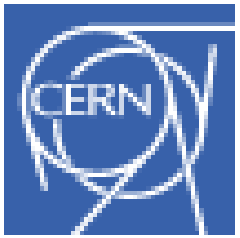
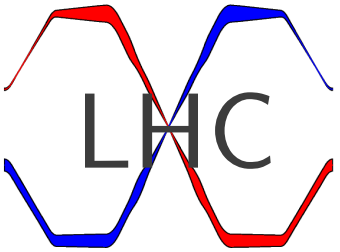




Summary of Future Plans

R. Calaga, E. Ciapala, E. Jensen

CM18/HiLumi LHC Meeting, May 9, 2012

LHC-CC11 execute summary & status

Next steps towards a prototype cryomodule

SPS tests preparation

Executive Summary

Myers/Collier

RF/beam tests ... before an LHC installation should be carried out in the SPS. Target for the SPS tests is 2015 and no later than 2016.

Important additional tests require a Point 4 setup with LHC beams.

Collaboration on SPS & P4 test cryostat development (& construction) is a priority.
Joint CM design will be set up, involving cavity designers, CERN and outside cryo experts.

Further studies for machine protection with crab cavities with realistic RF failure signals in conjunction with the upgraded collimation system are required.

Full summary:
https://indico.cern.ch/materialDisplay.py?materialId=paper&confId=149614

Basic Parameters

Voltage = 3 MV/cavity (2-3 cavities /module)

Frequency = 400 MHz

Qext = 10^6, R/Q ~300 Ω

Cavity tuning/detuning $\sim \pm$ 1.5kHz (or multiples of it)

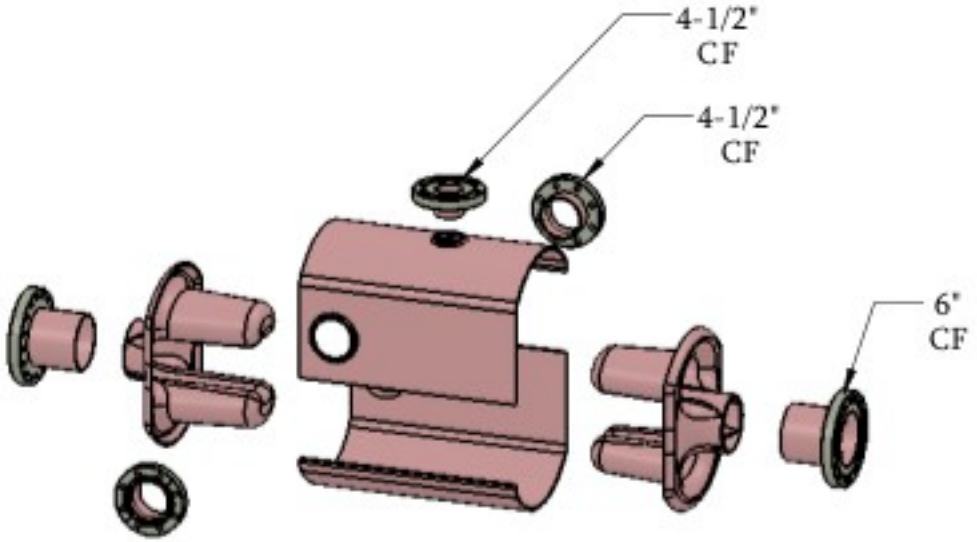
RF power source = 60 kW ($<$ 18 kW nominal)

Beam current $\sim$ 0.5-1 A

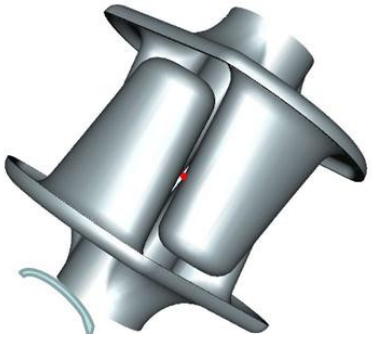
(Pressure specifications and vessel code, cavity impedance, LLRF, multipole requirements, RF power, cryogenics, tuning specifications, alignment, flanges, He-vessel, HOM power, static B-fields etc.. in a technical specification document soon)

4R Prototype

Courtesy: G. Burt et al.

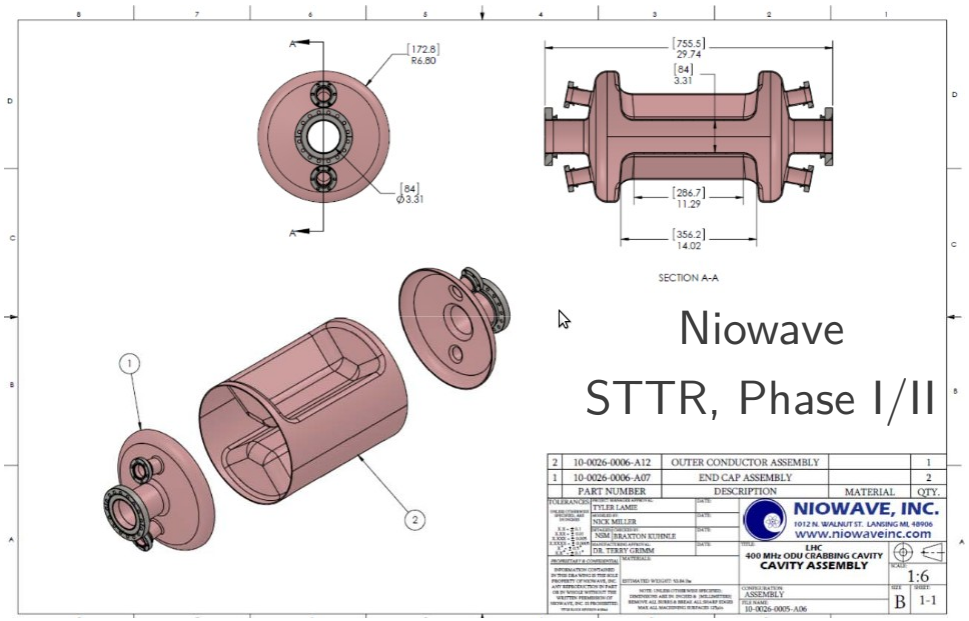


Nb rods from solid Ingot via EDM
(significant material saving)

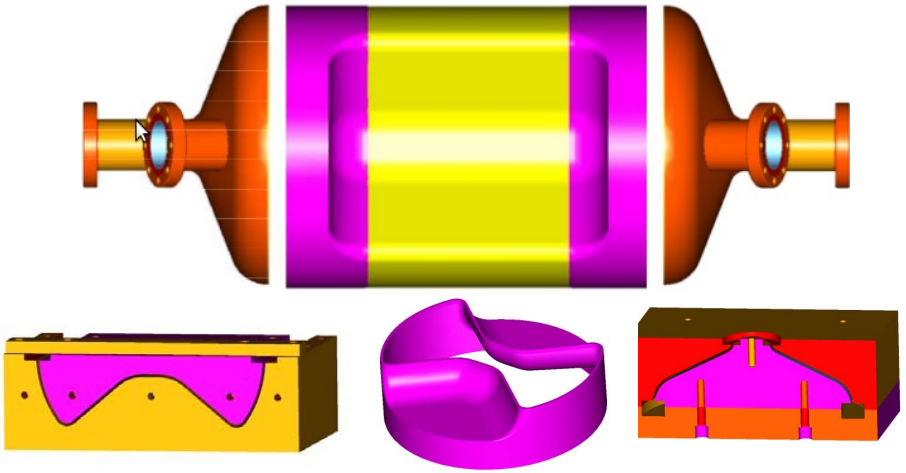


Cavity to come to CERN for
surface treatment & testing

Double Ridge Fabrication



Courtesy:J. Delayan, Niowave

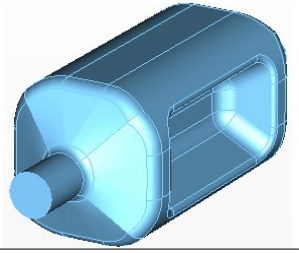


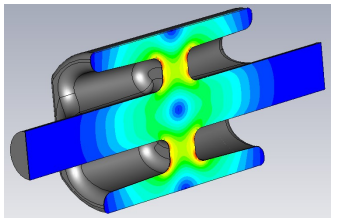
Nov 2011 ⟶ Jan 2012

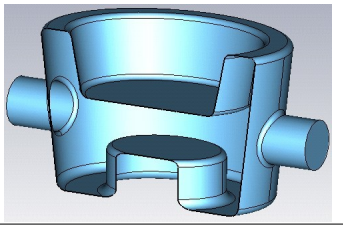
Testing April 2012

Performance Chart

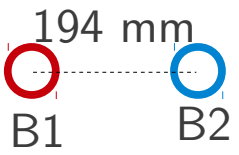
Kick Voltage: 3 MV, 400 MHz







	Double Ridge (ODU-SLAC)	4-Rod (UK)	¼ Wave (BNL)	
Geometrical	Cavity Radius [mm]	**147.5**	**143/118**	**142.5/122**
	Cavity length [mm]	597	500	405
	Beam Pipe [mm]	84	84	84
RF	Peak E-Field [MV/m]	33	32	43
	Peak B-Field [mT]	56	60.5	61
	R_T/Q [Ω]	287	915	345
	Nearest Mode [MHz]	584	371-378	657

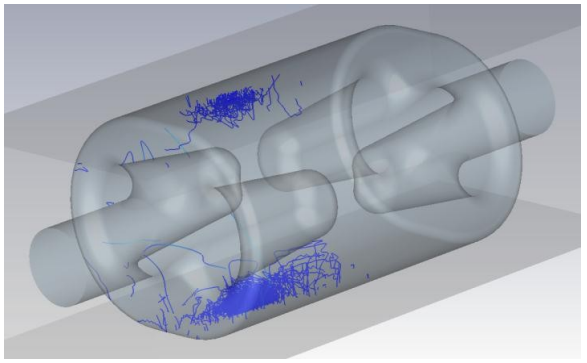


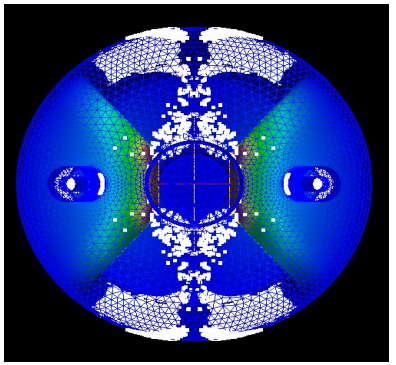
< 60 MV/m

< 100 mT

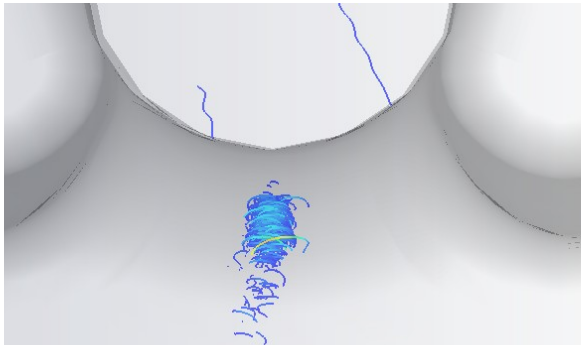
Multipacting

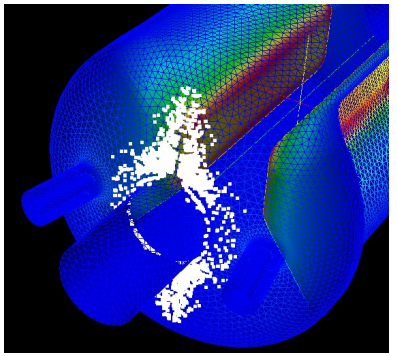
Low Field



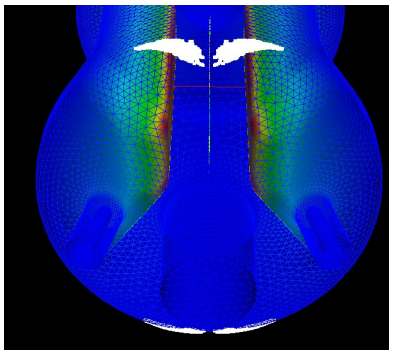


Medium Field

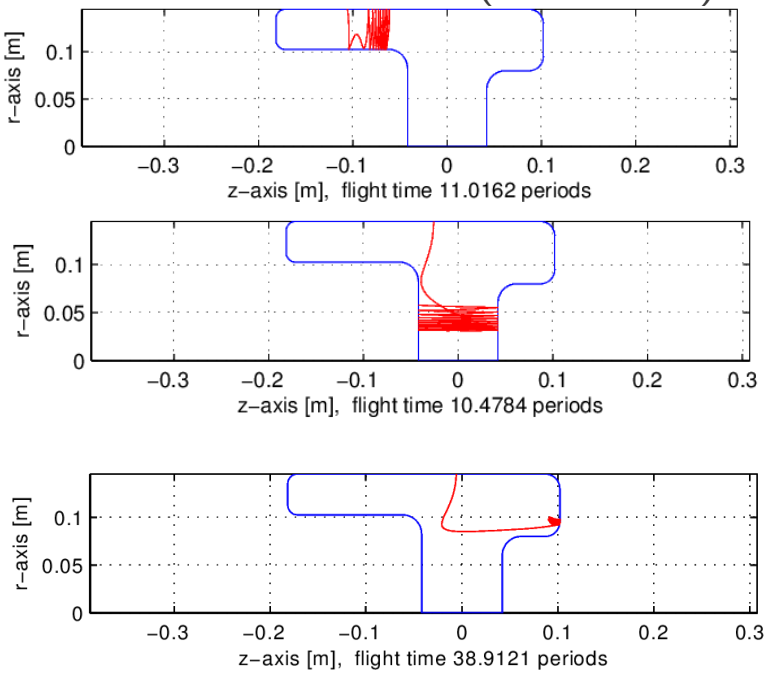




High Field



In 2D: all low field (< 0.3 MV)



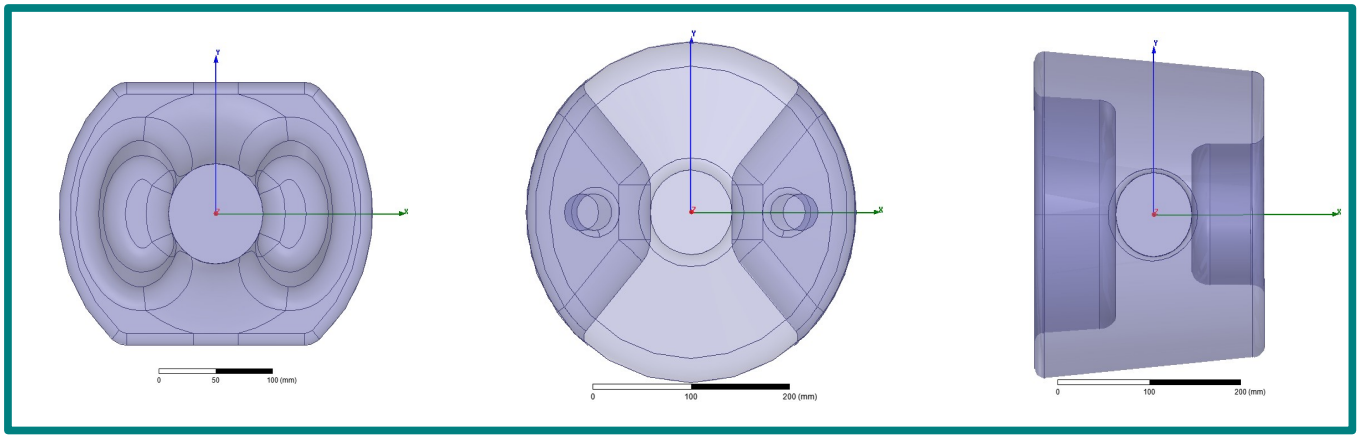
Not a serious worry

Can SLAC codes be applied for all 3 cavities (Z. Li)?

RF Multipoles

Courtesy: A. Grudiev et. Al

Long term simulations underway



mTm/m^{n-1}	MBRC	4-Rod	Pbar/DRidge	¼-wave
b_2	55	0	0	114
b_3	7510	900	3200	1260
b_4	82700	0	0	1760
b_5	2.9×10^6	-2.4×10^6	-0.5×10^6	-0.2×10^6
b_6	52×10^6	0	0	-1.7×10^6
b_7	560×10^6	-650×10^6	-14×10^6	0

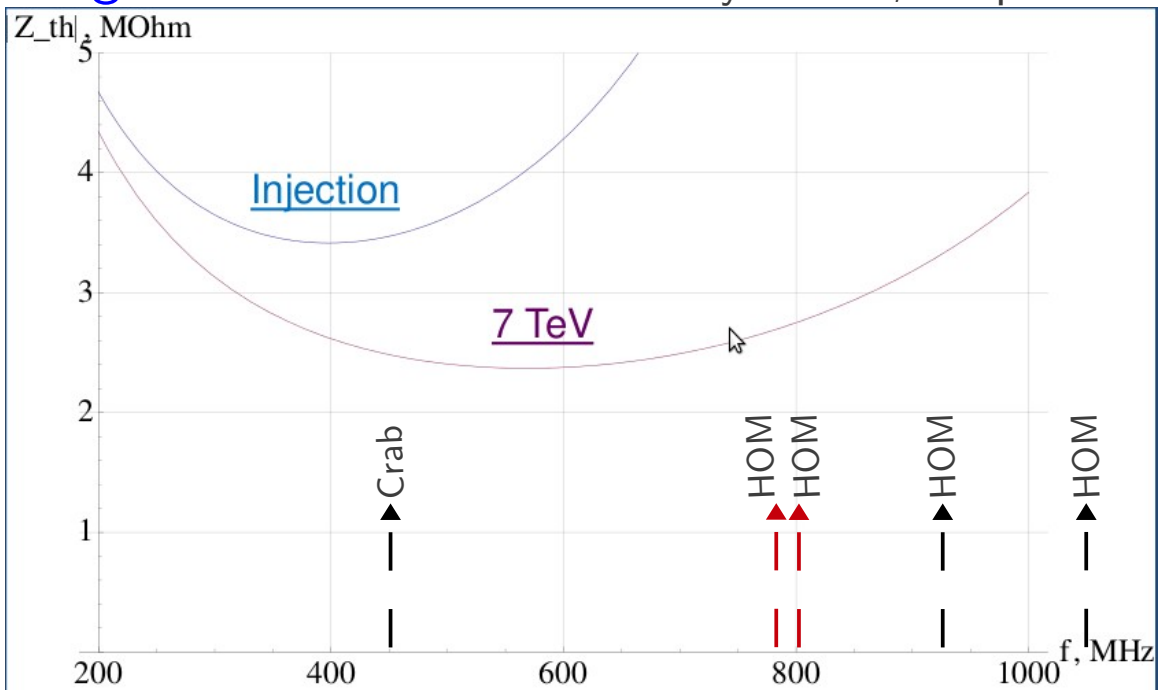
→ $\Delta Q \sim 10^{-3}$

→ $\Delta\xi \sim 10^{-3}$

Impedance Thresholds

Longitudinal

Courtesy: Burov, Shaposhnikova



Longitudinal impedance
2.4 MΩ total (7 TeV)

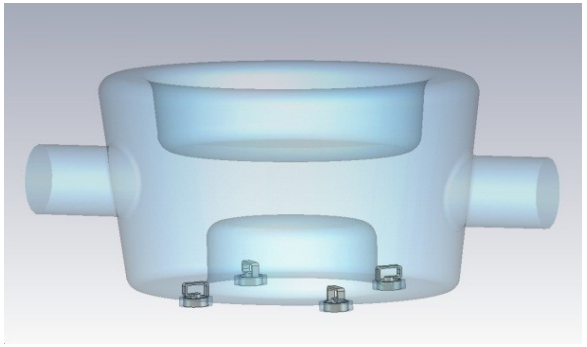
Strongest monopole mode:
R/Q=200Ω → Qe<1x10^3
Damping → Qe < 100-500

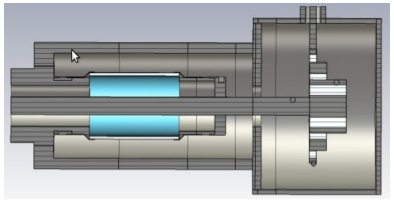
Transverse

Energy $\gamma m_p c^2$	Beta-function $\beta_{x,y}$	Impedance $-\mathrm{Re}\,Z_{th}$
450 GeV	150 m	2.7 MOhm/m
7 TeV	4 km	1.5 Mohm/m

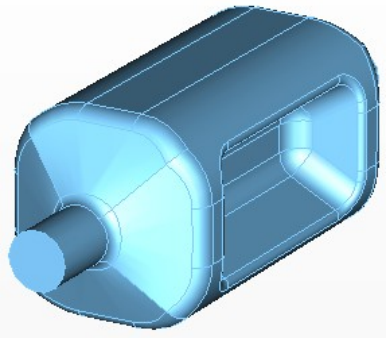
Strongest dipole mode:
Z < 0.6 MΩ/m (0.58 GHz)
(Qext = 500)

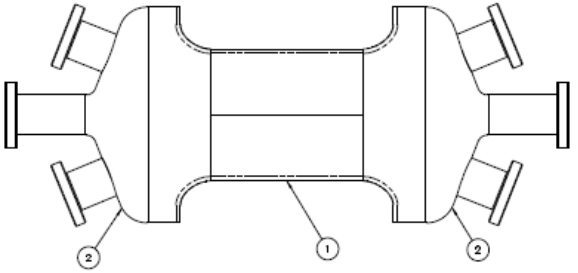
HOM Damping



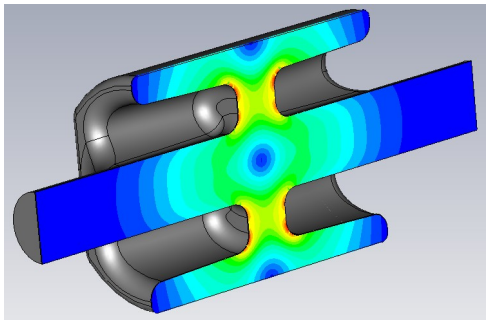


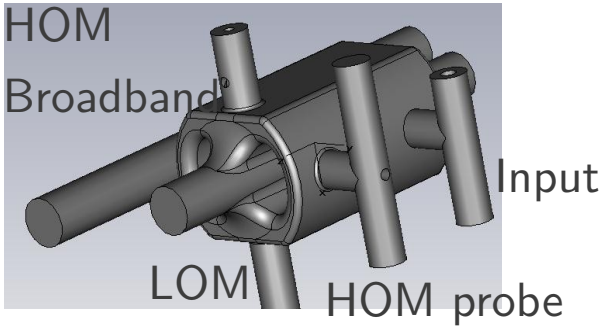
3-5 stage Chebyshev
High pass filter loops





4 Symmetric couplers
on the end caps
(notch/high-pass ?)

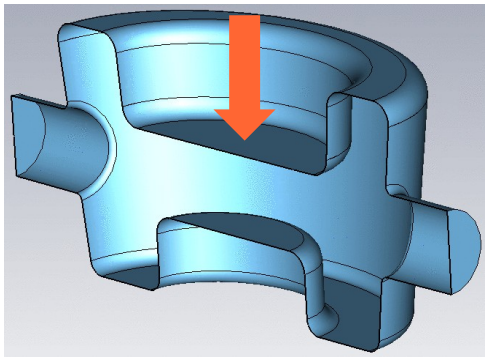




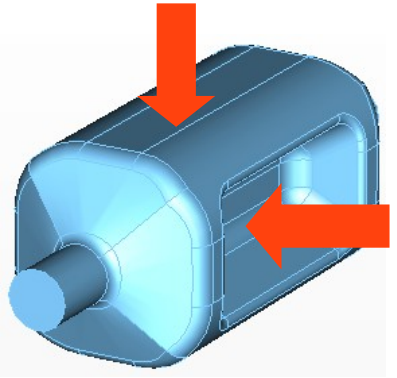
Symmetric HOM/LOM
couplers on cavity body

Cavity Tuning Thoughts

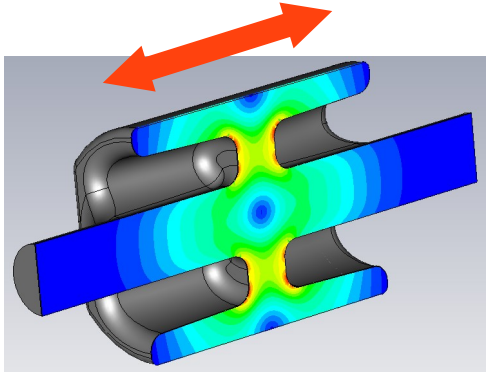
No spec yet (in operation ± 1.5kHz)



Up/down motion or change ellipticity

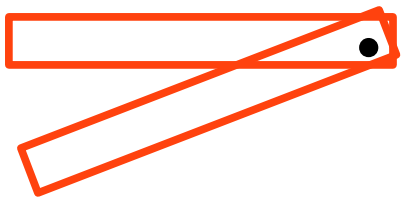


Push/pull on cavity body Inside He-vessel ?



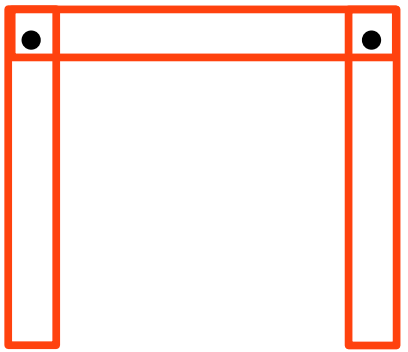
Scissor jack type mechanism

SM



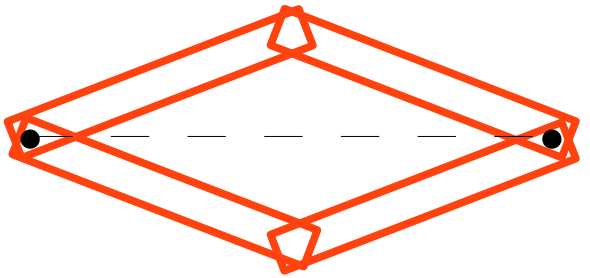
Double lever (Saclay type)

SM



Modified screw/nut (SOLEIL type)

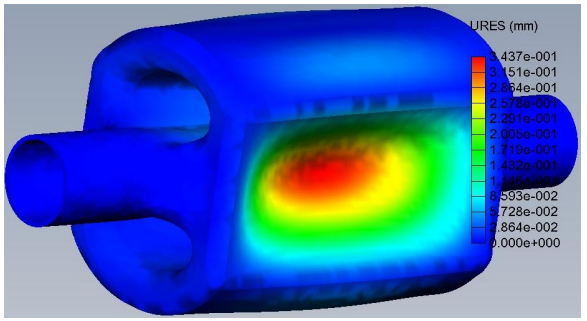
SM



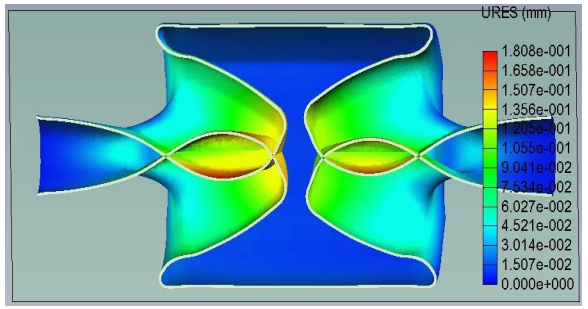
CEBAF Tuner

Cavity Sensitivity

~ 1mm displacement for 4mm thickness

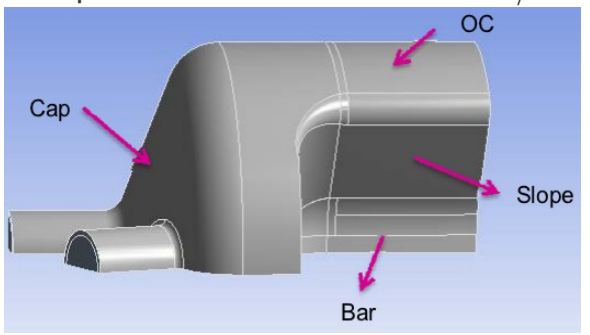


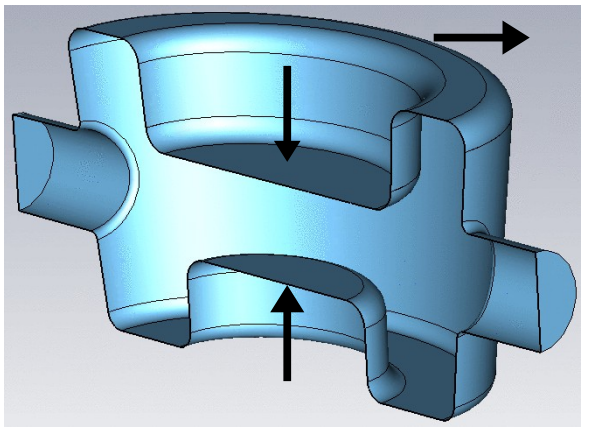
~ 0.1mm displacement for 4mm thickness



Vibrational modes are 450 Hz and above but detailed simulations underway

The ridges area needs to be constrained against pressure fluctuations ~ MHz/mm





Vibration of flat surfaces and/or change in ellipticity ~MHz/mm (constrain with stiffners)

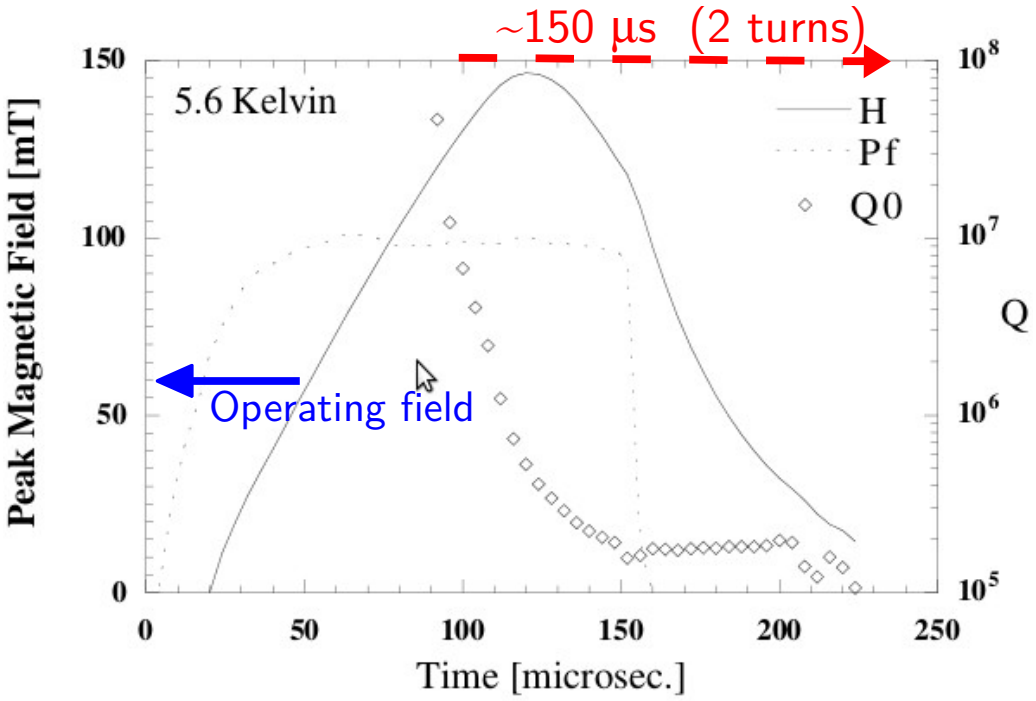
Operation is CW like, voltage is only slowly ramped up (hours)

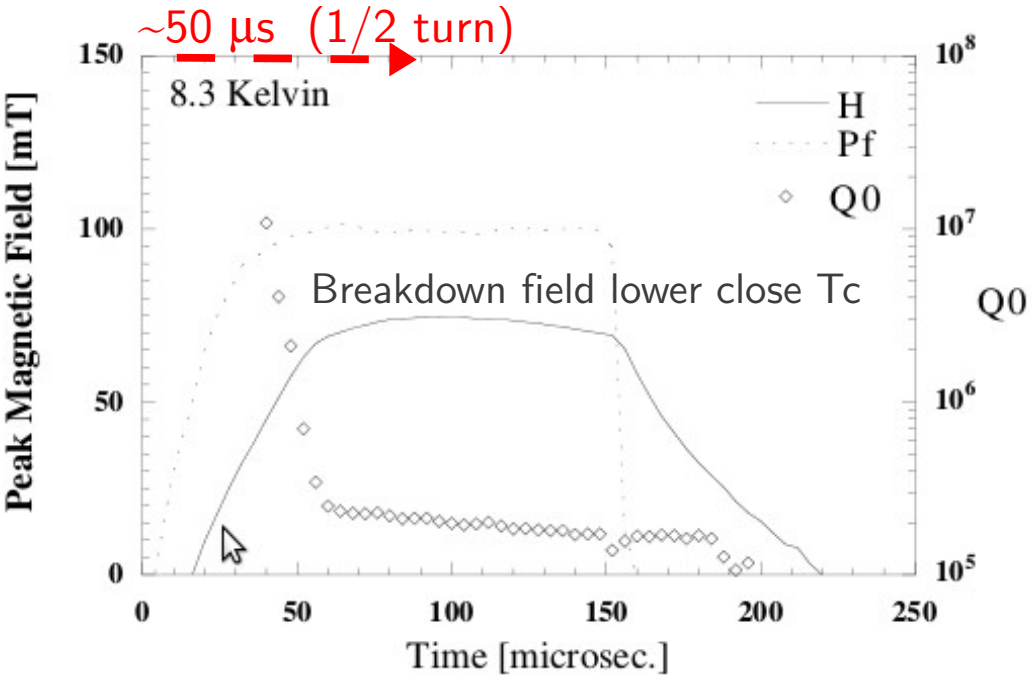
Lorentz force detuning $\rightarrow$ probably non-issue

Microphonics $\rightarrow$ Stiffners, should we consider fast tuning?

Cavity Quench

H. Padamsee et al., PAC95





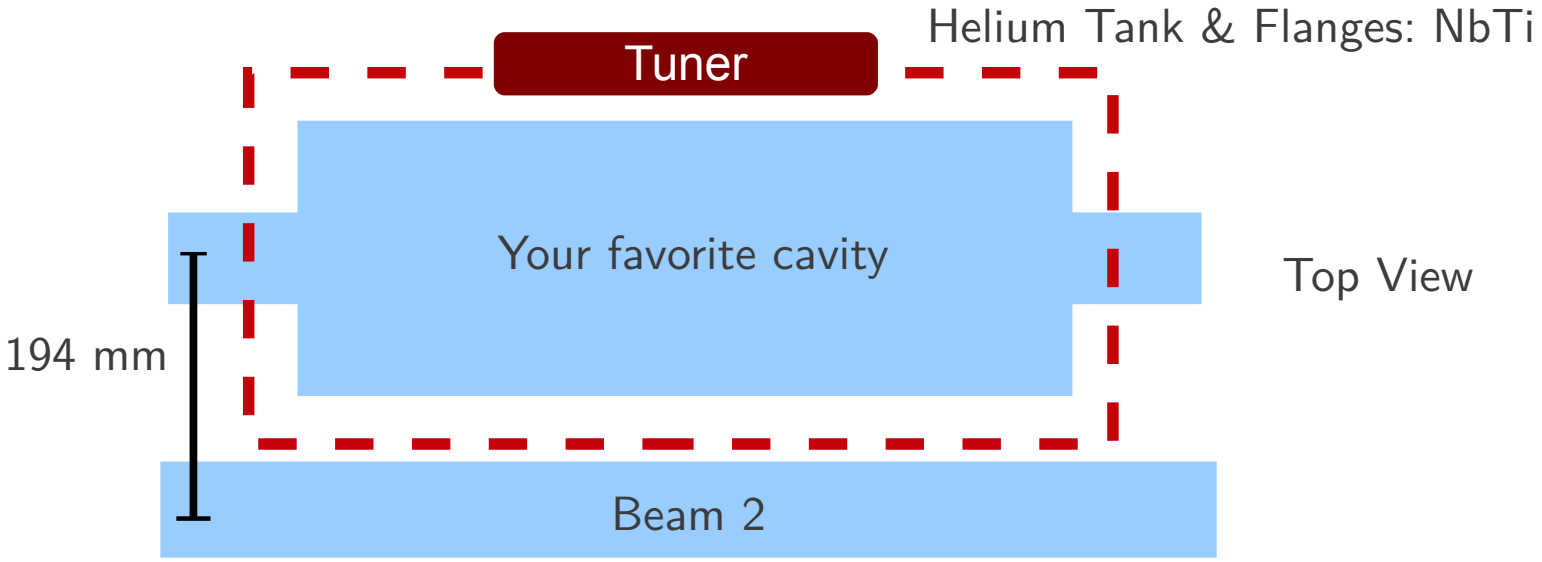
Transient cavity Q meas. from high power RF pulses → thermal breakdown

- Nominally performed during cavity processing (T_{start} 2K)
- Determine the "H_c^{RF}" limit for 2K

LARP contribution to either quench studies and/or machine protection, highly desired

- Such tests could be performed in prototypes to test robustness

He-Vessel & Tuner



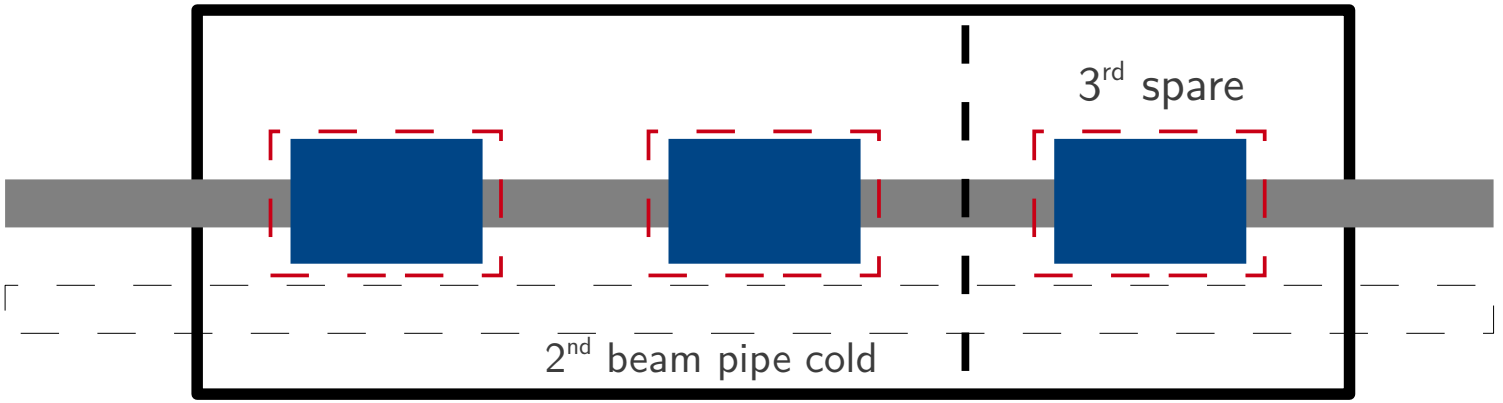
Second beam pipe inside or outside He-vessel ?

- Dynamic RF heat load ~5 watts maximum
- SPS tests → non-issue, Point 4 → 420mm spacing, Point 1/5 → 194mm

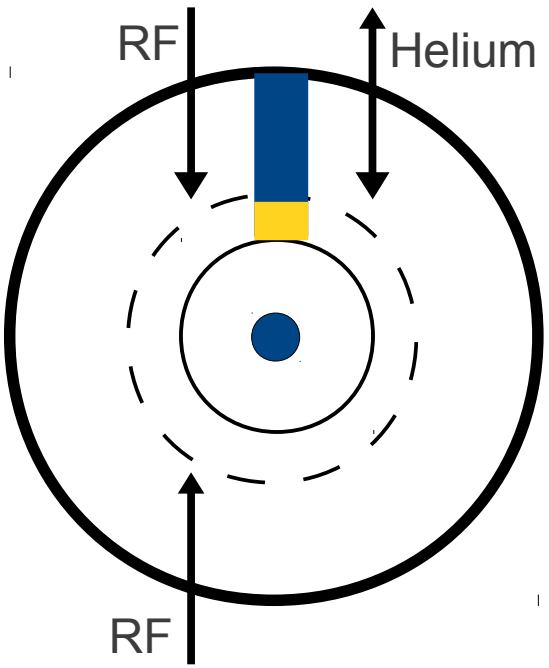
Pressure vessel code ?

- European directive exists (not Nb), categories I-IV
- Volume of helium $<$ 10 L, max pressure ~1.5 bar → category 0 (or I)

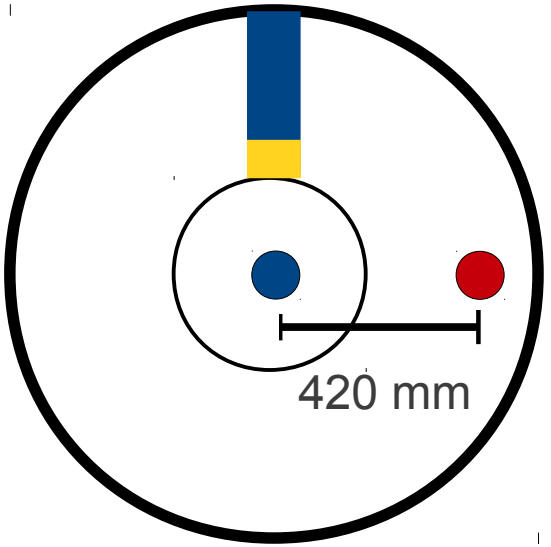
Cryomodule, BC



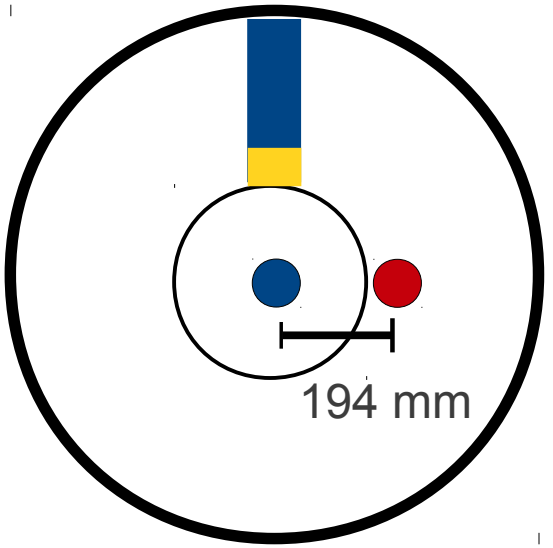
SPS Tests



Point 4 Tests



Final Scheme

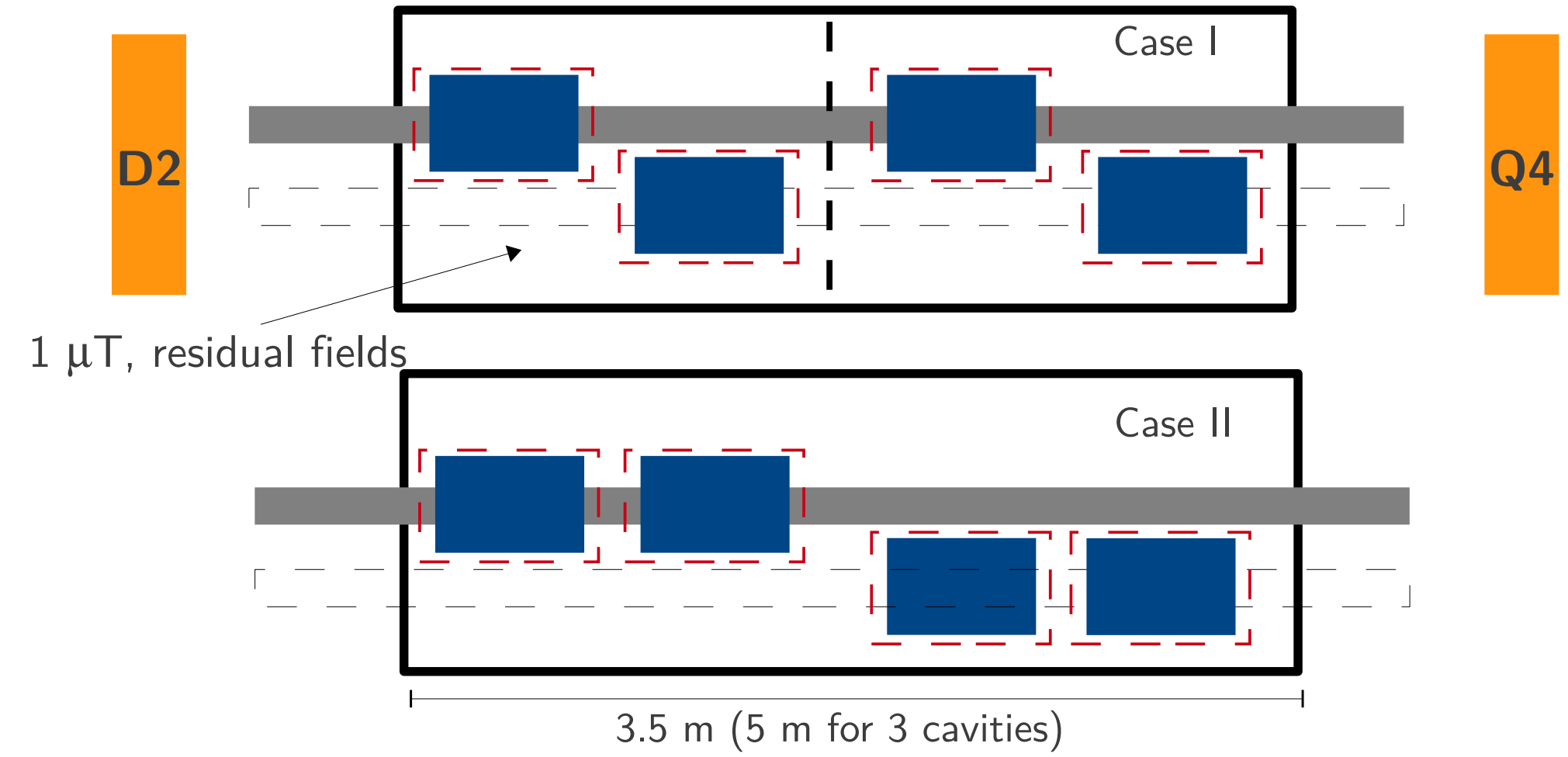


Module Layout

Case I might be preferable to equalize voltages for the two beams

Machine protection $\rightarrow$ minimize cavity quench propagation

Spare policy $\rightarrow$ nominally 8-modules for 2-IPs total + 2 spares



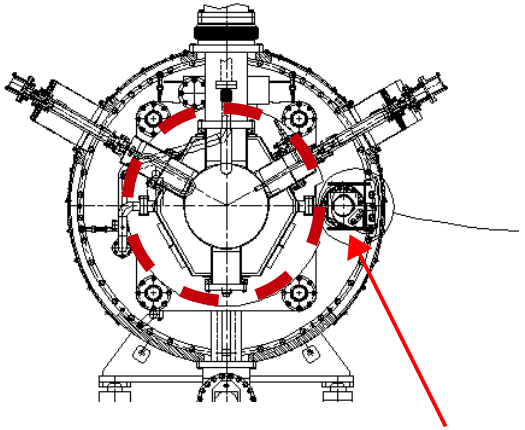
Cryomodule Development

Establish collaboration with US partners high priority

- Develop initial concepts in the next 6-8 months
- Focused meeting at the end of 2012 for conceptual review

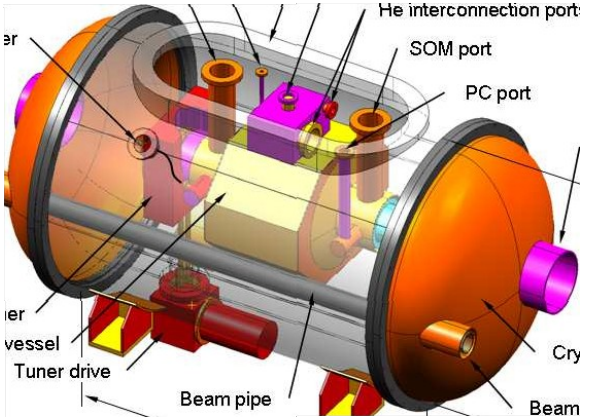
In parallel, SPS working for a complete integration study (A. Macpherson)

LHC Main RF



2^{nd} beam pipe (thermally shielded)

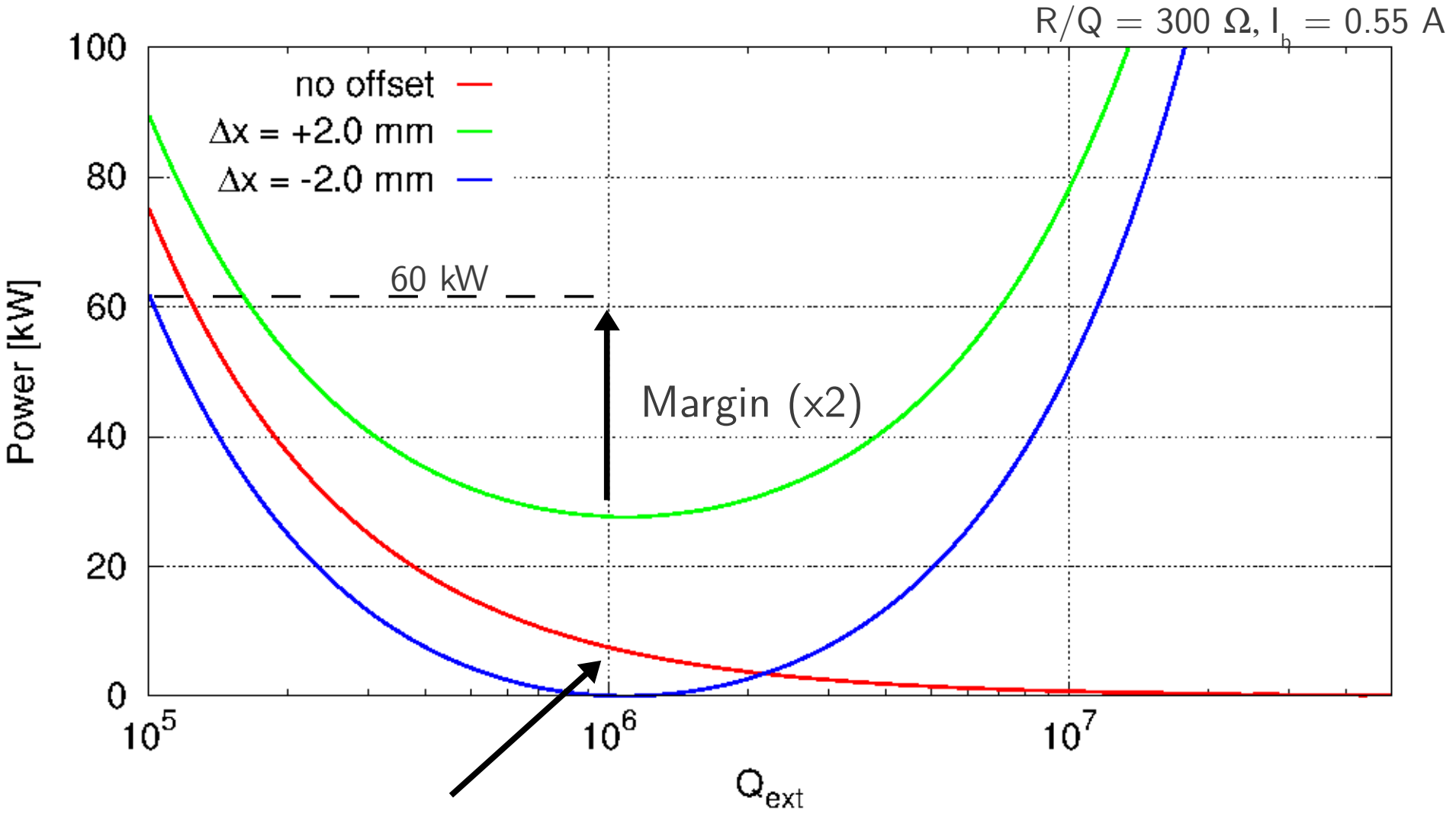
Some initial work done for P4 elliptical cavities



FNAL (Y. Yakovlev et. al)

RF Power

$$V_b \propto Q_L I_b \frac{R_T}{Q_0}(k\Delta x)$$



RF Power ~8kW (V_T=3 MV)

For Comparison,

Main RF 300kW (V=2 MV)

RF Coupler & Power

Courtesy E. Montesinos

60 kW/cavity, moderate power

- Simplified (modified) LHC coupler
- **Need** (ASAP) coupler interface to cavity
- Vacuum to air and RF source interface by CERN

RF power options

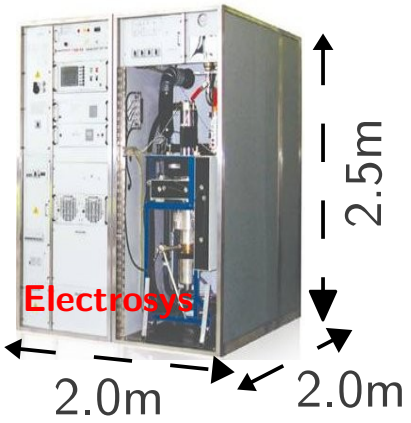
- For SPS tests, reuse Tetrodes used in SPS tests

Tetrode (SPS)

400 MHz, ~50kW

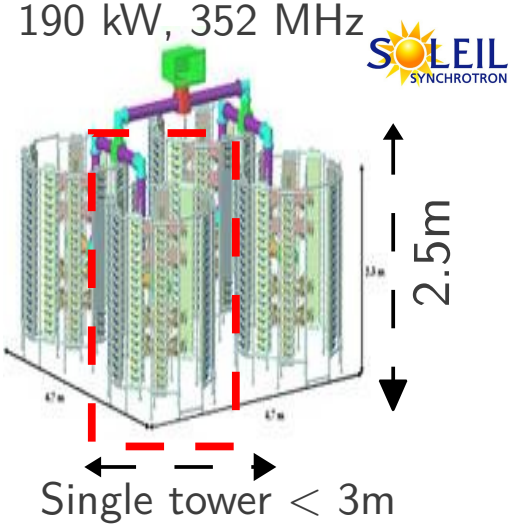
IOTs (TV Transmitter)

Light Sources



Solid State Amplifiers

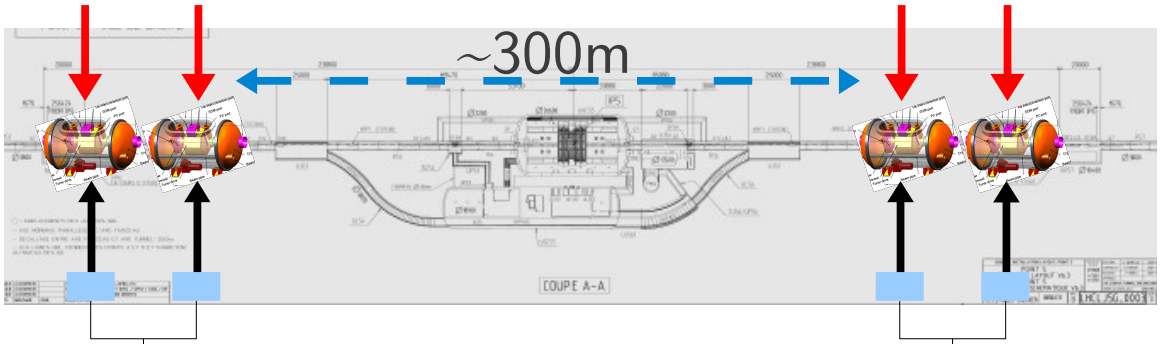
190 kW, 352 MHz



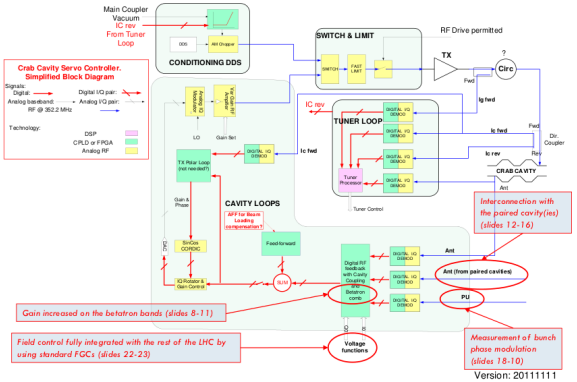
LHC RF Distribution

P. Baudrenghien (LHC-CC11)

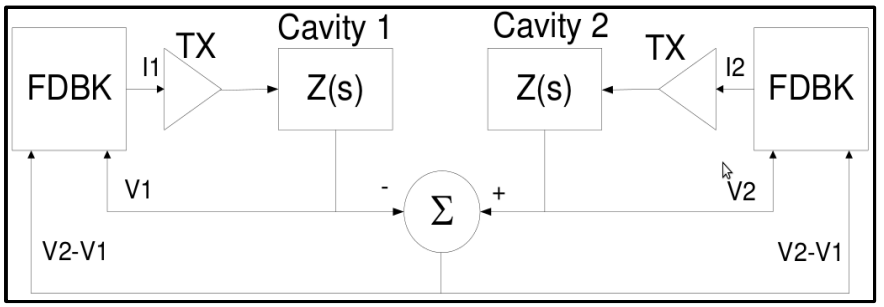
Independent high power RF (60 kW → IOTs)



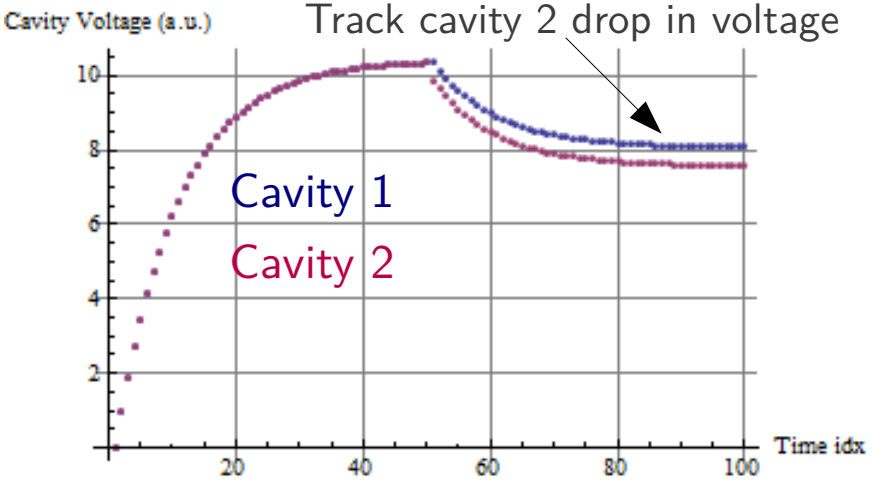
Crab cavity servo controller



LLRF (Strongly coupled feedback)



Track cavity 2 drop in voltage



Planning Overview

Final Implementation
(2022-23?)

Cavity Testing **Prototype Cryomodule** **Production**

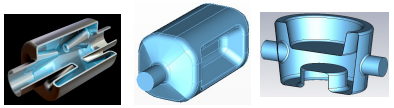
2012 2013 2014 2015 2016 2017 2018-23

LS1 *LS2* *LS3*

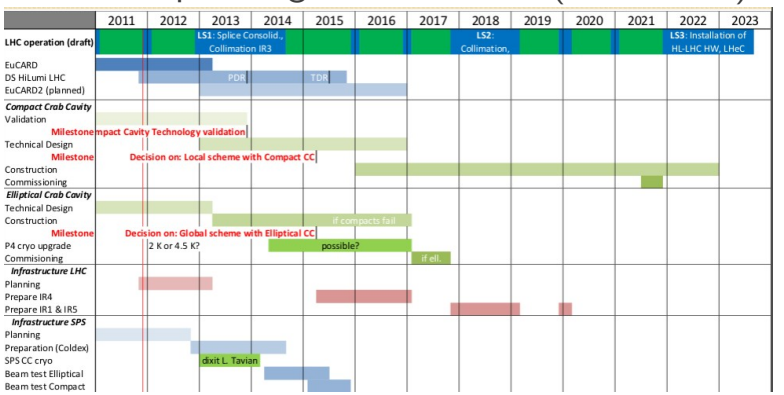
M1: Compact Validation
(mid 2013)

SM18
CM Tests

SPS
Beam Tests



Detailed planning, see E. Jensen (LHC-CC11)



Prototyping Status

- 4Rod cavity
  - Aluminum & Niobium cavities fabricated (Niowave)
  - BCP & testing (potentially at CERN)
- Pbar/Dbl ridge cavity (STTR-Phase I & II)
  - Aluminum (pbar) & Niobium cavities fabricated (Niowave)
  - BCP & testing to be done soon
- Quarter Wave Cavity
  - Call for tender to be released in May
  - Cavity expected by the end of the year (based on funding)

CERN SM18 Upgrade

Aim: Upgrade existing facility for high performance SRF

Test a variety of SRF cavities

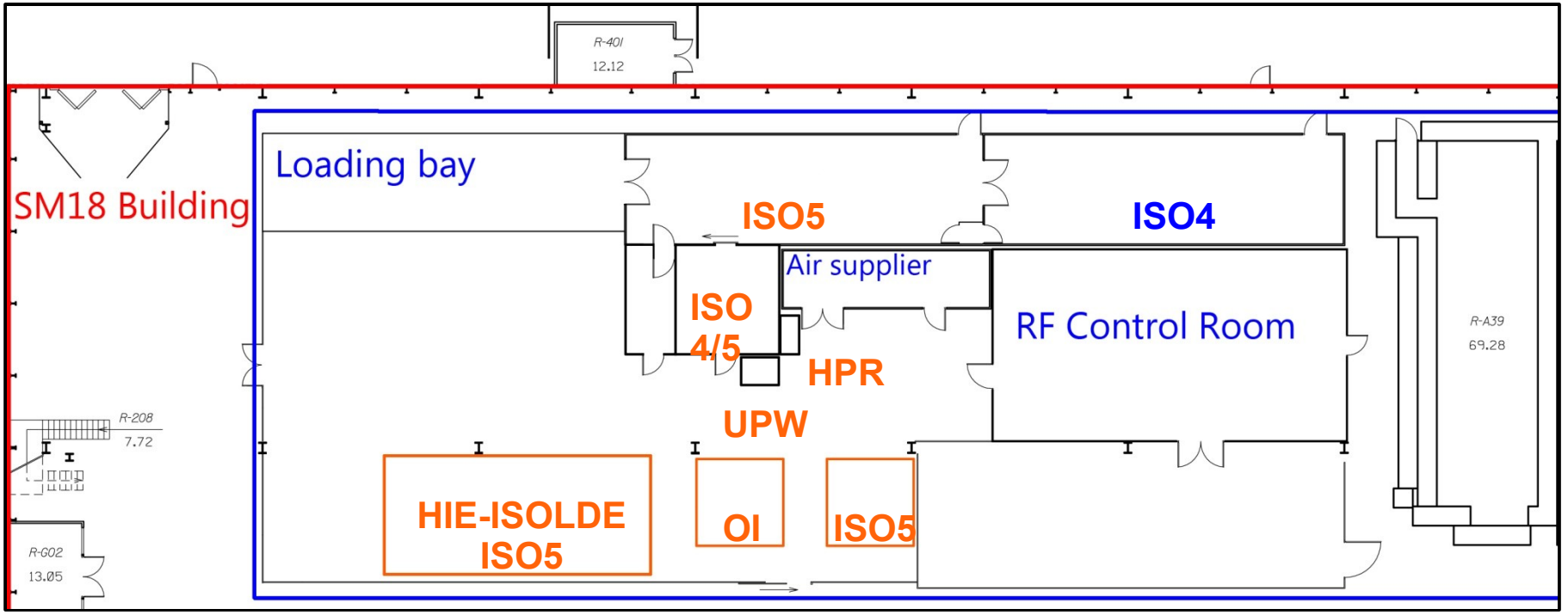
- LHC Main RF cavities (horizontal test bunker)
- SPL-ESS (single and multi-cell)
- HIE-ISOLDE sputtered cavities
- LHC Crab Cavities

As a result of recent request from Lancaster Uni, CERN will do BCP, High-T bake & test the 4Rod cavity

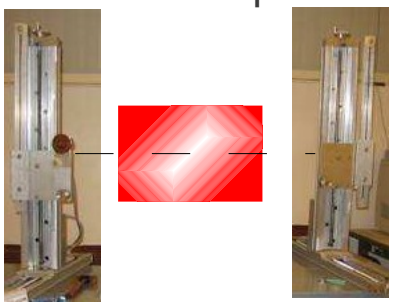
U.S. prototype cavities to come to CERN ? We hope soon.

SM18 Facility Upgrade

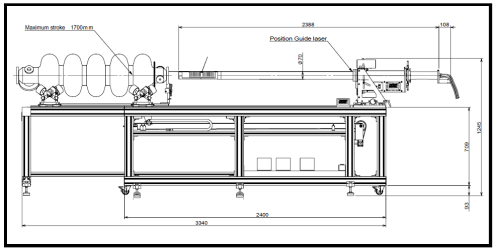
Courtesy, J. Chambrillon, K-M. Schirm



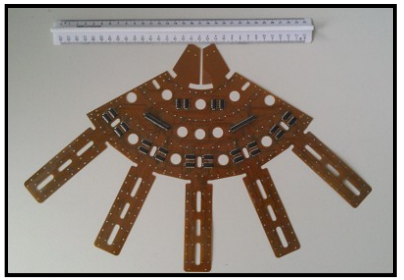
3D bead-pull



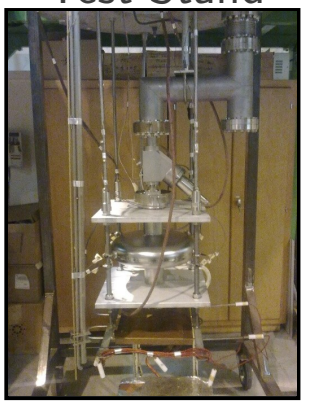
Optical Telescope



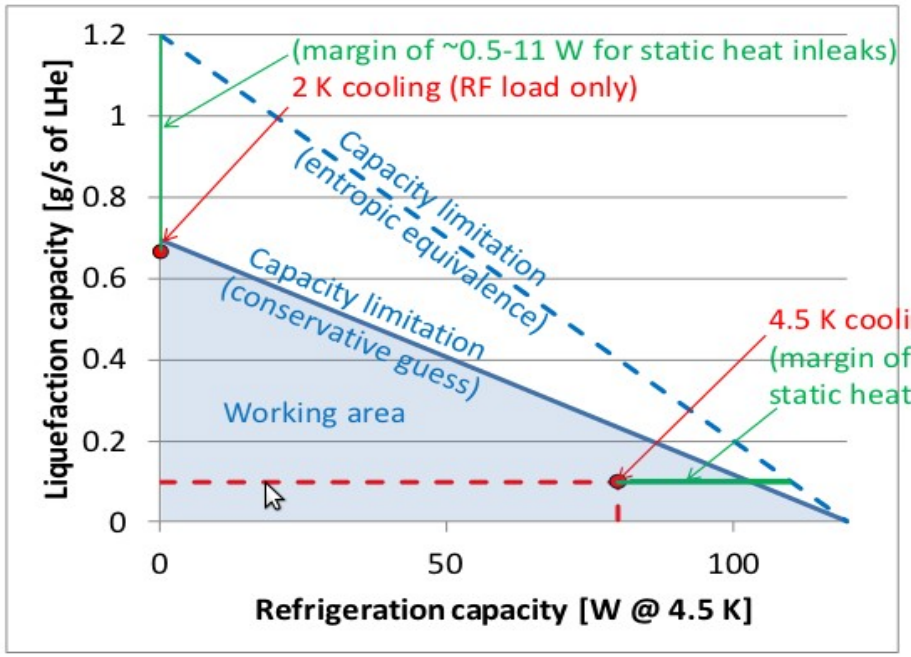
T-Mapping + 2nd Sound



Test Stand



Temp Choice → 2K Baseline



4.5 K, 300 kCHF

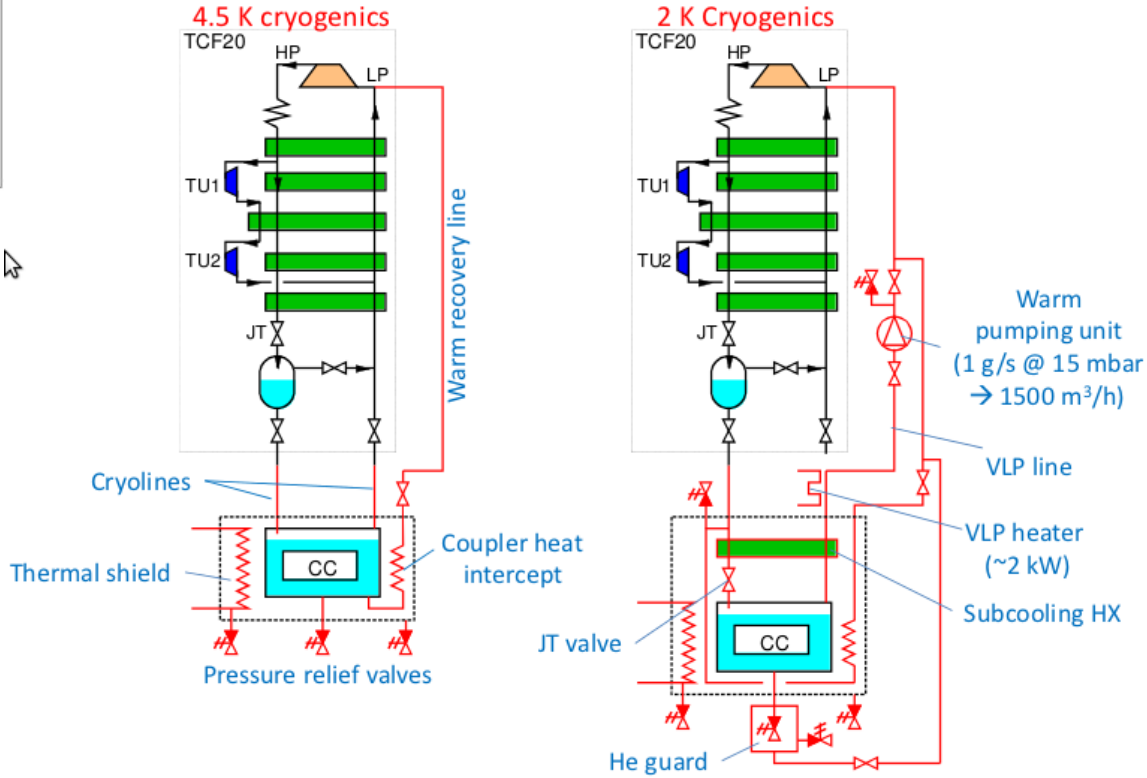
Capacity: 0.1 g/s, measured capacity 120 W.

2 K, add 150 kCHF

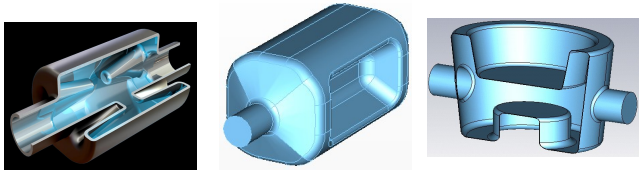
(Heat exchanger + JT valve + ..)

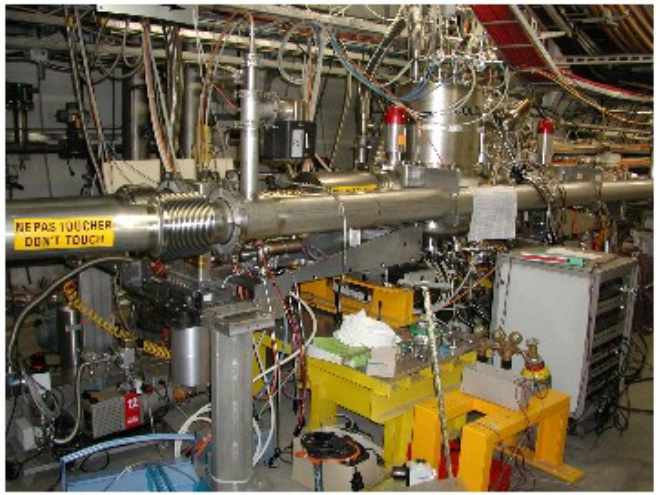
Capacity: 0.7 g/s

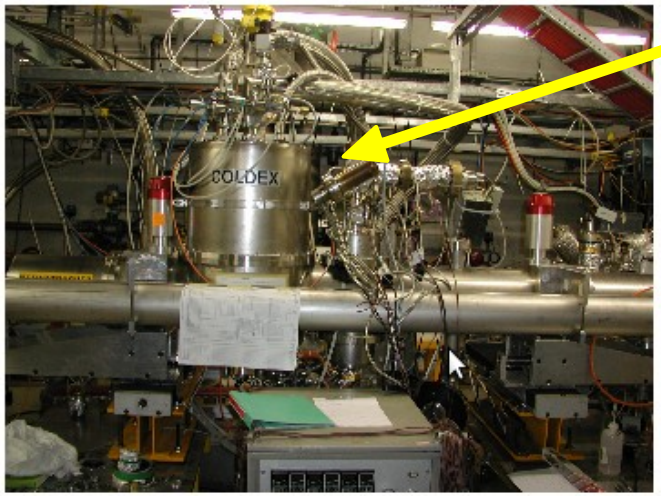
Measured capacity by the end of 2012

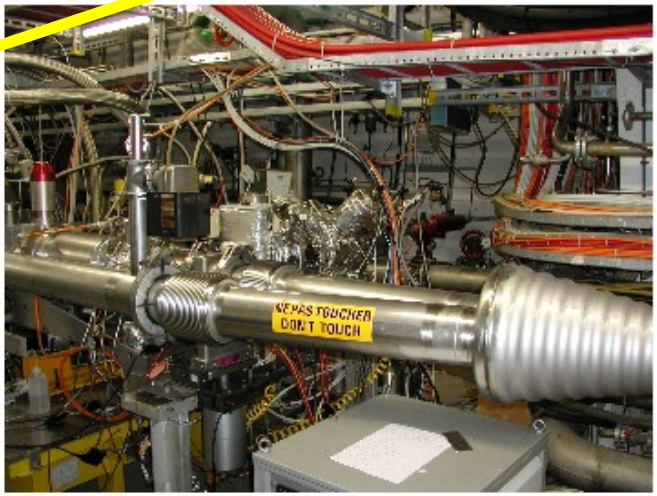


LSS4, COLDEX









Long. Position: 4009 m +/- 5m

Total length: 10.72 m

βx, βy: 30.3m, 76.8m

Tests foreseen in SPS ~2015-16

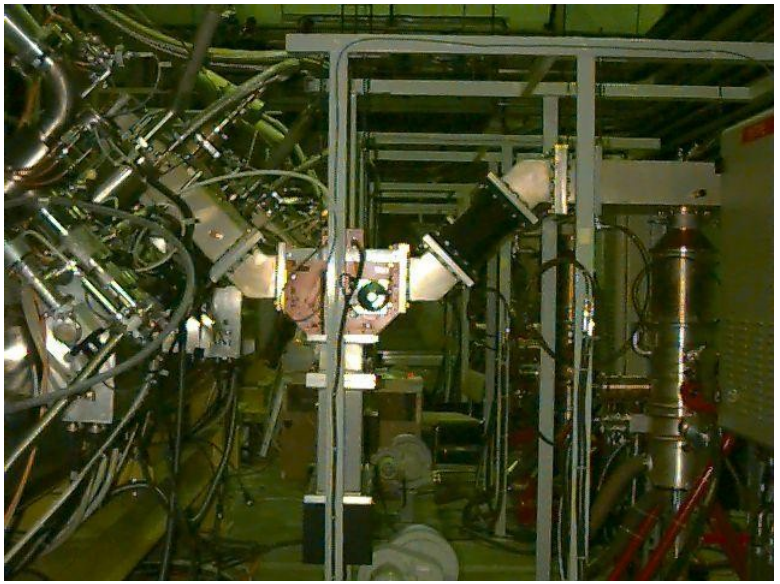
Cavity validation with beam (field, ramping, RF controls, impedance)

Collimation, machine protection, cavity transparency, RF noise, emittance growth, non-linearities,

Cryogenics, RF power and installation services (during LS1 ?)

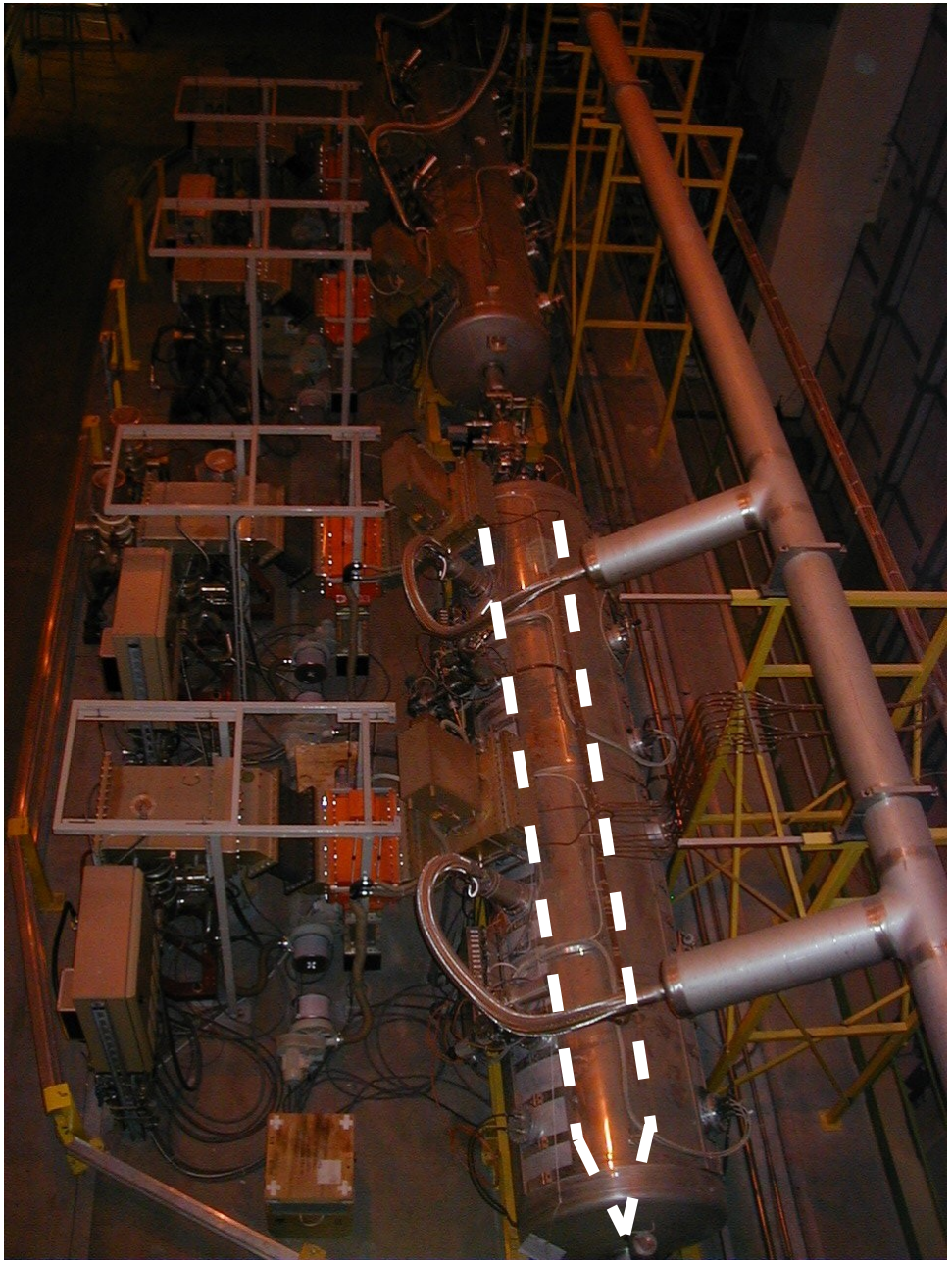
SPS, BA4 Setup

RF Power Setup (~50kW, Tetrode)



Courtesy E. Montesinos

4 LHC Cavities in SPS (1998)



Y-Chamber like, similar to present COLDEX

Conclusion

Cavities, end of 2012

- Two prototypes at hand and 3rd to come soon
- Cavity testing is the immediate focus $\rightarrow$ 1st milestone (end of year)

Cryomodule, end of 2014

- High priority to establish a joint effort NOW
- Forseen involvement from U.S. & Euorpe (Saclay, CNRS/IN2P3)
- Focused meeting at the end of year to review conceptual designs

SPS Tests, end of 2015

- CERN working group now for complete integration
- Preparation for SPS tests (already to take place in LS1)

More Parameters

Pressure sensitivity & pressure vessel code

- Cavity stiffness $<$ 20-30 kN/mm (tunability)
- Sensitivity $\sim$ 100 kHz/mm (coarse), Resolution $\sim$ 0.1 kHz
- Should we conform to higher category for safety

Mechanical alignment tolerances

- Longitudinal alignment at the level of β-beta (voltage compensation)
- Transverse alignment $<$ 100 microns (power compensation)
- Tilt alignment (residual x-angle in the other plane, few μrad)