Preparation for nTMM search

by regeneration at GP-SANS
(our next after summer 2023 HFIR experiment)

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$\boldsymbol{n}$TMM model assumes $\boldsymbol{\Delta m = 0}$

System (n, n') is in Center of Mass $KE = 0$, absorption is absent $W = 0$

$$\hat{H}_{nn'} = \begin{pmatrix} V + \mu\boldsymbol{B\sigma} & \epsilon + \eta\boldsymbol{B\sigma} + \eta'\boldsymbol{B'\sigma} \\ \epsilon + \eta\boldsymbol{B\sigma} + \eta'\boldsymbol{B'\sigma} & V' + \mu'\boldsymbol{B'\sigma} \end{pmatrix}$$

MM Model requires $\mu = \mu'$ - neutron magnetic moment $= 60.3\,\frac{neV}{T}$
and $\eta' = \eta = \kappa\mu$ - transition magnetic moment nTMM $\eta \ll \mu$; κ – is unknown
our goal to search for $\kappa = \eta/\mu \leq 10^{-5}$

Let's simplify the case by considering $B' = 0$ and $V' = 0$
and only one polarization of neutrons

$$\boxed{\hat{H} = \begin{pmatrix} \mathrm{V} - \mu B & \eta B \\ \eta B & 0 \end{pmatrix}}$$

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On the Neutron Transition Magnetic Moment

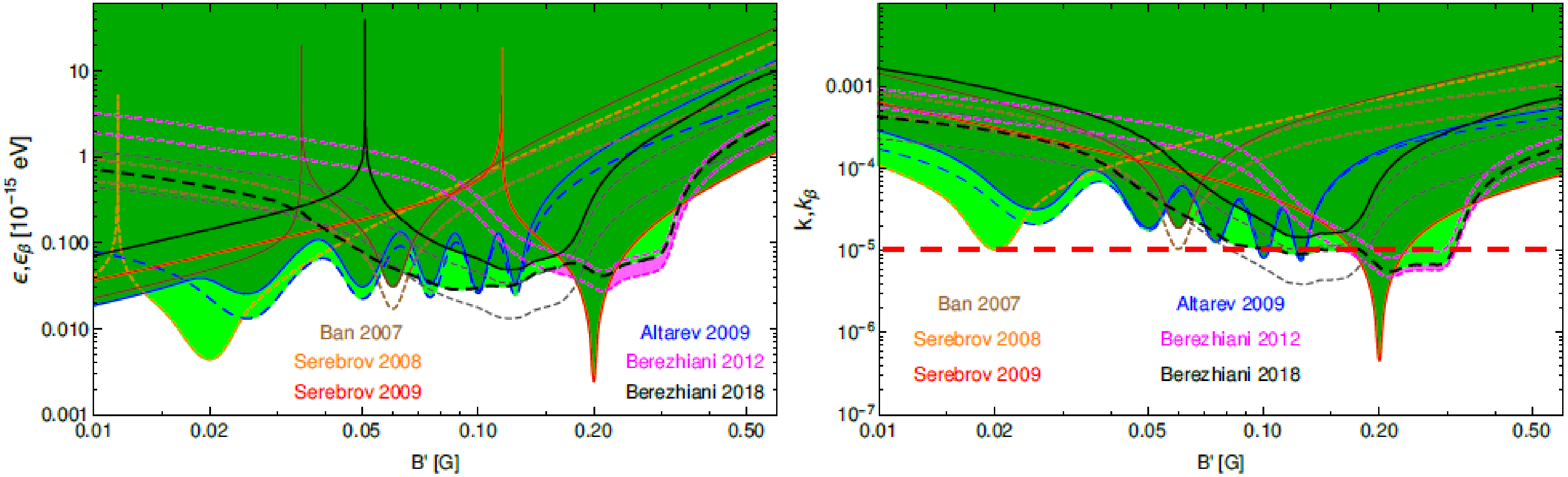


Figure 2. Upper limits for the oscillation parameters ε, ε_β assuming $\kappa = 0$ (**left panel**) and κ, κ_β assuming $\varepsilon = 0$ (**right panel**) as a function of the mirror magnetic field B'. The parameter areas excluded at 95 % C.L. by the experiments [49–54] for $\varepsilon(\kappa)$ are confined by solid curves of respective colors and are shaded in dark green, and for $\varepsilon_\beta(\kappa_\beta)$ are confined by dashed curves of respective colors and shaded by light green. Dashed pink curves confine the parameter area which can be relevant for 5.2σ anomaly in A_B reported in Ref. [55], and its part still not excluded by other data is shaded in pink. Let us remark, that the exclusion areas are obtained by assuming that the magnitude of mirror field $\mathbf{B}'$ and/or its direction with respect to the laboratory site remained unchanged during several years of time lapse between experiments [49–54] which however might not be the case.

Idea of TMM measurement

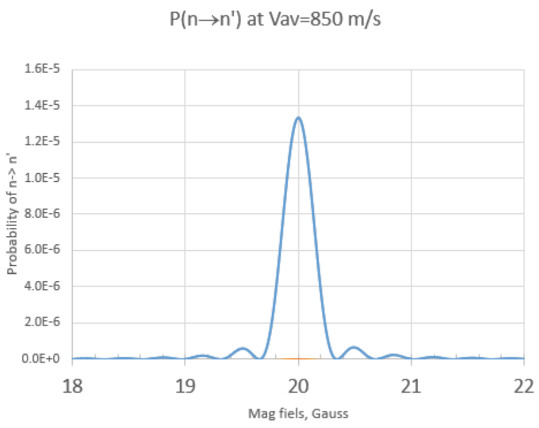
We will have not vacuum but air STP environment and B

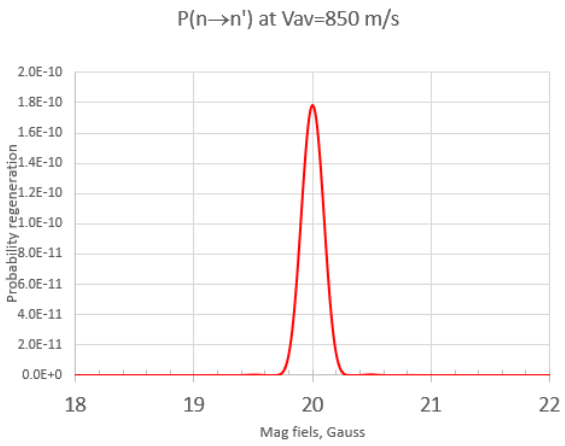
$$\mathcal{H} = \begin{pmatrix} V-\mu B & \eta B \\ \eta B & 0 \end{pmatrix}$$

B will be varied to have a resonance at $\mu B = V$ for one of polarizations

$$P_{nn'}(t) = \frac{(\eta B)^2}{\Omega^2} sin^2(\Omega t/\hbar) \qquad \Omega = \sqrt{\left(\frac{V-\mu B}{2}\right)^2 + (\eta B)^2}$$

In resonance $\Omega = \eta B$ *and* $P_{nn'}(t) = sin^2(\eta B t/\hbar)$





Position of the peak is in principle known $B = V_{air}/\mu_n$

$$V_{air(STP)} \approx 0.120\, neV$$

$$\mu B = \mu \cdot (20G) = 0.120\, neV$$

Our goal to reach $\kappa < 10^{-5}$

$$\Omega = \eta B = \kappa \mu B = 10^{-5} \cdot 0.120\, neV = \\ = 1.2 \times 10^{-15} eV$$

Time of flight 1.7 m $\Delta t \approx 2 \times 10^{-3} s$

$$P_{nn'}(\Delta t) = \left(\frac{1.210^{-15} \cdot 210^{-3}}{6.610^{-16}}\right)^2 \\ \approx 1.3 \times 10^{-5}$$

Collimated GPSANS 4x4 beam intensity 4.6$\times$ 10^9 s^{-1}
(9$\times$ 10^8 for aperture 2 cm dia)

Regeneration effect in the detector $\approx$ 0.78 n/s at peak with $\kappa = 10^{-5}$

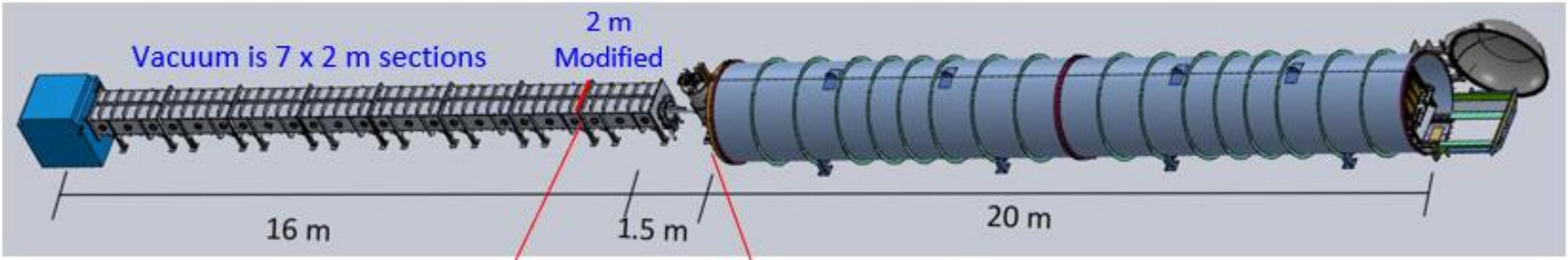
What is needed in theory study

1. $V_{air(STP)} \approx 0.120\, neV$ need to be calculated with high accuracy as the function of T, p, and humidity

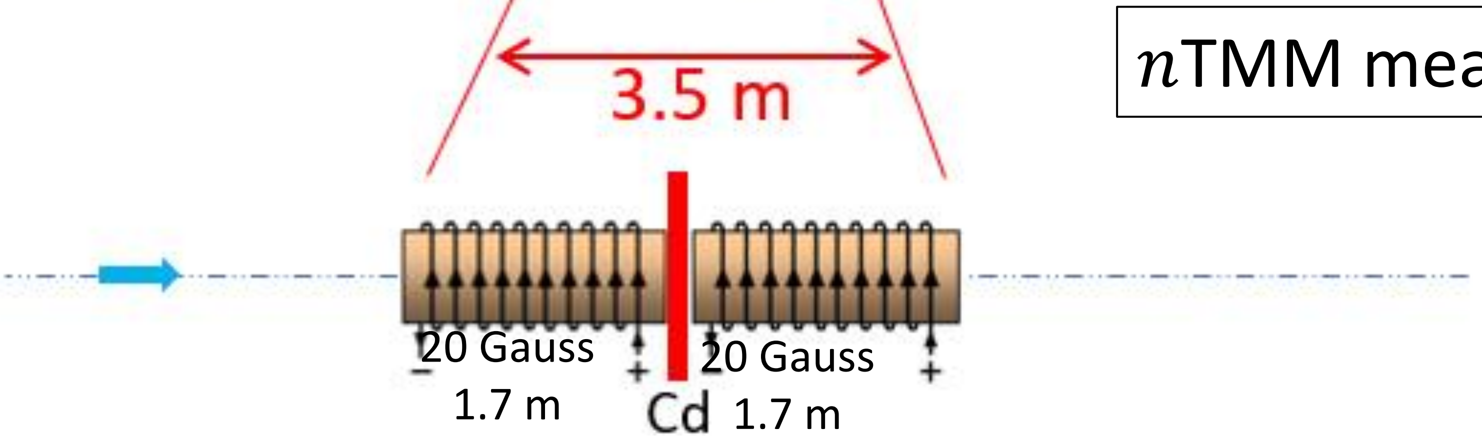
2. Effect of Cd absorber on further regeneration (evolution calculation).

3. Include in calculation the air and Cd absorption and scattering

4. Include effect of mirror B' and V' and ϵ



nTMM measurement scheme

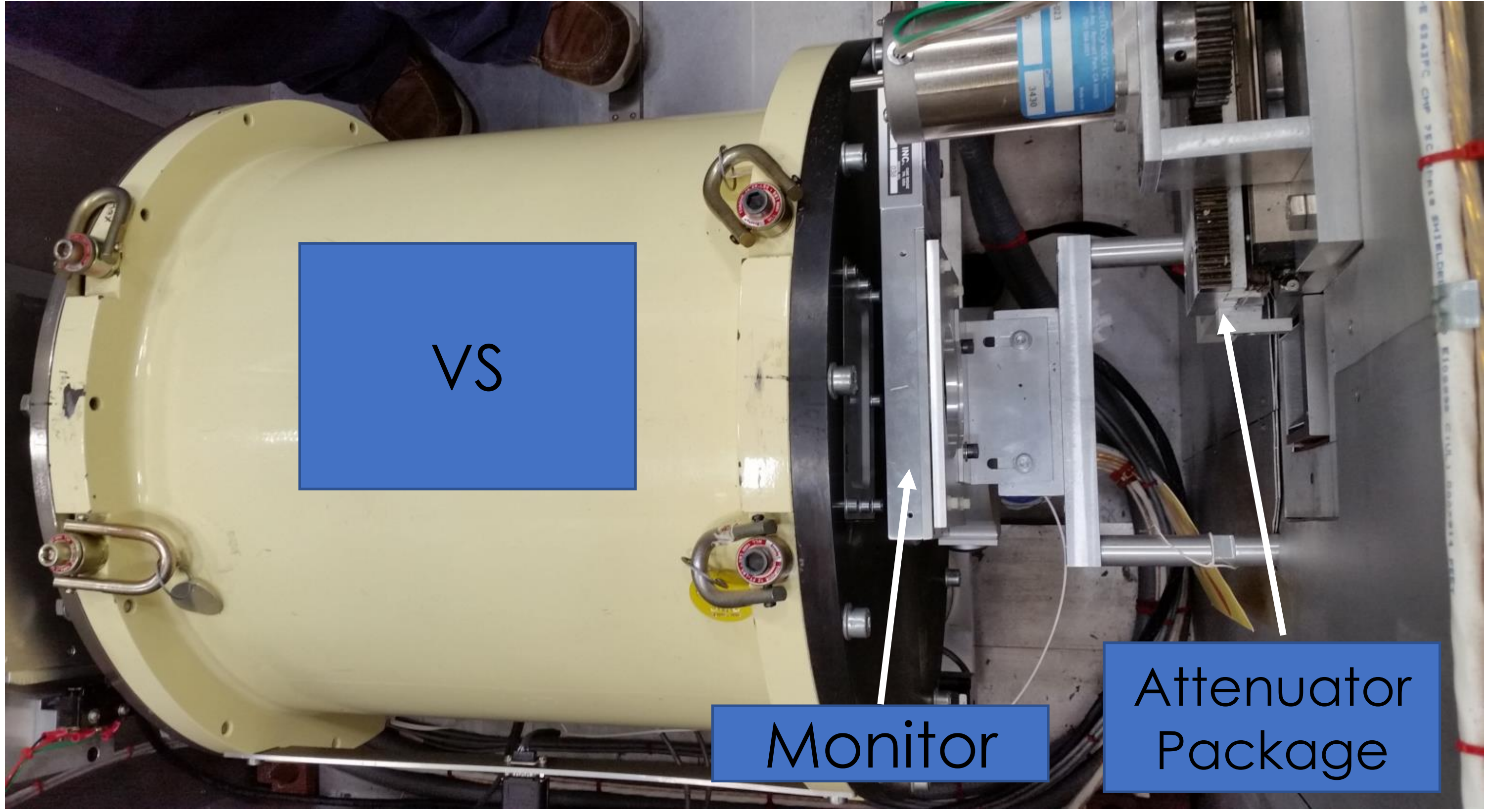


Two scenarios for magnets installation

1. replace last 2-m guide section with “experimental table” to be constructed. First magnet is on the table.
2. remove last guide section and install both magnets on the supports (to be constructed) – no table

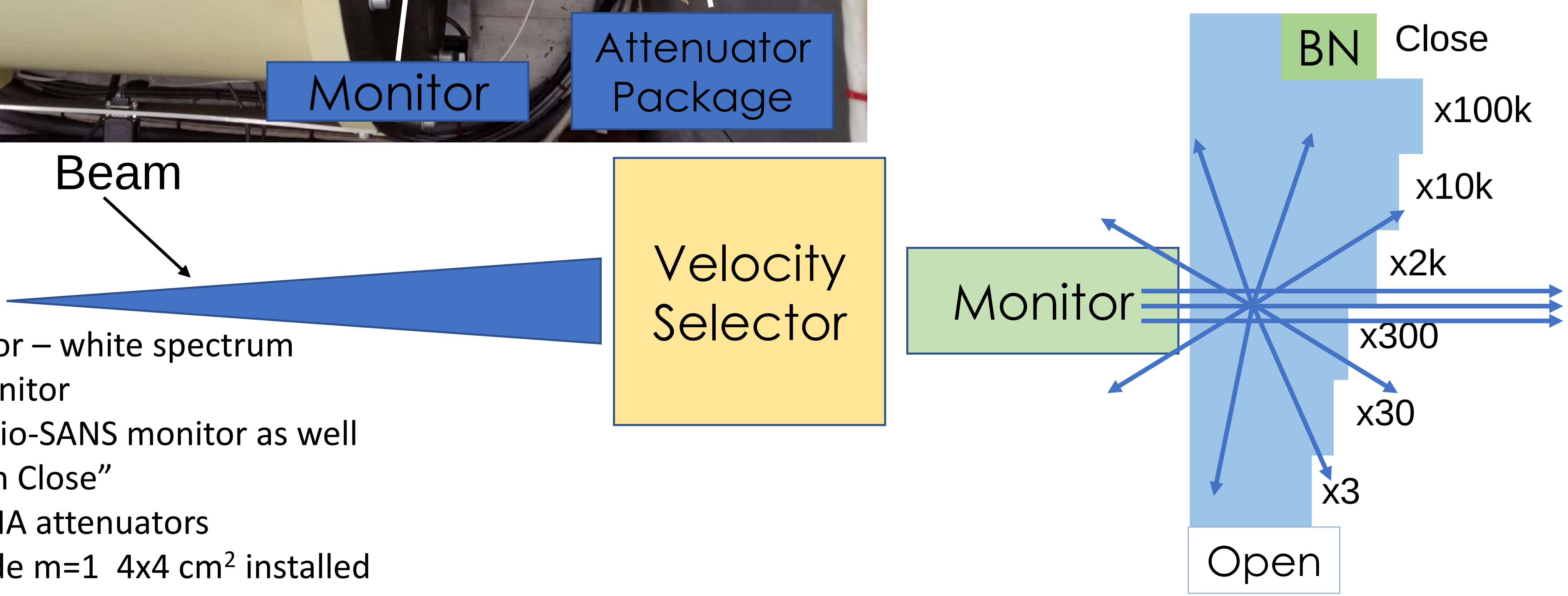
Need engineering support for accurate dimensions	and for the design of “experimental table”
Both magnets supports can be constructed at UT	Funds for the experimental table construction ?

In UT NP budget I have money for 2 magnets and supports construction



Attenuator Package:
Gray is varying thickness of PMMA
Pink is boron nitride

When we are in any position other than open, we get backscattering of the beam in the monitor.



We will use:

- No velocity selector – white spectrum
- Will use beam monitor
- Will need to use Bio-SANS monitor as well
- Will use "BN Beam Close"
- Will not use PMMA attenuators
- 14 m neutron guide m=1 4x4 cm^2 installed

Beam simulations Q: is it latest McStas files?

Lisa's McStas files generated on ~ 12 June 2021 :

(1) **CG2_Collimator_Guide_8_output.txt** with 8,575,528 lines or ~ 850 MB, $\bar{v}{\sim}850\ m/s$

(2) **CG2_velocity_selector_output.txt** with 10,033,399 lines or ~ 1 GB

- For nTMM search we'll will need 14 m - guided beam with full $4 \times 4\ \mathrm{cm}^2$ opening
- We will assume that 16-m McStas beam simulations will be good for 14-m guide.
- Guided files shows beam intensity (sum of weights) 1.95×10^{10} n/s ($4 \times 4\ \mathrm{cm}^2$)

Intensity calibration for aperture 20 mm (Matt, James)

Beam Intensity Measurements:

-Lowell Beam:	9.93 * 10^8 neutrons/s
-Au Foil:	7.4 * 10^8 neutrons/s
-Average Intensity:	8.7 * 10^8 neutrons/s
-Estimated Error:	1.3 * 10^8 neutrons/s
-Relative Error:	15%

→ extrapolating to 4x4 aperture beam intensity

$$\sim 4.43 \times 10^9\ n/s$$

Beam size / Magnet diameter

	X, cm	Y, cm	R,cm
Collimator end	± 2.0	± 2.0	
End of Mag 1	± 3.2	± 3.8	<4.5
End Magnet 2	± 4.6	± 5.8	<6.5
Detector @ 20 m	$\pm 20.$	$-32 + 28$	<35
Detector @ 6 m	$\pm 10.$	$-13 + 12$	<15

For the magnets we can use PVC tube with dia ~ 20 cm

Magnet design parameters :

Number of magnets	2
Length	1.7 m
Tube diameter (OD or ID)	8”
Tube wall	0.25”
Grove size machined	2.1x3 mm^2
Grove step period	4 mm
Nominal field required	20 Gauss
Designed for max field	31.5 Gauss
Required current	10 Amperes

PVC tube cost 8”x10’	2x$340
UT lathe machine	66” long = 167.6 cm
Copper wire 12 AWG (10A)	2 spools x 1000 ft = $670
Wire 12 AWG diameter	2.05 mm
12 AWG resistance/1000 ft	1.6 Ohms
Supports for two magnets	can be made at UT
Support for beam catcher	can be made at UT

Magnet power supply

https://www.ato.com/20a-dc-power-supply?affiliate=shopping&gclid=EAIaIQobChMIyabjh53y_AIVTBZMCh1RuwoVEAQYBCABEgL7PPD_BwE

20A 30V 600W Adjustable Linear DC Power Supply

★★★★★
5 out of 5 based on 1 reviews | Write a review

$528.46

600W dual output power supply is a DC regulated power supply with continuously adjustable 0-30V output voltage and 0-20A current, 4-digit LED display, precise accuracy of 0.001A and 0.001V. Featuring compact size and reliability, it is a great tool for notebook, mobile phone, flat panel maintenance, etc.

SKU: ATO-DCPS-20

Input Voltage * 110V AC

We need remote control and status read of the power supply

Other magnet issues

- We do not have magnetometers (like Bartington) for 20 Gauss

- Possibly can borrow magnetometer
  for the lab calibration Field vs Current

- External environmental field in the HFIR experimental hall
  is not uniform. Magnets can be wrapped from outside
  with $\mu -$ metal tape (Ref: Chris Crawford)

- Do we need construction material review and certification
  for beam use at HFIR? (Cu wire, hard PVC)?

https://www.lairdconnect.com/iot-devices/lorawan-iot-devices/sentrius-rs1xx-lora-enabled-sensors?utm_source=Electronic+Design&utm_medium=Product+Spotlight&utm_campaign=RS1xx

Using air at STP as an active media
We need to monitor near the magnets

1. Temperature
2. Atm. Pressure
3. Humidity

E.g.

GP-SANS Detector

- Nominal z-position at 20 m
- Better position is 6 m (if background allows)
- We can use additional shielding around the magnet and beam absorber (Cd sheets, Lawrence)

- Detector thresholds higher than in previous runs (Matt)

DAQ

- Need to included magnets current control/ reading and temperature, pressure, humidity sensors

- Use Matt’s ASCII format files for GP- and BIO-SANS information integration

General formulas for mixed system $\begin{pmatrix} n \\ n' \end{pmatrix}$

$$\mathcal{H} = \begin{pmatrix} x & d \\ d & y \end{pmatrix}$$

If H is real Hermitian matrix with eigenvalues determining the energy levels for two oscillating components:

$$\lambda_{1,2} = \frac{x+y}{2} \pm \sqrt{\left(\frac{x-y}{2}\right)^2 + d^2}$$ -- energy eigenvalues

$$\omega = \frac{\lambda_1 - \lambda_2}{2} = \sqrt{\left(\frac{x-y}{2}\right)^2 + d^2}$$ oscillation frequency

$$P_{n\to n'}(t) = \frac{d^2}{\omega^2} sin^2(\omega t/\hbar)$$ general case solution

$$P_{n\to n'}(t) = \left(\frac{d\cdot t}{\hbar}\right)^2$$ in quasi-free condition $\frac{\omega t}{\hbar} \ll 1$

$$P_{n\to n'}(t) = \frac{d^2}{\omega^2}\cdot\frac{1}{2}$$ in high-frequency regime $\frac{\omega t}{\hbar} \gg 1$