Common Beam Monitor Project

Status update

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CBMP brief status report

Main developments the last year

- Updated instrument requirements and schedule
- Updated BM technology scheme
- Proposed new technologies covering ESS's needs
- Aligning with ESS activities and Common projects
- Run performance tests for in-bunker monitors
  - Radiation hardness test being planned
- Main focus Tranche 1 – Moving to next levels

BIFROST	ESTIA	ODIN	TBL
BMs ordered (partially delivered)	BM delivered	BMs defined	BMs Ordered (half delivered)

Tranche 1 instruments status - All monitors expected at ESS before Q1 2024

Beam Monitor Scheme

Location	Features	Candidates
Bunker	• Flux measurement • Timing • n/γ discrimination • Fast n discrimination	• Ionisation chambers
Guides & Choppers	• Flux measurement • Timing • Beam profiling	• Ionisation chambers • MPGDs*
Sample	• Flux measurement • Timing • Beam profiling • Very low beam attenuation	• Ionisation chambers • MPGDs

**MPGD→ MicroPattern Gas Detector*

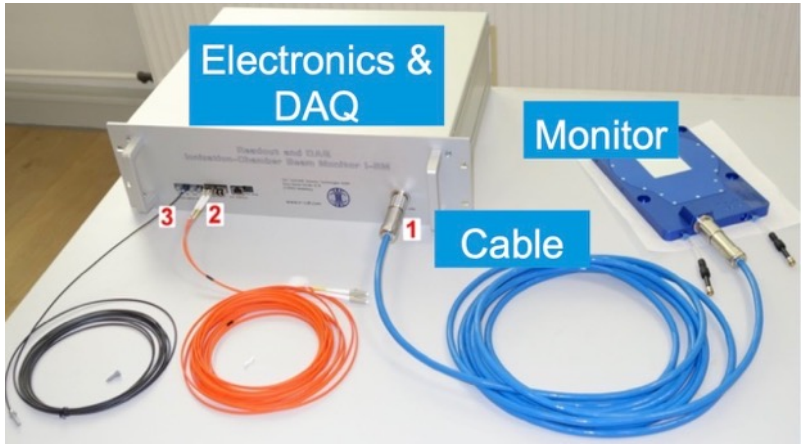
BM performance testing

Tests at AMOR (PSI) ToF neutron reflectometer (July 2023)

Main goals

- Beam attenuation studies
- Estimate timing capabilities
- Study signal over noise ratios
- Linearity
- Dynamic range

I-BM setups tested



DAQ Boxes x 3

- 0.3 MOhm
- 1.6 MOhm
- 14 MOhm

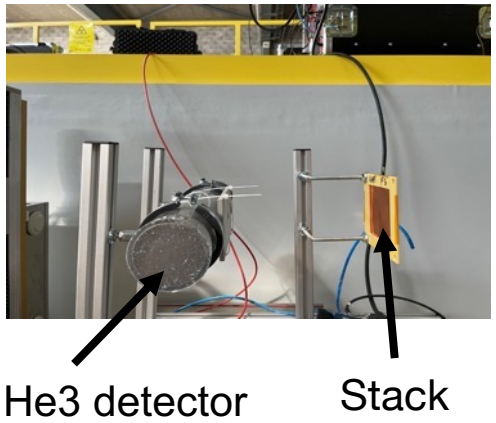
Cable lengths x 4

- 5 m
- 15 m
- 30 m
- 50 m

Attenuation tests for BM components:

Studied stakcs of:

- AlMg3 (several thicknesses)
- uRWELL stack
- I-BMs
- CASCADE GEM

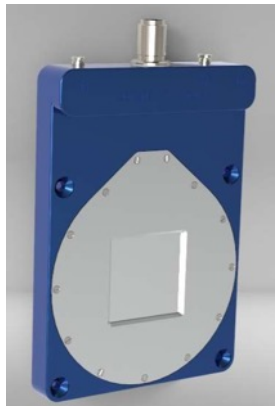


USE	^{10}B [nm]	Efficiency [%]
Bifrost	12	0.05
MAGIC	120	0.5
TBL	1000	5

Main beam monitor candidates

Technology overview

CDT I-BM



- ***Ionisation chamber***
  - Offers γ-discrimination
- ESS-driven development
- **The in-bunker solution**
- No in-bunker electronics
- Current mode operation
- Large dynamic range
- Low material budget

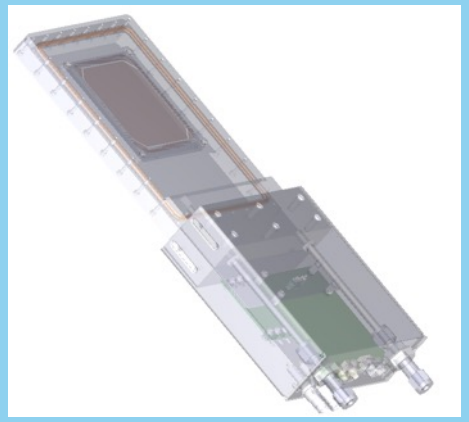
MPGDs

CDT CASCADE (GEM)

- High rate capabilities
- **Good 2D spatial resolution**
- Beam profiling
- Pulse mode operation

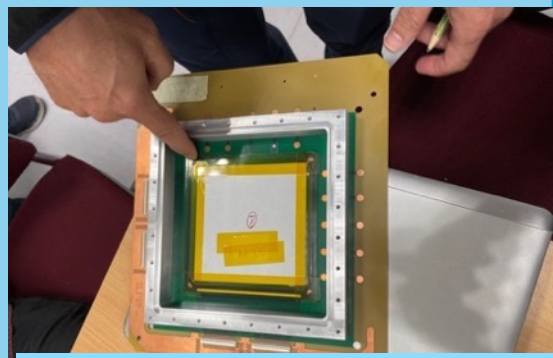
ESS - CEA Saclay - CERN

ESS-Flux monitor (MicroMegas)



- High rate capabilities
- One to few channels
- **Huge dynamic range**
  - From single neutron
- **Pulse & current mode operation**

ESS-1D monitor (uRWELL)



Sample design the 1D BM

- High rate capabilities
- **Good 1D spatial resolution**
- Beam profiling
- Pulse mode operation

FREIA Beam Monitors

Status update – Planning after original provider's withdrawal

#BM	Zone	Sector	Purpose	PSD	Beam profile (y×z, × mm2)	Placement	Technology
1	Bunker	N	WBC1 monitoring		231.5 x 30	Air	I-BM
2	Bunker		PSC1-3 monitoring		246.2 x 30	Air	I-BM
3	Cave		WBC2 & PSC4 monitoring		240.4 x 30	Air	ESS-flux
4	Cave		WBC3 & PSC5 monitoring		207.3 x 30	Vacuum	ESS-Flux
5	Cave		Pre-sample/fast-shutter diagnostics	1D	95 x 30	Vacuum	ESS-1D
6	Cave		Pre-sample/normalisation		60 x 35	Air	ESS-flux

Current status of FREIA's BM scheme

- **Moved with fast pace to developed an alternative solution for FREIA**
- **Development of 250 x 40 I-BMs for use in-bunker was discussed with company**
  - **First long I-BM to be purchases soon for testing**
- **Investigated the possibility to develop 250 x 40 ESS Flux monitors to operate in air or vacuum environment**
- **Discussed with CERN & CEA the development of ESS flux monitors for operation in air and vacuum environment**
- **GEMINI based readout electronics already developed by Nuclear Instruments**

Extra slides

Monitor categorisation and requirements

ESS - a very demanding environment- novel and diverse instruments with requirements above the state-of-art

- Bunker, Guides & Choppers and Sample BMs each with **special requirements**
- **Large dynamic range** required
  - Source power-up monitoring
  - Low and high intensity operation
- **Spatial resolution** is required by several instruments
- **Time resolution** below 1 μs is highly desired
- **In-vacuum operation** with position sensitivity required
- **Very low attenuation** required -especially for sample monitors- usually combined with position sensitivity
- Radiation hardness

Location	Features	Candidates
Bunker	• Flux measurement • Timing • n/γ discrimination • Fast n discrimination	• Ionisation chambers
Guides & Choppers	• Flux measurement • Timing • Beam profiling	• Ionisation chambers • MPGDs
Sample	• Flux measurement • Timing • Beam profiling • Very low beam attenuation	• Ionisation chambers • MPGDs • Neutron cameras

Summary of performance tests

Objectives

- Narrow wavelength band tests (2Å, 8Å, 15Å)
  - Attenuation (scattering to be included here)
  - Efficiency of each monitor
- Variable flux tests
  - ➢ Signal over noise (cable length test-ePlanning)
  - Linearity, with attenuation or by increasing slits size
  - Current vs flux
  - ➢ Timing vs flux (time resolution limits-ODIN)
  - Dynamic range vs timing edge
  - Sensitivity
- Timing measurements – Pulse features
  - Testing with wide pulse
  - Testing with narrow pulses
  - ToF measurements
  - Time resolution
- Spatial resolution measurement
  - Needs to be repeated
  - Beam profile per wavelength

➢ *First test took place at PSI*
➢ *Results to be shared soon*

There's no need to separate the beam scattering from absorption as scattering measurements can be difficult and with little to add.

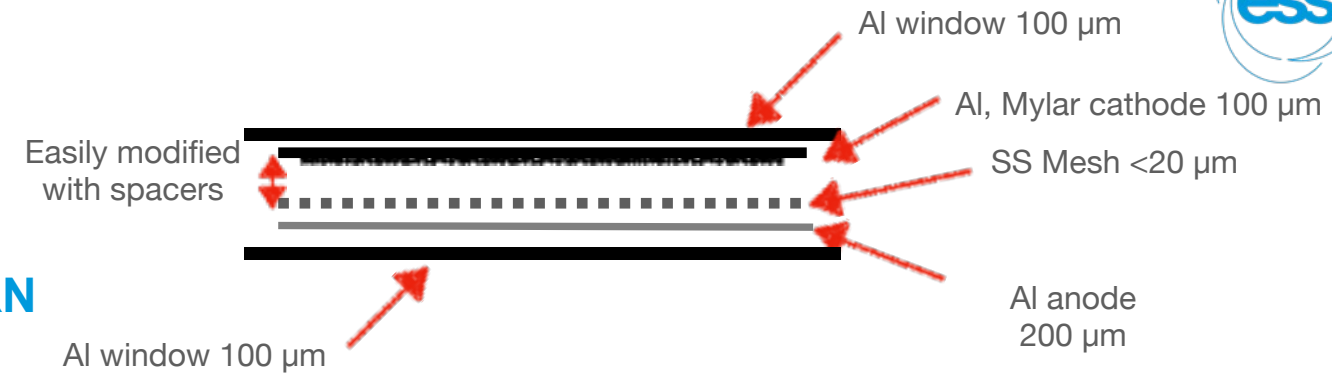
By using the chopper we can have sharp changes/bursts of neutrons to try and measure. This will indicate how quickly a monitor can respond.

The ToF signals given by the choppers can be used to identify specific parts of the neutron pulse measured for example the low rise or fall part with few events that can be used to estimate the sensitivity.

L. Segui et al 2023 JINST 18 P01013

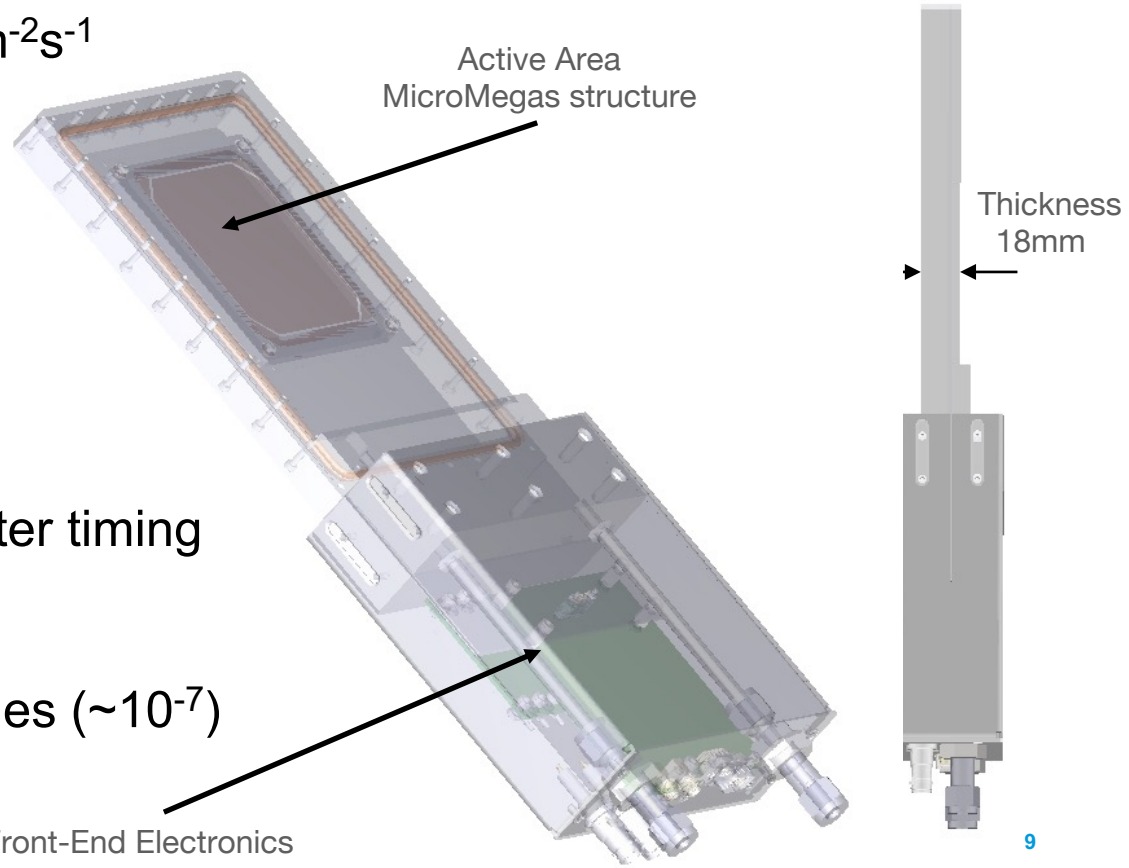
A versatile thermal neutron monitor (MM-D)

Micromegas based beam monitors



Established technology used at ESS (nBLM)
Now co-developed by ESS, CEA Saclay, CERN

- **Huge dynamic range** - Single neutron to over 10^9 n·cm^{-2}s^{-1}
  - Through dual pulse & current mode operation
- Operation with **single or multiple channels**
  - Excellent timing resolution (<µs)
  - High rate capability ~MHz·cm^{-2}
- Vessel adapted as needed
  - **Low thickness** down to 10 mm
  - **In-vacuum** monitors
- Modifiable design for improved energy resolution or faster timing
- Interchangeable windows for
  - variable efficiency
  - N_2 operation -no B4C layer- for minimised efficiencies (~10^{-7})



nBLM accelerator safety system

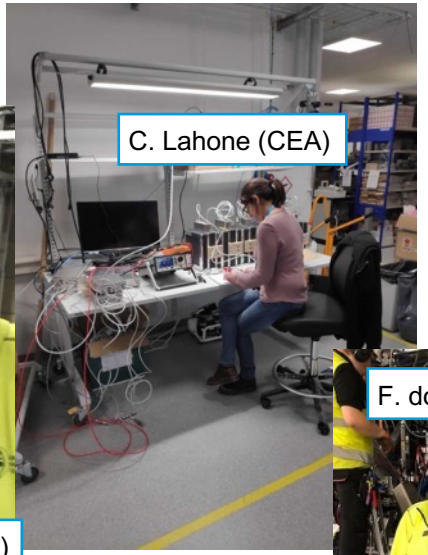
Installation and integration at the ESS LINAC (March 2023)

I. Dolenc Kittelmann (ESS)

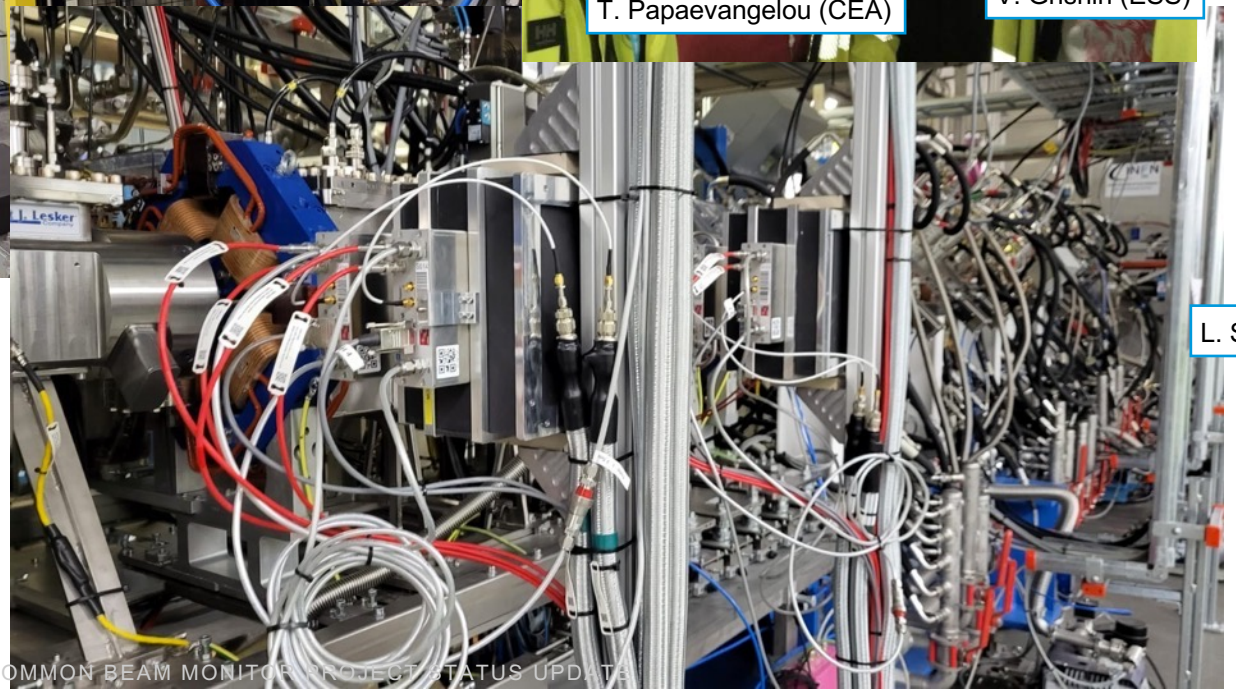
K. Aivazelis (CEA)

T. Papaevangelou (CEA)

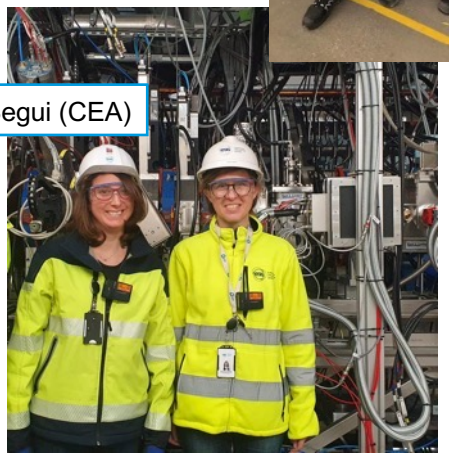
V. Grishin (ESS)



C. Lahone (CEA)



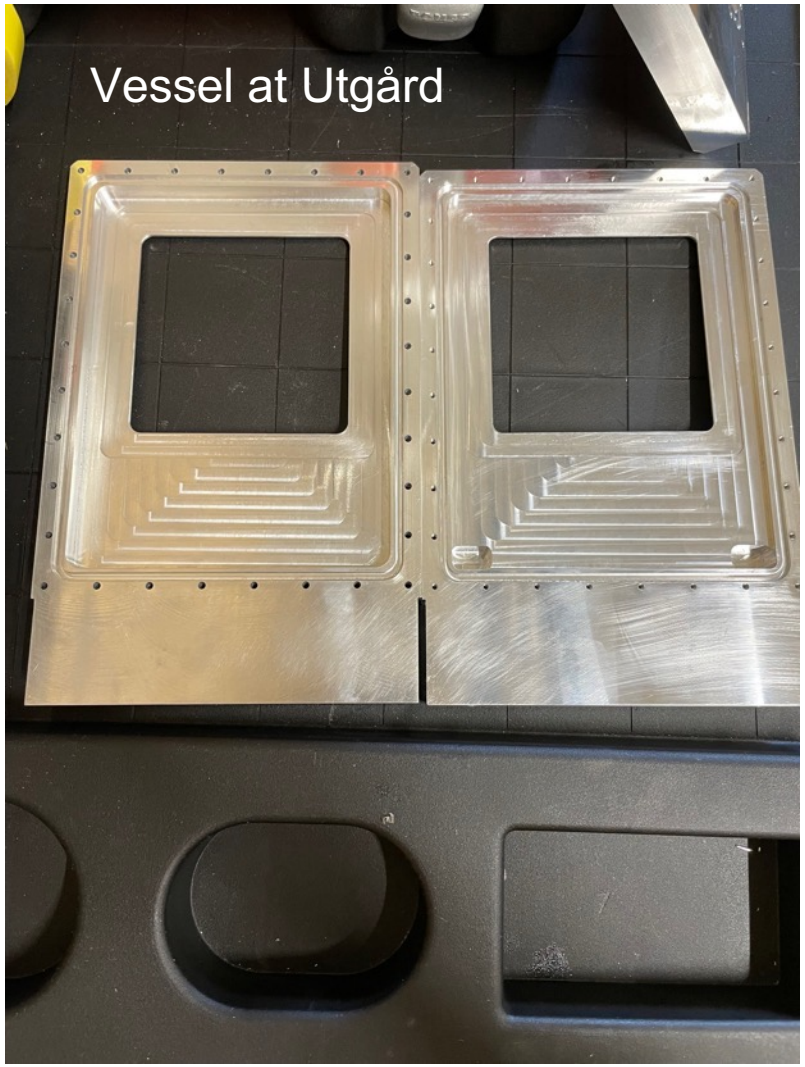
F. dos Santos Alves (ESS)



L. Segui (CEA)

Micromegas-based accelerator security system at ESS

Production of MM-0D based beam monitors



Status of prototypes

- Design v1 **done** by ESS and Saclay (~16mm thick active area, 25mm electronics area)
- Design v2 coming **later this summer** (thinner <15mm)
- **Vessel built** at Utgård
- Front end caps are **ready** at Saclay
- PCBs for v1 are **ready** at Saclay
- PCBs for v2 are **under development** at Saclay
- Micromegas on Al sheet **to be constructed at CERN** (by Fall)
- Back-end electronics **quote received from NI; Awaiting approval**
  - ✓ **8ch ADCs based on the GEMINI design**
  - ✓ **Compatible with ESS DAQ systems**
  - ✓ **140kEuro for 20 pieces – Cheaper for next orders**

First three monitors under construction → expected by last quarter 2023

Production of MM-1D based beam monitors

GEMINI and urWell/MM based monitors

- ✓ **Electronics delivered and integrated**
- ✓ **Detector ordered (CERN) – ETA fall**

Description:

- urRwell Stack up :
  - Top mesh layer 15um copper.
  - 50um Kapton
  - DLC 10nm around 60M ohms/square
  - 28um prepreg
  - Signal line layer 15um copper
- Active area : 25 cm x 5 cm.

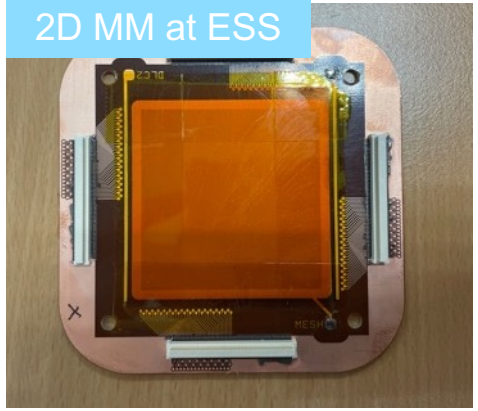
➢ In-vacuum variation possible

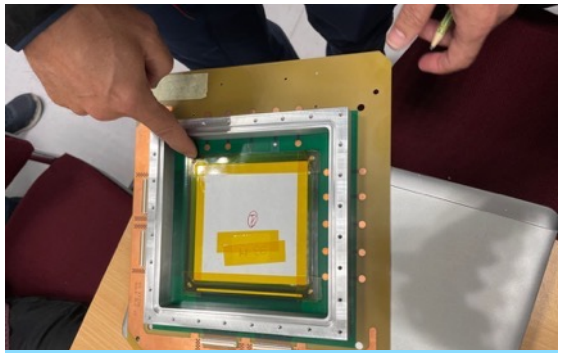
GEMINI at Utgård

Integration work at Utgård

Trying detector assembly at CERN

2D MM at ESS





Sample design for MM-1D

TBL-FREIA-MIRACLES-SKADI-TREX

NEXT STEPS: In-vacuum monitor
Performance testing

Tranche 1 instruments status

DREAM & LOKI →	• Not in CBMP ✓ Monitors ready • Integration with ESS DAQ on going • Need to discuss installation & maintenance plans • Included in CUP & CEP discussions
BIFROST →	✓ Monitors ordered and partially delivered • Integration with ESS DAQ on going • CEP updated, CUP started • Start of discussions with ECDC, DMSC, ICS
ESTIA →	✓ Monitor delivered ➢ Electronics to be defined • Integration with ESS DAQ on going • CEP updated, CUP started • Start of discussions with ECDC, DMSC, ICS
ODIN →	➢ Monitors defined ➢ Need to test I-BM's timing performance • Integration with ESS DAQ on going • CEP updated, CUP started • Start of discussions with ECDC, DMSC, ICS
TBL →	✓ Monitor 1 delivered – Monitor 2 being ordered ✓ Electronics delivered • Integration with ESS DAQ on going ✓ GEMINI Integration with Master Module done • CEP updated, CUP started • Start of discussions with ECDC, DMSC, ICS

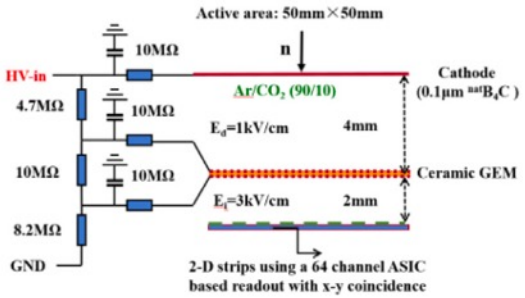
Topics to be addressed:

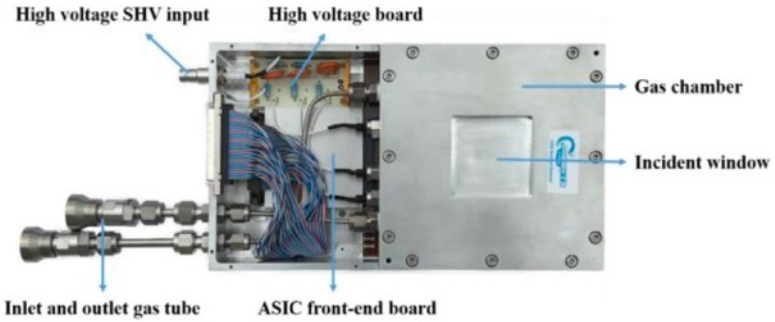
- ❑ Performance valuation for CDT monitors
  - ❑ I-BM noise levels for ~50m cables important
  - ❑ Tests for vibration and sound induced noise levels in I-BMs
- ❑ Radiation hardness valuation for in-bunker monitor components
- ❑ Micromegas-based monitors testing
- ❑ Rack positions for in-bunker monitors
  - ❑ Both for in-CBMP and out-of-CBMP instruments
- ❑ Position of in-bunker electronics for two type of monitors (ESTIA, BIFROST)
- ❑ Integration with ECDC, DMSC, and ICS
- ❑ Strategy for instruments not in CBMP

NMX →	✓ Monitors defined • CEP updated, CUP to start • Start of discussions with ECDC, DMSC, ICS

Beam Monitor developments in other facilities

MPGDs for beam monitoring



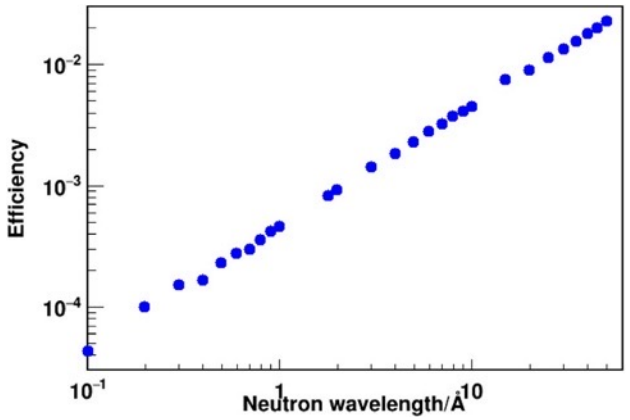


China Spallation Neutron Source

Their solution → Ceramic THGEMs

- Large area (253 mm x 144 mm x 39 mm)
- 2D PSDs
- Rate over 10 MHz
- Pulse mode operation
- CiPix based electronics

- High-flux pulsed neutron source (25 Hz)
- Power **100 kW**
- Beam monitor requirements
  - **Beam profiling** - 2D position sensitivity
  - Wavelength resolution
  - Counting rate over 1 MHz
  - Long term stability



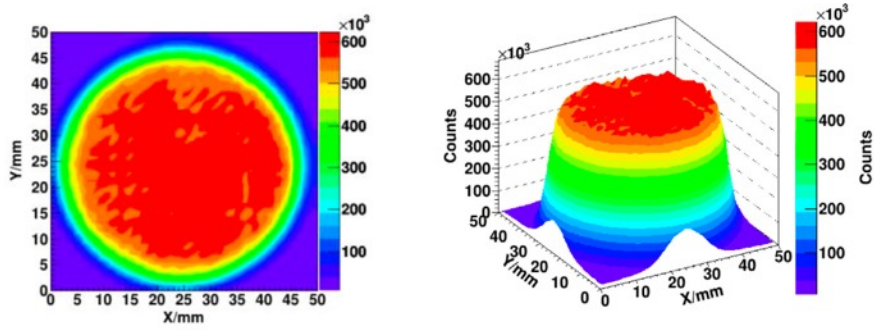


Fig. 5. First neutron beam profile at SANS.