Description of spreadsheet

Paul had given me a spreadsheet which calculates the

- electrical properties of the septum coils
  - Resistance
  - Voltage
  - Power
- Water cooling requirements
  - Water per coil
  - Flow rate
  - Pressure drop

The inputs to the calculations include the necessary $\int \vec{B} \cdot d\vec{\ell}$, conductor and water-cooling hole size, the number of turns and water circuits in each coil, as well as the resistive properties of copper.

Summary of inputs

	Ncoil	A	B	area	L/turn	Circuits
Coil1	16	4.2	4.8	20.16	360.3	2
coil2	48	8.4	7.2	60.48	388.2	6
coil3	48	8.4	7.2	60.48	380.6	6
	448					
SideA	0.95	cm		$t_{insulation}$ (cm)	0.010	cm
Sideb	1.15	cm				
				OD (cm)	0.670	
				A_{hole} (cm^2)	0.353	
				A_{cond} (cm^2)	1.093	
	water	1/8 pipe		A_{Cu} (cm^2)	0.740	
				ρ_{Cu} (Ω·cm)	1.80E-06	

α	0.00393
T (°C)	R (Ω)
20	1.7241
30	1.7634
40	1.8027
50	1.842
60	1.8813
70	1.9206
80	1.9599
90	1.9992
100	2.0385
110	2.0778
120	2.1171

Energy (GeV)	1.06	2.2
θ_{min} (degrees)	4.62	3

Estimate of $\int \vec{B} \cdot d\vec{\ell}$

- Uses this estimate of the bend angle and the beam energy

$$\alpha[rad] = \frac{\int \vec{B} \cdot d\vec{l}[T \cdot m]}{3.33\ E[GeV]}$$

IntB.dL Lerose, PREX?	
max	min
0.4581	0.4406

- The HRS minimum angle is 12.5° and thus the bend angle is either **7.9°** or **9.5°** for PREX and CREX, respectively
- The calculation of the $\int \vec{B} \cdot d\vec{\ell}$ for PREX and CREX as well as the current for PREX is then used to scale the current needed for CREX
- The total current is then used in the estimates of power and thus water cooling

Power Calculations

- Takes into account an “allowed” temperature rise to calculate the average resistance of the conductor per unit length
- Calculates the resistance per turn, then coil, then magnet based on the R/L of the conductor
- The voltage is then V=IR
- The power is P=IV

The only question about this calculation is what the minimum bend angle is in each experiment.

Water cooling calculations

- This is where it gets hard to understand the spreadsheet…
  - Assuming none of the values that are just numbers change
- He calculates the water flow per magnet for each "type" of coil $Flow\ rate, mag(gpm) = P_{type}/\Delta T_{allowed}/454/8 * 1000 * 60$
- Then he calculates the water flow per coil

$$Flow\ rate, coil\ (gpm) = Flow\ rate, mag(gpm)/4$$

- Then he calculates the water flow per circuit

$$Flow\ rate, circuit(gpm) = Flow\ rate, coil\ (gpm)/\#\ circuits/coil$$

- Then he calculates the pressure drop per 100ft

$$dP/100ft = 134.4 * (Flow\ rate, circuit(gpm)/2)^2$$

- Then he calculates the total pressure drop

$$dP = dP/100ft * (L_{circuit}/100) * (0.546/OD_{hole})^4$$

Summary of Results

	PREX	CREXa	CREXb
J	600	1501	858
A	323	323	564
NI	193536	484217	484217
IntB.dL tosca	0.4855	1.21	1.21
Coil1	12096	30264	17293
coil2	36288	90791	51880
coil3	0	0	51880
	193536	484217	484217
Current In PS	756	1891	1081
Voltage (V)	176	450	449
Current (A)	756	1891	1081
Power (kW)	133	851	486
flow rate (gal/min)	109.80	351.32	200.61
<Pressure drop> (psi?)	165.85	1697.89	183.89
Res/length	2.38E-06	2.44E-06	2.44E-06
Delta T	20	40	40

Volume flow rate

$$\frac{dV}{dt} = \frac{dm}{dt}\frac{1}{\rho} = \frac{1}{\rho}\frac{P}{c\Delta T_{allowed}}$$

$$= \frac{31.41kW\left(\frac{1000W}{1kW}\right)\left(\frac{1J/s}{W}\right)\left(\frac{60s}{1\ min}\right)\left(\frac{1\ gal}{3.785\ L}\right)\left(\frac{1000L}{m^3}\right)}{(1000\ kg/m^3)\big(4186J/(kg°C)\big)(20°C)}$$

$$= (0.375kg/s)\left(\frac{(1000)(60)}{(3785)}\right)$$

$$= 5.95gpm$$

$(454)(8) = 3632?$

In spreadsheet:

$$\frac{dV}{dt}(gpm) = \frac{P(1000)(60)}{\Delta T_{allowed}(454)(8)} = 25.94gpm$$

Pressure Drop

$$\Delta P = \frac{8\eta L}{\pi r^4}\frac{dV}{dt}$$

$$= \frac{8(1.79 \times 10^{-3} Pa \cdot s)(94.57ft)}{\pi(0.67cm/2)^4}(5.95gpm)$$

$$= 57\, psi$$

Use the 25.94 gpm, get 238 psi

In spreadsheet:

$$\Delta P = 134.4\left(\frac{dV/dt}{2}\right)^2\left(\frac{L}{100}\right)\left(\frac{0.546}{OD}\right)^4 = 147psi$$