Emittance Compensation in a Superconducting Photoinjector

Kathrin Goldammer

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Overview

- Excerpts from studies on superconducting photoinjector for the BESSY-FEL*

Important Issues:

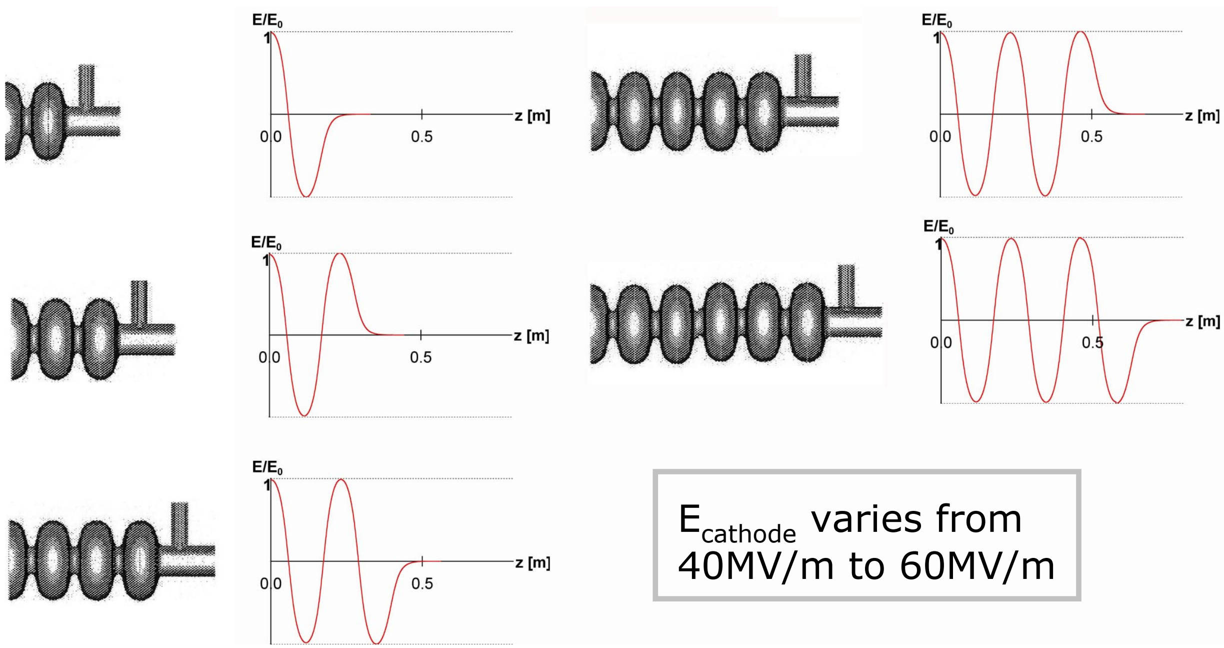
- Influence of solenoid position on emittance compensation

- Safe operation of superconducting gun in vicinity of solenoid field

*Taken from thesis „Numerical Investigations of Superconducting Mulitcell Photoinjector RF Gun Cavities“, K. Goldammer, 2004

Gun Simulation

- Electric field in gun cavity same as in TESLA cavities, scaled to different peak fields
- Cathode assumed as normal conducting Cs_2Te
- Five different guns created, varying number of full cells
- First half cell is a simple half of a TESLA cell, no rf focusing
- Bunch charges from 1nC to 2.5 nC

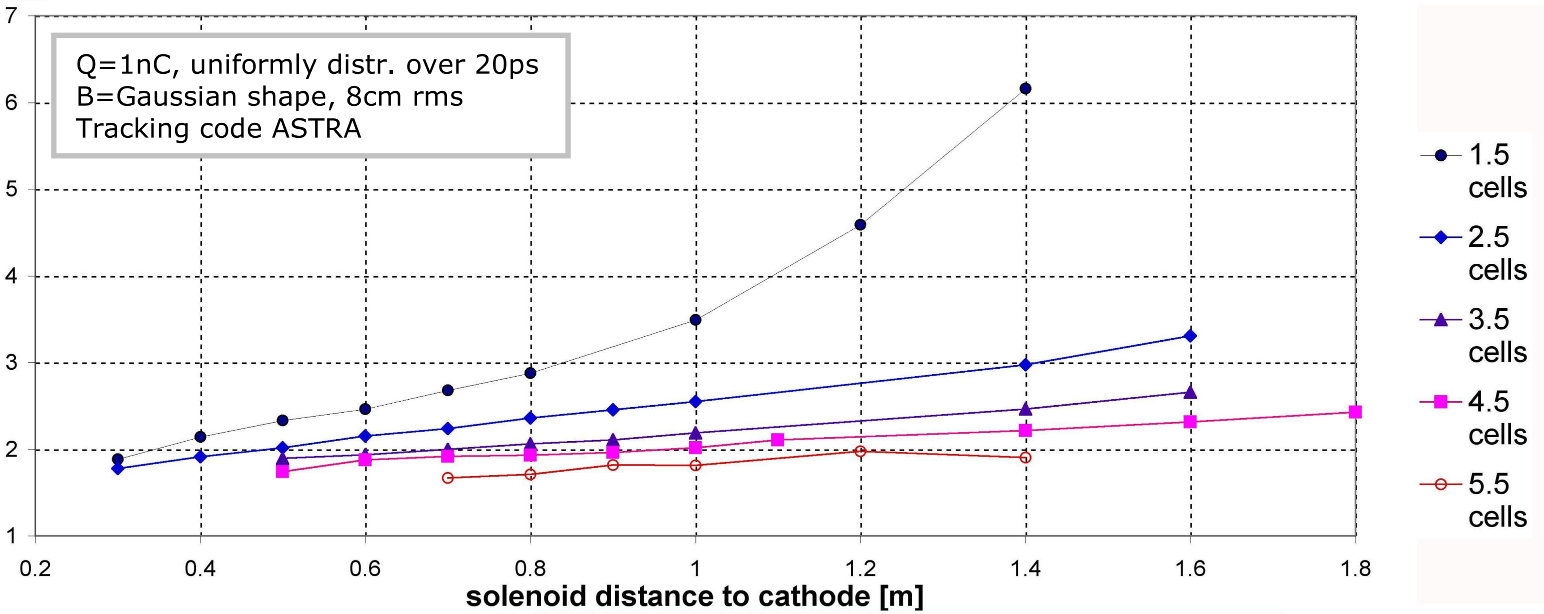


$E_{cathode}$ varies from 40MV/m to 60MV/m

Influence of Solenoid Position

$\varepsilon^*_{0,n}$ [π mm mrad] plot shows emittance at working point** for different solenoid positions

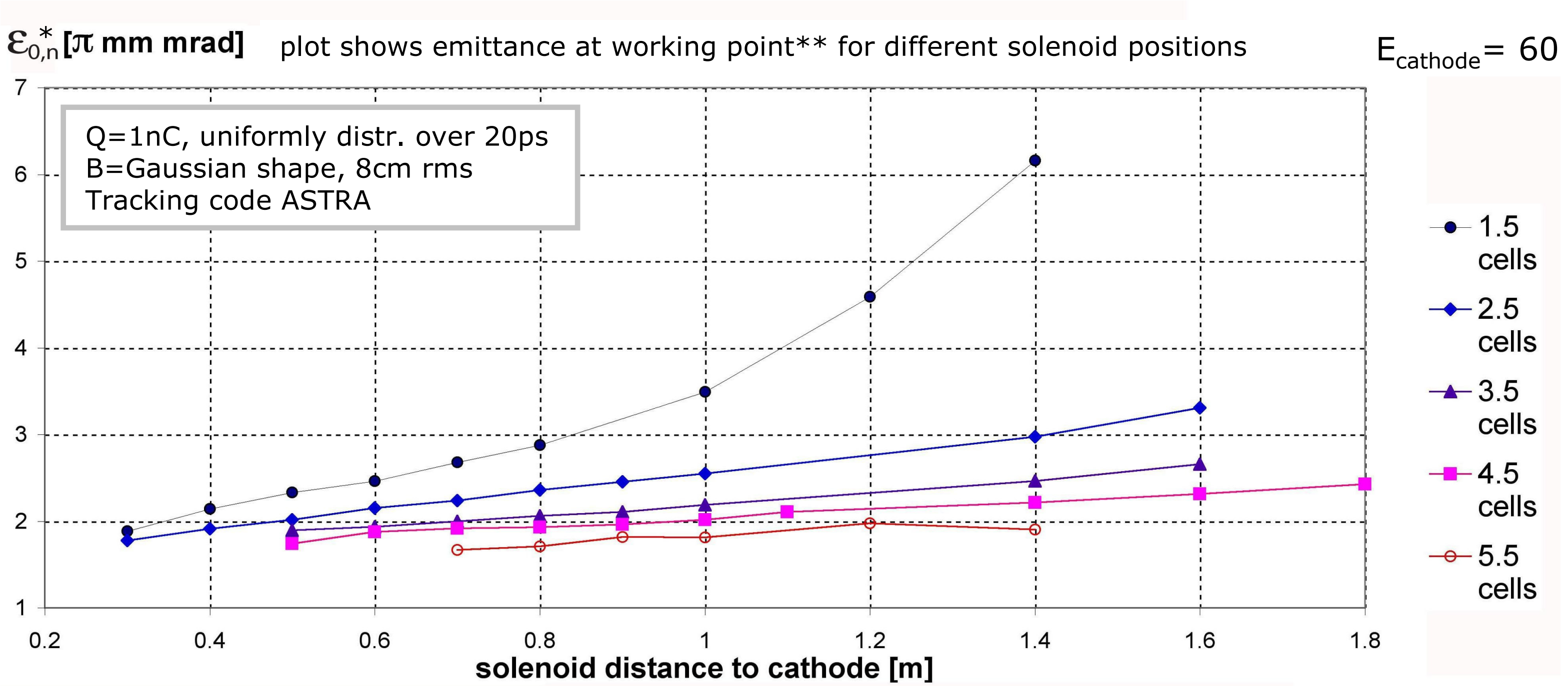
$E_{cathode}$ = 60MV/m



*projected emittance, not including thermal emittance

**defined as point where local maximum in emittance coincides with beam waist

Influence of Solenoid Position



*projected emittance, not including thermal emittance
**defined as point where local maximum in emittance coincides with beam waist

- Emittance decreases when moving solenoid closer to gun
- But: the shorter the distance, the more magnetic flux on cavity walls. B might be trapped when cooling down gun.

Derive sensible criteria for minimal distance of solenoid to gun.

SC material constraints

In order to work safely with SC components, we used following criteria:

- Unloaded quality factor of gun Q
- For operation at high fields, $Q=10^{10}$ mandatory
- Q given by

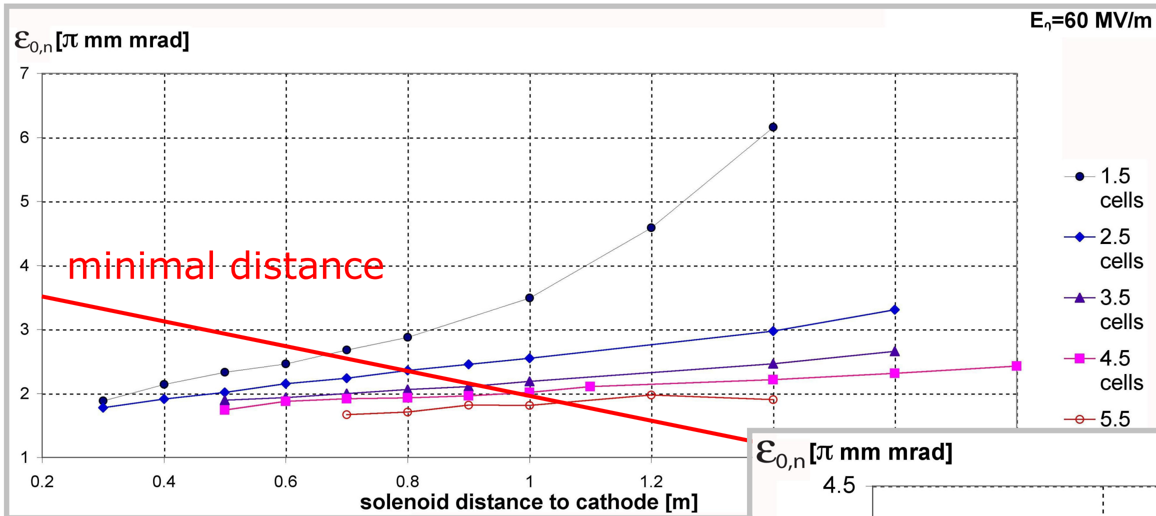
$$Q = \frac{G}{R_{total}} \text{ with } R_{total} = R_{BCS} + R_{res}$$

R_{BCS}: temperature dependant surface resistance
R_{res}: residual surface resistance dependant on B
G: geometry factor

} max. B on gun surface **3.5μT**

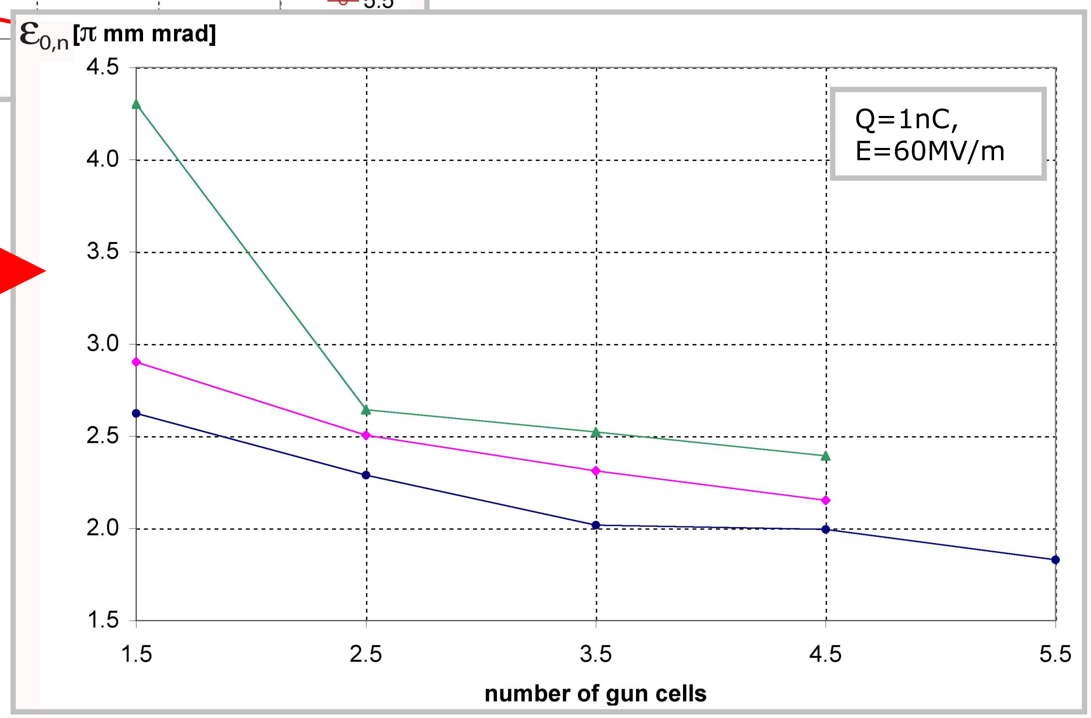
Assumptions for niobium: R_{BCS}=10nΩ@T=2K, G=220Ω, R_{res}=3.5nΩ/μT
Leads to maximal magnetic flux density on gun cavity walls

Results of Safe Solution



Plots depict working point emittances.

- Solenoid now moved as far away as to fulfill 3.5µT criterium
- This leads to rather large emittances
- Higher gun cell numbers yield lower emittances at working point



Conclusion

- Solenoid distance to gun is of ciritical importance.
- Superheating field not a problem but trapping of flux lines. In theory, this restricts operation of solenoid close to gun.

Point of discussion: how serious do we have to take this requirement?

Note:

- We also tracked everything through booster.
- Used invariant envelope matching condition (local ε max. coinciding with beam waist determines start of booster, invariant envelope formula determines gradient)
- Should we stick to this criterion? ⟶ D. Lipka‘s studies