WG2 SRF: WP3 Crab Cavities

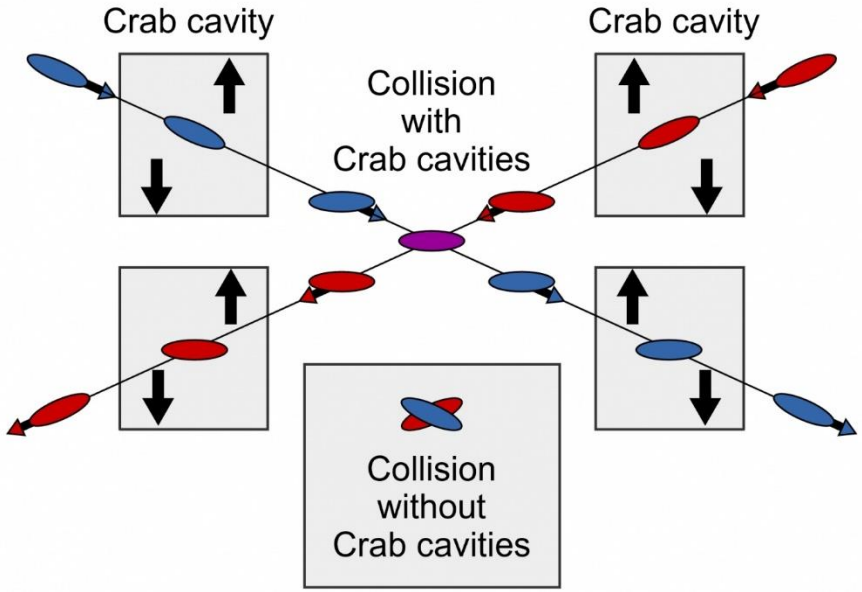
Design Review Workshop #2

Update for WG2

Peter McIntosh

UKRI-STFC Daresbury Laboratory

27th June 2022



Science and Technology Facilities Council

Agenda for Meeting (GMT)

Wednesday 22nd June 2022

13:30	Introduction and Remit for the Workshop	Peter McIntosh (STFC)	5 min
13:35	Specification Review	Peter McIntosh (STFC)	5 min
Cavity Design Updates			
13:40	Elliptical/Racetrack	Graeme Burt (Lancaster University)	15 + 5 min
14:00	RF Dipole (RFD)	Suba De Silva/Jean Delayen (ODU/JLab)	15 + 5 min
14:20	Double Quarter Wave (DQW)	Silvia Verdu Andres (BNL/CERN)	15 + 5 min
14:40	Wide Open Waveguide (WOW)	Binping Xiao (BNL)	15 + 5 min
15:00	Quasi-waveguide Multicell Resonator (QMiR)	Andrei Lunin (FNAL)	15 + 5 min
15:20	Preparations for Down-selection Review (Sept 27th 2022)	Peter McIntosh (STFC)	10 min
15:30	Meeting close		

https://agenda.linearcollider.org/event/9745/

Preparations for 2nd Design Workshop (22nd June 2022)

- Assess and compare CC EM designs, not likely finally optimised:
  - Cavity,
  - HOMs,
  - Couplers,
  - Multipacting,
  - Tuning.
- Clarifying then next steps to perform first CC down-selection on 27th Sept 2022:
  - All EM design aspects complete, including pressure stability and fabrication assessment.
  - Down-select 2 optimum CC designs for future prototype development (external review).
- Final CC down-selection, post-prototype validation at ~18-months later (Mar 2024).

As proposed at 1st Design Review – Dec 21

Workshop Remit

- For WP3 teams to identify progress made with CC designs.
- Identify outstanding issues which may exist regarding specifications as defined (v13).
- Agree the cavity parameters to define for down-selection review – finalise process today.

Specifications Update (v13)

Parameter	Recent Spec (After TDR)		10Hz Upgrade[1,2]	1 TeV CoM Spec [2]		
Beam Energy (GeV) e-	125			500		
Crossing Angle (mrad)	14					
Installation site (m from IP)	14					
RF Repetition Rate (Hz)	5		10	4		
number of bunches	1312		2625	2450		
Bunch Train Length (ms)	727		961	897		
Bunch Spacing (ns)	554		366			
Beam current (mA)	5.8		8.75	7.6		
Operating Temp (K)	2					
Cryomodule installation length (m)	3.25					
Horizontal beam-pipe separation (m)	0.1967 (centre) ±0.0266 (each end of installation length)					
Cavity Frequency (GHz)	3.9	2.6	1.3	3.9	2.6	1.3
Total Kick Voltage (MV)	0.615	0.923	1.845	2.5	3.7	7.4
Max Ep (MV/m)	45			45		
Max Bp (mT)	80			80		
Amplitude regulation/cavity (% rms)	3.5 (for 2% luminosity drop)					
Relative RF Phase Jitter (deg rms)	0.069					
Timing Jitter (fs rms)	49 (for 2% luminosity drop)					
Max Detuning (Hz)		200 TBC				
Longitudinal impedance threshold (Ohm)						
Trasverse impedance threshold (MOhm/m) (X,Y)	48.8, 61.7					
Cavity field rotation tolerance/cavity (mrad rms)	5.2 (for 2% luminosity drop)					
Beam tilt tolerance (H and V) (mrad rms and urad rms)	0.35, 7.4 (for 2% luminosity drop)					
Minimum CC beam-pipe aperture size (mm)	>25 (same as FD magnets)					
Minimum Exraction beam-pipe aperture size (mm)	20					
Beam size at CC location (X, Y,Z) (mm,um,um)	0.97, 66, 300					
Beta function at CC location (X, Y) (m,m)	23200, 15400					
CC System operation	assume CW-mode operation					

Updates from previous Design Review #1 meeting in Dec 2021

Preparations for Down-Selection Review

Sept 27th 2022

- Terms of Reference for the review to be developed (Myself, Akira and Kirk).
- Review panel membership to be determined and invitations solicited (Myself, Akira and Kirk):
  - Suggestions welcome from WP3 collaborators.
- Discussion of remaining requirements for all WP3 collaborators.

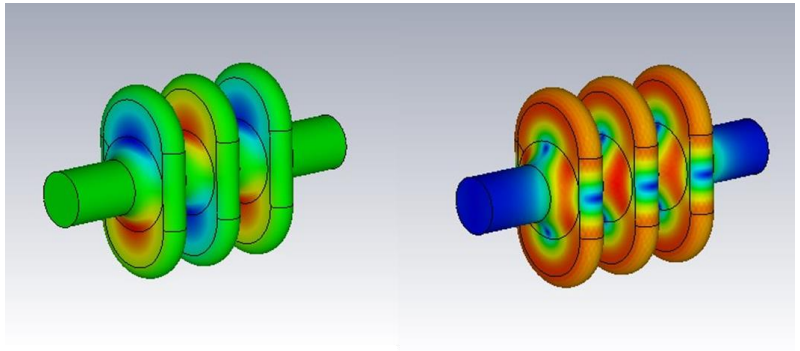
CC Design Parameters

- Propose standardised set of CC parameters for each design.
- This will become the basis for comparison at the Sept Down-selection review.

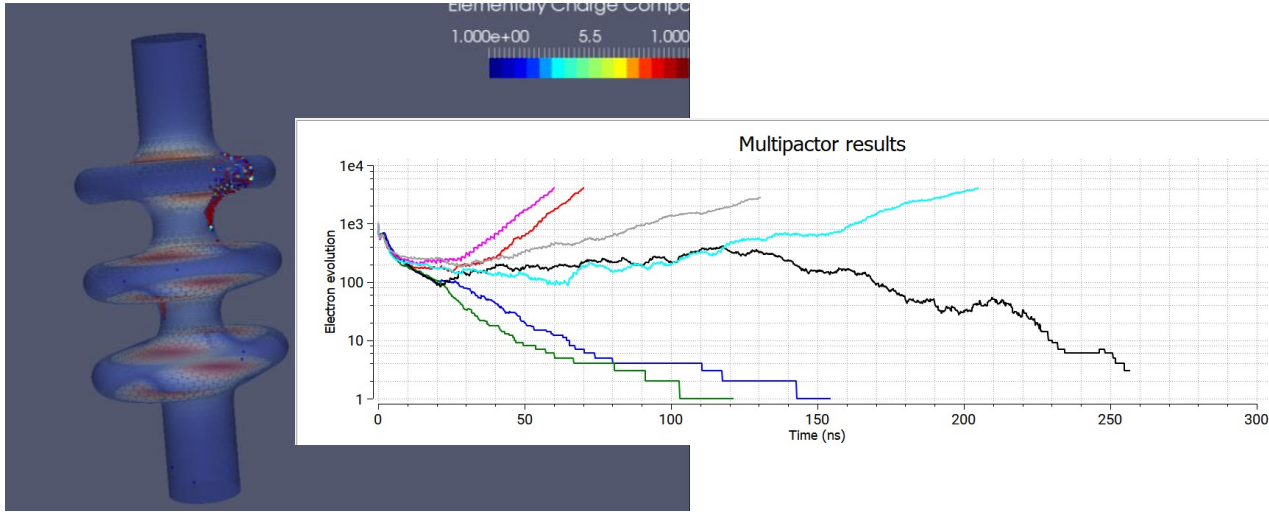
- No further feedback since Design Review meeting #1.

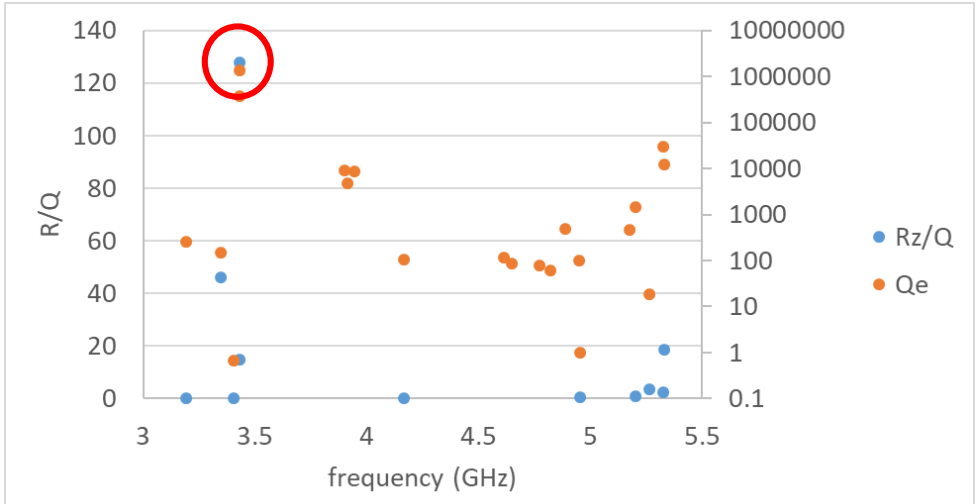
Parameter	Value	Units
Operating frequency		GHz
SOM		GHz
1st Longitudinal HOM		GHz
1st Transverse HOM		GHz
E_p/E_t^*		
B_p/E_t^*		mT/(MV/m)
B_p/E_p		mT/(MV/m)
G		Ω
R/Q		Ω
R_tR_s		$Ω^2$
V_t per cavity		MV
E_p		MV/m
B_p		mT
Total V_t		MV
Total No. of cavities		
Active Cavity Length		mm
Flange-flange Cavity Length		
Number of cells		
Cavity Diameter		mm
Minimum Aperture		mm
FPC Q_L		
Bandwidth		kHz
Cavity Input Power		kW
Horizontal Kick Factor k_x		V/pC
Vertical Kick Factor k_y		V/pC/m
Stored Energy W		J
HOM impedance (Longitudinal)		MΩ
HOM impedance (Transverse)		MΩ/m
First 3 multipole pararameters		

3.9 GHz Racetrack – G Burt (ULAN)

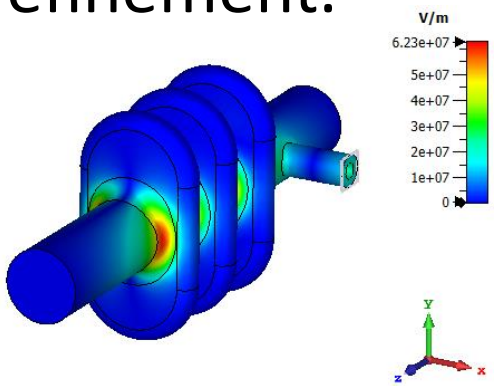


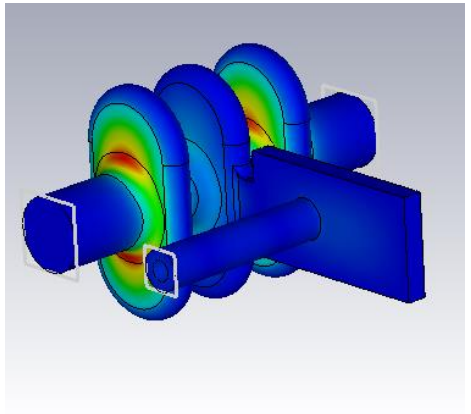
- 30mm external and 25mm internal beam-pipe diameter.
- Multipactor limits V_t to 7 MV.



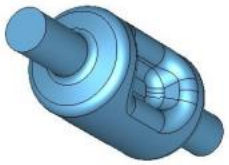


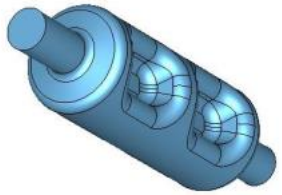
- HOM damping and coupler optimisation requires further refinement.

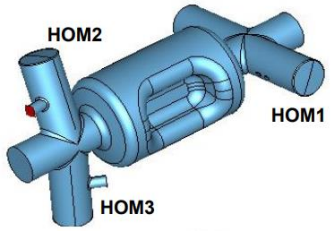


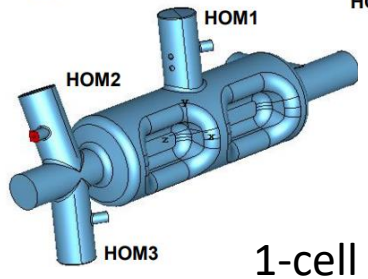


1.3 GHz RF Dipole – S De-Silva (ODU/Jlab)





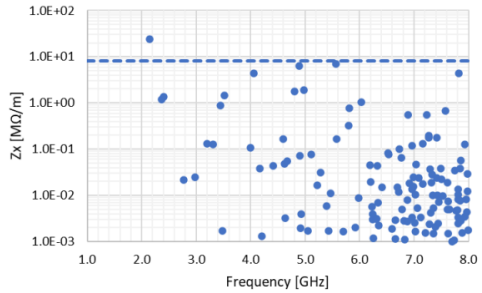


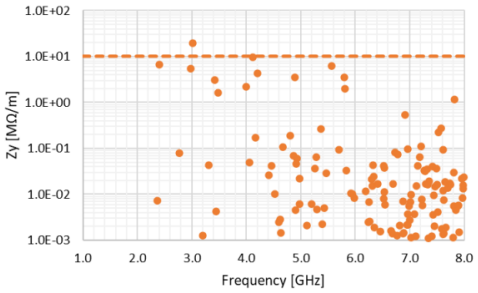


- Single (6-cav) and 2-cell (3 cav) RFD solutions being developed.
- 25mm pole-separation and 30mm beam-pipe diameter.
- Input coupler design optimised for 10mA, 0.5mm offset and 50Hz pk microphonics.

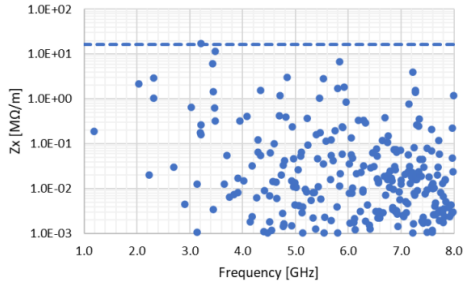
- Single additional HOM coupler needed for trapped mode in 2-cell cavity.

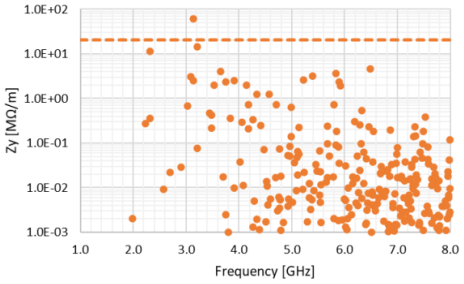
1-cell

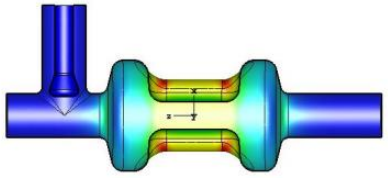


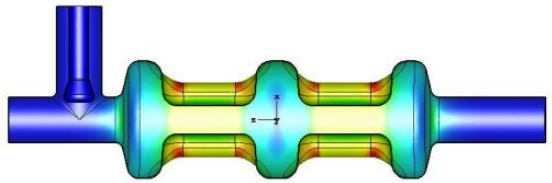


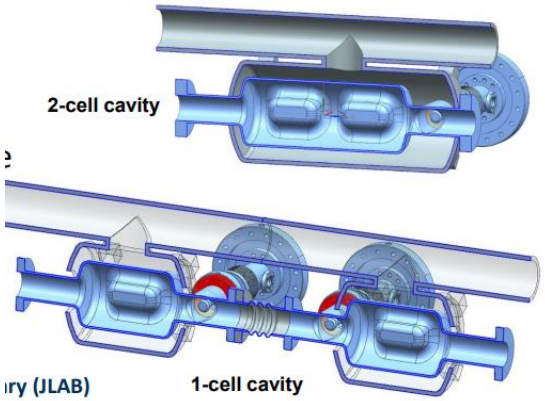
2-cell







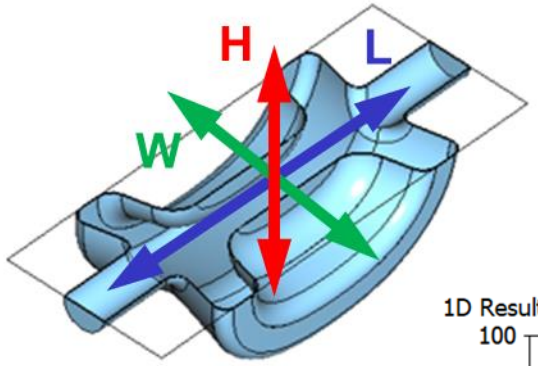


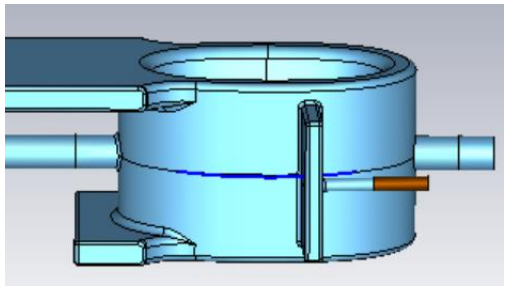


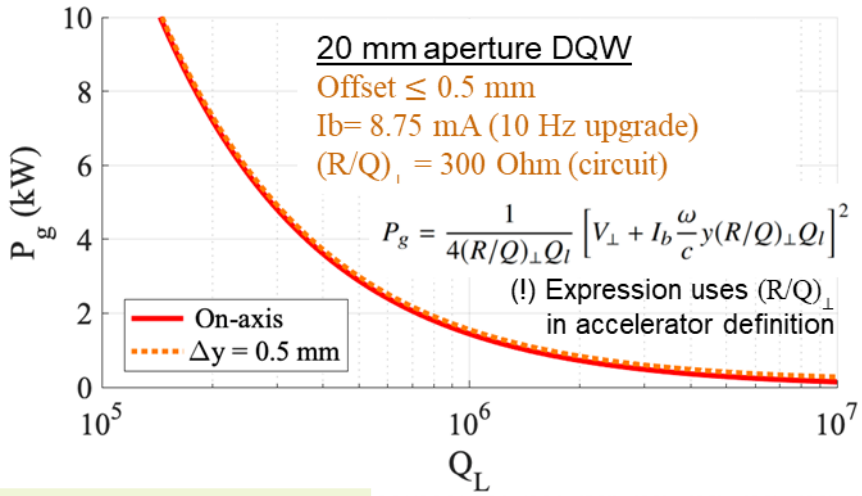
- V_t of 1.35 MV and 2.4 MV feasible for each design – within ILC CC spec for 125Gev and 500GeV modes.

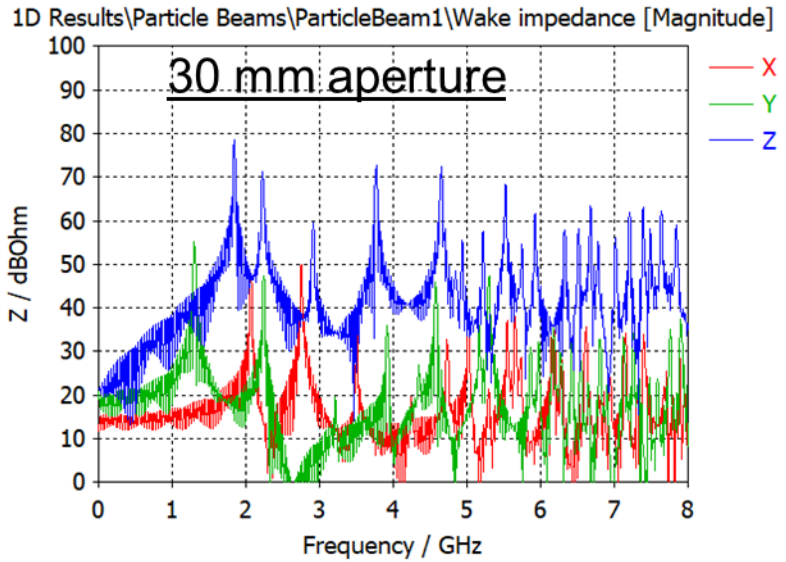
1.3 GHz Double Quarter Wave – S Verdu Andres (BNL)

- 2 cavities with 30mm aperture can achieve V_t = 1.8MV for 125GeV or 5 cavities for 500GeV.
- $Q_L = 10^6$, requires input power of 2kW.

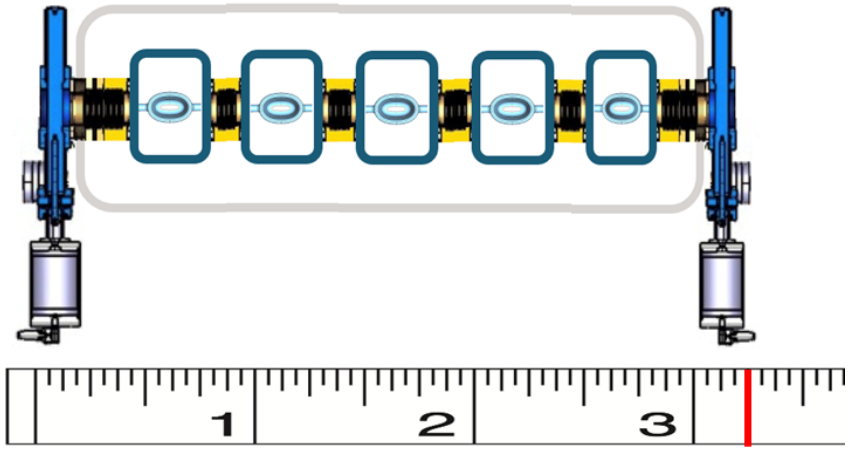




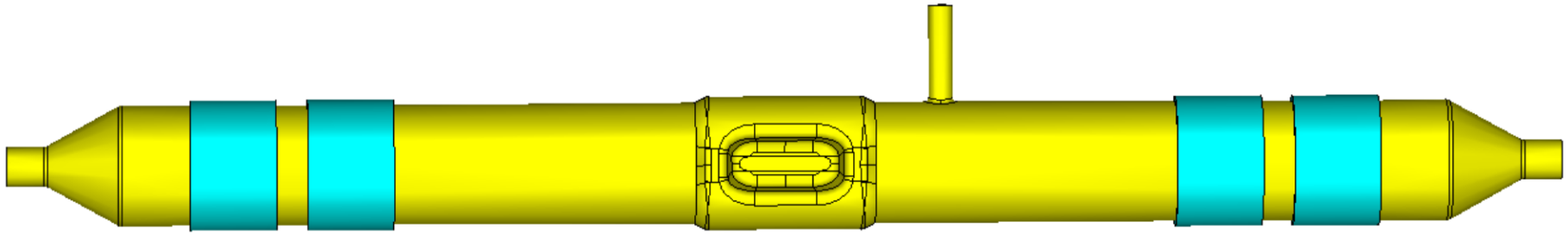




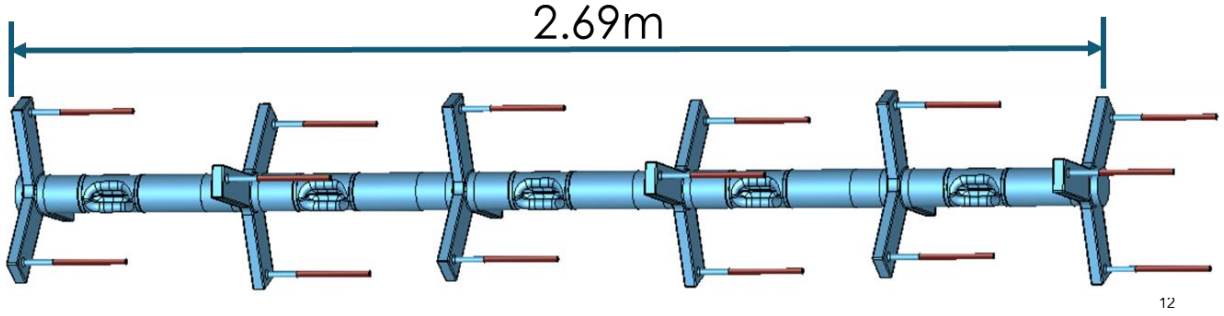
Side view, 5 DQW in cryomodule

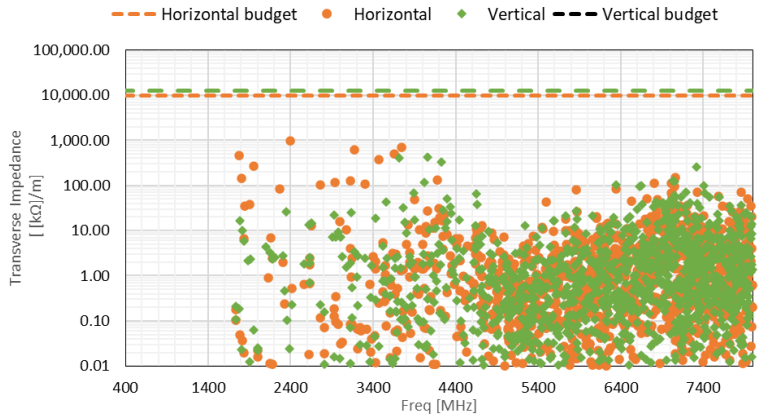


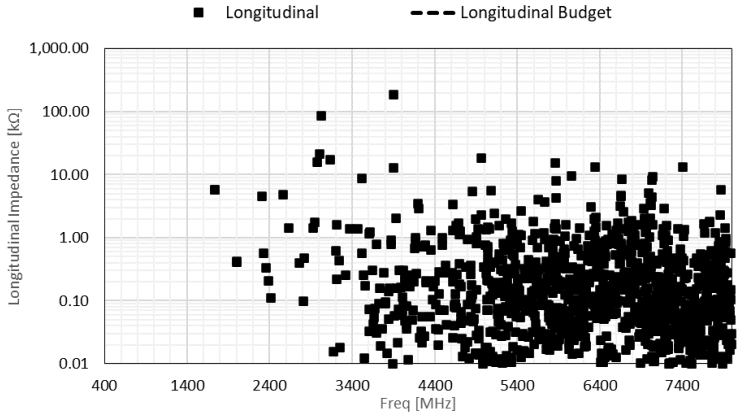
1.3 GHz Wide Open Waveguide – B Xiao (BNL)



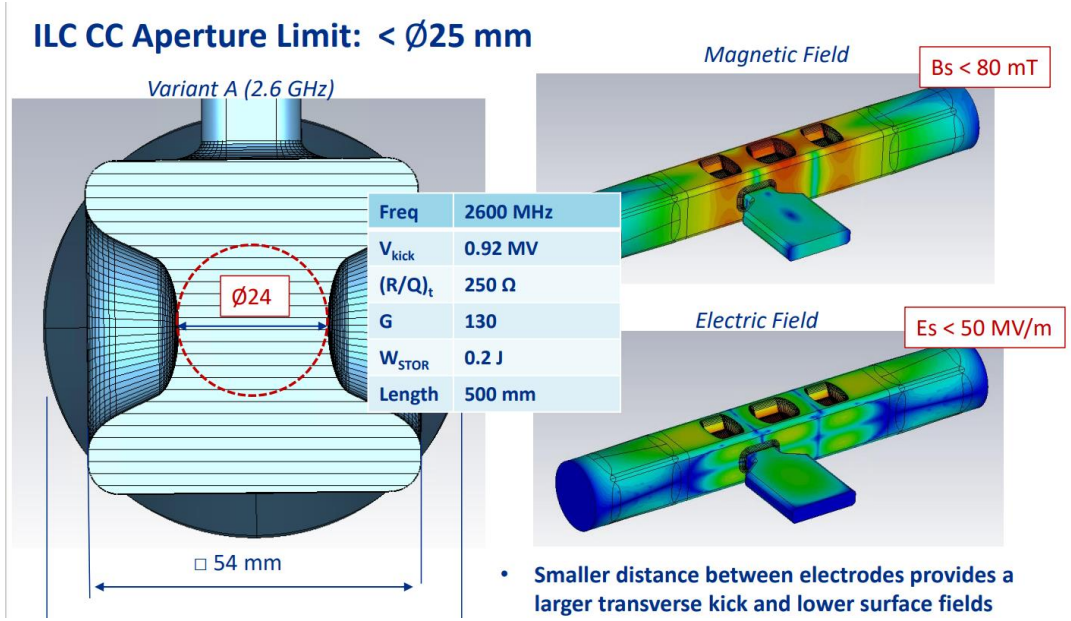
- Pole separation adjusted to 25mm for Vt = 1.48MV.
- Requires 2 cavities for 125GeV and 5 cavities for 500GeV modes, reaching V_t = 8MV peak.
- Waveguide damping of HOMs.

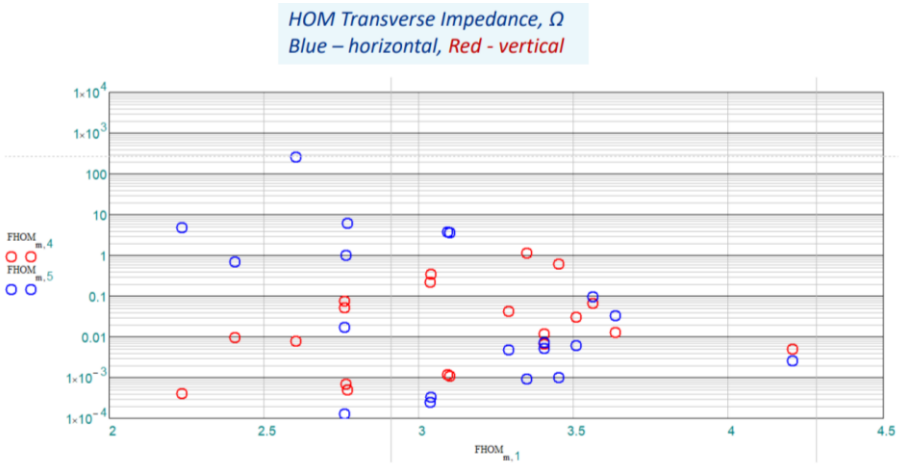






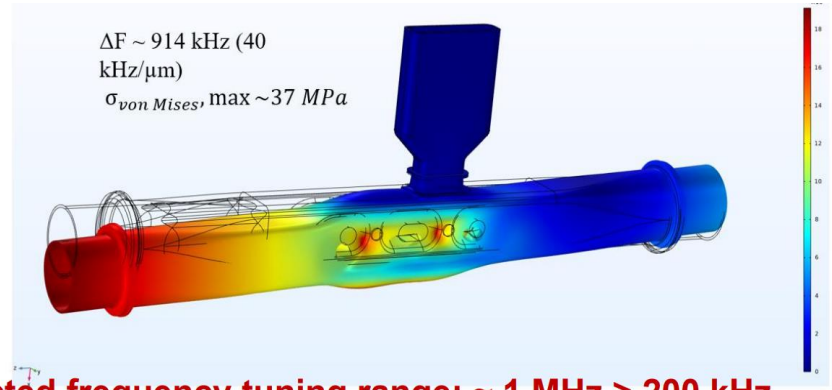
2.6 GHz Quasi-waveguide Multicell Resonator – A Lunin (FNAL)



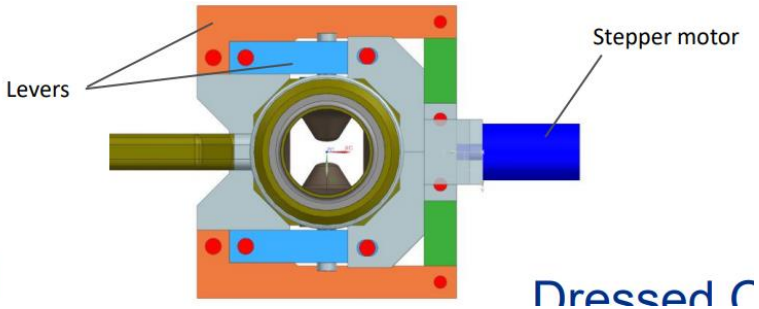


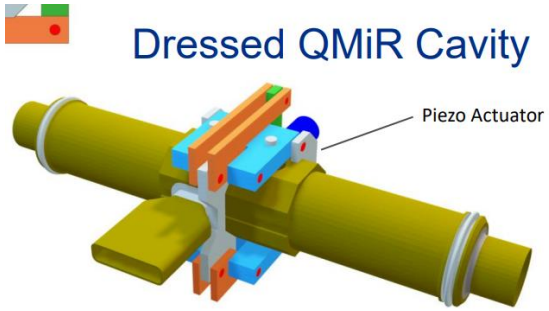
Cavity is HOM free above 4 GHz

- Q_L of 1e6, requires P_{gen} = 2kW for Vt = 0.9MV, with 200KHz tuning range defined.
- 1 cavity required for 125GeV and 4 cavities can provide 4MV for 500GeV.



Expected frequency tuning range: ~ 1 MHz > 200 kHz





Decisions and Actions from Meeting

Decision

1. Collectively agreed that the original date proposed for first cavity down-selection of 27th Sept 2022, should be re-designated as Design Review #3 meeting. With new date for the cavity down-selection review to be determined for early 2023.

Actions

1. Akira to follow-up with the BDS team to try and develop an expected schematic for CC cryomodule and its interfacing to external components. **Akira**
2. Each group please send me the max impedance value from the GDFIDL simulations performed by Alexey Lyapin (RHUL), so that we can issue an example to the BDS team for them to assess provisional longitudinal impedance compliance. **All**
3. Slava would also like to have the following parameters for each cavity design, so that he can assess the expected detune required for each CC solution: Operation frequency, R/Q and Loaded Q **All**

MANY THANKS

Questions?

Science and Technology Facilities Council