PROBING NON-LINEAR FIELDS WITH ORBIT BUMPS

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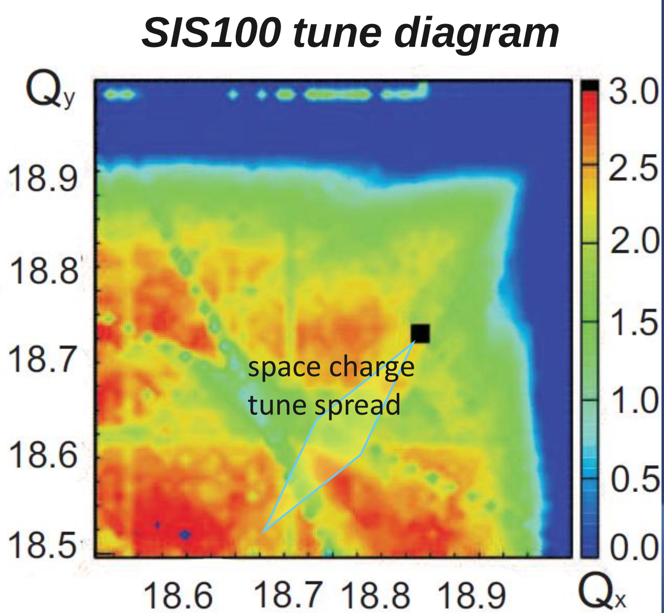
METHOD TO DIAGNOSE LATTICE NONLINEARITIES



G. Franchetti, EPAC 2008, Genova

KNOWLEDGE OF NONLINEAR ERRORS ALLOWS TO CONTROL AND COMPENSATE RESONANCE DRIVEN BEAM LOSS

NONLINEAR CHROMATICITY

G. Arduini et. al., PAC, Portland, USA, p. 2240 (2003)

RESONANCE DRIVING TERM

R. Bartolini et. al., ICAP, Chamonix, France, (2006)
R. Tomas et. al, Phys. Rev. ST 8, 024001 (2005)

ORBIT DEFORMATION via LOCAL BUMP

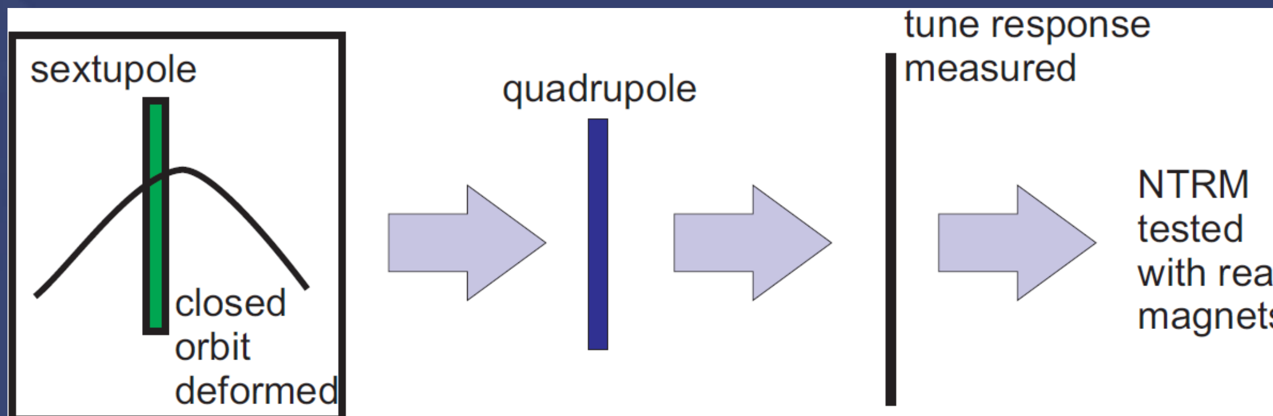
F. Pilat et al., PAC, Knoxville, USA, p. 601 (2005)

GLOBAL ORBIT DEFORMATION

NONLINEAR TUNE RESPONSE MATRIX (NTRM) METHOD

NONLINEAR TUNE RESPONSE MATRIX (NTRM) METHOD

EXPLORES THE FEED DOWN EFFECT OF THE NONLINEAR COMPONENTS AT LEVEL OF LINEAR TUNE ON THE CLOSED ORBIT



CONTRIBUTION TO THE MACHINE TUNES WITH RESPECT TO THE DEFORMED CLOSED ORBIT

$$\Delta Q_{x,y} = \frac{1}{4\pi}\int_0^C \beta_{x,y}(s)\tilde{k}(s)ds$$

$$\tilde{k}_1 = K_1 \qquad \tilde{k}_2 = K_2 x_{CO} - J_2 y_{CO}$$

$$\tilde{k}_3 = K_3(x_{CO}^2 - y_{CO}^2)/2 - J_3 x_{CO} y_{CO}$$

$\tilde{k}$ **AND** $\tilde{j}$ **ARE THE FEED DOWN COMPONENTS DUE TO THE DEFORMED CO**

Ref. G. Franchetti , A. Parfenova, I. Hofmann, PRSTAB 11, 094001 (2008)

EXPERIMENTAL BENCHMARKING WITH SET PROBING ERRORS

1ST ORDER CONTRIBUTION

$$\begin{cases} {}_xQ_t^x = \dfrac{1}{4\pi}\displaystyle\sum_{l=1}^{N_l}\beta_{xl}K_{2l}M_{lt}^x \\ \Delta Q_x = \displaystyle\sum_{t=1}^{N_t} {}_xQ_t^x\theta_{xt} \end{cases}$$

Ref. A. Parfenova et al., NIM A 646 (2011)

2ND ORDER CONTRIBUTION

$$\begin{cases} {}_xQ_{tt}^{xx} = \dfrac{1}{2}\cdot\dfrac{1}{4\pi}\displaystyle\sum_{l=1}^{N_l}\beta_{xl}K_{3l}(M_{lt}^x)^2 + \\ +O(2) \\ \Delta Q_x = \displaystyle\sum_{t=1}^{N_t} {}_xQ_{tt}^{xx}(\theta_{xt})^2 \end{cases}$$

1. SET PROBING **N** NONLINEAR ERRORS
2. USE **N** HORIZONTAL STEERERS

$$N_l = N_t = N$$

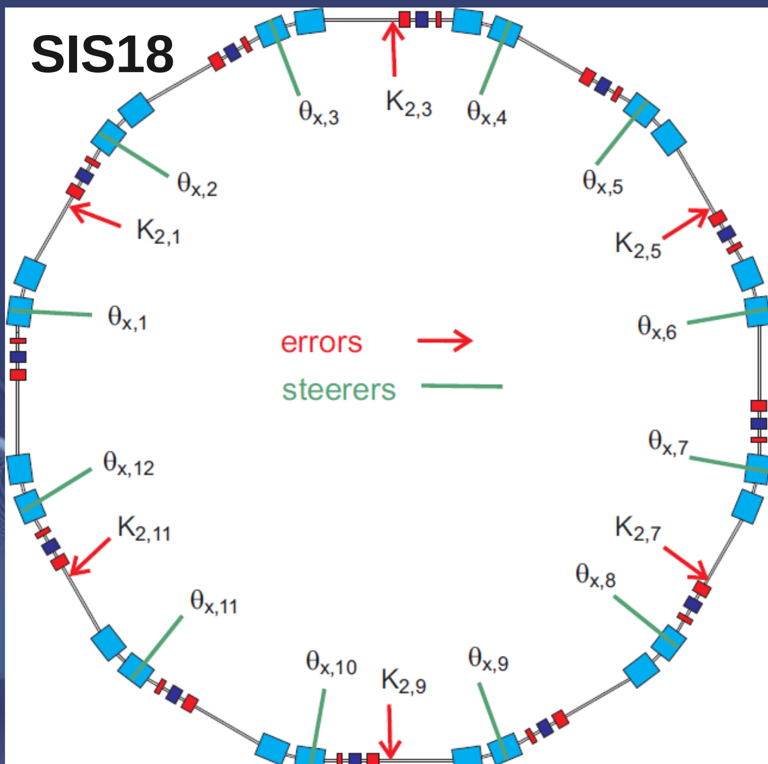
CHANGE THE CLOSED ORBIT AND MEASURE THE TUNE RESPONSE

?

RECONSTRUCT THE **N** NONLINEAR ERRORS

Ref. A. Parfenova et al., Contributed Invited IPAC Kyoto (2010)

PROOF OF PRINCIPLE WITH SEXTUPOLES



SETTING 6 SEXTUPOLAR ERRORS BY USING CHROMATIC SEXTUPOLE MAGNETS

CHOOSING ***ANY*** 6 OUT OF 12 HORIZONTAL STEERERS

RETRIEVING THE 6 SET PROBING ERRORS BY SOLVING:

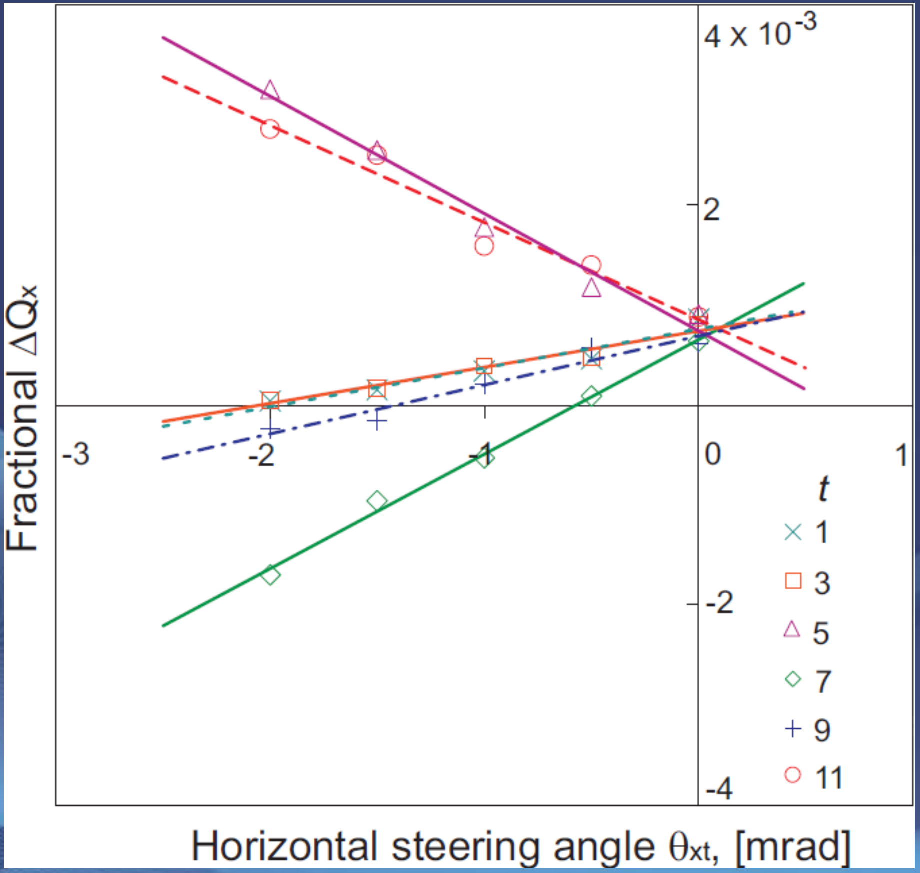
$$\begin{cases} {}_xQ_t^x = \dfrac{1}{4\pi}\displaystyle\sum_{l=1}^{6}\beta_{xl}K_{2l}M_{lt}^x \\ \Delta Q_x = \displaystyle\sum_{t=1}^{6} {}_xQ_t^x\theta_{xt} \end{cases}$$

NTRM-RECONSTRUCTION OF THE 6 CONTROLLED SEXTUPOLAR ERRORS

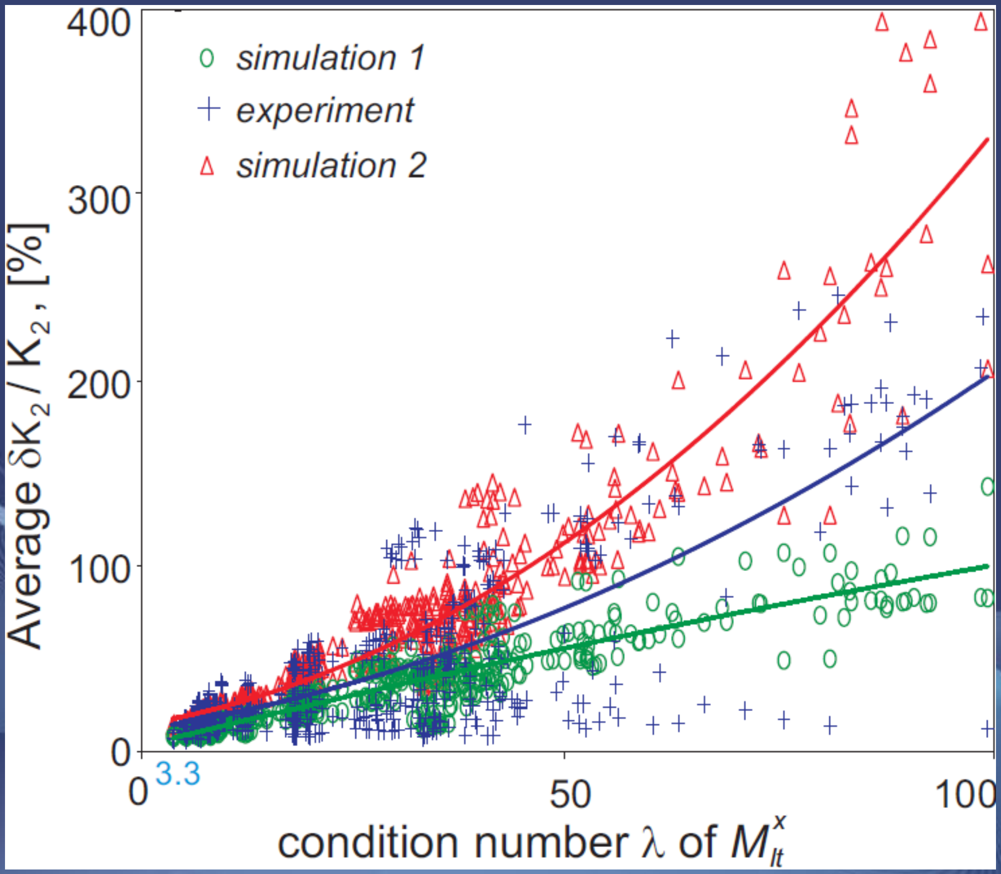
BEST ACHIEVED RECONSTRUCTION

ERR. #, *l*, *t*	SET ΔK_2 $X10^{-2}$ m^{-2}	EXP. ΔK_2 $X10^{-2}$ m^{-2}	REL. ERR. %
1	3	3.03	1
3	-4	-4.04	1
5	1	0.99	1
7	-1	-1.12	12
9	-2	-2.02	1
11	2	1.26	37

DIFFERENTIAL TUNE RESPONSE



NTRM APPLICABILITY: CONDITION № OF THE ORM



CHOOSING ***ANY*** 6 OUT OF 12 HORIZONTAL STEERERS

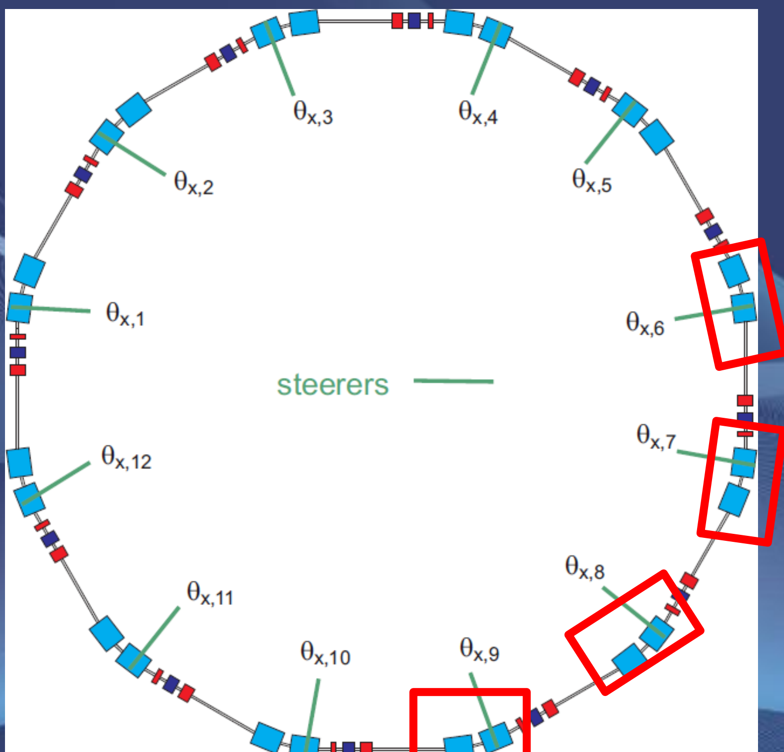
CHANGES THE ***ORM*** AND RESPECTIVELY ITS CONDITION NUMBER

$$\mathrm{cond}(M_{lt}^{x}) = \lambda$$

THE AVERAGE RELATIVE ERROR IN THE RECONSTRUCTED ERRORS GROWS WITH THE CONDITION NUMBER OF THE ORM

ERROR ALLOCATION MODEL

IN ORDER TO RECONSTRUCT LATTICE NONLINEAR MAGNET ERRORS ONE NEEDS TO HAVE A STEERER-ERROR CONFIGURATION WITH RATHER SMALL CONDITION NUMBER OF THE CORRESPONDING ORM



VIA CHOICE OF

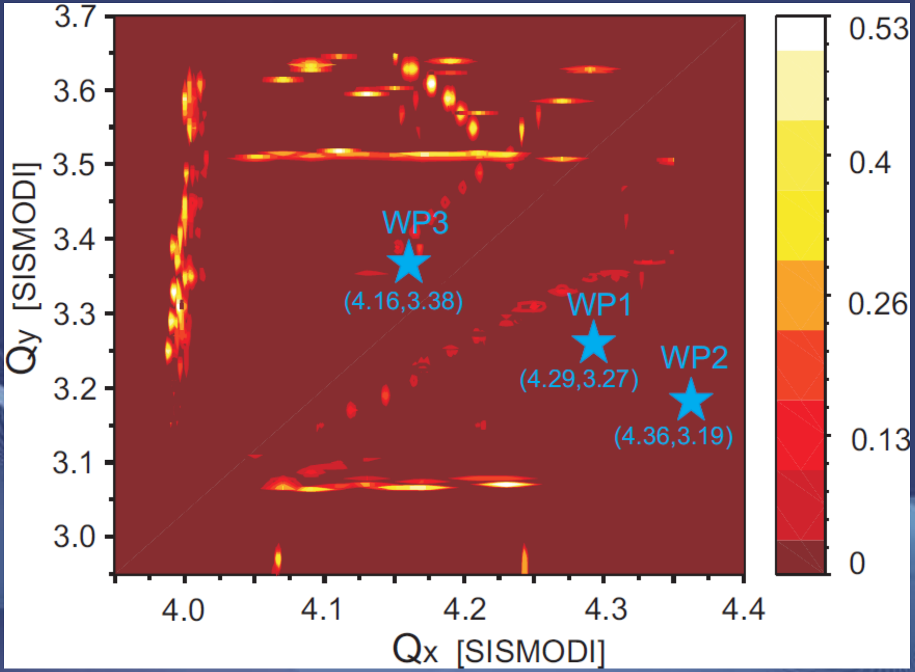
STEERERS OR SEXTUPOLE MAGNETS

12 INTEGRATED NORMAL SEXTUPOLAR COMPONENTS FOR THE TWO CONSECUTIVE DIPOLES

$\lambda \approx 8.5$

NORMAL SEXTUPOLAR COMPONENTS OF RING'S DIPOLES

3 DIFFERENT WORKING POINTS FOR STATISTICS

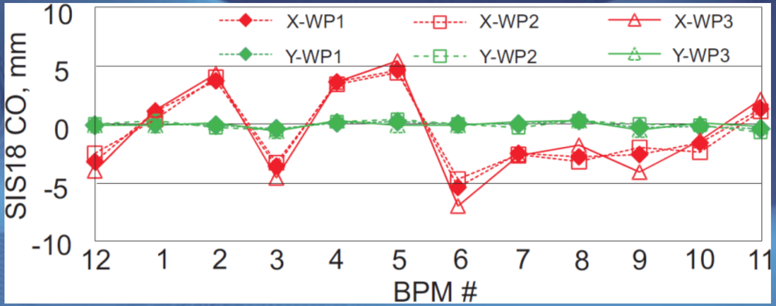


MEASURED SIS18 TUNE DIAGRAM (2010)

SOLVING 3 TIMES:

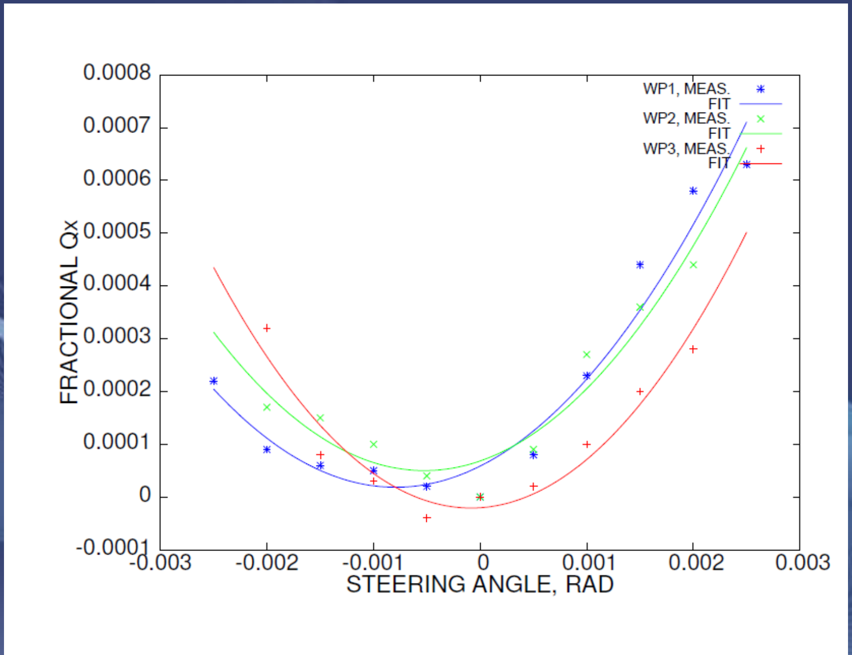
$$\begin{cases} {}_xQ_t^x = \dfrac{1}{4\pi}\displaystyle\sum_{l=1}^{12}\beta_{xl}K_{2l}M_{lt}^x \\ \Delta Q_x = \displaystyle\sum_{t=1}^{12}{}_xQ_t^x\theta_{xt} \end{cases}$$

BEST ACHIEVED CO CORRECTION

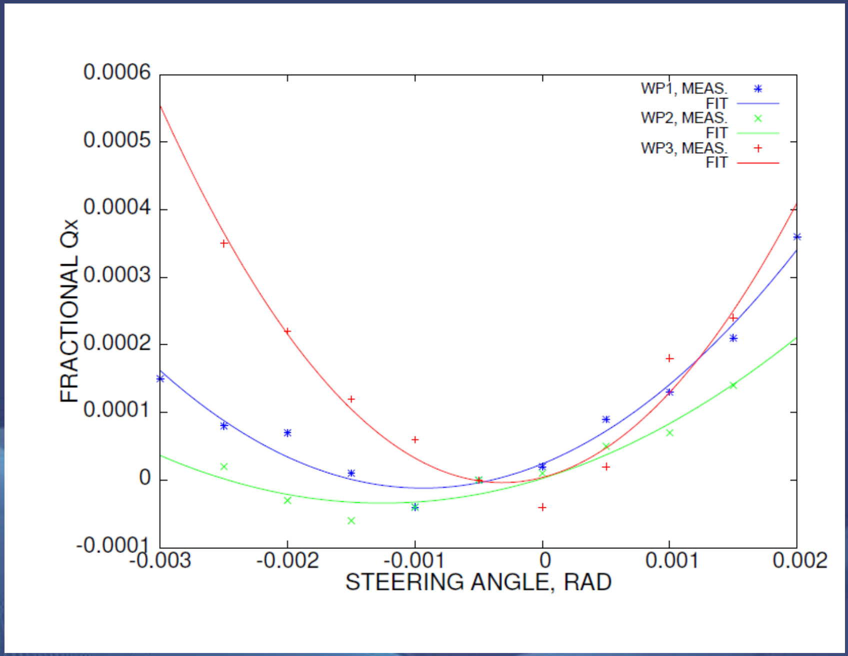


EXAMPLES OF MEASURED TUNE RESPONSE $Q\text{-}Q_{x0}$

X-STEERER *#/t = 2*



X-STEERER *#/t = 8*

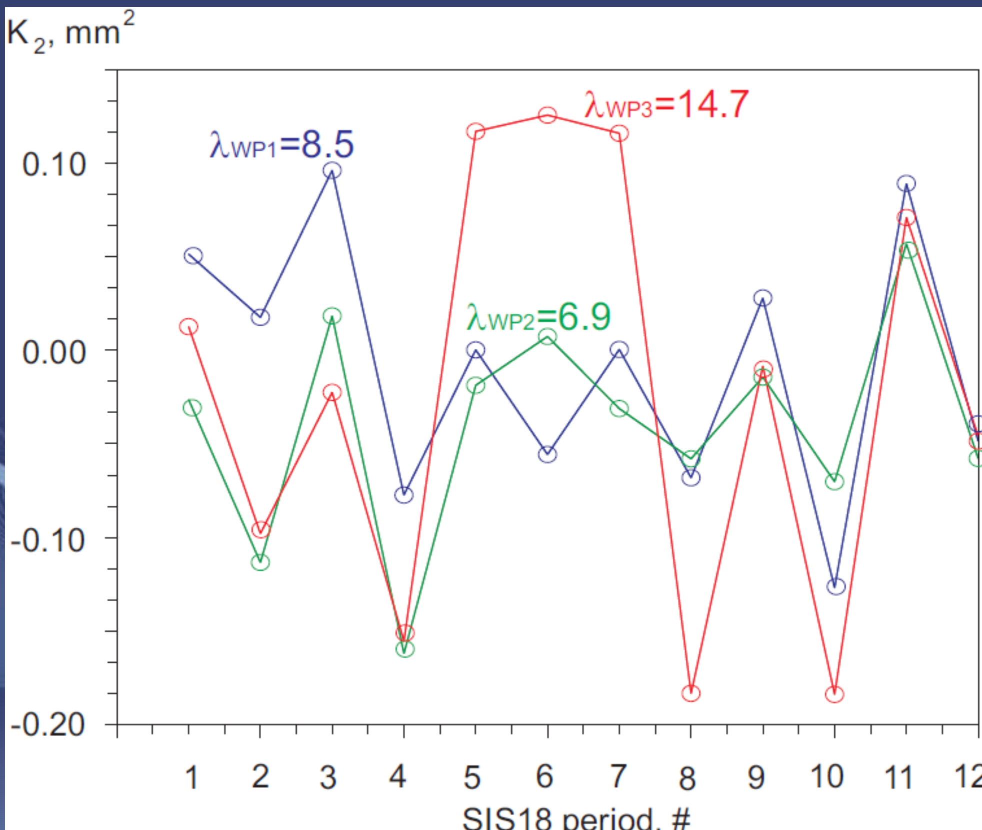


$$Q_x = a\theta^2 + \boxed{b\theta} + c$$

NORMAL SEXTUPOLAR TERM

$$b = {}_xQ_t^x$$

12 RECONSTRUCTED K_2 FOR THE 3 WORKING POINTS



$$\begin{cases} {}_xQ_t^x = \dfrac{1}{4\pi}\sum_{l=1}^{12}\beta_{xl}K_{2l}M_{lt}^x \\ \Delta Q_x = \sum_{t=1}^{12} {}_xQ_t^x\theta_{xt} \end{cases}$$

WP 3

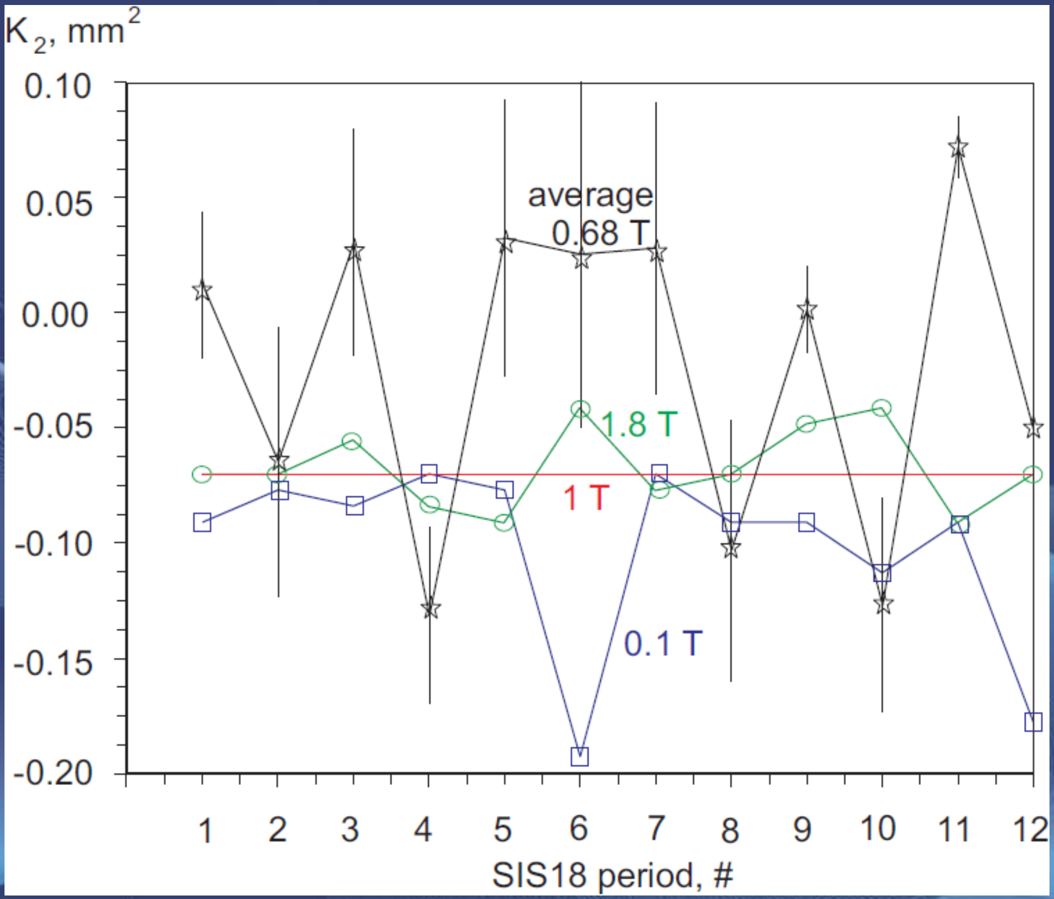
WP 2

WP 1

AVERAGING

12 AVERAGE RECONSTRUCTED K_2

MAGNET MEASUREMENTS (‘88)



DIPOLES SHIMMED AT 1 T

MEASURED AT 0.1 T

MEASURED AT 1.8 T

Ref. G. Moritz et al, Summary of magnet measurements on the SIS Magnet System, GSI Report 1988.

CONCLUSION

- ***AN ACCURATE NTRM- RECONSTRUCTION OF SEXTUPOLAR ERRORS CAN BE ACHIEVED FOR 'STEERER-ERROR' CONFIGURATIONS WITH RATHER SMALL CONDITION NUMBERS***
- ***EXPERIMENTAL BENCHMARKING WITH SIX PROBING SEXTUPOLAR ERRORS CONFIRMED THE NUMERICAL PREDICTIONS***
- ***DIPOLE'S SEXTUPOLAR ERRORS OF THE MACHINE HAVE BEEN RECONSTRUCTED AND WILL BE USED FOR THE IMPROVEMENT OF THE MACHINE***
- ***A FURTHER BENCHMARKING IS NEEDED, SINCE ERROR-RECONSTRUCTION DEPENDS ON OTHER PARAMETERS SUCH AS MAGNET CURRENT, COD, WP, BEAM QUALITY, ALLOCATION MODEL ETC.***

THANK YOU FOR YOUR ATTENTION