LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

Upcoming Change Requests

Benno List, DESY

TCMB Meeting

22.2.2017

What is the TCMB's Role?

- Make sure that the technical design of the ILC stays sound
- Make sure that the design is still based on an international consensus and supported by the international community
- Advice the ILC director

How do we achieve that?

- Demand that changes to the baseline design are documented as Change Requests
- Make sure that Change Requests are properly reviewed by a Change Review Panel
- Decide on Change Requests based on CRP recommendation
- Make sure that Change Requests are distributed to share holders (esp. P&D)

Constraints

- TCMB members have limited resources to perform studies / conduct work
- TCMB will be sort of an advisory panel
- Handle administrative tasks for Change Requests outside TCMB meeting (Benno will continue to serve as Change Administrator)

Where are We Heading?

- Conclusion from Morika seems to be:
  - We are heading for an initial 250GeV stage (saves ~25-30% cost)
  - We have to save money on top of staging -> higher gradient goal

My beliefs:

- The International ILC Community (the LCC) has to give a consistent message
- The LCC should work out a proposal for a 250 GeV stage that is
  - Financially acceptable for the funding agencies (primarily MEXT, but not only)
  - Appealing to and supported by the international experimental community
  - A consensus among the accelerator community
- This proposal needs to be defined by summer 2017

What to Do

- Formulate the proposal ahead of ALCW2017
- Form the consensus in Santa Barbara
- **Write a Report!**

Cryomodule Performance

- A.k.a. “new gradient goal” (31.5 -> 35MV/m?)
- Specify: New performance goal for cavities in cryomodules during beam op.
- Needs more than a single number:
  - Gradient in vertical test stand <-> assumption about performance loss in cryomodules
  - Q0 at operating gradient
  - Goal for fabrication cost (same as TDR?)
  - Goal for yield and acceptable gradient spread (stick to +/- 20%?)
  - Goal / strategy for tests
- Higher gradient goal is higher risk -> have to specify a risk mitigation strategy
  - Build to performance (target gradient) whatever the cost **versus**
  - Build to cost (target yield) and have room for addt’l modules
- New gradient goal is basis for all further studies -> need a consensus asap
- Basis for shorter tunnel
- Lots of technical implications (cryo load, klystron power, modulators, couplers) -> implications on top level parameters (bunches, current -> luminosity!)
- **Who formulates a new gradient consensus?**

250GeV Staged Machine Parameters

- Formulate a set of top-level parameters for a 250GeV stage
- TDR baseline set refers to 500GeV machine running at half gradient
  -> this is different!
- Consider a minimal machine (initial set up) plus a lumi upgrade
- Urgently needed by physics group
- Specify:
  - Beam energy, luminosity
  - Bunch charge, pulse length, current etc
  - Assumed IP characteristics (beta*, emittance, beam disruption,…)
    -> see „New Damping Ring Parameters“
- Develop some luminosity upgrade scenario, e.g.
  - install more klystrons, more cryo power, build 2nd positron DR
    -> double bunches per pulse -> double lumi
  - Install even more cryo and go to higher rep-rate?
  - Generally: buy equipment needed for 500GeV energy upgrade anyway
- Upgrade scenario puts constraints on initial configuration (extendability)
  -> layout of Main Linac, space for more cryo power

500GeV High-Level Parameters

- Choice of new gradient will affect either/or
  - Top level parameters: bunch charge, number of bunches, pulse length OR
  - Power consumption (HLRF, cryo, fill time, etc)
  - Cryogenic Power calculation
- These Documents are the basis for the specification of all subsystems, such as
  - Positron source
  - Damping rings
  - Cryo plants
  - Cryomodules, klystrons, couplers…

- Also: Top level parameter list should contain entries for lumi upgrades that correspond to H-20 scenario used by physics group
- And: Check if goals for emittance at IP may be adjusted (-> DR parameters)

Top-Level Parameters (D*925325)

IP and General Parameters

TF = Traveling Focus

								L Upgrade	*E_{cm} Upgrade*		
Centre-of-mass energy	E_{cm}	**GeV**	**200**	**230**	**250**	**350**	**500**	**500**	**1000**	**1000**	***comment***
									A1	*B1b*	
Beam energy	E_{beam}	GeV	100	115	125	175	250	500	500	500	
Lorentz factor	γ		1.96E+05	2.25E+05	2.45E+05	3.42E+05	4.89E+05	4.89E+05	9.78E+05	9.78E+05	
Collision rate	f_{rep}	Hz	5	5	5	5	5	5	4	4	
Electron linac rate	f_{linac}	Hz	10	10	10	5	5	5	4	4	
Number of bunches	n_b		1312	1312	1312	1312	1312	2625	2450	2450	
Electron bunch population	N_-	$\times 10^{10}$	2.0	2.0	2.0	2.0	2.0	2.0	1.74	1.74	
Positron bunch population	N_+	$\times 10^{10}$	2.0	2.0	2.0	2.0	2.0	2.0	1.74	1.74	
Bunch separation	Δt_b	ns	554	554	554	554	554	366	366	366	
Bunch separation $\times f_{RF}$	$\Delta t_b f_{RF}$		720	720	720	720	720	476	476	476	
Pulse current	I_{beam}	mA	5.8	5.8	5.8	5.8	5.79	8.75	7.6	7.6	
RMS bunch length	σ_z	mm	0.3	0.3	0.3	0.3	0.3	0.3	0.250	0.225	
Electron RMS energy spread	$\Delta p/p$	%	0.206	0.194	0.190	0.158	0.124	0.124	0.083	0.085	*See EDMS D*971945*
Positron RMS energy spread	$\Delta p/p$	%	0.190	0.165	0.152	0.100	0.070	0.070	0.043	0.047	*See EDMS D*971945*
Electron polarisation	P_-	%	80	80	80	80	80	80	80	80	
Positron polarisation	P_+	%	31	31	30	30	30	30	20	20	*Approximate numbers (Wanming Liu)*
Horizontal emittance	$\gamma\epsilon_x$	μm	10	10	10	10	10	10	10	10	*TeV numbers are potentially too optimistic. Check with K.Kubo.*
Vertical emittance	$\gamma\epsilon_y$	nm	35	35	35	35	35	35	30	30	*TeV numbers are potentially too optimistic. Check with K.Kubo.*
IP horizontal beta function	β_x^*	mm	16.0	14.0	13.0	16.0	11.0	11.0	22.6	11.0	
IP vertical beta function (no TF)	β_y^*	mm	0.34	0.38	0.41	0.34	0.48	0.48	0.25	0.23	
IP RMS horizontal beam size	σ_x^*	nm	904	789	729	684	474	474	481	335	
IP RMS veritcal beam size (no TF)	σ_y^*	nm	7.8	7.7	7.7	5.9	5.9	5.9	2.8	2.7	
Horizontal distruption parameter	D_x		0.2	0.2	0.3	0.2	0.3	0.3	0.1	0.2	
Vertical disruption parameter	D_y		24.3	24.5	24.5	24.3	24.6	24.6	18.7	25.1	
Horizontal enhancement factor	H_{Dx}		1.0	1.1	1.1	1.0	1.1	1.1	1.0	1.0	
Vertical enhancement factor	H_{Dy}		4.5	5.0	5.4	4.5	6.1	6.1	3.5	4.1	
Total enhancement factor	H_D		1.7	1.8	1.8	1.7	2.0	2.0	1.5	1.6	
Geometric luminosity	L_{geom}	$\times 10^{34}$ cm^{-2}s^{-1}	0.30	0.34	0.37	0.52	0.75	1.50	1.77	2.64	

al estimates

Power Consumption (D*965055)

AC Power
Scaling for low centre of mass running (including 10Hz)

Updated 19/03/2013

Initial beam en 15 GeV

			TDR Baseline Reference (KCS)	Baseline (scaled)	Baseline (scaled)				Baseline (scaled)				Baseline (scaled)			
	Ecm	GeV	500	350	250				230				200			
					e+	e- (lumi)	e- (e+ prod)	Totals	e+	e- (lumi)	e- (e+ prod)	Totals	e+	e- (lumi)	e- (e+ prod)	Totals
	Gradient	MV/m	31.5	21.4	14.7	14.7	18.1		13.4	13.4	18.1		11.4	11.4	18.1	
	Q0		1.0E+10	1.0E+10	1.0E+10	1.0E+10	1.0E+10		1.0E+10	1.0E+10	1.0E+10		1.0E+10	1.0E+10	1.0E+10	
	Energy gain	GeV	470	320	110	110	135		100	100	135		85	85	135	
	Rep. rate	Hz	5	5	5	5	5		5	5	5		5	5	5	
	Linac length factor		1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0		1.0	1.0	1.0	
	Particles per bunch	$x10^{10}$	2.0	2.0	2.0	2.0	2.0		2.0	2.0	2.0		2.0	2.0	2.0	
	Number of bunches		1312	1312	1312	1312	1312		1312	1312	1312		1312	1312	1312	
	Average beam power (dump)	MW	10.5	7.4	2.9	2.9	3.5		2.7	2.7	3.5		2.4	2.4	3.5	
	$\Delta t_b * f_{DR}$		360	360	360	360	360		360	360	360		360	360	360	
	Δt_b	ns	553.8	553.8	553.8	553.8	553.8		553.8	553.8	553.8		553.8	553.8	553.8	
	Beam pulse	us	726.6	726.6	726.6	726.6	726.6		726.6	726.6	726.6		726.6	726.6	726.6	
	Beam current	mA	5.79	5.79	5.79	5.79	5.79		5.79	5.79	5.79		5.79	5.79	5.79	
	Matched Q	x10	5.5	3.7	2.6	2.6	3.1		2.3	2.3	3.1		2.0	2.0	3.1	
	t_{fill}	us	925.9	630.4	433.4	433.4	531.9		394.0	394.0	531.9		334.9	334.9	531.9	
	RF pulse length	ms	1.65	1.36	1.16	1.16	1.26		1.12	1.12	1.26		1.06	1.06	1.26	
	RF to beam P eff.		44%	54%	63%	63%	58%		65%	65%	58%		68%	68%	58%	
RF	2x average linac beam power	MW	9.88	6.73	2.31	2.31	2.84	7.46	2.10	2.10	2.84		1.79	1.79	2.84	
	Average RF power	MW	22.5	12.6	3.7	3.7	4.9		3.2	3.2	4.9		2.6	2.6	4.9	
	AC-RF Efficiency		39%	39%	39%	39%	39%		39%	39%	39%		39%	39%	39%	
	Total RF AC power	**MW**	**58.1**	**32.5**	**9.5**	**9.5**	**12.7**	**31.8**	**8.4**	**8.4**	**12.7**	**29.5**	**6.8**	**6.8**	**12.7**	**26.2**
	Total efficiency		17%	21%	24%	24%	22%		25%	25%	22%		26%	26%	22%	
	RF power dumped	MW	48.2	25.8	7.2	7.2	9.9	**24.3**	6.3	6.3	9.9	**22.4**	5.0	5.0	9.9	**19.8**
Cryo	Static cryo power	MW	11.2	11.2		11.2				11.2				11.2		
	RF load		13.8	5.2	1.0	1.0	1.7		0.8	0.8	1.7		0.6	0.6	1.7	
	Input coupler		3.8	2.0	0.6	0.6	0.8		0.5	0.5	0.8		0.4	0.4	0.8	
	HOM coupler		1.0	1.0	0.5	0.5	0.5		0.5	0.5	0.5		0.5	0.5	0.5	
	HOM absorber		0.3	0.3	0.2	0.2	0.2		0.2	0.2	0.2		0.2	0.2	0.2	
	HOM (cavity)		1.0	1.0	0.5	0.5	0.5		0.5	0.5	0.5		0.5	0.5	0.5	
	Beam tube bellows		0.6	0.2	0.0	0.0	0.1		0.0	0.0	0.1		0.0	0.0	0.1	
	Gfac		*8.73E-04*	*3.29E-04*	*1.32E-04*	*1.32E-04*	*2.16E-04*		*1.05E-04*	*1.05E-04*	*2.16E-04*		*7.14E-05*	*7.14E-05*	*2.16E-04*	

Intro | AC Power KCS (US) | AC Power KCS (US) (upgrades) | 250 GeV 1st stage | Damping Ring | Sheet1 | +

Cryomodule Heat Loads (D*94395)

Tom Peterson
Revised for TDP parameters 26 June 2012
Iteration of this heat load table with input from Chris Adolphsen, 5 Jan 07

													10 Hz LP KCS e- (e- source baseline)				
	TESLA numbers provide basis for scaling, RDR numbers for reference										positron beam		positron production		electron beam		
Cryomodule	TESLA		ILC 9-8-9 (RDR)		RDR revised*		TDR M Linac KCS		TDR M Linac DKS		5 Hz LP KCS e+		1/2 of 10 Hz LP KCS e-		1/2 of 10 Hz LP KCS e-		ILC 9-8-9 refers to the number of cavities in the modules in a ML unit
E, [MV/m]	23.4		31.5		31.5		31.5		31.5		24.1		23.7		23.7		G
Q	1.E+10		1.E+10		1.E+10		1.E+10		1.E+10		1.E+10		1.E+10		1.E+10		
Rep rate, [Hz]	5		5		5		5		5		5		5		5		
Number of Cavities	12		8.667		8.667		8.667		8.667		8.000		8.000		8.000		avg number of cavities per module
Fill time [μsec]	420		597		597		924		924		471		463		463		Tf
Beam pulse [μsec]	950		969		969		727		727		727		727		727		Tb
Number of bunches	2820		2670		2670		1312		1312		1312		1312		1312		Nb
Particles per bunch [1e10]	2		2.04		2.04		2.00		2.00		3.00		3.00		3.00		Qb
Beam current (mA)	9.51		9.00		9.00		5.80		5.80		8.70		8.70		8.70		
Gfac			2.09		2.09		2.24		2.24		0.94		0.90		0.90		Stored Energy Factor = G^2*(Tb + 1.1*Tf)
Pfac			1.54		1.54		1.18		1.18		0.87		0.85		0.85		Input Power Factor = G*(Tb + 2*Tf)*Cfac
Bfac			0.99		0.99		0.46		0.46		1.04		1.04		1.04		Bunch Factor = Nb*Qb^2
Cfac			0.95		0.95		0.61		0.61		0.91		0.91		0.91		Beam Current Factor = Qb*Nb/Tb
	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	
Temperature Level	2K		2K		2K		2K		2K		2K		2K		2K		
RF load		4.95		7.46		7.46		8.02		8.02		3.09		2.97		2.97	Dynamic load scaled by the number of cavities and Gfac
Supports	0.60		0.60	-	0.60	-	0.60	-	0.60	-	0.60	-	0.60	-	0.60	-	Assume independent of number of cavities
Input coupler	0.24	0.48	0.55	0.16	0.17	0.53	0.17	0.41	0.17	0.41	0.16	0.28	0.16	0.27	0.16	0.27	Static load scaled by number of cavities, dynamic by Pfac also
HOM coupler (cables)	0.01	0.27	0.01	0.18	0.01	0.18	0.01	0.12	0.01	0.12	0.01	0.16	0.01	0.16	0.01	0.16	Static and dynamic load scaled by number of cavities, dynamic by Cfac also
HOM absorber	0.14	0.02	0.14	0.02	0.14	0.02	0.14	0.01	0.14	0.01	0.14	0.01	0.14	0.01	0.14	0.01	Dynamic load scaled by Bfac
Beam tube bellows		0.24		0.36		0.36		0.39		0.39		0.15		0.14		0.14	Dynamic load scaled by the number of cavities and Gfac
Current leads	0.04		0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	1.70	1.70	0.57	0.57	0.57	0.57	For ML weigh by a factor of 1/3 since only 1 in 3 modules have quads**
HOM to structure		1.68		1.20		1.20		0.56		0.56		1.17		1.17		1.17	Static load scaled by the number of cavities, dynamic by Bfac also
Coax cable (4)	0.05		0.05		0.05		0.05		0.05		0.05		0.05		0.05		Assume indepent of number of cavities
Instrumentation taps	0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07		Assume indepent of number of cavities
Scales as Gfac		5.19		7.83		7.83		8.41		8.41		3.24		3.11		3.11	
Scales as Pfac		0.48		0.16		0.53		0.41		0.41		0.28		0.27		0.27	
Independent of G,Tf	1.15	1.97	1.70	1.68	1.32	1.68	1.32	0.97	1.32	0.97	2.73	3.05	1.60	1.92	1.60	1.92	
Static, dynamic sum	1.15	7.64	1.70	9.67	1.32	10.04	1.32	9.79	1.32	9.79	2.73	6.57	1.60	5.30	1.60	5.30	Total for 9-8-9 TDR KCS RF unit below
2K Sum [W]	8.8		11.4		11.4		11.1		11.1		9.3		6.9		6.9		33.33
	5K		5K		5K		5K		5K		5K		5K		5K		
Radiation	1.95		1.41		1.41		1.41		1.41		1.30		1.30		1.30		Static load scaled by number of cavities
Supports	2.40		2.40		2.40		2.40		2.40		2.40		2.40		2.40		Assume indepent of number of cavities
Input coupler	2.40	3.60	1.48	1.32	1.73	4.00	1.73	3.06	1.73	3.06	1.60	2.10	1.60	2.04	1.60	2.04	Static load scaled by number of cavities, dynamic by Pfac also
HOM coupler (cables)	0.40	2.66	0.29	1.82	0.29	1.82	0.29	1.17	0.29	1.17	0.27	1.62	0.27	1.62	0.27	1.62	Static and dynamic load scaled by number of cavities, dynamic by Cfac also

Row	T	U	V	W	X
11			Mar-08	after RDR	
12			Substitute the data below		
13			for the TESLA TDR numbers		
14			Coupler data from Linac 2004		
15			by W-D Moeller et. al.		
16			2 K	4 K	70 K
17		0 power	0.02	0.20	1.90
18		TESLA	0.06	0.50	6.00
19	y conclusion net dyn		0.04	0.30	4.10
35	Total for one cavity below				
36	0.99	1.282			

Title | CM_ HeatLoad | RDR | RDR revised | TDR Power KCS | TDR Power DKS | TDR DKS TABLE | e+ 5 GeV source | e- 5 GeV source | summary | +

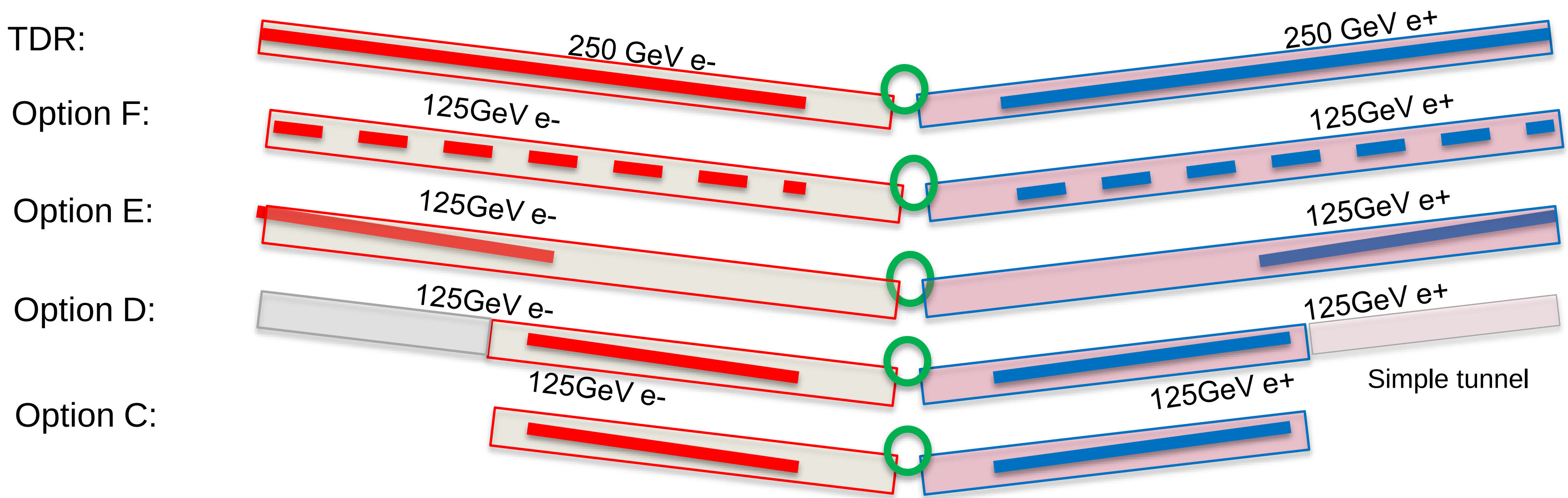
Cryogenic Power (D*94395)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Tom Peterson		ILC Cryogenic Power Estimates									
2	26-Jun-12											
3	This sheet:	TDR Power DKS										
4		1 standard cryogenic unit with DKS arrangement into cryo strings and cryo units										
5		Heat loads per attached CM_HeatLoad sheet (sheet 1)										
6		Module length based on Module-9-8-9-21Nov06.xls				approximate cryogenic unit length (km)						
7							2.434					
8	Total heat load (dynamic plus static) for 9-8-9 RF units, full cryogenic unit											
9												
10			40 K to 80 K	5 K to 8 K	2 K		Assumptions:					
11			Temperature leve	Temperature leve	Temperature level		Module length based on Module-9-8-9-21Nov06.xls					
12			(module)	(module)	(module)		12668	mm slot length for module with magnets and BPM				
13	Temp in	(K)	40.00	5.0	2.4		12668	mm slot length for module without magnets and BPM				
14	Press in	(bar)	16.0	5.0	1.2		189	modules in this cryogenic unit (longest anticipated)				
15	Enthalpy in	(J/g)	223.8	14.7	4.383			number of modules from cryogenics_parameters_DKS.xlsx				
16	Entropy in	(J/gK)	15.3	3.9	1.862							
17	Temp out	(K)	80.00	8.0	2.0		Note: cells highlighted in yellow are independent variables, parameters that are entered					
18	Press out	(bar)	14.0	4.0	saturated vapor							
19	Enthalpy out	(J/g)	432.5	46.7	25.04							
20	Entropy out	(J/gK)	19.2	9.1	12.58							
21												
22			40 K to 80 K	5 K to 8 K	2 K							
23	Predicted module static heat load	(W/module)	75.04	10.82	1.32							
24	Predicted module dynamic heat load	(W/module)	58.80	5.05	9.79		Heat loads per CM_HeatLoad sheet					
25												
26	Number of modules per cryo unit (9-8-9-cavity modules)		189.0	189.0	189.0							
27	Total module static heat per cryo unit	(kW)	14.18	2.04	0.25							
28	Total module dynamic heat per cryo unit	(kW)	11.11	0.95	1.85							
29												
30	Non-module heat load per cryo unit	(kW)	1.10	0.22	0.22		Add 10 W, 10 W, and 50 W load total for other heat					
31	Total predicted heat per cryogenic unit	(kW)	26.40	3.22	2.32			per cryo box at 2 K, 5 K and 40 K, respectively				
32	Total predicted mass flow per cryo unit	(g/s)	126.49	100.42	112.29			times 22 boxes per cryo unit				
33	Ideal power based on total estimated heat	(kW)	121.6	152.9	358.7							
34												
35	Heat uncertainty factor on static heat (Fus)		1.10	1.10	1.10		Heat uncertainty factor is margin for underestimating heat loads					
36	Heat uncertainty factor on dynamic heat (Fud)		1.10	1.10	1.10							
37	Heat load per cryogenic unit including uncertainty	(kW)	29.04	3.54	2.55							
38	Mass flow per cryogenic unit including uncertainty	(g/s)	139.14	110.46	123.52							
39	Weighted ideal power	(kW)	133.7	168.2	394.6							
40	4.5 K equiv weighted power	(kW)	2.0	2.6	6.0			Cryoplant coefficient of performance (W/W)				
41	Efficiency (fraction Carnot)		0.28	0.24	0.22			40 K - 80 K	5 K - 8 K	2 K		
42	Efficiency in Watts/Watt	(W/W)	16.4	197.9	703.0		TESLA TDR:	17	168	588		

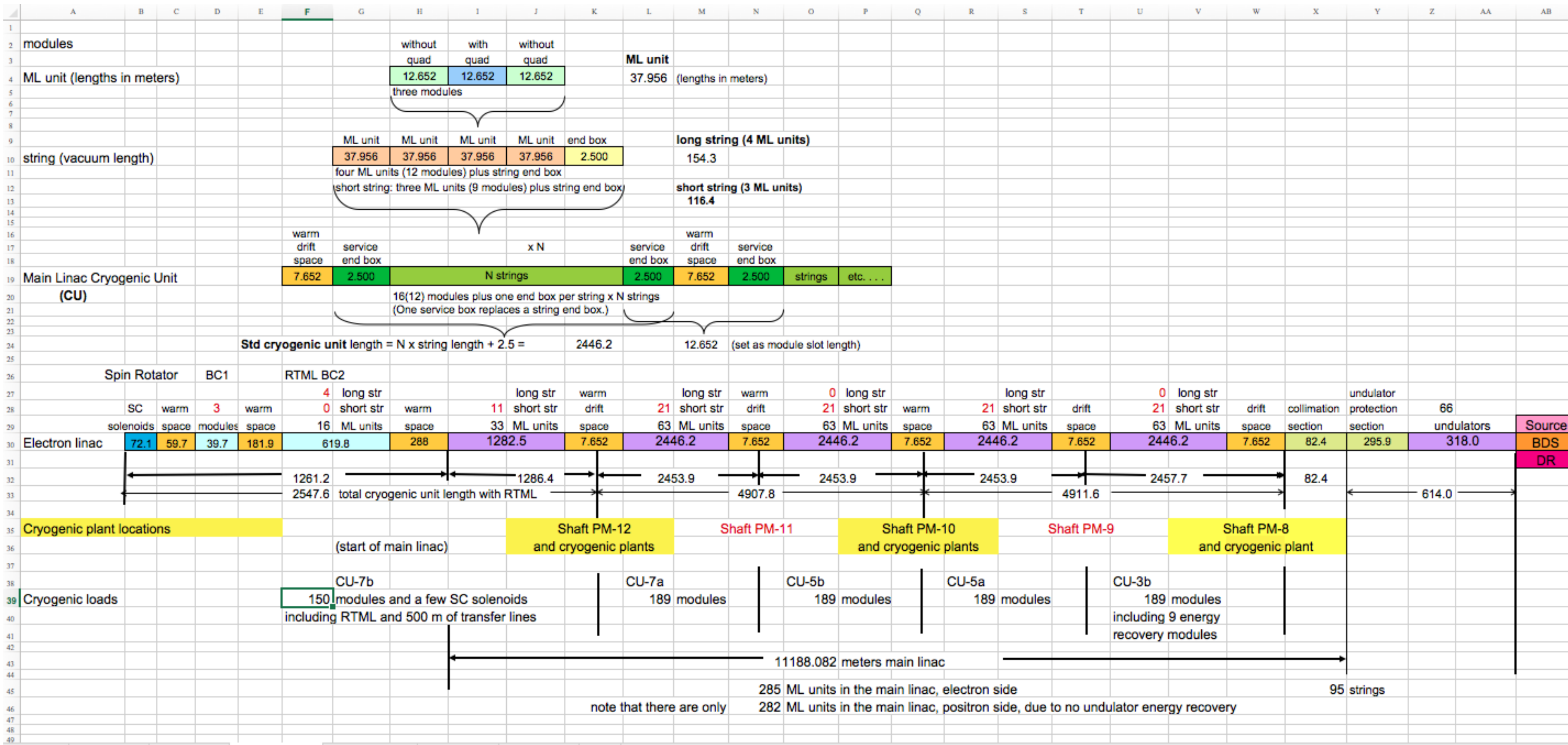
Title | CM_ HeatLoad | RDR | RDR revised | TDR Power KCS | TDR Power DKS | TDR DKS TABLE | e+ 5 GeV source | e- 5 GeV source | summary

New Main Linac Configuration

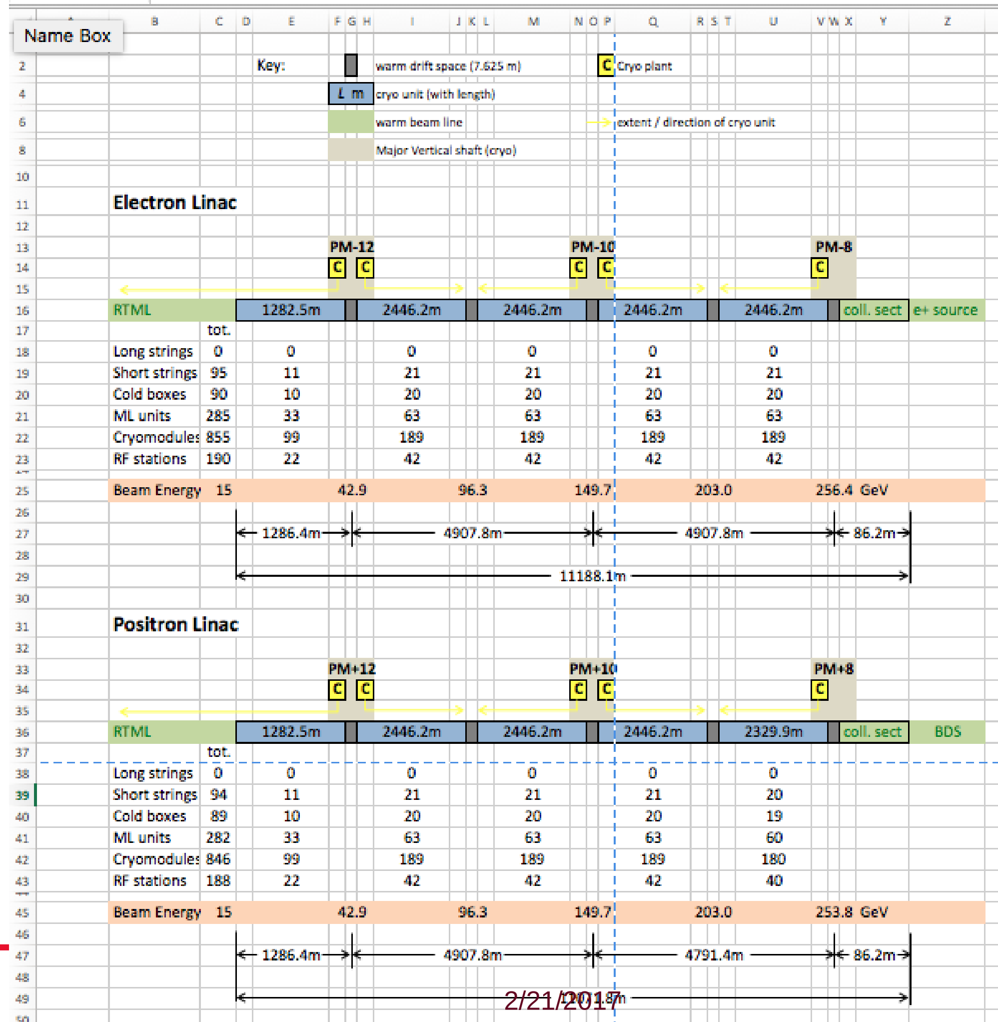
- New Gradient: Fewer cryomodules, shorter cryo strings, shorter tunnel
- Cryogenic configuration is basis for tunnel layout
- Need to decide on new ML tunnel length, and 250GeV stage cryo configuration



Cryo Configuration (D*991555)



TDR Main Linac Configuration (D*1008405)



Electron Linac

	tot.					
Long strings	0	0	0	0	0	0
Short strings	95	11	21	21	21	21
Cold boxes	90	10	20	20	20	20
ML units	285	33	63	63	63	63
Cryomodules	855	99	189	189	189	189
RF stations	190	22	42	42	42	42

Beam Energy: 15, 42.9, 96.3, 149.7, 203.0, 256.4 GeV

Positron Linac

	tot.					
Long strings	0	0	0	0	0	0
Short strings	94	11	21	21	21	20
Cold boxes	89	10	20	20	20	19
ML units	282	33	63	63	63	60
Cryomodules	846	99	189	189	189	180
RF stations	188	22	42	42	42	40

Beam Energy: 15, 42.9, 96.3, 149.7, 203.0, 253.8 GeV

New Positron Source Parameters

- Long overdue:
  make 231m long undulator baseline
  -> avoid 5+5Hz running for positron production at 250GeV
- Should give specifications for target heat loads, assuming H-20 running conditions, i.e.:
  - 125GeV electron beam
  - 2625 bunches
  - 10Hz

- Generally: we should set a target what the positron source should be able to provide in an extreme case (maximum luminosity upgrade)
- Any positron source concept needs to be measured against that target

New Damping Ring Parameters

- Damping Ring parameters were defined many years ago
- Low emittance rings have made lots of progress
- Damping Rings might achieve better emittance:
  - Lower vertical emittance from better alignment?
  - Lower horizontal emittance from special arc lattice (DBA, TBA, TME)
  - But beware of dynamic aperture (TME was tried aleready…)
- **If** beam transport to IP preserves lower emittance:
  might be a way to higher lumi, espec. at 250 GeV

- What is the timeline for a possible new DR lattice?

Towards a New Baseline

Note:
Order is dictated by urgency, not by inter-dependencies…

Gradient
- New Cryomodule Performance

250GeV Parameters
- New 250GeV parameter set for a staged machine

500GeV Parameters
- High-Level parameters based on new gradient

ML Configuration
- New Main Linac configuration

→ Allows new cost estimate

PS Parameters
- New Positron Source Parameters

DR Parameters
- New Damping Ring Parameters (and lattice)