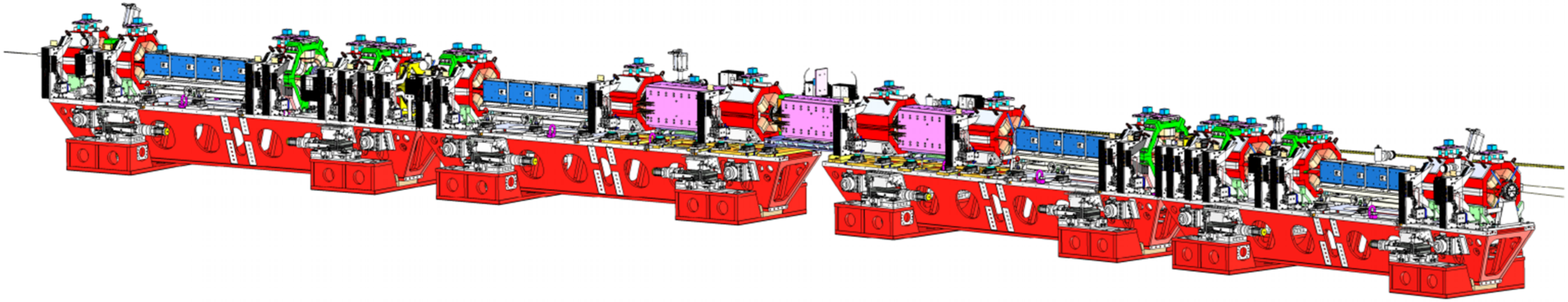


THE ESRF ACCELERATOR UPGRADE:

THE EXTREMELY BRILLIANT SOURCE (EBS) PROJECT

OVERVIEW AND ENGINEERING CHALLENGES

Philippe Marion, Jean-Claude Biasci, Loys Goirand, Yves Dabin

marion@esrf.fr

This presentation is given on behalf of many ESRF contributors.

A specific acknowledgement must be mentioned to **Pantaleo RAIMONDI** who proposed the project and is the EBS project manager.

The contribution of **Loys GOIRAND** and **Jean-Claude BIASCI** should be underlined as technical coordinators of all EBS engineering projects and of **Yves DABIN** for expertise and modeling works.

OUTLINE

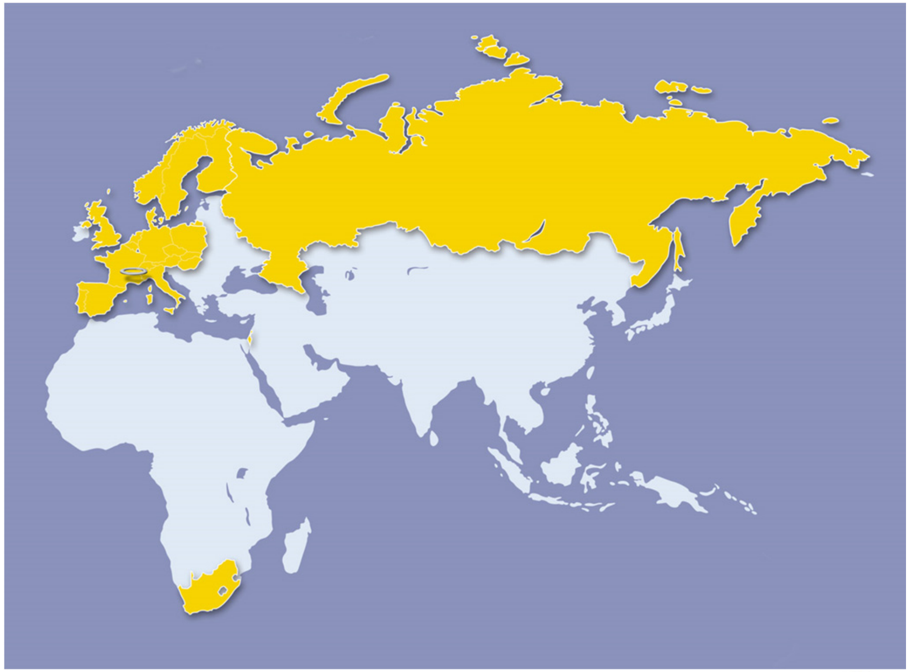
- **The ESRF Extremely Brilliant Source (EBS): context, time schedule, expected gain.**

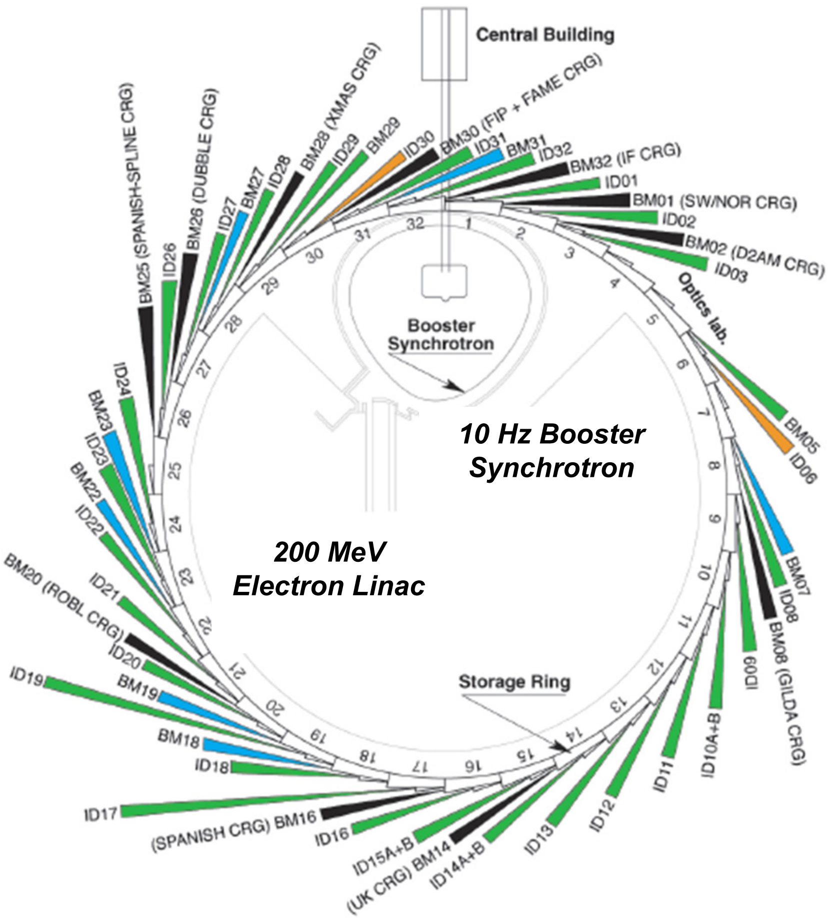
- **Engineering challenges**

The ESRF is a third generation light source

Location:	**Grenoble, France**
Staff:	**600**
Start User Mode	**1994**

Funded by	**21 countries**
Annual budget:	**100 million €**





42 Beamlines

(including 12 Bending Magnet Beamlines)

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

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

THE EBS PROJECT: MAIN FIGURES

The **Extremely Brilliant Source** Project: Design and Build **a new storage Ring** to be installed in place of the existing one, with the following objectives and parameters:

- Substantially **decrease** the Store Ring Equilibrium **Horizontal Emittance**
- **Increase the photon source brilliance and its coherence fraction**
- Green light in June 2014. Installation in 2019-2020. Budget: 100 ME
- Must fit in the same tunnel : same circumference as much as possible
- IDs at same locations: keep Beamlines where they are
- Re-use injector complex

THE EBS PROJECT: MAIN FIGURES

The **Extremely Brilliant Source** Project: Design and Build **a new storage Ring** to be installed in place of the existing one, with the following objectives and parameters:

- Substantially **decrease** the Store Ring Equilibrium **Horizontal Emittance**
- **Increase the photon source brilliance and its coherence fraction**
- Green light in June 2014. Installation in 2019-2020. Budget: 100 ME
- Must fit in the same tunnel : same circumference as much as possible
- 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

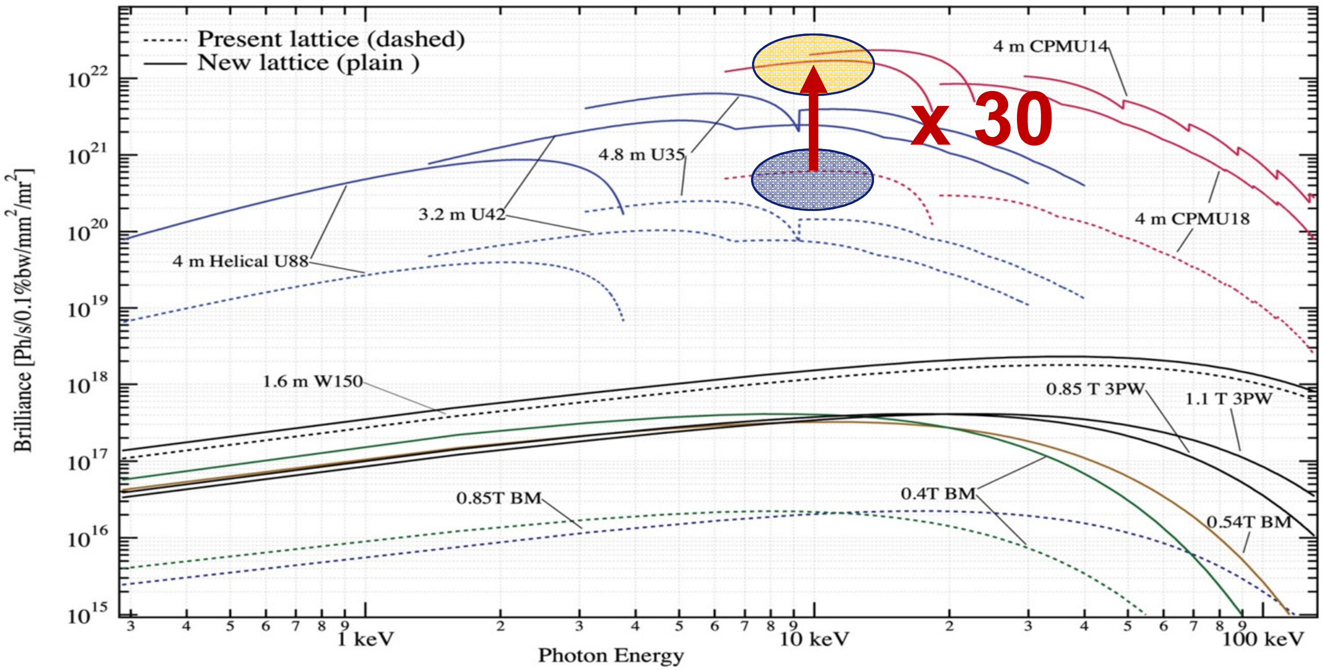
reduced by factor 29

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

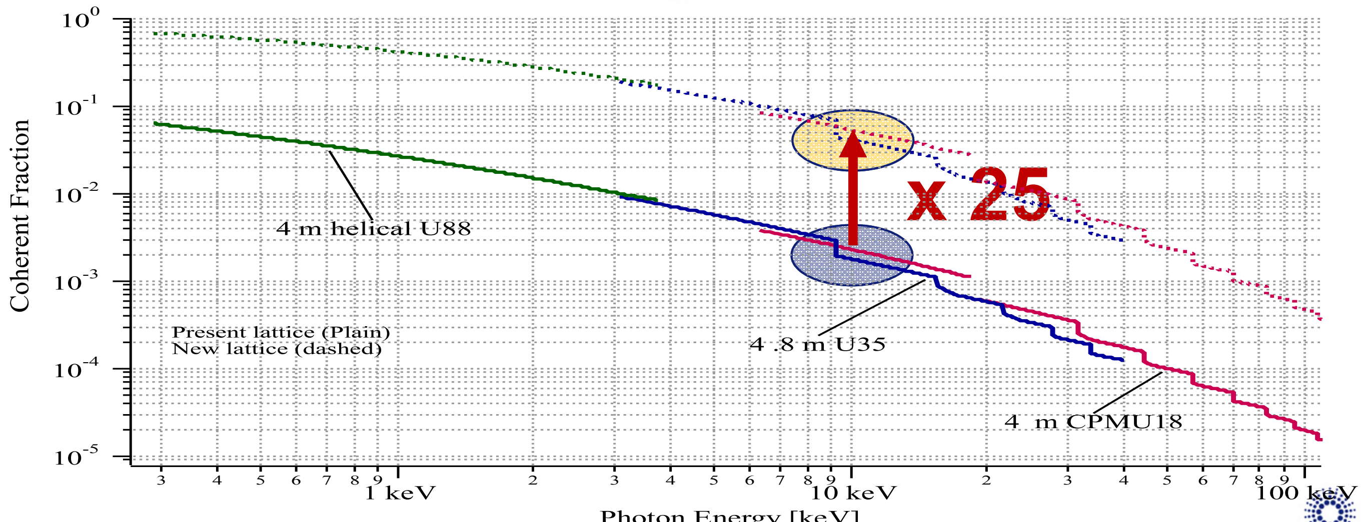
GAIN IN PHOTON BEAM BRILLIANCE & COHERENT FRACTION

***e- beam emittance* ↘**

***Undulators photon beam brilliance* ↗**



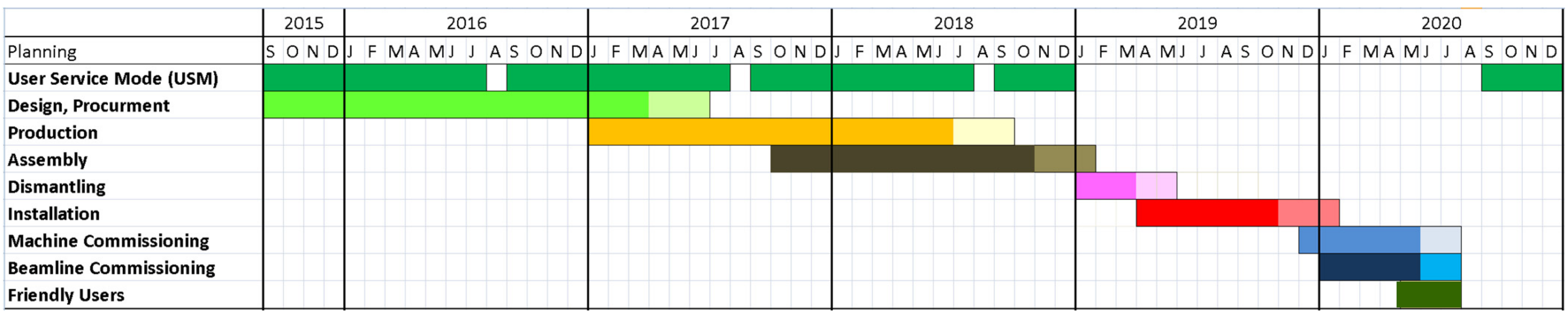
***Coherent fraction* ↗**



Courtesy Joel Chavanne

MEDSI 2016

The EBS Major Milestones

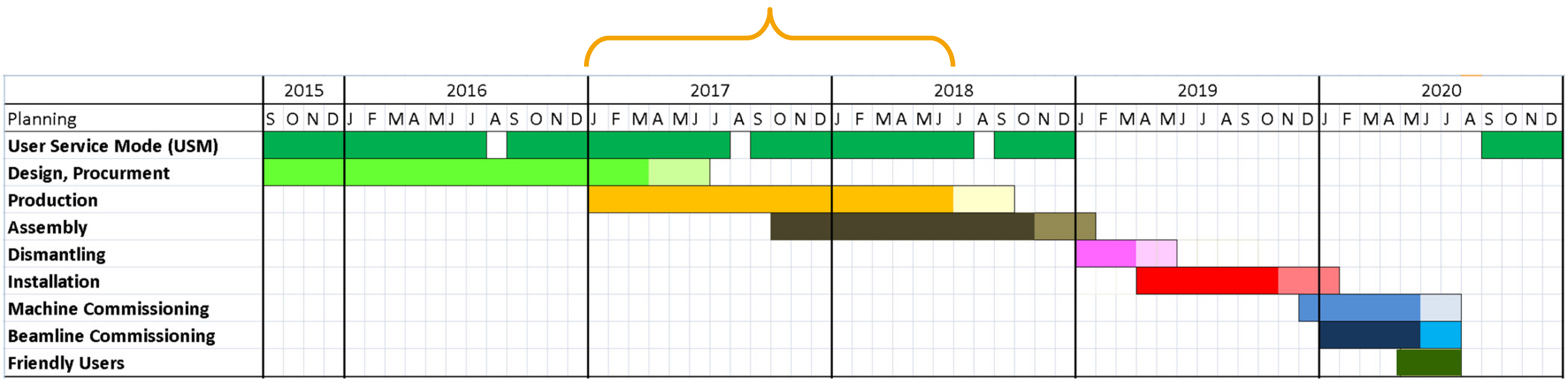


Courtesy of Pantaleo Raimondi

The EBS Major Milestones

➢ Pre-assemble fully equipped girders before end of 2018

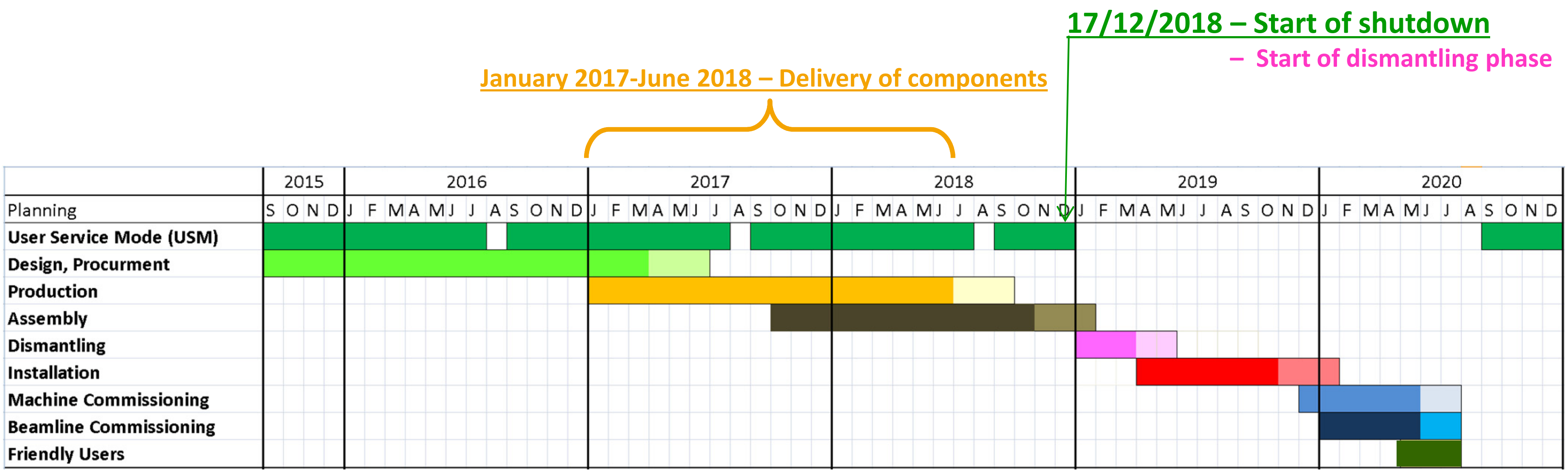
January 2017-June 2018 – Delivery of components



Courtesy of Pantaleo Raimondi

The EBS Major Milestones

- Pre-assemble fully equipped girders before end of 2018
- Shutdown for dismantling / installation from 01/2019 to 12/2019



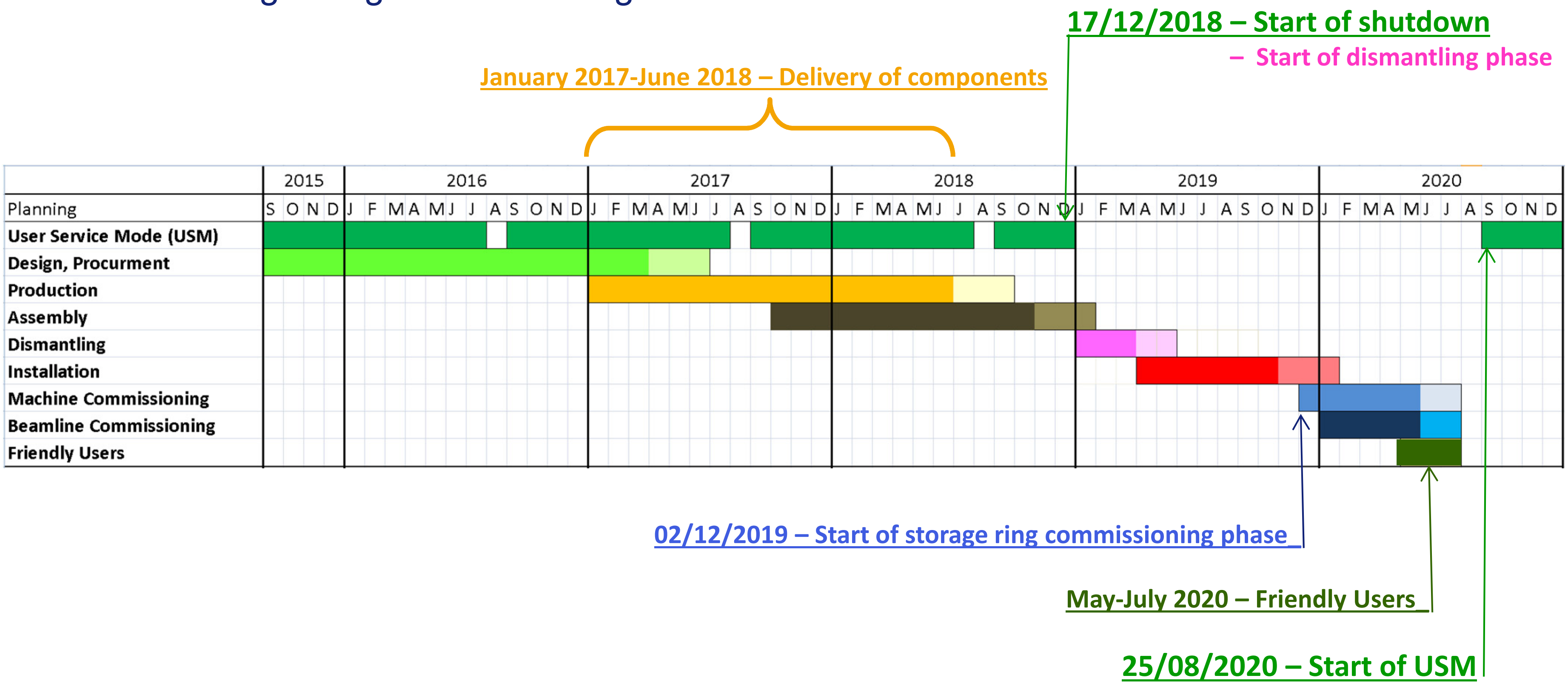
Courtesy of Pantaleo Raimondi

EBS MASTER PLAN (2015-2020)

MEDSI 2016

The EBS Major Milestones

- Pre-assemble fully equipped girders before end of 2018
- Shutdown for dismantling / installation from 01/2019 to 12/2019
- Start Storage Ring commissioning: 12/2019



Courtesy of Pantaleo Raimondi

EBS PROJECT CURRENT STATUS

EBS PROJECT CURRENT STATUS

- **Standard cells Magnets, Girders, Supports, Vacuum chambers, Absorbers:**

  Design completed

  Manufacturing contracts placed

  Pre-series components delivery planned from September to December 2016

EBS PROJECT CURRENT STATUS

- **Standard cells Magnets, Girders, Supports, Vacuum chambers, Absorbers:**

  Design completed

  Manufacturing contracts placed

  Pre-series components delivery planned from September to December 2016

- **Prototypes: Girder, Al vacuum chambers, Absorbers, RF fingers, … :**

  *Satisfactory results obtained after optimisation (**see details in dedicated presentations**)*

EBS PROJECT CURRENT STATUS

- **Standard cells Magnets, Girders, Supports, Vacuum chambers, Absorbers:**

  Design completed

  Manufacturing contracts placed

  Pre-series components delivery planned from September to December 2016

- **Prototypes: Girder, Al vacuum chambers, Absorbers, RF fingers, … :**

  *Satisfactory results obtained after optimisation (**see details in dedicated presentations**)*

- **Injection zone (*see poster from Trevor Mairs*), Diagnostics, collimators, Assembly & handling tools:**

  Design in progress

EBS PROJECT CURRENT STATUS

- **Standard cells Magnets, Girders, Supports, Vacuum chambers, Absorbers:**

  Design completed

  Manufacturing contracts placed

  Pre-series components delivery planned from September to December 2016

- **Prototypes: Girder, Al vacuum chambers, Absorbers, RF fingers, … :**

  *Satisfactory results obtained after optimisation (**see details in dedicated presentations**)*

- **Injection zone (*see poster from Trevor Mairs*), Diagnostics, collimators, Assembly & handling tools:**

  Design in progress

- **Temperature induced position drifts of girders, magnets and BPMs:**

  *Modeling and mock up tests in progress (**see details in dedicated presentation**)*

EBS PROJECT CURRENT STATUS

- **Standard cells Magnets, Girders, Supports, Vacuum chambers, Absorbers:**

  Design completed

  Manufacturing contracts placed

  Pre-series components delivery planned from September to December 2016

- **Prototypes: Girder, Al vacuum chambers, Absorbers, RF fingers, … :**

  *Satisfactory results obtained after optimisation (**see details in dedicated presentations**)*

- **Injection zone (*see poster from Trevor Mairs*), Diagnostics, collimators, Assembly & handling tools:**

  Design in progress

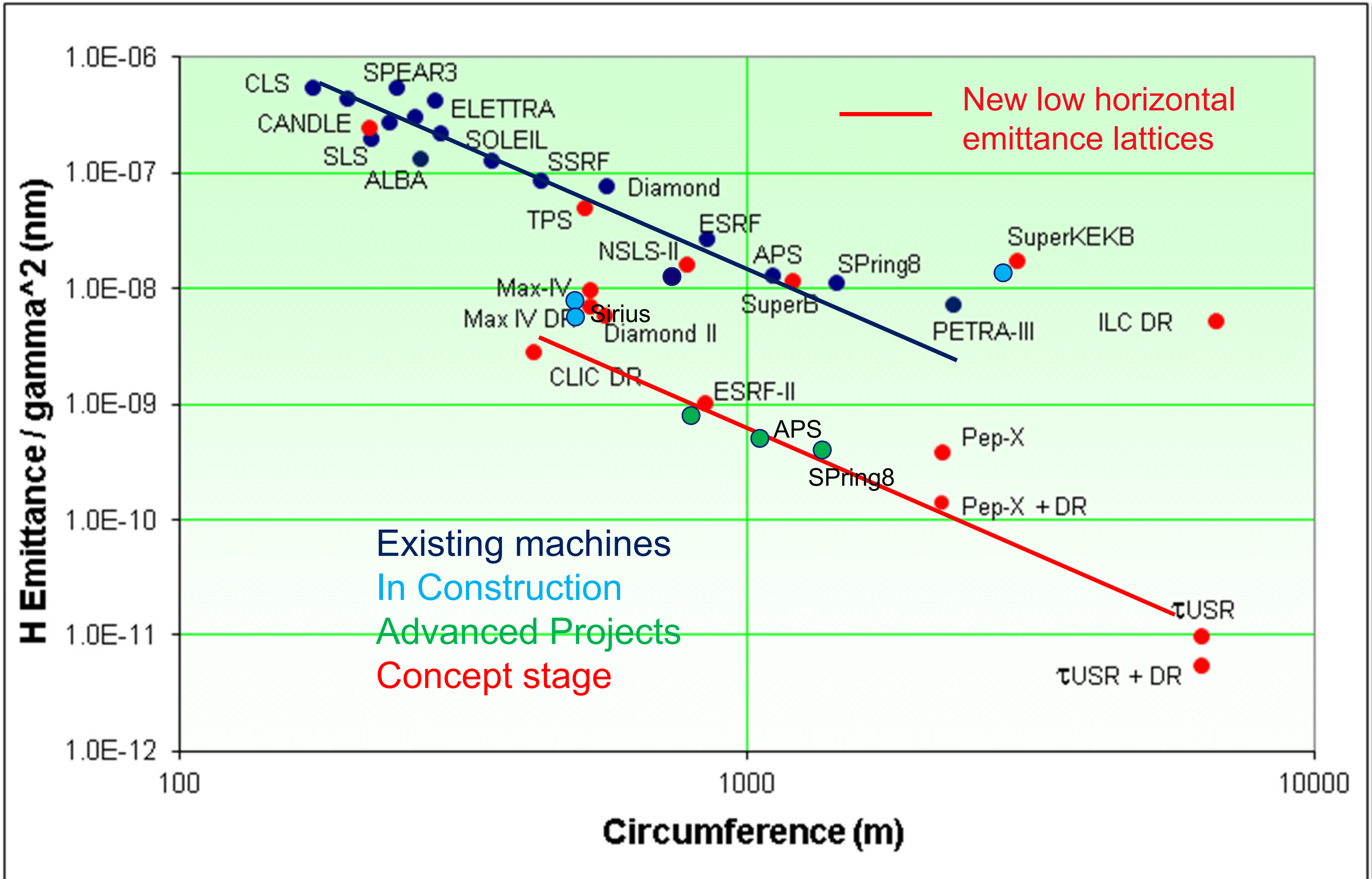
- **Temperature induced position drifts of girders, magnets and BPMs:**

  *Modeling and mock up tests in progress (**see details in dedicated presentation**)*

- **Infrastructure adaptations:**

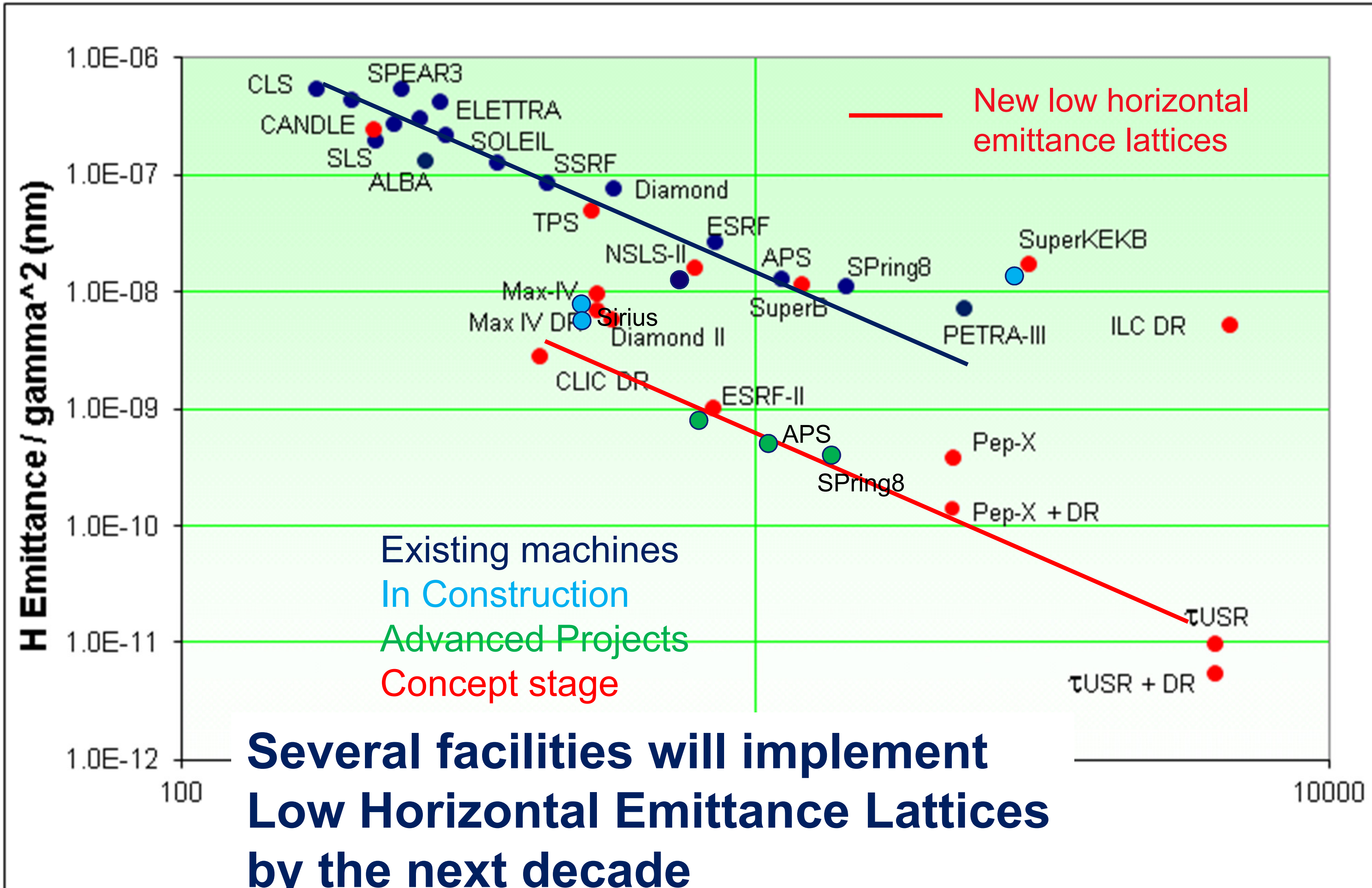
  Some contracts placed / some CFTs in progress

LOW EMITTANCE RINGS TREND



Courtesy of Pantaleo Raimondi

LOW EMITTANCE RINGS TREND



Several facilities will implement Low Horizontal Emittance Lattices by the next decade

Courtesy of Pantaleo Raimondi

OUTLINE

- The ESRF Extremely Brilliant Source (EBS): context, time schedule, expected gain.

- **Engineering challenges**

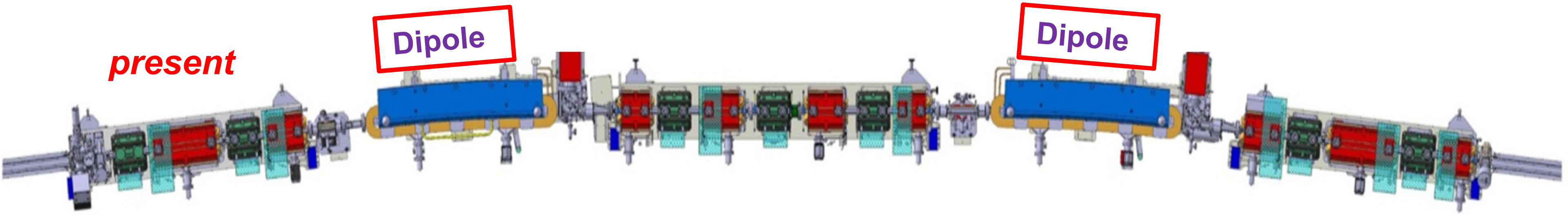
PRESENT LATTICE VS NEW ESRF LATTICE

ESRF storage ring = 32 cells   Each cell = 26.4m long (21.2m arc + 5.2m insertion device)

➢ **Present ESRF lattice**

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

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



PRESENT LATTICE VS NEW ESRF LATTICE

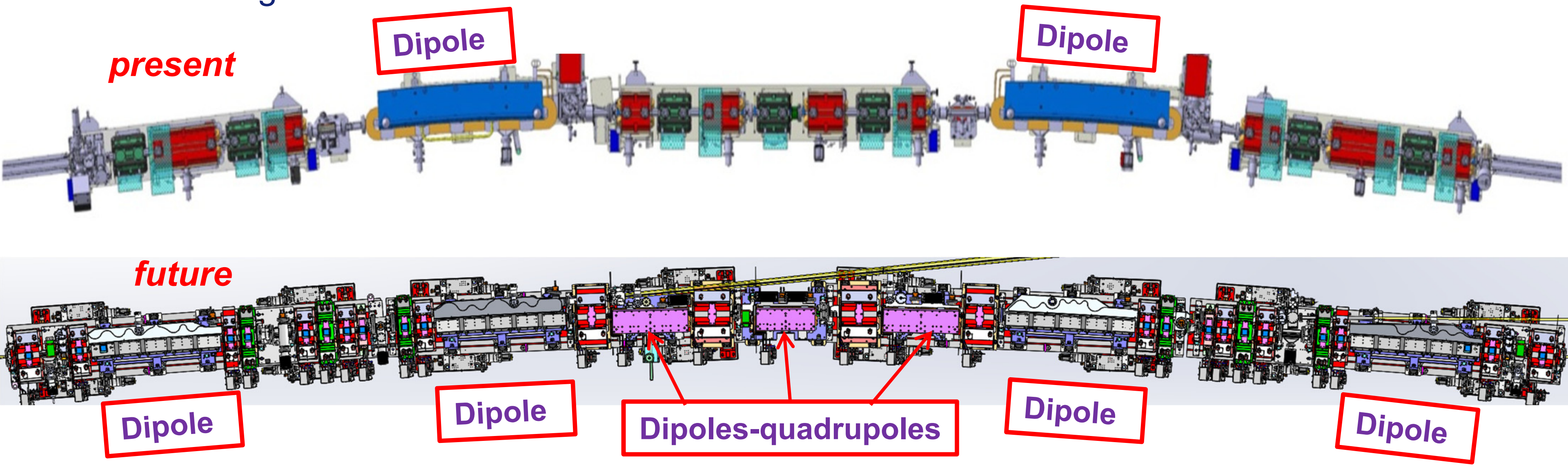
ESRF storage ring = 32 cells Each cell = 26.4m long (21.2m arc + 5.2m insertion device)

- **Present ESRF lattice**

Double Bend Achromat = (2 dipoles + 15 quad. sext.) per cell
ID length = 5 m (standard) / 6m / 7m

- **ESRF EBS lattice**

Hybrid 7 Bend Achromat = (4 dipoles + 3 dipoles-quad + 24 quad., sext., oct.) per cell
ID length = 5 m



PRESENT LATTICE VS NEW ESRF LATTICE

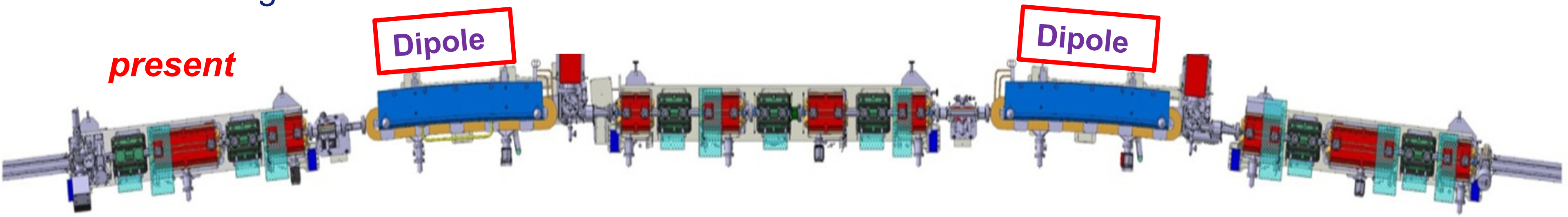
ESRF storage ring = 32 cells   Each cell = 26.4m long (21.2m arc + 5.2m insertion device)

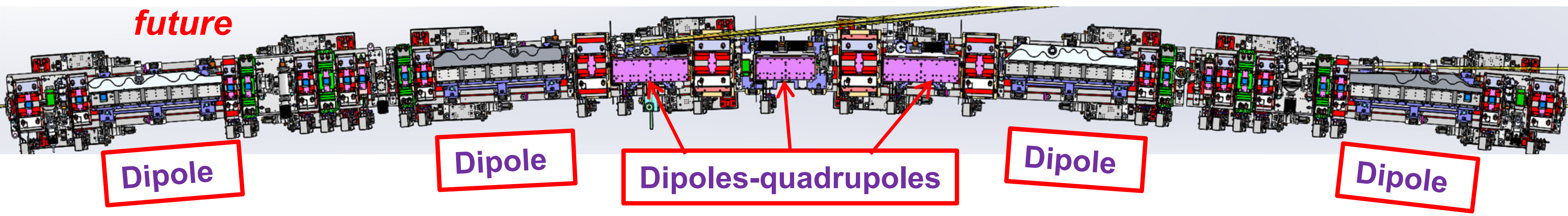
- **Present ESRF lattice**

Double Bend Achromat = (2 dipoles + 15 quad. sext.) per cell
ID length = 5 m (standard) / 6m / 7m

- **ESRF EBS lattice**

Hybrid 7 Bend Achromat = (4 dipoles + 3 dipoles-quad + 24 quad., sext., oct.) per cell
ID length = 5 m

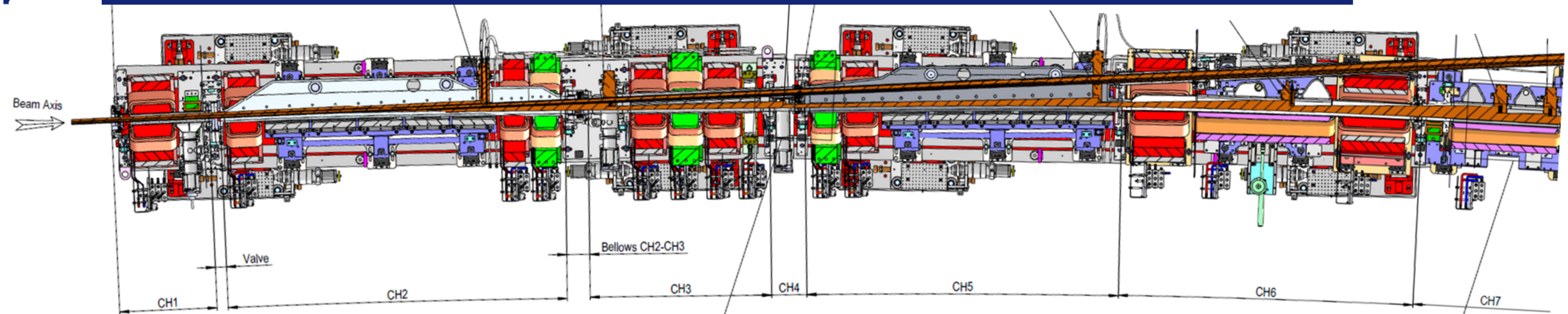


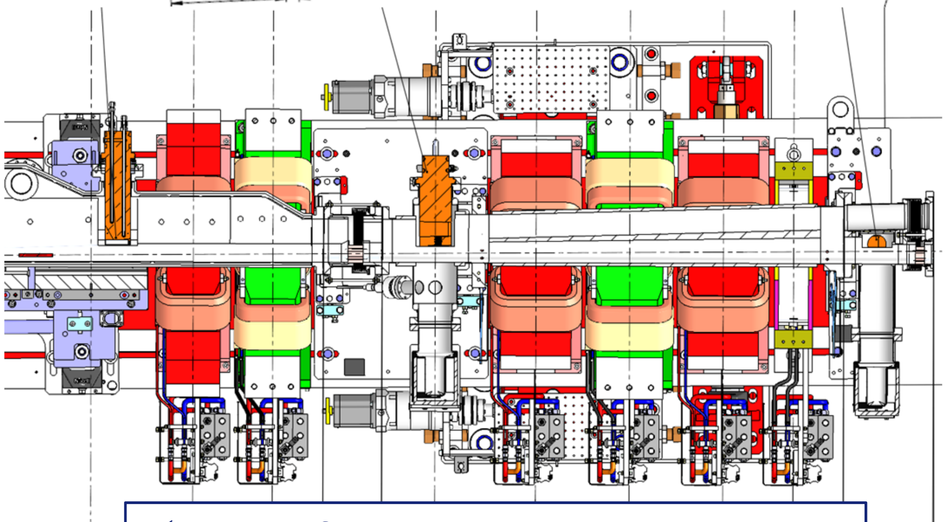


31 magnets per cell instead of 17 currently

Free space between magnets (total for one cell): **3.4m** instead of **8m** today !!

EBS – ENGINEERING CHALLENGE #1 = LACK OF SPACE





- More magnets (31 per cell instead of 17 now)

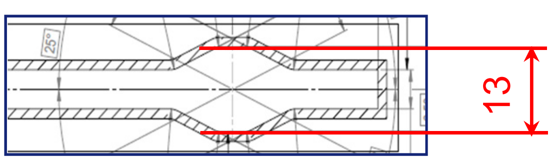
=> Very little space between magnets!!

⇒ Lack of space for flanges, valves, bellows, absorbers

+ Small magnetic gaps => vacuum chambers with small cross sections and tight tolerances

=> Vacuum chambers very difficult to design and manufacture.

✓ Low profile chambers section inside dipole-quadrupoles and HF quadrupoles:



See at 14:20 today presentation by L. Goirand: "EBS Vacuum chambers and contact fingers"

EBS – ENGINEERING CHALLENGE #2 = PRECISION AND STABILITY

Source stability specification: EBS vs “old” ESRF

		Average e- rms beam size [µm]	Beam position stability required = 0.1x e- beam size [µm]
EBS	H	26	2.6
	V	4	0.4
Old ESRF	H	310	31.0
	V	9	0.9

H = Horizontal
V = Vertical

Source stability specification: EBS vs "old" ESRF

		Average e- rms beam size [µm]	Beam position stability required = 0.1x e- beam size [µm]
EBS	H	26	2.6
	V	4	0.4
Old ESRF	H	310	31.0
	V	9	0.9

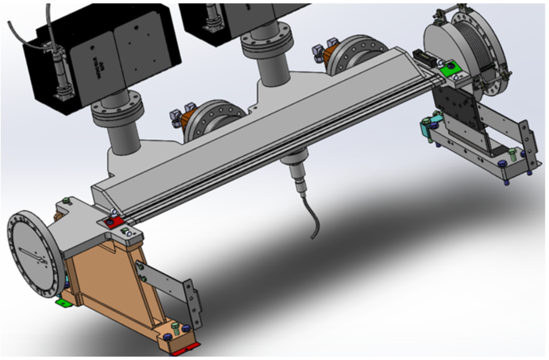
H = Horizontal
V = Vertical

- Still much more critical in V than in H (factor 6).
- In V, EBS is 2.2 times more demanding than old ESRF.

BPMs position stability requirements

Target specification for the position stability of e- Beam Position Monitors in Vertical:

Over 8 hour (Thermal + ground drifts): < 1μm RMS
Over 1-100Hz (Vibration): < 200nm RMS



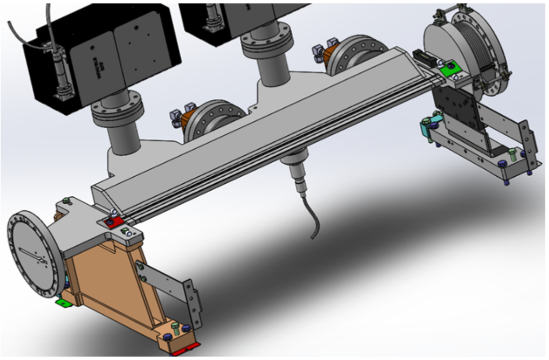
- Works in progress on the air temperature stability
- BPM stability will be measured on a mock up of a complete girder
- Careful management of ground drifts

EBS – ENGINEERING CHALLENGE #2 = PRECISION AND STABILITY (CTND)

BPMs position stability requirements

Target specification for the position stability of e- Beam Position Monitors in Vertical:

Over 8 hour (Thermal + ground drifts):	< 1µm RMS
Over 1-100Hz (Vibration):	< 200nm RMS



- Works in progress on the air temperature stability
- BPM stability will be measured on a mock up of a complete girder
- Careful management of ground drifts

Magnets static position requirements

Alignment specification requested by accelerator physicists:

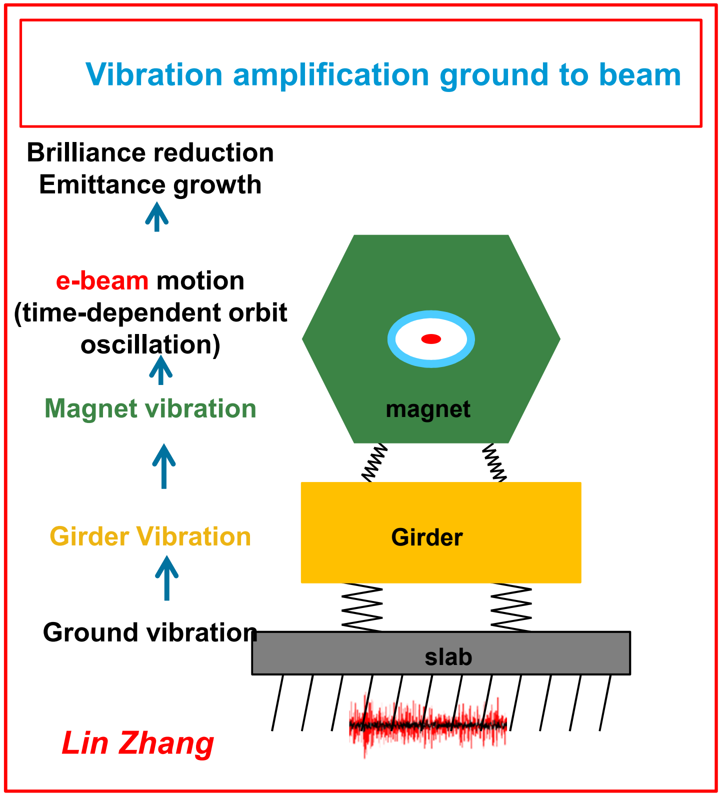
Magnet to Magnet and Girder to Girder:	Horizontal:	< 50µm
	Vertical:	< 50µm

- Challenging specification for the initial alignment considering all sources of errors of the alignment process.
- Careful management of thermal drifts required
- Careful management of ground drifts required

See today at 10:10: "Thermal stability of the new ESRF EBS" by B. Tampigny

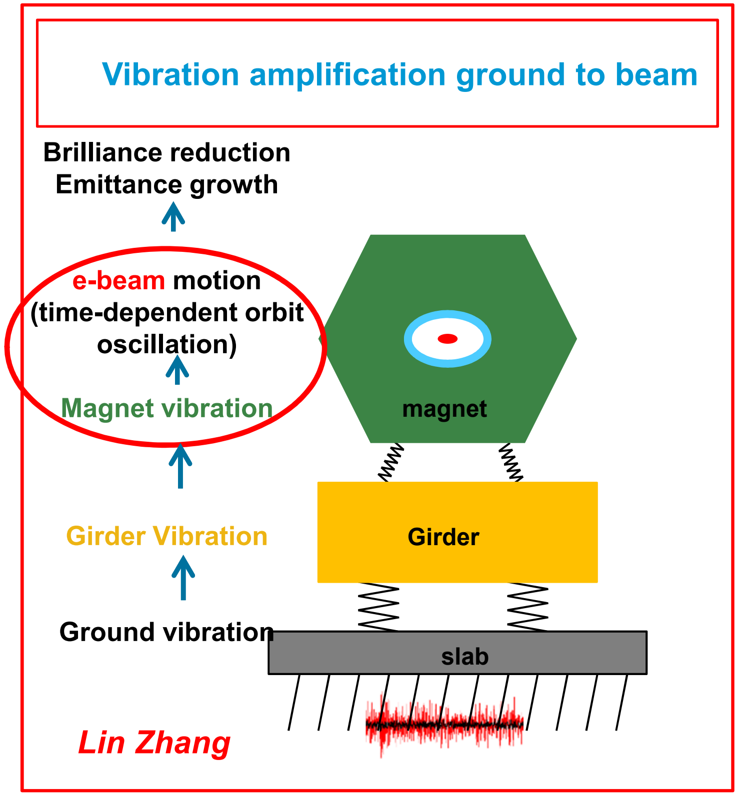
EBS – ENGINEERING CHALLENGE #2 = PRECISION AND STABILITY (CTND)

Magnets and Girders: Vibration stability. Sensibility to random magnets displacements



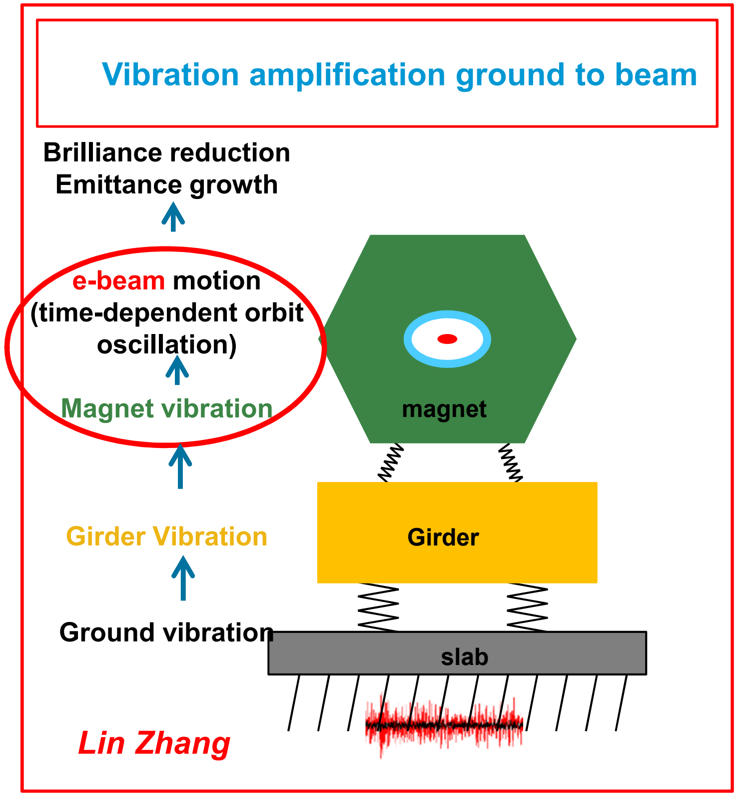
EBS – ENGINEERING CHALLENGE #2 = PRECISION AND STABILITY (CTND)

Magnets and Girders: Vibration stability. Sensibility to random magnets displacements



EBS – ENGINEERING CHALLENGE #2 = PRECISION AND STABILITY (CTND)

Magnets and Girders: Vibration stability. Sensibility to random magnets displacements



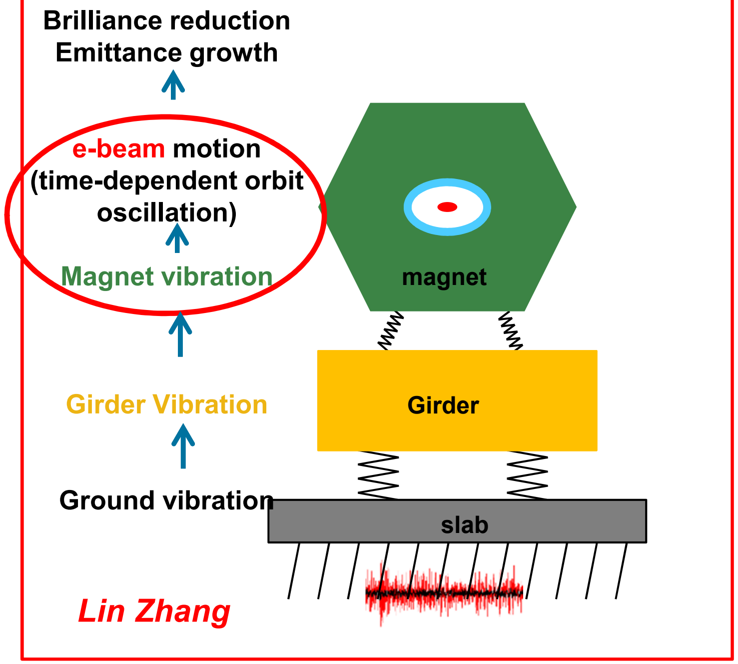
Calculate lattice amplification factor:
e- beam motion / random magnets motion
(L. Farvacque, ESRF Theory group)

Multiply by acceptable beam instability (0.1 x beam size)

		Acceptable magnets random motions [nm]
EBS	H	84
	V	8
Old ESRF	H	526
	V	18

Magnets and Girders: Vibration stability. Sensibility to random magnets displacements

Vibration amplification ground to beam



Calculate lattice amplification factor:
e- beam motion / random magnets motion
(L. Farvacque, ESRF Theory group)

Multiply by acceptable beam instability (0.1 x beam size)

		Acceptable magnets random motions [nm]
EBS	H	84
	V	8
Old ESRF	H	526
	V	18

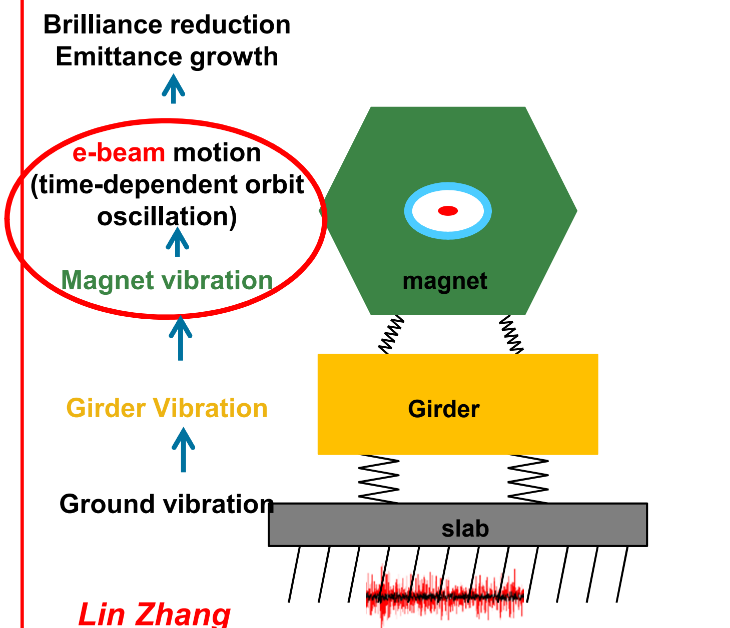
In V, EBS is 2.2 times more sensitive to magnets vibrations than old ESRF.

⇒ Girder designed to keep vibrations as low as possible .

EBS – ENGINEERING CHALLENGE #2 = PRECISION AND STABILITY (CTND)

Magnets and Girders: Vibration stability. Sensibility to random magnets displacements

Vibration amplification ground to beam



Lin Zhang

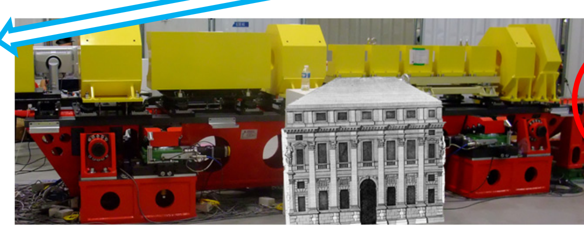
Calculate lattice amplification factor:
e- beam motion / random magnets motion
(L. Farvacque, ESRF Theory group)

Multiply by acceptable beam instability (0.1 x beam size)

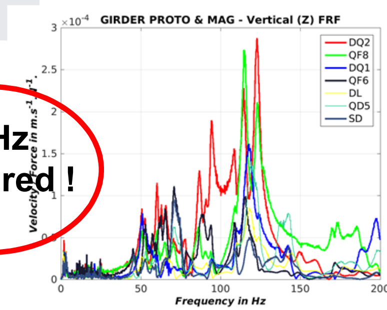
		Acceptable magnets random motions [nm]
EBS	H	84
	V	8
Old ESRF	H	526
	V	18

In V, EBS is 2.2 times more sensitive to magnets vibrations than old ESRF.

⇒ Girder designed to keep vibrations as low as possible .



51 Hz measured !

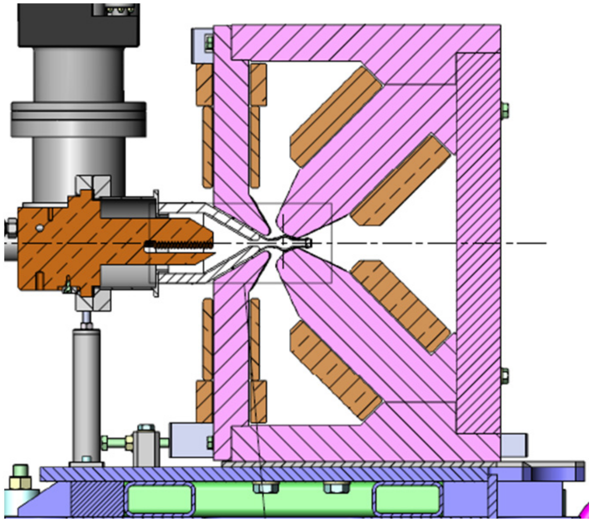


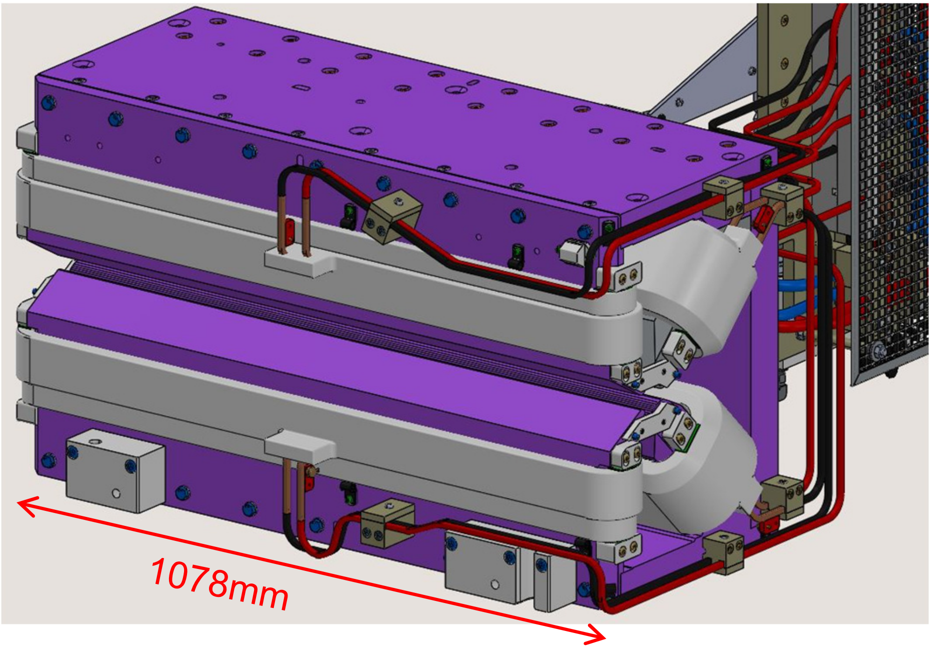
Refer to: "The girders system for the new ESRF Storage Ring" by F. Cianciosi presented yesterday.

Example: Combined Dipole-Quadrupole magnets

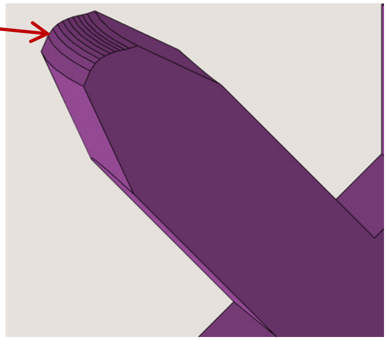
A novel design with an open shape, curved poles shapes and precise shape tolerances

- Combined dipole quadrupole (0.54T and 37T/m), 3 magnets per cell (x 32 cells)
- High accuracy mechanical assembly : 80µm tolerance on poles surfaces to be preserved after opening – closing and with magnetic forces.
- Mechanical design proposed by ESRF, recently finalised with magnets supplier.





The poles are curved to follow e- orbit and vacuum chamber.
Individual pole shape tolerance 40µm.



Courtesy of Gael Le Bec, Francois Villar

CONCLUSION

➢The EBS project (new ESRF storage ring) will enable x30 reduction the e- beam horizontal emittance. The design of the standard sections of the new storage ring is now completed and the main manufacturing contracts started.

CONCLUSION

- The EBS project (new ESRF storage ring) will enable x30 reduction the e- beam horizontal emittance. The design of the standard sections of the new storage ring is now completed and the main manufacturing contracts started.

- The main engineering challenges are:

  - Extreme compactness/lack of space which obliged to multiple design iterations and to complex vacuum chambers.

  - Static precision requirements: 2.2 times lower value than old ESRF (in vertical)

$\Rightarrow$ Demanding but achievable.
$\Rightarrow$ Modeling and measurements of thermal drifts of magnets and BPMs on a mock up in progress.

  - Vibration stability of magnets required: 2.2 times more demanding than old ESRF

$\Rightarrow$ Girders and magnets supports designed for maximum stiffness.
1st resonant frequency = 51Hz measured on prototype girder.

  - Manufacture of some magnets and vacuum chambers within the requested tolerances. We are impatient to inspect the pre-serie parts in the coming months…

CONCLUSION

➢The EBS project (new ESRF storage ring) will enable x30 reduction the e- beam horizontal emittance. The design of the standard sections of the new storage ring is now completed and the main manufacturing contracts started.

➢The main engineering challenges are:

- Extreme compactness/lack of space which obliged to multiple design iterations and to complex vacuum chambers.

- Static precision requirements: 2.2 times lower value than old ESRF (in vertical)

⇒ Demanding but achievable.
⇒ Modeling and measurements of thermal drifts of magnets and BPMs on a mock up in progress.

- Vibration stability of magnets required: 2.2 times more demanding than old ESRF

⇒ Girders and magnets supports designed for maximum stiffness.
1st resonant frequency = 51Hz measured on prototype girder.

- Manufacture of some magnets and vacuum chambers within the requested tolerances. We are impatient to inspect the pre-serie parts in the coming months…

➢ Most beamlines are compatible and some already optimised for the new source. However, to fully exploit the new source and explore new scientific ideas, the ESRF Upgrade program includes the construction of 4 new beamlines and the refurbishment of 7-9 beamlines in 2017-2022. No rest for the engineers !!

THANK YOU FOR YOUR ATTENTION

This presentation is given on behalf of many ESRF contributors.

A specific acknowledgement must be mentioned to **Pantaleo RAIMONDI** who proposed the project and is the EBS project manager.

The contribution of **Loys GOIRAND** and **Jean-Claude BIASCI** should be underlined as technical coordinators of all EBS engineering projects and of **Yves DABIN** for expertise and modeling works.