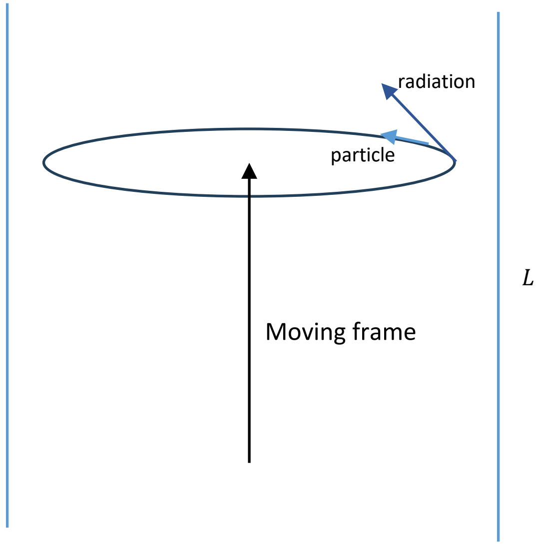
SI in the solenoid of the Test Stand

Goals and methods



Two methods of $T_\perp$ measurement:

- P_1 (radiating power)
- w_c (radiation frequency)

In moving longitudinally frame:

usual synchrotron radiation with really low gamma ($\gamma_\perp \sim 1$):

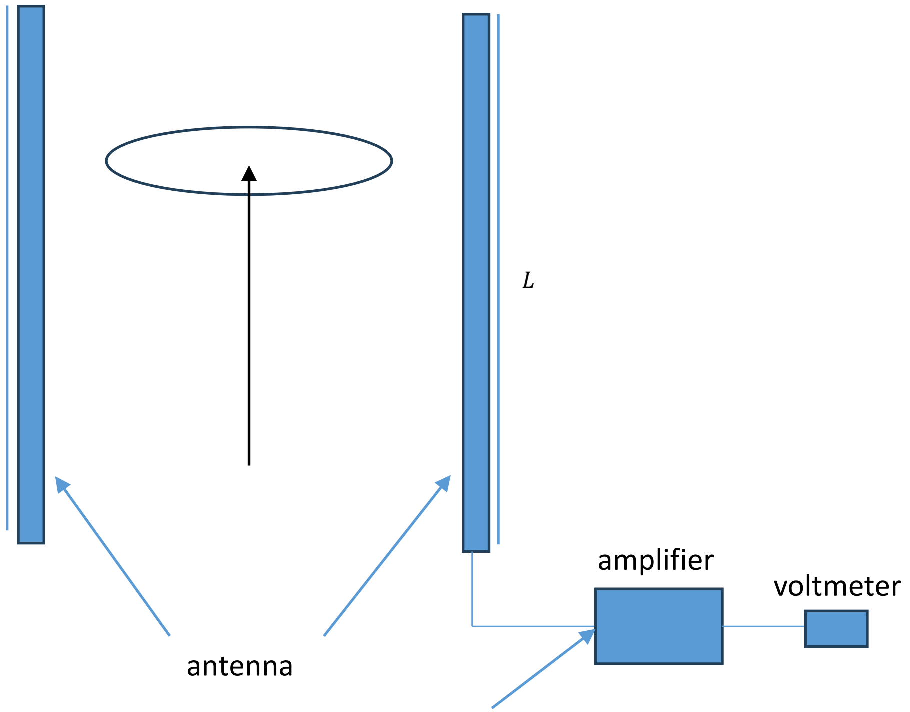
$$P_1 = \frac{2}{3}\frac{mr_e}{c}\gamma_\perp^4 w_c^2 v_\perp^2 = \frac{2}{3}\frac{mr_e}{c} w_c^2 \frac{2eT_\perp[\mathrm{eV}]}{m}$$

$$w_0 = \frac{eH}{m}$$

In laboratory frame:

$$w_c(\mathrm{mean}) = \gamma w_0 = \gamma\frac{eH}{m} = \left(1 + \frac{T_\perp}{mc^2}\right)\frac{eH}{m}$$

Experimental setup



Johnson–Nyquist Noise generated:

$$\frac{dW}{d\nu}_{noise} = KT = 40\ 10^{-22}\ \mathrm{W/Hz}$$

- Tuning the antenna → scanning through the spectrum
- Direct measurement of the power

Signal Prediction (Test Stand)

Spectrum ($w = n\, w_c$):

$$P_n = n\omega_c \frac{e^2}{\rho}\left[2\beta_\perp^2 J'_{2n}(2n\beta) - (1-\beta^2)\int_0^{2n\beta_\perp} J_{2n}(x)\, dx\right]$$

Low transverse energy → $n = 1$

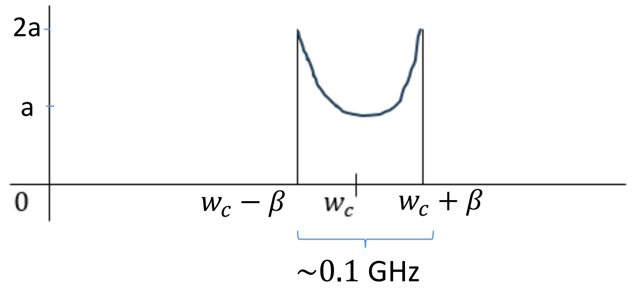
$$w_c = \frac{eH}{m} = \frac{1.6\ 10^{-19}\ 0.025}{9.1\ 10^{-31}} = 4.396\ 10^9 \mathrm{Hz}$$

Radiation is incoherent

$$P_{collected} = \underbrace{P_1 \frac{L}{\beta_\parallel c}}_{\text{energy collected by antenna from 1 electron}} \underbrace{I_{beam}[\mathrm{A}]\frac{1}{e}}_{\text{Electron flux}} = 1.1\ 10^{-13}\ \mathrm{W}$$

In laboratory frame:

$$\frac{dP}{d\nu}\left[\frac{\mathrm{W}}{\mathrm{Hz}}\right] = 7.74\ 10^{-11}\left[1 + \frac{1}{\beta_\parallel^2}\left(1 - \frac{w'}{w_c}\right)^2\right] I_{beam}[\mathrm{A}] T_\perp[\mathrm{eV}]$$



$$\frac{dP}{d\nu}_{mean}\left[\frac{\mathrm{W}}{\mathrm{Hz}}\right] = \frac{P_{collected}}{\Delta\nu} \approx 10.8\ 10^{-22}\mathrm{J}$$

Noise - 40

→ **Signal-to-noise ~0.25**

How to improve

Parameter	IOTA	Test Stand
H[T]	0.1	0.025
L[m]	0.7	0.5
$T_{\perp}$[eV]	0.1	0.1
$E_{\parallel}$ [keV]	1.36	1.36
I_{beam}[A]	0.1	0.1
w_c[GHz]	17.6	4.4
$P_{collected}[10^{-13}$ W]	24.8	1.1
Δν[GHz]	0.4	0.1
$\frac{dP}{df}[10^{-22}\ \mathrm{W/Hz}]$	60.82	10.8

IOTA SNR = 1.5

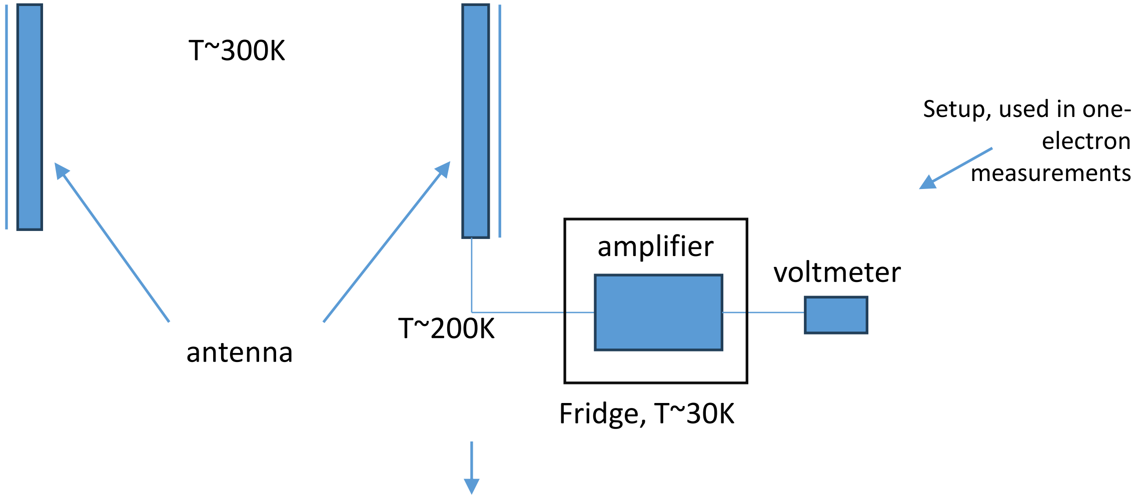
Test Stand SNR = 0.25

We assumed:

- large antenna – full solenoid enveloped
- Perfect receiving (no loss)

What can be done:

1) Increase the magnetic field: $\frac{dW}{d\nu} \sim B$
2) Increase the solenoid length: $\frac{dW}{d\nu} \sim L$
3) Increase the beam current: $\frac{dW}{d\nu} \sim I_{beam}$
4) Reduce the beam energy: $\frac{dW}{d\nu} \sim \frac{1}{\beta_{\parallel}} \sim 1/\sqrt{E}$
5) Reduce the amplifier temperature: $\frac{dW}{d\nu} \sim \frac{1}{T}$



SNR (IOTA) ~ 15, Test Stand – 2.5

End of slide show, click to exit.

Thank you! Questions time.