BEAM-LOSS MEASUREMENT AND SIMULATION OF LOW-ENERGY SNS LINAC

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Abstract

We have installed a number of Neutron detectors from the MEBT to the end of CCL (186 MeV). These detectors are made in collaboration with INR [Institute for Nuclear Research - Russia]. In this paper we present our implementation and simulation of the losses by inserting Faraday Cups at different energies. We also calibrated neutron detectors and their high voltage dependence. The measured losses are simulated by 3-D transport codes during SCL commissioning. We also discuss future improvements such as interpreting the loss signal in terms of beam current lost in warm part of SNS linac with accurate longitudinal loss distribution as well as plan to automate voltage dependence of the neutron detectors. We compare two different sets of Beam Loss Monitors: Ionization Chambers (detecting X-ray and gamma radiation) and Photo-Multiplier Tubes with a neutron converter (detecting neutrons). We outline such combination is better way to deal with the beam losses than relying on detectors of one type.

INTRODUCTION

While the beam is being accelerated in the LINAC not all particles manage to pass through the whole system, but some of them “are lost” meaning that the particle interacts with some material and absorbed (or penetrated) in the LINAC structure This causes many problems such as radiation around the LINAC, residual radiation and decreasing of the LINAC output. The best effort should be made to minimize these losses.

The Loss Monitoring System has the following major goals: finding the physical locations of losses (places that were hit by lost particles); estimating the fraction of lost particles; finding reasons that cause such losses; finding solutions to avoid the losses.

The primary methods of the system are: detection of secondary radiation; mathematical and computer modeling; comparison of the detected radiation and finding out the most probable scenario that would cause the same losses.

DETECTORS

Main instruments for measuring losses in LINAC are;BLMs (BNL [1]) sensitive to gamma radiation and NDs (INR, Russia [2]) (sensitive to neutrons). The first type is ionization chamber, and the second one is photomultipler tubes covered with scintillator sensitive to neutrons. The PMT’s sensitivity is controlled by High Voltage, which gives opportunity to use these detectors in a wide range of neutron flux intensity. The ionization chambers do not have such possibility.

Also several other types of detectors are used: Silicon Neutron Detectors (for fast neutrons), Low Level Beam Loss Detectors (sensitive to low intensity neutron fields), Fast Beam Loss Monitors (sensitive to gamma).

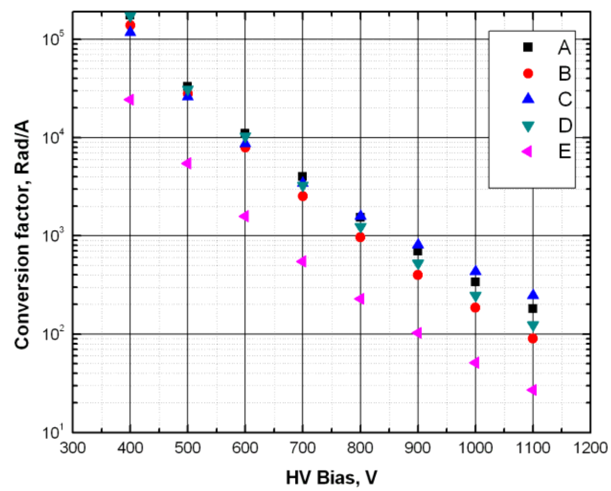

Figure 1: Typical HV dependence for NDs.

COMPUTER SIMULATION

Major goals of Computer Simulation and Codes to be used are:

- Simulate different scenarios of particles losses in the LINAC. (PARMILA[3])
- Simulate the full 3D transport of lost particle in the media of LINAC construction elements (including production of secondary particles and their further transport). Various Monte Carlo Transport Codes are used: SHIELD[4], MCNPX[5], GEANT4[6], EGS4[7], MARS[8].
- Simulate detectors response for different scenarios of losses.
- Resolve the detectors signals to obtain possible loss scenario followed by those signals.

The main challenge to be solved for accomplishing the above goals is bringing all the codes mentioned above in a single frame by incorporation of the strongest features of every code.

Unfortunately all the codes that are useful for the task use different interfaces, programming languages, organizational concepts, input and output formats, etc.

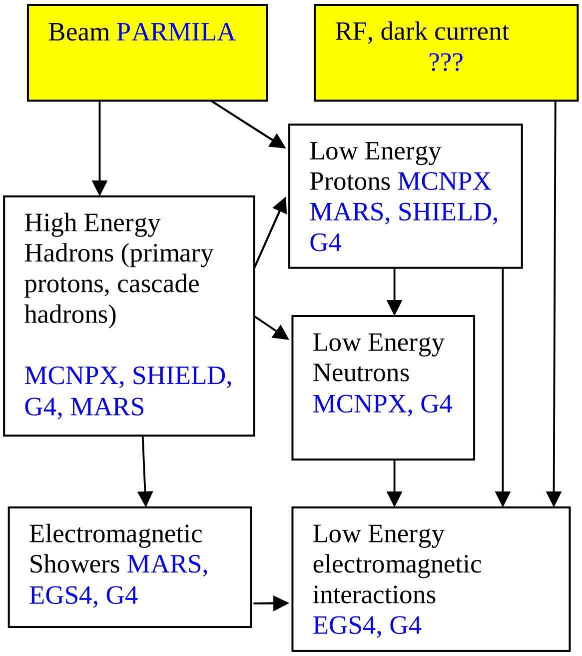

Figure 2: Simulation codes.

Ideally every interface (represented by arrows on the diagram) must be created. It will allow to use different codes at different stages of transport. (E.g. high energy hadrons calculated by SHIELD the EM showers by MARS, low energy neutrons by MCNPX, low energy EM by EGS4).

The rough calculation of low energy neutron yield under proton irradiation shows that we really need neutron detectors capable of detecting wide range of neutron flux intensity.

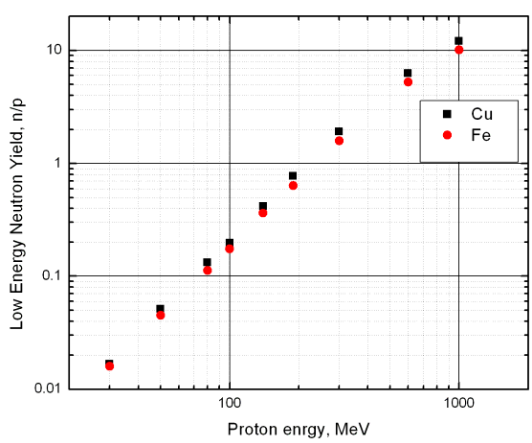

Figure 3: Calculated neutron yield from copper and iron targets.

WARM LINAC

The Loss Monitoring system of SNS warm LINAC consists of 36 BLM, 20 NDs and 6 LLBLMs. The BLMs were not sensitive to pick up any signals unless the loss is huge and is close to the BLM. So the BLMs were able to see the gammas flying out of the Faraday Cup (which effectively imitates the 100% loss in local place).

The following plots show signals from BLMs and NDs taken when different Faraday Cups were inserted (the detector number and FC number increases along the LINAC --Energy range from .065 MeV to 184 MeV)

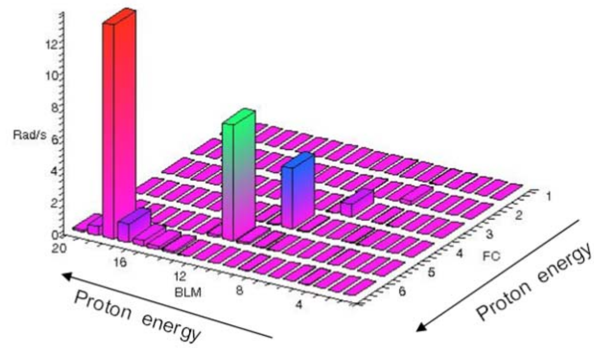

Figure 4: BLM Signals.

As one can see on these plots the NDs are more sensitive to remote losses and BLMs.

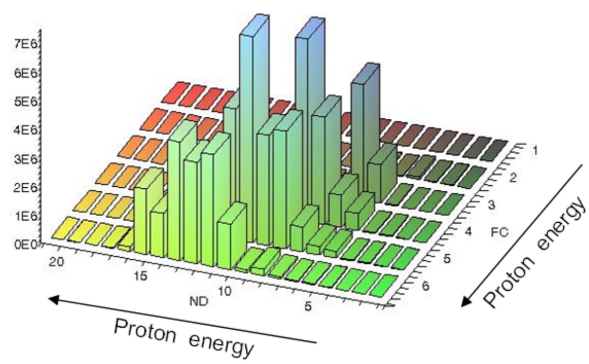

Figure 5: ND Signals.

This confirms the choice of two different types of detectors to be more efficient and giving more information about loss pattern.

The BLMs have advantage of being faster than NDs, this allows us to examine the beam pulse shape with ion chambers, while ND signal has long exponential tail (due to slowing down of neutrons in the moderator).

The ND signals were in good agreement with Monte-Carlo simulation of neutrons being produced in the Faraday Cup.

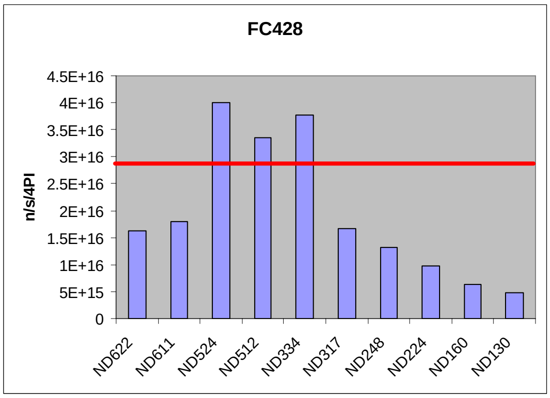

Figure 6: The calculated neutron intensity (red line) and measured results (blue bars)

This calculation was performed assuming that the neutron source in the Faraday Cup is isotropic (which is true to some extent since the main neutron production mechanism is neutron evaporation). But it shows that while this isotropic approach is good enough for rough estimation of neutron fluxes near the source (ND524, 512, 334 were close to the inserted FC), the more accurate simulation of geometry configuration and material composition is needed to fully understand readings of detectors picking up remote losses.

The above allows to conclude that both types of detectors have advantages and disadvantages: BLMs are less sensitive and pick up local losses only, NDs are much more sensitive and pick up remote losses as well, but are much harder to interpret).

At higher energy regions (SCL, Ring etc) the disadvantages of BLMs are not so important. The BLMs are able to detect signal from Wire Scanner induced losses

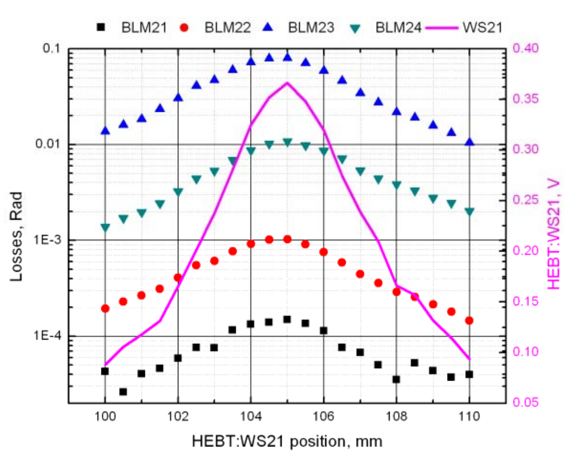

Figure 7: BLM signals correlate with WS position

But the neutron detectors are still necessary to estimate residual radiation which is high in high energy areas.

FUTURE DEVELOPMENT OF LOSS MONITORING SYSTEM

The BLMs and NDs showed themselves quite well for loss monitoring in warm sections of SNS LINAC. The fully automated software system is still under developement to fully understand the losses in SNS.

The additional issues were introduced by high x-ray noise originating from SCL cavity dark current. This forces to start research on separating neutron and gamma signals in NDs

CONCLUSIONS

Beam loss monitors are essential part of the SNS operations and power ramp up. We are continuously improving detector design in collaboration with INR. Simulations are used to validate measurements and understanding of the entire system. Residual radiation measurements and comparison with predictions is the focus of our team. This will assure hand-on maintainability and repairs.

ACKNOWLEDGEMENT

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