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SPL-based Proton Driver for a nu-Factory at CERN

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SPL-based Proton Driver

- Conceptual design & feasibility studies are completed
- 4 MW proton beam @ 5 GeV, from HP-SPL
- 10^{14} total p/cycle in:
  - 6 bunches baseline scenario
  - 3 or 1 bunch scenario
- Separate accumulator & compressor:
  - to adapt SPL time structure to target

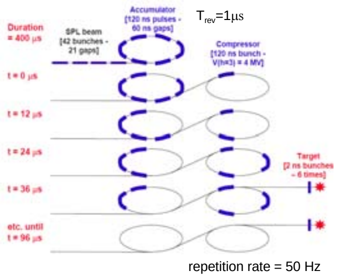
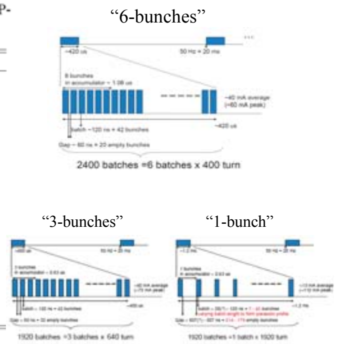
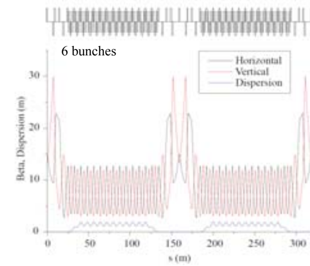


Table 1: Parameter list for the machine evolution from LP-SPL to HP-SPL. *F. Gerigk, Proc. of Beam'07*

	LP-SPL	HP-SPL
Energy [GeV]	4	5
Beam power [MW]	0.192	> 4
Repetition rate [Hz]	2	50
Av. pulse current [mA]	20	40
Chopping ratio [%]	62	62
Beam pulse [ms]	1.2	0.4 - 0.6
Protons p. pulse [10^{14}]	1.5	1.0-1.5
Filling time PS2 [ms]	1.2	0.6
Beam duty cycle [%]	0.24	2.0
No. SC cavities	194	234
No. klystrons (352 + 704 MHz)	19+28†	19+57
RF peak power [MW]	100	219
Av. power consumption [MW]	4.5	38.5
Length [m]	459	534

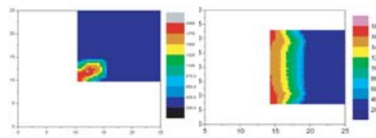


Accumulator

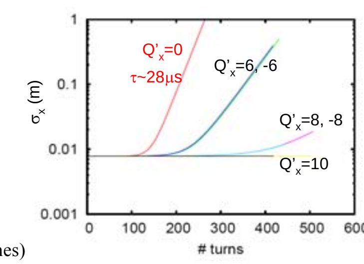


"6-bunches option" design
- C~318.5m
- γ_{tr}=6.33 → isochronous
- no RF
- Q_x=7.77, Q_y=7.67
- normal-conducting magnets
- ~400μs accumulation time

- Charge exchange injection: heating @ stripper foil
  - 2D painting → ok for 6 /3 bunch (~3π mm mrad → ~2000 K)
  - for 1 bunch NEED painting + moving H- beam (~5π mm mrad → ~1800 K)

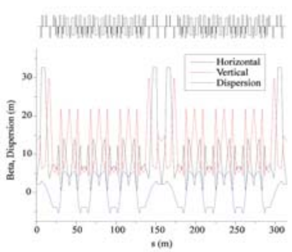


- Longitudinal Space Charge
  - Ok → flat profile w. smooth edges,
  - for 1 bunch NEED parabolic profile (→ RF is needed)
- Transverse beam stability
  - Isochronous ring → no damping from synchrotron motion
  - Narrow-Band impedance → neglected (no RF cavities, main contributors)
  - Resistive wall → not a problem (τ =8.2ms >> 400μs)
  - Broad-Band Impedance cured w. Chromaticity or Octupoles (ΔQ~0.02)
    - Simulations w. HEADTAIL
    - R_t = 1 MΩ /m
    - Q_R = 1
    - f_R ~ c/(2πb) ~ 1GHz
    - Need |Q'|>10 (Q'_{nat}= - 8.4)
    - Q'_{th} proportional to R_t



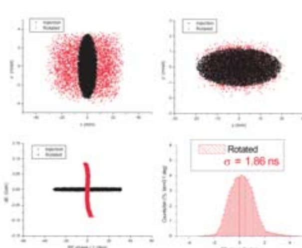
- e-cloud not an issue (long, flat bunches)
- Longitudinal beam stability
  - η_0=0 → consider 2nd order terms: $\alpha_0\alpha_1$= 0.117 (for Q'_{nat})
  - Narrow-Band → neglected (no RF)
  - Broad Band → Ok! (Zl/n) < 4Ω (f_R= 1GHz, Q_R=1) ~few Ω easily achieved

Compressor



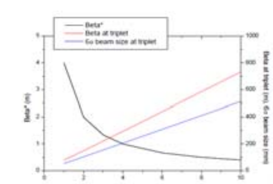
"6-bunches option" design
- C= 314.2 m
- γ_{tr}= 2.3
- strong RF → phase rotation 36 turn
- 3 bunches in the ring at same time
- Q_x=10.79, Q_y= 5.77
- super-conducting magnets → D_x~5m
- option w. n-c magnets → D_x~10m

- Fast longitudinal bunch rotation
  - Initial: τ_b~120 ns, $(\Delta p/p)_{rms}$~ 0.1%
  - Final: $\tau_{b,rms}$~2 ns, $(\Delta p/p)_{max}$~ 1.6%
- Dispersion → magnet aperture
- Space Charge
  - Simulations w. ORBIT
  - Final ΔQ_{SC}~0.2
  - Dispersion weakens Space Charge



Focusing at the target

- 6 (or 3-1) bunches: $\tau_{b,rms}$~2 ns, 12 μs spaced
- repetition .rate 50 Hz
- 3-5 π mm mrad transverse emittance
- beam size 2mm (rms) → β*~1.3m
- Triplet + 10m straight section



Parameters of final focusing as a function of the beam emittance

Parameters for "6-bunches" & "3-1 bunches" options

	6 bunches	3 bunches / 1 bunch
accumulator		
circumference	318.5 m	185.8 m
no. of accumulation turn	400	640 / 1920
transition gamma	6.33 (isochronous)	6.33 (isochronous)
no. of simultaneous bunches	6	3 / 1
magnet type	NC	NC
compressor		
circumference	314.2 m	200 m
rf voltage	4 MV	1.7 MV
no. of compression turn	36	86
transition gamma	2.3	2.84
no. of simultaneous bunches	3	2 / 1
magnet type	SC (bending)	NC
output beam		
bunch spacing	12 μs	30 μs / -
burst duration	60 μs	60 μs / -
bunch length	2 ns	2 ns
beam energy	5 GeV	5 GeV
beam power	4 MW	4 MW
repetition	50 Hz	50 Hz

Conclusions

- Conceptual design & feasibility study for SPL-based P-driver (6-bunches) completed
  - Lattice, magnet technology and RF manipulations in the two rings.
  - Critical issues not show-stoppers for "6-bunches scenario":
    - heating of the foil for charge-exchange injection,
    - space-charge in the compressor
    - beam stability in the accumulator
- Physics (and μ-collider) prefers smaller # bunches:
  - "3-bunches option" has been designed and seems feasible
  - "1-bunch scenario" challenging, but might be ok

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