WP3: 6th Crab Cavity Preparation Meeting

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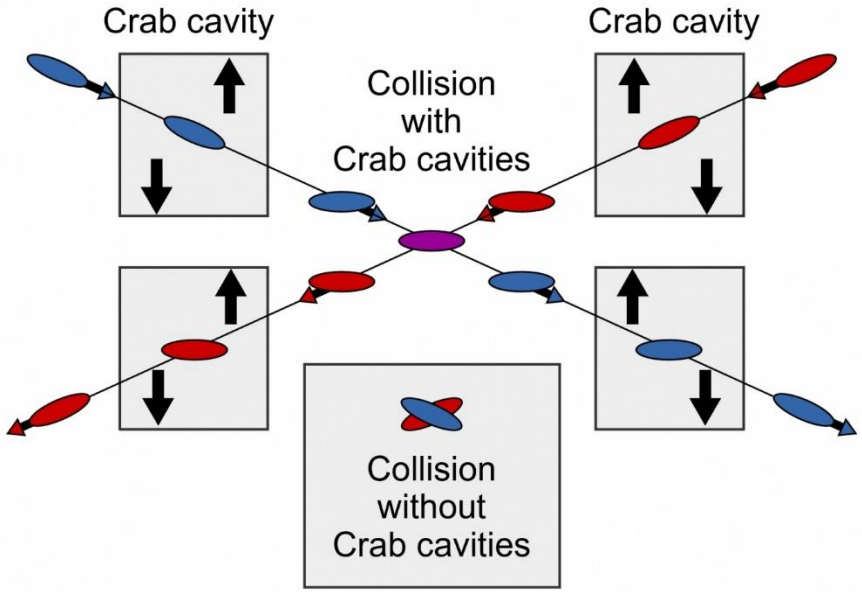

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Agenda for Today

1. Specifications Review P McIntosh

- Updates from Design Review Workshop #1 on 8/12 (https://agenda.linearcollider.org/event/9515/)
- Updates from Joint-BDS meeting on 16/2 (https://agenda.linearcollider.org/event/9589/)

2. Cavity Design Parameters P McIntosh

- Agree a basis for comparison

3. WG2 Steering Panel Pre-lab Update P McIntosh

- Provide indication of proposed 4-yr programme and priority WP3 objectives

4. Prep for next Design Review Meeting in June P McIntosh

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Actions from Design Review Workshop #1 (8/12/21)

1. BDS team requested to perform a 10sigma simulation, as this is expected to be more representative of beamline effects and likely to need a larger aperture, but how much larger? **Action: Okugi-san**

Analysis performed reinforcing requirement for larger aperture.

2. It was noted that the beam-size at the CC location will vary with energy and so parameters should be provided for 1TeV. **Action: Okugi-san**

Similarly identified for larger energy.

3. Important that the WP3 team have a clear specification for the interfacing beam-line components, which need to be confirmed. **Action: Akira**

This requires more detailed development of BDS interfacing of SC magnet systems, which is not likely to happen quickly.

4. It was noted that the Ep and Bp figures should be scaled for the various frequency options proposed. **Action: Andrei**

Agreed parameters for 1.3GHz, but need equivalent for 2.6 and 3.9GHz options.

5. Multipole components require further clarification, suggestion to use the parameters set for HL-LHC as a starting point. **Action: Rama**

Parameters added to Specification spreadsheet for collective WP3 review.

6. For all specification updates identified, a revised specification list would be distributed (v11). **Action: Peter**

Revision issued on 31/1.

7. How much do need to detune CC if it is to be parked, suggestion of >1000 x BW proposed, seems too high. Can BDS team provide some indication of scaling for linac vs circular machine. **Action: Okugi-san**

Slava provided an extensive analysis paper for evaluating CC detuning requirements, needs translating for 1.3GHz and 3.9GHz options and higher energy.

8. A proposed list of cavity design parameters were highlighted and posted into the V10 specification file. All WP3 collaborators requested to send updates for this list (to Peter M) identifying all needed parameters and also clarifying (where necessary) the nomenclature/definition used (i.e. circuit vs accelerator), along with the equation if necessary. **Action: All WP3**

No feedback received, propose to agree parameters today.

9. It is anticipated that further update meetings will also be scheduled, to deal with specific specification issues and information dissemination, which will be announced accordingly. **Action: Peter**

Conducted with today's meeting.

Note: **Underlined actions**, also reviewed at Joint-BDS meeting on 16/2

Actions from Joint-BDS meeting

1. CC detuning – Not a defining criteria for the cavity itself, WP3 to determine tolerable voltage wrt beam offset without impacting luminosity. **WP3**
2. Longitudinal space constraint – for 3.25m revised installation constraint, further discussions required with the BDS Engineering team with B Parker to clarify risk for increasing the 300mm cryostat interface, thereby reducing the 3.25m for the CC even further. **B Parker**
3. Longitudinal space constraint – a dimensioned schematic is required showing the upstream and downstream interfacing cryostats, along with the warm section components with then are expected to directly interface with the CC cryomodule. **T Okugi**
4. Horizontal aperture @ 250GeV – specific concerns regarding the QmiR cavity aperture changes to be reviewed with BDS team for any associated issues to be identified. **A Lunin**
5. **Horizontal aperture @ 1TeV – indications that aperture restrictions are more favourable at higher energies, a technology solution that works at 250GeV which can also work at 1TeV would be more favourable, however this is not a fundamental requirement. The WP3 team will identify a collectively agreed approach for the first down-selection process. WP3**
6. **Operational contingency – The WP3 team will also collectively agree the level of operational contingency or otherwise required redundancy for the solutions proposed. From this, the necessary criteria will be used for the first down-selection process. WP3**

ILC CC Specifications (v11)

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)	3.8 – reduced to 3.25m		
Horizontal beam-pipe separation (m)	0.1967 (centre) ±0.0266 (each end of installation length)		

Interface apertures – BDS team reduction

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 (kHz)		200				

Conservative levels to adopt – TBC

Scaling with frequency – S Yakovlev analysis

Longitudinal impedance threshold (MOhm)	
Trasverse impedance threshold (MOhm/m) (X,Y)	48.8, 61.7 (from TDR)
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)	≥20 (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

Cavity wakefields (GdfidL sims) – Update from teams?

Collimation studies – ideally ≥20mm!

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CC Design Parameters

Clarify/Agree?!?

Parameter	Value	Units	Nomenclature
Operating frequency [GHz]		GHz	
SOM [GHz]		GHz	
1st Longitudinal HOM [GHz]		GHz	
1st Transverse HOM (GHz)		GHz	
E_p/E_t^*			
B_p/E_t^* [mT/(MV/m)]		mT/(MV/m)	
B_p/E_p [mT/(MV/m)]		mT/(MV/m)	
G [Ω]		Ω	
R/Q [Ω]		Ω	
R_tR_s [$Ω^2$]		$Ω^2$	
V_t per cavity [MV]		MV	
E_p [MV/m]		MV/m	
B_p [mT]		mT	
Total V_t [MV]		MV	
Total No. of cavities			
Cavity Length [mm]		mm	
Cavity Diameter [mm]		mm	
Minimum Aperture [mm]		mm	
R_t/Q [Ω]		Ω	
FPC Q_L			
Bandwidth [kHz]		kHz	
Cavity Input Power [kW]		kW	
Horizontal Kick Factor k_x		V/pC/m	
Vertical Kick Factor k_y		V/pC/m	
Stored Energy W [J]		J	
HOM impedance (Longitudinal)		MΩ	
HOM impedance (Transverse)		MΩ/m	
Anything else?			

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WG2 Steering Panel Update – Pre-Lab Preparations

Priority	Items	2023 Y1	Y2	Y3	Y4	Japan		Europe		Americas	
						$M	FTE	$M	FTE	$M	FTE
A	Decision of installation location with cryogenics/RF location accelerator tunnel	All									
A	Confirm the complete CC system specifications	All									
A	Development of CC cavity/coupler/tuner integrated design (ahead of Preliminary CC technology Down-selection)	EU/AM	Already set for 27/9/22								
A	Preliminary CC technology down-selection (2 cavity options)	All									
A/B	CC Model-work and Prototype production and high-power validation of CC cavity/coupler/tuner integrated system (incl HPGS provision) for two primary candidates (ahead of Final CC technology Down-selection)	EU/AM	EU/AM			0.5		0.35	5.5	0.35	5.5
B	Perform harmonized operation of the two prototype cavities in a vertical test to verify ILC synchronization performance (cryo insert development and commercial optical RF synchronization system).		EU/AM	EU/AM						0.05	1
A/B	Final CC technology down-selection			All	Provisionally set for Q1 2024						
B	Preliminary Crab Prototype CM (pCM) design – confirming dressed cavity integration and compliance with beam-line specification (incl HPGS provision)			EU/AM	EU/AM				3.5		3.5
B	Final pCM engineering design prior to production			EU/AM	EU/AM				0.5		0.5
	Totals (Dependent on prioritised funding)					**0.5**		**0.35**	**9.5**	**0.4**	**10.5**

WG2 Steering Panel Update – Pre-Lab Preparations

				Cost (for Priority A/B)			FTE-yr(for Priority A/B)		
Area system	**Work packages**	**Items**	**Detailed items**	**Japan**	**Europe**	**Americas**	**Japan**	**Europe**	**Americas**
WP-3	Crab Cavity (CC) for BDS #CC prototype: 2 # CC-CM design: 1	Decision of installation location with cryogenics/RF location accelerator tunnel		0.00	0.00	0.00	0.00	0.00	0.00
		Confirm the complete CC system specifications	Design specifications complete	0.00	0.00	0.00	0.00	0.00	0.00
		Development of CC cavity/coupler/tuner integrated design (ahead of Preliminary CC technology Down-selection)	CC design options	0.00	0.00	0.00	0.00	0.00	0.00
		Preliminary CC technology down-selection (2 cavity options)	Down-select EM design (down to 2)	0.00	0.00	0.00	0.00	0.00	0.00
		CC Model-work and Prototype production and high-power validation of CC cavity/coupler/tuner integrated system (incl HPGS provision) for two primary candidates (ahead of Final CC technology Down-selection)	Prototype 2 CC options, including ancillaries	0.50	0.35	0.35	0.00	5.50	5.50
		Perform harmonized operation of the two prototype cavities in a vertical test to verify ILC synchronization performance (cryo insert development and commercial optical RF synchronization system).		0.00	0.00	0.05	0.00	0.00	1.00
		Final CC technology down-selection	Down-select prototype designs (down to 1)	0.00	0.00	0.00	0.00	0.00	0.00
		Preliminary Crab Prototype CM (pCM) design – confirming dressed cavity integration and compliance with beam-line specification (incl HPGS provision)	CM design	0.00	0.00	0.00	0.00	3.50	3.50
		Final pCM engineering design prior to production	CM design	0.00	0.00	0.00	0.00	0.50	0.50
WP-3 (beyond Pre-lab)	Crab Cavity (CC) for BDS #CC production: 2 # CC-CM production: 1	Build pCM to achieve ILC specifications (2 x cavities, couplers, mag/thermal shields, vac vessel, alignment system and instrumentation, including HPGS provisions and VT)	Prototype CM build	0.50	0.25	0.25	0.00	3.00	3.00
		Cold test validation of CC CM (Region TBD)	Cold test prototype CM	0.00	0.05	0.05	0.00	1.00	1.00
		CM Transport frame design and manufacture	Transport frame design	0.00	0.03	0.00	0.00	1.00	0.00
		CM transport frame validation - Transport CM to KEK and re-test (Region TBD)	Transportation test of prototype CM	0.00	0.03	0.00	0.00	1.00	0.00
		Infrastructure for CC and CM development and test (with each regional responsibility.)		0.00	0.00	0.00	0.00	0.00	0.00
				1.00	**0.70**	**0.70**	**0.00**	**15.50**	**14.50**

Post Pre-Lab Timescales TBD

Prep for next Design Review Meeting in June

- Meeting scheduled for 22nd June 2022, 13:30 – 16:00 (UK Time)
- Expectations to have updates for:
  - Cavity optimisation
  - Coupler developments (Input and mode extraction)
  - Pressure/Tuning analysis
  - Multipacting
  - Anything else?
- Criteria for down-selection scheduled for 27th Sept 2022, 13:00 – 18:00 (UK Time):
  - Compliance with specification
  - Technology compliance for 1TeV – identical technology would be preferred
  - Operational contingency – overhead capability, redundancy etc
  - Anything else?