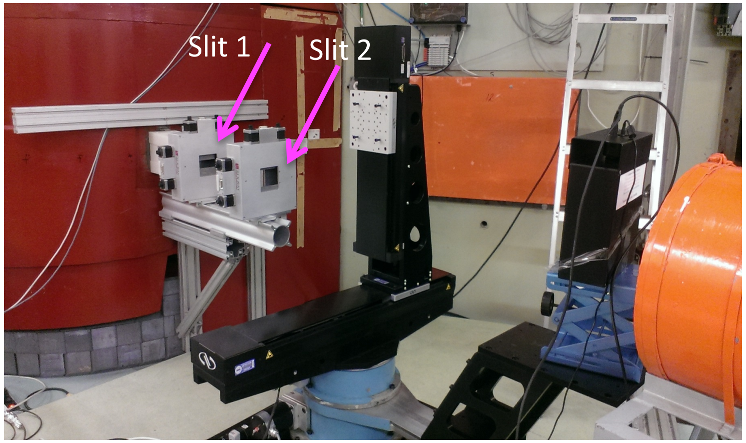
thermal flux 3.4x10^{4} n/cm^{2}.s → PHS with two peaks

thermal flux 4.1x10^{5} n/cm^{2}.s → saturation

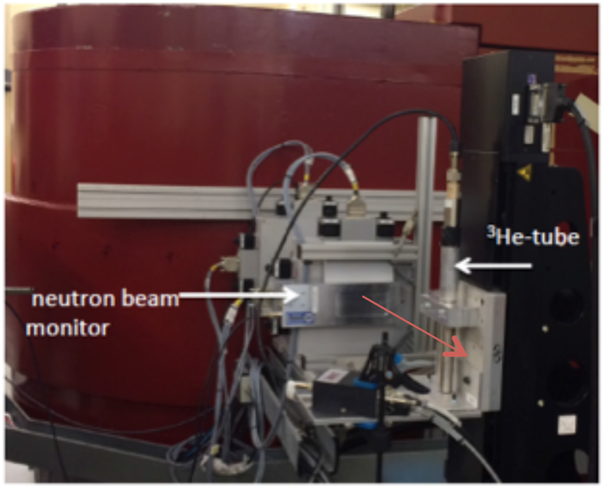
Saturation in most monitors (ORDELA_He, ORDELA_N, Mirrotron, fission chamber, LiG scintillator) probably due to the used electronics → off the shelf electronics not best choice

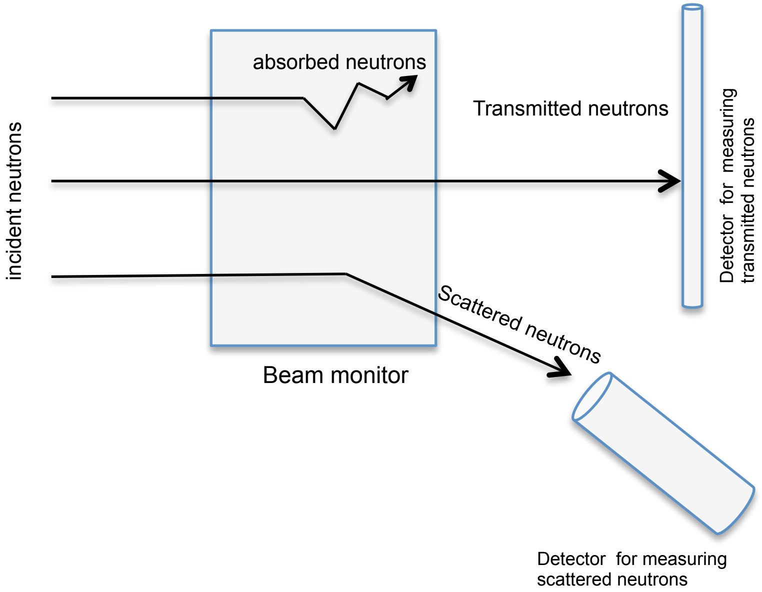
Beam Monitors- Neutron measurement at R2D2





Peak	wavelength (Å)
400	2.00
911	0.878
711	1.12
511	1.54
822	0.943
311	2.41
933	0.804





absorbed neutrons

Transmitted neutrons

incident neutrons

Detector for measuring transmitted neutrons

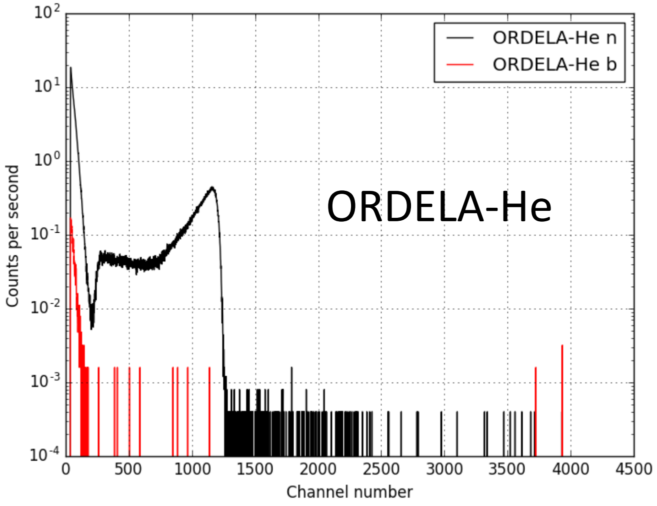
Scattered neutrons

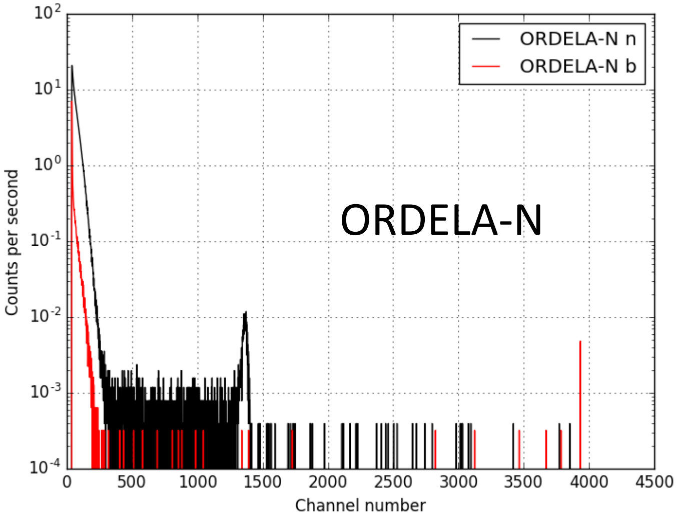
Beam monitor

Detector for measuring scattered neutrons

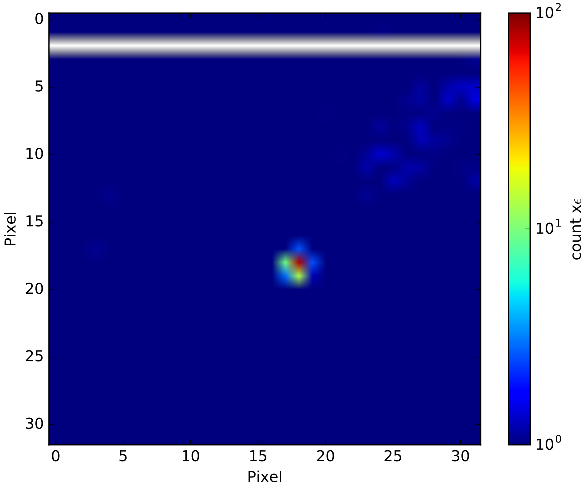
Beam Monitors- Neutron measurement

non-position sensitive BM

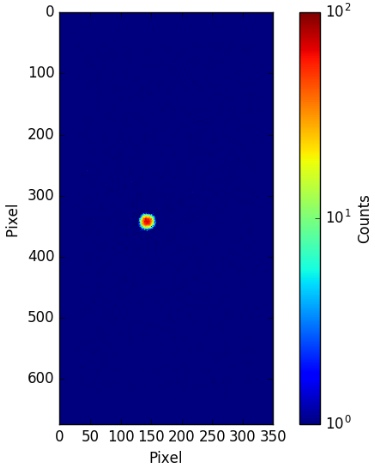




position sensitive BM



2D-GEM



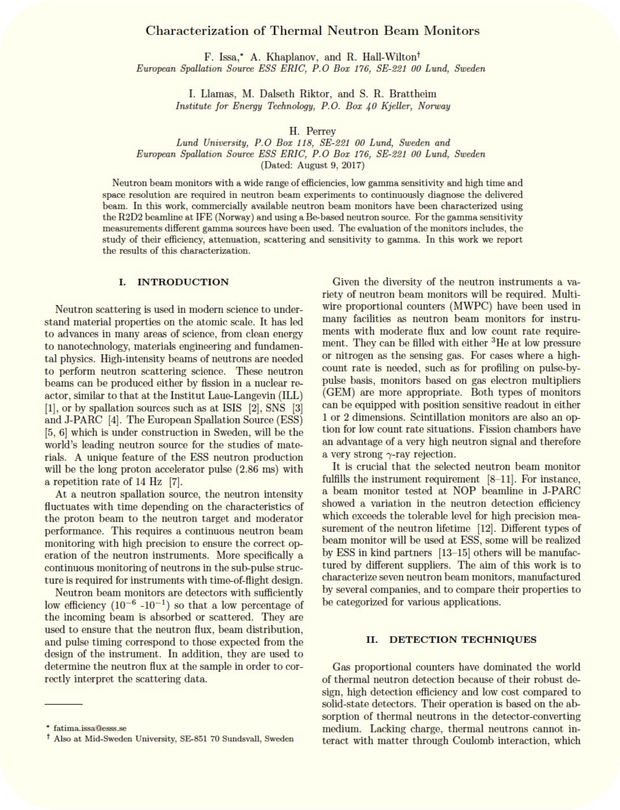
2D-MWPC

Beam monitors-main results

	MWPC	**MWPC**	**MWPC BM-100X50**	**2D-MWPC**	**2D-GEM**	**Scintillator**	**Fission chamber**
supplier	ORDELA	ORDELA	Mirrotron	Mirrotron	CDT	Quantum detector	LND
Isotope used for neutron capture	^{3}He	^{14}N	^{3}He	^{3}He	^{10}B	^{6}Li	^{235}U
Gas pressure mbar	Partial pressure 6,0795	Partial pressure 81,06	Partial pressure 6,5	Partial pressure 0.4	Total pressure 100	------	Total pressure 1013,2
Filled gas	^{3}He+^{4}He +CF_4	N+CF_4	^{3}He+CF_4	^{3}He+CF_4	Ar/CO_2	--------	P10
Active Area (mm^2)	114 x 51	114 x 51	100 x 50	100 x 50	Diameter 100 mm	28 x 42	Diameter 108.0 mm
Applied voltage (V)	850	850	1300	Anode at -3500V Drift at 1500V	-1000	650	300
Measured attenuation % at 2.4Å	4.5	4.4	2.5	7.3	10.6	0.4	3.8
Calculated attenuation % at 2.4Å	4.05	4.05	2.05	4.5	6.9	0.1	2.4
Measured Efficiency at 2.4Å	1.2×10^{-3}	2×10^{-5}	1.1×10^{-3}	1.5×10^{-4}	3×10^{-2}	5×10^{-3}	10^{-4}
Supplier Efficiency at 1.8 Å	10^{-3}	10^{-5}	10^{-3}	1.5×10^{-4}	3×10^{-2}	10^{-4}	10^{-4}
Scattering (%)	3.9 ± 0.4	3.8±0.4	4±0.9	9±1	10.3±0.7	0.74±0.2	3.8±0.3

Beam monitor characterization → Customization to match specific requirements

Horizon 2020 grant agreement 676548



Characterization of Thermal Neutron Beam Monitors

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(Dated: August 9, 2017)

Neutron beam monitors with a wide range of efficiencies, low gamma sensitivity and high time and space resolution are required in neutron beam experiments to continuously diagnose the delivered beam. In this work, commercially available neutron beam monitors have been characterized using the R2D2 beamline at IFE (Norway) and using a Be-based neutron source. For the gamma sensitivity measurements different gamma sources have been used. The evaluation of the monitors includes, the study of their efficiency, attenuation, scattering and sensitivity to gamma. In this work we report the results of this characterization.

I. INTRODUCTION

Neutron scattering is used in modern science to understand material properties on the atomic scale. It has led to advances in many areas of science, from clean energy to nanotechnology, materials engineering and fundamental physics. High-intensity beams of neutrons are needed to perform neutron scattering science. These neutron beams can be produced either by fission in a nuclear reactor, similar to that at the Institut Laue-Langevin (ILL) [1], or by spallation sources such as at ISIS [2], SNS [3] and J-PARC [4]. The European Spallation Source (ESS) [5, 6] which is under construction in Sweden, will be the world's leading neutron source for the studies of materials. A unique feature of the ESS neutron production will be the long proton accelerator pulse (2.86 ms) with a repetition rate of 14 Hz [7].

At a neutron spallation source, the neutron intensity fluctuates with time depending on the characteristics of the proton beam to the neutron target and moderator performance. This requires a continuous neutron beam monitoring with high precision to ensure the correct operation of the neutron instruments. More specifically a continuous monitoring of neutrons in the sub-pulse structure is required for instruments with time-of-flight design.

Neutron beam monitors are detectors with sufficiently low efficiency (10^{-6} -10^{-1}) so that a low percentage of the incoming beam is absorbed or scattered. They are used to ensure that the neutron flux, beam distribution, and pulse timing correspond to those expected from the design of the instrument. In addition, they are used to determine the neutron flux at the sample in order to correctly interpret the scattering data.

Given the diversity of the neutron instruments a variety of neutron beam monitors will be required. Multi-wire proportional counters (MWPC) have been used in many facilities as neutron beam monitors for instruments with moderate flux and low count rate requirement. They can be filled with either ^{3}He at low pressure or nitrogen as the sensing gas. For cases where a high-count rate is needed, such as for profiling on pulse-by-pulse basis, monitors based on gas electron multipliers (GEM) are more appropriate. Both types of monitors can be equipped with position sensitive readout in either 1 or 2 dimensions. Scintillation monitors are also an option for low count rate situations. Fission chambers have an advantage of a very high neutron signal and therefore a very strong γ-ray rejection.

It is crucial that the selected neutron beam monitor fulfills the instrument requirement [8–11]. For instance, a beam monitor tested at NOP beamline in J-PARC showed a variation in the neutron detection efficiency which exceeds the tolerable level for high precision measurement of the neutron lifetime [12]. Different types of beam monitor will be used at ESS, some will be realized by ESS in kind partners [13–15] others will be manufactured by different suppliers. The aim of this work is to characterize seven neutron beam monitors, manufactured by several companies, and to compare their properties to be categorized for various applications.

II. DETECTION TECHNIQUES

Gas proportional counters have dominated the world of thermal neutron detection because of their robust design, high detection efficiency and low cost compared to solid-state detectors. Their operation is based on the absorption of thermal neutrons in the detector-converting medium. Lacking charge, thermal neutrons cannot interact with matter through Coulomb interaction, which

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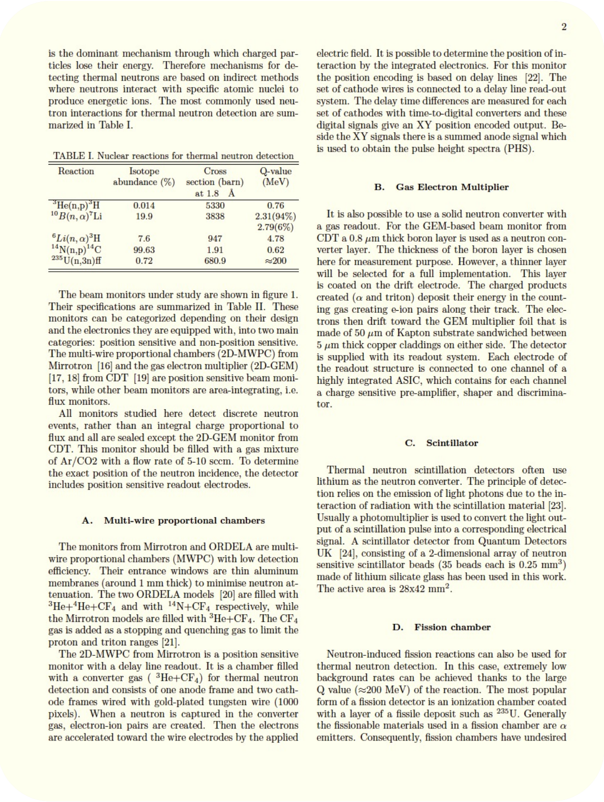

is the dominant mechanism through which charged particles lose their energy. Therefore mechanisms for detecting thermal neutrons are based on indirect methods where neutrons interact with specific atomic nuclei to produce energetic ions. The most commonly used neutron interactions for thermal neutron detection are summarized in Table I.

TABLE I. Nuclear reactions for thermal neutron detection

Reaction	Isotope abundance (%)	Cross section (barn) at 1.8 Å	Q-value (MeV)
^{3}He(n,p)^{3}H	0.014	5330	0.76
$^{10}B(n,\alpha)^7$Li	19.9	3838	2.31(94%) 2.79(6%)
$^6Li(n,\alpha)^3$H	7.6	947	4.78
^{14}N(n,p)^{14}C	99.63	1.91	0.62
^{235}U(n,3n)ff	0.72	680.9	≈200

The beam monitors under study are shown in figure 1. Their specifications are summarized in Table II. These monitors can be categorized depending on their design and the electronics they are equipped with, into two main categories: position sensitive and non-position sensitive. The multi-wire proportional chambers (2D-MWPC) from Mirrotron [16] and the gas electron multiplier (2D-GEM) [17, 18] from CDT [19] are position sensitive beam monitors, while other beam monitors are area-integrating, i.e. flux monitors.

All monitors studied here detect discrete neutron events, rather than an integral charge proportional to flux and all are sealed except the 2D-GEM monitor from CDT. This monitor should be filled with a gas mixture of Ar/CO2 with a flow rate of 5-10 sccm. To determine the exact position of the neutron incidence, the detector includes position sensitive readout electrodes.

A. Multi-wire proportional chambers

The monitors from Mirrotron and ORDELA are multi-wire proportional chambers (MWPC) with low detection efficiency. Their entrance windows are thin aluminum membranes (around 1 mm thick) to minimise neutron attenuation. The two ORDELA models [20] are filled with ^{3}He+^{4}He+CF$_4$ and with ^{14}N+CF$_4$ respectively, while the Mirrotron models are filled with ^{3}He+CF$_4$. The CF$_4$ gas is added as a stopping and quenching gas to limit the proton and triton ranges [21].

The 2D-MWPC from Mirrotron is a position sensitive monitor with a delay line readout. It is a chamber filled with a converter gas (^{3}He+CF$_4$) for thermal neutron detection and consists of one anode frame and two cathode frames wired with gold-plated tungsten wire (1000 pixels). When a neutron is captured in the converter gas, electron-ion pairs are created. Then the electrons are accelerated toward the wire electrodes by the applied electric field. It is possible to determine the position of interaction by the integrated electronics. For this monitor the position encoding is based on delay lines [22]. The set of cathode wires is connected to a delay line read-out system. The delay time differences are measured for each set of cathodes with time-to-digital converters and these digital signals give an XY position encoded output. Beside the XY signals there is a summed anode signal which is used to obtain the pulse height spectra (PHS).

B. Gas Electron Multiplier

It is also possible to use a solid neutron converter with a gas readout. For the GEM-based beam monitor from CDT a 0.8 μm thick boron layer is used as a neutron converter layer. The thickness of the boron layer is chosen here for measurement purpose. However, a thinner layer will be selected for a full implementation. This layer is coated on the drift electrode. The charged products created (α and triton) deposit their energy in the counting gas creating e-ion pairs along their track. The electrons then drift toward the GEM multiplier foil that is made of 50 μm of Kapton substrate sandwiched between 5 μm thick copper claddings on either side. The detector is supplied with its readout system. Each electrode of the readout structure is connected to one channel of a highly integrated ASIC, which contains for each channel a charge sensitive pre-amplifier, shaper and discriminator.

C. Scintillator

Thermal neutron scintillation detectors often use lithium as the neutron converter. The principle of detection relies on the emission of light photons due to the interaction of radiation with the scintillation material [23]. Usually a photomultiplier is used to convert the light output of a scintillation pulse into a corresponding electrical signal. A scintillator detector from Quantum Detectors UK [24], consisting of a 2-dimensional array of neutron sensitive scintillator beads (35 beads each is 0.25 mm^3) made of lithium silicate glass has been used in this work. The active area is 28x42 mm^2.

D. Fission chamber

Neutron-induced fission reactions can also be used for thermal neutron detection. In this case, extremely low background rates can be achieved thanks to the large Q value (≈200 MeV) of the reaction. The most popular form of a fission detector is an ionization chamber coated with a layer of a fissile deposit such as ^{235}U. Generally the fissionable materials used in a fission chamber are α emitters. Consequently, fission chambers have undesired

Manuscript accepted for publication in Physical Review Accelerators and Beams.

https://arxiv.org/abs/1702.01037

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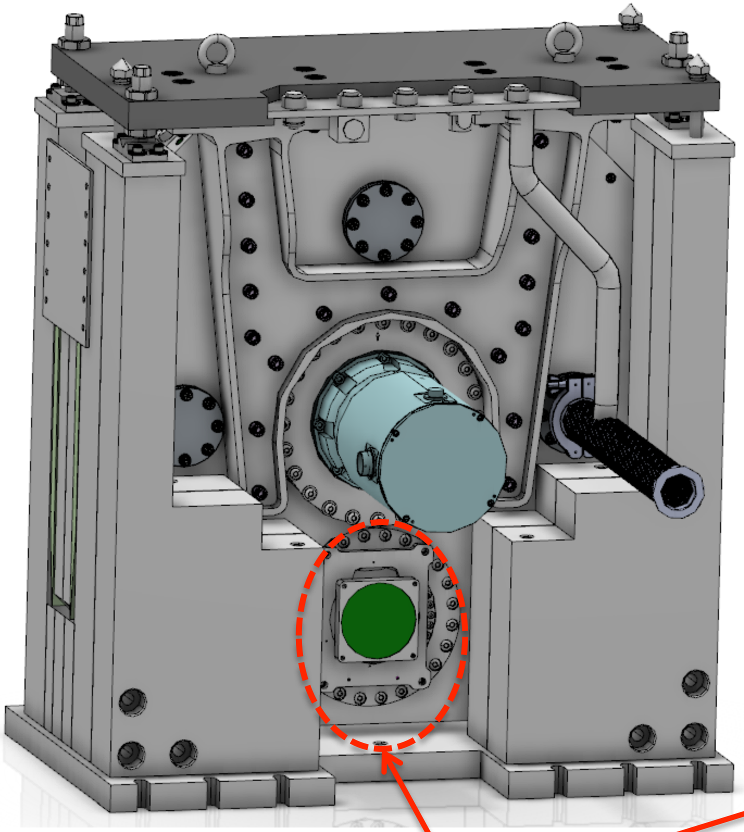
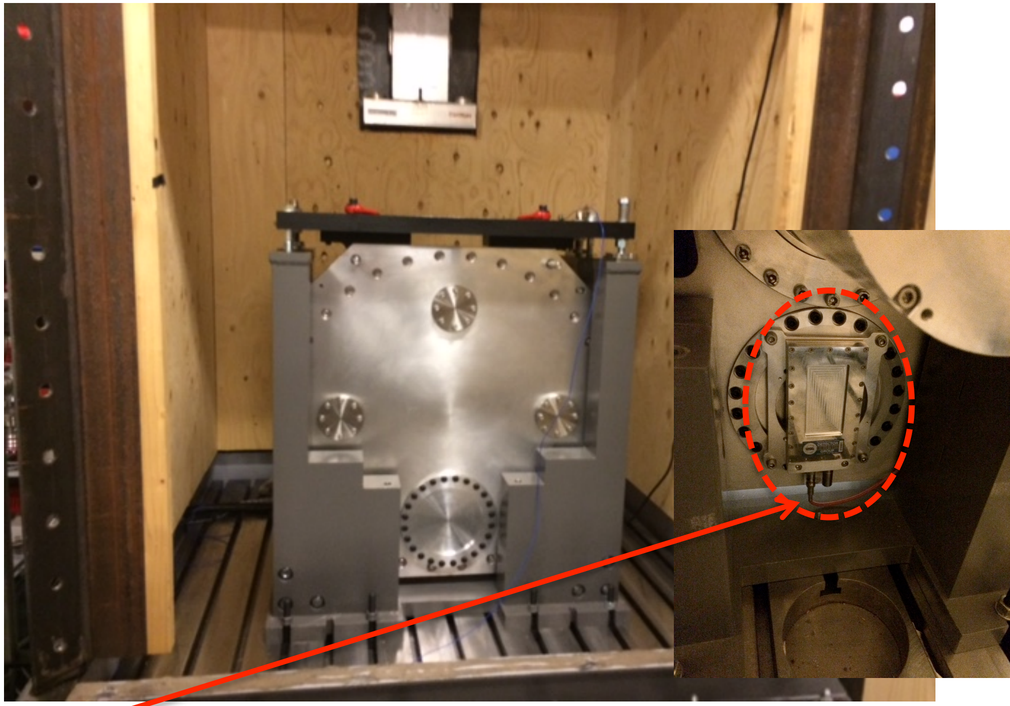
Mechanical integration

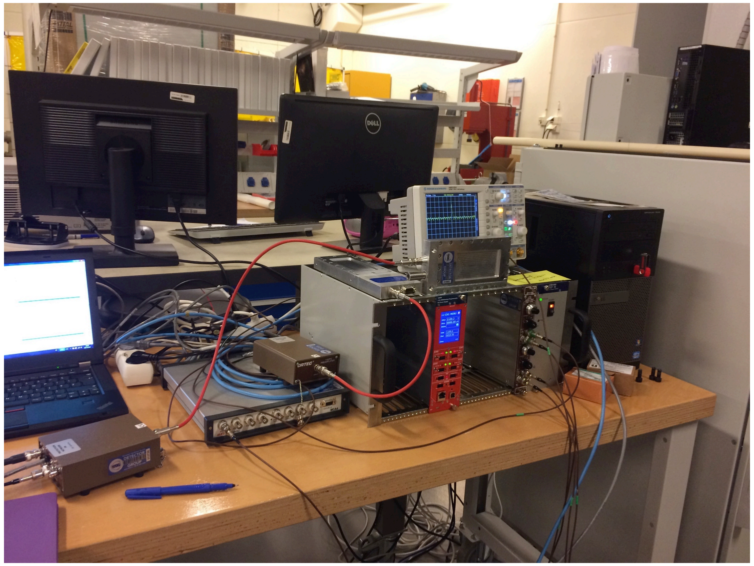


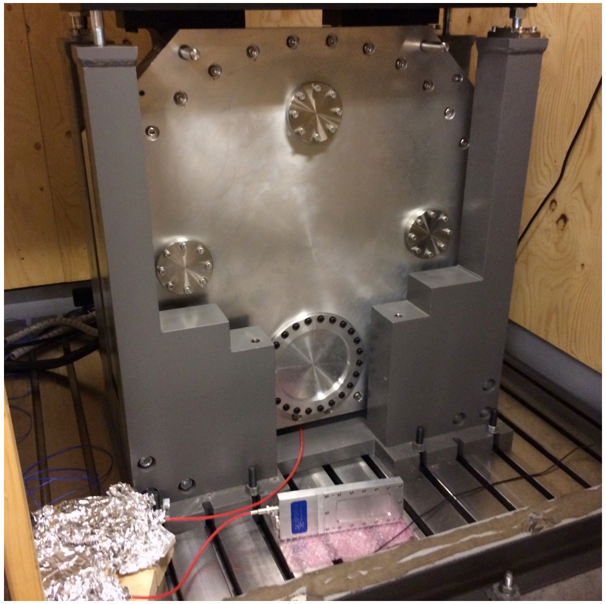


BM at the backside of the chopper @Embla

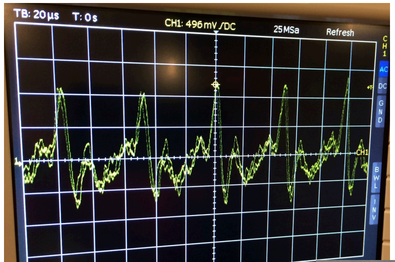
The chopper can run up to 22 Hz

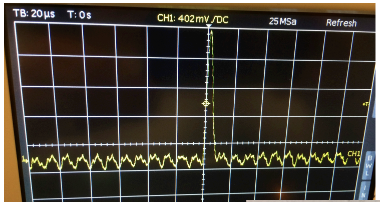
Mechanical integration



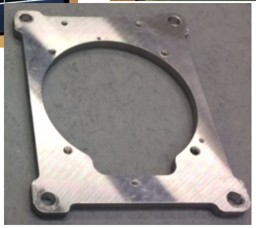


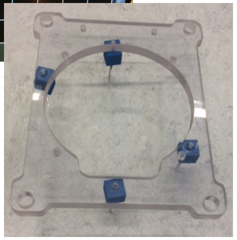
The BM should be electrically isolated from the chopper. Grounding is important follow grounding guidelines

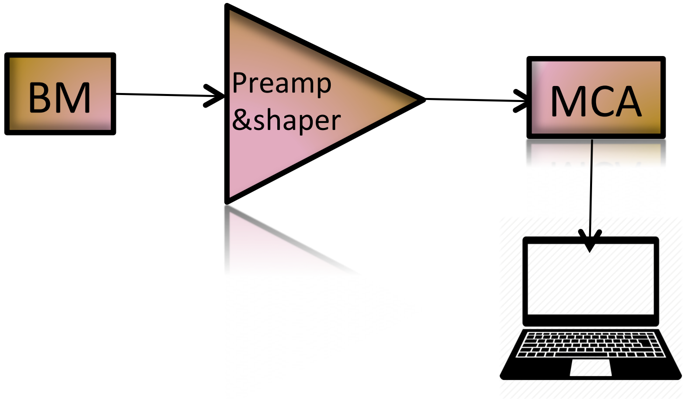




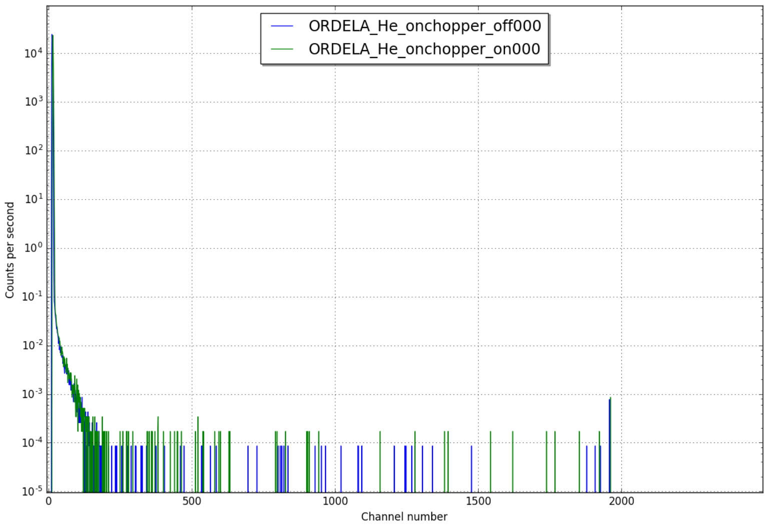
Electrical contact
→ Significant noise

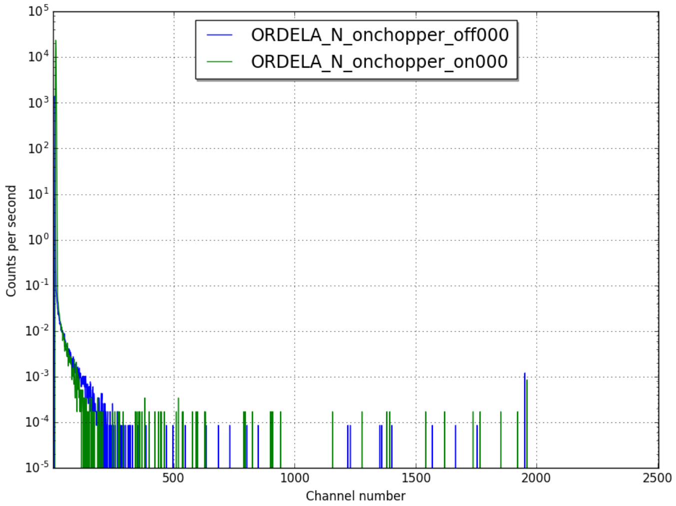


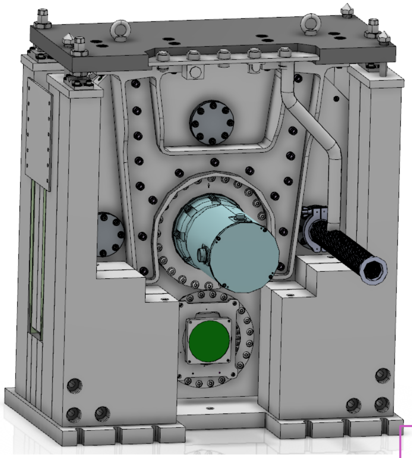


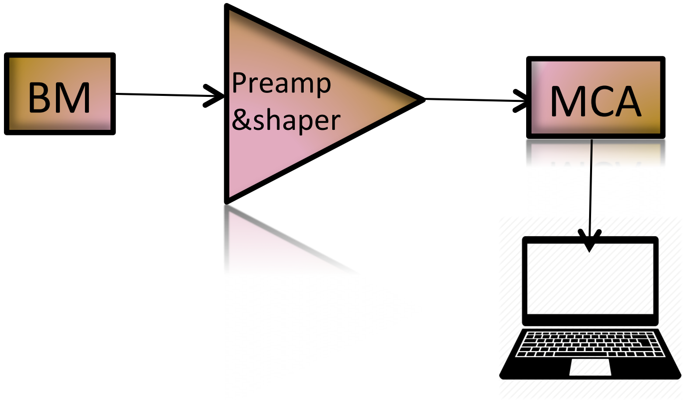


Mechanical integration





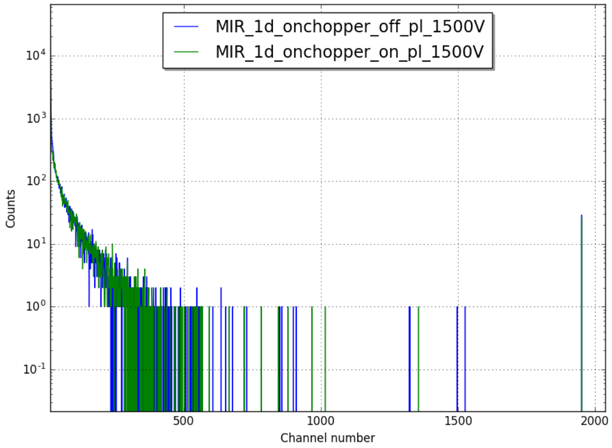




BM

Preamp
&shaper

MCA



At 22 Hz → no noticeable change in the BM response

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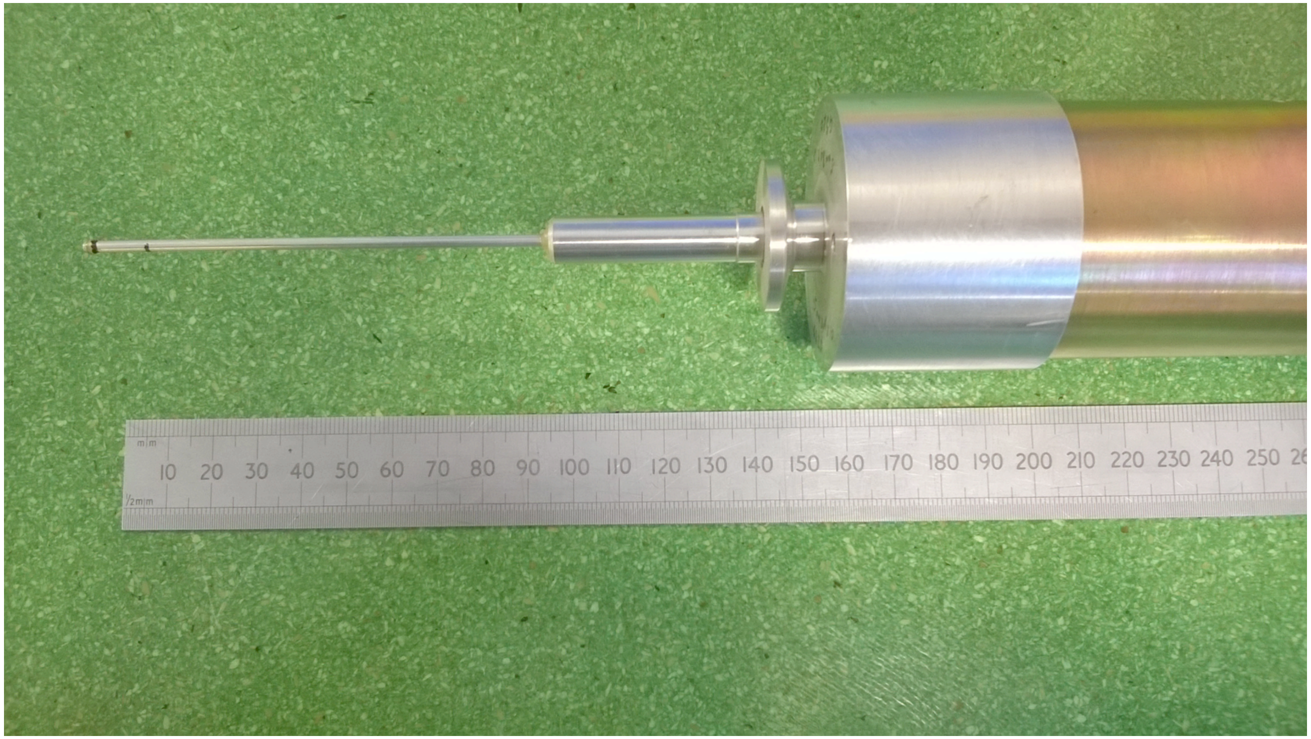
Beam monitor for chopper diagnostics



Fibre beam monitors
→ Used at LET

Info from Niko and Nigel
Thanks!

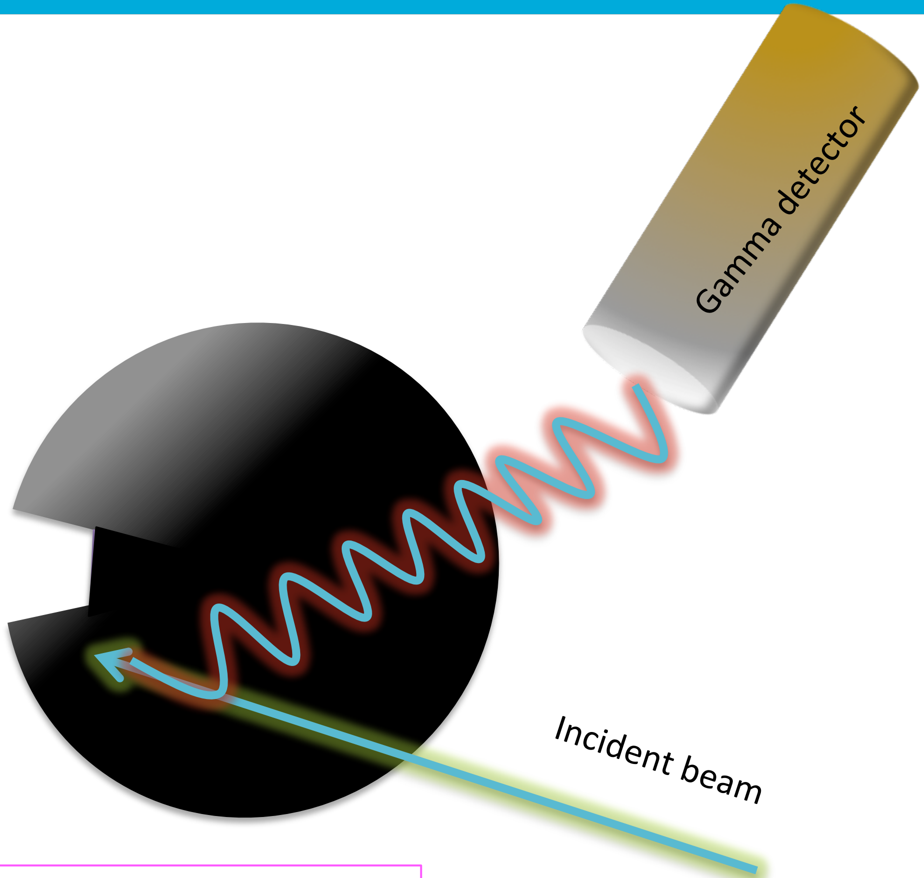
Aluminum tube is about 3 mm in diameter.
Small rods of GS glass scintillator, each about 10 mm in length and 0.5 mm in diameter

Monitoring using vanadium foil https://indico.esss.lu.se/event/870/

Parasitic methods for monitoring the beam

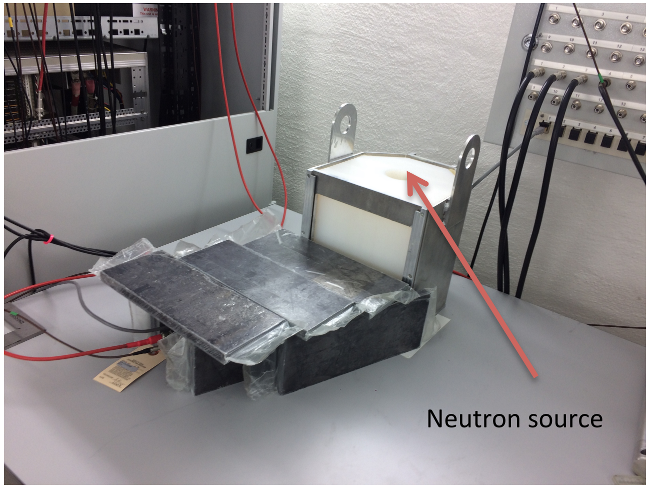
☐ Using Gamma detector

Using the boron layer on the chopper disc → information about the chopper rotation → this is done using a gamma detector outside the beam.



$$^{10}\mathrm{B} + \mathrm{n} \rightarrow\ ^{7}\mathrm{Li} +\ ^{4}\mathrm{He}(\mathrm{Q} = 2.72\mathrm{MeV}) \quad 6\,\%$$
$$^{10}\mathrm{B} + \mathrm{n} \rightarrow\ ^{7}\mathrm{Li}^{*} +\ ^{4}\mathrm{He}(\mathrm{Q} = 2.31\mathrm{MeV}) \quad 94\%$$

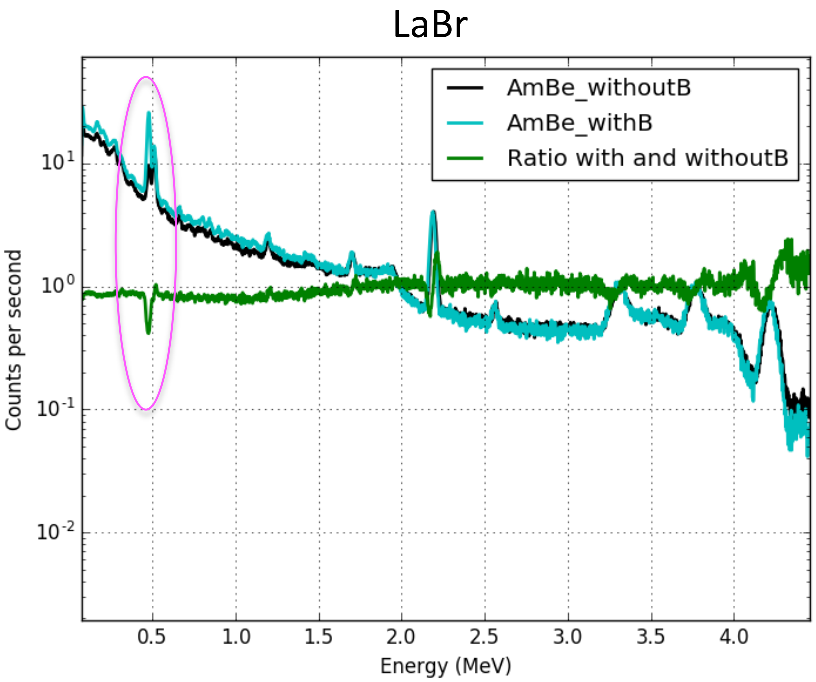
Parasitic methods for monitoring the beam

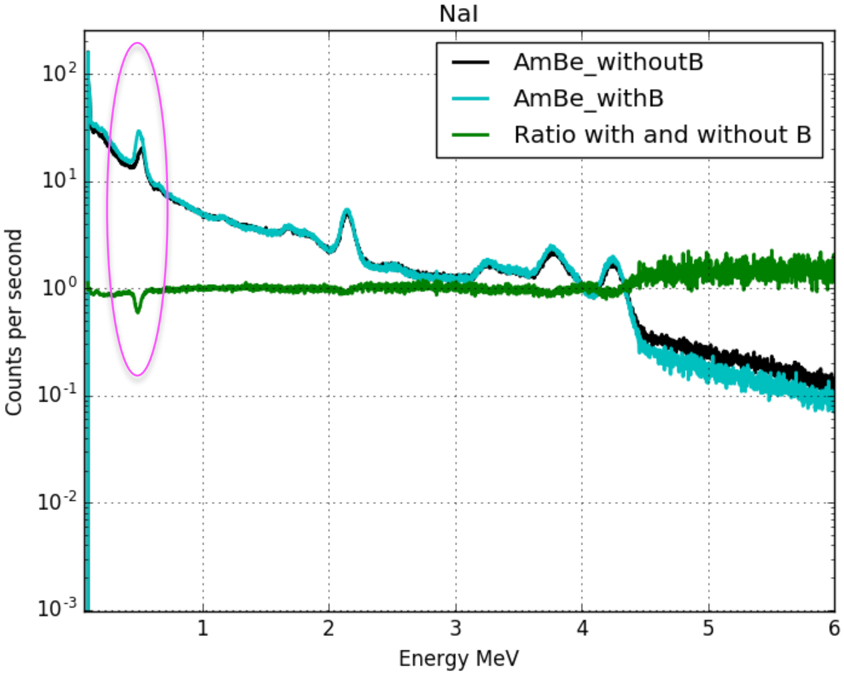


LaBr scintillator detector from Saint-Gobain is surrounded by a mirrobor 2mm (80% B4C)

Boron carbide

Parasitic methods for monitoring the beam





A gamma peak at 480 keV can be recognized in the presence of boron

The gamma peak at 480 keV can be recognized in the presence of different gamma sources

More measurements should be performed on a real beam line with time stamped electronics

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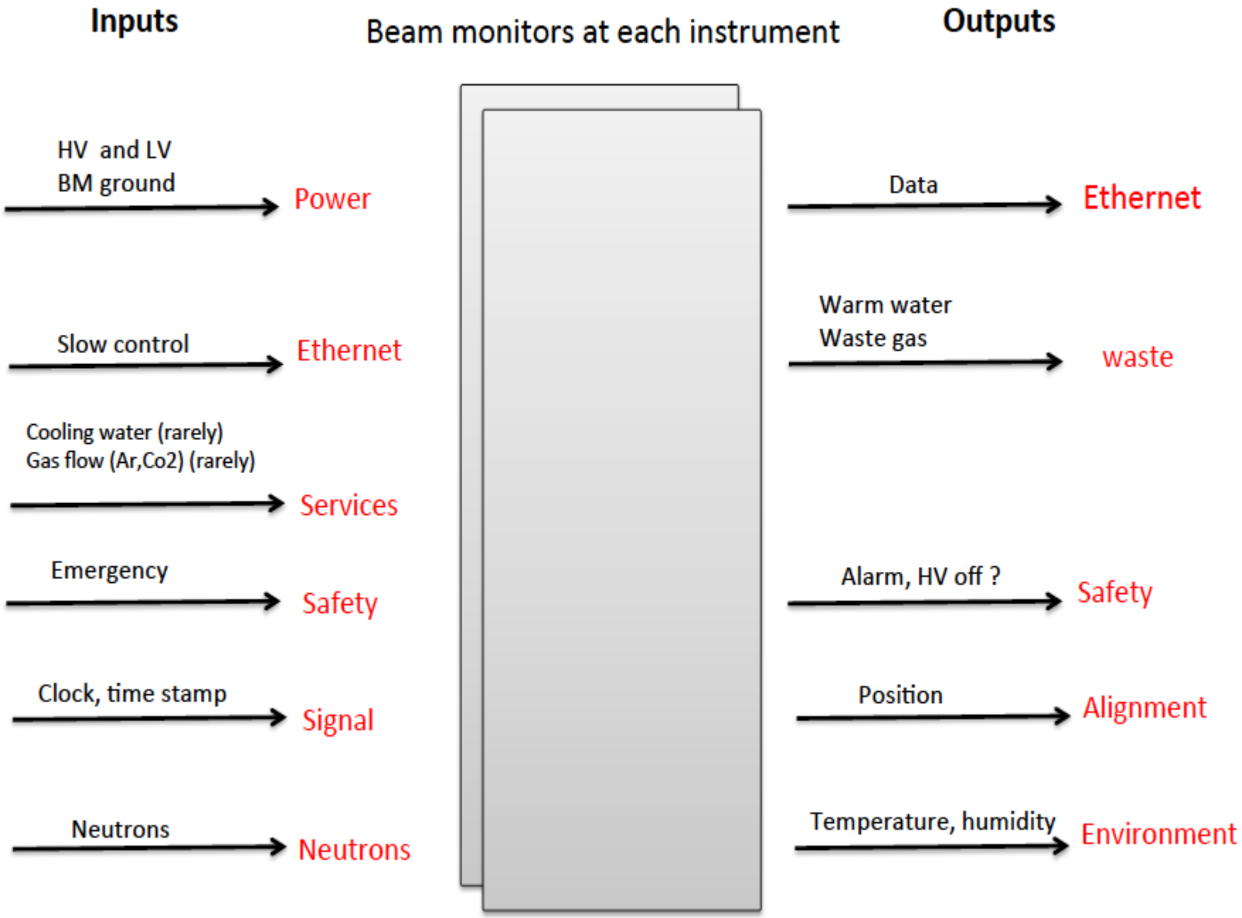
Beam monitor system Integration



Inputs

Beam monitors at each instrument

Outputs

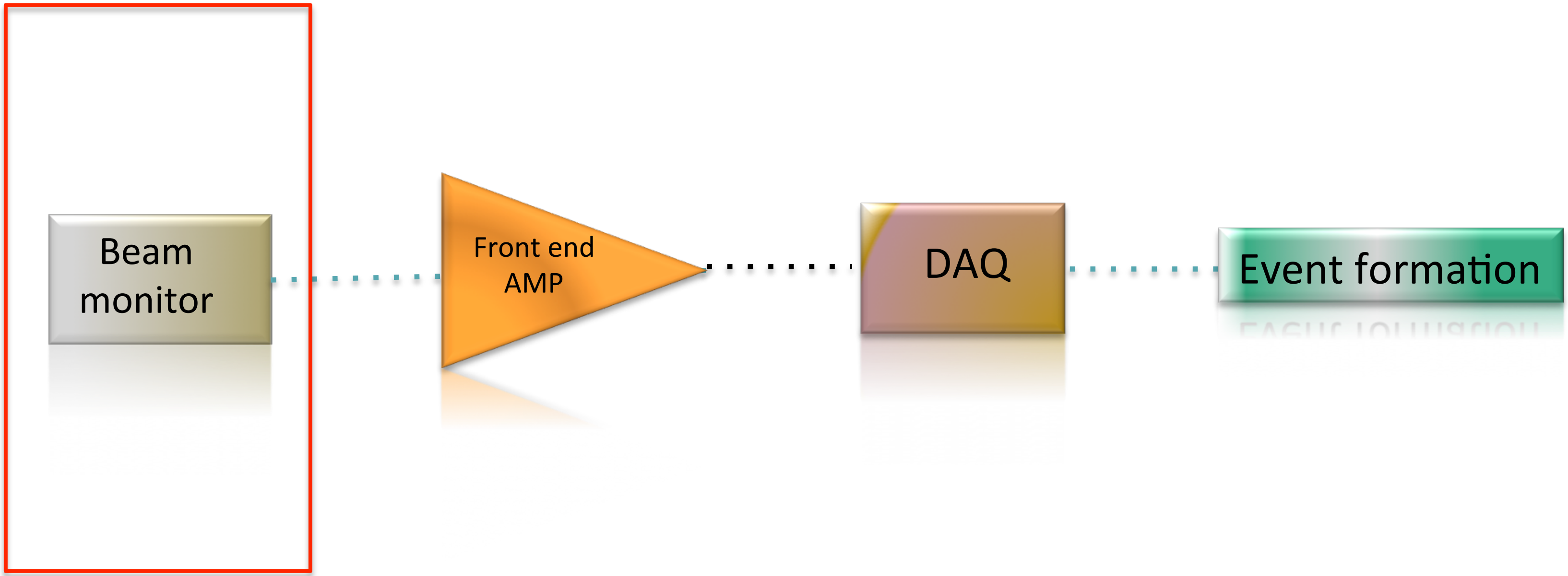
Inputs:

- HV and LV, BM ground → Power
- Slow control → Ethernet
- Cooling water (rarely), Gas flow (Ar,Co2) (rarely) → Services
- Emergency → Safety
- Clock, time stamp → Signal
- Neutrons → Neutrons

Outputs:

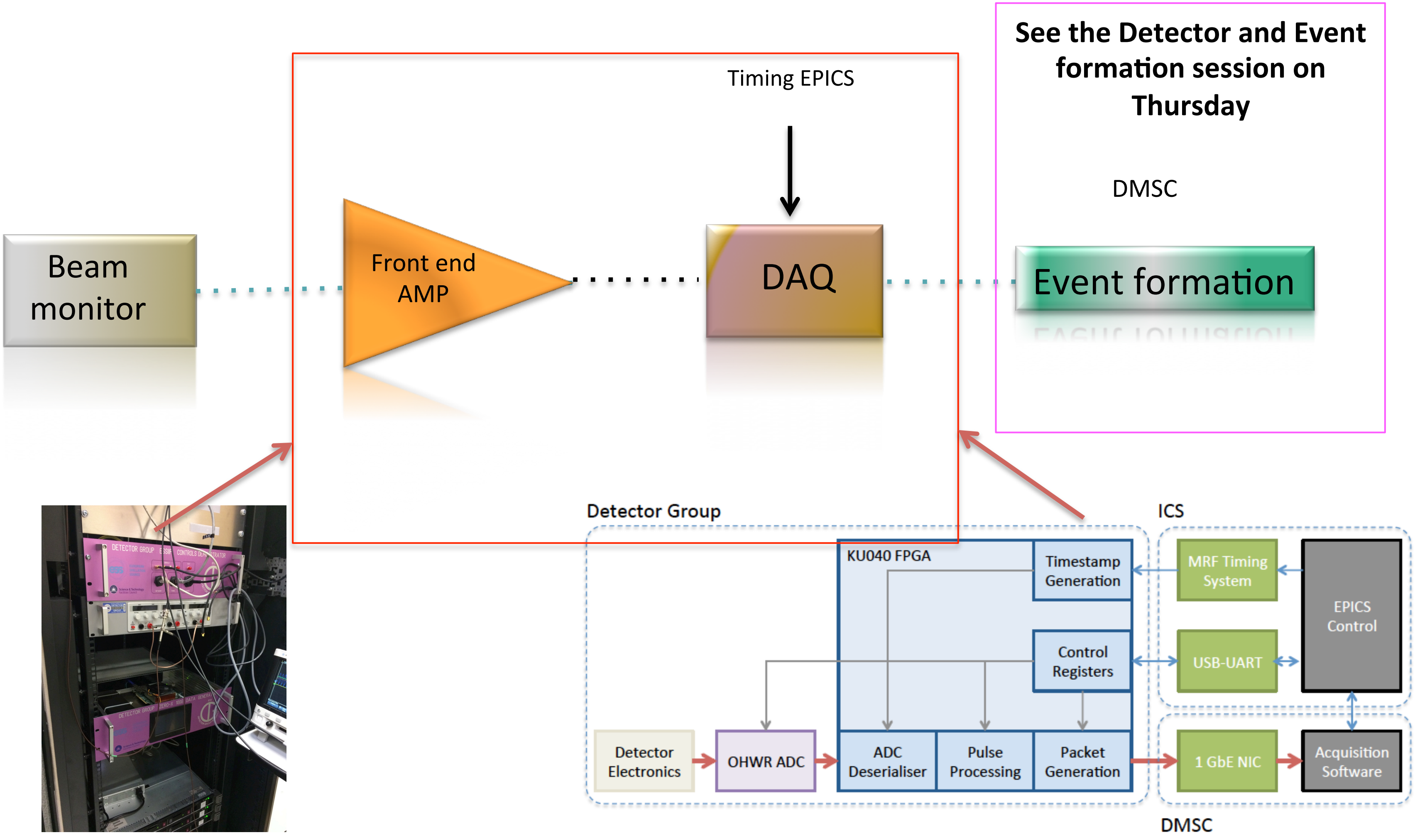
- Data → Ethernet
- Warm water, Waste gas → waste
- Alarm, HV off ? → Safety
- Position → Alignment
- Temperature, humidity → Environment

Beam monitor system Integration

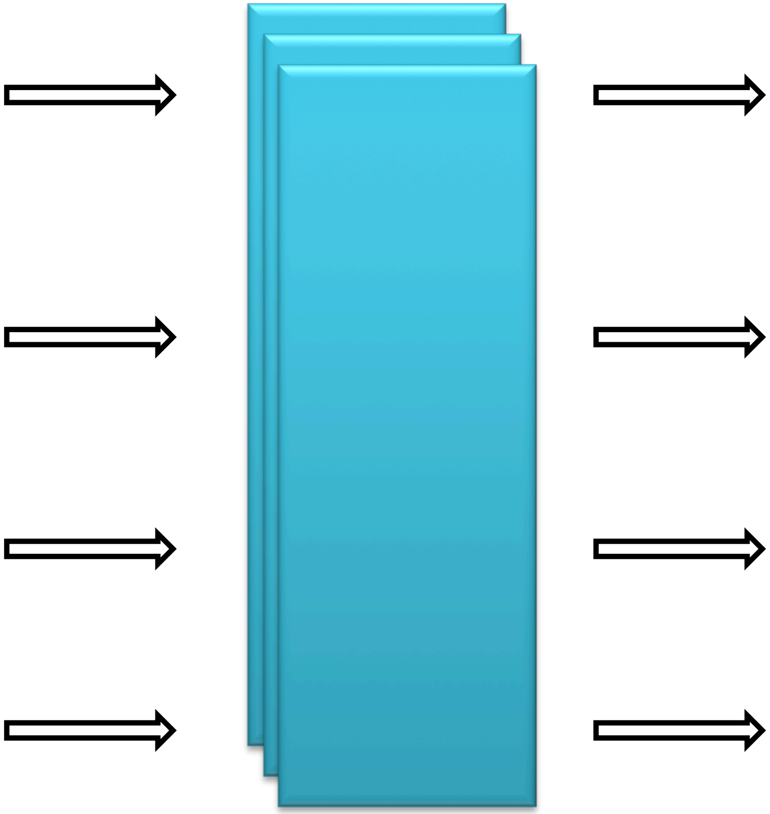


Beam monitor electronics

See the Detector and Event formation session on Thursday



Facility maintenance and operation Requirements



BM system

No access to the bunker just for BM maintenance

Diagnose flux lost

Flux along the beam line

T0 information

Environmental requirement (rate, humidity, temperature,..)

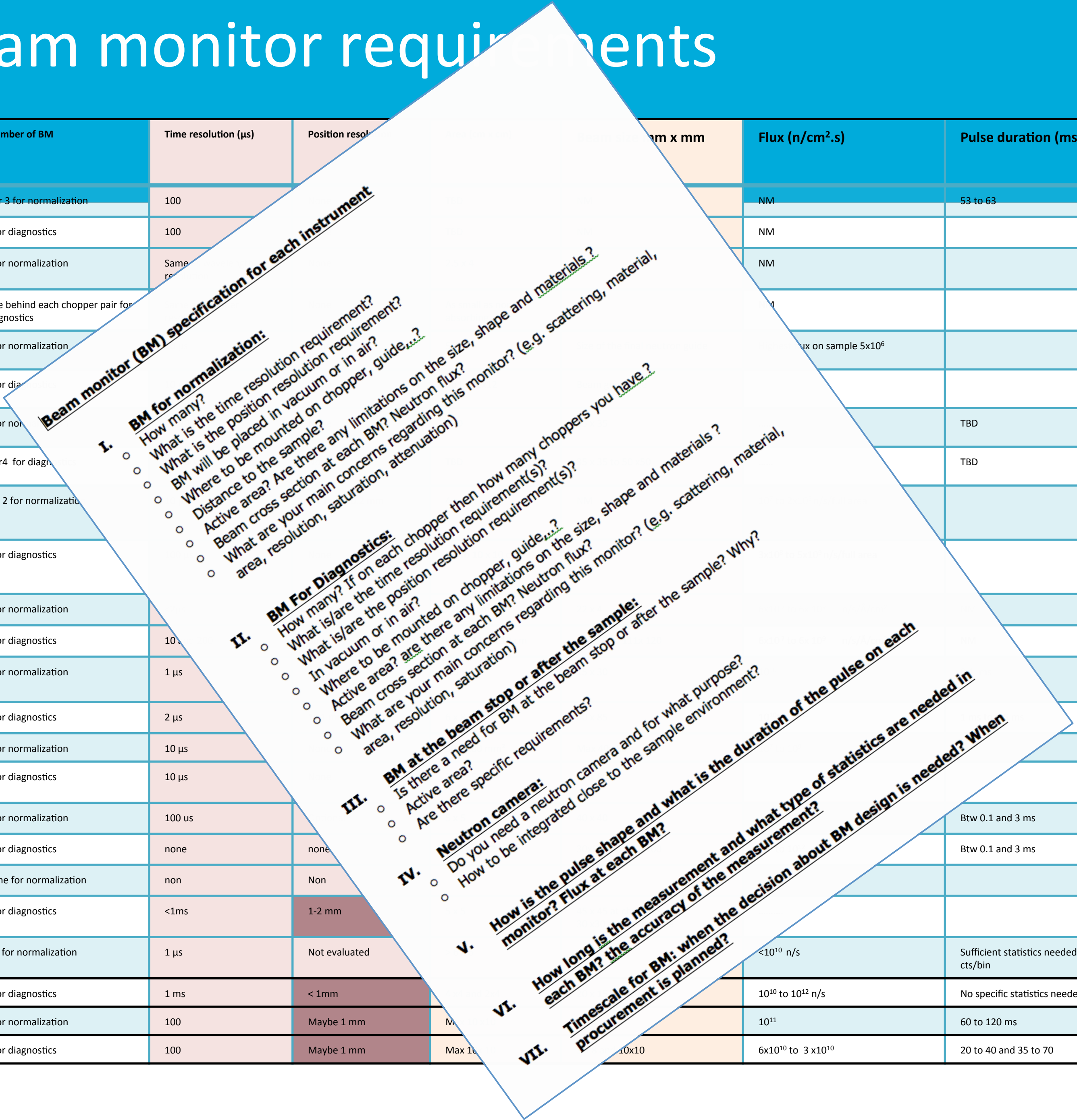
Stability

Cross-Calibration

Radiation hardness (lifetime >10years @ normal flux)

Beam monitor requirements

Instruments	Number of BM	Time resolution (µs)	Position resol	mm x mm	Flux (n/cm^2.s)	Pulse duration (ms)	Vacuum/air
LKOI	2 or 3 for normalization	100			NM	53 to 63	vacuum
	2 for diagnostics	100			NM		vacuum
FREIA	2 for normalization	Same re			NM		air
	One behind each chopper pair for diagnostics				NM		vacuum
MIRACLES	1 for normalization				ux on sample 5x10^6		vacuum
	2 for dia						vacuum
VESPA	1 for no					TBD	Vacuum (preferable)
	3 or4 for diagn					TBD	Vacuum (preferable)
HEIMDAL	1or 2 for normalizatio						air
	2 for diagnostics						vacuum
CSPEC	1 for normalization						vacuum
	4 for diagnostics	10					vacuum
T-REX	1 for normalization	1 µs					vacuum
	2 for diagnostics	2 µs					air
BEER	1 for normalization	10 µs					air
	1 for diagnostics	10 µs					Vacuum
BIFROST	2 for normalization	100 us				Btw 0.1 and 3 ms	air
	2 for diagnostics	none	none			Btw 0.1 and 3 ms	air
NMX	None for normalization	non	Non				
	3 for diagnostics	<1ms	1-2 mm				air
ESTIA	0-1 for normalization	1 µs	Not evaluated		<10^{10} n/s	Sufficient statistics needed 10^4 cts/bin	vacuum
	4 for diagnostics	1 ms	< 1mm		10^{10} to 10^{12} n/s	No specific statistics needed	vacuum
ODIN	1 for normalization	100	Maybe 1 mm	M	10^{11}	60 to 120 ms	
	2 for diagnostics	100	Maybe 1 mm	Max 1 10x10	6x10^{10} to 3 x10^{10}	20 to 40 and 35 to 70	



Beam monitor (BM) specification for each instrument

I. **BM for normalization:**
- How many?
- What is the time resolution requirement?
- What is the position resolution requirement?
- BM will be placed in vacuum or in air?
- Where to be mounted on chopper, guide,..?
- Distance to the sample?
- Active area? Are there any limitations on the size, shape and materials ?
- Beam cross section at each BM? Neutron flux?
- What are your main concerns regarding this monitor? (e.g. scattering, material, area, resolution, saturation, attenuation)

II. **BM For Diagnostics:**
- How many? If on each chopper then how many choppers you have ?
- What is/are the time resolution requirement(s)?
- What is/are the position resolution requirement(s)?
- In vacuum or in air?
- Where to be mounted on chopper, guide,..?
- Active area? are there any limitations on the size, shape and materials ?
- Beam cross section at each BM? Neutron flux?
- What are your main concerns regarding this monitor? (e.g. scattering, material, area, resolution, saturation)

III. **BM at the beam stop or after the sample:**
- Is there a need for BM at the beam stop or after the sample? Why?
- Active area?
- Are there specific requirements?

IV. **Neutron camera:**
- Do you need a neutron camera and for what purpose?
- How to be integrated close to the sample environment?

V. **How is the pulse shape and what is the duration of the pulse on each monitor? Flux at each BM?**

VI. **How long is the measurement and what type of statistics are needed in each BM? the accuracy of the measurement?**

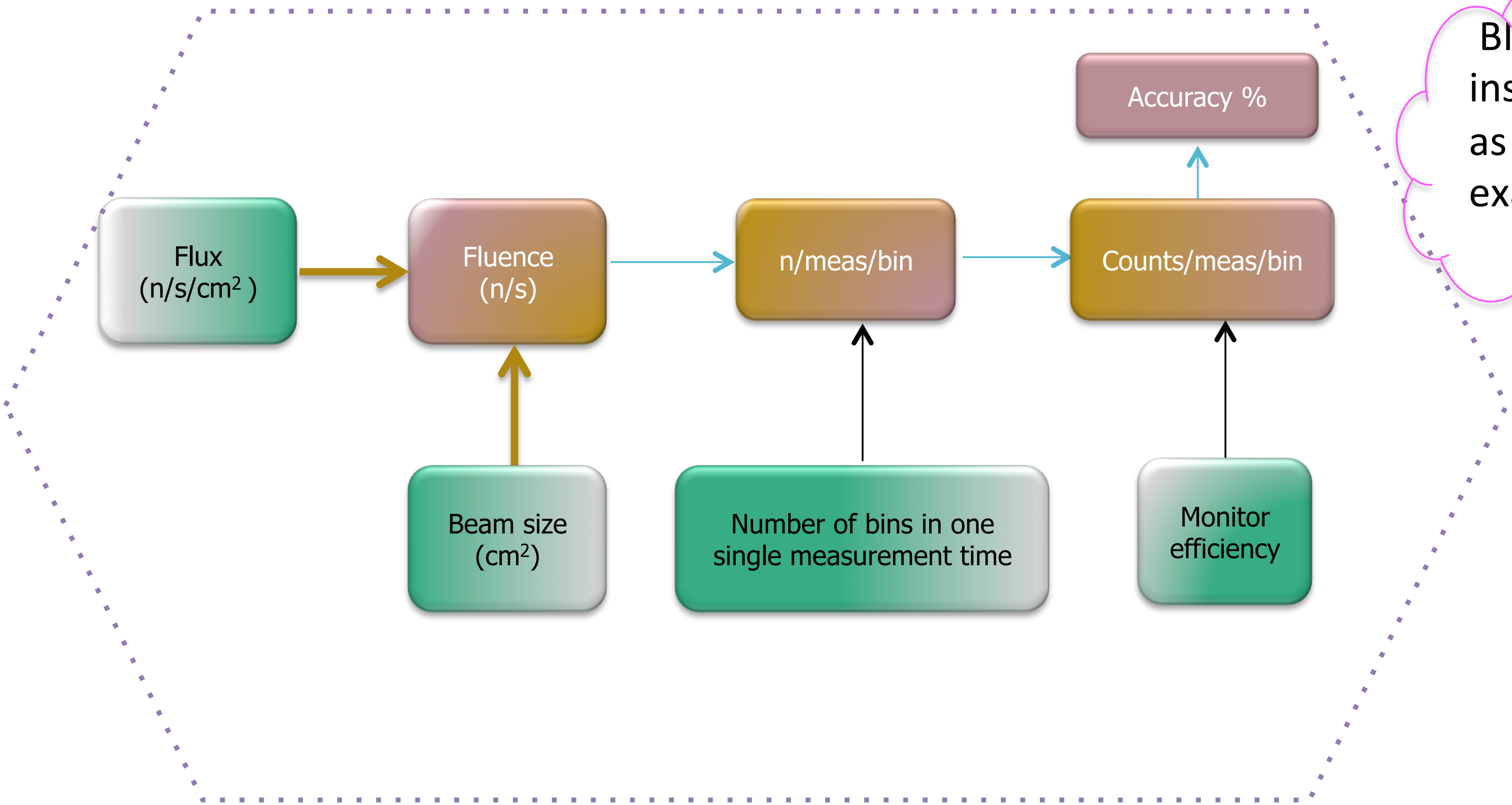
VII. **Timescale for BM: when the decision about BM design is needed? When procurement is planned?**

Beam monitor requirements

Preliminary

- Time resolution : 1 µs to 1ms
- Position resolution: 0.2mmx 0.2mm up to 3 mm
- Flux on each monitor: 10^7 n/s/cm^2 up to 10^{12} n/s/cm^2
- Beam size: 2x 15 mm up to 111x120 mm
- Active area: 15x 30 mm up to 120x120 mm
- Instruments with no Position sensitive BM: LOKI-FREIA-VESPA-BEER-BIFROST
- Majority of BM are in vacuum: LOKI-MIRACLES- VISPA- CSPEC-ESTIA-ODIN
- Main concern: attenuation, scattering, enough statistics per measurement

Beam monitor requirements



Flux (n/s/cm^2)

Fluence (n/s)

Beam size (cm^2)

n/meas/bin

Number of bins in one single measurement time

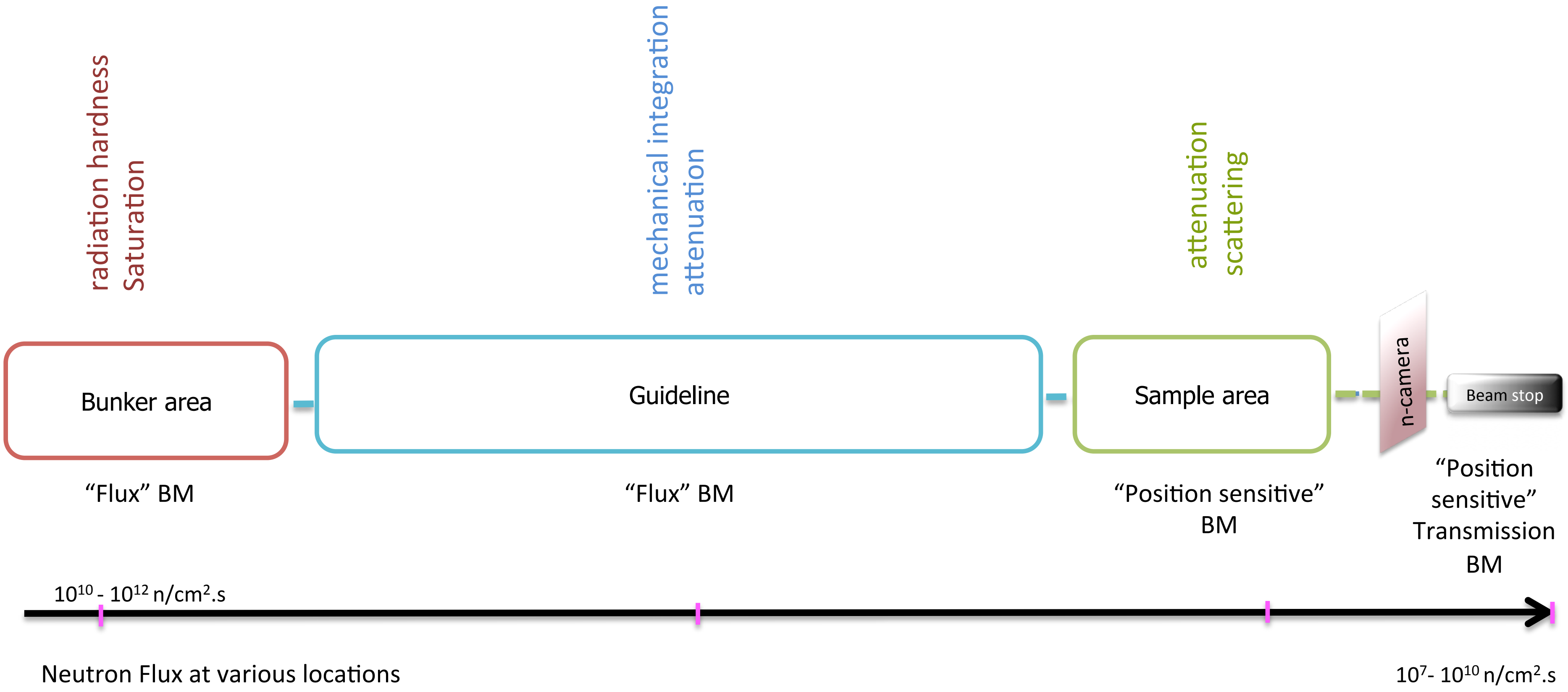
Counts/meas/bin

Monitor efficiency

Accuracy %

BIFROST instrument as an example

Beam monitor per zone



radiation hardness
Saturation

mechanical integration
attenuation

attenuation
scattering

Bunker area

Guideline

Sample area

n-camera

Beam stop

“Flux” BM

“Flux” BM

“Position sensitive” BM

“Position sensitive” Transmission BM

10^{10} - 10^{12} n/cm^2.s

Neutron Flux at various locations

10^7- 10^{10} n/cm^2.s

Beam monitor per zone

Instrument	Bunker	Guideline	Sample	Camera	Transmission
LOKI	0	2	2	1	2
C-SPEC	1-2	2	1	1	1
T-REX	0?	2?	1	0	0
NMX	0	2	1	1	0
BEER	1	0	1	1	0
HEIMDAL	1	1	1-2	0	0
ODIN	2	0	1	0	0
ESTIA	2?	1?	0?	1	0
FRIA	?	?	1-2	0	0
BIFROST	1	1	1-2	1	1
MIRACLES	0	1	1	1	1
VESPA	2	1	1	0	1

Preliminary based on
BM requirement document
and TG2 documents

Beam monitor Guidelines

Accessibility/reliability	Radiation hardness materials
Mounting	If along the chopper or the guide →electrically isolated
Movement	Not preferable option Mounting and positional reliability should be considered and cable rotation has to be reviewed Continuity of diagnostics?
Gas	Probably BM as sealed system
Failure/maintenance	Whenever possible parasitic maintenance → component should be reviewed and qualified for reliability and availability
Electronics	BM will have same backend electronics for maintenance and integration reasons
Racks	Racks maybe separated from detector rack maybe per grounding zone
Data	Event mode expected as default mode
Fission chambers	Preliminary recommendation →only in or around the bunker region not close to the sample because of fast neutron emission. Before losing line of sight to moderator and out of line of sight to sample. (main disadvantage of the fission chamber is that in addition to the desired fission products three fast MeV neutrons on average and MeV gamma radiation are produced during thermal fission) (flux of 10^{10} n/s → emission of 10^5 n/s fast neutrons)(assuming fission chamber efficiency 10^{-5})

Summary

- Different types of beam monitors (MWPC, 2D-GEM, scintillator, fission chamber) from different supplier have been tested
- Efficiency, attenuation and gamma sensitivity were studied
- Relatively high attenuation factor → mainly contributed to the window thickness
- Mechanical integration →No electrical contact between BM and choppers
- Low attenuation factor → Parasitic methods could be used
- Saturation with the current electronics → re-test with proper electronics
- For facility maintenance → min 3 BM per instrument (Diagnostics, normalization, transmission)
- Next steps → new beam monitors, electronics, full integration

THANK YOU