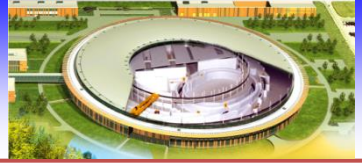
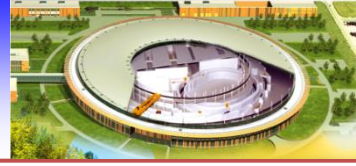
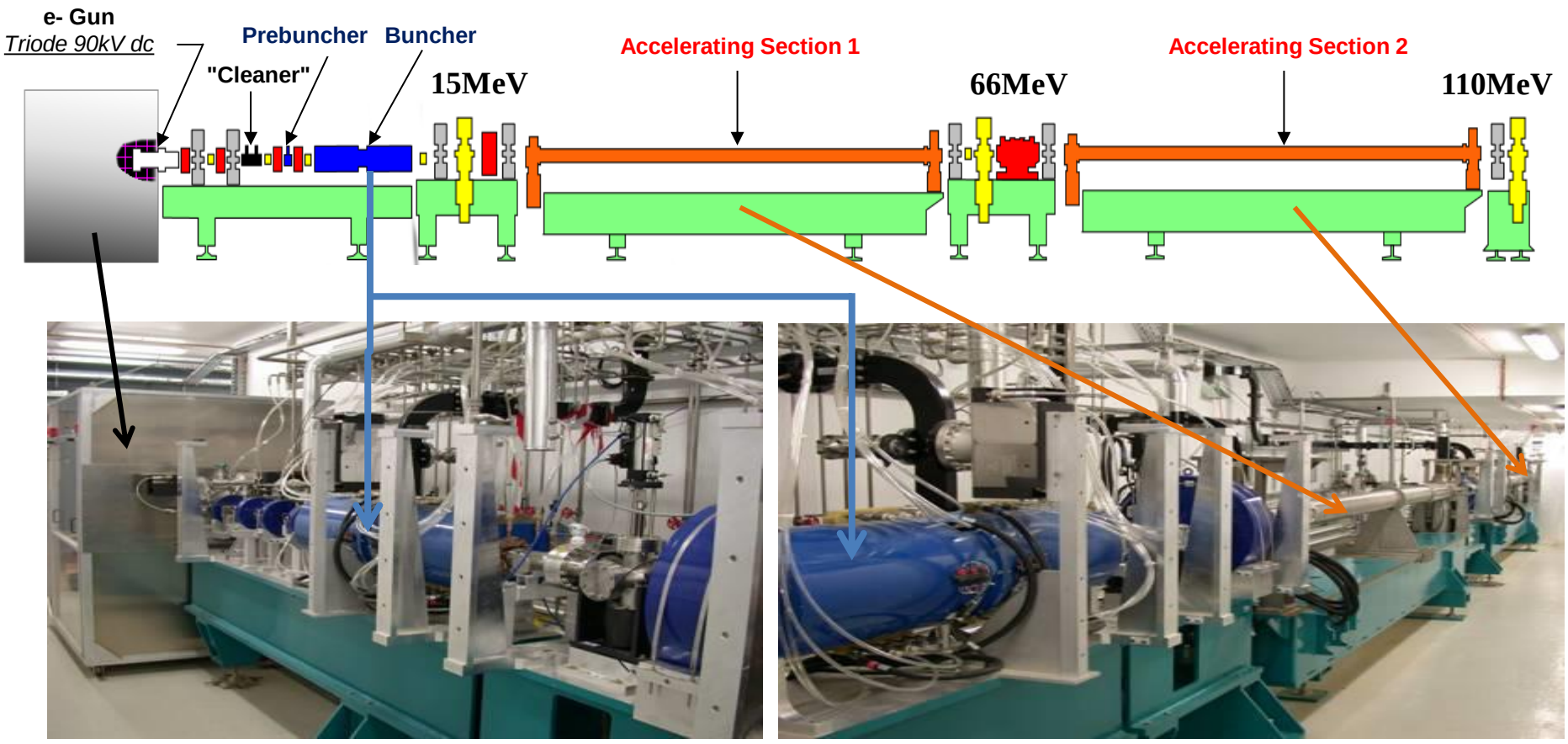


Operational experience with the SOLEIL LINAC and Status of the ThomX LINAC project



Operational experience with the SOLEIL LINAC

SOLEIL, the French SR facility, has a the 110MeV 3GHz pre-injector, which is designed to work in two operation modes : a Short Pulse Mode (2ns – 0.5nC) and a Long Pulse Mode (300ns – 0,3nC to 8nC), both at 3Hz (10Hz max) repetition rate



Cleaner (beam filter in short pulse mode)

Fast electric deflector: to avoid parasitic beam current from the gun
Allows a window of 2 ns eliminating the dark current and cutting the beam pulse head and tail

Dark current of 90keV is deflected in front of **a circular collimator** by **700 V DC**, this voltage droops to zero to 2 ns

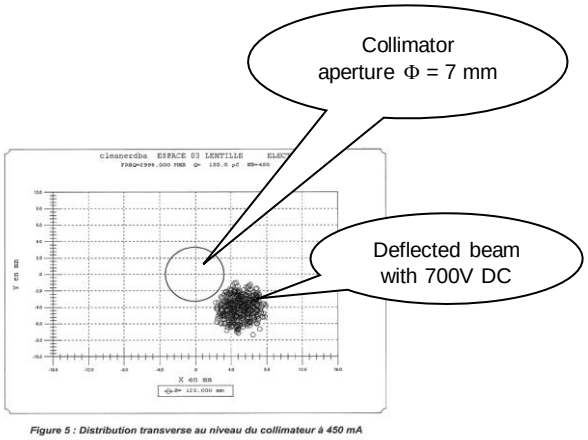
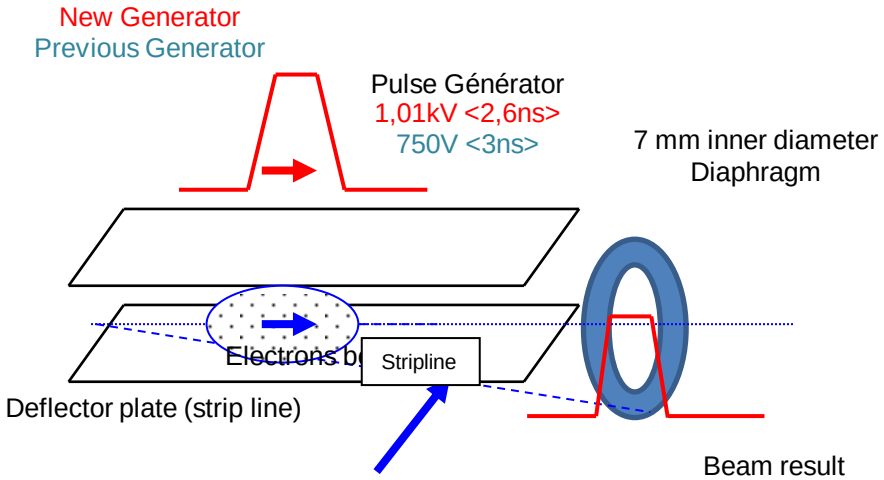


Figure 5 : Distribution transverse au niveau du collimateur à 450 mA

Transverse distribution at collimator for 0.1 to 1 mA of dark current with focus for a beam pulse of 450 mA

Its functionnality



Deflected by permanent coil
2Amps = 116,4mrad
1,6Amps = 93,1mrad

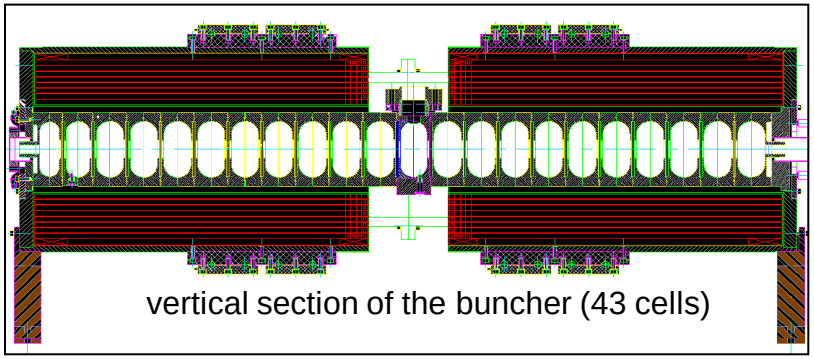
1 cell-cavity Prebuncher

ΔE = ± 10keV @ 200W RFin

Half Cavity before brazing

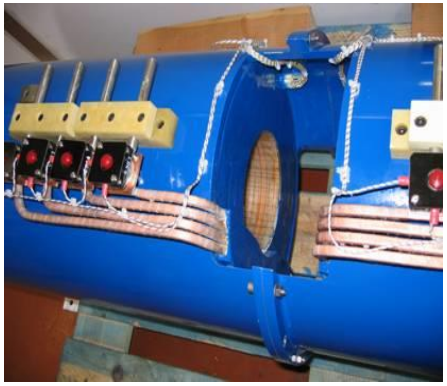
Buncher: standing wave

ΔE = 15MeV @ 5,5MW RFin



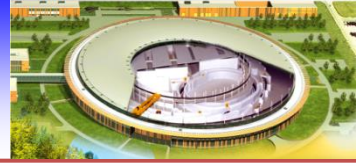
vertical section of the buncher (43 cells)

Copper cell alignment, 1m long, 15Mev



Solenoid focusing
2000Gauss

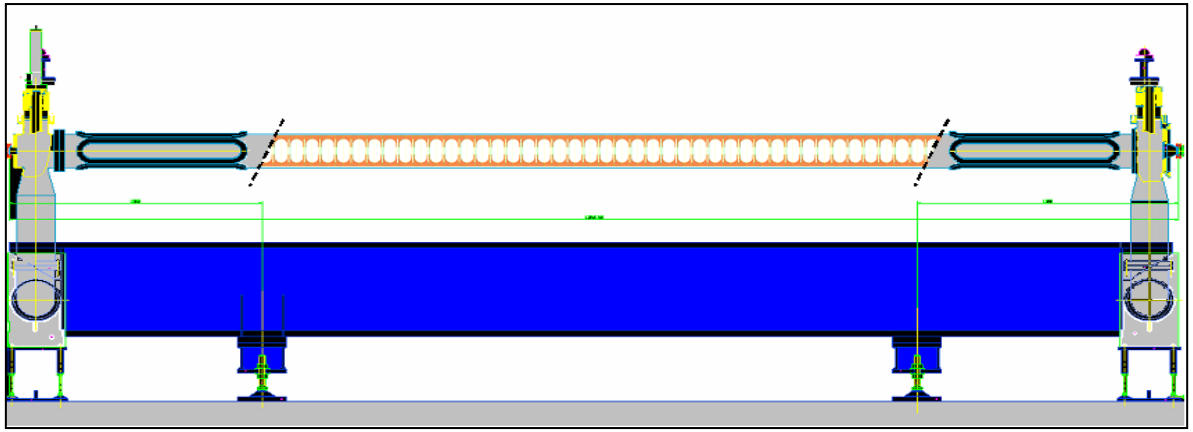
Four short shielded lenses provide the focusing between the gun and the buncher



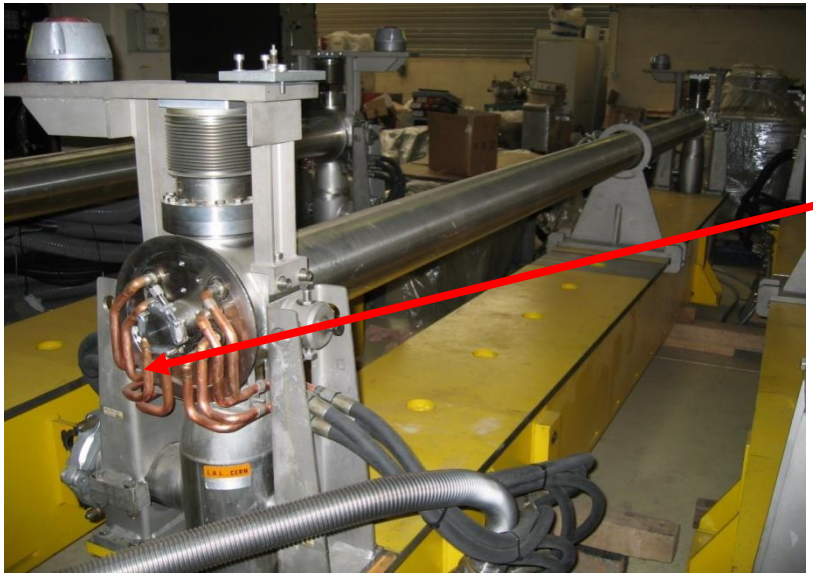
LIL type accelerating section, 2π/3 mode, travelling-wave

Length: 4.5m

Energy gain: 60MeV @ 15MW RFin

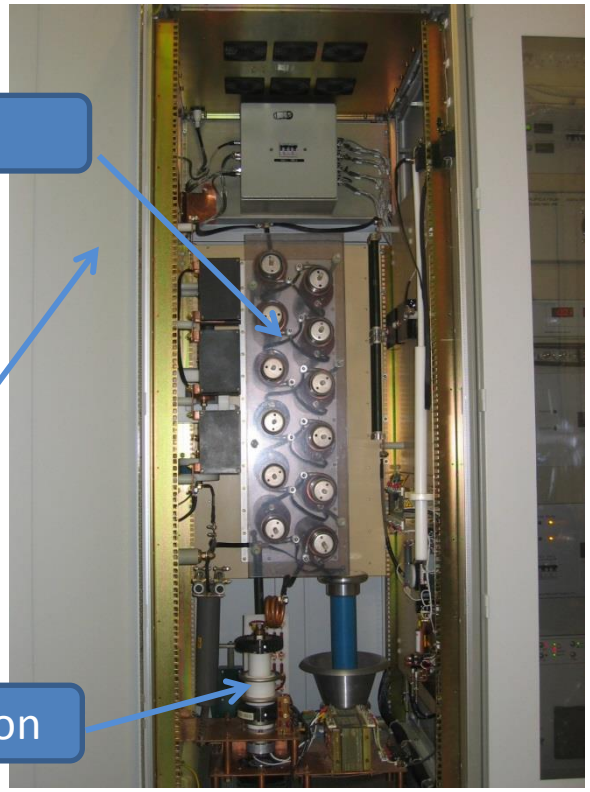


Vertical section of the structure *: 135 cells*



Temperature frequency tuning :
31,1°C@2998,41MHz, precision +/- 0,1°C

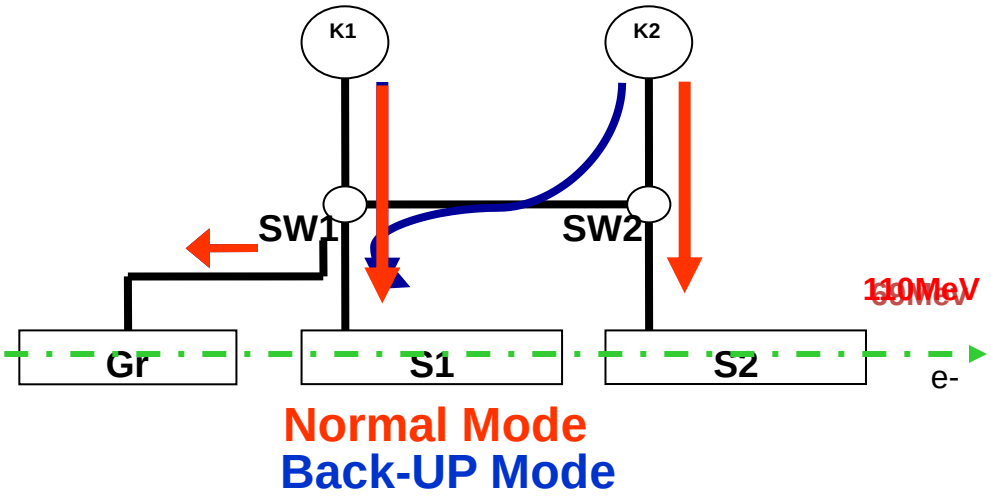
The accelerating structures have no solenoid. The focusing is made by a triplet of Q-poles between them and a Glazer lens between the buncher and the first accelerating structure



2 x 35MW TH2100 Klystrons & HV modulators (300kV, 280A, 6µs pulse at 3Hz)

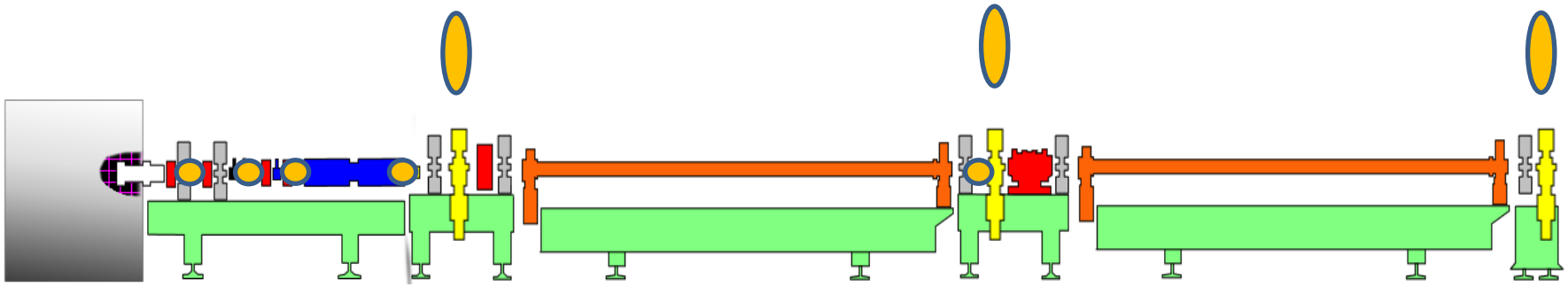
1st klystron feeds buncher + accelerating section1 & 2nd klystron accelerating section2

In case of a failure of one or the other klystron, two waveguide switches (SW1, SW2) allow to maintain the power in the buncher and section1. The objective is to reach 69MeV, which is still sufficient to insure a correct injection into the Booster.
This mode is re-validated at each machine restart, after a shutdown.



Diagnostics :

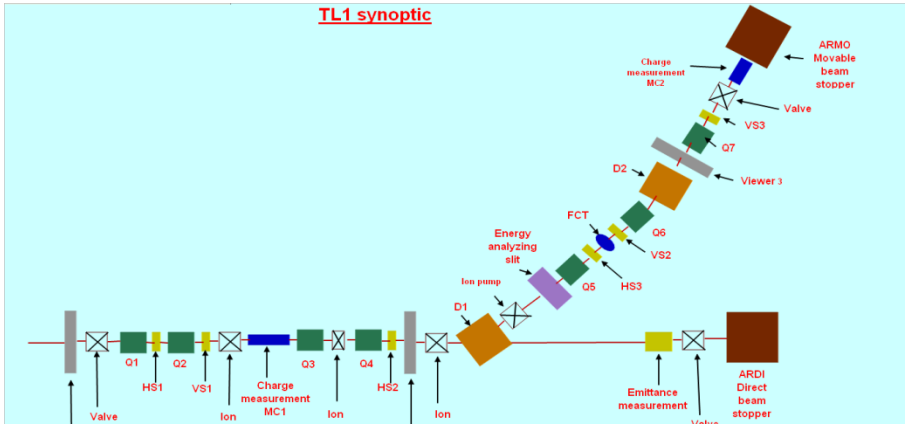
- Along the linac, 5 FCT (Fast Current Transformers) and 3 fluorescent screens



- Along the transfer line, with two bending magnets :

1 FCT, (blue ellipse)

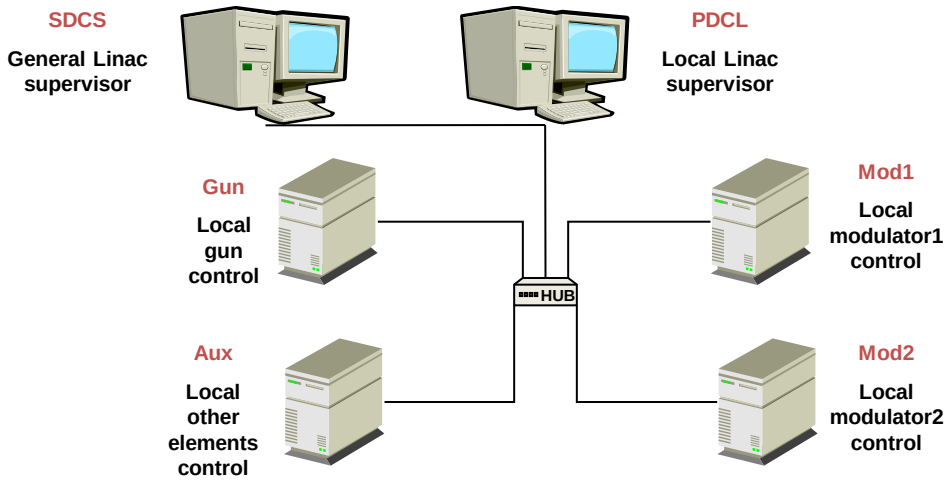
2 fluorescent screens, (in grey)
2 charge monitors, (in blue)
an energy analysing slit, (in purple)
and an emittance monitor, (in yellow)



The control system consists in 6 Window embedded PC's with LabVIEW application
Locally, 4 Industrial PC's (Mod1, Mod2, Gun, Aux) with NI acquisition cards
In the Linac Control Room (PDCL), 1 PC
In the SOLEIL Main Control Room (SDCS), 1 Labview application, compatible with Tango

The control-command system of the Linac is accessible via the TANGO DataSocket Device Server (5 DS)

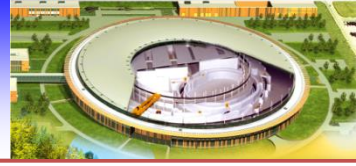
PDCL PC: local Supervisor (**expert access**)
SDCS PC: général Supervisor (**user access)**)
Mod1 PC: local modulateur 1 control
Mod2 PC: local modulateur 2 control
Gun PC: local gun control
Aux PC: local Aux control (**cooling, vacuum…)**



Aux. rack

Modulator racks (2)

Gun rack

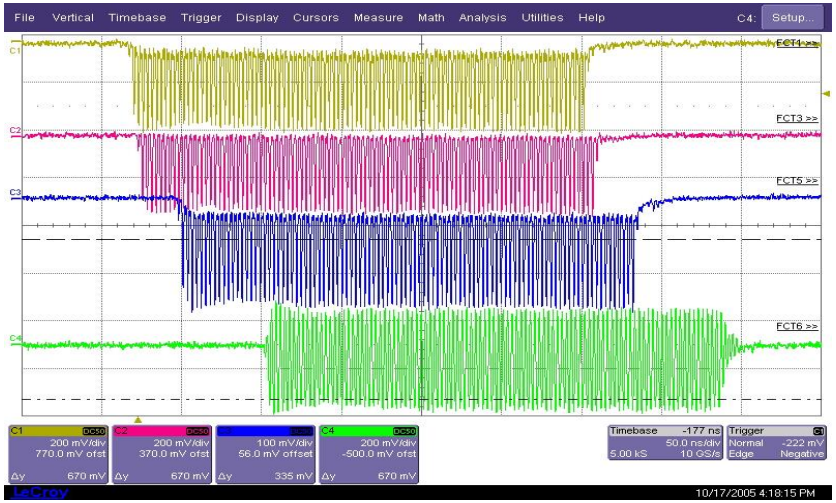


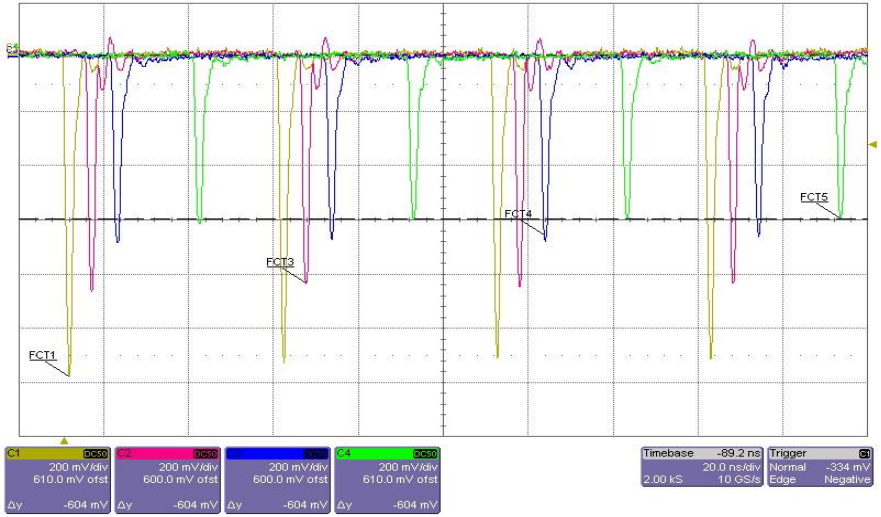
Two injection modes are available to fill the synchrotron ring

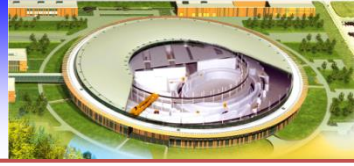
- **LPM mode** (Pulse length of 300ns)
  → 500 mA multibunch in SR

- **SPM mode** (1 to 4 Pulses) inside 300ns
  Min Delay between 2 pulses: 50ns
  → Single and 8-bunch mode in SR

→ hybrid modes in SR

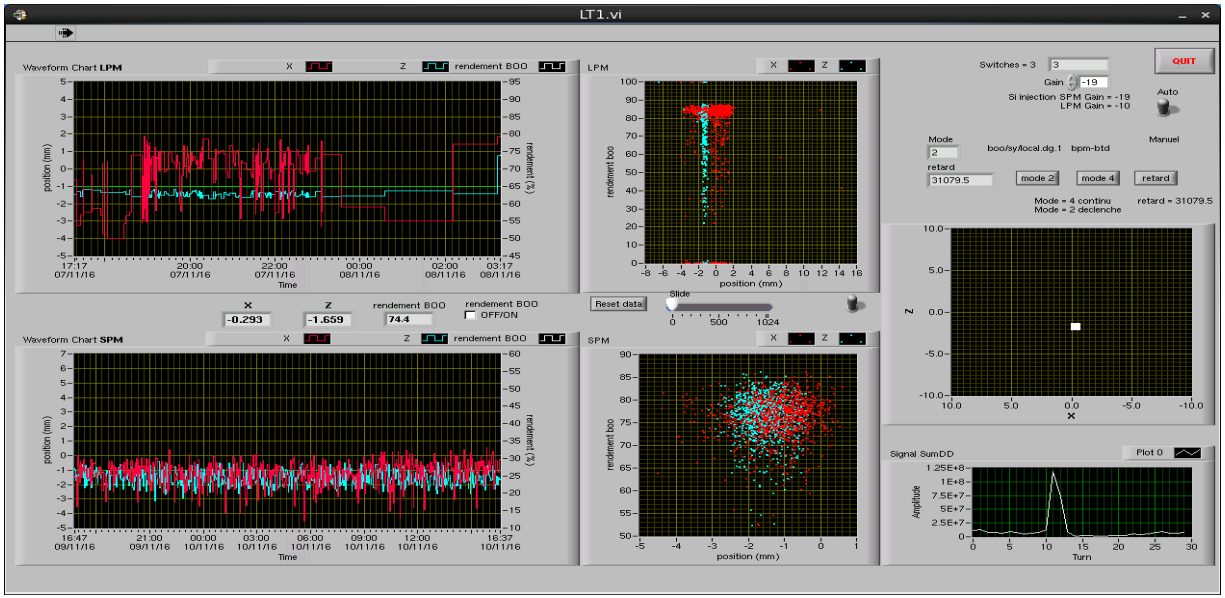


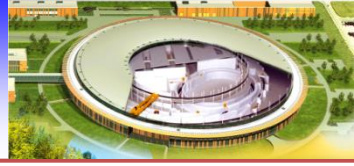




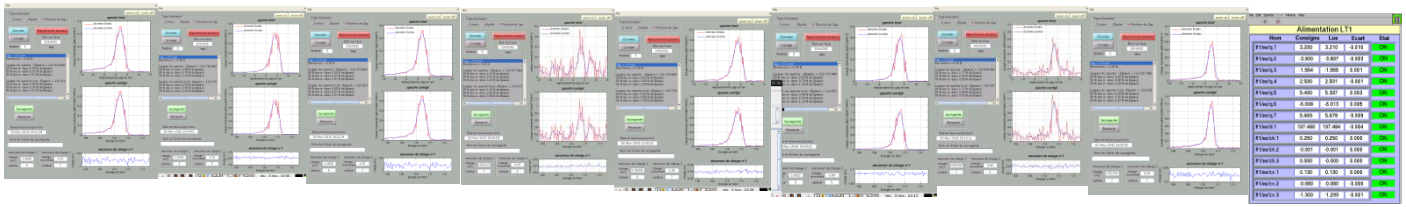
Since 2009, SOLEIL has adopted the TOP-UP mode of injection with the following features :

- Linac is always ready to inject
- Preheating sequence for temperature stabilization :
  - Pre-trigger to start the High Voltage power supply of the modulator klystron
  - 10s before injection, a 3Hz trigger to apply HF power in several equipments : Klystron pre-amplifier, Klystron, accelerating sections and buncher, during 21 cycles, each 2-5 minutes
- Automatic Reset by software, when a reverse current fault is detected in the modulator
- In the transfer line between Linac to Booster (LT1), a Bean Position Monitor, measures the pulse-to-pulse energy deviation and a Labview application (below) shows the injection efficiency vs beam position for the two modes of injection, SPM and LPM

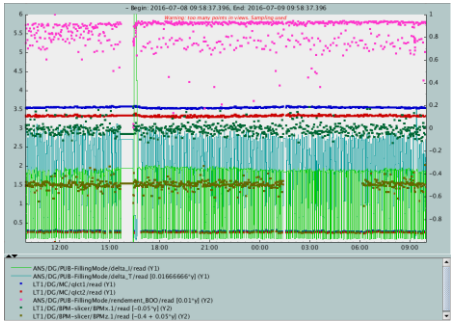


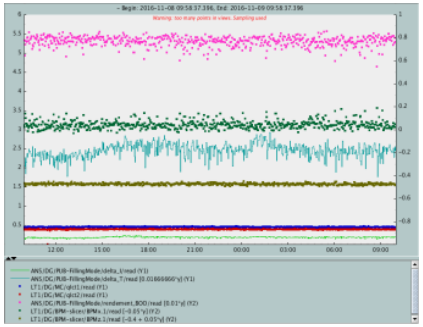


- **Before each machine restart :**
  - a high voltage reconditioning of the Klystron and gun is performed to ensure good operating conditions during the whole run (Klystron : 300kV/300A/3Hz ; Gun :100kV & vacuum : 1e-8.mbar.l/s)
  - Preventive maintenance : turnover of the modulator PS (every 6 months), check of the thyratron stability, …
- To each mode of operation in the storage ring (single bunch, 8 bunches, 500 mA uniform, 450 mA hybrid, low-alpha, slicing, …) corresponds a dedicated file of injection parameters. The group is in charge of verifying and updating all these files. **Each week**, during the period of 1or 2 hours, dedicated to the machine maintenance, they are revalidated by a measurement of the energy spread

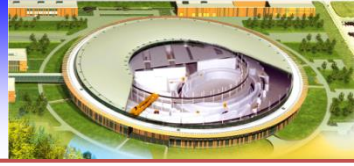


- **Each day**, the LINAC performance is checked (beam charge, position, pulse-to-pulse stability, …)





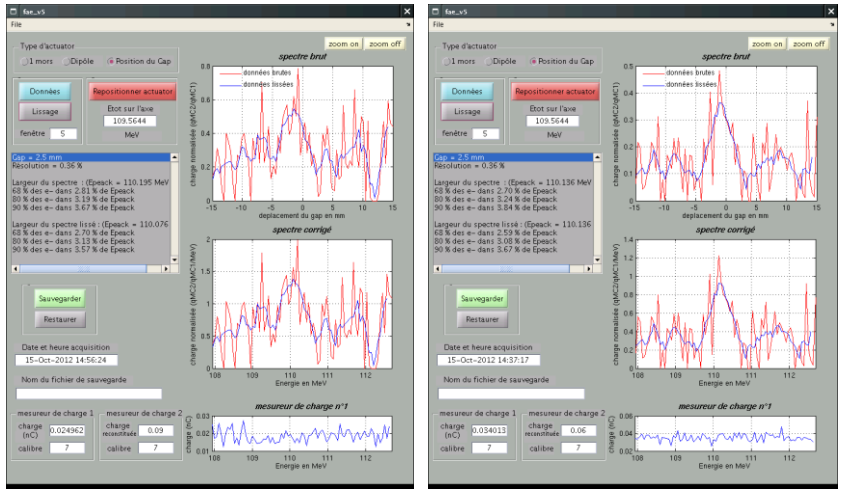
Operational experience with the SOLEIL LINAC
Achieved upgrades

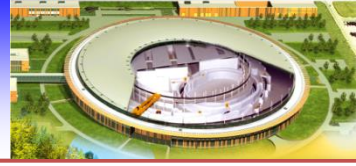


- Updating of the Industrial PCs : motherboard change, migration to Labview 2012, improved CPU load and reduced system iteration times
- Additional temperature diagnostics along the LINAC
- Replacement of the klystron heating power supplies → improved control and stability (0.1%)
- Optimization of the RF structure temperature working point
- Replacement of the optical device driving the gun, which was based on an OPC server, by an optical transmission module, based on a Siemens PLC; the communication has been validated with Labview
- Hardware linac load limitation procedure for the 500mA uniform of the ring for safety reasons
- Optimization of the injection parameters for the very low charge in the Low-Alpha mode → Implementation of a specific file (LPM, 0.3nC & 0,6nC, 280ns and SPM-30pC & 10pC). The LINAC is able to meet this low charge requirement but the diagnostics of the LT1 transfer line are at the limit of the noise level

LPM 0.6nC & 0.3nC

SPM 30pC & 10pC





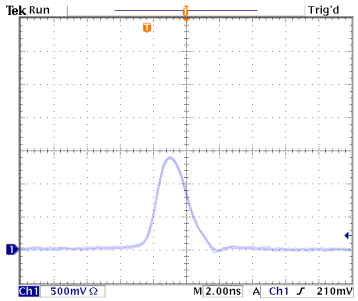
SPM, Single Pulse Mode ; Beam Charge : 0,5nC/1,4ns by bunch

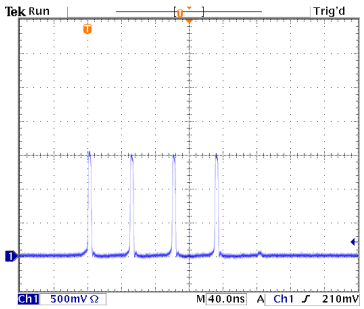
Our choice, the FID GmbH's solution, with the increase of the output voltage from 700V(previous generator) to 1010V (new generator)

This has improved the quality of the SPM beam (bunch purity) in the storage ring by in an order magnitude.

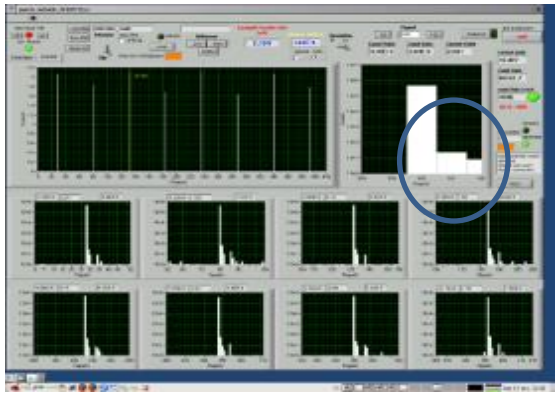
SPECIFICATIONS

Maximum amplitude into 50 Ohm	-	1,5 kV
Amplitude adjustment range	-	0,6-1,5 kV
Polarity	-	positive
Rise time	-	1-1,1 ns
Pulse duration at 50%	-	2-4 ns, adjustable
Fall time	-	1,2-1,3 ns
Maximum PRF	-	10 Hz
Burst operation	-	max 4 output pulses with delay 50-300 ns between them
Triggering	-	Internal and External 5 V, 100 ns
External triggering to output delay	-	not more than 100 ns
Jitter	-	better than 30 ps RMS
Variation of trigger/output delay	-	+/- 500 ps between 20-30° C
Remote control	-	amplituse and pulse duration by 0-10V DC



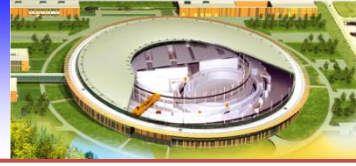


Previous Generator

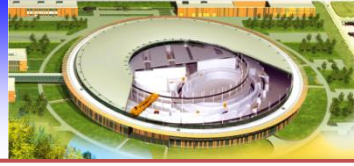


Previous Generator

New Generator

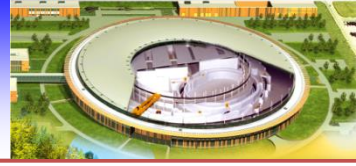


- Reprogramming all local PC's using a new « shared variables » protocol, in place of the datasockets server, which will not be supported by NI anymore, first semester 2017
  - Improve the communication between the localPC's (error and logging management)
  - Reduce the number of variables circulating on the network and centralization of the data on the « local Aux. PC»
- Test and commissionning of the Cleaner spare generator (new version), January 2017
- Implement phase measurements
- For low charge mode : Improve gun charge dynamic range and transfer line diagnostics
- Replacement of the klystron focusing power supplies to anticipate their obsolescence → modulator 1, 1st semester 2017



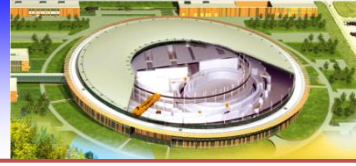
During the Linac life (in operation since 2005, 66 000 running hours)

- the Same Triode, with unchanged performance
- Failure of the optical fiber connection in the gun cabinet
- one klystron was changed following a faulty ionic pump cable → operation in back-up mode with a single klystron during five days for repairing



Status of the ThomX LINAC project

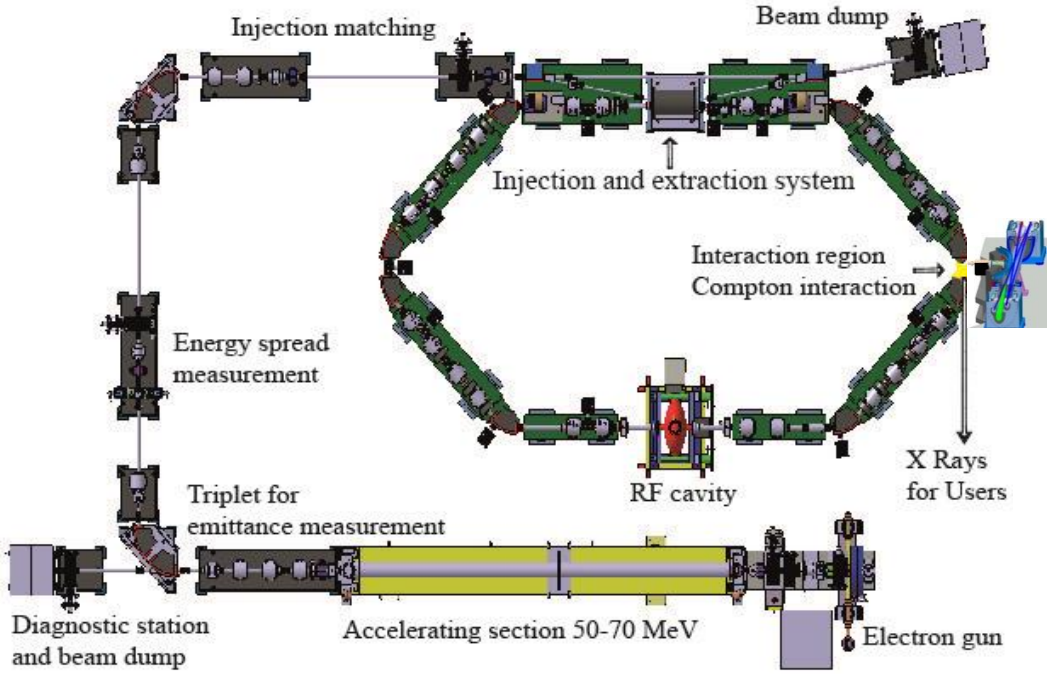
The ThomX project



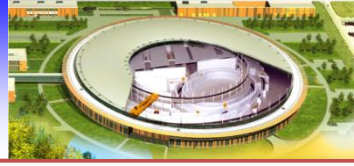
ThomX is a new ultra-compact source of X-rays, based on the Compton back-scattering effect.
This project was launched in 2012; the machine will produce its first photons in 2017.

The ThomX French consortium includes different leading laboratories in the Compton associated technology.

ThomX is being built on the Campus of the University Paris XI, Orsay. The accelerator complex consists in a 5 MeV photo-injector, a conventional S-band Linac injecting at full energy into a 50-70MeV storage ring of 16.8m circumference

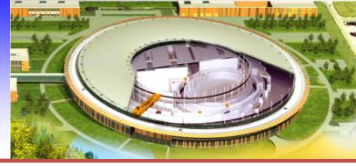


Rep. rate = 20 msec
RF pulse length : 3 μs
Energy : 50 - 70 MeV

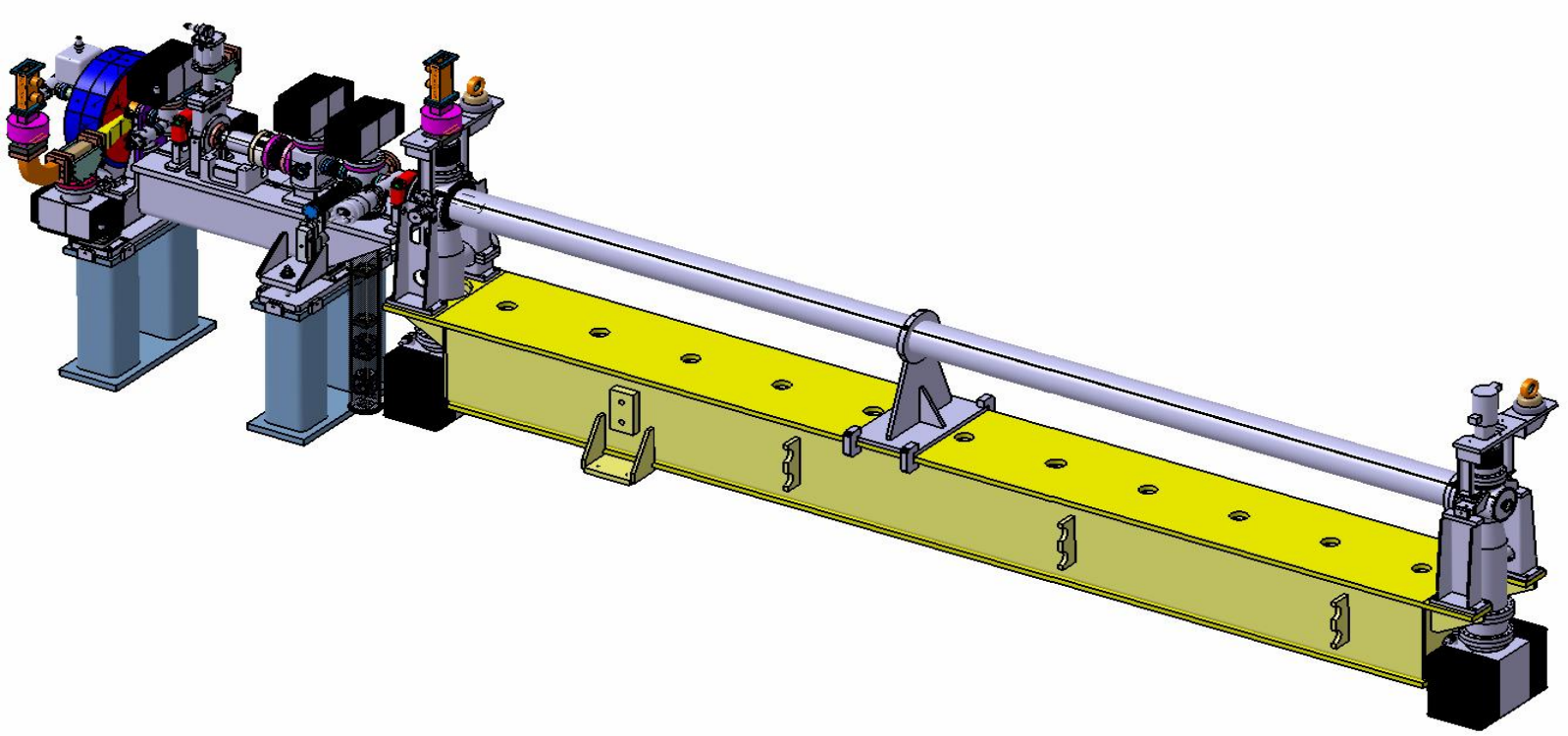


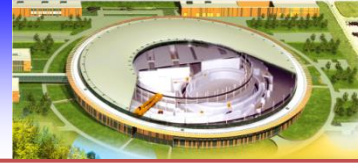
Specifications and Performances

Energy (MeV)	**50-70**
Number of bunches	1
Bunch Charge (nC)	0.1 to 1
Repetition rate (Hz)	50 max
Transverse size, RMS (mm)	1,4
Emittance (π.mm.mrad)	≤ 5
Energy Spread (%)	< 1
Bunch Length, RMS (ps)	4

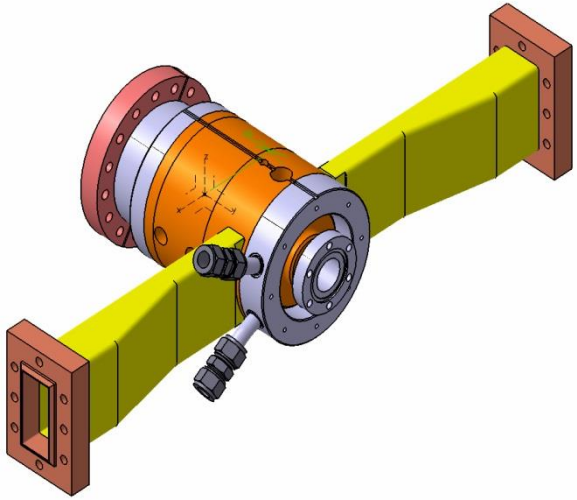


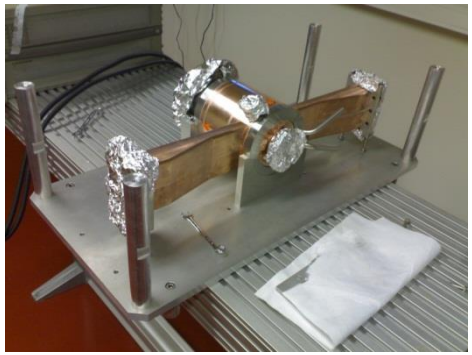
- **Two sections with S-band RF Structures** :
  - Gun section : CTF3 Probe beam photo-injector + diagnostics + steerers
  - Accelerating section : start with the spare SOLEIL accelerating section, lent to ThomX and to be later replaced by a new one ; a prototype is presently under fabrication (R&D LAL-PMB)

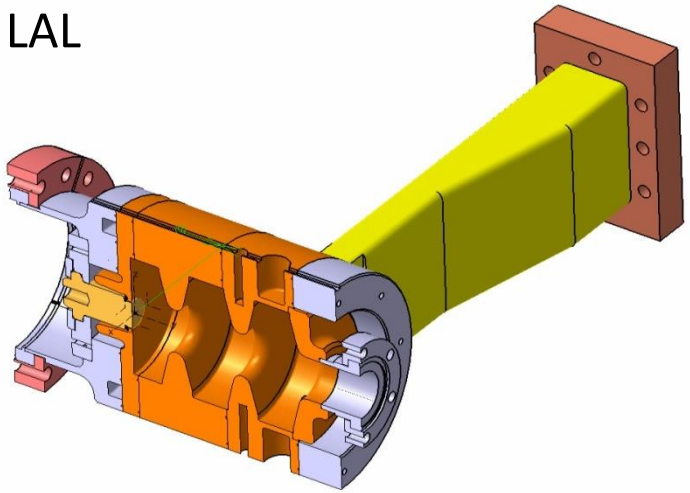




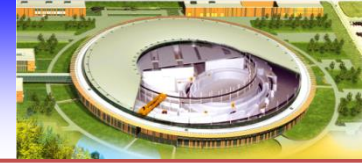
Manufactured by LAL



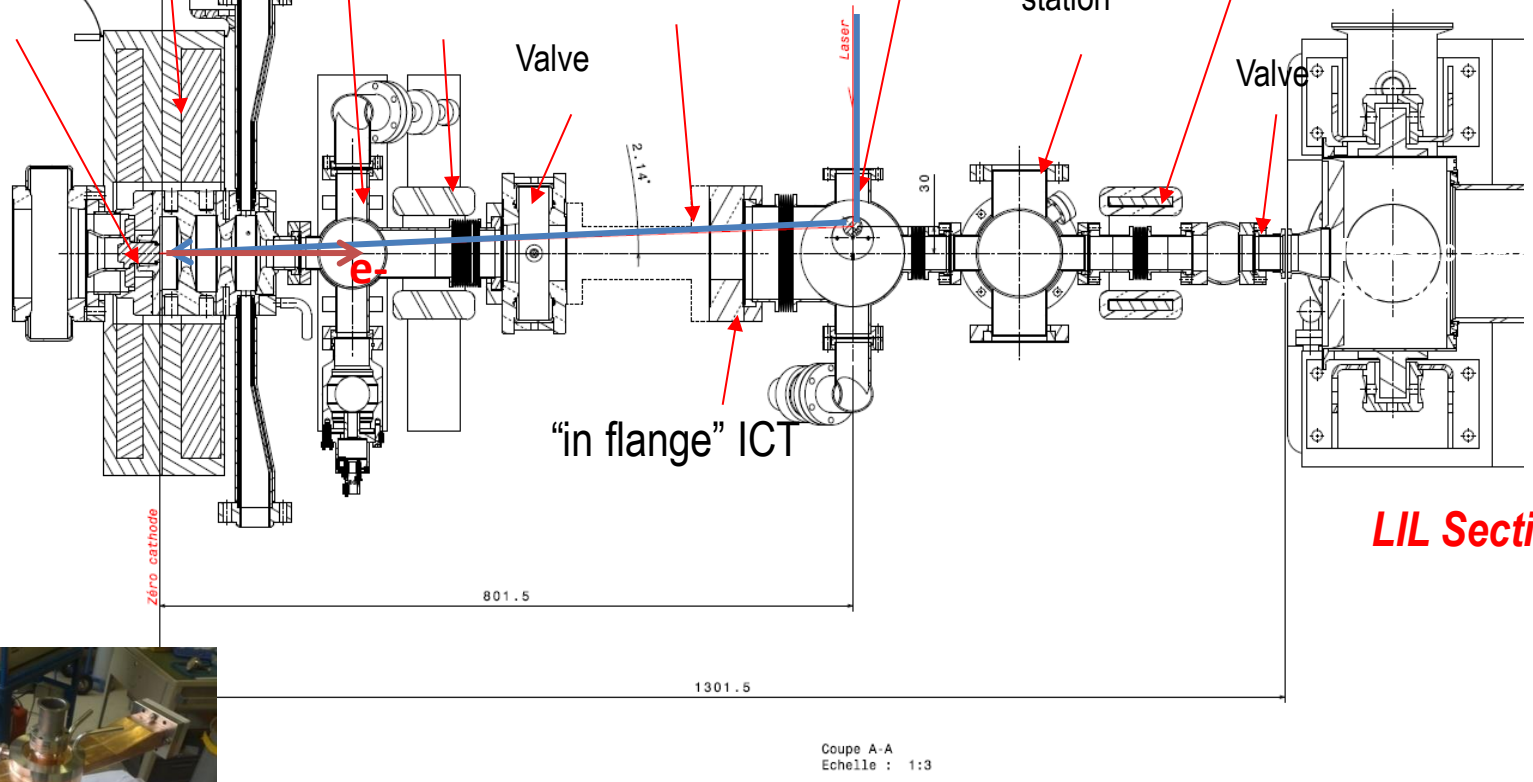




RF Frequency (MHz)	2998,55@30°C
E-Field at cathode plane (MV/m)	80 (100 max)
Number of cells	2,5
RF power (MW)	5 (10 max)
RF pulse length (µs)	3
Repetition rate (Hz)	50
Output electron beam energy (MeV)	5
Laser wavelength (nm)	260
Mg cathode efficiency	$5\ 10^{-5}$

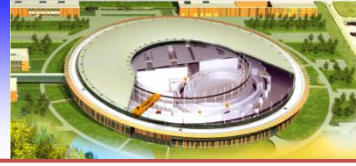


Pumping chamber
Coils
LASER insertion chamber
Short stripline BPM
From JC Denard
YAG/OTR Sreen station
Steerer
Steerer
Mg cathode
Valve
Valve
"in flange" ICT

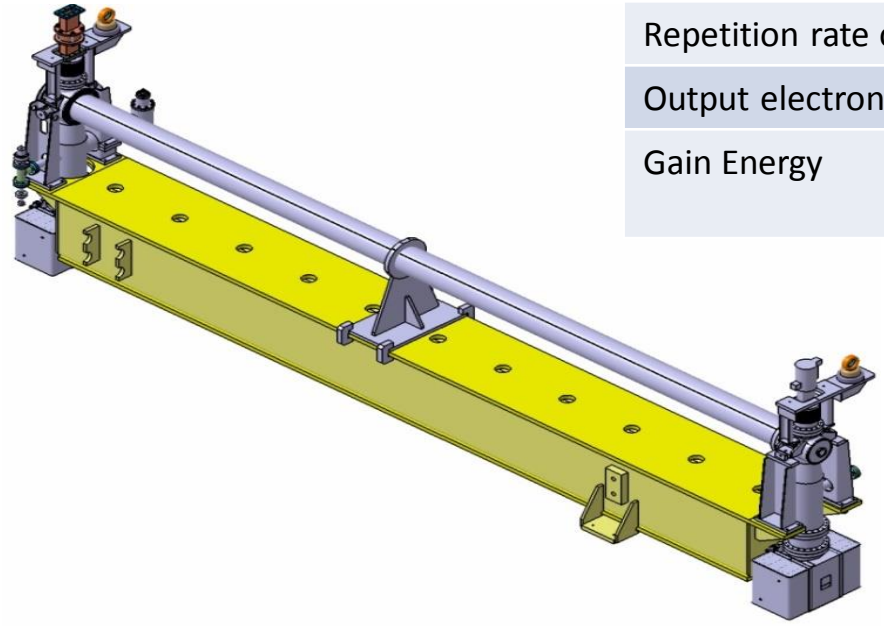


LIL Section

Status of the ThomX LINAC project
LIL accelerating section



RF Frequency (MHz), mode	2998,55@30°C, 2П/3
Field E (MV/m), Q	12 (18max), 14800
Number of cells	135
RF power (MW), phase stability	18 (25 max) , $\Delta\phi < 1°$
RF pulse length (μs), filling time (μs)	3 , 1.35
length (m) , distance from the cathode (m)	4.5 , 1,3
Repetition rate of (Hz)	50
Output electron beam energy (MeV)	50-70
Gain Energy	45MeV@9MW (gradient=12,5) 65MeV@18MW (gradient=18)



Modulator and Klystron

Following the call for tender, Scandinova was selected for supplying a modulator, based on the solid state technology, with a Toshiba Klystron

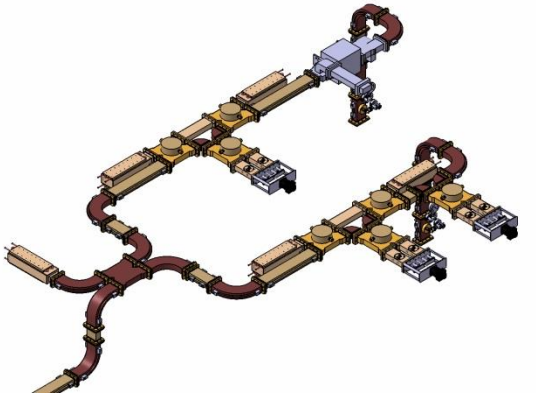
This is a very compact « turn key » solution

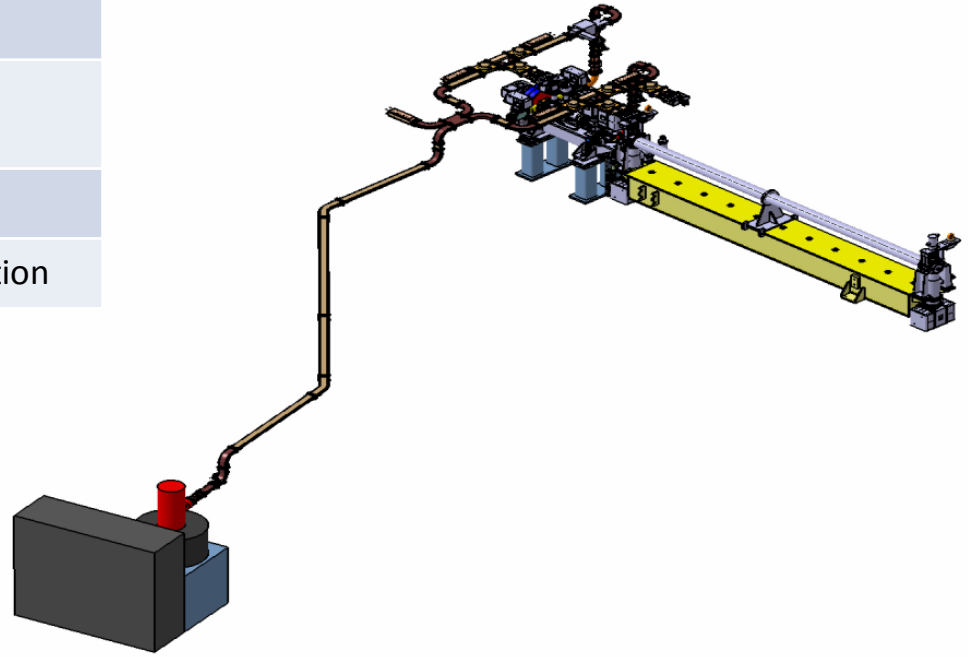
The factory acceptance tests of the modulator + klystron are scheduled for Dec. 2016 at Uppsala (Sweden)

RF Frequency (MHz)	2998,5
RF Peak Power (MW), RF average Power (kW)	35-37 , 10
Modulator Peak Power (MW), Average (kW)	90 , 28,5
Operational Voltage range (kV), Current range (A)	0-300 , 0-300
Repetition rate range (Hz)	0-50
Pulse length (µs)	1 - 4,5
Flat top stability (δV)	1% during 4,5µs 0,1% during 1µs
Rate of fall (kV/µs) , amplitude stability (%)	200-250 , <+/- 0,1
Trig delay, pulse to pulse jitter, pulse width jitter	1,2µs , <+/-4ns , <+/-8ns

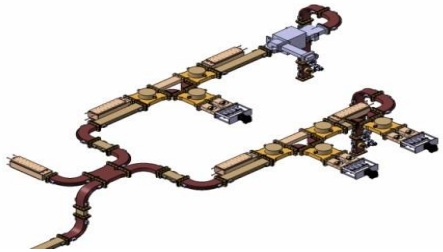
Main components

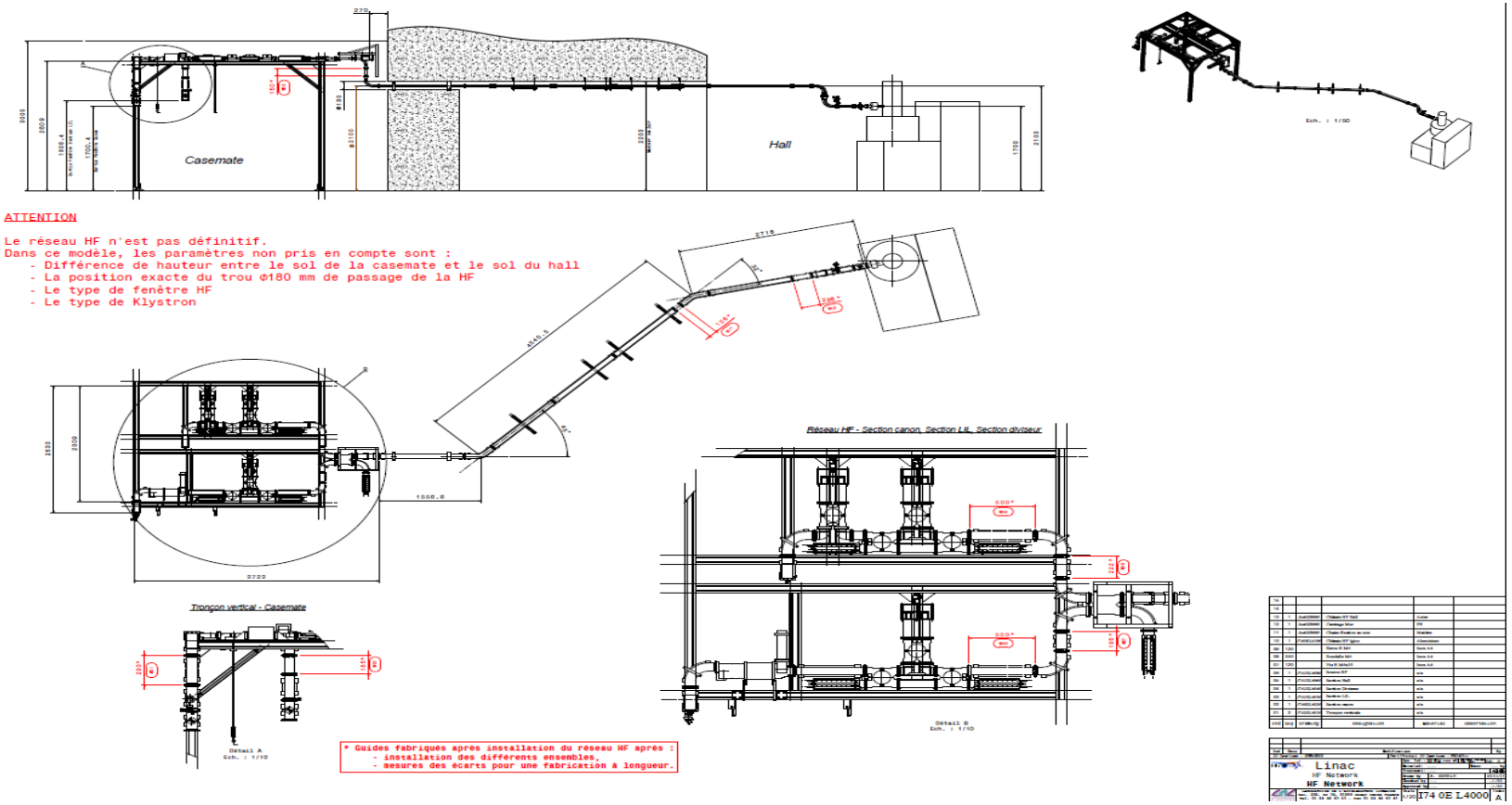
Klystron - Modulator	1
RF Klystron peak power (MW)	35
RF pulse length (µs)	3
Repetition rate (Hz)	50
RF wave guide network	WR284@SF6
2 Variable attenuators	0 - 20dB
1 phase shifter in acc. section branch	0° - 400°
Power splitter	5
2 RF Windows	Near the acc. section

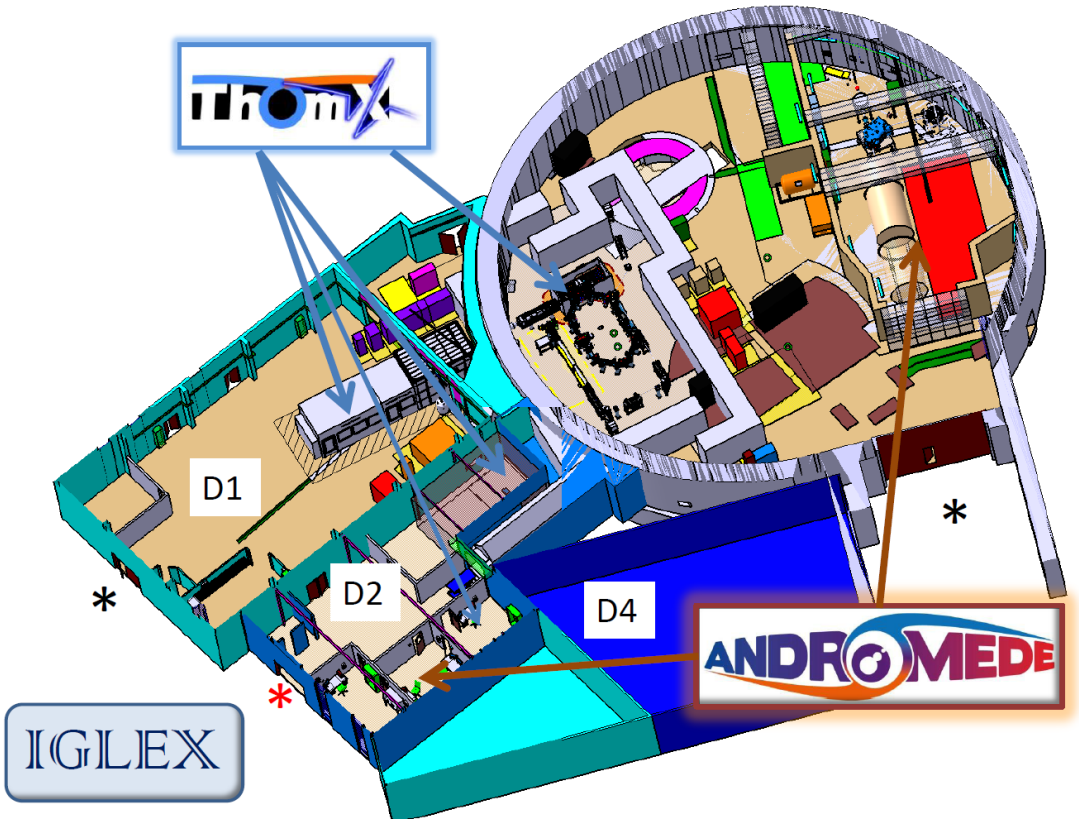


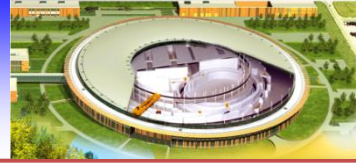


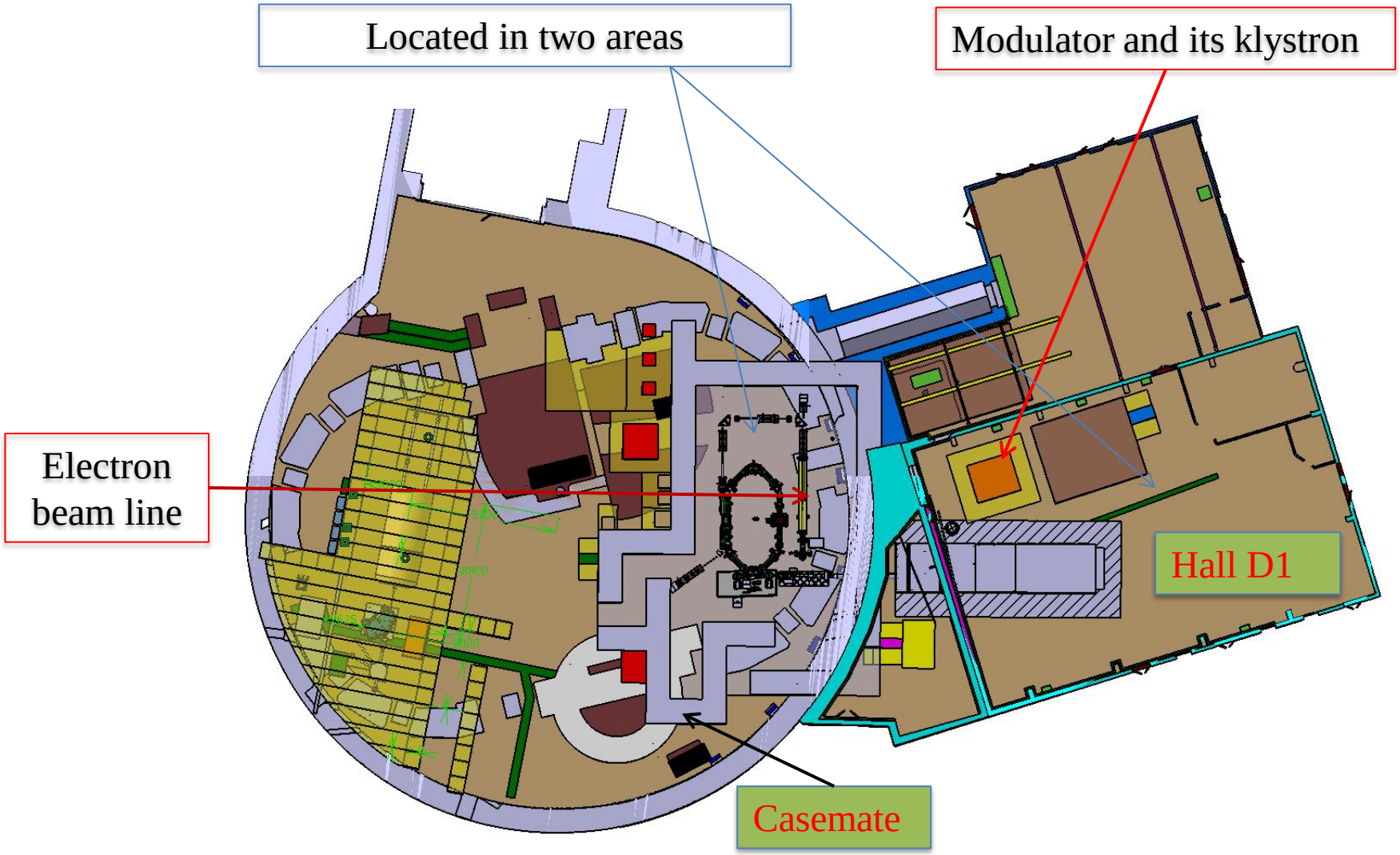
Main components are delivered
RF power attenuators and phase shifter
are waiting for repair (leaks)

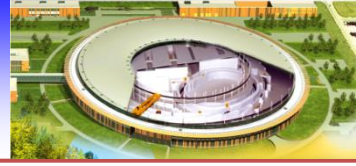





ThomX
D1
D2
D4
ANDROMEDE
IGLEX



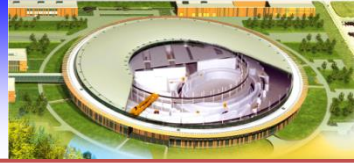

Located in two areas
Modulator and its klystron
Electron beam line
Hall D1
Casemate



Building availability is expected end of December 2016

The LINAC installation will begin in January 2017

The first beam is expected in the first semester 2017



Thanks for your attention