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TWO SOLUTIONS FOR DAMPING RING EXTRACTION KICKER FOR ELISA*

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General Specifications

1. $\theta_{\text{KICK}} = 2 \times 10^{-3}$ radians
2. $P_{\text{MAX}} = 2.2$ GeV/c
3. Aperture Width: $w = 100$ mm $= 0.1$ m
   Aperture Gap: $g = 30$ mm $= 0.03$ m
4. $T_{\text{Pulse Spacing}} = 27$ ns

Formulas:

l = Magnet Length (meters)

B = Magnetic Field (tesla)

ρ = Radius of Curvature (meters)

$$\theta_{\text{KICK}} = \frac{l}{\rho} \quad , \quad P = 0.3\, B\rho$$

Therefore,

$$\theta = \frac{0.3\, Bl}{P} \quad \text{or} \quad Bl = \frac{P\theta}{0.3}$$

Substituting the required P and θ gives

$$\boxed{Bl = 1.47 \times 10^{-2} \text{ Tesla Meters}}$$

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Ferrite Magnet (Fianders Solution)

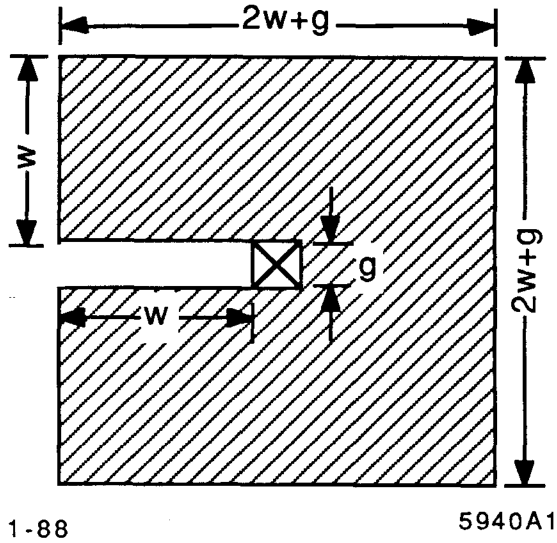

Figure 1

Define n:

$$n \equiv \frac{\text{Path Length in Ferrite}}{g}$$

$$\mu_f = \mu_{\text{Ferrite}}/\mu_0 \text{ (Relative } \mu\text{)}$$

$$L = \text{Inductance (Henries)}$$

Formulas:

$$B = \frac{\mu_0 I}{g\left(1+\frac{n}{\mu_f}\right)} \quad , \quad Bl = \frac{\mu_0 Il}{g\left(1+\frac{n}{\mu}\right)}$$

$$L = \frac{w}{g}\frac{\mu_0 l}{\left(1+\frac{n}{\mu}\right)}$$

For the geometry shown above

$$n \approx \frac{g + 2\pi\left(\frac{w+g}{2}\right)}{g} = 1 + \pi + \pi\frac{w}{g}$$

$n \approx 14$ for $w = 100$ mm , $g = 30$ mm

Putting the required $Bl = 1.47 \times 10^{-2}\ T$ m into the formula for Bl gets Il

$$Il = \frac{gBl\left(1+\frac{n}{\mu}\right)}{\mu_0}$$

Picking $\mu \approx 70$ for K6A (TDK)

$$\boxed{Il = 4.2 \times 10^2 \text{ ampere meters}}$$

The choice of I and l comes from the time structure of the beam. If T_{Total} is the separation of the bunches,

$$T_{\text{Total}} \geq T_{\text{Transit}} + \Im_{\text{Rise}} + \Im_{\text{Fall}} \simeq T_{\text{Transit}} + 2\Im_{\text{Rise}} = T_{\text{Max}}$$

$$T_{\text{Transit}} = \frac{L(l)}{Z}$$

$$\Im_{\text{Rise}} = K_1 I + K_2$$

The optimum solution is when

$$T_{\text{Transit}} = \frac{T_{\text{Max}}}{2} = 2\Im_{\text{Rise}} \,.$$

This will determine l and I.

As the Il of a magnet will be less than the required $Il = 4.2 \times 10^2$ A m, *several magnets in the series will be needed, each driven with its own pulser.*

Now $T_{\text{Transit}} = \frac{L(l)}{Z}$, so that large Z allows a large l for the same transit time. The magnet is connected to the pulser by coaxial cables so that the highest convenient Z for the magnet is 50 Ω.

Fixing $T_{\text{Max}} = 25$ ns leads to

$$T_{\text{Transit}} = \frac{T_{\text{Max}}}{2} = 12.5 \text{ ns } = \frac{L}{50}$$

$$L = 625 \text{ n Henries } = \frac{w}{g} \frac{\mu_0 l}{\left(1 + \frac{n}{l}\right)}$$

$$\boxed{l_{\text{max}} = 0.18 \text{ meters for a magnet}}$$

Best thyratrons (EEV) have T_{Rise} 10–90% of 200 Amps/ns.

To convert this into a $\Im_{\text{Rise}}$

$$\Im_{\text{Rise}} \simeq \left(\frac{1.8I}{200} + 2\right) \text{ ns}$$

$$2\Im_{\text{Rise}} = 12.5 \text{ ns}$$

$$\Im_{\text{Rise}} - 2 = 4.25 \text{ ns} = 9 \times 10^{-3}\ I$$

$$\boxed{I = 470 \text{ amps}}$$

The number of magnets required is

$$\frac{4.2 \times 10^2}{470 \times 0.18} = \boxed{5 \text{ magnets}}$$

For each magnet to have an impedence of 50 Ω, there must be a capacity such that $\sqrt{\frac{L}{C}} = 50$ or $C = \frac{L}{2500}$. As $L = 625$ nH, $C = 250$ pf. The natural capacity (Ferrite only) is (assuming $\epsilon_{\text{Ferrite}} = 10$) $\simeq 80$ pf. Therefore about 170 pf must be added. If this is added using a liquid dielectric between the outer ground and a set of spaced radial fins, a low inductance no corona magnet can be constructed. Ethelene glycol or water can be used.

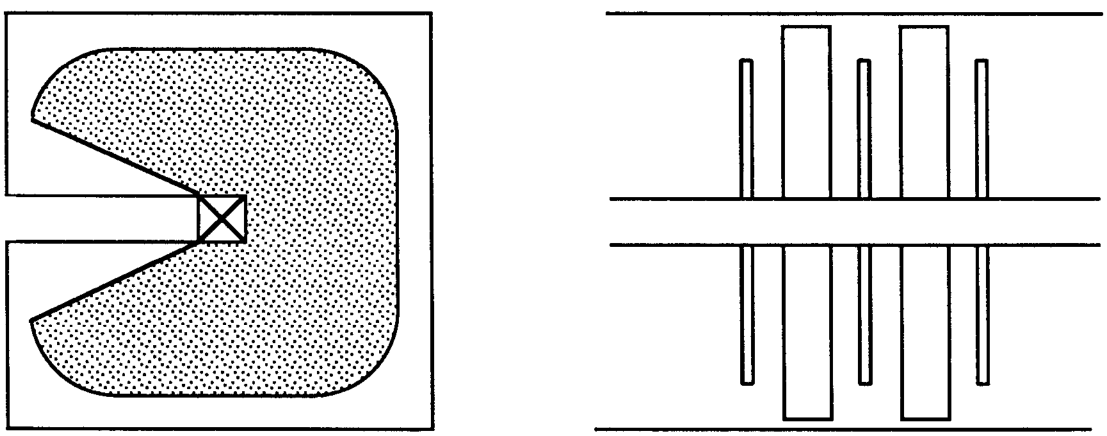

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Figure 2

The voltage on the magnet is V = 470 × 50 = 23,500 V requiring a pulser with 47 KV on it. Alternatively, a Blumlein pulser can be used with 23,500 V. The rise time may be slower as more current is required, so perhaps two thyratrons in parallel are required.

No Ferrite Solution

For a traveling wave, an "H" magnet design is better.

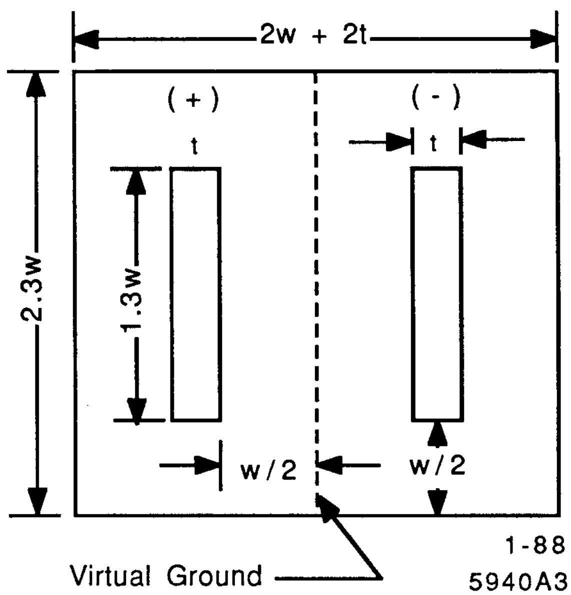

Figure 3

$1 + \frac{n}{\mu}$ for this design is about 15, instead of 1.2 in the ferrite case. Thus *Il* must be $\frac{15}{1.2}$ times as large or 12.5 times the 420 amp meters needed previously. We need 5250 amp meters of magnet. The magnet must be driven symmetrically with a positive and negative pulse (from a transformer). As the transit time does not count, $\Im_{\rm Rise} = 12.5$ ns. This permits currents of $\approx \pm$ 900 amp and hence a length of about 6 m for the magnet. The voltage is about ± 45 KV on 50 Ω. Depending on the turns ratio, the primary must be driven with rather high currents requiring the pulser to have many thyratrons in parallel.

To achieve high pulse to pulse stability, a second kicker whose kick angle is $\frac{\theta_2}{\theta_1} = \sqrt{\frac{\beta_1}{\beta_2}}$ is placed downstream at a betatron phase advance of π or 2π radians. This second kicker cancels variations in the first kicker.