



Laboratori Nazionali di Legnaro



UNIVERSITÉ DE GRENOBLE

# STATUS OF THE CHARGE BREEDER

**T. LAMY, J. ANGOT**

**LPSC - Université Grenoble Alpes - CNRS/IN2P3**

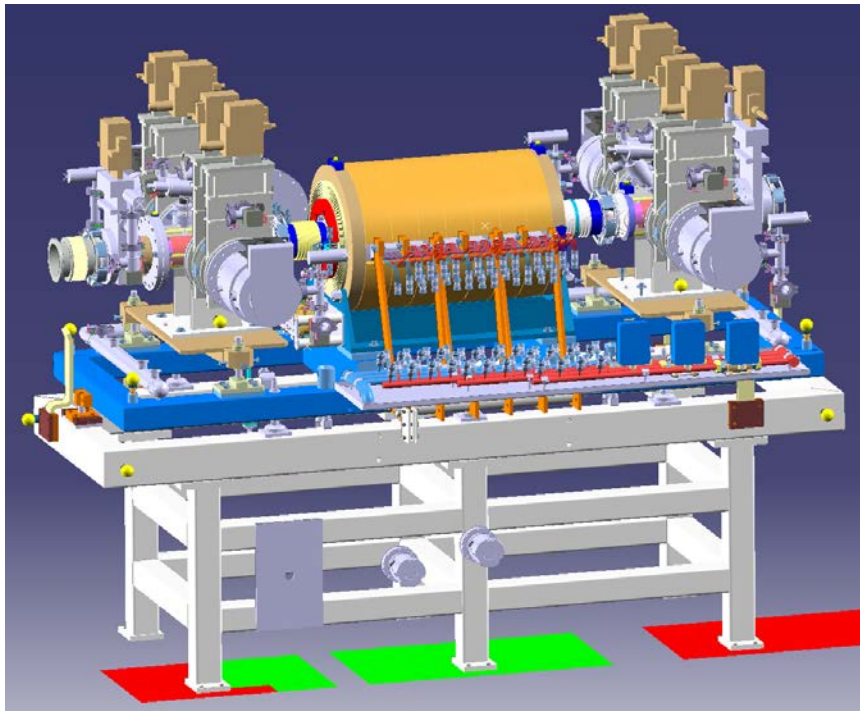
**A. GALATÀ**

**INFN/LNL**

# Contractual context

## Research collaboration contract signed by INFN and CNRS the 2<sup>nd</sup> of June 2014

- LNL and INFN made a remarkable effort to guarantee the LPSC-CNRS organization and rules
- LPSC-CNRS made its best to respects the LEA-COLLIGA agreement signed by INFN-SPIRAL2/GANIL (exchange of deuteron convertor and charge breeder 500 k€ each)



**SPIRAL2 Charge breeder**

**Final design satisfying LNL requests**  
(based on the LPSC design for SPIRAL2)

**Construction**

**Qualification on the LPSC test stand**

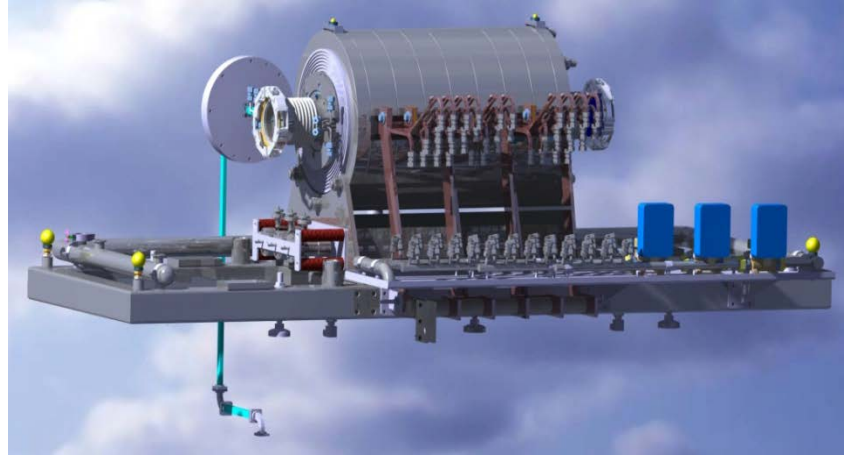
**End of spring 2015 delivery to LNL**

# SPES charge breeder

## Two main equipment

- Additional ones (HF, supplies..)
- Depending on the budget consumption

Same magnetic field as the LPSC one to guarantee the efficiency, improvements for vacuum, alignment systems and high voltage isolation



SPES Charge breeder

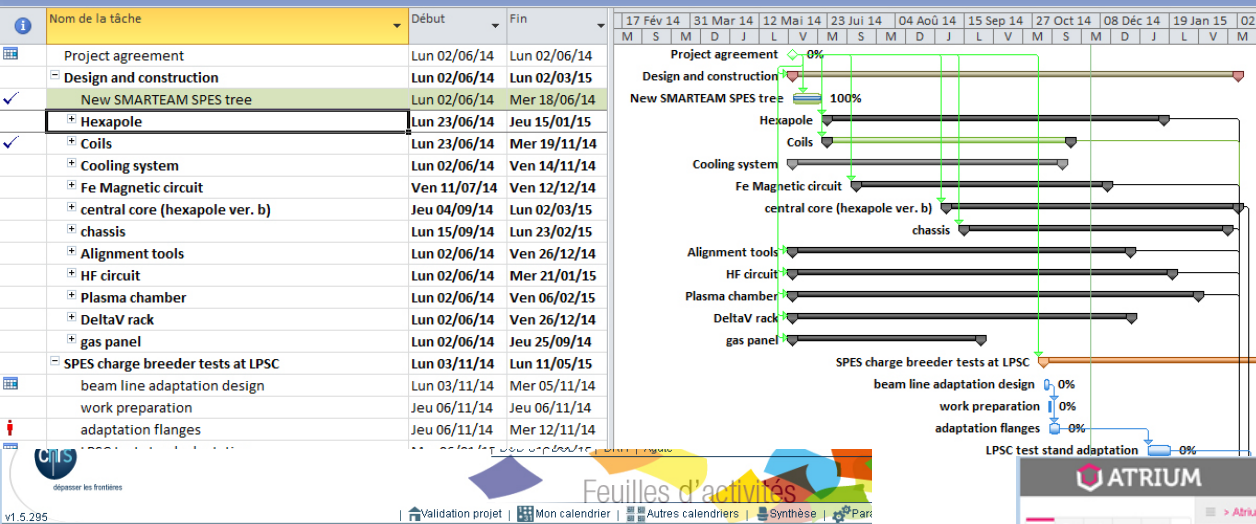


DeltaV bay



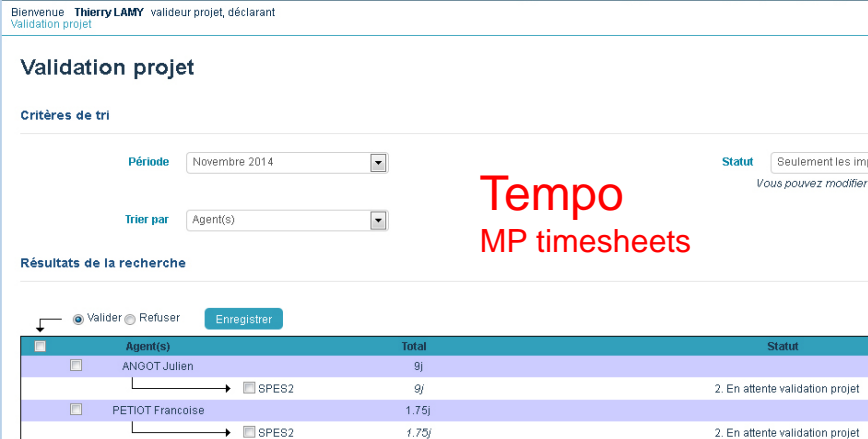
- **Research and development activities** are performed in NuPNET EMILIE contract
  - WP3 (Optimization of the performances of the Phoenix booster)
  - A. Galatà (LNL) coordinator
  - INFN-LPSC-GANIL-JYFL-Warsaw Uni.
- SPES may benefit in the future of the charge breeder characteristics improvements

# Methods

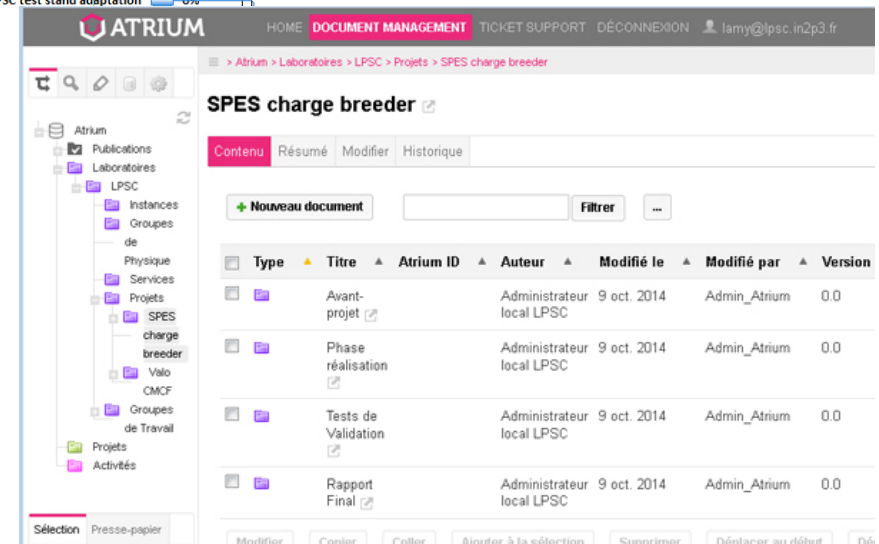


Msproject  
Precise planning

ATRIUM  
Document management



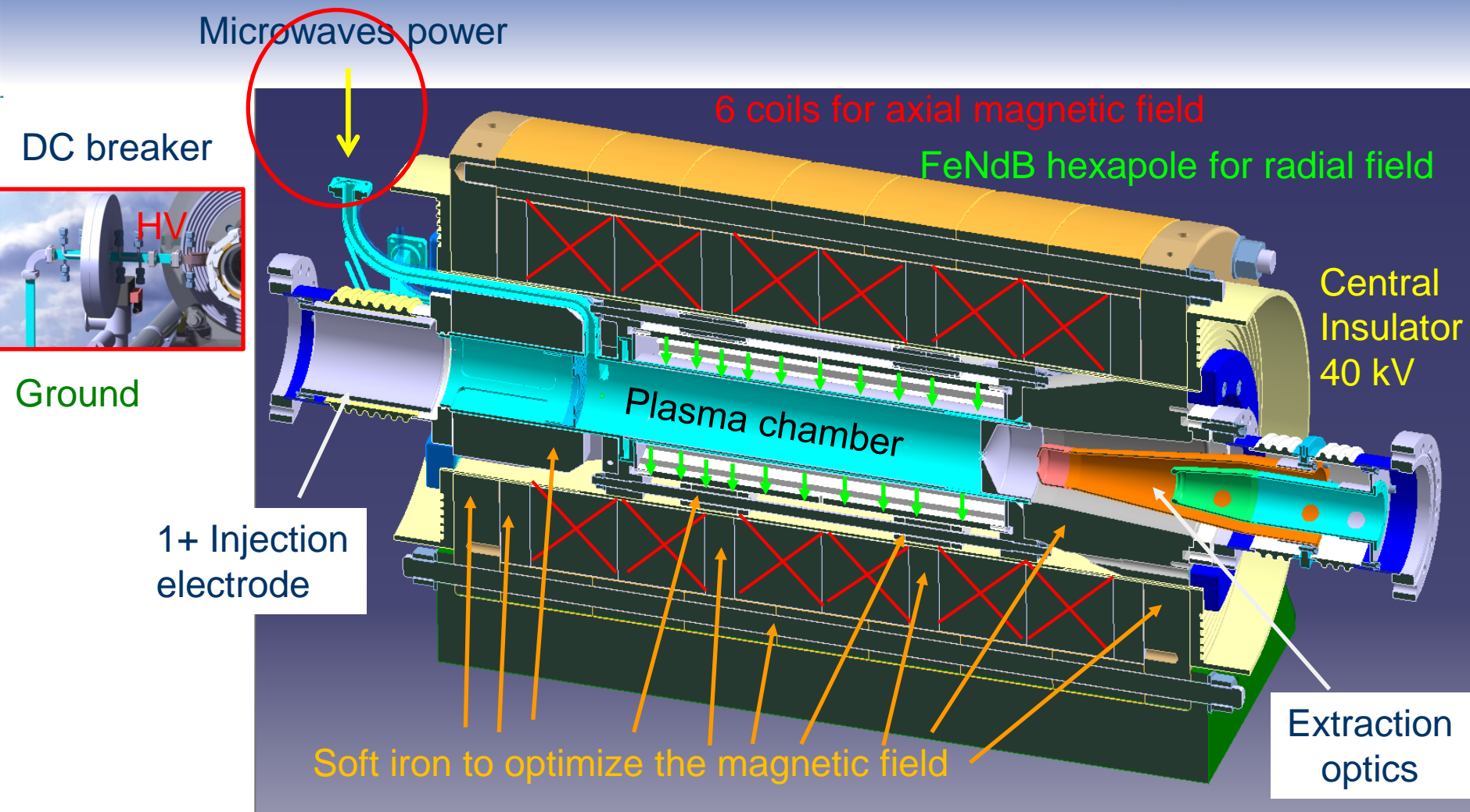
Tempo  
MP timesheets



Detailed 40 pages development plan

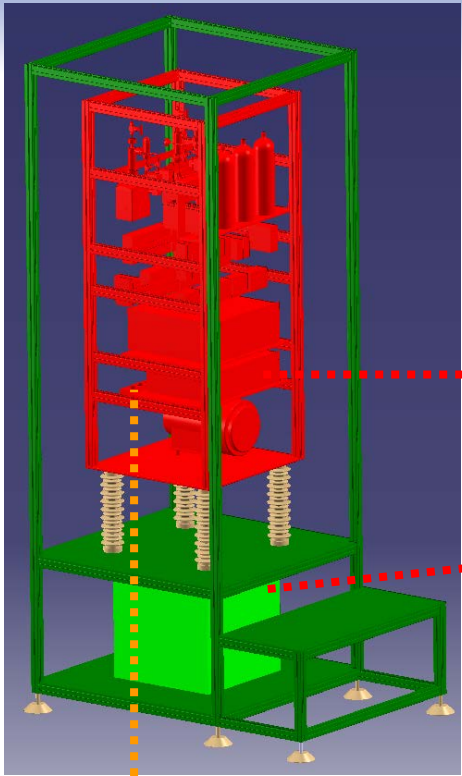
+ monitoring of the budget, + formalized documents for each sub system  
LNL-LPSC discussions then LNL agreement to LPSC before each realization

# Charge breeder basic description

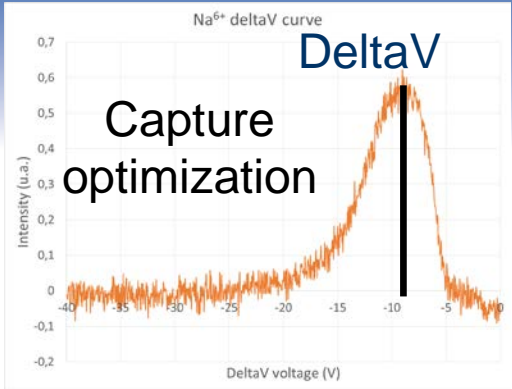


Efficiencies : 16%  $\text{Ar}^{8+}$ , 11%  $\text{Xe}^{20+}$ , 4%  $\text{Na}^{6+}$ , 7%  $\text{Rb}^{15+}$ , 10%  $\text{Cs}^{27+}$   
 About 10 ms/charge, typically  $30 \pi.\text{mm.mrad}$  (RMS) @ 20 keV

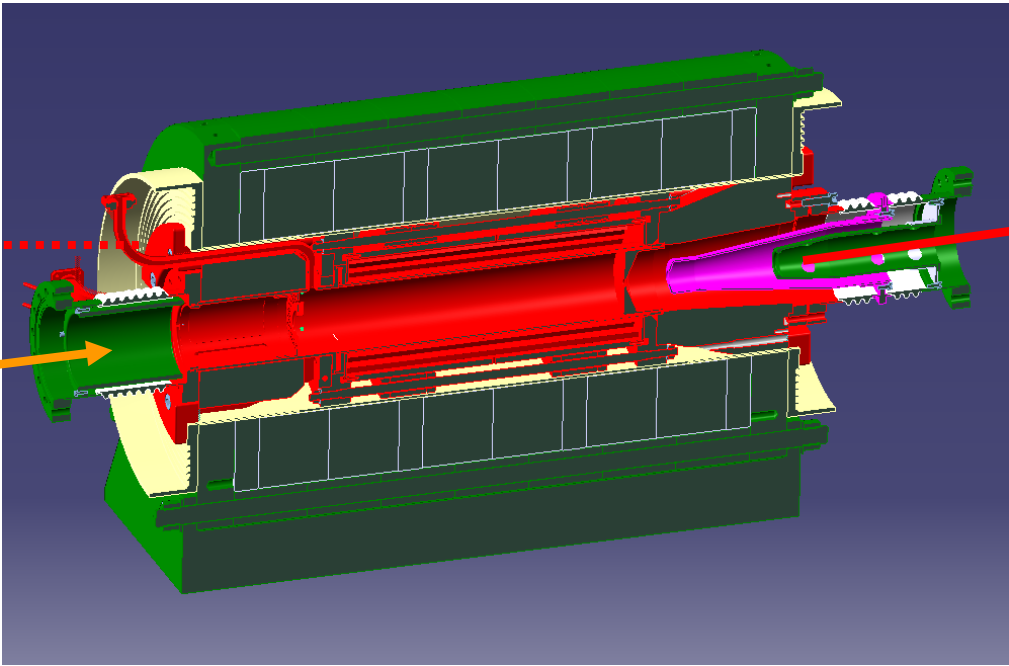
# DeltaV Principle



40 +/- DeltaV kV



q+ beam  
q\*(40 +/- DeltaV) keV



40 kV

40 keV  
1+ beam

1+ source



# The 6 coils for axial magnetic field

- Delivered in November
  - SEF order 19 980 € (Budgeted 21000 €)
  - Tested at 600 A



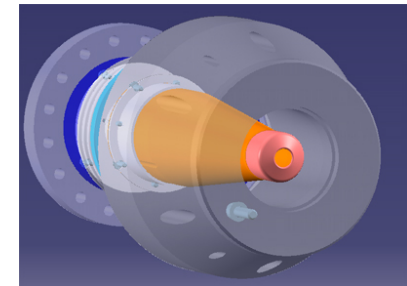
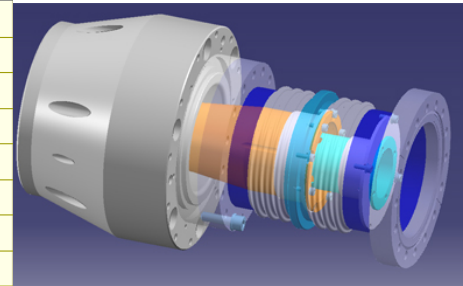
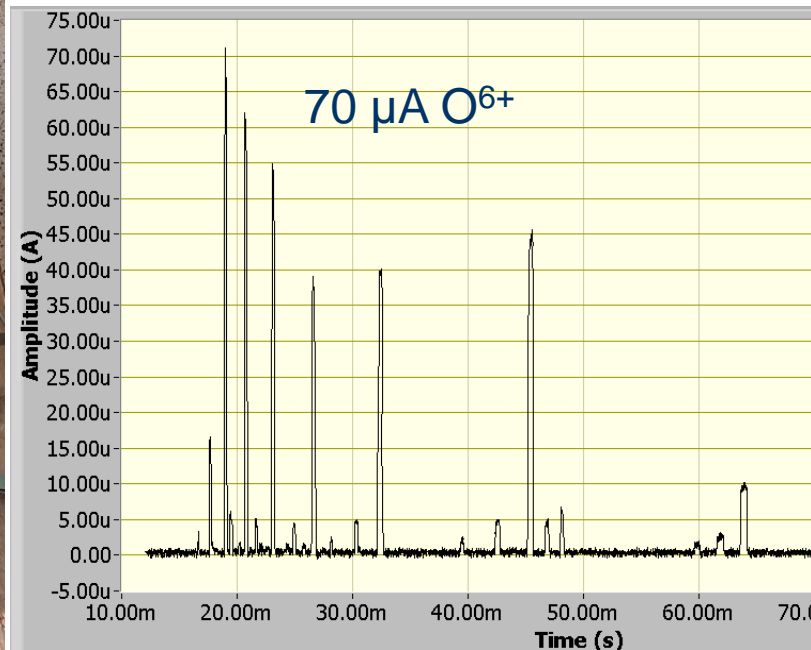
Instruments: Oscilloscope Hameg HM303:4 Z26529 ; dielectromètre MC5B ;  
 Alimentation: Hazemeyer 630A 100Vdc  
 Multimètre digital 7045 n°006652 ;

	UNITE	RESULTATS	TEST DATE
<b>SOLENOIDE N°001</b>			
Nombre de spires		64	7/11/2014
Conducteur 8mm x 8mm Ø4		OK	
Contrôle visuel		OK	
Résistance totale à 20°C		19.41	
Galette N°1(cote numéro)	mΩ	4.86	
Galette N°2	mΩ	4.86	
Galette N°3	mΩ	4.86	
Galette N°4	mΩ	4.85	
Bobine immergée		OK	
5000V DC -- 1min	MΩ	>200	
Isolation entre spire (secondaire de transformateur)	V	600v/9.3v/spire	
Contrôle champs magnétique 600A	Gauss	1725	
Test brasure sous pression statique 50bars during 15min			
Galette N°1 (cote numéro)	l/min	OK	
Galette N°2	l/min	OK	
Galette N°3	l/min	OK	
Galette N°4	l/min	OK	
Contrôle débit sous 15 bars			
Galette N°1 (coté numéro)	l/min	4.2	
Galette N°2	l/min	4.2	
Galette N°3	l/min	4.2	
Galette N°4	l/min	4.2	

# Magnetic circuit : soft iron

AKSTEEL 7518 €, budgeted 5500 €

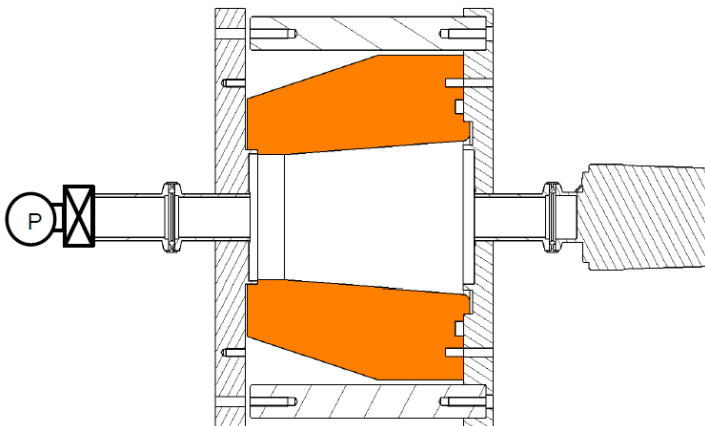
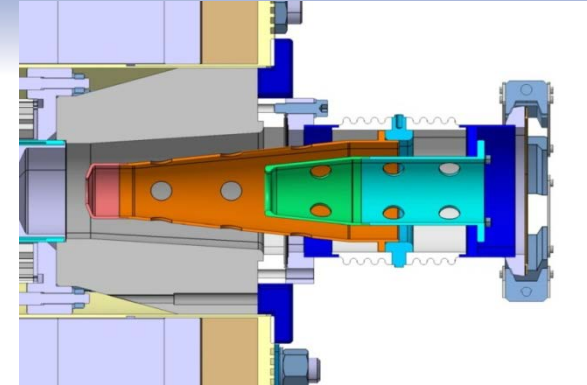
- All main parts are machined and under painting (bright orange)
  - To be delivered in the next 2 weeks
  - Injection plug pre-machined
  - Extraction plug under vacuum



Since years, charge breeder spectra dominated by oxygen without gas injection  
**We suspect soft iron degasing that can trap O<sub>2</sub> during production**

# Soft iron under vacuum manufacturing

- **LNL expertise on materials and baking facility**
  - Many LNL-LPSC exchange on the topic
- **Decided procedure**
  - Heat treatment: NORMALIZING
  - Machining
  - Welding of the 316LN 100CF flange
  - Electro polishing of the internal surface (option, to be defined)
  - Heat treatment: FINAL ANNEALING
  - Outgassing test at LPSC



Available LPSC plug without treatment will be measured then the SPES treated one

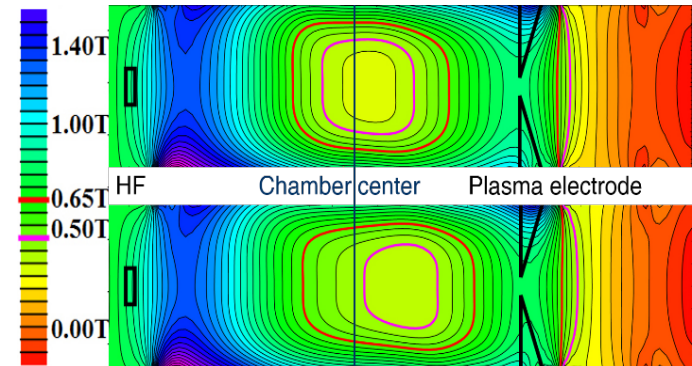
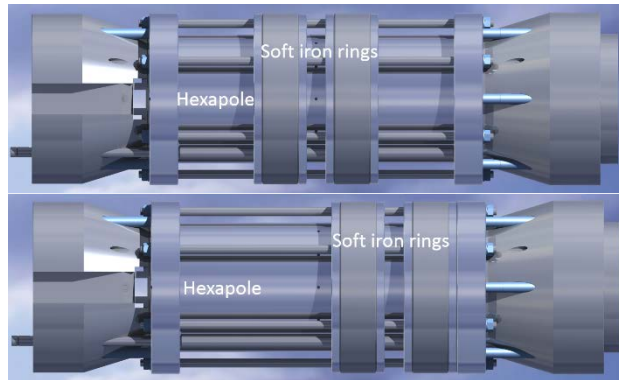
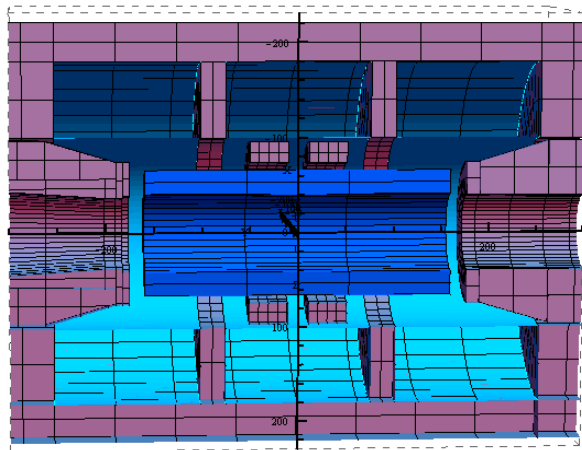


Degassing test stand for SPES

# Hexapole status

- The same as the LPSC one

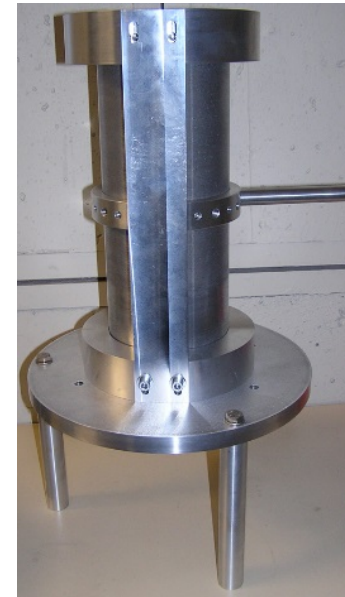
96 magnets (24\*4), length 320 mm, PHI Int132 mm  
 PHI ext145 mm, Two iron rings



Hexapole body  
 4400 € (8000€)



96 plastic magnets



Tools to  
 Assemble it

(The LPSC  
 one was  
 assembled by  
 hand...)

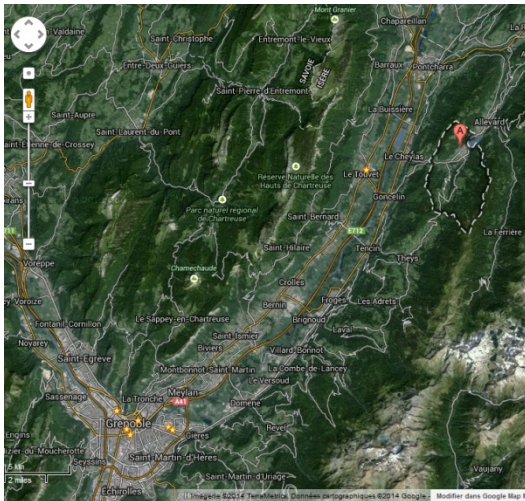
# Hexapole magnets

- EUROMAG

- NdFeB N45SH (Br typ = 1.36T / Hcj typ = 1600 kA/m)

Delivered 3 days ago...(16500 €, 65000 €...!!)

Magnetic and mechanical verifications performed in St Pierre d'Allevard



CNRS - LPSC

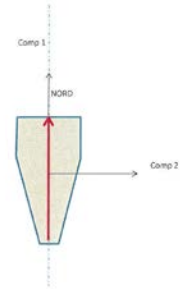
Hexapole de Charge Breeder SPES

58 le 20/11/2014

CONTROLES GEOMETRIQUE (Passage calibre) ET MAGNETIQUE DES AIMANTS

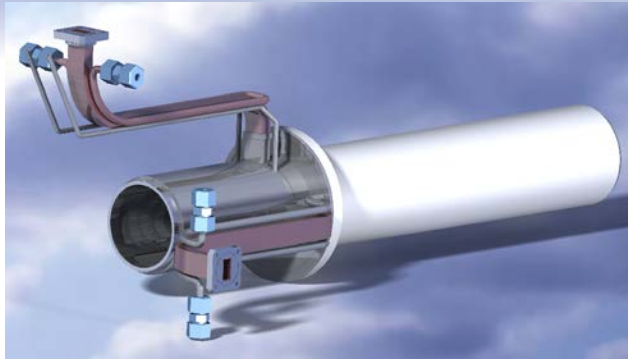
Aimants S254 A2 SZ 10 (Aimant 0° Nord)

#	Passage calibre			MOMENT MAGNETIQUE [mNm/cm³]				
	Ø1	Ø2	Ø3	Comp 1	Comp 2	Module	Angle (°)	
17	ok	ok	ok	3.615	5.43E-01	ok	3.61	+ 0.85
18	ok	ok	ok	3.608	5.11E-01	ok	3.61	+ 0.34
19	ok	ok	ok	3.613	5.10E-01	ok	3.61	+ 0.49
20	ok	ok	ok	3.612	4.97E-01	ok	3.61	+ 0.99
21	ok	ok	ok	3.599	3.40E-01	ok	3.60	+ 0.54
22	ok	ok	ok	3.615	6.54E-01	ok	3.62	- 1.04
23	ok	ok	ok	3.6	1.04E-01	ok	3.62	- 1.65
24	ok	ok	ok	3.599	2.81E-01	ok	3.60	+ 1.44
25	ok	ok	ok	3.610	4.22E-01	ok	3.62	- 0.57
26	ok	ok	ok	3.609	3.99E-01	ok	3.61	- 0.63
27	ok	ok	ok	3.628	1.75E-01	ok	3.63	- 2.28
28	ok	ok	ok	3.61	3.21E-01	ok	3.61	+ 0.51
29	ok	ok	ok	3.611	3.79E-01	ok	3.61	- 0.60
30	ok	ok	ok	3.629	7.36E-01	ok	3.63	+ 1.16
31b	ok	ok	ok	3.615	4.54E-01	ok	3.62	+ 0.77
Moyenne				3.611	0.29			
Min				3.599	1.65			
Max				3.628	1.18			
R				0.0129	2.81			
3σ				0.0283	2.38			
3σS				0.76				



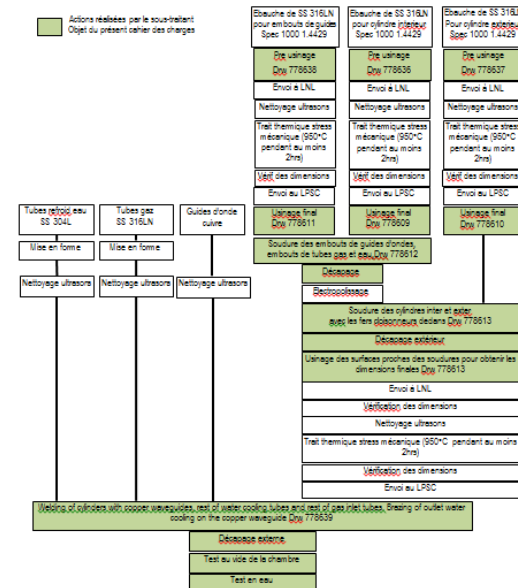
The classification, additional checks and mounting planned by the end of this year

# Plasma chamber status

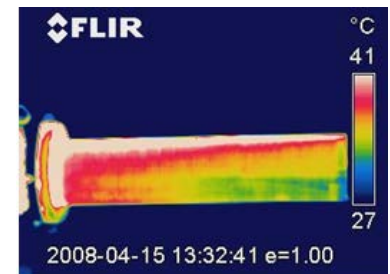


- LNL requirements for material (316LN) treatments and cleaning to limit impurities level
- Whole procedure established by LPSC

Waveguides received  
LPSC refused !



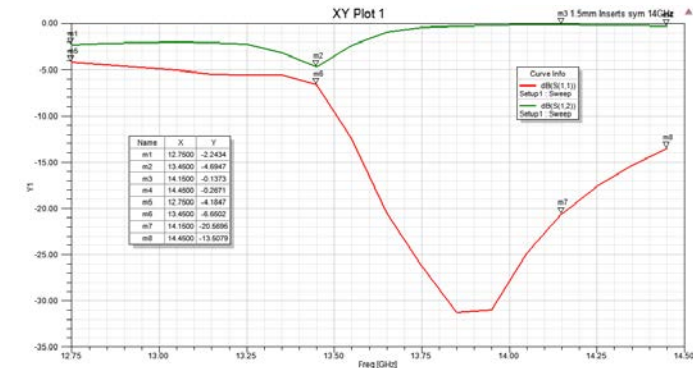
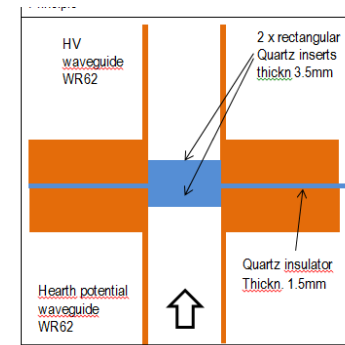
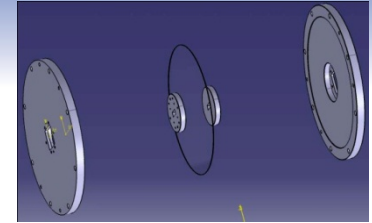
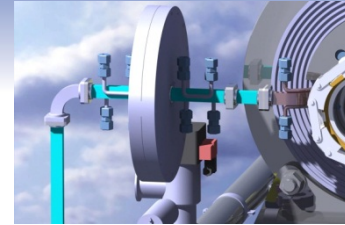
After delivery LPSC tests  
vacuum and cooling



- For 'classical' stainless steel chamber 2-3 months delivery time
- Material to be delivered next days
- Imminent invitation to tender
- In case of delay problem
  - Planning readjustment
  - Possible to use the LPSC plasma chamber for tests

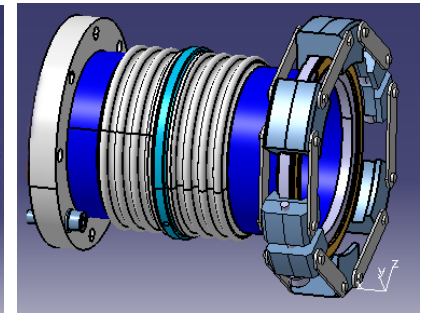
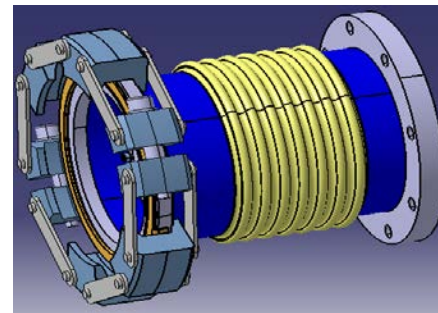
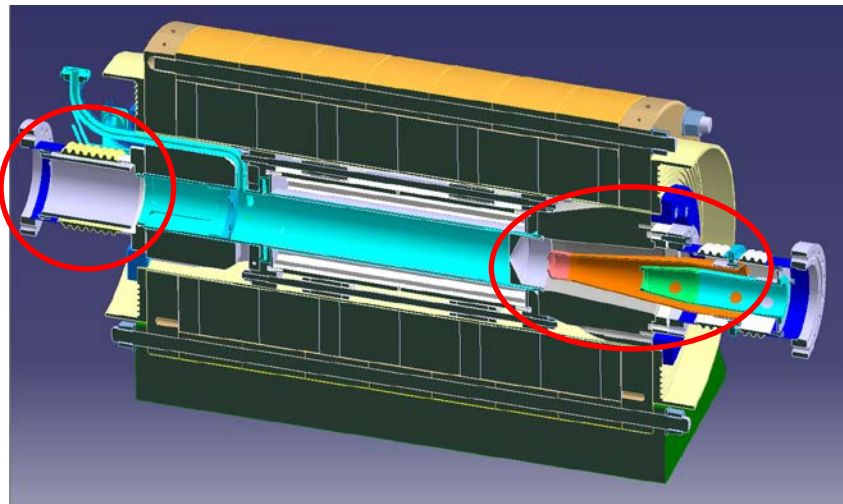
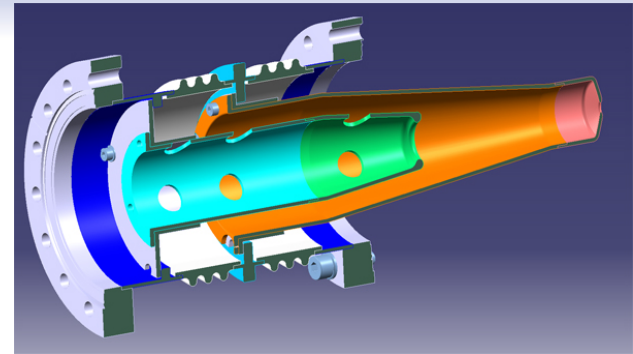
# DC breaker status for microwaves

- HF used at LPSC : 14.5 GHz
  - Classical DC breaker (Teflon foil)
  - **Now problem to find the convenient material**
- We developed a quartz based one for 18 GHz
  - Tested at 60 kV
  - 1300 W HF power  $\approx 2 \times$  P charge breeder
- LNL will use variable frequencies
  - 12.75 – 14.5 GHz
  - 17.3 – 18.4 GHz
- J. Angot made calculations
  - **Bandwidth of the present DC-breakers**
  - **A new development is necessary**
- Not the priority
- **The charge breeder can be tested at 14.5 GHz with the LPSC DC breaker**



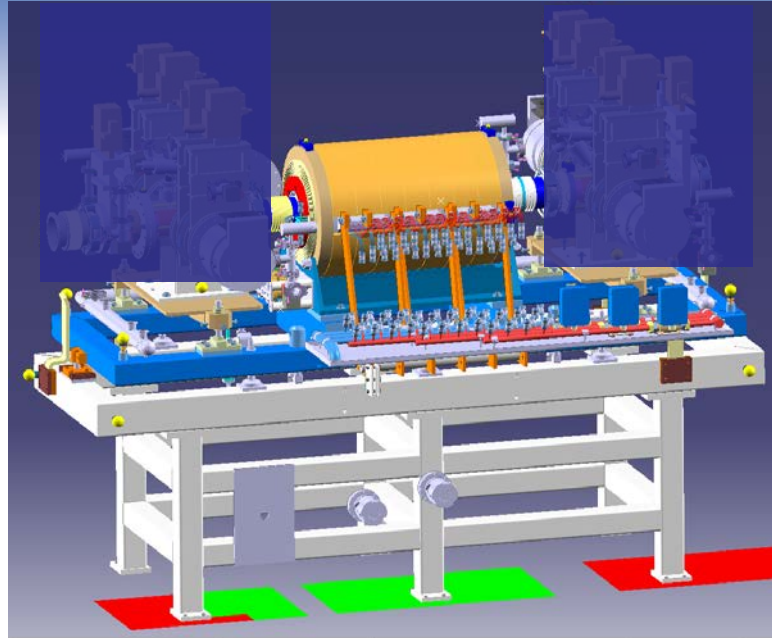
# Alignment procedures and systems

- Alignments
  - of the injection electrode
  - Of the extraction electrodes
  - Of the whole CB in the beam line
- LPSC proposed a scheme for electrodes
  - **Blocking point for design finalization of the central core**
    - (to avoid to have to modify some parts after realization)



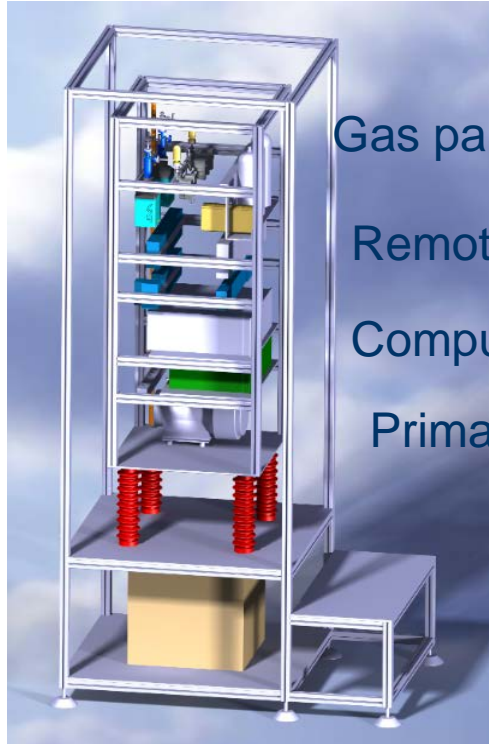
These parts are critical (cost, delay)

# Chassis



- Mobile chassis (blue) LPSC
- Fixed chassis (grey) SPES
- LNL will have to define technical specifications
  - Links between both, length
  - Alignment equipment
  - Anti seismic devices
  - Could be time consuming...
- LPSC will give access to 3D assemblies to LNL
- Not a blocking point for the tests at LPSC

# DeltaV bay



Gas panel

Remote control

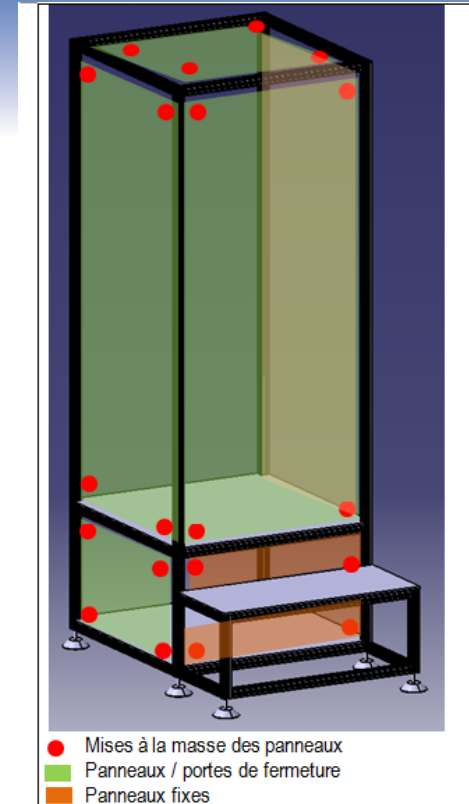
Computer

Primary pump



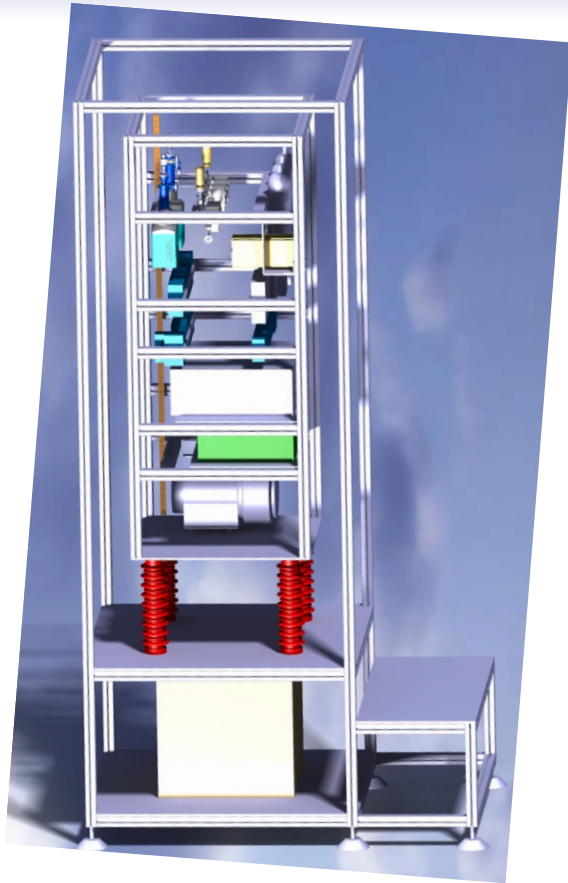
transformer

- Everything is defined
- Almost all parts delivered including the gas panel and command control
- To be mounted in January
- To be tested at 44 kV

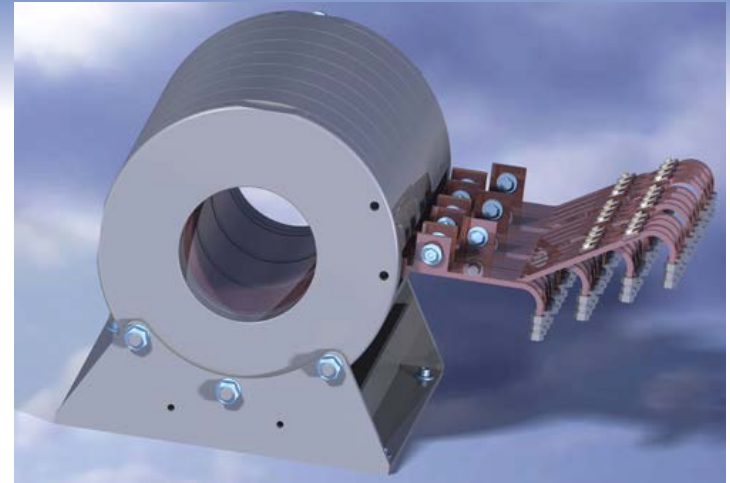


Safety

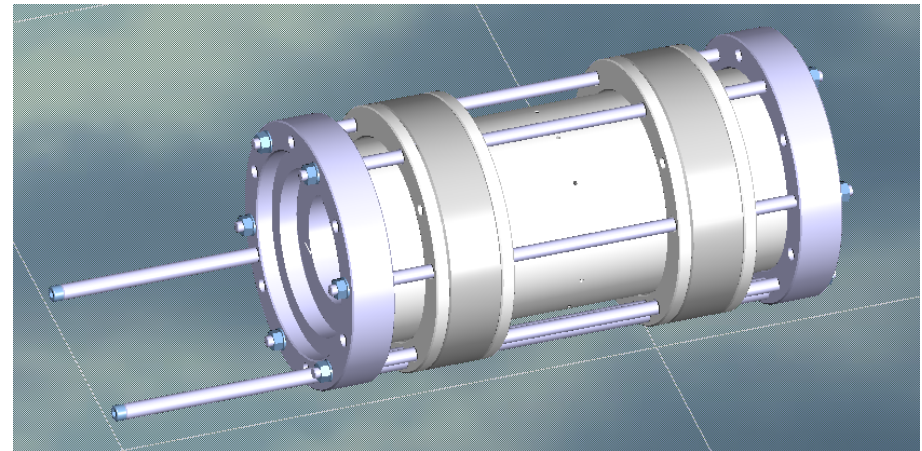
# Status in January 2015



DeltaV bay

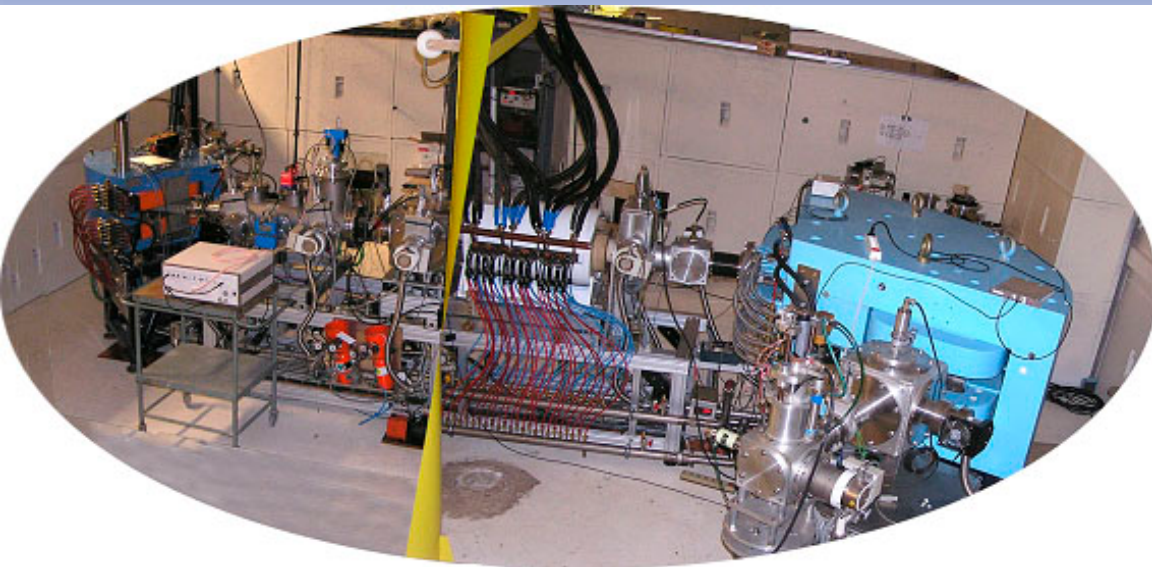


Magnetic circuit and coils

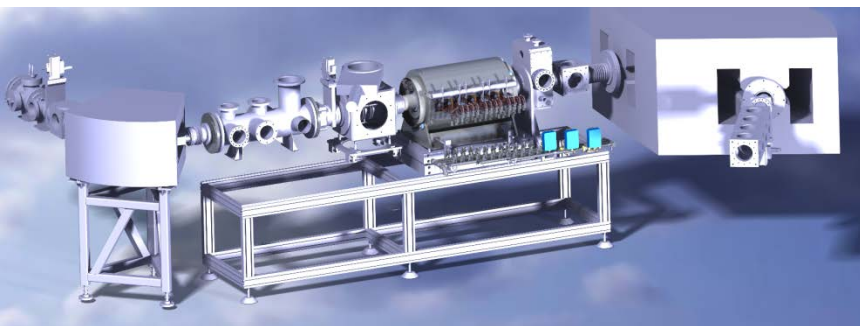
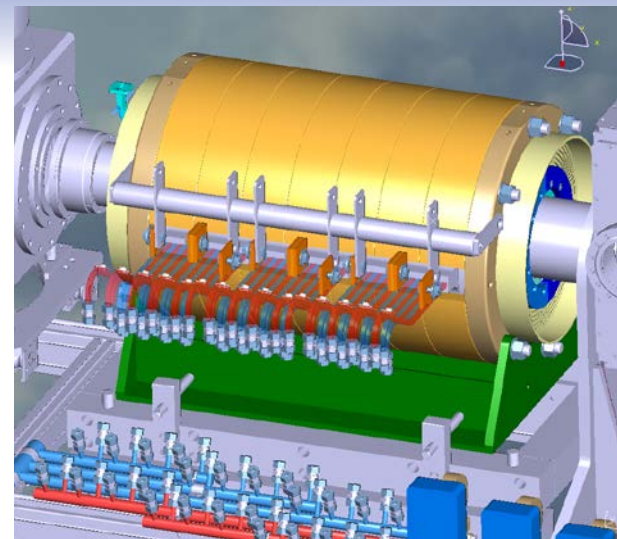


Hexapole with magnets

# Qualification of the SPES charge breeder at LPSC



LPSC 1+/n+ test stand



- All tests were jointly decided and precisely described
- As a normal source  $O^{n+}$
- As a Charge Breeder Ar, Xe, Rb  
Stability, emittances, efficiencies, charge breeding times
- To be performed in spring 2015

# Budget

- Manpower
  - Declared since June ~ 900 h (not yet counted november)
  - Remained to declare if necessary 2300 h
  - Cost declared ~ 55 k€ ( a bit less than 30%)
  - Remaining cost to possibly declare ~ 120 k€
- Equipment
  - Total spent 111 k€ (125 budgeted for this part)
  - Total equipment to be spent 285 k€

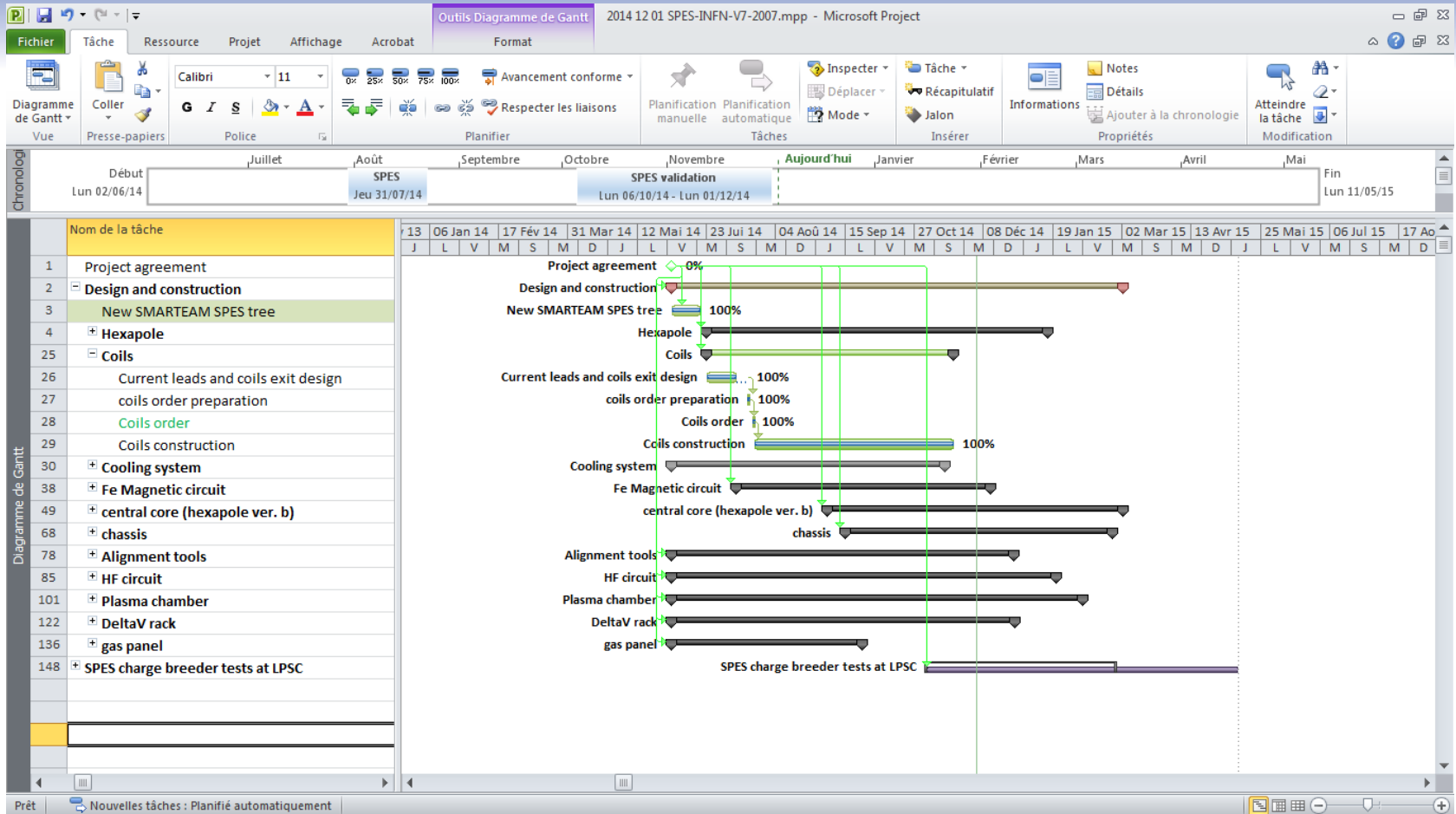
2014 09 24 Suivi Budget SPES.xlsx - Microsoft Excel

2014 09 24 Suivi Budget SPES.xlsx - Microsoft Excel

Isolator 12.75-14.5GHz WR75

Device	Manufacturer	Spent	Provision	Provisional amount	DA date	Order N°	Order date	Delay	Order received by manufacturer	Delivery date
<b>SPES charge breeder budget</b>										
Avance CNRS	CNRS		202100							
Coils	SEF	19980		21000	15/07/2014	64009	21/07/2014	30/10/2014		19/11/2014
Gas dosing valves	VAT	8928		10000	18/07/2014	64010	21/07/2014	18/08/2014		22/08/2014
Electro valves	VACOM	1422.5		0	18/07/2014	64045	24/07/2014	03/10/2014		27/08/2014
Insulator trans+ ground	Transfo industrie	2130		2500	24/07/2014	64044	24/07/2014	15/09/2014		22/09/2014
Hexapole body	Usinex	4390.8		8000	24/07/2014	64099	01/08/2014	15/10/2014		16/10/2014
Waveguides for chamber	Matech	1360		1200	01/08/2014	64209	25/08/2014	10/11/2014		refus 30/10/2014
Permanent magnets	Euromag	16500		65000	25/08/2014	64545	19/09/2014	03/11/2014		01/12/2014
Armco	AKSTEEL	7518		5500	04/09/2014	64591	22/09/2014	24/11/2014		16/10/2014
Hexapole assembly tools	CMME	2153.05		0	16/09/2014					
2x alims deltaV	FUG	12540		6200	19/06/2014					
Prélèvement CNRS		0	-113600							
Gauges and controller	Pfeiffer	2198.03		1500	23/09/2014	64688	29/09/2014			30/10/2014
Usinage culasse	Usinex	4218.2		0	24/09/2014	64687	29/09/2014			
Isolateurs supports	Stiprem	399.2		0	25/09/2014	64750	03/10/2014	20/10/2014		20/10/2014
Pieds anti vibration	Agilent	270.1		0	25/09/2014	64695	30/09/2014			31/10/2014
Contrôle commande	GOMA	9554		?	justif	64799	09/10/2014	21/11/2014		
Versement CNRS		0	22486	justif : chambre plasma + Goma		65002	21/10/2014	12/11/2014		
linear guiding	MICHAUD CHAILLY	177.36		0	justif	65002	21/10/2014	12/11/2014		30/10/2014
Electronics deltaV Ethernet link	ADM21	286.62		0	justif	65036	23/10/2014	06/11/2014		06/11/2014
Electronics deltaV Safety	Elec Isere	5032.78		3000	justif	65052	23/10/2014	10/11/2014		
Plasma chamber stainless steel	VACOM	2894.47		0	justif	65094	24/10/2014	24/11/2014		
DeltaV rack chassis	ELCOM	8450		1200	justif	65237	03/11/2014	01/12/2014		
Screws	OREXAD	85.42		0		65391	12/11/2014	24/11/2014		

# Planning



No real deviation from the original, however we have to follow it carefully

We took the responsibility to qualify the charge breeder of the SPIRAL1 upgrade in 2015

**Thank you for your  
attention**

**Let's go on this  
wonderful adventure...**