19th ESLS RF Meeting - MAXLAB

Lund, 30 Sept – 1 October 2015

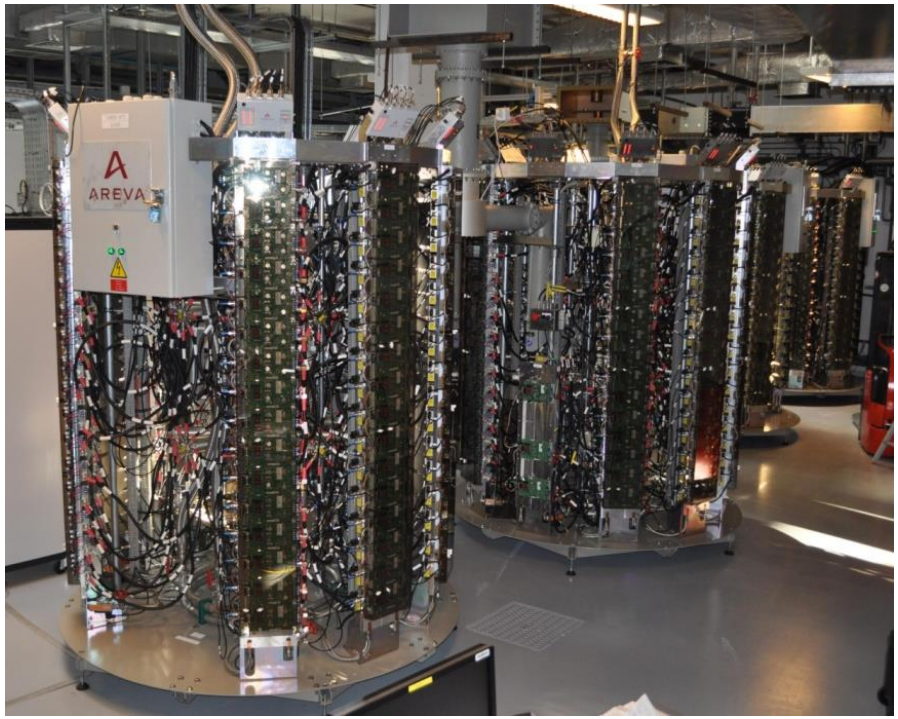
Status of the RF upgrade for the new ESRF Storage Ring

Jörn Jacob

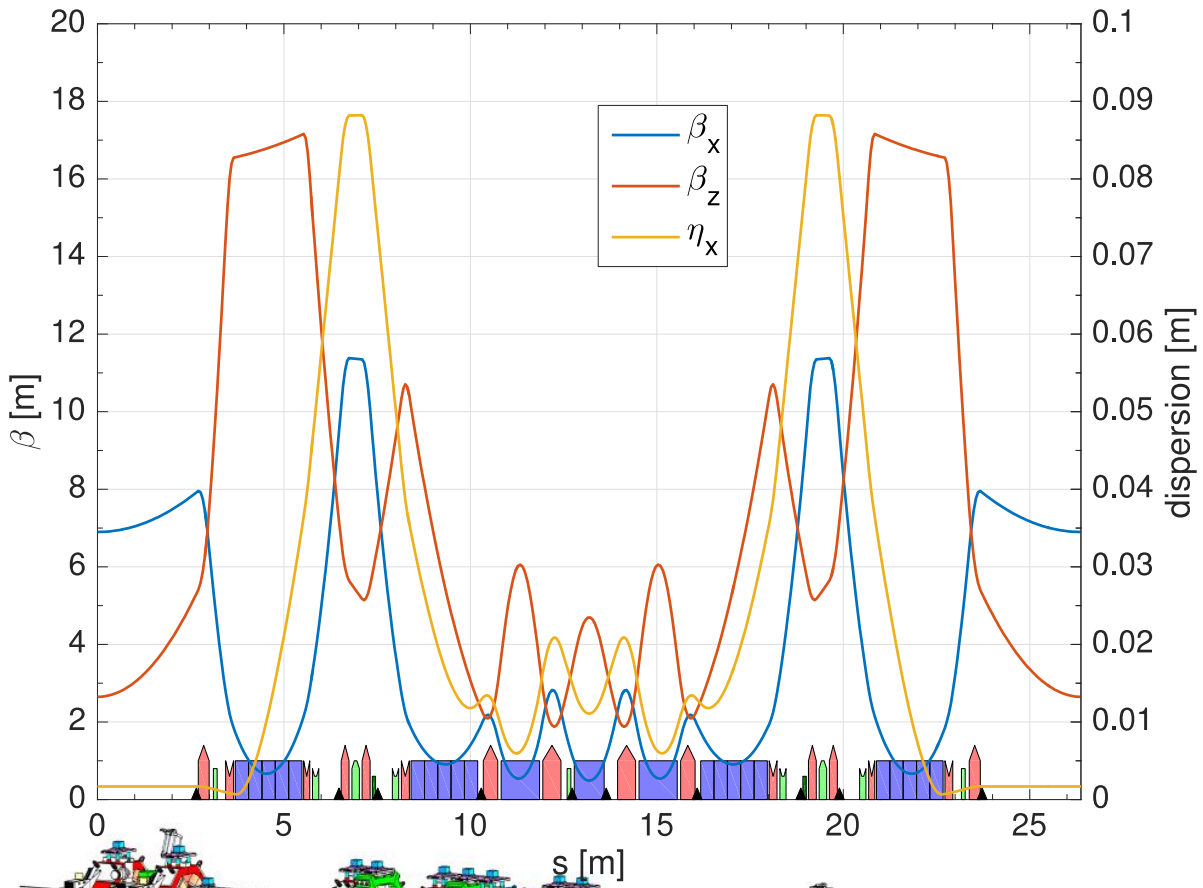
On behalf of the ESRF RF Group

ESRF | The European Synchrotron

[CINEL]



ESRF-EBS: NEW EXTREMELY BRILLIANT SOURCE FOR THE ESRF



Main features:

- 2 regions with large dispersion for efficient chromaticity correction
- Rough sextupole compensation by having a ≈π phase advance between the 2 sections

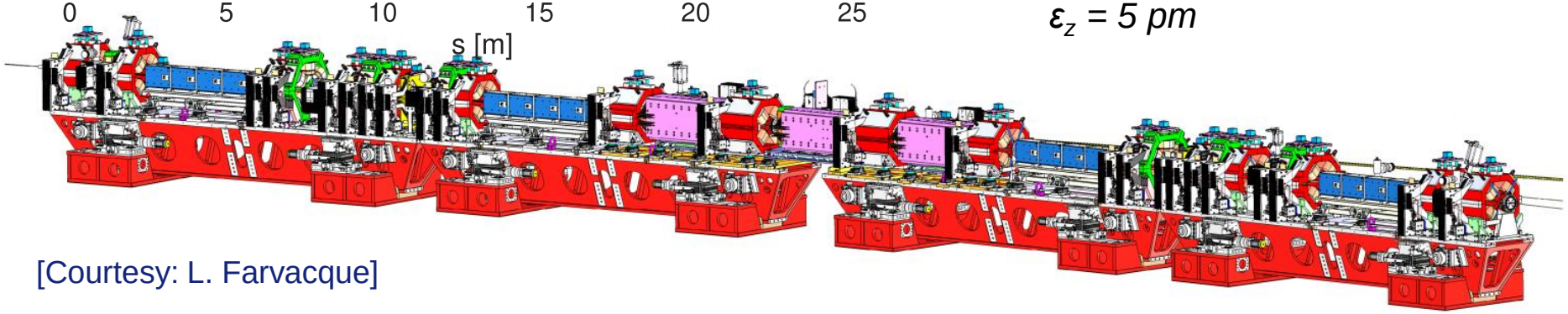
Performance:

- Natural equilibrium emittance:

  $\varepsilon_{x0} = 134$ *pm*
- Emittances with 5 pm coupled into the vertical plane and 0.5 MV radiation losses from ID's:

  $\varepsilon_x = 107$ *pm*

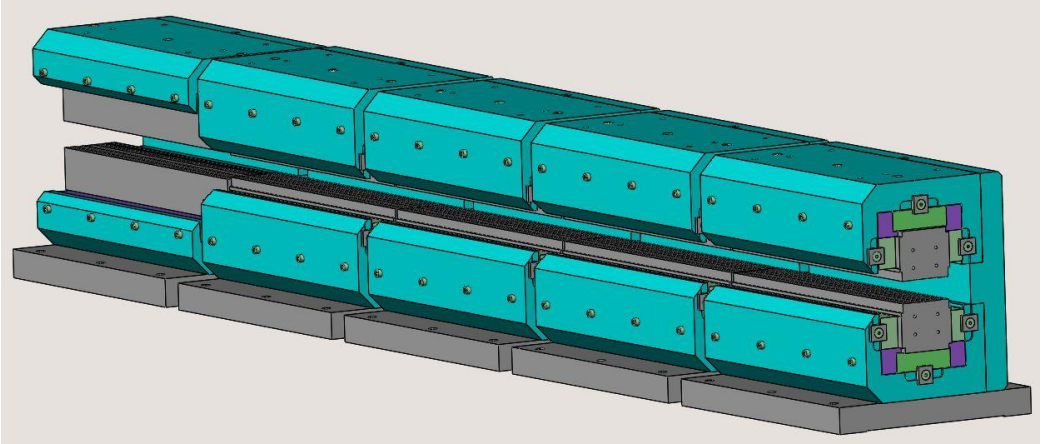
  $\varepsilon_z = 5$ *pm*



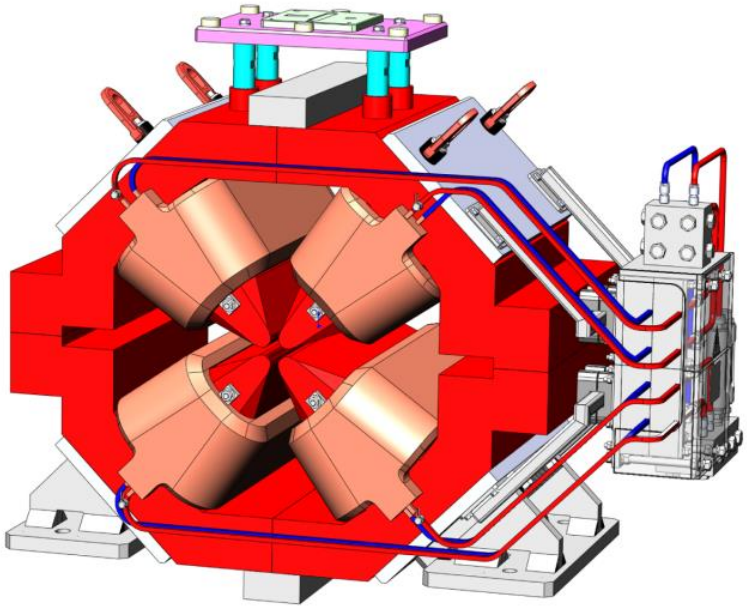
[Courtesy: L. Farvacque]

ESRF-EBS MAGNETS

DL
0.17 ➠ 0.67 T
permanent magnets,
5 modules



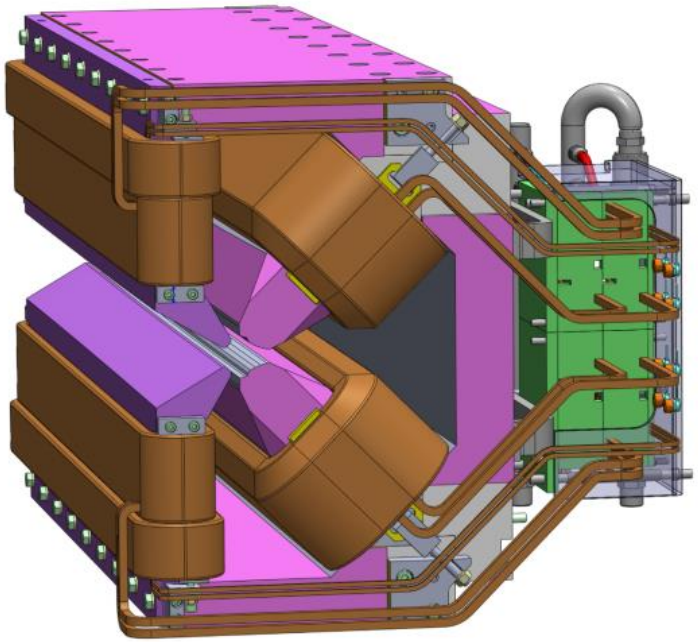
Quadrupole
91 T/m, ⌀25.4 mm

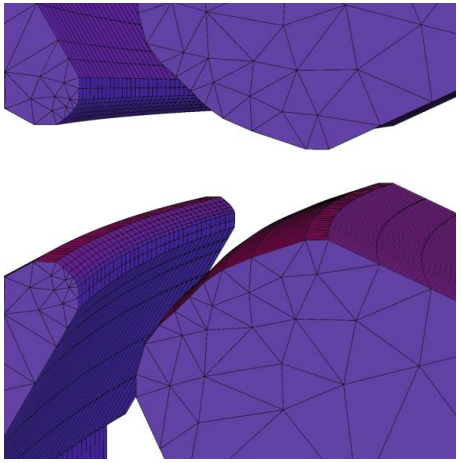


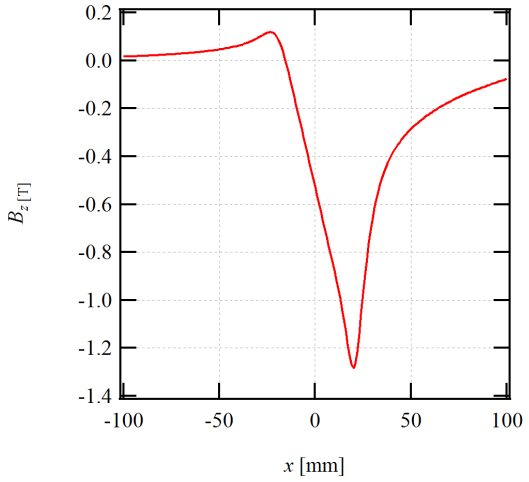
[Courtesy: Gael Le Bec]

ESRF-EBS MAGNETS

DQ
0.55 T, 37
T/m







[Courtesy: Gael Le Bec]

ESRF-EBS PARAMETERS

Energy [GeV]	6
Circumference [m]	843.978
Natural emittance [pm]	134
Damping time (H/V/L) [ms]	8.5/13/8.6
E_{loss}/turn [MeV]	2.61
Momentum compaction	$0.84\ 10^{-4}$
Tunes (H/V)	76.21/27.34
Natural chromaticity (H/V)	-109/-82
Operation chromaticity (H/V)	6/4
Oper. Emittance (H/V) [pm]	110/5
Lifetime multibunch at 200 mA [h]	19
Lifetime 16 bunch at 90 mA [h]	1.8
Lifetime 4bunch at 4 x 10 mA [h]	1.2

for ε_{vert} = 5 pm

[Courtesy: L. Farvacque]

RF DIMENSIONING FOR NEW MACHINE

Total energy loss: **3.1 MeV/turn**

- ☞ Energy loss from dipole radiation: 2.6 MeV/turn
- ☞ Energy loss from ID radiation: 0.5 MeV/turn

Maximum RF Voltage: **6.6 MV**

RF transmission losses: **15 %**

- ☞ including RF losses, spurious mismatches

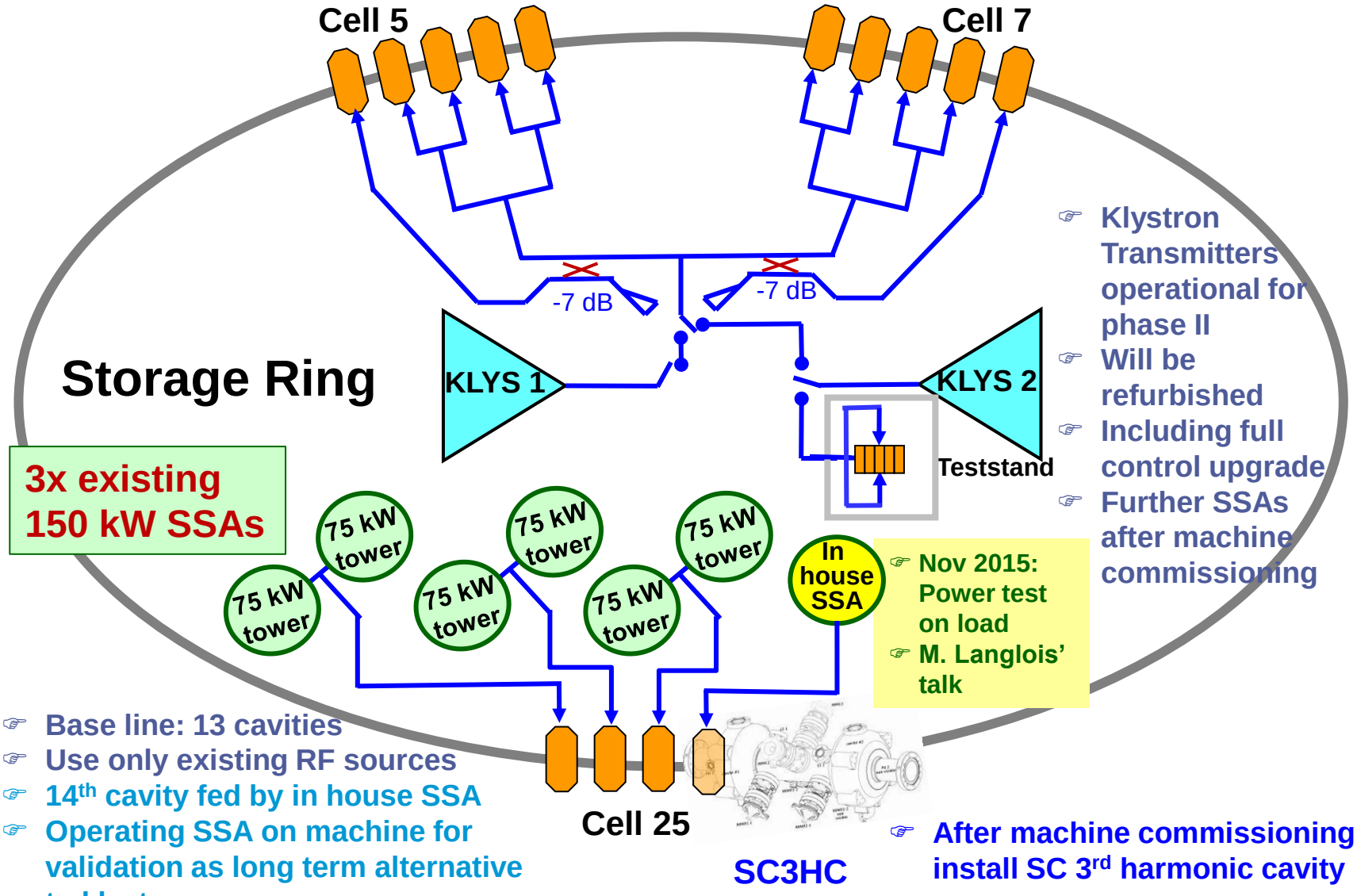
Stored current with operational margin: **220 mA**

HOM damped cavity prototypes: **validated for 0.6 MV / 150 kW**

~~**Splitting 3x 150 kW into 6x 75 kW SSAs:**~~ **abandoned**

- \+ Better exploits cavity power capability
- \+ Requires less cavities, less space for cavities
- \+ Increases power margin and redundancy of the RF system
- \- SSAs operated below $P_{nominal}$ $\Rightarrow$ lower RF/DC efficiency

SR RF CONFIGURATION



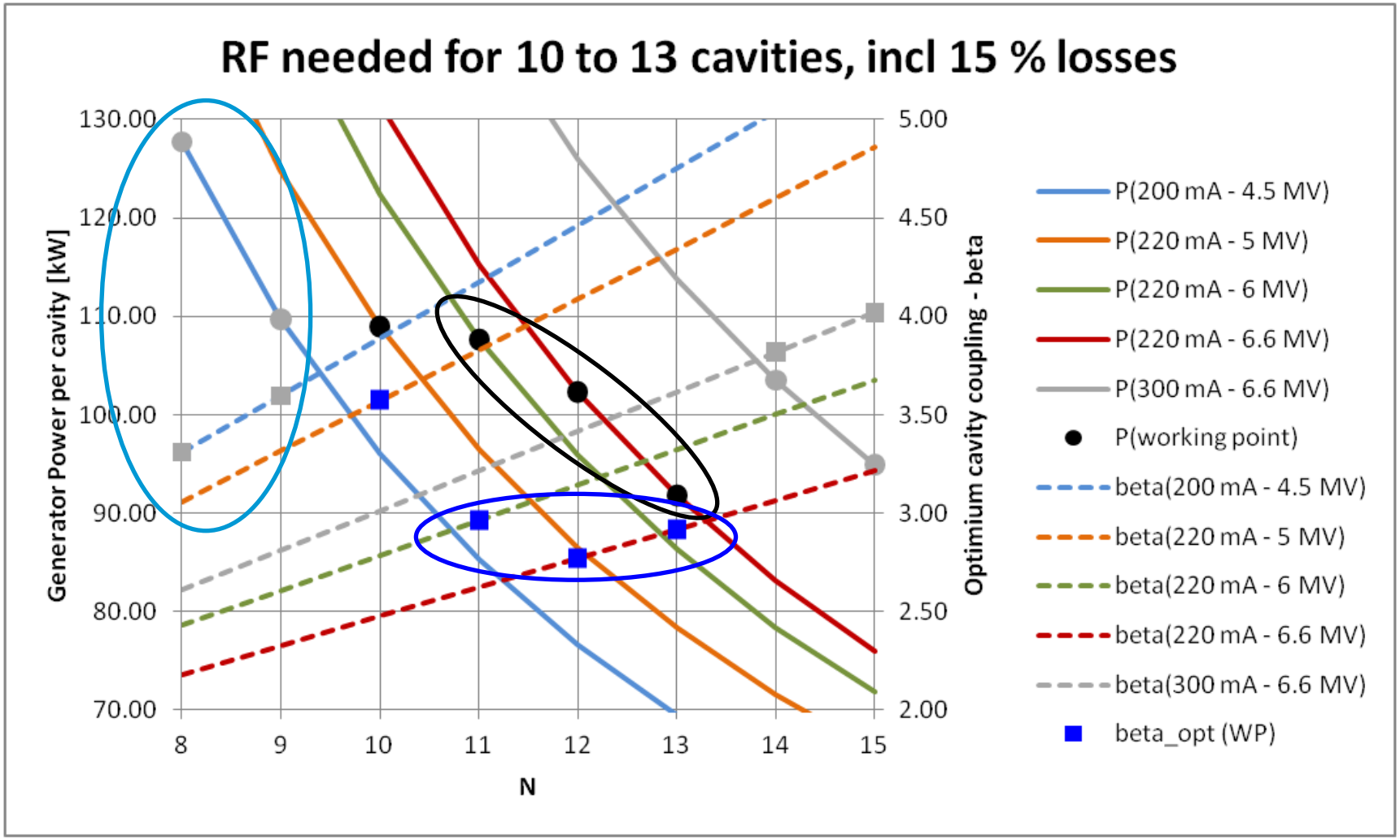
- Klystron Transmitters operational for phase II
- Will be refurbished
- Including full control upgrade
- Further SSAs after machine commissioning

- Nov 2015: Power test on load
- M. Langlois' talk

- Base line: 13 cavities
- Use only existing RF sources
- 14th cavity fed by in house SSA
- Operating SSA on machine for validation as long term alternative to klystrons

- After machine commissioning install SC 3rd harmonic cavity

HIGH OPERATIONAL MARGIN WITHOUT ADDITIONAL HARDWARE

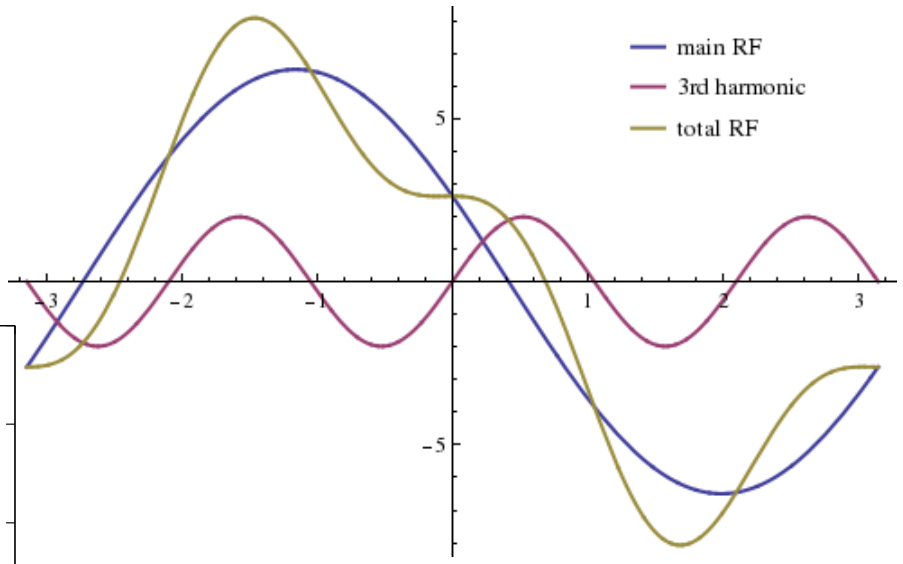


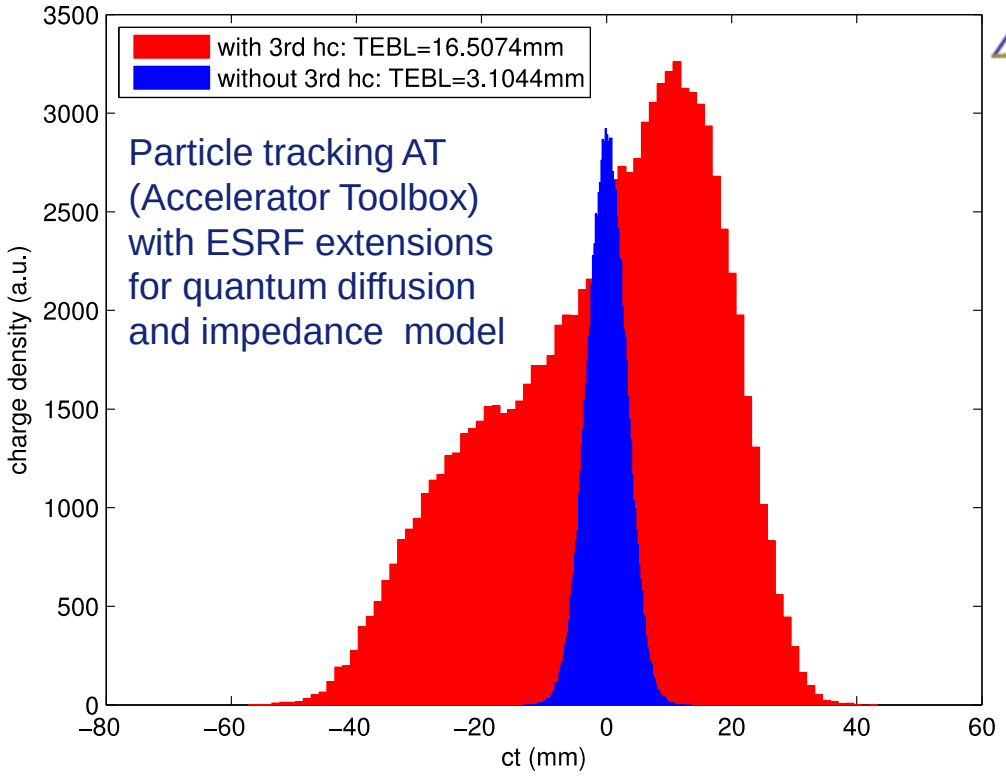
- Even with 5 cavities in fault (1 complete cell) ☞ operation at 4.5 MV / 200 mA still possible
- Also room left for performance upgrade

HARMONIC CAVITY, NO IMPEDANCE

TEBL is “Touschek Effective Bunch Length” to take into account non-Gaussian bunches.

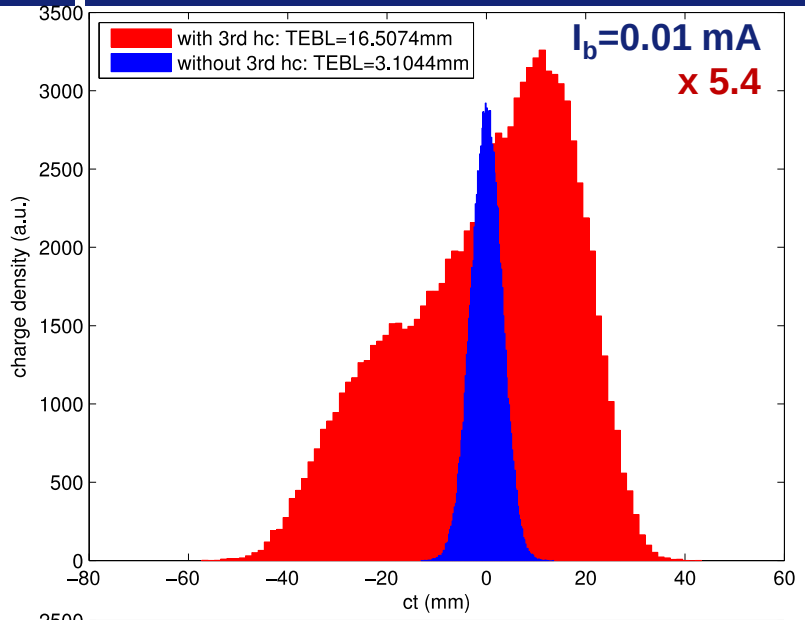
In optimum conditions (0 current, optimum voltage), the gain is a factor 5.4

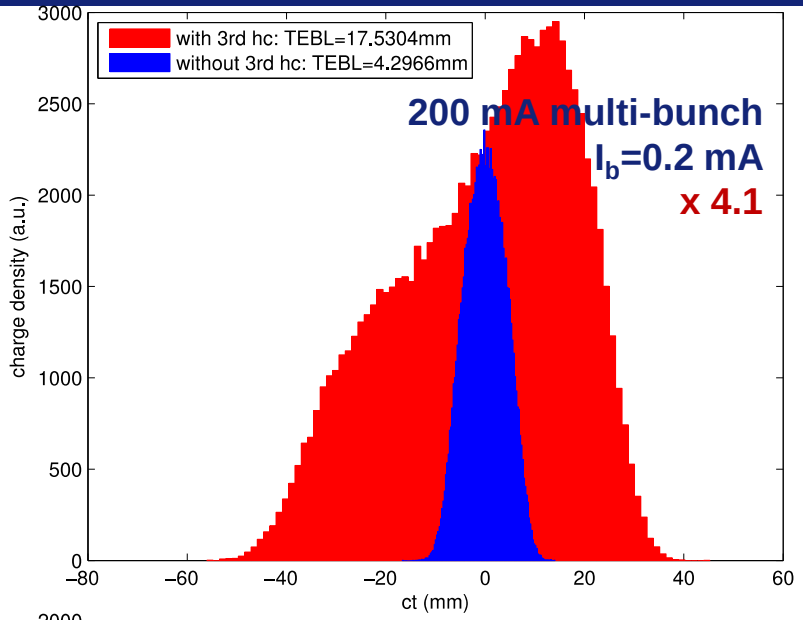


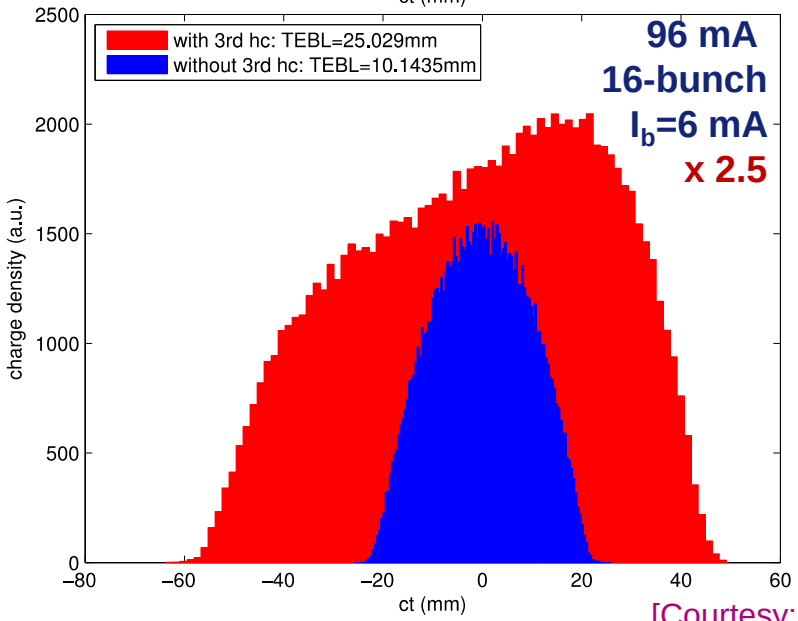


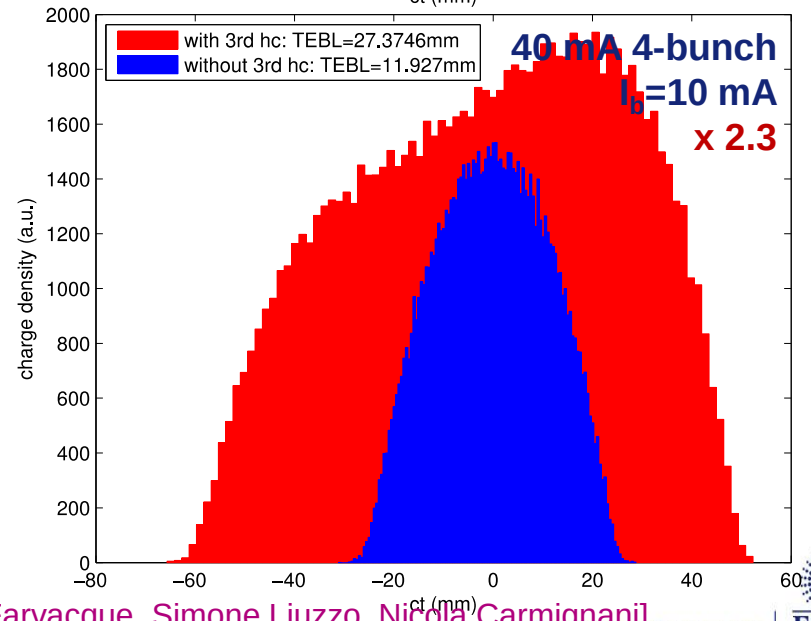
[Courtesy: Laurent Farvacque, Simone Liuzzo, Nicola Carmignani]

PURE INDUCTANCE 0.35 Ω + HARMONIC CAVITY









[Courtesy: Laurent Farvacque, Simone Liuzzo, Nicola Carmignani]

IMPROVED INJECTION EFFICIENCY THANKS HARMONIC RF

Particles with **a large betatron amplitude x:**

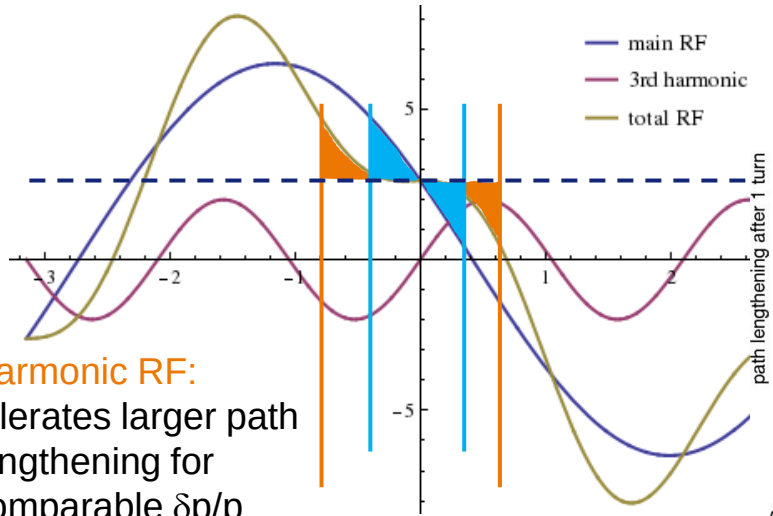
- have only a reduced energy acceptance $\delta p/p$
- experience path lengthening

$\Rightarrow$ start synchrotron oscillation $\Rightarrow$ some reach acceptance limit and eventually get lost

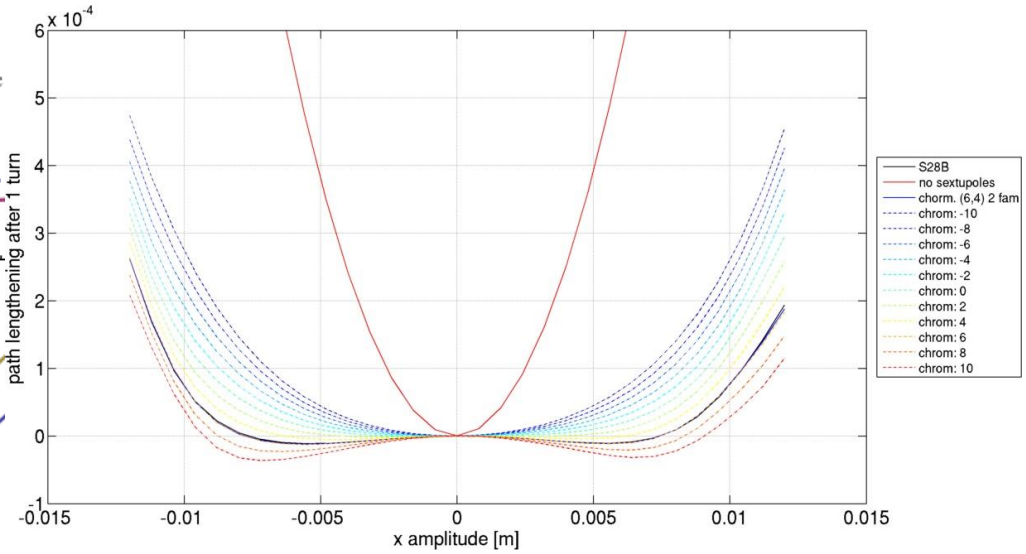
- non zero optimum chromaticity $\Rightarrow$ minimizes path lengthening $\Rightarrow$ maximizes lifetime
- Harmonic RF $\Rightarrow$ on-momentum aperture increased by 1 mm, no effect on lifetime (particle tracking result)

Injected beam at large offset x:

- Harmonic RF $\Rightarrow$ improves injection efficiency by a few percent (particle tracking result)



Harmonic RF:
tolerates larger path lengthening for comparable $\delta p/p$



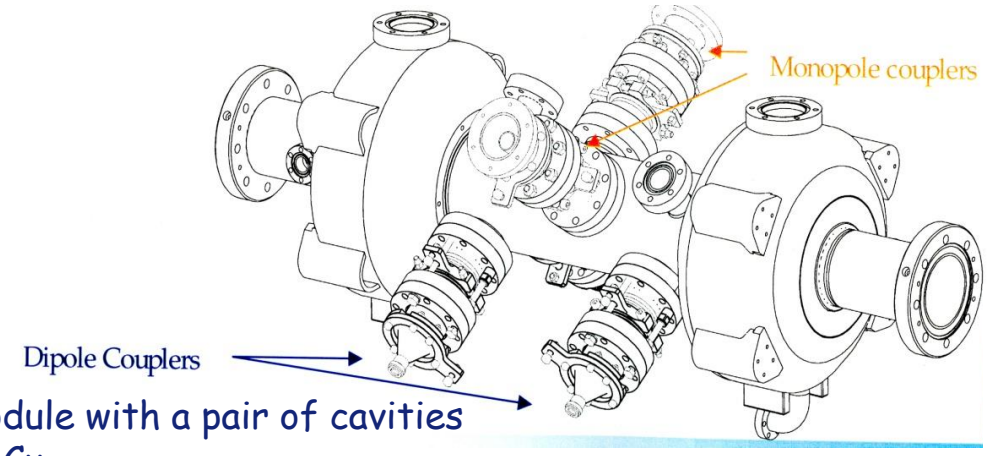
[Courtesy: Laurent Farvacque, Simone Liuzzo, Nicola Carmignani]

3RD HARMONIC SC PASSIVE CAVITY

Super-3HC cavity pair:

- 3rd harmonic cavity for: SLS & Elettra
- Scaling of the SC SOLEIL Cavity
- Construction: CEA & CERN

- $R_s/Q = 2 \times 45\ \Omega$
- Quality factor: $Q_0 = 2.10^8$
- $f_{res,hc} = 1.5$ GHz



Superconducting Module with a pair of cavities
- ☞ Nb sputtered on Cu
- ☞ Effective HOM damping

ESRF, $f_{rf} = 352.373$ MHz, $V_{rf} = 6$ MV → Scaling of passive Super-3HC in frequency

3rd harmonic: $f_{res,hc} = 1057.1$ MHz

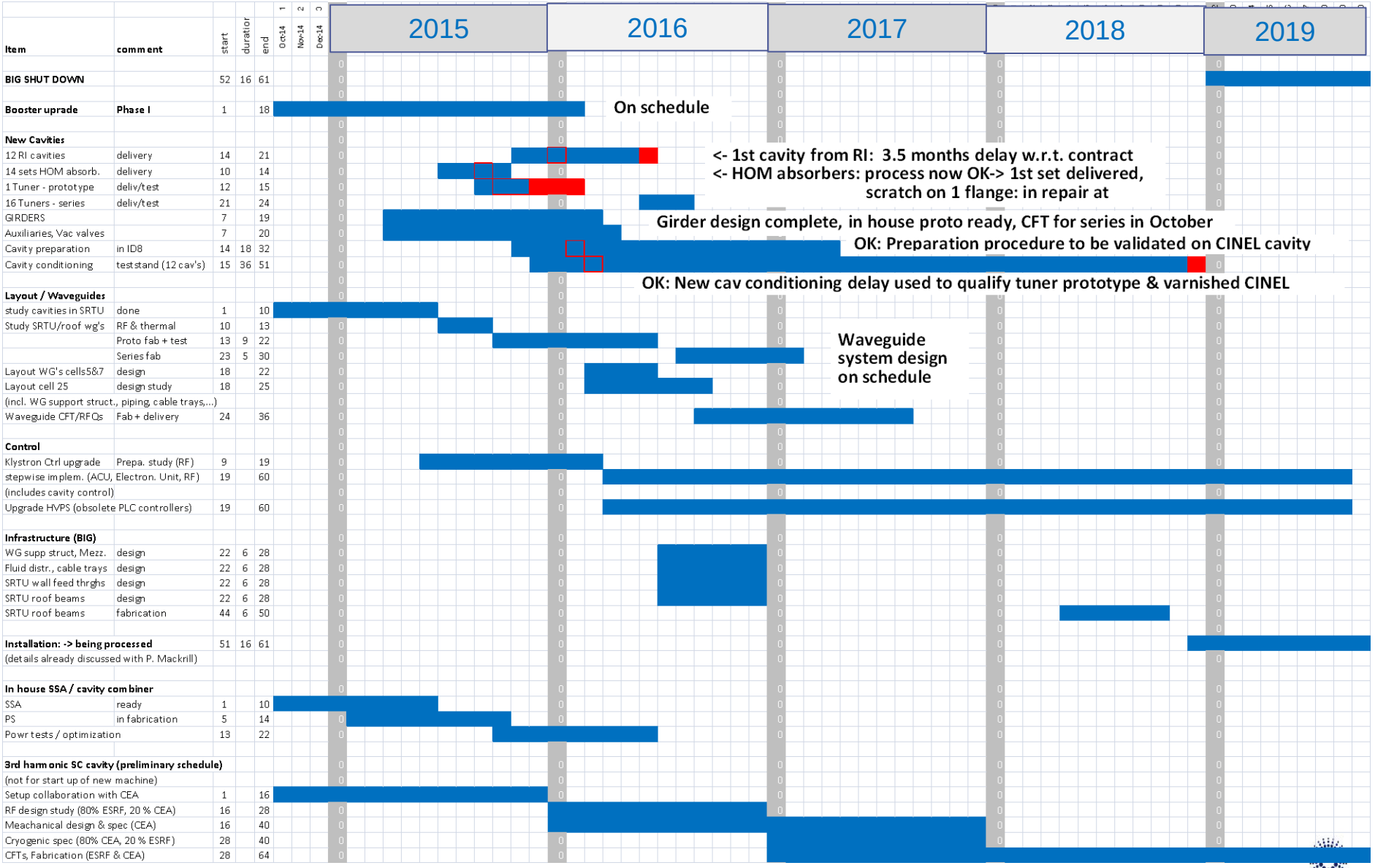
- $V_{hc,opt} = 1.70$ MV, $\varphi_{hc,opt} = -4.3°$ ($E_{max} = 6$ MV/m)
  - 40 mA: $\varphi_{hc,tune} = 89.93° \Rightarrow \varphi_{hc,real} = -0.07°$
  - 90 mA: $\varphi_{hc,tune} = 89.97° \Rightarrow \varphi_{hc,real} = -0.03°$
  - 200 mA: $\varphi_{hc,tune} = 89.99° \Rightarrow \varphi_{hc,real} = -0.01°$

- Collaboration with CEA / IRFU / SACM *(Service des Accélérateurs, de Cryogénie et du Magnétisme)*
- Development and implementation
- Work to be started in 2016

- AC Robinson stability / optimum HC tuning down to:
  - $I_{beam} > 30\ mA/n$ with n Super-3HC ☞ to be confirmed by particle tracking !

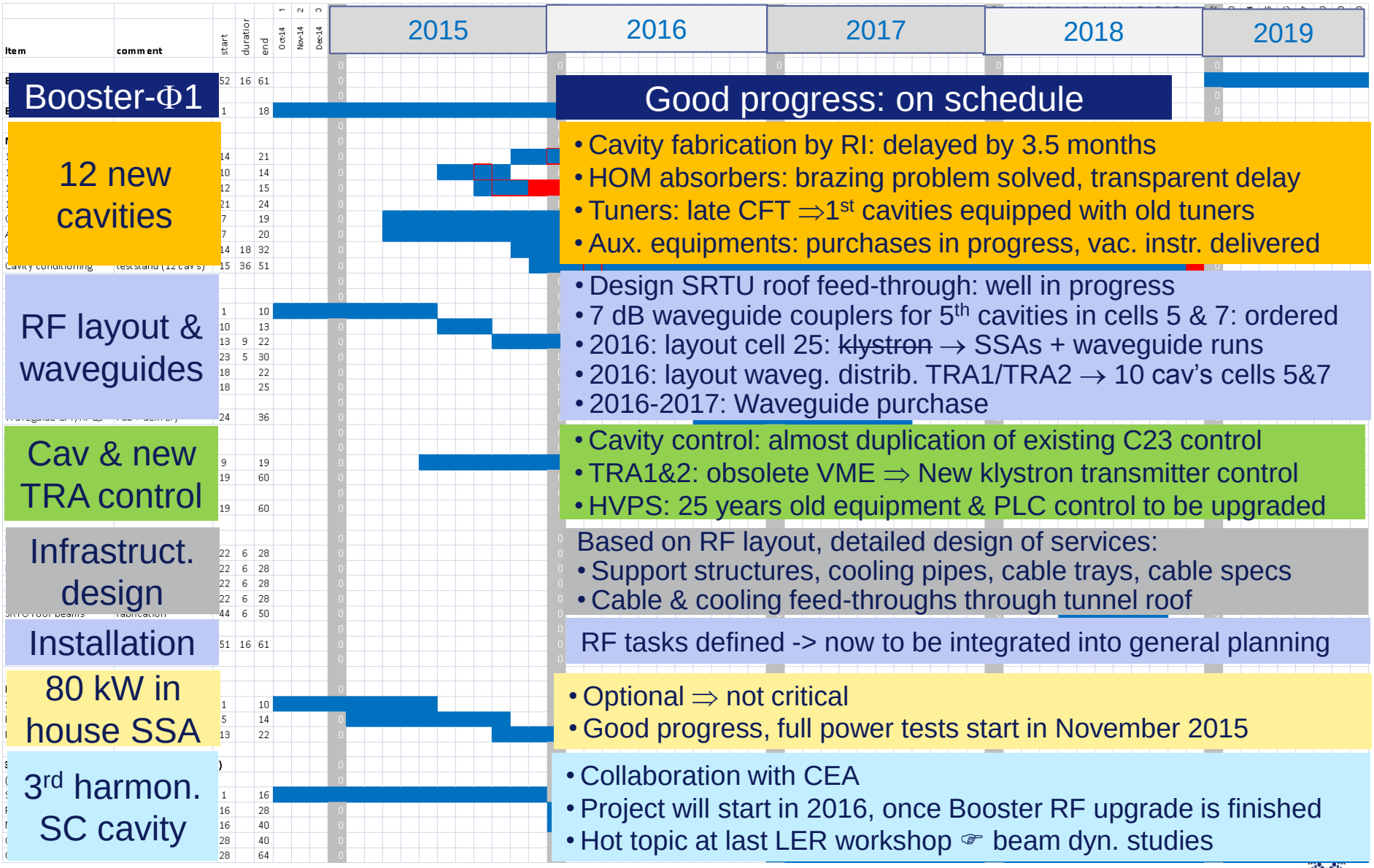
SCHEDULE AND STATUS

Item	comment	start	duration	end
BIG SHUT DOWN		52	16	61
Booster uprade	**Phase I**	1		18
New Cavities				
12 RI cavities	delivery	14		21
14 sets HOM absorb.	delivery	10		14
1 Tuner - prototype	deliv/test	12		15
16 Tuners - series	deliv/test	21		24
GIRDERS		7		19
Auxiliaries, Vac valves		7		20
Cavity preparation	in ID8	14	18	32
Cavity conditioning	teststand (12 cav's)	15	36	51
Layout / Waveguides				
study cavities in SRTU	done	1		10
Study SRTU/roof wg's	RF & thermal	10		13
	Proto fab + test	13	9	22
	Series fab	23	5	30
Layout WG's cells5&7	design	18		22
Layout cell 25	design study	18		25
(incl. WG support struct., piping, cable trays,...)				
Waveguide CFT/RFQs	Fab + delivery	24		36
Control				
Klystron Ctrl upgrade	Prepa. study (RF)	9		19
stepwise implem. (ACU,	Electron. Unit, RF)	19		60
(includes cavity control)				
Upgrade HVPS (obsolete	PLC controllers)	19		60
Infrastructure (BIG)				
WG supp struct, Mezz.	design	22	6	28
Fluid distr., cable trays	design	22	6	28
SRTU wall feed thrghs	design	22	6	28
SRTU roof beams	design	22	6	28
SRTU roof beams	fabrication	44	6	50
Installation: -> being processed		51	16	61
(details already discussed with P. Mackrill)				
In house SSA / cavity combiner				
SSA	ready	1		10
PS	in fabrication	5		14
Powr tests / optimization		13		22
3rd harmonic SC cavity (preliminary schedule)				
(not for start up of new machine)				
Setup collaboration with CEA		1		16
RF design study (80% ESRF, 20 % CEA)		16		28
Meachanical design & spec (CEA)		16		40
Cryogenic spec (80% CEA, 20 % ESRF)		28		40
CFTs, Fabrication (ESRF & CEA)		28		64



The European Synchrotron | ESRF

SCHEDULE AND STATUS



Booster-Φ1

Good progress: on schedule

12 new cavities

- Cavity fabrication by RI: delayed by 3.5 months
- HOM absorbers: brazing problem solved, transparent delay
- Tuners: late CFT ⇒1st cavities equipped with old tuners
- Aux. equipments: purchases in progress, vac. instr. delivered

RF layout & waveguides

- Design SRTU roof feed-through: well in progress
- 7 dB waveguide couplers for 5th cavities in cells 5 & 7: ordered
- 2016: layout cell 25: ~~klystron~~ → SSAs + waveguide runs
- 2016: layout waveg. distrib. TRA1/TRA2 → 10 cav's cells 5&7
- 2016-2017: Waveguide purchase

Cav & new TRA control

- Cavity control: almost duplication of existing C23 control
- TRA1&2: obsolete VME ⇒ New klystron transmitter control
- HVPS: 25 years old equipment & PLC control to be upgraded

Infrastruct. design

Based on RF layout, detailed design of services:

- Support structures, cooling pipes, cable trays, cable specs
- Cable & cooling feed-throughs through tunnel roof

Installation

RF tasks defined -> now to be integrated into general planning

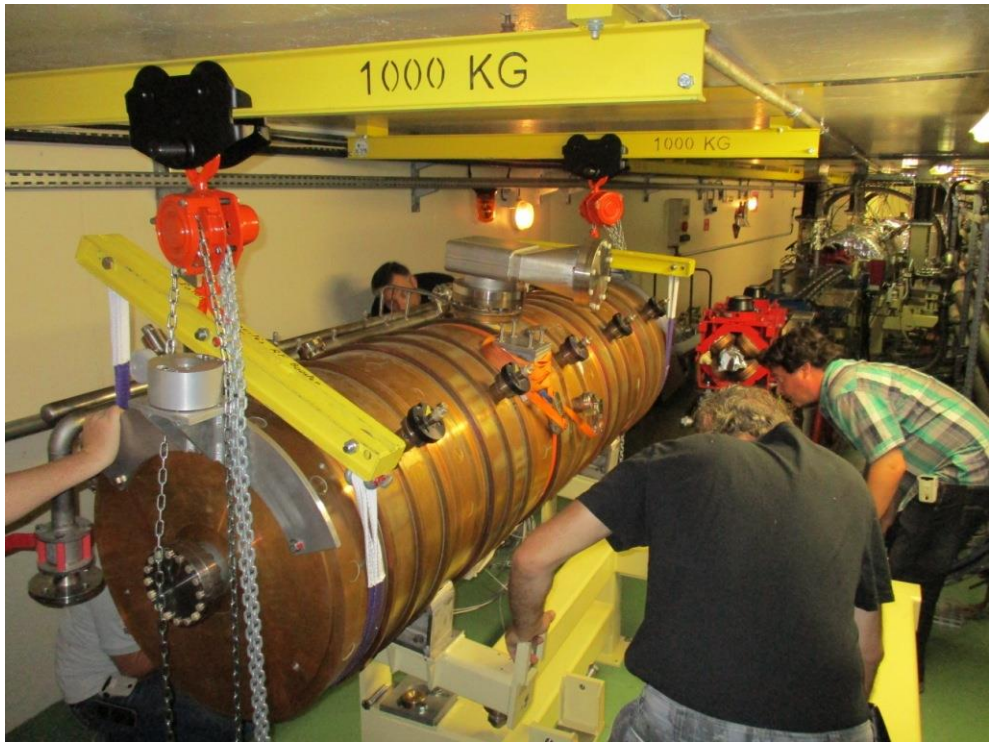
80 kW in house SSA

- Optional ⇒ not critical
- Good progress, full power tests start in November 2015

3rd harmon. SC cavity

- Collaboration with CEA
- Project will start in 2016, once Booster RF upgrade is finished
- Hot topic at last LER workshop ☞ beam dyn. studies

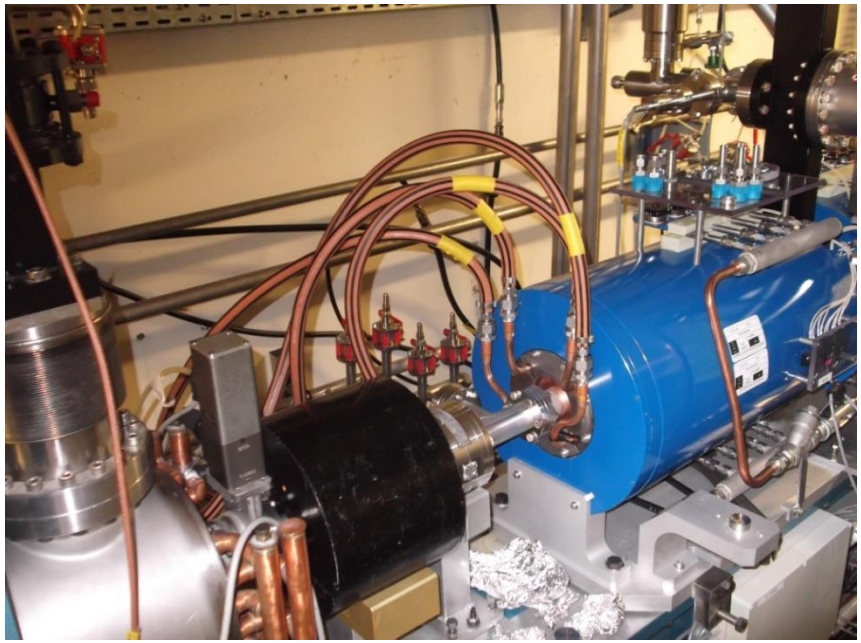
BOOSTER RF UPGRADE (PHASE I) : ON SCHEDULE



- August 15 shut down: installation of pre-conditioned 1st additional booster cavity (LEP)
- October 15 shut down: installation of 2nd additional LEP cavity
- December 15 shut down: **2 cavities x 2 SSAs/cav → 4 cavities x 1 SSA/cav**

LINAC UPGRADE (PHASE I)

Refurbishment program of the Linac



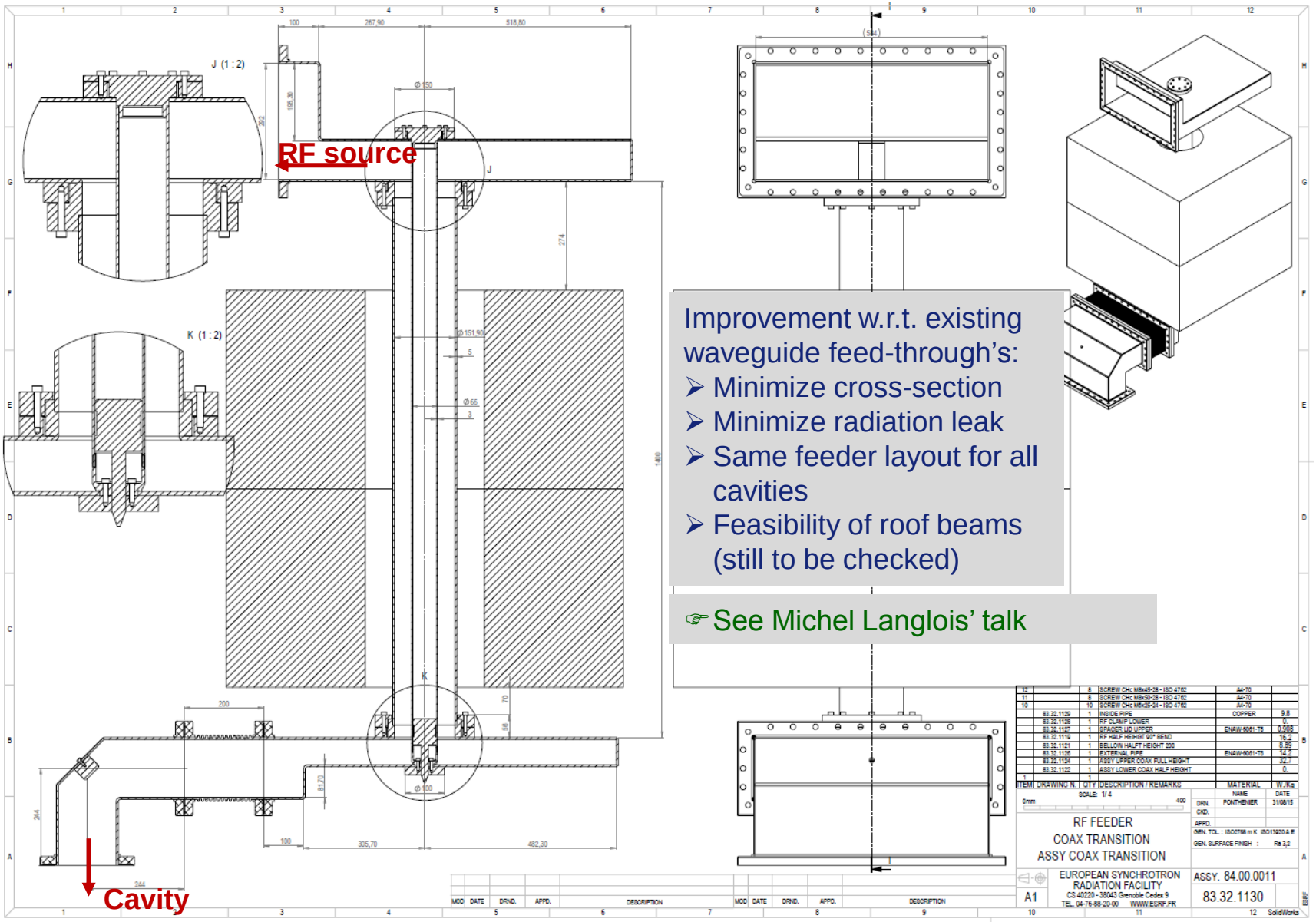
← New buncher from Thales

- ✓Commissioned in August 2015
- ✓Old one → spare

3rd modulator built in house

- ✓Hot spare to safeguard future top up operation
- ✓35 MW reached in August 2015
- ✓Still to be commissioned for operation

COAXIAL FEED-THROUGH FOR SRTU ROOF BEAMS



Improvement w.r.t. existing waveguide feed-through's:

- Minimize cross-section
- Minimize radiation leak
- Same feeder layout for all cavities
- Feasibility of roof beams (still to be checked)

☞ See Michel Langlois' talk

RF FEEDER
COAX TRANSITION
ASSY COAX TRANSITION

EUROPEAN SYNCHROTRON RADIATION FACILITY
CS 40220 - 38043 Grenoble Cedex 9
TEL. 04-76-88-20-00 WWW.ESRF.FR

ASSY. 84.00.0011
83.32.1130

OPERATION EXPERIENCE WITH 3 SSA'S ON SR

Operation of 3 SSA's operated in CW on the storage ring cell 23:

	C23-1	C23-2	C23-3	Comment
2013	2	0	1	C23-2 not in operation
2014	4	3	7	C23-2 idle for the last 4 months
2015	0	5	0	C23-3 idle since December 2014
Running hours	12000	4900	7450	
Total failures	6	8	8	• RF modules: DC input filters • DC/DC conv.: capacitances
Beam interruptions	1	1	1	• 2x Control box fuse → interlock • 1x SSA Drive amplifier

4 SSAs on the booster: 3 minor failures in 2015, no impact on operation

All 7 SSAs: not a single transistor failure during operation so far!

[Jean-Maurice Mercier]


Announcement:
CWRF'2016
21 to 24 June 2016
Grenoble / ESRF
Thank
you !!!