Improved on line performance of the installed ALPI Nb sputtered QWRs

Laboratori Nazionali di Legnaro

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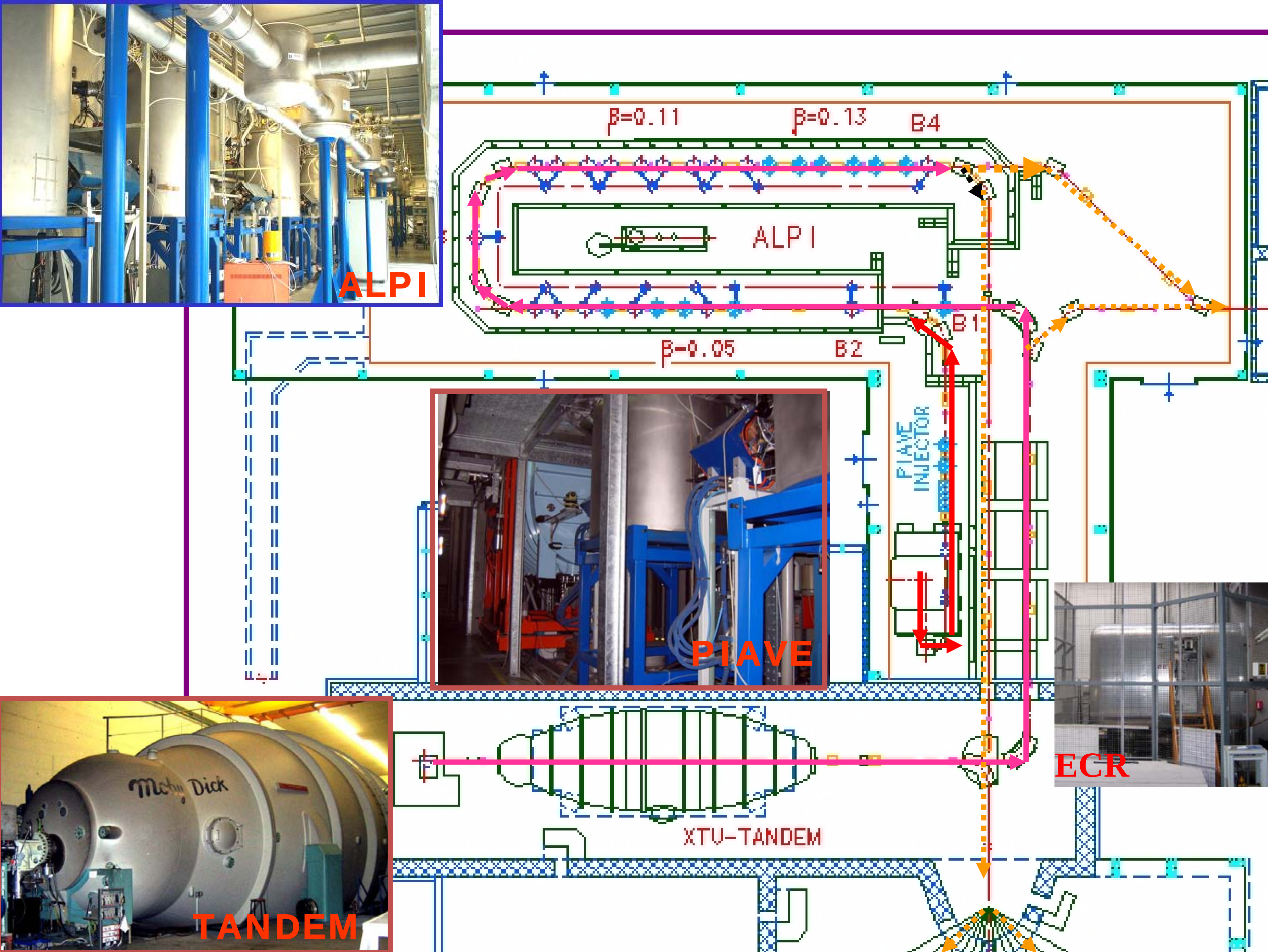
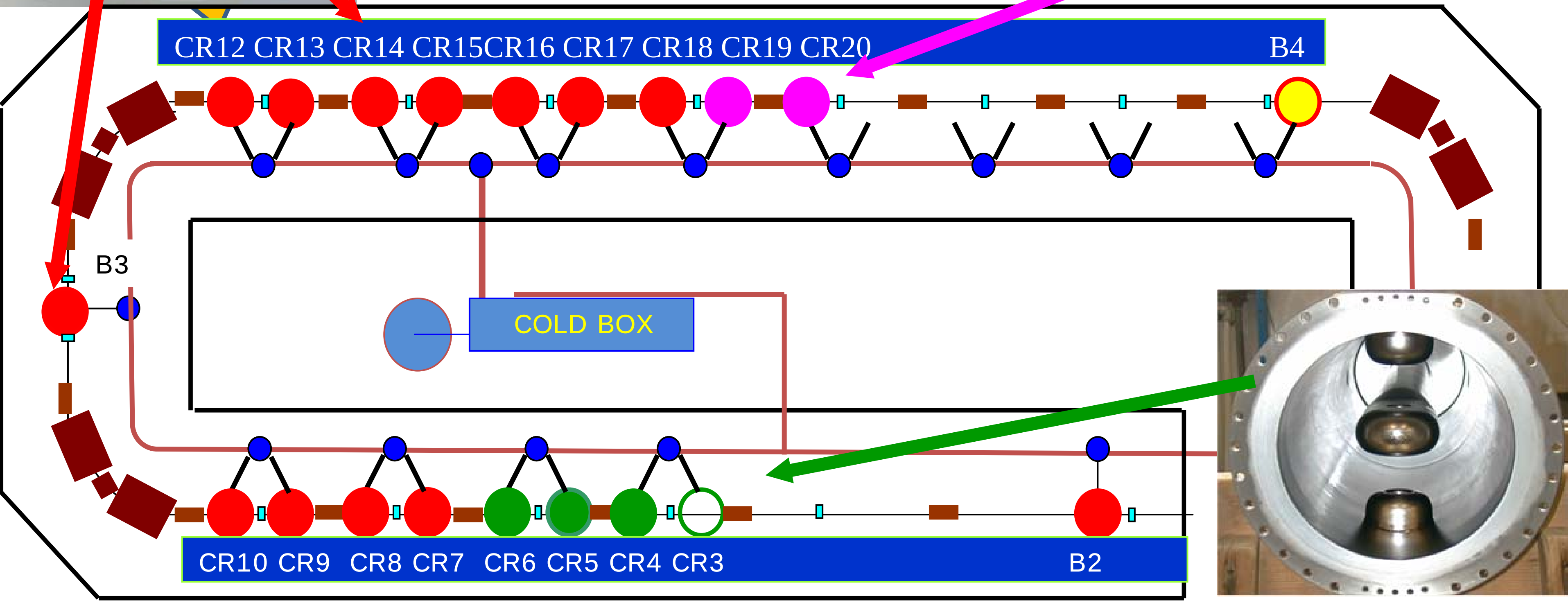


ALPI
β=0.11
β=0.13
B4
ALPI
B1
β=0.05
B2
PIAVE INJECTOR
PIAVE
ECR
XTU-TANDEM
Moby Dick
TANDEM

ALPI resonators



β=0.056, **80 MHz, full Nb**

β=0.11, **160 MHz,Nb/Cu**

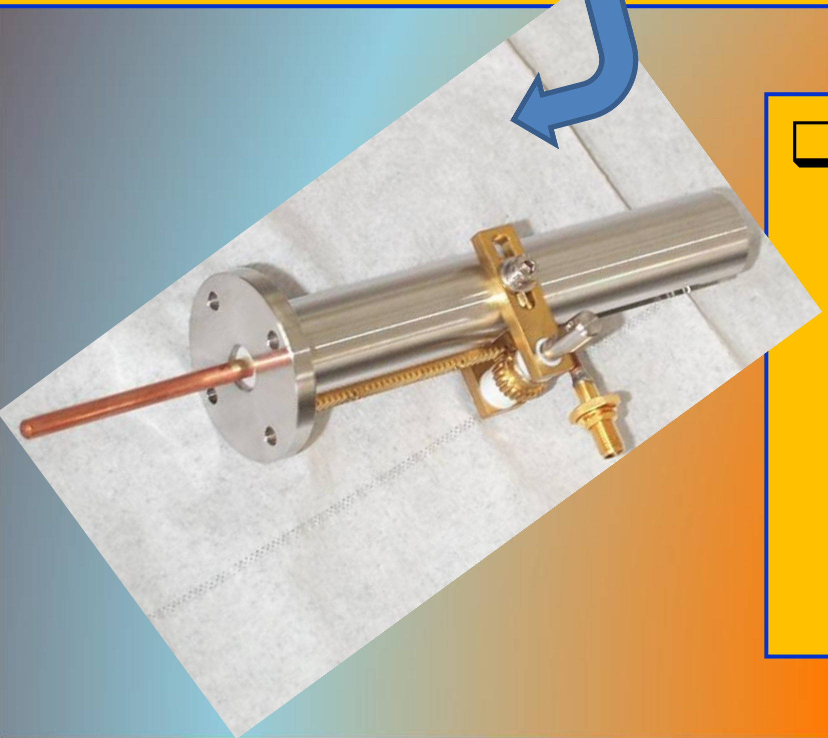
β=**0.13, 160 MHz, Nb/Cu**

β=0.11, **160 MHz, Pb/Cu**

ALPI high β QWRs

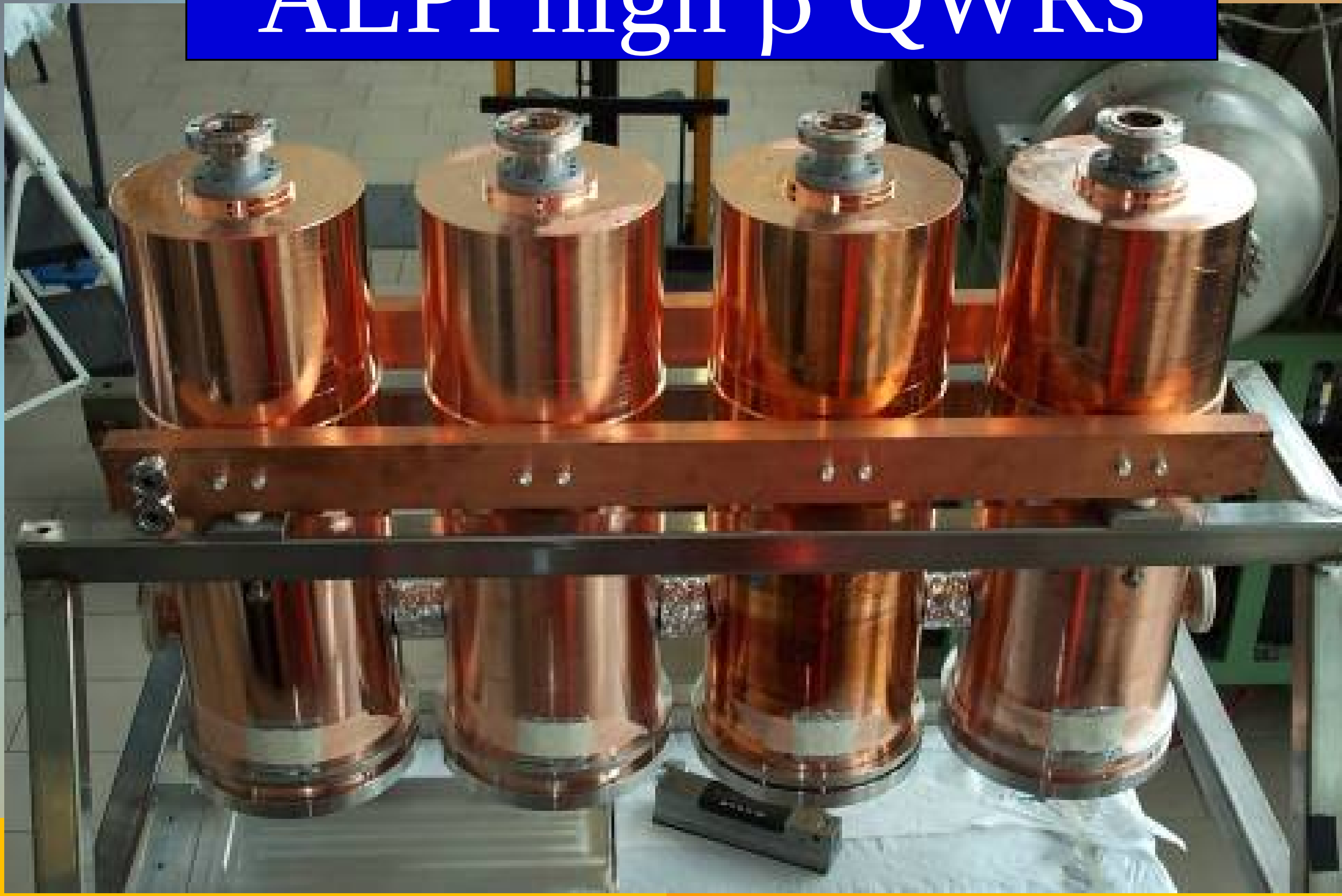
β=0.13;   f= 160 MHz

- Installed in CR20 and CR19
- Very simple shape
- External beam ports jointed by In gaskets
- Rounded shorting plate
- Capacitive coupler



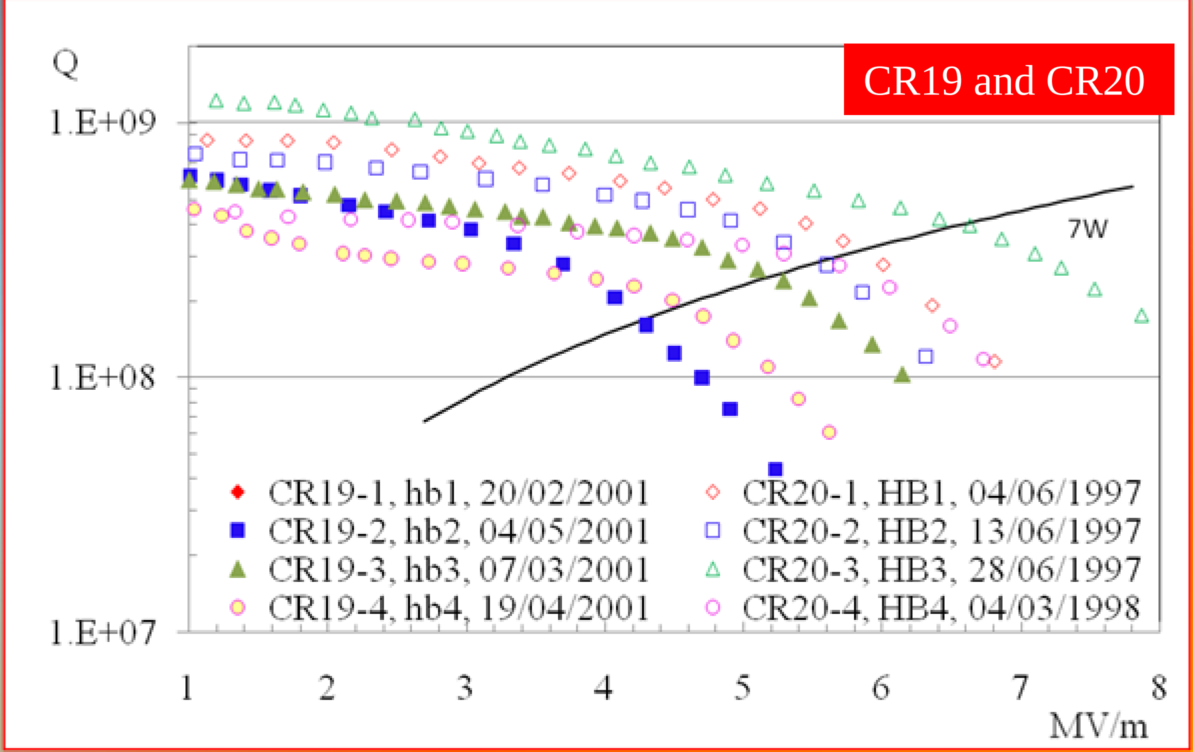
- **CR20 resonators**
  - ✓are in ALPI since 1998
  - ✓T are drilled from a billet of OFHC Cu, 99.95%
  - ✓ No brazed joints
  - ✓The average operational accelerating field is 6 MV/m

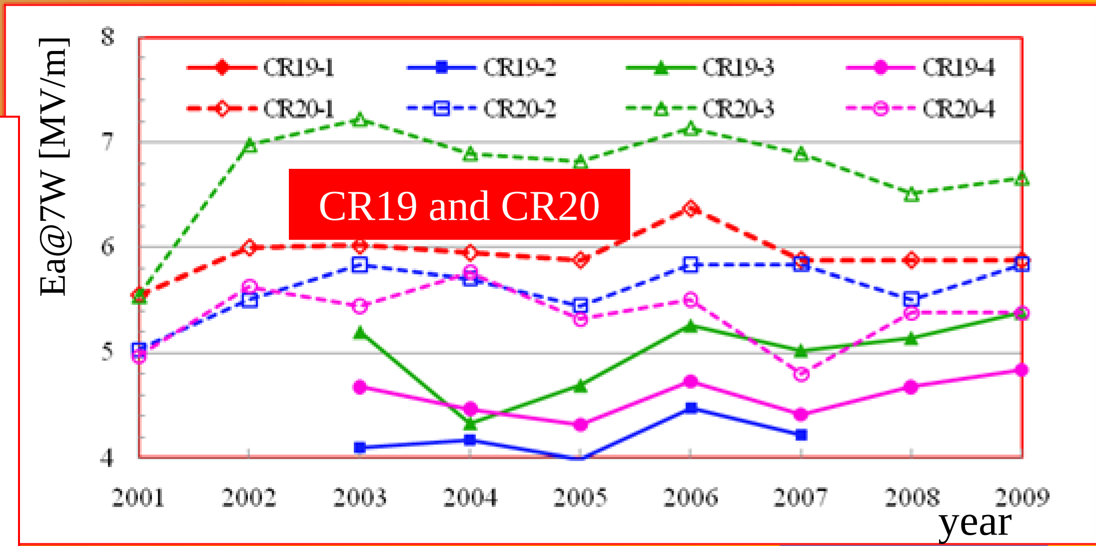
ALPI high β QWRs



- ❑ **CR19 cavities**
  - ✓installed ALPI in 2001,
  - ✓similar in inner shape to CR20 cavities
  - ✓made in SeCu
  - ✓ circumferential brazed joint
  - ✓brazed collar and supports

High β QWRs





- ❑ Better performance in CR20
- ❑Lower performance in CR19 (similar shape but different construction technology)
- ❑ 2 cavities to be repaired because of a stuck coupler and rf line damage,

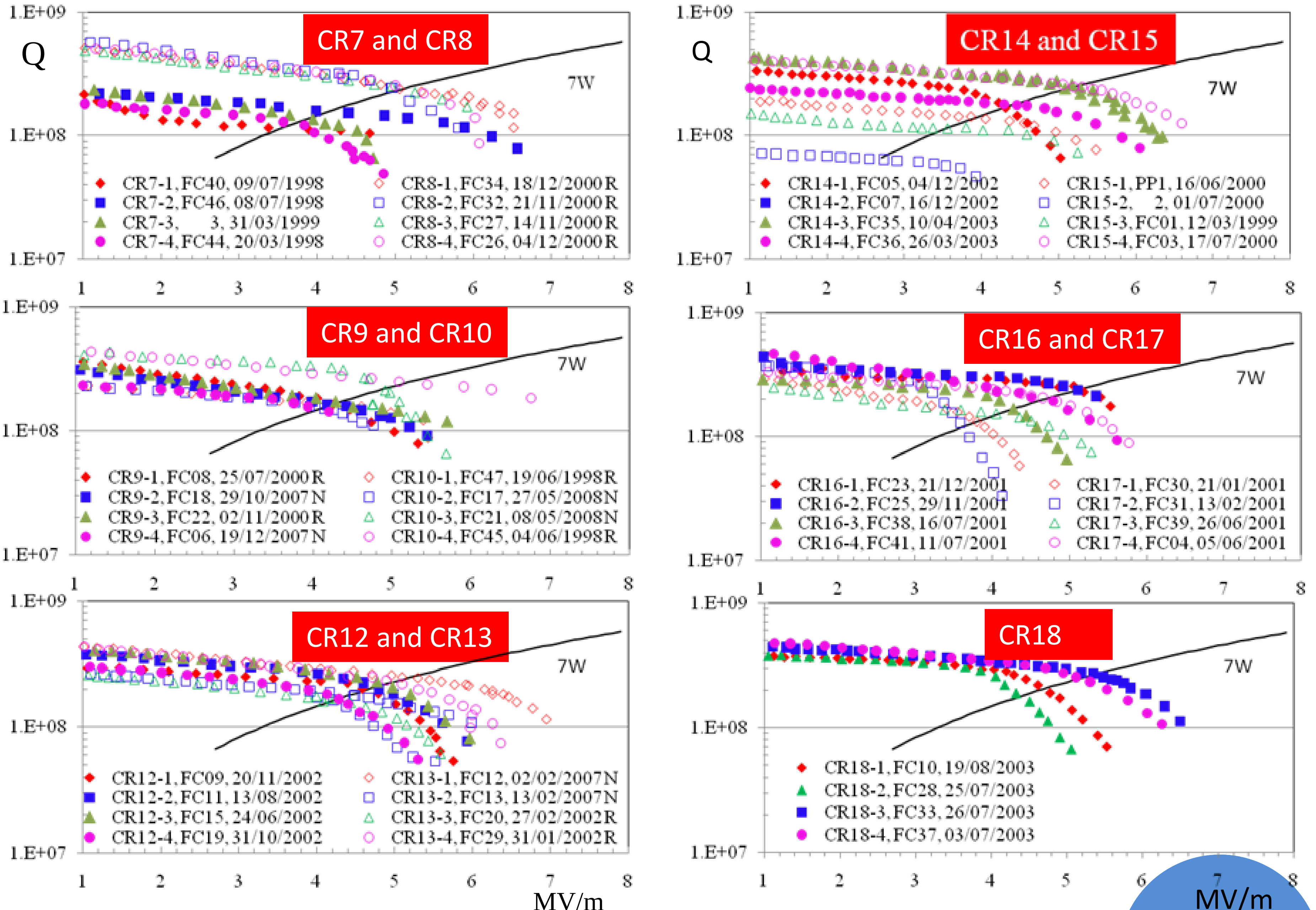
ALPI medium β QWRs

Originally Pb plated;
Nb sputtered in between 1998-2003

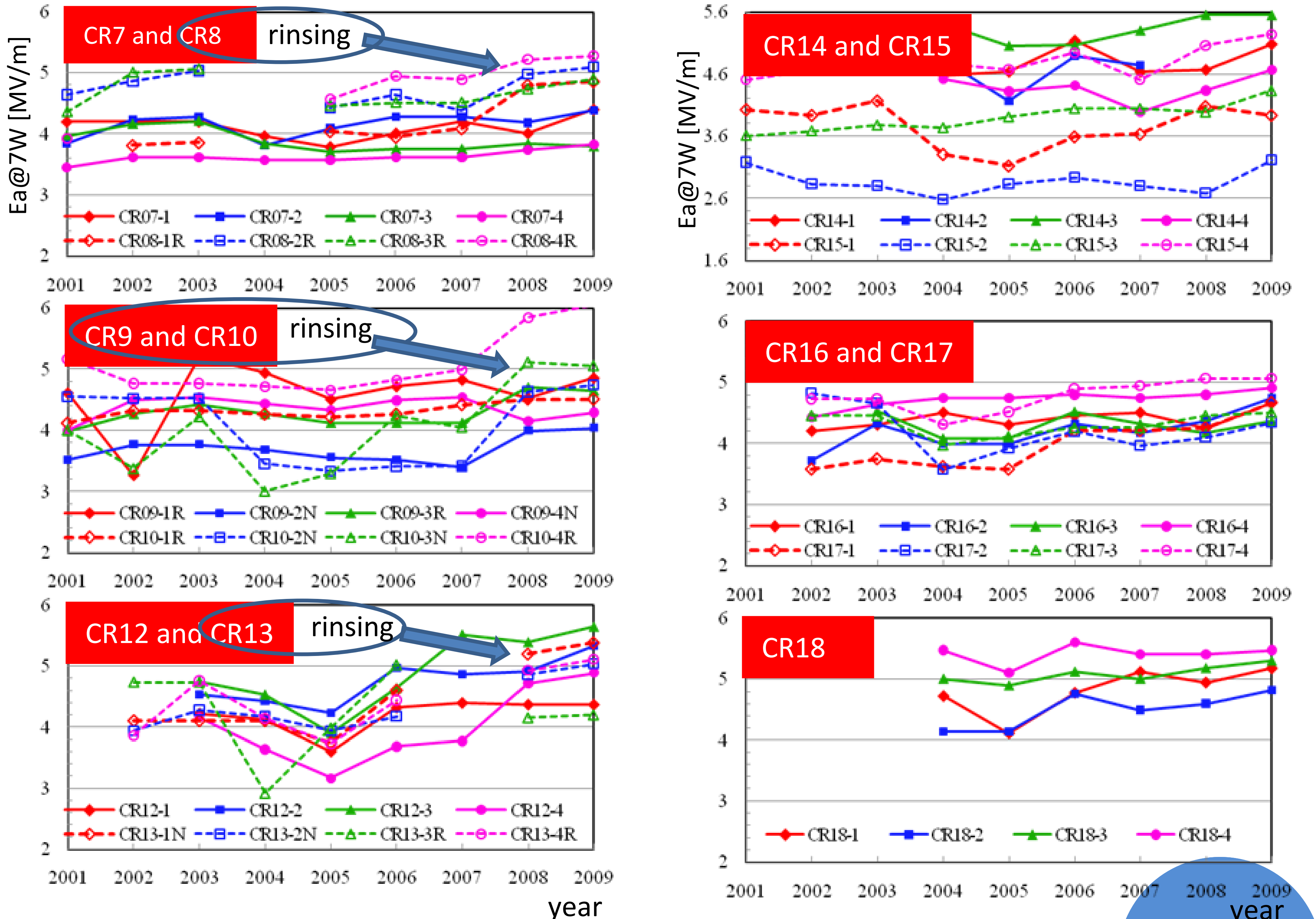
- ❑ Brazed joints (especially the ones in the outer resonator surface)
- ❑ Flat shorting plate
- ❑ Beam ports shape
- ❑ Inductive coupler (hole in high current region)

Limited the reached performance to 4.8MV/m @7W, a lower level than the ones of high β resonators.

ALPI β=0.11
160 MHz

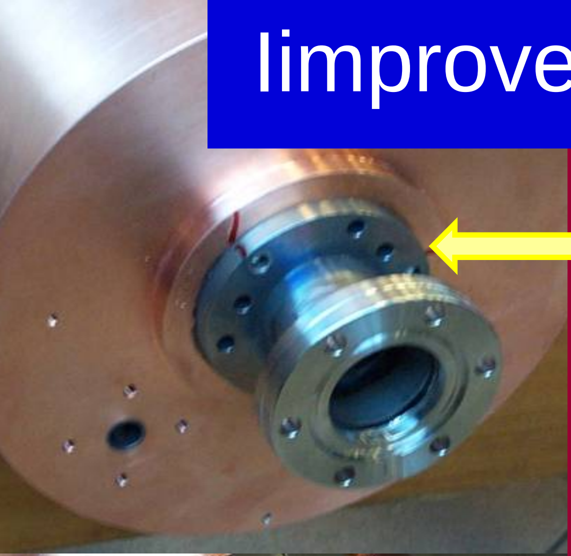


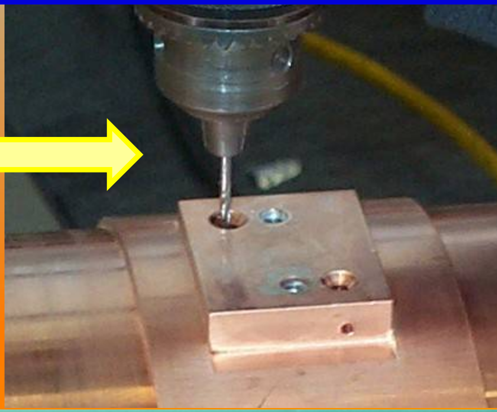
Q-curves of medium β cavities installed in ALPI cryostats



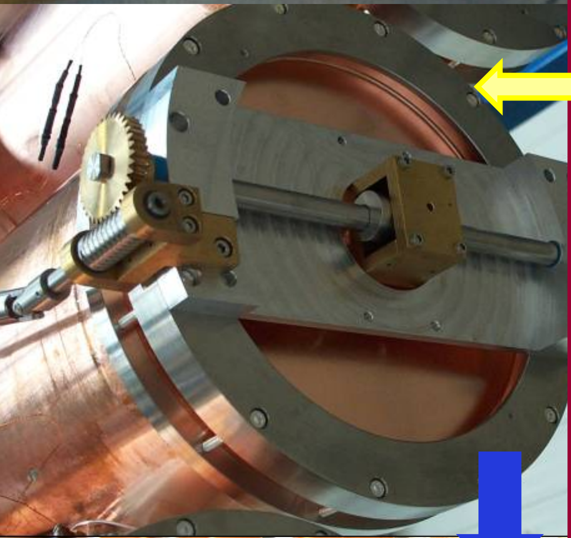
Operational Ea in QWRs of medium β cryostats

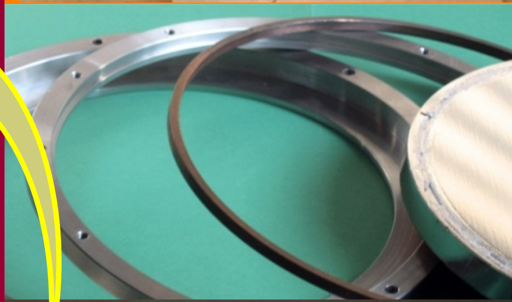
Iimprovements maintaining old substrates

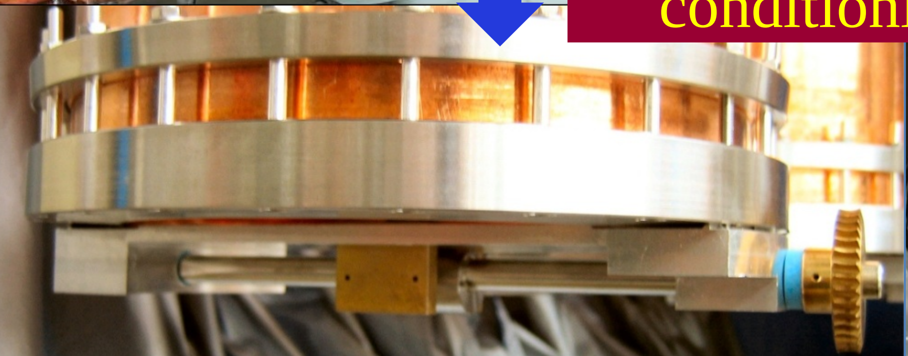




- More accurate "Lifting" of the old Cu substrate (the opening of all the trapped enclaves was not well performed in the first produced resonators)
- Better tuning plate contact to avoid Indium joint (by modifying the end plate and doubling its fixing screws)
- HPW resonator rinsing
- Cleaner assembling condition before and after sputtering
- Longer high power rf conditioning



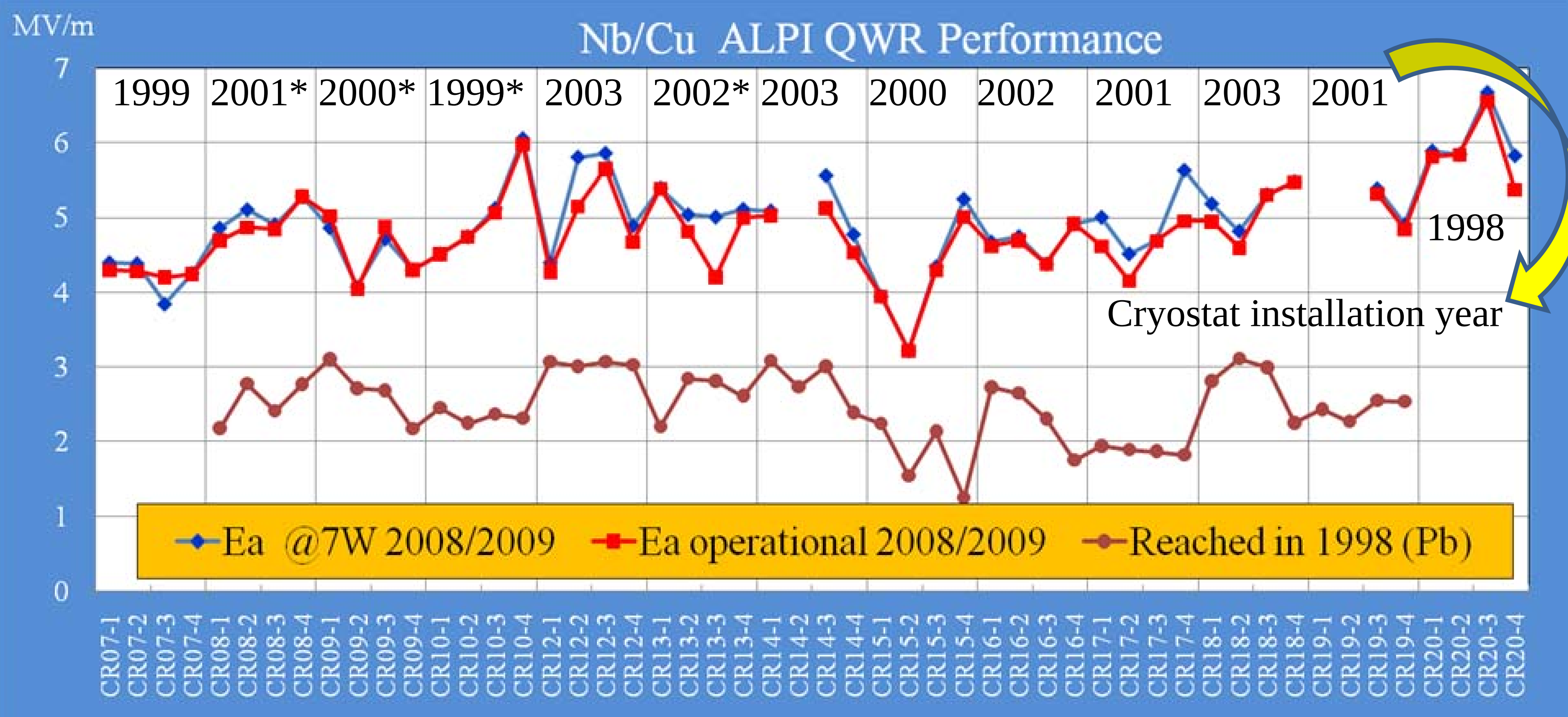




Drawbacks /possible improvements

- We have
  - ✓ To align the resonators with their beam port open to air.
  - ✓ To close the cryogenic circuits after the resonator assembling
- It would surely help:
  - Avoid cryostat venting to air (because of cryogenic circuits leaks)
  - Perform high pressure rinsing after resonator alignment (possible if we have not the In joint)
  - Longer rf and He conditioning (5 MV/m reachable @ 7W in old substrates)

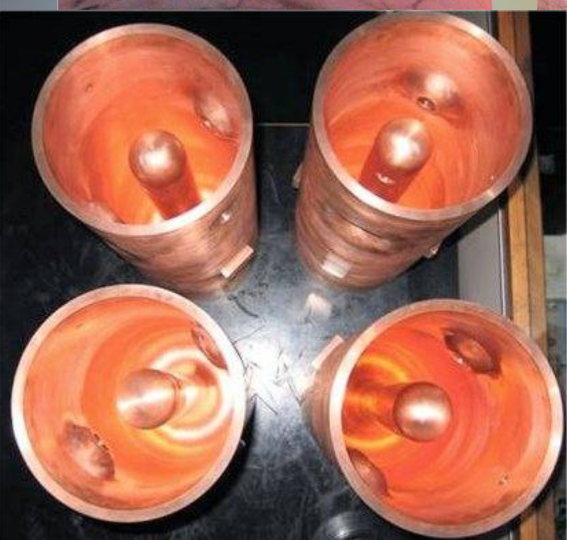
Nb/Cu ALPI QWR Performance



Nb/Cu Average Ea @7W: 4.83MV/m
Nb/Cu Operational Ea : 4.70 MV/m
Pb/Cu Average Ea: 2.48 MV/m

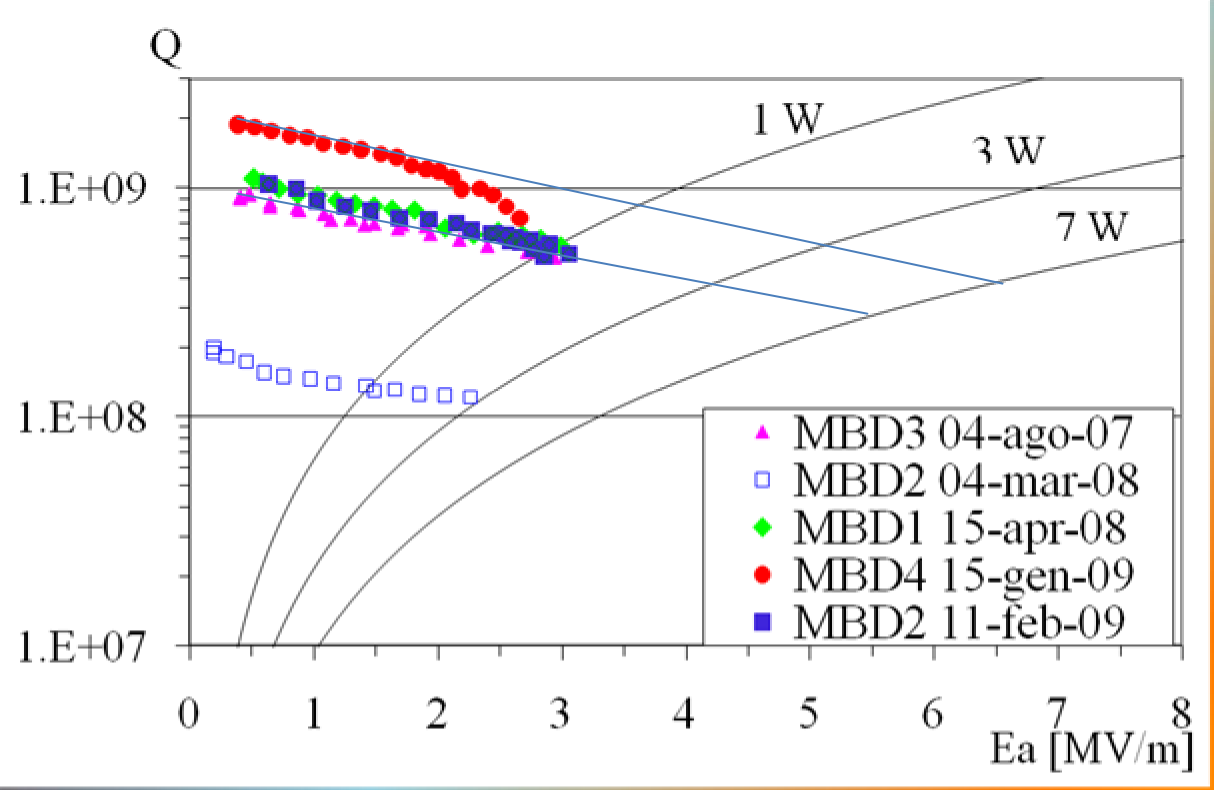
* Recent cryostat maintenance

New medium β QWRs



We have 4 new cavities ready with

- New beam port design
- A rounded shorting plate
- A capacitive coupler
- Without holes in high current regions
- Without brazing in the outer resonator body

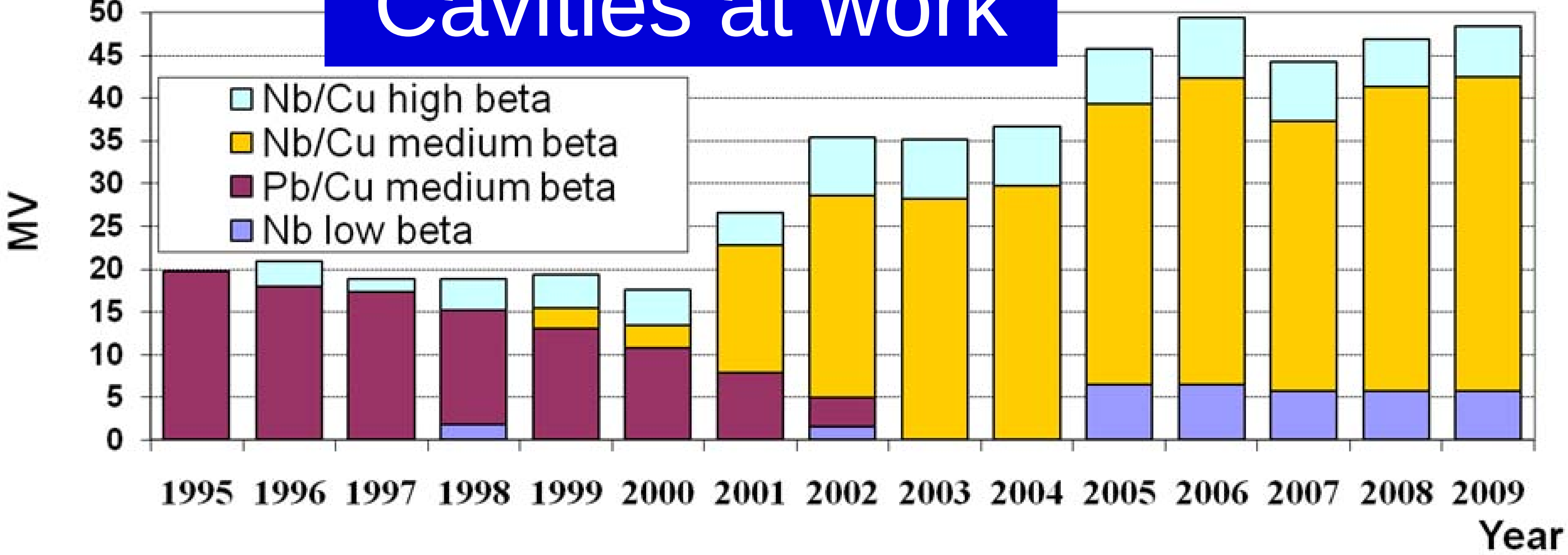


New medium β QWR performance

- 4 cavities produced (MBD2 sputtered twice)
- Improvement due to cathode optimization
- Tested up to 3MV/m in laboratory
- Ea between 5.5 and 6.5 MV/m @7W expected on line
- **Better results possible but we prefer to install them in CR15 as soon as possible**

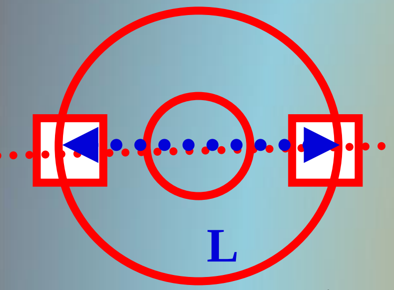
4 READY

Cavities at work



$$\Delta V = \sum E_a L$$

$$E_a = \max\left(\frac{W}{qL}\right)$$

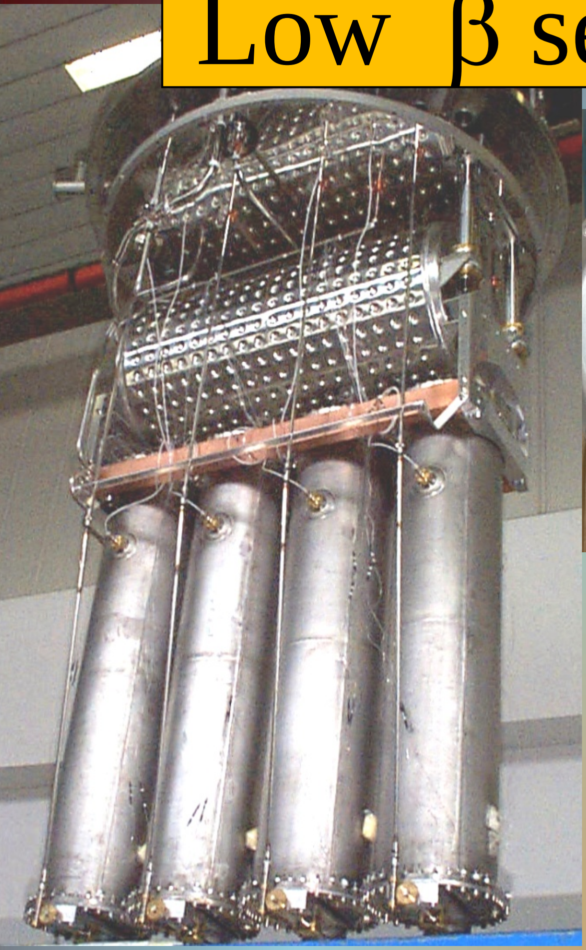


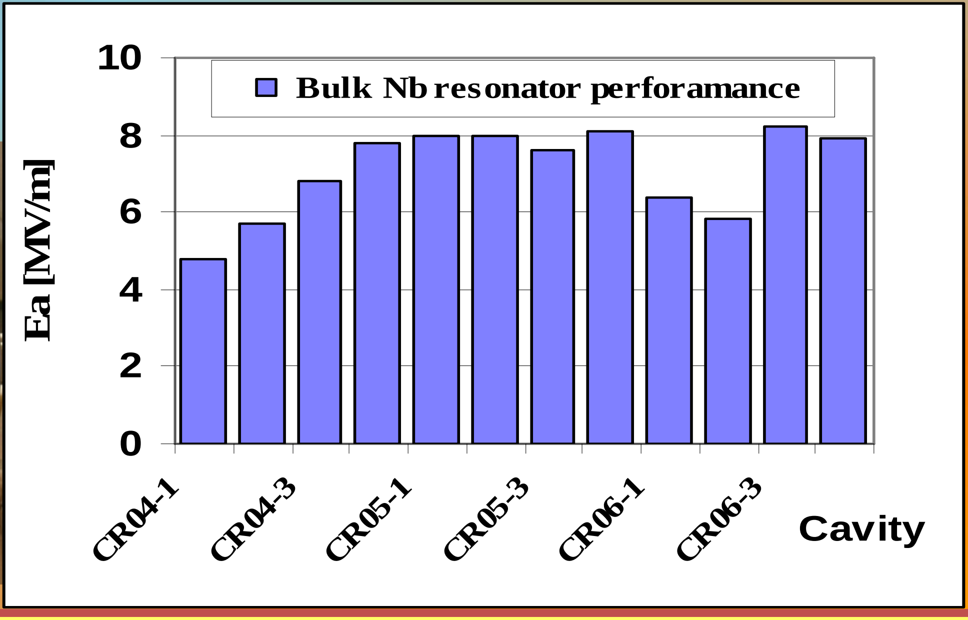
W=energy gain

q=State of charge

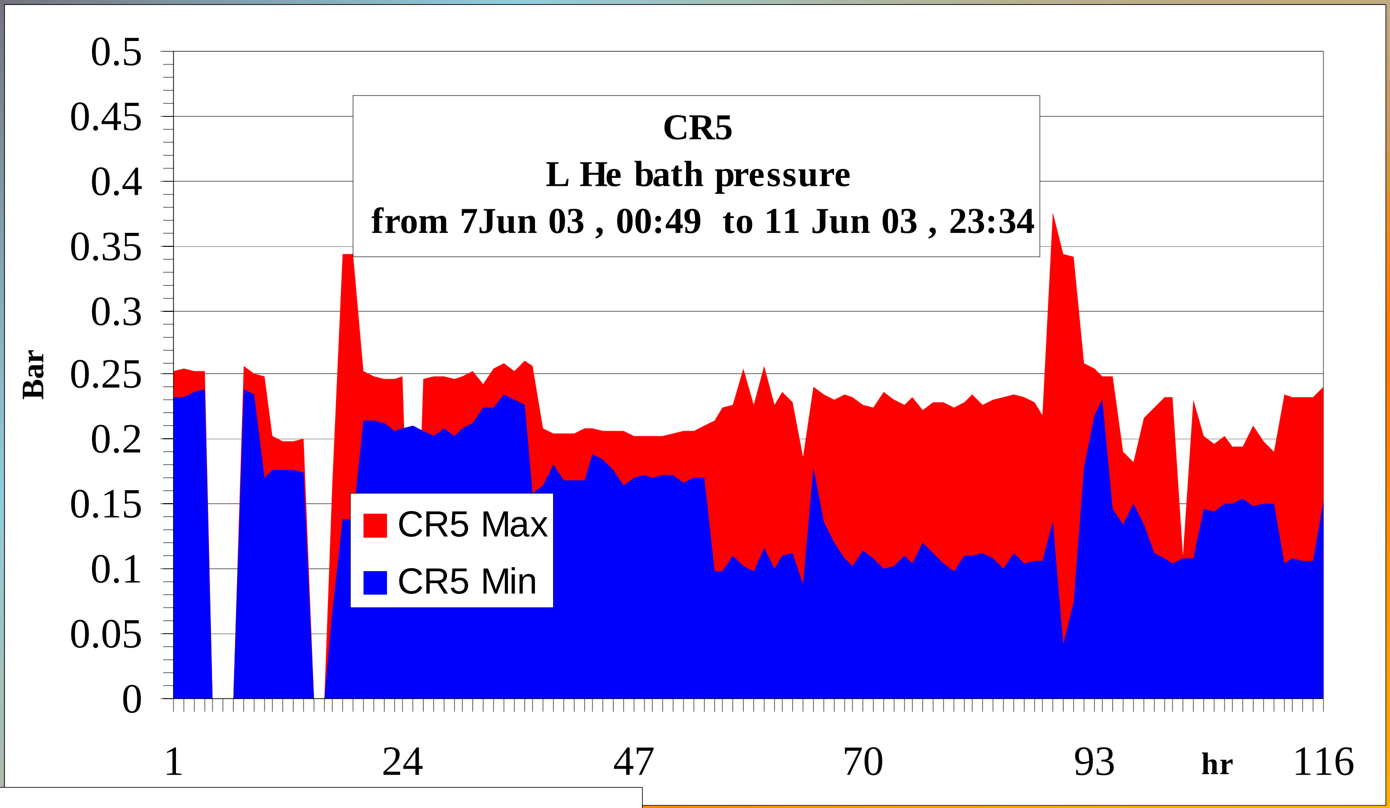
- Since 2001 **most of the ALPI equivalent voltage (ΔV) is provided by Nb/Cu cavities**
  - Operation at Ea determined by the available cryogenic power
  - No frequency tracking or fast tuning required
  - No degradation with time; average fields is still improving
- Low β have to be locked at Ea <3 .5 MV/m in ALPI
  - Higher operational Ea expected by increasing the rf driving power; new rf cryostat lines and a L.N cooled coupler required

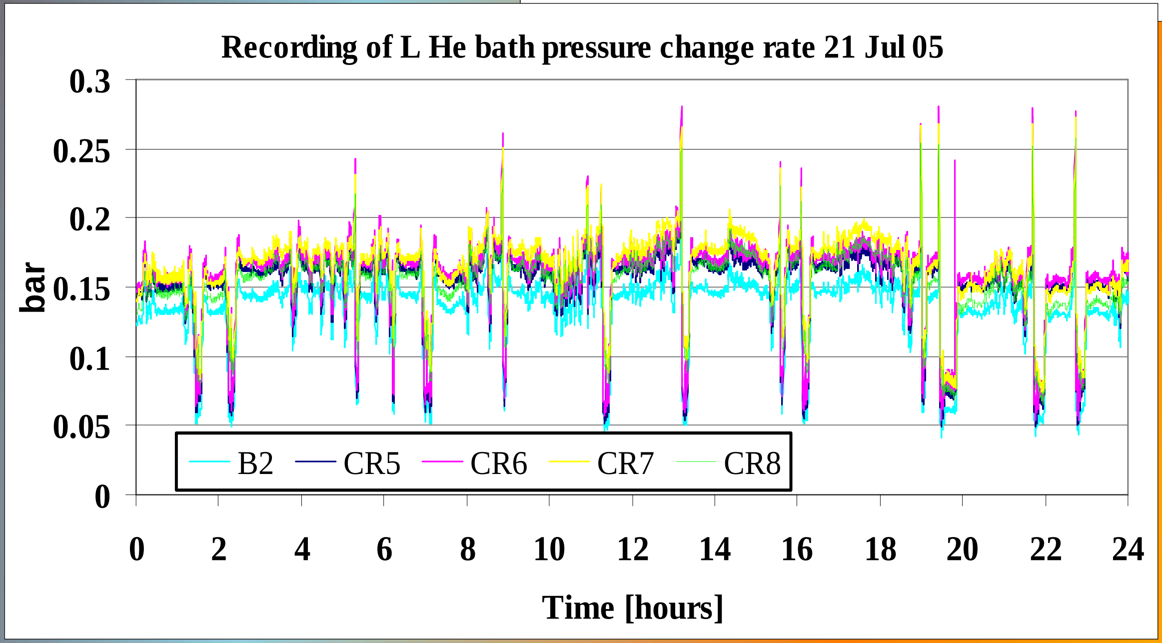
Low β section





- **Nb, 80 MHz, β=0.056, 12+(4) resonators**
- **Excellent performance: 6.7 MV/m @ 7W**
- Installed in between 1995-2000
- Mechanical dampers effectively reduce their sensitivity to acoustic vibrations
- Sensitivity to He bath pressure drifts (1Hz/mbar) made the cavity locking tricky when the resonators were cooled by the very noisy ALPI cryogenic system
- **Operating up to 3.5 MV/m in ALPI;4.2 MV/m in PIAVE; 2/3 out of work**
- Upgraded tuners, amplifiers, bottom plates…
- New L.N_2 cooled couplers coming soon
- Expected 5 MV/m in lock condition





Pressure excursions in ALPI cryostats

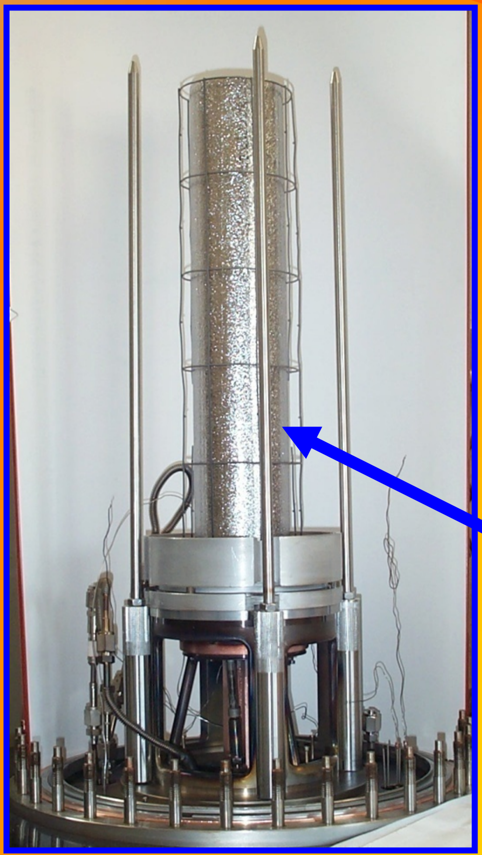
Surface finishing and chemical treatments

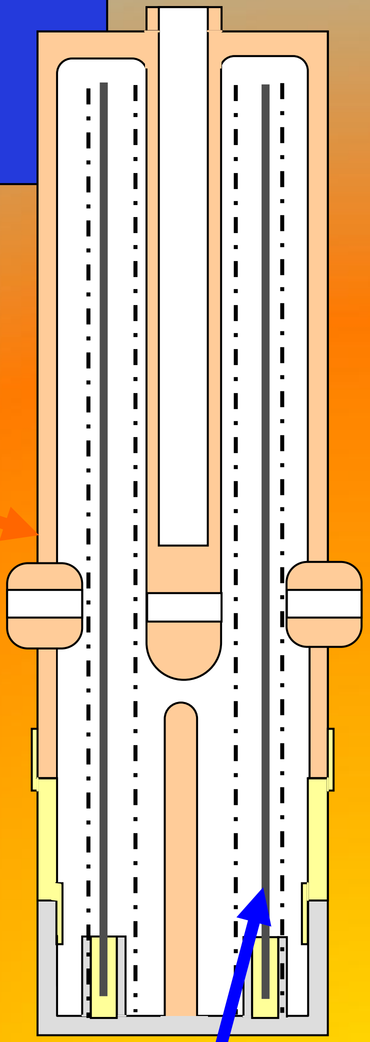
- Frequency adjustment by electro-polishing
- Electro-polishing **(20µm, 2 hours, phosphoric acid +butanol, computer controlled)**
- Rinsing **(water, ultrasonic water, HPR)**
- Chemical polishing **(10µm, 4 min, SUBU5)**
- Passivation **(sulphamic acid)**
- Rinsing **(water, ultrasonic water, HPR)**
- Drying **(ethanol, nitrogen)**

Biased Nb sputtering

Sputtering chamber

Cu base





Cathode: Nb tube

- Good vacuum
- Backing
- No discharges
- High substrate temperature

Sputtering performed in about 12 steps of 15’
Production cycle asks for 9 days

Nb sputtering advantages

- ***Mechanical stability*** (mechanical vibrations are not an issue)
- ***Frequency not affected by changes He bath (***Δp <0.01Hz/mbar, no frequency tracking)
- ***Reduced over-coupling*** (smaller amplifier, coupler do not need cooling, rf lines have reduced size and limited rf dissipation)
- ***High thermal stability*** (less prone to hot spots, conditioning easier)
- ***Stiffness*** (in case of loss of isolation vacuum leak…)
- ***Absence of Q-disease*** (less demand on cryogenic system cooling velocity and reliability)
- ***Insensitivity to small magnetic fields*** (no magnetic shielding)
- ***High Q of the N.C. cavity*** (easier coupling in N.C state, better multipactor conditioning)
- Lower X-ray production (lower power available for field emission)
- ***Absence of In vacuum joints*** (vacuum leaks less probable)
- Price (both material and construction)

Conclusion

- The Nb sputtering technology showed to be very effective in producing reliable resonators, which have high performance, are very steadily phase locked and are easy to put into operation.
- Even better results were obtained using suitable substrates.
- The reliability and simplicity of operation of Nb sputtered cavities is clearly shown in ALPI where they steadily operate in spite of pressure instability in liquid He cooling bath

Thanks for your attention!

Cryostat maintenance

- **Change of the leaking cryogenic valve** (external actuator)
- **Viton sealing in the cryostat beam line valves**, from resonator integral conditioning (changed + shielded through stainless steel rings)
- **Gaskets in the He circuits** (changed + fixed by silver plated screws)
- **Leaks on the cryostat upper thermal shield**
- **RF lines** (Mechanical adjustments + Cu re-plating)