European Synchrotron Light Source workshop XIX

ESRF Operation and Upgrade status report

J. L. Revol

On behalf of the
Accelerator & Source Division

Pascal Elleaume

École Normale Supérieure de Physique (Ulm)

1984: Thesis : «Laser à électrons libres sur l'anneau de collision d'Orsay» (Y. Petroff, Y. Farge)
Design of the Super-ACO FEL

1986: ESRF: Head of the Insertion Device Group

2001 : ESRF: Director of the Accelerator & Source Division

19/03/2011: Accidental death in the French Alps at 55

Pascal was the initiator of the accelerator upgrade

ESRF Upgrade 2009-2018

Funding for a first phase (from 2009 to 2015) secured to deliver:

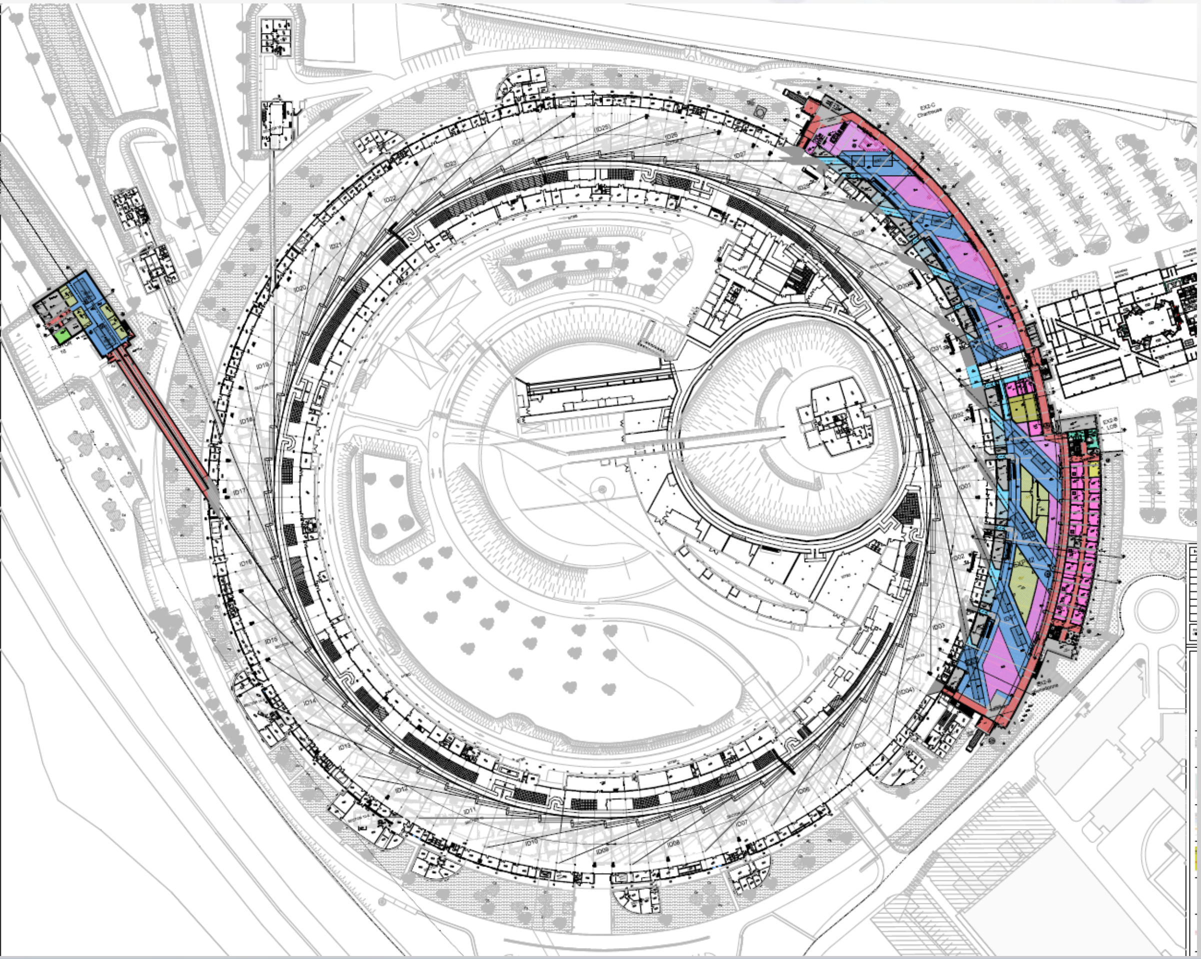
- **Eight new beamlines, with an extension of the experimental hall.**
- **Refurbishment of many existing beamlines**
- **Upgrade of the X ray source for availability, stability and brilliance**
- **Developments in synchrotron radiation instrumentation**

While maintaining an operational facility

New buildings

A light for Science

Longer beamlines
Increased capacity



Beginning of works:
October 2011

New buildings

Started !!!

With a long winter shutdown

A light for Science

Nov 2011				Dec 2011				Jan 2012				Feb 2012				Mar 2012				Apr 2012				May 2012			
Tue 01				Thu 01	.	.	.	Sun 01	s	s	s	Wed 01	s	s	s	Thu 01	s	s	s	Sun 01	s	s	s	Tue 01	M	M	M
Wed 02				Fri 02	.	.	.	Mon 02	s	s	s	Thu 02	s	s	s	Fri 02	s	s	s	Mon 02	s	s	s	Wed 02	M	M	M
Thu 03				Sat 03	.	.	.	Tue 03	s	s	s	Fri 03	s	s	s	Sat 03	s	s	s	Tue 03	s	s	s	Thu 03	.	.	.
Fri 04				Sun 04	.	.	.	Wed 04	s	s	s	Sat 04	s	s	s	Sun 04	s	s	s	Wed 04	s	s	s	Fri 04	.	.	.
Sat 05				Mon 05	s	s	s	Thu 05	s	s	s	Sun 05	s	s	s	Mon 05	s	s	s	Thu 05	s	s	s	Sat 05	.	.	.
Sun 06				Tue 06	s	s	s	Fri 06	s	s	s	Mon 06	s	s	s	Tue 06	s	s	s	Fri 06	s	s	s	Sun 06	.	.	.
Mon 07				Wed 07	s	s	s	Sat 07	s	s	s	Tue 07	s	s	s	Wed 07	s	s	s	Sat 07	s	s	s	Mon 07	.	.	.
Tue 08				Thu 08	s	s	s	Sun 08	s	s	s	Wed 08	s	s	s	Thu 08	s	s	s	Sun 08	s	s	s	Tue 08	M	M	M
Wed 09				Fri 09	s	s	s	Mon 09	s	s	s	Thu 09	s	s	s	Fri 09	s	s	s	Mon 09	s	s	s	Wed 09	.	.	.
Thu 10				Sat 10	s	s	s	Tue 10	s	s	s	Fri 10	s	s	s	Sat 10	s	s	s	Tue 10	s	s	s	Thu 10	.	.	.
Fri 11				Sun 11	s	s	s	Wed 11	s	s	s	Sat 11	s	s	s	Sun 11	s	s	s	Wed 11	s	s	s	Fri 11	.	.	.
Sat 12				Mon 12	s	s	s	Thu 12	s	s	s	Sun 12	s	s	s	Mon 12	r	r	r	Thu 12	s	s	s	Sat 12	.	.	.
Sun 13				Tue 13	s	s	s	Fri 13	s	s	s	Mon 13	s	s	s	Tue 13	r	r	r	Fri 13	s	s	s	Sun 13	.	.	.
Mon 14				Wed 14	s	s	s	Sat 14	s	s	s	Tue 14	s	s	s	Wed 14	r	r	r	Sat 14	s	s	s	Mon 14	M	M	M
Tue 15				Thu 15	s	s	s	Sun 15	s	s	s	Wed 15	s	s	s	Thu 15	r	r	r	Sun 15	s	s	s	Tue 15	M	M	M
Wed 16				Fri 16	s	s	s	Mon 16	s	s	s	Thu 16	s	s	s	Fri 16	r	r	r	Mon 16	s	s	s	Wed 16	.	.	.
Thu 17				Sat 17	s	s	s	Tue 17	s	s	s	Fri 17	s	s	s	Sat 17	r	r	r	Tue 17	s	s	s	Thu 17	.	.	.
Fri 18	.	.	.	Sun 18	s	s	s	Wed 18	s	s	s	Sat 18	s	s	s	Sun 18	r	r	r	Wed 18	s	s	s	Fri 18	.	.	.
Sat 19	.	.	.	Mon 19	s	s	s	Thu 19	s	s	s	Sun 19	s	s	s	Mon 19	M	M	M	Thu 19	s	s	s	Sat 19	.	.	.
Sun 20	.	.	.	Tue 20	s	s	s	Fri 20	s	s	s	Mon 20	s	s	s	Tue 20	M	M	M	Fri 20	r	r	r	Sun 20	.	.	.
Mon 21	.	.	.	Wed 21	s	s	s	Sat 21	s	s	s	Tue 21	s	s	s	Wed 21	M	M	M	Sat 21	r	r	r	Mon 21	.	.	.
Tue 22	M	M	M	Thu 22	s	s	s	Sun 22	s	s	s	Wed 22	s	s	s	Thu 22	M	M	M	Sun 22	r	r	r	Tue 22	M	M	M
Wed 23	.	.	.	Fri 23	s	s	s	Mon 23	s	s	s	Thu 23	s	s	s	Fri 23	M	M	M	Mon 23	r	r	r	Wed 23	.	.	.
Thu 24	.	.	.	Sat 24	s	s	s	Tue 24	s	s	s	Fri 24	s	s	s	Sat 24	M	M	M	Tue 24	r	r	r	Thu 24	.	.	.
Fri 25	.	.	.	Sun 25	s	s	s	Wed 25	s	s	s	Sat 25	s	s	s	Sun 25	M	M	M	Wed 25	r	r	r	Fri 25	.	.	.
Sat 26	.	.	.	Mon 26	s	s	s	Thu 26	s	s	s	Sun 26	s	s	s	Mon 26	s	s	s	Thu 26	M	M	M	Sat 26	.	.	.
Sun 27	.	.	.	Tue 27	s	s	s	Fri 27	s	s	s	Mon 27	s	s	s	Tue 27	s	s	s	Fri 27	M	M	M	Sun 27	.	.	.
Mon 28	.	.	.	Wed 28	s	s	s	Sat 28	s	s	s	Tue 28	s	s	s	Wed 28	s	s	s	Sat 28	M	M	M	Mon 28	.	.	.
Tue 29	M	M	M	Thu 29	s	s	s	Sun 29	s	s	s					Thu 29	s	s	s	Sun 29	M	M	M	Tue 29	M	M	M
Wed 30	.	.	.	Fri 30	s	s	s	Mon 30	s	s	s					Fri 30	s	s	s	Mon 30	M	M	M	Wed 30	.	.	.
				Sat 31	s	s	s	Tue 31	s	s	s					Sat 31	s	s	s					Thu 31	.	.	.

Accelerator Upgrade

- Upgrade of BPM electronics
  - Improvement of the beam position stability
  - Coupling reduction
  - New position feedback
- 6 m long straight sections
  - No change in magnet lattice
  - Canted straight sections
- 7 m straight sections
  - Lattice symmetry breaking
  - New magnets necessary
- Cryogenic in-vacuum undulators
- Diagnostics developments
- New RF Transmitters
- New RF Cavities

Upgrade of BPM Electronics

Slow Acquisition
(10 Hz, orbit correction)

Turn by Turn
(355 kHz, for lattice studies)

First Turn mode
(For injection tuning)

224 Libera Brillance

Post-Mortem
(on trigger, now operational)

Fast Acquisition (10 kHz)
For fast global orbit correction

Sum signal of the 4 buttons:

- Lifetime monitor
- Instant Fractional-Beamloss monitor

Coupling reduction

A light for Science

- Achieving lower coupling
  - Better resolution of the response matrices → improved model
  - New correction method: minimization of Resonance Driving Terms
  - Increased number of skew quad correctors: 32 → 64

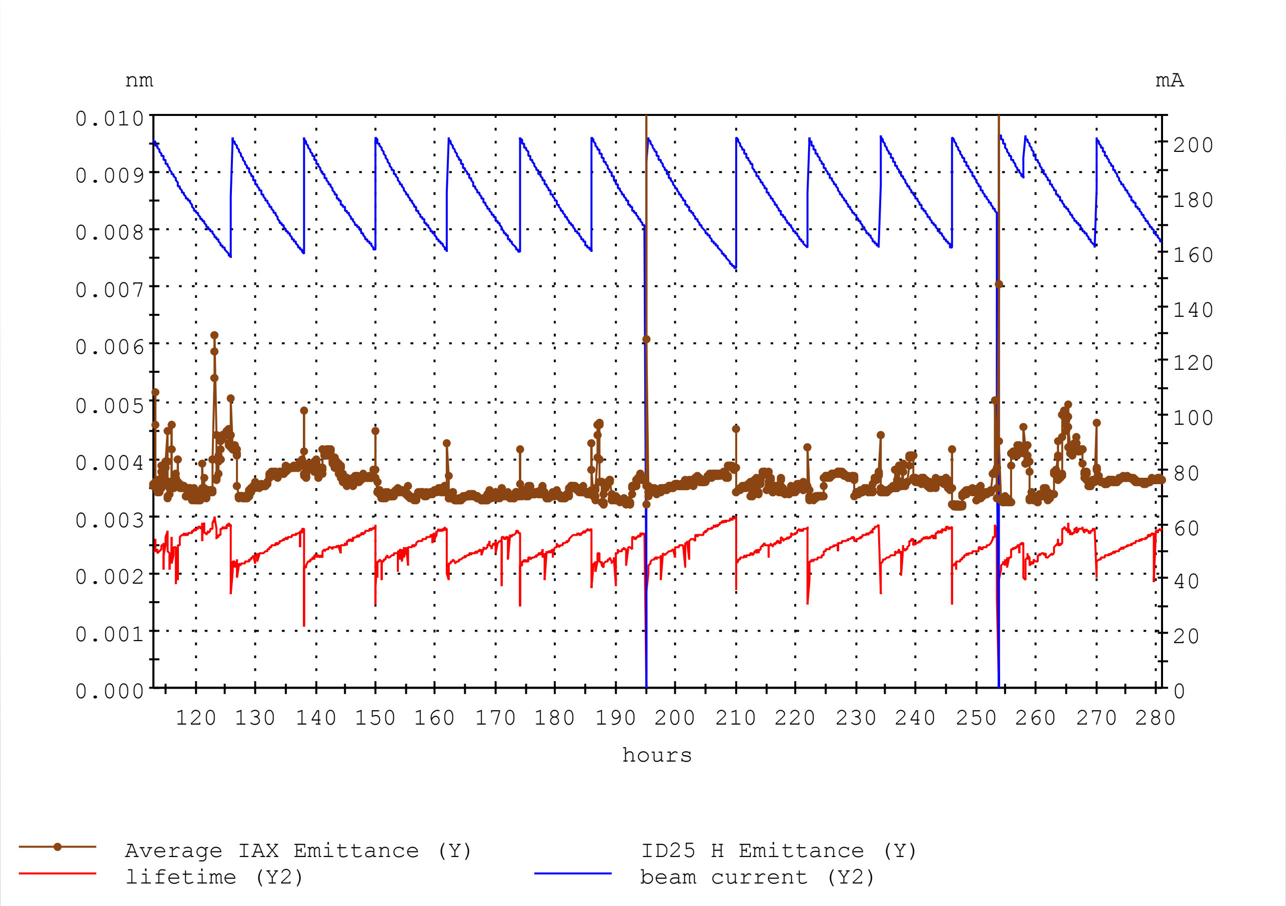
Down to 3.5 pm

- Maintaining small coupling
  - ID gap variations with magnetic field errors induce varying contributions to coupling (in-vacuum undulators)
  - Local correction of ID magnetic field errors
    - 2 skew quad correctors, lookup table
  - Automatic periodic retuning of the correction

4 pm < ε_z < 5 pm on medium term (1 week)

Coupling reduction

- Maintaining low emittance during USM: 1 week delivery

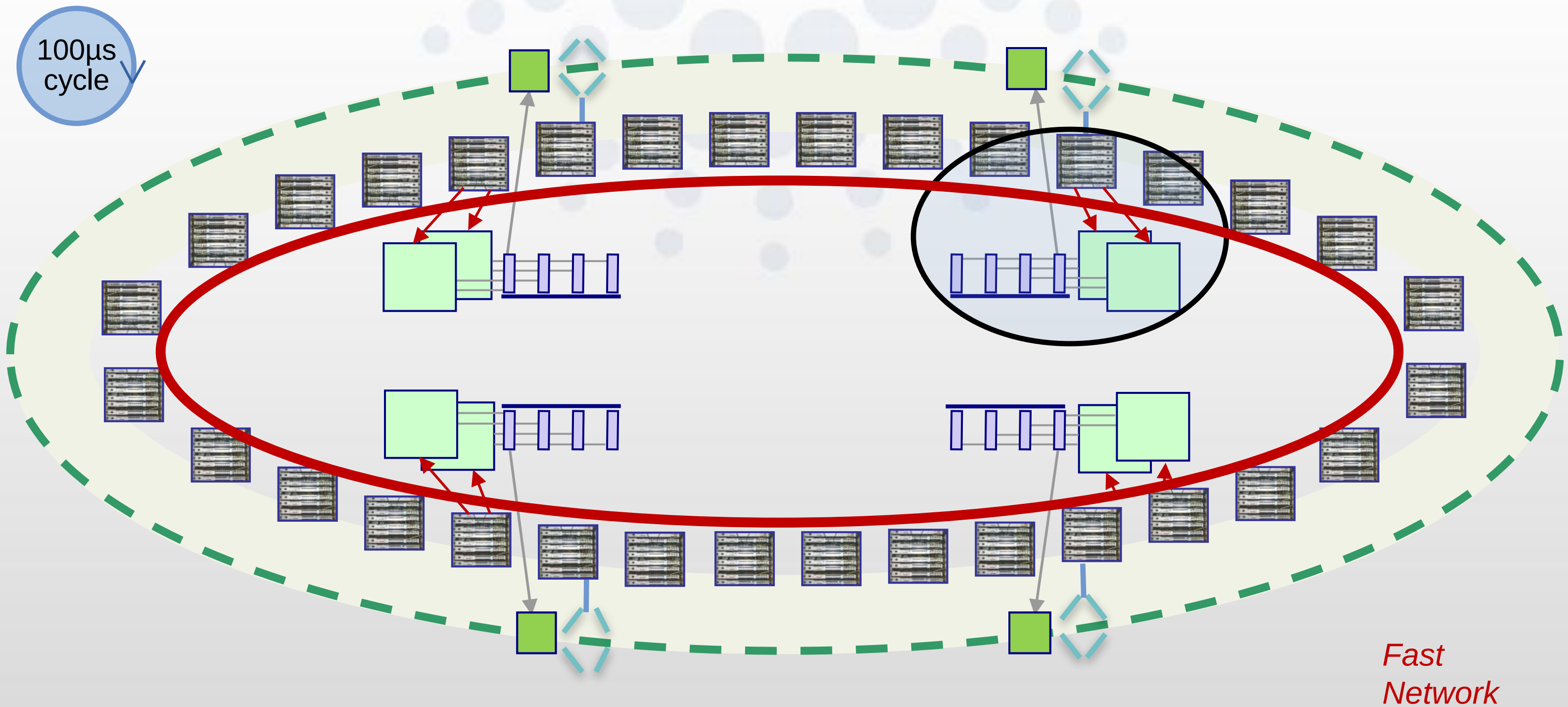


New orbit feedback

- Present
  - Slow feedback: 224 BPMs, 96 steerers, every 30 s
  - Fast feedback uses fewer monitors and steerers, (32 dedicated BPMs, 32 dedicated steerers)
  - Combination of the 2 systems is delicate

- Under commissioning
  - Single system from DC to 200 Hz
    - 224 Libera BPMs
    - 96 standard steerers up to 200 Hz (integrated in the sextupoles)
    - New power supplies
    - 10 kHz operation
  - Much better correction of the orbit distortion induced by IDs

New orbit feedback



One of the 224 Beam Position Monitors

Group of 7 Libera BPMs per cell

4 cabinets each containing 18 corrector channels

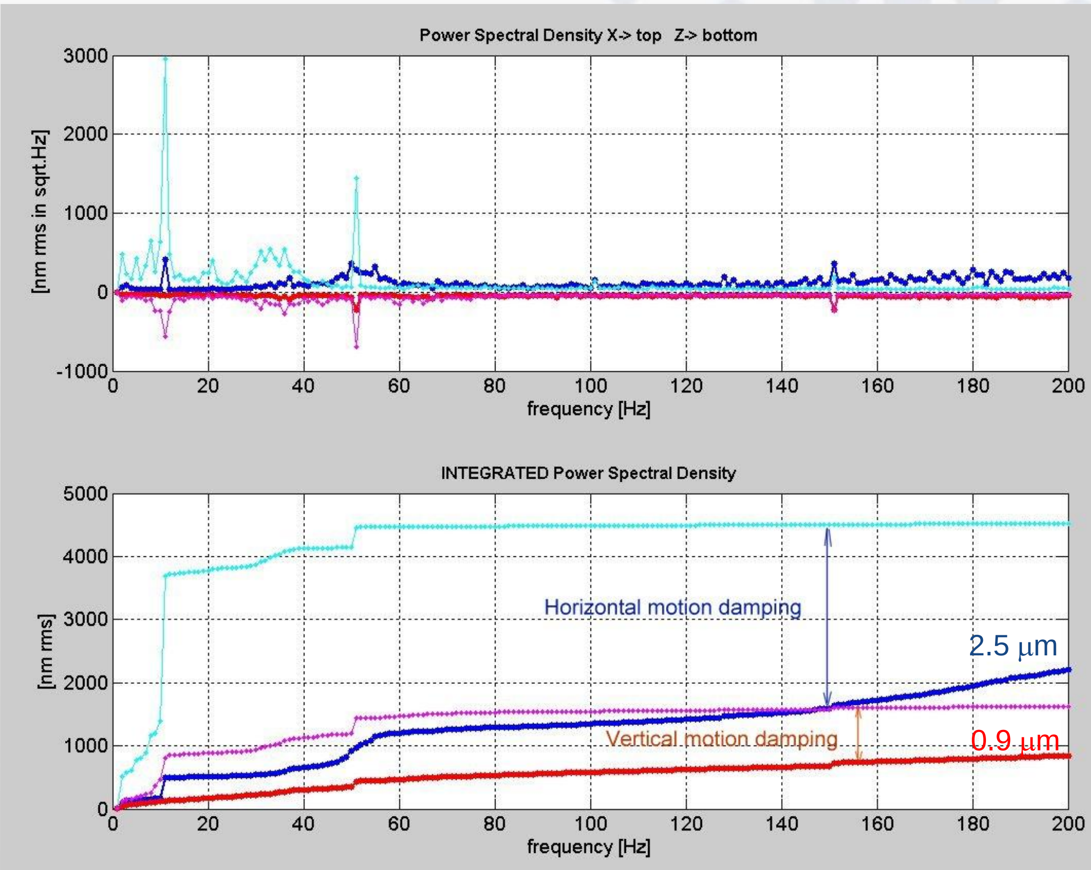
One of the 8 Feedback Processors

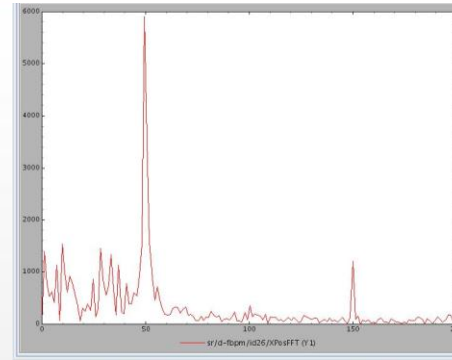
One of the 96 sextupoles housing the correctors

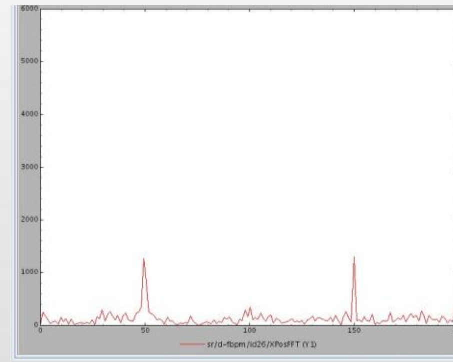
First tests of Fast Orbit Feedback

A light for Science

27/09/2011
224 BPMs / 96 steerers
Average over 224 BPMs







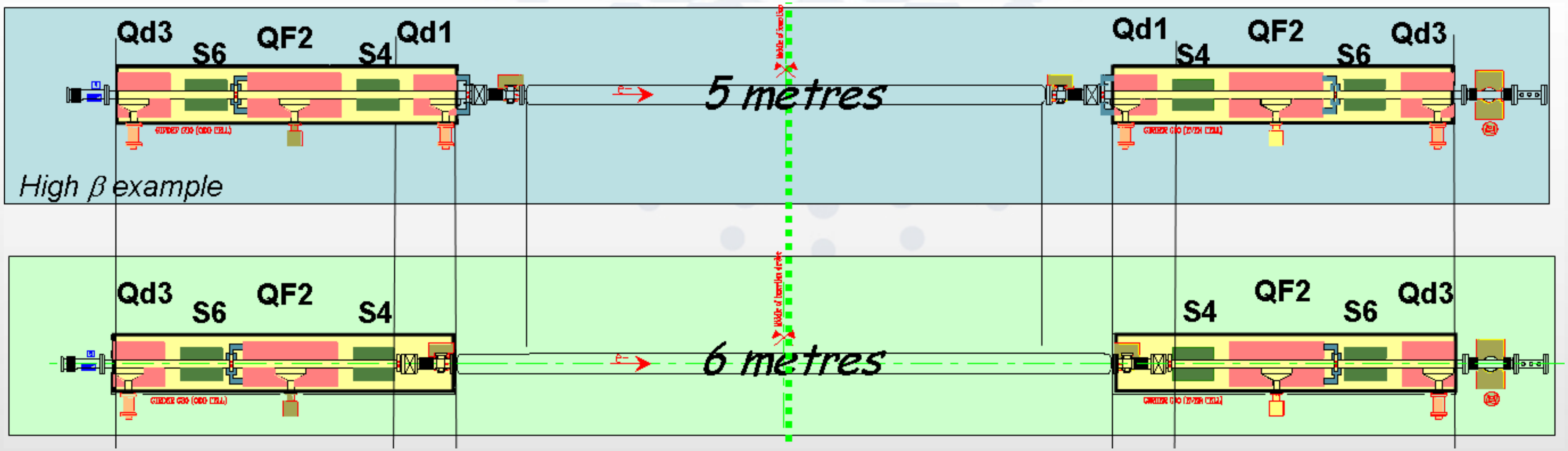
Horizontal OFF

Horizontal ON

Vertical OFF

Vertical ON

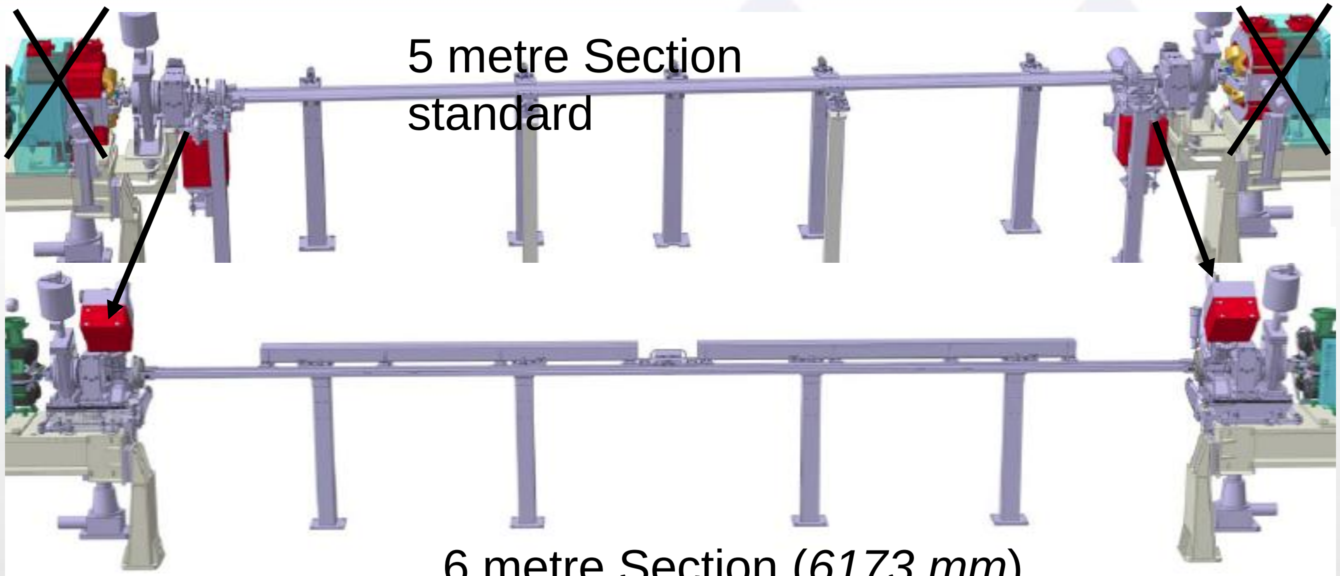
6 m sections



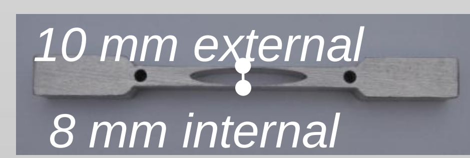
- 6 m section no canting
  - **Standard**
    - ID18, ID20 , ID14
    - ID 24 full 6m operational with 4 carriages
  - **With New 2.5 m in-vacuum undulator**
    - ID6
- 6 m Large Angle canting
  - ID30 (±2.2 mrad)
  - ID16 (±2.7 mrad)

No change in optics
New vacuum chambers

6 m sections

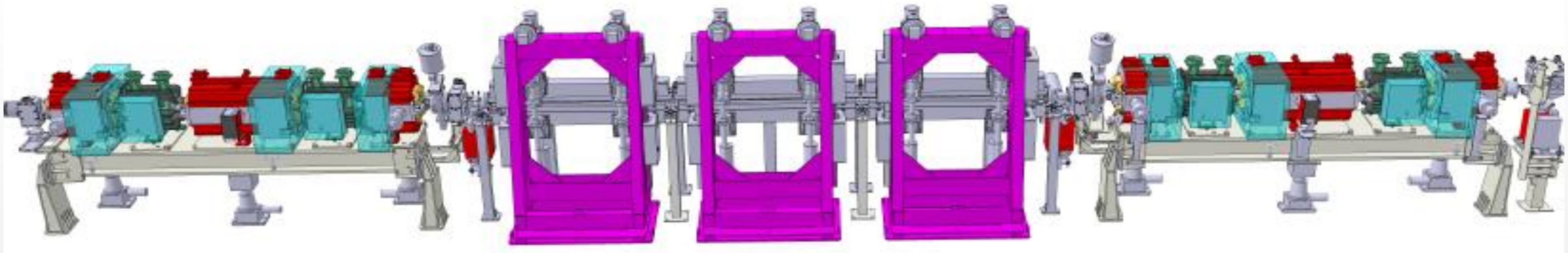


- ✓ **Modification of cabling, piping,**
- ✓ **Transfer of valves, pump transition chambers, bellows, BPM in place of the quadrupoles.**
- ✓ **Replacement of upstream and downstream chambers.**
- ✓ **Installation a 6 metre ID chamber (pre-conditionned)**



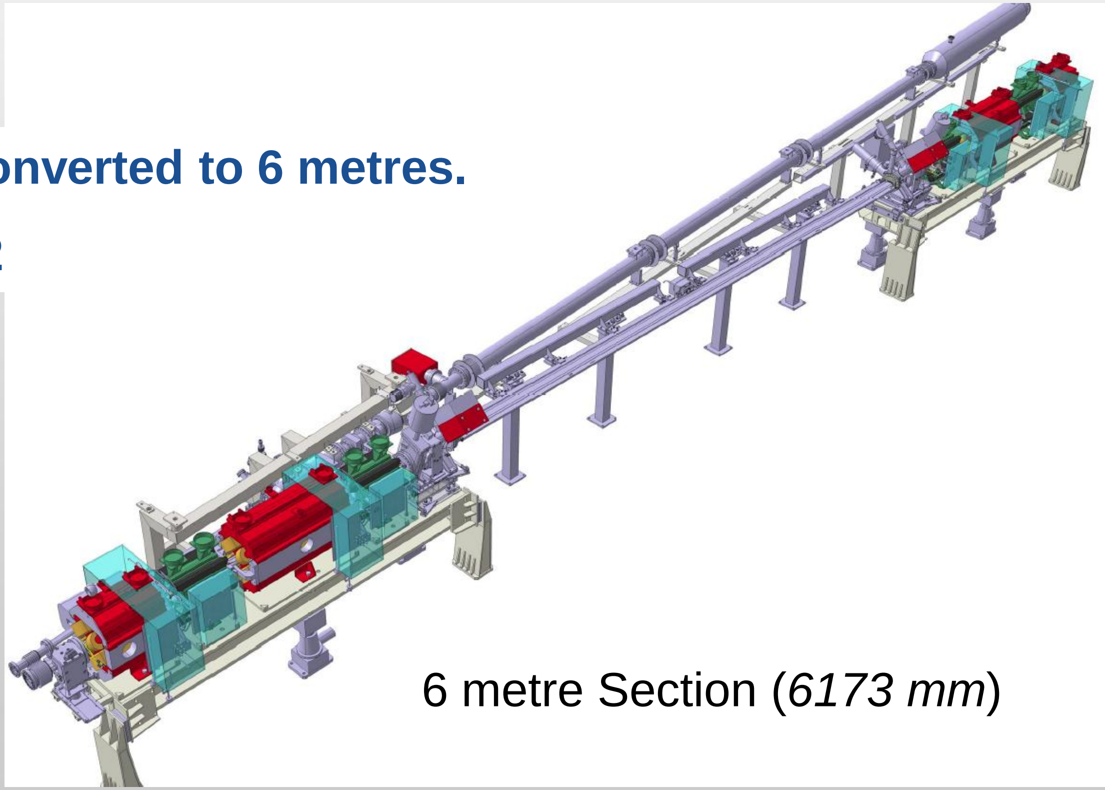
6 m sections

5 metre Section standard



4 straight sections already converted to 6 metres.

5 sections to be done in 2012

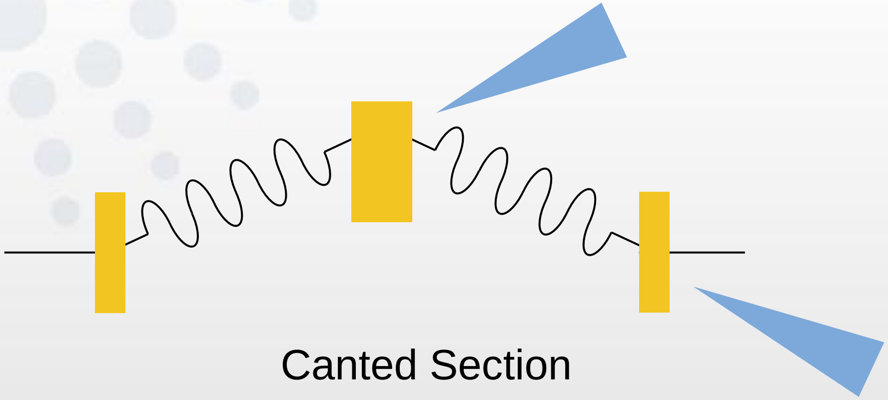


6 metre Section (*6173 mm*)

Steerers for Canted Straights

Permanent Magnet Steerers[1]

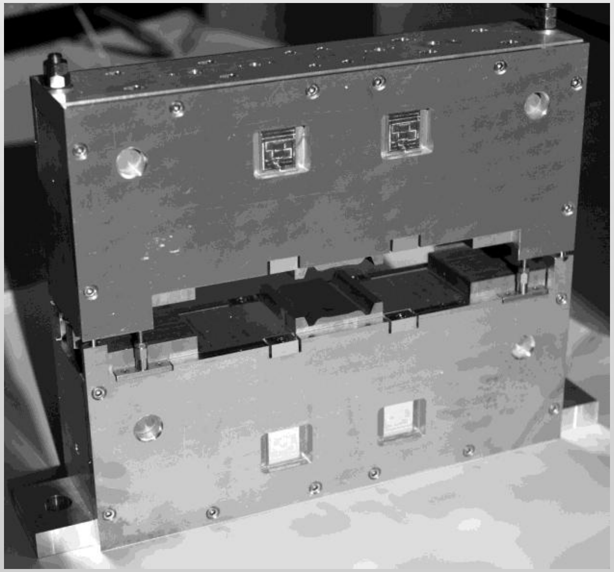
- Homogeneous field integral
- Low fringe field
- 11 Steerers manufactured



Canted Section

Steering angles in [mrad]

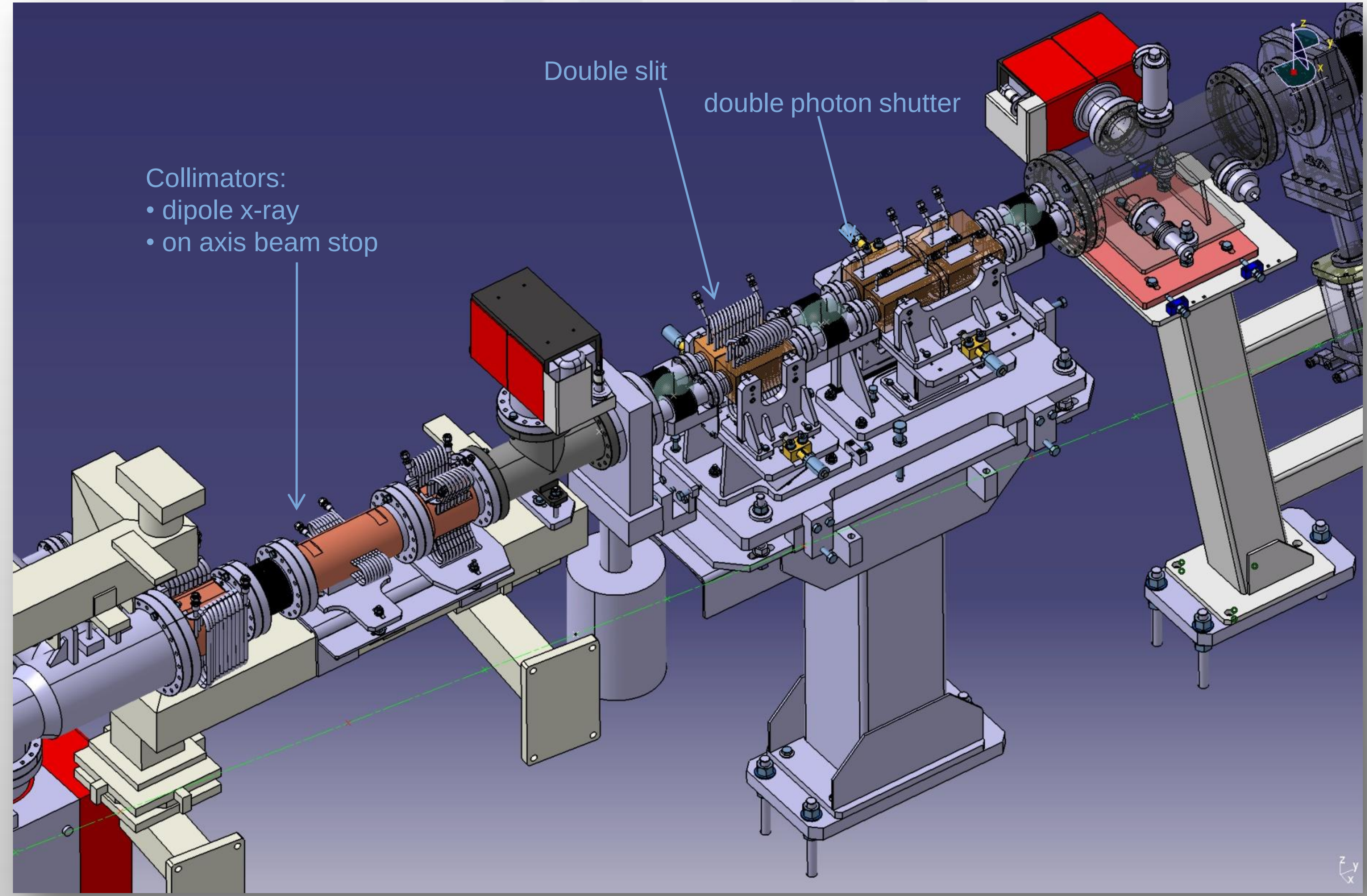
ID16	-2.70	5.40	-2.70
ID18	-1.2	2.71	-1.51
ID23	-0.75	1.5	-0.75
ID30	-2.2	4.4	-2.2



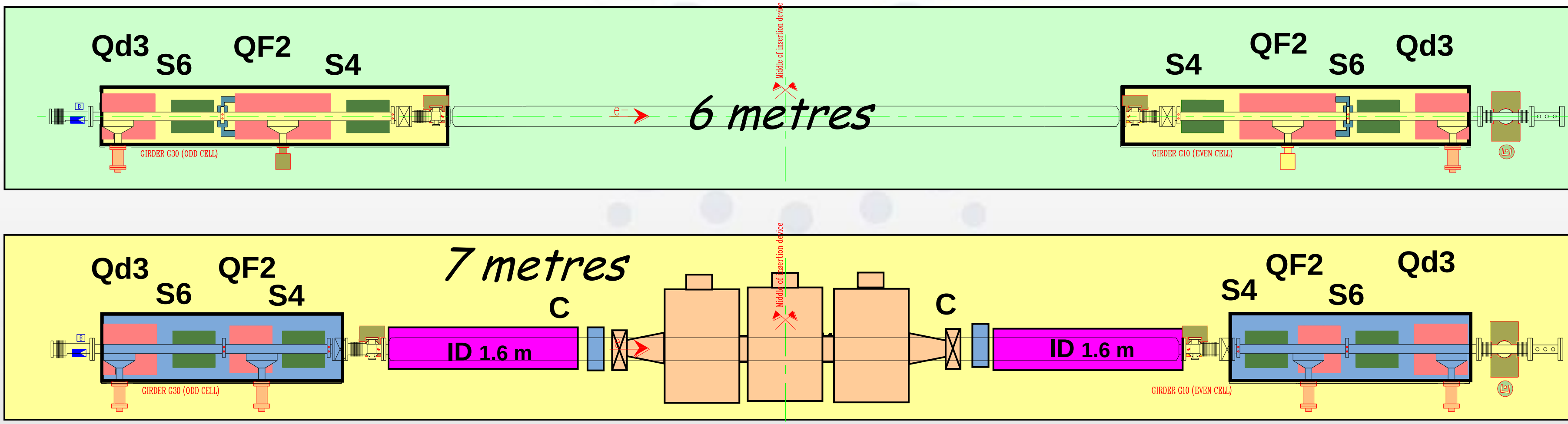
2.70 mrad End Steerer

[1] G. Le Bec and J. Chavane, NIMA, 2011, doi:10.1016/j.nima.2011.10.057

Canted Beamline Front-End



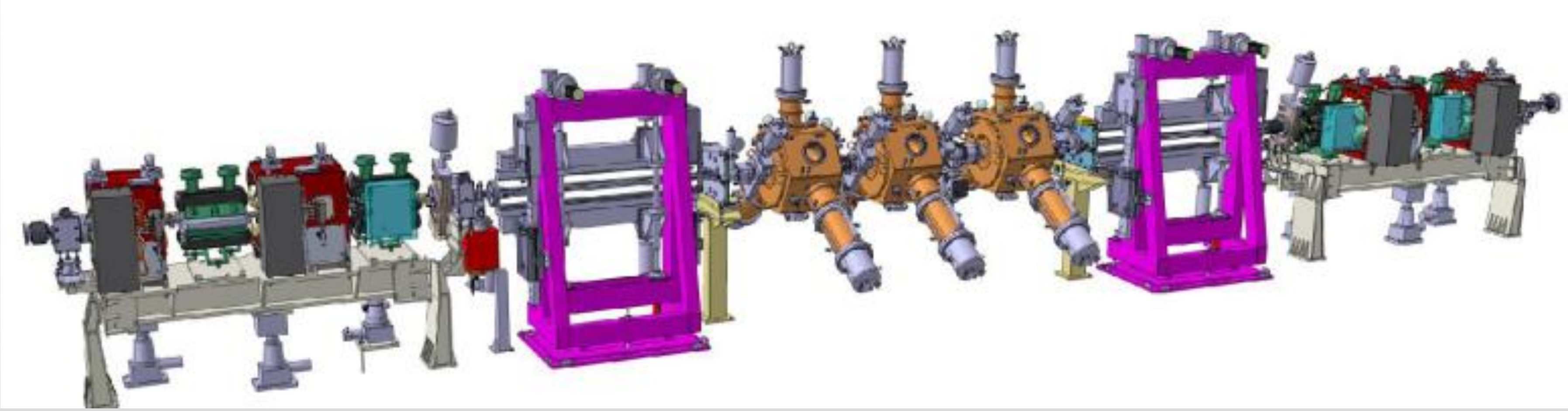
7 m ID straight Sections



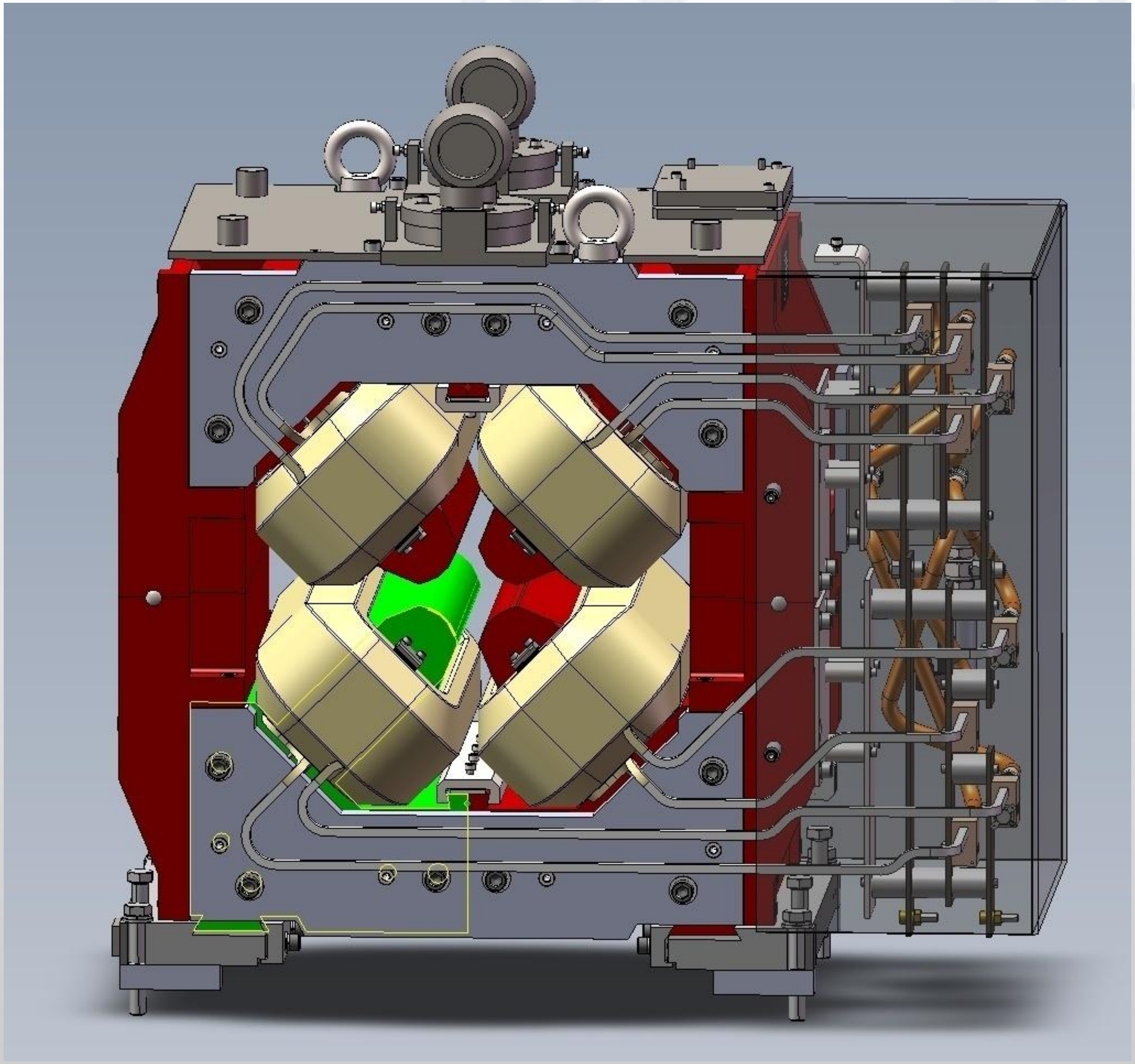
- New girders
- New quadrupoles
- Individual power supplies
- New vacuum chambers
- 1st symmetry breaking

Goal:
Redistribute RF cavities to gain useful straight sections

7 m straight sections



High gradient quadrupoles



- 12 units manufactured by ANTEC
- Needed for 7 m straight sections
- Gradient 26 T/m
- Diameter 66 mm

- Delivered
- Magnetic measurement at ESRF

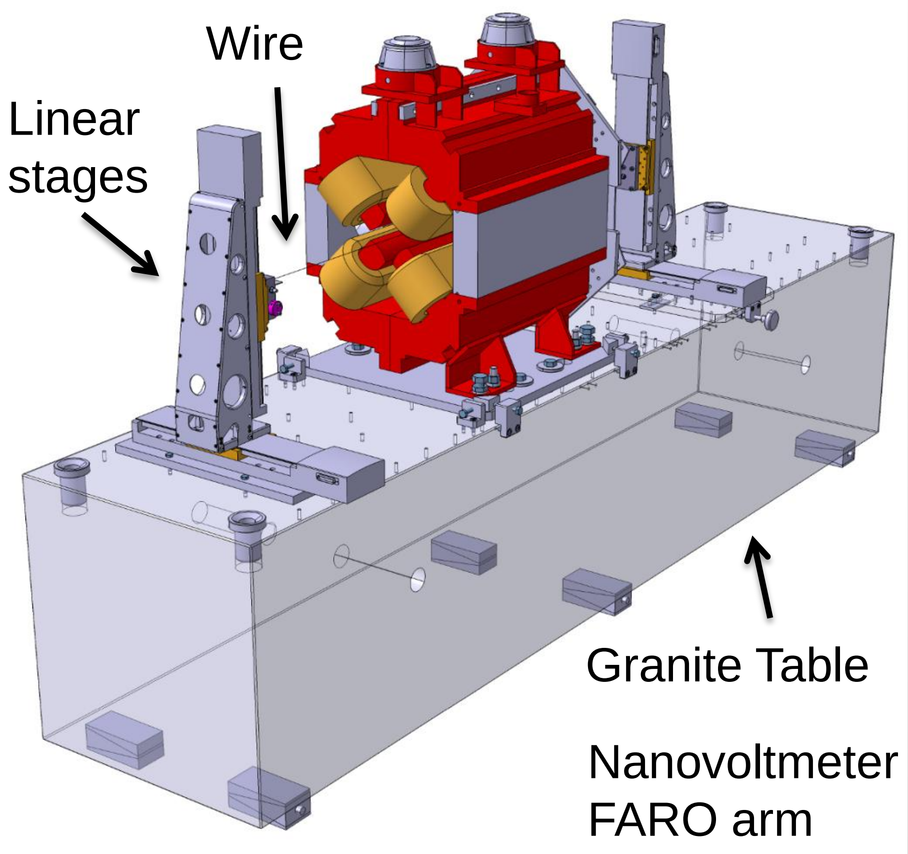
Stretched wire bench

Measurements

- Fiducialization
- Multipole analysis

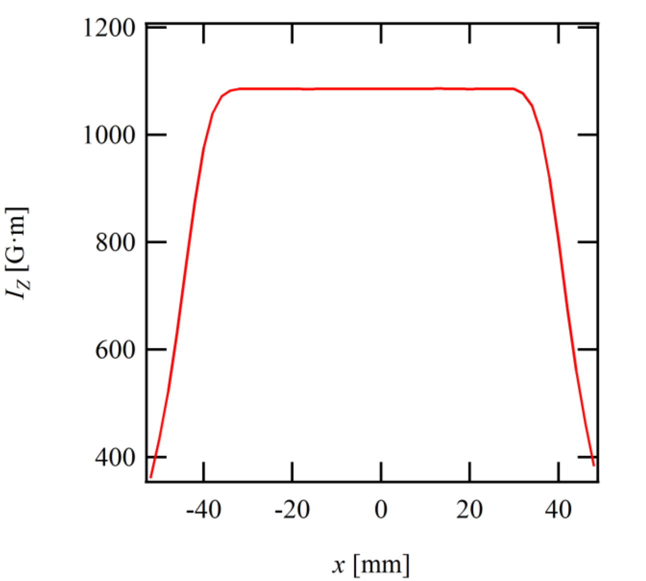
Applications

- Lattice magnets
- Insertion devices
- Steerers and correctors



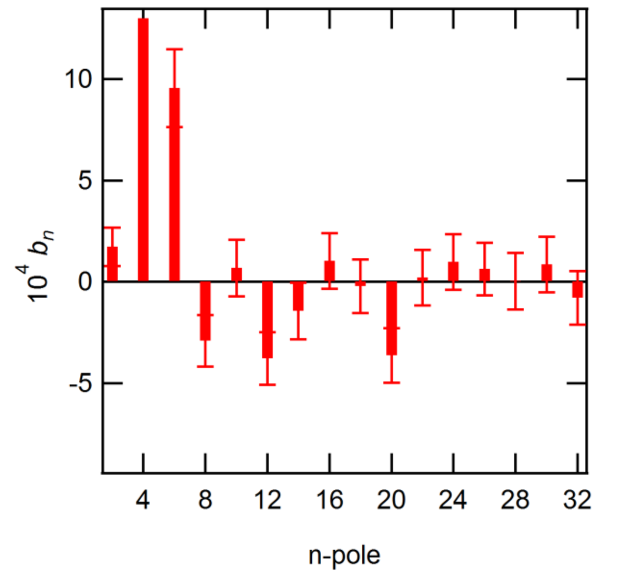
Magnetic measurements

Field integral



Permanent magnet steerer

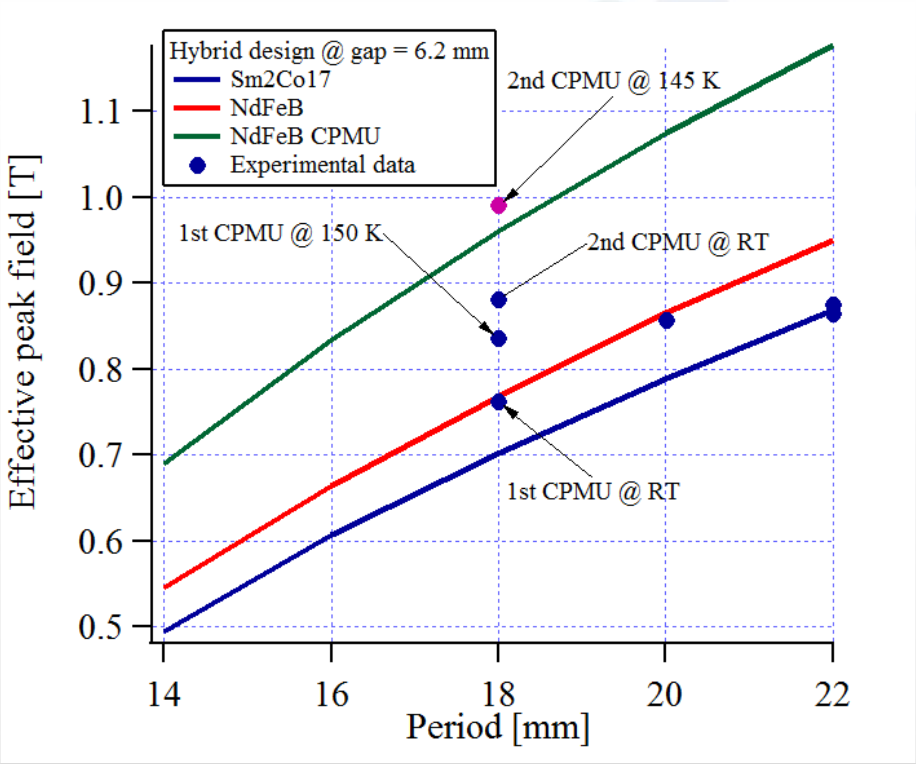
Multipoles



ESRF Quadrupole

- **Least square analysis**
- **Accuracy of ~10^{-4} of the main multipole**

Cryogenic permanent magnet undulators



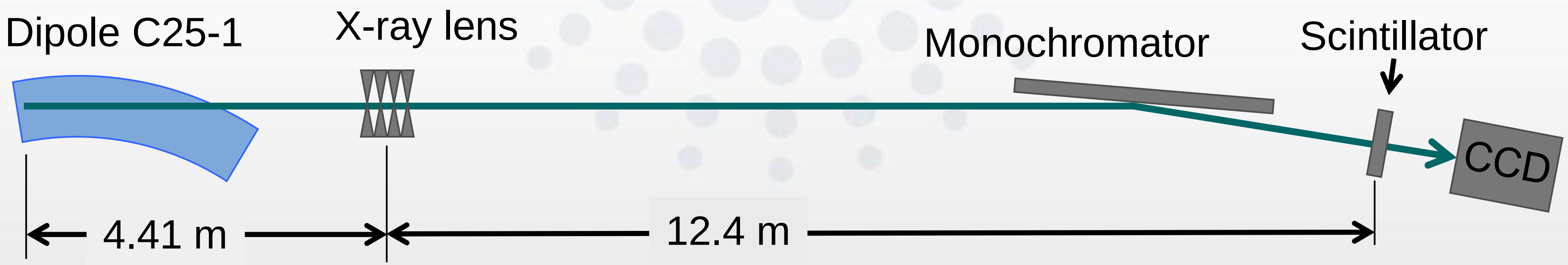
Low temperature magnets

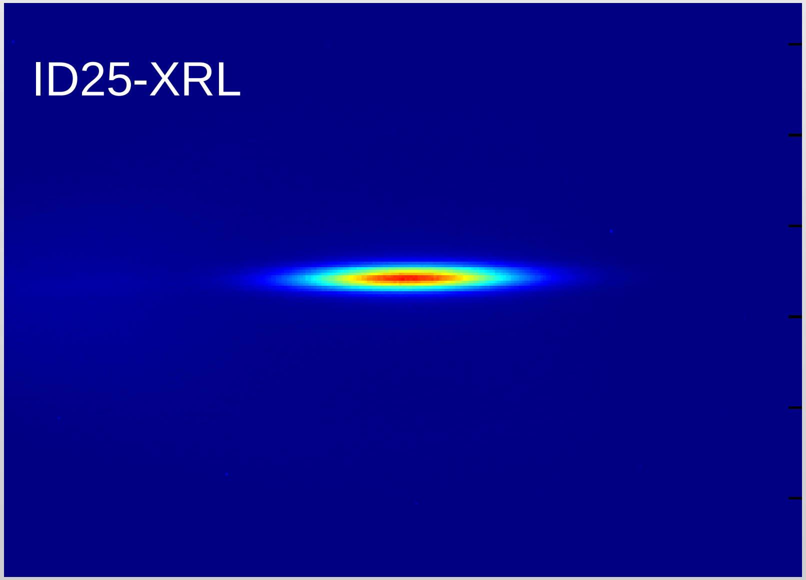
25 %Higher field

Increased brilliance at high energy

CPMU-II
18 mm period / 6 mm gap
0.99 T @ 150 K
3.0 deg RMS phase error @ 150 K (2.7 deg @ RT)

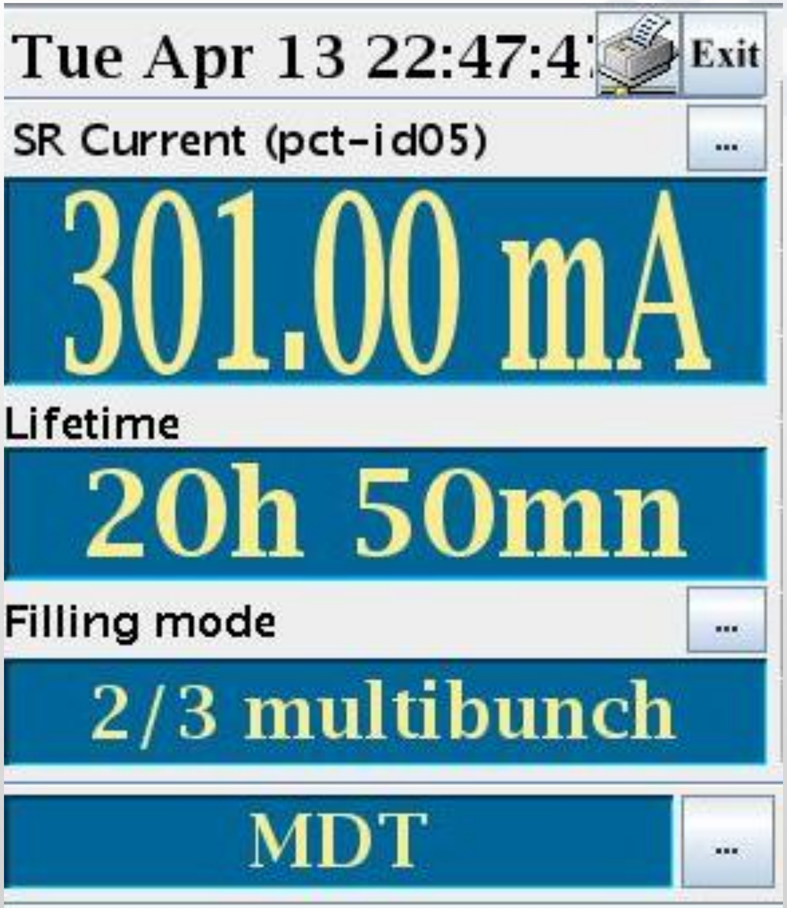
Beam Diagnostic Developments





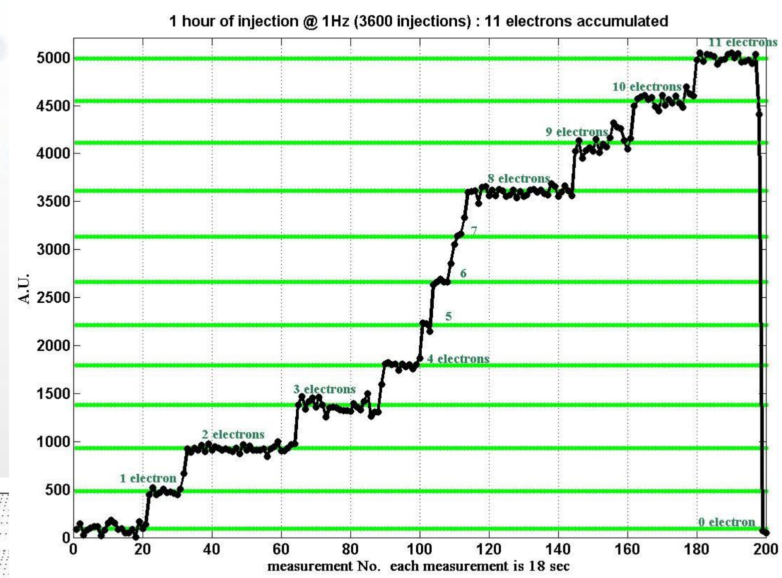
02/Feb/2011	01/Feb/2011
USM (7/8 +1)	MDT (7/8 +0)
32 skew correctors	64 skew correctors
ID25-b : 6.6 pm	ID25-b : 3.6 pm
ID25-xrl : 6.2 pm	**ID25-xrl : 3.7 pm**
IAX : 6.4 pm	IAX : 4.2 pm

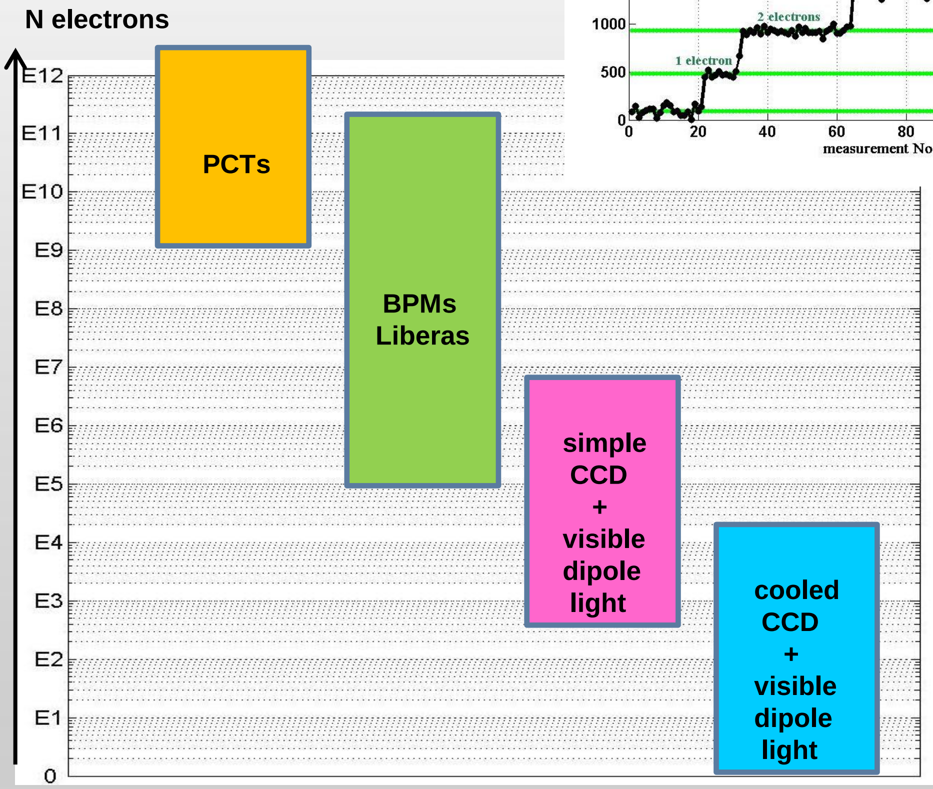
300 mA

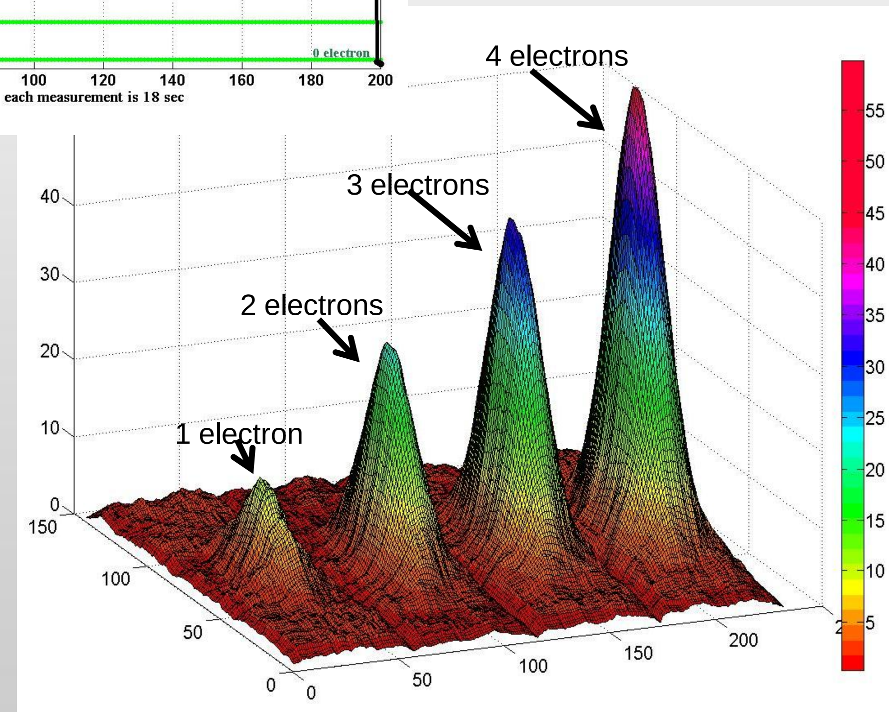


- 300 mA stored during MDT for validation of the accelerator developments and also for tests with some beamlines.
- No user mode at 300 mA before the end of Upgrade phase 1.

Measuring extremely low current detection

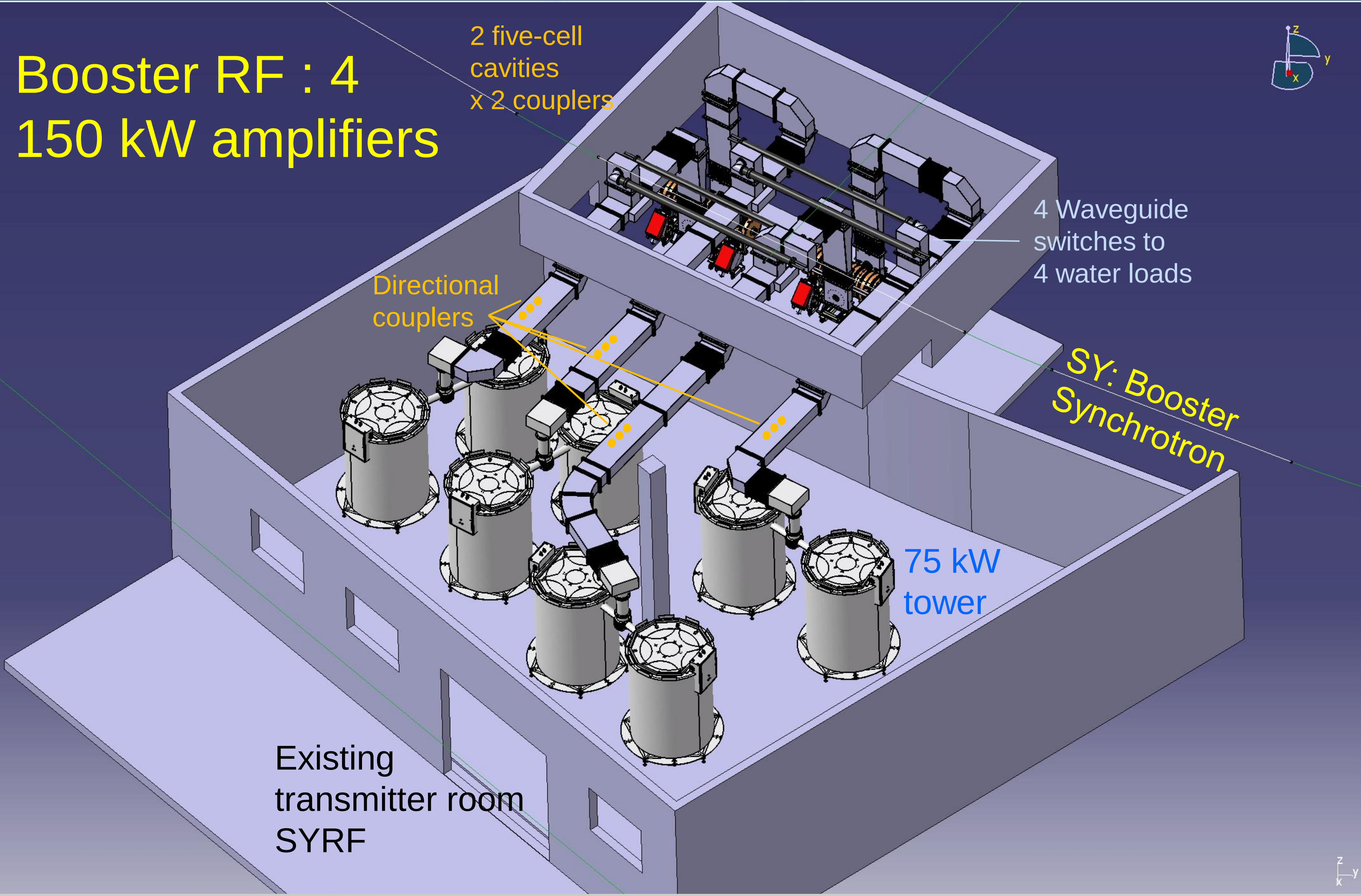




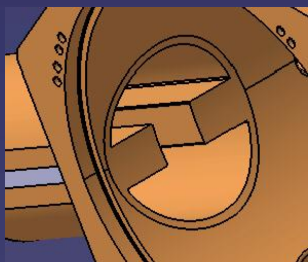


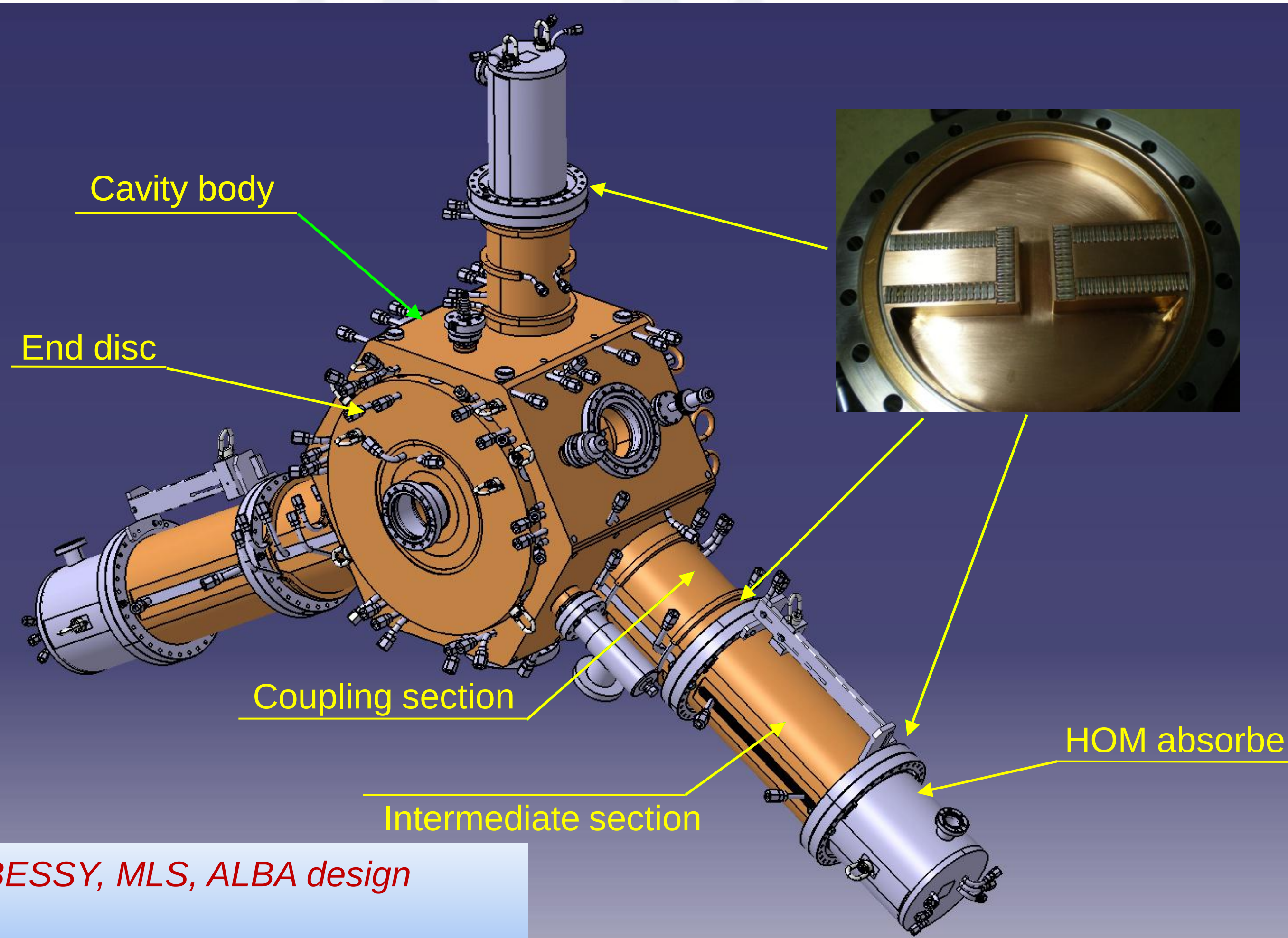
New RF transmitters

Booster RF : 4
150 kW amplifiers



New RF cavities



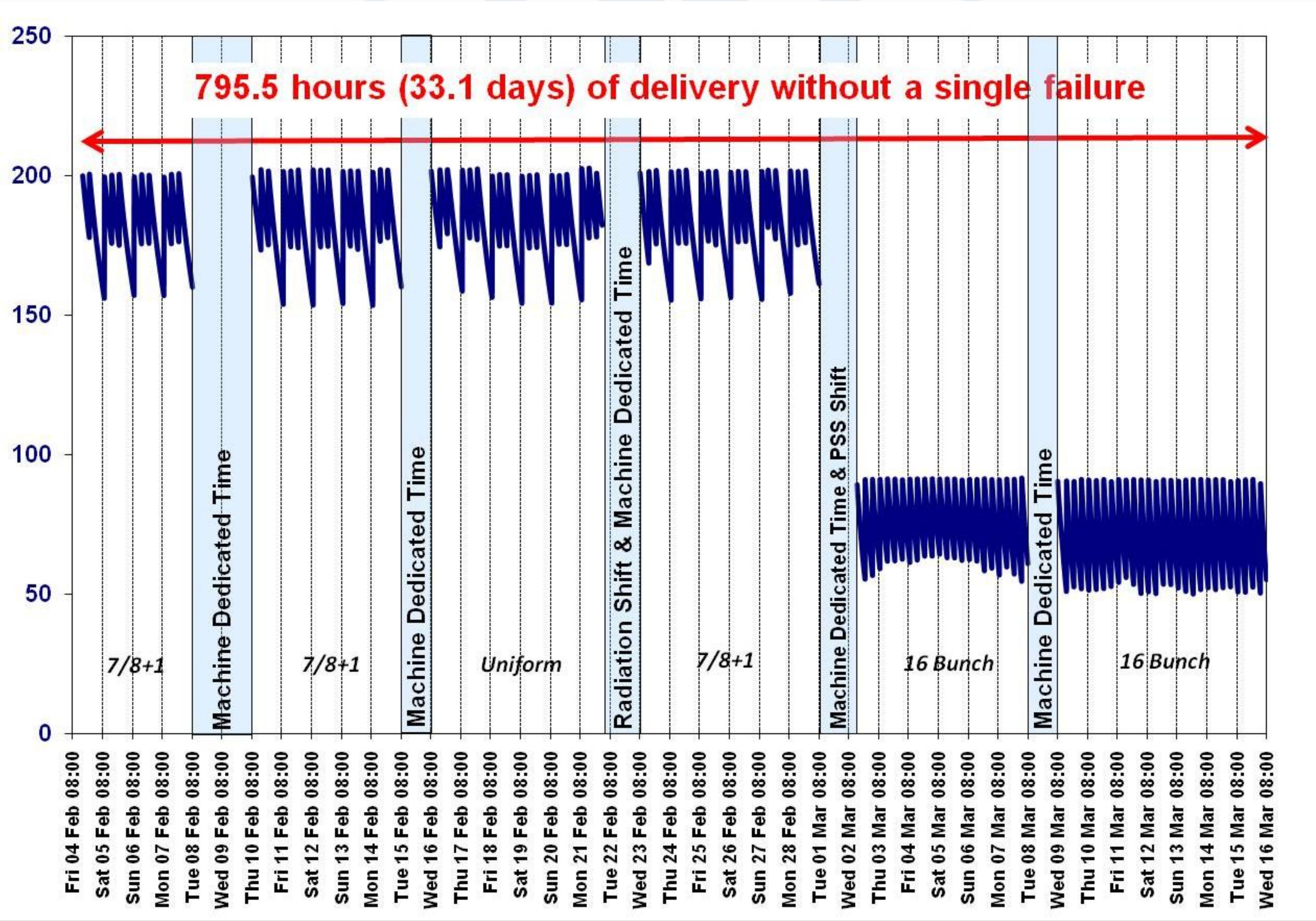


Based on 500 MHz BESSY, MLS, ALBA design
[E. Weihreter et al.]

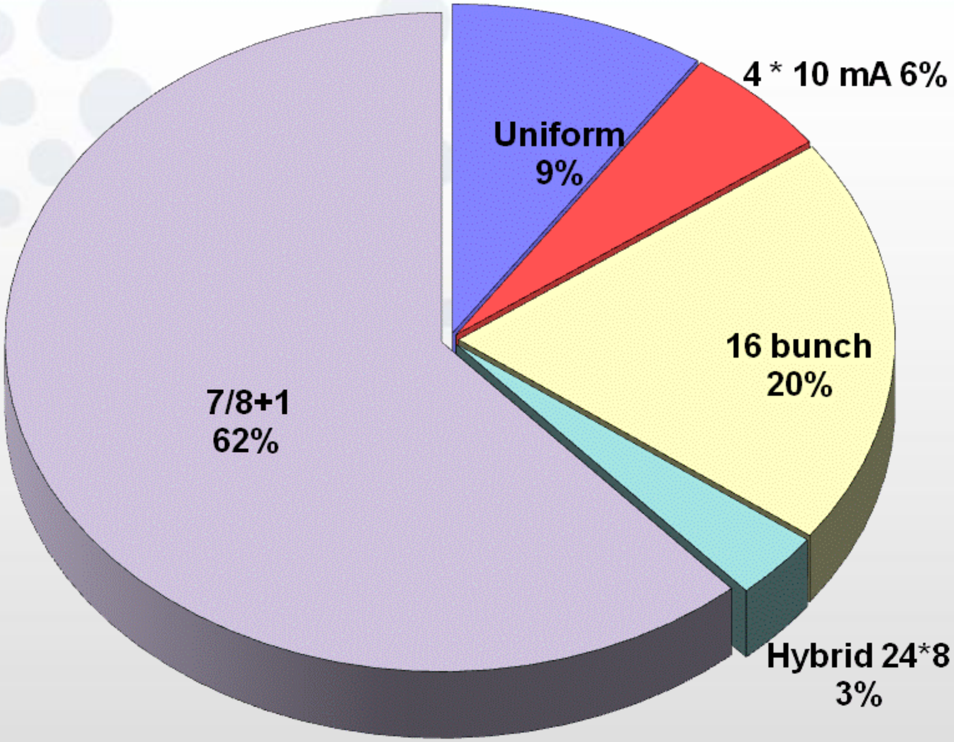
But while preparing the upgrade…

A light for Science

The priority is still machine operation:



Filling modes



Energy	GeV	6.04
Multibunch Current in 7/8+1	mA	200 4 (single)
Horizontal emittance	nm	4
Vertical emittance	pm	3.5

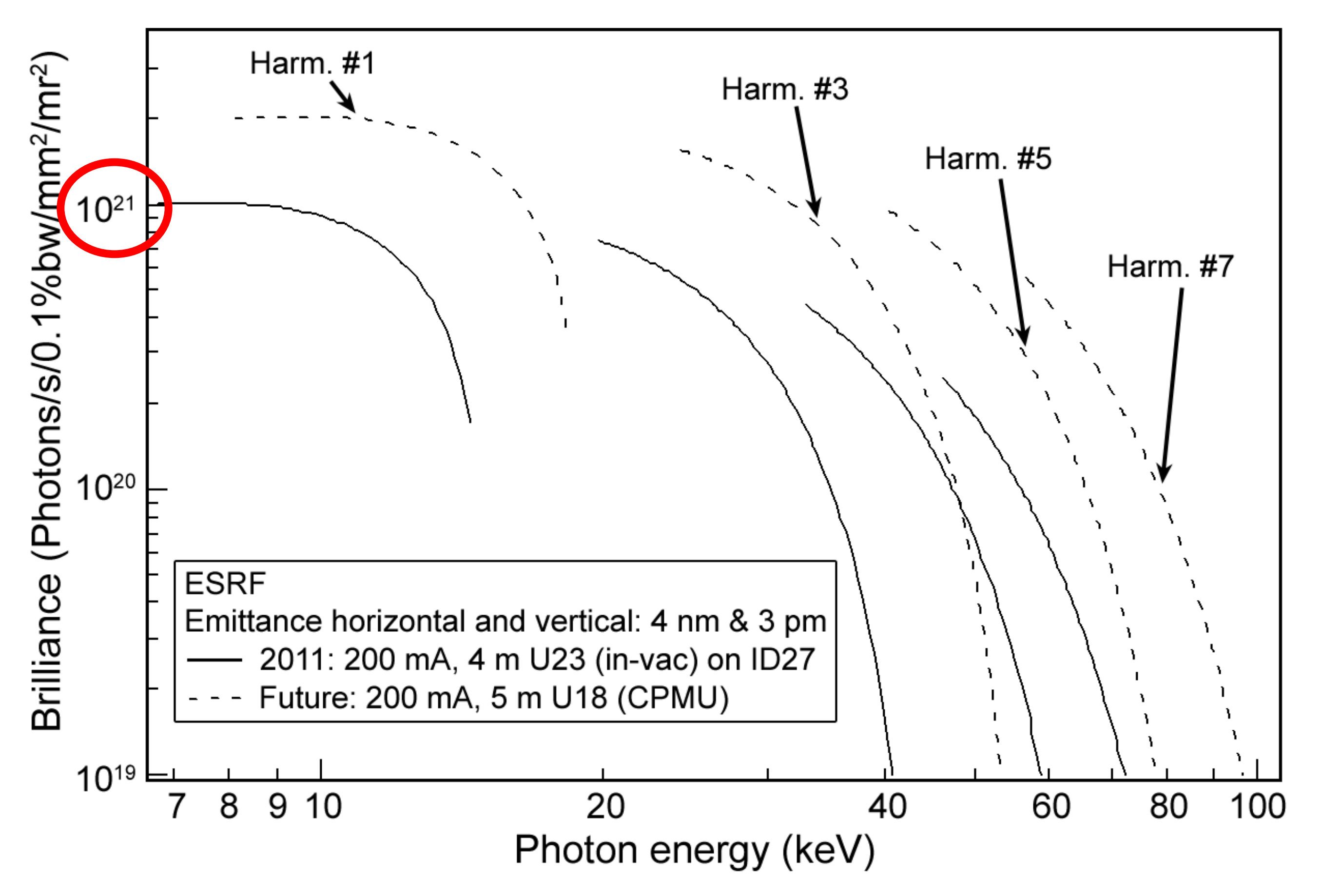
91 % of Beamtime available for Timing Experiments

Machine statistics	**2009**	**2010**	**2011** *To 27 October*
Availability (%)	99.04	98.78	98.83
Mean time between failures (hrs)	75.8	67.50	103.2
Mean duration of a failure (hrs)	0.73	0.82	1.21

In 2010:

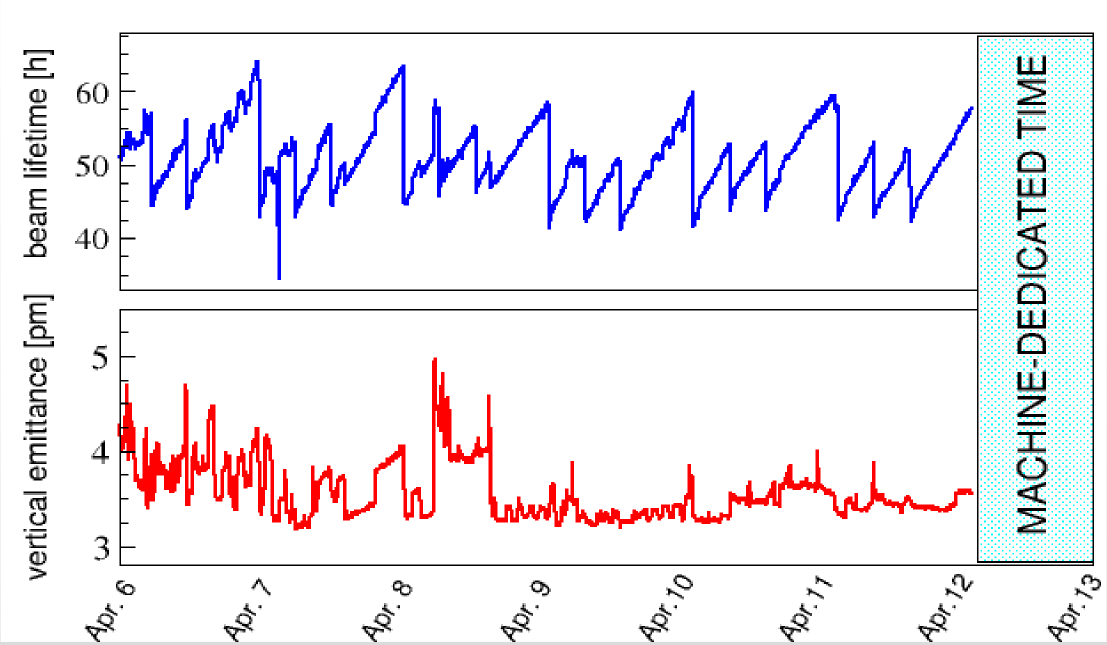
5538 hours of beam
2000 Research proposals
~ 6300 Users, 1500 Experiments
~ 1800 Referred publications

ESRF brillance record



Reduction and maintenance of the vertical emittance from 35 pm to 3.5 pm.

Lifetime maintained in excess of 45 hours in multibunch (7/8+1)



✓*Reduction of the lifetime in **multibunch** limited to less than 10 hours despite a reduction of the coupling by an order of magnitude*

==> Still no topping-up envisaged

✓ *The other modes do not benefit from the coupling reduction because the emittance is vertically blown up to get a reasonable lifetime*

==> Topping up would be valuable

MANY thanks
for your attention