

Mechanical  
Design Office  
@LAL

# Mechanics, Alignment



•Programme Investissements d'avenir de l'Etat ANR-10-EQPX-51. Financé également par la Région Ile-de-France. Program « Investing in the future » ANR-10-EQOX-51. Work also supported by grants from Région Ile-de-France.







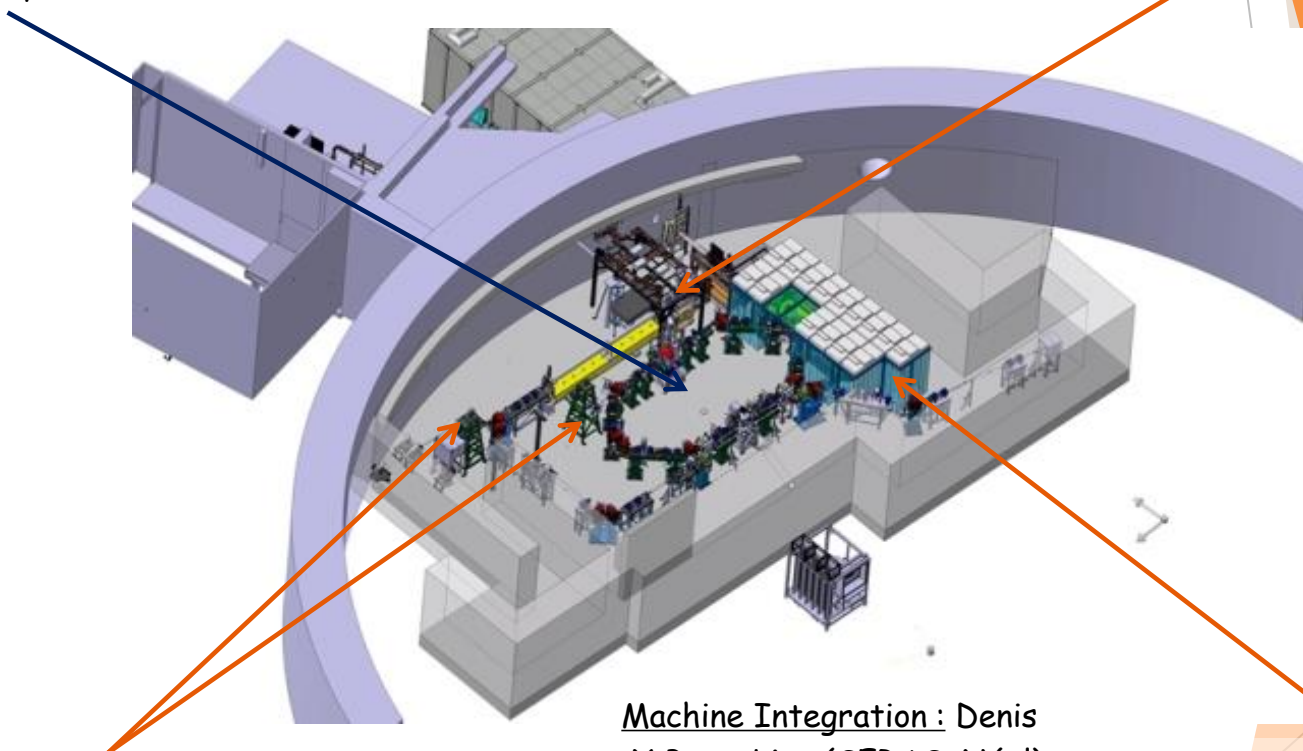
# Design Office @LAL

## Storage RING :

Magnets, Vacuum items, Assembly of the Ring by Rodolphe Marie  
Chambers by Alexandre Blin (-> INSU 4/2016) + Rodolphe  
Girders by Saïd (-> CDD IRFU 12/2016) + Gregory Iaquaniello (10/2016)  
Bellow RF + FBT by Damien Le Guidec

## LINAC & TL & ET :

Alexandre Gonnin & Didier Auguste



## Beam Transport Lines :

Cerenkov-Synchrotron-Laser : Saïd Bouaziz &  
Didier & Denis + Gregory

Machine Integration : Denis  
X Beam Line (SERAS, Néel)

Optical Cavity : Yann Peinaud

**From The Workshop :** Michel, Jean, Remy, Jean-Philippe, Frederick, Patrick, Emmanuel, Olivier, Guillaume, Bruno et Eric

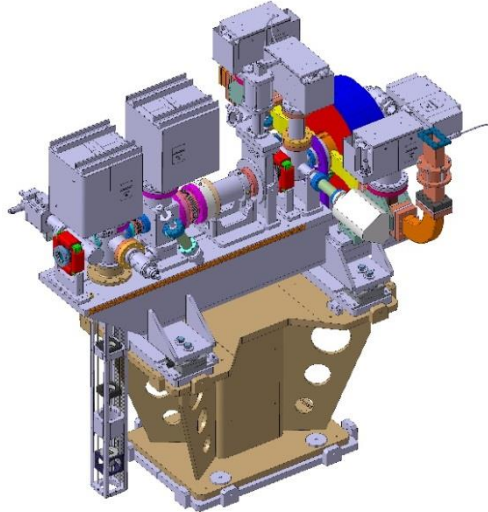
**All FE structural analysis (strength, thermal, vibration, topology optimization) by Julien Bonis (ANSYS)**







# LINAC

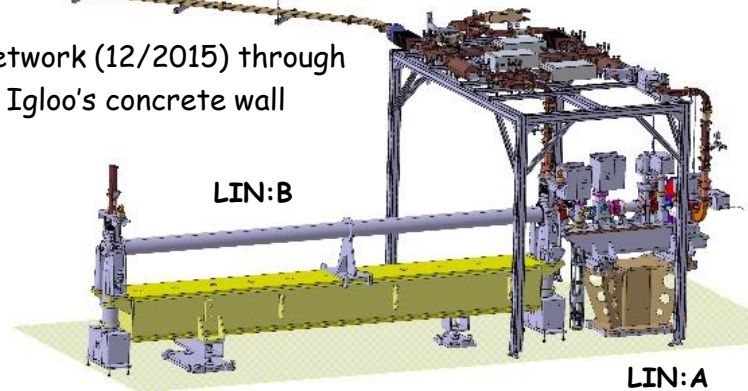


RF Gun (03/2017)



Klystron in Hall D1

RF Network (12/2015) through  
2,5m Igloo's concrete wall

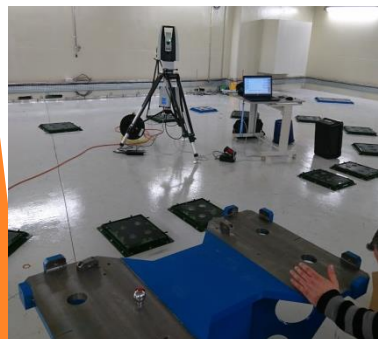


LIN:B

LIN:A



LINAC girder (02/2015)



LINAC foot installation (02/2017)



Section LIL (10/01/2017@LAL)  
Vacuum conditioning (03/2017)



LIL section (10/01/2017)  
From LINAC Roof at SOLEIL  
to LAL



# Transfer Line

Made in LAL-Workshop

• 5 BPM Stripline (12/2016)



frames (07/2015)

Straight chambers

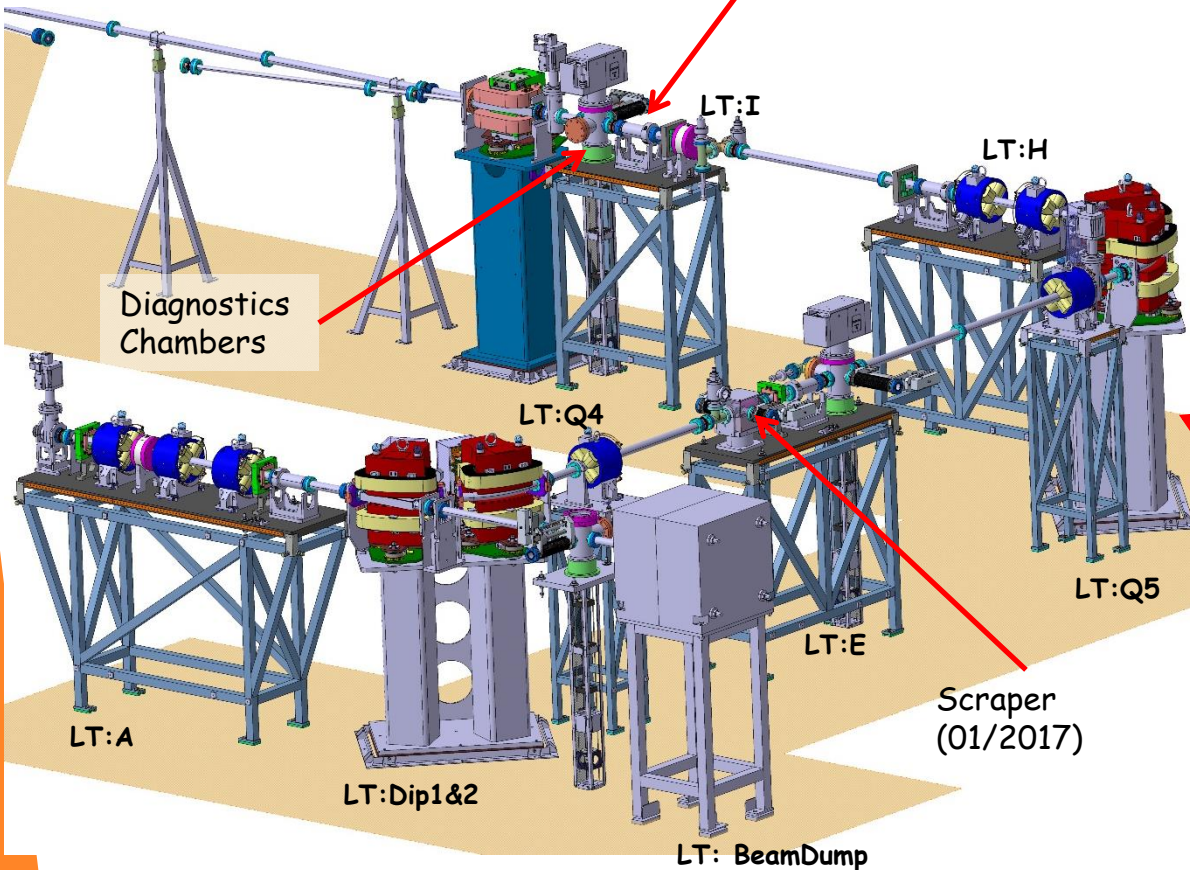


LT:Dip3&4



Dipole's supports  
10/2016

Scraper  
(01/2017)



Diagnostics  
Chambers

LT:A

LT:Dip1&2

LT:Q4

LT:E

LT: BeamDump

LT:H

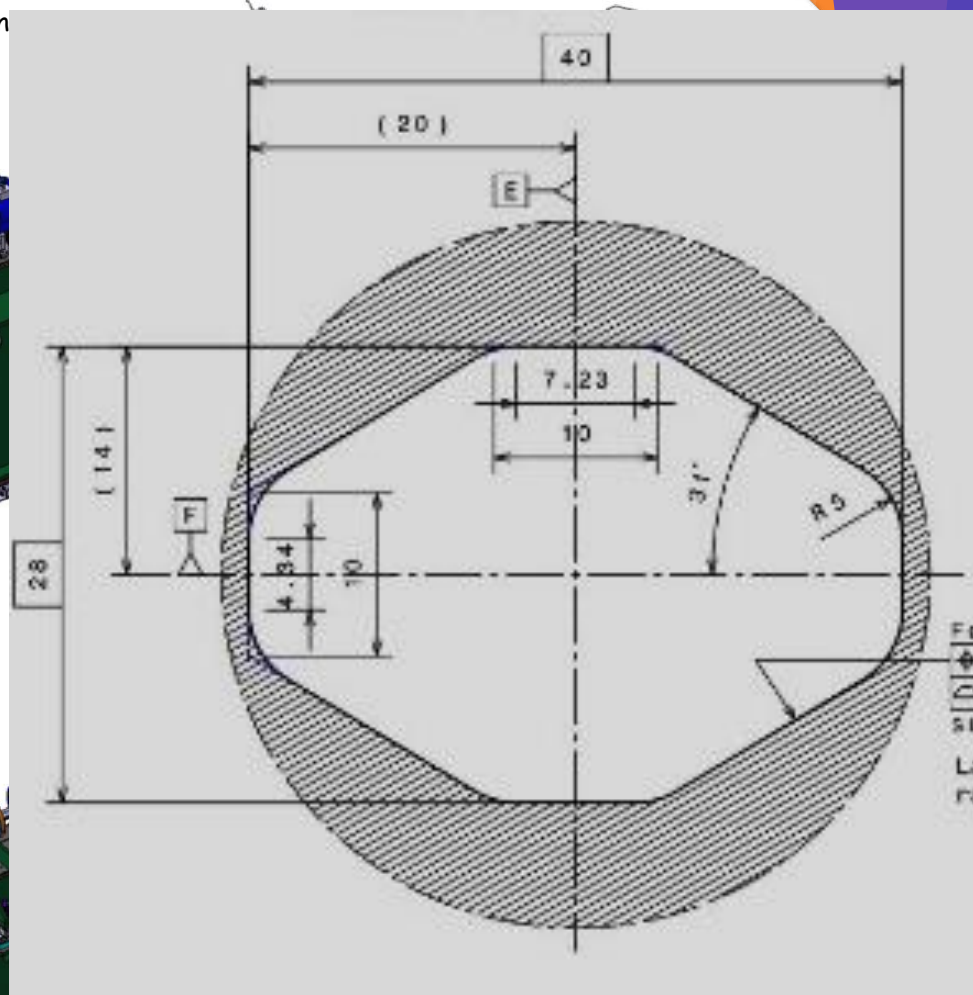
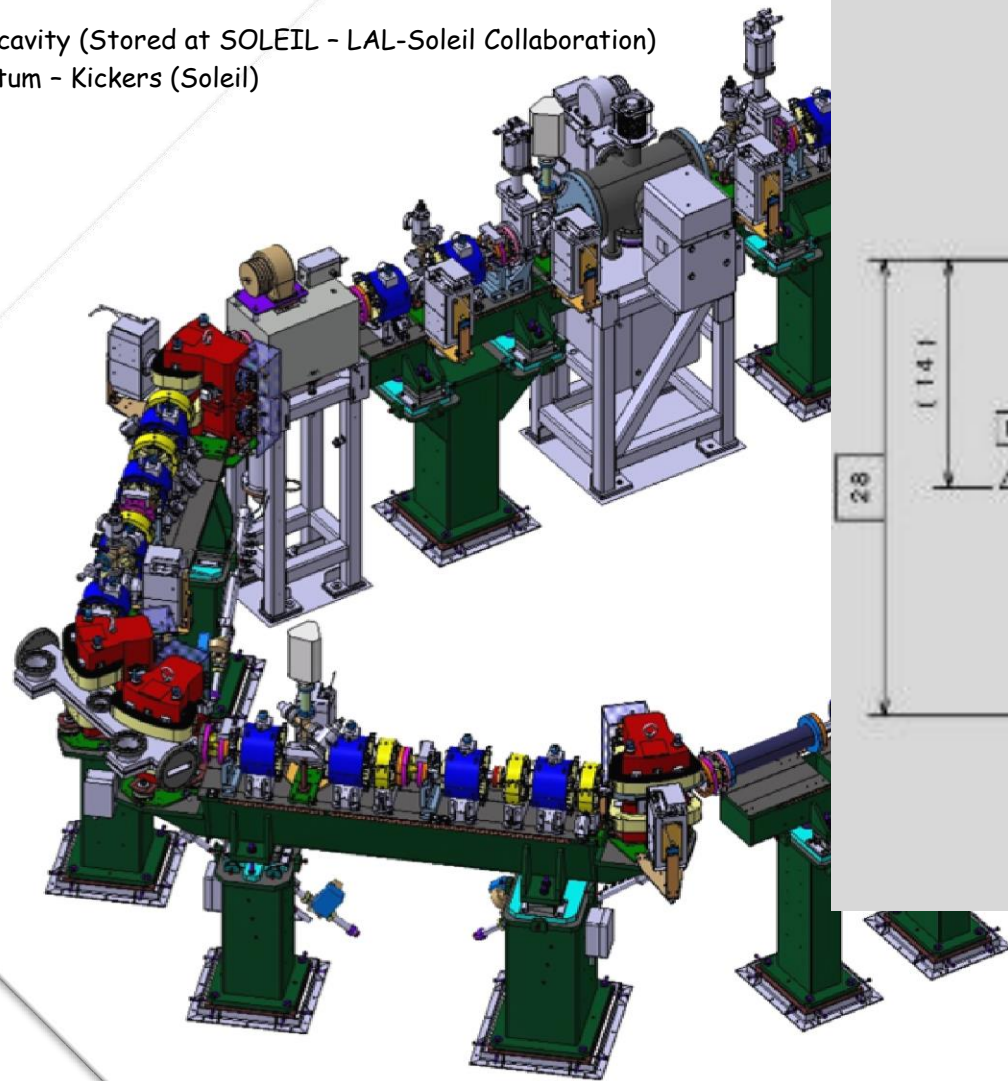
LT:Q5

LT:I



# Storage RING

- Assembly of straight or curved chambers in a  $\sim 18\text{m}$  perimeter ring under  $10^{-10}\text{mbar}$  pressure, baked-out, including BPM and connected by 18 RF bellows (thermic dilatation)
- Copper RF gasket for the vacuum tightness and the geometrical continuity
- 34 Quadrupoles, 13 Sextupoles, 15 Dipoles
- RF cavity (Stored at SOLEIL - LAL-Soleil Collaboration)
- Septum - Kickers (Soleil)

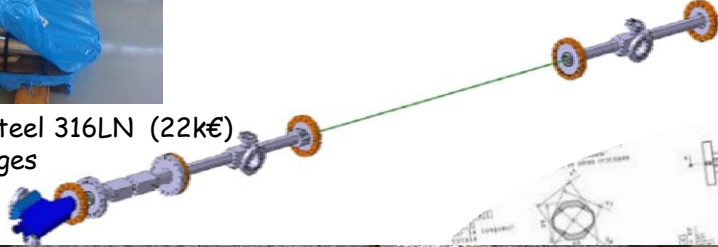




# RING : The Chambers



1,2t Stainless Steel 316LN (22k€)  
+ 500kg CF Flanges



Inside the magnet  $\Rightarrow$  magnetic permeability  $< 1,010$

Very close to the magnet  $\sim 1\text{mm}$ , without contact, fine positioning  $\Rightarrow$  mechanical machining with high precision

Including UHV design, pumping ports, BPM

Thermic dilatation (bakeout  $200^\circ$ , vacuum)  $\Rightarrow$  Brackets designed for supporting chambers without stress ( $\sim 3\text{mm}$ )

Internal octagon machined by EDM copper wire cutting (EDM=Electrical Discharge Machining)

TIG or EBM welding

Tender (PUMA) published the 3/3/2016

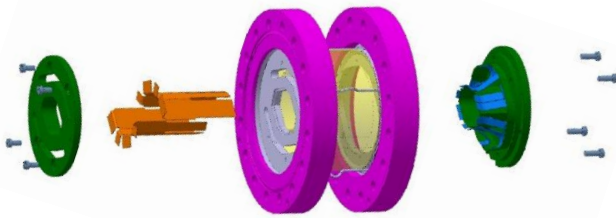
Notified le 31/5/2016 to Rial Vacuum in Parma (Italy)

198 628 €HT

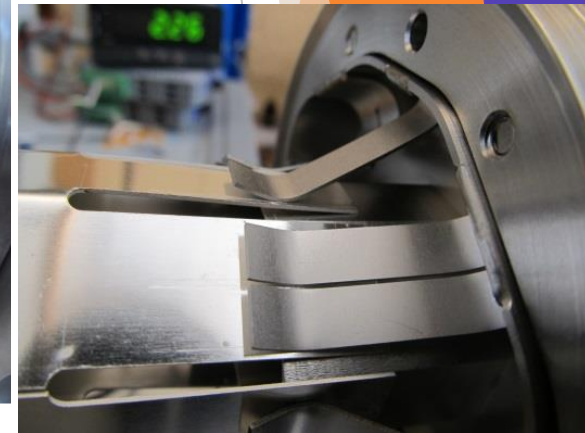
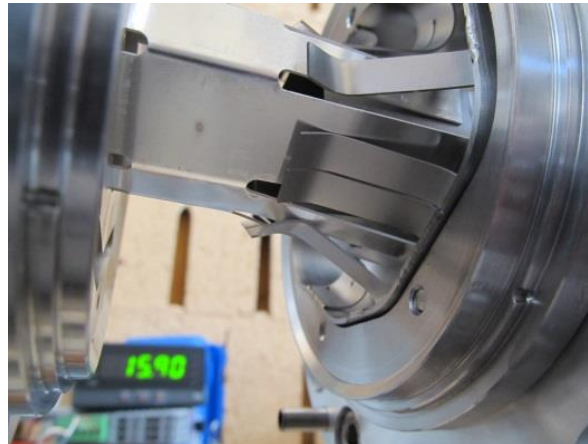
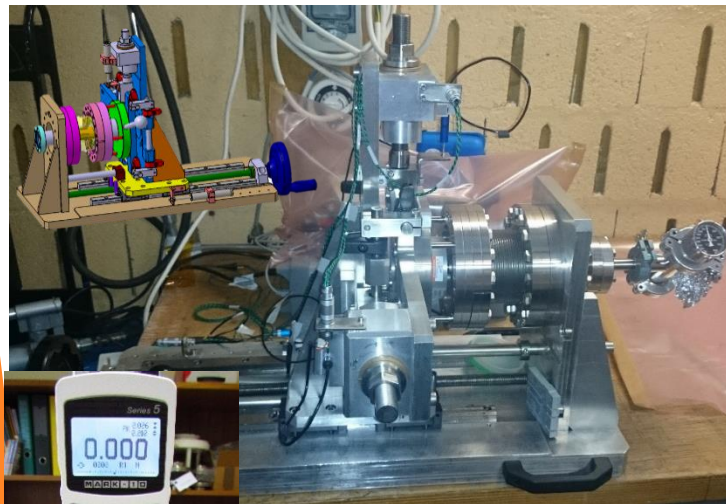
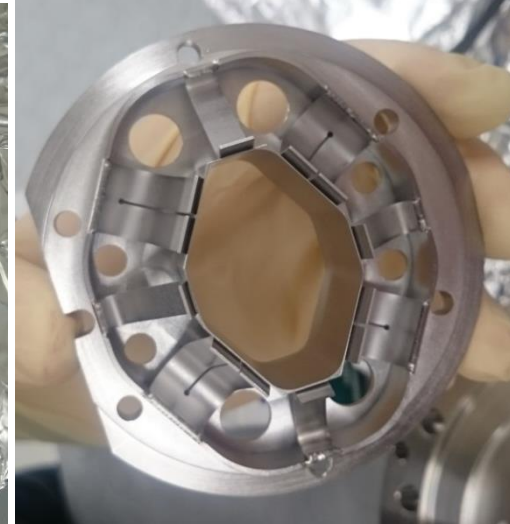
Step 1 : 3 chambers Kicker Type A link, bent chamber Type B & C, FBT-like, received 9/3/2017



# RING : RF Bellows



- ✓ Extension 4.5mm, compression 11.5mm, transverse  $\pm 3$ mm
- ✓ Realization (09/2015) of a test bench to measure the extension/compression of the bellow and strain of the RF spring blades : design of the geometry for a strain on the fingers between 150g to 180g all along the displacement.



- Tender (PUMA) published 4/4/2016
- t0=15/6/2016 pour 73 720 € HT to Rial Vacuum (Parma, Italy)
- 2 steps : Realization of 18 Bellows + 2 spares
- Step 1 : 1<sup>st</sup> bellow with CF100 flange, 02/2017
- Step 2 : 7 bellows with CF100 turning flange + 13 bellows with CF100 flange - 04/2017





# RING : Girders

Manufactured in 12/2015 by Nortemecánica (~Gijon, Spain)

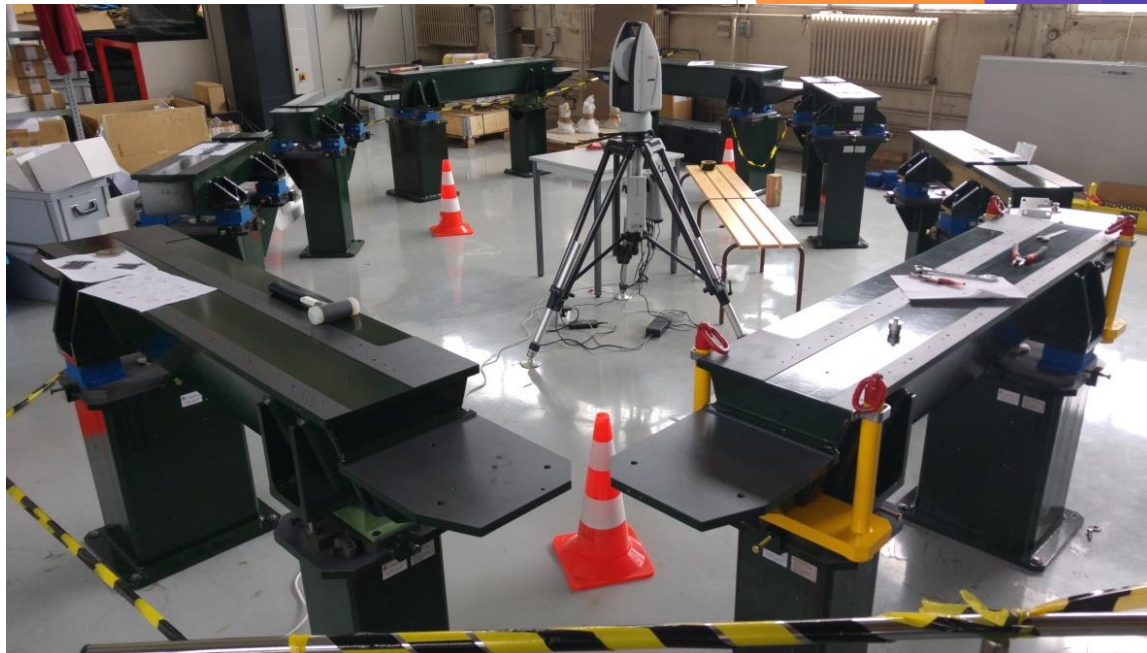
- ✓ Flatness of 0,03mm on 1,6m to allow fine adjustment between chambers of  $50\mu\text{m}$  and  $100\mu\text{m}$  between girders
- ✓ Very fine machining and holes localization to place the magnets ( $\varnothing 8\text{H7 } 40\mu\text{m}$ )

## Linear adjustment :

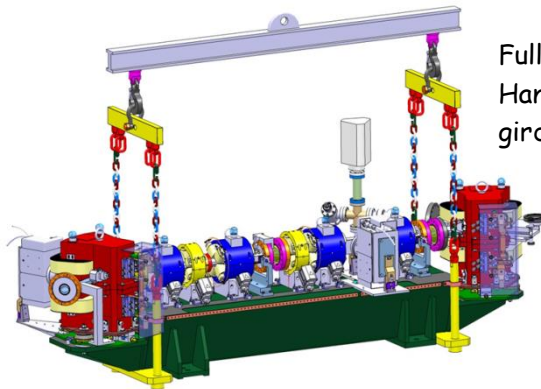
- X=  $\pm 20\text{mm}$
- Y=  $\pm 20\text{mm}$
- Z=  $\pm 20\text{mm}$

## Rotations:

- X=  $\pm 3^\circ$
- Y=  $\pm 0,38^\circ$
- Z=  $\pm 1,9^\circ$
- Resonant frequency  $> 40\text{Hz}$



•Assembly of the storage ring with Laser Tracker at LAL-208 - 01/2017



Full assembly Girders weight :1,5 tons.

Handling tool has been designed in order to safely bring the fully equipped girders from the 208 building to the ThomX bunker

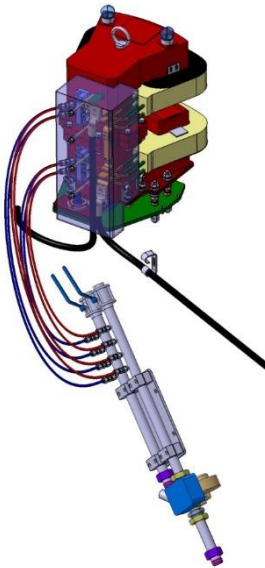


# RING : The Magnets

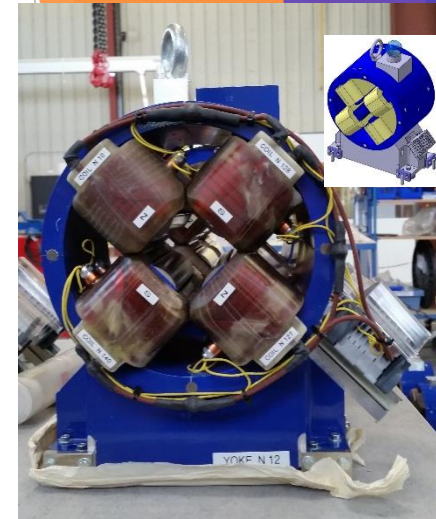
Full mechanical design at Design Office : poles, coil winding design, interface with girders



15 Dipoles



13 Sextupoles



34 Quadrupoles



LAL (C.Vallerand) & SOLEIL (F.Marteau) collaboration.

See C.Vallerand presentation



# RING : FBT

•Electrical Feedthrough(x8)

DN100CF Flange  
fixe (x2)

•End of Body Chamber(x2)

Body Chamber

Copper Sheet(x8)

Electrode fine nervurée (x4)

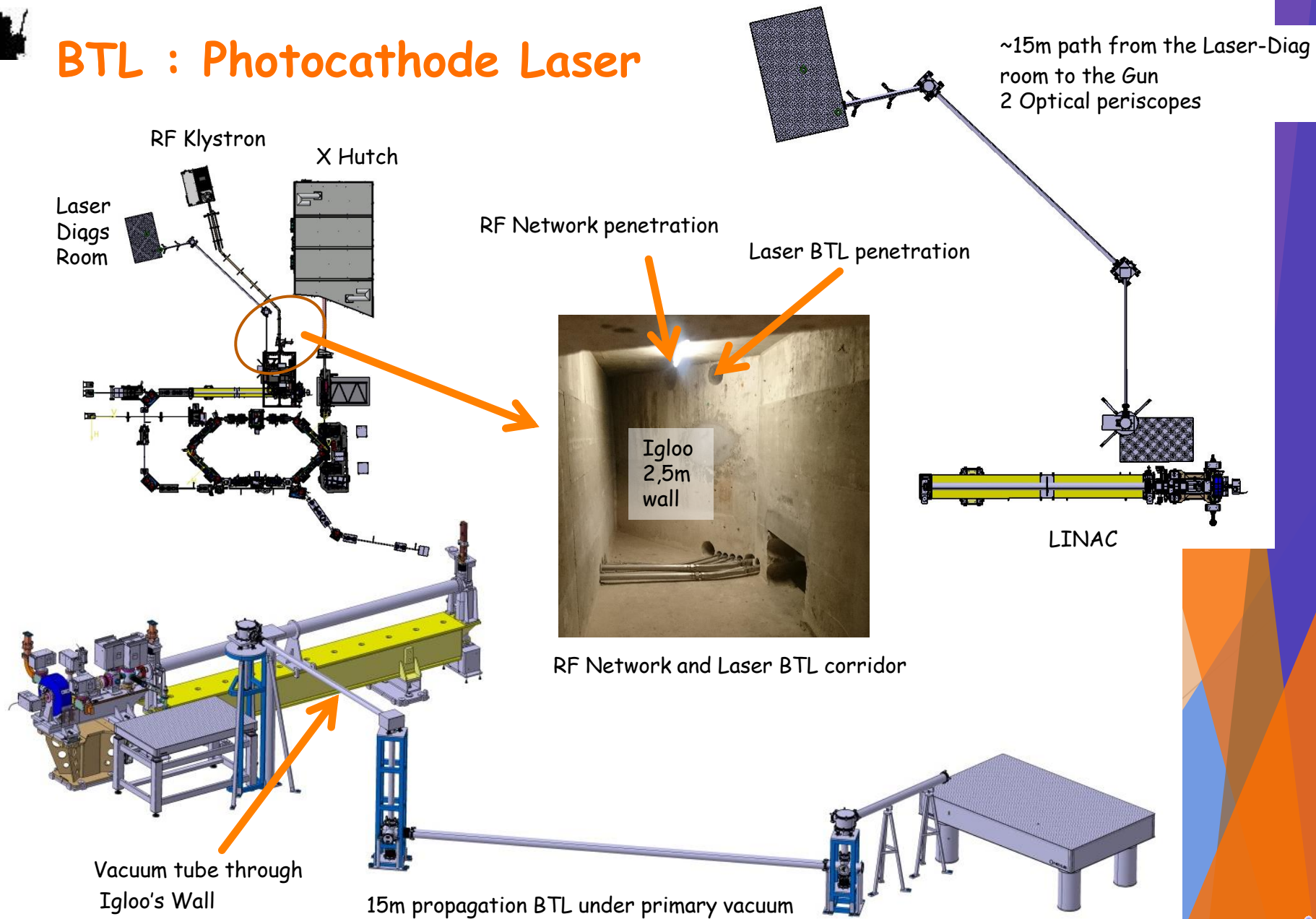
Ceramic column  
(x8)

Lentgh « Flange to flange » = 444,4 mm  
Matière : AISI 316 LN (d=7,9)  
Weight : 20,8 kg (hors support)  
UHV Surface : 2900,6 cm<sup>2</sup>





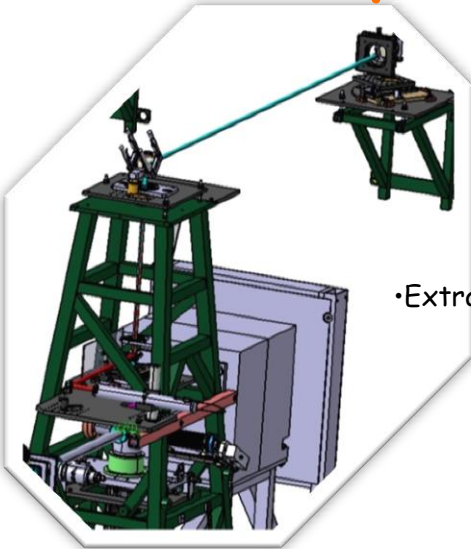
# BTL : Photocathode Laser







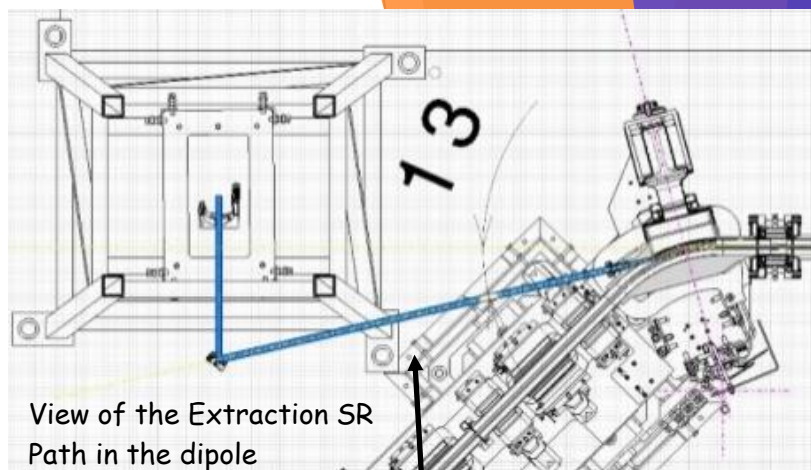
# BTL: Synchrotron, Cerenkov



•Extraction CR



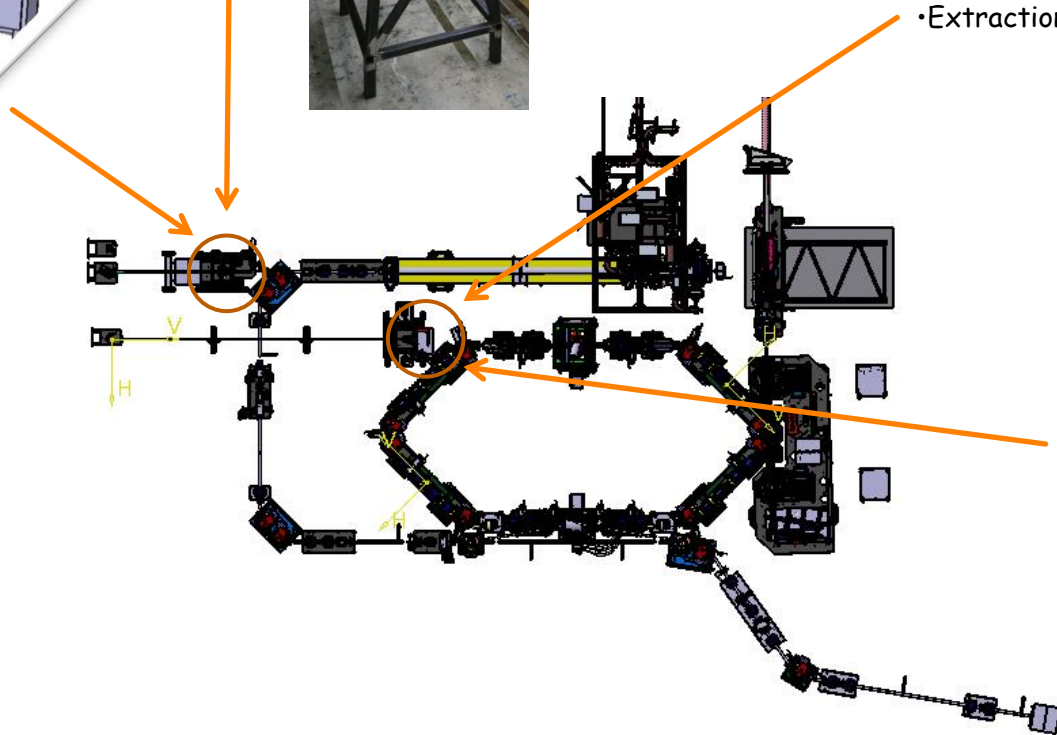
2 "Eiffel Towers" machined and welded at LAL-workshop



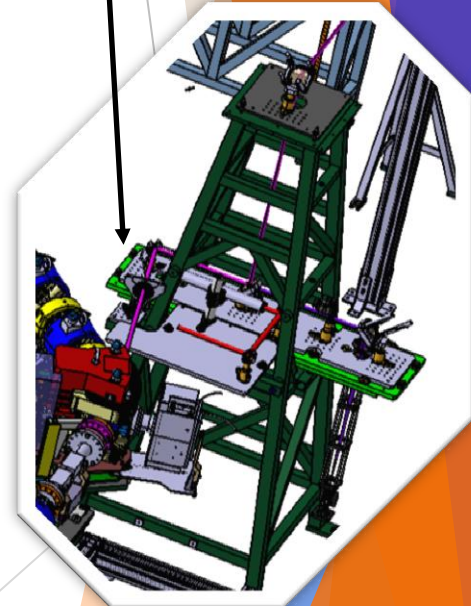
View of the Extraction SR Path in the dipole



•CR Screen



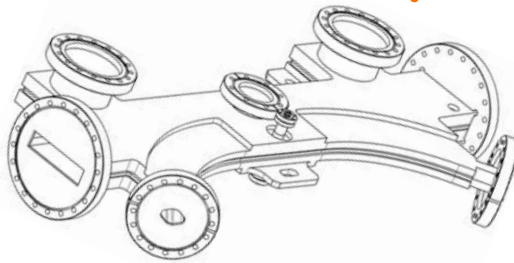
•Extraction SR





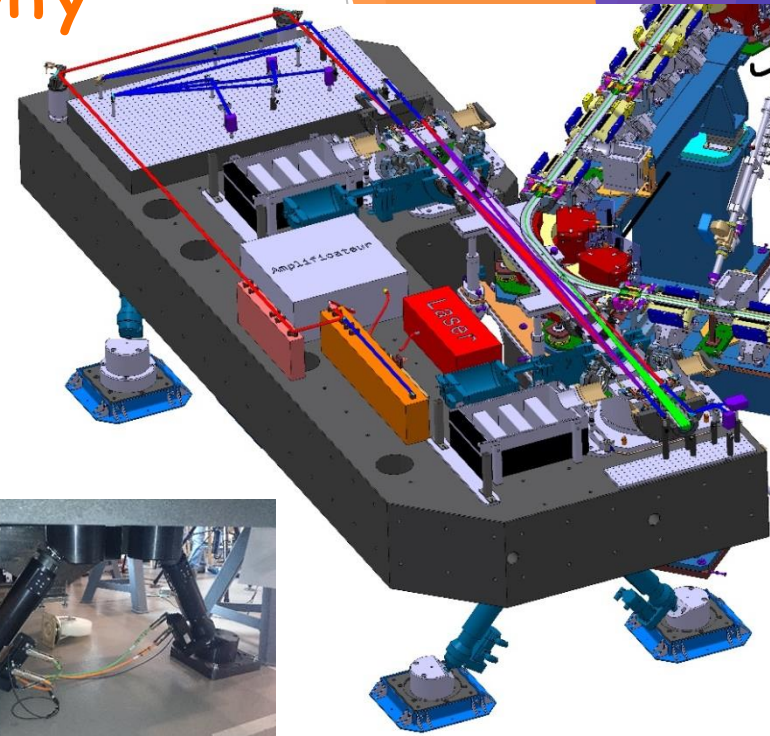
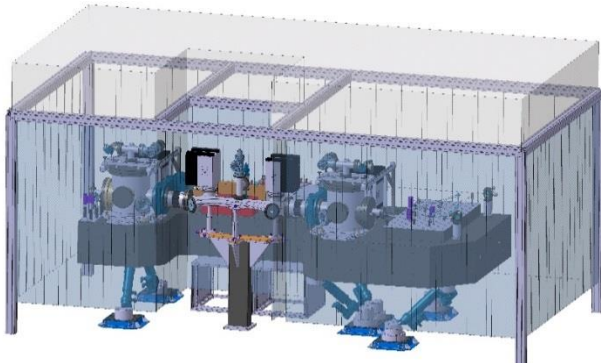


# Interaction Point : Optical Cavity

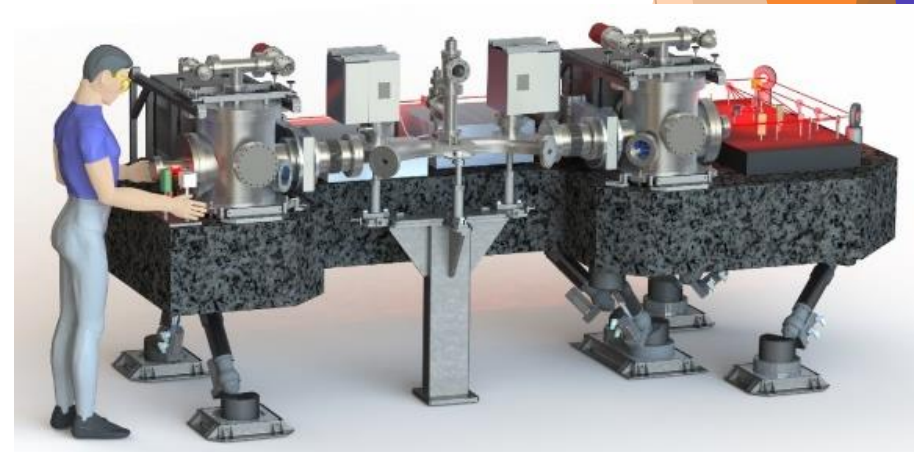


A Fabry Perot cavity inside two UHV chambers (delivered January 2015) connected by an Stainless Steel 316LN IP Chamber et 2 Bellows.

- Whole assembly in a clean room class ISO-5 with laminar flow
- Assembled on a 5t hexapod - granite table for a fine spatial matching of the cavity on the electron beam - Symétrie (Nîmes, France) - FAT June 2015



Degré de liberté hexapode	Déplacement axe par axe	Résolution	Répétabilité
Tx (e)	/	/	/
Ty (t)	± 2 mm	1 $\mu\text{m}$	0.8 $\mu\text{m}^*$
Tz (v)	± 5 mm	1 $\mu\text{m}$	0.8 $\mu\text{m}^*$
Rx / Pitch	± 1 mrad	2 $\mu\text{rad}$	0.8 $\mu\text{rad}^{**}$
Ry / Yaw	± 1 mrad	2 $\mu\text{rad}$	0.8 $\mu\text{rad}^{**}$
Rz / Roll	± 3.5 mrad	2 $\mu\text{rad}$	0.8 $\mu\text{rad}^{**}$





# Interaction Point : Inside the Optical Cavity

• Angular adjustment on flex mount with stepper motor

• Frequency or focalization adjustment

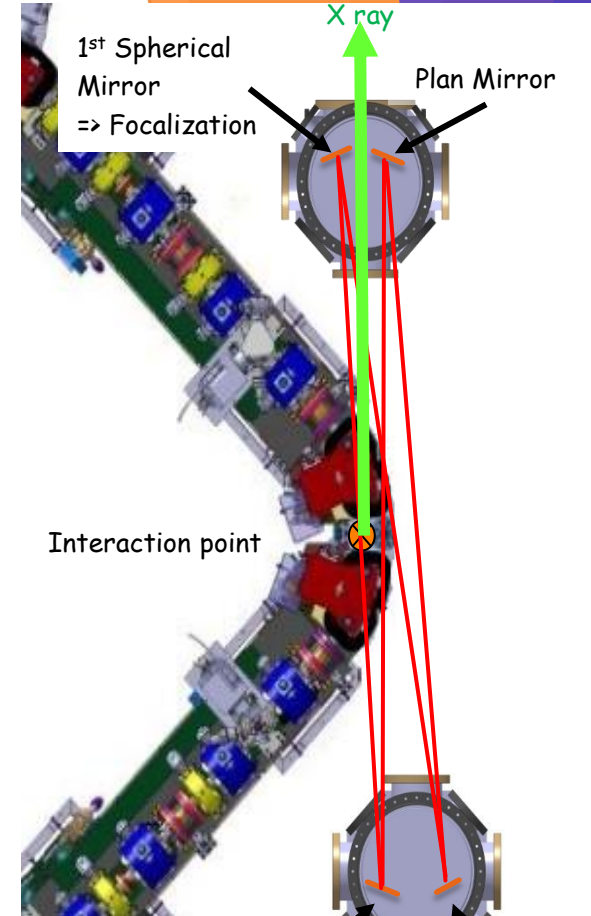
• Longitudinal adjustment with 2 balls on a V and one on a plane

Stepper motors in Vacuum Tight chambers 2015

• ThomX MAC 20&21/03/2017 Mechanics, Alignment

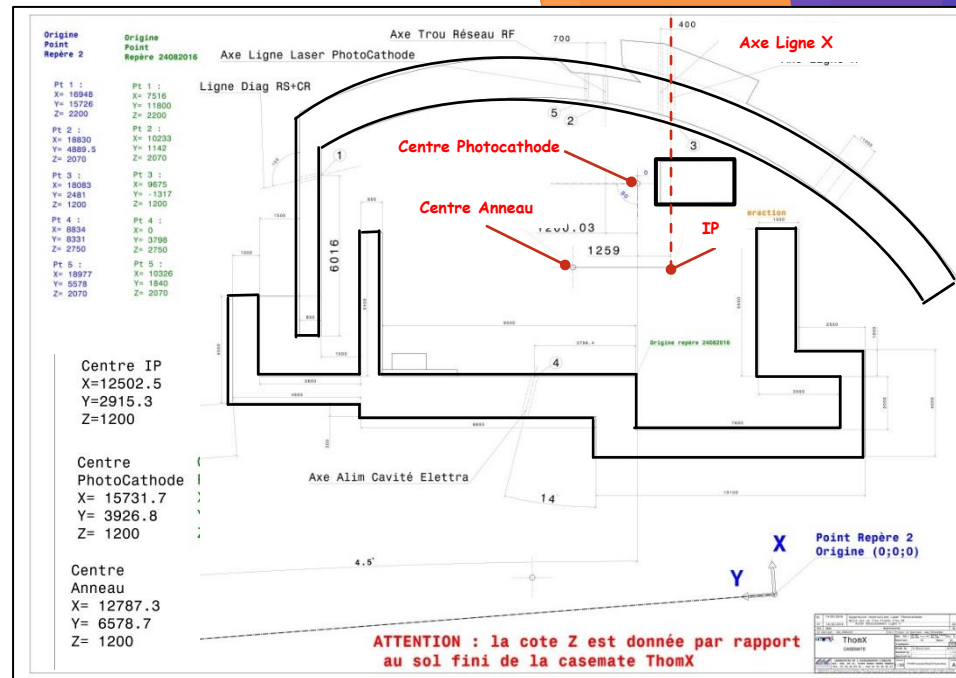
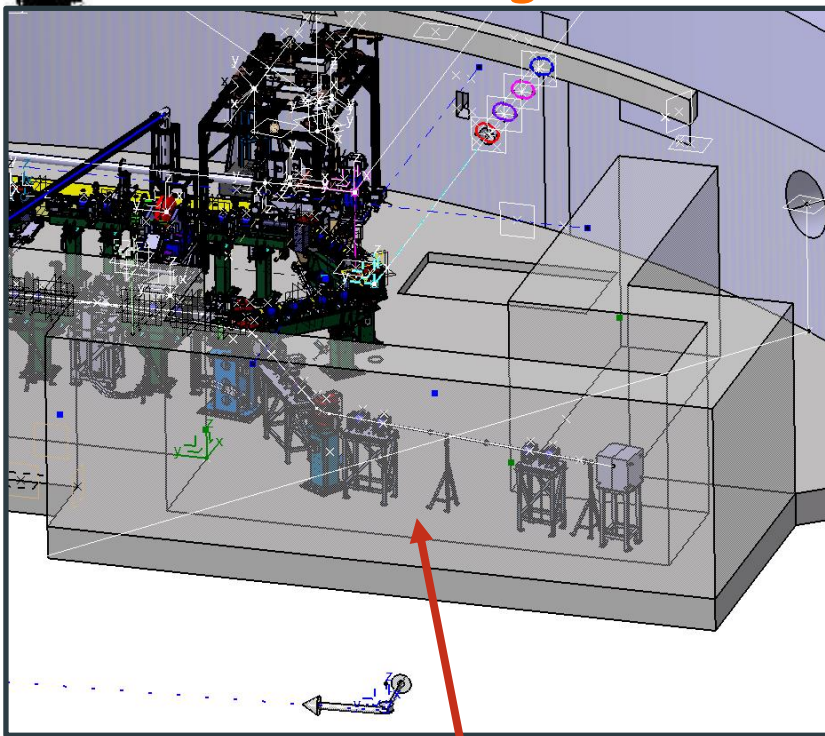
Flex Mount machined by EDM Wire cutting

• Denis Douillet (LAL) - Orsay, 20/03/2017





# IGLOO Integration



- ✓ Full 3D CATIA model (Machine + Igloo) => before 2014 to 2015
- ✓ 1<sup>st</sup> Localization of the machine (Axes & VIP of the machine) => 02/2016
- ✓ Construction Site Survey => from March to December 2016
- ✓ Permanent Cross-checking => from March to end 2016
- ✓ Final Choice of the X Line axis through the real hole (non perfect) to the X hut through the 2,5m wall => decision by the end of 2016



View of the X line Table 1 location and X Line hole

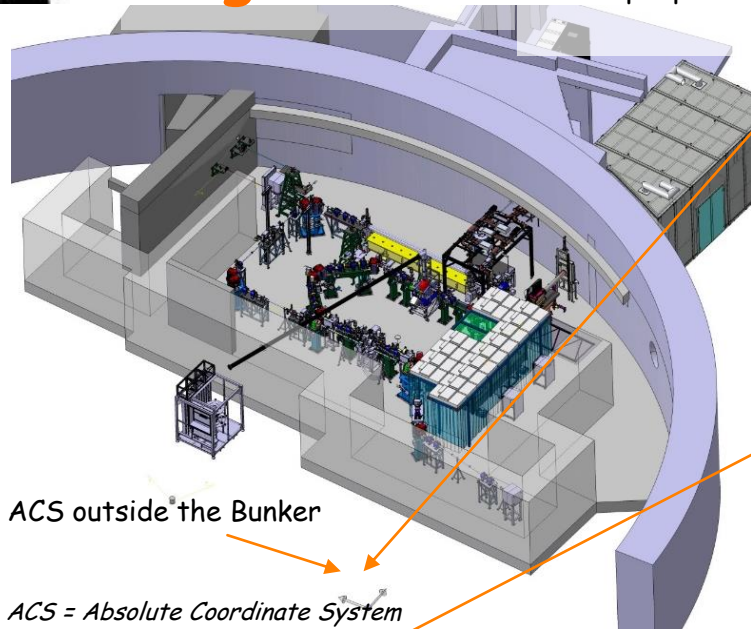


Drilling of the X Line penetration



# Alignment

Very 1<sup>st</sup> step : 11/2016, purchase of the AT930 Laser Tracker from HEXAGON METROLOGY  
6 LAL people from DO & Workshop trained by HM and SOLEIL Alignment Group  
(Thanks to A.Lestrades and M.Ros)



ACS outside the Bunker

ACS = Absolute Coordinate System  
Perfectly known by surveyors

• Step 1 : before construction of the walls, several targets sealed to the ground in the area of the machine, targets fully described in the ACS

• Step 2 : Once the bunker built, 8 targets glued on the bunker walls to establish a network. These 8 targets are connected to the 1<sup>st</sup> ground targets and to the ACS (not visible anymore)

=> The 8 final targets are fully described X,Y,Z in the ACS

• Step 3 : survey of the 8 targets in the bunker and localization of the tracker in the ACS.  
4 targets were bonded in the X hutch

• Step 4 : permanent marks on the principals axis of the machine and adjustment frames in order to adjust plates (bonded) with the tracker for components of the storage ring, transfer and extraction line and Optical cavity



SOLEIL's targets  
(gift from Ros & Lestrades)



LAL Alignment Group : A.Thiebault, A.Gallas,  
R.Marie, B.Leluan, O.Vitez, D.Douillet



Bonding of the Steel plates on the bunker ground



# Today in the Bunker







# 2017 Integration Schedule : January to March

Weeks  
number

→ 1->4		5->8			9->12					
LUN	2	30	•LIN : A = LINAC Girder Integration			27	LIN: A 209 EQ1	Alignement Casemate EQ align	Préparation Poutres C1 & C2 Bat 208	
MAR	3	31 FEV				28	MAR 1			
MER	4	1								
JEU	5	2				2				
VEN	6	3				3				
SAM	7	4				4				
DIM	8	5				5				
LUN	9	6	LIN: A 209 EQ1			6	LIN: A 209 EQ1	Alignement Casemate EQ align	Préparation Poutres C1 & C2 Bat 208	
MAR	10	Section LIL Bot 208	7		7	EQ1				
MER	11	Test Vide	8		8					
JEU	12		9		9					
VEN	13		10		10					
SAM	14		11		11					
DIM	15		12		12					
LUN	16	Fin Rognéage	13	Alignement Casemate EQ align	LIN: B LIL 208:HL EQ1 EQV	LIN: A 209 EQ1	13	LIN: A 209 EQ1	Alignement Casemate EQ align	Préparation Poutres C1 & C2 Bat 208
MAR	17		14				14			
MER	18		15				15			
JEU	19		16				16			
VEN	20		17				17			
SAM	21		18				18			
DIM	22		19				19			
LUN	23		20	Alignement Casemate EQ align	LIN: B LIL 208:HL EQ1 EQV	LIN: A 209 EQ1	20	LIN: A 209 EQ1	Préparation Poutres C1 & C2 Bat 208	
MAR	24		21				21			
MER	25		22				22			
JEU	26		23				23	Nettoyage du chantier		
VEN	27		24				24			
SAM	28		25				25			
DIM	29		26				26			

RING Integration  
at LAL-208

MAC





# 2017 Integration Schedule : April to June

Roof Opening

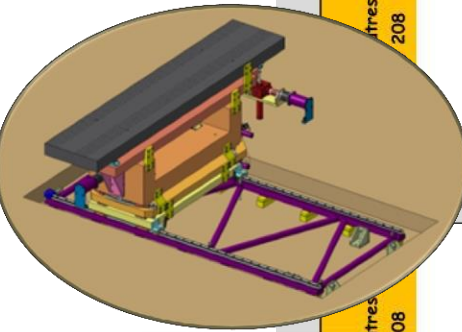
13->16				17->20				21->24			
27	LIN: A 209	LIN: B LIL 208 : HL	Préparation Poutres C1 & C2 Bat 208	24	LT: E 208 : S05	LT: A 3*Q 208 : S05	Préparation Poutres C1 & C2 Bat 208	22	Diags SR & CR Eq Diags	Quad Q4 Casemate EQ2	Préparation Poutres C1 & C2 Bat 208
28	EQ1	EQ1 EQV		25	EQ1	EQ2		23	RING Integration at LAL-208 : magnets		
Juverture Toit Casemate				26	Transfert Casemate			24			
Transfert Casemate				27				25			
Install Casemate				28				26			
29				29				27			
30				30				28			
1				1	LT: H 2*Q 208 : S05	LT: A 3*Q 208 : S05	Préparation Poutres C1 & C2 Bat 208	29	Diags SR & CR Eq Diags	Quad Q5 Casemate EQ2	Préparation Poutres C1 & C2 Bat 208
2	LIN: A 209	LIN: B LIL 208 : HL	2	EQ1	EQ2	30					
3	EQ1	EQ1 EQV	3	Transfert Casemate		31					
4	Install Casemate			4				1			
5				5				2			
6				6				3			
7				7				4			
8				8	LT: H 2*Q 208 : S05	Dip D1&D2 Casemate	Préparation Poutres C1 & C2 Bat 208	5	Diags SR & CR Eq Diags	Dip D3&D4 Casemate EQ2	Préparation Poutres C1 & C2 Bat 208
9				9	EQ1	EQ2		6			
10	Réseau HF Casemate	Klystron Eq4 HallD1	10	Transfert Casemate		7					
11				11				8			
12				12				9			
13				13				10			
14				14				11			
15				15	LT: I 208:S05	Beam Dump Casemate	Préparation Poutres C1 & C2 Bat 208	12	LE: A Casemate EQ2	Dip Injection Casemate EQ2	Préparation Poutres C1 & C2 Bat 208
16				16	EQ1	EQ2		13			
17	Réseau HF Casemate	Klystron Eq4 HallD1	17			14					
18				18				15			
19				19				16			
20				20				17			
21				21				18			

Addition of 2 Concrete Blocks : Scraper & Beam Shutter



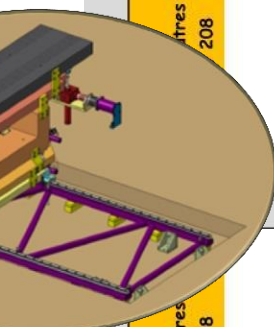


# 2017 Integration Schedule : July to September



Positioning and Sealing of X Line Table 1

25->28				29->32				33->36			
19	Préparation Poutres C1 & C2 Bat 208	LE:B Casemate EQ2	Fin Reception Chambres	17	C1:A (Septum-) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	Tests Vide Chambre + Traitement Thermique + Syst étuvage	14	Tests Vide Chambre + Traitement Thermique + Syst étuvage	C1:D (IP-) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	C2:A Casemate EqT+EqA2 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	
20				18			15				
				19			16				
				20			17				
				21			18				
22				22			19				
23				23			20				
24	Préparation Poutres C1 & C2 Bat 208	LE:C Casemate EQ2	Tests Vide Chambre + Traitement Thermique + Syst étuvage	24	C1:A (Septum-) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	Tests Vide Chambre + Traitement Thermique + Syst étuvage	21	Tests Vide Chambre + Traitement Thermique + Syst étuvage	C1:D (IP-) Av Cav FP Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	C2:A Casemate EqT+EqA2 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	
25				22			22				
26				23			23				
27				24			24				
28				25			25				
29	Préparation Poutres C1 & C2 Bat 208		Tests Vide Chambre + Traitement Thermique + Syst étuvage	31	C1:C (Septum+) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	Tests Vide Chambre + Traitement Thermique + Syst étuvage	28	Tests Vide Chambre + Traitement Thermique + Syst étuvage	C1:E (Ip+) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	C2:C Casemate EqT+EqA2 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	
30				1			29				
1				2			30				
2				3			31				
				4			1				
3	Cavité RF Casemate EQ2		Tests Vide Chambre + Traitement Thermique + Syst étuvage	5	C1:C (Septum+) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	Tests Vide Chambre + Traitement Thermique + Syst étuvage	2	Tests Vide Chambre + Traitement Thermique + Syst étuvage	C1:E (IP+) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	C2:C Casemate EqT+EqA2 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	
4				6			3				
5				7			4				
6				8			5				
7				9			6				
8	Cavité RF Casemate EQ2		Tests Vide Chambre + Traitement Thermique + Syst étuvage	10	C1:C (Septum+) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	Tests Vide Chambre + Traitement Thermique + Syst étuvage	7	Tests Vide Chambre + Traitement Thermique + Syst étuvage	C1:E (IP+) Casemate EqT+EqA1 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	C2:C Casemate EqT+EqA2 + EQV MeK/Align + Det Fuites/Vide Limite/RGA	
9				11			8				
10				12			9				
11				13			10				
12											
13							11				
14							12				
15							13				
16							14				



Delivery (?) of Ring chambers

JULY

RING I at LAL

Delivery (?) of Ring chambers

RING Integration at LAL-208 : magnets and chambers

J  
U  
L  
Y







# 2017 Integration Schedule (October to 2018 ...)

37->40			41->44			45->48			49->52		
11	Tests Vide Chambre + Traitement Thermique + Syst étuvage	C2:D	9	Septum	6	Mise sous vide Anneau	4	Mise sous vide Anneau			
12		Casemate	10	Casemate	7		5				
13		EqT+EqA2 + EQV	11	EQ2	8		6				
14		MeK/Align	12		9		7				
15		+	13		10		8				
16		Det Fuites/Vide Limite/RGA	14		11		9				
17			15		12		10				
18	Montage MeK Chambresur Poutres	C2:D	16	Kickers	13	Mise sous vide Anneau	11	Mise sous vide Anneau			
19		Casemate	17	Casemate	14		12				
20		EqT+EqA2 + EQV	18	EQ2	15		13				
21		MeK/Align	19		16		14				
22		+	20		17		15				
23		Det Fuites/Vide Limite/RGA	21		18		16				
24			22		19		17				
25	Montage MeK Chambresur Poutres	C2:E	23	Kickers	20	Mise sous vide Anneau	18	Mise sous vide Anneau			
26		Casemate	24	Casemate	21		19				
27		EqT+EqA2 + EQV	25	EQ2	22		20				
28		MeK/Align	26		23		21				
29		+	27		24		22				
30		Det Fuites/Vide Limite/RGA	28		25		23				
DEC 1			29		26		24				
2	Montage MeK Chambresur Poutres	C2:E	30		27	Mise sous vide Anneau	25	Mise sous vide Anneau			
3		Casemate									
4		EqT+EqA2 + EQV									
5		MeK/Align									
6		+									
7		Det Fuites/Vide Limite/RGA									
8											

Thanks for your attention

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2018 .... Optical Cavity, FBT  
Septum, Kickers and more ....  
but "You Never Can Tell"

