Power Supplies for PXIE Cryomodules

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Fermilab

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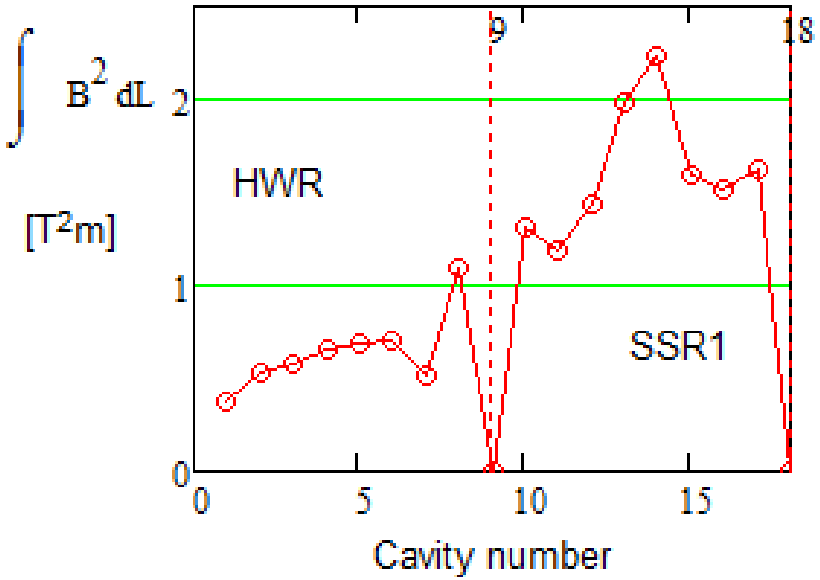
Focusing Strength of HWR & SSR1 Solenoids for PIP-II Optics and Corresponding Solenoid Currents



Focusing strength of focusing solenoids for nominal PIP-II optics

I_{HWR_k} = A

26.796
31.731
33.283
35.257
36.103
36.386
31.026
45.553

I_{SSR1_k} = A

37.42
35.496
39.024
45.973
48.646
41.162
40.093
41.483

Currents (in Amps) of focusing solenoids for nominal PIP-II optics

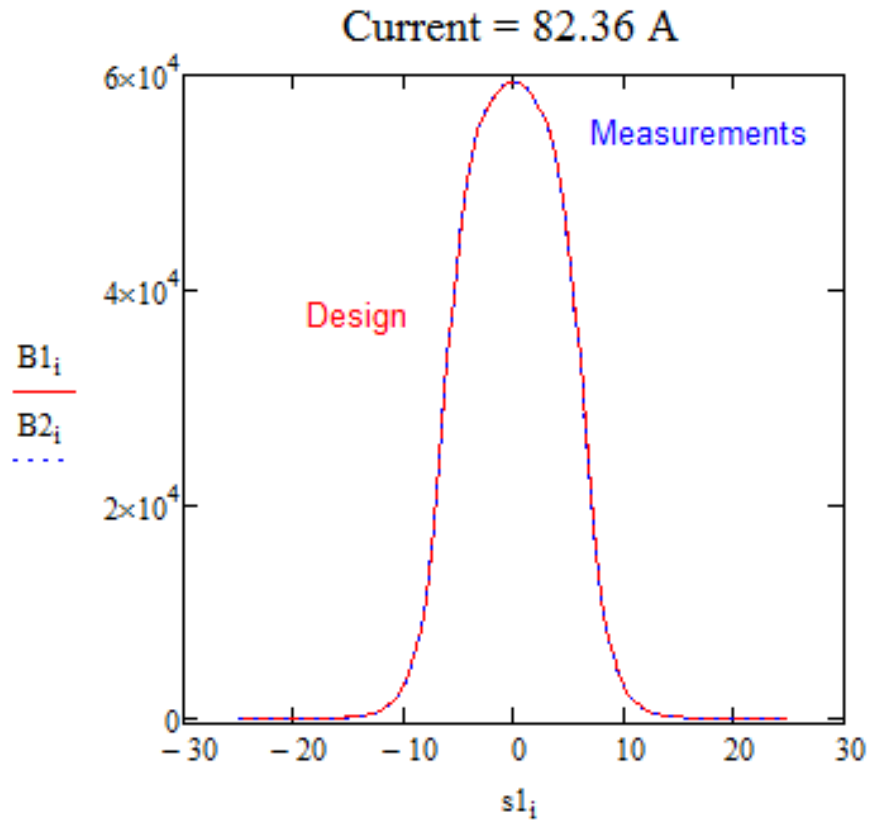
- Focusing strength of solenoid is proportional to its current squared

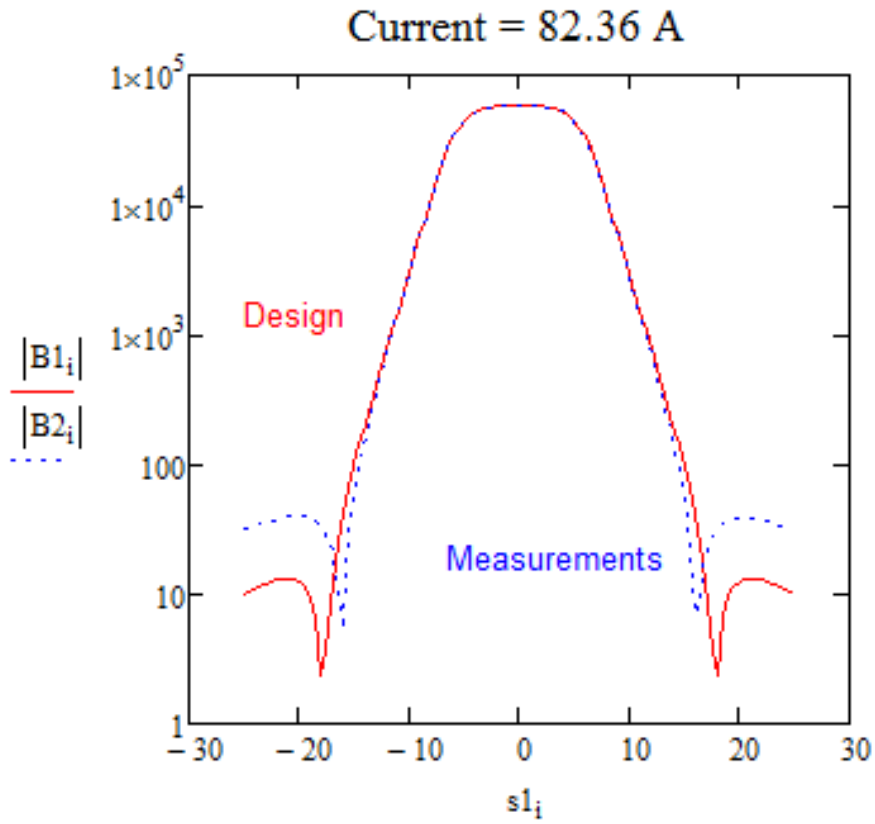
$$\frac{1}{F} = \frac{e^2 B_s{}^2 L_s}{4 p^2 c^2}$$

	HWR	SSR1
FRS required strength, T^2m	2	4
Solenoid current to achieve FRS strength, A	61.57	65.16

- 50 A power supplies are sufficient for both cryomodules

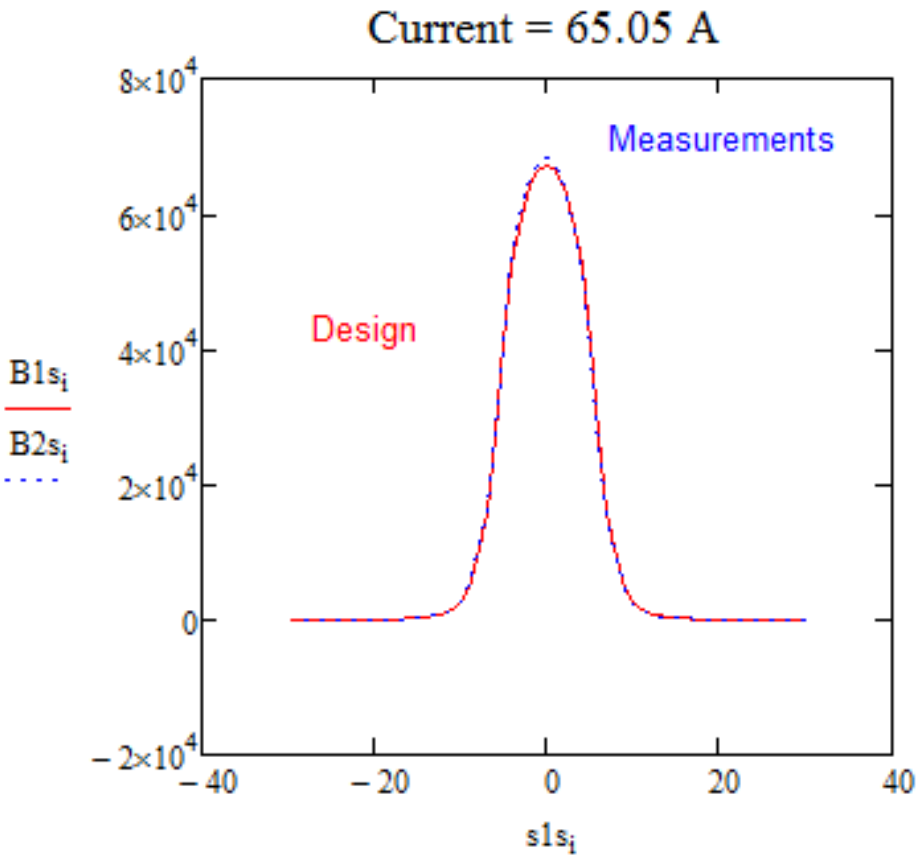
HWR Solenoid Test Results

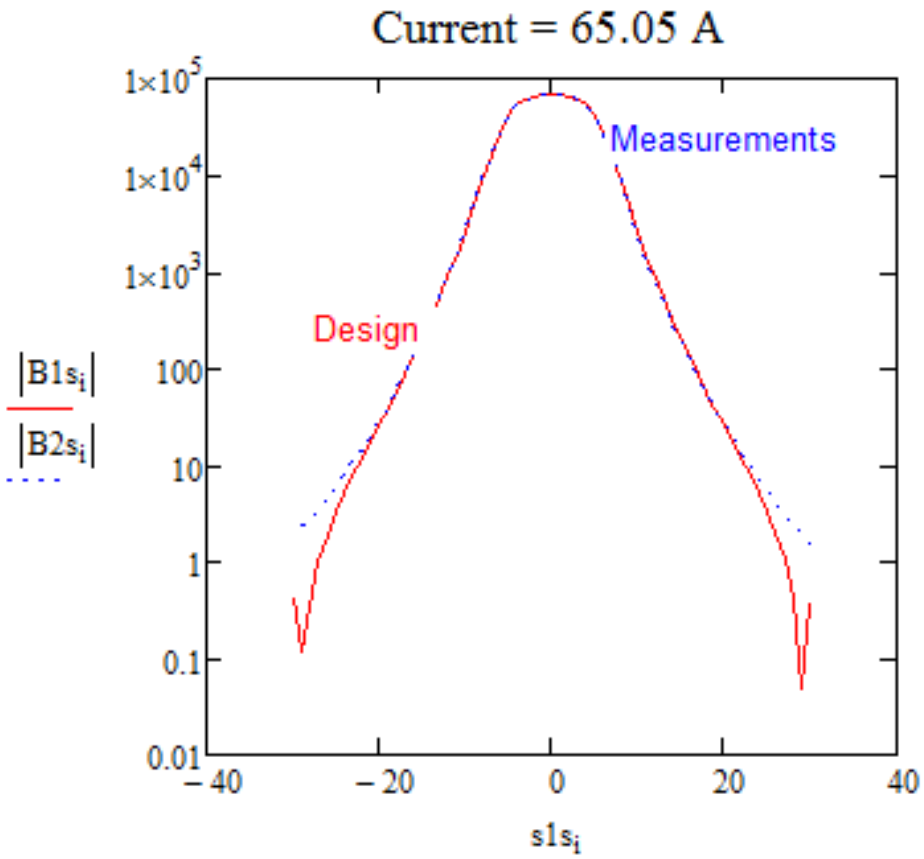




	HWR
Solenoid current	82.36 A
Peak magnetic field, B_o	5.935 T
Field integral, $\int BdL$	0.747 T m
Effective strength, $\int B^2 dL$	3.578 $T^2 m$
Effective Length, $\int BdL/B_o$	12.58 cm

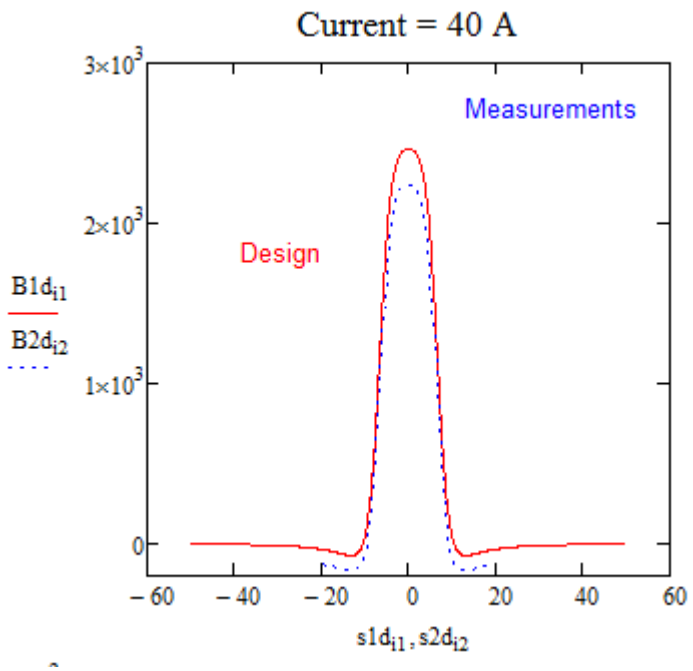
SSR1 Solenoid Test Results



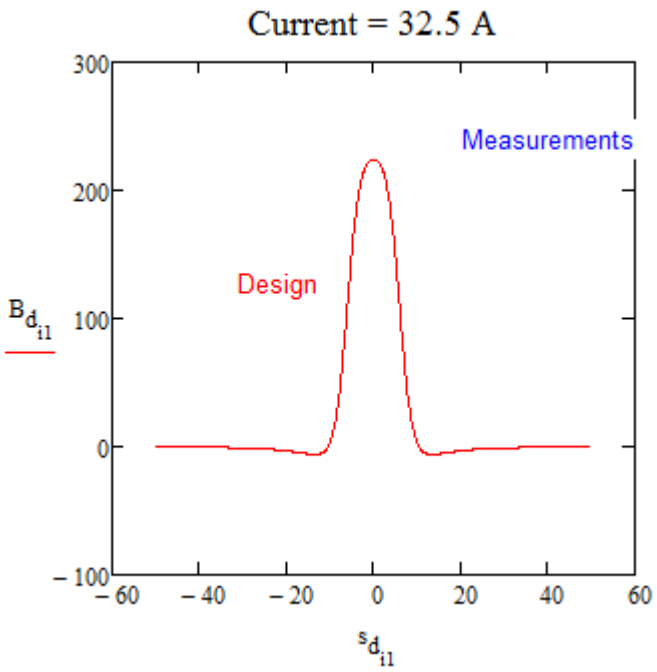


	SSR1
Solenoid current	65.05 A
Peak magnetic field, B_o	6.81 T
Field integral, $\int BdL$	0.762 T m
Effective strength, $\int B^2 dL$	3.986 T^2m
Effective Length, $\int BdL/B_o$	11.19 cm

Strength of the HWR and SSR1 Dipole Correctors



s [cm]



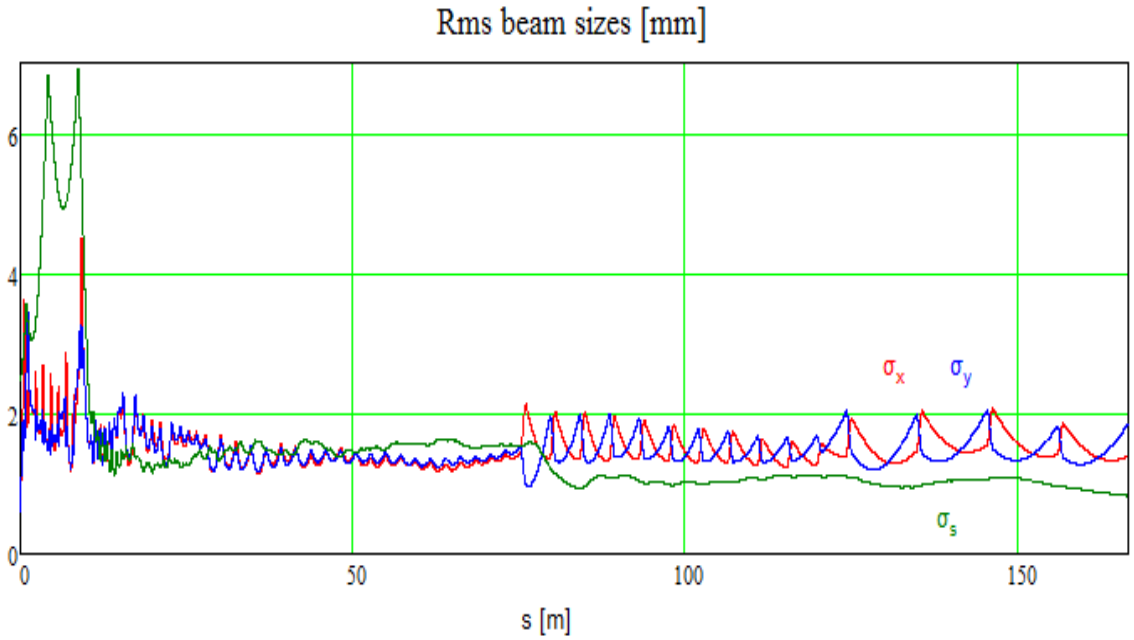
s [cm]

Dependence of corrector magnetic field (in Gauss) on distance along the axis for the HWR (left) and SSR1 (right) dipole correctors.

	HWR	SSR1
FRS required strength, mT m	2.5	2.5
Corrector current to achieve FRS strength, A	4	32.5
Solenoid angle which can be compensated by a corrector at FRS requirements for the solenoid and dipole corrector [mrad]	6.3	4.6

Required Accuracy/Ripple of Correctors

- RMS beam size ~1.5 mm
  - ⇨ rms beam motion at the linac end <0.3 mm (5% emittance growth)
- Optics measurements require accuracy <30 μm
  - ⇨ With 10 averages we obtain rms beam motion <100 μm



- There 40 correctors in PIP-II linac
  - Optimistically we can consider them uncorrelated 100/√40=16 μm
- Corrector at the FRS values excites 10 mm motion
  - ⇨Required rms relative accuracy of the corrector 16 μm/10 mm=$1.6 \cdot 10^{-3}$
- More accuracy is required if corrector ripple is coherent
- Finally we require:
  - Ripple <$\pm 1 \cdot 10^{-3}$ of maximum current
  - Regulation <$\pm 1 \cdot 10^{-3}$ of maximum current

Required Accuracy/Ripple of Solenoids

$$\frac{\delta\varepsilon}{\varepsilon} = \frac{\beta}{2}\frac{\delta F}{F^2} = \frac{\beta}{F}\frac{\delta I}{I} = 2\tan\left(\frac{\mu}{2}\right)\frac{\delta I}{I} \sim \frac{\delta I}{I}$$

- Assume 5% emittance growth due to lens current ripple
  - ⇨ For 40 lenses with uncorrelated ripple: $\delta I/I \sim 0.05/\sqrt{40}=0.01$
- Beam offsets with 1.5 mm will introduce comparable effect
- To avoid adverse effect of focusing ripple on optics measurements we require
  - Ripple $<\pm 1\cdot 10^{-3}$ of maximum current
  - Regulation $<\pm 1\cdot 10^{-3}$ of maximum current

Power supply requirements for the SC coils of HWR and SSR1 solenoids and correctors

	HWR		SSR1	
	Solenoids	Dipole correctors	Solenoids	Dipole correctors
Number of channels	8	16	4	16*
Minimum/Maximum current, A	-70/70	-5/5	-70/70	-50/50
Ripple, % of maximum current	±0.1♥	±0.1	±0.1♥	±0.1
Regulation, % of maximum current	±0.1♥	±0.1	±0.1♥	±0.1
Time required for change from minimum to maximum, s	20	1	20	1
Total inductance of all coils, mH	1083	80	3280‡	~2‡
Mutual inductance of other coils, mH	-	80	-	1/0.5‡

* Each coil has separate power supply to so that each plane corrector could be also used as skew-quad

♥ Accuracy near zero crossing is not required

‡ Numbers are obtained by rough estimate. More accurate values will follow.