TIARA-SVET Kick-off meeting

WP6 summary

Erk JENSEN

Yannis PAPAPHILIPPOU, CERN

With input from the TIARA/SVET collaborators

February 24th, 2011

WP6 (SVET)

- SVET: “SLS Vertical Emittance Tuning”
  - Russian “Свет” means “light”
- Objectives:
  - Convert the Swiss Light Source (SLS) to a *R&D Infrastructure*,
  - Demonstrate ultra-small emittances as required for future Linear Collider Damping Rings (5 nm normalized, <1 pm @ 2.86 GeV)
  - Enable to extend tests to lower energies (IBS dominated regime).

THE MAIN PLAYERS

- **PSI:** Masamitsu Aiba, Michael Boege, Natalia Milas, Andreas Streun
- **CERN:** Fanouria Antoniou, Hannes Bartosik, Erk Jensen, Eirini Koukovini Platia, Thibaut Lefevre, Helène Mainaud-Durand, Yannis Papaphilippou, Alessandro Vivoli
- **INFN/LNF:** Marica Biagini, Simone Liuzzo, Fabio Marcellini, Mario Serio, T. Dema, ...
- **Max-IV Laboratory** (via PSI): Åke Andersson, ...

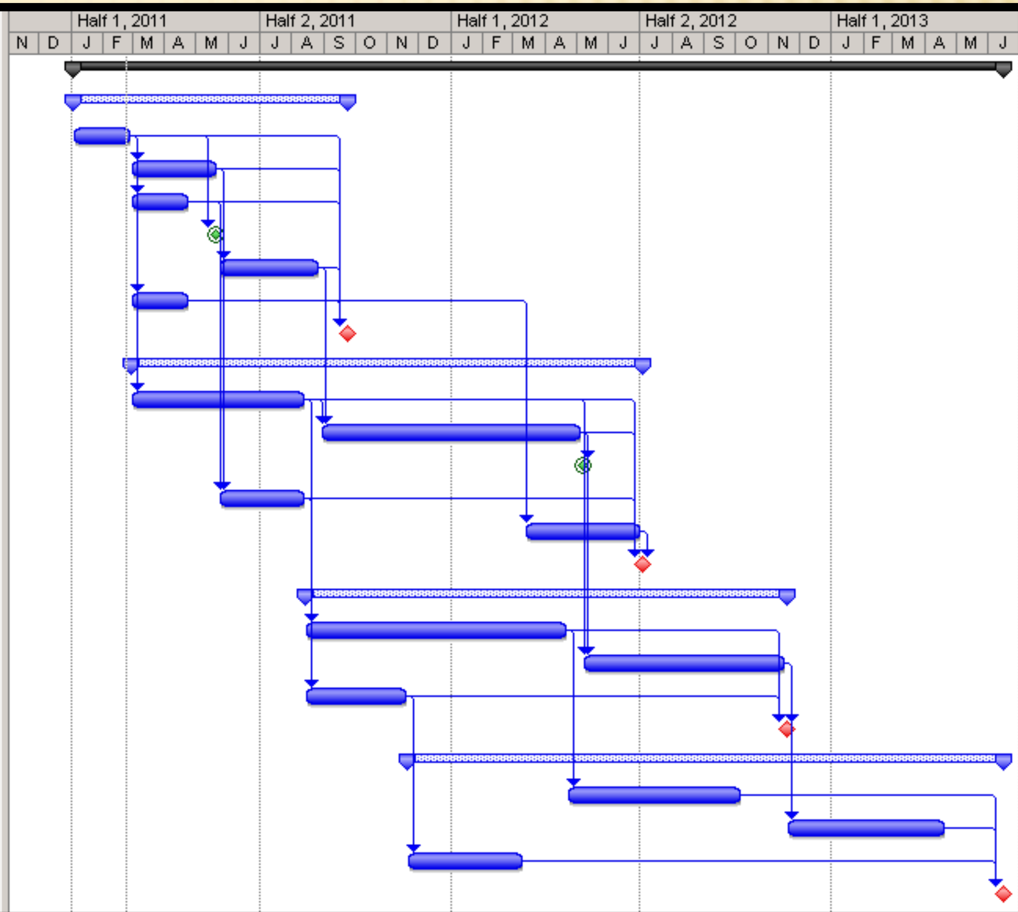
(underlined: present at Kick-Off Meeting)

WHAT IT TAKES: STEP 1

- **Step 1:** With the existing hardware:
- Ensure optimum measurement accuracy (beam size, position, emittance, coupling, ...)
- Minimize magnetic field errors
  - alignment of girders/magnets
  - alignment of BPM's
- Minimize betatron coupling (using existing skew quads)
- **Result:** Show what is possible & where improvements are needed.
  Interim report due in May, 2011 (Milestone),
  final report due: Month 9, September 2011

WP6 (SVET): GANTT CHART

WBS	Task Name
6	**WP6 Upgrade of SLS vertical emittance tuning system (SVET)**
6.1	**6.1 SLS_NOW: Experimental tests at SLS with existing systems**
6.1.1	6.1.1 EPS_Limit: emittance limit
6.1.2	6.1.2 EPS_Sens: emittance sensitivity
6.1.3	6.1.3 MON-RES: profile monitor resolution
MS25	MS25 M_INSTR: Interim report on existing beam instrumentation
6.1.4	6.1.4 COUPLING: coupling theory
6.1.5	6.1.5 MAG_Scale: magnet scaling
D6.1	D6.1 D_SLS_NOW: Report on existing hardware situation and limitations
6.2	**6.2 SPEC: Specification of necessary upgrades**
6.2.1	6.2.1 ORB_C_SPEC: Orbit Control Specifications
6.2.2	6.2.2 KNOB_SPEC: emittance knobs
MS26	MS26 M_KNOBS: Specification of emittance knobs ready
6.2.3	6.2.3 MON_SPEC: Monitor specification
6.2.4	6.2.4 ENERGY: Specification of knob for energy scaling
D6.2	D6.2 D_SPEC: Specifications ready
6.3	**6.3 IMPL: Implementation of the specified upgrade**
6.3.1	6.3.1 ORB_C_IMPL: Orbit Control upgrade
6.3.2	6.3.2 COUPL_IMPL: Coupling automation
6.3.3	6.3.3 MON_IMPL: Monitor installation
D6.3	D6.3 D_IMPL: Hardware ready and installed
6.4	**6.4: COMM**
6.4.1	6.4.1 ORB_C_COMM: Orbit Control Commissioning
6.4.2	6.4.2 COUPL_COMM: Coupling control
6.4.3	6.4.3 MON_COMM: Monitor commissioning
D6.4	D6.4 FINAL_R: Commissioning report



Preliminary specs needed by PSI/SLS before month 10
Final specs before month 18 (looks OK)!

WP6 (SVET): RESOURCES

- Person-months:

	CERN	INFN	PSI	total	direct k€	total k€
pm	16.5	11.5	45.5	73.5	556.83	785

- Material:

	CERN	INFN	PSI		direct k€	total k€
k€			215		215	258

- Travel:

	CERN	INFN	PSI	total	direct k€	total k€
units	16	9	11	36	22.5	34.5

- travel unit=625 €

k€	k€
794.33	1077.57

2-day kick-off meeting with 12 people corresponds to 1.2pm

KICK-OFF MEETING AGENDA

- Agenda and slides can be found in
  http://indico.cern.ch/conferenceDisplay.py?confId=127251
- Material for SLS in
  http://ados.web.psi.ch/tiara/

CLIC DR design goals

- Horizontal and **vertical** normalized emittance target of 500 and **5nm** (90 and **0.9pm** geometrical @2.86GeV) is unprecedented
- High bunch charge of 4.1×10^9 particles(0.7nC)
- Small longitudinal emittance (rms momentum spread of 0.1% and bunch length of ~1.8mm)
- High bunch density (brightness) triggers large number of collective effects, including intrabeam scattering dominating the steady-state emittance

PARAMETER	VALUE
bunch population (10^9)	4.1
bunch spacing [ns]	1
number of bunches/train	156
number of trains	2
Repetition rate [Hz]	50
Extracted hor. norm. emittance [nm]	<**500**
Extracted ver. norm. emittance [nm]	<**5**
Extracted long. norm. emittance [keV.m]	<**6**
Injected hor. norm. emittance [μm]	63
Injected ver. norm. emittance [μm]	1.5
Injected long. norm. emittance [keV.m]	1240

CERN/CLIC interests and contribution

- IBS theory and simulations
  - IBS effect on emittance at SLS versus different parameters (energy, bunch charge, etc.)
  - IBS simulations for SLS (SIRE)
- Beam measurements
  - Participate in machine developments for correcting vertical emittance
  - Learn/test procedures and numerical tools for reaching ultra-low emittance (orbit control, response matrix and frequency analysis)
  - Understand limitations and refine tolerances for CLIC damping rings (alignment, girder design, magnet errors and instrumentation)
  - Demonstrate ultra-low vertical emittance <1pm in IBS dominated regime (beyond TIARA)
- Beam instrumentation
  - Participate in technical specifications, design and commissioning of profile monitor

SuperB parameters

- IP and ring parameters (see Table) have been optimized in order to:
  - Maintain wall plug power, beam currents, bunch lengths, and RF requirements comparable to past B-Factories
  - Reuse as much as possible of the PEP-II hardware
  - Have ring parameters as close as possible to those already achieved in the B-Factories, or under study for the ILC Damping Ring or achieved at the ATF ILC-DR test facility
  - Simplify IR design as much as possible. In particular, reduce the synchrotron radiation in the IR, reduce the HOM power and increase the beam stay-clear
  - Eliminate the effects of the parasitic beam crossing;
  - Relax as much as possible the requirements on the beam demagnification at the IP
  - Design the FF system to follow as closely as possible already tested systems, and integrating the system as much as possible into the ring design
- Coupling control is crucial (beam-beam)

Marica Biagini (INFN/LNF)

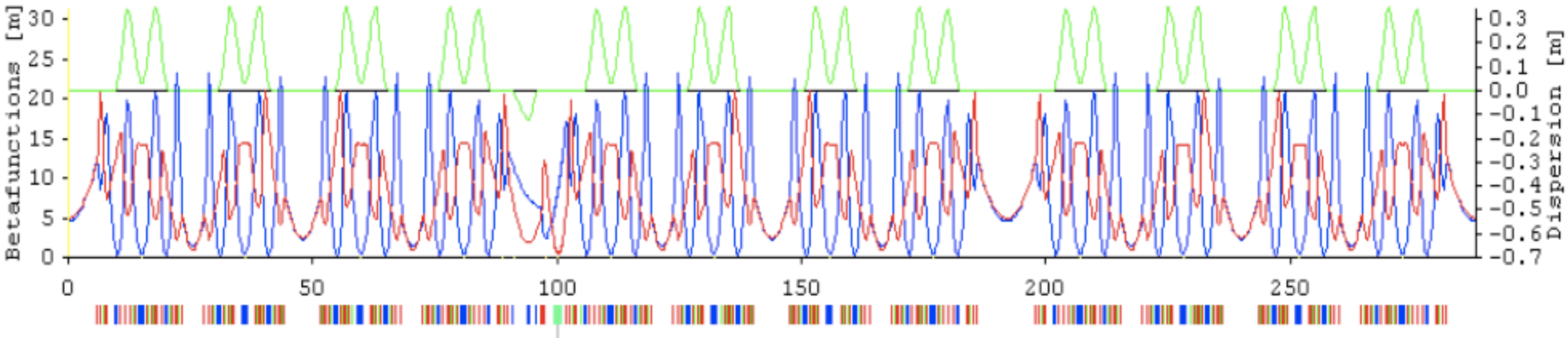
What LNF would like to achieve with SVET

- To learn on emittance measumement diagnostics
- To apply and check Simone's LET tools to SLS to achieve minimum emittance and coupling and detect misalignments
- To collaborate in studies and simulation of IBS (most for the τ/charm running)
- To study coupling control methods to optimize SuperB design
- To participate to MD shifts
- All this with very few resources... (11.5 p-m, 9 k€ for 3 years) !

Marica Biagini (INFN/LNF)

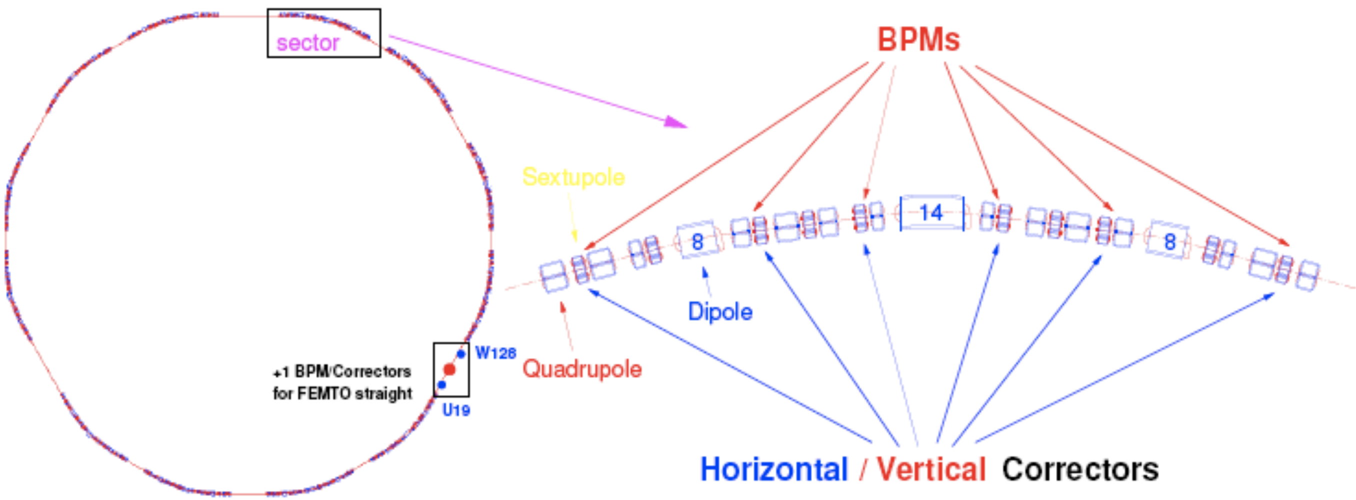
Andreas Streun (PSI):

The Swiss Light Source SLS



- 12×TBA lattice, 288 m circumference, 2.4 GeV
- 5.0...6.8 nm emittance (dep. on ID status)
- 400 ±1 mA top up operation
- User operation since 10 years; 18 beam lines
- Upgrades: laser slicing & 3 super-bends
- 1 micron photon beam stability at front ends
- 3 pm rad vertical emittance (0.05% coupling)

BPM/Corrector Layout



- The SLS Storage Ring is divided into 12 sectors.
- Pairs of 6 BPMs and 6 horizontal/vertical Dipole Corrector Magnets are distributed over one Sector (+1 BPM/Correctors set for FEMTO straight).
- The Corrector Magnets are implemented as extra windings on the Sextupoles, the BPMs are adjacent to the Quadrupols (nonzero orbit in a quadrupole field leads to a dipole kick).

Michael Böge (PSI):

Status of SLS Instrumentation and Achievements in Coupling Control

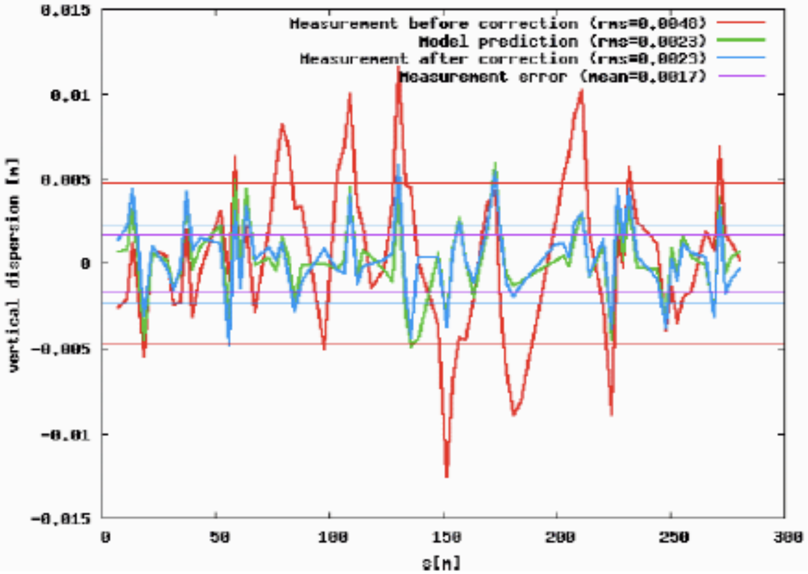
Vertical Dispersion/Betatron Coupling Correction - Summary

1. Suppression of η_y by 12 $\eta_x > 0$ skew quads:
   η_y from off-momentum orbit measurement and SVD fit
2. Suppression of $Q_x \pm Q_y$ by 24 $\eta_x = 0$ skew quads.
   response matrix measurement and SVD fit using model RM
3. + some empirical tuning of skew-quad Hamiltonian modes
   h_{00101}, h_{10100} and h_{10010}
   for best ratio $T/\sqrt{\varepsilon_y}$

➔ lowest V-emittance:

$\varepsilon_y = 2.8\ (\pm\ 0.4)$ pm rad
$= 5 \times \varepsilon_{yo}$ from $1/\gamma$
$= 0.05\%$ of ε_x

➔ option: η_y-wave to adjust $\varepsilon_y \leftrightarrow T$ on $T \propto \sqrt{\varepsilon_y}$ scaling curve



TIARA-SVET kick-off Meeting 23-24/02/11

Åke Andersson (Max-IV) & Natalia Milas (PSI):

Principle

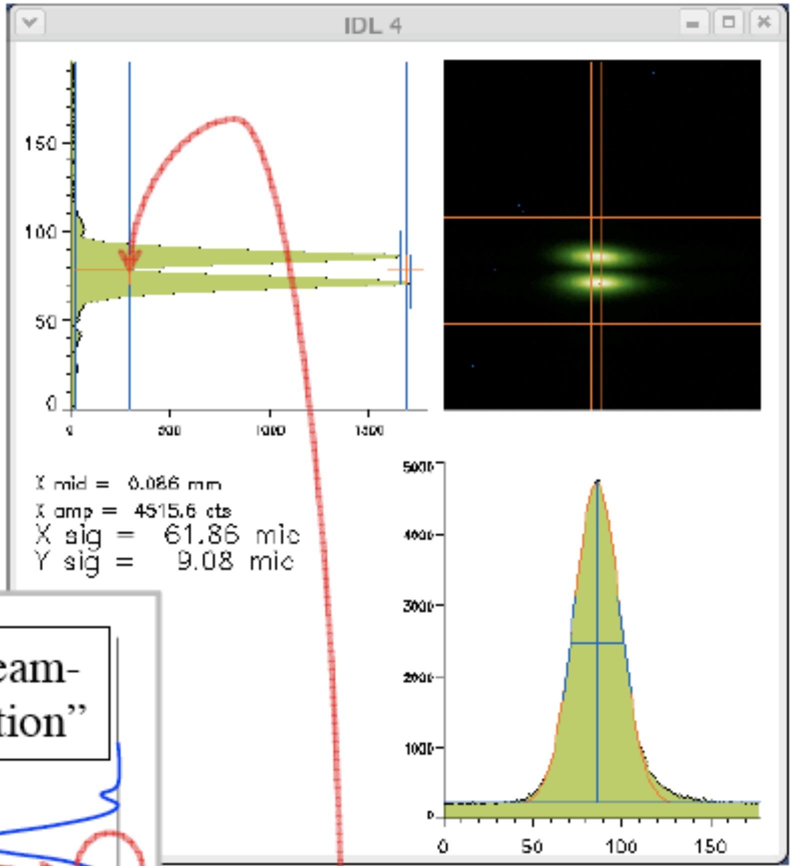
The π -polarization method*):

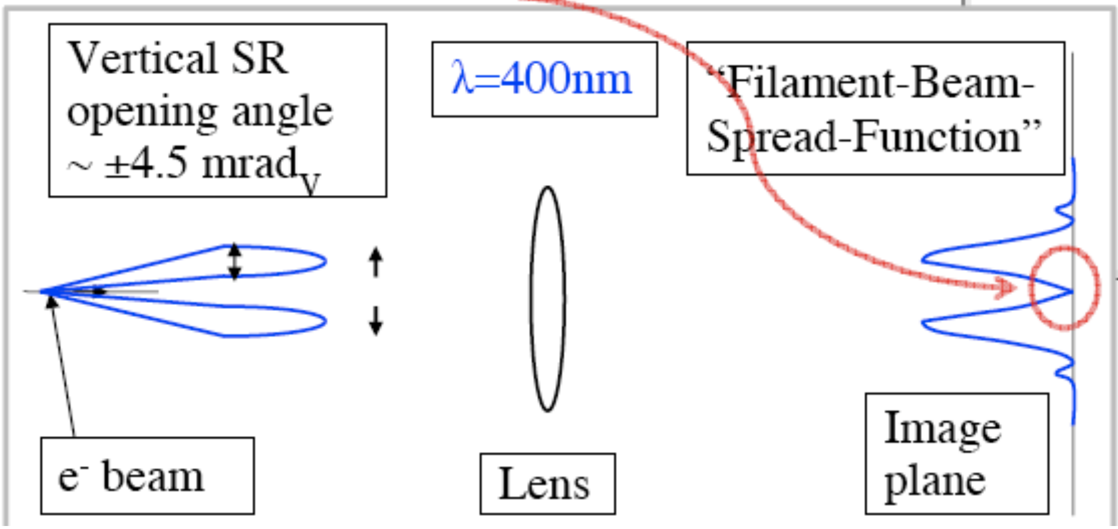
An image of the beam is formed from vertically polarized visible-UV synchrotron radiation.

A π phase shift between the two radiation lobes ==> $I_{y=0}$=0 in "FBSF"

(FBSF =filament beam spread function)

*) Old idea springing from MAX-lab, see EPAC'96 Andersson, Eriksson, Chubar





Finite vert. beam size ==>

Non-zero central intensity

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Error analysis

SLS

Nominal (no IDs) and measured parameter values at the observation point, together with derived emittances and emittance ratio

Parameter	Nominal value	Measured value	Max. error margin
σ_δ (%)	0.086	–	$+0.009/-0.000$
β_x (m)	0.452	0.431	± 0.009
η_x (mm)	29	27.3	± 1.0
σ_{ex} (μm)	56	57.3	± 1.5
ε_x (nmrad)	5.6	6.3	$+0.7/-0.9$
β_y (m)	14.3	13.55	± 0.14
η_y (mm)	0	2.3	± 0.55
σ_{ey0} (μm)	–	6.8	± 0.5
ε_y (pmrad)	–	3.2	± 0.7
g (%)	–	0.05	± 0.02

Åke Andersson (Max-IV) & Natalia Milas (PSI):

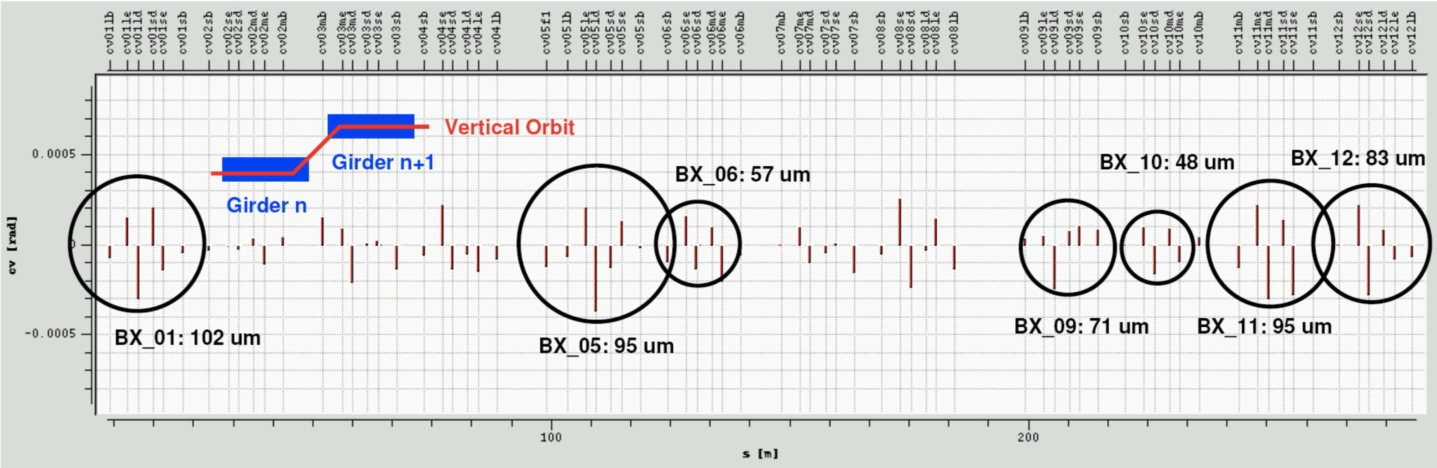
PAUL SCHERRER INSTITUT

Systematic errors

- The smallest rms beam height values so far measured at SLS are around 5 μm. In this region it is difficult to exclude systematic error contributions to the measured value from various non-perfect optical elements. The valley-to peak ratio is only ~ 5 %, and this number we should consider as a lower limit.
- However, for a rms beam height of 3 μm, we can keep the (intrinsic) valley-to-peak ratio to 6% with almost the same experimental set-up. In this case we have to introduce an extra finger absorber with larger height.
- The π-polarization method then very much resembles an interference method. The advantage will be to be able to swap between the modes in order to crosscheck the influence from non-perfect optical elements.
- This method seems more advantageous than moving to shorter wavelength.

7/15 Åke Andersson and Natalia Milas, The SLS beam size monitor, TIARA Kick-off meeting WP6, CERN Feb.23-24, 2011

Girder Re-alignment



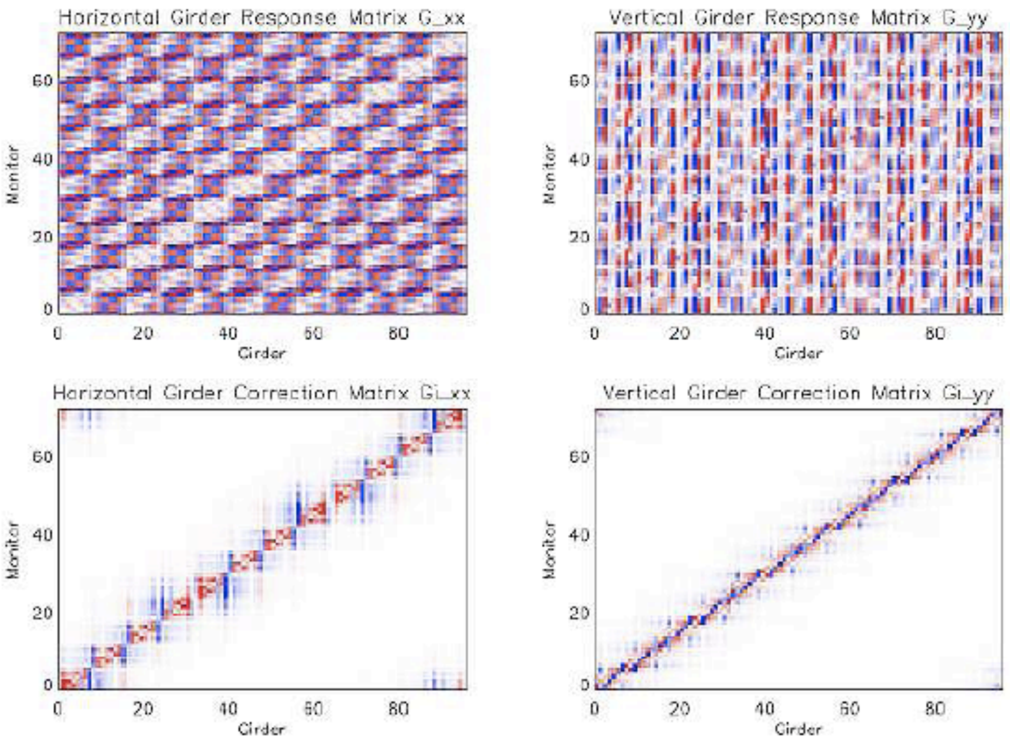
- Corrector Pattern can be used to determine alignment errors (→No Cutoff).
- Prominent girder-girder alignment errors related to local corrector patterns (circles).
- Girder-girder errors introduce mechanical steps driving the adjacent correctors.
- Leads to saturation of correctors in machines with large alignment errors (→Eigenvalue Cutoff = "Long Range Correction").
- →Beam-based girder alignment (magnets on girders as super-correctors).

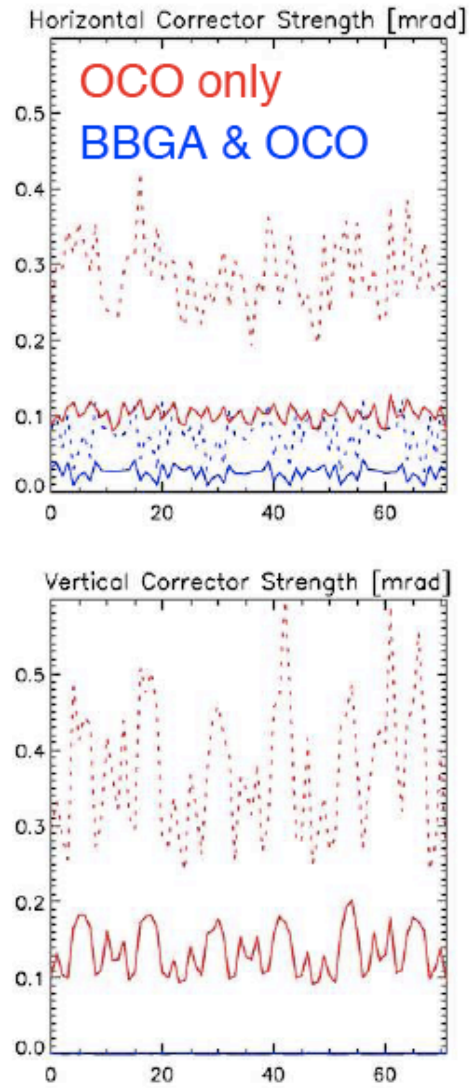
Andreas Streun (PSI):

Beam based girder alignment

48 girders = 96 horizontal and vertical “correctors”:
orbit kicks from displaced girder ends

Orbit response and correction matrices





Simulation:	horizontal	vertical
SVD: used/all weighting factors	60/96	96/96
saved magnetic corr. strength	**75%**	**100%**

Simone Liuzzo (INFN/LNF):

New correction scheme:

Orbit and Dispersion Free Steering +
Coupling and Beta-Beating Free Steering

$$m\left\{\begin{pmatrix}(1-\alpha-\omega)\cdot\vec{y}\\ \alpha\cdot\vec{\eta}_y\\ \omega\cdot ORM_{VC\vec{x}}\\ \omega\cdot ORM_{HC\vec{y}}\\ \vdots\end{pmatrix} = M_{m\times n}\begin{pmatrix}\vec{\theta}_y\\ \vec{K}_{skq}\\ \vec{T}_{tilts}\end{pmatrix}\right\}n$$

Measured at BPM

+ 2 (or more) columns of the off diagonal Orbit Response Matrix, being the vertical orbit generated by a Horizontal correctors (HC) and vice versa.
+ Skew quadrupole gradients may be added as correctors.
+ Tilts may be detected from dispersion and coupling vectors measurements adding a diagonal matrix to the system.
+ ALL MATRICES ARE CALCULATED FROM THE MODEL. FAST!

Same is done in horizontal plane with a different matrix sensible to the effect of β-beating (HC x orbit)

Vertical correction or Skew Quadrupoles correction using Coupling Free Steering provide 0.23%-0.24% emittance coupling and rms vertical Dispersion of 600 µm - 1mm after few reiterations.

Also simultaneous correction with skew quadrupole and vertical correctors have realized the same parameters.

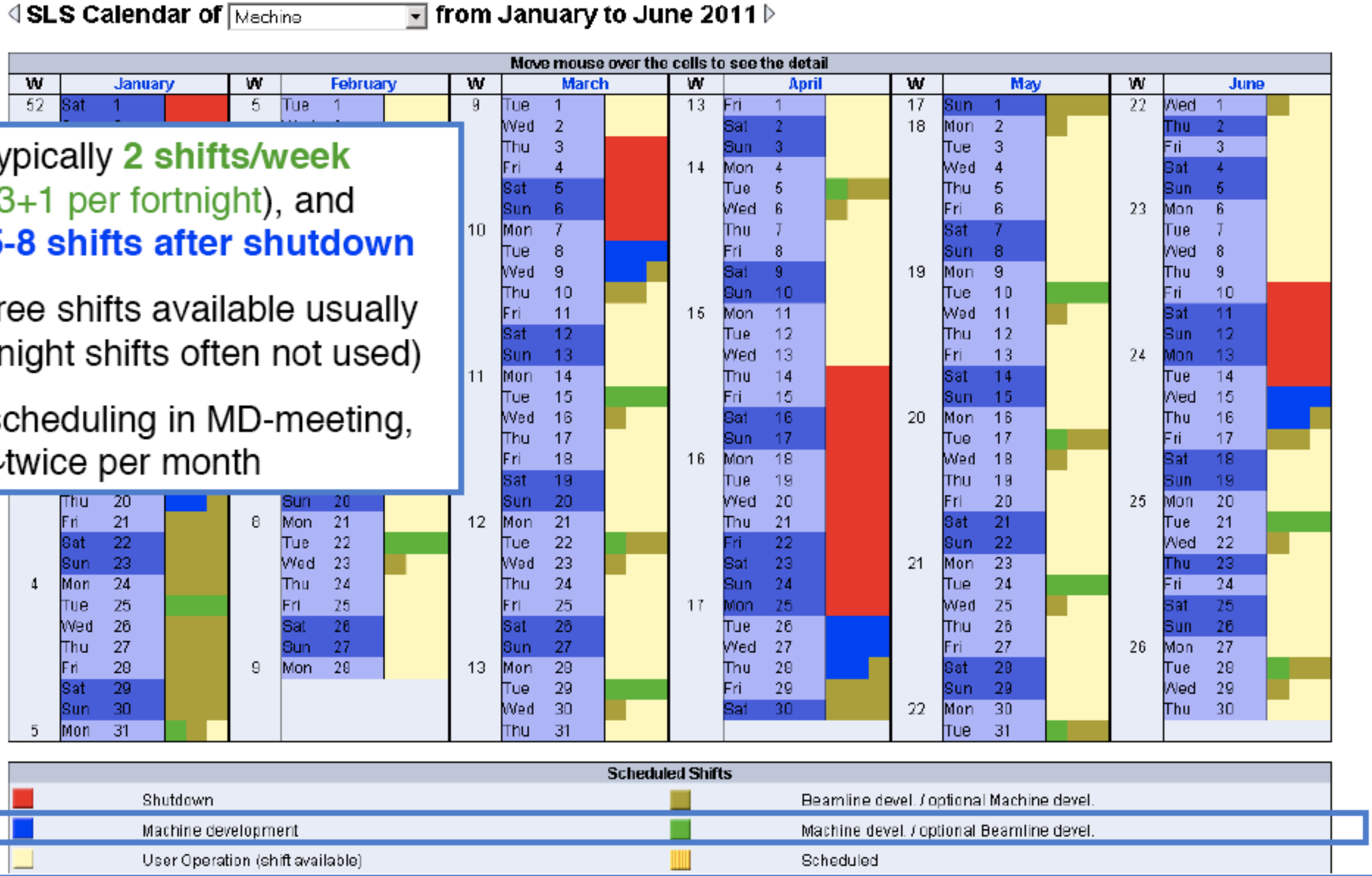
Comparison with LOCO has been performed a few hours ago.

NEXT STEPS

- Test horizontal correction (also beta-beating constrained)
- Try to better exploit coupling correction. Simulation discrepancy.

Simone Liuzzo (INFN/LNF)

Machine development shifts



typically **2 shifts/week** (3+1 per fortnight), and
5-8 shifts after shutdown

free shifts available usually (night shifts often not used)

scheduling in MD-meeting, ~twice per month

NEXT STEPS

- SLS lattice to CERN, INFN colleagues for coupling algorithm and IBS calculations
- Machine Development at SLS for familiarizing with machine and coupling correction
- Re-alignment of the biggest girder shifts
- Sextupole beam based alignment
- First guess on the specs of the new monitor
- Next meeting to be organized at PSI within the next months (April?)

OUTLINE

- SLS and its limitations are well understood.
- The methods and procedures are at hand.
- There is a number of very competent & enthusiastic people in the starting blocks!
- In addition to the improvement of SLS, there is interesting work on IBS dominated regime!
- PSI has approved the opening of a post-doc.
- SVET needs a communication platform (Collaboration workspace)!