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PS Performance and Limitations
(R. Cappi)

Present: B.W. Allardyce, J. Boillot, R. Cappi, M. Chanel, V. Chohan, J.P. Delahaye, R. Garoby, G. Gelato, J. Gruber, E. Hill, K. Hübner, S. Maury, F. Perriollat, J.P. Potier, L. Rinolfi, J. P. Riunaud, K. Schindl, H. Schonauer, D.J. Simon.

Absent: R. Barthélémy, M. Bouthéon, H. Haseroth, H. Koziol, C. Metzger, U. Raich, A. Riche, P. Tetu.

1. The purpose of R. Cappi's talk was to present the performance of the PS (and in certain cases the PSB, AAC and LEAR) for each of the different beams the CERN programme calls for, as well as to pin-print the limitations and the problem areas. He underlined that the tables he would show gave figures which were "typical good performance" and "not best ever achieved" and that the data to be presented were obtained from many of the members of the PPC.

2. After the data on individual beams, he presented summaries of the problems and possible cures for them, and there followed an animated discussion.
   Copies of the transparencies are included with these minutes.

3. The following points emerged as especially important during the discussion .

   (a) the optics of the PSB to PS transfer line must be improved. A PPM implementation is desirable for this line.

   (b) The GFA's for the poleface windings of the PS are inadequate, requiring more vectors than possible at present.

   (c) there must be an improvement in the wire monitors whose wires break too frequently.

   (d) profile monitoring improvements are essential for LHC-type beams.

   (e) train B pulses have became increasingly important and we must ensure that there are sufficient staff who look after the system.

(f) the Q measurements in the PS for electrons must be improved.

(g) as too much of the valuable time of engineers is at present lost due to problems with archiving, it is essential to improve the situation so that a previously-found good set of parameters can be reliably restored.

(h) start-ups must be better co-ordinated to reduce the time lost by engineers.

(i) a PS "Mr. Timing" is needed.

B. W. Allardyce

PS Performance and Limitations

***Introduction**

***Performance, problems and limitations of the beams that the PS delivers to its customers and receives as a client**
+ some other beams of the PS Complex

*** Summary**

RMKS : 1)The listed beam characteristics have to be considered as " typical good performance " ...not as "record" values
2) Some definitions:

$\varepsilon^*_{x,y} = \beta\gamma\ (2\,\sigma_{x,y})^2 / \beta_{x,y}$ .....except for e+- where :1 $\sigma_{x,y}$

$\varepsilon_l = \pi\, dE\, \tau_b / 2 \sim 4\pi\, \sigma_E\, \sigma_t$ i.e. $dp/p \sim 2\,\sigma_p/p$

and $\tau_b \sim 4\sigma_t$

THANKS to M. Chanel

V. Chohan

M. Martini

J.P. Potier

L. Rinolfi

T. Risselada

J.P. Riunaud

H. Schonauer

P. Tetu

PS to SPS ; protons for Fixed Target Physics (SFT)

cp [GeV]	I_p [p/p]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
14	$2.5\ 10^{13}$	420	48 (45 sps)	42 (27 sps)	0.1	1	5

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

5 turns CT
highest intensity beam(record Ip=2.7 10^{13}p/p)
adiab. debunching and rebunching at h=420 (200 MHz) ; eff. ~60%
extraction eff. ~ 90%

PROBLEMS and LIMITATIONS:

collective effects (space charge, long. and transv. coupl . b. instab., h-t. and μW instab., ...)
approaching acceptance limits (~10% losses at injection)
lossy extraction

PS to SPS ; ions (S^{16+}, O^{8+},...) for Fixed Target Phy. (SFT)

cp [GeV/u]	I_p [ch/p]	K_b	ε_x* [μm]	ε_y* [μm]	ε_l [eVs]	dp/p *10^{-3}	τ_b [ns]
10	...10^{10}	16	28	18	0.4	1.2	20

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

adiab. debunching and rebunching in PSB.
PSB eff.~60% ; PS eff. ~ 90%

PROBLEMS and LIMITATIONS:

Source and LINAC1 poor stability
Instrumentation (low intensity)

COMMENTS:
no more used

PS to SPS ; e+ e- for LEP

E [GeV]	Nb [e/b]	K_b	ε_x^* [μm]	ε_y^* [μm]	σ_E/E $*10^{-3}$	$4\sigma_t$ [ns]
3.5	**2.5 10^{10}**	**4**	**0.05**	**0.01**	**1**	**4.2**

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

h=8 + h=240 (200 kV +250 kV) to increase as much as possible $4\sigma_t$

$\sigma_E/E = 10^{-3}$ adjusted with wigglers ($J_E = 0.26$)

PROBLEMS and LIMITATIONS:

With $K_b = 8$: fast vert. instability due to trapped ions in e- beams

Bunch dimensions cannot be larger due to quantum life time

$N_b < \sim 5\ 10^{10}$ due to TMC ?

COMMENTS:

Studies for 8 bunch mode are foreseen this year

PS to SPS ; some MD's

1) p for LEP calibration

cp [GeV]	I_p [p/p]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
14	$3\ 10^{10}$	1-20	8	8	0.18	2	4

2) p for trans.beam loading /LHC

cp [GeV]	I_p [p/p]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
26	$1\ 10^{13}$	-	30	30	120	1.2	-

3)p for ion simulation and traj. meas.

cp [GeV]	I_p [p/p]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
20	$5\ 10^{10}$	20	8	8	0.2	2	4

PS to SPS ; p & pbar for SppbarS

cp [GeV]	N_b [p/b]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
26	$1\ 10^{11}$	1	12	8	0.5	3	4

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

Bright beam from PSB (scrapers)
Special synchronisation with SPS : time jitter < 0.5 ns i.e. ~0.5 RF deg
" bunch rotation with h = 6 + 12 : τ_b = 22 to 4 ns
High reliability and transmission >90% AA / PS extracted
Reinjection beam for PS-SPS energy calibration (10^{-4})
Special optics for transv. emittance conservation

PROBLEMS and LIMITATIONS:

...the most delicate PS operation...

COMMENTS:

discontinued

PS to AAC ; protons for pbar producion (AA)

cp [GeV]	I_p [p/p]	K_h	ε_x* [μm]	ε_y* [μm]	ε_l [eVs]	dp/p *10^{-3}	τ_b [ns]
26	1.6 10^{13}	5	50	35	2	2.5	20

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

Funnelling at PSB extraction (RF dipole)
Merging of 20 bunches into 5 over 1/4 of PS circumference
h = 20,10,12,14,16...20
Bunch rotation at extraction

PROBLEMS and LIMITATIONS:

Collective effects (space charge, long. and transv. coupl . b. instab., h-t. and μW instab., ...)
Transition crossing (acceptance limits ?)
Large vertical emittance close to acceptance limit at low energy

PS to AAC ; test beam for pbar simul. (TST)

cp [GeV]	N_h [p/b]	K_h	ε_x* [μm]	ε_y* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
3.5	$2\ 10^{10}$	1	15	5	0.5	1.3	70

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

h =20 to 6

PROBLEMS and LIMITATIONS:

no special problems

PS to LEAR ; pbar for Physics (LEA)

cp [GeV]	N_b [p/b]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
0.6	10^{10}	1	8	8	<1 0.2	2.4	160

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

Deceleration with h = 10
Transmission AA / LEAR ~ 80%

PROBLEMS and LIMITATIONS:

Acceptance limits approached at low energy
Instrumentation (low intensity)

PS to EAST HALL ; protons Physics (PHY25)

cp [GeV]	I_p [p/p]	ε_x* [μm]	ε_y* [μm]	dp/p *10^{-3} extr.	dp/p *10^{-3} sweep	T_{spill} [ms]
24	3.5 10^{11}	10	8	1	3	400

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

New slow extraction (ES internal position)
Extraction eff. >90%

PROBLEMS and LIMITATIONS:

No major problems (new operation in an optimisation phase)
Intensity has to be kept < 2 10^{11}part./target & 2 cycles/superc. for East Hall rad. protection

PSB to PS ; MD's for LHC studies

1) "h=2" high density beam

T [GeV]	I_p /1R [p/p]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
1	$1\ 10^{12}$	2	18	10	0.5	2.0	108

2) LINAC2 at 170 mA and 3 turns PSB injection

T [GeV]	I_p /1R [p/p]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
1	$1.6\ 10^{12}$	5	10	9	0.15	1.4	48

EPA to PS ; e+ e- for LEP

E [GeV]	N_b [e/b] max	K_b	ε_x [μm]	ε_y [μm]	ε_l [eVs]	σ_E/E $*10^{-3}$	$4\sigma_t$ [ns]
0.5	$5\ 10^{10}$	8	0.11	e+ .004 e- .045	0.02	0.7	4.4

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

e+ : (9+1) x 1.2 s of accumulation and 2x4 bunch extr.(accum.speed ~4 10^{10} e+/s)

e- : 2 x 1.2 s " " " " " " (accum. speed ~4 10^{11} e-/s)

PROBLEMS and LIMITATIONS:

Positron production

Accumulation efficiency (mom. spread, mom. stability, inj. efficiency by beam mismatch...)

Long. coupl. bunch instabilities

Trapped ion effects on e- beam

COMMENTS:

1)Special beam for LAA : .2<E<.7 GeV. New exp. area. Commisioning will start soon...

2)LHC Syncr. light test : .2<E<.57 GeV; $10^{10} < N_b < 10^{11}$

AAC to PS ; antiprotons for LEAR (LEA)

cp [GeV]	N_b [p/b]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
3.5	10^{10}	1	8	3	0.2	1.4	48

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

Stacking rate :~ 50 10^6 pbars for 1.5 10^{13} protons on target (~1.2 10^{10} pbars/h w 1 c/sc)
Highest stack in '92 :~ 5 10^{11}pbars

Stack emittances [μm]: $7 < \varepsilon_x^* < 18$; $2.5 < \varepsilon_y^* < 8$

PROBLEMS and LIMITATIONS:

Vertical cooling system not working
Sporadic longitudinal blow-up (?)
Start-up scheduling

LEAR to Physics; antiprotons for LEAR Physics

1) ULTRA SLOW EXTRACTION

cp = 61.2, 105,.., 200-2000 MeV, Ip = 10^9 - 10^{10}pbars, T_{spill} = 0.1 - 3 h , Df > 90%

LIMITS: space charge, IBS, stoch. cooling

2) SEMI SLOW EXTRACTION

cp = 61.2 MeV, Ip ~ 10^9pbars , T_{spill} ~ 500 μs , e-cool.

LIMITS: space charge, IBS, stoch. cooling

3) FAST EXTRACTION

cp = 105 MeV, Ip ~ 10^9pbars ,T_{spill} ~ 200 ns, ~ 10 shots , e-cool

LIMITS: space charge, IBS, stoch. cooling, acceptance of extr. channel, kicker rise and fall t.

4) JET SET

cp = 609-2000 MeV, Ip ~ 310^{10}pbars, $\varepsilon_x < 5$ & $\varepsilon_y < 1.3$ μm , $\Delta p/p < 3\ 10^{-3}$

LIMITS: transfer and inj. efficiencies

PSB to ISOLDE ; protons for Physics (ISO)

T [GeV]	I_p [p/p]	K_b	ε_x* [μm]	ε_y* [μm]	ε_l [eVs]	dp/p *10^{-3}	τ_b [ns]
1	3 10^{13}	20	55	30	0.16	1.4	48

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

The highest intensity PSB beam

PROBLEMS and LIMITATIONS:

Collective effects (sp ch. and long. instabilities)
Losses and irradiation minimisation
Disturbances by the PS stray field on inj. trajectories
Weak long. feedback
Microwave (?) instab. on ring 4 causing blow-up and few % losses
Controls

COMMENTS:

New operation still in an optimisation regime

PS to SPS ; protons for LHC

cp [GeV]	I_p [p/p]	K_b	ε_x^* [μm]	ε_y^* [μm]	ε_l [eVs]	dp/p $*10^{-3}$	τ_b [ns]
26	**1.4 10^{13}**	**140**	**<12**	**<12**	**0.5**	**1.4**	**9**

PROCESSES INVOLVED AND SPECIAL CHARACTERISTICS:

PSB at 1.4 GeV, 2 PSB shots / PS cycle

PS acceleration on h=8 then ad. debunching and rebunching on h=140 (66.7 MHz)

PROBLEMS and LIMITATIONS:

Emittance conservation

Collective effects (space charge, long. and transv. coupl . b. instab., h-t. and μW instab., ...)

Working point fine adjustement (new GFA on PFW ctrl?)

Pulse to pulse display and correction of injection errors FOR EACH BUNCH

Instrumentation : new TT2 SEM Grids, new wires, screen dig. signal processing

New CODD on h=8 or 16 and τ_b ~ 200 ns

continuous Q measurement

etc. etc.

SUMMARY **of** Problems **and** *Possible Cures*

High intensity beams (>10^{13}p/p)

* **Losses at low energy due to limited acceptance :** *optimise PSB/PS optics; PPM on PSB/PS inj. line; increase inj. energy*
* **Space charge effects :** *increase inj. energy ; change bunch shape*
* **Transv. coupl. bunch instabilities** : *transverse feedback; octupoles*
* **Long. coupl. bunch instabilities :** *reduce Z ; feedbacks; ctrld long. blow-up; red. nbr of b.*
* **Long. micro-wave instabilities :** γ*-jump; controlled long. blow-up*
* **Head-tail instabilities :** ξ *control; octupoles*
* **Emittance conservation :** *better instruments (e.g. reliable fl.wires); "new GFA"/ PFW's; cont. Q meas. ; signal processing; BTF*

Low intensity beams (<10^{11}p/p)

*** Instrumentation :** *new technologies ?(e.g. CCD cameras for TV screens)*
*** Reproducible " frequency loop" :** *reliable magn. field meas . ("B-train" follow-up)*

e+ e-

*** Ion trapping in e- :** *transverse feedback; x-y coupling*
*** Working point setting :** *Q measurement*

Performance follow-up and reproducibility

Tools

* **Archives :** *rigorously reliable*
* **Repeated setting-up's :** *increase the number of USERS (e.g. x 2)*
* **Powerful and smart programs :** *easy and user friendly programming tools*
* **Declining infrastructure (slow-down, less tech. support...) :** *how to live until new CO system ?*

Staff

* **Reduced nbr of machine specialists w.r.t. nbr of projects and pbs :** *better organisation; ext.consultants*
* **Decreasing knowhow potential of operation teams:** *promote machine physics*