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POTENTIAL FOR RELIABILITY IMPROVEMENT AND COST OPTIMIZATION OF LINAC AND CYCLOTRON ACCELERATORS

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Abstract

This document identifies and discusses the proper design strategies that have been followed in order to meet the reliability and availability specifications for a high intensity proton accelerator meant as the spallation neutron driver for an eXperimental Driven System (XADS) for nuclear waste transmutation. The document describes also how these strategies can be applied in the different components of the XADS accelerator design, and how design iterations can lead to reliability improvements. The Failure Mode and Effect Analysis (FMEA) methodology has been used on the suggested design for highlighting the reliability critical areas. Finally, a first rough cost estimation of the XADS accelerator is also provided.

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Introduction

The possibility of disposing of the radioactive waste accumulated by energy producing nuclear reactors and the perspective of a closure of the nuclear fuel cycle has been brought into consideration by C. Rubbia ten years ago (C. Rubbia, “An Energy Amplifier for Cleaner and Inexhaustible Nuclear Energy Production Driven by a Particle Accelerator”, CERN/AT/93-47(ET), 1993. Since then, Accelerator Driven Systems, where the protons produced by a high intensity accelerator impinge on a spallation target to provide the high neutron fluxes needed by a subcritical system, are being considered in the US, Japan and in various European countries as possible means for the transmutation of the nuclear wastes into smaller volumes and much shorter-lived elements.

Concerning the accelerator, one of the key elements is the required level of availability and reliability, needed for coupling with a subcritical nuclear assembly. The design requirement is for a high intensity (from a few to a few tens of milliamperes), medium energy (from a few hundredths of MeV fo a few GeV) proton accelerator capable of continuous wave operation for periods ranging from a few months to an year, with only few beam trips during operation.

Typically, accelerators for high energy physics experiments are designed for top performances, and not too much concern is placed on reliability, especially since the budget constraints usually do not allow the associated extra costs for reliability management. A step toward the integration of availability/reliability considerations in the accelerator community has been performed by 3rd generation synchrotron light sources, where the large user base demanded a high availability allocation since the start of experimental program on each machine.

A further step needs to be performed, with the integration of availability/reliability considerations into the conception phase of an XADS-class accelerator. Proper strategies for reliability design, and reliability allocation and management, need to be set as guidelines early on in the design phase of the system, and its subcomponents.

The PDS XADS Program

In the context of the 5th Framework of the EC, in October 2001 a specific initiative was funded for the “Preliminary Design Study of an eXperimental Accelerator Driven System” (PDS-XADS), with 25 partners representative of major Research Institutions and nuclear industries.

In PDS-XADS a working package (WP3) is specifically dedicated to the XADS accelerator design considerations, to a preliminary estimation of its reliability characteristics, to the compatibility with the subcritical assembly requirements, to the definition of key R&D topics, and to the perspectives of the extrapolation to industrial-class transmuters.

The Deliverable 57

One of the contractual deliverables of the PDS-XADS contract is represented by Deliverable 57: "Potential For Reliability Improvement And Cost Optimization Of Linac And Cyclotron Accelerator", to be issued under INFN coordination with contributions from CEA, CNRS (France), ENEA (Italy) and IBA (Belgium). This document is meant to primarily to highlight the design strategies that are needed in order to aim at the high reliability goal of the XADS accelerator.

The document contains also a qualitative reliability analysis of the reference design solution (of a 600 MeV superconducting proton linac), performed with a standard methodology used in risk-evaluation processes, the Failure Mode and Effects Analysis (FMEA): The FMEA is the initial step required along the path to a more quantitative reliability assessment of the proposed design.

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