# Optimization and Beam Dynamics in an SRF Gun


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INFN, UCLA, DESY


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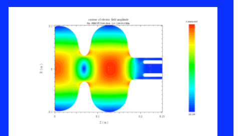
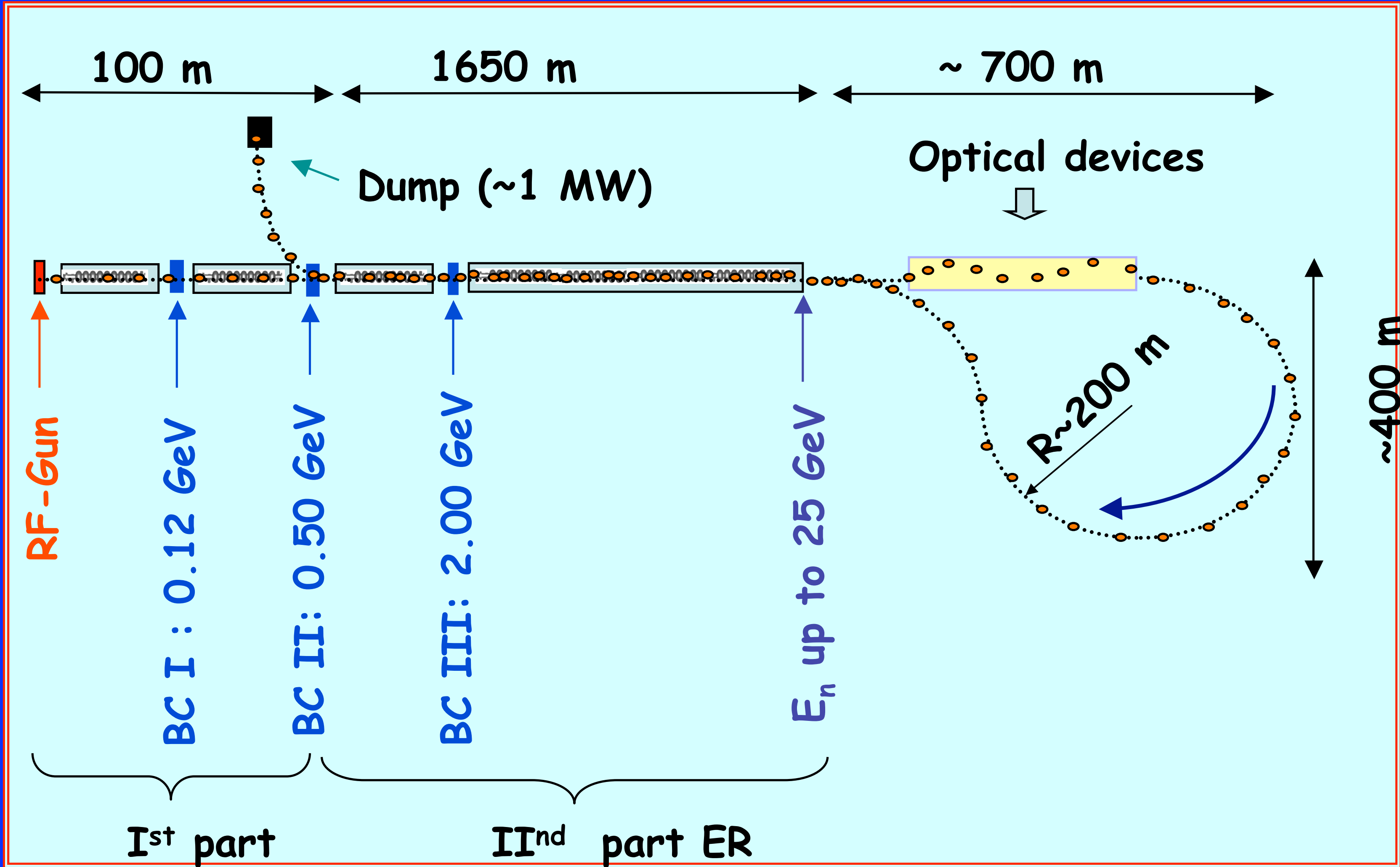


# Continuous wave energy recovery operation of an XFEL

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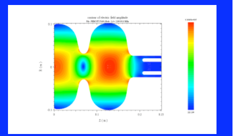
1 nC 1 MHz 1 mA

# Main Questions/Concerns

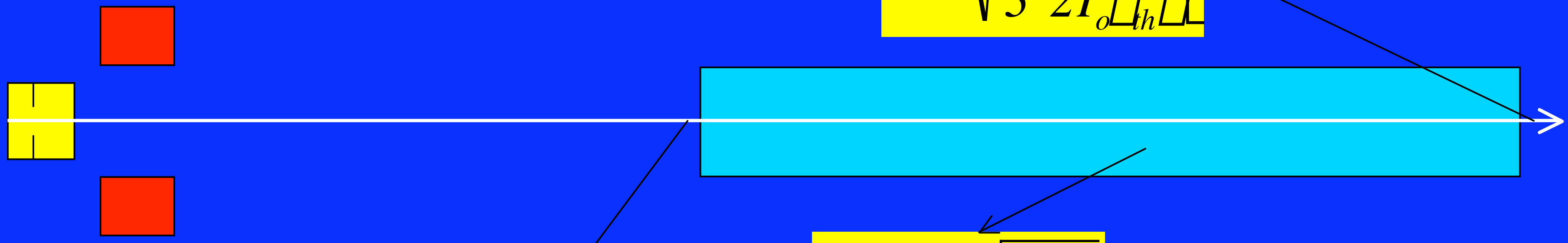
- Emittance Compensation ?
- Q degradation due to Magnetic Field ?
- High Peak Field on Cathode ?
- Cathode Materials and QE ?
- Laser System ?





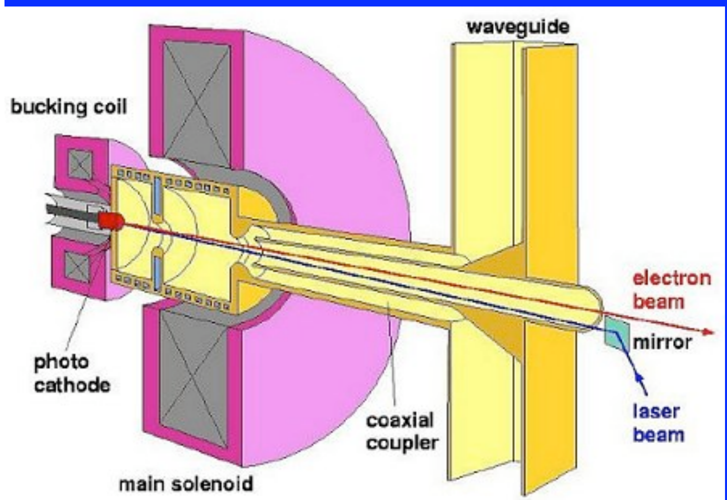
# Emittance Compensation: Controlled Damping of Plasma Oscillation (LS-JBR)

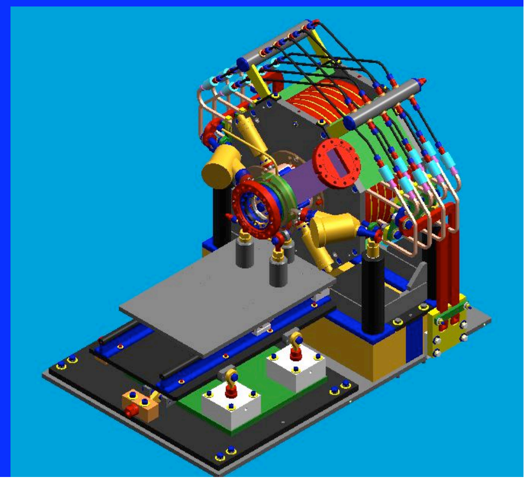
$$\square = \sqrt{\frac{8}{3}}\,\frac{\hat{I}}{2I_o\square_{th}\square\square}$$

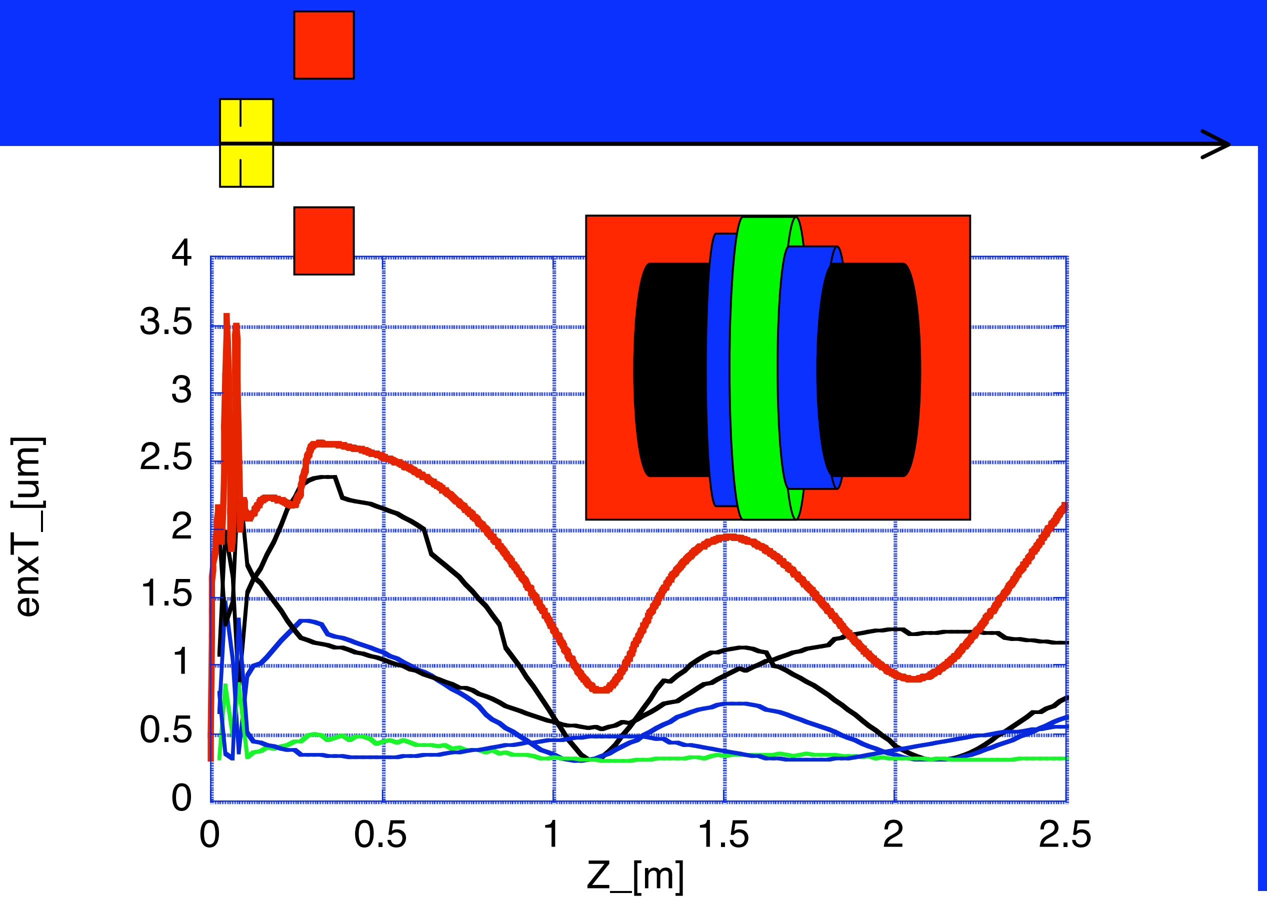


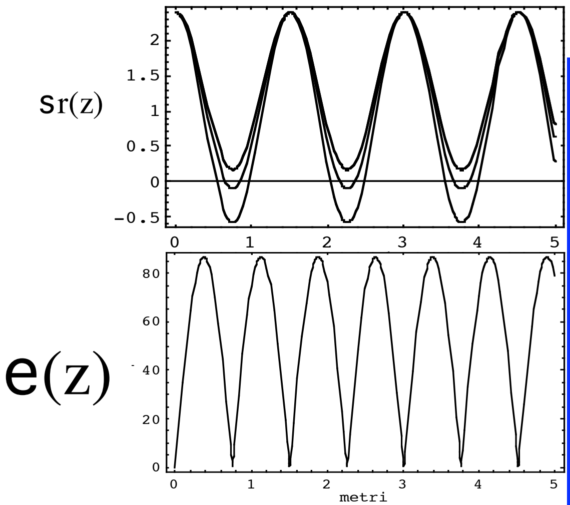
$$\square' = 0$$

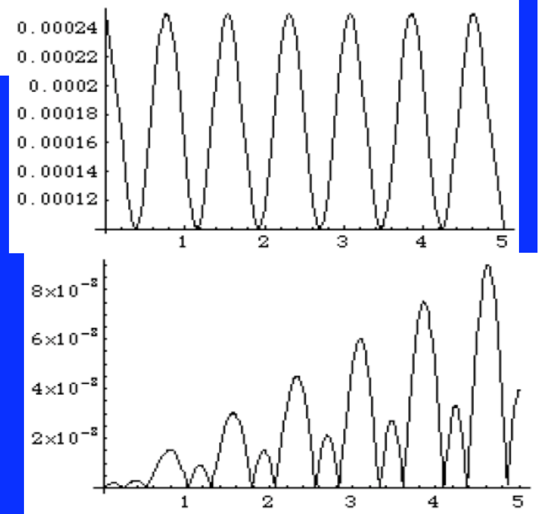
$$\square\square = \frac{2}{\square_w}\sqrt{\frac{\hat{\square}}{3I_0\square}}$$



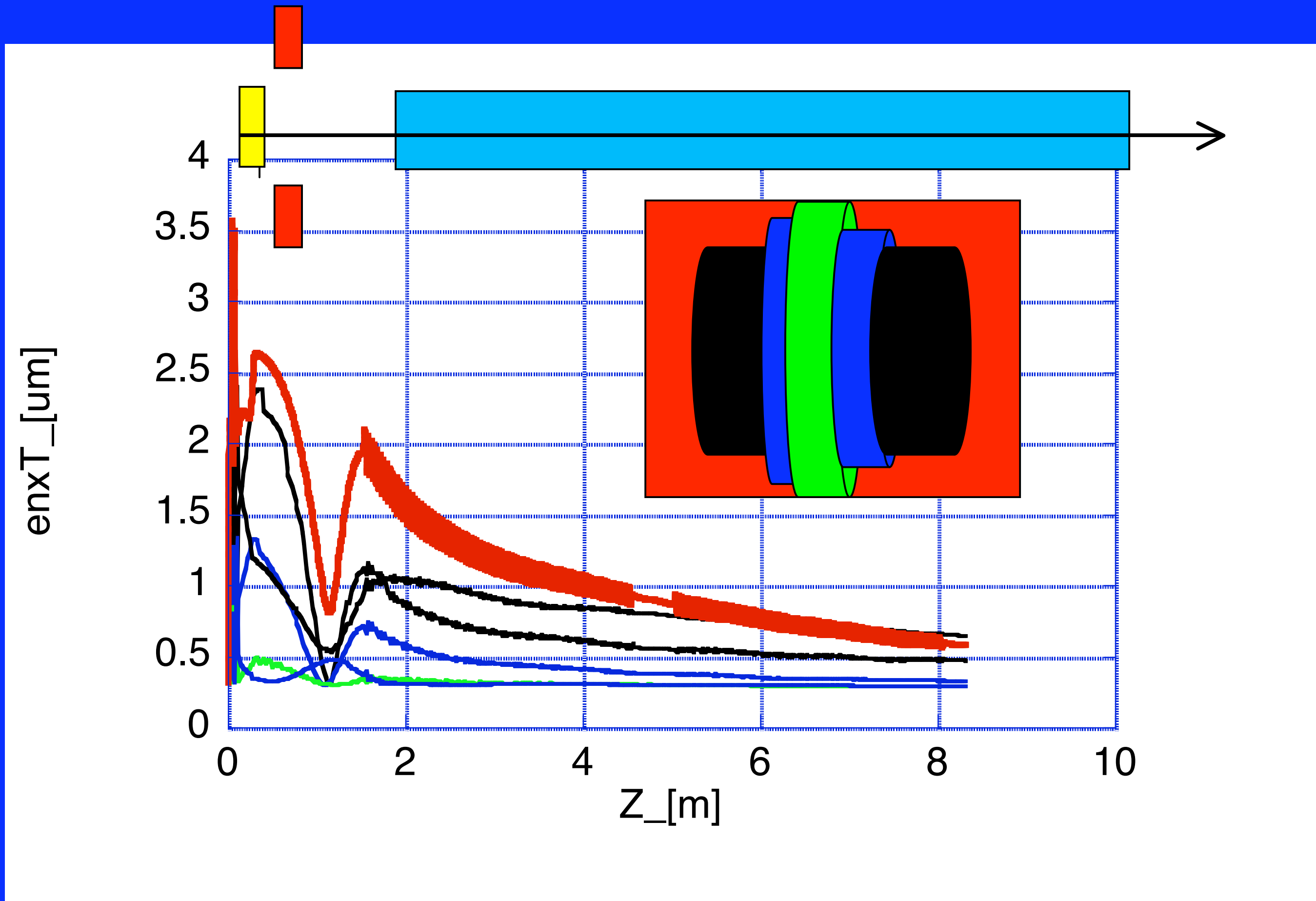




enxT_[um]
Z_[m]
0
0.5
1
1.5
2
2.5
3
3.5
4


sr(z)
e(z)
metri


0.00024
0.00022
0.0002
0.00018
0.00016
0.00014
0.00012

# Linac Working Point




The emittance compensation occuring in the booster when the invariant envelope matching conditions are satisfied is actually limited by the head and tail slice behavior

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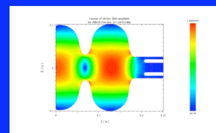

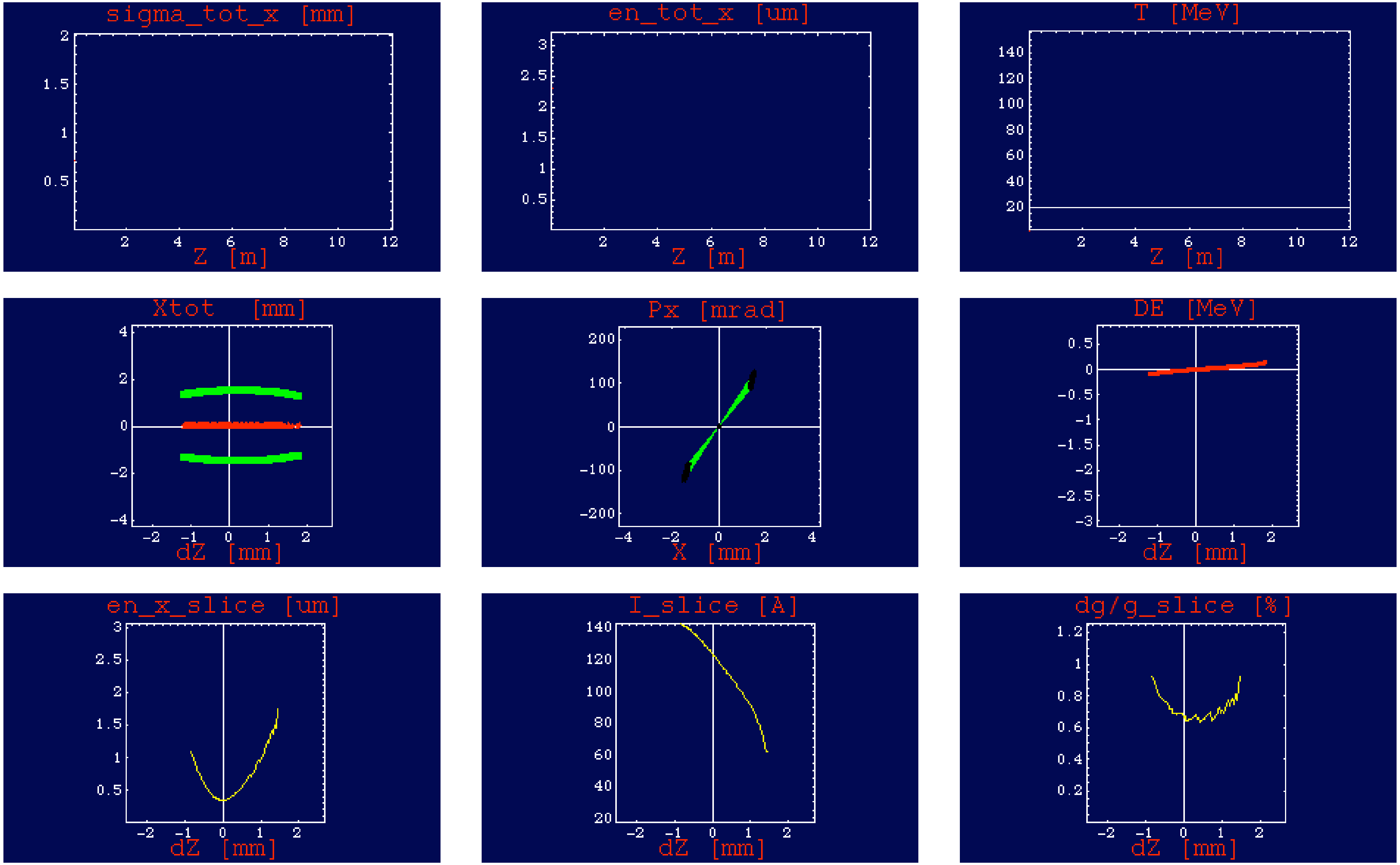


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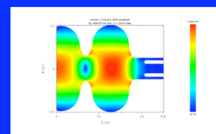
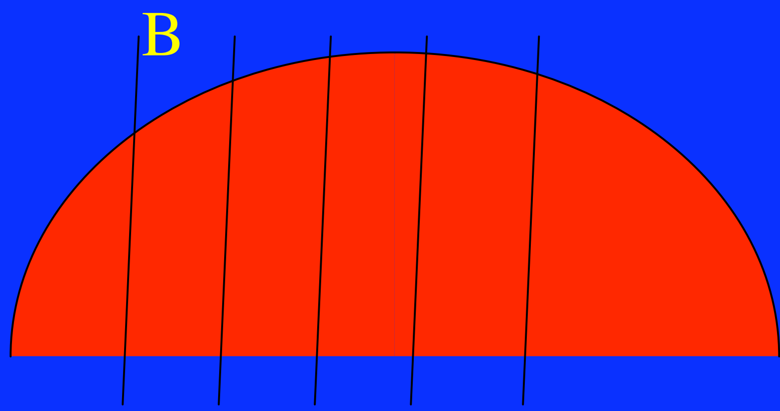
# Homdyn movie



*Superheating field.* Superconductivity breaks down when the rf magnetic field exceeds the critical field of the superconductor. In the high frequency case the so-called superheating field is relevant which, for niobium, is about 20% higher than the thermodynamical critical field of 200 mT [12,13].

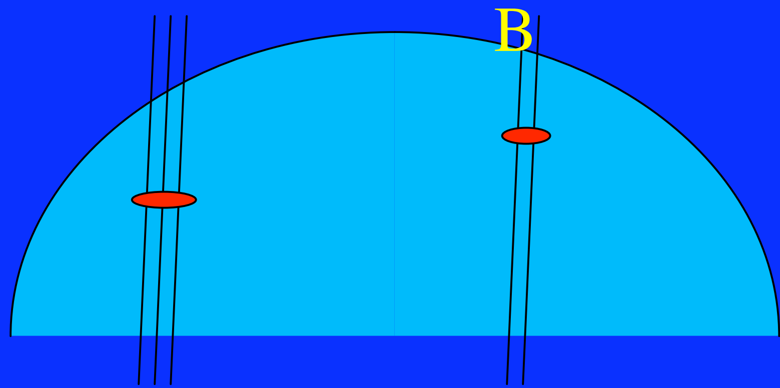



**Before Cool-Down**

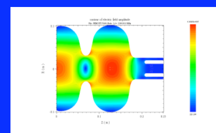
*Trapped magnetic flux.* Niobium is, in principle, a soft type II superconductor without flux pinning. In practice, however, weak magnetic dc fields are not expelled upon cooldown but remain trapped in the niobium. Each flux line contains a normal-conducting core whose area is roughly $\pi \xi_0^2$. The coherence length $\xi_0$ amounts to 40 nm in Nb. Trapped magnetic dc flux therefore results in a surface resistance [6]

$$R_{\mathrm{mag}} = (B_{\mathrm{ext}}/2B_{c2})R_n\,, \qquad (2.4)$$

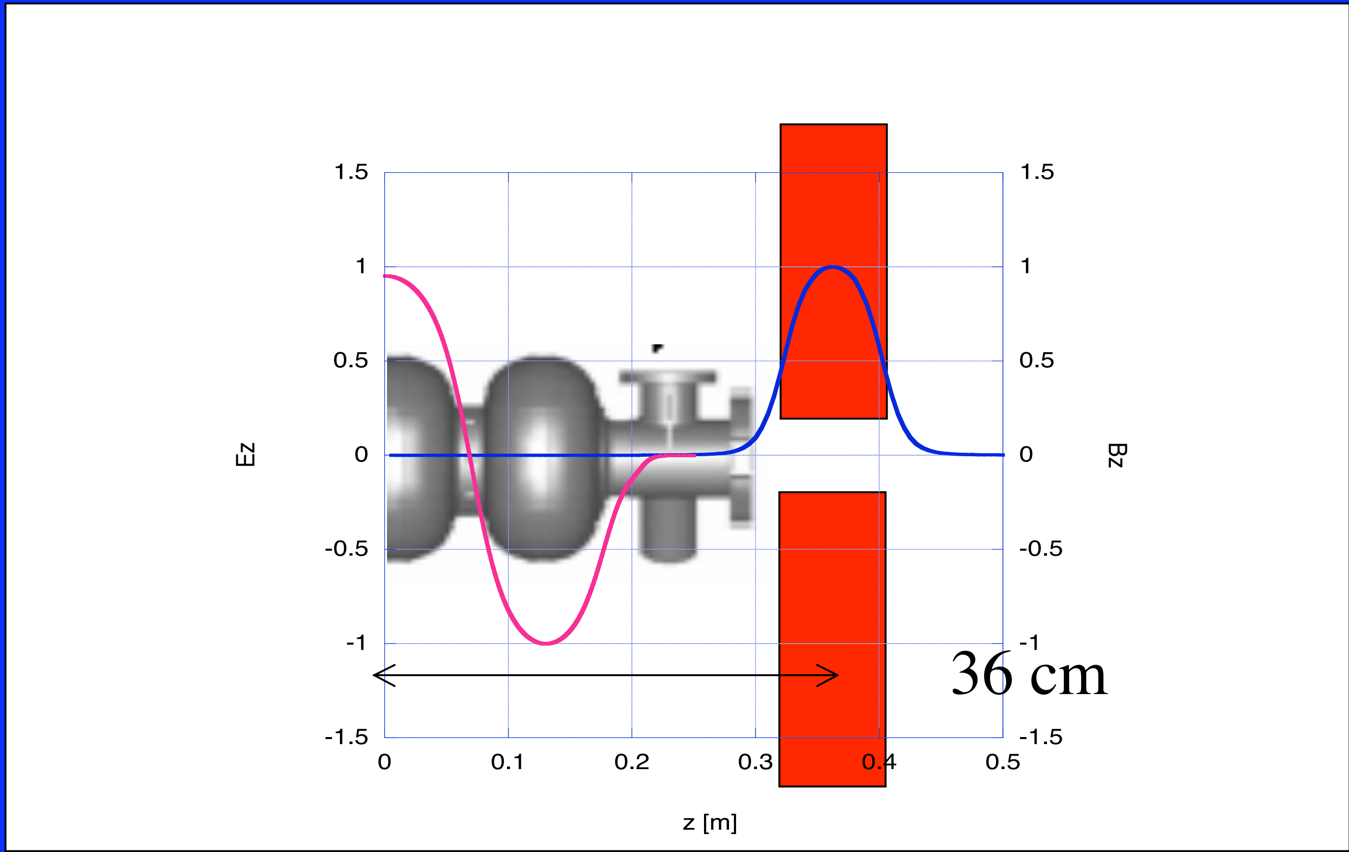
where $B_{\mathrm{ext}}$ is the externally applied field, $B_{c2}$ is the upper critical field, and $R_n$ is the surface resistance in the normal state.[3] At 1.3 GHz the surface resistance caused by trapped flux amounts to 3.5 $\mathrm{n}\Omega/\mu\mathrm{T}$ for niobium. Cavities which are not shielded from the Earth's magnetic field are therefore limited to $Q_0$ values below $10^9$.




**After Cool-Down**



# Splitting Acceleration and Focusing




- The Solenoid can be placed downstream the cavity

- Switching on the solenoid when the cavity is cold prevent any trapped magnetic field

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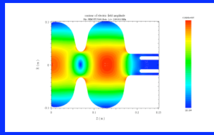
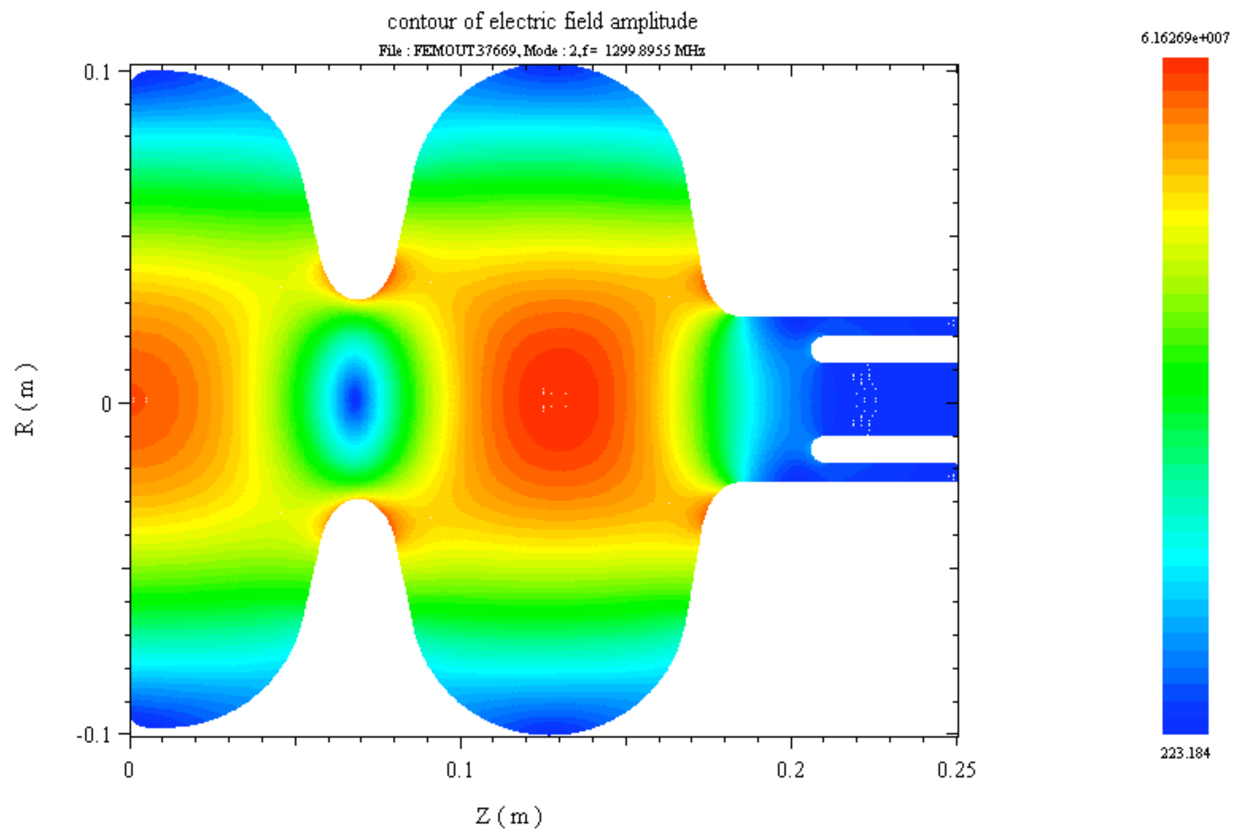


# L-band SC gun design with coaxial coupler




$$E_r \approx -\frac{r}{2}\frac{\partial}{\partial z}E_z(z,0) + \frac{r^3}{16}\frac{\partial^3}{\partial z^3}E_z(z,0) + \ldots\ldots$$

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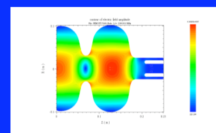
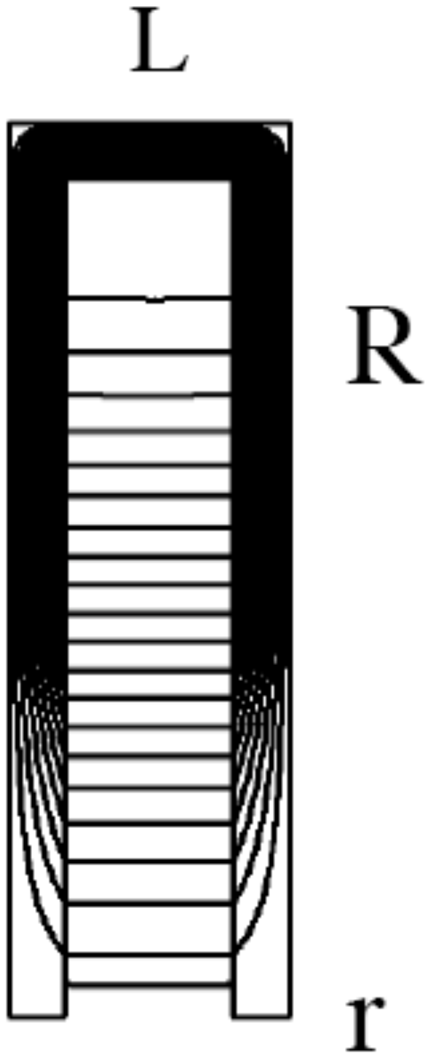


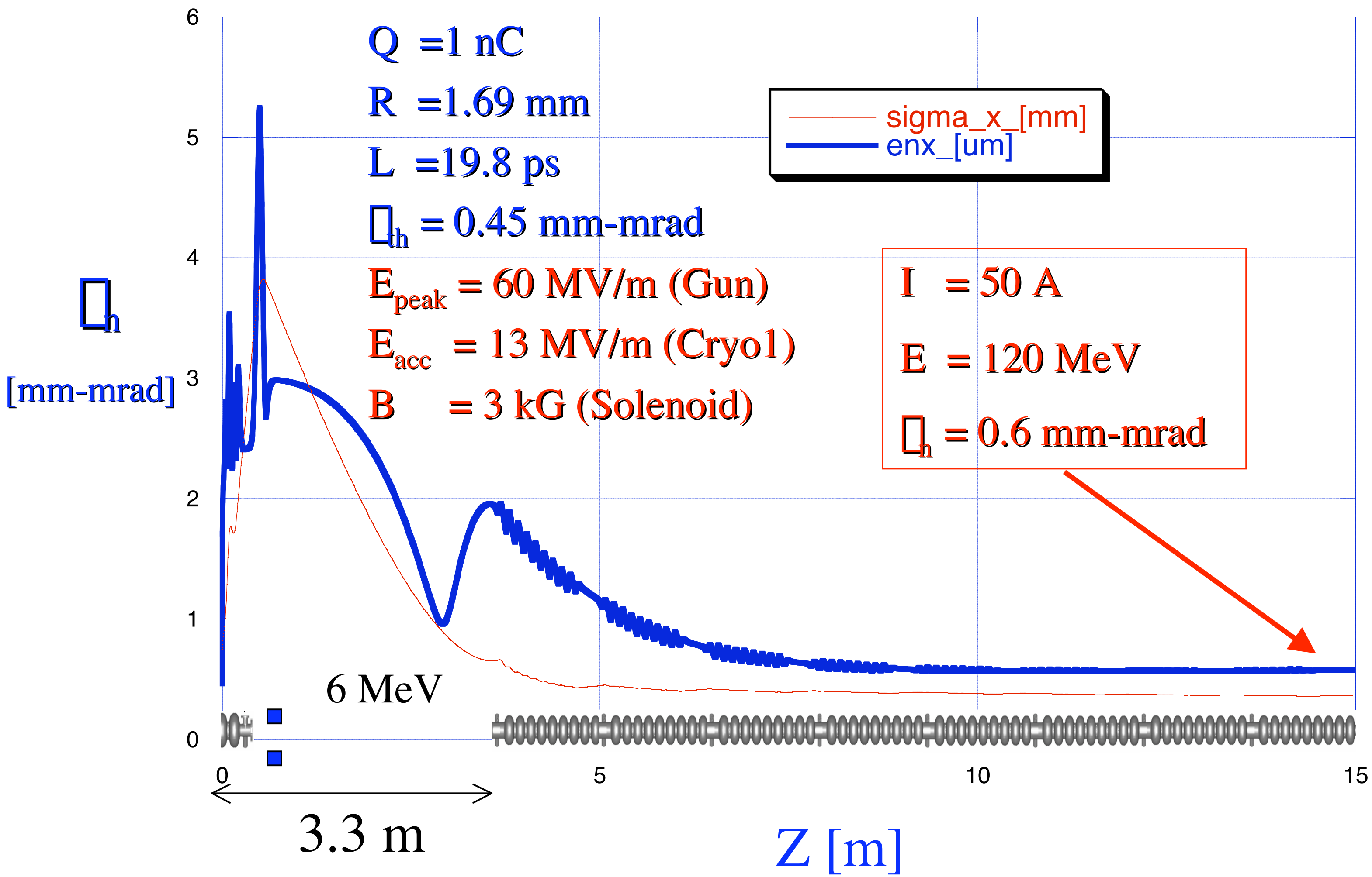
R = 40 cm

r = 2.6 cm

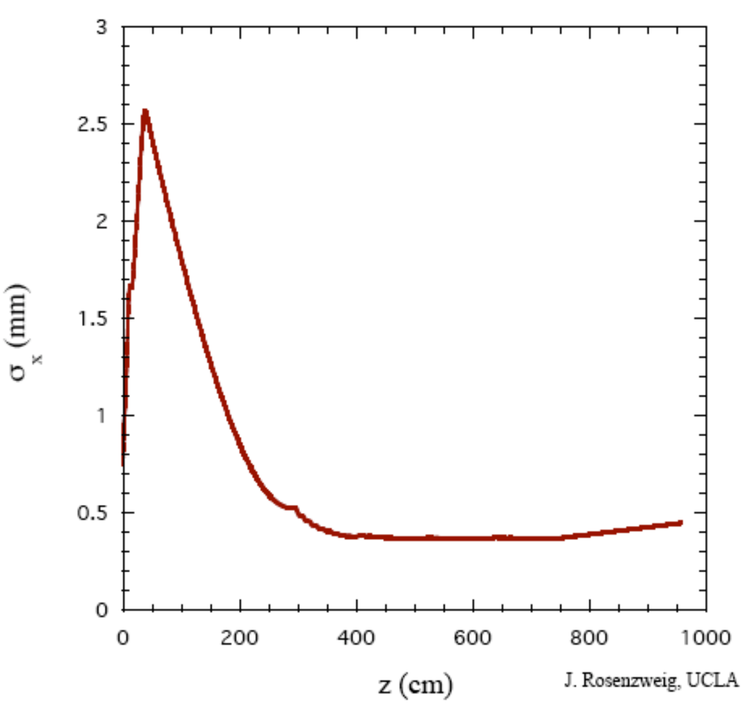
L = 10 cm

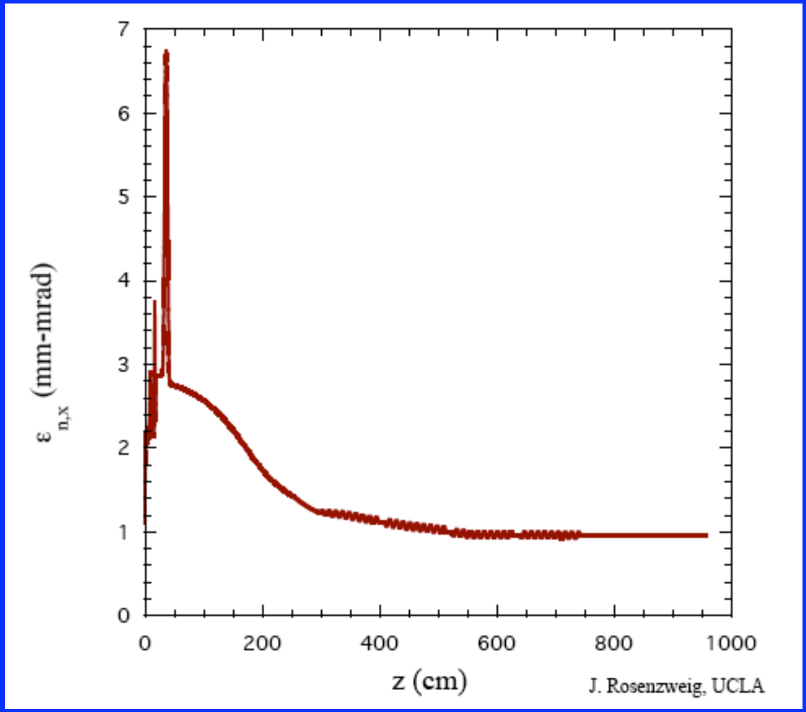


# HOMDYN Simulation



# PARMELA simulations

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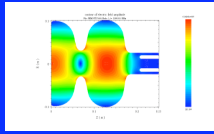
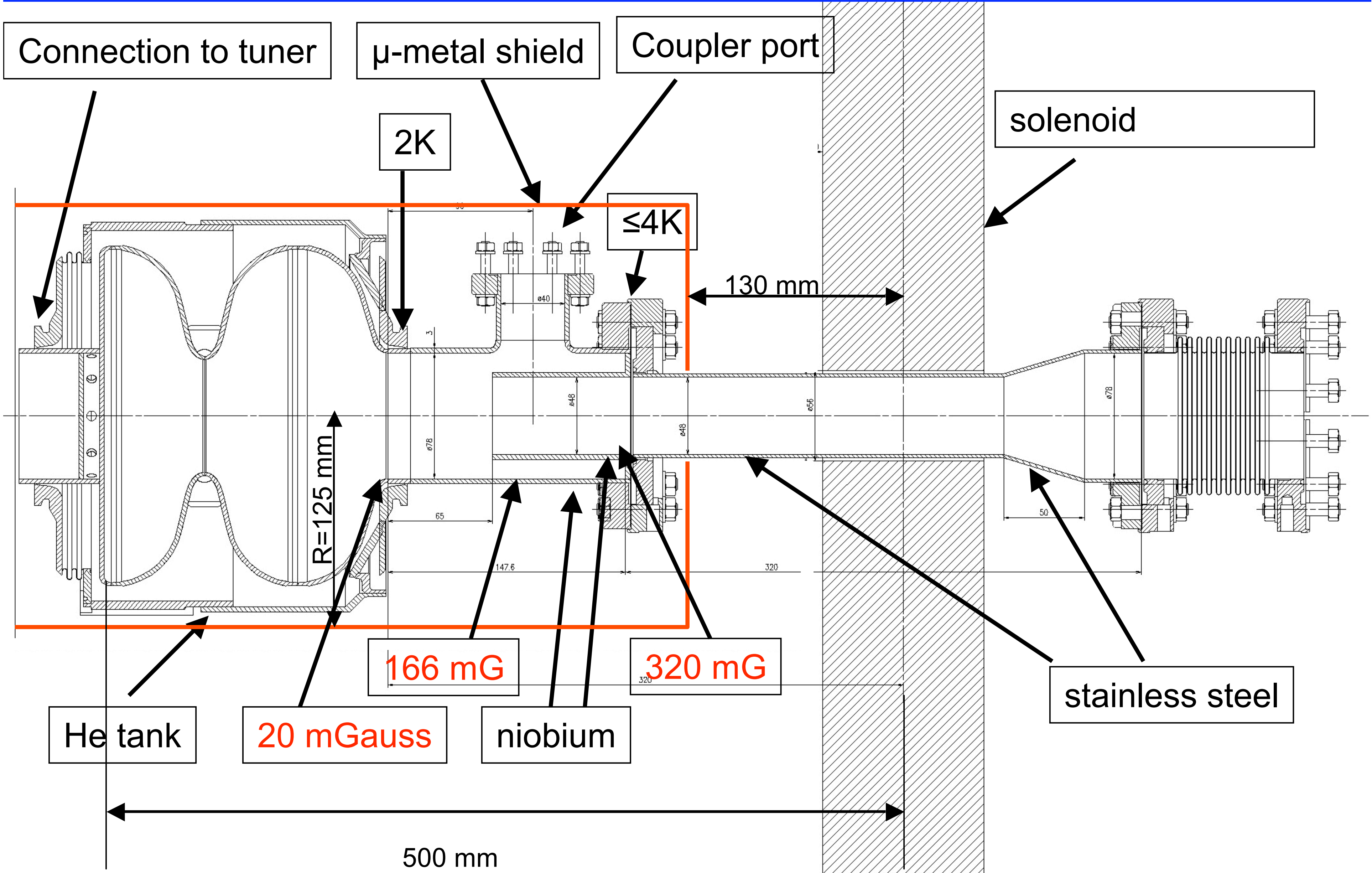
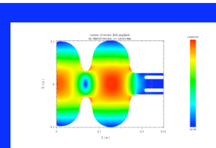



Connection to tuner
μ-metal shield
Coupler port
solenoid
2K
≤4K
130 mm
R=125 mm
166 mG
320 mG
He tank
20 mGauss
niobium
stainless steel
500 mm



# DEVELOPMENT OF ELECTROPOLSHING TECHNOLOGY FOR SUPERCONDUCTING CAVITIES

K.Saito[#], KEK, 1-1 Oho, Tsukuba-shi, Ibaraki-ken, Japan

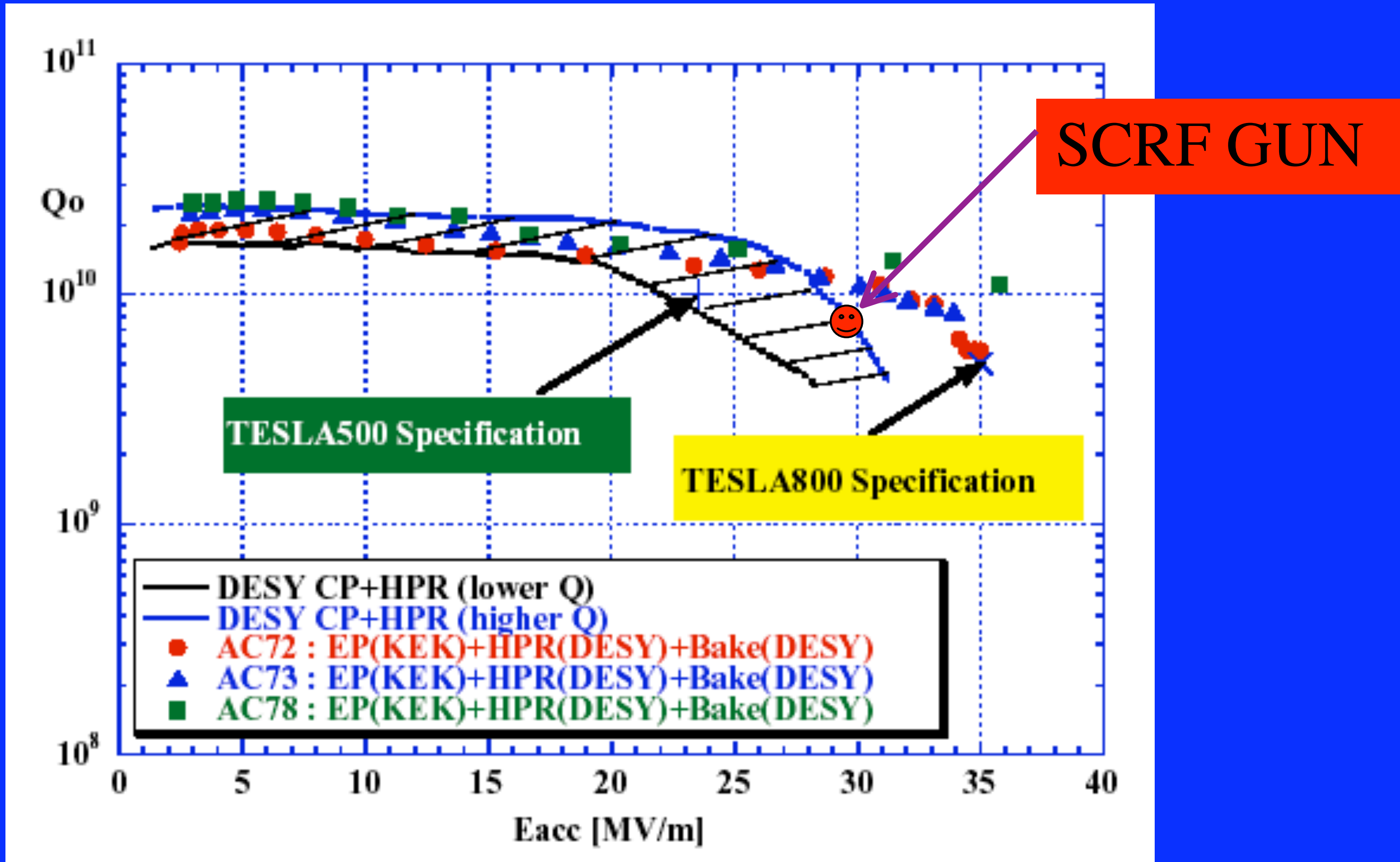



Figure 8: Results of electropolished TTF cavities.

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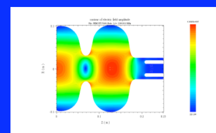
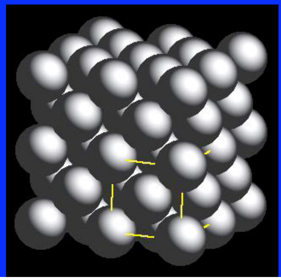


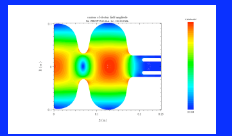
# Very preliminary results measured @ BNL

| Quantum Efficiency of Pb | |
|---|---|
| 248 nm | $1 \cdot 10^{-4}$ |
| 213 nm | $1.7 \cdot 10^{-3}$ |

$P_{uv} = f * (Q/ \square)*(h\square)$ = 3 W (3$\square$J)

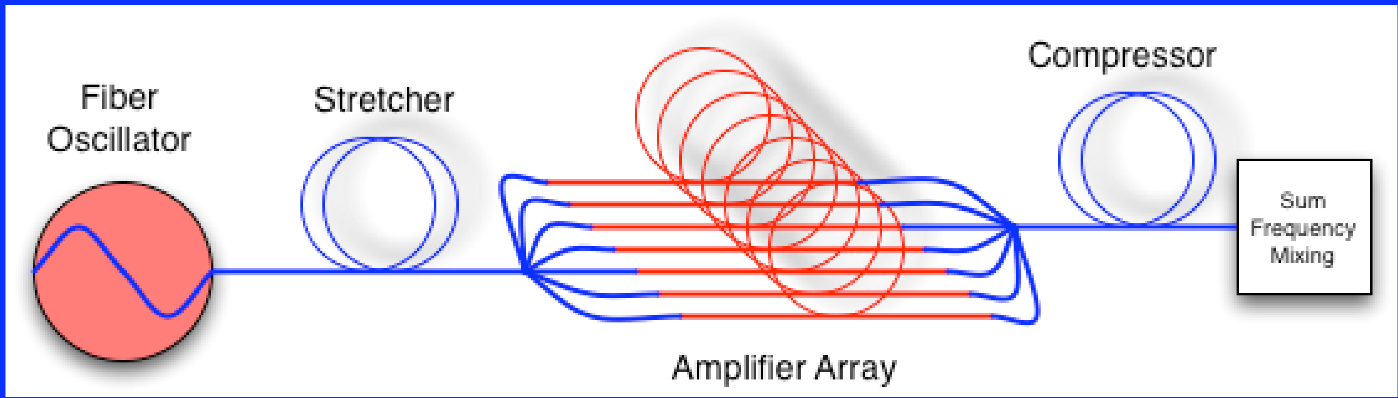
3 W laser @ 213 nm (V harmonic of 1064 nm laser) can generate 1nC @ 1MHz nominal beam



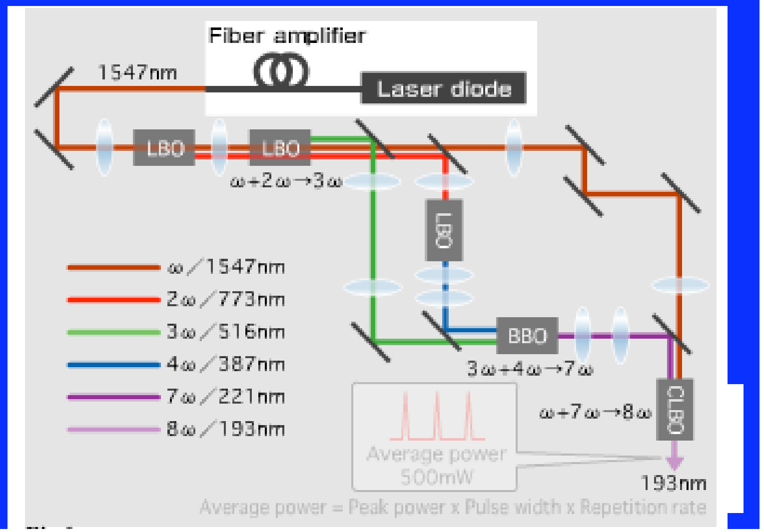


# Conceptual All Fiber System

Lots of development in Erbium and Ytterbium doped fiber systems
Commercially available 20W, 2MHz systems
Progress should be very rapid over next 1-2 years




Example: for UV lithography
x7 and x8 of 1.5 $\mu$m
Picture stolen from Nikon

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# CONCLUSIONS

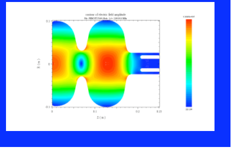
• Emittance compensation by external solenoid is possible

• 60 MV/m peak field in SC cavity have been already demonstrated

• Work in progress @ BNL to demonstrate

Pb QE ~$10^{-3}$ @ 200 nm

• Laser System: progress should be very rapid over next 1-2 years



The following workshop was approved by ICFA at its meeting Feb 10-11, 2005 in Vancouver:

# Physics and Applications of High Brightness Electron Beams

## Erice, Sicily, Italy, October 9-14, 2005

Organizers: L. Palumbo (Univ. Roma), J. Rosenzweig (UCLA), L. Serafini (INFN-Milano).