Interaction Point for GammaFactory POP

2019 03 28

LAL group & more

Outline

1. Design guidelines - where we are
2. Optical cavity
3. Laser system
4. Interaction point
5. Possible immediate R&D

Design Guidelines and integration strategies

- High stability **2 mirrors Fabry-Pérot resonant cavity 40MHz**
- **High power Yb-doped fiber laser system** seeded by a low-phase noise mode lock laser oscillator
- **Laser system** and locking **electronic** integrated inside the IP module **in SPS** with possibility of moving power unit part at least depending on radiation feedback
- **Interaction module** comes as a **block** already commissioned in LAL at high power with easily removable laser and electronics parts and with diagnostic of current status respect to radiation potential damage
- UHV 10^{-9} mbar nominal vacuum
- **Fully remotely controlled apparatus** within Tango / FESA interface or directly in FESA ?
- Ease integration in the SPS constraints environment.
- By design a day-zero time/spatial overlap of the beams

In the meantime

- build up a test-bench 2 mirrors cavity in the lab before end of 2019 with a high power laser to address the bottleneck of the system.
- Study of rad hard alternative to integrated standard electronics
- Investigate the possibility of testing radiation hardness on the PSI proton test facility

Status

- Converging status for the simulation for the definition of the laser parameters.
- Contacts with almost all the industrial suppliers for the foreseen design of the interaction point have been contact
- Ongoing completion of the list of all foreseen integrated electronics and radiation sensitive element
- Slow ongoing preparation of NDA between CNRS - supplier + CERN - supplier for complete review of the electronics from radiation hardness study
- Mechanical design started in the LAL design Office Y. Peinaud.
- Ongoing preparation of test of 2 mirrors optical cavity to address bottlenecks

Missing input for design

1. Synchronisation scheme
2. Phase delay setting. Beam arrival time synchronization signal
3. Radiation level, Radiation shielding relevance
4. Accuracy of the SPS fiducial network.

Laser parameters

- From simulations, the preliminary laser parameters are:

Parameters	Values	Unit	Comment
central wavelength	1030-1040	nm	On wavelength fixed in this range
Central wavelength tunability	0.2	nm	
spectral bandwidth [a]	0.1-0.5	nm	FTL pulse or chirped pulse possible
Pulse length	8-11	ps	Spectrum shap dependent, Gaussian assumption
Frep [b]	40	MHz	
Phase jitter	<10	fs	10Hz-10MHz, strongly limit possible supplier
average Power	40-50	W	vary vs the spectral setting / vs TBC
Energy/pulse	>1	uJ	vary vs the spectral setting
polarisation	circular	-	
beam diameter	1 - 2	mm	Ajustment with telescope for coupling optimization to OC
beam quality, M^2	<1.2	-	

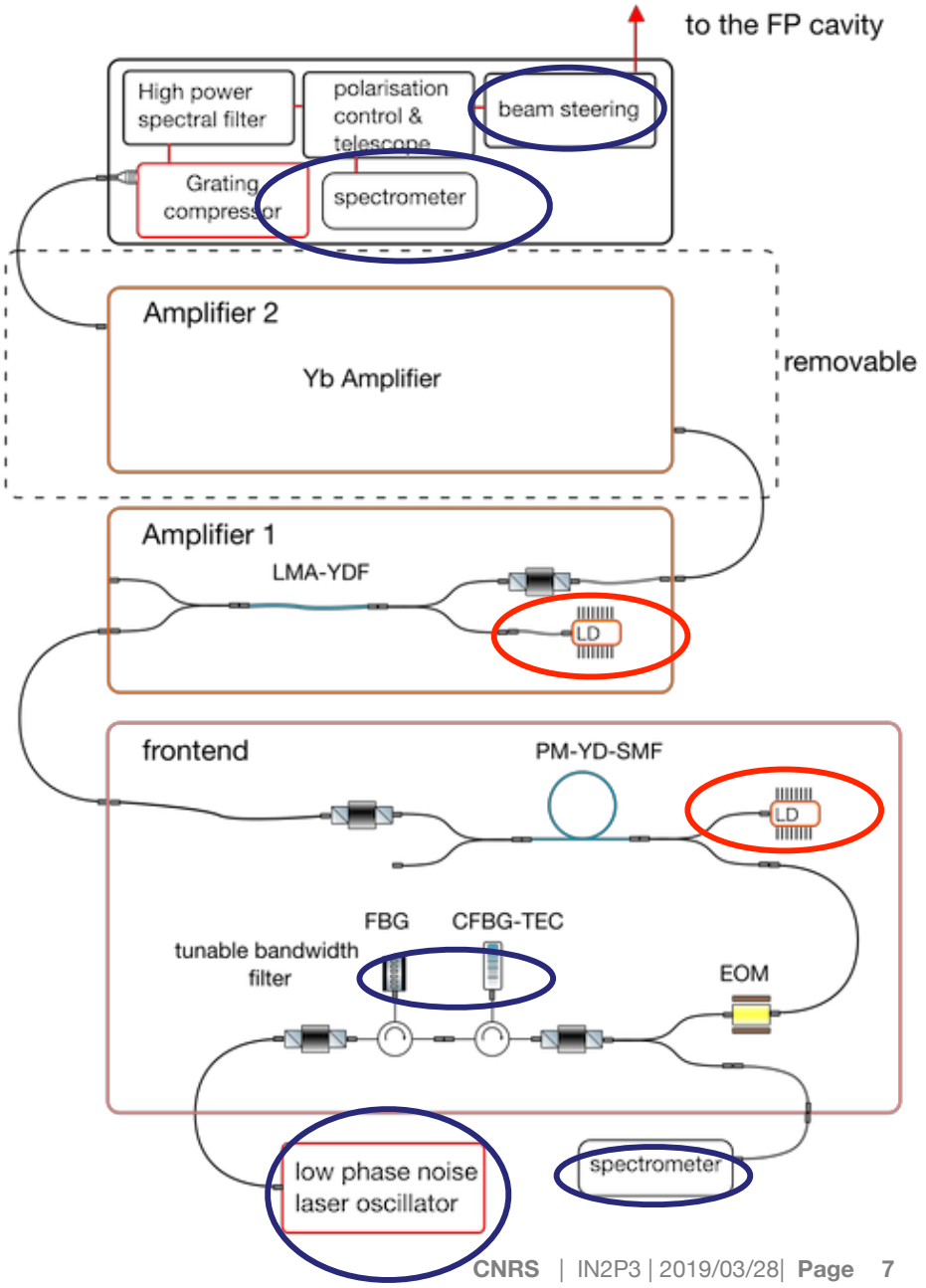
[a] possibly tunable but easier operation at fix value. Spectral shaping with sharp edge in the blue

[b] with a coarse (+/- 15kHz) and fine tuning with a piezo stack

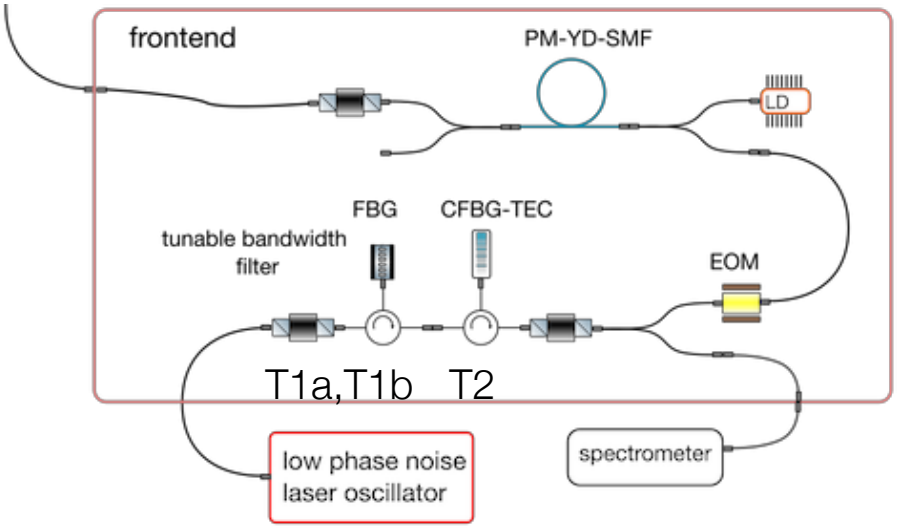
- Feasible custom commercial laser.

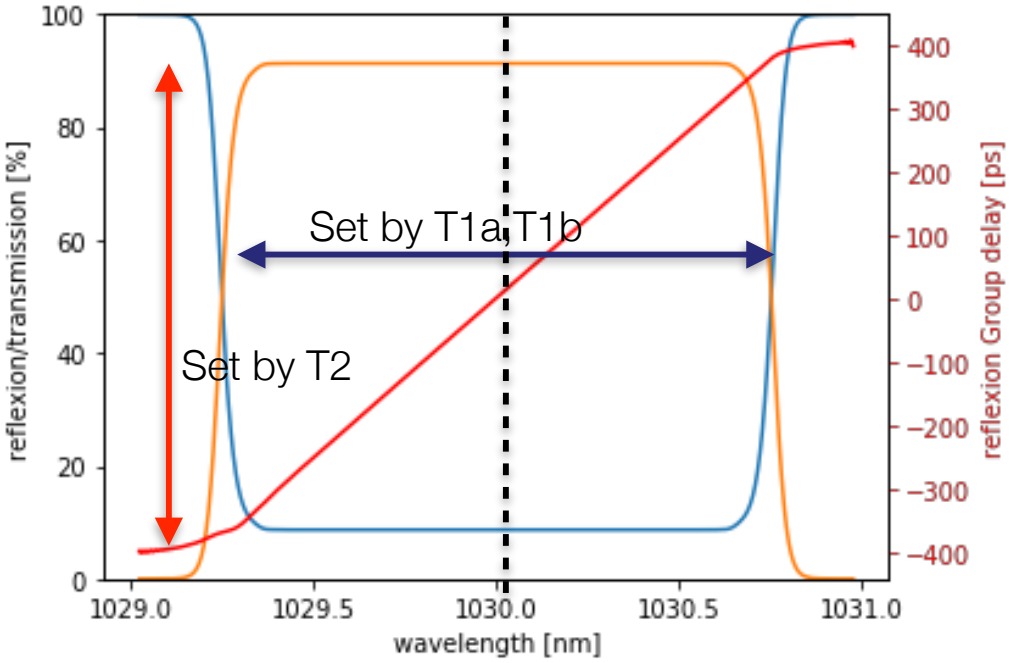
Laser System

- Low phase noise laser oscillator with rad hard component (not the electronics)
- First stage with bandwidth control with 2 FBG (LP, HP) and a chirped fiber Bragg grating temperature controlled and pre-amplifier to compensate for circulator losses. Micro controller for dispersion tuning and stabilization. Qualified space components …
- First amplifier stage to ~5 W,
- Second amplifier stage to ~ 50 W
- Rack 19” system with full safety interlock and status of components
- HR spectrometer (10pm resolution) based on SWIFTS technologies STmicroelectronics. Qualified space components …
- Agreement for NDA components on most of the components except laser diode but easy to test on radiation test facility



Spectral shaping and control





> From 6-7nm femtosecond laser spectrum we keep 0.3-2nm around a central wavelength

> Double FBG temperature controlled

> CFBG dispersion temperature controlled

Optical cavity proposal (see Aurélien's talk)

AM shows that a most simpler design with 2 mirrors (plan-concave) cavity is giving us :

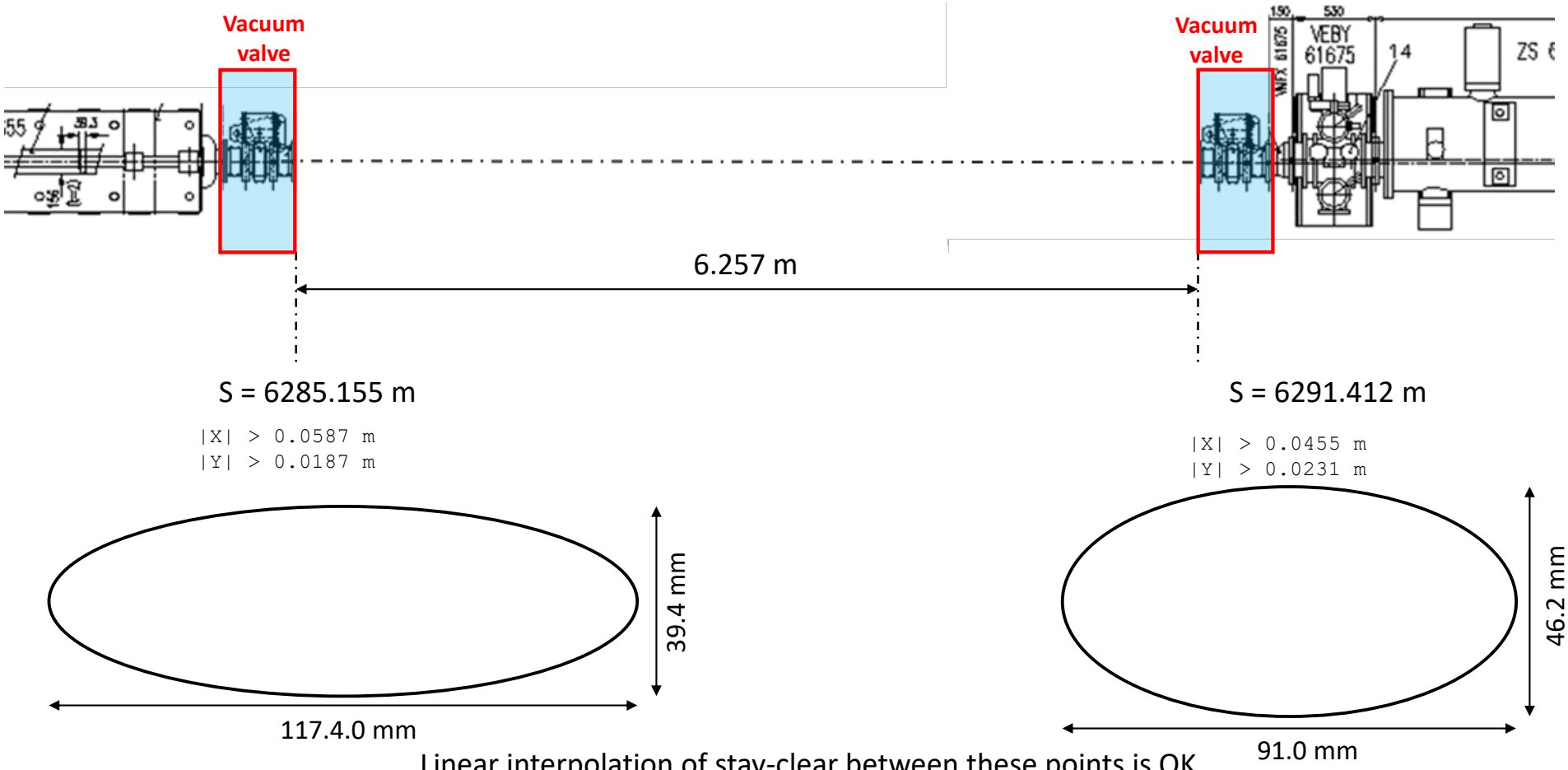
Parameters	Values 2-mirrors OC	Unit	Comment
Crossing angle	**2,6**	°	
waist_x @ IP	~1.4	mm	
waist_y @ IP	~1.4	mm	
Minimum waist	1.25	mm	On the coupling mirror
FSR = c/2L	**40**	MHz	
length L	**3747,405**	mm	
Beam diameter M1	1.25	mm	
Mirror diameter Dm	25.4	mm	
Coupling	~ 70	%	
Gain	> 5000		Limited by oscillator phase noise

The 2 mirrors OC has many advantages:

- simple design possible (cost-efficient solution for PoP experiment)
- easier alignment can be made without breaking vacuum
- easy integration with full remote control of the cavity possible.
- minimized opto mechanics under vacuum

Integration of the interaction point

LSS6.616: Stay-clear for IR elements



Linear interpolation of stay-clear between these points is OK

Integration foreseen constraints

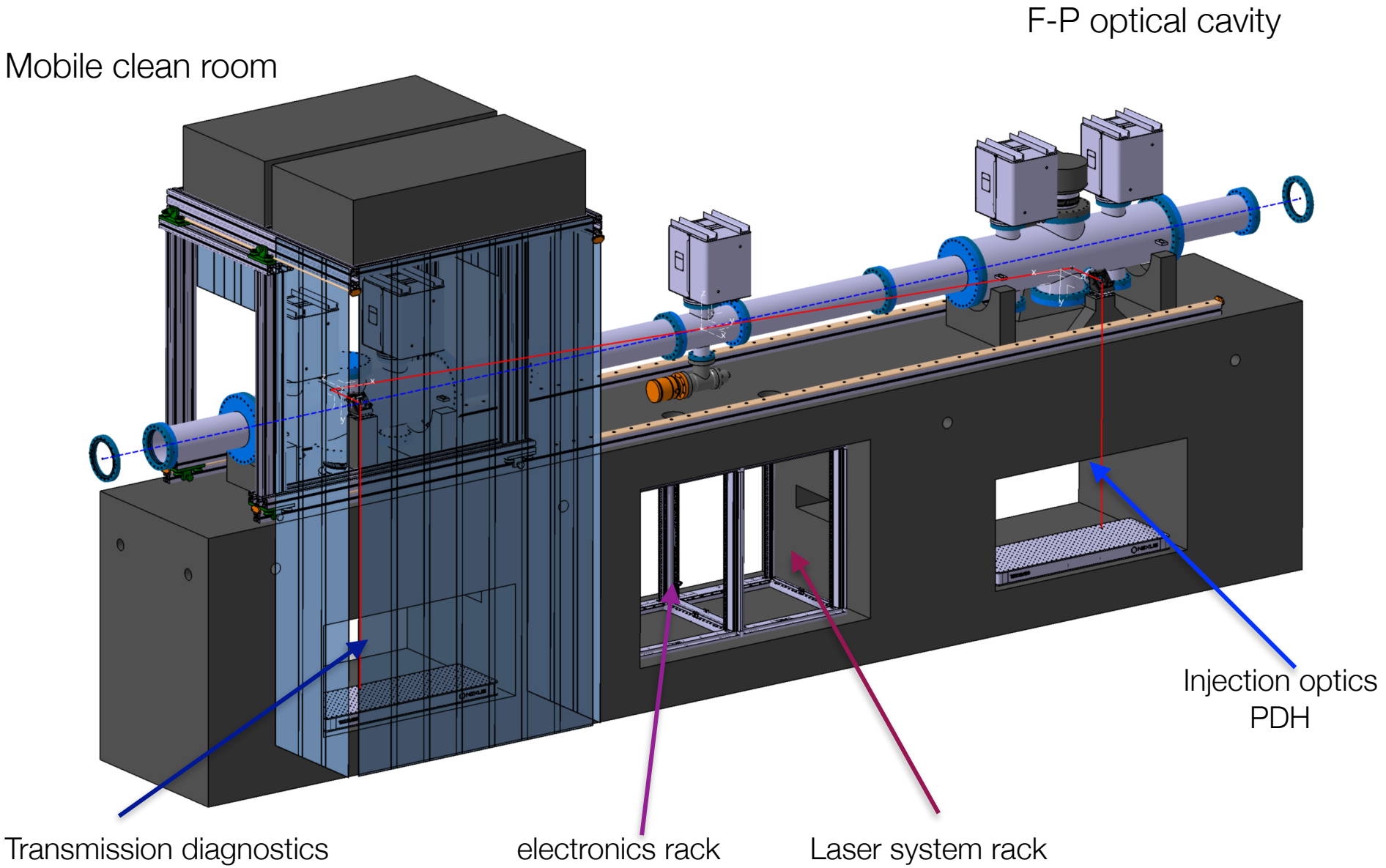
First list of the integration constraints :

- radiations
- limited integration time
- dirty air environment
- handling up to the LSS6-616
- fiducial network accuracy of the SPS

Assumptions:

- Good temperature (+/-0.5°K) and RH(40%-60%) stability in SPS tunnel
- Optical Cavity will not be opened on the SPS except for maintenance
- Rad hard issue : Laser an electronics are for the moment on the IP module
- +/-0.2 mm mechanical alignment of the IP considering a state of the art fiducial network and laser tracker alignment

3D view LSS6 optical cavity

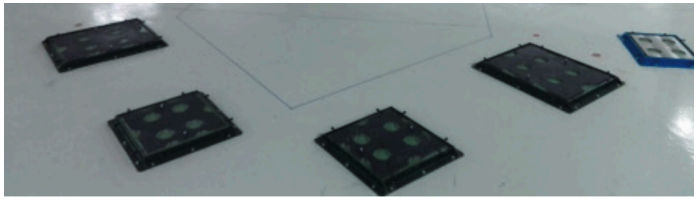


IP module mechanical integration

Some numbers

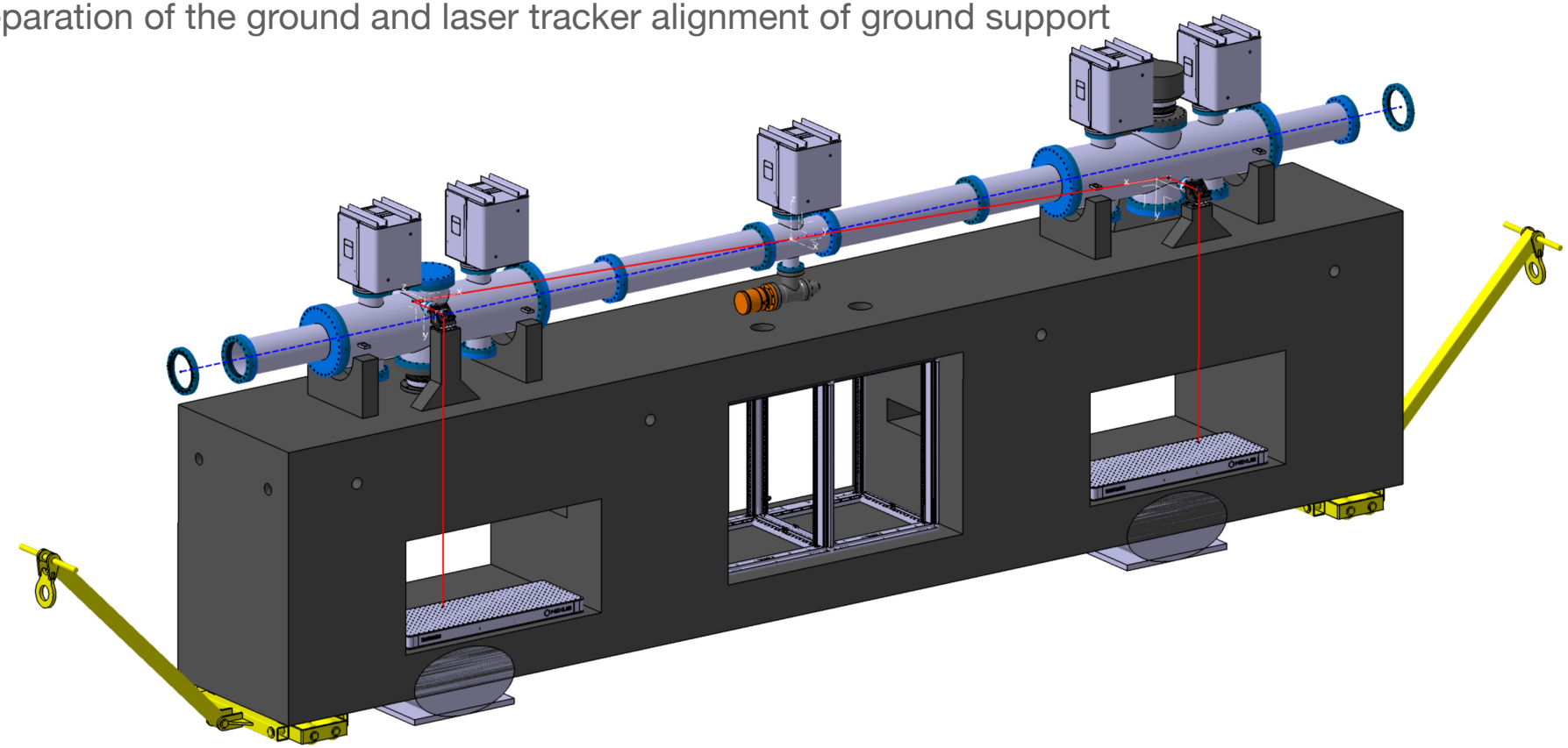
- length ~600cm

- width ~80 cm



- weight ~ 10 -11T epoxy granite with possible integration of radiation shielding (https://www.microplan-group.com/images/pdf/Schede%20tecniche/materials/celith-granito-composito-granit-reconstitue-polymerbeton.pdf)

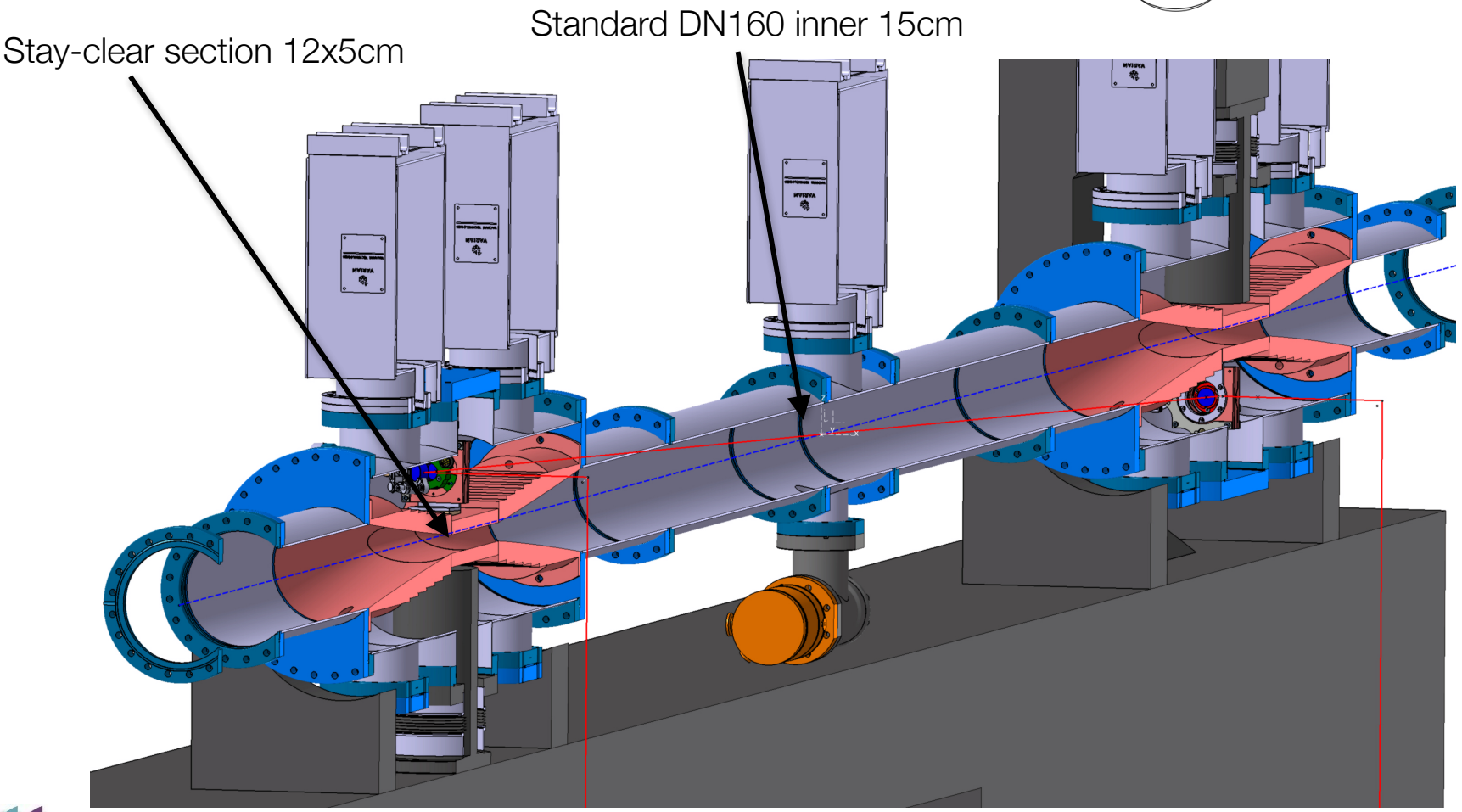
- manually handle in the SPS tunnel / air lifting cushion for final installation on predefine sorting pin. Preparation of the ground and laser tracker alignment of ground support



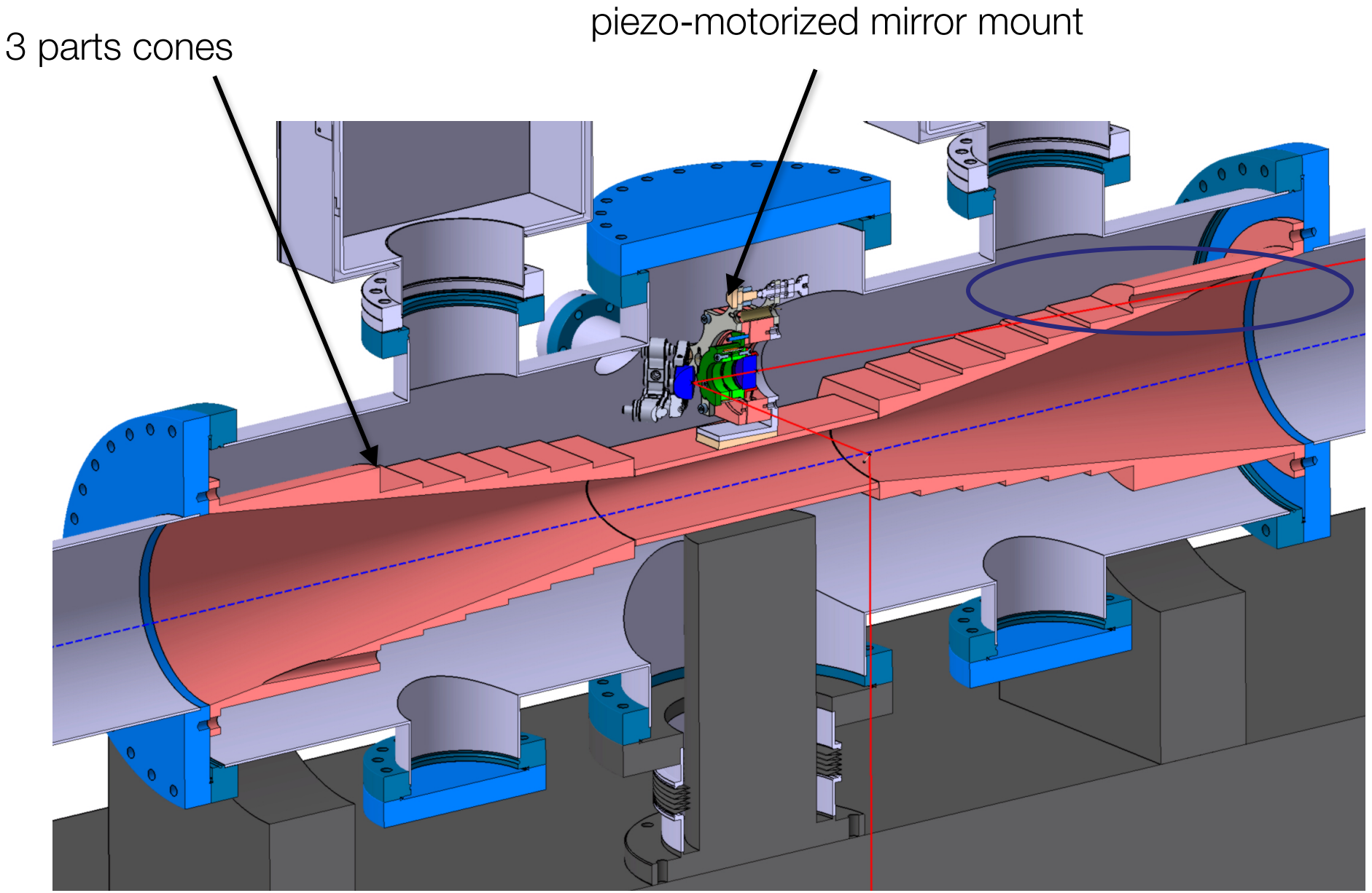
Beam impedance

3 differents sections

~~conic section are 40cm long INOX 316LN~~ => asymmetrical conic shape on the vertical axis only

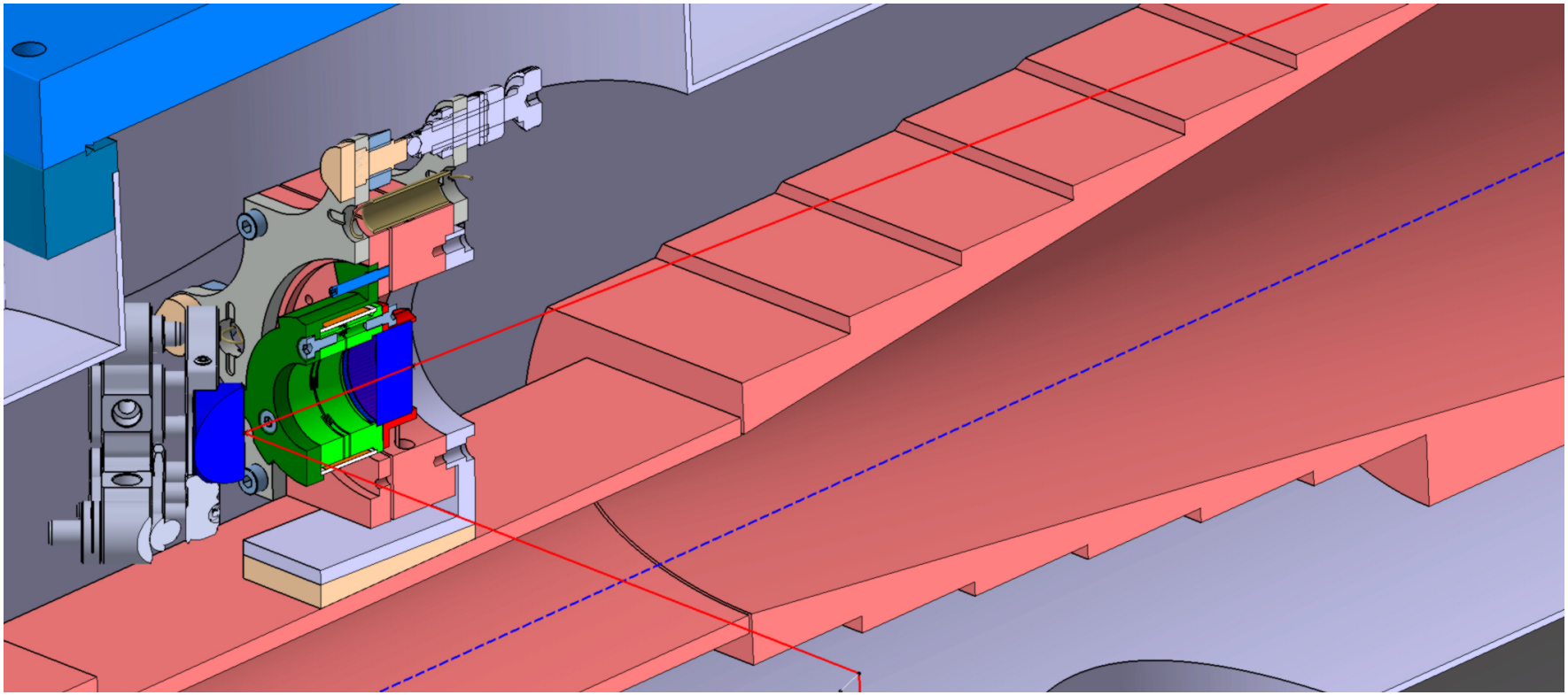


UHV mirror mount



UHV mirror mount

- piezo-motorized gimbal mirror mount with 2 tilts
- axial synchronization annular piezo
- Side ejection of the transmitted laser beam



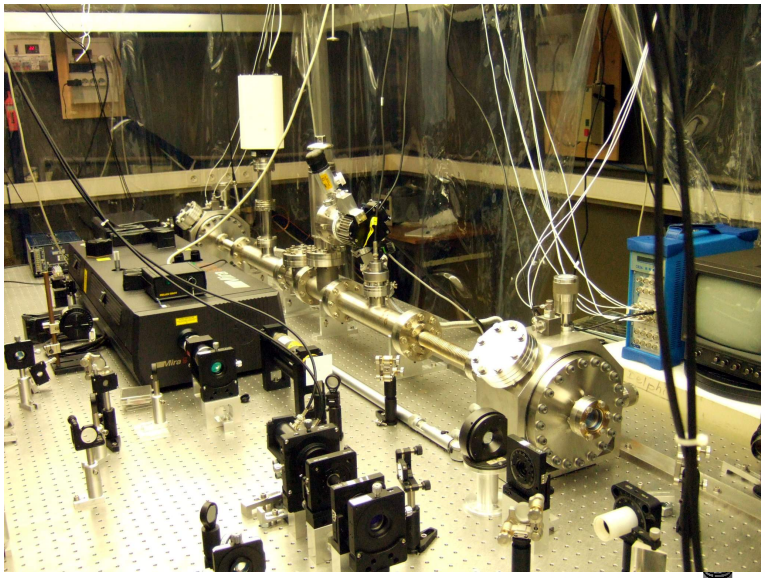
Development of a 62 MHz test cavity for GFPop @ LAL

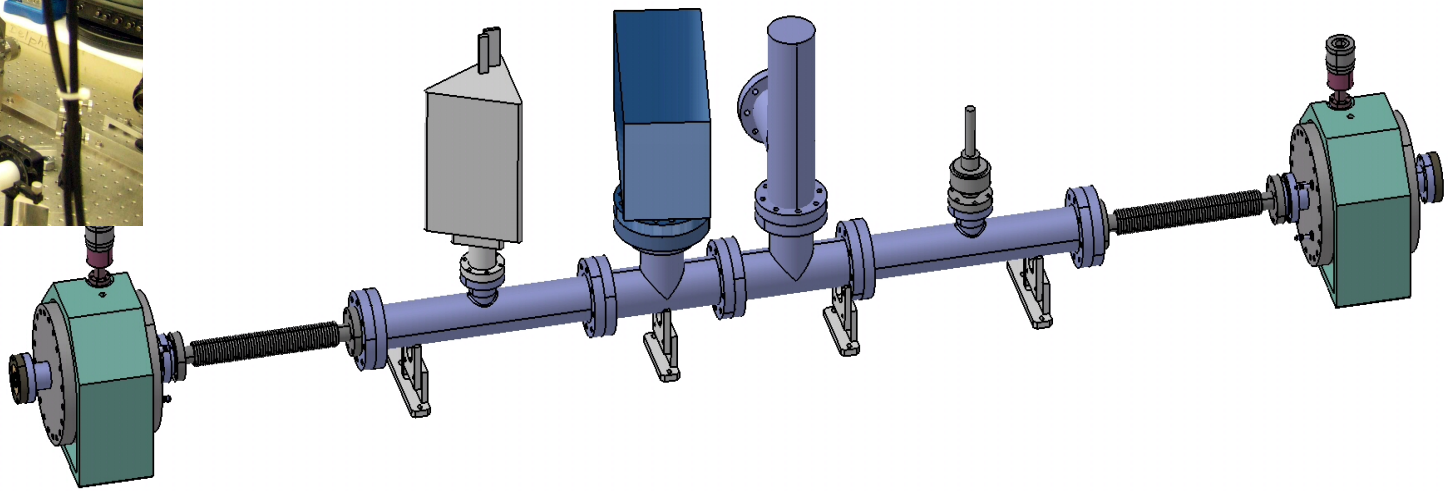
> The 75 MHz PLIC cavity can be upgraded: 2 new mirror HR (<1k€) @ 1030nm + 40cm CF tube (<1k€)

> Laser system : Onefive low phase noise oscillator + CFBG (TEC) + Mighty laser 50 W YDFA + (CVBG ?). On going quotation for the CPA elements.

> Diagnostic : HR spectrometer (18k€)

=> Demonstrate >150kW? with 2-mirror FP cavity and spectral control





Next step in coming weeks

> YELLOW REPORT …

> Data collection for NDA for all the electronics.

> Iteration and meetings with laser manufacturers to freeze a possible design

> From the GF POP experiment march meeting discussion list of actions and update

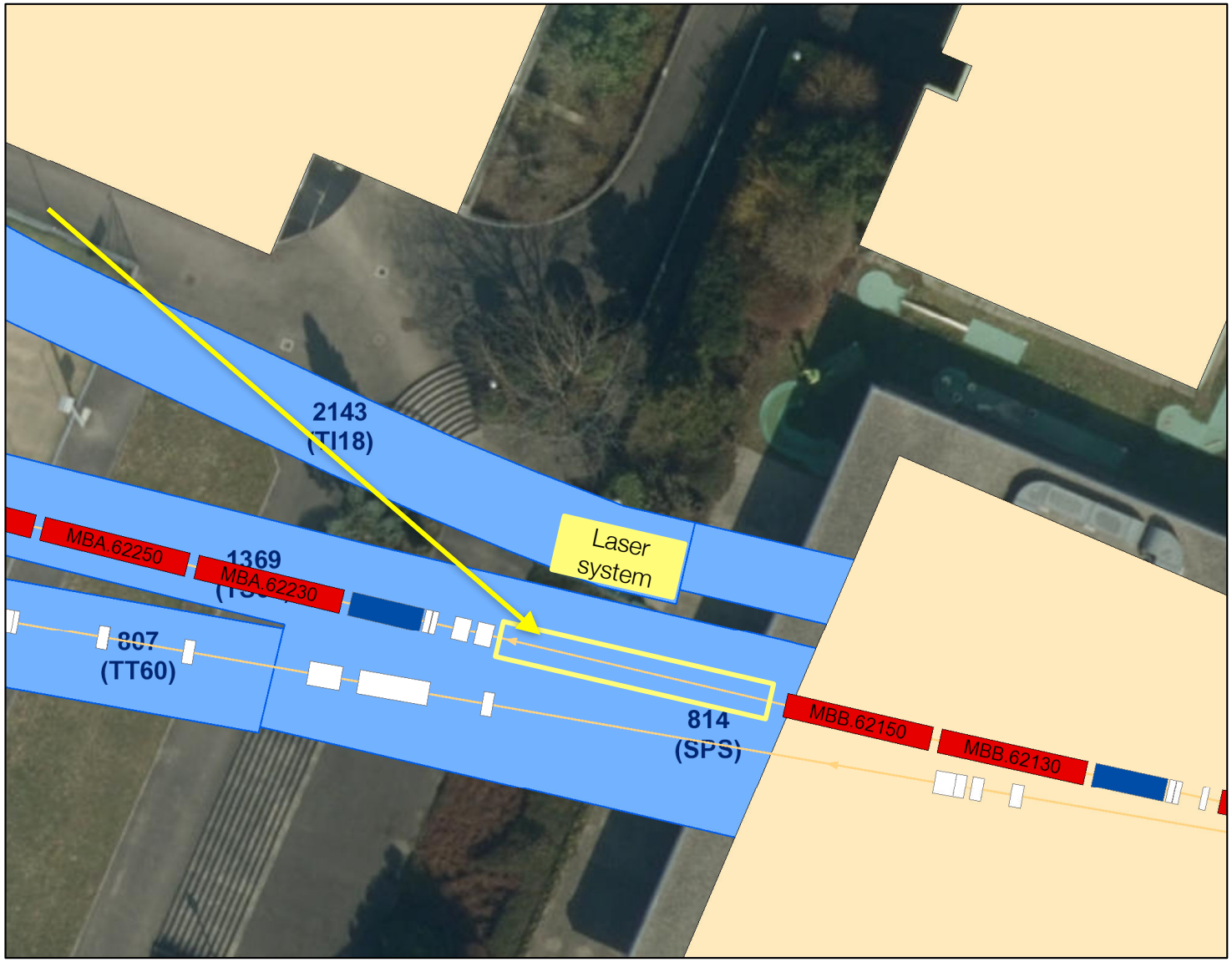
1. 2 BPMs will be added to the IP module => if have model please send it (80mm aperture possible rescaling at 150mm aperture ?)
2. The inner shape of the shielding will be modified following Aaron suggestion => updated drawing will be send with asymmetric section and RF coper finger
3. Synchronization scheme proposal from W. Höfle => write down page on requirement and foreseen operation and interface with the cavity locking
4. Integrate a first version of IP UV photons imaging system FS corning and UV sCMOS
5. Radiation / EEE : risk of damage during proton operation : installation of laser and electronics in 24hours slot.
6. SPS visit : crab cavity pumping system close to LSS6.616 … bad news for vibration / **BUT :** visiting the downstream part a section MBB62150 and QF62210 is close to (~5-8m laser transport line) the old TI18 tunnel with a potential more radiation safe place for the laser see next slide…

SPS visit

CERN Geographic Information System

Questions are:

- Beam sizes ?
- Radiation level?
- Any issue being after extraction for LHC ?
- Or other reason if I well remember Valentine mentioned this place in January



CERN, SITG
28/03/2019

SPS visit

LSS6 616

Vacuum group of the crab cavity