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Optics Considerations for the PS2

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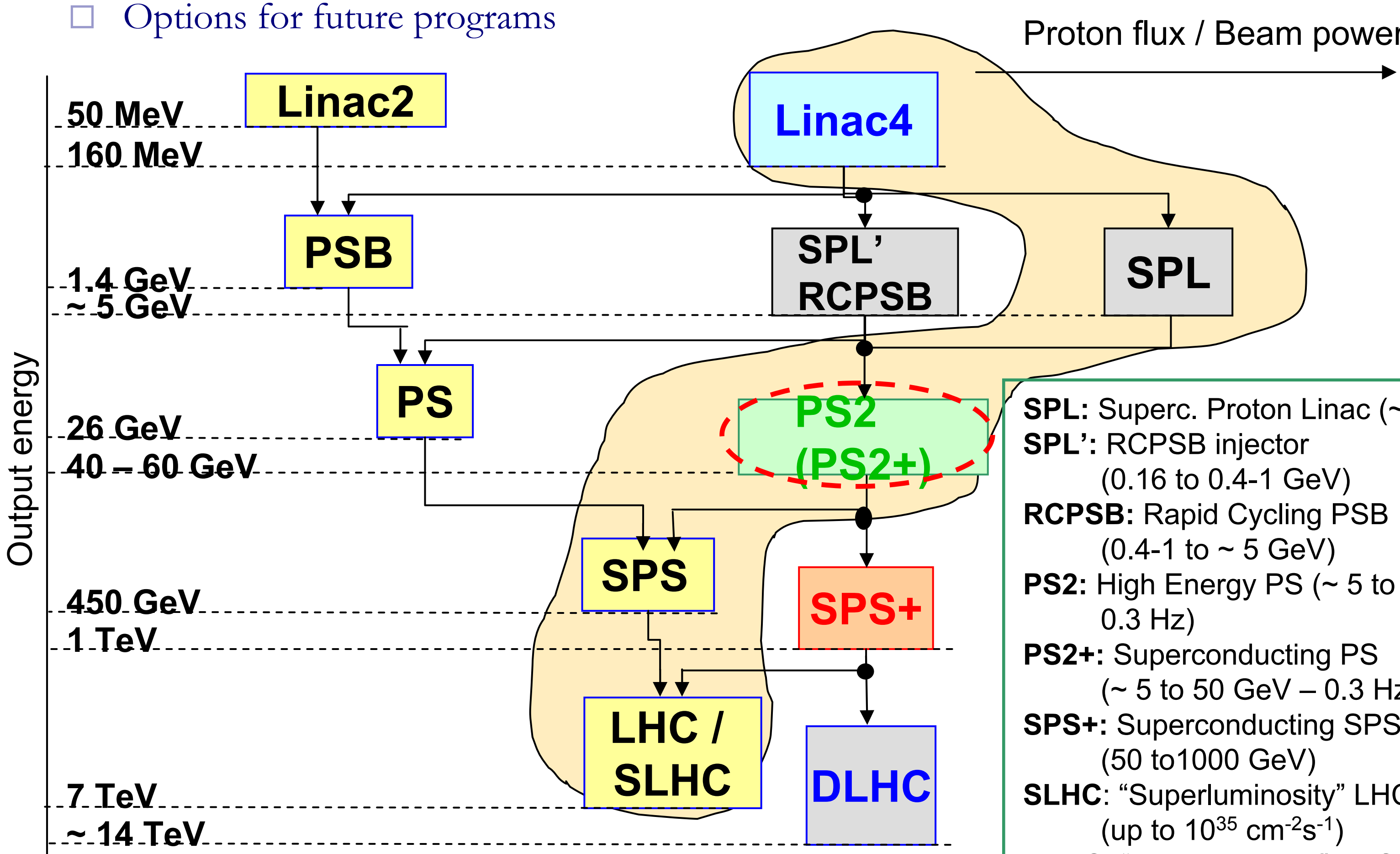
Introduction - Motivation

- Proton Accelerators for the Future (PAF) study – identify upgrade scenario
  - Reliable operation for the LHC (allow ultimate LHC beam)
  - Options for future programs



From: PAF study group, in particular R.Garoby

SPL: Superc. Proton Linac (~ 5 GeV)
SPL': RCPSB injector (0.16 to 0.4-1 GeV)
RCPSB: Rapid Cycling PSB (0.4-1 to ~ 5 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
PS2+: Superconducting PS (~ 5 to 50 GeV – 0.3 Hz)
SPS+: Superconducting SPS (50 to1000 GeV)
SLHC: "Superluminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)
DLHC: "Double energy" LHC (~14TeV)

Introduction – Requirements for PS2

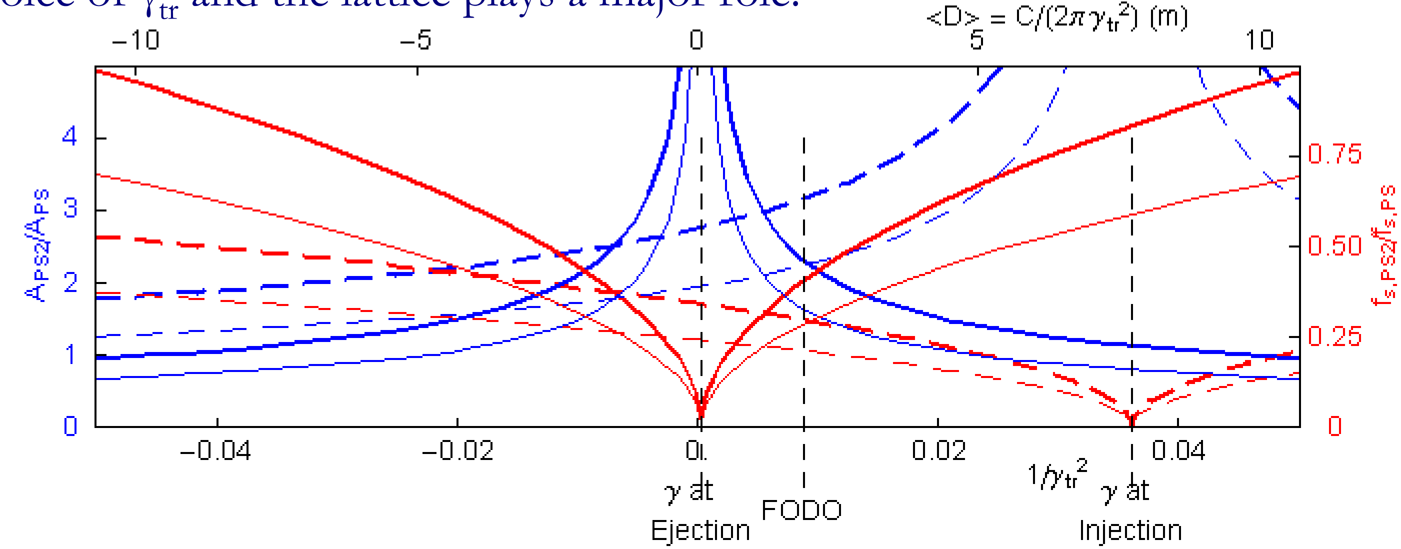
- Replace the ageing PS and improve options for physics
- Integration in existing complex
- Versatile machine:
  - Many different beams (and bunch patterns)
  - Protons and ions (performance if SPL injector ?)
- Transfer operations
  - Injections:
    - H- charge exchange injection for protons (assuming SPL as injector)
    - Fast injection for ions (low magnetic field)
  - Ejections:
    - Fast single turn ejection (e.g. LHC beams)
    - Multiturn ejection (beam cut transversally in ~5 pieces) for SPS fixed target
    - Slow ejection (~1s spill) for PS2 physics

Design Considerations

- Considerations on machine circumference C_{PS2} :
  - PS2 ejection energy: 50 GeV (improve SPS performance)
  - $C_{PS2} \sim 2\ C_{PS}$ (no superconducting high field magnets for robust operation)
  - SPS filling (5 turn PS2 ejection) and abort gap: $C_{PS2} \sim C_{SPS}/5 = 2.2\ C_{PS}$
  - Analysis of possible bunch patterns required: $C_{PS2} = (15/77)\ C_{SPS} = 1346.4$ m
- Required performance:
  - LHC scenarios: up to 4.0×10^{11} per LHC bunch (20% reserve for losses), spaced by 25 ns (average line density fixed), normalized rms emittances 3.0 μm
  - ➢ Fixes (with direct space charge tune shift: 0.2) injection energy: 4 GeV
  - High intensity SPS physics beam with single transfer from PS2 determines aperture
- RF for bunch pattern for LHC options
  - Extrapolation of present PS scheme:
    - Tunable "10 MHz" system and various RF gymnastics involving higher fixed frequency cavities
  - Single ~40 MHz RF system with little tuning for acceleration:
    - Incompatible with ion operation
    - Proton bunch structure implemented at injection with chopping of SPL

Longitudinal Aspects

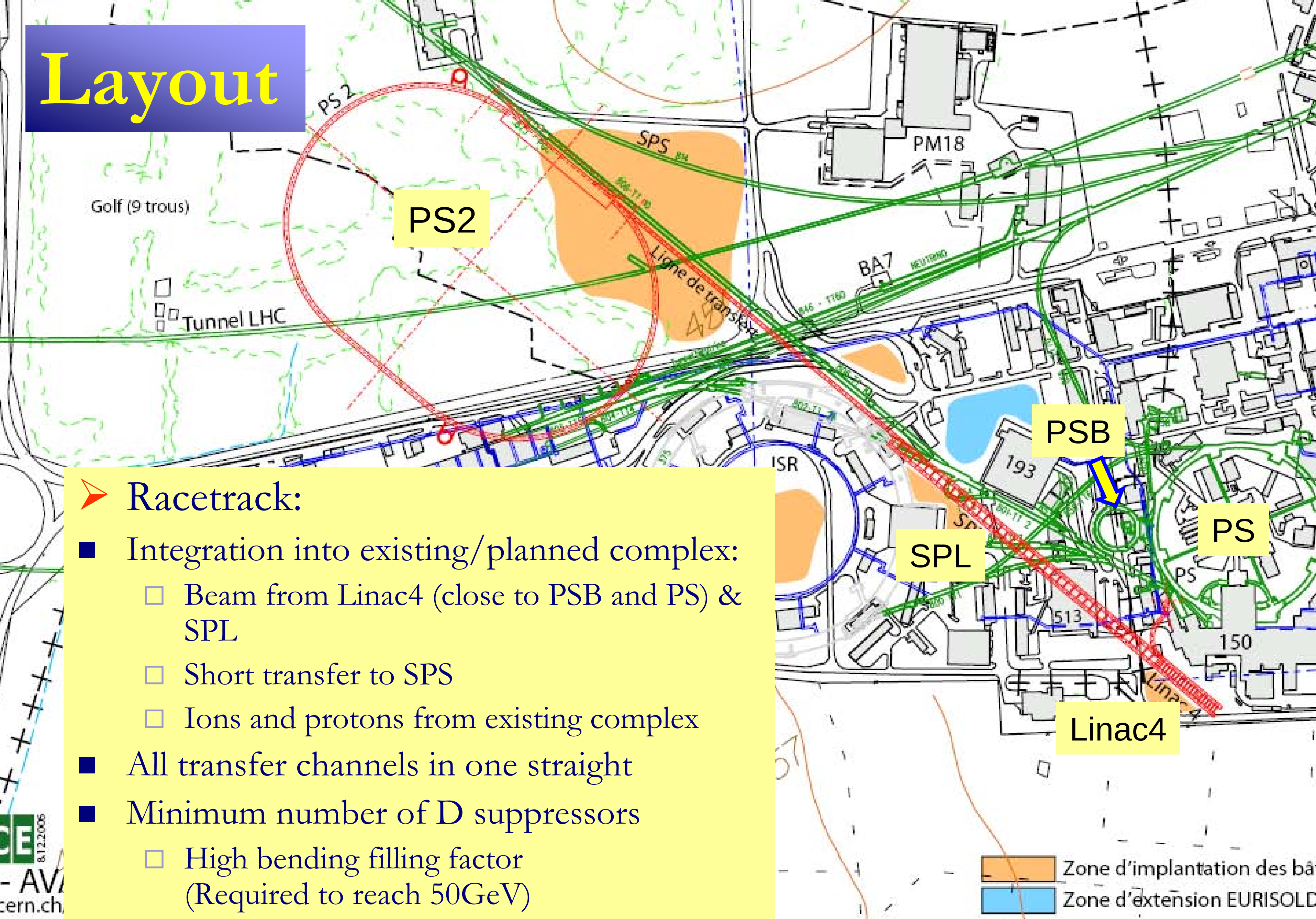
- The increase of working range (PS: 1.4 -> 26GeV, PS2: 4 -> 50GeV):
  - Slows down longitudinal motion while increasing acceptances
  - Impacts on RF gymnastics
- Choice of γ_{tr} and the lattice plays a major role:



Acceptance (blue) and adiabaticity (red) penalty functions
at injection (dashed) and ejection (solid)
keeping RF Voltages of present PS (thin lines) and doubling gradients (thick lines)

- Search for lattices with imaginary γ_{tr}:
  - Avoid transition crossing
  - Extrapolation of PS scheme: $1/\gamma_{tr}^2$ = -.01 implies a factor 2 longer gymnastics at ejection

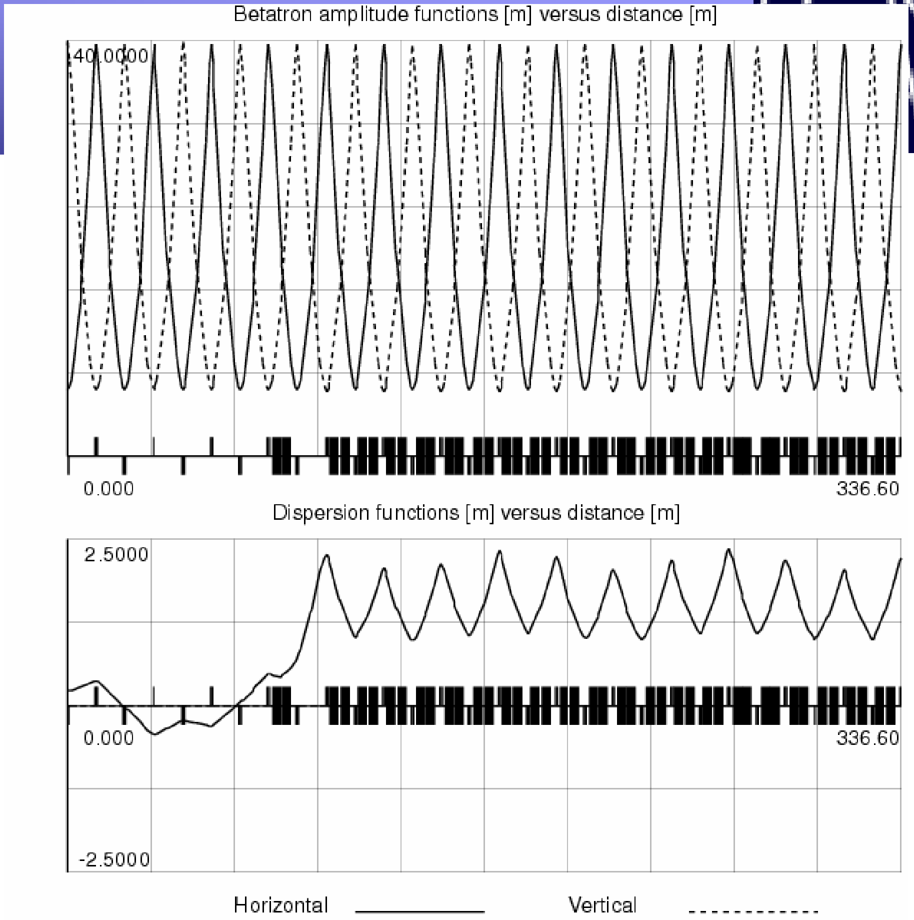
Layout

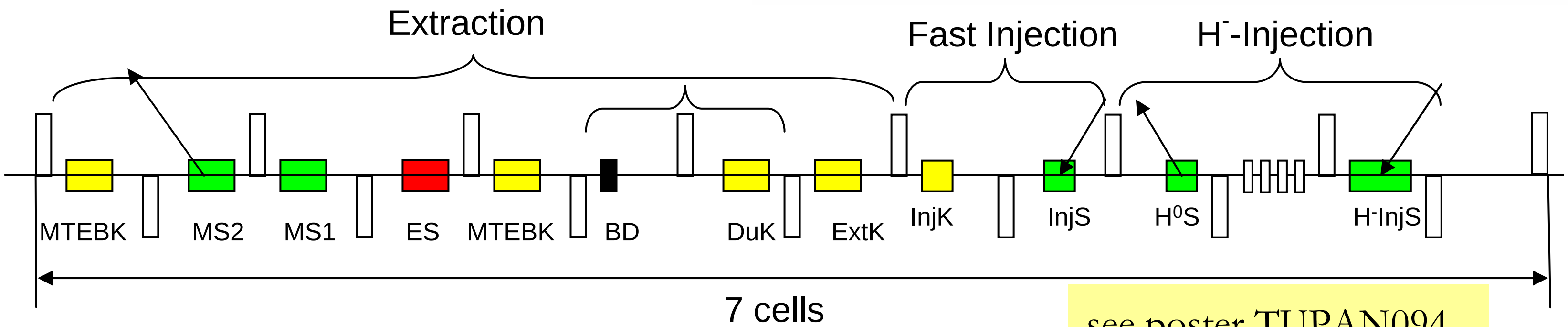


- Racetrack:
  - Integration into existing/planned complex:
    - Beam from Linac4 (close to PSB and PS) & SPL
    - Short transfer to SPS
    - Ions and protons from existing complex
  - All transfer channels in one straight
  - Minimum number of D suppressors
    - High bending filling factor (Required to reach 50GeV)

Plain FODO Lattice

- Conventional Approach:
  - FODO with dispersion suppressors for D = 0 m in straights
  - 90° phase advance per cell for injection/ejection equipment
  - 7 cells/straight and 22 cells/arc -> in total 58 cells
  - $Q_H = 14.5$, $Q_V = 14.5$
  - Only complete lattice at present

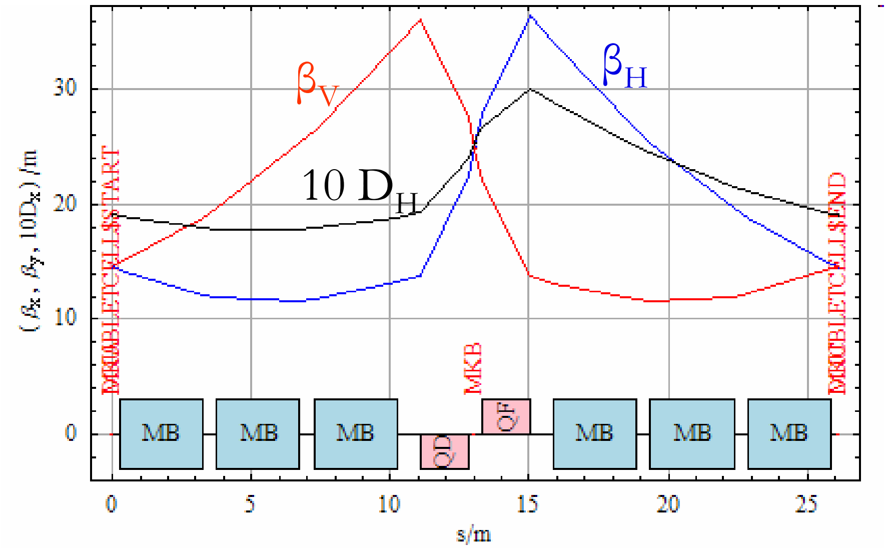




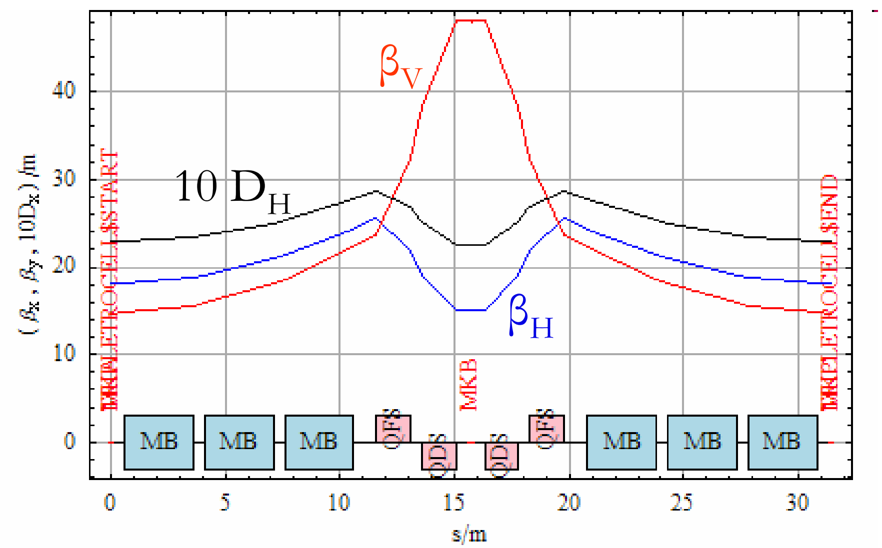
see poster TUPAN094

Doublet and Triplet Lattices

- Doublet:
  - Long straight sections
  - Inefficient focusing (high gradients)
  - Put aside at present

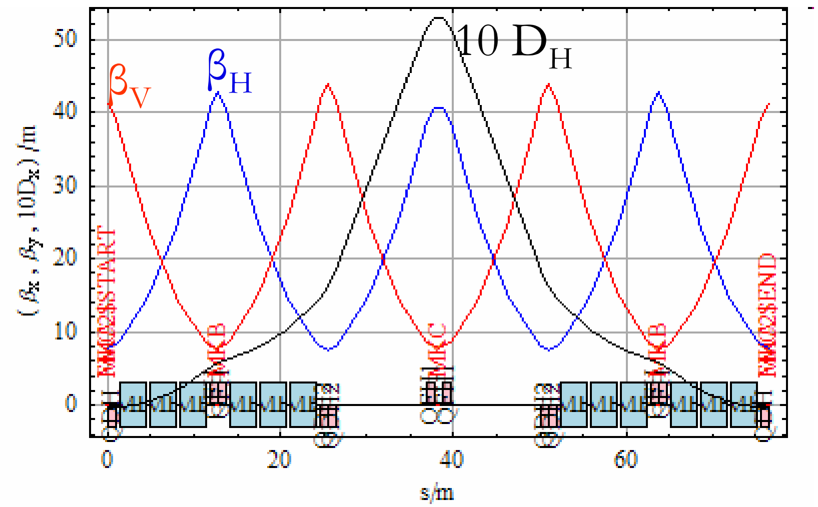


- Triplet:
  - Long straight sections
  - Small maximum ß's in bending magnets
  - Inefficient focusing (high gradients)
  - Put aside at present

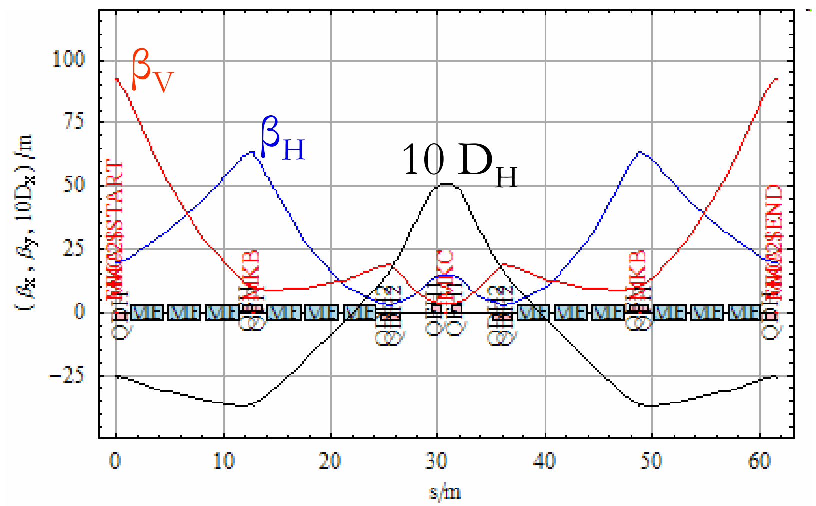


Negative Momentum Compaction (NMC) Modules

- Negative dispersion in bendings needed
- Similar to and inspired from existing modules (e.g. J-PARC, many studies)
- First approach (one module made of three FODO cells):
  - Match regular FODO (no bends in central cell) to given phase advance
  - reduced distance and rematch only central quads to given phase advance (in general three times that of the FODO)



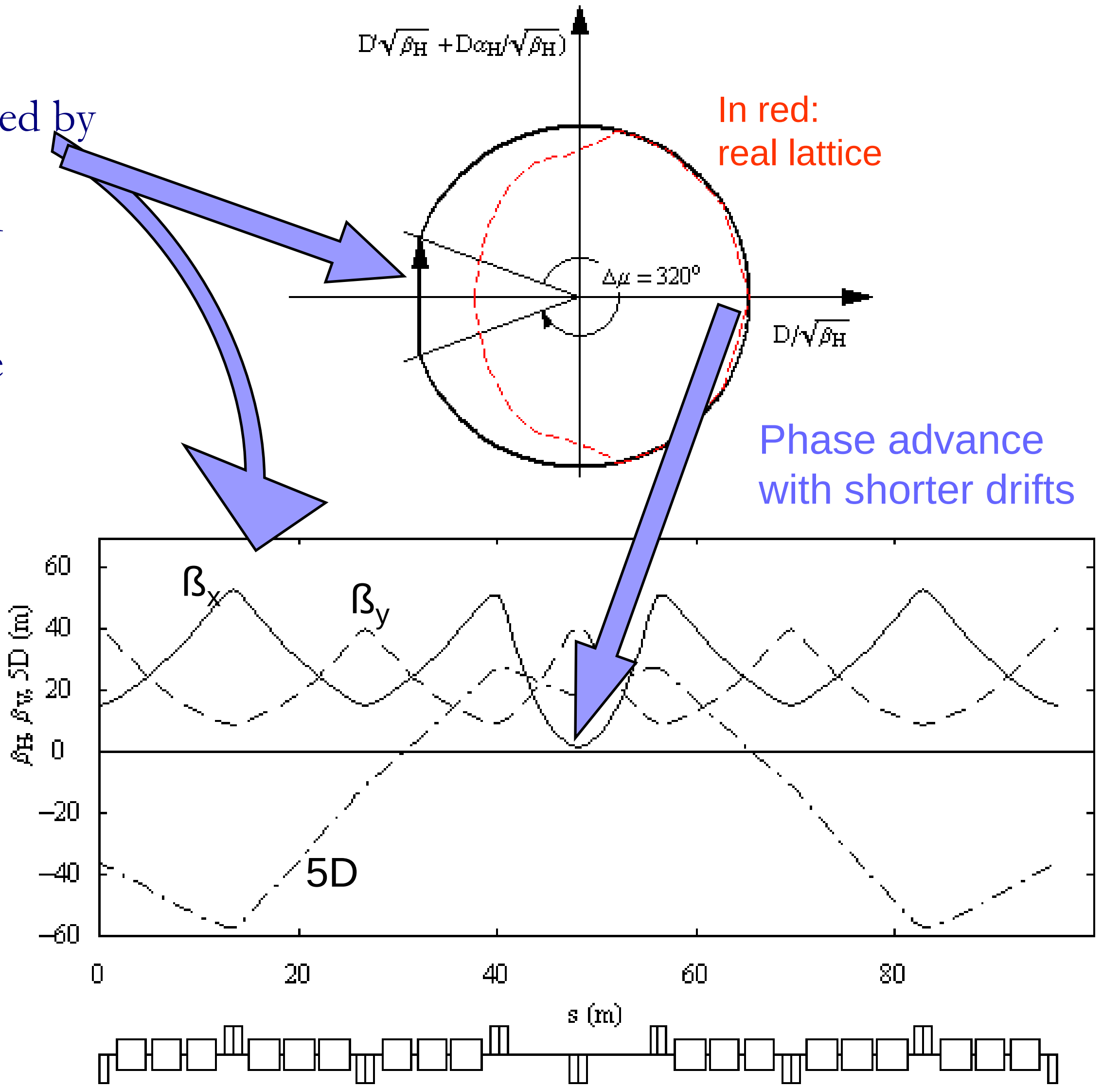
regular FODO 90°/cell
-> zero dispersion at beginning/end



reduced drift in center, average 90°/cell
-> negative dispersion at beginning/end
γ_{tr} ~ 10 i (for whole PS2)

Negative Momentum Compaction (NMC) Modules

- Second approach:
  - Dispersion beating excited by "kicks" in bends,
  - Resonant behavior: total phase advance < 2π
  - Improve filling factor: four FODO per module
  - Central drifts could be filled (price: increased momentum compaction)



- Challenges:
  - Filling factor
  - Straights with zero dispersion

Summary and Outlook

- Study on PS2 to replace the ageing PS started (in the frame of more general investigations on CERN complex upgrades)
- Different lattice types investigated
  - FODO type lattice a good candidate and well advanced
  - NMC lattice based on FODO a candidate
    - No transition crossing
    - Challenge: high dipole filling factor, matching to straights with zero dispersion
- Outlook:
  - Complete a lattice based on NMC modules
  - Revise longitudinal gymnastics (momentum compaction acceptable ?)
  - Thorough study of non-linear dynamics and instabilities
  - Foreseen schedule:
    - Completion of PS2 Study: 2010
    - Decision and start of construction : 2012 (?)