WPMAG – CEA IRFM
HWRC (CORC-like) Properties
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2025 CEA TS
HWRC (CORC-like) Properties

MAG-S.01.01-T025-D001

EU-CN: Deliverable on 2025 CEA CORC Conductor Performances Analyses

2025 CEA TS
HWRC (CORC-like) Properties

TS Title:	EU-CN: CEA CORC Conductor Performances Analyses		
TS Ref. Nr.:	MAG-S.01.01-T025	Task coordinator:	Alexandre Torre
Status:	In review	Date:	22-May-2025

Deliverables of the task:

Deliverable	Description
MAG-S.01.01-T025 - D001	*2025 CEA EU-CN CORC conductor Performances Analyses*

Already presented at EUCN meeting by C. Nguyen

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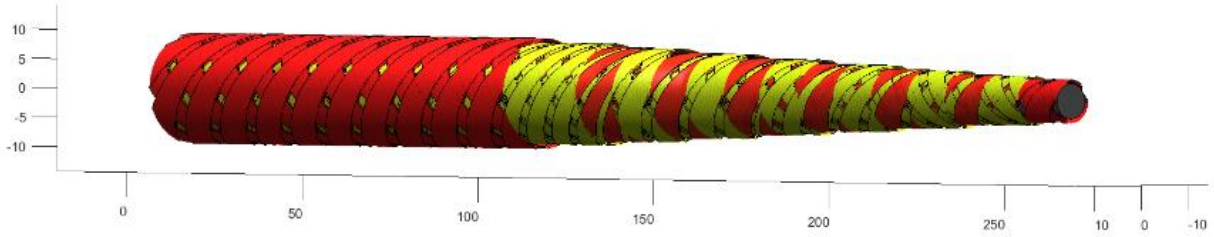
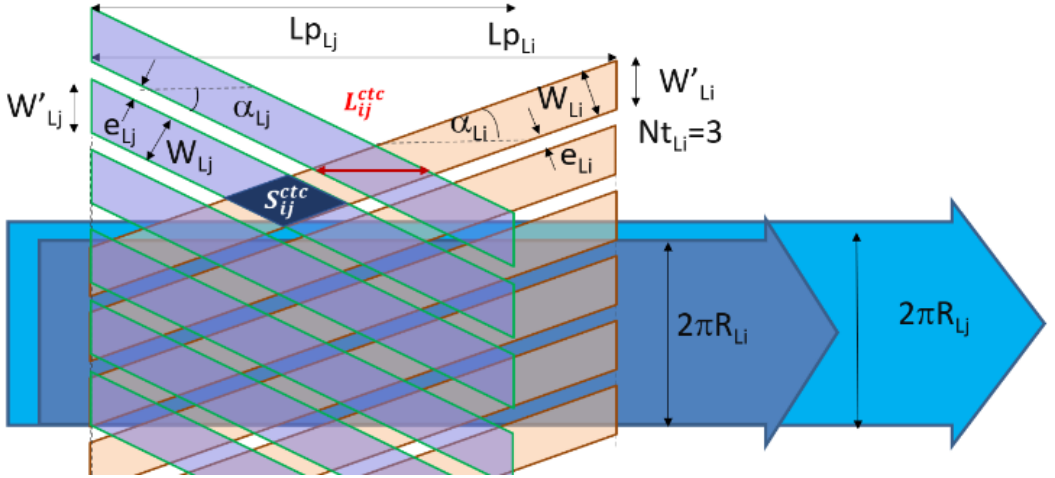
Geometrical description of Helically Wound Rebco Cables (HWRC)



Description of structures and as function of layer parameters

$$Lp_{Li} = \pm \frac{2\pi R_{Li}(e_{Li} + W_{Li})Nt_{Li}}{\sqrt{(2\pi R_{Li})^2 - (e_{Li} + W_{Li})^2\ Nt_{Li}^2}}$$

LpLi = Twist pitch
NtLi = # tapes
RLi = cabling radius
eLi = Gap
WLi = Tape Width



Important features for electrical/thermal models need to be deduced from geometrical considerations:

Contact lenghts:

$$L_{ij}^{ctc} = \frac{(WLj' + WLi')}{2\pi}\left(\frac{LpLj.LpLi}{LpLi.RLj + LpLj.RLi}\right)$$

Contacts surface:

$$S_{ij}^{ctc} = \frac{W_{Lj}W_{Li}}{\sin\left(\frac{\pi}{2} - (\alpha_{Li} + \alpha_{Lj})\right)}$$

Contacts posistions:

$$z_{kj}^{ki} = \frac{Lp_{Lj}.Lp_{Li}}{(Lp_{Lj} + Lp_{Li})}\left(\frac{(\theta_0^{Layj} - \theta_0^{Layi})}{2\pi} + \left(\frac{k_j}{Nt_{Lj}} - \frac{k_i}{Nt_{Li}}\right) + \gamma\right),$$
$$\gamma\ an\ integer, ki\ and\ kj\ from\ 0\ to\ (Nt_L - 1) \quad (6)$$

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Tape properties fit

Fit of SST properties using CERN 2014 scaling law

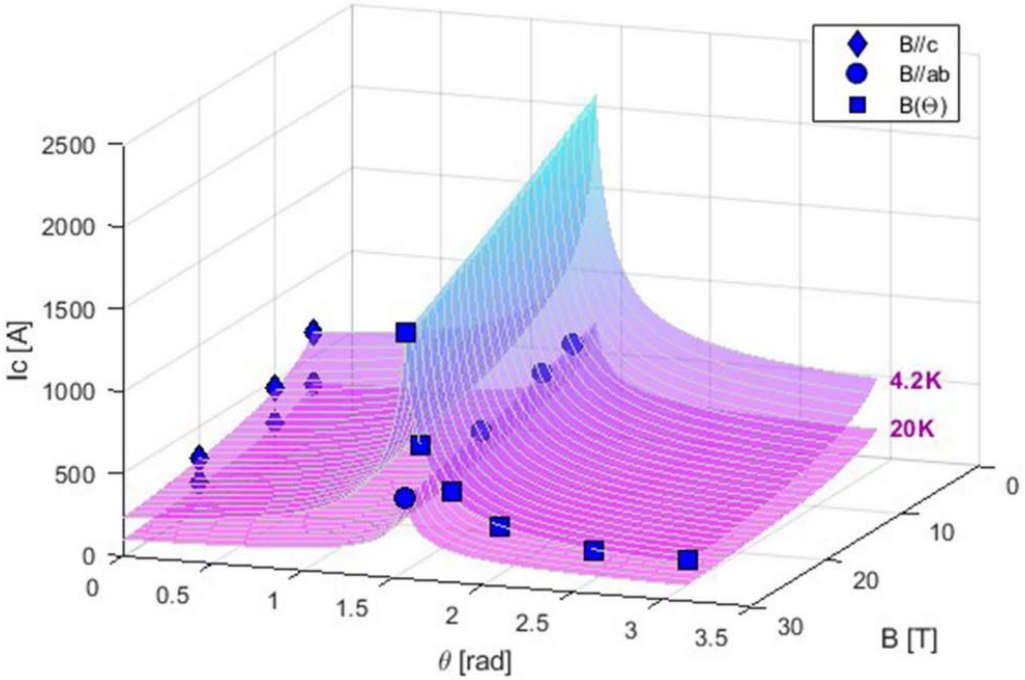
$$\boldsymbol{J_C(B,T,\theta)} = J_{C,c}(B,T) + \frac{J_{C,ab}(B,T) - J_{C,c}(B,T)}{1 + \left(\frac{\theta - \pi/2}{g(B,T)}\right)^{\nu}} \quad \frac{A}{m^2}$$

Deducing individual tapes critical current

$$\boldsymbol{I_c^{tape}(z)} = \frac{R_{Li}\cos(\alpha_{Li})}{W_{Li}} \int_{\theta 0 - \frac{\Delta\theta}{2}}^{\theta 0 + \frac{\Delta\theta}{2}} Ic(B,T,\theta)d\theta = I_c\left(B,T,\theta_{eff}(z)\right)$$

$$\boldsymbol{I_c^{tape}} = \left(L \Big/ \int_0^L \left(\frac{1}{I_C^{tape}(z)}\right)^n dz\right)^{\frac{1}{n}} = I_c(B,T,\theta_{eff})$$

Fit is OK within 10-15 %
Effective parameters (angle) can be deduced



General parameters			ab-axis parameters			θ sensitivity		
T_{C0}	[K]	93	$B_{i0,ab}$	[T]	250	ν	[-]	0.857
n	[-]	1	$\alpha_{\alpha\beta}$	[MA.T/mm²]	84	g_0	[-]	-0.005
c-axis parameters			p_{ab}	[-]	1.02	g_1	[-]	0.094
$B_{i0,c}$	[T]	140	q_{ab}	[-]	4.45	g_2	[-]	-0.0008
α_χ	[MA.T/mm²]	1.41	$\gamma_{\alpha\beta}$	[-]	4.73	g_3	[-]	0.0039
p_c	[-]	0.31	n_1	[-]	1.77	**REBCO properties**		
q_c	[-]	0.87	n_2	[-]	4.1	t	[µm]	1.5
γ_χ	[-]	3.09	a	[-]	0.1	w	[mm]	4

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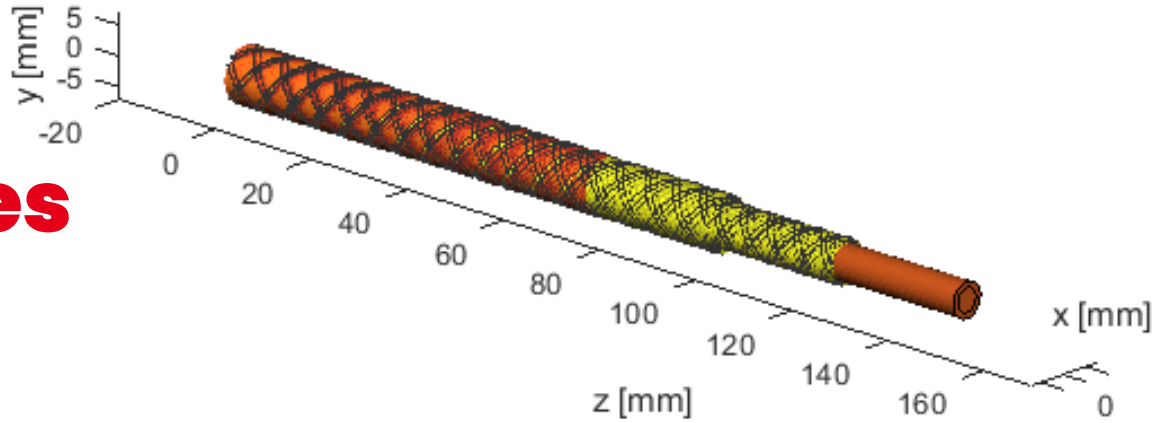

Cable properties

Definition of two analytical limiting cases:

$$I_{C\,LRL}^{cable} = \left(L \Big/ \int_0^L \left(\frac{1}{I_C^{cable}(z)} \right)^n dz \right)^{\frac{1}{n}}, I_C^{cable}(z) = \sum_k I_{C\,k}^{tape}(z)$$

$$I_{C\,HRL}^{cable} = \sum_k I_{C\,k}^{tape}, \qquad I_{C\,k}^{tape} = \left(L \Big/ \int_0^L \left(\frac{1}{I_{C\,k}^{tape}(z)} \right)^n dz \right)^{\frac{1}{n}}$$

Cable limiting cases between 20kA and 26kA (as expected)
SULTAN test program refined

Parametric study of dropouts impact

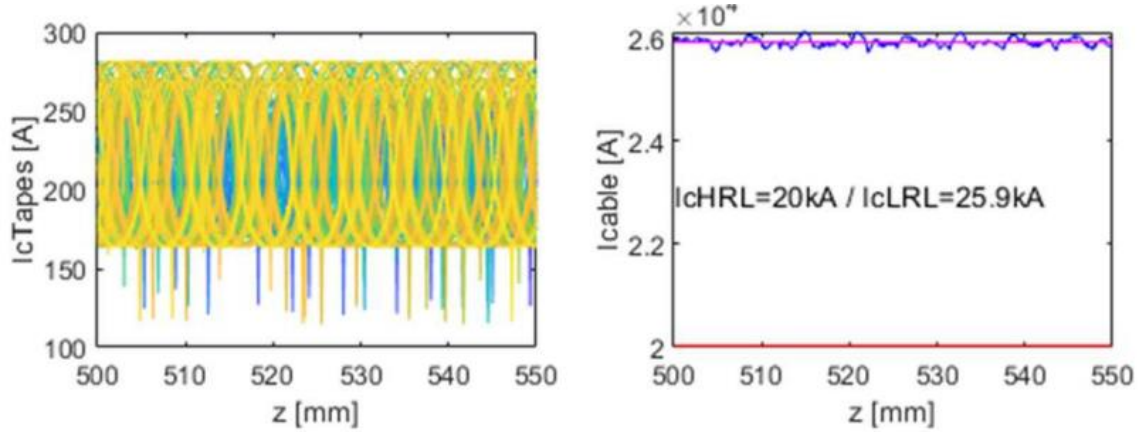

TABLE II
Operating Points of interest

Description	Test Conditions or Tcs	$Ic_{[HRL/LRL]}$ or I_{op}
OP1: CS design point	B_{op}=18T/T_{op}=20K	[21.4/25.9]kA
OP2: CS current margin	B_{op}=18T/T_{op}=4.5K	[47.2/61.7]kA
OP3: SULTAN low T	B_{op}=10.7T/T_{op}=4.5K	[61.2/76.3]kA
OP4: SULTAN Tcs	B_{op}=10.7T $Tcs_{HRL/LRL}$=[26.1/27.2]K	20kA
OP5: SULTAN IxB Tcs	B_{op}=10.7T/B_{grad}=+/-1.34T $Tcs_{HRL/LRL}$=[17.7/20.2]K	33.64kA

Extrapolated performance at given operating points

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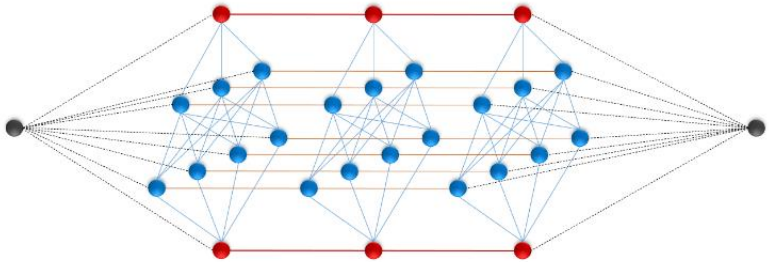
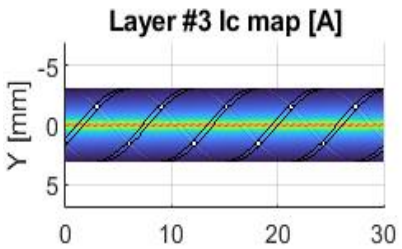
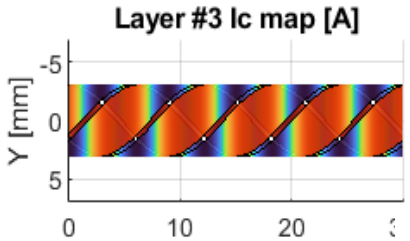
DC Electrical model for current re-distribution (CARMEN)

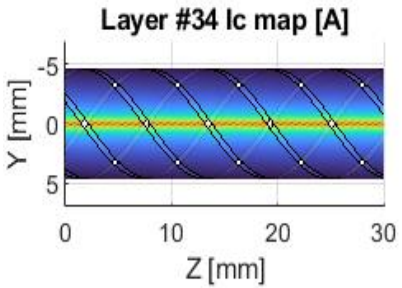
Resistive network model developed (only resistive): CARMEN tool

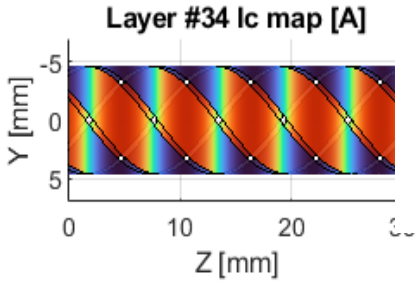


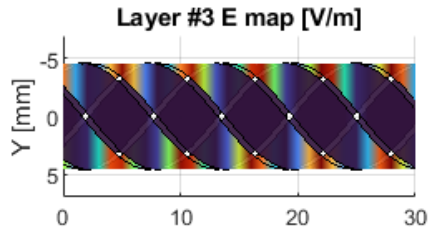
$$\begin{bmatrix} M.R \\ Q \end{bmatrix} I = \begin{bmatrix} 0 \\ I_{inj} \end{bmatrix}$$



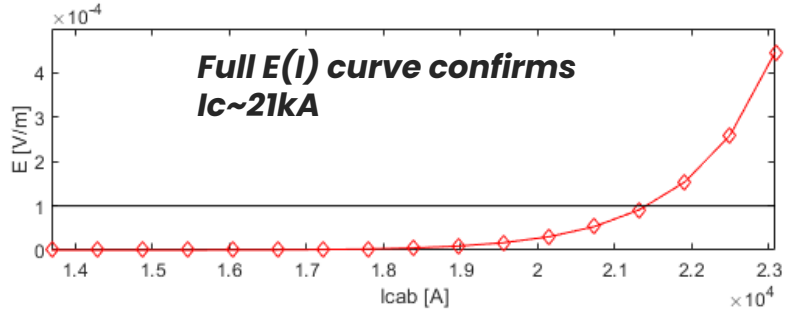


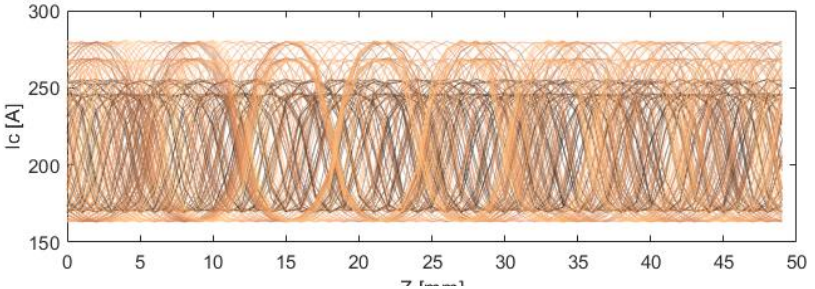


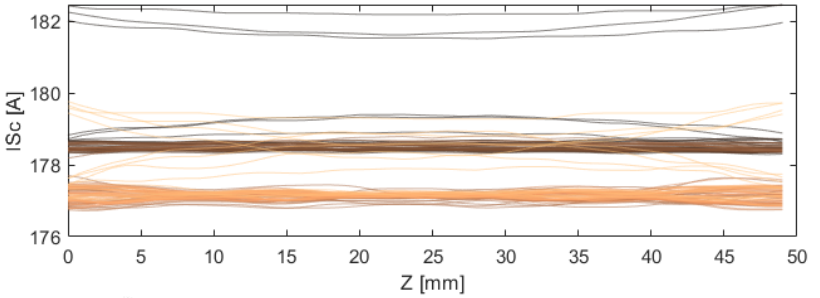


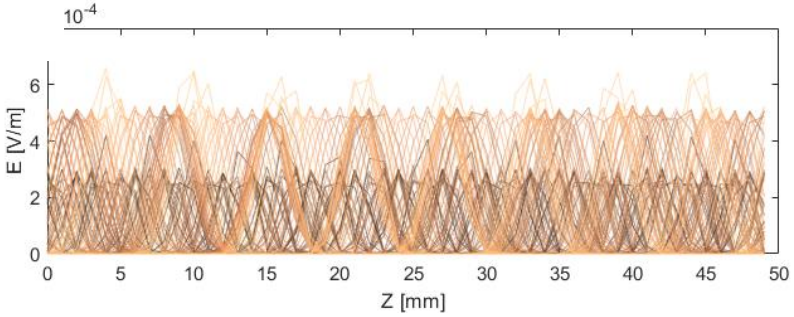


Electrical model able to see very small redistribution (negligible)
Performances confirmed around Ic=20kA









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Perspectives

Continue modelling (maybe smaller units, faster computation)

Vary the current injection (imbalance)

Maybe couple to Thermohydraulic model