2023 ASD Workshop

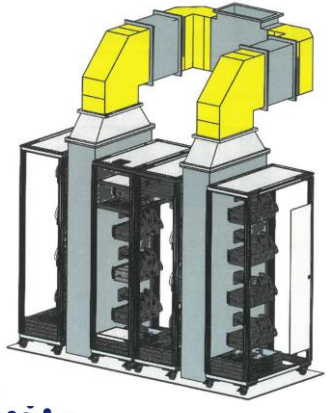
Grenoble, 1st February 2022

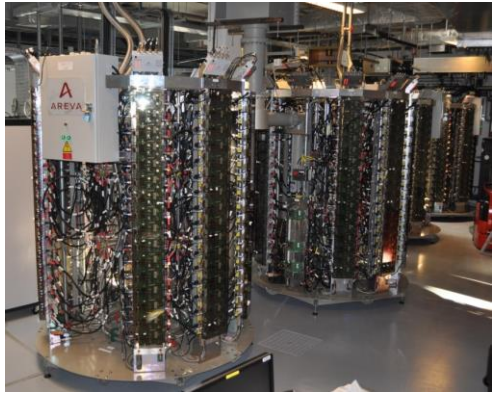
RF System

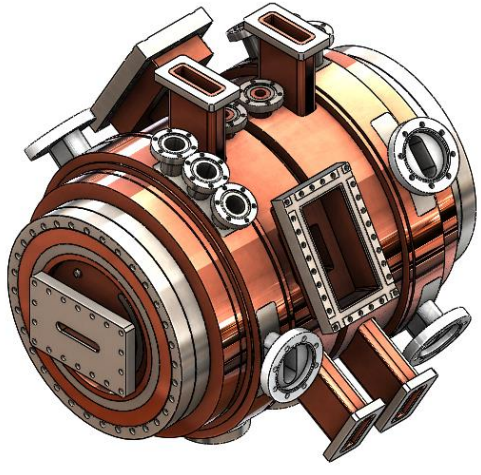
Including Linac, Injection/Extraction, Booster and Storage Ring 352 MHz systems

Jörn Jacob

On behalf of the RF Group







ESRF | The European Synchrotron

RADIO FREQUENCY - RF GROUP

On behalf of the RF Group


Jörn Jacob

Linac & Injection/Extraction


Marc Dubrulle


Mathieu Morati

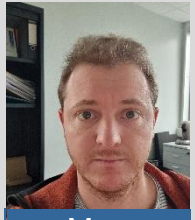

Hervé Delamare


Philippe Henrissat


Louay Khlaifi

Student Trainee, 2y

RF Design & Mechanical support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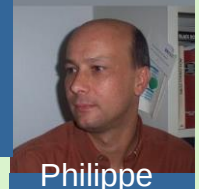
Vincent Serrière

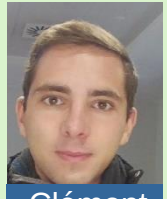

Bernard Cocat

RF Power Amp's - Klystrons, SSAs


Claude Rival


Pawel Borowiec


Philippe Chappelet

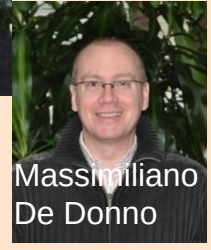

Clément Sestito

Student Trainee, 2y

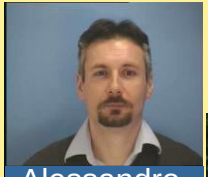
LLRF, Control, Timing…

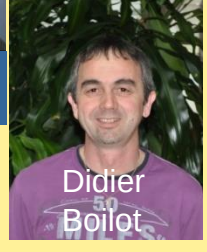

Nicolas Michel


Georges Gautier


Massimiliano De Donno

RF Cavities


Alessandro D'Elia


Didier Boilot

OUTLINE

- **Linac**
- **Injection /Extraction**
- **352 MHz RF System**
  - Operation
  - New SSA
- **4th harmonic RF system**

LINAC

Ongoing LINAC maintenance and update

- Improved pre-buncher amplitude and phase control
  - NB: Signal directlty coupled from high power RF pulse of 1st acceleration section
  - Motorized amplitude and phase modulators
  - 2022: first tests with new phase modulator
  - 2023: completion, including amplitude modulator

- Replacement of obsolete Klystron focus power supplies
  - New power supplies in house
  - New PLC controller
  - 2023: 1st cubicle for modulator MOD 3
  - Prototype for MOD 1 and MOD 2
  - On wheels ⇒ can be connected in short time to MOD 1 or 2 if needed

INJECTION EXTRACTION - INJEXT

Operation

- 6 beam losses attributed to injection kicker failures:
  - → *ongoing analysis and improvement of tricky interplay between fast kicker timing and non-synchronized high level control*
- 1 beam loss due to S3 water cooling interlock

Ongoing INJEXT preventive maintenance and upgrade

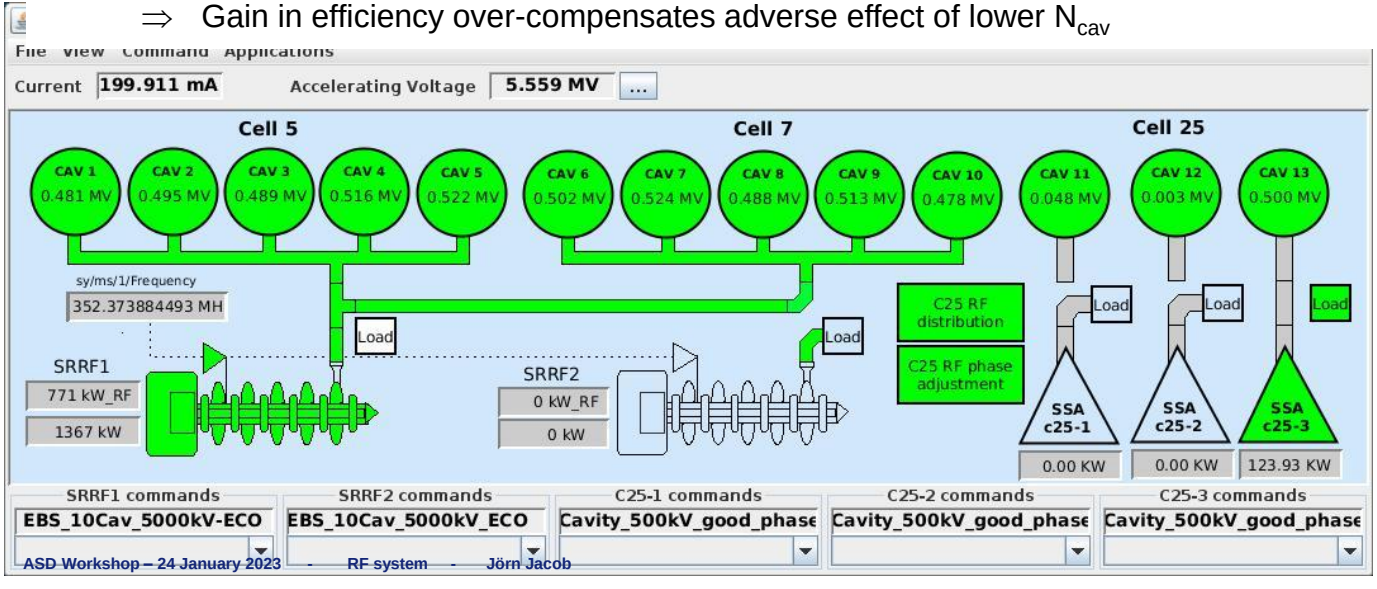
- 2022
  - New in house built SY-Bumper power supplies taken into operation for increased bump amplitude [→ Simon White's talk]
  - Spare S3 in-vacuum septum magnet: almost fully assembled
- 2023
  - Completion of spare S3
  - Improve control of S3 water cooling (implement flow measurement via PLC)
  - Procure spare booster in-vacuum septum Se1
    - *Spare tank → Vacuum Group*
    - *Planned CFT for spare magnet*
    - → *Part of update campaign of 30 y old spare stock*
  - Slow down kicker PS's to reduce stored beam perturbation [→ Simon White's talk]
  - Study of full sine excitation of S3 to minimize wake and stored beam perturbation, in view of moving S3 closer to the stored beam [→ Simon White's talk]

352 MHz STORAGE RING RF - ECO MODE SINCE END OCTOBER 2022

$$P_{AC} = [\ V_{acc}^{\ 2} / (N_{cav} \times 2R_s) + P_{beam}\ ] / \eta_{RF/AC}$$

ECO mode:

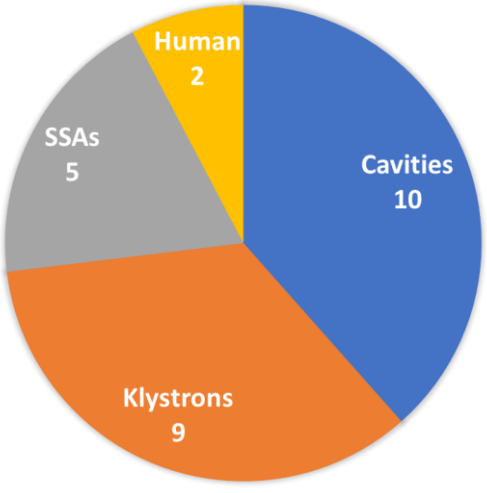
- **Reduction of total V_{acc}** from **6.0** to **5.5 MV**
- **Increase AC to RF conversion efficiency:**
  - → 10 years old 150 kW SSA in cell 25 haven't yet drain voltage modulation and are operated way below nominal power on EBS, at 90 …100 kW, where the efficiency is low. NB: new SSA from JEMA will have drain voltage modulation and better efficiency at low power like klystrons with anode modulation !
  - ⇒ Increase the share of Klystron power by increasing Cav 1 to 10 voltage from 4.5 to 5.0 MV
  - ⇒ Operate with only 1 SSA e.g. Cav 13 at 0.5 MV
  - ⇒ Gain in efficiency over-compensates adverse effect of lower N_{cav}

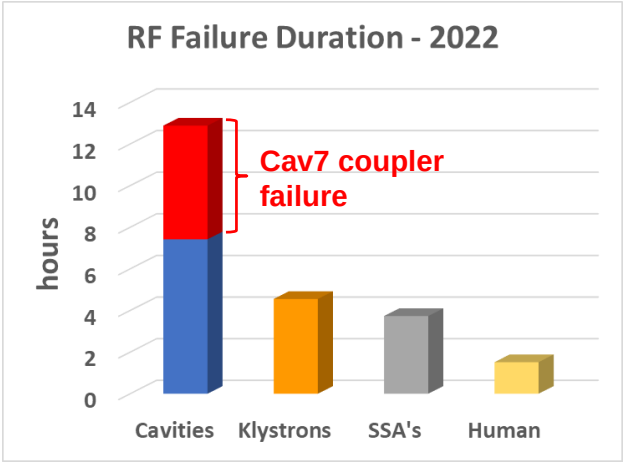


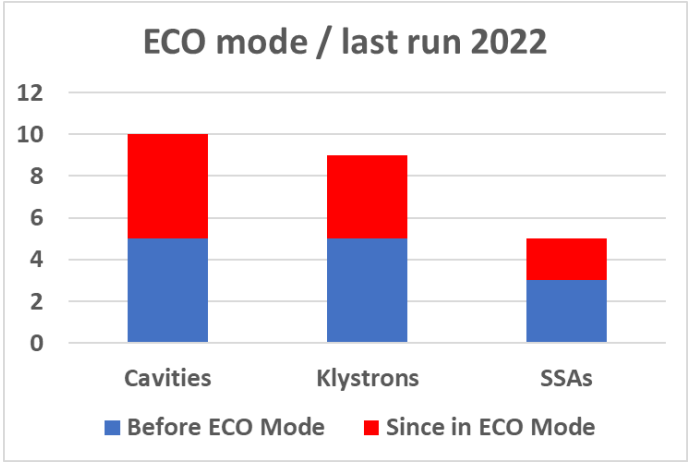
RESULT:

- **200 kW AC power savings** at 200 mA
- **Same beam lifetime** for typical ID losses around 0.4 … 0.5 MeV/turn
- 500 kW total savings possible if operation at 100 mA

352 MHz STORAGE RING RF – RF BEAM LOSSES IN USM 2022







26 Beam losses in USM due to RF

- Including agreed 4.5 hours intervention to put cavity 7 in passive on 24 June
- Each trip counted, even close-by trips that later concatenated to 1 longer interruption for EBS statistics

Remarkable events

- 8 cavity break downs on several cavities - followed by ceramic window leak on Cav7
  - → *Insufficient protection => set lower interlock thresholds for cavity reflected power*
  - → *Thresholds slightly too low => further trip on 29 June => intervention for threshold re-adjustment*
  - → *RF couplers should now be well protected !*
- SSA: twice wrong interlock from AC/DC converter PLC => CPU exchange
- TRA1: tricky hunt finally revealing false interlock from ion pump controller of IP2
  - → *4 trips => finally strapped interlock, relying fully on IP1 for protection*
  - → *Last week: new problem with IP controller of TRA1, now on both IP1 and IP2*
  - → *Klystron itself not incriminated => refurbishment of IP controllers under way*
- Human 1: @ Extremely hot June, mistake when reconnecting a fan (necessary urgent action)
- Human 2: EmOff button on idle TRA2 triggered a stop on TRA1 in operation

… SR CAVITIES

Cavity 4 coupler exchange

- September 22: glow discharge observed on cav#4 coupler subsequent to wrong file configuration
  - → *Degradation with time of this brand of couplers is known*
  - → *No impact on USM, however, Implementation of ECO mode postponed to last run*
  - → *Coupler exchanged in October shut down & successfully reconditioned at restart*
  - → *ECO mode applied at October restart for last run*

Cavity 2 – obstruction of 1 water cooling circuit

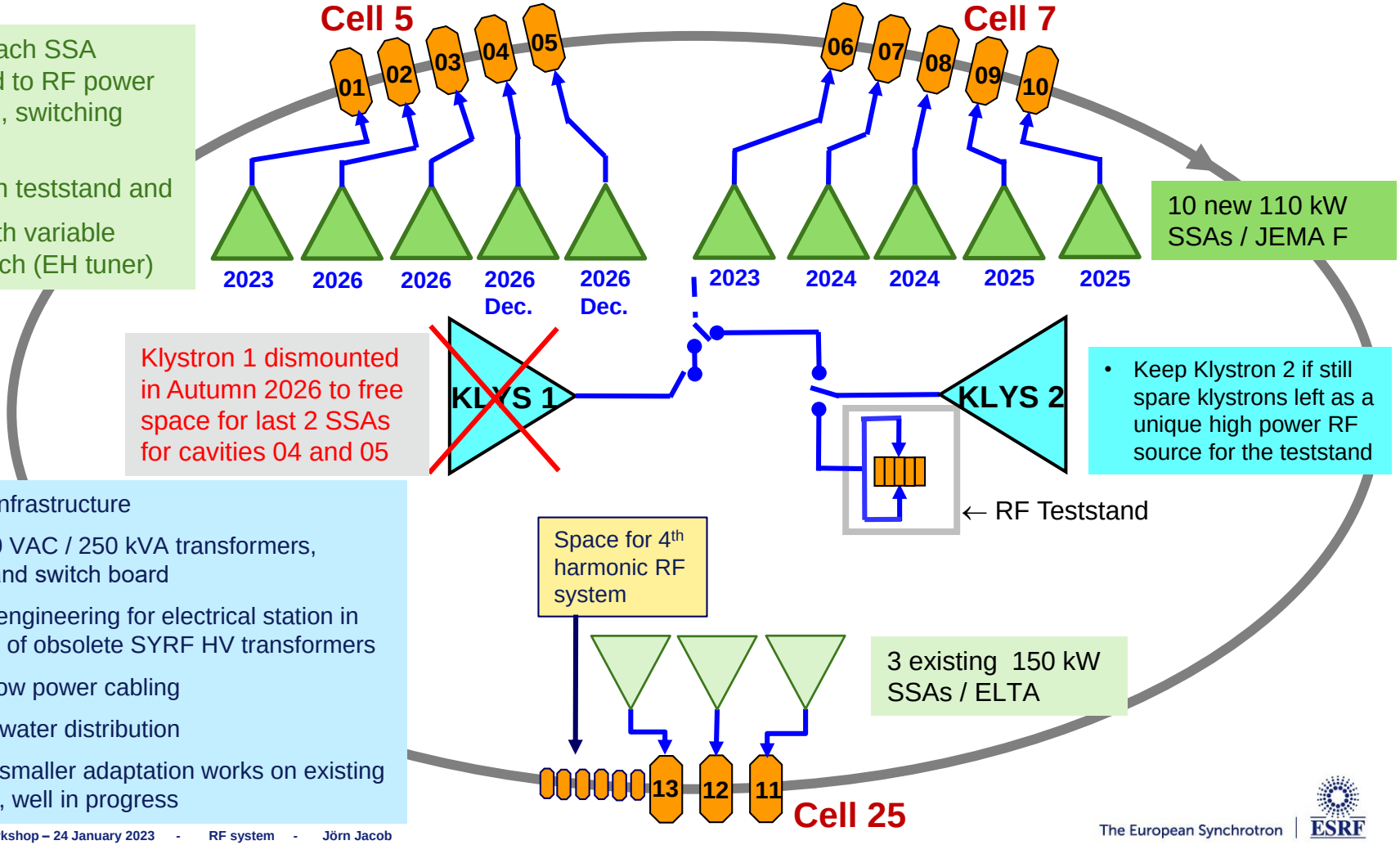
- Problem: bad tuning of cavity 2 in RF low state after a beam trips in run 5
  - → *Longer thermal time constant*
  - → *Suspected partial obstruction*
  - → *New highly sensitive phase detector installed on tuning loop: mitigated problem for operation*
- Winter SD: Obstruction of one cooling channel confirmed (Disc + Nose cone cooling)
  - → *Obstruction left inside manifold by piping supplier*
  - → *Present since the beginning of EBS operation*
  - → *Revealed during ECO mode due to increased Voltage and dissipation per cavity*

- Piece of cleaning paper probably forgotten by manifold manufacturer at factory
- Obstruction of one sub circuit at 1st pressurization on cavity 4 on the teststand

GRADUAL IMPLEMENTATION OF 10 SSA (EACH 110 KW RF, MAX 250 KW AC)

SAT for each SSA connected to RF power **teststand**, switching between:

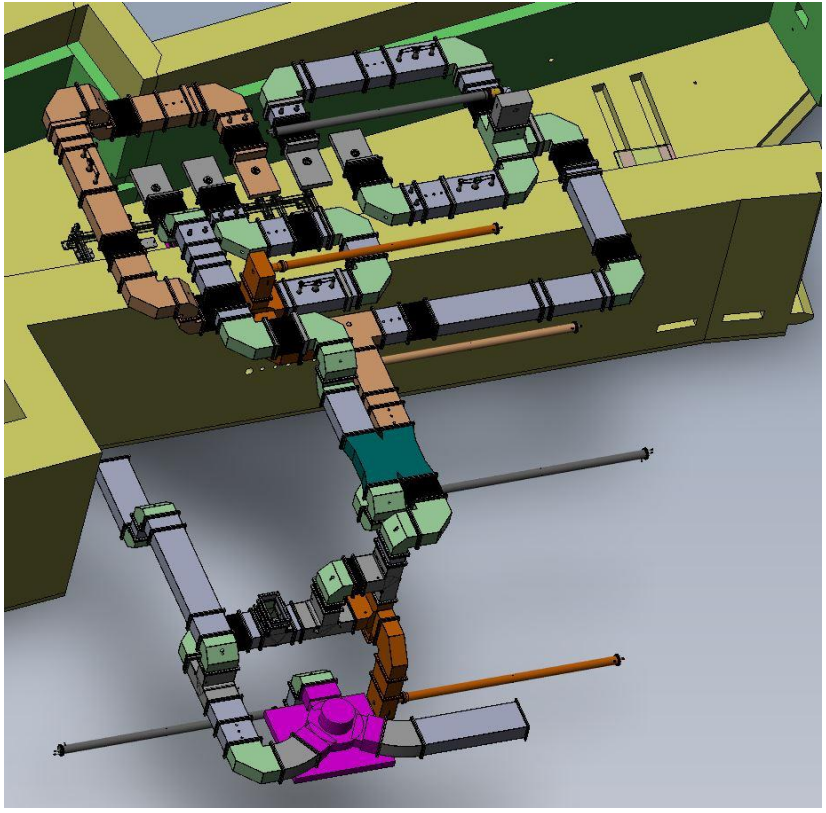
- cavity in teststand and
- load with variable mismatch (EH tuner)



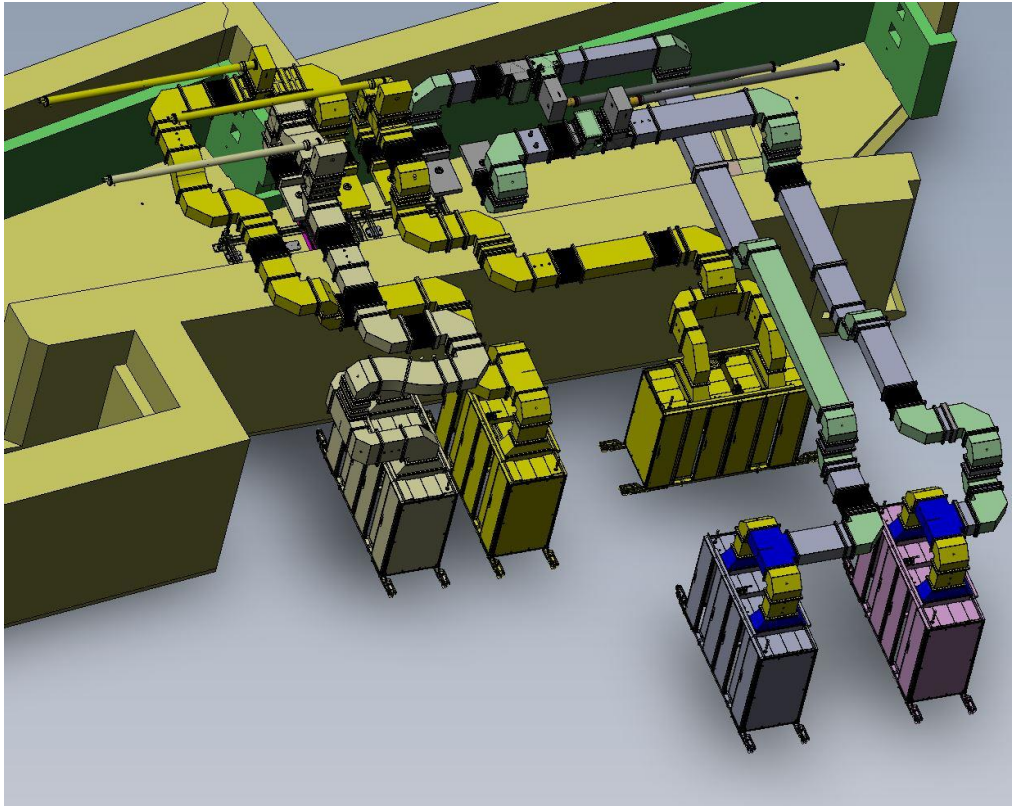
TID/BIG - Infrastructure

- 10 x 240 VAC / 250 kVA transformers, MCB's and switch board
  - ➢ Civil engineering for electrical station in place of obsolete SYRF HV transformers
- High & low power cabling
- Cooling water distribution
- Several smaller adaptation works on existing services, well in progress

CHALLENGE: GRADUAL INSTALLATION IN EXISTING KLYSTRON ROOM

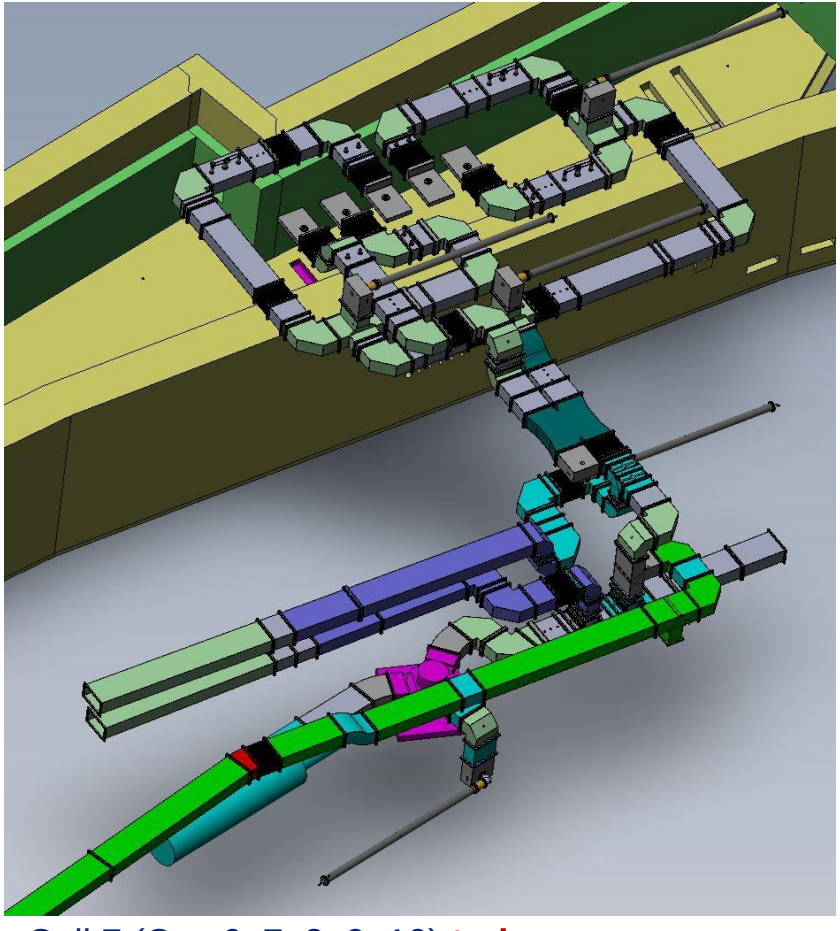


Cell 5 (Cav 1, 2, 3, 4, 5) **today**

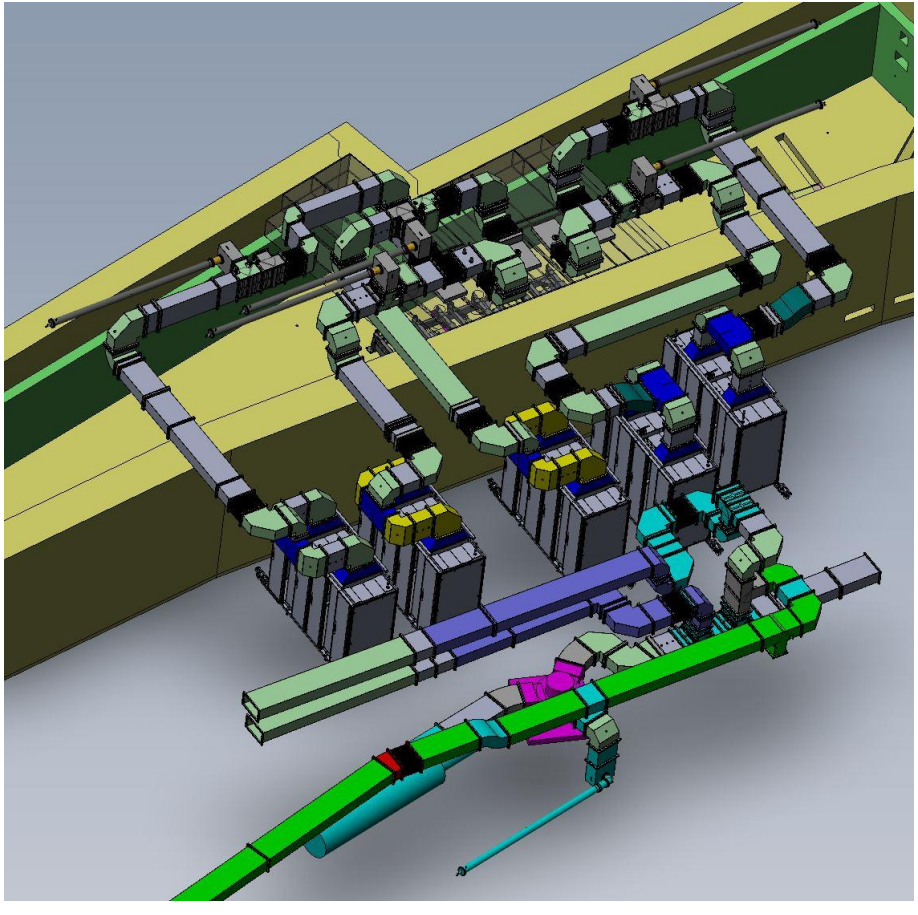


Cell 5 (Cav 1, 2, 3, 4, 5) **from January 2027**

CHALLENGE: GRADUAL INSTALLATION IN EXISTING KLYSTRON ROOM

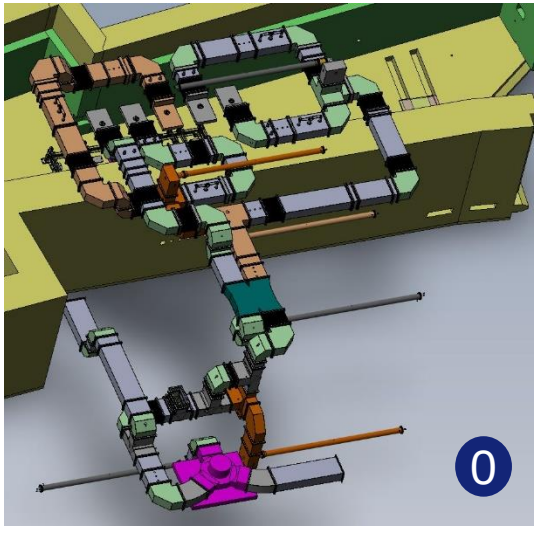


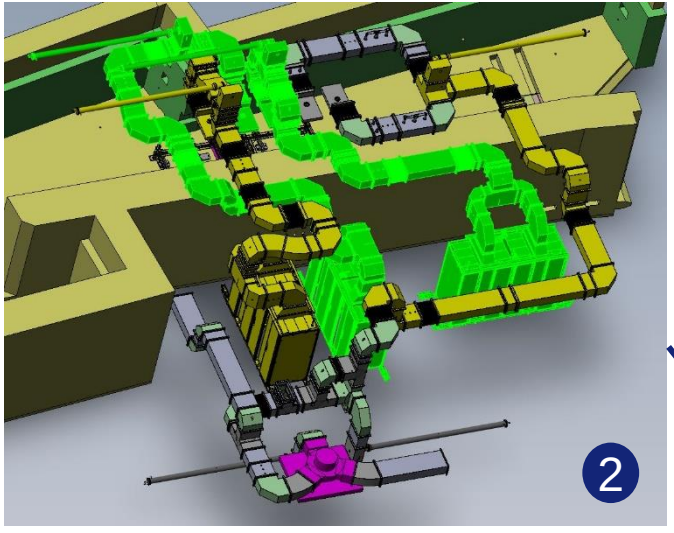
Cell 7 (Cav 6, 7, 8, 9, 10) **today**

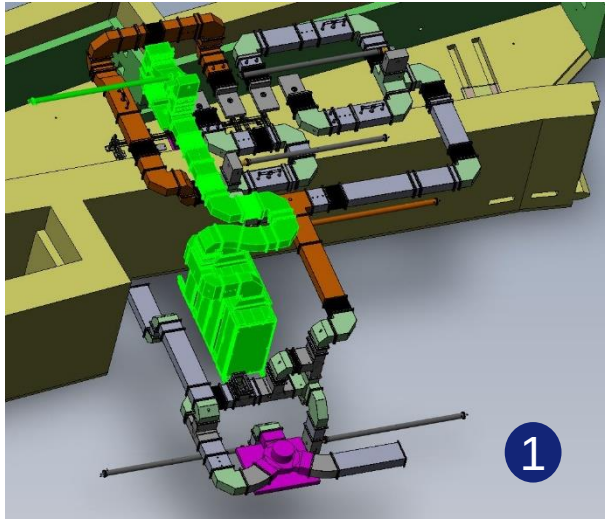


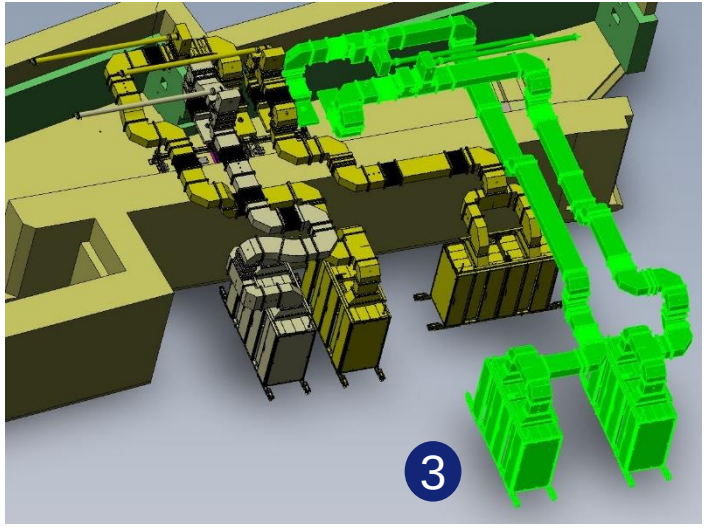
Cell 7 (Cav 6, 7, 8, 9, 10) **from August 2025**

CELL 5: GRADUAL IMPLEMENTATION SEQUENCE

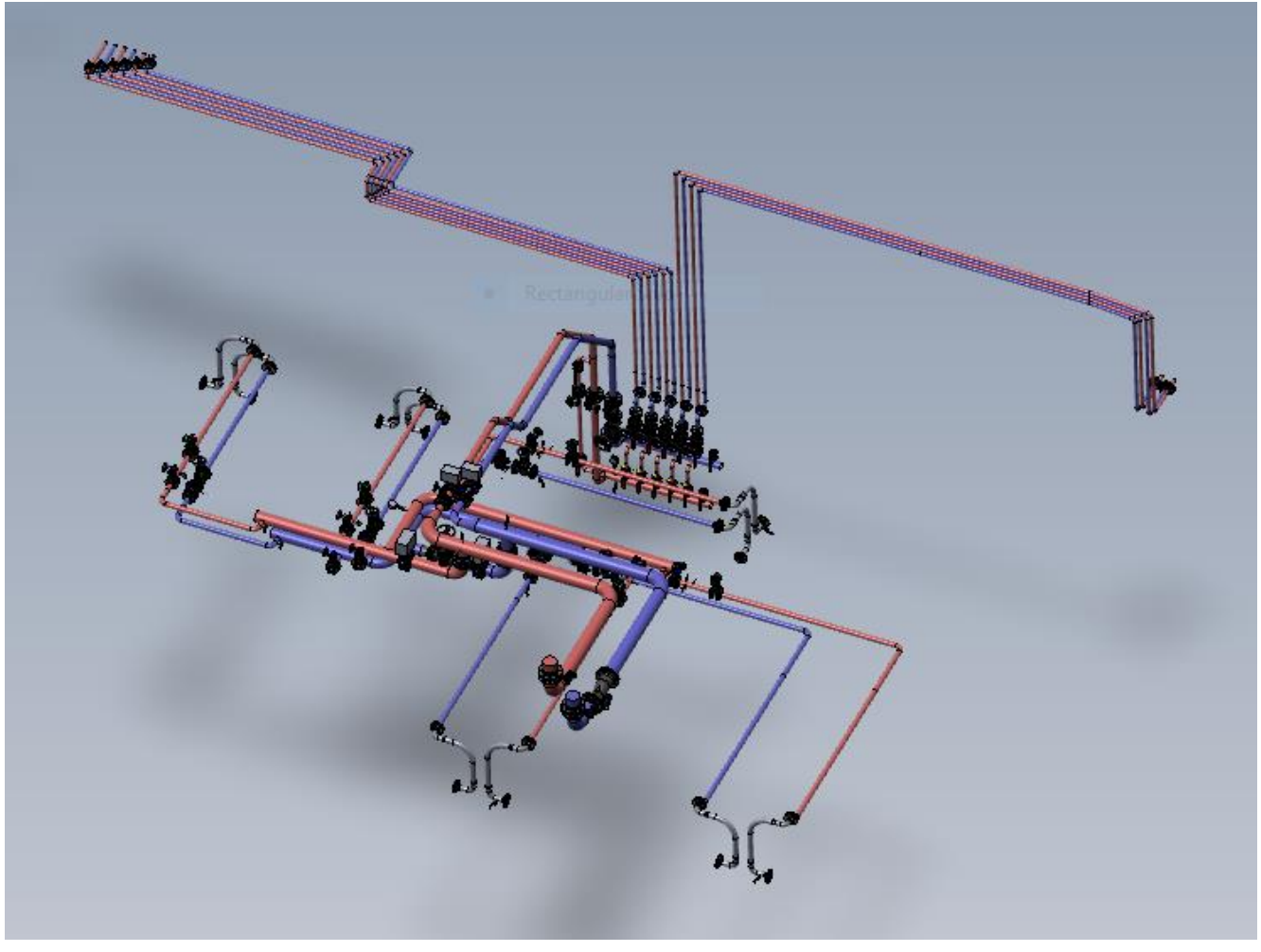








CELL 5: COOLING WATER DISTRIBUTION – SSA AND LOADS



352 MHz SSA PROJECT STATUS

ESRF preparation

- Model, drafting (RF, BIG, MEG, subcontractor ERIA)
  - ✓ 3D model of waveguides, incl. installation stages
    - *2D drawings for each stage in progress (for execution of works)*
  - ✓ Water cooling drawings ready for CFT / BIG
  - ➢ Cable tray layout: by end of January 23
- BIG Preparatory works on site
  - ✓ Agreed master plan to coordinate BIG and RF tasks (Microsoft Project planning)
  - ✓ Modification of water & compressed air manifolds, of LN2 line and existing cable trays
  - ✓ Installation of SRE outlets for SSA cooling
  - ➢ Installation of cable trays outside SRRF has started
- ACU
  - ➢ End January 23: controller from JEMA to start tests for the connection to ESRF control system
- RF
  - ✓ E/H tuner on teststand, for variable mismatch setting needed at SAT
  - ✓ Reorganization of spares storage to release space for SSA installation
  - ➢ LLRF system designed and under implementation

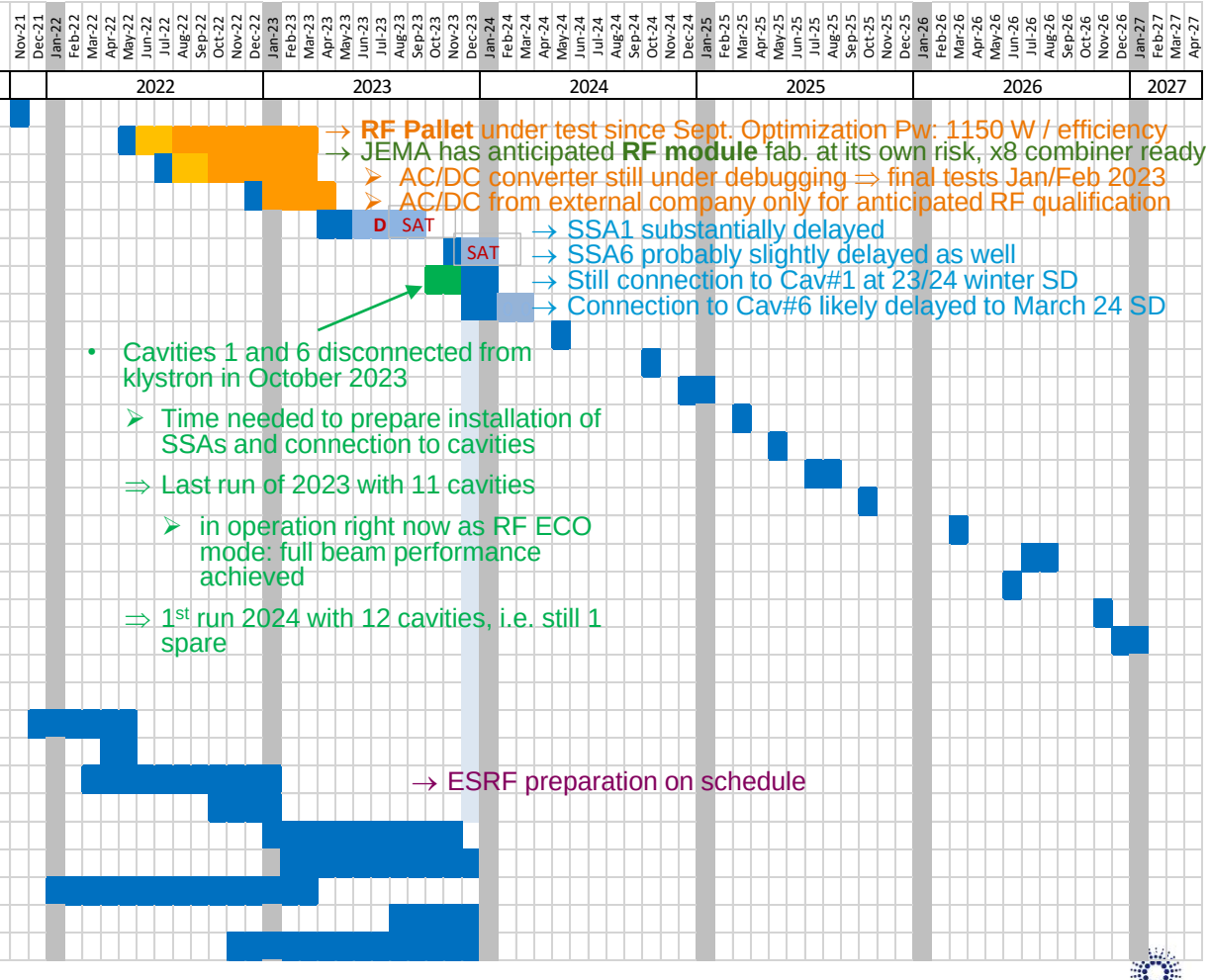
352 MHZ SSA PROJECT STATUS

SSA contract with JEMA France

- 1150 W RF pallet still requires some optimization to meet the specification. FAT for milestone 1 of the contract is further delayed.
- AC/DC converters under test also not ready for series production. JEMA proposes to use a commercial AC/DC converter to build the 9 kW RF module (8 RF pallets) and provisionally for the first 110 kW SSA.
- Nevertheless JEMA is purchasing necessary components for the future milestones at its own risk, allowing them to parallelize the work and minimize the delay for the first complete SSA.

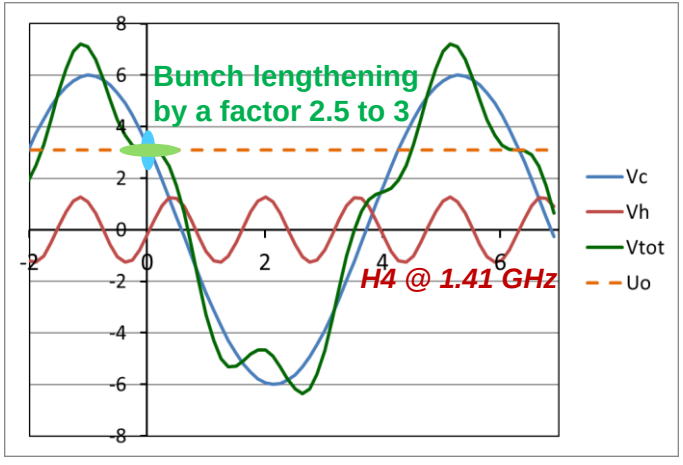
352 MHz SSA PROJECT STATUS

Item	comment
Contract JEMA France	Signature
Milestone 1	RF pallet
Miletsone 2	RF module (8 pallets + AC/DC conv.)
Milestone 2A	Successful ON/OFF fatigue test
1) SSA 1	Delivery & SAT (on RF power teststand)
2) SSA 6	Delivery and SAT
SSA 1	Conect. & Start OP/cav's
SSA 6	Conect. & Start OP/cav's (delayed ?)
3) SSA 7	Delivery and SAT
4) SSA 8	Delivery and SAT
SSA 7&8	Conect. & Start OP/cav's
5) SSA 9	Delivery and SAT
6) SSA 10	Delivery and SAT
SSA 9&10	Conect. & Start OP/cav's
7) SSA 2	Delivery and SAT
8) SSA 3	Delivery and SAT
SSA 2&3	Conect. & Start OP/cav's
9) SSA 4	Delivery and SAT
10) SSA 5	Delivery and SAT
SSA 4&5	Conect. & Start OP/cav's
ESRF preparation	
Waveguide layout	RF design
3D scan existing infra.	ALGE + subcontractor
Building integr./3D	RF, MEG + Subcontractor, ALGE, BIG
Electr + civil Eng. Study	outside buildg, transf. MCB, by BIG
Electr. Pw. proc & inst.	(transf, MCB, switchbox) by BIG
Water, Elec. distrib.proc & inst.	inside buildingBIG
LLRF and PLC racks	Design, Procurement, Assembly
Control, PSS	
Waveguides, WG switches	procurement



STATUS - 4TH HARMONIC RF SYSTEM FOR BUNCH LENGTHENING

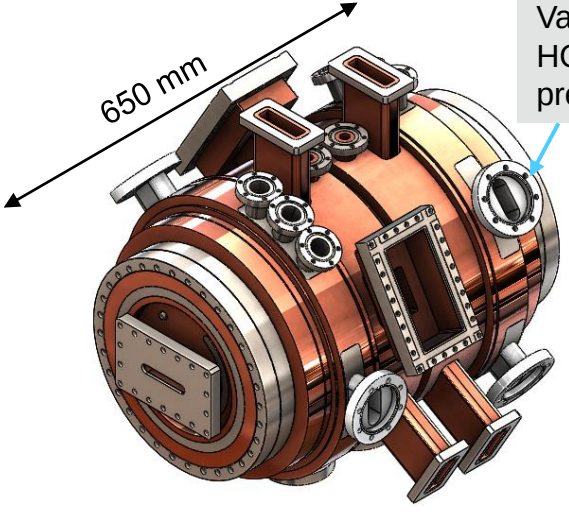
For all modes: Hor. Emit. ε_z = 135 pm	Multibunch 7/8 filling	16-bunches	4-bunches
Total current	200 mA	92 mA	40 mA
Current per bunch	0.23 mA	5.75 mA	10 mA
Bunch length (calc.)	13 ps	31 ps	37 ps
Vert. Emit. ε_z set at	10 pm	20 pm	20 pm
Touschek Lifetime	33 h	≈ 4,5 h	≈ 4 h

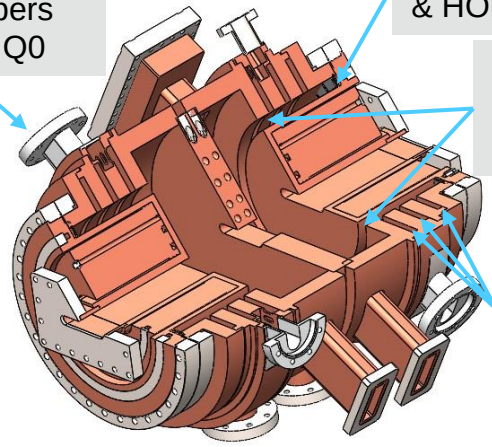


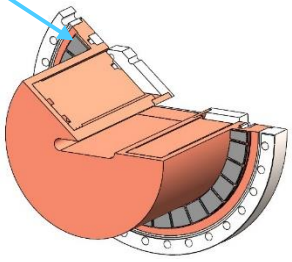
1st Priority for high I / bunch (16 bunch and 4 x 10 mA)

- Reduced Touschek scattering, IBS and microwave instability:
  - Increased lifetime → less frequent injections, reduced loss rate and radiation load
  - Improved overall stability
  - Room for smaller In-Vacuum ID gaps
  - alleviate possible impact from future lattice developments like mini-beta straights
  - Reduced emittance and energy blow up
- Reduced heat-load and stress of critical chambers, like ceramic chambers or In-Vacuum IDs

4TH HARMONIC 2-CELL - 1.41 GHz - E020 MODE CAVITY - IN HOUSE R&D







Vacuum ports on HOM dampers preserving Q0

Ferrite LOM (E010 mode) & HOM absorber

Coaxial HOM damper, at zero of E020 H-field, overmoded at 1.4 GHz

3 Stub filters to stop 4 propagating modes at 1.4 GHz otherwise damping accelerating E020 mode
(TEM, TE11, TE21, TE31)

Features:

- ✓ E020 mode: low R/Q and high Q_0 (first proposed by N. Yamamoto/KEK)
- ✓ Elaborate coaxial LOM/HOM damper (ESRF design)
- ✓ Magnetic inter-cell coupling: Q_0 degradation ⇒ abandoned:

→ Study of pair of adjacent but decoupled cells requiring additional azimuthal HOM dampers (as on drawings)

→ Retained recent solution: 2 electrically coupled cells (ESRF design):

- ➢ High $Q_0 \approx 35000$
- ➢ R/Q reduced from 44 to 33 Ohm/cell
- ➢ No additional azimuthal HOM dampers needed

Mechanical design well in progress

- ✓ Elaborate water cooling
- ✓ Detailed design including assembly processes and sequences
- ✓ 3D model in progress
- ✓ Then 2D drawings by MEG
- ✓ CFT planned this spring:
  - ✓ 1 prototype
  - ✓ Conditional order of 2 or 3 series cavities
- ✓ Launch also CFT for SSAs for power tests

THANK YOU FOR YOUR ATTENTION !

Thanks to the numerous colleagues from all ESRF divisions for their fruitful collaboration !


Jörn Jacob

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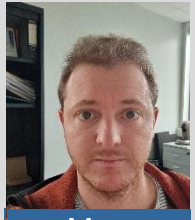
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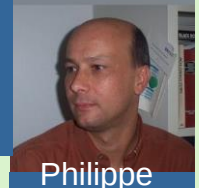
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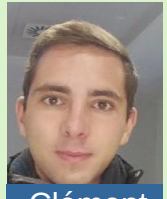
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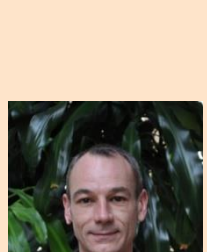
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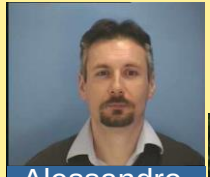
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