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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

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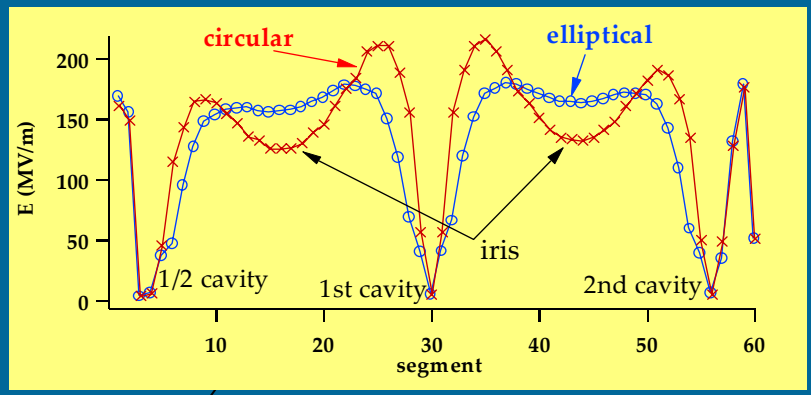
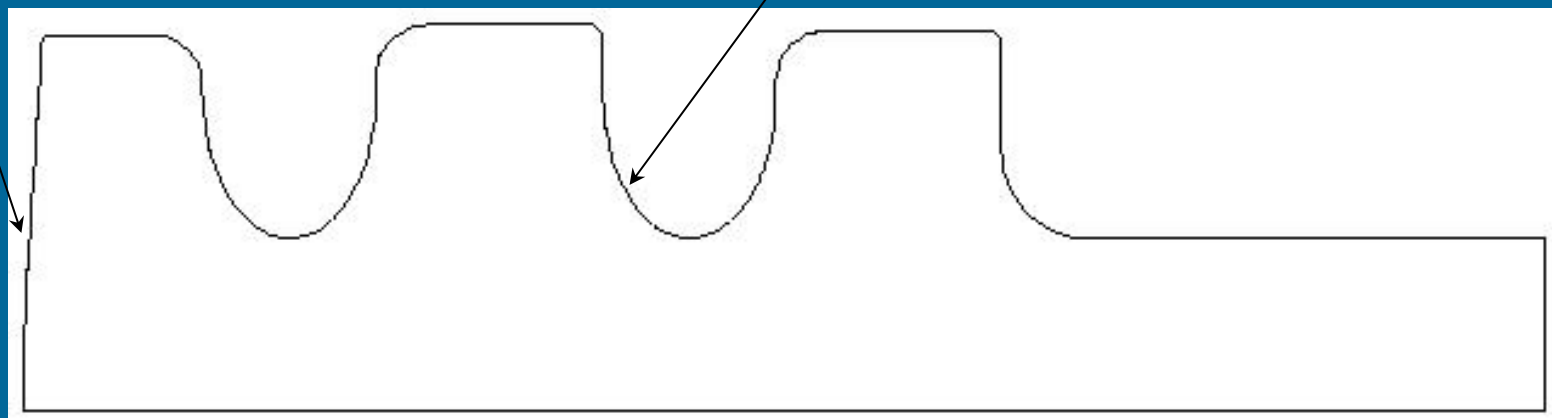
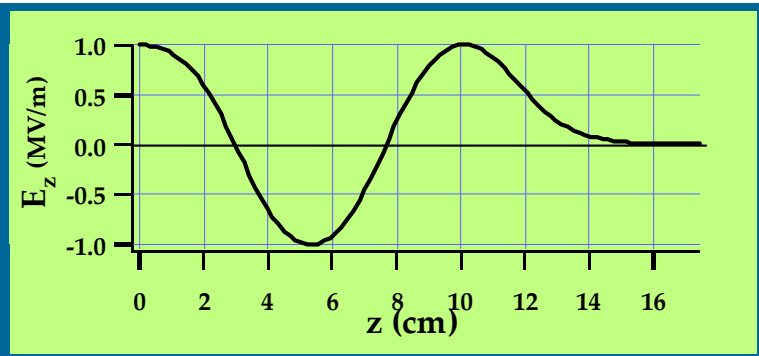


Angle of the wall
ε ↘ for I = 5 A



F_r = 3.003 GHz
R_s = 6 MΩ
Q = 14530



Beam loading and coupling

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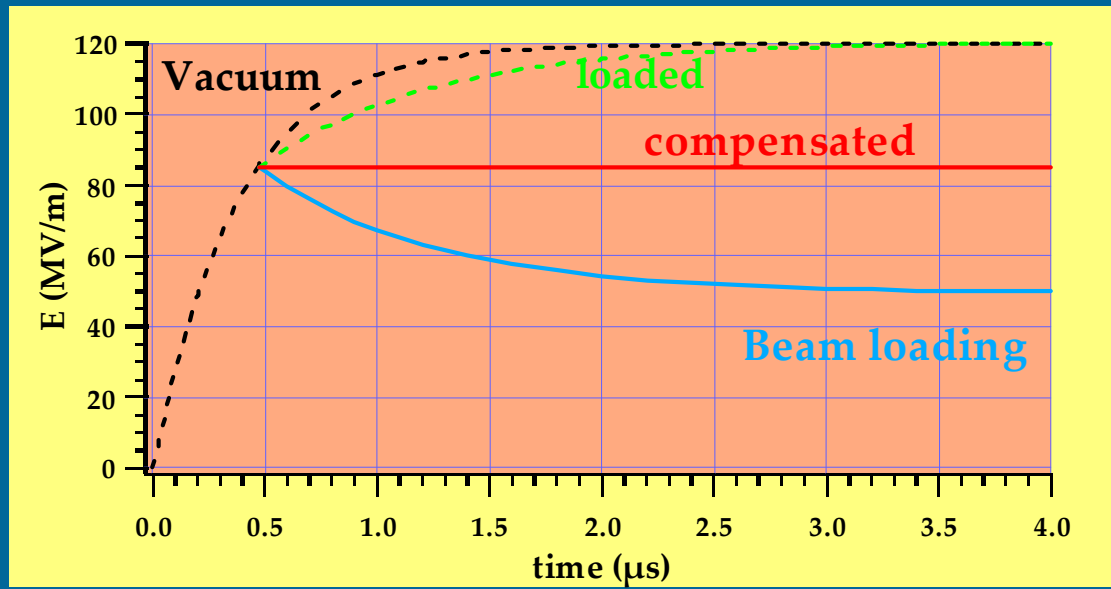
$$V_{ind}(t) = V_{sat}(1-\exp(-\frac{t}{\tau}))$$

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

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

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



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

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

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

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

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

3D RF design: HFSS

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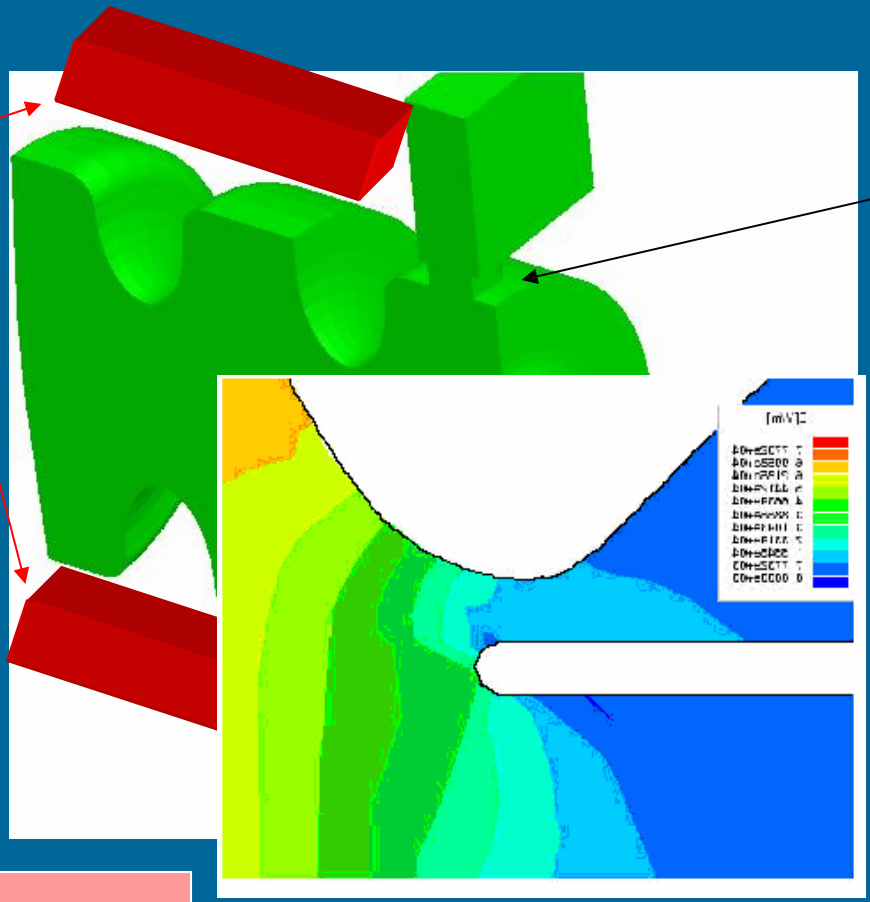
Coils



25 mm

10 mm

Hole coupling:
- Over-coupled
- symmetric

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

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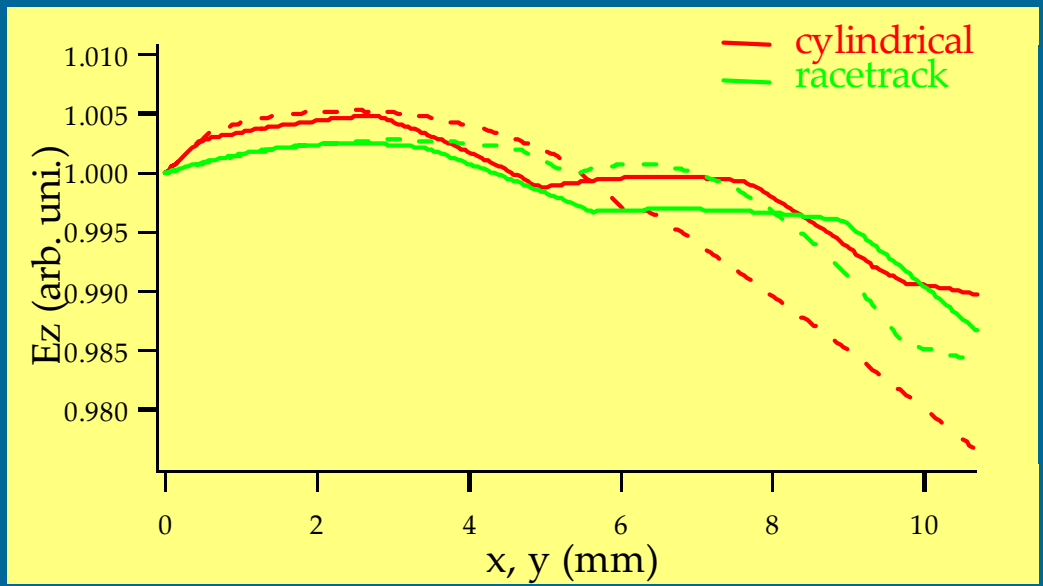
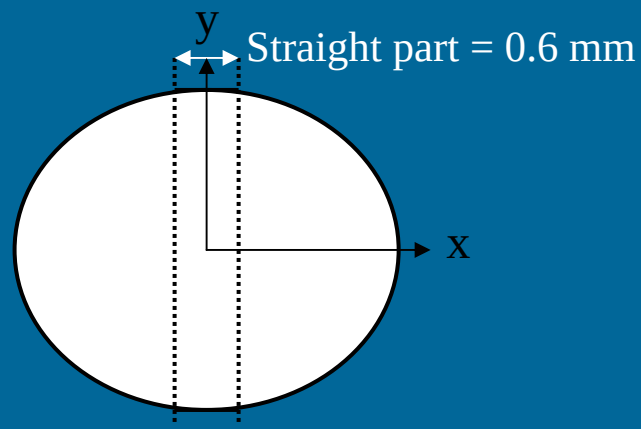
Field Symmetry in the 3rd cell

Asymmetry of transverse fields (couplers) → Blow-up of the emittance

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





$\frac{\Delta E}{E} = 7.10^{-4}$ Integral = 5.10^{-4}

$\frac{\Delta E}{E} = 3.5.10^{-5}$ Integral = 10^{-4}

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Dynamics of the electron beam

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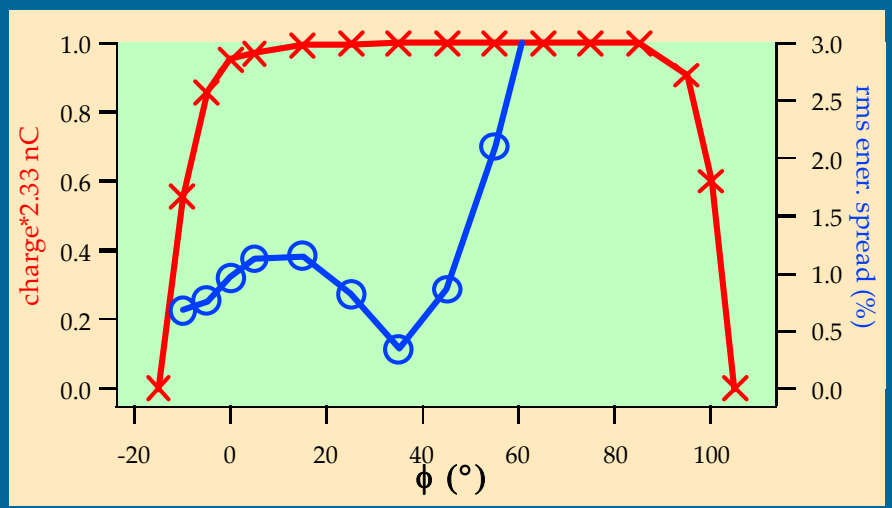
Electric field from 2D design → PARMELA →

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

I = 3.51 A



σ_{laser}(mm)	0.6	0.8	1	1.4	2.8
Particle losses (%)	1	0.3	0.3	0	0
ε_x (πmmmrad)	13.5	16	17.6	19.6	21.0
Bunch length (ps)	11	9.6	9	8.4	7.9
σ_γ/γ (%)	0.5	0.4	0.4	0.36	0.41

Φ_{opt} = 35 °

E_{RF} = 85 MV/m set by beamloading!

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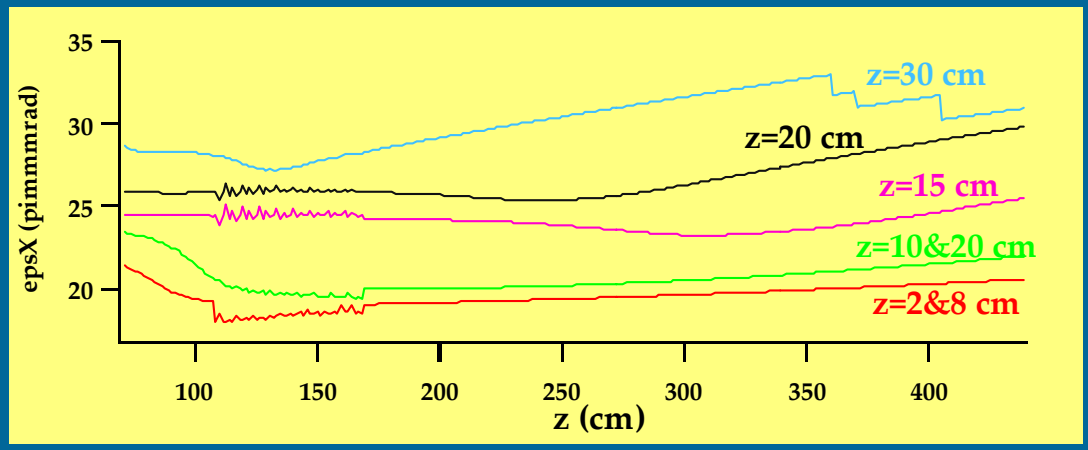
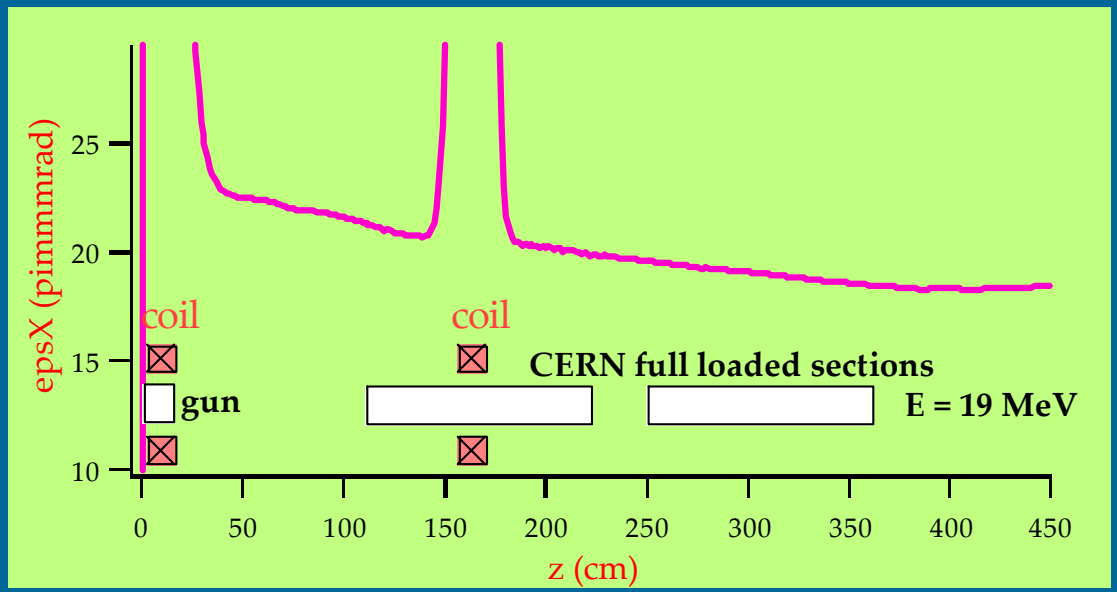
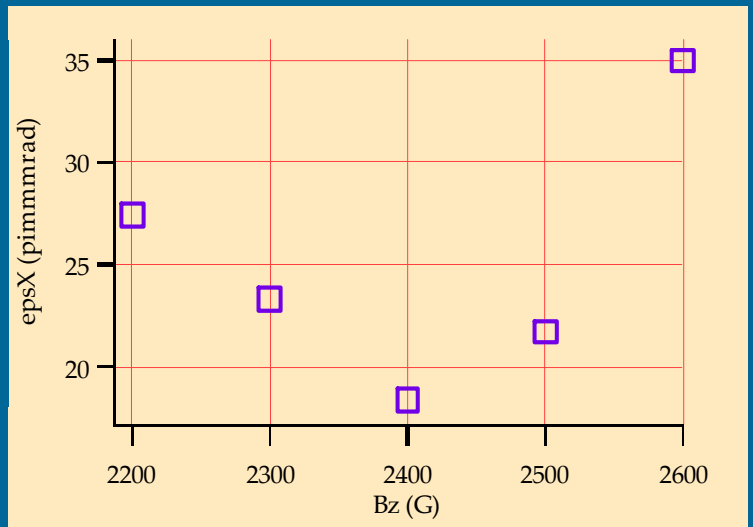
Compensation of the space charge forces



Best compensation:
Coils on the gun





Vacuum

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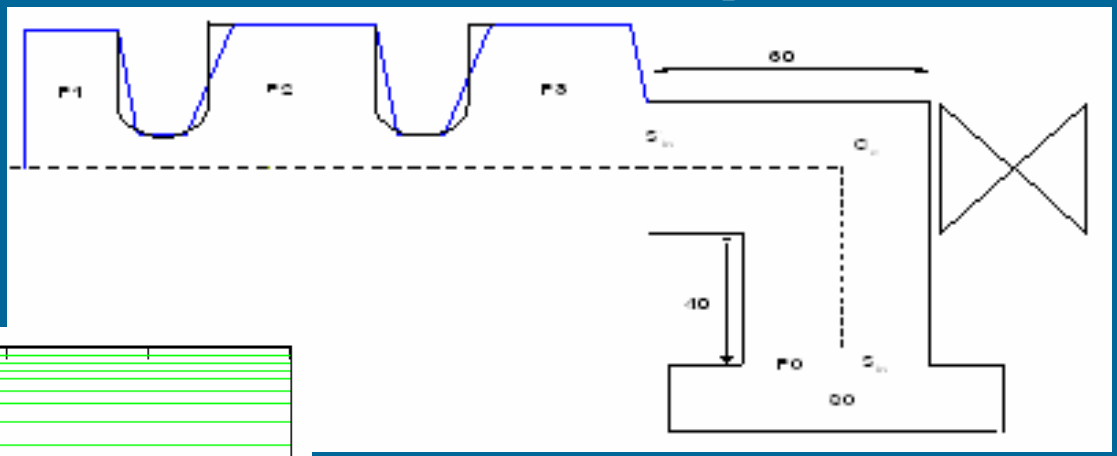
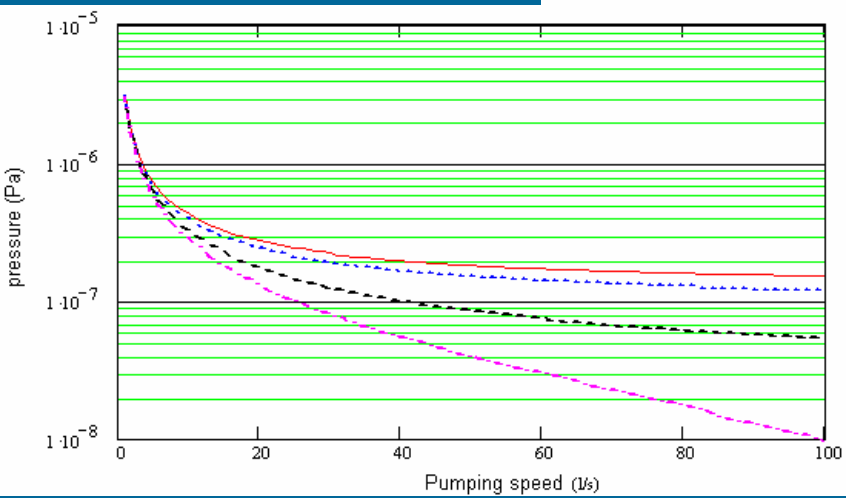
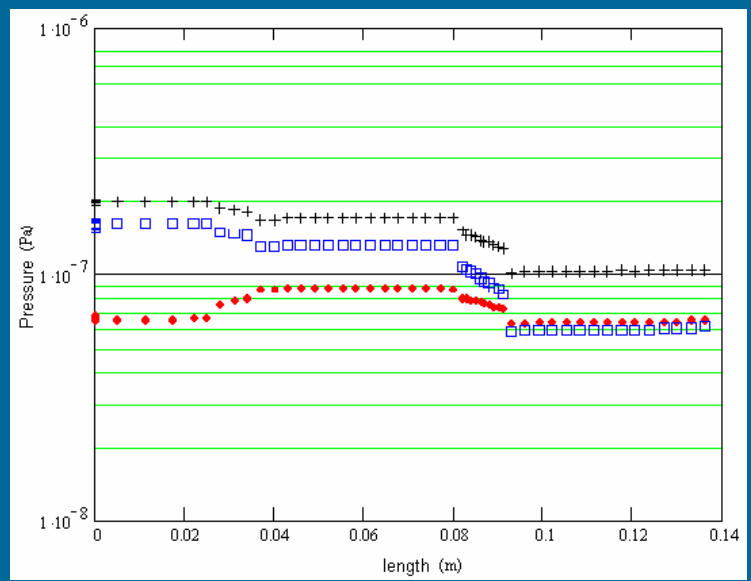
Monte-Carlo based simulations of the residual pressure







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

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Supplementary pumping

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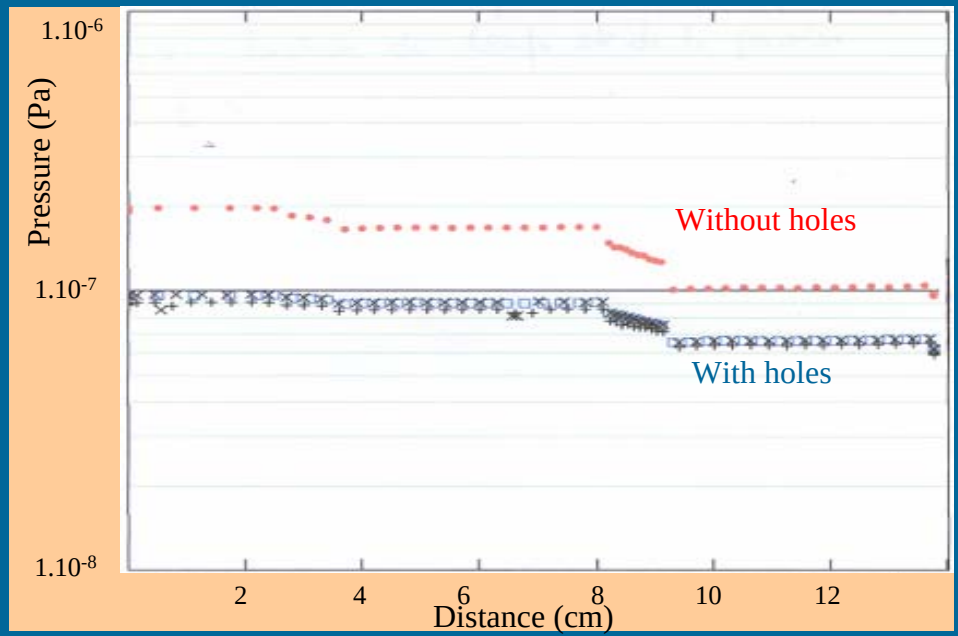
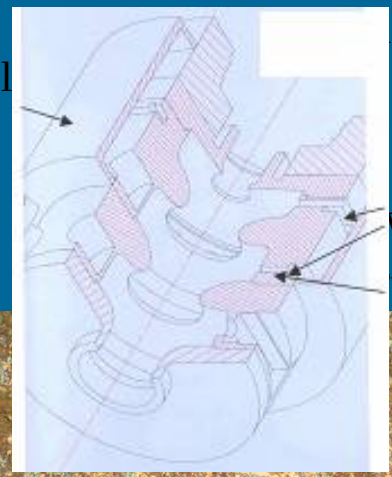
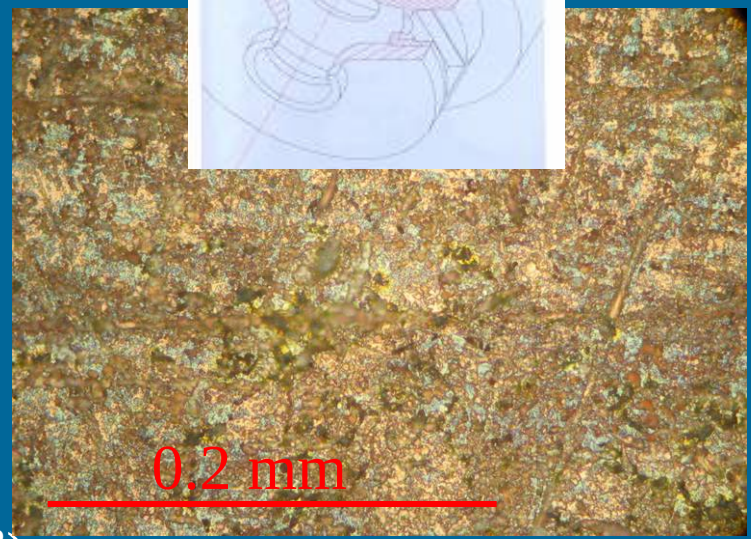
42 holes drilled in the gun walls Φ = 4 mm
Envelop around the gun coated with NEG







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

⇒ Residual pressure < 10^{-11}mbar

Copper in oven 3 days, t° = 550°C
Fast cooling with Ar jet 150°C
=>No grain

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Impact of the holes on the RF design

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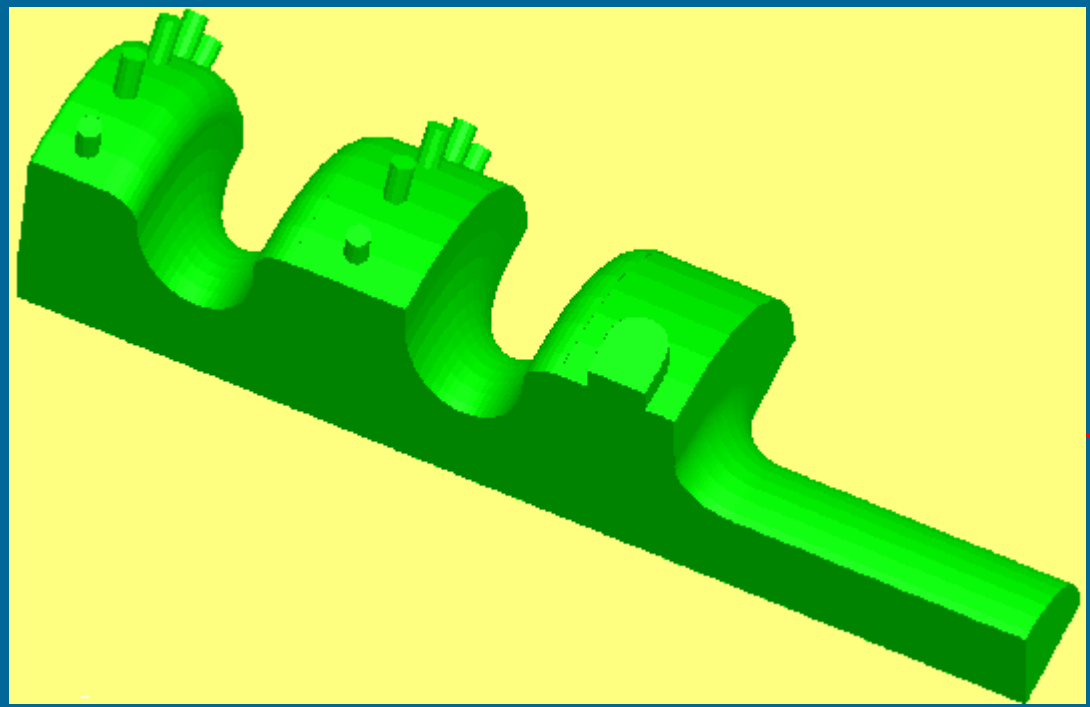

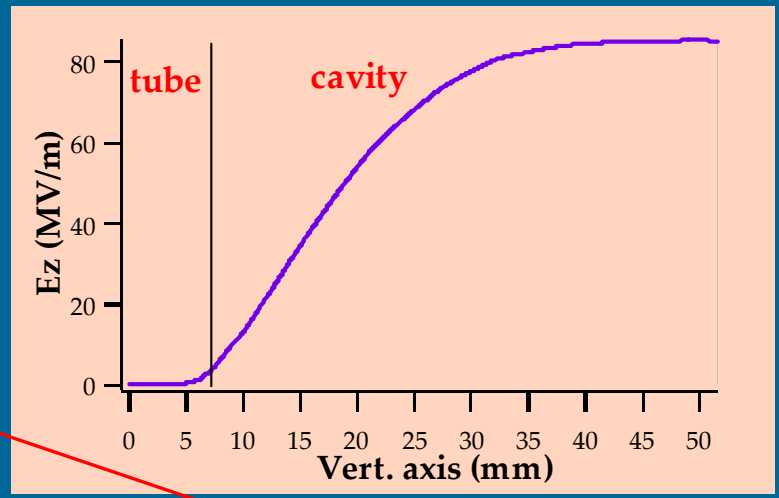

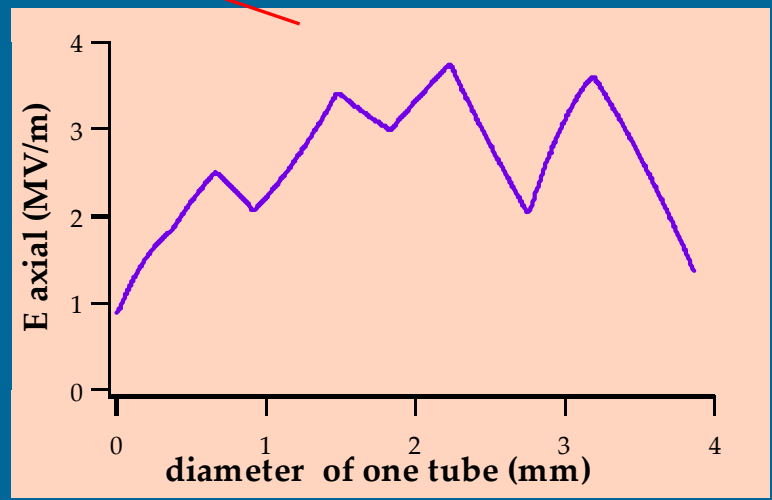

Impact on Q and R_s negligible (-5%)

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

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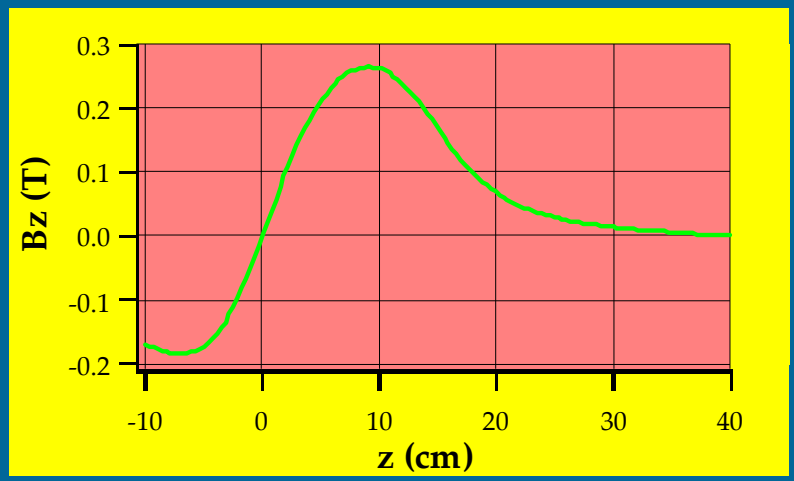
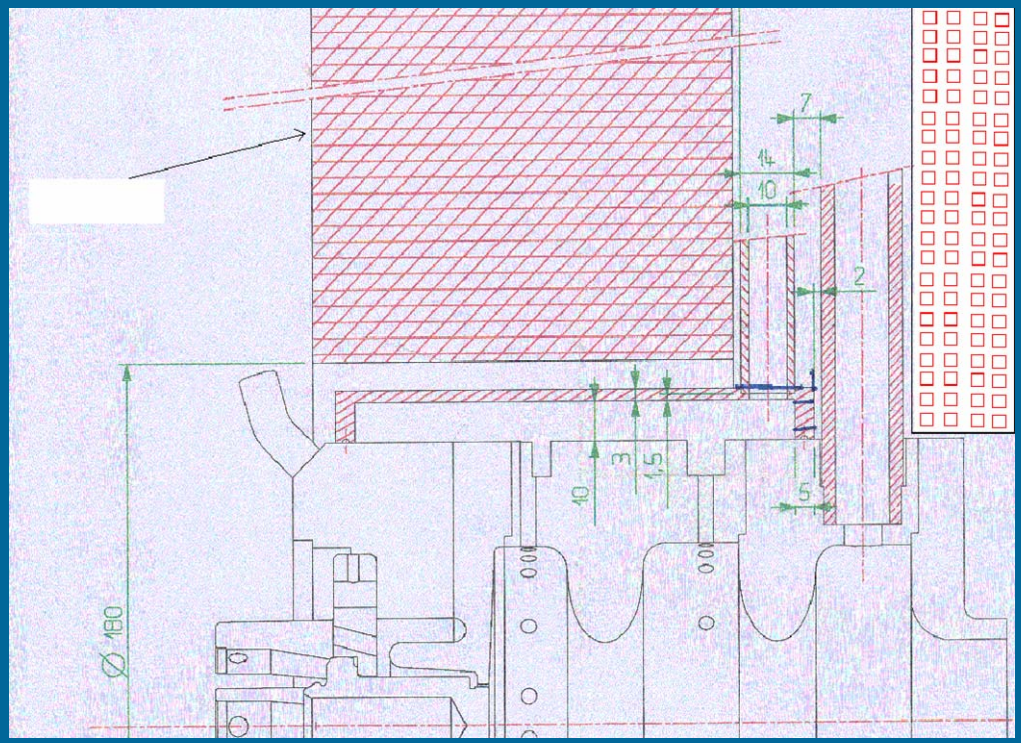
Aim: B_z max ≈ 0.27 T on the gun, 0 on the cathode
Difficulties: little available space, big inner diameter (180 mm)

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





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Conclusion&Perspectives

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1) RF gun

simulations completed, technical drawings 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.