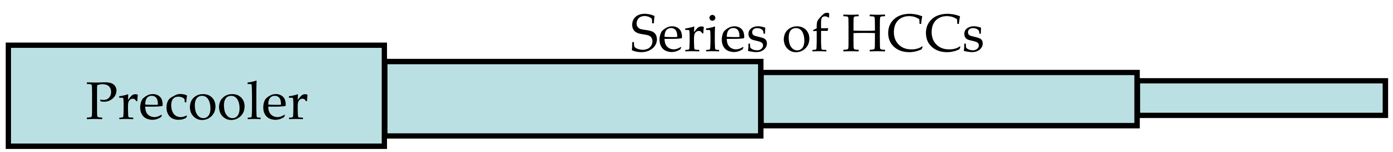
RF Requirements for GH2 HS HCC

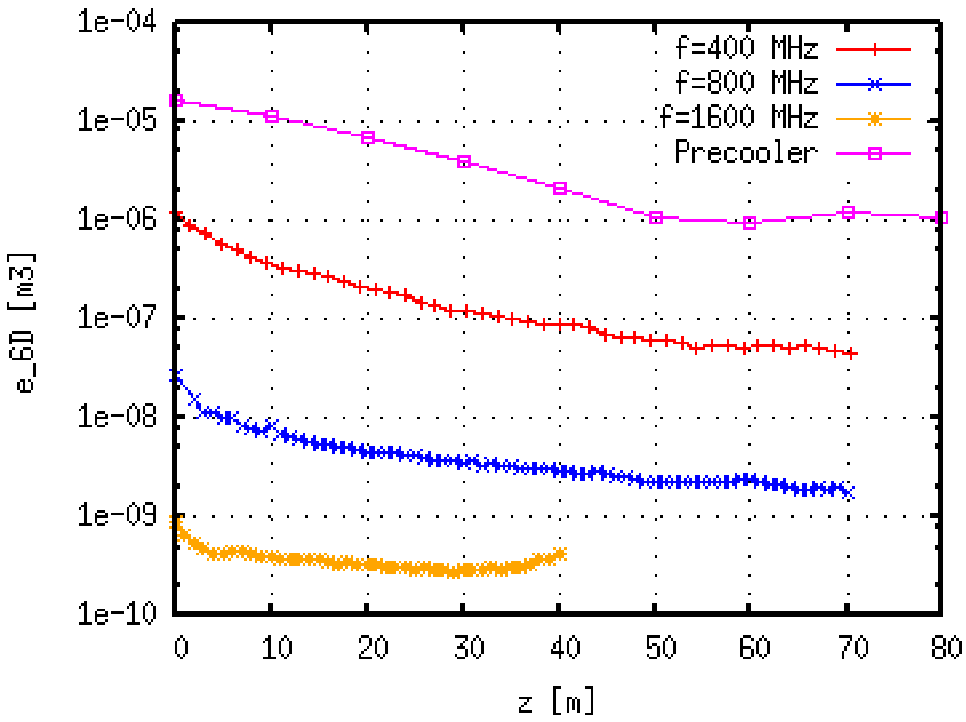
Lars Thorndahl

(Rol & Katsuya)

Precooler + HCCs
With first engineering constraints



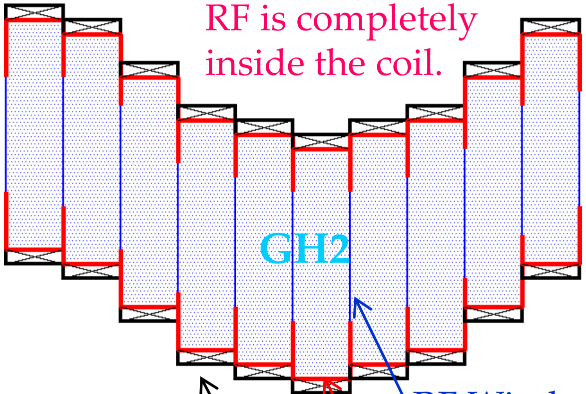
Solenoid + High Pressurized RF



- The acceptance is sufficiently big.
- Transverse emittance can be smaller than longitudinal emittance.
- Emittance grows in the longitudinal direction.

Incorporating RF cavities in Helical Cooling Channels

Engineering HCC with RF



- Use a pillbox cavity (closed, but 0 window thickness).
- RF frequency is determined by the size of helical solenoid coil.

→Diameter of 400 MHz cavity = 50 cm
→Diameter of 800 MHz cavity = 25 cm
→Diameter of 1600 MHz cavity = 12.5 cm

- The pressure of gaseous hydrogen is 200 atm at room temp
- (or 50 atm at 77k) so dE/dx matches 16.4 MV/m RF.

→The field gradient can be increased if the breakdown would be well suppressed by the high pressurized hydrogen gas.

parameters	*λ*	*κ*	*Bz*	*bd*	*bq*	*bs*	*f*	*Inner d of coil*	*Expected Maximum b*	*E*	*RF phase*
unit	*m*		*T*	*T*	*T/m*	*T/m2*	*GHz*	*cm*	*T*	*MV/m*	*degree*
1st HCC	*1.6*	*1.0*	*-4.3*	*1.0*	*-0.2*	*0.5*	*0.4*	*50.0*	*6.0*	*16.4*	*140.0*
2nd HCC	*1.0*	*1.0*	*-6.8*	*1.5*	*-0.3*	*1.4*	*0.8*	*30.0*	*8.0*	*16.4*	*140.0*
3rd HCC	*0.5*	*1.0*	*-13.6*	*3.1*	*-0.6*	*3.8*	*1.6*	*15.0*	*17.0*	*16.4*	*140.0*

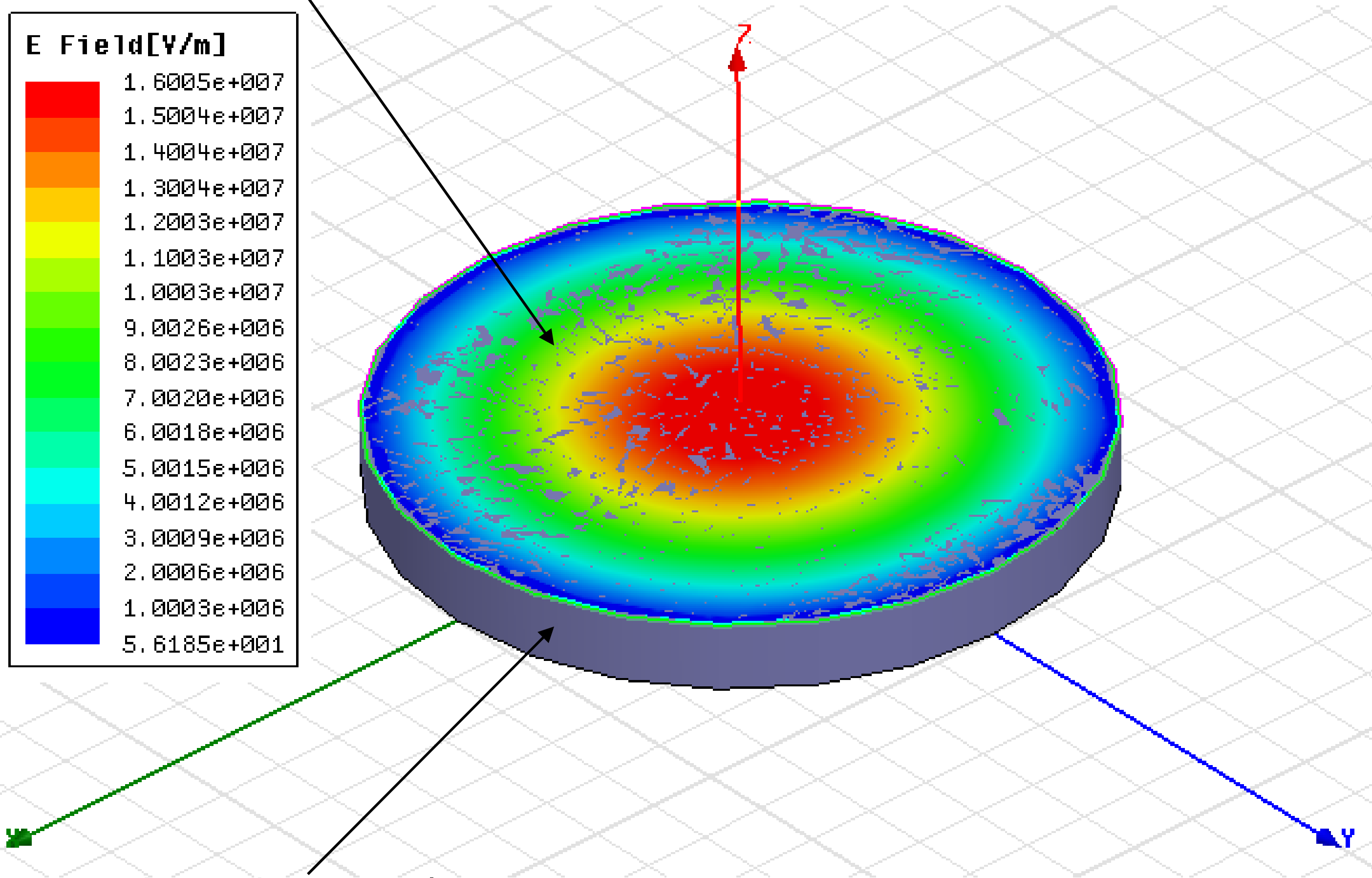
Muons, Inc.

Simple pillbox of Al at 400 MHz and LN2 temperature, resistivity 0.4 E-6 Ohm cm HFSS results

154 kW, on one side of 1 foil

Upeak = 800 kV, for crossing with betaparticle infinity (transit factor = 1)

$\varepsilon_{rel} = 1.32$



Radius = 0.25 m
Height .= 0.05 m

Q = 26630

W = 3 Joule/pillbox

R/Q =$(U_{peak})^2/2\omega W$
= 42.5 Ohm
circuit convention

63 kW on inner mantle

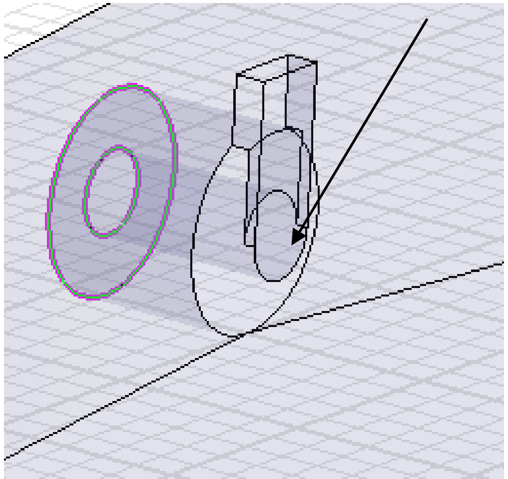
371 kW total/pillbox during passage of trains,
~6 kW average

Note that for a given Ez, and scaled dimensions R/Q remains unchanged: the 1.6 GHz pillbox has the same R/Q as the 400 MHz one.

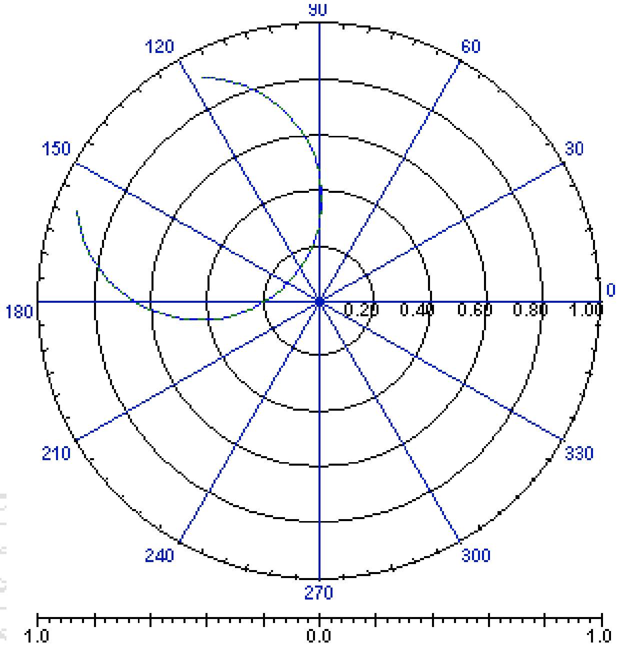
Muons, Inc.

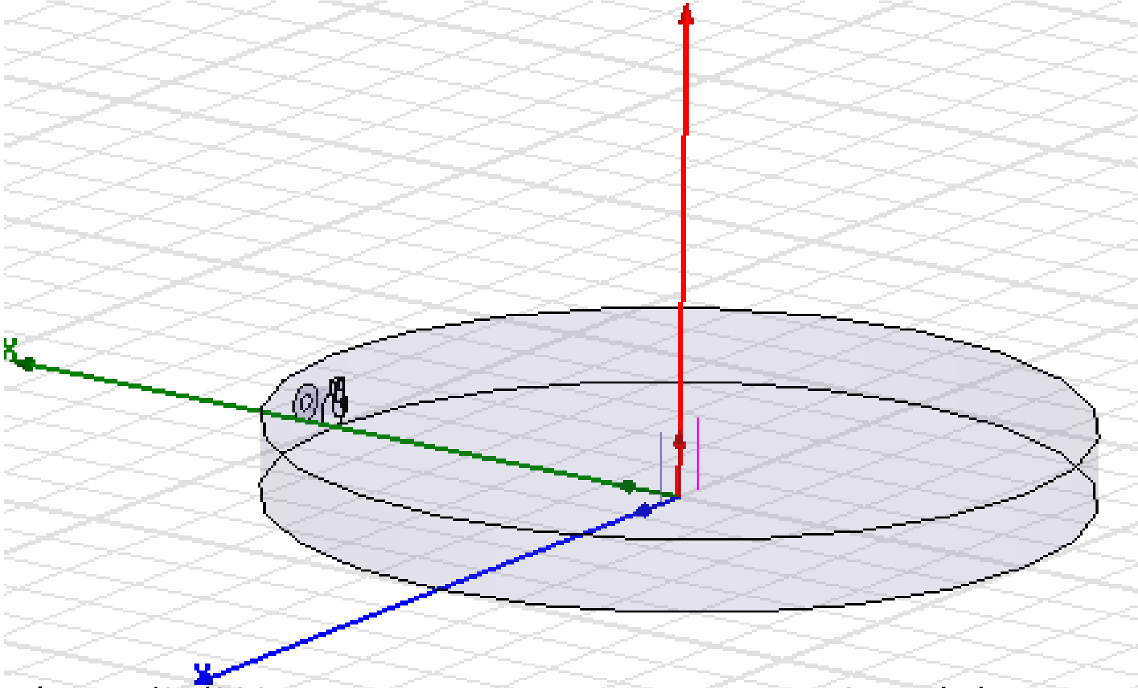
Approx. match for geometry and losses as indicated on the previous slide

Loop surface: 4 mm from wall



Smith: almost matched at 396 MHz

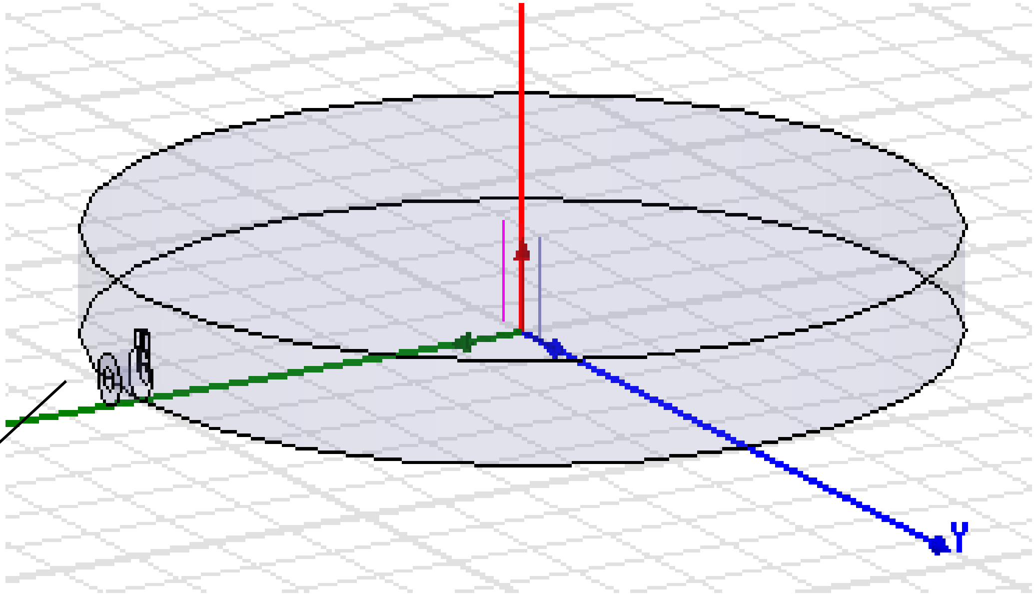




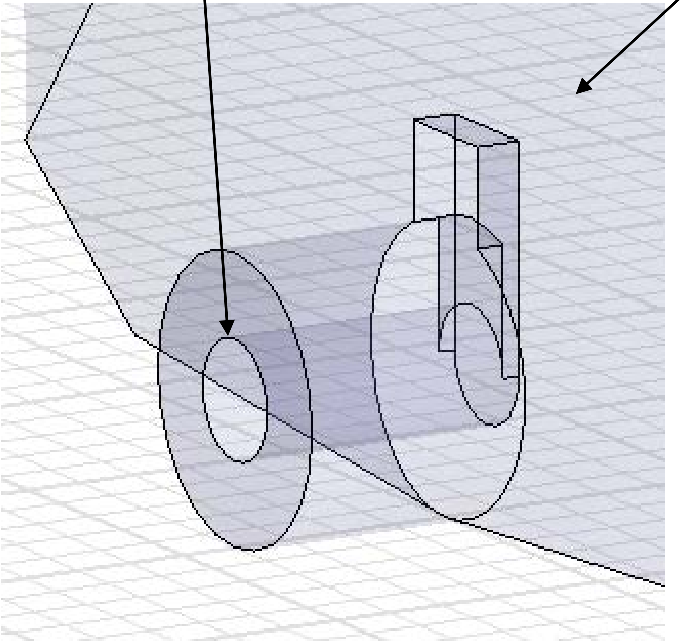
Note that the matching geometry changes with the wall losses.

Higher losses: bigger loop and lower Q-value

The coax. feed being an obstruction for the coils, it is of interest to reduce its diameter



Peak el. field on inner conductor = 1.04 E6 V/m, scales inversely with outer diam.



50 Ohm coax. feed
inner rad. 5.2 mm
outer rad 12.5 mm

Subj: **RE: Please review 'Pillboxshow'**

Date: 12/5/2007 4:36:06 A.M. Eastern Standard Time

From: Lars.Thorndahl@cern.ch

To: Roljohn@aol.com

Hi Rol,

I had a drawing showing 10 trains of 16 bunches and the trains were spaced by 50 microseconds. The assumption was that the rf would be on during the 10 trains, because of the high Q-value. Therefore it would be on for approx. 0.5 ms 32 times/s.

I now realise that I have not included that there are 2 types of muons.

Should the duty factor be doubled to 0.032 (~12 kW), which means that we have 20 trains of 16 bunches, or do you fit the second set of trains in between the first set and keep the duty factor at 0.016? *(The HCC only takes one sign, so need two of them-Rol)*

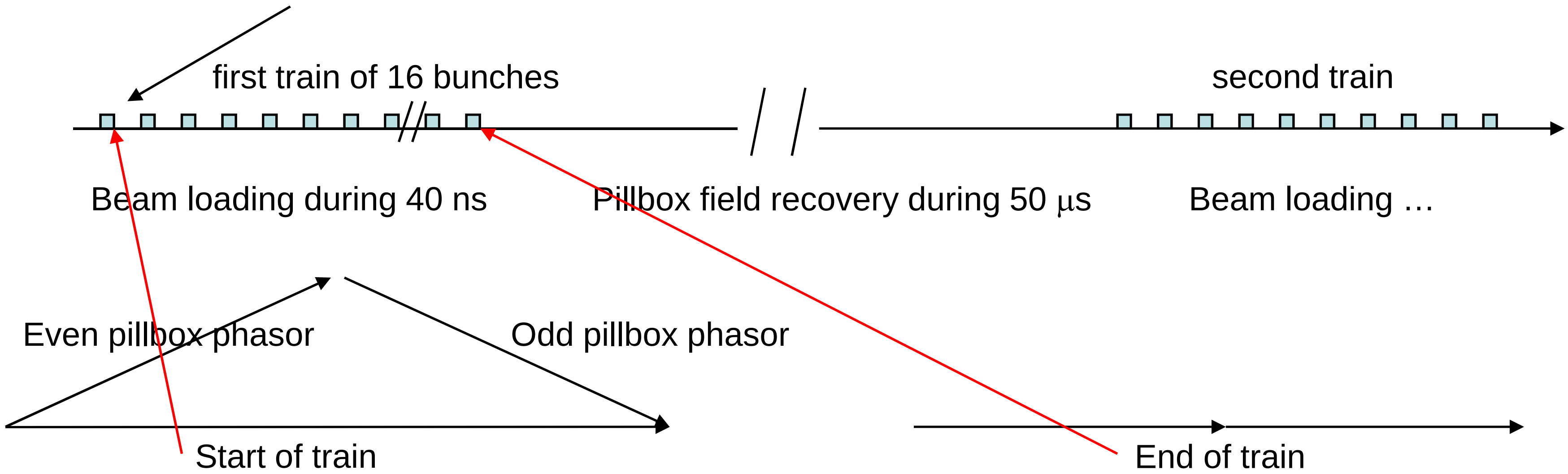
The R/Q - value is a very common notion in cavity design. It gives you the peak square acc. voltage divided by the stored rf energy. By including omega in the denominator the R/Q-value becomes an invariant also for cases where you decrease all dimensions by a factor F and increase the frequency by the same factor F. This applies conveniently to our 3 pillboxes.

I have not seen W. Weingarten yet but I shall try to reach him to-day. Good luck. Lars

(I asked Lars to look into anomalous skin depth and magnetostrictive effects-Weingarten is a CERN expert-Rol)

Pillbox beam-loading compensation method by initial outphasing

10 trains of 16 bunches with bunch spacing 2.5 ns and train spacing 50 μs, repetition rate 32 Hz



Even-numbered pillboxes have a small phase advance at the beginning of the train and a frequency slightly lower than the bunches.
Odd-numbered pillboxes have a small phase lag at the beginning and a higher frequency.

The real negative beam-loading phasors will reduce the pillbox phasors during the passage of the 16 bunches. The complex sum of the 2 pillbox phasors will however remain almost constant and real during the passage of the bunches.

At the arrival of the next train the pillbox phasors must again be outphased via a proper choice of pillbox frequencies.

Beam loading phasor amplitudes

Single bunch negative loading phasor:

Vbl = -R/Q q ω q is bunch charge ←

We look at the extreme cavities:

Vbl = 342 V for 400 MHz pillbox and one bunch of 2 E10 particles

Vbl =1368 V for 1600 MHz pillbox and one bunch of 2 E10 particles

Vbl = 21.9 kV for 16 bunches and 1600 MHz, small compared with 200 kV, 11 % drop in amplitude.

Conclusions

1. Important power losses on the foils (308 kW for both sides during the passage of the10 trains and for 400 MHz), for other materials than Al these losses scale as sqrt of the material resistivity.

2. Considering the high Q-values needed, the geometry must remain stable: the foils are not allowed to shift position or buckle.

3. Beam-loading causes an 11 % field reduction for the 1.6 GHz pillboxes, which can be compensated by the use of 2 frequencies.