Review of Non-Linear Beam Dynamics Workshop at Oxford

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Low-Emittance Ring Workshop 2010

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Goal of Workshop

Review developments of nonlinear beam dynamics

Issues with the correct modelling of ring lattices and progress with theory

Strategies for the optimization of the nonlinear beam dynamics

Strategies for the construction of a reliable model for the nonlinear behaviour of the ring

Sessions

Theory and Codes

Design and optimisation

Experiments

Technology

Low alpha lattices

A report of this workshop was already given by Bartolini at the XVII European Synchrotron Light Source Workshop 2009.

A summary was written with contributions from session chairs. This was done prompty while subjects and discussions were fresh in people's minds.

Classification of Talks (Bartolini)

Nonlinear beam dynamics for

- synchrotron light sources (20 talks)
- colliders (3 talks)
- damping rings (1 talk)
- intense ion beams with space charge (2 talks)

Theory (4 talks)

Technology -> BPMs (2 talks)

Celestial mechanics (1 talk)

All talks and summary found in

http://www.diamond.ac.uk/Home/Events/Past_events/NBD_workshop.html

Theory and Codes (Borland summarized)

J. Laskar's talk on stability of solar system orbits and particle accelerators.

FMA folding discussion. Folds may not be relevant in accelerators since that area of map disappears in presence of errors.

Problem of extracting frequency in large rings with decoherence. Use multiple bpms in frequency fit.

Movie of solar system orbit changes over Gyears was fascinating.

Theory and Codes

D. Einfeld presented on-going comparison of codes that started in May 2008, and relaunched at PAC2009

Codes are MAD, DIMAD, BETA, OPA, AT, TRACY, ELEGANT, and ACCELERATICUM, and are run by individuals

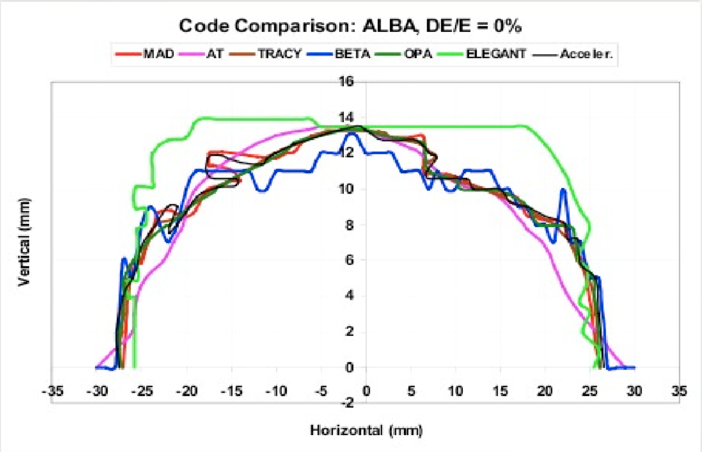
Reference lattices are SOLEIL, ALBA and APS (all no errors).

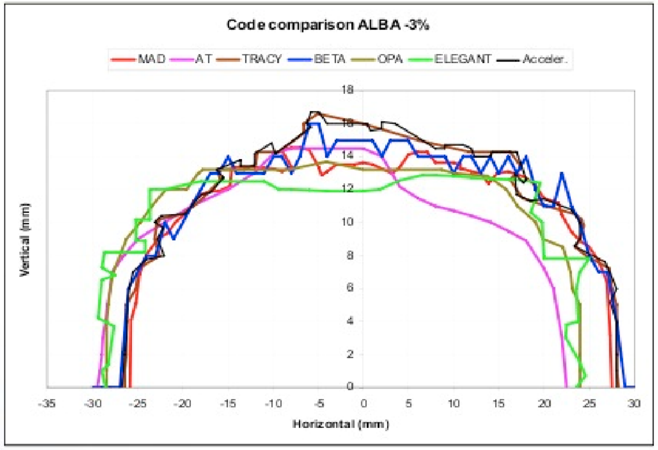
Compares simple things first: e.i. natural chromaticity, where some disagreement occurred

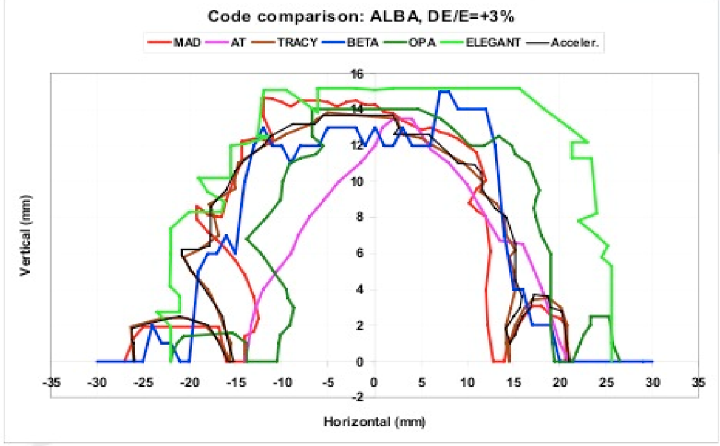
Then compared tune shift with energy and amplitude, and finally dynamic aperture and momentum aperture.

Example comparison of DA (Einfeld)

DA: ALBA







DE/E =0:Good agreement between the codes:
MAD, TRACY, OPA and Acceler.
No good agreement for the codes:
ELEGANT, BETA and AT

DE/E=-3%:Good agreement between the codes:
MAD, TRACY, BETA and Acceler.
No good agreement for the codes:
ELEGANT, AT and OPA

DE/E=+3%:Good agreement between the codes:
TRACY and Acceler.
No good agreement for the codes:
ELEGANT, AT, BETA ,MAD, and OPA

D. Einfeld/CELLS 2nd NLBD Workshop, Diamond

Theory and Codes

Agreement is good for 0% momentum error, but not so good for 3%. Some attendees commented that in actual use several of the codes agreed very well.

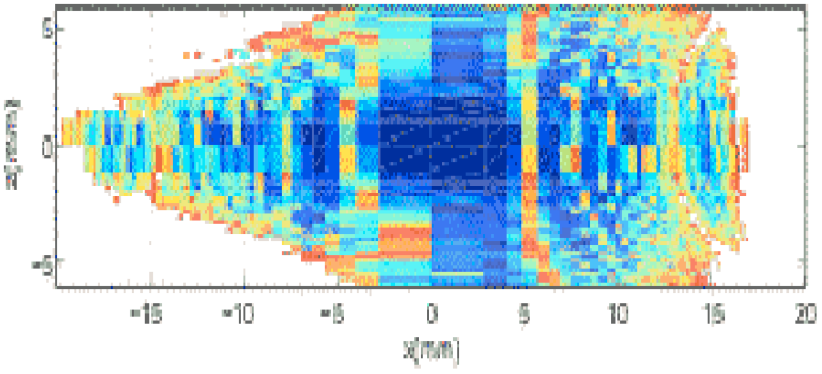
Source of disagreements will have to be determined by detailed work, say compare codes on single elements at a time. This highlights the need to document the physics (assumptions, approximations, limits)

Theory and Codes

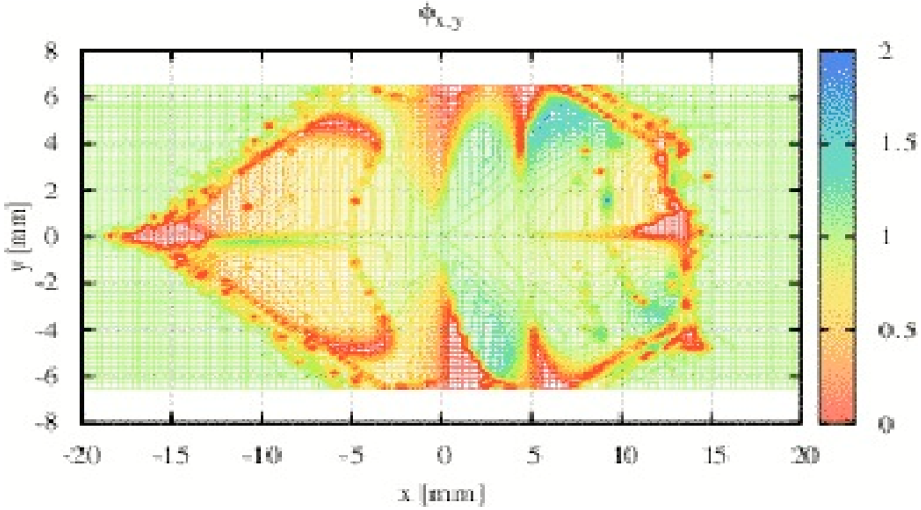
Analytical approaches to DA estimation:

J. Bengston calculated trajectories using perturbation theory with a renormalization of resonance denominators. Gave an instability criterion, which agreed with 4D tracking of NSLS-II

Tracking



Analytical evaluation of x-y stability border



Theory and Codes

L. Yu presented linear algebraic approach to map analysis. Found an expression for amplitude tune shift with amplitude that agreed with known expressions. Applied in 1D.

F. Schmidt gave history of DA analytical estimates (mostly for proton machines), and why we should continue to do 6D tracking. Discussed tracking methods for the LHC, which included bit-by-bit accuracy and running simulations using a combination of local batch system and a world-wide batch system with volunteers' PCs.

Design and Optimization (Nadolsky summarized)

10 presentations

Basic task is: large enough on-momentum aperture for injection, and large enough momentum aperture for lifetime.

Two approaches to optimization: semi-analytic, and brute force tracking.

Note that there is a trend to optimize both DA and MA at the same time (due to importance of lifetime), rather than DA first, then MA as an second stage. Optimizing the DA first may make the sextupole layout inflexible for MA optimization.

Design and Optimization

"Manual" methods:

Reduce first-order sextupole driving terms

NSLS added a new sextupole knob (by breaking the symmetry of sextupole locations) to reduce the 2^{nd} order chromaticity

Spring-8: Analyze resonances for off-momentum trajectories for improvement of MA

CLIC pre-DR: scan over possible TME cell phase advances of the resonance terms to select linear parameters (see next talk!)

Guidance from tune footprints in general

Design and Optimization

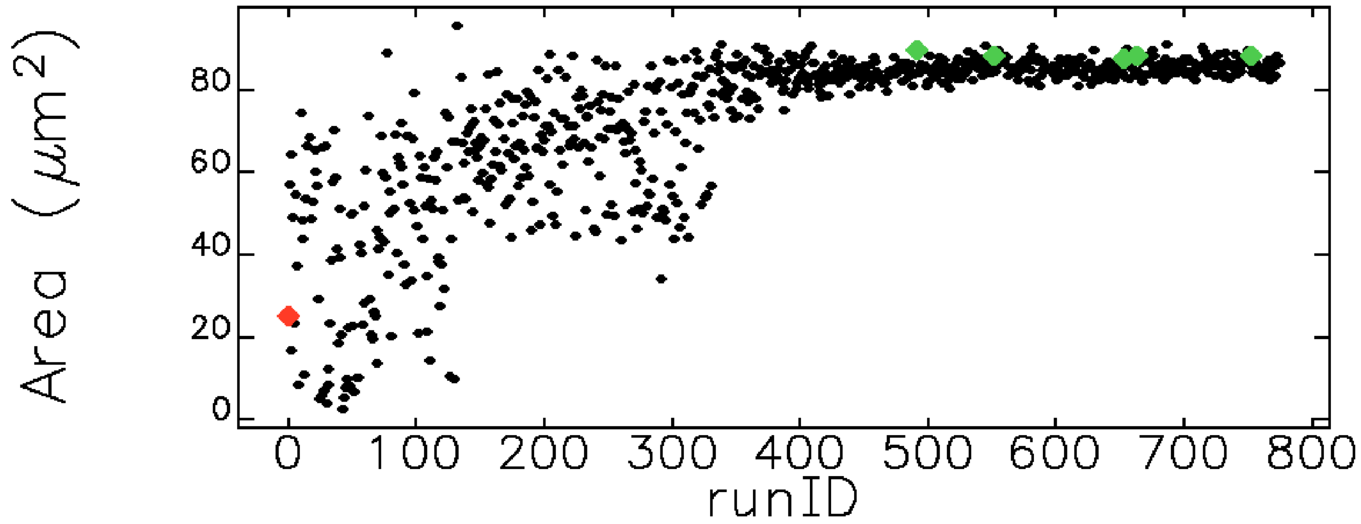
Brute force methods:

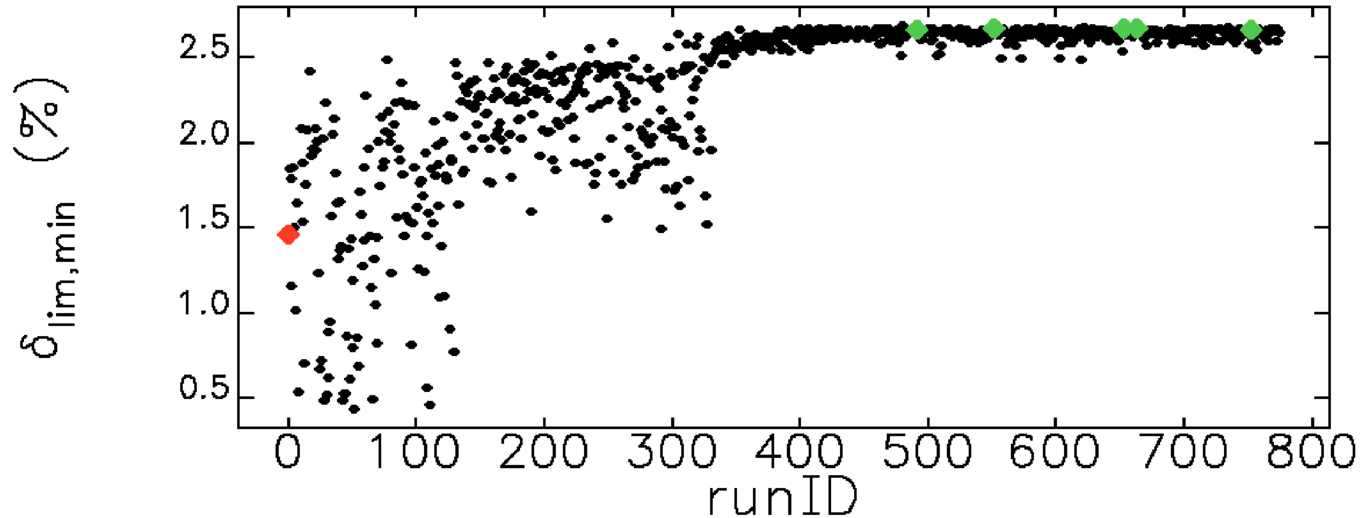
One example: Search linear optics solution exhaustively (ALS)

For larger parameter sets, use genetic algorithm to search for desired solutions

At APS, sextupole strengths and tune space are searched for optimum DA and MA. Need massive parallel computations. Results of >20% improvement of lifetime were found in APS and DLS. Found an improved NSLS-II design for various chromaticities. (More later)

Example of Optimization with NSLS-II lattice for $\xi_x = \xi_y = 2$





Experiments (Farvaque)

Experimental reports from Diamond, Soleil, VEPP-4M, CLS, SLS and GSI

Bartolini (DLS) described method for fitting sextupole strength from frequency lines in turn-by-turn data. (More this morning). Several other labs are attempting to use this method.

Soleil group showed fits of non-linear parameters: chromaticities, tune shifts with momentum and amplitude, experimental frequency maps. Agreement in general.

Aiba (PSI) related perturbation by IDs to excitation of resonance lines in TBT BPM data.

Experiments (Farvaque)

Streun of SLS showed the restoration of 3% MA with sextupole symmetrization. (Yesterday's talk)

Anderson showed MAX-IV design, and use of octupoles to reduce tune footprint.(Yesterday's talk)

Points raised this session:

Choice of working point to avoid effect of IDs.

Correcting linear effect before going to non-linear effects

Include all nonlinear model elements into model (higher-order multipoles, fringe fields, thick sextupoles)

Good processing of turn-by-turn bpm data where applicable

Use of octupoles for tune shift correction

Techonology (Kuske)

(Long) discussion of use of TBT data from Libera bpms which have a time filter applied to the stream of sampled data, which mixes the data between turns. This can be indone by an inverse numerical filter. In addition asynchronous (?) timing window affects amplitude and phase measurements.

Soleil's attempt to improve the measurement of tune with TBT bpm data of beams that decohere in ~50 turns. Adding more bpms can give a accuracy of $10^{-4.}$

Table of impact of experimental issues on measurement of frequency, amplitude, and phase.

Low-Alpha Lattices (Streun)

Anka:

DBA with negative dispersion in straight section.

Agreement of bunch profile with prediction of CSR wake field.

Diamond:

Two lattices: one with eta < 0 in SS, which was difficult to run, and one with eta > 0 in SS, which had lower emittance and was easier to inject into.

Soleil:

Similar optics to second one of Diamond, three beams of different energies were found to circulate due to three stable buckets.

In conclusion, 1st , 2nd , and 3rd-order alpha_c need to be considered.

Other DIscussions (Bartolini summarized)

Pursue a campaign of measurements, which might be linked to the effort of code comparison. We would need to agree on the measurement procedures and equipment used. A list of measurement was given:

- Energy (spin depolarisation)
- Momentum compaction
- Dispersion
- Natural chromaticity
- Nonlinear dispersion
- Detuning with momentum
- Detuning with amplitude
- Apertures (on/off momentum and engineering apertures)
- Lifetime
- Frequency Maps (x –z and x –dp/p)
- Resonance driving terms
- Chromatic phase advance
- Effect of IDs

Set up a website with lattices, experimental data and procedures.

Conclusions

A grand challenge is to provide a nonlinear model of a ring and operate according to the design. We already achieved this with the linear model of rings with LOCO.

We need to understand the disagreement in chromaticity measurement. Note that in large rings, the natural chromaticity is large, so an error of one unit may be within experiment error.

GA for optimization is becoming popular, though analytical treatment is still an active area.

Understand hardware limitation of some TBT BPMs systems.