SOME THOUGHTS!!

on

A High Power, Radiation Cooled, Rotating Toroidal Target for Neutrino Production

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ISIS

CLRC

A Cu-Ni Rotating Band Target for Pion Production at Muon Colliders

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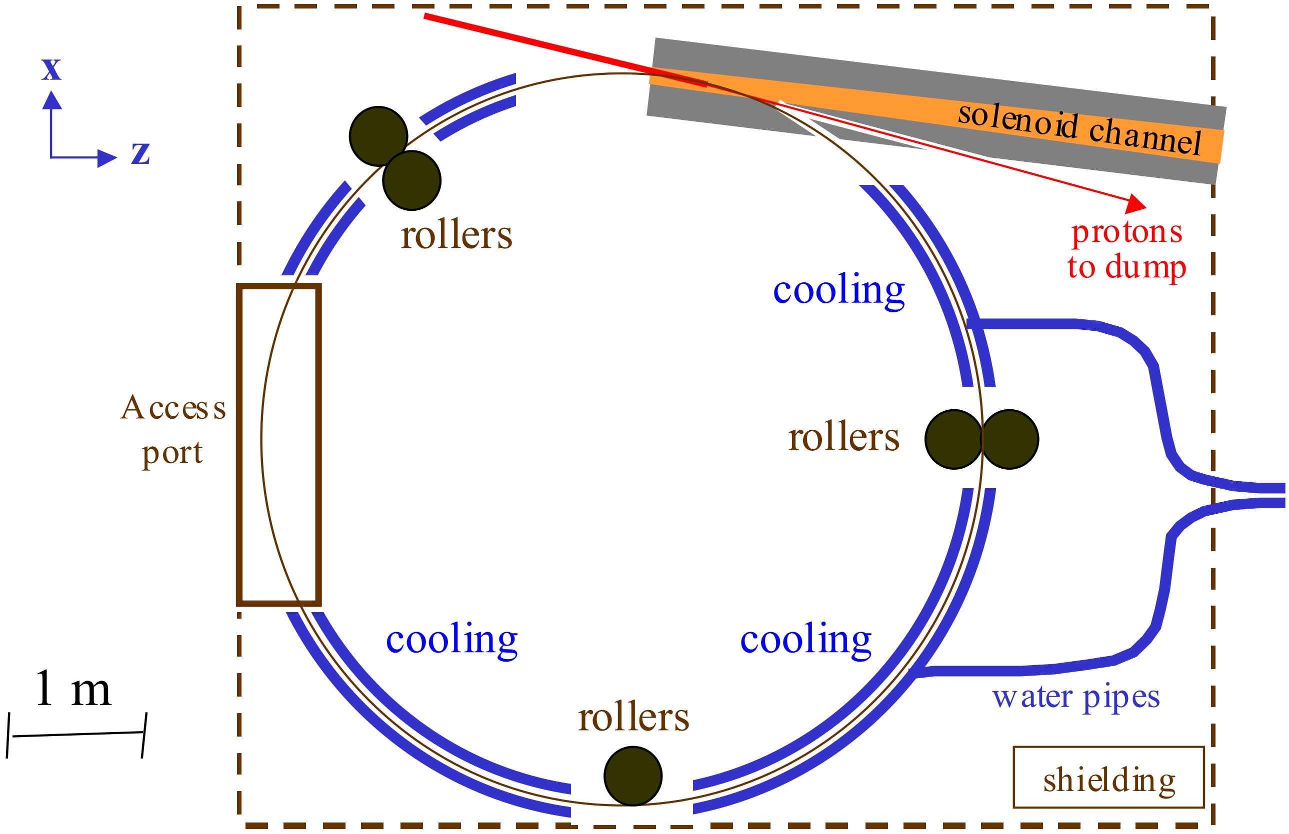
From PAC99 and Lyon Workshop, July 1999

Plan View of Targetry Setup



COOLING

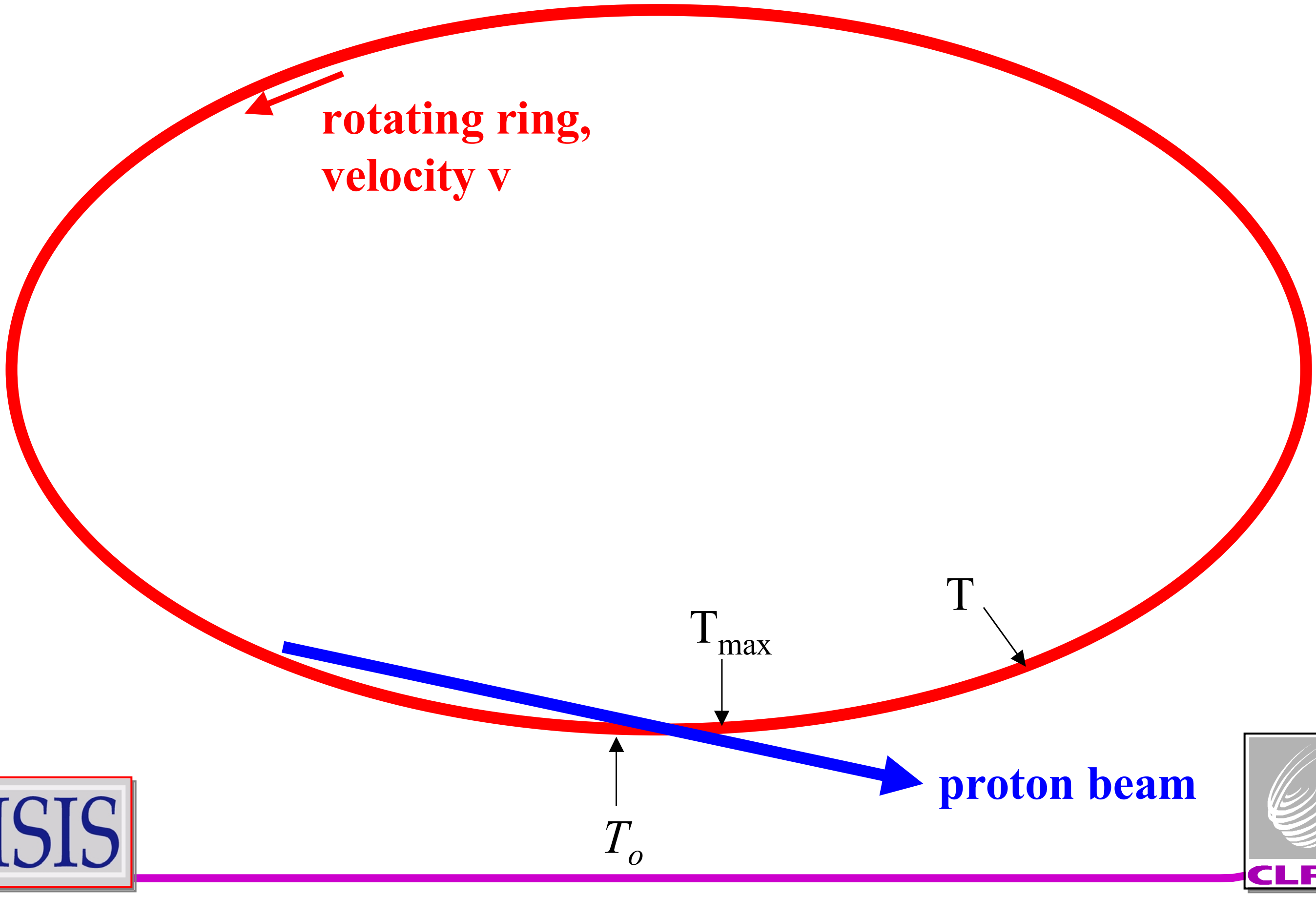
TOROID OPERATES AT 2500 K

RADIATION COOLED

ROTATES IN A VACUUM

VACUUM CHAMBER WALLS WATER COOLED

Schematic Diagram of the Toroid



rotating ring, velocity v

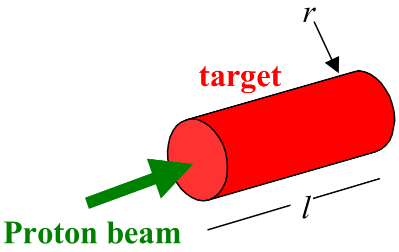
T

T_{max}

proton beam

T_o

Some Simple Heat Flow Equations



Stefan's Radiation Law

$$\frac{dq}{dt} = 2\pi r l \varepsilon \sigma g\left(T^4 - T_e^4\right)$$

Thermal Capacity

$$Q = \pi r^2 l \rho S\left(T - T_o\right)$$

which gives the power as:

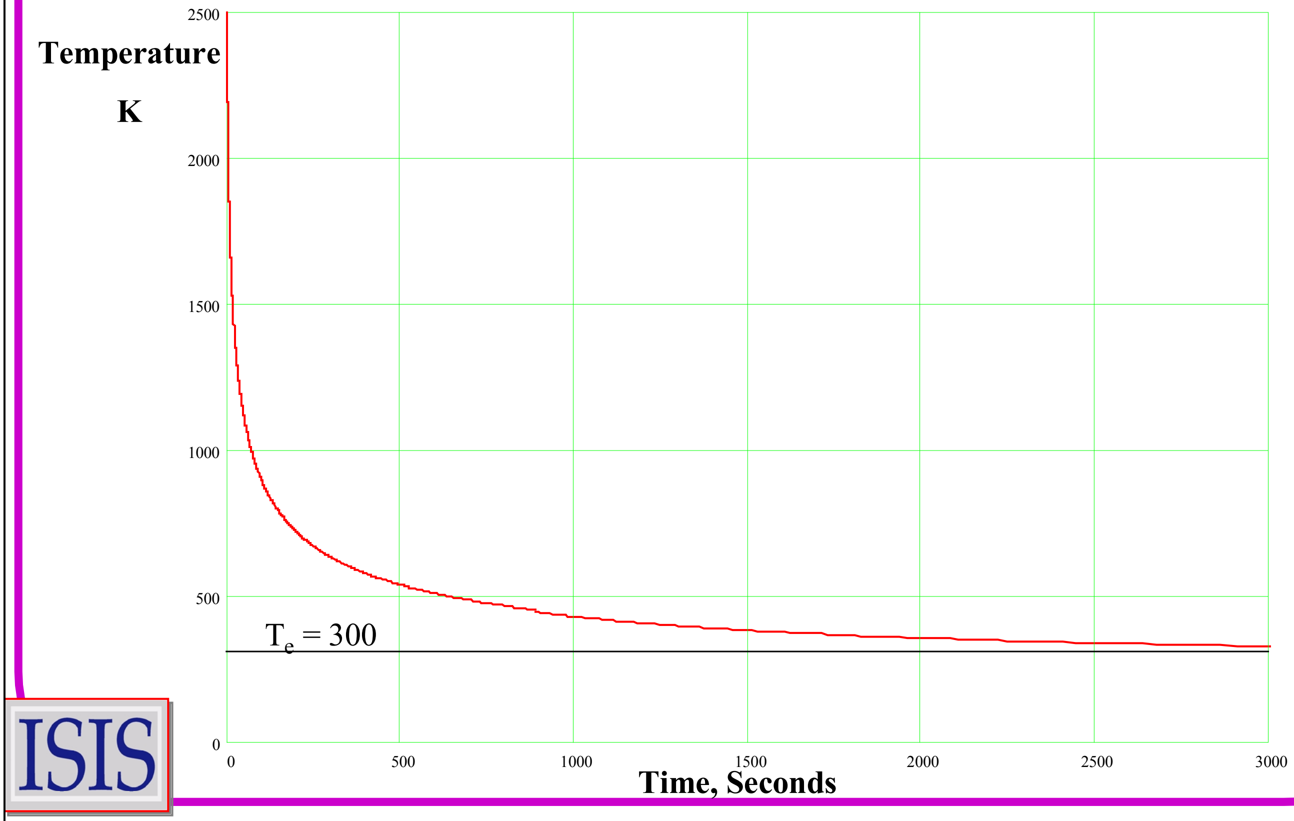
$$W = Q\frac{V}{L}$$

Assume dc proton beam

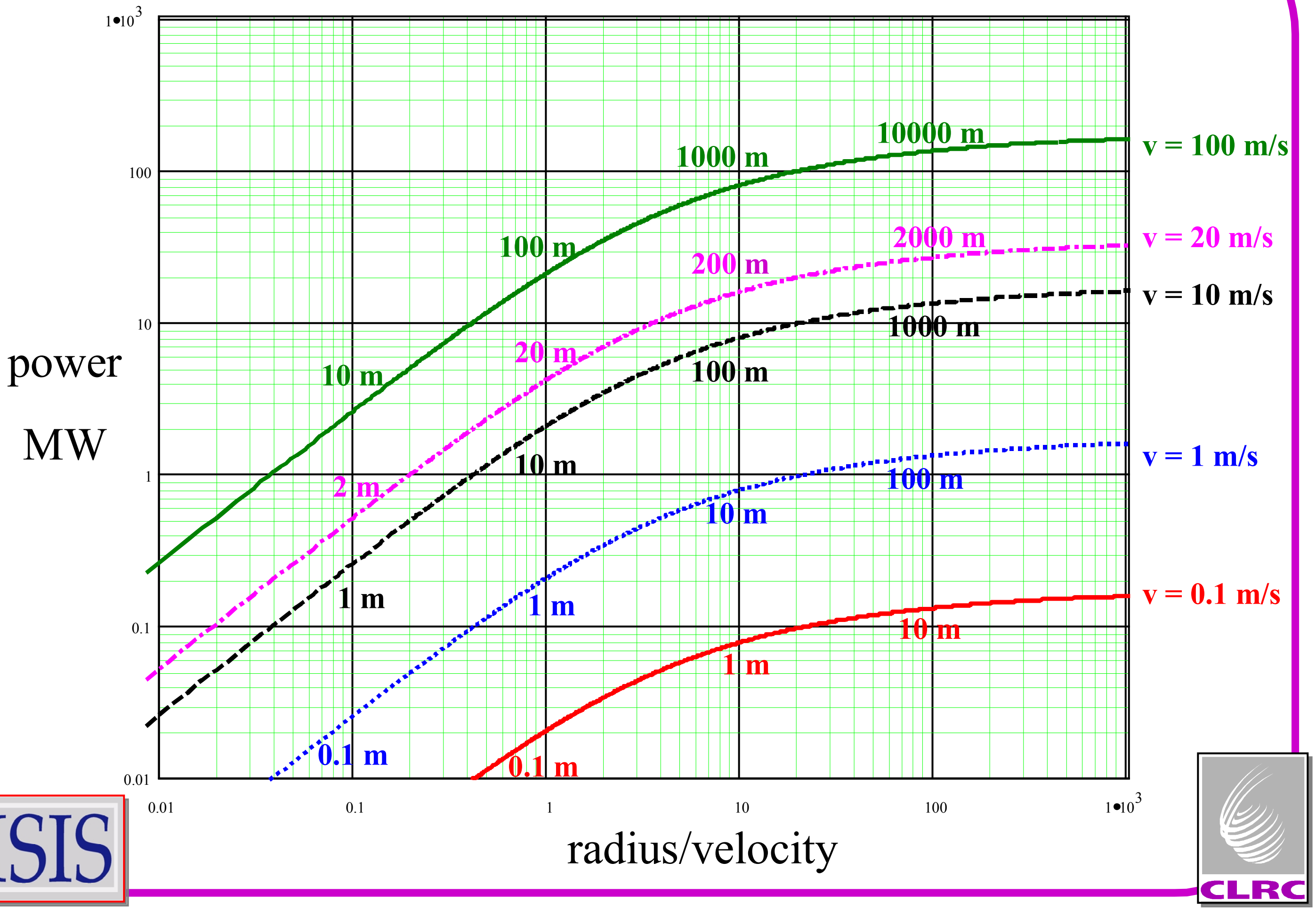
Where: r = the radius of the target section (1 cm)
l = the effective length of the target in the beam at any one time (20 cm)
ε = the thermal emissivity (0.3)
σ = Stefan's constant ($5.67\text{x}10^{-12}$ W cm^{-2} K^{-4})
g = geometry factor (1)
S = specific heat (Ta - 0.14 J g^{-1})
ρ = density (Ta - 16.7 g cm^{-3})
V = peripheral velocity of the toroid (cm/s)
T = temperature (K)
T_e = the temperature of the enclosure (300 K)
T_0 = the temperature of the target entering the beam (K)

Temperature Fall

due to thermal radiation from a 2 cm diameter tantalum bar from 2500 K to an enclosure at 300 K



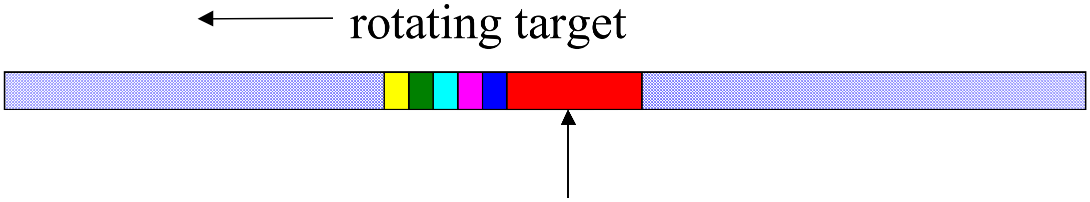
POWER DISSIPATION



PULSED EFFECTS

The proton beam has a very short pulse length (~1 ns) at 100 Hz rate.

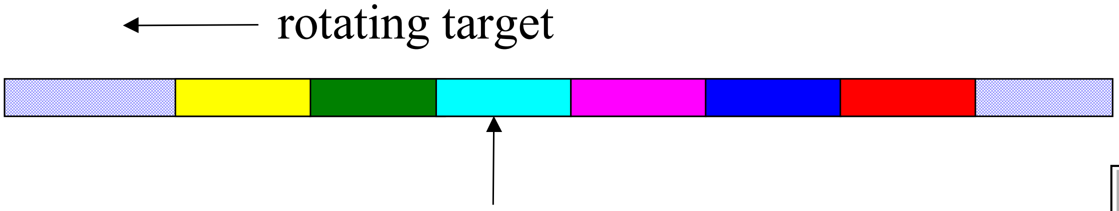
If the target rotation is slow - the areas illuminated by the pulses overlap



← rotating target

individual overlapping beam pulses on the target, 20 cm long

As the rotation gets faster the areas illuminated by each pulse separate until at v = 20 m/s they just touch.

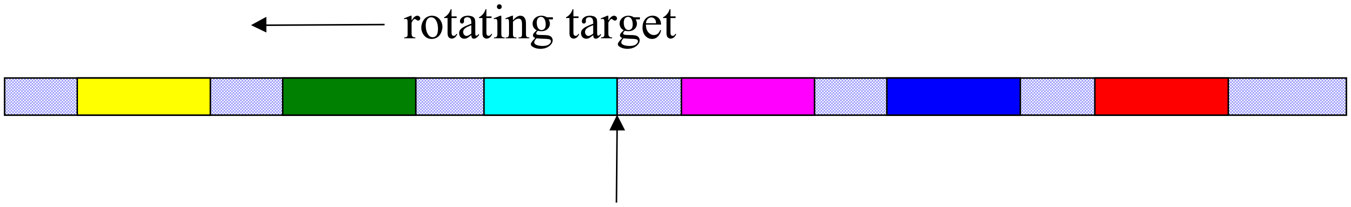


← rotating target

individual beam pulses on the target

PULSED EFFECTS

At speeds greater than 20 m/s the areas of each pulse separate



rotating target

individual beam pulses on the target

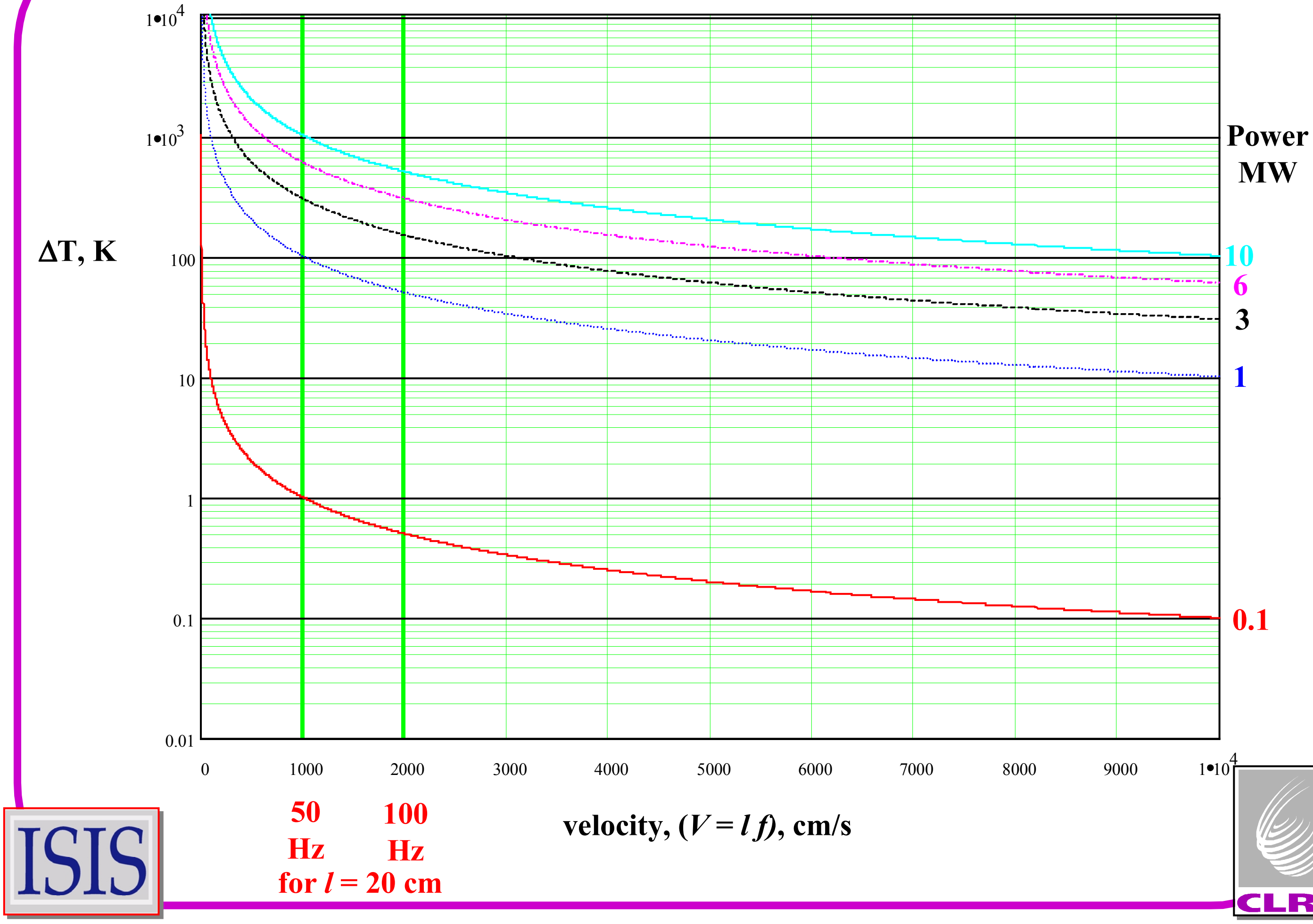
There is no point in getting into this regime since the target radius and velocity are larger than is necessary for optimum power dissipation.

The maximum power at a pulse repetition rate *f* is:

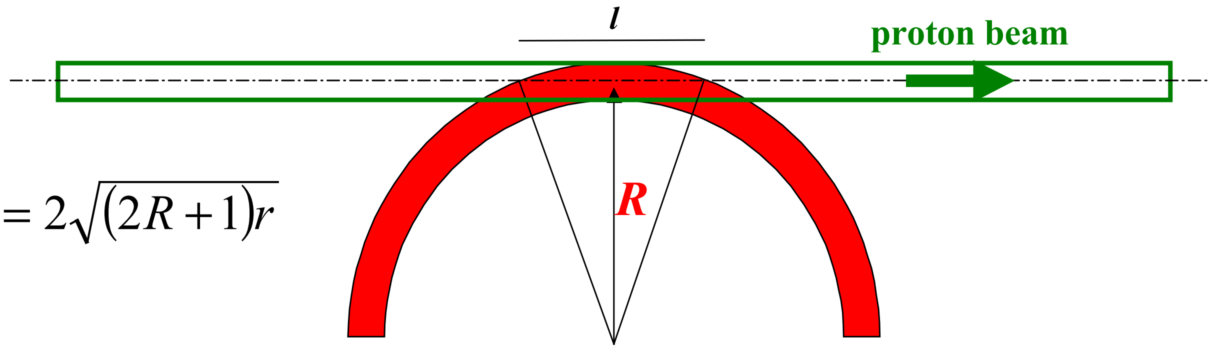
$$\mathbf{W = 0.322 \cdot f}$$

$$\mathbf{W = 32\ MW\ at\ 100\ Hz}$$

Temperature Rise v Velocity at Different Powers



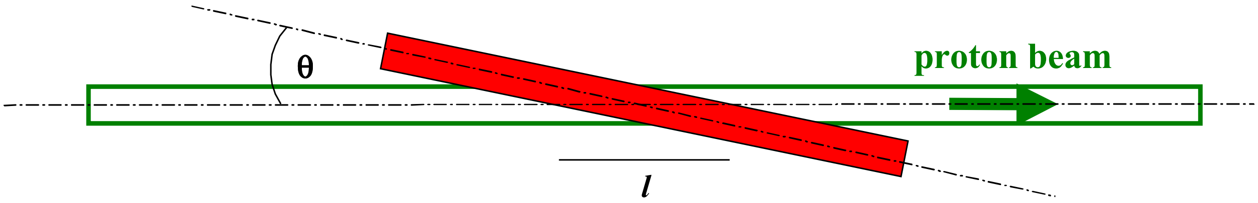
Target Length



$$l = 2\sqrt{(2R+1)r}$$

With l =20 cm, r =1 cm, R must be 45 cm - rather restrictive.

Better to tilt the plane of the toroid with respect to the proton beam centre line:



$$\theta \approx \frac{2r}{l}$$

θ = 1/10 radians = 5.7 degrees