13th ESLS RF Meeting 2009

DESY, 30th September – 1st October

Status of the RF Upgrade at the ESRF

Jörn Jacob, ESRF

on behalf of the colleagues of the RF Group and many other ESRF Groups

Upgrade of the ESRF 352.2 MHz RF system

Existing Operation at 200 mA

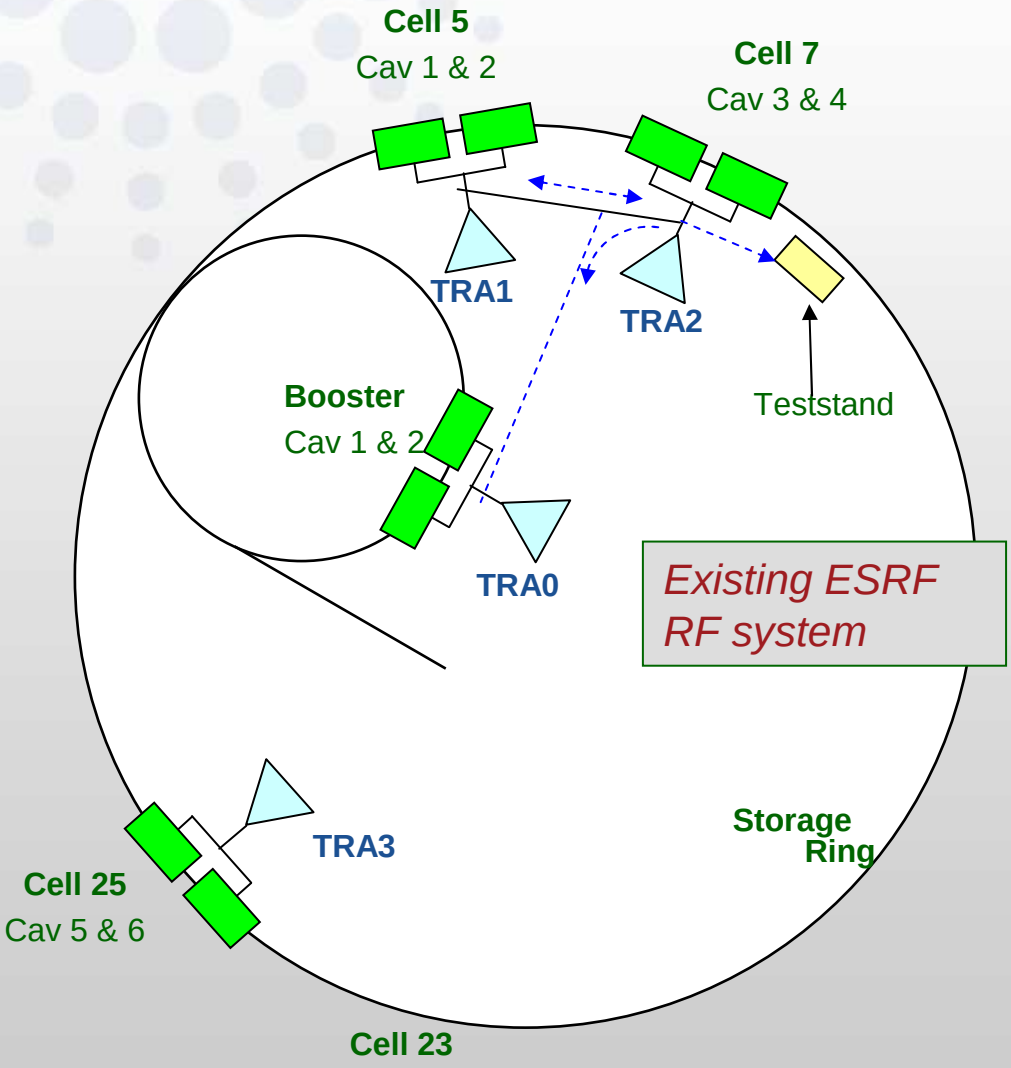
- 1.3 MW klystron transmitters: Redundancy in case of any transmitter failure (waveguide switching)
- Suppression of HOM driven Longitudinal Coupled Bunch Instabilities by Cavity Temperature regulation

Current upgrade to 300 mA

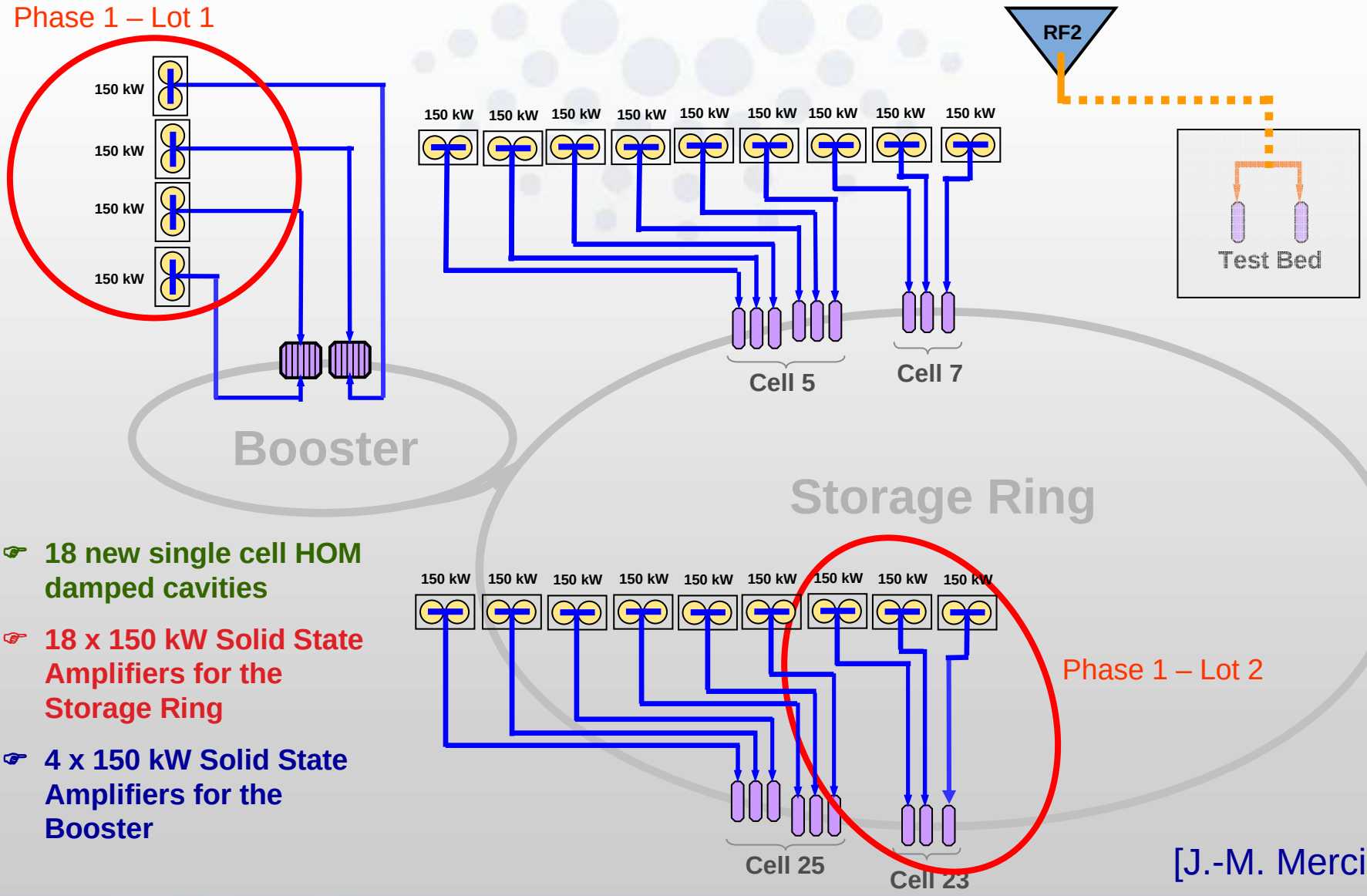
- No transmitter redundancy
- Need LFB to stabilize HOM driven instabilities
- Increased voltage to master Robinson Instability

Long term

- Only 1 klystron manufacturer left, possible obsolescence



Overview of ESRF RF upgrade



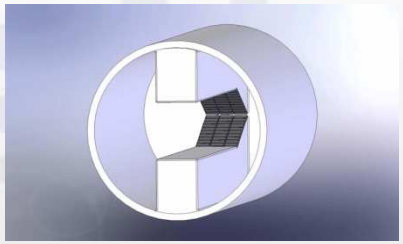
- **18 new single cell HOM damped cavities**
- **18 x 150 kW Solid State Amplifiers for the Storage Ring**
- **4 x 150 kW Solid State Amplifiers for the Booster**

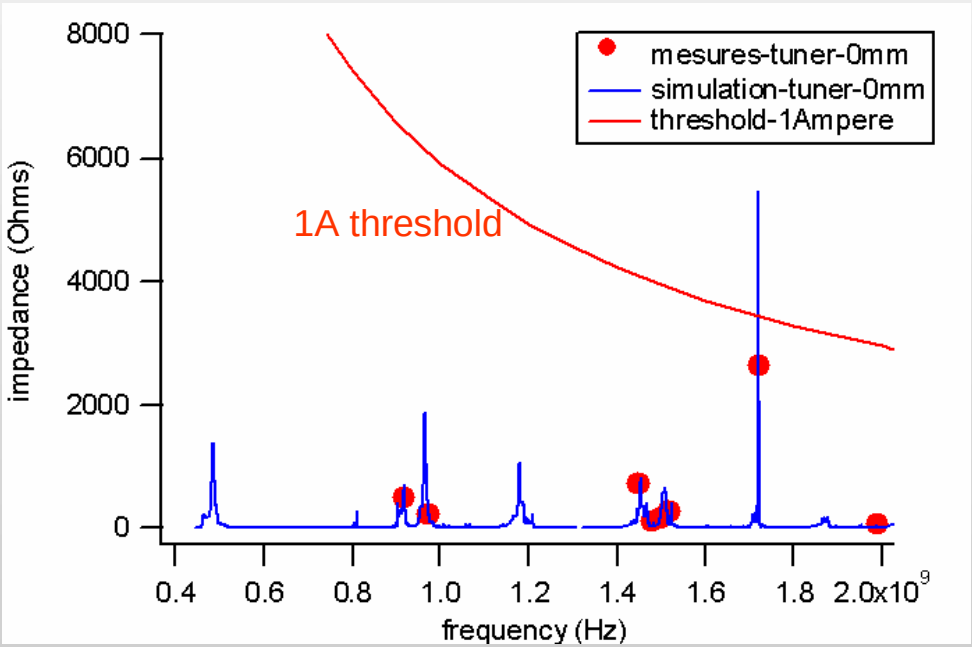
[J.-M. Mercier]

Single cell NC HOM damped cavity

Design study terminated in January 2009

⇒ R&D based on BESSY design with ferrite loaded ridge waveguides for selective HOM damping

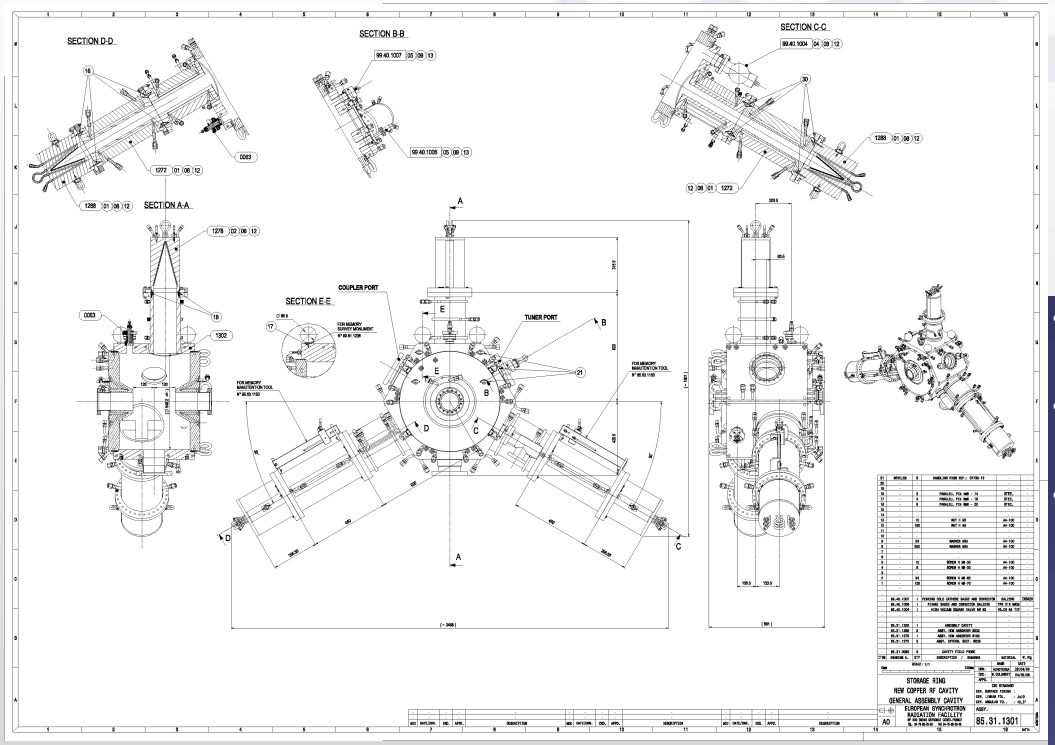




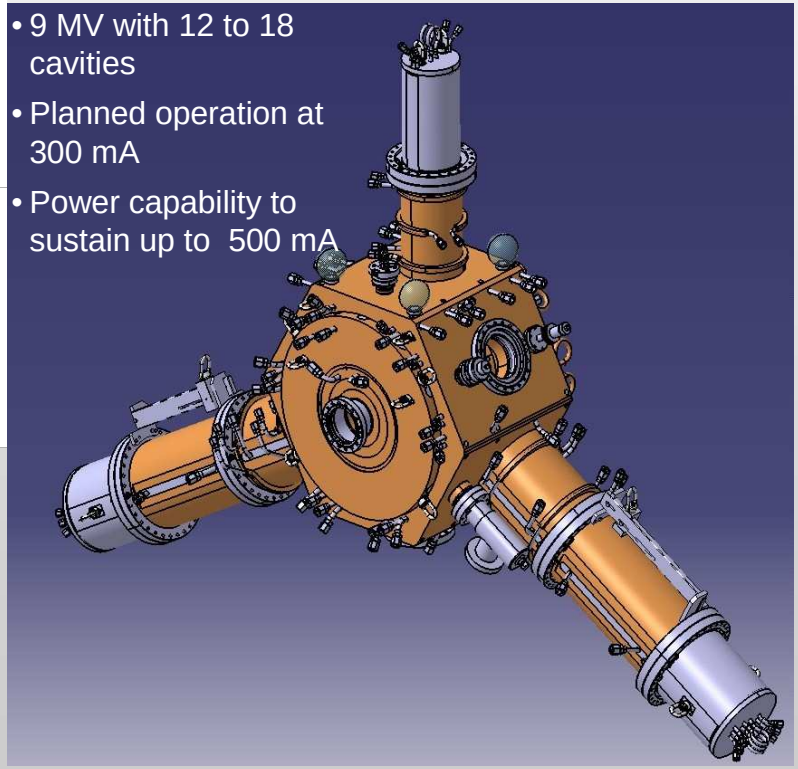
All the HOM impedances are well below the threshold of 1A / 18 cavities

** This work, carried out within the framework of the ESRFUP project, has received research funding from the EU Seventh Framework Programme, FP7.*

HOM damped cavity power prototype



- Validate the design
- Validate the manufacturing procedure
- Obtain operational cavity

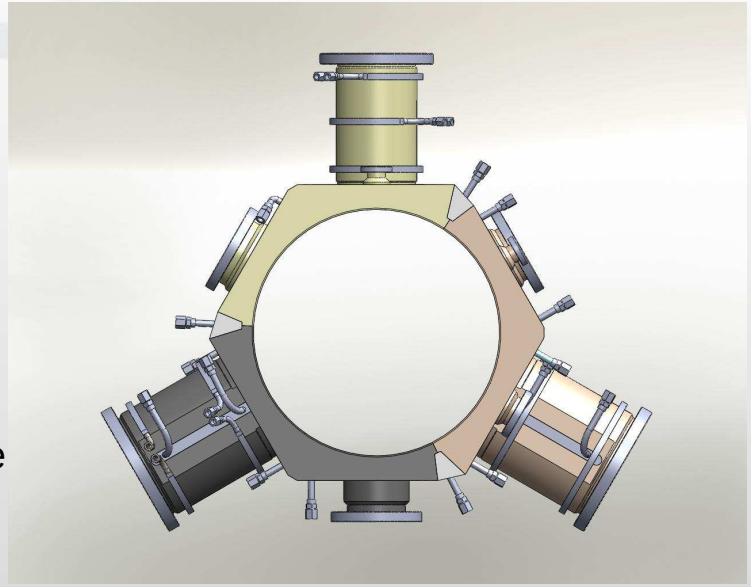


Detailed mechanical design by ESRF, including fabrication drawings:

- ready in March 2009

HOM damped cavity prototype fabrication

- March 2009: Pre-qualification exercise (29 companies)
- May 2009: Call for tender (4 pre-qualified companies)
- July 2009: 3 technically conforming offers received
  - 1st Prototype already ordered from RI - Research Instruments in July
  - 2nd Prototype: planned order from a second company
  - 3rd Prototype: deviating proposal from a third company, with an interesting alternative technical approach, order of a third prototype also foreseen
  - ☞ Maximizing the chances of success
  - ☞ Having a market for the fabrication of remaining 16 to 18 cavities
- August 2010: Delivery of 1st prototype
- End of 2010: Delivery of 2 additional prototypes
- Tests foreseen on the RF power teststand and with beam on the Storage Ring
- If all 3 prototypes OK:
  - Ready for Installation on cell 23 with 3 new SSA
  - Call for tender for remaining cavities specified according to best technical approach or both if equal performance



Alternative design:

- *Cavity body in 3 parts*
- *Most of the assembly by e-beam welding*
- *Minimization of vacuum brazing steps*

☞ A special acknowledgement to the cavity design team lead by V. Serrière !

☞ See detailed presentation of the new ESRF cavity tomorrow by Anna Triantafyllou

Solid State Amplifiers - SSA for the ESRF

ESRF transmitter upgrade with 150 kW SSA:

- SSA highly modular ⇒ redundant ⇒ intrinsically reliable
- Good experience at SOLEIL
- 20 dB less phase noise
- No HV
- No X rays
- Easy maintenance
- Likely to become the new standard for high power CW RF application: SSA considered for more and more projects at frequencies up to the GHz range
- Get prepared to a possible obsolescence of high power klystrons (small market)
- Phase 1 has started: procurement of 7 x 150 kW SSA:
  - 4 x 150 kW for the booster RF
  - 3 x 150 kW for the new RF in SR cell 23

Schedule for phase 1

- July - October 2008:
  - Pre-qualification exercise with preliminary specification sent to 10 companies.
  - 4 Companies pre-qualified out of 7 submitted proposals
- December 2008:
  - Approval of ESRF upgrade program by Council
- January 2009:
  - Call for Tender
- March 2009:
  - 3 offers received
  - 2 competing interesting offers from
    - ELTA who benefit from a technology transfer contract with SOLEIL.
    - Cryoelectra who based their offer on a 72 MHz 150 kW SSA developed for the ACCEL Superconducting Cyclotron.

SSA for the ESRF: Main figures of the specification

Amplifier Specification

- Frequency 352.2 MHz
- Bandwidth 1 MHz
- Input power: 1 W
- Output power P_{nom}: 150 kW
- Dynamic range: > 35 dB
- Redundancy: 2.5 %
  (% missing transistors still guaranteeing output P_{nom})
- MTBF per 150 kW SSA: 20 000 hours
  (transistor failures exceeding redundancy limit, any other failure leading to a trip of the amplifier)
- Supply Voltage: 280 V dc
- Total efficiency at P_{nom}: > 55 %
- Total efficiency at 2/3 P_{nom}: > 45 %
- Operating modes:
- CW
- Booster pulses at 10 Hz (25 ms width)
- 20 µs to 10 ms square pulses at 50 Hz
- Output connection: WR 2300
- Reflected power, any phase:
  - Full reflection during 20 µs at P_{nom}: 150 kW
  - Full reflection, permanently, at 80 kW
  - At P_{nom} partial reflecttion, permanently: 50 kW
- Phase noise: < -70 dBc
- 2nd harmonic: < -36 dBc
- Higher harmonics: < -60 dBc

RF module (or pallet)

- Nominal power per amplifier module: 300 to 1000 kW
- Full reflection, any phase at maximum forward power
- Uncondional stability …
- Gain tolerance between modules: < ± 0.2 dB
- Phase tolerance between modules: < ± 5 °
- No sorting of modules
- Transistor: 6th generation LDMOS with 50 V bias preferred
- Intrinsic overdrive protection
- Complementary, fast overdrive protection against transients
- At least 1 DC/DC converter per module: 280 V dc / 50 V dc:
  - Current monitoring (DC current of each transistor)
  - Secondary voltage ripple < 2 %
- Reliability → maximum RF module failure rate < 0.7 % / year
  (including DC/DC converters)

Reference design

= SOLEIL SSA

Order of 7 SSA of phase 1 from ELTA

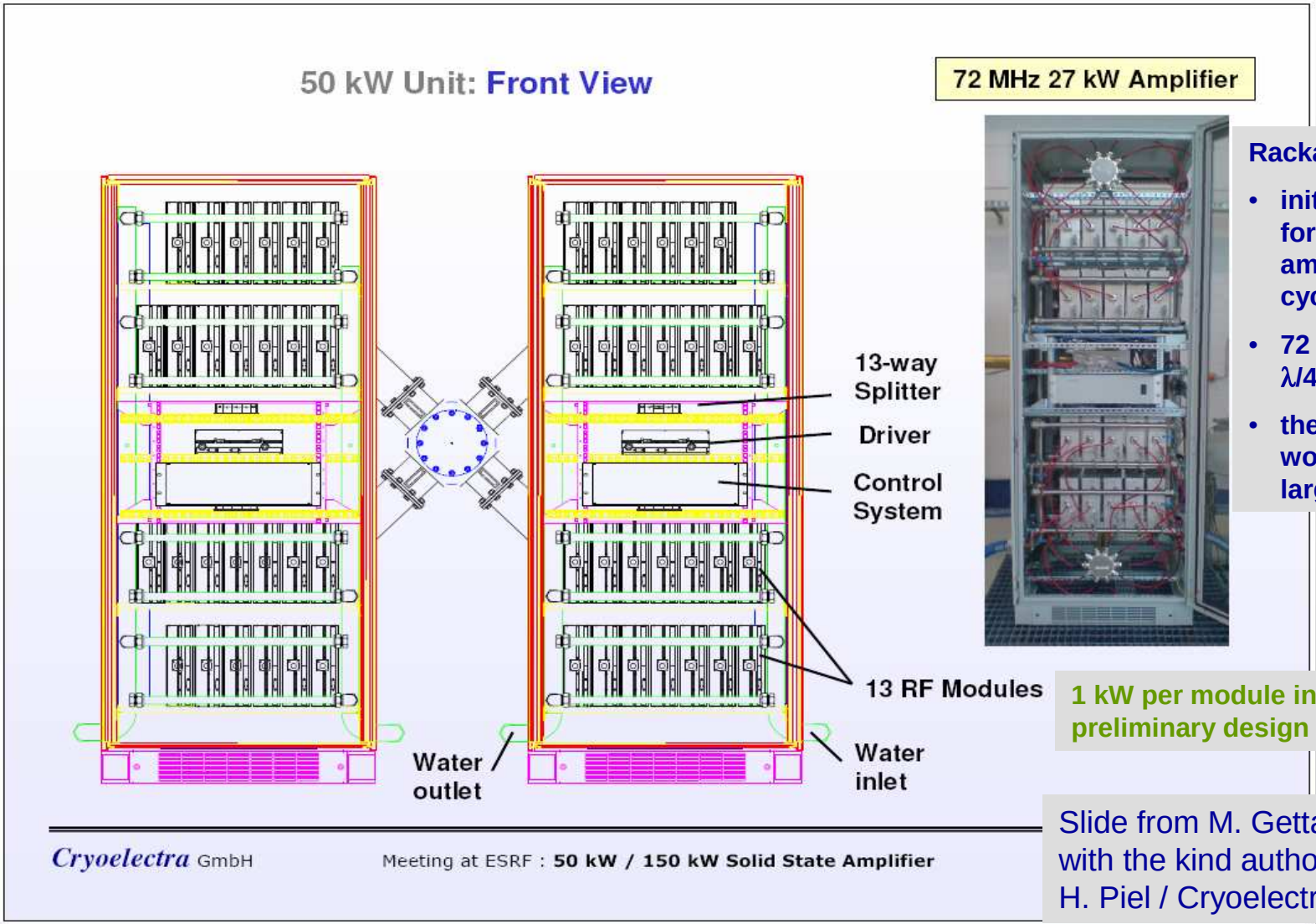
- Offer essentially along the initial SOLEIL design
- New transistors allow a more compact design with only **2 towers** to obtain **150 kW**
- A contract is about to be signed between ESRF and ELTA for the totality of
  - 4 x 150 kW SSA for the booster
  - 3 x 150 kW SSA for the SR
- First 75 kW tower built in close collaboration between SOLEIL and ELTA
- A functional acceptance test of the 1st tower will be performed at SOLEIL
- A 1000 h run test will then be carried out at ESRF

Schedule:

- March 2010: Test of the first combination of 8 (possibly 16) RF modules
- February 2011: Acceptance test of the first 75 kW tower at ESRF
- January 2012: commissioning of the 4 x 150 kW SSA connected to the ESRF booster cavities
- August 2012: commissioning of 3 x 150 kW SSA connected to the first 3 single cell HOM damped cavities in cell 23 of the Storage Ring

*) The content of this slide may still change until contract signature with ELTA

Proposal from Cryoelectra



Rackable solution:

- **initially developed for a 72 MHz 150 kW amplifier for SC cyclotrons / ACCEL**
- **72 MHz require long λ/4 combiners**
- **the SOLEIL design would lead to a very large tower diameter**

1 kW per module in this preliminary design

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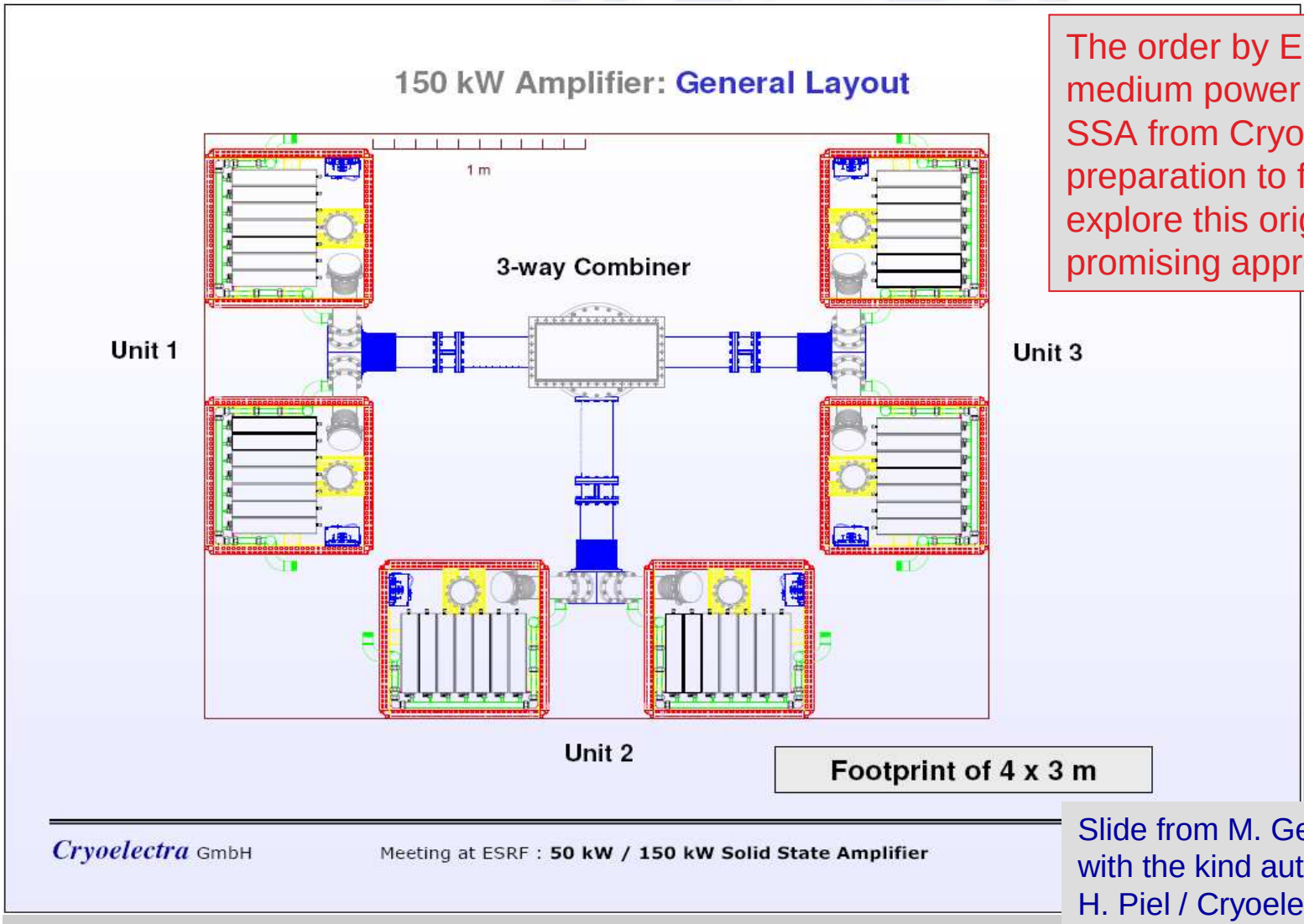
Proposal from Cryoelectra



The order by ESRF of a medium power prototype SSA from Cryoelectra is in preparation to further explore this original and promising approach

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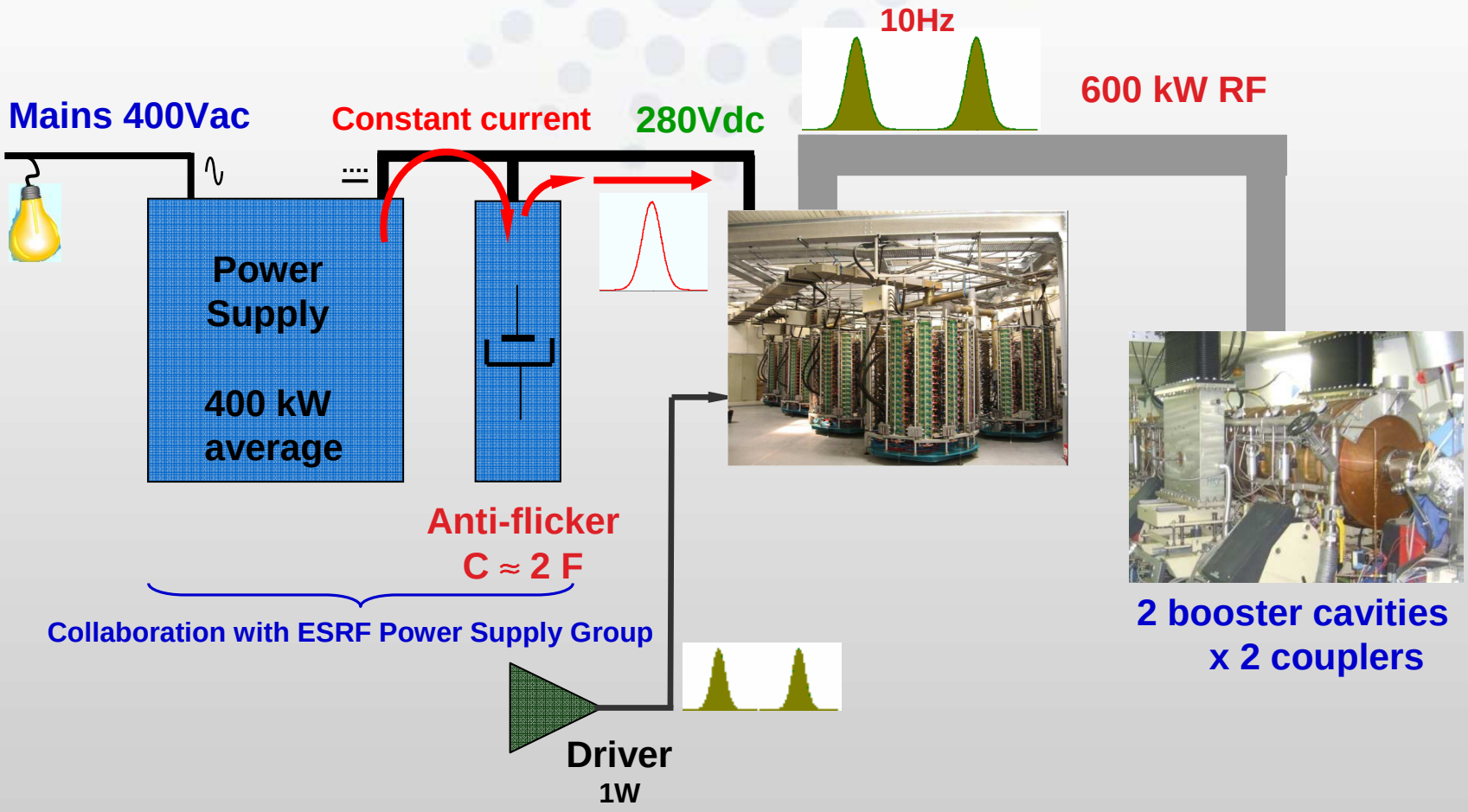
400 V ac / 280 V dc power supply for the booster SSA



[J.-M. Mercier]

Summary

- ESRF RF upgrade has started
- 3 Prototypes of the ESRF single cell HOM damped cavity will be fabricated by 3 different companies and allow to compare different technological approaches
- 7 x 150 kW SSA amplifiers of phase 1 are about to be ordered for a commissioning in 2012
- ESRF will explore other concepts of SSA
- ESRF is launching an internal R&D program, in order to gain the necessary competence to operate, maintain and develop SSA at a large scale.

Acknowledgement

- RF Group, and in particular
  - Cavity team
  - Transmitter team