HB2TF – WP3

The WP3 of HB2TF is devoted to the design, realization, installation of all the warm radio-frequency systems in the test facility. The core being the two normal-conducting RF, 650 MHz buncher cavities with all the ancillaries required to provide the design bunching and acceleration of the about 1 MeV, 5 mA, CW electron beam and namely:

- 80 kW (40/55 kW) in total, 650 MHz RF power amplifier
- Waveguides, circulator, RF load
- RF field amplitude and phase control systems

Within the scope of WP3 also lies the engineering design of the Superconducting RF booster linac able to increase the electron energies up to 5 MeV or 10 MeV with beam current up to 2.5 mA.

Milestones

Electro-magnetic design of the buncher cavities: June 2023
Technical specifications ready for CFT for all items: June 2024
Installation completed: June 2025
Commissioning completed: October 2025

Deliverables

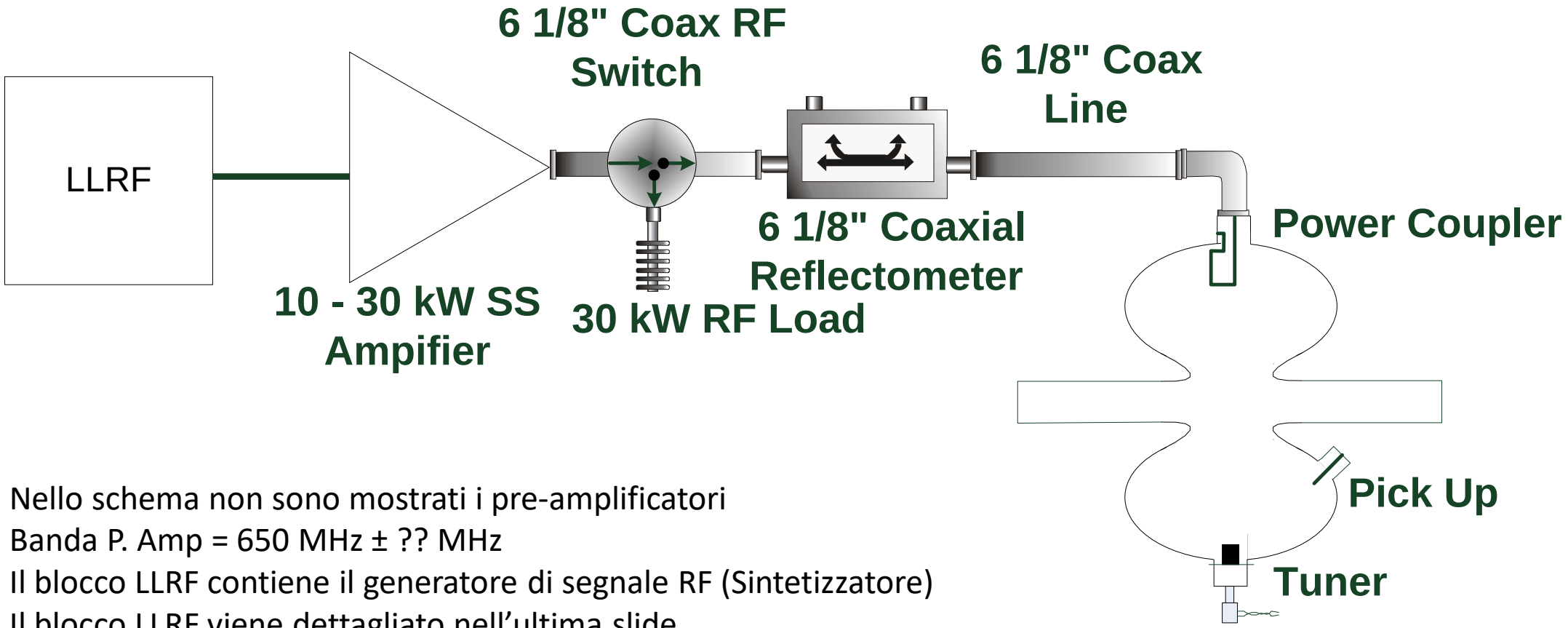
Electro-magnetic design and simulations report: June 2023
Buncher cavities technical specifications document: June 2024
First buncher, RF power chain and control systems at LASA: June 2025
SC booster linac engineering design report: December 2025

WP3 – The Radiofrequency System

	Unit	Name	Month/Year
1	Milano	Angelo Bosotti	2
2	Milano	Rocco Paparella	1
3	Milano	Elisa Del Core	1
4	Milano	Michele Bertucci	1
5	LNL	Oscar Azzolini	1
6	LNL	Cristian Pira	1
7	LNL	Giorgio Keppel	1
8	LNL	Eduard Chyhyrynets	1
9	LNL	Luca Torassa	6
10	LNF	Luigi Faillace	1
11	LNF	David Alesini	1
12	LNF	Fabio Cardelli	1
13	LNF	Luca Piersanti	1
14	LNF	Alessandro Gallo	1
15	Napoli	Maria Rosaria Masullo	3
16	Napoli	Andrea Passarelli	2
17	LNS	Luigi Giuseppe Celona	1
18	LNS	Giorgio Sebastiano Mauro	1
19	LNS	Ornella Leonardi	1

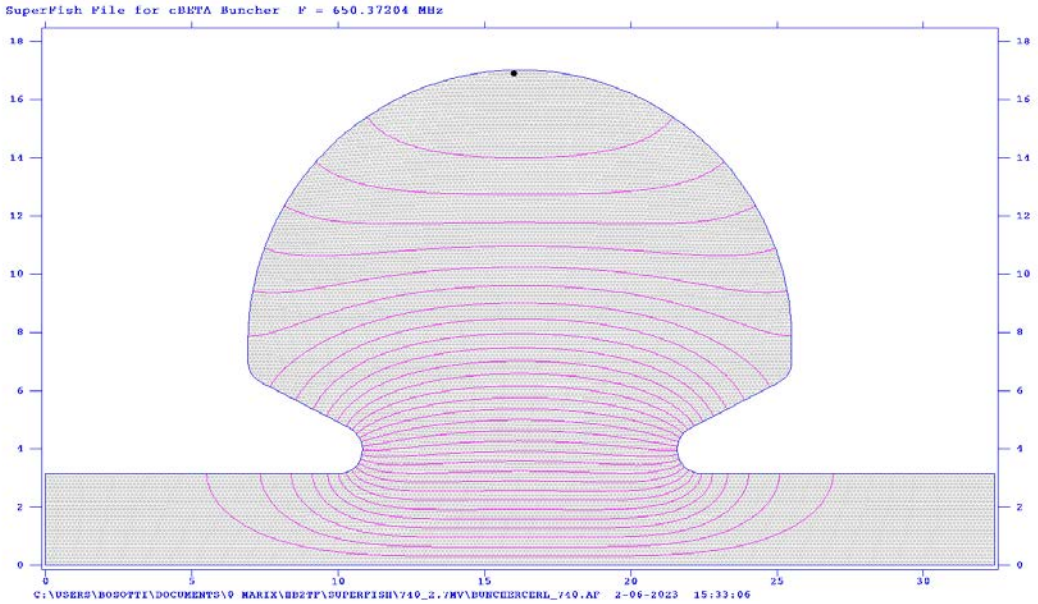
Schema di Principio Collegamento Amplificatore - Cavità

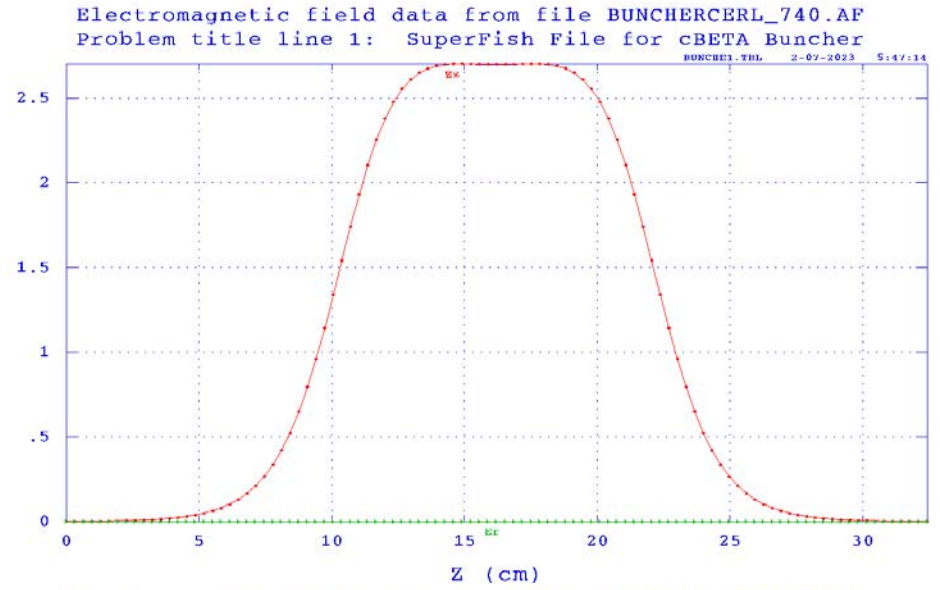
Il funzionamento previsto è CW ma non è escluso anche l'impulsato a tempi lunghi (T>100 μs)

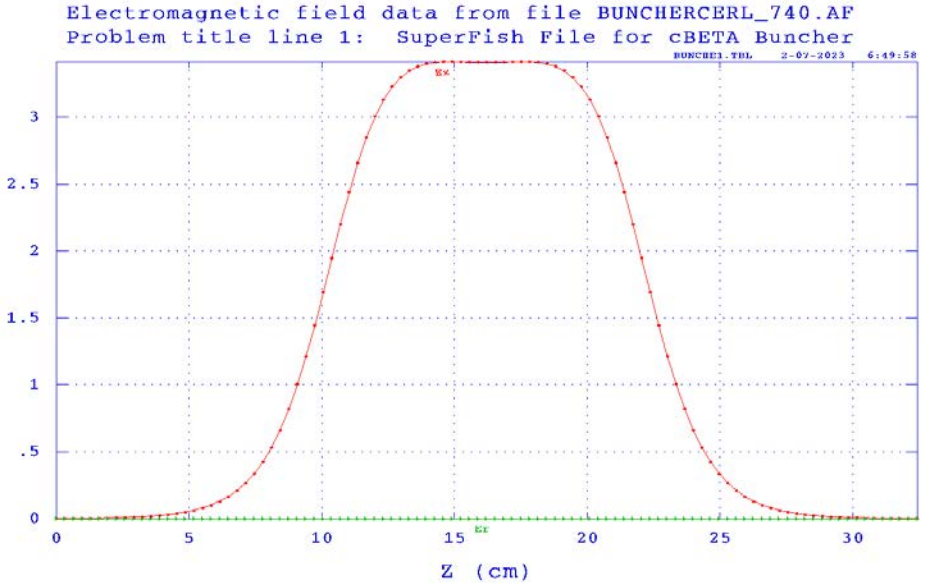


- Nello schema non sono mostrati i pre-amplificatori
- Banda P. Amp = 650 MHz ± ?? MHz
- Il blocco LLRF contiene il generatore di segnale RF (Sintetizzatore)
- Il blocco LLRF viene dettagliato nell'ultima slide
- Le connessioni fra amplificatore, componenti ancillari e cavità sono effettuate con linee coassiali di tipo 6 1/8''.

SHB1 - cERL scaled to 650 MHz – β = 0.740

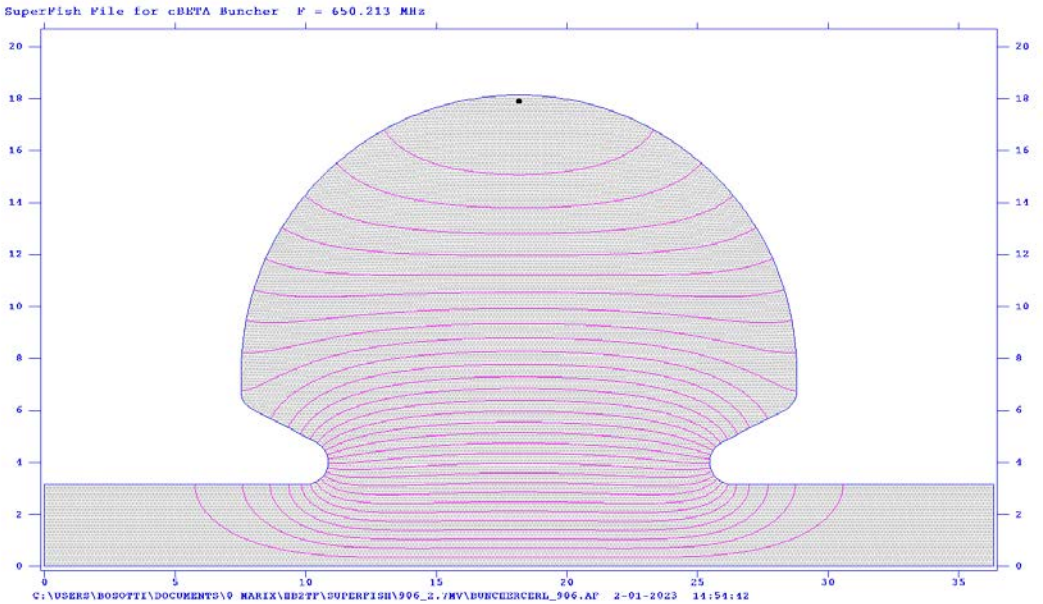


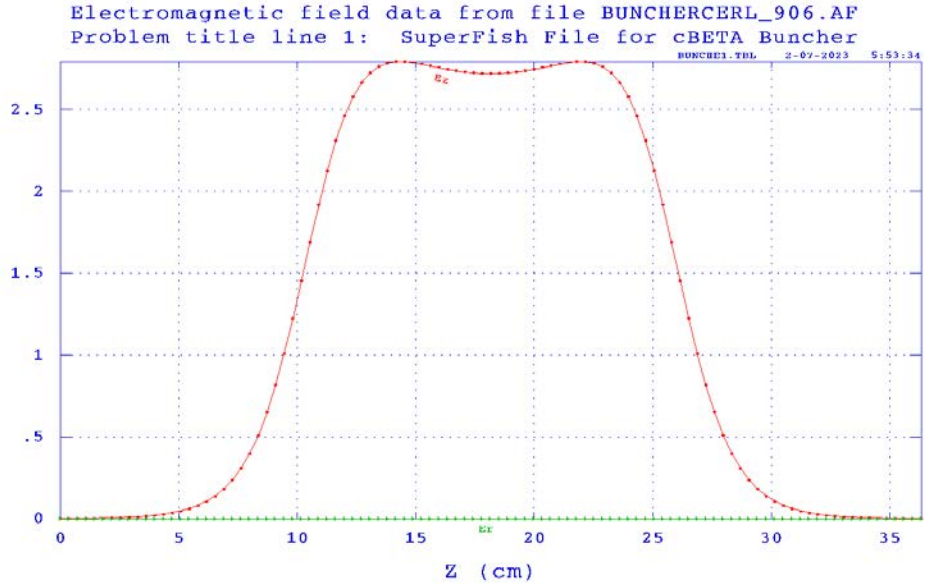


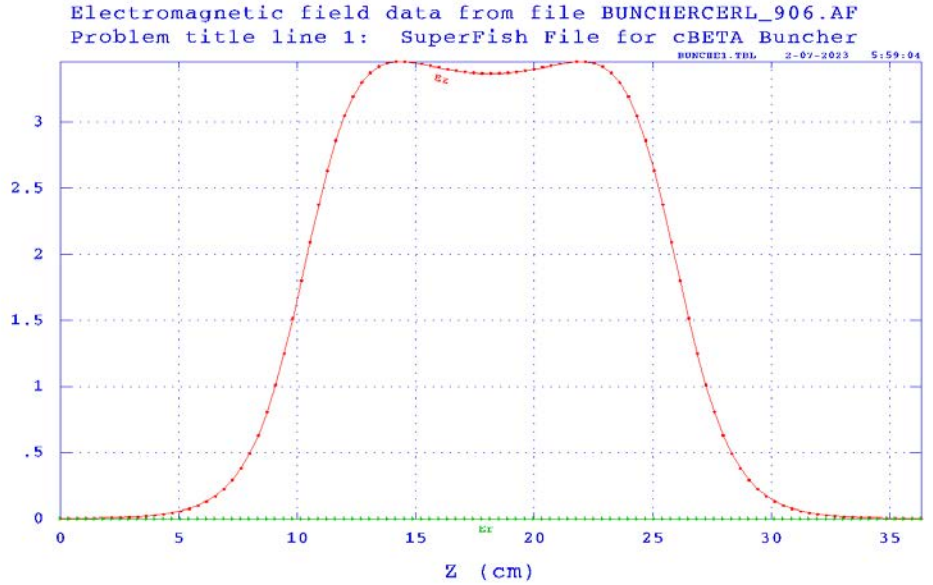


Highlights from Superfish SFO file		
SHB1	**Ez max 2.7 MV/m**	**Ez max 3.4 MV/m**
L [m]	0.171	0.171
f [MHz]	650.372	650.372
TTF	0.741	0.741
U [J]	0.080	0.127
Rs [mΩ]	6.653	6.653
Pc [kW]	10.280	16.411
Q0	31710.6	31710.6
RL [MΩ/m]	66.176	66.176
G [Ω]	210.982	210.982
E_0T [MV/m]	1.48	1.87
R/Q [Ω]	195.681	195.681

SHB2 - cERL scaled to 650 MHz – β = 0.906







Highlights from Superfish SFO file		
SHB2	**Ez max 2.7 MV/m**	**Ez max 3.4 MV/m**
L [m]	0.209	0.209
f [MHz]	650.213	650.213
TTF	0.730	0.730
U [J]	0.123	0.188
Rs [mΩ]	6.653	6.653
Pc [kW]	13.639	20.886
Q0	36743.1	36743.1
RL [MΩ/m]	73.658	73.658
G [Ω]	244.436	244.436
E_0T [MV/m]	1.6	1.98
R/Q [Ω]	222.932	222.932

Buncher cavities parameters from BriXSino TDR to HB2TF

Alcuni parametri (in rosso) vanno aggiornati oppure ridiscussi alla luce delle recenti simulazioni di dinamica del fascio

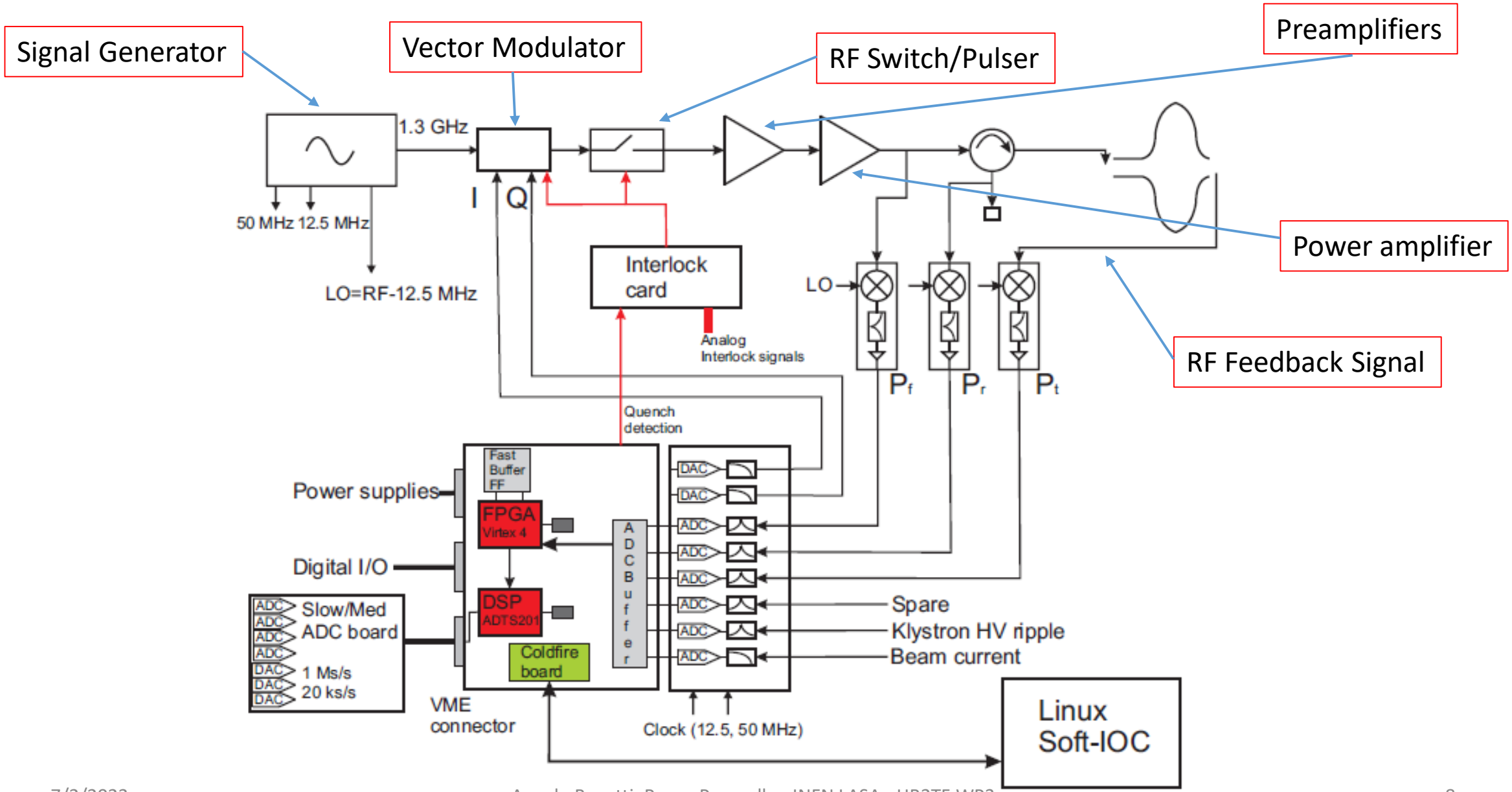
	Buncher1	**Buncher2**
Resonant frequency (π-mode) (*MHz*)	650	
β (v/c)	0.74	0.906
Accelerating voltage (*MV*)	~~0.45~~	~~0.424~~
Beam phase (°)	~~-30~~ (-25.45)	~~-17~~(-36.79)
Input beam energy (*MeV*)	0.25	0.638
Electric field amplitude (*MV/m*)	3.4/2.7	
Cell per cavity	1.0	
Active cavity length (*m*)	0.171	0.209
Cavity quality factor Q_0	3.2×10^4	3.67×10^4
Nominal external quality factor Q_{ext}	3.02×10^4	3.24×10^4
R/Q (*Ω*)	195.7	223
Cavity geometry factor G (*Ω*)	211	244
E_{pk}/E_{acc}	3.07	3.88
B_{peak}/E_{pk} $(mT/(MV/m))$	0.96	0.96
B_{peak}/E_{acc} $(mT/(MV/m))$	2.94	3.73

SHB1 & SHB2 – Power Amps

La potenza dissipata dalle cavità è calcolata con Superfish imponendo i valori massimi del profilo di campo Ez (R=0) uguale rispettivamente a 3.4 MV/m e 2.7 MV/m

	Ez Max = 3.4 MV/m		Ez Max = 2.7 MV/m	
	SHB1	**SHB2**	**SHB1**	**SHB2**
Pbeam [kW]	2	2	2	2
Pcav [kW]	17.0	21.3	11.0	14.0
Ptot [kW]	19.0	23.3	13.0	16.0
+20%	22.8	28.0	15.6	19.2
+15%	21.9	26.8	15.0	18.4
Proposta [kW]	**25**	**30**	**20**	**20**

Esempio di LLRF (cortesia CBETA)



WP3 Funding Request

Item Description	2023	2024	2025	Total	Unit	
Buncher Cavity		€61,000.00		€61,000.00	LNL	Assets
Power coupler		€30,000.00		€30,000.00	MI	Assets
Frequency tuner		€20,000.00		€20,000.00	MI	Assets
RF Amplifier 1st Buncher - 10 kW (upgradabile a 45 kW)		€135,000.00		€135,000.00	MI	Assets
Medium Power Pre Amplifiers			€12,000.00	€12,000.00	MI	Assets
~~Waveguides~~ Coaxial Lines			€12,200.00	€12,200.00	LNL	Assets
High Power RF Load			€10,000.00	€10,000.00	MI	Assets
~~Waveguide~~ Coaxial Stubs			€6,100.00	€6,100.00	LNL	Assets
~~Waveguide~~ Coaxial - other components			€6,100.00	€6,100.00	LNL	Assets
Directional Coupler			€8,500.00	€8,500.00	MI	Assets
Power meters (3)			€16,000.00	€16,000.00	MI	Assets
Power meter (2)				€0.00		Assets
RF Source - Frequency Generator		€2,500.00		€2,500.00	MI	Assets
LLRF Control Electronics		€12,200.00		€12,200.00	MI	Assets
CST License Contribution	€2,000.00	€2,000.00	€2,000.00	€6,000.00	NA	Consumables
RF Gaskets			€2,000.00	€2,000.00	MI	Consumables
Instrument Cables			€5,000.00	€5,000.00	MI	Consumables

Compiti (= ‘’Chi fa cosa’’)

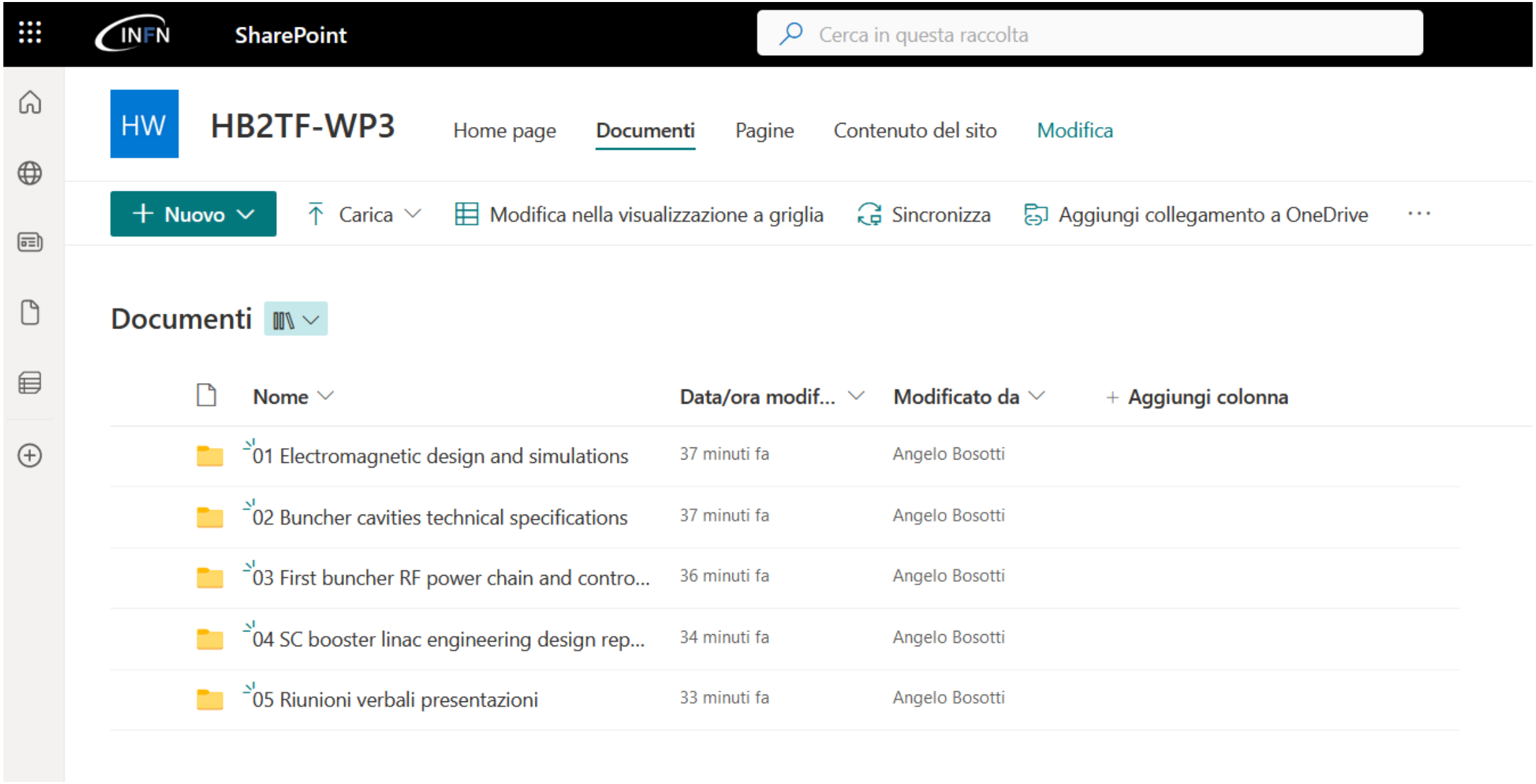
- Electro-magnetic design and simulations and technical specifications (compreso disegno meccanico)
  LNL (commissioning), Napoli, LNS, LNF, LASA

- RF power chain (amplifier, coax components)
  LNS, LNF, LASA

- Control systems (LLRF)
  LNS, LNF, LASA

- SC booster Linac design report
  LNL (Cryo?), LASA

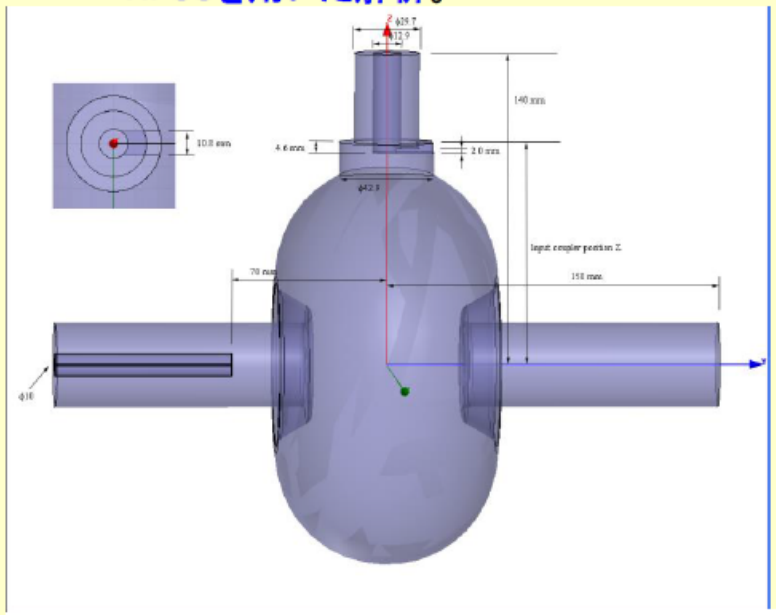
HB2TF-WP3 Repository (Provvisorio)



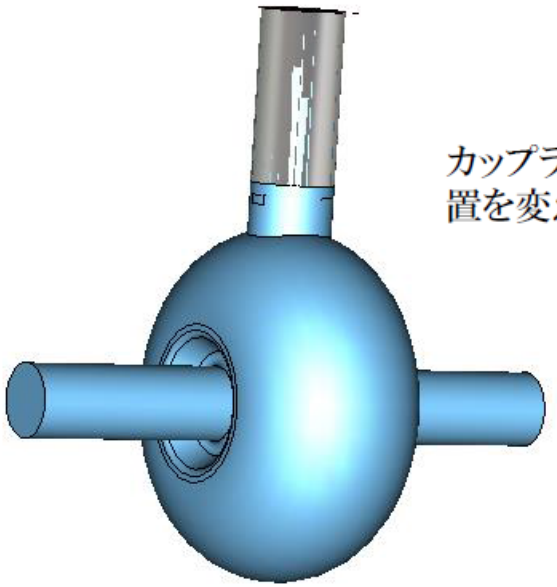
EXTRA SLIDES

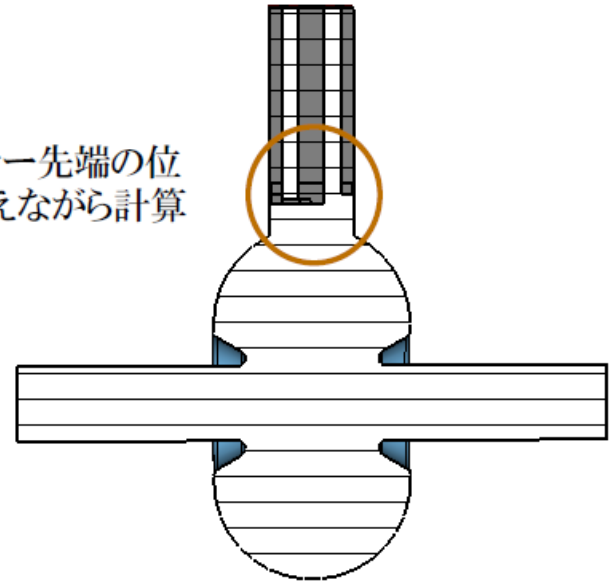
インプットカプラ突き出し量解析。

HFSSを用いた解析。

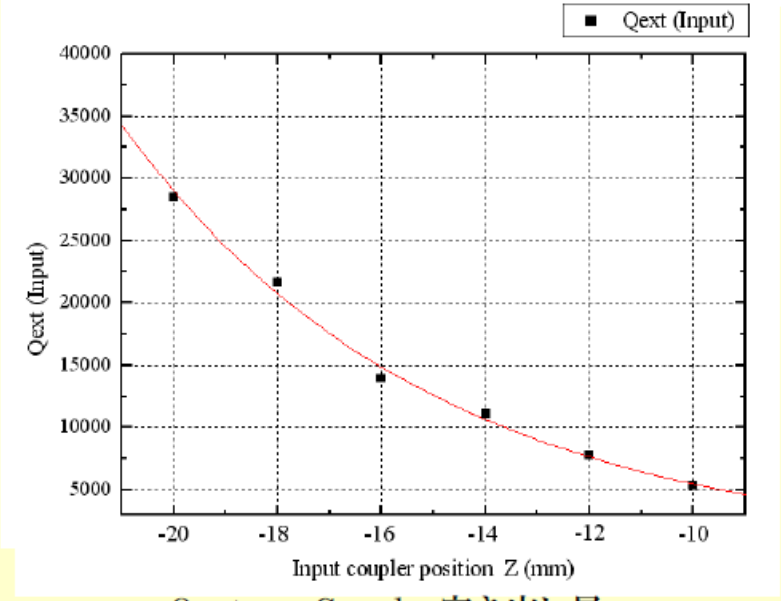


MW-studio を用いた解析

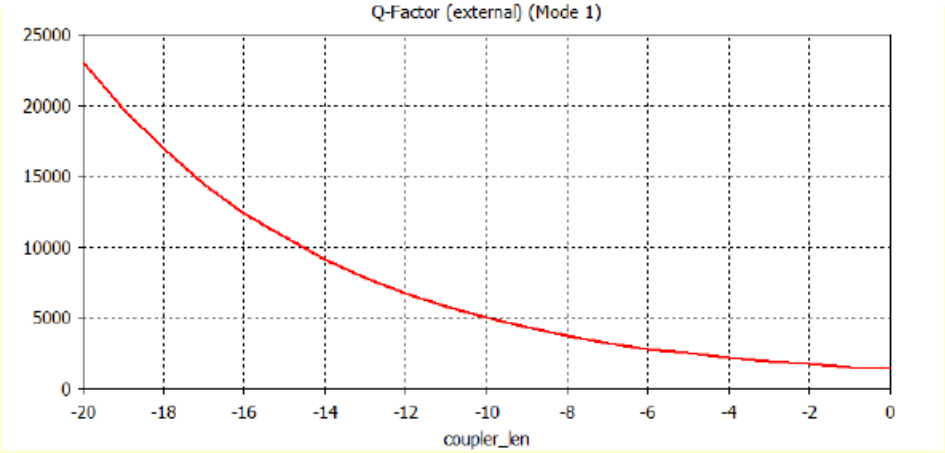




カップラー先端の位置を変えながら計算



Qext vs Coupler突き出し量



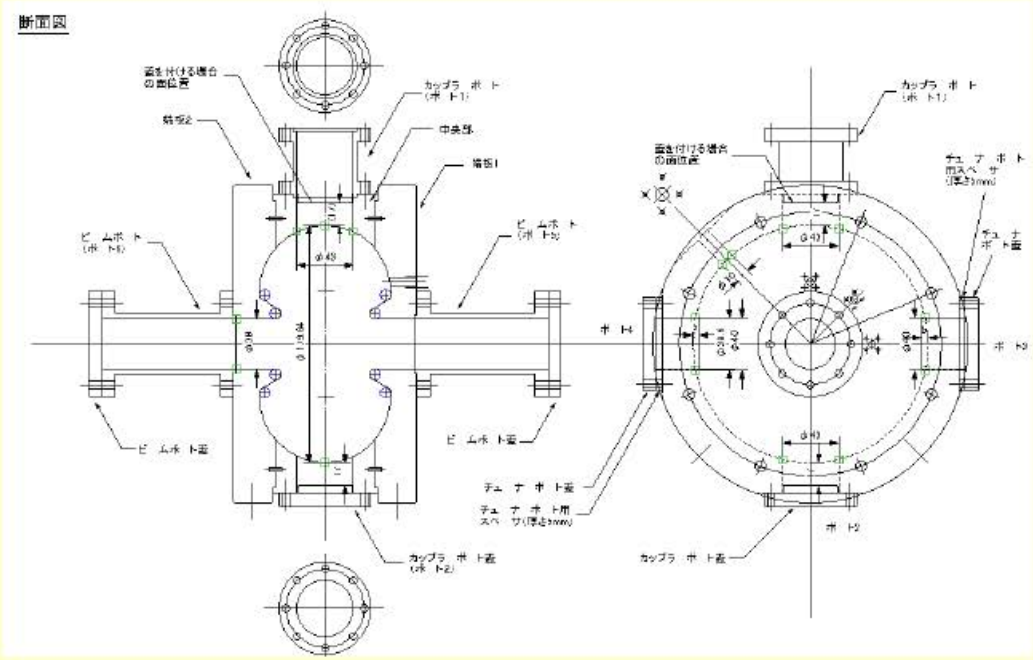
Qext vs Coupler突き出し量

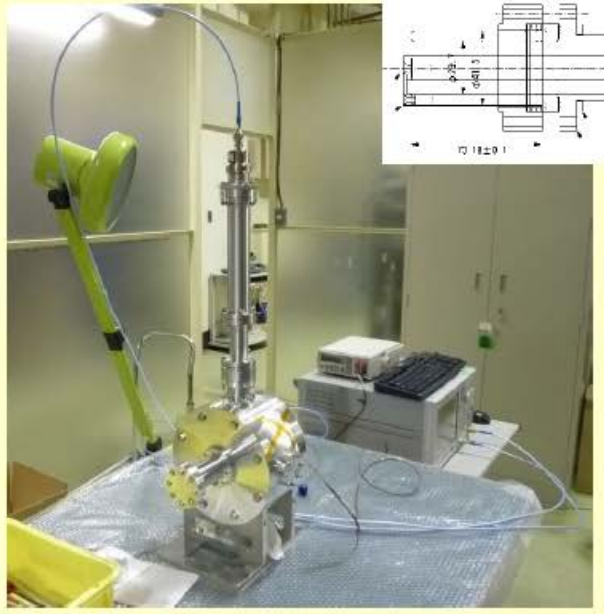
どちらの計算でも似たような結果を得た。Qin=12000程度となる位置（空洞赤道部より約16mm引っ込んだ位置）として設計を行う。

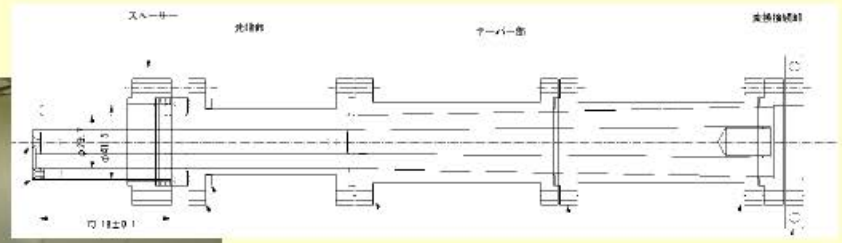
疑問点：PF空洞と比べるとインプットカプラの位置が引っ込みすぎ？

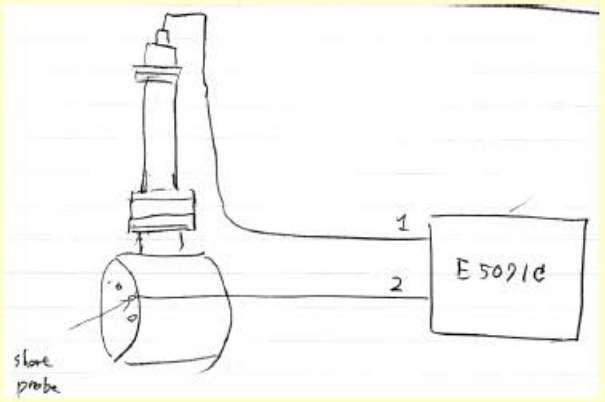
Al モデル空洞を作製しrf測定

Al モデル空洞









Al モデル空洞 測定風景

測定のセットアップ