

Design of the RF photo-injector CTF3

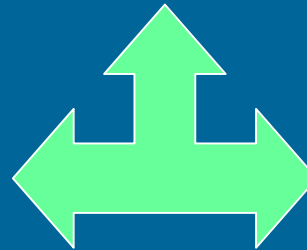
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-RF design 2D&3D
-Beam dynamics
-Magnetism

Technical drawings

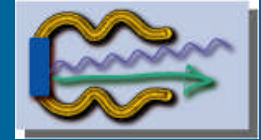


Vacuum



Test the calculations with a prototype

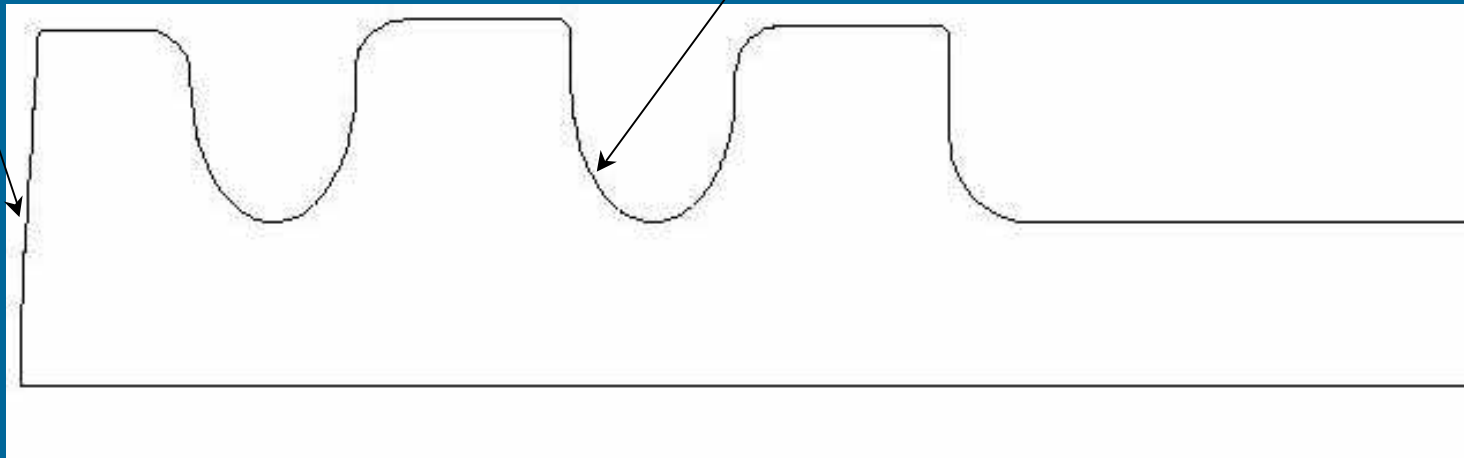
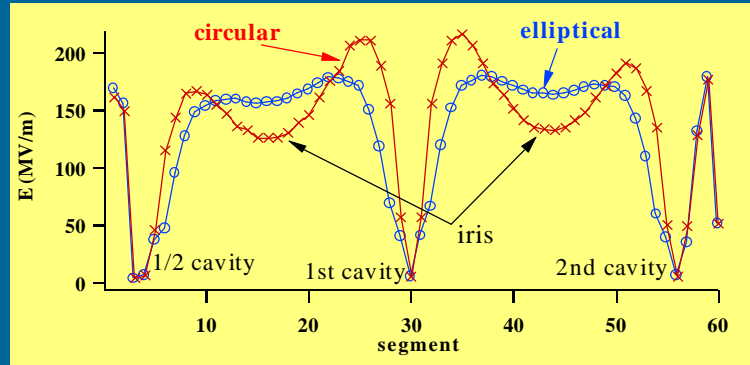
2D RF design: Poisson



PHIN

Angle of the wall

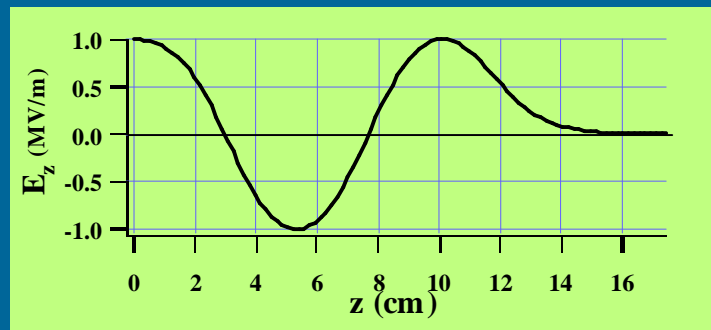
 ϵ for $I = 5$ A



$F_r = 3.003$ GHz

 $R_s = 6$ M Ω

 $Q = 14530$



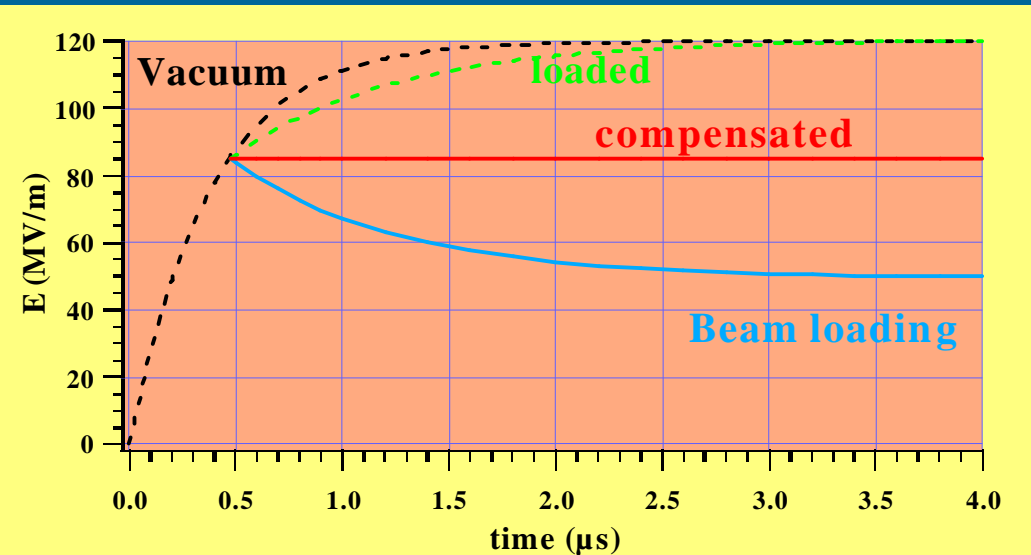
$$V_{\text{ind}}(t) = V_{\text{sat}} \left(1 - \exp\left(-\frac{t}{\tau}\right)\right)$$

$$V_{\text{sat}} = \frac{R_s T^2 I_{\text{harm}}}{(1 + \beta)}$$

$$\tau = \frac{2Q_c}{\omega_r}$$

$$Q_c = \frac{Q_0}{1 + \beta_1 + \beta_2}$$

$$\beta = \frac{\beta_0}{1 + \beta_{\text{beam}}} \quad \text{with} \quad \beta = \frac{P_{\text{beam}}}{P_{\text{cav}}}$$



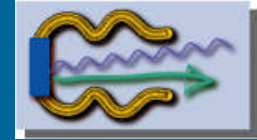
$$P_{\text{beam}} = 3.51 \text{ A} \times 5.5 \text{ MV} = 19.3 \text{ MW}$$

$$P_{\text{cav}} \approx 10 \text{ MW for } 120 \text{ MV/m}$$

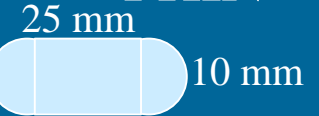
$$\beta = \frac{\beta_0}{1 + 1.9}$$

It requires a coupling = 2.9 for the gun to be matched in presence of beam

3D RF design: HFSS



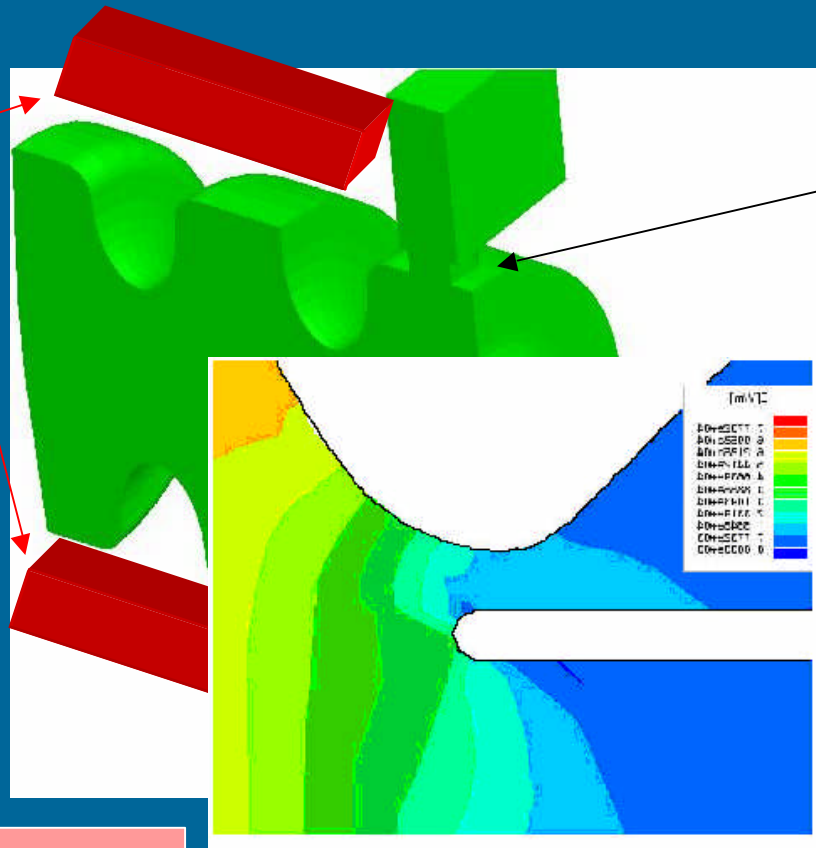
PHIN



Hole coupling:

- Over-coupled
- symmetric

Coils



Coaxial coupling

Strong coupling =>
Antenna goes deeply in the gun

High gradient with the iris
Breakdown hazards

3 conditions:

- F_r
- Coupling
- Field flatness



Dimensions
of the cells and the coupling hole

Field Symmetry
in the 3rd cell

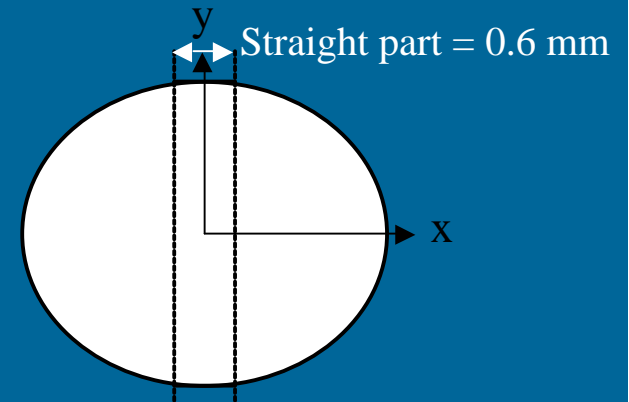
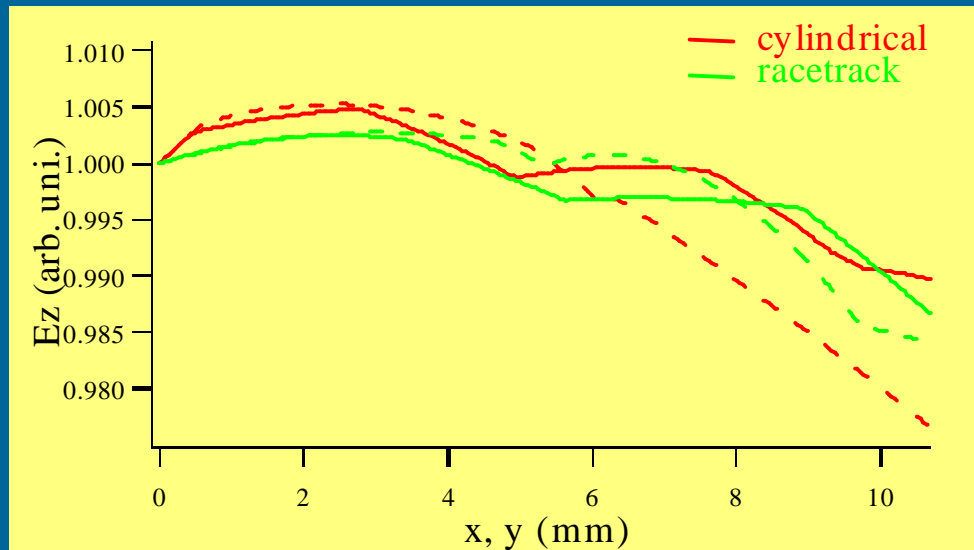
Asymmetry of transverse fields (couplers)



Blow-up of the emittance



Solution : racetrack shape of the cell instead of cylindrical
(J. Haimson)



$$\frac{\Delta E}{E} = 7 \cdot 10^{-4} \quad \text{Integral} = 5 \cdot 10^{-4}$$

$$\frac{\Delta E}{E} = 3.5 \cdot 10^{-5} \quad \text{Integral} = 10^{-4}$$

Dynamics of the electron beam



Electric field from 2D design



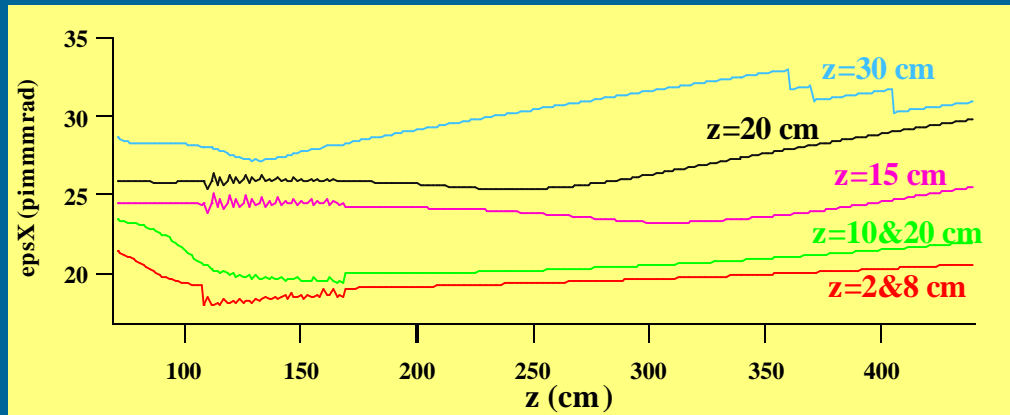
PARMELA



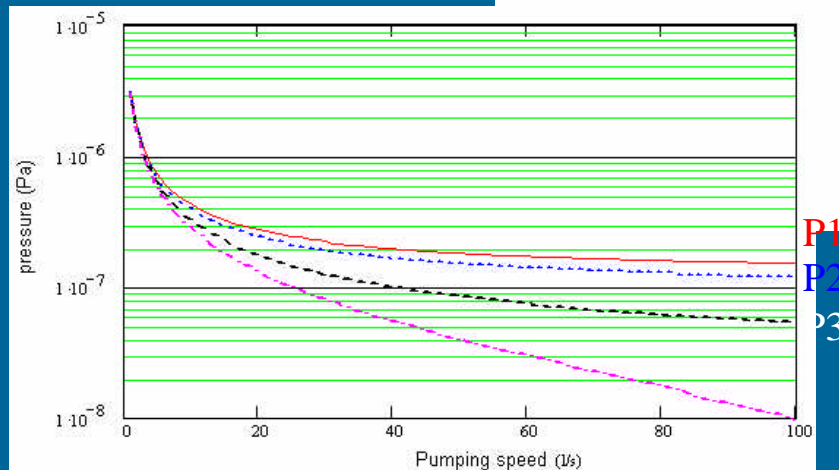
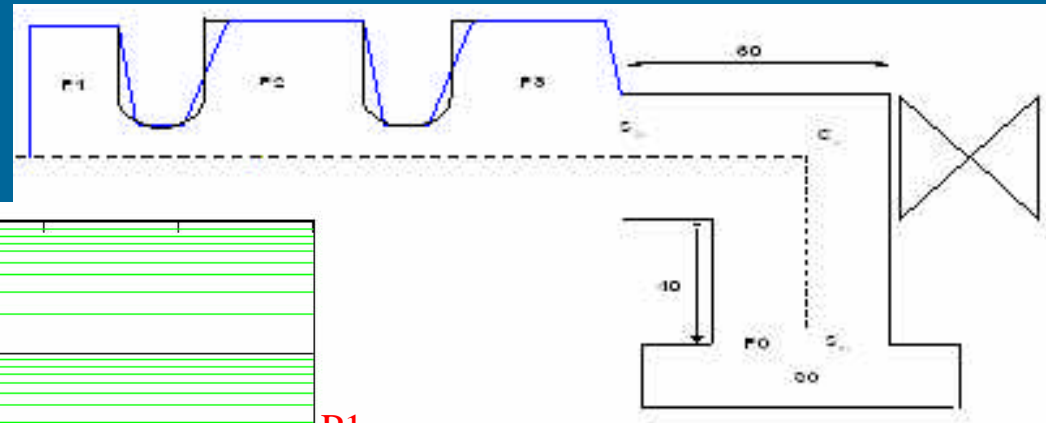
$I = 3.51 \text{ A}$

E (MeV)	5.45
ϵ_x (π mmrad)	19.6
σ_x (mm)	3.2
σ_z (mm)	1.07
σ_γ / γ (%)	0.36

Compensation of the space charge forces



Monte-Carlo based simulations of the residual pressure

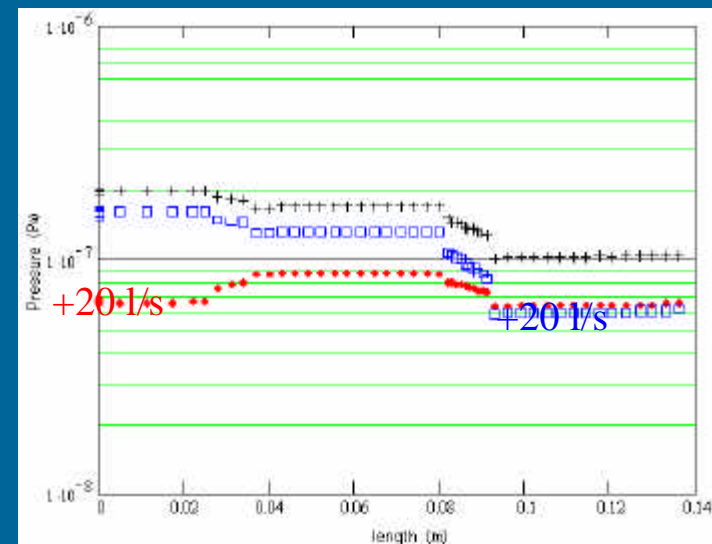


P1
P2
P3

- Useless above 40 l/s
- Weak help of a supplementary pumping



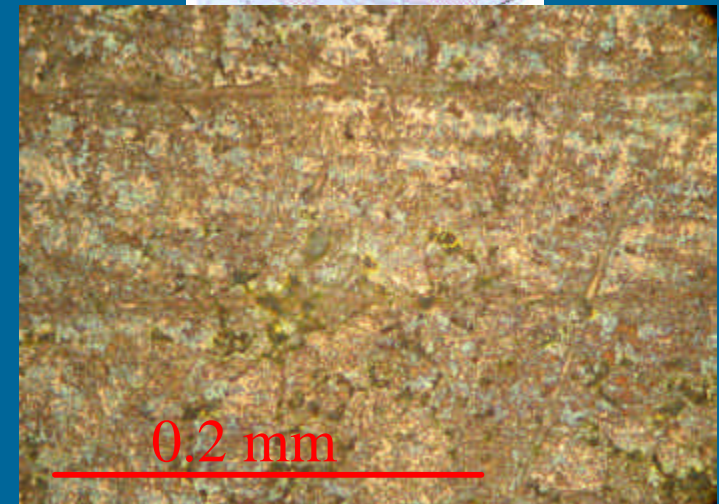
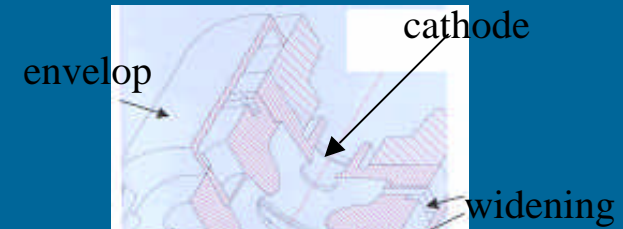
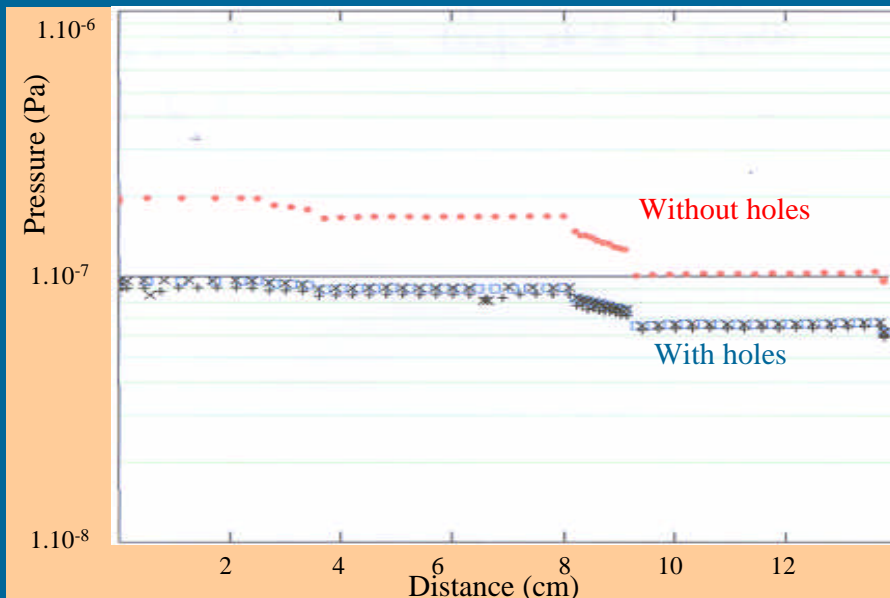
minimize the out-gassing rate
 High temperature bake



Supplementary pumping



42 holes drilled in the gun walls $\Phi = 4$ mm
Envelop around the gun coated with NEG

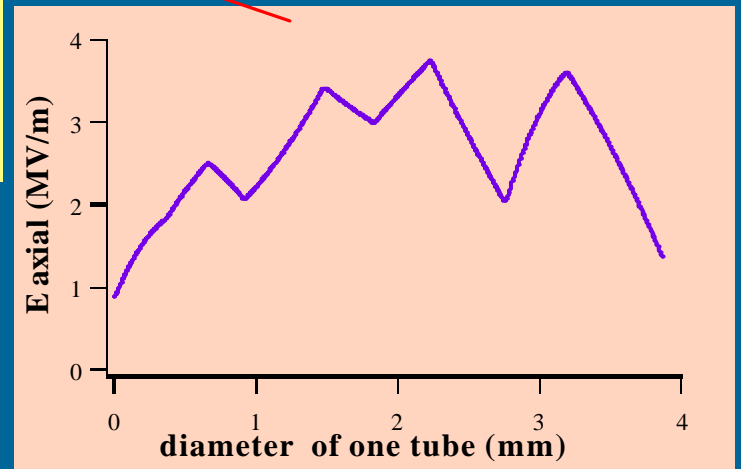
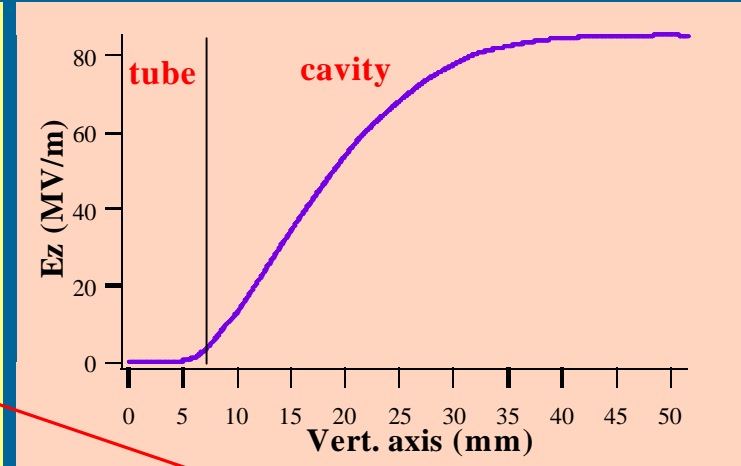
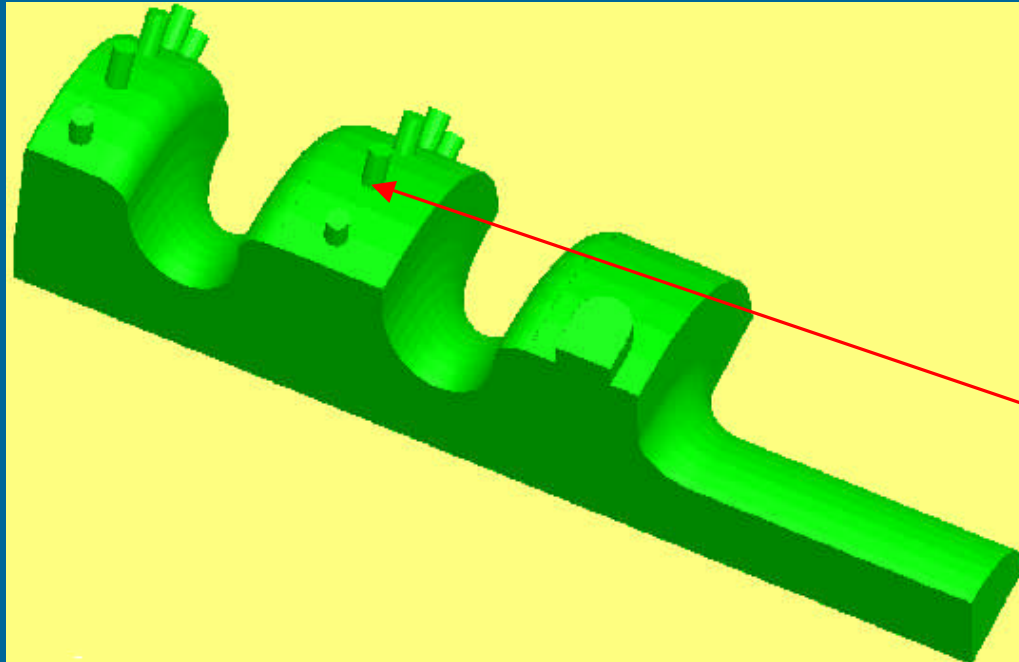


Only hope: reduce the out-gassing rate (10^{-3})
with a high t° bake-out

➡ Residual pressure $< 10^{-10}$ mbar

Copper in oven 3 days, $t^\circ = 550^\circ\text{C}$
Fast cooling with Ar jet 150°C
=> No grain

Impact of the holes on the RF design



Impact on Q and R_s negligible (-5%)

But presence of a 4 MV/m peak electric field at the entrance of the tubes => breakdown hazards?

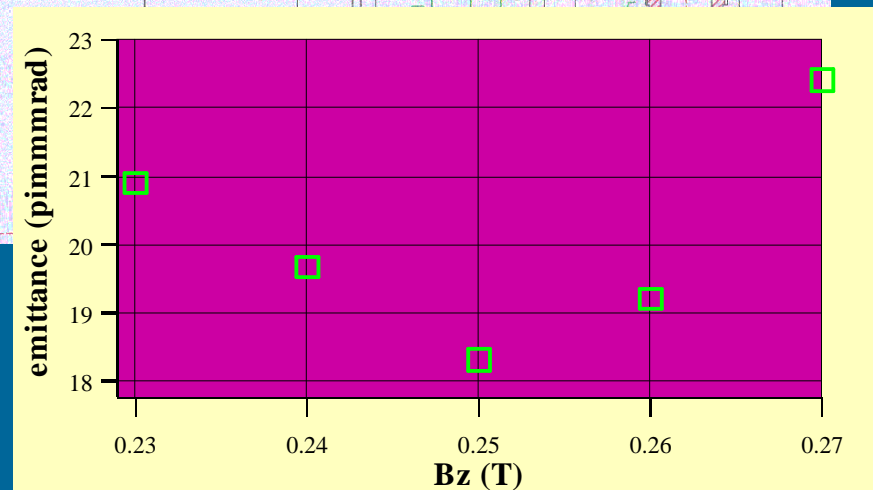
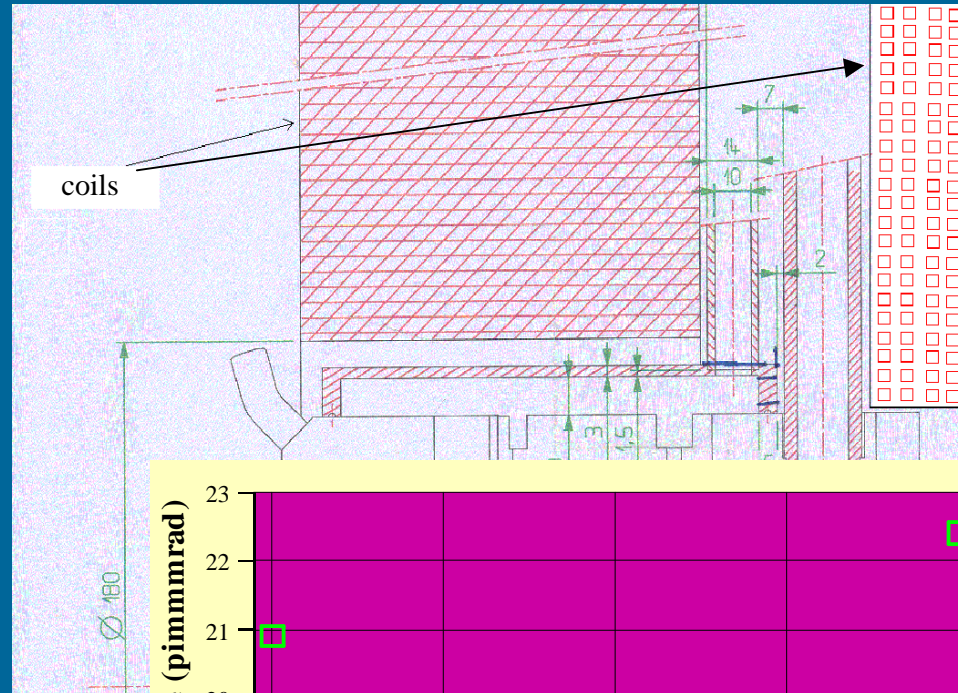
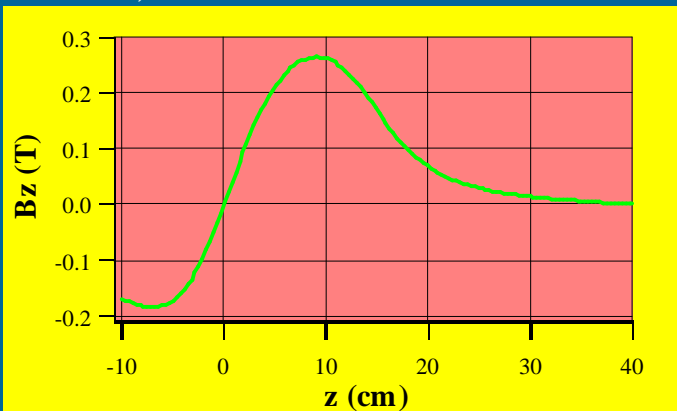
Impact of the holes on the magnetic coils



Aim: B_z max ≈ 0.27 T on the gun, 0 on the cathode
Difficulties: little available space, big inner diameter (180 mm)

Several magnetic arrangements studied with POISSON:

- 2 coils possible but too close to the current density limits
- => 3 coils with moderate currents
- 375 A, +170 A and + 250 A



Beam dynamics simulations done with the POISSON field:
 $\epsilon = 18.3 \pi$ mmmrad

1) RF gun

simulations completed, technical drawing for prototype ready, OFHC copper ordered
technical drawings of preparation chamber almost finished
(delays in the drawings due to improvements in RF design, vacuum and magnetism)

2) Laser

technical specifications document written, waiting for a decision from the administration

3) NEPAL test room

- RF source: new RF master oscillator with the synchronization with the laser almost finished
klystron available but waiting for a regional funding for the modulator
- renovation in progress
- radiation safety: 2 levels of security
 - to stay in the existing Basic Nuclear Installation (heavy to manage)
 - work elsewhere with a lower requirement on the radiation safety (ICPE in french)
but it means more work and money to build this new experimental hall.