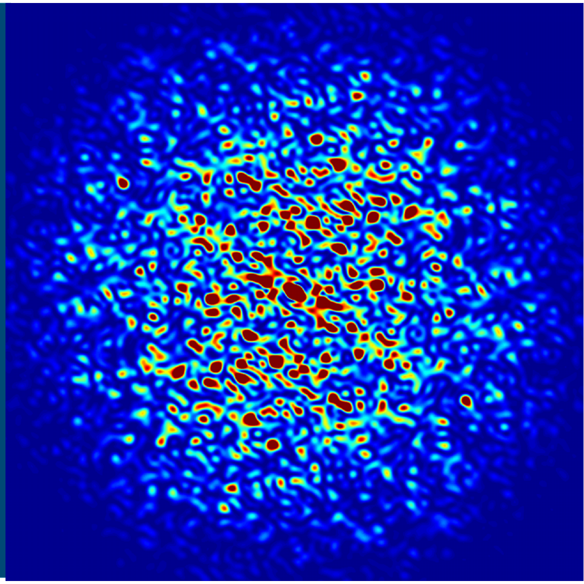
Commissioning Plan for APS-U



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Beam Tests and Commissioning of Low Emittance Storage Rings
Karlsruhe Institute of Technology
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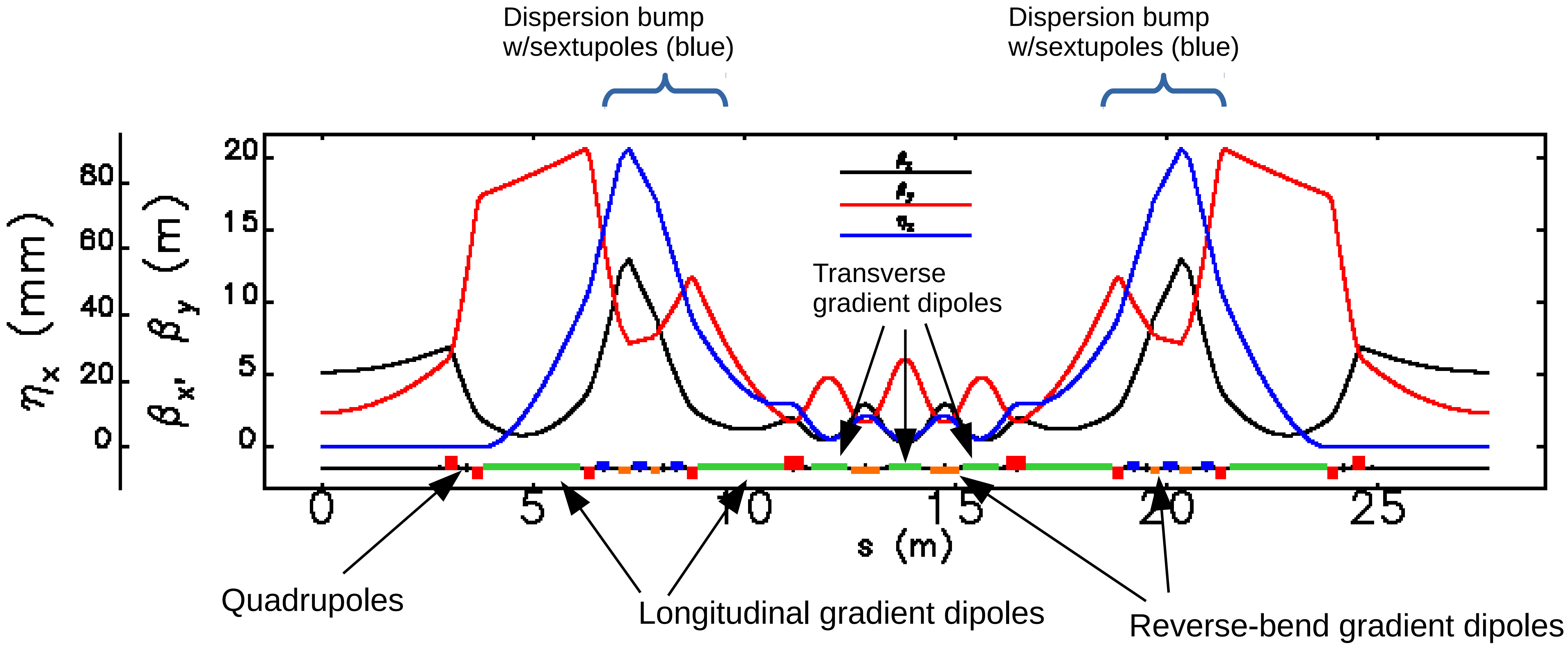
Outline

- Some lattice features first
- Some principles adopted
- Schedule of dark time
- Requirements before commissioning beam time
- Beam time activities

Hybrid 7BA Lattice Concept[1] Plus Weak Reverse Bends[2]



- Phase advance of $\Delta\varphi_x=3\pi$ and $\Delta\varphi_y=\pi$ between corresponding sextupoles chosen to cancel geometrical sextupole kicks
- Reverse bends (displaced quadrupoles) allowed the reduction of the emittance from 67 nm to 42 nm

1: L. Farvacque *et al*., IPAC13, 79.
2: J. Delahay et al., PAC89, 1161, A. Streun, NIM A 747, 148

Injector Requirement

Table 2.31: Injector requirements

Requirement	Value	Units
Charge per Bunch	≥ 17 (a)	nC
Charge stability	± 5	%
Horizontal emittance	60 (b)	nm-rad
Vertical Emittance	16 (b)	nm-rad
Energy	6	GeV
Energy stability (rms)	< 0.3(c)	%
Beam phase stability (rms)	100	ps
Injector Bunch Purity	$\leq 10^{-6}$	
Injection Rate	≤ 1	Hz
Injector Availability	> 97.5	%

Notes *Revised: 09-24-2018 (SVN Rev.541)*

[a] At storage ring injection septum
[b] Target numbers - minimum requirements are still under evaluation
[c] Present injector achieves 0.1%

Need to inject into booster with zero momentum error

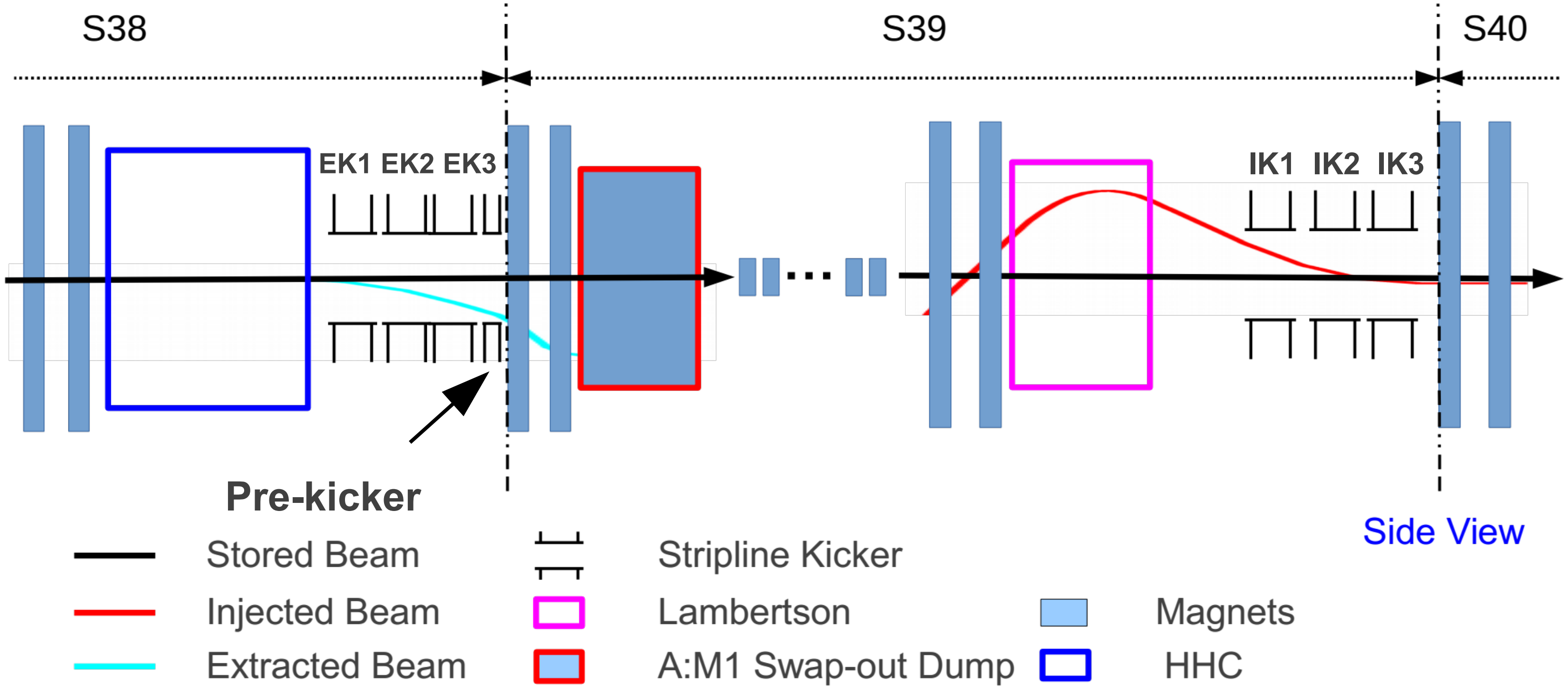
Need to extract from booster at negative off-momentum error, say -0.6% or more

Booster to SR synchronization

Booster frequency will vary during energy ramp according to adjustable ramp program in order to:
1) meet circumference requirement at each end of cycle
2) vary path length to target one of 1296 rf buckets in the ring

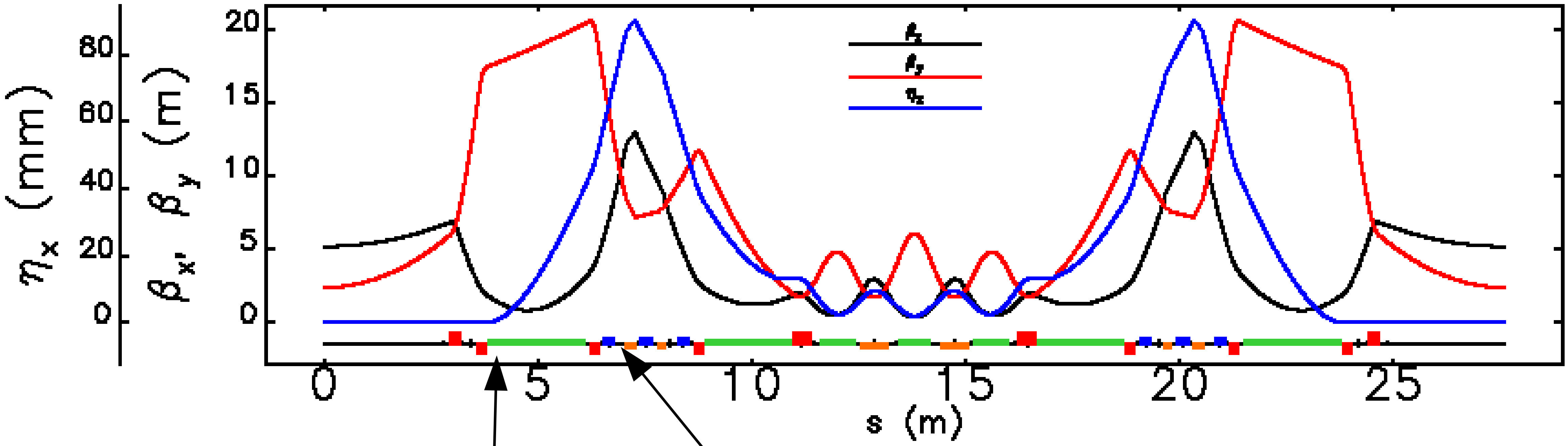
Swap-out Injection, Vertical plane

- On-axis "swap-out" injection[1,2,3] is an alternative to accumulation
  - Each injector shot replaces an existing stored bunch – brightness dips for one bunch for about two damping times
  - DA only needs to accommodate the injected beam size
- Pre-kicker for inflating the target stored bunch 50 turns before extraction



1: E. Rowe *et al*., Part. Accel. 4, 211 (1973).
2: R. Abela *et al*., PAC91, 486 (1992).
3: L. Emery *et al*., PAC03, 256 (2003).

Collimators and beam dumps



Vertical beam dump
in sectors 39 and 1
For swap out.
Also for bunch by bunch “slow” beam aborts with pre-kicker

Horizontal collimators for Touschek scattering
in sectors 36, 37, 38, 39 and 1
Whole beam aborts (4400 J), which damages surface, requires refreshment

Some principles followed

- Achieve more than the “Key Performance Parameters” promised to funding agency (DOE), but plan to do a little more in the 3 months of commissioning
- Full 200 mA not expected at end of three months. 50-100 mA?
  - don’t need fully operational LFB or Higher-harmonic Cavity (HHC)
- Accelerator interlock system (ACIS) to be the last thing to install before beam (for convenience of entering the tunnels for PS testing, etc)
- Presently thinking of installing and keeping IDs in the ring for the initial beam tests, as risk for damage is thought to be low
- Diagnostics to be made ready as much as possible before introducing beam
- In detailed plan, allot time for commissioning diagnostics along with beam or beam optics.
- Allot time for feature beamlines to use synchrotron light near end of commissioning period
- Invite some external machine physicists for commissioning
- Select fixed one/two days of the week for tunnel intervention, if necessary. (say Monday/Thursday)
- Once ACIS is implemented, control room operators (technician), two on shift, possibly a third one

Schedule of Dark Time

- Tentative Start on June 2022 (just to have some reference)
- 9 weeks of equipment removal, slowly transitioning to ...
- 6 months of installation
- 3 month of injector beam time and storage ring beam time (start, say, March 2023)
- Transition to operations June 2023 (say)
  - No intervening shut-down for a good start of operations!

Equipment requirements before beam time

- Goal is to make beam time efficient, i.e. no partial installations
- Essential hardware were identified for preparation
- Complete vacuum system installed and vacuum < 10 nT N2 equiv.. Includes HHC and LBF kicker cavities.
- All magnets in SR and new parts of BTS, measurements available in control system
- Main rf system and cavities (12) ready to support 30 kW/cav
- Injection kickers (striplines) and DC septum
- Booster to SR synchronization system operational (timing determined with beam later)
- Diagnostics:
  - all bpms to report single pass and turn-by-turn for 1 nC.
  - Beam current monitors
  - Tune measurement system
  - H and V diagnostics kickers
  - BTS emittance diagnostics
- Control system for above plus vacuum water, tunnel temperature, etc.
- Alarm handlers
- High-level applications (to be reviewed, re-written or created)

Equipment requirements before beam time (cont'd)

- Some way of doing slow orbit feedback using rf bpms
- Tunnel air regulation 2 deg F
- VC water cooling operational
- IDs installed and aligned and gaps open. Gaps control after one month of commissioning
- SC undulators installed and cooled down
- Data loggers for EPICS PVs are running
- Beam swap-out and abort systems operational
- Beam dumps are installed in correct positions
- MPS and ACIS are validated without beam to the extent possible, and ready to be validated with beam
- Synchrotron light monitor is ready to show a beam image

Equipment requirements for a higher current, say 10 mA

- Orbit feedback ready to operate at some reasonably high bandwidth (say 100 Hz) using the rf bpms
- Decoherence kicker and swap-out system fully validated
- Beam-position limits detectors fully validated
- RF system is conditioned and is ready to support high beam current ramp.
- Beam size monitor is ready to resolve 0.4 pm Y emittance
- Beam size monitor is ready to confirm 42 pm X emittance
- RF cavity temperature control is ready for current ramp up
- X-ray BPMs are operational
- Hydrostatic leveling system is operational
- Bunch lengthening cavity is ready to support ramp up to full beam current
- Transverse and longitudinal bunch-by-bunch feedback is ready for commissioning with beam

Beam time activities; tasks in rough time sequence

- Booster-SR synchronization, Part A (i.e. recommission injector system (booster on momentum)
- Commission new BTS line, Part A (trajectory)
- Booster-SR synchronization, Part B (booster off-momentum)
- Final rf frequency ramp of booster interleaved with SR first few days activities
- **First turn (plus rf bpm check-out), multiple turn trajectory, stored beam, one bunch** (Sajaev, tomorrow)
- Characterize lattice, Part A (including rf bpm offset)
- Swap out single bunch
- Vertical and Horizontal Collimators
- **Commission new BTS line, Part B (optics) – note that booster emittance Is large**
- **Booster-SR synchronization, Part C (booster on frequency ramp)**
- Stored beam in many bunches (>10 mA from here on)
- Test some undulator beams (shutters closed) – setup FF corrections
- Fast orbit feedback
- Photon diagnostics
- Emittance-ratio (coupling) control
- Various bunch patterns
- HHC cavity check-out for some voltage generation
- Condition vacuum with stored beam (target 10 A h)
- Characterize lattice, Part B (same as Part A but with higher current)
- TFB operational
- LFB operational single rf
- Undulator beams with users (feature beamlines)
- HHC operational for some bunch pattern and current (optional)