Insulation for Superconducting Magnets

Michael A. Green (LBNL)

Al Zeller (NSCL/MSU)

The Targetry Zone Radiation Problem

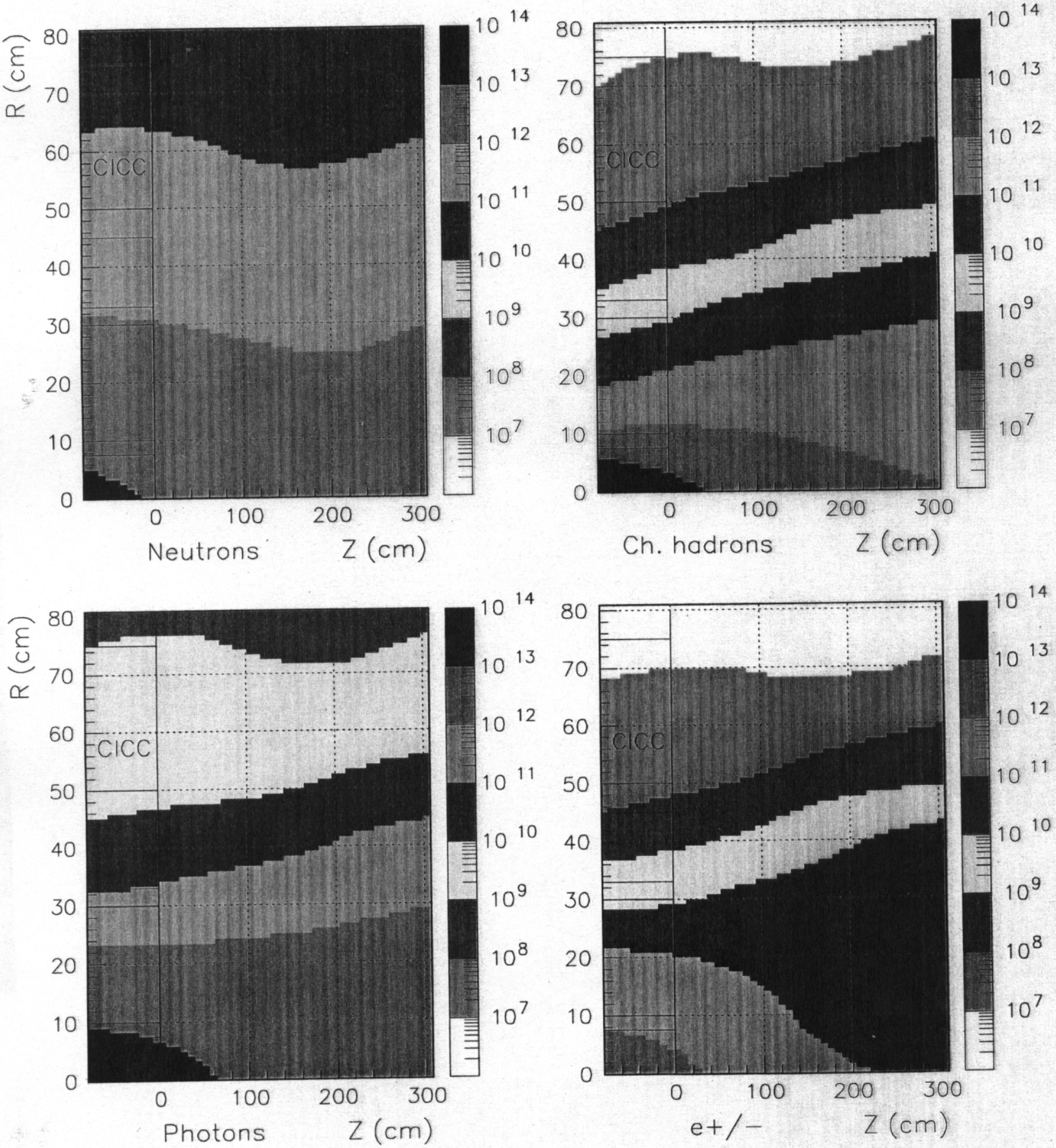
- Heating of the superconducting coils due to radiation energy affects the amount of helium refrigeration needed to cool the coils and the temperature at the high field point in the coils.

- Radiation damage to the insulating material in the coils is a severe problem. Resins and other plastics are badly affected.

- Radiation damage to the superconductor in the coils might be a problem particularly at the coil high field point.

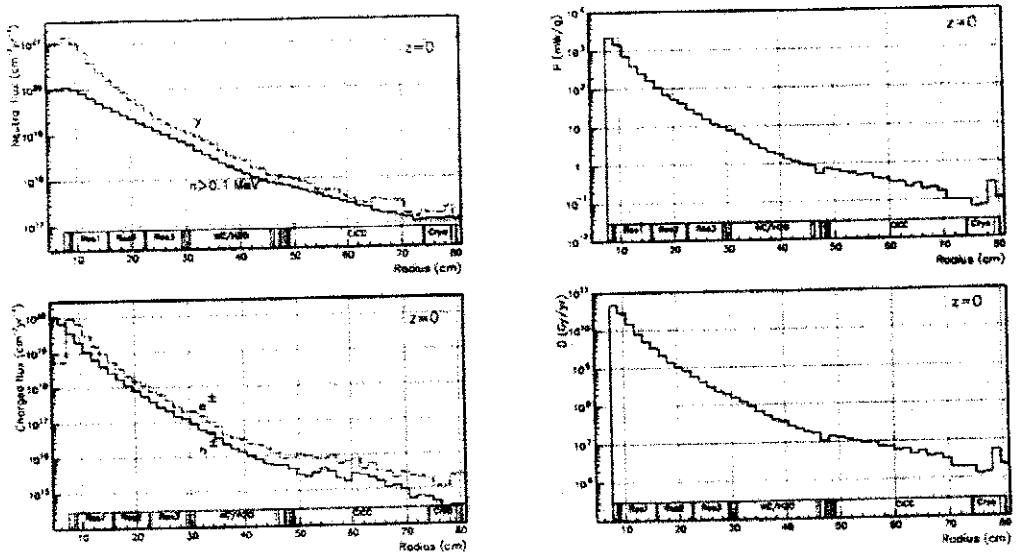
- Radiation damage to the superconductor matrix material is minimal because the superconductor and the coil insulation are damaged first.

99/12/21 16.18



16 GeV MuSR C-target/Solenoid at 3.75×10^{14} p/s, MARS φ-av flux ($cm^{-2}s^{-1}$)

MUSR TARGET STATION: FLUX AND DOSE



Radial distributions of particle fluxes ($cm^{-2}yr^{-1}$) (left) and power density (mW/g) and absorbed dose (Gy/yr) (right) at 1.5 MW

MARS predicts very high neutron fluxes in the target solenoids that determine component lifetime

Superconductor Heating

- A 1-meter long superconducting coil over the target with an inner radius of 0.49 m and an outer radius of 0.74 m will have about 1300 W of radiation heating within it. The down stream coils with an inner radius of 0.64 m will have about 400 W of heat deposited within them. In all cases heating is worst near the high field point in the coil.

- Forced cooled cable in conduit conductor coils may work in this heating environment.

- Moving the coils outward by 0.1 meters will reduce the coil heating by a factor of three. There is a trade off between coil inside diameter and the refrigeration needed to cool the coils.

Goals:

Find electrical insulation compatible with superconductor lifetime exposure limit (~500 Mgy)

Find material to "pot" CICC coil

CICC coils get their strength from the cable, so major requirement is dielectric strength

Inorganic insulators such as Al_2O_3 and $MgAl_2O_4$ (spinel) have excellent radiation resistance (>10^{11} Gy)

Epoxies

Probably best case is 10^8 Gy

Dielectric strength may be OK to 10^9, but would have to keep the powder and spacing intact

Table 3. Assumed Neutron Energy Distribution with Calculated Dose
(total neutrons: 7×10^{21} n/m^2 per year)

Fraction of Total Neutrons (%)	Energy (MeV)	Annual Dose (MGy)
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
20	5	7
20	1	4
20	0.5	3
10	0.1	1
Total (annual) dose		32

In epoxies:

Dose equivalent = fast neutron absorbed dose X "quality factor" + gamma dose

fast neutron "quality factor" = **10** (from energy deposition)

so

$(32X10)+10 = 3.3X10^8$ Gy/year

Inorganic probably better, but need some sort of potting method and a determination of how to make it work at 4 K

Materials exist, but a lot of engineering R&D needs to be done to make it work

Parameter	Maximum fast neutron fluence n/m^2, >0.1 MeV	
	Nb_3Sn	Nb_3(Ti or Ta)Sn
Critical temperature T_c		
<16 K	2×10^{22}	2×10^{22}
<5 K	5×10^{23}	3×10^{23}
Critical current I_c/I_0 at 14 T		
<0.9	1×10^{23}	9×10^{21}
<0.1	3×10^{23}	3×10^{22}
Critical field Bc_2, $H = 0$		
<16 T	2×10^{22}	–
<5 T	2×10^{23}	–
Limiting fluence estimated by Simon [3] for ITER 550–700 A/mm^2 specifications	–	3×10^{21}

Summary of Radiation Damage Issues

- The radiation heating for potted superconducting coils is close to the radiation damage limit for epoxy resins over the life of the targetry magnets. Improved resins may extend this limit to about $5x10^7$ to 10^8 Gy. At this level, liquid helium must be in the superconducting windings.
- Cable in conduit coils can operate at a heat limit that is ten times the radiation limit for resin based insulation systems. Inorganic insulation systems are probably needed in the target region unless these coils are moved radially outward.
- Damage to Nb-Ti in the coils is not an issue. The Nb_3Sn coils could be affected by radiation from neutrons.
- The copper matrix is not affected by radiation damage.