Status of the ESS MEBT FC

FC Team
ESS-Bilbao
Beam Instrumentation Group

October – 2016

Summary

- Introduction
- Conceptual Design
- Mechanical Design
- Signal Conditioning
- EEE Integration & IOC
- Conclusions

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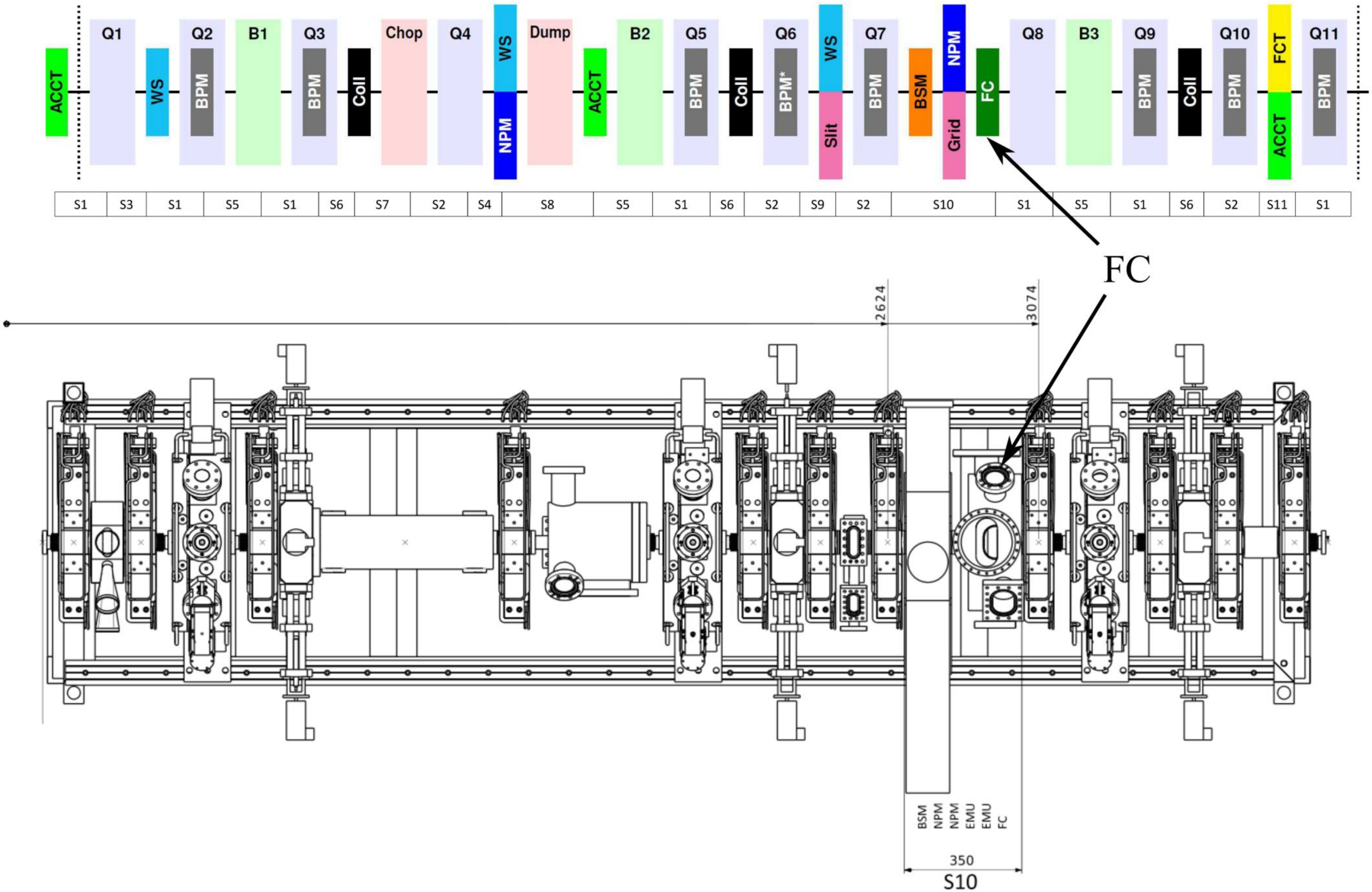
ESS MEBT



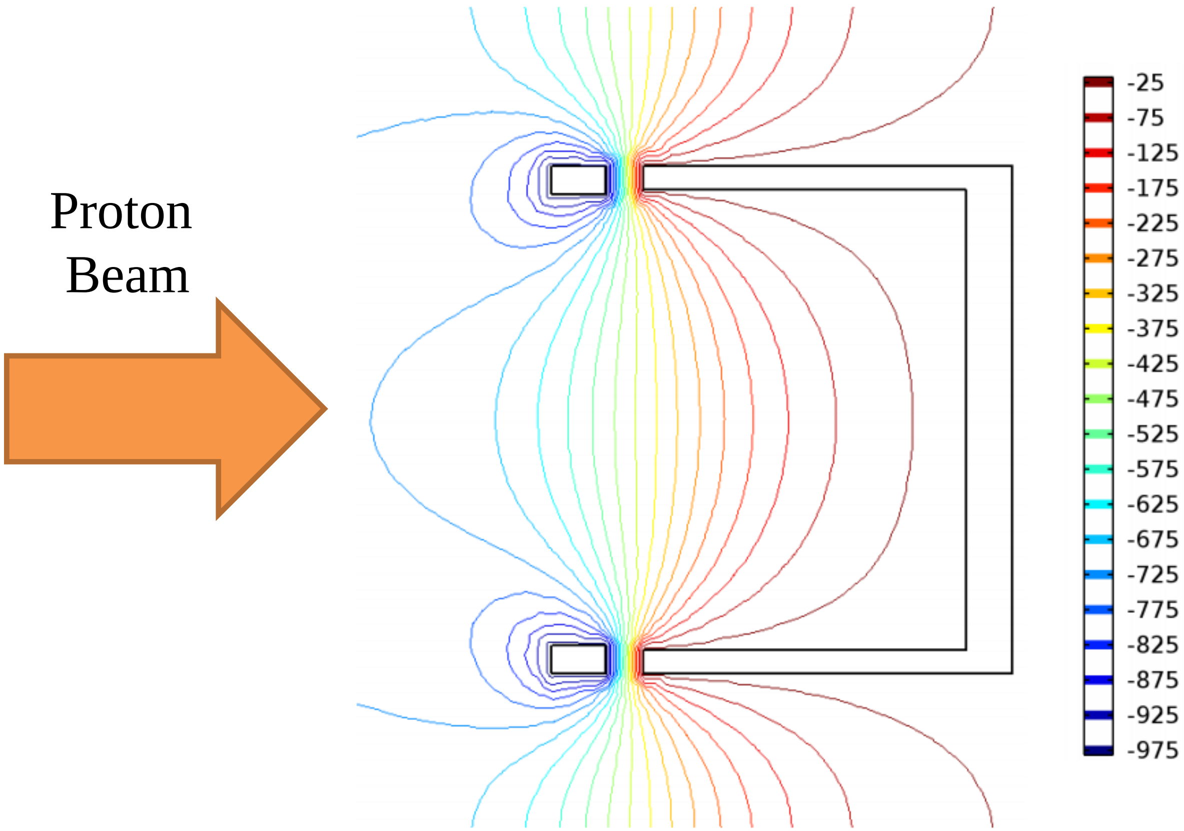
ACCT
Q1
WS
Q2
BPM
B1
Q3
BPM
Coll
Chop
Q4
WS
NPM
Dump
ACCT
B2
Q5
BPM
Coll
Q6
BPM*
WS
Slit
Q7
BPM
BSM
NPM
Grid
FC
Q8
B3
Q9
BPM
Coll
Q10
BPM
FCT
ACCT
Q11
BPM
S1 S3 S1 S5 S1 S6 S7 S2 S4 S8 S5 S1 S6 S2 S9 S2 S10 S1 S5 S1 S6 S2 S11 S1
FC
2624
3074
BSM
NPM
NPM
EMU
EMU
FC
350
S10

ESS MEBT FC

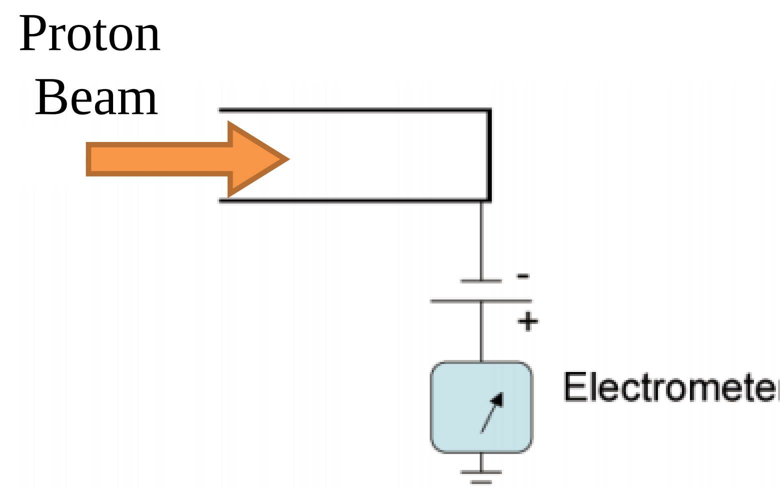
- Beam Instrumentation is required in order to characterize beam current, size, emittance, etc
- The Faraday Cup purpose is to stop a pulsed proton beam to measure the total beam current.
- Faraday Cup is irradiated in Fast and Slow tuning modes.

Parameter	**Value**	
Proton Energy	3.63	MeV
Intensity	62.5	mA
Mode I: Fast Tuning	5 μs - 14 Hz - 16 W	
Mode II: Slow Tuning	50 μs - 1 Hz - 11 W	
Beam size	σ_x	2.48 mm
	σ_y	2.62 mm

FC Scheme



Proton
Beam
-25
-75
-125
-175
-225
-275
-325
-375
-425
-475
-525
-575
-625
-675
-725
-775
-825
-875
-925
-975



Proton
Beam
-
+
Electrometer

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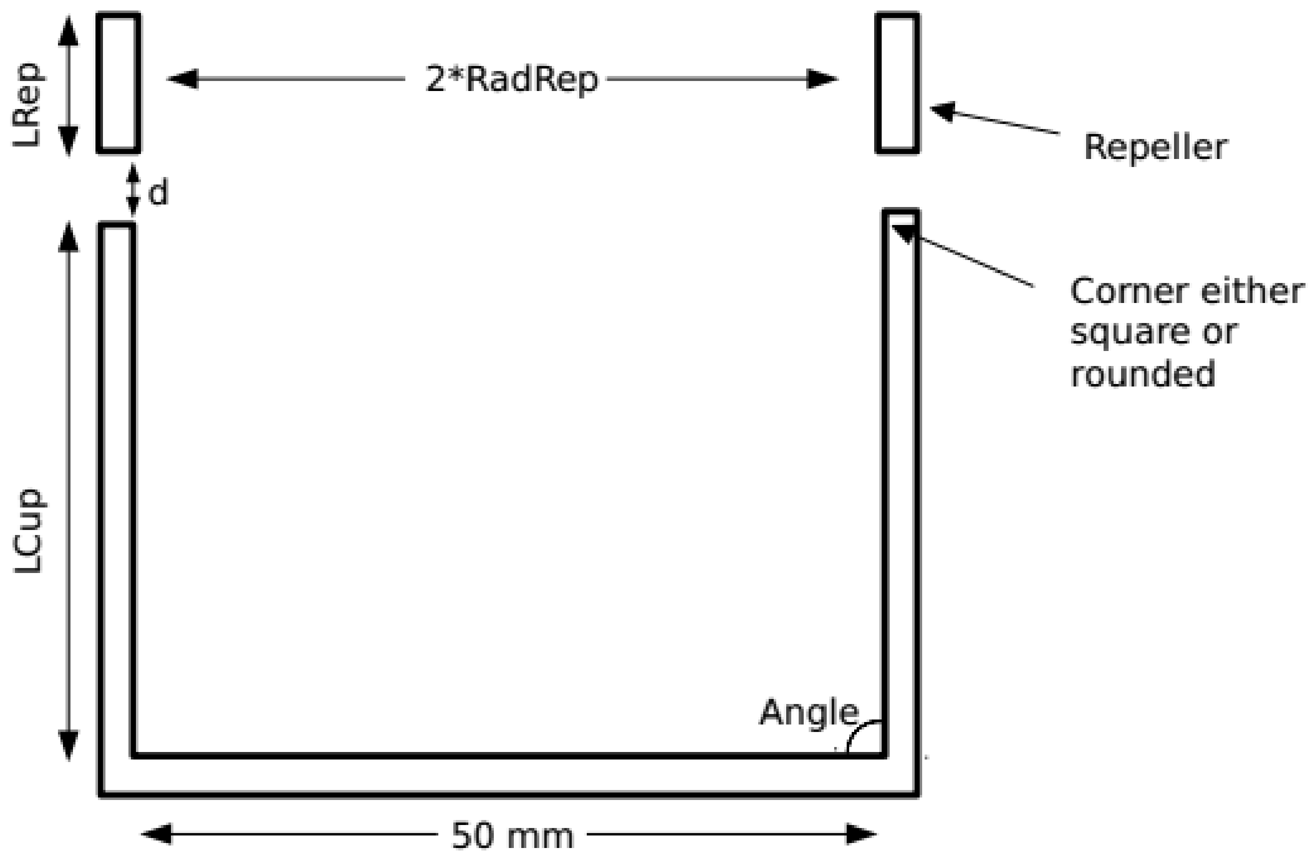
Repeller

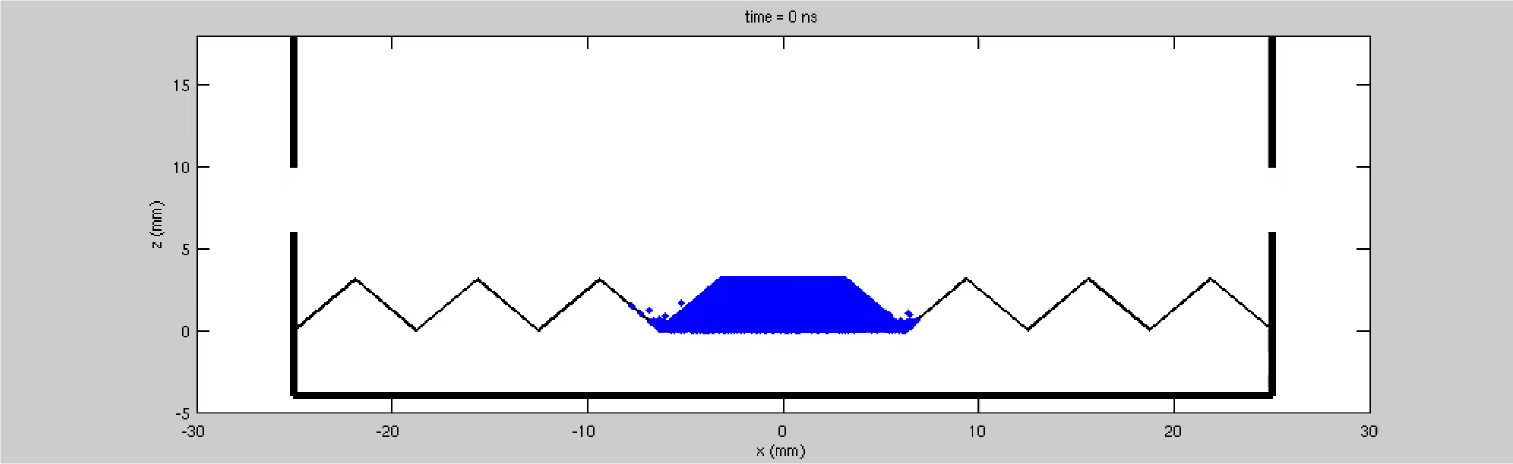
- Beam dynamics studies* carried out to determine the effect of several geometric parameters on the FC repelling ability.



(*) Presented at the Beam Instrumentation Forum I (Lund, February 2016)

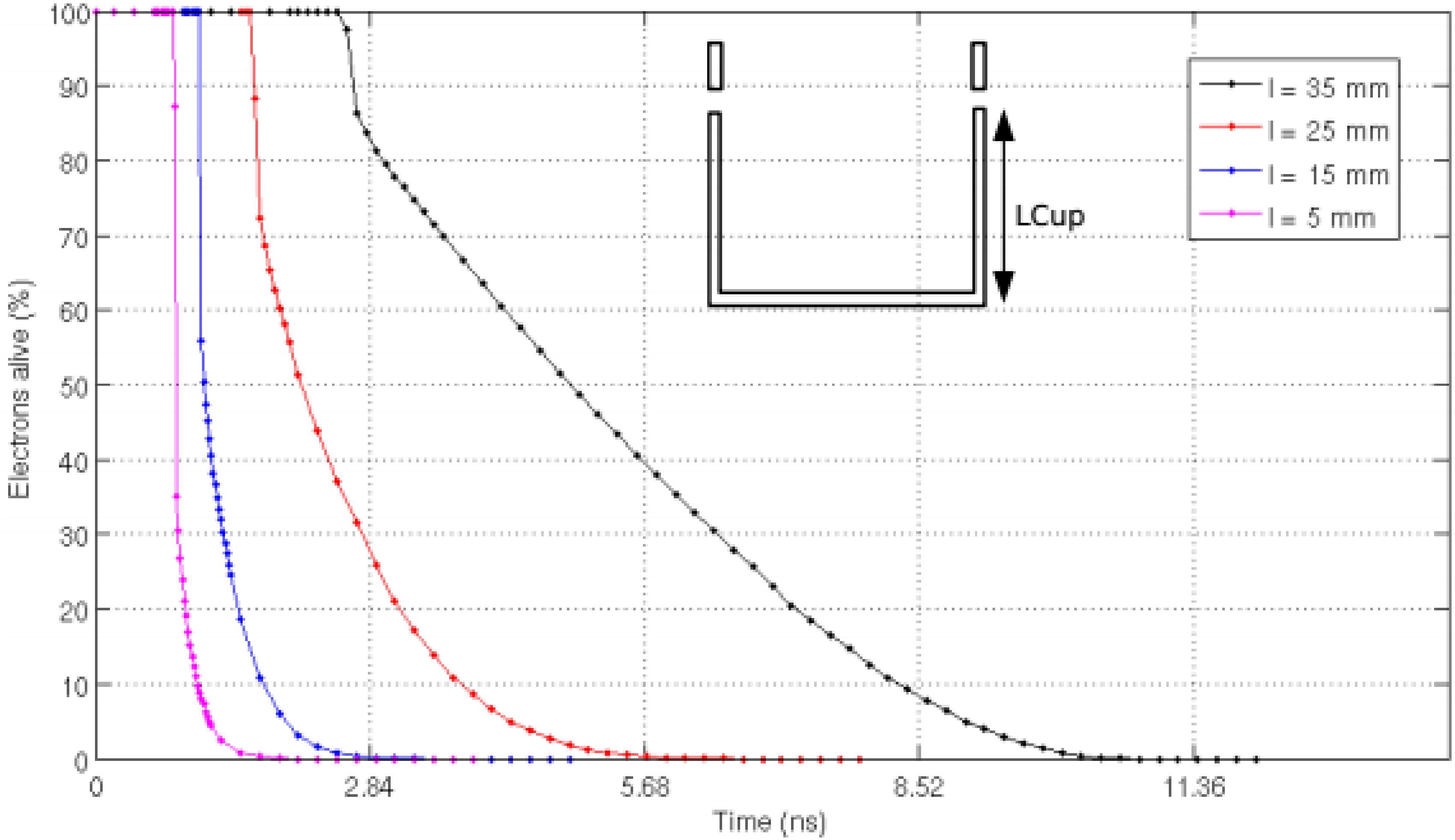
Repeller Analysis

- Electrostatic field simulations made with Comsol, particle dynamics studies performed with GPT.
- Considerable effort to create an accurate secondary electron beam (beam footprint, collector angle, emission angle probability and energy distribution, etc).
- The video shows a typical simulation, observing the electron trajectories, impact position and recapture time.



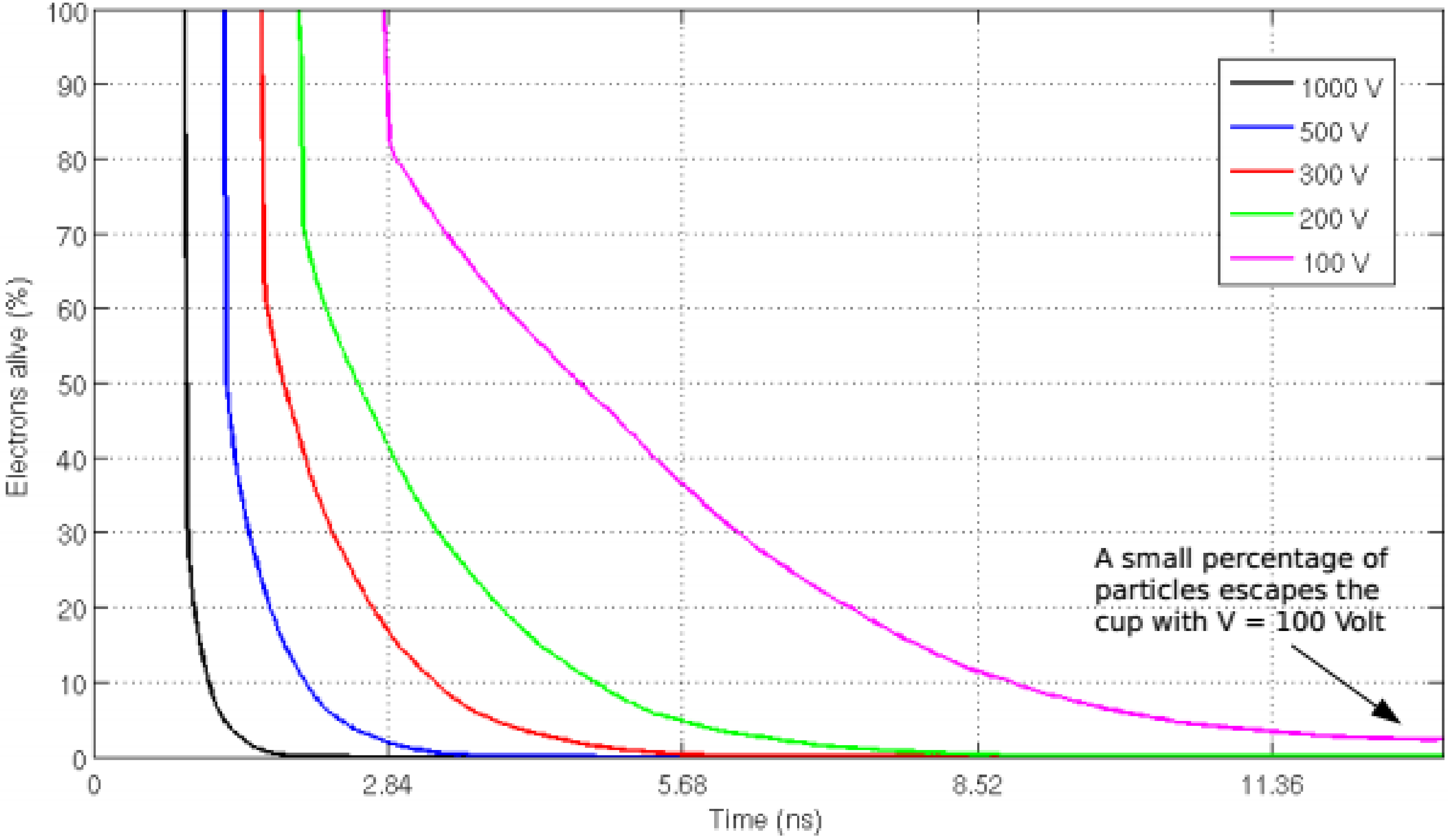
Repeller Analysis

Distance Collector-Repeller



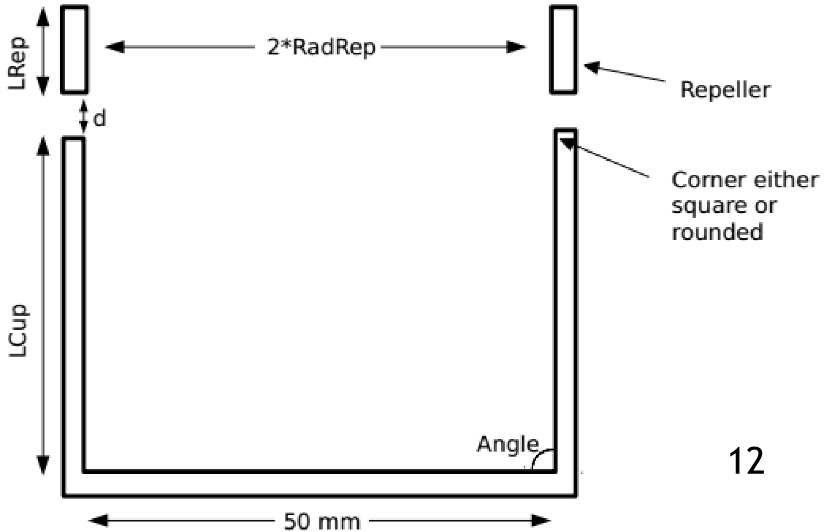
Repeller Analysis

Repeller Voltage



Repeller Analysis

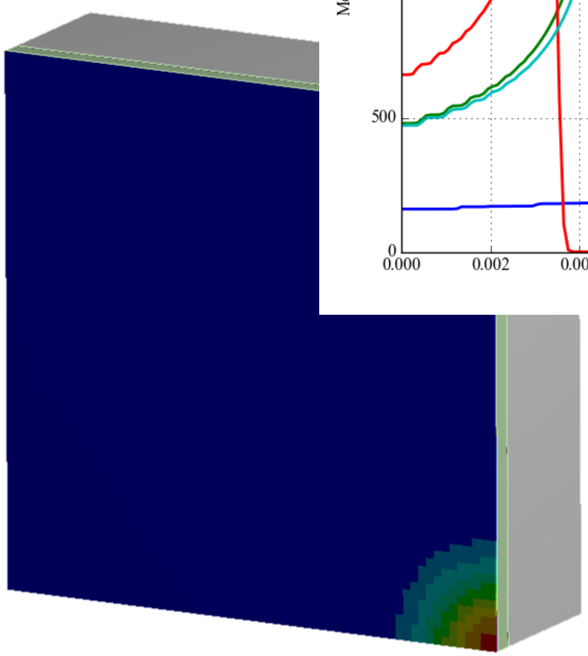
- Basic simulations indicate that we can achieve a 100% electron suppression in the Faraday Cup. Full recapture times typically take a few ns.
- A full recapture can also be achieved if the suppressor voltage is lowered down to 200 V, although the total capture time is obviously longer.
- The final design assumes:
  - Voltage: 1 kV
  - LCup: 10 mm
  - LRep: 10 mm
  - d: 4 mm

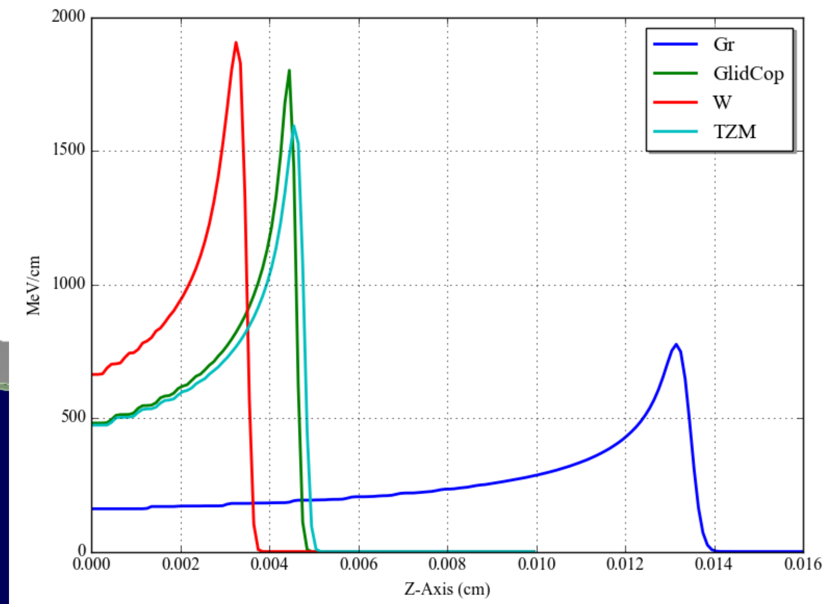


Thermomechanical effects

- Irradiation is highly concentrated in spots ~mm and depths ~100 µm. This leads to high temperatures and stresses during the transient (50 µs).
- Graphite is in contact with refrigerated substrate to dissipate heat in the steady state.

Parameter	Value
Proton Energy (MeV)	3.63
Beam Current (mA)	62.5
Pulse duration (µs)	50
Pulse Energy (J)	11
Peak Power (kW)	227
Beam Sigma (cm)	0.25
Beam Spot (cm^2)	0.4
Beam Current(mA/cm^2)	159
Beam Current($\mu C/cm^2$)	8.0
Stopping Power (MeV/cm)	775
Energy Deposition (MW/cm^3)	123
Energy Deposition (kJ/cm^3)	6





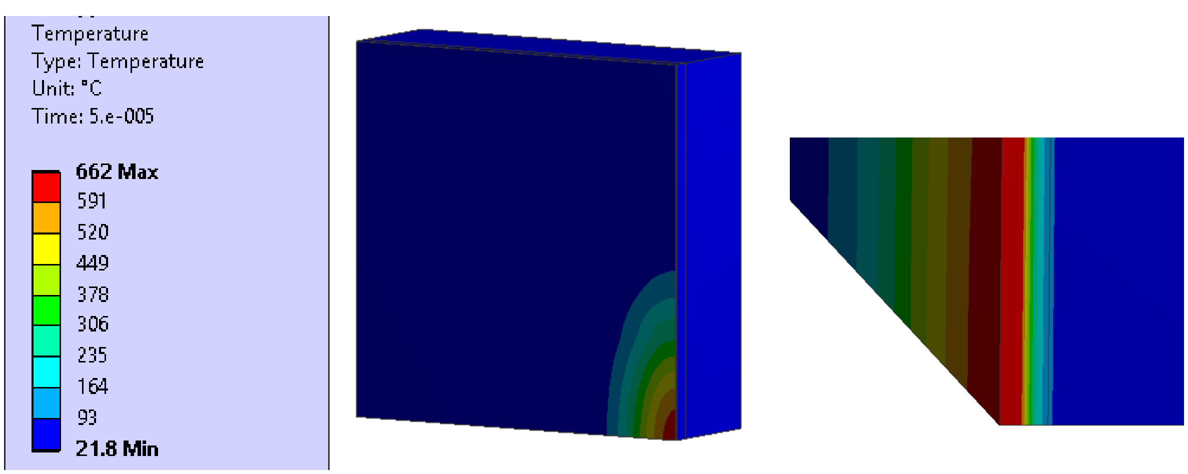
Transient

- High temperatures and stresses are attained during the pulse (50 µs).
- A criterion $\sigma_{Max} \leq 2/3\ \sigma_{Strength}$ is used.

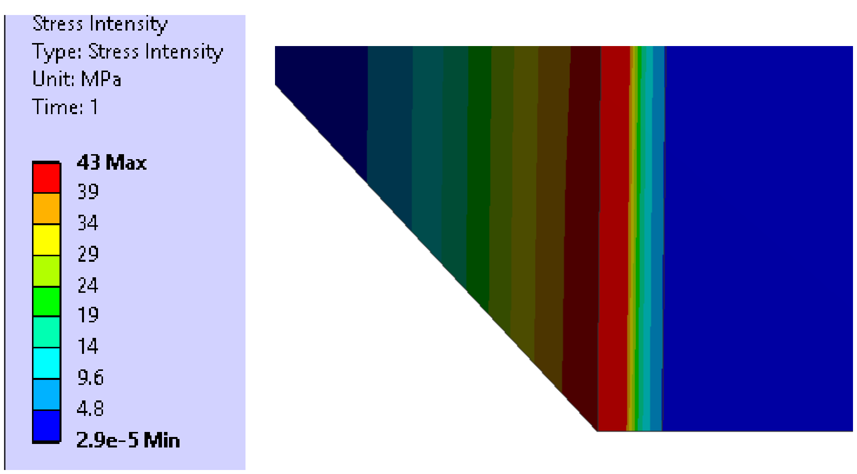
Mat. Limit	**Graphite**
Melt Temp. (K)	3773
Ult. Tensile Strength / Design Limit (MPa)	40 / 26
Ult. Comp. Strength / Design Limit (MPa)	125 / 83

Case	**I'' (µC/cm^2)**	**ΔT (K)**	**σ_{Int} (MPa)**	**$\sigma_{Int}/\sigma_{Lim.}$**
FC: 30º	4.0	640	43	51%

a) Temperature

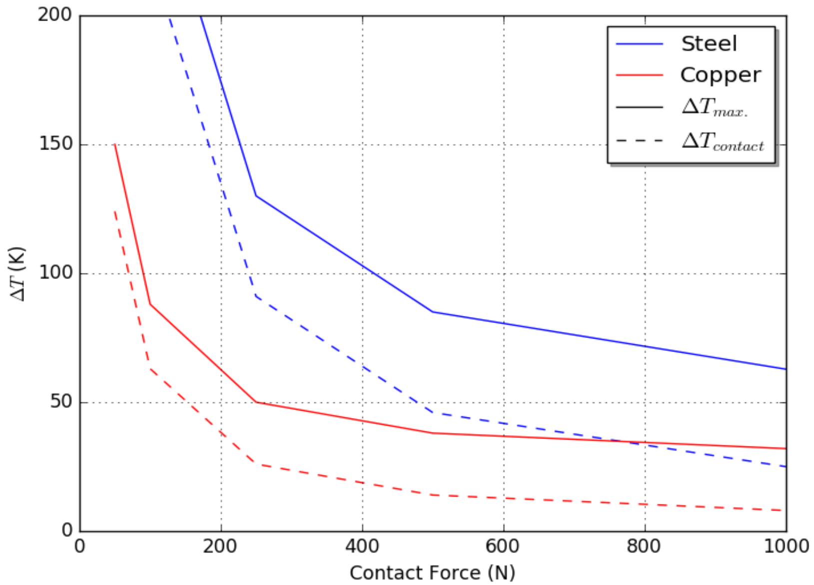


b) Stresses

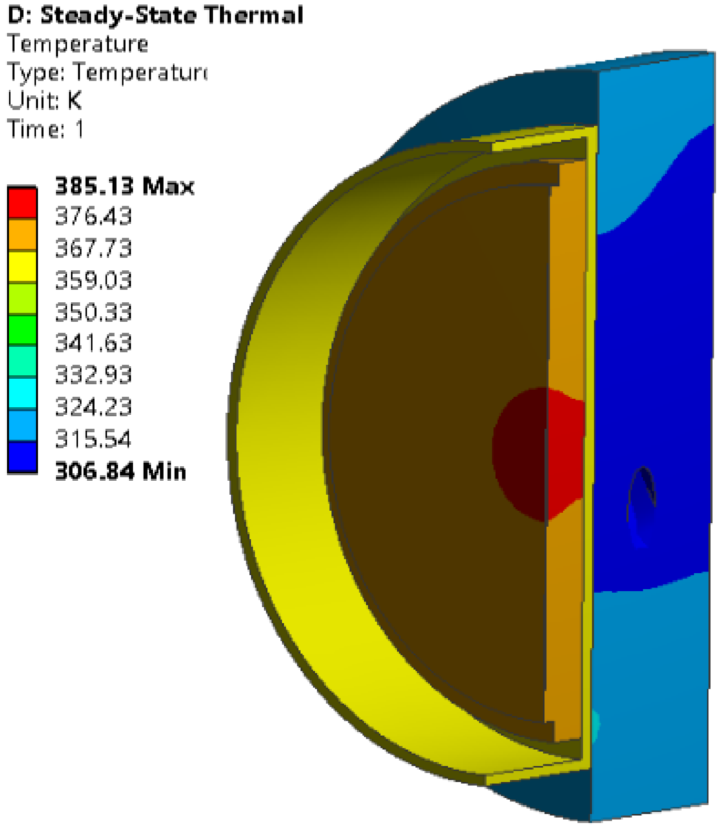


Stationary State

- Thermal contact between graphite/insulator/steel body.
- Cooled by water channels in the FC body
- Dependant on contact conductivity, roughness and microhardness
  - $$h_c \cdot \frac{\sigma_c / m_c}{k_c} = 1.25 \cdot \left(\frac{P}{H_c} \right)^{0.95}$$
  - Contact Pressure ~1 MPa, Force 500 N
- Stationary state is attained in ~300 s
- Low temperature gradient (<100 K)
- Low stresses (~1 MPa)
- Small Deformations (10-20 μm)



Steel - 500 N

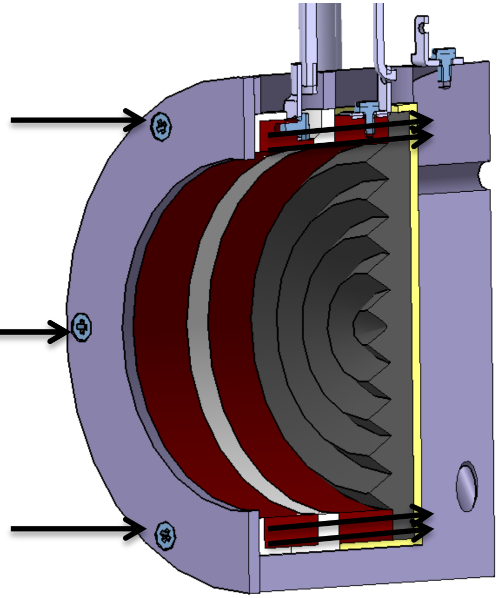


Stationary State

- We choose a steel substrate for a more simple manufacturing.
- Steel dissipates heat correctly if good thermal contact is applied, Force~500N.
- Thermal Contact is only effective where contact pressure is applied.

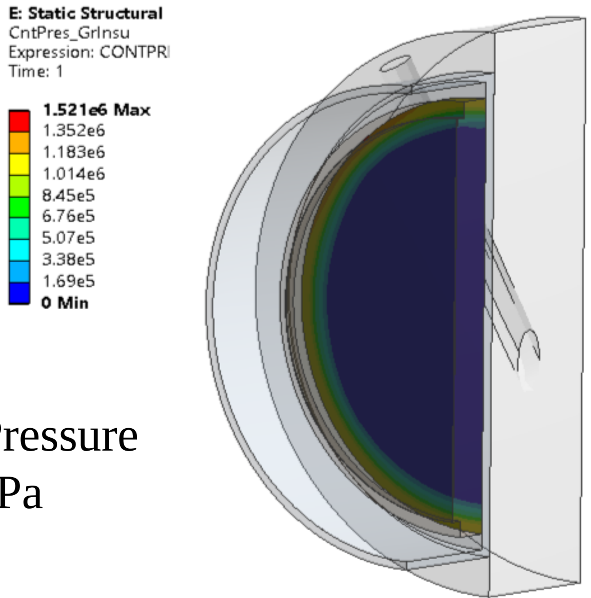
Component	Substrate	Contact Force (N)	Max. Temp. (K)	Max. Gr. Def. (µm)	Max. Gr. Stress (MPa)	Min. Gr. Stress (MPa)
FC	Steel	500	85	20	0.7	-1.8

Force



Contact Pressure
~MPa

Steel - 500 N



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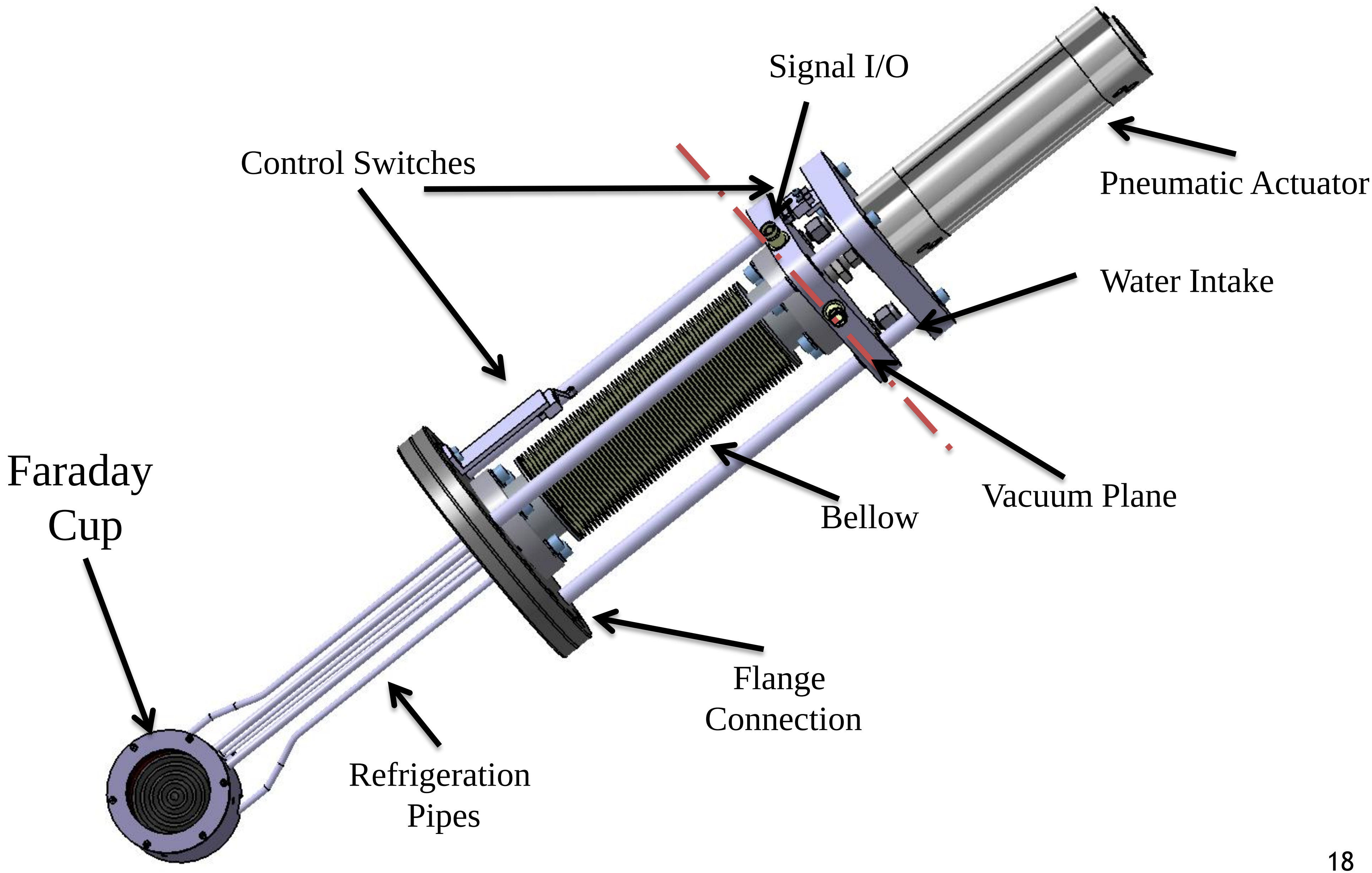
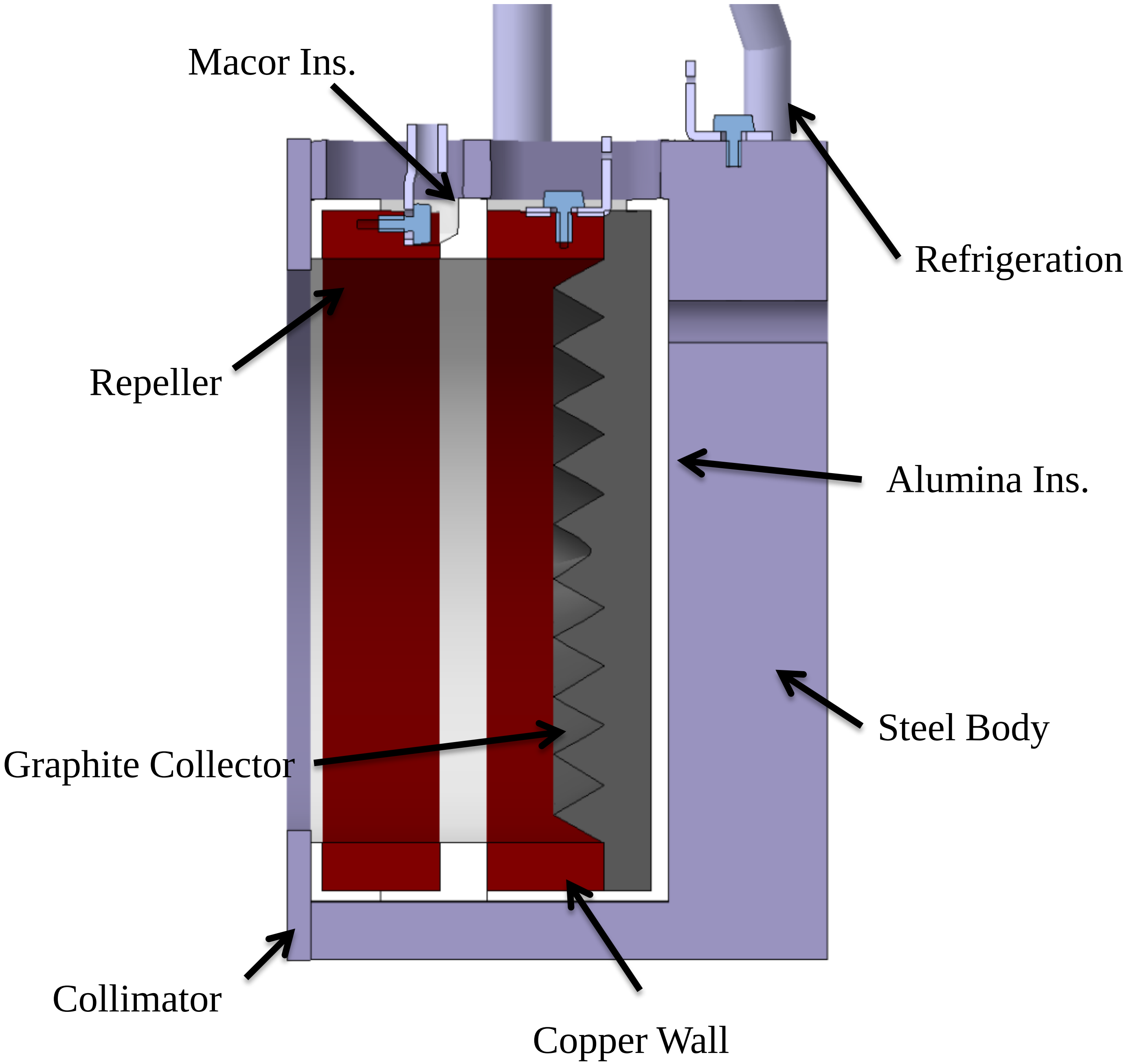
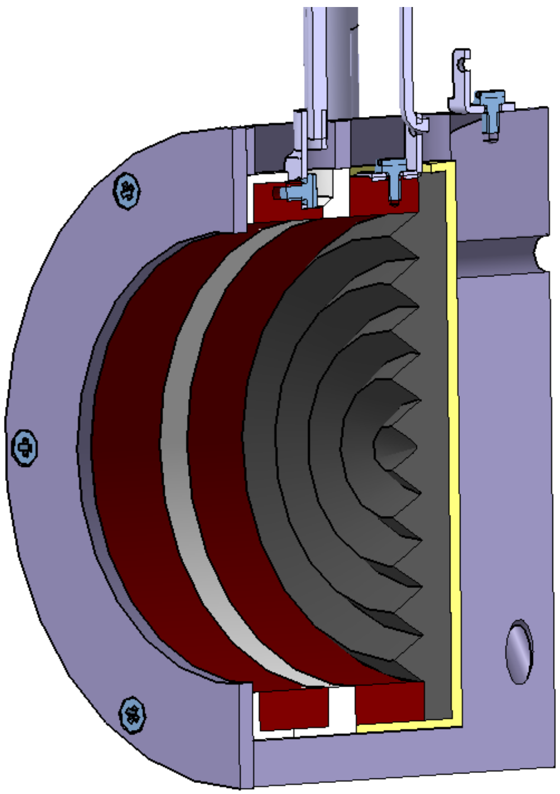
Mechanical Design

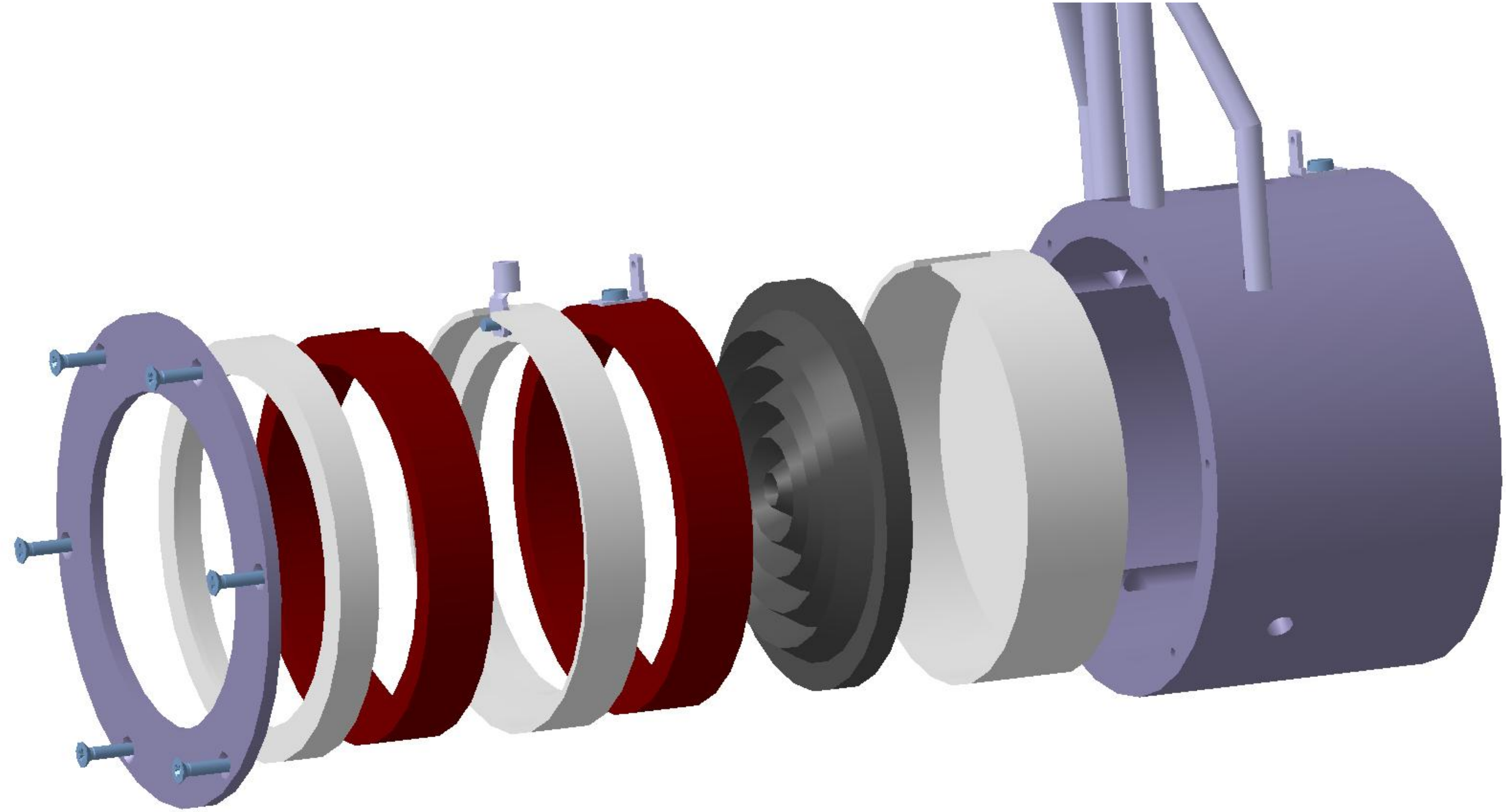


Mechanical Design





Mechanical Design

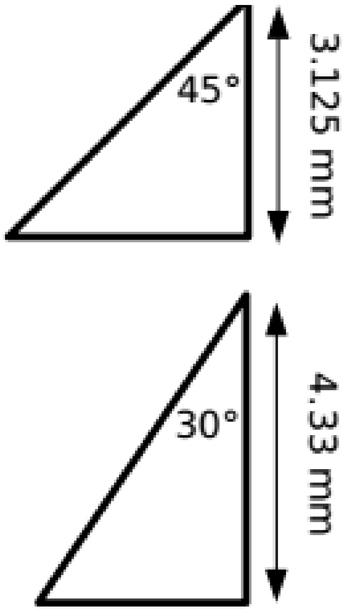


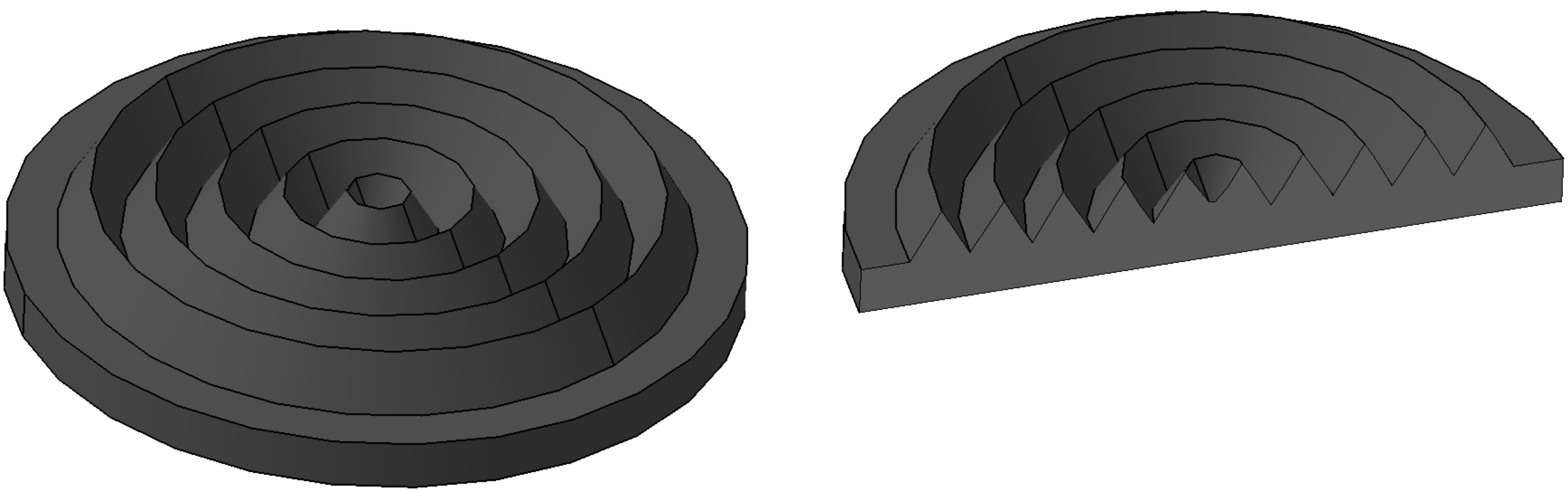
Graphite Collector

Graphite plate with indented surface for better performance under irradiation.

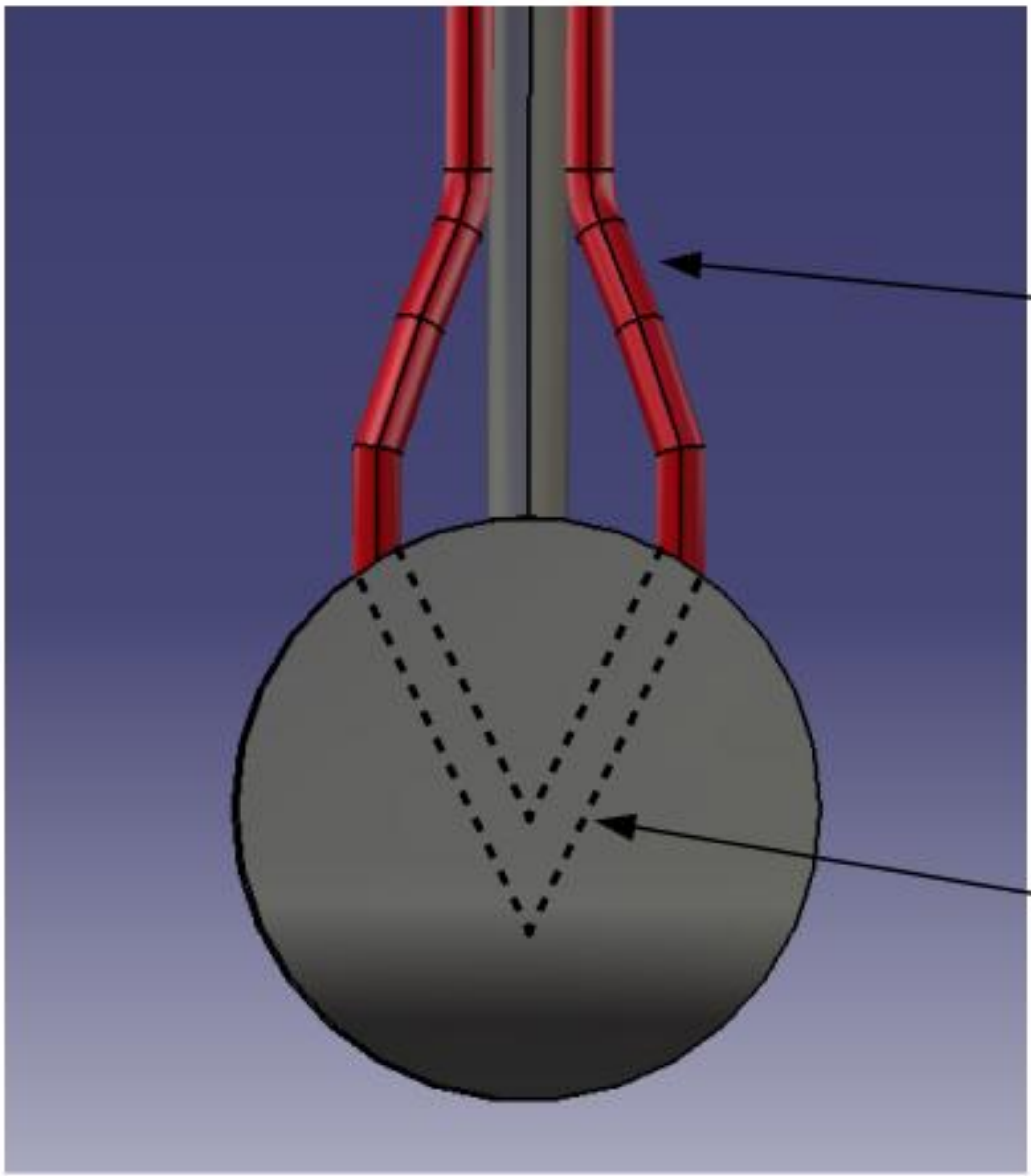
Plate of 58 mm diameter, 4 mm thickness and 4.33 sawteeth height.

Sawteeth with angles of 30º



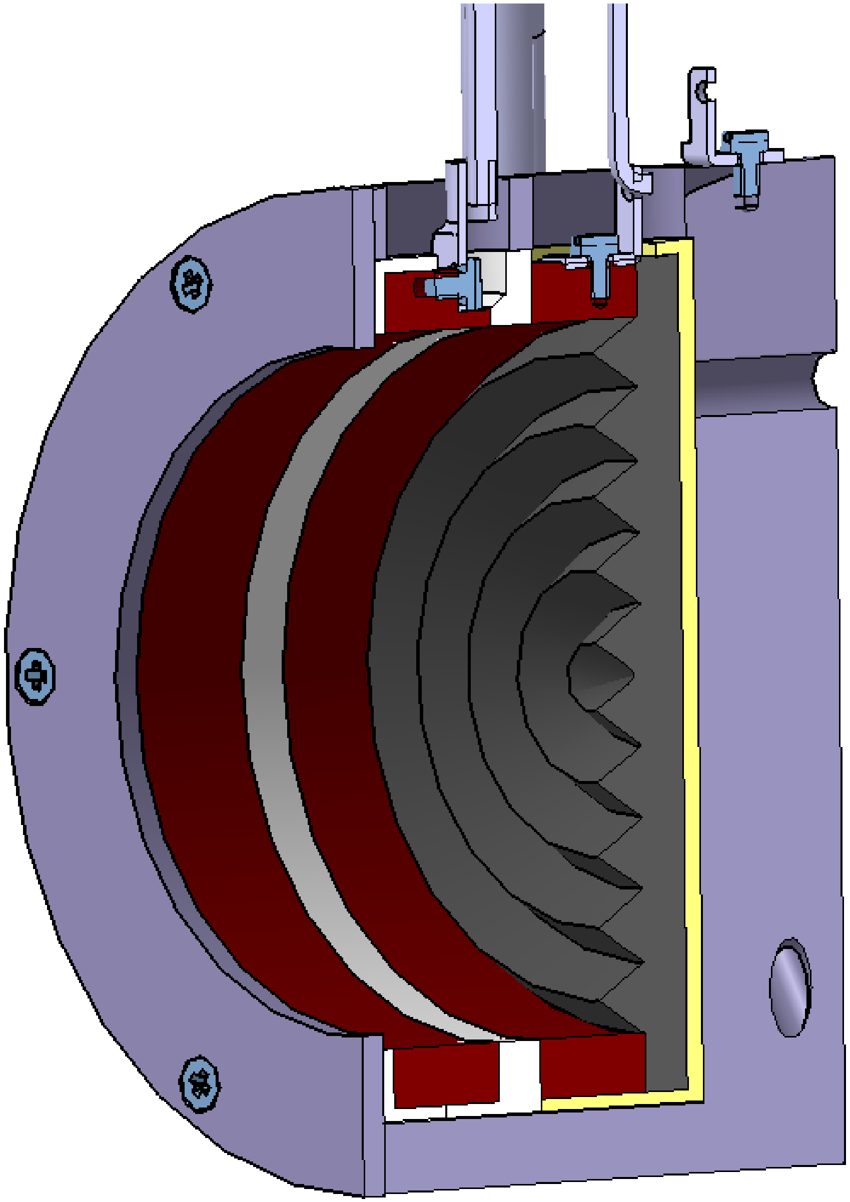


Cooling



Main Dimensions

- Nominal Diam.: 50 mm
- Width: 46 mm
- Ext. Diam.: 70 mm
- Collimator Diam.: 48 mm
- Actuator Stroke: 80 mm



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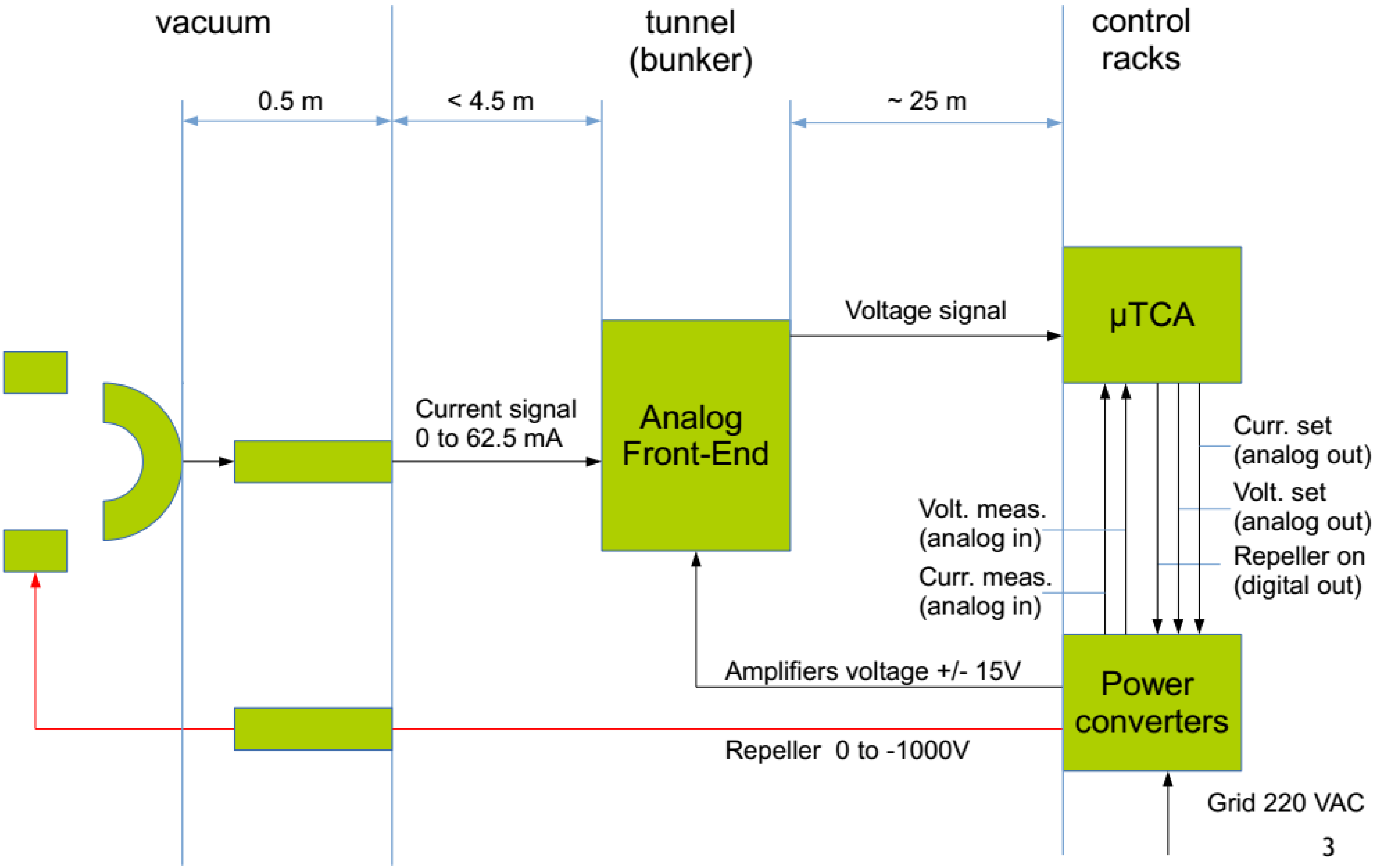
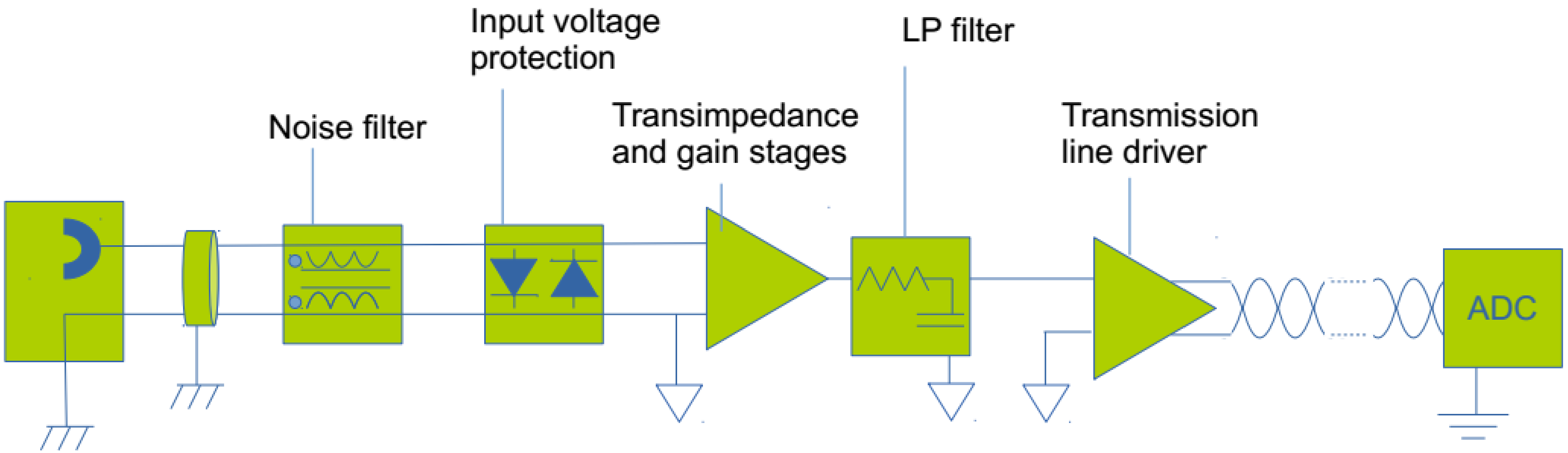
Design Parameters

Beam peak current	62.5 mA
Dynamic range	10
Beam mode 1	50 us & 1 Hz
Beam mode 2	10 us & 14 Hz
Sample frequency	>= 2 MHz
Total measurement error	< 0.1 mA
Measurement precision	σ < 0.01 mA
Output voltage range:	+/-10 V
ADC Resolution	16 bits
Remotely controlled power supply	0 to 1000V (negative)

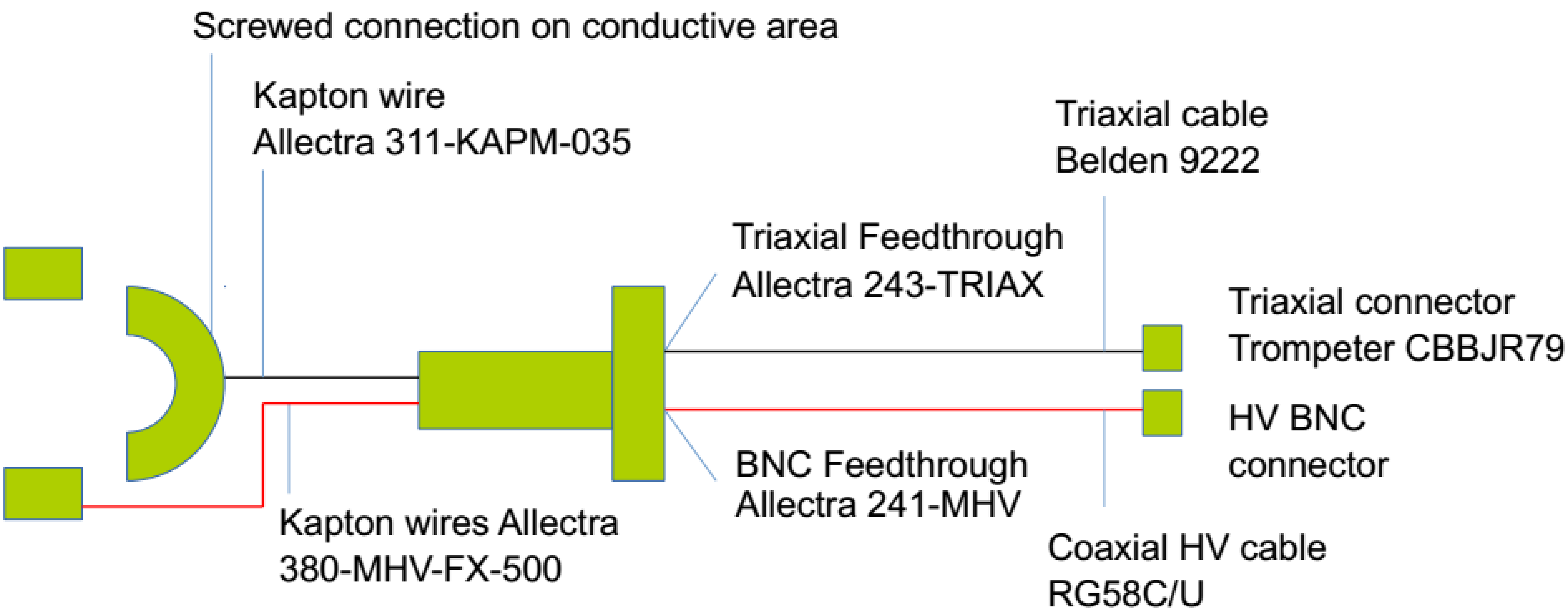
General Scheme



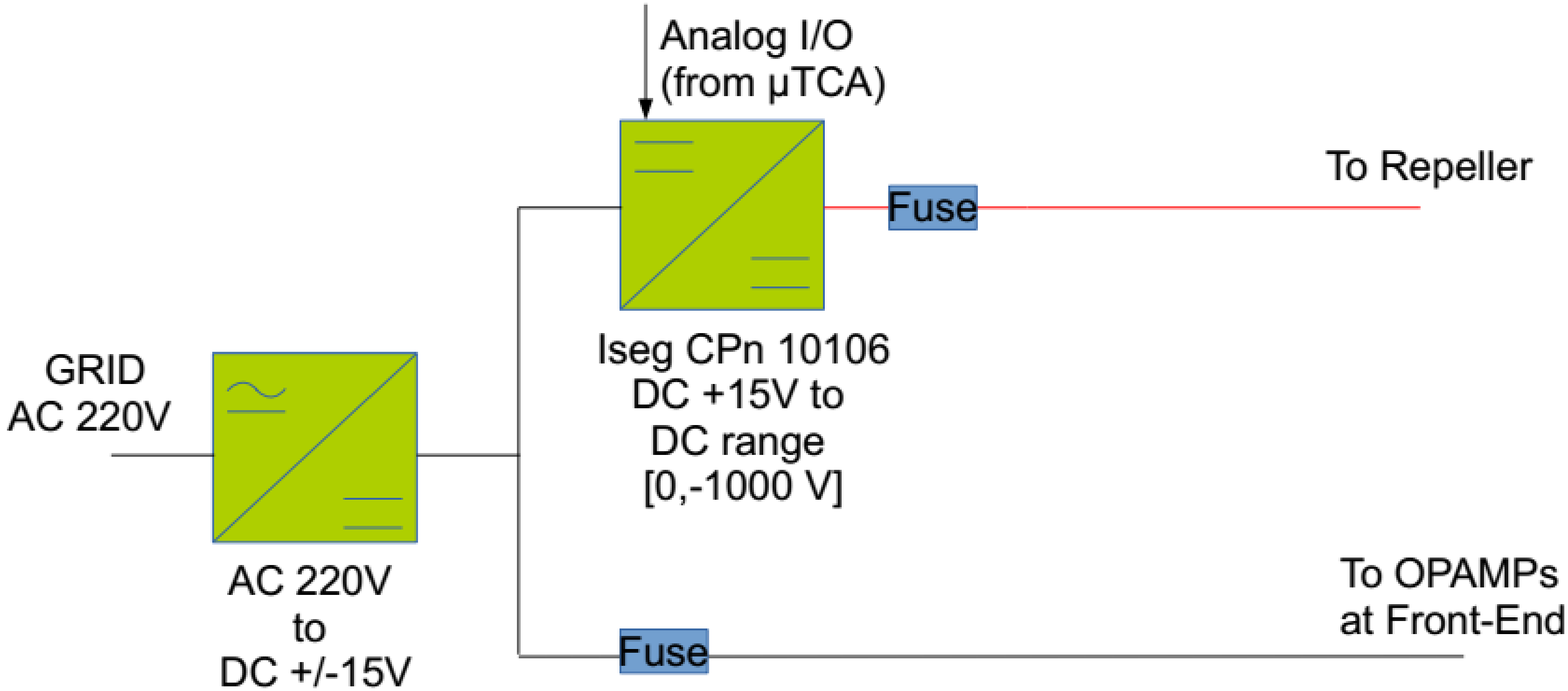
Analogue Front End



Cabling and Conections



Power converters enclosure



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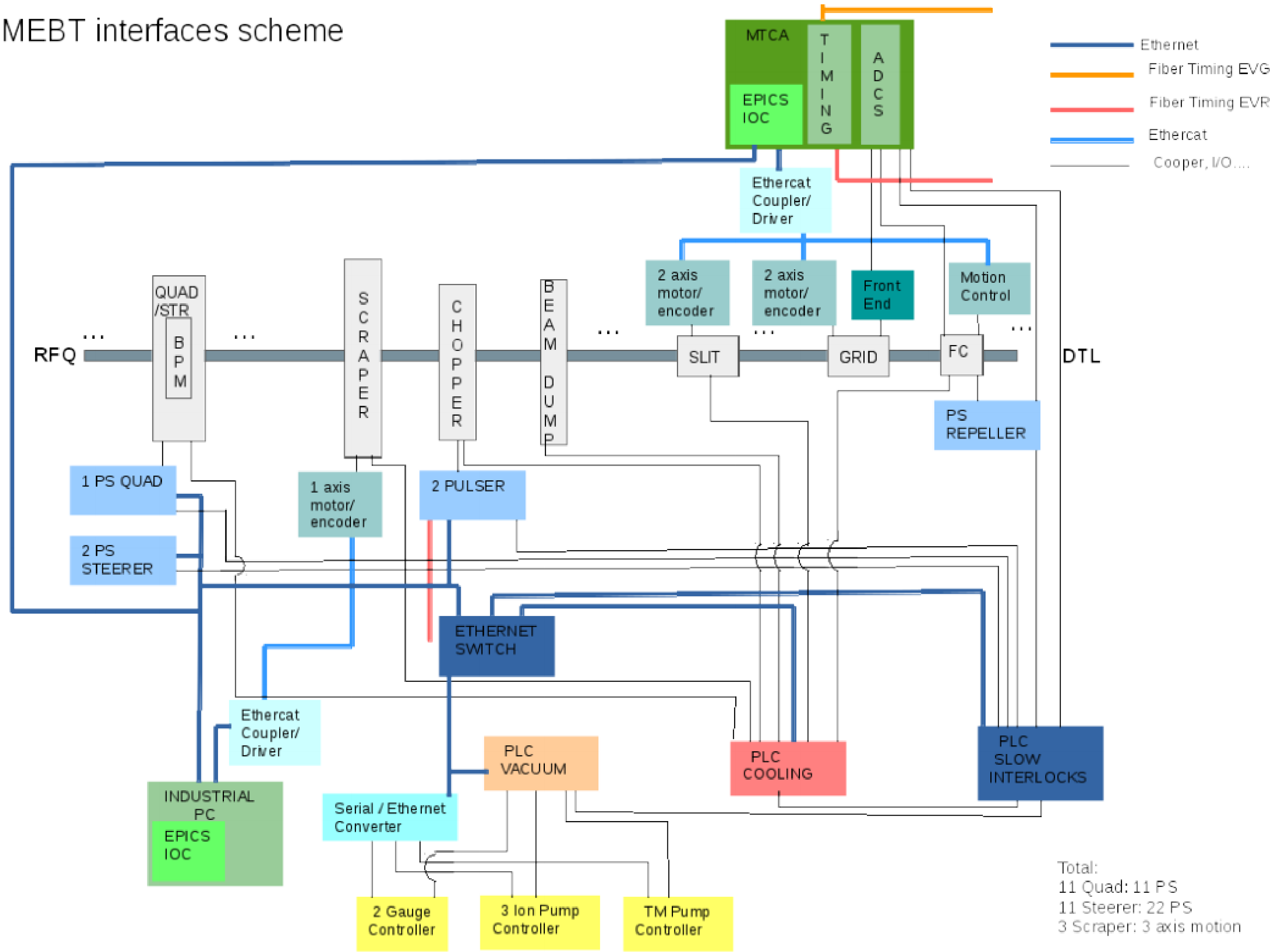
HW Description

MEBT interfaces scheme



Total:
11 Quad: 11 PS
11 Steerer: 22 PS
3 Scraper: 3 axis motion

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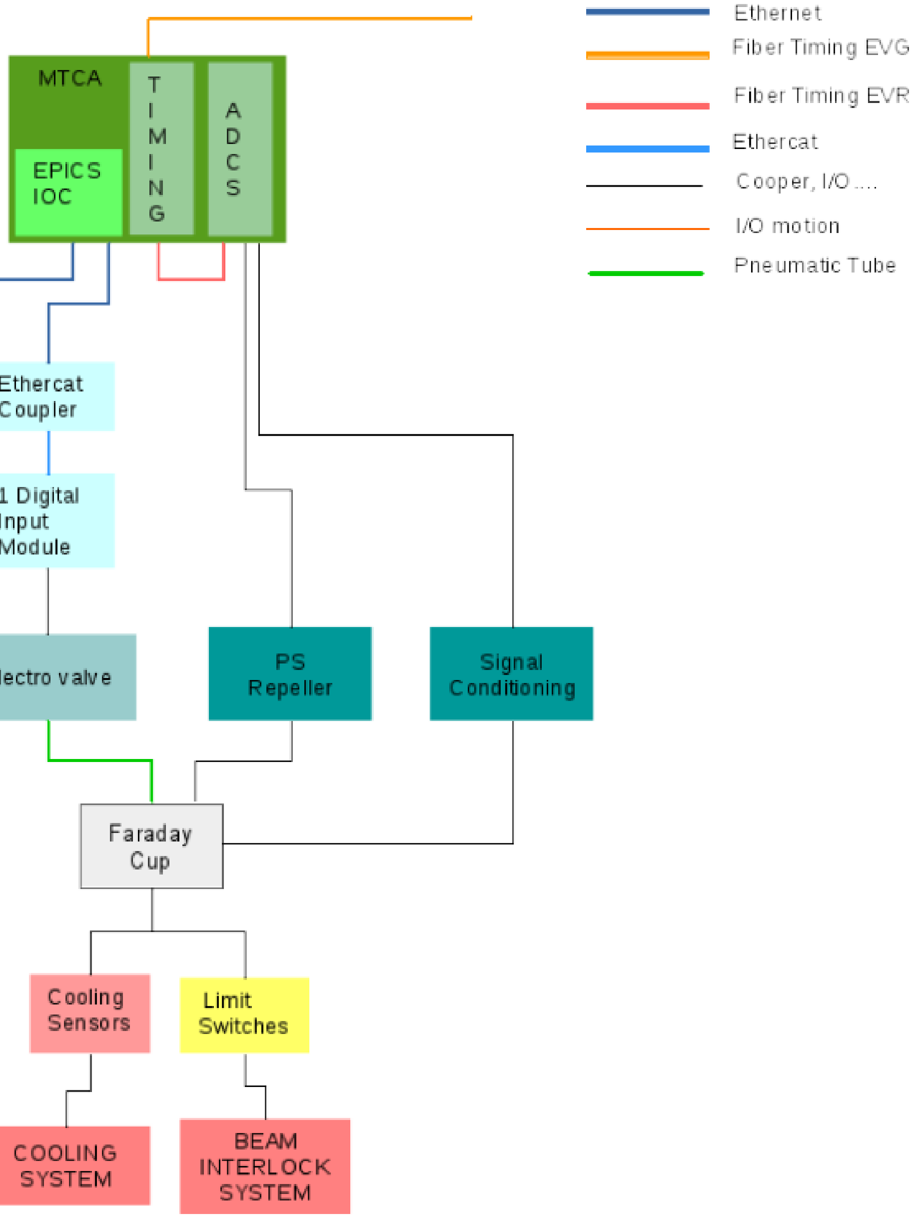
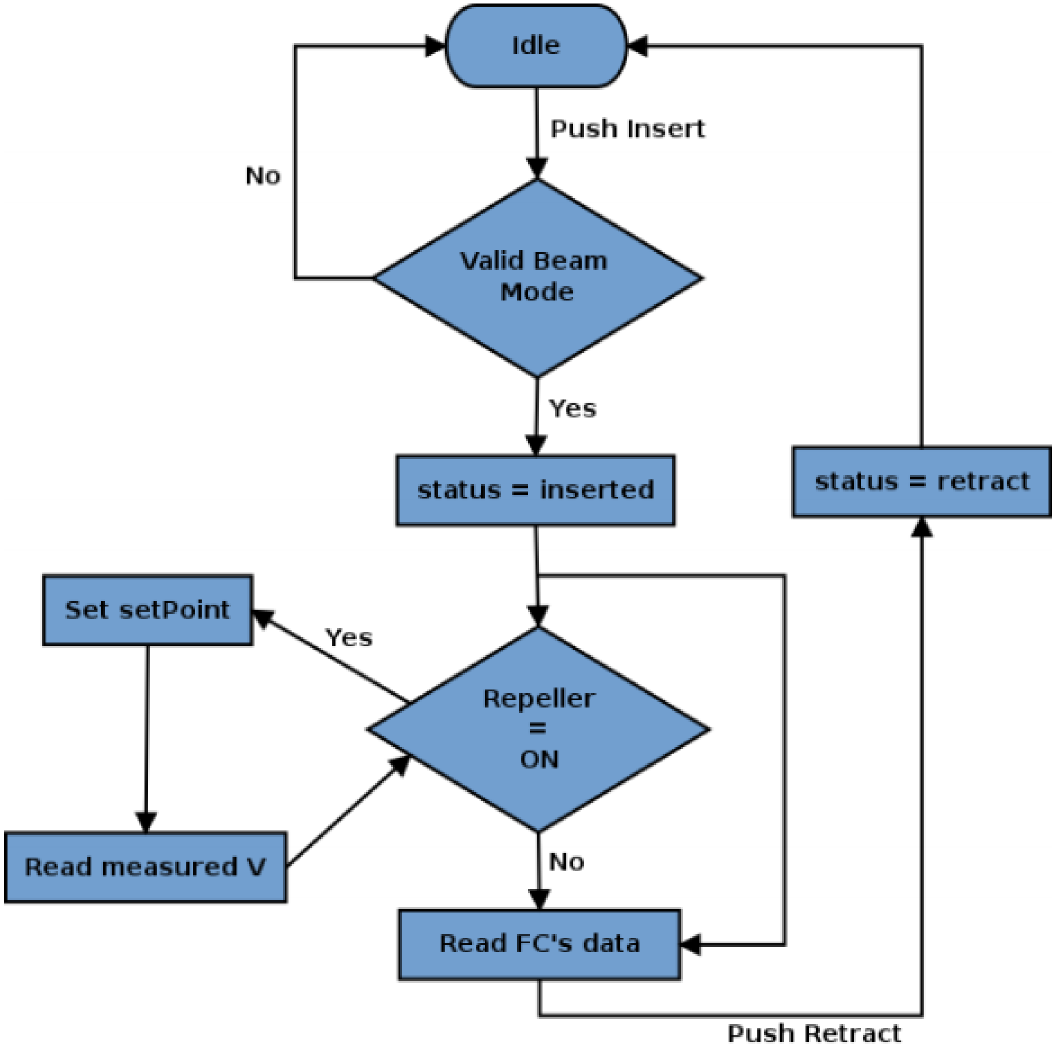
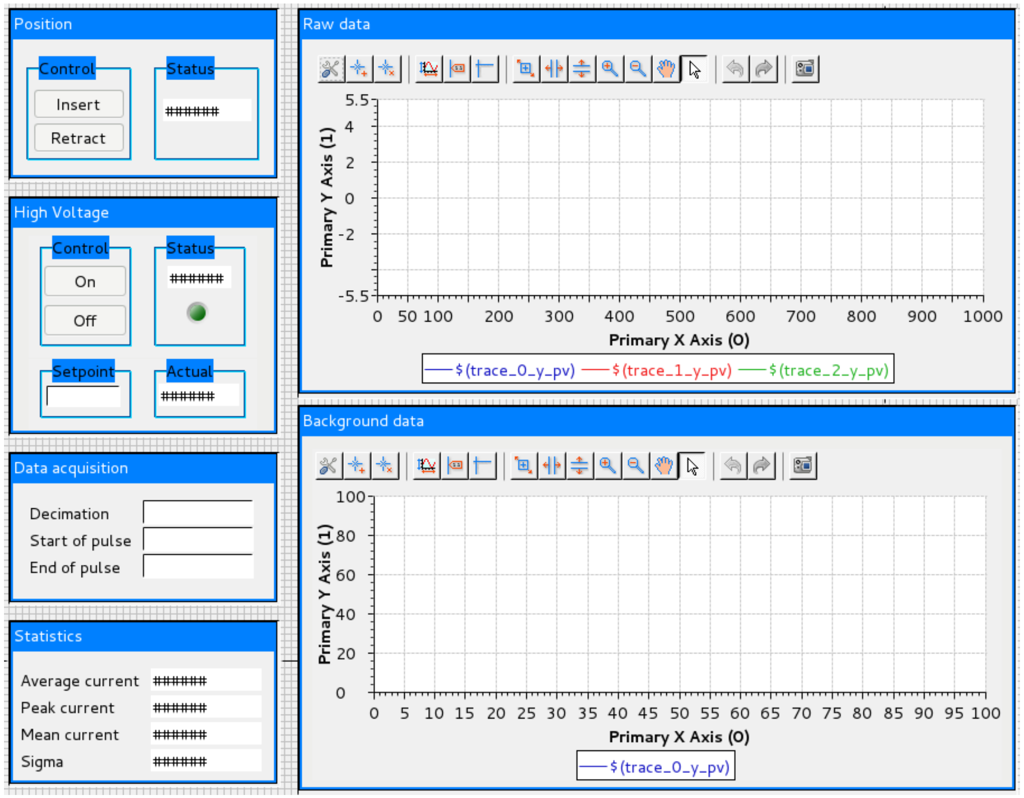
HW Description

MEBT FC scheme



Control Flow Diagram





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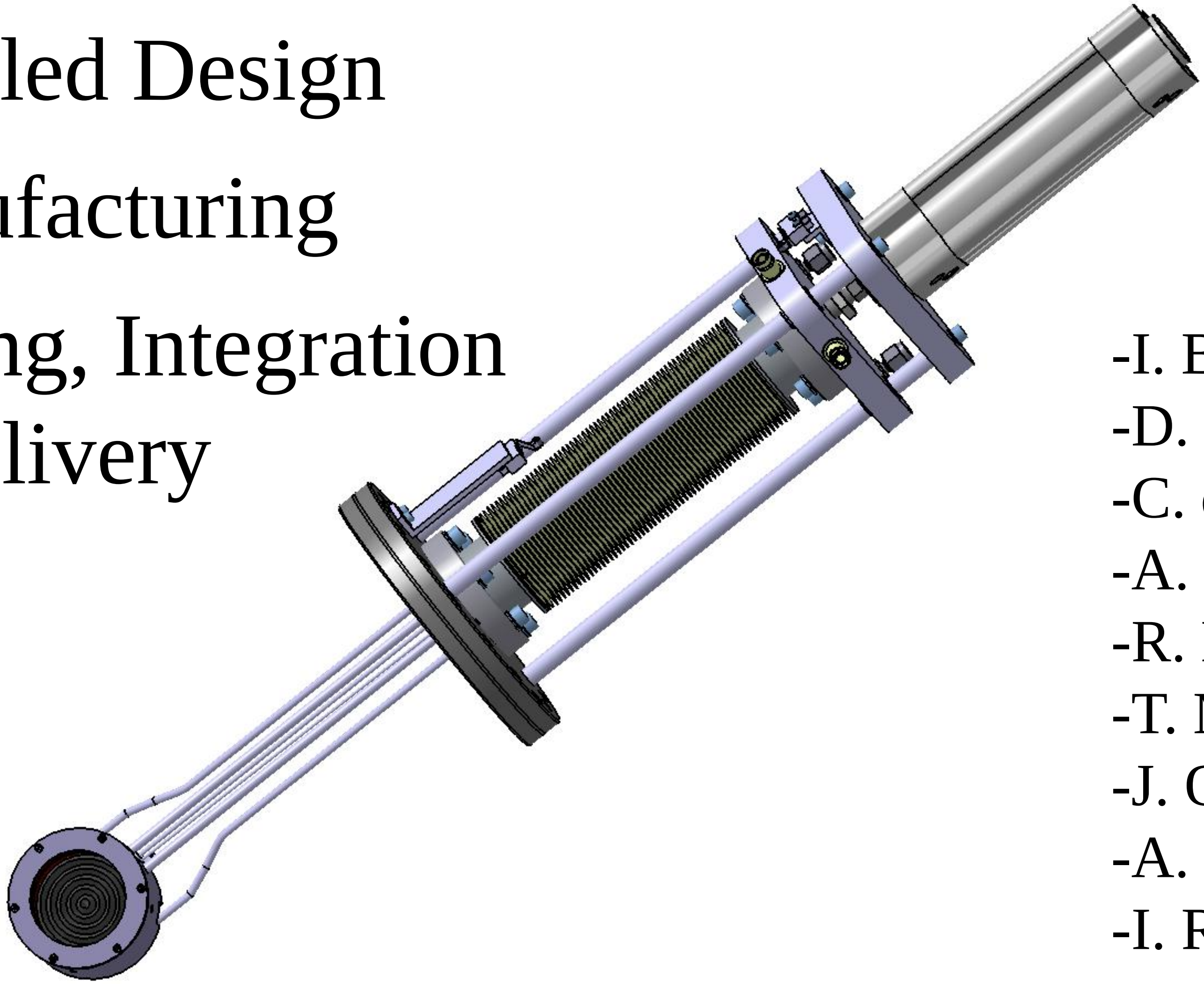
Conclusions

- Conceptual Design
- Detailed Design
- Manufacturing
- Testing, Integration & Delivery



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Conclusions

Thank you for your attention