Energy Ramping for DAΦNE II

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e^+ e^- in the 1 - 2 GeV range:
Physics and Accelerator Prospects

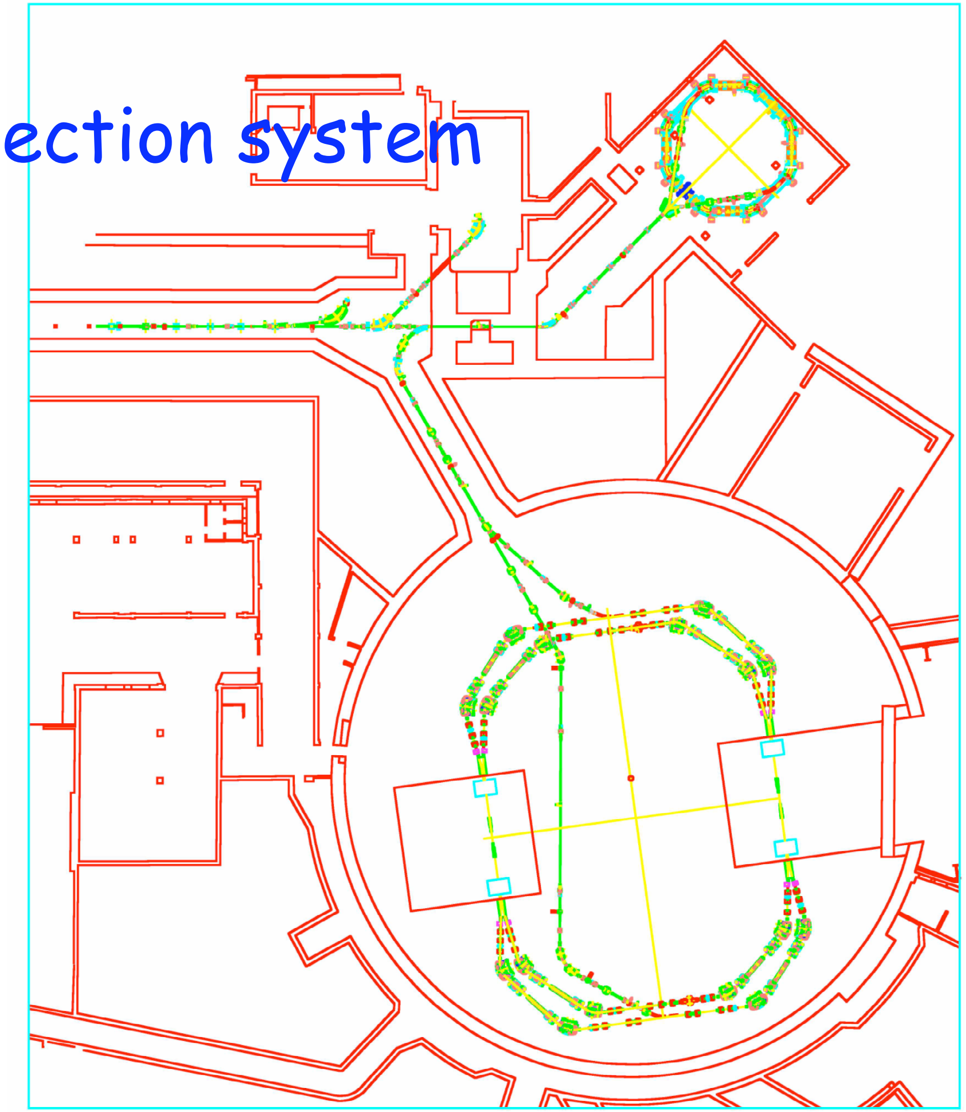
DA□NE II (high energy)

- 2 Rings sharing 2 IRs, only one used
- E_{inj} = .510 GeV
- E_{phy} ~ 1. GeV
- $B_{dip} \leq 2.2$ T
- optics with and without Wigglers
- low-□ based on SC Quadrupoles (fixed rotation)
- B_{exp} = .3 T

Operation framework

- fill few among the available 120 bunches
  $n_b \sim 30$
- $I_{max} \sim 500$ mA
- injection & ramping out of collision
- the 2 rings are ramped simultaneously
  E .51 GeV --> 1 GeV
- Get the beams in collision by the Phase - Jump

Why Ramping?



To use the existing injection system saving:

- time
- person-power
- money

Energy Ramping Issues

Change in the shortest time beam energy preserving beam:

- current
- stability
- final working point

In order to:

- get optimal collision conditions

  L_{peak} $L_{\int}$ $\square_{L}$
- avoid background on the experimental detector

Elements involved in the ramping

- Dipoles
- Quadrupoles, even in the IR
- Sextupoles
- Splitters
- Steering magnets

$$B_{dip} = \frac{E}{c\square} L_{mag} \square \; x_{ref}, y_{ref}$$

$$B_{qua} = \frac{E}{c} L_{mag} |K_{qua}| \square \; \square_x, \square_y$$

$$B_{sxt} = \frac{E}{c} |K_{sxt}| \square \; \square_x, \square_y$$

$$B_{spl} \qquad \square \; \square_{cross}$$

$$B_{steer} \qquad \square \; x_{cor}, y_{cor}$$

$$B = \square(I_{PS})$$

High Level Software tools provide

I_{PS}

according the magnet calibration curve

About the Wiggler

E (GeV)	.51		1.	
WGL	OFF	ON	OFF	ON
τ_x (ms)	68	40	11.	8.6
τ_E (ms)	41	31	5.	3.5

(G. Benedetti)

Lattice with Wigglers:

- increase damping times
- reduce beam-beam effects
- reduce multi-bunch effects

…@ .51 GeV beams are not in collision and I_{MAX}= .5 A

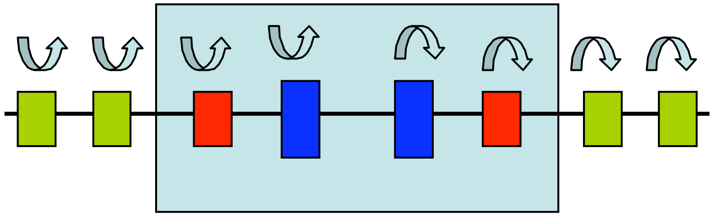
Lattice without Wigglers:

- simplify ramping procedure

@ 1. GeV Wigglers do not affect so much damping times

Wigglers are not ramped !

Beam coupling & ramping

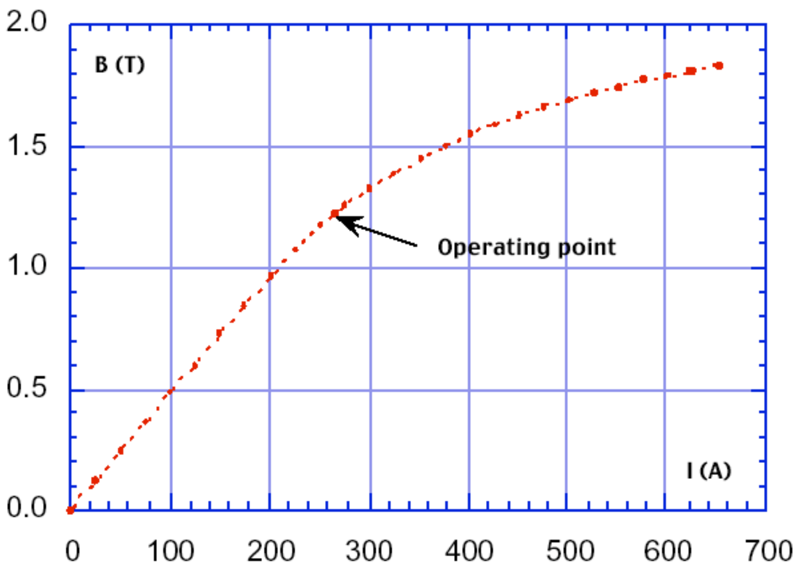


$$\square = \frac{\square_y}{\square_x} .3\%$$

- SC Quadrupoles have:
  - tunable strength
  - fixed rotation
- □ is no more compensated @ .51 GeV
- □ evolution must be evaluated during ramping it is beneficial for
  - beam lifetime
- coupling compensation scheme based on skew quadrupole windings can be considered

Ramping Speed

$$R_{speed} = \frac{I_{E_{phy}} - I_{E_{inj}}}{\Delta t}$$



Short dipole in the DAΦNE achromat

DAΦNE dipoles now:

$B = 1.2$ T

$I_{set} = 263$ A

slew-rate 75 ÷ 7.5 A/s

$t_{ramp} =$ 3.6 ÷ 36 s

Eddy-currents:

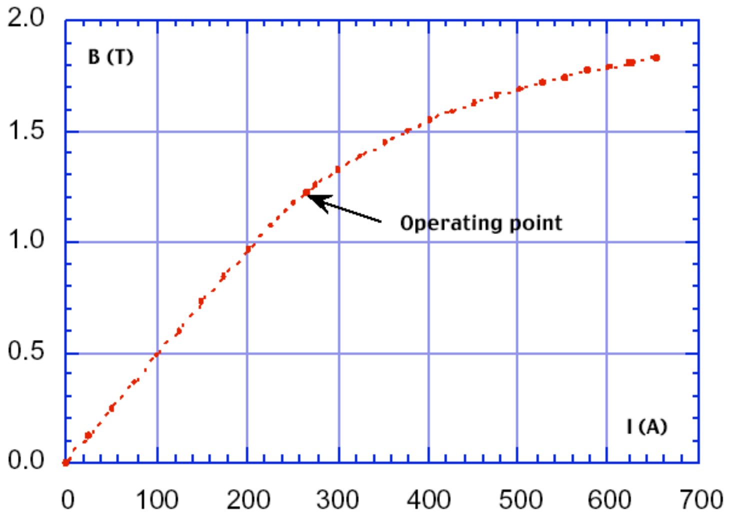
laminated dipoles

$t_{ramp} =$ 3.6 s requires thin wall vacuum chamber

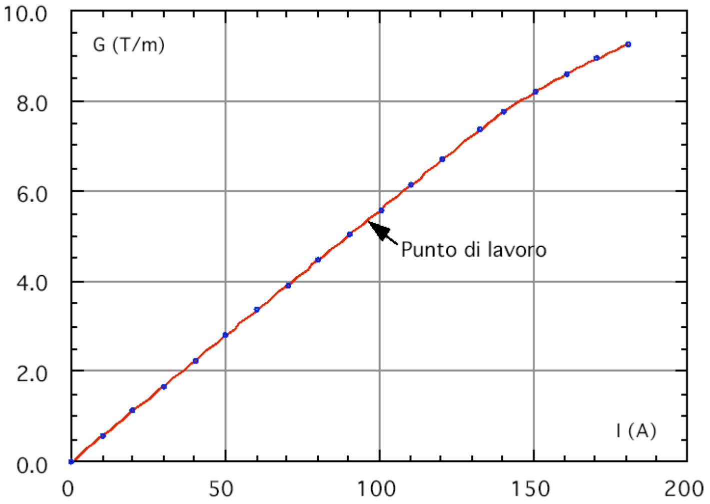
Element Ramp Synchronization (concepts)

Each element has its own
$B = f(I)$

- Evaluate the slew-rate in order to do the same ΔE in the same Δt
- Use ramp table to cope with element saturation



Short dipole in the DAΦNE achromat

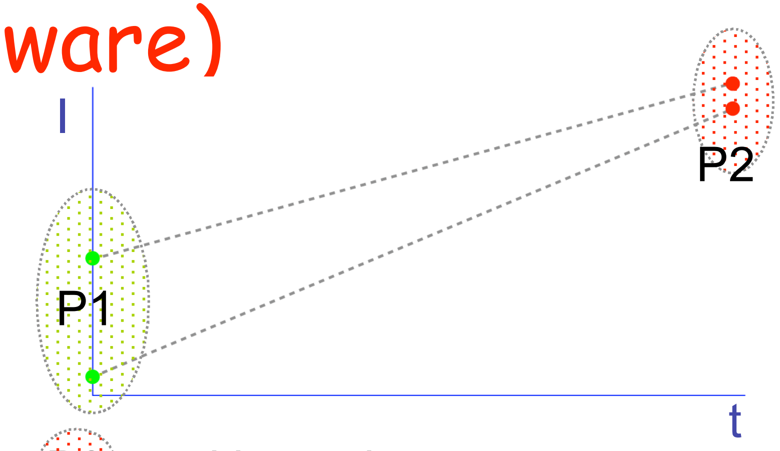


Large Quadrupoles

It seems reasonable to go .51 -> 1 GeV in 30 steps

Power supply ramping synchronization (hardware)

The DAFNE Power Supplies have:
the slew rate remotely settable from 1% to 10% of their current range
a BNC connector for a hardware trigger

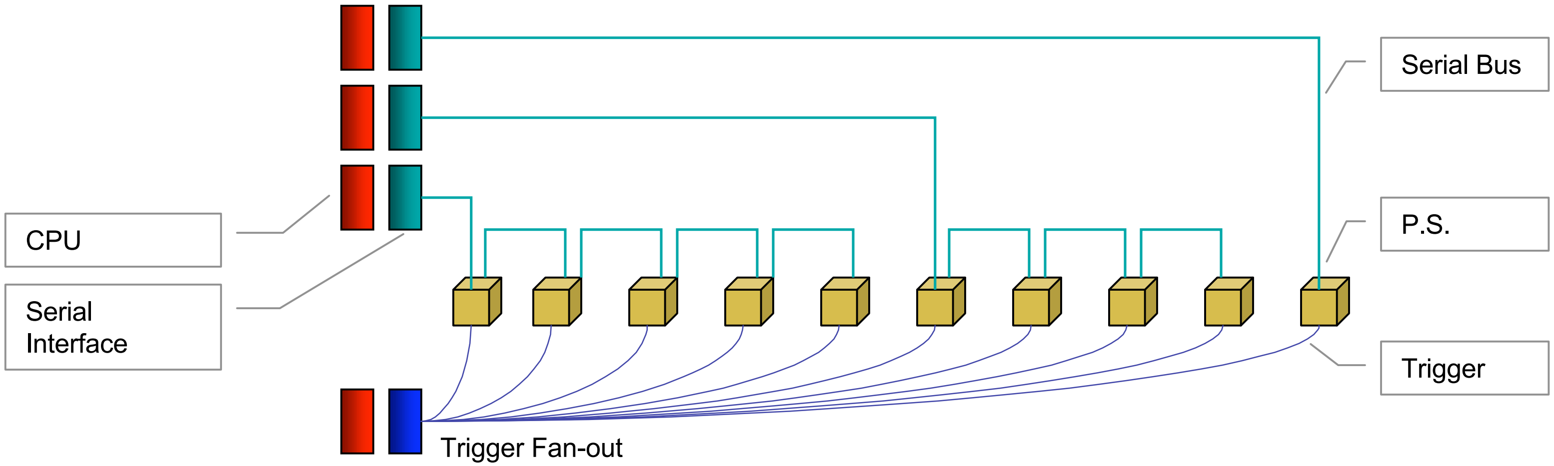


Synchronous ramp from a P1 to a P2 working point

Calculate the set of slew rates for the N Power Supplies as:
Send a PRESET command to all the Power Supplies
Send an hardware trigger to all the Power Supplies

PSET <elementName> <value>

HTRG <elementName>



Ramping Procedure

must provide capabilities to

- Build ramping table
  once fixed n_{step}
  slew rate □ element
  □I toward □E
- Run ramping
- If wiggler are present ramping steps must be interleaved with orbit and tune slow feedbacks

Injection time requirements

• ramping down (.51 GeV)	~ 120 s
• beam injection:	~ 30 s
from scratch	
$f_{inj} = 2$ Hz	
$I_{max} \sim 500$ mA	
• e^+/e^- switch	~ 180 s
• beam injection	~ 30 s
• ramping up (1. GeV)	~ 120 s
• slow feedbacks	~ 2 s
$\square_{x,y}$ and x y orbit	

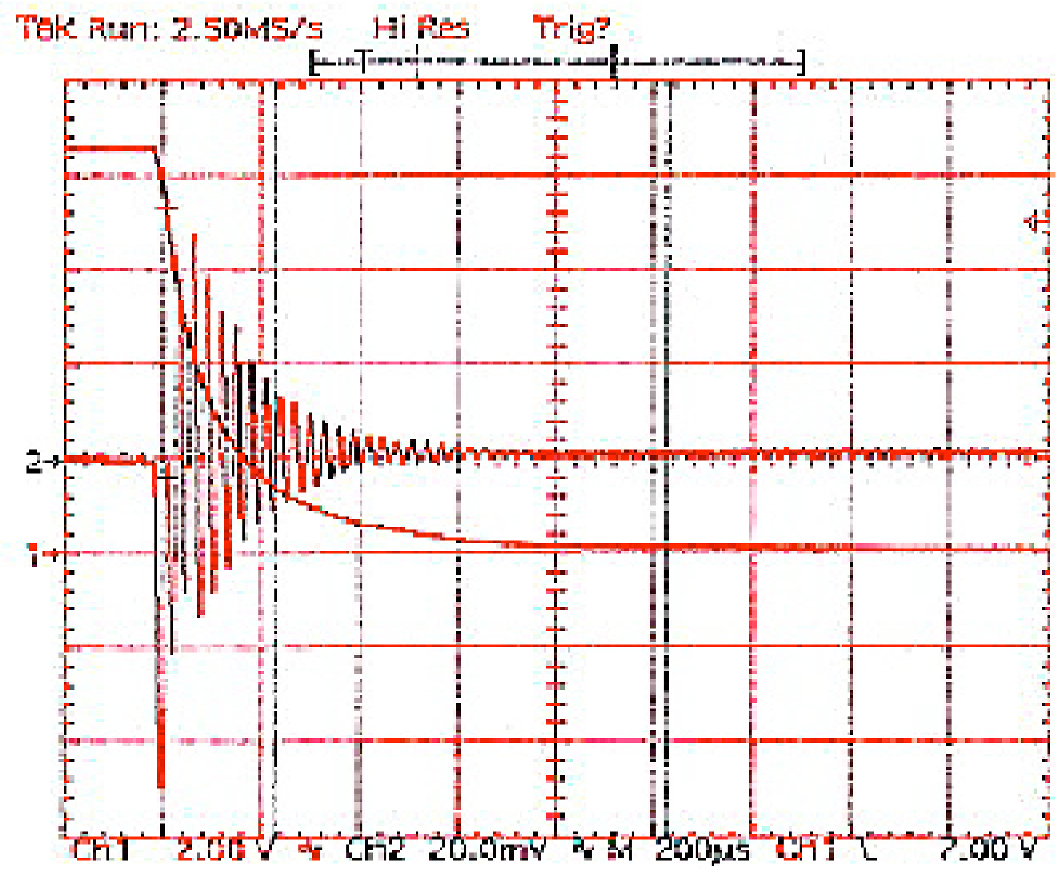
For complete injection

$\square_{inj} \sim 8$ min.

$\square_{L} \geq 2$ h @ 1 GeV

Phase-Jump

- Bunches are injected with longitudinal separation
- then put in collision varying the □$_{RF}$ of e^+ beam
- does not affect feedback efficiency



Tested at DA□NE with
40 and 30 bunches out of 120
with jump of 2 and 1.5 buckets

Longitudinal feedback

must manage frequency variation of the synchrotron oscillations during the ramp, this can be approached in four way:

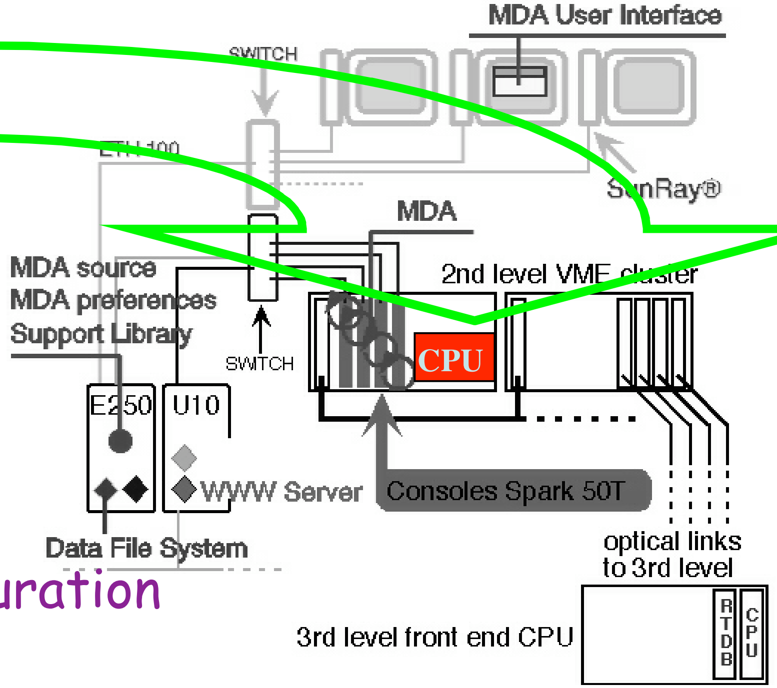
- using the adaptive features of the current system (capability of switching 8 different filters in real time)
- using a “all-seasons” feedback setup, i.e. a specific setup working enough well before, during and after the ramp
- compensating the ω_s variation with a V_{RF} ramp
- using a new generation adaptive feedback (see J. Fox et al. this workshop)

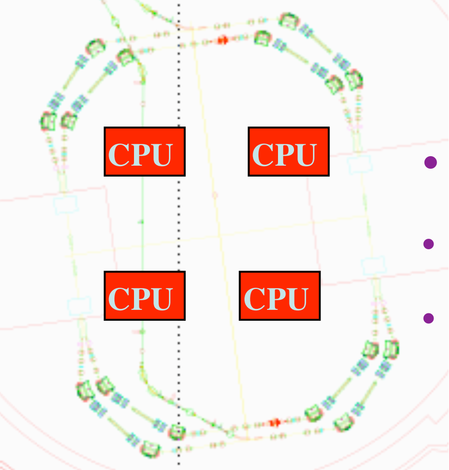
Transverse feedback

- can operate during Energy ramping
- it could be useful to damp coherent oscillation driven by not well compensated chromaticity

Orbit Slow Feedback

Control System Layout





- Orbit measurement
- Beam steering
- Apply steering configuration

- Orbit sampling time 6 Hz
- Correction rate 2 Hz in principle

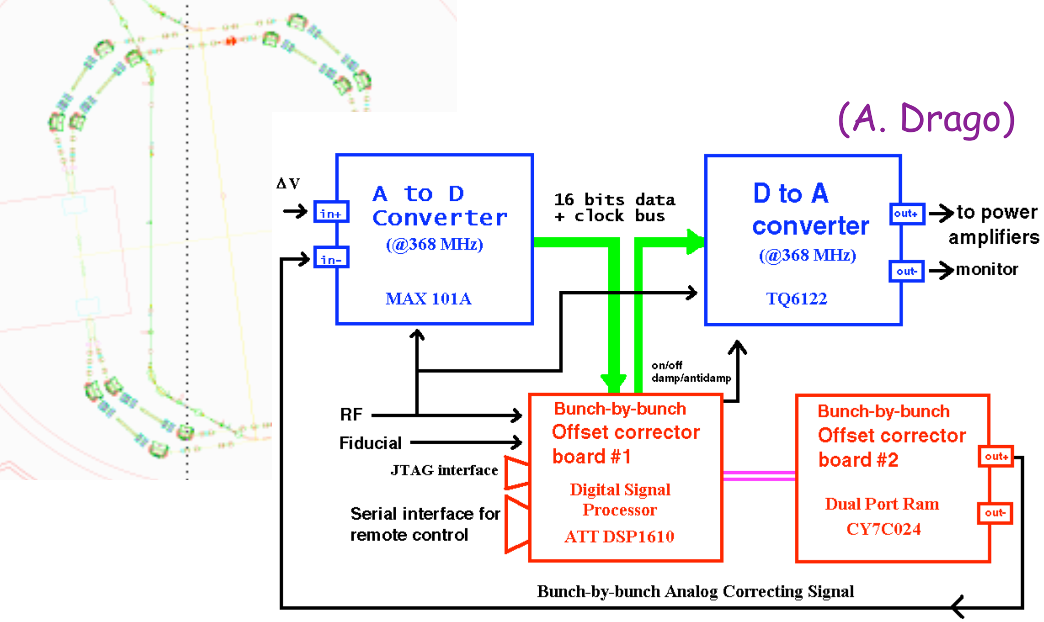
Beam Steering by Response Matrix

- Orbit Correction $\quad \bar{z} = A \square \bar{I}$
- Corrector strength reduction $\quad (\bar{z} + A\bar{I}_0) = A\bar{I}$
- Dispersion Correction $\quad \bar{u} = D \sqcap \bar{I}$

$$u = \begin{array}{c|c|} 2*\mathrm{n}_{\mathrm{mon}} & \begin{matrix} z_1 \\ \cdot \\ z_{n_{mon}} \\ \square_1 \\ \cdot \\ \square_{n_{mon}} \end{matrix} \end{array}
\qquad
D = . \begin{array}{c|ccccc|} & & & & \mathrm{n}_{\mathrm{kick}} & \\ 2*\mathrm{n}_{\mathrm{mon}} & \cdot & \cdot & \cdot & \cdot & \cdot \\ & \cdot & \cdot & \dfrac{\partial z_i}{\partial I_j} & \cdot & \cdot \\ & \cdot & \cdot & \cdot & \cdot & \cdot \\ & \cdot & \cdot & \cdot & \cdot & \cdot \\ & \cdot & \cdot & \dfrac{\partial \square_i}{\partial I_j} & \cdot & \cdot \\ & \cdot & \cdot & \cdot & \cdot & \cdot \end{array}$$

Equations are least square solved by Singular Value Decomposition

Tune slow Feedback



- tune measurements $\square_x$ $\square_y$
- $\square_x$ $\square_y$ correction
  by machine modeling tools
- quadrupole dataset application

Simultaneously
for e^+ e^- beams

Betatron tune measurement

(A. Drago)

Returns the tune fractional part:

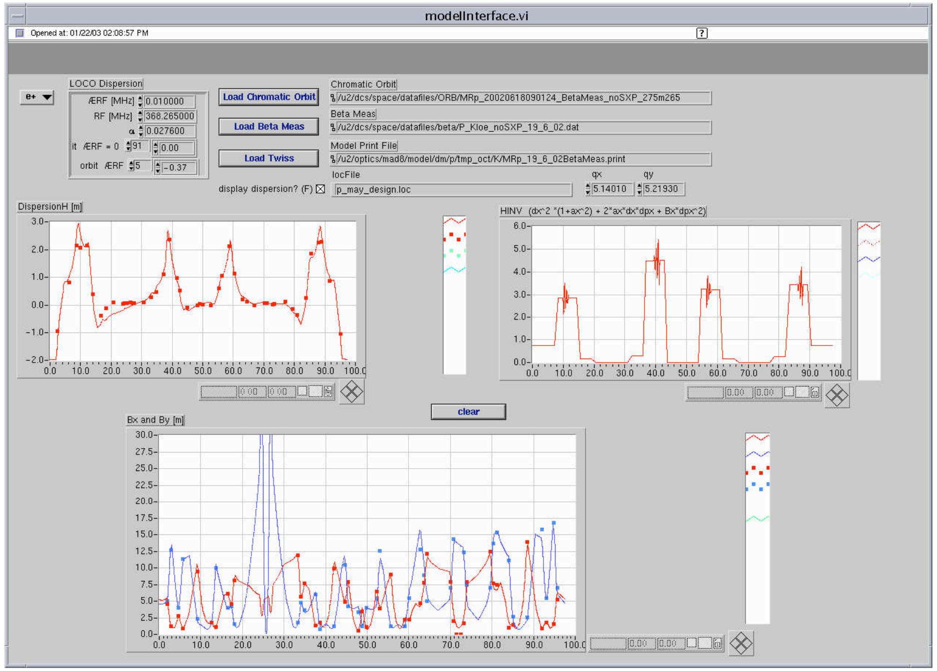
- real time
- it's based on a dedicated bunch
- simultaneous measurement of $\square_x$ and $\square_y$ both for e^+ and e^-

Machine modeling & Control System

Machine model is running within the CS

Successfully used for:

- lowering β_y (hour-glass limit)
- compute the DEAR low-β section
- ordinary operation:
  - optics fine tuning
  - energy scan



modelInterface.vi

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LOCO Dispersion

ÆRF [MHz] 0.010000

RF [MHz] 368.265000

α 0.027600

it ÆRF = 0 91 0.00

orbit ÆRF 5 -0.37

Chromatic Orbit: /u2/dcs/space/datafiles/ORB/MRp_20020618090124_BetaMeas_noSXP_275m265

Beta Meas: /u2/dcs/space/datafiles/beta/P_Kloe_noSXP_19_6_02.dat

Model Print File: /u2/optics/mad8/model/dm/p/tmp_oct/K/MRp_19_6_02BetaMeas.print

display dispersion? (F) ☒

locFile: p_may_design.loc

qx 5.14010

qy 5.21930

Conclusions

What we need for energy ramping?

- Define the lattice:
  - with or without WGLs
  - skew quads windings
- Know dipoles specifications
- Reconsider the existing Power Supply
- Built the ramping procedure within the CS
- Provide slow feedbacks:
  - orbit
  - tunes

… there is no particular problem in implementing energy ramping for DAFNE II

Whereas all the PS can be reused it is simply a problem of:

- High Level Software development
- careful hardware configuration.

Useful discussions with:
M. Serio, M. Preger, C. Biscari,
A. Drago, A. Stecchi, R. Ricci