Dipole Magnets for Collider Ring

Workshop on Muon Collider Superconducting Magnet Design

Milano, 07/10/2024

L. Alfonso [1], F. Mariani [2,4], A. Bersani [1], L. Bottura [3], B. Caiffi [1], S. Farinon [1], A. Gagno [1], S. Mariotto [4], D. Novelli [1,2], A. Pampaloni [1], T. Salmi [5]

[1] INFN – Genova
[2] Sapienza University of Rome
[3] CERN
[4] INFN – Milano
[5] University of Milan
[6] Tampere University

Outline

1. Requirements
2. Tape selection
3. Best configurations
4. Grading – Cable assumptions
5. Results
6. Fit comparison
7. Open points and next steps

Requirements

Parameter	Value	U.M.
Bore diameter	140	mm
Bore field	16	T
Operating temperature	20	K
Temperature margin	2.5	K

Goal: design optimization through sensitivity study of geometrical parameters

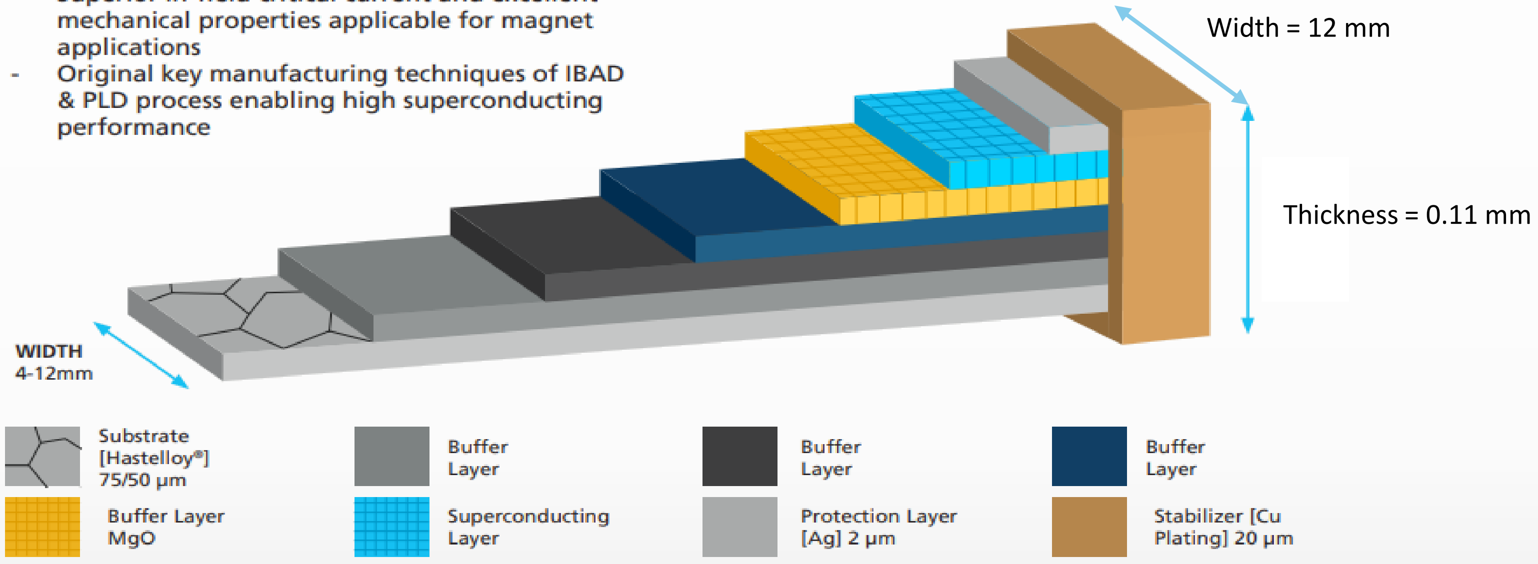
International MUON Collider Collaboration

INFN

Tape selection

CHARACTERISTIC FEATURE

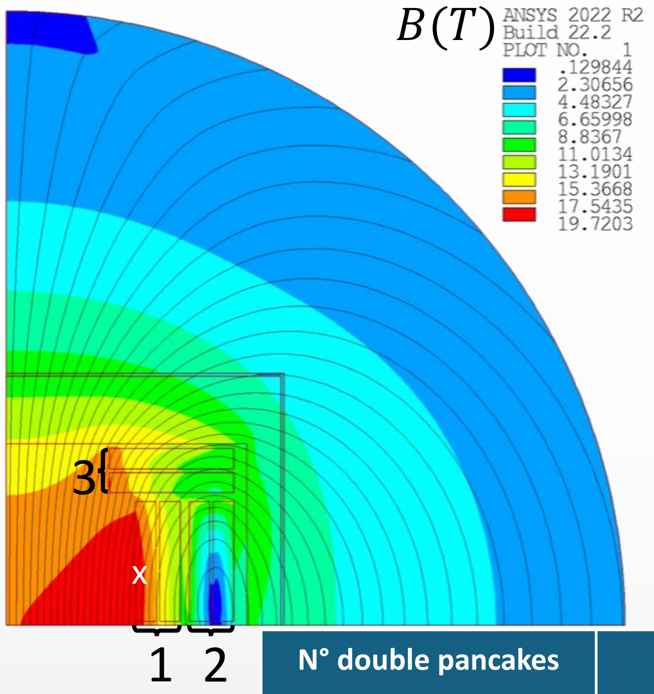
- Superior in-field critical current and excellent mechanical properties applicable for magnet applications
- Original key manufacturing techniques of IBAD & PLD process enabling high superconducting performance



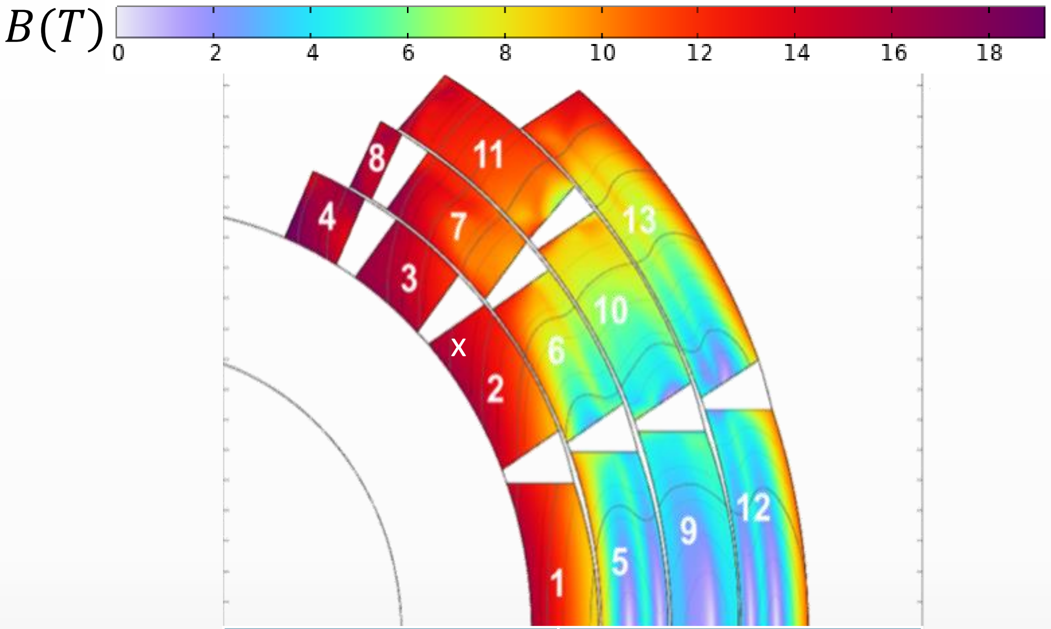
Products	Width (mm)	Thickness (mm)	Substrate (µm)	Stabilizer (µm)	Critical Current (A)	
					77K, S.F.	20K, 5T*3
FYSC-SCH04	4	0.13	75	20	≥165	368
FYSC-SCH12	12	0.13	75	20	≥550	-
FYSC-512 * 1	12	0.08	75	-	≥550	-
FESC-SCH04 * 2	4	0.11	50	20	≥85	514
FESC-SCH12 * 2	12	0.11	50	20	≥250	-

*1 HTS wire without copper stabilizer is available in only 12mm wide for current lead applications.
*2 Artificial pinning specification for use at low temperature and high magnetic field
*3 Ic@20K, 5T is a reference value and no guarantee of the actual performance.

Best configurations



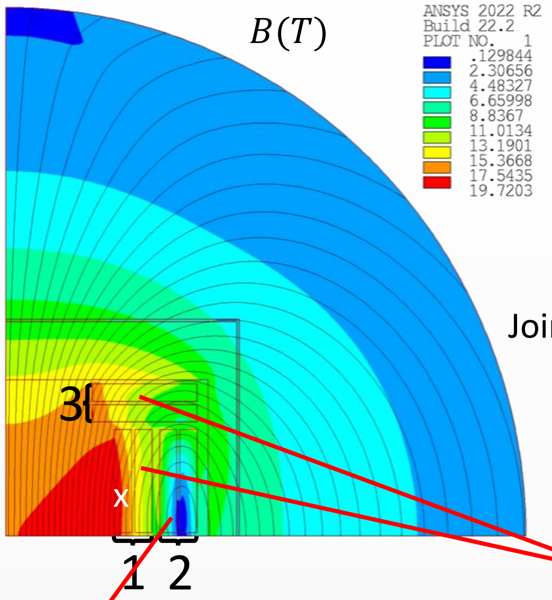
N° double pancakes	N° tapes (1/4 of magnet)
1	1048 (524+524)
2	1048 (524+524)
3	1080 (540+540)
Tot	**3176**
Total N° tapes	**12704**



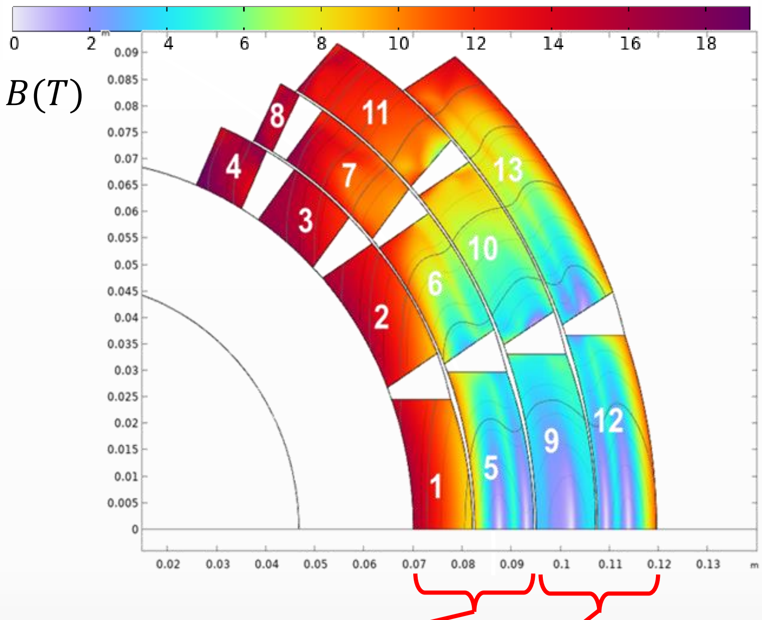
N° layer	N° tapes (1/4 of magnet)
1	546
2	612
3	780
4	746
Tot	**2684**
Total N° tapes	**10736**

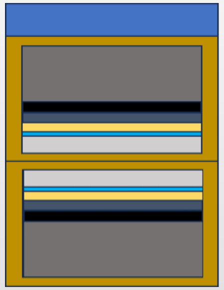
Grading – Cable Assumption

1. Requirements
2. Tape selection
3. Best conf.
4. Grading
5. Results
6. Fit comparison
7. Open points



Not twisted stacked tapes cable:
2 REBCO tapes co-wounded with SS layer





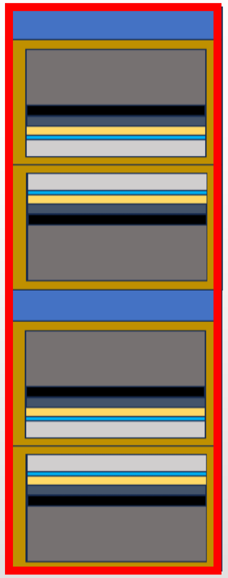
$50\ \mu m$

$$R_{Cu/SC} = \frac{A_{Cu}}{A_{SC}} = 16.15$$

$$f_f = \frac{A_{SC}}{A_{tot}} = 0.018$$

$$J_{eng} = 766\ (A/mm^2)$$

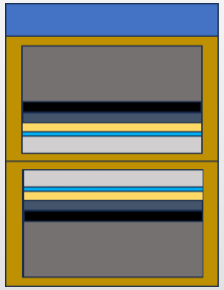
Joined together and powered as single unit



$50\ \mu m$

$50\ \mu m$

$$J_{eng} = 383\ (A/mm^2)$$

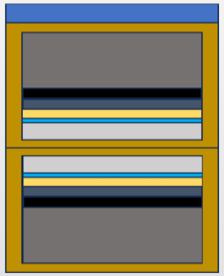


$50\ \mu m$

$$R_{Cu/SC} = \frac{A_{Cu}}{A_{SC}} = 16.15$$

$$f_f = \frac{A_{SC}}{A_{tot}} = 0.018$$

$$\overline{J_{eng}} = 525\ (A/mm^2)$$



$25\ \mu m$

$$R_{Cu/SC} = 16.15$$

$$f_f = 0.020$$

$$\overline{J_{eng}} = 579\ (A/mm^2)$$

Results

Parameter	Value	U.M.
I_{op}	2481	A
J_{eng13}	386	A/mm^2
J_{eng2}	766	A/mm^2
B_{bore}	17.5	T
B_{peak1}	19.7	T
$Margin$	2.5	K
E	7575	kJ/m
L	2461	mH/m

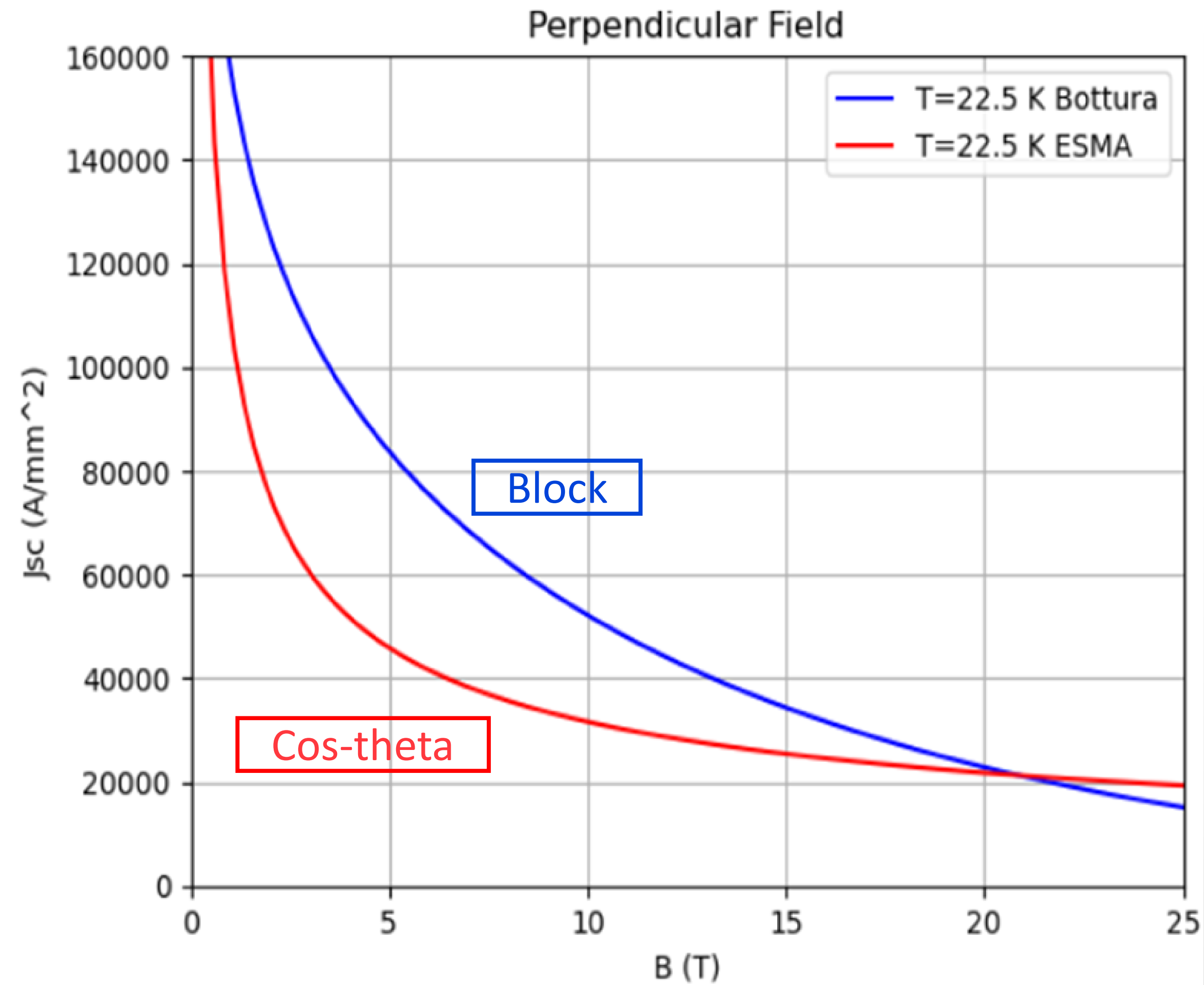
With the contribution of the iron

Parameter	Value	U.M.
I_{op}	1702	A
$\overline{J_{eng12}}$	525	A/mm^2
$\overline{J_{eng34}}$	579	A/mm^2
B_{bore}	16	T
B_{peak1}	19.2	T
$Margin$	0.7*	K
E	4927	kJ/m
L	3402	mH/m

*See fit comparison (next slides): J_c cos theta < J_c block coil

Without the contribution of the iron

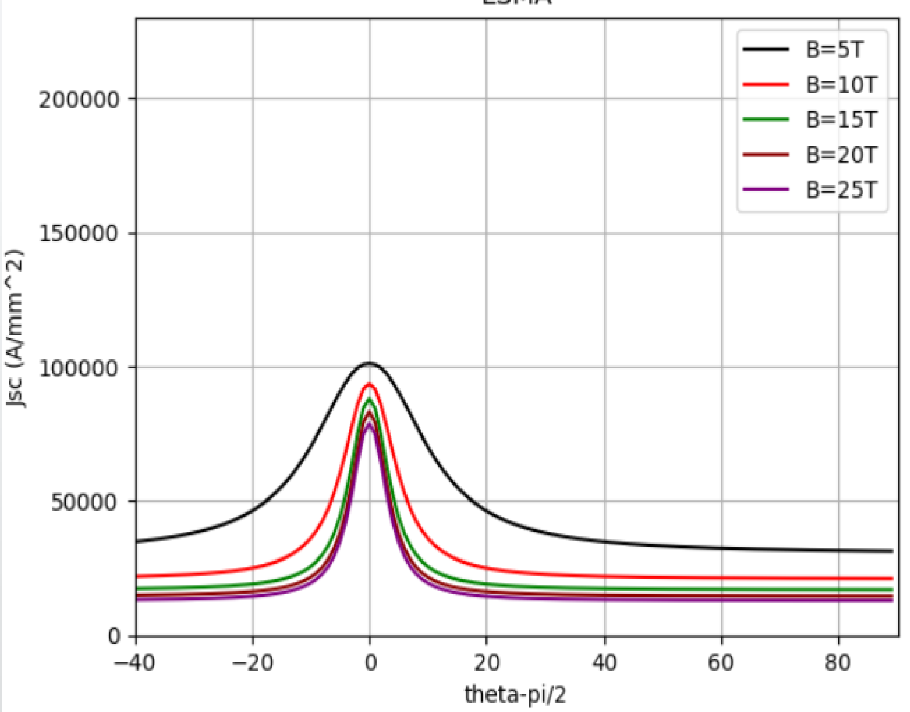
Fit comparison



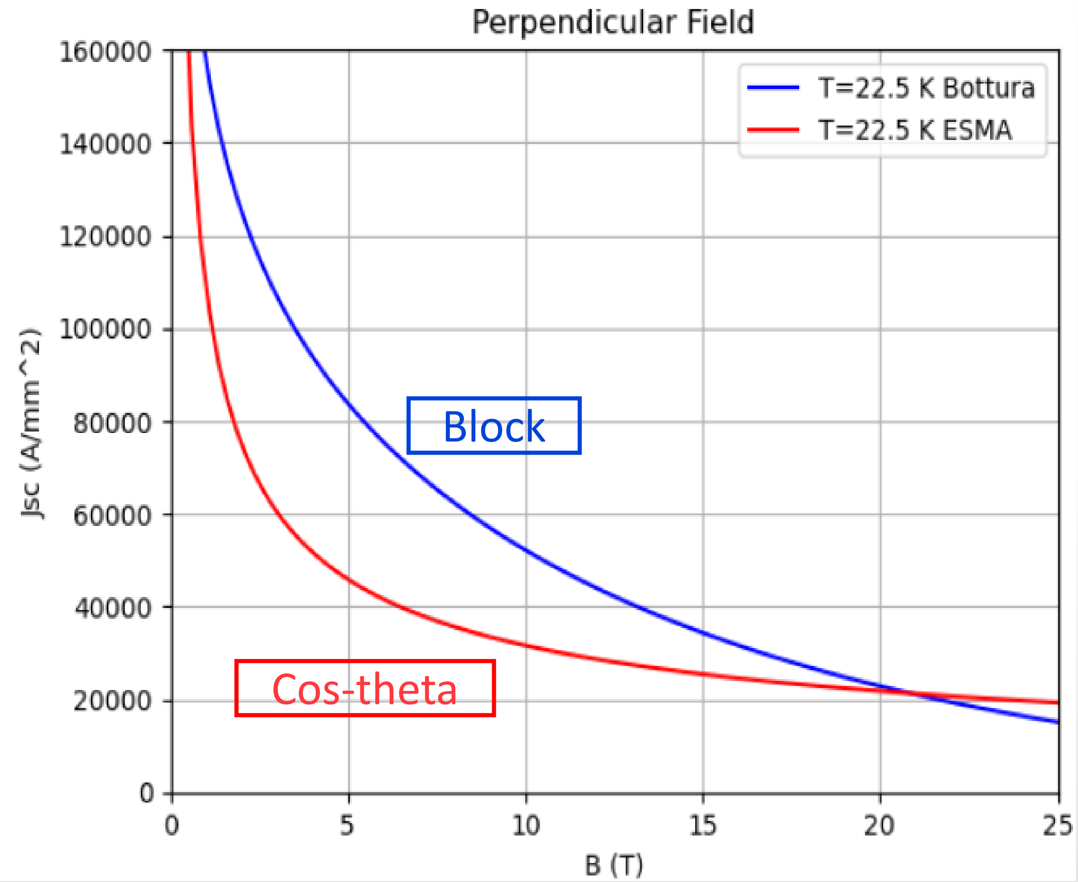
Only for cos-theta:

Angle dependence according to **"Parameterization of the critical surface of REBCO conductors from Fujikura"**

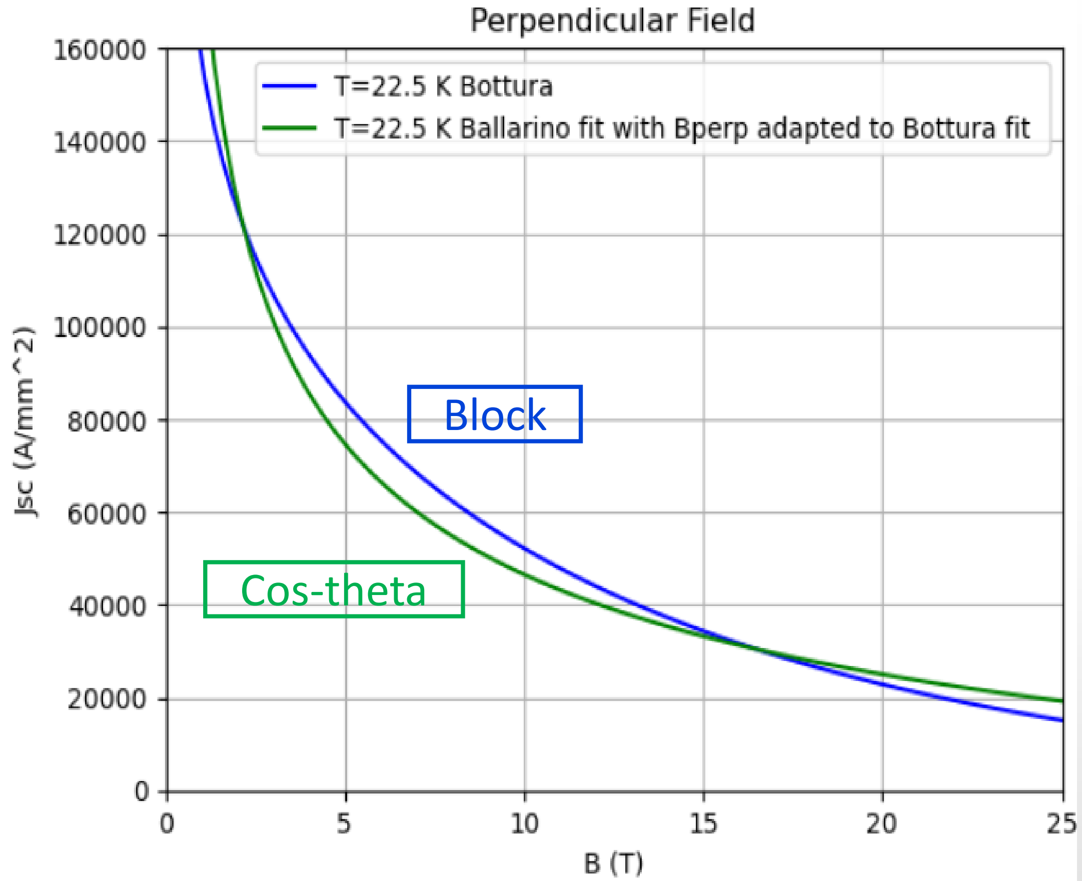
Jc_FIT_ANGLE_DEPENDENCE @ T=22.5 K
ESMA



Cos Theta Jc Fit

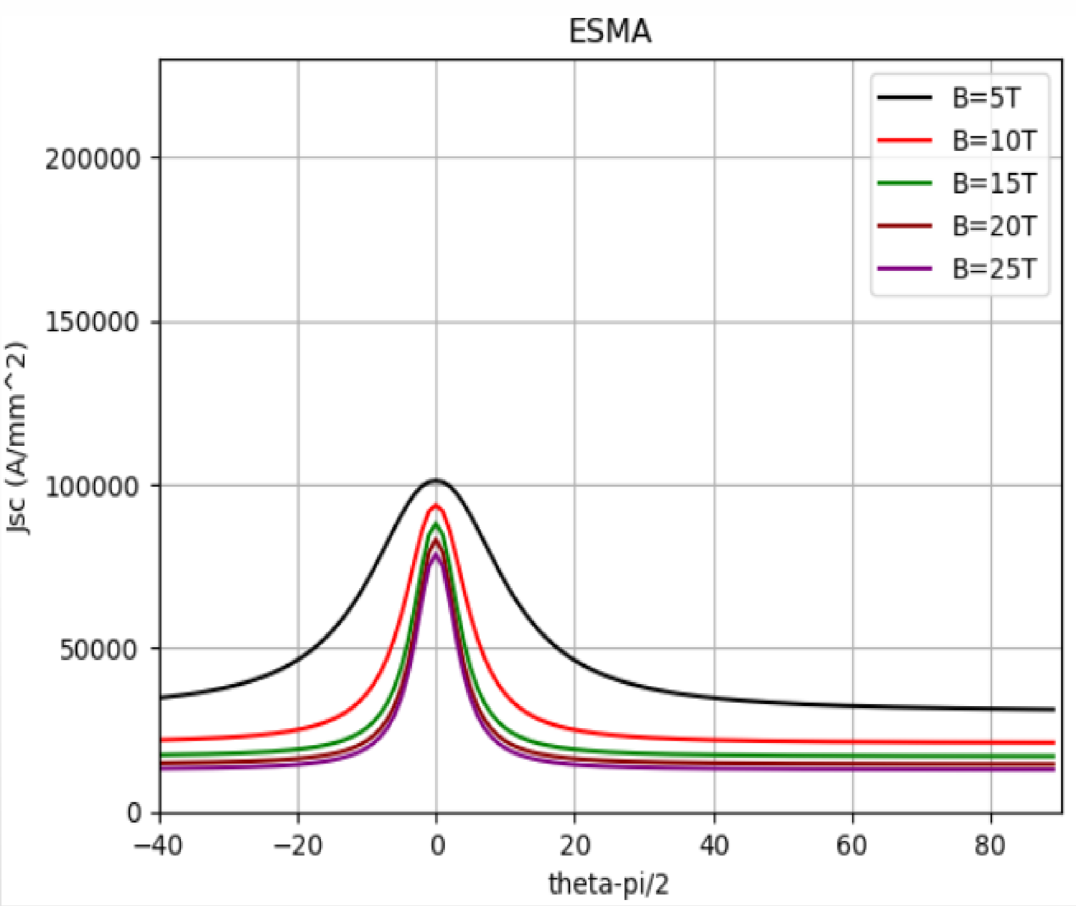


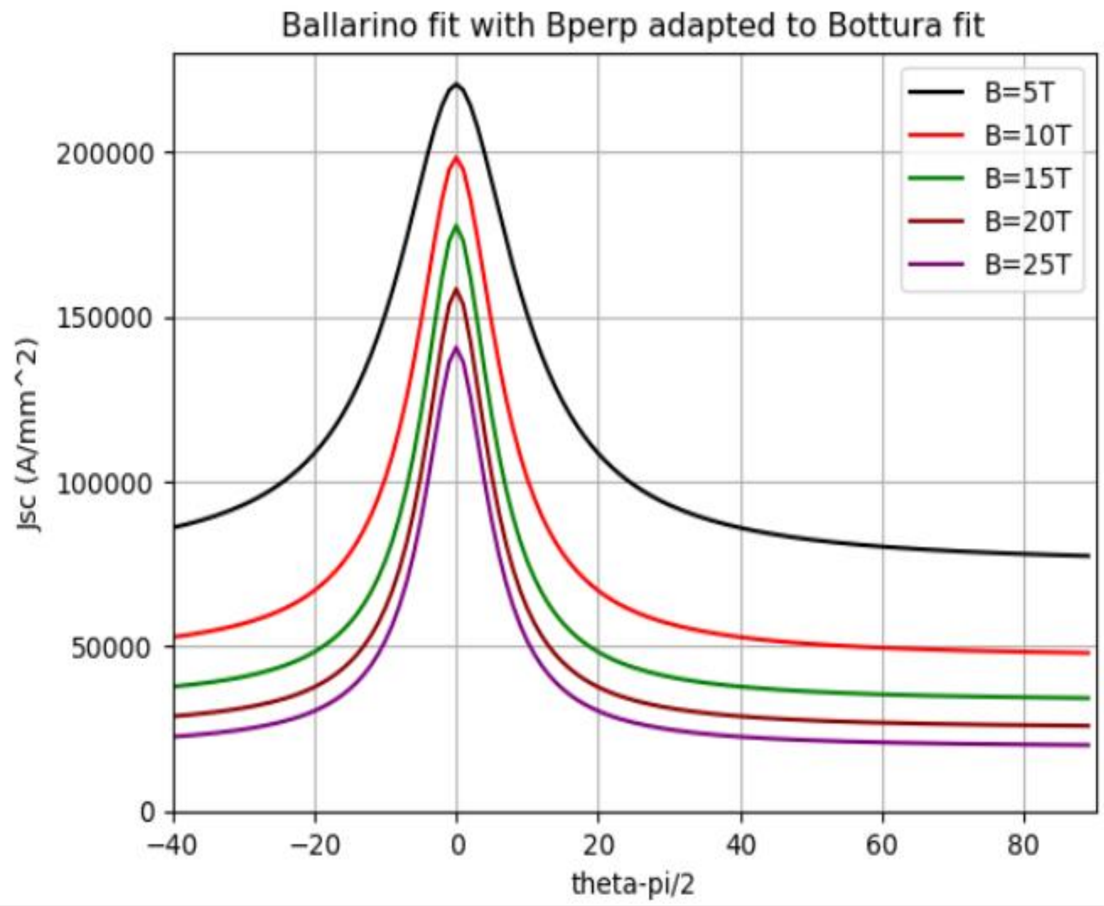
Margin	0.7	*K*



Margin	5.5	*K*

Cos Theta Jc Fit





Margin	0.7	*K*

Margin	5.5	*K*

Open points

Which cable assumption do we use ?
What is the minimum thickness of the SS layer ?

Shall we go back to considering a cost model ?

Considering the workforce and time schedule, Is it OK for everyone to study furthermore these two configuration ?

Goal: Uniform assumptions and hypothesis

Next steps

Which are the requirements for the field quality ?

How do we implement the critical current density fit in Roxie ?
We have 3 options:

1. Use Ballarino's updated fit (Succi)
2. Use Ballarino's fit but with ESMA parameter values.
3. Change the parameter value of Ballarino's fit in order to copy Bottura's fit.

Goal: field quality & margin