The Extremely Brilliant Source project

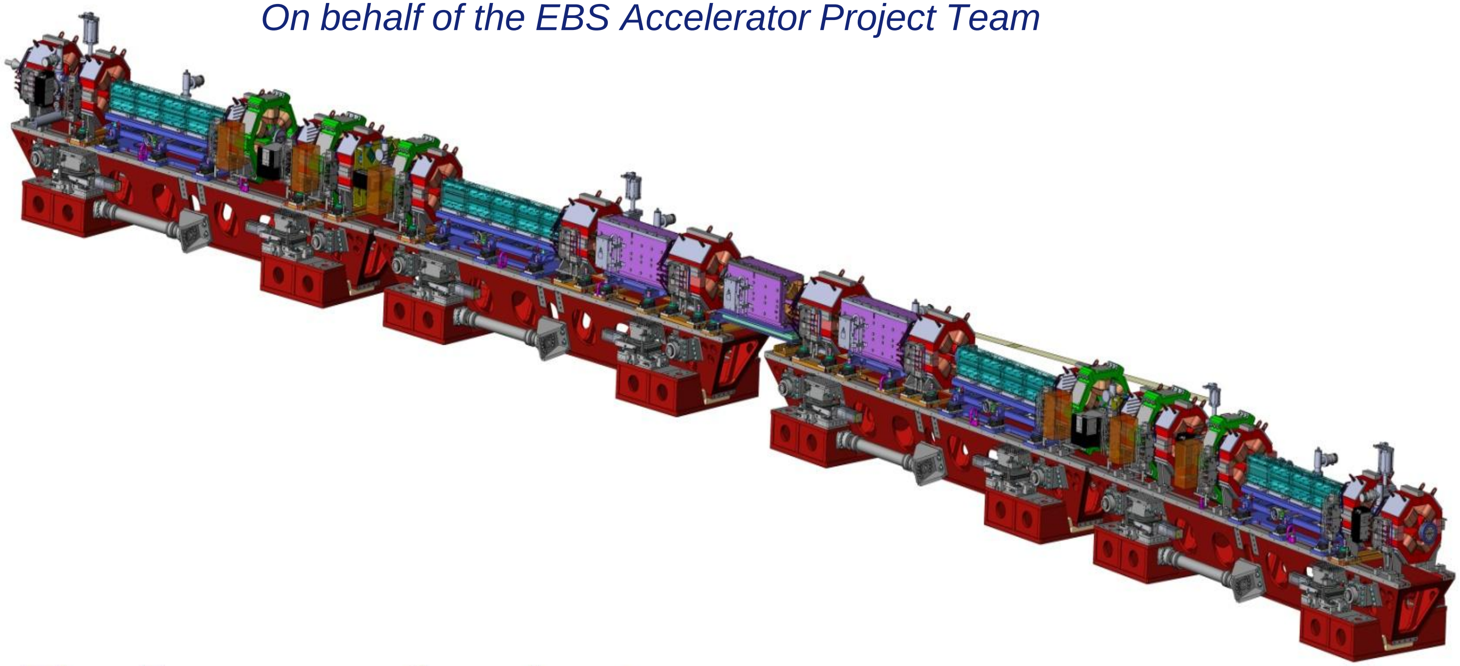
Project Overview

IWAA – October 04, 2016

R. Dimper

Technical Infrastructure Division

On behalf of the EBS Accelerator Project Team



ESRF | The European Synchrotron

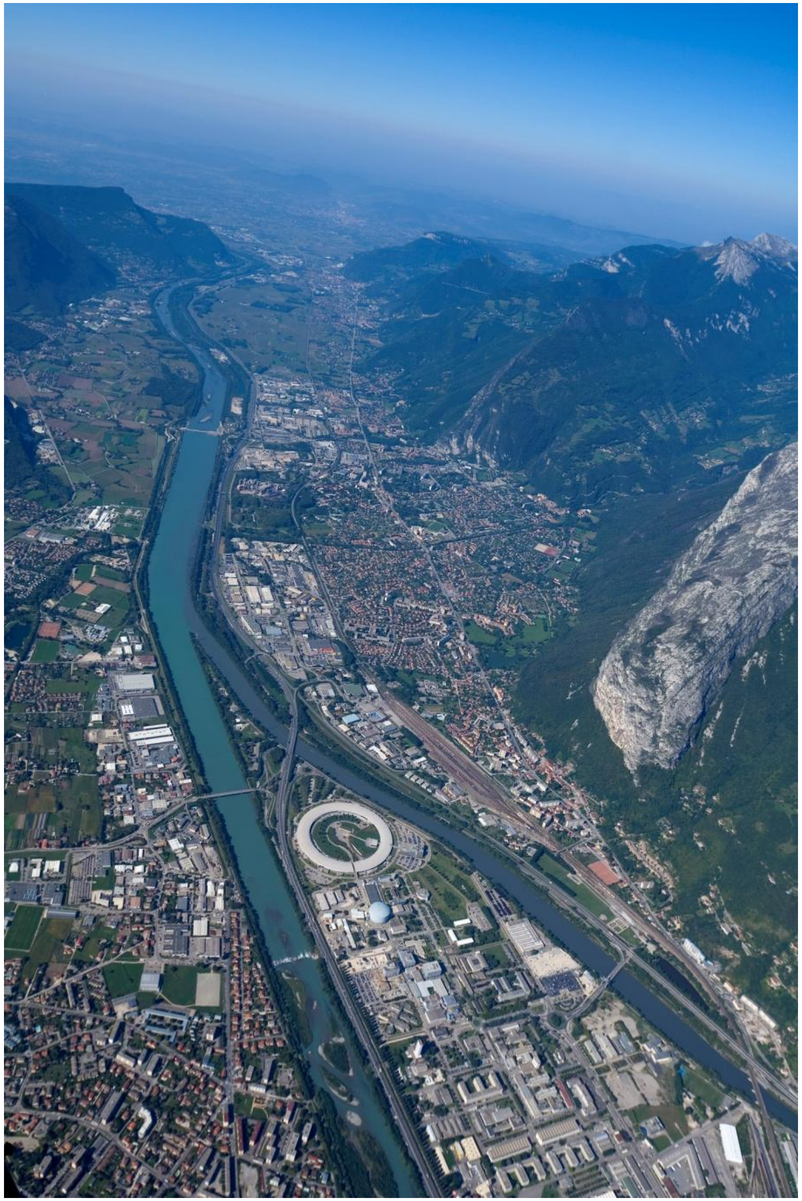
Acknowledgements

This presentation summarises the work of many ESRF colleagues.

The names of the main actors for each sub-project will appear on the slides.

I wish to acknowledge specifically the **ESRF Instrumentation Services and Development Division Engineering team and J-C. Biasci from the Accelerator and Sources Division** who prepared a lot of the slides.

Outline



- **ESRF-EBS Project**
  - Context
  - Project management
- **Main accelerator components**
  - Girders, magnets, vacuum chambers, absorbers, FE
- **From Assembly to Installation**
- Conclusion

ESRF EBS Project

ESRF – A model of international cooperation

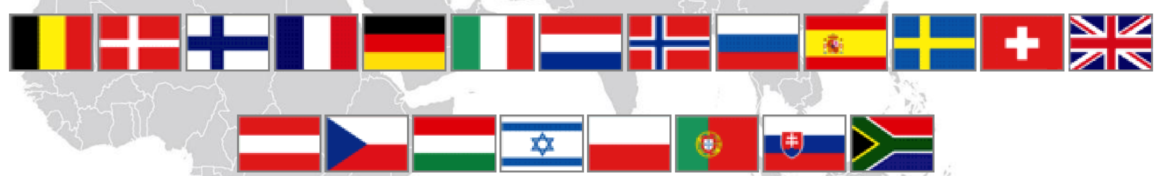
13 Member states:

France	27,5 %
Germany	24 %
Italy	13,2 %
United Kingdom	10,5 %
Russia	6 %
Benesync (Belgium, The Netherlands)	5,8 %
Nordsync (Denmark, Finland, Norway, Sweden)	5 %
Spain	4 %
Switzerland	4 %

8 Associate countries:

Israel	1,5 %
Austria	1,3 %
Centralsync (Czech Republic, Hungary, Slovakia)	1,05%
Poland	1 %
Portugal	1 %
South Africa	0,3 %

Contribution to the budget in %



21 partner nations
Annual budget: **100 million euros**
Staff: **630 of 40 different nationalities**
Legal status: **Private civil company subject to French law**

A unique site for Research and Innovation

Global scientific excellence

The ESRF produces the most intense synchrotron generated light in the world

ESRF - France

A research facility unique worldwide

- ✓ **6 500 scientific visitors** every year
- ✓ **2 000 proposals** per year: **900 accepted**, 1 550 experimental sessions
- ✓ **30%** of the research involves **industrial developments**

An ambitious and innovative project: The Upgrade Programme

2009–2015 Upgrade PHASE I – 160 M€

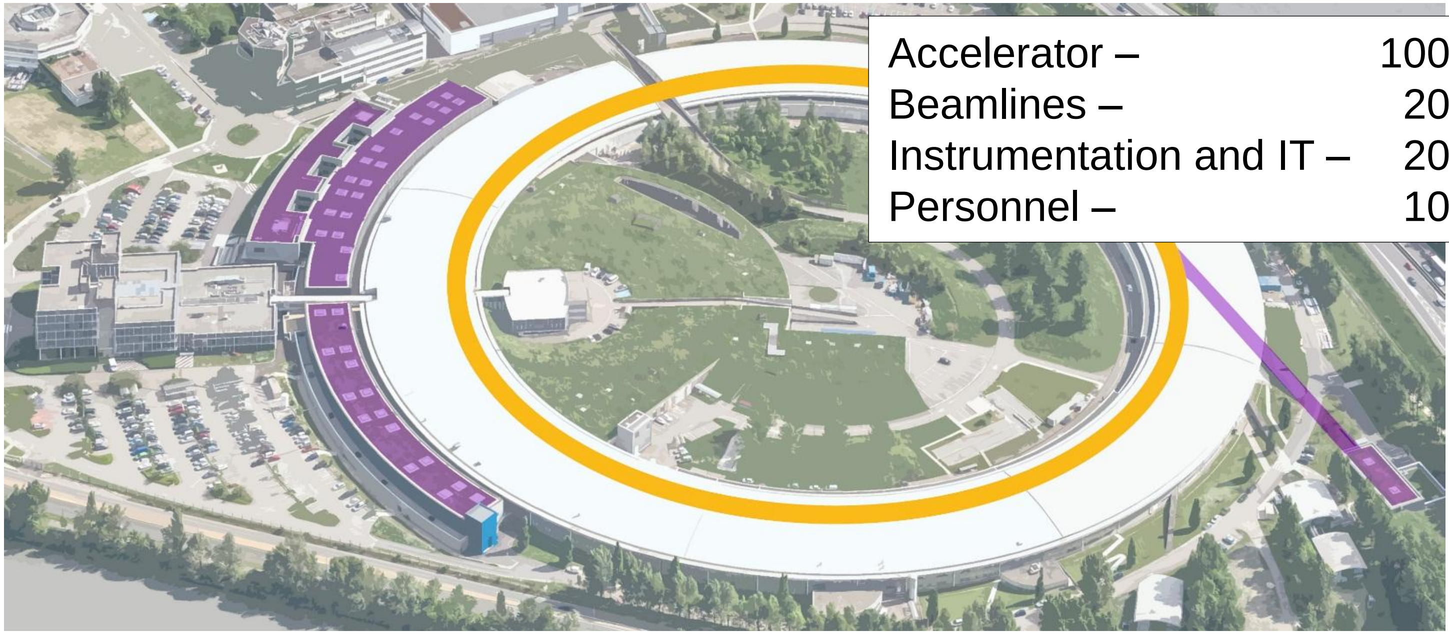
In time and within budget

- Construction of 19 new-generation experimental stations to explore the nanoworld
- Creation of a new ultra-stable experimental hall
- Improvement and refurbishment of most of the cutting-edge scientific equipment and accelerator infrastructure

2015–2022 ESRF-EBS – 150 M€

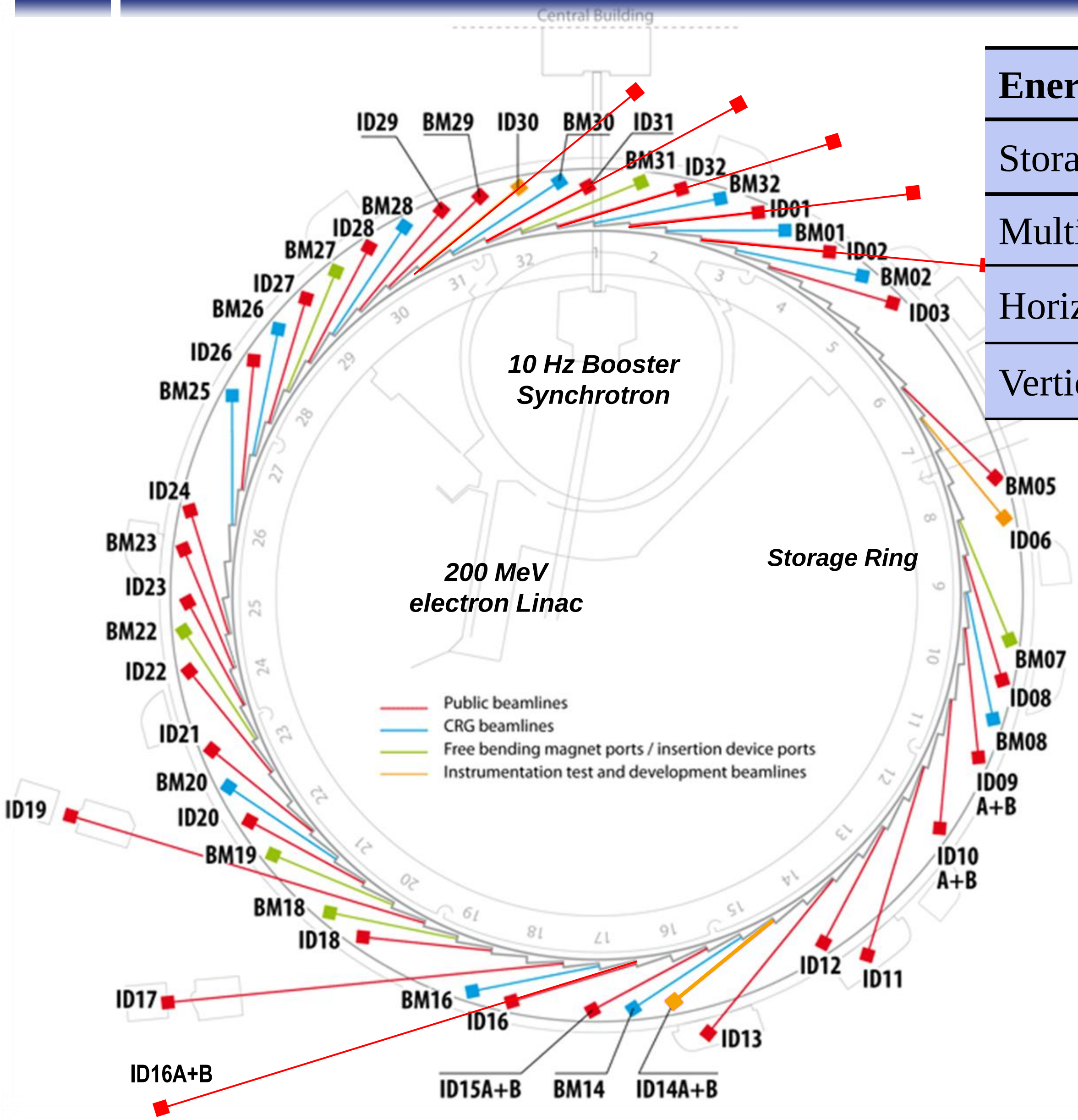
Launched in June 2015

- Construction of a new storage ring, inside the existing structure, with performance increased by a factor of 100
- Construction of new state-of-the-art beamlines
- Ambitious instrumentation programme (optics, high-performance detectors)
- Intensified big data strategy



Accelerator –	100M€
Beamlines –	20M€
Instrumentation and IT –	20M€
Personnel –	10M€

The ESRF



Energy	6.04	GeV
Storage ring circumference	844	m
Multibunch current	200	mA
Horizontal emittance	4000	pm.rad
Vertical emittance	4	pm.rad

ESRF operates 43 Beamlines

(including 13 Bending Magnet BLs with teams from Member States)

The EBS characteristics

The Extremely Brilliant Source Project aims to:

- Substantially decrease the store ring equilibrium horizontal emittance
- Increase the source brilliance
- Increase coherent fraction of the beam
- Must fit in the same tunnel: as much as possible same circumference
- IDs at same locations: keep beamlines where they are
- Re-use injector complex

e^- beam properties

	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 a factor of 29

New lattice vs present ESRF lattice

➢ **Present ESRF lattice**

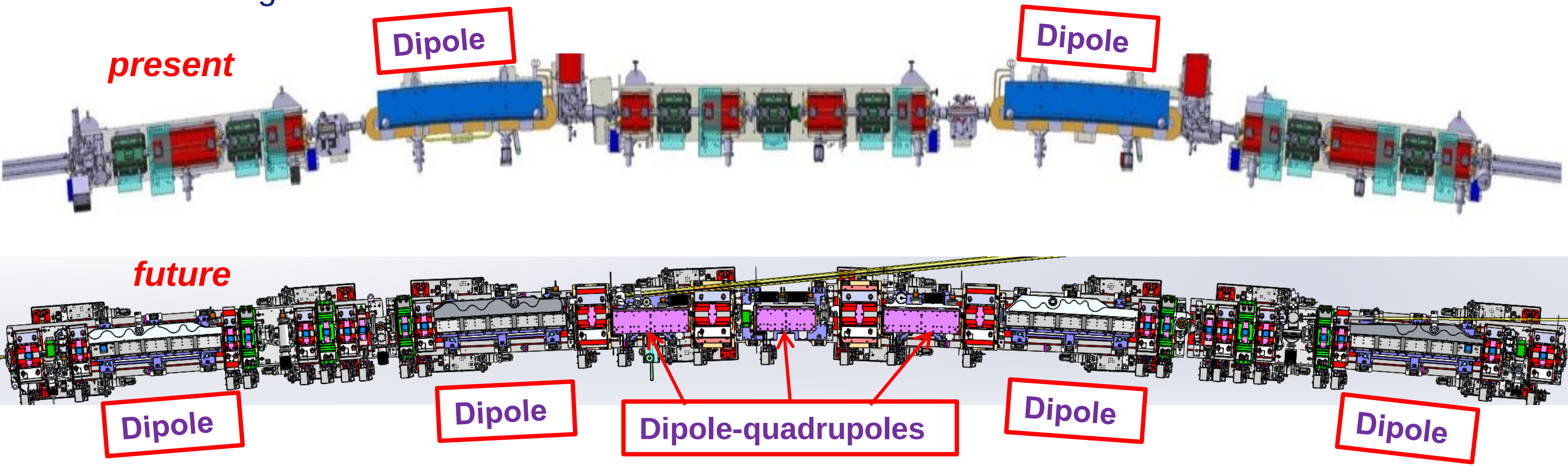
Double Bend Achromat = (2 dipoles + 15 quad. sext.) per cell

ID length = 5 m (standard) / 6m / 7m

➢ **Future EBS lattice**

Hybrid 7 Bend Achromat = (4 dipoles + 3 dipole-quad + 24 quad., sext., oct.) per cell

ID length = 5 m



31 magnets per cell instead of currently 17!

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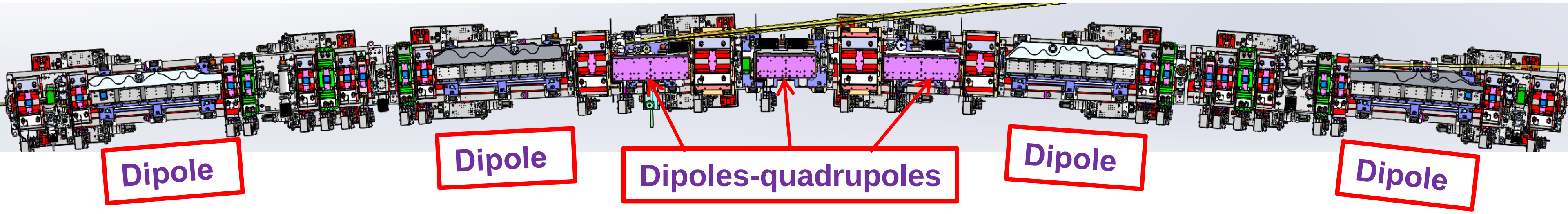
EBS lattice – engineering challenges and constraints

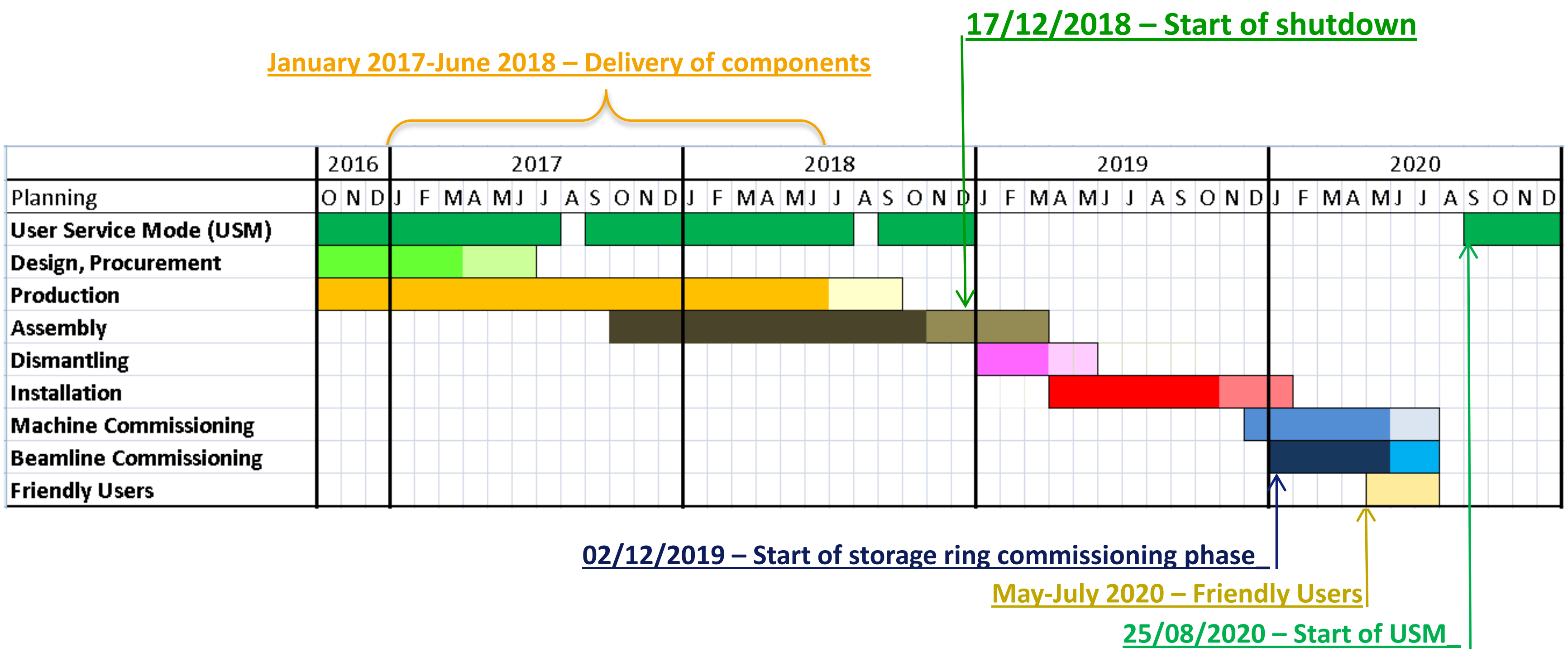
EBS



Main engineering challenges:

- Fit in the same tunnel. Same circumference.
- Insertion devices at the same locations: keep beamlines where they are!
- Little space between magnets, i.e. 3.4 m instead of 8 m today!!
- High precision & high stability positioning requirements
- Little time for the project and in parallel to the normal operation of the facility

EBS time line (2016-2020)



2018 – a normal year for Machine Operation

17 December 2018	Beginning of the long shutdown
03 January 2019	Dismantling starts
02 December 2019	Commissioning starts
09 January 2020	Beam available for beamline and machine commissioning
25 August 2020	Back to USM

EBS Project Structure

Accelerator Project Office
Accelerator Project Support

WP-0 **Management** P. Mackrill	WP-5 * **Radio Frequency** J. Jacob	WP-10 **Vacuum** M. Hahn
WP-1 **Beam Dynamics** L. Farvacque	WP-6 **Control System** J.-M. Chaize	WP-11 **Buildings & Infrastructure** T. Marchial
WP-2 **Magnets** G. LeBec	WP-7 **Diagnostics & Feedbacks** K. Scheidt	WP-12 **Reliability & Operation** L. Hardy
WP-3 **Accelerator Engineering** J.-C. Biasci	WP-8 **Photon Source** J. Chavanne	WP-13 **Radiation Safety** P. Berkvens
WP-4 * **Power Supply & Elec. Engineering** J.-F. Bouteille	WP-9 * **Injector Upgrade** T. Perron	

* WP 4, 5 and 9 have both Phase I and Phase II deliverables (and budgets).

Accelerator Project Office

Accelerator Project Office

Project Leader
P. Raimondi

Accelerator Physicist
D. Einfeld

Execution Manager
P. Mackrill

Technical Manager
J.-C. Biasci

Infra. Coordinator
R. Dimper

Accelerator Project Support

Planning Officer
Q. Brioulet

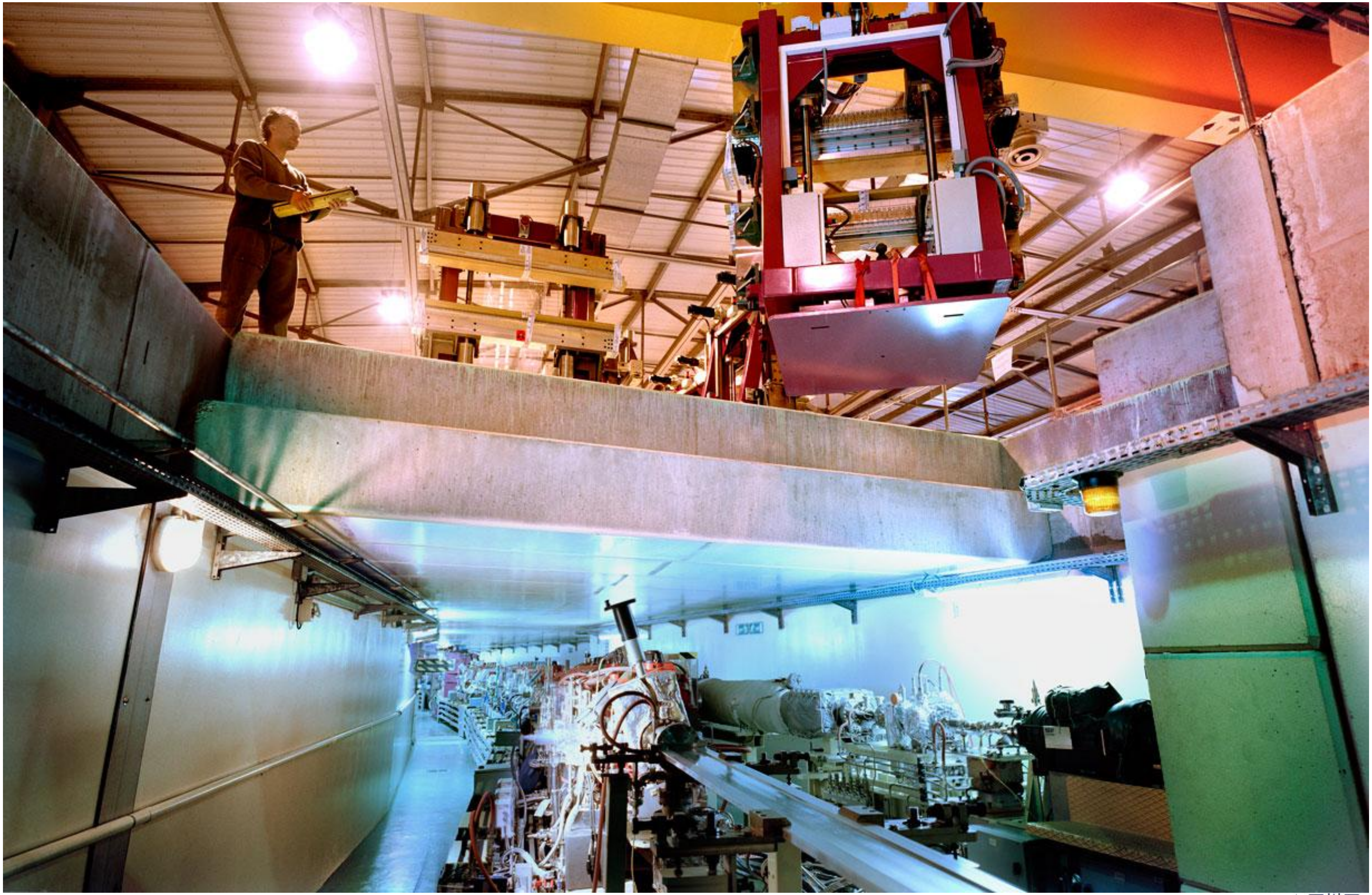
Installation Officer
P. Renaud

Project Assistant
S. Cardot

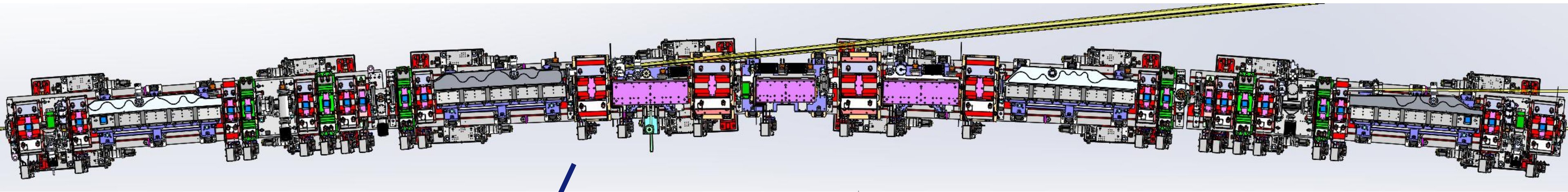
Admin + Finance Assistant
A. Dely

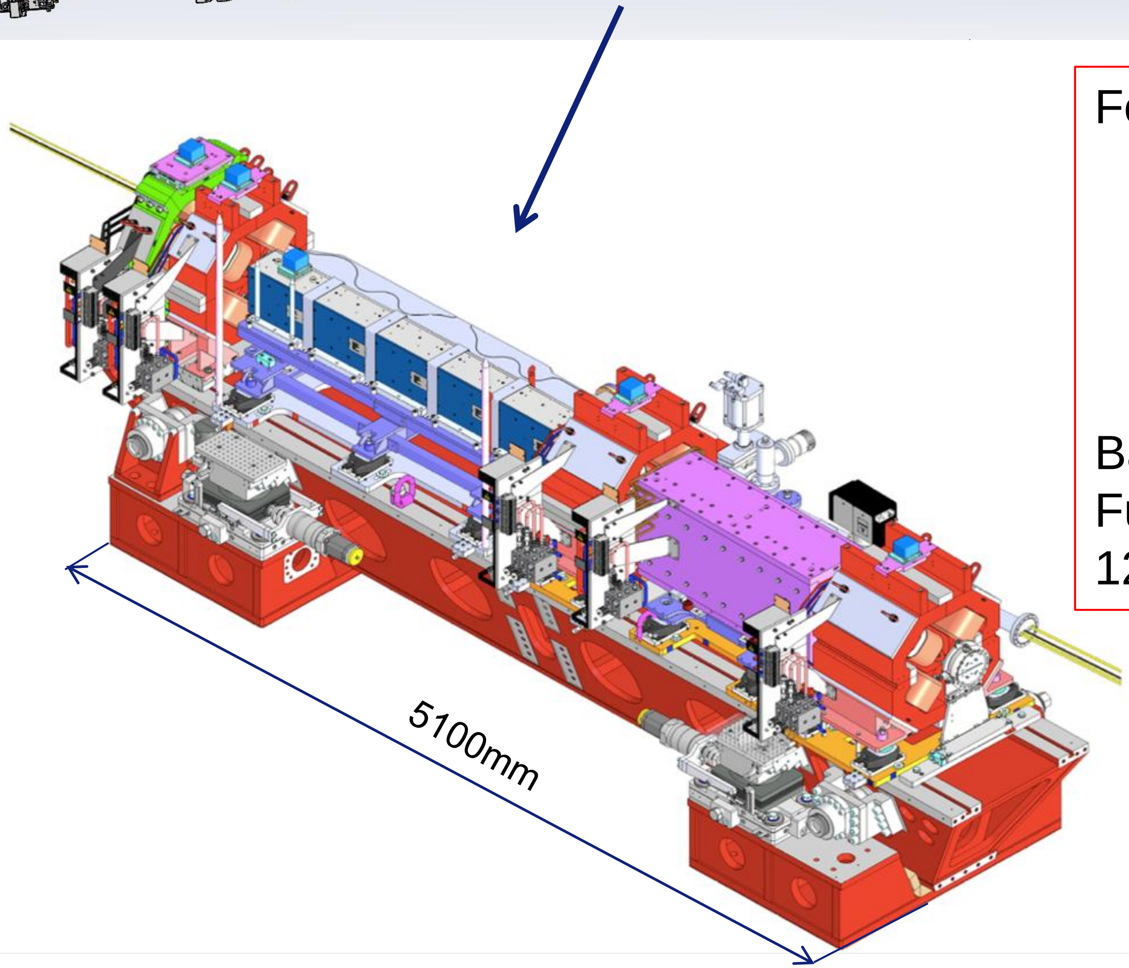
Docu + Comm Assistant
A. Joly

Main accelerator components



Girders





Four girders per cell to install:

- Magnet supports
- Magnets
- Vacuum equipment
- Diagnostics

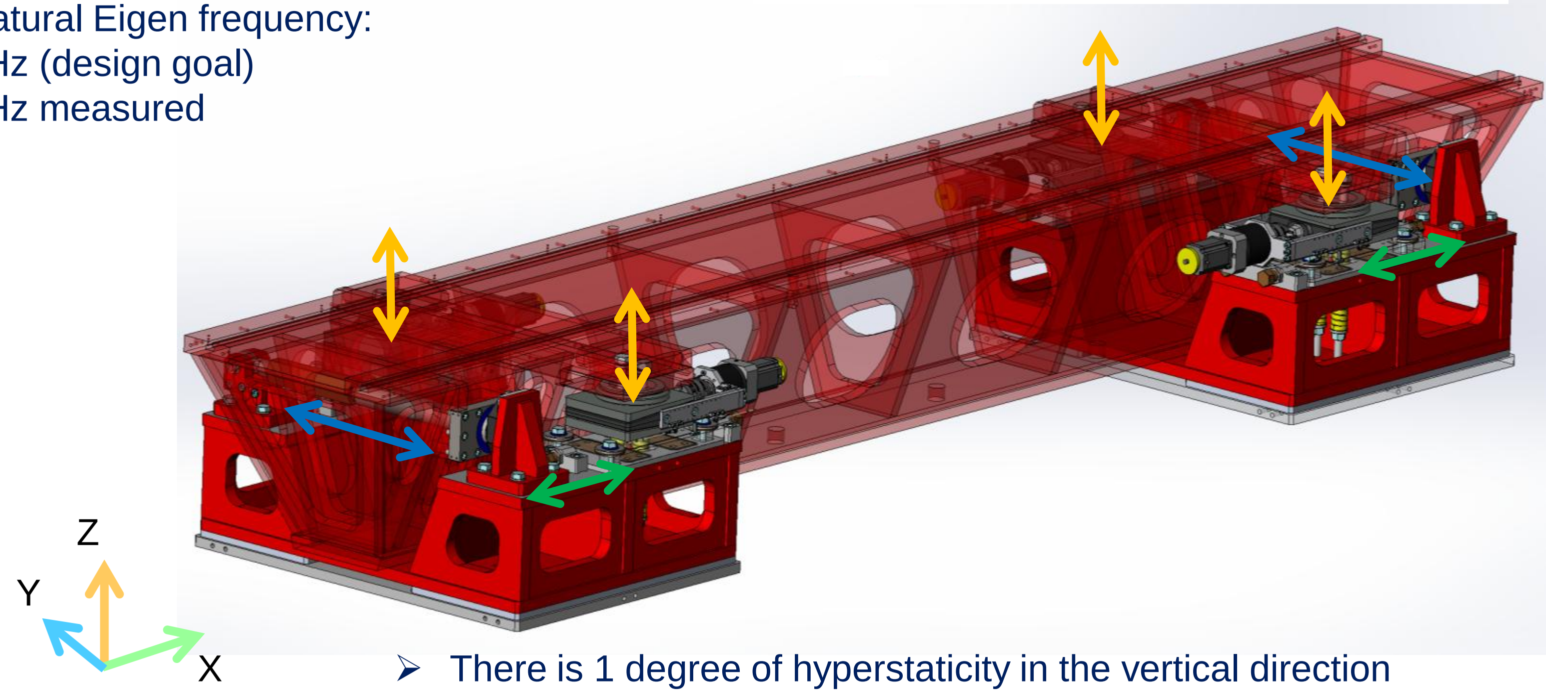
Bare girder weight: ~6t
Fully equipped girder: ~12-13t
128 girders in total

Girder design

- ➢ Girder supported by 4 adjustable Z feet made of motorised wedges
- ➢ Y adjustment by 2 manual jacks pushing the girder

- **Motorized Z adjustment** resolution 5μm
- **Manual Y adjustment** resolution 5μm
- 1st natural Eigen frequency:
  - 50 Hz (design goal)
  - 49 Hz measured

Z feet optimised for maximum stiffness



- ➢ There is 1 degree of hyperstaticity in the vertical direction managed by the girder "flexibility" for small displacements.

Courtesy: Filippo Cianciosi

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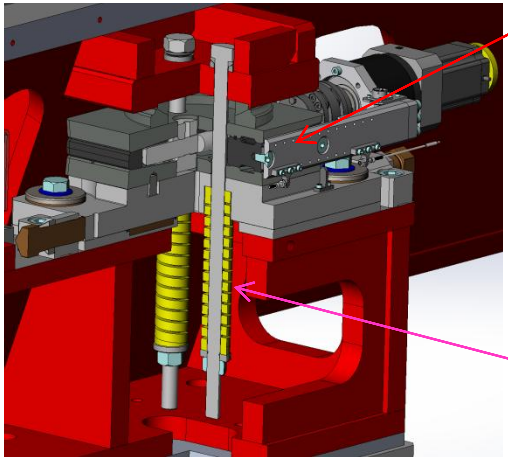
Girder design

- **Vertical movement**



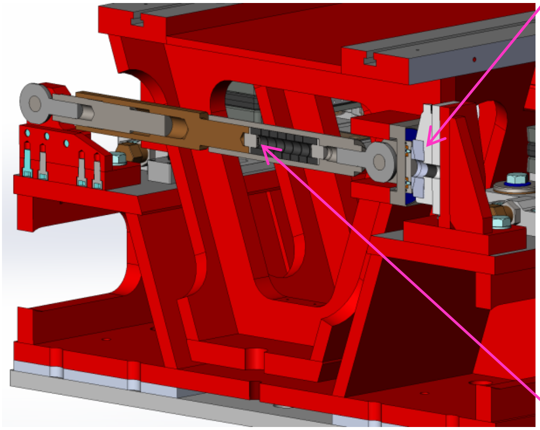
Airloc wedge 414-KSKC (modified for motorization)

Preloaded springs (2x0.7t)

Z movement:

- Accuracy: 10.8µm
- Repeatability: 3.3µm
- Increment: 0.3µm

- **Horizontal movement**



Wedge Nivell DK2

"push back" spring (3.5t)

Horizontal jacks have 3 functions:

- horizontal adjustment (+/- 3.5mm continuous, +/- 15mm global)
- guiding the vertical movement (ensuring no lateral diplacement during the vertical adjustement)
- improoving the stiffness of the girder

Courtesy: Filippo Cianciosi

Prototype girder

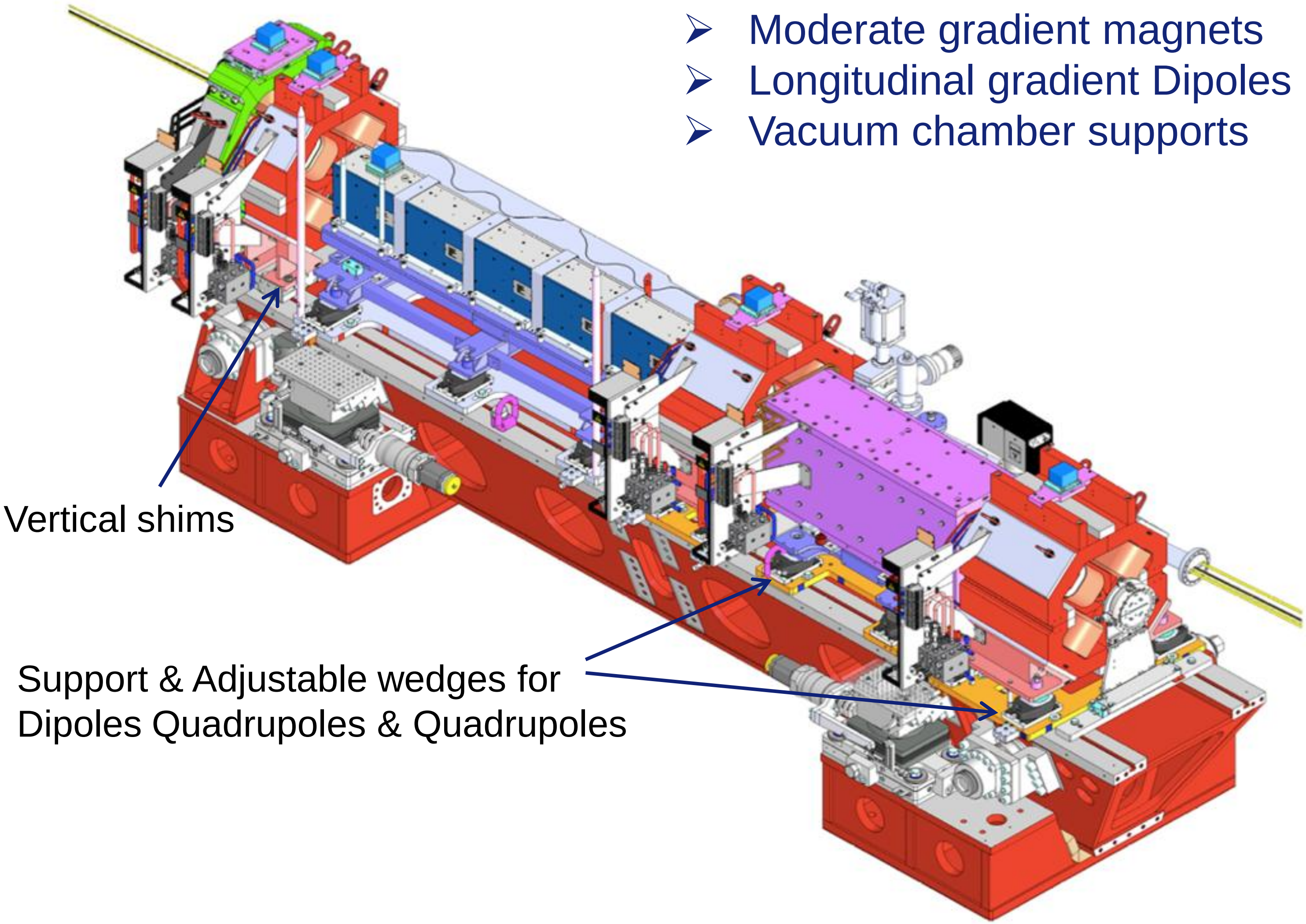
Prototype girder equipped with dummy magnets delivered in May 2015 → extensive tests:

- Validation of girder alignment motion systems
- Measurement of natural frequencies and vibration modes of the equipped girder
- Validation of magnets alignment systems (real magnet supports used)
- Reliability tests of motorized motion systems

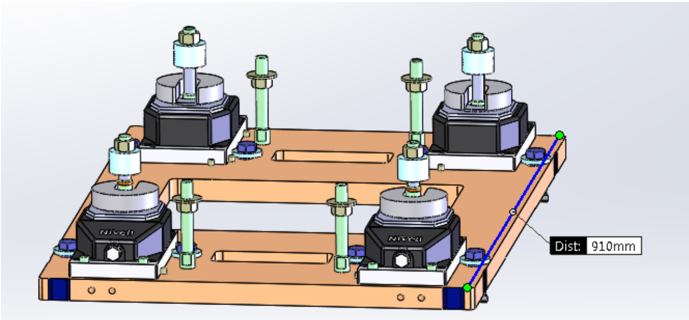
F Cianciosi, T Brochard, M Lesourd, D Martin

Supports

- Moderate gradient magnets
- Longitudinal gradient Dipoles
- Vacuum chamber supports

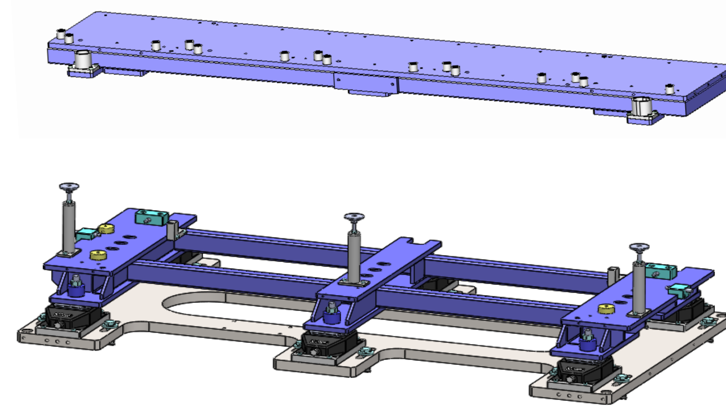


QF6/QF8- DQ SUPPORTS – DL SUPPORTS



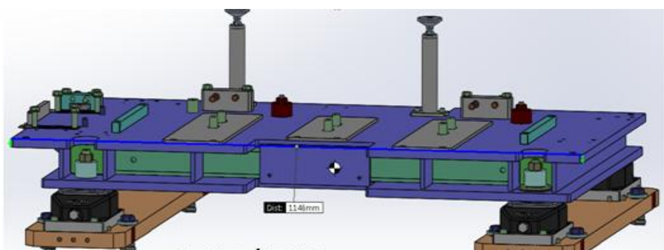
QF6/QF8 supports

Dipole support assembly



Top Frame

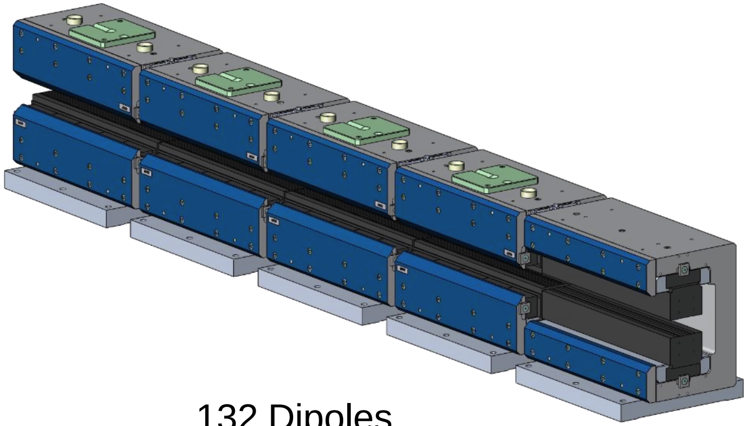
Base support



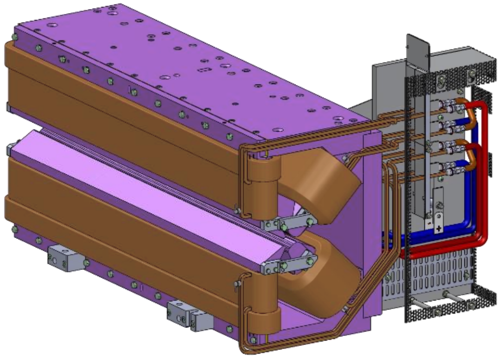
200mm

Courtesy: L Eybert

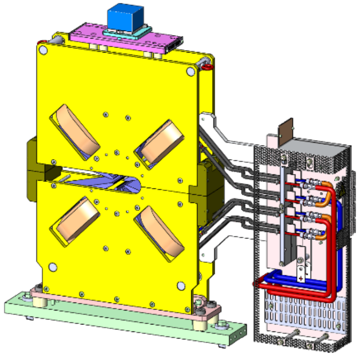
Magnets



132 Dipoles

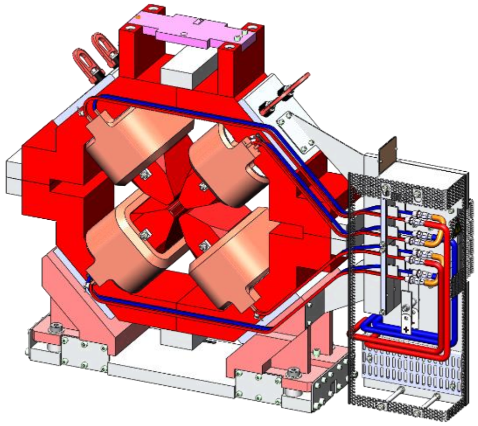


100 Dipole-quadrupoles

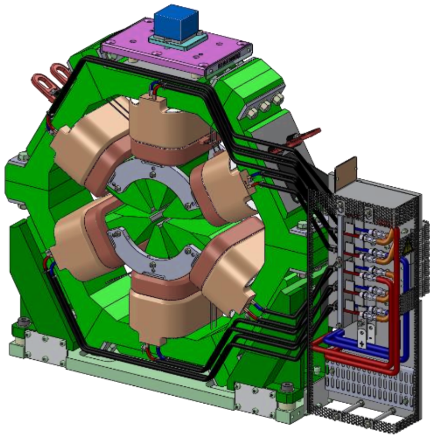


66 Octupoles

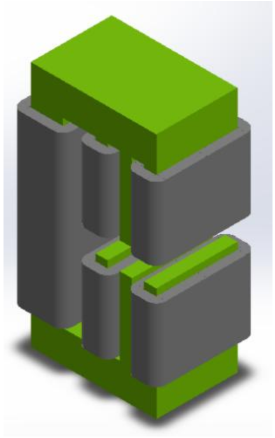
More than 1000 Magnets to be produced



524 Quadrupoles
(132 HG, 392 MG)



196 Sextupoles



98 Correctors

Magnet validation

Engineering Design validation

- Approval of the schedule
- Control of material proprieties
- Approval of the design, drawings and the quality control plan

Done for all the magnets

Pre-series magnet validation

- Mechanical and magnetic measurements
- Electrical and hydraulic tests
- Quality insurance documents

Under progress

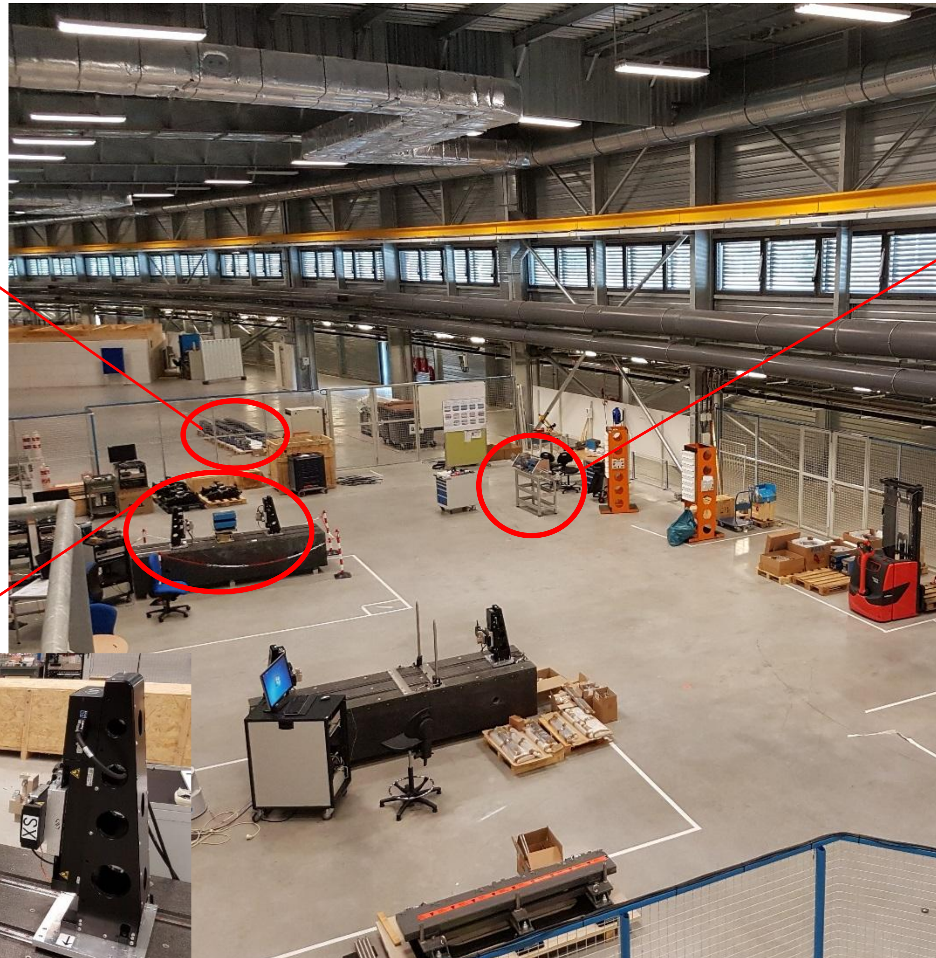
Series magnet validation

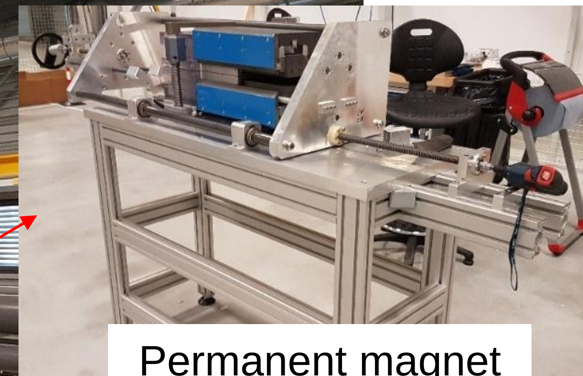
- Mechanical and magnetic measurements
- Electrical and hydraulic tests
- Quality insurance documents
- Measurement of some magnets at ESRF

Next step

Dipole assembly area – Chartreuse hall

Module yokes

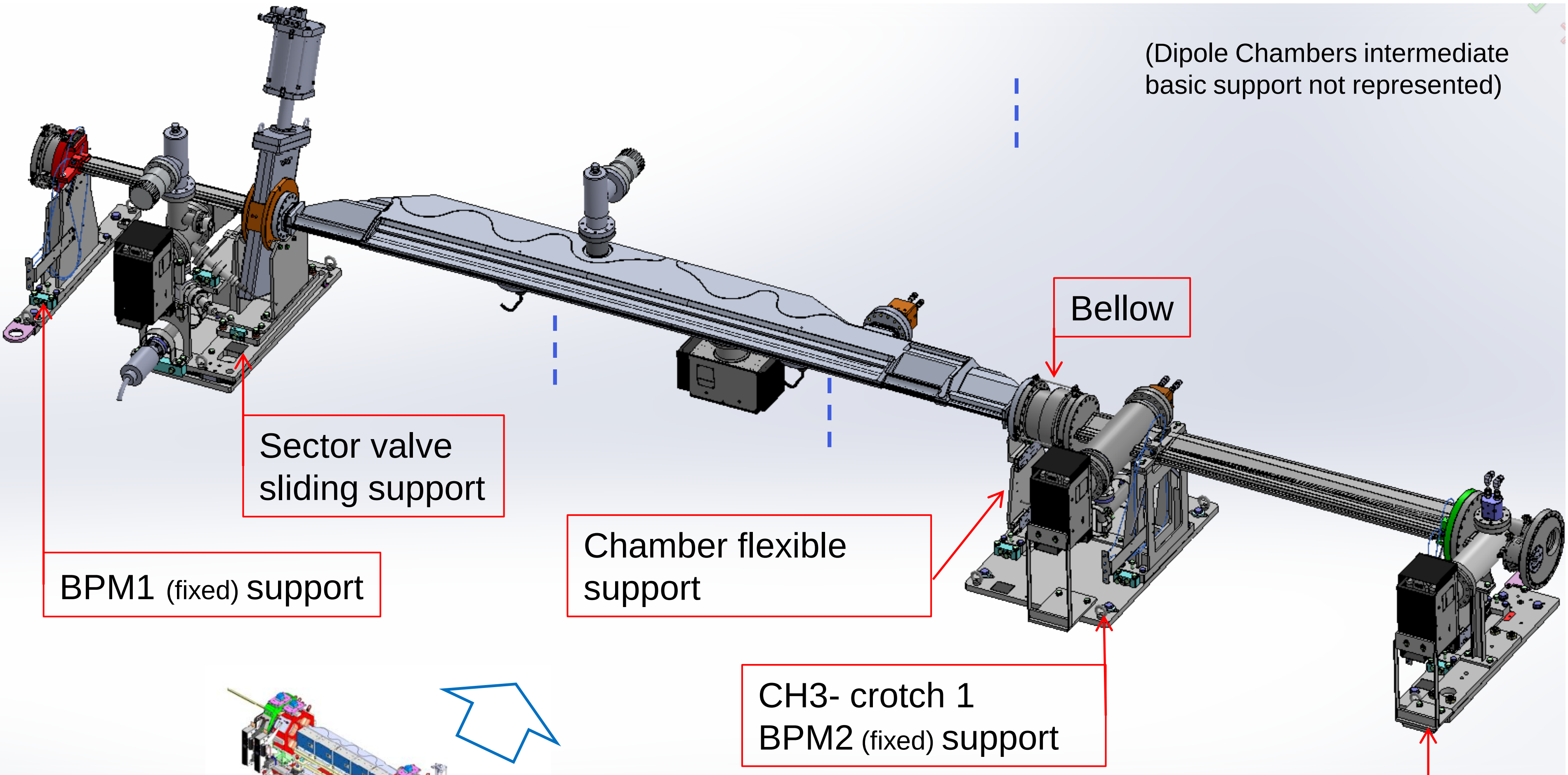


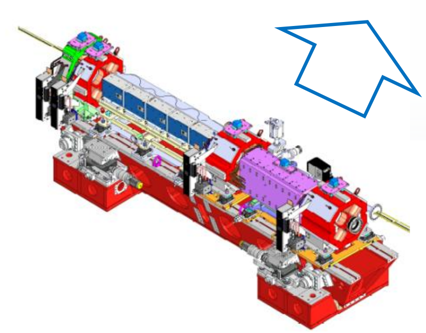


Permanent magnet assembly tool

Magnetic measurement bench

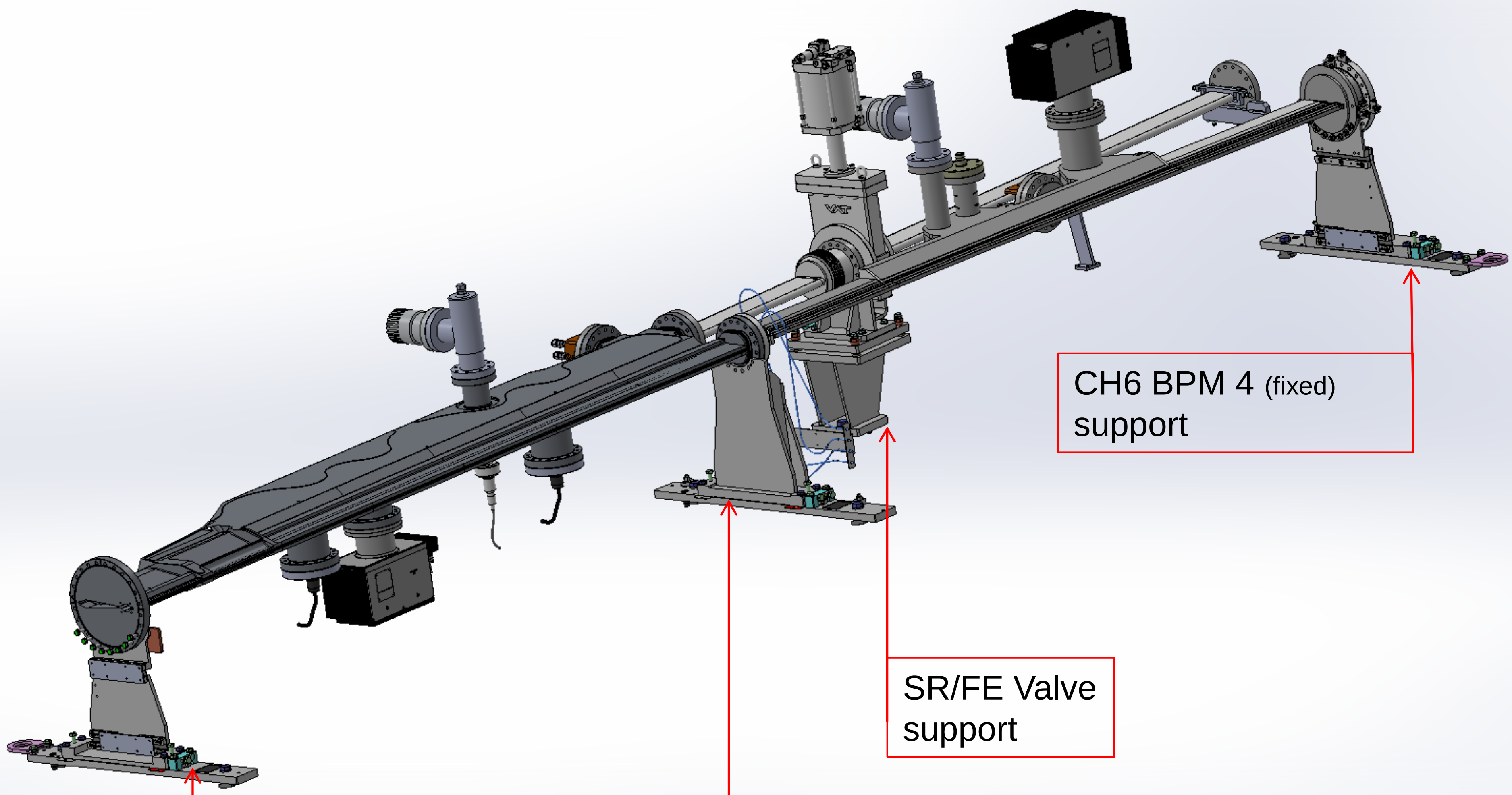
Girder 1 vacuum chamber supports





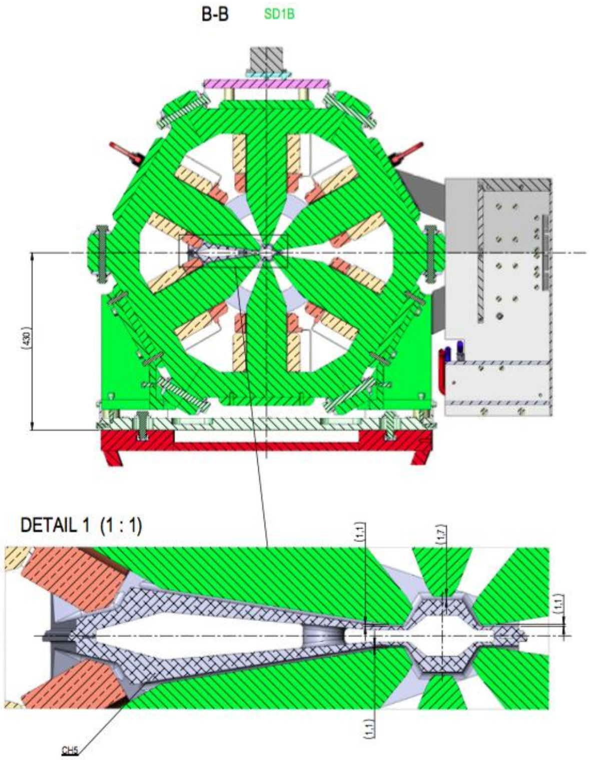
Courtesy: L Eybert

Girder 2 vacuum chamber supports



L Eybert

Vacuum chambers

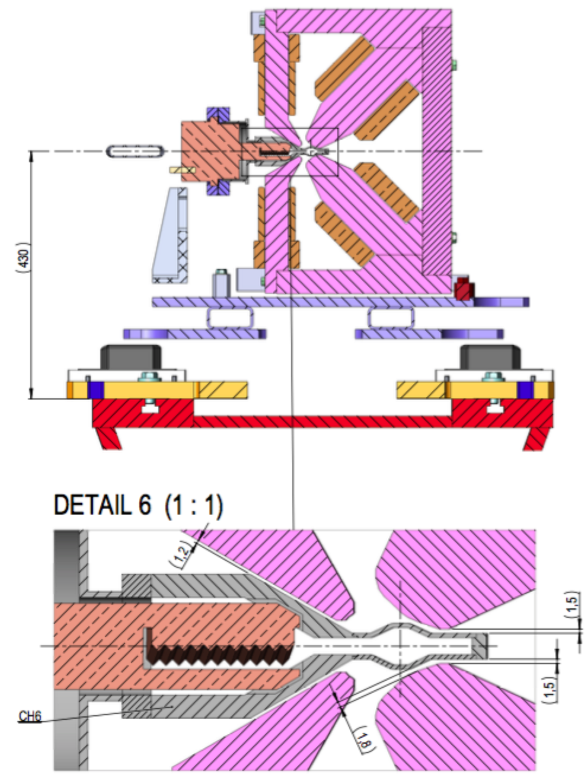


CH5 Dipole
Aluminium chamber
(section inside sextupole)

Limited space between Magnets and chambers

Minimum thickness required

- **Deflection (vacuum)**
- **Material stresses**

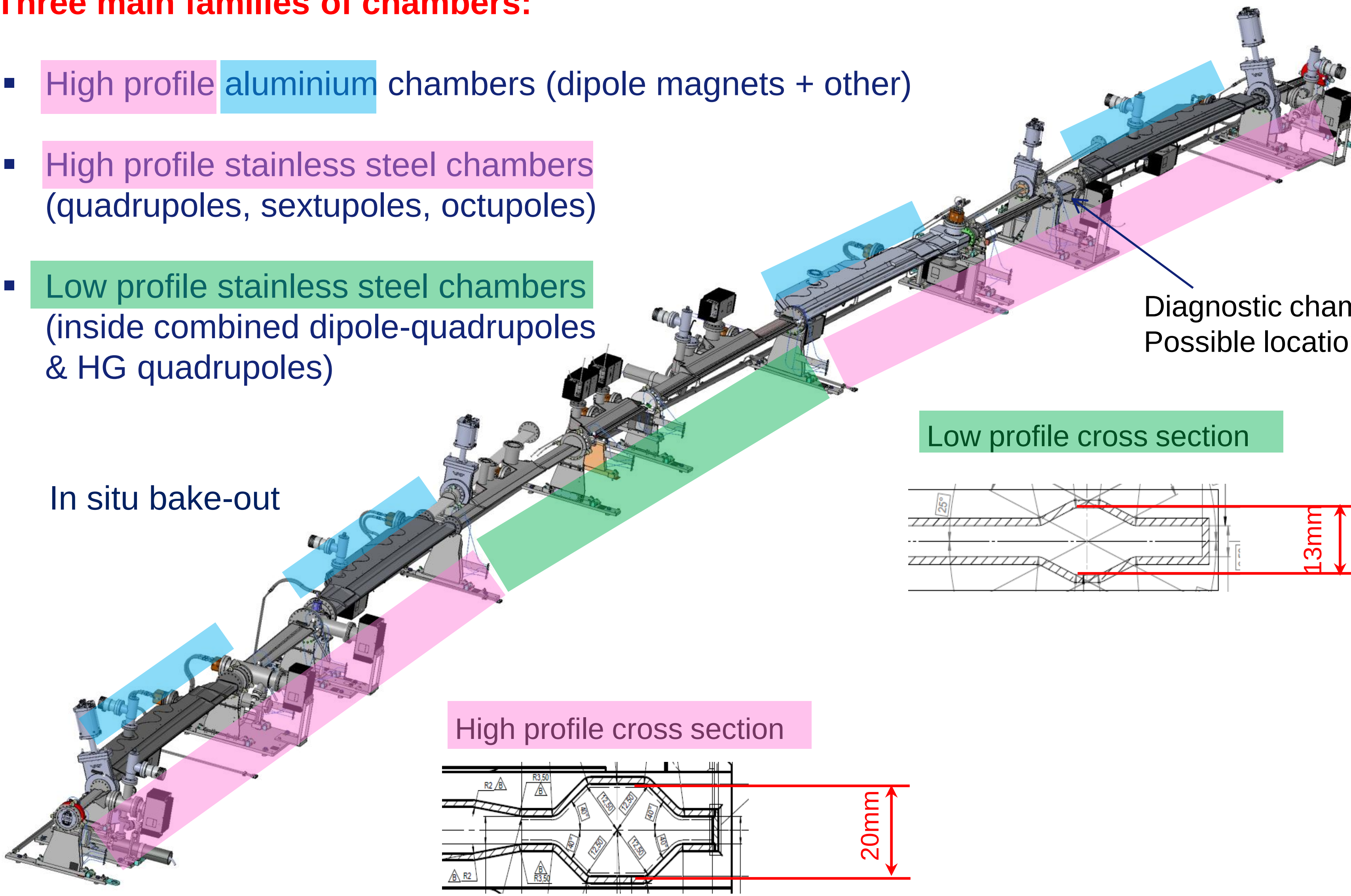


CH6
316LN chamber
(section inside DQ1C)

Vacuum chambers

Three main families of chambers:

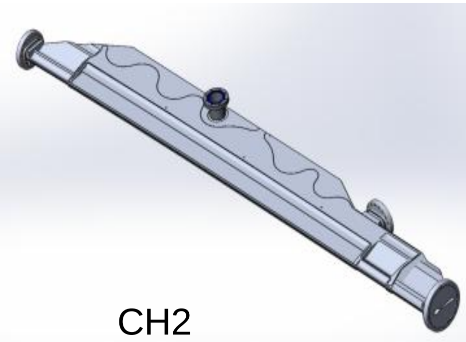
- High profile aluminium chambers (dipole magnets + other)
- High profile stainless steel chambers (quadrupoles, sextupoles, octupoles)
- Low profile stainless steel chambers (inside combined dipole-quadrupoles & HG quadrupoles)



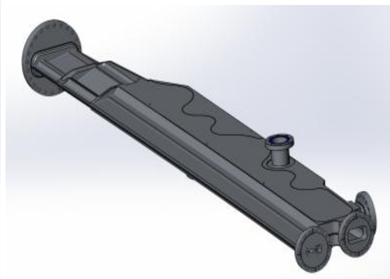
In situ bake-out

Family 1: aluminium dipole chambers

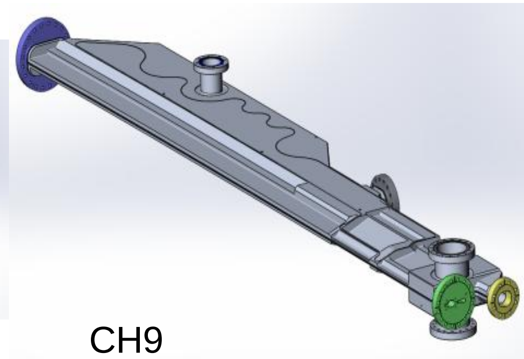
4 dipole chambers per cell made of Aluminum alloy 2219 T87



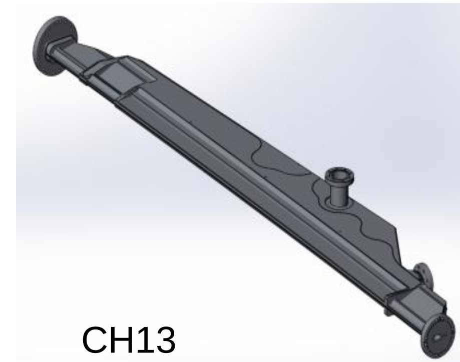
CH2



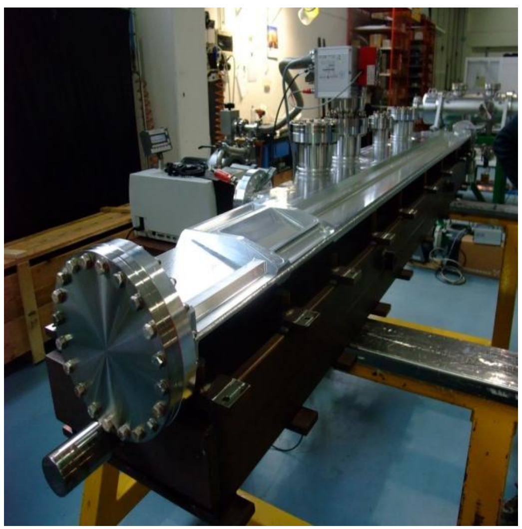
CH5



CH9



CH13



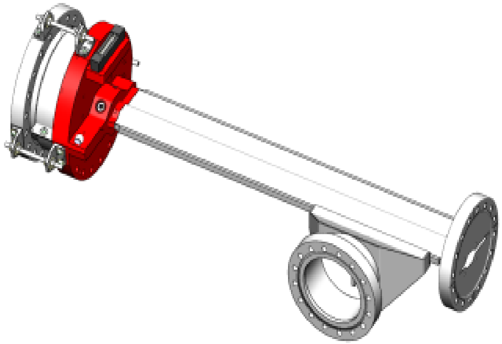
Designed in collaboration with INFN Frascati

- Design completed
- Prototype done
- Contract started

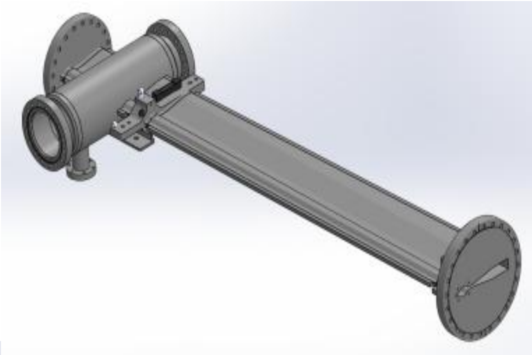
ESRF: Filippo Cianciosi

Family 2: high profile stainless steel chambers

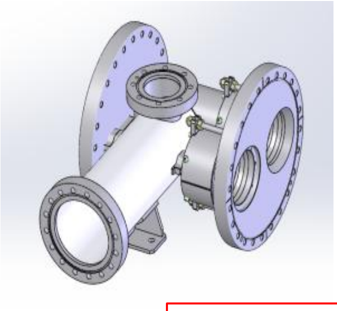
CH1



CH3

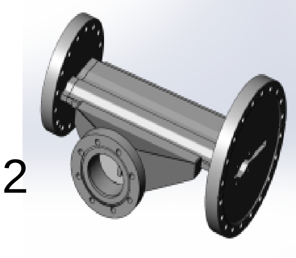


CH4



CH11

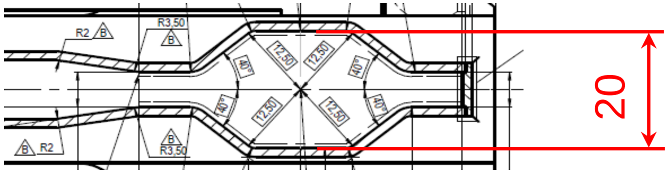
CH12



Straight Chambers

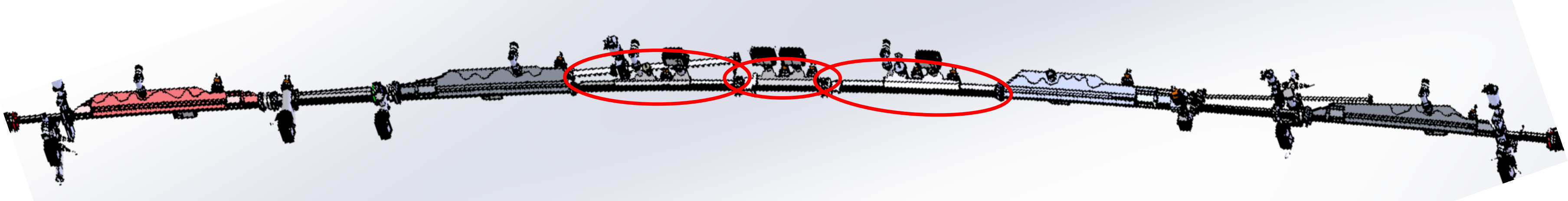
- ✓ Design completed
- ✓ Manufacturing in progress

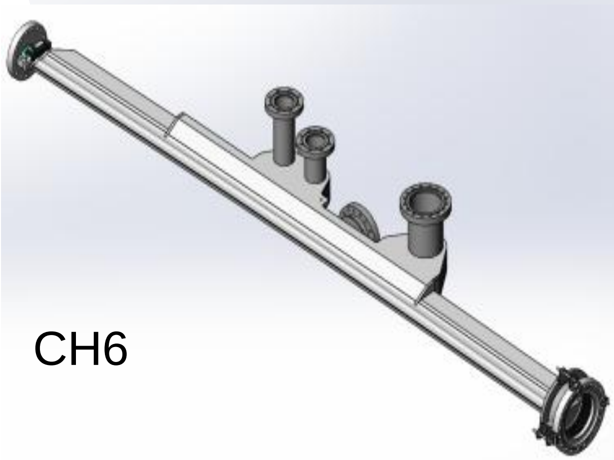
High profile cross section

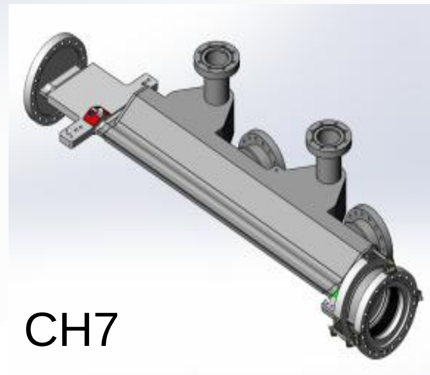


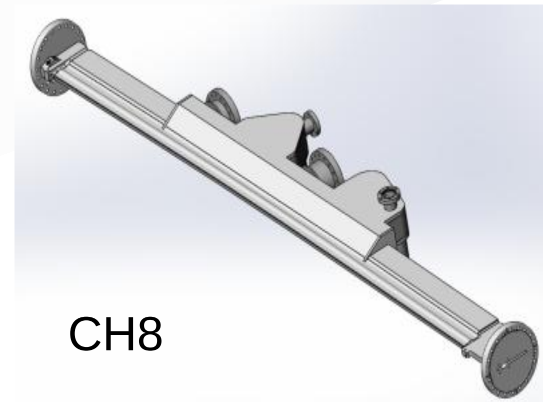
Pierre Van Vaerenbergh

Family 3: low profile stainless steel chambers





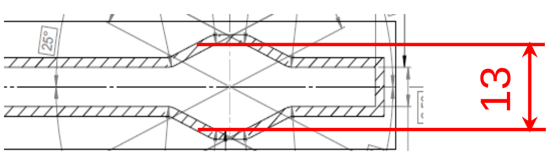




Curved chambers

- ✓ Design complete
- ✓ Manufacturing in progress

Low profile cross section (inside dipole-quadrupoles and HF quadrupoles)



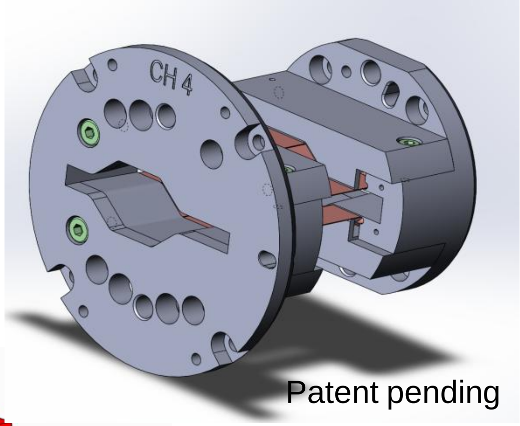
Joel Pasquaud

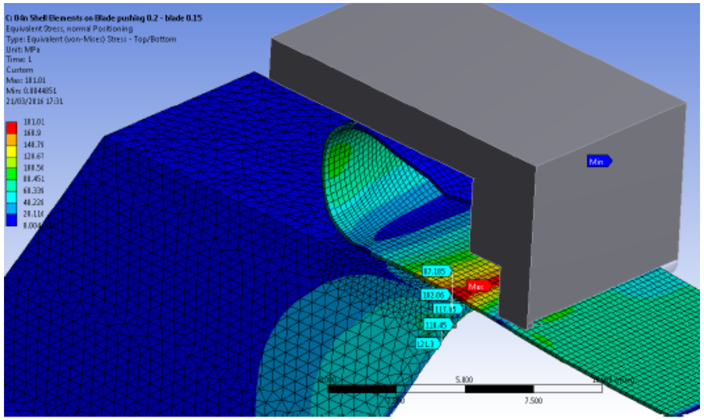
Vacuum pumps

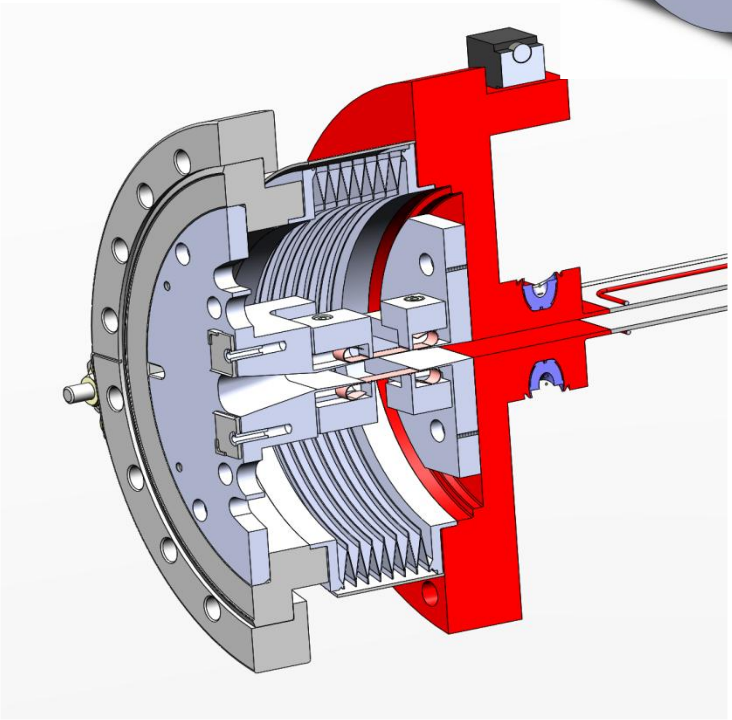
IP & NEG Pumps		CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7	CH 8	CH 9	CH 11	CH 12	CH 13	CH 14
IP	55 l/s							2				1		
	75 l/s	1	1	1	1	1	1		1	2		1	1	
NEG	GP100						1							
	GP200		2			5			1	2			2	

RF fingers

- 8 different bellows = 8 different RF Fingers
- Close collaboration with the vacuum chamber designer
- FEA model
- Prototype tested, additional tests in progress
- Design completed

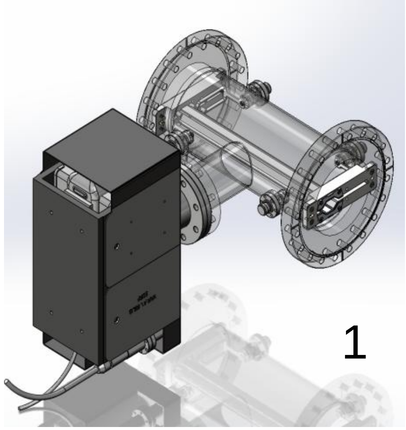






P Brumund,T Brochard, L Goirand, J Pasquaud

Vacuum chambers – Diagnostics



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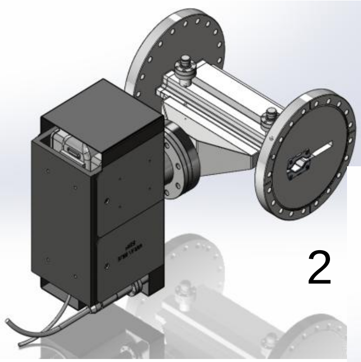
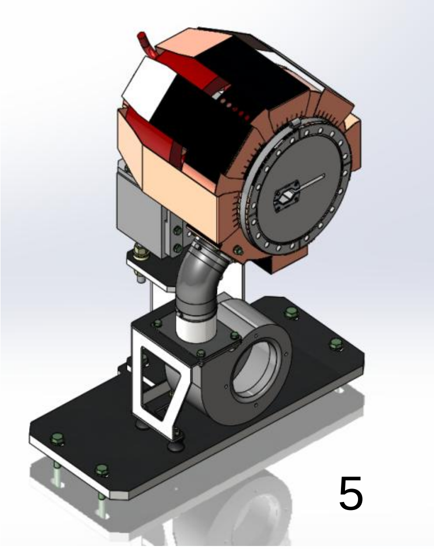


2

1. H stripline
2. V stripline
3. Shaker
4. Beam losses collimator
5. Current transformer

Procurement in progress



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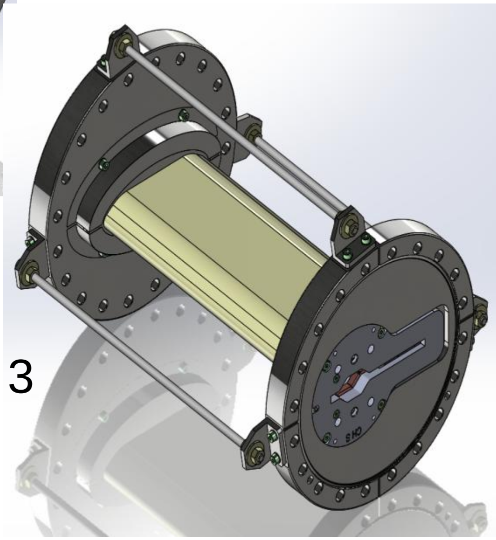

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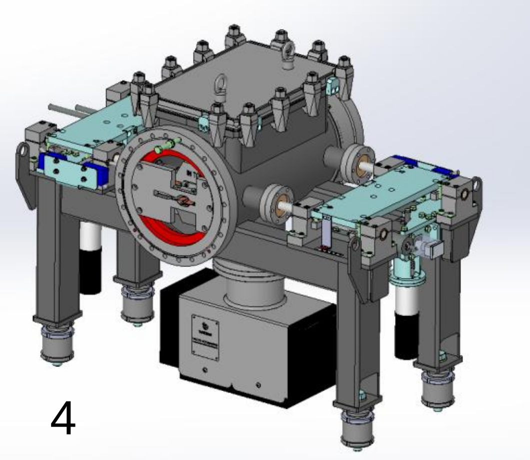

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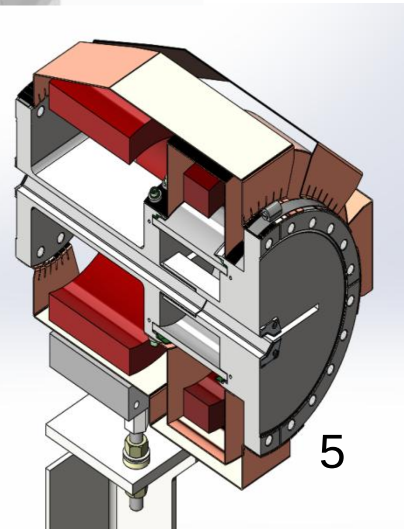
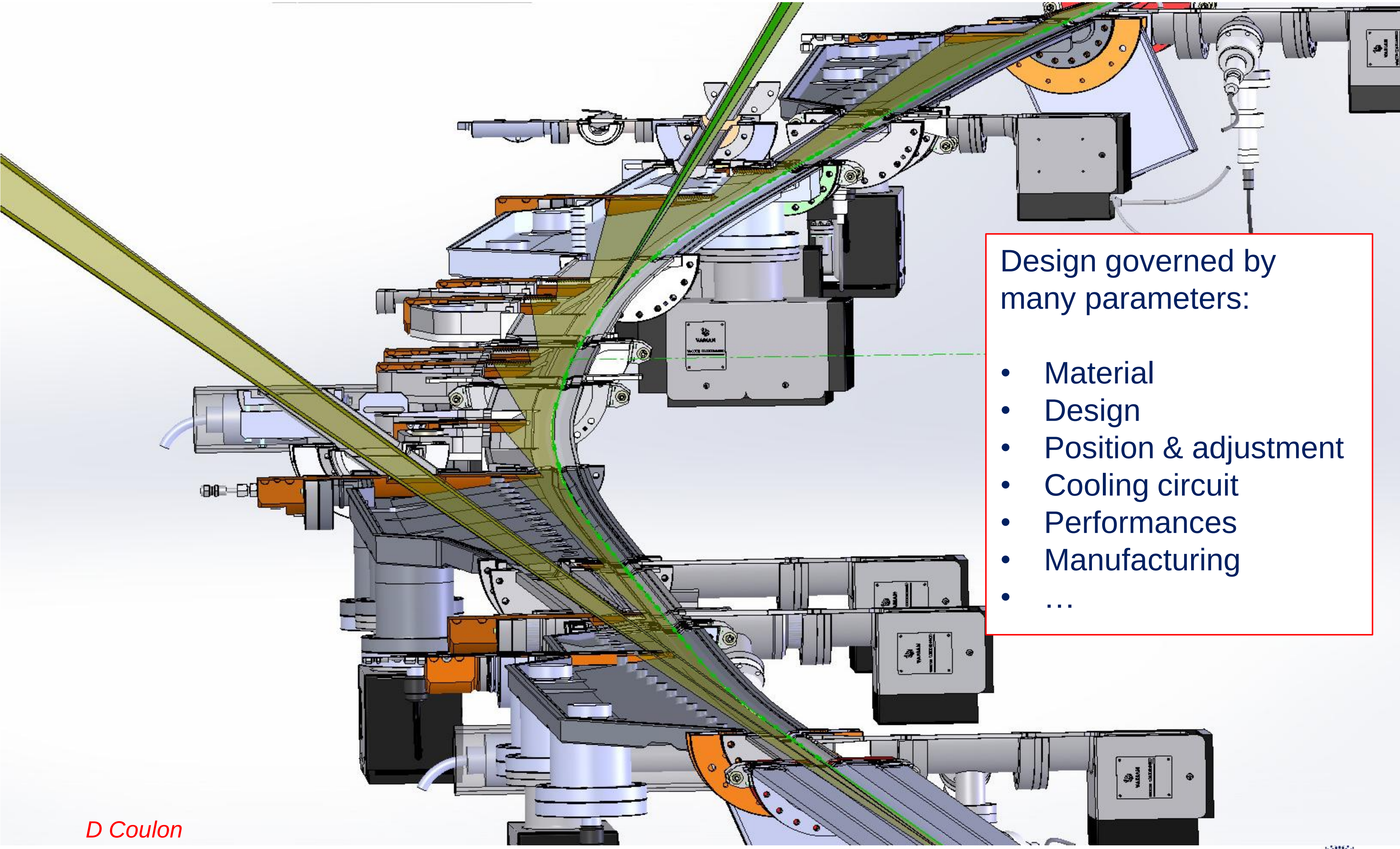


5

J Borrel

Photon absorbers – ray tracing



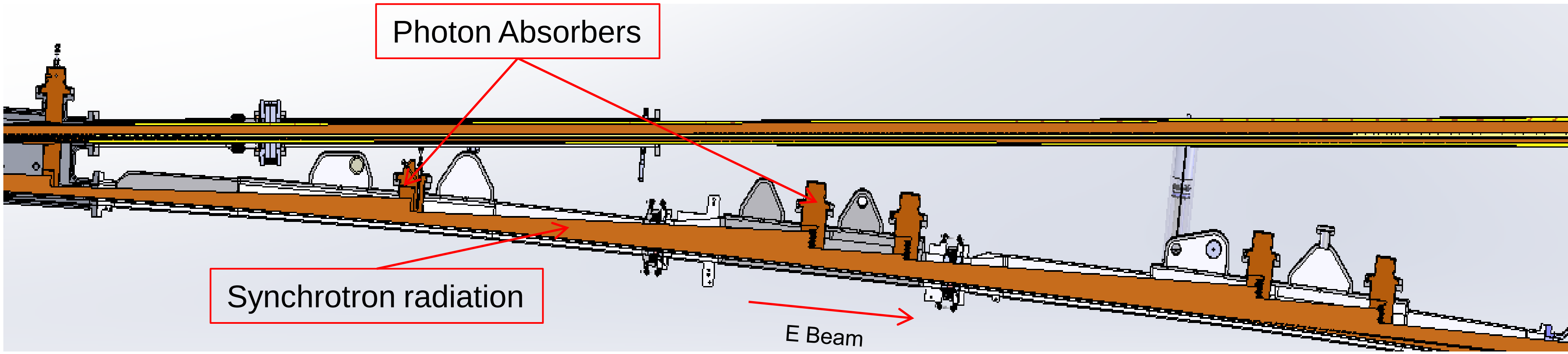
Design governed by many parameters:

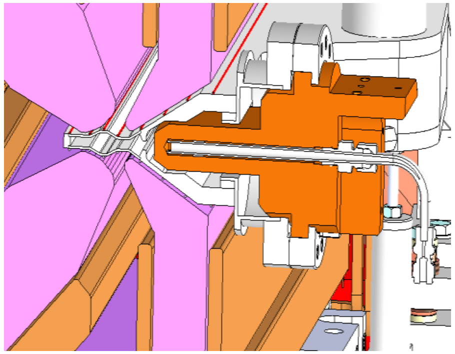
- Material
- Design
- Position & adjustment
- Cooling circuit
- Performances
- Manufacturing
- …

D Coulon

EBS photon absorbers

- ~391 absorbers
- Total power to be absorbed: 504.5 kW (30 x 15.795 kW + 2x 15.314) kW
- Power density: 10 to 110 W/mm^2
- → moderate power parameters compared to current ESRF



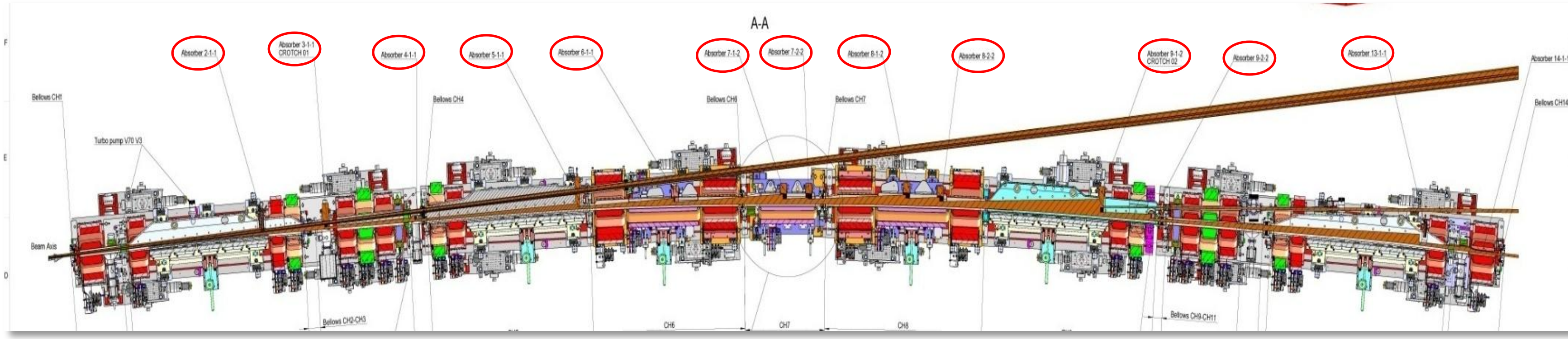


Absorber flange mounted on the ante-chamber

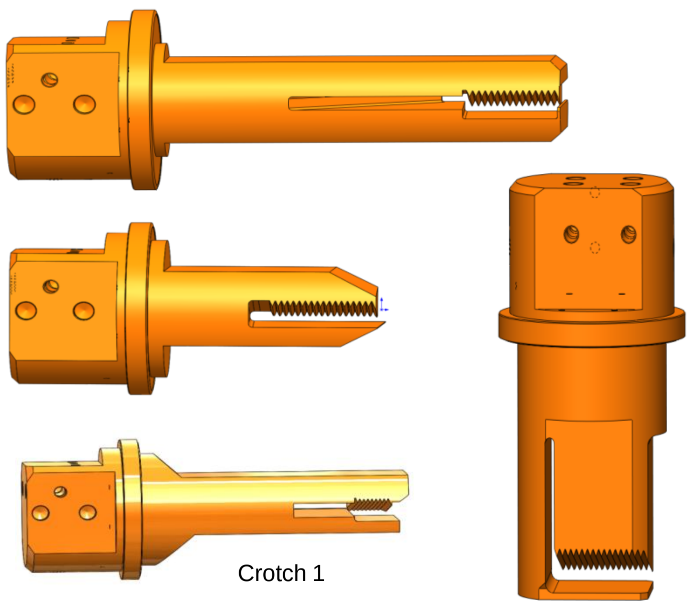
Tight space constraints

D. Coulon, Y. Dabin, Th. Ducoing, E. Gagliardini, Ph. Marion, F. Thomas

Absorber design: two families



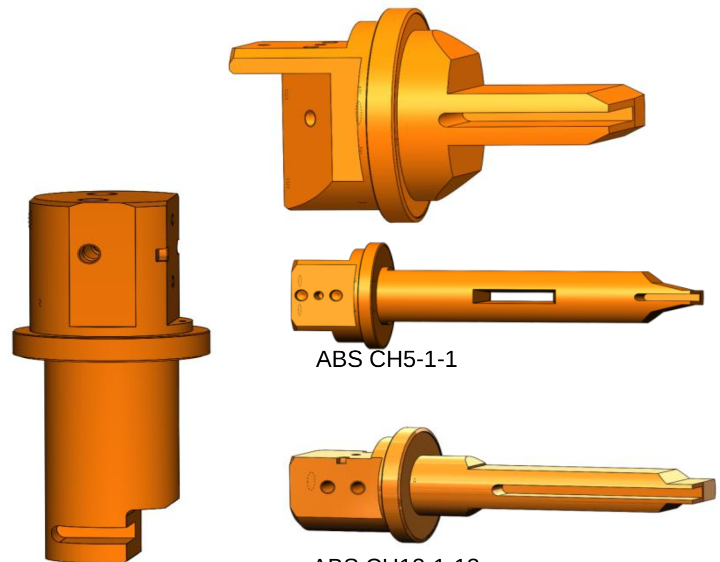
Toothed (up to 110 W/mm^2)



Crotch 1

ABS CH9-1-29

Frontal (up to 50 W/mm^2)



ABS CH4-1-1

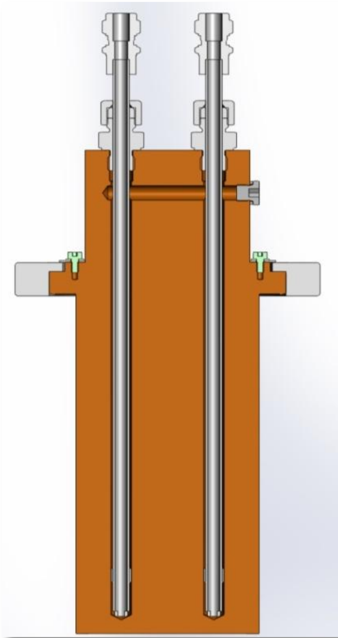
ABS CH5-1-1

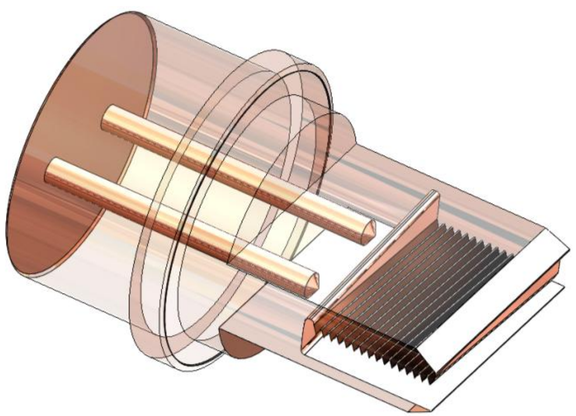
ABS CH13-1-13

No welding, no brazing

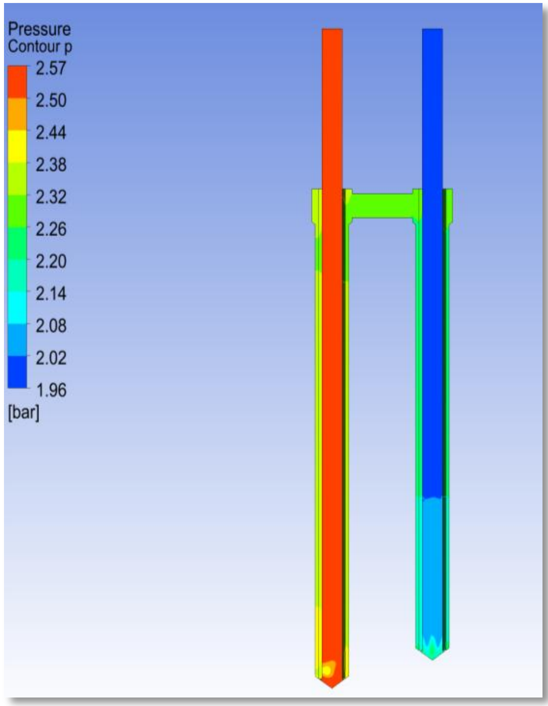
D. Coulon, Y. Dabin, Th. Ducoing,
E. Gagliardini, Ph. Marion, F. Thomas

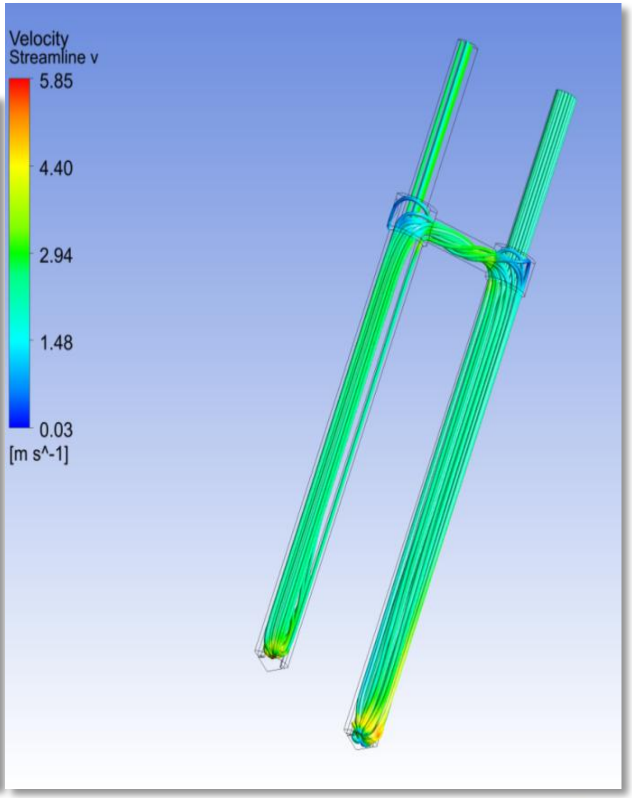
Absorber water channels: concentric flows





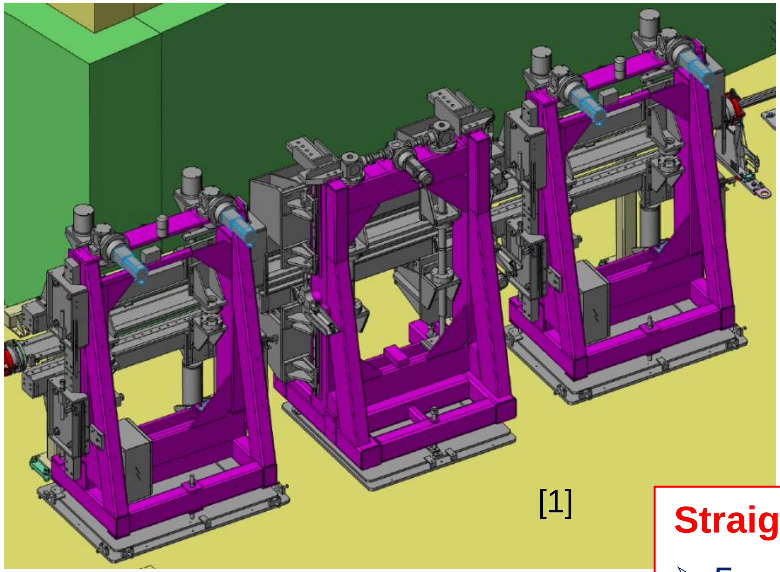
- Average water velocity: 2.5 m/s
- Heat transfer coefficient: 15 kW/m^2*K
- Pressure head loss per absorber: Δp = 0.6 bar

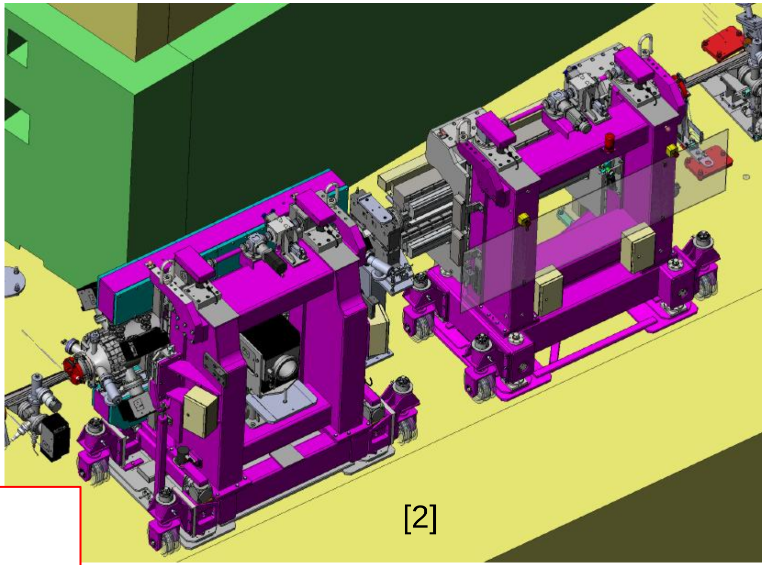




F. Thomas (ILL)

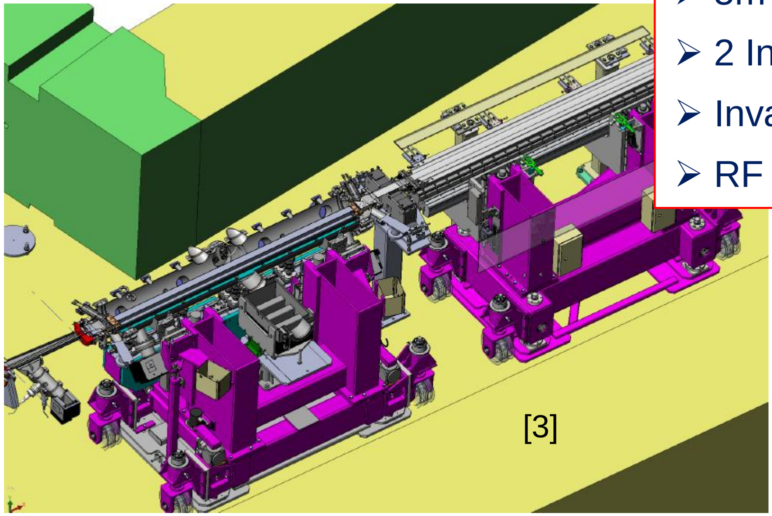
Straight sections

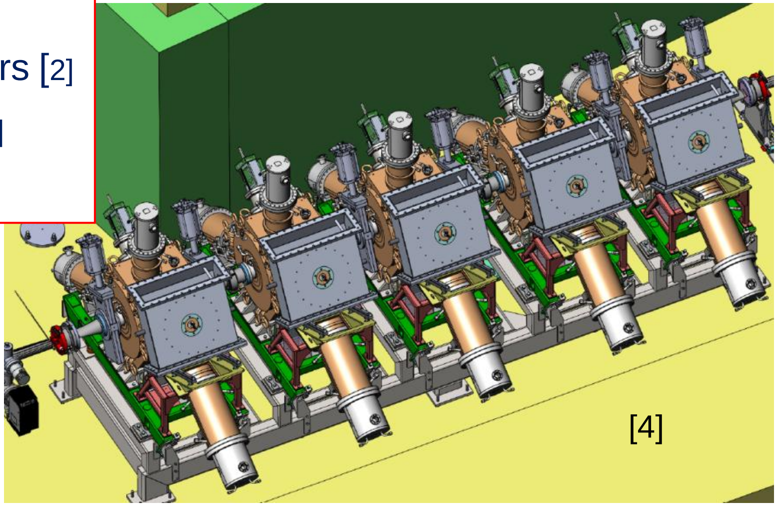




Straight sections

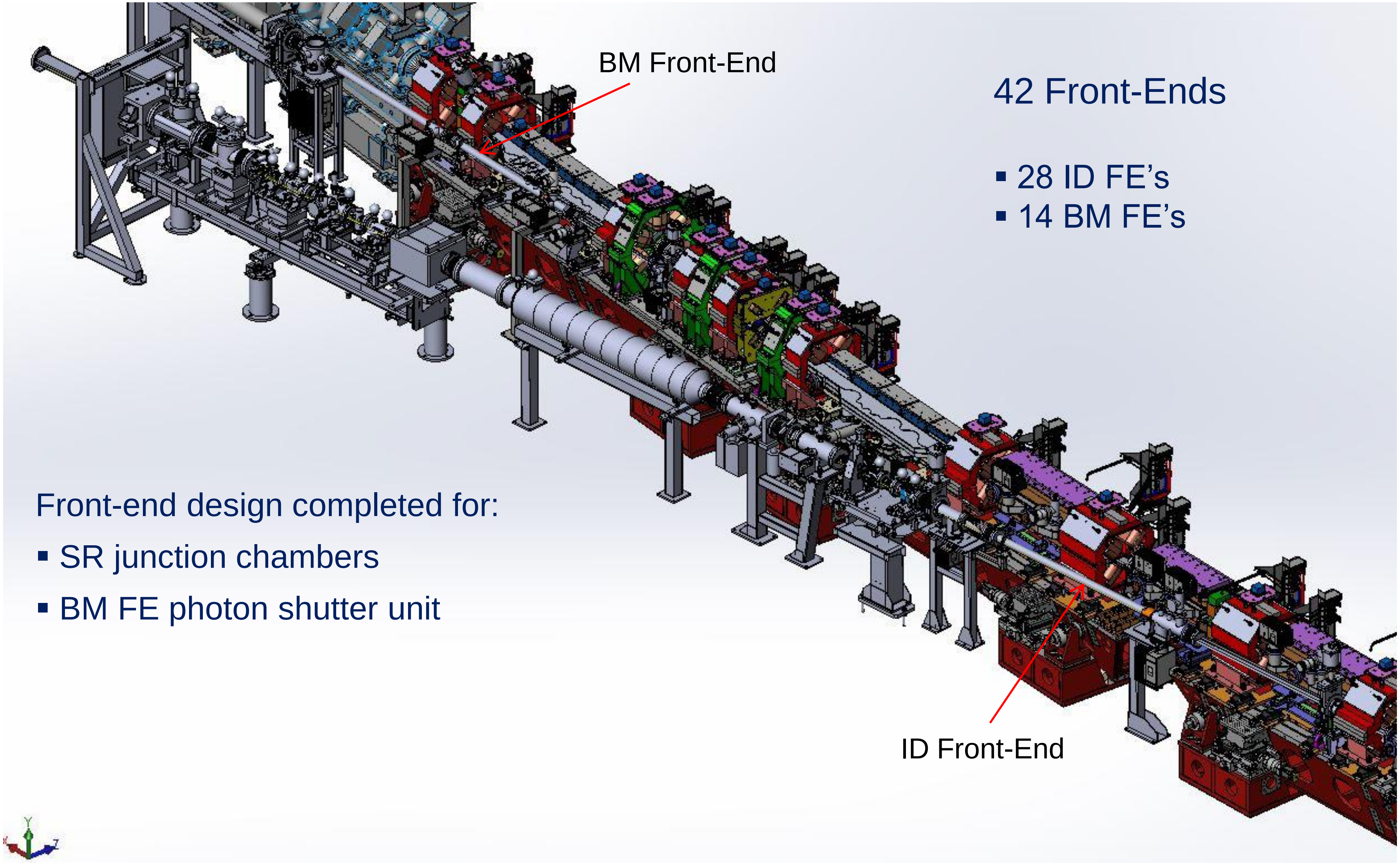
- 5m AL chamber [1]
- 2 In-vacuum undulators [2]
- Invac & Al chamber [3]
- RF cavities [4]





B Ogier, P Ponthenier

Front-ends



42 Front-Ends

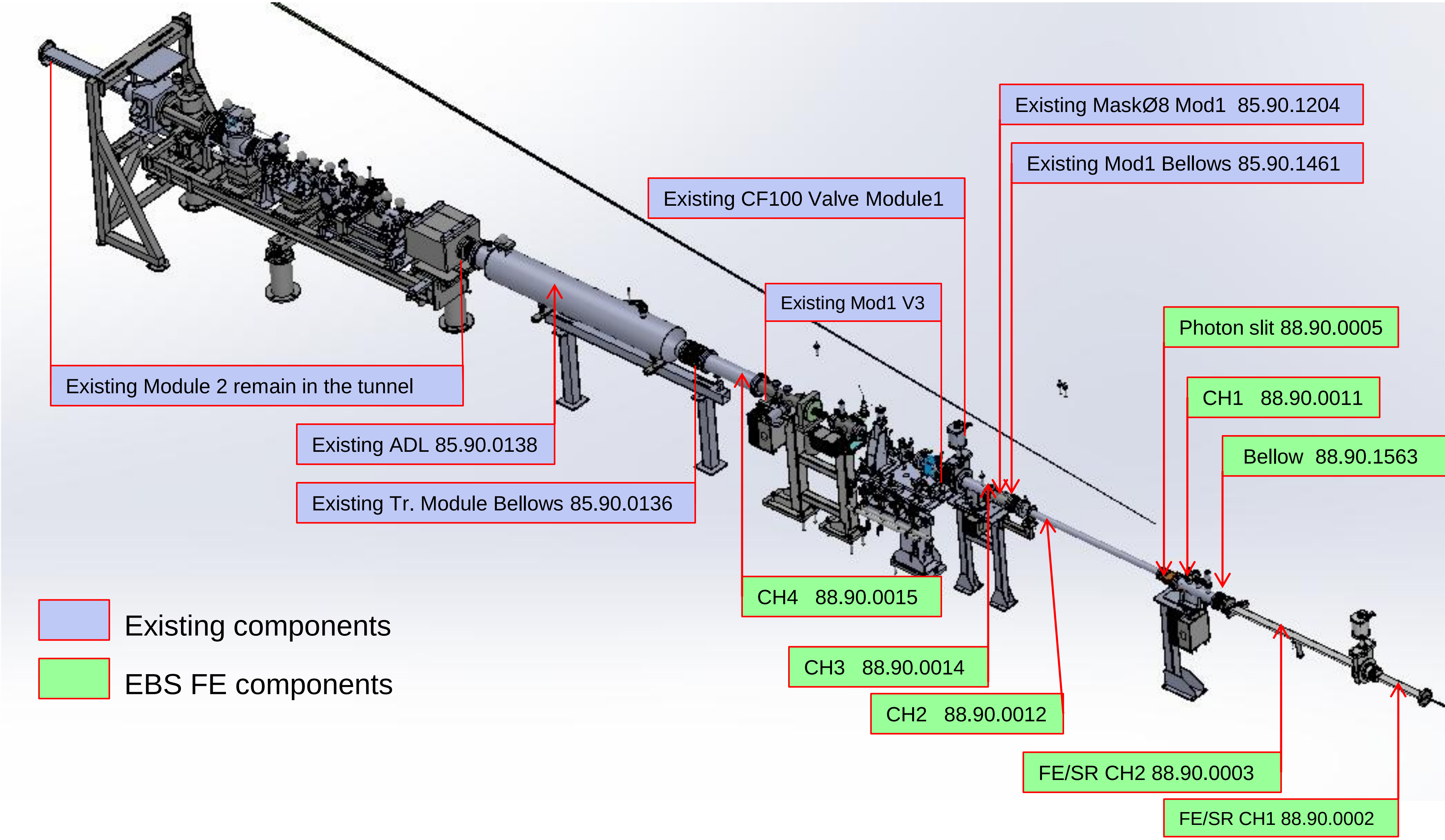
- 28 ID FE’s
- 14 BM FE’s

Front-end design completed for:

- SR junction chambers
- BM FE photon shutter unit

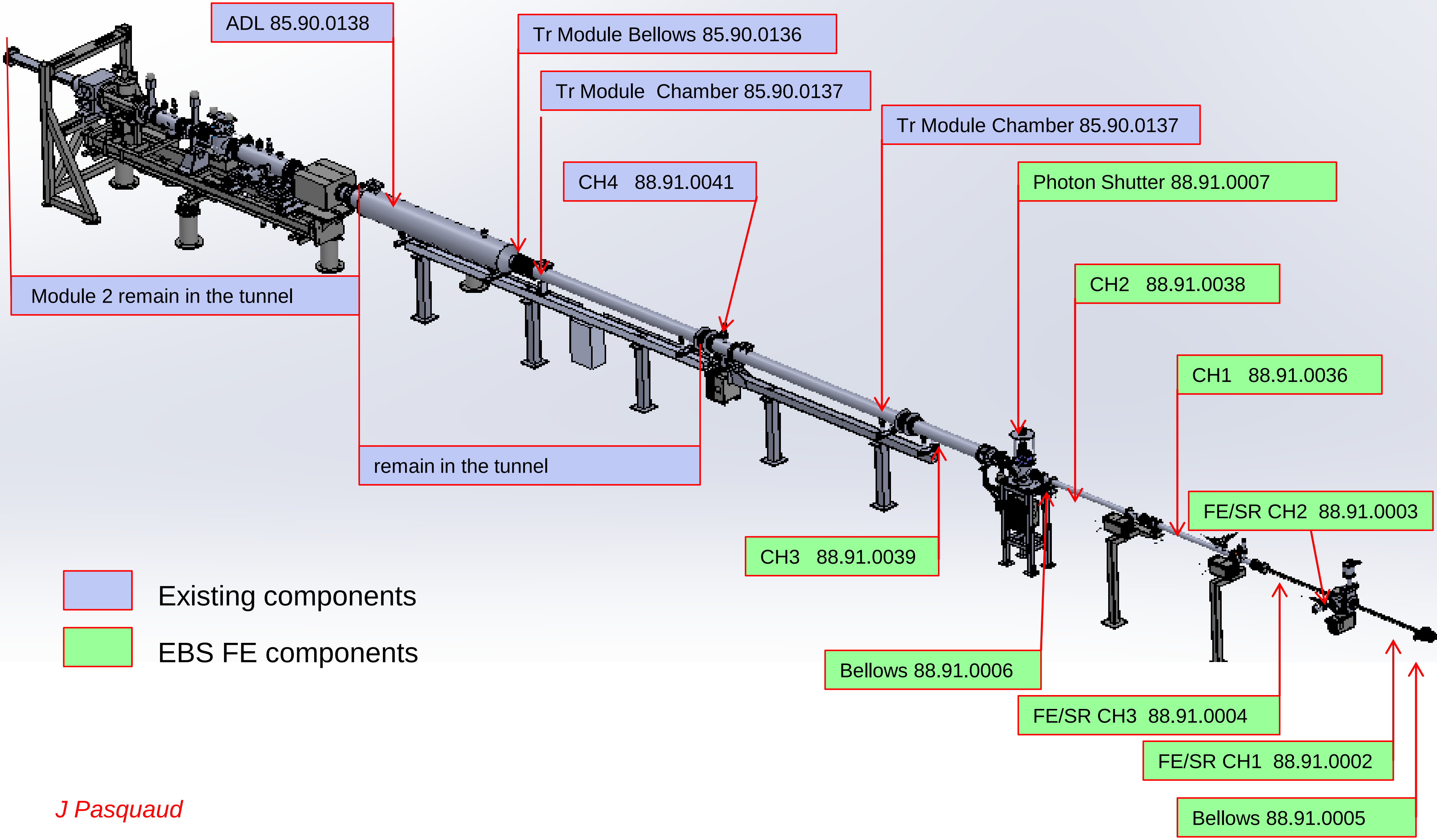
Courtesy of J Pasquaud

Insertion Device Front-ends



J Pasquaud

Bending Magnet Front-Ends



Existing components

EBS FE components

J Pasquaud

Front-ends

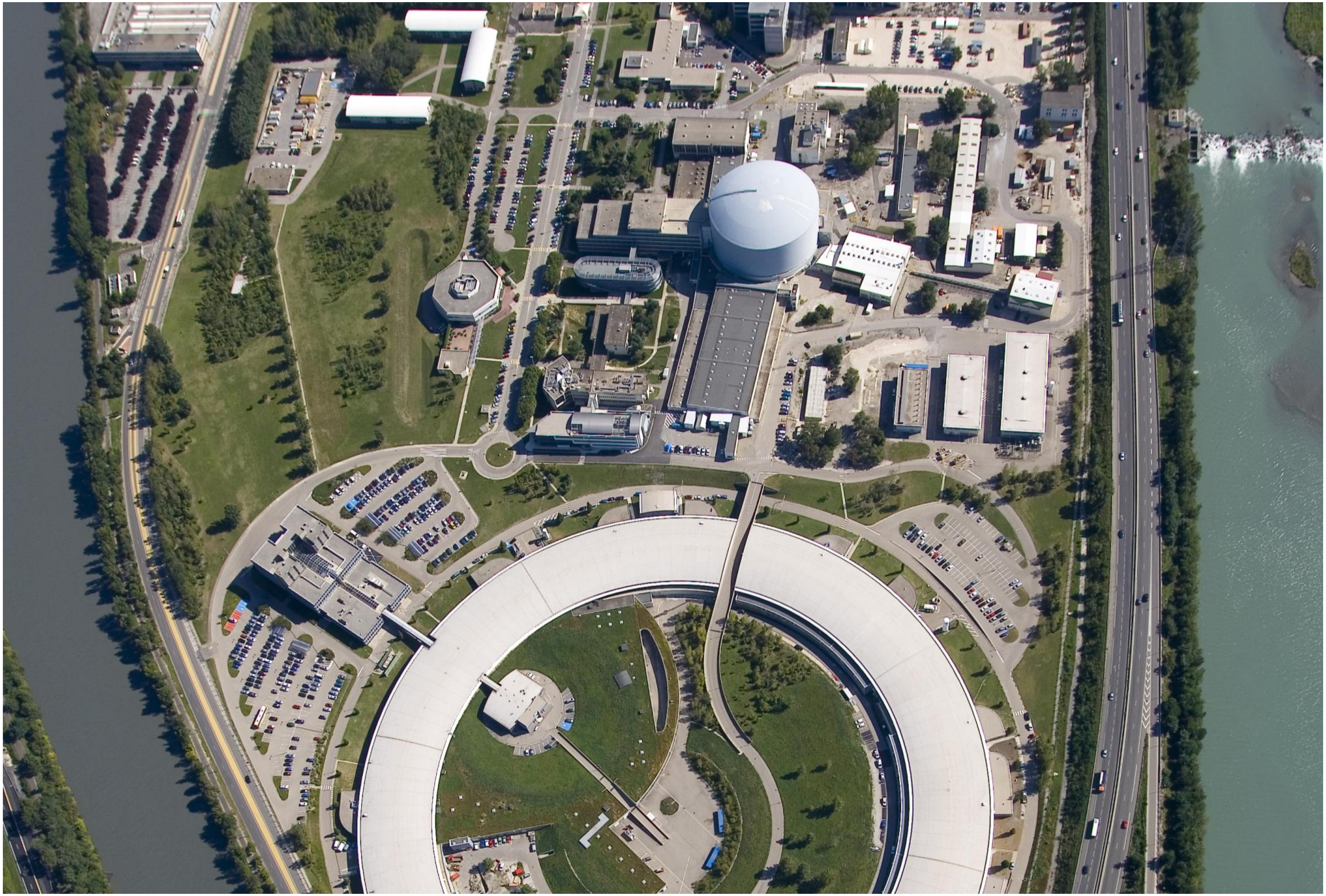
Insertion Device beamlines

- Keep beamlines at the same position (little offset for canted BL's)
- Module 2 remains as it is in the SR
- Re-use most of the components
- Minimize installation time
- Adjustable horizontal aperture (aligment with beam during commisioning)

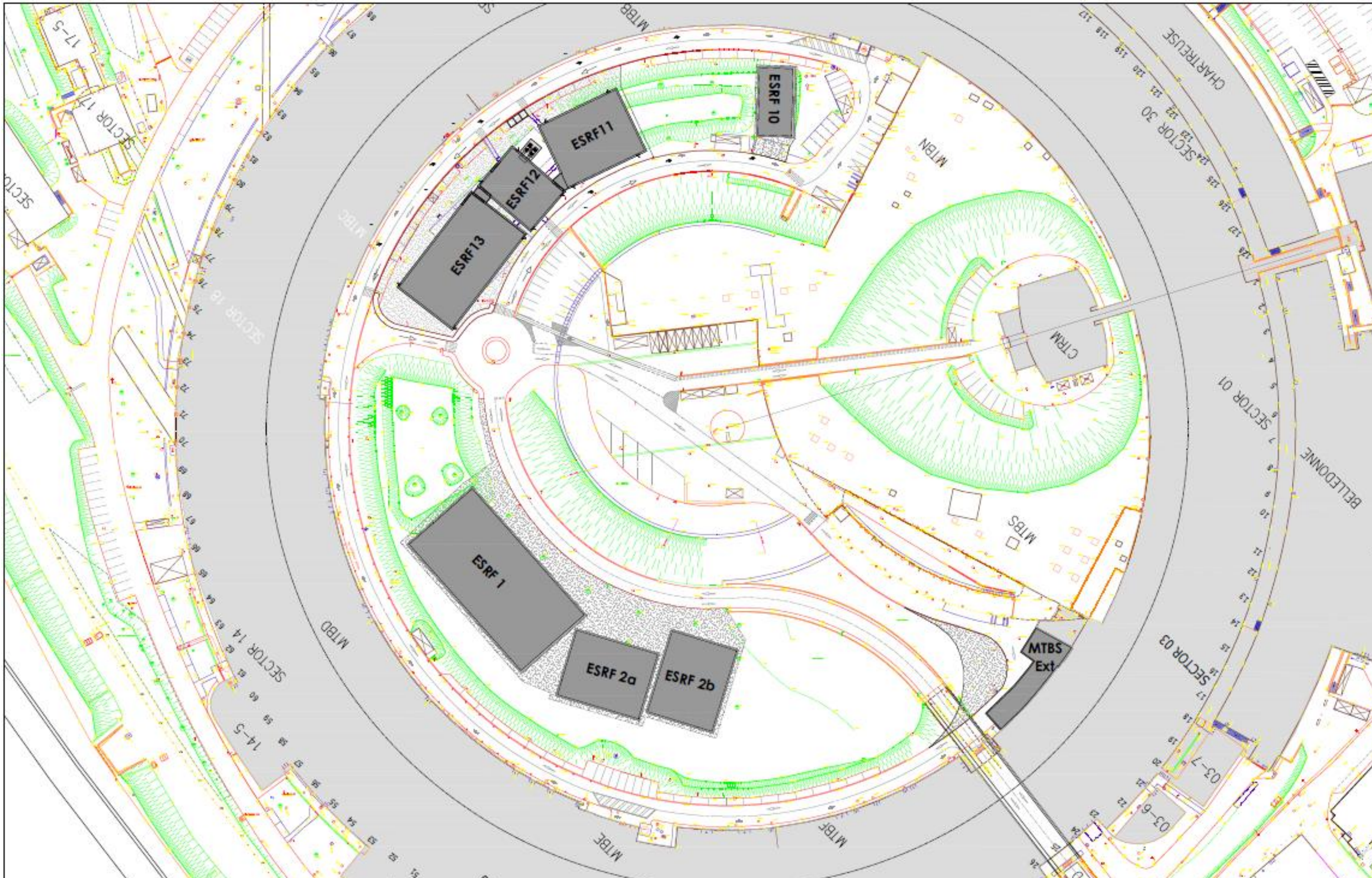
Bending Magnet beamlines

- Realignment needed
- Source choice under discussion
- FE to be adapted
- Low energy BL's: FE & BL to be realigned

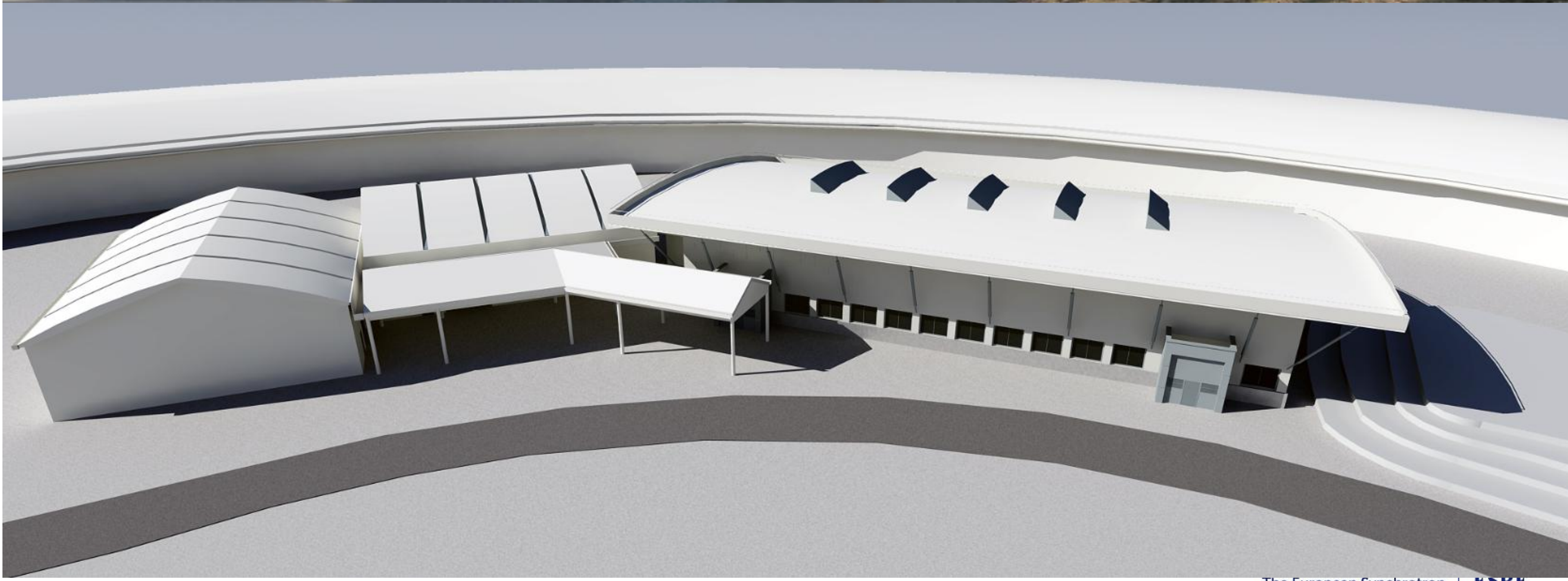
From Assembly to Installation



EBS Logistics buildings

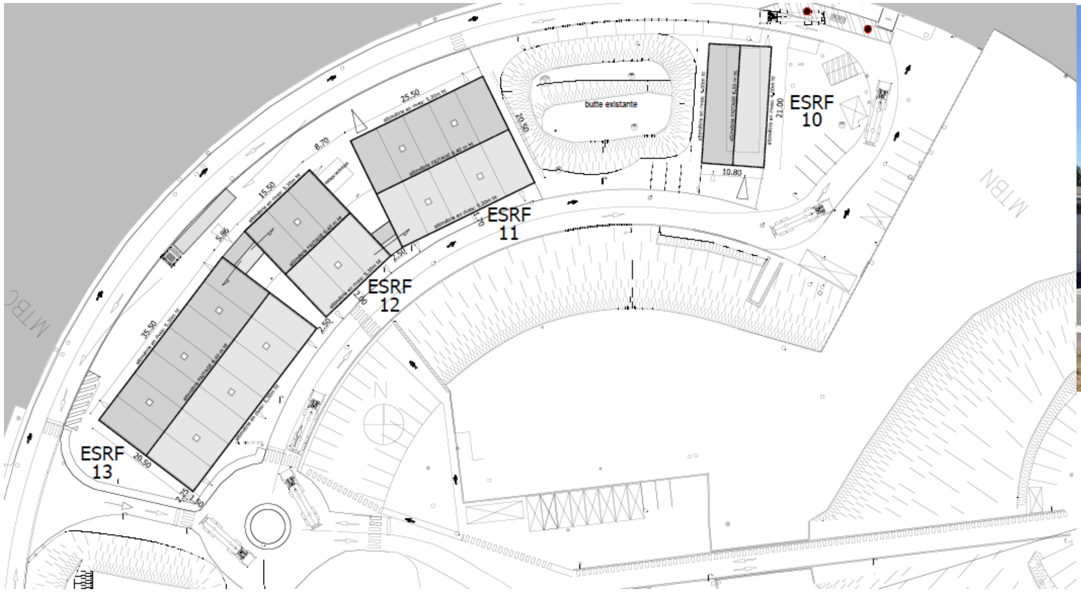


ESRF01 – ESRF02A/B architect view

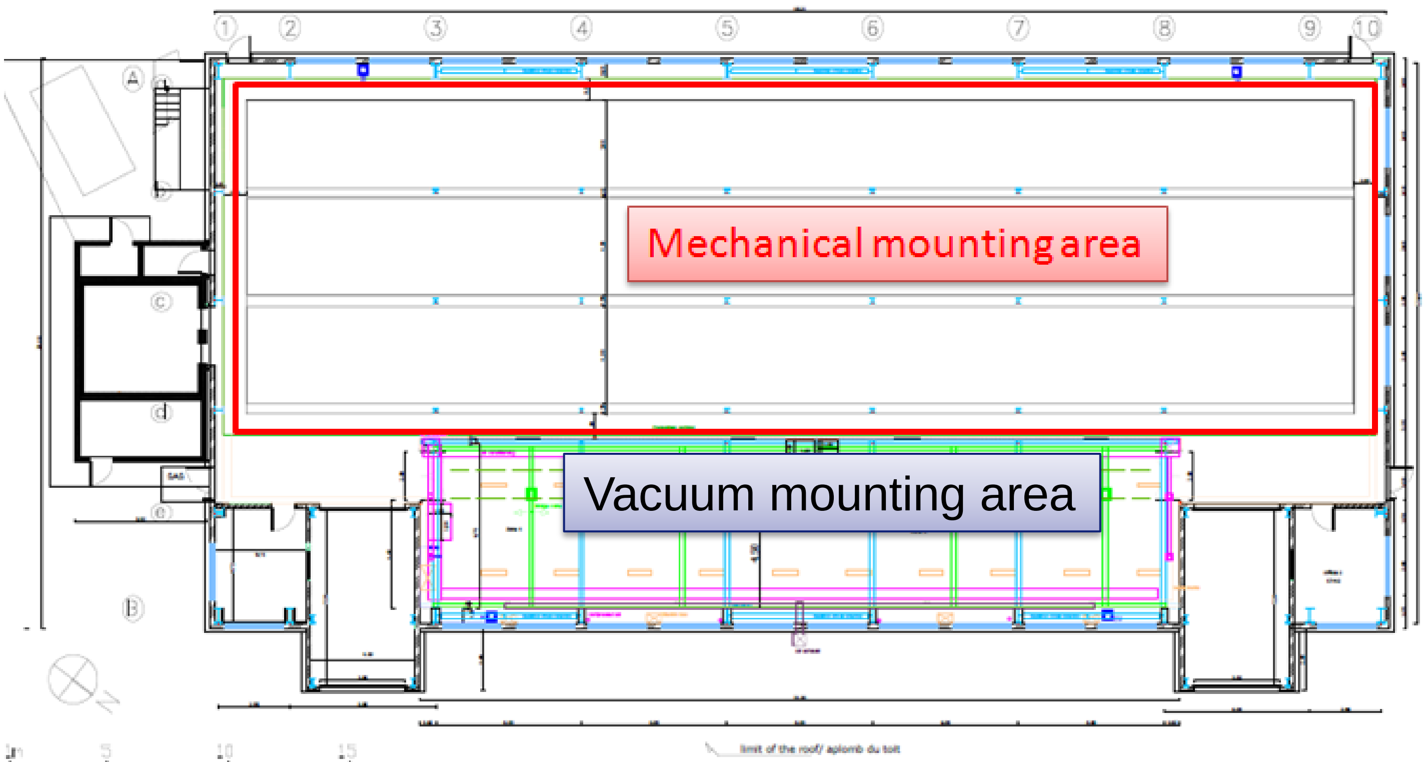


ESRF01 – ESRF02A/B – works in progress

Storage buildings for the dismantled machine – architect view

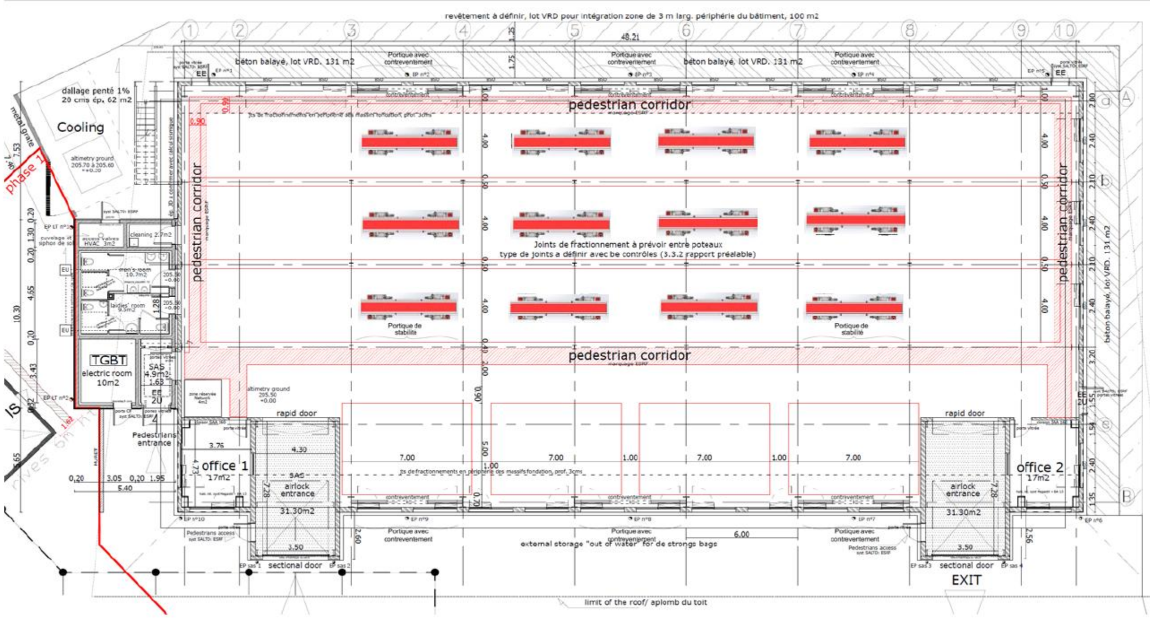


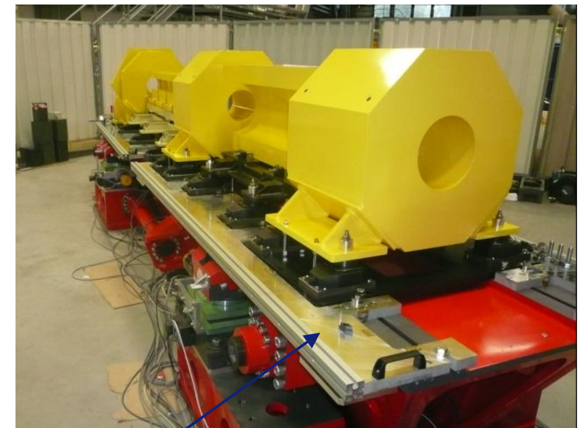
ESRF01: girder assembly building



All girders prepared from October 2017 to ~September 2018

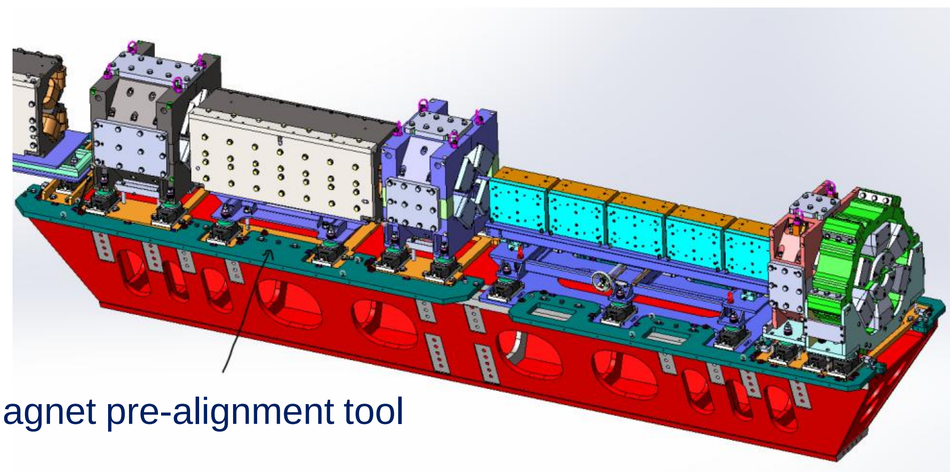
Mechanical assembly area





- Position girders
- Install magnets & align
- Open magnets
- Install pre-assembled chambers
- Align BPM's & chambers
- Close magnets
- Final alignment check

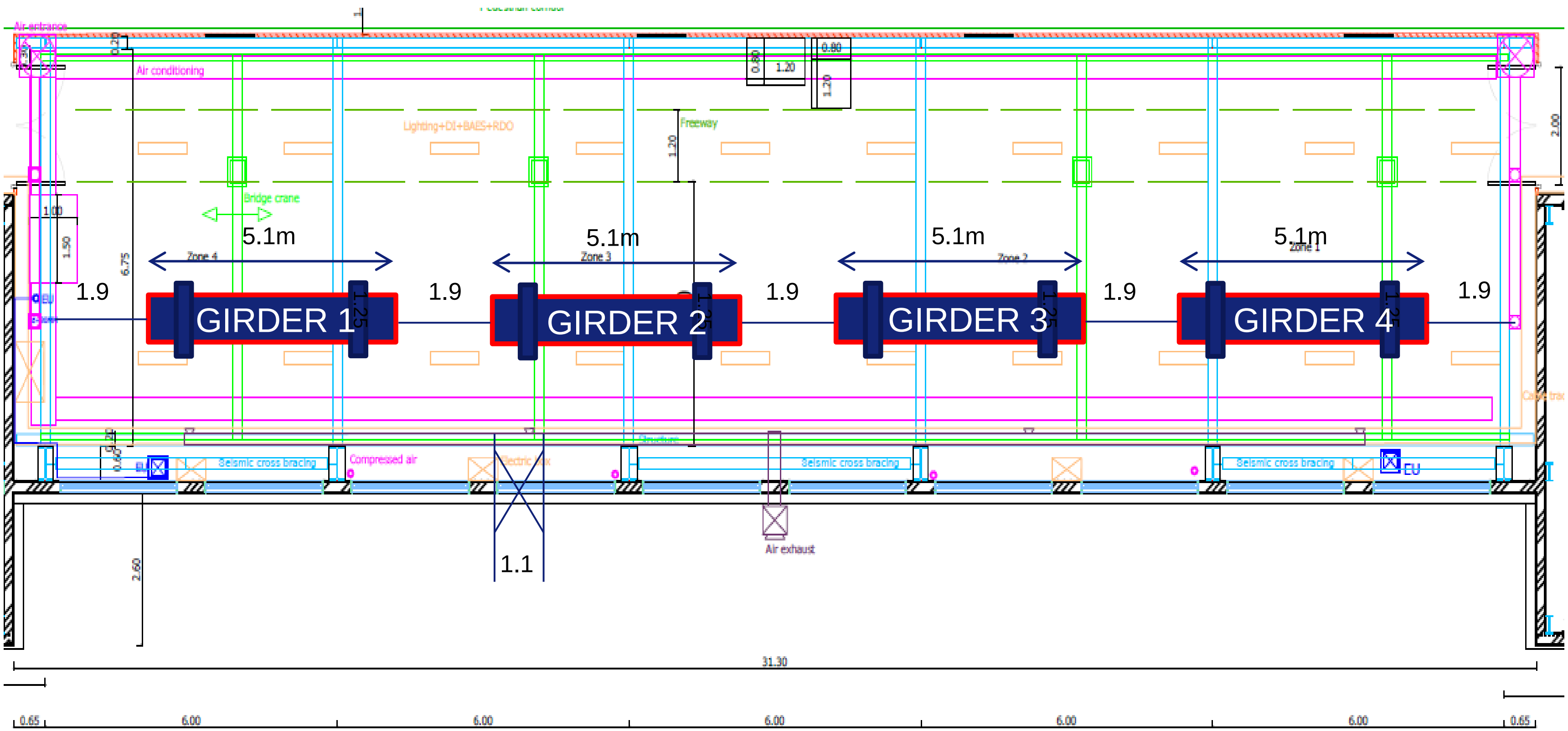
Magnet pre-alignment tool



Magnet pre-alignment tool

L Eybert

Vacuum assembly area



Chambers are equipped with bakeout sheath heaters before assembly

- Vacuum chambers assembled for each girder:
  Chambers, photon absorbers, gauges, pumps …
- Assembled chambers are baked

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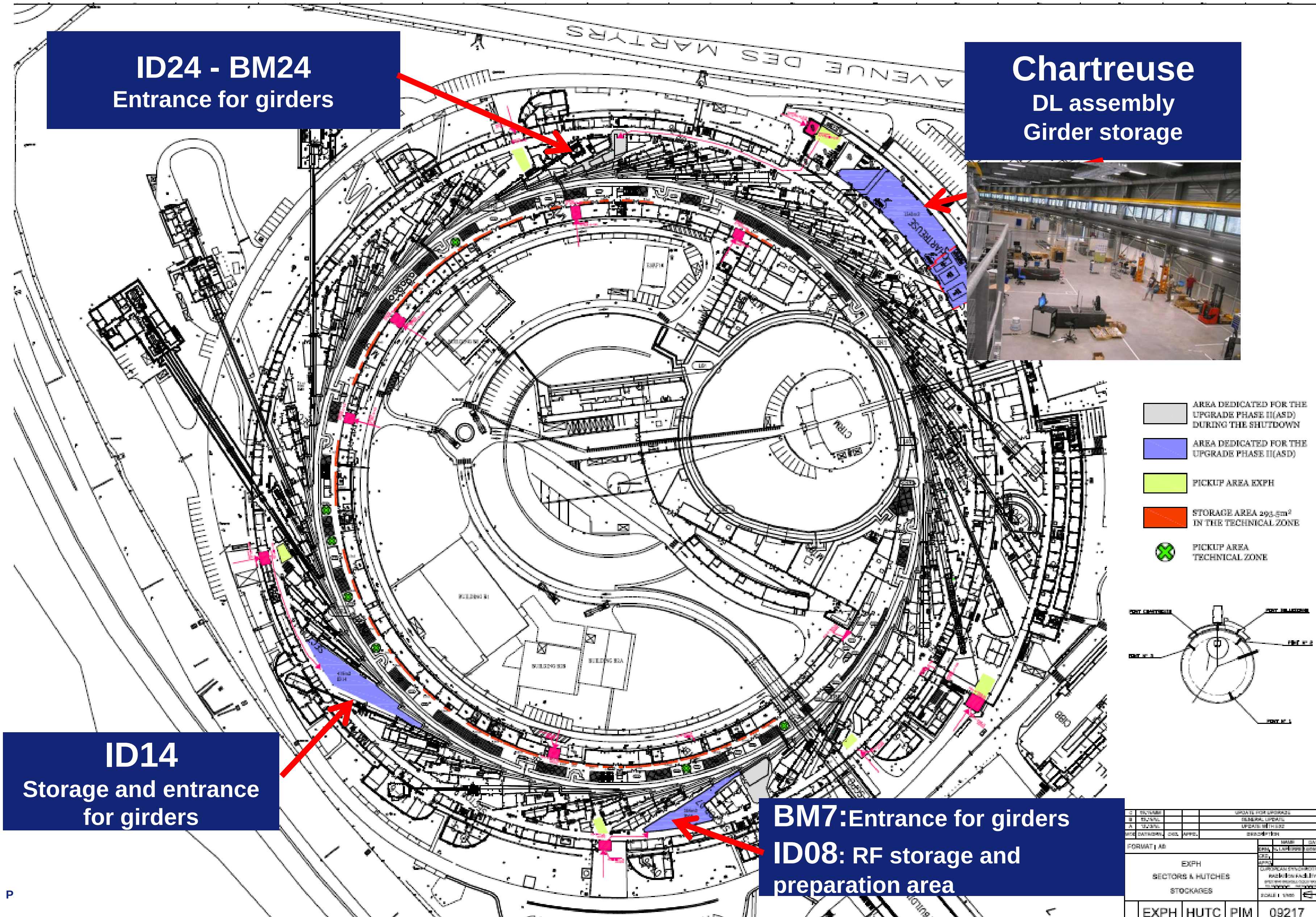
Logistics areas



ID24 - BM24
Entrance for girders

Chartreuse
DL assembly
Girder storage

ID14
Storage and entrance for girders

BM7: Entrance for girders
ID08: RF storage and preparation area

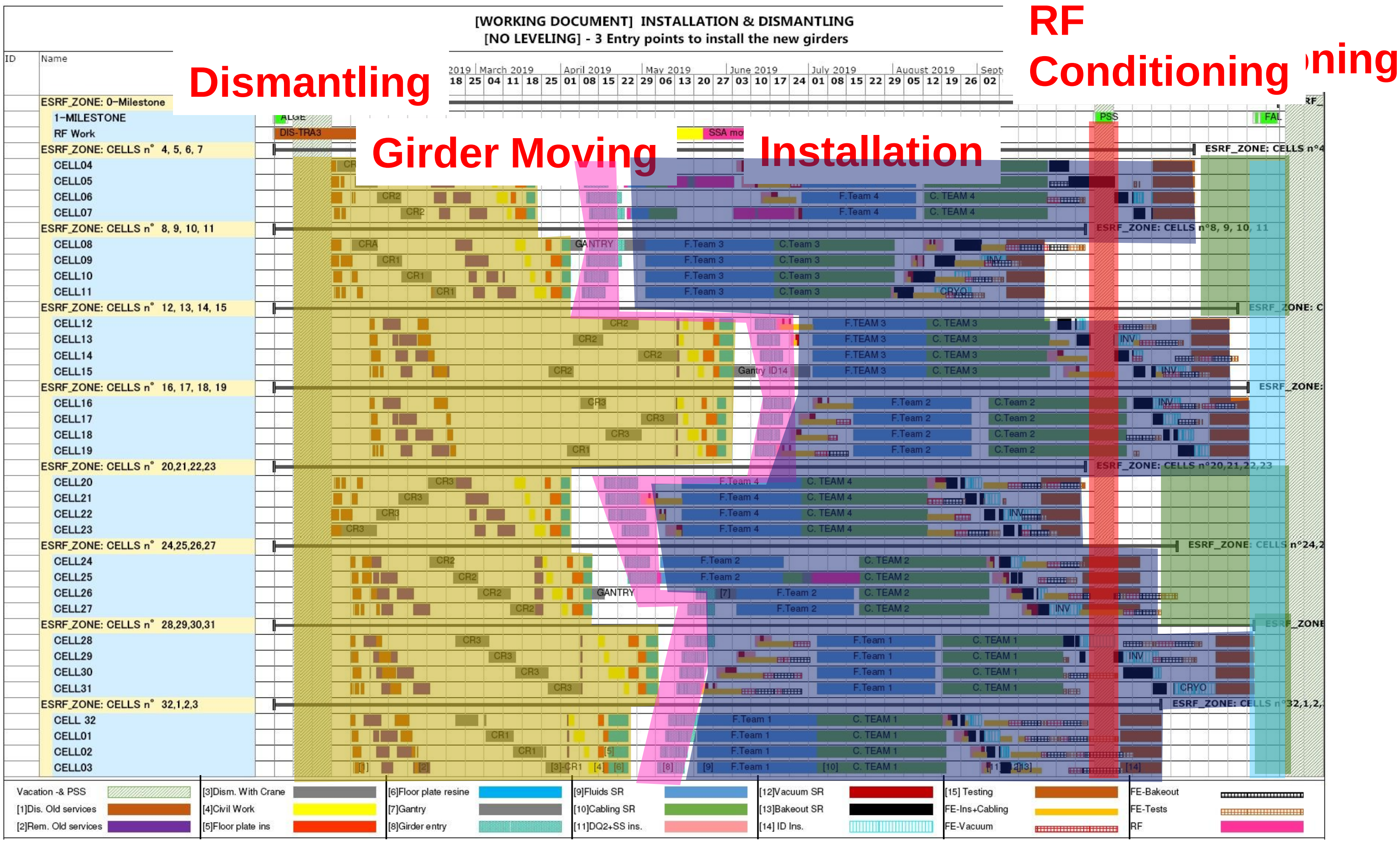
P

Transporting the girder and keeping the magnets aligned

- Max acceleration recorded: 1.5g
- Magnet alignment preserved

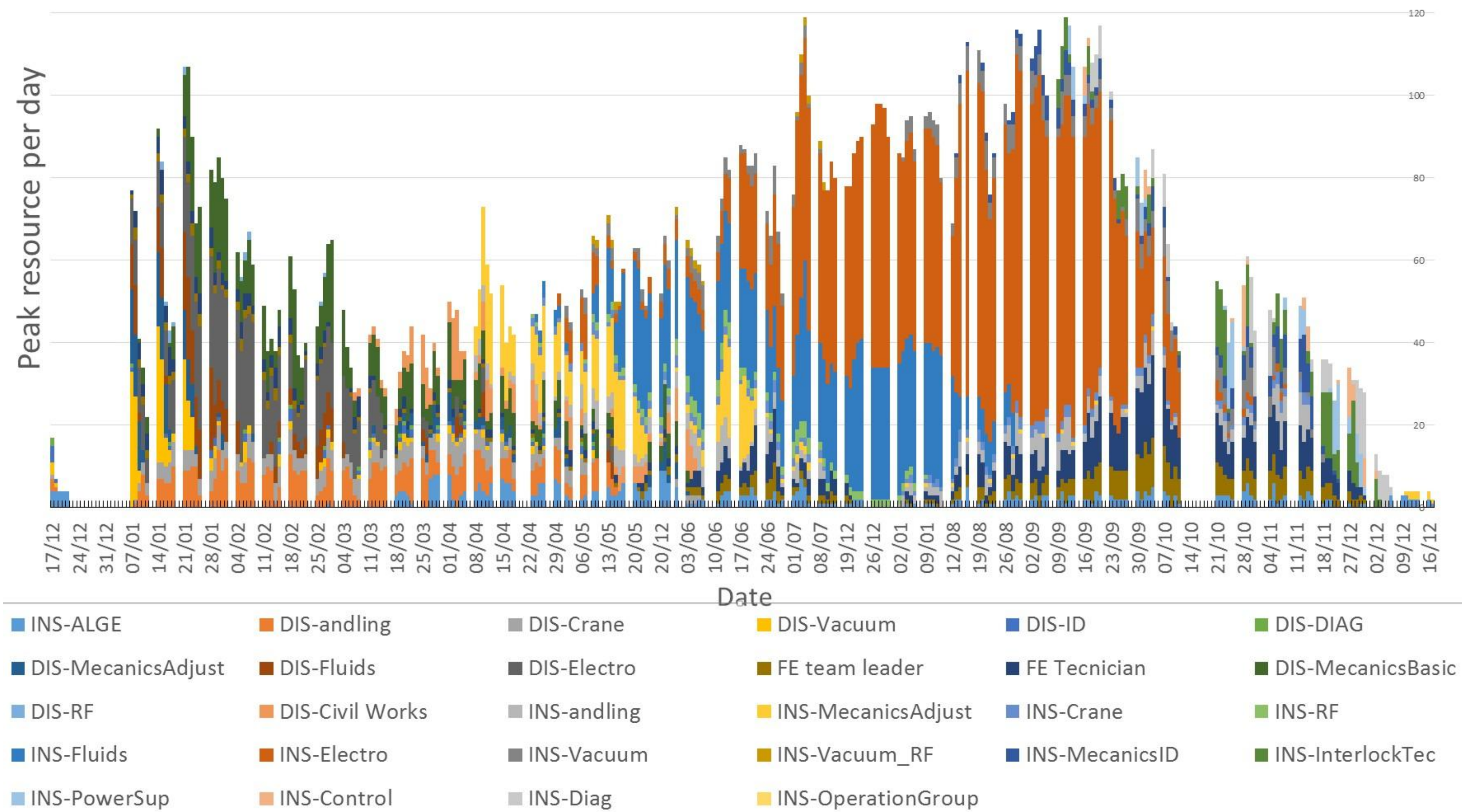
S Arnaud,T Brochard,
M Lesourd, D Martin

Dismantling + Assembly planning



Courtesy: Q Brioulet

Dismantling + Installation - Human Resource Requirements



Conclusions

- ✓The main engineering challenges are:
  - ✓Extreme compactness/lack of space which required multiple design iterations and complex vacuum chambers
  - ✓System integration
  - ✓Vacuum chambers tolerances
  - ✓Schedule & installation in existing tunnel
- ✓ Production of most of the components of ESRF-EBS is launched
- ✓ Pre-series for most components will be delivered in the coming months
- ✓ Follow up of contracts will the major activity over the next 12 months
- ✓ Planning and organisation charts will be finalised before the end of the year

- ✓ **The project is well under way!**

Many thanks for your attention

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