



# Characterisation of the Second Stable Orbit Generated by

# Transverse Resonance Island Buckets (TRIBs)

Felix Kramer<sup>[1], [2]</sup>

<sup>[1]</sup>Helmholtz-Zentrum Berlin, Germany

<sup>[2]</sup>Humboldt-Universität zu Berlin, Germany

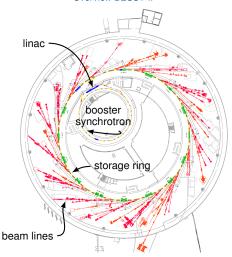
4<sup>th</sup> MT student retreat Berlin 11<sup>th</sup> of June 2018



Introduction Transverse Resonant Islands (TRIBs) TRIBs at BESSY II Characterisation of the Second Orbit Friendly User Test Week Epilogue



Overview BESSY II<sup>[1]</sup>



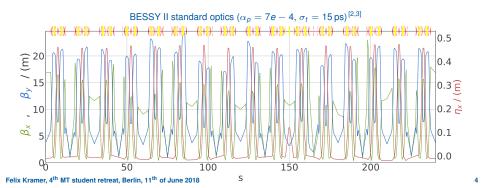
### Storage ring

Circumference	240m
RF-frequency	500MHz
Revolutiontime	800ns
Tunes $Q_X/Q_y$	17.8/6.6
Damping times $\tau_x/\tau_y/\tau_s$	7.8/7.7/3.9ms
Beamlines	$\approx 50$
Users per year	> 2000

- static structures: diffraction, scattering, spectroscopy, microscopy experiments
  - $\Rightarrow$  high average brilliance
- dynamic structures: pump-probe, time-of-flight experiments
  - $\Rightarrow$  special time structure

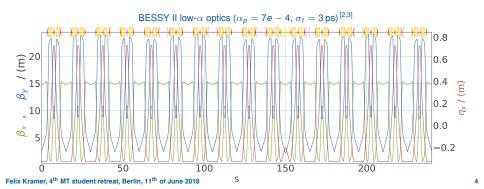


 $\Rightarrow$  special optics





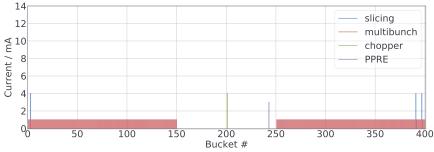
 $\Rightarrow$  special optics





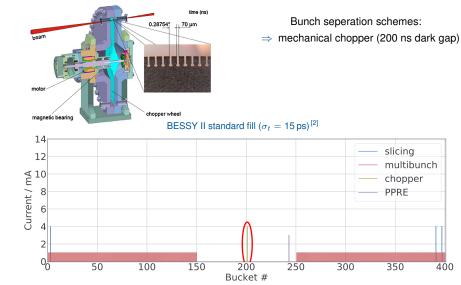
- $\Rightarrow$  special optics
- $\Rightarrow$  special bunches





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# Introduction: **Motivation for TRIBs**



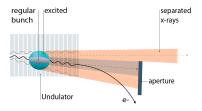
### Chopper<sup>[4]</sup>

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400

# Introduction: Motivation for TRIBs

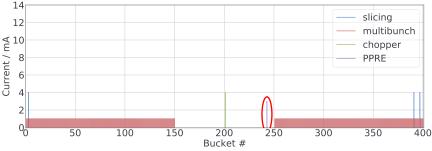
### PPRE<sup>[5]</sup>



Bunch seperation schemes:

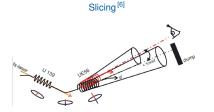
- $\Rightarrow$  mechanical chopper (200 ns dark gap)
- ⇒ pulse picking by resonant excitation (PPRE)

### BESSY II standard fill $(\sigma_t = 15 \text{ ps})^{[2]}$



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# Introduction: Motivation for TRIBs

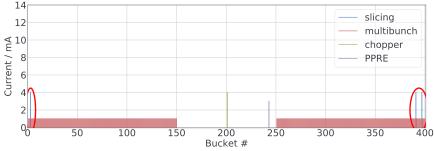


Bunch seperation schemes:

- $\Rightarrow$  mechanical chopper (200 ns dark gap)
- ⇒ pulse picking by resonant excitation (PPRE)

 $\Rightarrow$  slicing

BESSY II standard fill  $(\sigma_t = 15 \text{ ps})^{[2]}$ 



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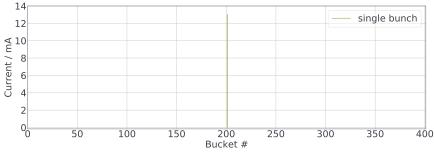
- $\Rightarrow$  special optics
- $\Rightarrow$  special bunches
- ⇒ special fill pattern

Bunch seperation schemes:

- $\Rightarrow$  mechanical chopper (200 ns dark gap)
- ⇒ pulse picking by resonant excitation (PPRE)

 $\Rightarrow$  slicing

### BESSY II single bunch mode<sup>[2]</sup>





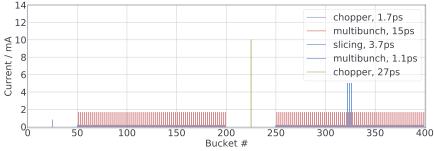
- $\Rightarrow$  special optics
- $\Rightarrow$  special bunches
- ⇒ special fill pattern
  - $\Rightarrow$  BESSY VSR

Bunch seperation schemes:

- $\Rightarrow$  mechanical chopper (200 ns dark gap)
- $\Rightarrow$  pulse picking by resonant excitation (PPRE)

 $\Rightarrow$  slicing

### BESSY VSR Possible fill<sup>[2]</sup>

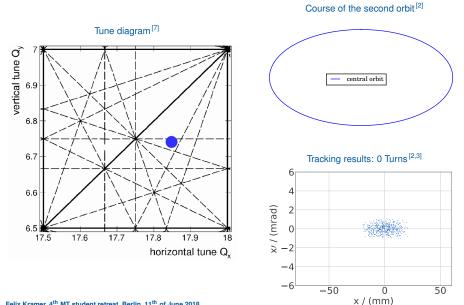


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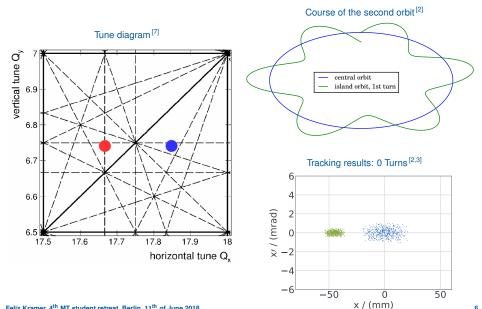


### why not use seperate orbits offering multiple operation modes simultaneously?

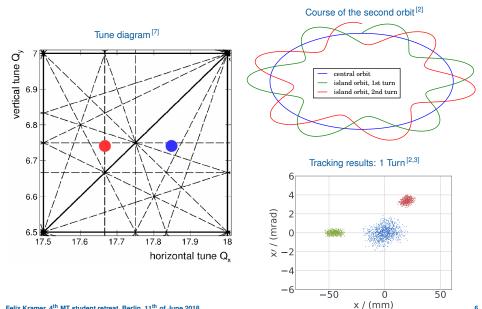
- ⇒ bunch separation by beamline adjustment
- $\Rightarrow$  bunch separation by chopper, PPRE, slicing obsolete
- ⇒ fill pattern induced tune transients and following stress for cavitys, feedbacks is reduced

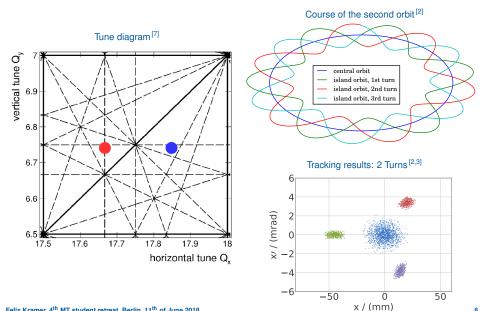


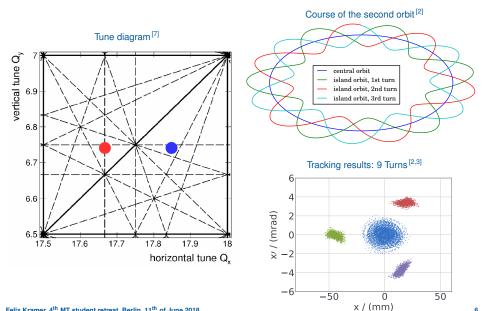
#### Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



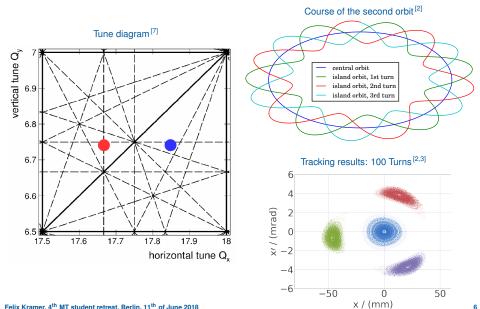
Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



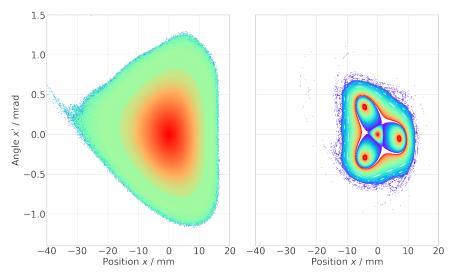




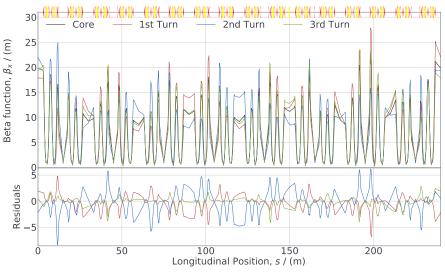
Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



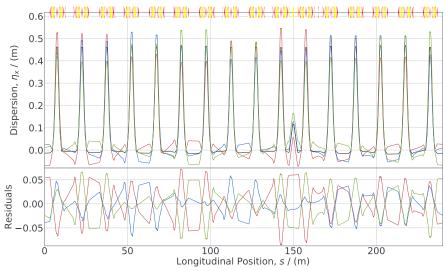
BESSY II - Standard and TRIBs Optics Phase Space @ Injection<sup>[2,3,8]</sup>



Betafunction of Core and Island Beam<sup>[2,3,8]</sup>

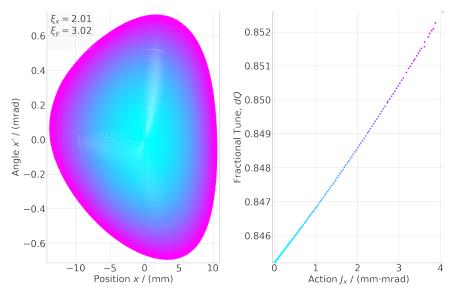


Dispersion of Core and Island Beam<sup>[2,3,8]</sup>



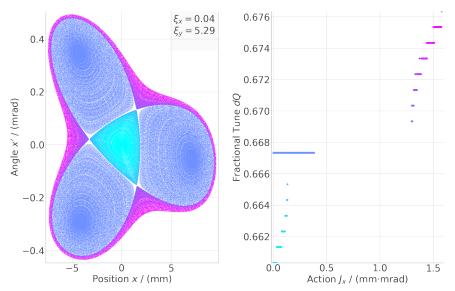
### TRIBs at BESSY II: Optics Simulation

Tuneshift with Action for BESSY II Standard Optics: 2.2 kHz mm<sup>-1</sup> mrad<sup>-1 [2,3,8]</sup>

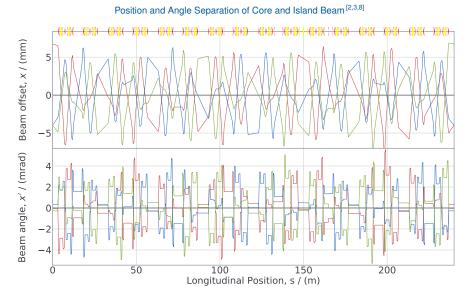


### TRIBs at BESSY II: Optics Simulation

Tuneshift with Action for BESSY II TRIBs Optics: 10.6 kHz mm<sup>-1</sup> mrad<sup>-1 [2,3,8]</sup>



# Characterisation of the Second Orbit: Separation



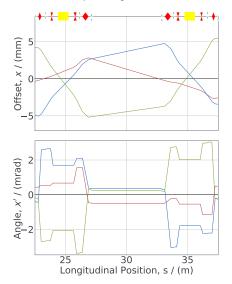
# Characterisation of the Second Orbit: Separation

I 🔶 I 🚺 I 🤇 🍋 Offset, x / (mm) 5 -5 4 Angle, x' / (mrad) 40 45 50

Triplet Straight T2<sup>[2,3,8]</sup>

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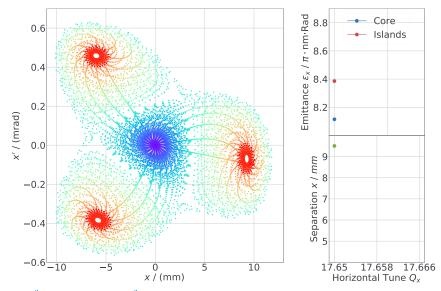
Longitudinal Position, s / (m)



### Overview of the Island Position/Angle in the Insertion Devices<sup>[3,8]</sup>

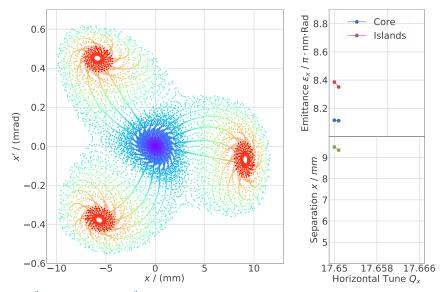
Section	ID	Displacement / mm			Angle / mRad		
3601011		1 <sup>st</sup> Turn	2 <sup>nd</sup> Turn	3 <sup>rd</sup> Turn	1 <sup>st</sup> Turn	2 <sup>nd</sup> Turn	3 <sup>rd</sup> Turn
D1	Injection BUMP	6.7174	-3.9578	-3.9932	-0.05376	0.32808	-0.27485
T1	BAM WLS 7T	1.3152	0.11078	-1.5561	-0.93677	1.5655	-0.26765
D2	U125ID2R	1.2981	3.6842	-4.4469	-0.49464	0.34677	0.2342
T2	HMI WIGGLER - MPW 7T	-0.58177	1.6588	-0.85216	-1.4422	0.11404	1.3989
D3	UE56ID3R	-3.8811	4.1013	0.56769	-0.2945	-0.2847	0.5317
Т3	U41IT3R	-1.5728	0.49419	1.1399	0.0043903	-1.4628	1.1512
D4	U49ID4R	-3.8081	-1.5582	4.9714	0.3163	-0.48362	0.061571
T4	UE49IT4R	-0.34921	-1.3378	1.3285	1.5663	-0.86625	-0.88968
D5	UE52ID5R	2.4581	-5.0744	1.4682	0.44419	0.039474	-0.48759
T5	UE46IT5R	1.4979	-1.2096	-0.67239	0.58948	1.073	-1.4958
D6	U139ID6R (Modulator) + UE56ID6R (Radiator)	4.8264	-0.77336	-4.5489	-0.1445	0.48775	-0.24696
T6	Collimator + UE48IT6R (EMIL)	1.5547	0.10857	-1.7177	-1.1195	1.3533	0.1174
D7	UE112ID7R	1.6858	3.686	-4.5171	-0.52521	0.26038	0.31483
T7	PSF WLS 7T	-0.72157	1.4625	-0.49279	-1.6324	-0.058378	1.6416
D8	U49ID8R	-5.0178	3.3645	2.2969	-0.23718	-0.31924	0.47859
Т8	4 x .54m 360kV CAVITIES (scraper at center)	-1.6938	0.15858	1.5113	0.43334	-1.4549	0.65292

Separation vs Core Tune  $Q_x = 17.65^{[2,3,8]}$ 



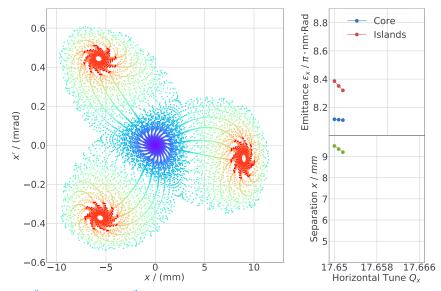
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6508^{[2,3,8]}$ 



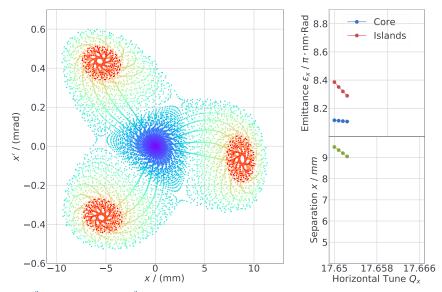
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6516^{[2,3,8]}$ 



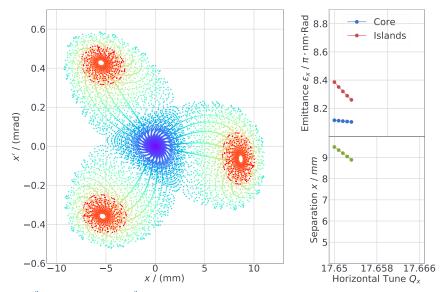
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6524^{[2,3,8]}$ 



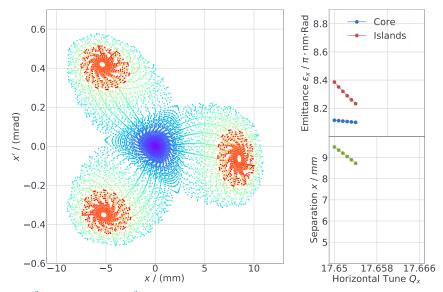
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6532^{[2,3,8]}$ 



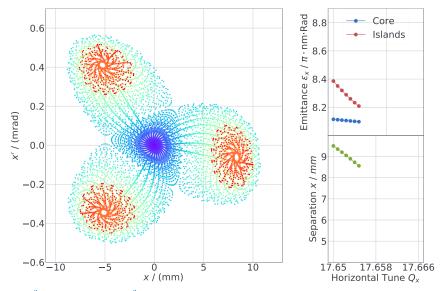
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.654^{[2,3,8]}$ 



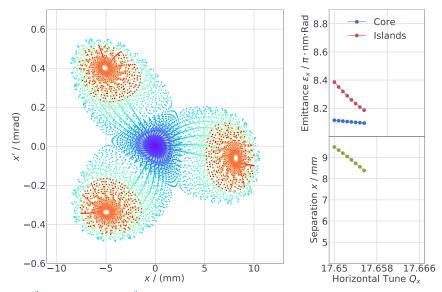
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6548^{[2,3,8]}$ 



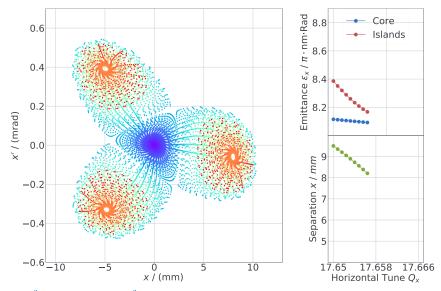
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6556^{[2,3,8]}$ 



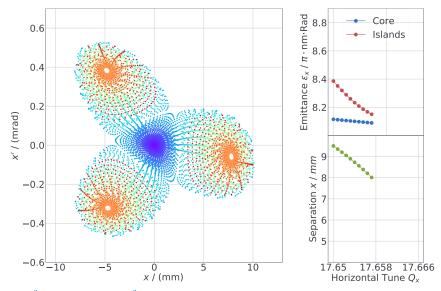
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6564^{[2,3,8]}$ 



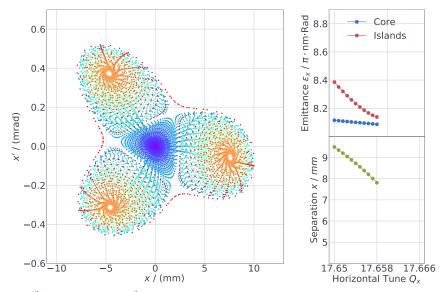
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6572^{[2,3,8]}$ 



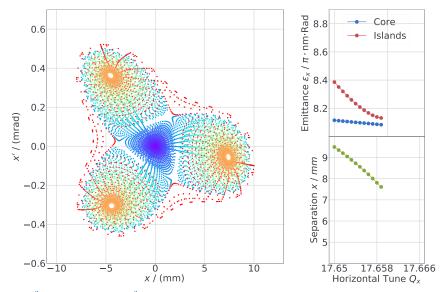
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.658^{[2,3,8]}$ 



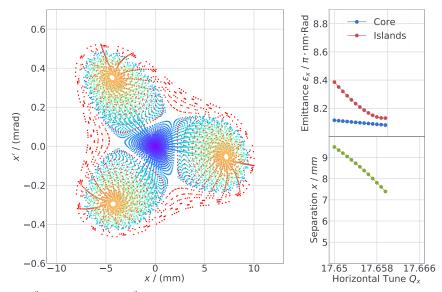
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6588^{[2,3,8]}$ 



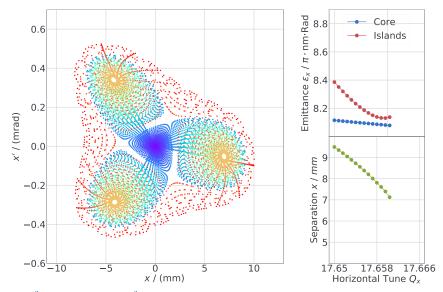
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6596^{[2,3,8]}$ 



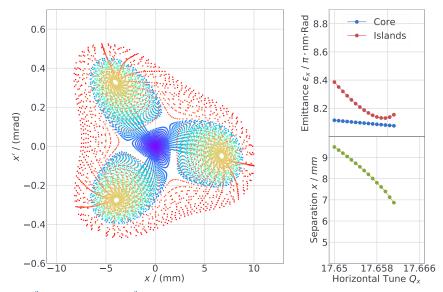
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6604^{[2,3,8]}$ 



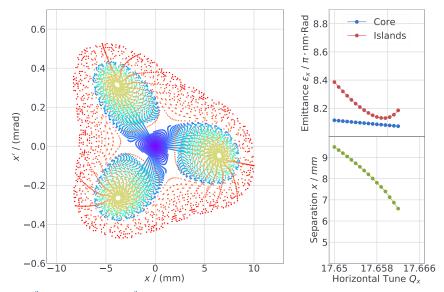
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6612^{[2,3,8]}$ 



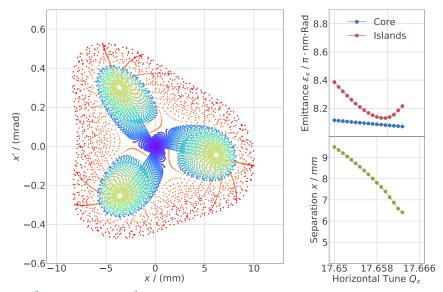
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.662^{[2,3,8]}$ 



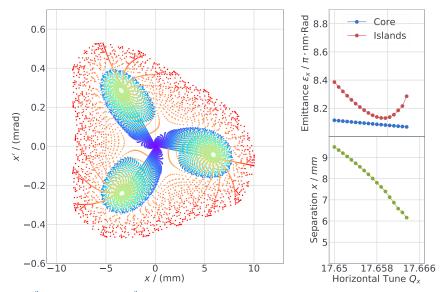
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6628^{[2,3,8]}$ 



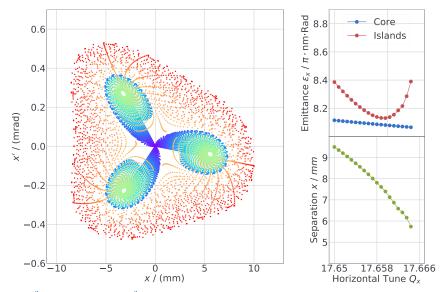
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6636^{[2,3,8]}$ 



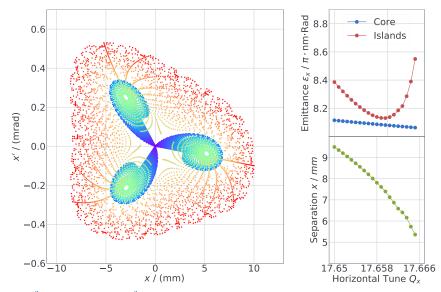
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6644^{[2,3,8]}$ 



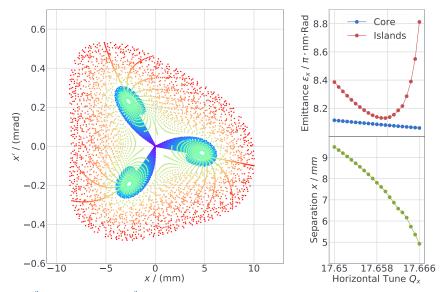
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.6652^{[2,3,8]}$ 



Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

Separation vs Core Tune  $Q_x = 17.666^{[2,3,8]}$ 



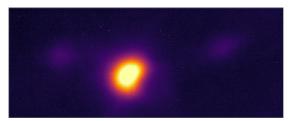
Felix Kramer, 4<sup>th</sup> MT student retreat, Berlin, 11<sup>th</sup> of June 2018

## Friendly User Test Week: Overview

#### All Current On Core Orbit<sup>[2]</sup>



#### Single Bunch on Island Orbit, Multibunch on Core<sup>[2]</sup>



### Only Single Bunch on Island Orbit<sup>[2]</sup>



- one entire week (KW 8, 2018) for friendly user experiments
- more external feedback

#### **Requirements:**

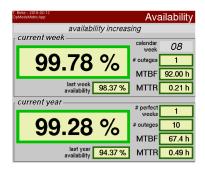
Injection efficiency	> 90 %
Lifetime	> 5 h

#### Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018

#### Open Beamshutters, Tuesday/Friday<sup>[9]</sup>

HZB	10	Status BESSY	II	Overview	IDs			Beampos
Descuellers	Beam	shutters ur	locked	/ Bea	m a	vaila	ble	
DIP 1.1 / EUV							UE49	
DIP 1.2 / KMC1			DIP 1.2 / F	M4 OPTIC				23.75 mm
7T WLS / -40mrad / B		W7IT1R	UES2				UE52	ID5R
7T WLS / Omrad / BAM			🛑 DIP 1.1 / F					
DIP 1.2 / HE-SGM			🛑 DIP 2.1 / F					
DIP 2.1 / IRIS			UE46 PC				<b>UE46</b>	
		U125ID2R	🛑 DIP 1.2 / f	's-laser				26.80 mm
DIP 1.2 / 5m NIM-2			UE56/1 PC				UE56	
7T MPW / -12mrad		W7IT2R	🛑 DIP 1.1 / F					
7T MPW / +1°			DIP 2.1 / 1				U139	
DIP 1.2 / ISISS								99.99 mm
UE56/2 PGML PGM2		UE56ID3R	🛑 UE48 / EM				<b>UE48</b>	
DIP 1.1 / PM-2		21.43 mm	🛑 DIP 1.2 / 3					92.93 mn
			UE112 PC				<b>UE11</b>	2ID7R
U41		U41IT3R	OIP 2.1 / H	KMC-3				68.91 mm
DIP 1.1 / LIGA			7T WLS / -	40mrad			W71T	
DIP 1.2 / PTB								6.80 T
U49/1 / PTB		U49ID4R					U491	
DIP 1.1 / DWL PTB		94.67 mm	DIP 1.2 / T	FGM-7				99.99 mn
DIP 1.2 / KMC DWL PT			OIP 1.1 / 0	DR-PGM				
DIP 2.1 / SX-700 PTB								
DIP 2.1 / SX-700 PTB Legend: open HZB 2018-00 1255-44	moving	closed	Y II	Overview	IDs	Beemsi	www.totog	Beampos
Legend: open	20 S							Beampos
Legend: open	20 S	tatus BESS		/ Bea	m a		ble	
HZB Contraction Co	<sup>23</sup> S Beam	tatus BESS	locked	/ Bea <sup>M-1</sup>	m a 7	vaila	ble UE49	IT4R
Legend: open HZB En state DIP 1.1 / EUV DIP 1.2 / KMC1	<sup>20</sup> S Beam 14.0 eV	tatus BESS	UE49 / PG	/ Bea <sup>M-1</sup>	m a 7	vaila 10.0 ev	ble UE49	<b>174R</b> 26.24 mn
Legend: open HZB En state DIP 1.1 / EUV DIP 1.2 / KMC1	22 S Beam 14.0 eV ESSY	tatus BESS' shutters ur	UE49 / PGI	/ Bea M-1 PM4 OPTIC PGM1	m a 7	1 <b>Vaila</b> 10.0 eV 75.0 eV	ble UE49	(T4R 26.24 mn (D5R
Legend: open HZB	22 S Beam 14.0 eV ESSY	tatus BESS' shutters ur w71T1R	UE49 / PGI DIP 1.2 / F UE52	/ Bea M-1 PM4 OPTIC PGM1 PM-1	m a 7	1 <b>Vaila</b> 10.0 eV 75.0 eV	ble UE49	(T4R 26.24 mn (D5R
Legend: open HZB Secondaria DIP 1.1 / EUV DIP 1.2 / KMC1 7T WLS / -40mrad / B 7T WLS / 0mrad / BAN DIP 1.2 / HE-SGM	22 S Beam 14.0 eV ESSY	tatus BESS' shutters ur w71T1R	UE49 / PGI DIP 1.2 / F UE52 DIP 1.1 / F	/ BCA M-1 PM4 OPTIC PGM1 PM-1 KMC 2	<b>m a</b> 71 21	1 <b>Vaila</b> 10.0 eV 75.0 eV	UE49 UE52 UE52	174R 26.24 mm 105R 27.20 mm
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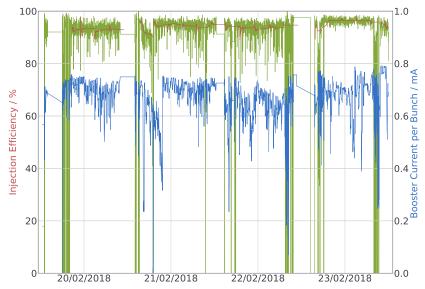
#### Total Availability<sup>[9]</sup>



#### Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



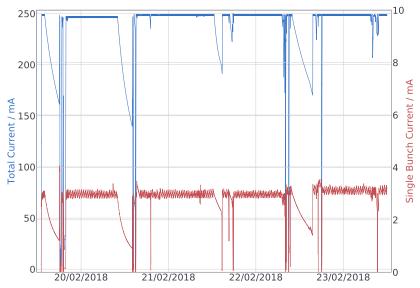
Injection Efficiency<sup>[2]</sup>



Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



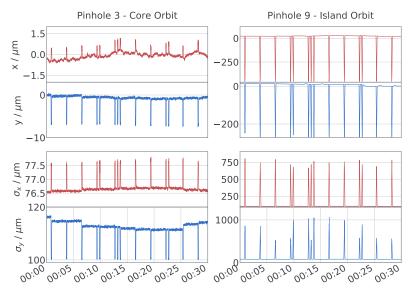
Storage Ring Current<sup>[2]</sup>



Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



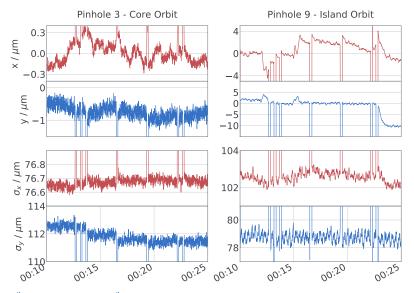
Beam Stability, Friday 23rd [2]



Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



Beam Stability, Friday 23rd [2]



Felix Kramer, 4th MT student retreat, Berlin, 11th of June 2018



#### General Tone

- No major unsolvable problems observed
- Roughly same quality for experiments
- UE52: very positive, seperation possible without bump
- UE56-2: Easy to switch
- Gregor: Easy separation, No problems with gas phase target as not dependant on beam pos/sigma
- signal cleaner than chopper, much smaller leftover signal

Main Problem: Injection Scheme

- Standard Top Up: 100ms pre and 50 posttrigger
- TRIBs Top Up: 8s widened beam with intensity drop
- Different beam conditions which not all users can compensate
- Big problem for spectroscopy and microscopy
- · Feedback loops steer away in this time
- Strong kick at Island Collapse
- ⇒ Provide Additional Pre- and Posttrigger for sensitive users
- ⇒ Reduce excitation to <500 ms (disregard 1 image from on the fly scan)</p>



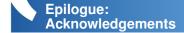
#### Summary

- · Resonant islands as bunch seperation scheme provides seems very promising
- · LOCO in combination with nonlinear optics from conversion factors not bad
- Chromaticity, TSWA, Separation and Tune dependany provide good observables to verify optics
- Tuneshift with amplitude (TSWA) is measurable with the bbfb system
- TSWA simulation with elegant gives results in order of measurement

## Outlook

Nonlinear optics are the key for optimization of TRIBs optics

- $\Rightarrow~$  Characterize the nonlinear lattice of BESSY II
  - $\rightarrow$  chromaticity
    - → chromatic sextupoles
  - $\rightarrow$  tune shift with amplitude
    - $\rightarrow$  harmonic sextupoles
- ⇒ Master control of resonance islands
  - $\rightarrow$  numerical optimization of trusted nonlinear lattice
  - ightarrow phase space of one-turn map from the general hamiltonian



# Thank you for your attention!

# AKNOWLEDGEMENT AND PARTNERS



Federal Ministry of Education and Research



BESSY VSR





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