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# Status and deployment plans for EMU and NPM

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for

ESS Lund: BD and ICS Teams

CEA Saclay Team

ESS Bilbao Team

European Spallation Source ERIC

BI Forum 23 Oct, 2019

# Overview



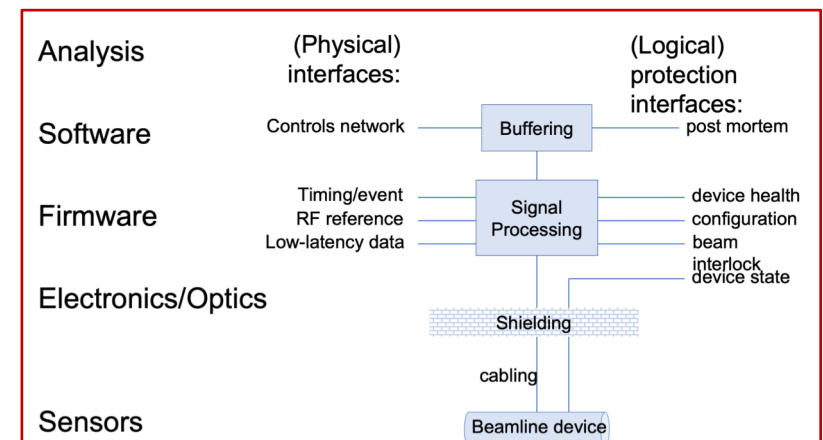
## – Emittance Measurement Units (EMU)

- Allison Scanner (AS) for LEBT
  - x 1 (H, V)
- Slit and Grid (SG) for MEBT
  - x 1 (H, V)

## – Non Invasive Profile Monitors (NPM)

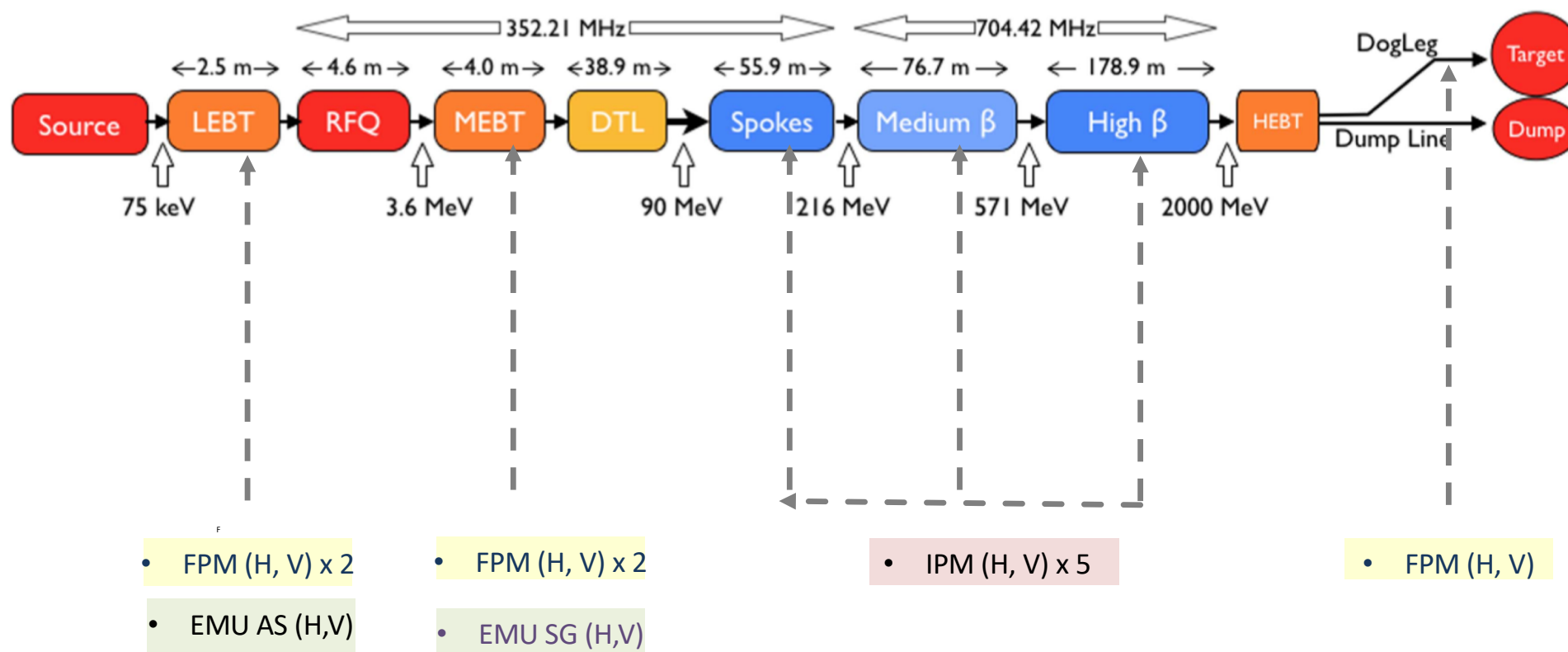
- Fluorescence Profile Monitor (FPM)
  - x 2 (H, V) @ LEBT
  - x 2 (H, V) @ MEBT
  - x 1 (H, V) @ A2T
- Ionization Profile Monitor (IPM)
  - x 1 (H, V) @ SPOKE
  - x 2 (H, V) @ MB
  - x 1 (H, V) @ HB

## Beam instrument architecture, interface



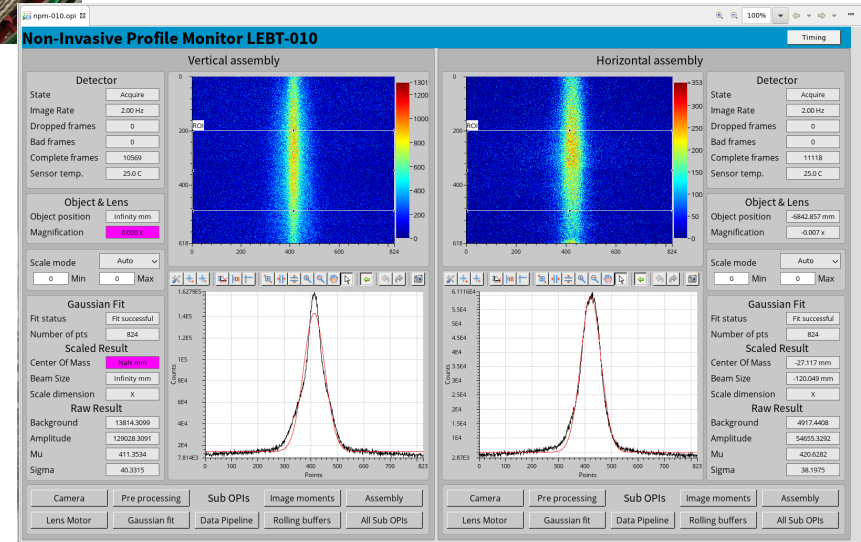
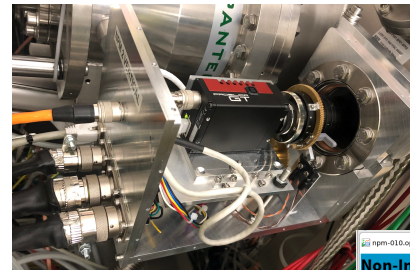
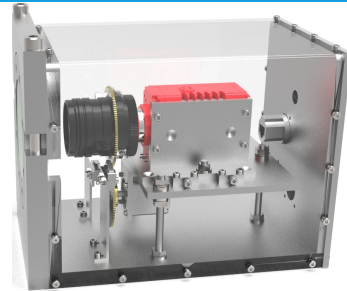
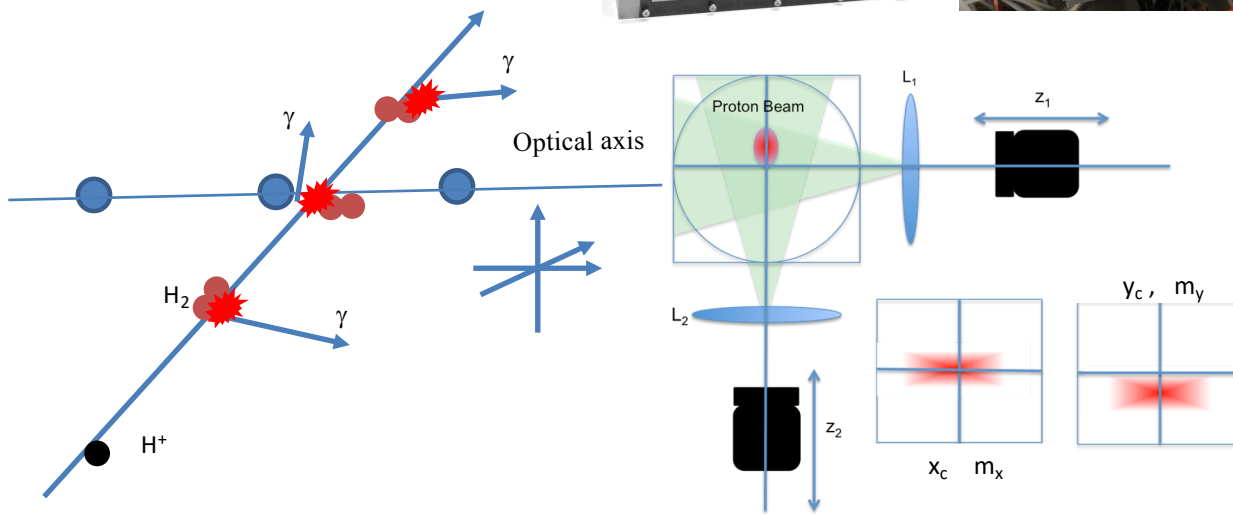
# EMU and NPM over ESS Linac Layout

NPM and EMUs provide information of particle beam distribution and position along entire normal and superconducting linacs.



# NPM . Fluorescence Profile Monitor

FPM is being used for beam position and possibly angle and emittance measurement.



FPM @ ESS LEPT

FPM operation principle

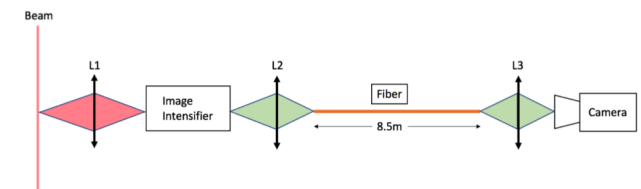
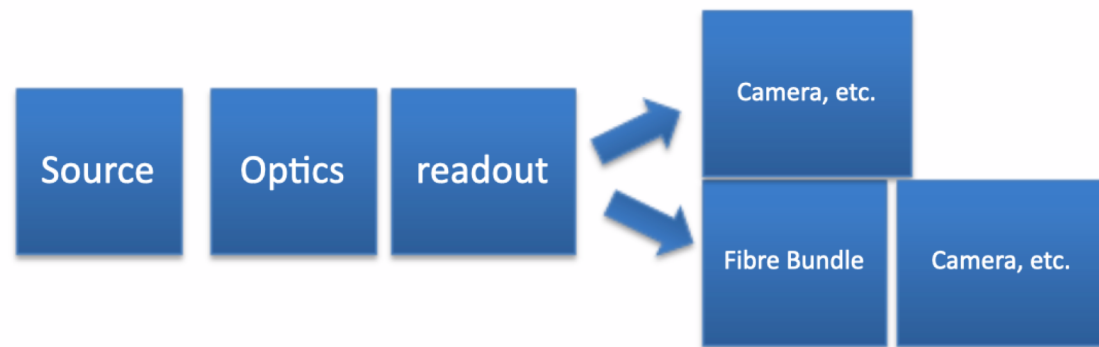
Transverse beam position measurement @ LEPT

# NPM. Fluorescence Profile Monitor

FPM is commissioned and aligned in LEBT and the light transport schemes for MEBT and A2T are under final test.



- Fiducialization of optical axis
- Knowledge of sensor distance to the focal plane: magnification
- Alignment of the camera with beam axis reference:  $30\mu\text{m}$  accuracy



*Maria Hoflund, Master thesis,  
'Single Photon Imaging System for the ESS Linac' 2019*

# NPM. Fluorescence Profile Monitor

FPM is capable of measuring position, angle and size of the beam.

Image analysis: Gaussian fit returns:

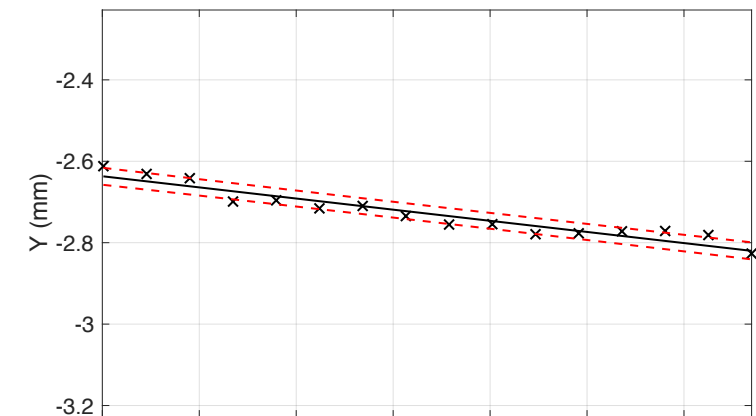
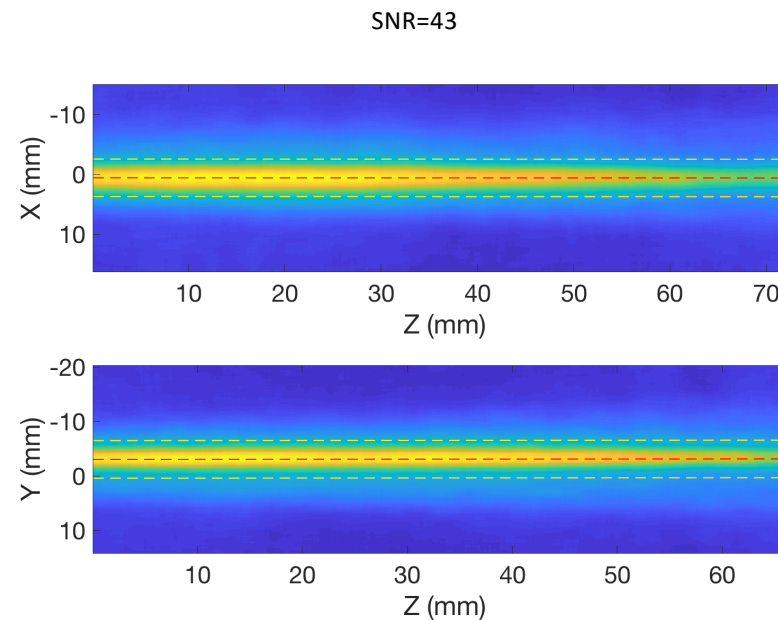
- centre
- Width
- Intensity
- Background

Centre trajectory: linear fit

- Position
- Angle

Width trajectory: quadratic

- Divergence
- Emittance



*Model of an NPM image with ESS LEBT beam parameters.*

# NPM. Fluorescence Profile Monitor

Beam position angle can be measured with ESS required precision.

(0.1 mm position accuracy)



## Statistical measurement errors

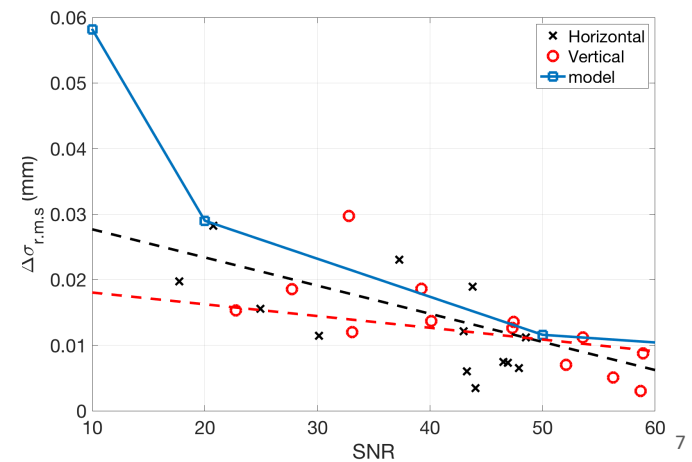
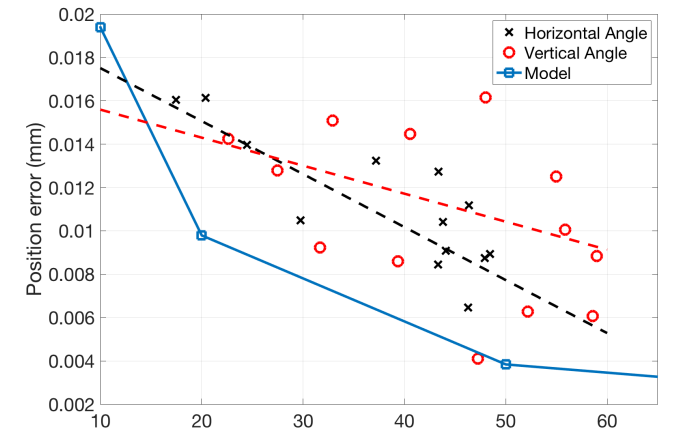
### Model:

- Generate NPM image with noise
- Perform Gaussian fit along Z
- Compare results to set beam conditions

### Measurements:

- Acquire set of images
- Measure beam characteristics
- Extract statistical variation

*Standard deviation of the beam size measurement as function of the SNR*

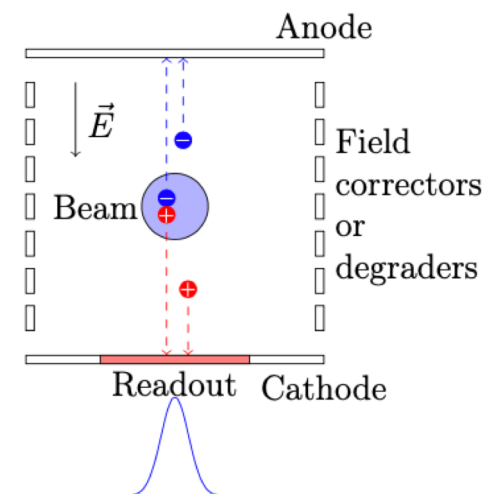


# NPM . Ionization profile Monitor

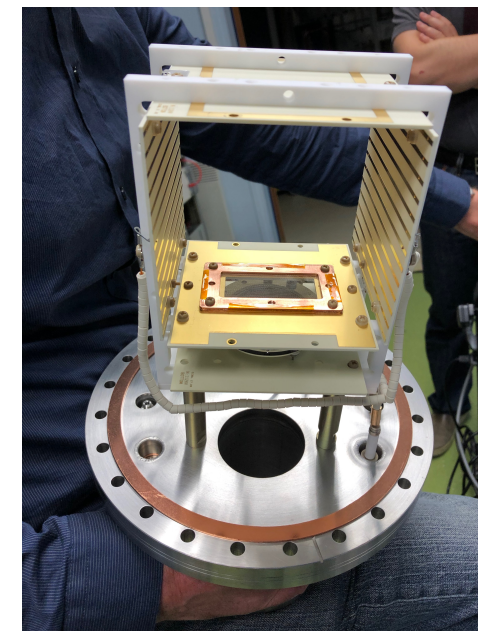
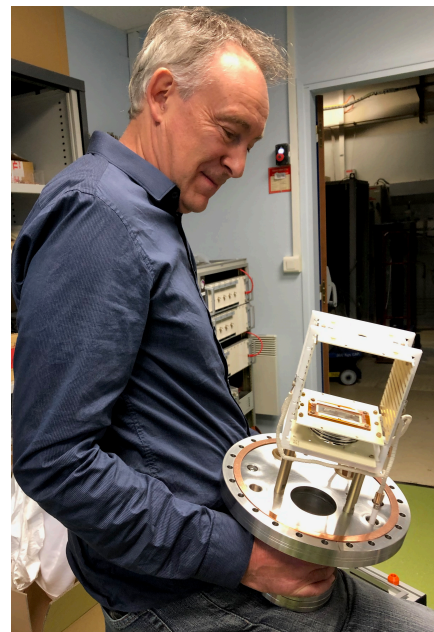
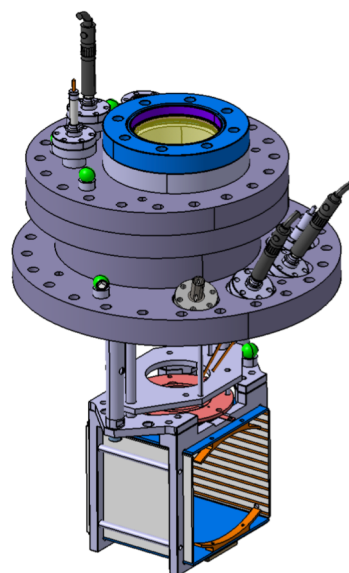
Pair of IPM will be used to measure the transverse beam profiles in transverse direction.



## IPM operation principle



## IPM developed at CEA for superconducting linac



Tests @ IPHI will be presented by Francescas, today.

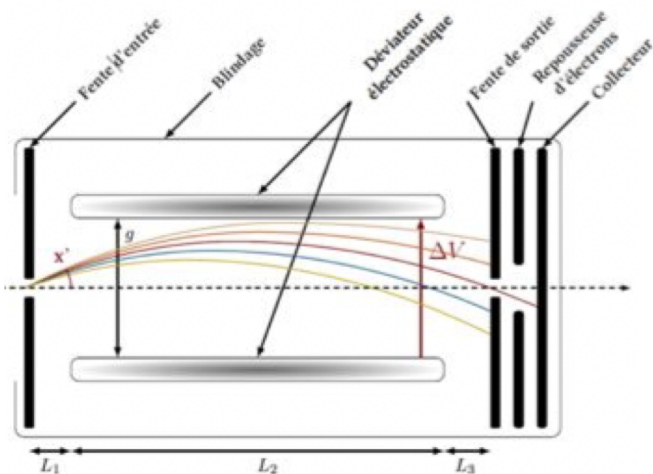


# LEBT Emittance Measurement Unit (EMU Allison Scanner)

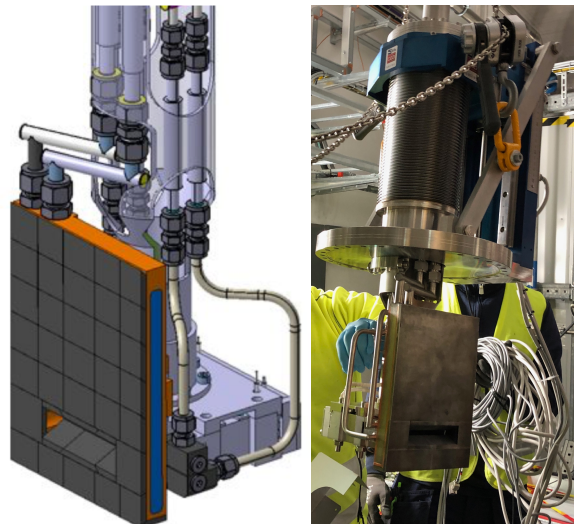
The Allison Scanner (AS) has been developed to measure the transverse emittance of low intensity beams at LEBT 70keV.



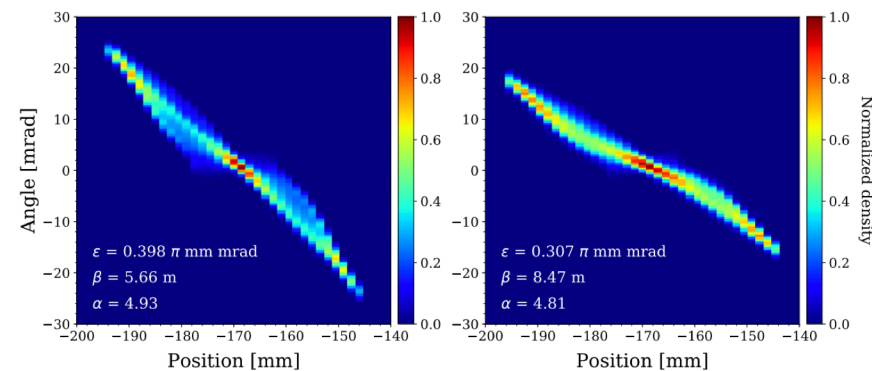
## EMUAS operation principle



## AS developed at CEA for ESS LEBT @ 70 keV



## Measured emittance at LEBT, 2019



# LEBT Emittance Measurement Unit (EMU Allison Scanner)

Progressive works are on going to improve performance of EMU AS, since BI Forum 2018.



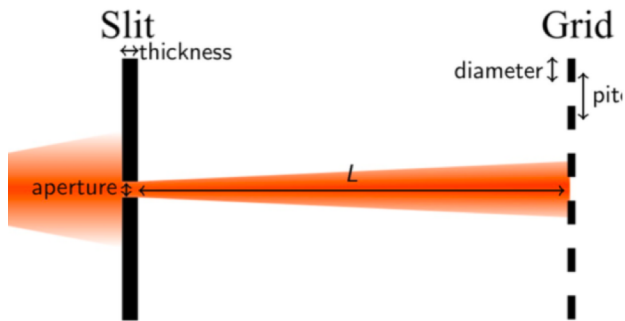
- Second axis (vertical) shielding box redesign
  - Development of collision protection with the FC at LEBT-01 location
  - Second axis installation on the beam line at ESS
  - Debug of the control system to obtain emittance measurement in the first commissioning phase (ISRC-LEBT 2019) ->
    - Porting of motion to ECAT
    - Change of long haul HV cable and in-rack control cables
    - Front End verification
- > Lead to a partially validated system
- > ToDo list is still long (full porting to mTCA etc)

# MEBT Emittance Measurement Unit (Slit and Grid)

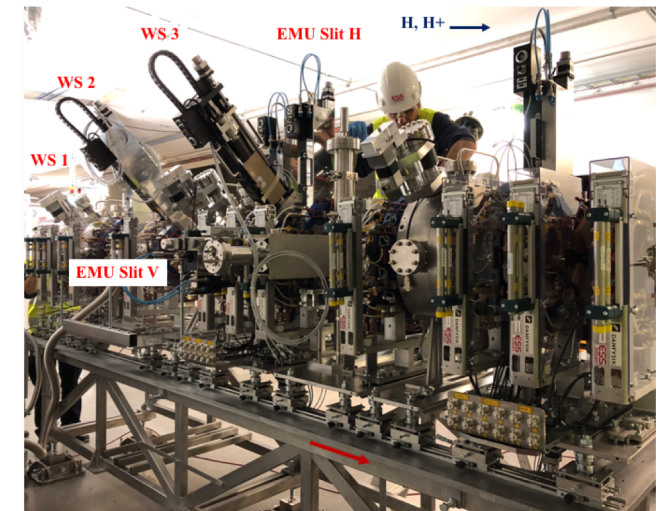
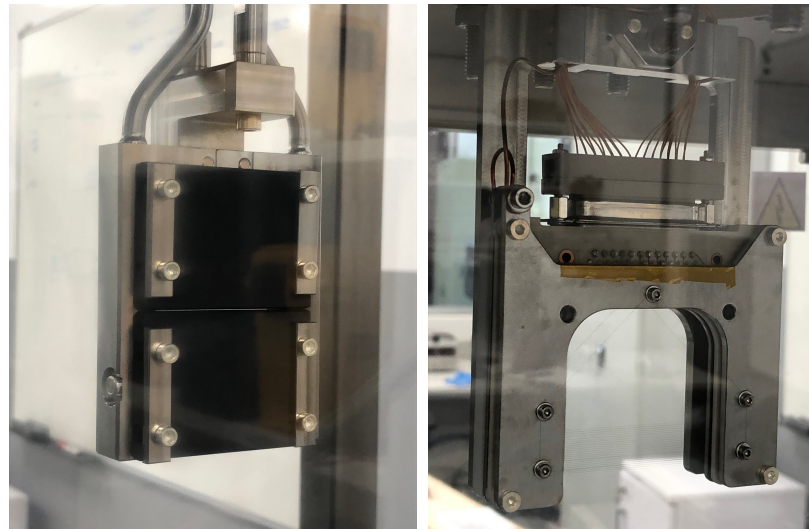
MEBT EMU is composed of slit and grid subsystems for the measurement of the phase space in the transverse directions.



## EMUSG operation principle



## AS developed at ESS Bilbao for ESS MEBT @ 3.65 MeV



## MEBT EMU (timeline)

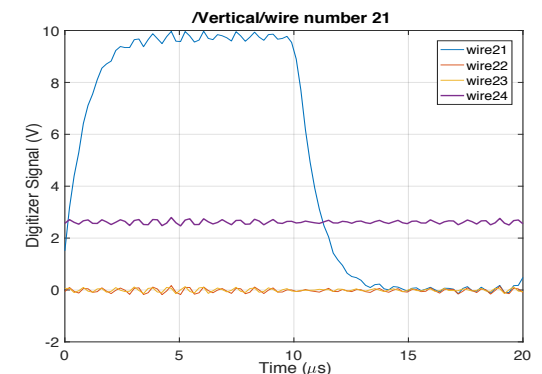
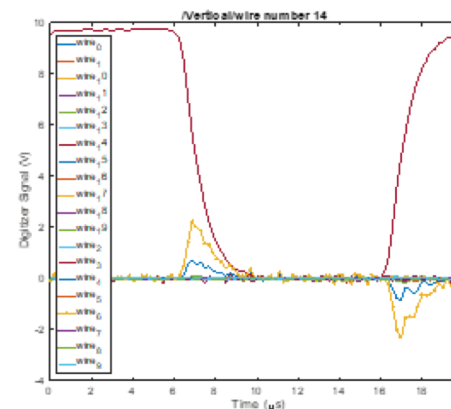
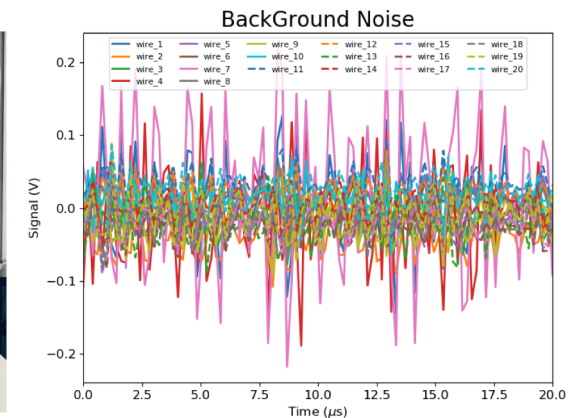
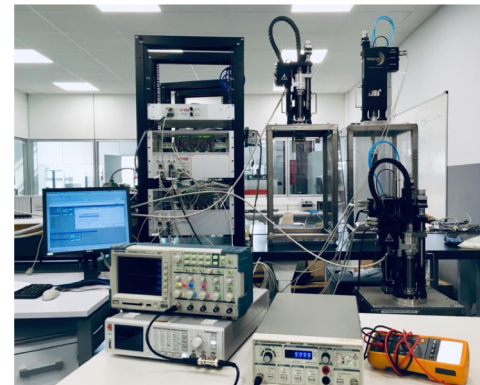
- Vertical Integration test at ESS Bilbao
- SAR at ESS Bilbao
- Reception tests in Lund on-going

# MEBT Emittance Measurement Unit (Slit and Grid)



Vertical Integration Test (VIT) showed cross talks, offset and noise in some channels that may be perturbing the emittance measurement.

- EMI VIT: Bilbao February 2019 (ESS-1066570)
- Motion Tests
- Back-End Test (Bias Voltage)
- Signal Integrity
  - $I_{in}$  100  $\mu$ A input  $\rightarrow$   $V_{out}=10$  V
- 24 Channels Checked
  - Both ADC3117 FMCs must be synchronized
  - Channel 24 shows an offset
  - Cross talking in some channels
  - Noise higher in some channels (from 20 to 100 mV)
- Test Signals
  - 0.5 V output
- PLCs

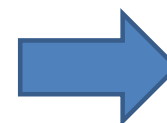
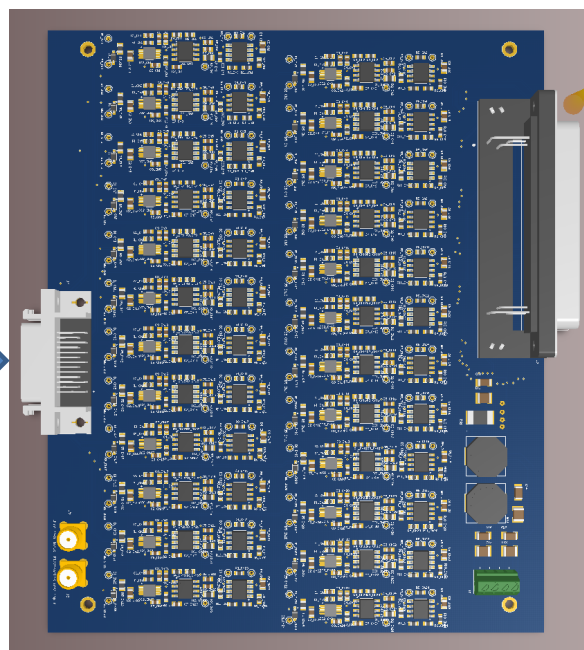
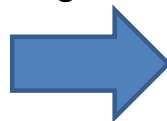


# MEBT Emittance Measurement Unit (Slit and Grid)

MEBT EMU Front-End upgrade: An upgraded AMC is under test to lower the electronic induced noise.

- During the MEBT SAR it has been reported by ESS Lund and Bilbao that the EMU Front-end had asymmetrical channels and some modifications and improvements were needed (crosstalk, noise higher in some channels, offset in some channels).
- Front-end has been evaluated and ESS Lund is collaborating on the upgrade of the design to try to solve these issues.

24 ch current inputs from grid  
200 nA – 200 uA  
2 MHz bandwidth

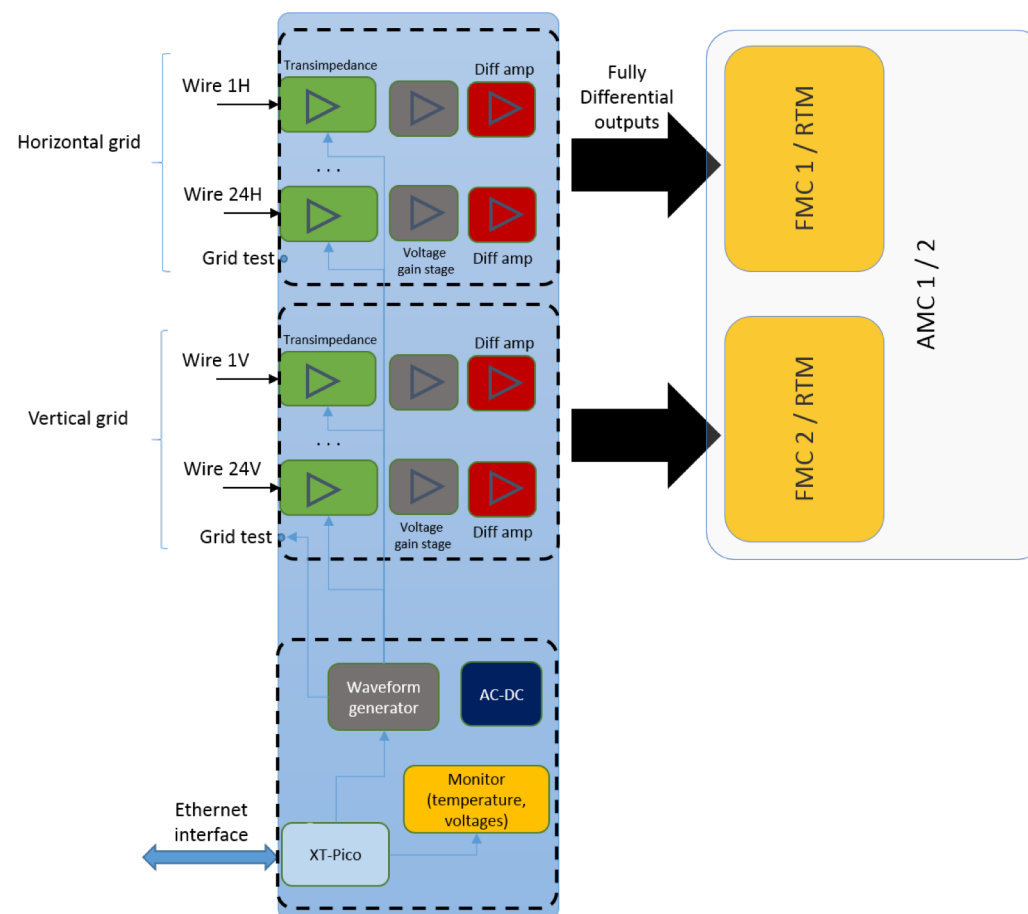


Fully differential outputs  
To FMC

# MEBT Emittance Measurement Unit (Slit and Grid)

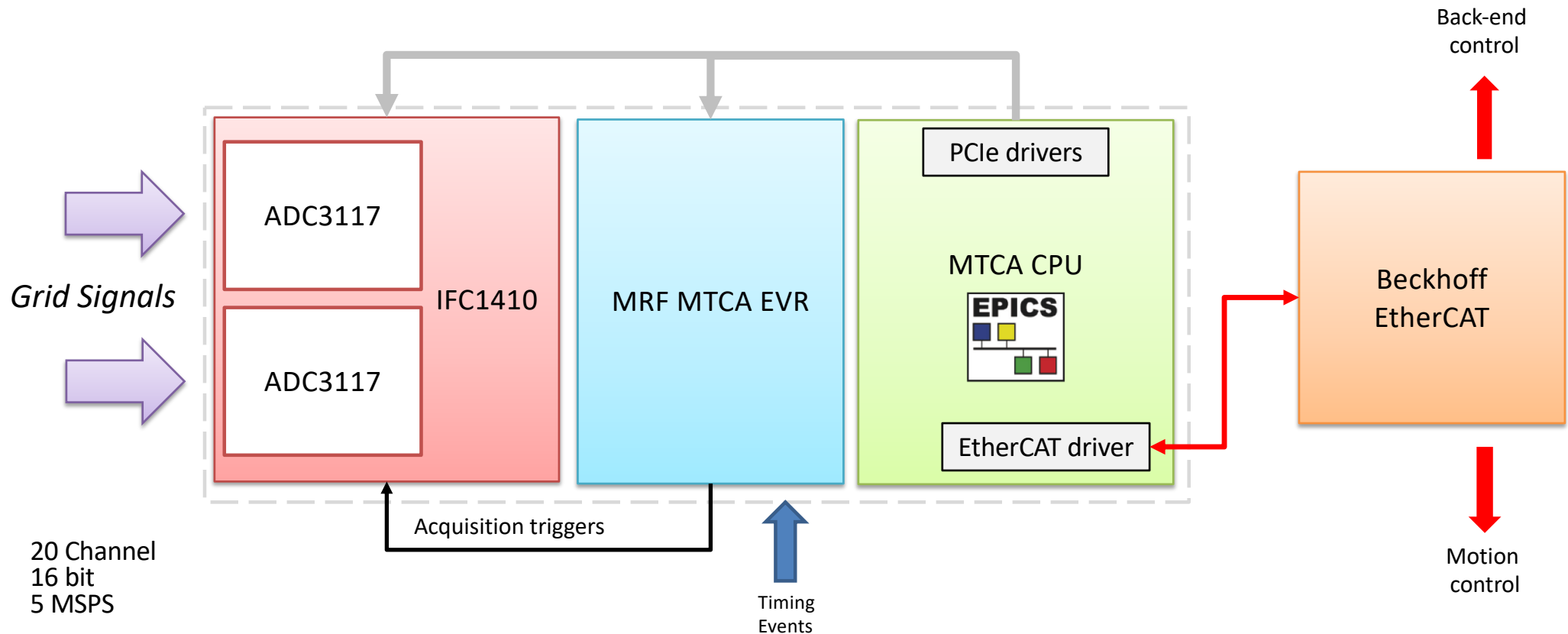
MEBT EMU Front End Upgrade: 2 AMC boards are proposed to process the 24 analog signals from each transverse wire grids.

- Prototype for 24 channels input.
- 2 AMC boards can be used with an additional cable from grid to rack.
- At this stage, adding more complex electronics increases the risk of issues.
- One AMC for horizontal grid, 1 for vertical grid.



# MEBT Emittance Measurement Unit (Slit and Grid)

The architecture of control System Hardware and Digitizers is shown – MicroTCA platform with 3 AMC boards (Digitizer, Even Receiver and CPU).



# MEBT Emittance Measurement Unit (Slit and Grid)

The EPIC driver for digitizer board is being adapted to use the same module as Struck card, leading to a transparent EPICS layer between all hardware.

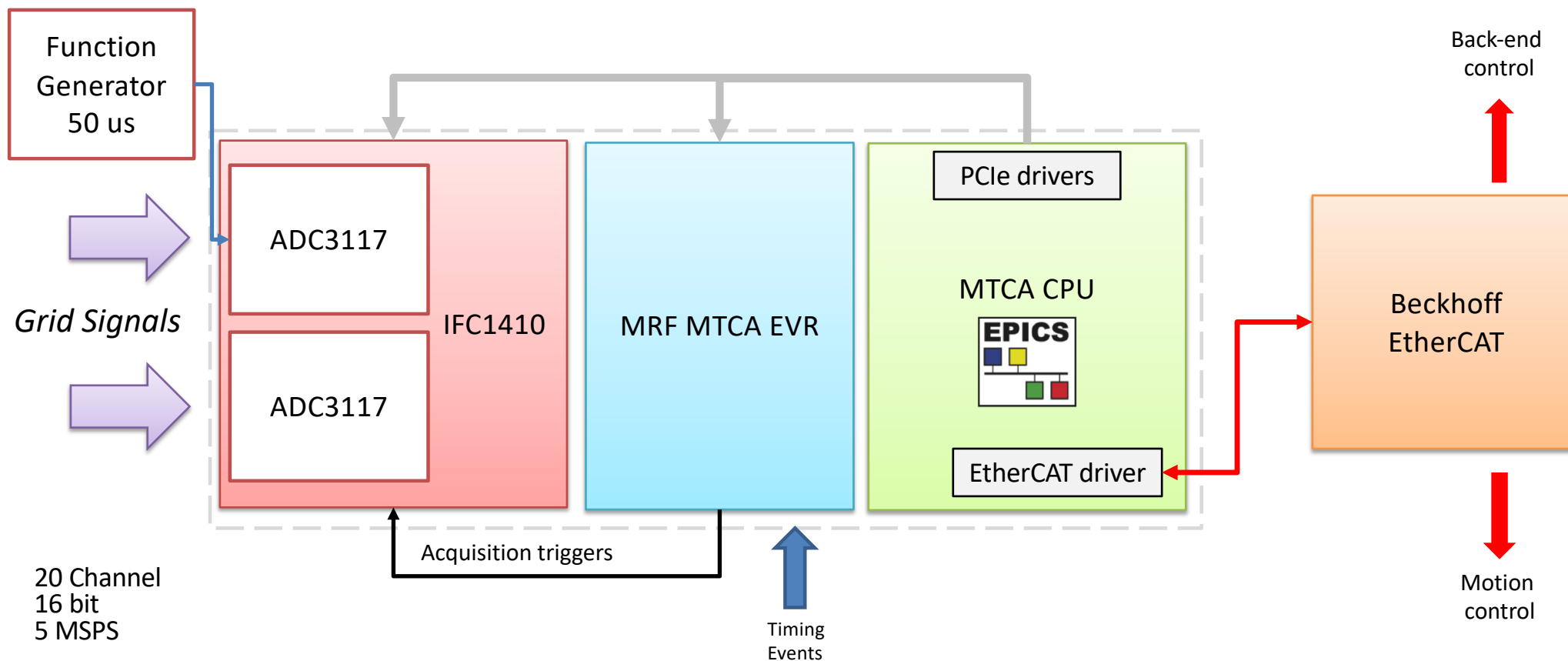


- In-house (ICS) firmware development for IFC1410 + (2x) ADC3117;
  - Integration with the timing system: backplane triggers;
  - Synchronized acquisition for all 40 analog channels;
  - Interrupts to MicroTCA CPU when acquisition done;
  - Acquisition buffers capable of acquiring ~2000 points at 5 MSPS (~410 us);
- New EPICS data acquisition module based on AreaDetector;
  - Same set of PVs and operation as the Struck SIS8300 EPICS drivers;
  - Already integrated in E3 (ESS EPICS Environment);
- Next step: develop the EMU IOC to automate the scanning procedure;
  - Based on EPICS SSCAN record (most used framework across EPICS community);
  - First version already developed by ESS Bilbao;



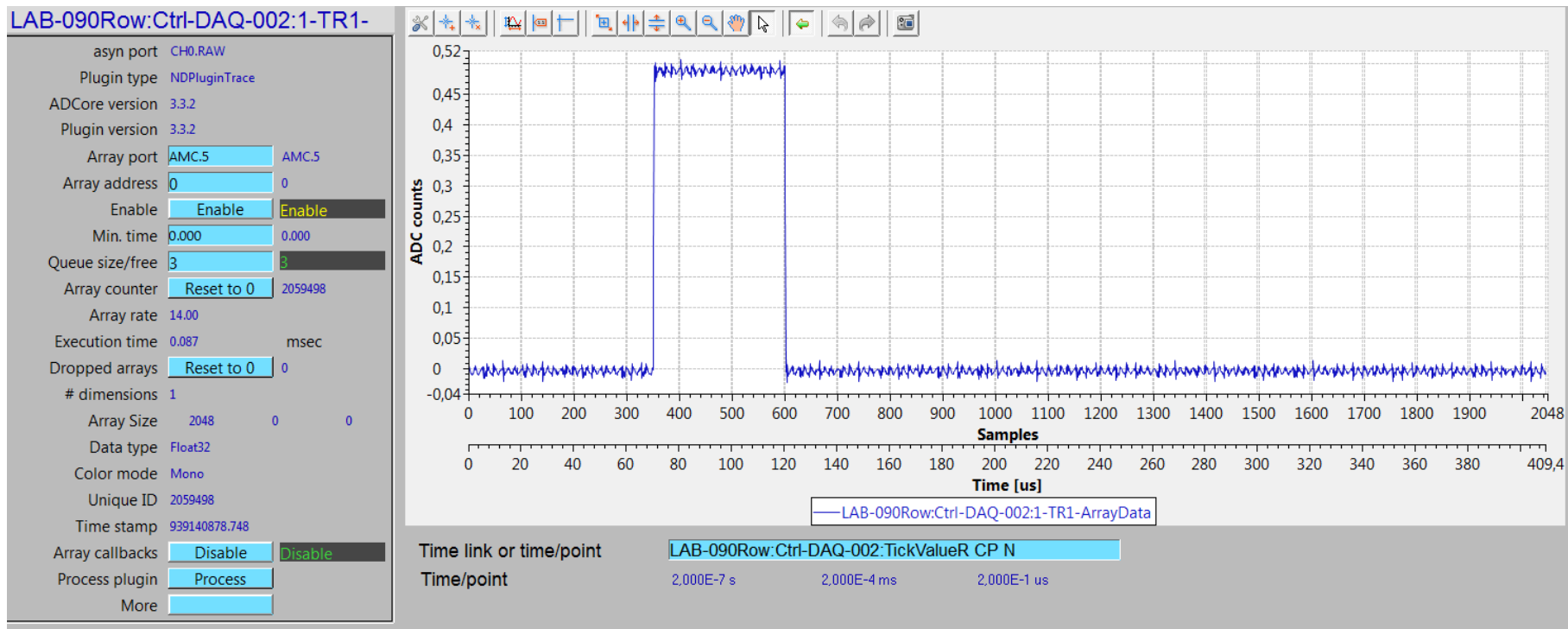
# MEBT Emittance Measurement Unit (Slit and Grid)

A 50 us pulse from a function generator directly to the digitizer; Acquisition is synchronized using the backplane triggers generated by the EVR.



# MEBT Emittance Measurement Unit (Slit and Grid)

Screenshot of an OPI showing that the IFC1410 EPICS IOC driver now is based on AreaDetector and can acquire 24 analog channels synchronously.



All the functionalities present on the Struck EPICS IOCs are present on the IFC1410 IOC.

# Summary

Status of NPM and EMU instruments (as for today 23 Oct 2019).

Verified On going Not started yet



## EMU - Allison Scanner

Task	LEBT
Design	
Hardware	
Firmware	
Software	
System Integration	

## EMU - Slit and Grid

Task	MEBT
Design	
Hardware	
Firmware	
Software	
System Integration	

## FPM

Task	LEBT	MEBT	A2T
Design			
Hardware			
Firmware			
Software			
System Integration			

## IPM

Task	Spoke	MB	HB
Design			
Hardware			
Firmware			
Software			
System Integration			

# Beam diagnostics confluence page

<https://confluence.esss.lu.se/display/BIG/Beam+Diagnostics+Home>



Browser address bar: <https://confluence.esss.lu.se/display/PBIEMUSG>

Navigation: Management, Accelerator, Target, ICS, Science, CF, Safety & Quality, Support, ESS Installation

## PBI Slit and Grid

Dashboard

### PBI Emittance Measurement Unit (EMU - Slit and Grid)

Created by Hinko Kocevar, last modified by Roxana Tarkeshian on Oct 18, 2019

#### Objectives

The transverse phase space (horizontal -vertical) describe the distribution of particles in  $x$  and  $x'$  ( $y$  and  $y'$ ), position and angle between particle trajectory and  $z$  axis, respectively. The EMU SG aims to measure the transverse emittance by sampling the transverse phase space.

The slit is used to select particles within a narrow slice in position, then, in the following drift space, the angular distribution of the particles transmitted through the slit is transformed into a position distribution and sampled using a profile monitor, in our case a secondary emission grid. By scanning the slit across the beam, the whole phase-space is reconstructed.

#### EMU Operation Principle

#### EMU Slit - Grid

#### EMU Slit and Grid at ESS

	name	location	rack location	beam energy (MeV)	Installation status	Operation status
1	<a href="#">MEBT-010:PBI-EMU-001 (H Slit)</a>	MEBT-010	FEB-050Row:CnPw-U-011	3.6	IN	OFF
2	<a href="#">MEBT-010:PBI-EMU-001 (H Grid)</a>	MEBT-010	FEB-050Row:CnPw-U-011	3.6	IN	OFF
3	<a href="#">MEBT-010:PBI-EMU-001 (V Slit)</a>	MEBT-010	FEB-050Row:CnPw-U-011	3.6	IN	OFF
4	<a href="#">MEBT-010:PBI-EMU-001 (V Grid)</a>	MEBT-010	FEB-050Row:CnPw-U-011	3.6	OUT	OFF

#### SPACE SHORTCUTS

PBI Slit and Grid

#### PBI Emittance Measurement Unit (EMU - Slit...

- > A. Project Planning
- > B. Design and Development
- > C. Test and Implementation
- > D. Integration in the Beamline
- > E. Software Development and Control
- > F. Operation Guideline
- > G. Meeting
- > H. References
- > I. Photo Gallery
- > J. Jira Task

#### RELATED PEOPLE

- Roxana Tarkeshian  
System Lead
- Clement Derrez  
BD Contact
- Rafael Baron  
BD Contact
- Joao Paulo Martins  
ICS Contact
- Hinko Kocevar  
Software Integration
- Idoia Mazkarian  
IKC Partner
- Angel Rodriguez  
IKC Partner

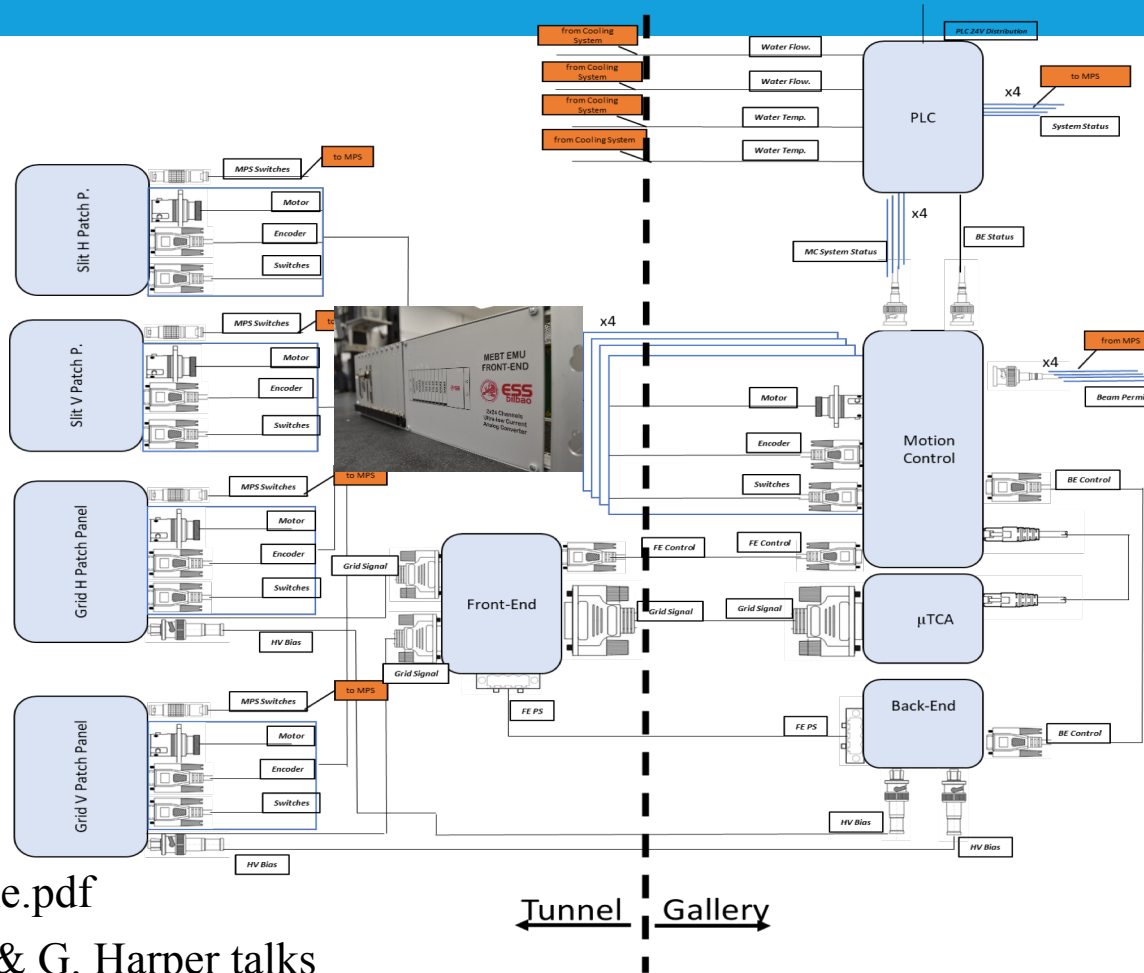
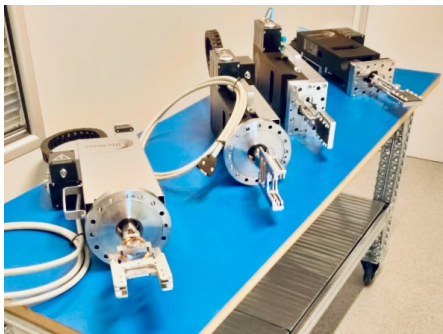
Thank you



# Appendix



# EMU Integration



\*EMU\_General\_Scheme.pdf

\*See also I. Mazkian & G. Harper talks