Status of the ESRF EBS Storage Ring Engineering and Construction

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OUTLINE

- The ESRF EBS accelerator Upgrade project
- Planning
- Manufacture of components: Status and feedback
- Mock-up of a complete cell
- Assembly of equipped girders
- Logistics, Installation
- Conclusion

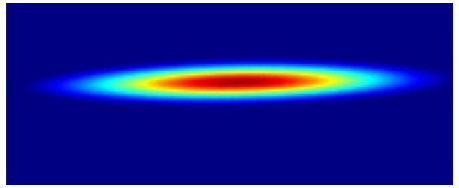
New Storage ring with **reduced Horizontal Emittance** installed in place of the existing one.

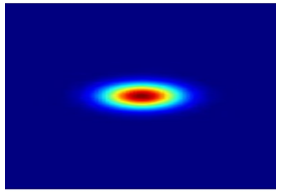
Reduced e- beam Horizontal Emittance => Higher Photon beam Brilliance and Coherence

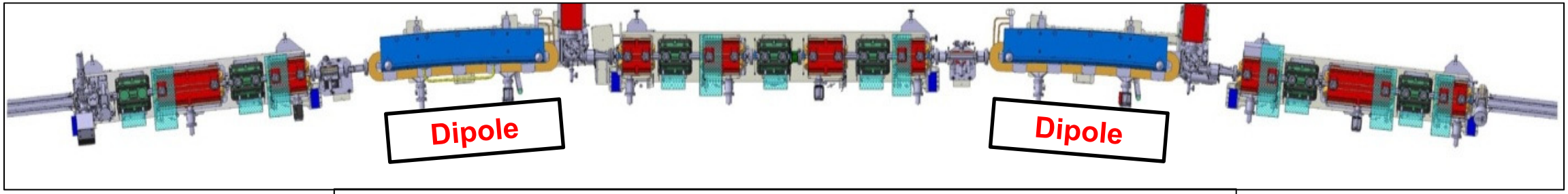
	Now	EBS
Energy (GeV)	6.04	6
Multibunch current (mA)	200	200
Circumference (m)	844.39	843.98
Horizontal emittance (pm.rad)	4000	140
Vertical emittance (pm.rad)	4	5

reduced by x 30

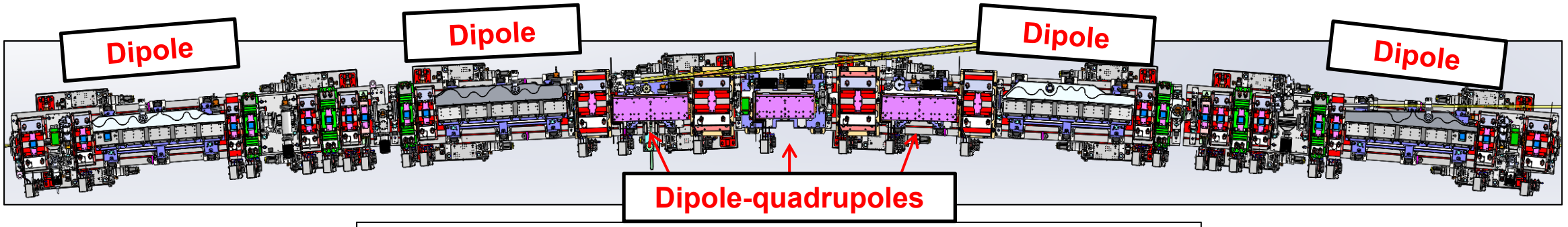
emittance ~ beam size x beam divergence
emittance = cst along the ring







Present : Double bend achromat lattice

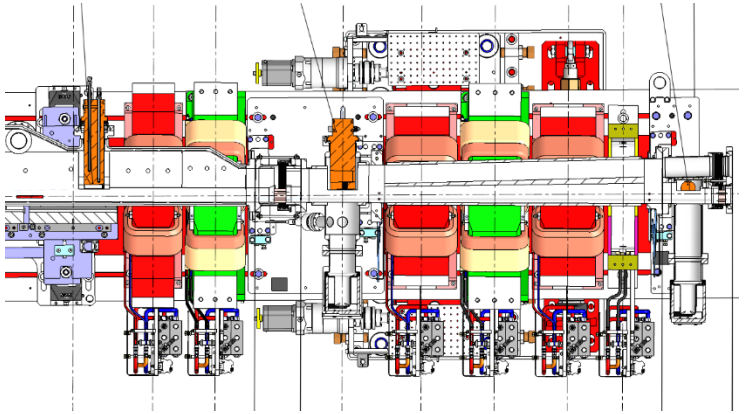


EBS : 7 bend achromat lattice

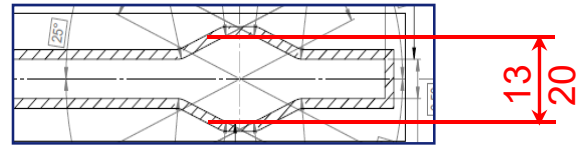
- **Twice as many magnets**
- New Storage ring in place of existing one

⇩

Very little space



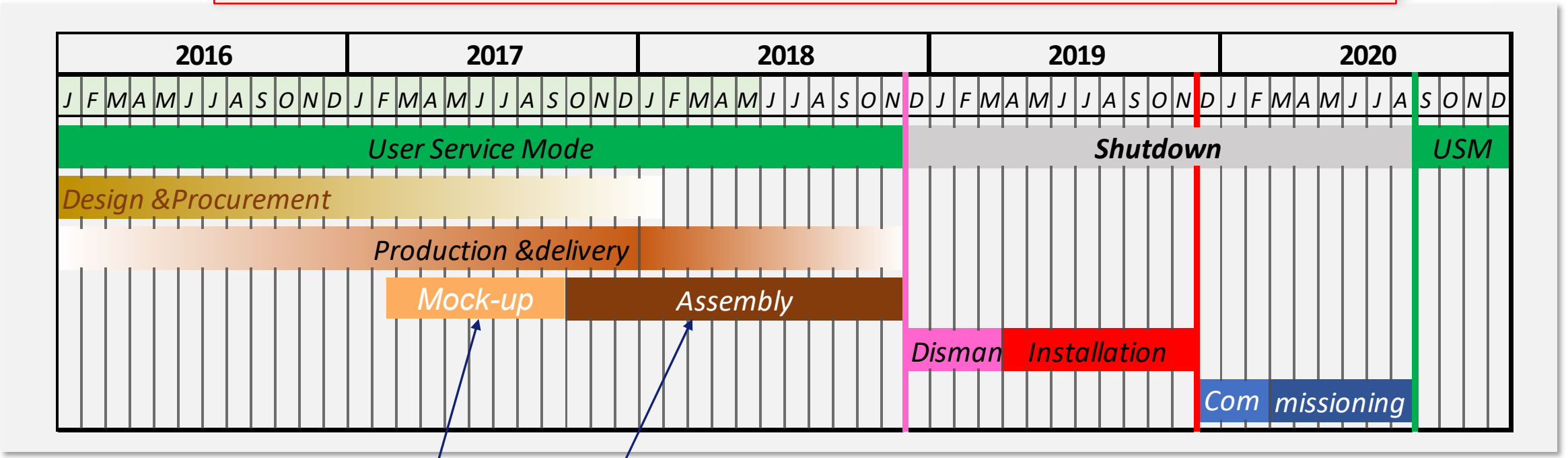
Small magnetic gaps & lack of space for flanges => vacuum chambers very difficult to design and manufacture (tight tolerances)



PLANNING

Green light: June 2014

20 October	2017	Start girder assembly *(14 months)*
10 December	2018	Start long shutdown *(20 Months)*
		Dismantling *(3 months)* and Installation *(9 months)*
19 November	2019	Start accelerator commissioning
04 March	2020	Start beamlines commissioning
25 August	2020	Back to USM



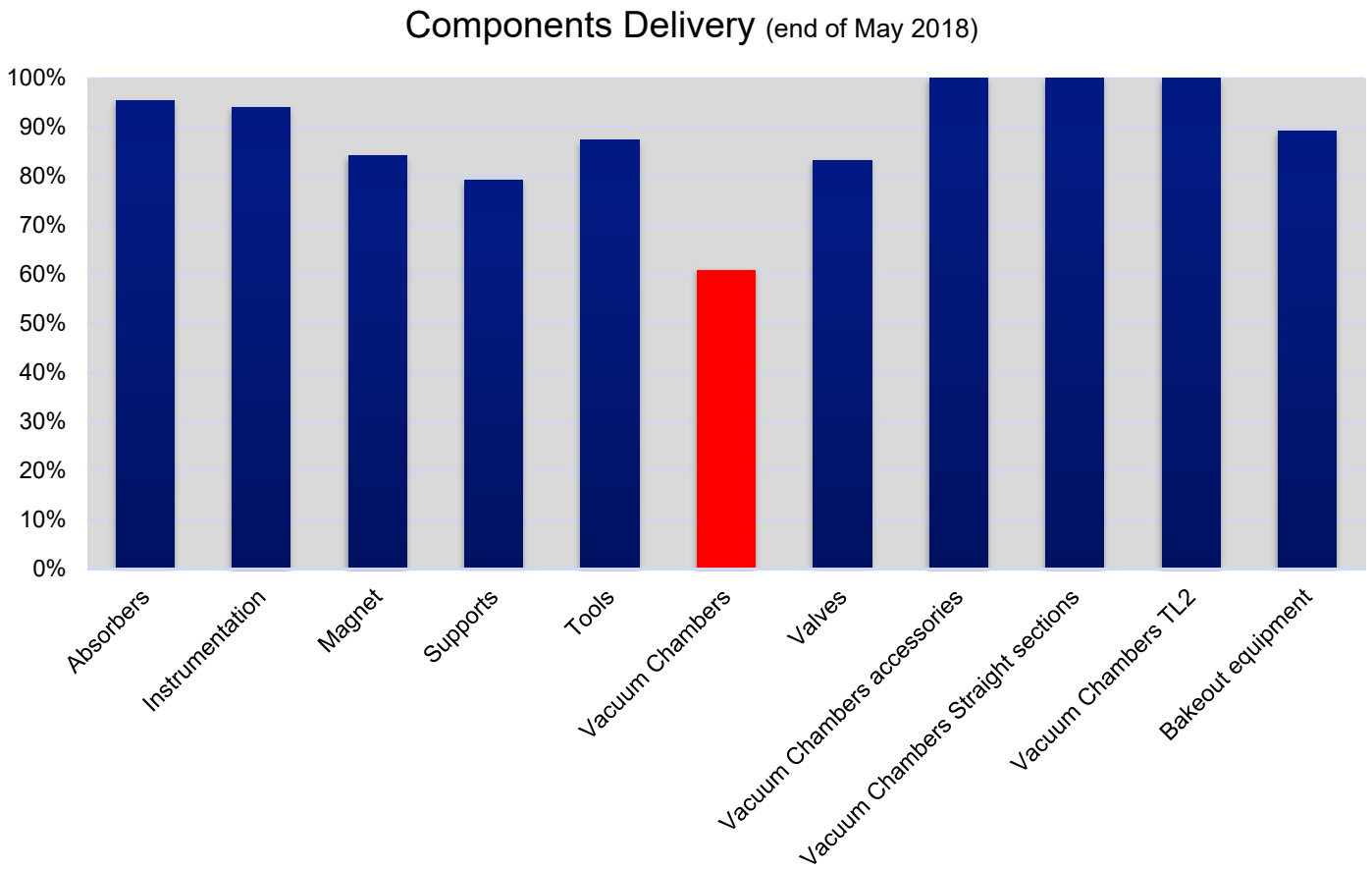
Assembly = assemble equipped girders with all components aligned and tested

Mock-up = assemble a complete cell with pre-series components

Courtesy of P. Raimondi

FEEDBACK FROM MANUFACTURE OF COMPONENTS

STATUS OF DELIVERY OF COMPONENTS



Courtesy of J.C. Biasci

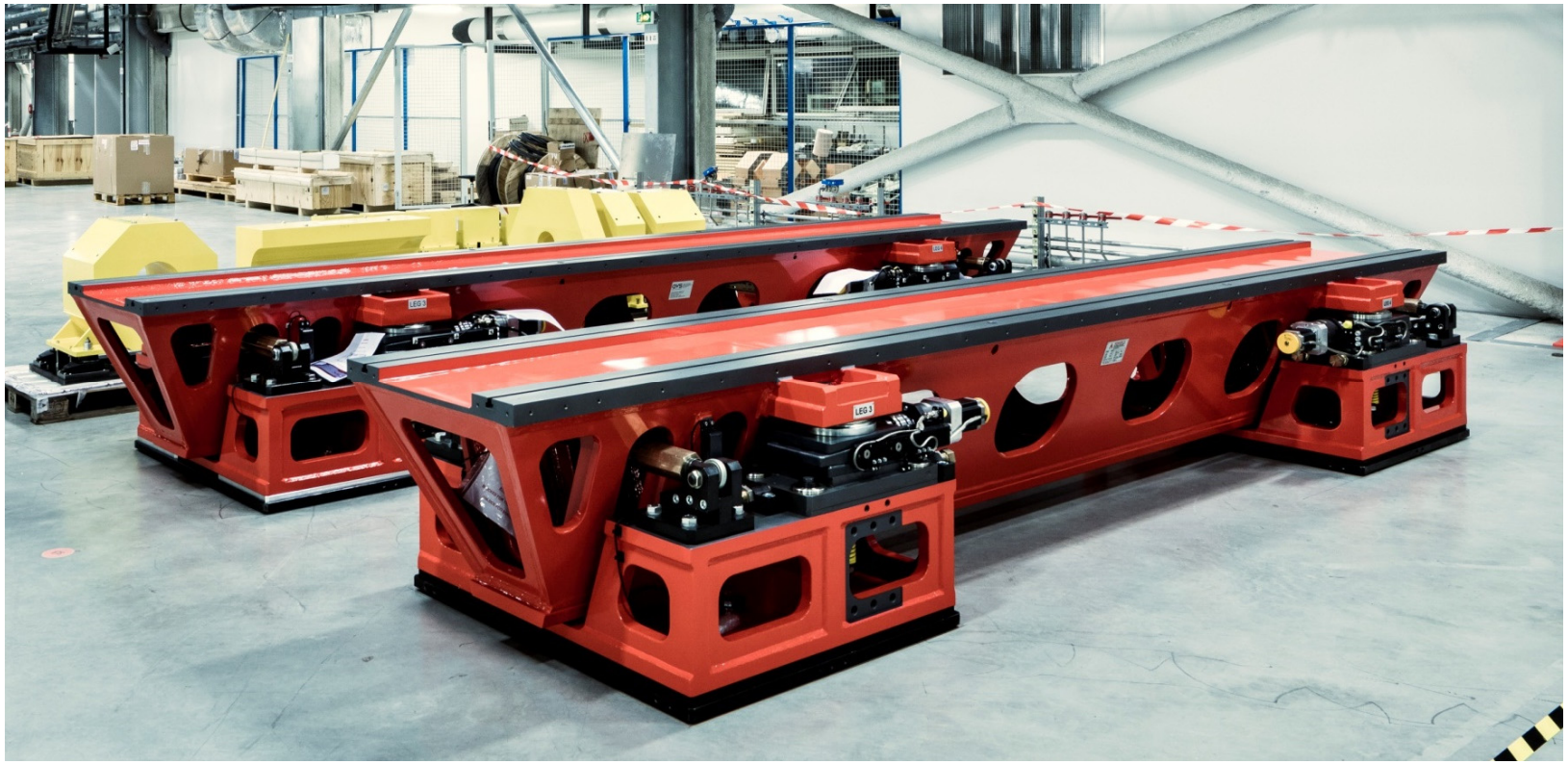
Most components >80% delivered

Critical path = Vacuum chambers

After June 2018:

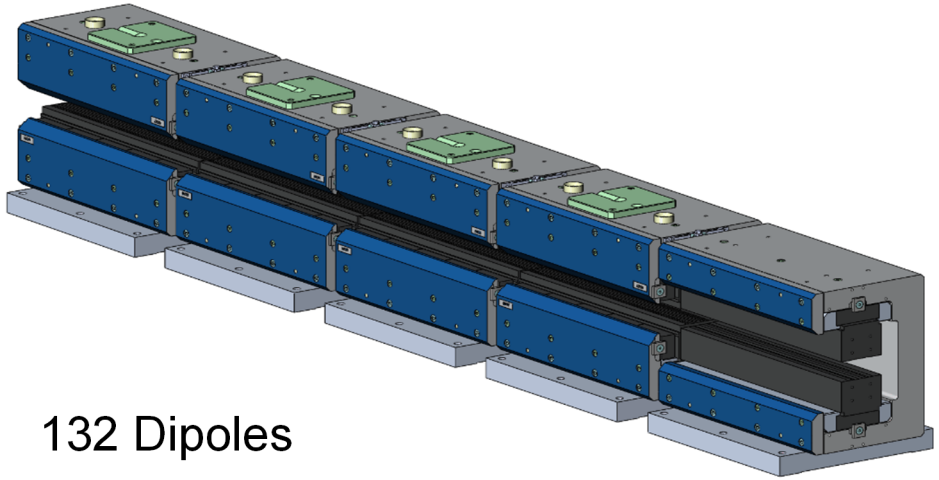
- DQ2 magnets
- Vacuum chambers

FEEDBACK FROM PRODUCTION OF GIRDERS

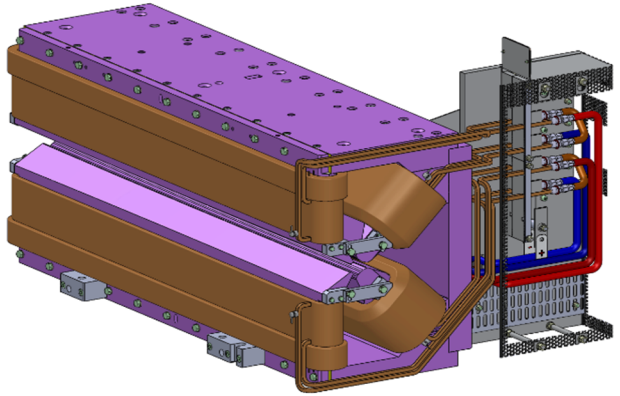


- 125 from the 131 ordered girders are now delivered, 2 years after signature of contracts.
- Flatness of top face: Mean: 50 µm; Best: 21 µm.
- Schedule and specifications respected without problems.

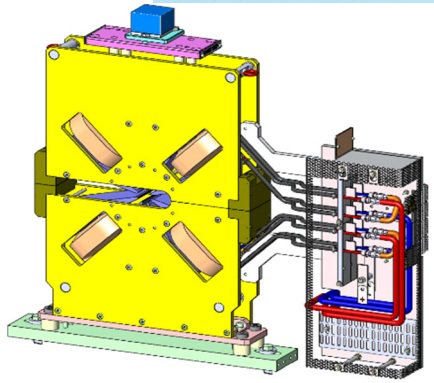
FEEDBACK FROM MANUFACTURE OF MAGNETS



132 Dipoles



100 Dipole-quadrupoles

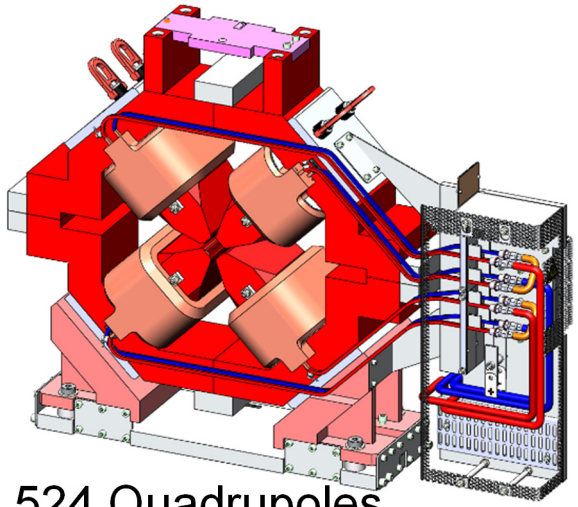


66 Octupoles

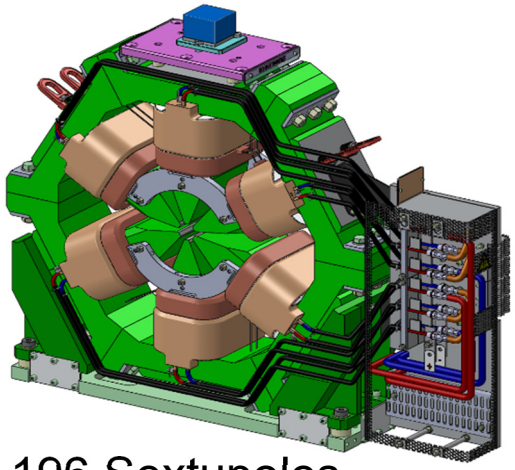
More than 1000 Magnets to procure in less than 3 years

June 2018: 100% of magnets delivered except Dipole-quadrupoles (DQ1: 80%; DQ2: 10%)

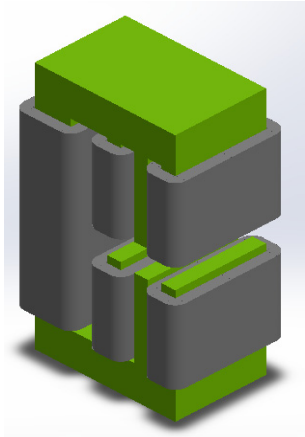
DQ2 not critical because installed between girders



524 Quadrupoles
(132 HG, 392 MG)



196 Sextupoles

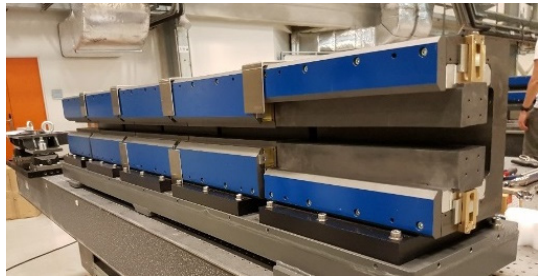


98 Correctors

Courtesy of C. Benabderrahmane

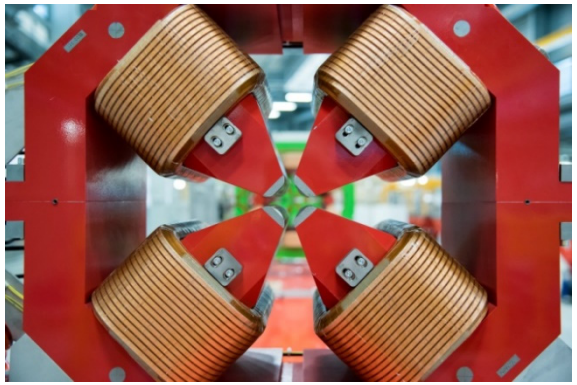
PRODUCTION OF MAGNETS

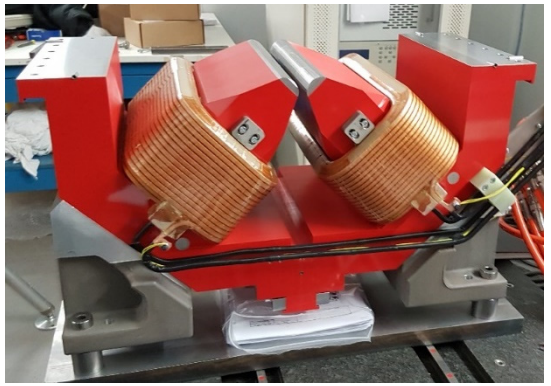
- **Dipoles (permanent magnets):** Designed and assembled by ESRF

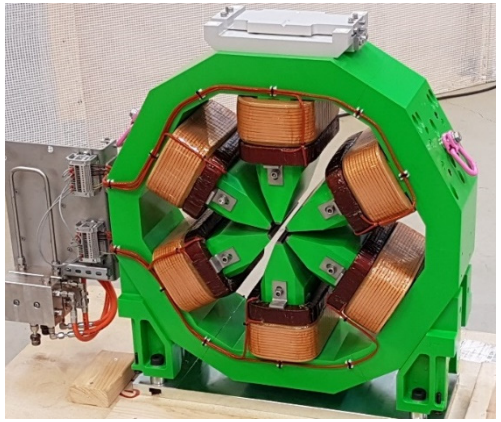


- **Quadrupoles, Sextupoles, Octupoles:** Concept by ESRF, Detailled design by manufacturers. Good results except fiducialisation.

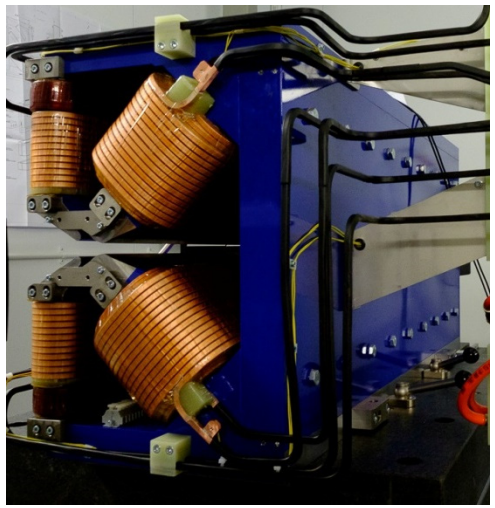
  Magnet opening – closing repeatability of poles positions: 5 to 10 µm

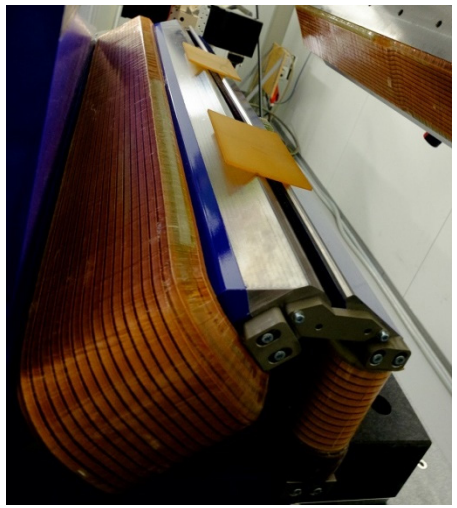


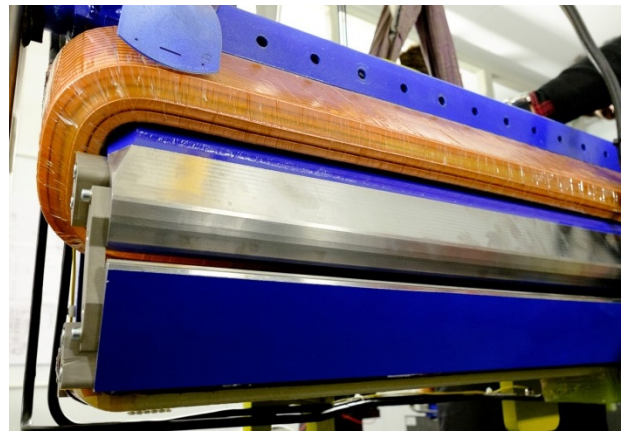




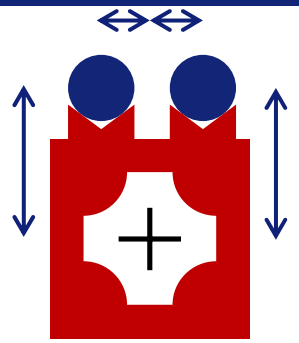
- **Dipoles-Quadrupoles:** Most delicate to design and manufacture. ESRF design.
  - Shape tolerance on curved pole profile and gap regularity (100 microns) => required optimised machining process.
  - Open structure => Gap variation when powered must be mastered.





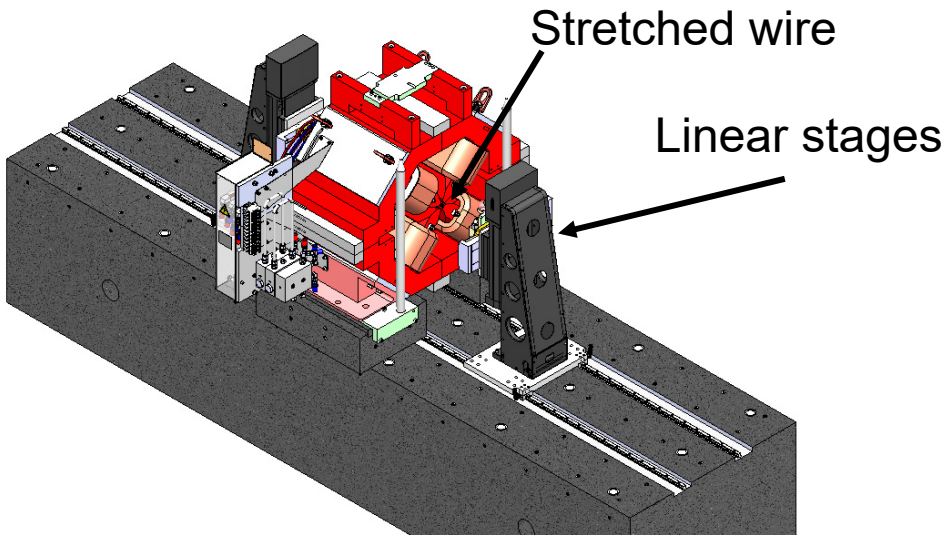


Fiducialization = Measure position of magnets fiducial monuments wrt magnetic center



Accurate fiducialization is crucial to reach the specified magnets position accuracy (i.e. 50 to 100 µm depending on magnet and axis)

- Magnetic center measured with a stretched wire
- Distances to fiducial monuments measured by laser tracker



Fiducialization initially planned by magnets suppliers

=> error up to 200 µm

Finally done at ESRF => uncertainty reduced to 22 µm

800 magnets fiducialized at ESRF from 09-2017 to 08-2018

Additional manpower required but did not delay the assembly schedule.

FEEDBACK FROM MANUFACTURE: VACUUM CHAMBERS

- Stainless steel chambers: Stainless steel sheet folded then welded.

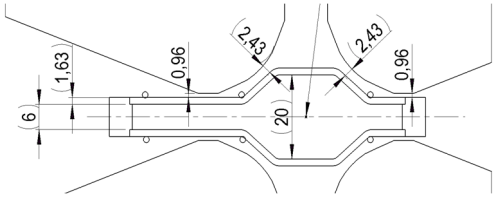
  Specified tolerances difficult to obtain (500µm shape accuracy over full length, flanges perpendicularity <1mrad)

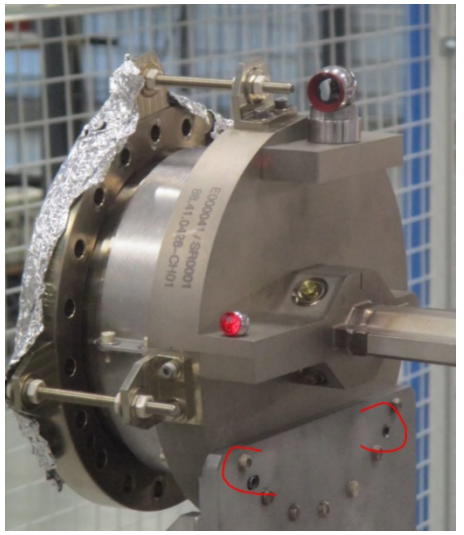
  Leaks on BPM buttons

⇒ Delays

⇒ On the critical path of the assembly process.

See Poster TUPH35 (P. Van Vaerenbergh).



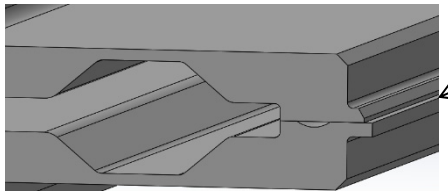


- Aluminium chambers: Two half shells machined from bulk material then welded together. Bi-metallic flanges (Alu alloy / 316LN).

  Very good manufacturing results.

  Chambers based on this technique integrating BPMs have been launched as an alternative to replace some of the stainless steel chambers.

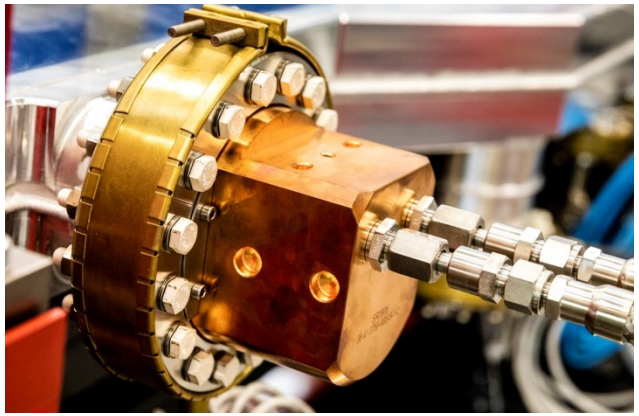
See Poster TUPH08 (F. Cianciosi).

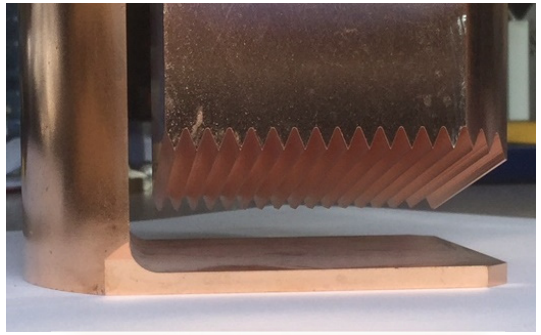


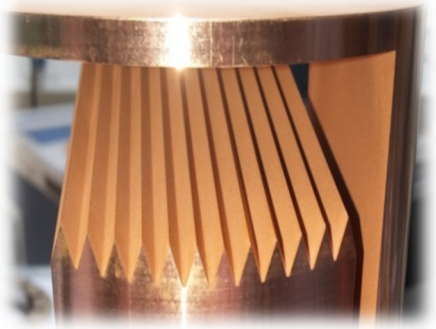
FEEDBACK FROM MANUFACTURE: ABSORBERS

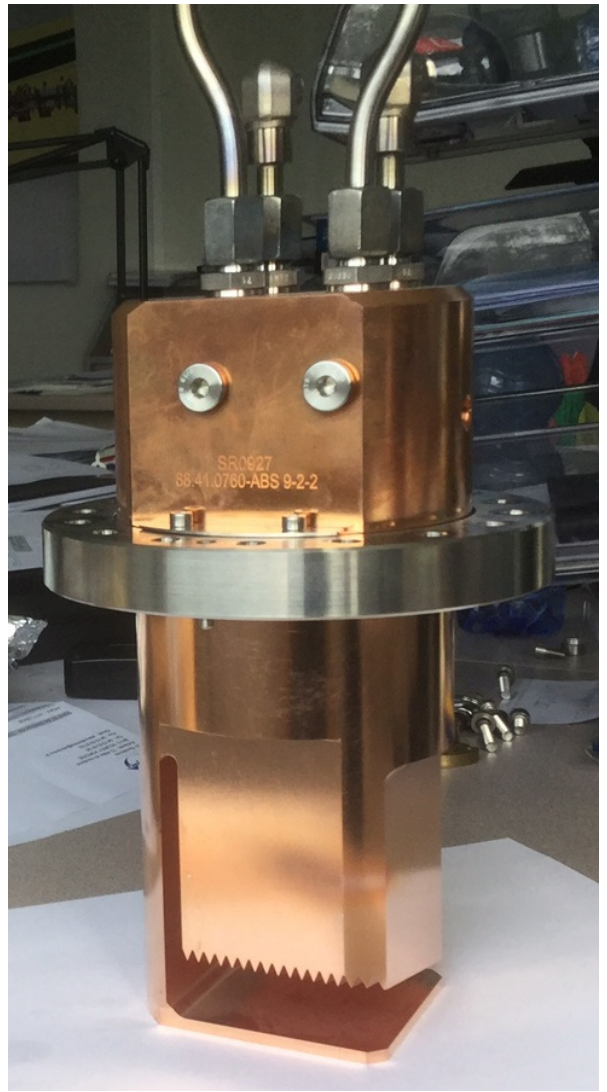
- 400 absorbers made of CuCr1Zr.
- CF knife edge machined in the absorber body

  => No braze, no weld. Simple manufacturing process.
- CuCr1Zr forged material purchased separately from ESRF specification in order to master the chemical content (outgasing) and hardness (> 120 Brinell for knife edge reliability)
- All std absorbers delivered. No vacuum tightness issue during assembly and tests.









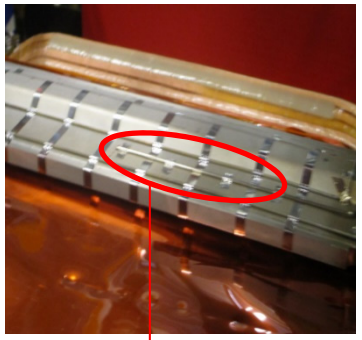
MOCK-UP OF A COMPLETE CELL

Mock-up = Assemble a complete cell using pre-series components February to September 2017

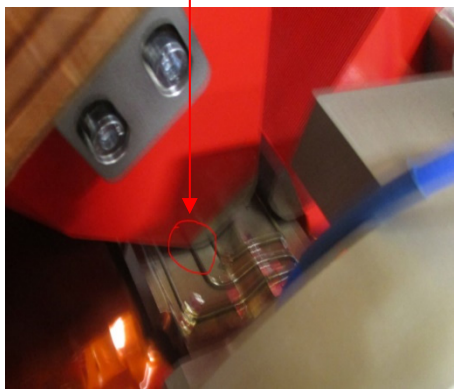
Objective 1: Check that all parts fit together. Apply corrections from pre-series to series.

No major issue discovered. Several small modifications & improvements on series parts.

Improvements implemented thanks to the mock-up have been crucial to ensure a smooth assembly process.



Temperature sensor

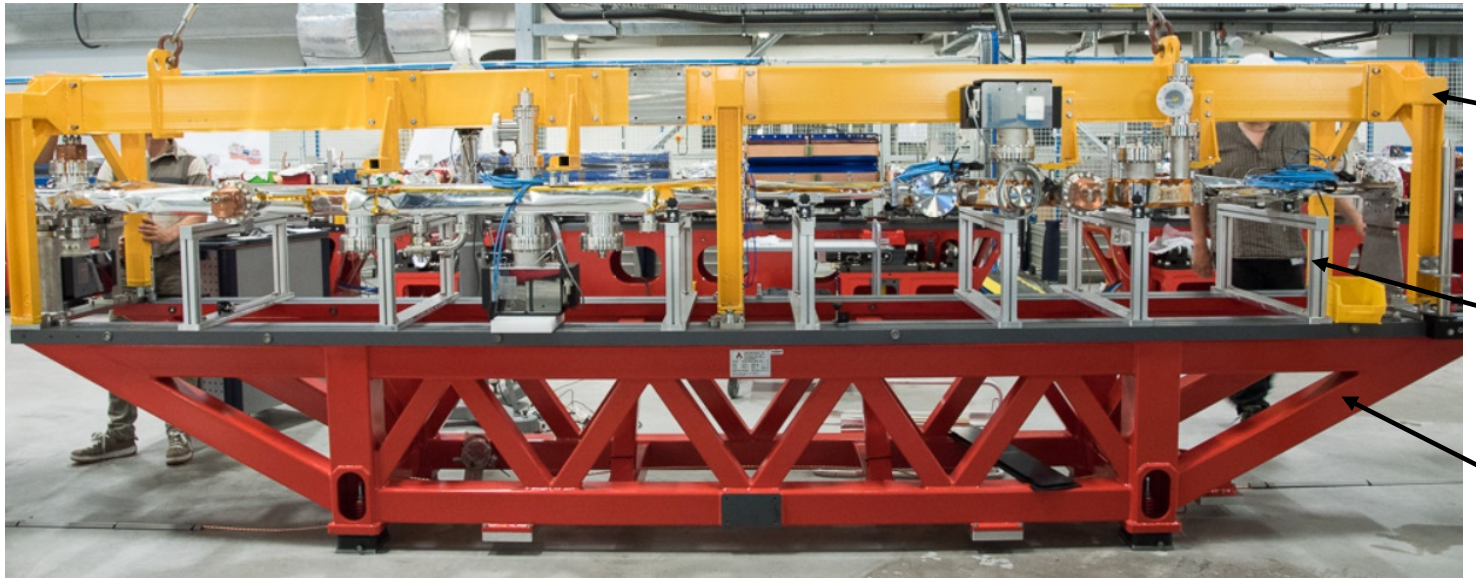


MOCK-UP OF A COMPLETE CELL

Objective 2:

Validate assembly tools.

Validate assembly and alignment process & procedures.



Vacuum section lifting tool

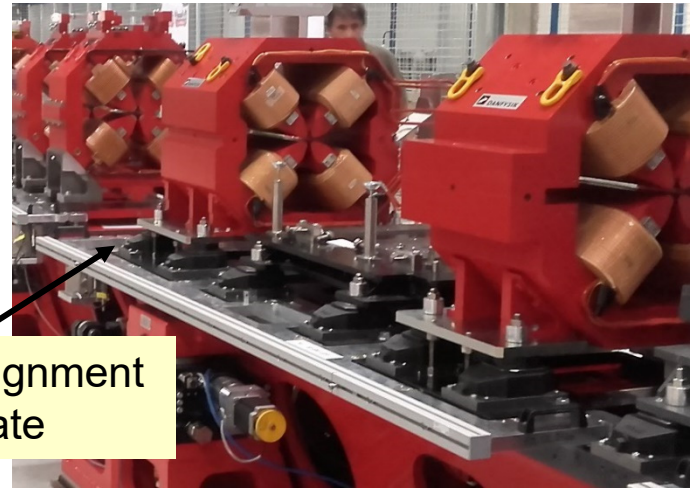
Vacuum section temporary supports

Vacuum section assembly table

Objective 3:

Validate design of pipes, cable access,…

Insertion of vacuum section in magnets section



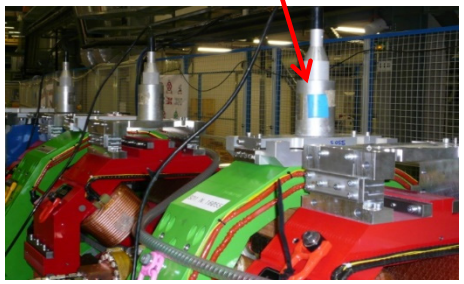
Magnets alignment template

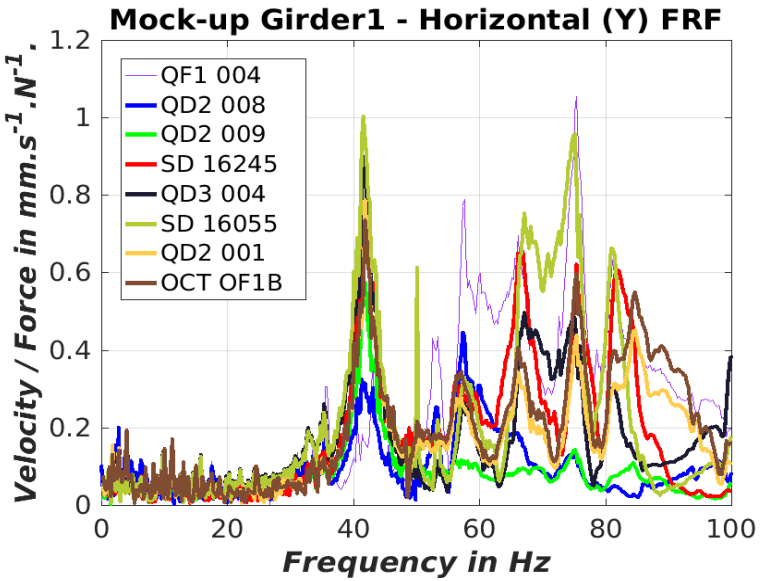
MOCK-UP OF A COMPLETE CELL – VIBRATION MEASUREMENTS

Objective 4 of the mock-up: Measure the vibration behavior of each girder loaded with its magnets.

=> Detailed measurements on each girder.

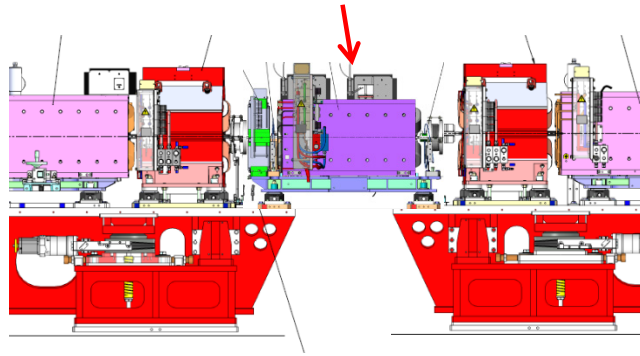
Geophone sensors on each magnet





	1st Global mode Horizontal transverse direction [Hz]	Broadband Amplification [1-100 Hz] (Magnets to Floor)
G1 Mock-up	42	1.1
G2 Mock-up	32	1.1 (DQ2: 1.2)
G3 Mock-up	35	1.1 (DQ2: 1.2)
G4 Mock-up	40	1.1

G2 and G3 are impacted by DQ2 magnet supported by these two girders



Courtesy of M. Lesourd

Results considered largely acceptable by our accelerator physicists

ASSEMBLY OF EQUIPPED GIRDERS

Objective: Prepare most of the 129 girders, fully equipped, aligned and tested before the shutdown

Time line: November 2017 to December 2018.

A dedicated building has been built to efficiently produce up to 4 girders per week

ESRF staff is complemented by a team of 12 technicians experienced in assembling accelerators

ASSEMBLY OF EQUIPPED GIRDERS

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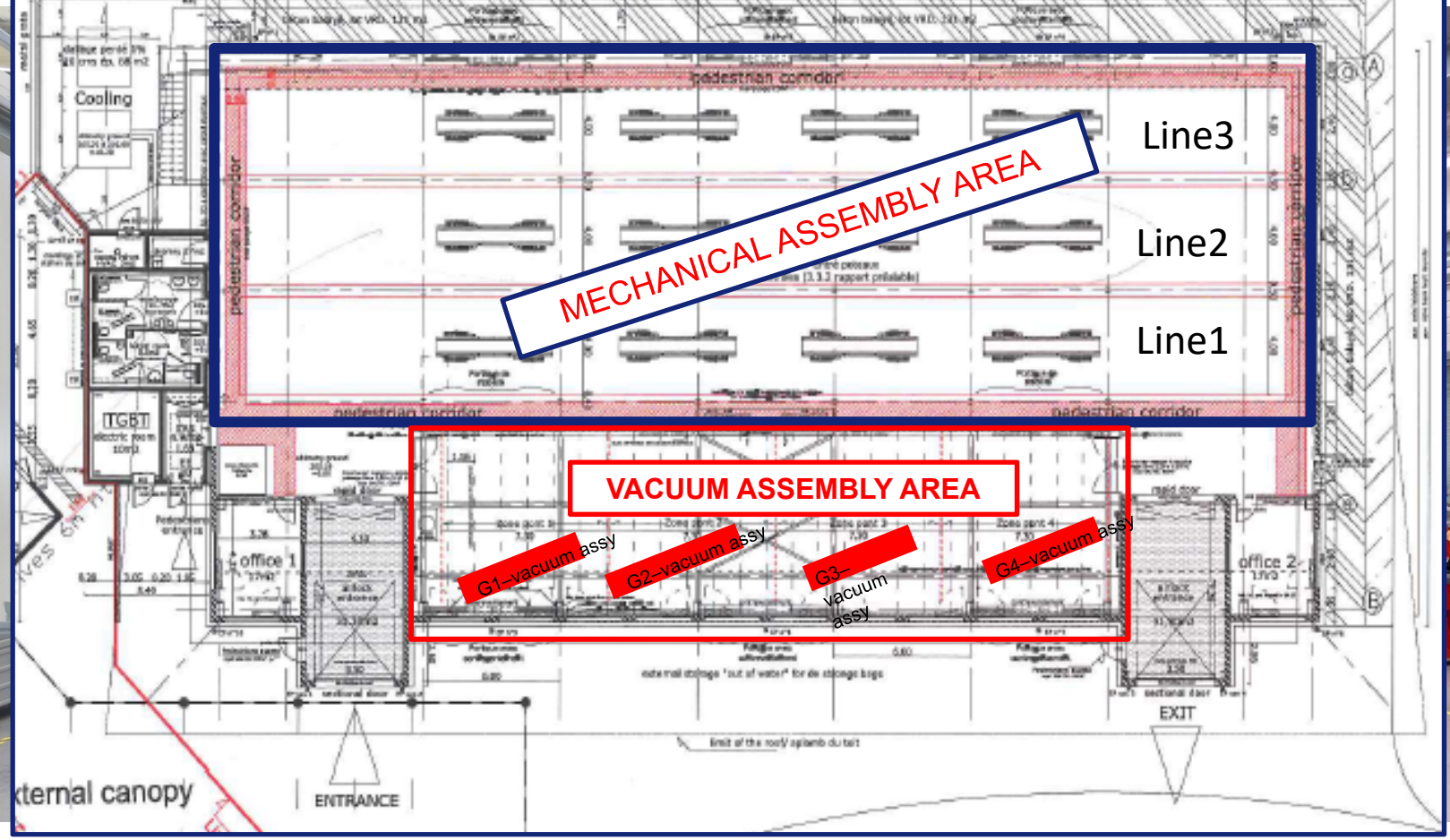
in assembling accelerators

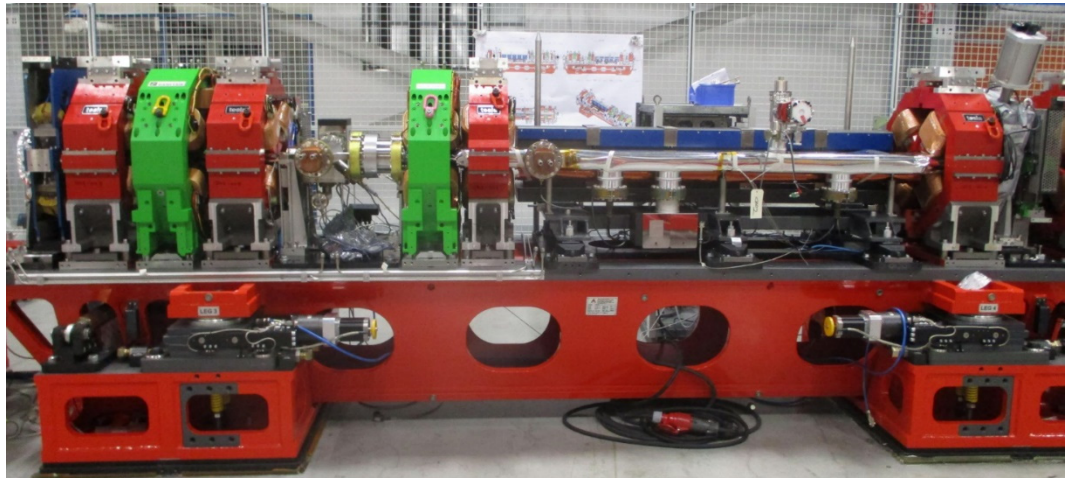


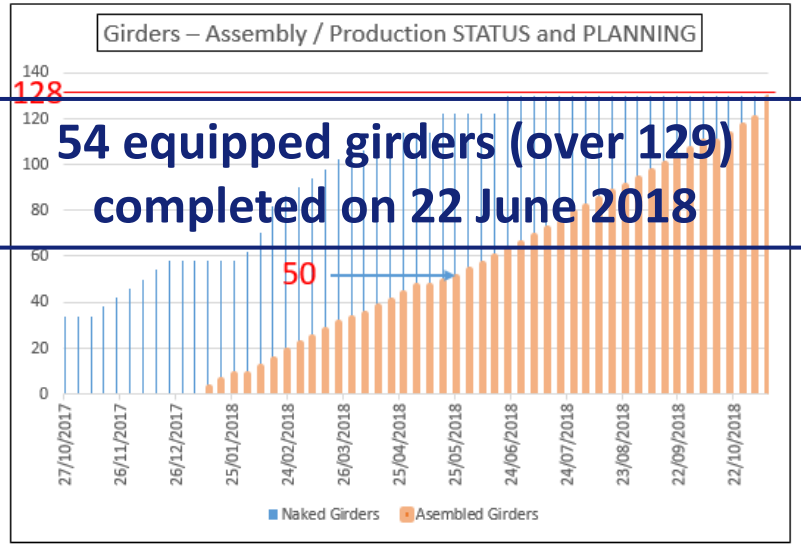
ASSEMBLY OF EQUIPPED GIRDERS

1-a) The vacuum chambers sections are assembled , baked out and tested separately in the Vacuum assembly area.

1-b) In the Mechanical area, magnets are installed and aligned on girders. The chambers section is then installed in the magnets.

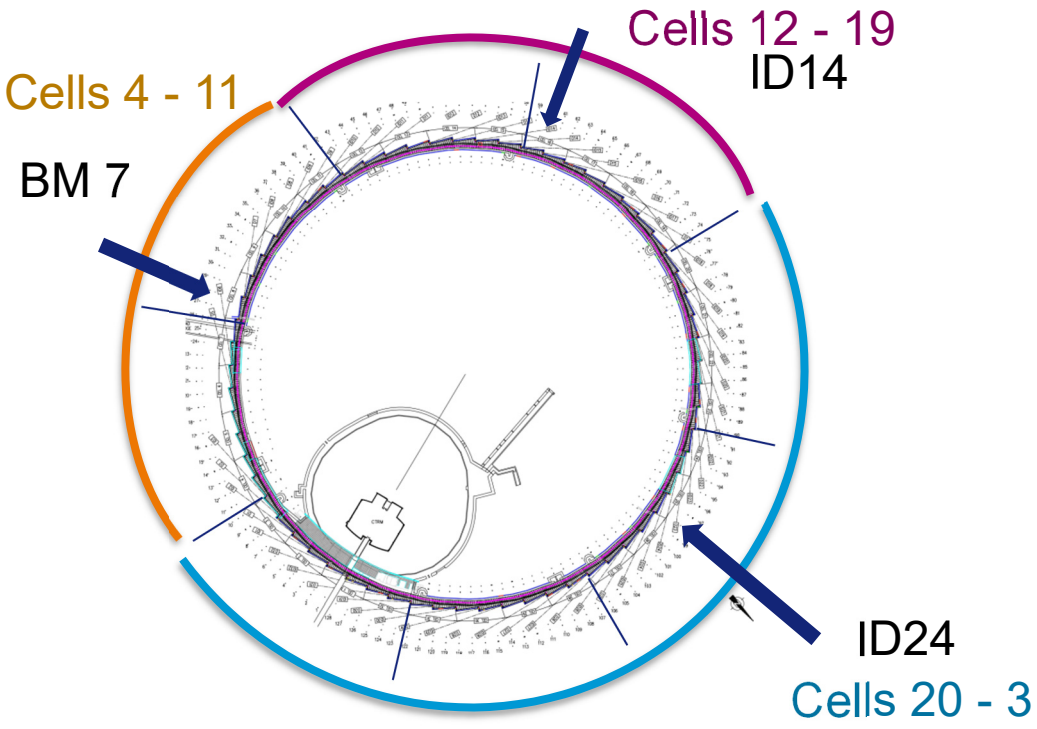
2) The magnets are closed and the alignment is finalised



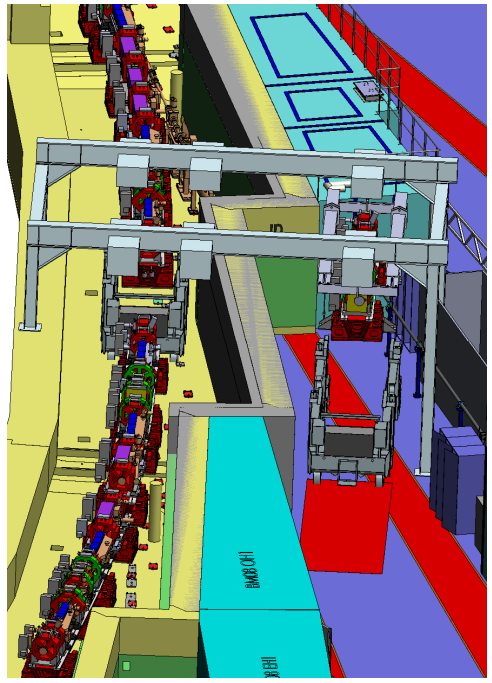


LOGISTICS & INSTALLATION

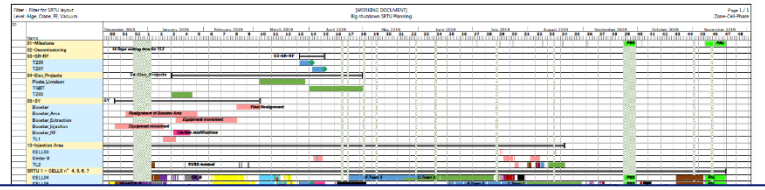
The equipped girders will be inserted in the ring tunnel at three entry points.



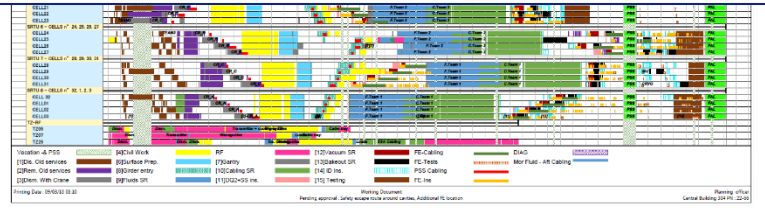
Gantry handling system at each girder entry point



Girder transport module to move girders inside the tunnel



Intense planning and coordination efforts to organize all tasks during installation phase inside the tunnel



Handling (12 tons each), transport and storage space (>1000m2 required!) for the 129 equipped girders
=> Strong logistics issues mostly solved

CONCLUSION

- Most components for the ESRF EBS storage ring are now delivered. The fabrication of some vacuum chambers takes longer than expected (difficulties to obtain the specified tolerances). This does not compromise the overall planning.
- The mock-up of a complete cell, built in 2017 was very useful to validate the design, solve a few minor issues and validate the assembly tools and assembly process.
- 54 of the 129 fully equipped, aligned and tested girders are now completed. The assembly is progressing at a rate of 3 girders per week.
- The project is progressing according to planning. The existing ring will be stopped on 10 December 2018 for 3 months dismantling and 9 months installation.

THANK YOU FOR YOUR ATTENTION !