ESS-B Contribution: MEBT WS, EMU, FC

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ESS Diagnostics Forum
10-11 Feb 2016 LUND

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- EMU - Grid
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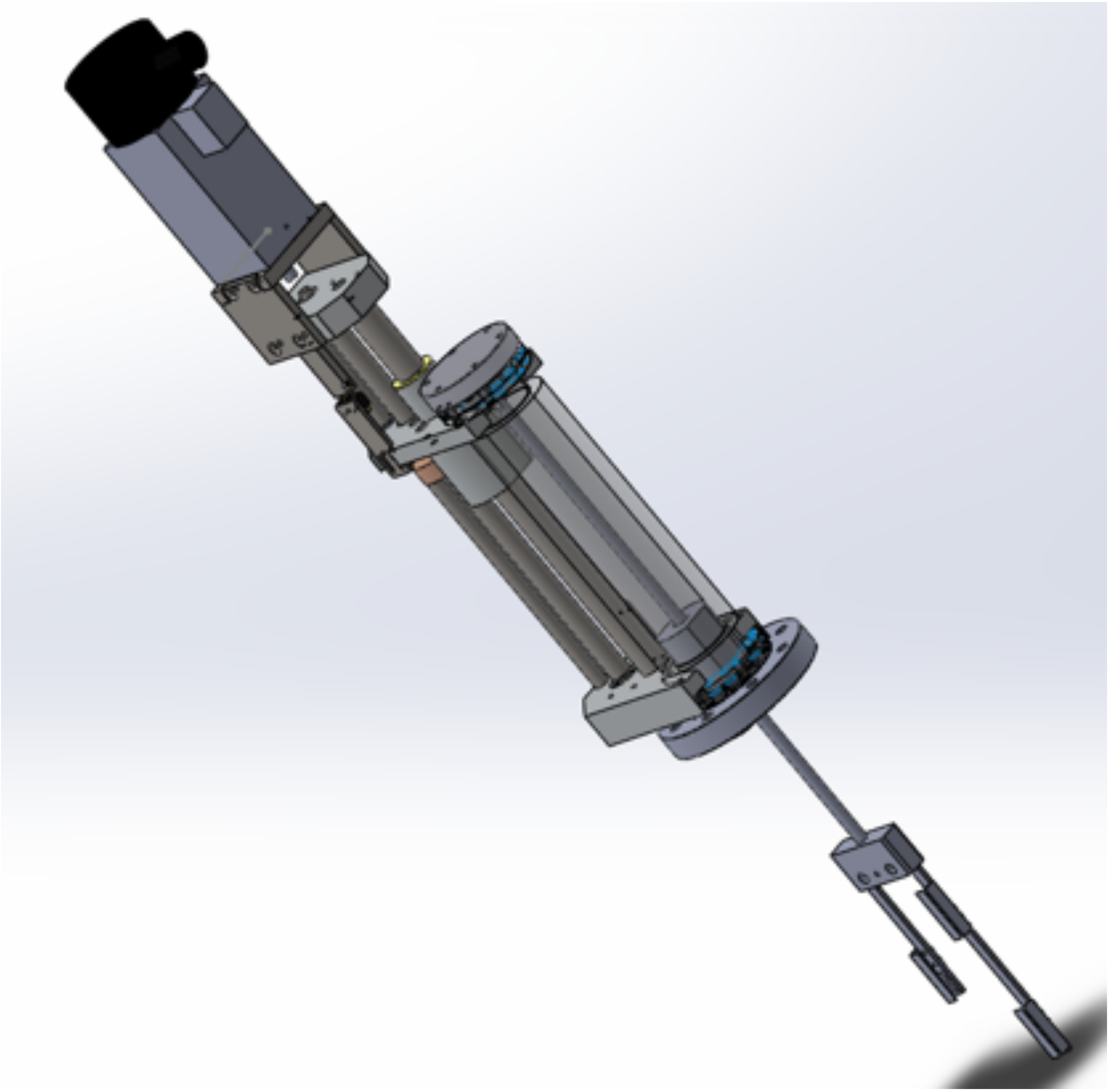
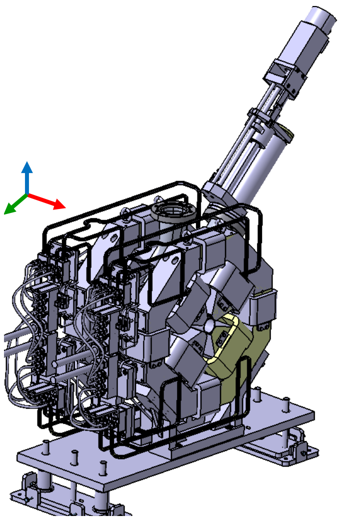
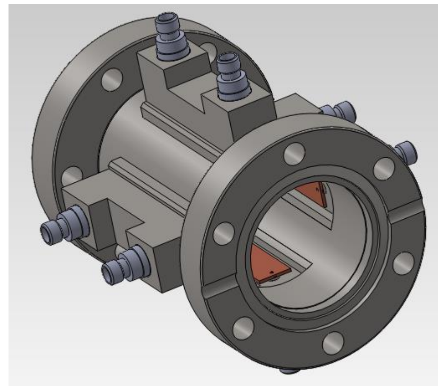
  - Possible solutions
- FC
- Thermo-mechanical issues

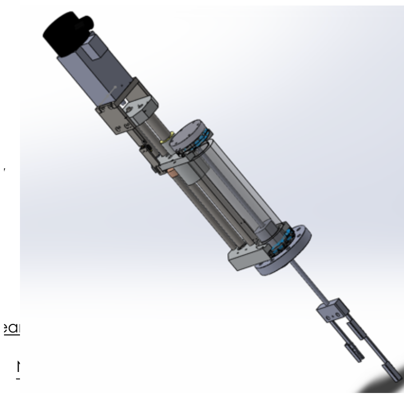


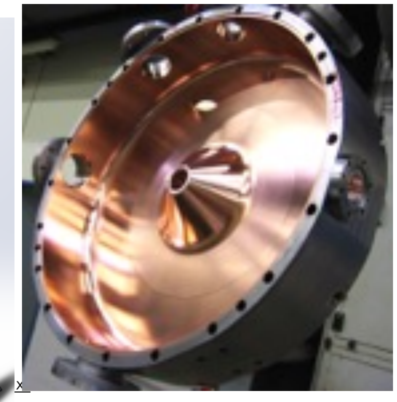
Layout

- 3.62 MeV, 62.5mA
- 6 BPMs
- 3 WS
- 1 EMU
- 1 BSM
- 1 FC
- 2 NPMs
- 1 BCT
- 1 FCT

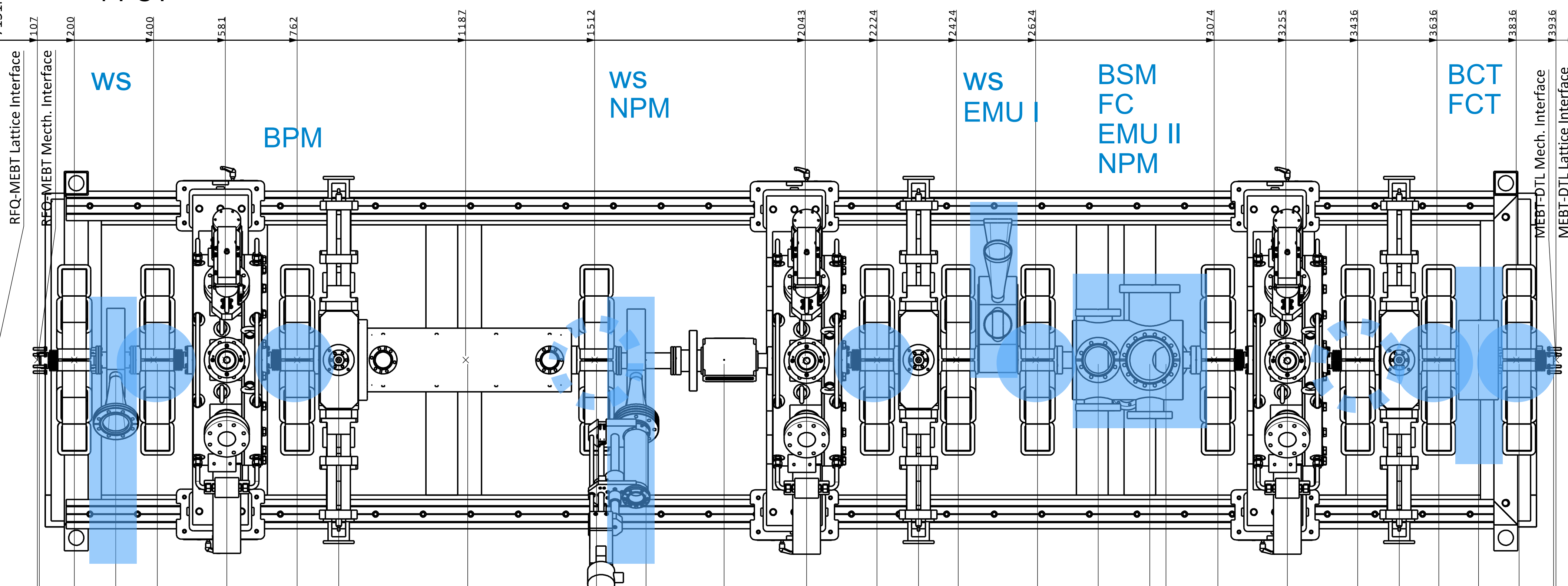






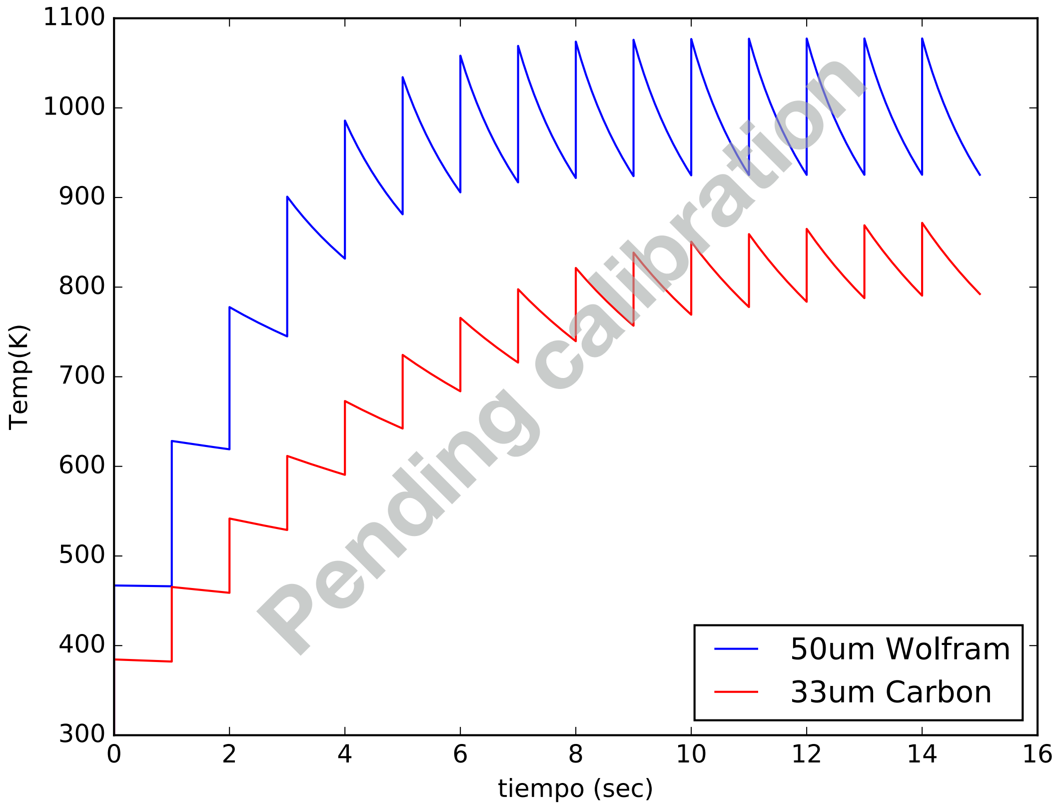


TraceWin dimensions



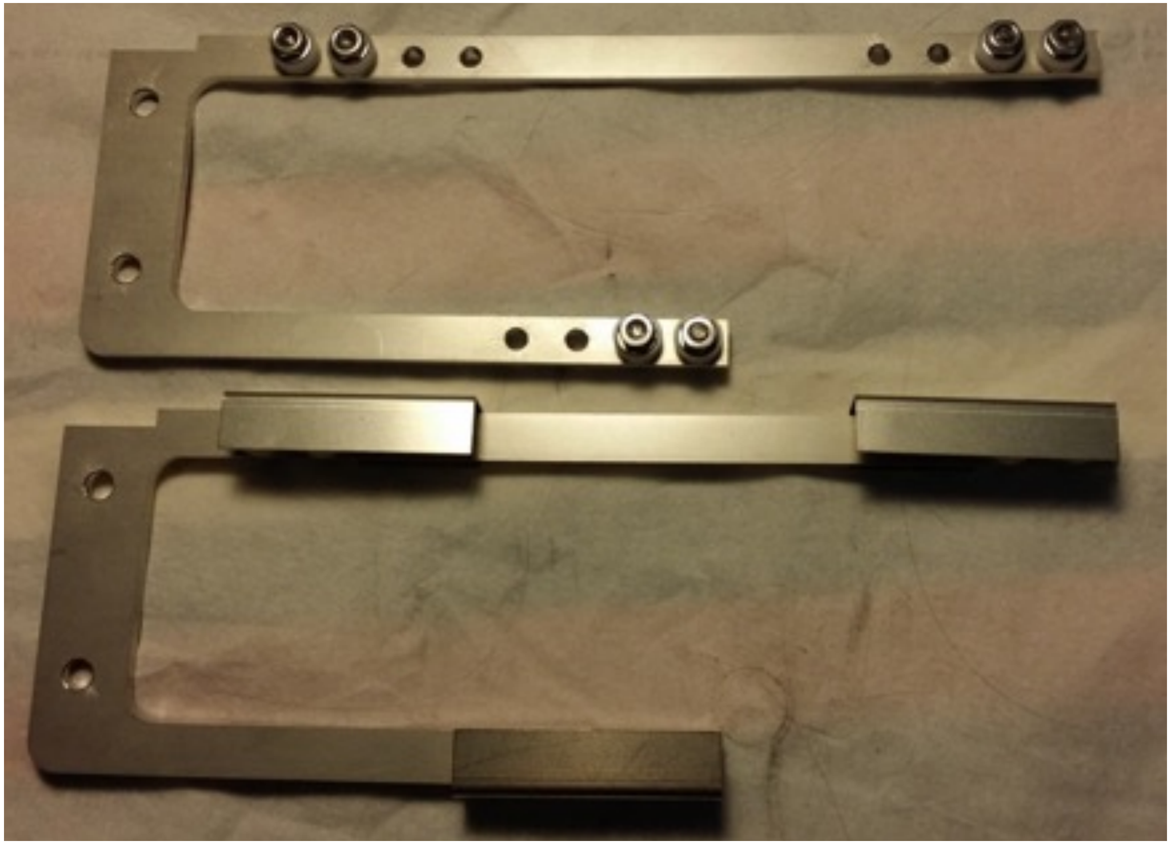
WS: Fork

- Wire Scanner Specifications:
  - Wire material under study: 33µm Carbon
  - In the ESS warm linac (<90MeV), carbon wire has been chosen due the better thermal properties of the material compare to tungsten.
  - A larger wire diameter will increase the signal level and also the maximum temperature on the wire.



Wire Scanner

- Mechanical Design
  - First Design

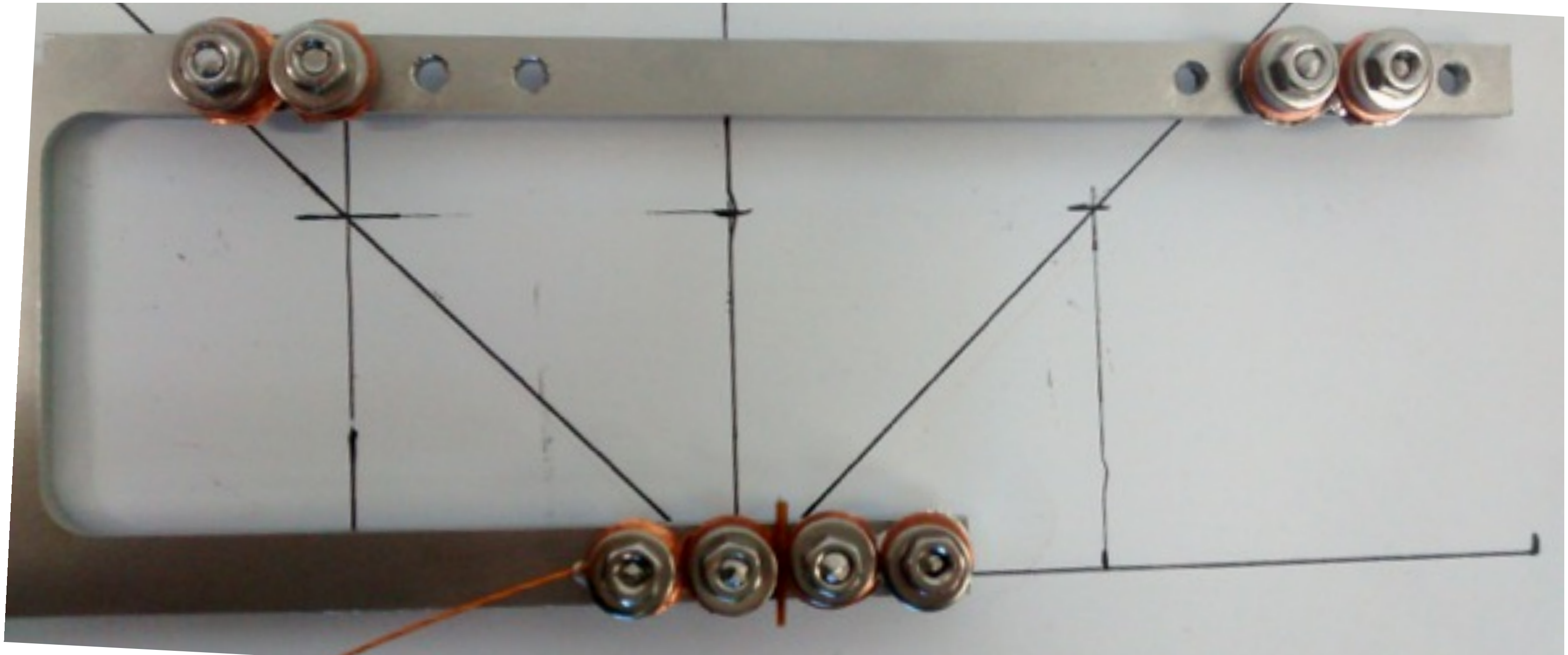


WS: Fork

- Mechanical Design
  - First Design (Problems)
    - Difficult to assemble the wires in the correct position with the correct tension.
    - Carbon wires broken due to the pressure in the washer fixation.
    - Loss of tension in the wires after mounting.

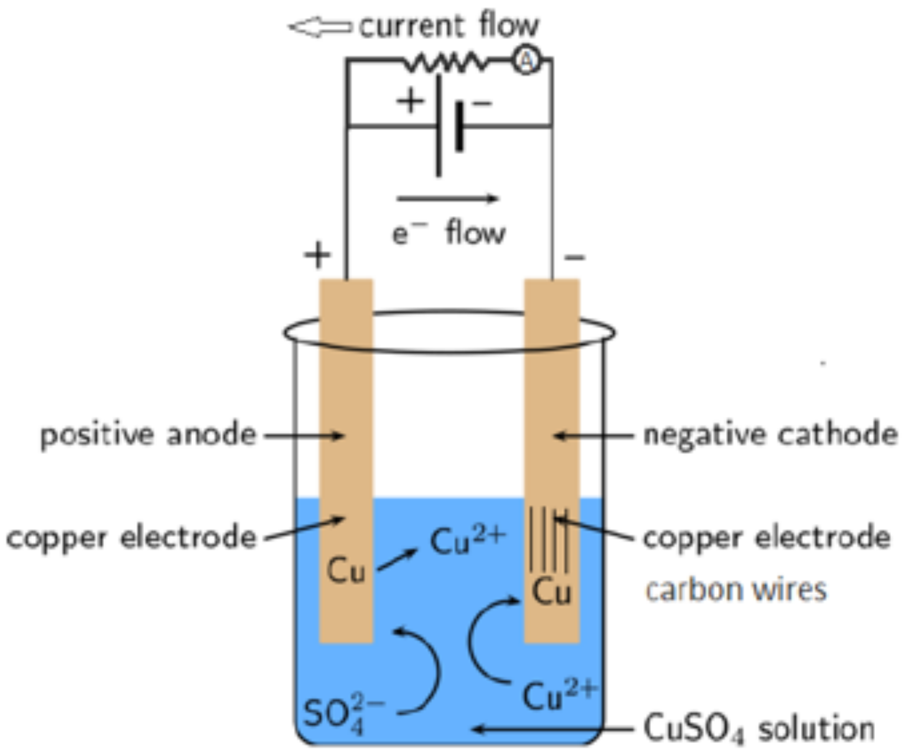
WS: Fork

- Mechanical Design
  - First Design (Possible solutions)
    - A new mechanical design have been design.
    - A process of plating for the carbon wire ends with copper is under developing.

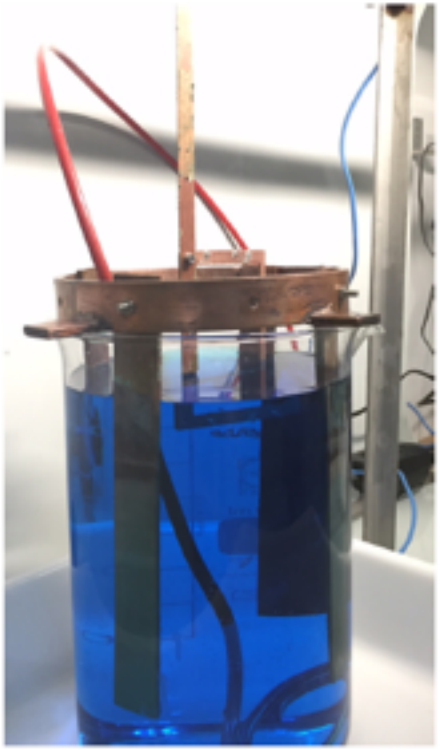


WS: Cu plating

- Carbon Wire Plating (Process and Setup)
  - The copper plating is required to give mechanical strength to the carbon wires.



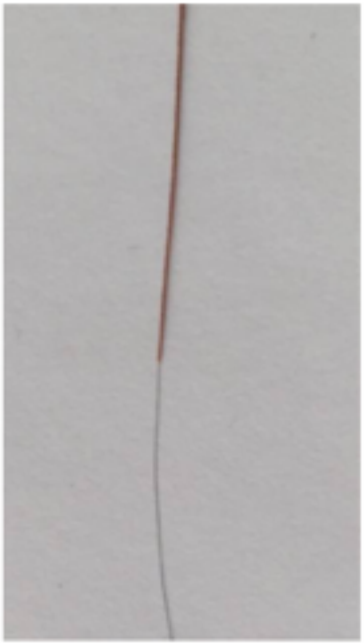
(a) Squeme of the process.

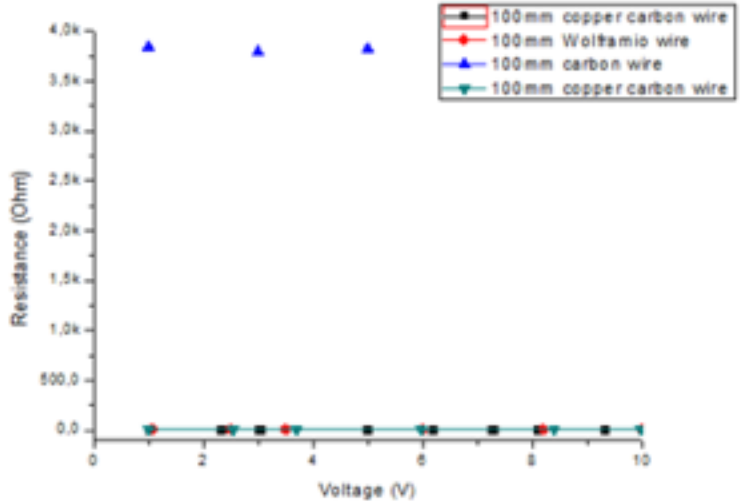


(b) Setup in our laboratory.

WS: Cu plating

- Different experiment performed, best results obtained for low current (0.5A) & long time (>90min)
- Good uniformed coated copper
- Good conductivity
- Difficult process, thin gap between correct plating and burned plating

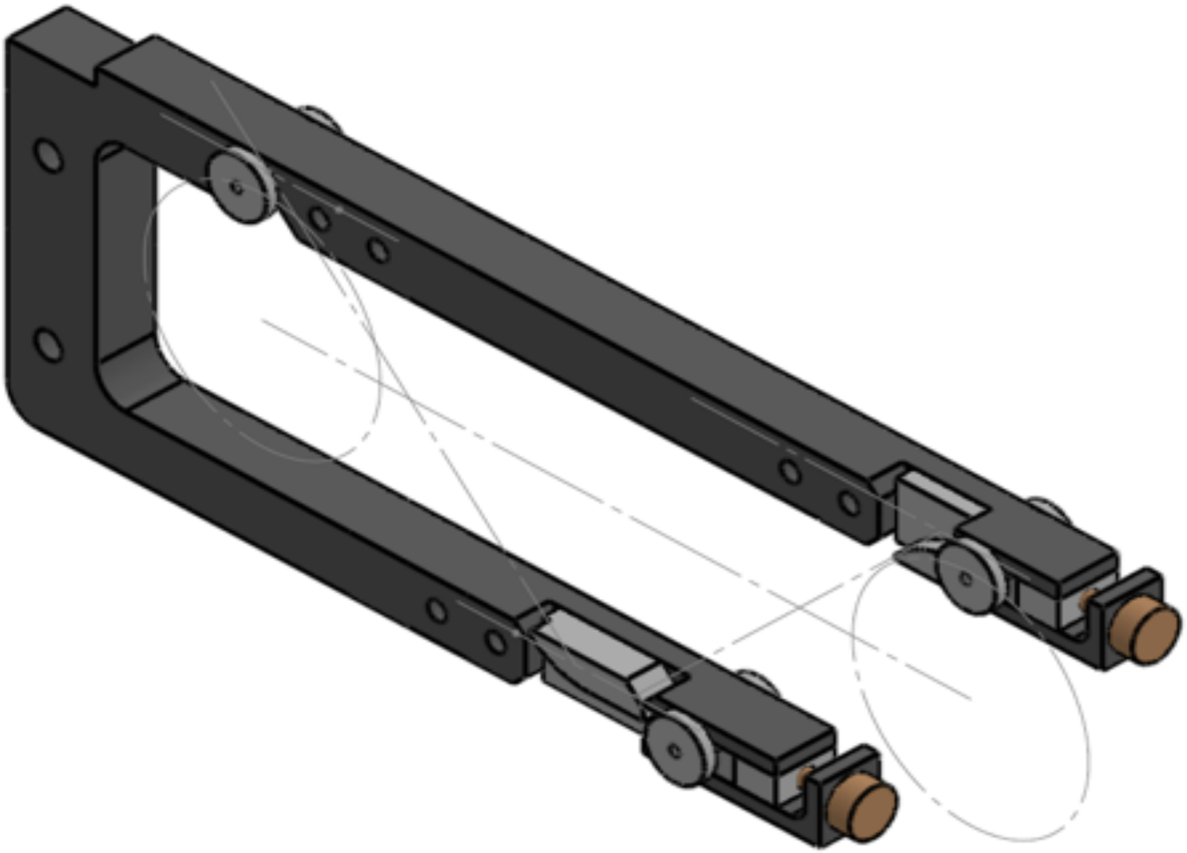


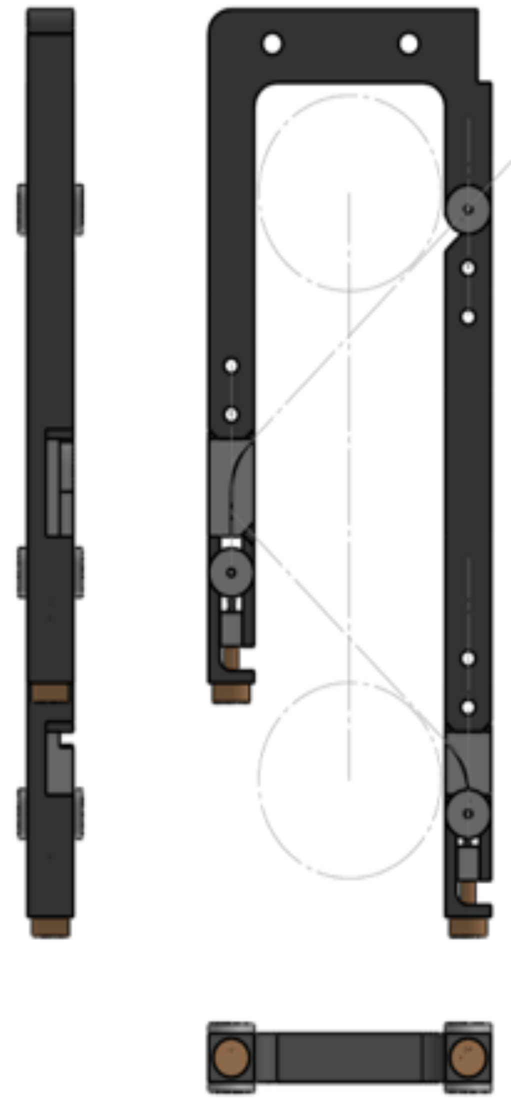


Courtesy of C. Cruz

WS: Fork

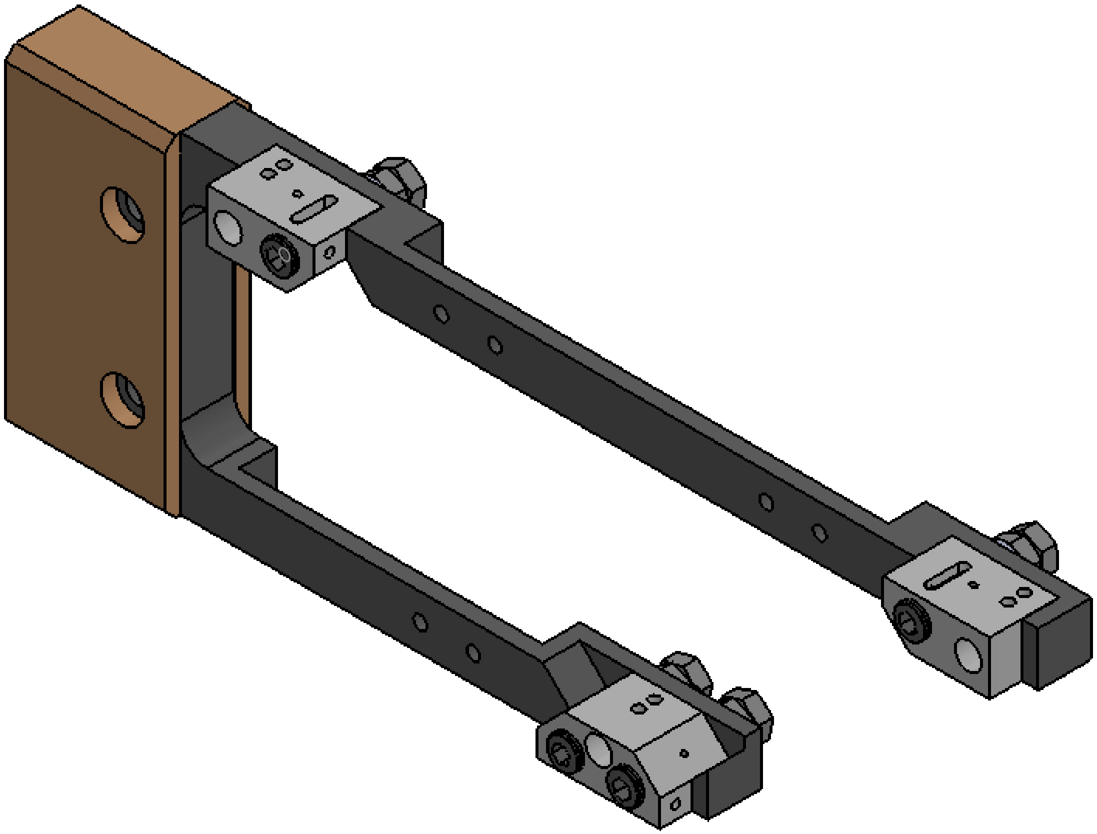
- Mechanical Design 2.0

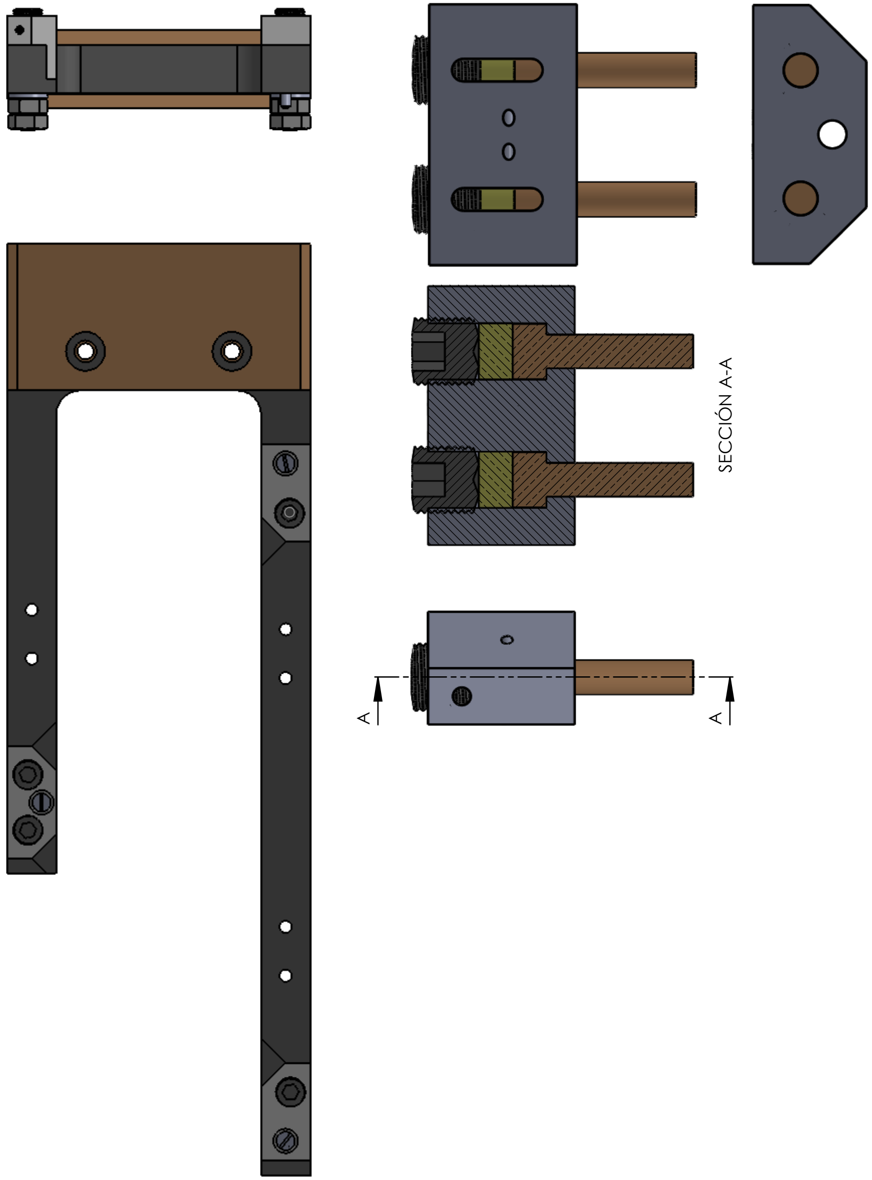




WS: Fork

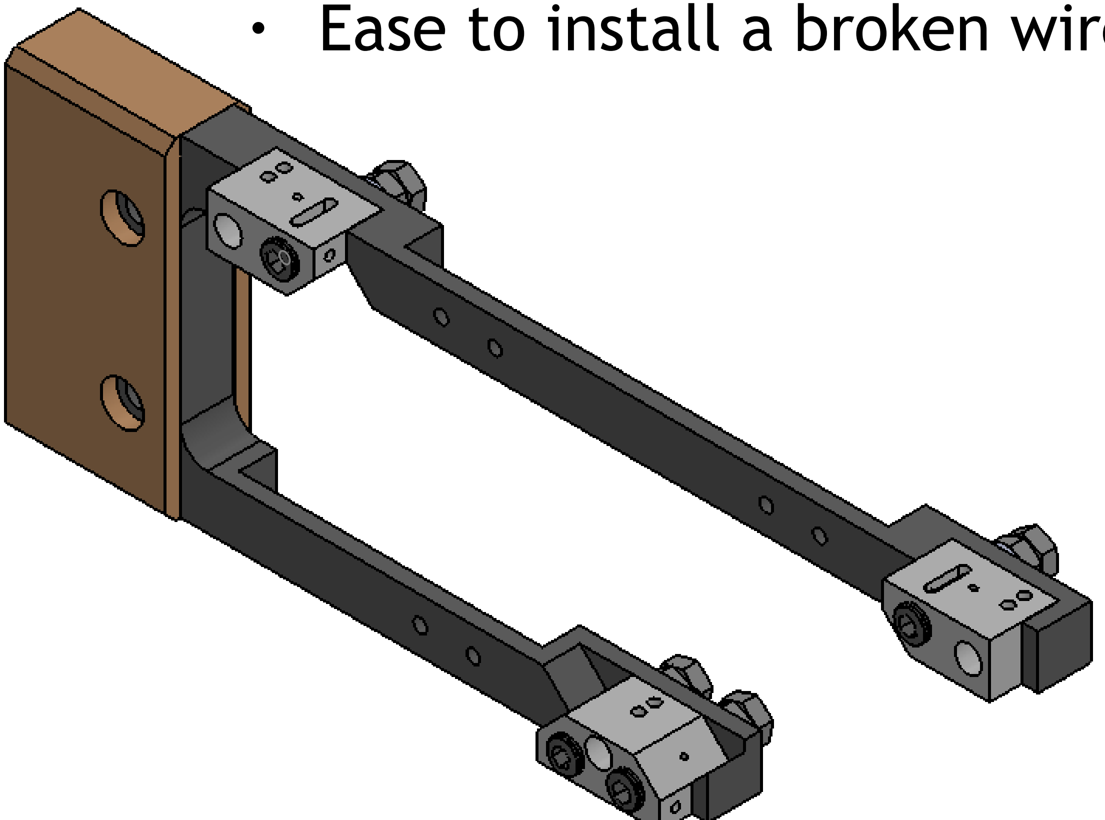
- Mechanical Design 3.0





Wire Scanner

- Mechanical Design
  - Advantages of the New Design
    - Ease of assemble of the carbon wires
    - The tension of the wires can be controlled
    - Ease to install a broken wire sensor



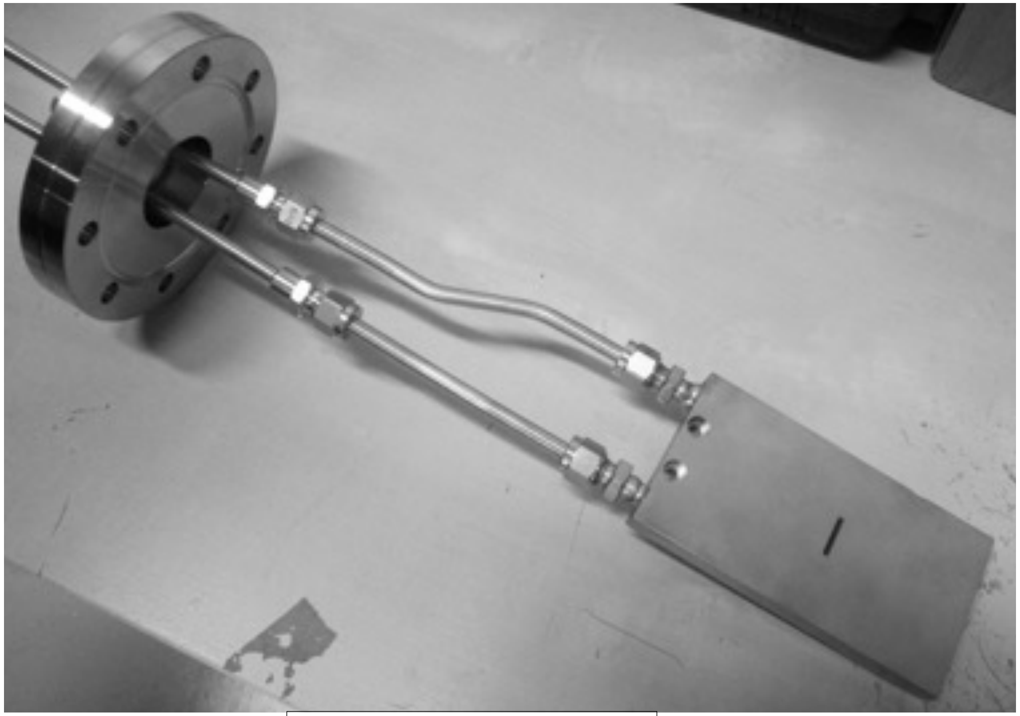
WS: Actuator

Actuator First Prototype

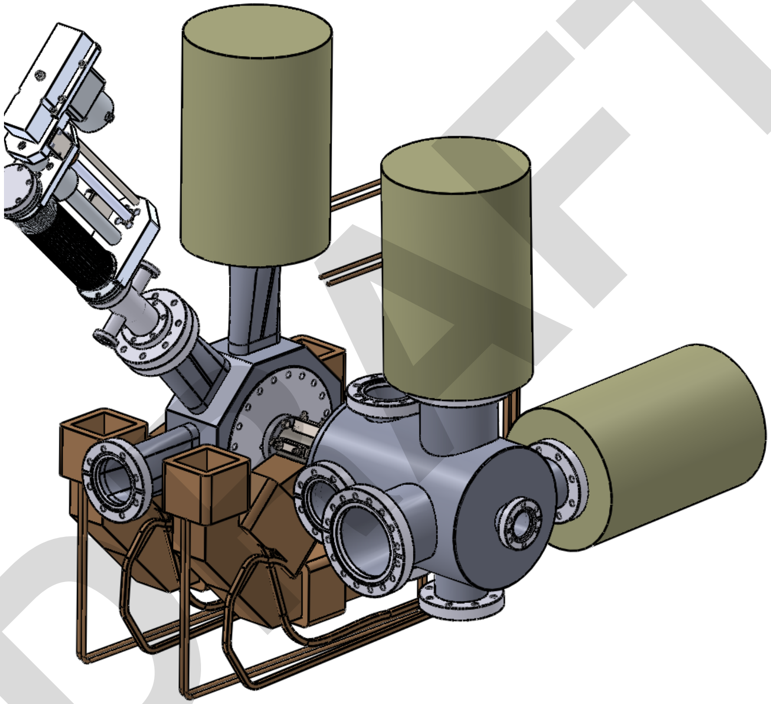
- Versatile system.
- Tested under vacuum (10^{-6}mbar)
- Interlock end-switches
- DN-63
- 200mm span
- Customised for particular motor-encoder.
- Sneider in current configuration

EMU: Slit

- Slit: Thermo-mechanical calculations in place.
- Detailed Assembly **pending** of PBI integration



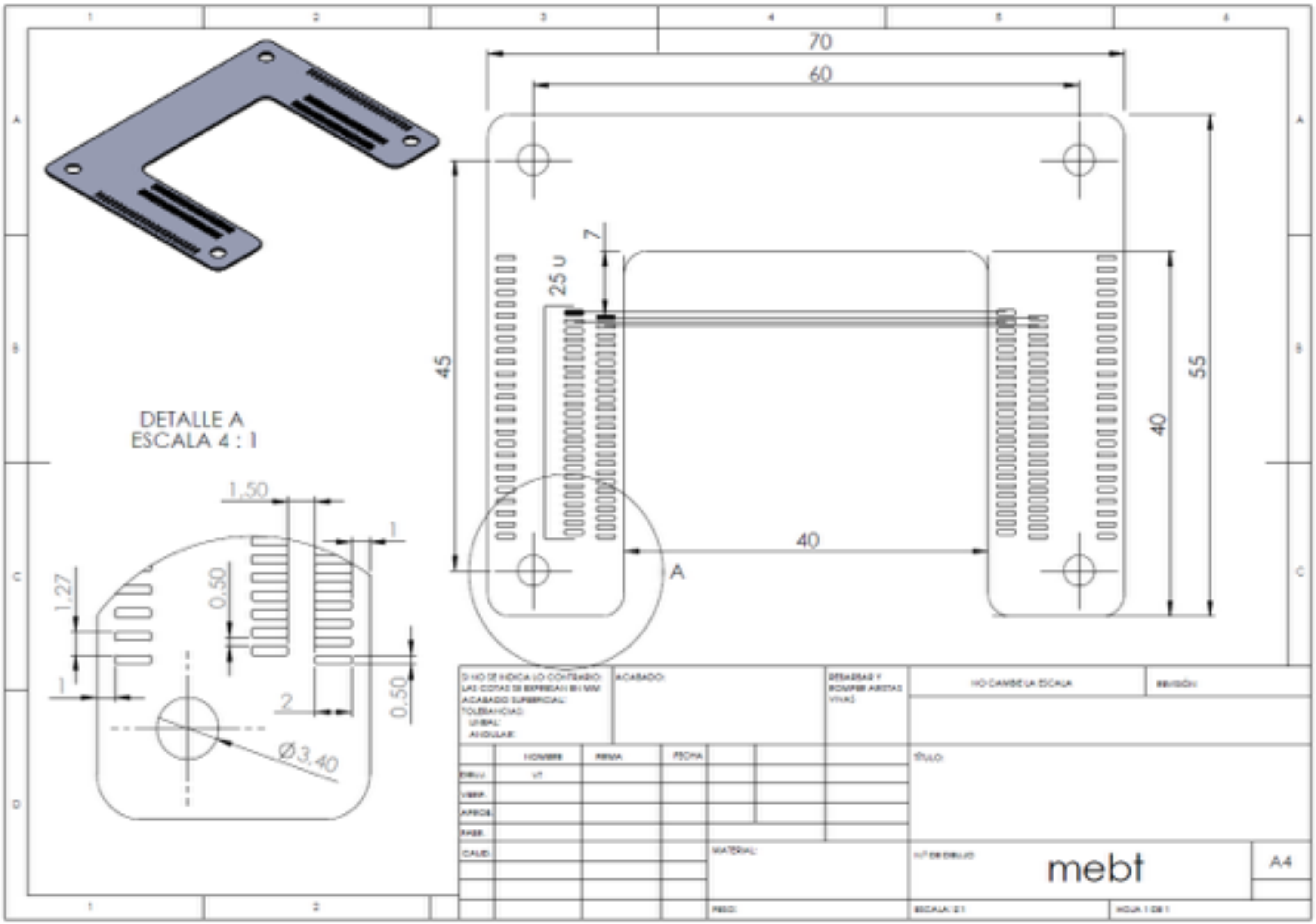
Wien Filter Slit



SLIT GRID schematics

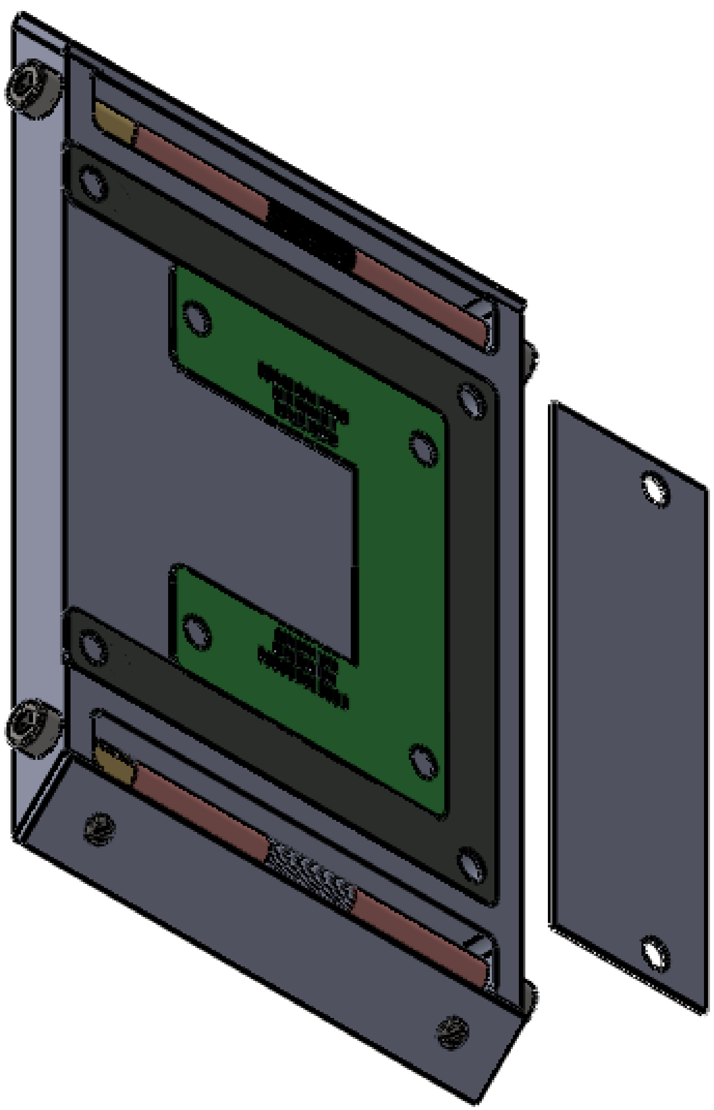
EMU - Grid

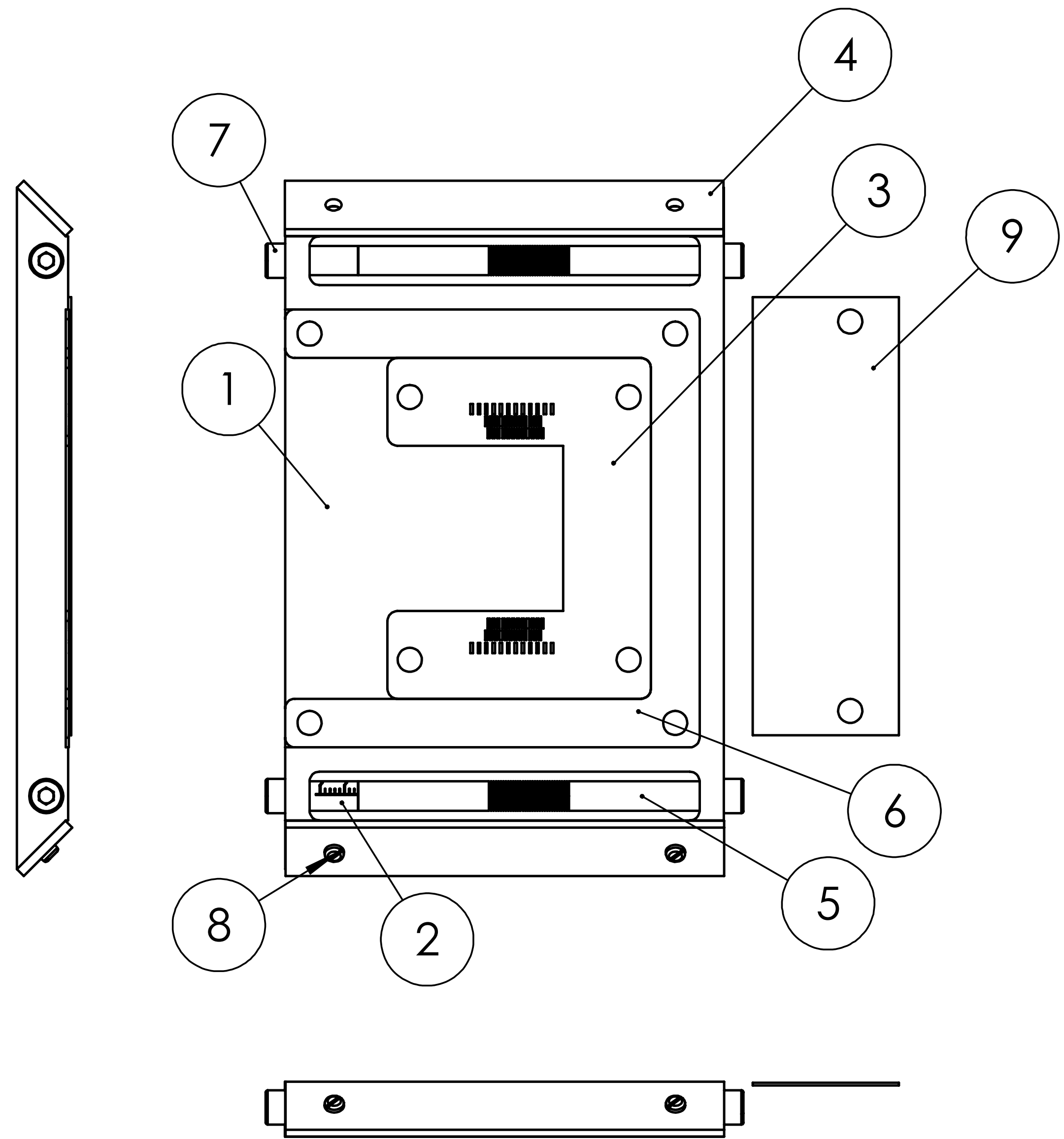
- First Prototype



EMU - Grid

- First Prototype wire tensor tool



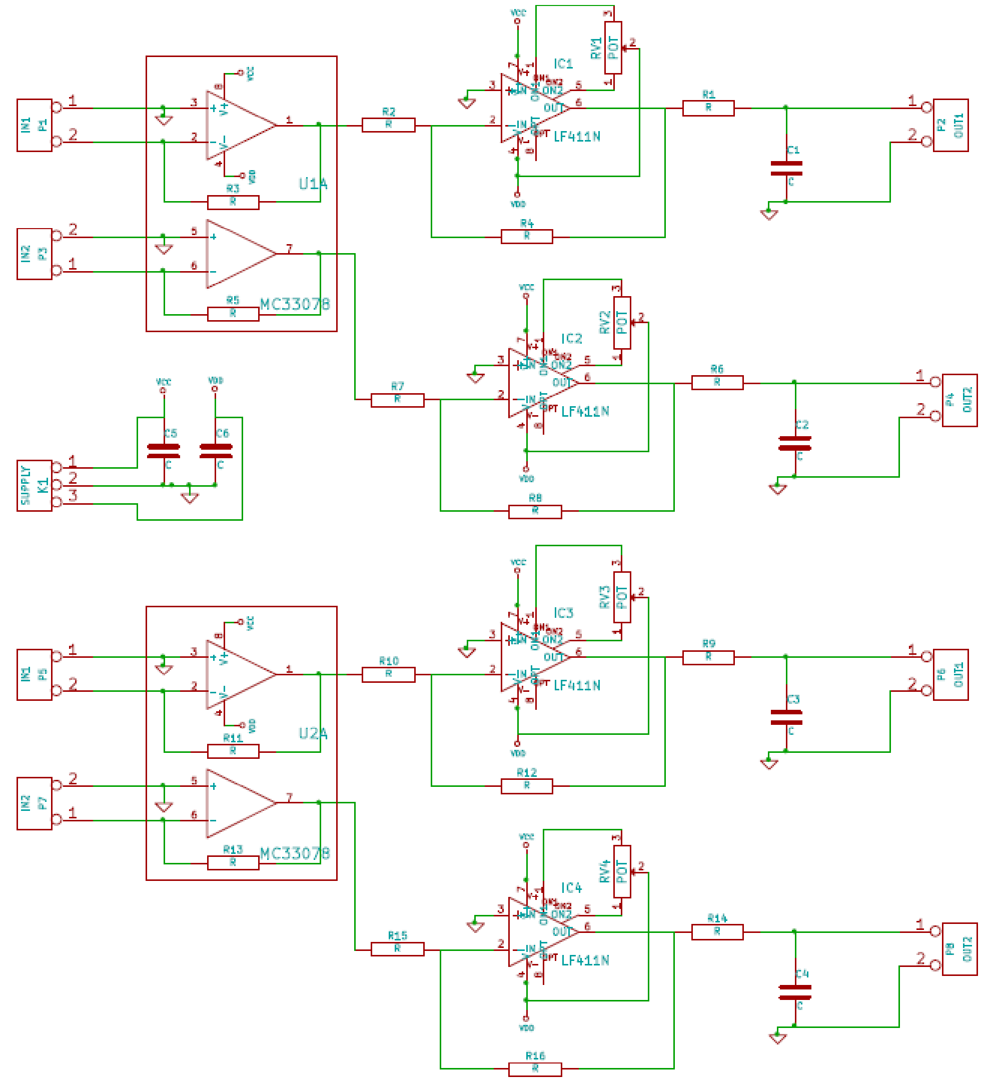


EMU - Grid

- First design characteristics:
  - Wire material under study: Tungsten.
  - Wire width: 20μm.
  - Protected ceramic PCB
  - Wires shall be glued to the PCB. Vacuum approval in process.
  - In order to test the integrity and calibration of each wire, a resistor is needed. This resistor needs to be soldered to the PCB.

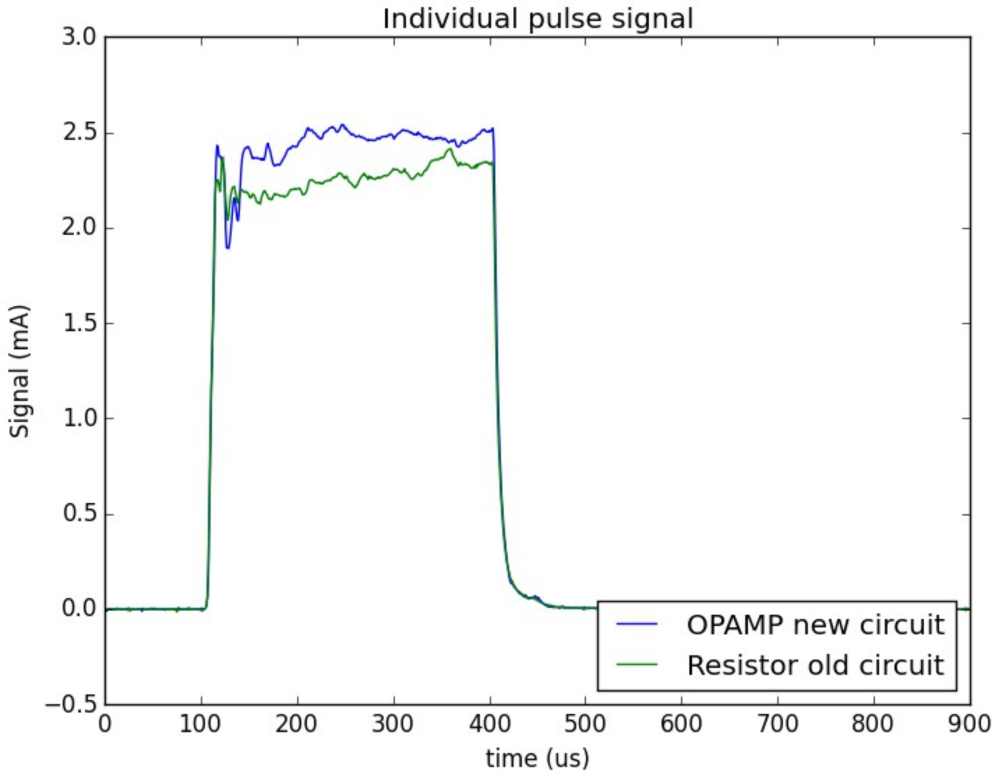
EMU: Electronics I

- Features of the **Acquisition box**:
- 2 amplification stages
- Offset and output filter adjustable
  Input [10 uA to 5 mA]
- Output [18 mV to 9 V]
- Total Gain 554 uA/V
- Bandwidth [DC to 80 kHz]
- Rise time 4,5 µs



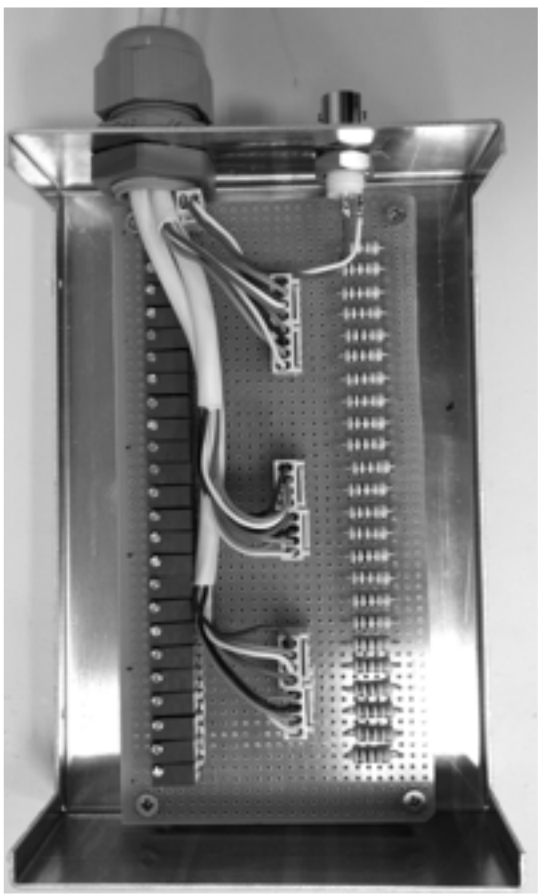
EMU: Electronics II

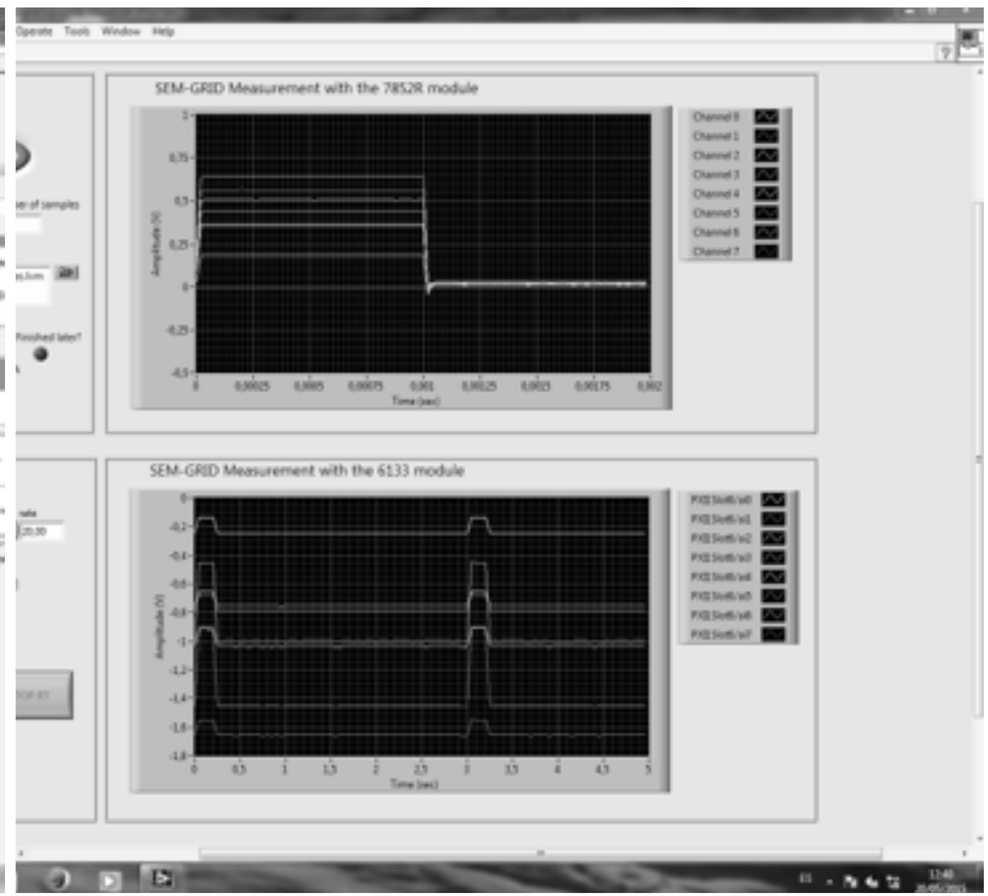
- Electronics: first analog stage design and implementation tested for a two channel problem (WS)
  - **e-gun** test stand, with 100V biased voltage, currently in progress
  - **45 keV** H^+ beam, showed significant increase in current collected over the previous solution.



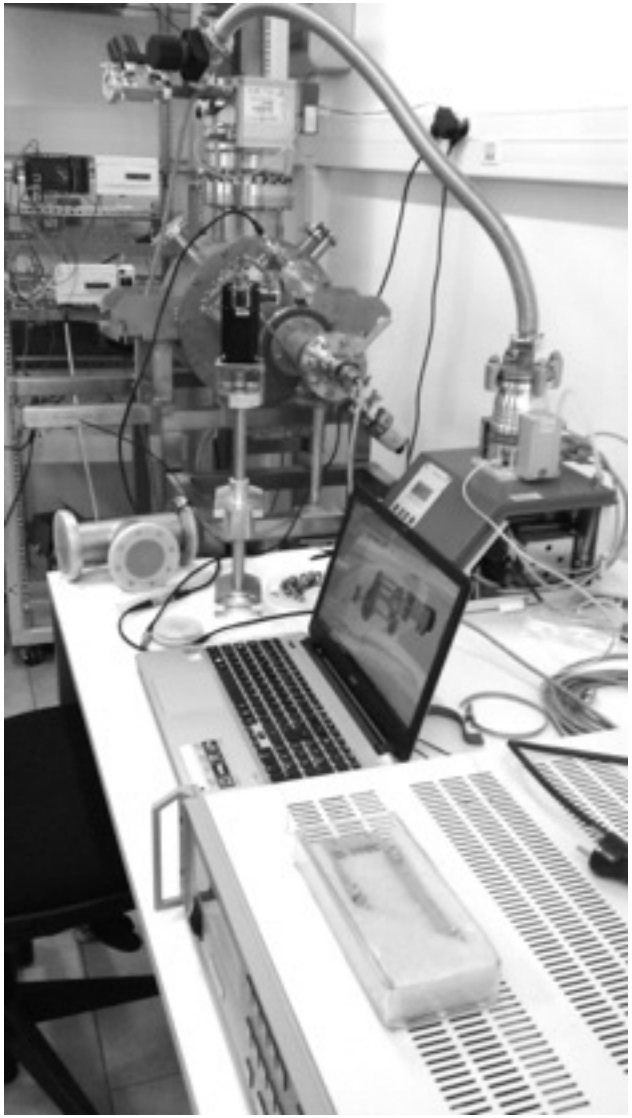
EMU: Acquisition

- First tests developed with NI PXI system
  - **24 channels** signal generator was used to test the acquisition software.
  - Each channel amplitude can be adjusted.

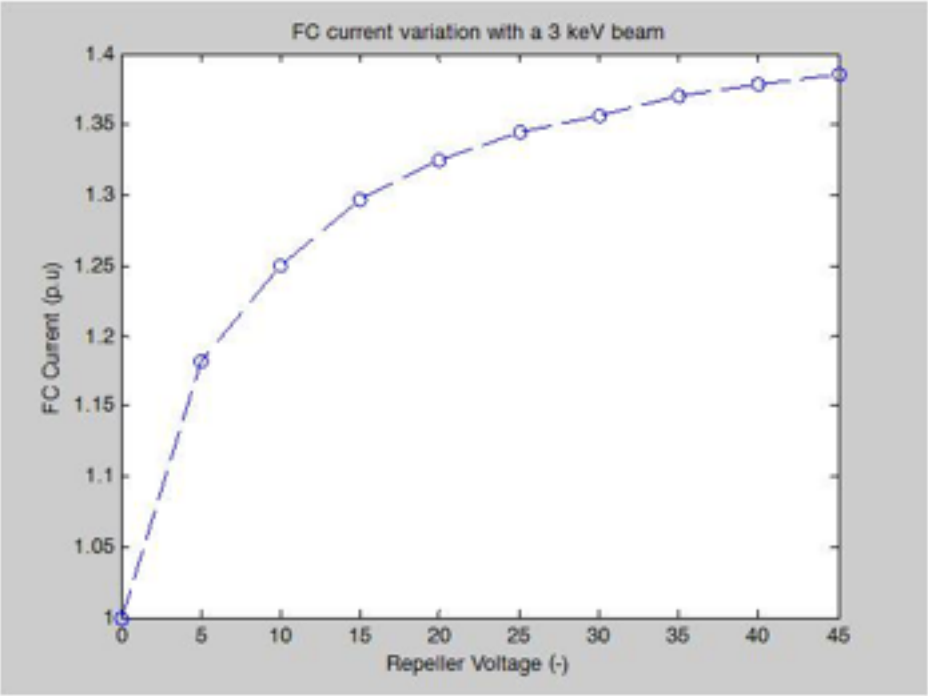




Tests under e⁻ beam

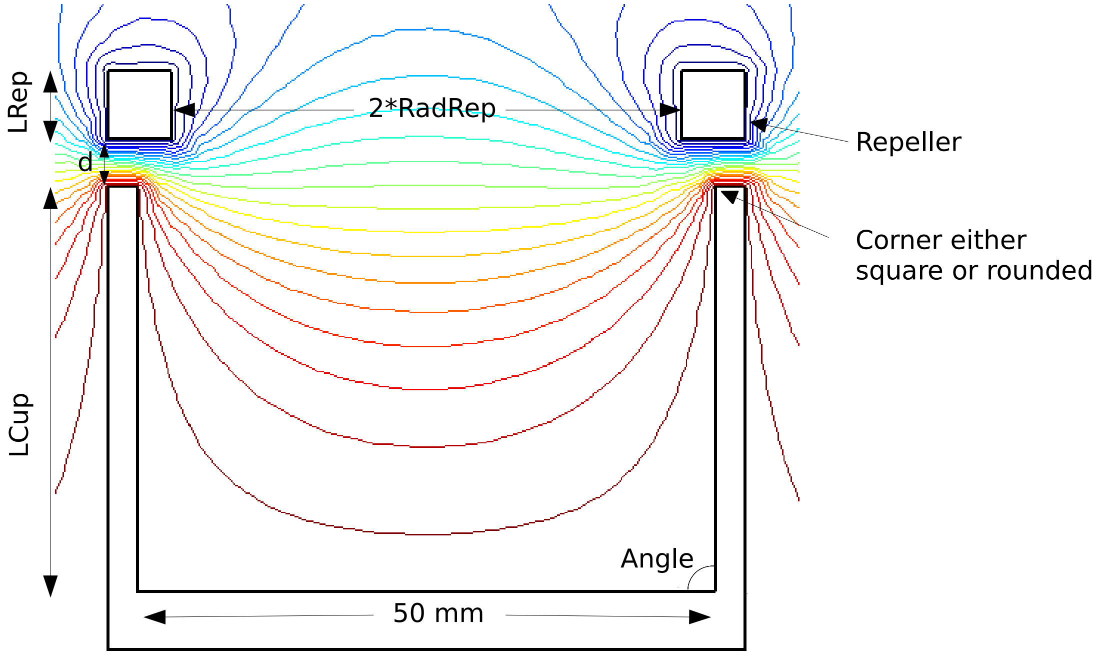


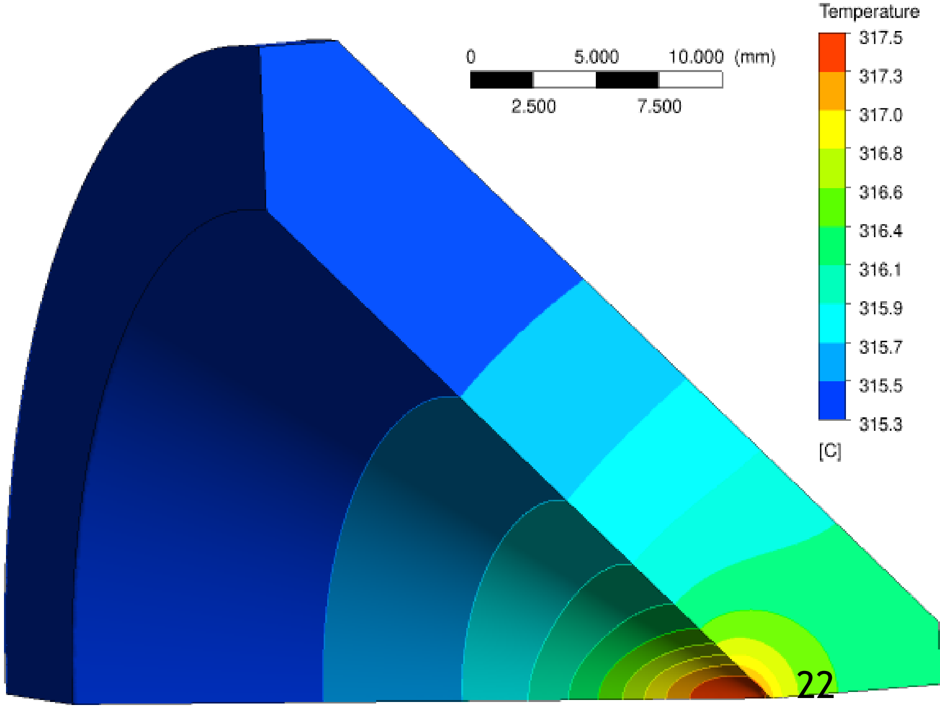
- Energy: 5 keV Max.
- Current: 250 uA Max.
- Typical emission: 1-20 uA
- Filament: 2-3 V, 2.2 A Max.
- Operation Modes: Continuous and pulsed mode
- Beam chopper: 660 ns-102 us (FWHM)
- FC tests successful
- WS (Tungsten 50μm) biased 100V



FC

- Faraday Cup:
- Part1: Parametric analysis have been performed to improve geometry (based on the material kindly provided by **David de Cos**)
- Part2: Thermo-mechanical analysis done. (based on the material kindly provided by **Tomas Mora**)





Part1: Summary

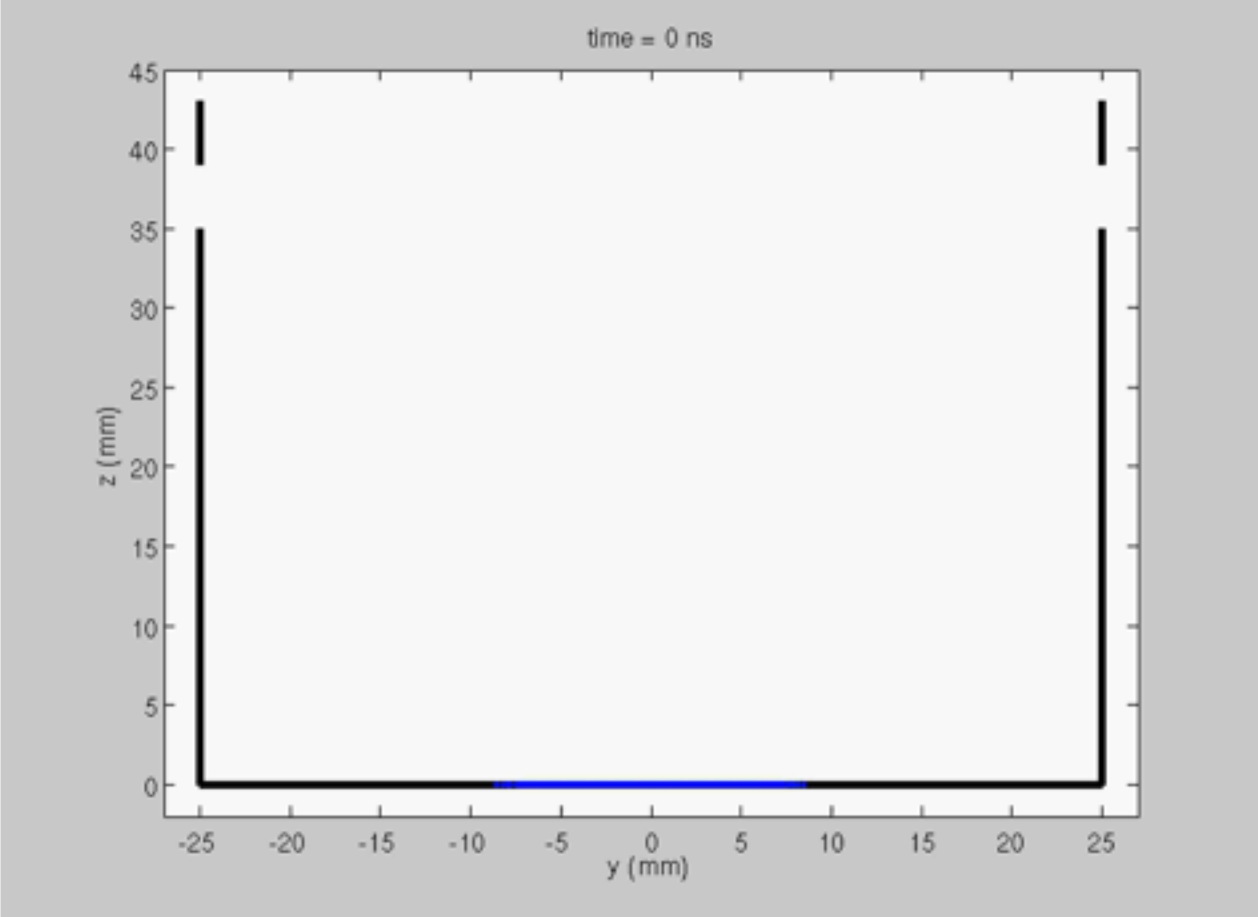
- Purpose of the study and figures of merit.
- Conditions of the study.
- Basic geometry and overview of the studied parameters.
- Results of the parametric simulations.
- Basic tentative design.
- Conclusions.

Purpose of the study and figures of merit

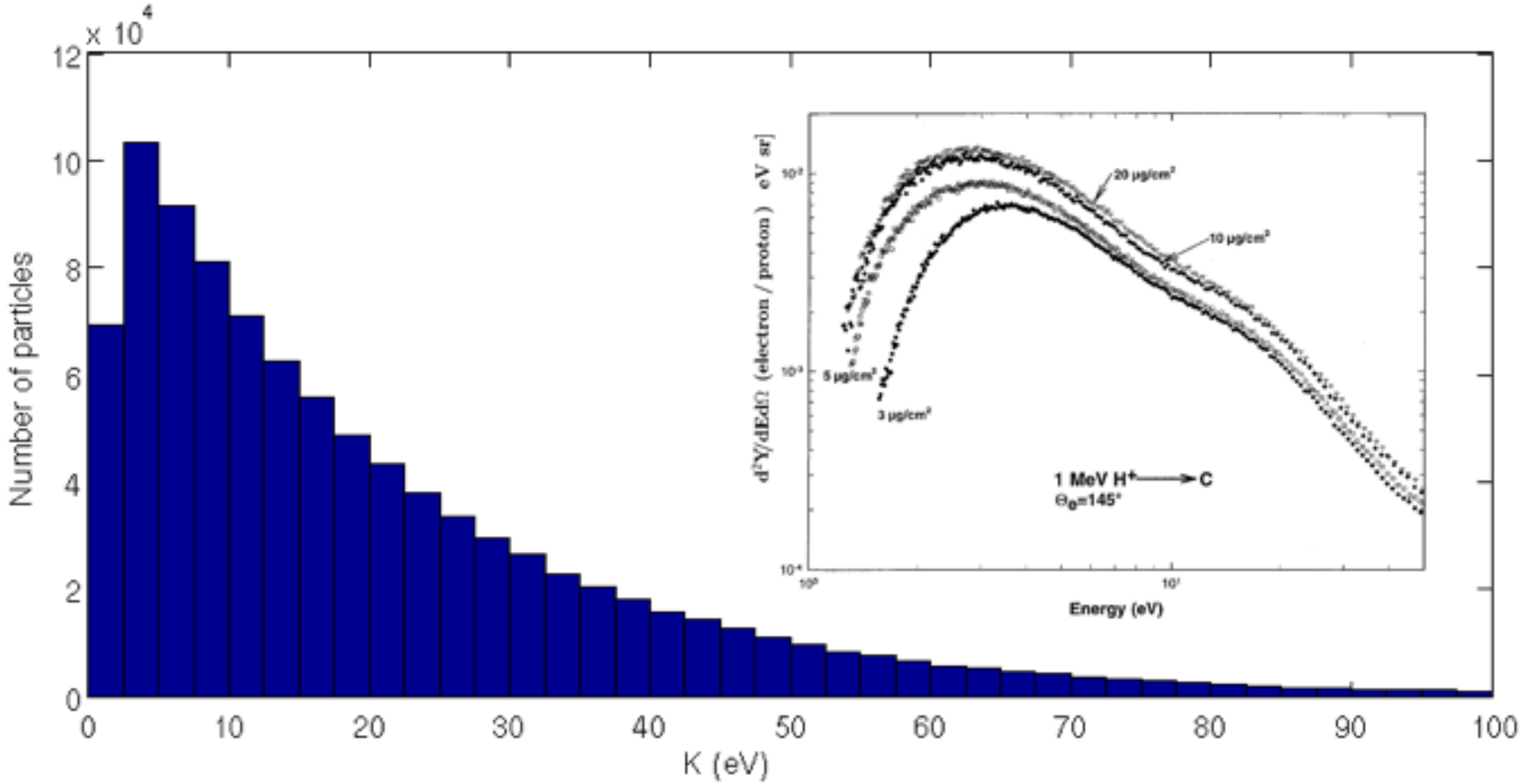
- The aim of this study is to **characterise the geometry** of the Faraday Cup through several basic parameters, and to understand how those parameters qualitatively affect the suppression of the secondary electrons.
- Therefore, **no parameter optimisation** has been carried out. A finer study may be done after other design aspects are settled, if deemed necessary.
- The models are evaluated through computer simulations of the dynamics of the secondary beam: **generation**, **repelling** and **capture** by the Cup.
- The results are evaluated in terms of:
    1) **Ability to capture** 100% of the secondary beam (easy to achieve with the specified repelling voltage of **1 kV**).
    2) **Capture speed** (highly dependent on the geometry)
- An orientate design is proposed based on the findings of the study. This design is also evaluated for repelling voltages lower than 1 kV.

Conditions of the study: software

- The electric field generated by the repeller is calculated by Comsol.
- The dynamics of the secondary electrons in the Faraday Cup is simulated with GPT. Particles impacting the walls of the Cup are recaptured.

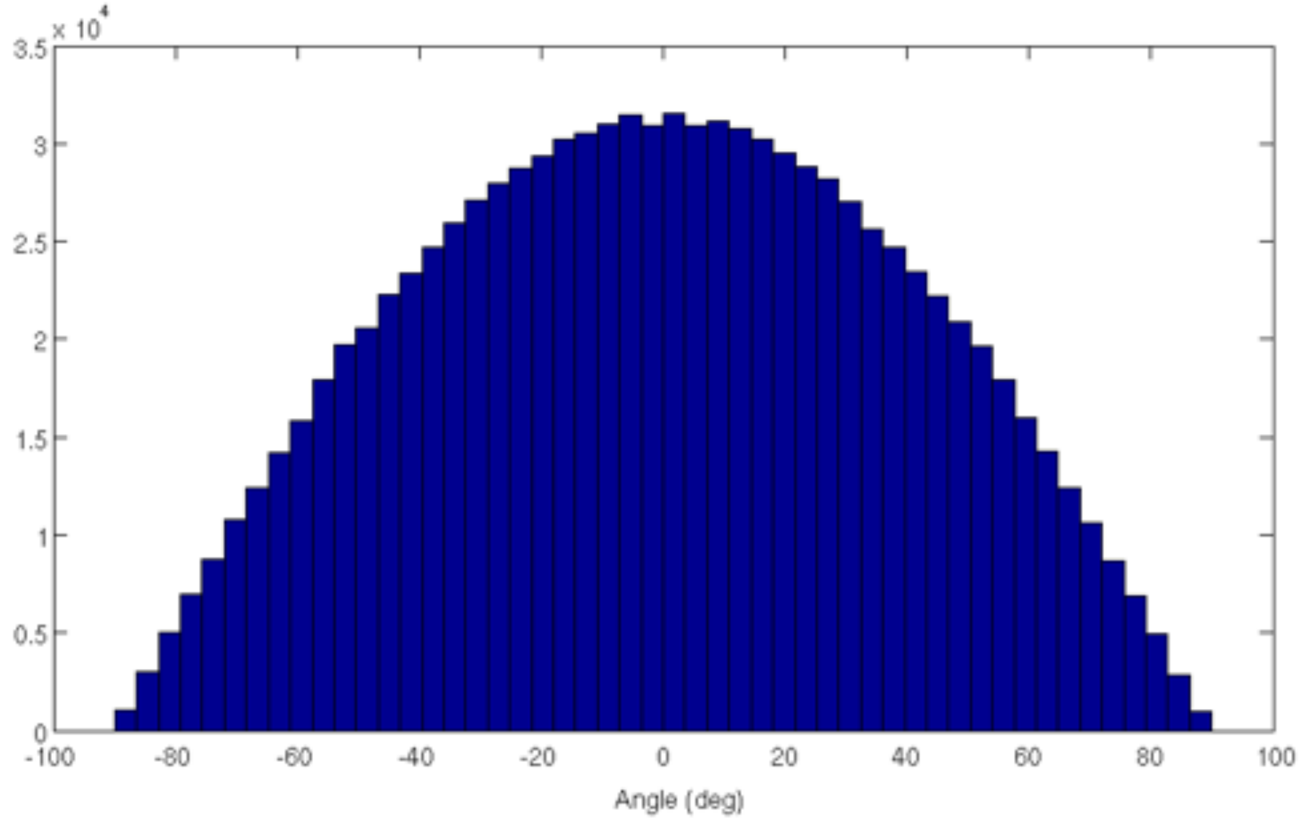


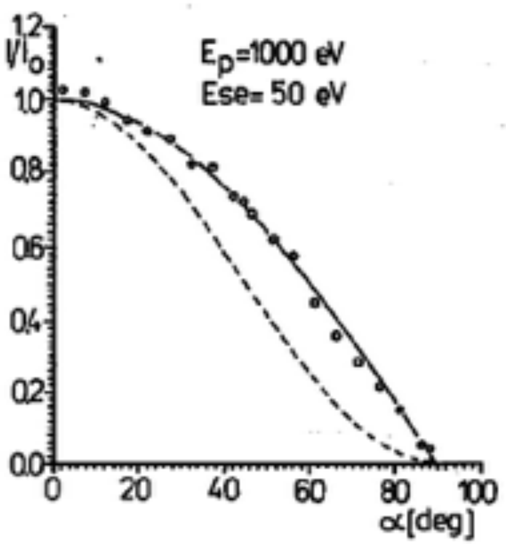
Electron beam energy distribution



- Histogram calculated from a set of 1e6 particles
- *C. G. Drexler, R. D. Dubois, Physical Review A, 53 (3), 1996.*

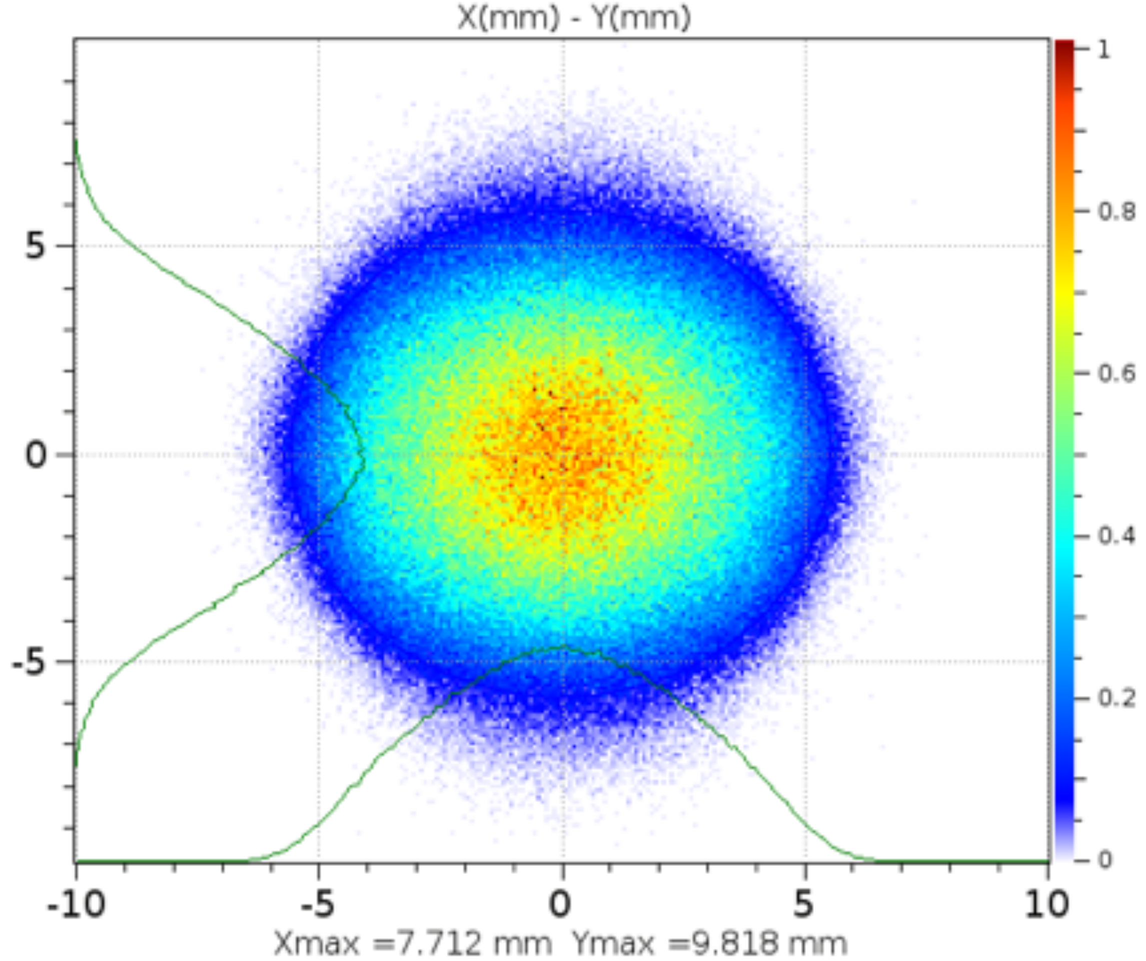
Electron beam angular distribution





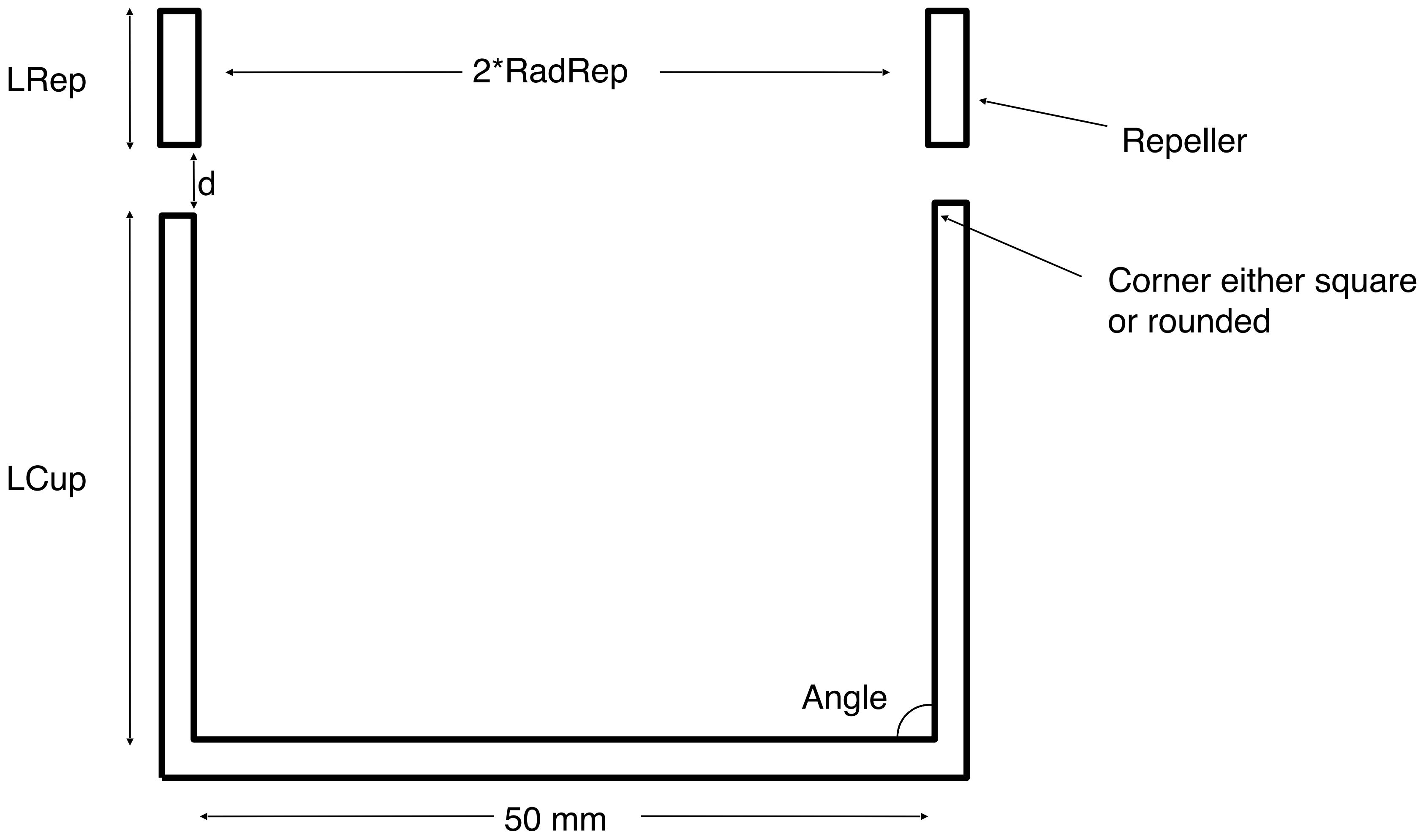
- Histogram calculated from a set of 1e6 particles.
- Distribution approximates to a cosine, with emission perpendicular to the surface being the most probable.
- *W. Dolinsky et al, Acta Physica Polonica A (81), 1992, p. 211—222.*

Electron beam footprint

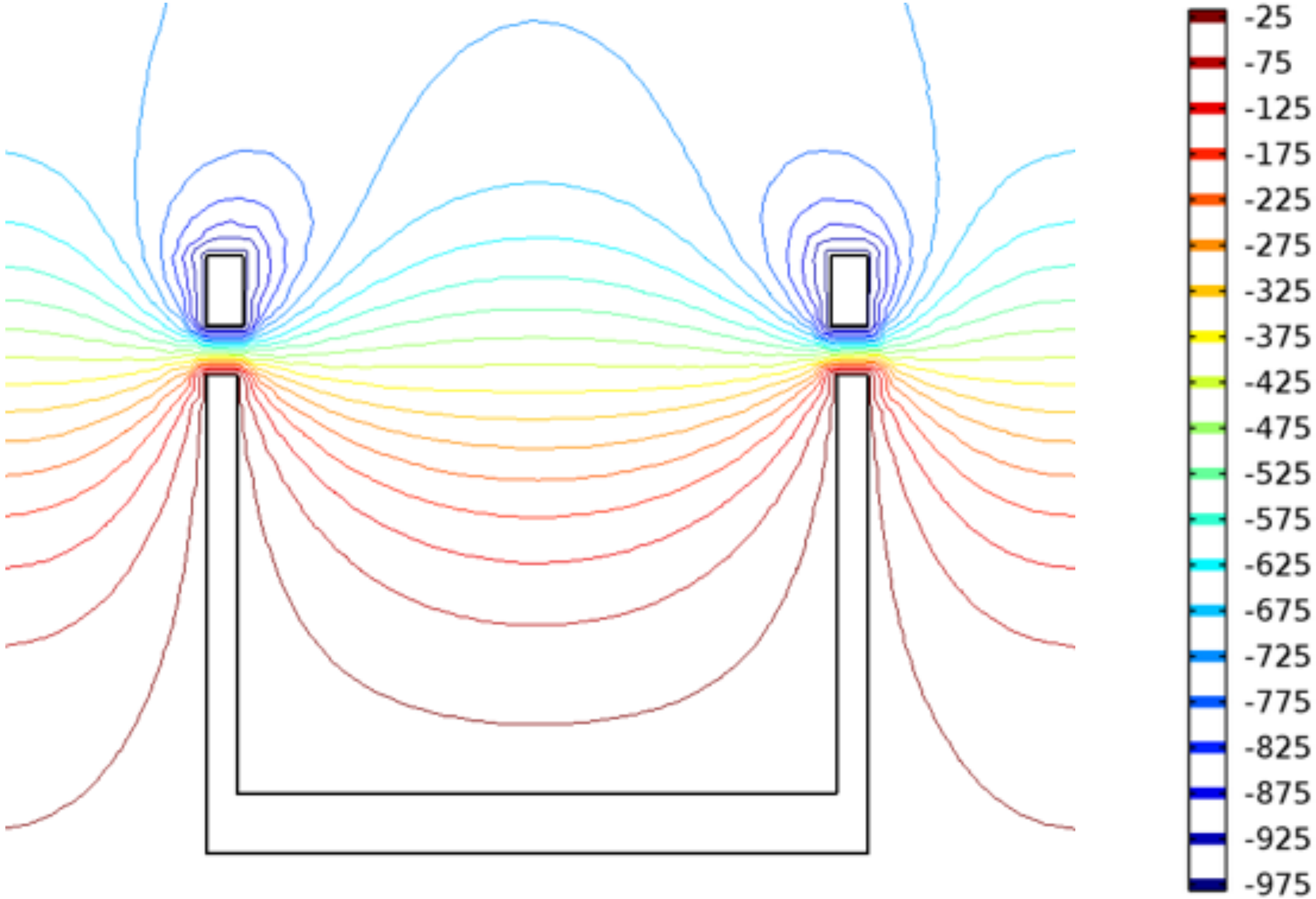


- Initial transverse space distribution equal to that of the proton beam at the plane of the Faraday Cup impact face.

Basic geometry parameters



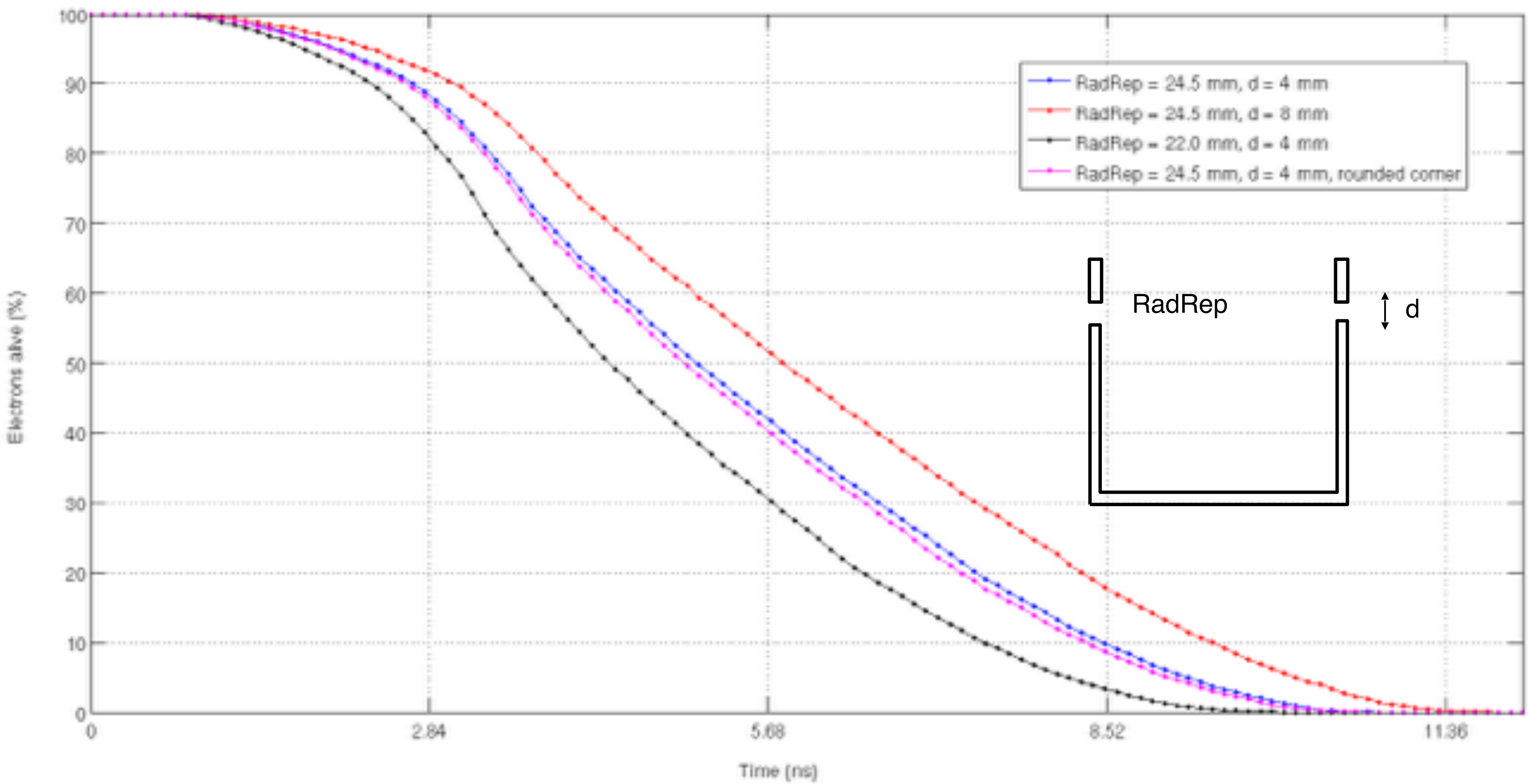
Typical isopotential lines



- With a 1000 V repeller, a potential barrier higher than the maximum electron energy is found about half way through the Cup depth.
- However, we can try to move that barrier as close to the impact plate as possible.

Study 1: RadRep, d, corner shape

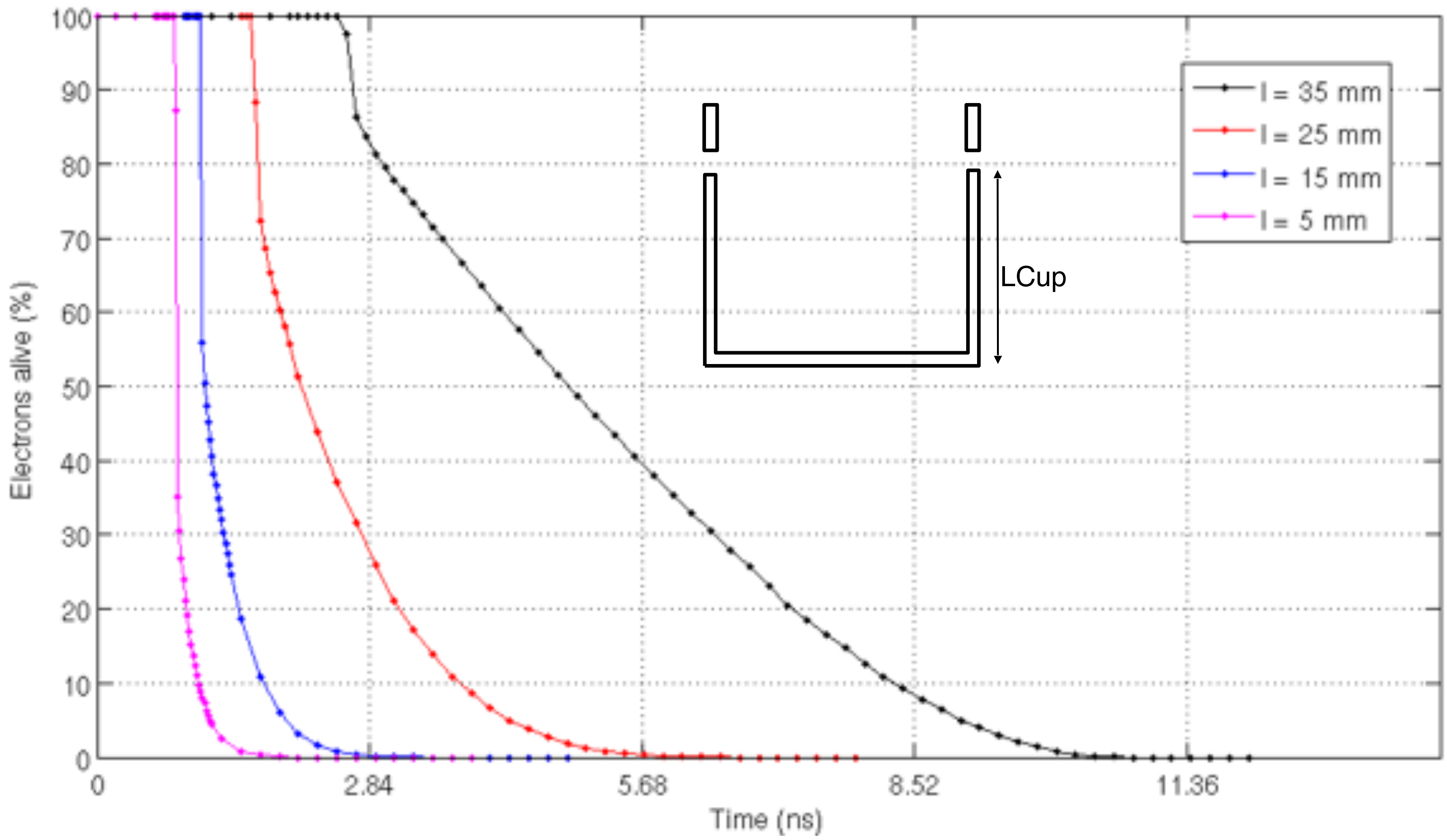
Fixed parameters: Angle = 0, LCup = 35 mm, LRep = 6 mm.



- Reducing the repeller radius and the distance to the FC help accelerate the electron capture rate.
- Rounding the FC corner also accelerates the process, but very slightly.

Study 2: LCup

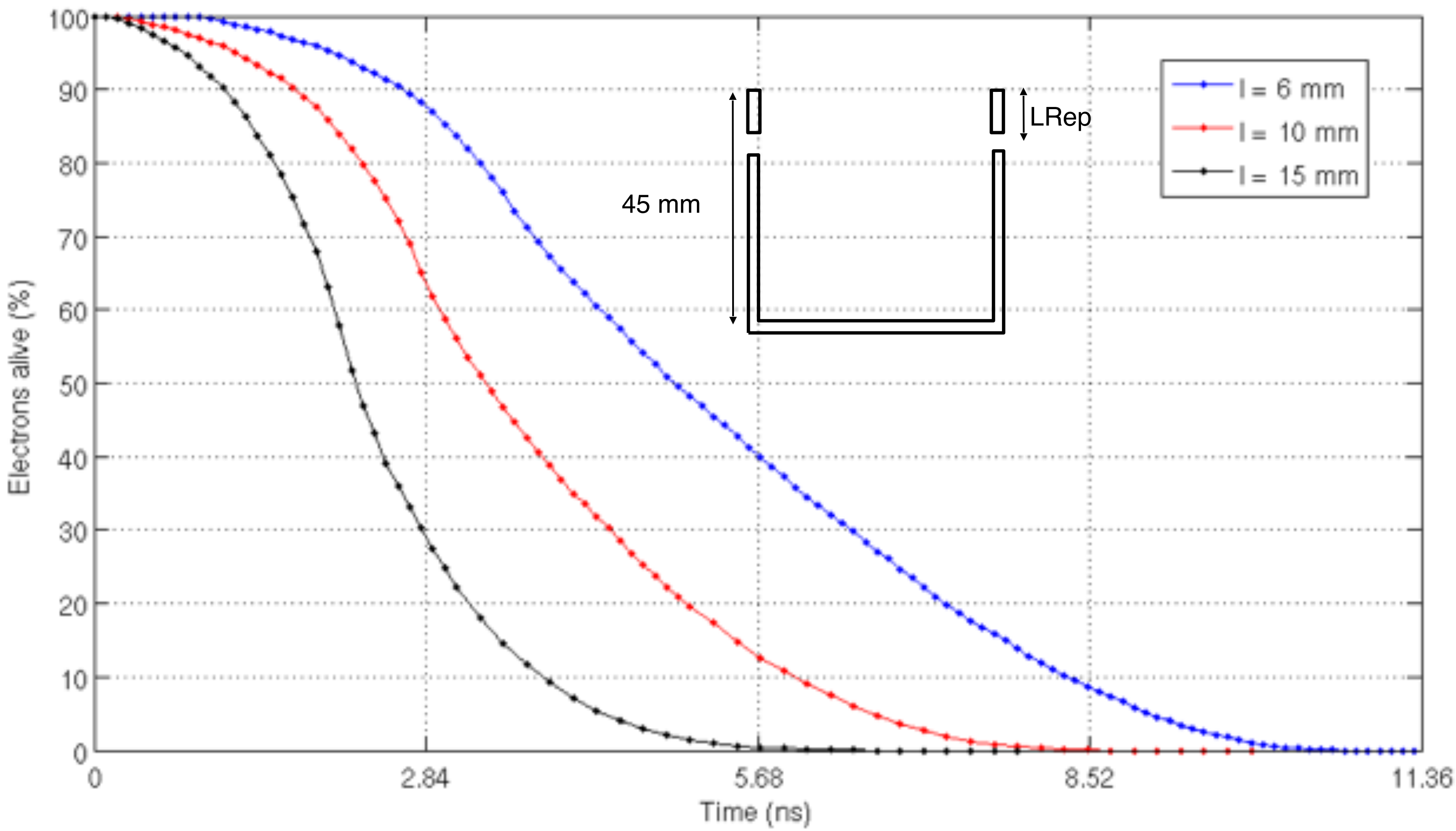
Fixed parameters: Angle = 0, RadRep = 24.5 mm, d = 4 mm, LRep = 6 mm.



- Reducing the cup length accelerates the electron capture time critically.
- Lengths below 15 mm achieve a 100% electron capture in a time shorter than a RF period.

Study 3: LRep

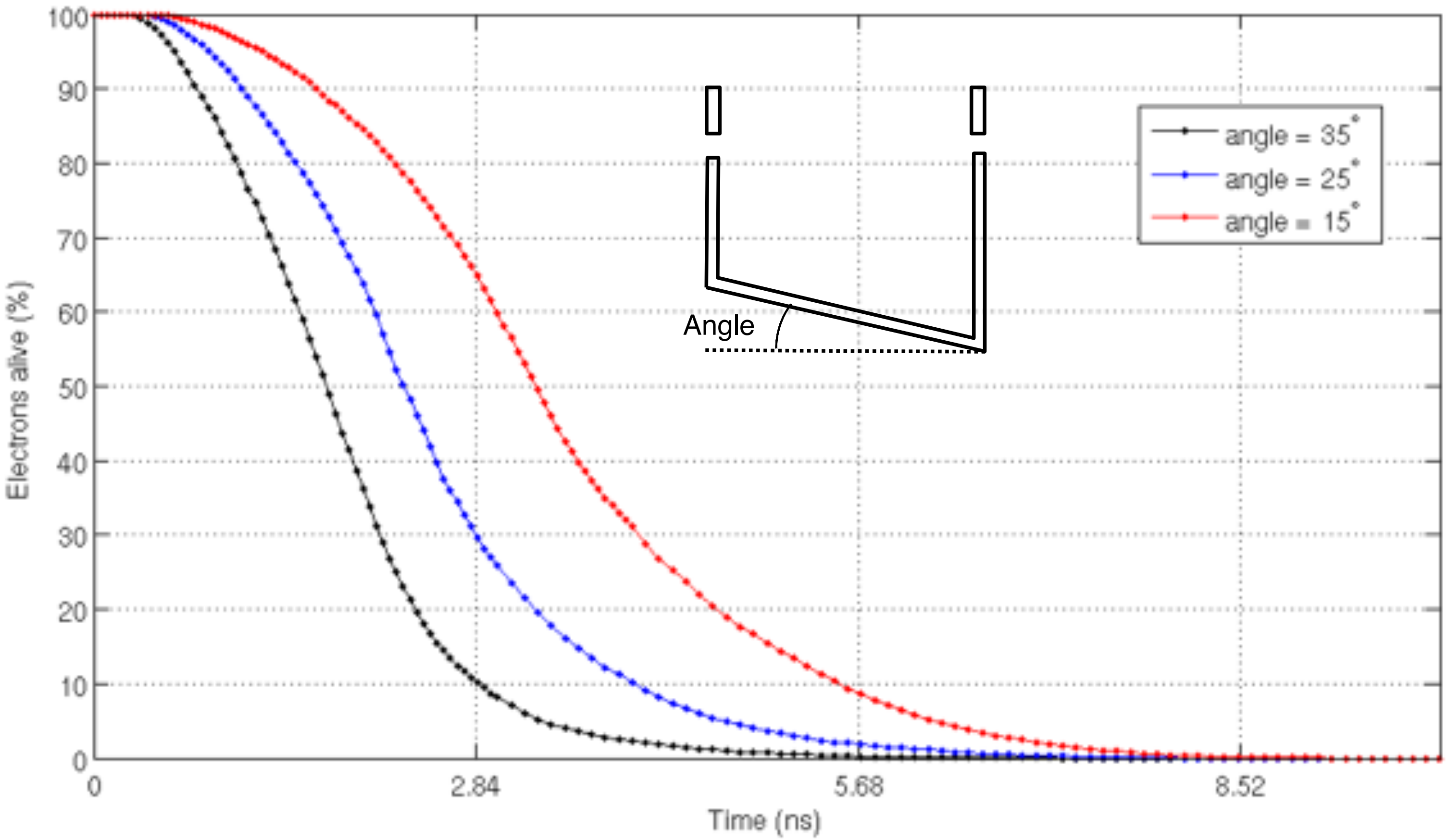
Fixed parameters: Angle = 0, RadRep = 24.5 mm, d = 4mm, LCup = 41 mm - LRep



- Increasing the cup length accelerates the electron capture time.
- The effect is the sum of the increased repeller length and the decreased cup length.

Study 4: Angle

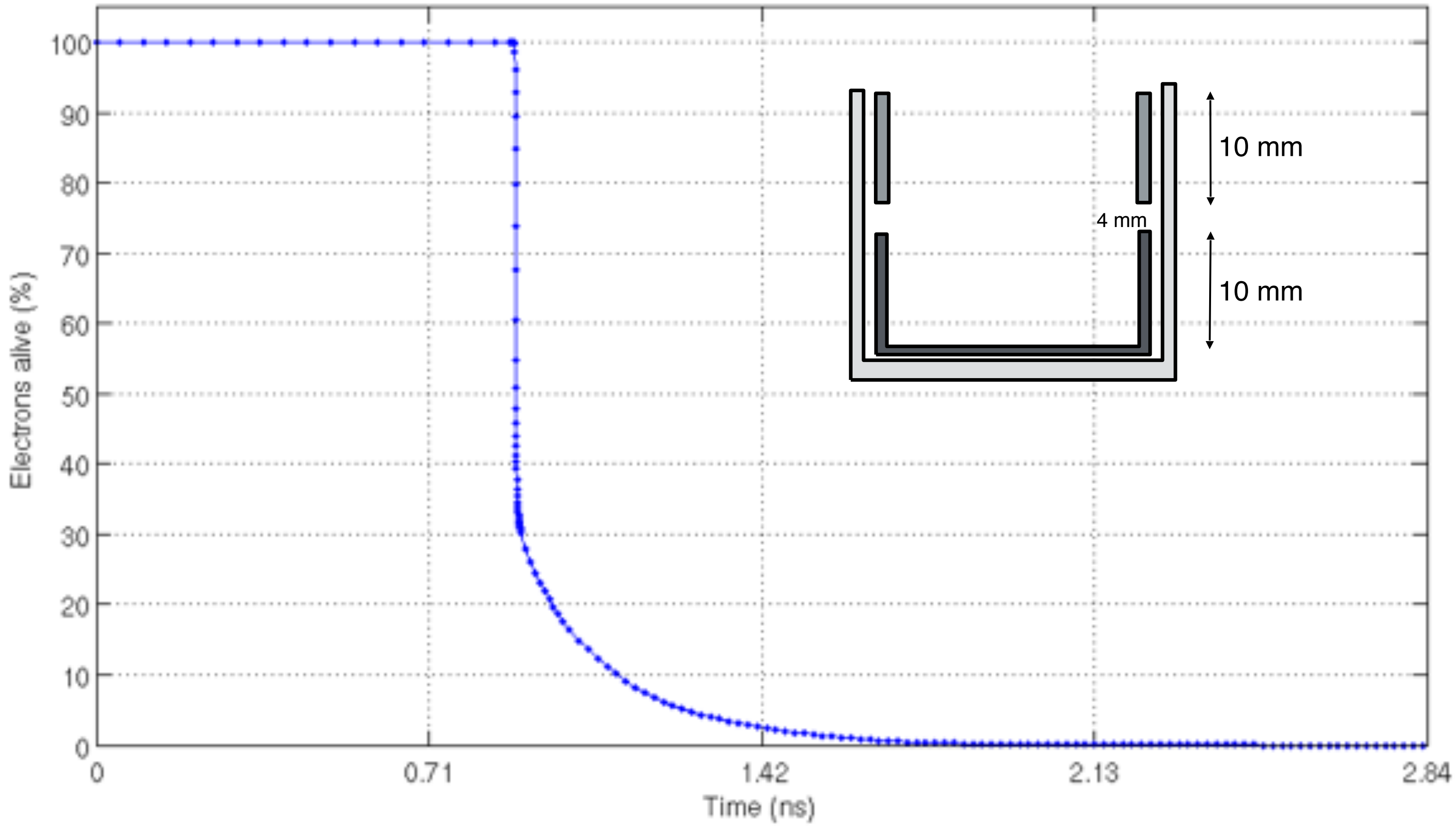
Fixed parameters: RadRep = 24.5 mm, Lcup = 35 mm, d = 4mm, LRep = 6 mm



- Increasing the cup angle accelerates the electron capture time, possibly due to the fact that one of the cup sides becomes shorter.
- In any case, the need to have an inclined face might come from thermo-mechanical requirements, not from repelling efficiency.

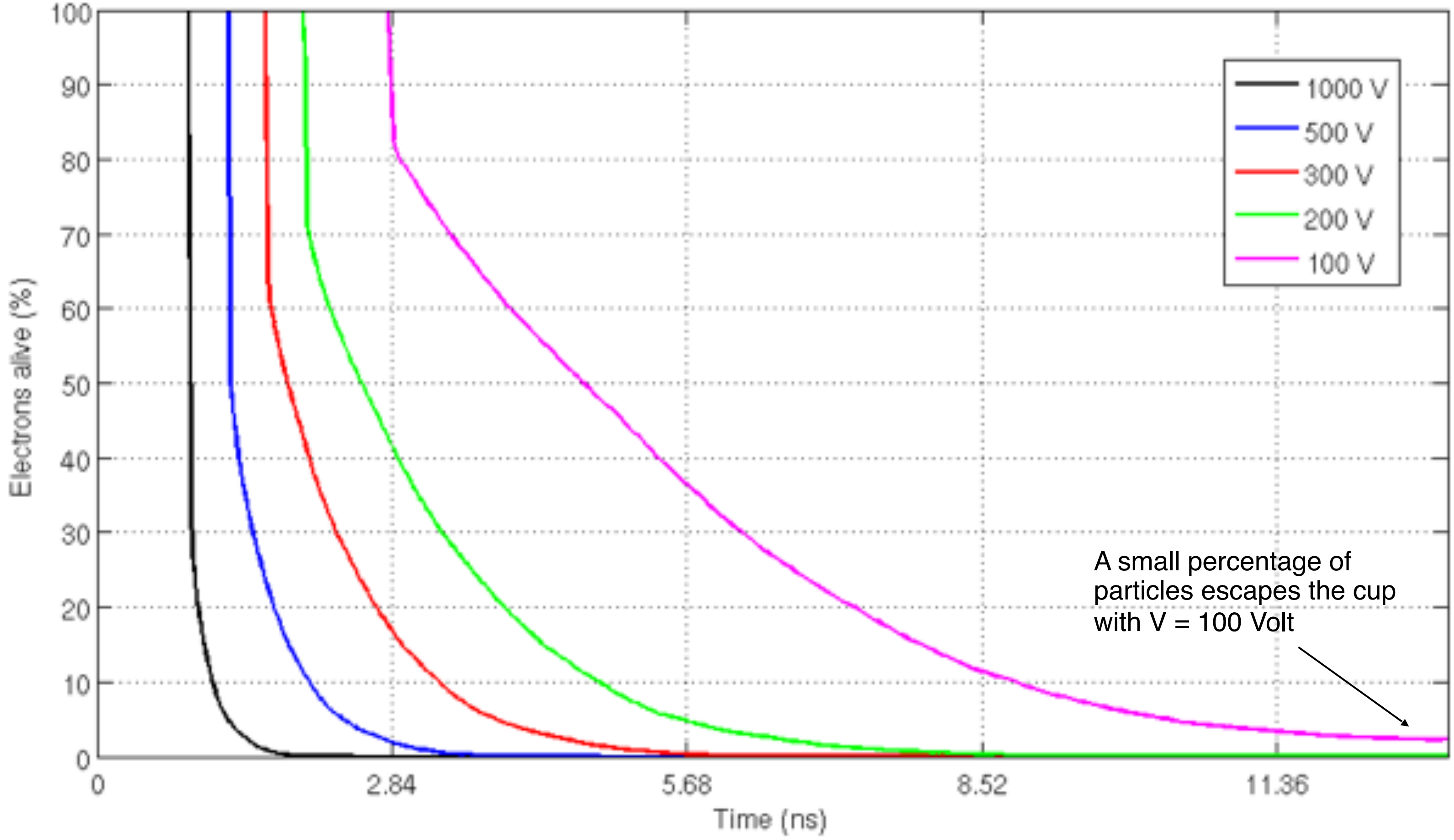
Basic design proposition

Fixed parameters: RadRep = 24.5 mm, Lcup = 10 mm, d = 4mm, LRep = 10 mm, Angle = 0



- This design comprises a side length of 24 mm, with plenty of space to fit other elements needed.
- The full electron suppression occurs at ~2 ns, well shorter than a RF period. Moreover, 97% of the suppression is achieved in half a RF period.

Repelling time for lower V



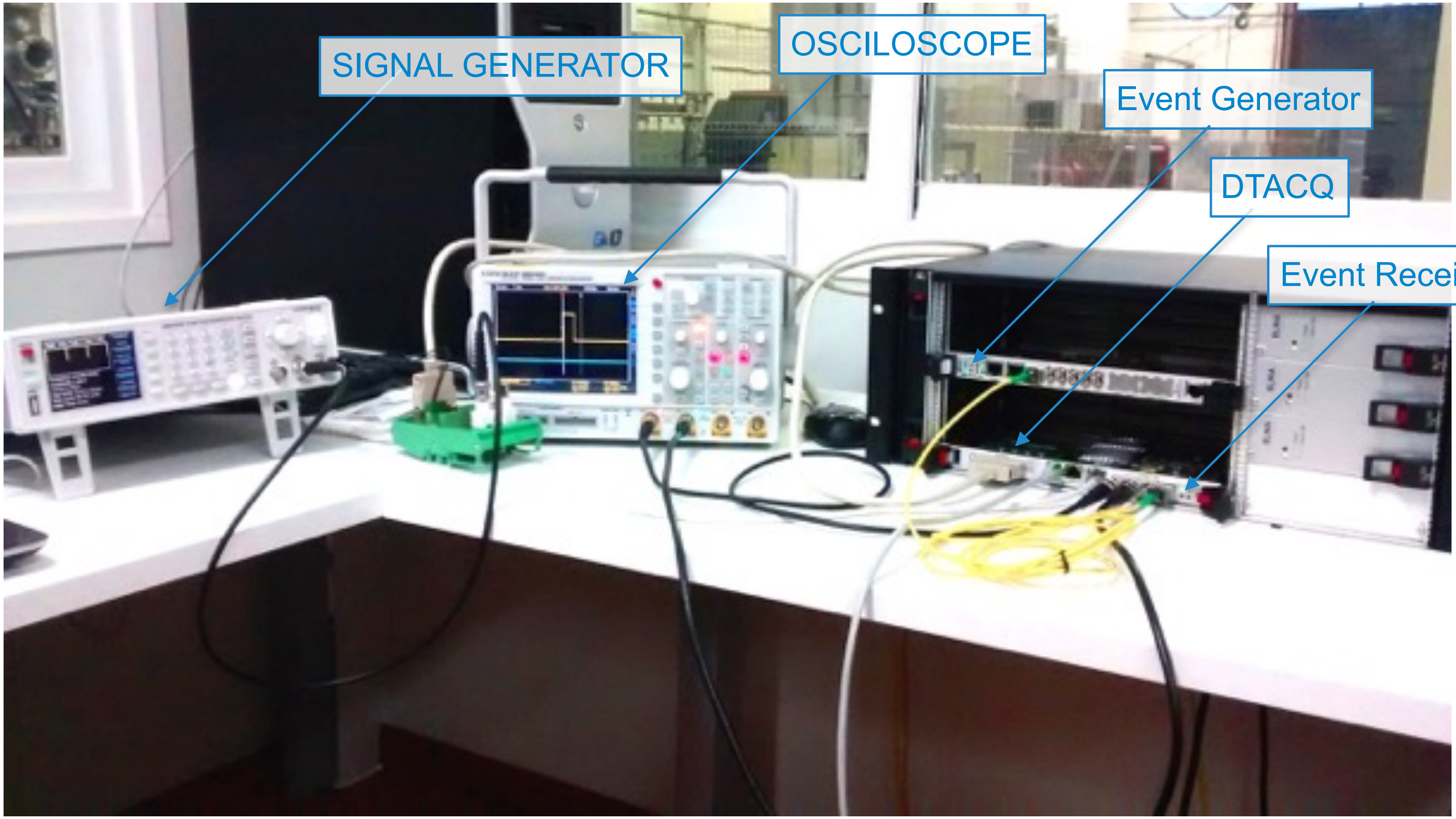
- A lower voltage than the specified 1000 V can be used if necessary.
- With a repelling voltage as low as 200 V, a 100% recapture is still achieved in about 9 ns.

Conclusions

- Basic simulations indicate that we can achieve a **100% electron suppression** in the Faraday Cup. Full recapture times typically take **a few ns**.
- By tweaking some of the main geometric parameters, we can achieve a full recapture **in less than a RF period**.
- A full recapture can also be achieved if the suppressor voltage is lowered down to **200 V**, although the total capture time is obviously longer.
- More accurate simulations and a finer parameter optimisation are to follow, **once the thermo-mechanical studies are completed.**

Integration

Timing and Digitising tests over VME crate: A SW trigger is generated from Event Generator, that is received by the Event Receiver which output is a pulse shown in the scope, and the signal for being digitised is inserted from the signal generator as well as the trigger for capturing the signal.



Integration: EPICS module

LEAMSEDOS EPICS MODULE

Database

lebt@lebt:(unreachable)/Dosimetro_EPICS/compilado_Carlos/db

File Edit View Search Terminal Help

```
record(stringin, "ISHP:DOS:MSG") {
  field(DTYP, "stream")
  field(INP, "@dosimetro.proto get_msg moxaport")
  field(DESC, "Cabecera")
  field(SCAN, "I/O Intr")
  field(FLNK, "ISHP:DOS:TMed")
}

record(scalcout, "ISHP:DOS:TMed") {
  field(INAA, "ISHP:DOS:MSG")
  field(CALC, "(SSCANF(AA,'%*17c%3d')/100)")
  field(SCAN, "Passive")
  field(EGU, "uSV/h")
  field(LOW,  "0")
  field(LSV,  "MINOR")
  field(HIGH, "1")
  field(HSV,  "MINOR")
  field(HIHI, "1.5")
  field(HHSV, "MAJOR")
  field(FLNK, "ISHP:DOS:TMax")
}

record(scalcout, "ISHP:DOS:TMax") {
  field(INAA, "ISHP:DOS:MSG")
  field(CALC, "(SSCANF(AA,'%*25c%3d')/100)")
  field(EGU, "uSV/h")
  field(LOW,  "0")
  field(LSV,  "MINOR")
  field(HIGH, "1")
  field(HSV,  "MINOR")
  field(HIHI, "1.5")
  field(HHSV, "MAJOR")
  field(FLNK, "ISHP:DOS:DTotal")

}

record(scalcout, "ISHP:DOS:DTotal") {
  field(INAA, "ISHP:DOS:MSG")
  field(CALC, "(SSCANF(AA,'%*28c%6d')/100)")
  field(EGU, "uSV")
  field(FLNK, "ISHP:DOS:AlarmType")
}

record(scalcout, "ISHP:DOS:AlarmType") {
  field(INAA, "ISHP:DOS:MSG")
                                                   1,1           Top
```

Protocol

lebt@lebt:/run/media/lebt/KINGSTON/Dosimetro_EPICS/compilado...

File Edit View Search Terminal Help

```
# Tiempo de respuesta corto
PollPeriod = 1;
# Timeout mayor que tiempo de muestreo del equipo
ReplyTimeout = 6000000;
LockTimeout = 7000000;

# Etapa de inicialización
get_cab {
    out 0x01,"V11P";
    in 0x01,"V11S";
    out 0x01,"V11S";
    in 0x01,"M2011","%*s";
    in 0x01,"V11S";
    out 0x01,"V11S";
    in 0x01,"M1011","%s";
}

# Bucle de adquisición de
get_msg {
    in 0x01,"V11S";
    out 0x01,"V11S";
    in 0x01,"M1011","%s";
    @init {
    get_cab;
    }
}
```

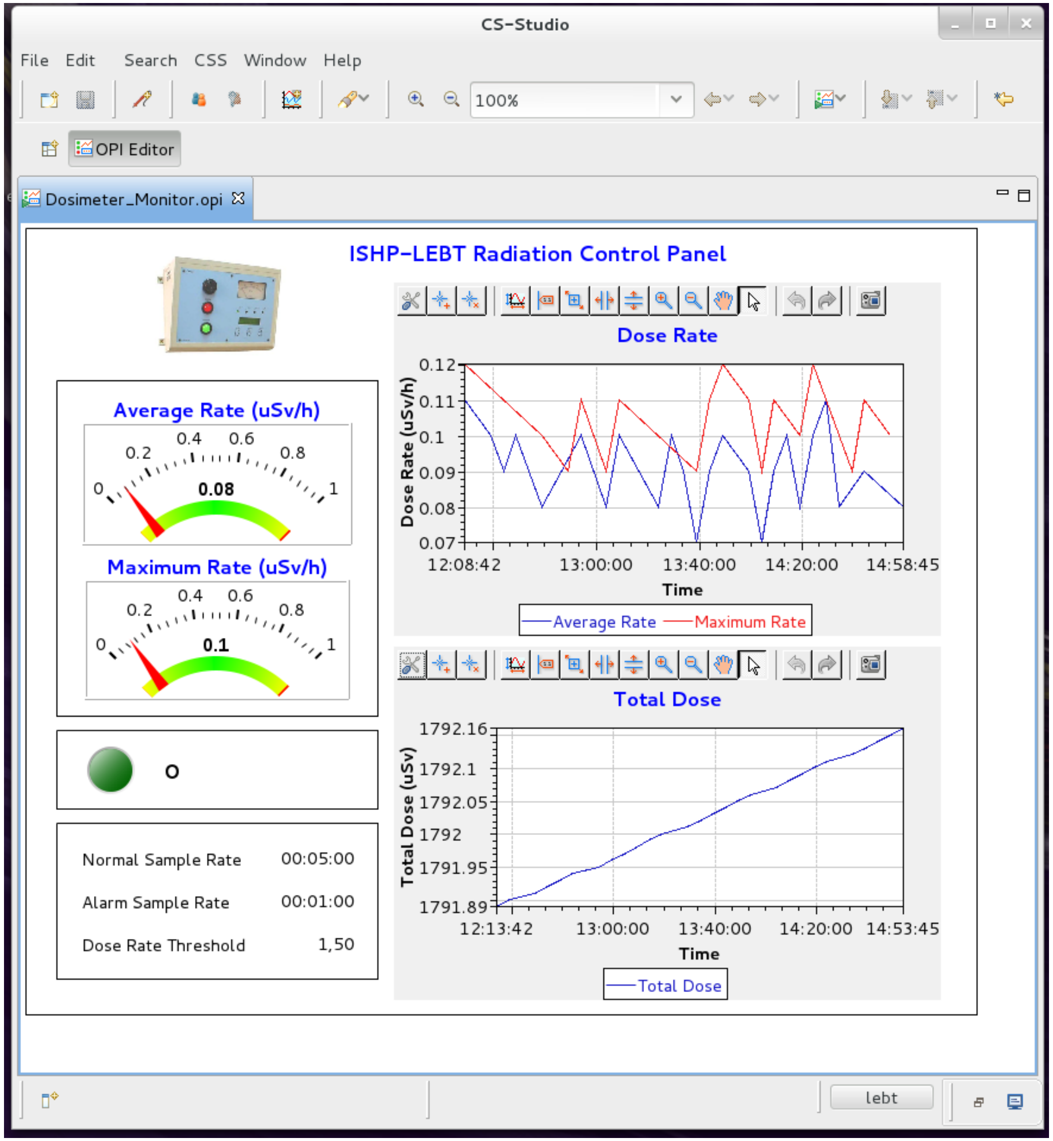
IOC

lebt@lebt:(unreachable)/Dosimetro_EPICS/compilado_Carlos/startup

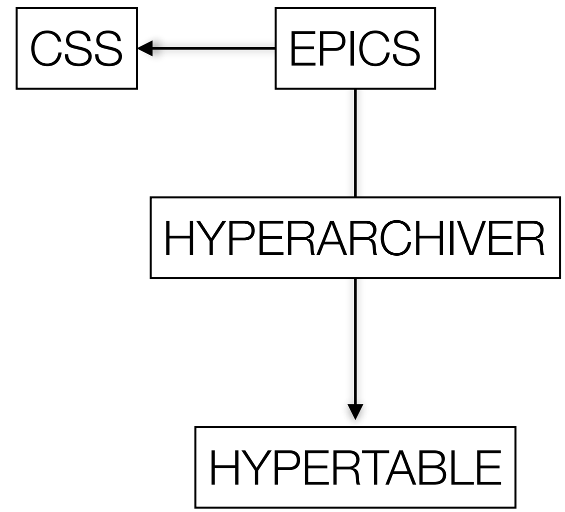
File Edit View Search Terminal Help

```
# Se requiere streamdevice para comunicación serie y calc para lo
s records scalcout
require streamdevice
require dosimetro
require calc

# Configuración a utilizar con Moxa en modo "RealCOM" mapeando un
 puerto virtual ttySX
drvAsynSerialPortConfigure ("moxaport","/dev/ttyS0")
asynSetOption ("moxaport", 0, "baud", "19200")
asynSetOption ("moxaport", 0, "bits", "8")
asynSetOption ("moxaport", 0, "parity", "none")
asynSetOption ("moxaport", 0, "stop", "1")
asynSetOption ("moxaport", 0, "clocal", "N")
asynSetOption ("moxaport", 0, "crtscts", "N")

# Configuración a utilizar con Moxa en modo "TCP Socket"
#drvAsynIPPortConfigure("moxaport","192.168.0.100:4001",0,0,0)

# Carga de la base de datos con los EPICS records
dbLoadRecords(dosimetro.db)
~
~
~
```

Integration: EPICS module



LEAMSEDOS EPICS MODULE



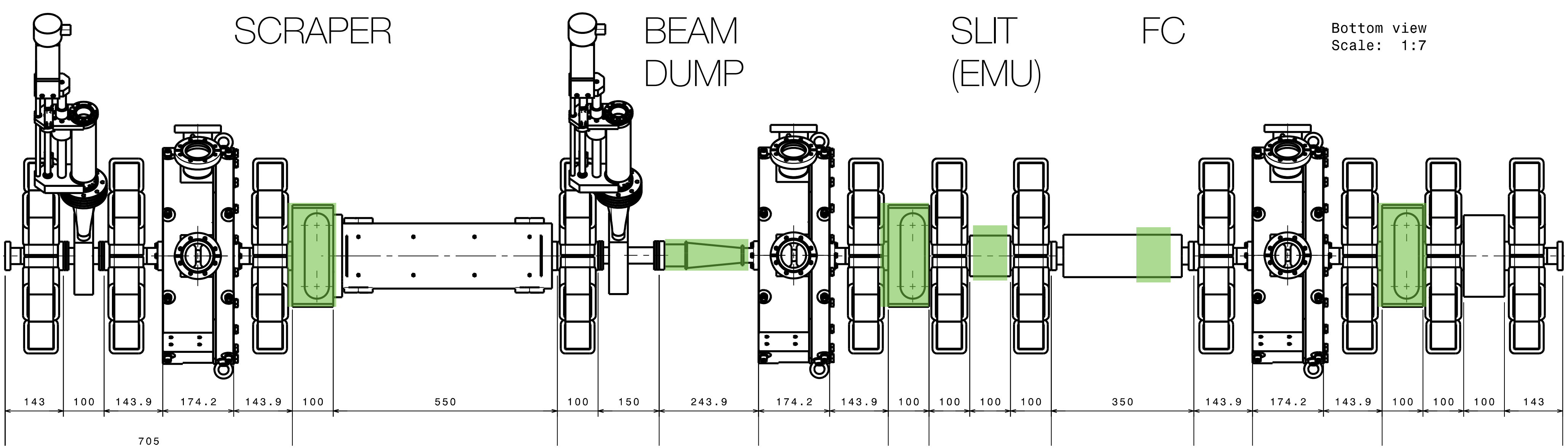
People

FC	People
Conceptual	D. deCos, R. Miracoli
Measurements	S. Varnassari
Analog procesing	C. de la Cruz
Thermo-mechanical	T. Mora, R. Vivanco, F. Sordo
Acquisition	I. Mazkiaran, I. Ortega
Integration	A. Milla

Beam stoppers

Problem Description

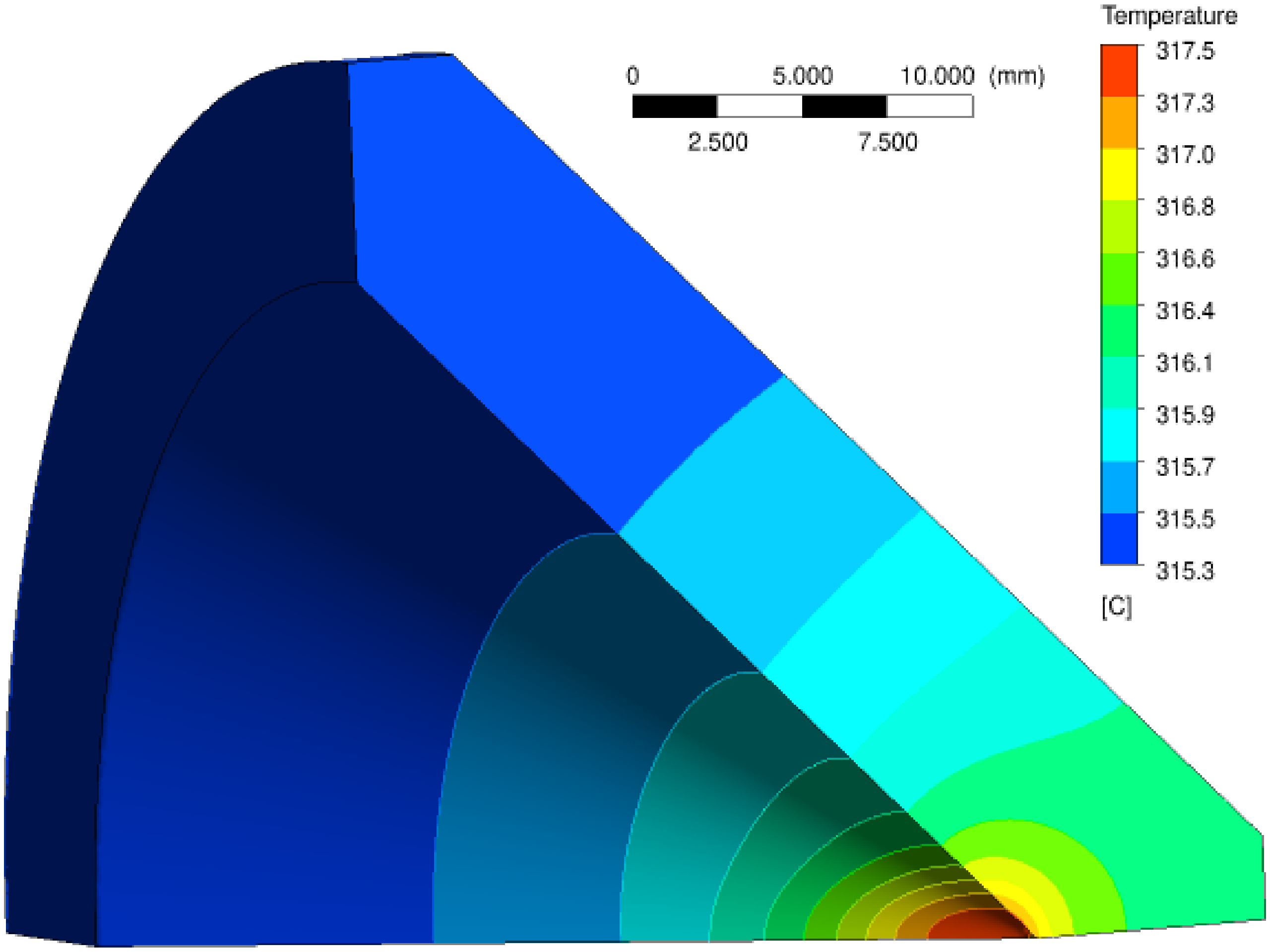
- From the **transient state** calculations, one can infer that this model has to be discarded given the combination of **high power** distributed in a **very concentrated** beam size and a **swallow deposition surface**.
- Please note that current and energy combination result in a **230 kW** peak power which exceeds other MEBTs, SNS peak power **130 kW**, LINAC4, RAL, JPARC (~**180 kW**).



Part2: Summary

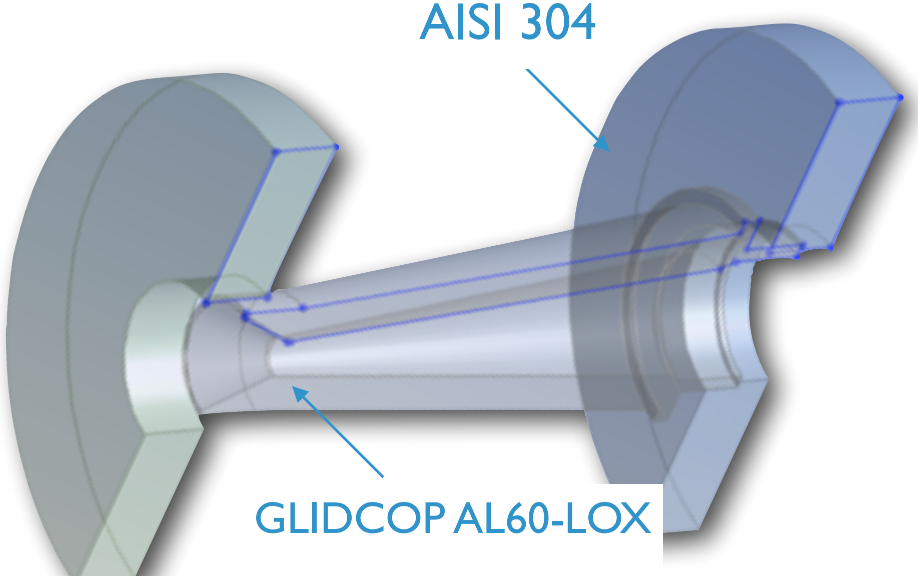
Contents:

- Copper Study
- Activation Study
- Tungsten Study
- Graphite Study

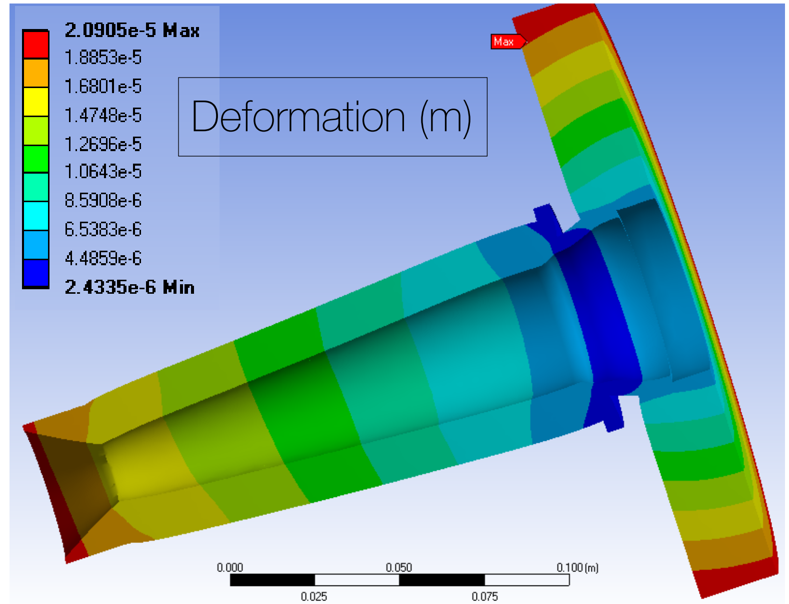


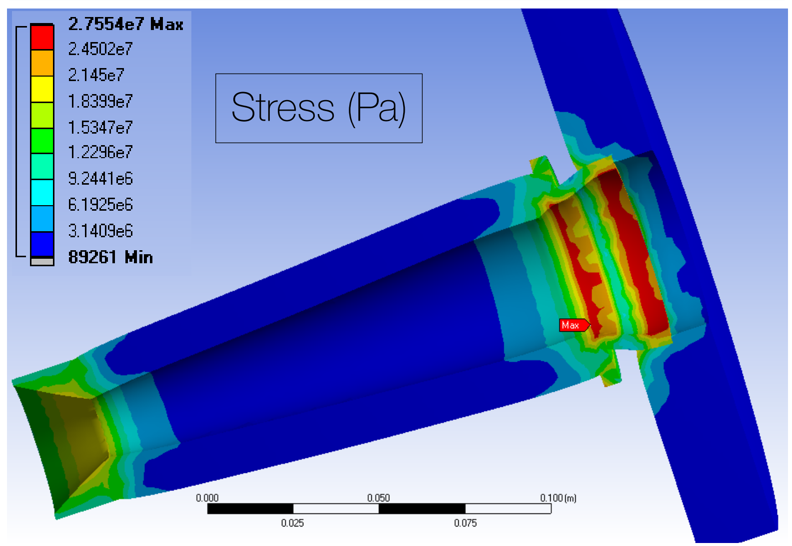
Beam Dump Copper

- Copper valid for Beam Dump, but not for the rest. (mechanical stresses in the joins)



MEBT-CH-BD01-04

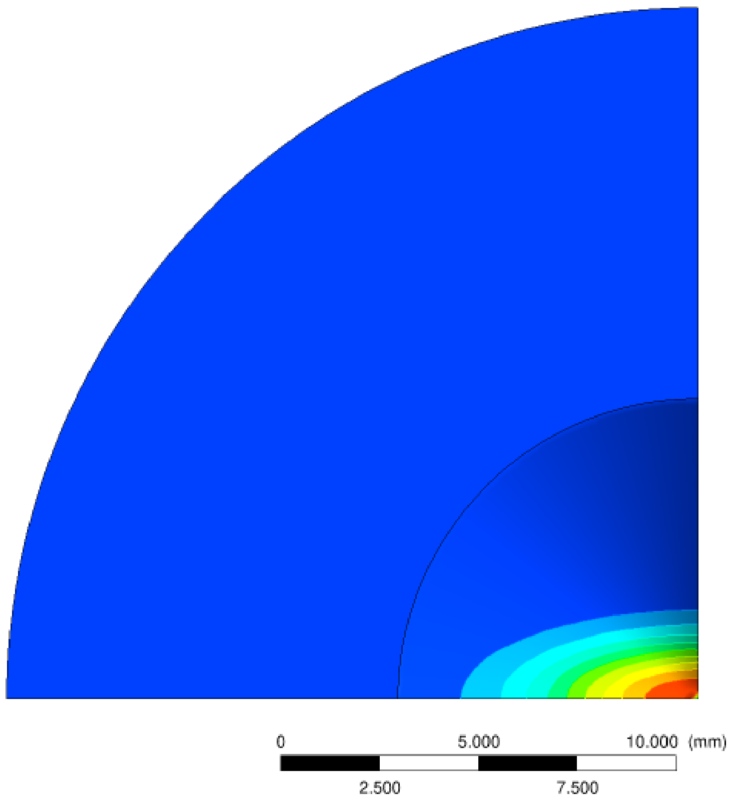




FC copper

- Beam Mode 2: (50μs; 1Hz)
- Copper
- Conical shape: maximum temperature is 2322ºC (beam footprint area). Thermal gradient >1900ºC.
- 90º(45º): the temperature reaches 307ºC on the steady state and it reaches peaks of 3327ºC (2430ºC) on the transient state.
- Copper melting point 1100ºC.

MEBT-BI-FC03-03



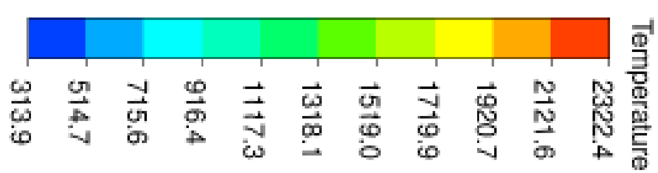
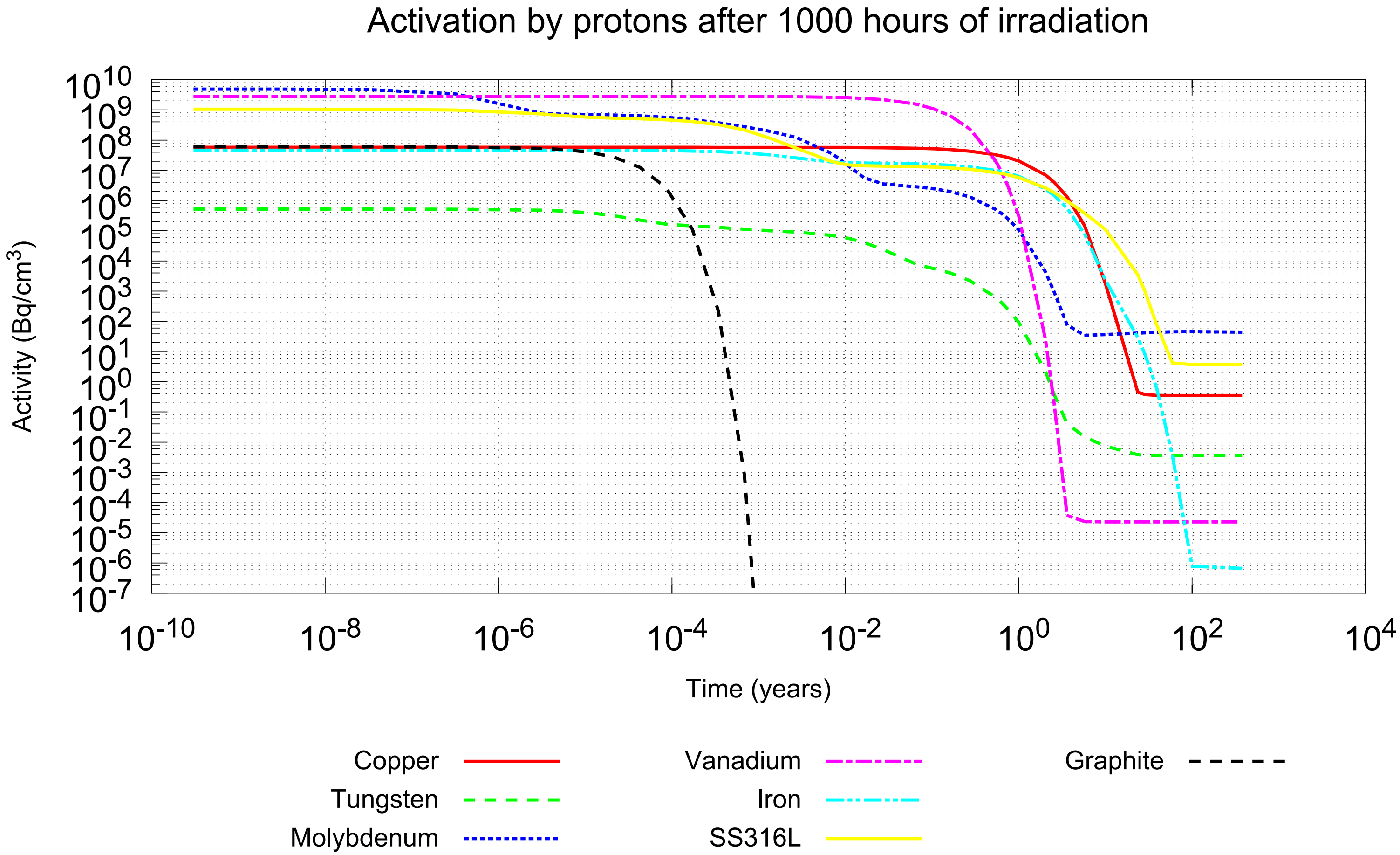


Table: Main results for copper

Geometry	mode	max temp steady (^oC)	max temp transient (^oC)
Conical shape	1	432	1071
	2	317	2322
90^o straight plate	2	307	3327
45^o straight plate	2	307	2430

Activity

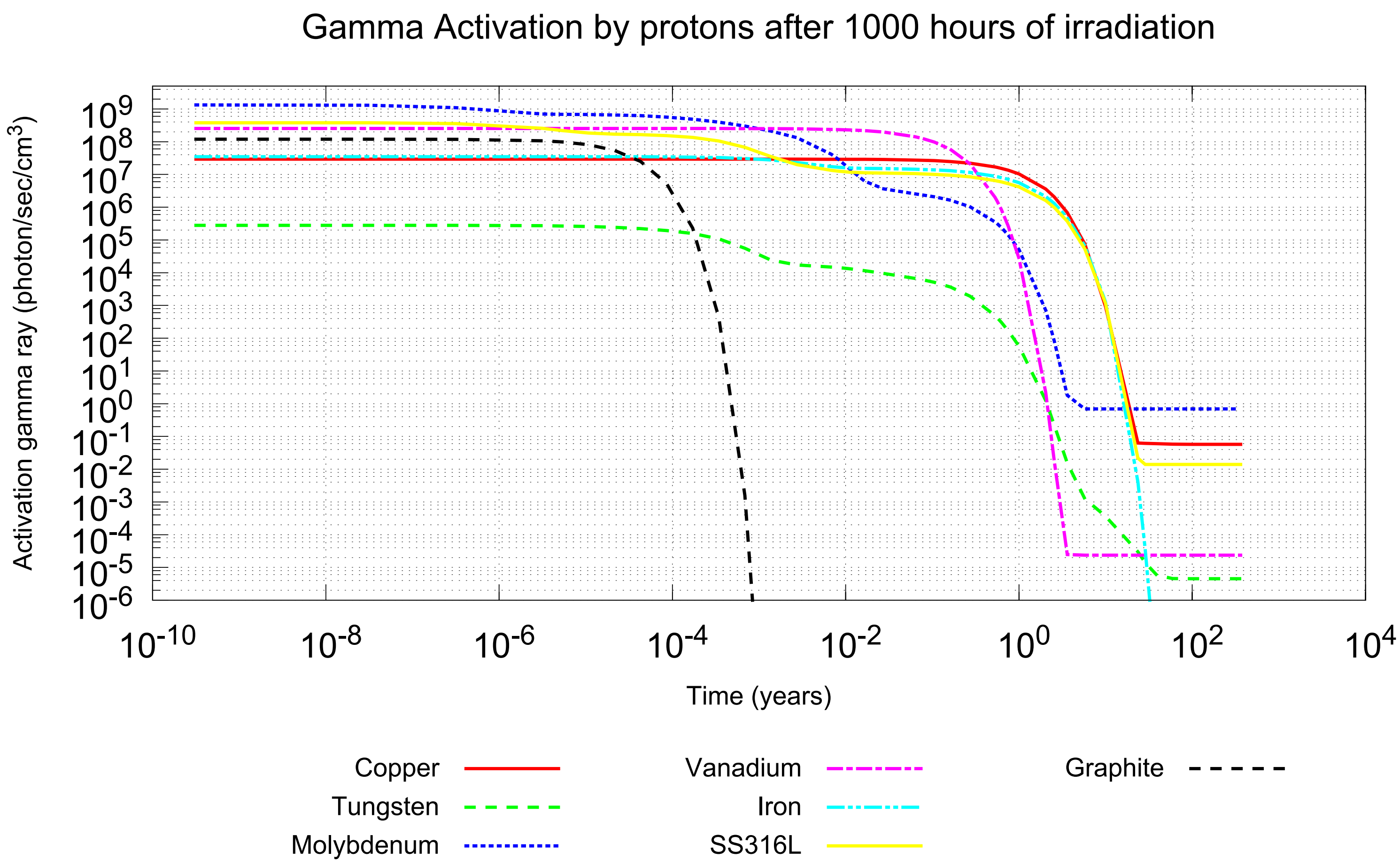
- **Total Activity:** MEBT-BI-FC03-04
- The material that produces lower total initial activity is tungsten, followed by copper, iron and graphite.
- The activity produced by graphite decays quickly and it is very low after few hours.
- After 1 – 5 years, the total activity produced by vanadium and tungsten are the lowest values, after graphite.



Activity

MEBT-BI-FC03-04

- **Gamma Activity:**
- The gamma activity has the same tendency than the total activity.
- The gamma activity in the graphite is produced by the isotope N-13. This isotope is the most important and it
  decays in β+, with the emission of two 0.511 MeV gammas.



50μs pulse length

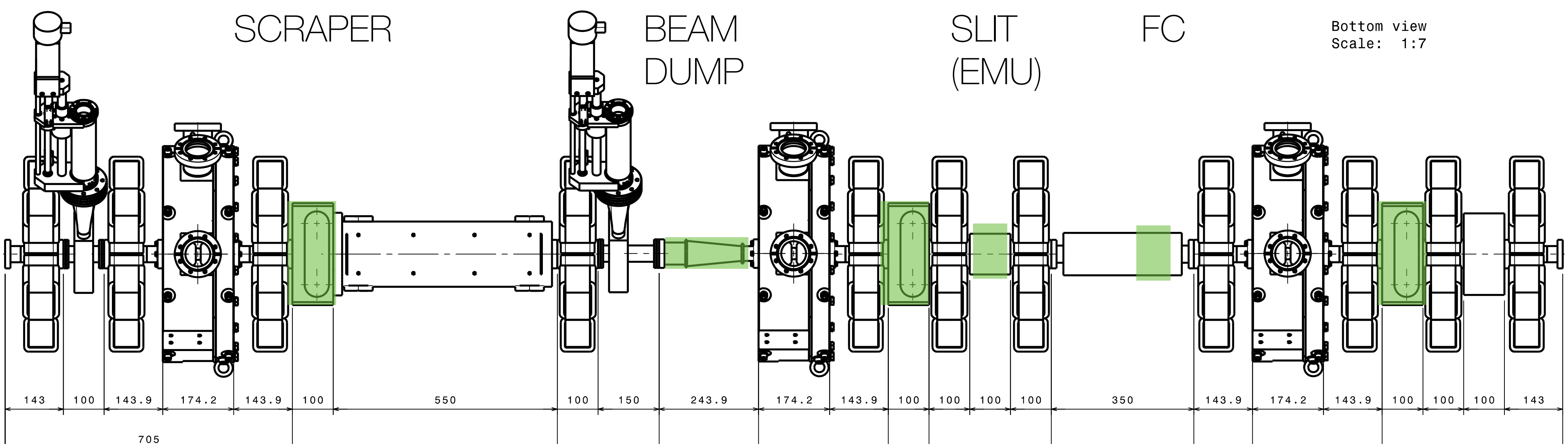
MEBT-BI-FC03-06

Proton beam parameters

- Beam size: $\sigma_x = \sigma_y = 2.5\ mm$
- Protons energy: $3.62\ MeV$
- Current peak: $65\ mA$
- Pulse length: $50\ \mu s$
- Pulse frequency: $1\ Hz$

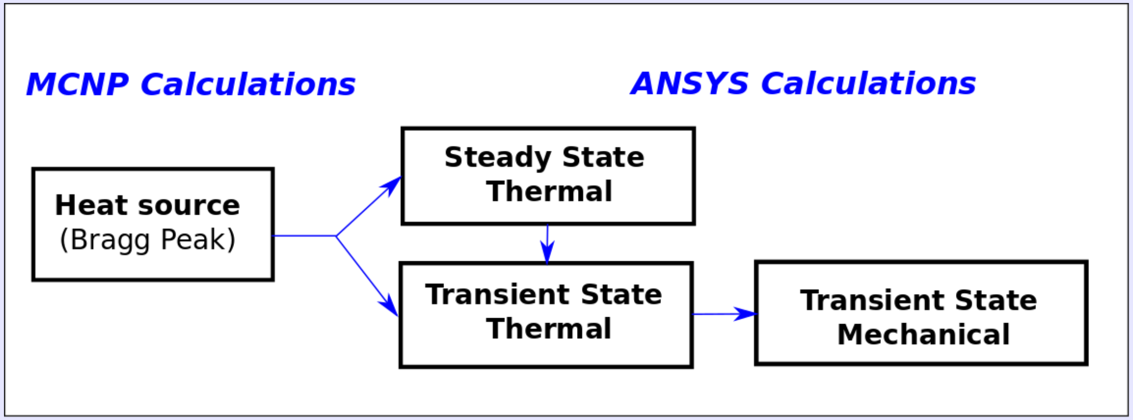
Calibrated with ESS-BI

(B. Cheymol)

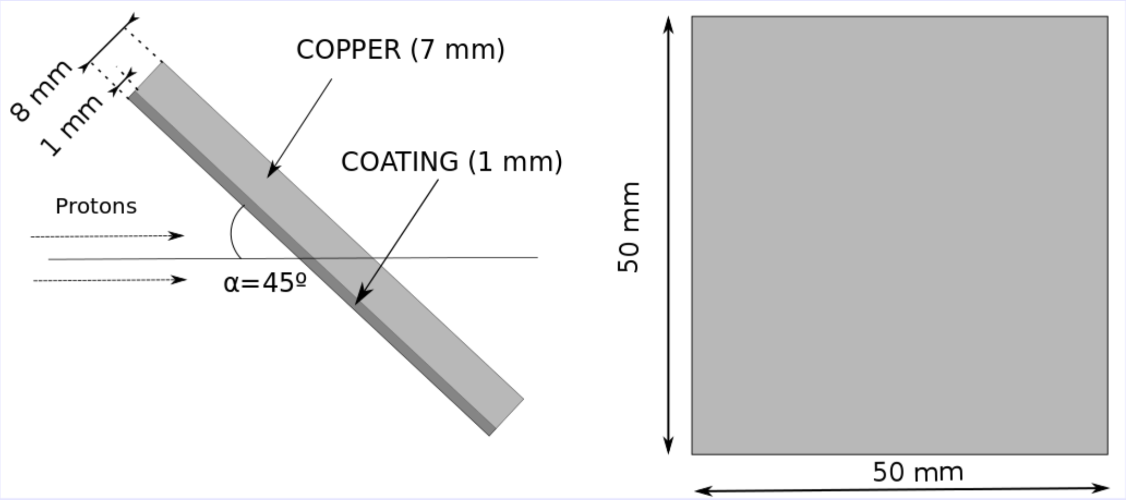


50μs pulse length

Methodology



Faraday Cup geometry

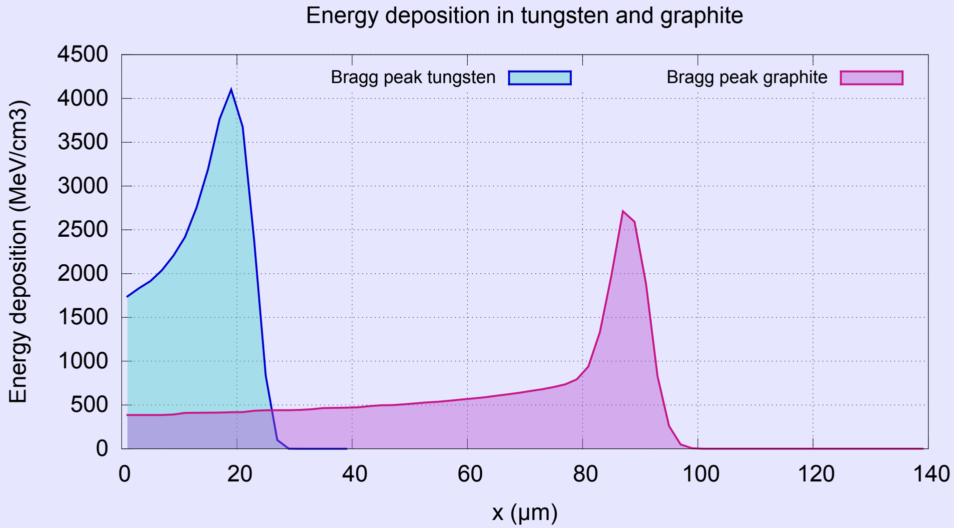


50μs pulse length

Material conclusions

The main difference between graphite and tungsten for the FC coating comes from the Bragg Peak. In the case of graphite appears deeper ($100\ \mu\ m$) and shallower in tungten ($30\ \mu\ m$). Moreover, the volumetric energy deposition on the tungsten is a 50% greater ($2.6 \cdot 10^5 W/mm^3$ against $1.7 \cdot 10^5 W/mm^3$).

Furthermore, the shape of the deposition of the Bragg peak is flatter in tungsten and is closer to superficial deposition case (which is most unfavorable). However in graphite it occurs more gradually and away from the surface, leaving "more space" to conduct heat.

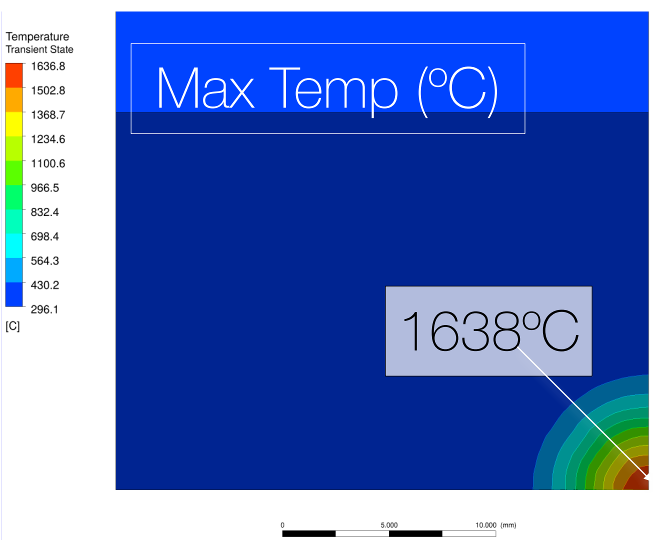


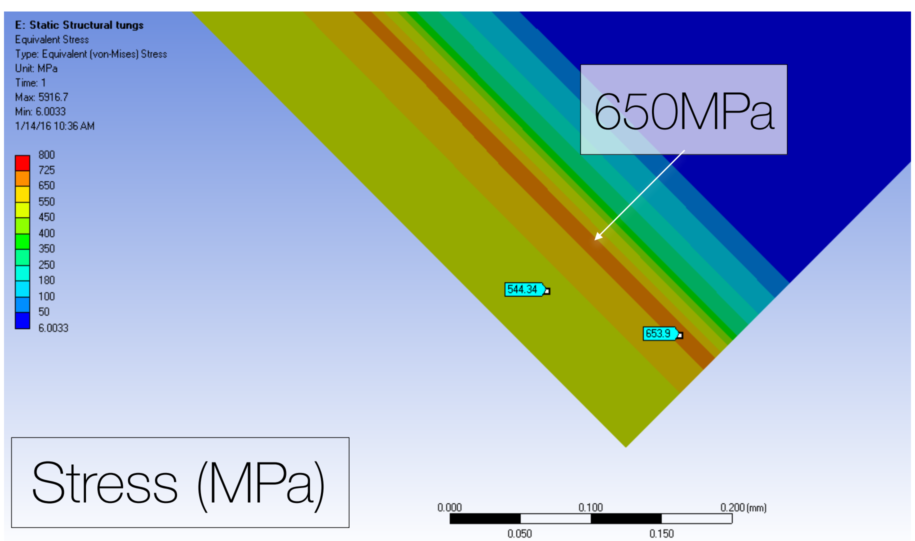
Graphite coating
Tungsten coating

Tungsten

Tungsten:

- The energy deposition in the tungsten is hight from the beginning and the Bragg peak appears at **30µm** of the FC surface.
- The **steady** state temperature with this proton beam is **300ºC**.
- The **maximum temperature** reached by the tungsten (**1638ºC**) is far from the melting point (3400ºC) but it is close to the maximum service temperatures recommended (1925ºC). This maximum temperature appears in the FC surface.
- The mechanical analysis reveals that the **maximum stress** (650 MPa) is **over the tensile strength** (500 MPa).

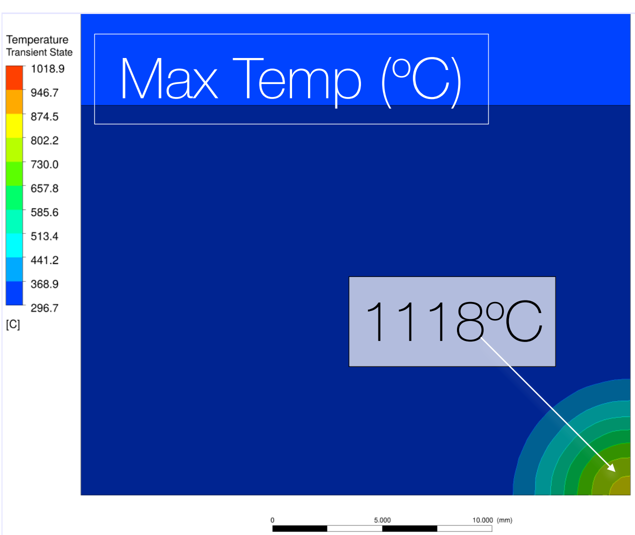


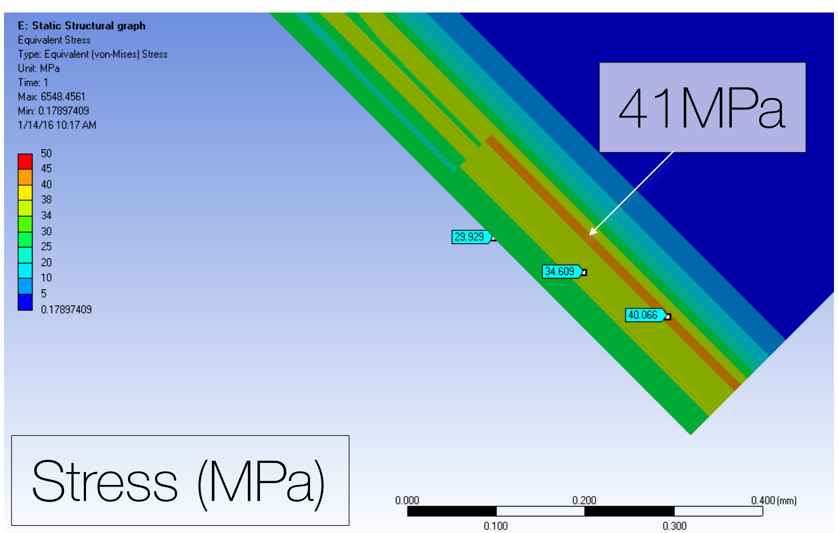


Graphite

Graphite:

- The energy deposition in the graphite has low slope until the Bragg peak appears at **100 µm** of the FC surface.
- The **steady** state temperature with this proton beam is **300ºC**.
- The maximum temperature reached by the graphite (**1018ºC**) is far from the melting point (3500ºC) and it appears near the surface but **not in the surface**.
- The mechanical analysis reveals that the **maximum stress** (40 MPa) is **over** the **tensile strength** (38 MPa) and it is **far from the recommended limit** of 2/3 of the tensile strength (25 MPa).



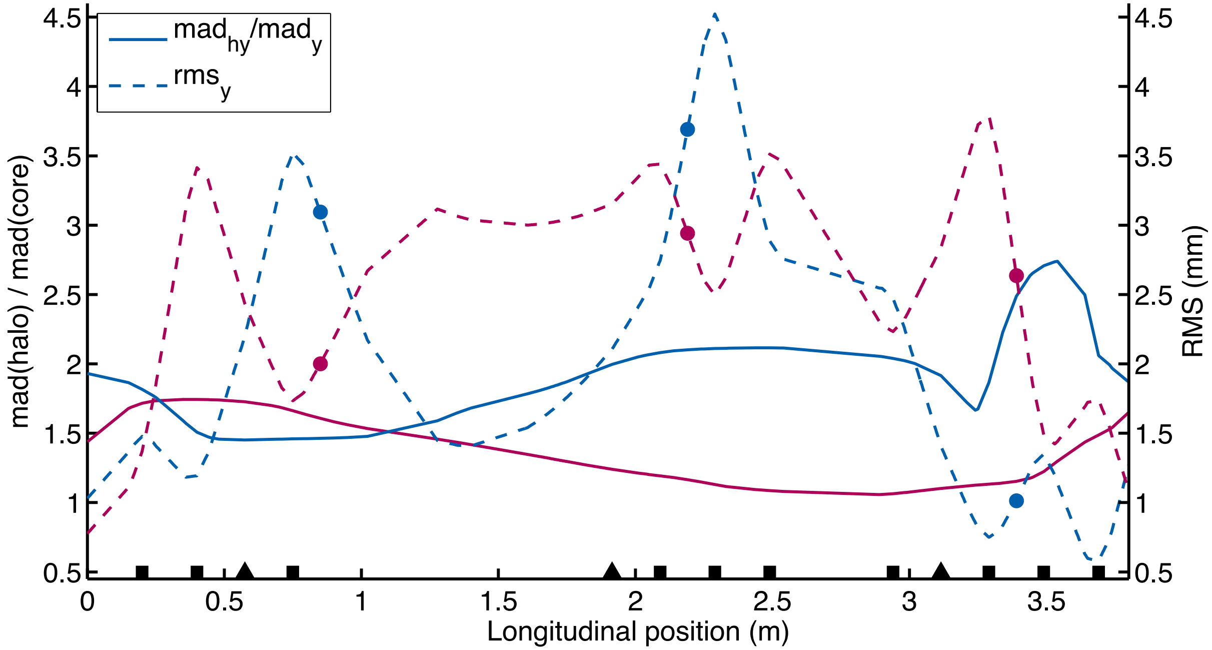


50μs pulse length

Detected issue:

- The proton beam parameters established for the FC or any other beam stopper are higher to the ones which ensure the physical integrity of this component. These calculations have been done taking into account only one pulse, so the fatigue process had not been simulated, which can produce even worst results.

- On top of this, the agreed beam size on this occasion (σx = σy = 2.5 mm) will be different in other parts along the MEBT, like the Scraper 3, in which the footprint is 2.5 times lower than in the given FC footprint, and this could increase the peak temperature approximately 2.5 times.

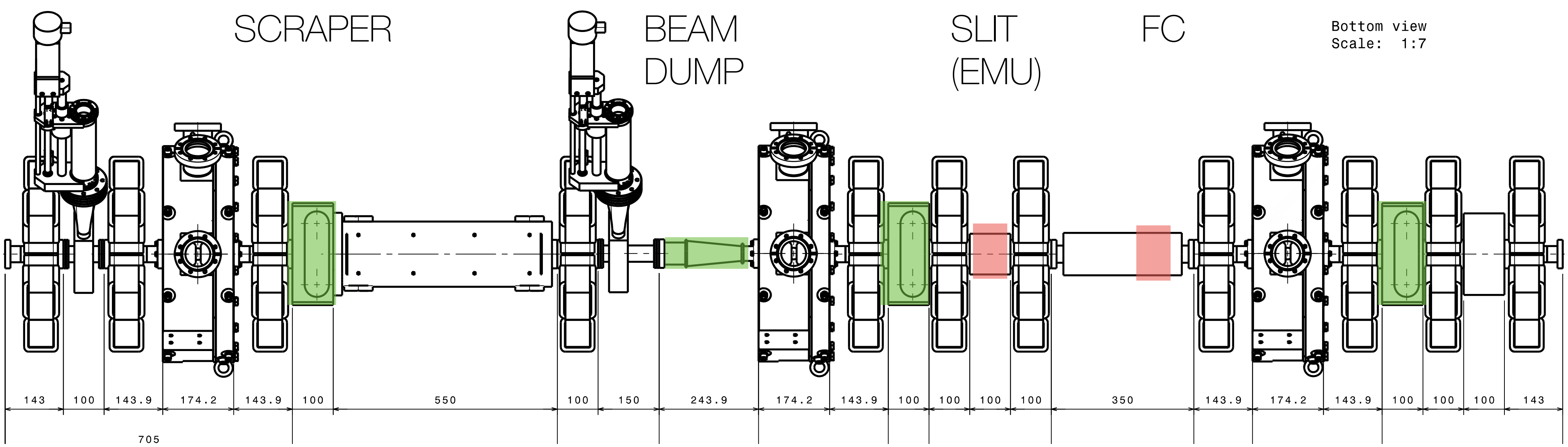


50μs pulse length

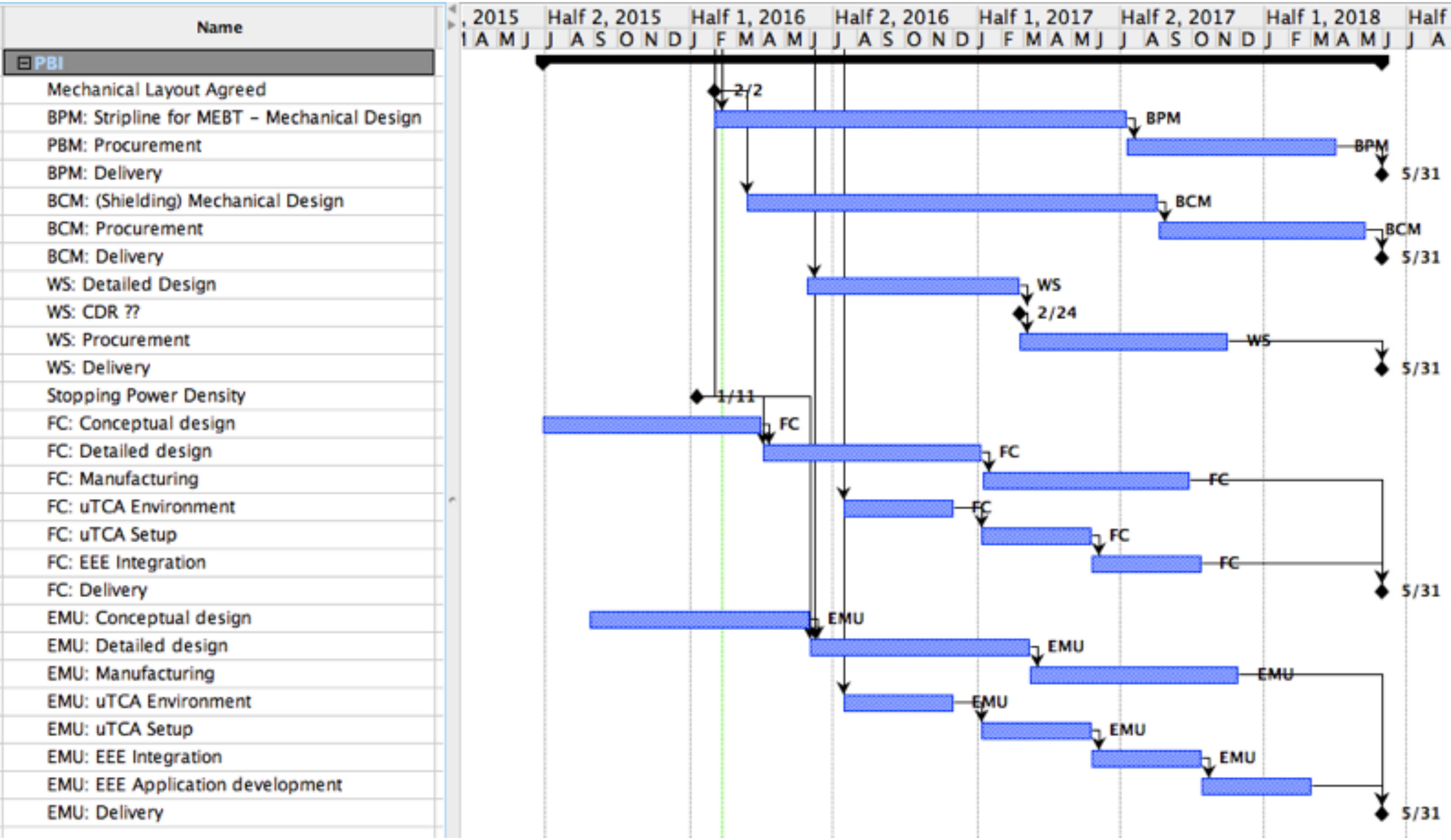
Detected issue:

- For the reasons explained above, a limit of proton beam power density per unit of time and area allowed should be identified. This is crucial in order to ensure thermo-mechanical integrity of different interceptive devices along the MEBT.

- I (mA) x W(MeV) x pulse length(μs) x $\sigma_{(x,y)}$ (mm^2)



Planning


Name
PBI
Mechanical Layout Agreed
BPM: Stripline for MEBT – Mechanical Design
PBM: Procurement
BPM: Delivery
BCM: (Shielding) Mechanical Design
BCM: Procurement
BCM: Delivery
WS: Detailed Design
WS: CDR ??
WS: Procurement
WS: Delivery
Stopping Power Density
FC: Conceptual design
FC: Detailed design
FC: Manufacturing
FC: uTCA Environment
FC: uTCA Setup
FC: EEE Integration
FC: Delivery
EMU: Conceptual design
EMU: Detailed design
EMU: Manufacturing
EMU: uTCA Environment
EMU: uTCA Setup
EMU: EEE Integration
EMU: EEE Application development
EMU: Delivery
, 2015
Half 2, 2015
Half 1, 2016
Half 2, 2016
Half 1, 2017
Half 2, 2017
Half 1, 2018
Half
A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
2/2
BPM
BPM
5/31
BCM
BCM
5/31
WS
2/24
WS
5/31
1/11
FC
FC
FC
FC
FC
FC
5/31
EMU
EMU
EMU
EMU
EMU
EMU
5/31

Eskerrik asko!

Fork & Grid Mech.	A. Vizcaino
Copper plating	C. Cruz, V. toyos, A.Salas
Wire tensor tool	C. Cruz
Actuator	A. Salas, I. Rueda
FC Conceptual	D. deCos, R. Miracoli
e-gun test bench	S. Varnassari
Analog procesing	C. de la Cruz
Thermo-mechanical	T. Mora, R. Vivanco, G. Bakedano, F. Sordo
Acquisition	I. Mazkiaran, I. Ortega
Integration	A. Milla, C. de la Cruz