ICONE
Neutrons for Materials Sciences

https://www.icone-neutron.fr/

ICONE
prêt à construire

Nicolas Pichoff

Neutrons ?

Diffusion inélastique

Diffusion élastique

Spin

Peu d'interaction

Interaction nucléaire

Diffusion inélastique
STUDY DYNAMICS

Neutron energies are comparable to the time scales of molecular diffusion, vibrations and rotations.

Diffusion élastique
STUDY STRUCTURE

Neutron wavelengths are comparable to the spacings of atoms and molecules.

Peu d'interaction
PENETRATION POWER

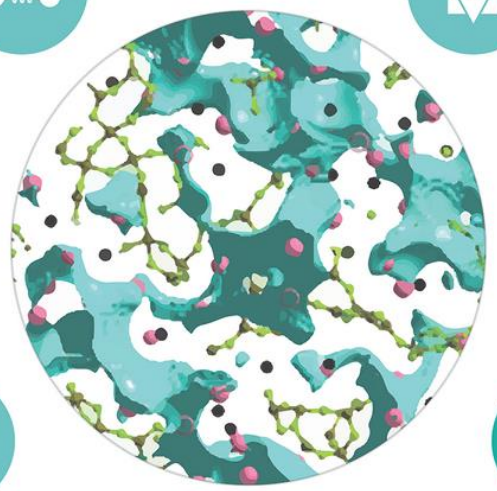
Neutrons can penetrate deep into matter (including many different metals) enabling the study of large samples - even within complex sample environments.

Spin
STUDY MAGNETISM

The neutron's magnetic moment can be used to study the microscopic magnetic properties of materials.

Peu d'interaction
NON-DESTRUCTIVE

Neutrons are suitable for the characterisation of delicate and precious samples.



Peu d'interaction
VERSATILE SAMPLE ENVIRONMENTS

Sophisticated sample environments enable studies under operating conditions, including extreme temperatures and pressures.

Interaction nucléaire
SENSITIVITY TO LIGHT ELEMENTS

The neutron scattering power of nuclei varies in a quasi-random manner such that lighter atoms (e.g. H, Li) can be studied in the presence of heavier ones.

Interaction nucléaire
COMPLEMENTARITY

Neutron scattering is highly complementary to other techniques, such as X-ray scattering, electron microscopy, magnetic resonance and computational methods.

Interaction nucléaire
ISOTOPIC CONTRAST

Neutrons are sensitive to different isotopes of the same element, so isotopic substitution (e.g. H/D) can be used to highlight specific features.

https://lens-initiative.org/wp-content/uploads/2022/08/LENS-Report-fin_doublepages.pdf

ICONE ?

Etude de la matière (inerte ou vivante)

Proposer ~300 expériences de neutronique/an

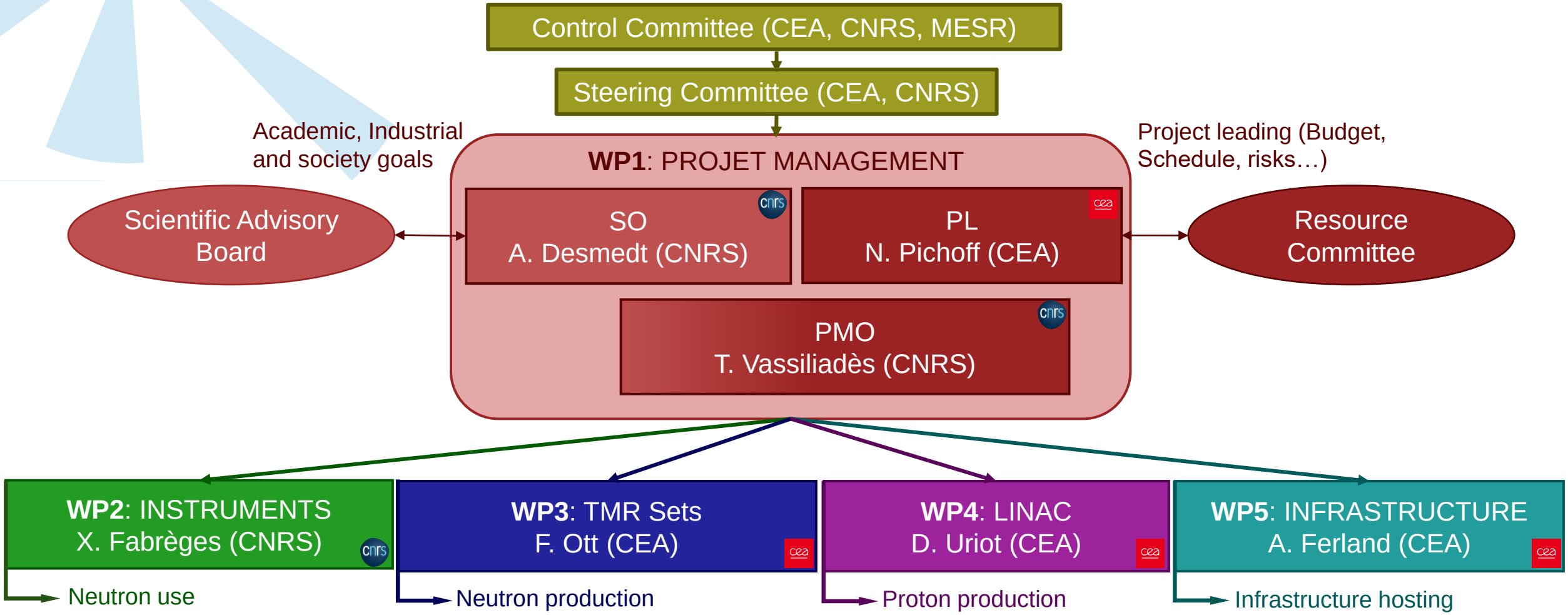
→ **12 instruments** : Suivant le besoin scientifique

→ **2 source de neutrons** : Haut Flux (HF) : ~2 ms@20Hz (4% DC)
Haute Résolution (HR) : ~400 µs@50Hz (2% DC)

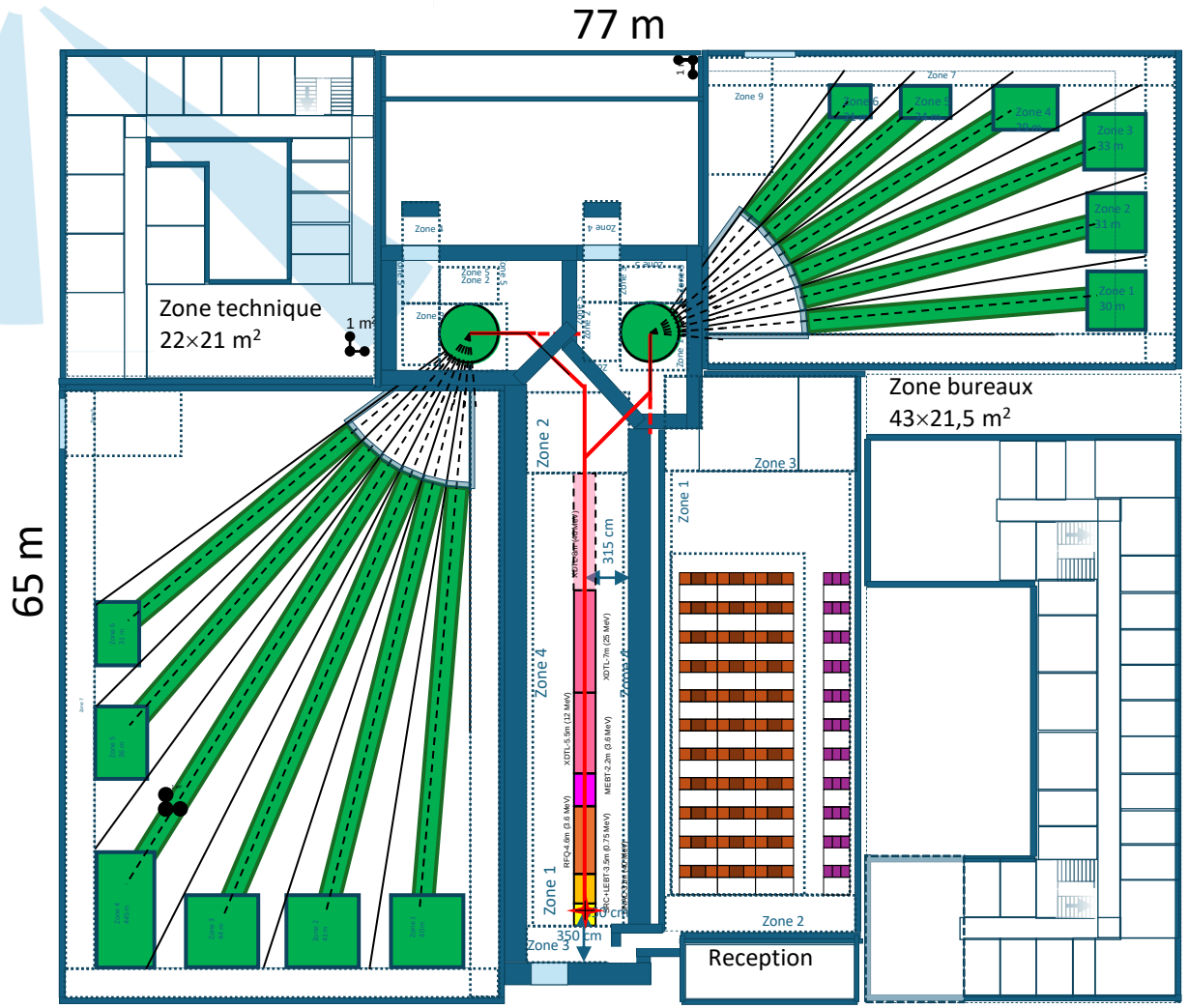
→ **1 accélérateur de protons**: 25 MeV, 80 mA @ 8% of Duty Cycle (DC)

Former des ingénieurs/chercheurs en matériaux

Organisation du Projet



Vue d'ensemble



- Accelerateur p^+, 80 mA, 25 MeV @ 8%DC

- Brillance neutrons:
~ 5 10^{11} /s/cm²/sr/Å @ 1 Å et 2.5 Å
~ 10^{11} /s/cm²/sr/Å @ 5 Å

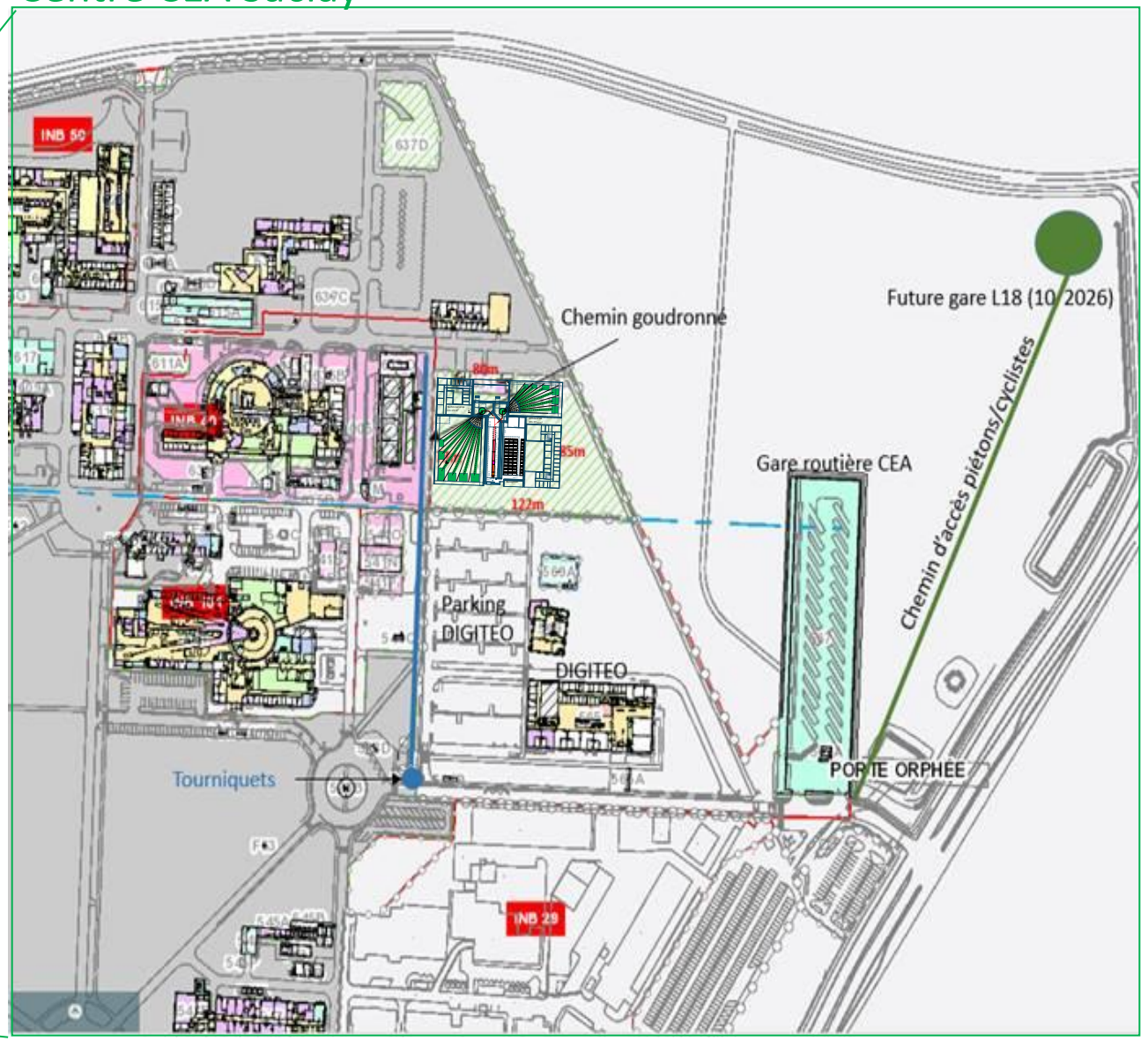
- Cible 1 : 0,4 ms@50 Hz (2% DC)
  - 6 instruments HR (<44 m)

- Cible 2 : 2,0 ms@20 Hz (4% DC)
  - 6 instruments HF (<33 m)

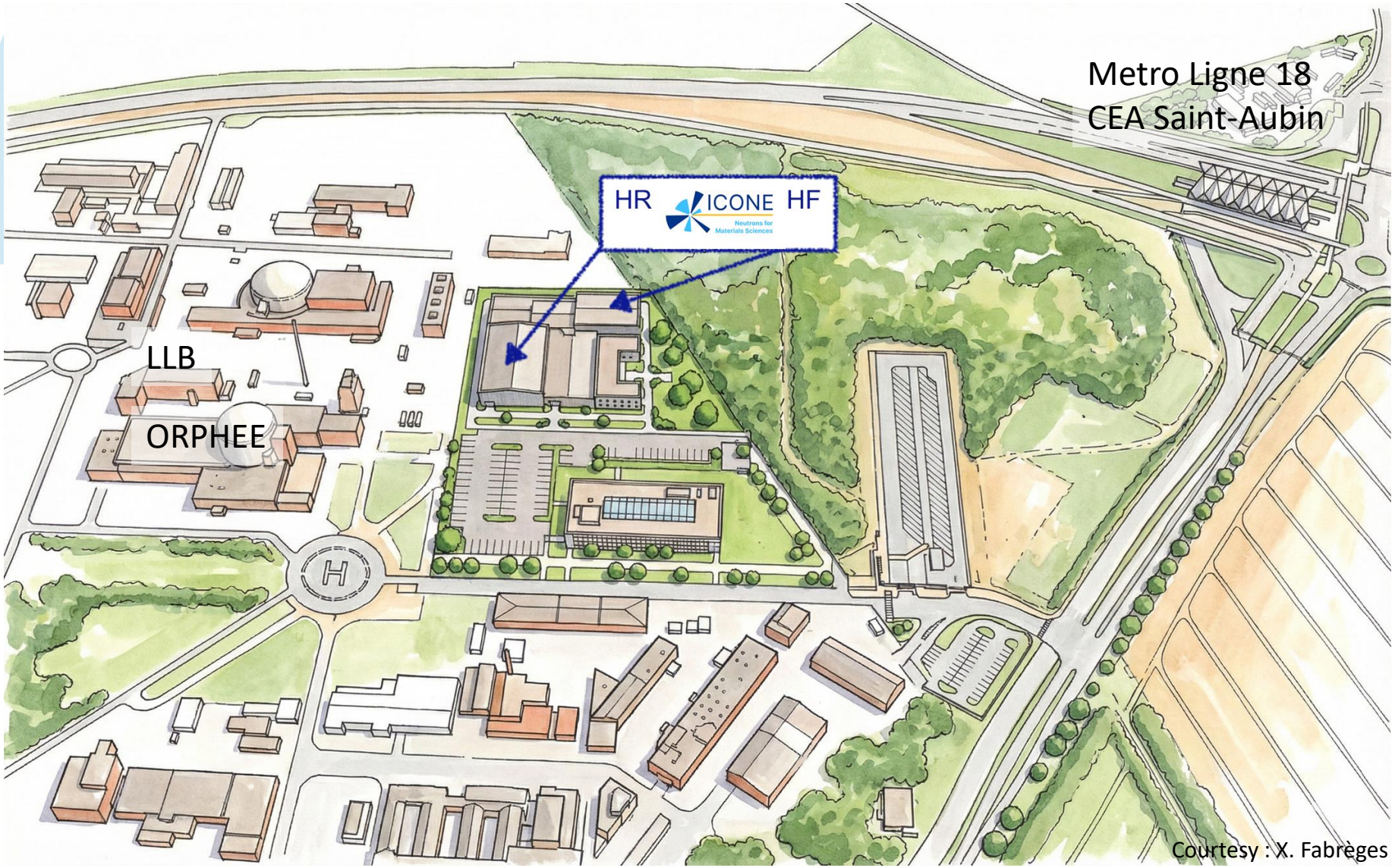
- Bâtiments personnel :
  - Zone technique (~1000 m²)
  - Zone bureau (~1500 m²)

Position

Centre CEA Saclay



Vue d’artiste



Cas scientifique (WP1)

→ Spécification des performances espérées et des instruments

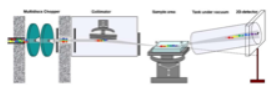
Diffraction

PRESTO IIII
(with polarisation)

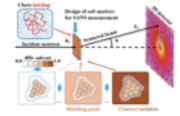
PRECIS IIII
High resolution

Large Scale Structures

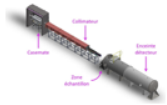
PREMS ▬
Reflectometer



LAMBDA ▬
SANS

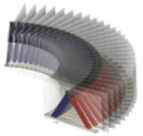


NANOSANS ▬
Nanostructure

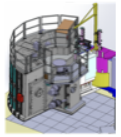


Spectroscopy

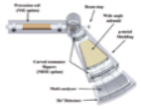
FANTASTIC IIII
Inelastic



INEDIT IIII
ToF



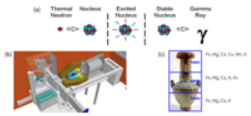
PULSE
Spin-echo ▬
or back-scattering? IIII



Material and engineering

IMAGING ▬
Radiography

GOLF ▬
PGAA - Analyse élémentaire



LITE HF + HR
▬ IIII

Instr. Phase 1 ▬ Long pulse (HF x6)
Instr. Phase 2 IIII Short pulse (HR x6)

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

Plan de construction (WP1)

RBS - Requirements

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 - Work

1	1	ICONE	573 sem.	Lun 05/01/26	Ven 26/12/3(	########	########	########	########	########	########	
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 26/12/3(	########	########	########	########	########	########	
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	########	########	########	########	########	########	

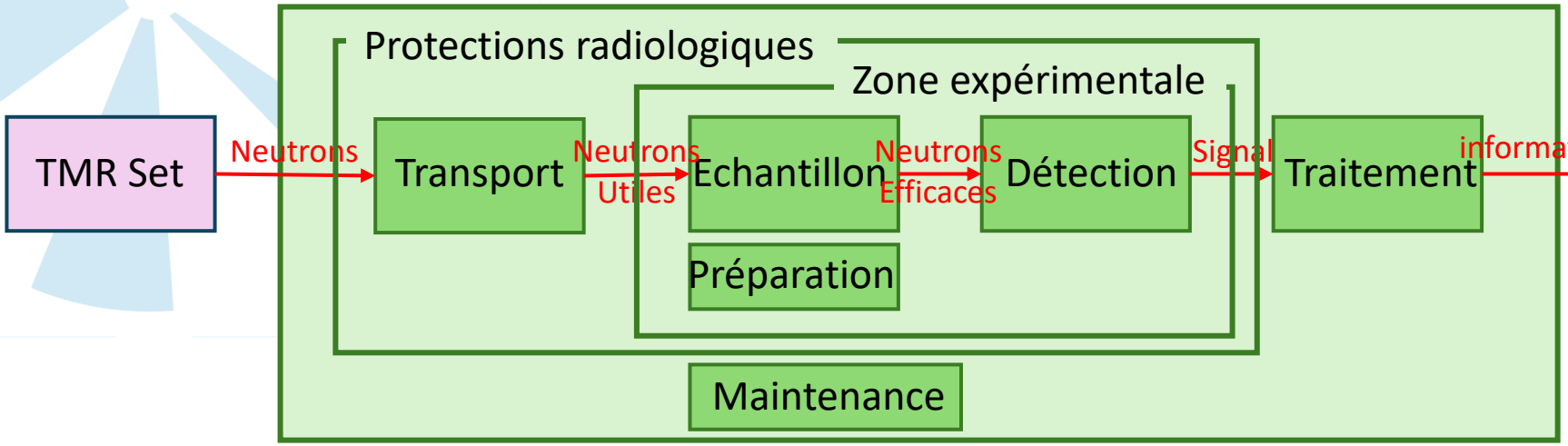
Du besoin au produit…

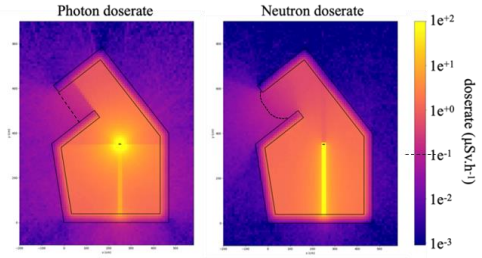
… au plan

PBS - Product

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	

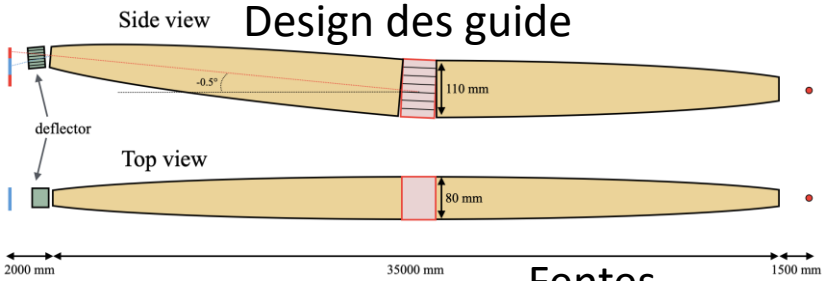
Instruments (WP2) – maturités diverses



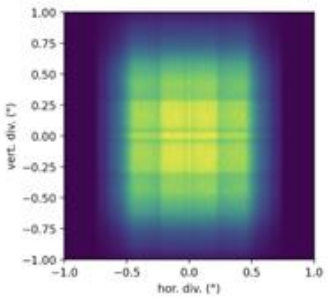


Radioprotection

Design des guide



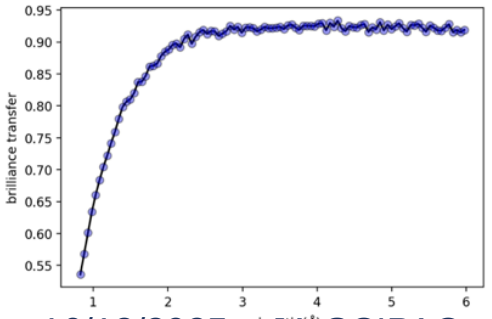
Irradiation



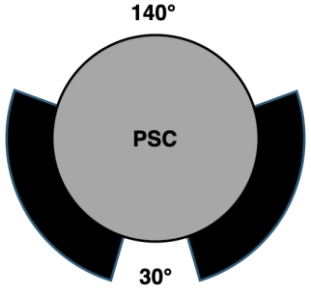
Détecteur

Détecteur neutron

Calcul de transmission



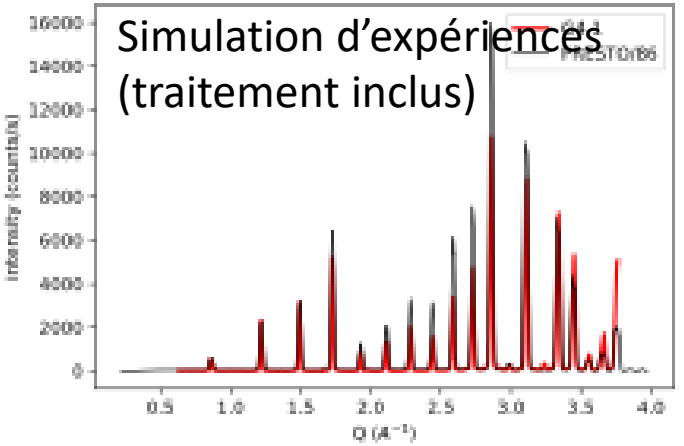
Fentes



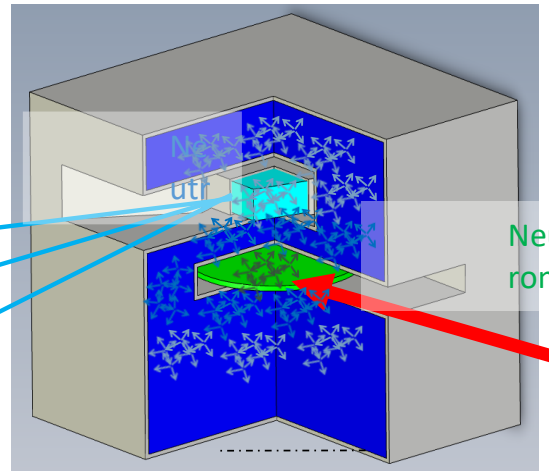
Choppers

Environnement

Simulation d'expériences (traitement inclus)



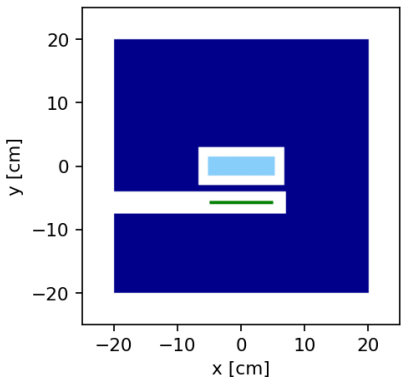
Cible-Modérateur-Réflecteur (WP3)



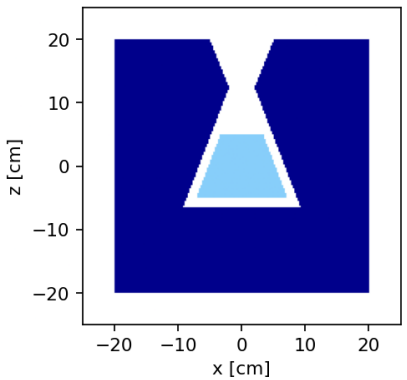
Water (thermal moderator)
Hydrogen (cold moderator)
Be target
Aluminum containers

Le réflecteur (non représenté) est en Be

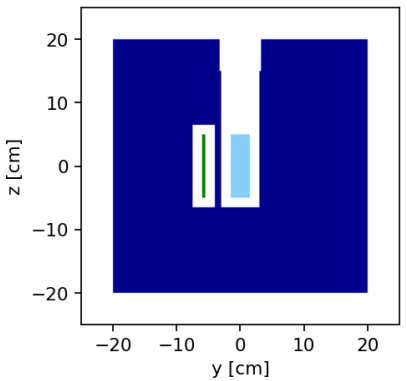
SIDE VIEW

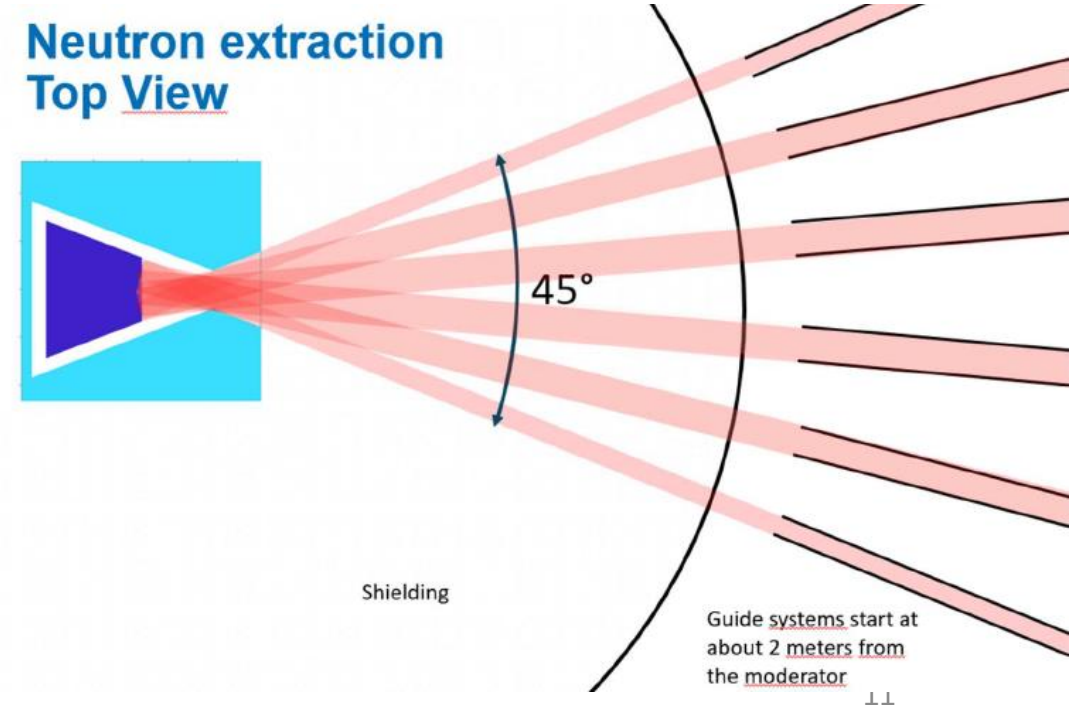


TOP VIEW



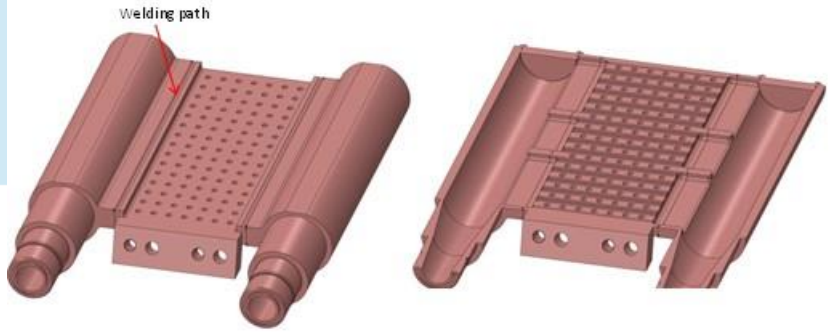
SIDE VIEW



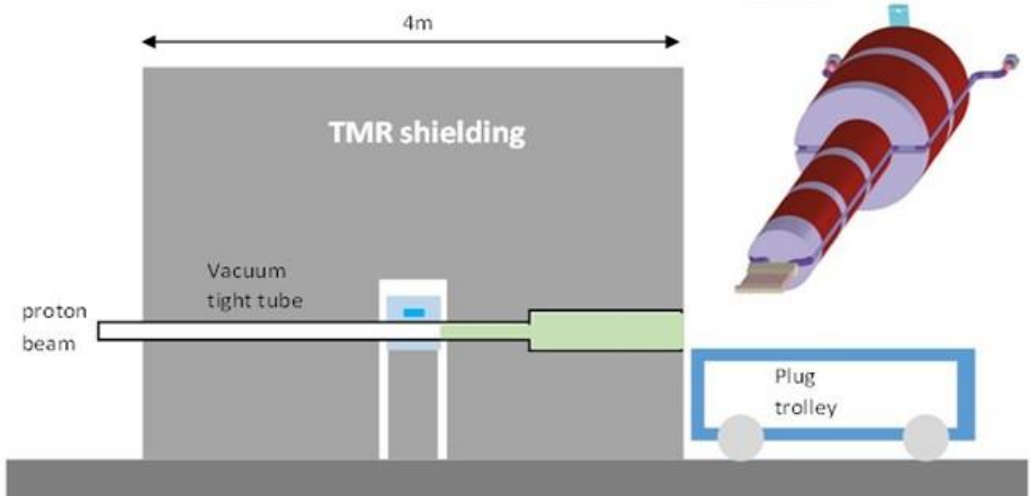


Cible-Modérateur-Réflecteur (WP3)

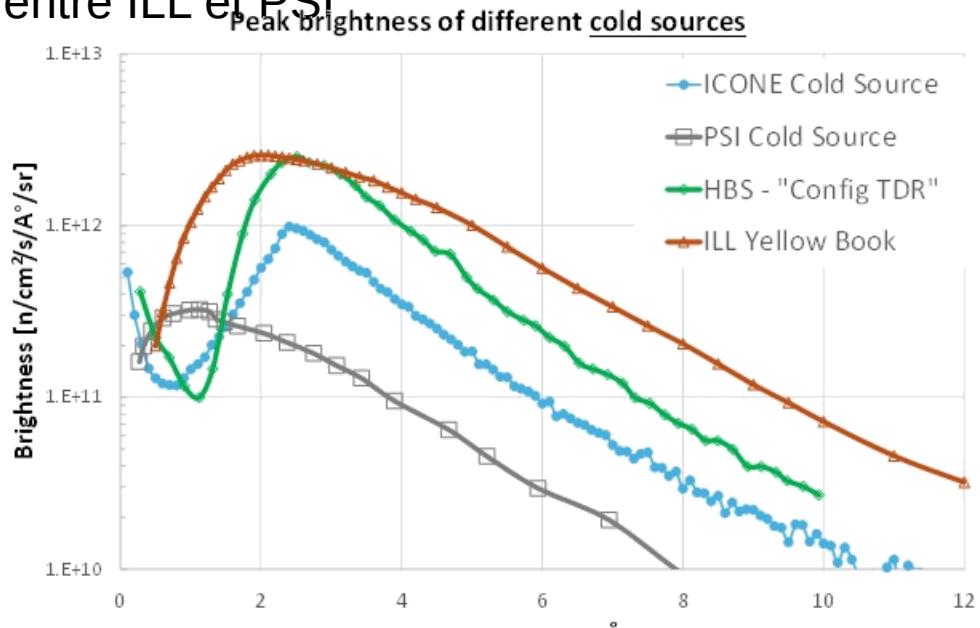
Prototype de support cible:
Tests mécaniques

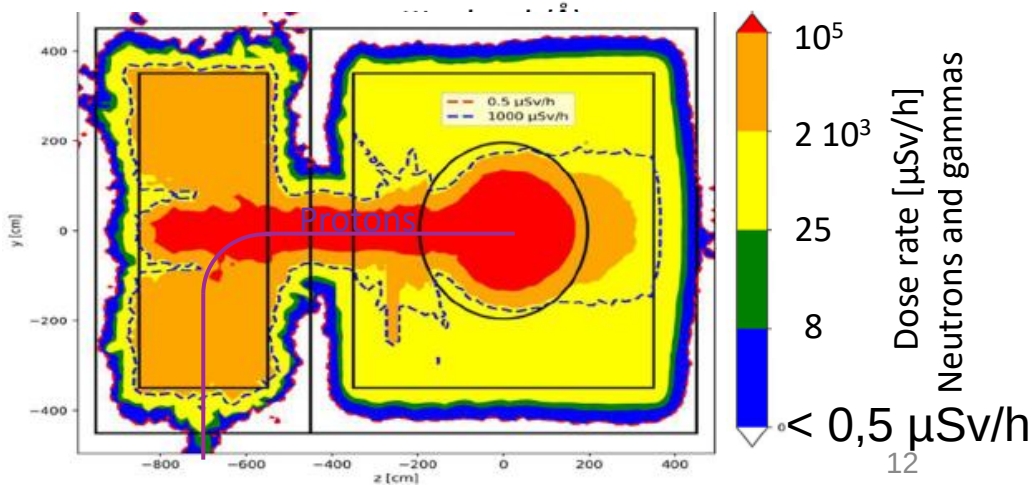


Radio-protection: monolithe + casemate
Débit de dose : 10^{12} µSv/h → <0,5 µSv/h



Performances: **Brillance crête**(cold)
entre ILL et PSI





WP4-Linac

Linac (WP4)

ICONE :
Ingénierie système

WP4: MANAGEMENT

D. Uriot CEA/Irfu

Dynamique faisceau
J. Dumas

Mécanique, 3D
Seraphin Vetter

Activités transverses

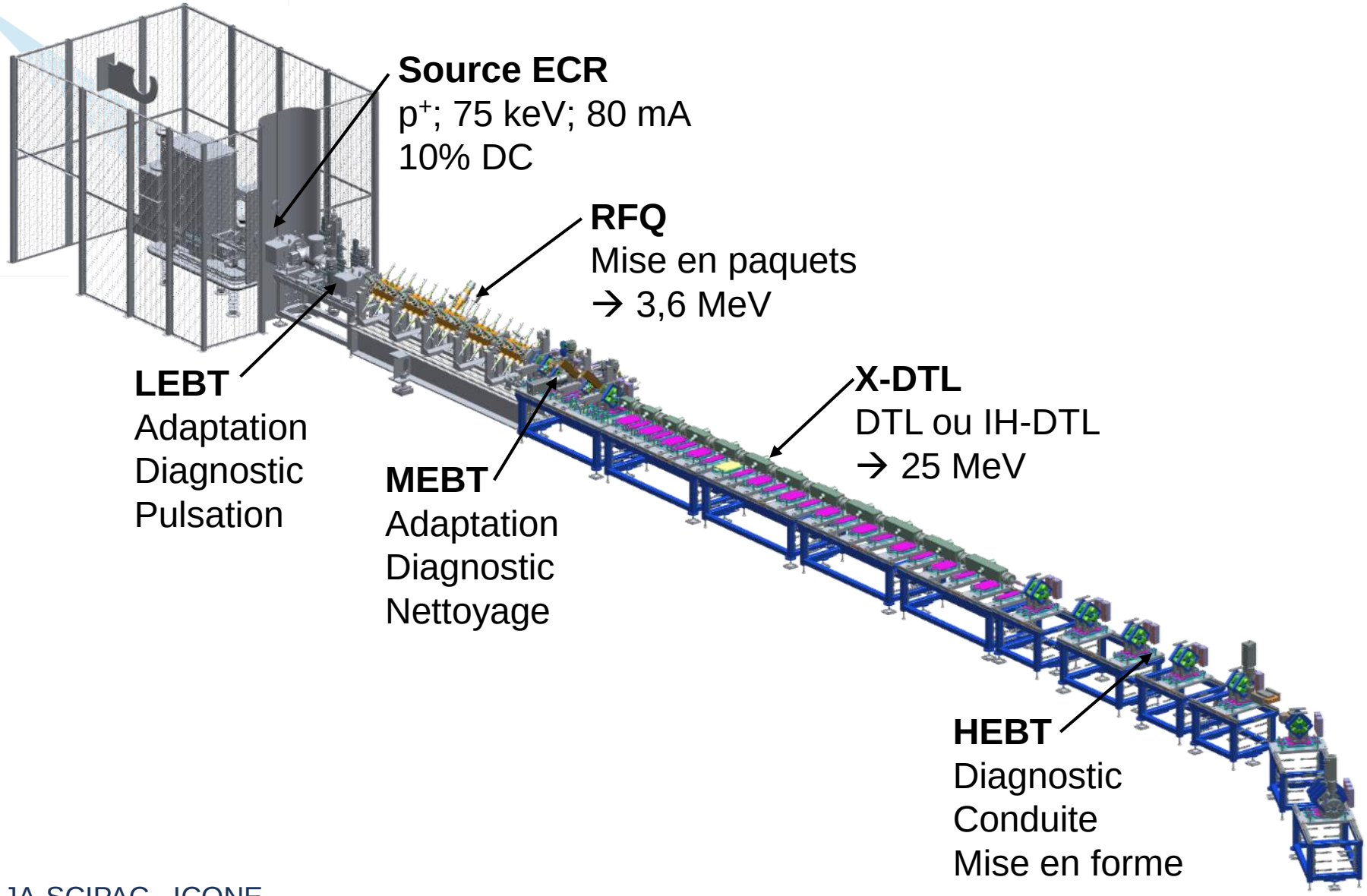
Eléments magnétiques, Alimentations	*O. Delferriere*
Refroidissement	*E. Giner-Demange*
Commande contrôle	*A. Gaget*
Systèmes RF	*P. Hamel*
Système Vide	*D. Chirpaz-Cerbat*
Diagnostics	*B. Bolzon*

Organisation phase ADP
- En phase construction certaines activités transverses seront des taches ou intégrées à l'équipe management.
- Le management devra évidement s'étoffer

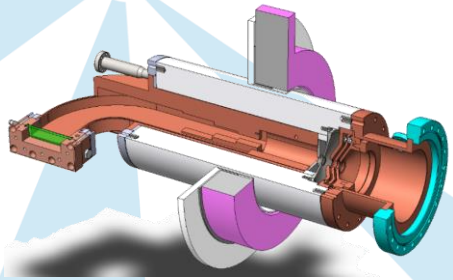
Taches principales

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

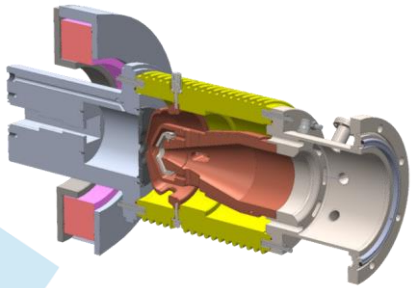
Linac (WP4)


Source ECR
p^+; 75 keV; 80 mA
10% DC
RFQ
Mise en paquets
→ 3,6 MeV
LEBT
Adaptation
Diagnostic
Pulsation
MEBT
Adaptation
Diagnostic
Nettoyage
X-DTL
DTL ou IH-DTL
→ 25 MeV
HEBT
Diagnostic
Conduite
Mise en forme

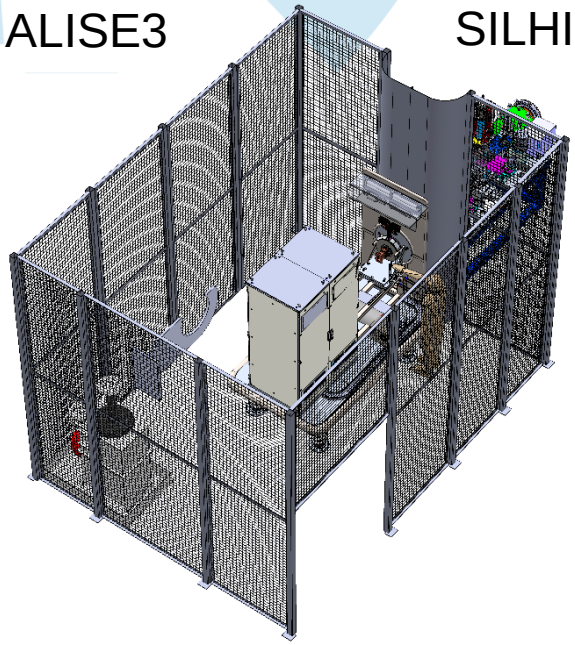
Source + LEBT (qq eV → 75 keV)

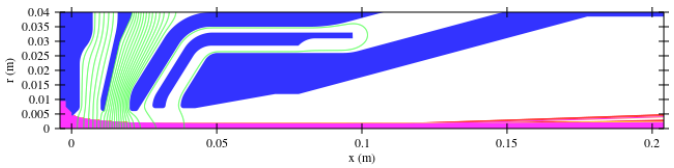


ALISE3



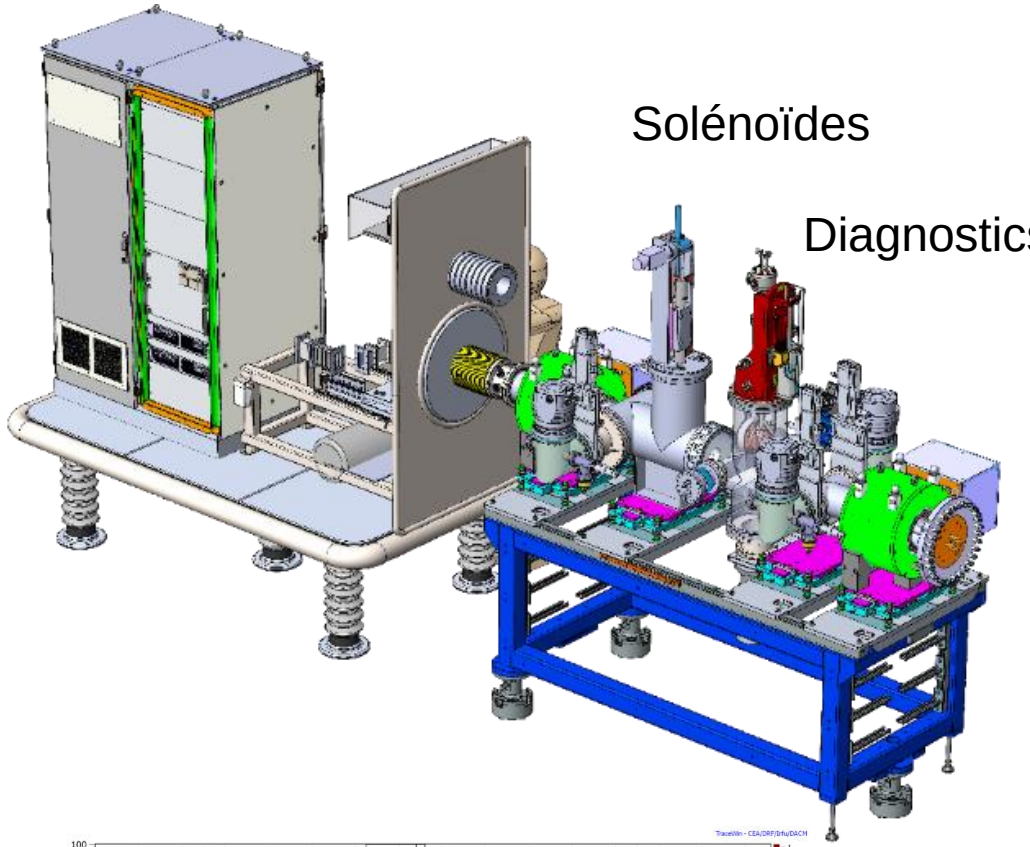
SILHI3

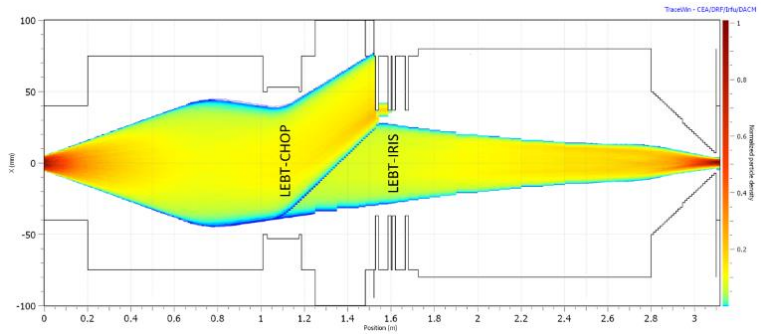




Solénoïdes

Diagnostics

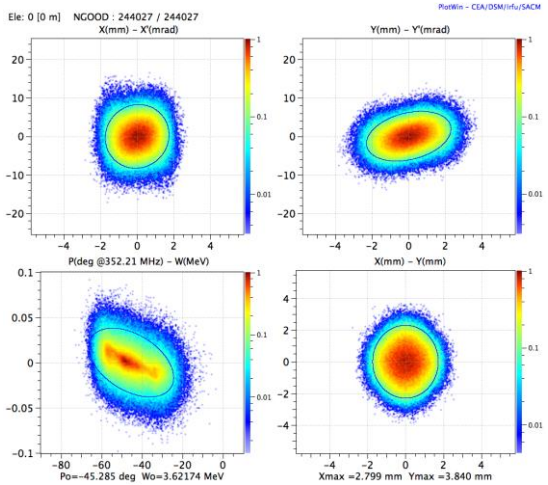




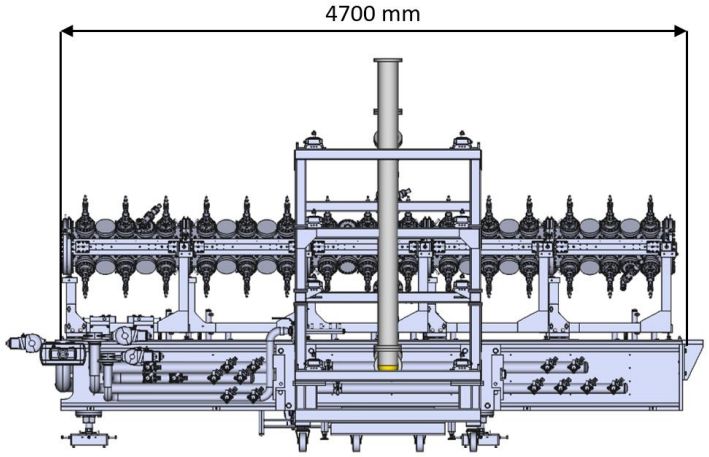
RFQ (75 keV → 3,6 MeV)

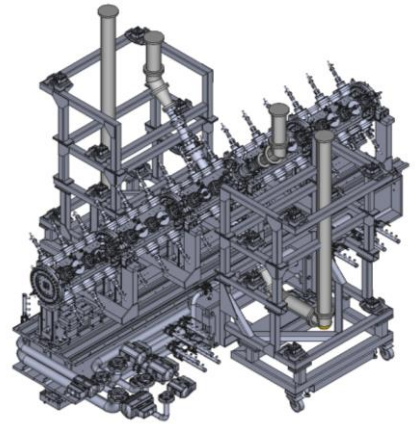
ESS RFQ (3,6 MeV)

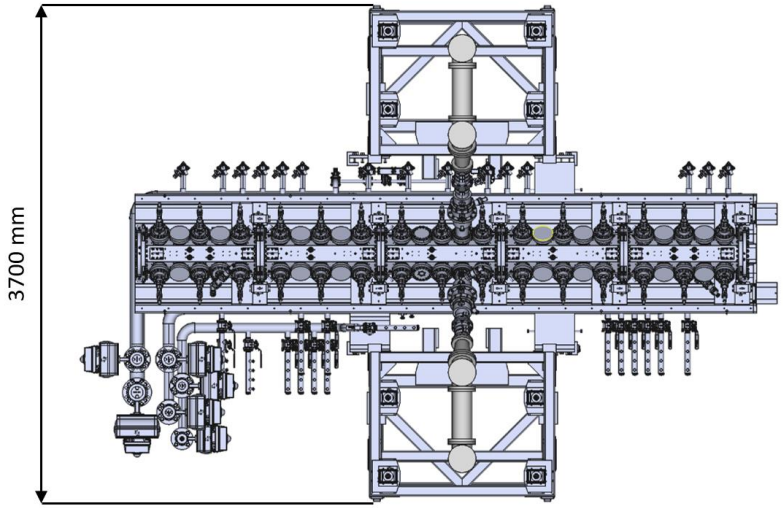
Faisceau ICONE en sortie

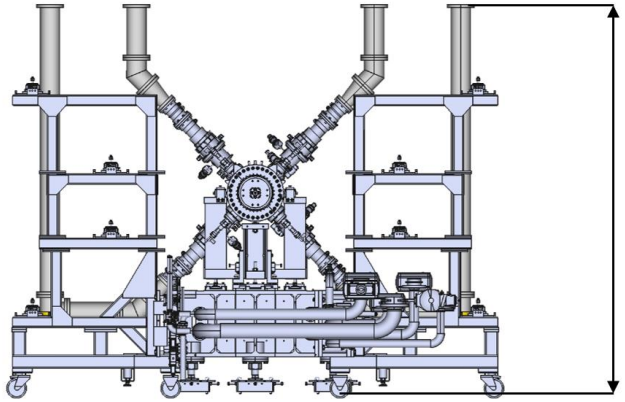


ICONE intégration



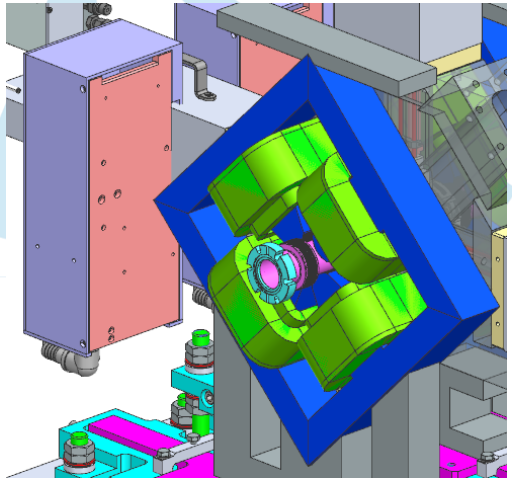




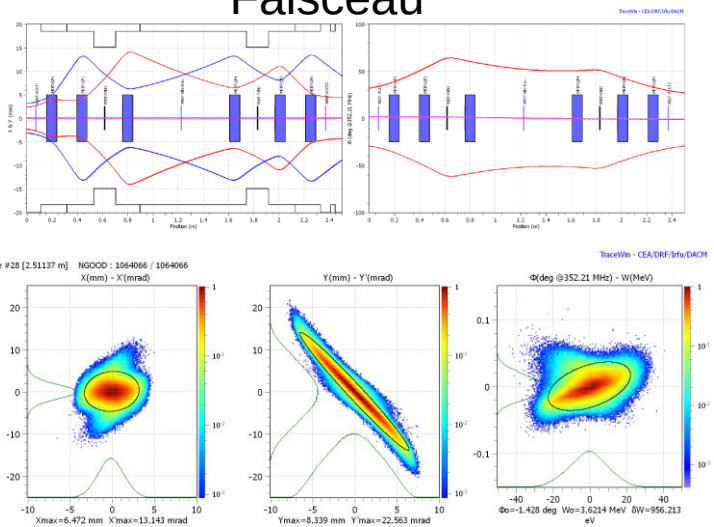


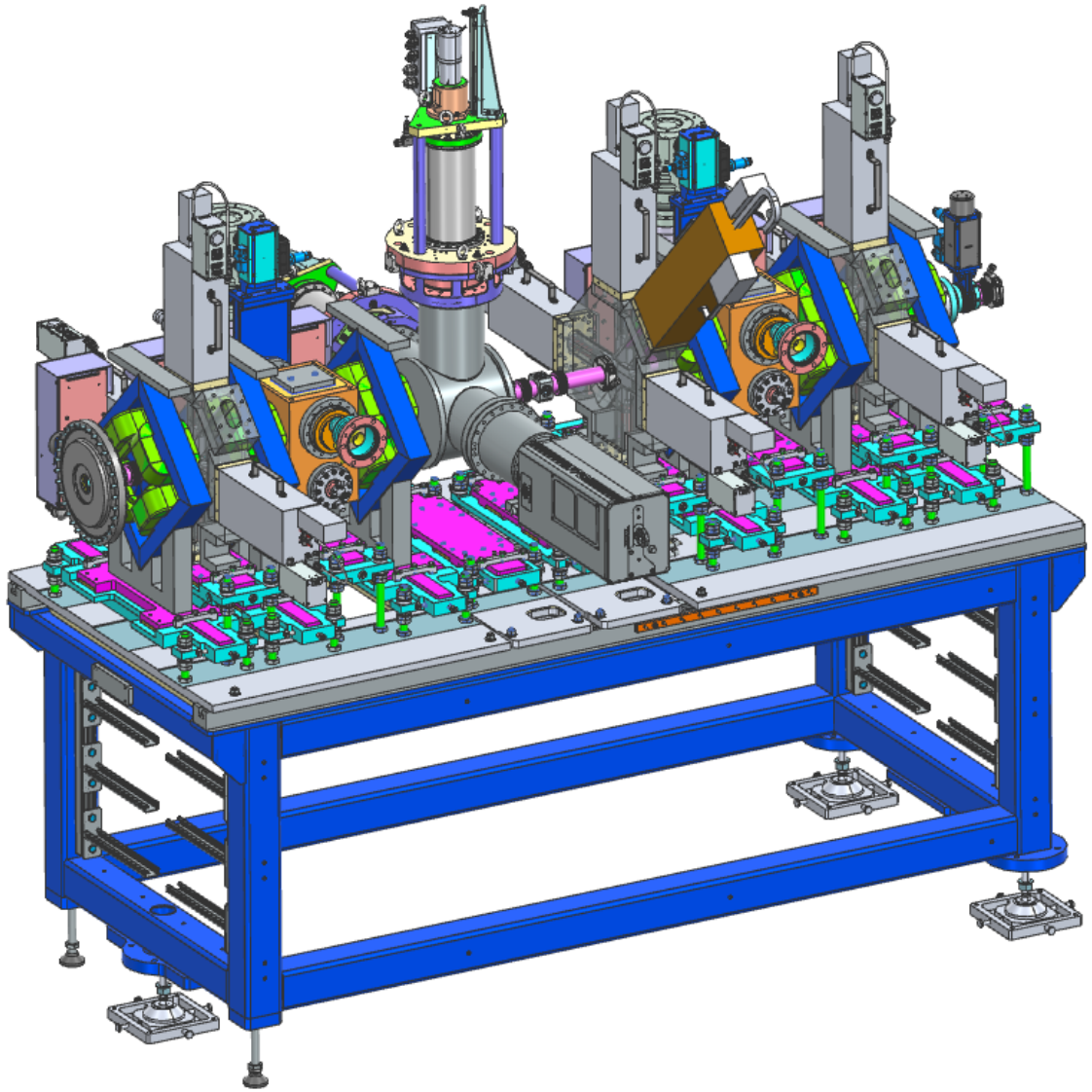
MEBT (3,6 MeV)

EM Qpole

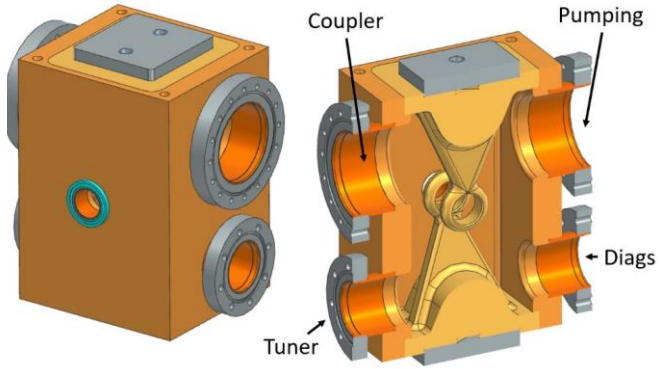


Faisceau

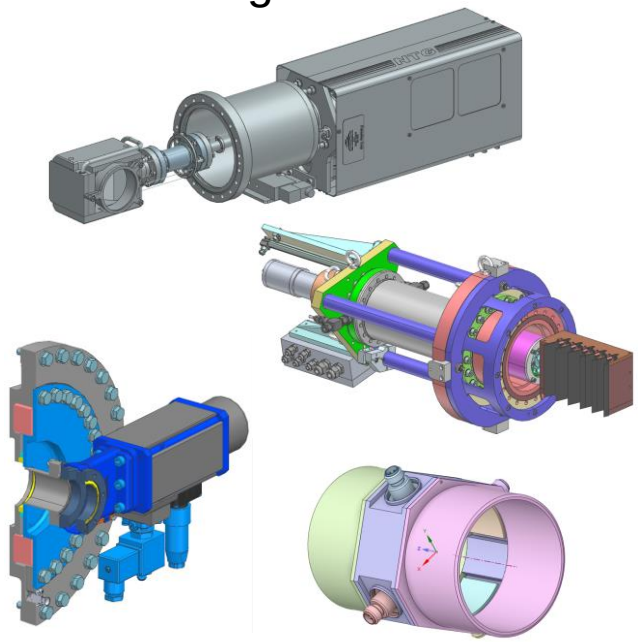




Cavité IH

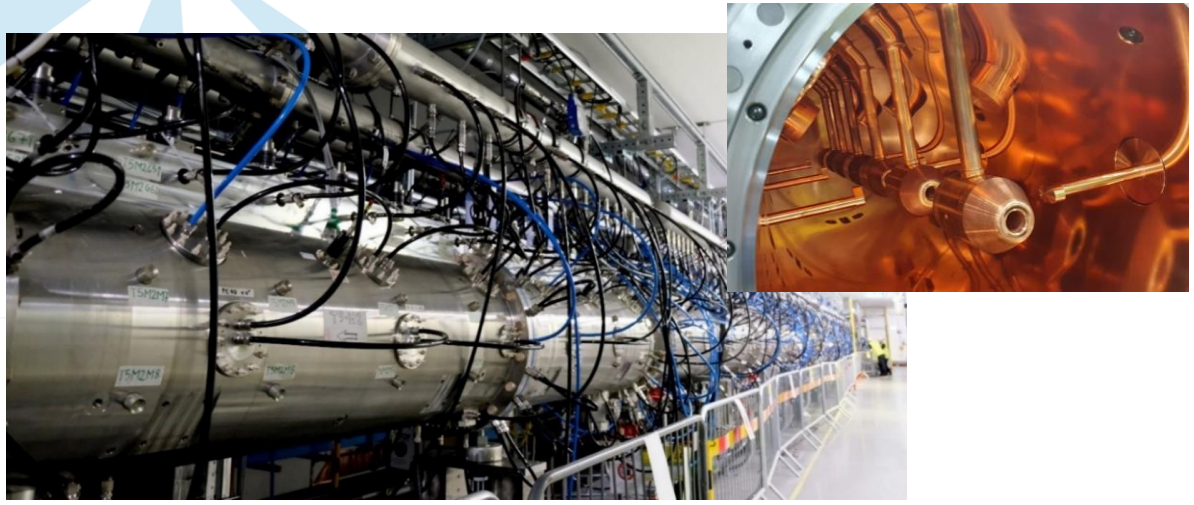


Diagnostics

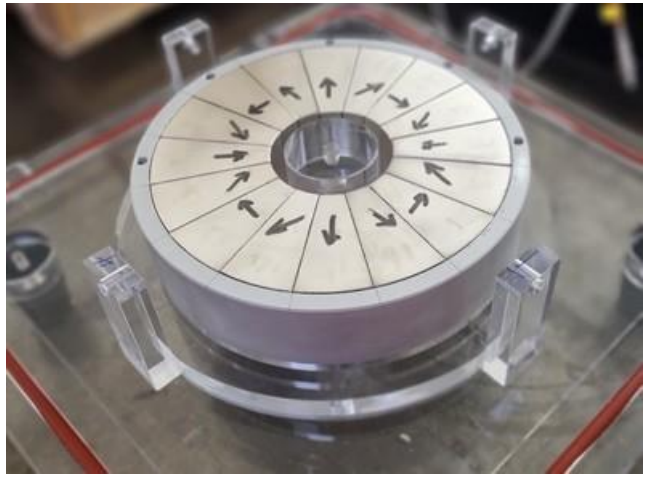


X-DTL (3,6 MeV → 25 MeV) (INFN + Irfu)

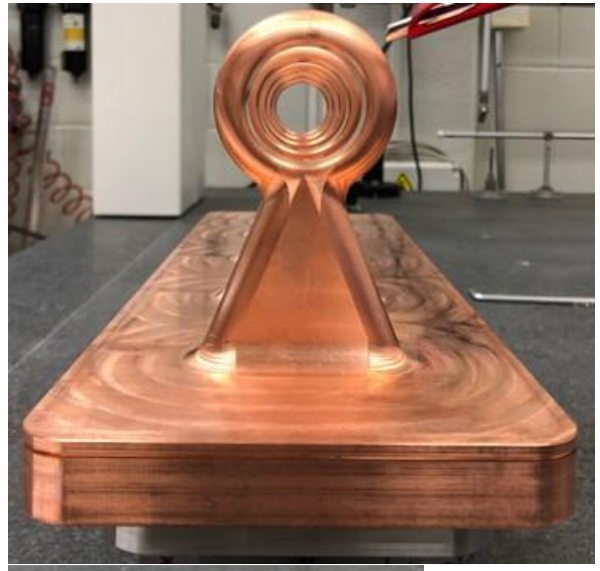
DTL ESS : Solution proposée par INFN

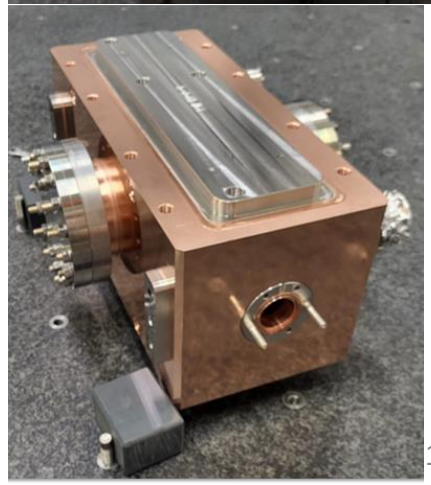


Proto Qpole : fabriqué,
Tests magétiques en 2026 à SOLEIL



Proto cavité IHDTL : fabriquée
Qualifiée f0, Q0, étanchéité eau et vide
Tests puissance en 2026 à l'Irfu

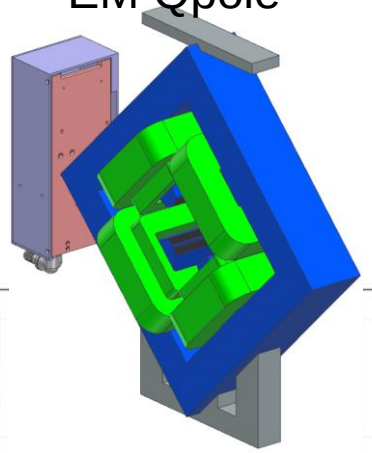




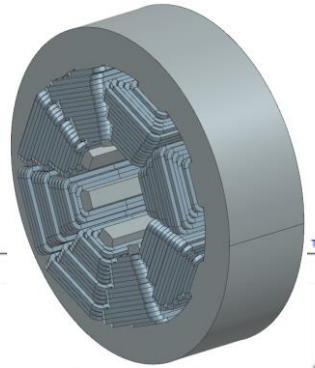
HEBT (25 MeV) (LPSC + Irfu)

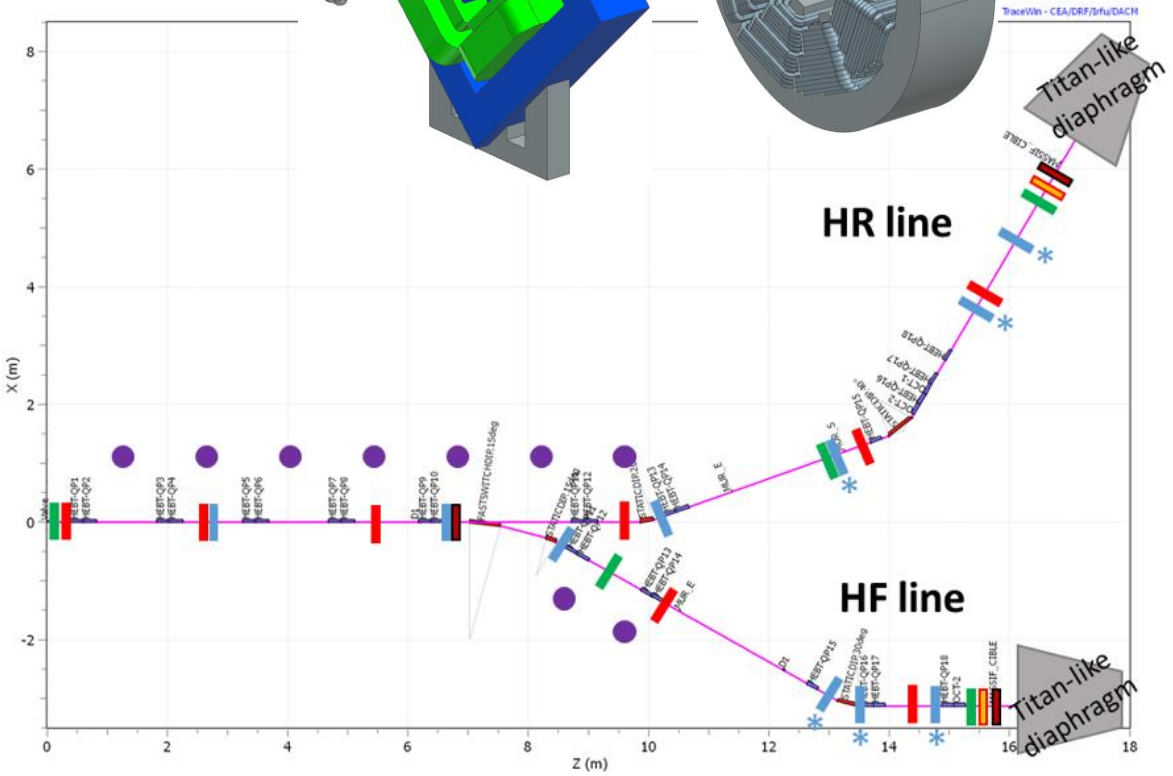
- nBLM
- BPM (* for stripline)
- ACCT
- WireScanner
- SEMgrid (51 wires/plan)
- Faraday cup 1Hz 100µs

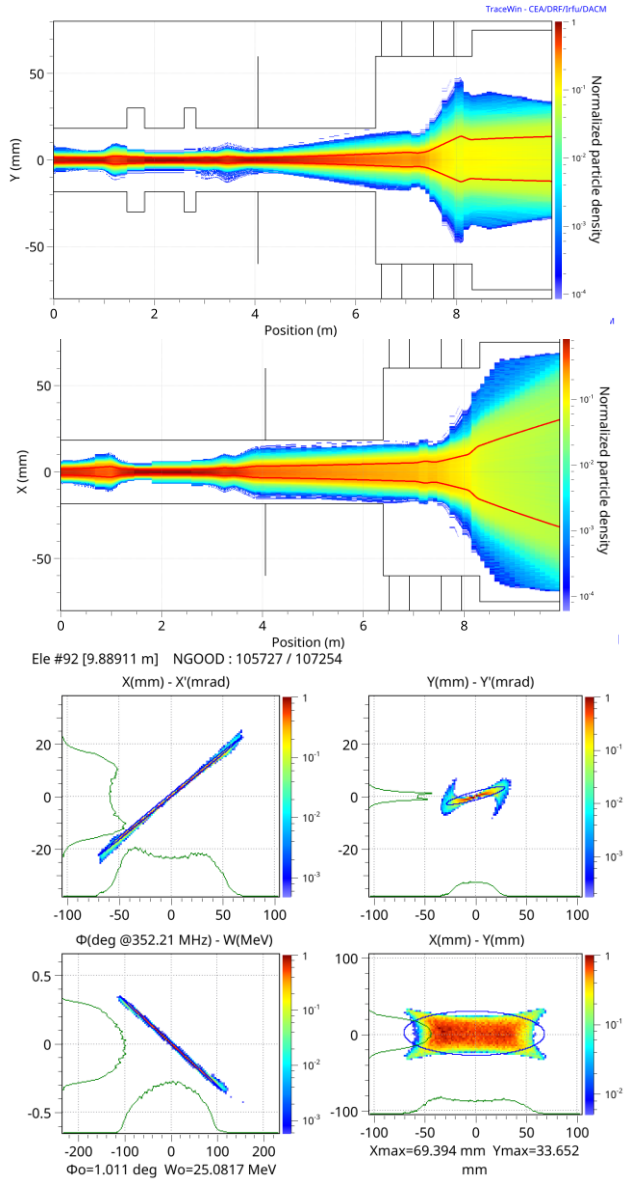
EM Qpole



EM Octupole

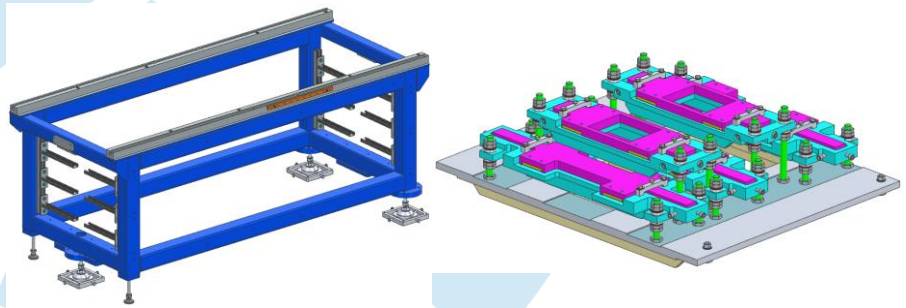




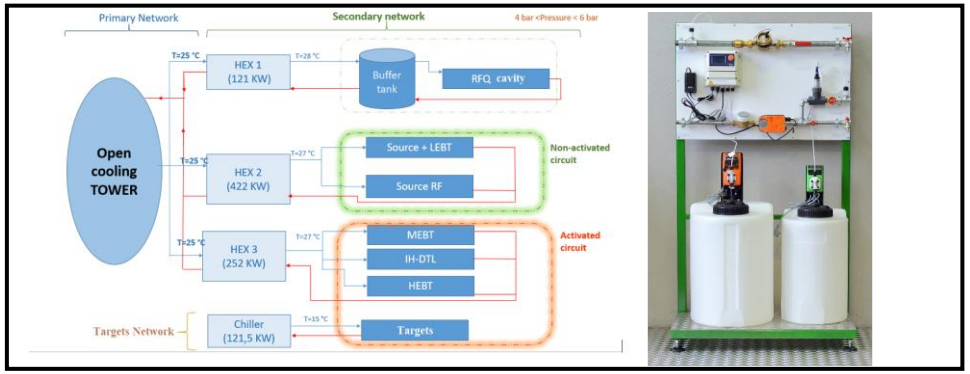


Systèmes LINAC

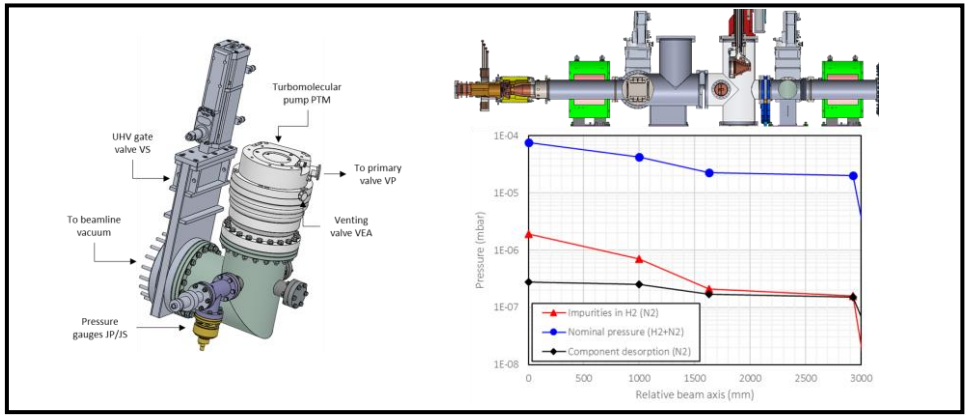
Mécanique



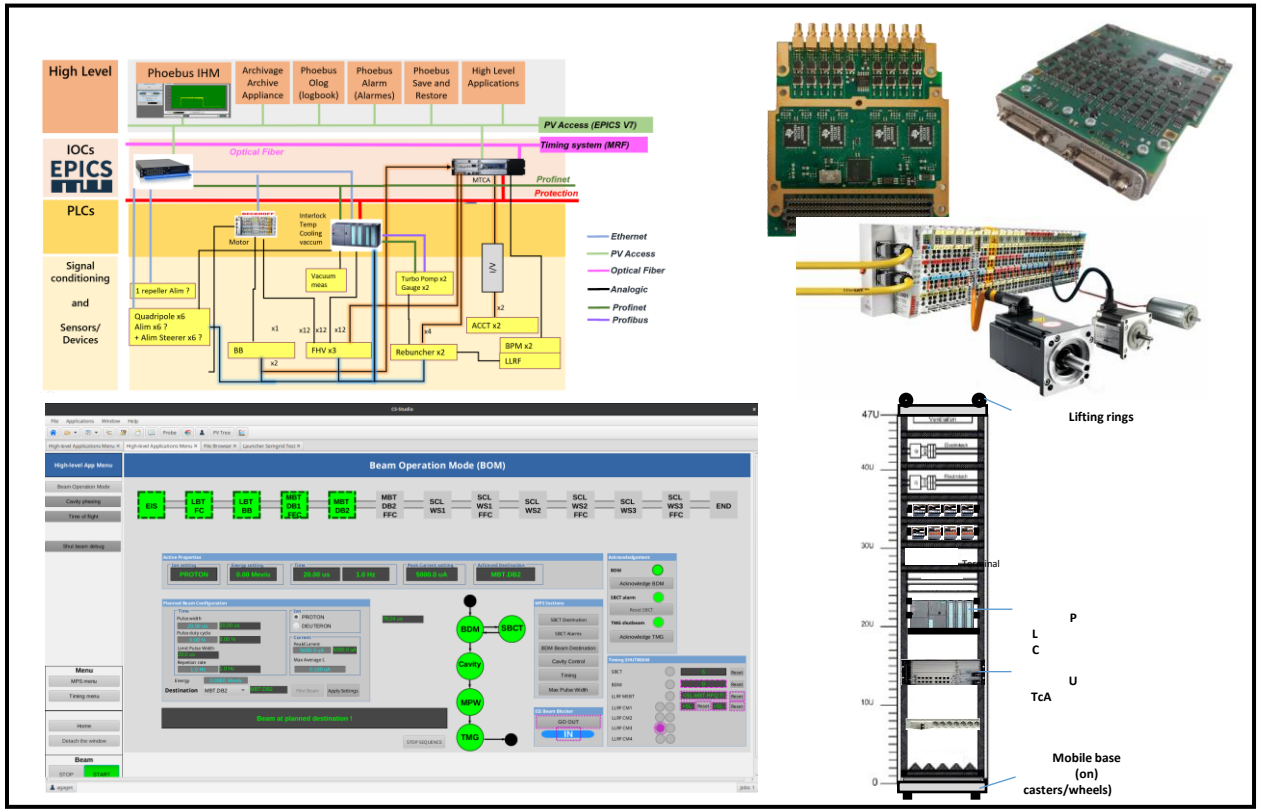
Refroidissement



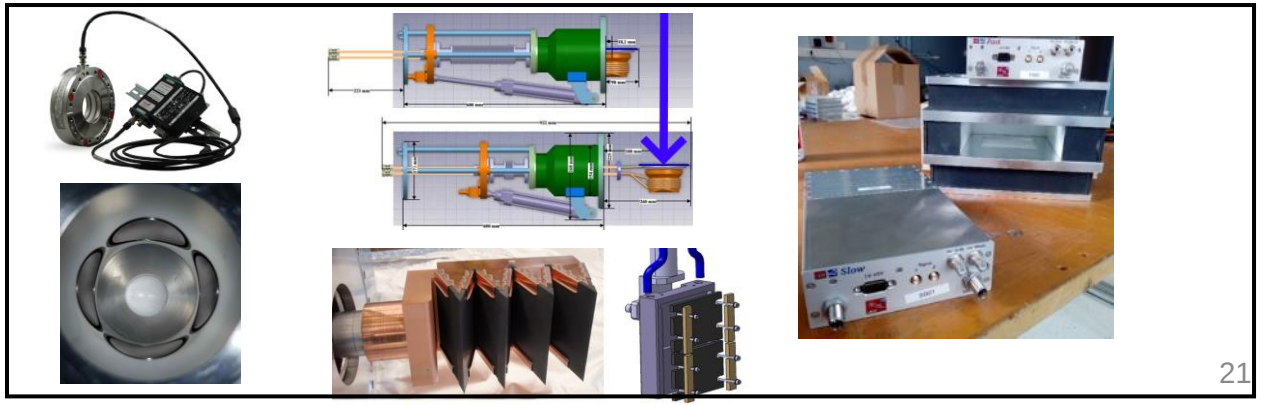
Vide



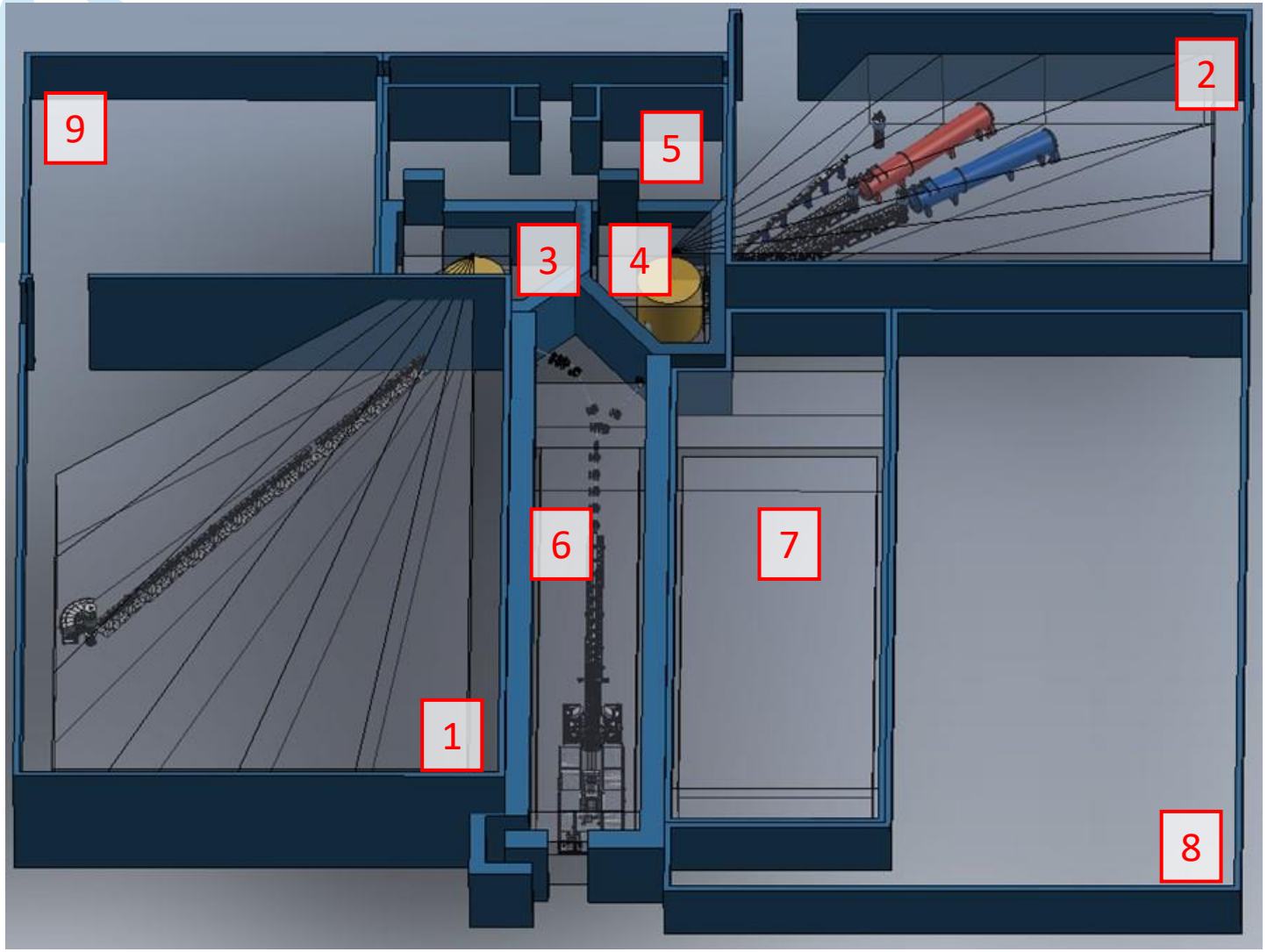
Control-commande



Diagnostics

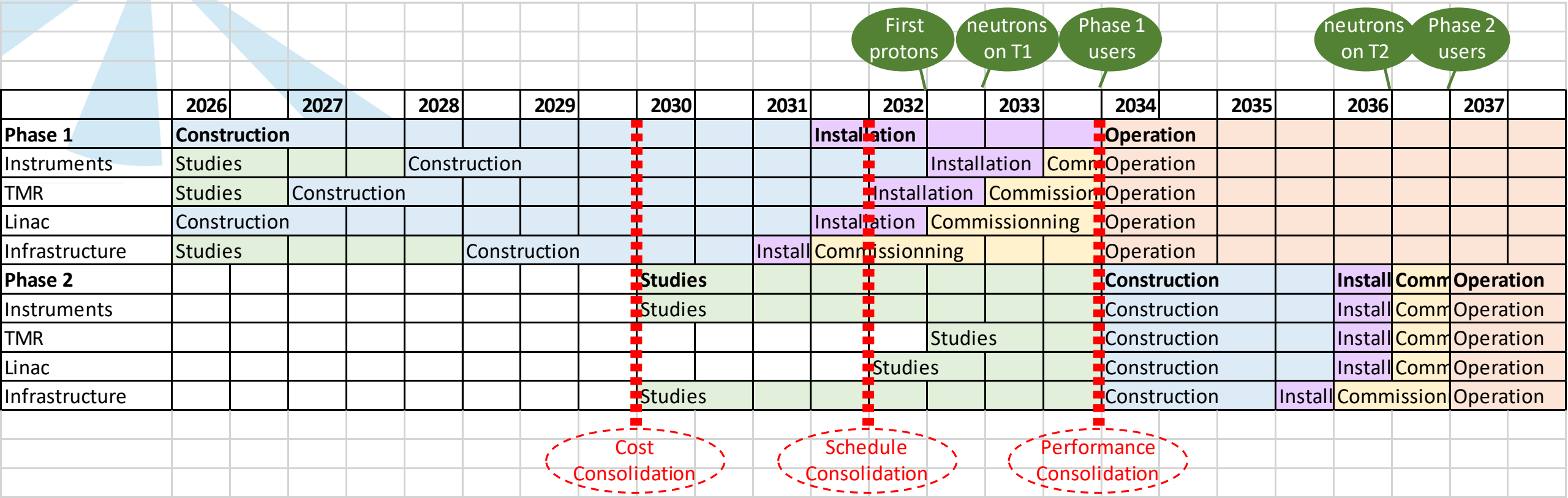


Infrastructure (WP5) - Spécifications



1 Hall HR
2 Hall HF
3 Bunker TMR 1
4 Bunker TMR 2
5 Maintenance TMR
6 Tunnel Linac
7 RF hall
8 Office area
9 Technical area

Planning


First protons
neutrons on T1
Phase 1 users
neutrons on T2
Phase 2 users
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
Phase 1
Construction
Installation
Operation
Instruments
Studies
Construction
Installation
Comm
Operation
TMR
Studies
Construction
Installation
Commission
Operation
Linac
Construction
Installation
Commissionning
Operation
Infrastructure
Studies
Construction
Install
Commissionning
Operation
Phase 2
Studies
Construction
Install
Comm
Operation
Instruments
Studies
Construction
Install
Comm
Operation
TMR
Studies
Construction
Install
Comm
Operation
Linac
Studies
Construction
Install
Comm
Operation
Infrastructure
Studies
Construction
Install
Commission
Operation
Cost Consolidation
Schedule Consolidation
Performance Consolidation

Conclusion

La plupart des composants sont définis.

Le linac est l'élément le plus avancé.

Nous sommes prêts à démarrer la construction des composants sur le chemin critique:

- RFQ.
- Infrastructure.

Nous devons encore finir quelques optimisations et ingénieries d'éléments non critiques.

La situation budgétaire n'est pas encore stabilisée.