CARE-HHH-APD BEAM'07

BEAM'07 summary PS2

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Aims for the PS2 session

- Discussion of the lattice options for PS2
  - Classical approach with transition crossing
  - Flexible (Negative) Momentum Compaction latttices with imaginary transition gamma
- First considerations on impedances
- First discussion on vacuum design issues

Presentations for the PS2 session

- PS2 optics, Yannis Papaphilippou
- Impedance estimates and requirements, Valeri Lebedev
- Modern schemes for transition crossing, Mei Bai & Steve Peggs
- Possible lattices with imaginary gammaT, Yurij Senichev
- E-cloud remedies and PS2 vacuum design, Jose Miguel Jimenez

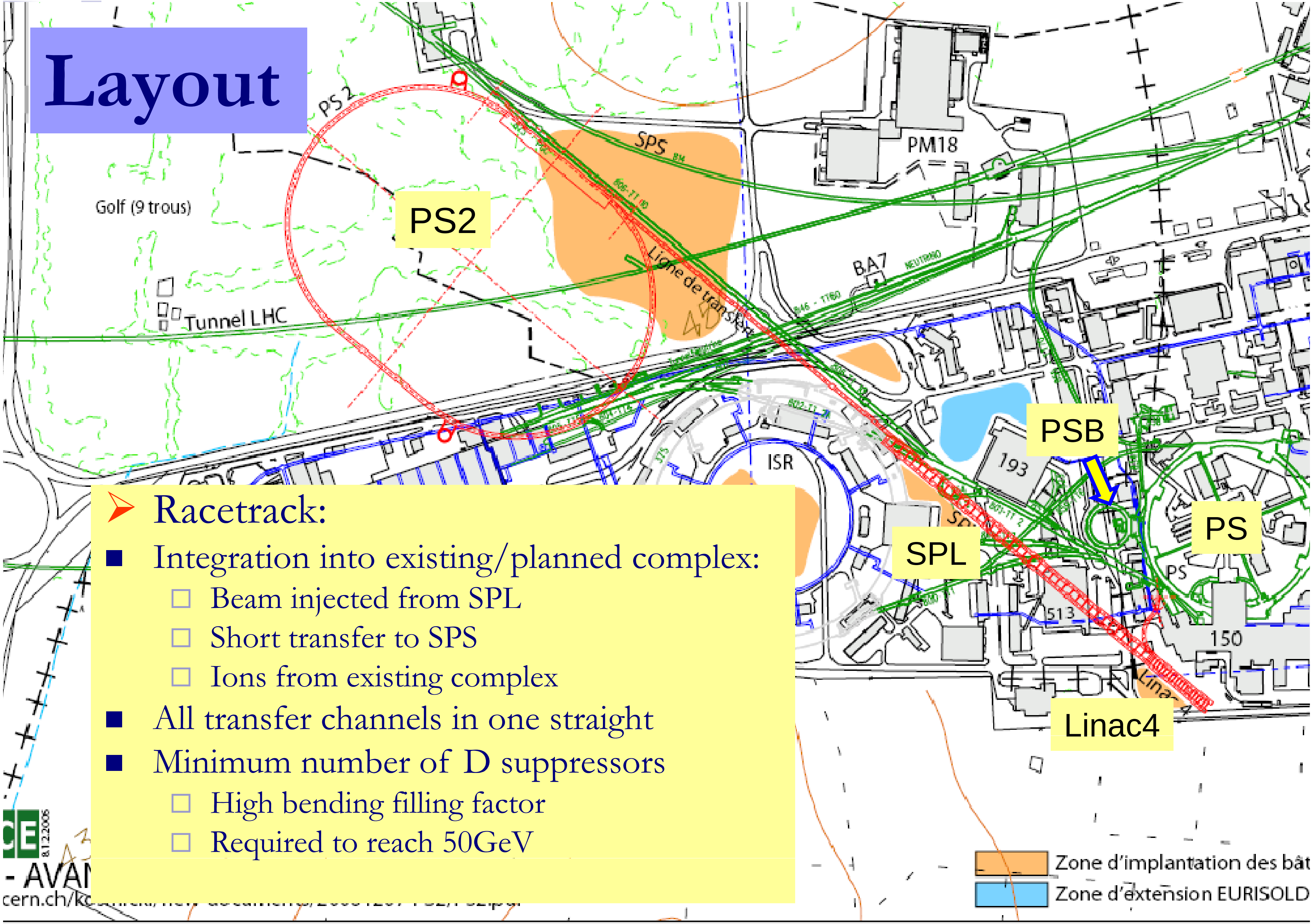
Design and optics constraints

- Replace the ageing PS and improve options for physics
- Integration in existing CERN accelerator complex
- Versatile machine:
  - Many different beams and bunch patterns
  - Protons and ions

Basic beam parameters	PS2
Injection kinetic energy [GeV]	4
Extraction kinetic energy [GeV]	~ 50
Circumference [m]	1346
Transition energy [GeV]	~10/10i
Maximum bending field [T]	1.8
Maximum quadrupole gradient [T/m]	17
Maximum beta functions [m]	60
Maximum dispersion function [m]	6
Minimum drift space for dipoles [m]	0.5
Minimum drift space for quads [m]	0.8

- Injection kinetic energy: Constrained by incoherent space-charge tune-shift (~0.2)
- Extraction kinetic energy: Improve SPS performance
- Circumference: Analysis of possible bunch patterns: $C_{PS2} = (15/77)\ C_{SPS}$
- Transition energy: Longitudinal aspects
- Maximum bending field, maximum quadrupole gradient: Normal conducting magnets
- Maximum beta functions, maximum dispersion function: Aperture considerations for high intensity SPS physics beam
- Minimum drift spaces for dipoles and quads: Space considerations

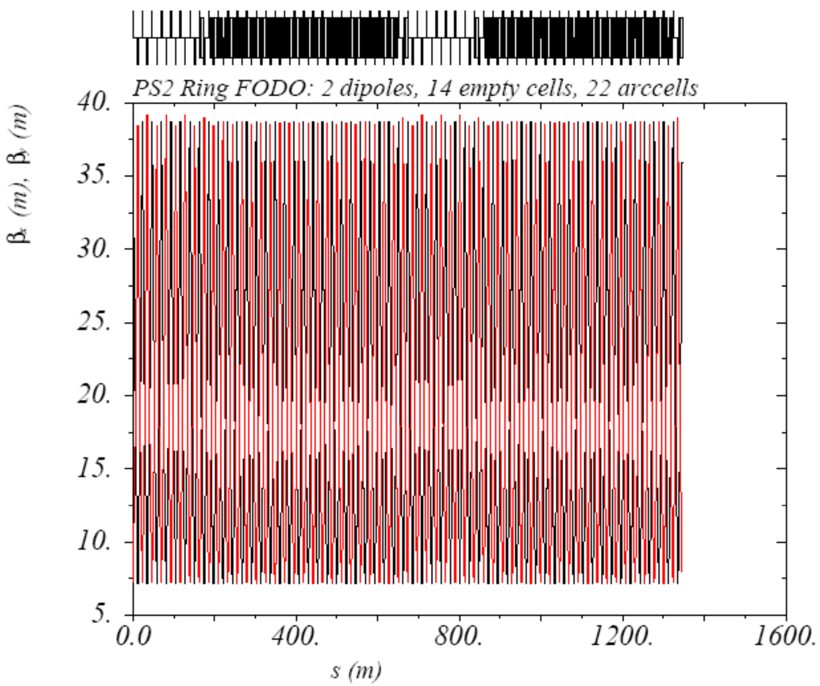
Layout

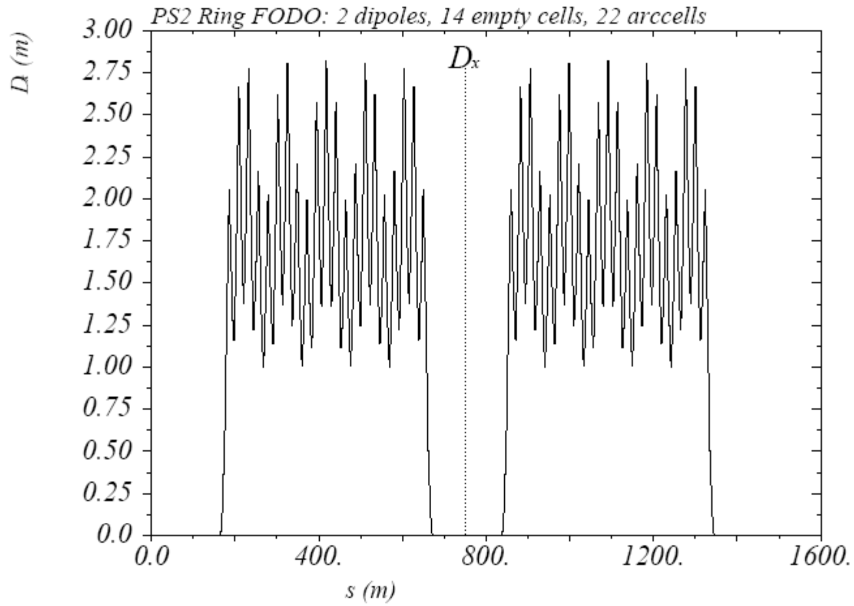


- **Racetrack:**
  - Integration into existing/planned complex:
    - Beam injected from SPL
    - Short transfer to SPS
    - Ions from existing complex
  - All transfer channels in one straight
  - Minimum number of D suppressors
    - High bending filling factor
    - Required to reach 50GeV

FODO Lattice

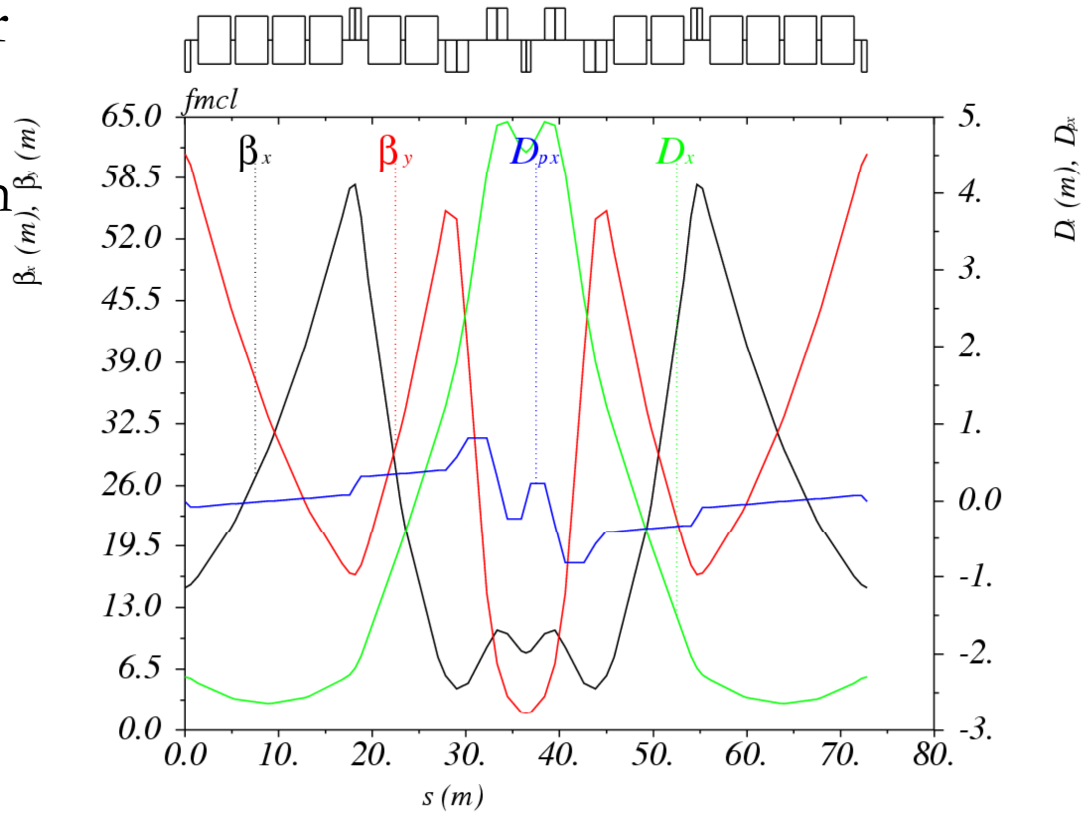
- Conventional Approach:
  - FODO with missing dipole for dispersion suppression in straights
  - 2 dipoles per half cell, 2 quadrupole families
  - Phase advance of **88°**, γ_{tr} of **11.4**
  - 7 cells/straight and 22 cells/arc => in total 58 cells
  - $Q_{H,V}$ = **14.1-14.9**
  - Alternative design with matching section and increased number of quadrupole families





The "short" FMC module

- Aim to have high filling factor with NMC
- 1 asymmetric FODO cell with 4 + 2 bends and a low-beta doublet
  - Phase advances of **280,260º** per module
  - γ_t of **9.4i**
  - Five families of quads, with max. strength of $\mathbf{0.1m^{-2}}$
- Main problem is dispersion suppressor design to long straight.



- Considering an arc of 6 modules + 2 dispersion suppressors of similar length, the total length of the arc is around **510m**

Conclusion PS2 Optics

- Different lattice types for PS2 optics investigated
  - FODO type lattice a straightforward solution
  - FMC lattice possible alternative
    - no transition crossing
    - challenge: matching to straights with zero dispersion
    - Tuning possible in the NMC arcs, not llimited to D=0 straight sections.

Impedance estimates & requirements

	FNAL Main Injector		PS-2
	Present	New(project X)	
Injection kinetic energy, GeV	8		5
Extraction kinetic energy, GeV	120 (max. 150)		50
Circumference, m	3319.42		~1200
Number of particles per bunch	$7 \cdot 10^{10}$	$3.1 \cdot 10^{11}$	$4 \cdot 10^{11}$
Beam current at injection, A	0.49	2.45	2.5
Cycle duration, s	2.2	1.4	1.5 (3.3?)
Normalized 95% emittance, π mm mrad	15/15	25/25 [1]	18
Norm. acceptance at injection, π mm mrad	40/40	40/40	100[2]
90% longitudinal emittance, eV s/bunch	0.4	0.5	0.5
Total number of particles	$3.4 \cdot 10^{13}$	$1.7 \cdot 10^{14}$	$6.5 \cdot 10^{13}$
~ γ-transition, γ_t	21.62	21.62	~12
Betatron tunes, Qx/Qy	26.42/25.41	26.45/25.46	~15
Maximum Coulomb tune shifts, $\Delta Qx/\Delta Qy$	0.033/0.038	0.043/0.046	0.07/012!!!
Harmonic number	588	588	160
Accelerating frequency, MHZ	53	53	40
Average beam power on the target, MW	0.3	2.3	0.37

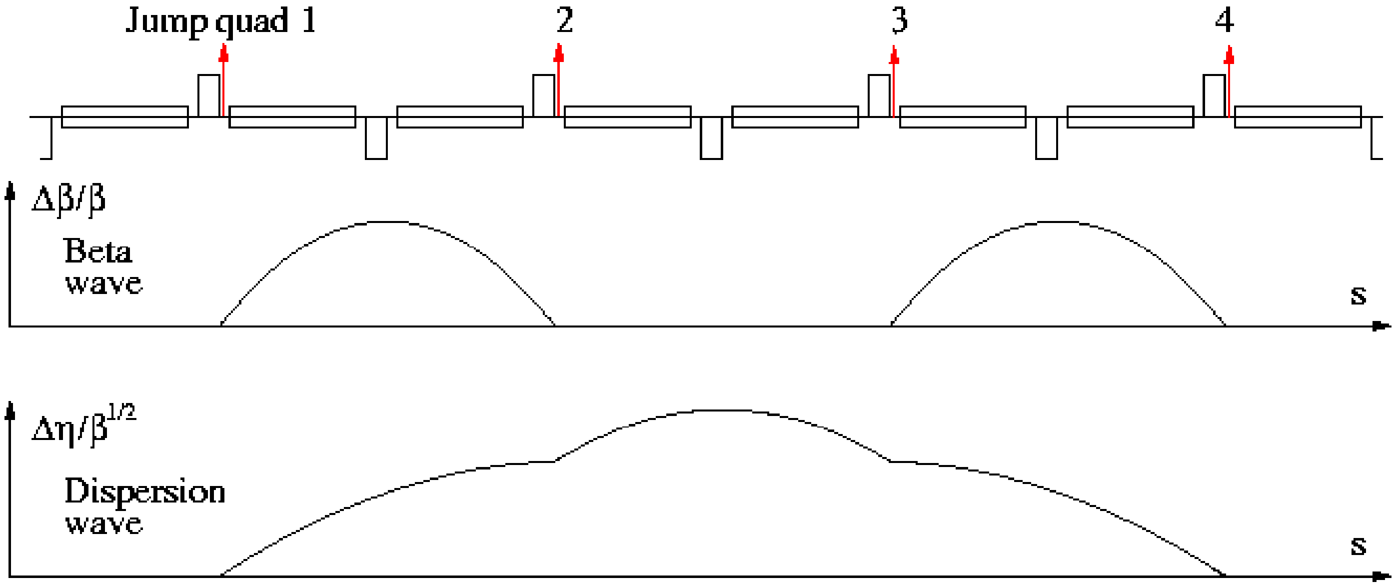
- Analysis of transverse resistive wall and longitudinal wideband impedance.
- For short cycle time of ~(1 – 3) s eddy currents limit the vacuum chamber conductivity. Taking into account the mechanical stability of the vacuum chamber the elliptical stainless steel vacuum chamber looks as a preferable choice
- Covering it with thin layer of better conducting material (gold, silver of copper) would be helpful to reduce resistive wall. To prevent the domination of bending field screening by this layer its thickness should not exceed 30-50 mm
- Gain in the transverse impedance will be only for high enough frequencies, ≥20 MHz
- Impedance at revolution frequency will be set by limitation on the bending field screening

Conclusion Impedance Estimates

- To keep the impedance at minimum:
- Good electromagnetic screening of bellows and other interruptions of the vacuum chamber
- No septum magnets with laminations seen by the beam
- **There are no fundamental limitations on the vacuum chamber impedance for PS-2 parameters**
- **Use of transverse and longitudinal dampers is the must**

Transition jumps in RHIC

First order jump scheme with closed perturbation waves



Beta waves advance twice as fast as dispersion waves

Pairs of jump quad doublets confine dispersion

Real phase advances are never exactly 90 degrees

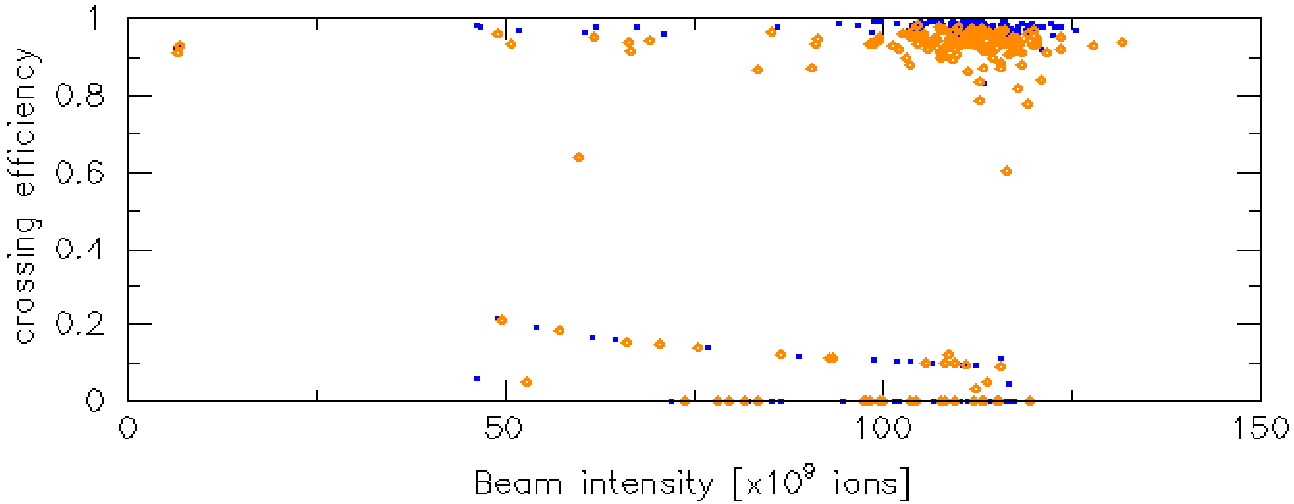
Compensation for tune outside dispersive region.

Chromaticity jump – not in original design of RHIC

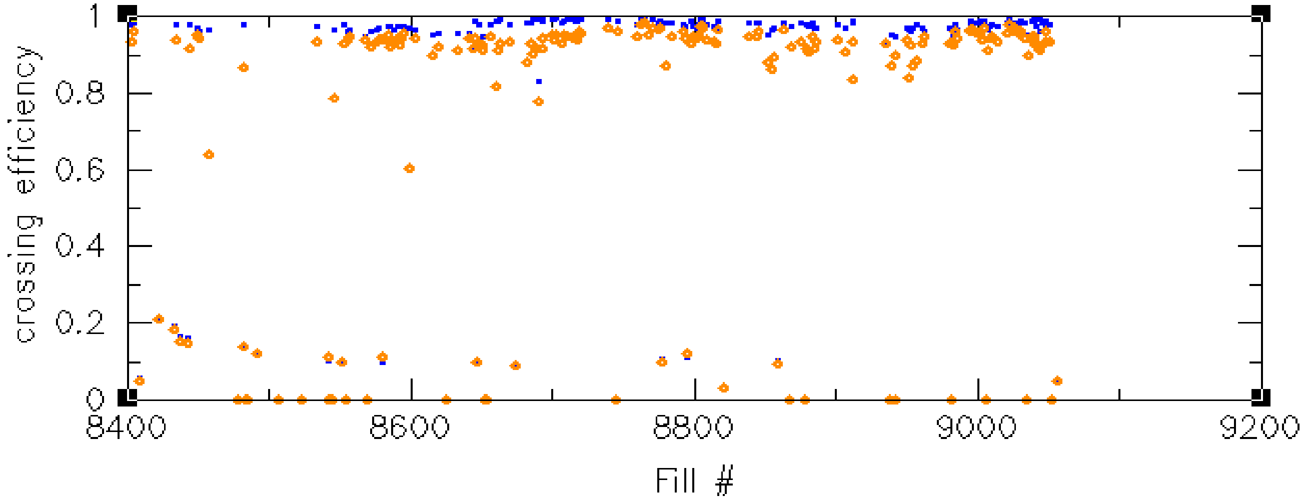
Tansition jump works

Blue & Yellow crossing efficiencies reach 98% & 94%

NO strong correlation with the total beam intensity



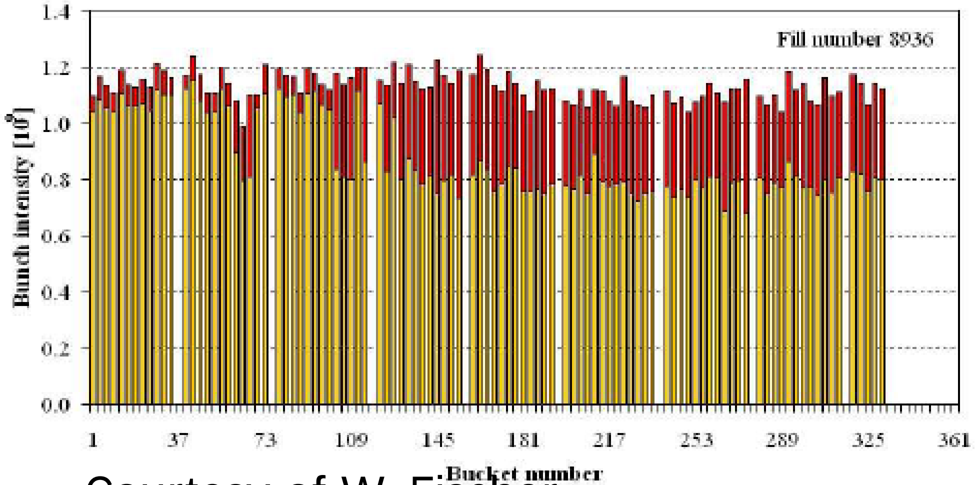
2007 Au run



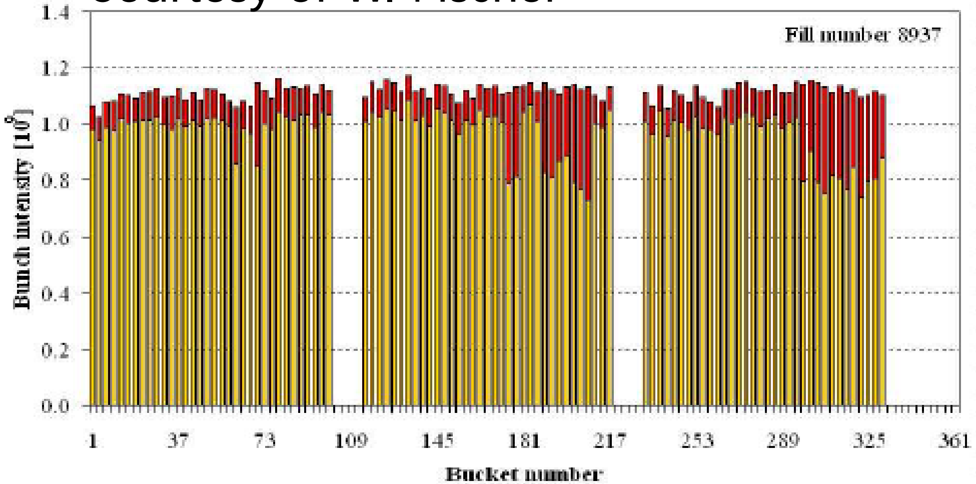
Some issues for operations

- Tune swing at transition causing beam loss
- Transverse instability leading to blow-up
- Longitudinal quadrupole oscillations
- Electron cloud hypothesis
  - More transition losses close to bunch train ends.

- *Need for more sophisticated chromaticity jumps (not only sign but also shape)?*



Courtesy of W. Fischer



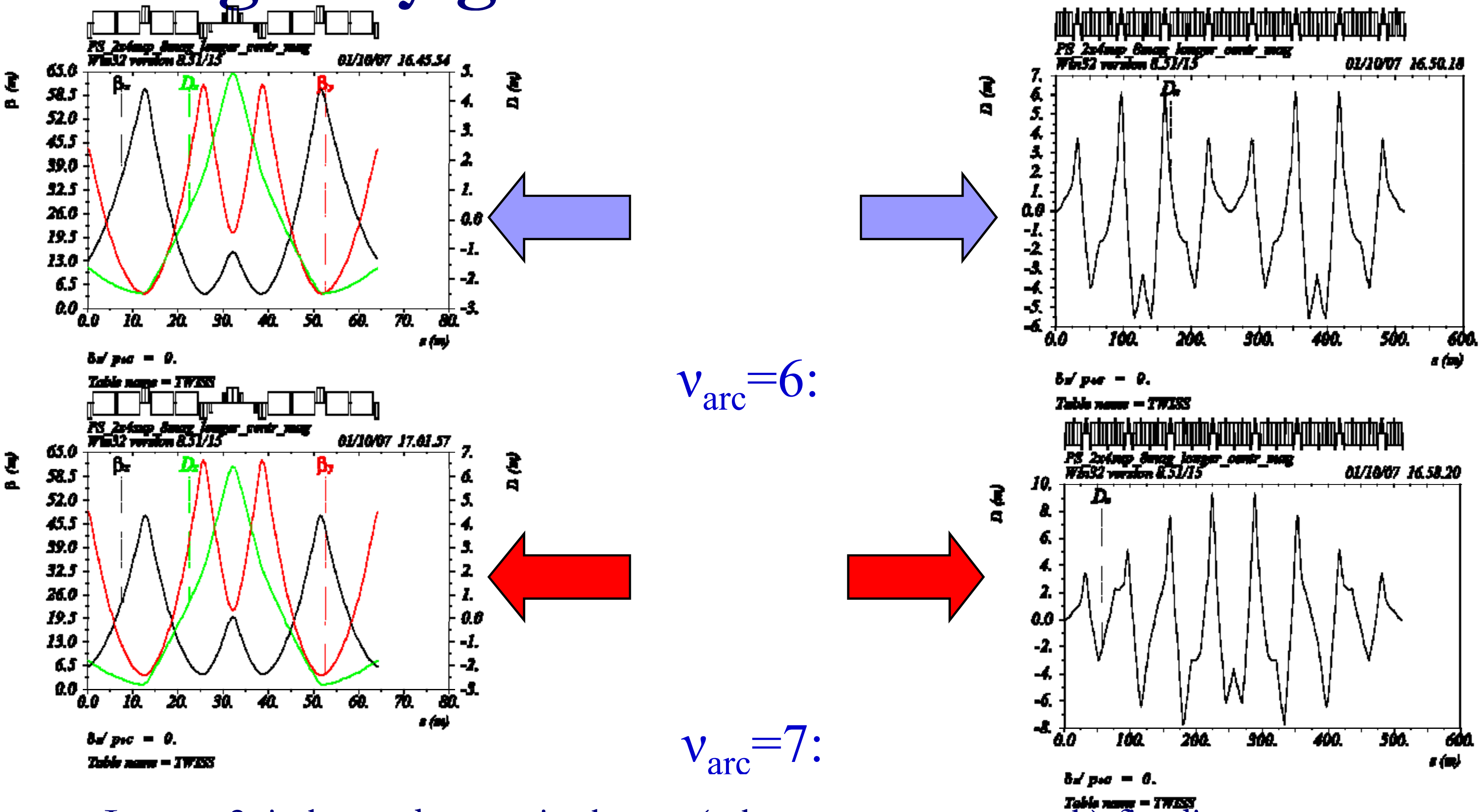
Imaginary gamma T lattices for PS2

- "Resonant" lattice with resonantly correlated modulations of curvature and gradient
- Achieve the negative momentum compaction factor with minimum circumference and control of gamma transition in a wide region;
- Dispersion-free straight section without special suppressor;
- Low sensitivity to multipole errors and sufficiently large dynamic aperture.
- Minimum families of focusing and defocusing quadrupoles and separated adjustment of gamma transition, horizontal and vertical tunes
- Convenient sextupole chromaticity correction scheme

To fulfill all conditions strictly fixed sets of **Superperiods** $\mathbf{S_{arc}}$ and Tunes $\boldsymbol{\nu_{arc}}$:

4:3;   6:5; 8:6; 8:7,…. and so on.

Imaginary gamma T lattices for PS2



- Integer 2pi phase advances in the arc (achromat type-approach) fixed!
- Tuning has to be achieved with straight section, ev. special modules
- Length of these modules similar to classical FODO arc!
- Larger dispersion oscillation than other NMC because of "achromat" approach

PS2 vacuum systems and e-cloud remedy

- The PS2 Vacuum System will have:
  - The complexity of the PS accelerator in term of integration and space available for vacuum and beam components,
  - The complexity of the LHC LSS for the impedance and HOM issues,
  - The requirements of LHC LSS for the dynamic vacuum,
  - The radiation issues comparable to the SPS extraction areas.
- Based on today's knowledge, the electron cloud suppression & vacuum requirement imply a UHV design i.e. baked vacuum system with NEG coatings to ensure vacuum stability

PROS & CONS

of a first order transition jump

(from Steve Peggs and Mei Bai)

PROS

1) Highest Packing Fraction (smallest footprint) and/or

2) smoothest possible optics

3) As few as 3 main quad types & 2 dipole types

4) RHIC OK with unoptimized optics, at medium intensity

5) Fermilab MI will show an optimized jump at high intensity

6) More beam studies OK!

CONS

1) Pass through transition!

2) Fast pulsed power supply families

3) Careful orbit & tune control

4) Transverse instability – electron cloud?

5) Longitudinal quadrupole oscillations

6) Need better design of chromaticity jump

7) *RF requirements (R. Garoby)*

Q: Should PS2 jump, or avoid, transtition?

The answer should not be based in religion.