- Least populated... 2 contributions

- Cryostat and tuner compatibility: Slava Yakovlev
  - conceptual layout of a module for Phase I, 800 MHz SLAC cavity
- Mechanical & thermal issues: PP
  - generic consideration on module design

- Conceptual design advanced with respect to material presented at previous meetings
  - but for a single cavity design
    - which is still “moving” and “conceptual”, far from fabrication stage
    - still couplers/tuners are not defined, substantial work needed
  - still far from being complete
  - definition of all ancillaries (couplers, tuner, ...) needed to finalize important details for module design (supporting, thermal mgt.)

Outcome of many discussion during workshop

- What is the timeline for the 800 MHz module to be ready for LHC?
  - if it happens at all...

- This changes a lot the perspective of our comments, depending on the time for developing a complete design and engineering for the crab cavity module
  - main points raised by Slava and me concern technical details towards the module engineering effort to meet the Phase I schedule

- No fundamental objections or showstoppers concerning the module feasibility, but surely there is still a lot of detailed engineering to do, which will take years from its start

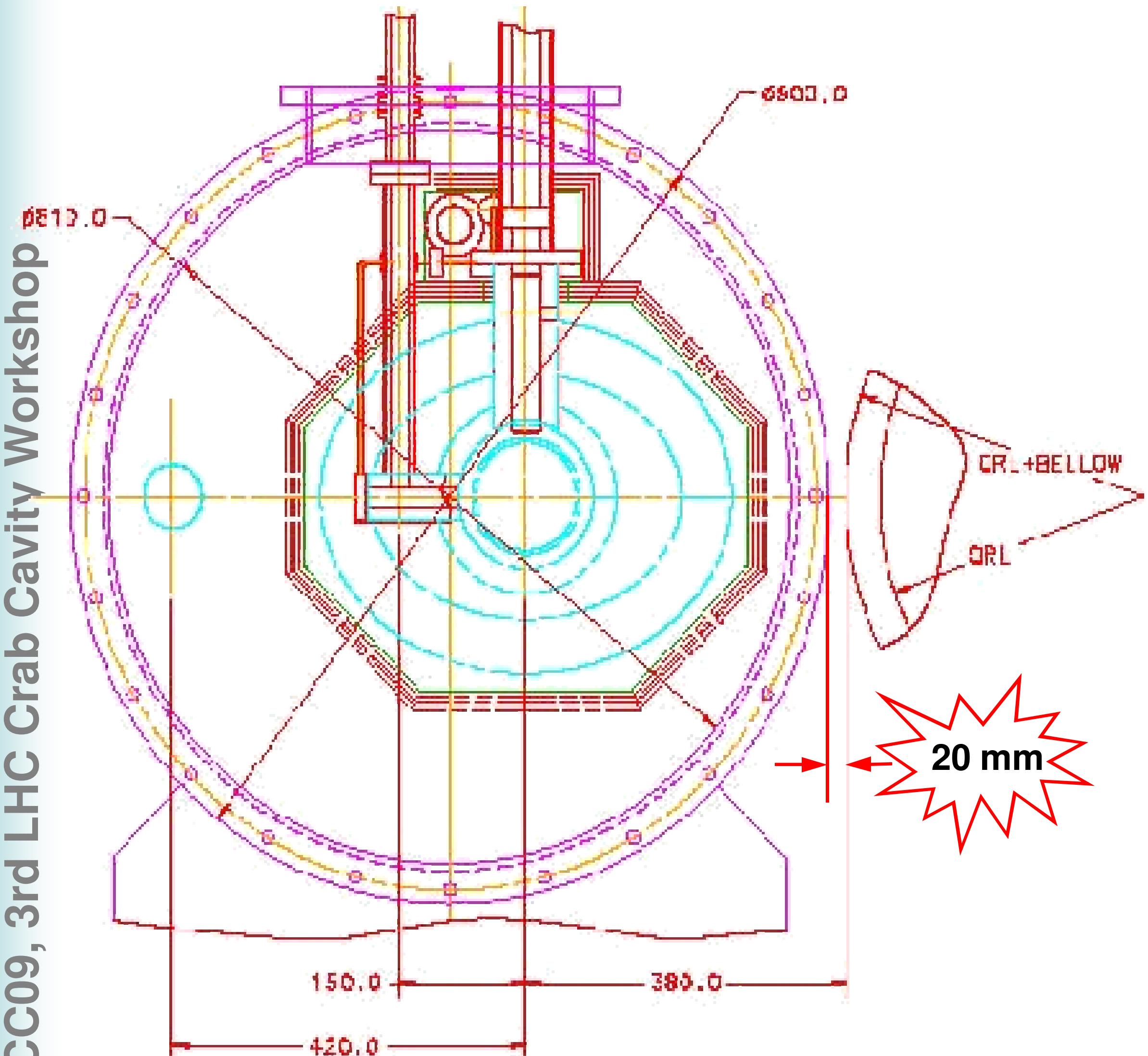
Abstract

- The complex LHC crab cavity design and the beam-line configuration pose very tight constraints for the cryostat design.
- An initial assessment of the LHC main RF cryostat points to a new design both from the RF and engineering point of view.
- The cavity and tunnel constraints are discussed in detail and an initial cryostat design along with the cryogenic circuit is presented.

Initial FNAL design

Left of IR4, ADT (View from the Door)

strong geometrical constraints

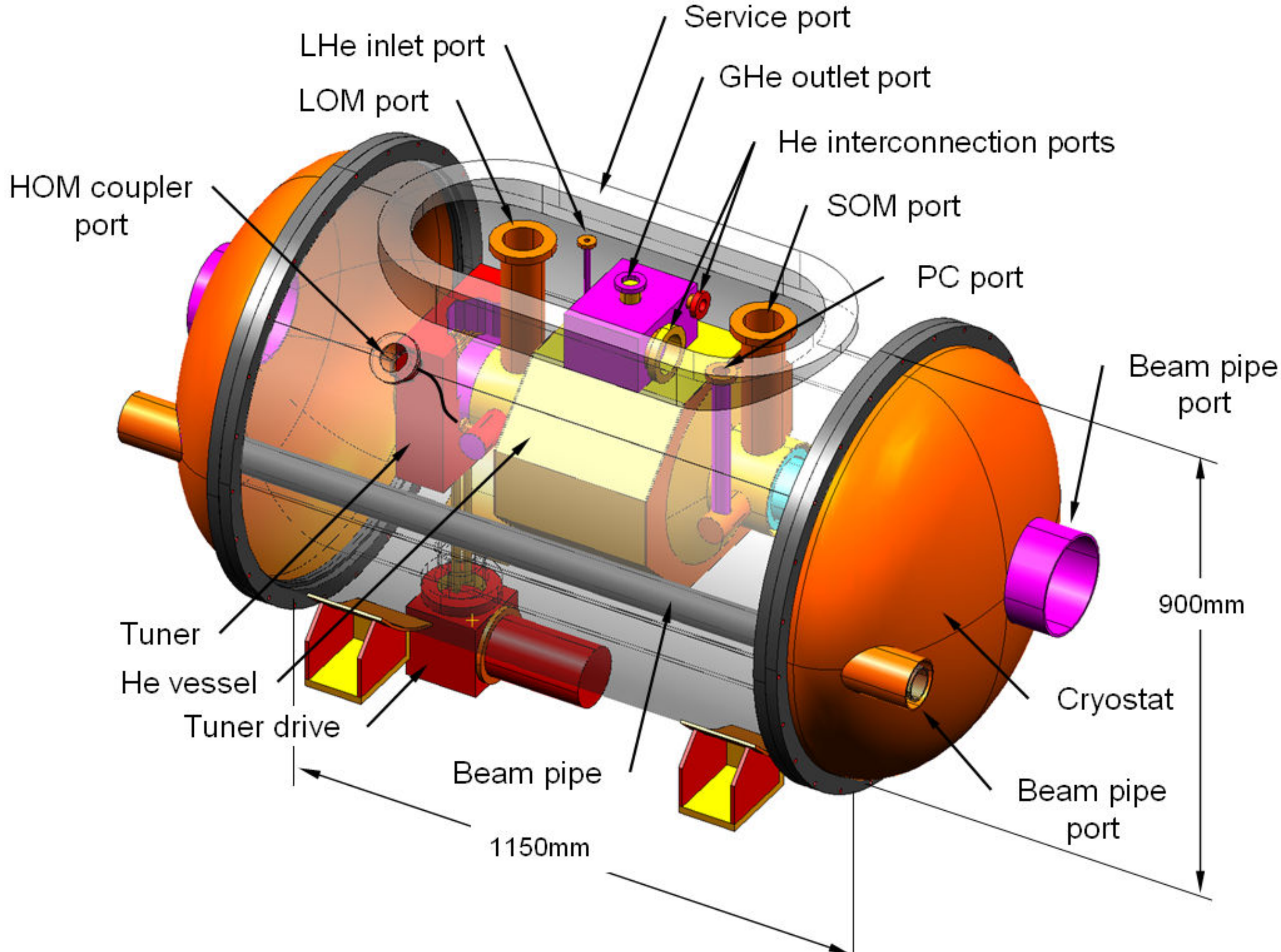


- Diameter of CM is ~ 900mm
- Very limited space between Helium vessel and cryostat wall (QRL position vs. beam)
- No way for horizontal main coupler output (limits from both sides).
- Design of the main coupler with vertical output is required. Horizontal part of the coupler is limited (< 15cm)
- LOM and SOM couplers are already in vertical plane, HOM coupler is connected by cable
- Cavity position in the cryostat is asymmetric. It will probably complicate alignment, which is more severe than for accelerating cavity

conceptual design advanced since last year meeting

- During the first test, a two cell cavity for each beam is anticipated to provide a transverse kick of 2.5 MV.
- The cryostat design must satisfy the environment limitations for the both beam-lines.

- The cryostat should have a modular structure similar to cavities of the LHC main RF system. This allows for additional cavities to be installed if a higher kick voltage is deemed necessary.
- Thus, the helium box contains interconnection ports for the second cavity.
- A service port is suggested for the He inlet/outlet ports as well as for the RF couplers (main, LOM and SOM).

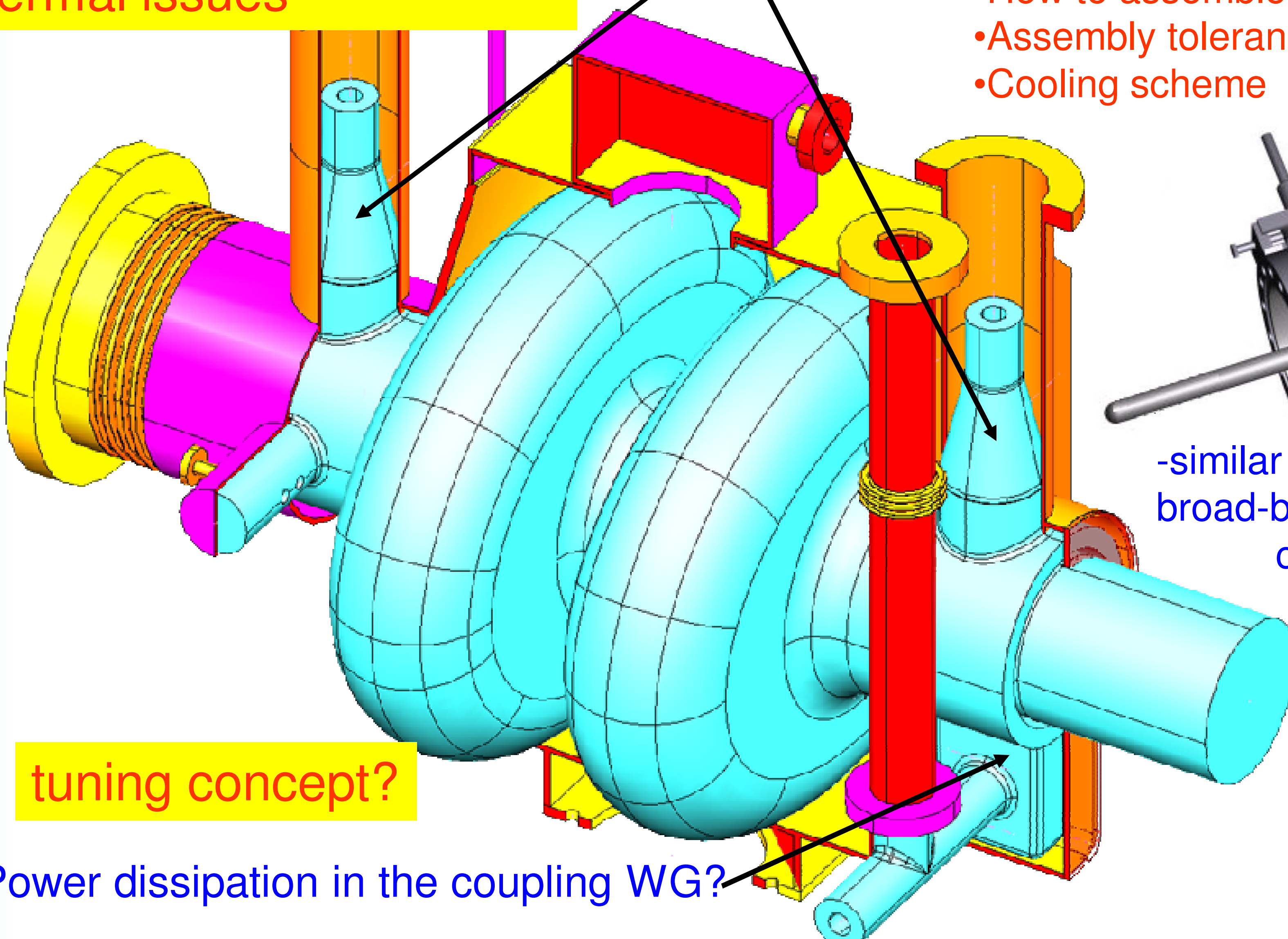


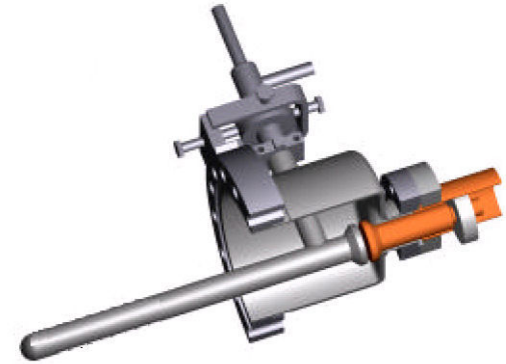
Schematic of the LHC Crab Cavity cryostat. The outer diameter (900 mm) is constrained by the limited space between Helium vessel and cryogenic line. The length is 1150mm.

concerns for the multiple couplers: mechanical and thermal issues

Realistic concept of the all the couplers is required for the complete cryostat design that includes:

- •How to assemble
- •Assembly tolerances
- •Cooling scheme





-similar to CERN broad-band HOM coupler.

tuning concept?

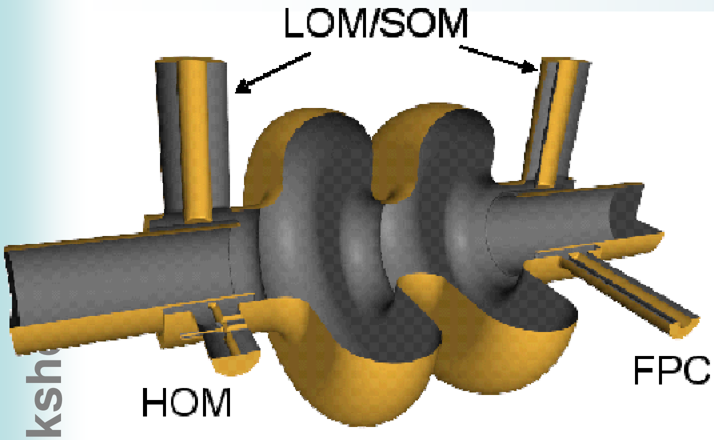
Power dissipation in the coupling WG?

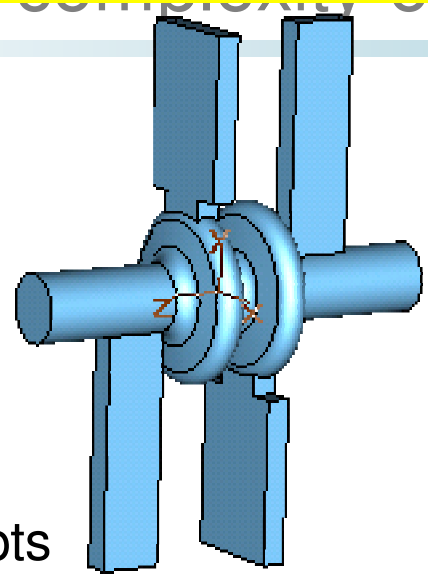
Summary:

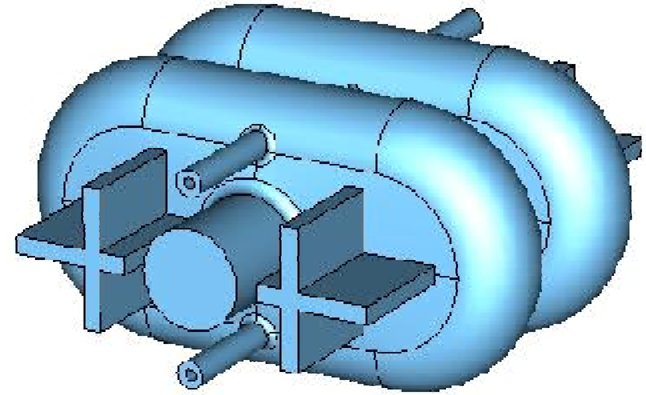
- The work on the cryostat mechanical design is started;
- The details of the cryostat position and distances to the critical elements of the environment are to be clarified;
- Working closely with RF designers to finalize the cavity and coupler dimensions to advance the cryostat design to the next phase :
  - Specification (cooling, tuning, forces, etc…) and mechanical/alignment tolerances;
  - Mechanical design of the cavity including Helium vessel;
  - Real EM and mechanical design of the couplers (FPC, LOM, SOM. HOM) - cooling, supports, assembly.

lot of detailed engineering to perform

same concern expressed by Slava concerning complexity







- Non trivial He Vessel concepts
- Multiple penetrations to the cavity from the outer world
  - in order to prevent large heat flows at operating temperature one or more thermal intercepts need to be devised
  - spurious mode power should be carried outside of module with minimal losses
- Usually cavities are kept mechanically constrained at main coupler, to minimize stresses/deformation
  - issue of differential thermal contraction, and its control
  - when all radial penetrations see the thermal gradient from R.T. to operating condition, what are the stresses? Can the cavity preserve alignment and relative tolerance of all components (e.g. antennas...)?

full analysis missing

mass flow calculations

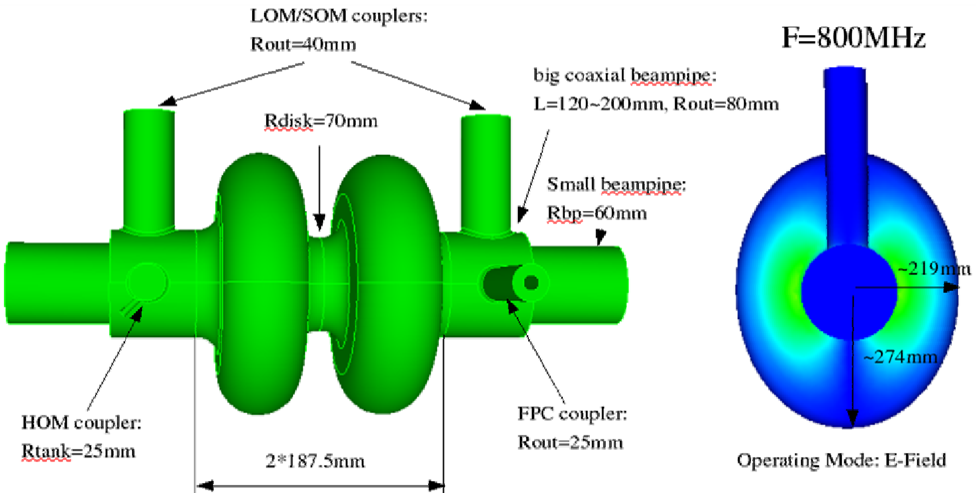
Cryogenic table "à la TP"

		50 K to 75 K	5 K to 20 K	2 K
		Temperature level	**Temperature level**	**Temperature level**
Temp in	**(K)**	50.00	5.0	2.2
Press in	**(bar)**	19.0	3.0	3.0
Enthalpy in	**(J/g)**	277.0	14.6	5.024
Entropy in	**(J/gK)**	16.1	4.2	1.618
Temp out	**(K)**	75.00	20.0	2.0
Press out	**(bar)**	19.0	1.3	saturated vapor
Enthalpy out	**(J/g)**	409.2	118.4	25.04
Entropy out	**(J/gK)**	18.3	17.0	12.58
Enthalpy difference	**J/g**	**132.2**	**103.9**	**20.0**
Predicted module static heat load	**(W)**	?	?	?
Predicted module dynamic heat load	**(W)**	?	?	?
Non-module heat load	**(W)**	?	?	?
Total predicted heat load	**(W)**	Sum of all above	Sum of all above	Sum of all above
Total predicted mass flow	**(g/s)**	Convert via ΔH	Convert via ΔH	Convert via ΔH

Comment: SRF cryomodules have large dynamic (RF on/off) loads also on the higher temperature circuits.

choice of operating temperature

- There is more than RF losses on the operating mode...
- 2 K operation requires more attention to all conduction paths to the bath
  - Crab Cavities are more complex than usual (LOM, SOM and HOM couplers lead to heat inleak to cavity)
    - Thermalization at 4.5 K level close to vessel is mandatory
    - The use of the evaporated gas from the bath for the thermalization, possible in 4.5 K operation (e.g. KEKB), seems difficult for 2 K (Pressure drop, cooling with low pressure vapor at low flows)



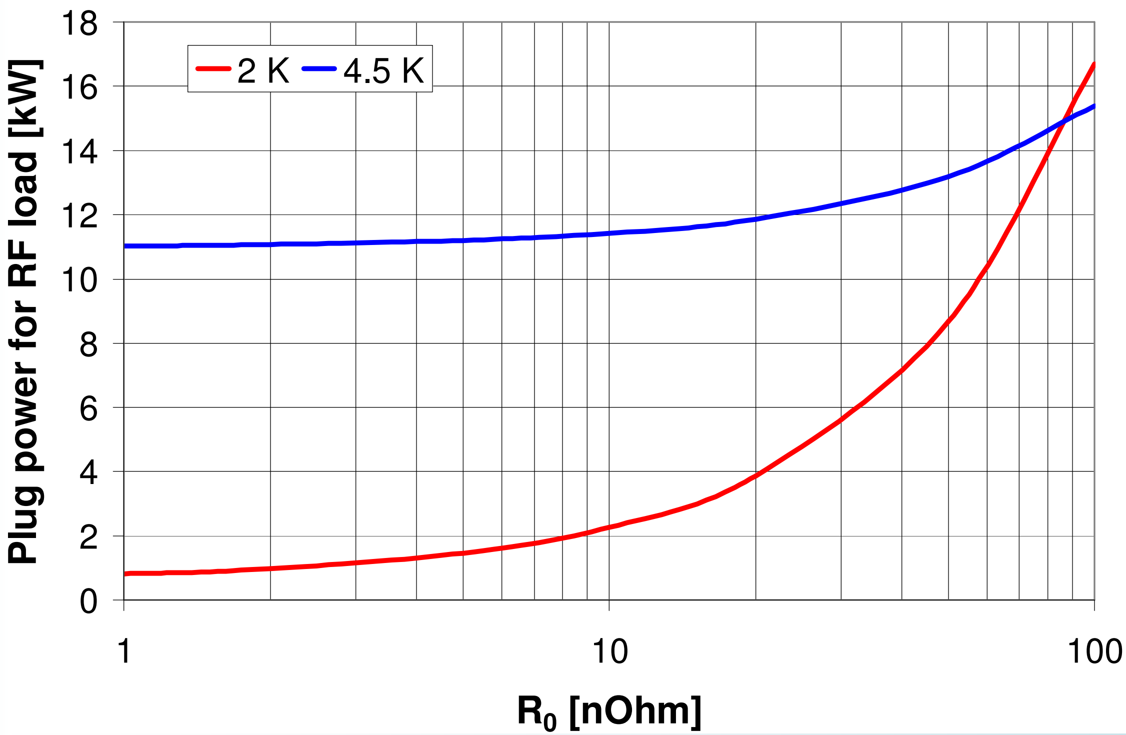
- Vessel Jacketing
- Magnetic shield
- Fixed point for alignment
- Static/Dynamic load estimations of all couplers

Easy to spoil 2 K advantage at 800 MHz if technological processes are not properly tuned to the geometrical complexity

- Roughly speaking, considering efficiency of cycle
  - 800 W/W at 2 K (20% Carnot)
  - 220 W/W at 4.5 K (30% Carnot)

State of the art SRF technology is needed for 2 K

- From an efficiency point of view at 800 MHz a bad surface can rapidly spoil any advantage of 2 K



- Unshielded earth field R_{mag}~80nOhm
  - seems substantial even at 4.5 K, need shield?
- This only for main RF load, balance need to take into account full heat load budget

i.e. metal cutting on cryogenic lines

2 K: Needed circuits

- 2 K operation via QRL Line C, through J-T valve + counterflow heat exchanger
  - return gas to low pressure line B
  - relief for overpressure condition? Possibly not to 20 K return line, to avoid risk of pressurizing He Vessels (cavity plastic detuning)
- Thermal sinking at 5 K for all couplers
  - additional cooling circuit from Line C: 5 K, 3 bar line B, returning to the Line-D (20 K, 1.3 bar), as suggested by TP?
    - “one could take a very low flow rate for a thermal intercept and allow warming up to 20 K”
- Thermal shield using the 50-75 K circuit of line E-F
  - possibly providing a second sinking for couplers
- Need to provide a **cooldown-warmup line** with controlled temperature decrease to limit thermal gradients in structure (keep aligned and safe...)

KEKB experience

Long development...

History of KEKB Crab Cavity

0)	1/3 scale model 1.5 GHz		1994	10 years
	3 Nb Cavities			
	Fabrication & surface treatment of non-axial symmetric cavity			
1)	Full Scale Prototype Crab Cavity	500MHz	1996	
	2 Nb Cavities # 1 & # 2			
	Coaxial Coupler			
	Prototype Horizontal Cryostat		2003	
2)	KEKB Crab Cavity	509MHz		
	Installation of 2 crab cavities in KEKB was decided		2004	3 years
	2 Nb Cavities for LER, HER			
	Cold Tested in Vertical Cryostat		2005	
	Assembling and High power test		2006	
	Installation and Commissioning		2007	1 year
			Jan. ~	

From EPAC08 KEK Cavity Talk

Test infrastructures will be needed at CERN

Testing prior to installation

- CC should not hit performance or availability
- R&D phase needed
- Also, extensive testing of critical components beforehand
  - Warm
    - Tuner characterization
    - Coupler conditioning
  - Cold
    - Integrity of inner circuits (leaks at 2 K...)
    - Cooldown monitoring and reproducibility
    - Integral heat loss tests
    - thermal cycling: alignment reproducibility, leak development, ...
  - cfr. KEK experience

less concern if Phase I in LHC is postponed

Conclusions

- Substantial more work needed towards the module
  - especially in setting specifications
- Develop a heat load budget table to verify the integration with LHC cryogenics
  - are dynamic/static conditions an issue (when RF is on/off)?
- Cryostat will be complex in structural and thermal managment due to the many coupler penetrations
- Analysis for static and transient conditions (cooldown/warmup) will be needed to assess the design
- Module test stand definitely needed