SOLEIL SYNCHROTRON experience

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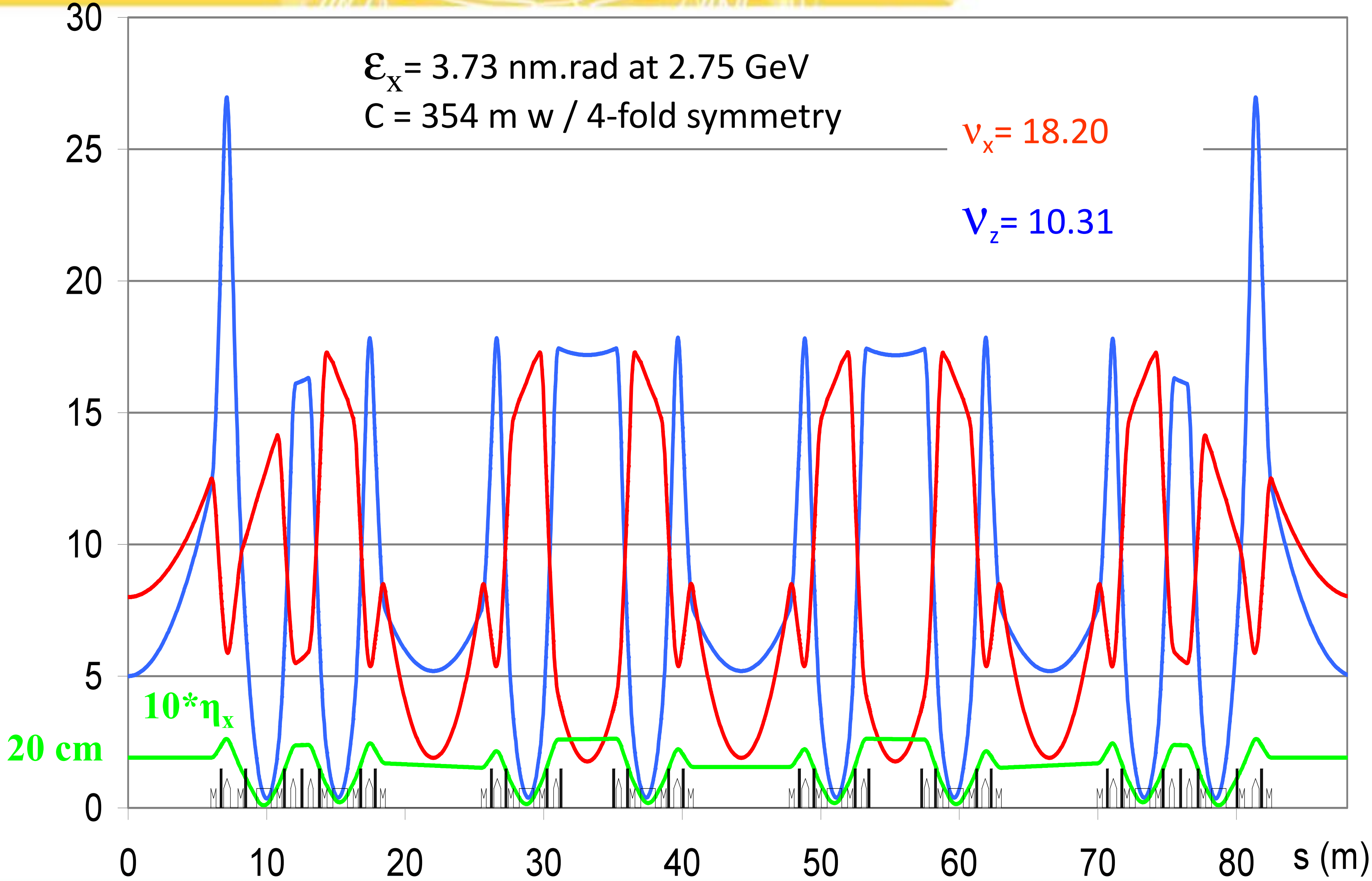
On behalf of the Sources and Accelerator Division

Outline

- ★ SOLEIL key parameters
- ★ Linear optics achievements
- ★ Closed orbit
- ★ Energy measurement
- ★ Exploring non-linear beam dynamics
  - ★ Off axis local orbit bumps
  - ★ Turn by turn data (FMA)
- ★ Conclusion

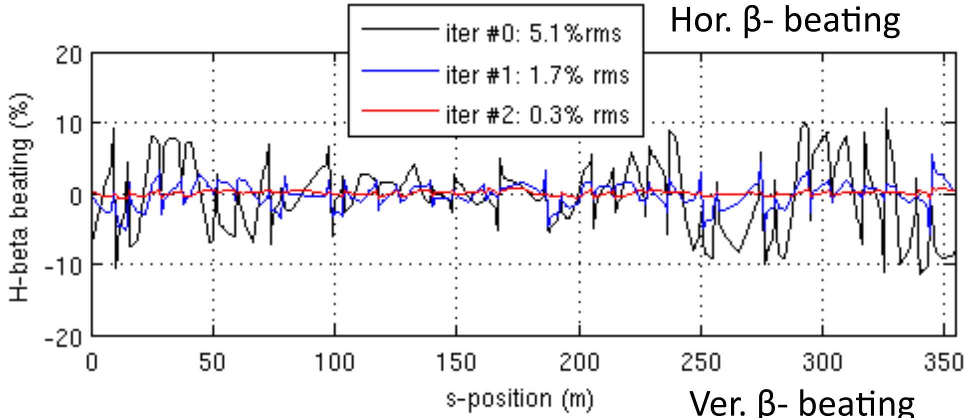
Storage Ring Optical functions

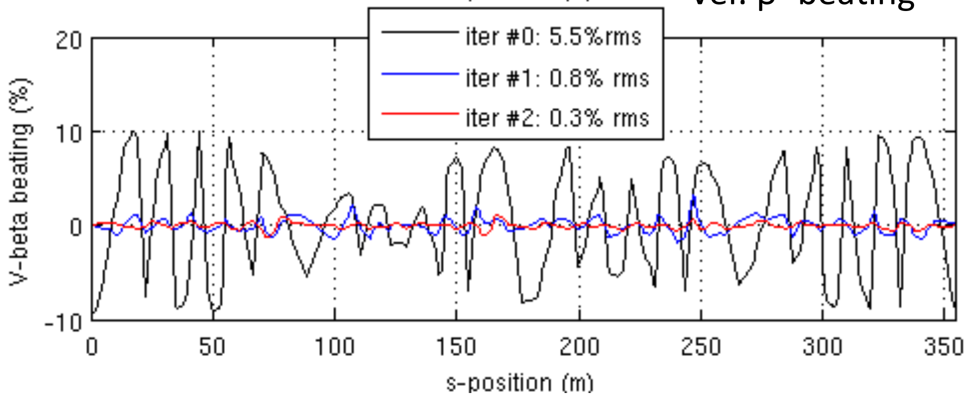


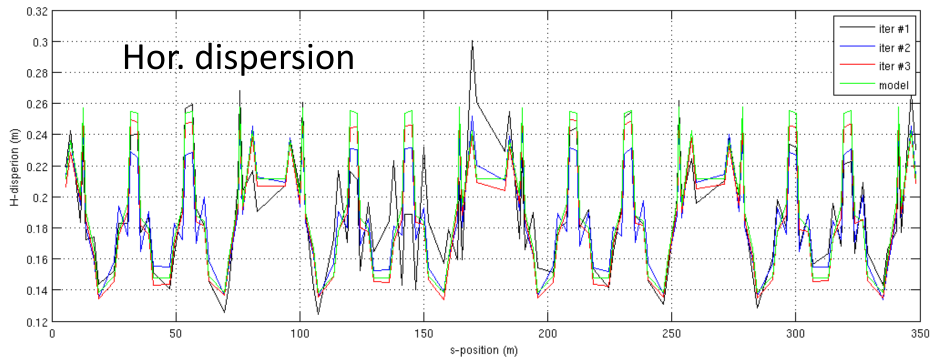
SOLEIL parameters

Parameters	Design	Achieved as of Dec 2010
Energy (GeV)	2.75	2.74
RF frequency (MHz), harmonic number h	352.197 416	
Betatron Tunes	18.20 / 10.30	18.202/10.310
Natural Chromaticities	-53 / -23	-51/-21
Momentum Compaction α_1 / α_2	4.5×10^{-4} / 4.6×10^{-3}	4.5×10^{-4} / 4.6×10^{-3}
Emittance H (nm.rad)	3.73	3.73
Energy spread	1.016×10^{-3}	1.016×10^{-3}
Coupling, $\varepsilon_V/\varepsilon_H$	<1%	0.3% (without correction)
Current Multibunch mode (mA)	500	500 (400 for Users operation)
Average Pressure (mbar)	1×10^{-9}	1×10^{-9} @ 500 mA
Beam Lifetime (h)	16 h	20h @ 400 mA / 14h @ 500 mA
Single bunch current (mA)	12	20
Beam position stability, mm (H)	20 (rms)	3 peak to peak (top-up)
Beam position stability, mm (V)	0.8(rms)	1 peak to peak (top-up)

Linear optics modelling with LOCO: SOLEIL case
Linear Optics from Closed Orbit response matrix
J. Safranek et al.







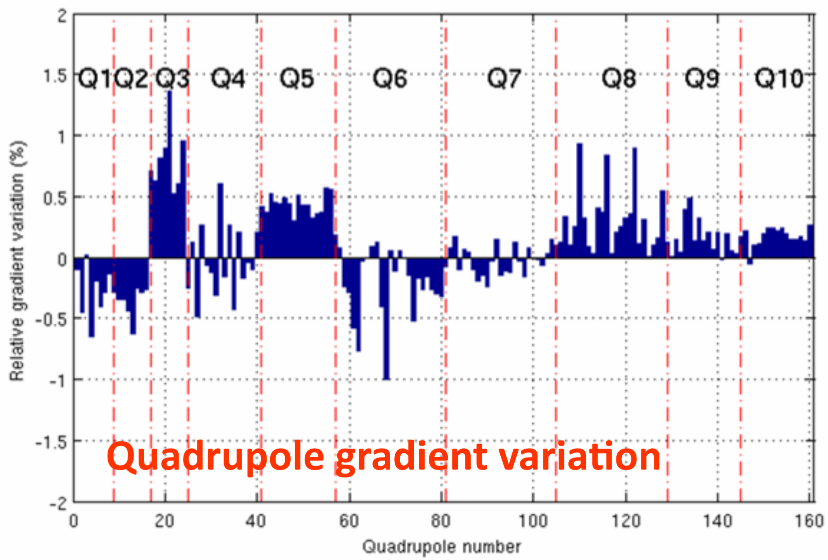
Modified version of LOCO with constraints on gradient variations

Due to lattice compactness

(see ICFA News letter, Dec'07)

β- beating reduced to 0.3% rms

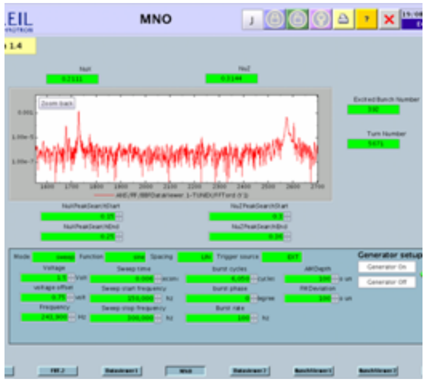
Results compatible with mag. meas. and internal DCCT calibration of individual power supply



Linear Orbit Restoration

- **Beta-beating, tune shift**
  - Compensation
    - Precise but takes machine dedicated time: 30 min
    - Static (e.g. LOCO) or Dynamics (e.g. feedforward systems)
  - Local or global compensation for perturbations induced by IDs
    - IDs are freely controlled by users, many different combinations:
      - → the storage ring is alive!
    - Need of a global tune feedback. **Excitation through FBT on a single bunch**
  - Impedance induced tune-shift with current intensity (coherent and incoherent)
    - How to correct for it (locally, globally?)

→ **Necessary steps for going to low coupling value and fine resonance correction**

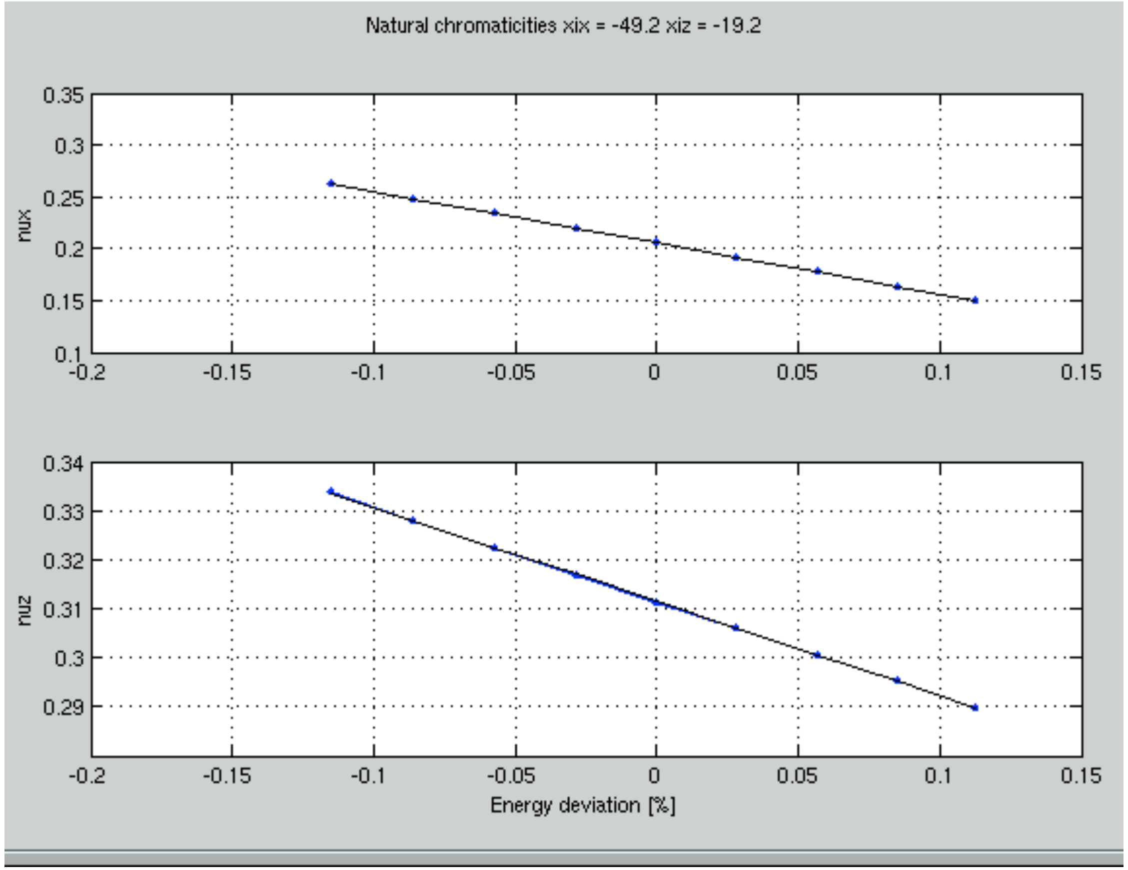


- **Is it possible to get online measurements during user operation?**
  - Tracking beta beating for all ID configurations (21 IDs in 2011)?
  - How to get LOCO precision with turn by turn data?
    - Use of residual orbit distortion during top-up injection
  - How to get enough turns while a TFB is running?

Natural chromaticities

Two main methods

1. **Varying bending magnet field: feasible**
2. **Switching off sextupole magnets: unfeasible for large ring**



	ξ_x^{nat}	ξ_z^{nat}
Model	-51	-21
Measurement	-49	-19

Measurement of dipole field performed using NMR probe.

Natural chromaticities: How much do we trust tracking codes?

★ Interesting experiment performed at LNLS (Brazil, Campinas)

Parameters	Values
Energy (GeV)	1.371
Circumference (m)	93
Horizontal emittance (nm.rad)	93

	Type of data	Horizontal chromaticity	Vertical chromaticity
Models	AT: version LNLS	-9.5	-13.2
	AT: Version SOLEIL	-9.5	-16.1
	MADX/PTC (MAD8)	-9.4	-15.6
	BETA (SOLEIL)	-9.4	-15.1
Measurement	Measurement: sextupole magnets off	-7.9	-12.0
	Measurement: Dipole variation	-8.5	-10.5

-0.6

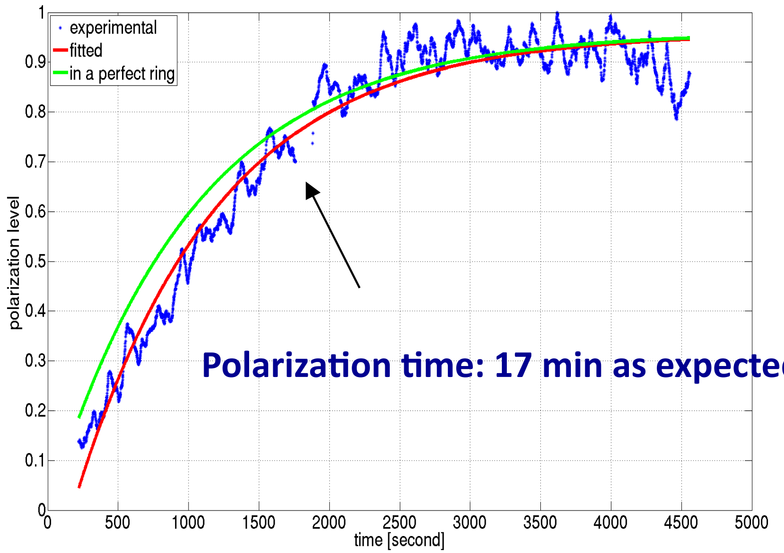
+2

★ 2 methods are fully not equivalent

★ Do tracking codes systematically overestimate chromaticity?

Measuring the electron beam energy by spin depolarization: difficulties

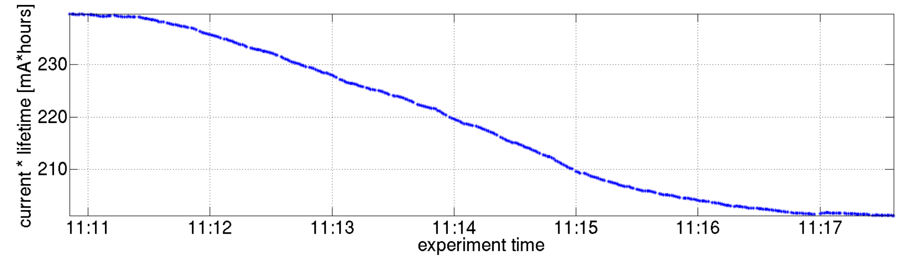
Polarization build up nicely observed using Touschek lifetime as a polarimeter

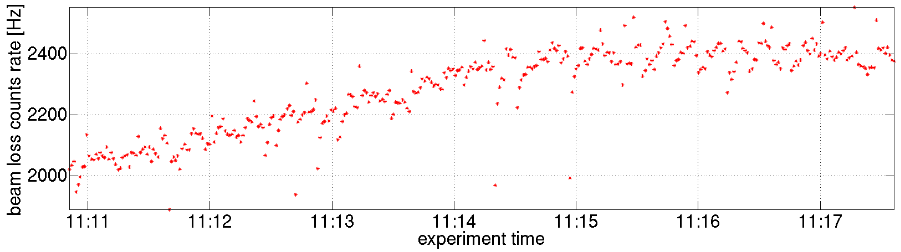


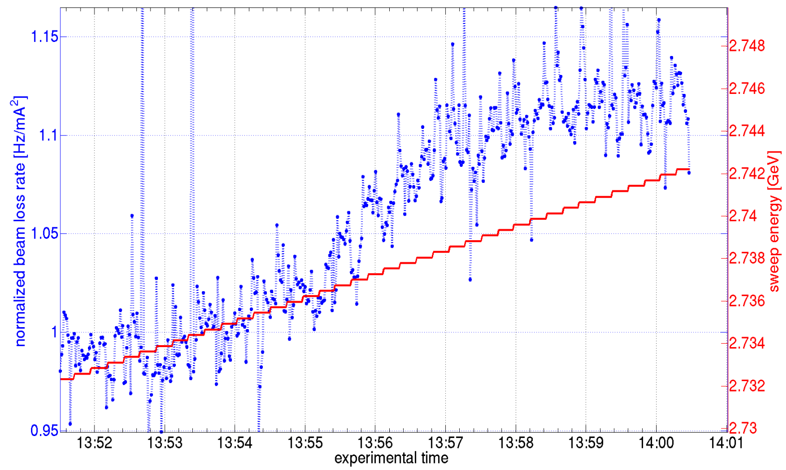
E ≈ 2.7385 GeV but at 0.1% (very wide dep. frequency range)

Beam energy measurement by spin depolarization is not an easy task: success in ALS, ANKA, BESSY II, SLS, … not for the last built light sources!

Beam depolarization

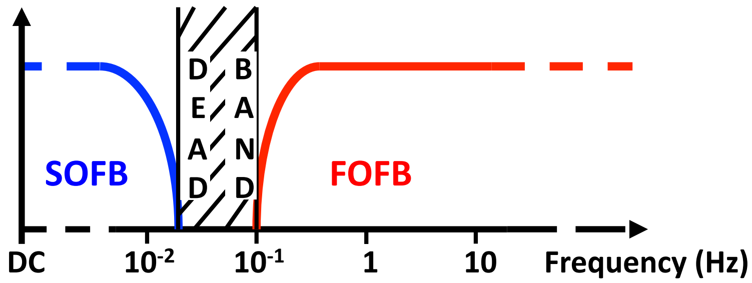






Orbit feedback systems Correction Down to DC

- **How to make slow and fast orbit feedback systems work together?**



Dead band approach **not suitable**

- FOFB efficiency is suppressed at low frequencies (< 0.1 Hz)
- **ID motion frequency band**

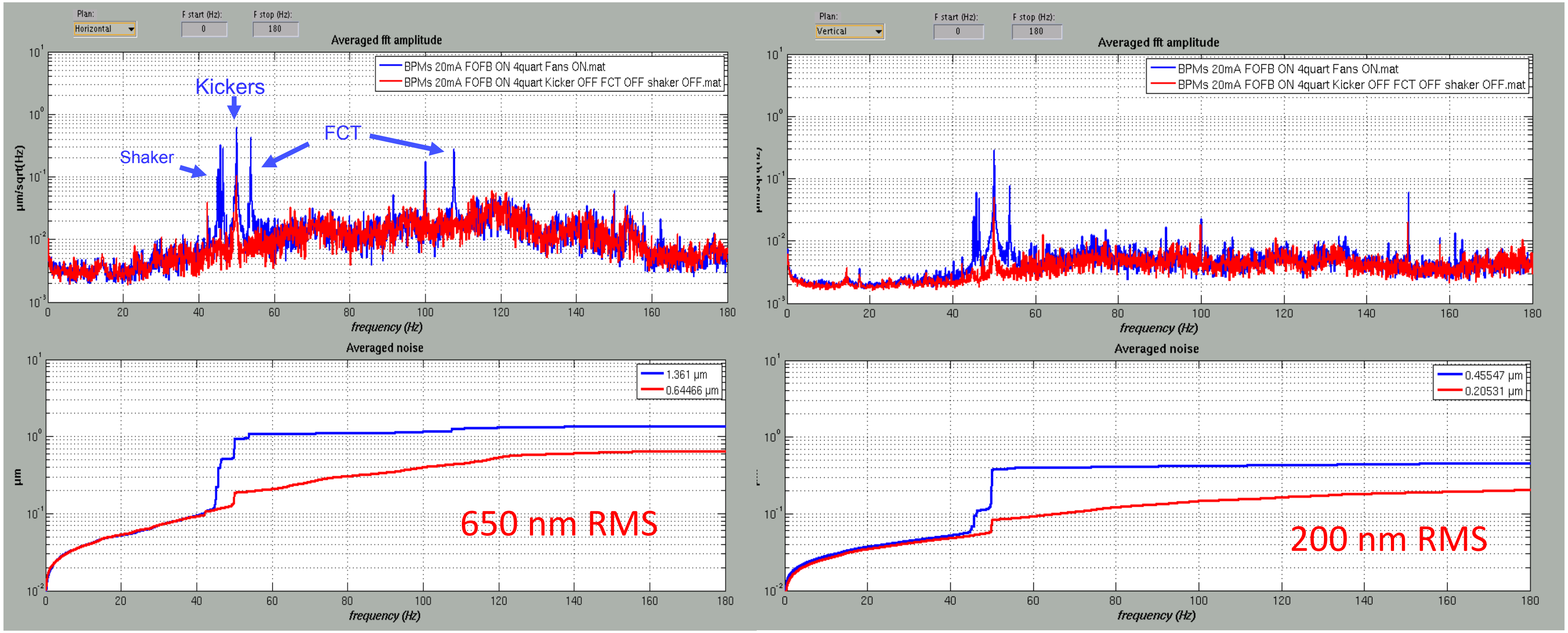
- **Slow and fast orbit feedback systems are not compatible if they have a common frequency domain:**
  - Both systems fight each other (120 BPMs, 56 slow, 32 fast in both planes)
  - The weakest correctors from FOFB saturate after a few iterations of the slow system
- **Since April 2009, both feedback systems work in harmony**
  - FOFB (10 kHz, 360 µs latency time) around residual closed orbit of SOFB
  - SOFB make to zero the average current of fast dipolar correctors
- **Stability reached**: 650 nm RMS in H-plane **200 nm RMS in V-plane**

Beam position stability

Origin of some noise around 50 Hz identified:
Air fans which cool the ceramic vessels at different places of the ring
Noise level extremely now in vertical plane to 200 nm (0-500 Hz)

Horizontal noise integrated from BPM

Vertical noise spectrum from BPM



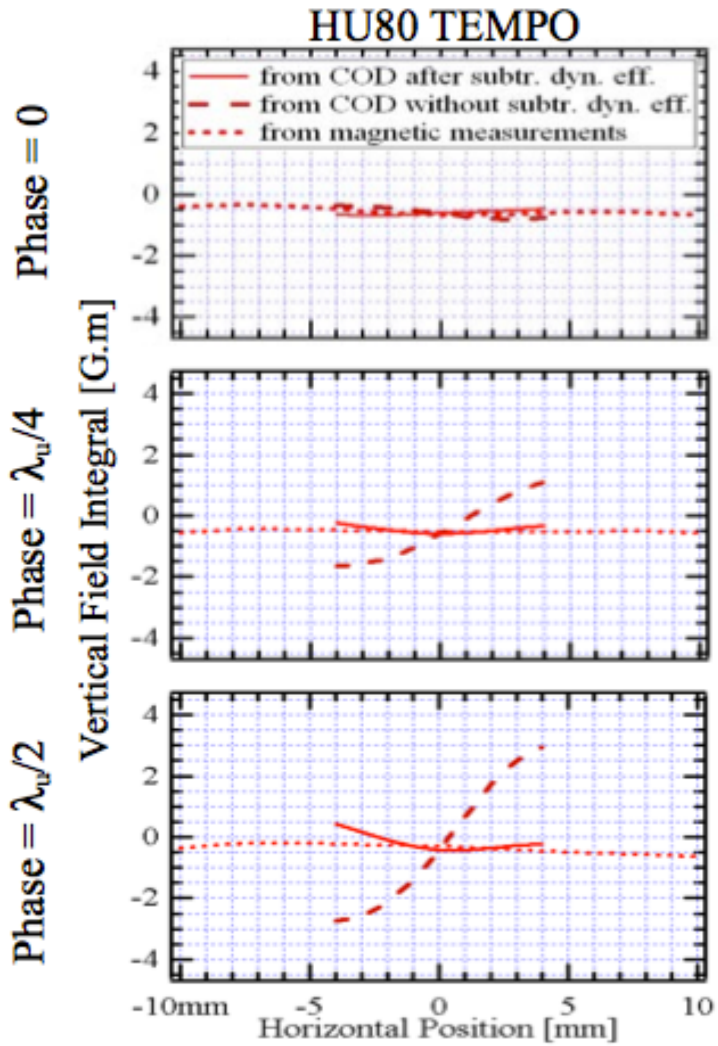
Off axis integrals
Probing non linear dynamics of IDs

- ★ Orbit distortion

$$\begin{cases} \Delta\mathbf{X}(x,y) = \mathbf{R}_x \Delta\boldsymbol{\Theta}_x(x,y) + \mathbf{R}_{xd} \Delta\theta_{xd}(x,y) \\ \Delta\mathbf{Y}(x,y) = \mathbf{R}_y \Delta\boldsymbol{\Theta}_y(x,y) + \mathbf{R}_{yd} \Delta\theta_{yd}(x,y) \end{cases}$$

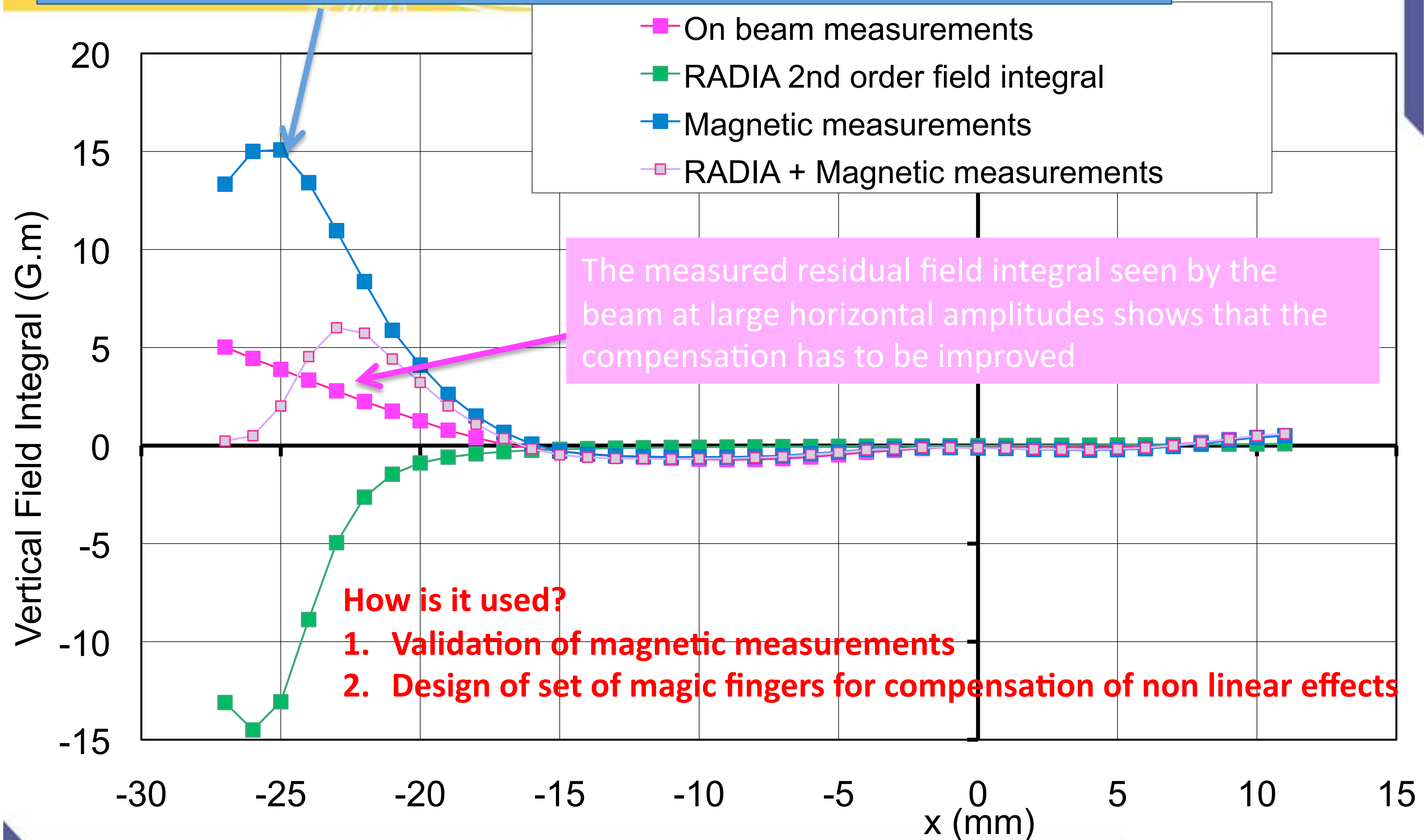
  - ★ First order effect induced by ID imperfections
  - ★ Second order due to oscillating trajectory of the electrons (computed by RADIA code)

- ★ Good agreement with magnetic measurement if dynamic effects are deduced



In-vacuum 2T wiggler

Magnetic correction was done to compensate for the 2nd order field integral

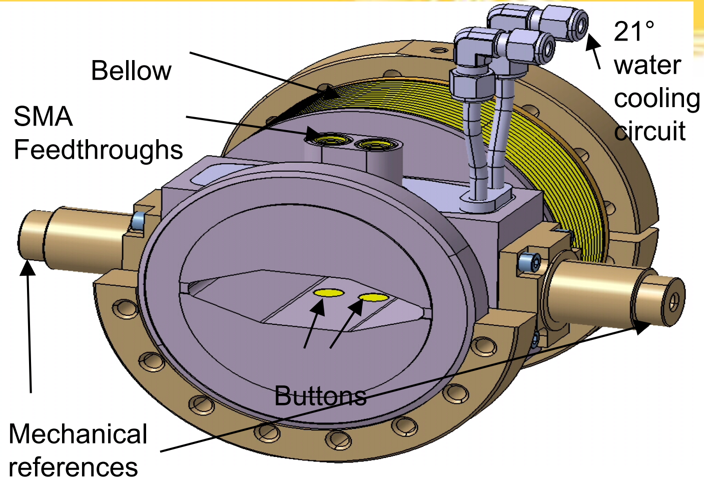


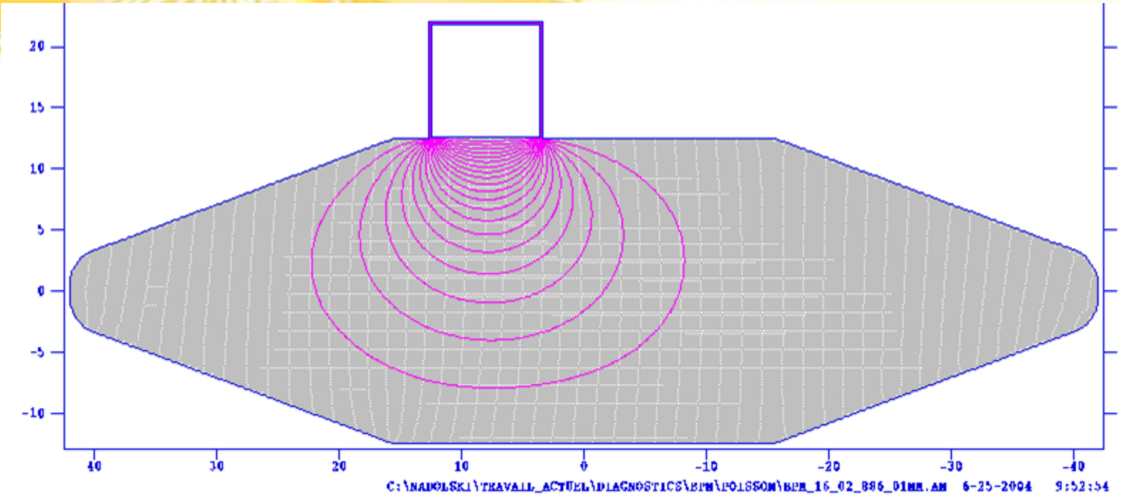
The measured residual field integral seen by the beam at large horizontal amplitudes shows that the compensation has to be improved

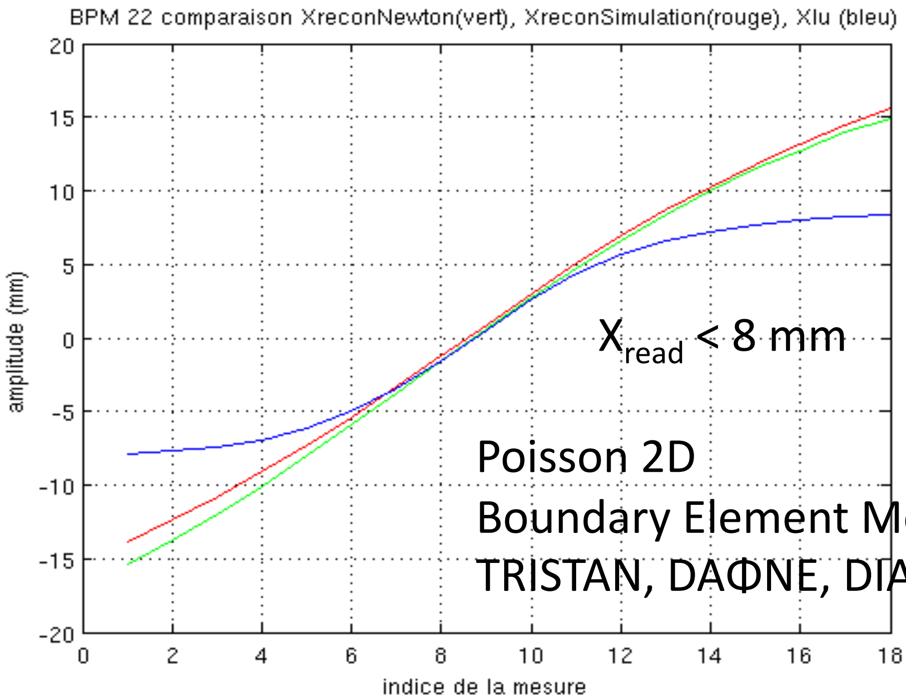
How is it used?

1. **Validation of magnetic measurements**
2. **Design of set of magic fingers for compensation of non linear effects**

BPM nonlinear response

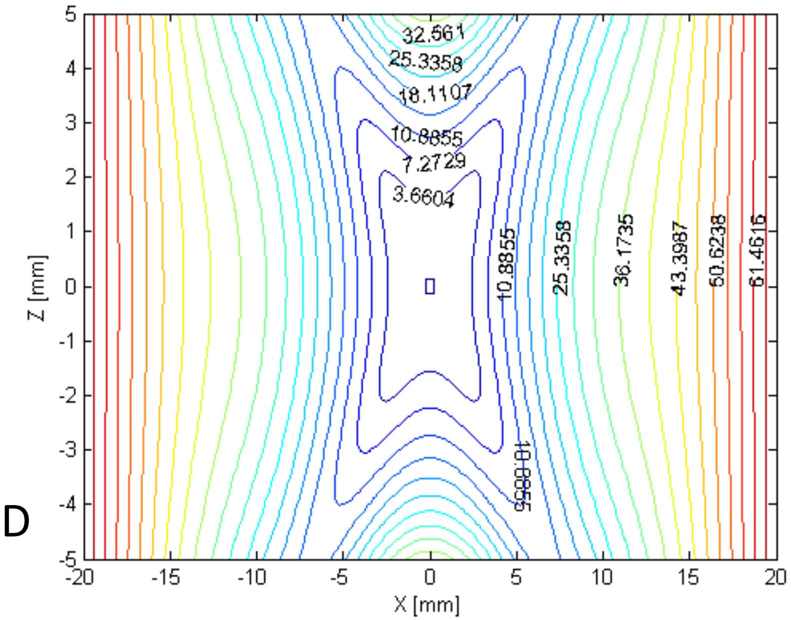






$X_{read} < 8$ mm

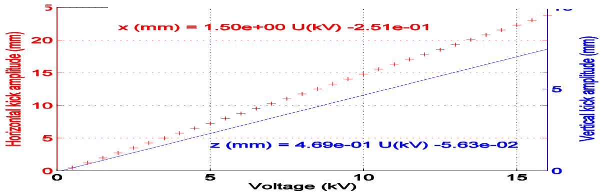
Poisson 2D
Boundary Element Method
TRISTAN, DAΦNE, DIAMOND



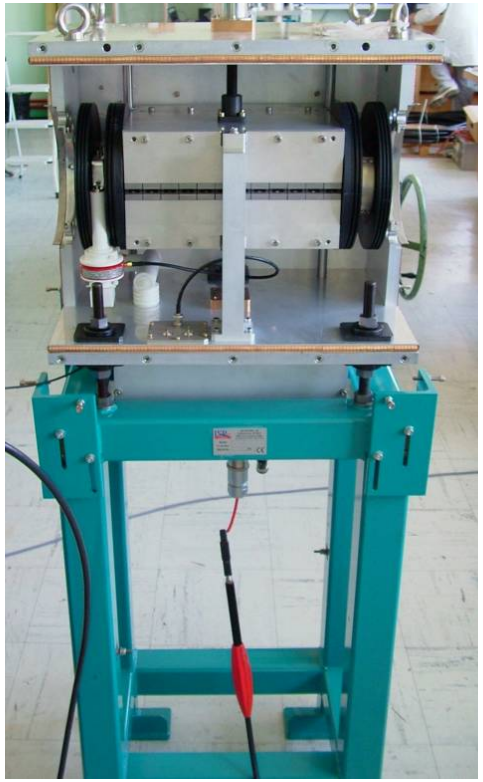
Equipment for turn by turn experiments

Since August 2007, the 12 meter long injection section of the SOLEIL storage ring is equipped with **one horizontal and one vertical machine study kicker** (or pinger magnets)

The pingers have an **excellent reproducibility (10^{-3})** and linearity of the magnetic field.



BPM Electronic Module : Liberaf rom Instrumentation Technologies

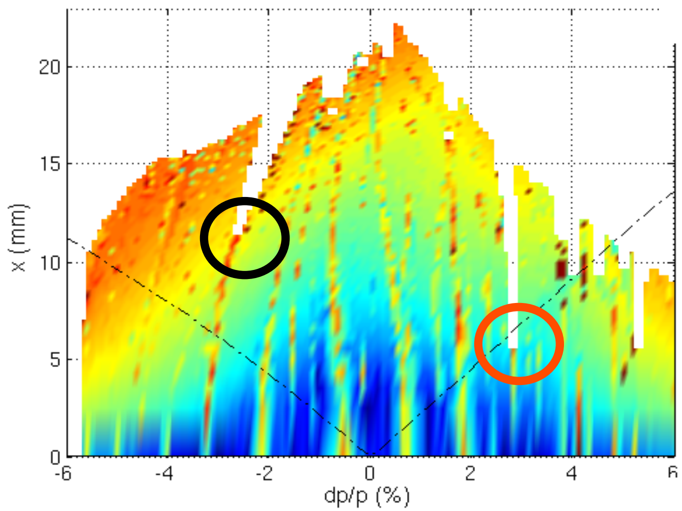


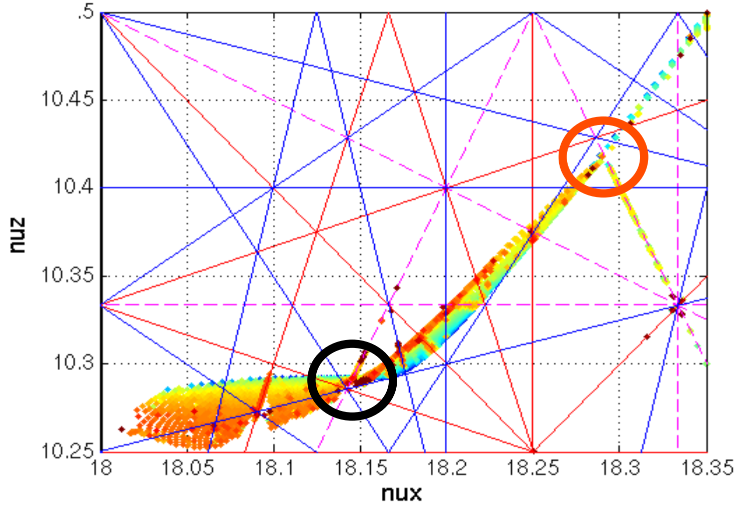
- Thanks to their **Libera electronics**, the 120 BPMs can run at 846 kHz in turn-by-turn acquisition
- The **standard filtering**, optimized for the slower acquisition rates **does not fully decouple the position** of a specific turn from its previous and following ones. A new filter isolating each turn position will be fully implemented in the coming months.
- In the linear region (±4 mm) , the BPM resolution is better than 3 μm RMS

	Active Length	Angle	B nom	Plateau
	mm	mrad	mT	ns
Kicker H	600	2	30.56	420
Kicker V	300	0.6	18.33	456

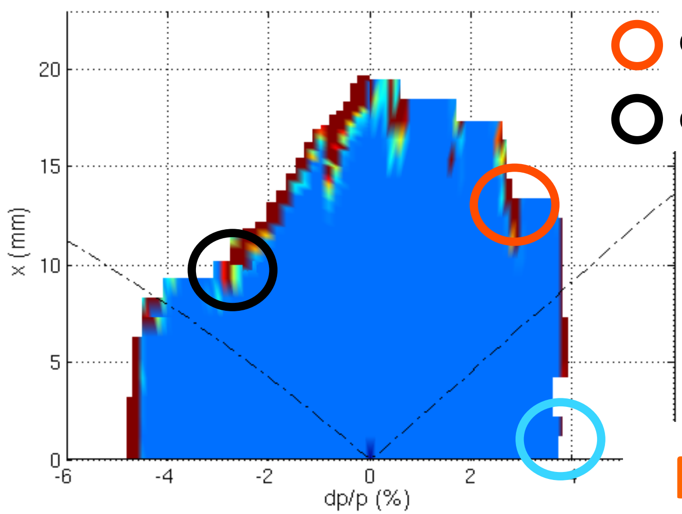
The energy acceptance of the bare machine is large : +/- 4%.
Off-momentum FMA experiments have confirmed calculation results

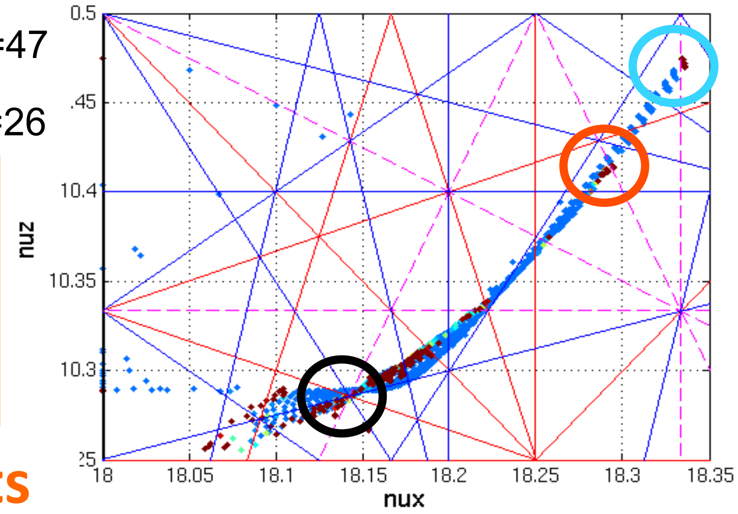
Simulations





- dp/p = + 4 % : $3\nu_x=55$.
- dp/p = + 3 % : $2\nu_x+\nu_z=47$
- dp/p = - 3 % : $2\nu_x-\nu_z=26$





Measurements

Non linear dynamics

- Today FMA like techniques
  - Are precious tools for diagnosis non linear beam dynamics for both on and off momentum particles
  - Guide optimization strategy for increasing accelerator performance
  - Start being exploited for resonant driving term minimization

- Future: novel design and improvement of diagnostics
  - Turn by turn data: small crosstalk, better resolution
  - BPM resolution for large amplitudes
  - Is it time for individual power supplies for sextupoles?
  - SOLEIL: strong limitation for probing off-momentum dynamics. Large RF frequency shifts make aging the cold tuning system of the superconductive cavities
    - A special cavity for kicking the beam energy over one turn would be very valuable

Conclusion

- Linear optics is well understood
- Still a lot of work for tuning complex lattices with many sextupole families, trends to introduce octupole magnets to control tune shift with amplitude, second order chromaticity, increase longitudinal energy acceptance
- Non-linear optics correction and measurement based on turn by turn data is still challenging and requires improved BPM systems
  - → individual sextupole PSs?
- Other challenging parts
  - Maintaining performance with many insertion devices freely controlled by users.
    - Fast switching devices, low beam sizes drive orbit feedback improvement
    - Local control of beam sizes
  - Top-up operation means beam delivered over many day period of time

Development of on-line continuous tools to measure beta-beats, chromaticity evolutions, local coupling, performance degradation but without perturbing the user experiments