LHC CC10

Summary of Sessions on Cavity Technology and Cryomodule and Integration

E. Ciapala

Cavity Technology and Cryomodule Sessions

- ICFA Deflecting Cavity Workshop (Alireza Nassiri)

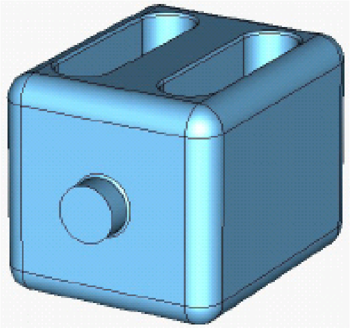
- EuCARD Cavity Developments (Graeme Burt)
- LARP Cavity Developments (Zenghai Li)
- ODU/JLAB Cavity Developments (Jean Delayen)
- KEK Cavity Developments (Kenji Hosoyama)
- Quarter wave resonator as a Crab Cavity (Ilan Ben-ZVI)
- Slim Elliptical Cavity (Luca Ficcadenti)

- Coupler Concepts for Compact Cavities (Wolfgang Weingarten)
- Thermal & Mechanical analysis for CCs (Vittorio Parma)
- Tuner Concepts for Crab Cavities (Alireza Nassiri)

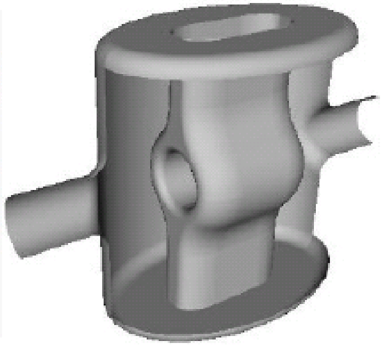
= > Progress on moving towards realizing CCs, ancilliaries and their cryostat.

Proposed Strategy for Crab Cavities CC09

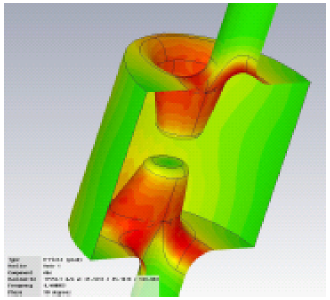
HWDR, JLAB,OD



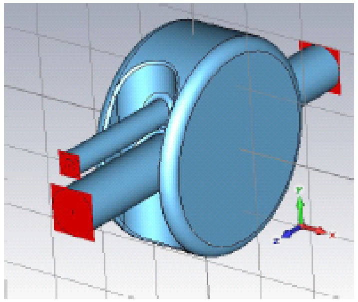
HWSR, SLAC-LARP



DR, UK, TechX



Kota, KEK



Compact cavities aiming at small footprint & 400 MHz, ~5 MV/cavity

Main Goal : Compact Crab Cavities for LHC Local Scheme

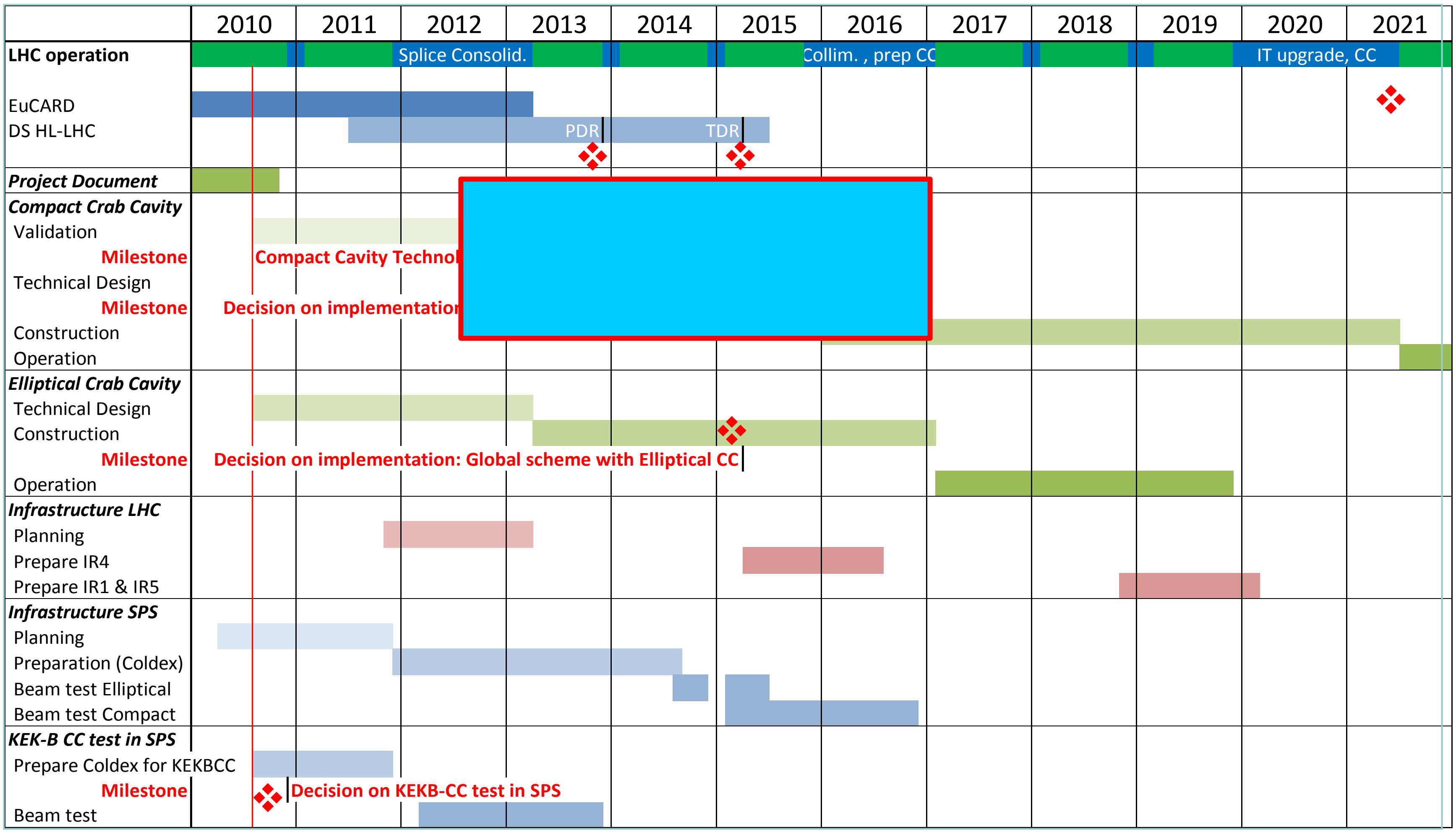
CC09 workshop recommendation:

! Future R&D focus should be on compact cavities which are suitable for both schemes.

- Complete conceptual designs of the main candidates
- Down-select to at least two designs, with full spec. and mechanical drawings of the cavities. Conceptual designs for tuner and He tank, the SOM,HOM and LOM coupler and the cryostat
- Hardware prototyping and test on above, tooling, construction of prototype bare cavities prototypes, surface treatments and tests to confirm gradient and performance

Crab Cavities for HL-LHC – Tentative Plan

Overall schedule of the crab cavity project synchronized with the expected LHC operation schedule and the HL-LHC project proposal.

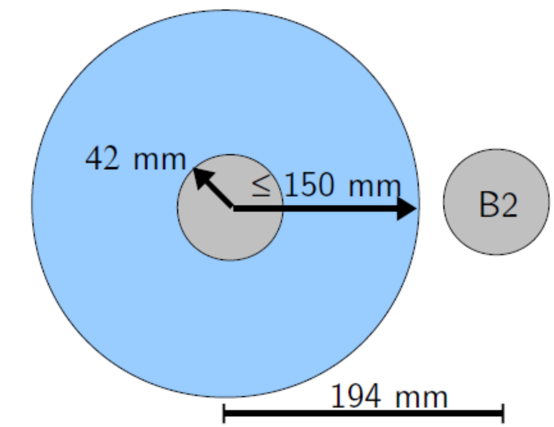


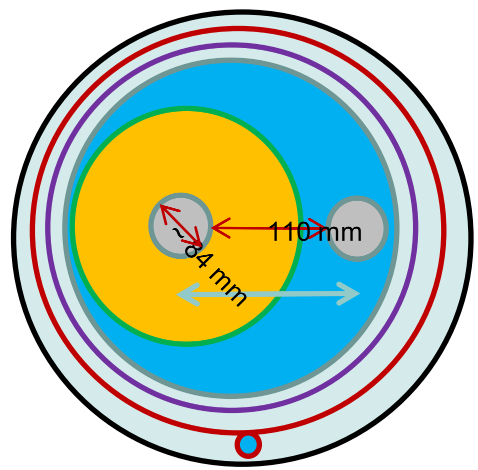
Cryostat and Ancilliaries

- Couplers – see later
- Tuners – Basic concepts reviewed, not ready to specify design..
- Cryostat layout (V. Parma)LHC…

Cavity in He Tank – V. Parma

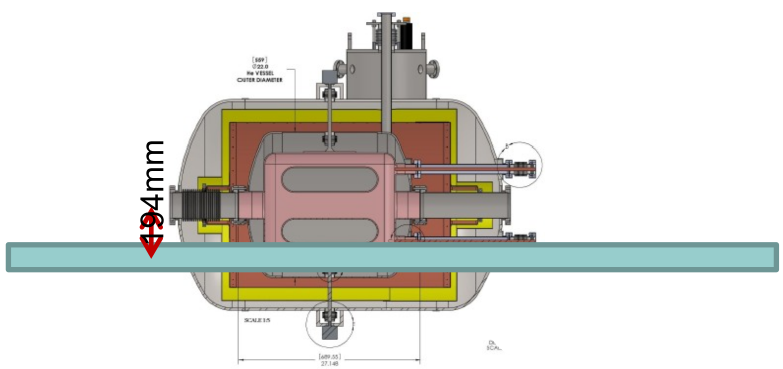
LHC IR 1,5 constraints



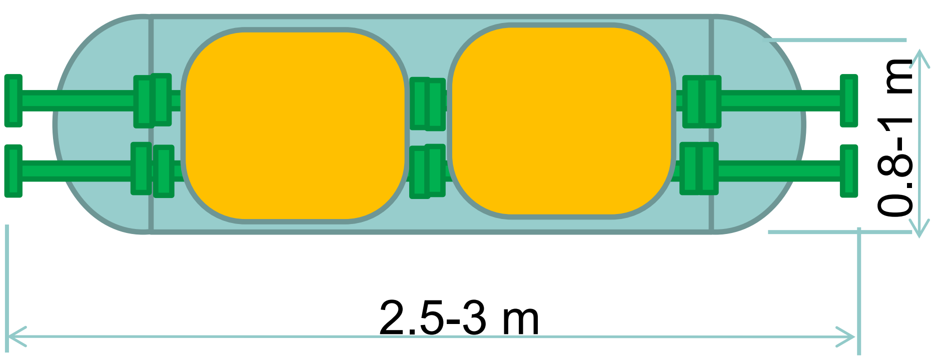


Baseline for Local CC: Second beam INSIDE the He tank!

Global as LHC...



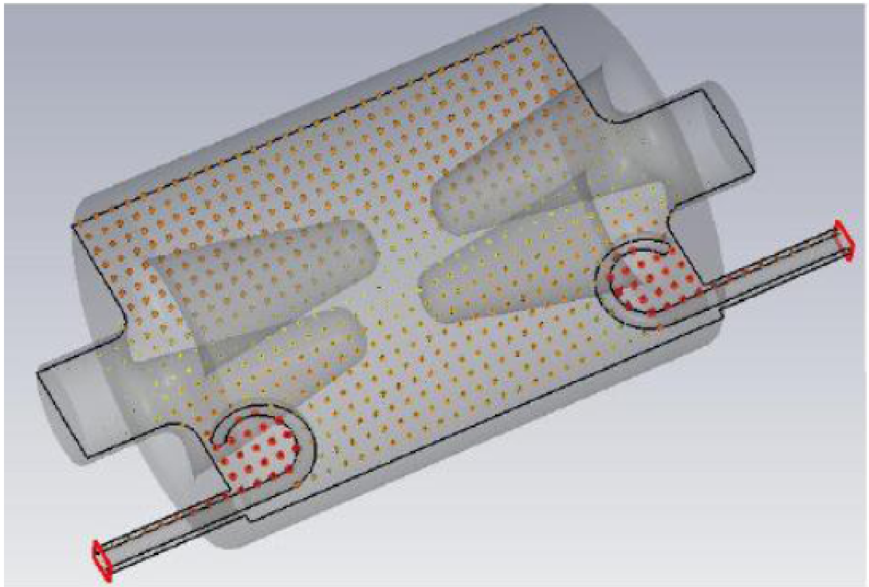
- Typical envelope (2 cavity one cryo-module), strongly depends on choice of cavity

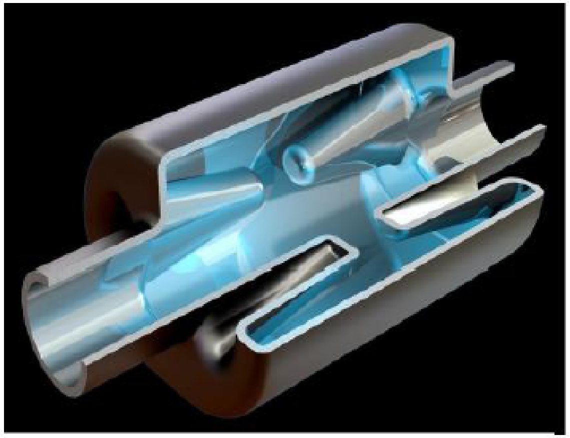


Cavities and Technology

Four Rod CC (Cockroft)

Four Rod Compact Crab
Cavity (Cockcroft)



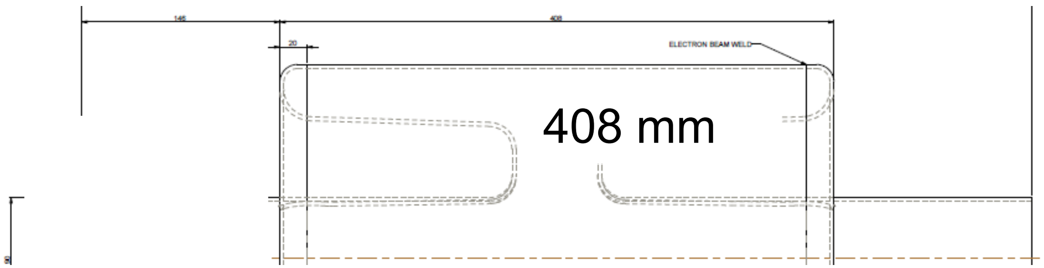


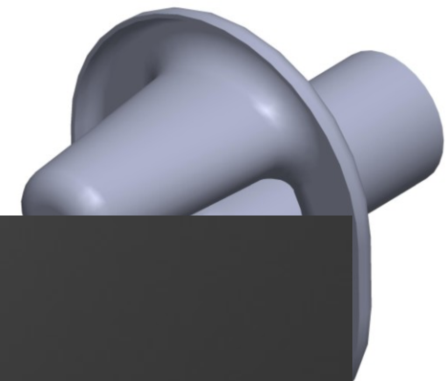
FPC: on cell waveguide coupler

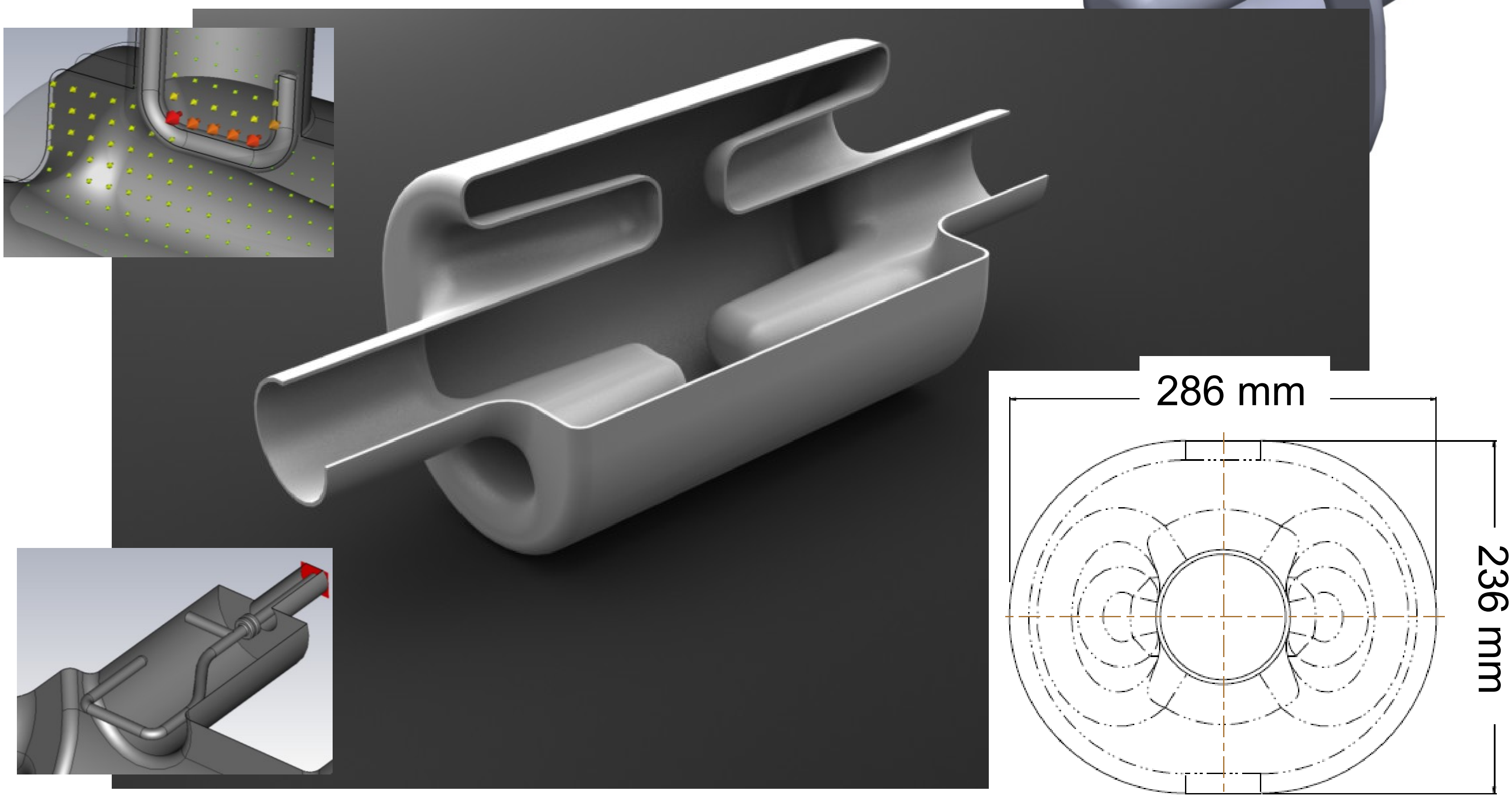
LOM/HOM coupler: on cell waveguide coupler, achieved Q_{ex} ~ 100; on cell coaxial loop couplers under study, meet requirement Q_{ex} ~ 70

→ promising ongoing design

4-Rod Final(ish) Cavity Design

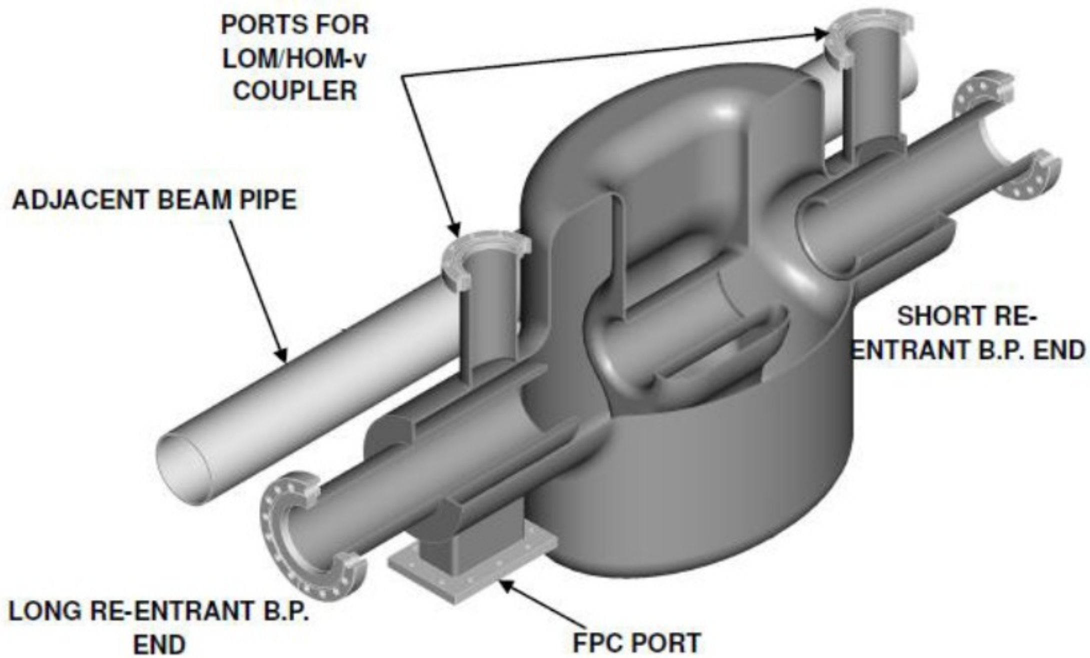






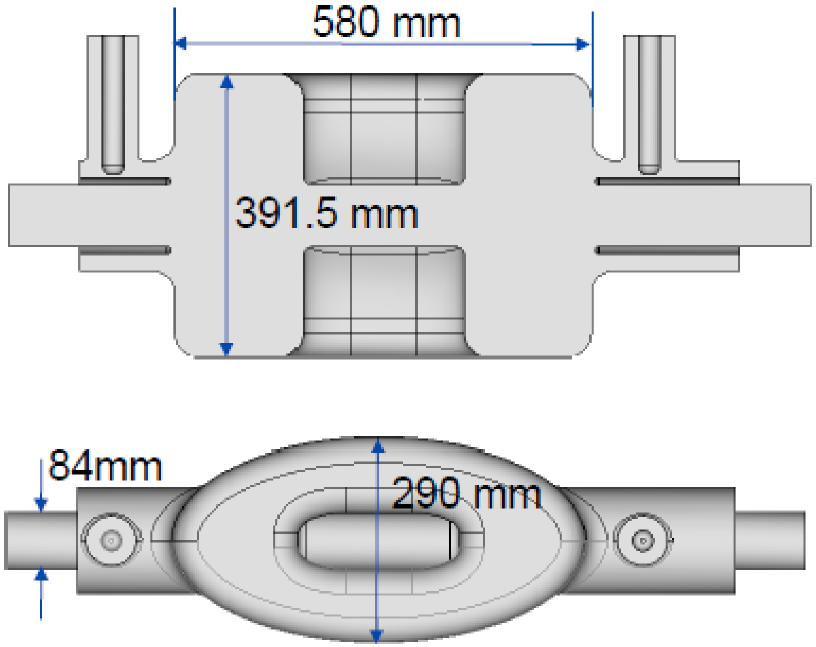
Half Wave Spoke Resonator (SLAC)

Half wave spoke resonator (SLAC)



FPC: waveguide coupler
LOM/HOM coupler: coaxial on beam tube with notch filter to reject crab mode, achieved $Q_{ex} < 4 \cdot 10^4$ for long. modes, no SOM, LOM 65 MHz below deflecting mode; multipacting analysis underway →**well advanced and robust design**

400 MHz HWSR Cavity Parameters



Parameters	
Cavity Width (mm)	290
Cavity Height (mm)	391.5
Cavity Length (mm)	580
Beam pipe radius (mm)	42
$(R/Q)_T$ (ohm/cavity)	215
E_S/V_T ((MV/m)/MV)	**10.4**
B_S/V_T (mT/MV)	**19.5**

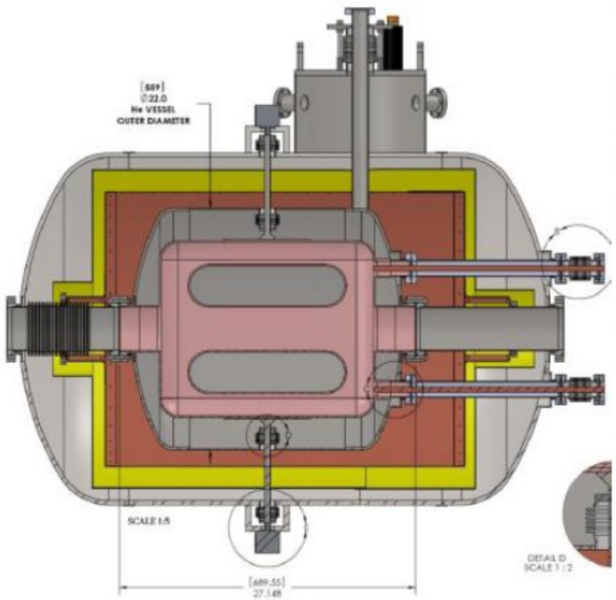
RF parameters calculated with all damping features included

- 10 MV deflecting voltage required
- 2 cavities/beam, 5 MV each

TESLA TDR cavity peak fields for comparison
Eacc: 35 MV/m: Epeak: 66 MV/m; Bpeak: 140mT

Parallel Bar TEM Cavity (UDU/JLAB)

Parallel bar TEM cavity (JLAB)



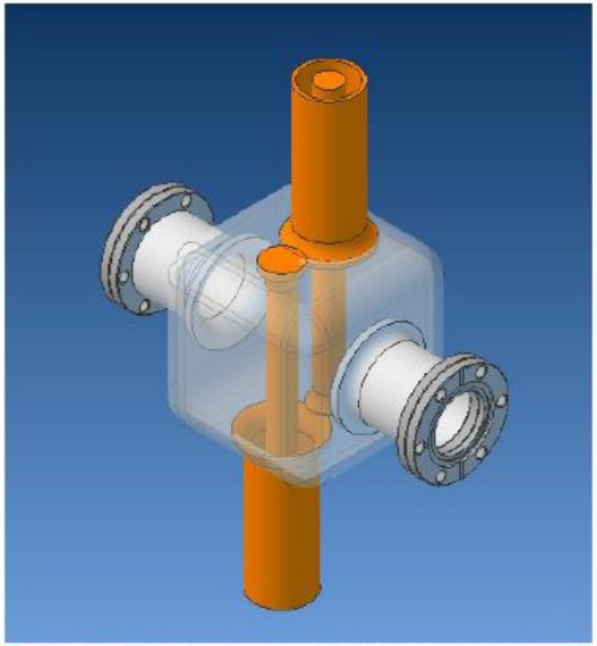
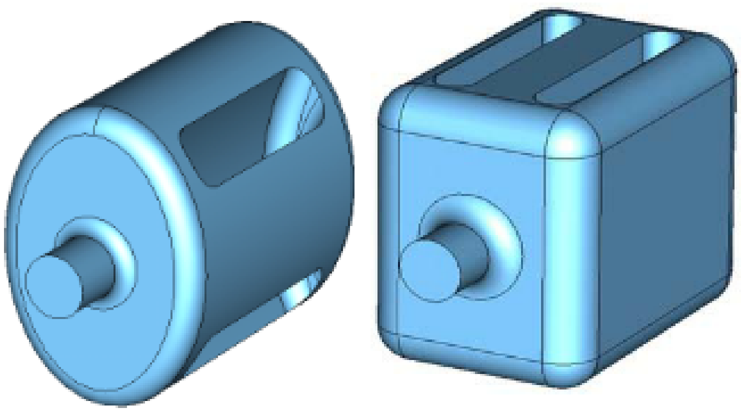


Figure 1: Conceptual view of two-bar structure with coaxial RF input

FPC: coaxial and variable, mind idea of Neubauer et al., IPAC'10
LOM/HOM coupler: coaxial and variable, achieved Q_{ex} not known to me; no LOM mode existing, acc. mode (SOM) 12 MHz above crab mode → **well advanced and robust design**

Cavity Properties – Elliptical Design

Parameter	Rectangular Shaped	Elliptical Shaped	Unit
Frequency of π mode	400.0	400.1	MHz
λ/2 of π mode	374.7	374.7	mm
Frequency of 0 mode	411.0	677.1	MHz
Nearest mode to π mode	411.0	609.2	MHz
Cavity reference length	444.7	445.0	mm
Cavity width / diameter	300.0	295.0	mm
Cavity height	383.2	406.0	mm
Bars length	330.0	330.0	mm
Bars width	55.0	60.0	mm
Aperture diameter	84.0	84.0	mm
Deflecting voltage (V_T^*)	0.375	0.375	MV
Peak electric field (E_P^*)	2.2	2.7	MV/m
Peak magnetic field (B_P^*)	7.9	6.03	mT
B_P^* / E_P^*	3.6	2.23	mT / (MV/m)
Geometrical factor ($G = QR_S$)	74.1	108.9	Ω
$[R/Q]_T$	413.34	262.63	Ω
$R_T R_S$	3.1×10^4	2.7×10^4	Ω^2
At $E_T^* = 1$ MV/m			

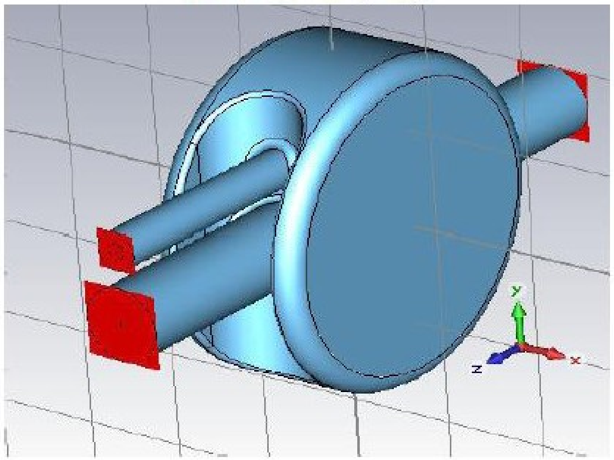


- Surface magnetic fields have improved by 24%
- Frequency separation of the first two modes ~ 209 MHz compared to 11 MHz in the rectangular design
- Reduced cavity width to meet the LHC crab cavity specifications

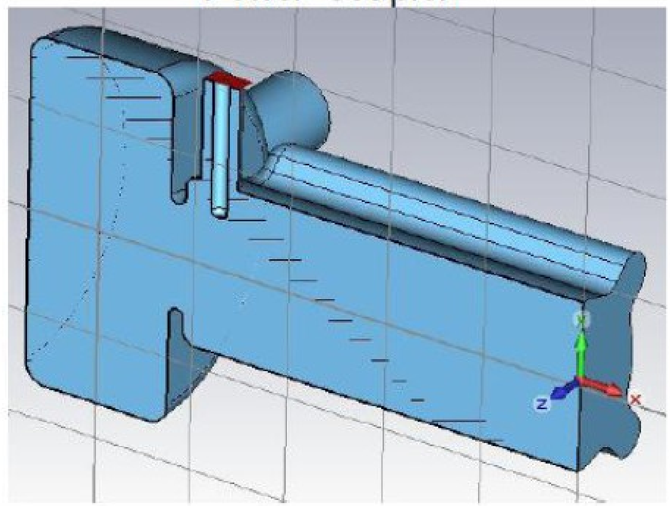
Kota Compact Crab cavity (KEK)

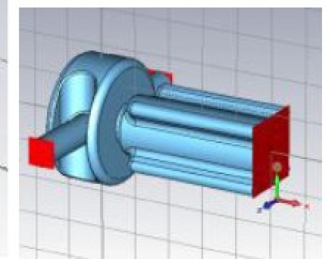
Compact crab cavity (KEK)

HOM Damping



Power Coupler

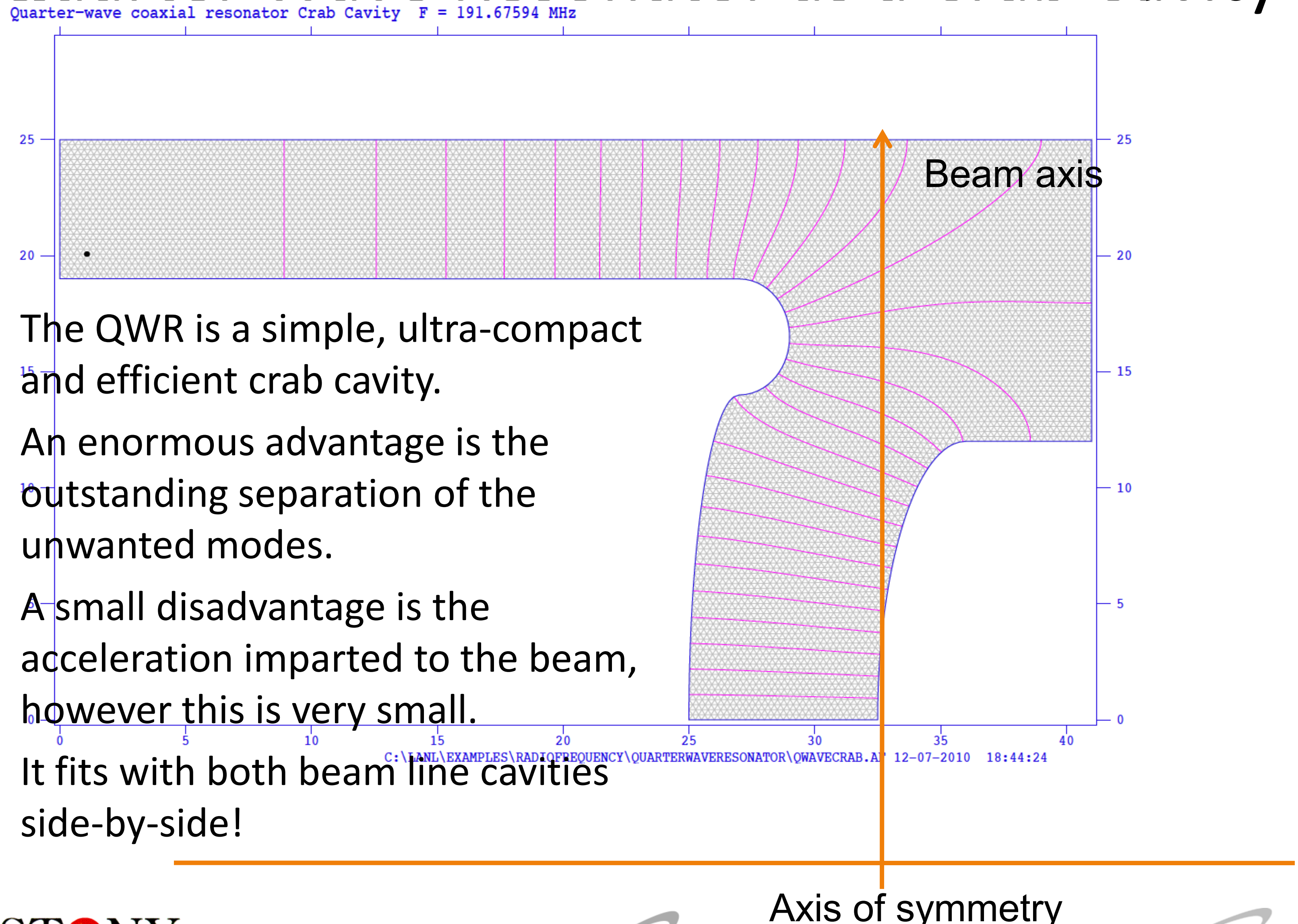




FPC: coaxial, $Q_{ex} \sim 10^5$ - 10^6

LOM/HOM coupler: alternative damping schemes: “fluted” beam tube, $Q_{ex} > 150$, or coaxial, $Q_{ex} > 1480$, crab mode is lowest mode → **promising ongoing design, but RF field too large (unless I made a mistake)**

Quarter Wave Resonator as a Crab Cavity



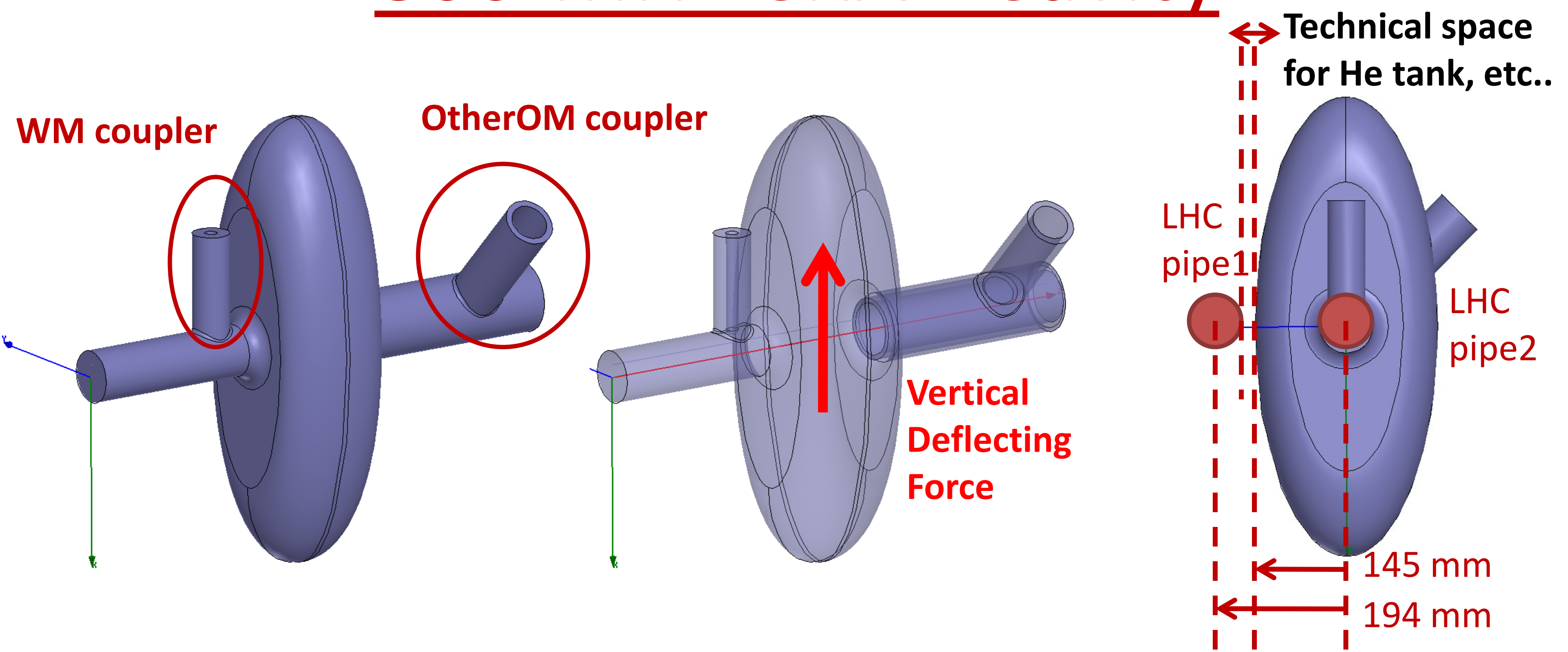
- The QWR is a simple, ultra-compact and efficient crab cavity.
- An enormous advantage is the outstanding separation of the unwanted modes.
- A small disadvantage is the acceleration imparted to the beam, however this is very small.
- It fits with both beam line cavities side-by-side!

STONY BROOK

CASE Center for Accelerator Science and Education

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

800-MHz CRAB Cavity



- Cavity design fits both GLOBAL and LOCAL schemes
- Surface field and RF parameters optimized
- Other Order Mode Coupler to be optimized
- Working Mode Coupler optimized
- Preliminary Multipacting analysis performed

CC Designs – Session Goals

- Status of design & developments
- Detailed cavity coupler design, deflecting mode characteristics
- HOM spectra and achievable damping
- Coupler configurations
- Mechanical tolerances
- Multipactor
- Tuning concepts
- Cavity fabrication, treatment,
- Assembly of couplers
- He vessel, Ancilliary equipment
- Non linearity of deflecting voltage with transverse displacement

Have reached the stage where there is no fundamental show stopper for embarking on first hardware prototypes

Conclusions

- Three CC design presented, they have reached initial design specifications
- Good progress made since CC09.
- Engineering designs advanced or complete
- For all, plans exist on how to to reach HL-LHC Milestone 1 of bare cavity test and validation
- We are ready for prototyping
- The designs of cryomodules and ancilliaries will continue in order to be finalized for Milestone 1

Open Issues:

- Precise impedance budget for beam stability with current of baseline of 8 cavities/beam
- Dynamic failures (multipacting and fast quenches) to be experimentally verified
- Should we aim for early construction of a full prototype CC for a test in the SPS ?

Thanks to all the speakers in these two sessions

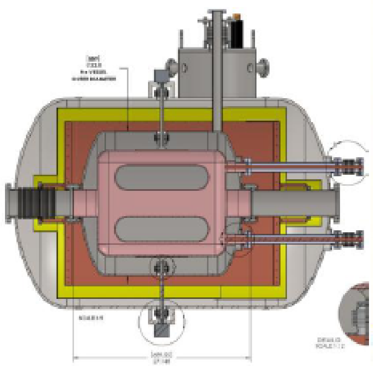
Comparison

	Saclay	Saclay II	INFN BT	KEK SJT	KEK Coax
Coarse Range	± 220 kHz	± 250 kHz	± 250 kHz	± 500 kHz	± 1000 kHz
Coarse Res.	<1 Hz	<1 Hz	<1 Hz	<1 Hz	<1 Hz
Tuning Stiffness	17 N/μm	30 N/μm	13 N/μm	80 N/μm	60 N/μm
Fast Actuator	Piezo	Piezo	Piezo/Magnetost.	Piezo	Piezo
No. of FA	2	2	2	1	1
FA environment	5K/Vac	5K/Vac	5K/Vac	Warm	80K/Vac
Motor environment	5K/Vac	5K/Vac	5K/Vac	Warm	80K/Vac

Coupler Concepts – W. Weingarten

Cavity geometry including accessories

Parallel bar TEM cavity (JLAB)



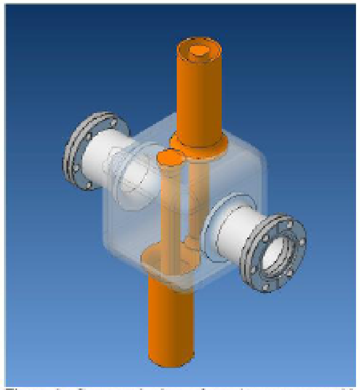
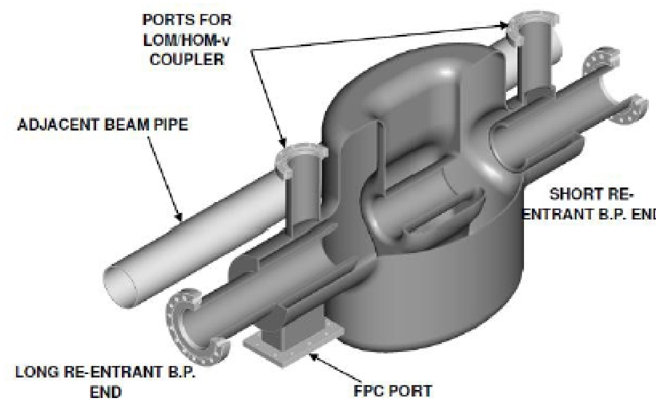


Figure 1: Conceptual view of two-bar structure with coaxial RF input

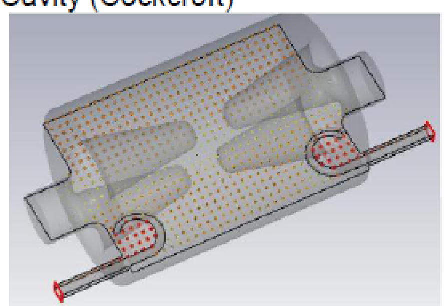
FPC: coaxial and variable, mind idea of Neubauer et al., IPAC'10
LOM/HOM coupler: coaxial and variable, achieved Q_{ex} not known to me; no LOM mode existing, acc. mode (SOM) 12 MHz above crab mode → **well advanced and robust design**

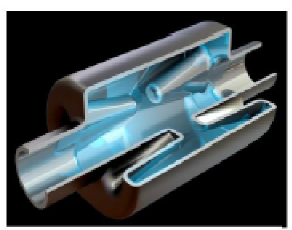
Half wave spoke resonator (SLAC)



FPC: waveguide coupler
LOM/HOM coupler: coaxial on beam tube with notch filter to reject crab mode, achieved $Q_{ex} < 4{\cdot}10^4$ for long. modes, no SOM, LOM 65 MHz below deflecting mode; multipacting analysis underway →**well advanced and robust design**

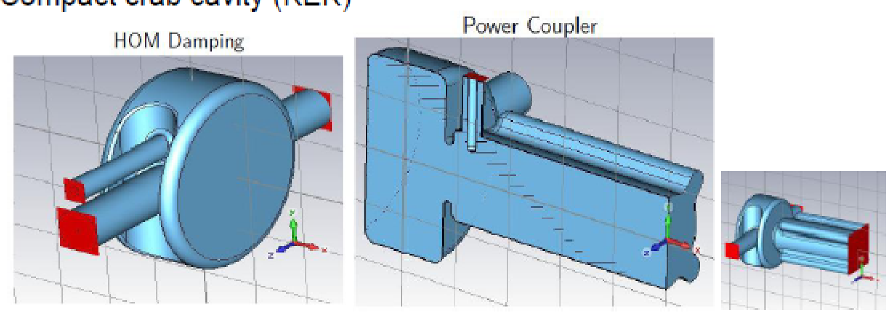
Four Rod Compact Crab Cavity (Cockcroft)





FPC: on cell waveguide coupler
LOM/HOM coupler: on cell waveguide coupler, achieved Q_{ex} ~ 100; on cell coaxial loop couplers under study, meet requirement Q_{ex} ~ 70
→ **promising ongoing design**

Compact crab cavity (KEK)



FPC: coaxial, Q_{ex} ~ 10^5 - 10^6
LOM/HOM coupler: alternative damping schemes: "fluted" beam tube, Q_{ex} > 150, or coaxial, Q_{ex} > 1480, crab mode is lowest mode → **promising ongoing design, but RF field too large (unless I made a mistake)**