MINUTES OF A MEETING ABOUT THE TIMING OF CHANNEL A IN SERPUKHOV, HELD ON 31.7.70

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The timing sequence has been revised for channel A in Serpukhov. Four groups are involved and have to be synchronized by a common timing system:

1) Fast Ejection, requiring a stable ejection energy of ± 1 o/oo.

2) Primary Beam Transport, requiring a trigger pulse 5 ± 0,1 ms before ejection.

3) RF Separators, requiring two trigger pulses:
   a) 30 ... 150 ± 5 ms } before ejection
   b) 25 ± 0,1 μs } before ejection

4) Mirabelle Bubble Chamber, requiring a trigger pulse about 150 ± 1 ms before ejection. The exact figure and its tolerance will be confirmed by Mosca by the end of August.

Basically the timing pulses can be derived from two different pulse trains of the accelerator:

a) B-Train, number of pulses proportional to the magnetic field of the accelerator, respectively the energy of the accelerated beam. One B-pulse equals a field increase of 1 oerstedt or an energy increase of 5,8 MeV.

b) T-Train, clock frequency of 10 KHz, derived from a quartz oscillator with a stability of better than $\pm 10^{-4}$.

In order to get a stable ejection energy during acceleration, the fast ejection equipment is triggered by an ejection pulse derived from the B-train. For constant energy at the flat top of the magnetic cycle, the ejection pulse is derived from the T-train. For further details, see TN-132 and TN-143.

The timing pulses for the primary beam transport, RF-separators and Mirabelle bubble chamber are specified in terms of time before ejection.

Measurements of the time intervals at the rise of the magnetic field are reported in appendix A and B. The measurements show that for two trigger pulses derived from the B-train, a time jitter of more than $\pm$ 0,1 ms can exist for intervals of about 0,5 ... 5 ms. The time jitter increases depending of the energy level and the time interval between two B-pulses.

It can be shown by appendix B, that the two trigger pulses for the fast ejection and the primary beam transport cannot be derived both from the B-train with a time jitter of less than $\pm$ 0,1 ms. Consequently the trigger pulse of the primary beam transport will be derived from the B-train, and fast ejection will be delayed exactly 5 ms by a crystal clock. The energy jitter for a 5 ms interval amounts about $\pm$ 2,9 MeV and can be easily tolerated:

$$\Delta E = \frac{dE}{dB} \cdot \frac{dB}{dt} \cdot \Delta t = 5{,}8 \text{ MeV/oe} \cdot 5000 \text{ oe/s} \cdot 0{,}1 \text{ ms} = \underline{\pm\ 2{,}9 \text{ MeV}}$$

The trigger pulse for the RF-separators at 30 ...150 $\pm$ 5 ms before ejection probably can be derived as a prepulse from the B-train. The time jitter of two B-pulses in an interval of about 30 ... 150 ms must be evaluated by a new serie of measurements in Serpukhov. The trigger pulse 25 - 0,1 µs can be delivered by the RF-timing of fast ejection with a stability of a few nanoseconds.

Difficulties arise for the generation of the trigger pulse for the Mirabelle bubble chamber about 150 $\pm$ 1 ms before ejection. The time jitter for two B-pulses in an interval of about 150 ms will be possibly larger than $\pm$ 1 ms. This, however, has to be clarified by the new serie of measurements in Serpukhov. Delaying fast ejection by exactly 150 ms after the trigger pulse of the bubble chamber does not work, because a time jitter of larger than $\pm$ 1 ms between two fixed B-pulses corresponds to an energy jitter of more than $\pm$ 29 MeV for a fixed time interval at 30 GeV, i.e. the ejection energy will vary by more than $\pm$ 0,97 o/oo and will just exceed the limit tolerated for fast ejection.

$$\Delta E = \frac{dE}{dB} \cdot \frac{dB}{dt} \cdot \Delta t = 5{,}8 \text{ MeV/oe} \cdot 5000 \text{ oe/s} \cdot 1 \text{ ms} = 29 \text{ MeV}$$

$$\frac{\Delta E}{E} = \frac{29 \text{ MeV}}{30 \text{ GeV}} = \underline{\pm\ 0{,}97 \text{ o/oo}}$$

Therefore it should be attempted by Saclay to shorten the time interval of 150 ms before ejection and to extend the margin of $\pm$ 1 ms. Saclay will inform CERN about the exact internal timing of the Mirabelle bubble chamber.

CERN will ask IHEP to execute further measurements of time intervals between two B-pulses in intervals of about 30 ... 150 ms at different energies during the rise of the magnetic field. The switch-over from the rise to the flat-top of the magnetic cycle has to be examined carefully. It has been shown by previous measurements (see appendix A, table 1 and 7), that this region is fairly unstable.

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Appendix A

Rise time of synchrotron magnet power supply

see PS/FES/TN-135

Table 1 : Rise time from 73 oe to 12 000 oe (injection - 70 GeV) at three subsequent days.

dates :	15.12.69	16.12.69	17.12.69
t_i =	2680 ms	2717 ms	2723 ms
	2677	2718	2723
	2675	2719	2719
	2681	2719	2702
	2690	2725	2711
	2693	2724	2706
	2687	2722	2697
	2689	2712	2695
	2680	2720	2705
	2677	2719	2700
$t \pm \Delta t$ =	2684 $\pm$ 9 ms	2718 $\pm$ 7 ms	2709 $\pm$ 14 ms

Table 2 : Rise time from start to 73 oe

t_i =	11 107 µs
	11 074
	11 131
	11 116
	11 076
	11 116
	11 154
	11 113
	11 137
	11 171

$t \pm \Delta t = 11\,123 \pm 49$ µs

Table 3 : Rise time from 73 oe to 5100 oe and from 5095 oe to 5100 oe

30 GeV

H	=	73 oe - 5100 oe	H	=	5095 oe - 5100 oe
t_i	=	978,6 ms	t_i	=	1005 μs
		979,2			978
		978,6			1060
		979,7			1059
		979,8			978
		979,8			1000
		980,1			990
		979,1			982
		979,3			1018
		979,3			1013
$t \pm \Delta t$	=	979,4 ± 0,8 ms	$t \pm \Delta t$	=	1019 ± 41 μs

Table 4 : Rise time from 73 oe to 6857 oe and from 6852 oe to 6857 oe

40 GeV

H	=	73 oe - 6857 oe	H	=	6852 oe - 6857 oe
t_i	=	1341,1 ms	t_i	=	1118 μs
		1343,0			1183
		1342,4			1094
		1342,7			1044
		1342,7			1025
		1344,0			1080
		1342,9			1038
		1344,2			983
		1342,8			1073
		1343,5			1102
$t \pm \Delta t$	=	1342,7 ± 1,6 ms	$t \pm \Delta t$	=	1083 ± 100 μs

Table 5 : Rise time from 73 oe to 8571 oe and from 8566 oe to 8571 oe
50 GeV

H =	73 oe - 8571 oe	H =	8566 oe - 8571 oe
t_i =	1815,8 ms	t_i =	1213 μs
	1816,4		1240
	1816,9		1292
	1816,4		1210
	1816,2		1187
	1815,8		1167
	1816,4		1198
	1816,1		1189
	1816,6		1172
	1816,0		1237
$t \pm \Delta t$ =	1816,4 ± 0,6 ms	$t \pm \Delta t$ =	1230 ± 63 μs

Table 6 : Rise time from 73 oe to 10200 oe and from 10195 to 10200 oe
60 GeV

H =	73 oe - 10200 oe	H =	10195 - 10200 oe
t_i =	2120,8	t_i =	1195 μs
	2120,6		1258 μs
	2120,4		1175
	2120,2		1228
	2121,1		1370
	2120,0		1259
	2119,4		1233
	2119,6		1303
	2119,1		1219
	2119,6		1350
$t \pm \Delta t$ =	2120,1 ± 1 ms	$t \pm \Delta t$ =	1273 ± 98 μs

Table 7 : Rise time from 73 oe to 12 000 oe and from 11 195 oe to 12 000 oe.

H = 73 oe - 12 000 oe	H = 11 195 oe - 12 000 oe
t_i = 2687,1 ms	t_i = 1458 µs
2690,0	1387
2699,4	1443
2688,3	1435
2683,3	1511
2684,6	1407
2683,9	1437
2688,4	1311
2693,1	1486
2683,2	1422
$t \pm \Delta t$ = 2691,3 ± 8,1 ms	$t \pm \Delta t$ = 1411 ± 100 µs

It must be noted, that the time jitter of the magnetic cycle during the rise of the magnetic field is ± 1,6 ms (see tables 3...6), whereas for the beginning of the flat-top a time jitter of ± 14 ms has been observed for short time intervals of ten cycles (see tables 1 and 7).

Appendix B

Time intervals (μs) between preselected B ejection pulse and two B pre-pulses

see PS/FES/TN-166

Table 1

preselected eject. pulse (ejection energy)	30 GeV		50 GeV		70 GeV	
corresponding number of B pulses	5087		8527		11977	
preselected pre-pulse (see note 1)	A	B	A	B	A	B
corresponding number of B pre-pulses	3	25	2	21	2	18
cycle No 1	539	5049	526	5144	623	5099
2	531	5131	538	5234	711	5135
3	569	5053	413	5169	535	5324
4	546	5121	379	5152	443	5351
5	541	5072	437	5098	468	5209
6	473	4998	423	5132	598	5304
7	554	4991	414	5115	655	5294
8	525	5060	428	5269	654	5152
9	488	5041	433	5130	574	5193
10	559	5050	416	5135	434	5190
max. jitter (μs)	± 48	± 70	± 80	± 86	± 139	± 108

Note

1) The pre-pulses A and B simulate the trigger of the firing pulse delays for two cases, when the maximum duration of the BTS magnet pulses is 1 ms (A) and 10 ms (B).