PIP-II 650 MHz Low-Beta Cryomodule Options

T. Nicol – Fermilab
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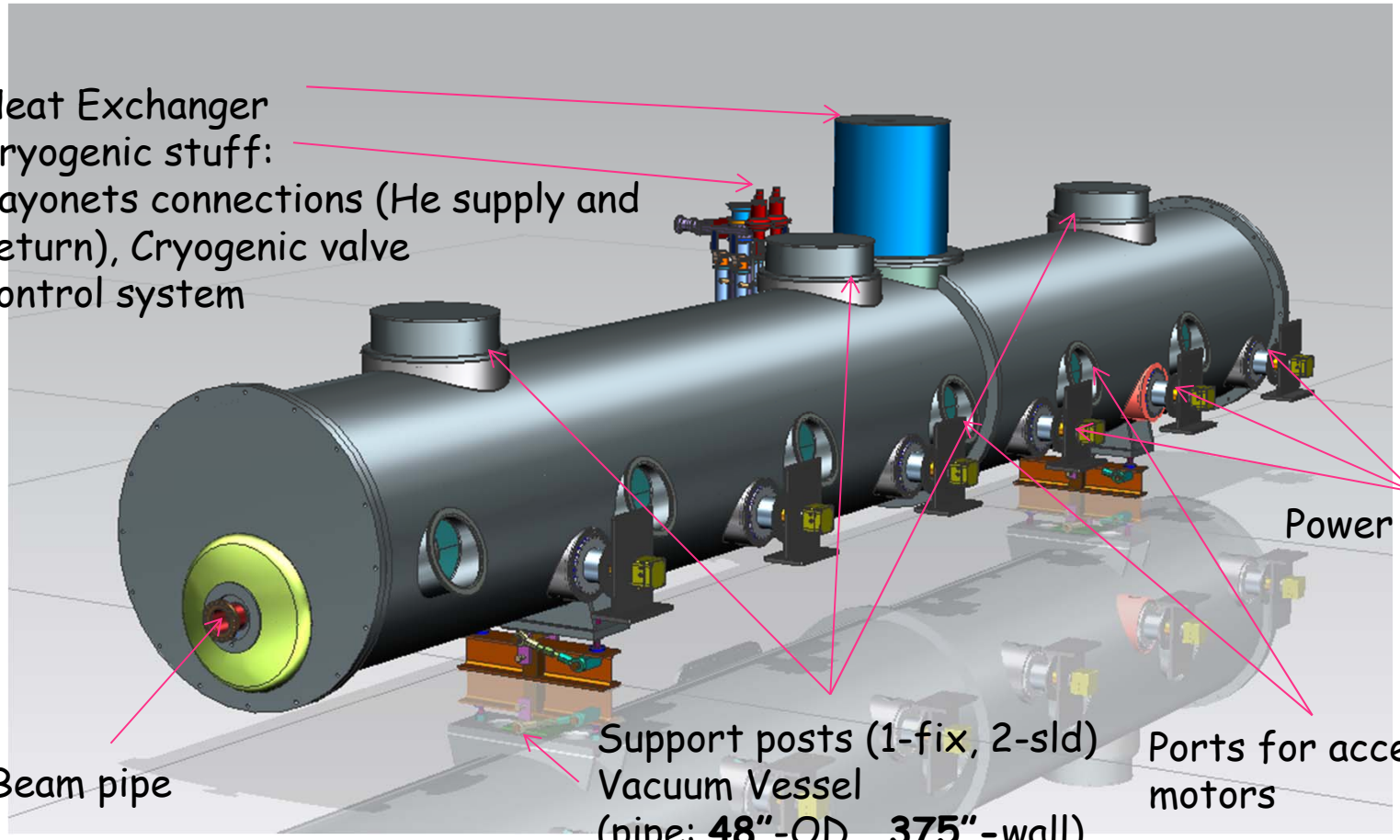
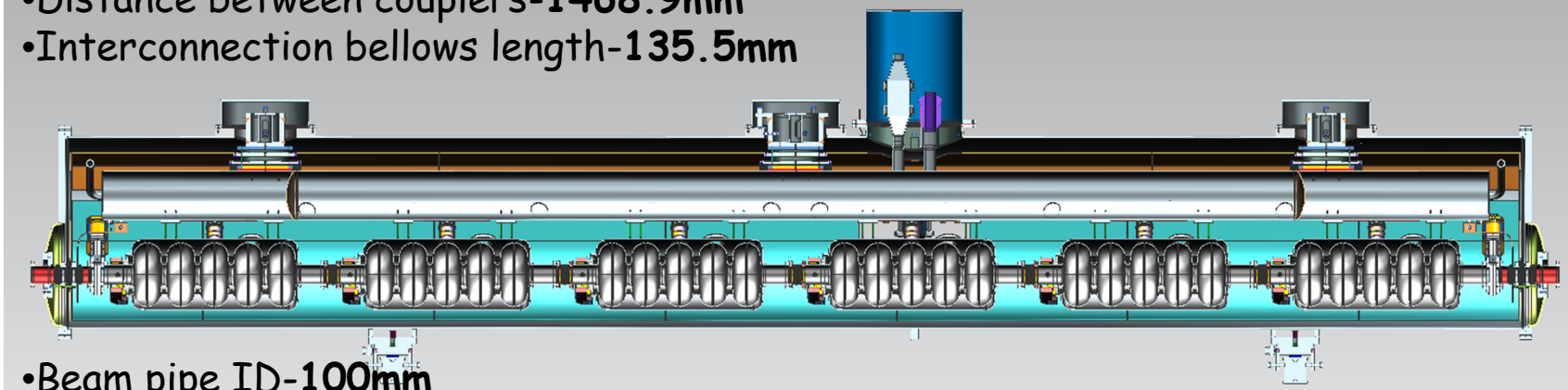
650 MHz High and Low Beta Cryomodule



650 MHz High and Low Beta Cryomodule

- Overall length (CS-Flange to Flange)-**9654mm**
- Number of Cavitis-**6**
- Distance between couplers-**1468.9mm**
- Interconnection bellows length-**135.5mm**



- Beam pipe ID-**100mm**
- **1** gate valve for each end of Beam Pipe (cold)
- Number of Support posts-**3** (1-Fix, 2-Sliding)
- **300mm** pipe (concept) serves as strong back, as the 2-phase helium pipe, also providing a large vapor buffer volume.
- Heat exchanger
- Insulation Vacuum Relief valve

650 MHz Low-Beta Cryomodule Options

- Option 1 – 3 cavities per CM, warm magnets in interconnect
  - Pros
    - Shorter cavity string to handle during assembly
    - No cold magnets or current leads
    - Easier to replace a single cryomodule in tunnel
    - Lower cost of spares
  - Cons
    - Slightly higher cryogenic distribution cost
    - Higher total project cost
- Option 2 – 6 cavities per CM + 1 superconducting quadrupole doublet
  - Pros
    - Lower cryogenic distribution cost
    - Lower total project cost
  - Cons
    - Cold magnet and current leads
    - Higher spares cost

650 MHz Low-Beta Heat Load Estimates

Option 1 - 3-cavities per CM							
650 MHz	Each unit			Mult	Total		
3 cavities	70 K	4.5 K	2 K		70 K	4.5 K	2 K
Input coupler static	5.36	2.82	0.50	3	16.08	8.46	1.50
Input coupler dynamic	25.00	0.00	0.25	3	75.00	0.00	0.75
Cavity dynamic load	0.00	0.00	24.00	3	0.00	0.00	72.00
Support post	2.76	0.36	0.05	6	16.56	2.16	0.30
Conduction lead assembly	36.80	13.20	1.24	0	0.00	0.00	0.00
MLI (total 70 K + 2 K)	30.59	0.00	1.46	1	30.59	0.00	1.46
Cold to warm transition	0.72	0.08	0.01	2	1.44	0.16	0.02
Total static + dynamic (per CM)					**139.7**	**10.8**	**76.0**
Total static (per CM)					**64.7**	**10.8**	**3.3**
Total static + dynamic all CMs)				10	**1396.7**	**107.8**	**760.3**
Total static (all CMs)				10	**646.7**	**107.8**	**32.8**

Option 2 - 6 cavities + quadrupole doublet per CM							
650 MHz	Each unit			Mult	Total		
6 cavities + 1 quad doublet	70 K	4.5 K	2 K		70 K	4.5 K	2 K
Input coupler static	5.36	2.82	0.50	6	32.16	16.92	3.00
Input coupler dynamic	25.00	0.00	0.25	6	150.00	0.00	1.50
Cavity dynamic load	0.00	0.00	24.00	6	0.00	0.00	144.00
Support post	2.76	0.36	0.05	14	38.64	5.04	0.70
Conduction lead assembly	36.80	13.20	1.24	1	36.80	13.20	1.24
MLI (total 70 K + 2 K)	60.88	0.00	2.97	1	60.88	0.00	2.97
Cold to warm transition	0.72	0.08	0.01	2	1.44	0.16	0.02
Total static + dynamic (per CM)					**319.9**	**35.3**	**153.4**
Total static (per CM)					**169.9**	**35.3**	**7.9**
Total static + dynamic all CMs)				5	**1599.6**	**176.6**	**767.2**
Total static (all CMs)				5	**849.6**	**176.6**	**39.7**

PIP-II

650 MHz Low-Beta Cost Summary

650 MHz cryomodule for Project X - Cost summary

Estimate in $FY2013

	Option 1	**Option 2**	**Difference**
No. Low-B CMs	10	5	
Cryo distribution cost (total)	$651,250	$488,750	
Low-B one-time costs without overhead (total)	$1,656,330	$1,656,330	
Low-B without overhead (per CM)	$2,260,716	$3,618,989	
Total without overhead	**$24,914,737**	**$20,240,027**	***-18.76%***
Total without overhead + 1 spare	**$27,175,453**	**$23,859,017**	***-12.20%***
Cryo distribution cost (total)	$781,500	$586,500	
Low-B one-time costs with overhead (total)	$2,764,313	$2,764,313	
Low-B with overhead (per CM)	$3,185,667	$5,044,844	
Total with overhead	**$35,402,488**	**$28,575,034**	***-19.29%***
Total with overhead + 1 spare	**$38,588,155**	**$33,619,878**	***-12.88%***

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650 MHz Low-Beta Cost Assumptions

- Estimate template is that from our ESS medium-B cryomodule estimate (4-704 MHz cavities).
- Cold mass and cryomodule design effort for high-B is half that of low-B (assume we do the low-B first).
- Tooling and other one-time items are applied in the low-B cost estimate only.
- Length multipliers are 0.9 for 3-cavity, 1.0 for 4-cavity, 1.1 for 6-cavity, and 1.2 for 8-cavity cryomodules (apply only to long cryomodule components, e.g. vacuum vessel, shields, etc.)
- Cavity EM and mechanical designs are complete.
- High-B assembly takes twice as long as low-B.
- The cost of the superconducting quadrupole doublet is not included in Option 2.

Summary

- Total 2 K heat load differences are insignificant, 760 W for Option 1 vs. 767 W for Option 2.
- Cost difference is not insignificant, but becomes less when considering at least 1 spare cryomodule.
- The lack of a cold magnet and associated current leads is a big advantage for Option 1 due to a simplified assembly and avoidance of trapped cavity flux caused by magnet quench.