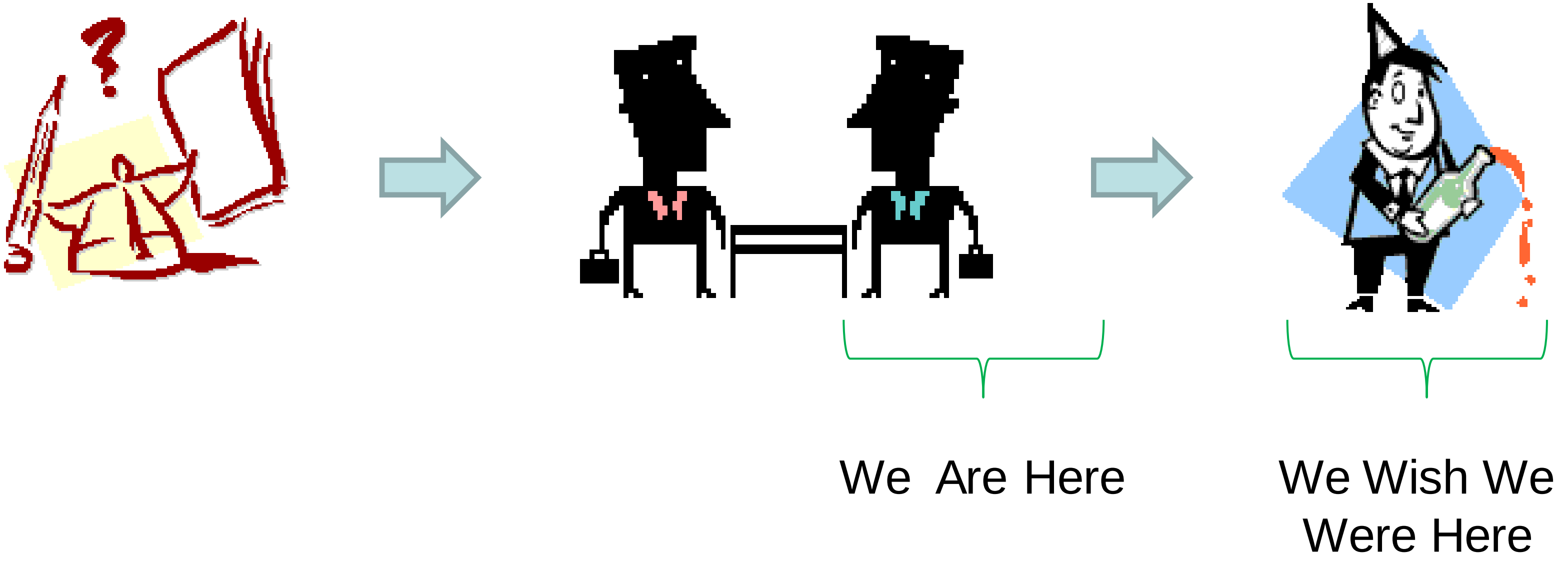


MLI Homework in the Homestretch

Chris Adolphsen
KILC
4/23/12

- Provide a complete ML lattice with 9+4Q4+9 cryomodule unit,
- Confirm requirement of energy overhead (1.4%) w/ additional ML length for operational availability (provide rationale)
- Fix total numbers of CM including ML, RTML, e-source (# add. CMs to be fixed)
- Q + corrector +BPM package design (w/ energy dependent design?)
- Plan for full power upgrade at 500 GeV, and scenario up to 1 TeV
  (→ such as quad. configuration, FDFD up to 500 GeV, and FFDD at 1 TeV?

IP and General Parameters

							L Upgrade	E_{cm} Upgrade	
Centre-of-mass energy	GeV	200	230	250	350	500	500	1000	1000
								A1	B1b
Beam energy	GeV	100	115	125	175	250	500	500	500
Collision rate	Hz	5	5	5	5	5	5	4	4
Electron linac rate	Hz	10	10	10	5	5	5	4	4
Number of bunches		1312	1312	1312	1312	1312	2625	2450	2450
Electrons/bunch	$\times 10^{10}$	2.0	2.0	2.0	2.0	2.0	2.0	1.74	1.74
Positrons/bunch	$\times 10^{10}$	2.0	2.0	2.0	2.0	2.0	2.0	1.74	1.74
Bunch separation	ns	554	554	554	554	554	366	366	366
Bunch separation $\times f_{RF}$		720	720	720	720	720	476	476	476
Pulse current	mA	5.8	5.8	5.8	5.8	5.79	8.75	7.6	7.6
RMS bunch length	mm	0.3	0.3	0.3	0.3	0.3	0.3	0.250	0.225

Main Linac

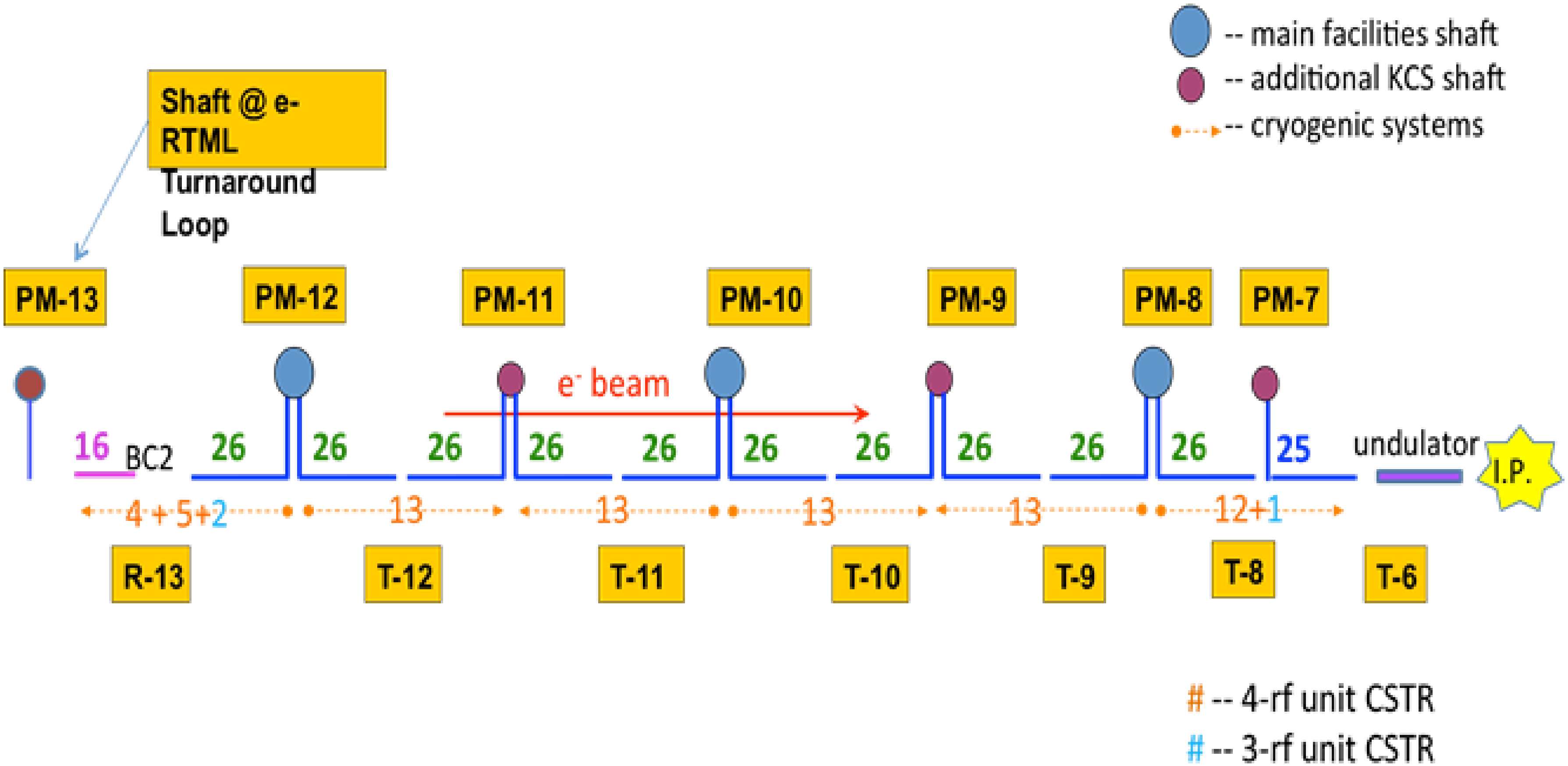
Cryomodule & Cavity Counts				
	CM9	CM8Q	Cavities	Quad Pkg
e-	570	285	7410	285
e+	564	282	7332	282
Totals	1134	567	14742	567

Nick Walker

	Main Linac Energy Gain		Kamaboko		Upgrade (and KCS)	
	Required energy gain	GeV	235		235	
	Cavities / LPDS		39		26	
	Cavity					
	RF voltage	MV	32.70		32.70	
	phase	deg	5		5	
	loss factor (beam loading)	MV	0.04384		0.04384	
	dE/cavity	MV	32.53		32.53	
	DE per LPDS unit	GeV	1.27		0.85	
e+	# LPDS units		186		279	
	Energy gain	GeV	235.96		235.96	
e-	Required OH for e+ src	GeV	2.6		2.6	
	Total e- energy gain	GeV	237.6		237.6	
	# LPDS units (rounded)		188		282	
	Energy gain	GeV	238.50		238.50	
	Overhead (LPDS units)		2		3	
	Electron linac LPDS units		190		285	
	Positron linac LPDS units		188		282	
	Total LPDS units		378		567	
	Max. e- energy (IP)		253.44	1.4%	253.44	1.4%
	Max. e+ energy (IP)		253.50	1.4%	253.50	1.4%

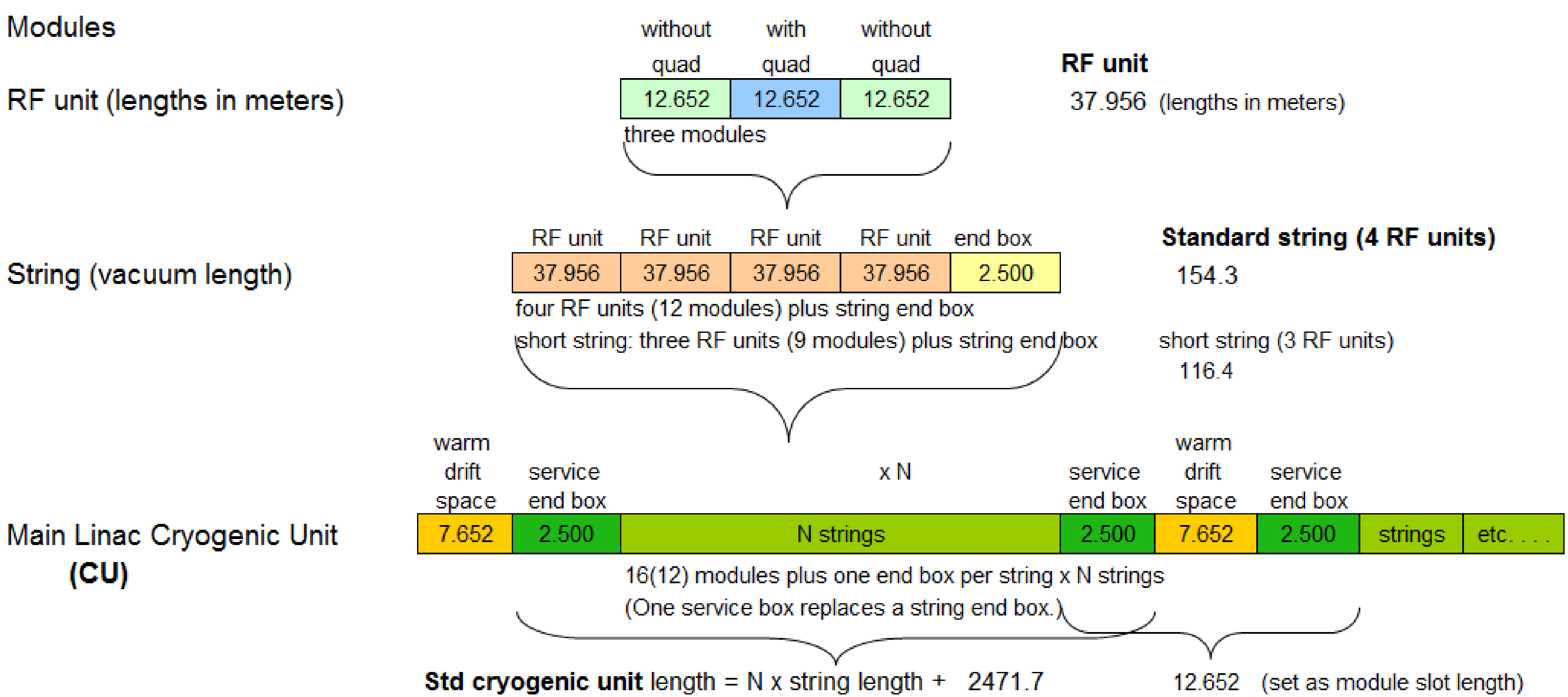
Nick Walker

Electron Linac Cryo Segmentation



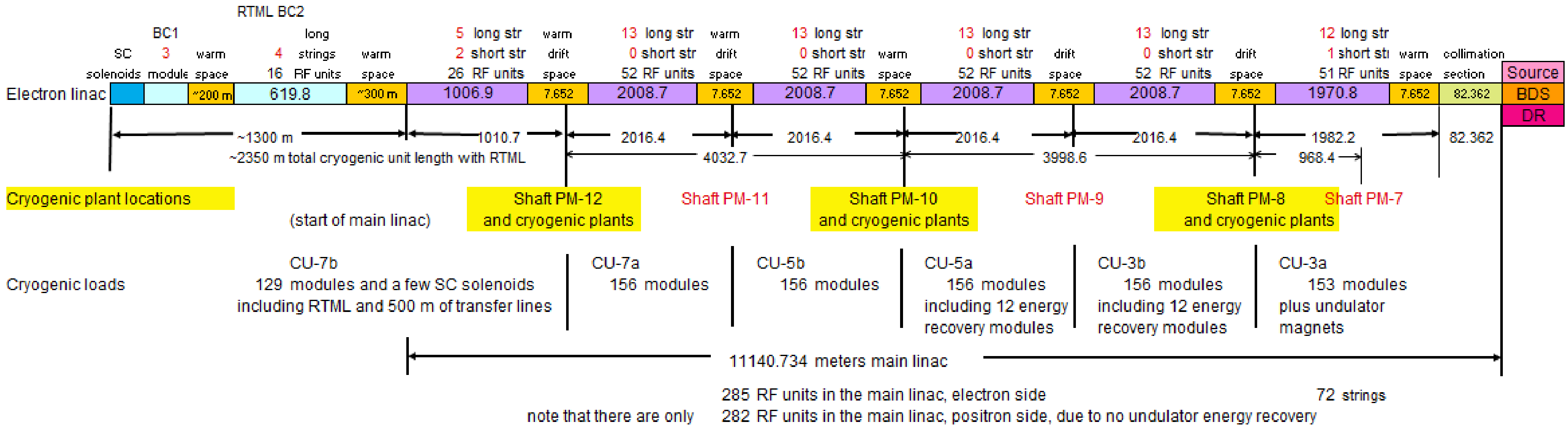
Tom Peterson / Chris N

Cryo Strings and Units



Tom Peterson

Detailed Layout



Tom Peterson

Which has been translated into tracking code decks (N Solyak)

Section	Name	Length	Type	X-Position	Y-Position	Z-Position	Ebeam
ELIN	TERTML2ML	0	MARK	104.5245	0	-14471.8	14.9904
ELIN_T13	BEG_ELIN	0	MARK	104.5245	0	-14471.8	14.9904
ELIN_T13	YELIN2I	0	VKIC	104.5245	0	-14471.8	14.9904
ELIN_T13	KML7M	0	MULT	104.5245	0	-14471.8	14.9904
ELIN_T13	KML7V	0	VKIC	104.5245	0	-14471.8	14.9904
ELIN_T13	BEGMLUNIT	0	MARK	104.5245	0	-14471.8	14.9904
ELIN_T13	MLSERVBOX	2.5	CRYB	104.507	0	-14469.3	14.9904
ELIN_T13	BEGMLSTR	0	MARK	104.507	0	-14469.3	14.9904
ELIN_T13	BEGMLRFU	0	MARK	104.507	0	-14469.3	14.9904
ELIN_T13	MLCMC9	12.652	CRYO	104.4184	0	-14456.6	15.13312
ELIN_T13	MLCMC8Q	12.652	CRYO	104.3299	0	-14444	15.4027
ELIN_T13	MLCMC9	12.652	CRYO	104.2413	0	-14431.3	15.67228
ELIN_T13	ENDMLRFU	0	MARK	104.2413	0	-14431.3	15.815
ELIN_T13	BEGMLRFU	0	MARK	104.2413	0	-14431.3	15.815
ELIN_T13	MLCMC9	12.652	CRYO	104.1527	0	-14418.7	15.95772
ELIN_T13	MLCMC8Q	12.652	CRYO	104.0642	0	-14406	16.22729
ELIN_T13	MLCMC9	12.652	CRYO	103.9756	0	-14393.4	16.49687
ELIN_T13	ENDMLRFU	0	MARK	103.9756	0	-14393.4	16.63959
ELIN_T13	BEGMLRFU	0	MARK	103.9756	0	-14393.4	16.63959
ELIN_T13	MLCMC9	12.652	CRYO	103.8871	0	-14380.7	16.78231
ELIN_T13	MLCMC8Q	12.652	CRYO	103.7985	0	-14368.1	17.05189
ELIN_T13	MLCMC9	12.652	CRYO	103.7099	0	-14355.4	17.32147
ELIN_T13	ENDMLRFU	0	MARK	103.7099	0	-14355.4	17.46419
ELIN_T13	MLENDBOX	2.5	CRYB	103.6924	0	-14352.9	17.46419

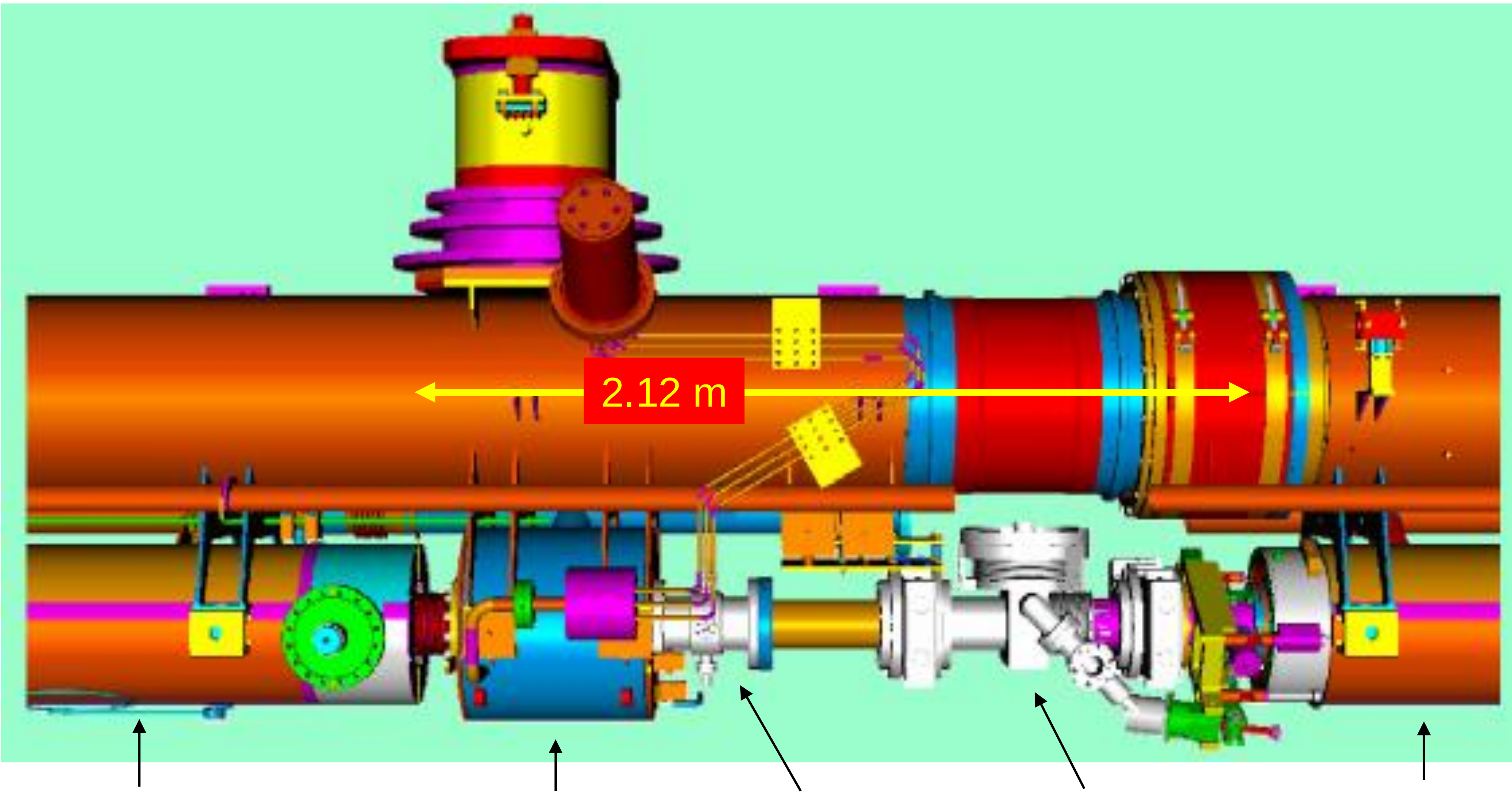
Mean Energy Loss per Linac Due to Component Failures in RDR Layout

Component	Beam Energy Loss (MeV)	MTTR (Hr)	MTBF (M Hr)	Mean Loss (MeV)
Electrical - .05<<0.5 klystron	1270	2	0.36	1
Electrical - >0.5 klystron	1270	4	0.36	3
Klystron Controls	1270	1	0.30	1
Klystron Timing	1270	1	0.30	1
Cryo String JT valve	2540	2	0.30	2
CM Cryo Vac Enclosure	2540	8	10.00	0
CM Insulating Vacuum Pumps	2540	8	0.10	19
Cryo String Insulating Vacuum Pumps	2540	8	0.10	19
Klystron Solenoid PS	1270	4	0.05	19
Klystron Driver	1270	1	0.10	2
Klystron	1270	8	0.04	47
Modulator	1270	4	0.05	19
HV cables	1270	8	0.20	9
Klystron Vac Gauge + Controller	1270	1	0.10	2
Klystron Vacuum Pump	1270	8	10	0
Klystron Vacuum PS	1270	1	0.10	2

Mean Energy Loss per Linac Due to Component Failures (Cont)

Component	Beam Energy Loss (MeV)	MTTR (Hr)	MTBF (M Hr)	Mean Loss (MeV)
Cavity	32.6	6480	100	15
Cavity Piezo Tuner	16.3	6480	1	1511
Cavity Tuner	32.6	6480	1	1521
Coupler Interlock Electronics	32.6	1	1	0
Coupler Interlock Sensors	32.6	1	5	0
Cavity LLRF System	32.6	1	0.30	1
Klystron LLRF System	1270	1	0.30	31
Coupler	32.6	6480	10	153
Coupler Vacuum Pump	1270	4	10	4
Coupler Vacuum Pump PS	1270	1	0.10	92
Klystron Flow Switch	1270	1	2.50	0
Klystron Water instr	1270	2	0.30	2
Klystron Water Pumps	1270	4	0.12	8
			Total Loss (MeV)	3484
MTBF and most MTTR values from Himel's 2006 availability talk			% Energy Loss	1.4

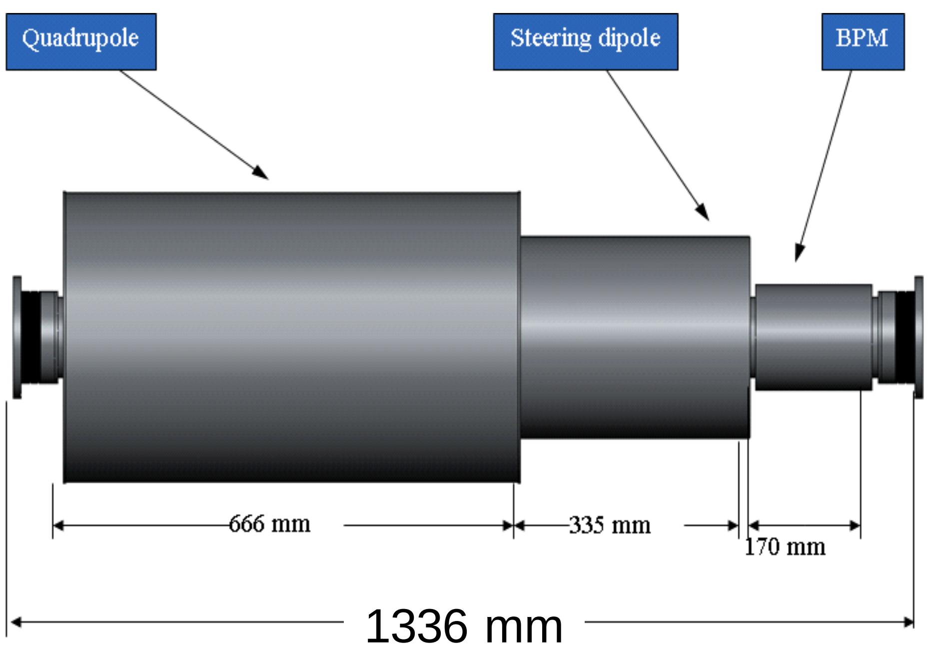
TESLA Quad Package



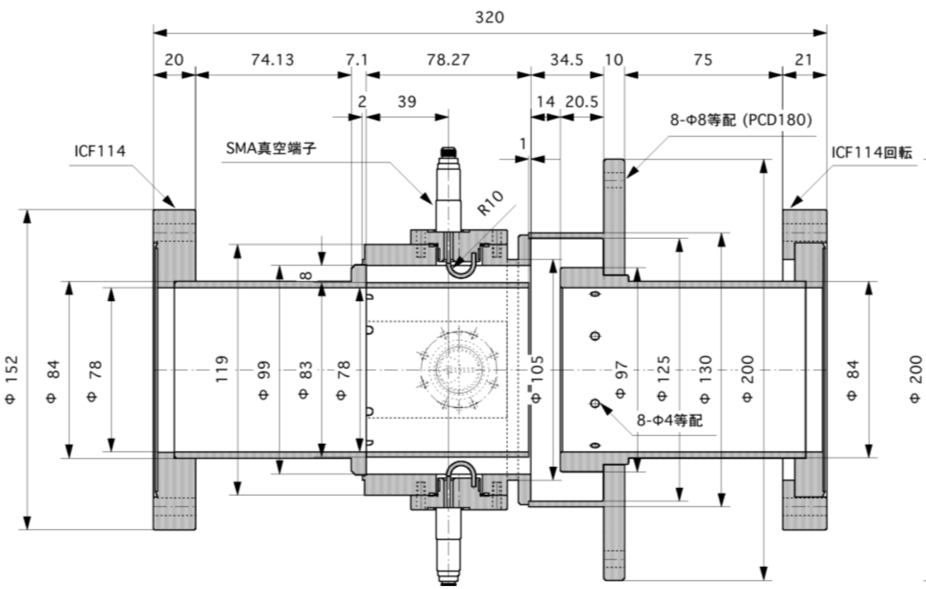
Quad / Corrector / BPM Package

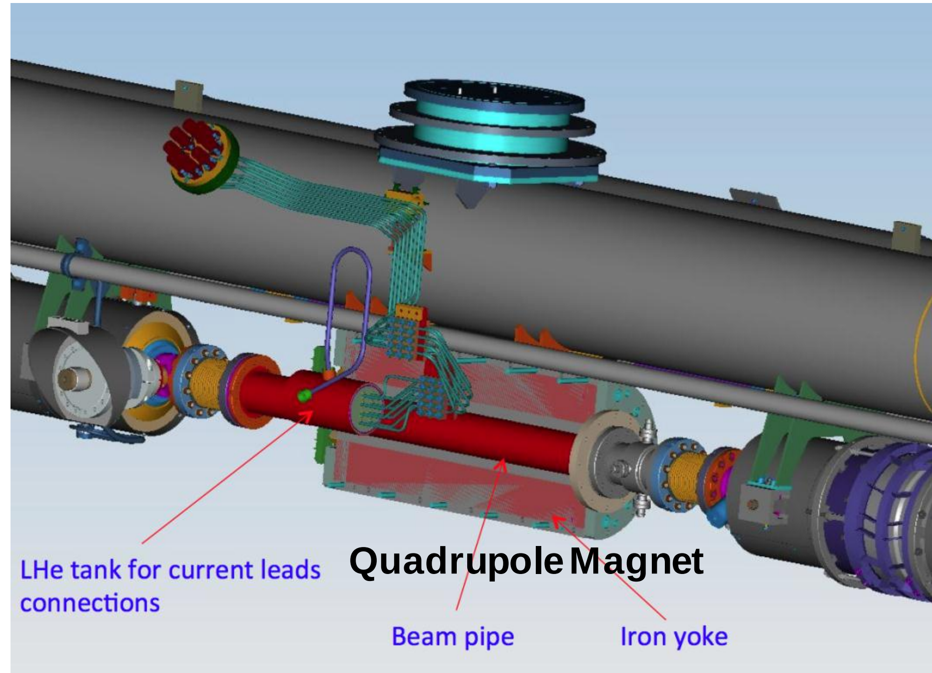
- Need to fit BPM + Quad + Correctors in a 1336 mm space or else linacs become longer
- Have BPM design, but have not finalized Quad/Correctors as split quad still in development – leave this as a TBD in the TDR ?
- However, will need weaker Quads and Correctors (less turns) in the upstream (10% ?) of the linac

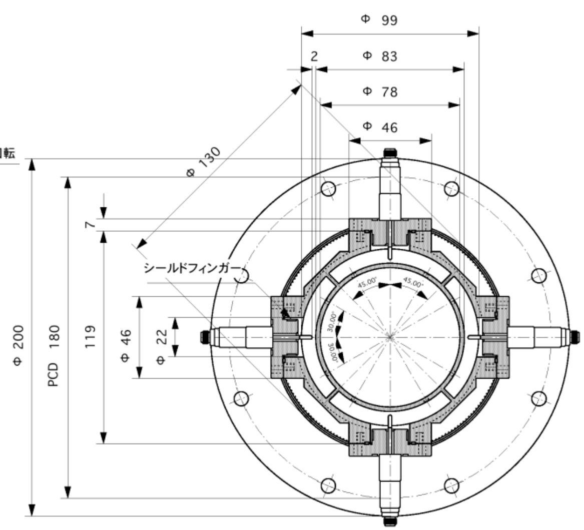
RDR Proposal

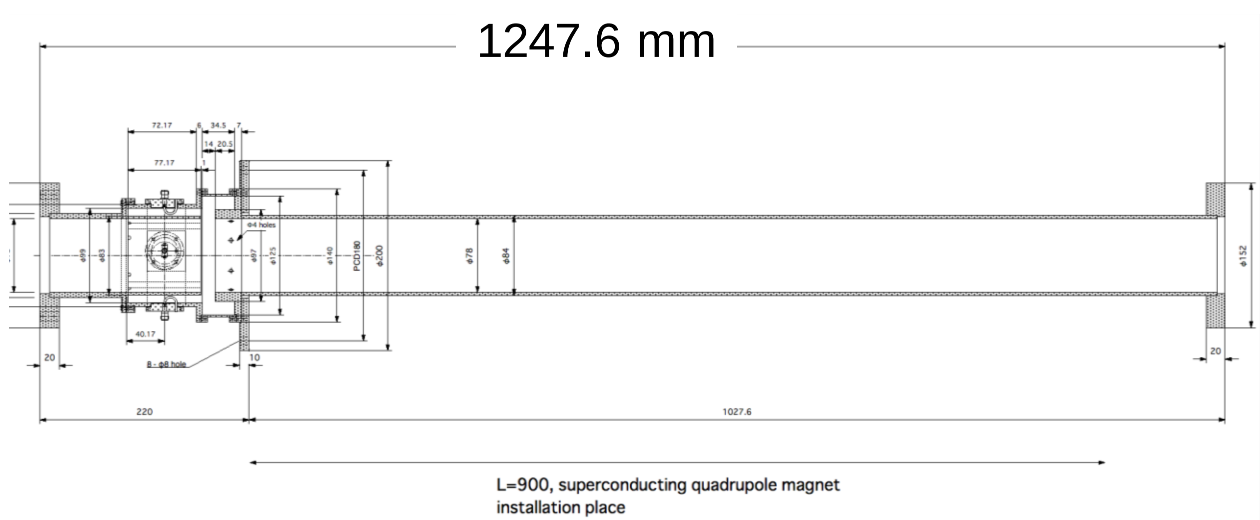


ML Cold-BPM in Cryomodule (H. Hayano)



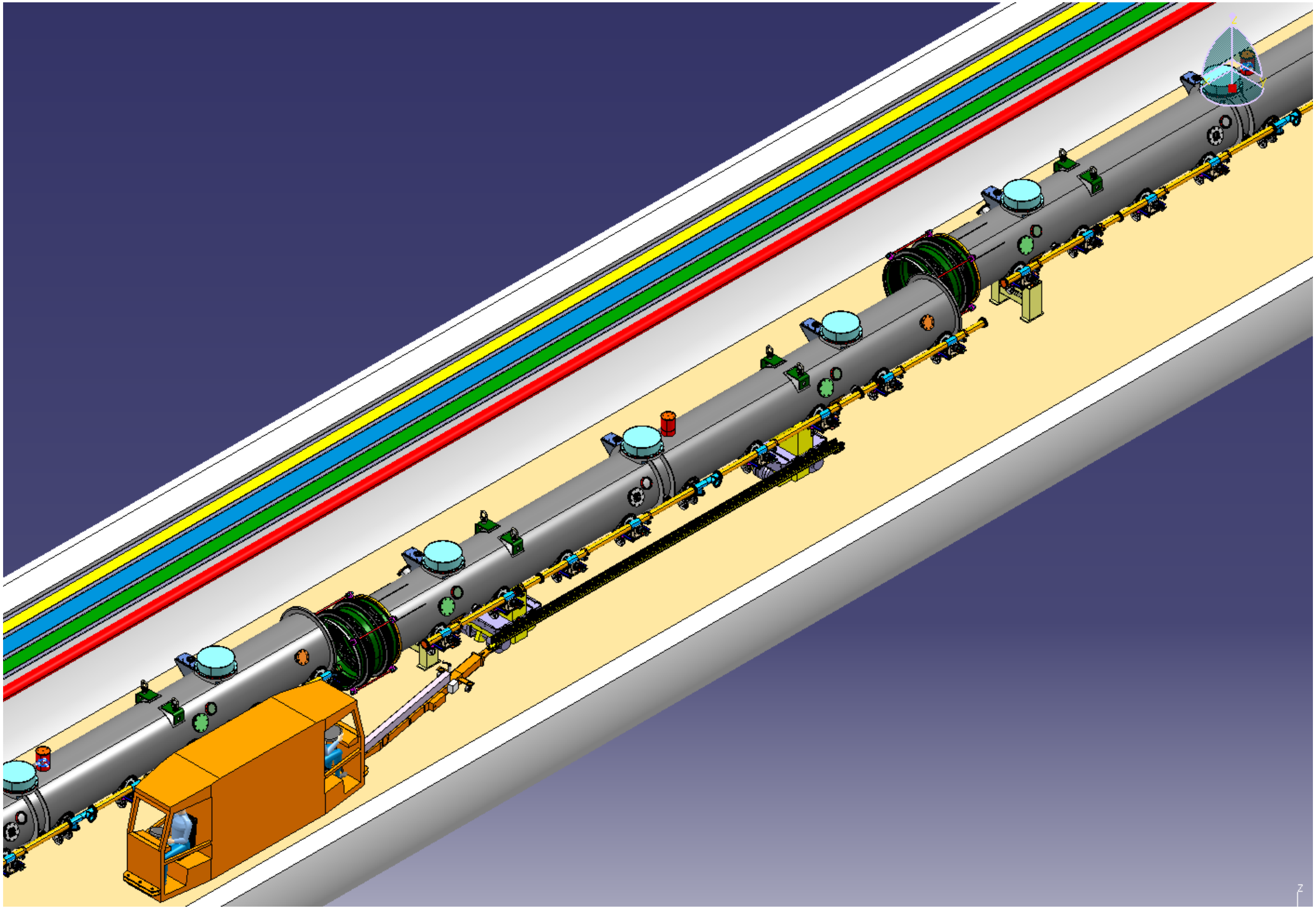






One TeV Upgrade

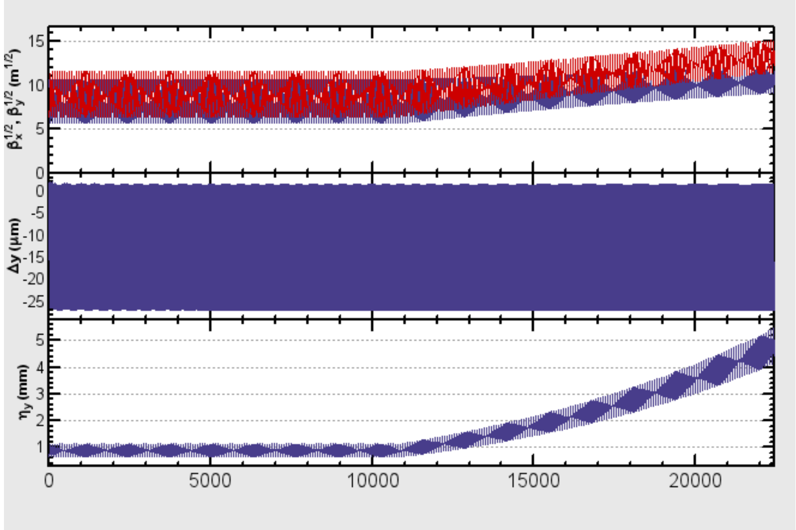
- At minimum need to move or re-build the turn-arounds and undulator section in the extensions to the linacs.
- The quads and probably correctors in the 5 GeV to ~ 25 GeV of the linac need to have less turns to suppress persistent current effects, and as such, cannot be used for a 250 GeV beam. So what to do:
  - Move these CMs to the beginning of the 500 GeV linac – expensive and do not want to change what works
  - For these CMs, if split magnets can be used, include a side panel on the cryostats so the magnets can be swapped.
- For the rest of the quads in the original linac, they would run near their maximum strength for the 250-500 GeV beam.



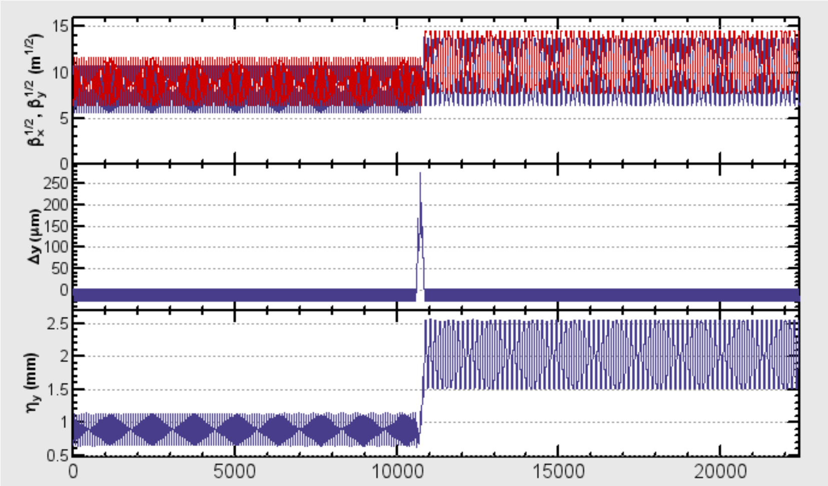
ILC CFS Baseline Technical Review - Handling and Installation, 23 March 2012

Allow beta to increase in 250-500 GeV region so Quads do not have to be stronger

3 modules/quad FODO



3 modules/quad FOFODODO



Strengths of quads in E_beam > 250 = Strength at 250 GeV
Or, K1 ~ 1/E_beam

Strengths of quads at E_beam = 500 = Strength at 250 GeV
Or, K1(E_beam > 250 GeV) = 1/2 K1(E_beam < 250GeV)

FFDD has smaller beta and dispersion compare with FDFD with the same quad strengths.

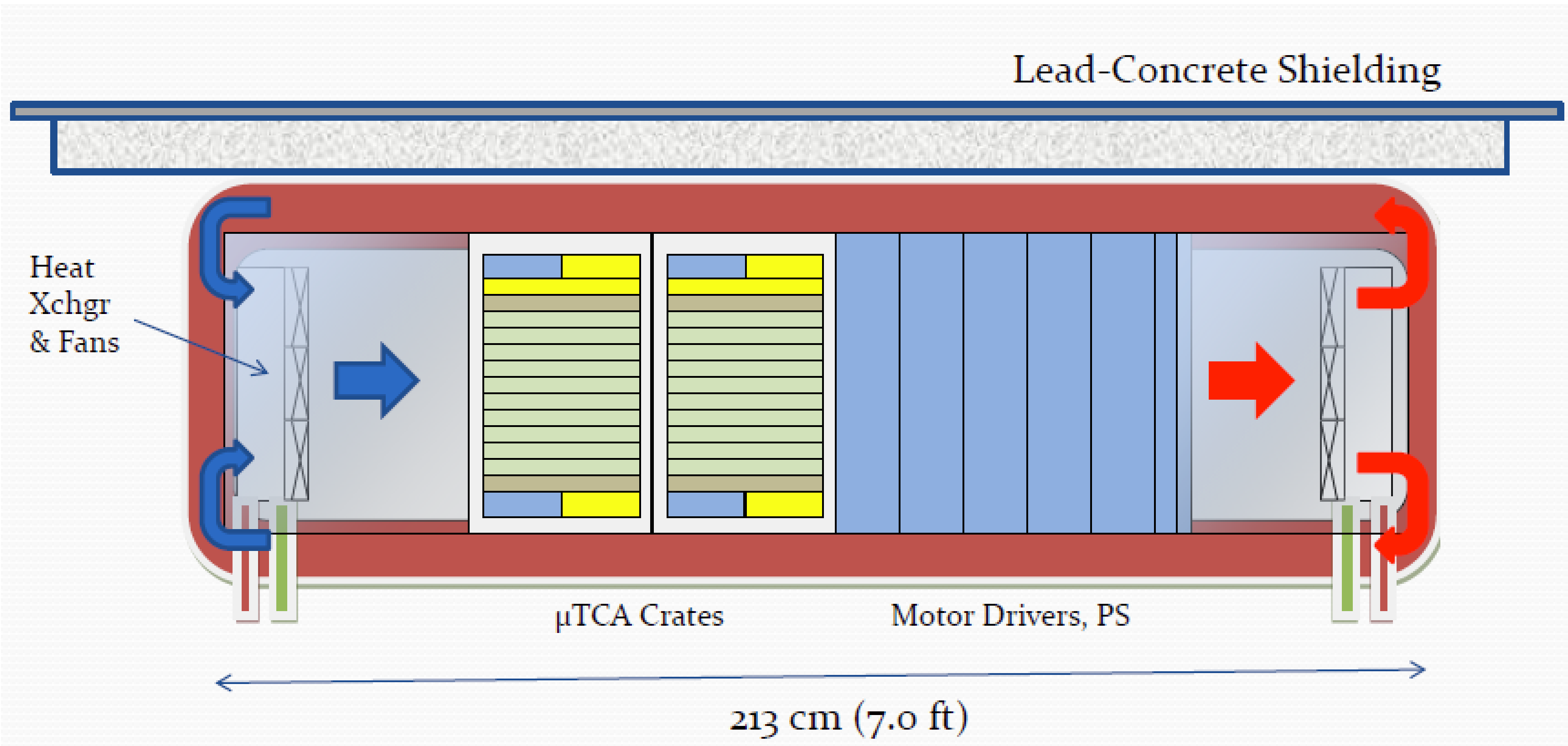
Kiyoshi Kubo

Slides from Jan, 2012 BTR in KEK

RDR – TDR Change Highlights

- Lower Beam Current (6 mA instead of 9 mA)
  - One of every three klystron slots empty in RDR scheme
- Added the ‘Klystron Cluster Scheme’ Option
  - Beam/CM electronics radiated/inaccessible
- Marx Modulator instead of Pulsed Transformer / Bouncer
- Variable power feed to each cavity to accommodate +/- 20% gradient spread
  - Increases cost and rf power requirements
- Add phase shifters, eliminate 3-Stub tuners and retain circulators
- Changes to ‘Quad Package’
  - Still located in center of every third CM
- Undulator move to the end of the electron linac

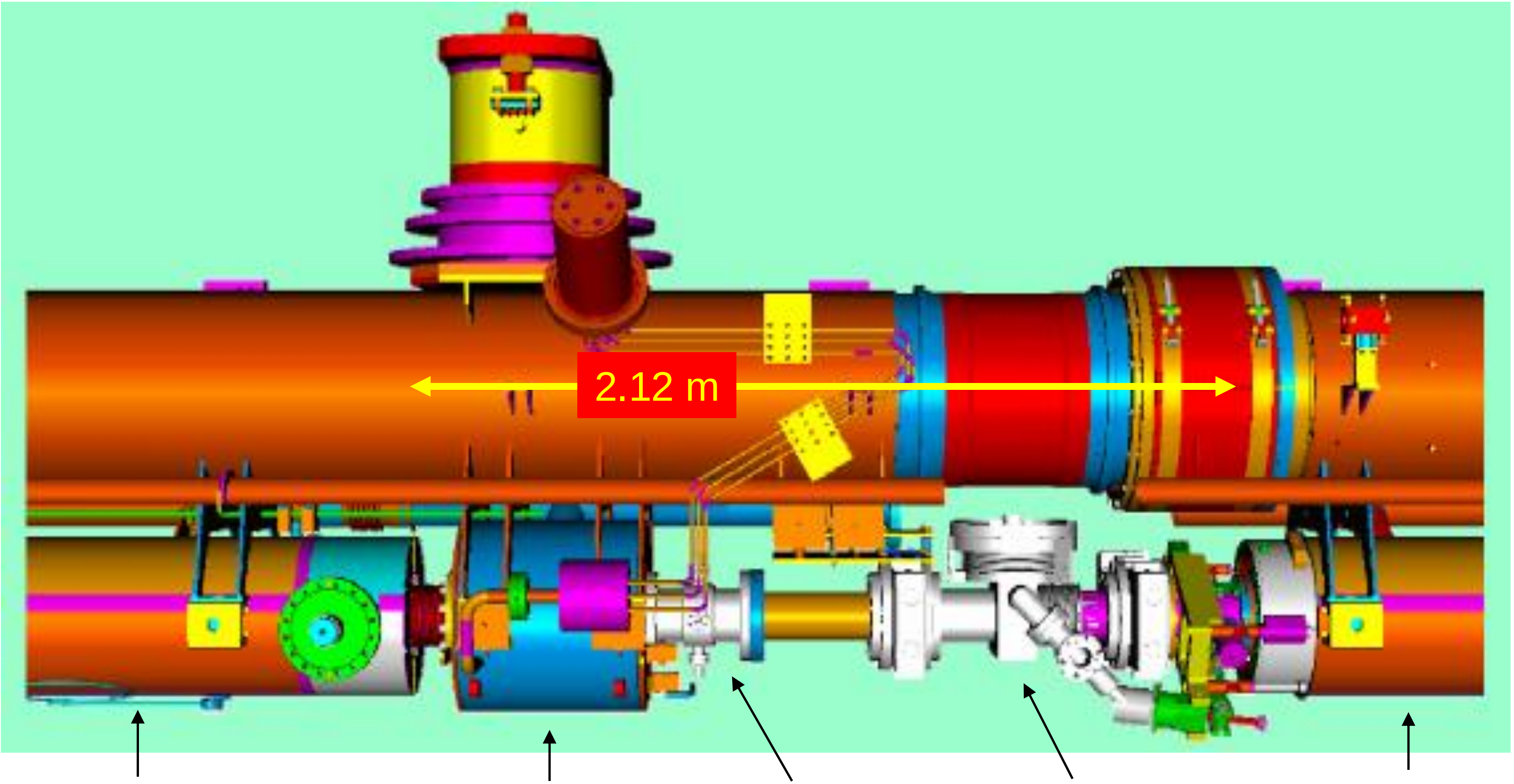
KCS: Electronics Under Each CM



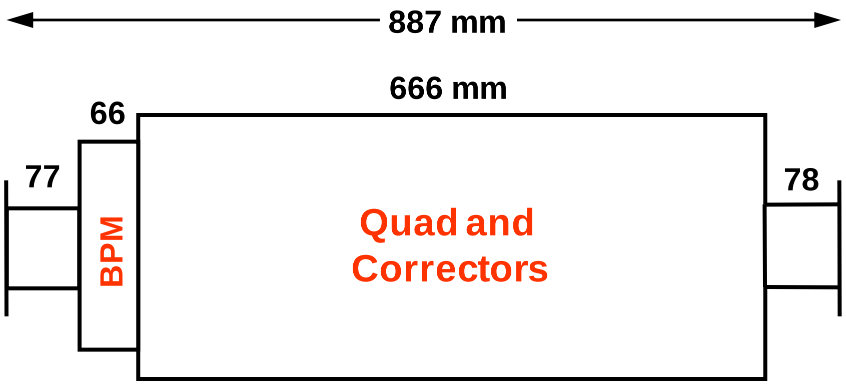
Some Outstanding Issues

- Detailed quad package layout including quad, cooling scheme, BPM and beamline absorbers
- Stand alone dipole correctors and required response time
- BPM design to achieve micron level position resolution (re-entrant style looks promising but not fully demonstrated)
- Quad design (CIEMAT cos(phi) w/o correctors would work – split superferric quad in development)
- Exact linac length to meet DR fill requirements
- Global alignment scheme and impact on beam dynamics
- Reevaluate rf overhead given operation experience
- Extra linac length for gradient overhead (differs for RDR and KCS HLRF schemes)
- Availability reassessment

TESLA Quad Package

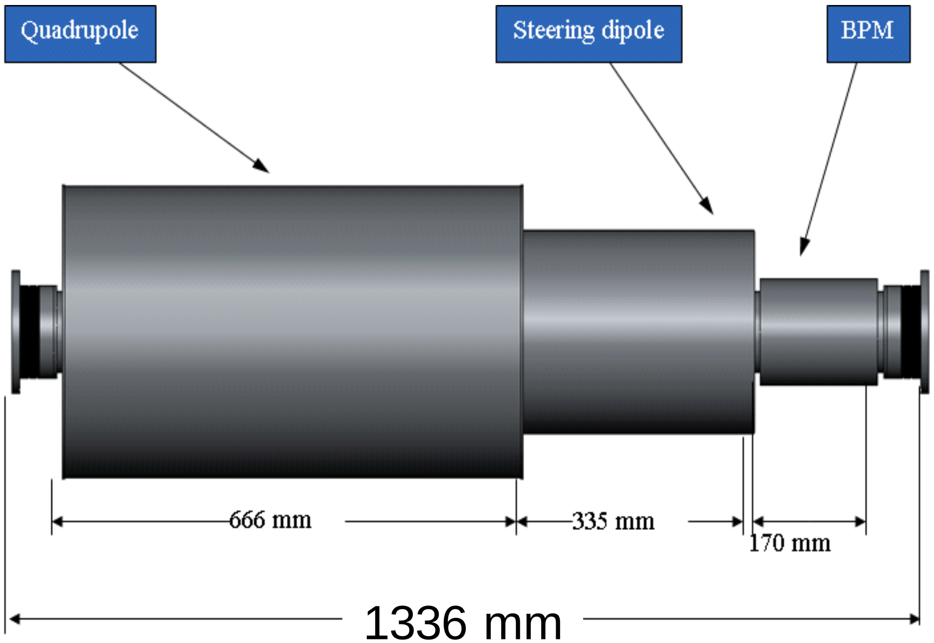


Quad / Corrector / BPM Package

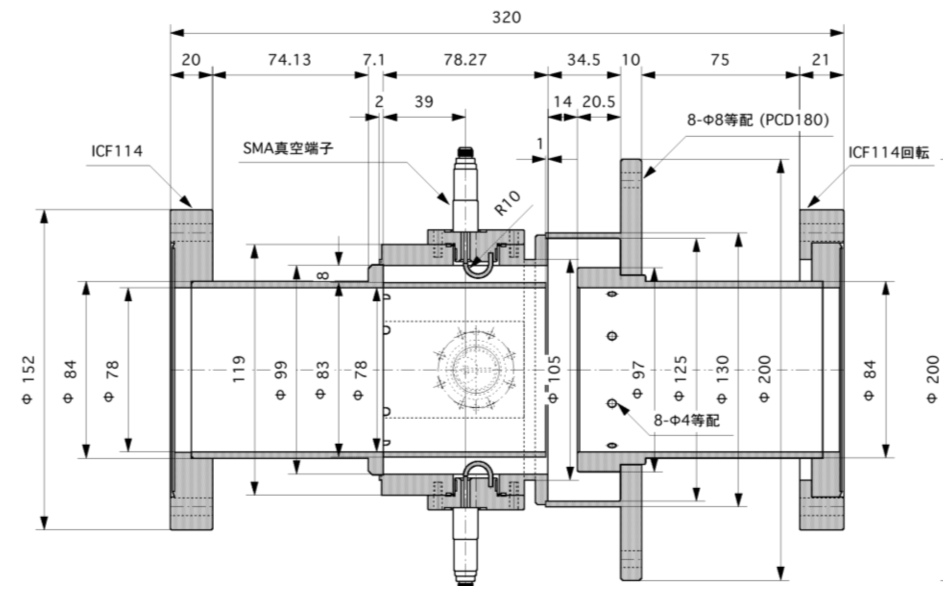


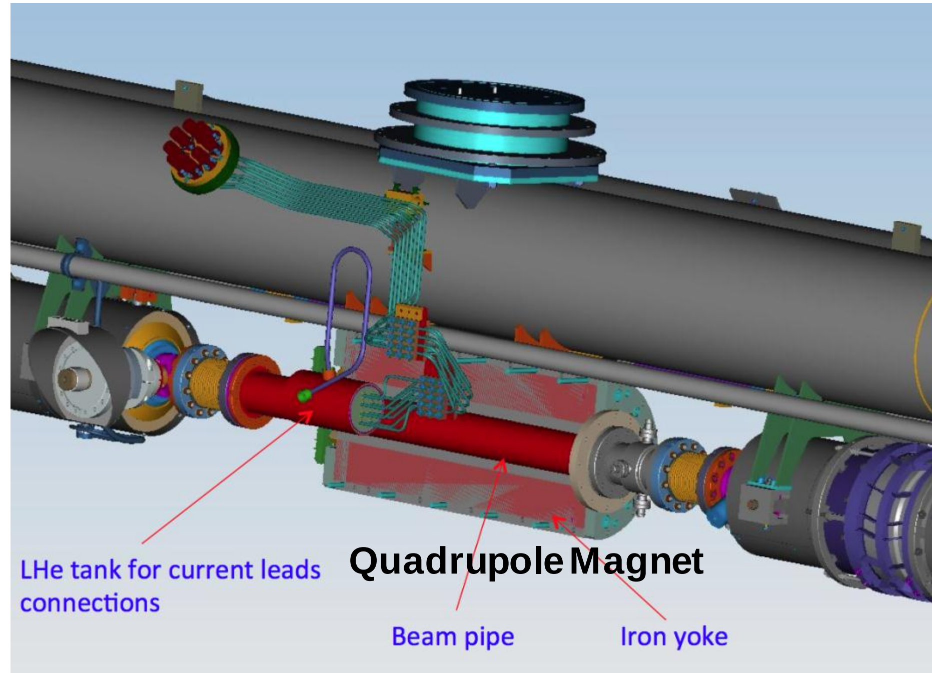
TESLA TDR

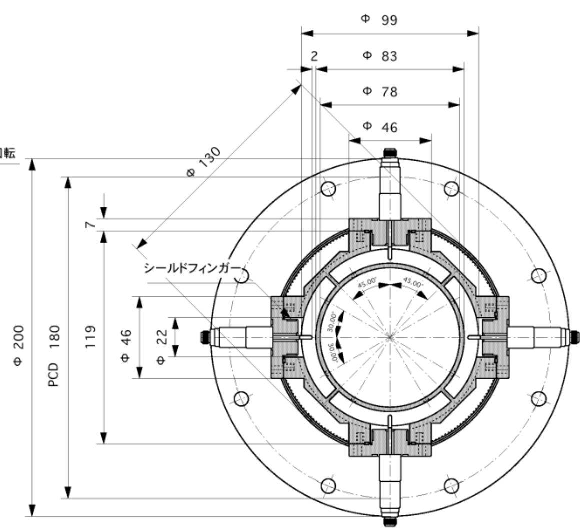
RDR
Proposal

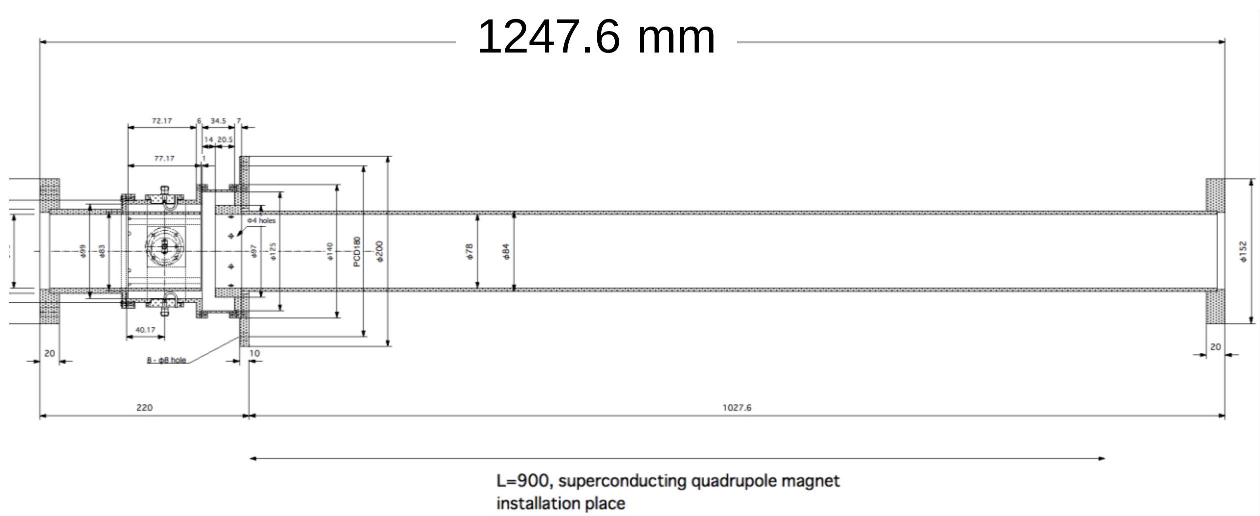


ML Cold-BPM in Cryomodule (H. Hayano)

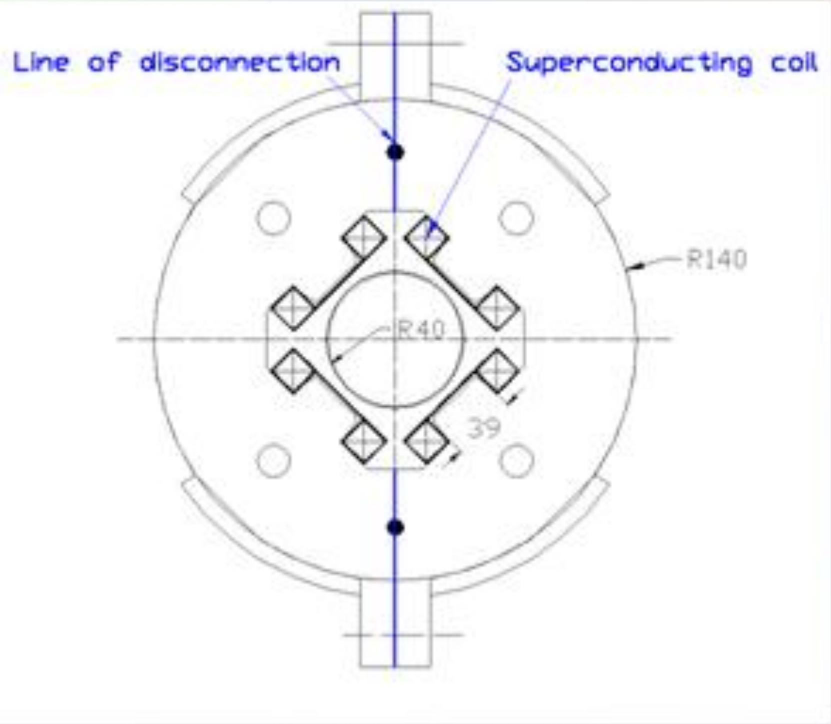


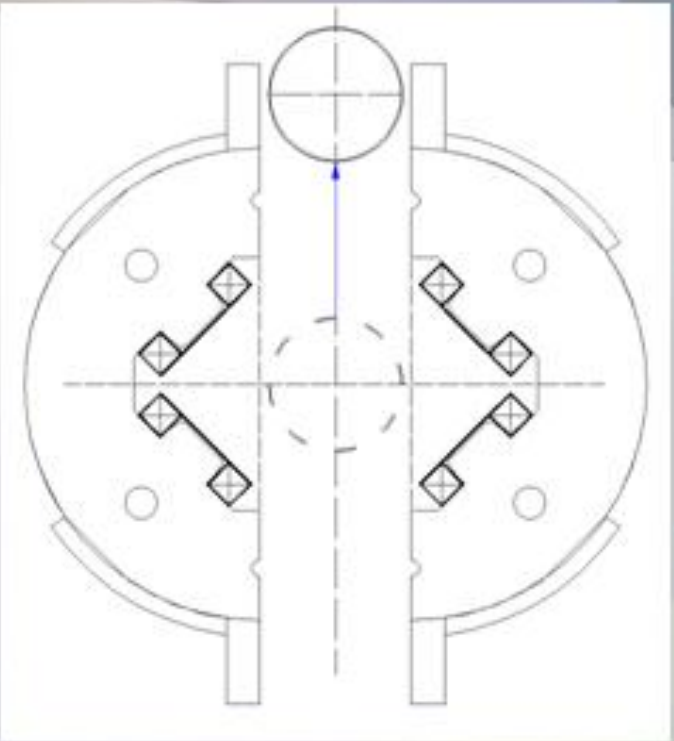






Quadrupole Mechanical Concept





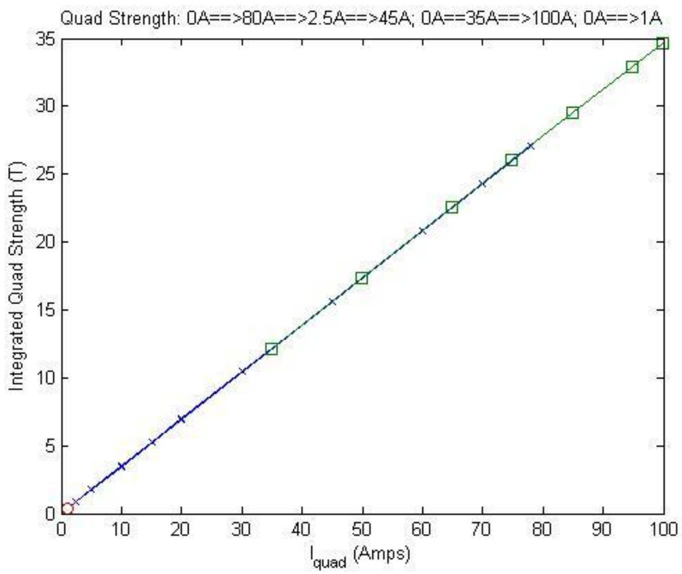
It was chosen the quadrupole design with racetrack coils which easy to split in vertical or horizontal direction.

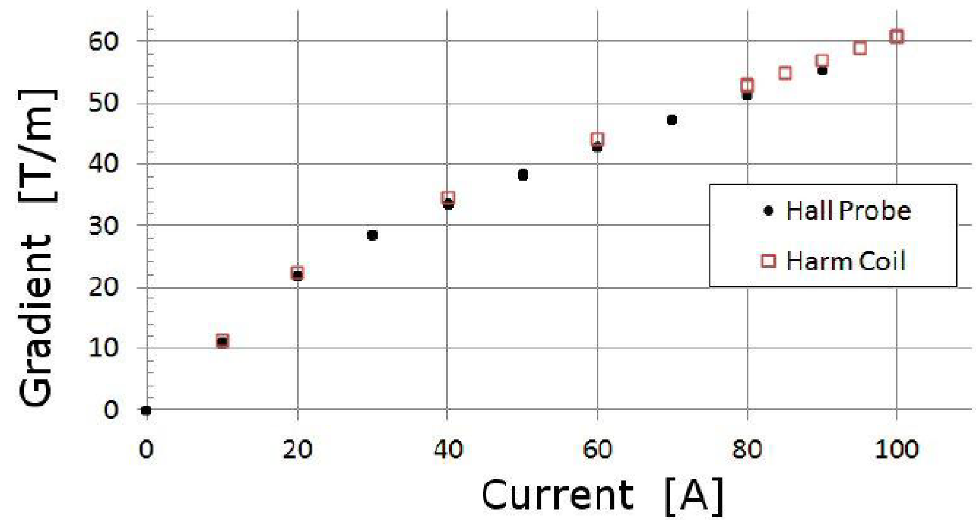
QUADRUPOLE MODEL PARAMETERS

Parameter	Unit	Value
Peak current at 36 T gradient	A	100
Magnet length	mm	680
NbTi superconductor diameter	mm	0.5
Superconductor filament size	µm	3.7
Superconductor critical current at 5 T and 4.2 K	A	200
Coil maximum field	T	3.3
Quadrupole coil number of turns/pole		700
Yoke outer diameter	mm	280

ILC Quad Prototypes

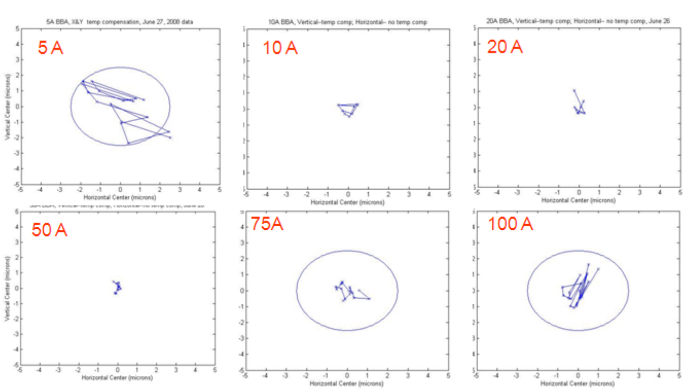
Left: CIEMAT Cos(ϕ) Right: FNAL Split Superferric





Center Motion with 20% Field Change

Motion Shown in Plots with +/- 5 µm Horizontal by +/- 5 µm Vertical Ranges



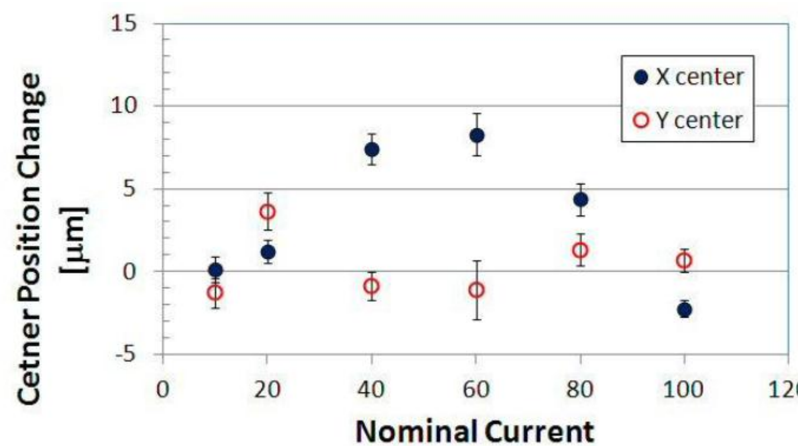
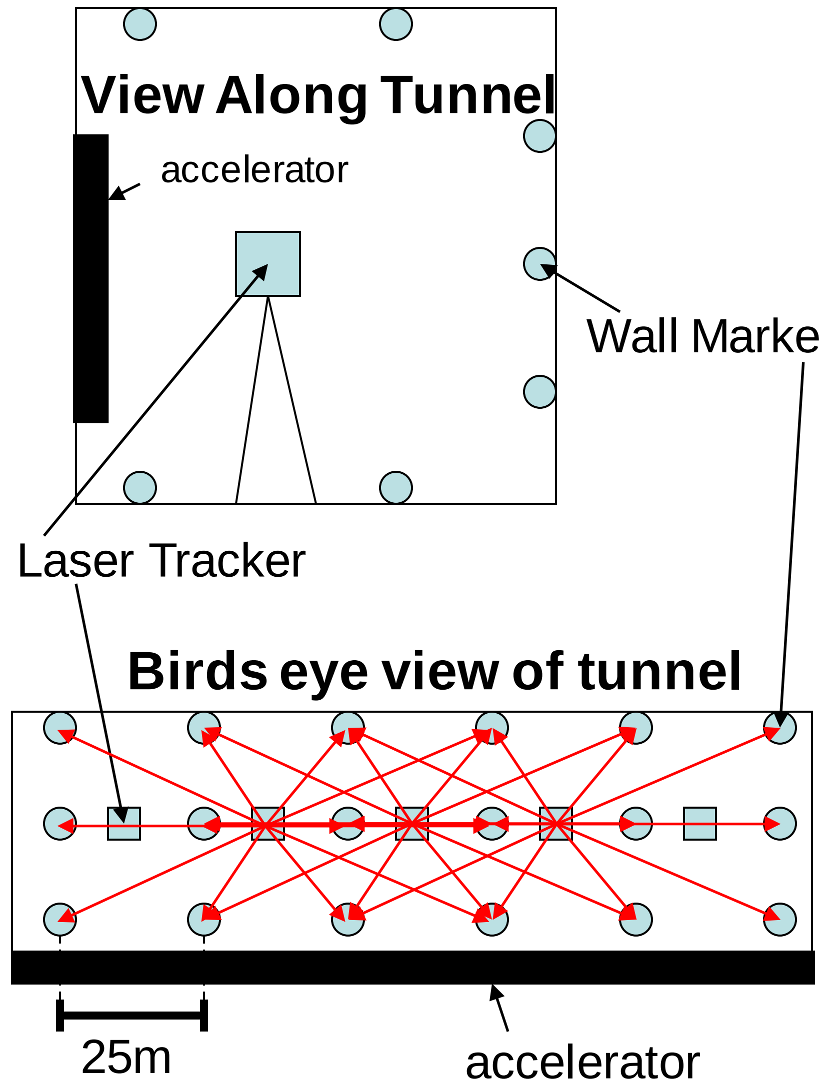


Fig. V-19. Summary of center position shifts as a function of operating current for a 20% gradient change.

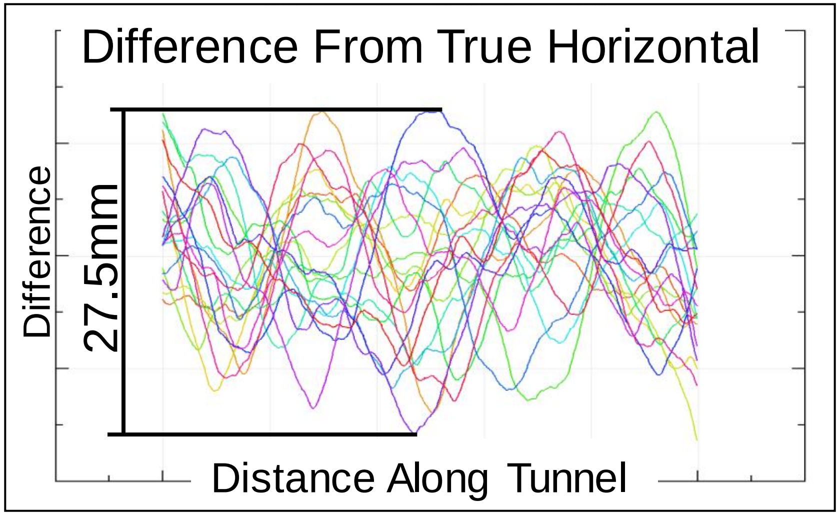
Linac Alignment Network

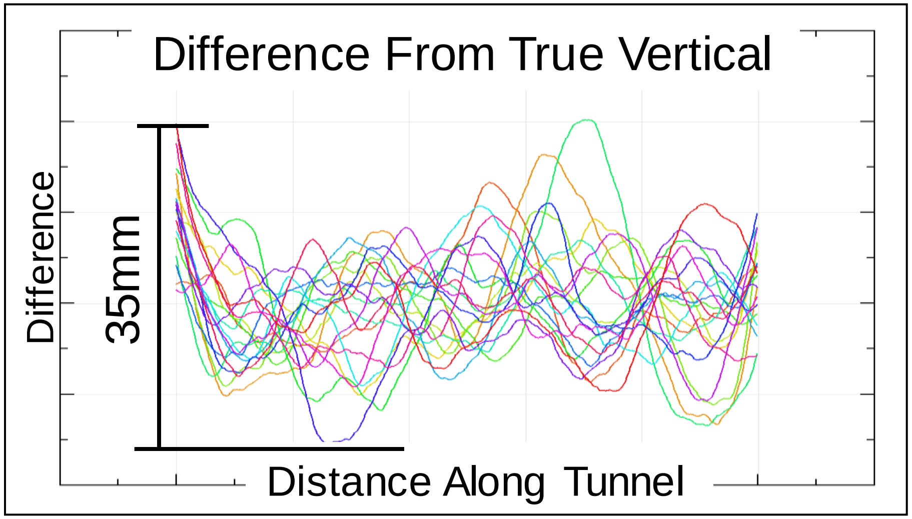
- Rings of 7 markers placed every 25m
  - Would like every 10m but current adjustment software not capable
- Network is Measured by a Laser Tracker
  - Laser tracker is placed between marker rings
  - Measures 2 rings up and down the tunnel
  - Statistical measurement Errors
    - Distance : 0.1mm+0.5ppm
    - Azimuth : 4.7 µrad
    - Zenith : 4.7 µrad
    - Errors estimated by experienced surveyors and laser tracker operators from DESY
  - Ignored all systematic errors from refraction in tunnel air (top hotter than bottom)



Alignment Simulations

- Use PANDA to calculate error propagation through network
- 20 Reference Networks were simulated in JAVA
  - Length 12.5km
  - Including GPS every 2.5km assuming 10 mm rms errors
- Problem with vertical adjustment under investigation at DESY and by authors of PANDA





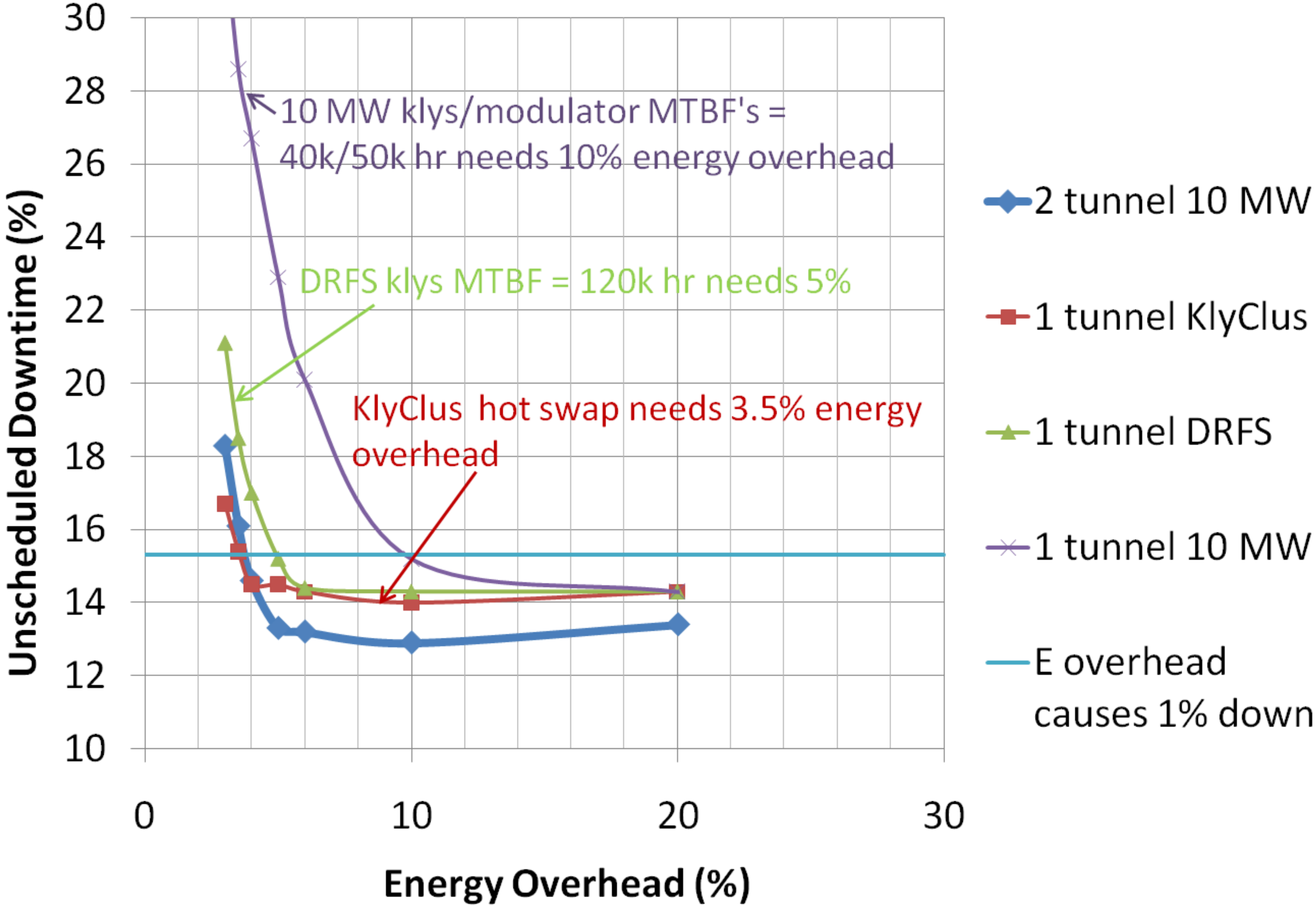
RDR RF Station Power Budget
(Brian Chase 2008 ?)

	Voltage loss	Power loss	Available Power (MW)
High Level RF Loss Factors			
Maximum Klystron Output Power		0.0%	10.00
De-rating of klystron for end of life time		0.0%	10.00
Modulator Ripple Spec = 1% (Often worse)	0%	0.0%	10.00
Waveguide and circulator losses		8.0%	9.20
Power loss due to cavity gradient variation		0.0%	9.20
Parameter variation	0.5%	1.0%	9.11
Low Level RF Loss Factors			
Peak power headroom	2.0%	4.0%	8.75
Dynamic Headroom	1.0%	2.0%	8.57
Beam current fluctuations of 1%pk		1.0%	8.49
Detuning errors of 30 Hz	1.0%	2.0%	8.32
Klystron drive noise sidebands	1.0%	2.0%	8.15
Beam Power Requirments for 26 cavities			
Power Required for 9.0ma @ 31.5 MV/m			7.651098
Excess Power Headroom			0.50 MW

Power to Spare !

Note: Lower power per cavity -> higher Ql and longer fill and decay times
This requires a longer modulator pulse and higher cryo loading
30 Hz detuning errors are the sum of microphonics and Lorentz force detuning. (Even if microphonics=0, we

Availsim Results



Tom Himel