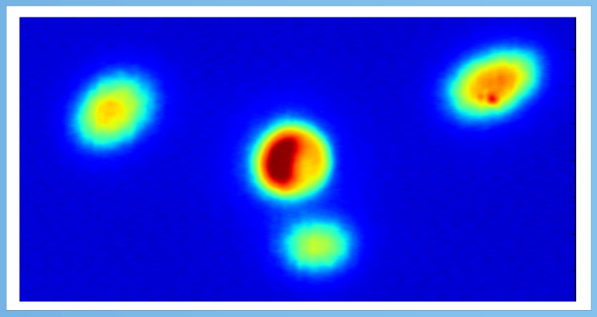
Two Beam Operation at Storage Ring Light Sources

TRIBs (Transverse Resonance Island Buckets) at BESSY II / MLS

P. Goslawski, M. Ries et al.
Institut for Accelerator Physics
Helmholtz-Zentrum Berlin

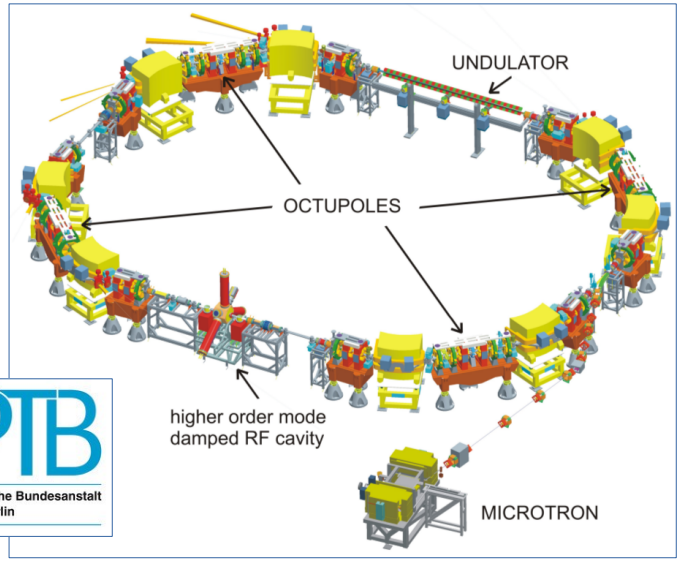


13th June 2018
4th MT Meeting, HZB, Berlin

Overview

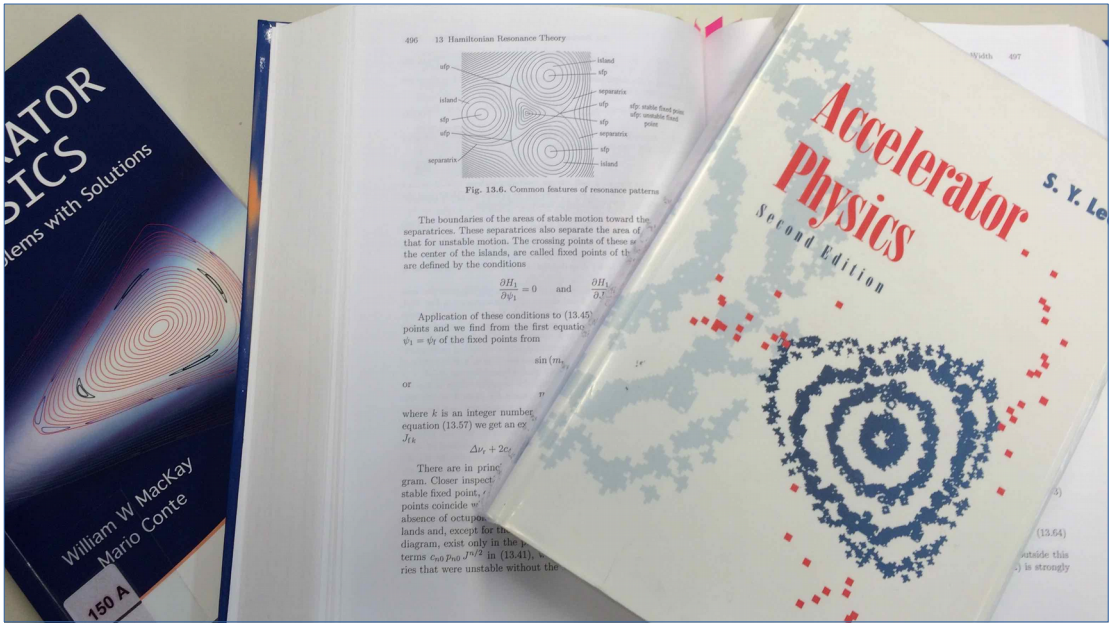
- Motivation
  - Why TRIBs at BESSY II and MLS (Metrology Light Source) ?
  - TRIBs for BESSY VSR ?
- **T**ransverse **R**esonance **I**sland **B**uckets – **TRIBs** at HZB, i.e., at BESSY II and MLS
  - Studies, Experiments and Application

HZB Helmholtz Zentrum Berlin



PTB Physikalisch-Technische Bundesanstalt Braunschweig und Berlin

TRIBs - Not new



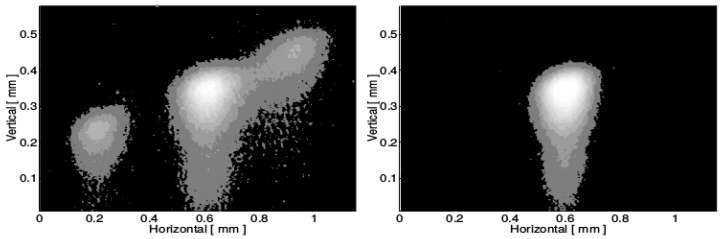


FIG. 14. Synchrotron radiation image of the beam near the $3\nu_x$ resonance. Left is the situation before the optic is corrected and right is the situation after the optic is corrected. (The plane of the camera is rotated with respect to the plane of the beam.) Also there is a distortion in the light optic in the vertical plane that is responsible for the image's vertical asymmetry.

No Application at Lightsources so far

- Do not store beam on resonance
- "Accelerator operators are keen to avoid low order strong resonances because of visibly short lifetime."
- "Accelerator physicists are eager to to apply their skill to correct or compensate the resonance for minimizing their effects on the beams."

Accelerator Physics, S.Y. Lee

Application: Multiturn (slow) extraction

- R.Cappi and M.Giovannozzi, "Multiturn extraction and injection by means of adiabatic capture in stable islands of phase space", Phys. Rev. ST Accel. Beams 7, 024001 (2004)

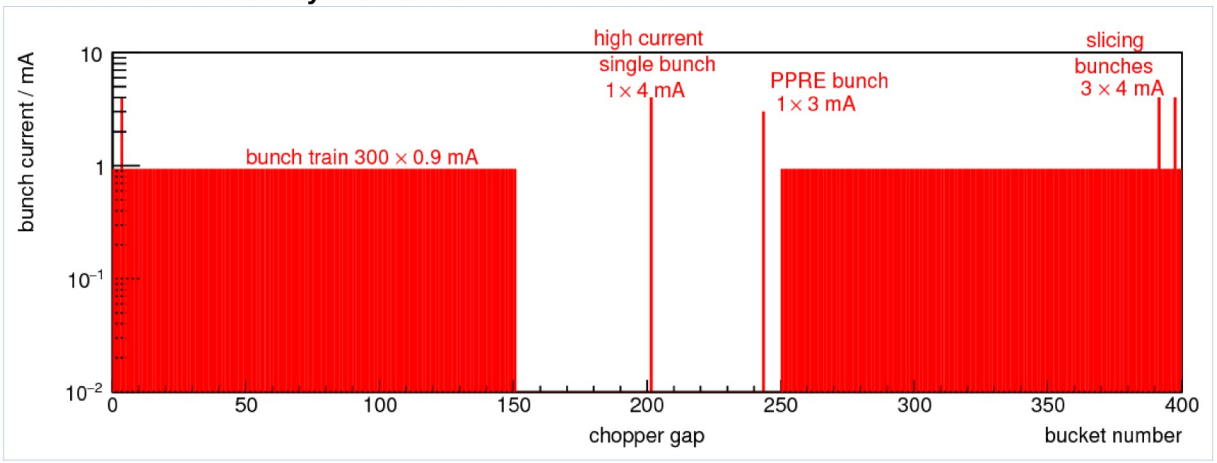
"Realizing the benefits of restored periodicity in the advanced light source" D.Robin, J.Safranek, W.Decking PRST-AB 2, 044001 (1999)

Stable 2nd closed orbit for bunch separation

Aim: Multiple beam storage with island buckets

Motivation: Electron Bunch Separation Schemes to serve the broad diverse user community with different requirements, **simultaneously !**

Standard Multi Bunch Hybrid Fill Pattern at BESSY II

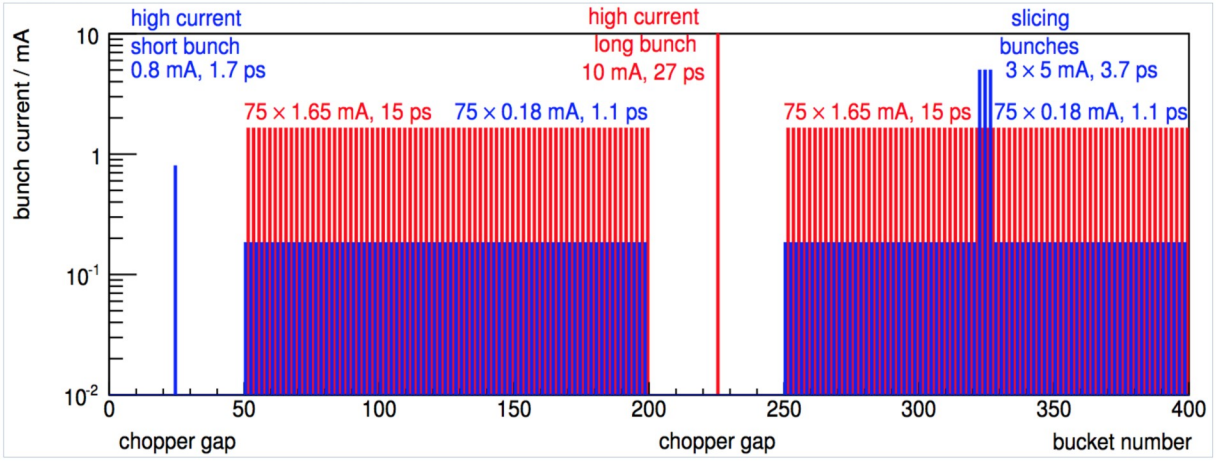


In addition:

Single Bunch mode 2-3 weeks per year
Few Bunch mode 2-3 days per year
Low alpha mode 2 weeks per year

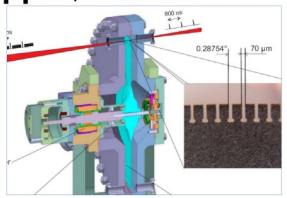
See – https://www.helmholtz-berlin.de/quellen/bessy/betrieb-beschleuniger/betriebsmodi_en.html
or google: BESSY II operation modi

Future BESSY VSR Fill Pattern

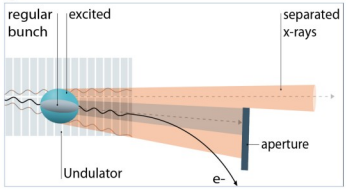


Pulse separation schemes

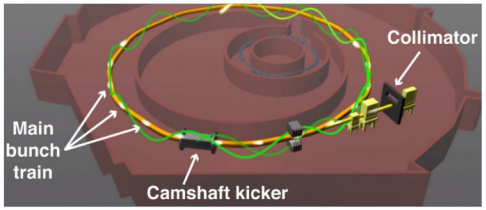
- **X-ray MHZ Chopper**, local at beam lines, photon pulse separation (FZJ, HZB)



- **Pule Picking Resonant Excitation PPRE**, e⁻ bunch separation (HZB)



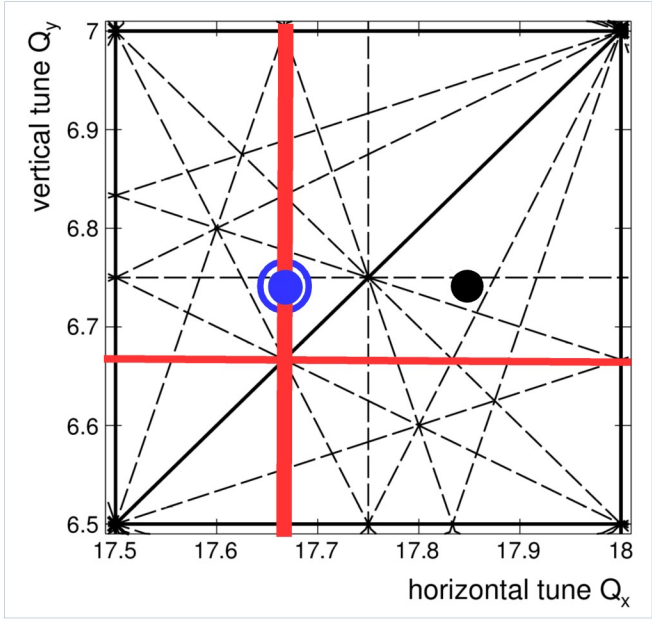
- **Pseudo Single Bunch** Scheme, **vertical kicking** with a fast (50 ns) kicker, e⁻ bunch separation (ALS)



TRIBs – Working point “on” resonance

Transverse Resonance Island Buckets - **TRIBs** - at BESSY II

- Operating machine close to horizontal 3rd order resonance
- Tackle non-linear beam dynamics
- Minor impact on linear beam optics expected

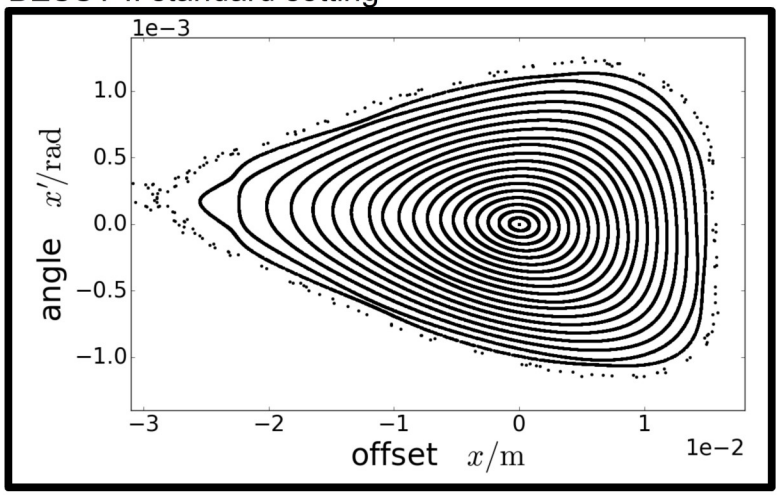


BESSY II working point (17.85, 6.73)

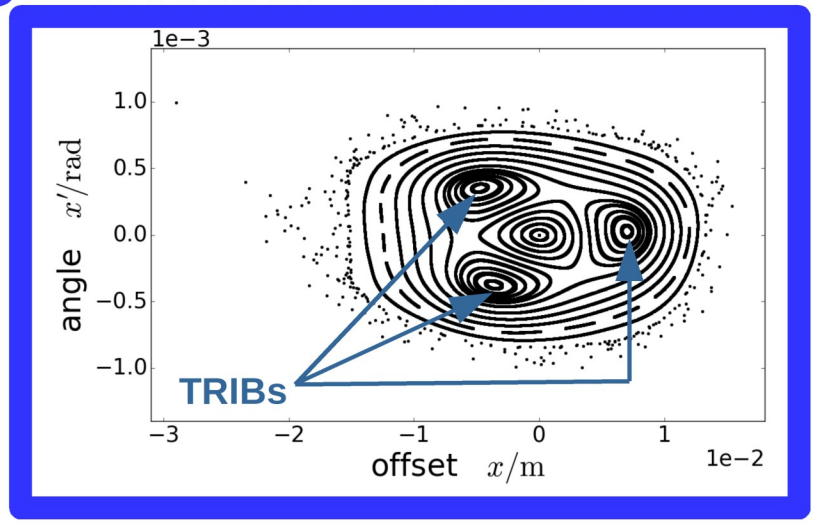
BESSY II TRIBs at 3rd order (17.66, 6.73)

2nd stable fix point & orbit

BESSY II standard setting

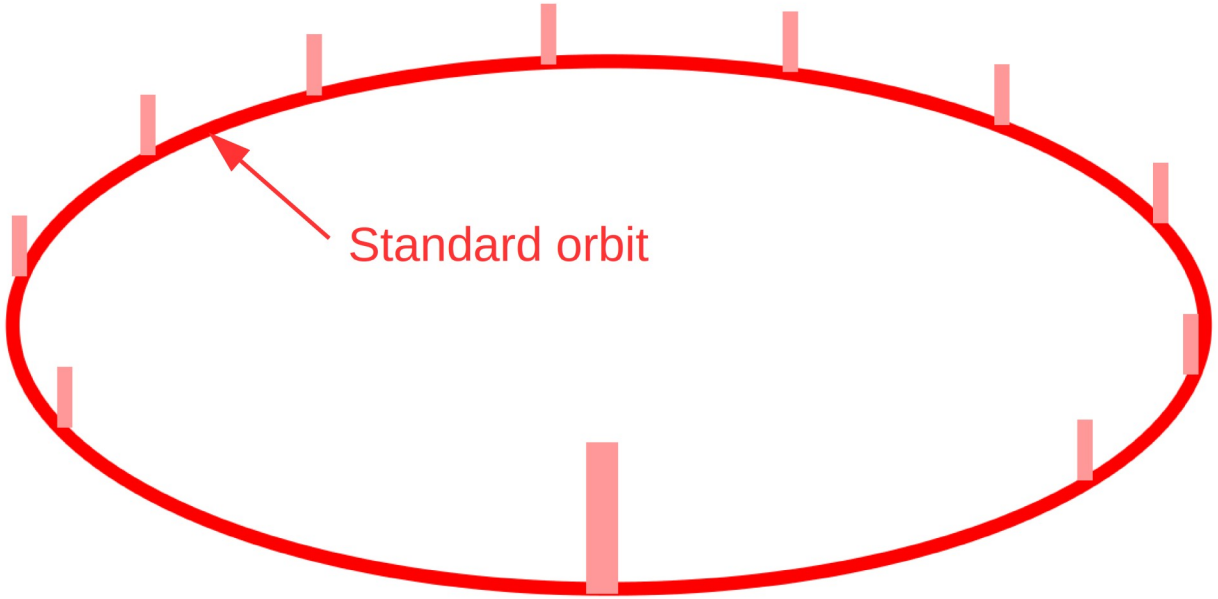


BESSY II TRIBs at 3rd order resonance



Application: A new electron bunch separation scheme

2nd stable orbit with **T**ransverse **R**esonance **I**sland **B**uckets - **TRIBs**



Driving forces behind TRIBs – G.Wüstefeld, M.Ries, P.Goslawski, F.Kramer

M. Ries et al., "Transverse Resonance Island Buckets at the MLS and BESSY II"
Proceedings of IPAC2015, Richmond, VA, USA, MOPWA021

P. Goslawski et al., "Resonance Island Experiments at BESSYII for User Applications"
Proceedings of IPAC2016, Busan, Korea, THPMR017

P. Goslawski et al., "Status of Transverse Resonance Island Buckets as Bunch Separation Scheme",
Proceedings of IPAC2017, Copenhagen, Denmark, WEPIK057

F. Kramer et al., "Characterisaton of the second stable orbit generated by transverse resonance island buckets (TRIBs)", Proceedings of IPAC2018, Vancouver, BC, Canada, TUPML052

See talk of **F. Kramer at Student Retreat**

Common Verbundforschungsprojekt (Uni Mainz, Uni München):

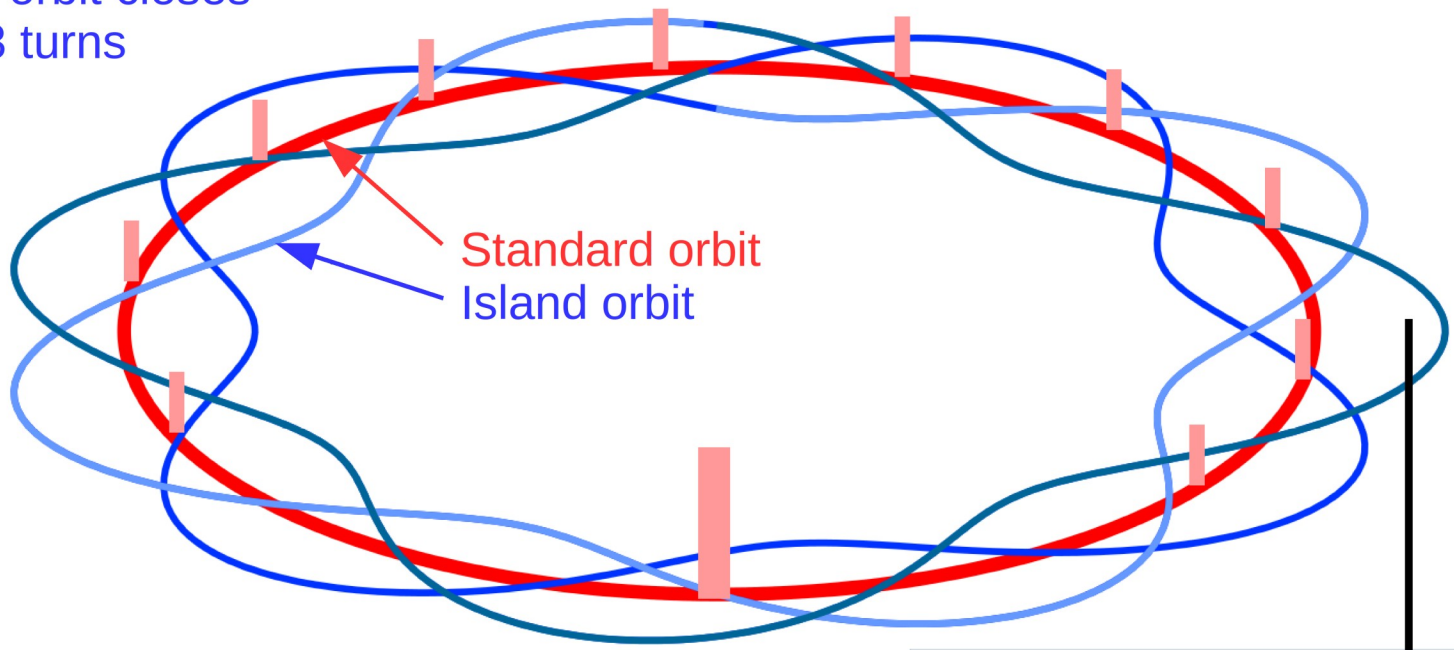
PhD student: TRIBs as separation scheme

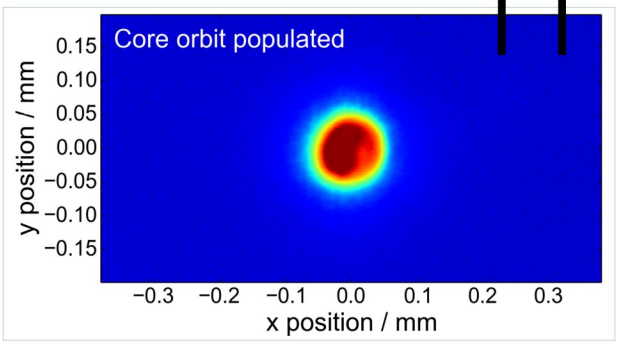
Bundesministerium für Bildung und Forschung

Application: A new electron bunch separation scheme

2nd stable orbit with **T**ransverse **R**esonance **I**sland **B**uckets - **TRIBs**

3rd order resonance
island orbit closes
after 3 turns



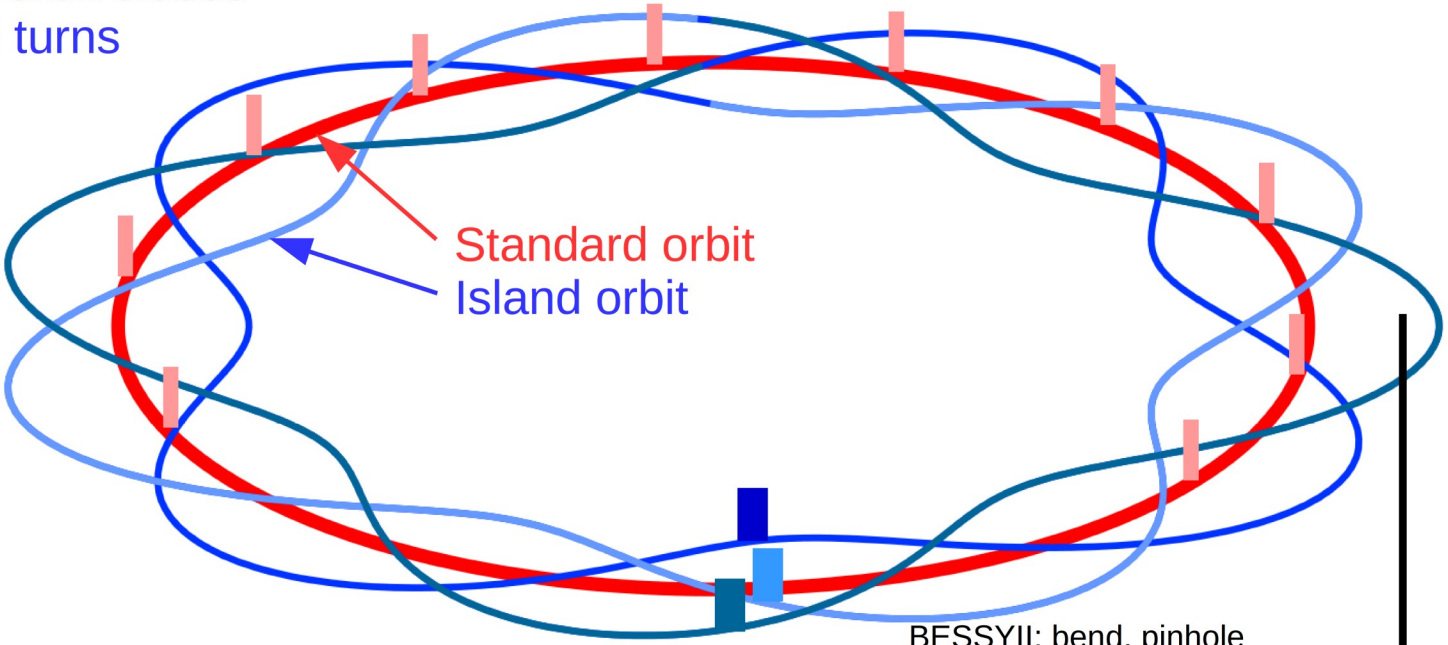


Two stable independent orbits
capable to store
two independent fill pattern

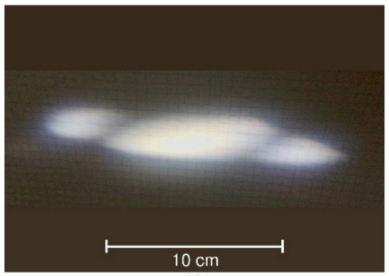
Application: A new electron bunch separation scheme

2nd stable orbit with **T**ransverse **R**esonance **I**sland **B**uckets - **TRIBs**

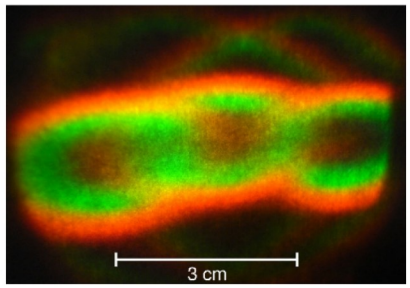
3rd order resonance
Island orbit closes
after 3 turns



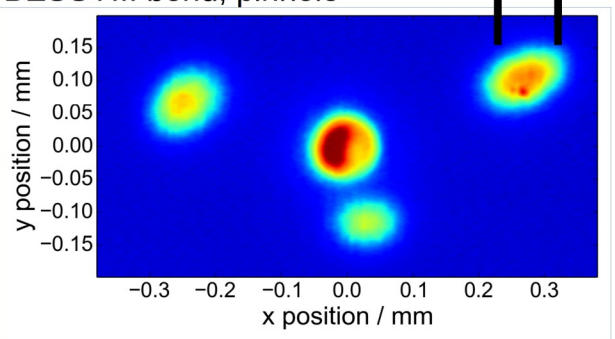
MLS: bend radiation



undulator radiation



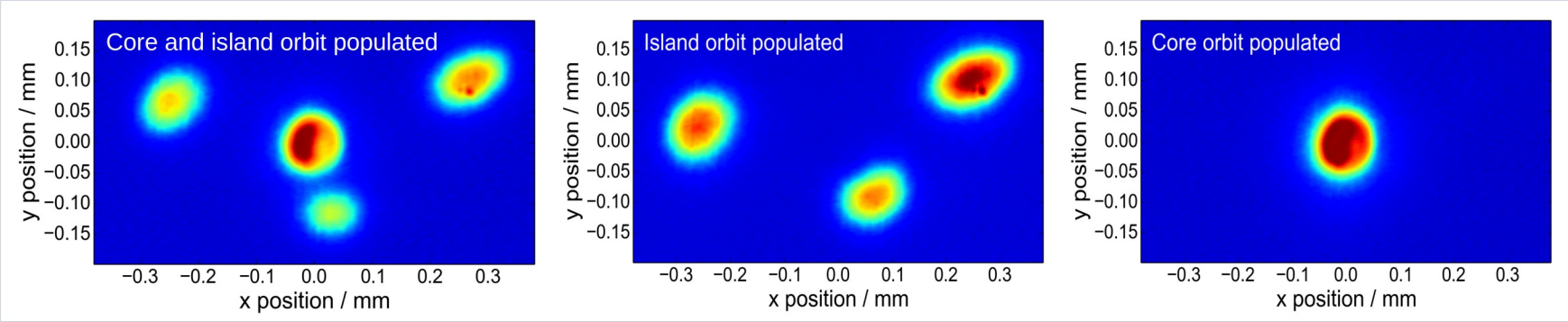
BESSYII: bend, pinhole



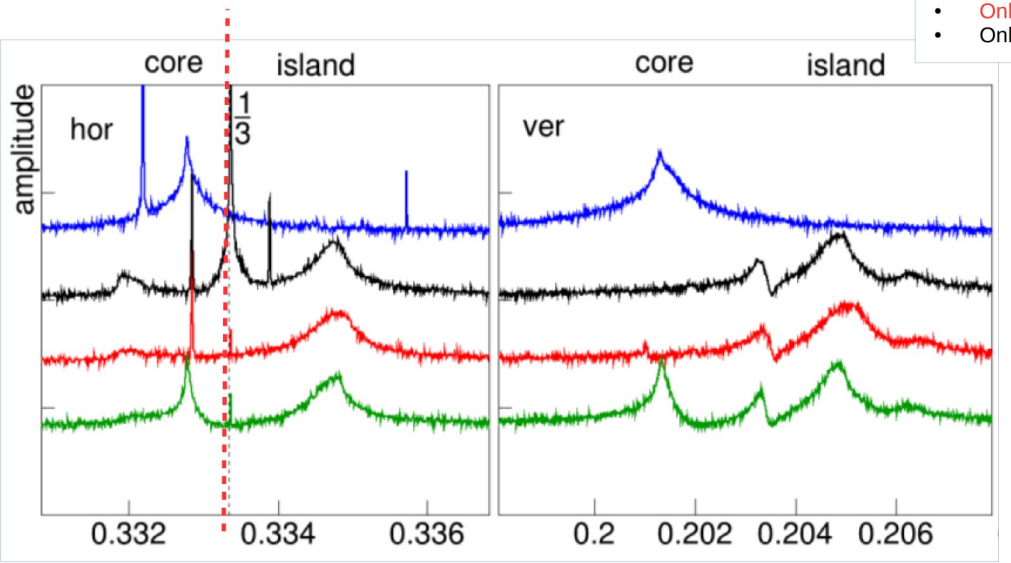
TRIBs (2015, 2016): Fill pattern manipulation

Fill pattern (or current) manipulation and tunes

- Electrons can be shuffled between both orbits without losses



- Core and island orbit populated
- Only core orbit populated
- Only island orbit populated
- Only one island populated

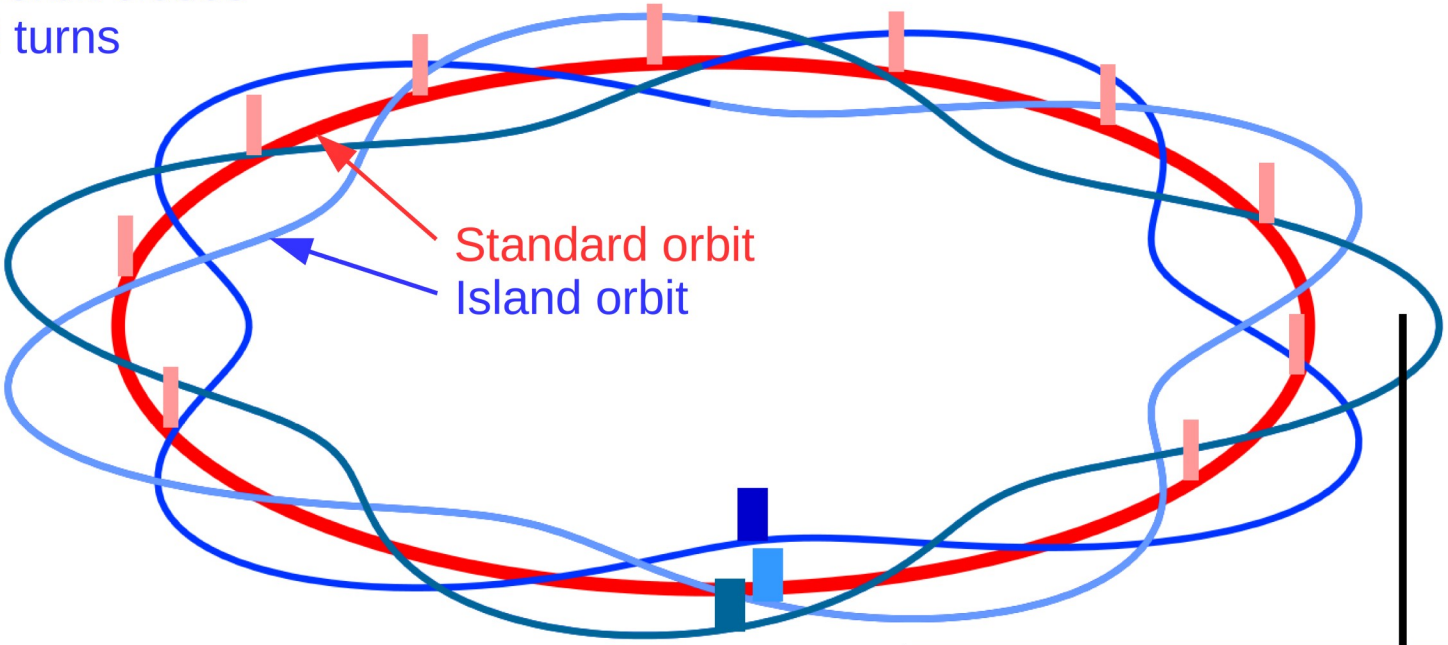


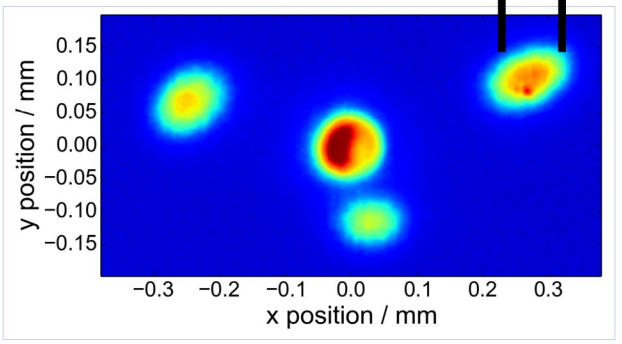
Arbitrary fill pattern within seconds

Application: A new electron bunch separation scheme

2nd stable orbit with **T**ransverse **R**esonance **I**sland **B**uckets - **TRIBs**

3rd order resonance
Island orbit closes
after 3 turns

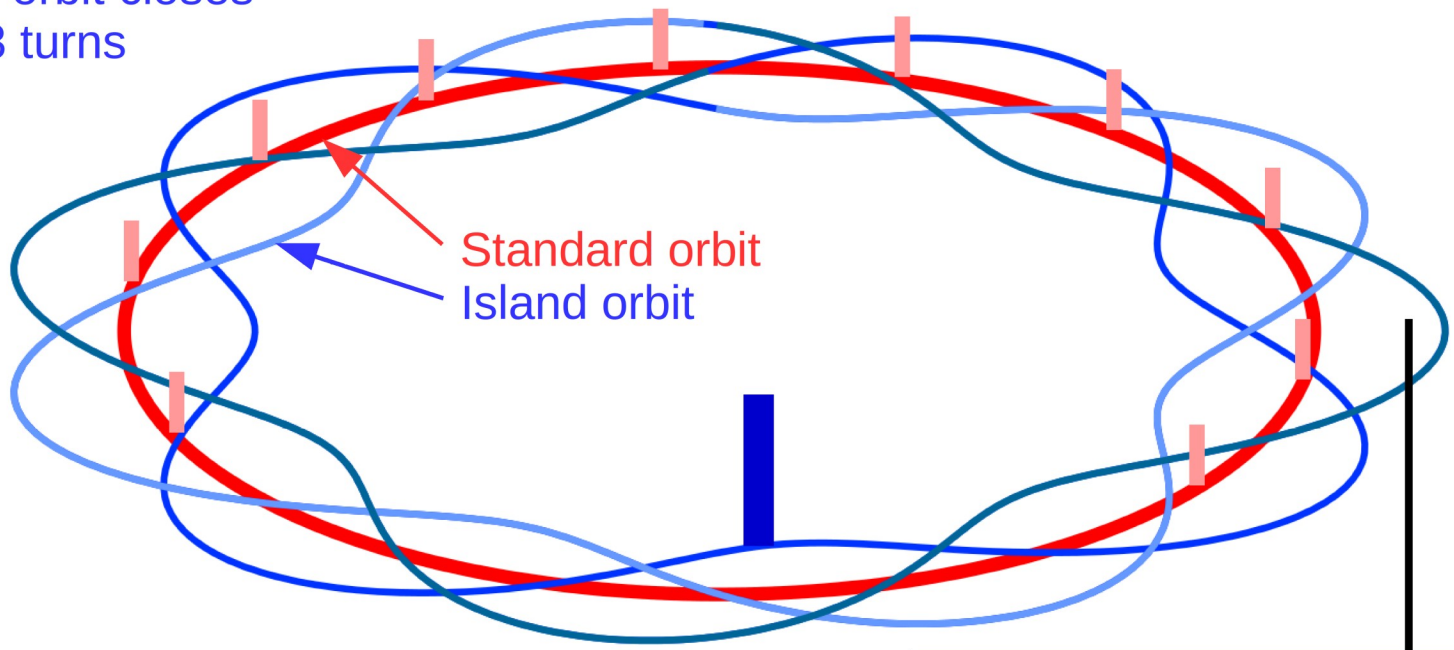




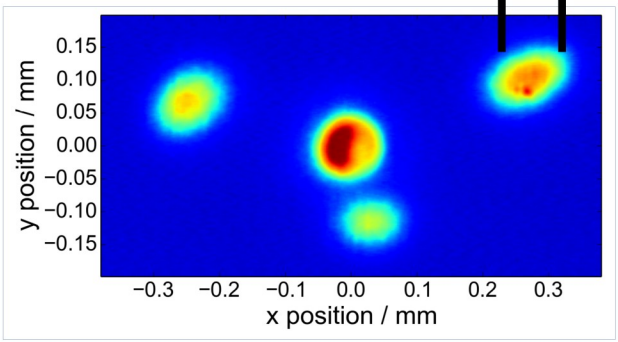
Application: “elongate your ring” - increase revolution time

2nd stable orbit with **T**ransverse **R**esonance **I**sland **B**uckets - **TRIBs**

3rd order resonance
Island orbit closes
after 3 turns



1st Turn



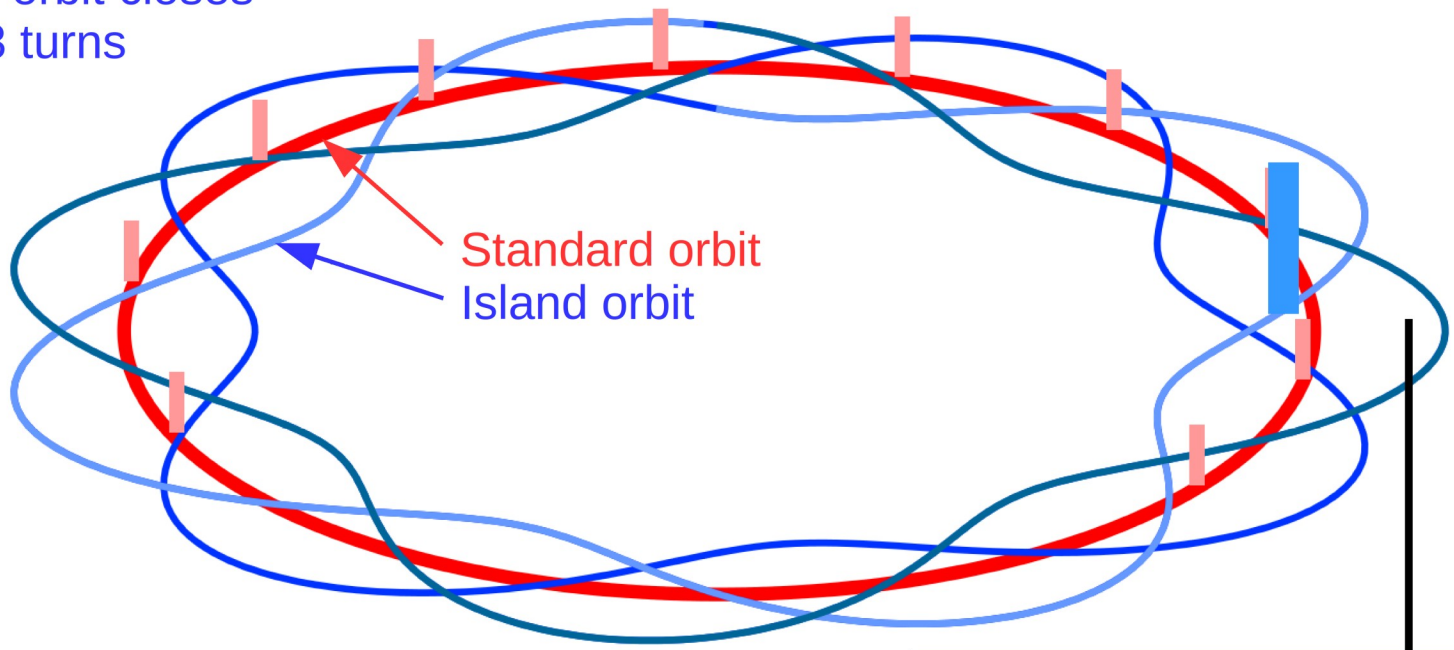
Increasing revolution time

- By the factor = order of resonance

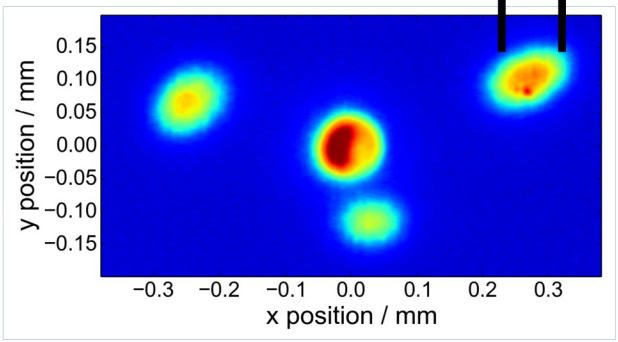
Application: “elongate your ring” - increase revolution time

2nd stable orbit with **T**ransverse **R**esonance **I**sland **B**uckets - **TRIBs**

3rd order resonance
Island orbit closes
after 3 turns



2nd Turn



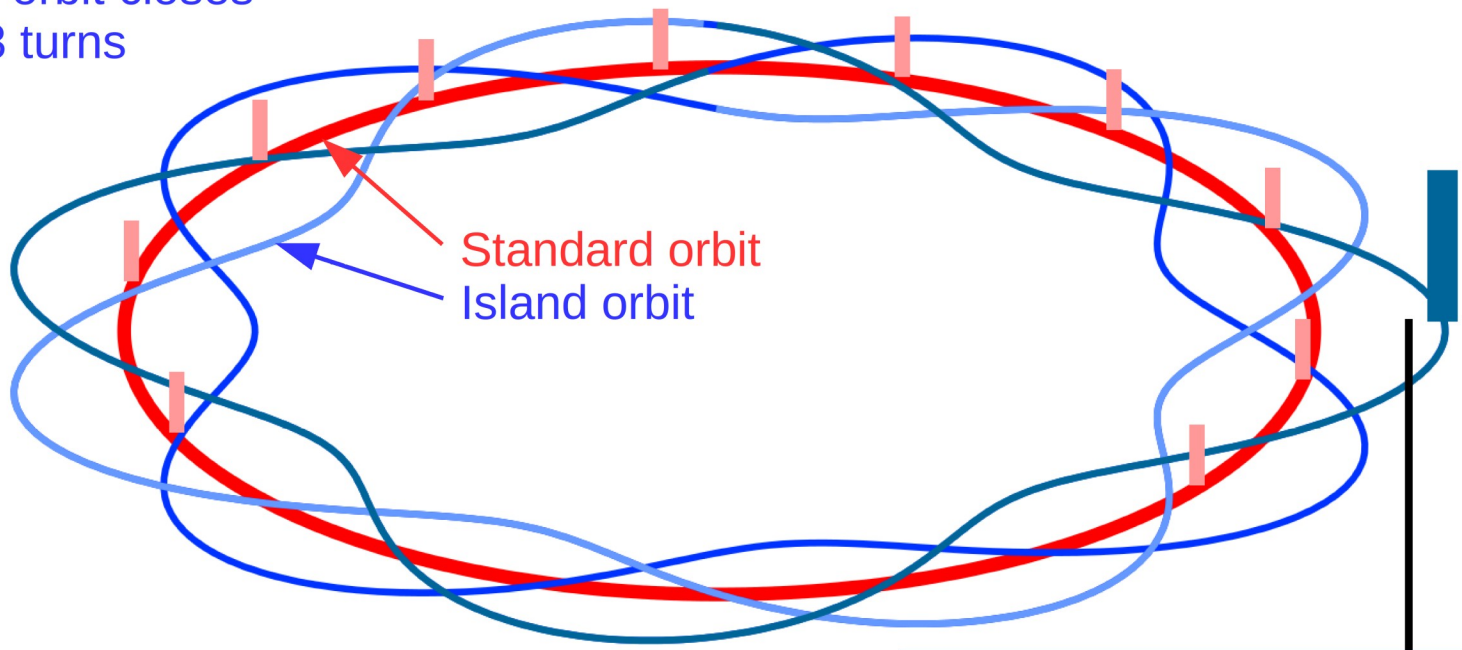
Increasing revolution time

- By the factor = order of resonance
- Decrease repetition rate at small storage rings for TOF experiments

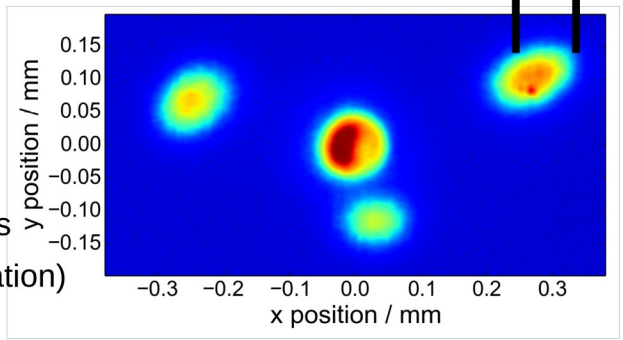
Application: “elongate your ring” - increase revolution time

2nd stable orbit with **T**ransverse **R**esonance **I**sland **B**uckets - **TRIBs**

3rd order resonance
Island orbit closes
after 3 turns



3rd Turn



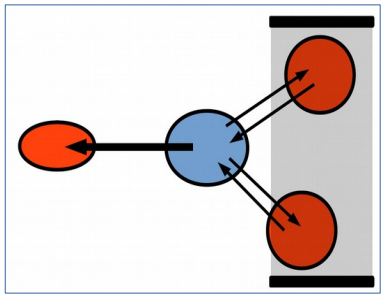
Increasing revolution time

- By the factor = order of resonance
- Decrease repetition rate at small storage rings for TOF experiments
- First successful user experiment at the MLS (publication in preparation)

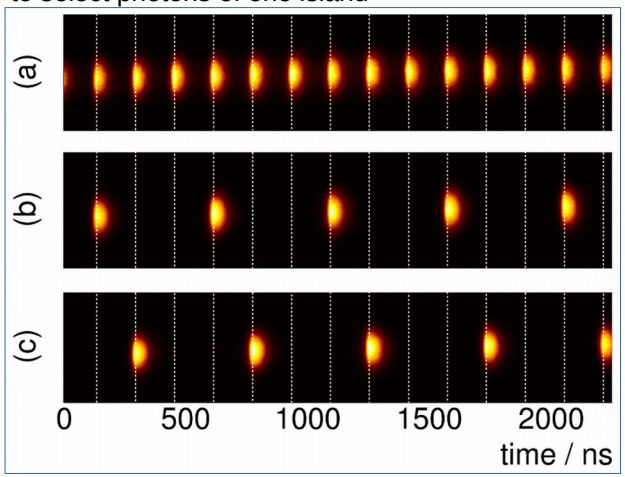
First successful user experiment at MLS (2015)

Current manipulation, sub-revolution frequency

- How to populate only one island?
- Non linearity of stripline kicker
- Kick (or pause) every 3rd turn:
  2.083 MHz instead of 6.25 MHz
  pause-pause-kick

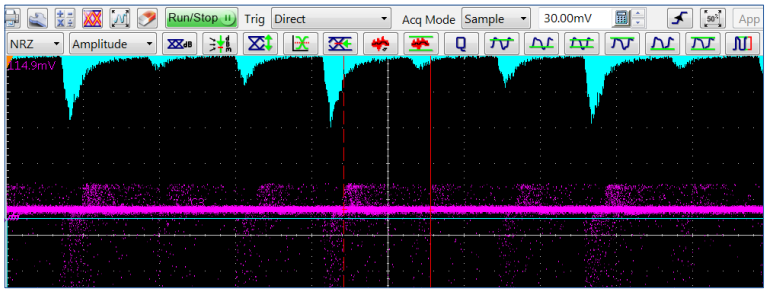


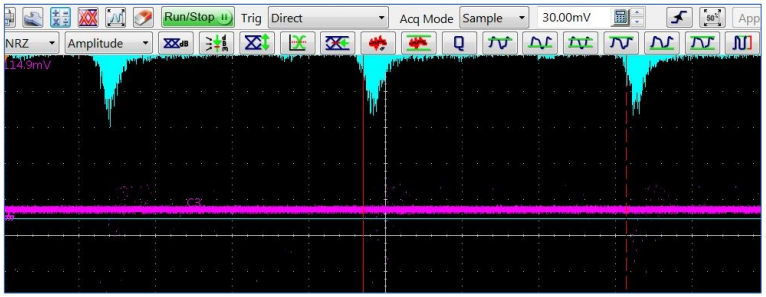
Streak camera with aperture
to select photons of one island



a) islands equally populated, kick every turn
b, c) only single island populated, pause-pause-kick
kick every 3rd turn

Signal measured at ID beamline with channeltron





First successful user experiment

- ARTOF spectrum at photon energy of 44 eV
  of Au(111) single crystal sample
- Reduced revolution frequnecy of 6.25 MHz to
  2.083 MHz (revolution time 160 ns to 480 ns)
- Two successful user runs of 10 h each in decay mode
- Vertical and horizontal position shows good long term
  stability of island orbit

- Paper in preparation
- MLS access perfect for development and first tests

TRIBs at BESSY II - Towards realistic user operation

Proof of principle experiments

Since 2015

- Island operation compatible with
  - High current operation (300 mA)
  - IDs: moving undulator gaps and SC devices (7T MPW)

Fall 2015 – 2016

- **Separation - good enough?**
  Electron separation --> Photon pulse separation?
  - Beam parameters: orbit stability, emittance, ...
  - Align island orbit on bend/ID beamline
  - Purity, Diffusion rates, SNR
  - Usable at all beamlines at the same time ?
  - Impact of radiation from island orbit on standard orbit?

Fall 2016 – 2017

- **Injection - TopUp operation possible?**
  - Injection Efficiency (>90%) and Lifetime (>5h@300mA) ?
  - Difference between new working point (17.66) and old one (17.84)? (synchrotron source points from standard orbit)
  - Impact of radiation from island orbit on standard orbit?

User test week in February 2018

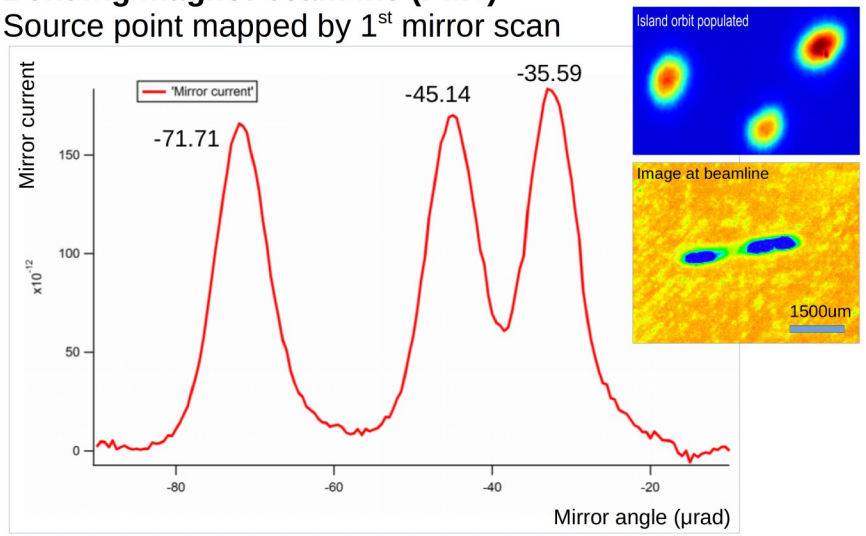
TRIBs at BESSY II (2016): Separation at beam lines

Common experiments with beam line scientists and in-house users

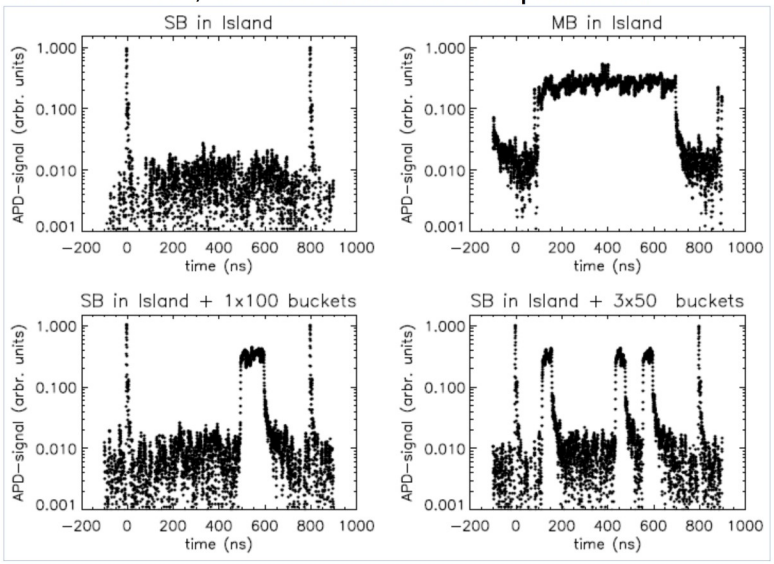
K.Holldack, F.Kronast, R.Ovsyannikov, E.Schierle, G.Schiwietz

Successful separation at bending magnet and undulator beam lines

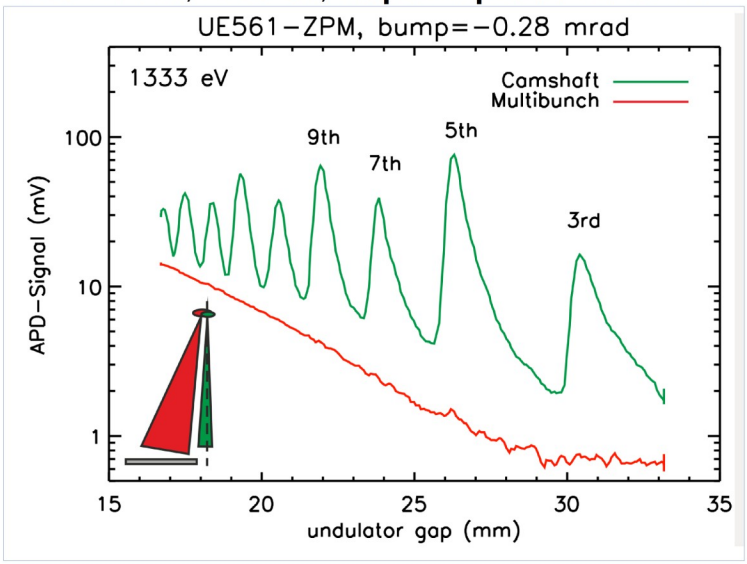
Bending magnet beamline (PM4)
Source point mapped by 1st mirror scan



4 ID beam lines (**UE56-1, UE112**, UE49, UE46)
UE56-1 ZPM, 831 eV linear vertical polarized

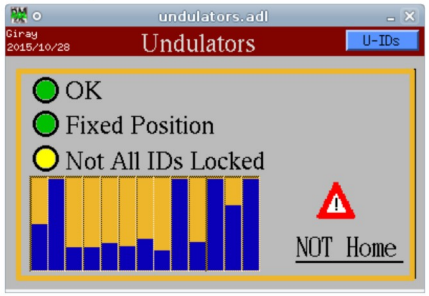


UE56-1 ZPM, 1333 eV, **elliptical polarized mode**

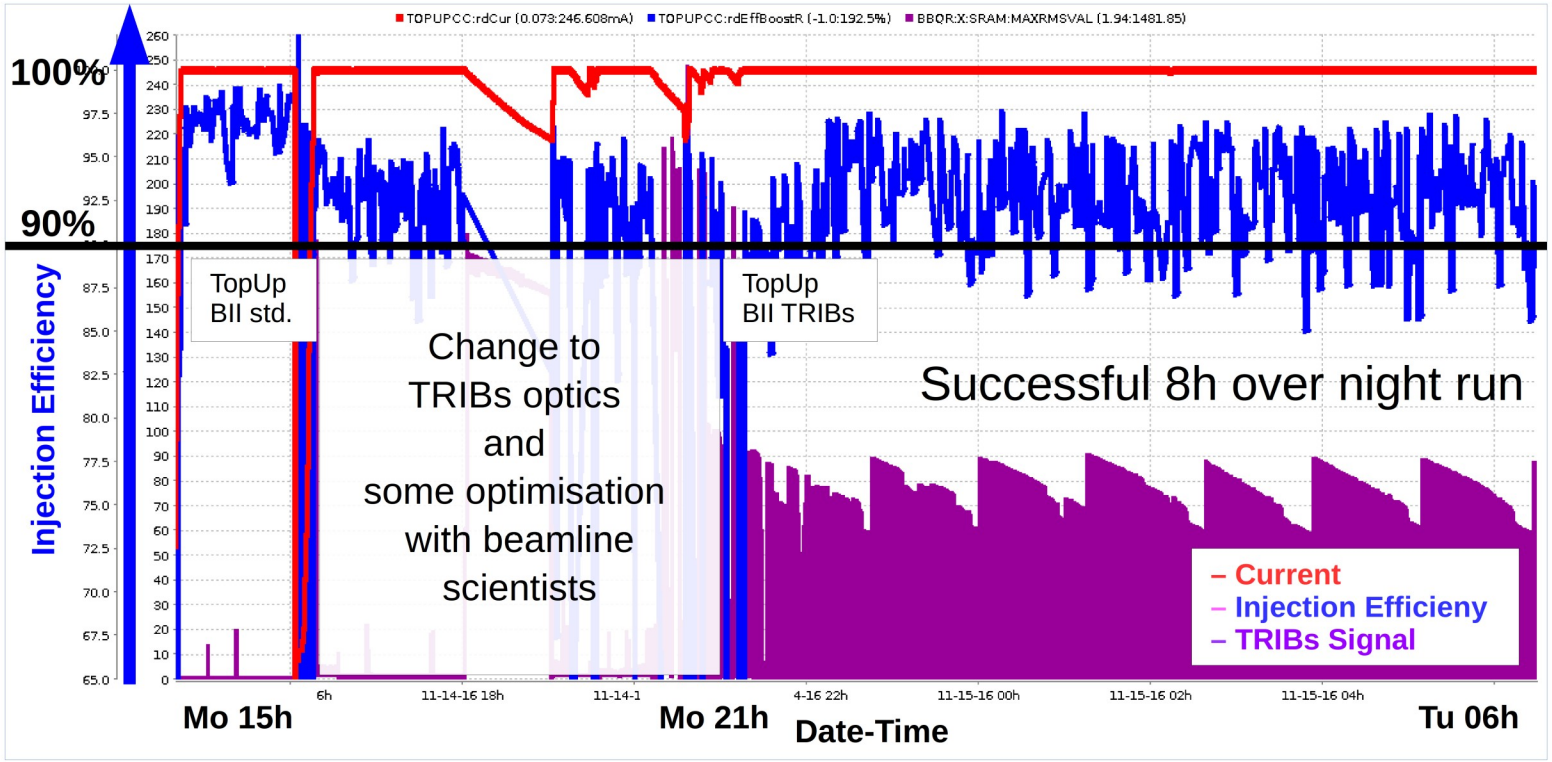


TopUp injection conditions for user operation

- Average injection efficiency > 90 %
- Shot by shot injection efficiency > 60 %
- Lifetime > 5 h @ 300 mA
- Stable user conditions over night !!



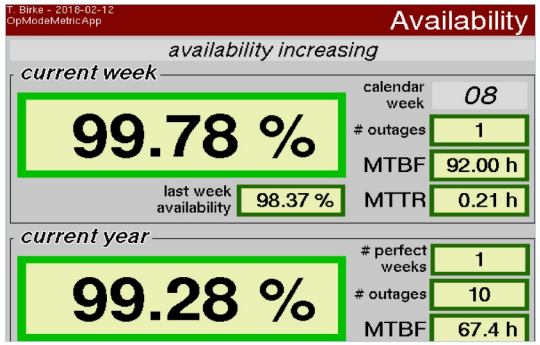
TRIBs feasible with TopUp injection and many closed IDs



TRIBs at BESSY II (2018) – Twin Orbit Test Week, CW08

TRIBs move towards realistic User Operation

- Verify if beam quality necessary for realistic user operation mode is reached in terms of
  - electron orbit, i.e., photon signal stability
  - simultaneous use of multiple IDs
  - injection efficiency and lifetime, i.e., TopUp conditions
- Verify that multibunch signal from main orbit is not disturbed by the island orbit signal
- Increase accessibility of the island orbit at most beamlines
- Daily schedule:
  07 – 10h: Storag ring optimisation
  10 – 15h: Common experiments
  15 – 18h: Restoring TRIBs for
  18 – 07h: TRIBs User Run

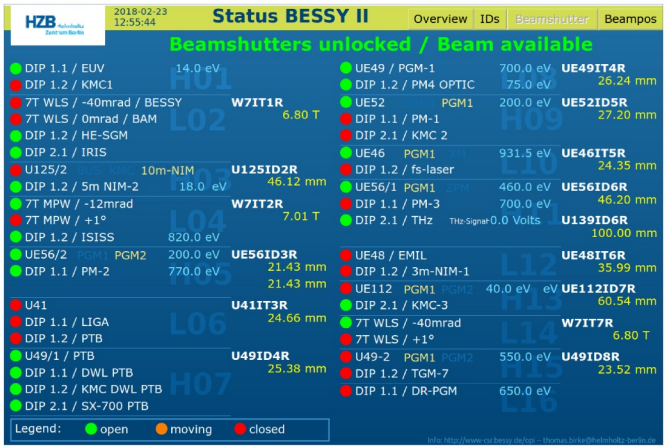


- 11 Feedbacks so far under evaluation !

Open beam shutters / beamlines

20.02.2018 Tuesday 18:00 22/39

23.02. 2018 Friday 13:00 20/39



TRIBs at BESSY II (2018) – Twin Orbit Test Week, CW08

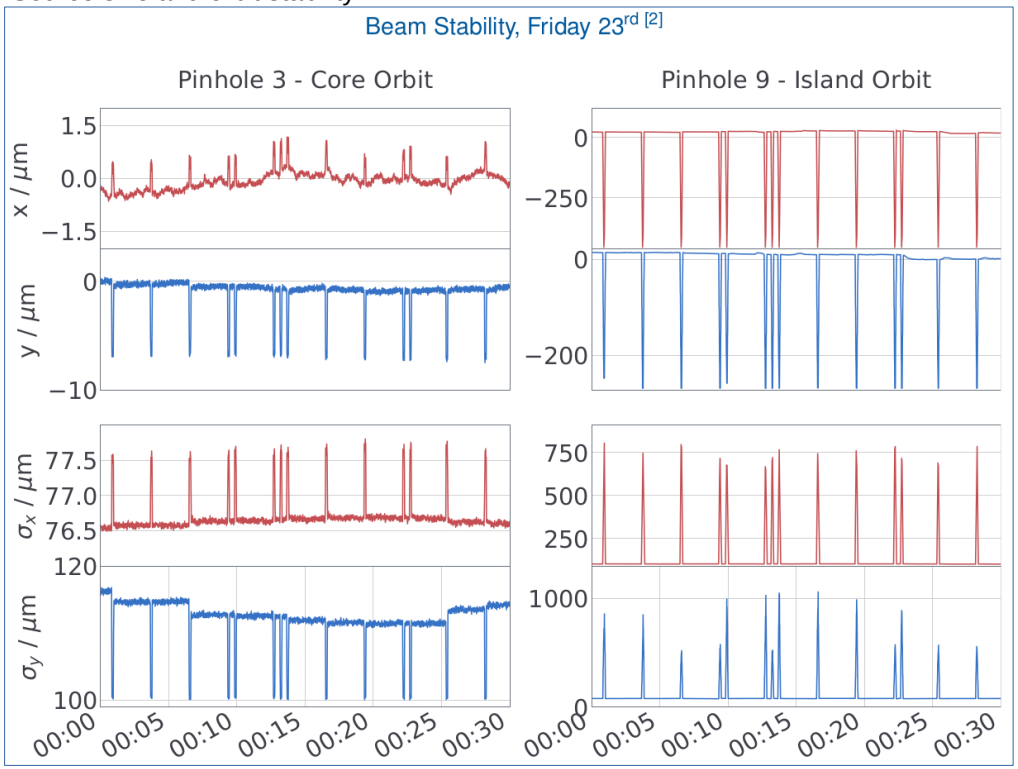
Challenges for better user operation

- 11 User feedbacks so far … under evaluation!
- TopUp Injection... Injection disturbances
- Transparent orbit bumps for IDs
- Slicing, bending beamlines without focus

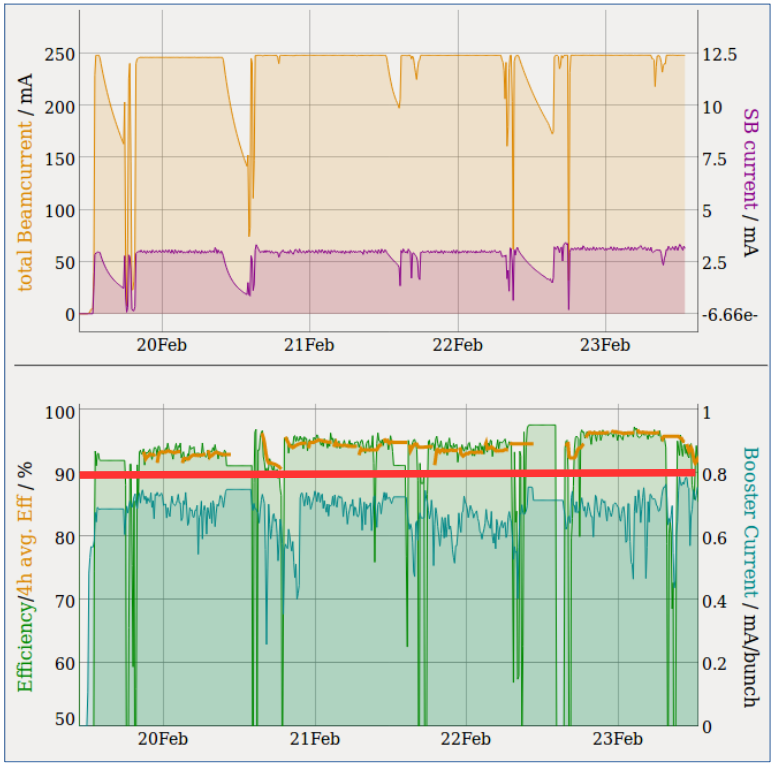
New quality, new options

- Operation and separation without gap, avoiding beamloading (especially for VSR)
- Fast switching of fill patterns, two different sources at one sample (x-ray optics)
- Two repetition rates at same time
- … (injection, …)

Source size and orbit stability



Stored current and Injection Efficiency



Summary: TRIBs at BESSY II / MLS

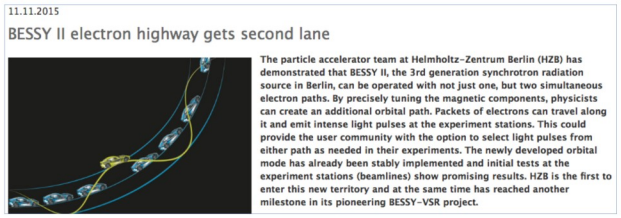
Proof-of-Principles Experiments done !

- **Separation scheme**, two stable orbits in one machine, 2nd lane, 2nd fillpattern
  (average brightness and timing)
- Established user operation at decaying machine with one ID (MLS),
  --> increasing revolution time
- Studies towards user operation in a 3rd generation light source,
  --> combine with TOPUP injection scheme, many IDs (BESSY II / VSR)

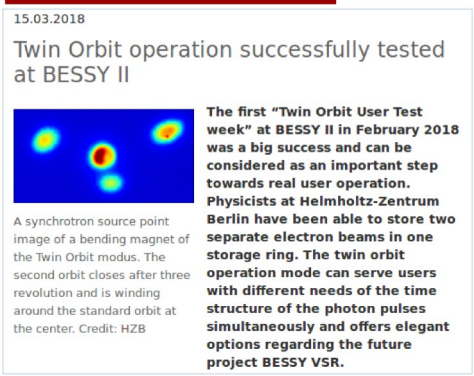
BESSY VSR
Helmholtz-Zentrum Berlin

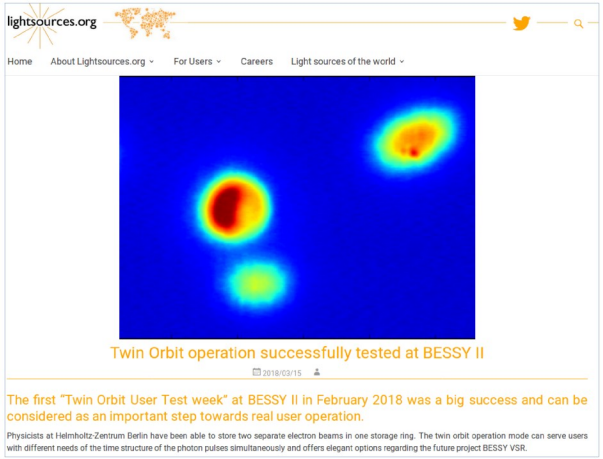
will provide long and short intense bunches simultaneously → pulse separation mandatory

Fall 2015 see news HZB and lightsource.org

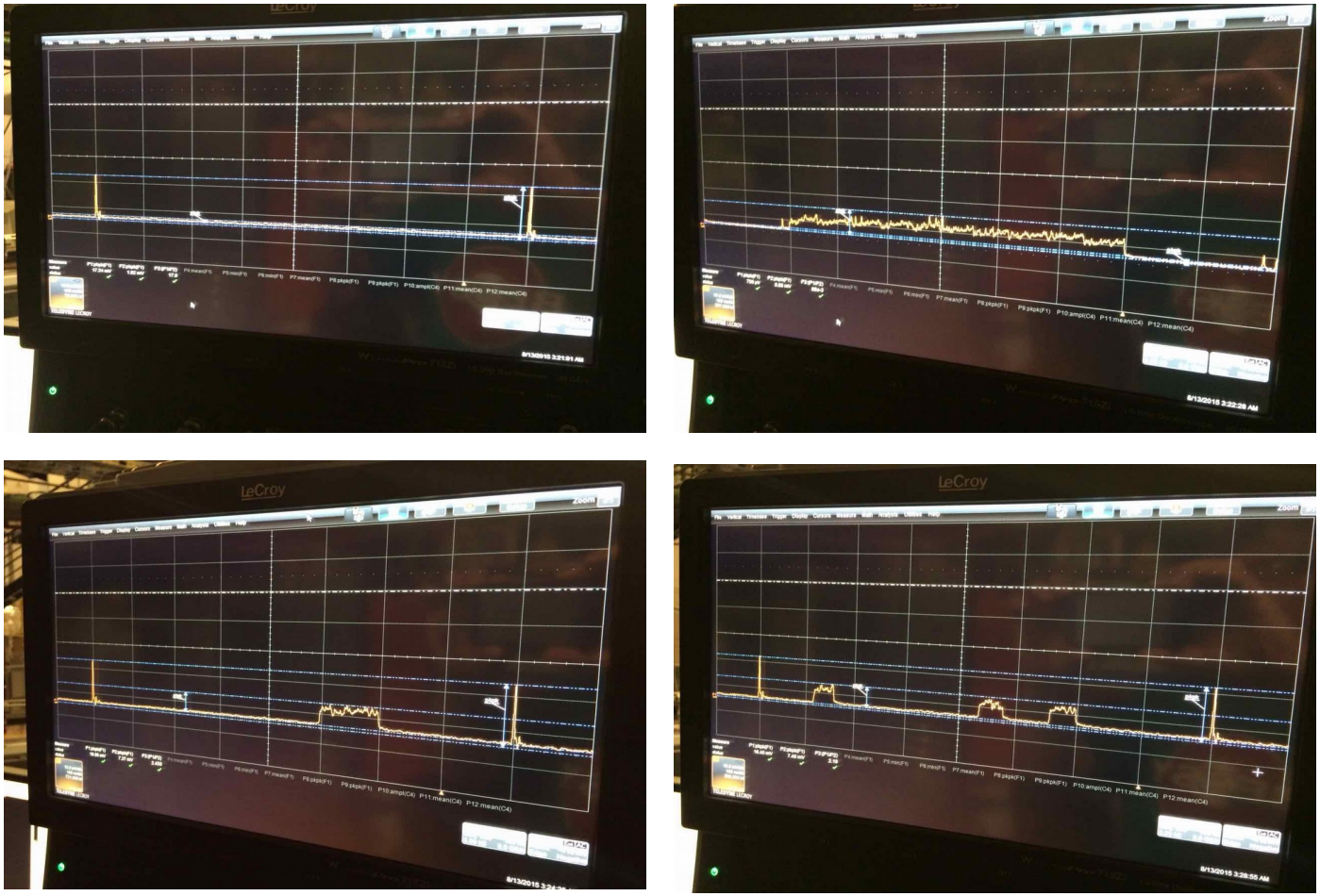


Spring 2018 see news HZB and lightsource.org





Thank you for your attention



Thanks to all Colleagues at HZB and external users contributing to TRIBs