Two Orbit – first scheduled week of TRIBs user operation at BESSY II

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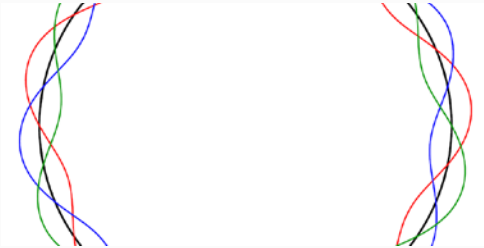
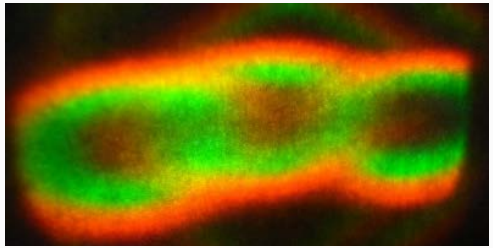
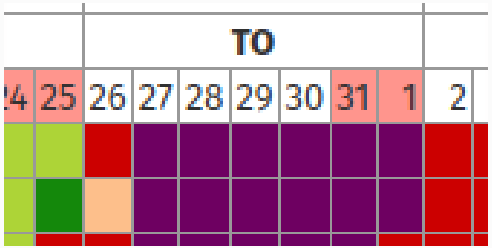
BESSY II / MLS machine group

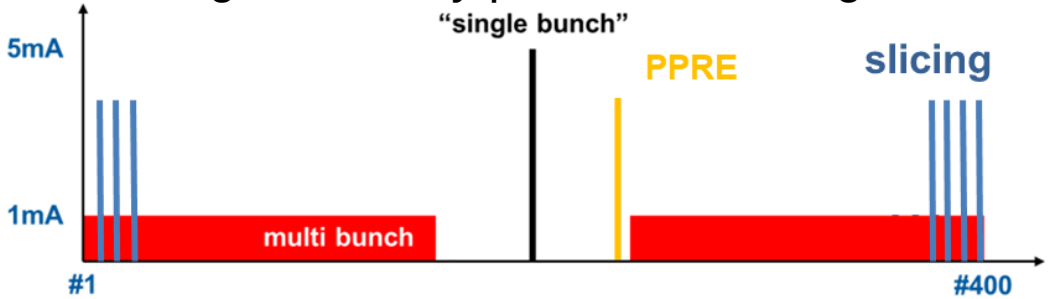






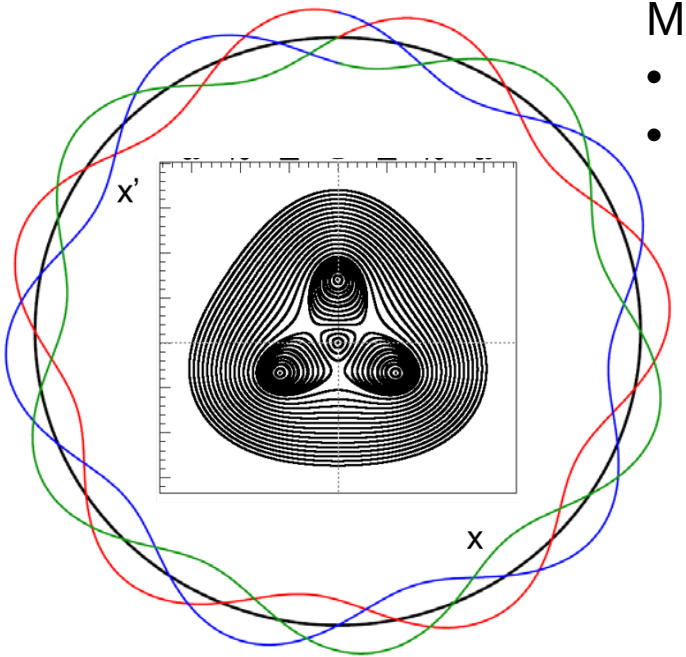
BESSY II

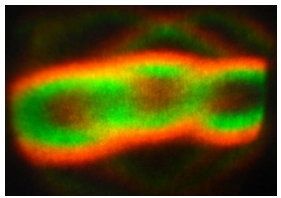
- in user operation since 1998
- diverse user community
- offering short x-ray pulses and timing



Parameters	
Energy	1.7 GeV
Circumference	240 m
Horizontal emittance	7 nm rad
Beam current	300 mA
RF frequency	500 MHz
max. RF voltage	2 MV
Bunch length (zero current) low-α	10 ps 2 ps
Mom. Comp. factor low-α	7.5×10^{-4} 3.5×10^{-5}

The idea – Transverse resonance island buckets (TRIBs)



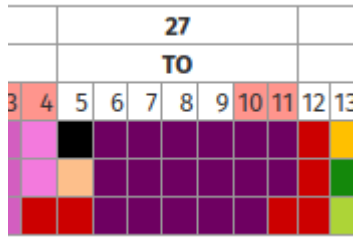


MLS

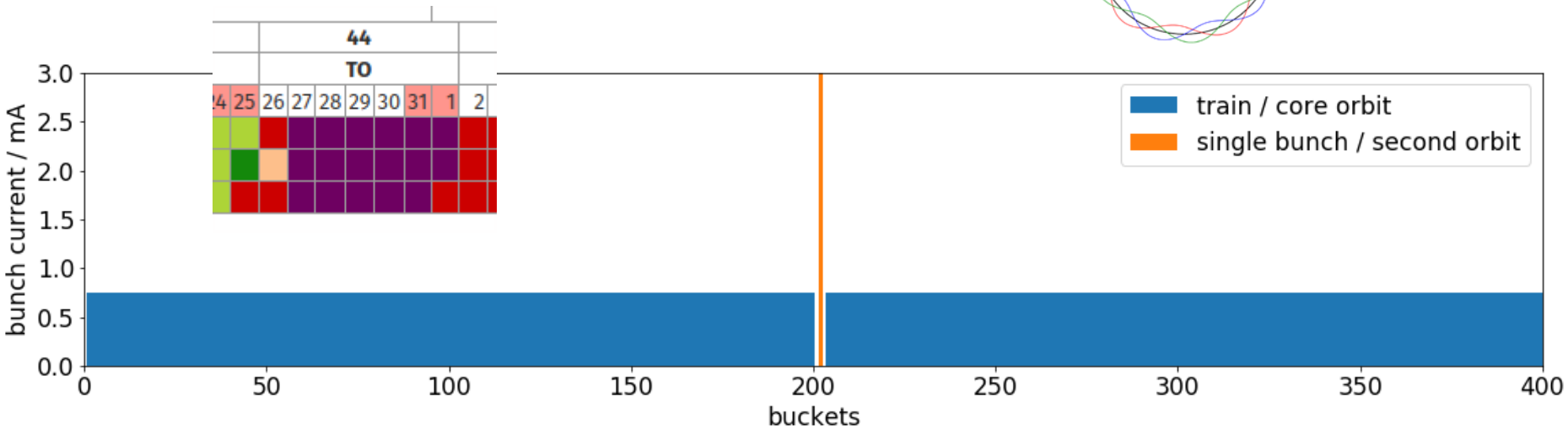
- first observation
- development of techniques and basic understanding
  - nonlinear dynamics
  - resonant population
  - Single island population with nonlinear resonant kicking
- proof of principle user operation

BESSY II

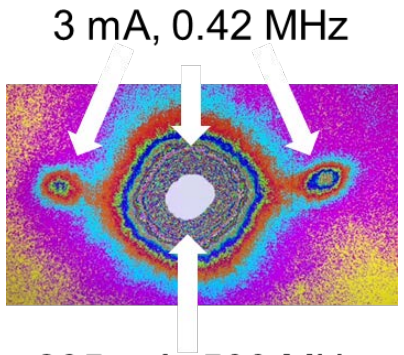
- TopUp as additional challenge
- 2018:
  User test week
- 2019:
  MHz-XMCD demo
- 2020:
  scheduled user operation
- 2021:
  scheduled user operation



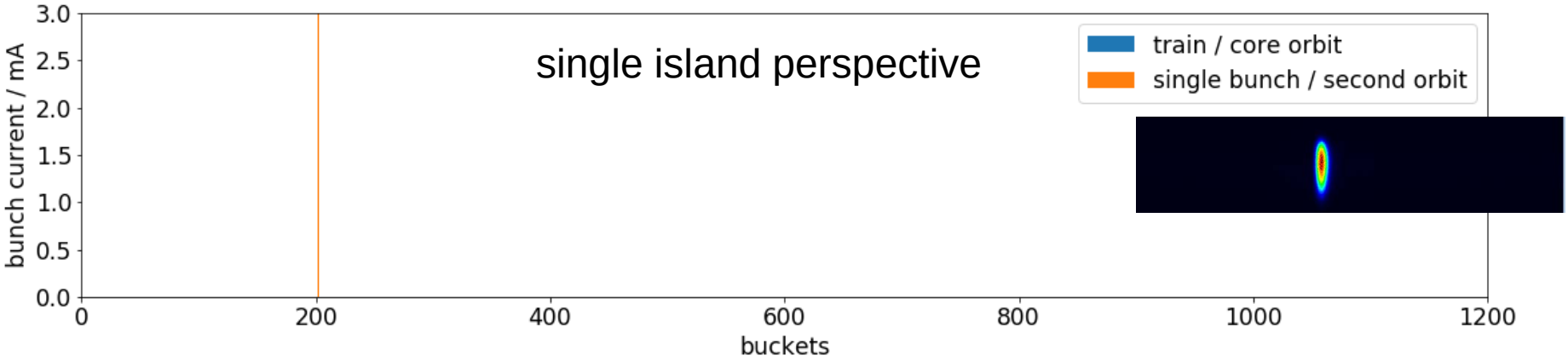
Scheduled TRIBs user operation week

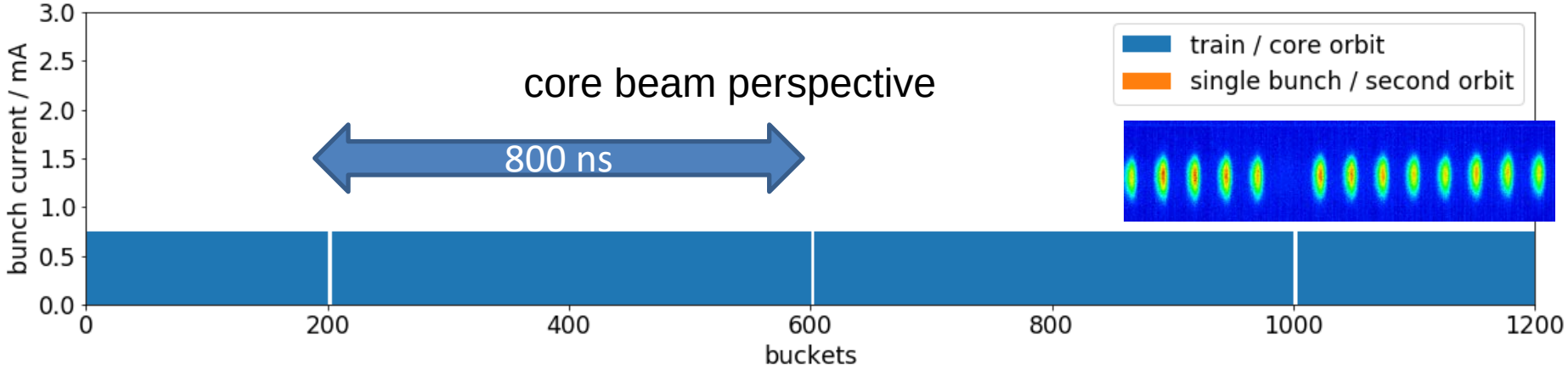


- steady operation for the full week
- separation tweaked towards horizontal plane
- all IDs usable (except U17 → MPS)
- no slicing (no efforts in this direction at the moment)



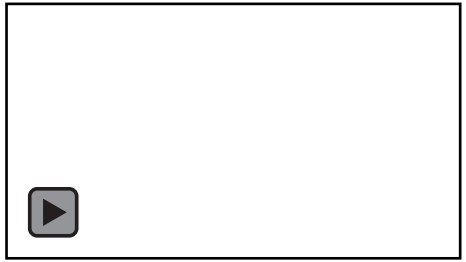
What filling pattern was offered?



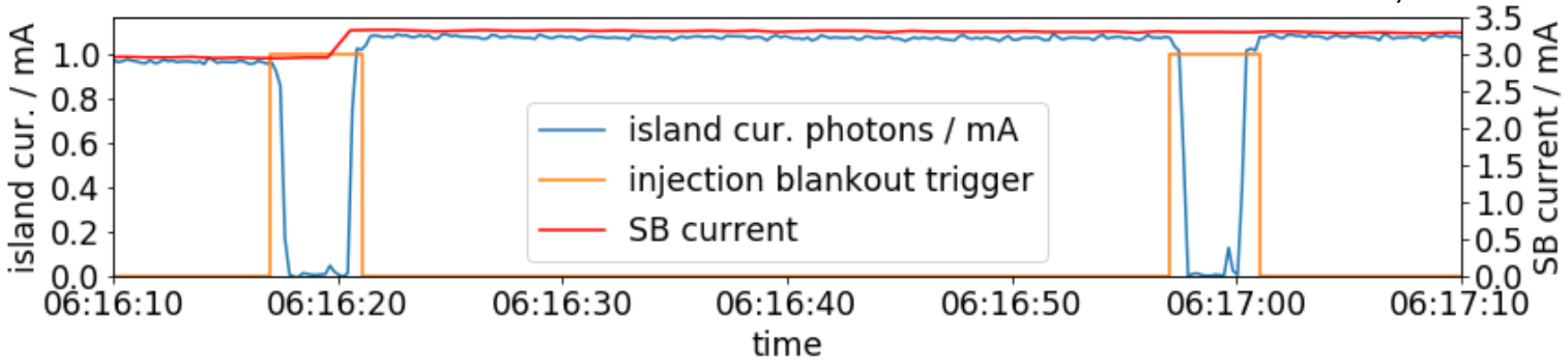


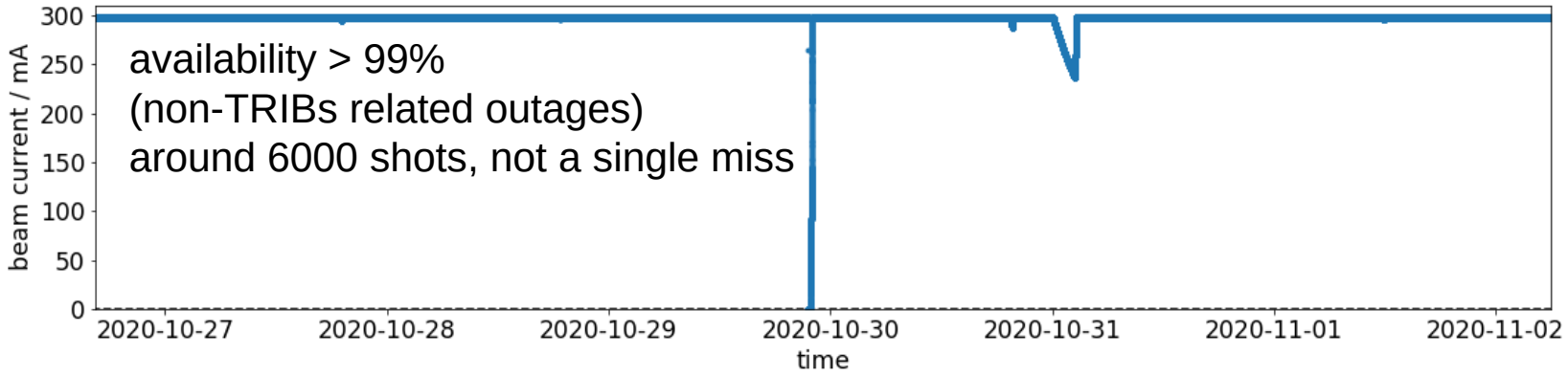
- island charge collapsed to core bucket for the injection process
- nonlinear resonant clearing of the train to avoid diffusion to island buckets
- resonant nonlinear & dipole repopulation of filled island buckets
- blank-out signal of 4s (control system based)

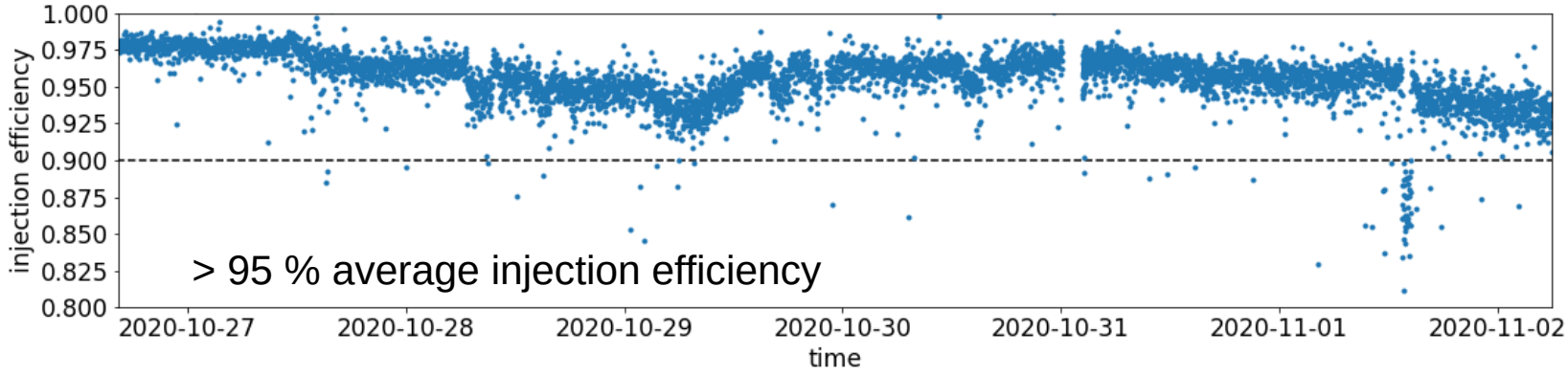
3 mA, 0.42 MHz



295 mA, 500 MHz

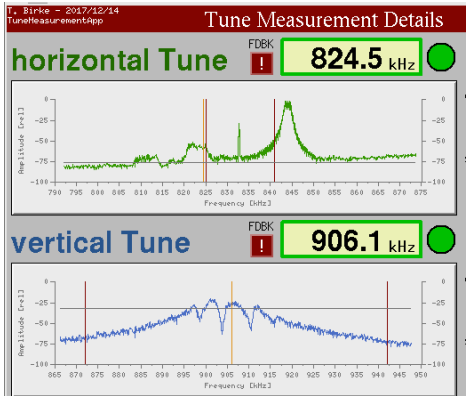



availability > 99%
(non-TRIBs related outages)
around 6000 shots, not a single miss
beam current / mA
300
250
200
150
100
50
0
2020-10-27
2020-10-28
2020-10-29
2020-10-30
2020-10-31
2020-11-01
2020-11-02
time


> 95 % average injection efficiency
injection efficiency
1.000
0.975
0.950
0.925
0.900
0.875
0.850
0.825
0.800
2020-10-27
2020-10-28
2020-10-29
2020-10-30
2020-10-31
2020-11-01
2020-11-02
time

General machine setup parameters

parameter	value	Unit
beam current	300	mA
island current	3	mA
Hor. Tune (core / island)	17.660 / 17.681	
Vert. tune. (core / island)	6.728 / 6.730	
coupling	~1%	
chromaticity (hor/ver)	0.3 / 3.2	
bunch by bunch feedback	X/Y/Z ON	
fast orbit feedback	running	
tune feedback	Slow (6s), core only	



- it works!
- there is potential for improvement

- required injection efficiency achieved
- resonant repopulation works reliable and has not yet reached speed limits
- high electron population purity achieved and maintained (> 1000)
- no issues with ions observed
- phase tracking of core tune & feedback works
- effects of IDs on island beam are smaller than expected but need to be taken care of at smallest gaps (SB user disturbed)

  U49D4 → island orbit / potential well / diffusion rates

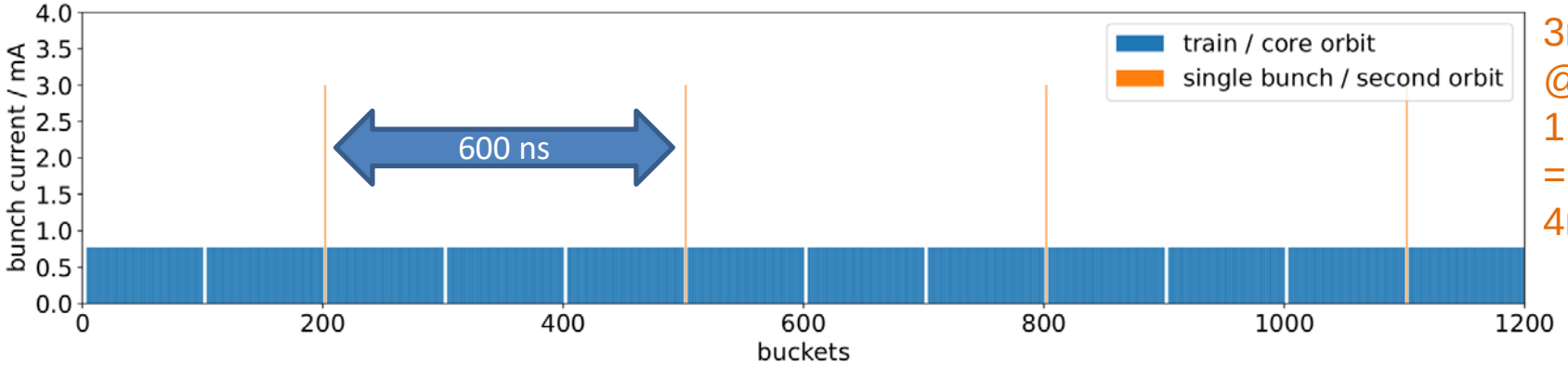
  UE52 → injection efficiency

- beam position not easily determined…
  requires bunch resolved measurement as well as single-island population
  → CPMU17 – locked for machine protection considerations
- small chromaticity has consequences

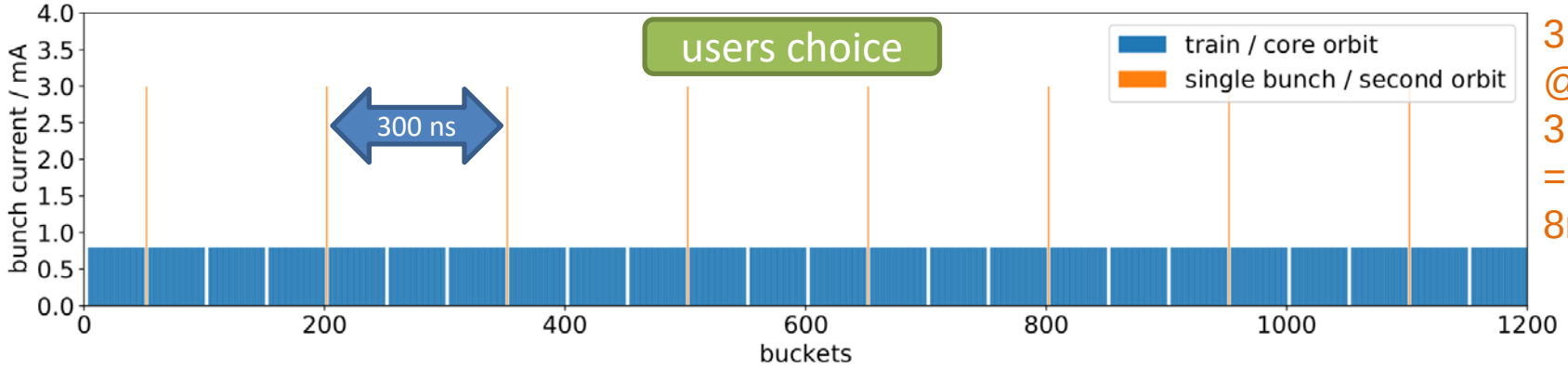
- effect of gap & shifts visible, crucial to be improved for selected (old) IDs
- test harmonic sextupole feedforward tables

- Users have to get used to this mode of operation (as we have to)
  - Normalization
  - Different rep rate “rhythm”

Proposed filling patterns for TwoOrbit operation

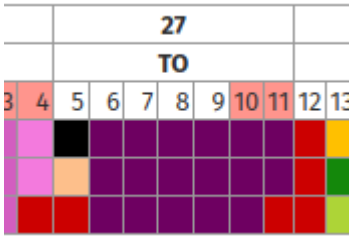


3mA @ 1.67MHz = 4mA/800ns



3 mA @ 3.33MHz = 8mA/800ns

Summary



- machine point of view: TRIBs user operation successful!
  close to established quality, more improvements seems to be in reach
- next week: CW27 2021
- coupling / vertical displacement of islands reduced in a first step
- IDs: feedforward tables to be optimized, harm. sextupole feedforward to be done
- Speed up injection process → sub second, hardware blank out trigger

- Investigation of dedicated operation modes exploiting new beam qualities
  - TRIBs MHz XMCD
  - TRIBs two color

- machine protection remains an issue
- from our experience many things get easier with higher energy and smaller emittance…

ACKNOWLEDGEMENT

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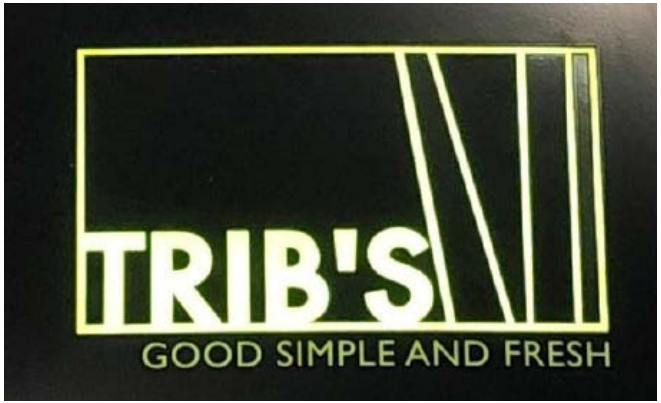
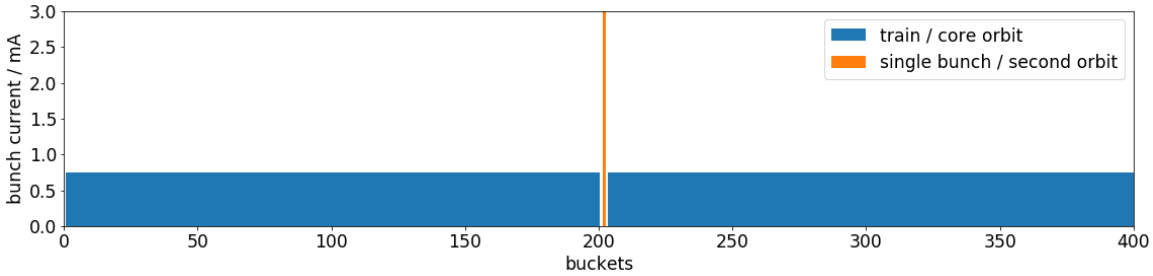
THANK YOU FOR YOUR ATTENTION

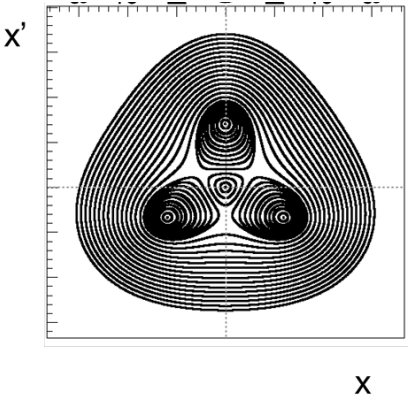


Backup

15

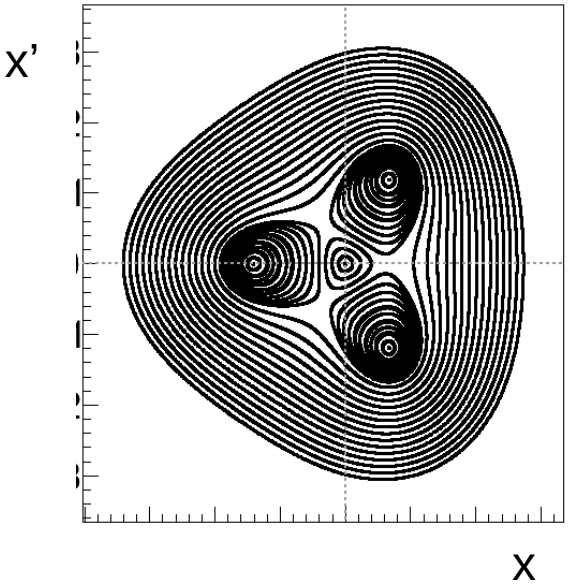
- transverse chromaticity will spoil the amplitude dep. Dynamics, i.e. smear out the phase space
- high chromaticity is the standard approach for high bunch charges
- in contrast: alpha buckets in longitudinal phase space → chromaticity and amplitude dependency are naturally aligned

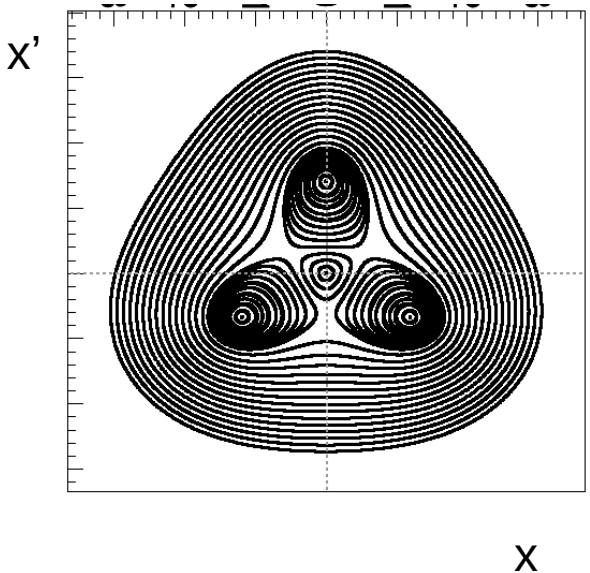




- 1x stripline kicker
  - used as dipole kicker
  - affects core beam and island beam (res. frequency)
  - used for bunch by bunch feedback
  - attached to a bunch-by-bunch-generator
- 1x stripline kicker
  - used as nonlinear kicker
  - attached to a bunch-by-bunch-generator (3 x harmonic number)
  - affects mainly island beam (amplitude, res. frequency)
  - used for single island population
  - poor accelerator physicists approach: half a stripline kicker

NONLINEAR RESONANT KICKING TO POPULATE A SINGLE ISLAND

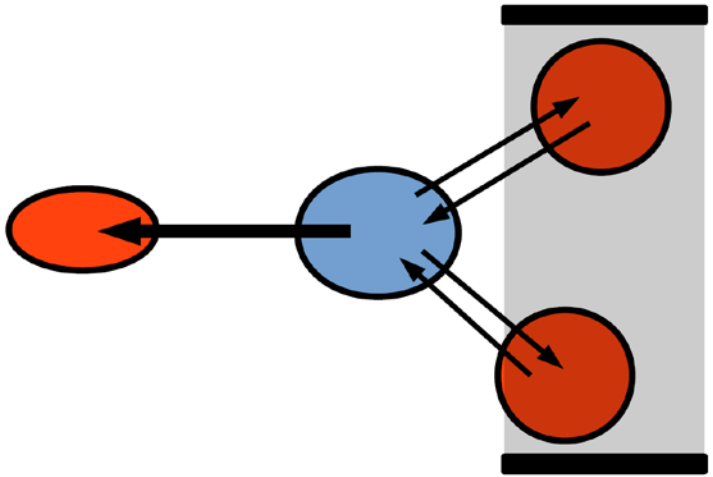




NONLINEAR RESONANT KICKING TO POPULATE A SINGLE ISLAND

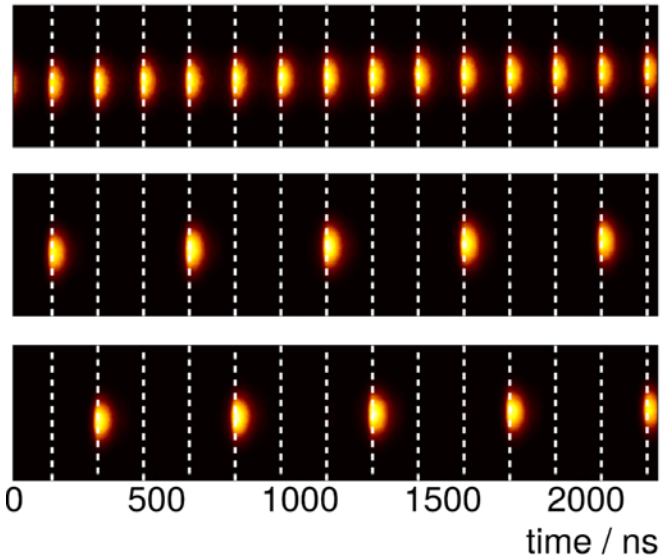
How to populate a single island?

→ Nonlinear kicking (half a stripline kicker)



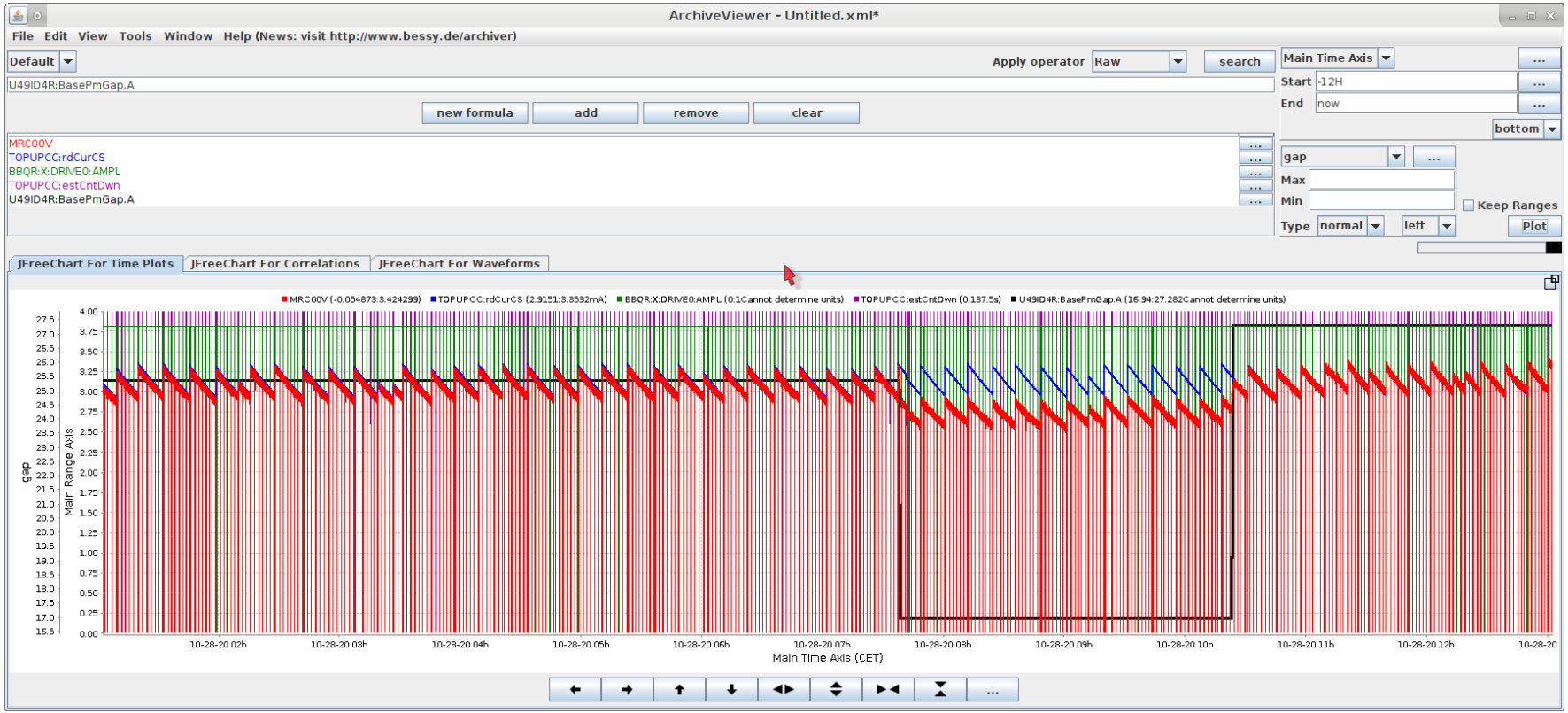
kick-kick-pause or kick-pause-pause scheme depending on phase space rot.

streak measurement (aperture used to exclusivley select photons from a single island)

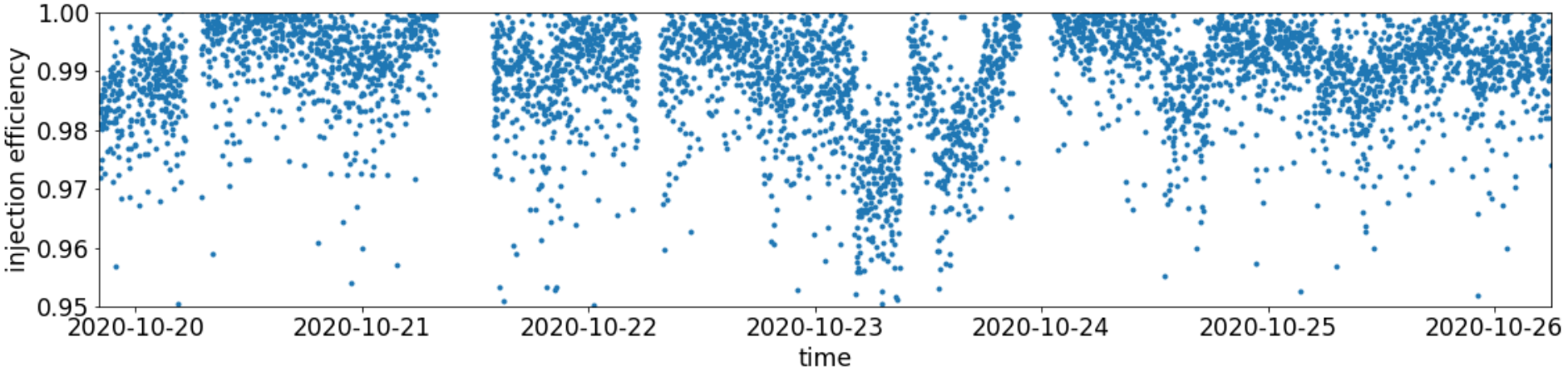


- top: equally populated islands
- mid/bot: single island populated

Open challenges & lessons learnt



Side effects…



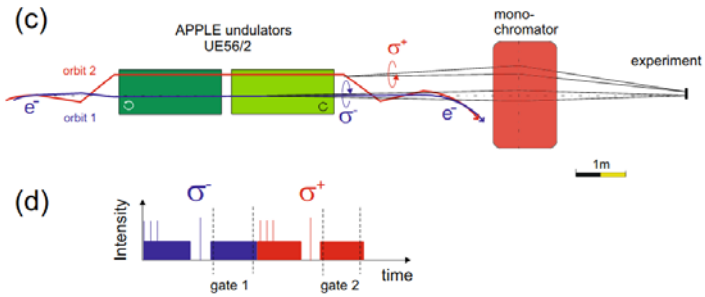
the standarduser week before the first scheduled TwoOrbit week had the best injection efficiency ever recorded… 98.5%

HZB Helmholtz Zentrum Berlin

https://doi.org/10.1038/s42005-020-0331-5 OPEN

Flipping the helicity of X-rays from an undulator at unprecedented speed

Karsten Holldack[1✉], Christian Schüssler-Langeheine[1], Paul Goslawski[1], Niko Pontius[1], Torsten Kachel[1], Felix Armborst[1], Markus Ries[1], Andreas Schälicke[1], Michael Scheer[1], Winfried Frentrup[1] & Johannes Bahrdt[1✉]



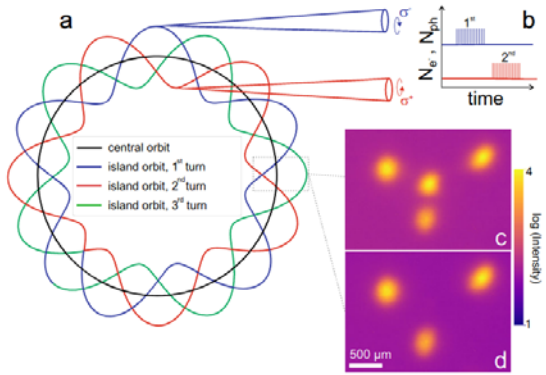


Fig. 3 Principle of bunch-by bunch or turn-by-turn helicity flip of elliptically polarized X-rays from an undulator in a storage ring using transverse island buckets from a third-order resonance. a Sketch of the

- 2 full days spent in July 2019 for a pioneering experiment at UE56/2
- XMCD detection used as probe to detect turn-by-turn helicity reversal of circular X-rays
- tricky combination of stable TRIBs settings in machine and UE56/2 twin undulator at special setting
- first two TRIBs orbits accepted by beamline

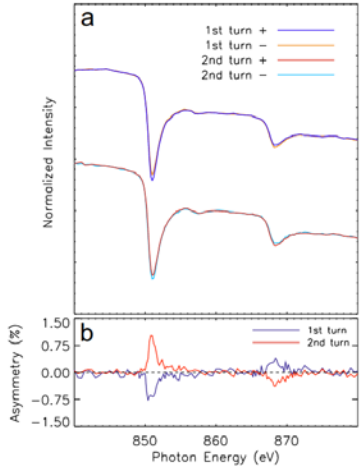


Fig. 6 A typical X-ray circular dichroism (XMCD) measurement using the gated detector signal from first and second turn for both magnetization directions of the sample. a XMCD spectra normalized to the 800 eV value

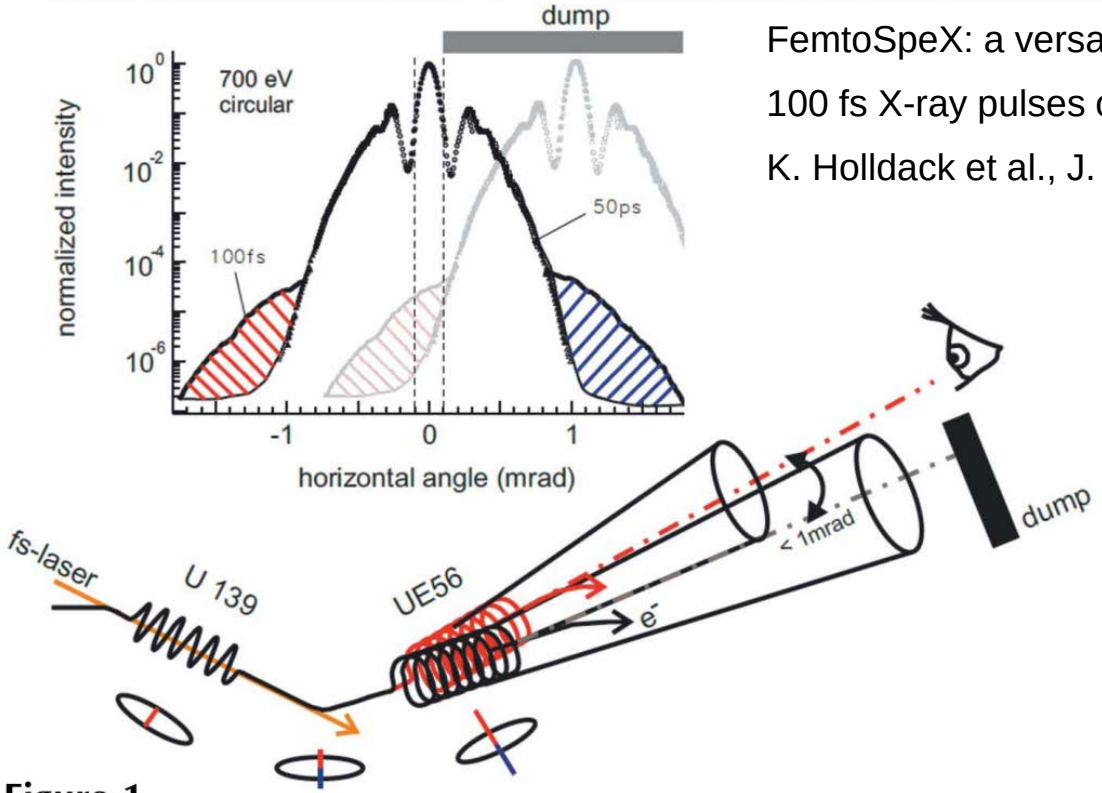


Figure 1
Principle of femtoslicing at BESSY II. After being laser-energy

FemtoSpeX: a versatile optical pump–soft X-ray probe facility with 100 fs X-ray pulses of variable polarization

K. Holldack et al., J. Synchrotron Rad. (2014). 21, 1090–1104

- rep. rate limited to 6kHz by laser
- S/N dominated by halo-dynamics
- bunch number increased from 3 to 7
- bunch current decreased from 4 mA to 3 mA