LOSS MONITORING OF 70 GEV PROTON BEAM

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Abstract

With the goal to increase the efficiency of beam loss monitoring at a transportation of 70 GeV proton beam the detailed characteristics of background radiation outsaide a beampipe have been calculated. The main background components, their energy spectrums and spatial distributions are obtained for typical cases of beam losses. The values of an ionization energy and electric charge were estimated for an interelectrode space of one of beam loss monitors (BLM) are designed at IHEP.

1 INTRODUCTION

One of the beam diagnostic systems, used at a tuning and a steady operation of beamline for a transportation of intensive beams, is a BLM system. Usually, BLM are measuring a secondary background radiation outside of a beampipe. Series of the simple and reliable BLM are designed at IHEP for an external proton beam with energy of 70 GeV and intensity more than 10^{13} ppp. These BLM represent the nonhermetic air (at an atmospheric pressure) ionization chambers. One of monitors of such type - Modular Radiation Monitor (MRM) [1] is shown in a Fig. 1. MRM contains 4 modules (ionization chambers) are moved one relatively another. MRM can be installed on the beampipe with cross-section of the arbitrary form and of the sizes up to 220 mm. The electrodes of ionization chambers are manufactured from standart bilateral (central electrode) and unlateral (lateral electrodes) rolled aluminium profiles. An electrode system with electrostatic screen are placed into a rectangular plastic container.

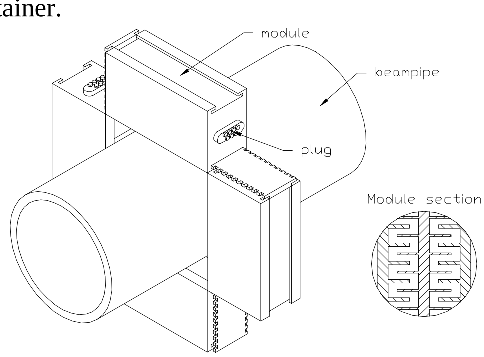

Figure 1: General view of the modular radiation monitor

The main reasons of losses of primary protons are their interaction with beam detectors, diaphragms, residual gas and a beampipe wall. The background radiation is formed by nuclear-electromagnetic cascades (NEC) into the elements of the beamline and surrounding equipments. In calculations of background characteristics for these cases the code "MARS 96.18" [2] was used. This code allows of the NEC modelling by the Monte-Carlo simulation. From beamline elements only cylindrical aluminium beampipe was taken into account. Outer diameter of the pipe equal 200 mm and wall thickness of 10 mm. Besides, atmospheric air in a beamline environment and the elements of BLM were allowed for.

2 PROTON LOSSES ON RESIDUAL GAS

It was assumed that the beam has two-dimensions Gaussian distribution of the proton density on a radius with a dispersion (RMS) equal 4 mm and zero angular divergence. It corresponds to the beam parameters on the free long sections of the beamline, when running normally. The average background characteristics were calculated for the ring region in limits from 100 mm up to 200 mm, that corresponds to a cross-section of the used BLM. For this area the background is formed from an interaction of the secondary particles, generated by primary protons in residual gas, with the pipe wall. In longitudinal direction (on an axes Z) the background intensity grows from the beginning of the secondary generation (Z=0) and reachs a constant value at Z>100 m. In Table 1 the values of a fluense of the main background components are given.

Table 1: Fluence of particles at losses on residual gas

Particles	**Fluence (cm^{-2})**	
Photons	$3.3{\cdot}10^{-1}$	$(4.4 \cdot 10^{-7})$
Electrons	$5.9{\cdot}10^{-2}$	$(7.9{\cdot}10^{-8})$
Pions	$1.2{\cdot}10^{-2}$	$(1.6{\cdot}10^{-8})$
Neutrons	$1.4{\cdot}10^{-2}$	$(1.9{\cdot}10^{-8})$
Protons	$6.3{\cdot}10^{-3}$	$(8.4{\cdot}10^{-9})$

These values are normalized on one primary proton, interacted with the residual gas on 1 m of pipe length. In brackets the values of a fluense are given when gas pressure of 1 Pa. These values are normalized on one proton of an incident beam. Number of interacting protons on 1 m (N1p) as function of a gas pressure (P [Pa]) and an incident beam intensity (Np) is determined by a following expression:

$$N_{1p} = 1.34{\cdot}10^{-6} \cdot P \cdot N_p$$

3 PROTON LOSSES IN A DEFOCUSSED BEAM

The conditions of the calculation correspond to the case of the proton losses at the primary proton interaction with the beampipe wall, when the beam is defocussed. It was assumed, incoming beam at the pipe has the Gaussian distributions of the proton density on a radius and a angle with the dispersions (RMS) equal 30 mm and 0.15 mrad, respectively. For such beam the uniform irradiation of the protons on the pipe wall is modelling on the Z-interval of 200 - 500 m from an entry point of the beam. The values of a fluence of the background components are listed in Table 2. The normalization are same, as in the previous case.

Table 2: Fluence of particles at wide beam losses.

Particles	Fluence (cm^{-2})
Photons	$2.4 \cdot 10^{-1}$
Electrons	$5.2 \cdot 10^{-2}$
Pions	$1.1 \cdot 10^{-2}$
Neutrons	$8.0 \cdot 10^{-3}$
Protons	$4.2 \cdot 10^{-3}$

4 PROTON LOSSES ON PROFILOMETERS

The beam parameters correspond to the normal regime of the beam transportation. It was considered the proton interaction with the beam profilometers of two types: first is performed on the basis of the copper foils of 20 mkm thickness; second is performed on the basis of the kapton films of 16-30 mkm. In the longitudinal direction the profilometers have the material density of 89 mg/cm^2 and 7 mg/cm^2, respectively.

The fluence of the ionizing background components as function of the distance from the profilometer is shown in Fig. 2.

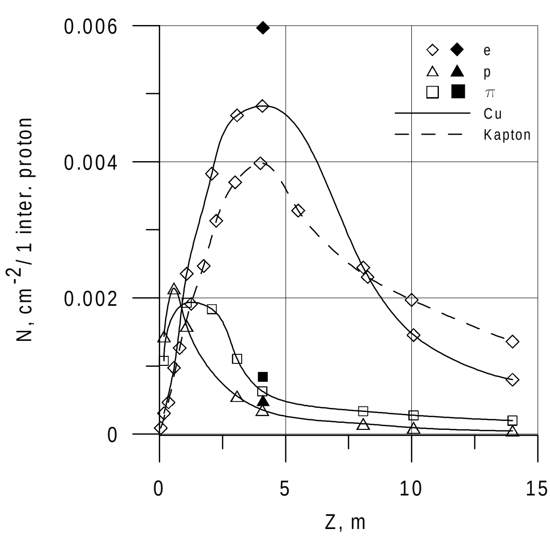

Figure 2. The calculated longitudinal distributions of a fluence of ionizating particles of background from profilometers; MRM - dark symbols.

The value of a fluence in Fig. 2 is normalized on one proton interacting with profilometer. In Fig. 2 the dark symbols represent the fluence in the working volume of MRM. In corresponding calculation the design elements of MRM were taken into account. These elements promote the development of NEC.

Fig. 3 gives the experimental curve for the longitudinal distribution of the BLM signal is created by ionizing particles of the background from the copper profilometer. As can be seen from Fig.2, 3 the calculated and measured data agrees very well.

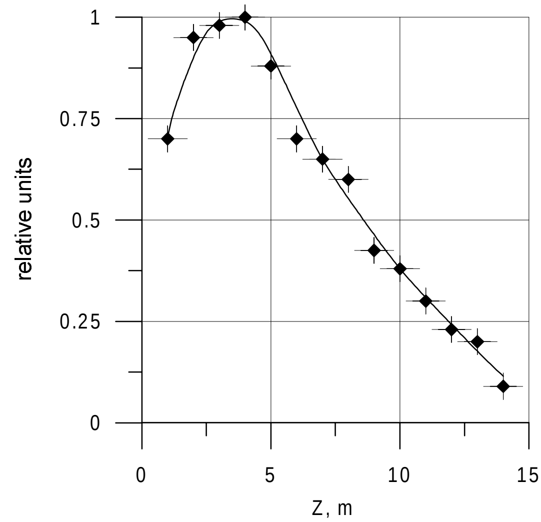

Figure 3. The measured longitudinal distribution of the BLM signal at the copper profilometer into the proton beam.

Fig. 4 illustrates the energy spectrums of electrons, pions and protons in the working volume of MRM. These spectrums and well-known curves of the ionization energy losses of charged particles in air were used for calculations of an ionization energy deposition and formed ion charge in MRM. The low limit of the particle energy equal 1 MeV.

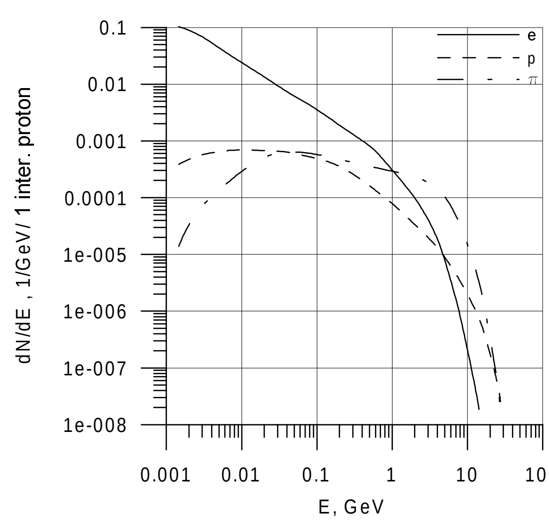

Figure 4. Energy spectrums of ionizating particles of the background from the kapton profilometer.

For the main ionization background components the values of an energy deposition density (in eV/cm^3 on 1 primary proton) are listed in Table 3 for electrons (w_e), pions (w_π,), protons (w_p). In two last lines of the Table 3 the values of a summary energy deposition (W) and a corresponding ion charge (Q) in MRM are given at a beam intensity of 10^{13} ppp.

Table 3: Energy deposition and charge into MRM

Parameter	Values
w_e, eV /cm^3 /1ppp	$1.39 \cdot 10^{-3}$
w_π, eV /cm^3./1ppp	$2.25 \cdot 10^{-4}$
w_p, eV /cm^3 /1ppp	$2.35 \cdot 10^{-4}$
W, eV / 10^{13}ppp	$1.65 \cdot 10^{13}$
Q, nC / 10^{13}ppp	83

5 PROTON LOSSES OF AN INCLINED BEAM

A beam direction has a non-zero angle with an axis Z from coordinate of Z=0. At this point the beam axis coincides with the pipe axis. Another beam parameters correspond to normal conditions of the beam transportation. Such situation arises at a disturbance of the bending magnet regime. In this case the source of the background radiation is essentially inhomogeneous on the azimuth and the axis of the pipe. For a beam deviation angle of 2.5 mrad in Fig.5 the longitudinal distribution of fluense of electrons, pions and protons are shown for the background on a side of the beam fall (symbol A) and on the opposite side (symbol B).

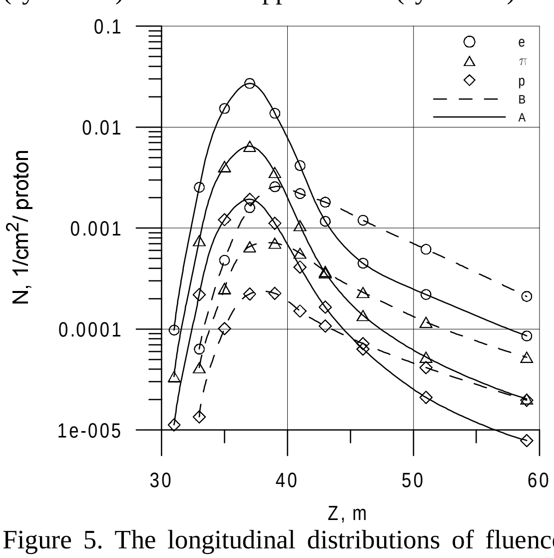

Figure 5. The longitudinal distributions of fluence of ionizating particles of the background from an inclined beam; the deviation angle of 2.5 mrad.

Fig. 6 illustrates the maximum values of a fluence as function of the deviation angle. The angle of 15 mrad corresponds to a total bend angle of the beamline magnet. In Fig. 5, 6 the value of a fluence is normalized on one proton of the incident beam.

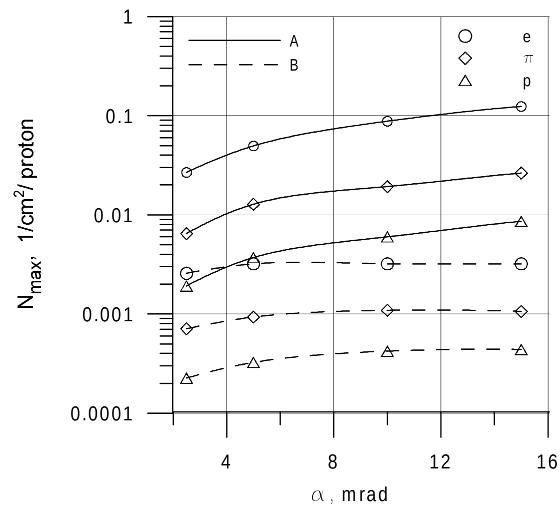

Figure 6. The maximum values of a fluence at an inclined beam as function of the deviation angle.

6 CONCLUSION

As is followed from the calculated results, the main ionizing component of the background outside of the beampipe are the electrons (and positrons). The spatial distribution of the background essentially depends on a type of loss. The enough diveloped system of BLM measuring features of distribution of the background will allow to determine the reasons and places of existence of random beam losses, and also to control the input/output of detectors and other devices into the beam.

7 REFERENCES

[1] Inventor's certificate No. 1929884, Russia, 1992.

[2] I. Azhgirey et al, Proc. XV Conference on Charged Particles Accelerators, p.74, Protvino, 1996.