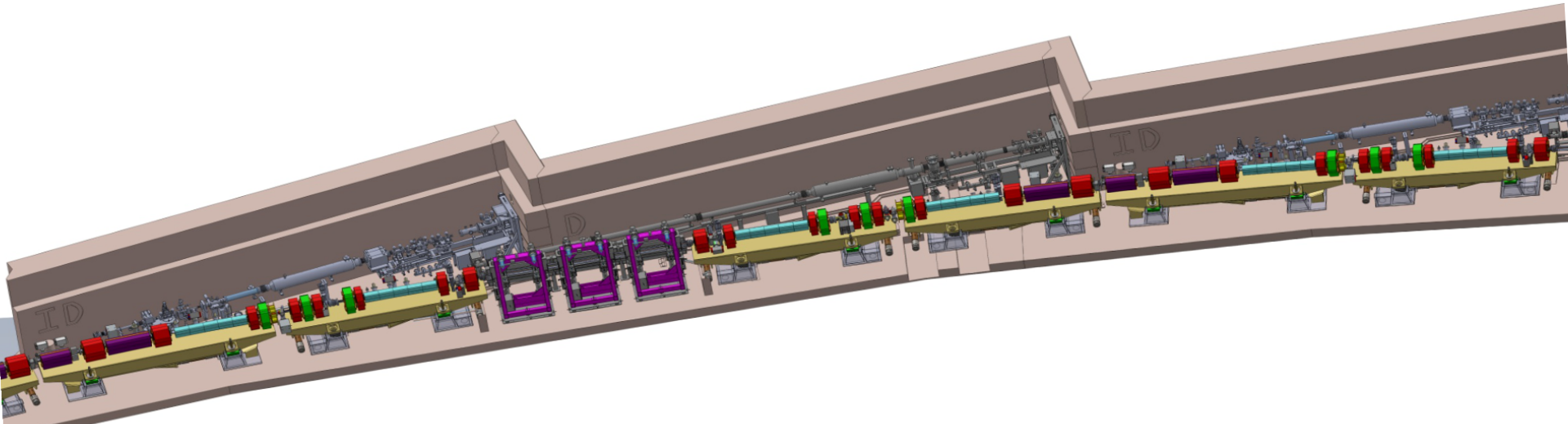
ESLS 2015

Böttstein, 23-25 Novembre 2015

ESRF Status and Upgrade Program

T. Perron, on behalf of the ESRF Accelerator & Source Division

ESRF | The European Synchrotron



Outline

ESRF I operation and improvement:

- Operation Statistics
- Main hardware problems encountered.
- Top up implementation
- RCDS optimisations
- Beam Shaping in transfer line

ESRF II:

- Project presentation
- Beam dynamics issues
- Technical issues

Operation Statistics

Machine Statistics for 2012-2015 at the ESRF
5544 USM hours scheduled in 2015

	2012	2013	2014	May 2015
Availability (%)	98.58	98.93	**99.11**	**97.61**
Mean Time Between Failures (hrs)	60.00	79.70	**105.5**	**62.40**
Mean duration of a failure (hrs)	0.85	0.85	**0.94**	**1.49**

RUN2015-01 started badly with a tricky master source problem to solve.

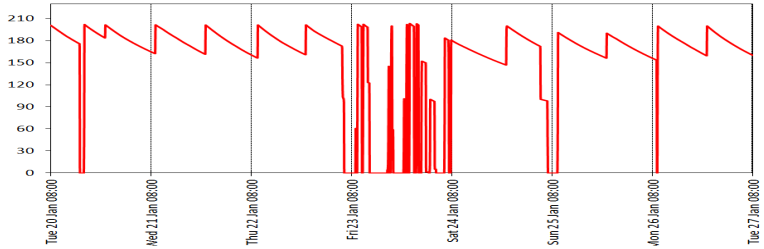
(Until June 2015)

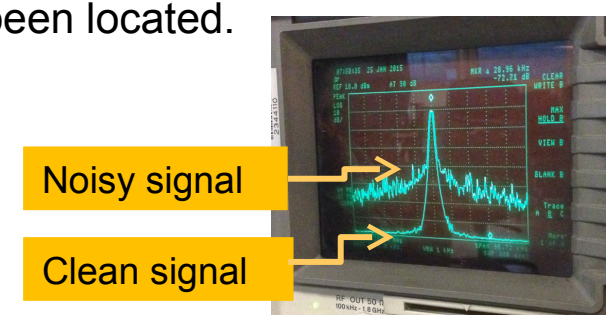
Operation: The worst failure of the year

Exceptional event on 23rd January 2015: 32 hours lost (no beam + bad beam quality)

The result of a conjunction of 3 events:

- An old RF frequency generator with a degraded noise filter
- A bad electromagnetic compatibility in the Control Room electronic cabinets
- A strong earth noise pollution which origin has never been located.



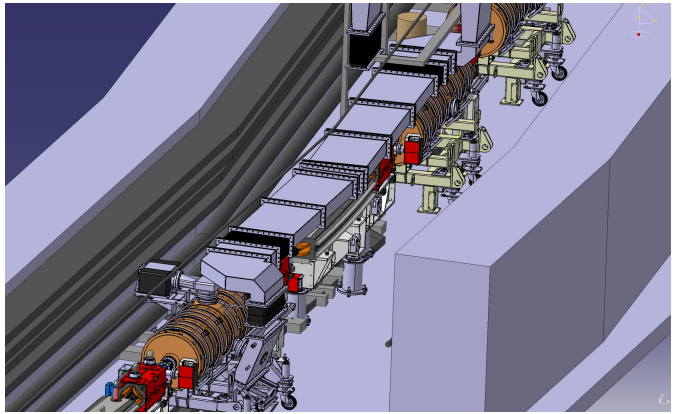


- Temporary solution for 4 months: a more robust spare master source in a better EMC location
- In June 2015:
  - Control Room EMC has been completely refurbished
  - A new and robust master source has been installed

Courtesy L. Hardy

Top-Up Implementation (1)

On the injector side:



Courtesy A. D'elia, B. Ogier, J.M. Mercier

Add 2 cavities to the 2 existing ones. For the same power consumption the RF voltage is enhanced by a factor √2. Cavities are installed (but passive) and will be connected in January.

It will allow redundancy.

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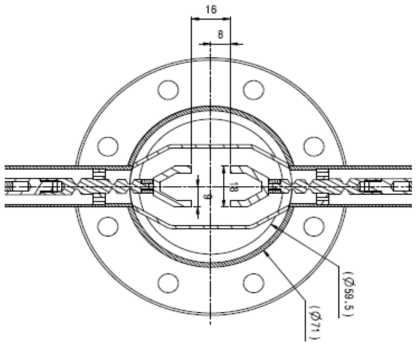
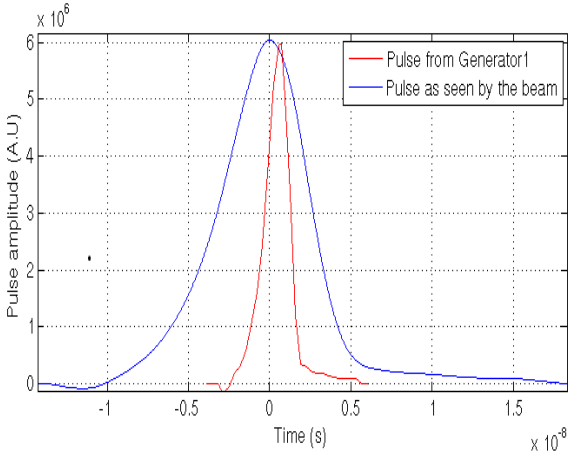
Cleaning in the injector:
Using bunch selection via a fast strip line injection kicker for the booster allows to inject a specific bucket and disables injection of the impurities coming from the linac. Ongoing tests show promising results.



Strip-line geometry

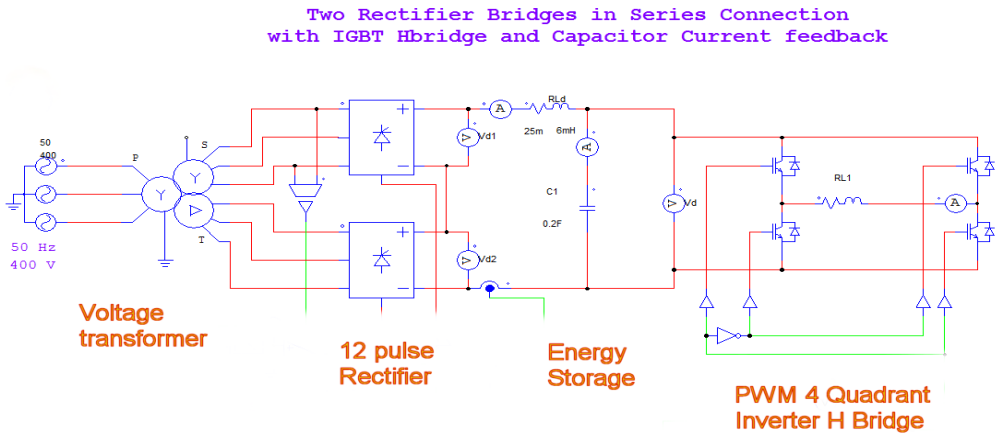


Pulse shape

Courtesy B. Ogier,E. Plouviez, M. Dubrulle

Top-Up Implementation (2)

New Booster magnets power supply to be commissioned 1rst semester 2016.
The maximum repetition rate will be 4hz compared to the actual 10Hz which requires adaptation of the timing distribution.



Courtesy J. F Bouteille, O. Goudard, K. Bulstra, P. Phalaise, J.M Koch

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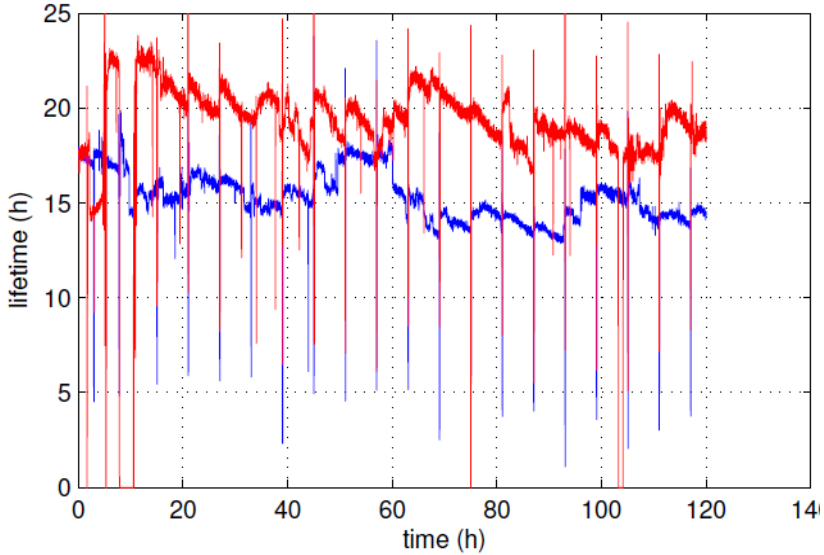
Large linac refurbishment including a new buncher and a spare modulator

Top-up should be delivered to users end of spring 2016

RCDS Optimisation

A “line optimizer” package developed by X.Huang at SLAC has been extensively used to optimise operation of the ESRF:

The optimiser can be interfaced with the control system and do real life optimisation:



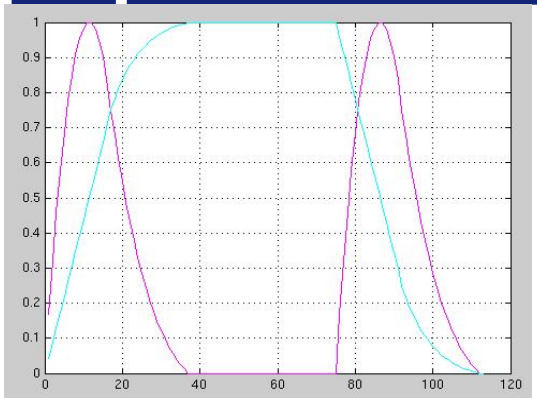
Lifetime in 16 bunch operation for one week of operation. Red curve shows the value after optimisation

Lifetime improvement optimising sextupoles families

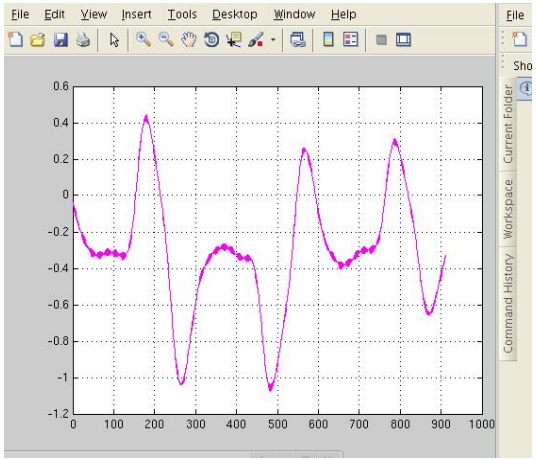
Tuning of injected beam trajectory

See S. Liuzzo presentation

Damping of injection perturbations



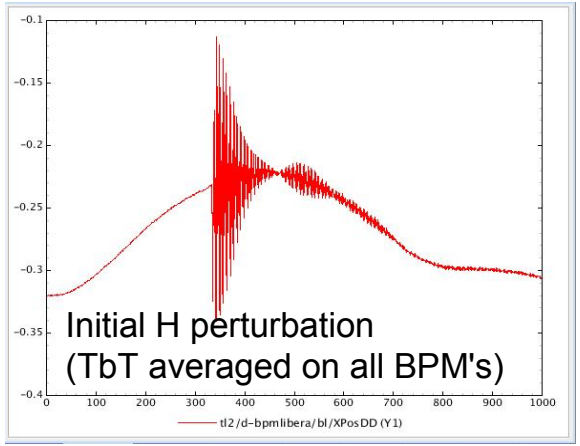
Parasitic kick due to sextupoles in the injection bump

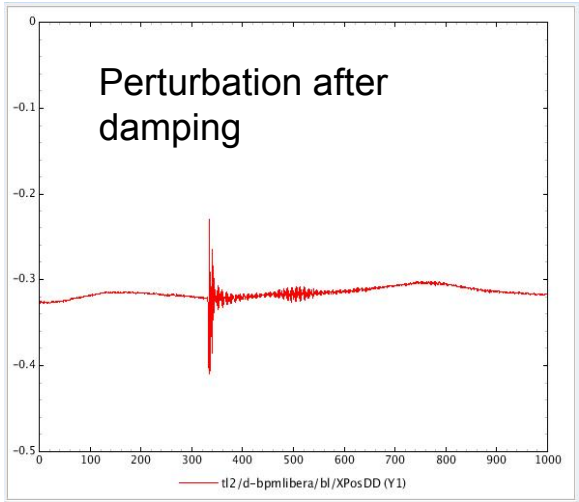


Resulting orbit (3 turns)

The kick resulting from the sextupoles in the injection bump is damped via a 1Mhz bandwidth shaker and over 20 turns. The correction signal is calculated once looking at the perturbation signal and then triggered by the same trigger as the injection kickers.

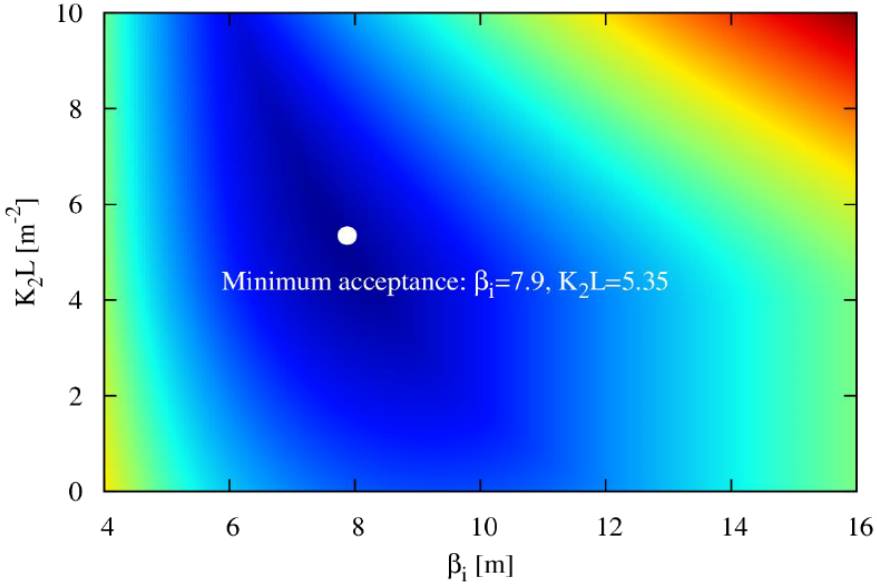
Also the slow perturbation coming from the septum leakage is damped using a dedicated fast orbit corrector and an arbitrary correction signal.

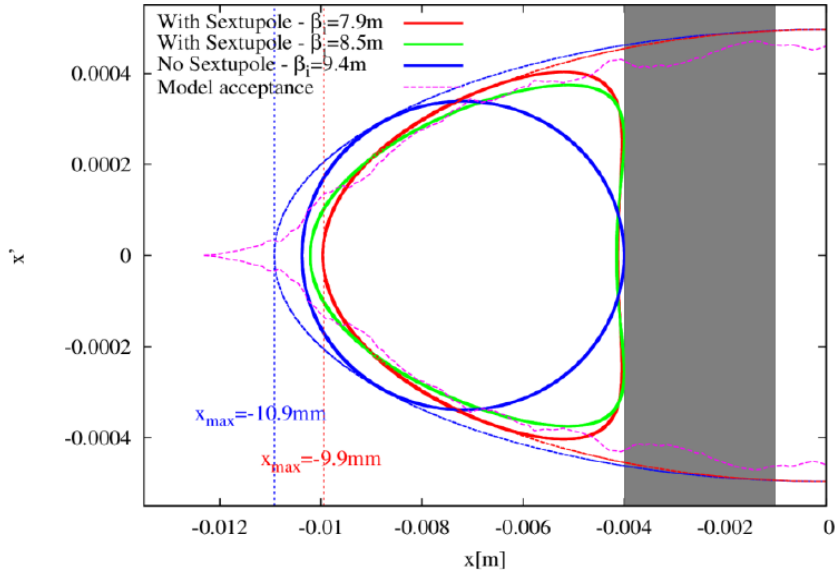




Courtesy E. Plouviez

Beam Shaping in Transfer Line using a sextupole





- The optimum β_x and sextupole strength can be computed assuming an elliptical acceptance (red curve)
- Further improvement is possible by fine tune tuning using the real acceptance (green curve)
- **At most we expect a gain of ~5% for the ESRF upgrade**

Tracking simulation of injection efficiency for ESRF upgrade

TL2 sextupole	β_i m	ϵ=120 nm	ϵ=60 nm
0.0 m^{-2}	22.1	56± 2%	79± 1%
0.0 m^{-2}	9.4	79± 1%	92± 1%
6.0 m^{-2}	8.5	82± 1%	94± 1%
5.35 m^{-2}	7.9	83± 1%	95± 1%

Courtesy of S. White

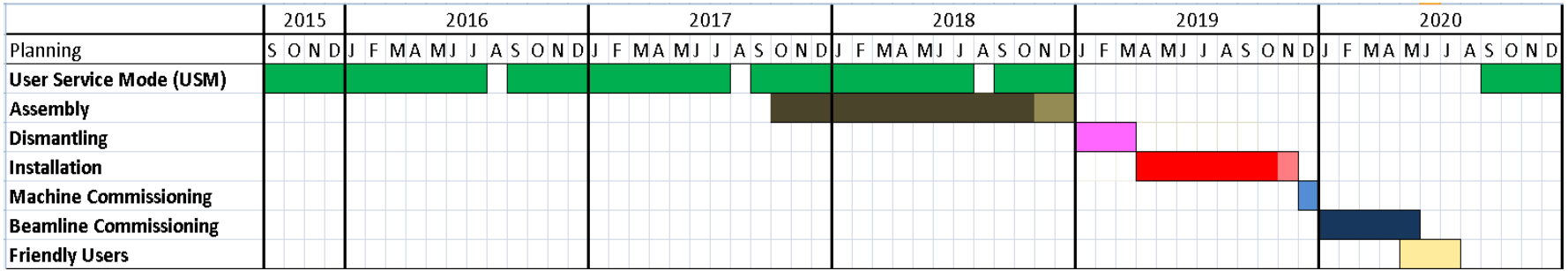
Sextupole installed and first test show a 2% injection efficiency increase

ESRF II project overview

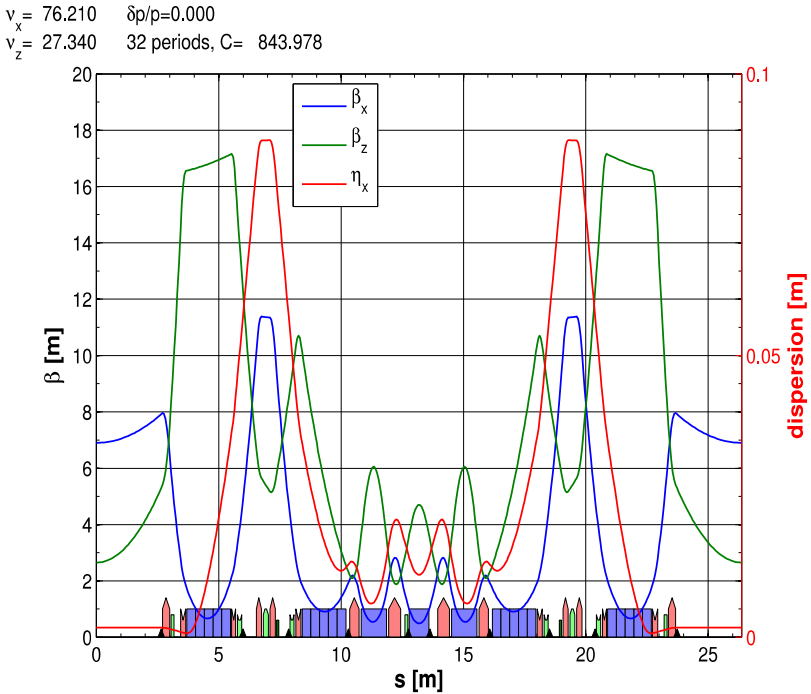
Cost of the accelerator:
~100 M€ financed.

The project has been approved by the council in Jun 2014.

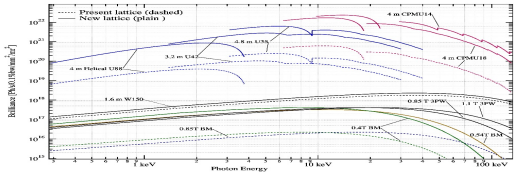
	Upgrade	ESRF
Energy [GeV]	6.00	6.04
Tunes	75.21, 26.34	36.44, 13.39
Emittance x [pmrad]	135	4000
Energy loss per turn [MeV]	2.6	4.9
RF voltage (acceptance) [MV]	6 (5.6%)	9 (4%)
Chromaticity	6, 4	4, 7
Circumference [m]	843.98	844.39
Beam current [mA]	200	200
Lattice type	HMBA	DBA



ESRF II project overview

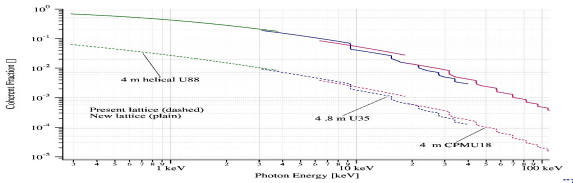


Brilliance



Brilliance and coherence are enhanced by more than one order of magnitude especially for high energy photons.

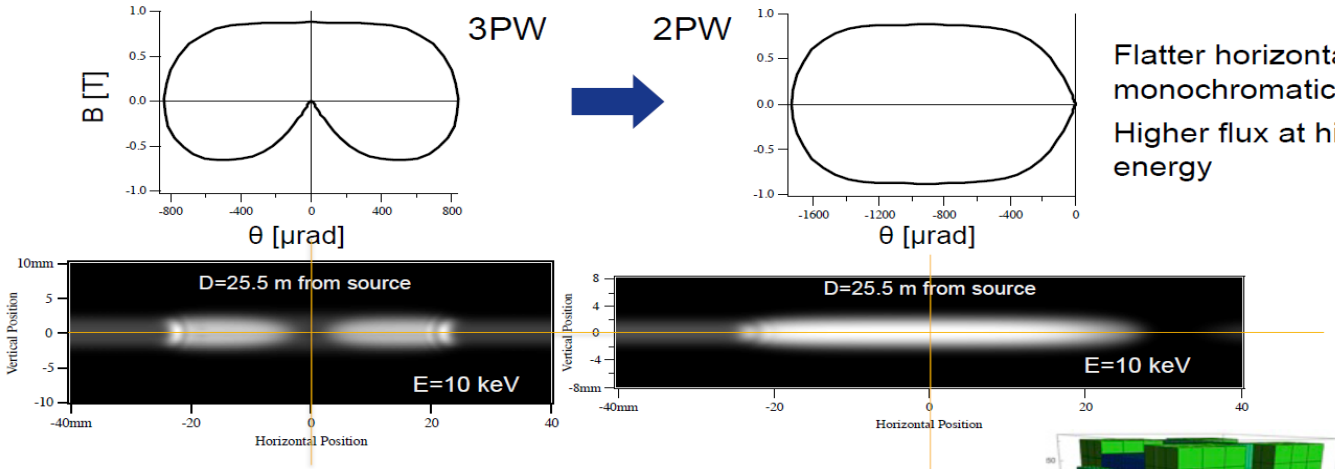
Coherence



Courtesy J. Chavanne

2 pole Wiggler

Source points for beam lines do not move:
Two-pole wiggler are replacing the bending magnets beam lines photon source.

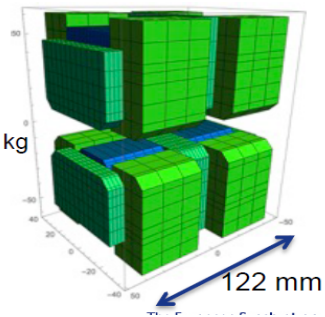


Flatter horizontal monochromatic profile

Higher flux at high energy

Magnetic gap 18 mm
Peak field: 0.86 T
Magnetic length: 99.1 mm
Weight of mag. material: 4.9 kg

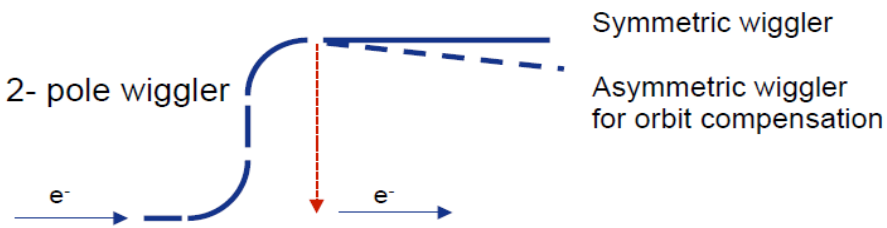
Angular aperture:
H 0.8: ±mrad
V 0.25: ±mrad



Courtesy J. Chavanne

2 pole Wiggler

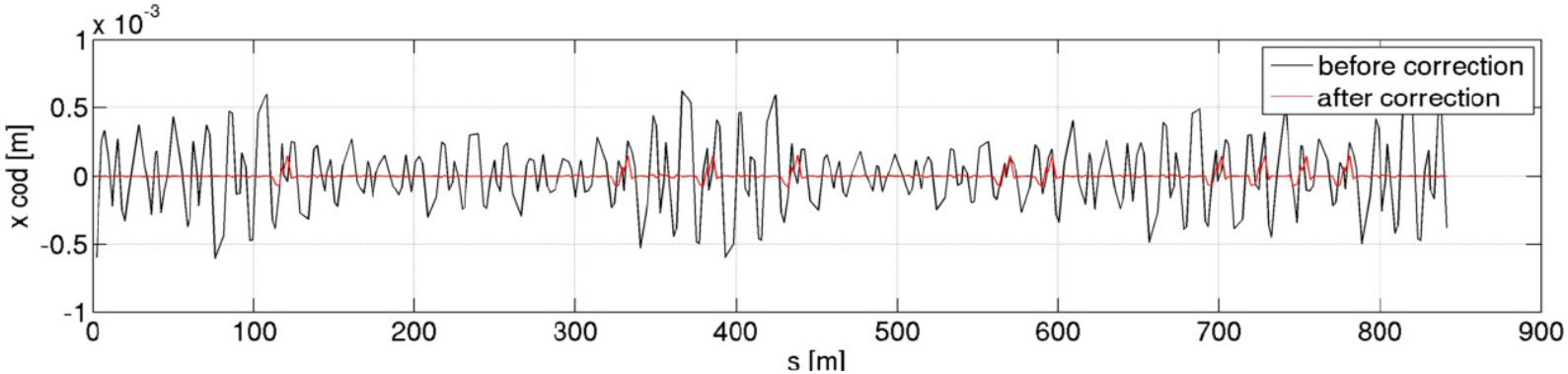
2-pole wigglers induce a “position step”:



The 2-pole wiggler is modeled as two sector dipoles and a change of reference orbit at the exit of the second dipole.

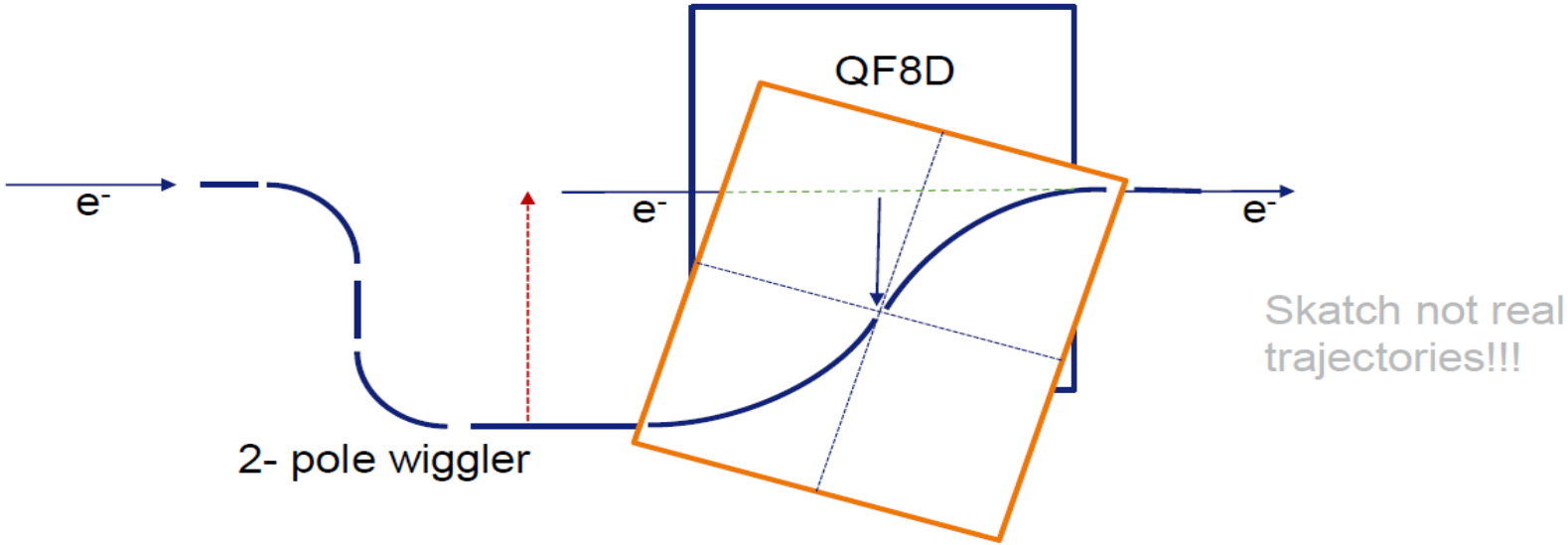
The change of reference allows to study the orbit introduced by the wiggler even if it has been described using dipoles (dipoles define the reference trajectory)

Orbit distortion corresponding to 10 wigglers:



Courtesy of L. Farvacque, S. Liuzzo

2 pole Wiggler



- Translation of half the trajectory change
- Rotation fitted to close the bump

Rotation ~2.5mrad
Displacement ~65μm

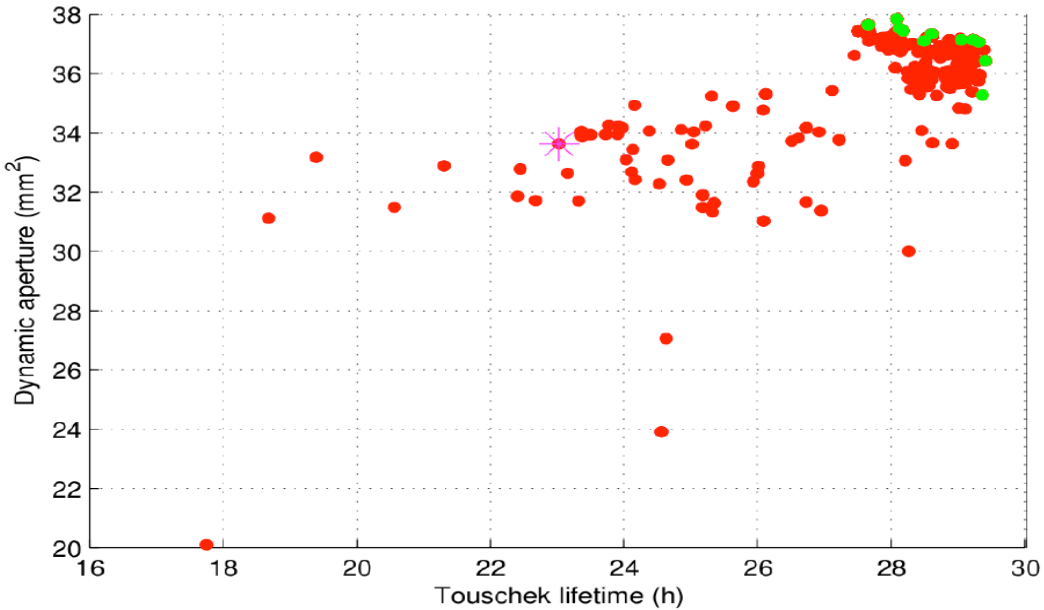
Sextupole optimisation

Lifetime and Dynamic aperture have been optimised by searching optimal settings for sextupoles.

It was done using the multi objective genetic algorithm NSGA-II.

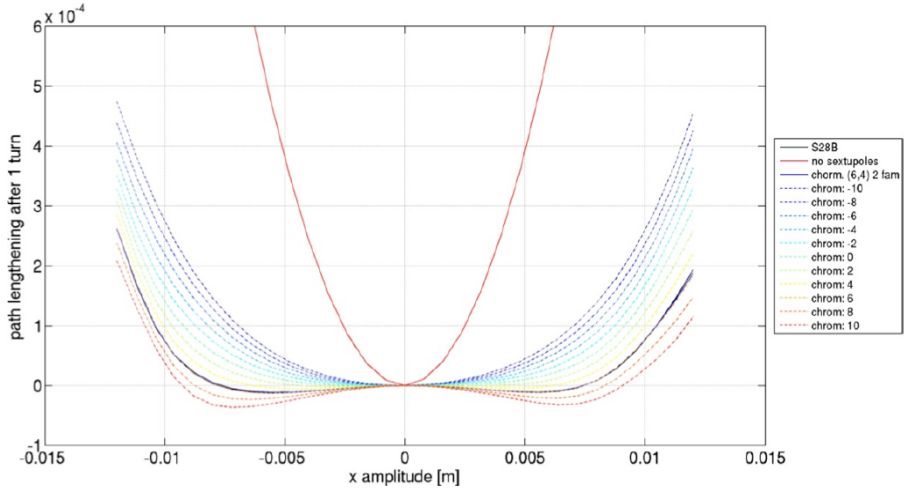
- Lifetime of several hours depending on the operation modes.
- Dynamic aperture of 8mm at injection point (βh=17.4) could be reached.

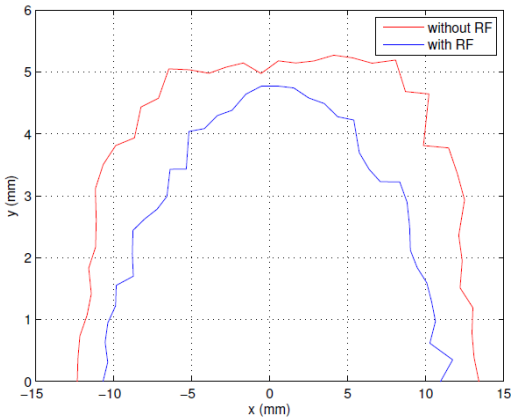
Courtesy N. Carmignani



High chromaticity operation

On-energy particles with large amplitude have a longer trajectory and arrive later to the cavity, so they change their energy. This effect is smaller at high chromaticity and can be seen comparing DA with and without RF cavity.





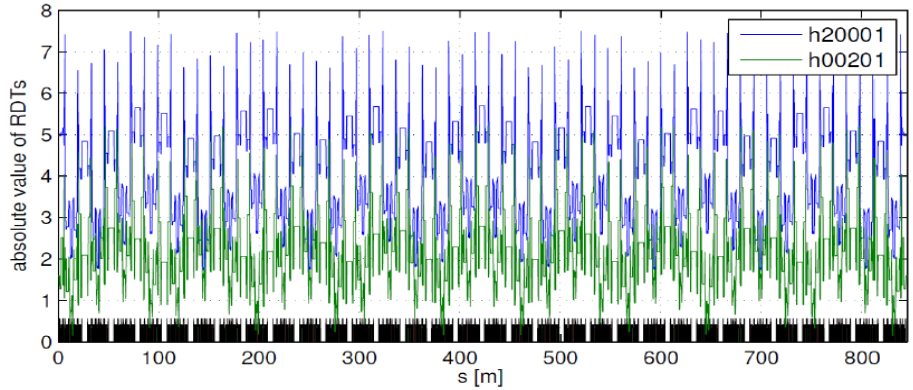
Courtesy S. Liuzzo, N. Carmignani

To reduce the detrimental effect of path lengthening with H amplitude working at high chromaticity is beneficial. Very helpful for what concerns collective effects.

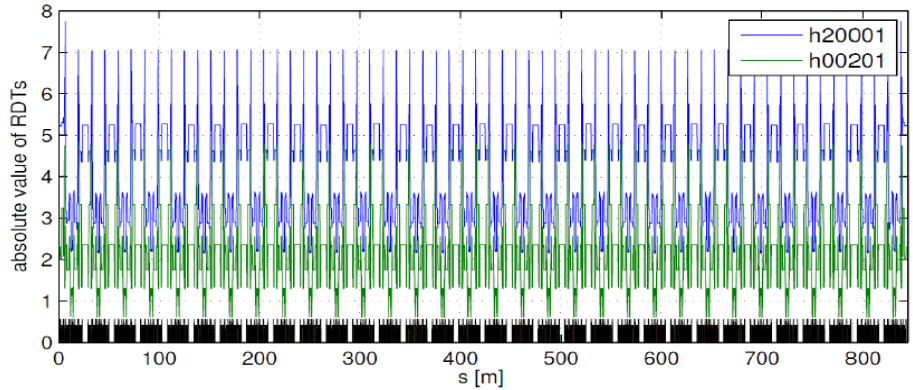
Symmetry breaking due to injection section

Classical off axe injection using a 4 kicker bump is foreseen To get higher beta at injection point, injection cell is different from the regular ones.

Chromatic beating terms asymmetry induced by the injection cell.
It has a strong effect on lifetime



Tuning individually the injection cell sextupoles to recover symmetry

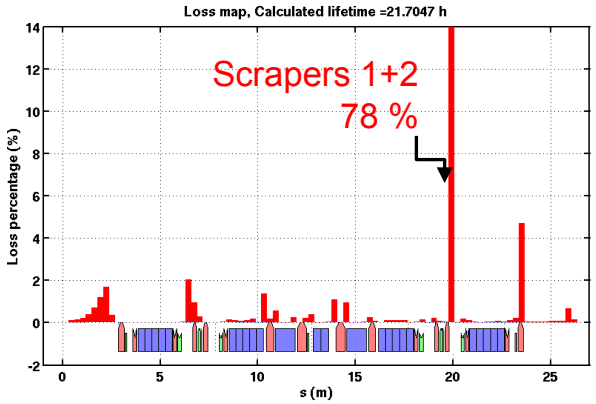


Lifetime of a symetric machine almost recovered.

Collimation using scrapers

To reduce distributed losses and eventually radiation safety issues it was decided to concentrate losses at two specific positions where extra shielding will be placed.

Collimation will be done using horizontal scrapers with the constrains of not impacting the lifetime by more than 10%.



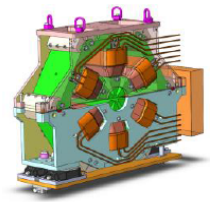
Simulated loss map of a cell

Two scrapers in DR_37 of cells 13 and 24. All cells losses are superimposed

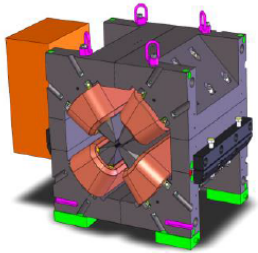
80% of the losses can be relocated on the scrapers with a lifetime reduction of 4%.

The in-house code used for simulations shows reasonable agreement with losses observed on actual machine.

Magnets



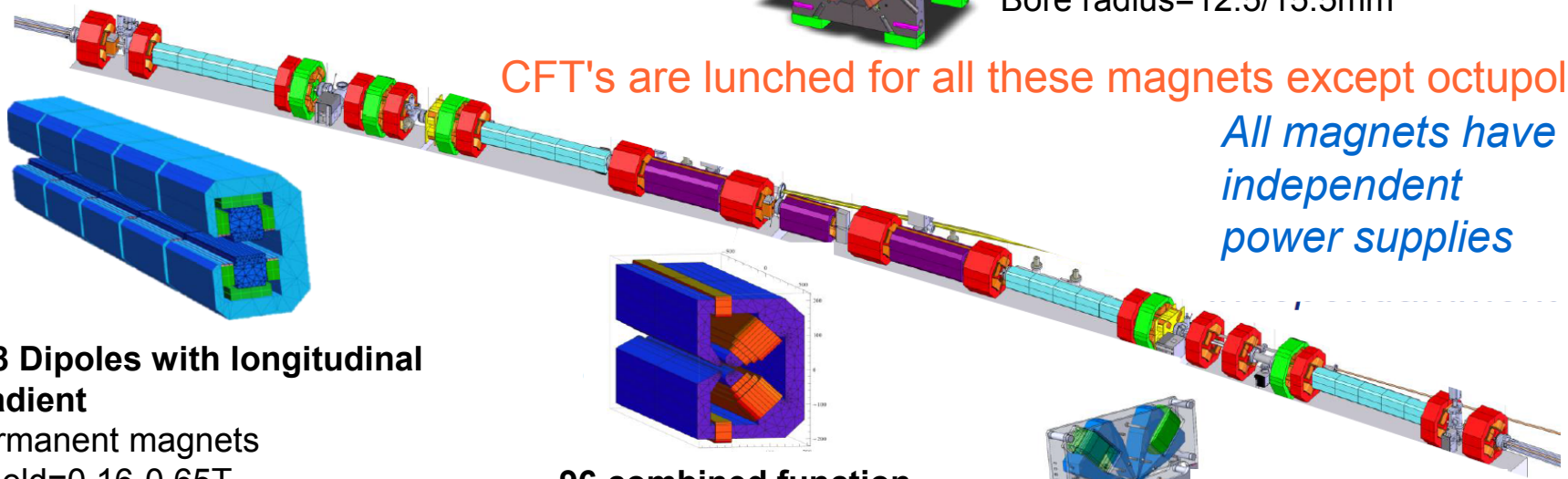
192 Sextupoles
L=200mm
900-2200T.m-2
also used as correctors



512 Quadrupoles
G=85/51 T/m
L=160-490
Bore radius=12.5/15.5mm

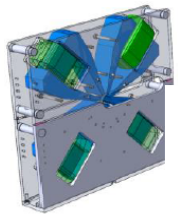
CFT's are lunched for all these magnets except octupoles

All magnets have independent power supplies



128 Dipoles with longitudinal gradient
Permanent magnets
B field=0.16-0.65T
Gap: 26mm
1 dipole=5 modules
Hybride Sm2Co17/Strontium Ferrite

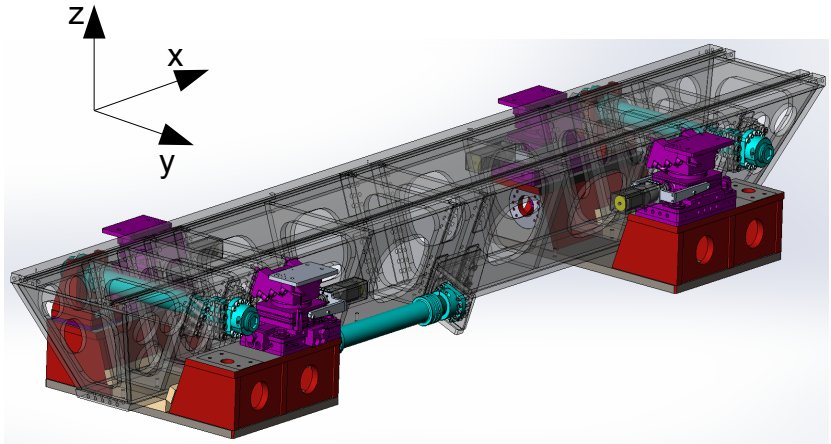
96 combined function magnets.
0.54T/34 Tm-1
0.43T/34 Tm-1



64 Octupoles
51200T/m-3

Courtesy of G. Le Bec, C. Benabderrahmane

Girders

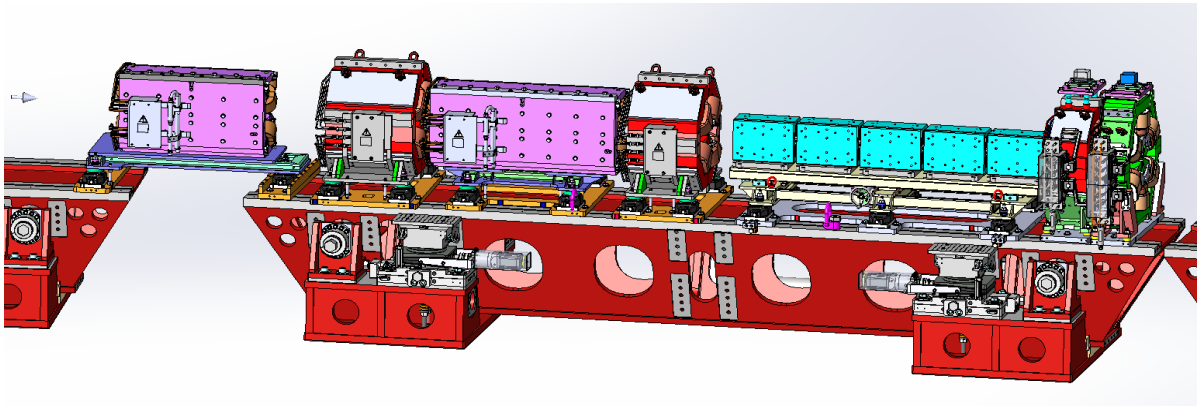


Hyperstatic Girder of 5 T (~9T loaded)

4 Motorised adjustments in z
2 Manual adjustments in y
1 manual adjustment in x

No resonating mode bellow 80hz

Prototype tested and CFT will be lunched in December



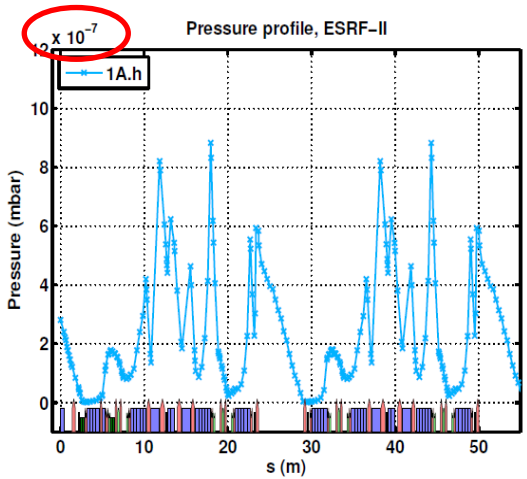
Magnets are pre-aligned by mechanical stops (+-0.5mm) when installed. Dedicated supports enable fine alignment (< 50μm).

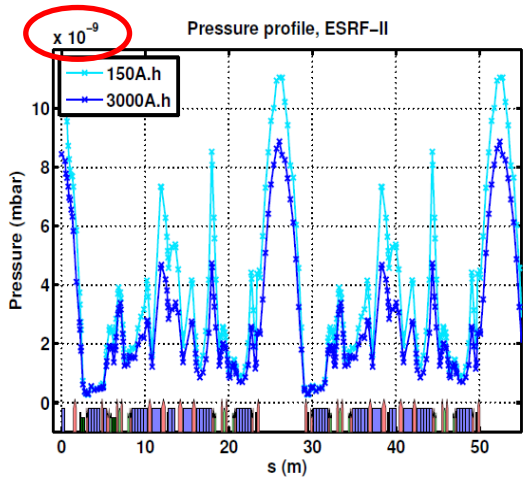
Courtesy F. Cianciosi, I. Eybert

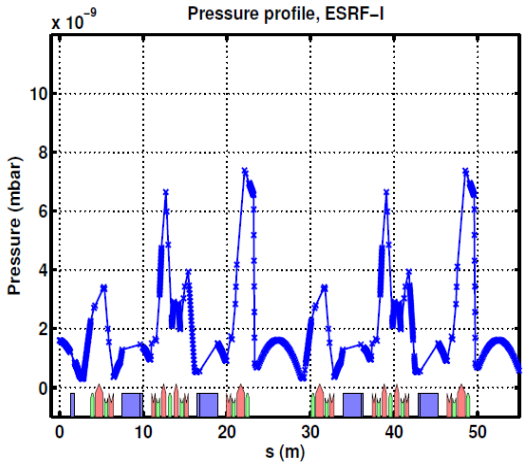
Vacuum Chambers

- 15 different vacuum chambers per cell.
- 17 pumps per cell.
- Stainless steel chambers except for dipoles chambers and straight section chambers made out of aluminium. Only the straight section chamber are coated with NEG.
- Beam stay clear: 8*57mm in SS, 11*16mm in central region and 20*30mm elsewhere.

150 A.h will be needed to condition the machine during commissioning







CFT's campain for vacuum chamber batches has started

Courtesy M. Hahn, R. Versteegen, H. Pedroso Marques

MANY THANKS FOR YOUR ATTENTION