ICONE

Neutrons for
Materials Sciences

ICONE

Innovative COmpact NEutron facility

Projet de source de neutrons compacte

Didier URIOT et al.

cea

cnrs

NEUTRONS - CONTEXTE HISTORIQUE

Une bonne partie du **progrès scientifique et technologique** repose sur notre capacité à comprendre et modeler la matière (inerte ou vivante).

Le neutron est une **sonde privilégiée** (voire essentielle) pour explorer sa constitution/structure/dynamique.

→ Un besoin estimé à ~800 expérience/an - (communauté: ~600 utilisateurs)

20ième siècle
- 1971 : **L'Europe** se dote d'une installation basée sur un **réacteur** : le **RHF** (ILL).
- 1980 : **La France** se dote d'une installation basée sur un **réacteur** : **ORPHÉE** (LLB).

Jusqu'en 2019, la recherche et l'industrie françaises ont donc pu bénéficier d'ORPHÉE, pour assoir une position de choix dans la compétition internationale. Cette installation a servi environ 500 expériences/an.

Sa fermeture n'est pas la conséquence d'un manque d'utilisateurs.

2036 : Fermeture annoncé de l'ILL

Changement de technologie : Réacteurs → Accélérateurs.

21ième siècle
- **L'Europe** se dotera d'une installation basée sur un **accélérateur de particules** : **ESS**.
- → Doter **la France** d'une installation basée sur un **accélérateur de particules** : **ICONE**.

HiCANS : **HI**gh **C**urrent **A**ccelerator-driven **N**eutron **S**ources

ICONE - HICANS

Objectif : doter la France d'une source « *accessible* » à l'échelle d'un pays, et qui ne recourent ni à la construction de réacteurs nucléaires coûteux (type ILL), ni à la construction d'accélérateurs à très haute énergie (type ESS), dont il sera complémentaire.

HiCANS :

- Ions légers, qq 10 MeV, pulsé et courant crête élevé
- Sans matière fissile
- Pas une INB
- De 20 M€ à 200 M€ (ESS : 3G€)
- Empreinte au sol ~1 terrain de foot vs 50 pour ESS
- Evolutif (upgradable)
- Plusieurs cibles
- Jusqu'à 5 instruments par cible (eg. powder diffraction, SANS, reflectometer, imaging, TOF spectroscopy, etc...)
- Des performances similaires à celles des réacteurs à flux moyen

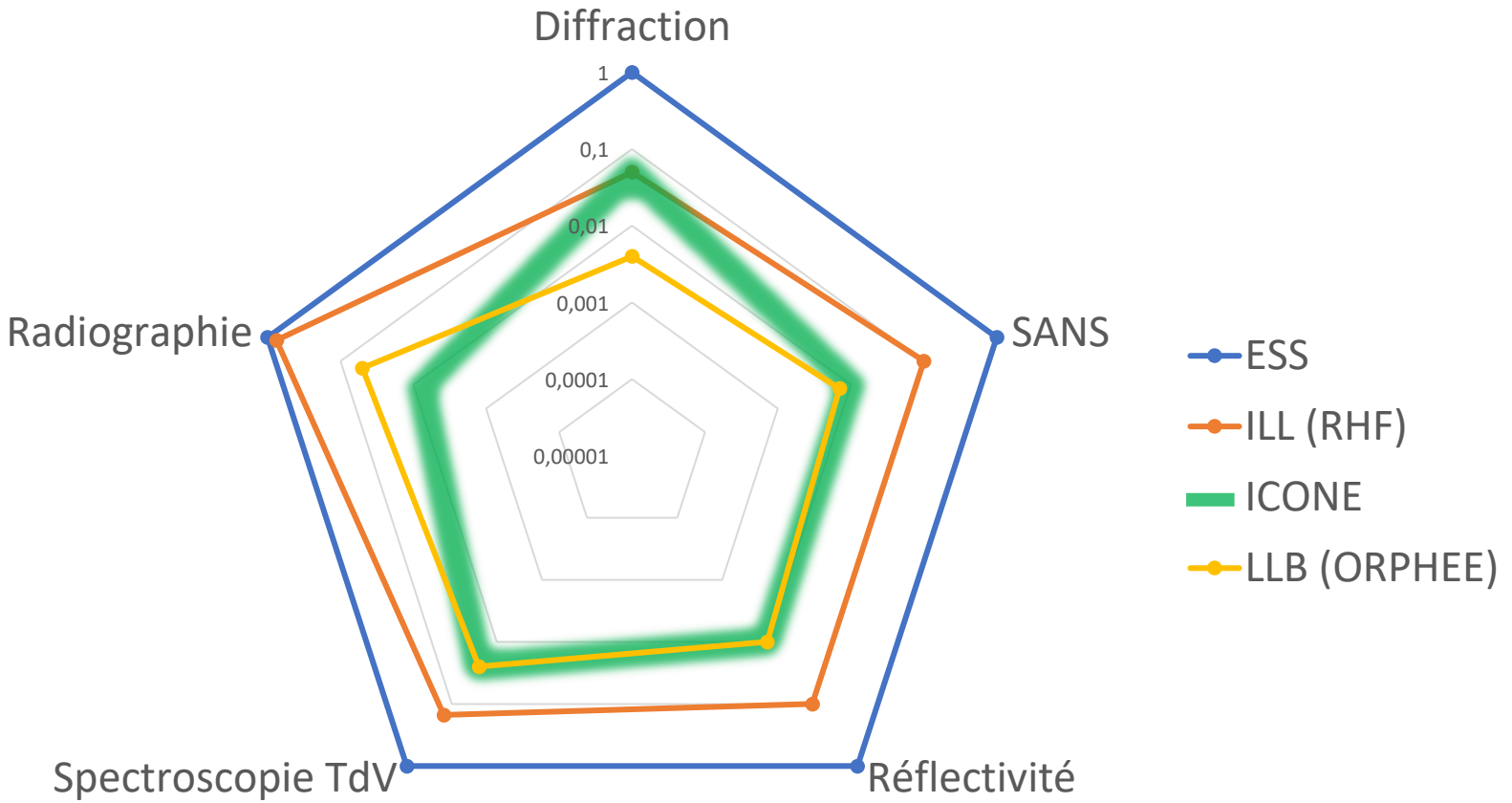
ICONE EN FLUX

Réacteurs : $Flux_{ORPHÉE}$ ~ 1/10 $Flux_{RHF\text{-}ILL}$

Accélérateurs : $Flux_{ICONE}$ ~ 1/30 $Flux_{ESS}$

France : $Flux_{ICONE}$ ~ $Flux_{ORPHÉE}$

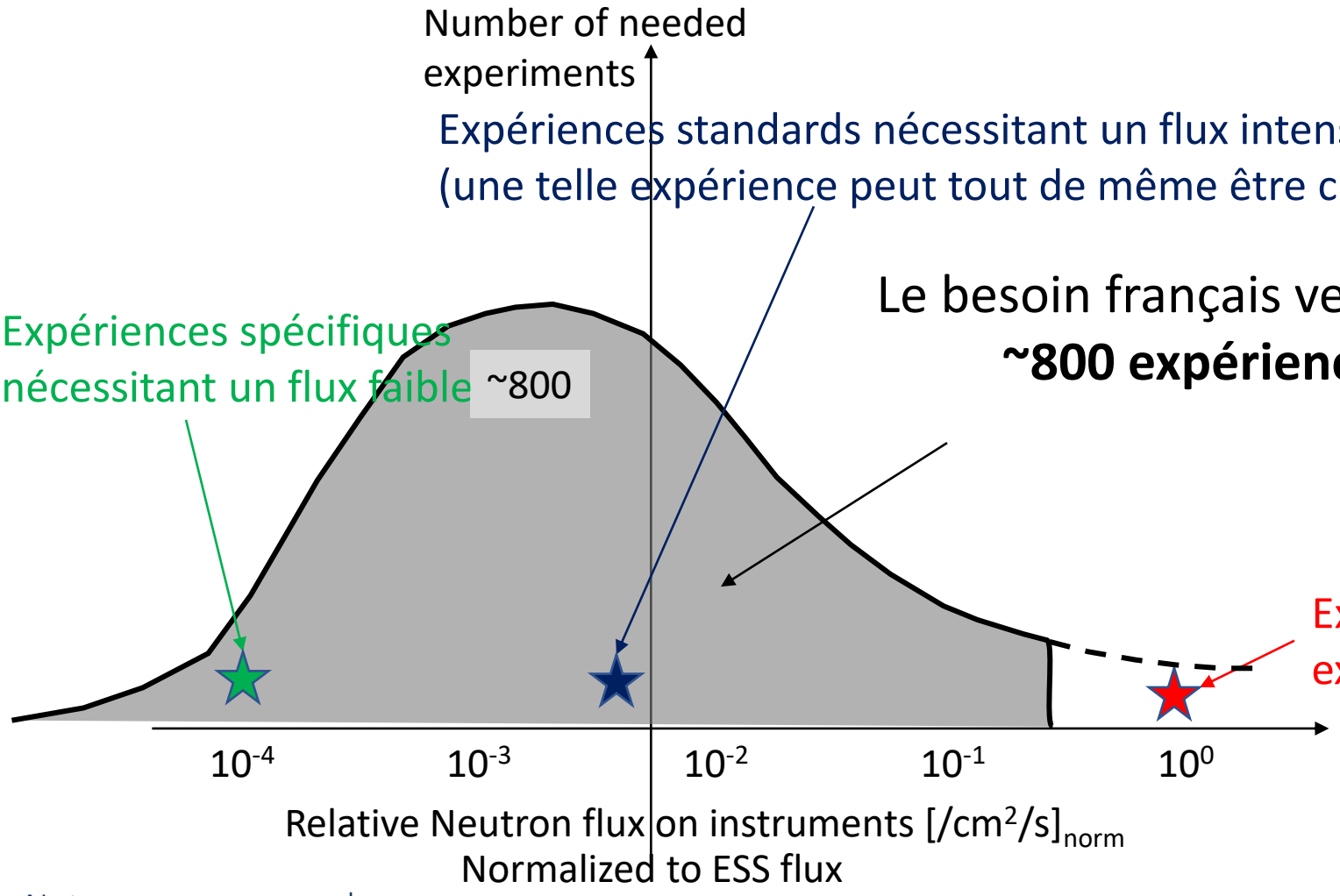
Flux sur échantillon [/s/cm^2-normalisé]



NB : du fait de la variété des instruments et des sources, seuls les ordres de grandeur sont vraiment pertinents.

ANALYSE BESOIN (~2010)

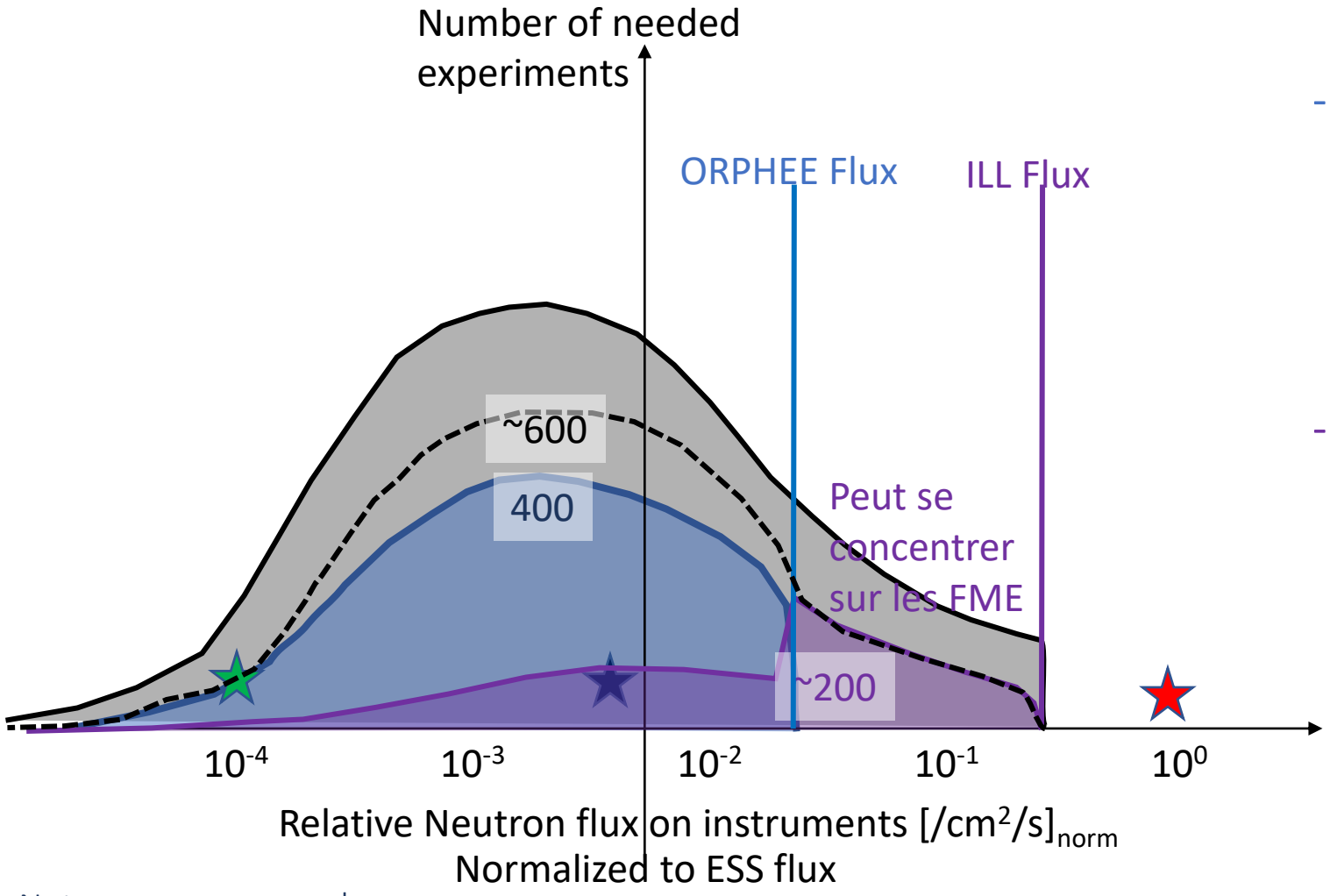
Chaque besoin nécessite un flux différent sur tel ou tel instrument



Le besoin français vers 2010 est/était de l'ordre de :
~800 expériences par an (*données ILL + ORPHEE*).

Notes pour comprendre

ORPHEE+ILL (<2019)



- Flux Moyen Intense de neutrons → **LLB**
  1/6,5 [exp/j/inst] ×~15 [inst] × 180 [j/a]
  ≃ **400** expériences par an pour la France

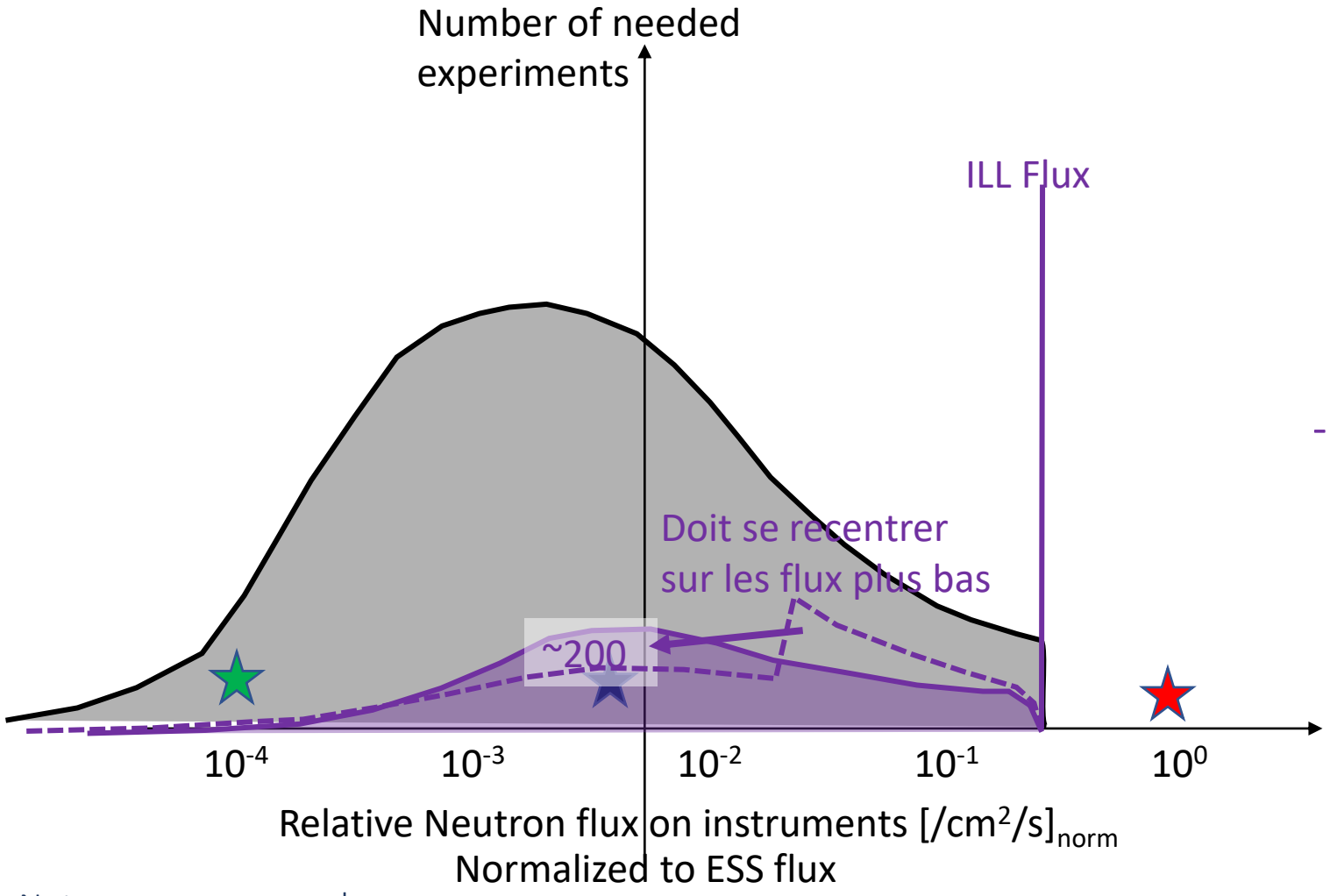
Un excellent complément de l'ILL

- Flux Moyen Extrême de neutrons → **ILL**
  1/4 [exp/j/inst] ×~20 [inst] × 160 [j/a] × 25%
  ≃ **200** expériences par an pour la France

Arbitré par l'excellence et FME

Notes pour comprendre

ILL SEUL (<2030)

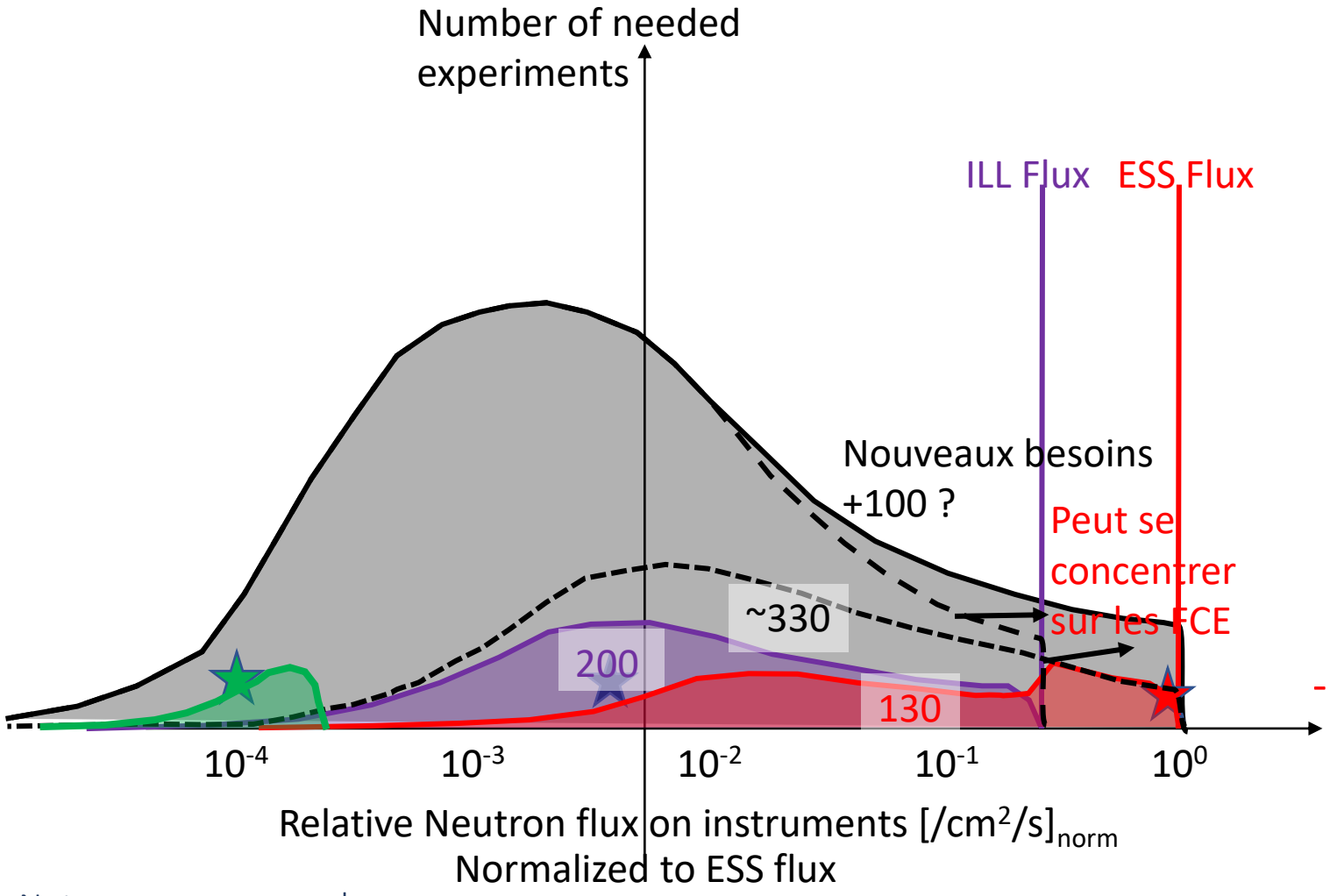


- Flux Moyen Extrême de neutrons → **ILL**
  1/4 [exp/j/inst] ×~20 [inst] × 160 [j/a] × 25%
  ≃ **200** expériences par an pour la France

Arbitré par l'excellence seule

Notes pour comprendre

ILL+ESS (<2036)



1/4 [exp/j/inst] × ~20 [inst] × 160 [j/a] × 25%
≃ **200** expériences par an pour la France

Un excellent complement au besoin

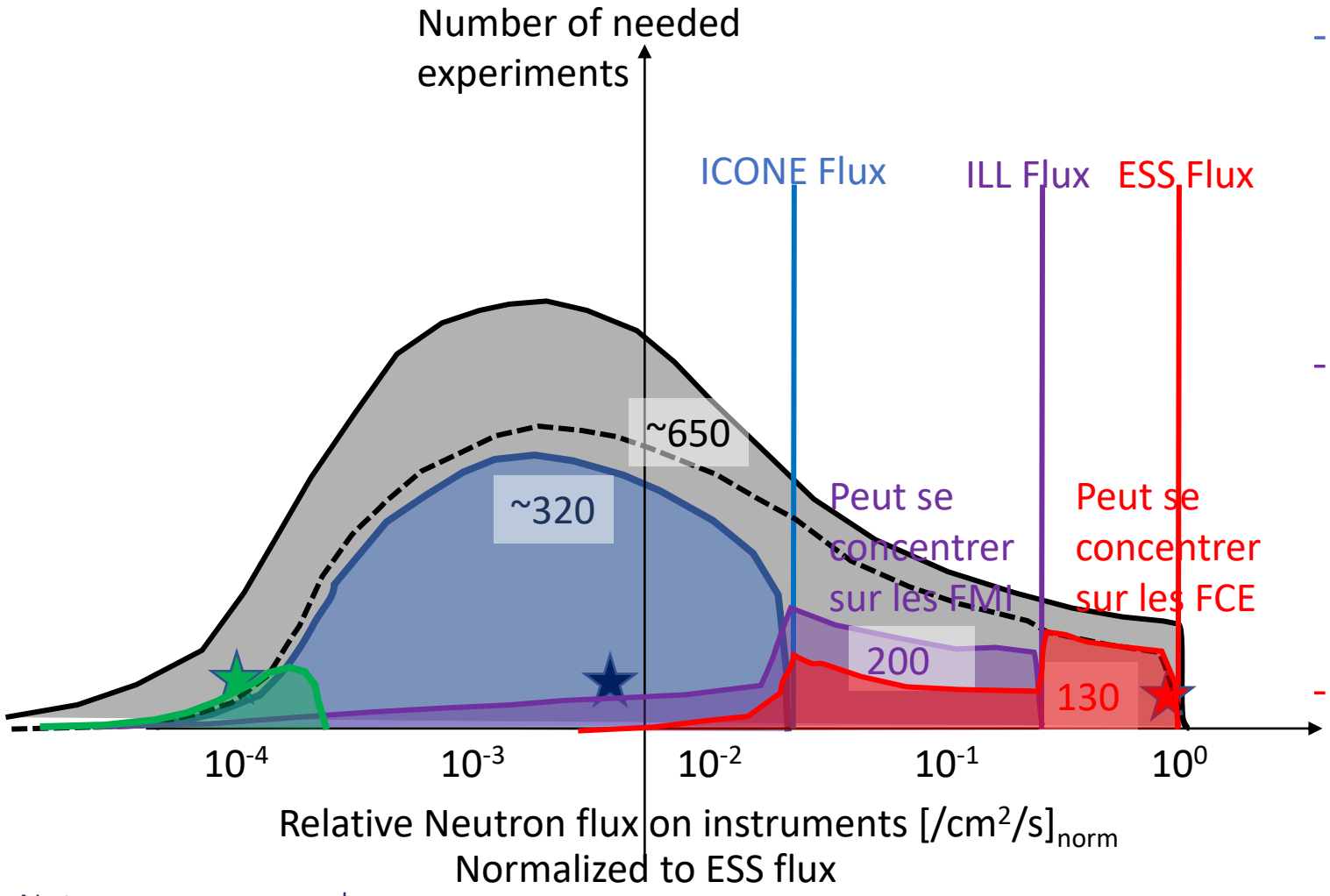
- Flux Crête Extrême de neutrons → **ESS**

1/3 [exp/j/inst] × 15 [inst] × 180 [j/a] × 14%
≃ **130** expériences par an pour la France

Arbitré par l'excellence et FCE

Notes pour comprendre

ESS+ILL+ICONE (<2036)



- Faibles flux dédiés → **CANS**

- Flux Crête Intense de neutrons → **ICONE**
  1/5 [exp/j/inst] × 10 [inst] × 160 [j/a] × 100%
  ≃ **320** expériences par an pour la France
  Un excellent complément au besoin

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  1/4 [exp/j/inst] × ~20 [inst] × 160 [j/a] × 25%
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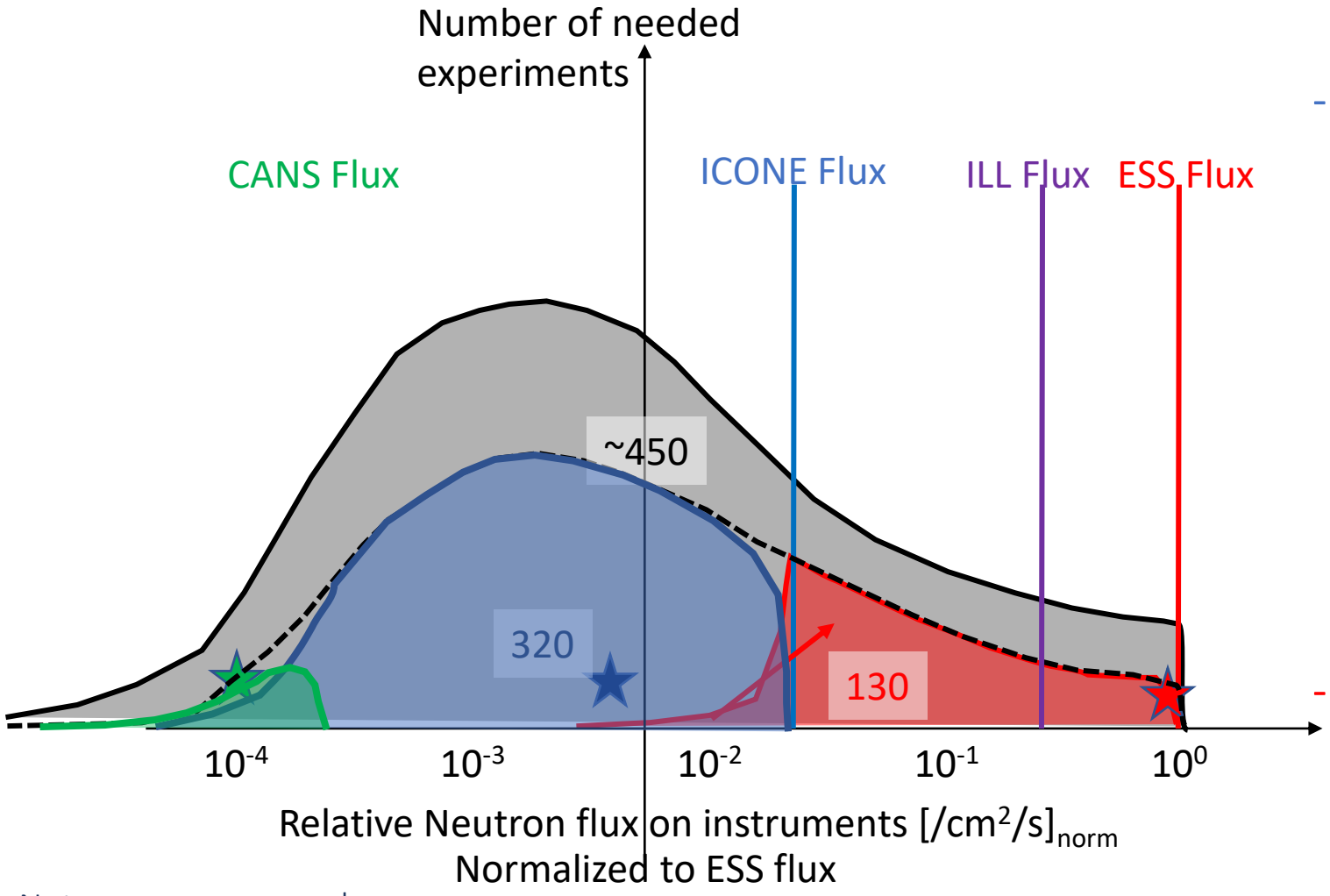
Notes pour comprendre

ESS+ICONE (>2036)



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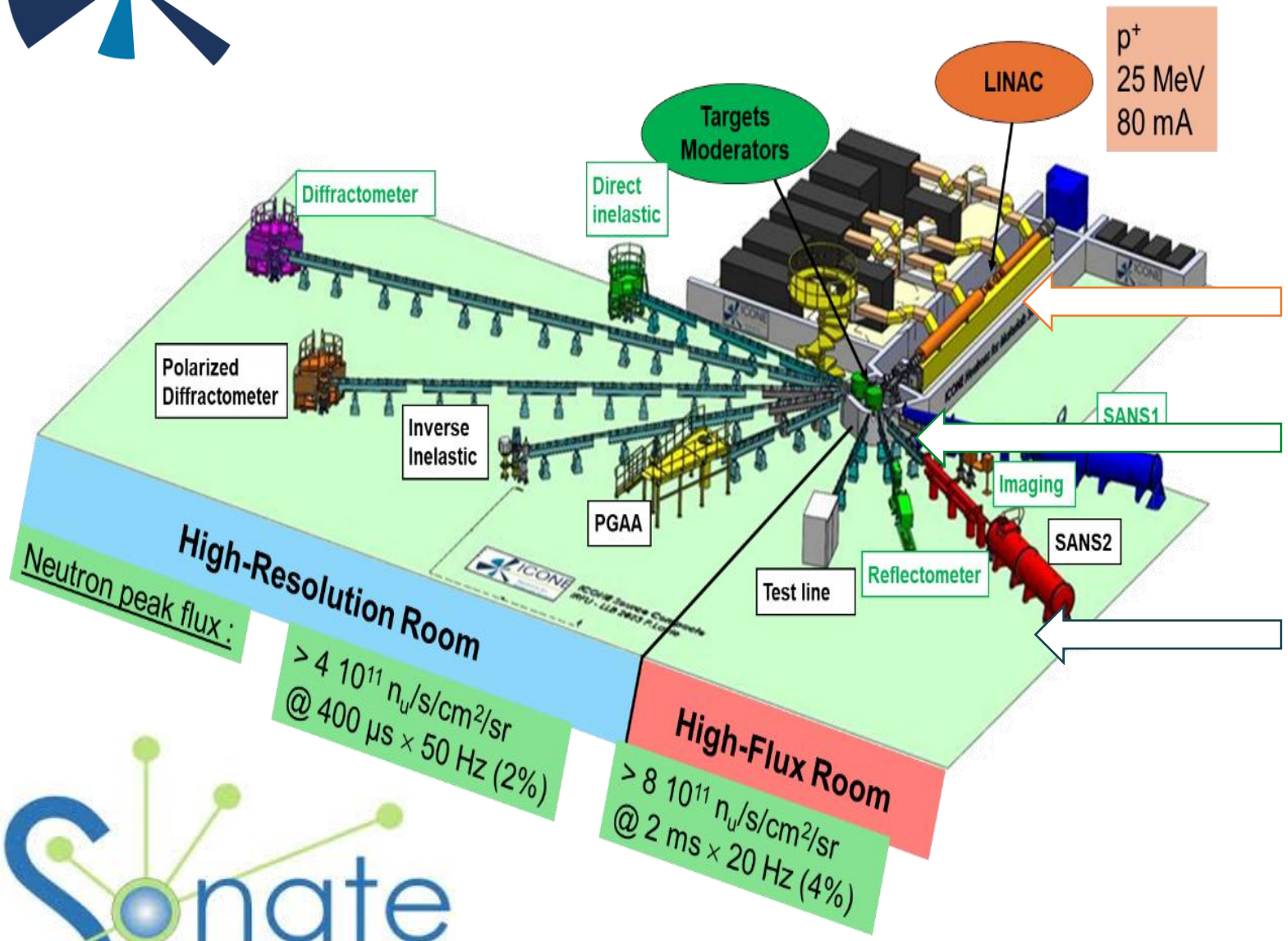
Arbitré par l'excellence et FCE

Notes pour comprendre

White Book – 2023 - SONATE



Accélérateur

Faisceau de protons
de basse énergie
(25MeV / 80mA)

Irfu - CEA Saclay
Institut de recherche
sur les lois fondamentales
de l'Univers

Cibles et modérateurs (x2)

Production de Neutrons
(froids + thermiques)

Instruments (x10)

Explorer la matière
par diffusion neutronique
(structure, spectroscopie, imagerie)

Sonate
NEUTRONS FOR
MATERIALS SCIENCE

ICONE: an Innovative COmpact NEutron facility

Suivi projet:
- COPIL : Semestrielle
- Conseil scientifique : Semestrielle
- Réunion management projet : Hebdomadaire
- Réunion d'avancement WP4 : Mensuelle

APD : 2024-2026

Comité de Direction (CEA, CNRS, Ministère)

Comité de Pilotage (CEA, CNRS)

Enjeux académiques, industriels et sociétaux

Pilotage du projet (Budget, Planning, risques…)

WP1: MANAGEMENT DE PROJET

Conseil Scientifique

RS
A. Desmedt (LLB)

CP
N. Pichoff (IRAMIS)

Comité des Ressources

①

⑥

PMO
M-A. Cavrois-Desmier (LLB)

WP2: INSTRUMENTS
X. Fabrèges (LLB)

WP3: CIBLES-MODERATEURS
F. Ott (LLB)

WP4: LINAC
D. Uriot (IRFU)

WP5: INFRASTRUCTURE
A. Ferland (IRAMIS)

Utilisation des neutrons ②

Production des neutrons ③

Production des protons ④

Hébergement de l'installation ⑤

IMPLANTATION POSSIBLE

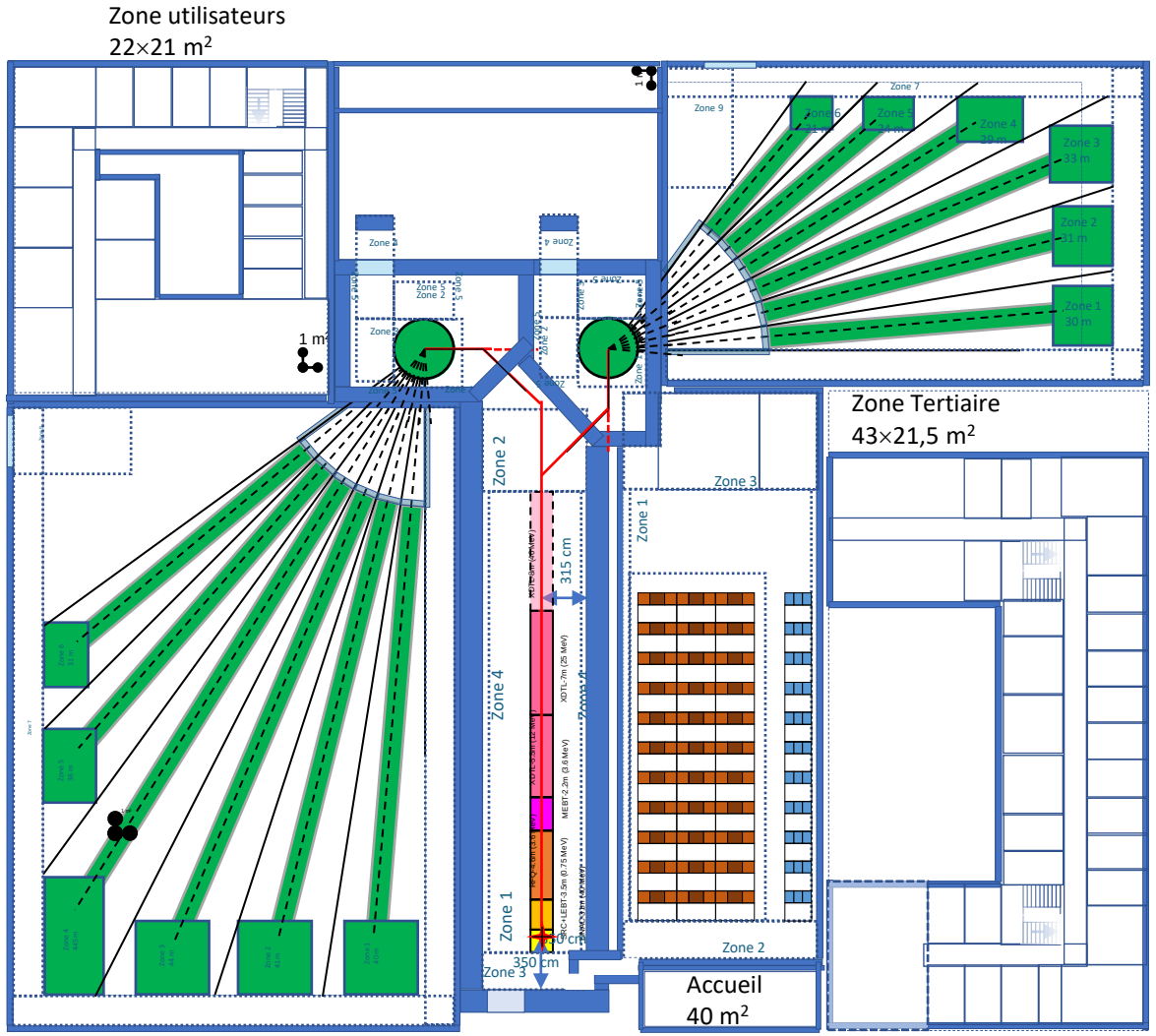
L'implantation n'est pas encore décidée par les tutelles.

Le centre de Saclay nous a proposé d'évaluer le terrain ci-contre →

Sa surface est bien adaptée.

Il est tout proche du LLB (<200 m) et de la future gare (<400 m).

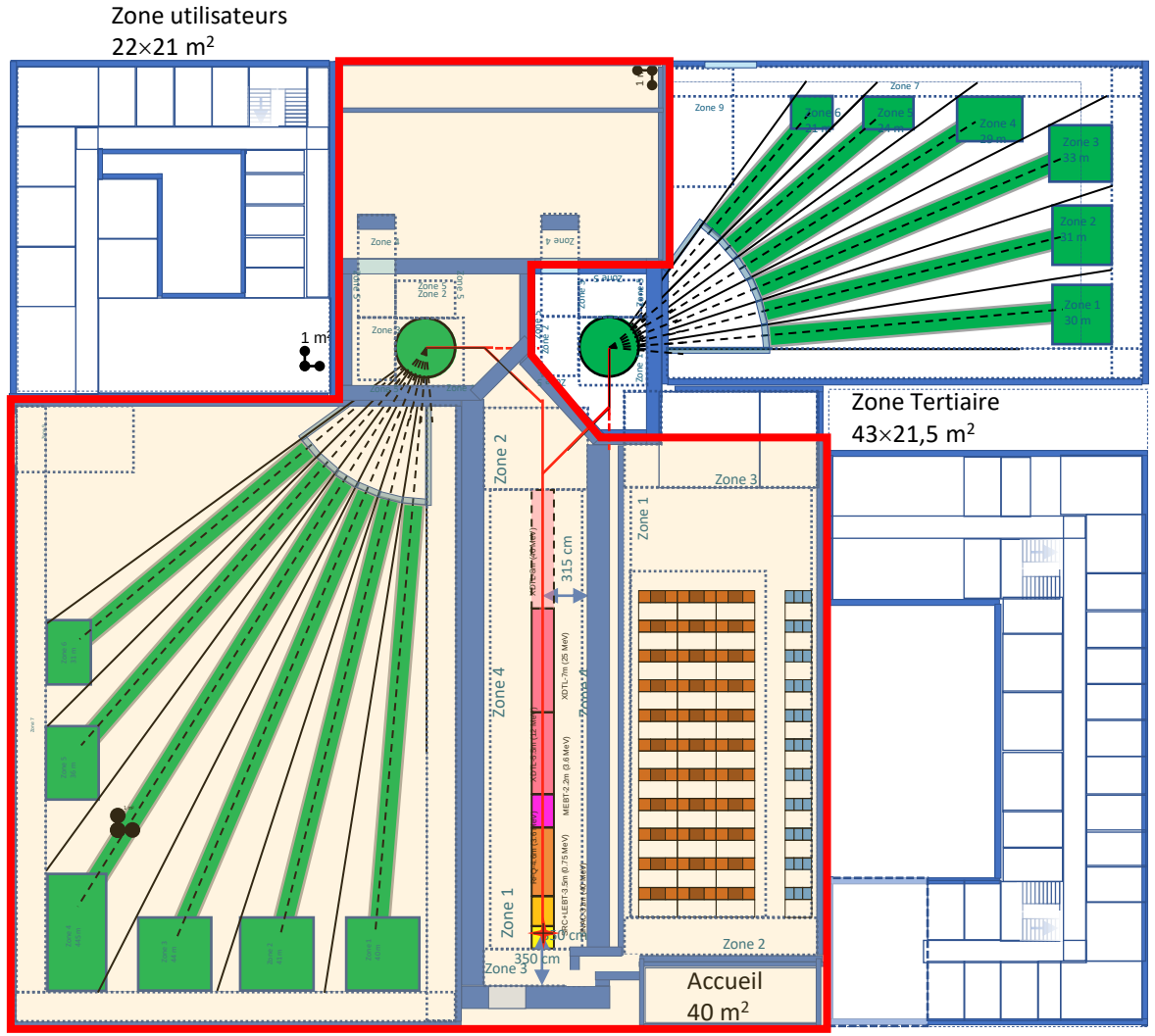
CONFIGURATION POSSIBLE PHASE 1&2



Hall
Haut Flux
80 kW

Hall
Haute Resolution
40 kW

CONFIGURATION POSSIBLE PHASE 1

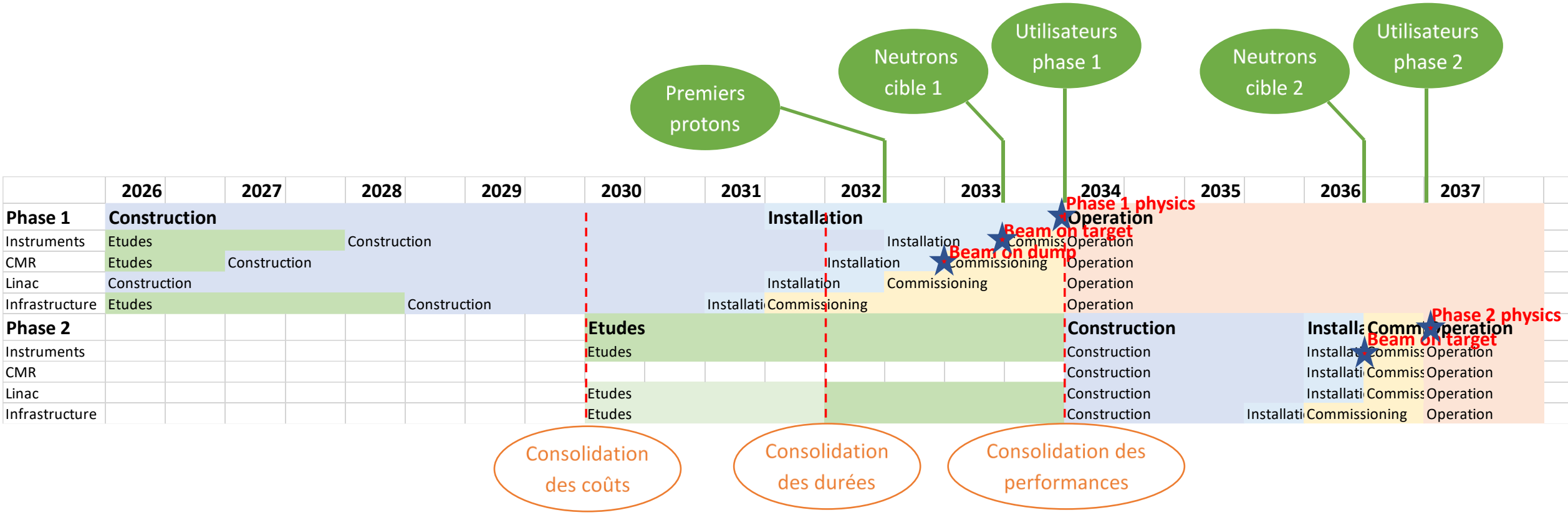


Phase 1

Hall
Haut Flux
80 kW

Hall
Haute Resolution
40 kW

PLANNING (WP1)



	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Phase 1	**Construction**						**Installation**		**Operation**			
Instruments	Etudes		Construction					Installation	Commiss	Operation		
CMR	Etudes	Construction					Installation	Commissioning	Operation			
Linac	Construction						Installation	Commissioning	Operation			
Infrastructure	Etudes		Construction			Installati	Commissioning		Operation			
Phase 2					**Etudes**				**Construction**		**Installa Comm peration**	
Instruments					Etudes				Construction		Installa Commiss Operation	
CMR									Construction		Installati Commiss Operation	
Linac					Etudes				Construction		Installati Commiss Operation	
Infrastructure					Etudes				Construction	Installati	Commissioning	Operation

JALONS DE L'APD

Pré-2024 : Etudes APS avec rédaction du livre blanc

Janvier 2024 : Démarrage de l'APD

15/01/2024 : COPIL#01

08/04/2024 : Réunion de lancement

04/05/2024 : Conseil Scientifique #01

30/06/2024 : Etablissement des exigences

18/11/2024 : Conseil Scientifique #02

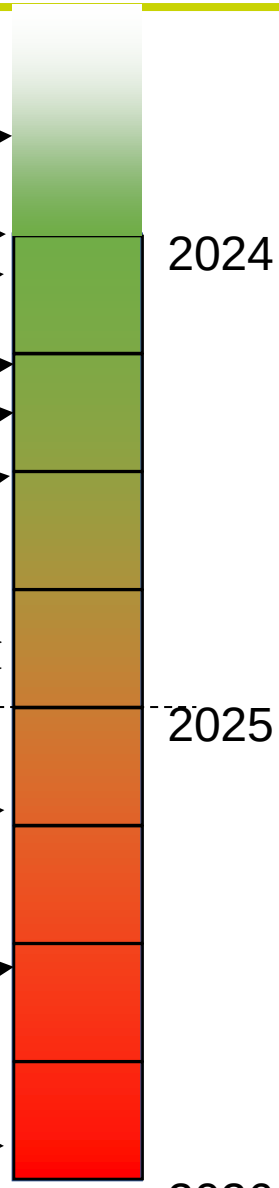
09/12/2024 : COPIL#02

28/03/2025 : CODIR#01

Mai 2025 : Revue préliminaire de design - Premières versions des livres APD

Juillet 2025 : Transmission des livres APD préliminaires

Décembre 2025 : Revues de design



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DÉLIVRABLES – WP1

Exigences

Level	Label	Unit	Limits	Value	Comments
0	ICONE				
1	INSTRUMENTS				
2	From ICONE (WP1)				
2	From INSTRUMENTS (WP2)				Internal Requirements
2	From TMRs (WP3)				
2	From LINAC (WP4)				
2	From INFRASTRUCTURE (WP5)				
1	TMRs				
2	From ICONE (WP1)				
2	From INSTRUMENTS (WP2)				
2	From TMRs (WP3)				Internal Requirements
2	From linac (WP4)				
2	From INFRASTRUCTURE (WP5)				
1	LINAC				
2	From ICONE (WP1)				
2	From INSTRUMENTS (WP2)				
2	From TMRs (WP3)				
2	From LINAC (WP4)				Internal Requirements
2	From INFRASTRUCTURE (WP5)				
1	INFRASTRUCTURE				
2	From ICONE (WP1)				
2	From INSTRUMENTS (WP2)				
2	From TMRs (WP3)				
2	From LINAC (WP4)				
2	From INFRASTRUCTURE (WP5)				Internal Requirements

WBS - Travail

1	1	ICONE	573 sem.	Lun 05/01/26	Ven 26/12/36	########	########	########	########	########	########	
2												
3	1.1	Phase 1 - Construction	417 sem.	Lun 05/01/26	Ven 30/12/33	########	########	########	########	########	########	
4	1.1.1	Début Construction Phase 1	0 jr	Lun 05/01/26	Lun 05/01/26	0,00 €	0,00 €	0 sem.	0,00 €	0,00 €	0,00 €	
5	1.1.2	Fin Construction Phase 1	0 jr	Ven 30/12/33	Ven 30/12/33	0,00 €	0,00 €	0 sem.	0,00 €	0,00 €	0,00 €	
6	1.1.3	WP1-MANAGEMENT	417 sem.	Lun 05/01/26	Ven 30/12/33	########	########	########	########	########	########	
49	1.1.4	WP2-INSTRUMENTS PRODUCTION	417 sem.	Lun 05/01/26	Ven 30/12/33	########	########	########	########	########	########	
186	1.1.5	WP3-TMRs PRODUCTION	417 sem.	Lun 05/01/26	Ven 30/12/33	########	########	########	########	########	########	
284	1.1.6	WP4-LINAC PRODUCTION	417 sem.	Lun 05/01/26	Ven 30/12/33	########	########	########	########	########	########	
986	1.1.7	WP5-INFRASTRUCTURE PRODUCTION	364 sem.	Lun 05/01/26	Ven 24/12/32	########	########	########	########	########	########	
1182												
1183	1.2	Phase 2 - Construction	364 sem.	Sam 05/01/3	Ven 26/12/36	########	########	########	########	########	########	
1184	1.2.1	Début Phase 2	0 jr	Sam 05/01/30	Sam 05/01/30	0,00 €	0,00 €	0 sem.	0,00 €	0,00 €	0,00 €	
1185	1.2.1.1	Début Construction Phase 2	0 jr	Sam 05/01/30	Sam 05/01/30	0,00 €	0,00 €	0 sem.	0,00 €	0,00 €	0,00 €	
1186	1.2.1.2	Début Construction Phase 2 seule	0 jr	Ven 30/12/33	Ven 30/12/33	0,00 €	0,00 €	0 sem.	0,00 €	0,00 €	0,00 €	
1187	1.2.2	Fin Construction Phase 2	0 jr	Ven 26/12/36	Ven 26/12/36	0,00 €	0,00 €	0 sem.	0,00 €	0,00 €	0,00 €	
1188	1.2.3	WP1-MANAGEMENT	364 sem.	Lun 07/01/30	Ven 26/12/36	########	########	########	########	########	########	
1220	1.2.4	WP2-INSTRUMENTS PRODUCTION	364 sem.	Lun 07/01/30	Ven 26/12/36	########	########	########	########	########	########	
1347	1.2.5	WP3-TMRs PRODUCTION	156 sem.	Lun 02/01/34	Ven 26/12/36	########	########	########	########	########	########	
1430	1.2.6	WP4-LINAC PRODUCTION	364 sem.	Sam 05/01/30	Ven 26/12/36	########	########	########	########	########	########	
1608	1.2.7	WP5-INFRASTRUCTURE PRODUCTION	364 sem.	Lun 07/01/30	Ven 26/12/36	########	########	########	########	########	########	

PBS - livrable

Level	System	Short name	Type	Status	Delivery date	Cost [k€]
0	ICONE	ICO	Lvb	Rqr	31/12/2035	
1	Instruments	IST	Lvb	Rqr	31/12/2035	
2	SAMBA (SANS)	SA1	Lvb	Rqr	31/12/2032	
2	NANOSANS (SANS)	SA2	Lvb	Rqr	31/12/2035	
2	PRESTO (Diffration)	PST	Lvb	Rqr	31/12/2032	
2	DIFFHR (Diffration)	DIF	Lvb	Rqr	31/12/2035	
2	REFLEX (reflectometer)	REF	Lvb	Rqr	31/12/2032	
2	FANTASTIC (Spectrometer)	FAN	Lvb	Rqr	31/12/2032	
2	INEDIT (Spectrometer)	INE	Lvb	Rqr	31/12/2035	
2	IMAGING (Imaging)	IMA	Lvb	Rqr	31/12/2032	
2	HRSPEC (Spin-echo; RD)	HRS	Lvb	Rqr	31/12/2035	
2	PPGA	PGA	Lvb	Rqr	31/12/2035	
2	HF Test Line	TLF	Lvb	Rqr	31/12/2032	
2	HR Test line	TLR	Lvb	Rqr	31/12/2035	
1	TMRs	TMR	Lvb	Rqr	31/12/2035	
2	TMR-High Flux	THF	Lvb	Rqr	31/12/2032	
2	TMR-High Resolution	THR	Lvb	Rqr	31/12/2035	
2	TMR-Common	TCM	Lvb	Rqr	31/12/2035	
1	Linac	LIN	Lvb	Rqr	31/12/2035	
2	ECR proton Source	EPS	Lvb	Rqr	31/12/2030	
2	LEBT	LBT	Lvb	Rqr	31/12/2030	
2	RFQ	RFQ	Lvb	Rqr	31/12/2031	
2	MEBT	MBT	Lvb	Rqr	31/12/2031	
2	IH-DTL	DTL	Lvb	Rqr	31/12/2031	
2	HEBT	HBT	Lvb	Rqr	31/12/2031	
2	RF Systems	RFS	Lvb	Rqr	31/12/2031	
2	Control System	CS	Lvb	Rqr	31/12/2031	
2	COOLING	COOL	Lvb	Rqr	31/12/2031	
2	Vacuum	MBT	Lvb	Rqr	31/12/2031	
1	Infrastructure	INF	Lvb	Rqr	31/12/2035	
2	Espaces contrôlés	ECN	Lvb	Rqr	31/06/2031	
2	Espaces support froid	ESF	Lvb	Rqr	31/06/2035	
2	Espaces tertiaires	ETR	Lvb	Rqr	31/06/2035	
2	Espaces Extérieurs	EXT	Lvb	Rqr	31/06/2031	

ICONE

Neutrons for Materials Sciences

APD-ICONE-WP4-LINAC

Didier URIOT et al.

ORGANISATION DU WP4

ICONE :
Ingénierie système

WP4: MANAGEMENT

D. Uriot CEA/Irfu

Dynamique faisceau
J. Dumas

Mécanique, 3D
Seraphin Vetter

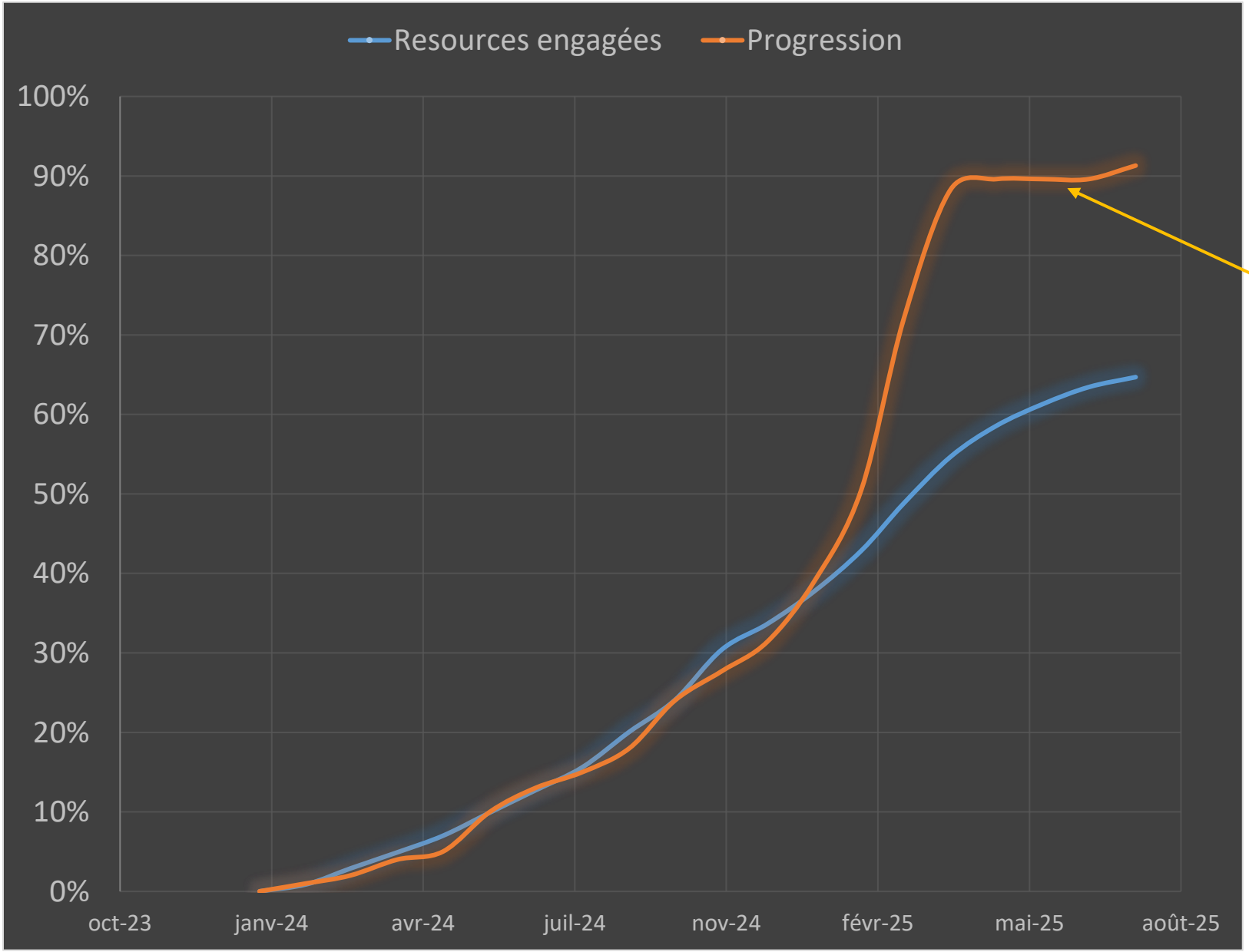
Activités transverses

Eléments magnétiques, Alimentations	*O. Delferriere*
Refroidissement	*E. Giner-Demange*
Commande contrôle	*A. Gaget*
Systèmes RF	*P. Hamel*
Système Vide	*D. Chirpaz-Cerbat*
Diagnostics	*B. Bolzon*

Taches principales

Tache1: Source + LBE *O. Tuske*	**Tache2:** RFQ *T. Hamelin*	**Tache3:** MEBT *D. Chirpaz-Cerbat*	**Tache4:** X-DTL *G. Ferrand*	**Tache5:** LHE *J. Dumas*
Produire 80 mA proton Structure temporel	Accélérer à qq MeV	Mise en forme Qualification RFQ	Accélérer à qq 10 MeV	Distribution aux cibles

AVANCEMENT – DASHBOARD APD - LINAC



Livre #4

BOOK#4 - AUTHORS

[1]AOUIJ Kaouther, [1]BOLZON Benoit, [1]CADOUX Tanguy, [1]CHIRPAZ-CERBAT Didier, [3]Michele Comunian, [2]Benjamin Cheymol, [1]DELFERRIERE Olivier, [1]DIA Ali, [1]DISSET Gael, [1]DUBOIS Augustin, [1]DUMAS Jonathan, [1]FERRAND Guillaume, [3]Francesco Grespan, [2]Emmanuel FROIDEFOND, [1]GAGET Alexis, [1]GINER-DEMANGE Emeline, [1]GOUGNAUD Francoise, [1]HAMEL Pierrick, [1]HAMELIN Thibault, [1]KHLIFI Sabrine, [1]LOTRUS Paul, [1]LUONG Michel, [1]Olivier Piquet, [3]Andrea Pisent, [1]ROSSI Fabrizio, [1]SINANNA Armand, [1]TUSKE Olivier, [1]URIOT Didier, [1]VETTER Seraphin.

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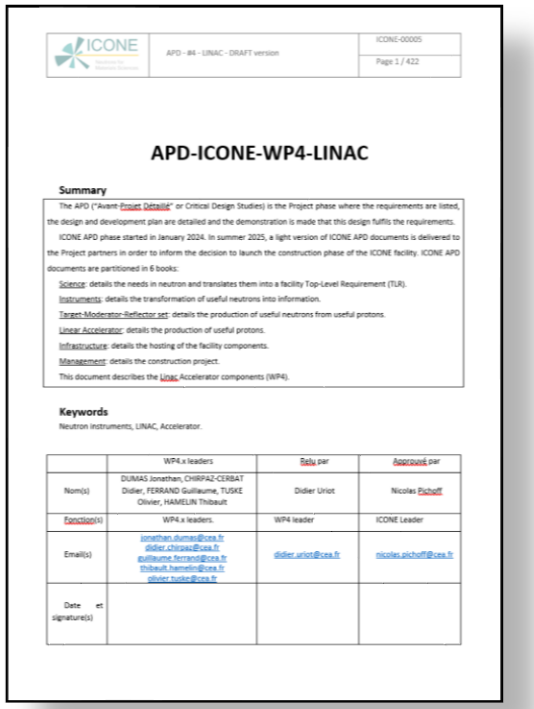
[2]CNRS, Nucléaire & Particule, LPSC, France

[3]INFN Legnaro, Italie



ICONE | APD - #4 - LINAC - DRAFT version | ICONE-00005 | Page 1 / 422

APD-ICONE-WP4-LINAC

Summary

The APD ("Avant-Projet Détaillé" or Critical Design Studies) is the Project phase where the requirements are listed, the design and development plan are detailed and the demonstration is made that this design fulfils the requirements.
ICONE APD phase started in January 2024. In summer 2025, a light version of ICONE APD documents is delivered to the Project partners in order to inform the decision to launch the construction phase of the ICONE facility. ICONE APD documents are partitioned in 6 books:

Science: details the needs in neutron and translates them into a facility Top-Level Requirement (TLR).
Instruments: details the transformation of useful neutrons into information.
Target-Moderator-Reflector set: details the production of useful neutrons from useful protons.
Linear Accelerator: details the production of useful protons.
Infrastructure: details the hosting of the facility components.
Management: details the construction project.
This document describes the Linac Accelerator components (WP4).

Keywords

Neutron instruments, LINAC, Accelerator.

	WP4.x leaders	Relu par	Approuvé par
Nom(s)	DUMAS Jonathan, CHIRPAZ-CERBAT Didier, FERRAND Guillaume, TUSKE Olivier, HAMELIN Thibault	Didier Uriot	Nicolas Pichoff
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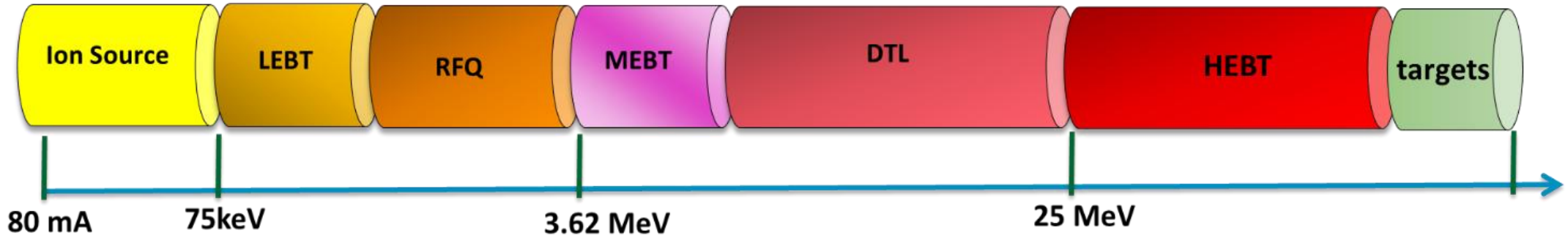
Date et signature(s)			

PBS : ~1500 items
Cout ~ : 33 M€ +20 M€

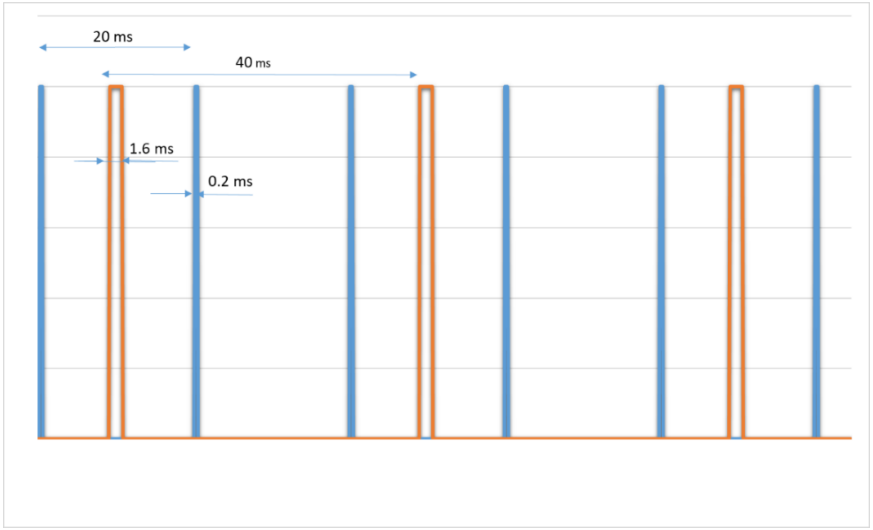
Livre 1 – Science (58 pages)
Livre 2 – Instruments (134 pages)
Livre 3 – Ensemble cibles-Modérateurs-réflecteurs (92 pages)
Livre 4 – Linac (450 pages)
Livre 5 – Infrastructure (25 pages)
Livre 6 – Management (18 pages)

ACCELERATOR



Main technical choices:

- Linac
- Reuse of existing developer bricks
- Minimize risks and R&D
- Warm solution

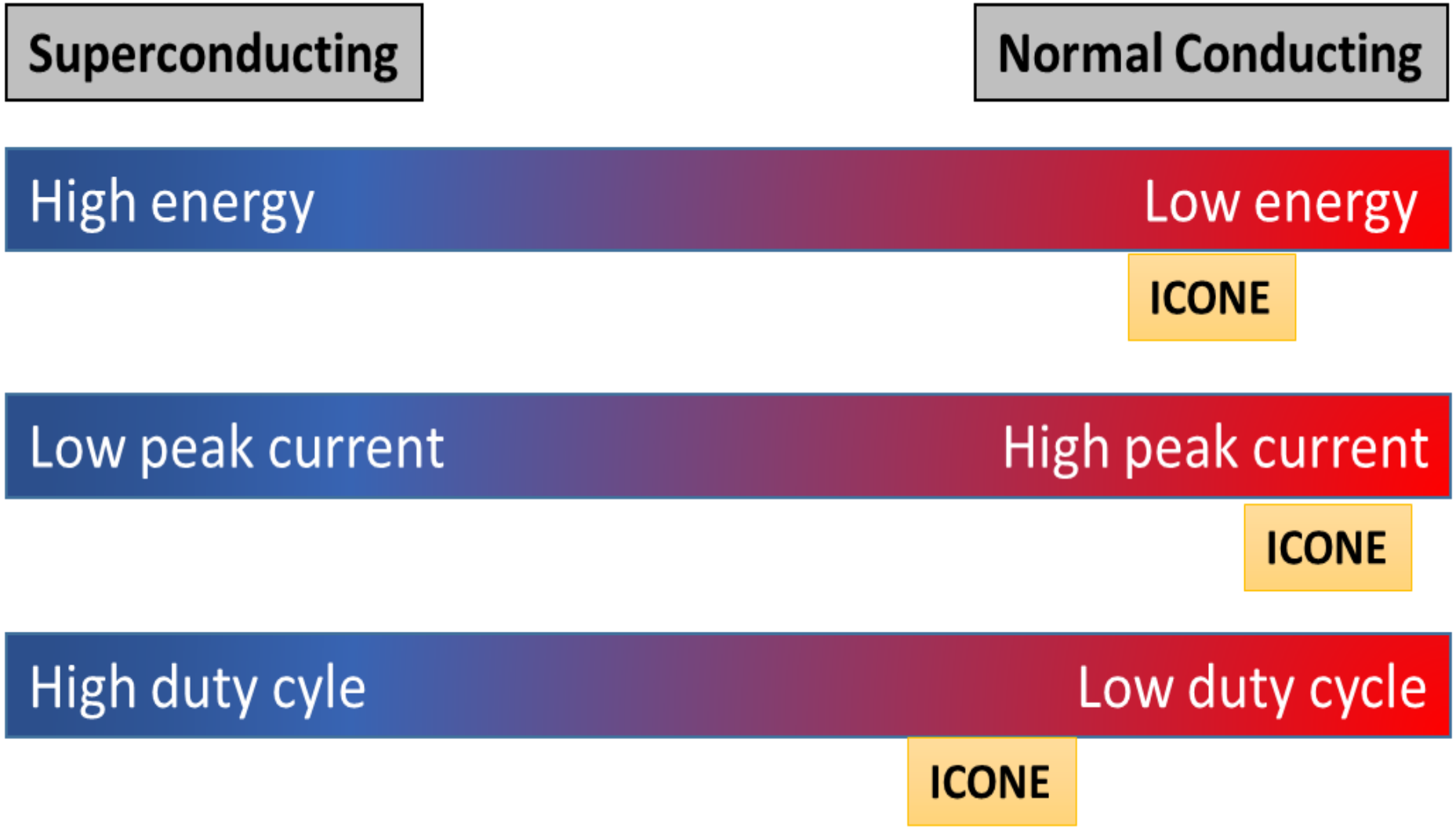


Top level performance requirements

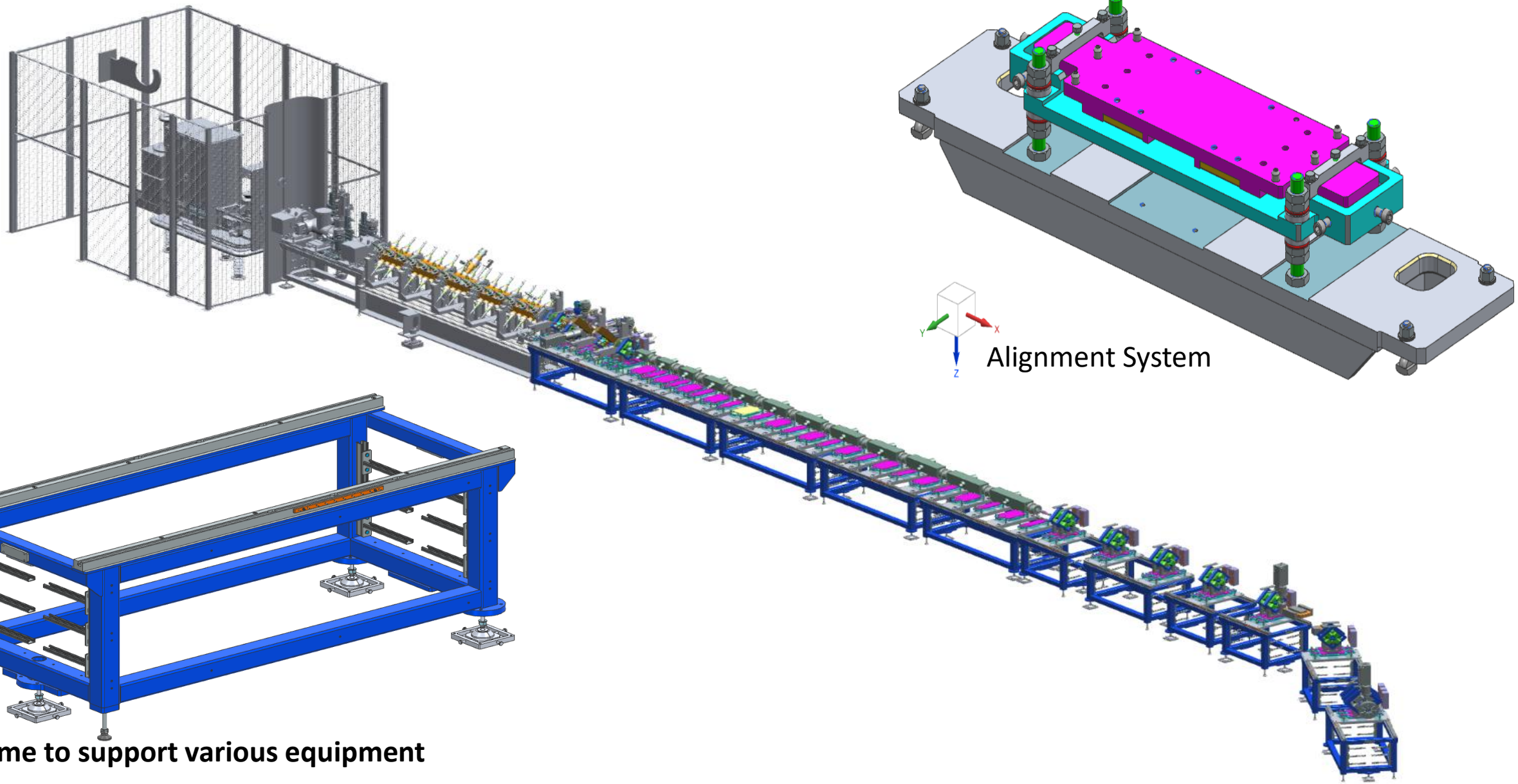
Required	Unit		Specifications
Particle			Proton
Final Peak Current	mA	≥	80
Final Energy	MeV	≥	25
Final Energy upgrade	MeV	≥	40
Beam Duty-Cycle Max	%	≥	6%
Construction time	y	≤	5
Linac operation time	h/y	≥	3600

Structure temporelle	2 ms – 20 Hz 0.2 ms – 100 Hz

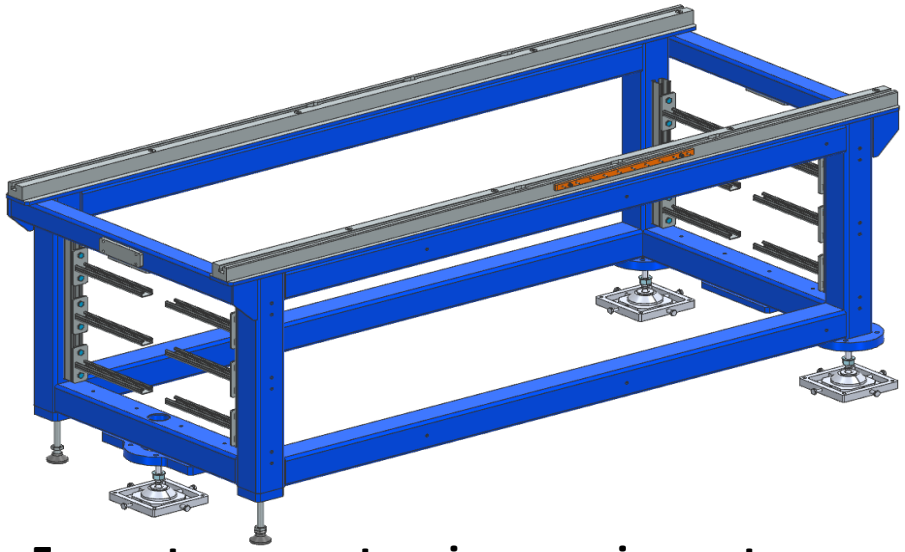
CHAUD OU FROID ?



ACCELERATOR DIMENSIONS



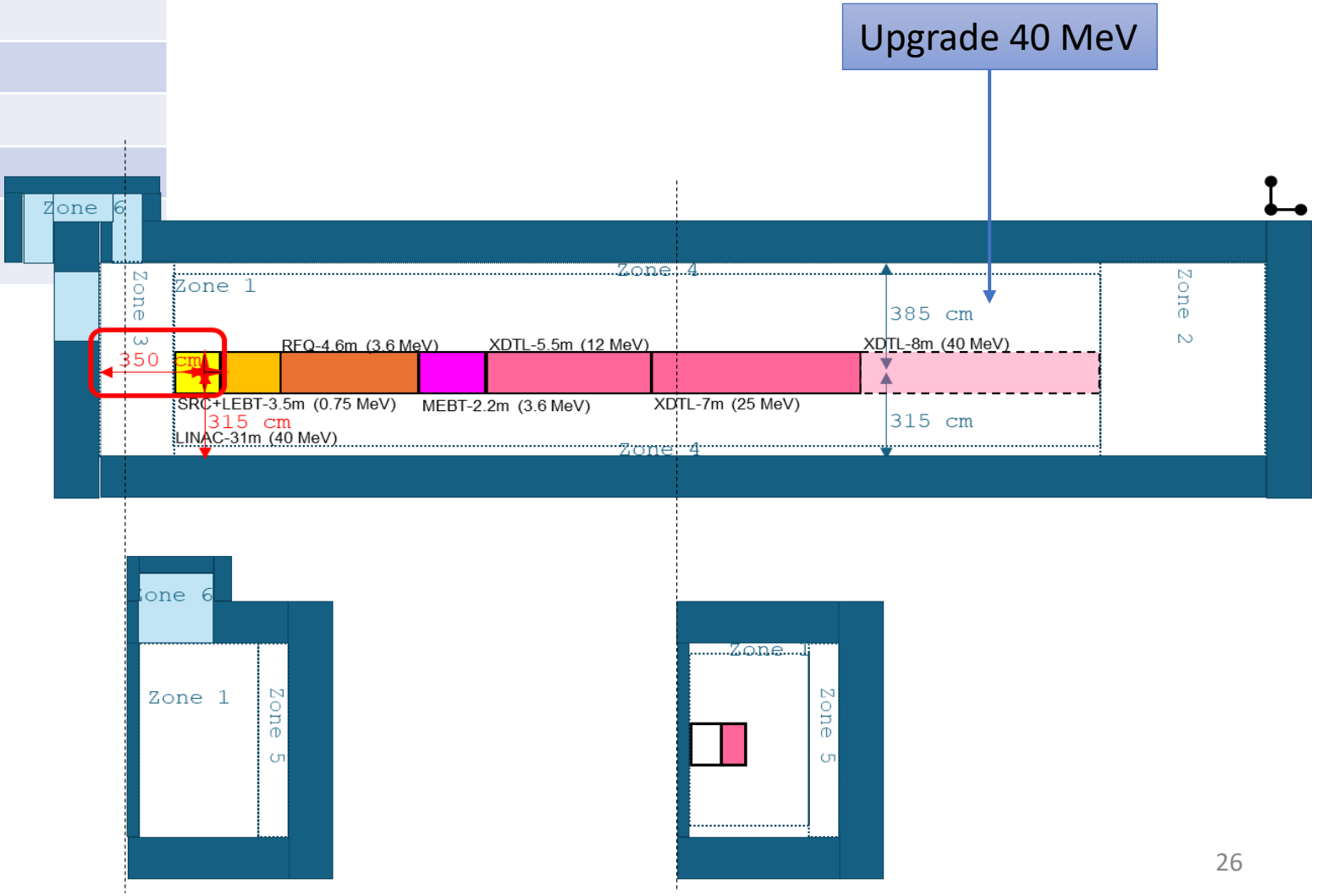
Alignment System



Frame to support various equipment

ACCELERATOR DIMENSIONS

Zone#	Use	Length & Surface
1	Linac	31×6.2×4 m^3
2	Distribution	5.5×7.0×4 m^3
3	Manoeuvring	2.5×7.0×4 m^3
4	wall guards	0.4 m
5	ceiling guard	1 m
6	Pedestrian chicane	9×1,2×2.5 m^3



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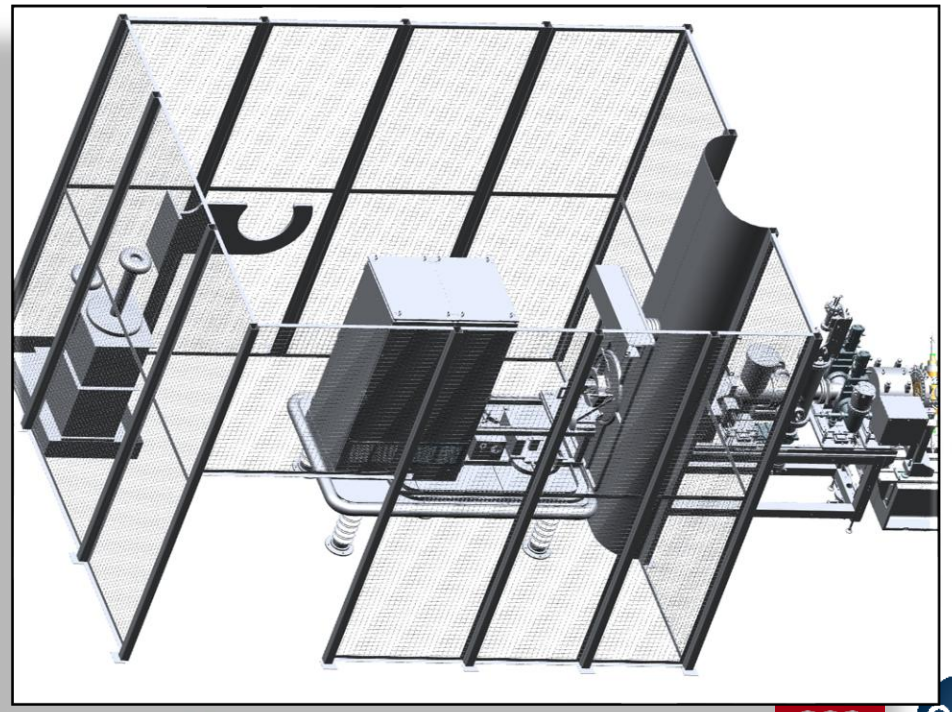
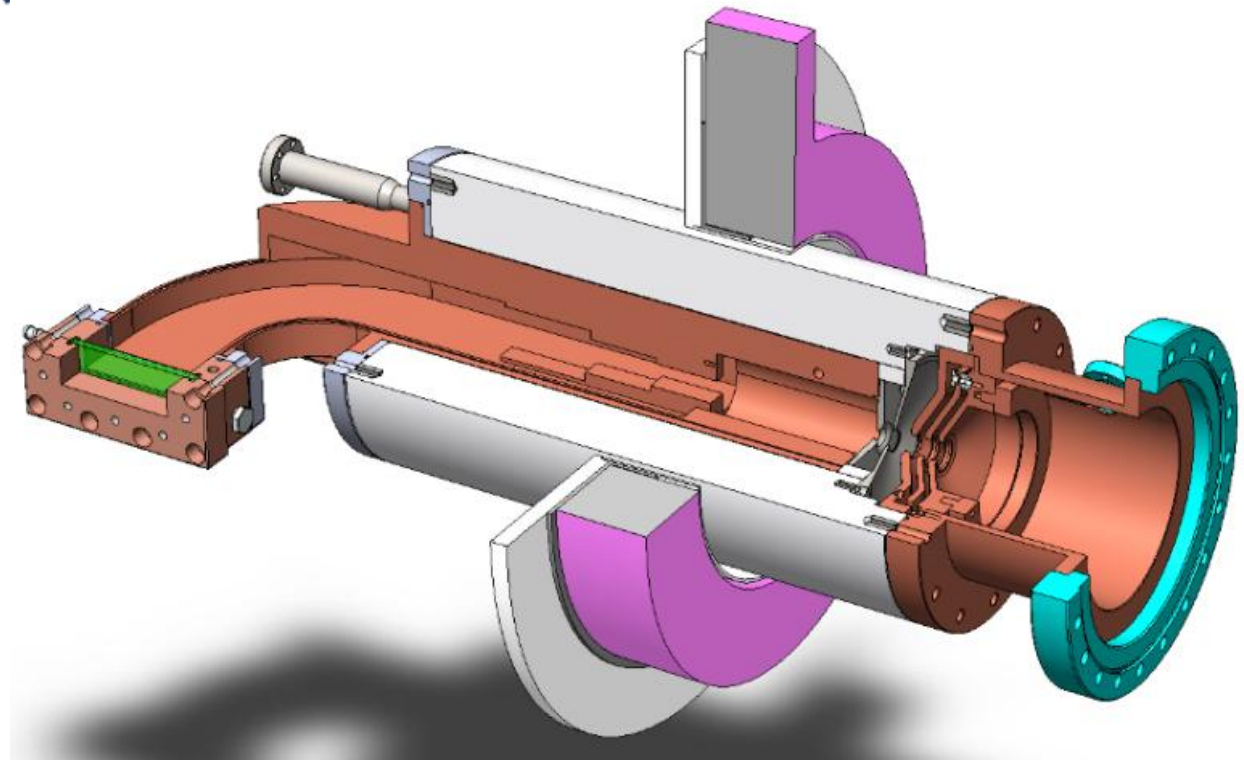
WP4.1 SOURCE + LEBT

OLIVIER TUSKE, IRFU



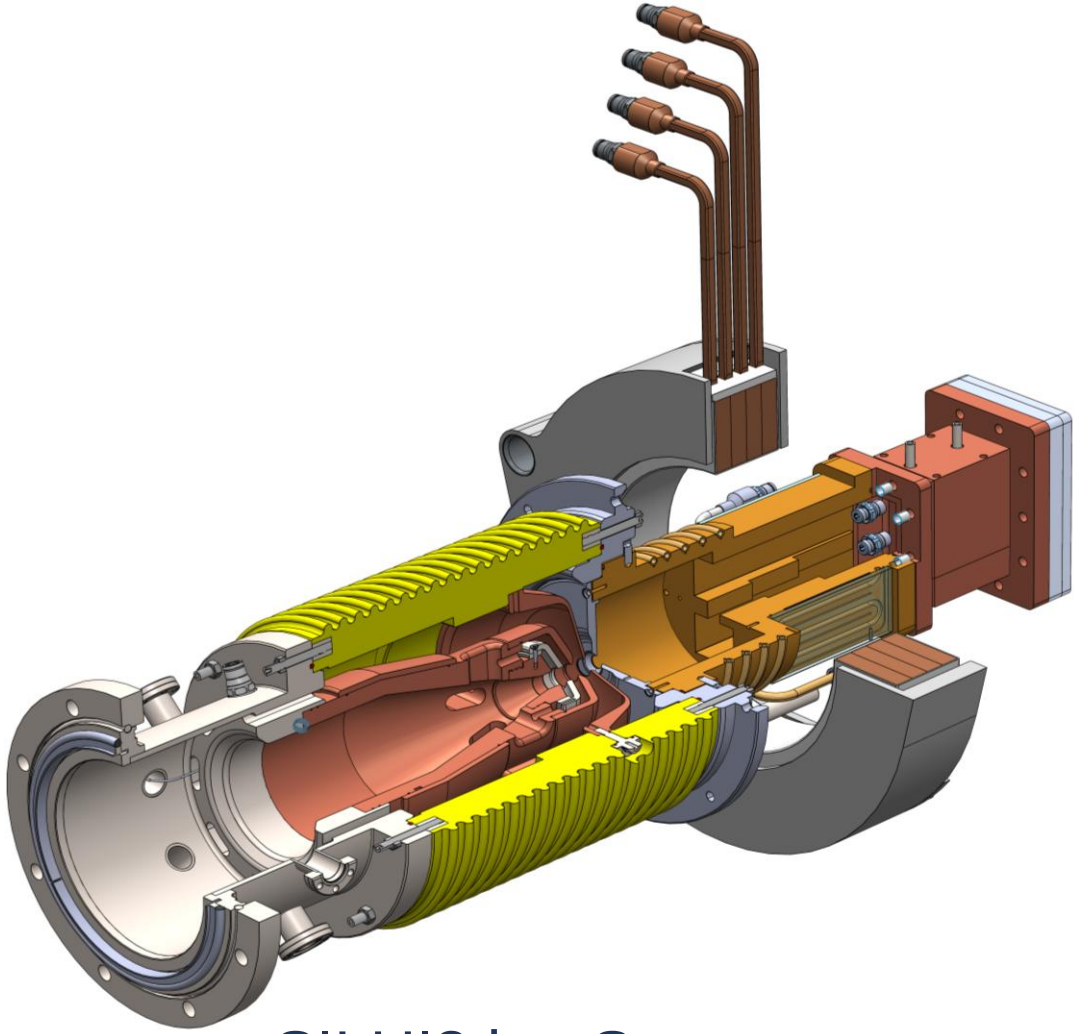
ION SOURCES FOR ICONE



- ALISES3 ion Source
- with 4 electrodes

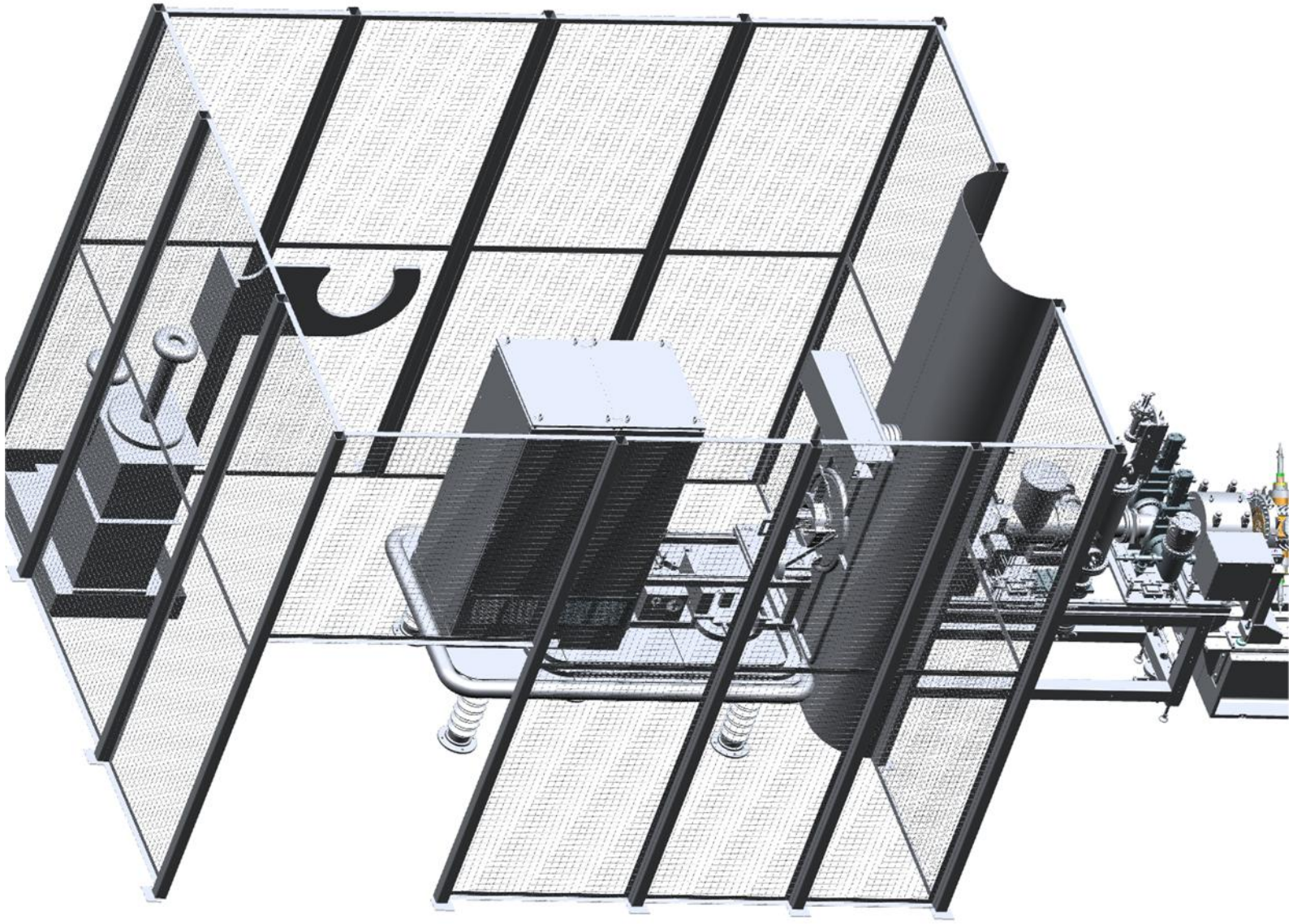
AMELIORATIONS

- Diminution du nombre de joints
- Concentricité des électrodes
- Encombrement réduit (diamètre)
- Poids diminué
- Nombre de pièces diminué
- Maintenance facilitée
- Décharges Penning réduites (simulations OPERA)
- Alignement sur la ligne au laser tracker

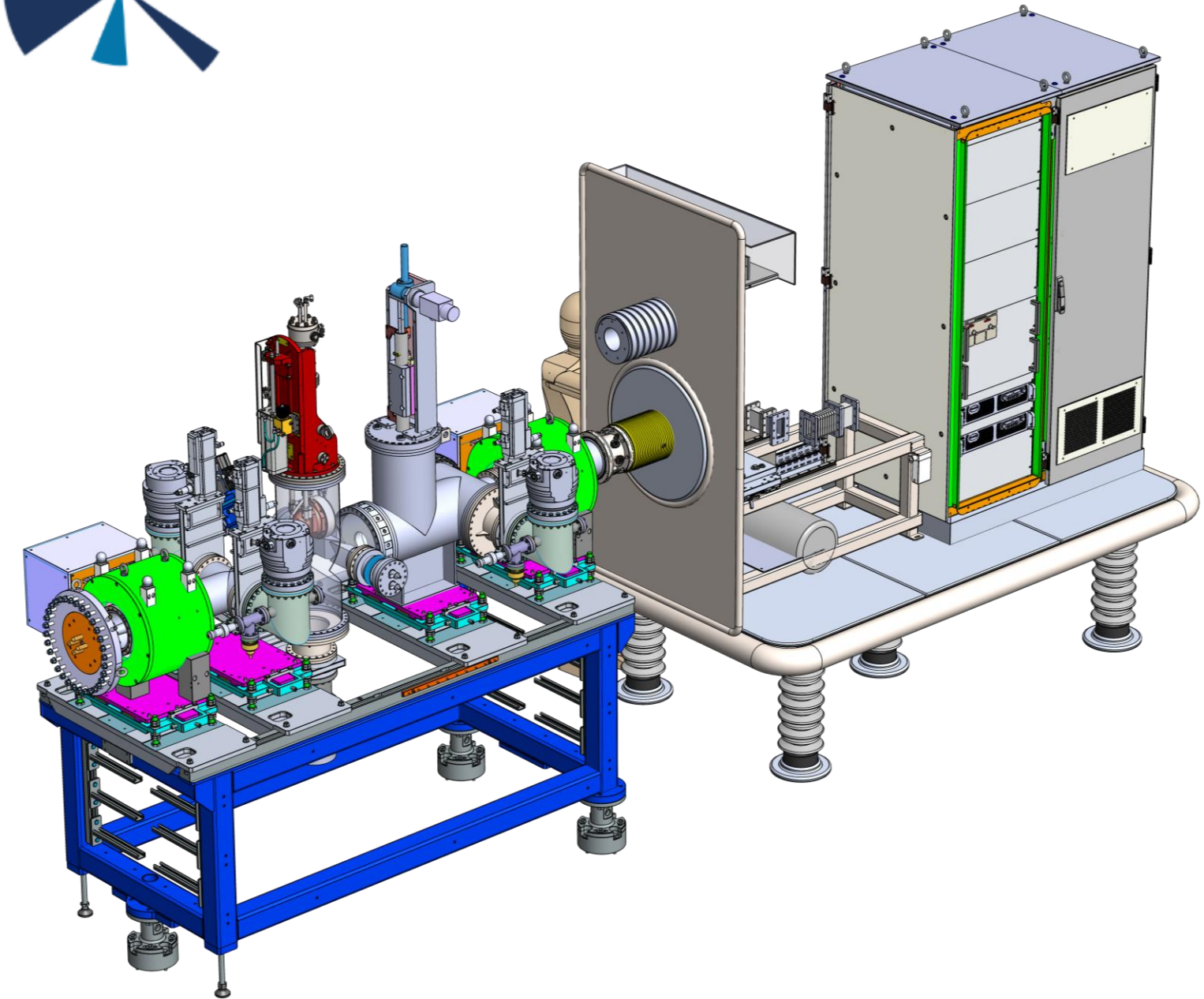


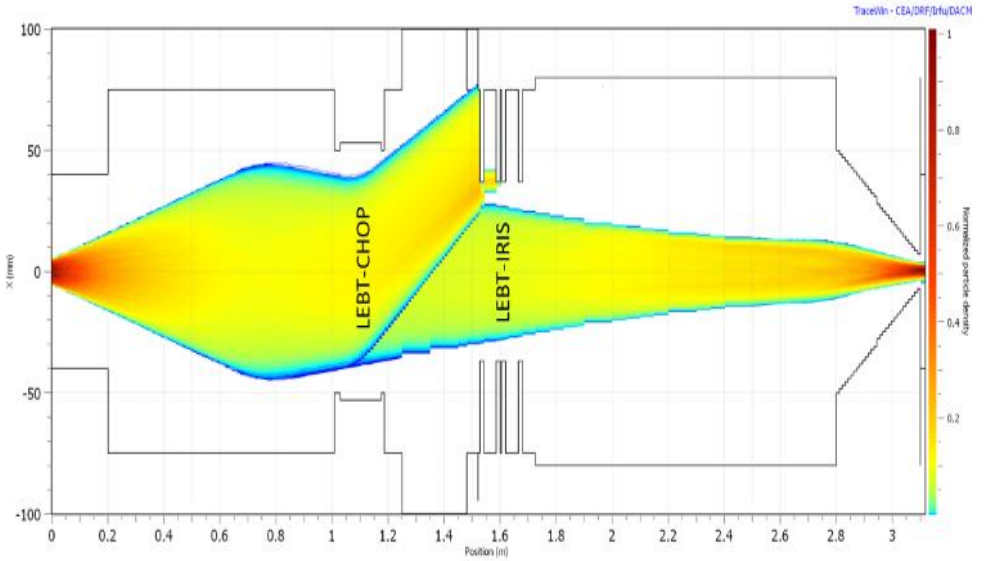
- SILHI3 ion Source
- with 5 electrodes

HIGH VOLTAGE PLATFORM INSIDE THE HIGH VOLTAGE CAGE



LEBT ON ITS BLUE SUPPORT AFTER THE HV CAGE





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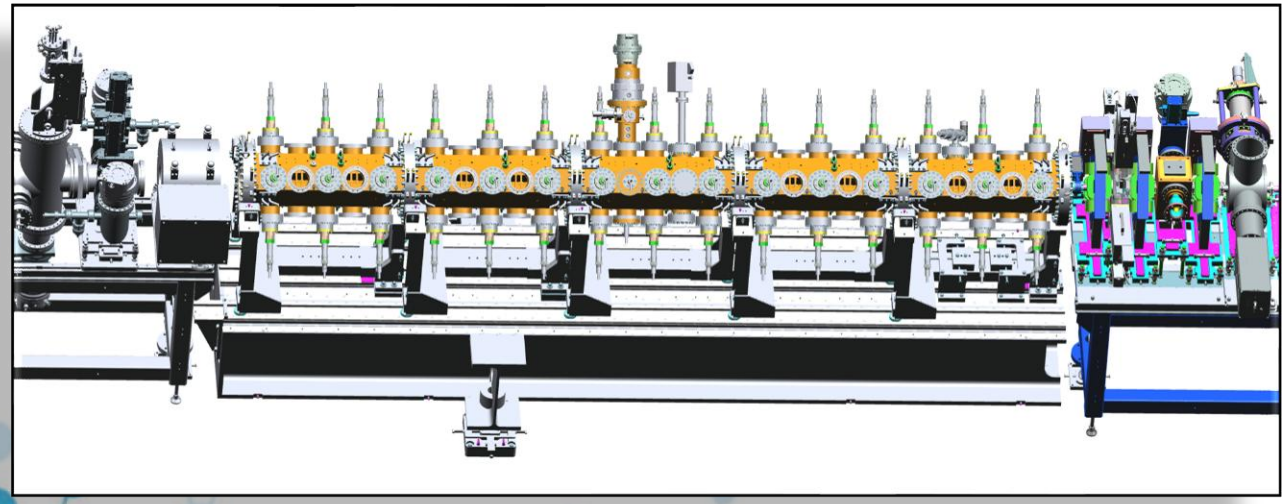
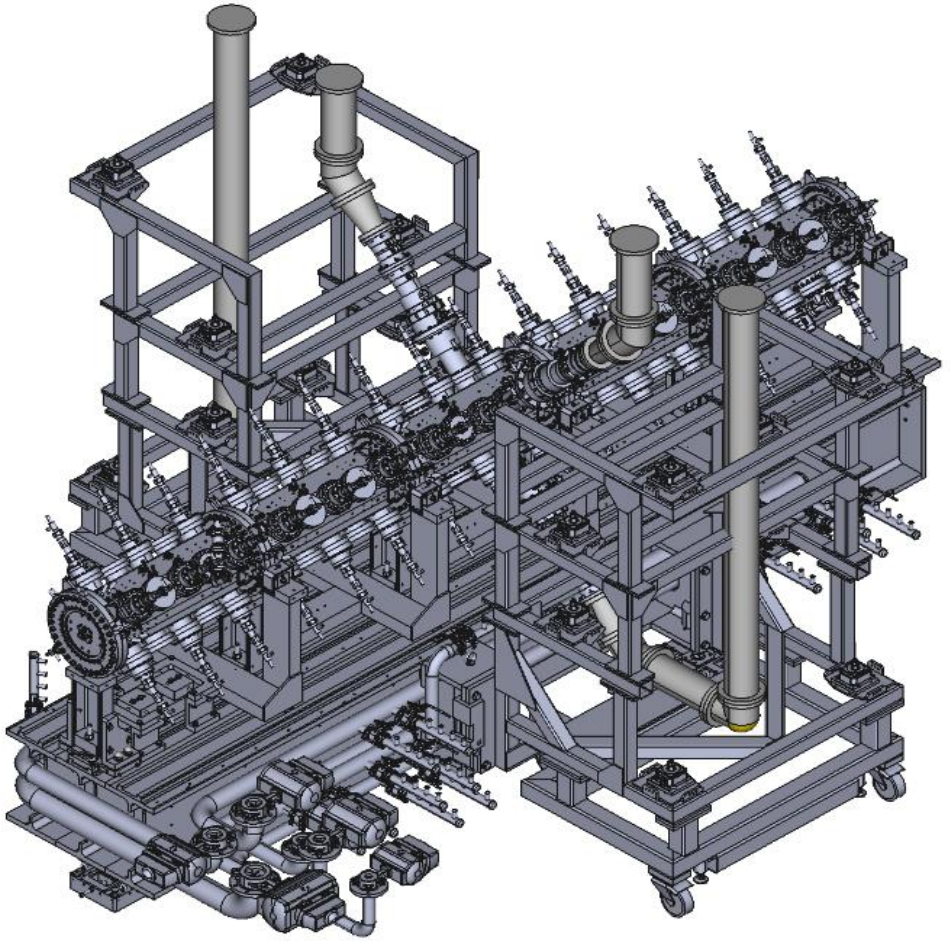
WP4.2 RFQ

THIBAULT HAMELIN, IRFU



RFQ : Proposition technique

- Proposition basée sur le même appel d'offres ESS : livrée en 2019 et opérationnelle depuis 2021 avec des résultats satisfaisants.
  - La seule différence est une augmentation du cycle de fonctionnement de 5 % (ESS) à 10 % (ICONE).
- Les simulations RF et thermomécaniques ont validé la conception de l'ESS RFQ pour le cycle utile d'ICONE en y apportant deux modifications mineures :
  - Modification de l'emplacement du canal de refroidissement. Facile à gérer pendant l'appel d'offres sans modification des dessins de l'appel d'offres de l'ESS.
  - Le doublement du nombre de coupleurs. Les ports de ces coupleurs supplémentaires sont déjà intégrés dans la conception de l'appel d'offres ESS.The adaptation of the ESS RFQ to the ICONE
- Économies de coûts et de ressources humaines sur les parties étude, conception et rédaction... de l'appel d'offres. Ces parties ont déjà été réalisées pour le projet ESS.
- Minimisation du risque technique lié au fonctionnement du RFQ. Les premiers tests ont mis en évidence l'excellente performance du RFQ.



Representation of the ICONE RFQ

RFQ : Technical proposal

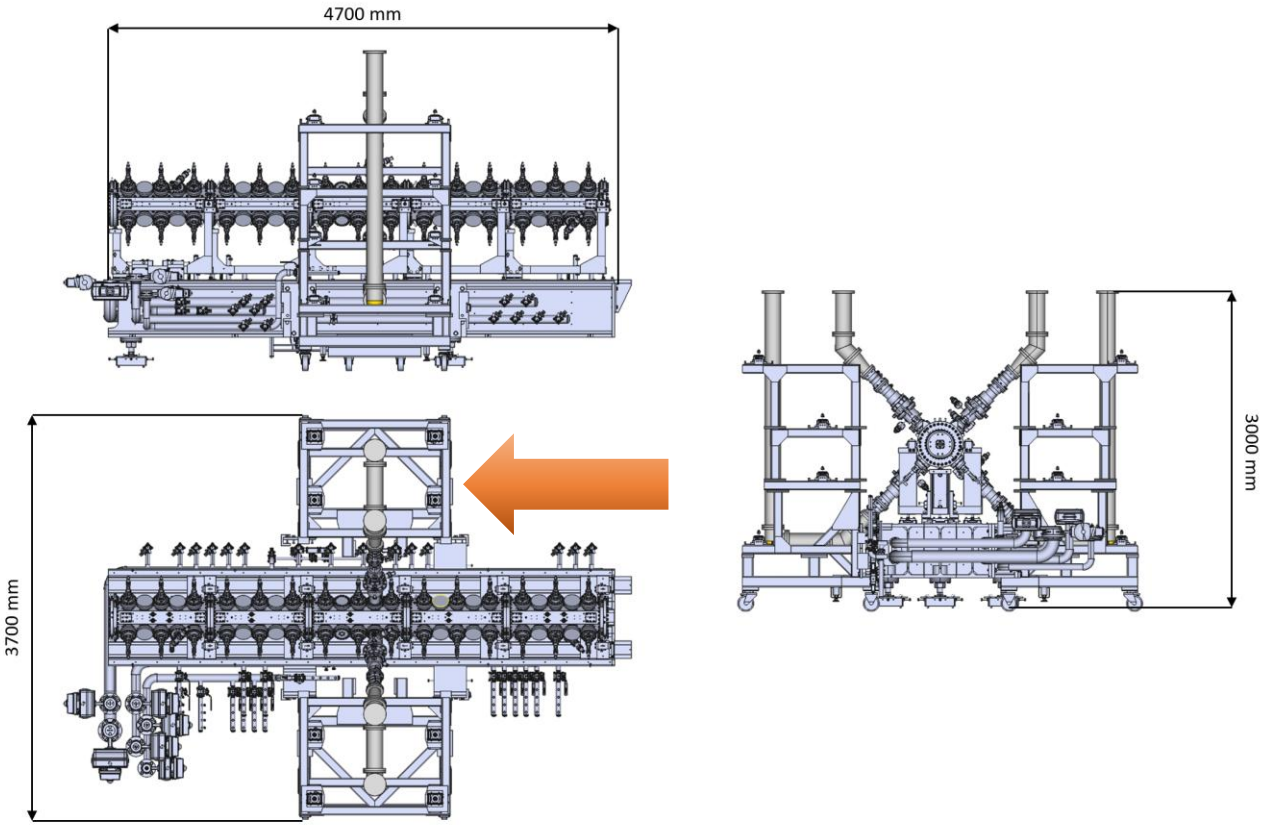
RFQ requirements

Parameter	Requirement
Frequency	352.21 MHz
Nominal beam current	80 mA
Output beam energy	≥ 3.6 MeV
Local peak electric field	< 2 kilp
Inter-vane Voltage	≤ 120 kV
Transmission	*> 90 %*
Beam duty cycle	6 %
RF duty cycle	10 %
Total length	< 5 m
Max beam losses 99% of error cases	< 1W/m

RF power required for RFQ operation

Parameter	Value
Power dissipated in copper structure :	
power dissipation in 3D design	750 kW
power dissipation added by tuning with tuners	225 kW
power dissipation added by wall roughness (Ra)	75 kW
power dissipation added by reflected power	210 kW
total dissipated power for theoretical 3D design	P_{Cu} = 1260 kW
Beam power	P_B = 288 kW
Maximum total coupled power	$P_{Cu} + P_B$ = **1548 kW**

Typical dimension of the ICONE RFQ



The RFQ sections design are ready for manufacturing.
The tender documents ready before end of 2025

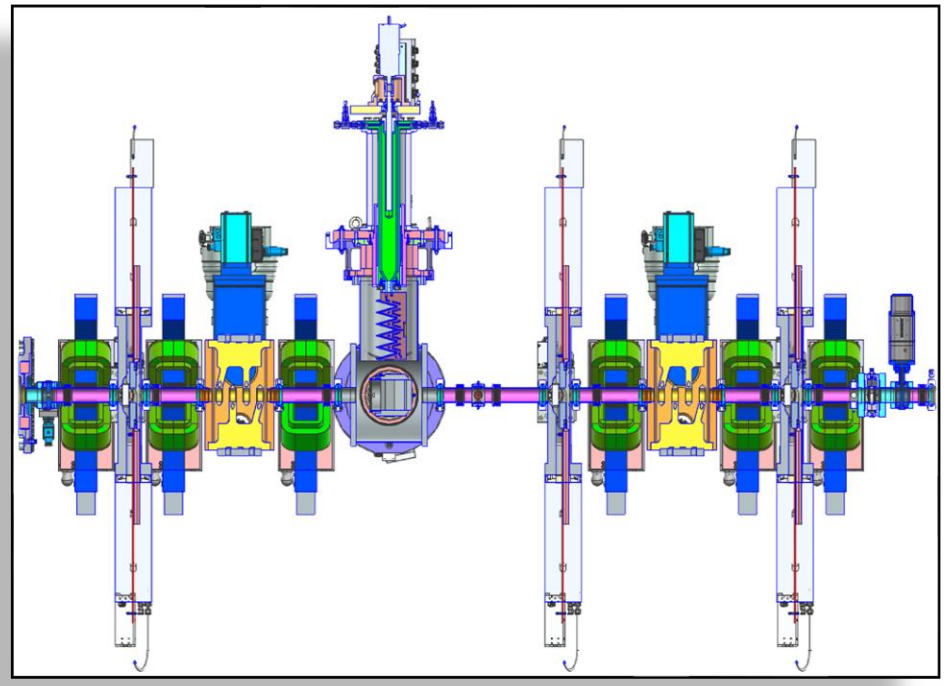
RFQ : ESS

ICONE

Neutrons for Materials Sciences

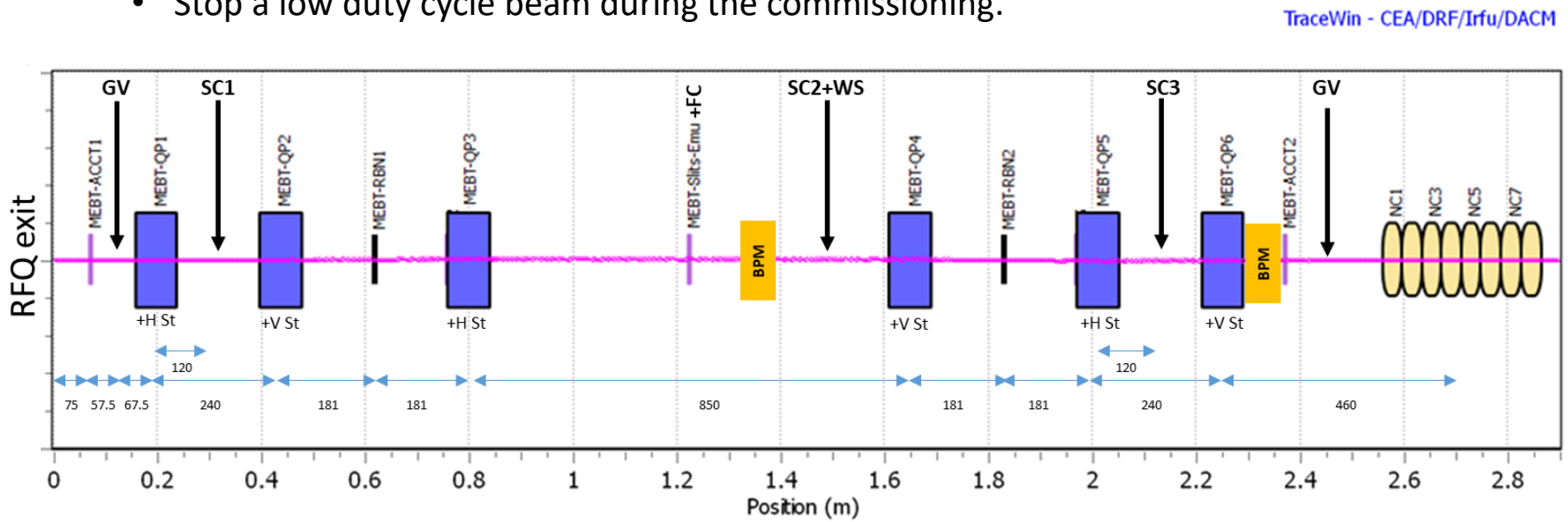
MEDIUM ENERGY BEAM TRANSPORT

DIDIER CHIRPAZ-CERBAT, IRFU



BEAM DYNAMICS AND REQUIREMENTS

- Match the beam from the RFQ exit to the IH-DTL entrance,
- Steer the beam to the IH-DTL axis,
- Refine the beam by scraping the beam halo,
- Measure beam parameters, including:
  - Current,
  - Longitudinal and transverse emittance,
  - Position,
- Stop a low duty cycle beam during the commissioning.

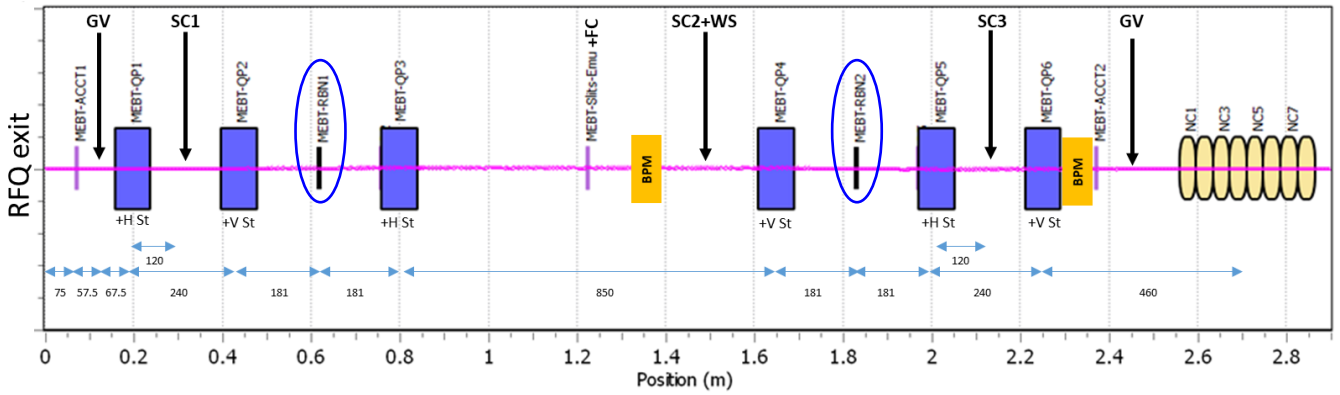


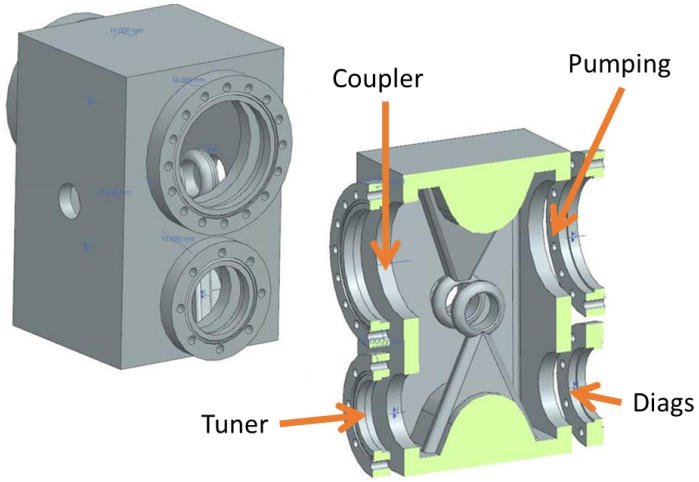
Medium Energy Beam Transport layout, from Beam dynamics studies.

Main requirements for MEBT.

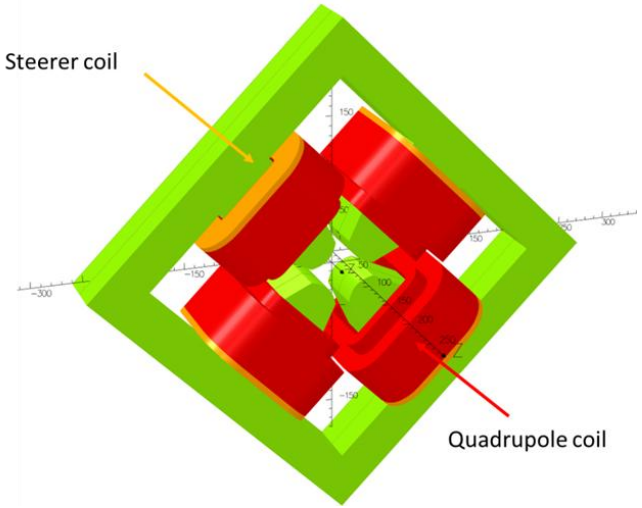
Parameter	Requirement
Nominal beam current	*80 mA*
Input beam energy	*3.6 MeV*
Particle	*Protons H^+*
Beam duty cycle	*6 %*
Number of quadrupoles	*6*
Quadrupole gradient	*32 T/m*
Steerer strength	*3 mT.m*
Number of buncher cavities	*2*
Frequency	*352.21 MHz*
Peak power per cavity	*< 20 kW peak*
Total dissipated RF power (w/o beam)	*< 40 kW*
Effective accelerating field	*143 – 113 kV*
Local peak electric field	*< 1.5 kilp*
RF duty cycle	*10 %*
MEBT total length	*< 2.5 m*
Max beam losses 99% of error cases	*< 1 W/m*

REBUNCHERS (RBN1..2) & QUADRUPOLES (QP1..6)

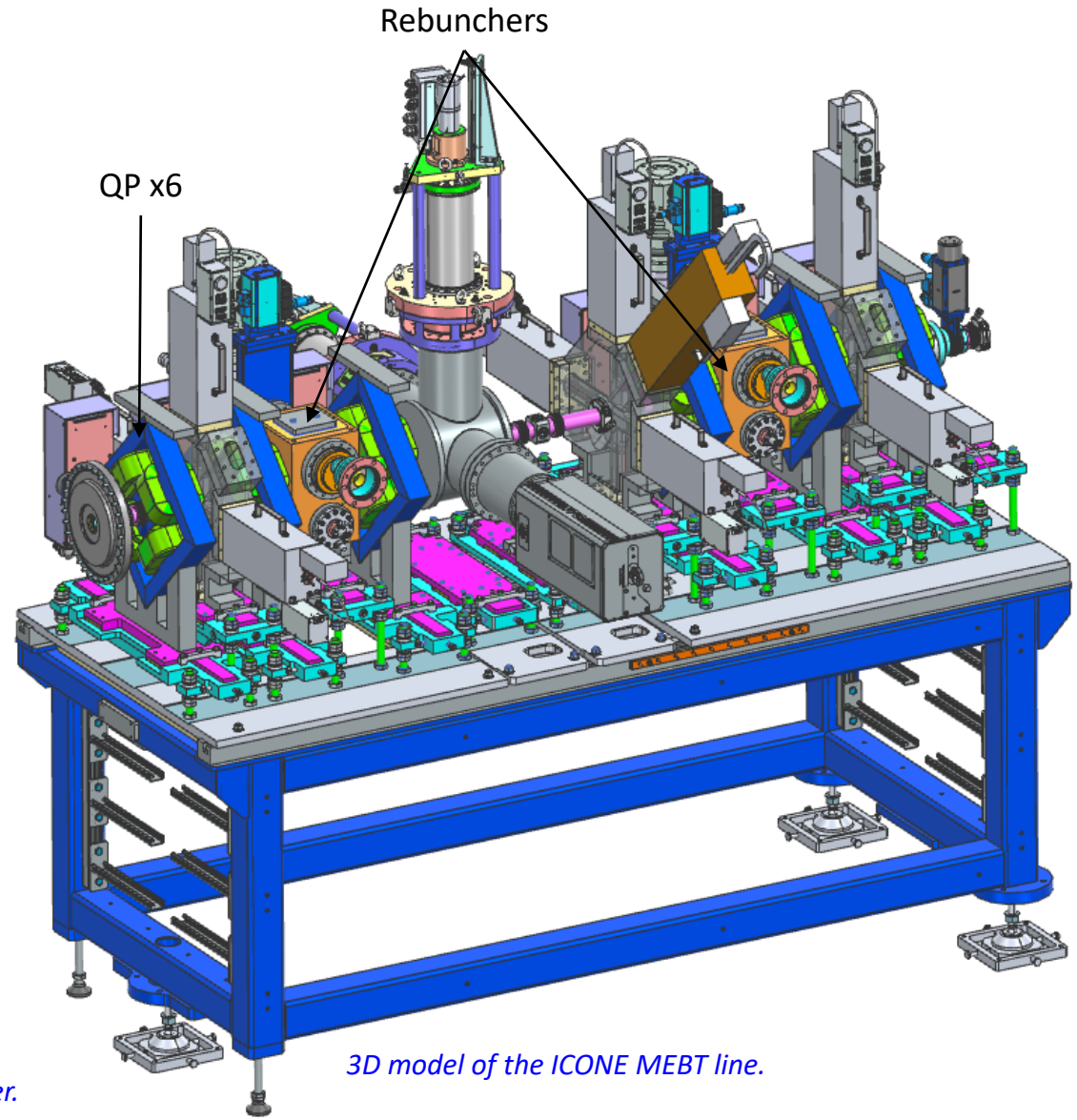




ICONE MEBT's Rebuncher, with 4 gaps.

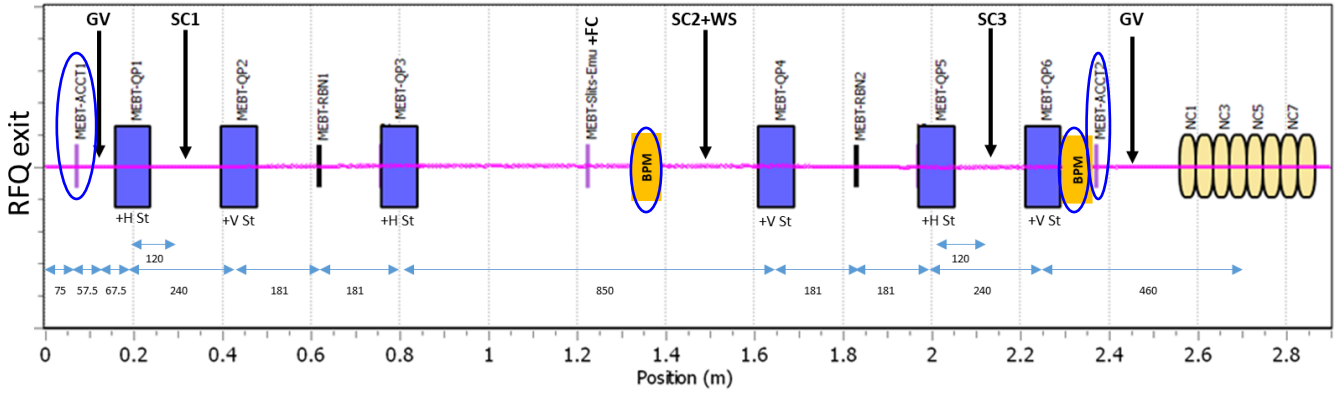


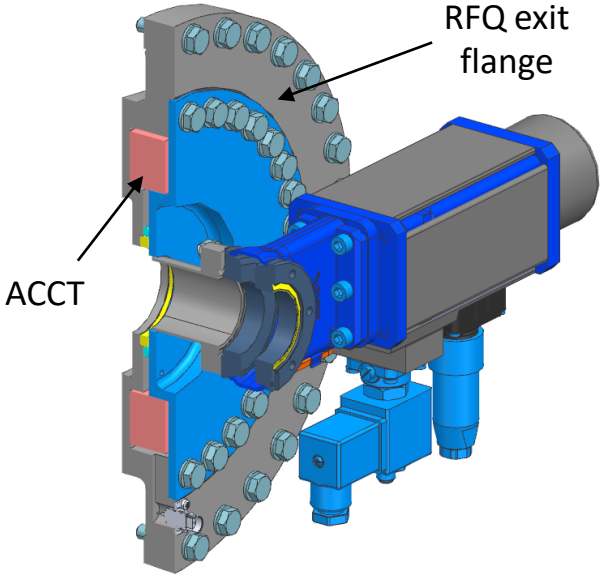
ICONE MEBT's quadrupole geometry, including steerer.



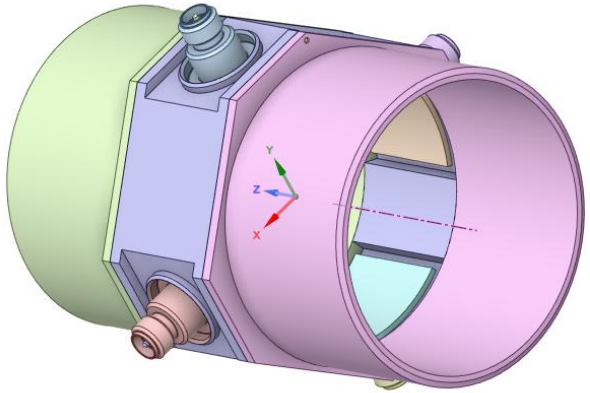
3D model of the ICONE MEBT line.

DIAGNOSTICS (ACCT, BPM, …)

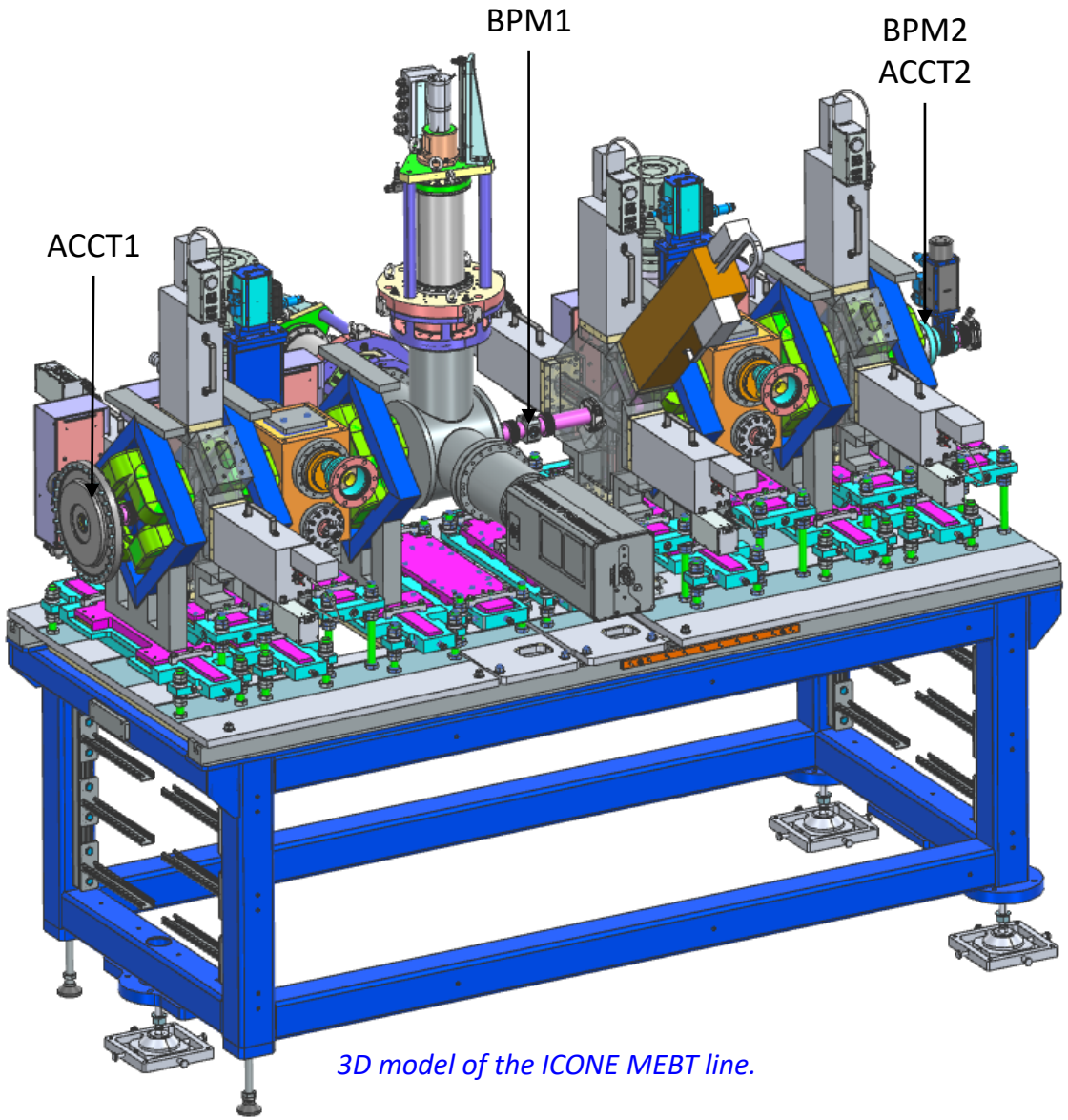




ACCT1 solution, implanted in the exit flange of the RFQ.

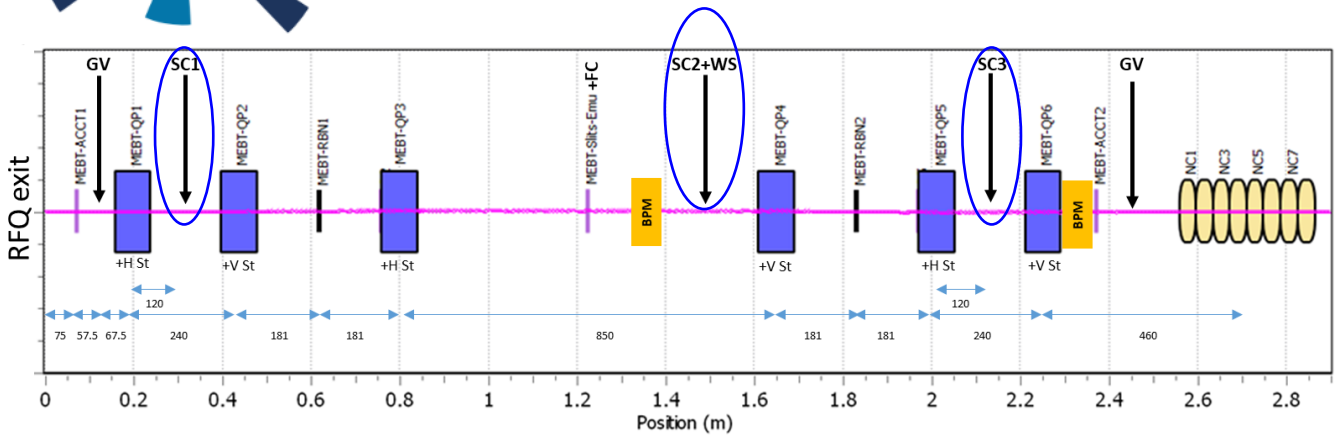


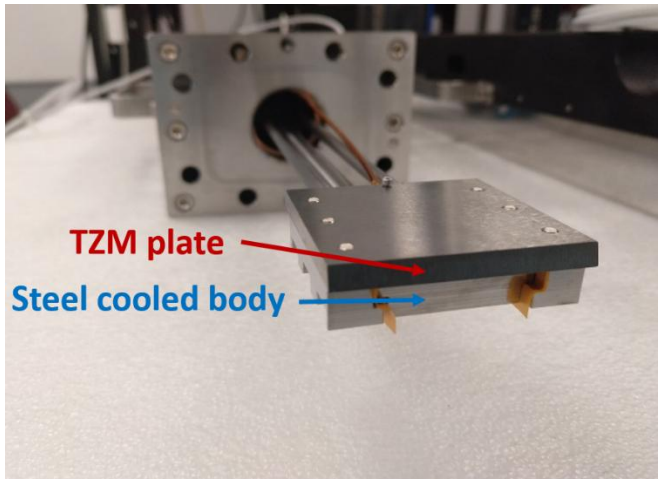
SARAF BPM with welded buttons.



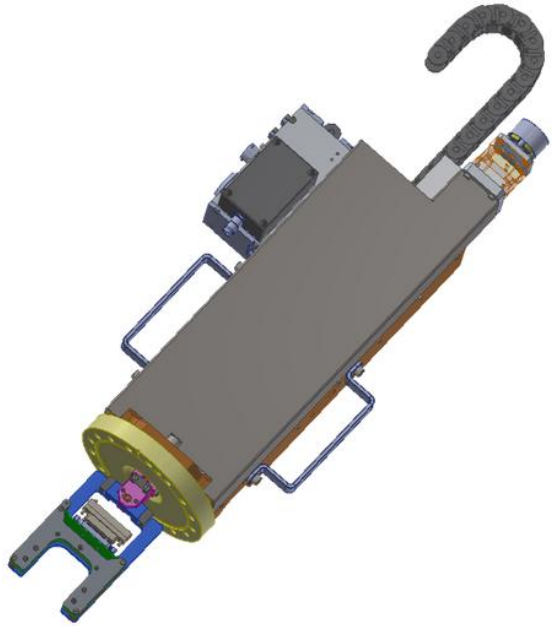
3D model of the ICONE MEBT line.

DIAGNOSTICS (…, SCRAPER, WIRE SCANNER, …)

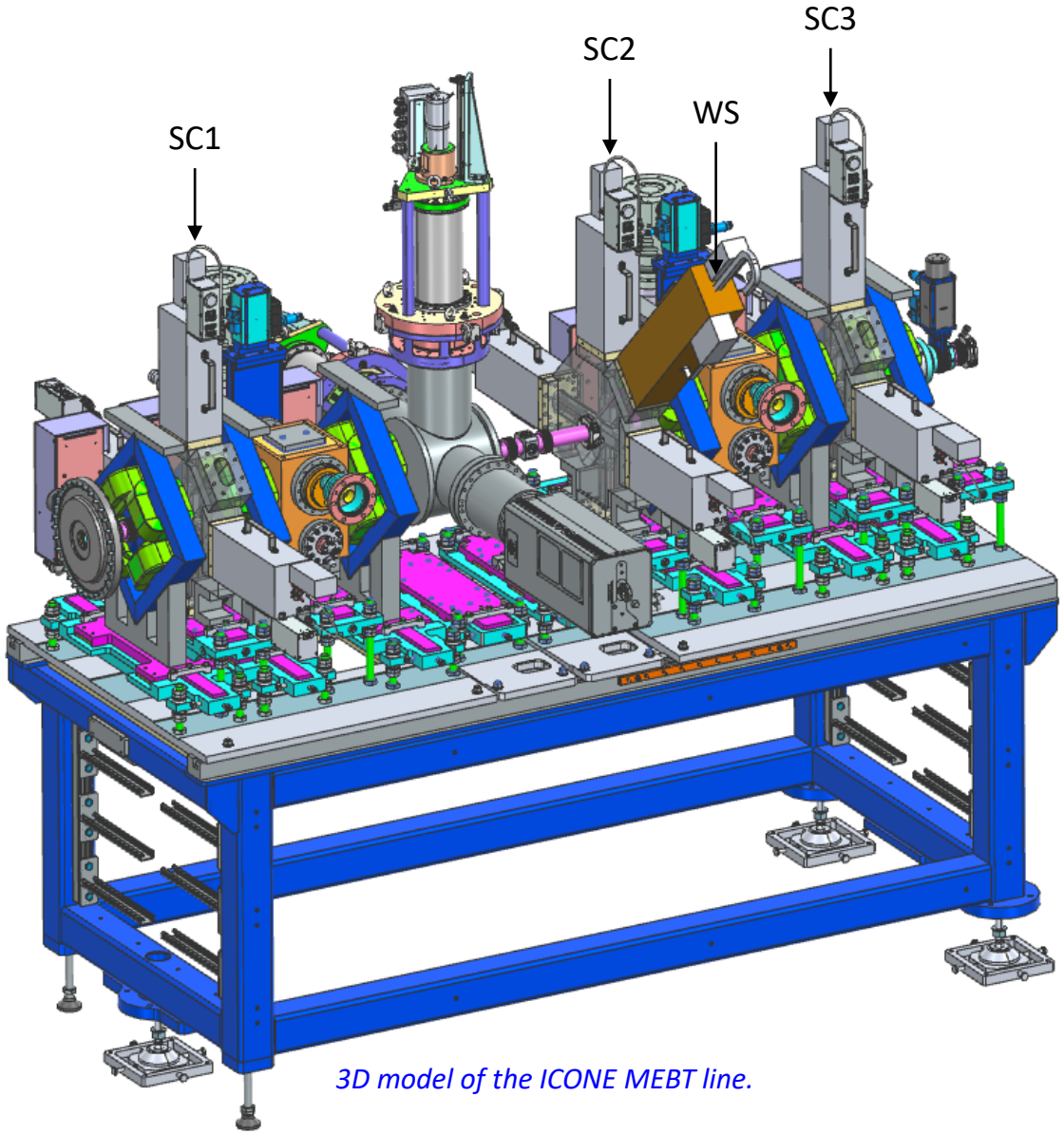




One jaw of the scraper, ESS MEBT design.

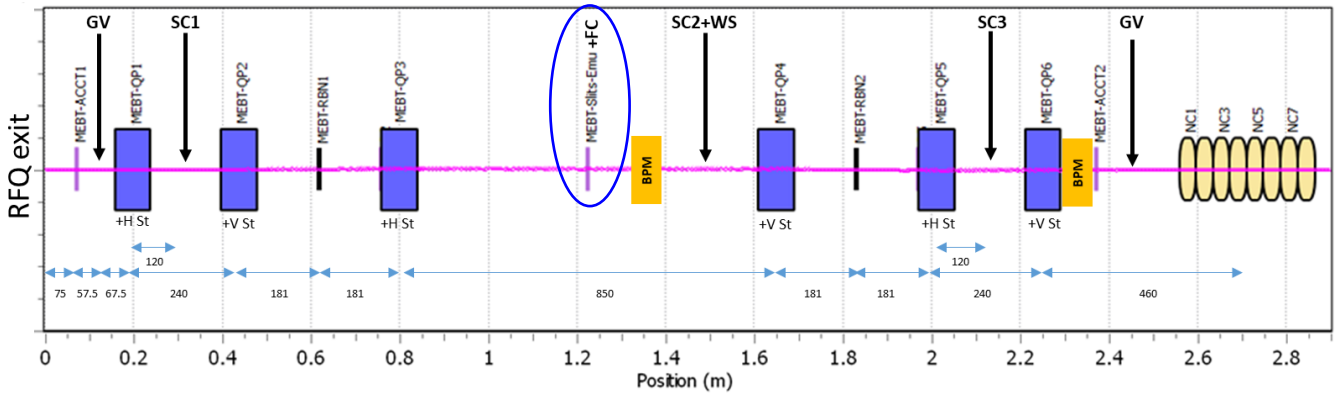


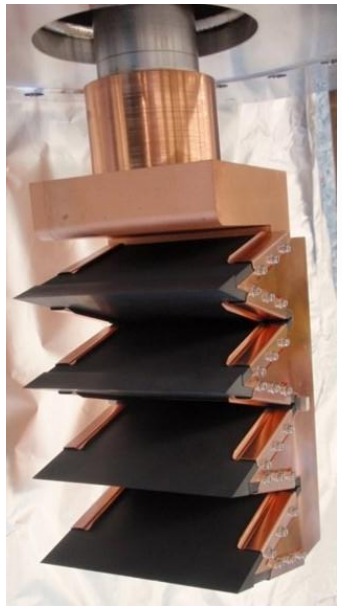
ESS MEBT Wire Scanner

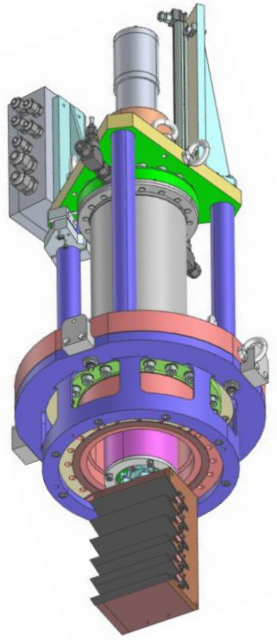


3D model of the ICONE MEBT line.

DIAGNOSTICS (…, EMU SLITS, FARADAY CUP)

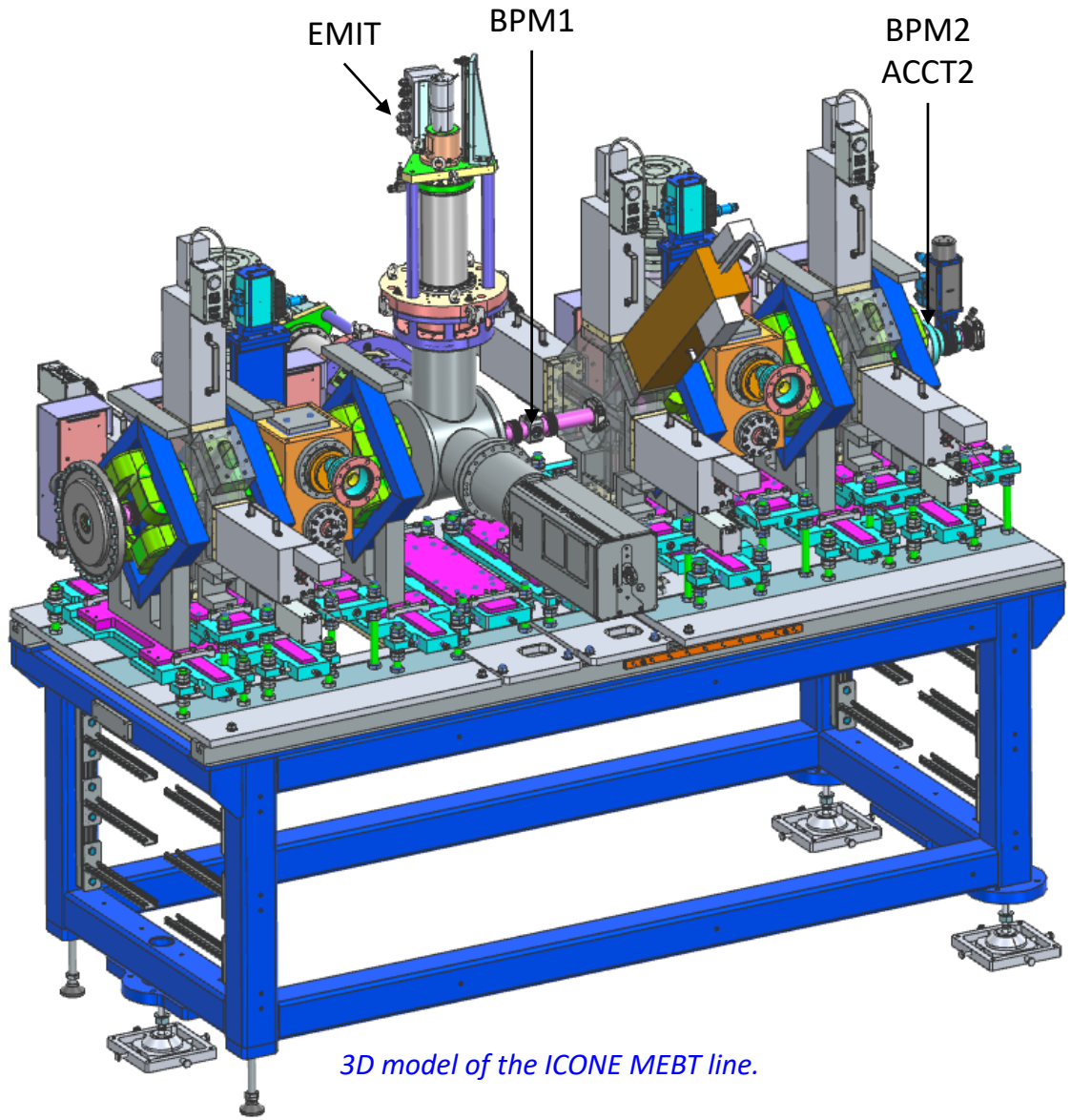






Emittance meter slid based on LINAC4 design.

Faraday Cup based on the SARAF design.



3D model of the ICONE MEBT line.

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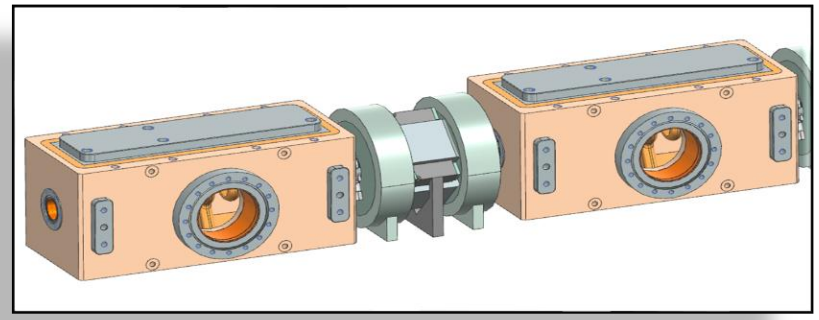
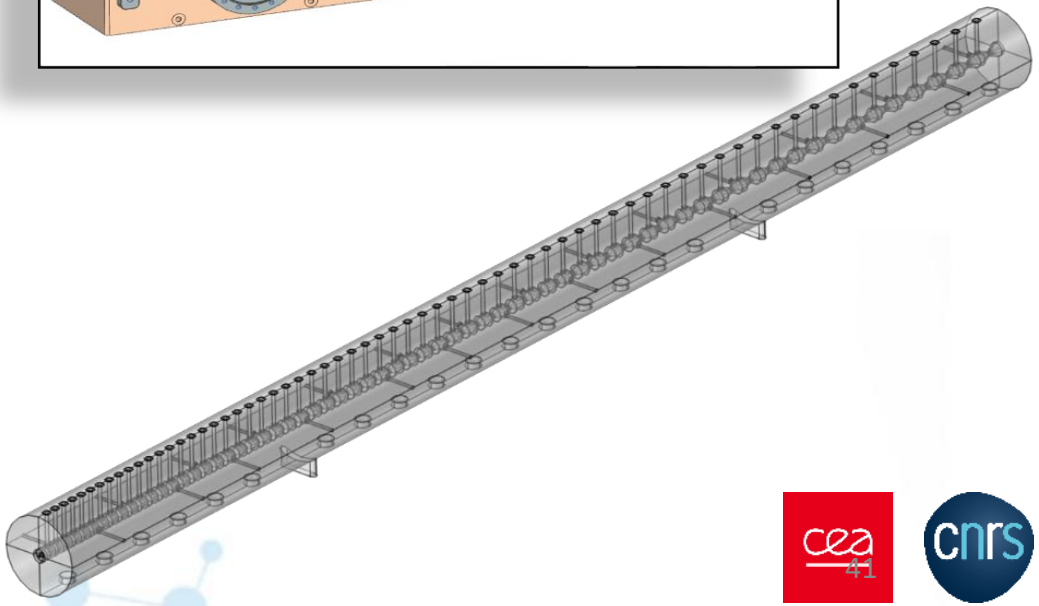


LINAC DTL

GUILLAUME FERRAND, IRFU



IH-DTL VS ALVAREZ DTL

IH-DTL solution:

- A set of cavities known as "IH" for "interdigital H-mode".
- Between the cavities, 2 permanent quadrupoles (doublet).
- In all: 12 cavities, from 40 cm to 70 cm, and 24 quasi-identical quadrupoles.
- Steering à chaque period

Alvarez DTL solution:

- A single Pillbox-type cavity.
- A set of drift-tubes, containing the quadrupoles, included in the cavity.
- 2 couplers to power the cavity.
- This solution was studied by INFN for the ICONE project.
- Aucun steering

IH-DTL, ADVANTAGE VS DISADVANTAGES

Advantages:

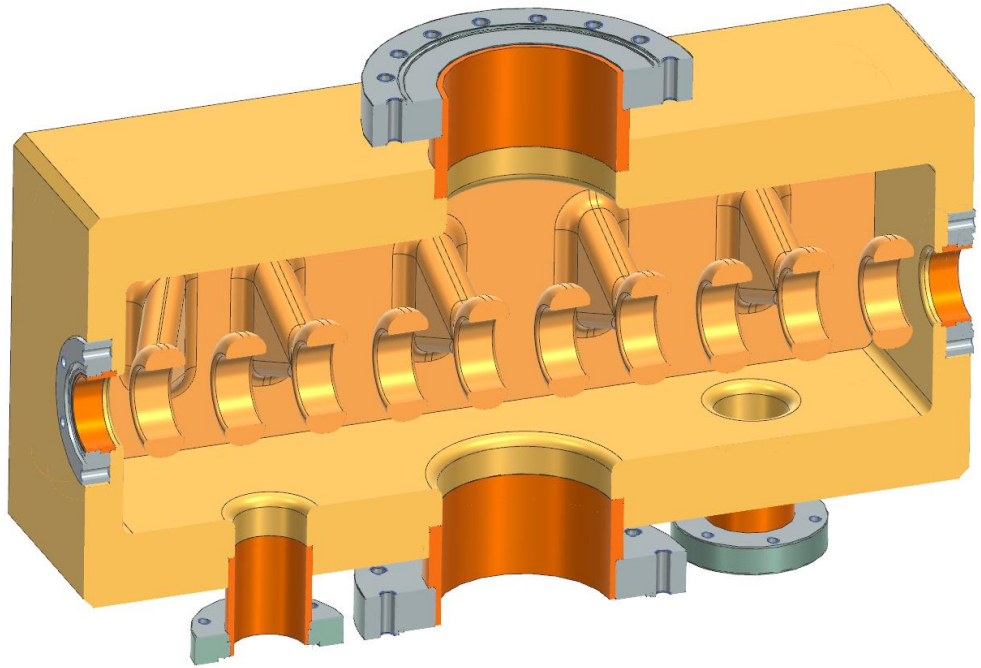
- Small pieces (less than one meter), easy to replace if necessary.
- Low RF power in each cavity. Greater robustness of pieces.
- Independent adjustment of each cavity (phase/amplitude).
- Very little sensitivity to misalignment and manufacturing tolerances.
- Irfu maintains control of manufacturing.

Disadvantages:

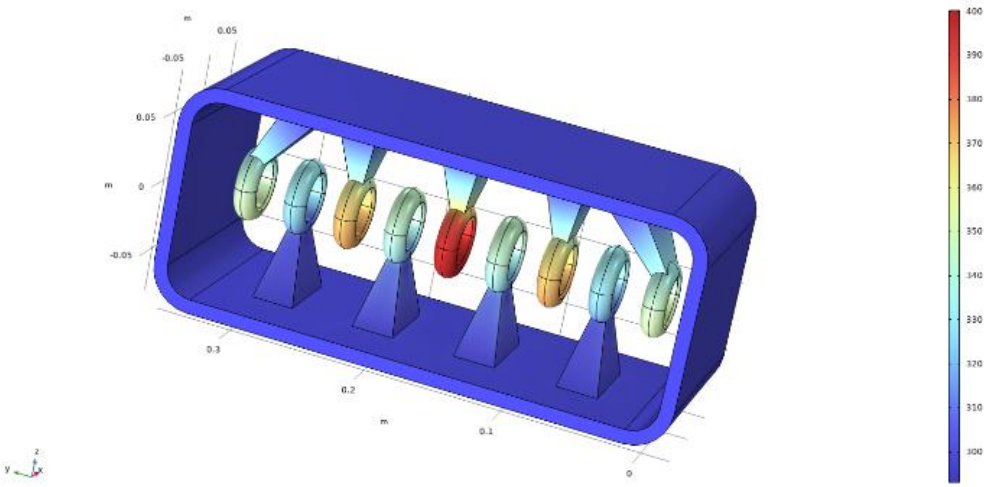
- Low feedback on this type of cavity.
- Requires a large number of different RF amplifiers.

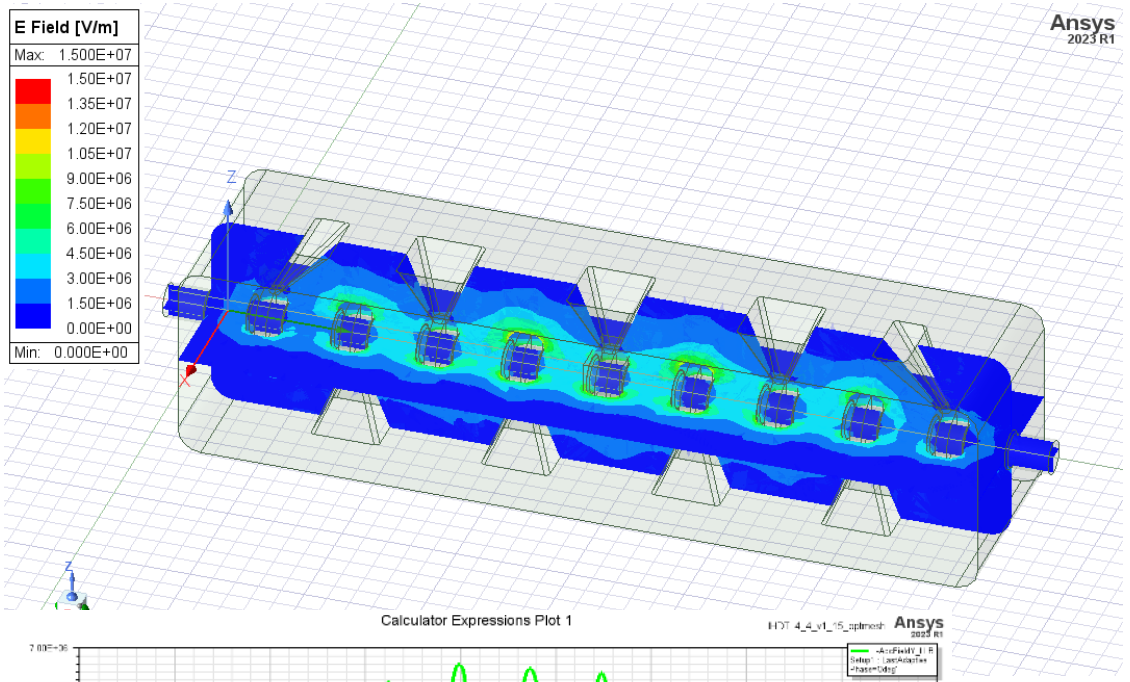
IH-DTL (UNE ALTERNATIVE AU DTL)

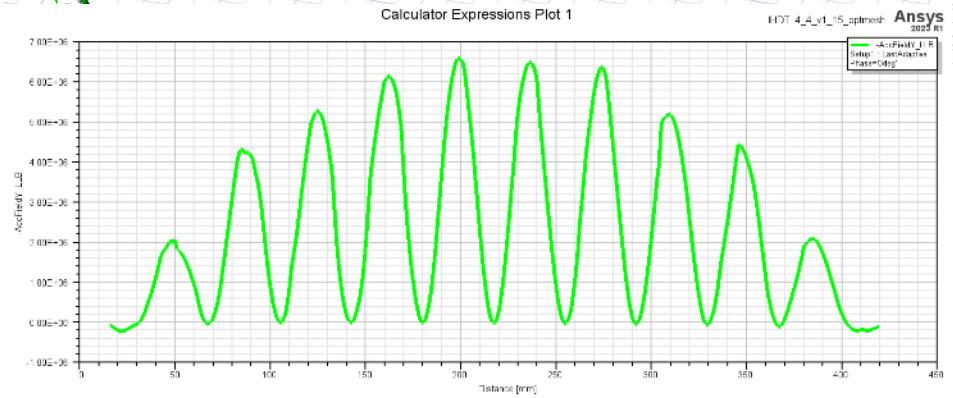
(H-mode Drift-Tube-Linac)



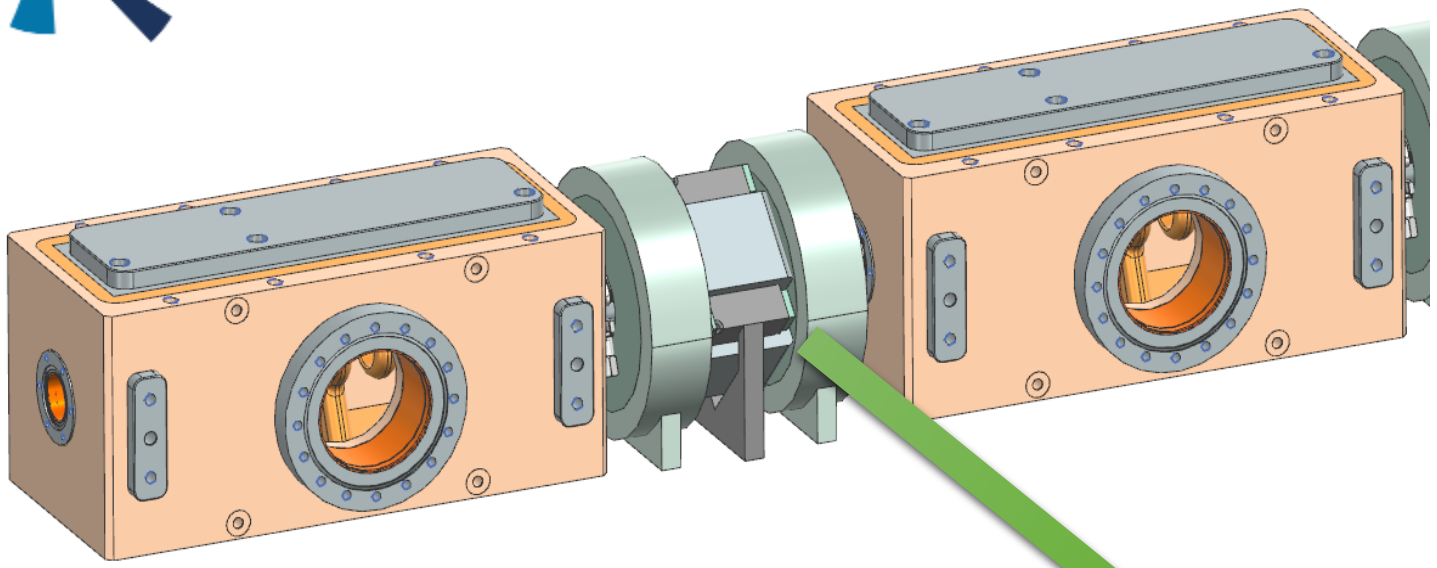
Length (x11)	: 400 à 750 mm
Sides	: 260 x 190 mm
Alignment	: Pas de contraintes fortes

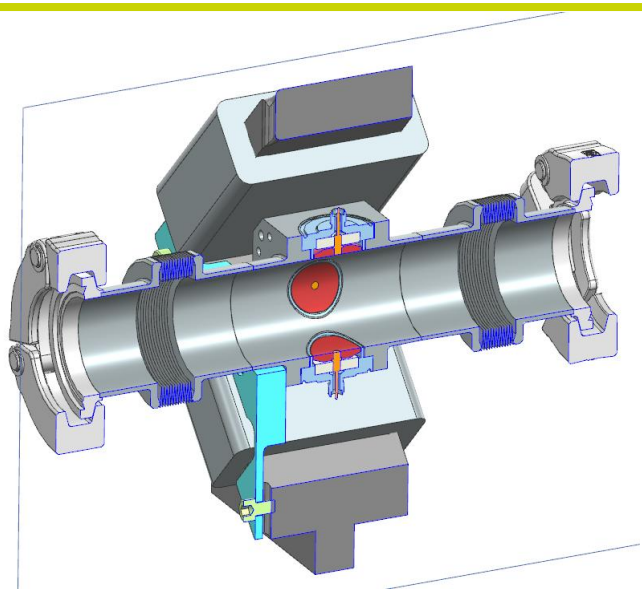




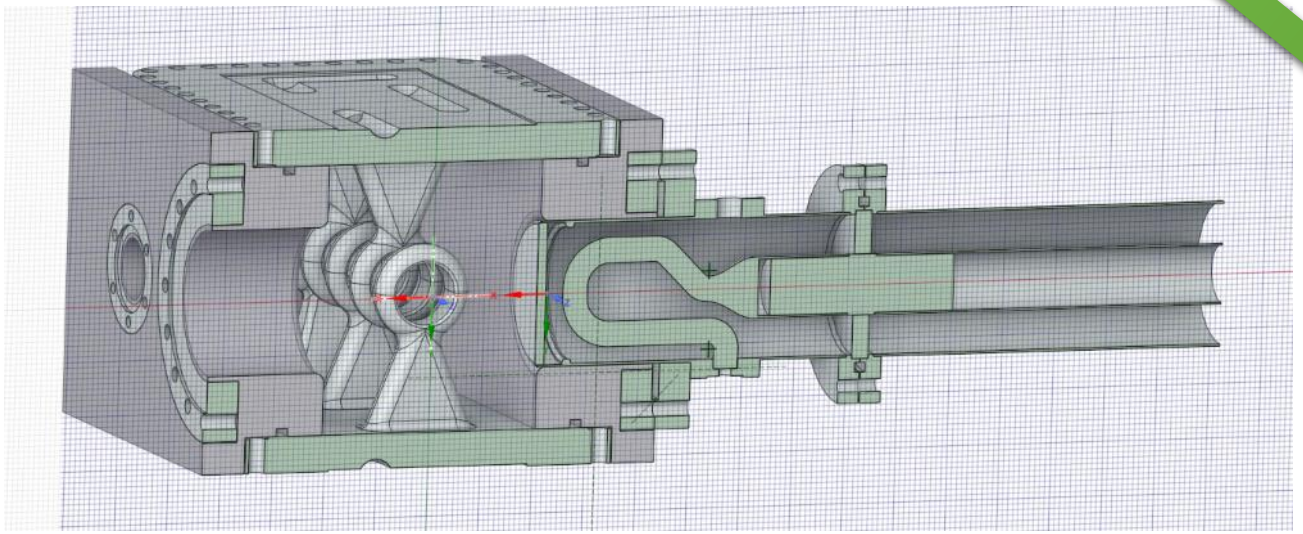


IH-DTL



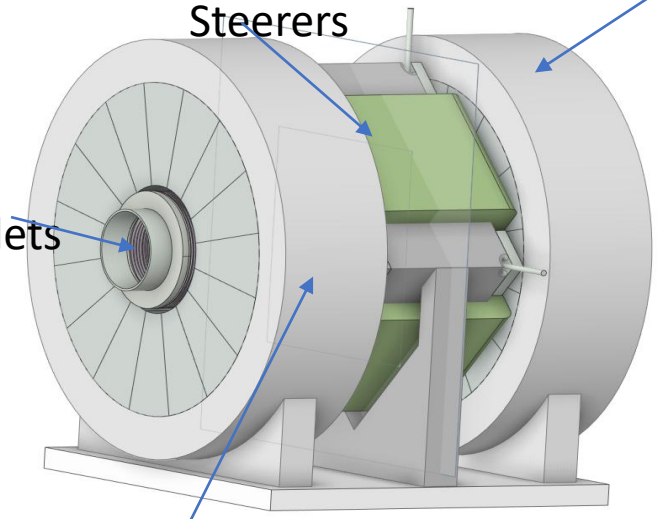


2 quads permanents



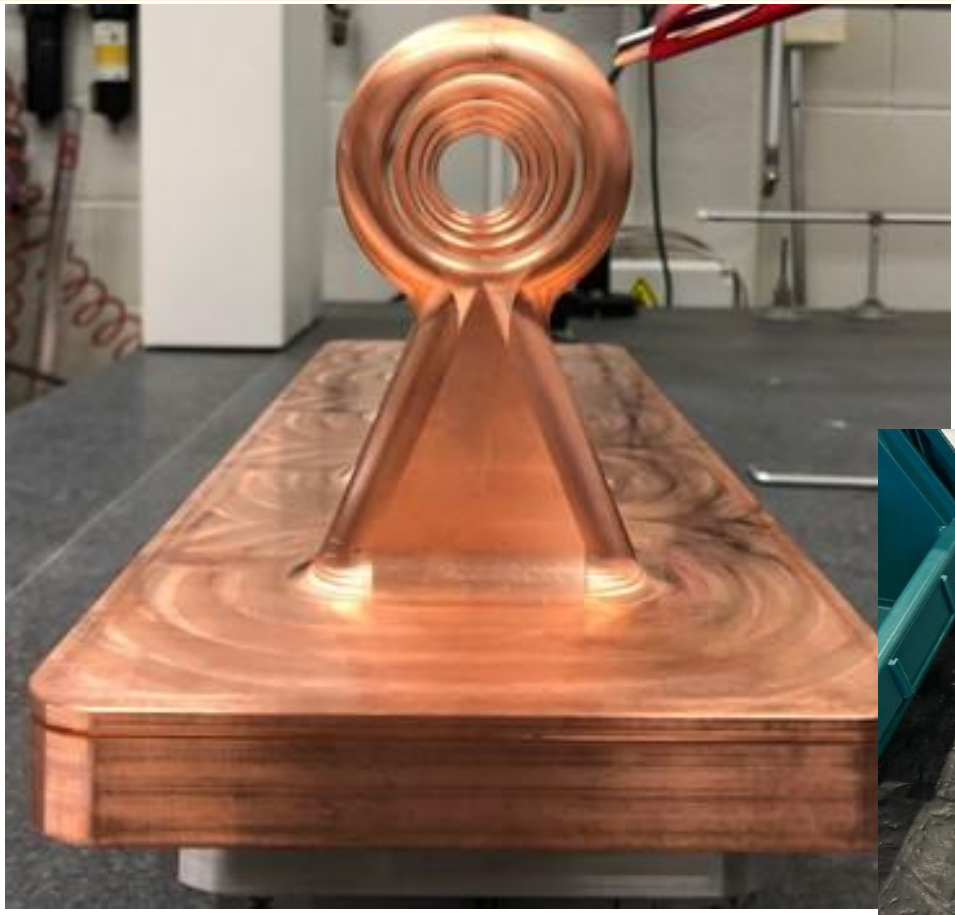
Steerers

Soufflets



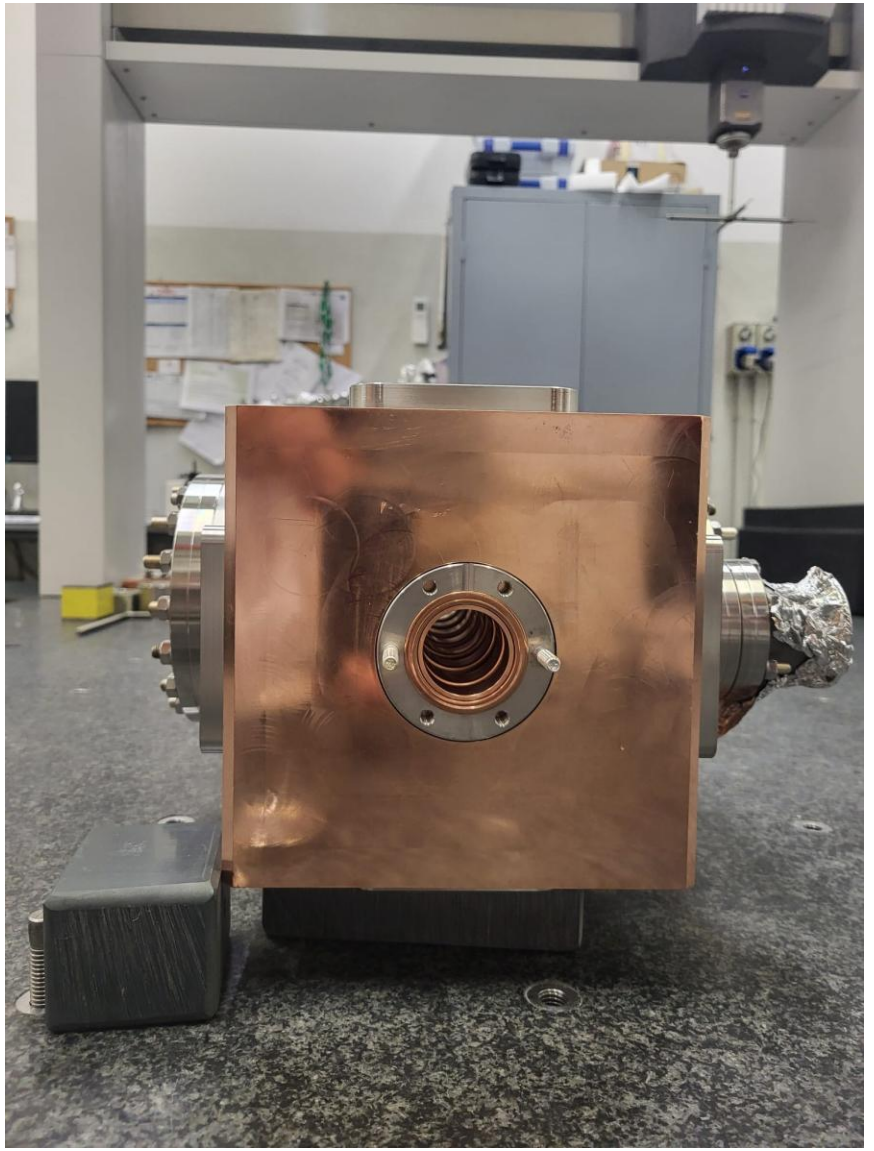
BPM dans le steerer

IH-DTL prototype (First cavity, CINEL-Italie)

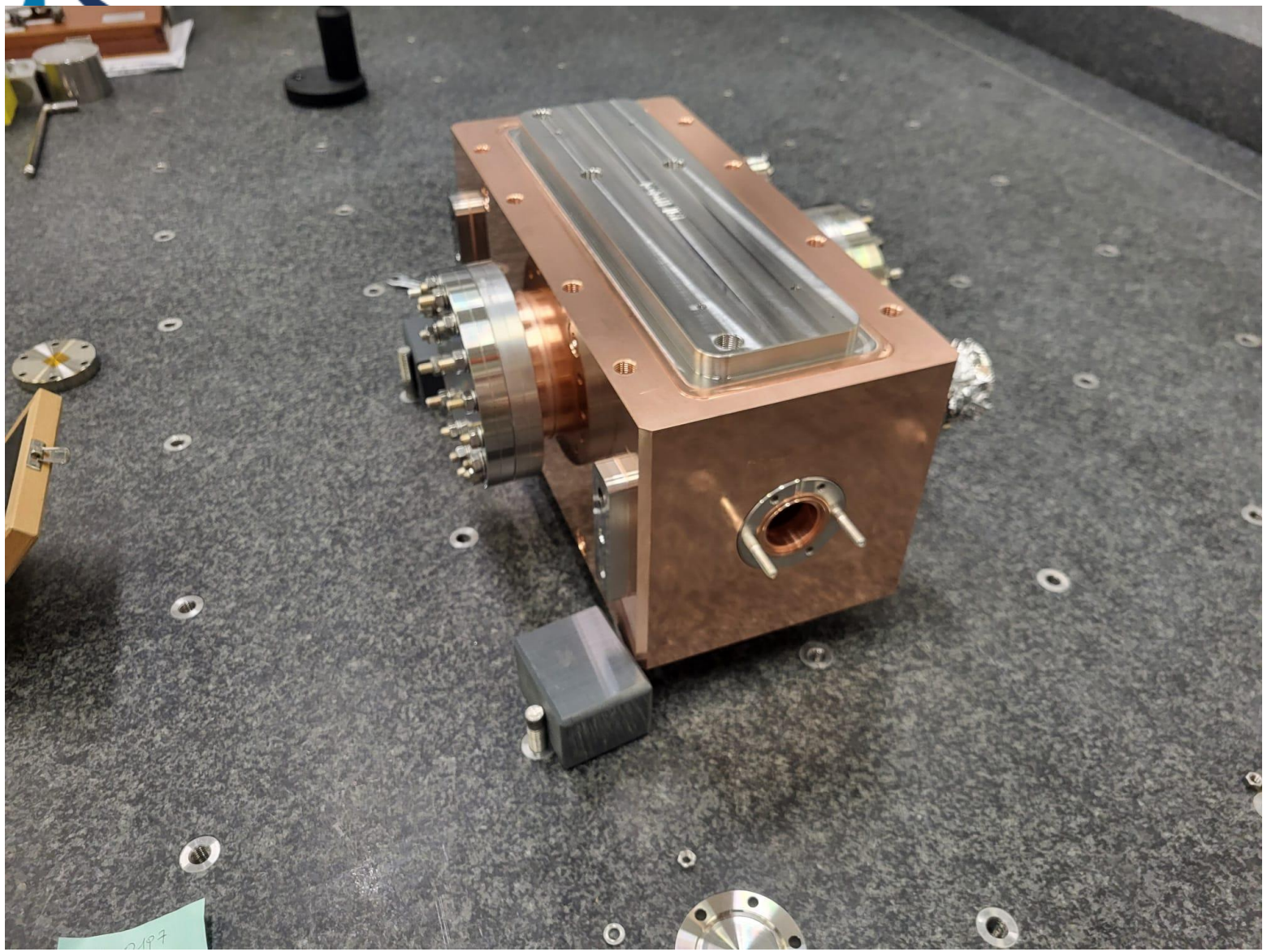


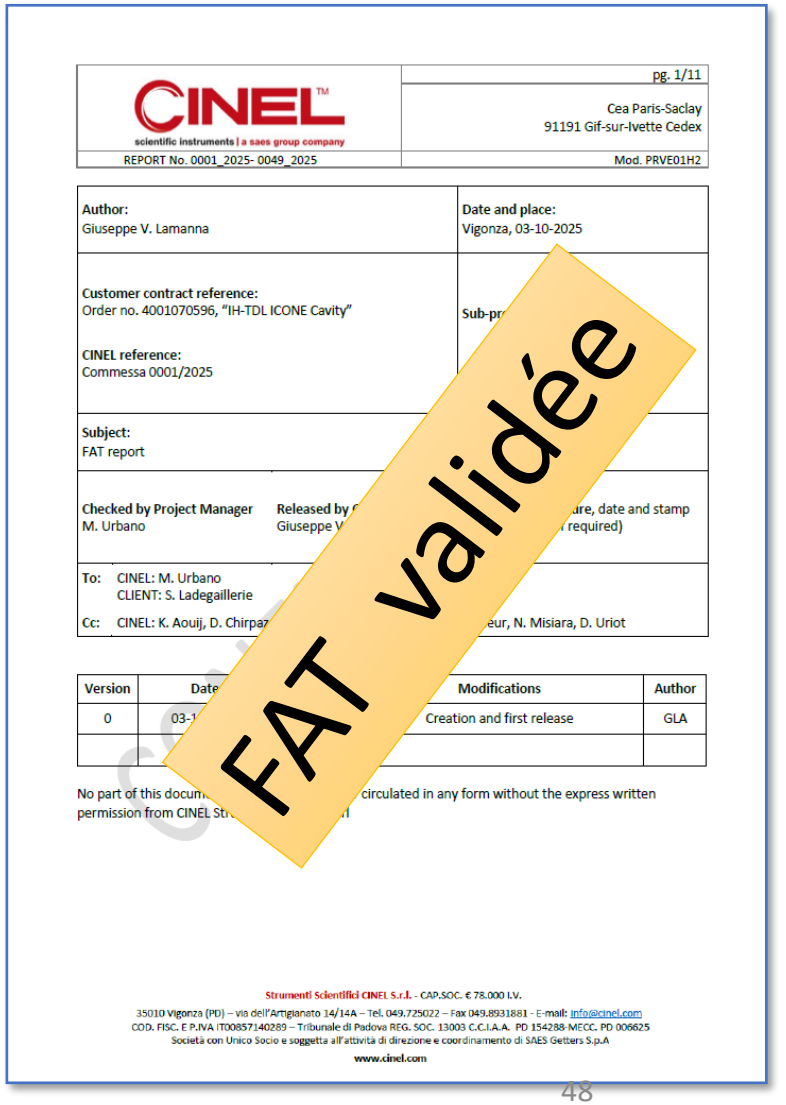
IH-DTL

ORIGINAL CEA CODE
00067888
Attenzione
NON SOLLEVARE !!
I COPERCHI NON SONO
FISSATI



IH-DTL





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pg. 1/11

Cea Paris-Saclay
91191 Gif-sur-Ivette Cedex

REPORT No. 0001_2025- 0049_2025 | Mod. PRVE01H2

Author:
Giuseppe V. Lamanna

Date and place:
Vigonza, 03-10-2025

Customer contract reference:
Order no. 4001070596, "IH-TDL ICONE Cavity"

CINEL reference:
Commessa 0001/2025

Sub-pr

Subject:
FAT report

Checked by Project Manager
M. Urbano

Released by
Giuseppe V

ure, date and stamp required)

To: CINEL: M. Urbano
CLIENT: S. Ladegaillerie

Cc: CINEL: K. Aouij, D. Chirpaz

eur, N. Misiara, D. Uriot

Version	Date	Modifications	Author
0	03-1	Creation and first release	GLA

FAT validée

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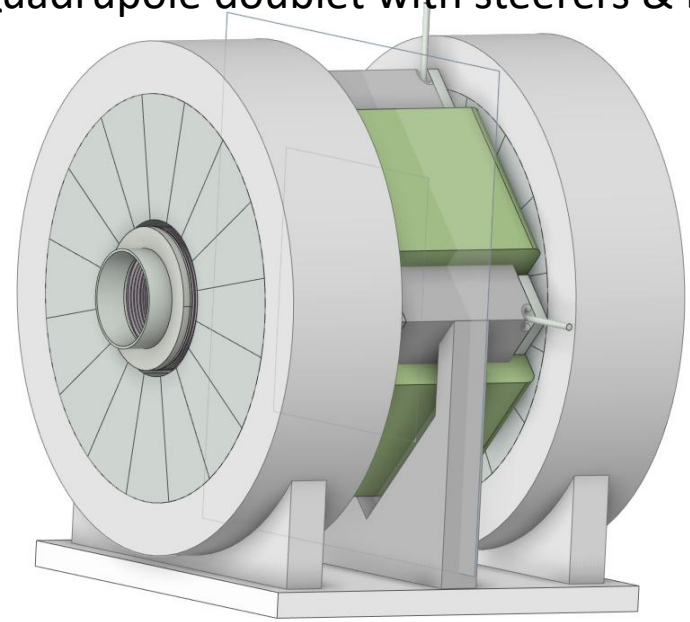
Società con Unico Socio e soggetta all'attività di direzione e coordinamento di SAES Getters S.p.A
www.cinel.com

QP PROTOTYPE

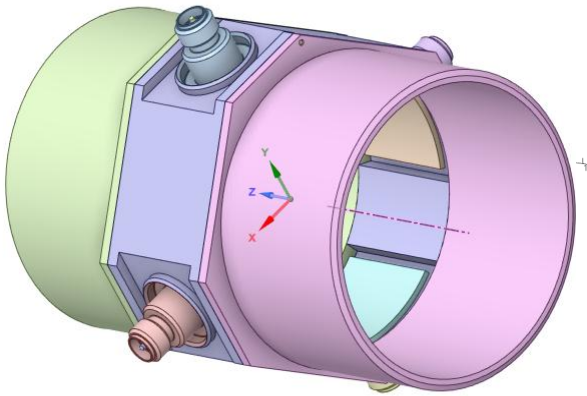
Length	Inner block Radius	Outer block radius	Gradient	Gradient integral
50 mm	65 mm	95 mm	37.1 T/m	2.47 T

- A base de neodymium iron boron (NdFeB), sensible aux neutrons, approvisionnement difficile.
- Alternative : Samarium cobalt, moins sensible aux neutrons, mais gradients atteignables plus faibles.

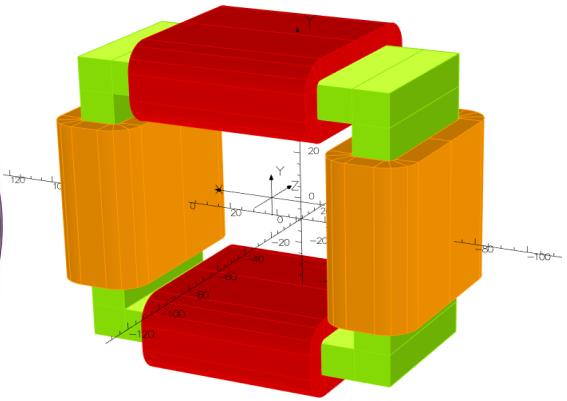
Quadrupole doublet with steerers & BPM



BPM

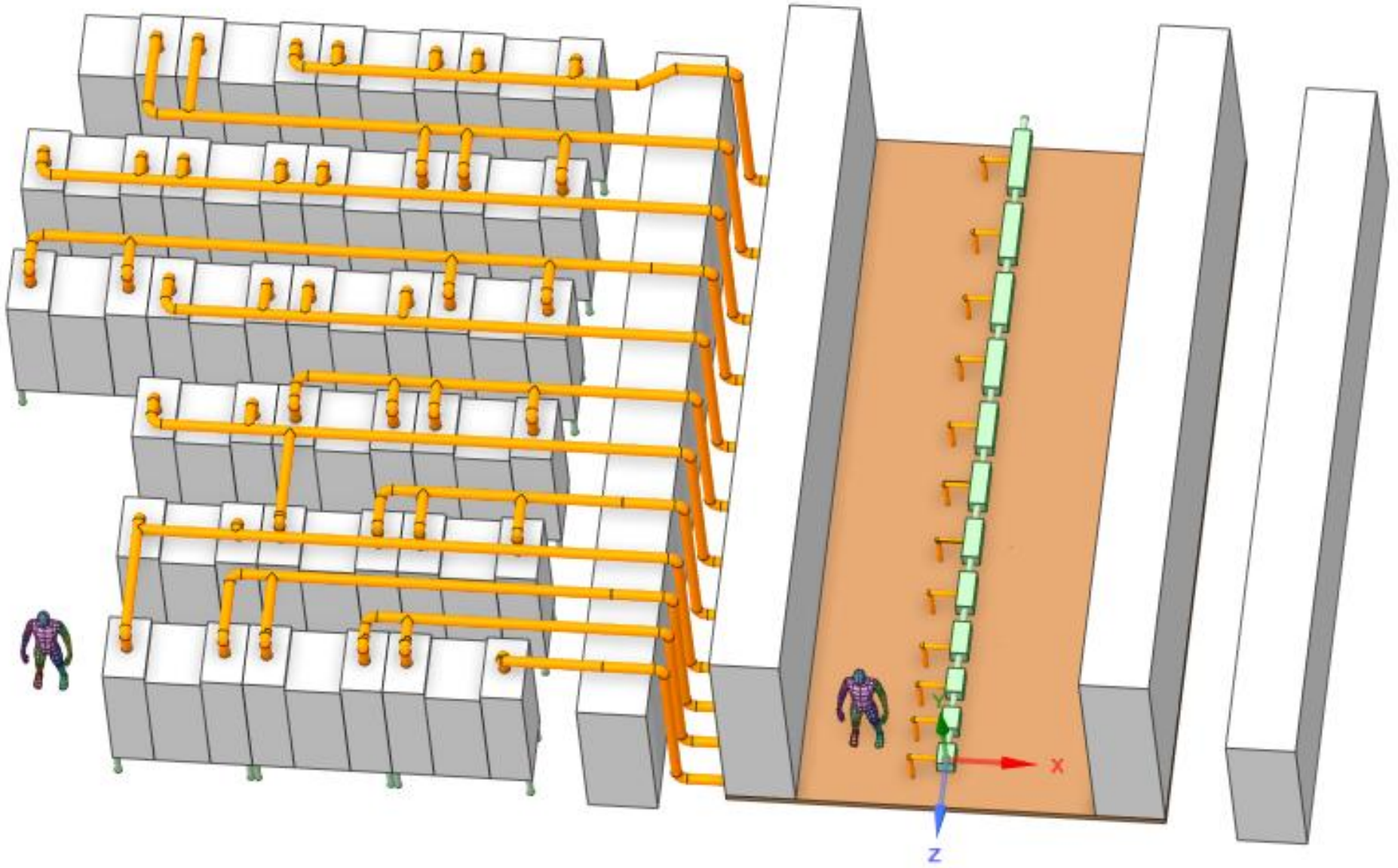


Steerer



IH-DTL (RF DISTRIBUTION)

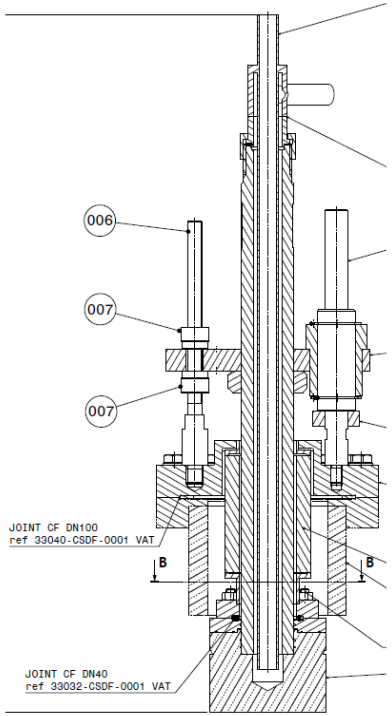
Amplis à état solide
Distribution lignes coaxiales



IH-DTL : MAIN COMPONENTS

Coupler (SPIRLA2)

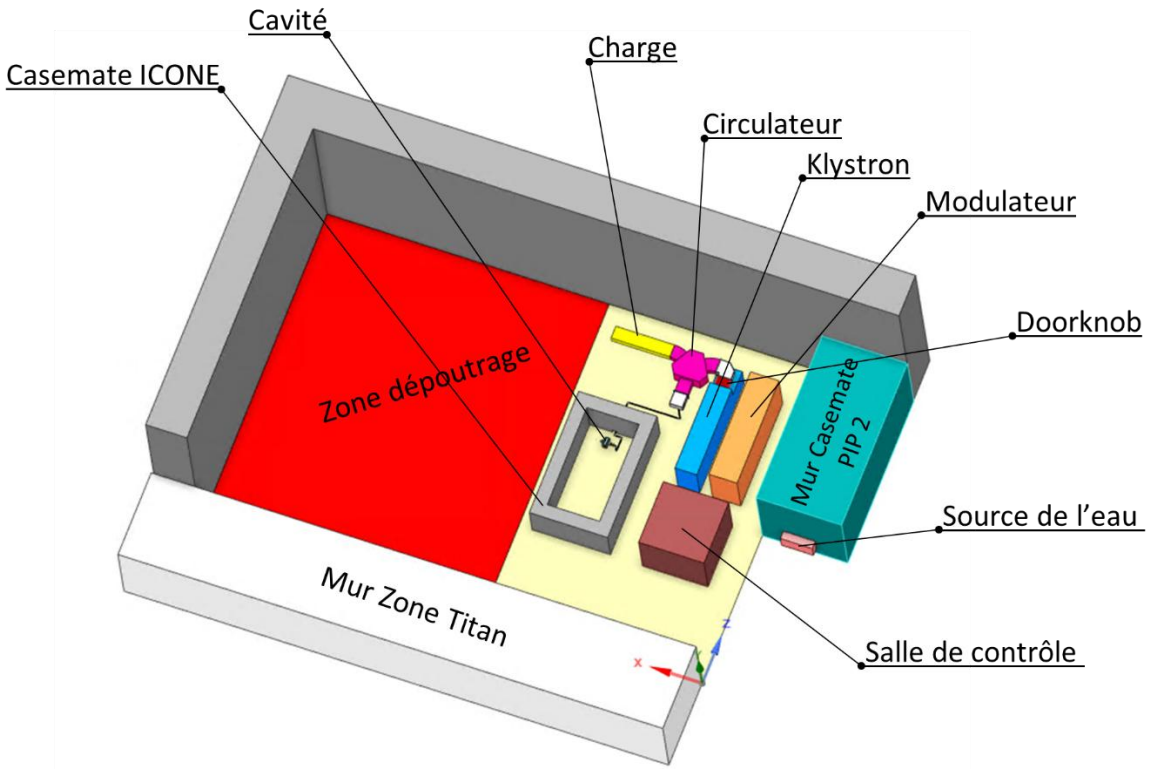
Tuner (ESS)

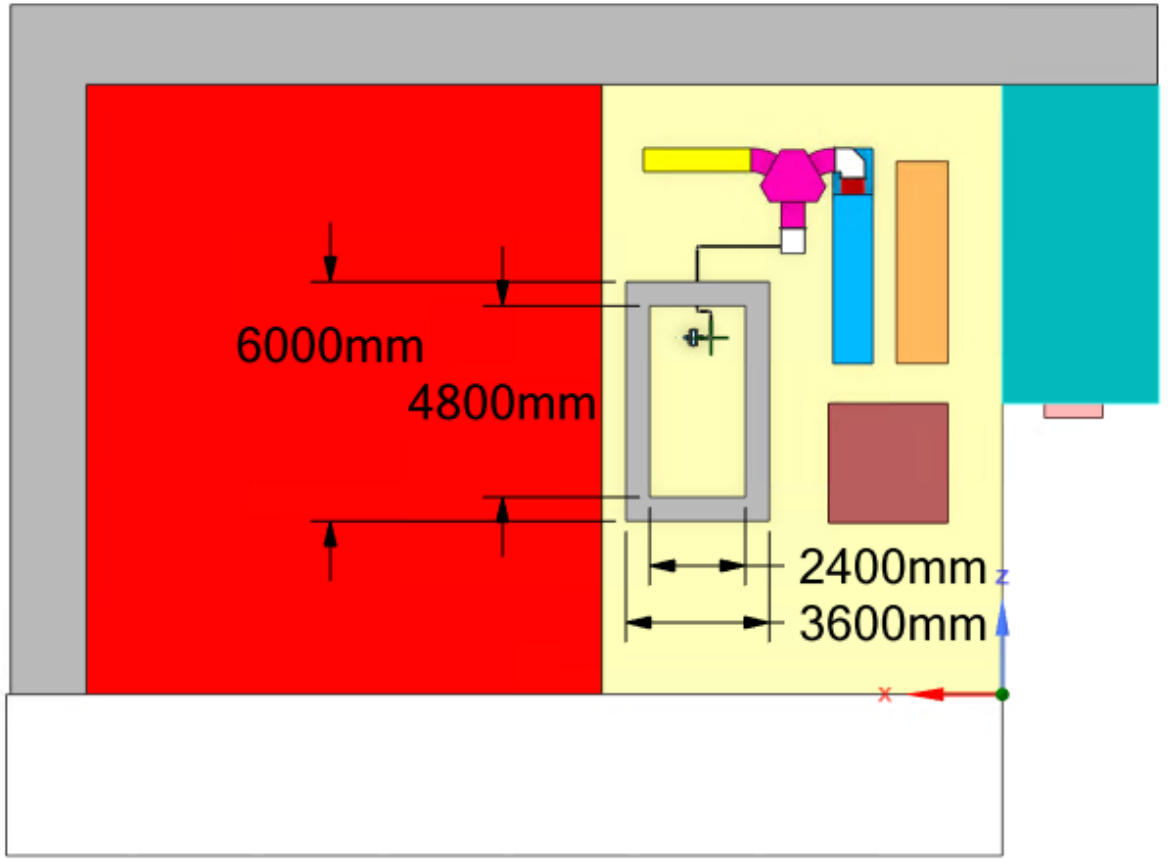


Cav.	Beta	Acc. Gradient (MV/m)	RF losses (kW)	Peak E (MV/m)	RF to beam (kW)
1	0.0900	1.4	11.2	10.2	28.1
2	0.0963	2.95	50.1	21.1	63.5
3	0.1058	3.5	74.0	24.3	82.7
4	0.1167	3.12	74.8	21.8	104.1
5	0.1289	3.4	96.8	24.3	128.1
6	0.1418	3.4	106.6	23.5	142.3
7	0.1548	3.4	117.2	23.7	156.9
8	0.1679	3.4	130.0	24.1	170.2
9	0.1810	3.4	143.6	23.5	185.2
10	0.1941	3.4	158.8	23.7	202.2
11	0.2073	3.4	175.5	22.6	219.5
12	0.2204	3.4	194.5	22.5	233.4
Total:			1333		1716

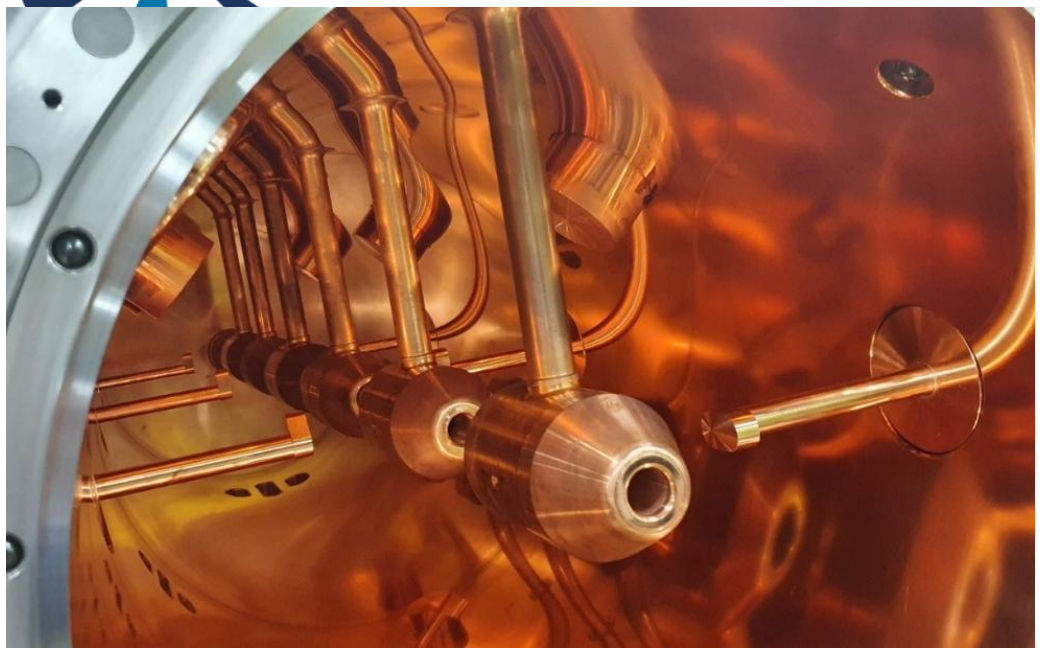
Rendement : 57 %

CASEMATE DE TEST À SACLAY

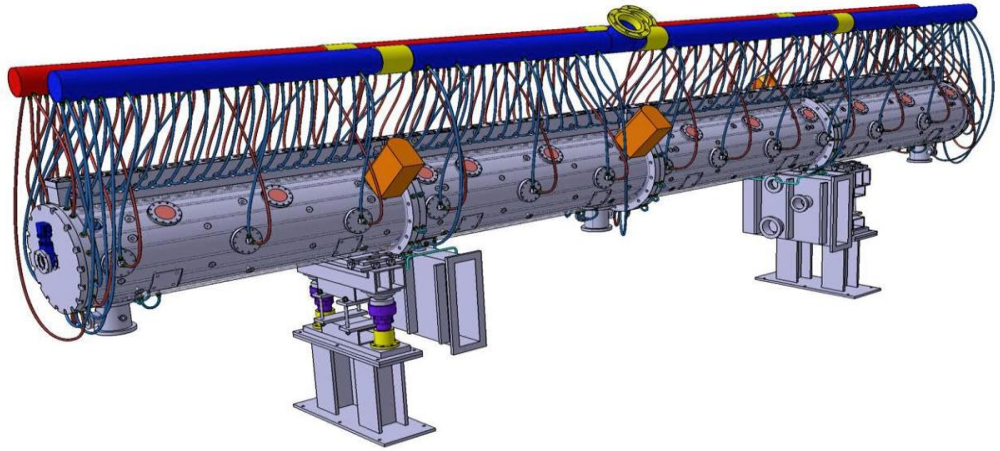




ALVAREZ DTL : ESS EXPERIENCE



Alvarez DTL for ESS project



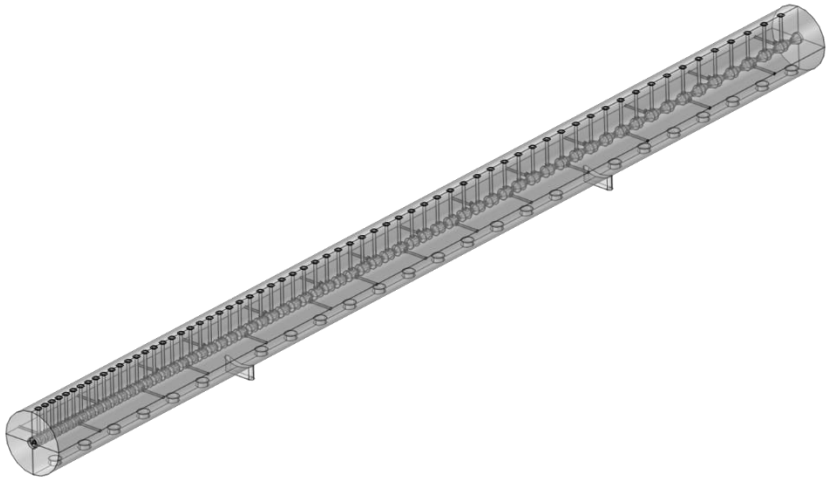
Advantages :

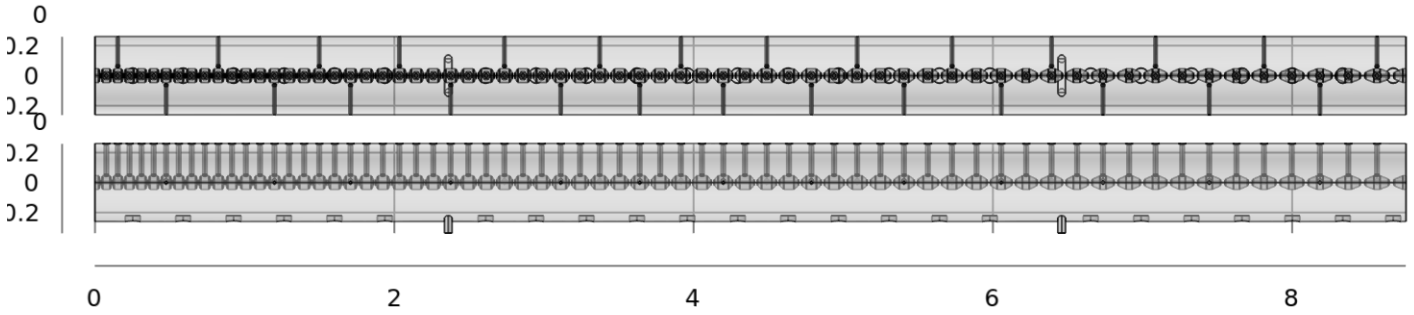
- Allows you to benefit from the experience acquired by the INFN for the ESS project.
- ESS DTL is qualified. Little additional development required to adapt it to ICONE.
- One piece, with one very large RF amplifier.

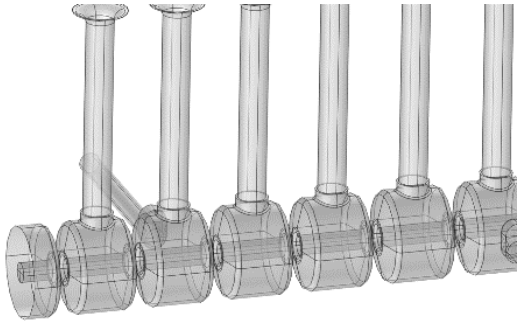
Disadvantages :

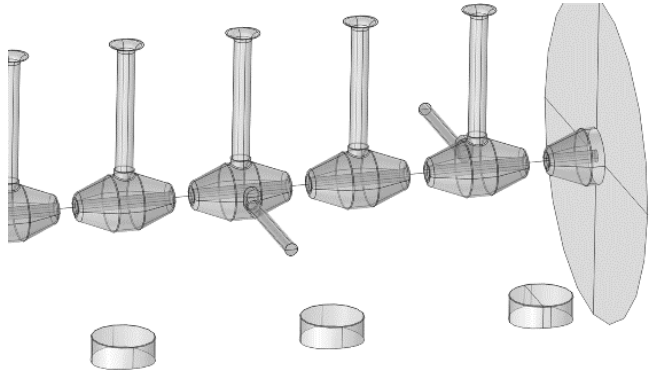
- No experience at CEA. INFN would have complete control over the manufacture and installation of the DTL.
- In the event of a problem, repair would require dismantling a large part of the cavity.
- CEA risks being dependent on INFN for maintenance.
- High sensitivity to misalignment.
- Longer manufacturing time.
- Complicated RF tuning.

ALVAREZ DTL : 3D MODEL





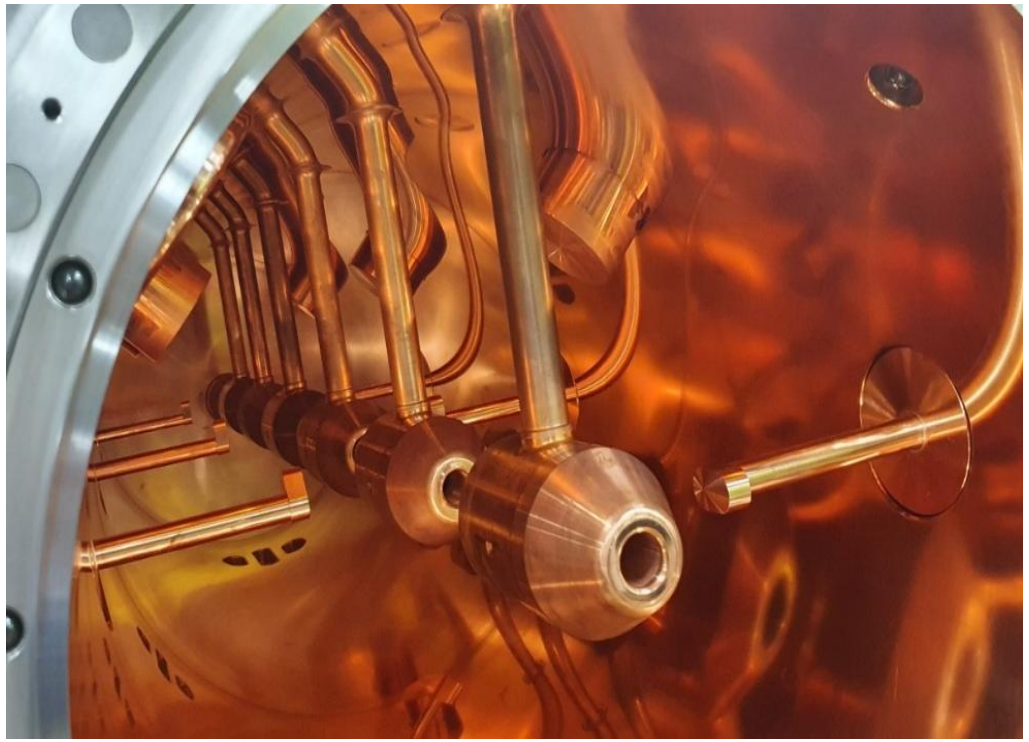




Drift tube	: 66
Post-coupler	: 27
Tuners	: 24
Steering	: No
Length (m)	: 8.7

Samarium Cobalt quadripole

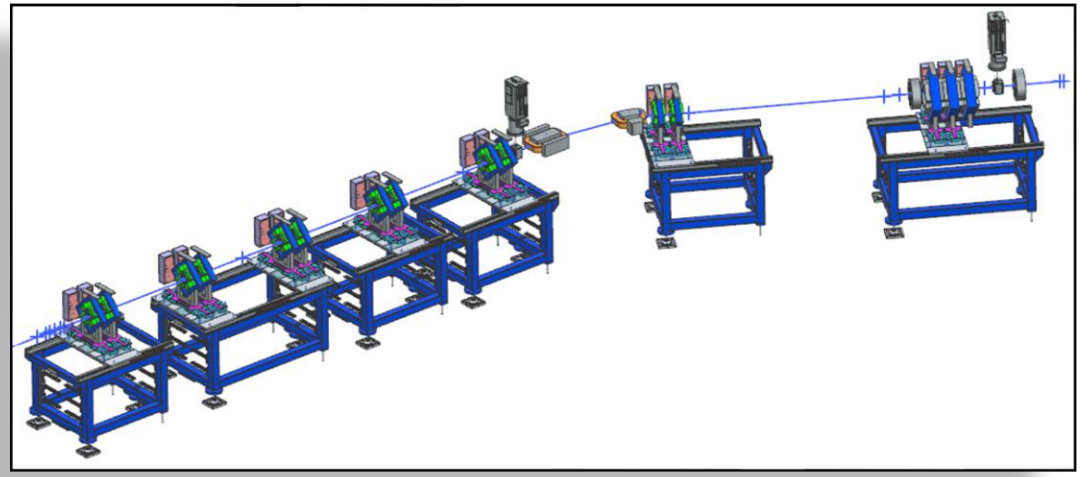
ALVAREZ DTL : @ESS



ICONE

Neutrons for Materials Sciences

HIGH ENERGY BEAM TRANSPORT

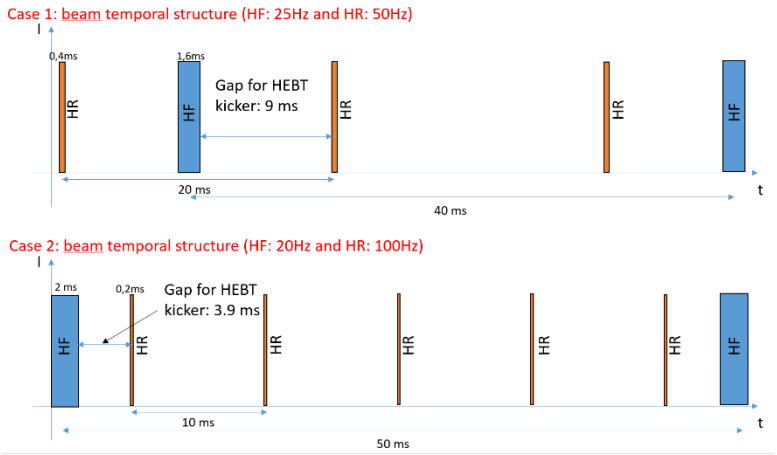


JONATHAN DUMAS, IRFU

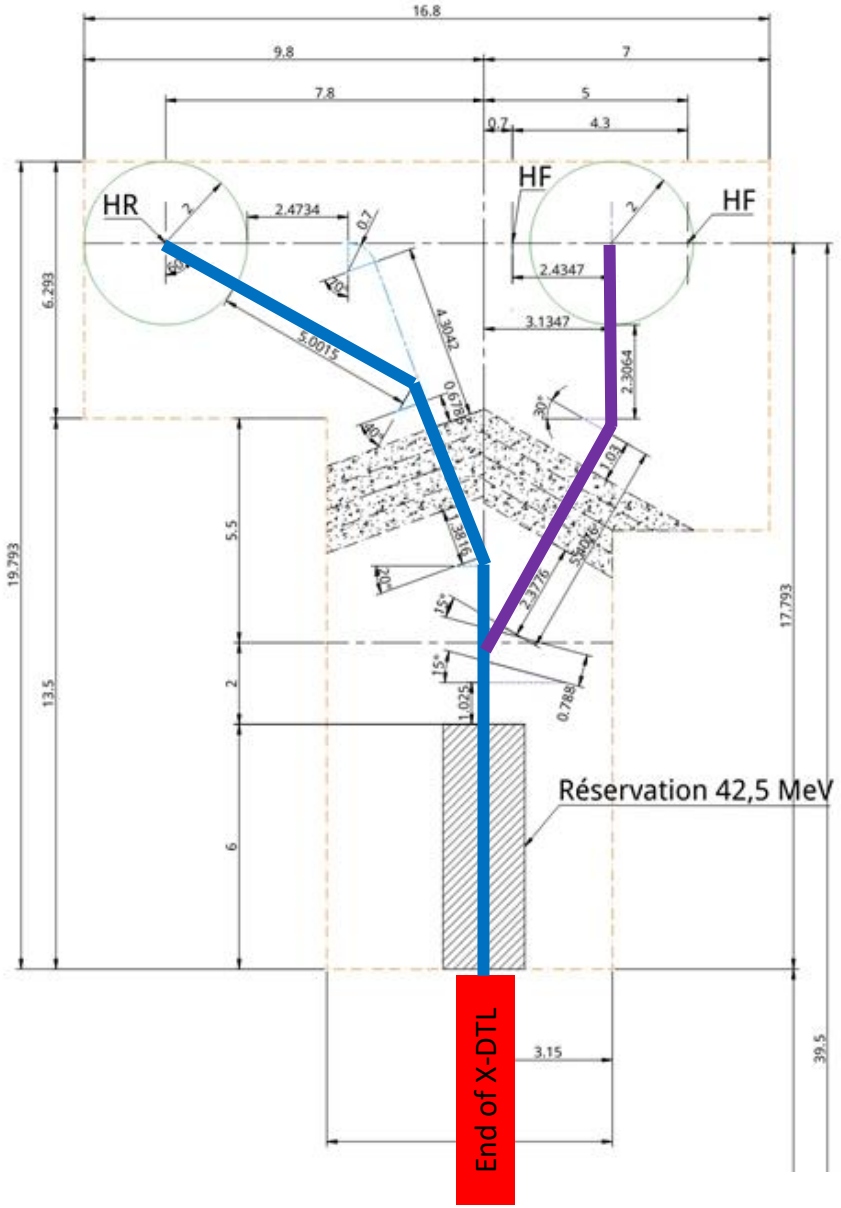
HEBT: SCOPE AND IMPLANTATION

Purpose of the HEBT:

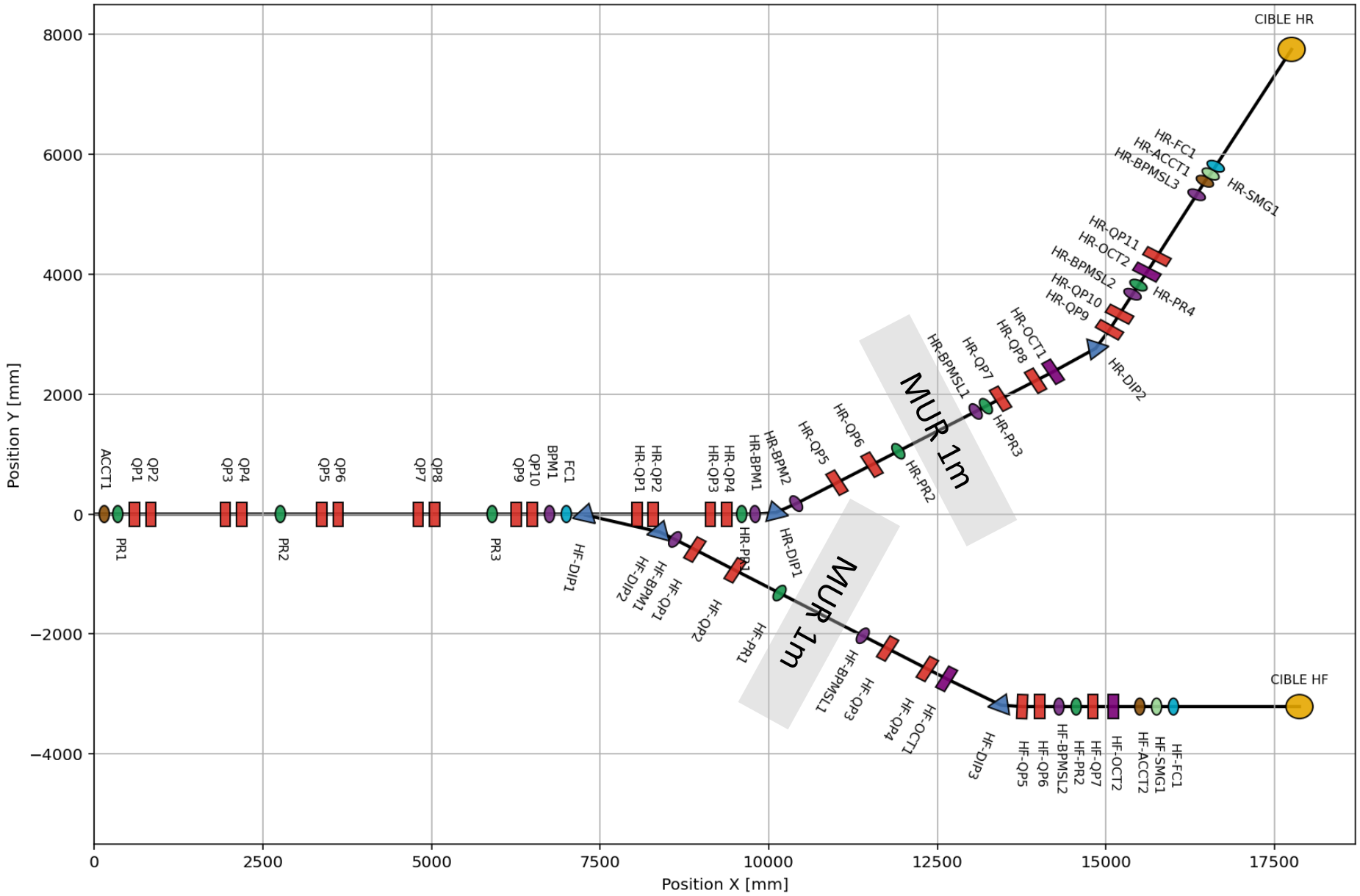
- Final beam delivery from X-DTL to HF and HR targets
- Room for possible upgrade to 40 MeV
- Split beam according to pulse timing



- Prevent neutron backstreaming to the linac with 2 dipole setup per line
- Rectangular uniform beam shaping at targets with octupoles for stability
- Achromaticity



HEBT: SCHEME

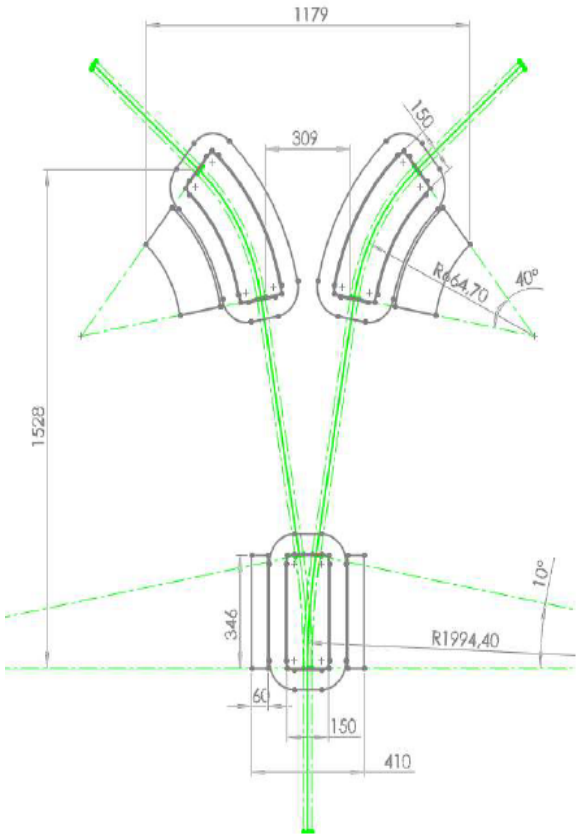


Element d'optique

Diagnostique

HEBT: DIPOLE AIGUILLAGE RAPIDE

Concept retenu: 1 dipôle d'aiguillage rapide +/- 10° suivi de 1 dipôle DC de déviation à gauche et 1 dipôle DC de déviation à droite



Concept compact, poids réduit

Tension et courant de fonctionnement de l'ordre de 820 A & 3.5 kV

Paramètres dipôle rapide:
Quantité 1
Gap 30 mm
Champ 0.4T
Rayon de déviation 1994.4 mm
Angle de déviation +/-10°
Fonctionnement Pulsé
Géométrie Window frame bobines nuques relevées
Culasse Ferrite
Hors vide
Chambre à vide en céramique ou en fibre de verre/epoxy suivant le niveau de vide attendu

Paramètres alimentation dipôle rapide:
Quantité 1
Mode pulsé 820 A x 3500 V
Aimant inductance 0.37 mH & résistance 6.2 mΩ
Variation du champ de +Bo (+In) à –Bo(-In) en moins de 0.2 ms
Pulse long durée 2 ms à 20 Hz
Pulse court durée 0.1 ms à 400 Hz
Stabilité en courant et répétabilité des pulses 0.1%

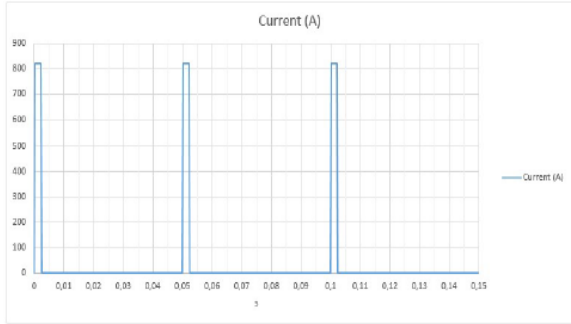
CUSTOMER:		CEA
SIGMAPHI REFERENCE:		x
DESIGNATION:		Dipole Rapide
REVISION:		
Beam magnetic rigidity	T.m	0,7977
Gap	mm	30,0
Nominal field	T	0,40
Ampere turns per pole	A.t	4900
Deviation radius	mm	1994,3
Deviation angle	°	10,00
Magnetic effective length	mm	348,1
Number of coils per magnet	/	2
Current	A	816,7
Inductance estimation	H	3,68E-04
Magnet resistance at warm	Ω	6,2E-03
Energy step	%	100,00%
Time step for energy change	s	1,00E-04
Duty factor	/	0,26
Peak magnet voltage	V	3344,1
Peak magnet power	kW	2731,0
Magnet DC power	kW	1,41
Magnet total weight estimation	Kg	150

Paramètre dipôles C:
Quantité 2
Gap 30 mm
Champ 1.2 T
Rayon de déviation 664.7 mm
Angle de déviation 35° - 40°
Fonctionnement DC
Géométrie en C type window frame bobines nuques relevées
Culasse XC10
Blindage passif

Paramètres alimentation dipôles C
Quantité 1
Mode DC 450 A x 40 V
Commune pour les 2 dipôles câblés en série
Stabilité en courant 0.05 %

CUSTOMER:		CEA
SIGMAPHI REFERENCE:		x
DESIGNATION:		Dipole C
REVISION:		
Beam magnetic rigidity	T.m	0,7977
Gap	mm	30,0
Nominal field	T	1,20
Ampere turns per pole	A.t	15000
Deviation radius	mm	664,8
Deviation angle	°	40,0000
Magnetic effective length	mm	464,1
Number of coils per magnet	/	2
Current	A	416,7
Inductance estimation	H	1,73E-02
Magnet resistance at warm	Ω	4,3E-02
Duty factor	/	1,00
Peak magnet resistive voltage	V	18,0
Power cable voltage drop	V	1,38
Peak magnet voltage	V	19,7
Magnet DC power	kW	8,09
Material	/	Solid Steel
Magnet total weight estimation	Kg	549

Profil du courant du dipole d'aigullage pour le faisceau du LINAC 20 Hz



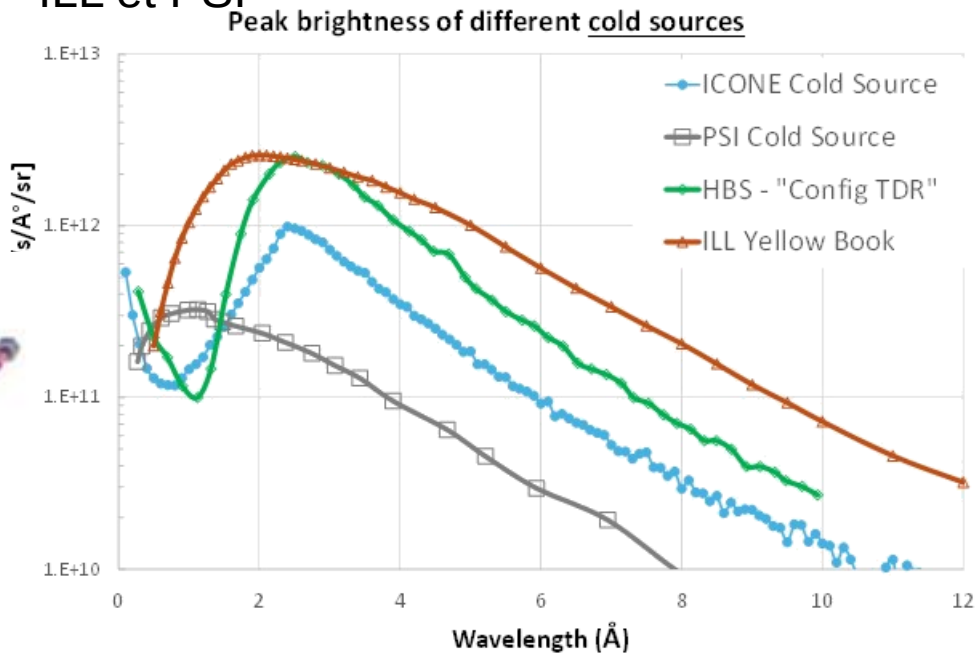
0,1 ms

Version		CEA Linac 20Hz
Current	A	820
Ramping time	s	1,00E-04
Flat top	s	2,00E-03
Ramp down	s	1,00E-04
Frequency	Hz	20
Period	s	0,05
Duty factor triangular shape	/	0,57735027
Duty factor sinus shape	/	0,70710678

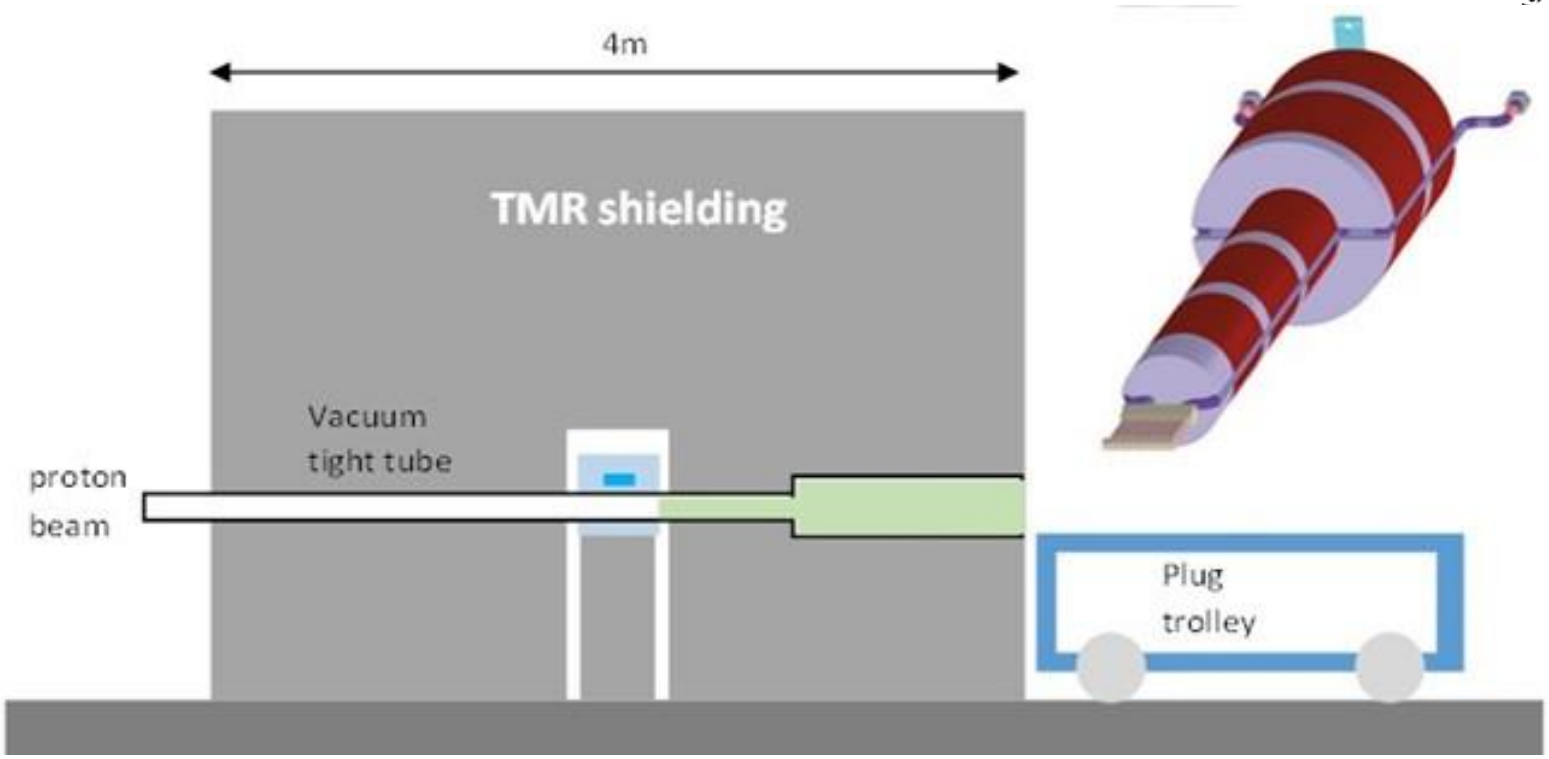
Time (s)	Current (A)	Duty factor	I²t	I dc (A)	Duty factor
0	0				
0,0001	820,0	0,577	22		
0,0021	820,0	1,000	1345		
0,0022	0	0,577	22		
0,05	0	0,000	0	167	0,20330601

CIBLES-MODÉRATEURS (WP3)

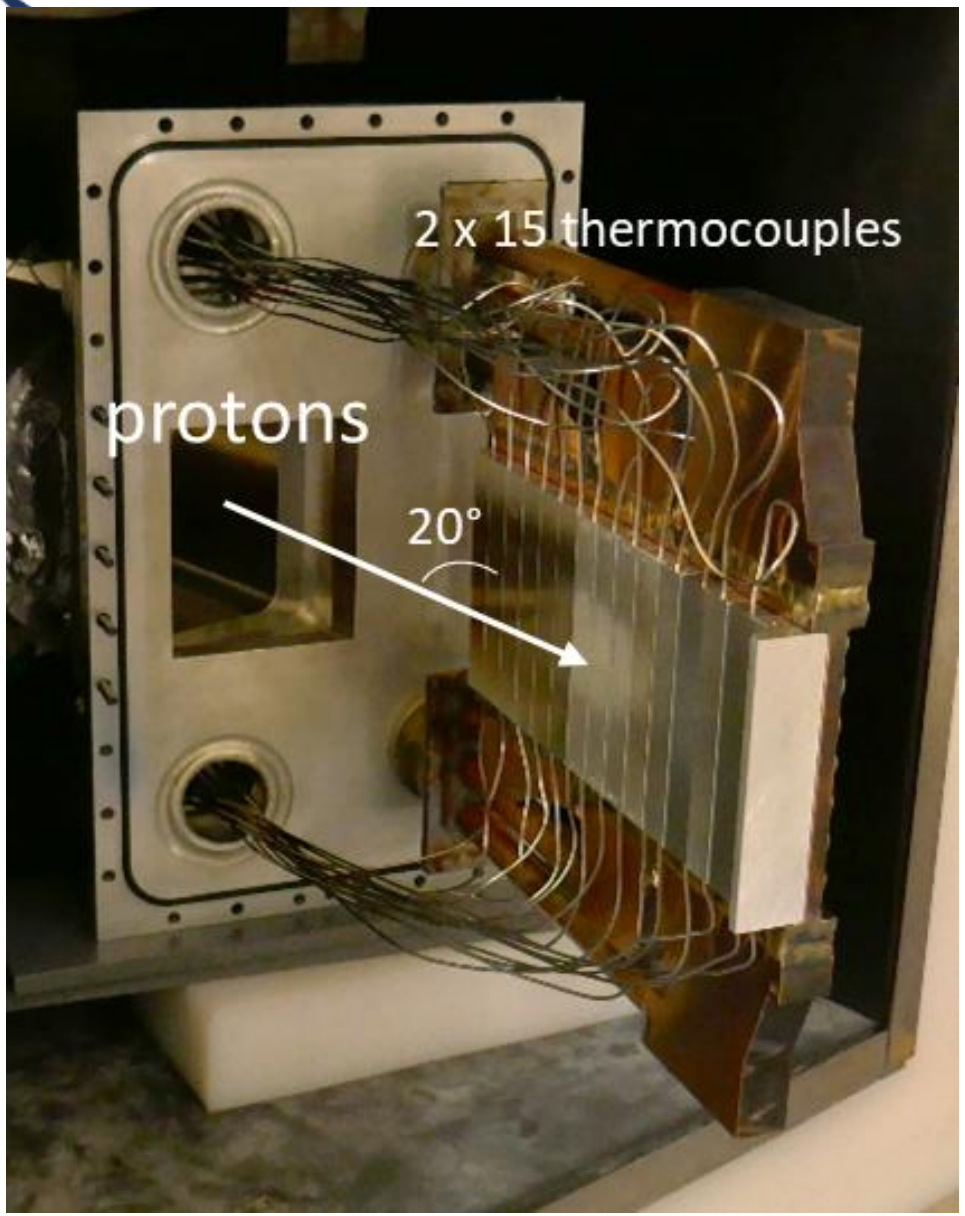
Performances: Brillance intermédiaire entre ILL et PSI



Radio protection : monolithe + casemate
Dose : 10^{12} µSv/h → <0,5 µSv/h



CIBLE BÉRYLLIUM



Proto V2 IRAMIS/LLB

Forte production de neutrons

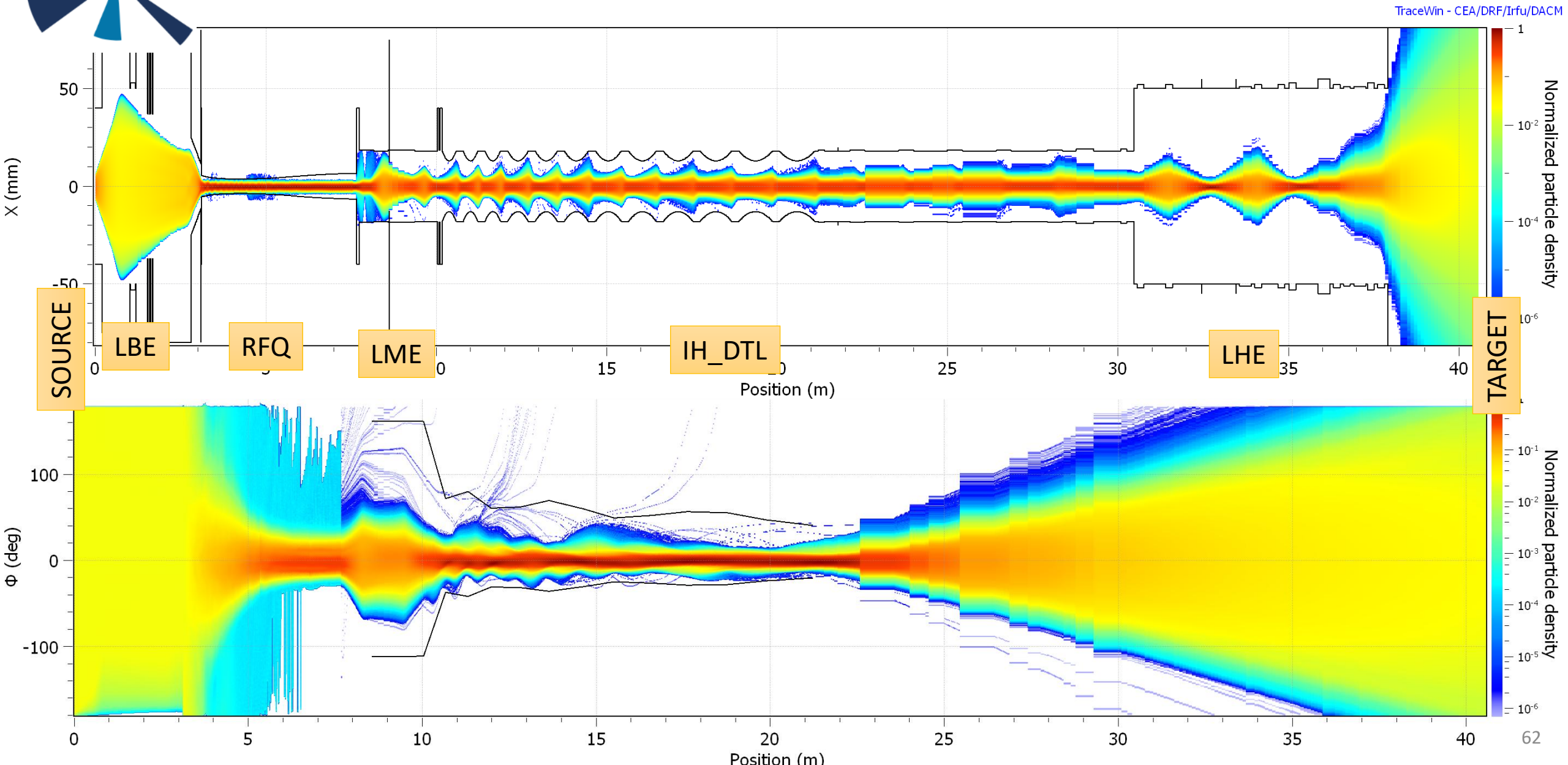
Testée 110 heures sur IPHI (éq. 500 h sur ICONE)
Faible activation

MAIS

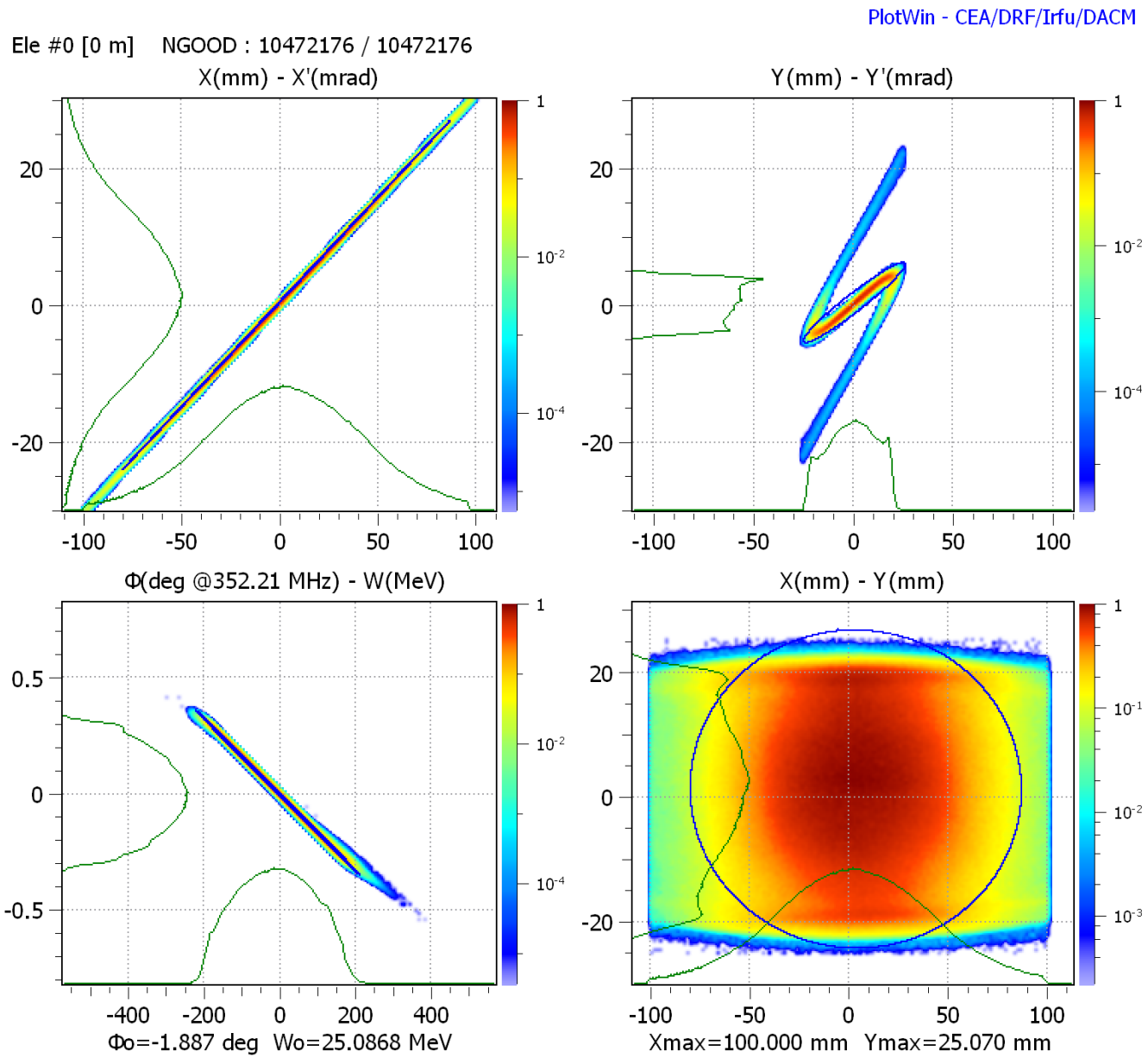
- Grande surface (P_s ~ 500 W/cm²)
- Gestion béryllium
- Durée de vie max. inconnue
  (on vise 1000 heures min)

Le design de référence pour le moment

SIMULATION (10 M PARTICLES, HF)

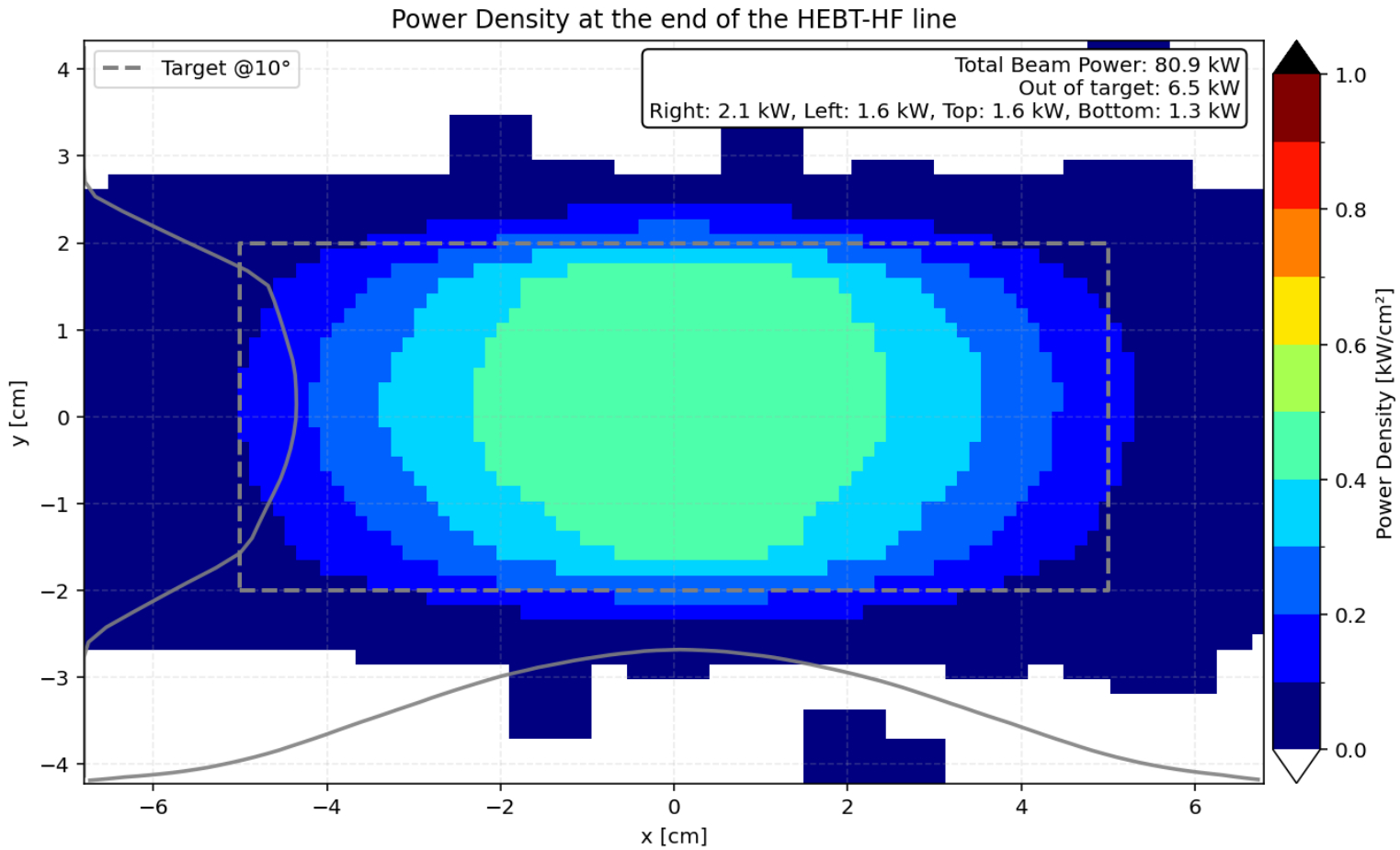


SIMULATION, BEAM ON TARGET



POWER ON TARGET

Inclinaison de la cible à 10



6,5 kW sur IRIS < 7 kW
493,6 W/cm2 max

DTL & IHDTL error calculations

~10^4 sets of error on the optics and diagnostics to estimate the robustness of the design

ICONE DTL ESS Errors

MEBT		Static	Dynamic
Quad	ΔG/G	± 1 %	± 0.2 %
Rebuncher	ΔE/E	n.a.	± 1 %
	ΔΦ (phase)	n.a.	± 1 °

BPM Precision : +/-0.25mm

LINAC		Static	Dynamic
Quad	$\delta x, y$	± 0.1 mm	
	$\theta_{x,y}$	± 1°	
	θ_z	± 0.2°	
Cavities	$\delta x, y$	± 0 mm	
	$\theta_{x,y}$	± 0°	

ICONE IH-DTL Saraf errors

MEBT		Static	Dynamic
Quad	ΔG/G	± 1 %	± 0.2 %
Rebuncher	ΔE/E	n.a.	± 1 %
	ΔΦ (phase)	n.a.	± 1 °

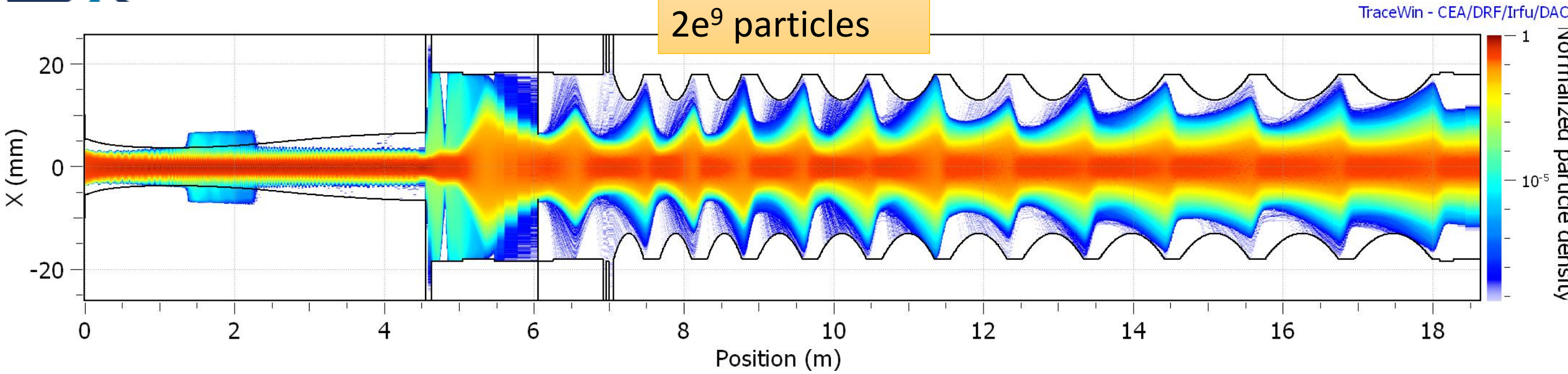
BPM Precision : +/-0.25mm

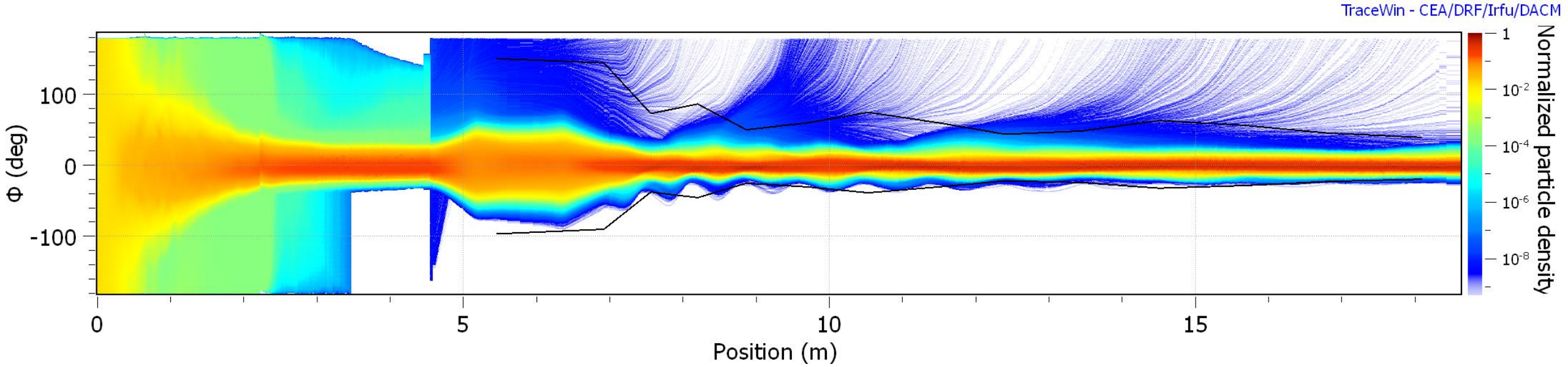
MEBT		Static	Dynamic
Quad	$\delta x, y$	± 0.22 mm	± 0.022 mm
	$\theta_{x,y}$	±0.16°	±0.016°
	θ_z	±0.08°	±0.008°
Rebuncher	$\delta x, y$	± 0.62 mm	± 0.062 mm
	$\theta_{x,y}$	±0.18°	±0.018°

Schéma de correction appliqué
10000 linac de 10^6 particules

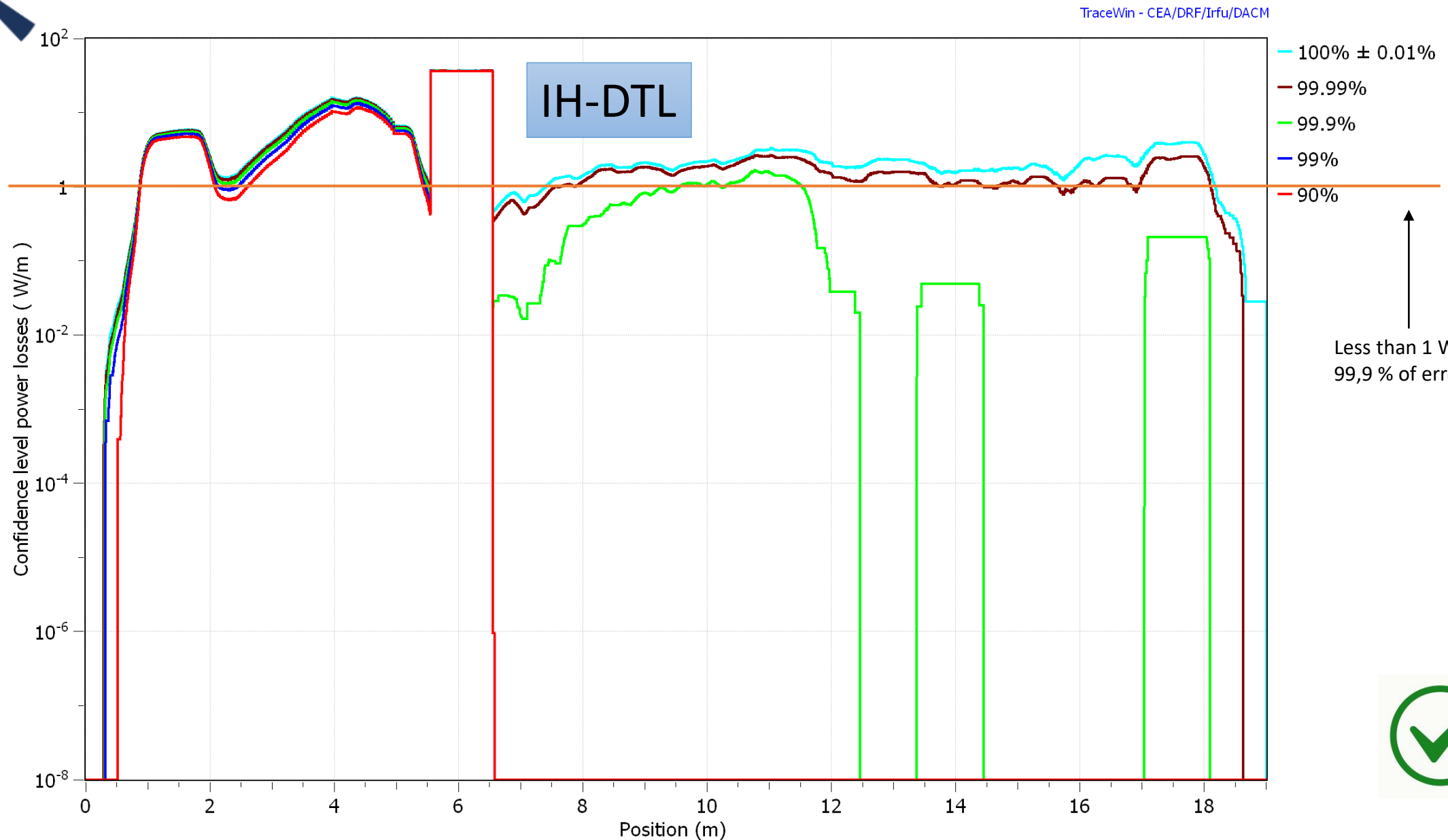
CALCUL STATISTIQUE

2e^9 particles

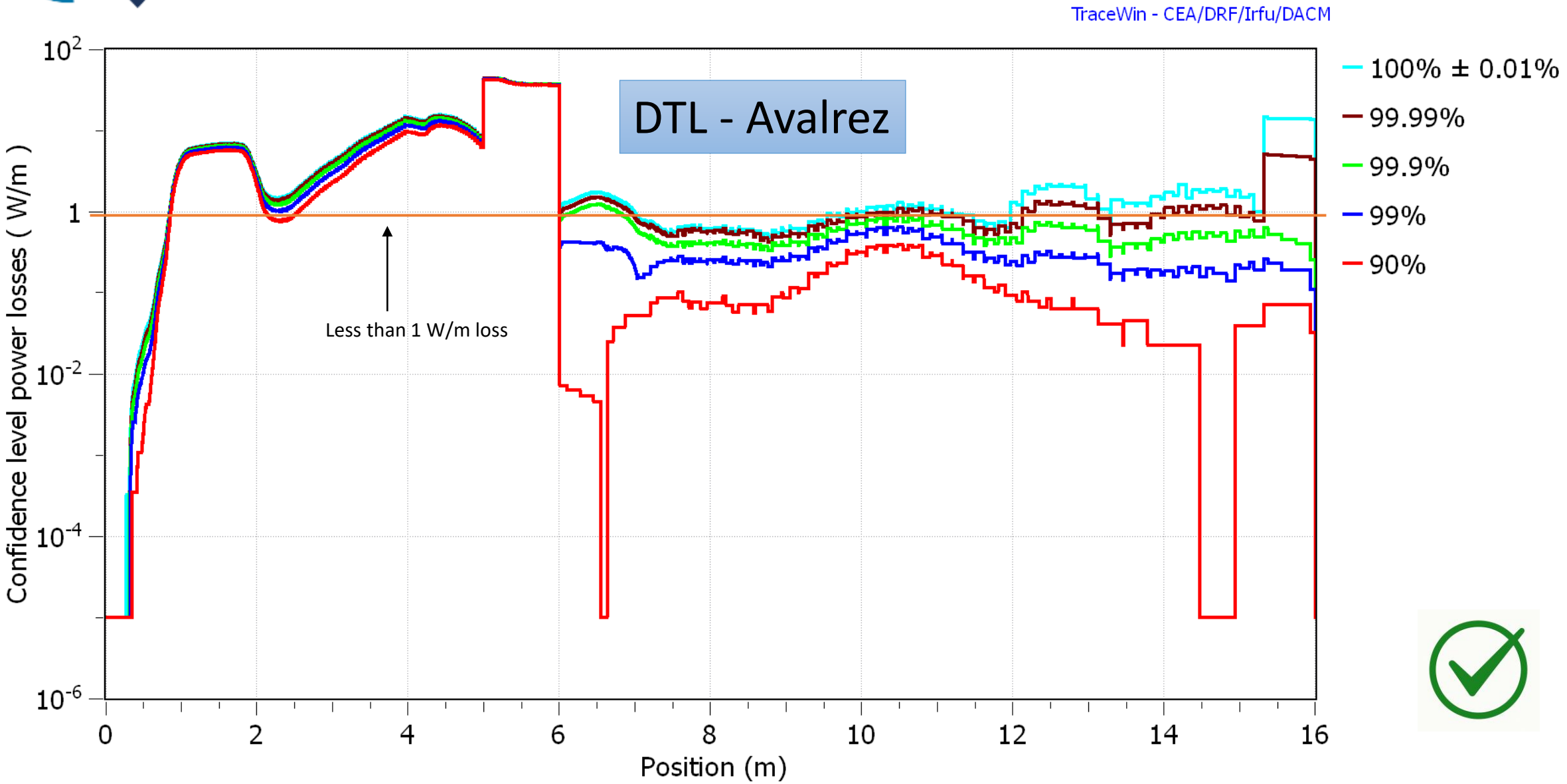




CALCUL STATISTIQUE, PERTES FAISCEAU



CALCUL STATISTIQUE, PERTES FAISCEAU



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BEAM DIAGNOSTICS

B. Bolzon, IRFU
B. Cheymol, LPSC

REQUIREMENTS FOR BEAM DIAGNOSTICS

Beam parameters to be measured		Type / Number of beam diagnostics
LEBT	Current measurement	1 ACCT on the RFQ cone + 1 FC FC: also to stop the beam
MEBT	Current measurement	1 ACCT at the RFQ-MEBT interface flange + 1 ACCT at the end of MEBT + 1 FC (N.B.: FC used also to stop the beam)
	Cut and measurement of halo	3 scrapers
	Position and phase measurement	2 BPMs
	Emittance measurement	1 slit + 1 wire scanner
IHDTL	Position and phase measurement	11 BPMs
	Loss measurement	6 nBLMs
HEBT	Current measurement	5 ACCTs + 3 FCs (N.B.: FC used also to stop the beam)
	Position measurement	4 BPMs
	Transverse profile measurement	7 wire scanners
	Loss measurement	7 nBLMs
1st target	Position measurement	1 BPM
	Transverse profile measurement	1 SEM-Grids
	Halo and aperture monitoring	1 diaphragm
2nd target	Position measurement	1 BPM
	Transverse profile measurement	1 SEM-Grids
	Halo and aperture monitoring	1 diaphragm

RESPONSE TO REQUIREMENTS

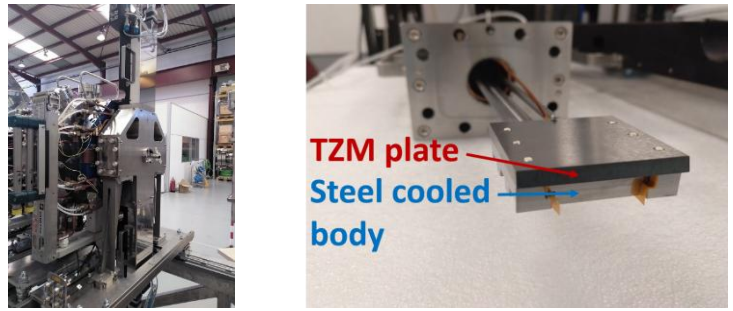
ACCT from Bergoz company (8)

- In-air and In-flange type
- Need customized solution for MEBT (In-air with customized flange)

Faraday Cup (5)

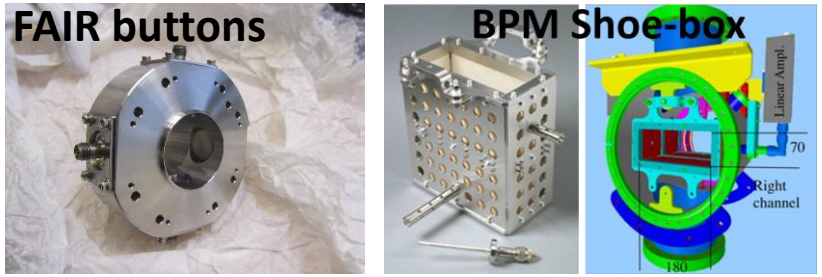
- LEBT: CEA homemade
- MEBT: NTG company 8 kW
- HEBT: Need studies (NTG ?)

MEBT Scraper from ProActive company (3)



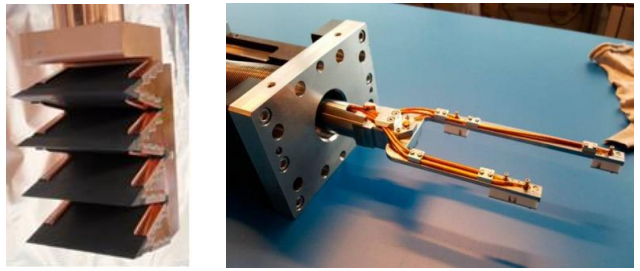
- From ESS design (very compact)
- 4 jaws (X/Y) + current measurement
- Cut 0.8% of halo (625 W peak / jaw)

BPM (19)



- MEBT, IHDTL: FAIR buttons (C. Simon)
- HEBT, A2T: Need specific design (stripline or shoe-box BPMs ?)

EMU MEBT: Slit - Wire scanner system (1)



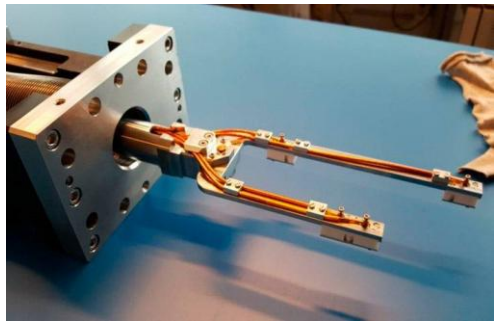
- Slit: LINAC4 or ESS design (need more simulations)
- Wire scanner: from Proactive co.

nBLM (13)

- Fast and Slow nBLMs from DEDIP
- Do not need additional studies

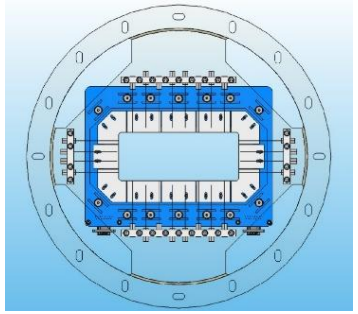
RESPONSE TO REQUIREMENTS

Wire Scanner in the HEBT (7)



- Could be from ProActive company
- Need more studies to define material / Ø of wires

Halo / Aperture monitoring next to the targets (2)



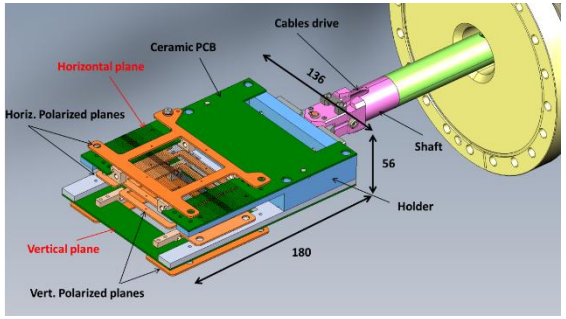
APTM assembly for the Proton Beam Window plug

E.M. Donegani et al., "Proton Beam **AP**er**T**ure **M**onitor instrument design and overview for the Commissioning and Operation of ESS High Power Beam on Target", *JINST* **19** P07009 (2024).

- Design can be similar to SNS and ESS targets
- Need more design studies (≥ 4 blades to be used as a virtual BPM)

Profile monitor next to the targets: IPMs (2) and/or SEM-Grids (2)

SEM-Grids



- Could be from ProActive company
- **Can work at full beam power (large beam Ø)**
- Need more studies (material / Ø of wires)

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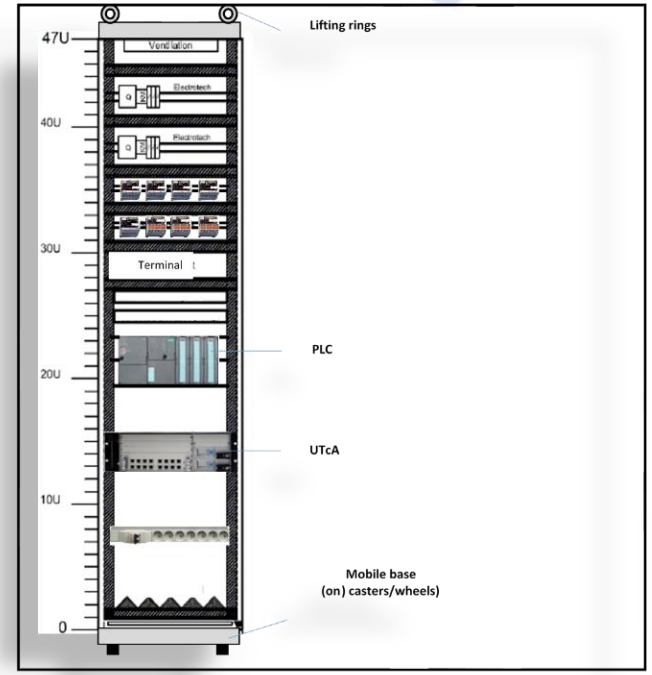


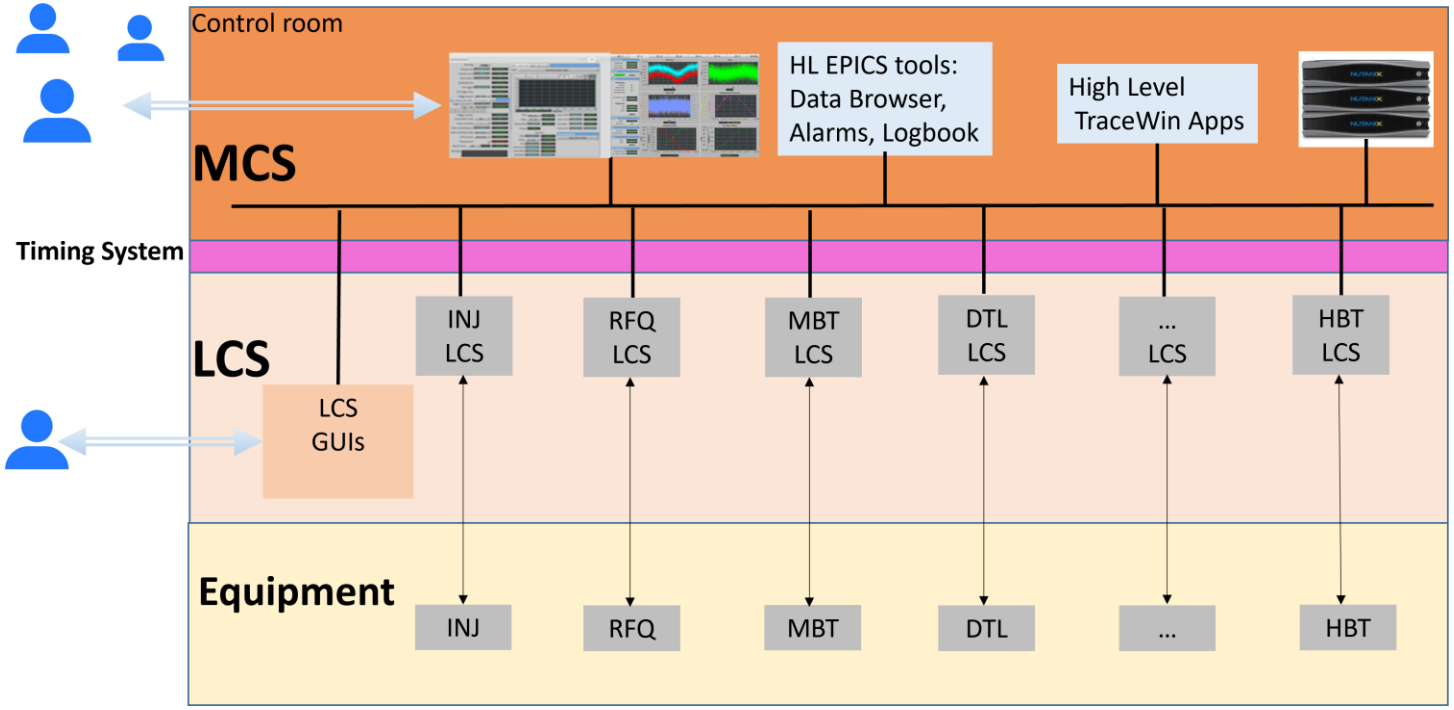
COMMAND SYSTEM

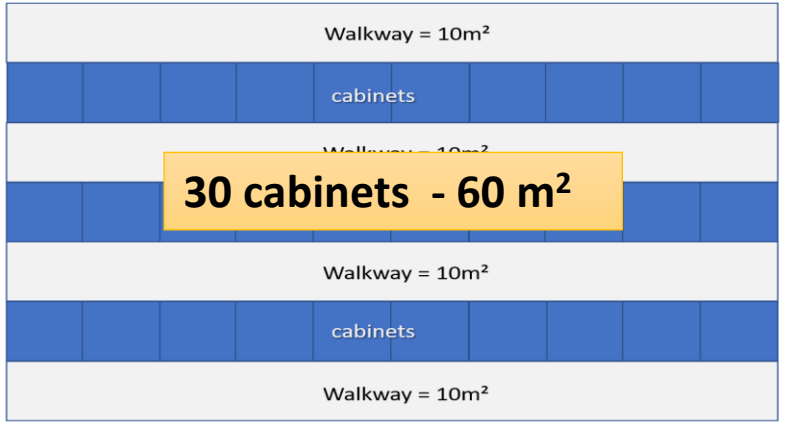
ALEXIS GAGET, IRFU
FRANÇOISE GOUGNAUD, IRFU

EPICS CHOSEN FOR ICONE CONTROL

SAME PRINCIPLES AS SARAF AND TITAN

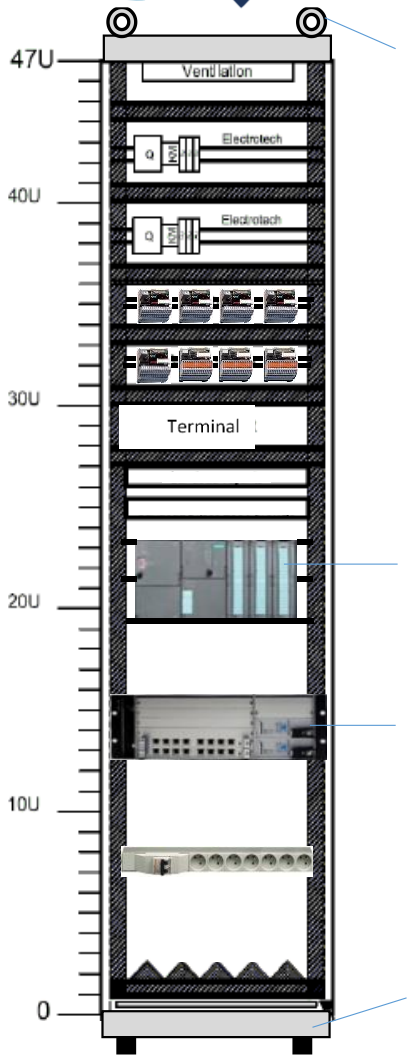
- **Main Control System**
  - High Level EPICS tools used for
    - Archiving and Visualisation
    - Alarms
    - Logbook
- **Several Local Control Systems**
  - Injector, RFQ, MEBT, DTL, … LCS
- **Timing System**
- **Machine Protection System**





HARDWARE STANDARDIZED PLATFORM

USED FOR SARAF AND TITAN



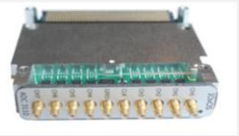
Lifting rings

PLC

UTcA

Mobile base
(on) casters/wheels

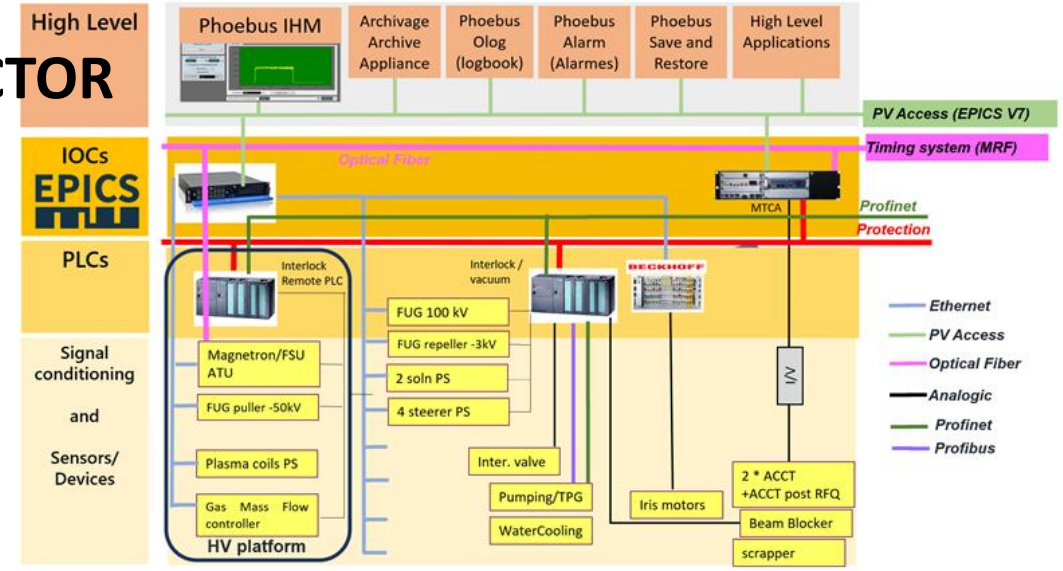
MTCA Native R2

Requirements of the devices	Sampling/monitoring frequency range	COTS solutions
Fast acquisition	**5 MS/s up to 250 MS/s**	**MTCA.4** IOxOS IFC 1410 & FMC ADC-3111 
Semi-fast acquisition	**50 KS/s up to 5 MS/s**	**MTCA.4** IOxOS IFC 1410 & IOxOS FMC ADC-3117 **MTCA.4** Desy Z7IO && D-Tacq ELF24
Remote I/Os control LAN	**100 ms up to 1s**	Beckhoff modules
Vacuum & Interlock	**100 ms up to 1s**	Siemens 1500 PLC & I/O boards/ Profinet/Profibus Fieldbuses & remote I/Os

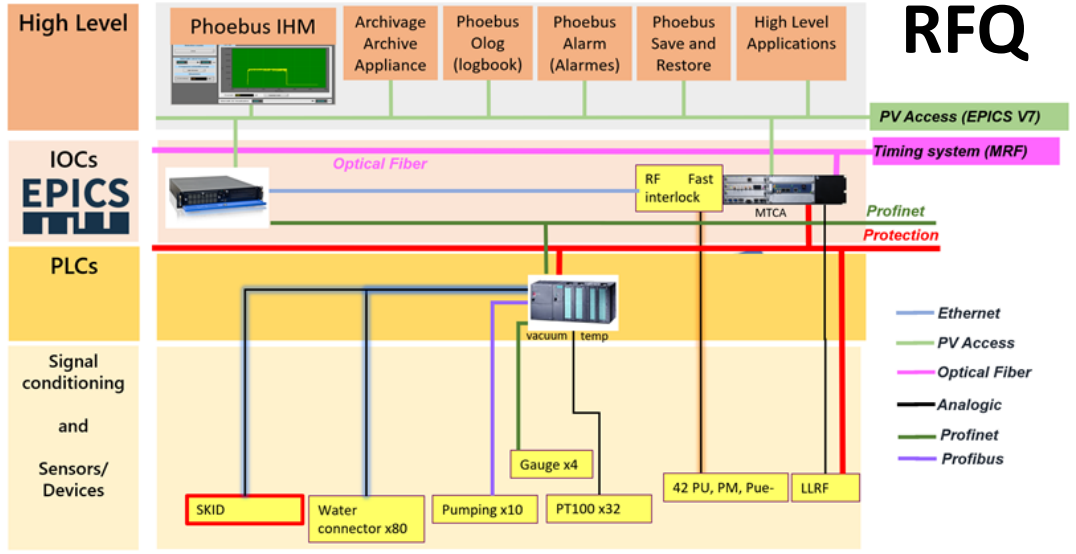
INJ, RFQ, MEBT, IH-DTL LCS ARCHITECTURE

Fast acquisition and slow control requirements were studied for each device enabling a preliminary architecture to be defined for each section.

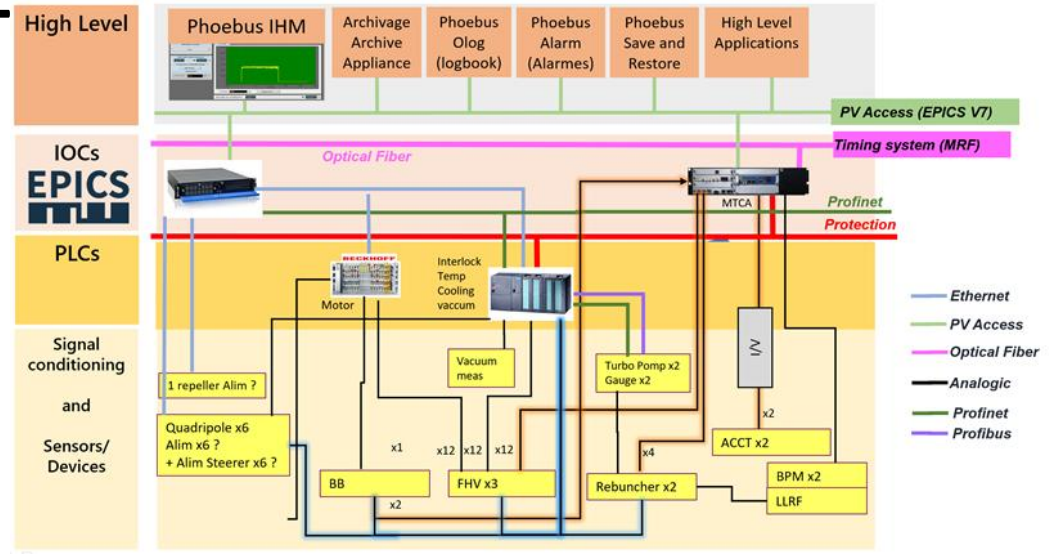
INJECTOR



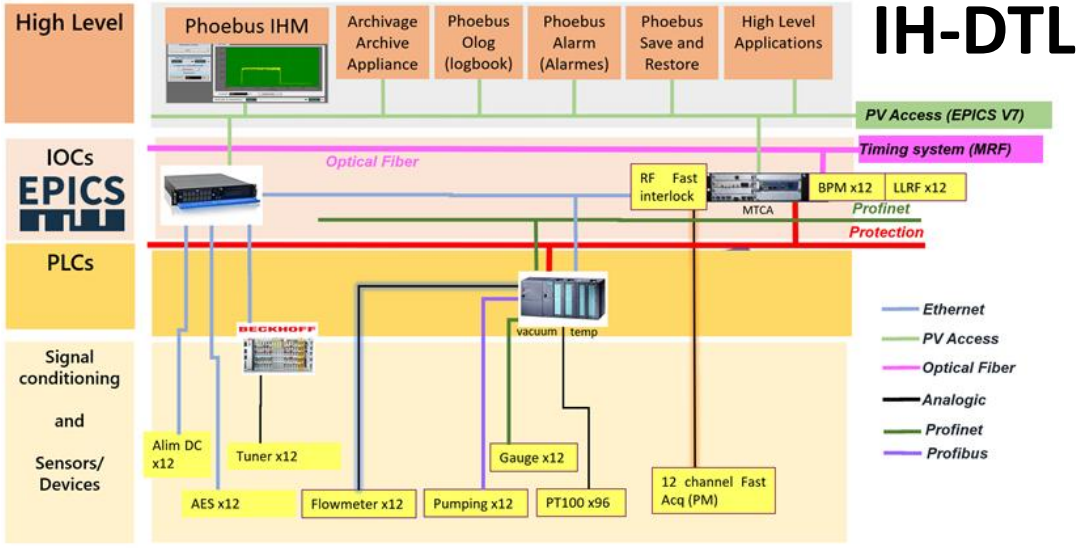
RFQ



MEBT



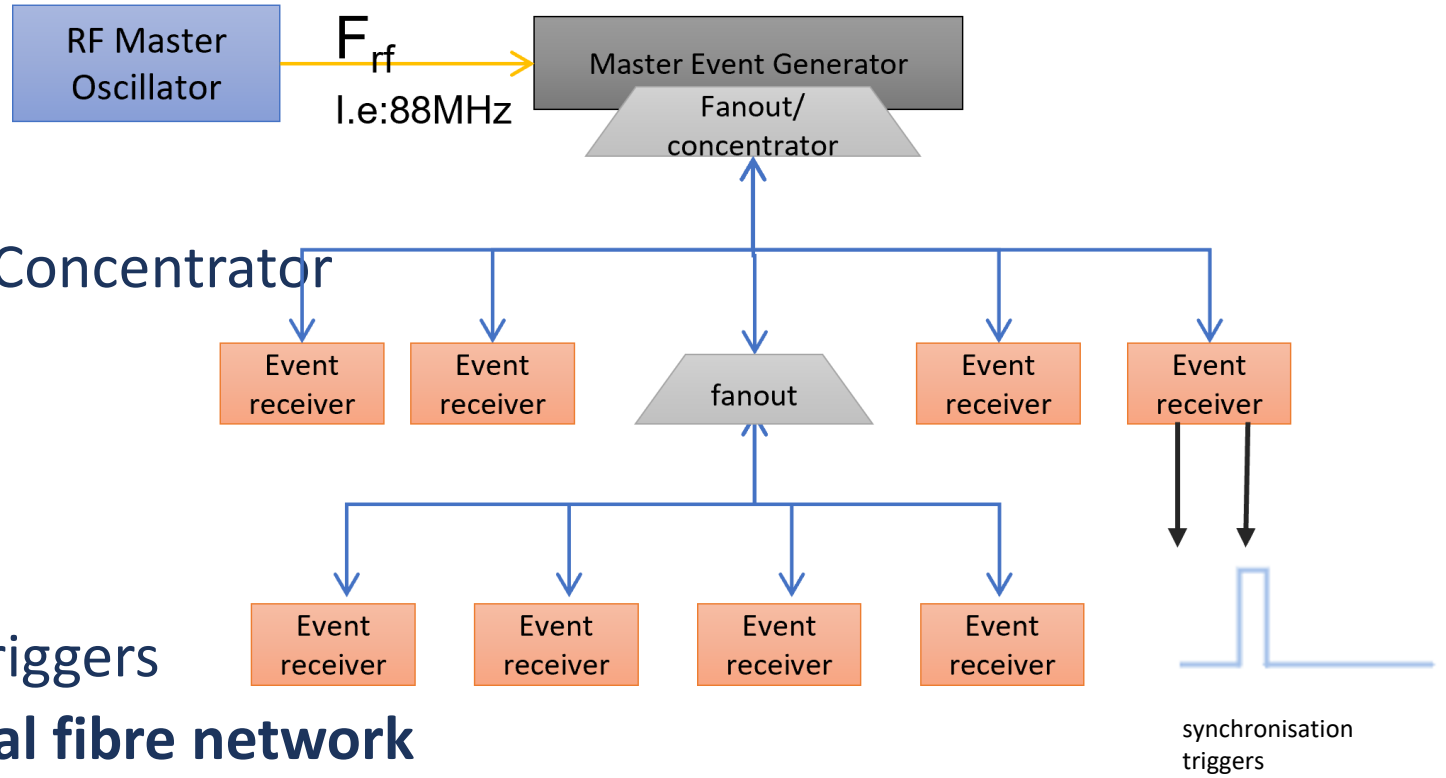
IH-DTL



TIMING SYSTEM

BASED ON SARAF AND TITAN EXPERIENCE

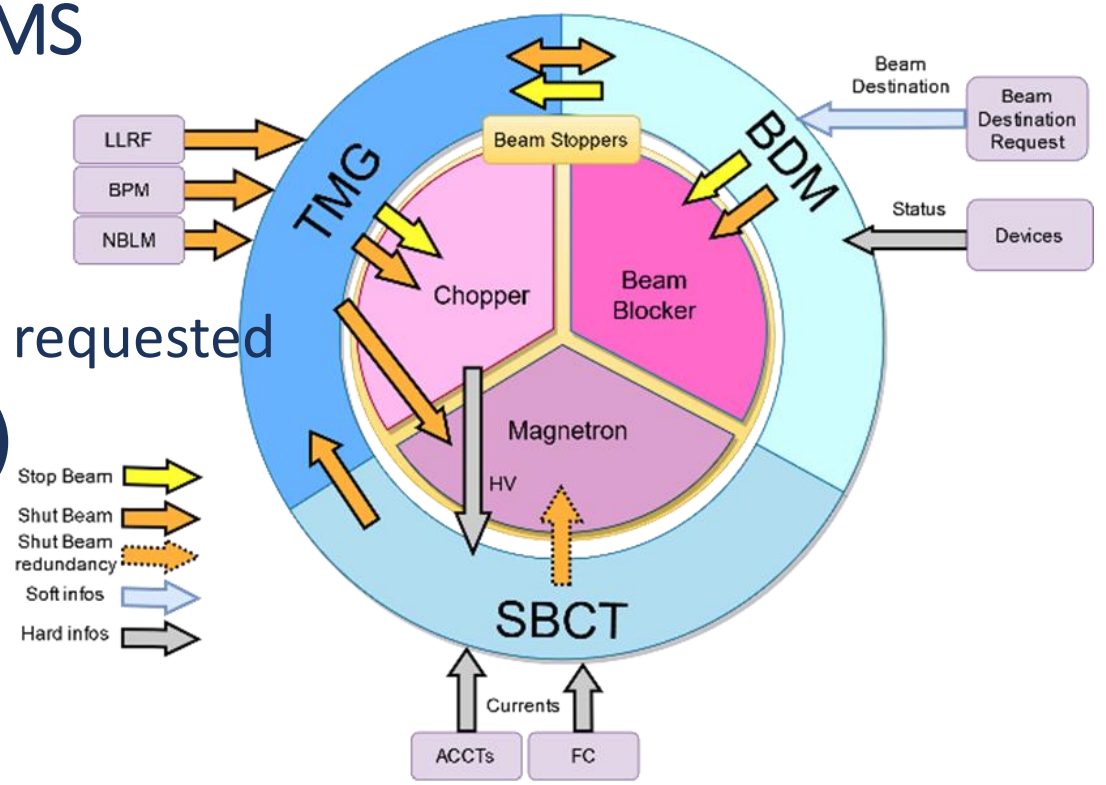
- **MRF COTS based**
  - MTCA EVM 300 used as
    - Event Generator, Fanout and Concentrator
  - MTCA EVR 300U Event Receiver
  - distributed among MTCA crates
    - in the various cabinets
    - along the accelerator
  - responsible for synchronisation triggers
  - **uses the bidirectional MRF optical fibre network**



MACHINE PROTECTION SYSTEM (SARAF)

BASED ON A SET OF 3 SUB-SYSTEMS

- **Beam Destination Master (BDM)**
  - based on a Siemens PLC, slow protection
  - checks conditions according to the destination requested
- **Section Beam Current Transmission (SBCT)**
  - MTCA IOxOS boards, fast protection
  - beam status, response time 5 µseconds
- **Timing (TMG)**
  - messenger for starting or shutting down the beam
  - uses upstrem events for fast protection



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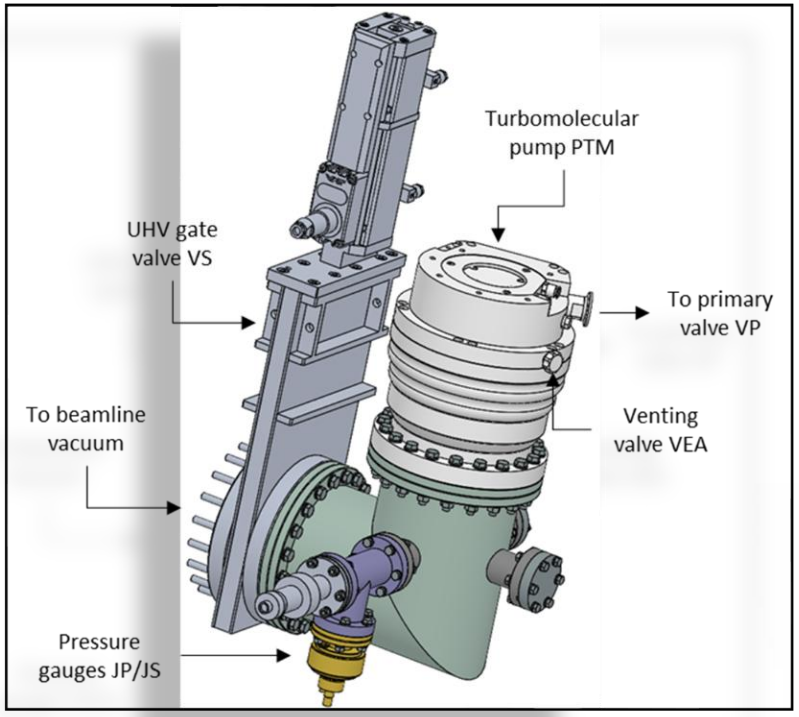
VACUUM SYSTEM

DIDIER CHIRPAZ-CERBAT, IRFU



VACUUM SYSTEM REQUIREMENTS

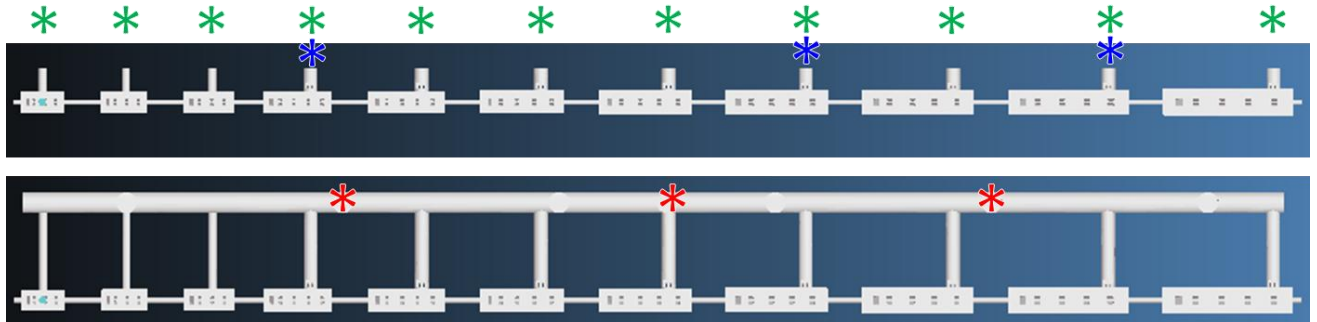
- Summary of the main requirements for the vacuum system

Sub-system	Requirement	*Notes*
LEBT	*< 5.10^{-5} mbar*	*Before RFQ entrance with hydrogen injection*
RFQ	*< 5.10^{-8} mbar*	*At 10 hours of pumping, w/o RF*
MEBT	*< 5.10^{-8} mbar*	*Within rebunchers, at 10 hours of pumping, w/o RF*
IH-DTL cavities	*< 5.10^{-8} mbar*	*Within each cavity, at 10 hours of pumping, w/o RF*
HEBT	*< 2.10^{-5} mbar*	*Along the beam axis*
	< 5.10^{-5} mbar	*Near to proton targets*

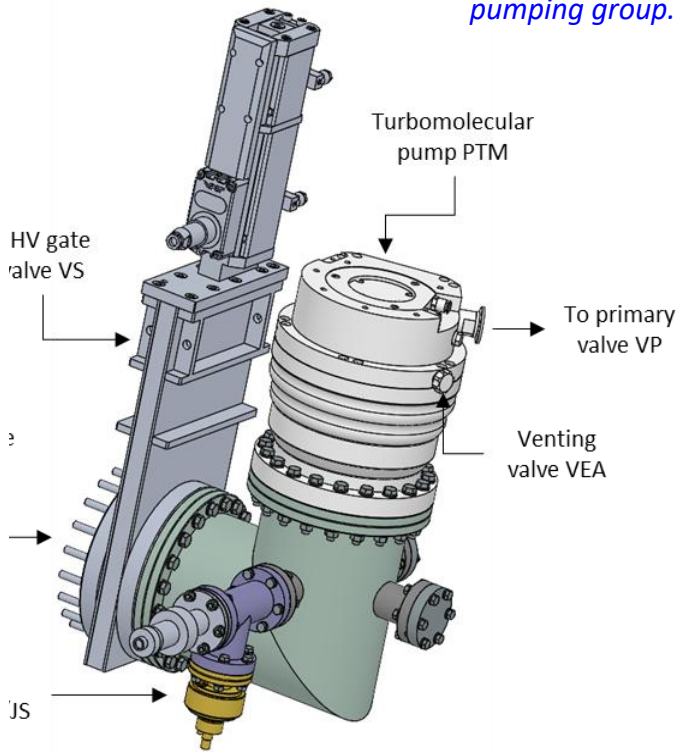
- Strategy:
  - Pre-pumping and nominal pumping using turbomolecular groups
  - Exception for the IH-DTL cavity: nominal pumping ensured by an ion pump (*a similar proposal is under study for the RFQ)

- Design of the ICONE Vacuum System:

Sub-system	Turbomolecular group	Ion pump
LEBT	*4*	*0*
RFQ	*12**	*0**
MEBT	*2*	*0*
IH-DTL	*3*	*11*
HEBT	*6*	*0*



3D-view of a standard turbomolecular pumping group.



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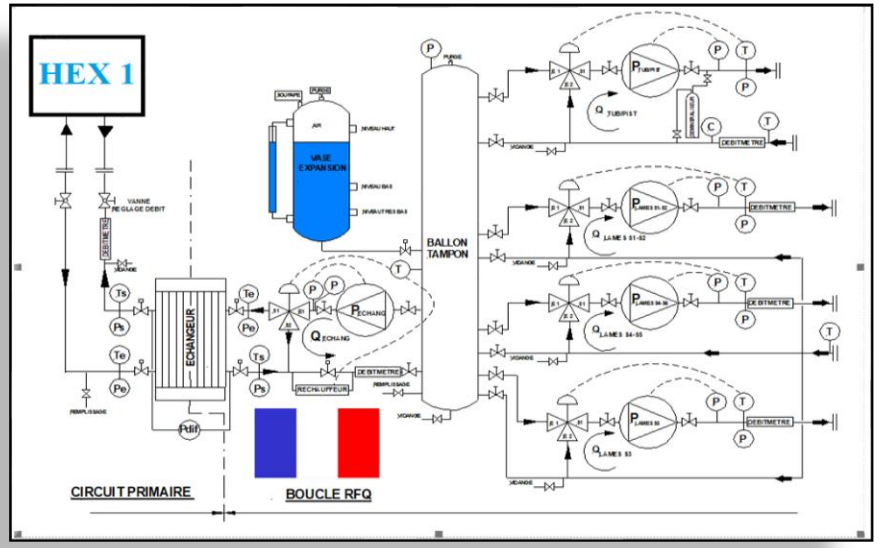
COOLING SYSTEM

SABRINE KHLIFI, IRFU



Potential Cooling Solutions

The cooling system includes three networks: **primary**, **secondary**, and **tertiary**.

•The **primary network** uses an **open air-cooled tower** (1.2 MW, 364 m³/h) to transfer heat to the secondary network via **three plate heat exchangers**.

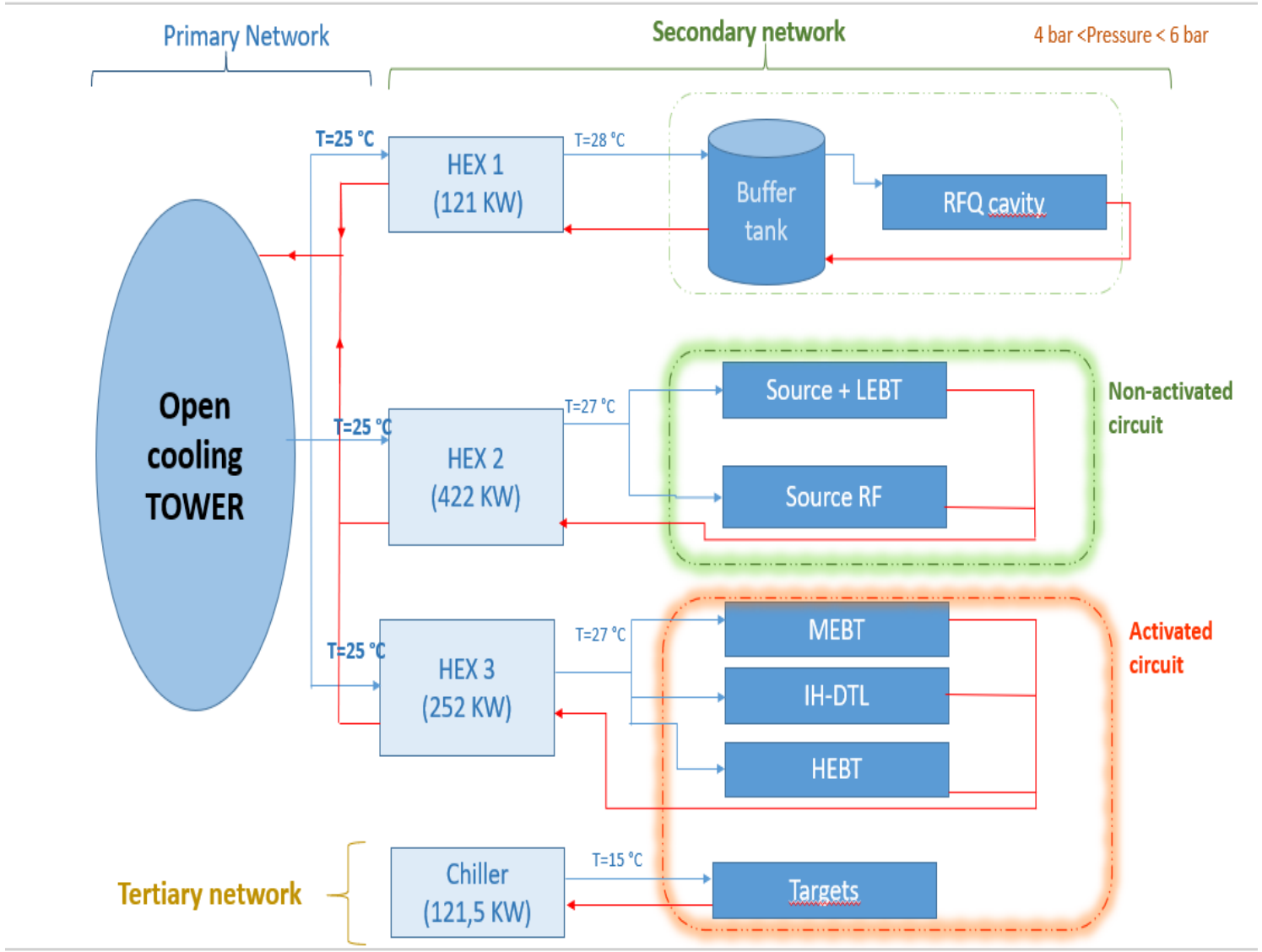
•The **secondary network** distributes chilled water through **three loops**:

- **Loop 1** (RFQ cavity): 121 kW exchanger, 50 m³/h, regulated at **28 ± 1°C**.
- **Loop 2** (Source + LEBT, RF source, IH-DTL amplifiers): 422.7 kW, 224.1 m³/h, **27 ± 1°C**.
- **Loop 3** (MEBT, IH-DTL, HEBT): 252.9 kW, 59.5 m³/h, **27 ± 1°C**.

  ➤ *Physically separated due to potential water activation from beam interception.*

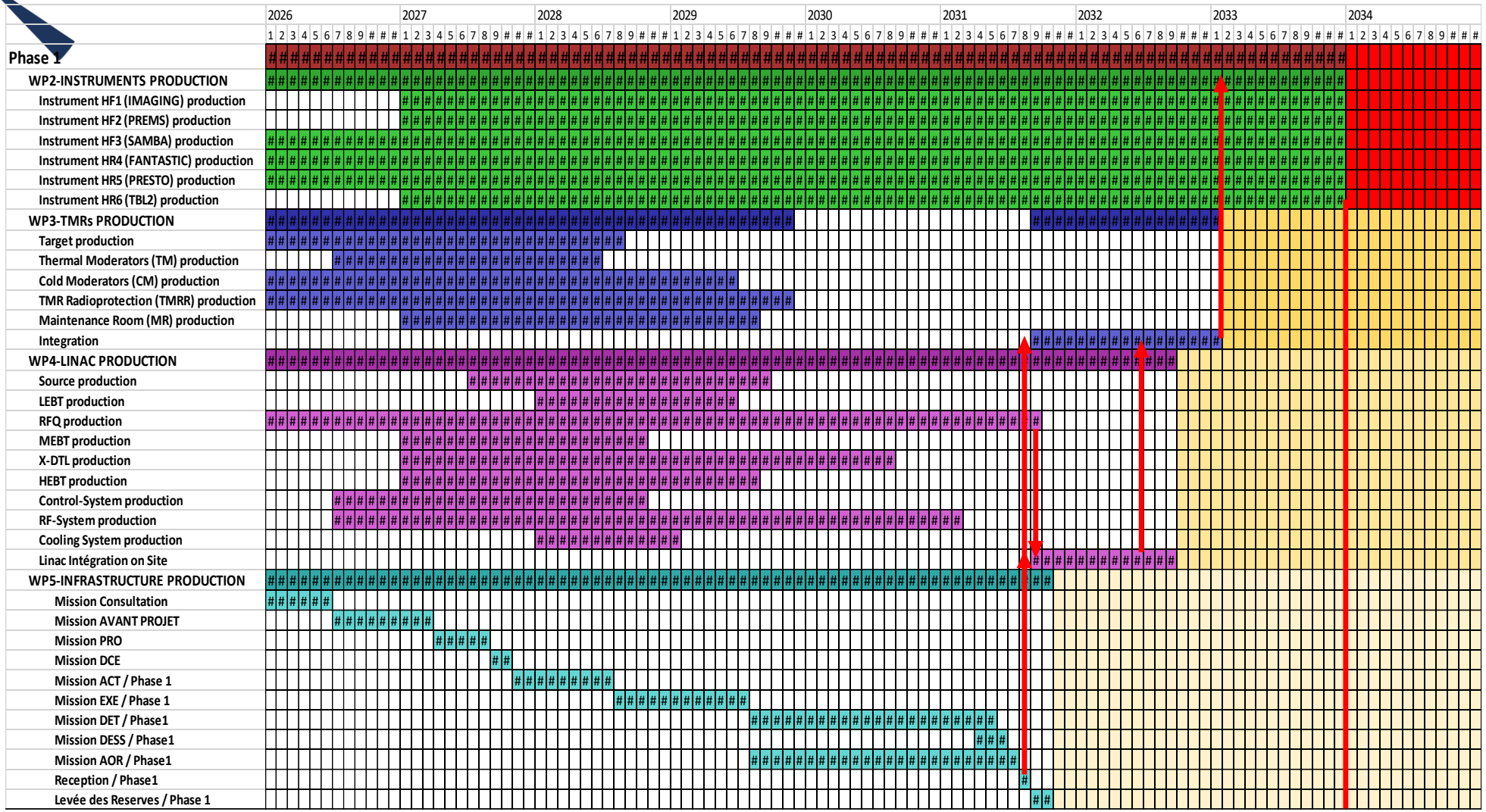
•The **Targets network** is powered by a **standalone 121.5 kW chiller (groupe froid)** (16.8 m³/h), cooling the **targets** at the end of the beamline, with water inlet regulated at **15°C**.

All circuits include a **20% safety margin** and use **deionized water** via resin-based units to protect sensitive components.



Débit total de 364,45 m³/h et une puissance thermique de 1.2 MW

PLANNING GÉNÉRAL



Phasage de l'installation des composants du linac en partie pilotée par un lissage des dépenses du projets

WEB

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ICONE
LES NEUTRONS
ICONE
ACTUALITÉS
UTILISATEURS
Contact
ICONE : une nouvelle source de diffusion neutronique française
ACCÉLÉRATEUR DE PROTONS
CIBLE 1
CIBLE 2
INSTRUMENTS HAUT-FLUX
DÉTAILS D'UNE CIBLE
INSTRUMENTS HAUTE-RÉSOLUTION
2024
2026
> 2032
> 2036
Avant-projet
Construction
Neutrons Haut-Flux
Neutrons Haute-Résolution

Merci de votre attention

Commissariat à l'énergie atomique et aux énergies alternatives
Centre de Saclay | 91191 Gif-sur-Yvette Cedex
T. +33 (0)1 69 08 82 64 |
Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

Instruments (WP2)

Diffraction

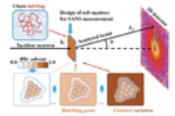
PRESTO IIII
(with polarisation)

PRECIS IIII
High resolution

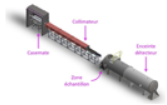
Large Scale Structures

PREMS ▬
Reflectometer

LAMBDA ▬
SANS

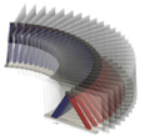


NANOSANS ▬
Nanostructure

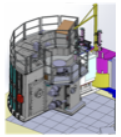


Spectroscopy

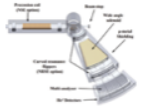
FANTASTIC IIII
Inelastic



INEDIT IIII
ToF



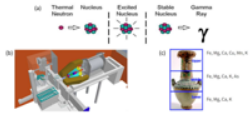
PULSE
Spin-echo ▬
or back-scattering? IIII



Material and engineering

IMAGING ▬
Radiography

GOLF ▬
PGAA - Analyse élémentaire



LITE HF + HR
▬ IIII

Instr. Phase 1
Instr. Phase 2

▬ Long pulse (HF x6)
IIII Short pulse (HR x6)

Soft matter
Biology
Magnetism
Engineering and geoscience
Material sciences
Archeo and culture heritage
Industry

4

ATOUTS D'ICONE

Productivité

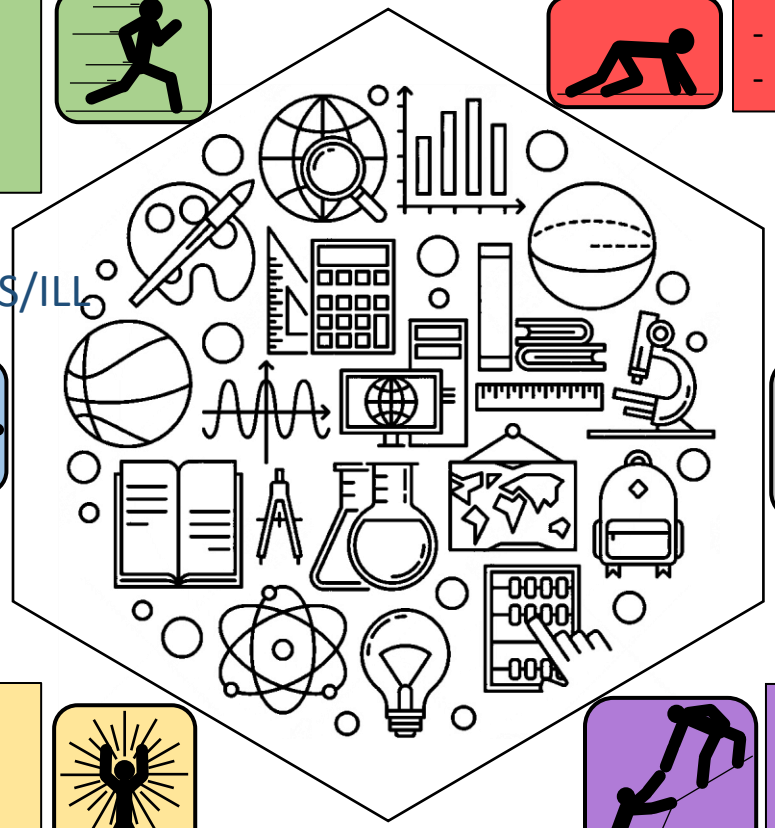
- Flux ~ **ORPHÉE**
- Impulsionnel → nativement **résolues en temps**
- **2 cibles** : HF (ESS-like) et HR (SNS-like).
- **10 instruments** → grande variété d'analyses
- Des points **sources libres** pour explorer et apprendre
- Des programmes de **recherche interne**

Réactivité

- Lignes/créneaux **réservés** à la demande réactive
- **Souplesse** opérationnelle (accès et environnement)
- **Soutien** des « utilisateurs » par une équipe locale
- **Coût** d'expériences plus abordable qu'ESS

Synergie/ESS/ILL

- Exp. nécessitant **moins de flux**
- **Accessible** (temps, procédure, coût)
- **Priorité différentes**
- **Préparation** pour ESS
- **Formation** pour ESS/ILL
- **Entrainement** pour ESS



Efficacité

- **Acceptation sociétale** bonne
- Pas une **INB**
- Pas de **combustible** nucléaire
- **Maturité** technologique CEA-CNRS
- **Coût** réduit (versus ESS) ~1/10.
- **Phasage** possible.
- Possibilité d'**upgrade**.
- Possibilité d'**exportation**.

Rayonnement

- A jamais **la première** HiCANS !
- Un institut de **recherche dynamique**
- Un centre de **formation de pointe**
- **Réactivité** = **créativité** des utilisateurs
- Une **attractivité** inégalée
- Au centre d'un **pôle scientifique** de pointe

Transmission

- Dispositif **unique** pour l'exploration de la matière
- TP sur des **lignes/créneaux dédiés** à la formation
- **Alternance** sur les lignes de production
- **Environnement académique** de pointe
- **Mutualisation** avec d'autres méthodes d'analyse
- Implication des **chercheurs/enseignants locaux**

Notes pour comprendre