Medium Energy Beam Transport

Technical Advisory Committee

April 7th 2016

Lund

Ibon Bustinduy

on behalf of ESS-Bilbao Team

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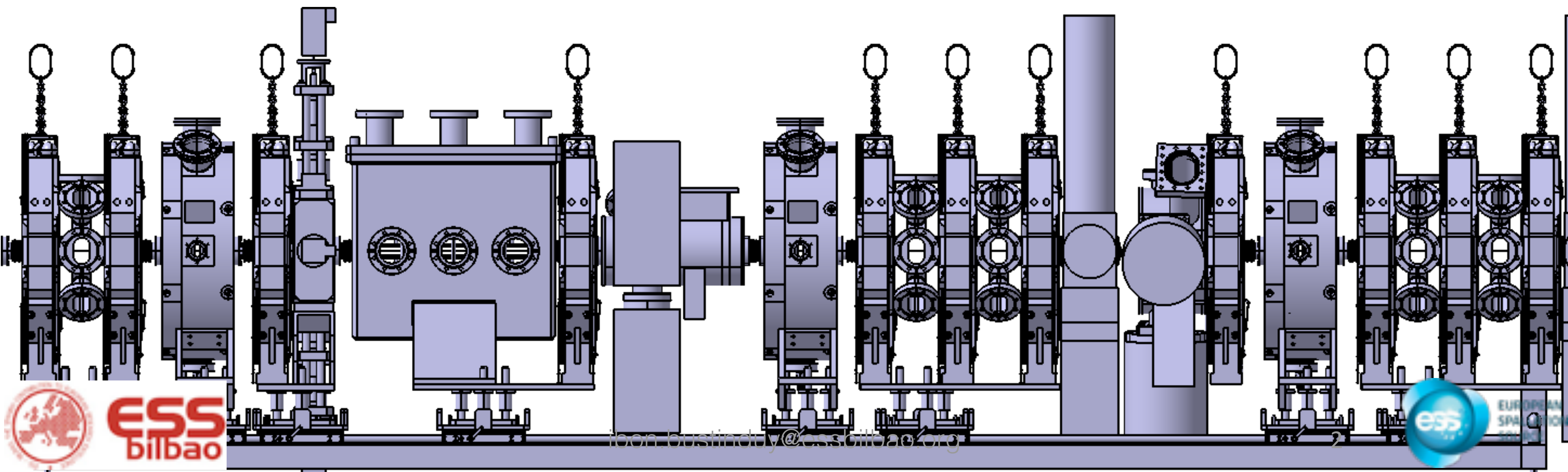
Overview

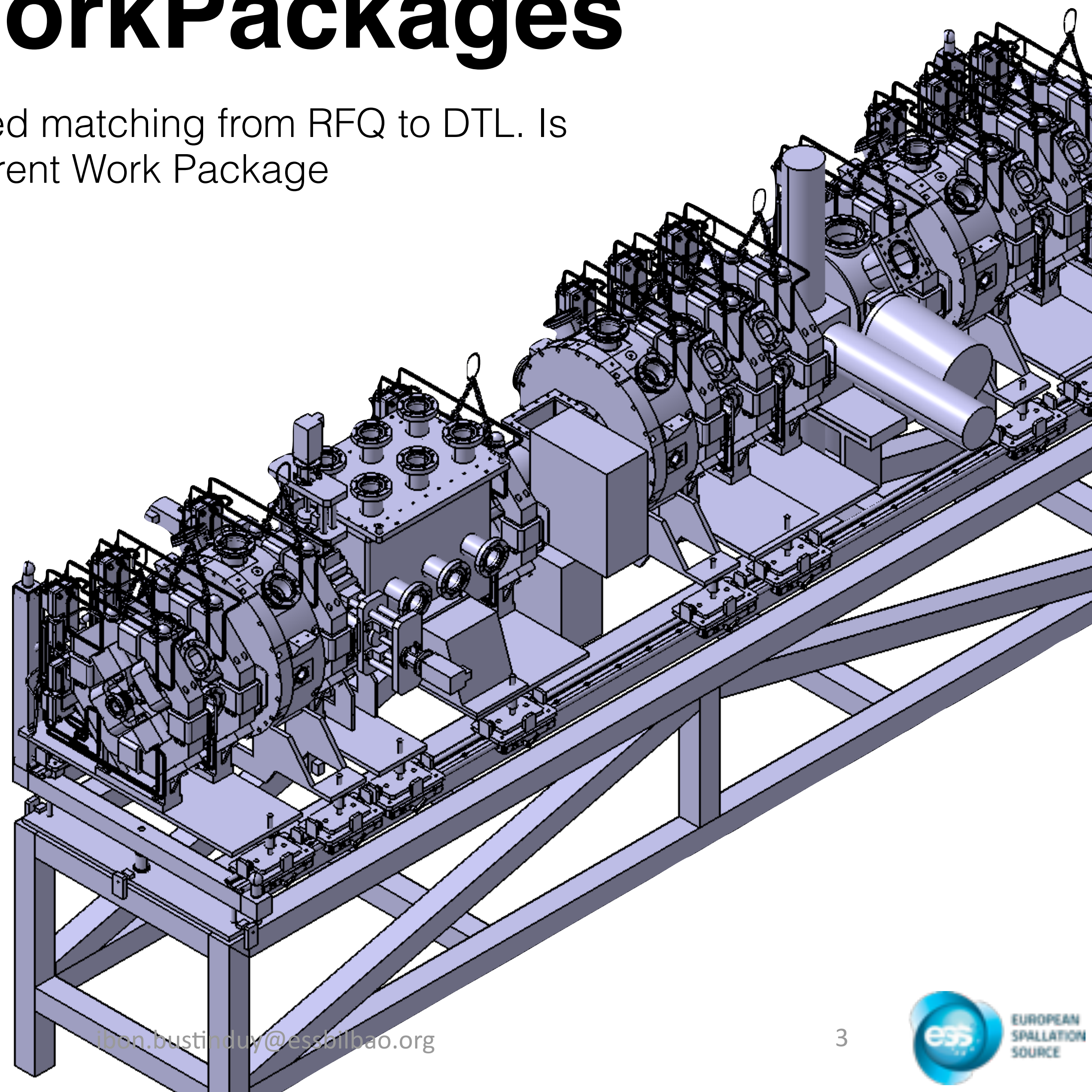
- During 2013 the ESS linac cost was reevaluated, important modifications were introduced.
- Each MEBT is unique (Broken periodicity)
- The name of the game is **compromise** and **iteration**
- MEBT is designed primarily to match the RFQ output beam characteristics to the DTL input both transversally and longitudinally.
- Beam Instrumentation, Fast chopper, Scraping blades impose certain restrictions
- linac design that affectedMEBT IKC is composed of different Work Packages, this talk will only cover WP3 (30% of the contribution), **Strong Interfaces with RF, Beam Instrumentation, Vacuum, ICS.**
- 36 people are directly involved in Bilbao the Contribution, +23 support staff.



WorkPackages

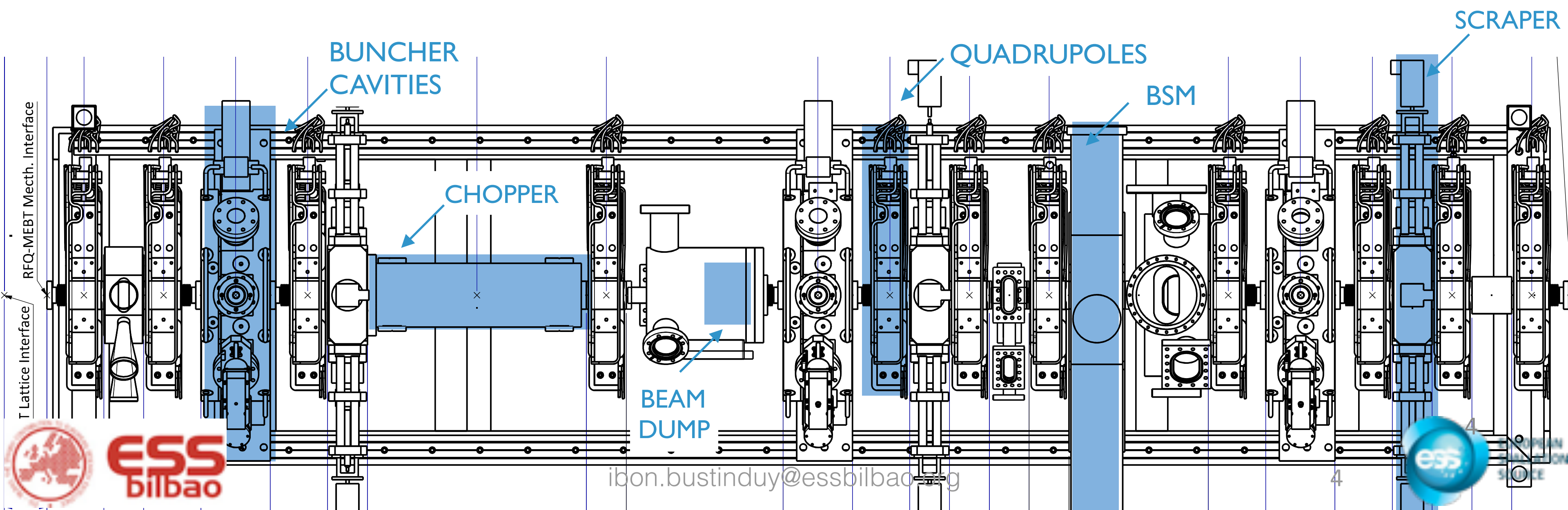
MEBT provides the required matching from RFQ to DTL. Is currently divided into different Work Package contributions.

- MEBT
  - WP2 Beam Physics
  - WP3 Normal conducting linac
  - WP7 Diagnostics
  - WP8 RF
  - WP12 Vacuum
  - ICS Control



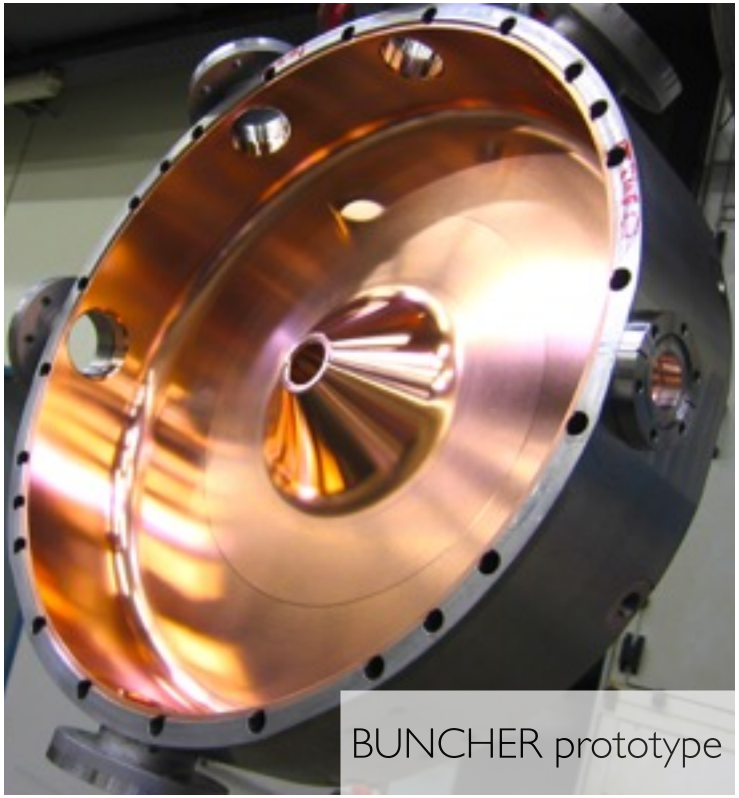
Schedule

- Schedule is driven by **QUAD** and **BUNCHER**
- Each sub-component has a different life cycle: Conceptual Design, Detailed Design, Fabrication, Testing: Difficult to separate into one single CDR.
- MEBT PDR/CDR involves more than just WP3 (warm linac unit)
- Linac design that affected MEBT IKC is composed of different Work Packages: **RF**, **Beam Instrumentation**, **Vacuum**, and with **ICS** division.



Integration and Verification

- CHOPPER, QUAD, and BUNCHER pose many challenges, rapid prototyping strategy to get a successful product in 2018. These activities are aimed at addressing uncertainties in the ability of the design to satisfy the stated functional requirements:
  - Stage 1: Conceptual Design (Interfaces with WP2, WP7, WP8, WP12)
  - ✓ Internal Review (verified by ESS)
  - Stage 2: Detail Design
  - ✓ Review
  - Stage 3: Manufacturing
  - Stage 4: Assembly and tests
  - ✓ Review
  - Stage 5: Series Production



BUNCHER prototype

Team in Bilbao

I. Bustinduy	**WU Leader / Accelerator Physics**
JL. Muñoz, D. Fernandez, O. Gonzalez	**ElectroMagnetic and Magnetic Design**
F. Sordo, M. Magán, R. Vivanco, T. Mora, G. Bakedano	**Thermo-mechanical design**
P. Gonzalez, N. Garmendia, L. Muguira, T. Poggi, A. Kaftoosian, O. Gonzalez	**RF System**
I. Rueda, A. Zugazaga, A. Salas	**Mechanical Design, Supporting Structure, Vacuum and Alignment**
A. Vizcaíno, Z. Izaola, I. Ortega, S. Varnassari, C. Cruz, A. Megia, D. de Cos, Z. Izaola	**Diagnostic System**
I. Mazquiaran, A. Milla, A. Serrano, C. de la Cruz, J. Bilbao, X. Gonzalez, A. Serrano	**Control System**
G. Harper, X. Gonzalez, J. Bilbao	**Power Systems**
F. G-Toriello	**Building & Infrastructures**

Milestones

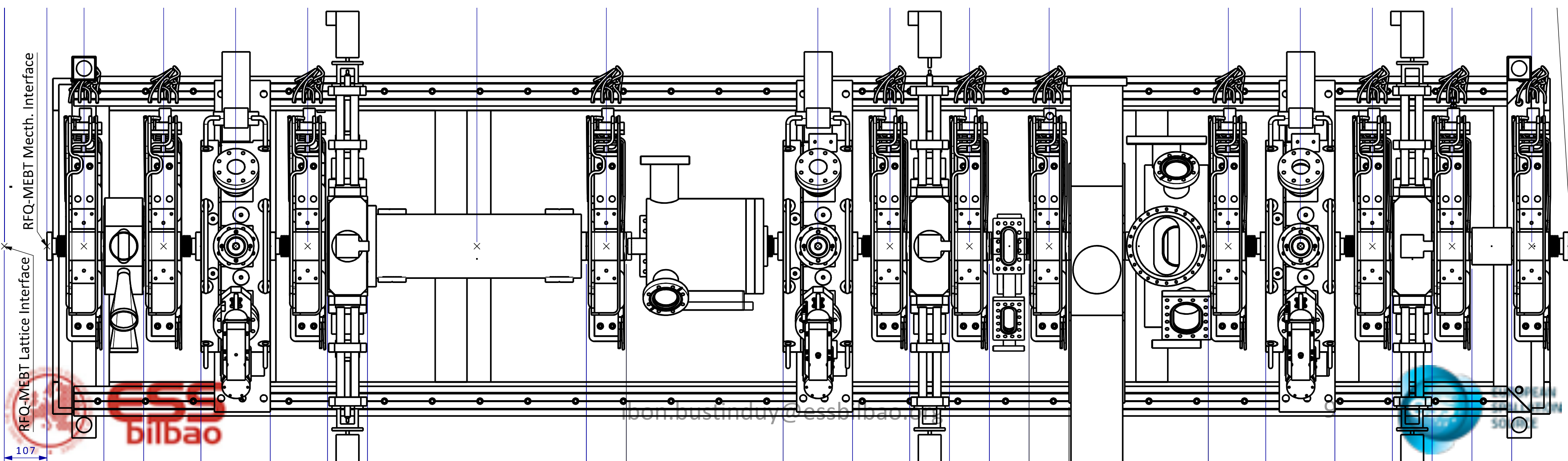
	Item	Date
X	Quad & Buncher PDR	February 2016
X	Mech. Layout Integration	March 2016
O	Maximum Beam Power Density allowed per area and time	April 2016
O	Proton Beam Instrumentation PDR	June 2016
O	MEBT CDR	December 2016
O	Buncher Vertical Integration	December 2016
O	Assembly Stage #1 (BILBAO) starts	September 2017
O	Assembly Stage #2 (RATS) starts	May 2018
O	Assembly Stage #3 (TUNNEL) starts	June 2018

Assembly Stages

	Stage Description	Date	Location
○	**Assembly Stage #1** Mechanical assembly of most systems in top of the supporting structure. Vacuum test of each component and assembly Verification of all parts and interfaces EEE Integration	September 2017	BILBAO
○	**Assembly Stage #2** Verification of all parts	May 2018	RATS
○	**Assembly Stage #3** Reassembly and final alignment	June 2018	TUNNEL

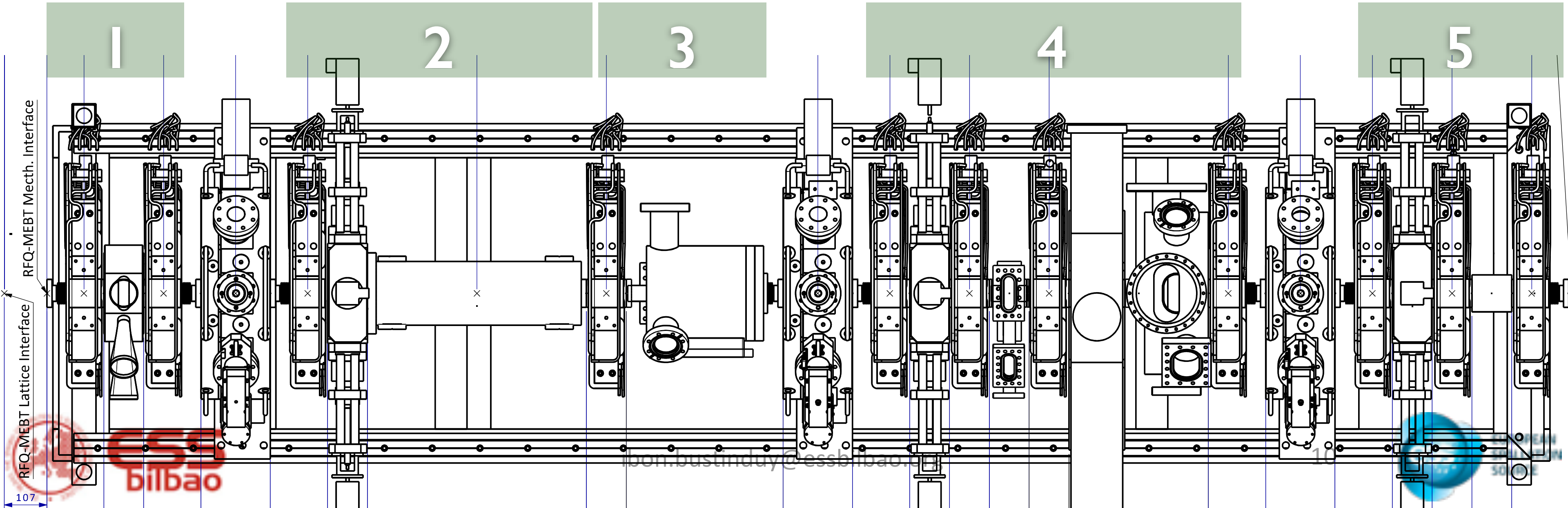
Mechanical Integration

- Deeply entangled problem.
- The adoption of a project mentality was the key.
- Three stage problem: Optical elements first. Assembly and alignment strategy agreed. Then, beam instrumentation.
- Each system has an space budget to finalise detailed design.



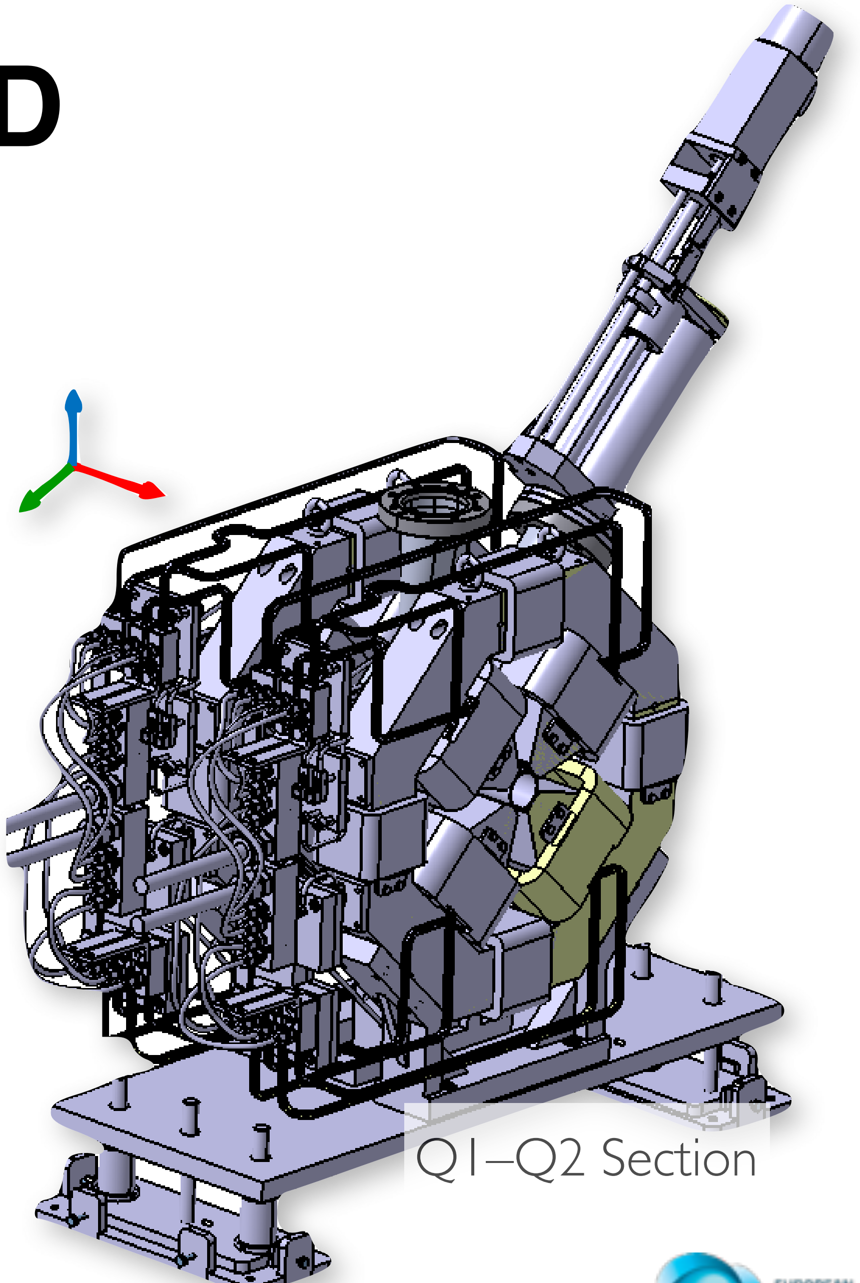
Mechanical Integration

- This milestone unlocks:
  - Support Frame.
  - Assembly and Alignment strategy refinement
  - Diagnostics (FC, BPM, EMU, WS, CT) and corresponding boxes detail design.
  - Chopper Beam Dump finalisation.
  - Chopper Vessel
  - Vacuum simulations refinement.



QUAD

- MEBT needs of 11 Quadrupoles for focusing and steering the beam.
- The magnet series from a unique design to generate the required quadrupole and dipole fields.
- A full magnetic design developed to generate the maximum quadrupole fields plus 10% contingency.
- The magnetic design calculated with ROXIE and COMSOL software throughout a combination of 2D and 3D simulations.
- Design deeply correlated to embedded BPMs.
- Dismountable in 2/4 parts
- PDR held in Feb.2016 (https://indico.esss.lu.se/event/503/)
- Call for tender in progress

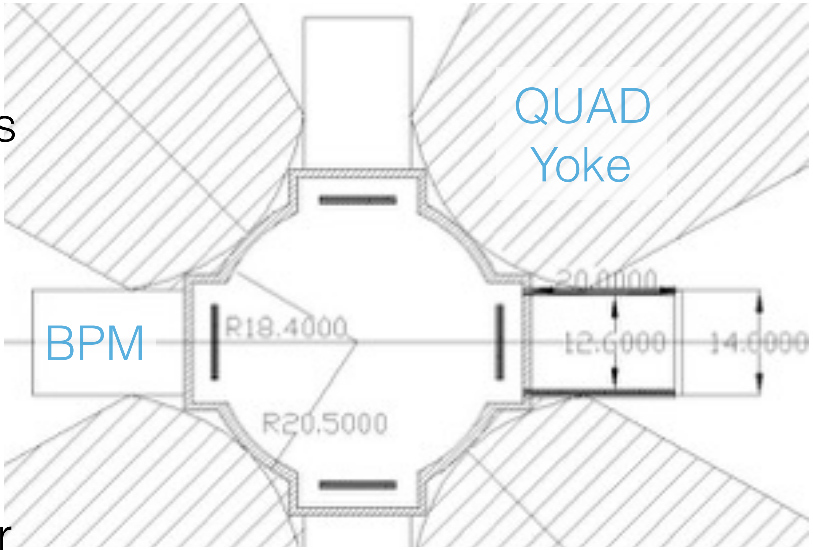


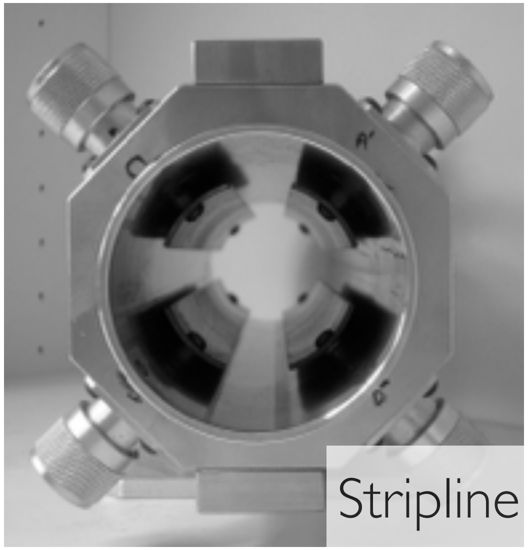
Q1–Q2 Section

QUAD

BPM

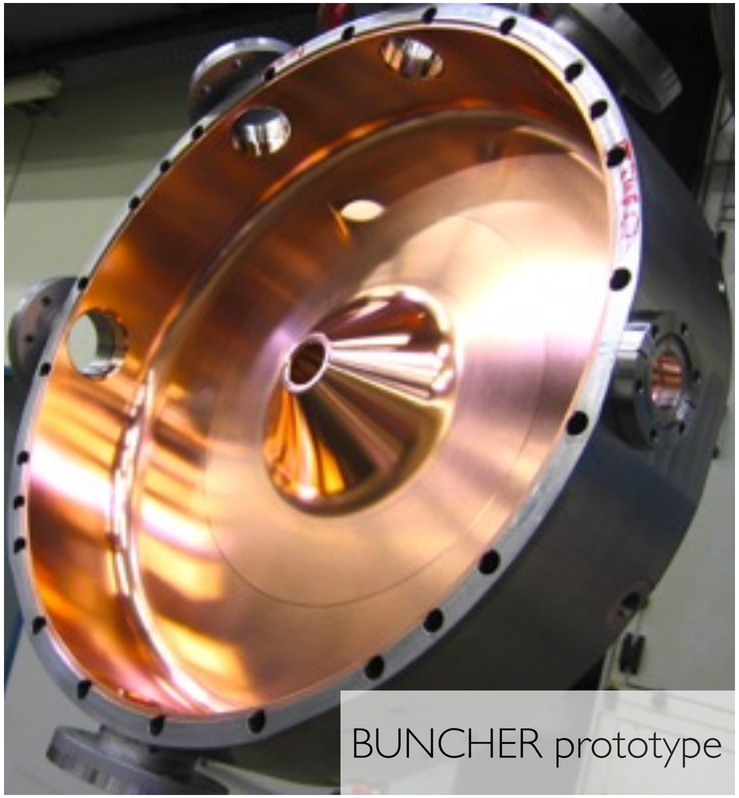
- **Stripline** type with electrode length of less than 40 mm
- BPMs will be installed inside **quadrupoles**
- They are based on 50Ω matched transmission lines with shorted ends
- Functional in both **352.2** & **704.4 MHz**
- All the materials and components used in the BPM structure are non-magnetic in order not to affect the quadrupole field





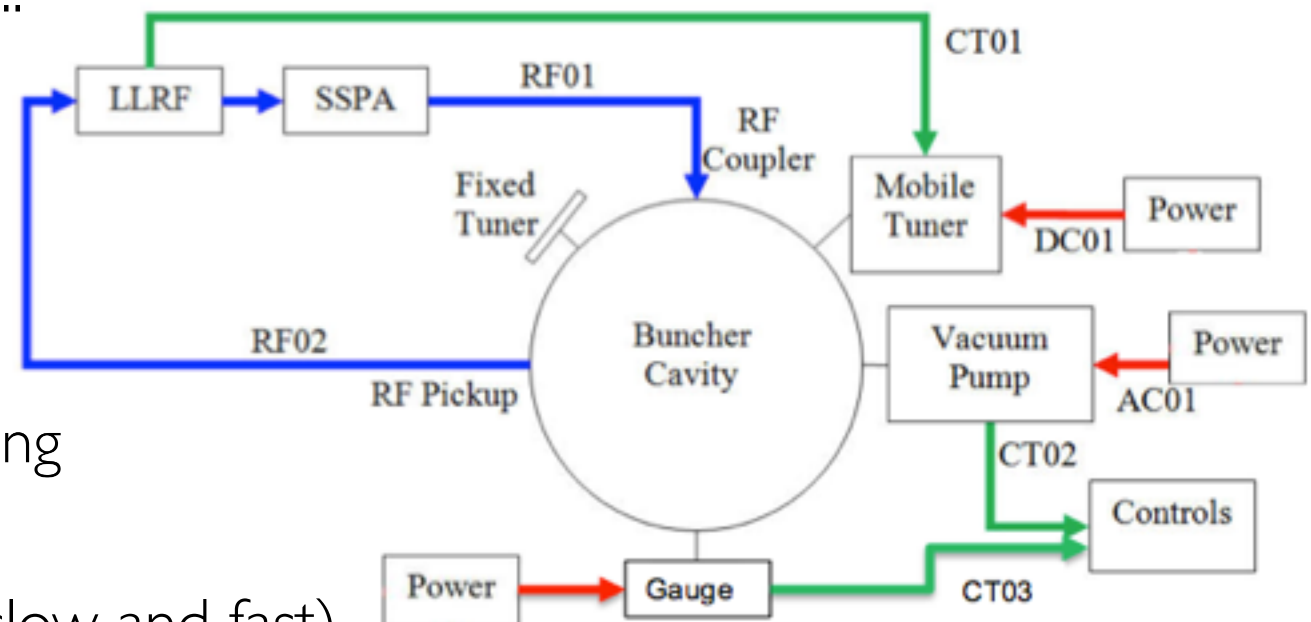
BUNCHER

- Layout: Optical design & engineering design.
- For an EoTL≈150kV, get higher ZT^2 with compromise.
- Best diameter and location for the tuners.
- Efficient cooling circuit (max temp. in the "nose cone" is ~194ºC).
- Power coupler to hold ~22.5kW peak power.
- 190mm max. length. 136 mm cavity width (vacuum)
- Room-temperature copper, bulk resistivity of 1.7241 μΩ-cm.
- Different parametric studies: SUPERFISH (2D), COMSOL (3D), HFSS (3D)
- Prototype designed, manufactured, measured (metrology & RF), and characterised by bead pull.

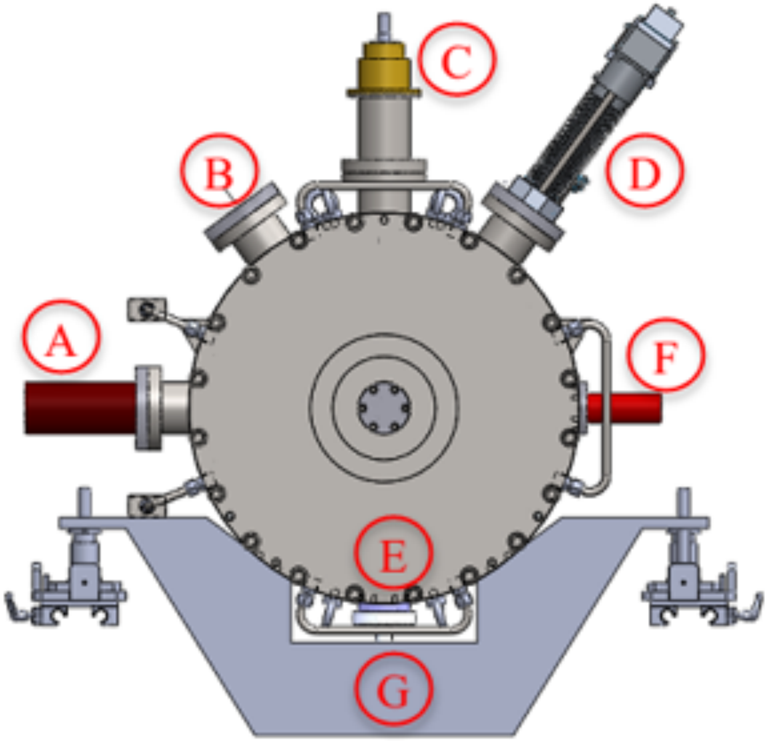

BUNCHER prototype

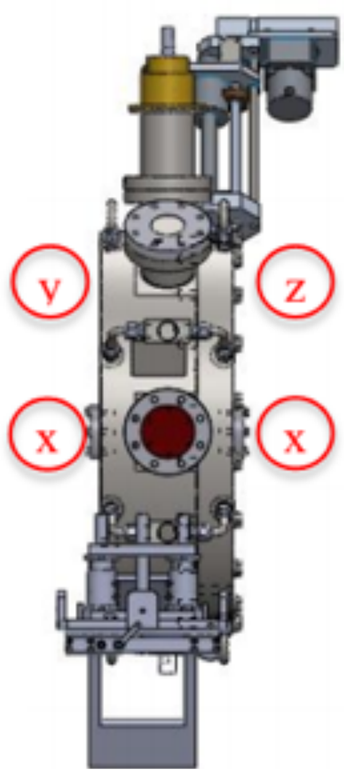
BUNCHER Integration

- BUNCHER constitutes the best system to test the validity of the complete vertical system, naming convention, etc..
- It contains:
    - RF
    - LLRF
    - Vacuum
    - Water cooling
    - Alignment
    - Interlocks (slow and fast)



BUNCHER Interfaces





Interfaces

A: DN63 CF – Ion Pump
B: DN63 CF – Tuner
C: DN63 CF – Coupler
D: DN63 CF – Tuner
E: DN40 CF – Pick Up
F: DN40 CF – Gauge
G: Support

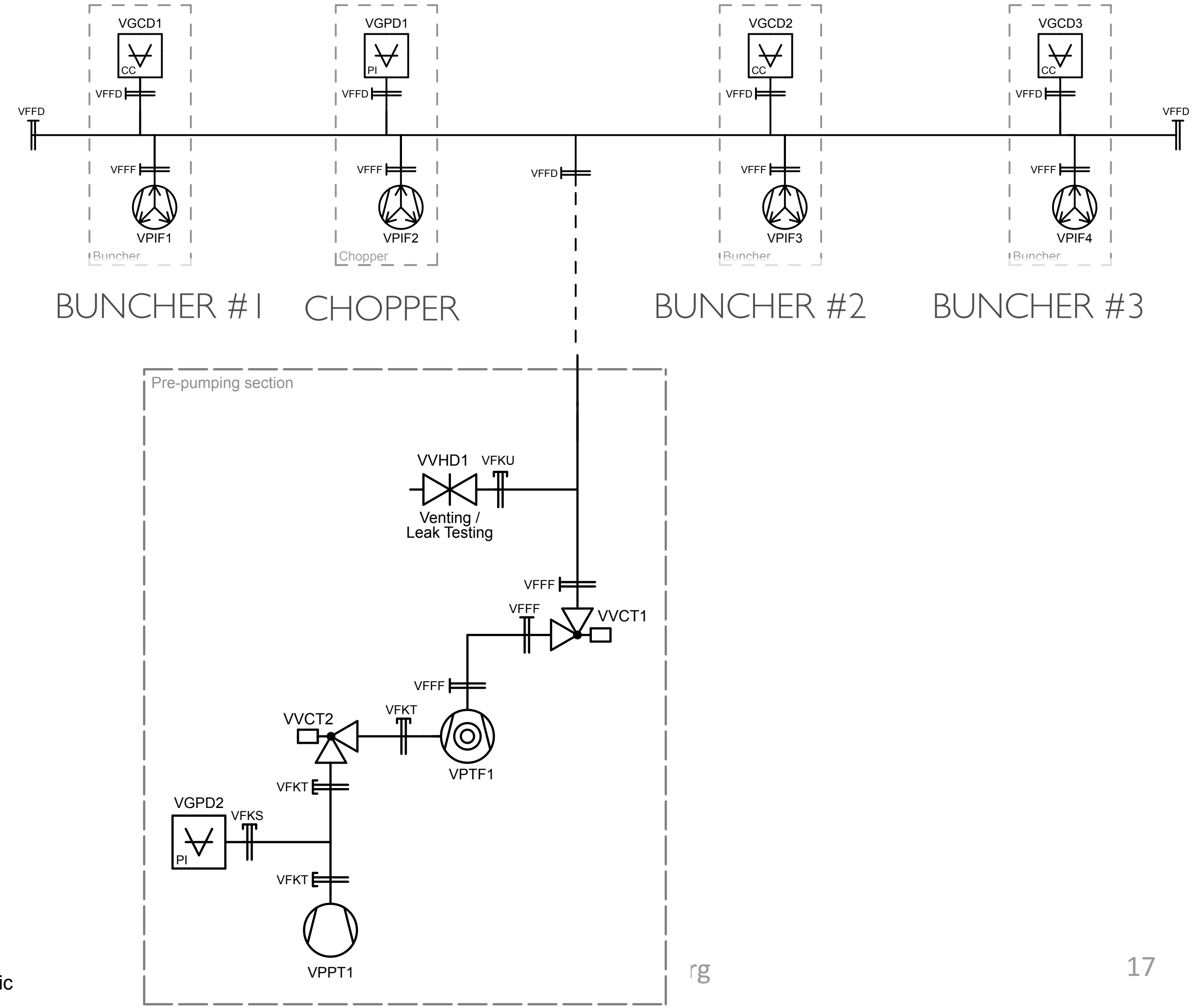
x: DN40 CF – Beam Pipe
y: Body (Helicoflex seal groove)
z: Cover (Helicoflex seal flat surface)

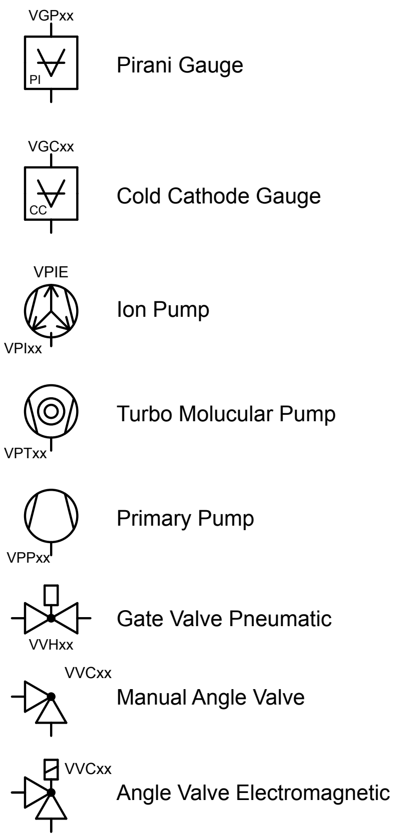
- All DN CF Flanges according to ISO/TS3669-2 Vacuum technology—Bakable flanges —Part 2: Dimensions of knife-edge flanges
- All pipes on DN CF Flanges according to ISO 9803-1 Vacuum technology — Mounting dimensions of pipeline fittings — Part 1: Non knife-edge flange type

BUNCHER

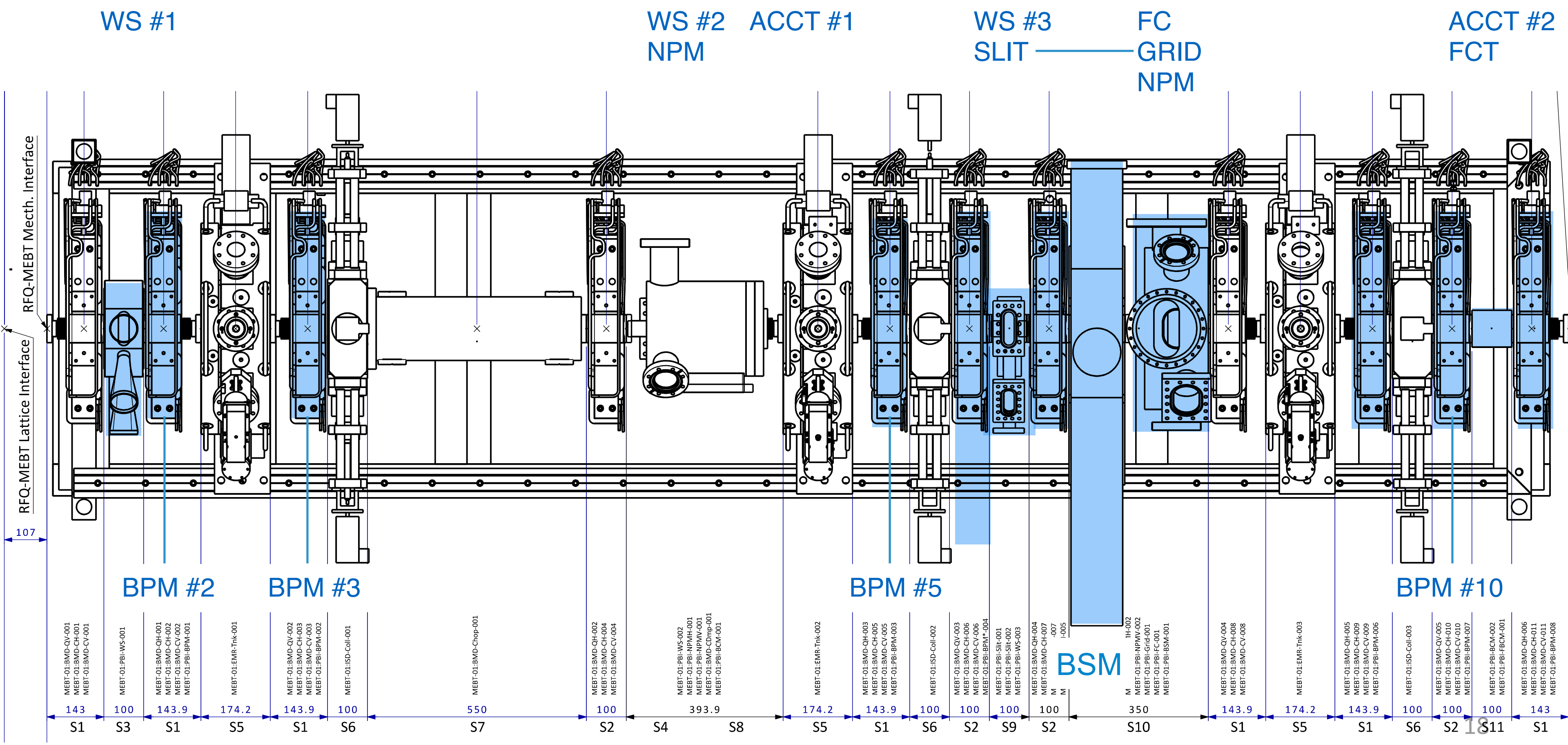
Bunchers (3x)	Time	ESS-Bilbao	ESS
PDR			
Contract	**80 days**		– **EEE workflow ready (ICS)** – **RF ready (WP8)** – **LLRF ready (WP8)** – **VAC ready (WP12)** – WTRC systems (sensors, etc) ready.
Production	**142 days**		
		– Integration in EEE of BU (WTRC, VAC, etc.) – Infrastructures ready – Implementation of local MPS – Implementation of local PPS	
Testing	**161 days**	**Jan 2017**	
		– VAC, WTRC, Metrol. – Low Power RF – Interlock tests – High Power RF	

VACUUM


VGCD1
CC
VFFD
VFFF
VPIF1
Buncher
VGPD1
PI
VFFD
VFFF
VPIF2
Chopper
VFFD
VGCD2
CC
VFFD
VFFF
VPIF3
Buncher
VGCD3
CC
VFFD
VFFF
VPIF4
Buncher
VFFD
VFFD
BUNCHER #1
CHOPPER
BUNCHER #2
BUNCHER #3
Pre-pumping section
VVHD1
VFKU
Venting /
Leak Testing
VFFF
VFFF
VVCT1
VFFF
VVCT2
VFKT
VPTF1
VFKT
VGPD2
VFKS
PI
VFKT
VPPT1


VGPxx
PI
Pirani Gauge
VGCxx
CC
Cold Cathode Gauge
VPIE
VPIxx
Ion Pump
VPTxx
Turbo Molucular Pump
VPPxx
Primary Pump
VVHxx
Gate Valve Pneumatic
VVCxx
Manual Angle Valve
VVCxx
Angle Valve Electromagnetic

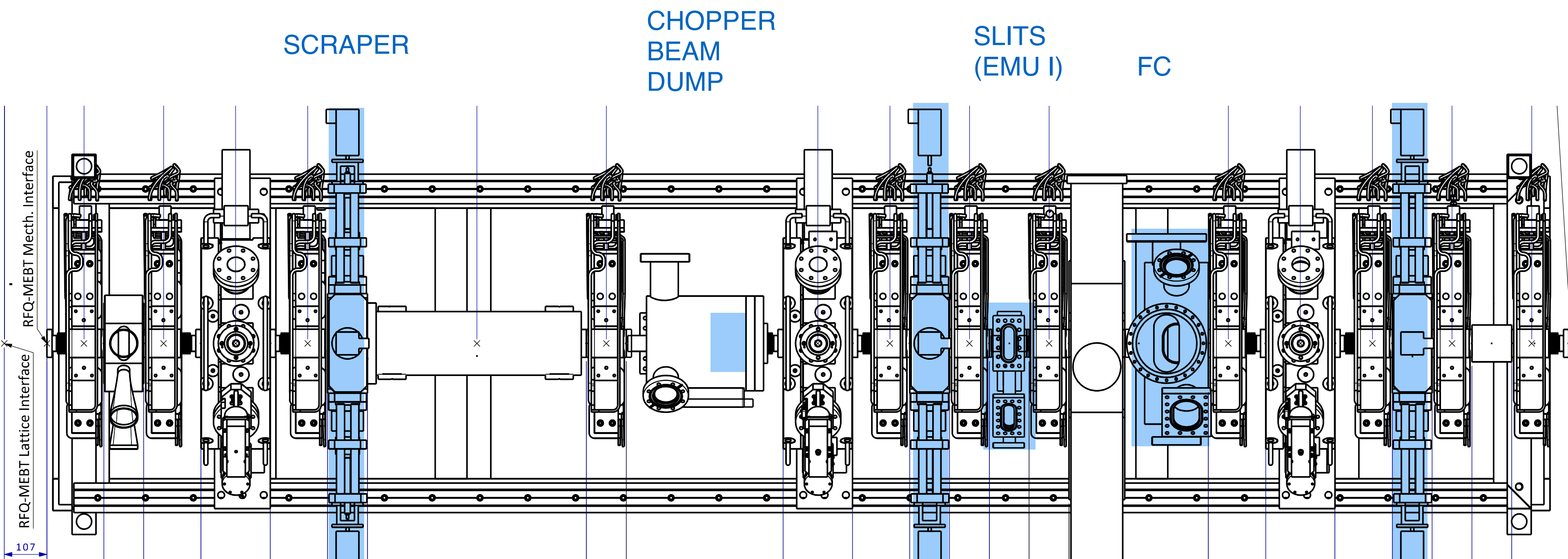
Diagnostics



Beam Stoppers

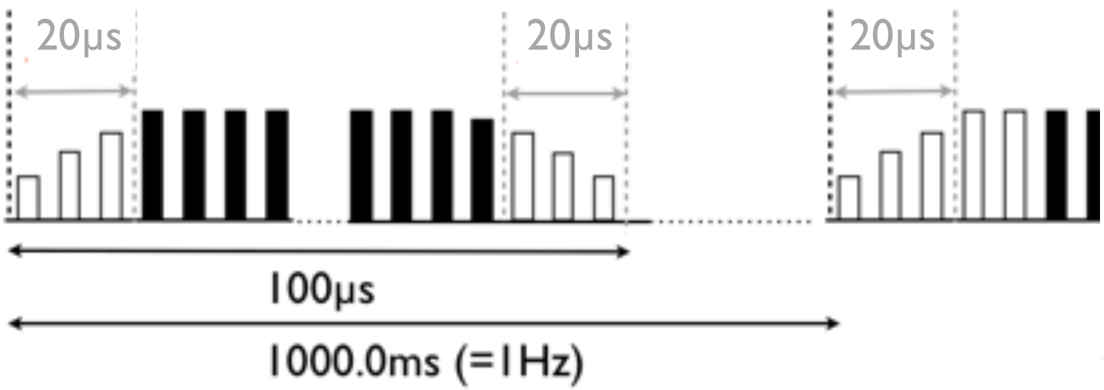
Problem Description

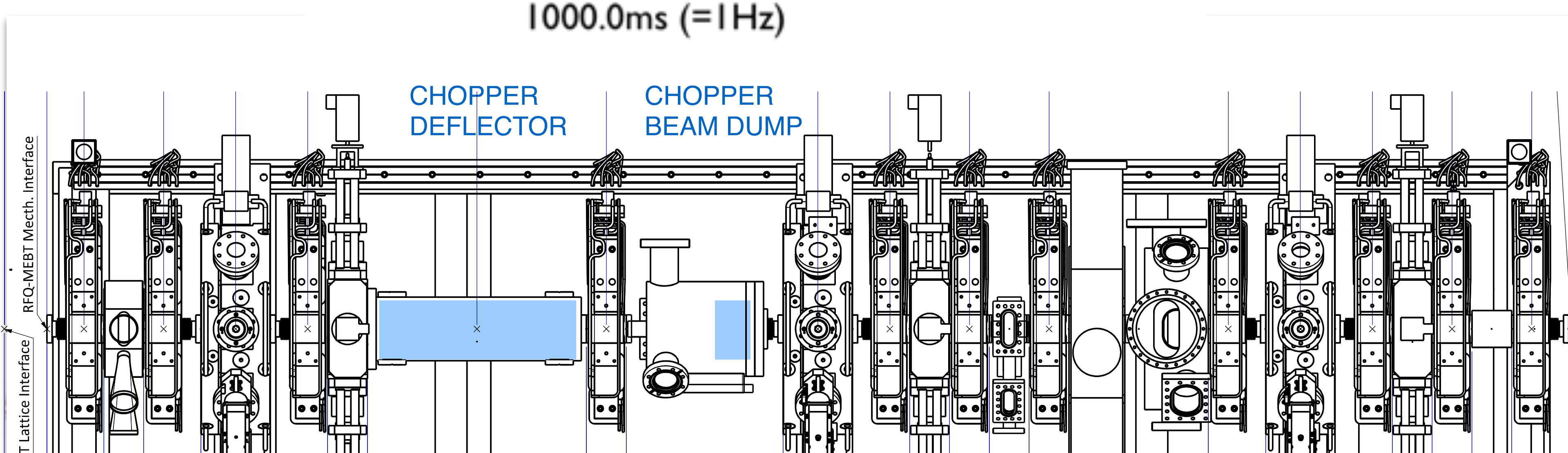
- From the **transient state** calculations, one can infer that this model has to be discarded given the combination of **high power** distributed in a **very concentrated** beam size and a **swallow deposition surface**.
- Please note that current and energy combination result in a **230 kW** peak power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



Chopper

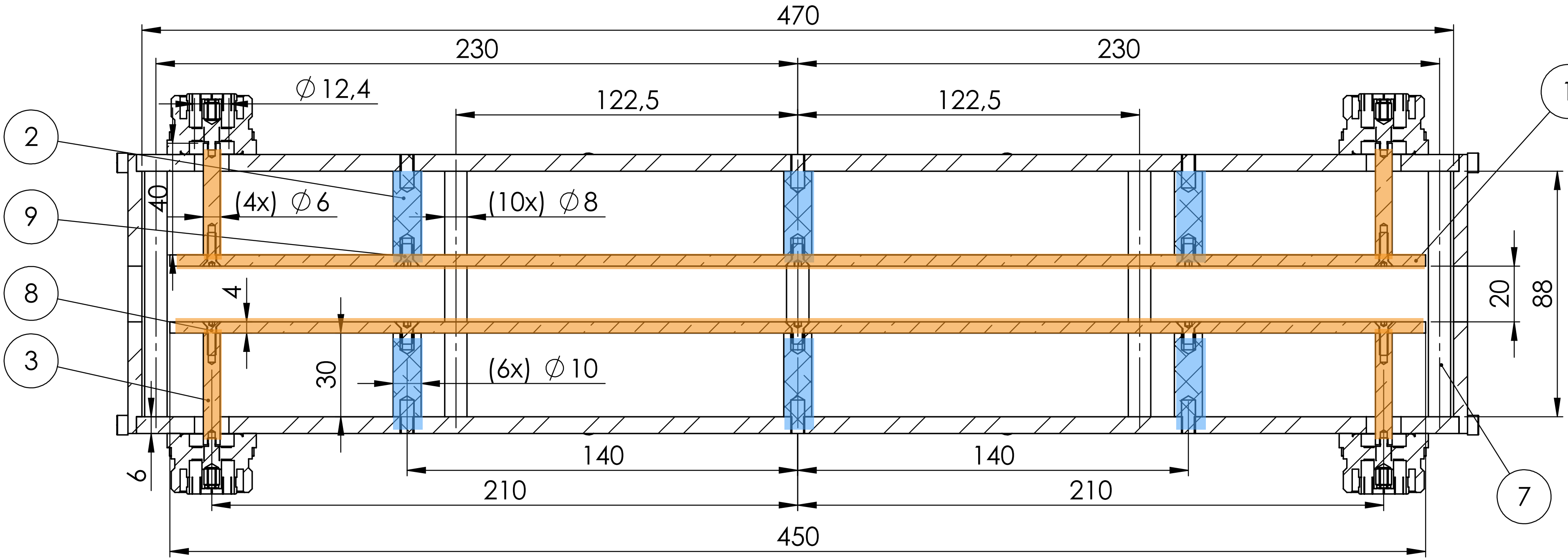
- Chopper workshop held in Bilbao Jan-2015 with a world-wide experts panel selection. (https://indico03.esss.lu.se/indico/event/285/)
- Strip-line approach ΔV~ 5kV; 450mm; ø20mm; 10ns rise-time; 20μs steady





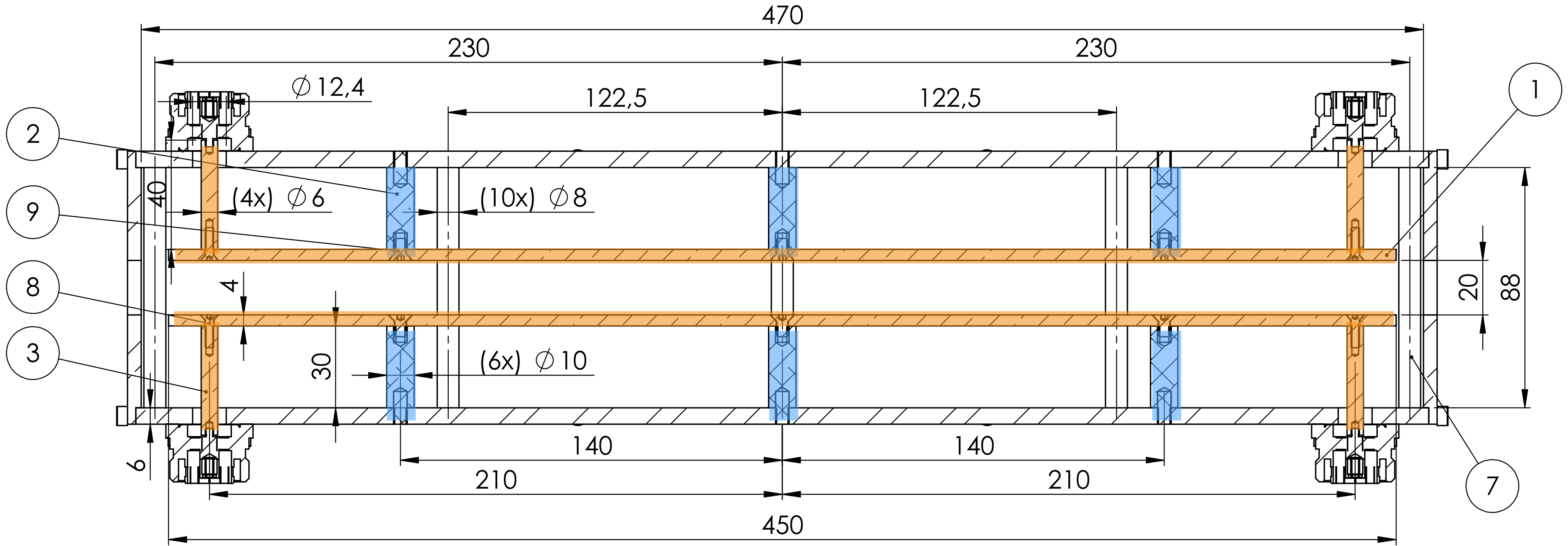
Deflector: Strip-line

- The design is based on fast transmission line strips, which the perpendicular electromagnetic fields will deflect the beam in the vertical position.
- The strip-line is designed to match with 50 ohm termination loads, therefore removing the voltage reflections and maximising the power transfer.
- The strip-lines have matched input ports from pulser and matched output ports to the load.
- Chopper Strip-line is based on fast transmission line scheme with overall rise time less than 10 ns and maximum differential voltage of 5 kV.



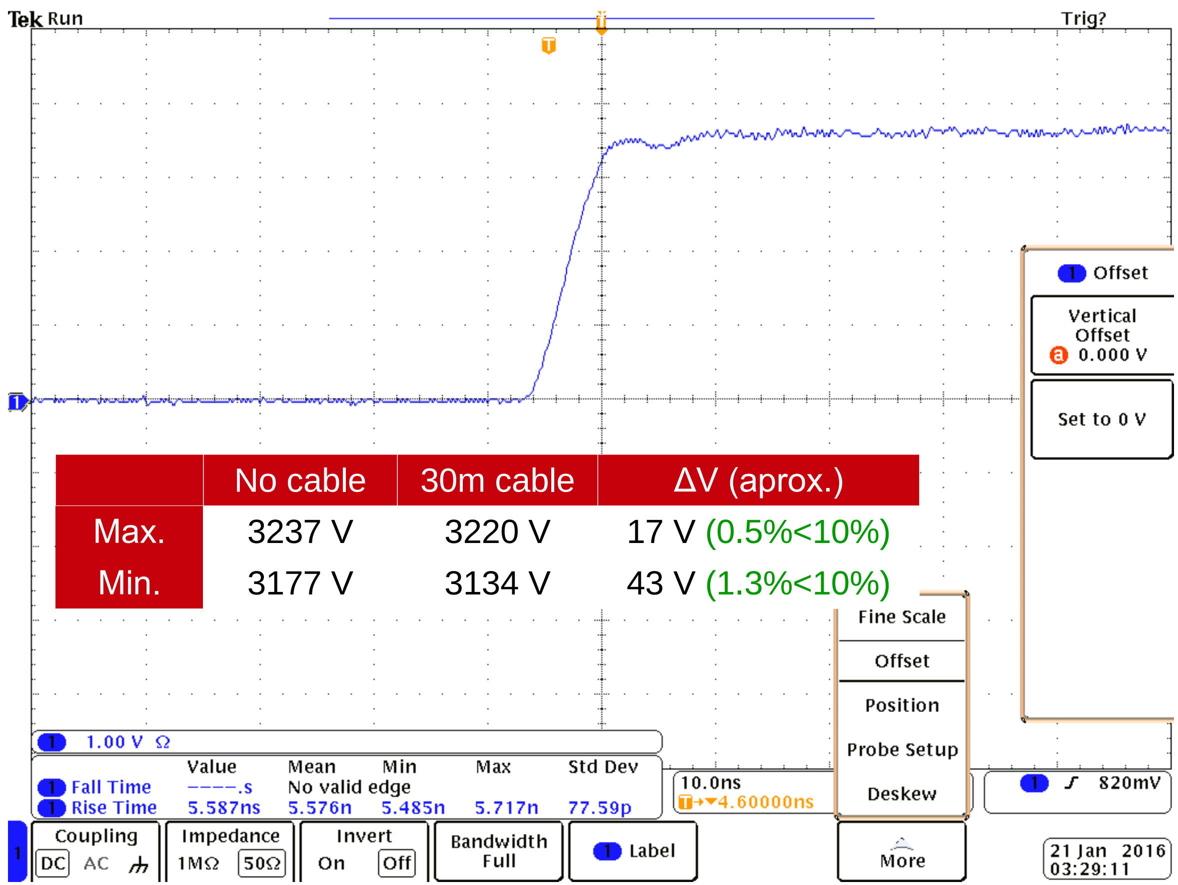
Deflector: Stripline

Deflector Type	TEM Stripline
Beam energy	3.62 MeV
SL Gap	20 mm
Deflection angle	13.84 mrad
Deflector length	450 mm
Deflecting voltage	±2250 V
Characteristic impedance	50 Ω
Good field region	±15mm
E flatness in GFR	5%



Pulser

In-factory acceptance test stage, Many tests performed, including effects of employed load, jitter, cable length, etc. Overall, performance is promising, still a few adjustments need to be done in factory before shipping to Bilbao.



	No cable	30m cable	ΔV (aprox.)
Max.	3237 V	3220 V	17 V (0.5%<10%)
Min.	3177 V	3134 V	43 V (1.3%<10%)

3KV - 10 μs

Rise time: 5.5 ns

Cable delay: 0.8 ns < 1ns

Dates

Finished

Strip-line Detailed Mechanical Design

The positive polarity pulser prototype was launched in 2015.

In process

Strip-line Manufacturing

Detail design of strip-line vacuum vessel

Pulser factory acceptance test. The first phase of the tests have been realised in February 2016. Results are promising.

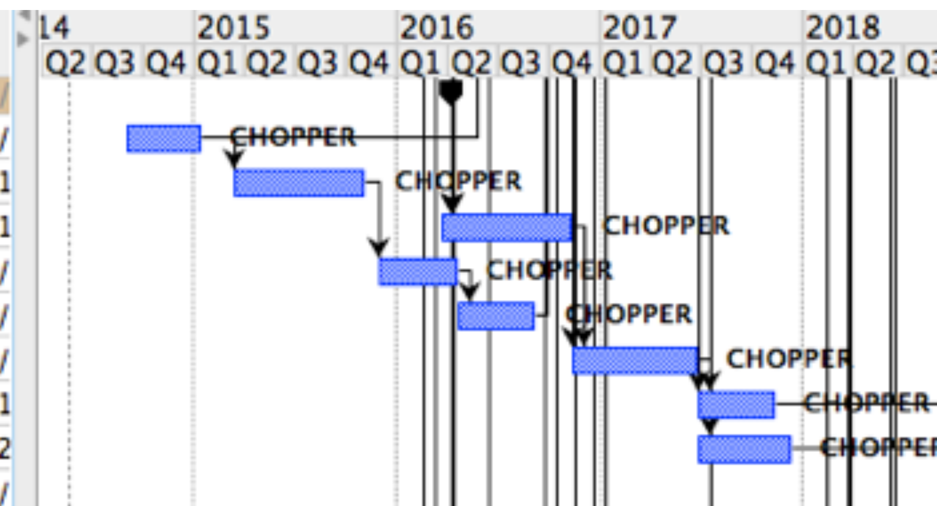
Future Steps

May 2016 final phase of factory tests

September 2016 The components delivered to ESS-Bilbao, acceptance tests performed.

November 2016 Assembly and measurements with and without pulser

Name	Duration	Start	
⊟ CHOPPER	1,250.37...	9/4/14...	6/
Chopper Specifications and technology	95 days?	9/4/14...	1/
Chopper Eng. design	170 days	3/16/1...	11
Beam dump Detailed design	170 days?	3/22/1...	11
Chopper PoP	100 days?	12/2/1...	4/
Chopper PoP Lab Tests	100 days?	4/20/1...	9/
Chopper & Beam Dump	160 days?	11/15/...	6/
Beam Dump tests	100 days?	6/27/1...	11
Pulser Tests	120 days?	6/27/1...	12
Chopper & Beam Dump Tests	30 days?	5/10/1...	6/



Overall

- **Mechanical integration Layout** has been agreed in a collaboration spirit.
- It is highly advisable to start all the preparations on the **buncher as a complete vertical system**. ICS will play a vital role.
- Future key activities:
  - Proton Beam Instrumentation Preliminary Design Review (June 2016).
  - MEBT Critical Design Review (Dec 2016)
  - Buncher machining and copper plating follow up.
  - Buncher integration (Vacuum, RF, LLRF, MPS, PPS)
  - Quad call for tender and follow up.