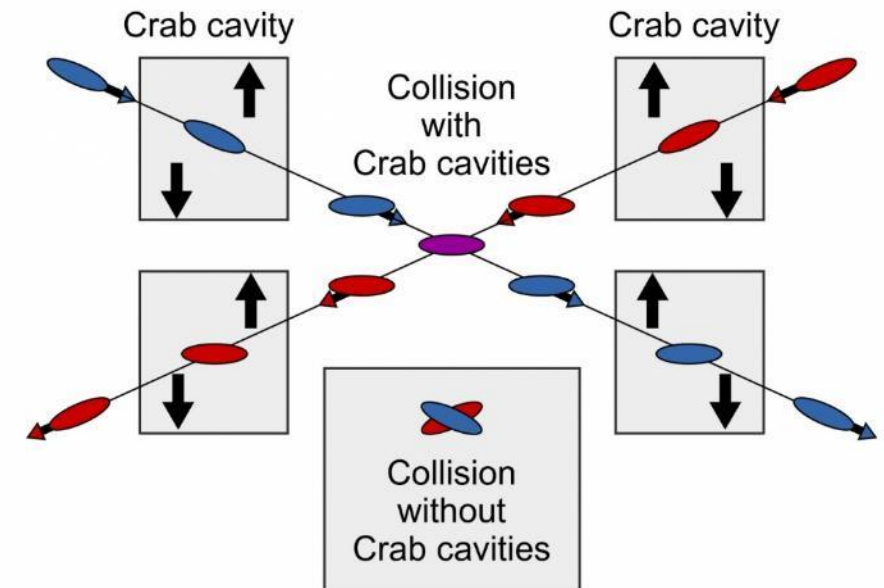


WG2 SRF: WP3 Crab Cavities

Design Review Workshop #4

Peter McIntosh
UKRI-STFC Daresbury Laboratory

27th January 2023



Agenda for WP3 Design Review #4 (GMT)

Friday 27 th January 2023			
13:30	Introduction and Remit for the Workshop	P McIntosh (STFC)	5 min
13:35	Specification and Cavity Parameter Review	P McIntosh (STFC)	10 min
13:45	Down-selection review update	P McIntosh (STFC)/K Yamamoto (KEK)	20 min
14:05	Nb material procurement preparation and HPG safety constraints	A Yamamoto (KEK)	30 min
Cavity Design Updates			
14:35	Elliptical/Racetrack	Graeme Burt (Lancaster University)	15 + 5 min
14:55	RF Dipole (RFD)	Suba De Silva/Jean Delayen (ODU/JLab)	15 + 5 min
15:15	Double Quarter Wave (DQW)	Silvia Verdu Andres (CERN)	15 + 5 min
15:35	Wide Open Waveguide (WOW)	Binping Xiao (BNL)	15 + 5 min
15:55	Quasi-waveguide Multicell Resonator (QMIR)	Andrei Lunin (FNAL)	15 + 5 min
16:30	Meeting close		

<https://agenda.linearcollider.org/event/9944/>

Scope Design Review #4

- Assess and compare CC EM designs, not likely finally optimised:
 - Cavity,
 - HOMs,
 - Couplers,
 - Multipacting,
 - Tuning.
 - Fabrication (**Sheet/Ingot/Mixed, Nb material required, readiness detail**)
- Clarifying next steps to ‘head towards’ a down-selection process:
 - All EM design aspects complete, including pressure stability and fabrication assessment.
 - Down-select 2 optimum CC designs for future prototype development (external review)*.
- **Down selection review now set for April 4 – 6 2023, in-person at KEK.**
- Final CC down-selection, post-prototype validation at ~18-months later*.

*As proposed at Design Review #1 – Dec 21

Specifications Update (v17)

Parameter	Post-TDR Specification	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)	3.8 (incorporating gate valves)		
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					
Max Bp (mT)	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 (kHz)	240	170	100 - 180	240	170	100 - 180
Longitudinal impedance threshold (Ohm)	Cavity wakefield dependent					
Transverse 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 Extraction 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					
Horizontal kick factor (kx) (V/pC/m)	<< 1.6 x 10 ³					
Vertical kick factor (ky) (V/pC/m)	<< 1.2 x 10 ²					
CC System operation	assume CW-mode operation					

Slava Yakovlev updated H/V kick factor specs

Crab Cavity Parameters (Updates from Design Review #3)



Parameter	Elliptical/Racetrack	RFD	DQW	WOW	QMIR	Units
Operating frequency	3.9	1.3	1.3	1.3	2.6	GHz
SOM	5.07	N/A	N/A	NA	2.217	GHz
1 st Longitudinal HOM	3.32	2.396	2.00	1.765	3.46	GHz
1 st Transverse HOM	5.07	2.0885	2.21	2.299	2.82	GHz
E_p/E_t^*	3.55	3.76	3.60	3.24		
B_p/E_t^*	8.3	6.8	6.14	5.75		mT/(MV/m)
B_p/E_p (including ports)	8.3	1.8	1.71	1.77		mT/(MV/m)
G	164	129.54	102	130.9	130	Ω
R/Q (accelerator definition per cavity)	47.6	440.4	422	454.3	225	Ω
$R_t R_s$	7830	57000	43044	59446	13.5	Ω^2
V_t max per cavity	0.5	1.35	1.28	1.60	0.92	MV
V_t operational per cavity (125 GeV)	2.5	0.9225	0.93	0.9225	3.7	MV
E_p operational	23.05	30.2	29.0	45.0	40	MV/m
B_p operaytional	53.9	54.4	56.4	79.8	75	mT
Total No. of cavities (125 GeV beam)	5	2	2	2	4	
Extendability (500 GeV beam)		6	5	5		
V_t max/ V_t operational	0.20	1.46	1.38	1.73	0.25	
Flange-flange Cavity Length	177	310	TBD	514	500	mm
Number of cells	2	1	1	1	3	
Cavity Diameter (RF model ID largest transverse horizontal dimension closest to 2nd beam-pipe)	108.6	99.4	104	97.2	75	mm
Minimum Aperture	25	25	25	25	25	mm
FPC Q_L		1.5×10^7	$1.00E+07$	$1.00E+07$	$1.00E+06$	
Loaded Bandwidth		86.7	0.13	130	2.6	Hz
Cavity Input Power		0.31	0.3	0.16	1.5	kW
Longitudinal Loss Factor k_z		44	TBD	2.71		V/pC
Horizontal Kick Factor k_x		TBD	TBD	23.3 w/o 1.3GHz, 36.2 w/	45	V/pC/m
Vertical Kick Factor k_y		TBD	TBD	15.6	< 0.05	V/pC/m
Stored Energy W (at V_t operational)	0.11	0.125	0.0039	0.23	< 0.2	J
HOM impedance (Longitudinal)	29.1		TBD	0.14	130	M Ω
HOM impedance (Transverse) H	22.8		TBD	3.65	150	M Ω /m
HOM impedance (Transverse) V			TBD	4.87		
First 3 multipole pararameters		b3=4.4E3 b5=5.4e6	TBD	TBD		
Nb material quantity (Kg) per cavity prototype		25.9	15.00	10.04	100	
Nb material sheet/ingot		ingot and tubes	Ingot for main body: 100 mm x 120 mm x 130 mm. Sheets or ingot for ports.	sheet	ingot, Ø100	
Maximum stresses, max pressure at RT (weakest)?		25.1	TBD	28		

Down-selection Review Update

- Review to be held at KEK Tsukuba:
 - 305-0801 Ibaraki Prefecture Tsukuba City Oho 1-1
- 3-day in-person review:
 - Tuesday 4th April – Thursday 6th April, synchronised at JST time-zone
- A ‘Neutral’ international review panel being appointed:
 - 2 x SRF experts from each region, plus Toshiyuki Okugi (KEK) ILC-BDS
 - 5 out of 6 panel members appointed, awaiting final response.
- KEK to assist participants with local logistics arrangements.

Proposed Review Panel Charge

1. Review the **crab cavity (CC) designs** proposed, to assess their **predicted compliance against the functional Specifications** for the **ILC-250**, extended capability for the **ILC-500**, and the **feasibility for higher energy**.
2. Review the **status of the design** of these CC solutions and identify their **risk in comparison to other comparable systems** presently in operations or in development elsewhere in the world.
3. Review the proposed CC solutions for their **choices of materials, fabrication processes, fast and slow tuning systems, power coupler, HOM couplers, SRF performance**, etc.
4. Review the **plan for the prototype development** including **possible cooperation (or consortium effort) with other laboratories and companies/industry**.
5. Provide appropriate **advice and feedback for the criteria and further processes to be scoped for the final CC down-selection**, based on the prototype development and subsequent high-power tests.

Preliminary Agenda – for discussion

Day 1: Tuesday 4th April 2023				Day 2: Wednesday 5th April 2023				Day 3: Thursday 6th April 2023			
Start	Topic	Duration	Who	Start	Topic	Duration	Who	Start	Topic	Duration	Who
08:30	Arrival and Refreshments	30-min		08:30	Arrival and Refreshments	30-min		08:30	Arrival and Refreshments	30-min	
09:00	Welcome, Logistics and Introductions	15-min		09:00	CC2 presentation	90-min		09:00	CC5 presentation	90-min	
09:15	Agenda overview and panel charge	15-min		10:30	Coffee break	15-min		10:30	Coffee break	15-min	
09:30	IDT Project Introduction	30-min		10:45	CC2 panel discussion	60-min		10:45	CC5 panel discussion	60-min	
10:00	Coffee Break	20-min		12:00	Lunch	60-min		12:00	Lunch	70-min	
10:20	ILC BDS and CC Expectations	60-min		13:00	CC3 presentation	90-min		13:00	Panel closed discussion	120-min	
11:20	ILC CC Design Specifications	30-min		14:30	CC3 panel discussion	60-min		15:00	Coffee Break	15-min	
11:50	Panel discussion on requirements	60-min		15:30	Coffee Break	15-min		15:30	Panel closeout preparation	60-min	
12:50	Lunch	70-min		15:45	CC4 presentation	90-min		16:30	Panel decision and recommendations	30-min	
14:00	CC1 presentation	90-min		17:15	CC4 panel discussion	60-min		17:00	Meeting Close		
15:30	Coffee Break	15-min		18:15	Meeting Close						
15:45	CC1 panel discussion	60-min									
16:45	Panel closed session	60-min									
17:45	Meeting close										
19:00	Evening dinner										

Provisional CC Design Update (Per design)

Cavity Design	15-min
Couplers - HOMs and FPC	15-min
Multipacting Analysis	10-min
Pressure Sensitivity	10-min
Cavity tuning	15-min
Cavity fabrication	15-min
Cryomodule configuration	5-min
Compliance with specifications	5-min
	90-min

KEK Logistics for the Review

See slides from Kirk

Nb material procurement preparation and HPG safety constraints



See slides from Akira

CC Design Updates Today

- Elliptical/Racetrack
- RF Dipole (RFD)
- Double Quarter Wave (DQW)
- Wide Open Waveguide (WOW)
- Quasi-waveguide Multicell Resonator (QMIR)

G Burt (Lancaster U)

S De Silva/J Delayen (ODU/Jlab)

S Verdu Andres (CERN)

B Xiao (BNL)

A Lunin (FNAL)

MANY THANKS

Questions?