Calculating Heat Loads of Normal Conducting ILC Magnets

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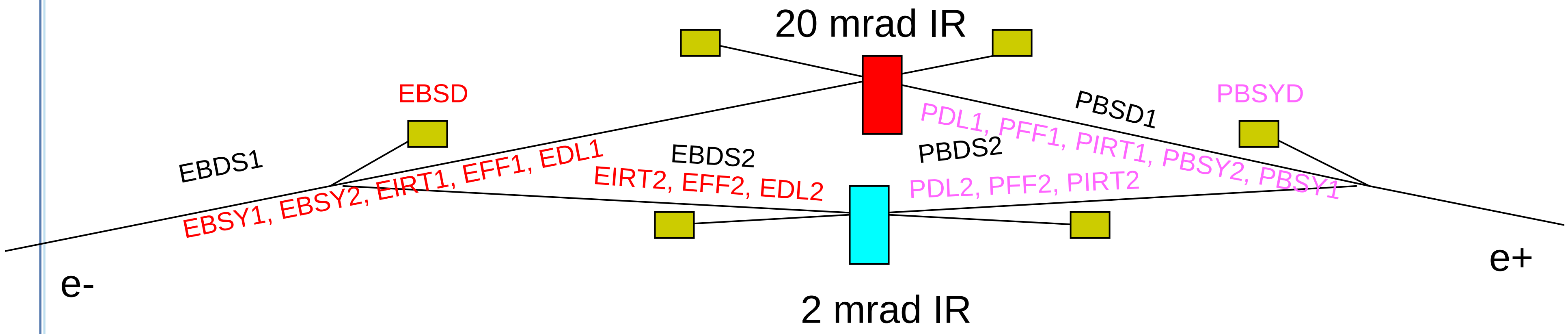
CFS wants to know: How much heat does each ILC magnet transmit into the tunnel air ?

- Depends on whether magnet coils are air-cooled or water cooled
- Depends on the ambient air temperature in the tunnel around the magnet
- Depends on how much cooling water (LCW) is passing through the coils
- Depends on temperature of incoming LCW
- Consider some BDS magnets to show how I've estimated the heat load

Names of various beamlines in BDS

EBDS0	EBDS1	EBDS2	PBDS0	PBDS1	PBDS2
EBSYD	EBSY1	EIRT2	PBSYD	PBSY1	PIRT2
	EBSY2	EFF2		PBSY2	PFF2
	EIRT1	EDL2		PIRT1	PDL2
	EFF1			PFF1	
	EDL1			PDL1	



Consider the dipoles in the dump line after the 20mr (=14mr) interaction point "EDL1" - amongst the most powerful and largest magnets in the ILC.

Assumptions used for heat load calculations

- If magnet is air-cooled then ALL its power is transmitted to the tunnel air. Most of the air-cooled magnets are below 35 watts.
- Some parameter values for water-cooled magnets in the BDS EDL1 line.
  - Incoming LCW temperature = 35°C (Magnet Systems decision)
  - Differential pressure across any magnet's cooling circuits in EDL1 = 180psi (Magnet Systems decision)
  - Ambient air temperature = ?. Discussion with Fred Asiri led to preliminary choice of 35°C, but would like to know what CFS is aiming for in the various ILC areas
- I have designed each magnet so the temp of the LCW passing through any magnet will increase by less than 25°C (Magnet Systems Design Standard) : $\Delta T < 25°C$

Method for calculating heat load to air

- I design the cooling circuits of a magnet so most of the heat generated by the electric current is removed in the LCW passing through them
- All parts of the magnet will eventually reach the average temperature of the LCW passing through its coils (have observed this on actual magnets)
  - Ave temp = [LCW(in) + LCW(out)]/2 = LCW(in) + $\Delta T/2$
- If the average temp of the magnet is more than the ambient air then it will convect heat into the air
- Calculate how much heat using text-book free convection equations for a box of known width, height and length at a known surface temp (= ave temp of magnet)

See examples in spreadsheets

Conclusions

- The fraction of a water-cooled magnet's power that is transmitted by free air convection is exceedingly small (if the magnet has been properly designed and its required LCW flow is provided)
  - E.g. for a 70.2kW, 2m long, dipole just 88 watts goes into the air (assuming air temp is constant at 35°C)
- Using Bellomo's choice of power cables for a string of 4 such dipoles, he calculates a heat loss of 17.4kW for 200m of #1250AWG cable carrying the 1119 amps to the 4 dipoles.
- Therefore the heat loss to the air from the power cables is much higher than from the magnet itself.