PS2 Project and Status

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for the PS2 Working Group

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– **Machine integration in the complex**

– **Technical choices on lattice design and RF system**

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Performance requirements and parameters

- **Starting point for the design is brightness (N/ε_n) for LHC beams**
  - **Design goal: Twice higher brightness than "ultimate" 25ns beam with 20% intensity reserve for transfer losses**
    - **4.0×10^{11}ppb = $2 \times 1.7\times10^{11} \times 1.2$ in transverse emittances 3μm**

- **Injection energy**
  - **Determined by the beam brightness of the LHC beam**
  - **High density means defocusing (Coulomb) force that must be counteracted by attractive force of parallel currents →overall $\propto (N/\varepsilon_n)/(\beta\gamma^2)$**
    - **4 GeV injection energy, for conditions similar to existing PS**

- **Extraction energy**
  - **Injection into SPS above transition energy to reduce space charge effects**
  - **Higher energy gives smaller transverse emittances and beam sizes and therefore reduced losses**
  - **Potential for long-term SPS replacement with higher energy**
    - **~50 GeV extraction energy**

PS2 machine size

- **Constraints from desired extraction energy ~50 GeV**
  - **Iron dominated dipoles B ≤ 1.8 T**
    - **PS2 will have roughly twice PS size i.e. R ~ 200 m and C ~ 1250 m.**
- **Constraints from filling SPS for physics**
  - **Complete filling of SPS circumference is desired for HI FT physics**
  - **Using an island multi-turn extraction scheme, similar to PS (5-turns)**
    - **Ideal PS2 length 1/5 SPS = 11/5 PS = 2.2 PS.**
- **Constraints from PS2-SPS synchronisation (rf cogging)**
  - **$N \times h_{PS2} = K \times h_{SPS}$ is needed for correct synchronisation**
    - **(N/K) = 77/15 is best choice (5 PS2 slightly shorter than the SPS.)**
    - h (200MHz SPS) = 4620, h (40MHz SPS) = 924, h (40MHz PS2) = 180
- **Optimum length for PS2 from above arguments**
  - **PS2 = 15/77 SPS = 15/77 * 11 PS = 15/7 PS.**
    - **1346.4 m circumference, 214.3 m average radius**

PS2 main parameters

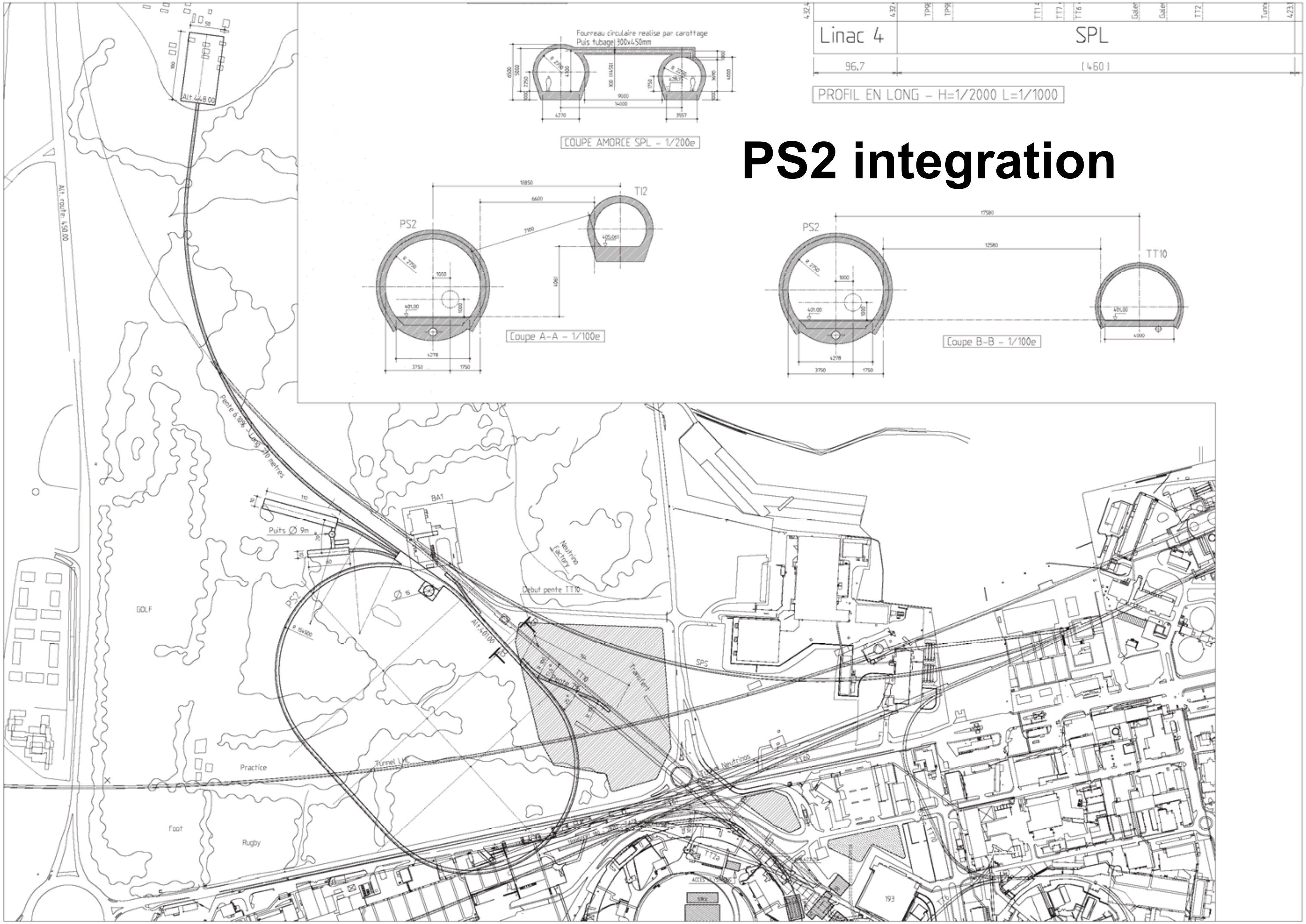
Parameter	unit	PS2	PS
Injection energy kinetic	GeV	4.0	1.4
Extraction energy kinetic	GeV	~ 50	13/25
Circumference	m	1346	628
Max. intensity LHC (25ns)	ppb	4.0×10^{11}	1.7×10^{11}
Max. intensity FT	ppp	1.2×10^{14}	3.3×10^{13}
Max. stored energy	kJ	1000	70
Linear ramp rate	T/s	1.5	2.2
Repetition time (50 GeV)	s	~ 2.5	1.2/2.4
Max. effective beam power	kW	400	60

Machine integration and shape

- **Location of the machine at end of TT10 transfer line from PS to SPS at -50m under ground.**
  - **Injection from SPL (parallel to TT10) (with short transfer line)**
  - **Injection of ions from LEIR directly from TT10**
  - **Injection of protons from PS complex directly from TT10**
    - If required for commissioning before SPL or during intermediate period.
  - **Extraction towards the SPS via TT10 and existing SPS injection channel in point 1 with short transfer line**

- **Optimisation leads towards a racetrack shape of the machine**
  - **Two compact arcs and two long zero-dispersion straight sections**
  - **One long straight section for injection and extraction**
    - One single extraction channel for three different extractions for three different destinations (SPS, Dump, Physics if required)
  - **Second long straight section dedicated for RF**

PS2 integration

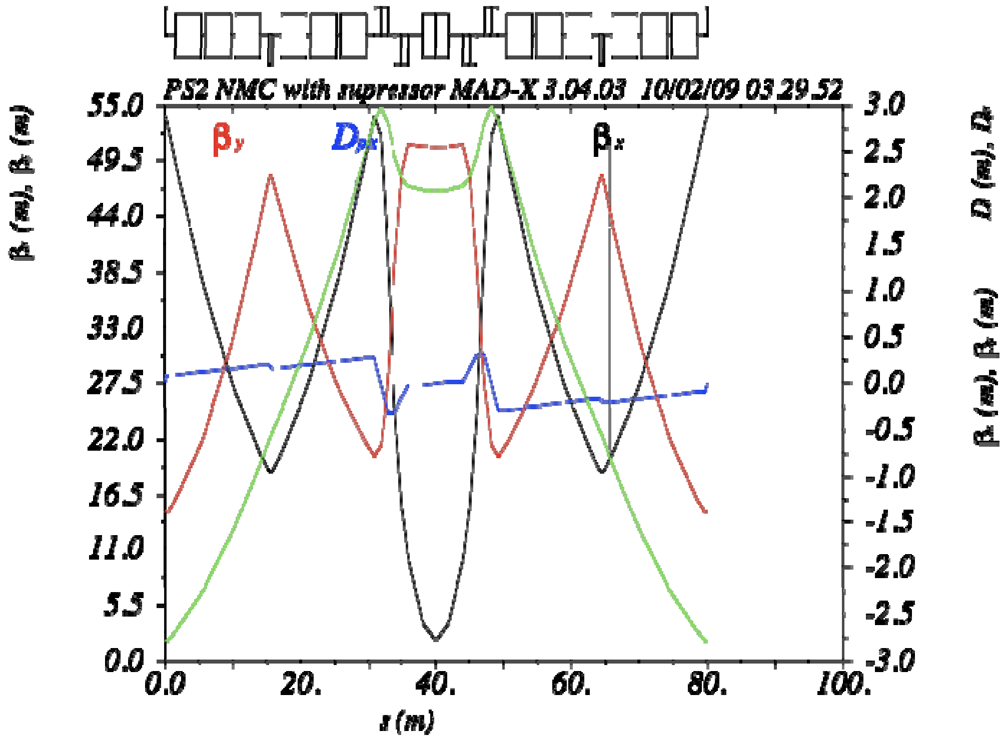


PS2 lattice design

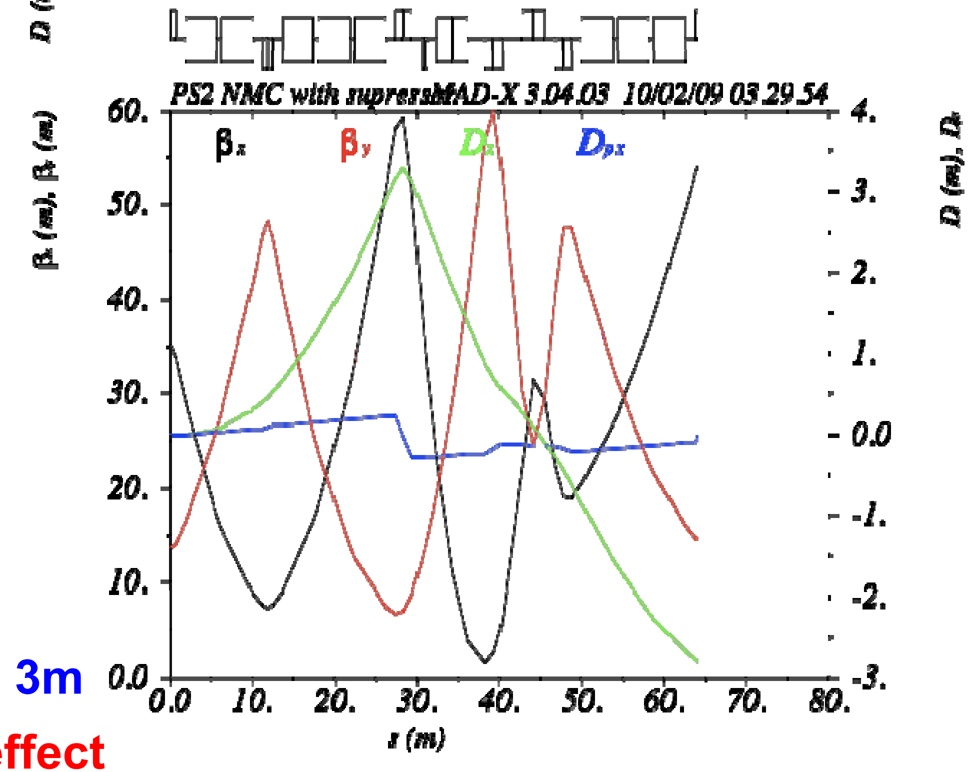
- **Lattice design to avoid the problem of transition crossing:**
  - **Low energy: acceleration goes into particle velocity gain**
    - Particle with slightly positive momentum error has ***shorter revolution time*** even though moving at a larger average radius (i.e. on a longer orbit).
  - **High energy: acceleration goes into particle mass gain, v≈c**
    - Particle with positive momentum error has ***longer revolution time***
  - **At transition energy:**
    - ***Identical revolution time*** → no longitudinal stability → beam losses

- **Lattice with imaginary γ_{tr}**
  - **Avoids transition crossing → simpler operation, reduced losses.**
  - **More complicated lattice design and more magnet types/families than in e.g. regular FODO lattices**
    - Orbit for particles with positive momentum error has to be SHORTER than nominal orbit! → Negative Momentum Compaction factor (NMC).

PS2 NMC module and dispersion suppressor

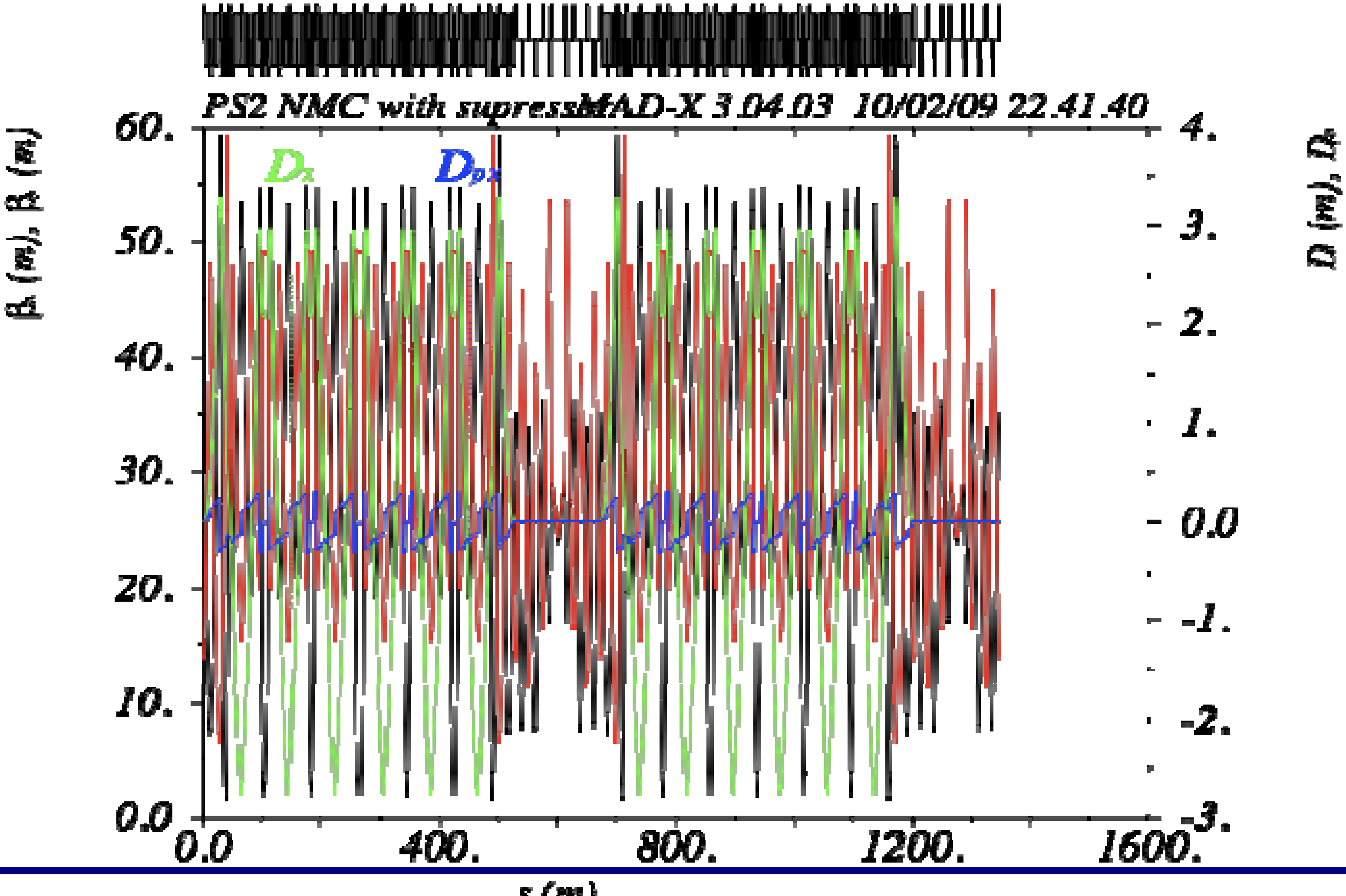


- Dispersion suppressor module

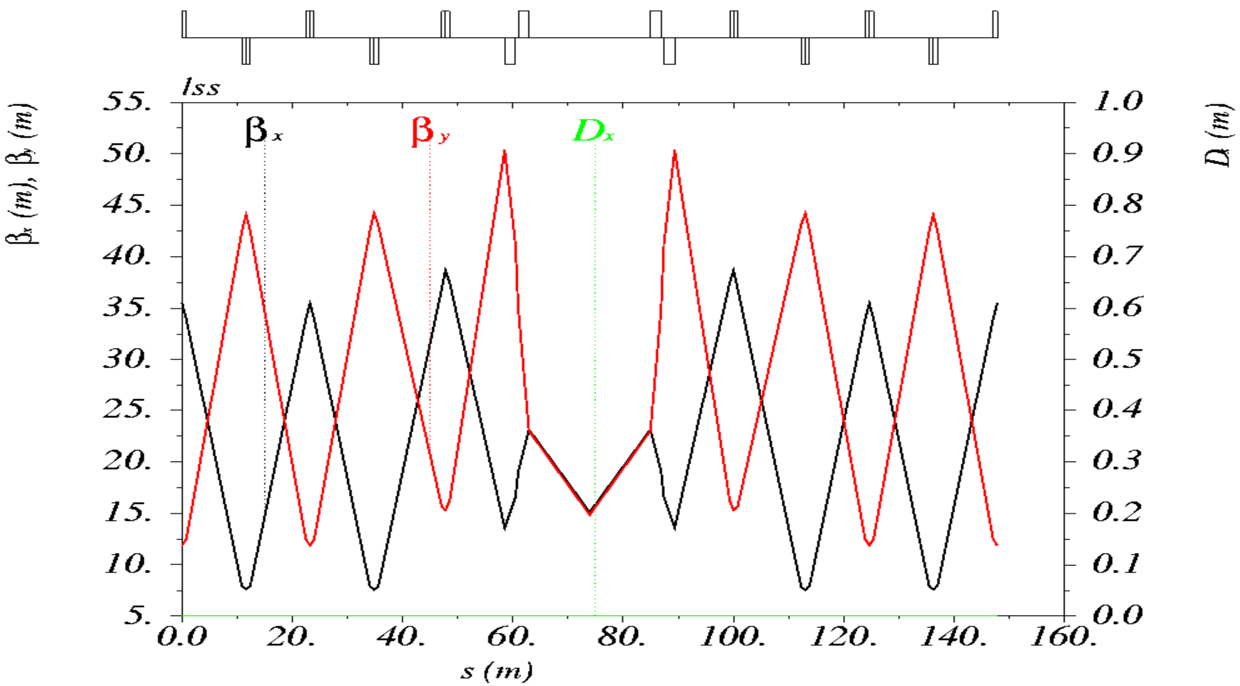


- NMC module tuned to γ_t 26i
- Min. and max dispersion of -2.6 and 3m
- Negative dispersion gives desired effect

PS2 NMC ring lattice



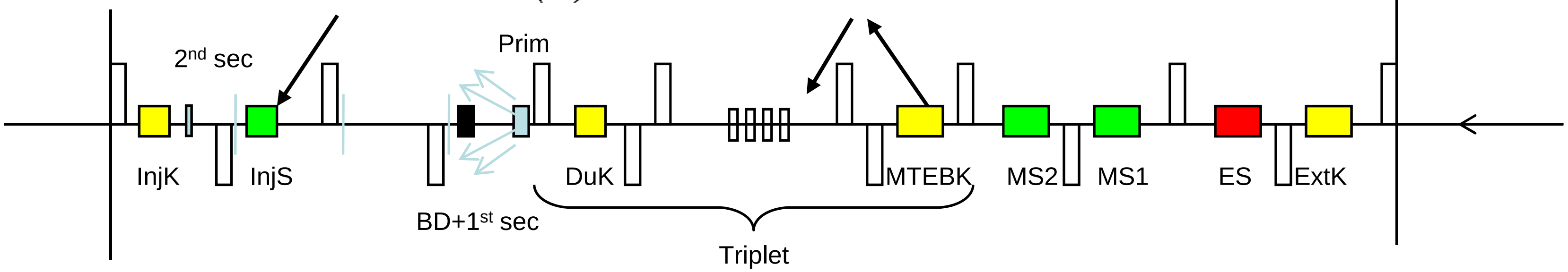
Long injection/extraction straight section



-Common usage of extraction channel for all extractions

-“Split-triplet” insertion at centre for H- injection

-90 deg hor. in regular FODO



PS2 RF system

- **RF system requirements:**
  - **Proton acceleration: revolution frequency ratio : 1,024 (3% tuning)**
  - **Pb54+ ions revolution frequency ratio in PS&PS2 with injection directly from *upgraded LEIR* at 6.7 Tm: 2,1 (210% tuning range)**
  - **All LHC bunch spacings and beams for SPS FT operation**

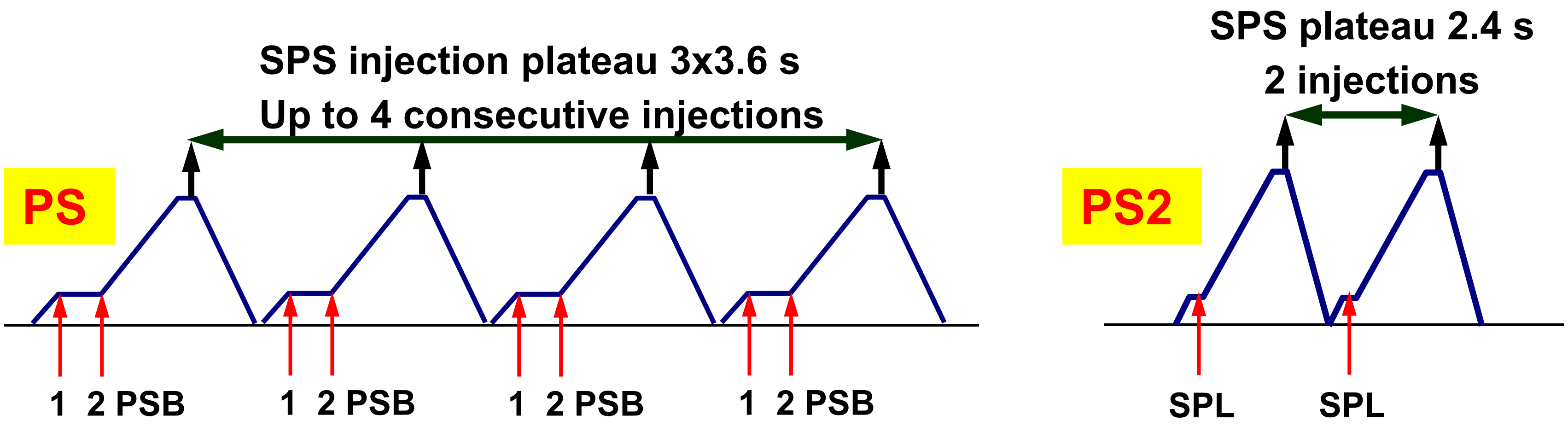
- **Preferred RF option**
  - **Tuneable 40 MHz system (18 – 40 MHz)**
    - Motivated by (LP) SPL 40 MHz chopping that will allow direct painting of any LHC bunch pattern up to 40 MHz already at injection
    - Minimizes rf gymnastics in PS2 and RF systems (→impedance reduction)
  - **Feasibility of tuneable 40 MHz system (factor 2) to be demonstrated**
    - R&D program for RF system development being launched.

LHC beam from PS2 (i)

- **Nominal bunch train at extraction**
  - **h=180 (40 MHz) with bunch shortening to fit SPS 200 MHz.**
  - **168 buckets filled leaving a kicker gap of ~ 300 ns (50 GeV!)**
    - Achieved by direct painting into PS2 40 MHz buckets using SPL chopping.
    - No strong impact on LHC filling scheme.
- **Any other bunch train pattern down to 25 ns spacing**
  - **Straightforward with SPL 40 MHz chopping and 40 MHz system**
    - (Would be limited to present schemes (75 ns, 1, 12, bunches etc…) with a 10 MHz RF system and "classical" splitting.)
- **Beam parameters**
  - **Extraction energy: 50 GeV**
  - **Maximum bunch intensity: 4E11 / protons per LHC bunch (25 ns)**
  - **Bunch length rms: 1 ns (identical to PS)**
  - **Transverse emittances norm. rms: 3 microm (identical to PS)**

LHC beam from PS2 (ii)

- **Example 25 ns beam from SPL – PS2:**
  - **PS2 will provide "twice ultimate" LHC bunches with 25 ns spacing**
  - **Bunch train for SPS twice as long as from PS**
  - **Only 2 injections (instead of 4) from PS to fill SPS for LHC**
  - **PS2 cycle length 2.4 s instead of 3.6 s for PS**
    - Reduces SPS LHC cycle length by 8.4 of 21.6 s (3x3.6 – 1x2.4)



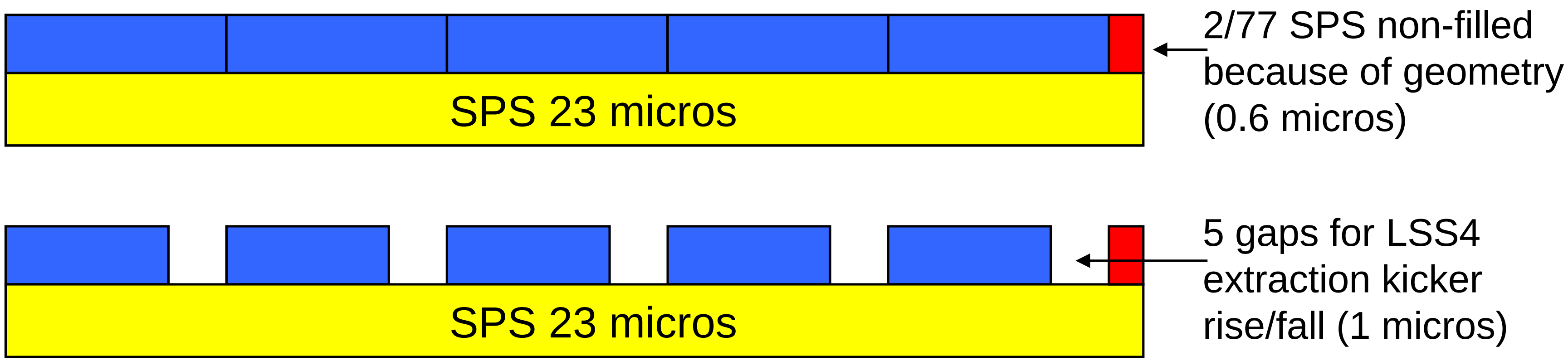
High-intensity physics beams from PS2

- **SPS fixed target type beam:**
  - **PS2 provides up to twice line density of PS high-intensity FT beam**
  - **Twice circumference gives up to 4 times more intensity in total**
    - ~1.2E14 per PS2 cycle (~1E14 with a longer kicker gap)
  - **Five-turn extraction will fill SPS with single shot instead of two from PS**
    - Twice more intensity in SPS via twice higher line density.
    - No injection flat bottom in the SPS
  - **Clean bunch to bucket transfer PS2 40 MHz to SPS 200 MHz (cf. LHC)**
    - ~7E11 protons per PS2 40 MHz bucket
    - Reduced by factor 5 to ~1.7E11 in one out of five SPS 200 MHz buckets
  - **Transverse emittances: like upper limits of present CNGS beam**
    - Norm. sigma emittances 15/8 mm mrad (h/v)
    - Adiabatic emittance damping at 50 GeV by $(\beta\gamma)_{13} / (\beta\gamma)_{50} = 0.27$
    - Therefore ~1/2 present beamsize due to emittance.

CNGS-type upgrade beam from PS2

- **Filling the SPS with 5 turns from PS2**

PS2 = 15/7PS = 15/77 SPS



  - **SPS filling is achieved in a single PS2 pulse**
  - **Extraction kicker gap corr. to ~40 unfilled 40 MHz buckets.**
    - ~140 filled 40 MHz buckets in PS2 (out of 180 buckets), kicker gap 1 micros.
    - 17.4 micros of SPS filled out of 23 micros.

General planning 2009 - 2011

- **12/08 – 03/09 Finalize linear lattice and machine integration**
  - Linear lattice design and machine geometry studies
  - Transfer lines from TT10, from SPL, to SPS
  - Injection and extraction studies
- **04/09 – 06/09 Iteration on element integration with technical groups and refinement of lattice studies**
- **06/09 Freeze linear lattice, machine layout and integration**
- **07/09 – 12/10 Conceptual design phase**
  - Conceptual design of all technical systems
  - Refinement of beam dynamics
  - Civil engineering and technical infrastructure design
  - Cost estimates, resource estimates, implementation planning
- **01/11 – 05/11 Preparation of conceptual design study**

Conclusions

- PS2 main parameters are defined, based on LHC requirements
- Choices have been made for lattice design and RF concept
- Machine performance (beam power) will be ~ factor 10 above PS
- Question of a dedicated experimental area for PS2 needs to be addressed soon, for integration and machine optimization aspects

- I would like to thank all PS2 WG members and all colleagues that contribute to the study