Diagnostics, controls, automation and feedbacks

Beam tests and commissioning of low emittance storage rings
KIT 18-20 Feb 2019
Session chairs: Ubaldo Iriso, Ian Martin, Ilya Agapov

Automated Commissioning Plans for the APS Upgrade

Vadim Sajaev

Beam Tests and Commissioning of Low-Emittance Storage Rings
February 19, 2019

Automation is a key to fast commissioning

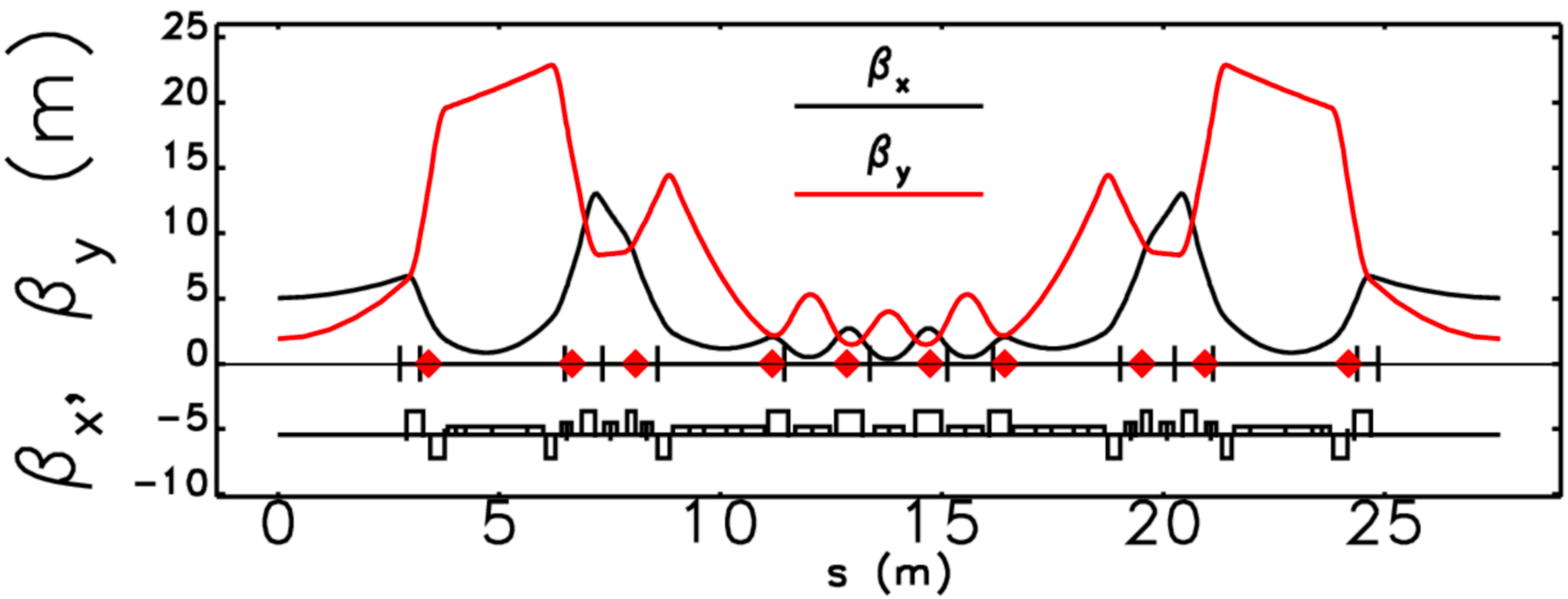
- APS-U will have to be commissioned is 3 months
- We see automation as a key to fast commissioning

V Sajaev

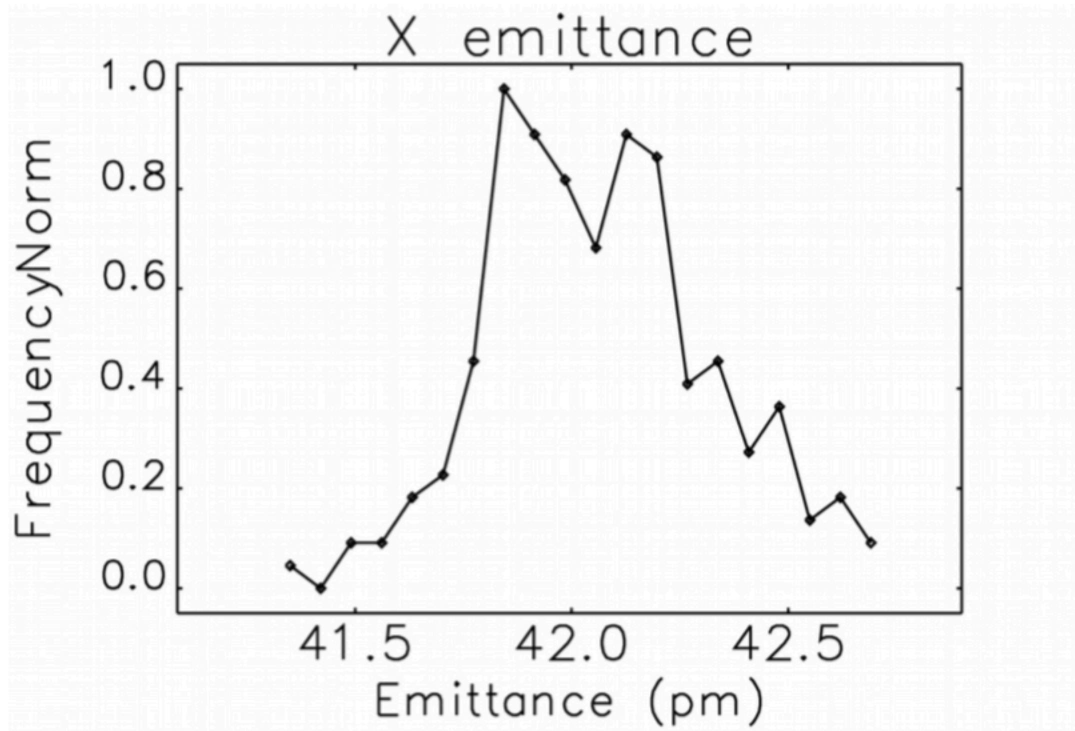
- Lattice commissioning consists of
  - Establishing first turn
  - Multi-turn trajectory correction
  - Orbit correction
  - Beta function and coupling correction

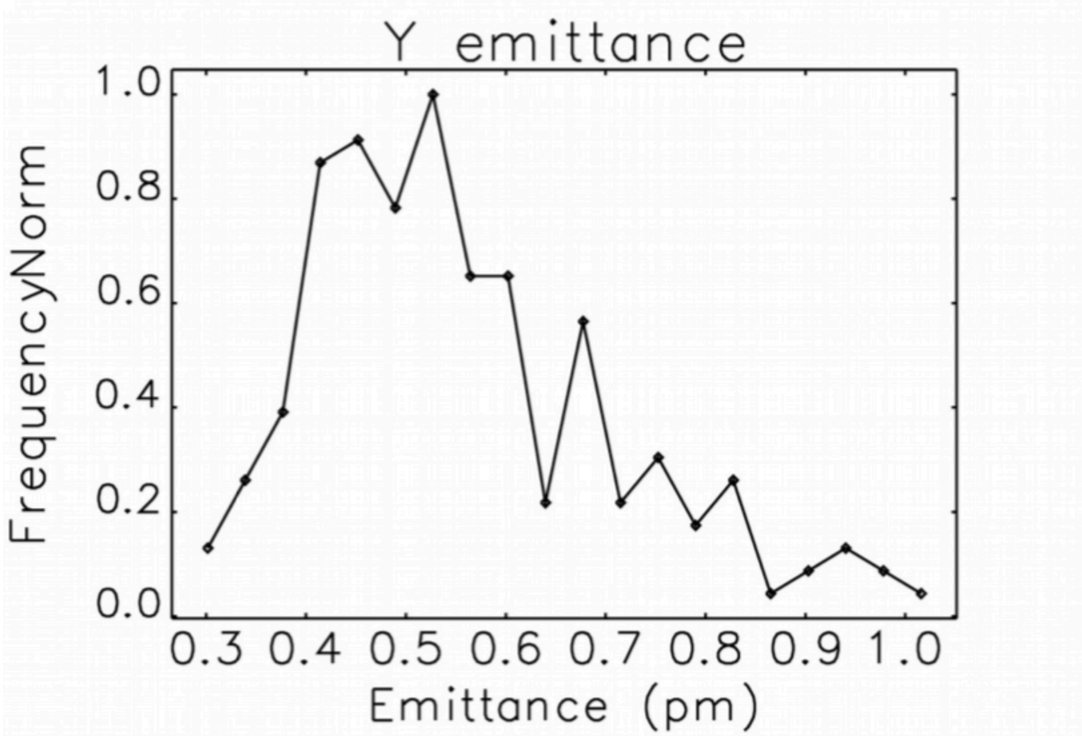
Errors used in commissioning simulation:

Girder misalignment	100 μm
Elements within girder	30 μm
Dipole fractional strength error	$1 \cdot 10^{-3}$
Quadrupole fractional strength error	$1 \cdot 10^{-3}$
Dipole tilt	0.4 mrad
Quadrupole tilt	0.4 mrad
Sextupole tilt	0.4 mrad
Corrector calibration error	5%
Initial BPM offset error	500 μm
BPM calibration error	5%
BPM single-shot measurement noise	30 μm
BPM orbit low-current noise	3 μm
BPM orbit high-current noise	0.1 μm
BPM and corrector tilts	1 mrad



V Sajaev





In simulations machine will start up after 800 injections (closed orbit)

Design parameters (emittance) reached

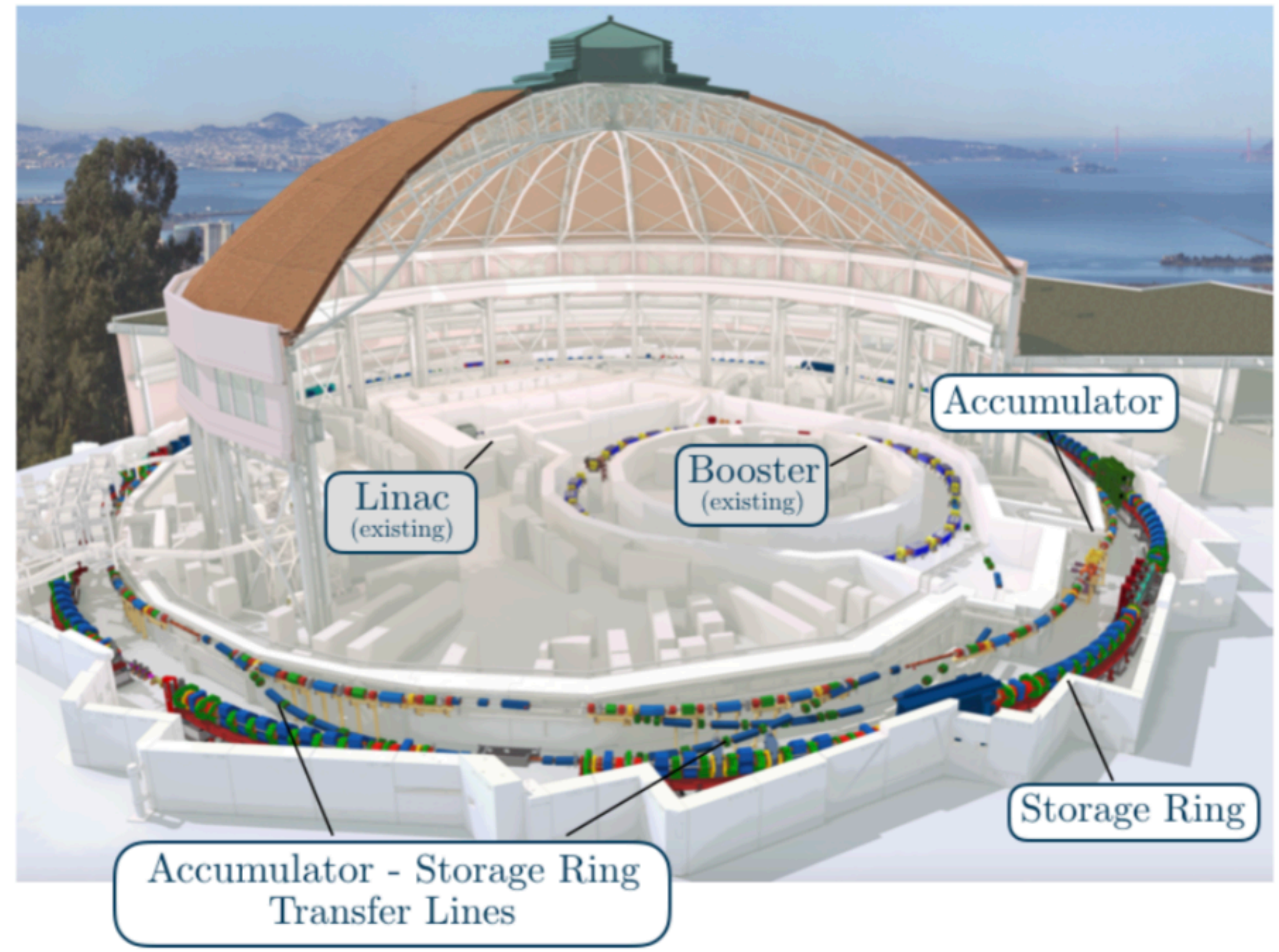
Hope to commission fully automatically

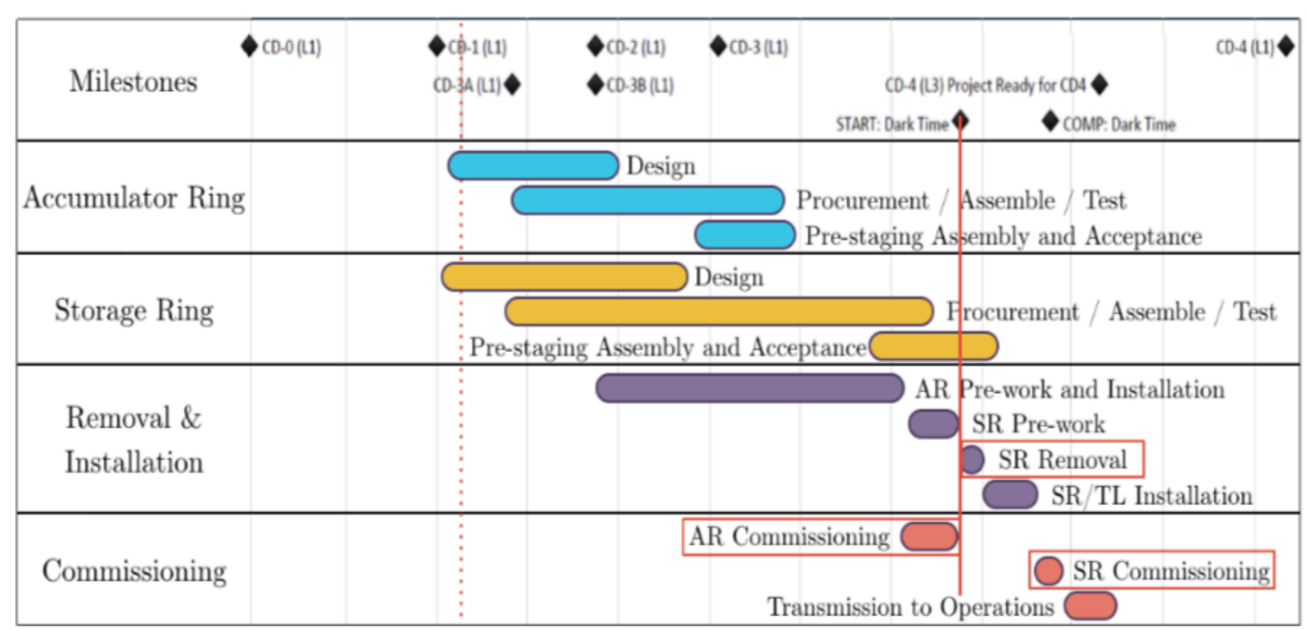
A toolbox for simulated commissioning of light sources

Thorsten Hellert, LBNL

- Magnet errors
  - Magnet offset = 30 µm
  - Raft offset = 25 µm
  - Plinth offset = 100 µm
  - Arc offset = 100 µm
  - Magnet roll = 0.2 mrad
  - Magnet strength = 0.1%
- Diagnostic errors
  - BPM offset = 500 µm
  - BPM cal. error = 5%
  - BPM noise (TbT) = 3 µm
  - BPM noise (CO) = 1 µm
  - BPM roll = 0.4 mrad
  - CM cal. error = 5%
  - CM roll = 0.4 mrad

Advanced Light Source Upgrade (ALS-U)



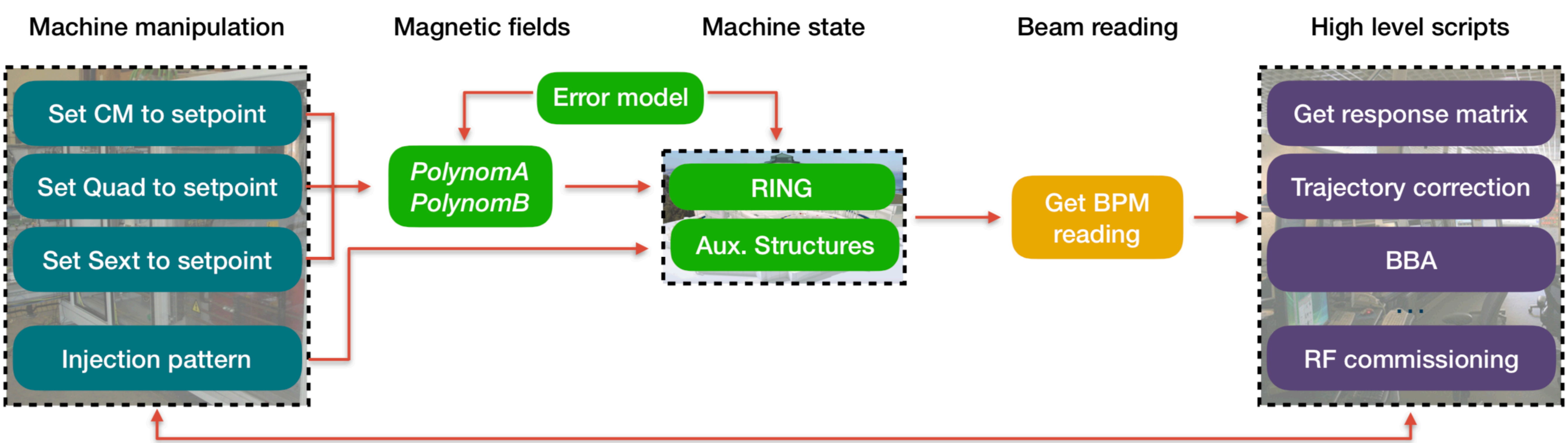


A toolbox for simulated commissioning of light sources

Thorsten Hellert, LBNL

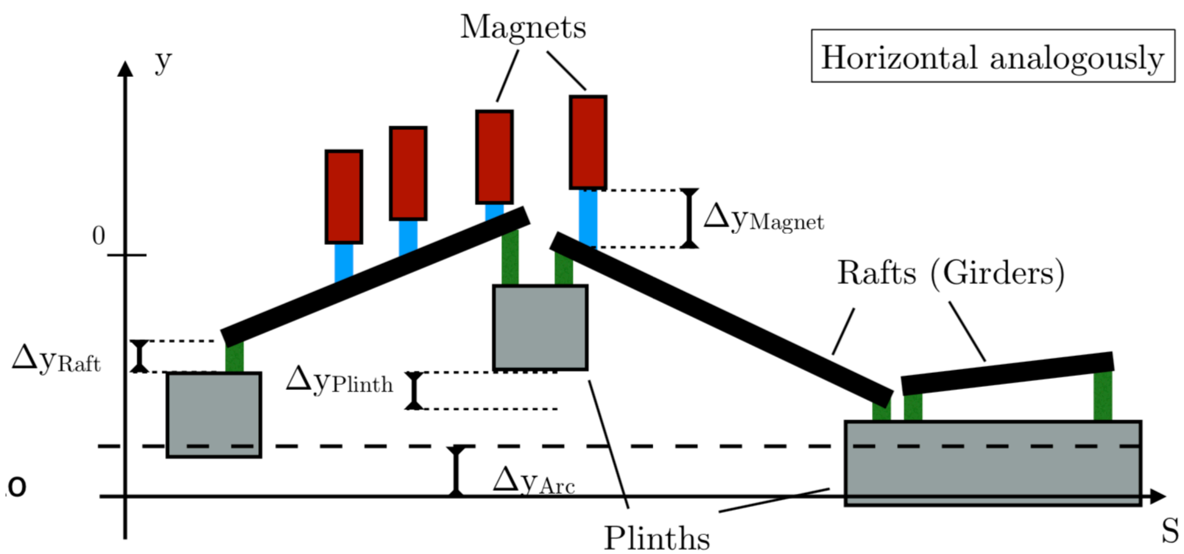
- Choice of toolbox implementation
  - Commissioning simulation required for two different machines
  - ALS-U will be operated with *Matlab Middle Layer* (MML)
  - Easy communication between MML and *Accelerator Toolbox* (AT)
  - AT implementation of ALS-U commissioning allows for experiments at current ALS

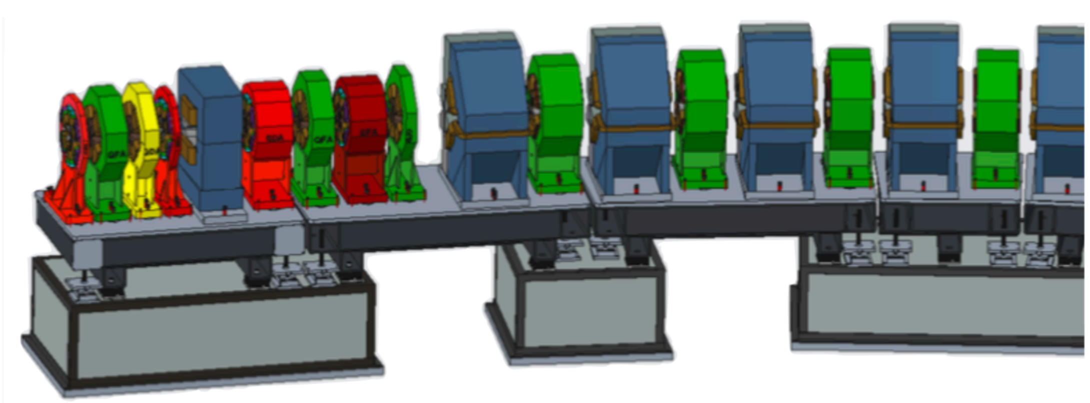
Realistic workflow of toolbox important



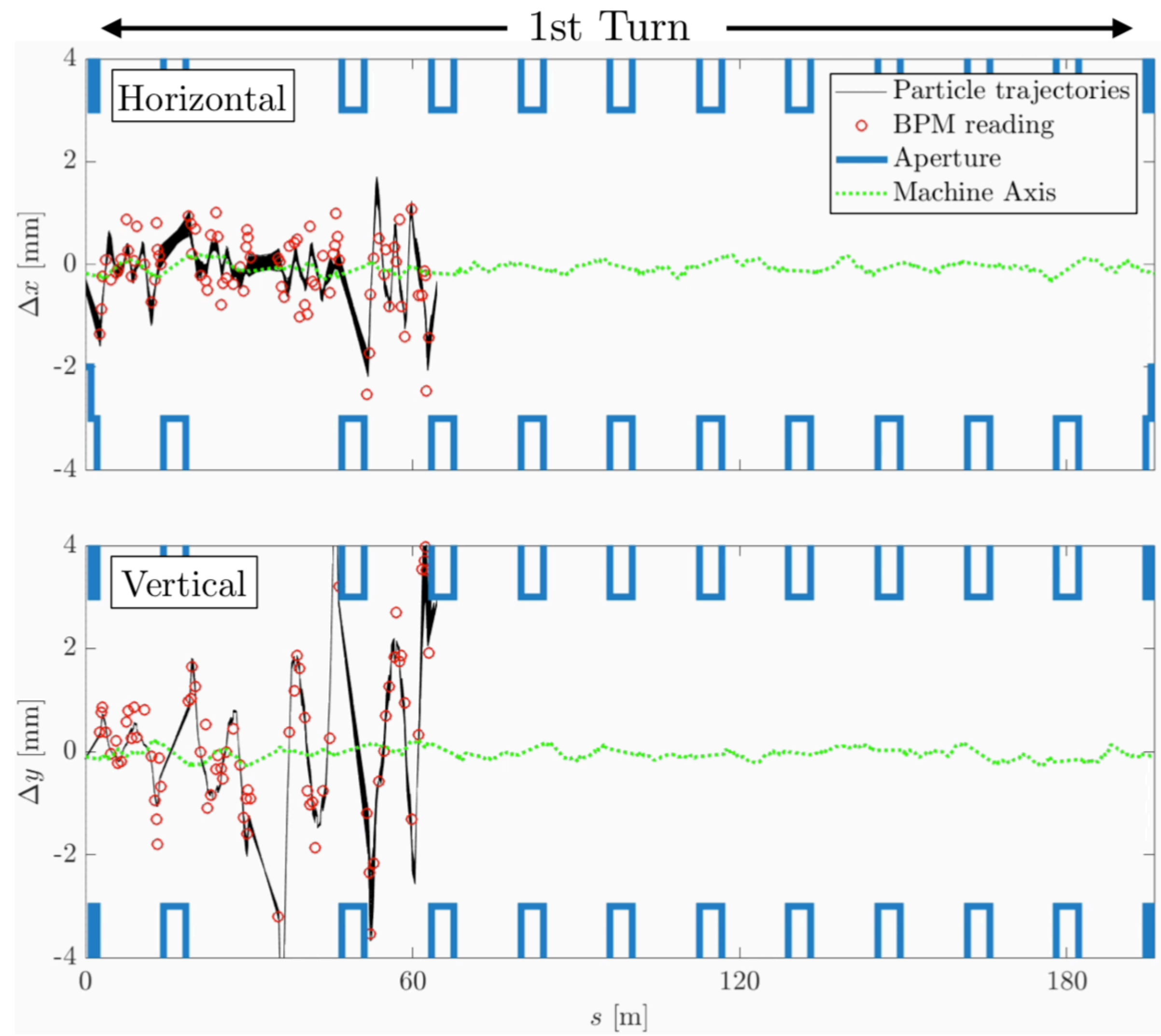
T. Hellert

Detailed alignment model

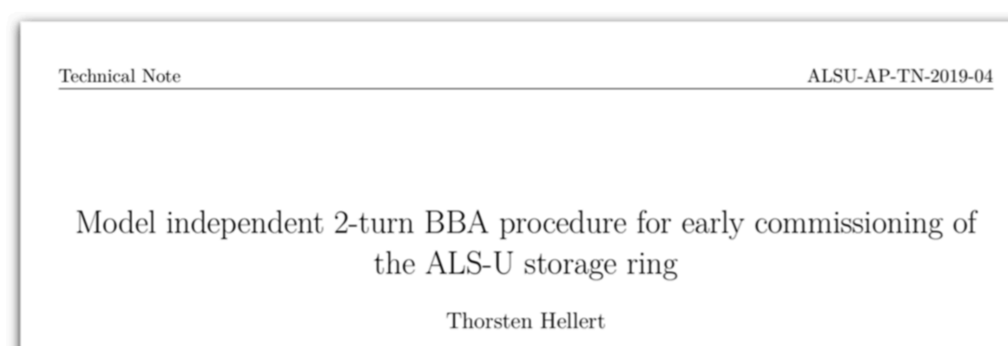




Startup demonstrated in simulations



ALS-U Technical Nodes


Technical Note ALSU-AP-TN-2019-04

Model independent 2-turn BBA procedure for early commissioning of the ALS-U storage ring

Thorsten Hellert

The role of bunch by bunch real time feedbacks in LESR

Alessandro Drago

INFN Frascati & Tor Vergata Rome University

- Having in mind this goal, the bunch-by-bunch feedback is not only a control system but also a diagnostic device that can work both as a simple bunch-by-bunch acquisition system and as a flexible generator of special excitations.

A Drago

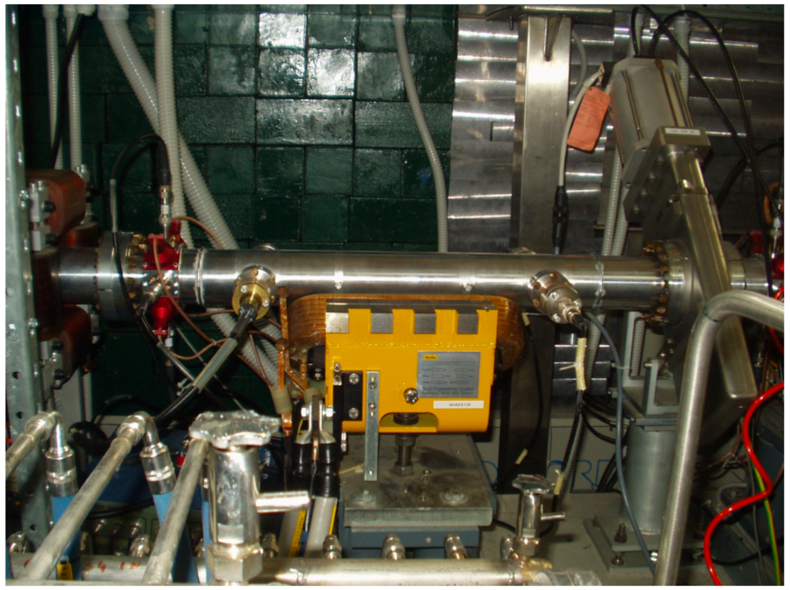
The basic R&D ideas to adapt the DAFNE transverse bunch-by-bunch feedback systems for low emittance beams were the followings:

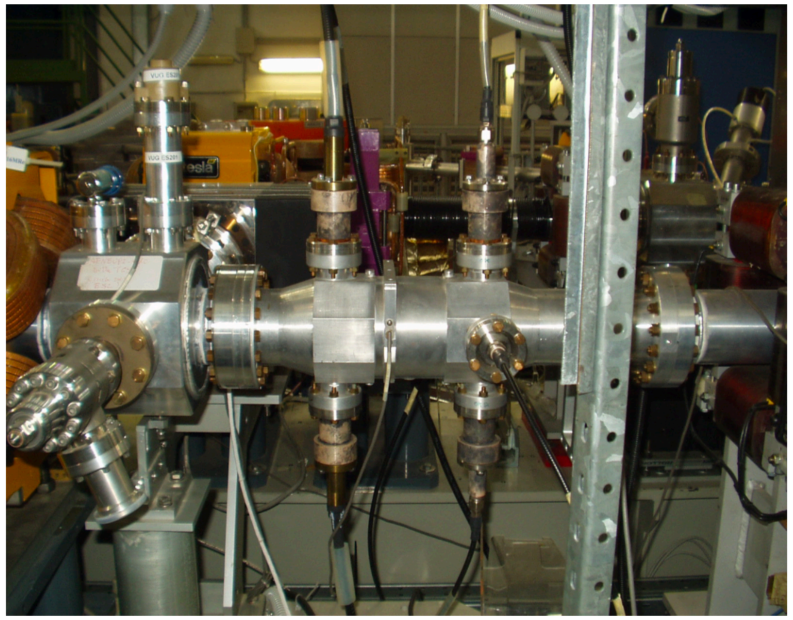
1) Less noise ==> low noise analog fe, ADC & DAC @ 12/16/20 bits
2) More sensitivity ==> low noise analog fe, ADC & DAC @ 12/16/20 bits
3) Larger dynamic range ==> ADC & DAC @ 12/16/20 bits
4) Better use of power signals ==> new kickers
5) Better beam diagnostics ==> bunch-by-bunch tune monitor
6) Adaptive control ==> automatic vertical gain control

Looking inside these points we can observe that they are strongly correlated, in particular for the first 4 items

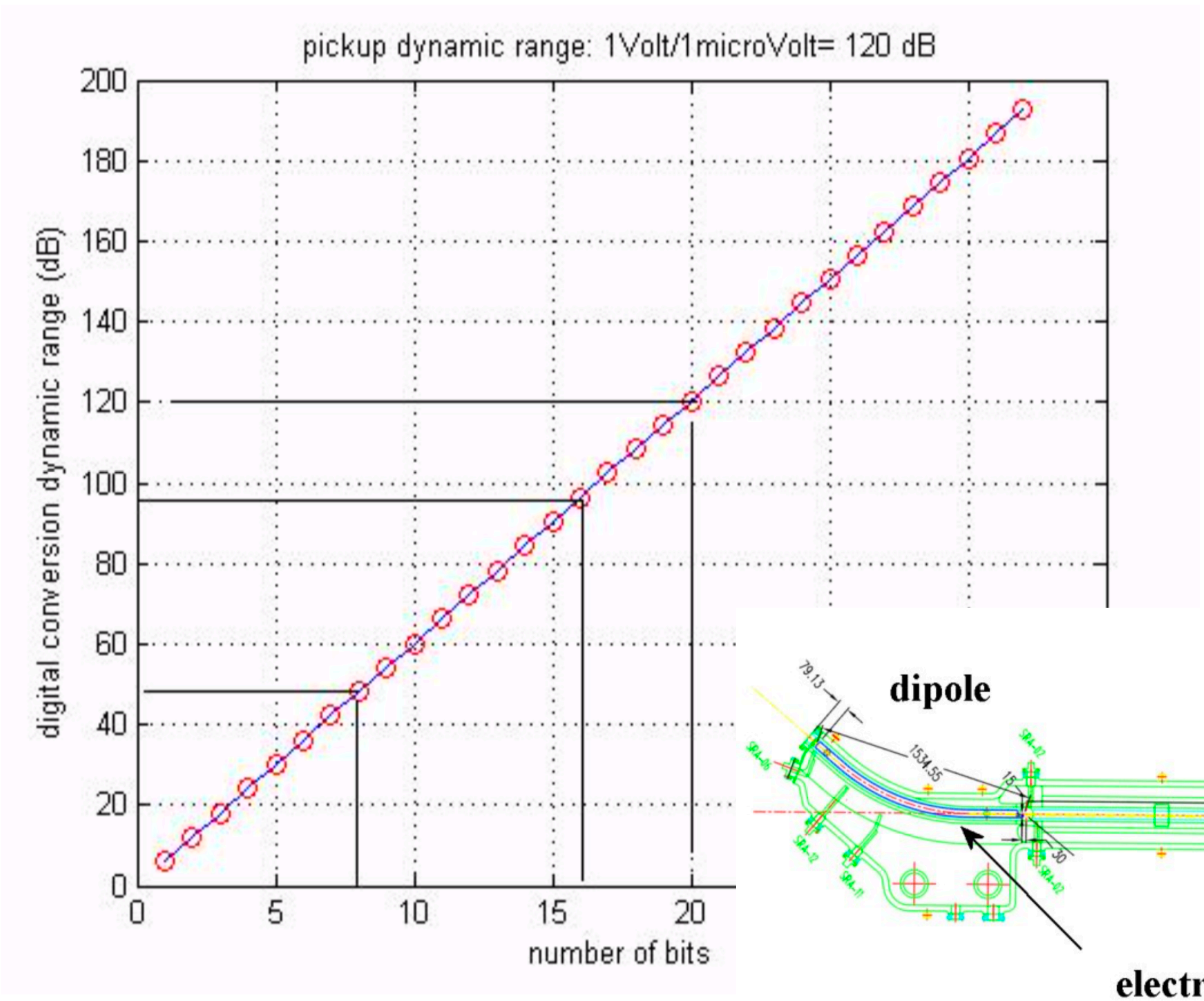
A Drago

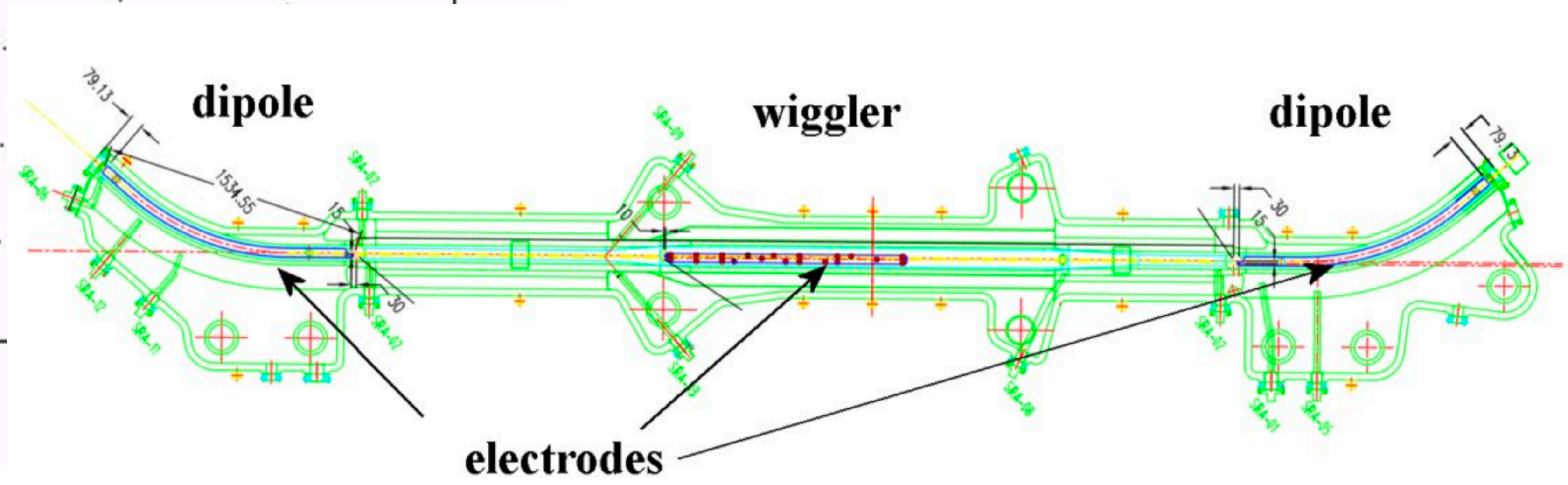
kickers





ADC matched to amplifier range (90-85 dB)



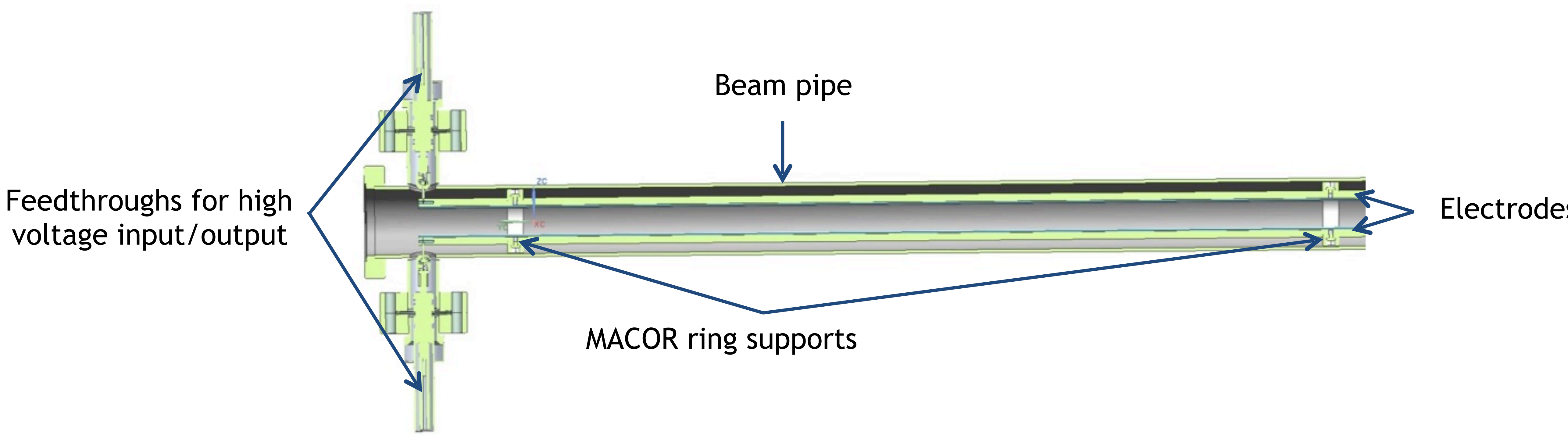


Summary Ilya Agapov:

- **Controls**
  - Unfortunately no talk
  - No apparent need for advanced modern software stacks
  - High level tools established at 3G rings largely adequate for 4G rings (e.g. MML)
- **Commissioning simulations and automation**
  - High sensitivity of 4G rings leads to need of highly automated startup procedures
  - No problems seen in simulations
  - However, error assumptions often quite optimistic
  - Procedures tested at 3G rings — ESRF will show if we are missing something out
- **Feedbacks**
  - 3G feedbacks concepts adequate for 4G in terms of e-beam stabilisation
  - No discussion of beam stabilisation at sample (e.g. for nano-focusing)

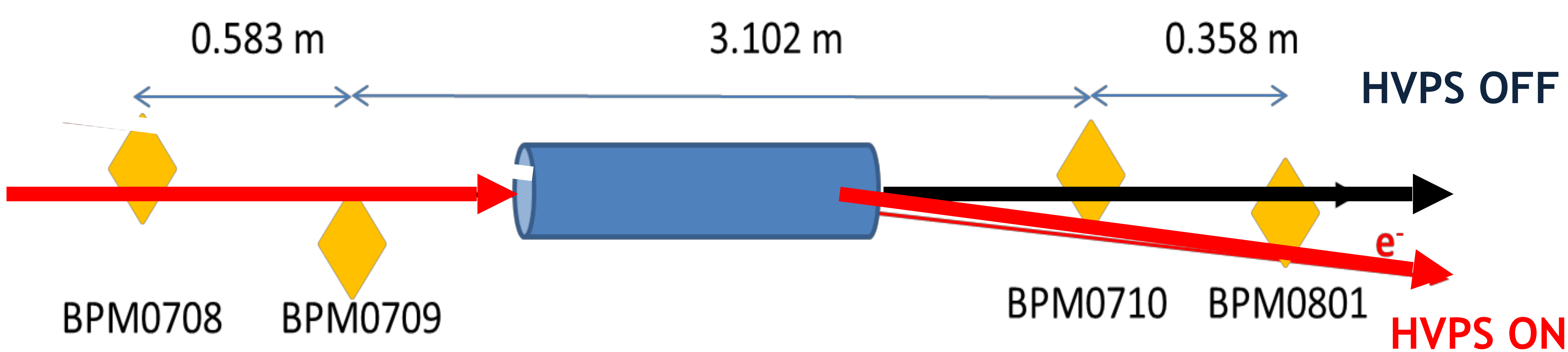
Commissioning of the CLIC extraction kicker at ALBA
U. Iriso

- Extraction kicker for CLIC has stringent stability requirements to guarantee stability, with high homogeneity and reproducibility (variable flat-top, 100 ns rise/fall time)
- Installed at ALBA for tests, with 2 additional BPMs to measure kick angle.
- Rotated 90 degrees for aperture reasons
- Issues with uncontrolled pressure rise above 120 mA – had to remove after 2 days
- Indications that synchrotron radiation impacting MACOR rings, and Loctite used to fix screws
- Re-installed after MACOR ring apertures modified and Loctite removed
- 2nd installation more successful, but limited to 140 mA.
- Indications from tunes and beam size that out-gassing / ion trapping occurring
- Decided to uninstall / reinstall every time it was tested



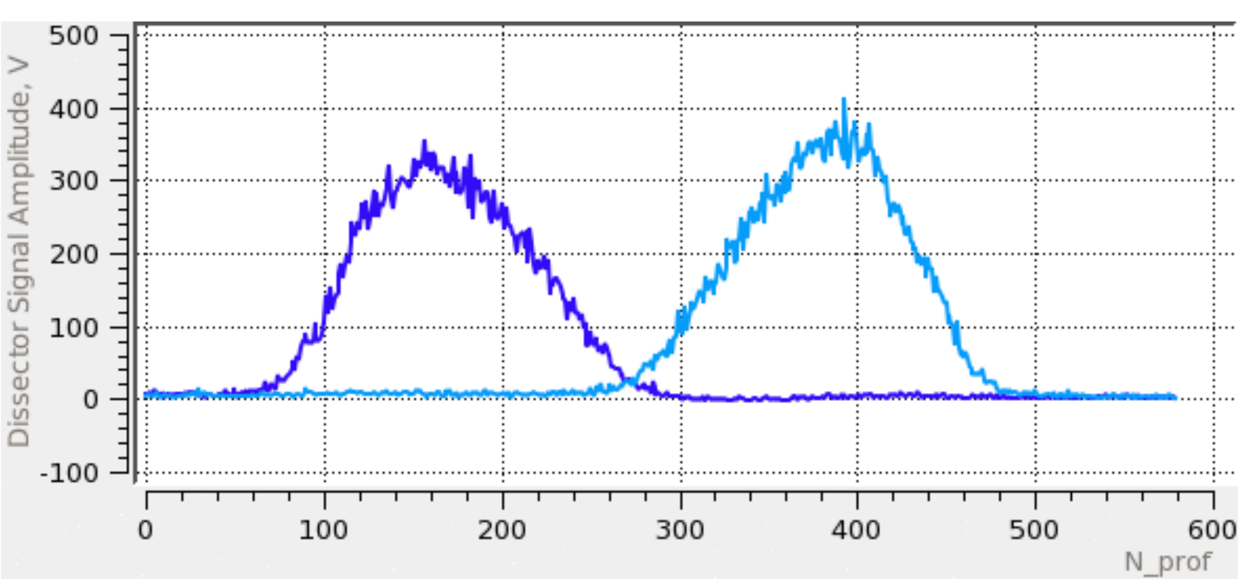
Commissioning of the CLIC extraction kicker at ALBA
U. Iriso

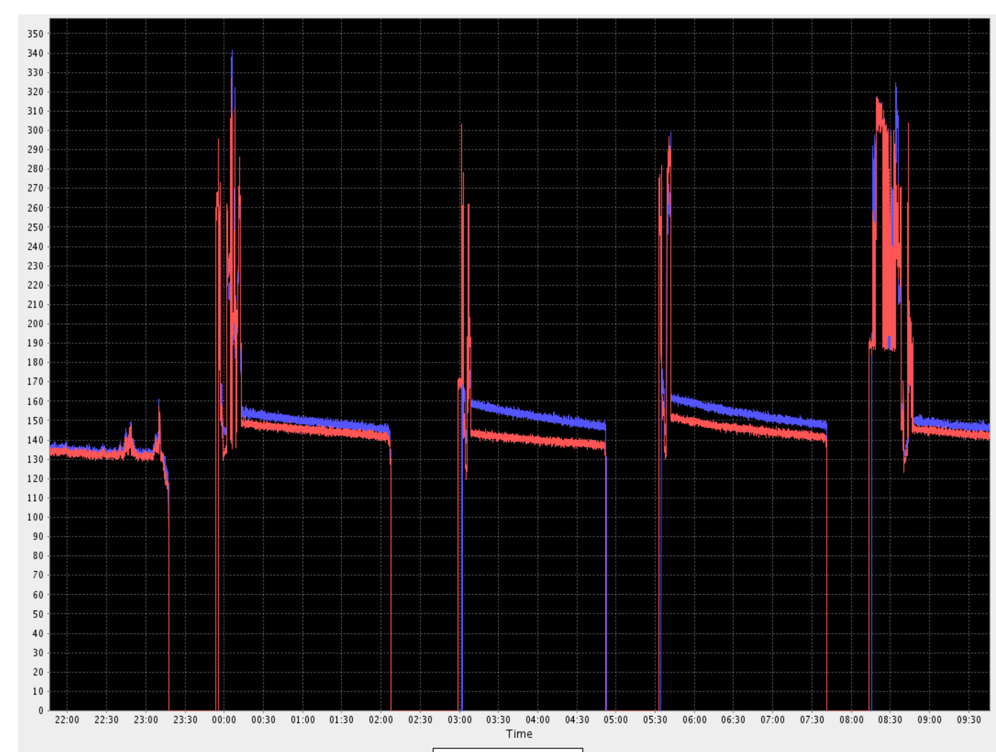
- Kick angle measured using 4 BPMs; had to calibrate BPM gain roll and offsets
- Kick at 10 kV close to theoretical value
- Homogeneity 3.7E-4 close to CLIC requirement (2E-4)
- Stability / repeatability measured by scanning single bunch delay
- Found inductive adders produced significant droop. Flat top improved to 0.02% after compensation
- Transverse impedance probed via TCMI threshold and tune slope. Noisy, but consisent with Gdfidl simulations
- Also measured using kick from local orbit bumps. Again noisy, but consistent with Gdfidl.



New Instrumentation for Optical Beam Diagnostics
O. Meshkov

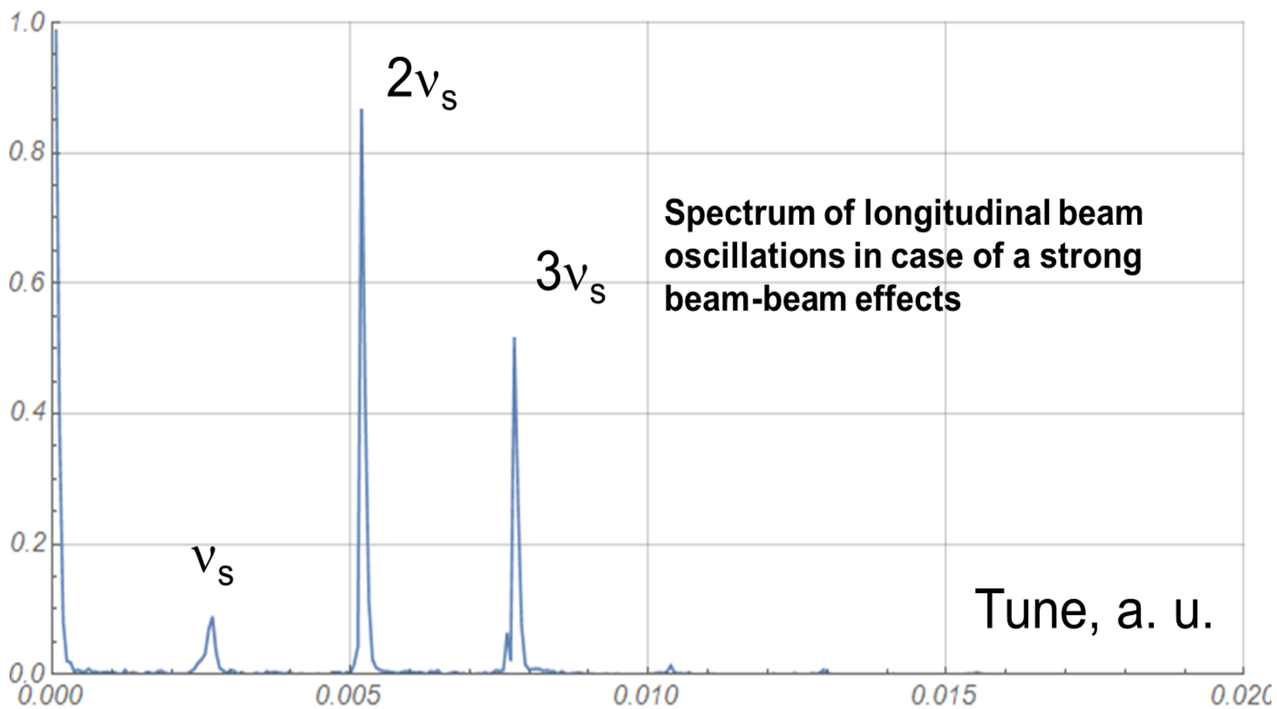
- Dissector – electro-optical device developed at BINP for measuring longitudinal bunch profile
- Provides continuous monitoring of bunch length / phase
- Under development for new synchrotron light source and e+e- collider projects
- Low frequency sweep voltage plus fast RF sweep. Head of streak camera combined with electron multiplier tube.
- Longitudinal profile obtained by measuring electron charge scanning across narrow slit
- Achieved temporal resolution of 1.7 ps
- Can offset slit wrt centre of the bunch to study dipole/quadrupole oscillations within the bunch

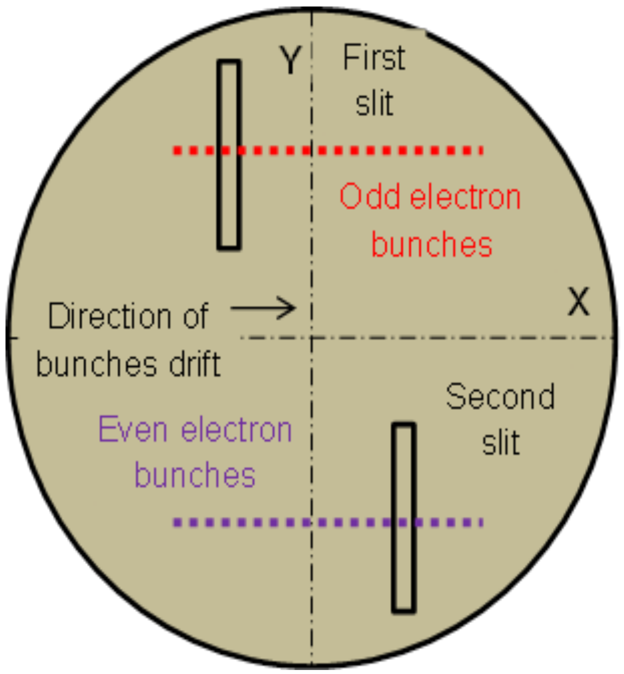


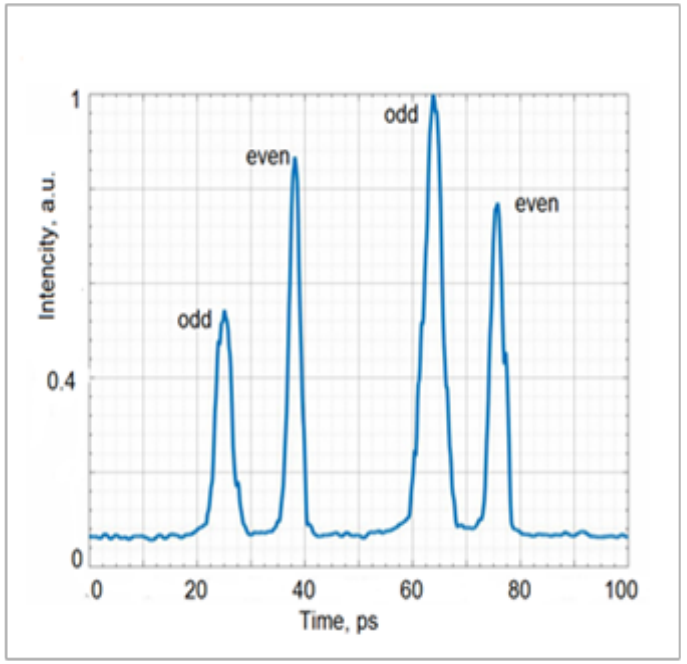


New Instrumentation for Optical Beam Diagnostics
O. Meshkov

- Can offset slit wrt centre of the bunch to study dipole/quadrupole oscillations within the bunch
- Use as phase detector to monitor synchrotron oscillations, or as turn by turn profile monitor
- Some issues still with isolating individual bunches in multibunch train
- Can use two slits to separate bunches occupying odd/even RF buckets
- Developing higher sweep frequency to improve temporal resolution







Some Considerations on First Turn Dedicated Diagnostics for LE Storage Rings
V. Schlott

- Number of challenges associated with LER (small apertures, small initial DA, poor match of injected bunch to SR, limited injector diagnostics, jitter/drift, …)
- Pre-requisites for BPMs: Excellent mechanical alignment of BPM pickups, mature design of components, equal cable lengths, correct cabling, calibration in lab, online integrity check.
- Ideal: DIAGNOSTICS SUPPORT COMMISSIONING, NOT OTHER WAY AROUND

- Desirable to have well understood / tuned injector before SR commissioning
- Transfer line: monitor position, emittance, profile, loss points, Twiss parameters, bunch charge, collimation(?)

- BPMs in first-turn / turn-by-turn mode main tool for storage ring
- Sum signal gives bunch current vs location in ring (beam threading, loss points)
- Build application for first turn corrections and identification of aperture restrictions
- Limited BPM accuracy for initial first turn (alignment error, displacement of feed-throughs, cabling, resolution at low charge)
- Can expect few hundred microns offsets
- Calibrate out if sufficient turns / closed orbit available
- BPM nonlinearity significant for small apertures – 1-2 mm linear region
- TBT data used for tune measurement / correction

Some Considerations on First Turn Dedicated Diagnostics for LE Storage Rings
V. Schlott

- Beam loss monitors provide diversity / back-up to BPM data
- High resolution for transfer line / injection straight (cerenkov fibre loss monitor)
- Distributed monitoring for storage ring (scintillator + PMT)

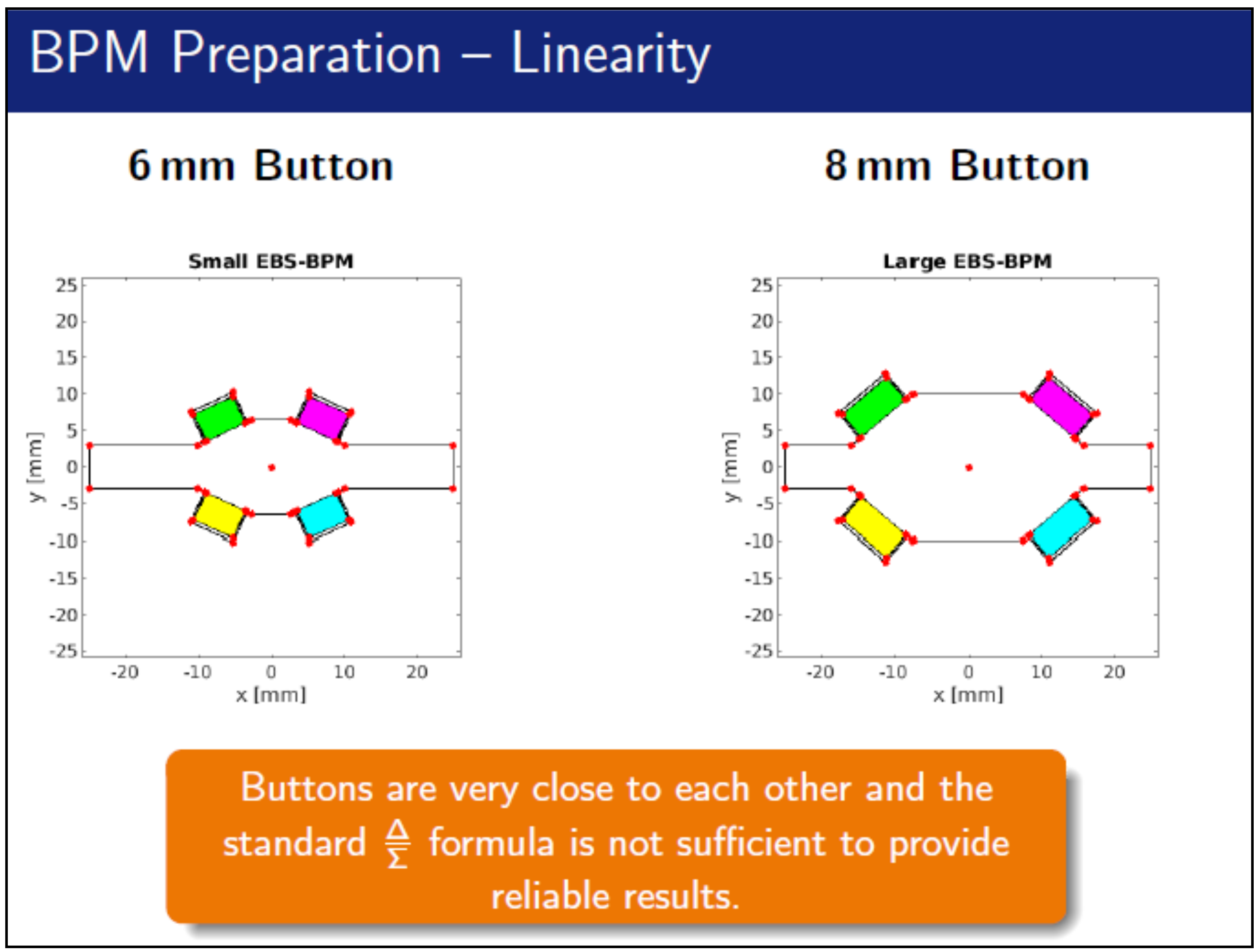
- Screens can be useful in transfer line / injection straight
- Synchrotron light monitor to image beam (later: also fill pattern, streak camera, emittance monitor..).
- Current monitors in booster, transfer line, storage ring for charge transfer. Used to calibrate BPM sum signal.

- Longitudinal on-axis injection diagnostics: streak camera (dynamic range for injected / stored bunch discrimination), Longitudinal multi-bunch feedback

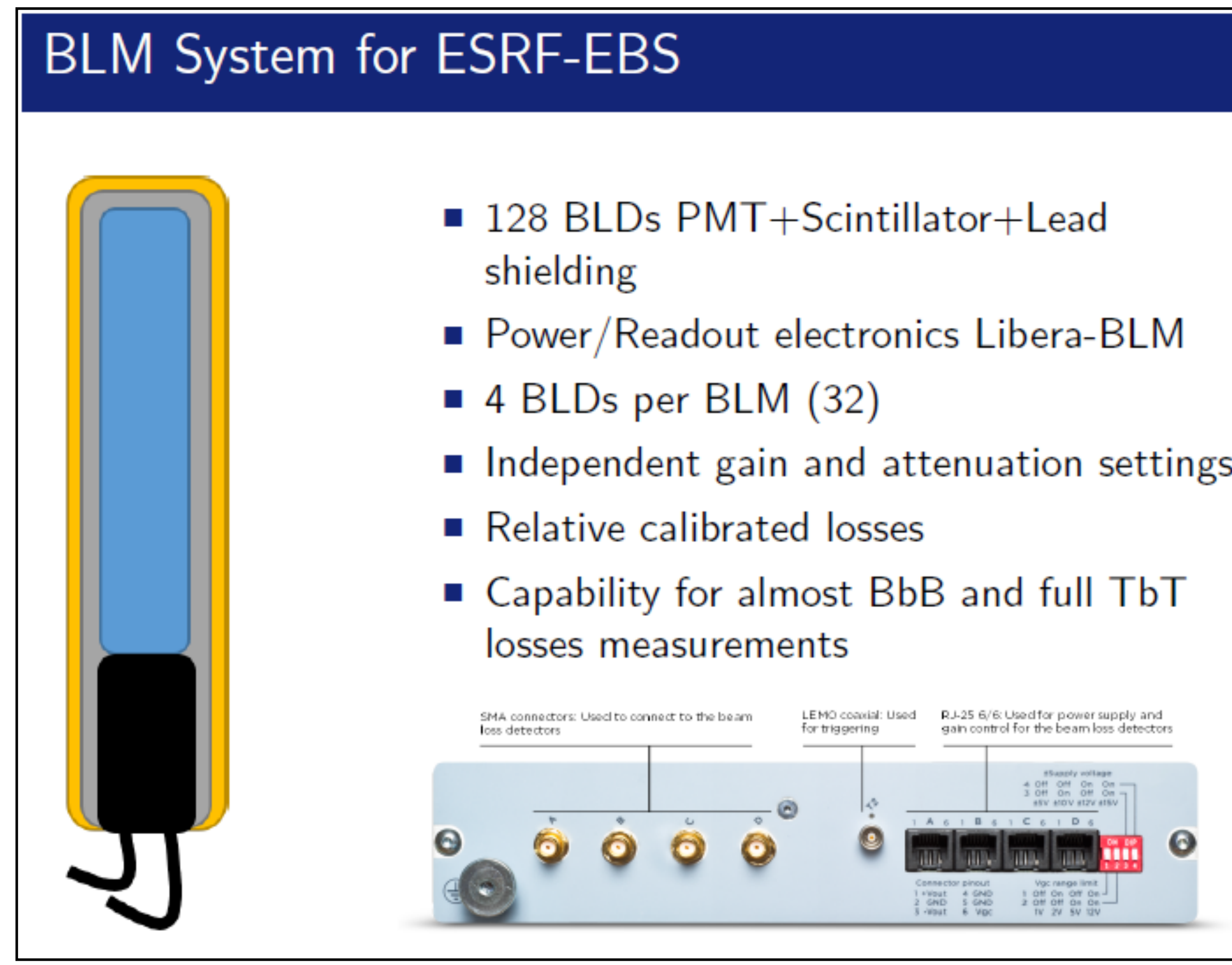
- Profile / emittance monitor during commissioning to verify optics / control coupling

Diagnostics for First Turn Commissioning and Beam Loss Detection, L. Torino (ESRF)

With small chambers, BPM linearity is compromised and need to use polynomial correction from Day-1



Extra-eyes are always good, so ESRF will use BLM with TBT capabilities from Day-1

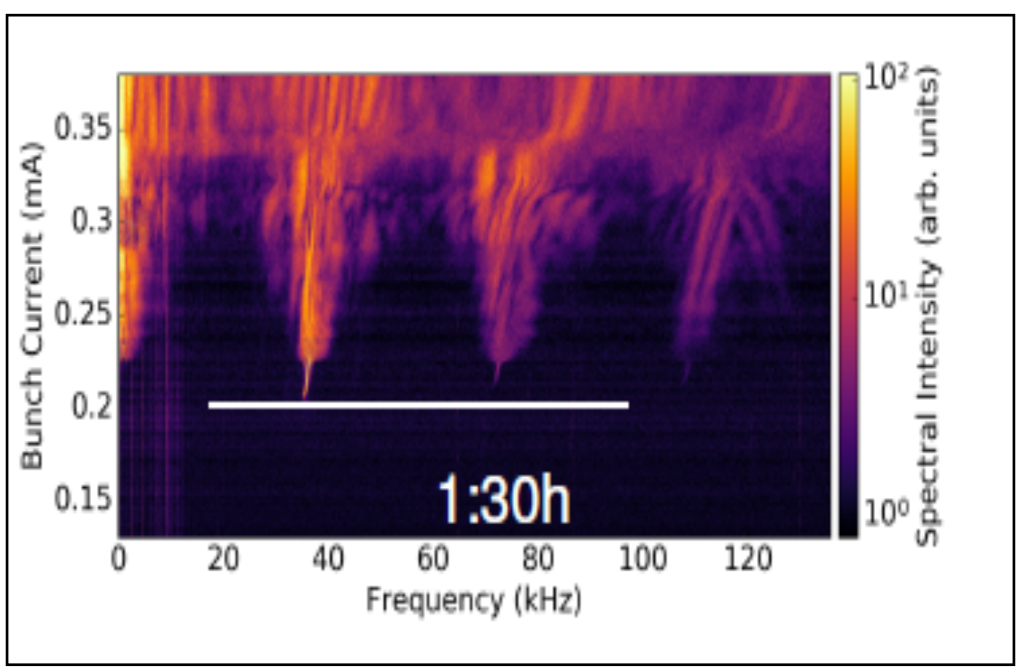


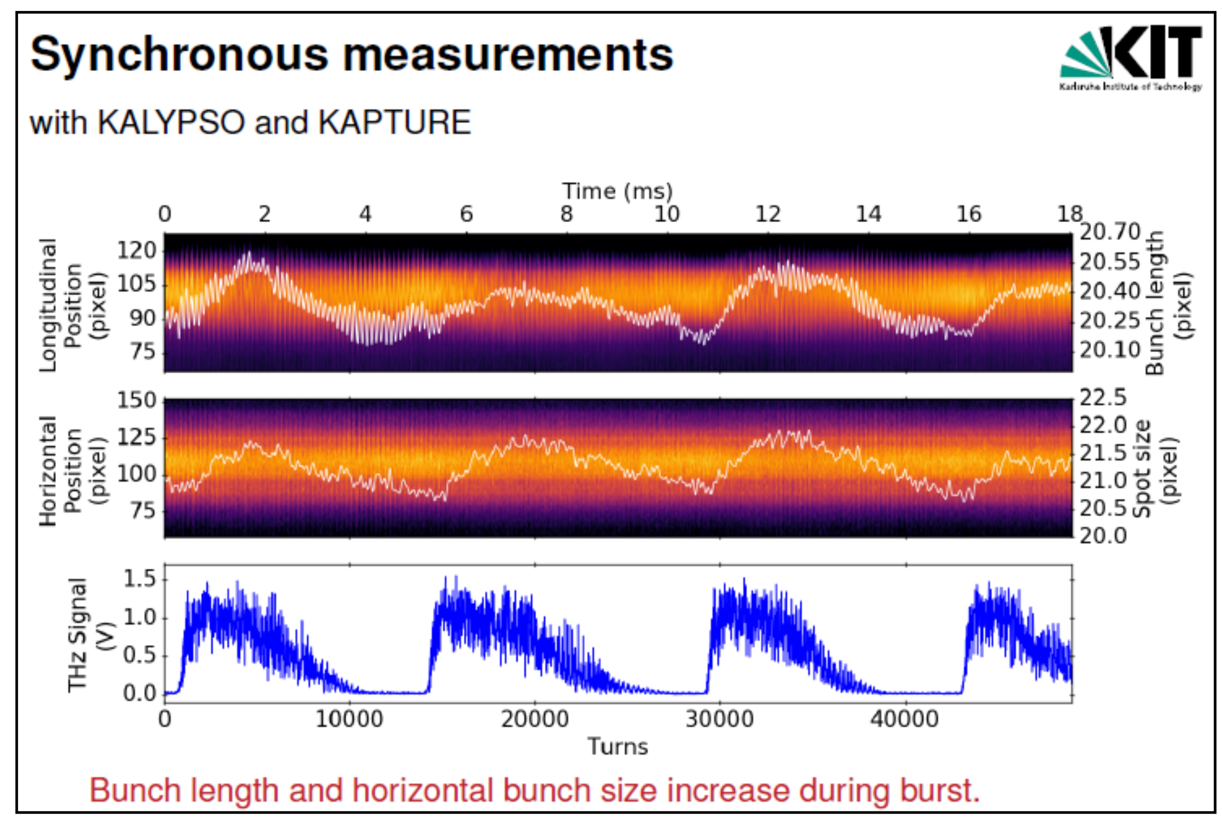
Studies of Microbunching Instability at KARA, M. Brosi (KIT)

Diagnostics Challenges: how do you get???
high resolution (ps) – high sampling rate (500 MHz) – long term observations (minutes)

Use dedicated Fast THz detectors
+
Home-developed Fast Electronics KAPTURE

Measurements of Energy Spread using KAPTURE and KALIPSO electronics





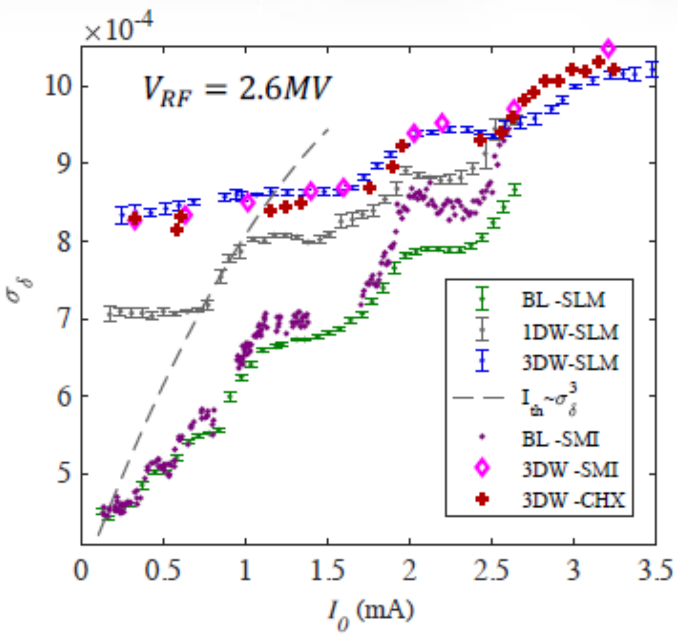
Novel Features in Longitudinal Instabilities in e- Storage Rings, A. Blednykh (BNL)

Different methods to diagnose Microwave Instability – diagnose Energy Spread

Using IVU spectra and SLM coincide

Energy Spread vs. Single-Bunch Current

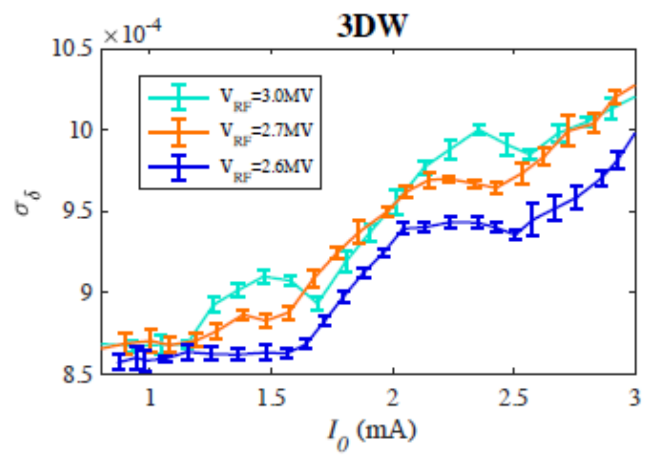
Experimental Data



Comparison of the measured $\sigma_\delta(I_0)$

$$\sigma_\delta(I_0) = \frac{1}{\eta_x}\sqrt{\sigma_x^2(I_0) - \varepsilon_x\beta_x}$$

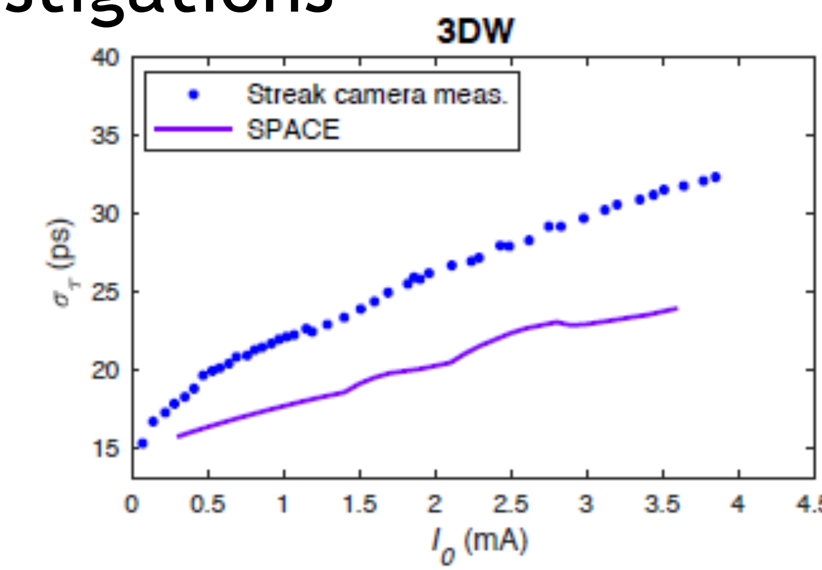
With $\sigma_x = 123um$, $\beta_x = 2.77m, \eta_x = 0.13m$ and $\varepsilon_x = 0.9nm$ for the 3DW - $\sigma_\delta = 0.087\%$



SLM data for the 3DW lattice

- Both methods detect well the local minima and maxima at different I_0

Bunch length measurements with the streak camera needs further investigations



- We believe, the instability thresholds can be detected from the bunch length measurements with a streak camera resolution better than $0.5ps$.