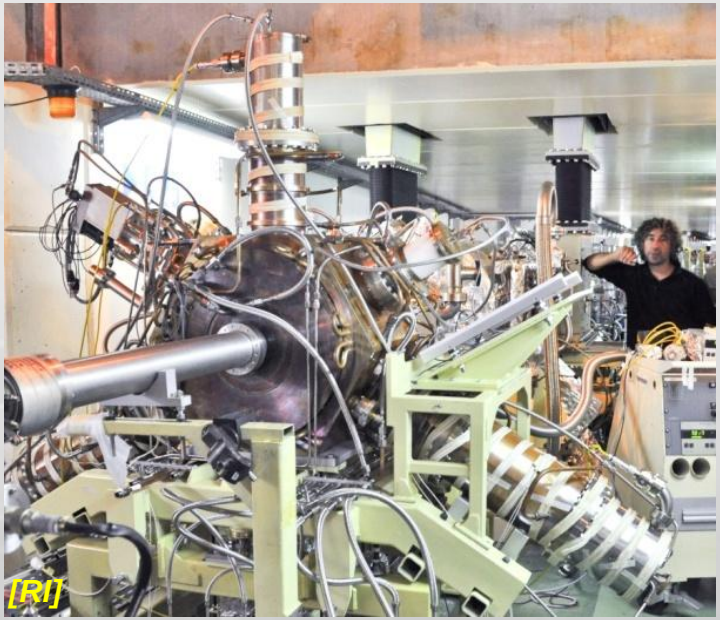
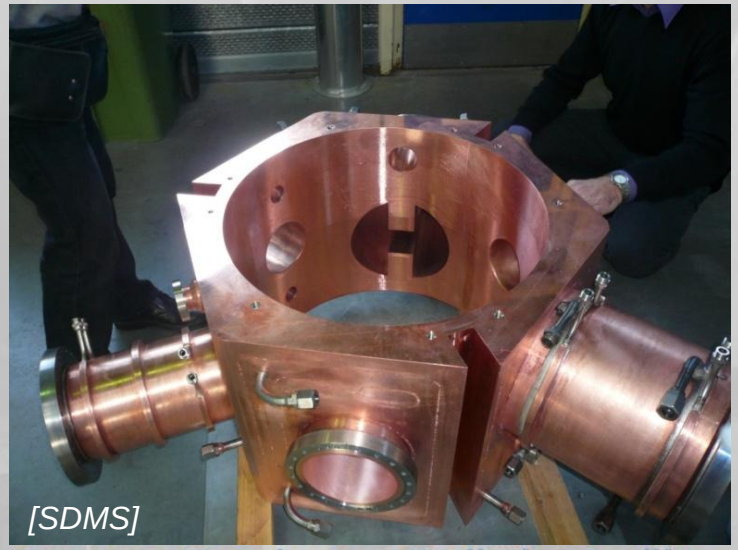

[RI]


[SDMS]

European Synchrotron Radiation Facility

CWRF'2012
Brookhaven, 8-11 May 2012

New HOM Damped Cavity at the ESRF

Vincent Serrière (project leader), Jörn Jacob, Loys Goirand, Bernard Ogier, Anna Triantafyllou, Ayan Bandyopadhyay

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

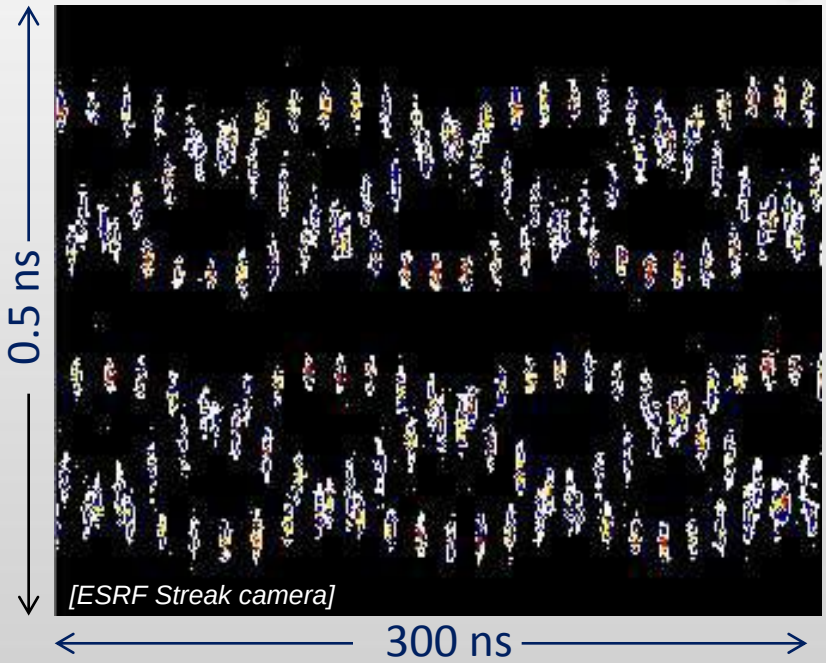
Existing ESRF 5-cell copper cavity

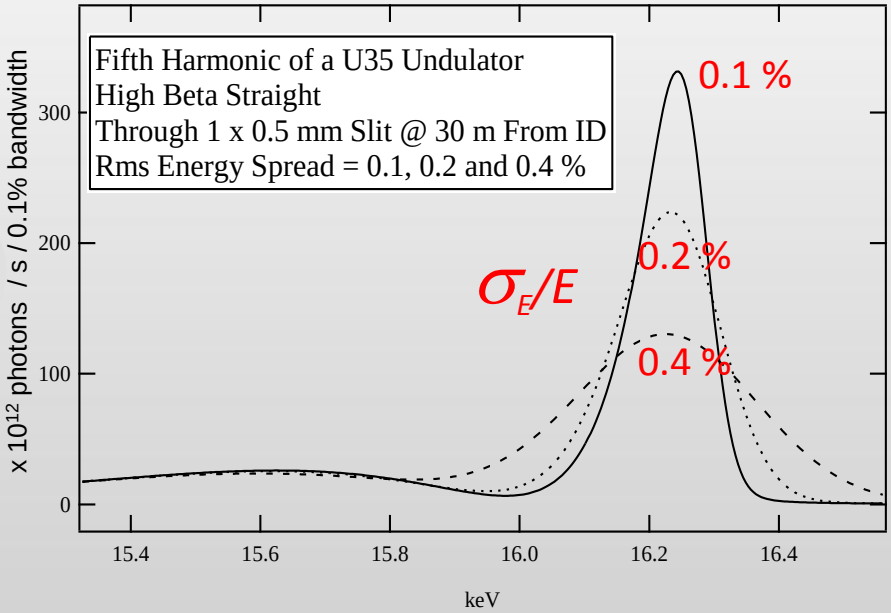
- Synchrotron radiation losses in Storage Ring:
  - 5 MeV/turn for each electron
- 6 highly efficient accelerating RF cavities with five coupled cells:
  - Fundamental resonance = accelerating mode at 352.2 MHz for electron re-acceleration:
    - 300 kW to obtain 9 MV RF voltage
    - 1000 kW to compensate the synchrotron radiation losses of 200 mA of beam
  - **BUT** Higher Order Modes = **HOMs:**
    - If HOM in resonance with eigenfrequencies of the beam ⇒ possible **instabilities above**

$I_{threshold} \approx 50$ mA

HOM driven Longitudinal Coupled Bunch Instabilities – Energy/Phase oscillations

Energy oscillation ⇒ Energy spread of electrons ⇒ Reduction of brilliance





Nice picture for machine physicist

Disaster for ESRF users

Beam stabilization at high currents

+

→

HOM detuning by precise control of cavity temperatures

$T = T_{set} \pm 0.05\ ^{o}C$

⇒ ***200 mA***

stable beam / any filling pattern

+

Fast Bunch-by-Bunch Feedback system
[Eric Plouviez et al.]

→

During MDT' 2010

⇒ ***300 mA***

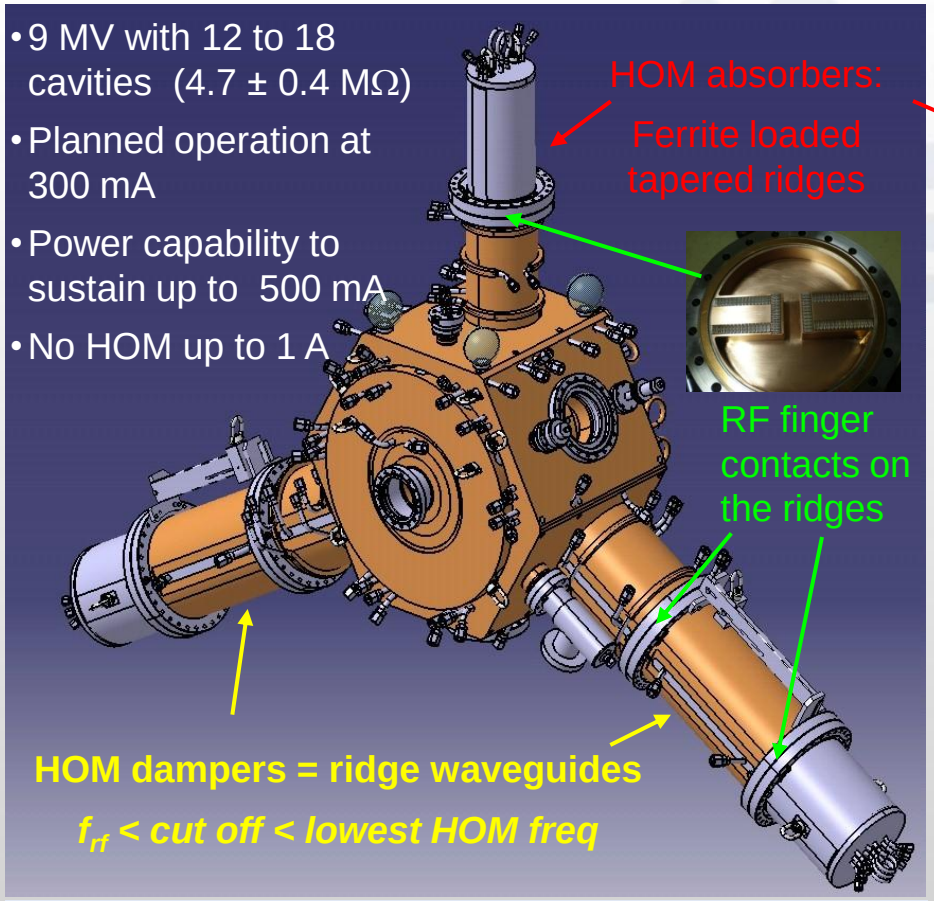
☞ ALTERNATIVE for high operation reliability at 300 mA:

Cavities with strongly damped HOMs

- 2004 start R&D with a PhD thesis *[Nicolas Guillotin]*
- 2007-2011 ESRFUP / WP13 = design, build & test an **operational cavity**

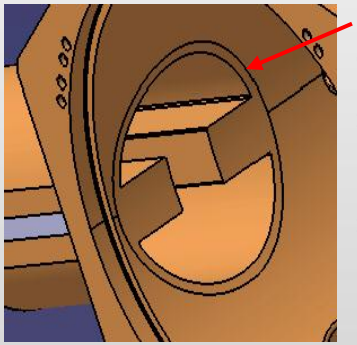
352.2 MHz Single cell NC HOM damped cavity

- 9 MV with 12 to 18 cavities (4.7 ± 0.4 MΩ)
- Planned operation at 300 mA
- Power capability to sustain up to 500 mA
- No HOM up to 1 A



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

ESRF 352.2 MHz design: several improvements



E-beam welding of HOM coupling sections to the body

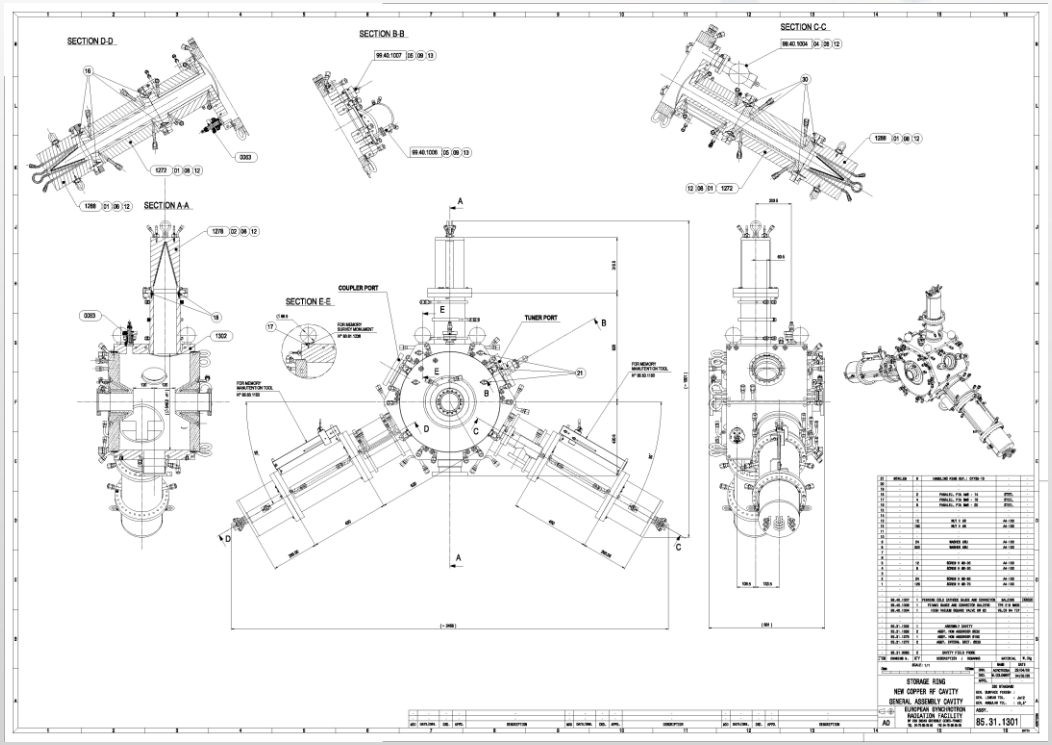
⇒ to avoid a gap between ridges and cavity body, and thereby

⇒ to suppress residual HOM and flange over- heating (observed on BESSY/ALBA cavity)

ESRF optimization of ridge waveguides:

- ☞ Optimum coupling to all HOM
- ☞ Short HOM dampers despite lower RF frequency
- ☞ Numerical EM simulations and low power RF measurements on full scale aluminum models

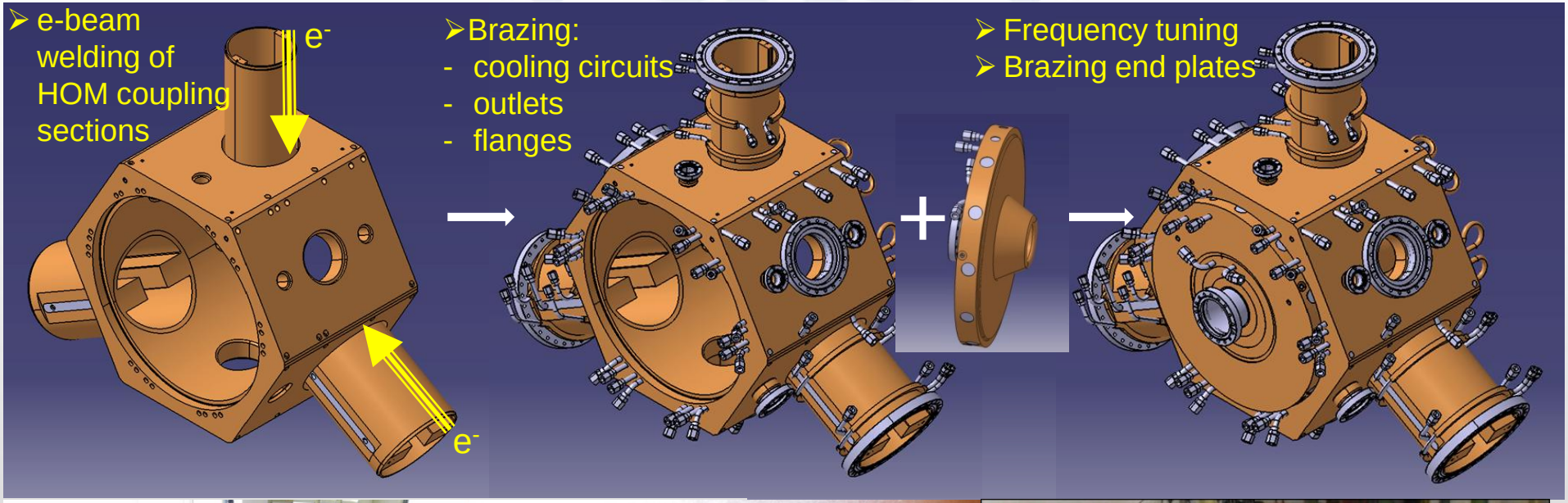
Procurement of 3 operational copper cavities



- May 2009: Call for tender
  - mechanical design by ESRF
  - full set of detailed ESRF drawings
- Order of 3 power prototypes
  - validate the design
  - qualify 3 companies for a later series fabrication :
    - RI (D),
    - SDMS (F),
    - CINEL (I)
  - validate 2 different manufacturing procedures
  - obtain 3 operational cavities for phase 1 of ESRF upgrade

Initially specified mechanical design & manufacturing procedure

applied by RI - Research Instruments (photos)



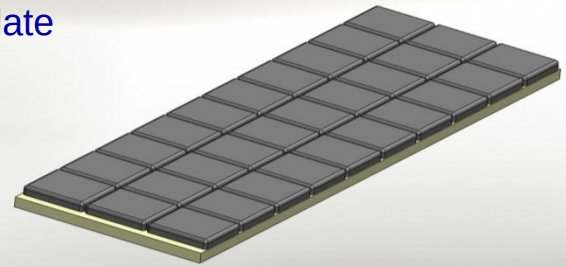
After e beam welding

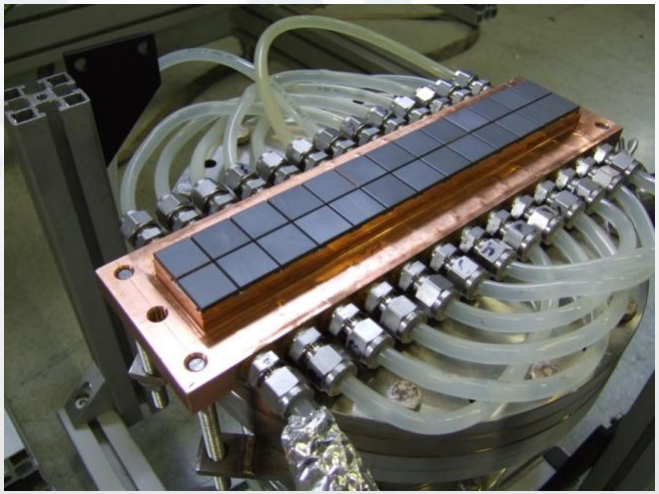
Laser smoothing of pores

After brazing body & end disc 1

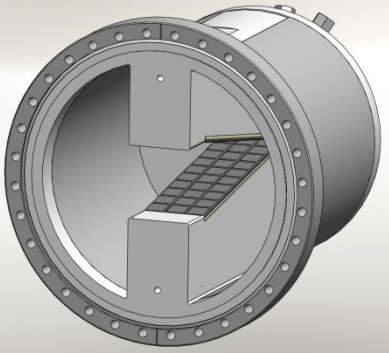
HOM absorbers

C48 ferrite tiles brazed on Cu plate

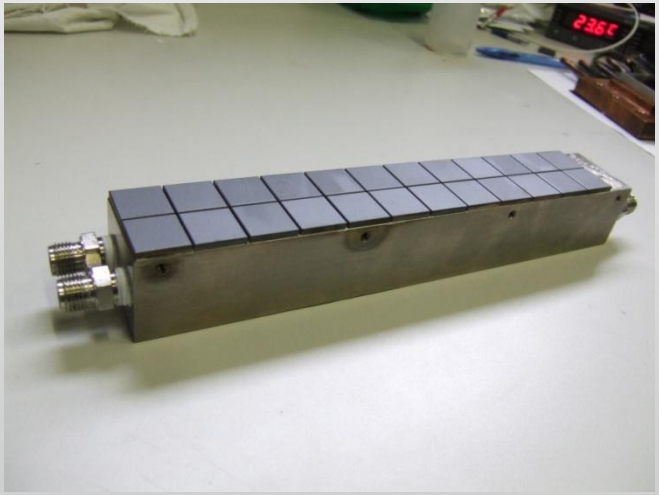




RI: Ferrite HOM absorber for IR thermal test at ESRF



Ferrite/Cu plate brazed on tapered stainless steel absorber

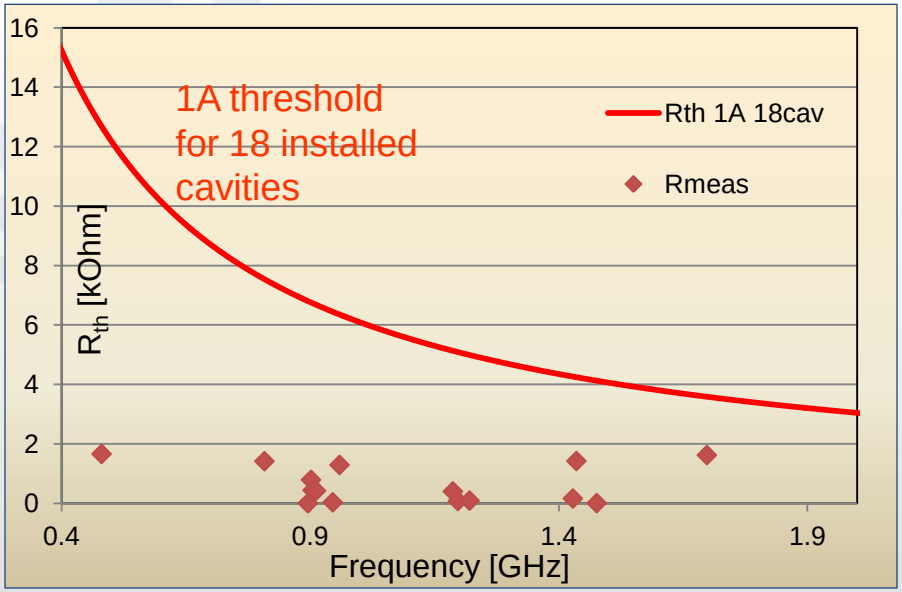


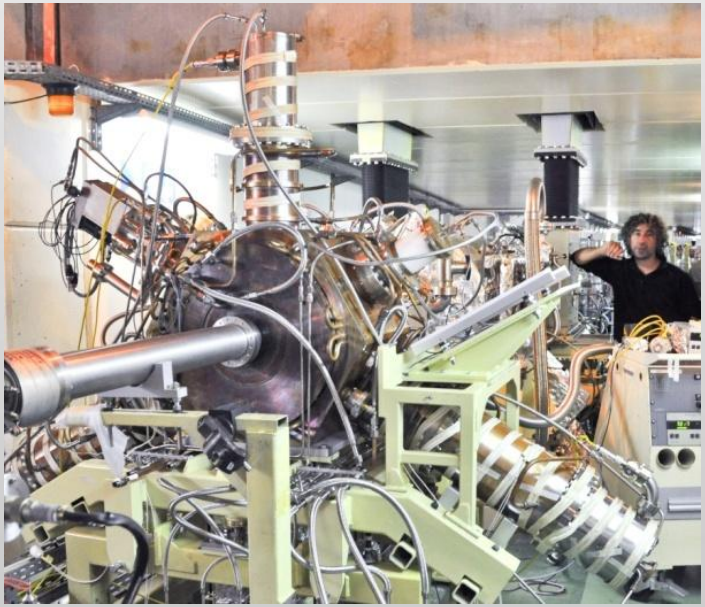
SDMS: direct brazing to stainless steel – successful IR thermal test at ESRF

1st cavity delivered by RI – Research Instruments

- ✓ Delivered 15 June 2011
- ✓ Excellent fundamental mode impedance:

  R_s = 4.9 MΩ,
  Q_0 = 33800 (expected 30000 to 35000)
- ✓ HOM spectrum a factor two lower than design goal
- ✓ **600 kV obtained in CW** on RF power test stand
  - ☞ Inspection of RF fingers between HOM coupling sections and dampers: no sign of degradation



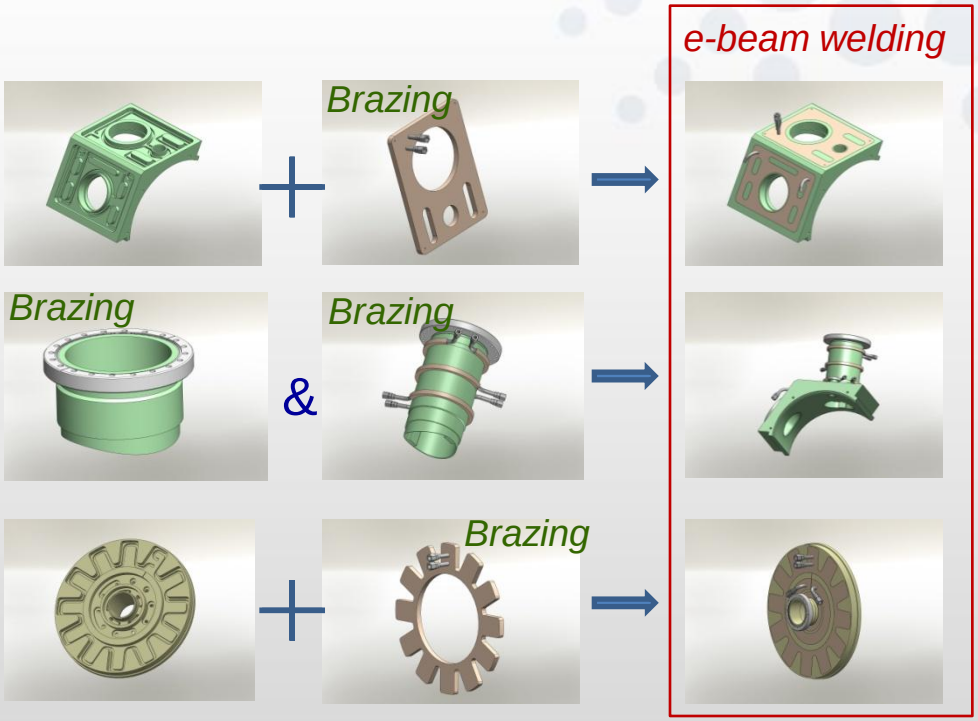


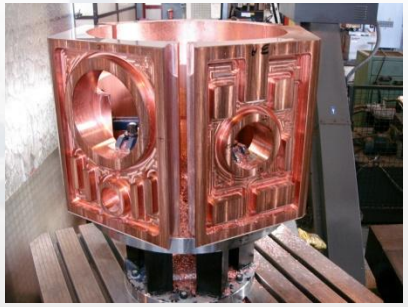
October 2011: Installation on Storage Ring cell 25

- ➢ Passive operation with **excellent vacuum behaviour** at
  - ✓ 200 mA in mutlibunch fillings (a few hours after machine restart)
  - ✓ 95 mA in 16 bunch filling (most demanding for HOM dampers)
- ➢ Active operation - first tests with **beam acceleration very satisfactory**
  - ✓ Vacc = 0.4 MV with 20 kW
  - ✓ Ibeam = 168 mA with total of 63 kW into new cavity

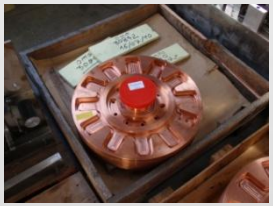
Alternative design proposed by SDMS, engineered by V. Serrière / ESRF

applied by SDMS and CINEL

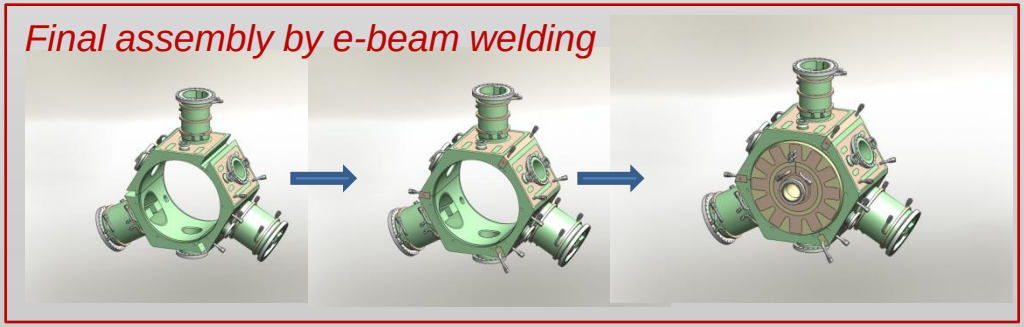




CINEL: 3 body sectors after machining of the water cooling channels, September 2010

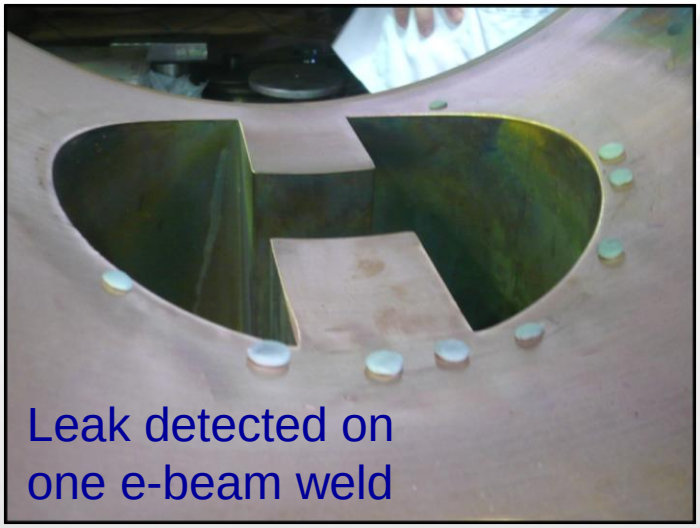


SDMS parts of end discs ready for e-beam welding

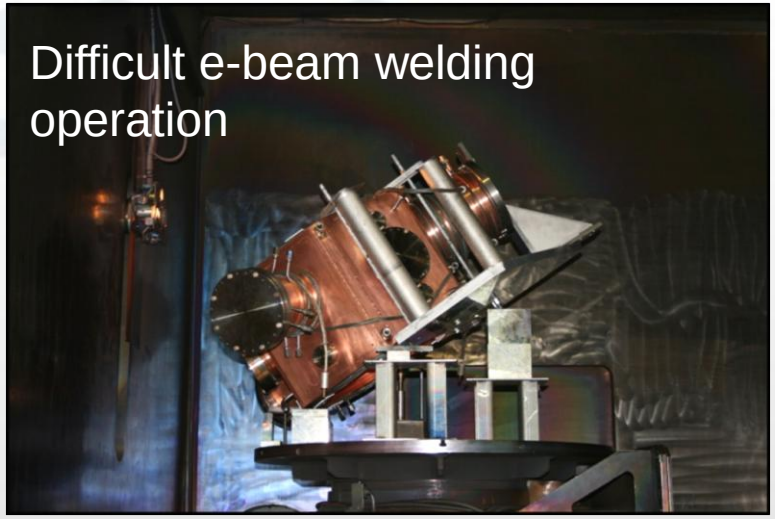


SDMS: Body after e-beam assembly of the 3 sectors, November 2010

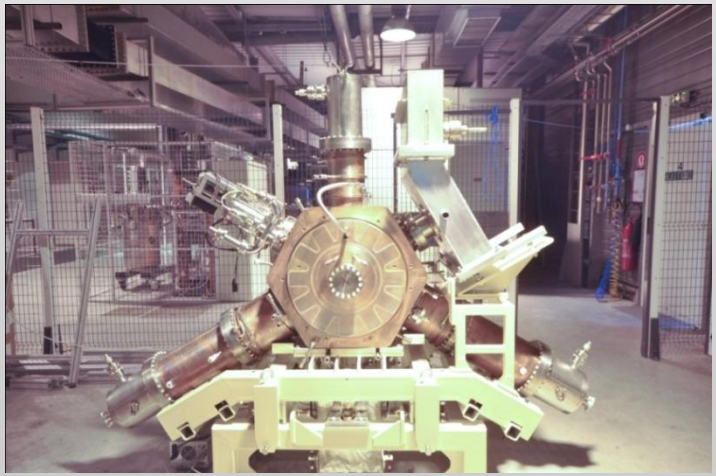
Difficult e-beam weld Cavity / HOM coupling section - SDMS cavity



1st attempt to repair: MIG welding, not successful



2nd attempt: further e-beam weld from inside with an intermediate copper ring



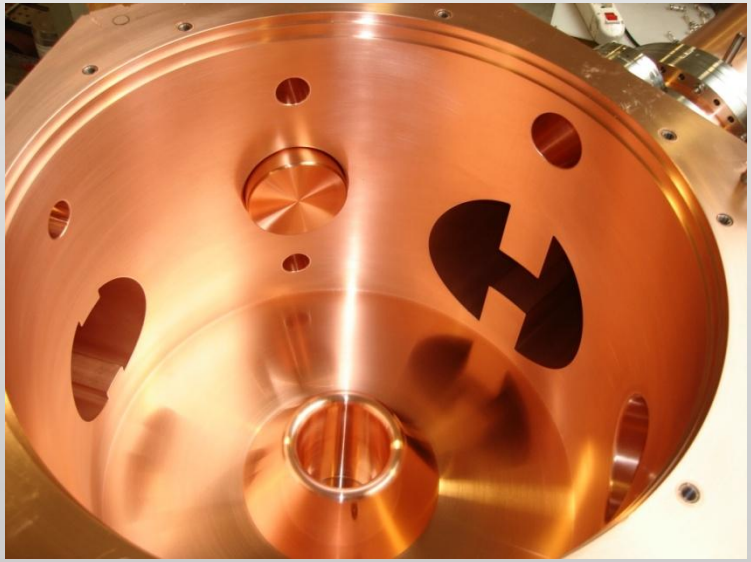
2nd delivery: SDMS cavity

- Delivered on 20 July 2011
- Successful vacuum test
- Qo = 32000
- RF conditioning May-June 2012
- Installation for beam test on cell 25 in summer 2012

Very smooth fabrication of CINEL cavity (also alternative design)

3rd cavity: CINEL

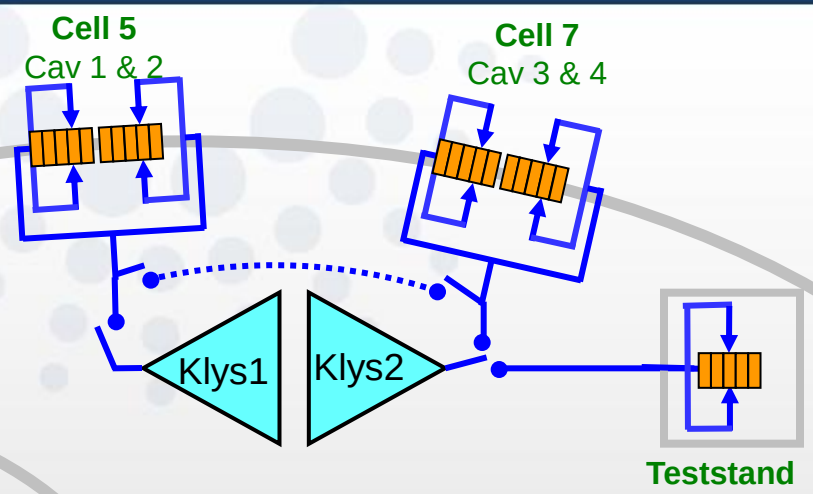
- Last weld in April 2012
- All welds and surfaces perfect
- Vacuum test: these days
- HOM absorbers: assembly brazing still to be done
- Installation for beam test on cell 25 in winter 2013

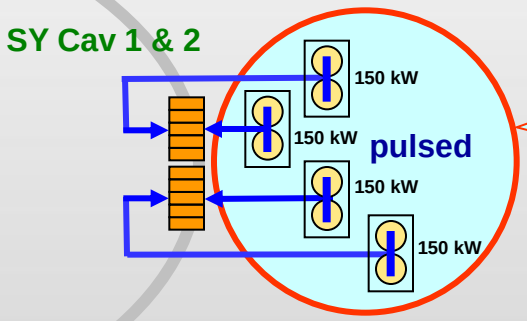


Frequency tuning before assembly welding

RF upgrade phase 1

well in progress !





3 SSA from ELTA for SR:

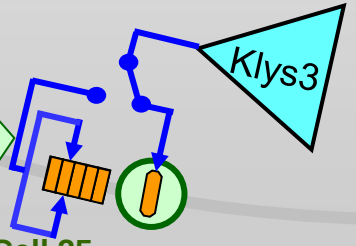
- ☞ Powering 3 new HOM damped cavities on the storage ring
- ☞ In fabrication

4 SSA from ELTA for the booster:

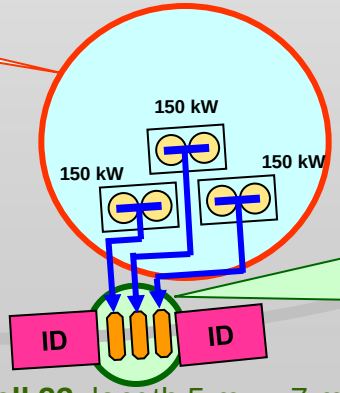
- ☞ In operation since March 2012

3 prototype HOM damped cavities …

- ☞ Test with beam one by one on cell 25 with klystron transmitter TRA3:
- ☞ **1st cavity (RI) installed in October 2011:** excellent behaviour with beam



Cell 25
Cav 6 & new cavity for test



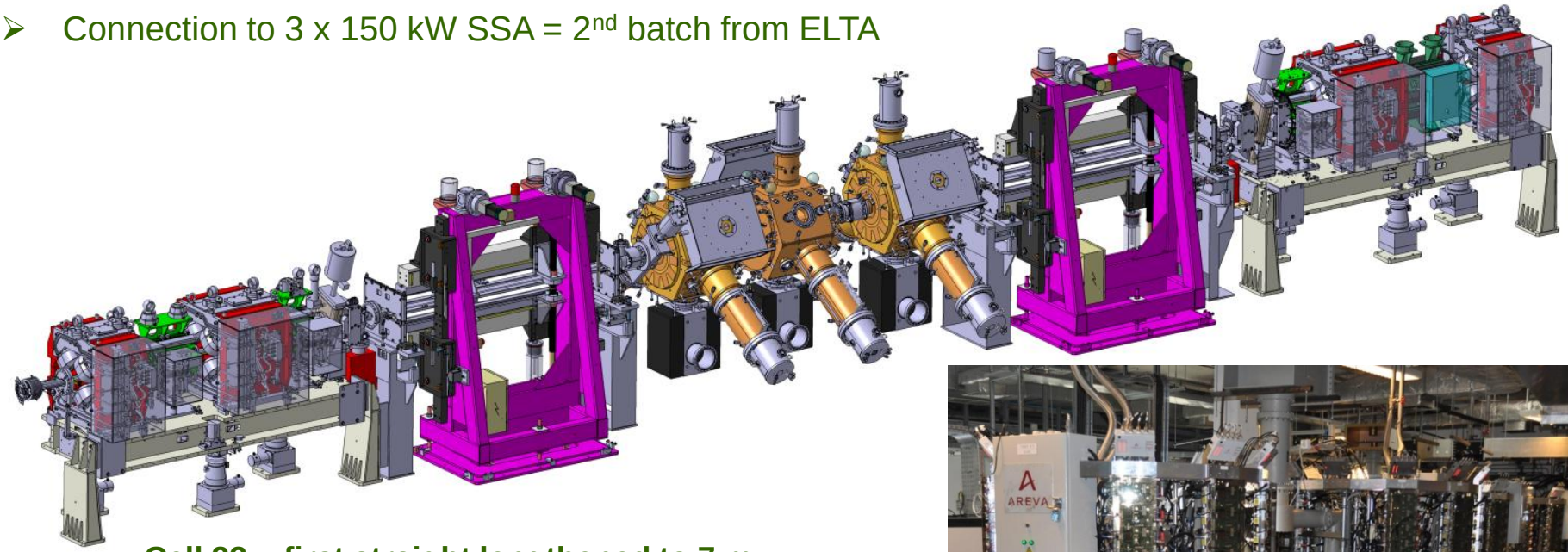
Cell 23, length 5 m → 7 m

… 3 prototype HOM damped cavities

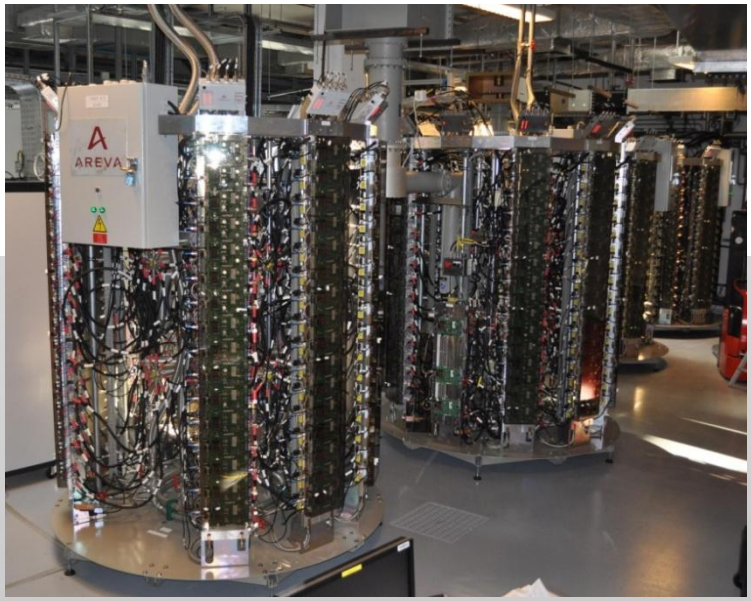
- ☞ 2013: all 3 cavities in new 7 m section/cell 23 with 3 SSA

First new Storage Ring RF unit with 3 HOM damped cavities

- Summer 2013: Installation of all 3 cavities on cell 23
- Connection to 3 x 150 kW SSA = 2nd batch from ELTA



Cell 23 = first straight lengthened to 7 m



THANK YOU !