CERN

Availability Studies for CLIC

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Kick-off meeting 03/11/2017

1. **RF system of main linac and drive beam linac.** Contact person: Steffen Doebert

2. **RTML, transfer lines examples.** Contact person: Andrea Latina

3. **Infrastructure, water, ventilation, electricity,…** Contact person: Gerry McMonagle

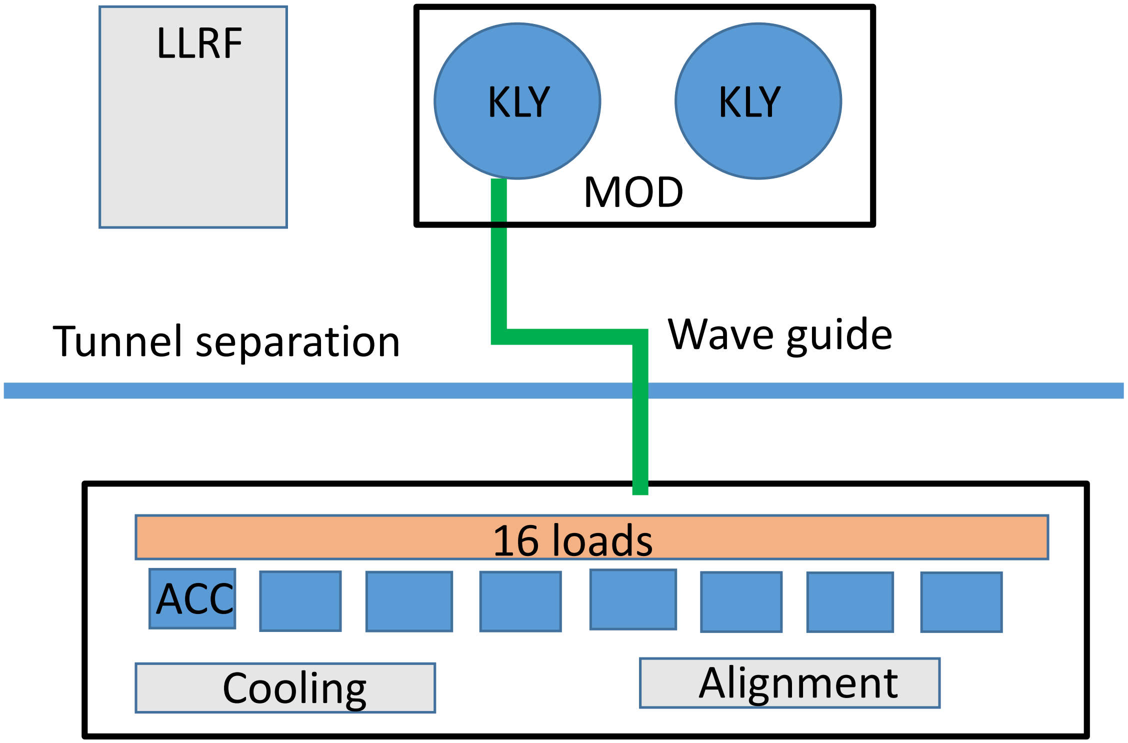
4. **Top down approach, check tables and give input.** Contact person: Roberto Corsini

5. **Luminosity evaluation, beam switching scenarios etc.** Contact person: Daniel Schulte

CLIC Availability models

Estimating CLIC availability from its components reliability

Klystron availability study, fault logic



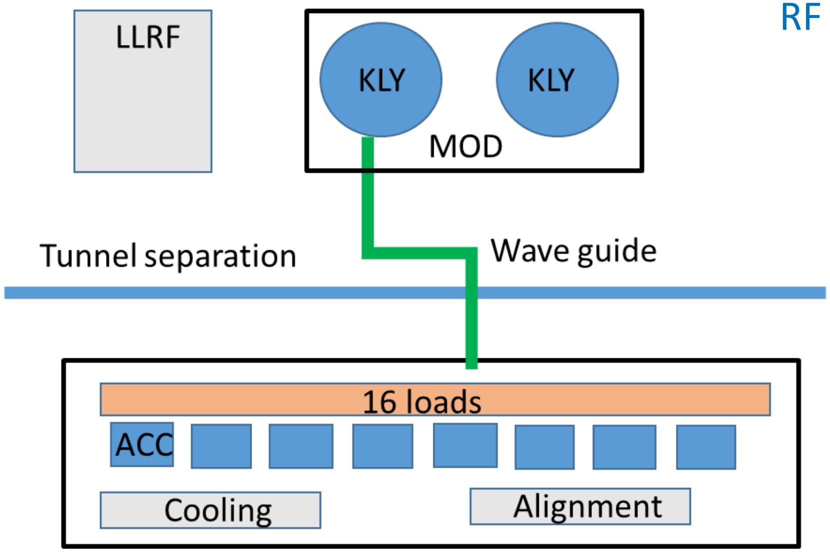
Each element can fail with a MTTF and then can be fixed with MTTR

One can define the consequence of the failure.
Fix offline
Need to be exchanged/repaired in next shutdown

Total of 1500 units (per linac)
150 hot spares

Main Linac Klystron based RF Powering System

CLIC Availability models



RF POWERING SYSTEM

Restart time = 8 h
Access time = 8 h

x 1500
+
150 hot spares

RF MODULE

Restart time = 8 h
Access time = 8 h

x 1500
+
150 hot spares

Failure Mode Name	Distribution	Parameters	Ref.	De sc rip	StandbyState	F a il	A f f	L e g	Corrective Maintenance MTTR	Ref.	I a r	I c .	On-Off Site maintenance	RepairStrategy	Reference System	Simultaneous repairs? (y/n)
Sparking	exponential	8760			COLD				0.03				off	Repairable	0	y
Pressure on the water system	exponential	43800			COLD				6.00				on	Swappable	1	y
Klystron failure	exponential	50000			COLD				12.00				on	Swappable	1	y
Modulator failure	exponential	100000			COLD				12.00				on	Swappable	1	y
Modulator failure 2	exponential	10000			COLD				1.00				off	Repairable	0	y
Loads failure	exponential	50000	2		COLD				3.00	2			on	Swappable	1	y
Wave-guides failure	exponential	100000	2		COLD				3.00	2			on	Swappable	1	y
LLRF failure	exponential	26300			COLD				3.00				off	Swappable	1	y
Alignment failure	exponential	100000			COLD				3.00				off	Swappable	1	y

Main Linac Klystron based RF Powering System

CLIC Availability models

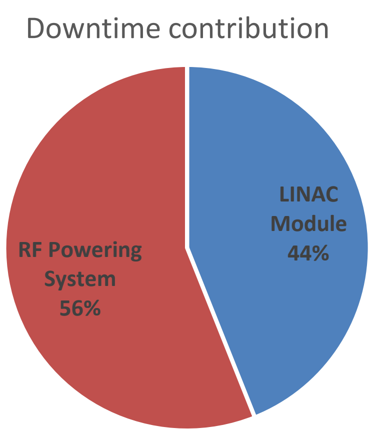
Assumptions

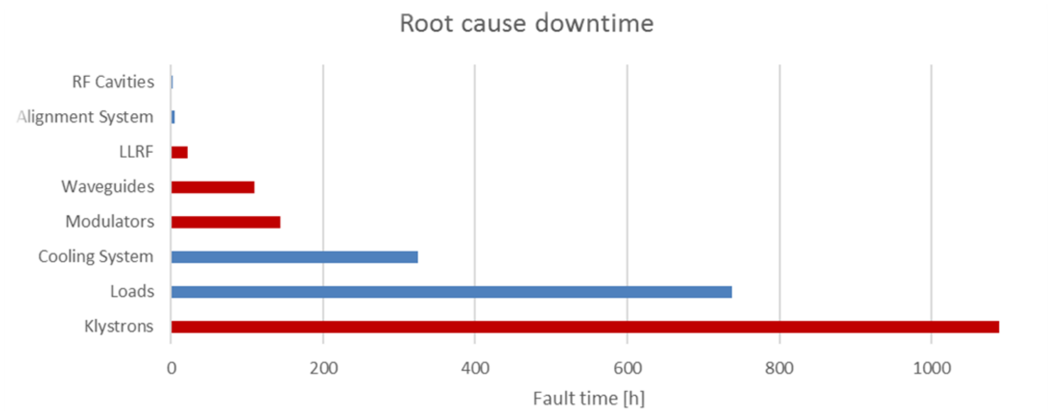
- Simulation period: 1 year (operation 24/7)
- Components failure behaviour follow an exponential distribution
- 150 hot standby spares available every time operation (re)starts
- Maintenance/ repairs:
  - Only repairs when the system is down due to components failures *
  - Repairs can be done simultaneously
  - All repairs must be finished before restating the system

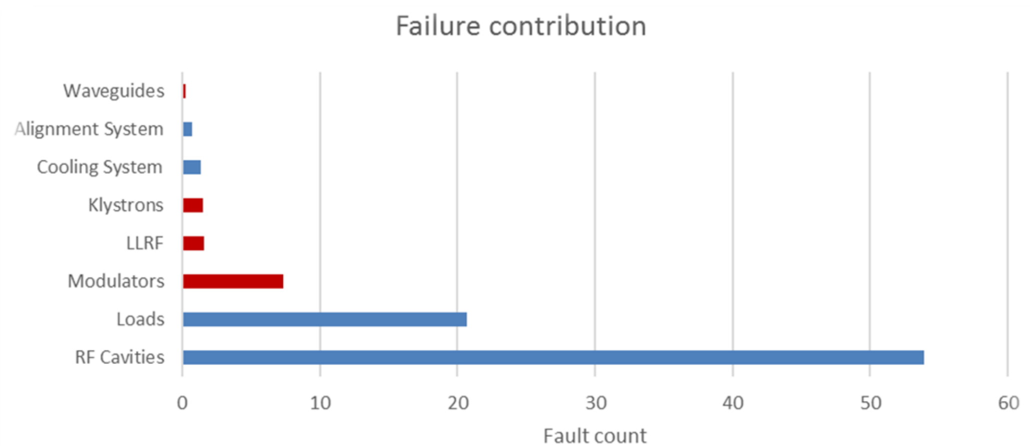
Main Linac Klystron based RF Powering System

CLIC Availability models

Availability	Times Down	Uptime (days)	Downtime (days)	Standard deviation	MTTR (h)	MTBF (h)
72.5%	**87.2**	263.7	101.3	0.002	**27.87**	**100.5**

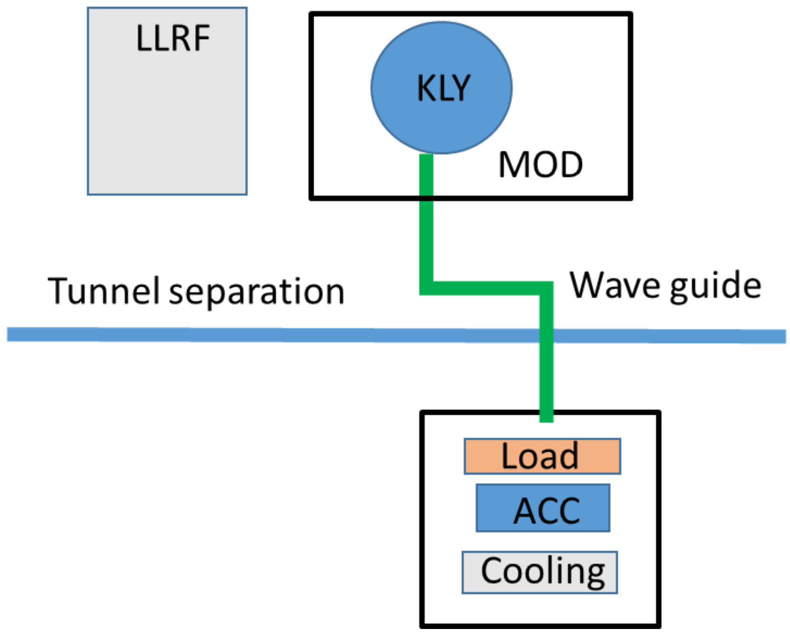






Main Linac Drive Beam based RF Powering System

CLIC Availability models



RF POWERING SYSTEM

Restart time = 1 h
Access time = 8 h

x 500
+
50 hot spares

DB LINAC MODULE

Restart time = 1 h
Access time = 8 h

x 500
+
50 hot spares

Failure Mode Name	Distribution	Parameters	Ref.	StandbyState	Failure during maintenance?	Corrective Maintenance MTTR	Ref.	On-Off Site maintenance	RepairStrategy	Reference System	Repair (y/n)
Sparking	exponential	8760		COLD	NO	0.03		Off	Repairable	0	y
Pressure on the water system	exponential	43800		COLD	NO	6.00		On	Swappable	1	y
Klystron failure	exponential	50000		COLD	NO	12.00		On	Swappable	1	y
Modulator failure	exponential	100000		COLD	NO	1.00		On	Swappable	1	y
Loads failure	exponential	50000	2	COLD	NO	3.00	2	On	Swappable	1	y
Wave-guides failure	exponential	100000	2	COLD	NO	3.00	2	On	Swappable	1	y
LLRF failure	exponential	26300		COLD	NO	3.00		Off	Swappable	1	y
Alignment failure	exponential	100000		COLD	NO	3.00		Off	Swappable	1	y

Main Linac Drive Beam based RF Powering System

CLIC Availability models

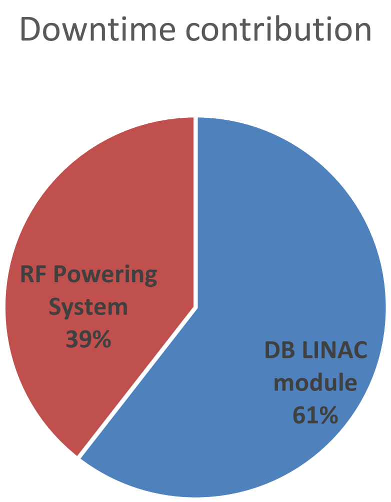
Assumptions

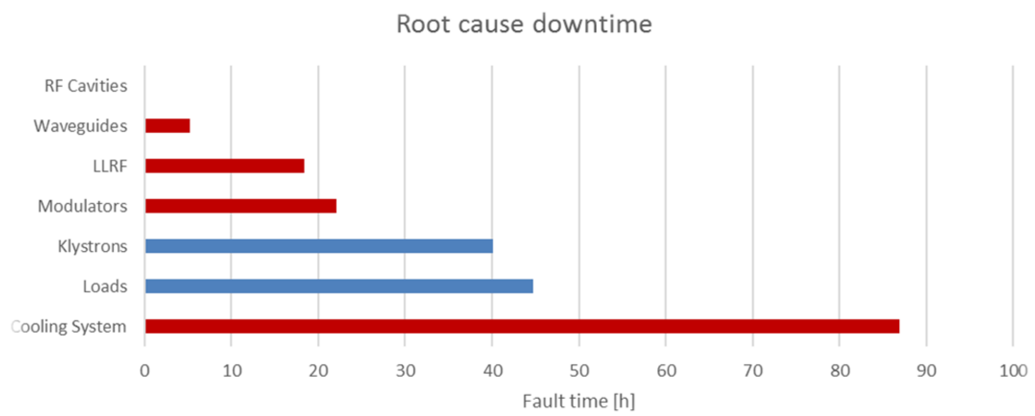
- Simulation period: 1 year (operation 24/7)
- Components failure behaviour follow an exponential distribution
- 50 hot standby spares available every time operation (re)starts
- Maintenance/ repairs:
  - Only repairs when the system is down due to components failures *
  - Repairs can be done simultaneously
  - All repairs must be finished before restating the system

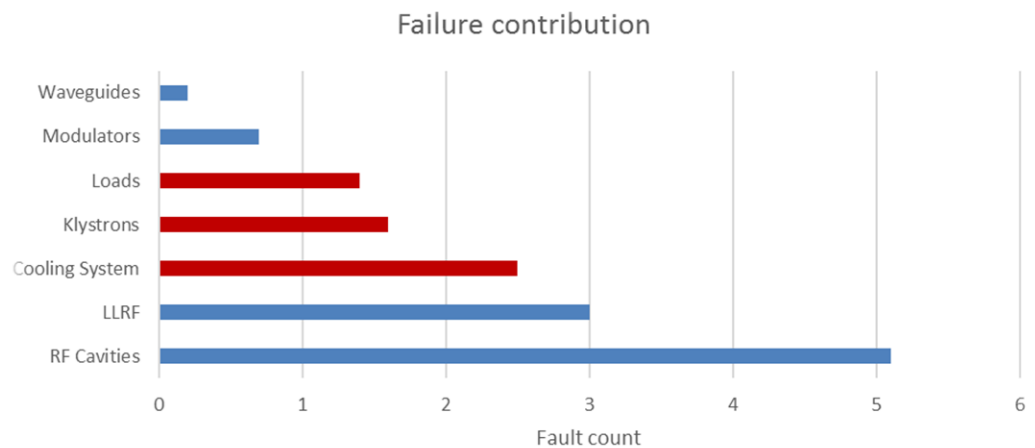
Main Linac Drive Beam based RF Powering System

CLIC Availability models

Availability	Times Down	Uptime (days)	Downtime (days)	Standard deviation	MTTR (h)	MTBF (h)
97.6%	**14.5**	355.9	9.1	0.001	**15**	**604.1**



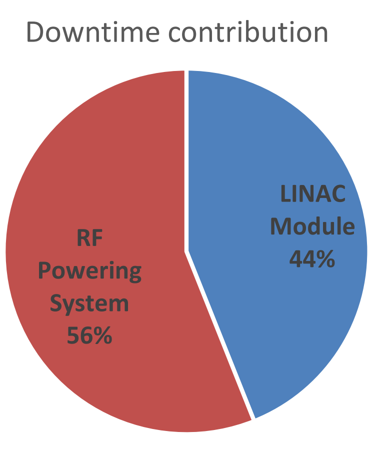


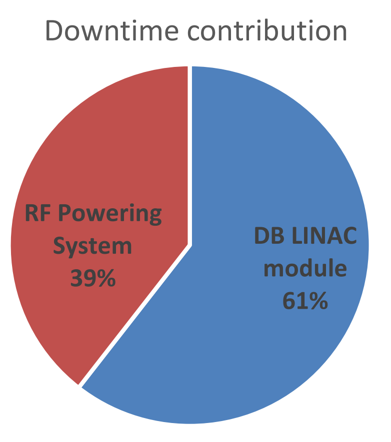


Main Linac RF Powering System

CLIC Availability models

	Availability	Times Down	Uptime (days)	Downtime (days)	Standard deviation	MTTR (h)	MTTF (h)	No. of components
Klystron based	**72.5%**	**87.2**	263.7	101.3	0.002	**27.87**	**100.5**	46 500
Drive Beam based	**97.6%**	**14.5**	355.9	9.1	0.001	**15**	**604.1**	3 500





Main Linac RF Powering System

CLIC Availability models

Conclusions

Klystron based powering

- The components in greater number (klystrons, loads) are governing the system availability
- The powering system could operate for around 100 hours before running out of spares

Drive Beam based powering

- Components with high failure frequency and repair time (cooling system, loads) are governing the system availability
- The powering system could operate around 600 hours before running out of spares

Next steps…

- Analyse impact of failures repairable at the moment of occurrence on the results * -> Expected higher availability
- Estimate the number of spares needed to survive until certain point in time
- Sensitivity analysis of failure rates
- Further extension of models

Infrastructure and technical services

CLIC Availability models

Status

- Hardware description completed
- Failure modes analysis on-going

Next steps…

- ➢ Organize meetings with system experts to gather data on the failure modes
- ➢ Run first simulations
- ➢ Gradually increase complexity of the model by adding access-times by location, dependencies among systems, etc.

RTML and Damping Rings

CLIC Availability models

- Table exported from the RTML optics files
- More than 4000 lines

-1* <STR>		<STR>	[m]	[m]	[GeV]	[m^-1]	[m^-1]	[m^-2]	[m^-2]	[m^-1]	[rad]	[rad]	[rad]	
0* NAME	sub region (guessed)	KEYWORD	S	L	E0	K1L	K1SL	K2L	K2SL	KS	ANGLE	E1	E2	proto strength parameter
1	SRmatchIN	BPM	0.0	0	2.86	0	0	0	0	0	0	0	0	--
2SRmatchIN	SRmatchIN	QUADRUPOLE	0.2	0.15	2.86	0.101521	0	0	0	0	0	0	0	Q_0.101521
3DIQ-SRmatchIN-1	SRmatchIN	KICKER	0.2	0	2.86	0	0	0	0	0	0	0	0	--
4	SRmatchIN	BPM	3.2	0	2.86	0	0	0	0	0	0	0	0	--
5SRmatchIN	SRmatchIN	QUADRUPOLE	3.5	0.3	2.86	-0.247039	0	0	0	0	0	0	0	Q_0.247039
6DIQ-SRmatchIN-2	SRmatchIN	KICKER	3.5	0	2.86	0	0	0	0	0	0	0	0	--
7	SRmatchIN	BPM	6.5	0	2.86	0	0	0	0	0	0	0	0	--
8SRmatchIN	SRmatchIN	QUADRUPOLE	6.8	0.3	2.86	0.203042	0	0	0	0	0	0	0	Q_0.203042
9DIQ-SRmatchIN-3	SRmatchIN	KICKER	6.8	0	2.86	0	0	0	0	0	0	0	0	--
10	SRmatchIN	BPM	9.8	0	2.86	0	0	0	0	0	0	0	0	--
11SRmatchIN	SRmatchIN	QUADRUPOLE	10.1	0.3	2.86	-0.247039	0	0	0	0	0	0	0	Q_0.247039
12DIQ-SRmatchIN-4	SRmatchIN	KICKER	10.1	0	2.86	0	0	0	0	0	0	0	0	--
13	SRmatchIN	BPM	13.1	0	2.86	0	0	0	0	0	0	0	0	--
14SRmatchIN	SRmatchIN	QUADRUPOLE	13.4	0.3	2.86	0.203042	0	0	0	0	0	0	0	Q_0.203042
15DIQ-SRmatchIN-5	SRmatchIN	KICKER	13.4	0	2.86	0	0	0	0	0	0	0	0	--
16	SRdiag	BPM	16.4	0	2.86	0	0	0	0	0	0	0	0	--
17SRdiag	SRdiag	QUADRUPOLE	16.7	0.3	2.86	-0.247039	0	0	0	0	0	0	0	Q_0.247039
18DIQ-SRdiag-1-2	SRdiag	KICKER	16.7	0	2.86	0	0	0	0	0	0	0	0	--
19	SRdiag	BPM	19.7	0	2.86	0	0	0	0	0	0	0	0	--
20SRdiag	SRdiag	QUADRUPOLE	20.0	0.3	2.86	0.203042	0	0	0	0	0	0	0	Q_0.203042
21DIQ-SRdiag-1-2	SRdiag	KICKER	20.0	0	2.86	0	0	0	0	0	0	0	0	--
22	SRdiag	BPM	23.0	0	2.86	0	0	0	0	0	0	0	0	--
23SRdiag	SRdiag	QUADRUPOLE	23.3	0.3	2.86	-0.247039	0	0	0	0	0	0	0	Q_0.247039
24DIQ-SRdiag-2-2	SRdiag	KICKER	23.3	0	2.86	0	0	0	0	0	0	0	0	--
25	SRdiag	BPM	26.3	0	2.86	0	0	0	0	0	0	0	0	--
26SRdiag	SRdiag	QUADRUPOLE	26.6	0.3	2.86	0.203042	0	0	0	0	0	0	0	Q_0.203042
27DIQ-SRdiag-2-2	SRdiag	KICKER	26.6	0	2.86	0	0	0	0	0	0	0	0	--
28	SRdiag	BPM	29.6	0	2.86	0	0	0	0	0	0	0	0	--

RTML and Damping Rings

CLIC Availability models

- Post processing: Count by region and Component type
- Magnets of same strength powered together?

Frist Elem	N Elem	sub region (guessed)	sub region (guessed and completed)	S-start	SBEND	QUADRUPOLE	SEXTUPOLE	KICKER	BPM	CAVITY	SOLENOID	total	comments	SBEND families	QUADRUPOLE families	SEXTUPOLE families	SOL families
1	15	SRmatchIN	0010_match_dr_to_rtml	0	0	5	0	5	5	0	0	15		--	1x1Q, 2x2Q		
16	99	SRdiag	0030_dump_and_match_diag_to_sr	16.35	0	33	0	33	33	0	0	99		--	4x1Q, 1x14Q, 1X15Q		
115	101	SR	0040_spin_rotator	124.45	6	30	1	30	30	0	4	101		1x6D	8x1Q, 2x3Q, 2x8Q	1xS	2x2SOL
216	15	SRmatchOUT	0050_match_sr_to_bc1_rf	254.85	0	5	0	5	5	0	0	15		--	5x1Q		
231	32	060	0060_bc1_rf	267.65	0	4	0	4	4	20	0	32		--	2x2Q -- (2x2Q strength 120)		
263	12	BC1match1	0070_match_bc1_rf_to_chicane	310.05	0	4	0	4	4	0	0	12		--	4x1Q		
275	4	080	0080_bc1_chicane	338.65	4	0	0	0	0	0	0	4		1x4D	--		
279	15	BC1match2	0090_match_bc1_to_diag	367.73	0	5	0	5	5	0	0	15		--	5x1Q		
294	87	BC1diag	0100_diagnostics_2	385.03	0	29	0	29	29	0	0	87		--	1x14Q, 1x15Q -- 1x15Q strength Srdiag		
381	16	BC1matchOUT	0110_dump_and_match_diag_to_booster	480.73	0	5	0	5	6	0	0	16		--	5x1Q		
397	480	120	0120_booster_linac	493.58	0	68	0	68	68	276	0	480		--	2x34Q -- all need trimmers		
877	66	Boomatch	0130_dump_and_match_booster_to_ca	1031.8	0	22	0	22	22	0	0	66	4 FF1BPM	--	6x2hQ, 1x10(4+6)hQ		
943	896	CA	0140_central_arc	1132.8	149	209	120	209	209	0	0	896		1x149D -- strength CA	3x60Q, 1x29Q -- trimmers for e-loss?	2x30S, 1x60S	
1839	31	140	0140_central_arc	2084.7	6	7	4	7	7	0	0	31		1x6D -- strength CA	3x2Q, 1x1Q -- (3x2Q strength CA	4X1	
1870	174	150	0150_vertical_transfer	2121.3	6	54	4	57	54	0	0	175	4 FF1 kicker	1x2D, 1x4D	1x1Q, 4x2Q, 2x4Q, 1x7Q,1x8Q + 6x2hQ, 1x10(4+6)hQ -- mixture of half and whole quads, need to split region	1X4	
2044	55	160	0160_match_vt_to_ltl	3668.1	5	15	4	15	15	0	0	54		1x5D -- strength CA	9x1Q, 3x2Q -- (3x2Q strength CA	4X1 -- same strength as 140	
2099	72	170	0170_long_transfer_line	3820.4	0	24	0	24	24	0	0	72		--	1x24Q		
2171	72	180	0180_dump_and_match_ltl_to_tal	9078.3	4	30	0	30	8	0	0	72	4 FF2BPM	1x4D	4x2hQ, 3x4hQ, 1x10(4+6)hQ-- 10hQ strength Boomatch		
2243	297	left	0190_turn_around_loop	9265.1	50	69	40	69	69	0	0	297		1X50D -- strength CA	3x20, 1x9 -- strength CA -- trimmers for e-loss?	2x20S -- strength CA	
2540	63	middle	0190_turn_around_loop	9580.4	0	21	0	21	21	0	0	63		--	3x2Q, 7x1Q, 1x8Q		
2603	1197	right	0190_turn_around_loop	9934	200	279	160	279	279	0	0	1197		1X200D -- strength CA	1x39Q, 3x80Q -- strength CA -- trimmers for e-loss?	4x40S -- strength CA	
3800	66	match	0200_match_tal_to_bc2_rf	11209	0	22	0	22	22	0	0	66		--	6x2hQ, 1x10(4+6)hQ -- 1x10hQ strength 150		
3866	114	210	0210_bc2_rf	11238	0	12	0	12	12	78	0	114		--	1x12Q		
3980	12	220	0220_match_bc2_rf_to_chicane_1	11265	0	4	0	4	4	0	0	12		--	4x1Q		
3992	4	230	0230_bc2_chicane_1	11280	4	0	0	0	0	0	0	4		1x4D	--		
3996	12	240	0240_match_bc2_chicanes	11310	0	4	0	4	4	0	0	12		--	4x1Q		
4008	4	250	0250_bc2_chicane_2	11326	4	0	0	0	0	0	0	4		1x4D	--		
4012	12	260	0260_match_bc2_to_diag	11355	0	4	0	4	4	0	0	12		--	4x1Q		
4024	24	270	0270_diagnostics_3	11368	0	8	0	8	8	0	0	24		--	1x8Q		
4048	19	280	0280_dump_and_match_rtml_to_main_linac	11450	0	6	0	6	7	0	0	19		--	1x0Q, 5x1Q		
4067		ml		11467	0	0	0	0	0	0	0	0	main linac				
		total			**438**	**978**	**333**	**981**	**958**	**374**	**4**	4066					

RTML and Damping Rings

CLIC Availability models

Status

- Hardware description exported from the RTML and Damping Rings optics files
- Post processing: Count by region and Component type
- Magnets of same strength powered together?

Next steps…

- Organize meetings with magnet experts to see witch type of magnets to be used (based on magnet strength) and then with power-converter experts for powering schemes.
- Define how we can determine redundancies in BPMs and correctors.
- Failure modes analysis

Availability allocation by complexity criteria

Top-down approach

Availability allocation by complexity criteria

1. List the CLIC systems

i	System
1	Main Beam Injectors
2	Damping Ring Complex
3	Beam Transport - RTML
4	Drive Beam Injectors
5	Recombination Complex
6	Long Trasnfer Lines and TA Loops
7	Two Beam Modules
8	Post decelerators
9	Beam delivery system
10	Post-collision line
11	Technical Network
12	Machine Interlocks
13	Access Safety and Controls system
14	Technical Alarm system

Availability allocation by complexity criteria

1. Determine scales

Factor		*RPN	Repair time	Criticality	Intricacy	State of art	Performance time	Environment
Importance weight			0.166666667	0.166666667	0.166666667	0.166666667	0.166666667	0.166666667
Scoring scale		Only if FMEA available, Average of all system failure modes RPN	10: highest repair time 1: lowest repair time	Scale from 1 to 10	Scale from 1 to 10 10: highly intricate system 1: less intricate system	1: Innovative 0.67: existing 0.33: established	1: whole mission time 0.67: Continious and long times 0.33: instantaneous	1: highly radioactive 0.67: average radioactive 0.33: low radioactive
System	Main Beam Injectors	_	8	10	9	0.67	1	0.67
	Damping Ring Complex	_	4	10	8	1	1	0.67
	Beam Transport - RTML	_	5	6	5	0.67	1	0.67
	Drive Beam Injectors	_	4	10	7	0.67	1	0.67
	Recombination Complex	_	5	8	7	1	1	0.67
	Long Transfer Lines and TA Loops	_	3	6	5	0.67	1	0.67
	Two Beam Modules	_	10	9	10	1	1	0.67
	Post decelerators	_	7	1	1	0.33	1	1
	Beam delivery system	_	6	7	6	1	1	0.67
	Post-collision line	_	9	2	2	0.67	1	1
	Technical Network	_	6	6	4	0.33	1	0.33
	Machine Interlocks	_	2	5	3	0.33	1	0.33
	Access Safety and Controls	_	1	5	2	0.33	1	0.33
	Technical Alarm system	_	2	4	2	0.33	1	0.33

Availability allocation by complexity criteria

2. DEMATEL procedure

M(i,j): degreee to which system i affects system j. Would a failure in system i affect the operating state of system in column j?

0: None / No influence
1: Very Minor / Low influence
2: Minor / High influence
3: Low / Very high influence

i	j	1 Main Beam Injectors	2 Damping Ring Complex	3 Beam Transport - RTML	4 Drive Beam Injectors	5 Recombination Complex	6 Long Trasnfer Lines and TA Loops	7 Two Beam Modules	8 Post decelerators	9 Beam delivery system	11 Post-collision line	12 Technical Network	13 Machine Interlocks	14 Access Safety and Controls system	15 Technical Alarm system
1	Main Beam Injectors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Damping Ring Complex	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Beam Transport - RTML	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Drive Beam Injectors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Recombination Complex	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Long Trasnfer Lines and TA Loops	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Two Beam Modules	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Post decelerators	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Beam delivery system	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Post-collision line	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Technical Network	2	2	2	2	2	2	2	2	2	2	0	1	1	1
13	Machine Interlocks	2	2	2	2	2	2	2	2	2	2	0	0	0	0
14	Access Safety and Controls system	1	1	1	1	1	1	1	1	1	1	0	0	0	0
15	Technical Alarm system	1	1	1	1	1	1	1	1	1	1	0	0	0	0

Availability allocation by complexity criteria

3. Computation of complexity index

- **FOO technique – ISPE factors – FOUR Factors product**

  Intricacy, **S**tate of Art, **P**erformance Time, **E**nvironment

- **Average weighting allocation method - ALL Factors product (Karmiol, Geometric)**

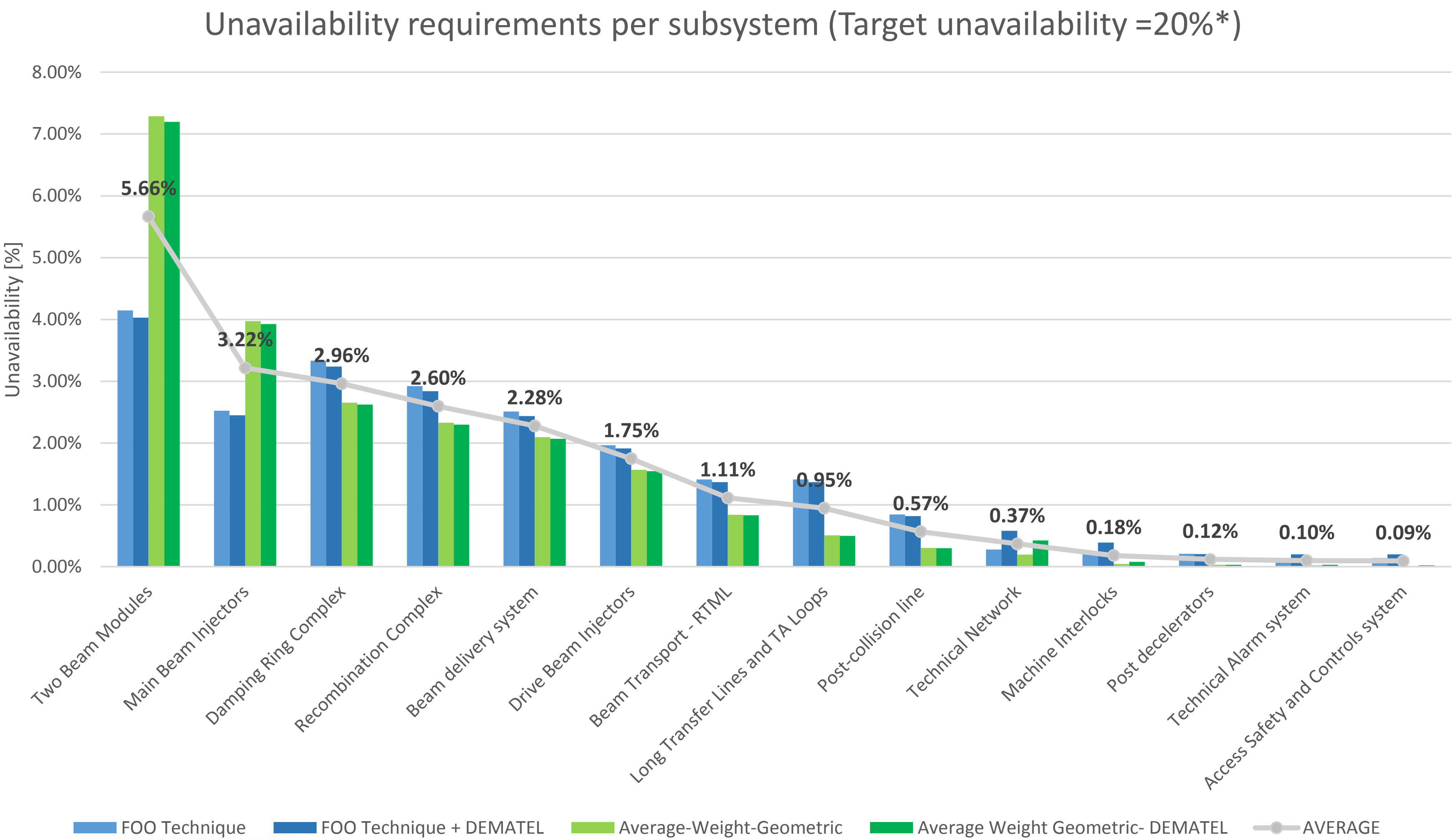
+ + + DEMATEL procedure

- An expert evaluates the relationship between subsystems of paired alternatives
- The pair wise comparison scale is designated into 4 levels
- Higher indirect relationship, higher complexity weight allocation

Availability allocation by complexity criteria

4. Availability allocation

***Data from CLIC CDR vol. 3**
Total days in production=177
Production=221 days
Fault induced downtime=44 days



Availability allocation by complexity criteria

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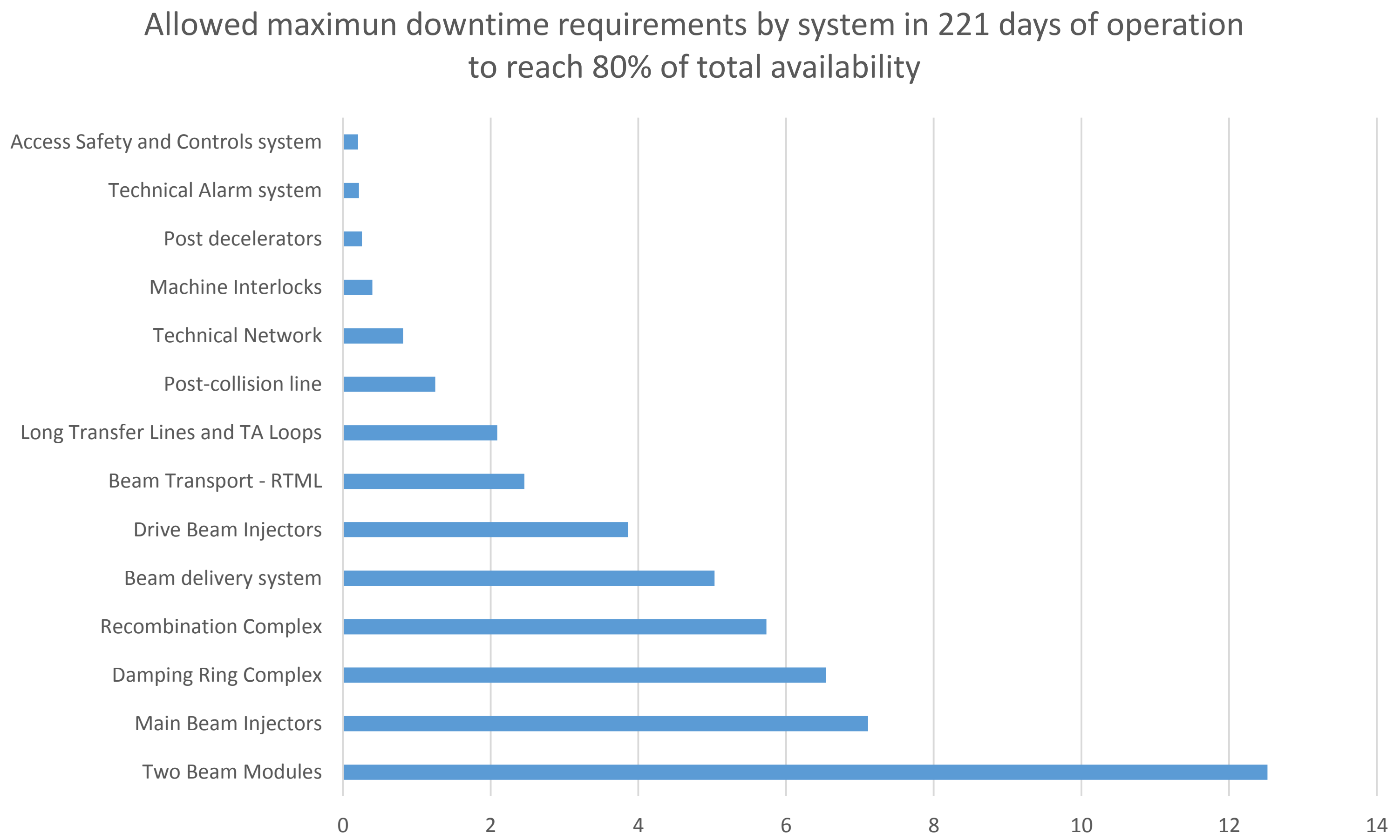
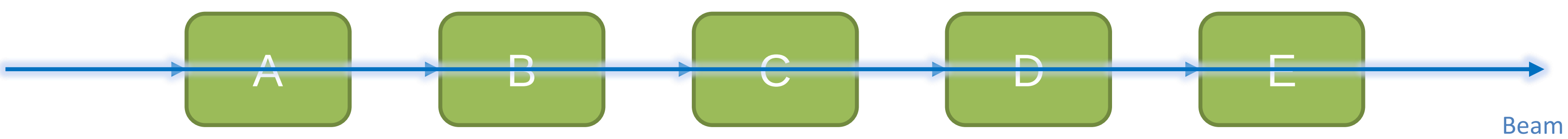


Integrated luminosity as a function of availability

Understanding CLIC operating cycle

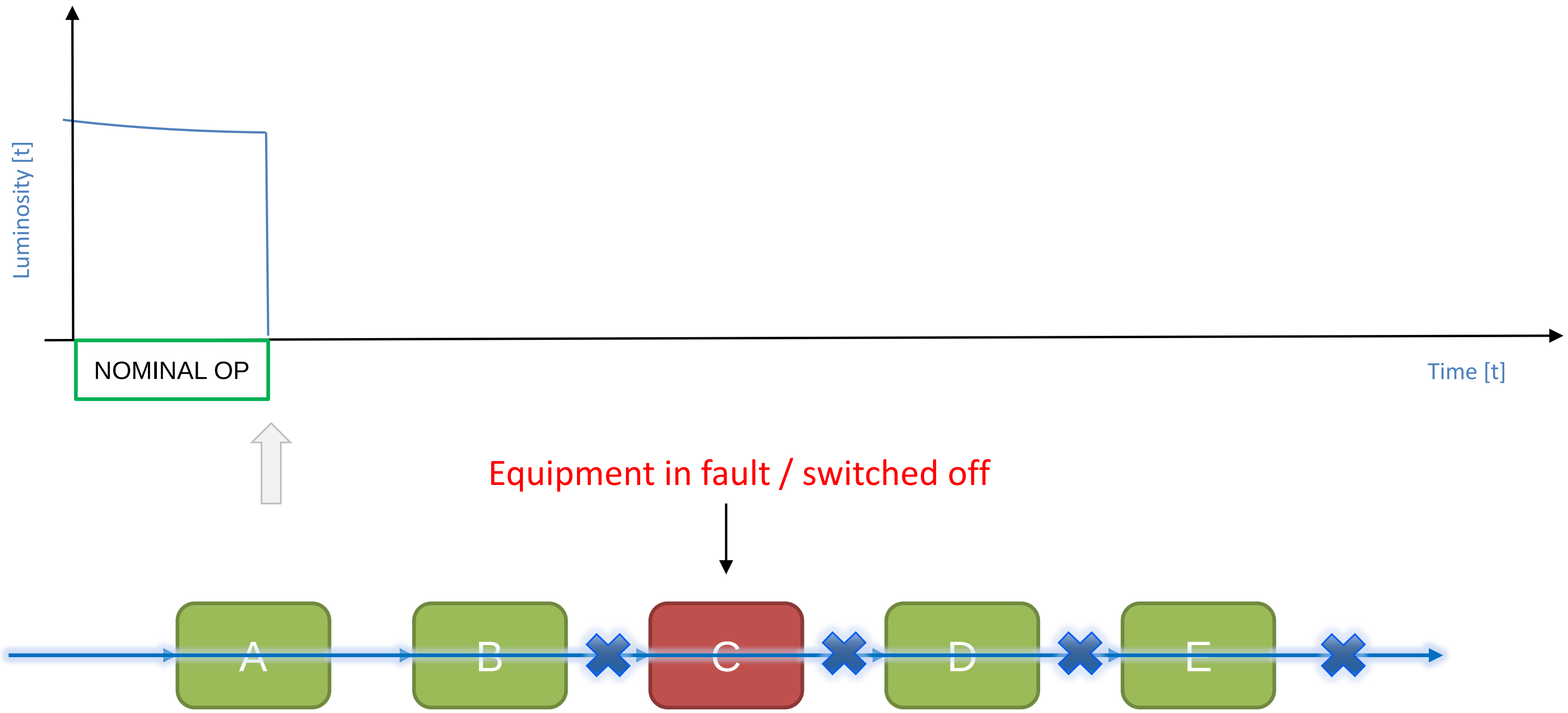
Understanding CLIC Operating cycle

Successive subsystems in CLIC complex



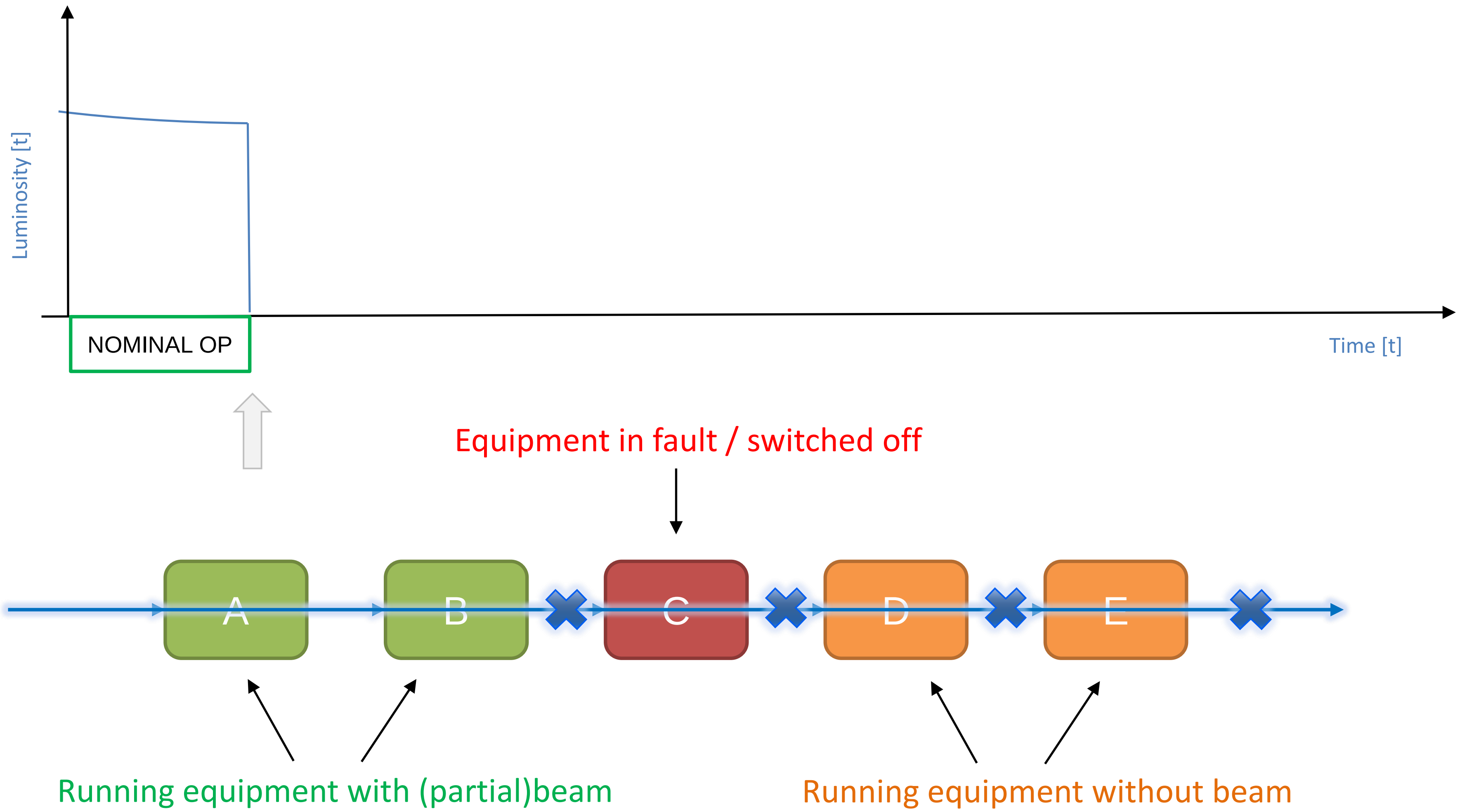
Understanding CLIC Operating cycle

Fault time



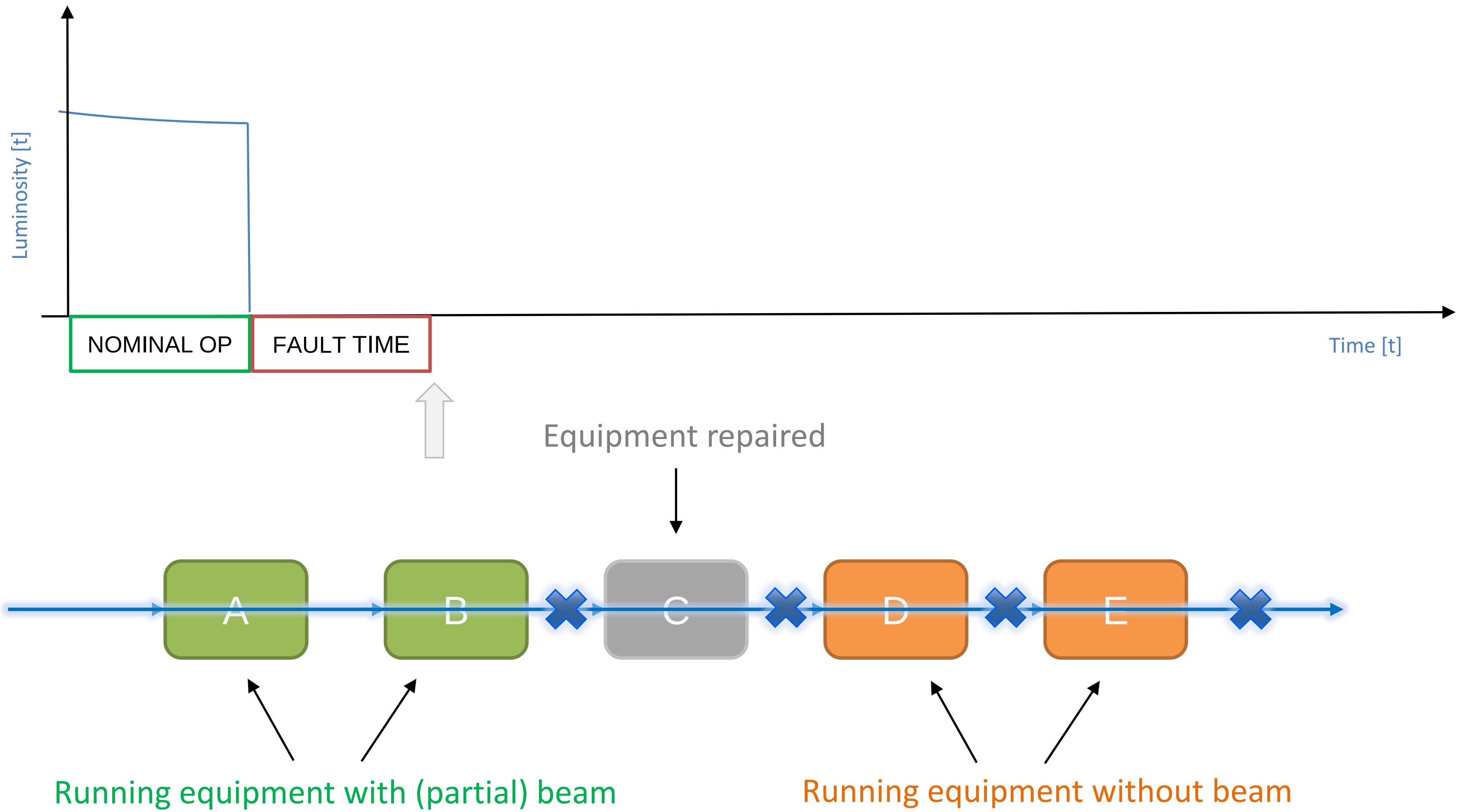
Understanding CLIC Operating cycle

Fault time



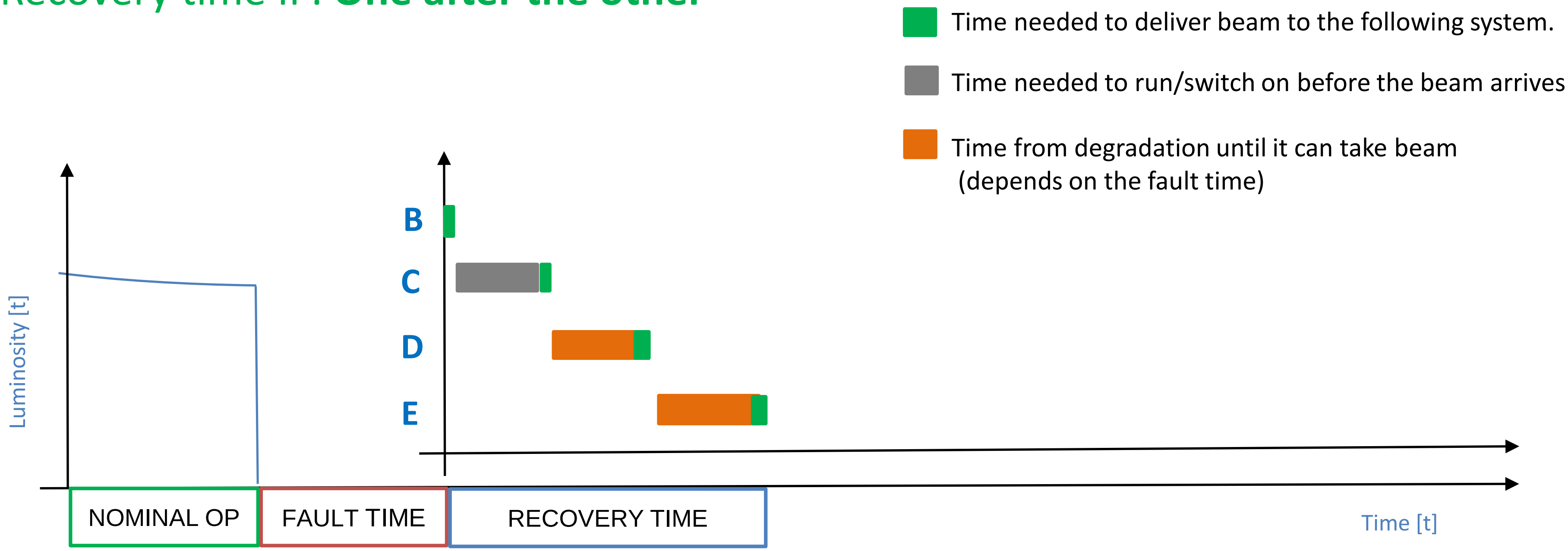
Understanding CLIC Operating cycle

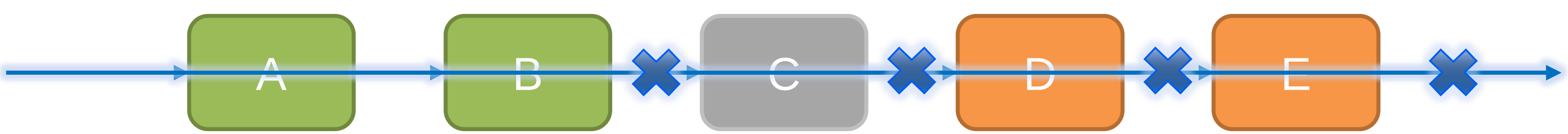
Fault time



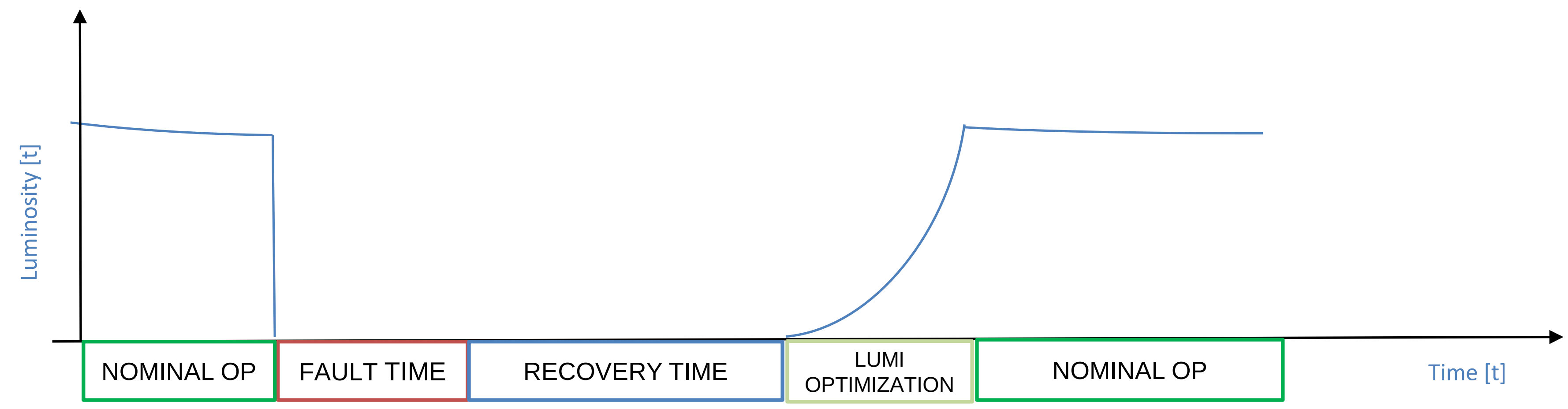
Understanding CLIC Operating Cycle

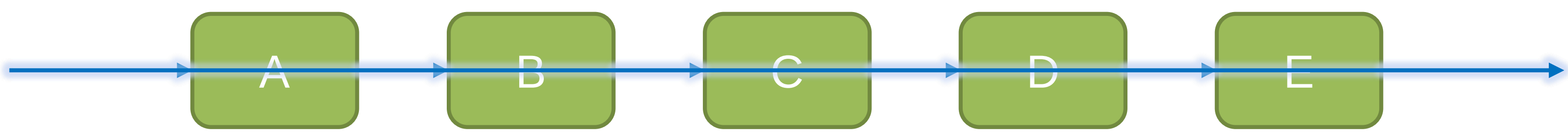
Recovery time II : **One after the other**





CLIC Operating cycle





- **Luminosity optimization:** Time to reach nominal operating conditions/ luminosity after the first collisions.
- **Nominal operation / Luminosity production**

CLIC failure scenarios I

Operational Impact of faults, tuning and recovery

- **Short trips without beam interruption** -> Minimal Luminosity loss

  Example: RF Breakdown

  Expected rate: every 100 pulses, i.e 100x20ms = 2 seconds.

  Recovery: None, occasionally a minor Luminosity Optimization could be needed.

- **Short trips with short beam interruption** -> Short Luminosity loss

  Example: Spurious machine protection interlocks, possibly due to glitches in the BLM, possibly caused by some of the RF breakdown

  Expected rate: every ~ 100^2 pulses, 5 minutes.

  Recovery: Short (2 second?) Machine Validation with luminosity interruption, but not affecting machine performance.

CLIC failure scenarios II

Operational Impact of faults, tuning and recovery

➢ **Beam-off for repair without access to the accelerator housing**

- If the beam off time is short (**Fault time ~30 min**) -> **equipment running with (partial) beam** -> recovery will only require short tuning -> Recovery ≈ 0.5h (re-steering the golden orbits with some final IP tuning, machine validation)

  Example: Equipment breakdown and swap with hot spare (either remote controlled in the accelerator housing or on the surface by operator on duty.)

- If the beam off time is long enough (**30 min < Fault time < 4 h**)
  - **Running equipment with (partial) beam:** Unaffected systems -> recovery will only require short tuning -> Recovery = Time needed to deliver beam to the following system
  - **Running equipment without beam:** Affected systems -> equipment performance will be degraded-> Recovery = time from degradation until it can take beam (depends on the fault time) + time needed to deliver beam to the following system

  Example: Equipment breakdown requiring expert to come to change hardware (outside the accelerator housing).

CLIC failure scenarios III

Operational Impact of faults, tuning and recovery

- **Beam-off for a repair with access to the accelerator housing (Fault time >4h)**

  - If **Fault time short < ?? h** -> Partial beam kept

    - **Running equipment with (partial) beam:** Unaffected systems -> recovery will only require short tuning -> Recovery = Time needed to deliver beam to the following system

    - **Running equipment without beam (**Affected systems) -> equipment performance will be degraded-> Recovery = time to recover from degradation until it can take beam (depends on the fault time) + time needed to deliver beam to the following system

    - **Faulty or off systems**: Equipment switched off without beam -> will be switched on when fault cleared-> Recovery= Time needed to run/switch on before the beam arrives + time needed to deliver beam to the following system

  - If **Fault time long>> ?? h** -> Beam is switched of to safe power comsumption

    - **Faulty or off systems**: Equipment switched off without beam -> will be switched on when fault cleared-> Recovery= Time needed to run/switch on before the beam arrives + time needed to deliver beam to the following system

Failure effect relations

	Standby with beam	Standby with reduced beam	Standby partial with beam	Standby no beam	Out
Description	Running equipment with beam	Running equipment with partial beam	Running equipment with/ and without beam	Running equipment without beam	Faulty / Off equipment
Recovery = Time needed to…	send beam to the following sytem	send beam to the following sytem		recover from degradation + send beam to following system	run before beam arrives + send beam to the following system

Failure \ Effect	MB source	MB injector	MB PDR	MB DR	MD Booster Linac	MB RTML	Main Linac	BDS	Collision/Interaction Point	Dump	DB source	DB linac	DB CBR	DB transport	DB Post decelerators
MB source	out	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with reduced beam
MB injector	Standby with beam	Out	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with reduced beam
MB PDR	Standby with beam	Standby with beam	out	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with reduced beam
MB DR	Standby with beam	Standby with beam	Standby with beam	out	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with reduced beam
MD Booster Linac	Standby with beam	Standby with beam	Standby with beam	Standby with beam	out	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with reduced beam
MB RTML	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	out	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with reduced beam
Linac	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	out	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with reduced beam
BDS	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	out	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam
Collision	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	out	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam
Dump	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Out	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam
DB source	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	out	Standby no beam	Standby no beam	Standby no beam	Standby no beam
DB linac	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	out	Standby no beam	Standby no beam	Standby no beam
DB CBR	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	out	Standby no beam	Standby no beam
DB transport	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby no beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	out	Standby no beam
DB decelerators	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Standby partial with beam	Standby no beam	Standby no beam	Standby no beam	Standby with beam	Standby with beam	Standby with beam	Standby with beam	Partial Out

Understanding CLIC Operating Cycle

Failure frequency and repair times

System	Failure frequency	Fault Repair time [h]
MB source		
MB injector		
MB PDR		
MB DR		
MD Booster Linac		
MB RTML		
Linac		
BDS		
Collision		
Dump		

DB source		
DB linac		
DB CBR		
DB transport		
DB decelerators		

Understanding CLIC Operating Cycle

Recovery times

System \ Duration [h]	Standby with beam	Standby with reduced beam	Standby partial with beam	Standby no beam	Out
MB source			x		
MB injector			x		
MB PDR			x		
MB DR			x		
MD Booster Linac			x		
MB RTML			x		
Linac			x		
BDS		x	x		
Collision		x	x		
Dump		x	x		
DB source		x	x		
DB linac		x	x		
DB CBR		x	x		
DB transport		x	x		
DB decelerators		x			

Summary & Outlook

Availability models

Summary and Outlook

Main Beam RF Powering System

- Analyse impact of failures repairable at the moment of occurrence on the results * -> Expected higher availability
- Estimate the number of spares needed to survive until certain point in time
- Sensitivity analysis of failure rates
- Further extension of models

Infrastructure and technical services

- Organize meetings with system experts to gather data on the failure modes
- Run first simulations
- Gradually increase complexity of the model by adding access-times by location, dependencies among systems, etc.

RTML and Delay Loops

- Organize meetings with magnet experts to see witch type of magnets to be used (based on magnet strength) and then with power-converter experts for powering schemes.
- Define how we can determine redundancies in BPMs and correctors.
- Failure modes analysis

CLIC Availability allocation

Summary and Outlook

- Exercise done at high level, good results
- Next step: Allocation at lower level
- Complexity assessment by more than one expert

Luminosity Production model

Summary and Outlook

- Agreement on the phases definition and failure scenarios
- Estimate recovery and tuning times
- Monte-Carlo Model implementation

Thank you!

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