Twisted stacked/ block-type HTS insert towards partially insulated solution

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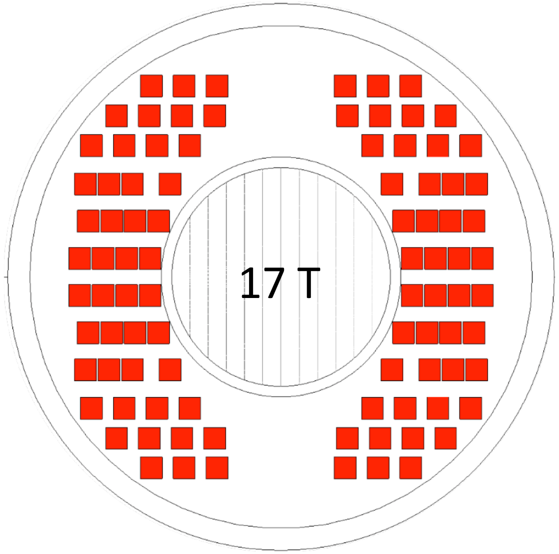
Introduction 1/2

Twisted stacked/ block-type HTS insert

Parameter	Value
Center field B_0	17 T
Current density J_{op}	650 MA/m^2
Operating current I_{op}	10.4 kA
Field quality B_3/ B_5	1.5/ 0.78 units

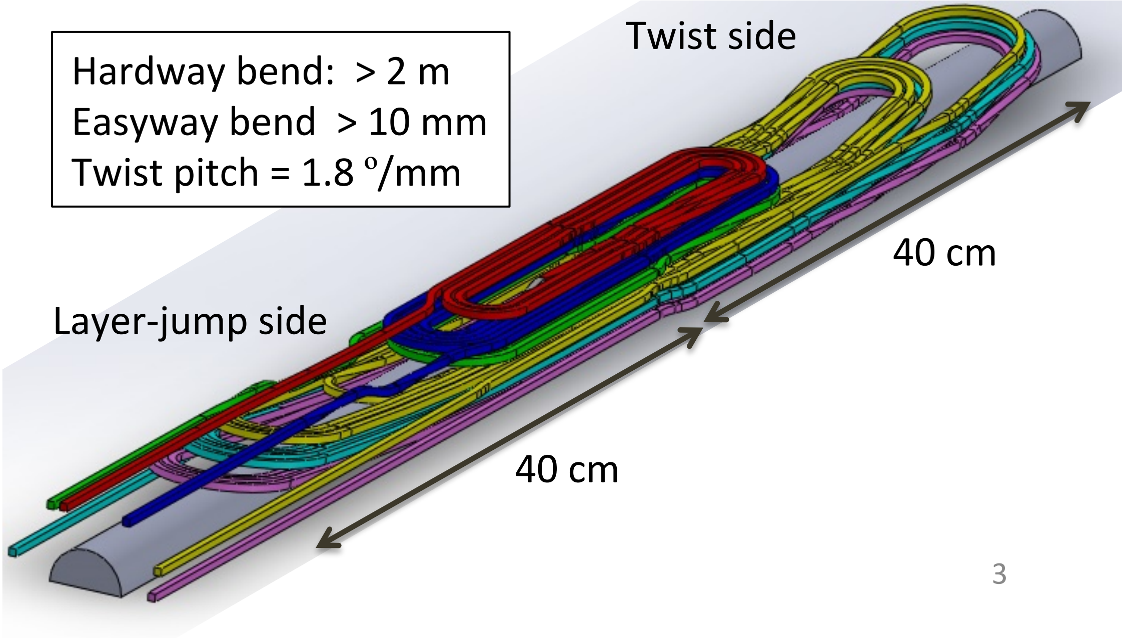
2D cross-section

46-turns/ 4x4 mm block



3D magnet ends: 1 twist/ turn

Hardway bend: > 2 m
Easyway bend > 10 mm
Twist pitch = 1.8 °/mm



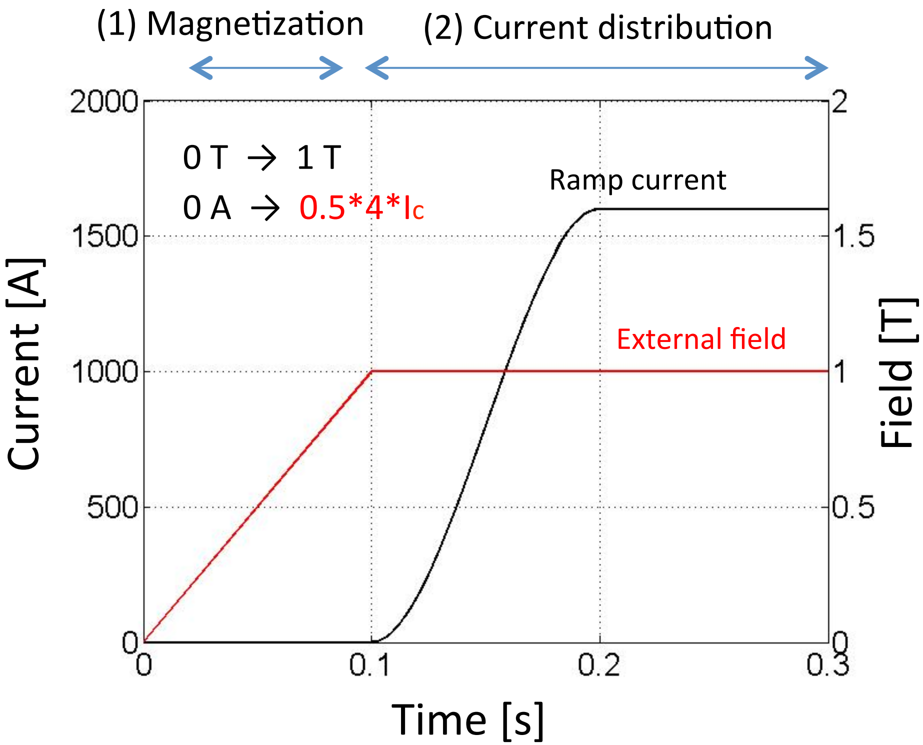
Introduction 2/2

- Non-insulated? Insulated? twisted stacked cable

  Twisted Stacked Cable (TSC) has only 1 twist/turn over 15m long insert.

- Cable requirements under operation

  1. Low magnetization
  2. Uniform current distribution
  3. Current redistribution under fault-mode condition



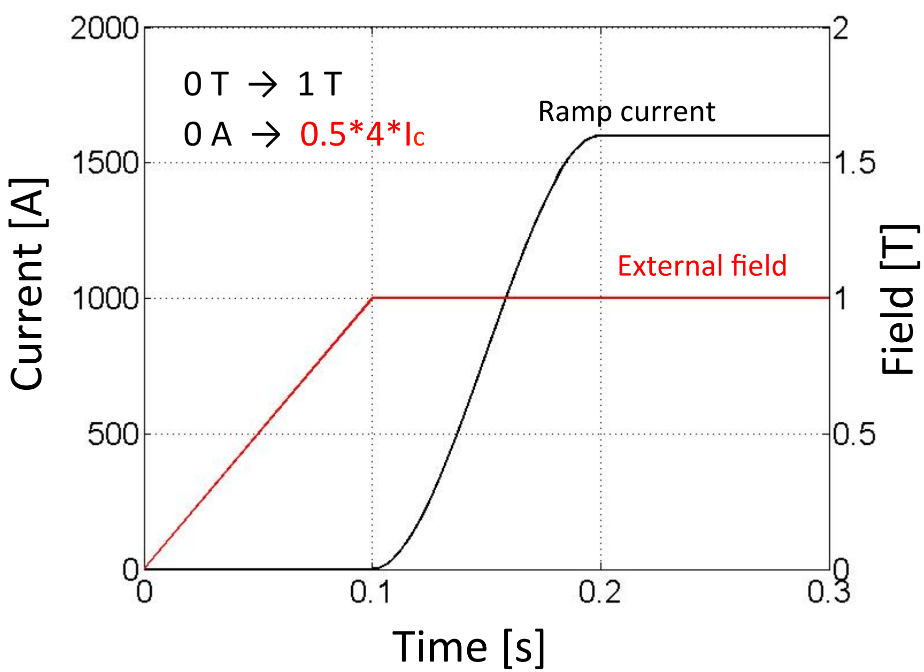
Numerical analysis on TSC with 4 stacked tapes

Non-insulated? Insulated? TSC

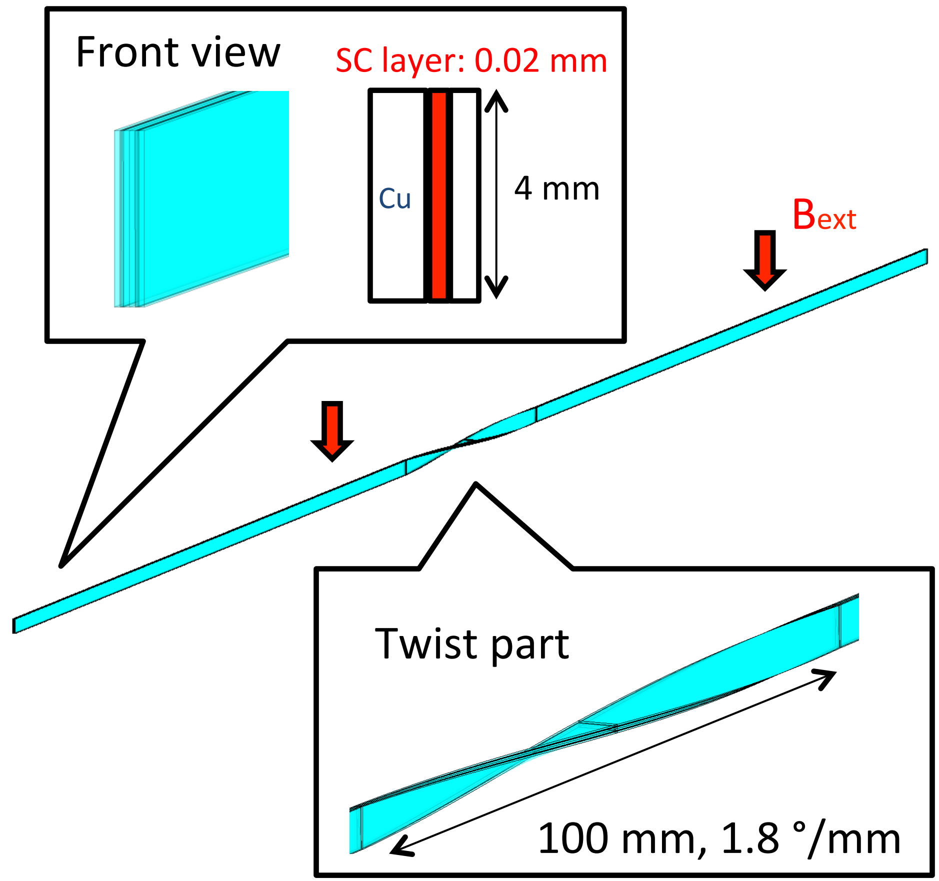
- Specification for HTS tape

Critical current I_c	800 A
n-value	20

- Operating condition



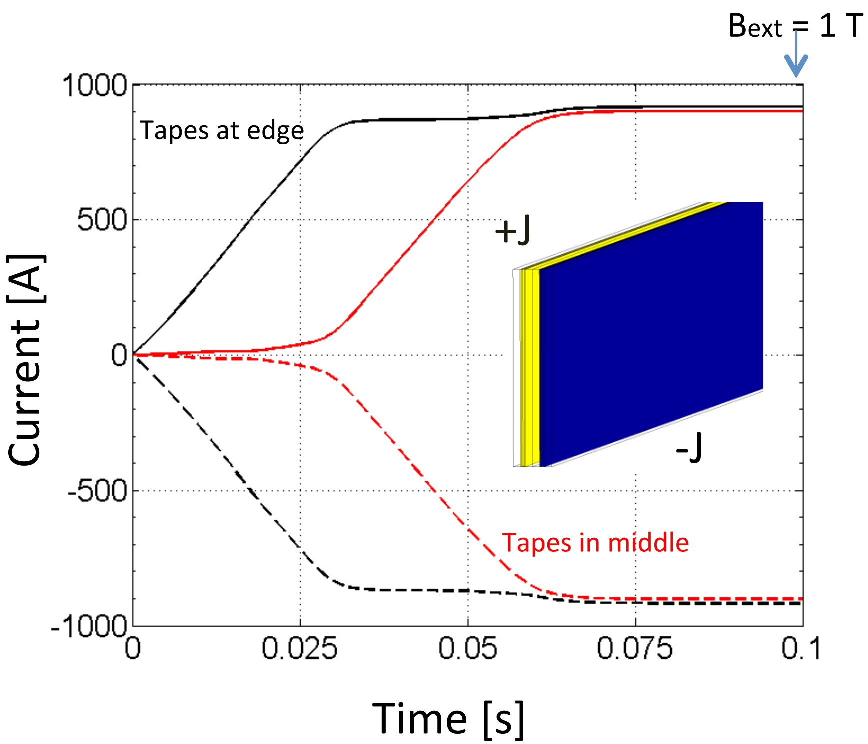
TSC composing 4 HTS tapes



Magnetization

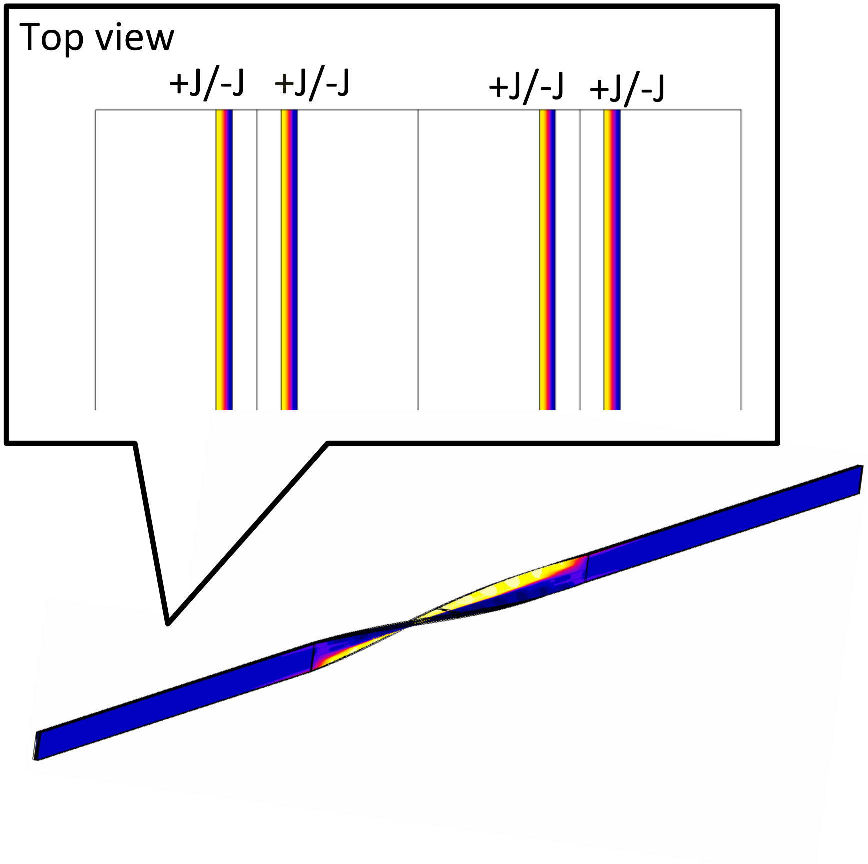
Non-insulated: More magnetization

Act as stacked cable (coupled model)…
Twist is meaningless



Insulated: Less magnetization

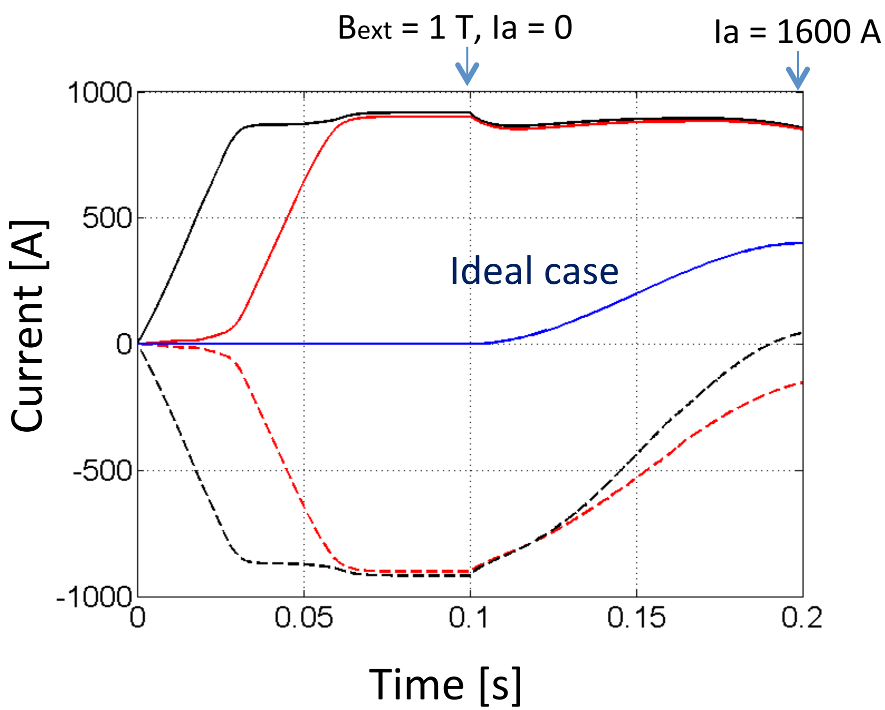
Net current of tape is zero.



Current distribution/ redistribution

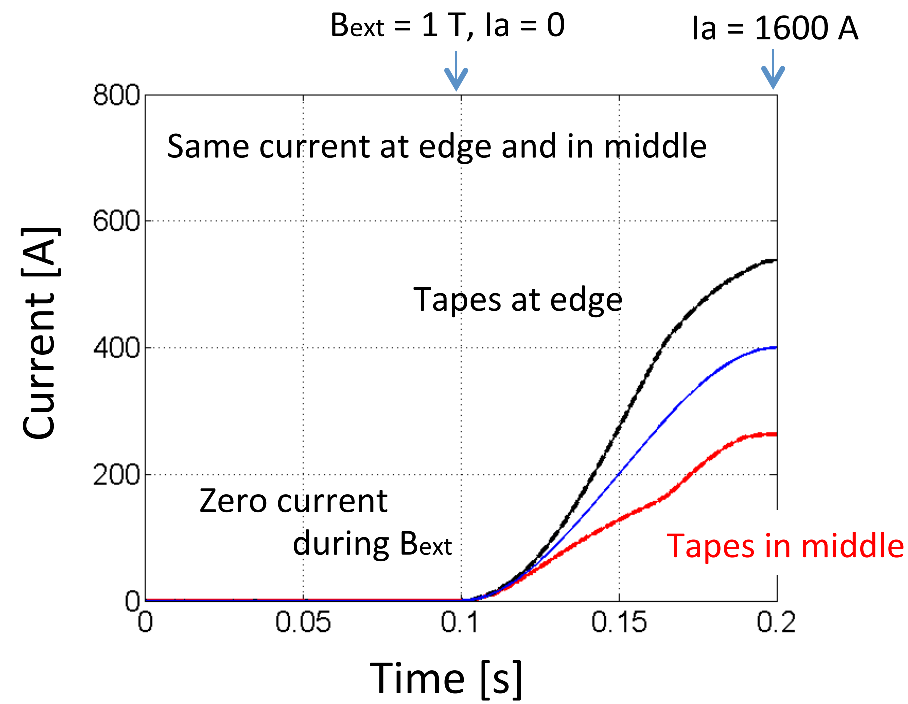
Non-insulated: Inhomogeneous

Current sharing after ramping!
But not sure for unifrom distribution
in case for coil



Insulated: Still inhomogeneous

No current sharing…
Strongly depends on contact resistance!



Partially insulated twisted stacked cable

Summary: Non-insulated? Insulated? TSC

1. Magnetization: Insulated TSC
2. Current distribution: Not good candidate due to the lack of current sharing
3. Current redistribution: Non-insulated TSC

Partially insulated twisted stacked cable (PI-TSC)

<Concept>

Make good use of the advantages of both the non-insulated and insulated.
Low magnetization and uniform current distribution during normal operation and good current redistribution in case of fault condition such as hot spot.

Where to locate the non-insulated part? And how long?

Partially insulated twisted stacked cable

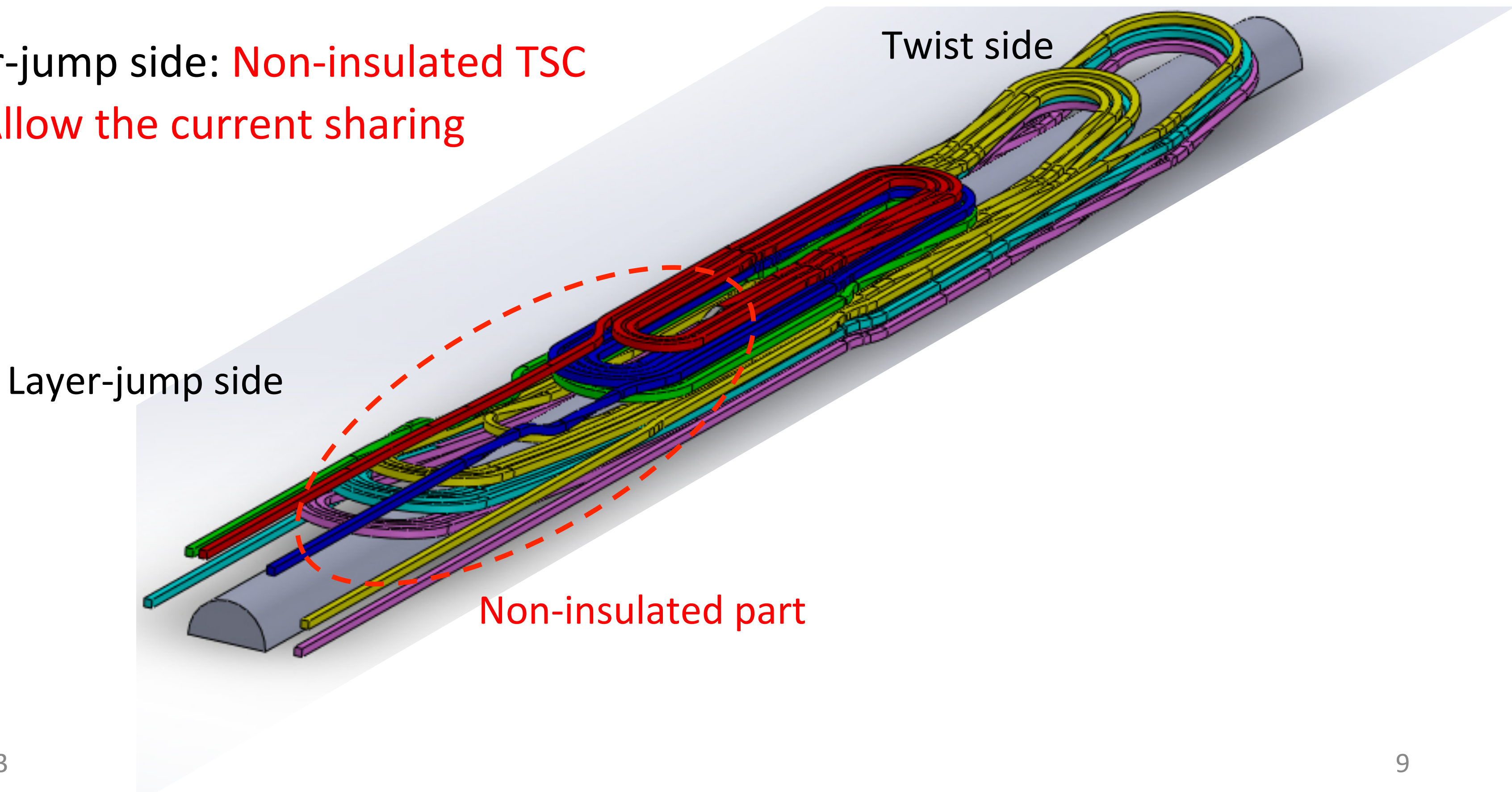
Straight part: Insulated TSC

Low magnetization for good field quality

Twist side: Insulated TSC

Layer-jump side: Non-insulated TSC

Allow the current sharing



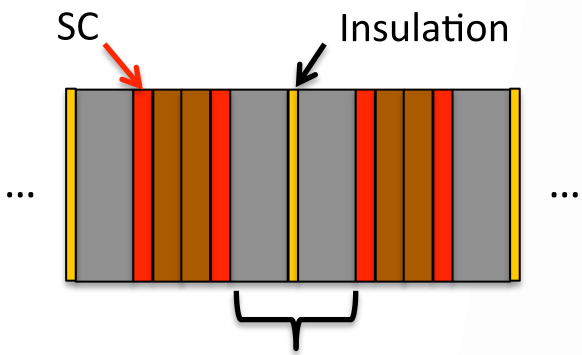
1^{st} *Numerical analysis for PI-TSC*

<u>1-turn racetrack coil with PEEC method</u>: 8 stacked tapes with adjacent contact

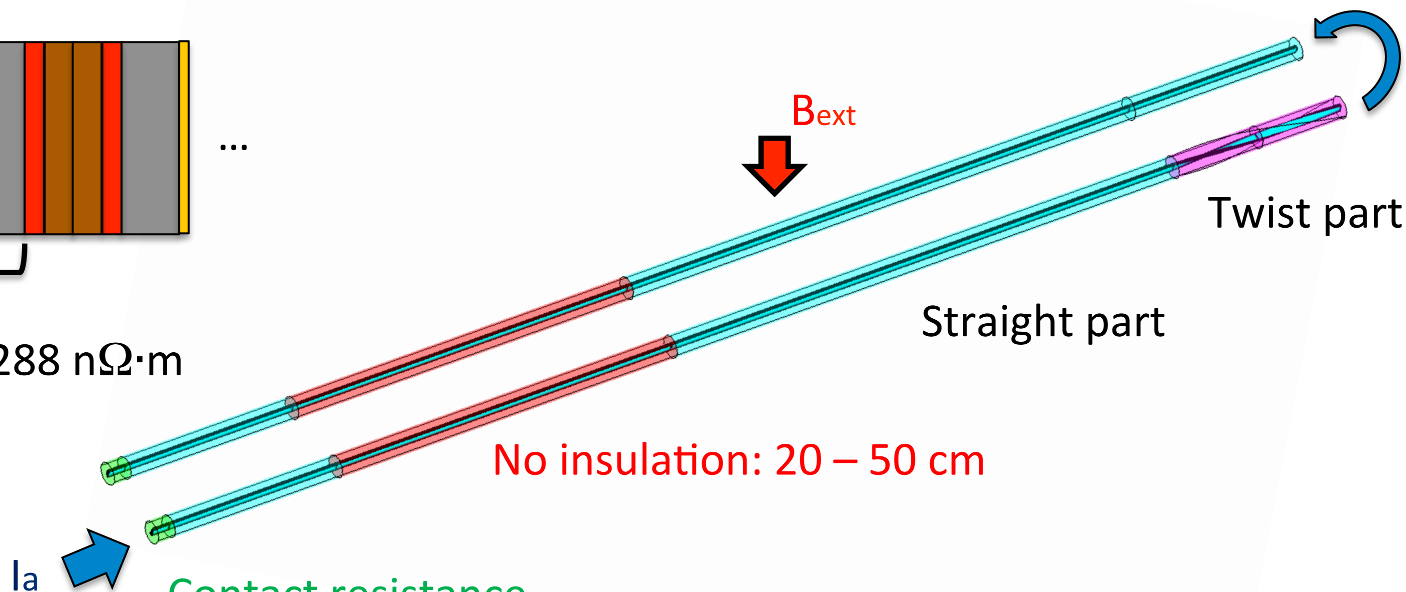
Cable structure at straight part

1) Perfect insulation: All stacked tapes are insulated

2) Face-to-face stacked tapes: Faster current redistribution



ρ_{ad} = 10, 50, 288 nΩ·m

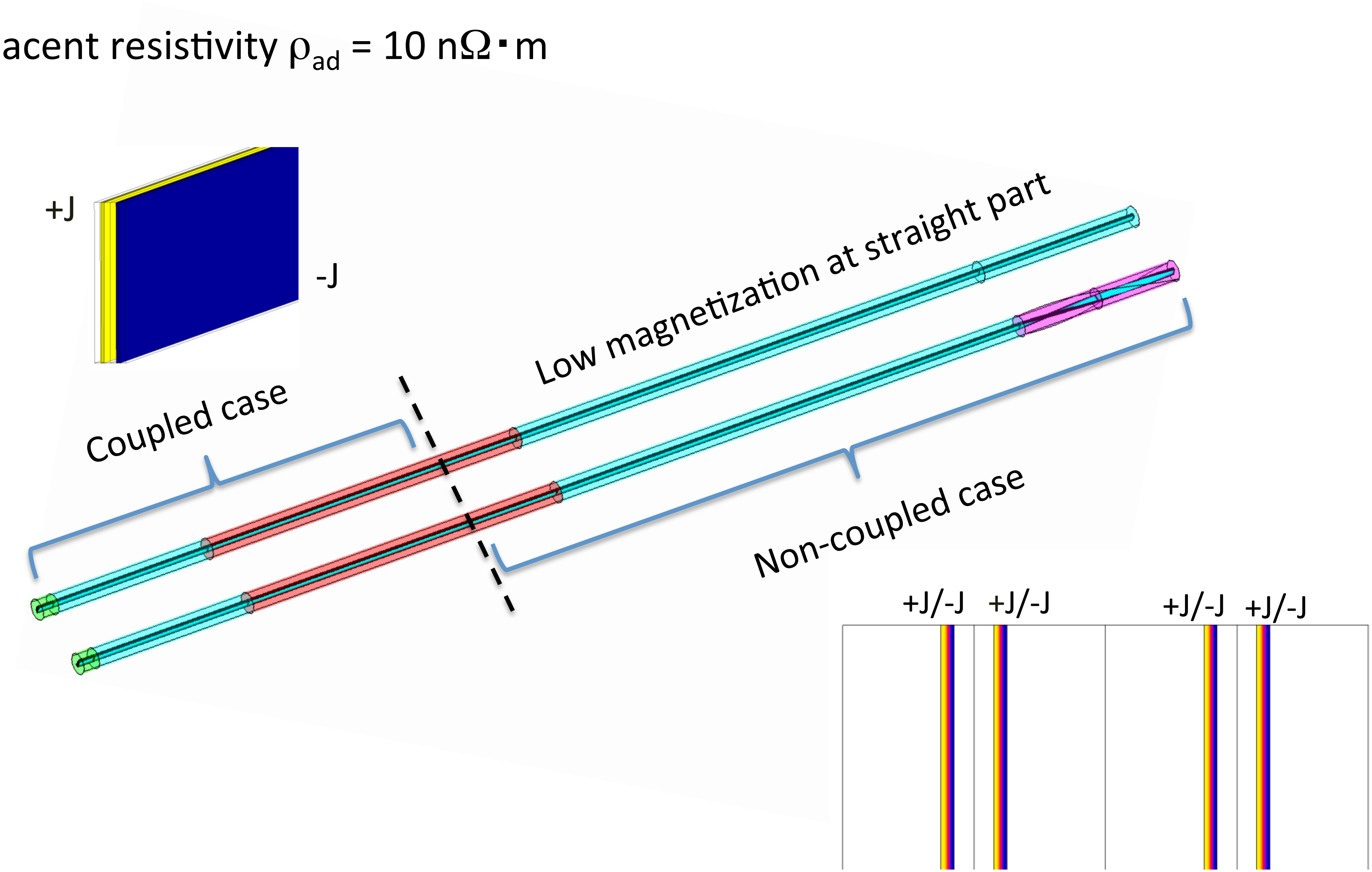


Contact resistance

R_1 = 50 nΩ , R_2 = 20 nΩ , R_3 = 40 nΩ , R_4 = 30 nΩ

Magnetization PI-TSC

Adjacent resistivity ρ_{ad} = 10 n$\Omega \cdot$m



Next step PI-TSC

Modeling: 1-turn of racetrack coil (May.2016)

- Analysis on current distribution is still ongoing ...
- Model with equivalent inductance of 46-turns HTS insert
- Non-insulated TSC with high adjacent resistance

Modeling: 2-turns of racetrack coil (May - June.2016)

- Magnetization for 2nd turn

    Non-coupled? Coupled? model

Current distribution test for partially insulated TSC

1st winding test with dummy stacked cable

Conclusion

- Non-insulated model allows current sharing; while insulated model has low magnetization (non-coupled case). Both of cases result in inhomogeneous current distribution.

- Partially insulated TSC HTS insert has the insulation at twist and straight part and the no insulation at the layer jump side. This allows to make good use of both advantages.

- Magnetization of 1-turn racetrack coil shows non-coupled model at twist and straight part, and coupled model at layer jump side.