VLHC Magnet Technologies Workshop

Fermilab, May 24-26, 2000

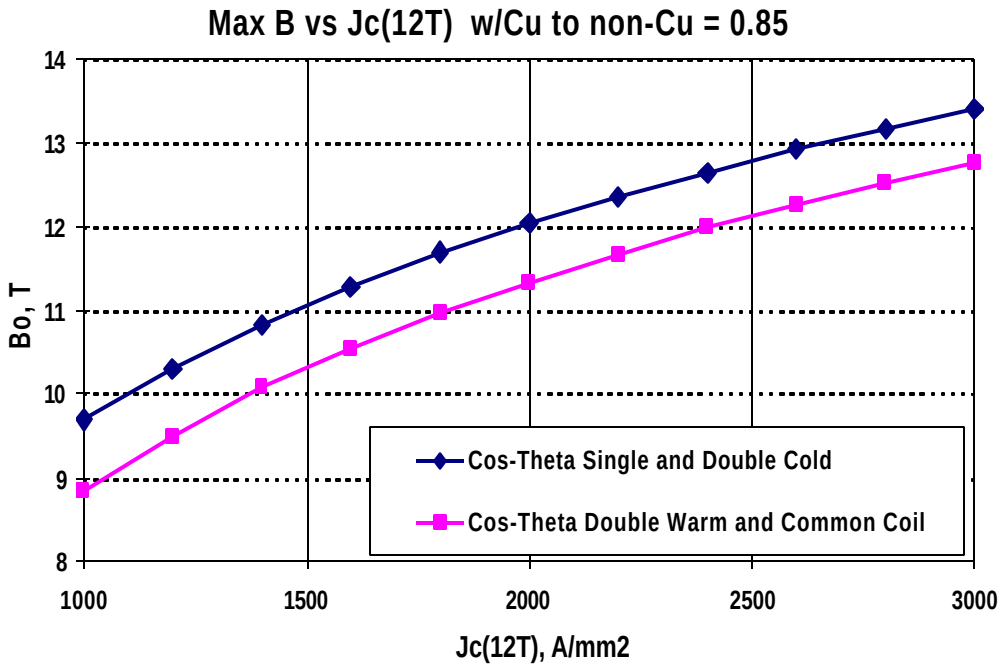
Superconducting Strand and Cable Studies for Nb_3Sn High Field Dipole Magnets

Emanuela Barzi

Outline

- **Target requirements for Nb_3Sn**
- **Where are we? Work in progress on:**
  - *** Strand characterization**
  - *** Cable optimization**
- **Can we improve performancies?**
  - *** HT times ® Breakthrough for Internal Tin**
  - *** J_c, d_{eff}, stability**
- **Conclusions**

Target Requirements



W/Cu to non-Cu=1.2

10%-20% Degradation

15% Margin

Nominal field, T	Maximum field, T	Jc(12T,4.2K), kA/mm^2	
		Cos-theta	Common coil
10	11.5	2.2	3.0
11	12.7	3.0	4.4
12	13.8	4.4	6.1

Jc > 3000A/mm2 **Deff < 30-40 micron**

Piece length > 1 km **Cu to non-Cu up to 1.5**

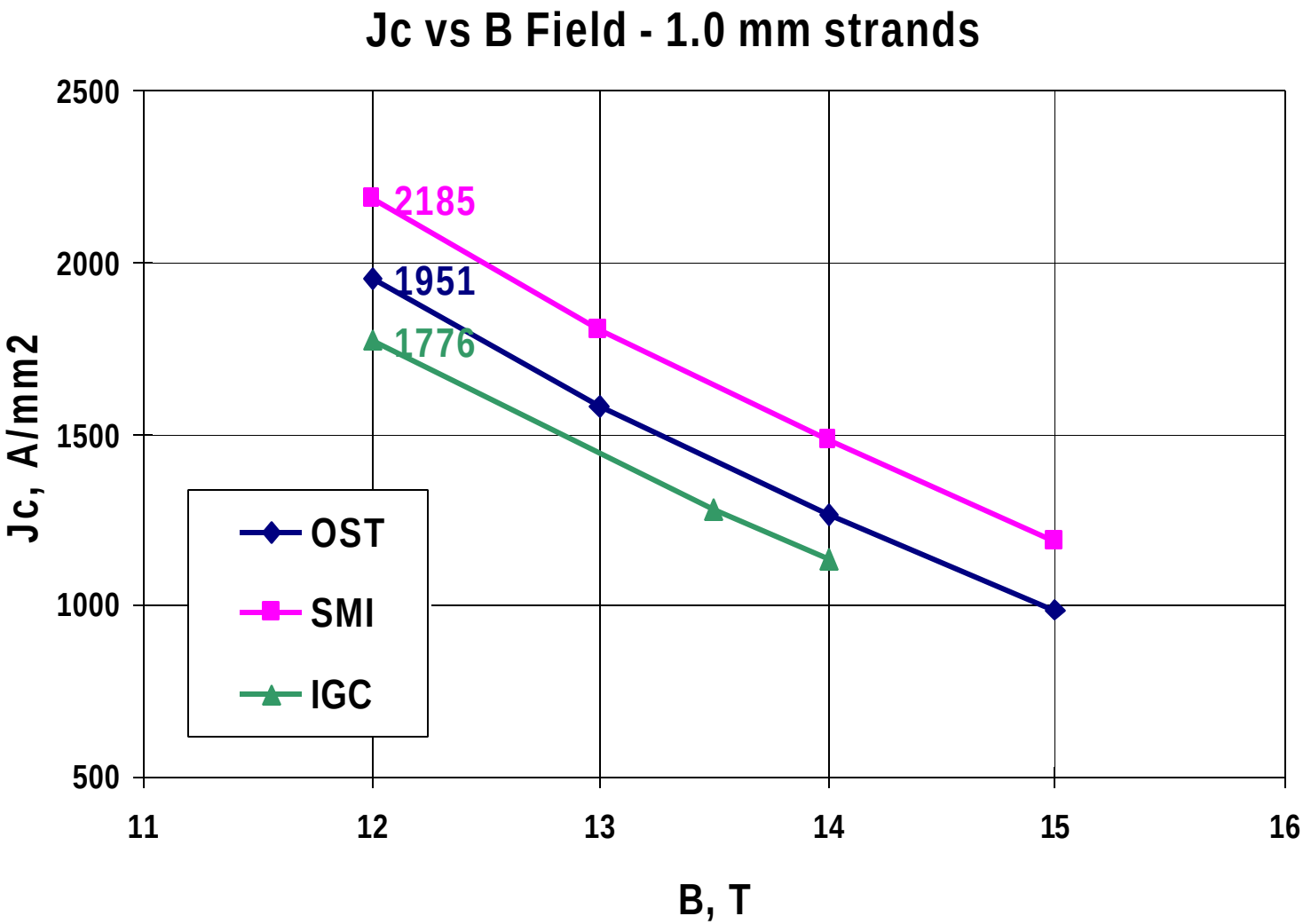
As short as possible reaction cycles

As cheap as possible

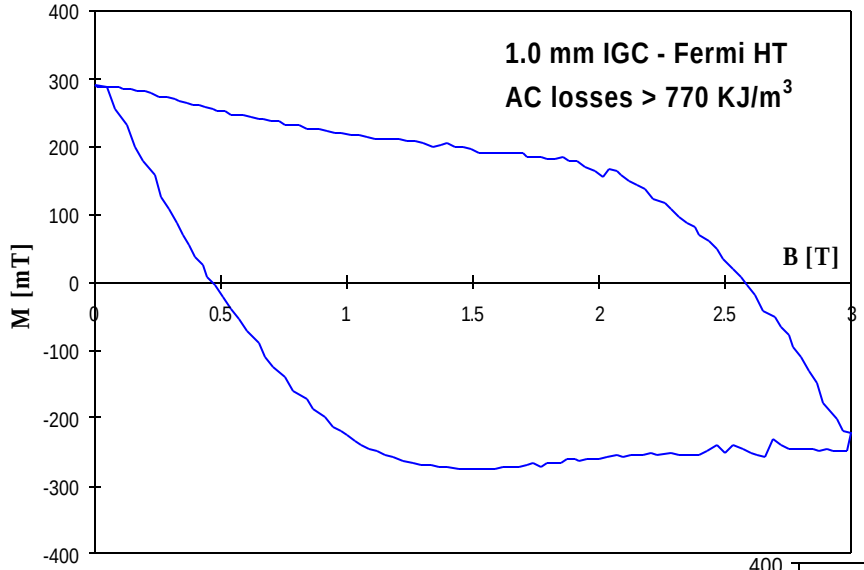
Strand Description

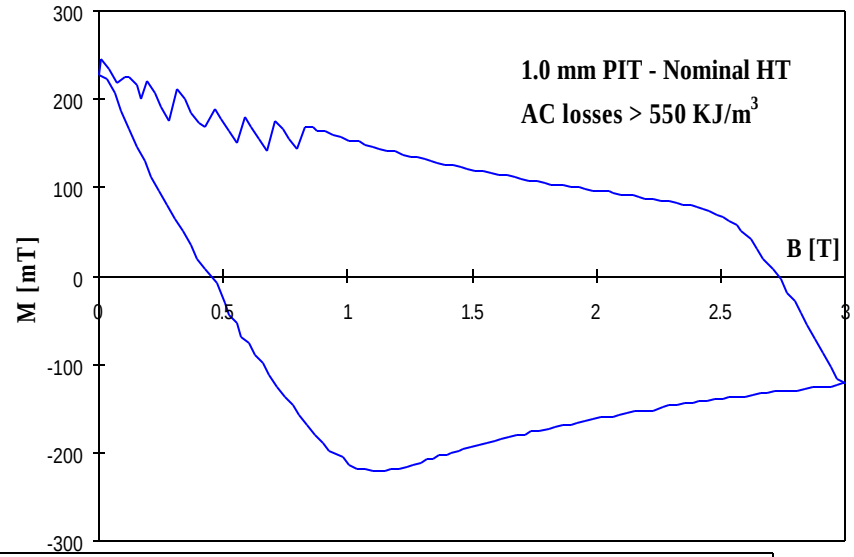
Technology	Company	Diameter	Cu to non-Cu	Quantity	Cost/kg
Modified Jelly-roll	OST	0.8 - 1.0 mm	0.90 - 0.93	150 kg	$ 1070
Powder-in-Tube	SMI	1.0 mm	0.82 - 0.84	37 kg	$ 2965
Internal Tin	IGC	0.3 - 1.0 mm	0.61 - 1.42	75 kg (+ 300 kg ITER)	$ 770 ($ 100 ITER)

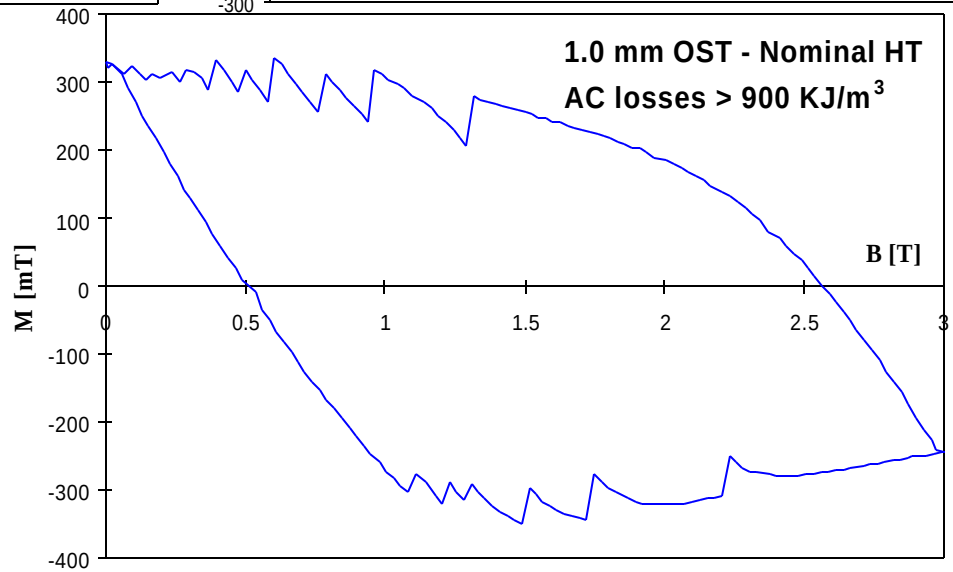
J_c vs. B


Jc vs B Field - 1.0 mm strands
2500
2000
1500
1000
500
Jc, A/mm2
2185
1951
1776
OST
SMI
IGC
11
12
13
14
15
16
B, T

Low Field Magnetization



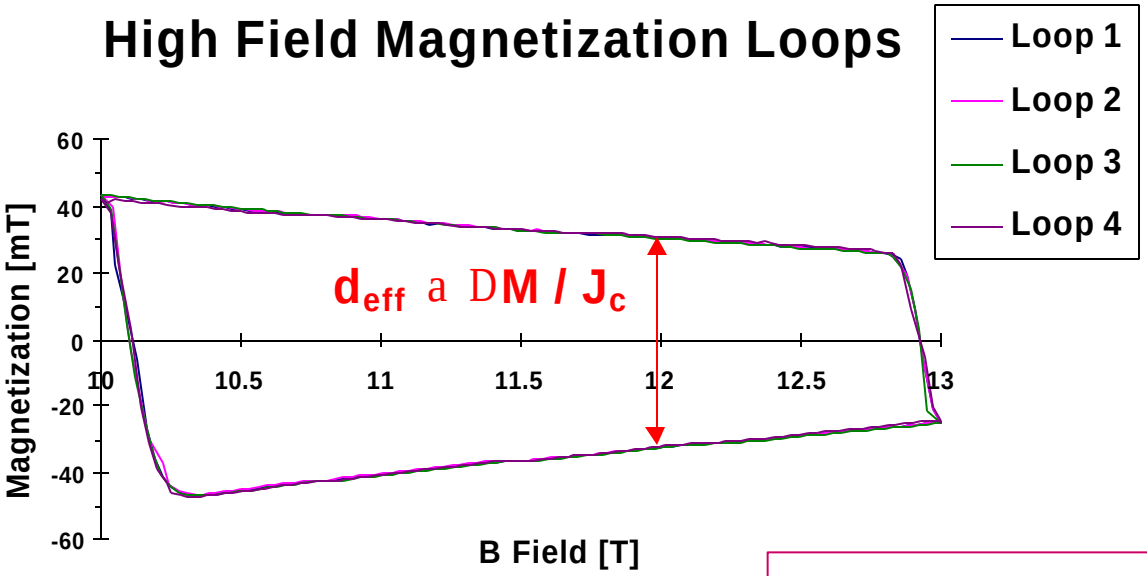




3-0-3 T Hysteresis Loops

@ 1T/min.

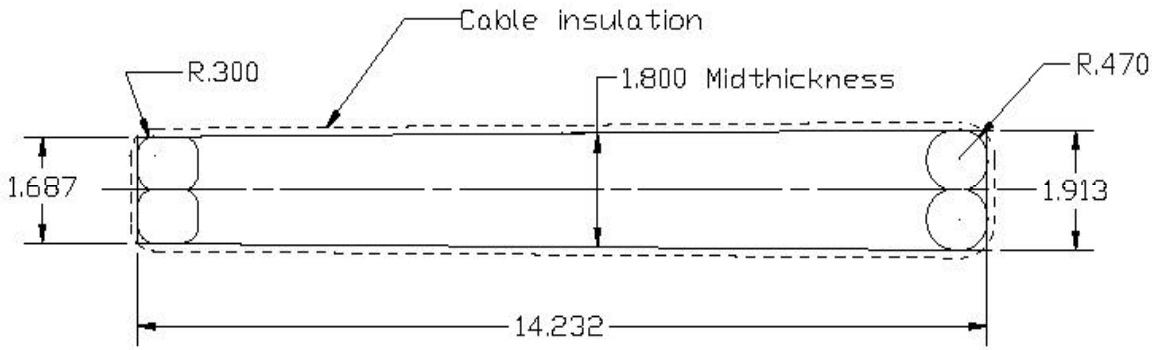
Effective Filament Diameter



d_{eff} - 1.0 mm strands

OST	**114 - 121 mm**
IGC	**89 - 142 mm**
PIT	**54 mm**

Cable Samples for Cos-Theta

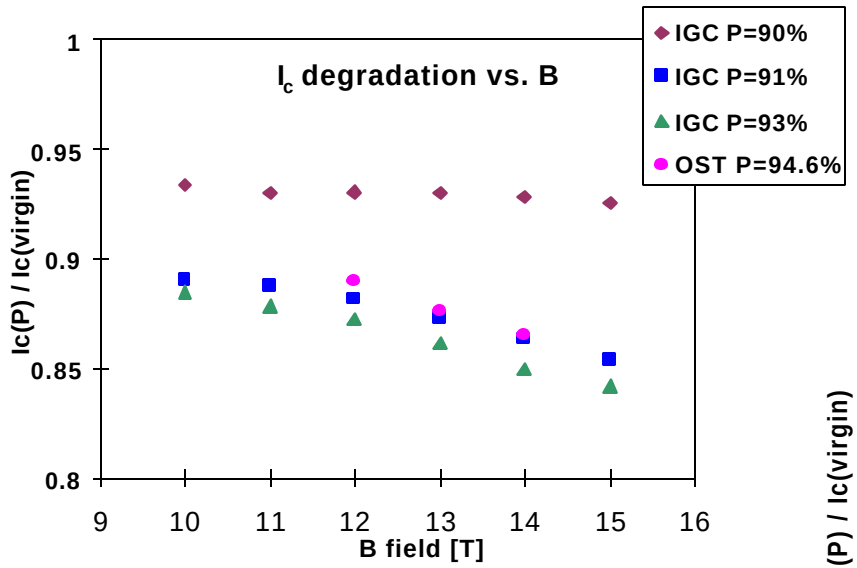


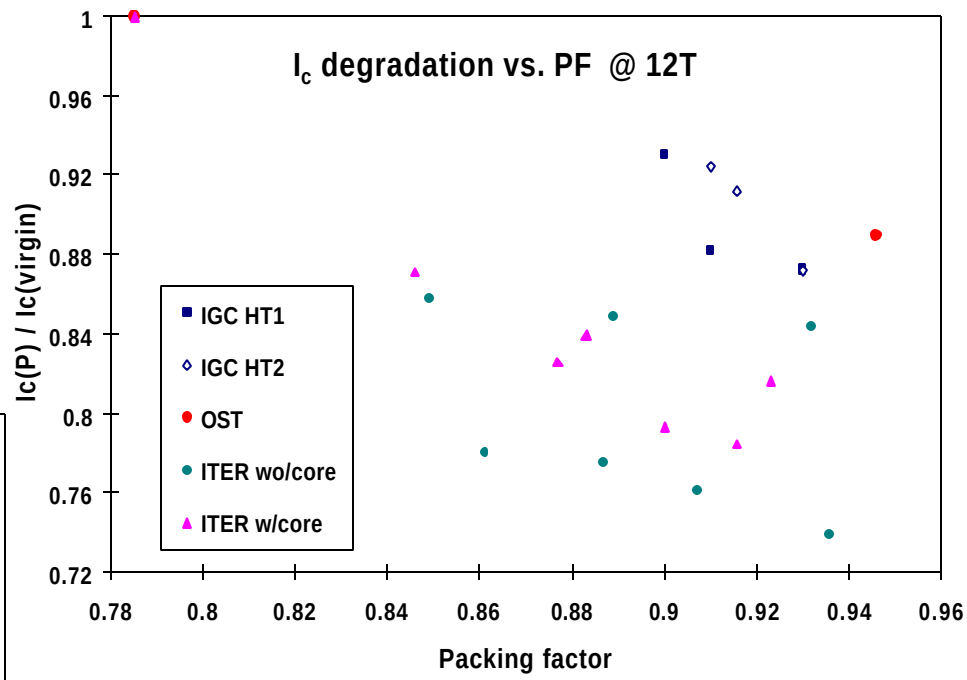
Cable Short Samples

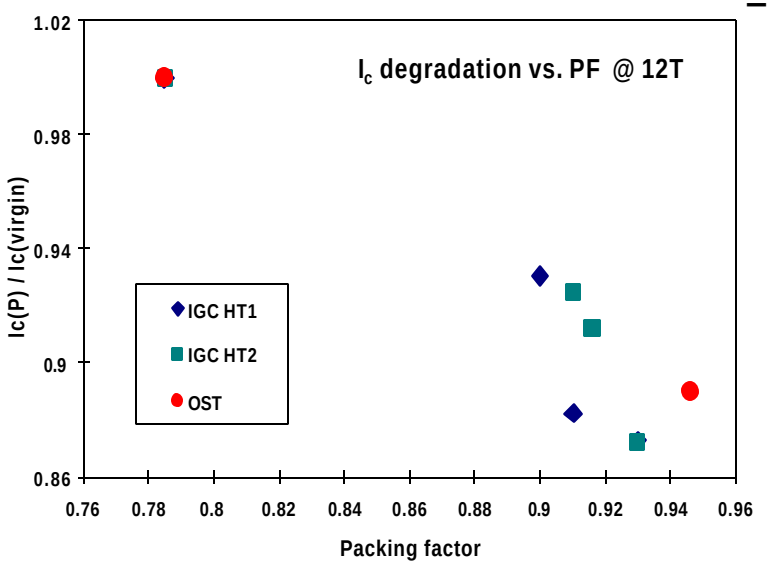
Number of strands	28
Keystone Angle	0.91deg
Cable width	14.24 mm
Mean thicknesses	**1.706-1.885 mm**
SS core	0.025*12 mm^2

Packing Factor range 85-95 %

I_c Cabling Degradation

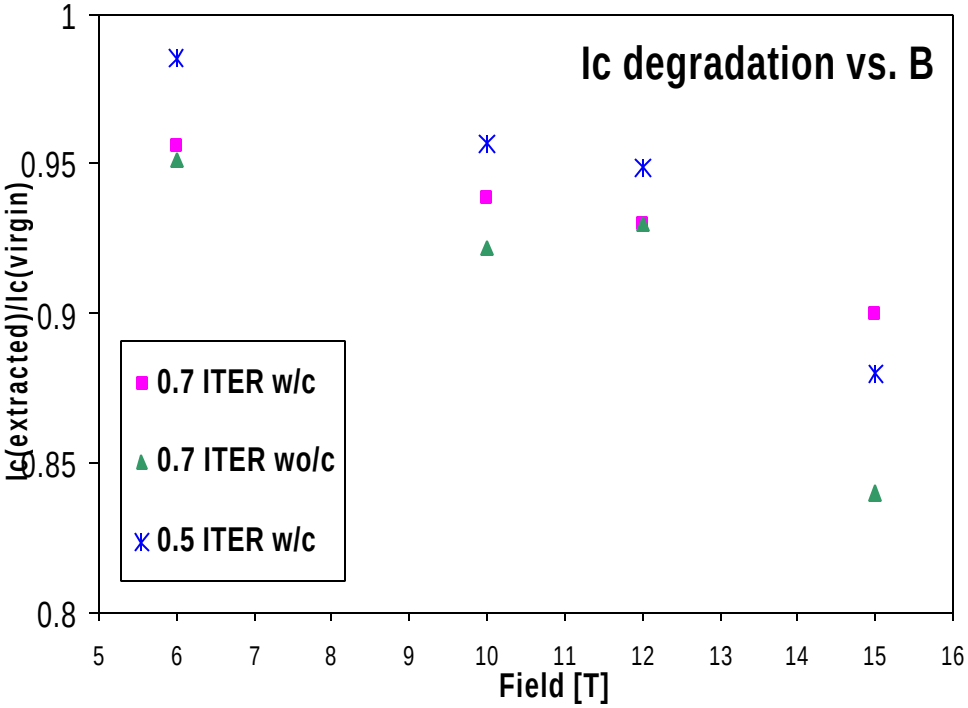






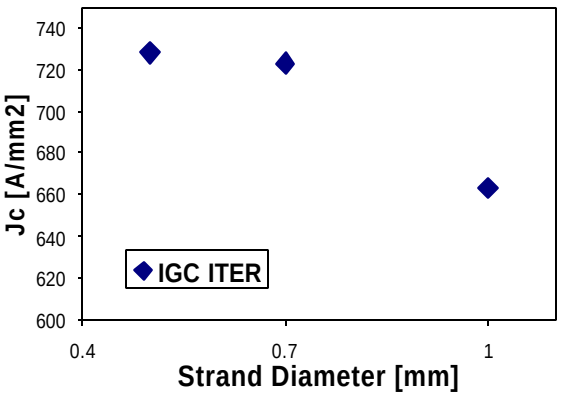
Common Coil Rectangular Cables

Cable Name	Strand diameter, mm	Number of strands	Packing Factor	SS core 0.025*12.7mm2
0.7 w/c	0.702	41	0.865	yes
0.7 wo/c	0.702	41	0.866	no
0.5 w/c	0.502	57	0.879	yes
0.5 wo/c	0.502	57	0.886	no
6 around 1	0.301	7	0.96	-



Nb_3Sn - State of the art

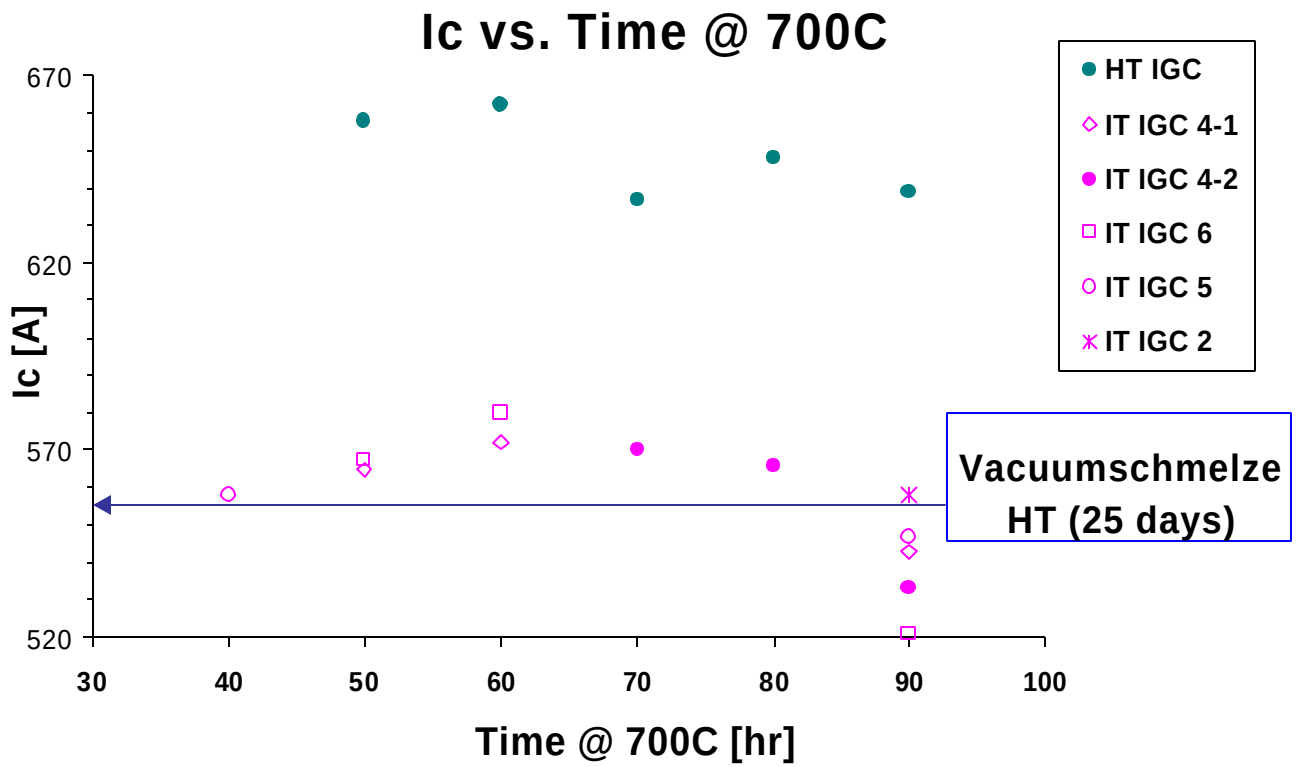
	J_c, A/mm^2 1.0 mm	J_c 0.8 mm	J_c 0.6 mm	deff, mm 1.0 mm	deff 0.8 mm	RRR
OST	1950	2260	-	120	108	14
IGC	1775	-	1950 ?	109	-	160
SMI	2185	-	-	54	-	200



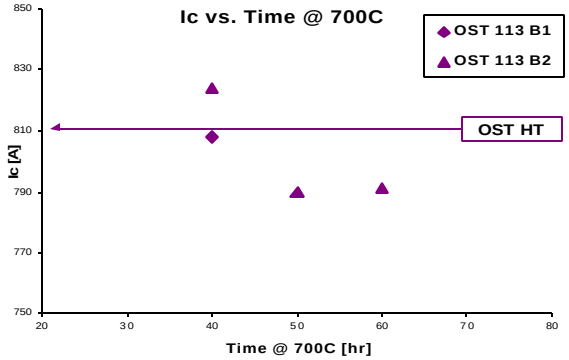
	Heat treatment	Step 1	Step 2	Step 3	Step 4	Total time
Ramp rate, $^oC/h$	**Vacuumschmelze**	6	6	25	25	
Temperature, ^oC		185	460	570	650	
Duration, h		48	100	200	175	**25 days**
Ramp rate, $^oC/h$	**OST**	-	25	50	75	
Temperature, ^oC		-	210	340	650	
Duration, h		-	100	48	180	**2 weeks**

Heat Treatment Optimization -1

Jc

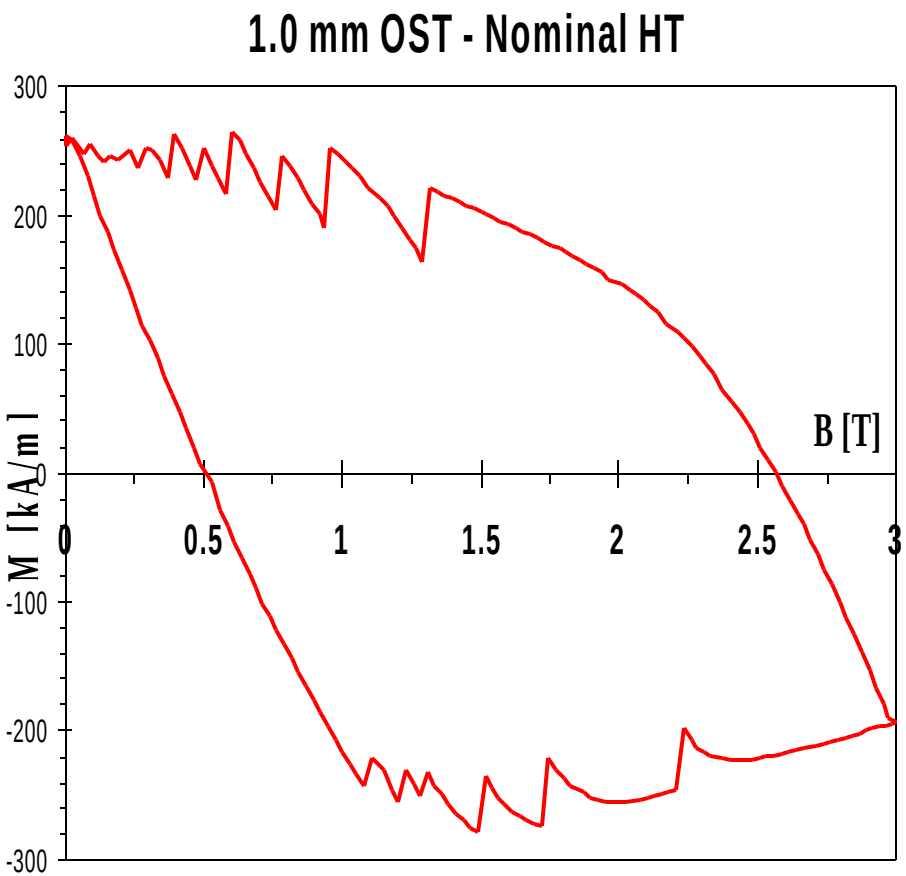


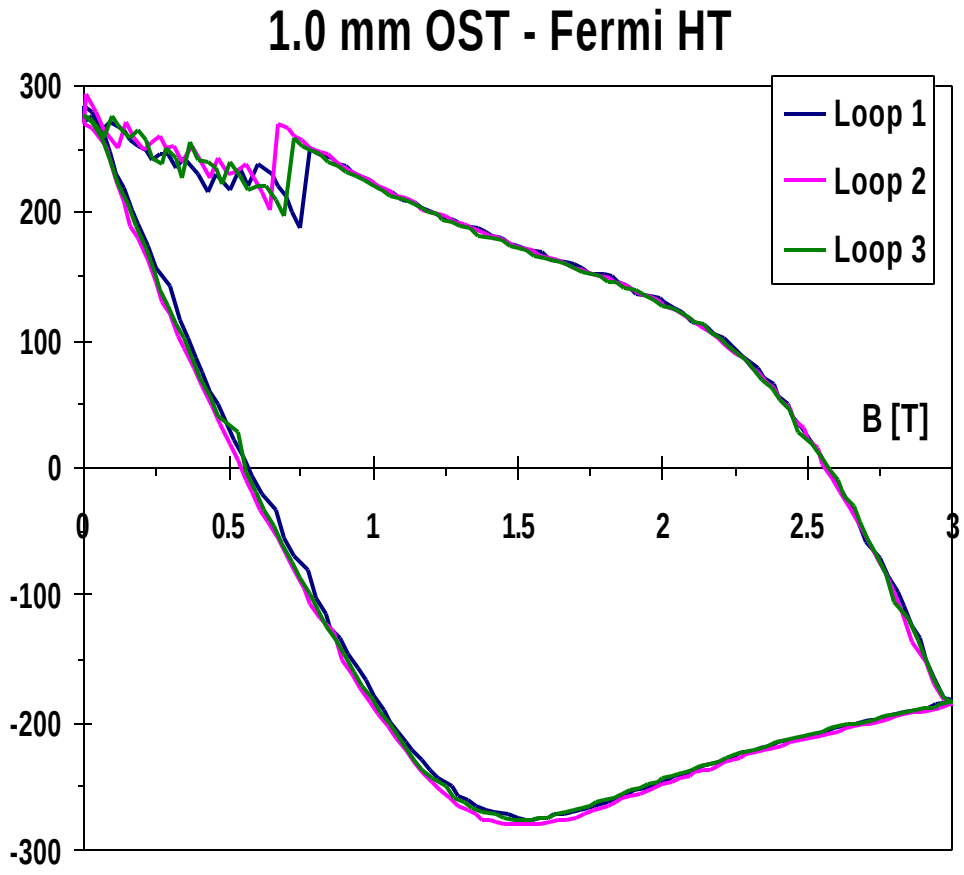
	Heat treatment	Step 1	Step 2
Ramp rate, ^{o}C/h	HT-n	25	25
Temperature, ^{o}C		575	700
Duration, h		200	90-40



Heat Treatment Optimization -2

Magnetic Stability



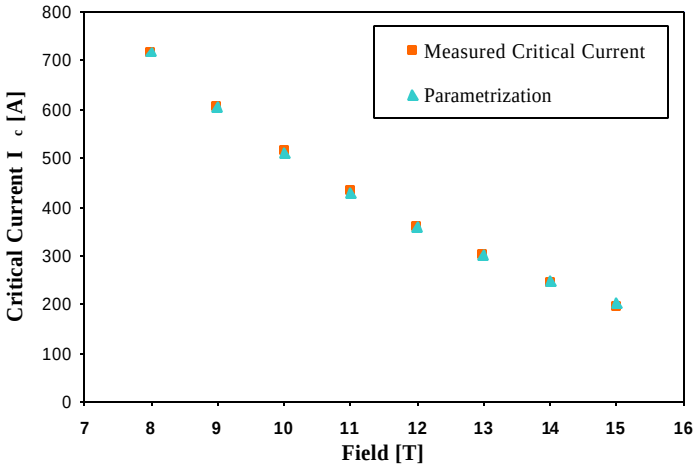


Conclusions

- **More work**

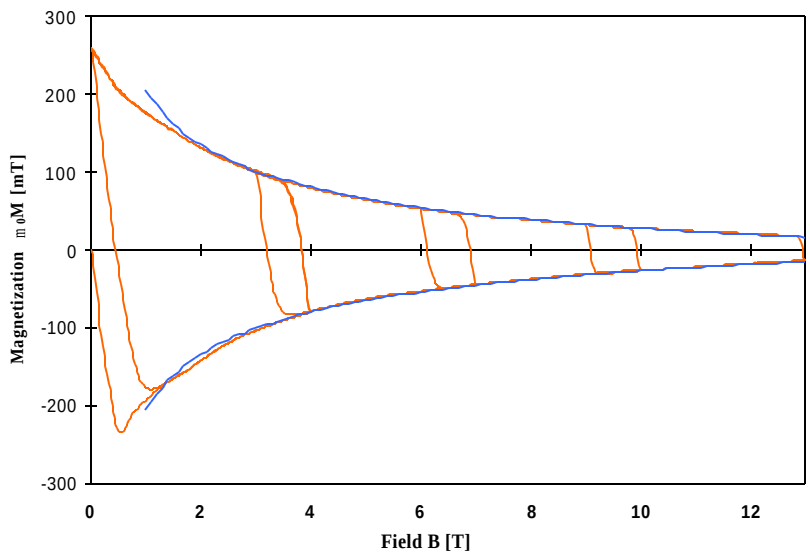
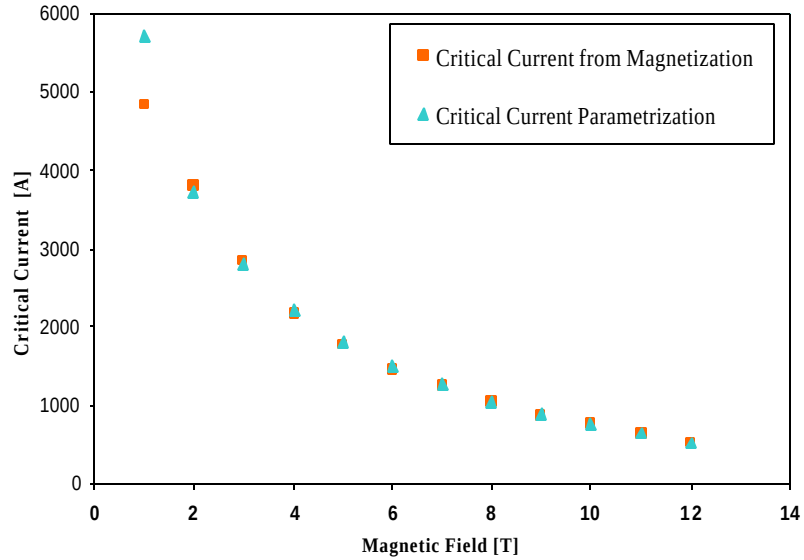
Is d_{eff} a geometrical parameter?

Fit measured Ic with parametrization.



Hysteresis Curve

IGC Intermediate Tin Nb_3Sn 61 subelements - Fermi HT



Use a constant d_{eff}(12T) to infer Ic from M.
Check with parametrization.