Dark Current Dynamics in Helical Channel

Gennady Romanov, Vladimir Kashikhin
Fermilab

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Outline

• On electron trajectories in HCC
• Helical Cooling Channel with 805 MHz RF cavity
• High field emission model
• Dark current in RF field
• Dark current in uniform solenoidal field combined with RF field
• Dark current in HCC fields combined with RF field
• Comparison and conclusion.
V. Kashikhin pointed out: The muon trajectories in HCC are helical. The dark current electron trajectories should be helical too.
CSTSS model

<table>
<thead>
<tr>
<th>Helix Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period of Helix</td>
<td>1.6 m</td>
</tr>
<tr>
<td>Helix pitch</td>
<td>1.0</td>
</tr>
<tr>
<td>Coil inner diameter</td>
<td>0.4 m</td>
</tr>
<tr>
<td>Equilibrium orbit radius</td>
<td>0.255 m</td>
</tr>
<tr>
<td>Current×turns</td>
<td>9.7 kA×10</td>
</tr>
<tr>
<td>Coil max flux density</td>
<td>7.0 T</td>
</tr>
<tr>
<td>Helical dipole field</td>
<td>1.75 T</td>
</tr>
</tbody>
</table>

RF cavity model inside HCC. Some coils are removed for clear view. The left insert shows solenoidal field distribution in middle plane of the cavity ($B_z$), the right one – dipole field distribution ($B_x$). 805 MHz cavity closed with Be windows, accelerating field 30 MV/m on axis.
Emission model

This particle source produces a burst of electrons at the moment of highest electric field. The emitted electrons are uniformly distributed over the iris, with initial energy uniformly distributed from 0 to 4 eV, and uniform angular spread within normal and 45°. When an electron hits the wall it is elastically reflected, or absorbed, or rediffused, or it can produce true secondary electrons, according to Furman probabilistic re-emission model. We can exclude true secondary emission though.
A number of models consider high field emission intense bombardment near a field emission site with high surface field as a most probable trigger for breakdown or at least as an essential component of breakdown mechanism (J. Norem, R. Palmer and others)

In addition to the high field emitted electrons there is small amount of backscattered electrons: \( \approx 10\% \) of incident current. In presence of solenoidal field they also have linear trajectories, bounce between irises 3-4 periods and acquire energy up to 2-4 MeV. Since high field emission happens each half-period, there may be an accumulation of these high energy electrons.

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Primary electrons miss opposite irises almost completely. But…

- There is a small overlapping, it can be enough to initiate breakdown
- Some backscattered electrons fly back to the points of origin
- In low field area on the cavity walls the primary electrons can initiate and support one-surface multipacting (needs more study)
Dark current electron trajectories in field of tilted solenoid.

The simulations show different dark current dynamic in HCC, than that in uniform solenoidal field. There is a reason to expect some cavity improvement may be excepted. But the backscattered focused electrons, overlapped areas of bombardment and possible one side MP create doubts.

A high power test of the cavity in uniform solenoidal field, while the angle between cavity axis and solenoid one is up to 20°, can give us a final answer. Simulations show that dark current dynamic in this configuration is very similar to that in HCC.
CONCLUSIONS

- In HCC fields dark current emitted from iris misses opposite iris almost completely.
- There are small areas where electron bombardment of emission sites still exists.
- Backscattered electrons will hit emission sites.
- There is indication that one-surface multipacting is possible in low level area.
- High power tests of a cavity which is non-parallel to solenoid field can give us additional important information.