(1)

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Be window issues:

RF Heating on Be windows

$$\langle P \rangle = \frac{R_s}{2} \eta \left(\frac{\epsilon_0}{\mu_0}\right) E_0^2 \oint_S J_1^2(kr)\, ds$$

$\eta \sim$ duty factor

$E_0 \sim$ peak electric field (pillbox model)

$$k = \frac{\omega}{c} = \frac{\mu_{01}}{a}$$

radius of pillbox cavity

Linear approximation,

$$\langle P \rangle = \oint_S \alpha r^2\, ds$$

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$$\frac{dQ}{dt} = -\kappa A \frac{dT}{dr}$$

$\kappa = 200$ W/mK for Be at room temperature

$A \sim$ across area

Temperature distribution,

$$T(r) = T(0) - \frac{\langle P \rangle}{8\pi\kappa d}\left(\frac{r}{R}\right)^4$$

$$\Delta T = \frac{\langle P \rangle}{8\pi\kappa d}$$

$d \sim$ thickness of a flat window

How to keep $T(0)$ low:

$\langle P \rangle \downarrow$, $\kappa \uparrow$

$d \uparrow$

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Numerical simulation shows,

foil deflection $\propto \Delta T$

Experiments conducted on a 805 MHz Be window ( 8 cm radius, 5 mill thick and pre-stressed)

Flat $< 40°K = \Delta T$

$\Downarrow$

Thicker & <u>Stiffer</u> windows

$\left.\begin{array}{l} \rightarrow \text{flat} \\ \rightarrow \text{tapered} \\ \rightarrow \text{Step} \end{array}\right\}$ windows

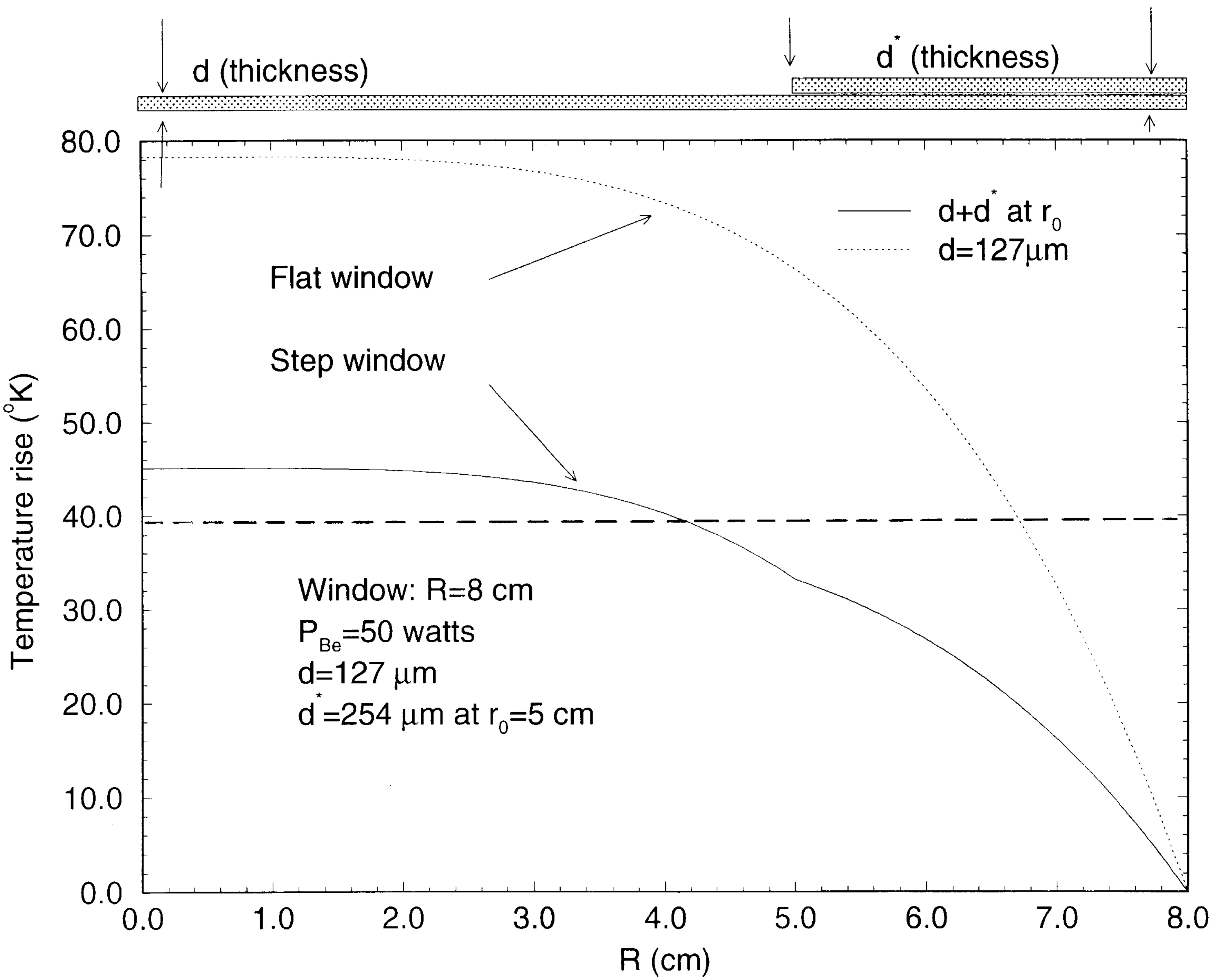
# Normal conducting RF systems - Feasibility study II parameters

Muon Collaboration

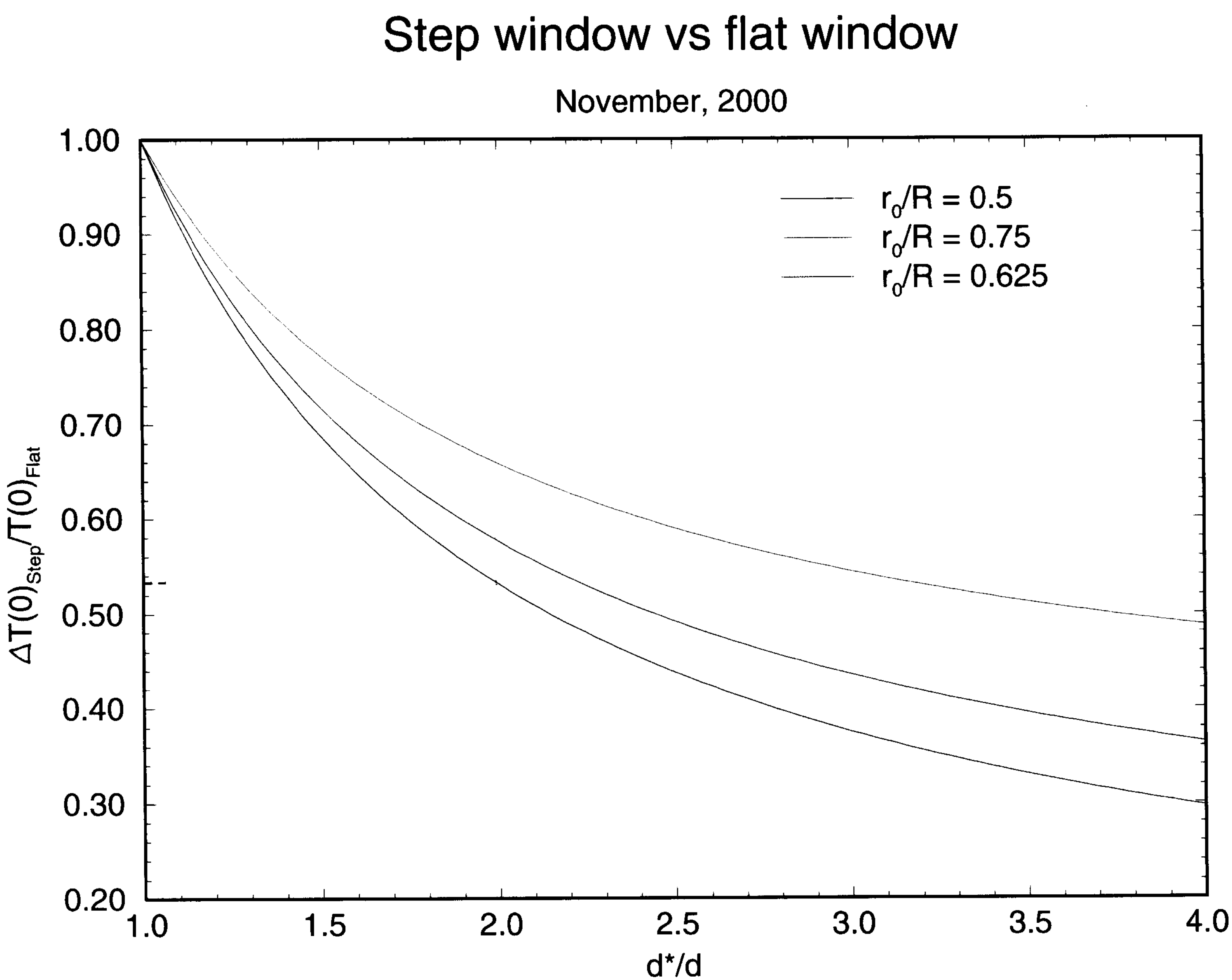
- Optimize cell lengths for maximum efficiency given lattice constraints
  - Maximum multi-cell pillbox shunt impedance at 105° per cell
    - 23.5 $M\Omega m^{-1}$
  - Maximum single-cell pillbox shunt impedance at 160° per cell
    - 20 $M\Omega m^{-1}$

| | Frequency | Cell length | # cells per RF section | Gradient | Windows at ends of RF structures | | Windows between cells | | # sections | Total # RF cells | Shunt impedance | RF input power per cell | Total RF power per cell type | Windows at ends of RF structures | | Windows between cells | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Thickness | Radius | Thickness | Radius | | | | | | RF power | Temp. | RF power | Temp. |
| | GHz | cm | | MV/m | μm | cm | μm | cm | | | MΩ/m | MW | MW | W | °C | W | °C |
| Buncher section | | | | | | | | | | | | | | | | | |
| | 402.5 | 18.6 | 1 | 6.4 | 100 | 20 | | | 2 | 2 | 30.1 | 0.2 | 0.4 | 17 | 34 | | |
| | 402.5 | 18.6 | 1 | 6 | 100 | 20 | ? | ? | 4 | 4 | 30.1 | 0.17 | 0.68 | 15 | 30 | ? | ? |
| | 201.25 | 37.3 | 4 | 6.4 | 125 | 21 | 250 | 25 | 1 | 4 | 23.4 | 0.5 | 2 | 16 | 26 | 32 | 26 |
| | 201.25 | 37.3 | 4 | 6 | 125 | 21 | 250 | 25 | 2 | 8 | 23.4 | 0.43 | 3.44 | 14 | 22 | 28 | 22 |
| | 201.25 | 37.3 | 4 | 8 | 125 | 21 | 250 | 25 | 2 | 8 | 23.4 | 0.77 | 6.16 | 25 | 40 | 50 | 40 |
| Cooling section | | | | | | | | | | | | | | | | | |
| [1,1; 1,2; 1,3] | 201.25 | 46.6 | 4 | 16.29 | 125 | 21 | 250 | 25 | 6 | 24 | 22.6 | 3.5 | 84 | 118 | 189 | 448 | 359 |
| [2,1] | 201.25 | 55.9 | 2 | 17.6 | 75 | 18 | 125 | 21 | 14 | 28 | 20.3 | 4.4 | 123.2 | 85 | 227 | 304 | 487 |
| [2,2] | 201.25 | 55.9 | 2 | 17.6 | 75 | 18 | 75 | 18 | 10 | 20 | 20.3 | 4.4 | 88 | 85 | 227 | 170 | 453 |
| [2,3a] | 201.25 | 55.9 | 2 | 17.6 | 75 | 15 | 75 | 18 | 16 | 32 | 20.3 | 4.4 | 140.8 | 43 | 115 | 170 | 453 |
| [2,3b] | 201.25 | 55.9 | 2 | 17.6 | 50 | 15 | 50 | 15 | 16 | 32 | 20.3 | 4.4 | 140.8 | 43 | 172 | 85 | 340 |

# Step Window



$r_0$
d (thickness)
$d^*$ (thickness)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Temperature rise ($^oK$)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
R (cm)
Flat window
Step window
$d+d^*$ at $r_0$
$d=127\mu m$
Window: R=8 cm
$P_{Be}$=50 watts
$d=127\ \mu m$
$d^*=254\ \mu m$ at $r_0=5$ cm



Step window vs flat window
November, 2000
$\Delta T(0)_{Step}/T(0)_{Flat}$
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
1.0
1.5
2.0
2.5
3.0
3.5
4.0
d*/d
$r_0/R = 0.5$
$r_0/R = 0.75$
$r_0/R = 0.625$

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Let's look at an example,

$$\Delta T = 487 \rightarrow \begin{cases} 5 \text{ mill thick} \\ 21 \text{ cm radius} \end{cases}$$

How can we bring $\Delta T$ below 40K ?

d : from $125\,\mu m \longrightarrow \underline{0.5\text{ mm}}$

$$\Delta T \sim 122\text{ K} \quad (\text{linear})$$

$$d^* = 4d \rightarrow \text{Step @ } \frac{r_0}{R} = 0.5$$

$$\Delta T \sim 37\,^\circ\text{K}$$

A factor 13.3 reduction !

This not optimized, and how bad the scattering is, needs to be studied.

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Step or tapered windows are better than flat ones

- adding thickness at $\frac{r_0}{R} < 0.5$ does not help much (may make windows stiffer)

- adding more material at larger radius helps a lot due to RF heating power distribution

Other issues:

→ How to make the windows stiffer? need new ideas, makable

→ Multi-pactoring, 2nd emission

→ physical shock from beam

→ EM force

→ TUNER.