Can we avoid a copper coating for 1.3 GHz ILC coupler?

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As experience shows, a copper coating is not easy procedure. Some times copper flakes of coating can be found in superconducting cavities. Avoiding copper coating can make coupler more reliable and less expansive.

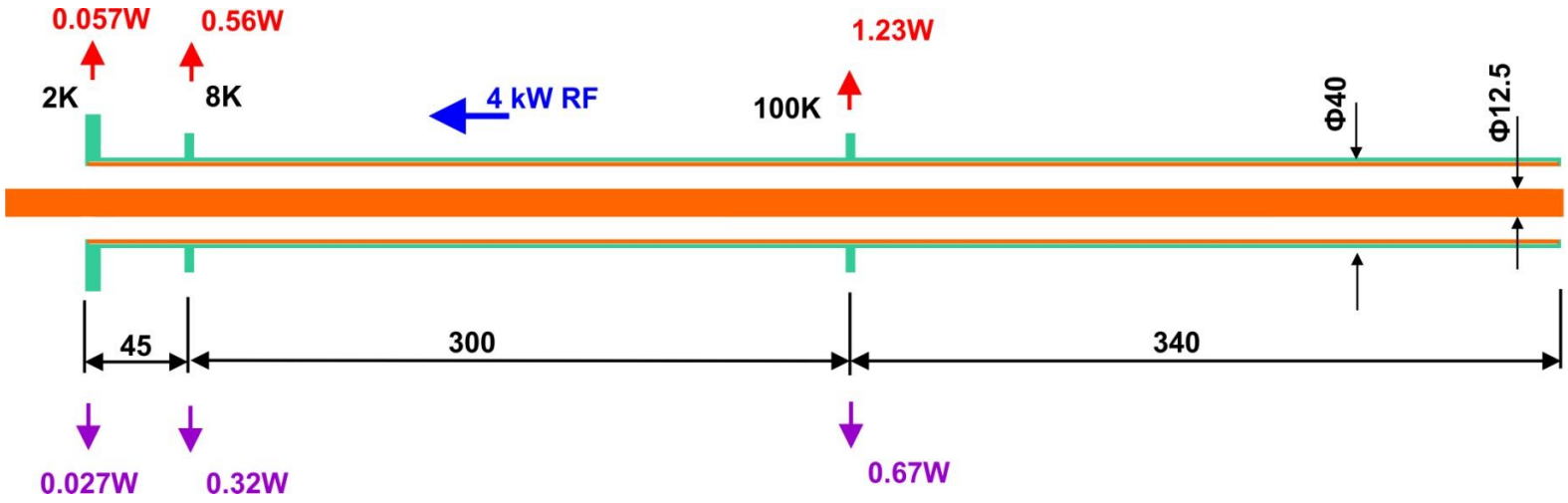
We see two ways to eliminate copper coating:

1) **Increasing coupler outer diameter up to 60mm and use SS bellows. Estimations show that level of cryo-load of 4kW average power coupler is tolerable.**

2) **Increasing coupler outer diameter up to 60 mm and use copper inserts. It reduces cryo-load drastically. This approach works for large average power as well.**

Both will be considered below.

Lets consider 'optimized' coaxial coupler with parameters close to TTF-III coupler.
Optimized means that all lengths is optimal to minimize total (dynamic + static) cryogenic load.
Coupler parameters:
Outer conductor: SS, diameter 40mm, thickness 0.4mm, coated by 10μ copper.
Inner conductor: copper, diameter 12.5mm, warm – all losses are translated to 300K
Average RF power 4 kW.



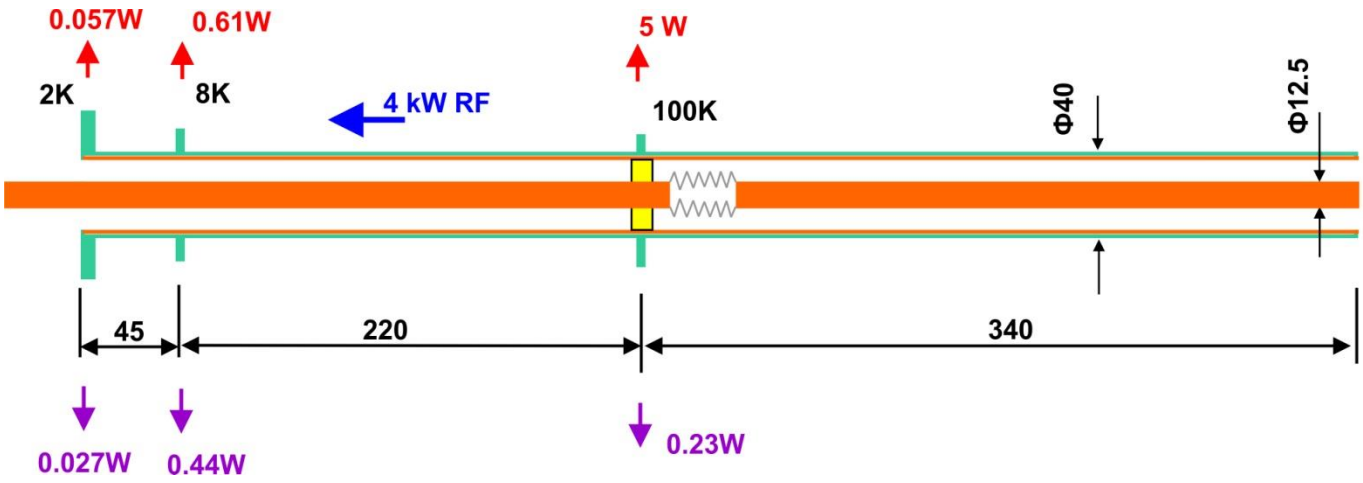
Red values – total losses, dynamic + static; Purple values – static losses.

Coupler scores:

Total: 0.057*890 + 0.56*260 + (1.23+4)*20 = 51 + 146 + 25 = 222
Static: 0.027*890 + 0.32*260 + 0.67*20 = 24 + 83 + 13 = 120

(890, 260, 20 – conversion factors to room temperature)

Cold antenna: part of antenna losses are translated to 100 K



Coupler scores:

Total: 0.057*890 + 0.61*260 + 5*20 = 51 + 159 + 100 = 310
Static: 0.027*890 + 0.44*260 + 0.23*20 = 24 + 114 +5 = 143

TTF III coupler
from "TESLA RF POWER COUPLER THERMAL CALCULATIONS", Dohlus M., et al, LINAC 04

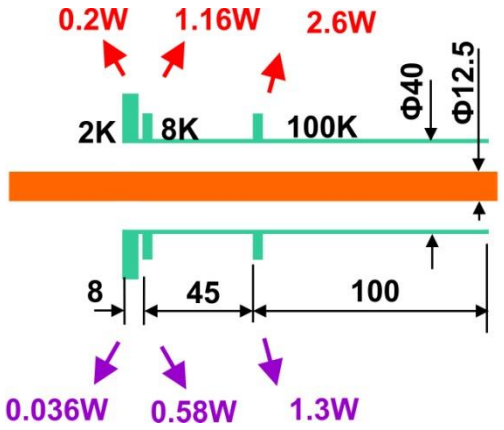
2K – 0.05W, 4K – 0.5W, 70K – 6.8W,
Score: 0.05*890+0.5*260 + 6.8*20 = 45+ 130+136 = 311

TTF III specifications:

0.06*890 + 0.5*260 + 6*20 = 53 + 130 + 120 = 303

Lets compare different couplers made of pure SS without copper coating:

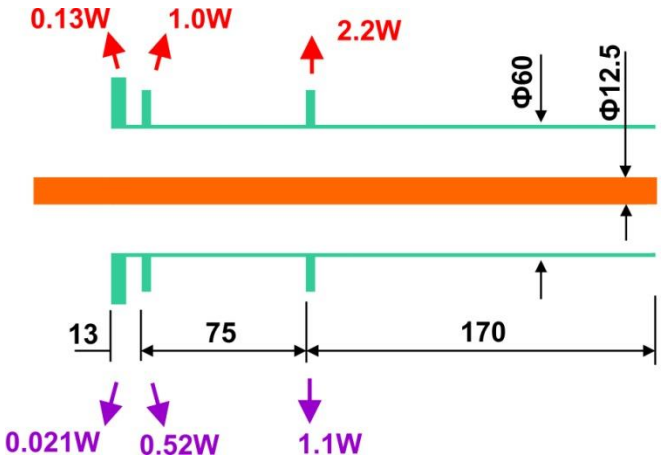
40mm, 12.5mm coupler (lengths are optimal):



Coupler scores:

Total (warm ant.): 0.2*890+1.16*260+2.6*20 = 178+302 + 52 = 532
Total (cold ant.): 0.2*890+1.16*260+4*20 = 178+302+80 = 560
Static: 0.036*890 + 0.58*260 + 1.3*20 = 32 + 151 + 26 = 209

60mm, 12.5mm coupler:



Coupler scores:

Total (warm ant.): 0.13*890+1.*260+2.2*20 = 116+260+44 = 420
Total (cold ant.): 0.13*890+1.*260+3.7*20 = 116+260+74 = 450
Static: 0.021*890 +0.52*260 +1.1*20 =19+135+22 = 176

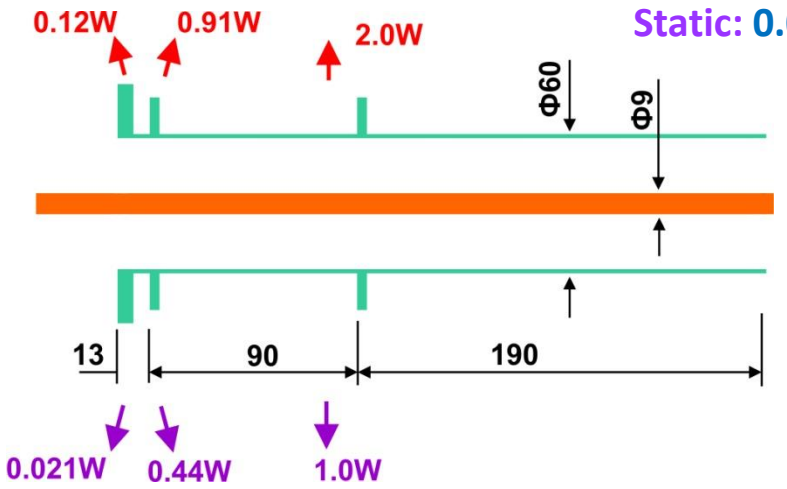
Coupler scores:

60mm, 9mm coupler:

Total (warm ant.): 0.12*890+0.91*260+2*20=107+237+40 = 384

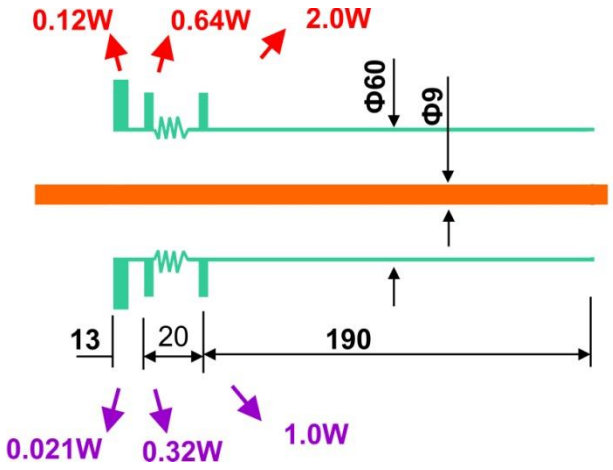
Total (cold ant.): 0.12*890+0.91*260+3.8*20=107+237+76= 420

Static: 0.021*890 + 0.44*260 + 1*20 = 19+114+20 = 153



We need bellows to compensate thermal expansion/shrinking and to tune coupling. Bellows improve situation.

Coupler 60mm, 9mm, bellows thickness 0.2mm.

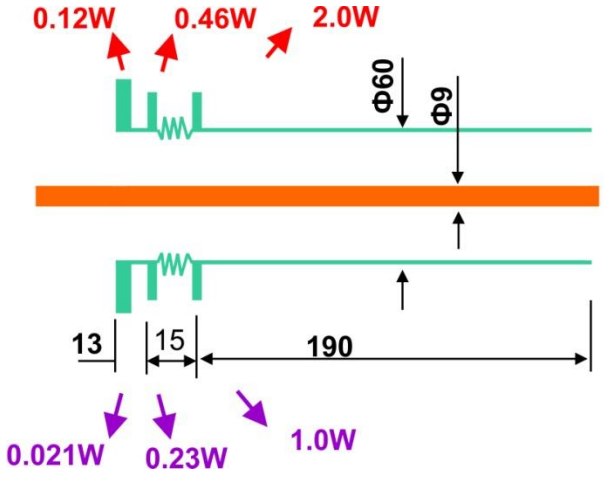


Coupler scores:

Total (warm ant.): 0.12*890+0.64*260+2*20=107+166+40= 313
Total (cold ant.): 0.12*890+0.64*260+3.1*20=107+166+62= 335
Static: 0.021*890+0.32*260+1*20 = 19+83+20 = 122

Optimal length of bellow - 61mm

Coupler 60mm, 9mm, bellows thickness 0.1mm.



Coupler scores:

Total (warm ant.): 0.12*890+0.46*260+2*20 = 107+120+40 = 267
Total (warm ant.): 0.12*890+0.46*260+3*20 = 107+120+40 = 287
Static: 0.021*890+0.23*260+1*20 =19 +60+20 = 99

Optimal length of bellow 43mm

'Ideal' 40mm copper coated coupler, TTF III coupler scores:

Total (cold ant.): ~ 310

SS 60mm with bellows coupler score:

Total (cold ant.) : ~ 290

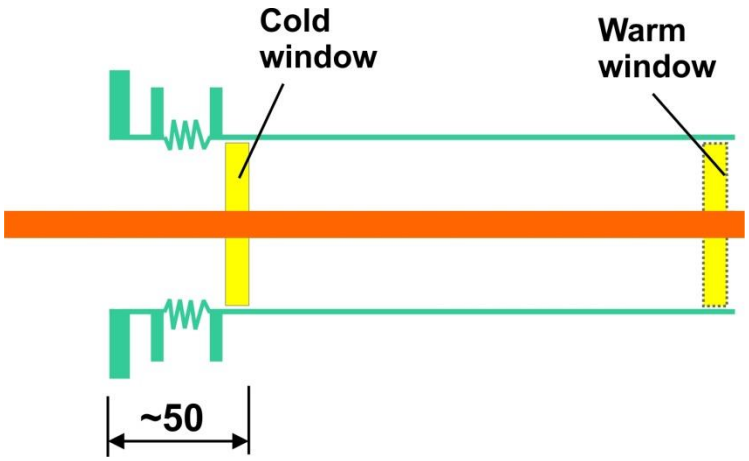
Can we make SS coupler without coating with cryogenic load as current TTF III coupler?

For reference:

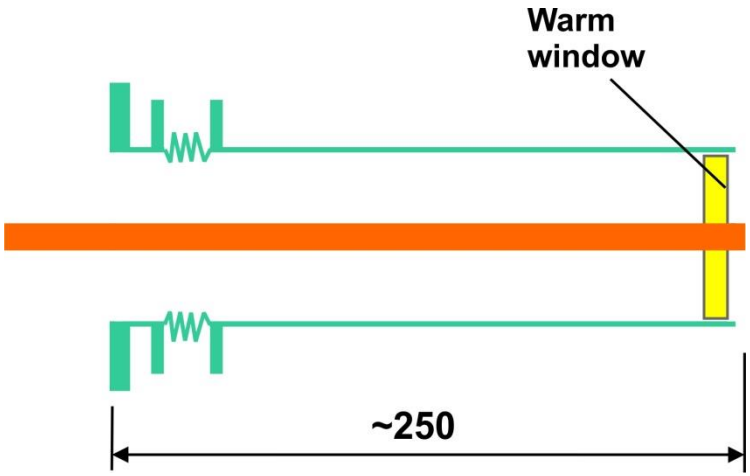
Cryogenic load of accelerating cavity ~ 1W at 31.5MV/m (fundamental mode and HOMs). Score of cavity ~ 890

SS coupler is compact and can be used in both configurations, with one and two windows:

Two window configuration:



One window configuration:

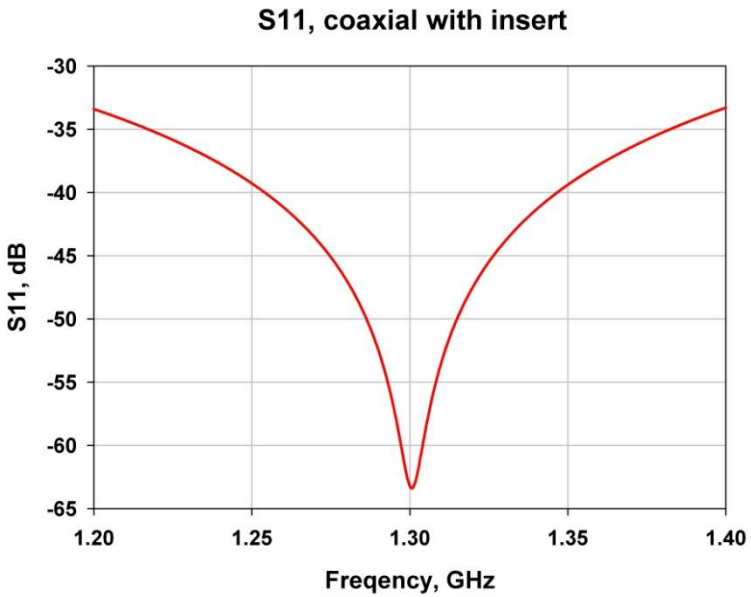


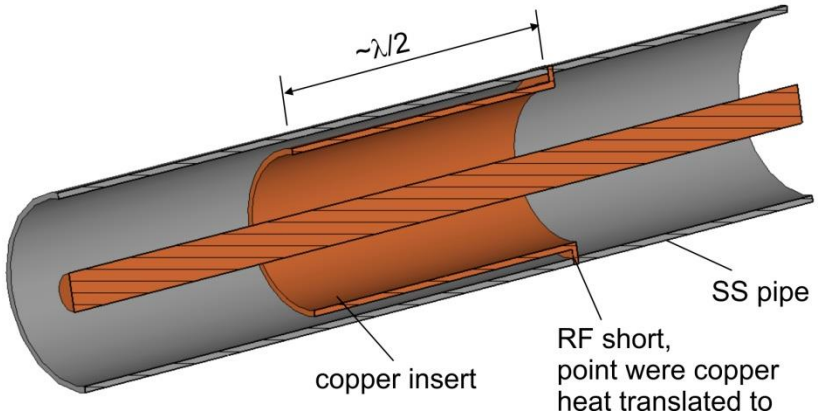
~ 250mm should fits ILC cryomodule

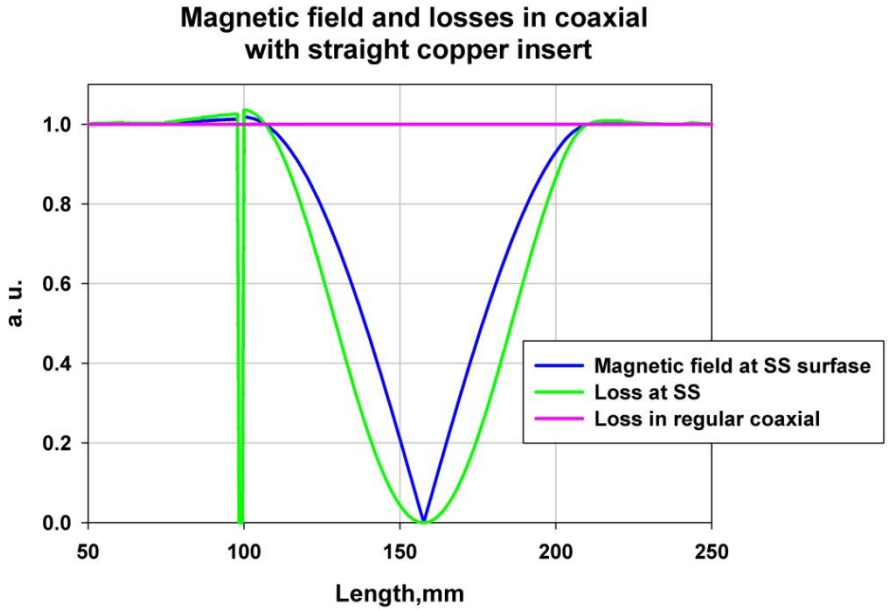
We can improve cryogenic properties of SS coupler without coating even more by using special copper inserts.

Shielding SS wall by copper insert

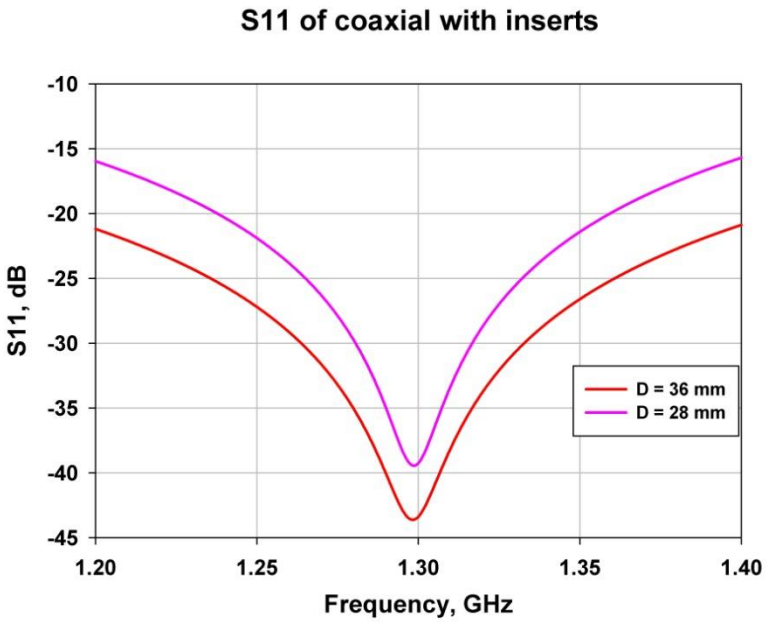
Idea was published at SRF 2011: "How to eliminate a copper coating and to increase an average power of main coupler", S. Kazakov

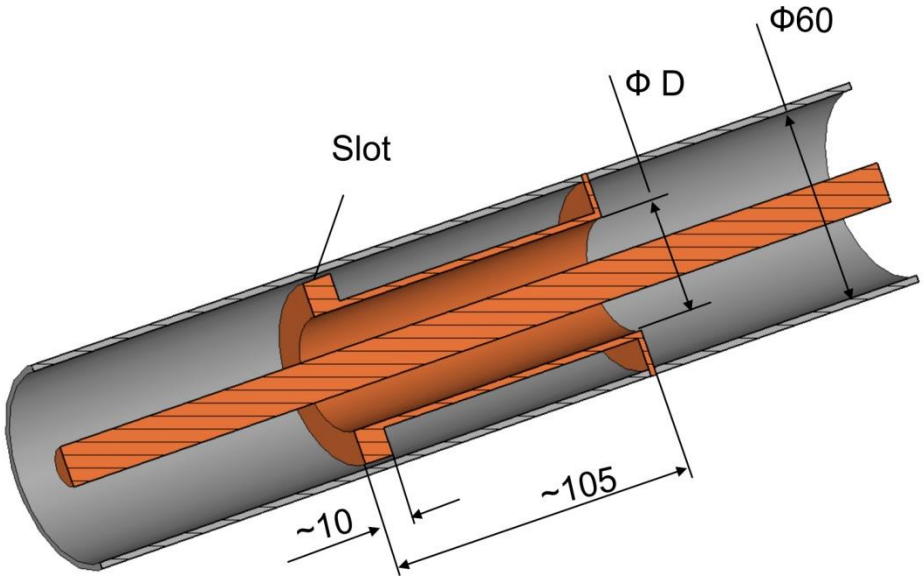


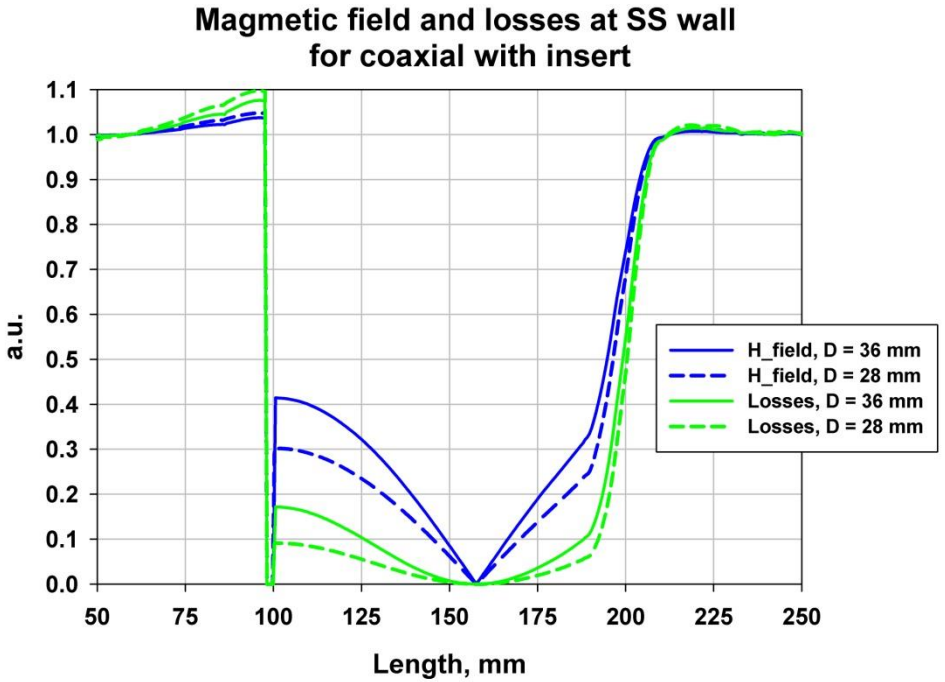




Straight insert derrises average losses in SS wall 2 times ('increases' SS conductivity 4 times). Insert losses are translated to one point of joint of insert and SS piper.

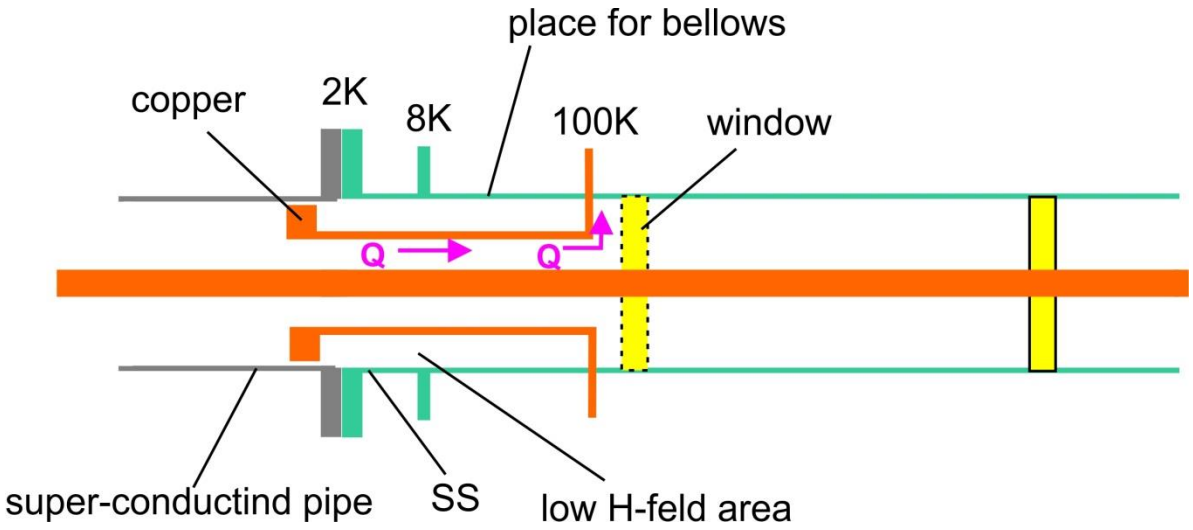


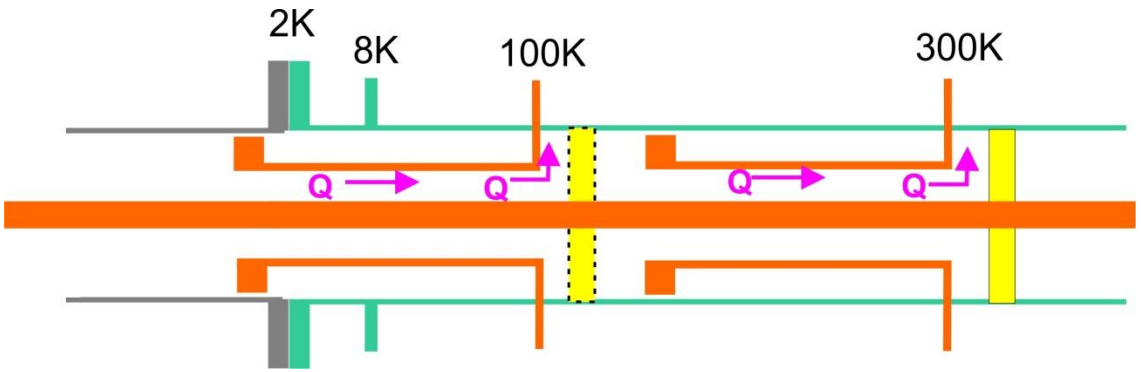




This shape insert decreases losses in SS wall 10 – 20 times ('increases' conductivity of SS 100-400 times)

Possible geometries of coupler with one and two inserts (and with one or two windows)





Conclusion:

We should pay attention to possibility to make ILC coupler without copper coating.
More detailed investigation is necessary.

Copper inserts decrease cry-load drastically and allow to avoid copper coating .
Multipactor simulations are necessary.