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Damping Ring Kickers

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Abstract:

The principle of the design of these magnets was discussed in CN-72. Fig. 1 shows what the total system looks like. Such a system was completed last January and since then we have been evaluating its performance.

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SINGLE PASS COLLIDER MEMO CN-166

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TITLE: DAMPING RING KICKERS

The principle of the design of these magnets was discussed in CN-72. Fig. 1 shows what the total system looks like.

Such a system was completed last January and since then we have been evaluating its performance.

To remind the reader:

1) Space available along the beam allows a magnetic length of 33 cms max, while the physical length should not exceed 40 cms.

2) Magnetic kick amplitude jitter should be $\leq$ .03%; 8 mr kick is required at 1.2 GeV.

3) Magnetic kick should reach max in $\leq$ 1/2 ring period, and fall back to zero in $\leq$ 1/2 ring period. The ring period is $\approx$ 117 ns.

In order to select the matched impedance of the system, designs were worked out for various impedances. Cable availability dictated that $Z = \frac{50\ \Omega}{N}$ where N is an integer. Table I illustrates various designs. An impedance of 16.7 Ω was chosen as the best compromise between thyratron performance and power supply requirements. Also experience with thyratrons and Blumleins indicated that the electrical pulse length should not exceed 40 ns in order to satisfy the time requirements and allow for filling (transit) time.

System Performance

(A) PFN: The line performed as expected up to the max voltage of 20 kV available at test time. Fig. 2a shows the pulse obtained at 18 kV with a Pearson transformer of rise time 10 ns, using a 519 scope. Rise time 10 - 90% $\approx$ 15 ns, and flat top $\approx$ 20 ns.

The thyratron showed a jitter of < ± 1 ns at 10 kV. At 18 kV jitter seems to increase reaching $\approx$ ± 1.0 ns. More accurate measurements are in progress. Full voltage ($\approx$ 40 kV) jitter should also be measured.

(B) Magnet: The impedance, transit time, magnetic kick amplitude and times came out as calculated, and as far as duration of magnetic kick we are safe by a few nanoseconds. Fig. 2b shows a typical $\int Bd\ell$ for the magnet.

Preliminary value of the amplitude jitter due to a time jitter of the thyratron of ± 1 ns was estimated at $\simeq$ .1%. This is a difficult measurement to make, and a more precise method to measure stability is being developed by R. Larsen group.

Originally we aimed at a "flat" top of the magnetic kick of 5 ns to take care of the max jitter expected from a good thyratron. This goal was not achieved. The reason can be understood from Fig. 3a which shows the electric pulse at the beginning and end of the magnet. In travelling through the magnet, the rise time deteriorated more than was expected. This is due mainly to the high frequency response of the ferrite. To achieve a 5 ns flat top the pulses from beginning and end of the magnet should overlap at their maxima by 5 ns. Fig. 3a shows that they are barely beginning to overlap.

If the more accurate measurement of flatness confirms this picture something has to be done — what?

In anticipation we list all possible approaches in order of preference. These schemes were discussed with various experts at Berkeley, FNL and Livermore. They all agree with the analysis.

1. Find a ferrite with better frequency response. Such a ferrite will have a lower μ and will require more voltage to generate the required field. For example a μ = 50 requires 43 kV, a μ = 25 requires 52 kV.

2. Lengthen the electric pulse by 5 ns and shorten the magnet to $\simeq$ 2/3 its present length. This also requires an increase of voltage. For example shortening the magnet to 26 cms requires an increase in effective voltage from 36 kV to 46 kV. This reduces transit time by 3.5 ns and gains a small improvement in rise time. The overall gain in overlap would be > 5 n.s.

3. Change the impedance of the magnet to 25 Ω. This is similar to 2 above except that the ferrite volume is reduced considerably without shortening the magnet. One may also lengthen pulse. Voltage required is 48 kV. The gain is ≈ 4 ns in transit time (Table I), plus whatever improvement results from volume reduction. If magnet is also shortened as in 2 the voltage needed is 61 kV.

4. Z magnet 25 Ω, Z line 12.5 Ω. Divide magnet electrically into two halves feeding each with 2 x 50 Ω cable. This is harder on the thyratron. Gain is 6 ns in transit time, kV needed ≃ 36 kV.

Common to all schemes is an increase in power supply voltage. Except for 4 and 2nd alternative of 3, the power supply has to increase from its present 25 kV to 30 kV. The supplier says it is not difficult. We recommend this be done.

Obviously 1. is the easiest. We considered the following ferrites STACKPOLE C12, C14; TOSHIBA M4C21A, M4D21A. Their properties are not as well documented and it is not clear that their slight improvement in frequency response compensates for some of their undesirable features. C12 is probably the best.

Our 1st choice is 2, 2nd choice is 3. changing the length and/or impedance of the linac is very easy. Shortening the ferrite is trivial. So let us increase the DC supply voltage to 30 kV which will keep options 1 to 3 open.

It is amusing to contemplate an air transmission line (no ferrite). With the space available to us we need in excess of 600 kV!! This voltage is independant of the impedance of the line.

TABLE I

Using μ = 125, ε = 12.5, Ferrite thickness 1.91 cm (The 4C4 Ferrites we have), g = 2.25 x 2.25 cm, Magnetic length = 33 cms.

$Z(\Omega)$	50	25	16.7	12.5
ℓ_f(cm)	7	27	55	89.5
μ_e	4	11.8	21.3	30.9
ε_e	9.7	11.6	12.0	12.2
I(kA)	1.77	1.92	2.12	2.37
V(kV)	88.5	48.0	35.5	30.0
τ(ns)	6.3	11.7	16	19.5

Where: ℓ_f = cross-sectional length of ferrite

μ_e = Effective μ

ε_e = Effective ε

V = Voltage delivered at magnet

τ = Transit time

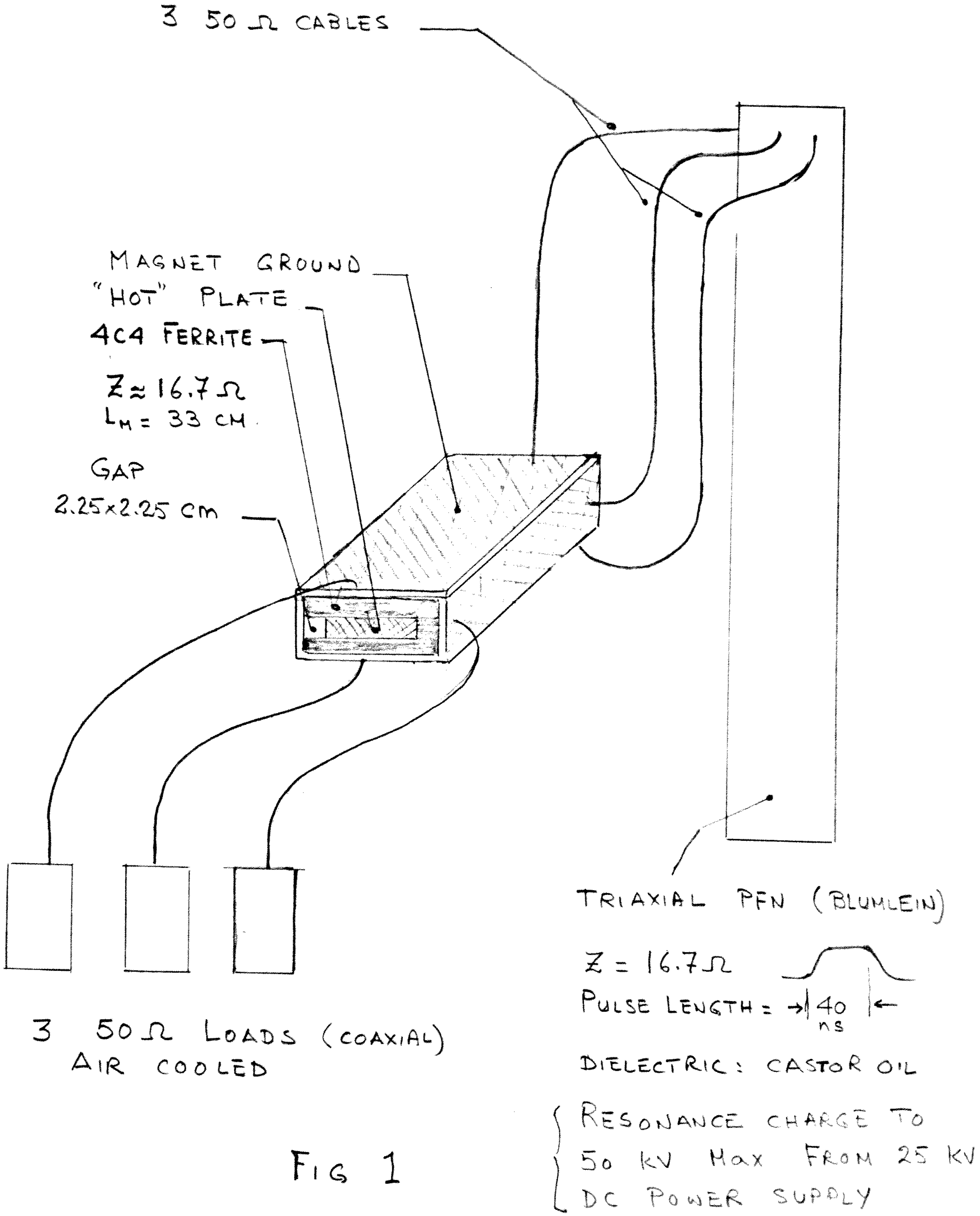
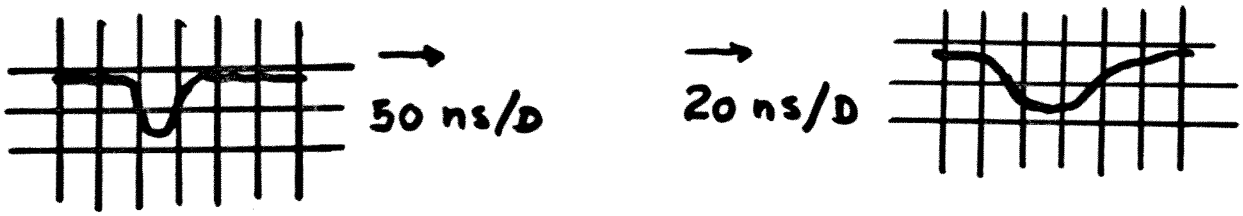
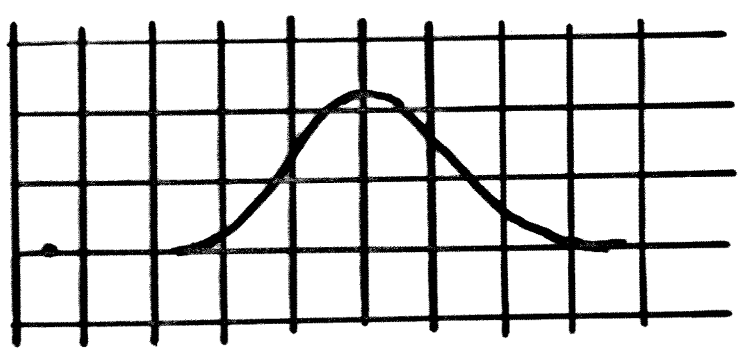

3 50 Ω CABLES
MAGNET GROUND
"HOT" PLATE
4C4 FERRITE
Z ≈ 16.7 Ω
L_M = 33 CM
GAP
2.25x2.25 cm
TRIAXIAL PFN (BLUMLEIN)
Z = 16.7 Ω
PULSE LENGTH = →| 40 ns |←
DIELECTRIC: CASTOR OIL
RESONANCE CHARGE TO
50 KV MAX FROM 25 KV
DC POWER SUPPLY
3 50 Ω LOADS (COAXIAL)
AIR COOLED

FIG 1



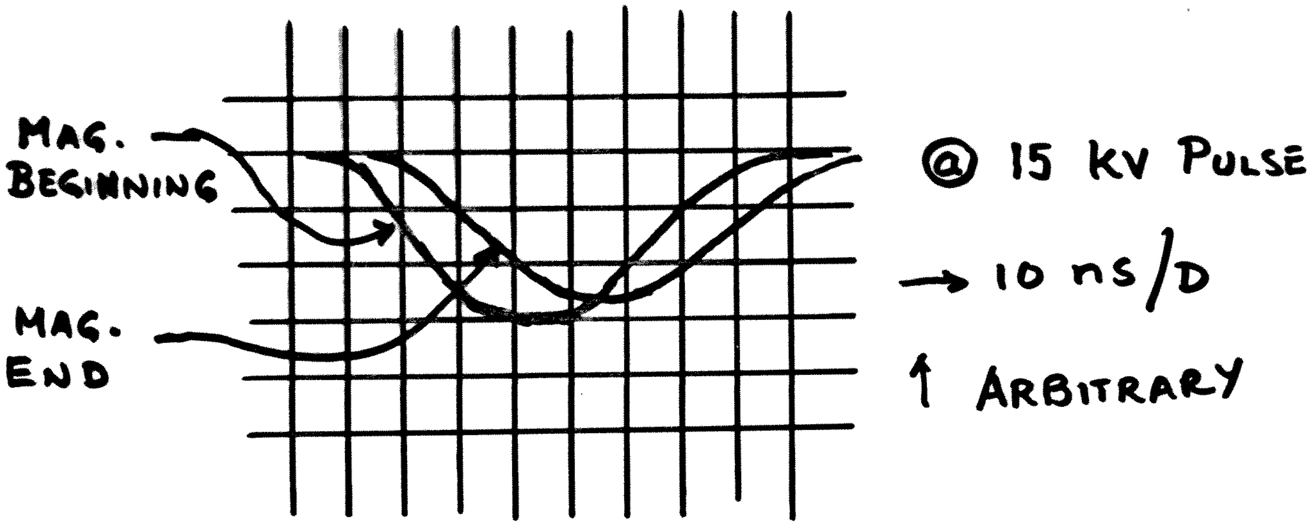
PULSE AMPL. = 18 kV

FIG 2a



→ 20 ns/D ; ↑ ARBITRARY

FIG 2b: $\int B\,dl$ IN GAP



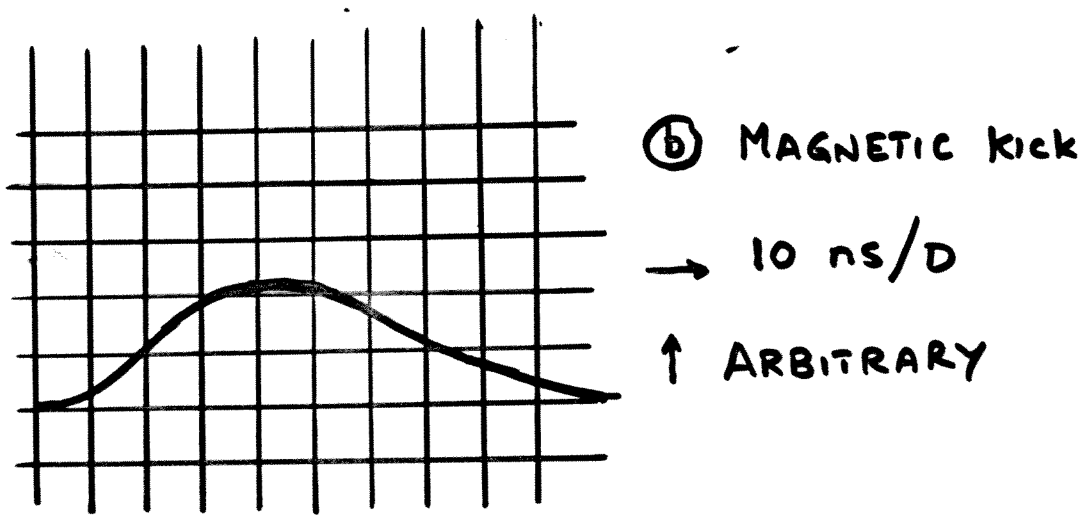


FIG 3: 15 KV PULSES, AND KICK