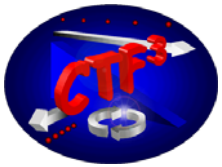
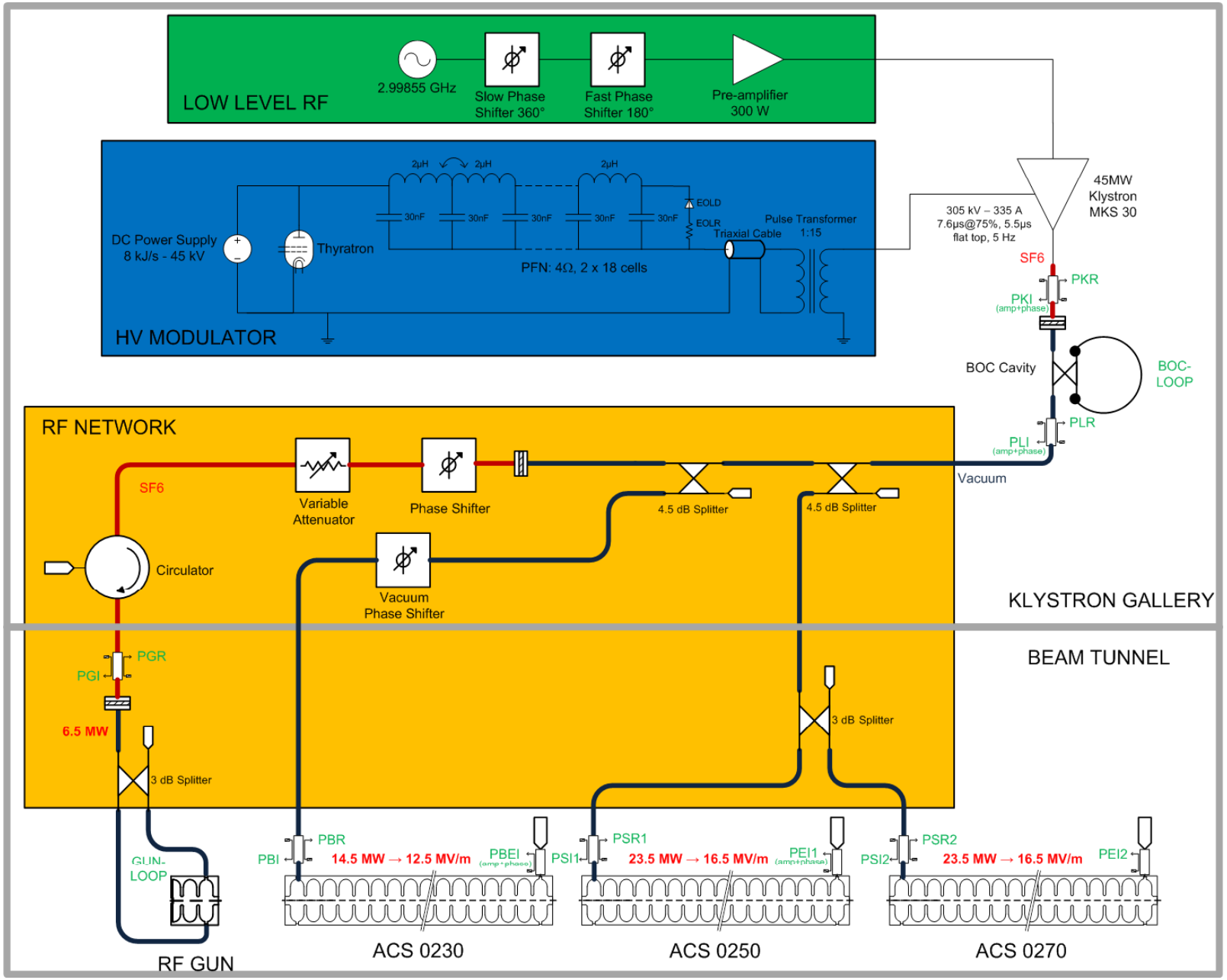
Irfu
cea
saclay



RF SYSTEM OF CALIFES

- Modulator
- RF Network
- Power Phase Shifter

RF System layout of CALIFES

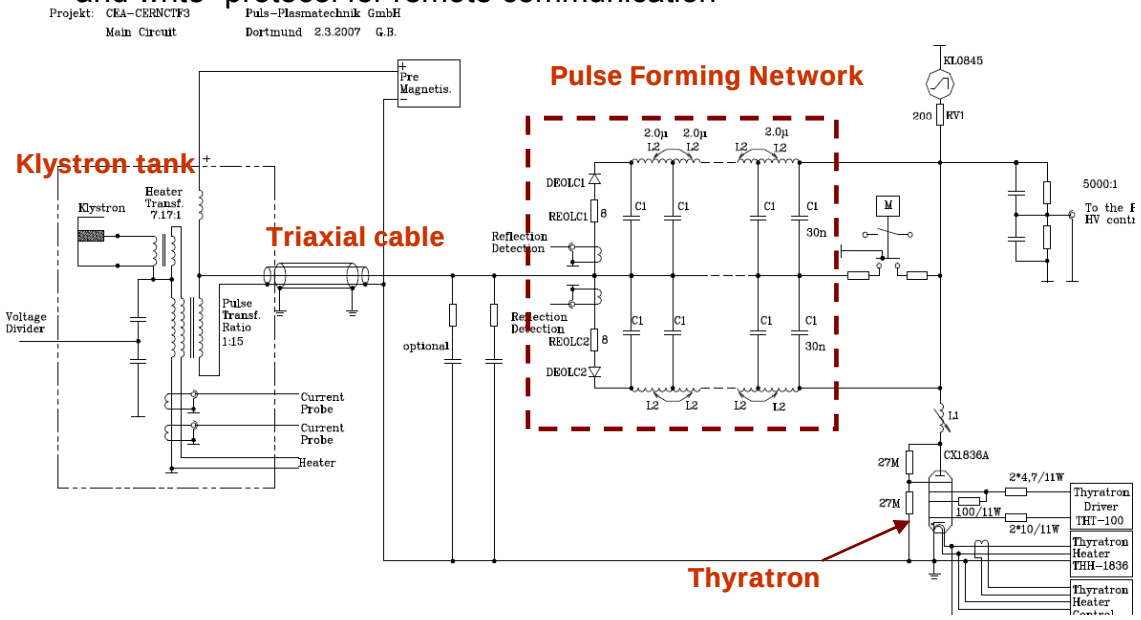


RF System with the linac

Modulator

- **Procured by Puls-Plasmatechnik GmbH (Germany)**
- Capacitor charging unit 45 kV / 8 kJ/s from PPT/Poynting
- Thyratron CX1836A from EEV for high voltage switch
- Pulse Forming Network (PFN): 4Ω impedance, 2 lines in parallel, 2 x 18 cells (30nF/2µH each)
  - Inductance = single layer coil + aluminium core
  - mutual coupling between the inductances

  Better approximation of a rectangular pulse shape (Guillemin type E network [1])
- Pulse transformer ratio 1:15 and tank with x-y-z frame from Stangenes
- Associated power supplies (magnet, heater, ion pump)
- Transport system to remove the klystron in the maintenance area
- Control system based on a PLC SIEMENS S7 300, with ethernet interface and “fetch and write” protocol for remote communication



Parameters	Specifications	Units
Peak voltage	320	kV
Peak current	360	A
Pulse length (flat top)	5.5 min	µs
Pulse repetition rate	5	Hz
Inverse voltage (out of the pulse)	70 max	kV
Pulse voltage ripple	± 0.25 max	%
Pulse to pulse stability	± 0.1 max	%
Rise time 10 – 90 %	1 max	µs
Fall time 90 – 10 %	2 max	µs
Pulse width at 75 %	7.6 max	µs

[1] Glasoe and Lebacqz: « Pulse Generators », MIT Radiation Lab Series, vol. 5, McGraw-Hill Book company, New York, 1948

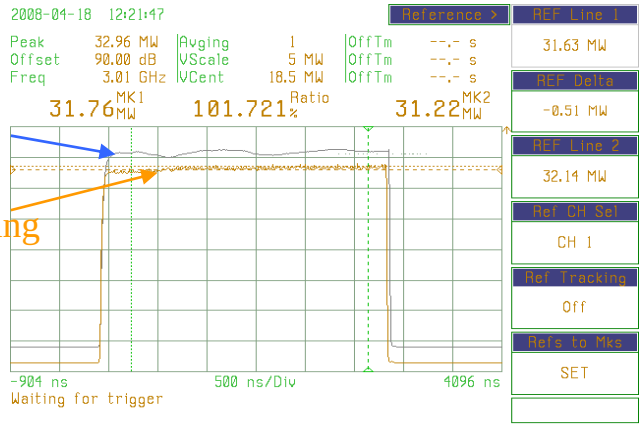
Modulator

Done in 2008:

- Feb. 08: Factory test of the TH2100C klystron: 45 MW – 4.5 µs RF – 100 Hz
- Apr. 08: Acceptance test of the modulator at CERN with RF:

Before PFN tuning

After PFN tuning

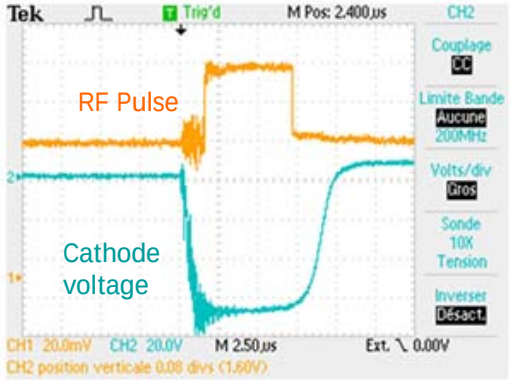


Ripple:

$$\frac{\Delta V_k}{V_k} = \frac{2}{5}\cdot\frac{\Delta P_{RF}}{P_{RF}} = 0.4\times\frac{0.51MW}{31.76MW} = 0.64\% \Rightarrow \pm 0.32\%$$

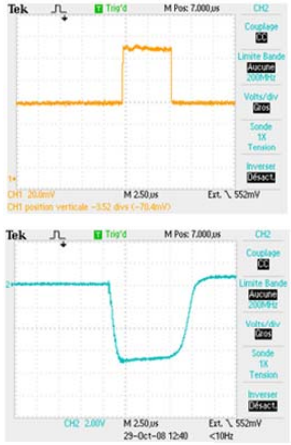
> ± 0.25% specified but acceptable value for CALIFES (beam during 150 ns only)

- Oct. 08: Noise problem on cathode voltage and RF pulses, with complete LLRF system



BEFORE

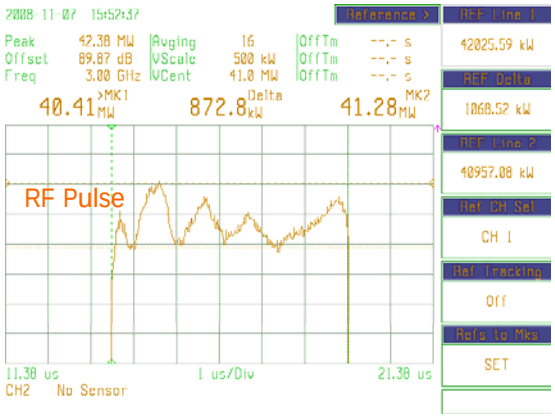
The noise problem has been very well reduced by shielding the timing module connections and bringing the ground of some measured signals closer to the delay line and thyratron rack.
Some doubts still remains concerning the ground connection system between the racks but no modification has been done yet.
The best ripple measured with RF is about ± 0.35 % but this is a sensitive measurement and depends deeply on the signal (cathode voltage, RF diode, peak power meter)



AFTER

Modulator

- Nov. 08: PFN tuning (Stephane Curt)



$$\frac{\Delta V_k}{V_k} = \pm 0.42\%$$

- From 27 Nov. to 15 Dec 08: Operation with beam in CALIFES

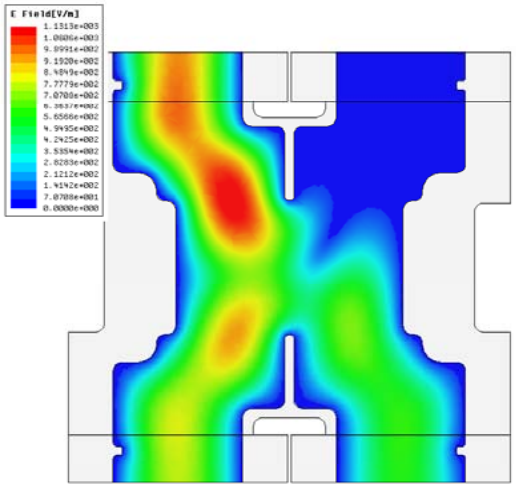
To be done in 2009 :

- AC Filament Power supply: parasitic shutdown, sent back to PPT (fuse problem)
- Touch panel for local control: failure in a component (password problem, range limitation…), to be replaced by a new one provided by PPT (Feb. 09)
- Remote PLC modifications by PPT (password, range for PFN voltage, …): tele-service adapter received, to connect to the phone when new touch panel received
- Charging power supply (45 kV DC from PPT-Poynting): pulse-to-pulse instability to study (March 09), 1% measured in Dec. 08 after some minutes instead 0.1% specified

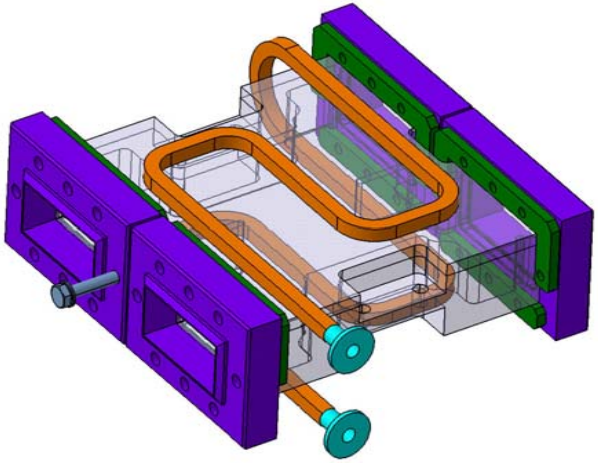
4,5 dB Splitter

RF and Mechanical design and drawings made by CEA, machining and brazing made by CERN (Thanks Gerry and Serge Mathot), installed and tested successfully up to 30 MW – 1,3 µs – 5 Hz (Thanks Jean for cold tests and conditioning)

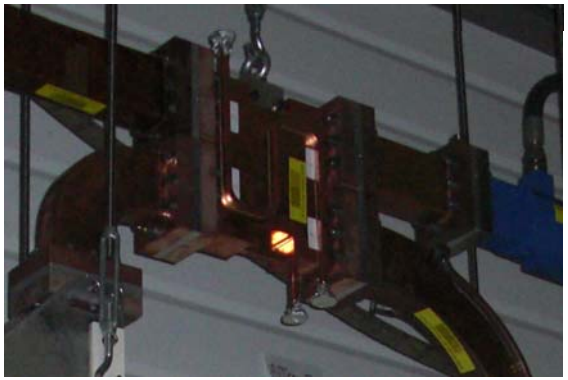
RF Design



Mechanical design

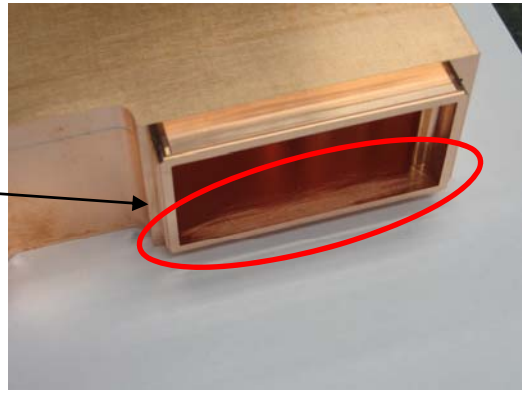


Fabrication and installation



Scratches…

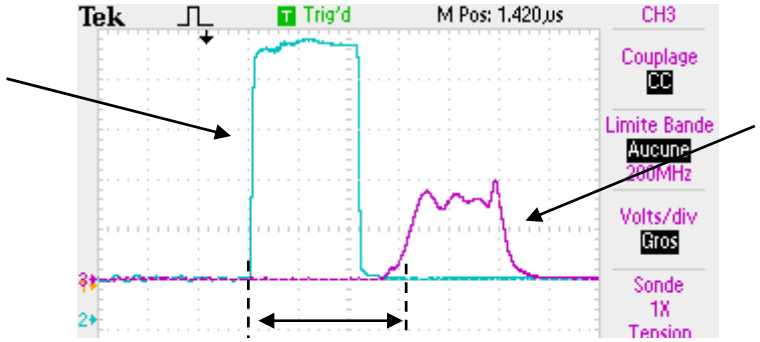
removed by hand after brazing



RF start and conditioning

Sept. 08: a power 43 MW has been reached very quickly in the three sections, for an RF pulse length of 1 µs at 5 Hz

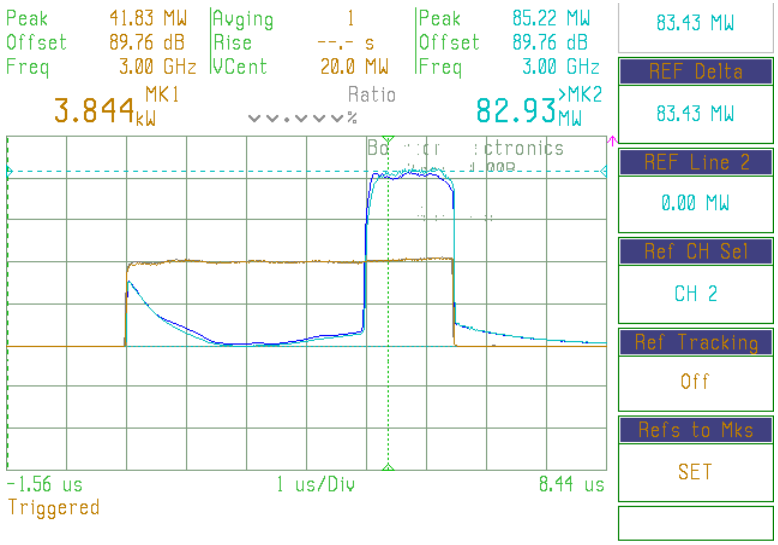
LIL section RF input



LIL section RF output

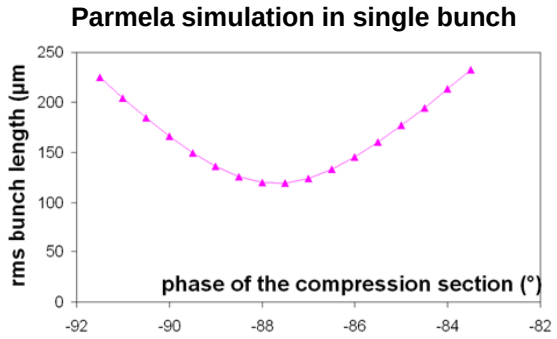
Filling time = 1.3 µs + dispersion effect

Dec. 08: a compressed pulse of 82 MW has been achieved after some weeks of conditioning (Jean, Luca, Stephane)



Power Phase shifter

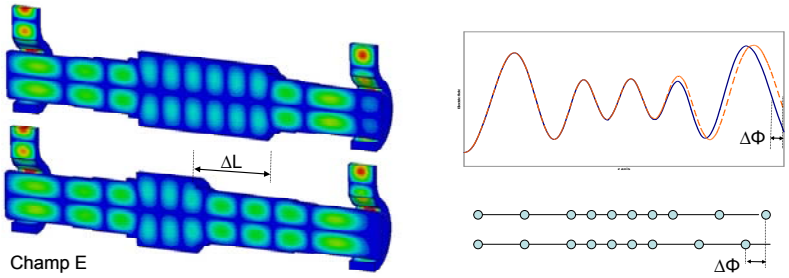
➢ a variation of 1° of the RF phase in the bunching section induce a variation of 20% of the rms bunch length σ_Z



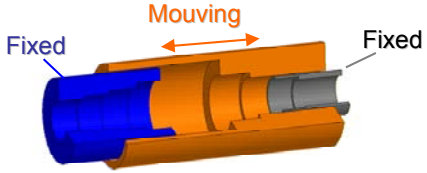
➢ Main specifications of the phase shifter

Parameters	Specifications
Frequence	3 GHz
Puissance RF crête	25 MW
Impulsion	1.5 µs, 5 Hz
Course max	200 °
Precision	0.5 °
Stabilité	0.1 °
Bande passante $\|S_{11}\|$	< 27 MHz @ -30 dB

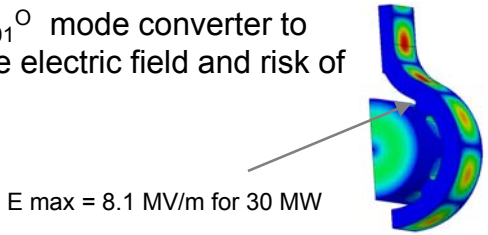
➢ Principle: phase shift by variation of guided wavelength



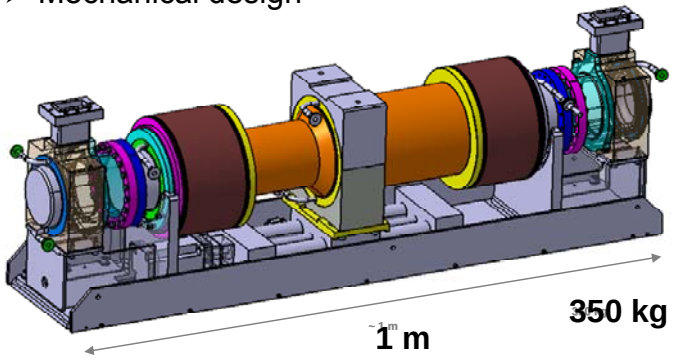
➢ Mechanically feasible by three circular waveguides



➢ $TE_{10}^{\square}$ - TE_{01}^{O} mode converter to avoid surface electric field and risk of breakdown



➢ Mechanical design

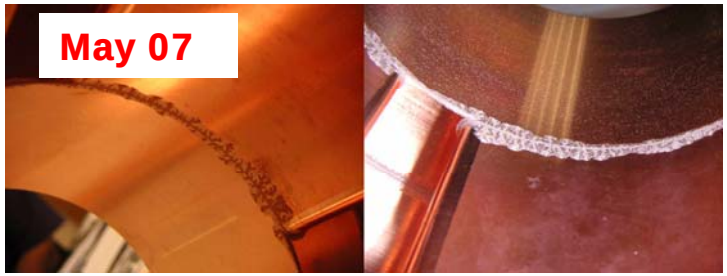


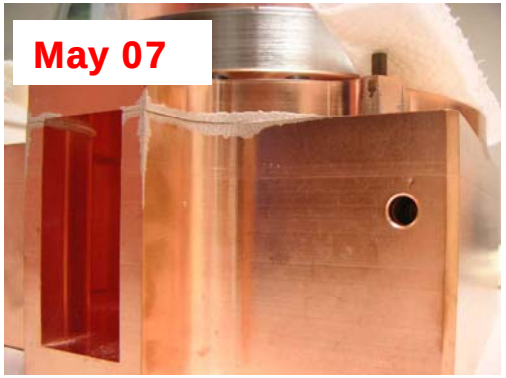
Power Phase Shifter: Mode Converters

- Precise milling of annealed copper: CLM Industrie (Dijon, France)

- Vacuum brazing: BODYCOTTE - ABMT (Annecy, France)

Leakage: bad behavior of the brazing alloy





Power Phase Shifter: Mode Converters

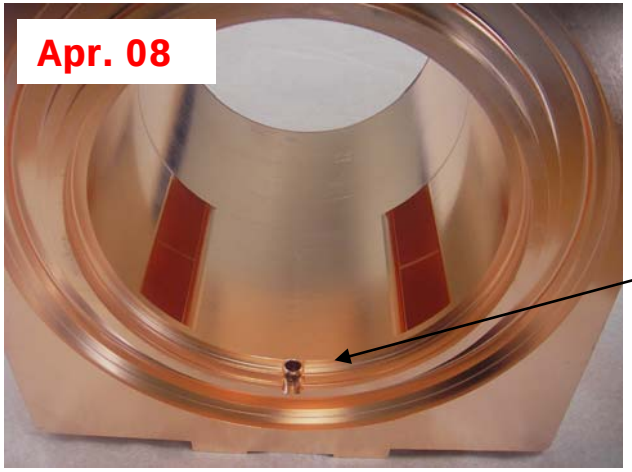
- From May 07 to Nov. 07: discussion, negociation of the contract

- Test of brazing on samples:

Reduction of Palladium amount in the brazing alloy

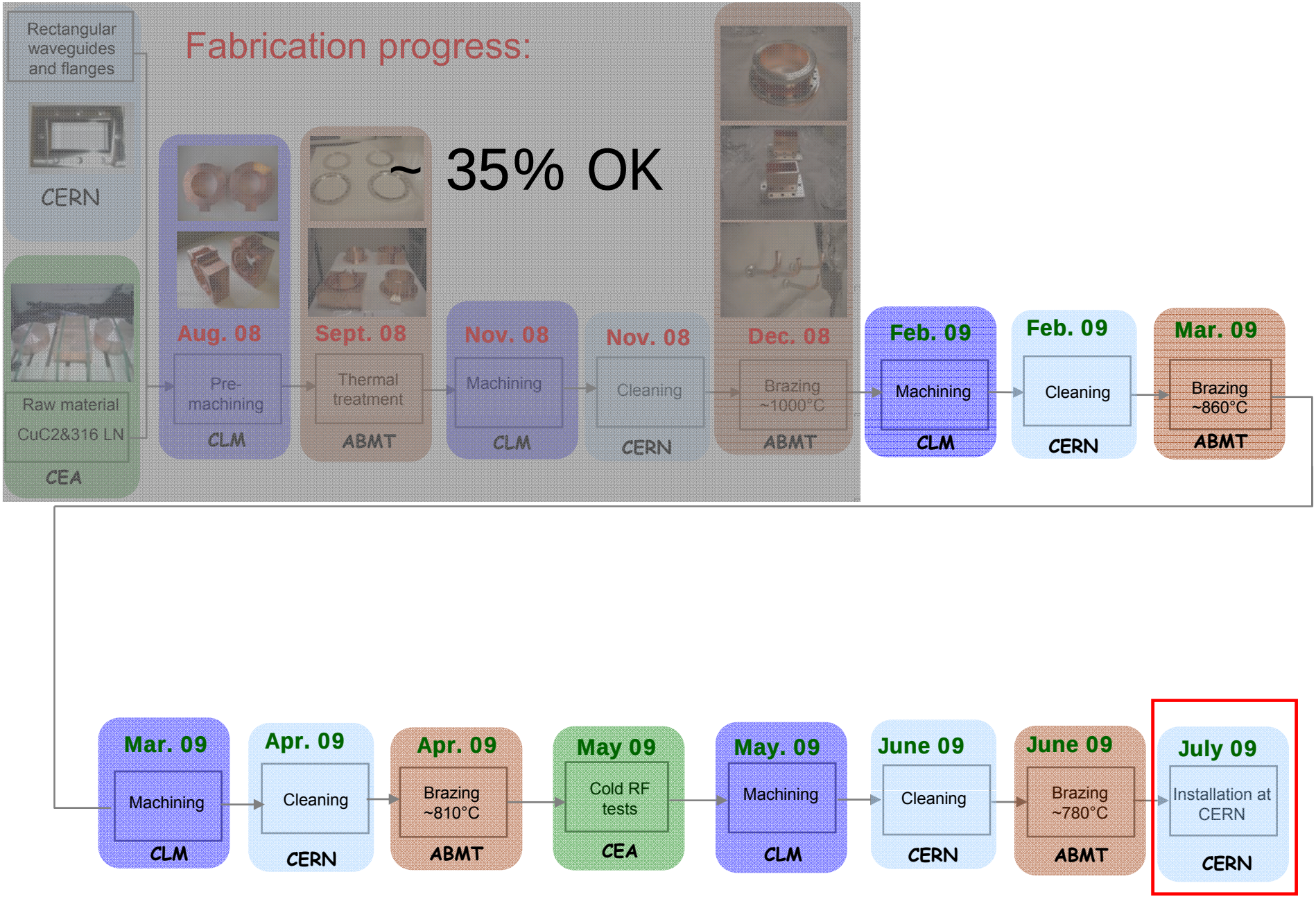
- Test of brazing on scale 1 prototype:

Succeeded !



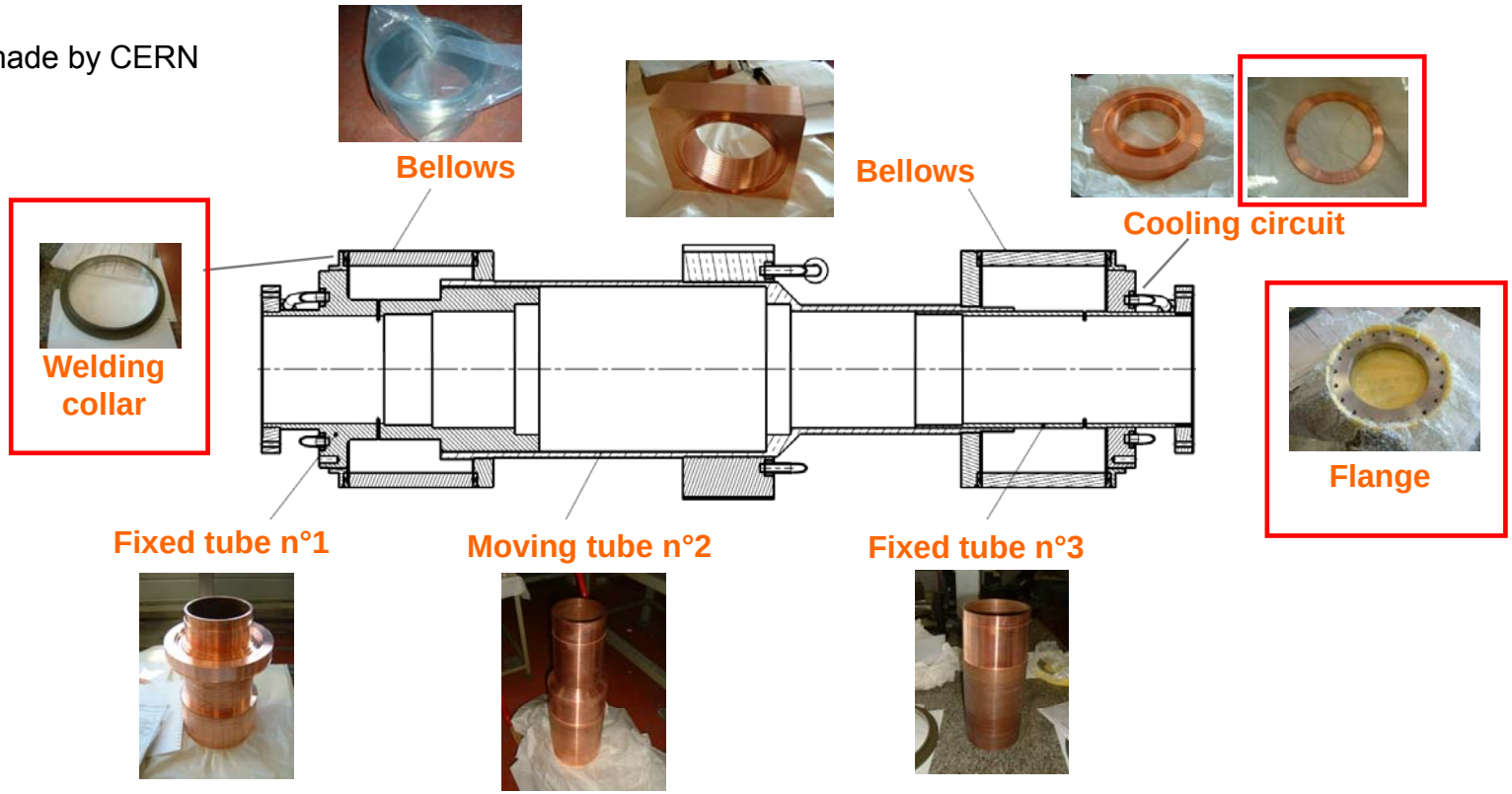
Temperature probes to control the brazing process

Power Phase Shifter: Mode Converters



Power Phase Shifter: Circular waveguides

- Turning operations made by CLM in two steps
  - Pre-machining
  - Thermal treatment at 250 °C for CuC2 and 950°C for 316LN (done at CERN)
  - Final machining
- Brazing made by CERN



Feb 08: 8 pieces (welding collars, flanges and cooling circuits) were not accepted by the brazing team (CERN) because of the tolerances were 0.07 to 0.09 mm instead of 0.05 mm max…

Power Phase Shifter: Circular waveguides

- March – July 08: Negotiation of the CLM contract
- Aug. – Sept. 08: New raw material CuC2&316 LN purchased by CEA
- Oct. 08: Pre-machining of the 8 new pieces at CLM
- Nov. 08: Thermal treatment at CERN
- Dec. 08: Final machining at CLM
- Jan. 09: Dimensional control in progress at CERN …

- Feb.09: Chemical treatment at CERN and cleaning
- March 09: Brazing at CERN
- April 09: Bellows welding at CLM

Conclusion

- HV modulator accepted on site, noise problem on cathode voltage solved
  - Pulse to pulse stability: March 09 with high voltage divider (before the delay line)
- Power phase shifter
  - Mode converters: qualification tests for machining and brazing OK, fabrication under progress (35% achieved)
    - end of fabrication: July 09
  - Circular waveguides: problem of tolerance on 8 pieces
    - end of fabrication: April 09

Thank you for your attention