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Particle fluence and spectra outside the TDE

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Abstract

The type and energy distributions of particles escaping from the TDE during a beam abort have been calculated with FLUKA. Results demonstrate that there is no reason to add a thermal neutron shield around the TDE frame, and that a monitoring of the radiation field is a difficult task.

1 Introduction

The knowledge of particle abundances and spectra at the TDE surface is needed both to investigate possible improvements of the TDE particle containment (the addition of a thermal neutron absorber has been suggested) and to eventually design a radiation monitoring system.

The TDE design, especially for what concerns the outer frame and the cooling system, has not yet been frozen. For the present calculation,a realistic configuration has been assumed:

- The "optimised"[2, 3] density profile in the graphite core (1 metre normal density , 3 metres light graphite, 3 metres normal.)
- A core radius of 350 mm

- A Steel (70% Fe, 18%Cr, 9% Ni) jacket of 10 mm thickness, surrounding the graphite core
- An Aluminium frame, 30 mm thickness, around the steel jacket. Its outermost 10 mm are modelled as an homogeneous mixture of 99.17% Al and 0.83% water, to take into account 20 cooling water tubes.
- The graphite dump is followed by a shielding, one metre aluminium, one metre iron.
- To approximate the sweeping path, the beam has an annular shape, concentric with the dump axis, with radius equal to the maximum distance of the swept beam from the dump centre (240 mm), and with radial spread equal to four times the beam σ ($\sigma = 1.4$ mm).

Table 1: For each particle type escaping from the TDE: the number per unit area (N), the kinetic energy globally carried (Tot. E_k), and the average kinetic energy per particle ($< E_k >$). All quantities are normalised to one incident proton at 7 TeV

Particle type	Lateral surface			All surfaces		
	Tot. E_k	$< E_k >$	N	Tot. E_k	$< E_k >$	N
	GeV		$\frac{part}{cm^2}$	GeV		$\frac{part}{cm^2}$
Neutron	253	0.047	$3.07 10^{-2}$	268	0.043	$3.27 10^{-2}$
Muon	6.95	0.311	$1.27 10^{-4}$	9.48	0.378	$1.32 10^{-4}$
Charged Hadron	395	0.471	$4.77 10^{-3}$	407	0.470	$4.56 10^{-3}$
Neutral kaon	11.6	0.856	$7.74 10^{-5}$	12.2	.856	$7.48 10^{-5}$

2 Simulations and results

Simulations have been performed with FLUKA[1], discarding the electromagnetic component to gain in computer speed. Particle spectra have been scored in 14 segments of the external aluminium boundary, around the downstream shield, at the dump entrance and at the downstream shield exit.

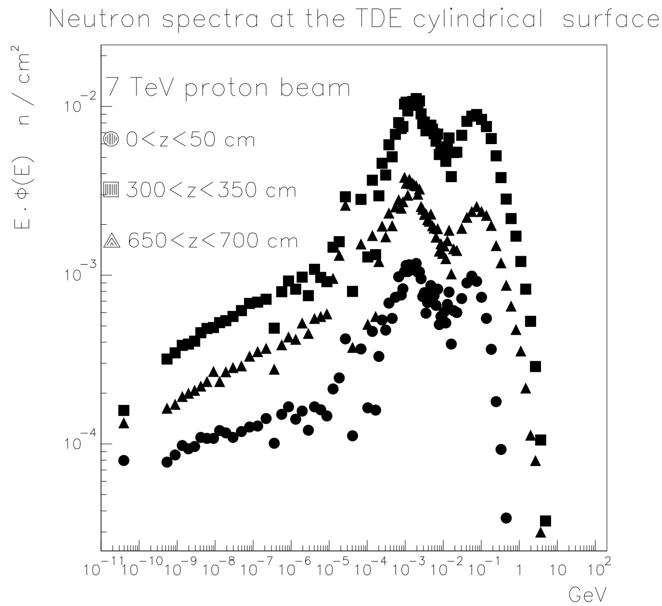

Figure 1: Neutron spectra at different positions along the TDE cylinder, normalised to one incident proton.

The energy-integrated results are collected in tab.1. Around 60% of the kinetic energy escaping from the TDE is carried by charged hadrons (protons, $\pi^{\pm}$,$K^{\pm}$), small fractions by muons and neutral kaons, and the rest by neutrons. Neutrons are by far the most abundant specie, but their average energy ($< E_k > \approx 50$ MeV) is much lower than the average energy of charged hadrons ($< E_k > \approx 470$ MeV).

Neutron spectra at some of the scoring surfaces are plotted in fig.1. It is evident from this figure that the spectra are dominated by a fast component in the GeV range and an evaporation component around 1 MeV, while the thermal fraction is quite small. This fact, together with the dominance of the charged hadron field, demonstrates that there is no reason to add a thermal neutron shield.

It is also evident from the results in table 1 that the combination of the graphite core and the downstream shield ensures an almost perfect longitudinal shower containment.

The spatial distribution of the radiation field is shown in fig.2 as a global map for neutrons, and in fig3 for neutrons and charged hadrons along the lateral surface. The radiation fields follow the profile of the shower distribution in the core, with a broad maximum at the centre. With respect to

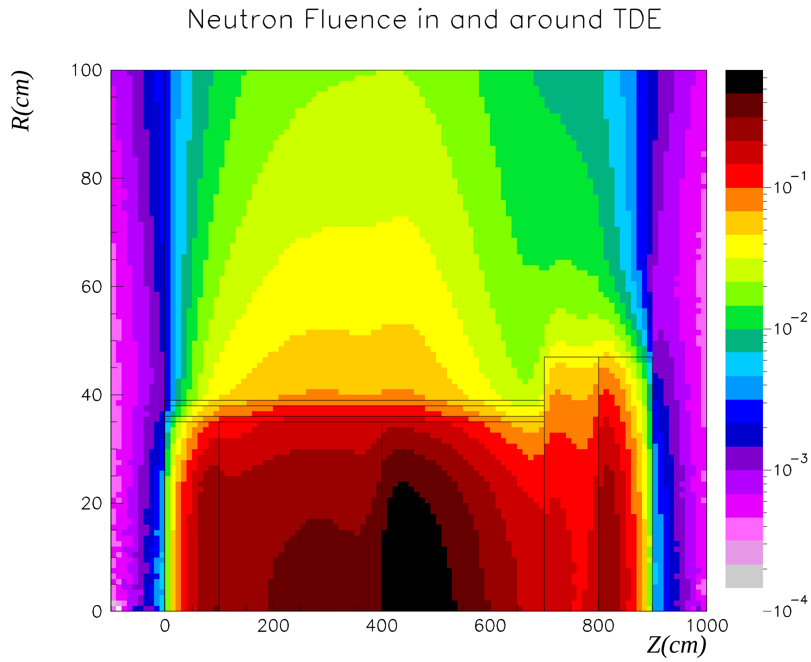

Figure 2: Neutron fluence in and around the TDE (neutrons/cm^2), normalised to one incident proton, in the annular beam approximation.

the possibility of monitoring these shapes to detect core failures, it should be noticed that the radiation levels will be extremely high. The neutron fluence at nominal intensity will be as high as 0.07*3.09 10^{14} = 2 10^{13} n/cm^2 per dump, or 3.6 10^{15}n/cm^2/yr. Energy deposition has not been scored in the present calculation, but a lower limit, coming from the estimation of ionization energy losses of charged hadrons, already amounts at about 500 Gy per dump, that means 90 kGy per year. Moreover, the spatial anisotropy shown in fig.3, which is already not very large, could be smeared by the radiation diffused by the iron-concrete shielding that surrounds the core. More studies and thoughts are needed in order to conceive an efficacious dump monitoring system.

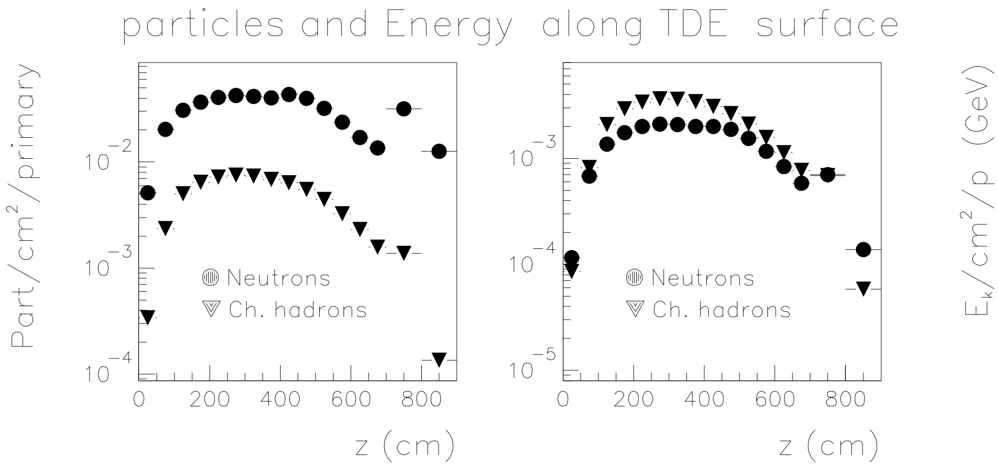

Figure 3: Longitudinal dependence of particle current(left) and transported kinetic energy(right) along the TDE cylindrical surface and the forward shielding.

3 Conclusions

The energy escaping from the TDE is mainly carried by charged hadrons, while the most abundant particle type are neutrons, which are not thermalized in the TDE core. Thus, a thermal neutron shield around the TDE would not be useful.

The radiation field at the TDE surface presents a longitudinal anisotropy that could in principle be monitored to detect core failures. However, the high radiation level and the limited anisotropy impose severe requirements on the monitoring system.

References

[1] A. Fassò *et al* in Proc. SARE-3, KEK-Tsukuba, ed H. Hirayama, KEK report Proceedings 97-5, (1997) 32; A. Fassò *et al*, "Electron-photon transport in FLUKA: status", and "FLUKA: Status and Perspectives for Hadronic Applications", in Proc. of MC2000 (Lisbon, Oct. 2000) (in press); http//www.cern.ch/fluka .

[2] L. Bruno et al, LHC-PROJECT-NOTE-217, 1999

[3] L. Bruno et al, LHC Beam Dump Design Study - Part IV, in preparation