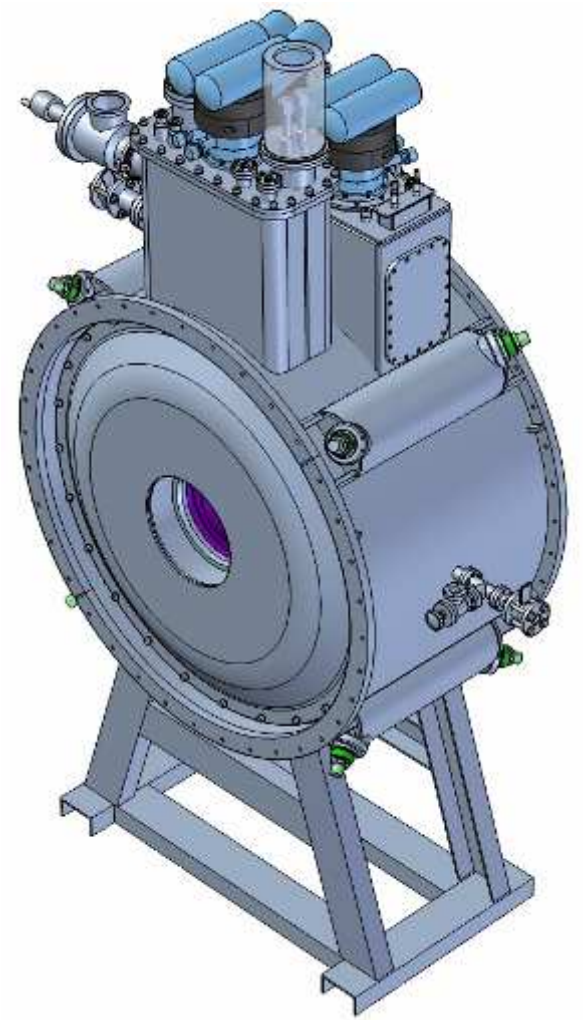
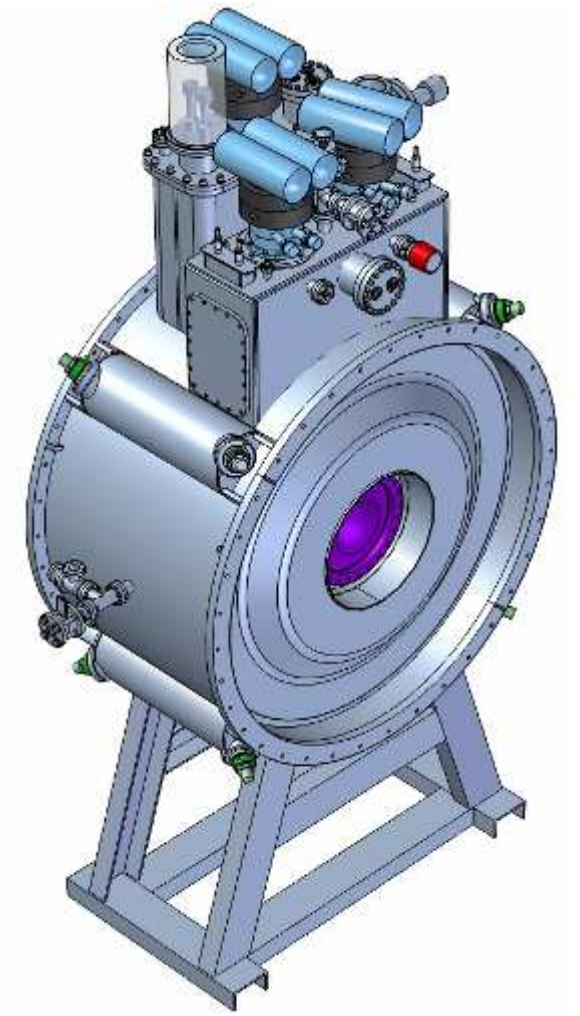
FC MODULE STATUS October 2010





PEOPLE

Elwyn Baynham	Consultant
Tom Bradshaw	RAL
Victoria Bayliss	RAL
John Cobb	Oxford
Mike Courthold	RAL
Tom Frame	Tesla (new engineer)
Fred Goldie	Tesla
Matt Hills	RAL
Wing Lau	Oxford
Mike Nakatsu	Tesla
Mark Savill	Tesla
Engineers & designers	Tesla

MONITORING PROGRESS

Meet ~ once a month *chez* Tesla as well as email & 'phone.

Discuss technical & design questions, and progress

Frequency of visits will increase to ~ 1 / week when production starts in earnest

Latest visit 30 September

TWB maintains web page with all technical notes, slides &c

Very conscious of problems with SSs

MICE Absorber and Focus Coil Project Page

File List

List of files and status.....	FileList.xls

Schedule and Action Item List

1	Project plan - add 2-3 months delay	Ver= 01/06/2009	AF79 ProjectPlan 090602.pdf
2	Project plan - issued March 2010	Ver= 01/03/2010	AF79 ProjectPlan 100315.pdf

Contractual

1	Techical Specification	Ver= Final	AFC Tech spec 29 06 07 Final.pdf
2	Tesla offer letter	Ver=	E4304_311007.pdf
3	Tesla schedule	Ver=	E4304_ProjectPlan311007.pdf
4	Tesla Quote	Ver=	Tesla Quote 100807.pdf
5		Ver=	
6	Cover letter	Ver=	2008-04 Cover Letter AFC Procurement.pdf
7	Milestone and Payment Plan updated	Ver= 2nd June 2009	AFC Tesla Milestone Payment Plan.pdf
8	Price confirmation from KO mtg 18th April 2008	Ver=	E4304 price confirmation 180408.pdf
9	MICE Tender activities	Ver=	MICE AFC tender activities 07.pdf
10	STFC requisition	Ver=	2008-04 Requisition AFC Tesla.pdf
11	Tesla Commercial Variance - Line 13 Req	Ver=	MICE commercial variance offerletter 19 05 09.pdf
12	Tesla Commercial Variance - line 14	Ver=	MICE commercial variance offer letter 24 02 10.pdf

Production Readiness Review

STATUS

1. **Interface issues with absorber have been resolved**

2. **Metal is being cut**
   - **Small items such as metalwork for turrets**
     - ***We haven't seen these yet***
3. **Instrumentation list ~ complete**
   - **May be another iteration after discussion last week**
4. **Winding**
   - **Some delays**
5. **Quench protection has been decided**

6. **Ongoing design of thermal anchoring of current & HTS leads**

7. **Assembly plan**

More on 4 – 7 in following

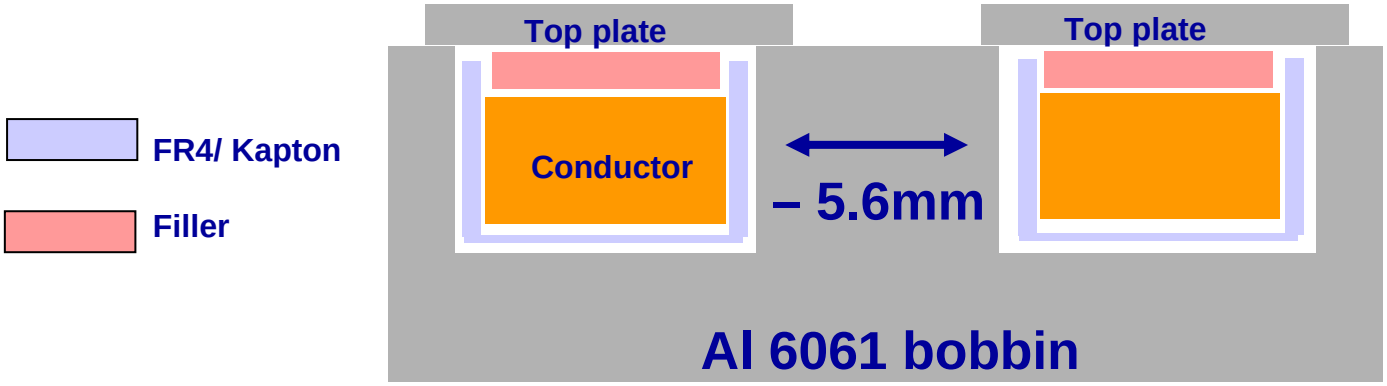
BOBBIN ON WINDING MACHINE

Old picture. Now moved to cleaner but ‘commercially sensitive’ area

Problems with second-hand winding machine have been fixed

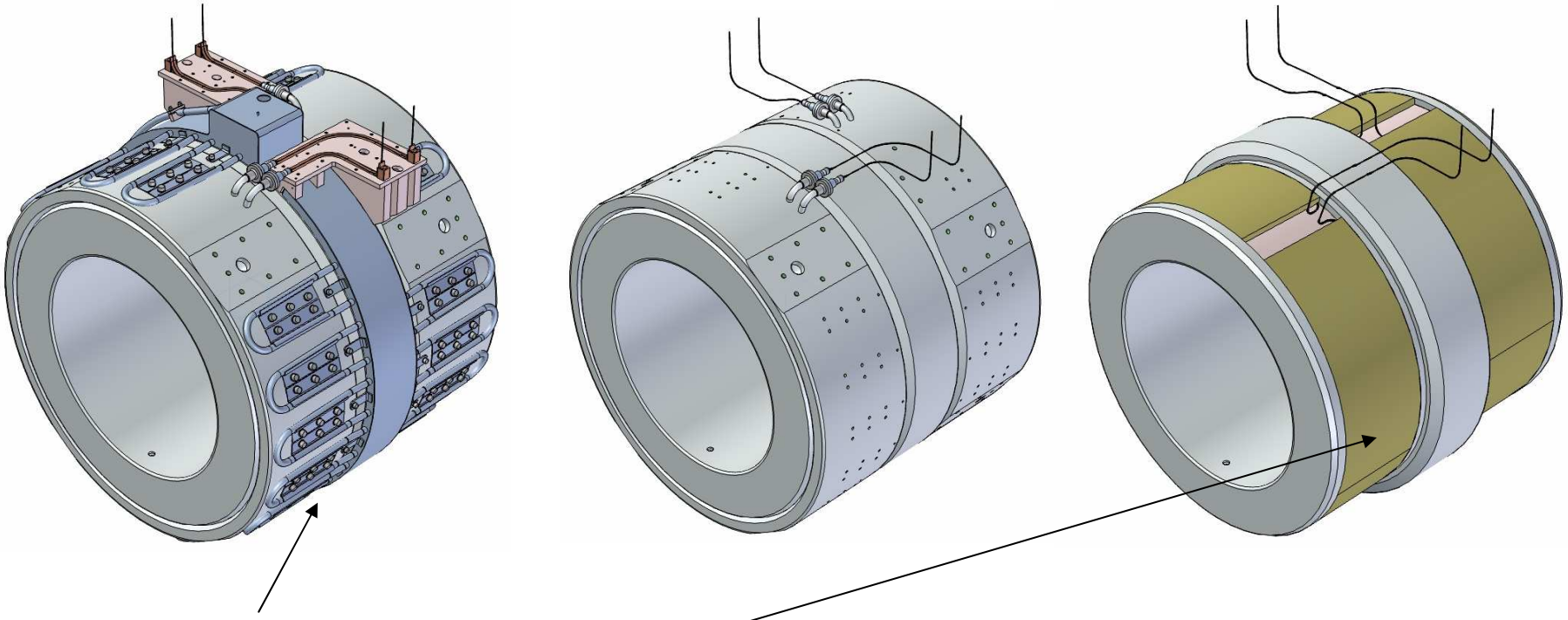
Had hoped that winding would have started by now…

BOBBIN & WINDING



1 Need slip coating between coil and bobbin
- Planned to use PTFE
  - But temperature for coating would destroy temper of Al-6061
- Some delay whilst Kapton + release agent alternative developed (~done)

2 Need insulation and lead-in for conductor at sides – takes some space
- Increase width of slot to accommodate integral number of turns (133)
- ➔ Remove 2.8mm on inside of each slot (~done)



3 LHe cooling is on outside

- **ΔT through epoxy & filler is larger than necessary**
- **Overwind & fill space with copper – tbd exactly how**
  - **(Heaters – see below – will also be in this space)**

4 Welds of top plates to bobbin are critical

- **➔ Weld(er) qualification happening now (employing welding consultant)**

- **Winding advertised to start in 2 – 3 weeks**
  - **Will be short test winding first**

QUENCH PROTECTION

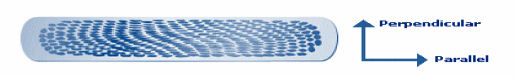
- **Many many discussions about this**
  - **'Quenchback' had been assumed**
- **Tesla made many simulations using VF software**
  - **Various assumptions**
    - **Thermal contact between coils & bobbin**
    - **AC losses….**
  - **For 240 Flip & Non-flip modes**
- **A few kV can occur if quenchback mechanisms fail**
  - **~700V if OK**
  - **Insulation tests @ ~2.5 – 3 kV**
- ***'...Tesla is not confident that either quenchback or AC losses offer a convincing secondary quench mechanism….'***

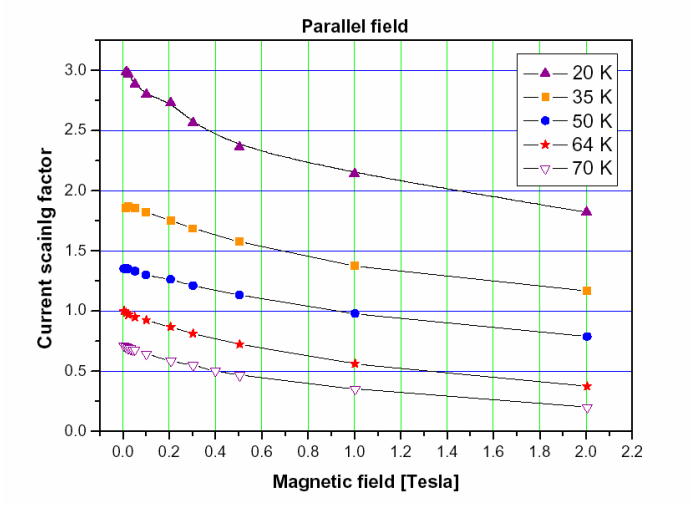
- **Tesla proposes heaters on outside of each coil**
  - **We concur**
    - **Belt & braces approach**
  - **Has been simulated for FCs**
  - **Tesla have successfully used similar system on another project**

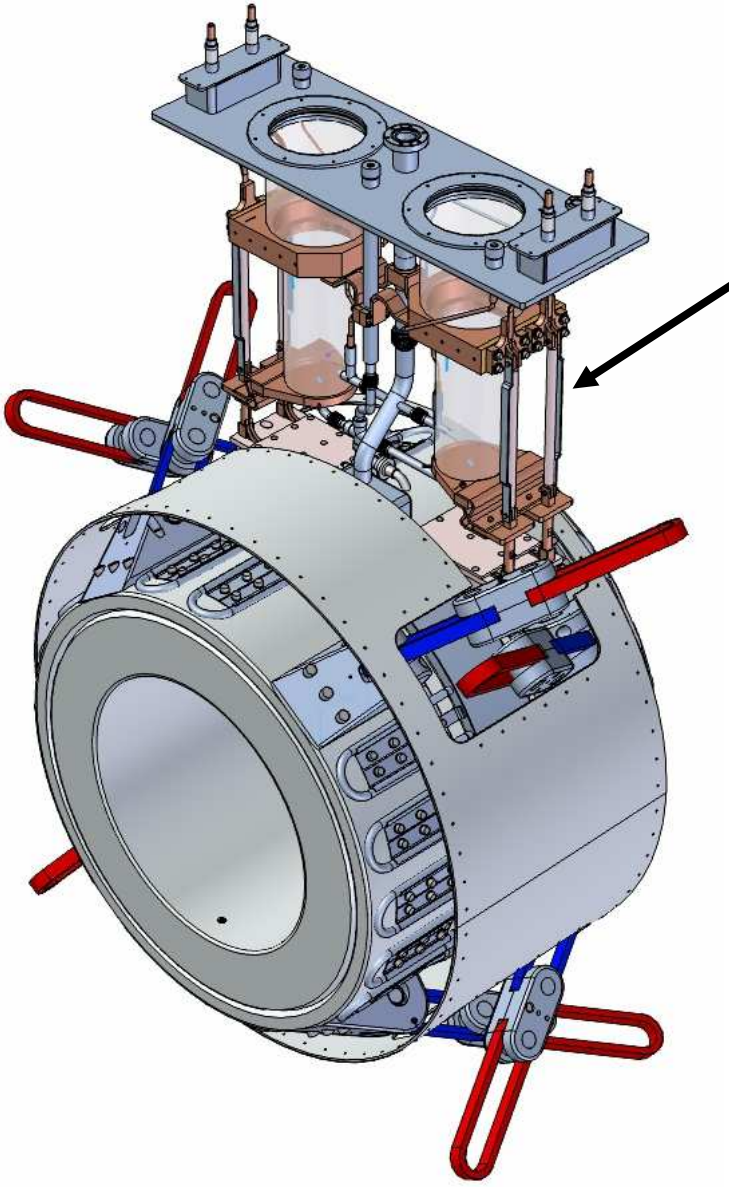
- **Each coil will have 100W heaters**
  - **Powered by voltage developed across discharge resistors**
  - **Three/coil for redundancy**
  - **Cross-coupled**
    - **Quench in one coil forces quench in the other coil in module**
- **Entirely passive system for quench of coils**
  - **(Need quench detection to turn off PSU)**
- **Active system required to protect HTS leads**
  - **DL developing; some details to clarify**

HTS LEADS

Each module has four 500 A HTS-110 leads







- **HTS leads had been moved for space reasons**
- **Critical current of HTS leads depends on**
  - **Temperature at top (warm end)**
  - **Components of magnetic field parallel and perpendicular to leads**
- **Had to check still OK**
  - **Identify worst cases from many operating 'cases' for MICE**
    - **2 positions of leads / module**
    - **3 positions of modules**
      - **Leads asymmetrically placed & feel field of SSs**
    - **2 possible orientations of leads**
    - **2 field components – parallel and perpendicular**
    - **3 'Steps' – IV, V and VI**
- **Check something like 400 different cases….**
  - ***Thanks to C. Tunnell for a very handy field calculator***

07-Sep-10

	Module	Z lead (m)	Bz(r=900)	Br(r=900)	r (mm)	x(mm)	*Flats parallel to z* Bparallel = Bz	Bperp = Bx	Derate 64K Parallel	Derate 64K Perp	Derate 50K Parallel	Derate 50K Perp	Margin = Iop / Ic 64K Parallel	Margin = Iop / Ic 64K Perp	Margin = Iop / Ic 50K Parallel	Margin = Iop / Ic 50K Perp
FC only, Sol, 244A		0.07	-0.187	0.038	850	306	-0.187	0.014	0.89	0.82	1.27	1.23	**1.82**	**1.67**	2.59	2.51
		0.16	-0.174	0.086	850	306	-0.174	0.031	0.89	0.82	1.27	1.23	**1.82**	**1.67**	2.59	2.51
FC only, flip 244A		0.07	0.042	0.164	850	306	0.042	0.059	0.93	0.63	1.30	1.10	**1.91**	**1.29**	2.66	2.25
		0.16	0.085	0.132	850	306	0.085	0.047	0.92	0.63	1.29	1.10	**1.88**	**1.29**	2.64	2.25
FC, Only, Downstream		0.07	-0.114	-0.063	850	306	-0.114	-0.023	0.90	0.82	1.28	1.23	**1.84**	**1.67**	2.62	2.51
		0.16	-0.130	-0.023	850	306	-0.130	-0.008	0.90	0.91	1.28	1.29	**1.84**	**1.86**	2.62	2.64
FC only, upstream coil, 244A		0.07	-0.072	0.101	850	306	-0.072	0.037	0.92	0.82	1.29	1.23	**1.88**	**1.67**	2.64	2.51
		0.16	-0.044	0.109	850	306	-0.044	0.039	0.93	0.63	1.30	1.10	**1.91**	**1.29**	2.66	2.25
Sol 2, Step IV	Upstream	-2.68	-0.068	0.015	850	306	-0.068	0.006	0.92	0.91	1.29	1.29	3.60	3.57	5.08	5.07
		-2.59	-0.062	0.034	850	306	-0.062	0.012	0.93	0.91	1.30	1.29	3.66	3.57	5.12	5.07
Sol 5, Step IV	Upstream	-2.68	-0.132	0.029	850	306	-0.132	0.010	0.90	0.91	1.28	1.29	2.24	2.26	3.18	3.20
		-2.59	-0.122	0.064	850	306	-0.122	0.023	0.90	0.82	1.28	1.23	2.24	2.03	3.18	3.05
240 Flip, Step IV	Upstream	-2.68	-0.042	-0.255	850	306	-0.042	-0.092	0.93	0.50	1.30	0.95	**1.91**	**1.02**	2.66	**1.95**
		-2.59	-0.084	-0.224	850	306	-0.084	-0.081	0.92	0.57	1.29	1.03	**1.88**	**1.16**	2.64	2.10
Sol 2, Step V	Upstream	-2.68	0.096	-0.118	850	306	0.096	-0.043	0.90	0.63	1.28	1.10	3.54	2.48	5.04	4.33
		-2.59	0.122	-0.125	850	306	0.122	-0.045	0.90	0.63	1.28	1.10	3.54	2.48	5.04	4.33
	Centre	0.07	0.071	0.119	850	306	0.071	0.043	0.92	0.63	1.29	1.10	3.60	2.48	5.08	4.33
		0.16	0.062	0.123	850	306	0.062	0.044	0.93	0.63	1.30	1.10	3.66	2.48	5.12	4.33
Sol 5, Step V	Upstream	-2.68	-0.059	-0.026	850	306	-0.059	-0.009	0.93	0.91	1.30	1.29	2.31	2.26	3.23	3.20
		-2.59	-0.041	-0.001	850	306	-0.041	0.000	0.93	0.91	1.30	1.29	2.31	2.26	3.23	3.20
	Centre	0.07	-0.071	0.071	850	306	-0.071	0.026	0.92	0.82	1.29	1.23	2.28	2.03	3.21	3.05
		0.16	-0.067	0.101	850	306	-0.067	0.036	0.92	0.82	1.29	1.23	2.28	2.03	3.21	3.05
240 Flip, Step V	Upstream	-2.68	0.113	-0.375	850	306	0.113	-0.135	0.90	0.50	1.28	0.95	**1.84**	**1.02**	2.62	**1.95**
		-2.59	0.092	-0.367	850	306	0.092	-0.132	0.90	0.50	1.28	0.95	**1.84**	**1.02**	2.62	**1.95**
	Centre	0.07	0.169	0.347	850	306	0.169	0.125	0.89	0.50	1.27	0.95	**1.82**	**1.02**	2.59	**1.95**
		0.16	0.197	0.303	850	306	0.197	0.109	0.88	0.50	1.25	0.95	**1.79**	**1.02**	2.56	**1.95**
Sol 2	Upstream	-2.68	0.136	-0.092	850	306	0.136	-0.033	0.90	0.82	1.28	1.23	3.54	3.21	5.04	4.82
		-2.59	0.161	-0.103	850	306	0.161	-0.037	0.89	0.82	1.27	1.23	3.49	3.21	4.98	4.82
	Centre	0.07	0.240	-0.015	850	306	0.240	-0.005	0.84	0.91	1.23	1.29	3.30	3.57	4.82	5.07
		0.16	0.252	-0.036	850	306	0.252	-0.013	0.84	0.82	1.23	1.23	3.30	3.21	4.82	4.82
	Downstream	2.82	0.108	0.085	850	306	0.108	0.031	0.90	0.82	1.28	1.23	3.54	3.21	5.04	4.82
		2.91	0.099	0.082	850	306	0.099	0.030	0.90	0.82	1.28	1.23	3.54	3.21	5.04	4.82
Sol 5 240	Upstream	-2.68	-0.039	-0.007	850	306	-0.039	-0.002	0.93	0.91	1.30	1.29	**1.92**	**1.87**	2.68	2.66
		-2.59	-0.018	0.019	850	306	-0.018	0.007	0.97	0.91	1.33	1.29	**1.99**	**1.87**	2.73	2.66
	Centre	0.07	0.006	0.020	850	306	0.006	0.007	0.98	0.91	1.34	1.29	2.03	**1.87**	2.76	2.66
		0.16	0.022	0.043	850	306	0.022	0.015	0.97	0.82	1.33	1.23	**1.99**	**1.68**	2.73	2.53
	Downstream	2.82	-0.054	0.057	850	306	-0.054	0.020	0.93	0.82	1.30	1.23	**1.92**	**1.68**	2.68	2.53
		2.91	-0.050	0.086	850	306	-0.050	0.031	0.93	0.82	1.30	1.23	**1.92**	**1.68**	2.68	2.53
Sol 5 200	Upstream	-2.68	-0.033	-0.006	850	306	-0.033	-0.002	0.97	0.91	1.33	1.29	2.39	2.25	3.28	3.19
		-2.59	-0.015	0.016	850	306	-0.015	0.006	0.97	0.91	1.33	1.29	2.39	2.25	3.28	3.19
	Centre	0.07	0.005	0.016	850	306	0.005	0.006	0.98	0.91	1.34	1.29	2.43	2.25	3.31	3.19
		0.16	0.018	0.036	850	306	0.018	0.013	0.97	0.82	1.33	1.23	2.39	2.02	3.28	3.03
	Downstream	2.82	-0.045	0.047	850	306	-0.045	0.017	0.93	0.82	1.30	1.23	2.30	2.02	3.22	3.03
		2.91	-0.042	0.072	850	306	-0.042	0.026	0.93	0.82	1.30	1.23	2.30	2.02	3.22	3.03
240 Flip	Upstream	-2.68	0.101	-0.371	850	306	0.101	-0.134	0.90	0.50	1.28	0.95	**1.84**	**1.02**	2.62	**1.95**
		-2.59	0.079	-0.363	850	306	0.079	-0.131	0.92	0.50	1.29	0.95	**1.88**	**1.02**	2.64	**1.95**
	Centre	0.07	0.014	0.467	850	306	0.014	0.168	0.97	0.43	1.33	0.87	**1.98**	**0.87**	2.72	**1.77**
		0.16	0.022	0.446	850	306	0.022	0.160	0.97	0.43	1.33	0.87	**1.98**	**0.87**	2.72	**1.77**
	Downstream	2.82	-0.158	-0.344	850	306	-0.158	-0.124	0.89	0.50	1.27	0.95	**1.82**	**1.02**	2.59	**1.95**
		2.91	-0.187	-0.300	850	306	-0.187	-0.108	0.89	0.50	1.27	0.95	**1.82**	**1.02**	2.59	**1.95**
			0.25	0.47			0.25	0.17					**1.79**	**0.87**	**2.56**	**1.77**
			-0.19	-0.37			-0.19	-0.13								
			0.187224	0.374818			0.187224	0.134934								
Max Fields			**0.252**	**0.467**			**0.252**	**0.168**			**MIn Margins**		**1.79**	**0.87**	2.56	**1.77**

Flats // to z

Highlighted for Ic/Iop < 2.0 , <1.5

			Flats parallel to z		Minimum Margin = Iop / Ic				Iop (Amps)	
	Bz max	Br max	B// = Bz	Bperp = Bx	64K		50K			
					//	Perp	//	Perp		
Max Fields	0.252	0.467	0.252	0.168	1.79	0.87	2.56	1.77	244	Central FC, 240-Flip, Step VI
			Flats perp to z							
			B// = Bx	Bperp = Bz						
Max Fields	0.252	0.467	0.168	0.252	1.82	0.72	2.59	1.60	244	Downstream module, 240 Flip, Step V

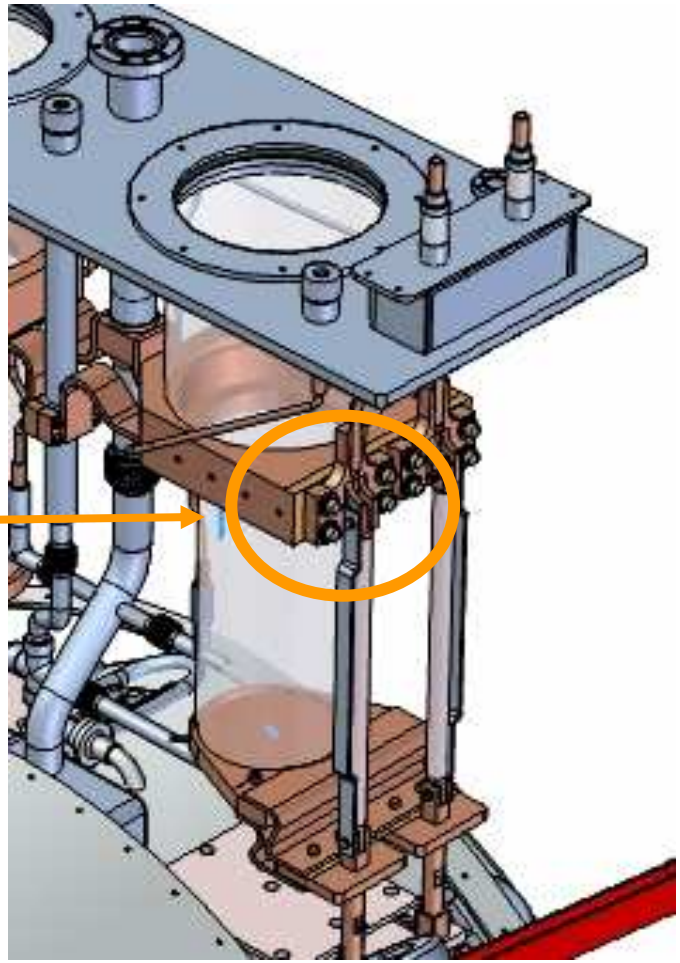
- Worst cases are 240 Flip mode (could have guessed, perhaps)
- 64K is too warm
  - But expecting ~45K at warm end
- Better if flats on leads are parallel to z
  - Were perpendicular to z in model
- Ongoing dialogue with HTS-110 about accuracy of de-rating curves

Comfortable margin if top of lead is at 45K and leads rotated 90 degrees

Most recent thermal model gave warm end of lead as 52K– not much margin

Check (DEB) of calculation suggested higher ΔT across joint to Stage 1 of cryocooler ➔ T ~64K – too warm

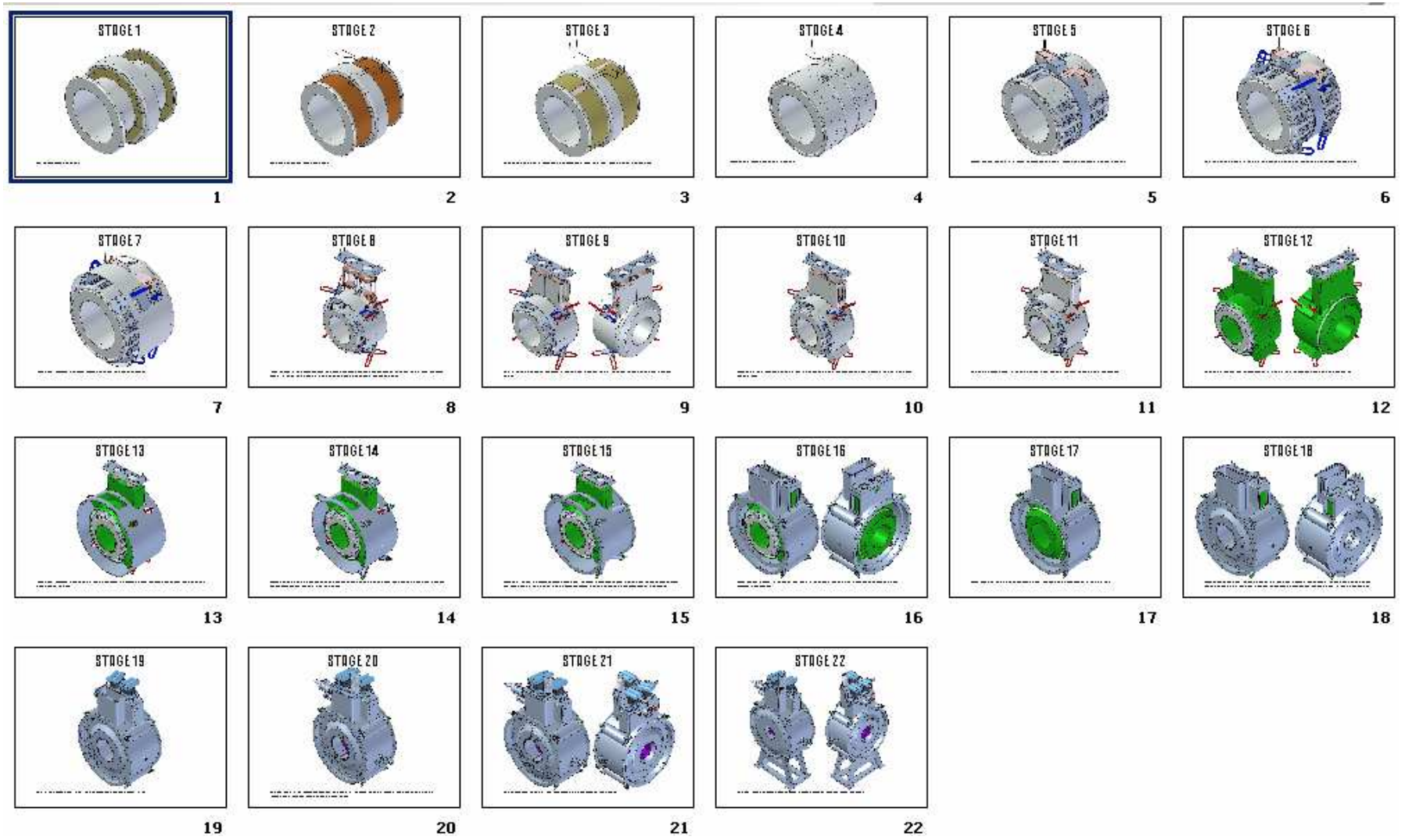
Some (small) concerns about electrical insulation – must test to 2.5 kV – here, too



- ***These can be fixed with some redesign***
- ***We have proposed some design modifications & insulation test* before *assembly***

- ***Must take the time to get these right***

ASSEMBLY



Tesla have a draft assembly plan *aka* 'Story Board'

- **We have reviewed assembly procedure and identified some questions, e.g:**

- **Assembly**
  - **At what stage is flange welded to cryostat?**
  - **How are pre-tensions in CM supports set up?**
  - **How is CM aligned?**
  - **When are legs attached?**

- **Metrology**
  - **How is position of cold mass transferred to external fiducials?**

- **These are all being addressed by Tesla**
  - **We shall monitor them**

SCHEDULE

Task Description	2010				2011						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Focus Coil Magnet #1											
Design											
Delivery of components											
Manufacture											
Assembly											
Test											
Delivery to RAL											
Integration activities										Required Q3 2011	
Focus Coil Magnet #2											
Manufacture											
Assembly											
Test											
Delivery to RAL											
Absorber integration										Required 2012	

As shown to MPB by TWB

Currently under review – estimate will be +1 month

SUMMARY

- Winding should start soon
- Quench protection has been decided
- Ongoing design of thermal anchoring of HTS leads
- Assembly plan being reviewed & revised
- Schedule being reviewed
- Need to keep watching details
  - Even if it means going rather slowly