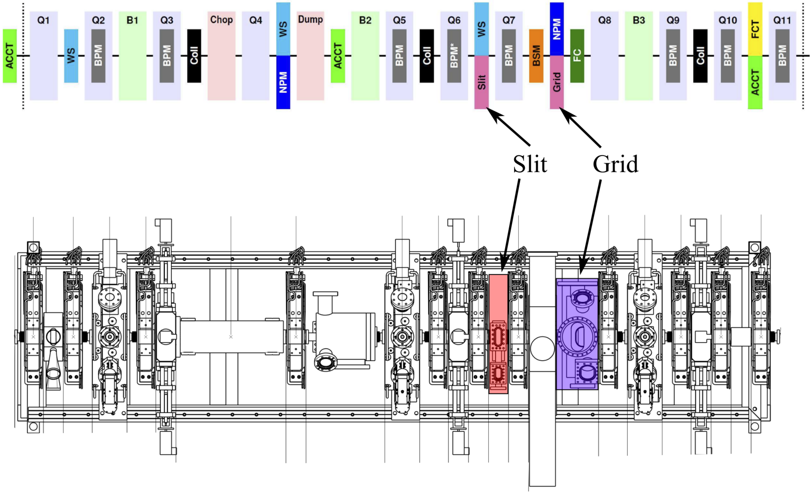
Emittance Unit Meter:
Bema Instrumentation Forum

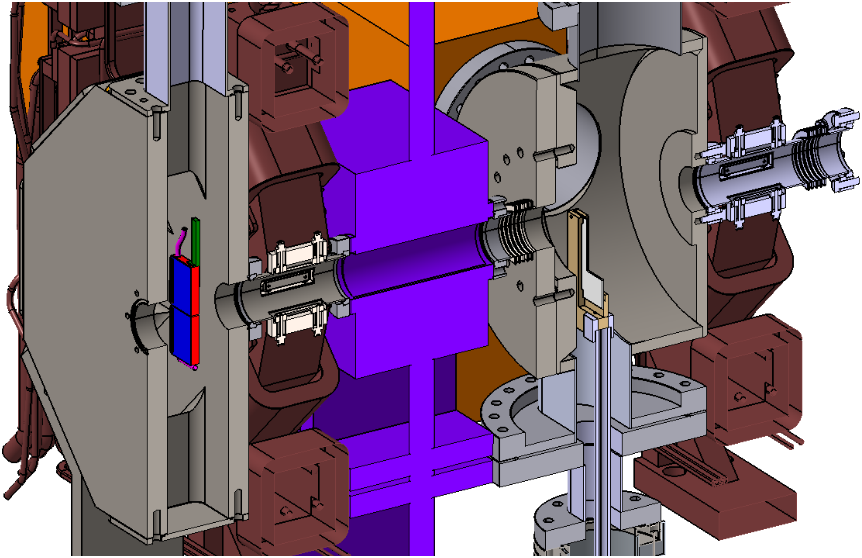
EMU Team
ESS-Bilbao
Beam Instrumentation Group
September 30, 2016

Part I

General overview


ACCT
Q1
WS
Q2
BPM
B1
Q3
BPM
Coll
Chop
Q4
WS
NPM
Dump
ACCT
B2
Q5
BPM
Coll
Q6
BPM*
WS
Slit
Q7
BPM
BSM
NPM
Grid
FC
Q8
B3
Q9
BPM
Coll
Q10
BPM
FCT
ACCT
Q11
BPM
Slit
Grid

Integration



Requirements

Two planes for the measurements

The transverse emittance containing 95 % of the beam shall be measured with a total measurement error of less than ±10 % of the measured value.

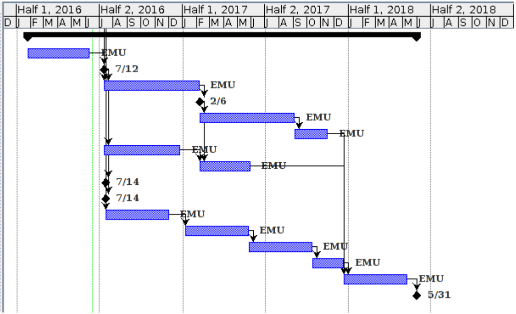
- Slit-Grid distance: 400 mm
- Wire-to-Wire distance 500 μm × 24 Wires = 115 mm
- Slit aperture and thickness referencee values: 100 μm and 200 μm
- Wire diameter and distance between wires (at measurement) with reference values: 20 μm and 100 μm.

The transverse RMS emittance shall be measured with a total measurement error of less than ±10 % of the measured value.

The transverse phase space measurement shall have a dynamic range of 1000.

Schedule

Name	Duration	Start
⊟EMU	614 da...	**1/25/16 8:00 AM**
EMU: Conceptual design	100 days?	1/25/16 8:00 AM
EMU: PDR	0 days?	7/12/16 8:00 AM
EMU: Detailed design	150 days?	7/12/16 8:00 AM
EMU: CDR	0 days?	2/6/17 5:00 PM
EMU: Manufacturing	150 days	2/7/17 8:00 AM
EMU: Test	53 days?	9/5/17 8:00 AM
EMU: Analog electronics detailed desigr	120 days?	7/12/16 8:00 AM
EMU: Analog electronics manufacturing	80 days?	2/7/17 8:00 AM
EMU: Software specification frozen	0 days?	7/14/16 5:00 PM
EMU: Hardware specification frozen	0 days?	7/14/16 5:00 PM
EMU: uTCA Environment	100 days?	7/15/16 8:00 AM
EMU: uTCA Setup	100 days	1/6/17 12:00 PM
EMU: EEE Integration	100 days	5/26/17 1:00 PM
EMU: EEE Application development	50 days	10/13/17 1:00 PM
EMU: Final tests and integration	100 days	12/22/17 1:00 PM
EMU: Delivery	0 days	5/31/18 5:00 PM



Part II

Slit

Beam Parameters

Two operational modes are studied:

- **Mode I: Fast tuning** is used for steady state analysis, the average power if 16 W, for pulses of 5 μs at 14 Hz.
- **Mode II: Slow Tuning** is used in the transients analysis. The coating materials has to withstand ~230 kW during 50 μs with a frequency of 1 Hz, for an average power of 11 W.

Table: Beam Parameters in the slit

Parameter	**Value**
Proton energy	3.63 MeV
Intensity	62.5 mA
Mode I: Fast Tuning	5 μs - 14 Hz
Mode II: Slow Tuning	50 μs - 1 Hz
Beam size (σ_x)	3.16 mm
Beam size (σ_y)	3.84 mm

Geometrical Constraints

The beam envelop is ϕ 40 mm, therefore the blades width has to be >40 mm, for a total height >80 mm.
For the slit, the reference values are an aperture of 100 μm and a slit thickness of 200 μm.

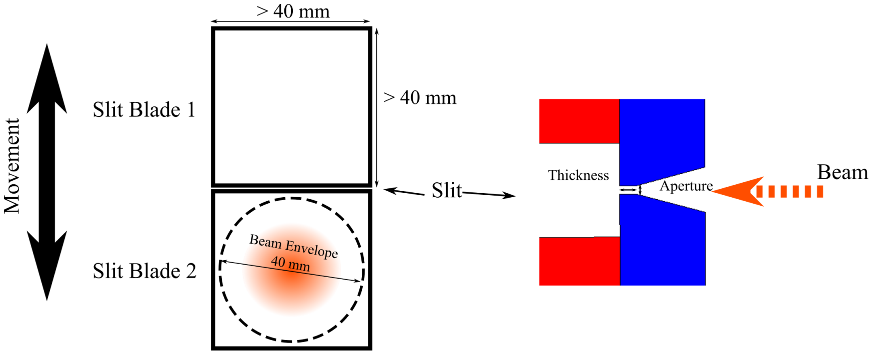


Figure: Scheme showing the geometrical constraints for the slit assembly.

Main Characteristics

Table: Main characteristics of the design of the EMU/Slit: materials and main dimensions.

Parameter	**Value**
Coating Material	Graphite
Substrate Material	Steel
Slit Angle	90°
Graphite Thickness	$\sim$ 1 mm
Substrate Thickness	$\sim$ 7 mm
Slit Blade Width	$>$40 mm
Slit Blade Height	$>$80 mm
Integrated Current Flux	4.1 $\mu\mathrm{C}\ \mathrm{cm}^{-2}\ \mathrm{pulse}^{-1}$

Materials

- Graphite is chosen due to its good thermo-mechanical properties, withstanding the high temperatures that appear during the irradiation pulse.
- Steel is chosen for the body due to its good manufacturing conditions.
    - Copper is selected as a secondary option for the substrate, in case of high thermal gradients.
- Graphite Stress Criterion (Rankine):
    - $\sigma_{max} < 2/3 \cdot \sigma_{T.S}$
    - $|\sigma_{min}| < 2/3 \cdot \sigma_{C.S}$

Table: Material limits for Graphite and Substrate.

Mat. Limit	**Graphite**	**Steel**	**Copper**
Melt Temp. ($T_{melt.}$)	3773 K	1700 K	1357 K
Tensile Yield Strength ($\sigma_{T.Y.S}$)	40 MPa	207 MPa	209 MPa
Comp. Yield Strength ($\sigma_{C.Y.S}$)	125 MPa	207 MPa	209 MPa

Note The 2/3 criterion is used for test stand slit in linac4.

Thermo-Mechanical Analysis

Case	**I” ($\mu C/cm^2$)**	ΔT	$\sigma_{int.}$	$\sigma_{int.}/\sigma_{Lim.}$
EMU/Slit	4.1	491	29	35 %

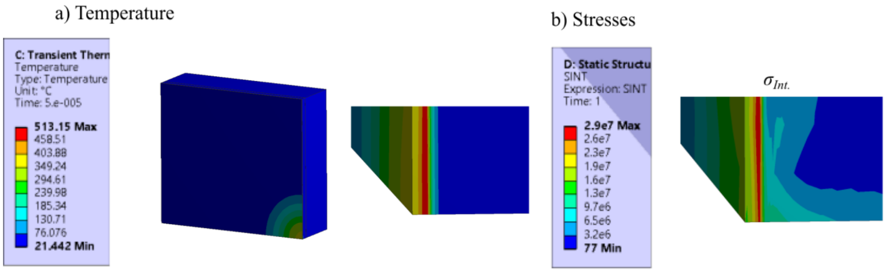
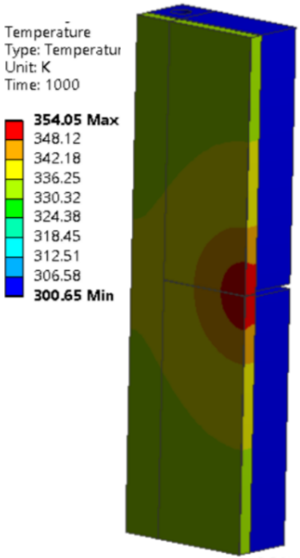


Figure: Temperature variation (ΔT) and stress intensity (σ) at the end of the pulse ($50\mu s$).

Steady State

- Thermal contact between graphite and steel body.
- Dependant on contact conductivity, roughness and microhardness
    - $h_c \cdot \frac{\sigma_c/m_c}{k_c} = 1.25 \cdot (\frac{P}{H_c})^{0.95}$
    - Contact Pressure ∼1 MPa, Force 250 N
- Steady State attained in ∼ 300 s
- Low temperature gradient (<100 K)
- Low stresses (∼1 MPa)
- Small Deformations (1-10 mm)



Preliminary Design

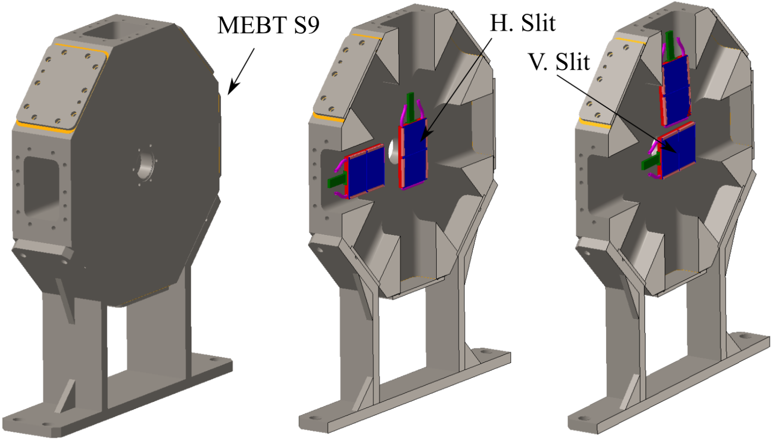


Figure: Horizontal and Vertical Slit distribution in the S9 Vessel of the MEBT.

Preliminary Design

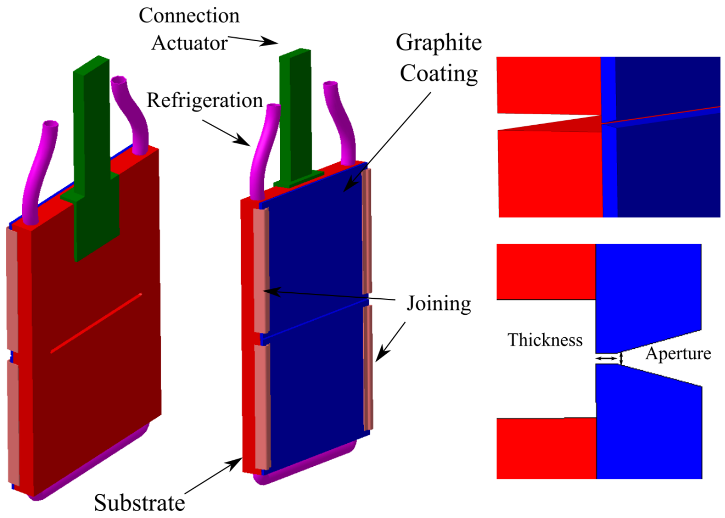


Figure: Sketch with the different parts of the slit assembly.

Summary

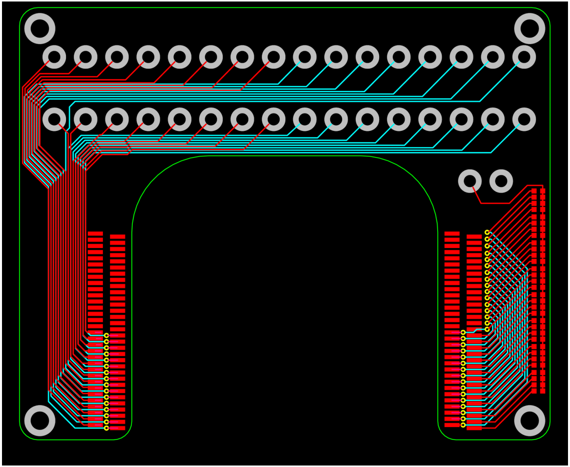
Table: Summary of the operating conditions in the slit.

Parameter	Value
Proton energy	3.63 MeV
Intensity	62.5 mA
Mode I: Fast Tuning	5 μs - 14 Hz
Mode II: Slow Tuning	50 μs - 1 Hz
Beam size (σ_x)	3.16 mm
Beam size (σ_y)	3.84 mm
Integrated Current Flux (I_I'')	4.1 μC cm^{-2} pulse^{-1}
Peak Power	227 kW
Avg. Power	16 W
Temperature Variation (ΔT)	491 K
Tensile Stress ($\sigma_{max.}$)	7 MPa
Comp. Stress ($\lvert\sigma_{min.}\rvert$)	29 MPa

Part III

Grid

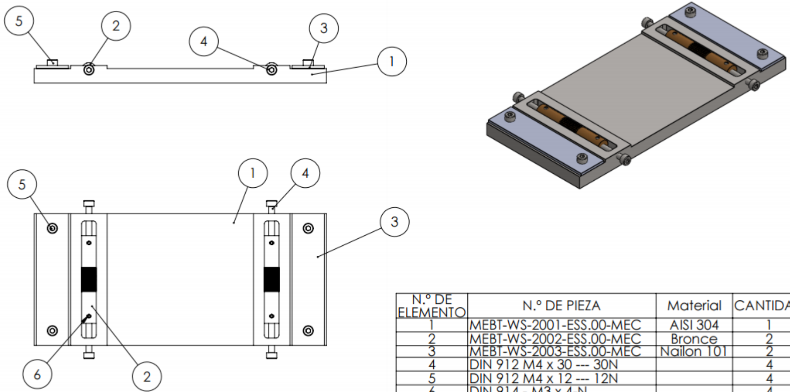
PCB Prototype Design



The main characteristics of the prototype design are:

- Mechanical unions of signal cables with screws.
- PCB design in two faces.
- 24 Wires
- 500 micrometers distance between wires
- Ceramic PCB
- Additional calibration resistors integrate on design

PCB Design – Wires alligment tool



N.° DE ELEMENTO	N.° DE PIEZA	Material	CANTIDAD
1	MEBT-WS-2001-ESS.00-MEC	AISI 304	1
2	MEBT-WS-2002-ESS.00-MEC	Bronce	2
3	MEBT-WS-2003-ESS.00-MEC	Nailon 101	2
4	DIN 912 M4 x 30 --- 30N		4
5	DIN 912 M4 x 12 --- 12N		4
6	DIN 914 - M3 x 4-N		4

Acabado

rebarbar y romper aristas

Tolerancias generales en roscas DIN 13: 6H • 6g

Tolerancias dimensionales generales: ISO 2768 • 1(m)

Lineales

> ≤ tol	0.5 6 ±0.1	6 30 ±0.2	30 120 ±0.3	120 400 ±0.5	400 1000 ±0.8	1000 2000 ±1.2	2000 4000 ±2

radio/chaflán

> ≤ tol	0.5 3 ±0.2	3 6 ±0.5	6 - ±1

ángulo

> ≤ tol	0 10 ±1°	10 50 ±30'	50 120 ±20'	120 400 ±10'	400 - ±5'

Tolerancias geométricas generales: ISO 2768•2(K)

Medidas en milímetros

Rugosidad

Ra	50	12.5	6.3	3.2	1.6	0.8	0.4	0.2

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	Nombre	Fecha
Diseñado	A. Zugazaga	12/11/2014
Dibujado	A. Zugazaga	20/11/2014
Verificado		
Aprobado		

ESS bilbao

P.T. Zamudio
c/ Laida Bidea 201, Pab 4
48170 ZAMUDIO (Bizkaia)
tel: 946076855
www.essbilbao.org

MATERIAL:

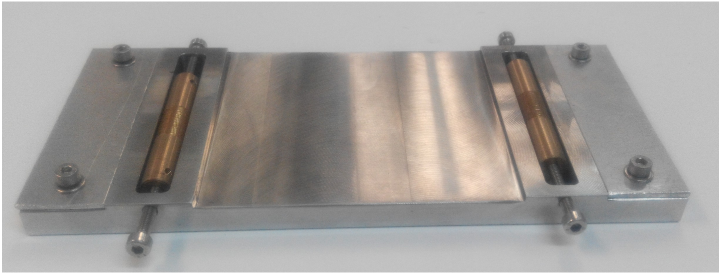
PESO (g): 1485.09

TÍTULO: Wire Tensor Tool

N.° DE DIBUJO: MEBT-WS-2000-ESS.00-PCK

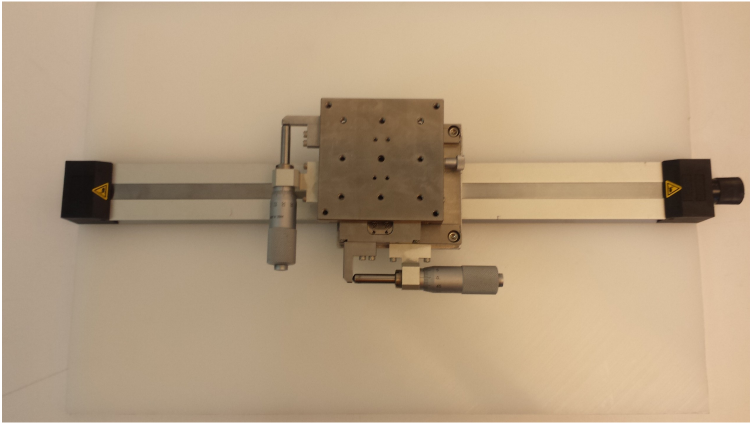
A4

PCB Design – Wires alignment tool



PCB Design – Micrometer table

A X-Y Micrometer table will be used to move the final PCB under the fluid dispenser and glue the wires one by one on position. This table is shown in the picture.



Part IV

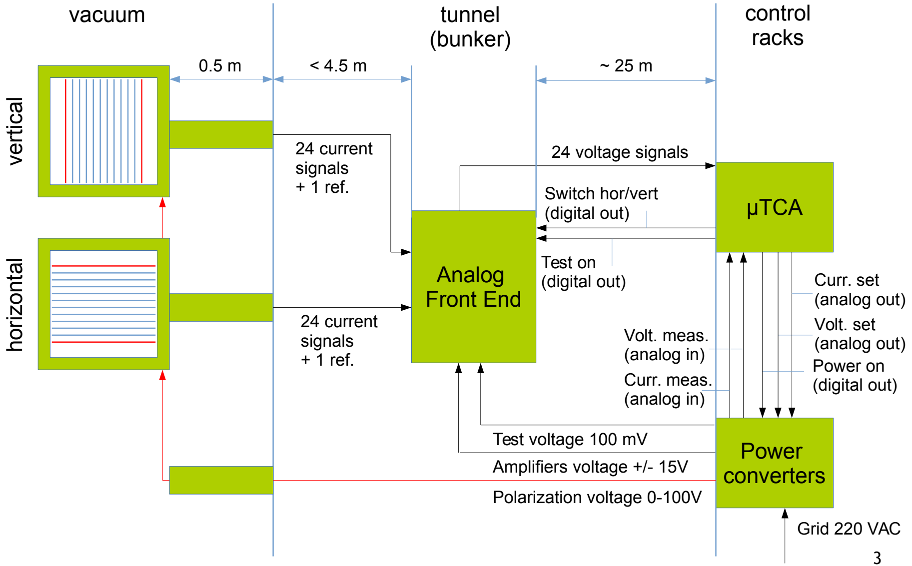
Signal conditioning

Design Parameters

Number of channels	24 (switched vertical/horizontal)
Peak current	100 µA
Dynamic range	1000
Beam mode 1	50 us & 1 Hz
Beam mode 2	10 us & 14 Hz
Sample frequency	>= 1 MHz
Output voltage range:	+/-10 V
ADC Resolution	16 bits
Self test	Online checking for wire integrity
Polarization power supply	0 to 100 V

2

General Scheme



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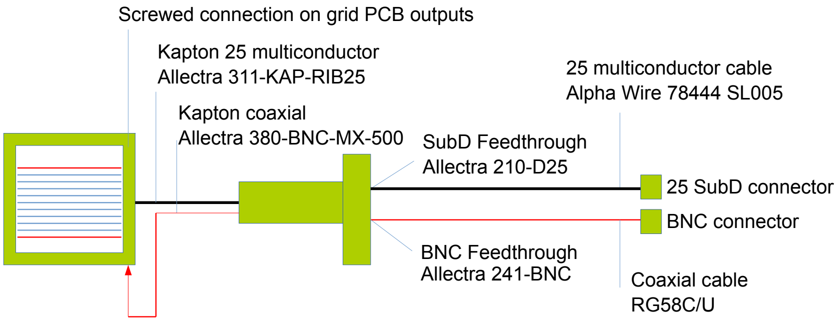
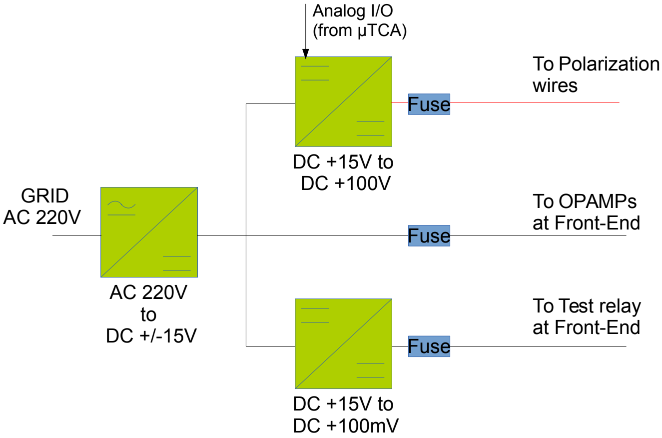
Cabling and connections



4

Power converters enclosure



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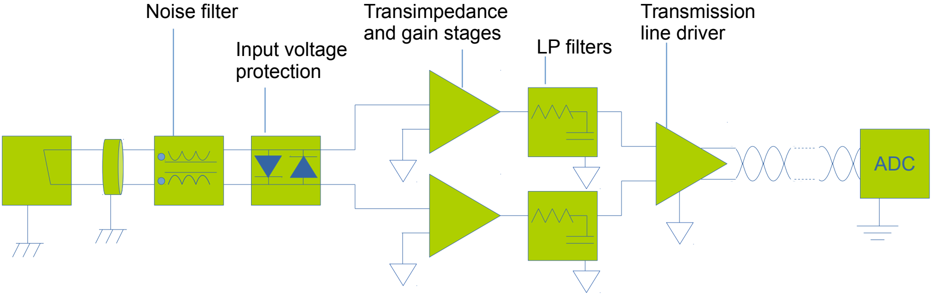
Front-end signal conditioning



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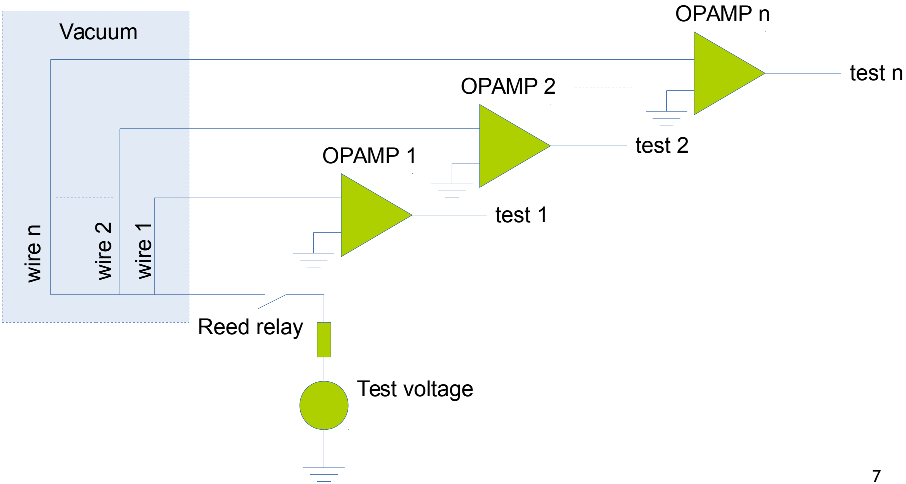
Wire checking and calibration system



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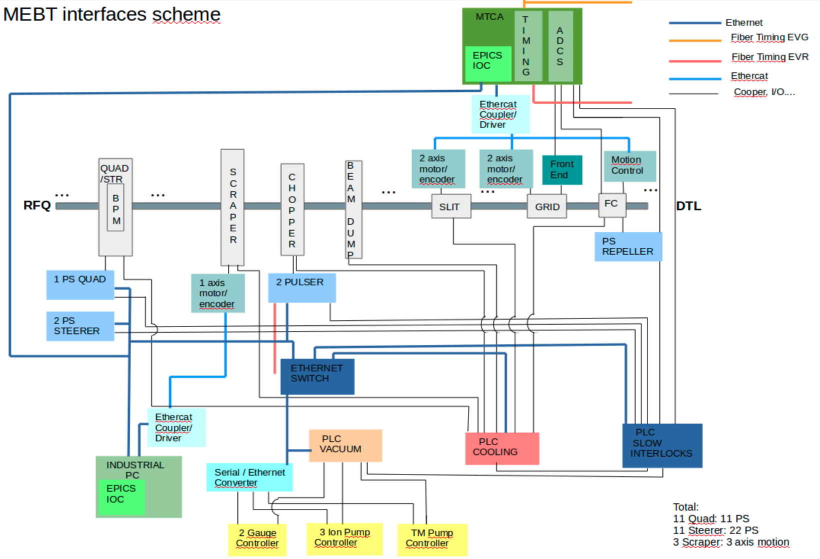
Part V

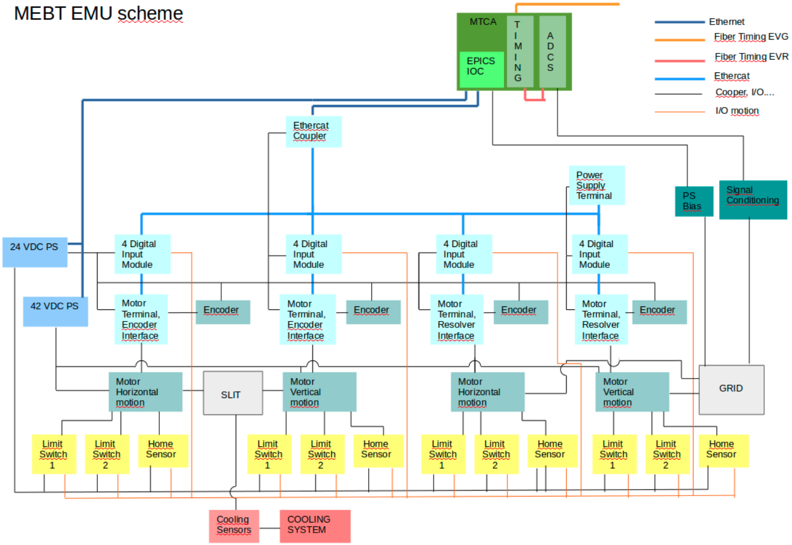
Control & Acquisition

HW General Interface Layout



HW General Interface Layout

MEBT EMU scheme



HW description

- Main systems in the EMU are controled by a µTCA chasis:
  - Motion Control:
    - Bus ethercat
    - Lineal motion and incremental encoders, two limint switches and one home sensor for each movement axis.
  - Power supply control for motion control feeding
  - Analog front-end interrelation for signal conditioning: amplify the signal before being digitazed. Also a front-end feeding power supply is controlled. A BIAS voltage is applied to the grid.
  - Inserted in the crate are Event Receiver Timing board and Analog to Digital Sample Acquisition board.
  - Beam Interlock System will be also considered, mainly for EMU power supplies, two extra limit switches, slit over temperature...

- Actual developments based on VME HW platform.

SW Description (1)

The control will base following the EEE’s recommendation.

Drivers needed for HW and VME standirzation:

- IOxOS VME drivers
- MRF (Timing) drivers.

- The SW is based on EPICS
- Those are the EPICS modules that take part in the SW solution:
  - System and device support related modules: **environment, pevdrv, nds3epics, nds3, asyn**
  - Specific digitizer hardware related modules: **mrfioc2, ifcdaq, ifcdaqdrv**
  - Specific application related module: **EMU_daq**, where EMU functionality is implemented, and its IOC will be feeding the EMU GUI.
  - Motion Control module **eemcu** also will be needed.

  - mrfioc2: MRF timing module.
  - pevdrv: Reading and writing to different areas of memory, different buses and doing DMA transfers.
  - Ifcdaqdrv: Abstracts away differences between the FMC modules. Provides a generic data acquisition interface.
  - Ifcdaq: EPICS device support.
  - EMU_daq: EMU implementation.

SW Description (2)

The control will base following the EEE's recommendation based on EPICS.

Main control architecture based on aSub records.

- **Development Design divided in separated application files :**
  - State machine controlling all the process and ADC acquisition. The central state machine sends the commands to move the slit and the grid, and sets orders to get the samples acquisitions.
  - Motion Interface communication: Request / respond protocol for robustness of the communication.
  - Emittance algorithms and Twiss parameters.

- **EPICS Data base are distributed in those conceptual files:**
  - General records declaration
  - State Machine declaration and inputs / outputs flow, settings initialization...
  - Motion Interface
  - Channel definition
  - IFCDAQ module EPICS data base files

- **GUI based on testing .opi file**

At this development step, motion is running over a different IOC.

What are we working on?

Slit	Refine design (cooling, substrate, unios graphite-substrate, ...) Contact graphite manufacturers
Grid	PCB prototype designed Wire gluing tests in collaboration with the University of Cantabria
Motors & actuators	See talk by Á. Vizcaíno (16:00)
Analog electronics	Prototype, test, redesign cycle
Digital & Control	Started programming of motion control and signal acquisition

EMU Team

Ángel Rodríguez Páramo

Álvaro Vizcaíno

Valentín Toyos

Carlos de la Cruz

Ion Ortega

Idoia Mazkiaran

Zunbeltz Izaola