Possible Approach to the Creation of Systems for High Energy Proton Beam Losses Measurements (part 1. Physical Aspects and Experimental Results)

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Abstract

The new approach to the beam losses monitoring system (BLMS) creation is proposed. It is based on the using of radiation monitors (RM) with quasi 2π-geometry and linear model of beam losses development and BLMS performance. Such a BLMS obtains some features of the beam diagnostic tool in addition to its usual status as part of technological equipment, because using it one can study not only radiation field distribution along the machine but also the distribution of the initial sources of beam losses. Some new notions are introduced. The results of such system prototype testing at the high intensity 70 GeV proton beam extraction line are presented.

1 INTRODUCTION

BLMS exist almost as long as proton synchrotrons do. They are an obligatory attribute of all the accelerators round the world. But up to now their place and status among the other proton accelerators equipment are rather vague and ambiguous. The results they present are sometimes contradictable and unpredictable. Accelerator's people avoid use them widely because can hardly interpret the obtained from BLMS results in usual terms. On the other hand nobody says these systems are vain, because some tasks exist and should be solved. The most common task (except for the some specific ones) for all known BLMS is to measure, more or less accurately, the dose field map along the accelerator circumference and thus the beam losses-induced radiation load on the accelerator equipment to protect it. In such application BLMS should be considered as an additional technological system. Although the measured radiation field is originated by the beam losses, but the task of transition from the dose field map measurements to the initial sources distribution hasn't been solved for high energy beams yet. After this task solving the BLMS value increases considerably and it may be classified as a beam diagnostic tool with unique possibilities.

2 THE CURRENT SITUATION WITH BLMS

Nevertheless even in the first traditional application the BLMS effective performance became very important and crucial for the SC accelerators operation, because in this case the radiation load above tolerable level leads to SC magnets quenching. In ideally the BLMS should indicate the dangerous situation timely and thus the quench may be prevented by beam abort system launching in advance. But in reality the information obtained from the BLMS is semi-quantitative and, with the measurements accuracy achieved, the efficiency of BLMS is low [2]. Such a state shouldn't be considered as the acceptable neither for the existing SC collider - Tevatron nor, moreover, for the future much more advanced machines: UNK, SSC and LHC. The only way to improve the BLMS efficiency is increasing of it accuracy. To do that, we think, one has to take into account the strong assymetry of the radiation field from the losed high energy protons hitting the thick targed (beam pipe, because the typical accident angles are very small) [3]. But it is only the first step, we think, should be done for increasing the BLMS efficiency in its traditional application only. We offer to get over it by using the RM, often called as beam losses monitors (BLM), with a quasi 2π-geometry [4], installed immediately on the beam pipe - see fig.1. Calculations show [2, 3] that in the TeV-region the accuracy of beam losses control may be improved significantly (about for order) if the traditional RM are replaced with a 2π-geometry ones. We have already designed a set of such RM to be used in the BLMS at the UNK different stages. In details they will be described in a separate article. We notice only that this way we have a local hermetic beam losses control. If now we find a way to create in addition to it a total hermetic beam losses control without gaps along the beam line, it opens the possibility to accomplish the next mentioned step in the BLMS development - to pass to the initial sources distribution study.

3 MODEL OF BLMS PERFORMANCE AT HIGH ENERGIES

As the response function of proposed RM in the TeV-region is rather

extended (about 20-30 m) [5] it is possible to cover all the beam trace without blind gaps with a reasonable amount of RM. Such BLMS, called as 'full', should be the total hermetic in any case. But it is interesting to create

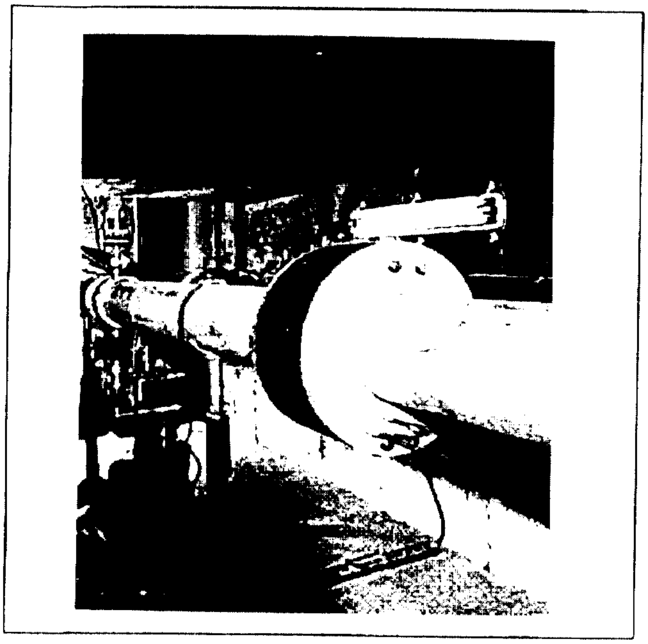


Figure 1: The view of 2π-geometry RM on the beam-pipe.

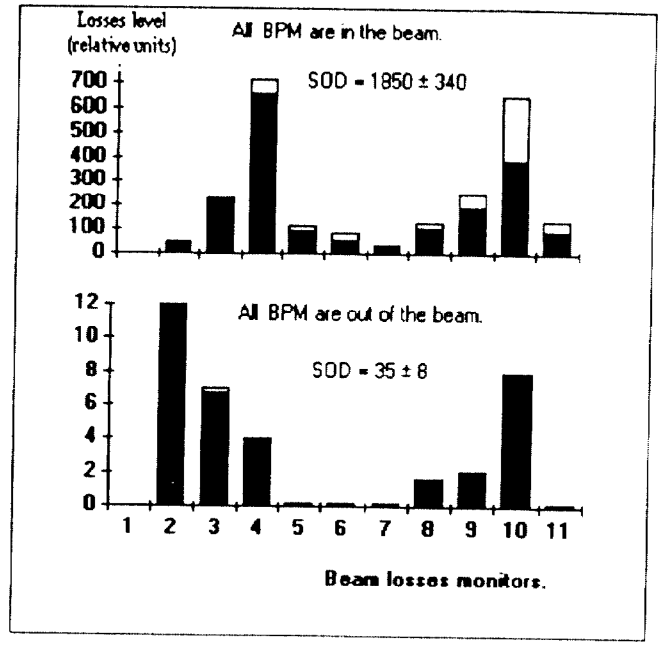
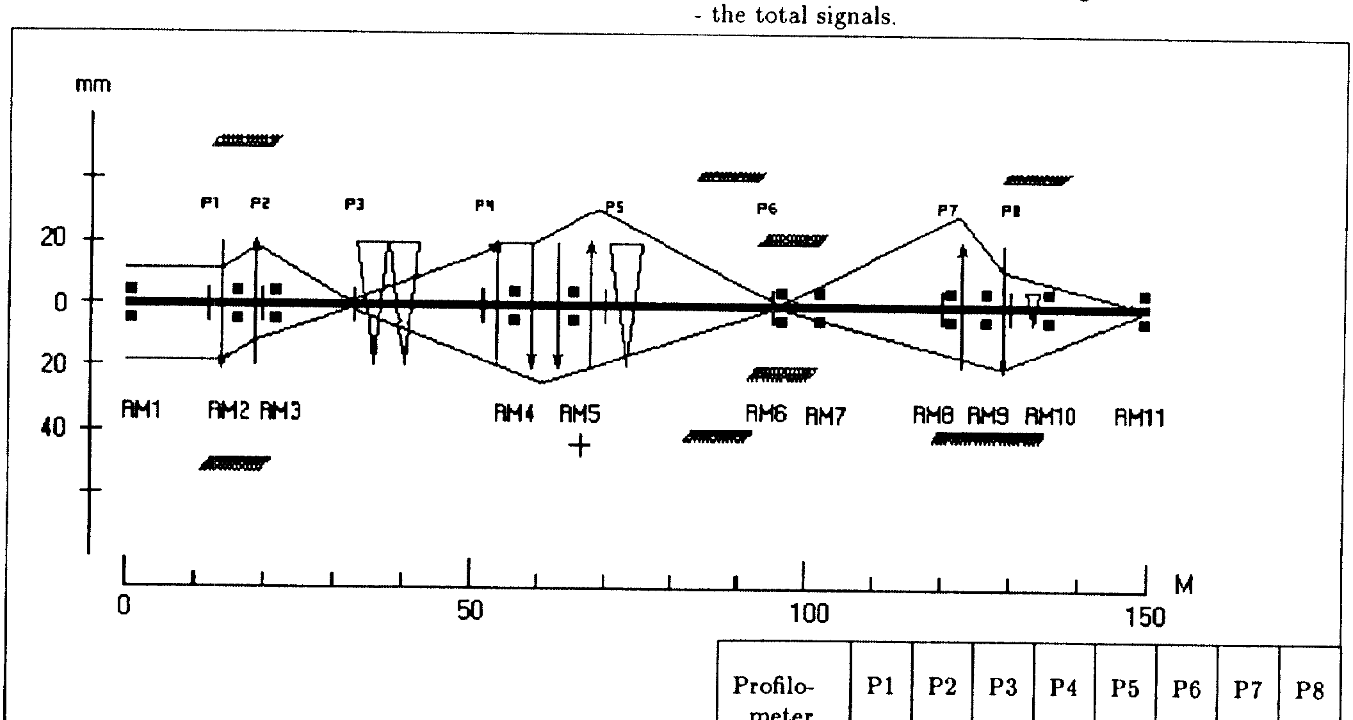


Figure 3: The RM outputs distribution along the channel. The top histogram correspond to all profilometers inserted in the beam and the bottom one - to "pure" channel. Dark columns mean the "own" part of signal and the whole ones - the total signals.



Profilometer	P1	P2	P3	P4	P5	P6	P7	P8
Matter mg cm^{-2}	7	7	46	92	7	17	7	92

Figure 2: Experimental set up layout. P - profilometers. RM - radiation monitors.

the hermetic BLMS with a significant lesser amount of RM and insensitive to loss of part of them. Let assume now we have the total hermetic BLMS and can measure beam losses - induced radiation field with high accuracy (about 5-10%). How one should interpret these data? We can define the beam losses as part of the initial beam particles with E_o energy hitting the thick target - beam-pipe wall. Produced charged particles distribution has characteristic view: the near region of low energy (less than 0.7 E_o) particles and some remote regions due to the high energy positive charged particles transport through the magneto-optical system. These regions locations depend mainly from facility parameters and weakly from the original sources ones. For circulated beams they may be distributed over the half turn [2]. Thus each RM see not only 'own' sources (situated within it response function region) but in addition the remote ones. So the data obtained from the even hermetic BLMS cannot be used directly to define the initial sources distribution. As the RM operate in the current mode we cann't use the coincidence method to pick out the 'own' parts of RM signals and have to use the statistical methods only. On the other hand as the number of high energy particles from remote source is proportional to it intensity and the transport equations are linear we can presume for the hermetic local beam losses control the strong linear dependence between each RM response and all previous ones to this remote source. Besides, we saw the strong correlations between RM outputs. Thus in the frames of the linear model of BLMS performance described in part 2 we examined the possibilities of the BLMS [6] of 'own' sources apportioning in different configurations and these BLMS tightness.

4 EXPERIMENTAL RESULTS

We worked on the 70 GeV fast extracted $2 \cdot 10^{13}$ ppp beam line designed for the ν-experiments. The statistics above 1000 accelerators cycles was accumulated. The layout of the used set up is shown in fig.2. RM were disposed at the places of the most probable beam losses developments. The matter of profilometers active areas and their frames were used for beam indignation. The thicknesses of the each profilometer active area are given in the table in fig.2. In fig.3 the bottom histogram presents the case of 'pure' channel (all profilometers were out of beam). One can see the 'own' parts of signals obtained through processing are approximately equal to the directly measured values. We interpreted the obtained 'own' data distribution as the initial sources one and their sum to be proportional to the total beam losses along the beam line - if BLMS is hermetic. There were not local beam losses sources in this case except the distributed ones from the residual gas scattering, beam halo etc. The quite opposite situation is presented in the top histogram where all profilometers were inserted in the beam (about 275 mg cm^{-2}). One can see the most powerful source near the BLM4. We notice the two most thick profilometers are situated in this area. The estimated level of the relative beam losses due to the influence of inserted matter of profilometers is about $5 \cdot 10^{-3}$ (from the inelastic interactions only). From compairing of the integral 'own' data of both these histograms we estimate this level for 'pure' channel about 10^{-4}. The similar result was obtained independently for background level in the ν beam-dump experiment. Thus we have the absolute calibration of our BLMS in the (mg cm^{-2}) units. The tests of the studied BLMS for tightness we carried out by including the different sets of RM in processing. The invariance of the 'own' data sum was used as a criterion for the BLMS tightness. These results are presented in the part 2. We observed the sum of the 'own' data remained invariant even the half of RM were eliminated from processing. The only advantage of the more full BLMS configurations is higher accuracy of initial sources definition.

The results obtained on the high intensity extracted beam line with a prototype of proposed BLMS show that such a system may occur an effective tool to optimize the single passing beam facility operation and keep the established facility's operation mode. We are going now to examine this approach on the 70 GeV circulating beam with the RM designed for the UNK-I. We are waiting for some new results at the regular lattice and think a lot of experimental study should be done to learn the ways of the most efficiently using of the proposed approach, to be ready when future SC machines begin their operation.

In addition to the search of sources we can use a priori information about the artificial source to study the machine parameters. For example, inserting insignificant amount of matter between the beam-pipe wall and 'dynamic' aperture area and using the proposed BLMS one can study the beam halo distribution and dynamics. This task solving is very important for the SC colliders effective performance [1].

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