NON-RESONANT SLOW EXTRACTION OF PROTONS TO THE TAGGED NEUTRINO FACILITY.*

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ABSTRACT

The results of extraction of 70 GeV protons scattered by internal targets from the IHEP accelerator(A-70) towards channel 23 are presented. The use of an electrostatic deflector gave one the possibility to extract $\geq 5 \cdot 10^{10}$ protons during ~1.7s of the flat top of a magnetic cycle that is about an order of magnitude higher than it was obtained before in analogous regimes.

1 INTRODUCTION

Due to its high sensitivity, the Tagged Neutrino Facility (TNF) has, besides the experiments with the tagged neutrino beams, a possibility to investigate the rare decays of K-mesons. For this purpose one needs a beam of 70 GeV protons of intensity below 10^{11} protons per cycle (ppc) but with the maximum spill time, high stability of parameters and the time structure which is available during the internal targets work only.

Extraction of protons in non-resonant slow extraction mode (NRSE) simultaneously which generation of secondary particles by 3-4 internal targets allows one to increase an efficiency of the accelerator use by 25-30 %. Another advantage of this method is in a higher efficiency of the experimental setup work due to high quality of the extracted beam parameters. For example, due to the quality of a beam time structure, the extracted intensities for the TNF differ by two orders of magnitude at about the same rate of statistics collection: $\sim 10^{10}$ ppc for a "good" (ripples are $\leq 10\%$) time structure at NRSE and $\sim 10^{12}$ ppc for the case of a high ripples time structure ($\geq 50\%$) at extraction under a resonance $Q_r = 9\frac{2}{3}$.

Estimation of an extraction efficiency that derived from the real distribution of the accelerated beam intensity during the A-70 cycle between the users is given in the article. Intensity of a beam interacting with internal targets was found from the callibration curves of the individual monitors looking at the approprite target.

2 EXPERIMENTAL RESULTS

It was required during investigations to learn a principle possibility of extraction the beam of an intensity about 10^{10} ppc which is necessary for the new experiment. As it was mentioned above, this level of intensity was not reached before under NRSE of protons towards channel 22. The next stage of investigations was receiving the maximum intensity which is possible to be reached at this regime when all of the deflectors of the slow extraction system available at A-70 are used.

2.1 Extracting schemes

Two schemes of extraction were used for these purposes. The first one consists of four magnetic deflectors, the first of which is a septum-magnet of the straight section N° 18 (SM-18). It has a septum of 0.5 mm thick. The second scheme has, as a first element, an electrostatic deflector of the straight section 106 (ED-106) and includes all magnetic deflectors of the first scheme. Thickness of the ED-106 septum is 0.1 mm, it consists of the wires of W-Re alloy which are spaced at 2 mm interval on the 3 m length [1]. The whole extraction scheme is shown in fig.1 where one can see local distortions of the closed orbit (bumps) at the regions of ED-106, septum-magnets and targets T_1, T_2 (curves 1, 1') as well as the trajectory of the extracted beam after its jumping into the ED-106 aperture (curve 2, 2').

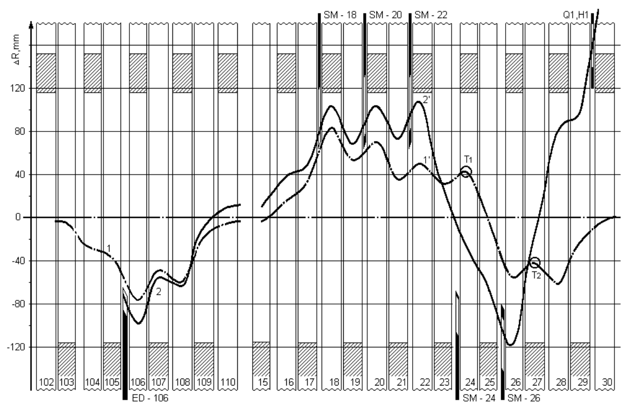

Figure 1: The scheme of a proton beam extraction. ED-106, SM-18, 20, 22, 26 are the electrostatic and magnetic deflectors; Q_1, H_1 are the first elements of the beam transport system; SM-24 is the septum--magnet of the fast ejection system; T_1, T_2 are the internal targets of channels 2(14) and 4, respectively.

Fig.2 shows the intensity of extracted protons (curve 1) at the beginning of channel 23 and K-mesons after a target of the experimental setup (curve 2) in the case of a

* This work was supported in part by Grant N° RMK000 from the International Science Foundation

beam extraction by the first scheme (SM-18 as the first deflector). It is seen here that the extracted beam intensity ~10^{10} ppc is obtained. It gives ~ 10^6 K-mesons after the external TNF target which is enough to start experiments with the beam obtained for the new program.

In the case of using the second scheme, protons were extracted during 1.7 s that is practically maximum time allowed for a beam interaction with internal targets on the flat top of the A-70 magnetic cycle. But since the pulse duration of the SM-18 under a nominal current is 1.3 s only, the current was reduced by about 20% to keep power dissipation in the septum unchanged during 1.7 s of the extraction time.

The intensity of an extracted proton beam of $\geq 5 \cdot 10^{10}$ppc was obtained in this case while the number of K-mesons fixed at the TNF after its external target was about $5 \cdot 10^6$. It is far beyond the requirements of a new experiment for the intensity of both the primary extracted beam and secondary K-mesons.

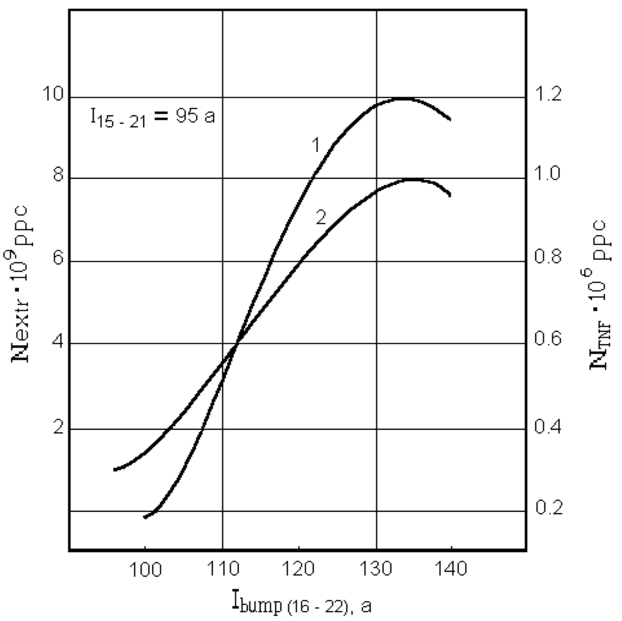

Figure 2: Dependencies of intensity of extracted protons (curve 1) and K-mesons after the target of the experimental setup (curve 2) versus the current of a bump formed by magnetic blocks 16, 22 of the accelerator.

It is worth to be mentioned here that becides of the two main parameters obtained, namely, an extracted beam intensity and a duration of the spill one more parameter is very important for it directly influences on the efficiency of the statistics collection of the experiment. It is a time structure of the extracted beam.

As it was shown somewhere (see,for example,[2]) the ripples of the time structure of the extracted beam are kept at the level of ≤10% when the thin target of a carbonic cloth [3] is being used. The thin target works almost permanently thus providing the best conditions for statistics collection by the experimental setups and keeping high an efficiency of the experiments.

2.2 Evaluation of the extraction efficiency.

The efficiency of extraction at NRSE was evaluated taking into account the intensity of the primary beam interacted inelastically with internal targets, number of particles scattered by targets as well as the intensity measured in the channel. All these data are put in the table.

Table 1: Distribution of the intensity at the NRSE (in units of 10^{11} ppc)

I_Σ	Intensity for Internal targets				ΔI	ΔI
of A-70	ΔI_{24}	ΔI_{27}	ΔI_{35}	ΔI_Σ	NRSE	EXTR
24.0	11.0	10.0	1.0	22.0	2.0	≥ 0.5*)

*) Limit of measurement where the ionization chamber used was saturated.

Meanings in the table:

ΔI_i is the intensity of a beam interacted with internal targets (i is the magnetic block number where the corresponded targets are installed),

ΔI_{NRSE}, ΔI_{EXTR} are the intensities of particles which were scattered by the targets and extracted, respectivly.

In our case the extracting efficiency was evaluated as follows:

$$\varepsilon = \frac{\Delta I_{EXTR}}{\Delta I_{NRSE}} \geq \frac{5 \cdot 10^{10}}{2 \cdot 10^{11}} \geq 25\%$$

This value of efficiency was obtained for NRSE mode at the IHEP accelerator for the first time. It is expected that after energizing the SM-18 with a nominal current and optimizing the regime the extracting intensity ≥ 10^{11} ppc may be obtained.

It is necessary to mention here that the maximum value of the extracted intensity forecasted for this mode of extraction on the base of calculations reported in [4] is 10^{10} ppc. It is more than 5 times less of the intensity obtained experimentally and about an order of magnitude lower than it is expected when the SM-18 works with a nominal current. The main of possible sourses of the error was in considering the hypothetical case of using the internal targets of Al and Cu. Those materials are out of use more than 20 years already. The author could have forecasted the result to be much closer to the experiment for the really used combination of Be and C targets.

For example, for the case of T24(C)+T27(Be) the intensity of $1.2 \cdot 10^{11}$ could be derived. It would have been corresponded well to the estimates of the extracted intensity for our case ($\geq 10^{11}$ ppc).

3 EVALUTION OF THE EFFECTIVE JUMP WIDTH FOR SCATTERED PARTICLES

It is known that two main processes bring to the amplitude growth for particles interacting with internal targets. They are multiple Coulomb scattering and ionization energy losses. Due to the common effect of these processes, particles are jumped into the field of the first deflector (electrostatic or a magnetic one) and extracted from the accelerator.

Taking into account the effects mentioned above, the horizontal betatron amplitude growth of a particle on the deflector asimuth(at a single interaction with the target) will be evaluated according to the formula:

$$\Delta A_{r\alpha\Sigma} \sim \left[\beta_d \beta_t \Phi^2 + 2\frac{\beta_d}{\beta_t} A_{0rt} \psi_t \frac{\Delta p}{\Delta p_0}\right]^{1/2}, \quad (1)$$

where $\beta_{d,t}$ are the accelerator β functions on the asimuth of a deflector and a target, respectively; Φ is a projection of the r.m.s. scattering angle of a particle; ψ_t is a dispersion function; $\Delta p/p_0$ is a momentum spread; A_{0rt} is an initial betatron amplitude.

Analysis shows that at extracting the beam by the first scheme we have a gap between the circulating and extracted beams about 2.3 mm. Taking into account a thickness of the SM-18 septum 0.5 mm, one can see that the real value of a particle jump whidth is ~1.8 mm. Counting the influence of the momentum spread, beam instabilities, precision of an alignment etc. one can see that the possibility of extraction of high intensity by the first scheme is restricted. In the case of using the electrostatic deflector ED-106 one will have the gap between the beams of 3.1 mm. It means that if the ED-106 strength is enough just to throw particles over a septum of the SM-18, the gap between the circulating and extracted beams at the SM-18 asimuth will be about 3 mm. It is obvious that it provides a meaningful decrease of particles loss on the SM-18 septum and, respectively, increase of the extracted beam intensity.

So, in our case, increasing the gap between the beams by 1.5-2 times due to the electrostatic deflector use gave an extracted intensity growth more that 5 times from $\sim 10^{10}$ at extraction by the first scheme to $\geq 5 \cdot 10^{10}$ protons per cycle extracted by the scheme two.

4 CONCLUSION

The use of the electrostatic deflector as the first element of the extraction system allowed one, in the non--resonant slow extraction mode, to decrease the particle losses on the septums and, even under reduced current of the SM-18, obtain the intensity $\geq 5 \cdot 10^{10}$ ppc. It is about an order of magnitude higher the intensity obtained before when the SM-18 was used as the first deflector of the system [2]. Evaluations show that under optimal conditions it is possible to extract $\geq 10^{11}$ ppc keeping the high quality time structure of the extracted beams.

Non-resonant slow extraction is only the method at the medium energy accelerators which allows one to extract the high quality proton beams of $\sim 10^{11}$ ppc simultaneously with extraction of secondary particles for other experiments. The particle beams of this level of intensity, large duration, high quality of the time structure as well as the stability of other parameters were not obtained so far by other methods of extraction at simultaneous work of a few experimental setups.

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