SL-MD Note 250

Collimation studies in a 120 GeV coasting proton beam

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Summary

Following the series of experiments done in 1996 [1], two machine development sessions in 1997 were dedicated to study the LHC collimation scheme using the SPS as a test-bench. The straight section LSS5 hosted the experiment, where the radiation level is well below the one observed at LSS1.

Three identical tanks were equipped with aluminium jaws, and formed a three stage collimation system similar to previous experiences.

The predictions of the numerical model also used for LHC studies are compared with the data acquired during both MD's.

1 Introduction

In this note we report the measurements carried out during the 1997 MD sessions on collimation. Previous experiments were reported on SL-MD Note 235 [1].

The goal of this studies is to check the software model used for the design the LHC collimation scheme [2]. This software model incorporated to the K2 program [3], consists of true scattering through the collimator jaws, as well as linear tracking around the machine. To check the validity of the model, we arrange three collimators as primary, secondary and tertiary aperture limitations. We simulate and measure the rate of inelastic interactions at the three collimators as a function of the secondary and tertiary aperture.

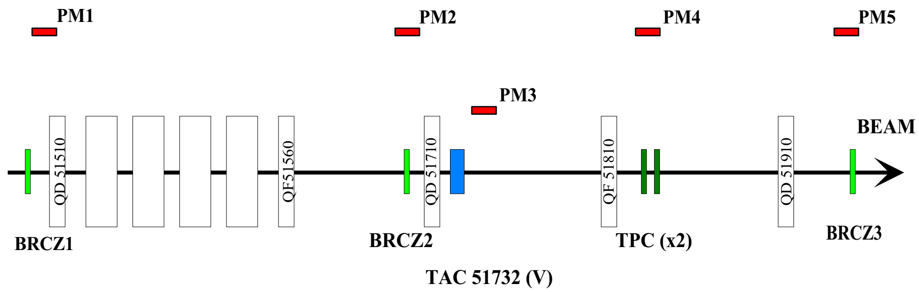


Figure 1: Schematic layout of LSS5

In the first session in April we set the nominal aperture for the main tanks as 6, 7, and 9 sigma respectively. No time was left to calibrate the detectors. In November, we measured again the main rates after calibrating our counters. This time the aperture was set to 12, 14, and 18 sigma.

We will limit ourselves to describe the measurements and cite the facts known after the experiment session. Any further analysis of the data will be the subject of future publications [4]. Preliminary results are shown on section 5.

2 Experimental set-up

For the first collimation studies on the SPS [1], three different tanks on the straight section LSS1 were used as a three stage collimation system. The high radioactivity levels forced us to displace some of the detectors and to increase their gain what led to saturation of the measured signal. This year experiments were carried on at LSS5 where the detectors could also be located at optimum positions without fearing a high level of noise.

During the winter shutdown in 1997, three LEP-like collimators tanks were installed in LSS5 with aluminium jaws of 250mm. Using identical tanks and jaws reduces the uncertainty of the calibration factor for the signal-to-absorbed-proton ratio caused by different geometry and material. It allows a straight comparison of the signals on the three corresponding scintillators.

The schematic layout of the experiment is shown in figure 1. The three main collimator tanks are named BRCZ1, 2 and 3. An existing tank (TAC) with two long jaws made of stainless steel was used to collimate vertically the protons scattered at large amplitudes. The two TPC tanks used on LSS1 were installed on LSS5 and provided with tungsten horizontal jaws to enlarge the choice of phase advances.

The experimental zone extend from QD51510 to some meters after QD51910. The phase advance between the BRCZ collimators was $\mu_{1-2} = 90°$ and $\mu_{1-3} = 200°$. The TPC tanks were installed at a phase advance of $\approx 150°$ next to the

TEC tank, formerly used for crystal extraction experiments. First measurements done in April revealed a high background signal in BRCZ3 coming from the tungsten jaws. In November the TPC collimators were therefore retracted and not used for experiment.

Five small counters made of the assembly of a scintillator and a Photo-Multiplier (PM), were located next to each tank and their signals were remotely read by the COLMON system [5]. The software associated to this system also reads the intensity of the stored beam through a Beam Current Transformer(BCT). For our experiment, we used the second BCT of BA4 with a dynamic range of $2.0 \cdot 10^9 - 4.0 \cdot 10^{12}$ ppp and a resolution of $1.0 \cdot 10^9$ppp.

A modification on the software made for the second MD session in November enabled the automatic log of the acquisitions of the PM's as well as the BCT readout every SPS-cycle of $14.4s$ for an arbitrary long period.

3 Machine conditions

For both experiments a coasting beam at 120 GeV/c was used. The intensity at the beginning of the coast was around $2 \cdot 10^{12}$ protons from which we lost between 10^7 and 10^8 protons per second. When necessary, we applied some noise to a damper to have a sensible level of losses [6].

Some basic beam parameters measured in April are presented in table 1. The same tune values were used in our simulations.

	Hor.	Vert.
Fract. tune	0.620	0.578
Chromaticity	0.017	-0.175
Emmitance (2σ)[mm]	1.458	0.807

Table 1: Beam parameters measured before the machine development session on April the 23th.

The closed orbit at each collimator was measured before positioning the jaws. To measure it, we entered one jaw at some distance from the beam and we approached with the opposite jaw till we saw a spike in the scintillator signal. This indicated that both jaws were at the same normalised aperture and we calculated the closed orbit as the middle point between both jaws. The values of the closed orbit at the moment of the measurements presented here, are shown on table 2.

We observed changes of these values from one coast to another even during the same MD session. We had to measure the closed orbit every filling of the machine.

	BRCZ1 H	BRCZ2 H	TAC V	TPC H	BRCZ3 H
April 23th	2.95	0.28	0.80	-1.22	1.15
November 12th	-0.95	-0.45	-0.70		1.16

Table 2: Closed orbit displacement at the collimator tanks.

Correction of the beta values.

For all series of measurements, the beta values given by MAD and K2 were used to calculate the aperture of collimator jaws. During the measurements of November we observed that the ratings at the primary and secondary jaws, did not correspond to their relative aperture. Even when BRCZ2 jaws were theoretically at a narrower aperture, the signal coming from BRCZ1 was still more important indicating that this last tank was still acting as primary collimator.

We proceeded to measure the sigma at BRCZ2 in a similar way to the closed orbit measurement. With the BRCZ1's jaws inside the beam 12σ[1], we approached one of the jaws of BRCZ2 till we saw a spike at $x_{12\sigma}$. The closed orbit $x_{c.o.}$ being known, we calculated the sigma value at BRCZ2 as $\sigma_{BRCZ2} = (x_{12\sigma} - x_{c.o.})/12$. We obtained a value of 0.762mm that compared to 0.810mm at BRCZ1. This indicates a beta beating of 12% between both positions.

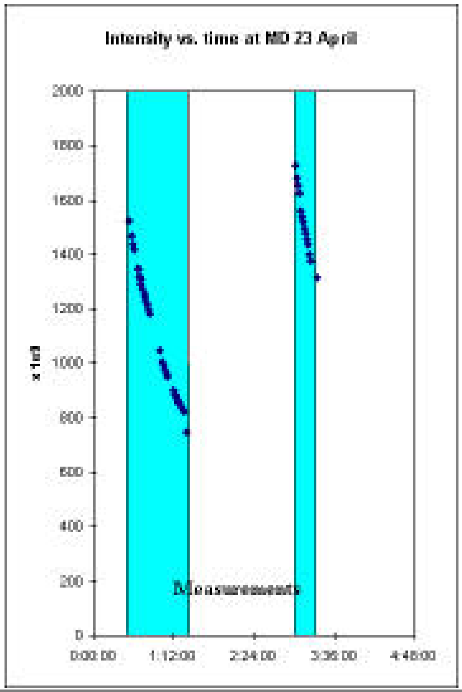
4 Losses

In the April session, we closed the jaws well inside the beam (primary aperture $n_1 = 6$) and the natural beam diffusion was important enough to cause the required loss rate. In November, the aperture of all jaws was twice larger. We had to introduce some noise in order to force a steady diffusion and an adequate rate of losses. The evolution of the stored intensity during both sessions can be seen on figure 2.

The lifetime in November was much longer even with the use of the damper noise and only one filling was necessary.

Due to the extensions in the software, in November we were able to measure and save the BCT acquisitions. This allows us to monitor the intensity for long periods and compare with the signals detected on the PM's. While a normal measurement is typically made during a cycle, longer acquisition periods were dedicated to calibrate the photo-Multipliers. In a time interval of twenty to fifty cycles, the intensity read by the BCT decreases sensibly and a reasonable estimation of the losses during the same time can be determined. Measuring the

[1]Note that what we can measure is the ratio between sigma at both collimators. We took arbitrarily the sigma value for BRCZ1 as the reference size.



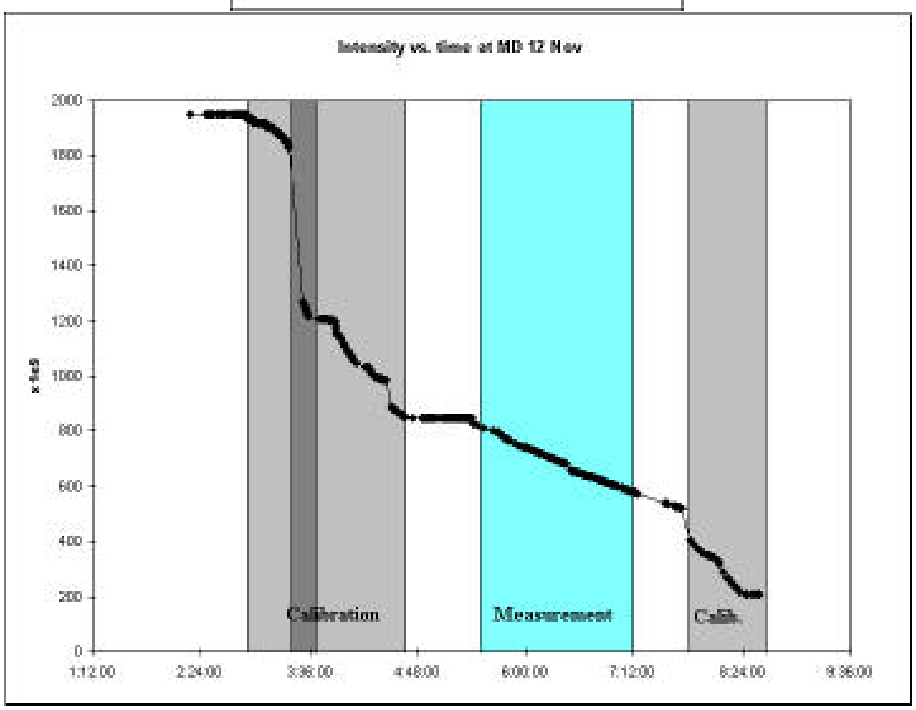


Figure 2: Intensity in the SPS during the MD sessions of April and November. on the first experiment, only the intensity corresponding to the measurements is known. On November, the intensity was measured almost continuously during the MD.

rates in the scintillator that is being calibrated, we can evaluate the signal-to-absorbed-proton factor. First results show equal calibration factors for all BRCZ tanks within a few percent. We also could see a good agreement between shower simulations and the measured values. A more refined study is needed to correct this values taking in account any other losses in the ring.

5 Preliminary results.

As a first check of the agreement between K2 predictions and the reality, we compare the rates detected in PM1, PM2 and PM5 (corresponding to BRCZ1, BRCZ2 and BRCZ3). Calibration factors are taken equal so that the rate between measured signals have to be comparable to that between absorbed protons given by K2. In figure 3 we see this comparison for the experience on April 23th.

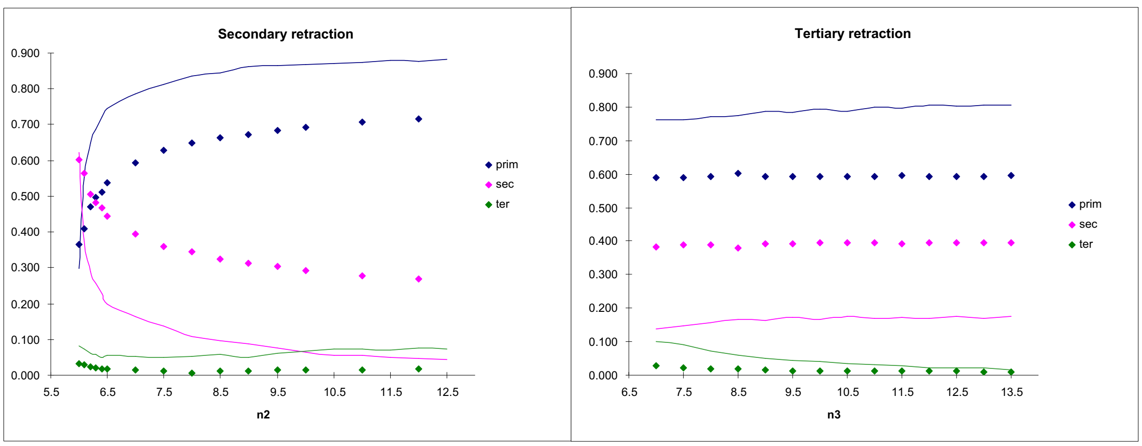


Figure 3: Comparison of the rates of detection on April the 23th. We assume the calibration factors for the system BRCZ+PM are identical for all three tanks.

In the figure 4, the same comparison is shown for the experiment done in November. There are two main differences between this two experiences.

- First, the aperture in November is twice as large as in precedent sessions. In April, we measured an emmitance larger than the corresponding to our simulations. No damper noise was needed to blow up the beam. Natural diffusion was enough to cause losses twice as large as those of November when we were using the damper noise. In the same context, while in April we have natural, hence isotropic diffusion, in the last session we just have horizontal diffusion coming from the damper. This can influence the results in several ways. The positioning of the jaws is calculated in sigma units from the theoretical value used in simulations while the scattered angle only depends on the energy and material and is beam independent. In K2

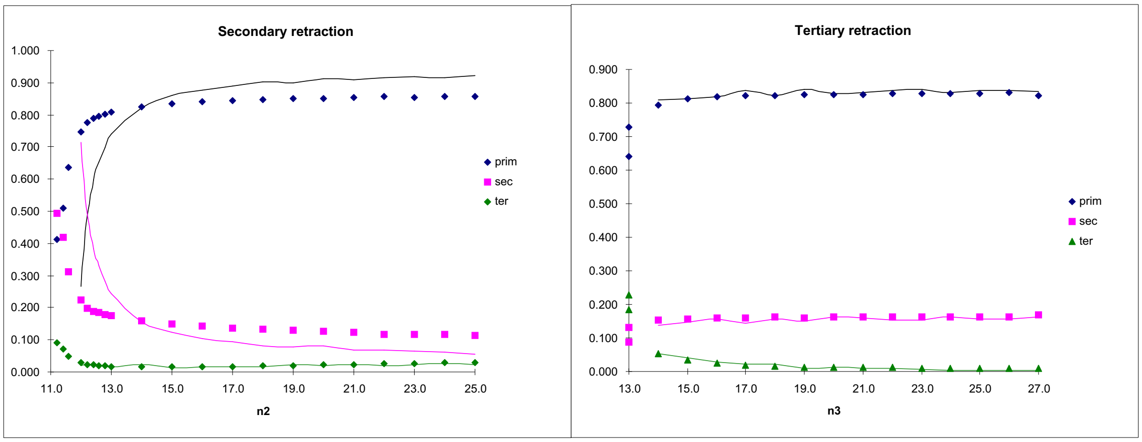


Figure 4: Repartition of the losses between the three collimators as a function of the retraction of the test collimator on November the 12th. This time the agreement with the simulations is better.

the drift velocity also has sigma units. If the emmitance for simulations is wrong, it can bias the distribution of the secondary halo and the final results.

- Secondly, the voltage applied to the PM's was different. The choice of the new values was done after a calibration on a muon beam prior to the MD. In November the PM's were calibrated with a better resolution and we found differences up to 20 V for PM2 and PM5.

  To check this last hypothesis, the last measurement was repeated during the MD after changing the voltages back to their old values. The aperture of the collimators and noise level were kept identical. The comparison between this two measurements is shown on table 3.

	PM1	PM2	PM5	%prim	%sec	%ter
Voltage Nov.	1800	1800	1802			
	7.68e+5	1.57e+5	2.75e+5	64.0	13.1	22.9
	7.71e+5	1.58e+5	2.75e+5	64.1	13.1	22.8
	8.18e+5	1.67e+5	2.87e+5	64.3	13.1	22.6
Voltage Apr.	1800	1780	1790			
	6.21e+5	7.48e+4	1.57e+5	72.8	8.8	18.4
	6.75e+5	8.08e+4	1.72e+5	72.8	8.7	18.5

Table 3: Signal measured on the scintillator for different amplification voltage. Even if the absolute rate for PM1 does not change significantly, the relative ratios do. For the same voltage values, the measurements show a good reproducibility.

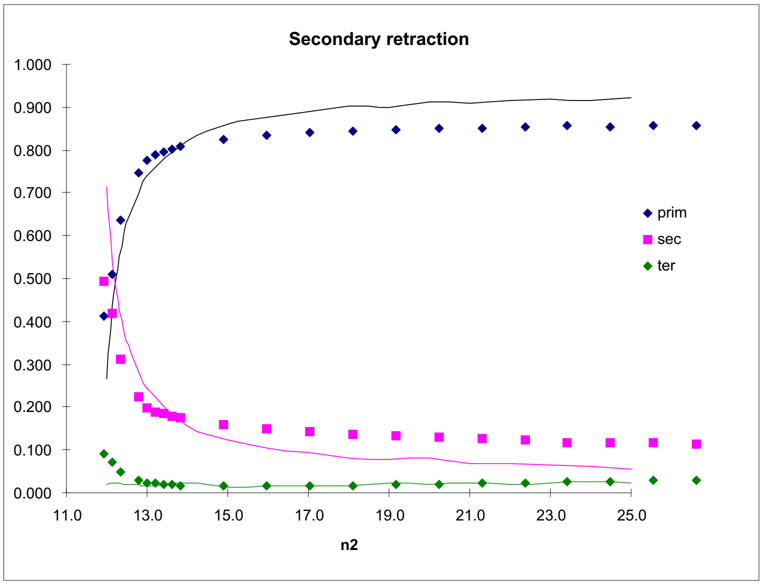


Figure 5: The secondary retraction in sigma units (n_2) has been corrected following the measurements on November the 12th. Some points have still to be simulated.

One correction can be already applied to the last results. As said before, a different sigma value was measured for BRCZ2. This will imply a correction of the scale of figure 4. In figure 5 we can see the same comparison between measured points and simulation with n_2 corresponding to the measured value for the sigma value, i.e. 0.762 mm instead of 0.810mm. The corrected results is much better.

The influence of other factors like impact parameter, possible aperture restrictions in the ring, beta beating, etc., will be the subject of future analysis.

6 Conclusions

The increased accuracy of the measurements allowed to obtain better results than in previous experiments. In view of the agreement between theory and simulations no further experiments are foreseen. The unavoidable uncertaintity of simulations, calibrations and other uncontrolled factors might justify the small differences between simulation and measurements.

Nevertheless, a deeper analysis will be done based on the observations made during those MD sessions. An effort is being made in determine the weight that diffusion, impact parameters or any other factor can have in the simulations. Data already measured will be used to validate our conclusions.

Acknowledgements

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