LAGUNA-LBNO HP-PS

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The HP-PS basics

- High Power Protons Synchrotron:
  - 2 MW beam power (@ 30 – 50 GeV)
  - Dedicated to neutrinos for LAGUNA-LBNO
  - Keep in mind possible use for LHC in future
- 3-fold symmetric machine is considered:
  - About 1 km in circumference
  - Imaginary gamma transition
  - Injection/Extraction straight section
  - Collimation straight section
  - RF straight section

Beam Power

$$P = qf_r N_p E_k$$

❑ High average beam power
❑ High repetition rate
  ❑ Increased power supply voltage, electrical power, eddy currents, cooling, cost
❑ High Energy
  ❑ Increased circumference (and/or high-field magnets), power consumption, cost
❑ High particle population per pulse
  ❑ Increased linac pulse, beam loss, radio-activation

Different Options explored

	50 GeV	65 GeV	50 GeV	30 GeV
Parameters	**PS2**	**HE HP-PS**	**SF HP-PS**	**LE HP-PS**
Circumference [m]	1346.4	1520	1174	
Protons/pulse [10^{14}]	1.1	1.9	2.5	4.2
Harmonic number	180	202	156	
Number of bunches	168	196	150	
Protons/bunch [10^{11}]	6.5	10.4	18.0	30.2
Rel. β/γ @ inj.	0.98/5.26			
Norm. emit. H/V [μm]	9/6	7.0/5.9	11.1/9.3	18.7/15.6
SC tune-shift H/V	-0.13/-0.2		-0.2/-0.2	

$$\Delta Q_{x,y} = -\frac{r_0 N_p C}{2(2\pi)^{3/2}\sigma_z \beta \gamma^2 \epsilon_{x,y}}$$

❑ Beam considered as for PS2 with a 25ns bunch structure, although this is not necessary

❑ Machine filled with bunches leaving a 150ns gap for kicker rise/fall time (300ns for PS2)

❑ Assumed that bunch length is scaled with square root of harmonic number

❑ For keeping space-charge tune-shift below -0.2, vertical emittance increased accordingly, and transverse acceptance reduced

❑ Large increase of emittances for LE HP-PS, whereas for HE HP-PS even smaller than PS2

SPL options/parameters

PARAMETER CONSOLIDATION:
SINCE 2010

design version	LP-SPL	HP-SPL low-current	HP-SPL high-current
kinetic energy	4 GeV	5 GeV	5 GeV
beam power	0.144 MW	4 MW	4 MW
repetition rate	2 Hz	50 Hz	50 Hz
beam pulse length	0.9 ms	0.8 ms	0.4 ms
average pulse current	20 mA	20 mA	40 mA
peak pulse current	32 mA	32 mA	64 mA
chopping ratio	62%	62%	62%
protons p. pulse	1.13×10^{14}	1×10^{14}	1×10^{14}
peak power/cavity	0.5 MW	0.5 MW	1 MW

LP-SPL intensity

POSSIBLE MODIFICATIONS TO INCREASE INTENSITY

- **easy & cheap**: higher rep-rate or longer pulse length (impact on modulator stored energy, increase in cryogenic load, little difference for klystrons),

- **expensive**: higher pulse current (means higher peak power, direct impact on klystron price, higher coupler peak power + all of the above), if absolutely necessary 40 mA can be possible, but not higher,

- **very expensive**: higher energy (longer tunnel, more hardware...)

LP-SPL parameters, F. Gerigk, HP-PS meeting 21.11.2012,

Injection / Extraction

- Should be easier than PS2 injection/extraction LSS
  - Fewer beam transfer requirements
  - Extract only at 50 GeV
- The well-worked out H- injection system designed for PS2 at 4 GeV can basically be plugged into HP-PS
  - 24 m central drift
  - 1 m space for laser stripping elements
- Fast extraction in the same LSS possible
  - 12 m for the outer drifts
  - Imposes large aperture doublet quadrupoles
- Can we already start working with basic parameter set
  - 4 GeV, 1 ms injection; 50 GeV extraction, rise time?
  - Target emittances??

Collimation

Lessons learned in the PS2 for the HP-PS

- In order to optimize the collimation system performance its design should be carried in parallel with lattice design, collective effects studies, etc.

- A lattice and an aperture model are the basic ingredients to start producing beam loss maps. Have a code ready.

- If apertures like PS2, an available phase advance of $\mu = 150°$ for placing secondaries is desirable.

- Close collaboration from the beginning between the optical design of the collimation system and FLUKA simulations to provide loss thresholds. The 1 W/m is just a figure of merit, final validation should simulating the full geometry of the magnet.

- FLUKA studies showed no strong preference between light and heavy materials for PS2, but for a higher power in HP-PS it might be advisable to go to ligther materials. TBC by FLUKA simulations.

- If HP-PS features a racetrack shape the momentum collimation might be an issue.

- Space charge simulations would be needed at some point to estimate the halo population. At first approximation PS measurements could be scaled up.

- Failures scenarios. Collimation system withstand full beam impacting it (misfiring kicker, etc.).

Next Steps

- Consolidate the basic options and optics (Fannouria & Andoula).
- Investigate further the Super Ferric options
  - Support form L. Bottura and his team (Javier)
- Injection/Extraction (Angelina & Brennan)
- Collimation (Christos, ..)
- RF cavities etc (BE/OP PJAS + Elena, …).