2/3 Resonance Corrections

Y. Luo for the team

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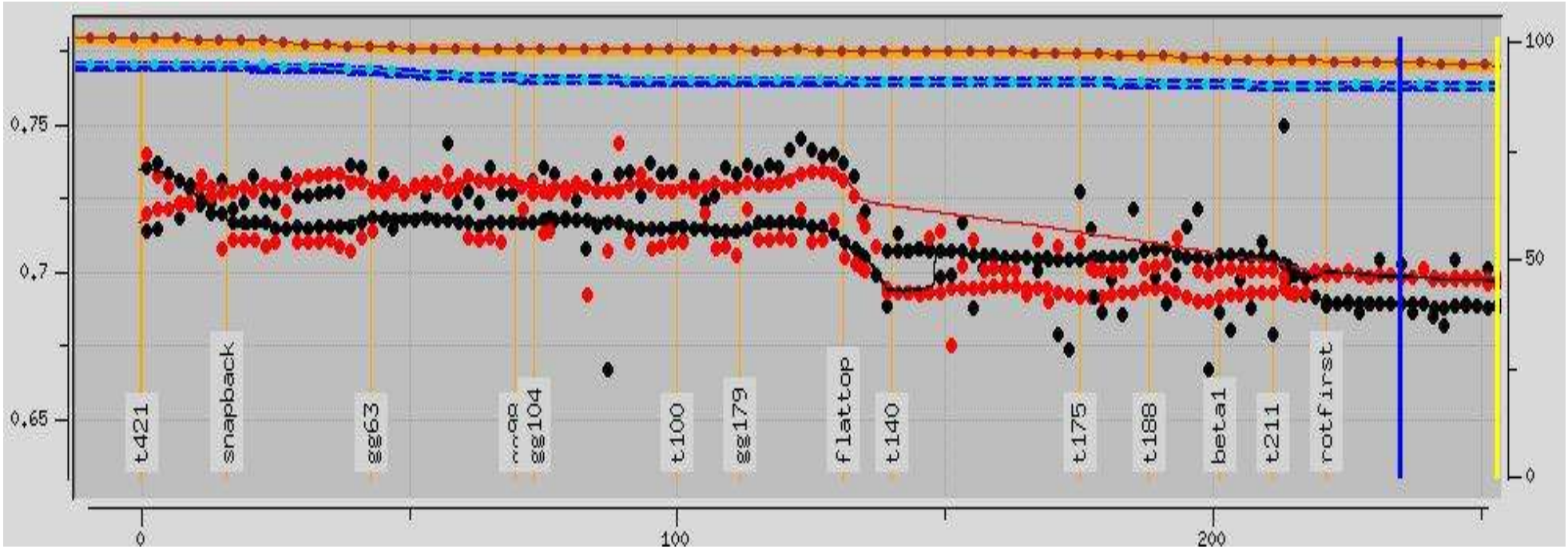
RHIC beam experiment workshop, Nov.9-10, 2005

Goal

- To avoid the tune swing in the polarized proton (pp) run



Polarization prefer the SPS tunes about (0.685, 0.695).

However, at injection, we couldn't work there.

At injection, the beam normally works at at 0.715 to 0.735.

What we did

- Summary

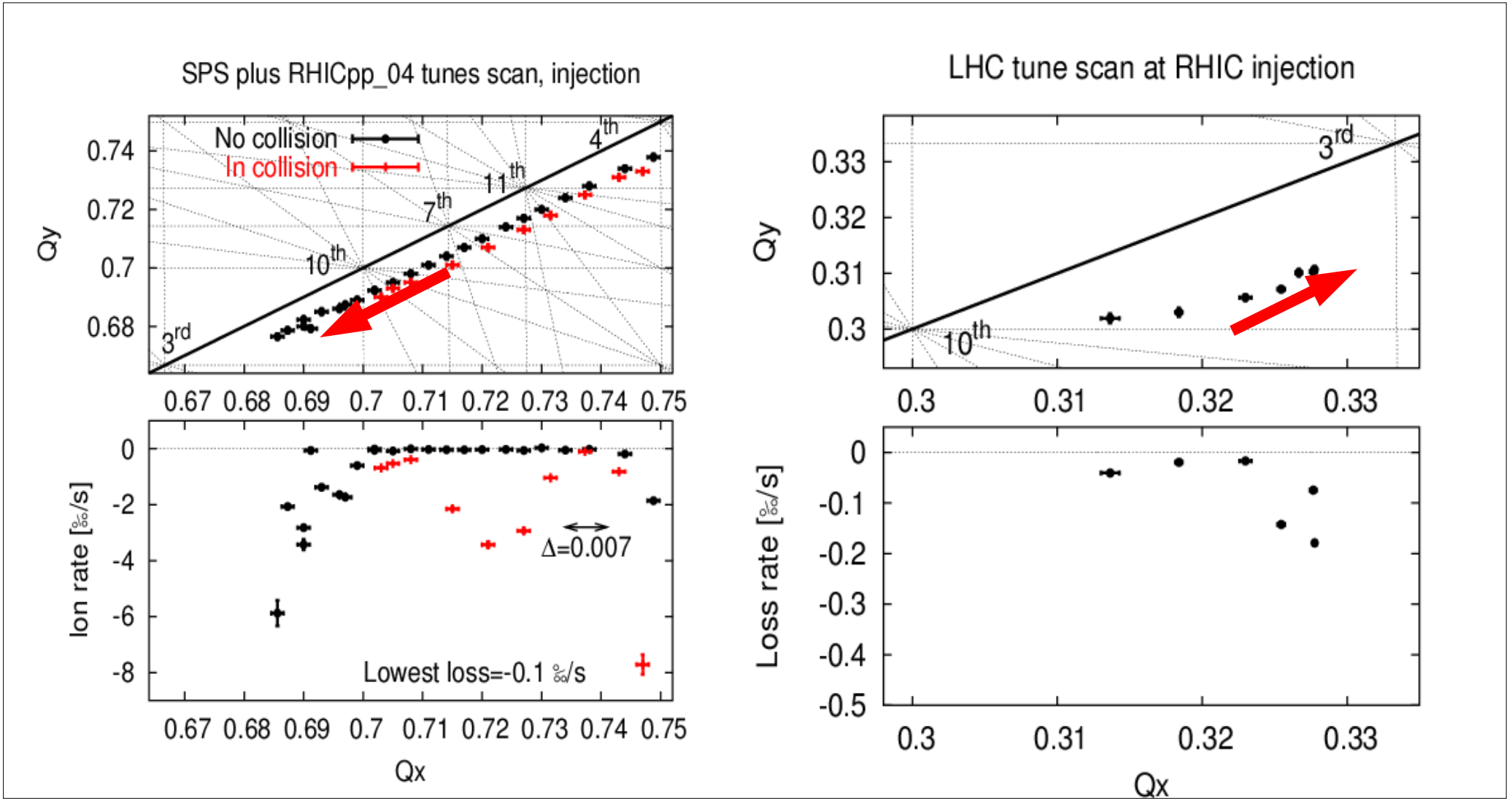
1) In RHIC run05, 2/3 resonance correction proposed by F. Pilat, V. Ptitsyn, but not carried out.

2) In RHIC run04, some driving term measurements done by R. Tomas. No correction applied.

3) Before RHIC run 03, 1/4 and 1/5 resonance islands observed by mismatching injection.

- Beam loss close to (2/3,2/3) working point

  - **Measurements**



R. Tomas, AP Note #163

- **What we learn from this measurement**

R. Tomas:

1) Since we can push Qx to very close to 1/3 with good lifetime, sextupole is not for blame.

2) And we couldn't push (Qx,Qy) very close to (2/3,2/3), **skew sextupole** is then for blame.

My question ?

1) Measurement data are not enough to draw this conclusion. Independent Qx or Qy scan from both directions to (2/3,2/3). Detuning will affect one direction scan result.

2) If Rogelio is right, where come these ' huge' skew sextupoles?

Suggestion:

further verifying needed to determine the domain resonance.

- 1/4 and 1/5 resonance island observations
  - **Method**

- Setup to create/enhance the resonance island:
- Tune to 0.245/246
- Chromaticity to 0
- Octupole induced tune spread (arc octupoles)

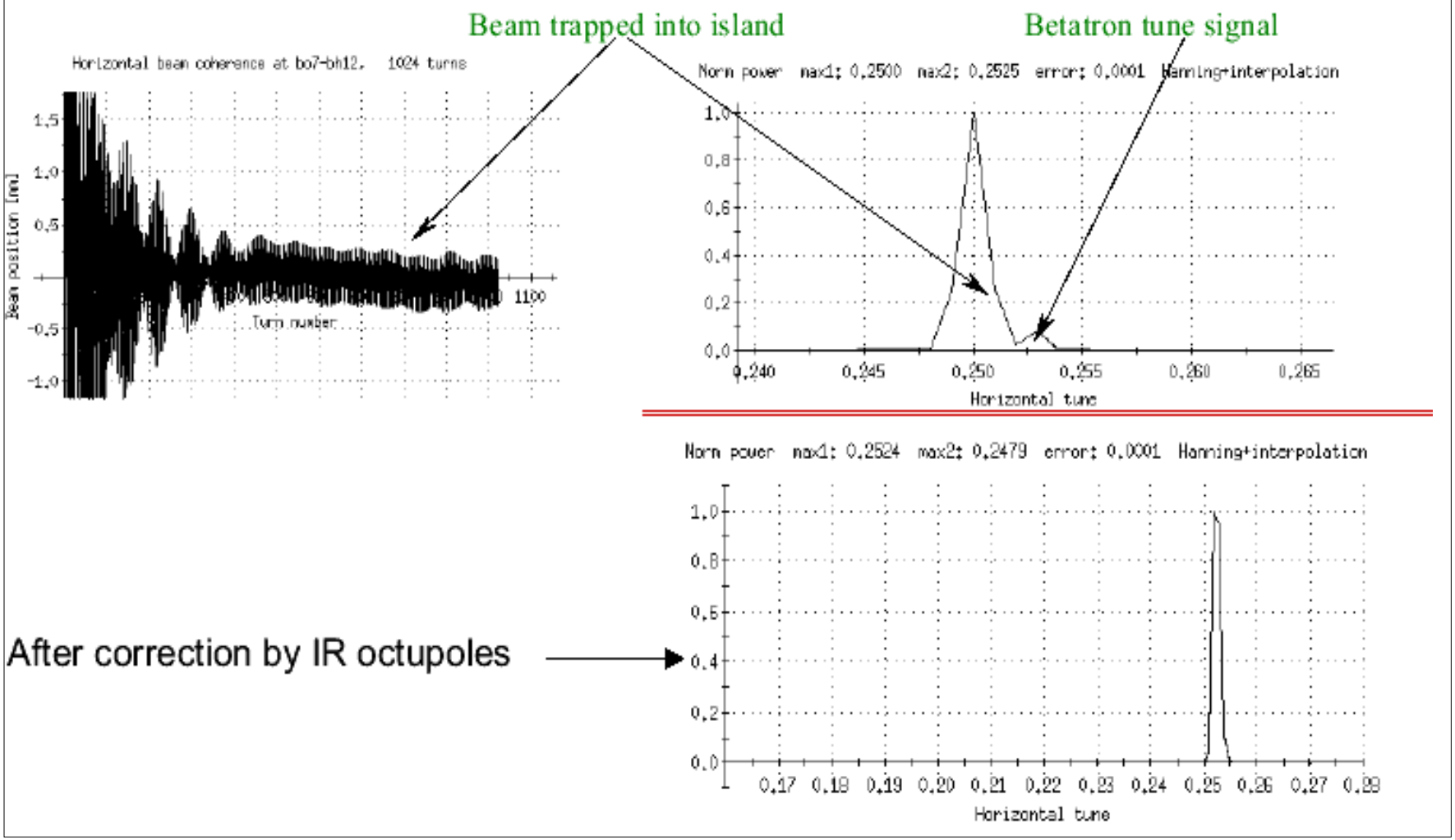
- Balance resonance detuning and tune spread to get clearly resonance picture

- RhicInjection (TBT data), TuneMeter, Beam Transfer function and Schottky monitor have been used to observe the resonance signal

V. Ptitsyn, 2003 beam experiment workshop

➢ Observations

- Octupole or decapole corrections was used to eliminate resonance signal



After correction by IR octupoles

V. Ptitsyn, 2003 beam experiment workshop

- Driving term measurements

  - **Measurement in RHIC**

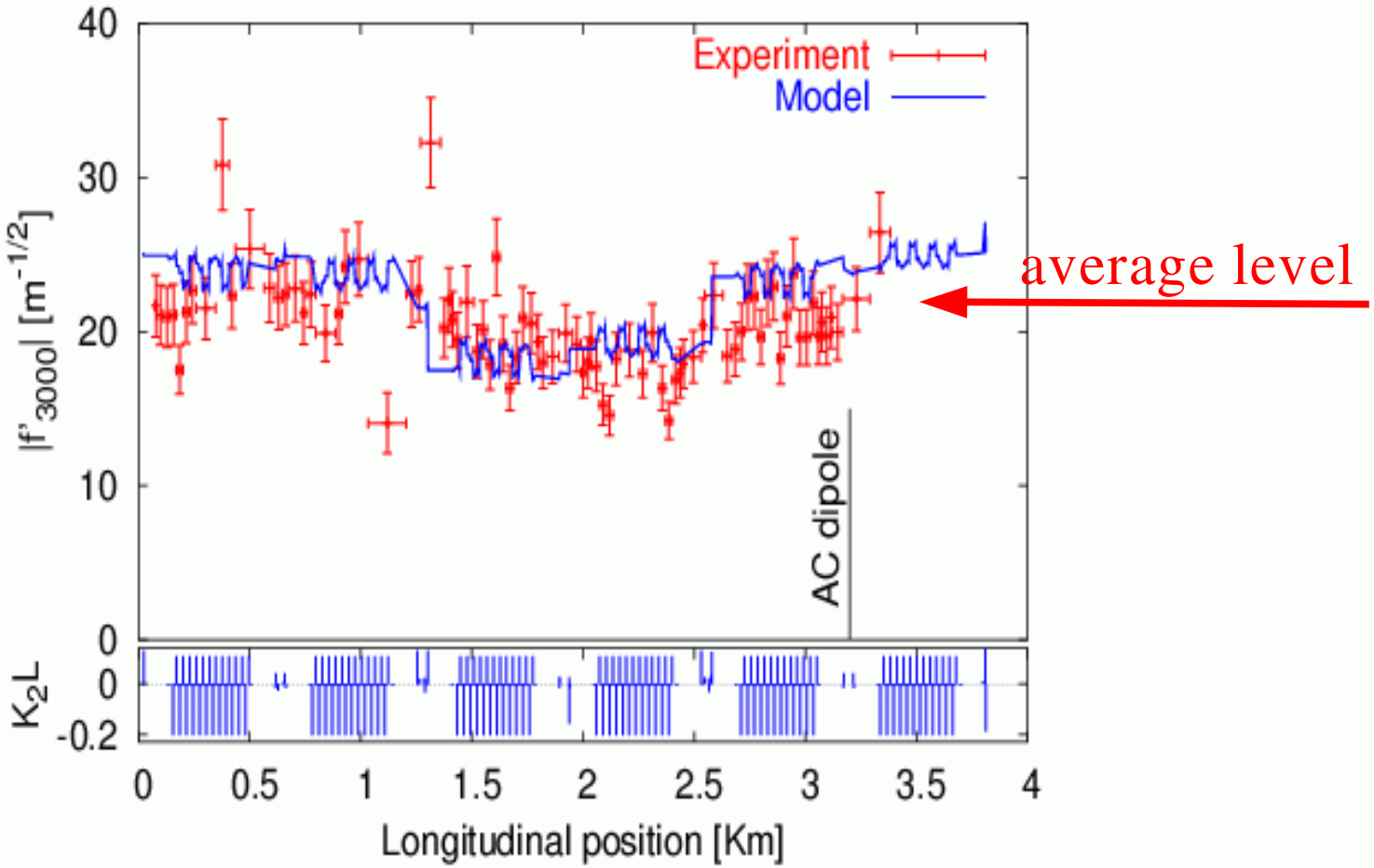
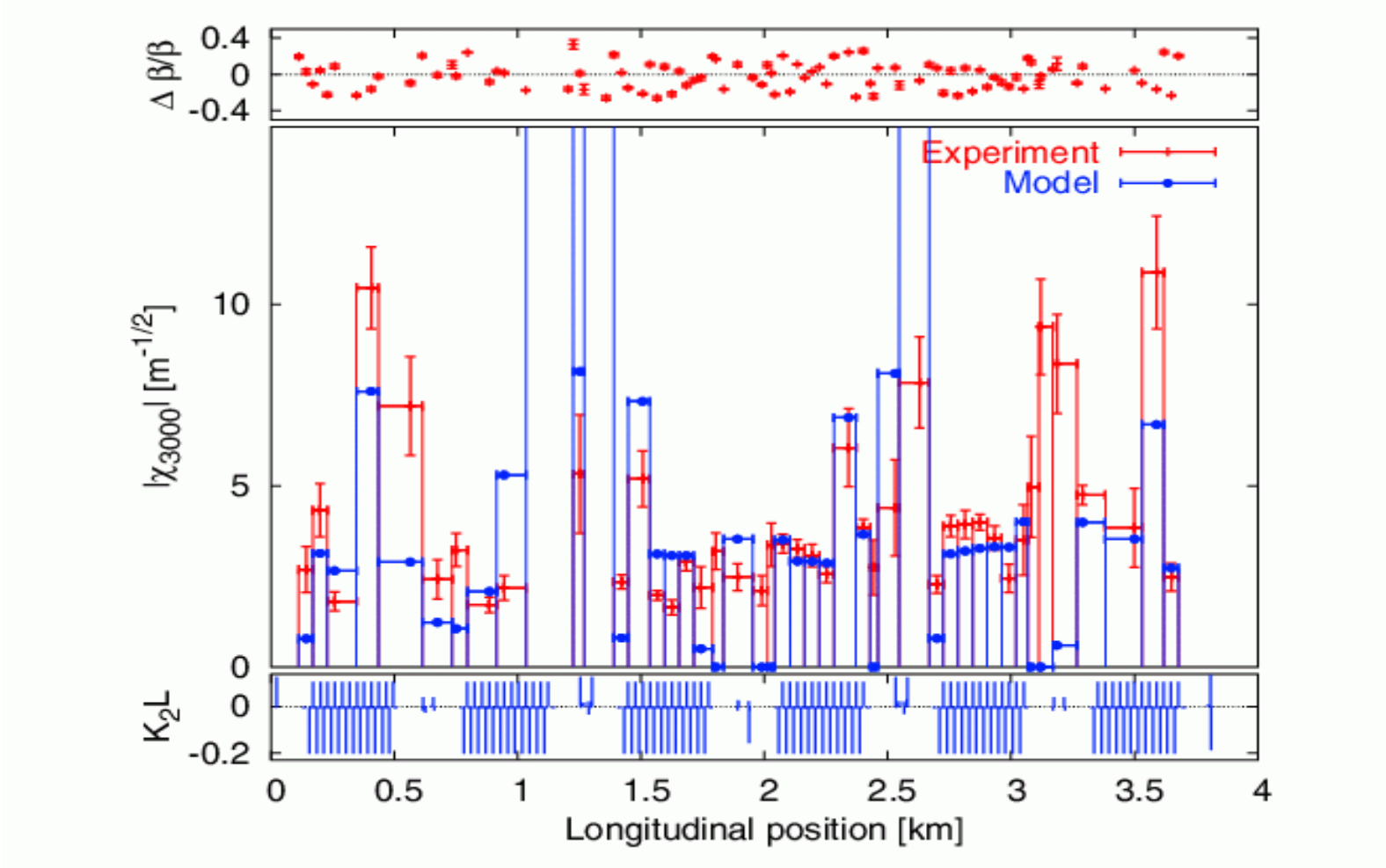


Figure 3: Measurement of f'_{3000} with an AC dipole for the Yellow ring with working point (0.31,0.22).

R. Tomas, et al., Phys. Review STAB 8, 024001

- **Driving terms for error location and corrections**



F. Schmidt, PAC'05, "just like closed orbit correction"?

Methods and Tools

- Hamiltonian perturbation theory

  - Perturbation Hamiltonian:

$$H_1 = \sum_N H_1^{(N)}\left(x, p_x, z, p_z, 0\right) = \sum_N \sum_{\substack{J,K,L,M=0 \\ J+K+L+M=N}}^{N} h_{JKLM}^{(N)}(\theta)\, x^J p_x^K z^L p_z^M \,.$$

reduce it

  - Hamiltonian resonance term:

$$h_{jk\ell m}^{(N)}(\theta) \sim b_{JKLM}^{(N)} \sqrt{\frac{\beta_x}{2R}}^{(j+k)} \sqrt{\frac{\beta_z}{2R}}^{(\ell+m)} \exp\left\{-i\left[(j-k)Q_x + (\ell-m)Q_z\right]\theta\right\},$$

responsible for (j-k)Qx +(l-m)Qz =p resonance

  - Reference:

A. Schoch, CERN 57-21

G. Guignard, CERN 76-06, CERN 78-10

- Modern approach
  - Lie Algebra and Norm Form

    Simplectic high order nonlinear map

    Tune dependence calculation

    TPSA technique is the key.
  - Many applications

    analytical nonlinear tune shift calculations, ..

    simplectic trackings,..

- Driving term measurement from TBT data

General Beam spectrum:

$$\hat{x}(N) - i\hat{p}_x(N) = \sum_{j=1}^{\infty} a_j e^{i[2\pi(m_j\nu_x + n_j\nu_y)N + \psi_j]} \quad m_j, n_j \in \mathbf{Z},$$

Normal Form approach:

$$\begin{array}{ccc} \mathbf{x} & \xrightarrow{\mathbf{M}} & \mathbf{x}' \\ \mathbf{\Phi}^{-1}\downarrow & & \downarrow\mathbf{\Phi}^{-1} \\ \zeta & \xrightarrow[\mathbf{U}]{} & \zeta' \end{array} \qquad h_z^{\pm} = \hat{z} \pm i\hat{p}_z = \sqrt{2J_z}e^{\mp i(\phi_z + \phi_{z_0})}.$$

driving term

$$\boxed{\begin{aligned} h_x^-(N) &= \sqrt{2I_x}e^{i(2\pi\nu_x N + \psi_{x_0})} \\ &\quad -2i\sum_{jklm} j f_{jklm}(2I_x)^{\frac{j+k-1}{2}}(2I_y)^{\frac{l+m}{2}} e^{i[(1-j+k)(2\pi\nu_x N + \psi_{x_0}) + (m-l)(2\pi\nu_y N + \psi_{y_0})]}. \end{aligned}} \tag{15}$$

J. Bengsson, CERN 84-05 (Ph.D dissertation)
R. Bartolini and F. Schmidt, Part. Accel. 56

FFT (with interpolation, courtesy of E. Asseo, LEAR) of the linear invariant gave:

f	A_x	ϕ_x [deg]	A_y	ϕ_y [deg]
$3\nu_x$	5.3×10^{-9}	-45.1	-	-
$\nu_x - 2\nu_y$	2.9×10^{-9}	-82.6	5.8×10^{-9}	94.6
$\nu_x + 2\nu_y$	1.0×10^{-9}	49.6	1.9×10^{-9}	49.0

Table 6: Estimated First Order Sextupolar Modes from Tracking ($\nu_x - 2\nu_y$ appears with the opposite sign due to aliasing).

Conclusion:

The sextupolar modes for a real accelerator can be measured, and hence compensated, i.e. by introducing a correction with the opposite sign. In particular, if the sextupoles have individual power supplies.

J. Bengsson, C-AD seminar

- Observables and Knobs for RHIC

  - Observables

    beam decay
    TBT data for driving term measurement
    available from tunemeter kicker and AC dipole excitations

  - Orthogonal Knobs

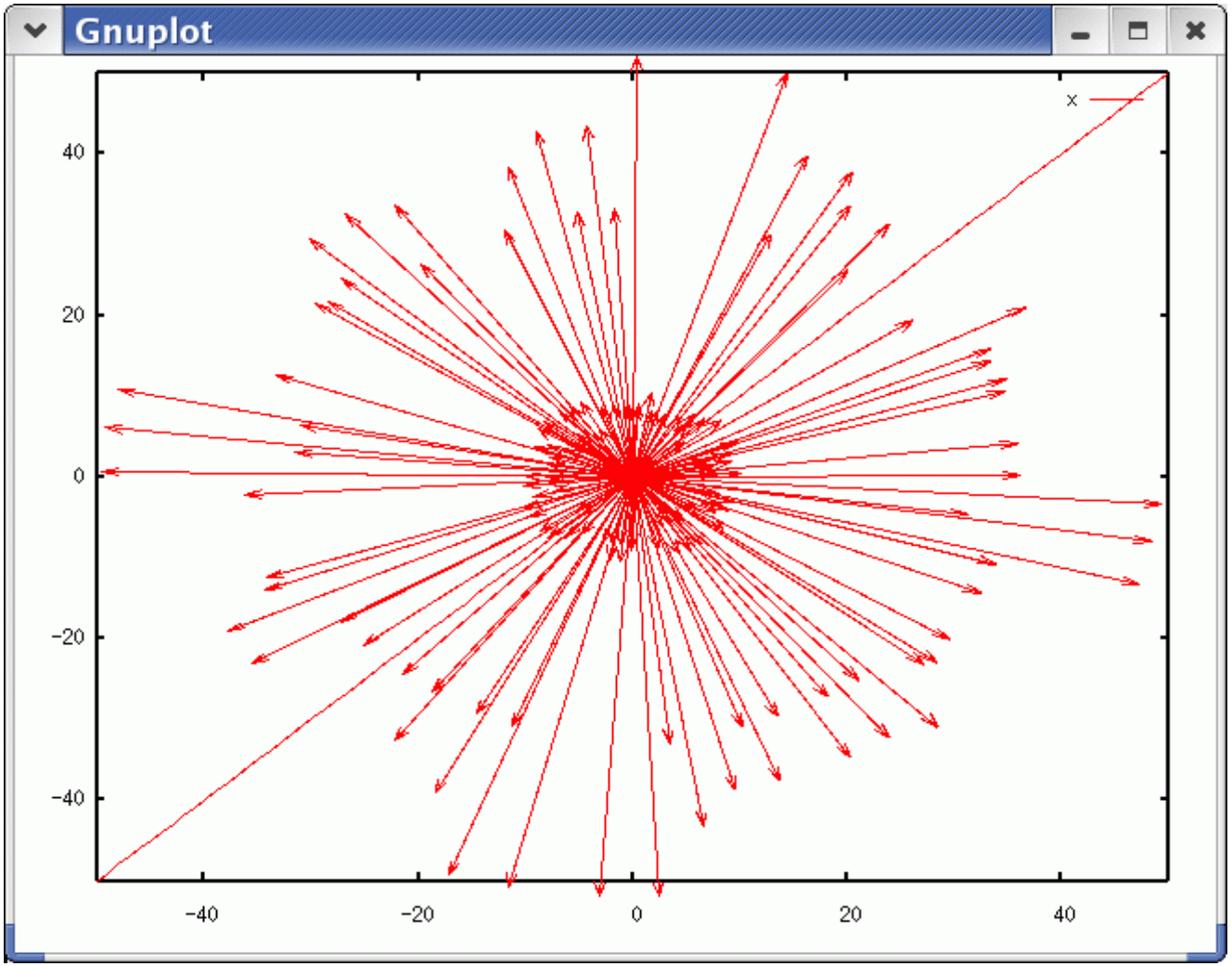
    one family of SF, one family of SD

    6 power supplies for SF, 6 power supplies for SD

    Sextupole correctors in triplets

    some limited octupoles

- Individual sextupole contribution to third resonance coefficient



High harmonic phase advance in resonance strength makes the sextupole sorting difficult.

Plans

- Analytical work

1) Import nonlinear calculation tool

with J. Bengsson's help

2) Calculate the resonance strengths / driving terms

3) Sort out the effective ORTHOGNAL knobs

4) Other calculations

- Beam experiment

1) Identify limitation from 3Qx or 3Qy resonance.

2) Measure the resonance strengths/driving terms

3) Knobing, knobing, knobing, ...

sextupoles or octupoles

4) If **ONE** solution is found,

check its reliability
propagate to the whole ramp.
then **DONE**!

Who we are

Core team members:

F. Pilat, Y. Luo, V. Ptitsyn

Collaborators:

J. Bengsson, N. Malisky,.....