Electron Beam Dynamics Simulations for the Low Emittance Gun

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100 keV Test Stand

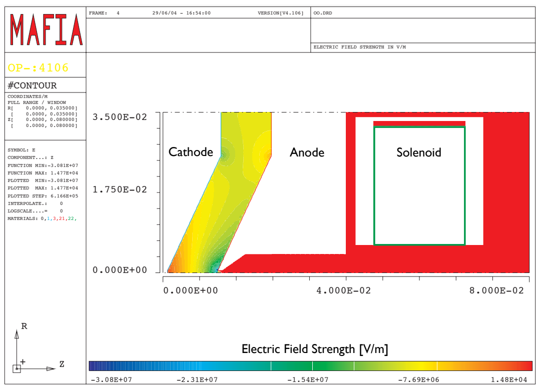
Input Parameters

- Cathode Potential: -100kV
- Active Emitter Radius: r_{act} = 100μm
- Pulse: Gaussian, cut-off at $\pm 3\sigma_t$, σ_t=20ps, Q≈-5·10^{-12}C (Î=100mA)
- Initial Energy: γ_0=1.0001, initial divergence is set to zero
- Iris: r_{iris}=500μm
- Tracked Macro-Particles: N=20000
- Tracked Path: 1mm < z < 342 mm (from cathode surface to end of drift)
- Solenoid: 7A/mm² capabale of delivering B_z=200mT on axis

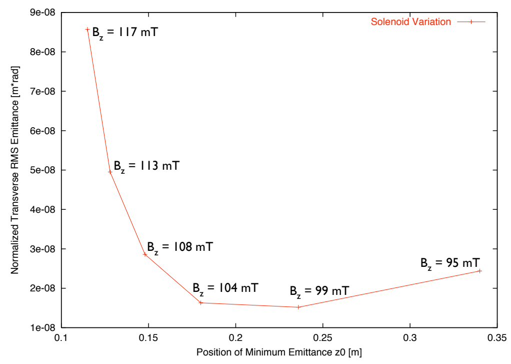
—> Peak electric field strength below 19MV/m

—> Norm. transv. emittance at gun exit < 2·10^{-8} m·rad

Test Stand Gun Design



Simulated Emittance (MAFIA)



Projected Emittance vs. Slice Emittance

Projected Emittance
(property of one entire bunch)

$$\varepsilon = \sqrt{\langle r^2\rangle\langle p_r{}^2\rangle - \langle r p_r\rangle^2} \simeq \gamma\beta\sqrt{\langle r^2\rangle\langle r'^2\rangle - \langle r r'\rangle^2}$$

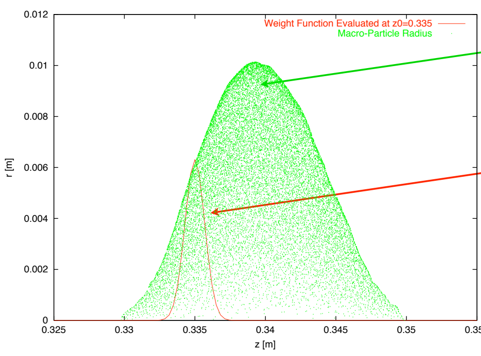
Slice Emittance
(depends on the location t_0 of the slice within the bunch and the width σ_t of the slice)

$$\varepsilon_{t_0} = \gamma\beta\sqrt{\langle r_{t_0}^2\rangle\langle r'_{t_0}{}^2\rangle - \langle r_{t_0} r'_{t_0}\rangle^2}$$

$$\langle r_{t_0}^2\rangle = \frac{1}{W_0}\sum_{i=1}^{N} r_i{}^2\cdot w_{i,0}$$

$$w_{i,0} = e^{-\frac{(t_i-t_0)^2}{2\sigma^2}} = e^{-\frac{(z_i-z_0)^2}{2\beta^2c^2\sigma^2}} \qquad W_0 = \sum_{i=1}^{N} w_{i,0}$$

Sampling the Bunch

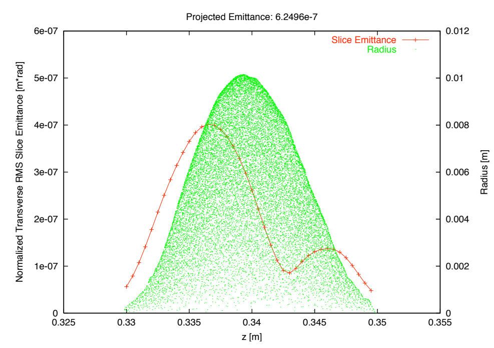


$$\langle r_{t_0}^2\rangle = \frac{1}{W_0}\sum_{i=1}^{N} r_i{}^2\cdot w_{i,0}$$

$$w_{i,0} = e^{-\frac{(t_i-t_0)^2}{2\sigma^2}} = e^{-\frac{(z_i-z_0)^2}{2\beta^2c^2\sigma^2}}$$

$$W_0 = \sum_{i=1}^{N} w_{i,0}$$

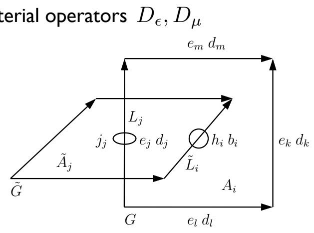
Slice Emittance Calculation



Simulations with Capone

Dynamic Field Solver

- Finite Integration Technique (FIT)
- Discretization of volume on two rectilinear grids: $G, \tilde{G}$
- Cells with volumes $V_i, \tilde{V}_i$, cell faces $A_i, \tilde{A}_i$, and grid lines $L_i, \tilde{L}_i$
- Store integrated field components $e_j = \int_{L_j} \vec{E}\cdot d\vec{s}$
- Discrete curl operators $C, \tilde{C}$ and divergence operators $S, \tilde{S}$
- Discrete material operators D_ϵ, D_μ



Discrete Maxwell's Equations

$$C\ e = -\frac{\partial b}{\partial t}$$

$$\tilde{C}\ h = \frac{\partial d}{\partial t} + j$$

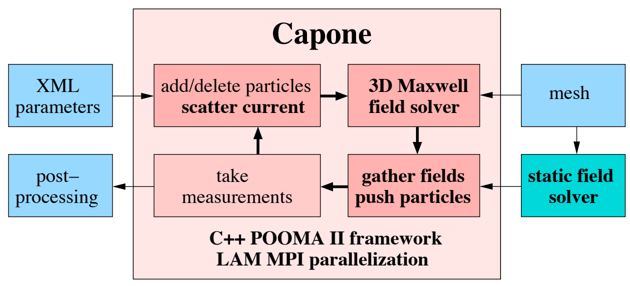
$$\tilde{S}\ d = q$$

$$S\ b = 0$$

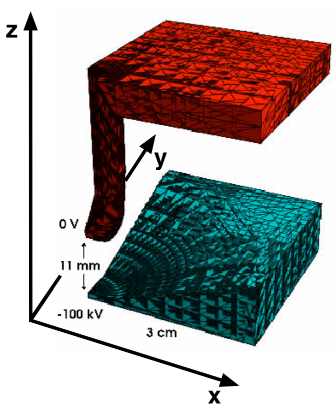
$$d = D_\epsilon e$$

$$b = D_\mu h$$

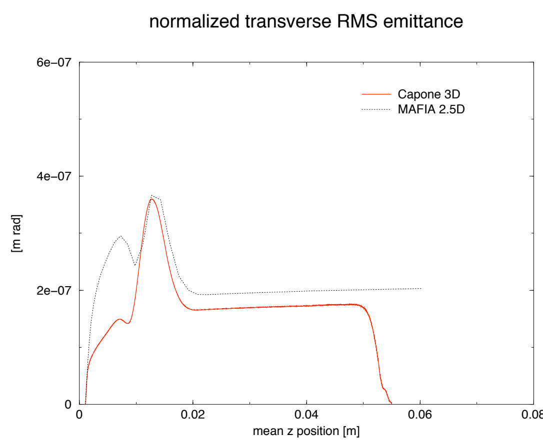
Program Structure



Simulated Gun Geometry



Comparison: Capone vs. MAFIA



Slice Emittance Calculations