Neutron fluence effects on SC coils and comments

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YBCO

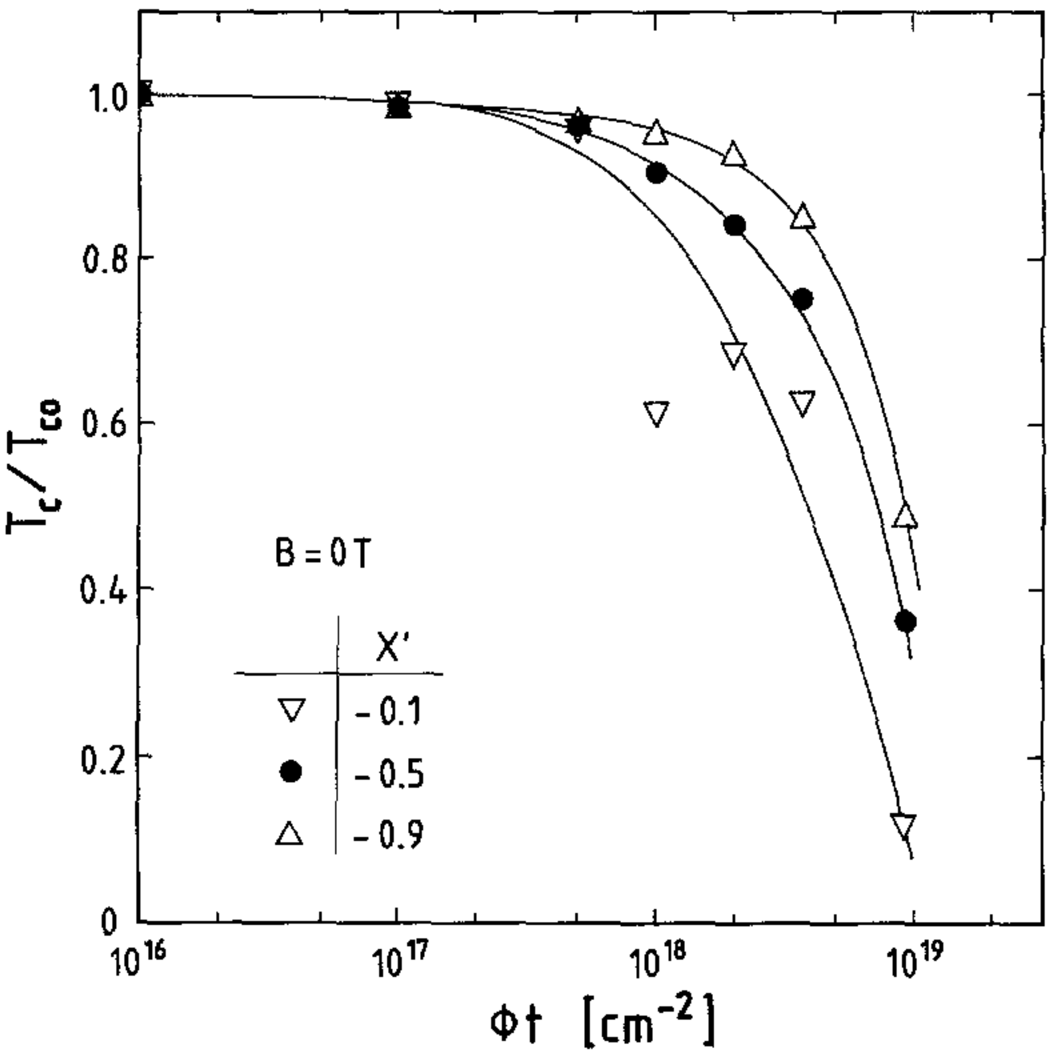


Fig. 2. Onset ($\chi' = -0.1$), midpoint ($\chi' = -0.5$) and downset ($\chi' = -0.9$) of the superconducting transition in zero field versus fast neutron fluence

Z. Phys. B – Condensed Matter 69, 167–171 (1987)

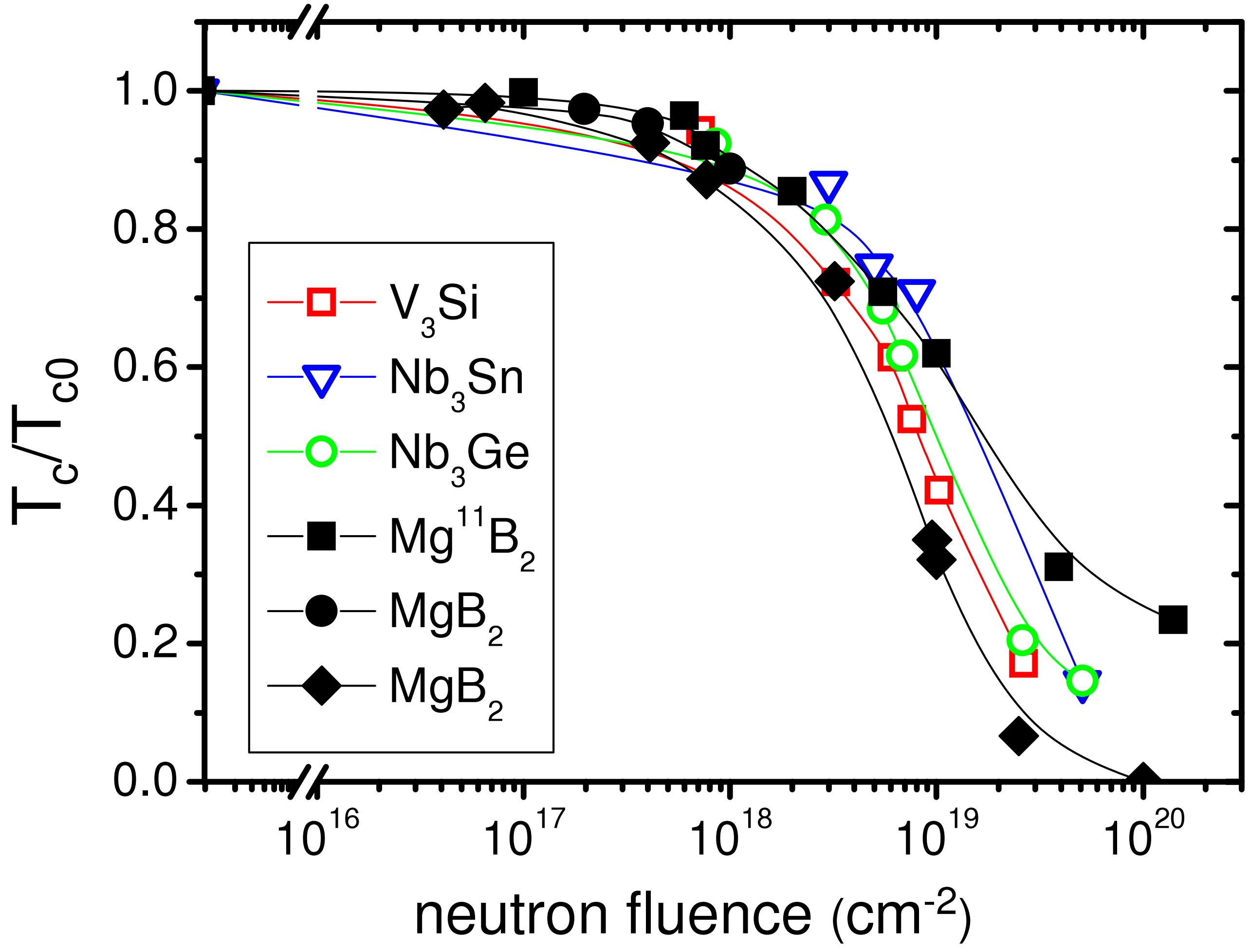
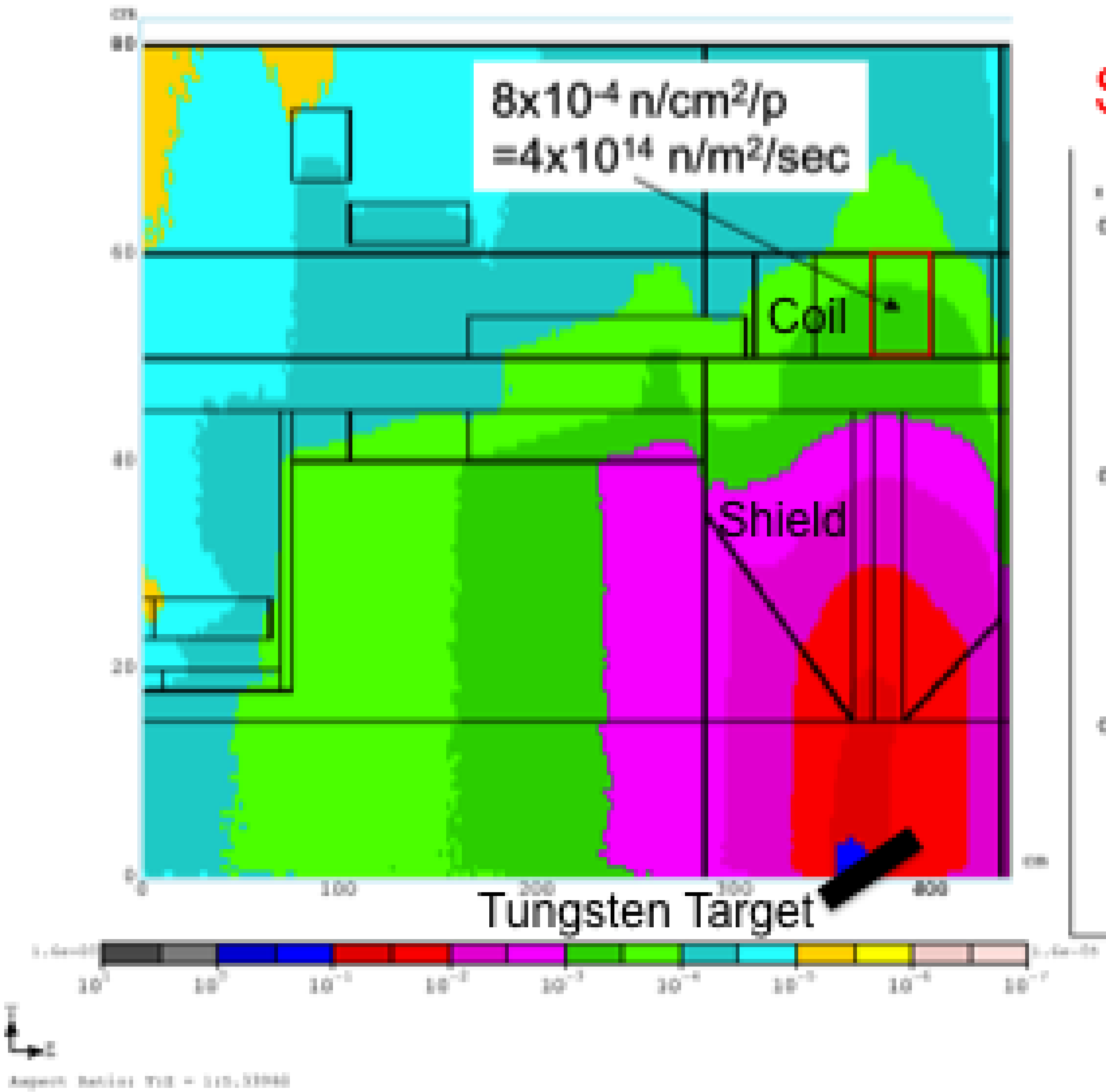


Figure 5. T_c/T_{c0} versus neutron fluence for V_3Si, Nb_3Sn, Nb_3Ge [30, 31] and MgB_2 single crystals [25] (circles), thin films [29] (diamonds) and $Mg^{11}B_2$ polycrystals [27] (squares).

Supercond. Sci. Technol. **21** (2008) 043001

Pion Capture Solenoid in the COMET CDR

Irradiation: Neutron Fluence



8×10^{-4} n/cm²/p
$=4\times10^{14}$ n/m²/sec

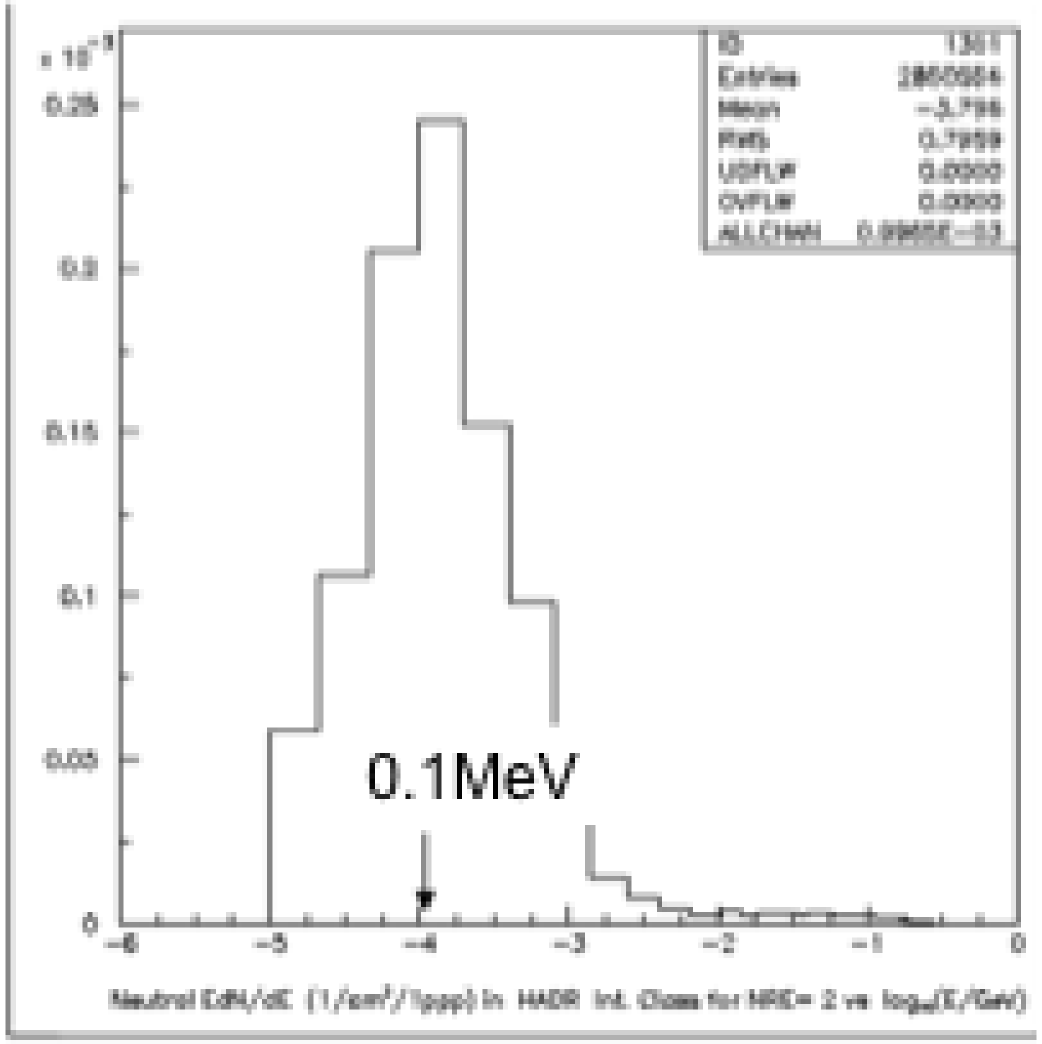
Coil

Shield

Tungsten Target

~10^{22} n/m² for 10^{21} POT

Same order of ITER spec!!



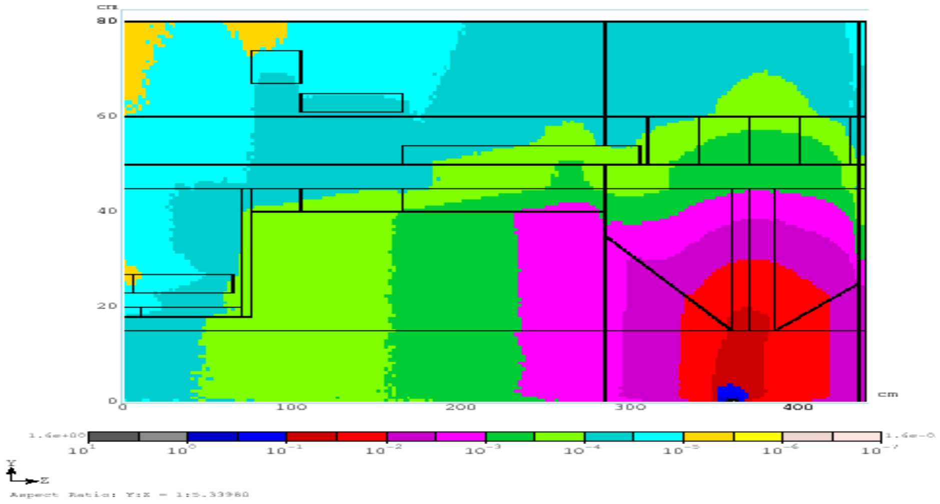
0.1MeV

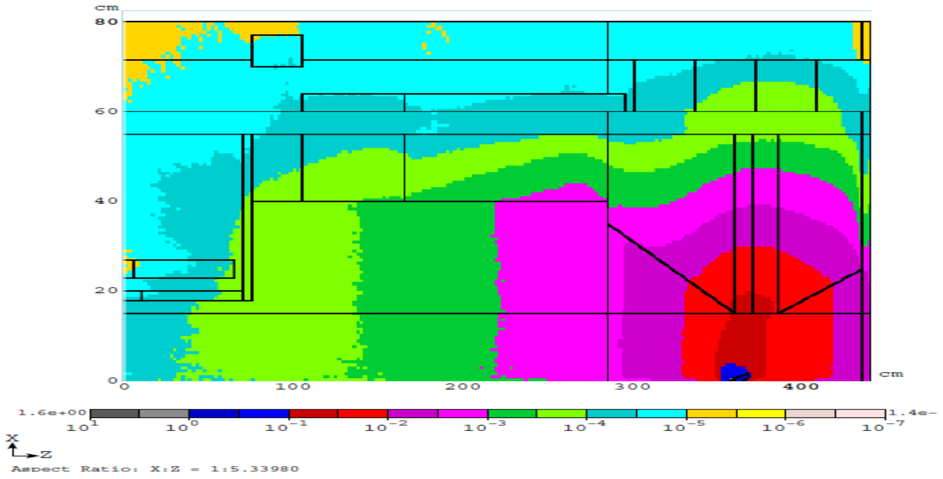
COMET

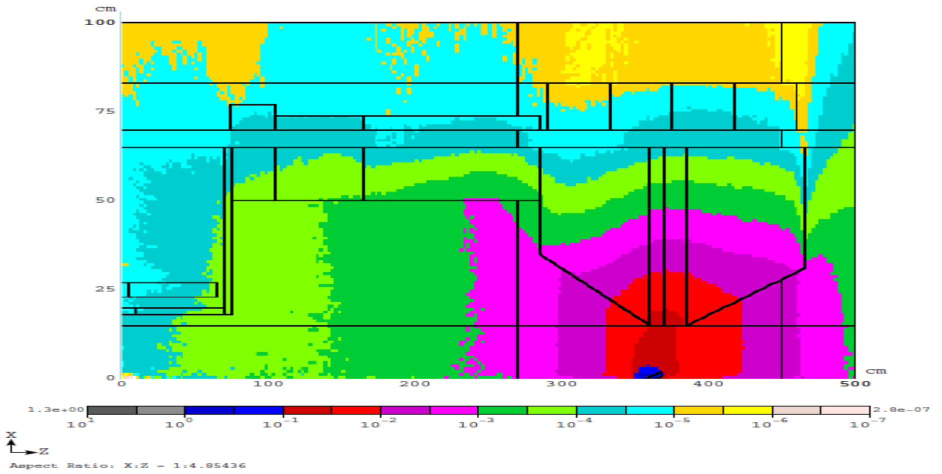
Refinement of solenoid system

- Enlarge magnet bore to insert more shield
- Estimate degradation from estimated DPA
- Cost?
  - ☐ 3 step mandrel : smaller stored energy
  - ☐ 2 step mandrel
  - ☐ single mandrel : easier support structure

	MGy/10^{21}p	n/m^2/10^{21}p	DPA/10^{21}p
R500(CDR)	0.6	8×10^{21}	2×10^{-5}
R600	0.1	2×10^{21}	0.6×10^{-5}
R700	0.05	0.7×10^{21}	0.3×10^{-5}



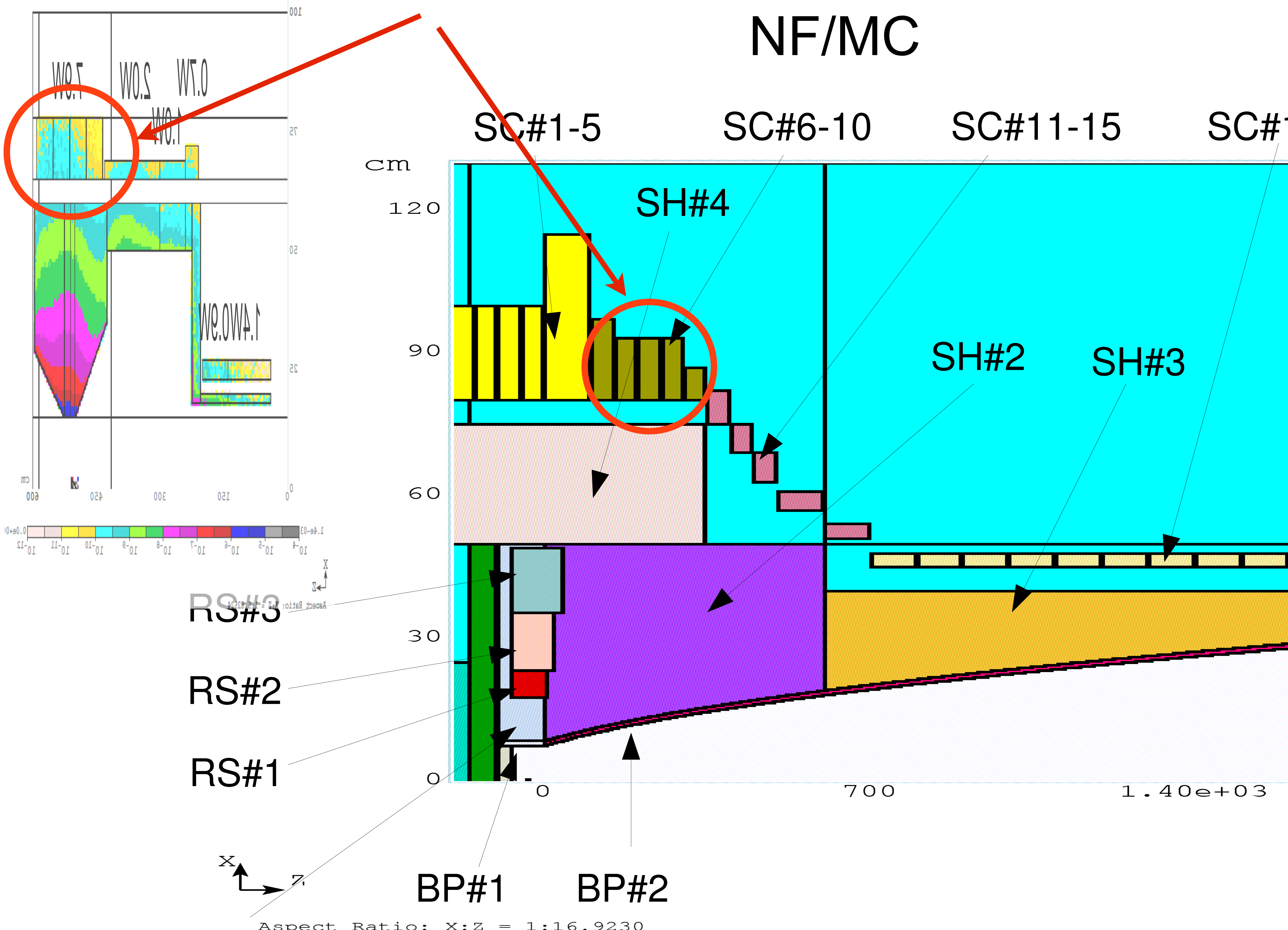




COMET

Same size SC wires

NF/MC

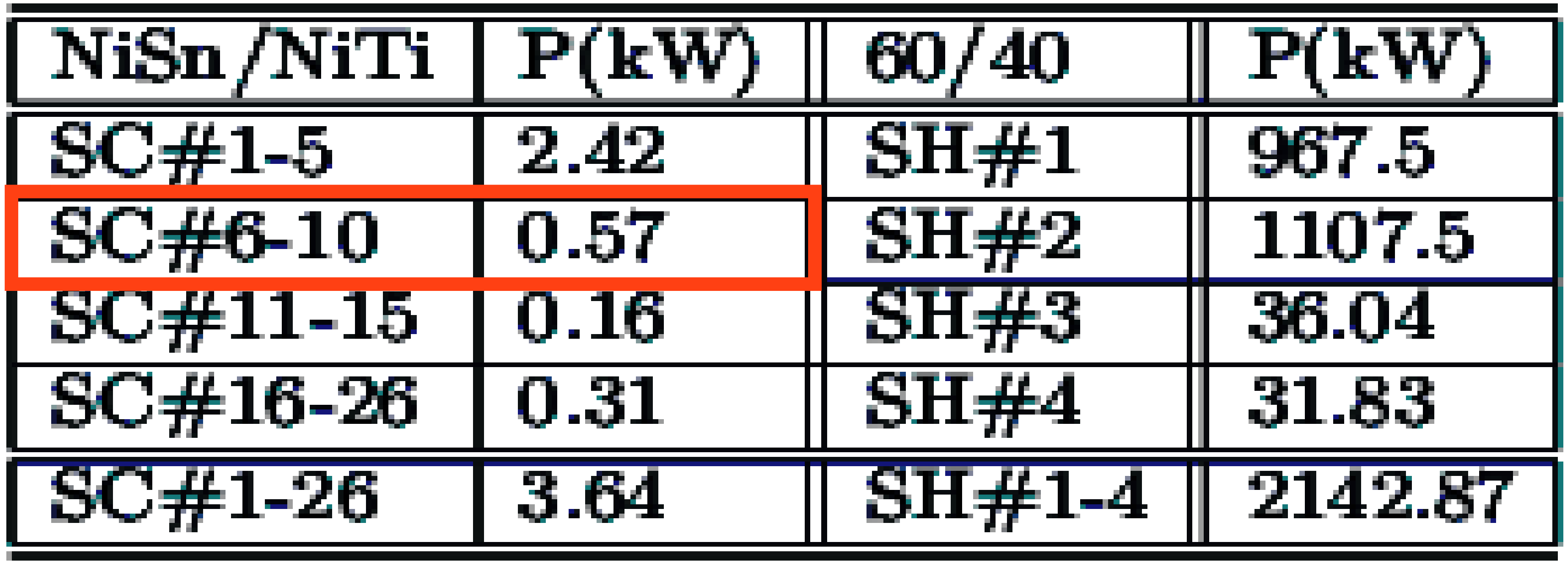


The Proton Beam Parameters

Proton Beam Energy	**8 GeV**
Rep Rate	**50 Hz**
Bunch Structure	**3 bunches, 320 μsec total**
Bunch Width	**2 ± 1 ns**
Beam Radius	**1.2 mm (rms)**
Beam β^*	**$\geq$ 30cm**
Beam Power	**4 MW (3.125 × 1015 protons/sec)**

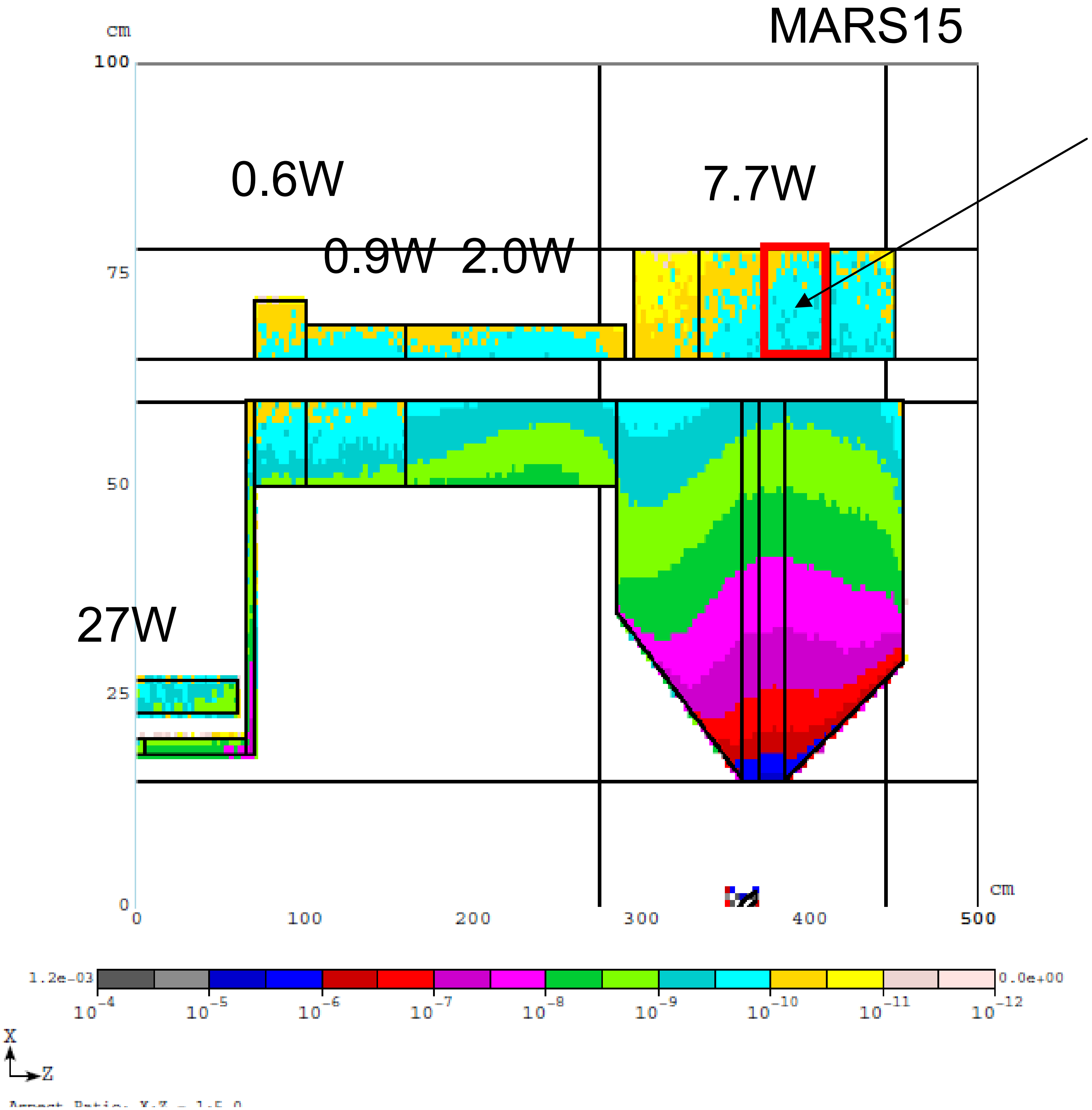
COMET: 56kW proton beam
  -> 7.9W on the pion capture SC coils
MC/NF: (4000kW/56kW)*7.9W = 564kW

ENERGY DEPOSITED IN SC SOLENOIDS (SC#), SHIELDING (SH#).



NiSn/NiTi	P(kW)	60/40	P(kW)
SC#1-5	2.42	SH#1	967.5
SC#6-10	0.57	SH#2	1107.5
SC#11-15	0.16	SH#3	36.04
SC#16-26	0.31	SH#4	31.83
SC#1-26	3.64	SH#1-4	2142.87

Radiation dose for the new Pion Capture Solenoid of COMET



- 0.07 MGy/10^{21}p
- 1.3x10^{21} n/m^2/10^{21}p
  - 6.4x10^{20} n/m^2/10^{21}p for >0.1MeV n
- 3x10^{-6} DPA/10^{21}p

COMET : 1.3 x 10^{21} n/m^2/10^{21}p = 1n/m^2/p

MC/NF 3 x 10^{15} p/s ---> 3x10^{15}n/m^2/s

to get 10^{22} n/m^2 on SC#6-10

: 3 x 10^6 s = 35 days

This means that we need to increase the SC wire temperature (may be up to the room temperature) to recover their property by anneal effect every 35 days. The 35-days is too short period. It should be more than 1 year.

to get 10^{21} n/m^2 on SC#6-10

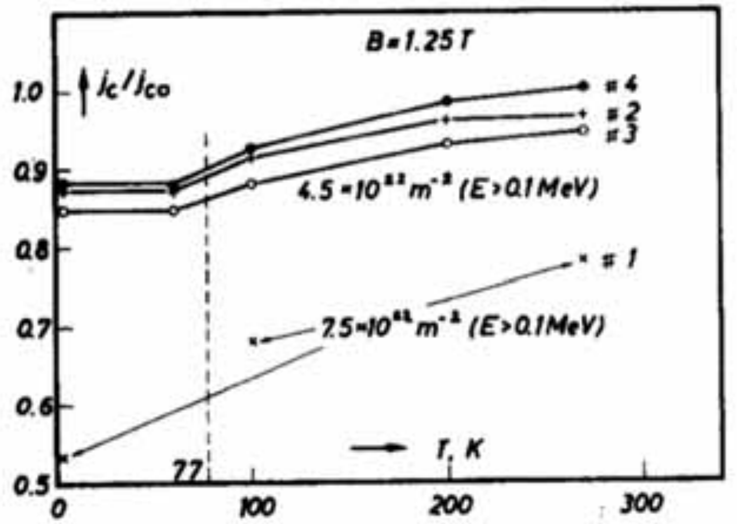
: 3.5 days

HTS instead of resistive magnets looks no hope.

Anneal Effect: SC -Tc&Jc-

Irradiated at LT, and warmed up to RT.

J. Nucl. Materials, 108&109, p572 (1982)



NbTi
neutron

Fig. 9. Recovery of j_c/j_{c0} up to room temperature fc
ent samples of Nb–50 wt% Ti (measured at 4.2 K ar
after [44]. The measurements were made on one filar
1–3: 11 μm filament diameter, No. 4: 21 μm) of mu
tary wires.

NbTi
30GeV proton

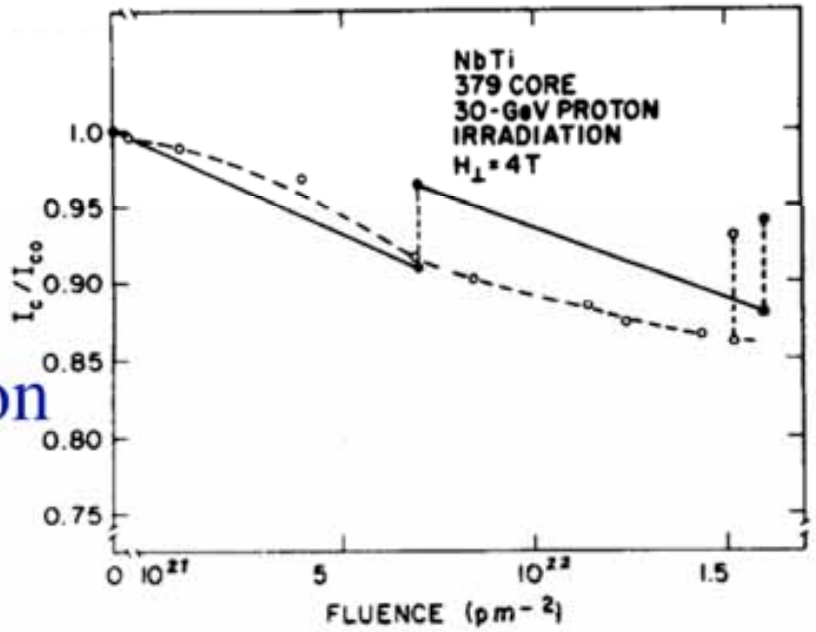
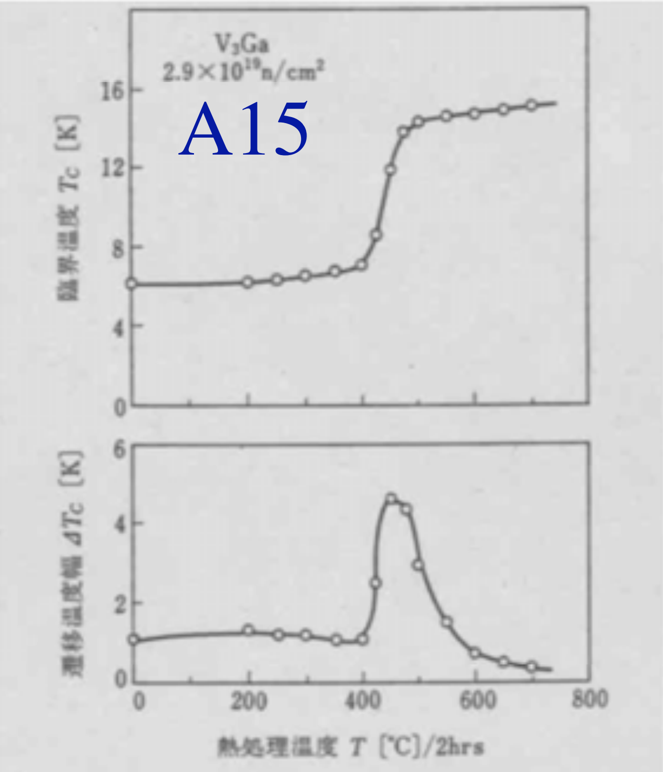


Fig. 10. Changes of critical currents measured at 4 T with proton fluence (Nb–45 wt% Ti, 379 core conductor). ○○○ irradiation at 4.2 K, final anneal at room temperature; … irradiation at 4.2 K, one intermediate and one final anneal to room temperature [33].

For NbTi, some recovery can be expected even after irradiation ~5*10^22/m2.

超伝導・低温工学ハンドブック p487 (1993)



A15

図 3・31　中性子照射した V_3Ga の臨界温度 T_c の熱処理（T(℃)，2 時間）による回復（ΔT は T_c での常伝導遷移温度幅）[Shiota 1981]

Anneal effect only occurs beyond 400 °C.

T. Nakamoto (KEK)

Anneal Effect: Stabilizer - Elec. conductivity-

Irradiated at 4K, and warmed up to RT.

J. Nucl. Materials, 49, p161 (1973&74)

Reactor n
on Al

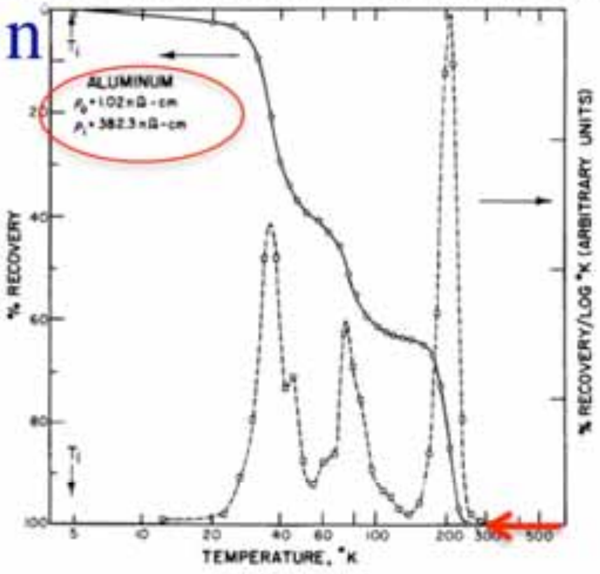


Fig. 3. Recovery and differential recovery versus logarithm of absolute temperature for aluminum irradiated at 4.5 K to 2 × 10^{18} n/cm² of E > 0.1 MeV.

Reactor n
on Cu

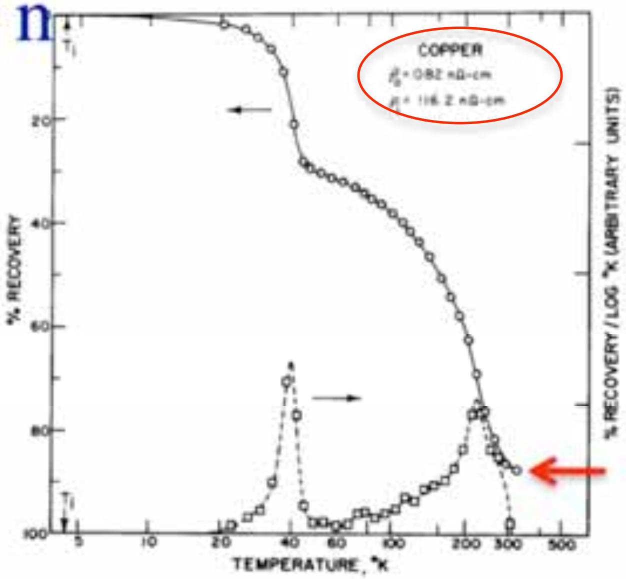


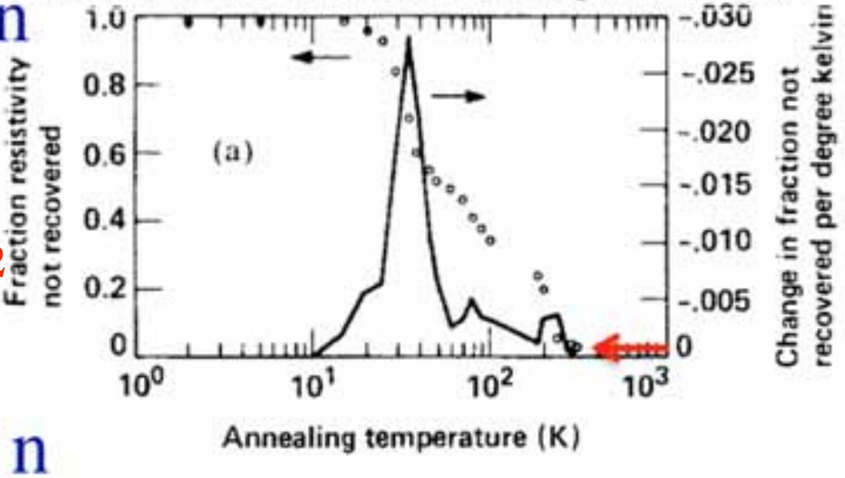
Fig. 5. Recovery and differential recovery versus logarithm of absolute temperature for copper irradiated at 4.5 K to 2 × 10^{18} n/cm² of E > 0.1 MeV.

fluence up to 2*10^22/m2.

J. Nucl. Materials, 133&134, p357 (1985)

14MeV n
on Al

ρ0: 0.386
ρ-irrad: 0.772
(nΩm)



14MeV n
on Cu

ρ0: 0.098
ρ-irrad: 0.191
(nΩm)

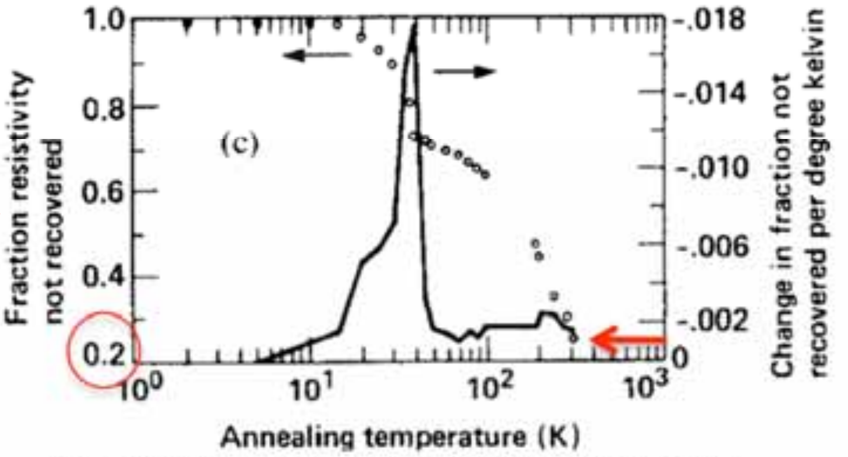


Fig. 2. Post-irradiation, isochronal annealing results for (a) Al, (b) Ni, (c) Cu and (d) Pt. Annealing results below 50 K for Ni and Pt were lost because of warming.

fluence up to 1*10^21/m2.

- **Double of electrical conductivity can be observed at 10^21/m2.**
- **Full recovery in Al expected by T.C.**
- **Degradation in Cu will be accumulated even after T.C.**

T. Nakamoto (KEK)

Comments

- There are many paper on the SC magnet requirements, design, and study for fusion magnets (ex. ITER) for the radiation effects. We need to learn many things from the papers.
- Then set the requirements on the SC magnets design for the NF/MC.
- Collaboration with fusion group would be very useful.