OPERATION MODES OF THE METROLOGY LIGHT SOURCE

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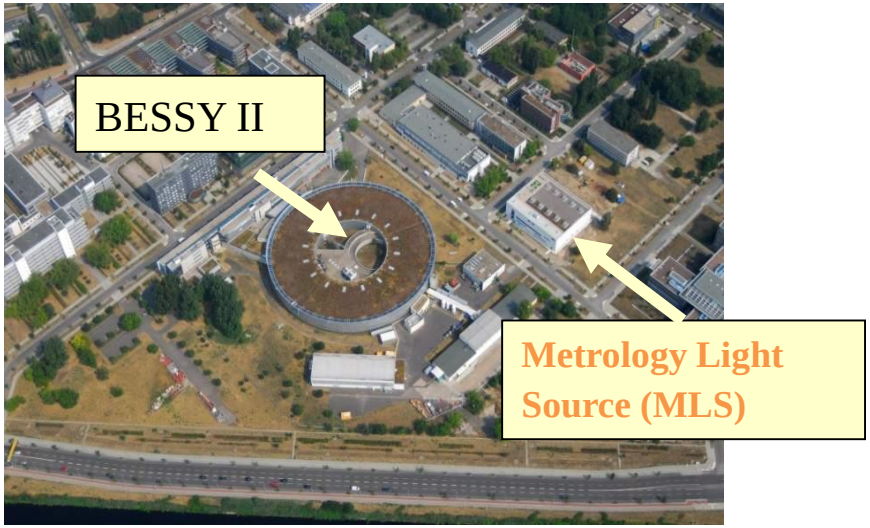
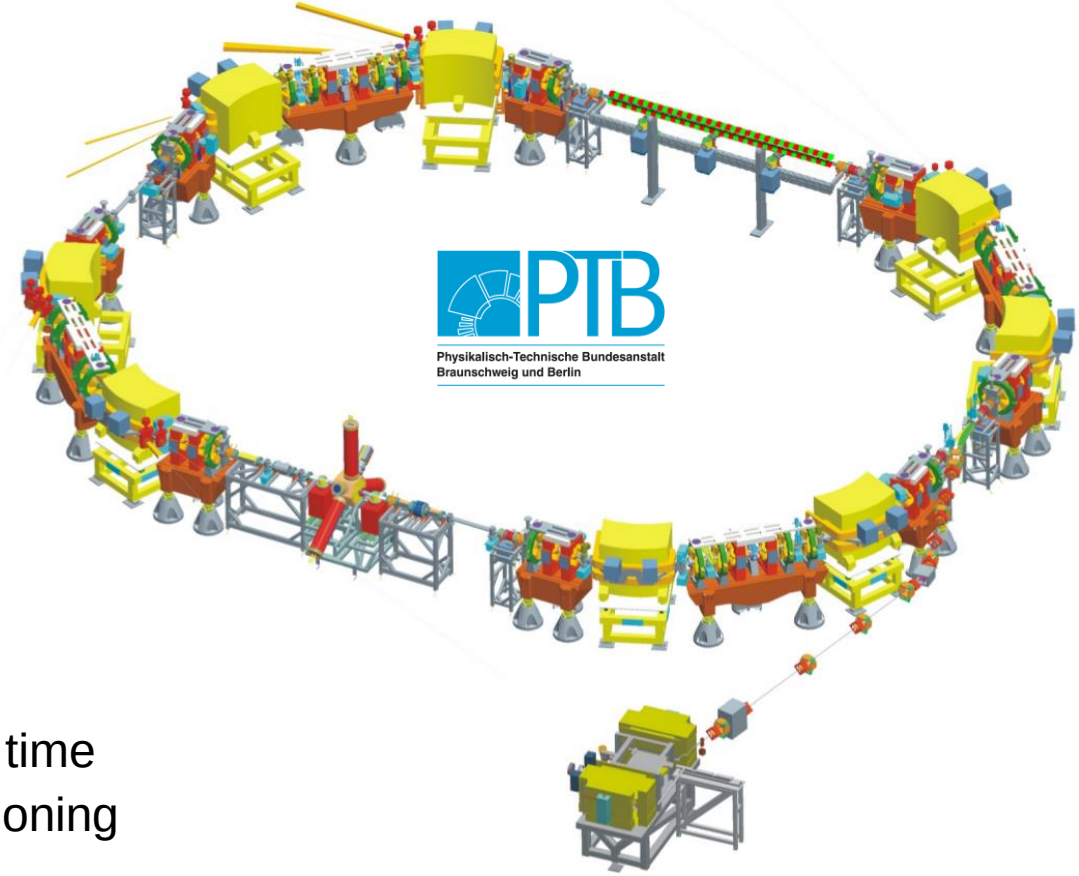
OUTLINE

- RF incident
- Established User Modes
- Exotic Operation Modes

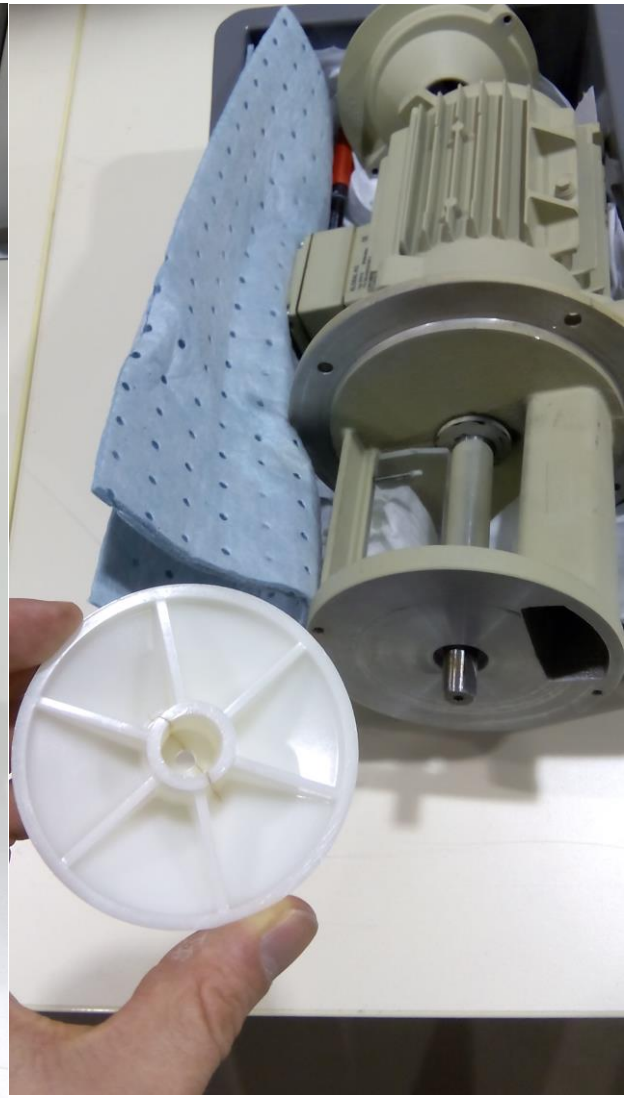


OPERATION OF THE METROLOGY LIGHT SOURCE

- operation since 2008
- purpose: metrology
- two operators sharing duty for BESSY II and MLS
- manned operation
  Mo – Fr / 7-23
- unmanned operation (user & machine) during nights and weekends
- highly automated operation (machine & users)
- 10 h of machine commissioning time per week (+ Sunday + commissioning weeks)

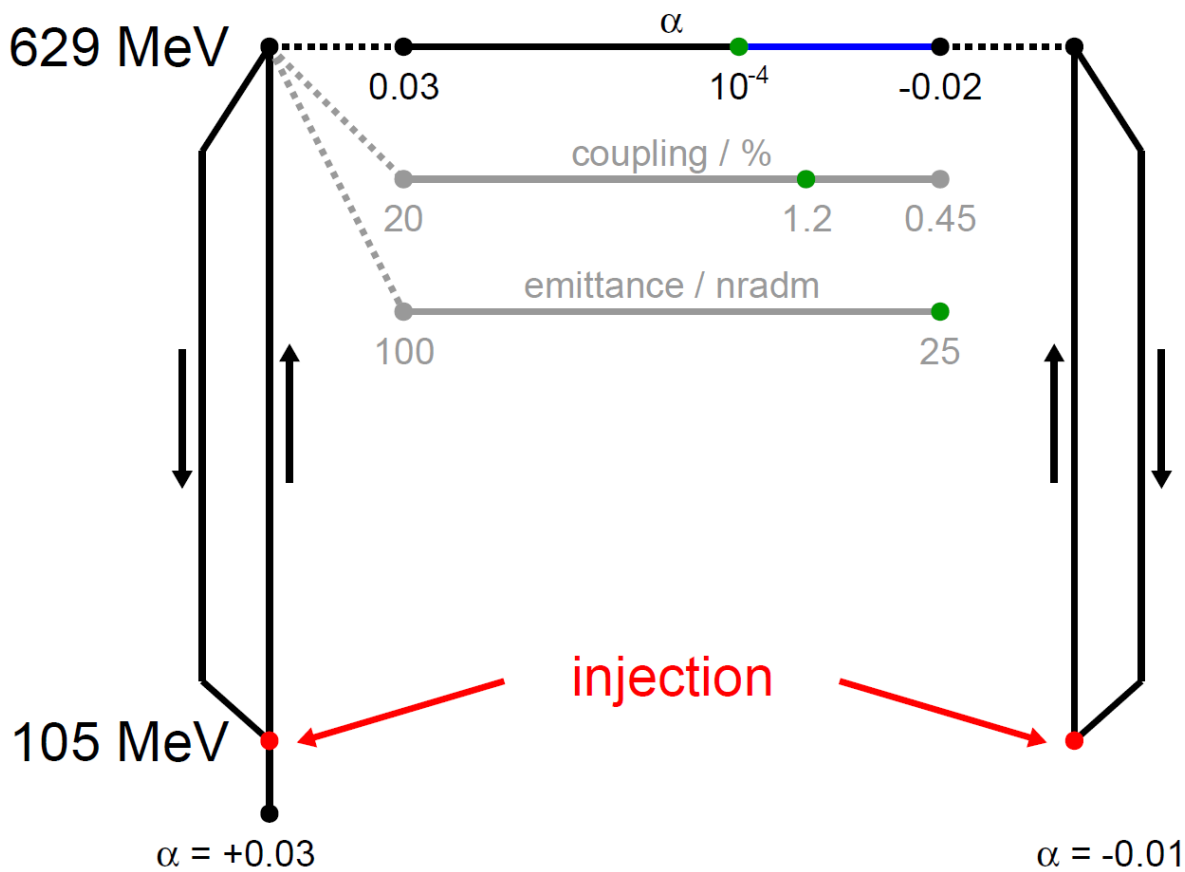


RF FAILURE – IOT POWER SUPPLY



- IOT power supply (the only RF cavity) faulted during user operation
- overheat protection
- reason: oil pump
- Time to recover was 3 days
- stock spares
- replace on time

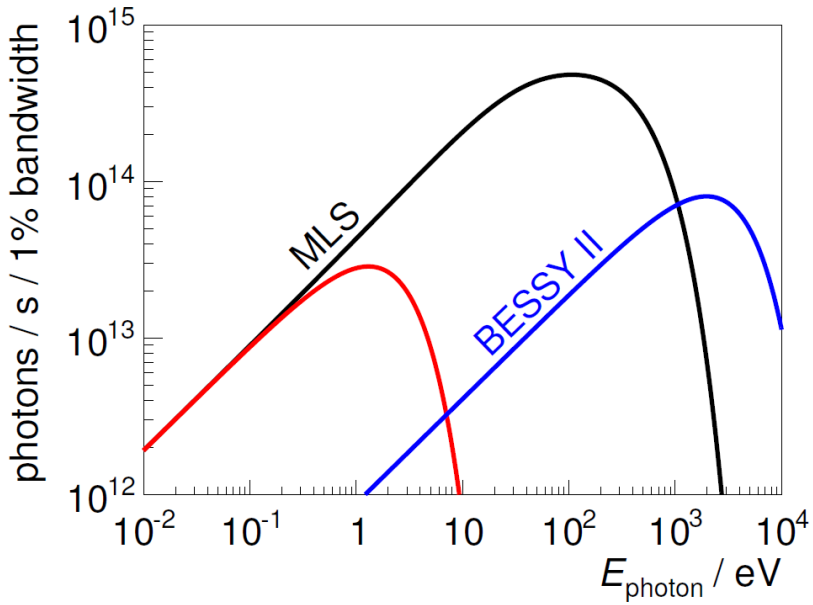
ESTABLISHED USER MODES

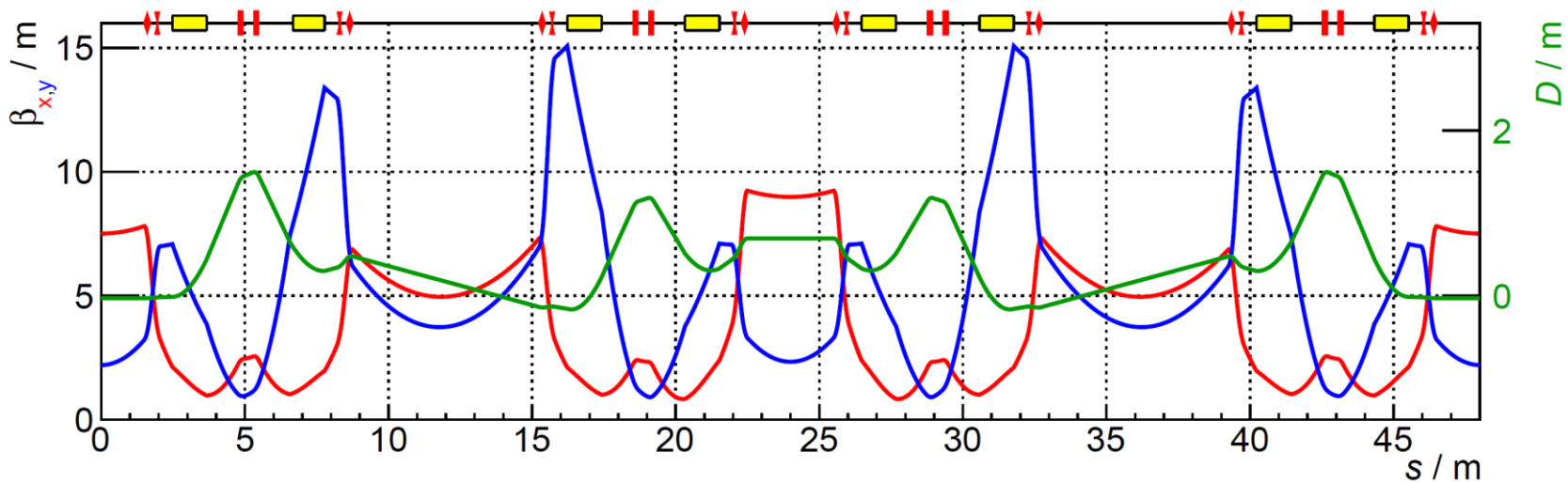


- fully automated (push-button)
- change optics ≈ 10 s
- reinject ≈ 15 min
- homogeneous filling, 200 mA, no gap
  → ions ☹

MOTIVATION: DESIGN USER

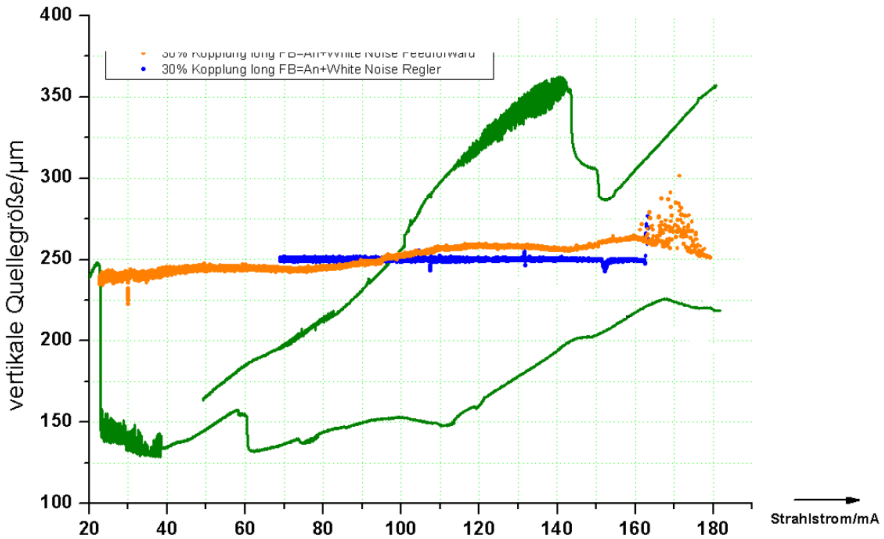
- $\xi_{hor} \approx 120$ nrad m
- $I\tau \approx 1000$ mAh
- >80 % of scheduled user time
- $\alpha = 0.03$





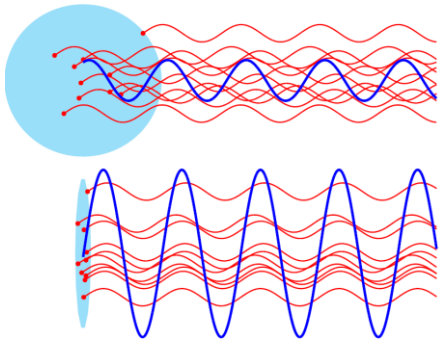
HOW TO GET THERE?

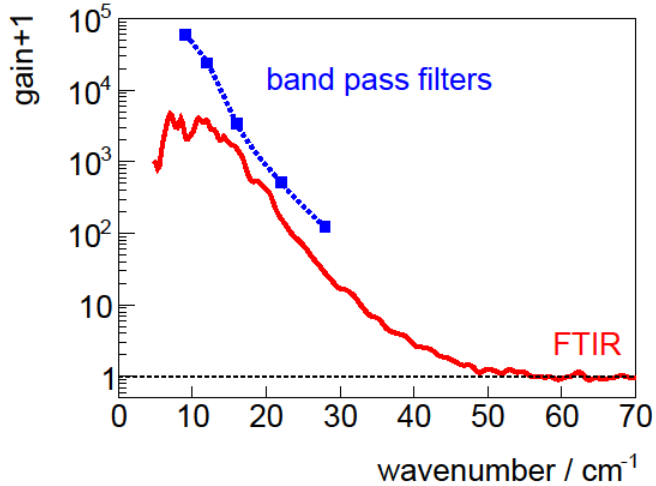
- Ions
  - clearing electrodes
  - sinusoidal excitation
  - white noise excitation applied to the vertical plane (minimized coupling)
  - white noise feedforward as a function of current
- Tune feedforward (U125)
- active longitudinal multi bunch feedback



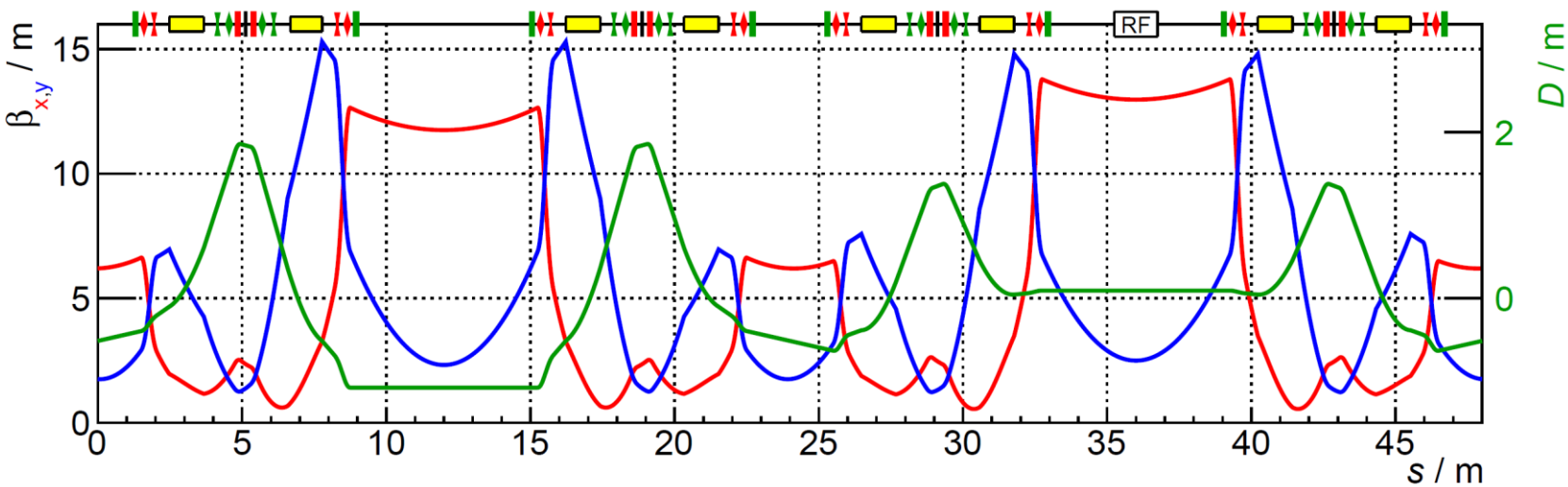
Verlauf der vert. Quellgröße vs Strahlstrom/mA für versch. Maschineneinst.

MOTIVATION: GENERATE COHERENT SYNCHROTRON RADIATION



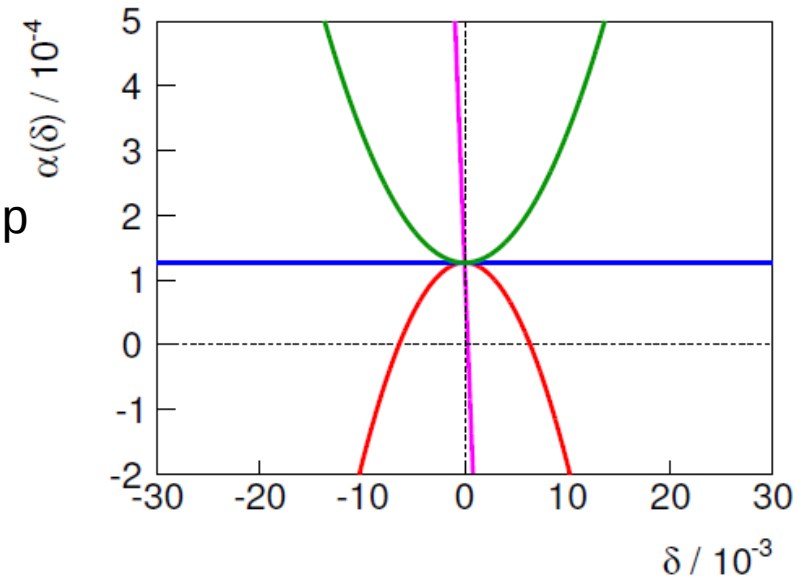


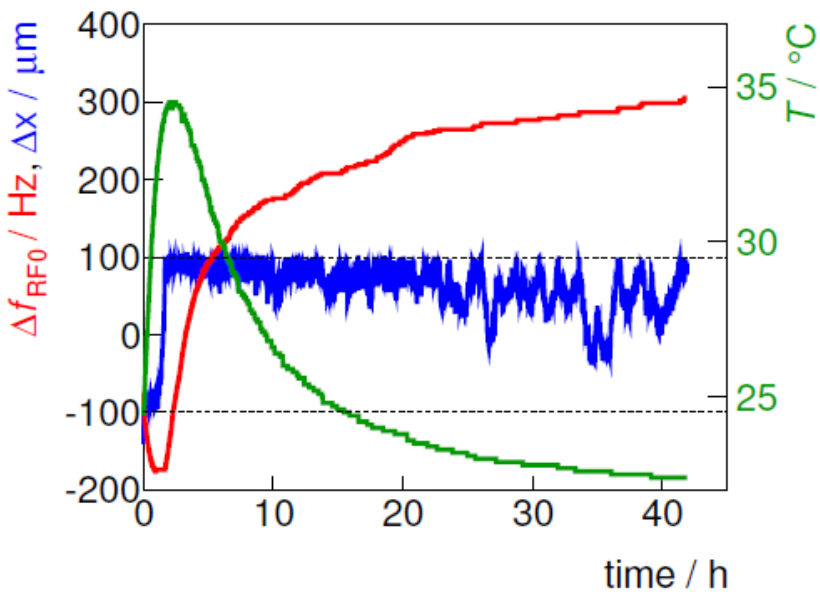
- $\xi_{hor} \approx 200$ nrad m
- $I\tau \approx 1600$ mAh
- α = +1.3e-4
- Usually used in the bursting region... $I \approx 100\ I_{th}$

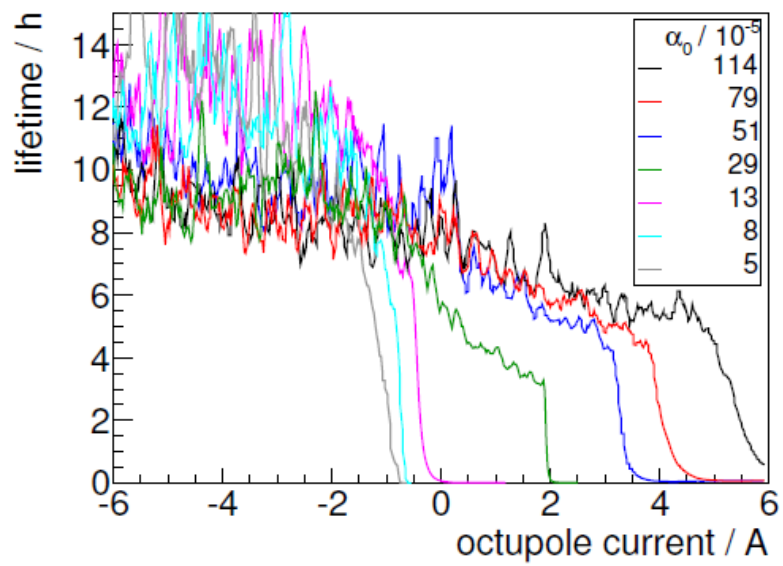


HOW TO GET THERE?

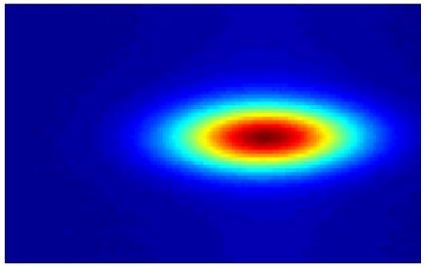
- carefully set up 3D chromaticities on optic ramp (while squeezing the beam)
- octupole
- Introduce coupling to improve S/N ratio of spectra
- Masterclock frequency controller



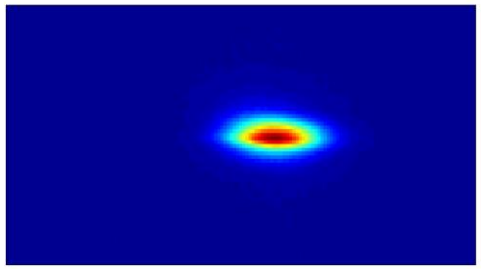




MOTIVATION: NEAR FIELD MICROSCOPY

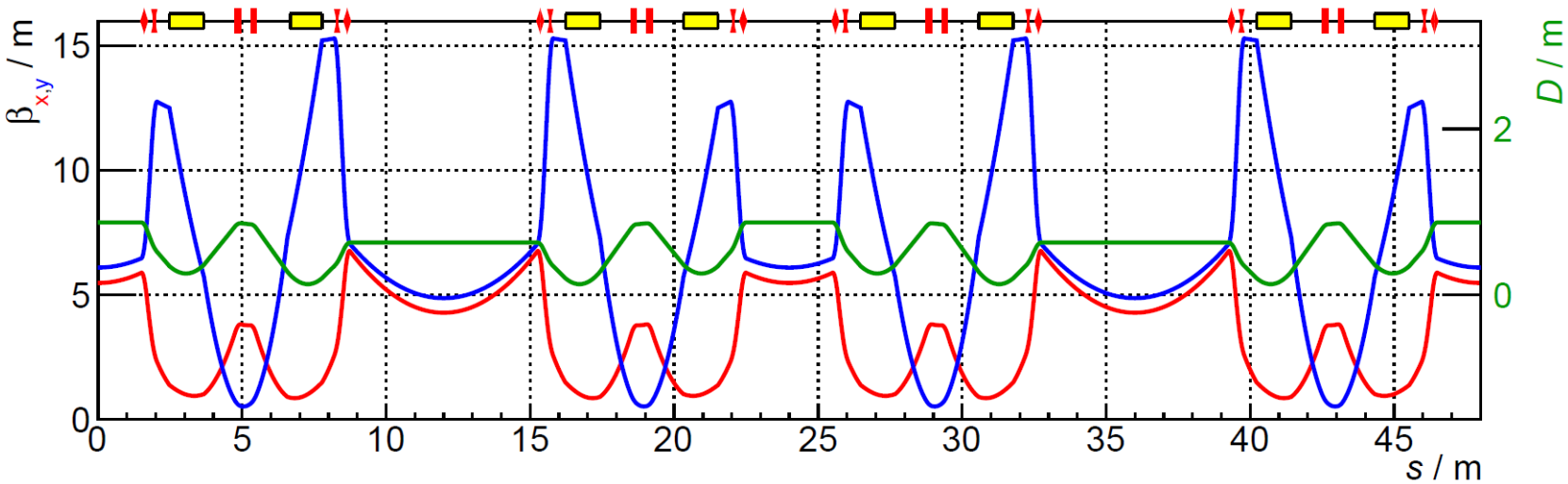


sstandard user

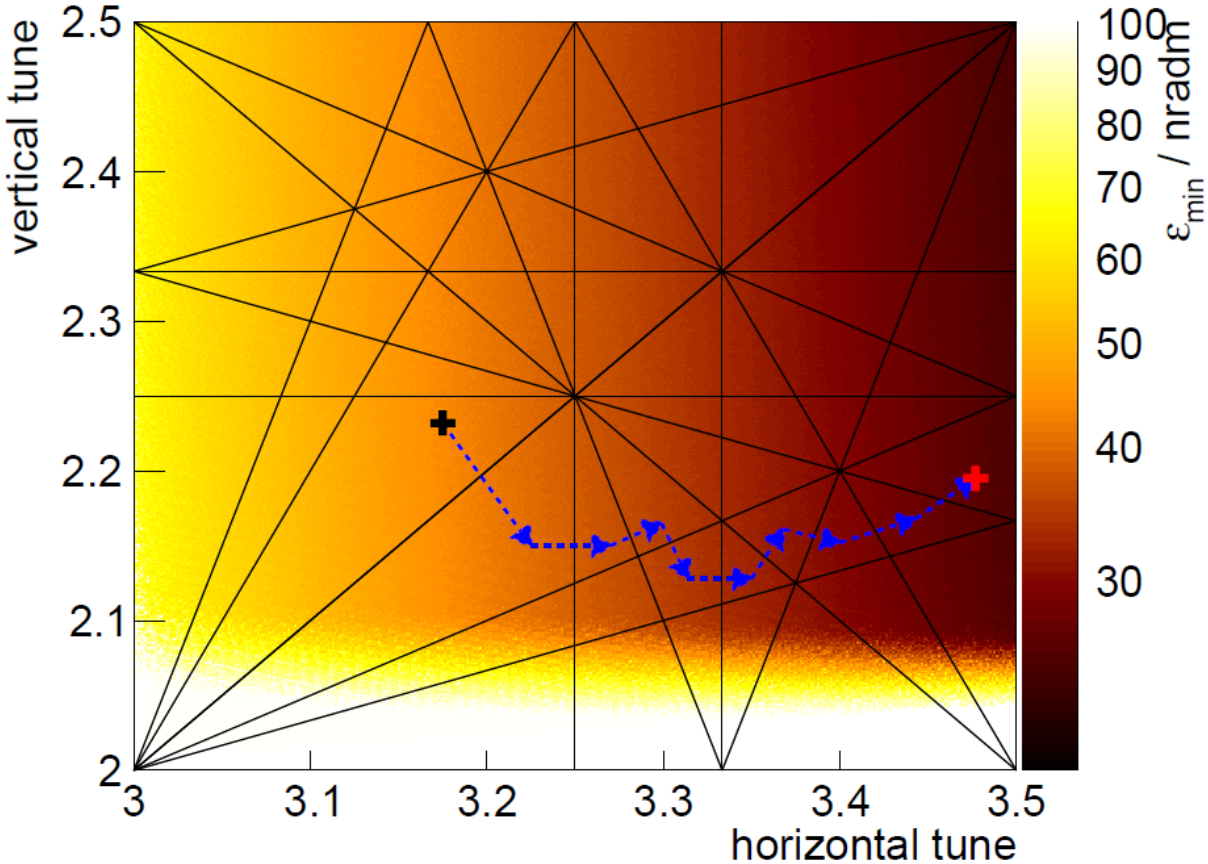


low emittance

- $\xi_{hor} \approx 30\ \mathrm{nrad\ m}$
- $I\tau \approx 400\ \mathrm{mAh}$
- increasing part of user time
- dynamics heavily ion-dominated
- outperforming similar experiments at other sources



HOW TO GET THERE?



- preserve usage of the existing energy ramp
  → allow fast optic changes
- cross multiple 3rd order resonances with full current
- sextupole settings adjusted on ramp and in user state

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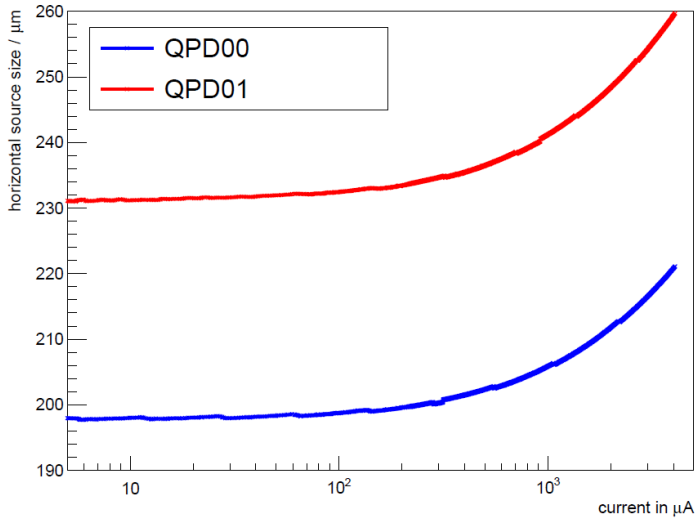
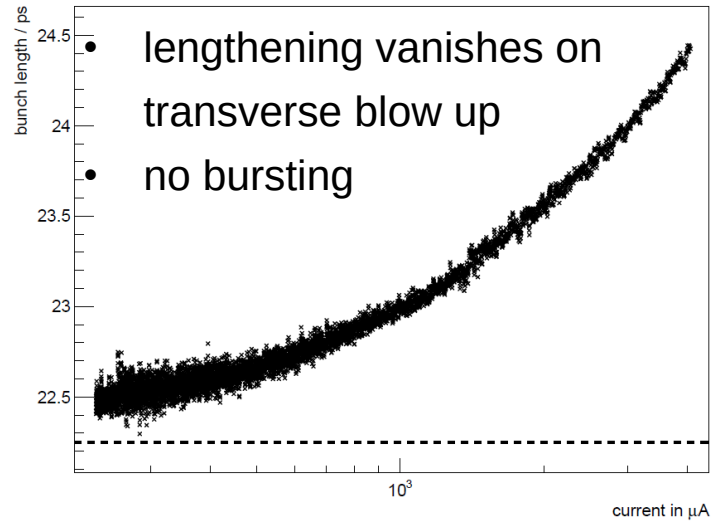
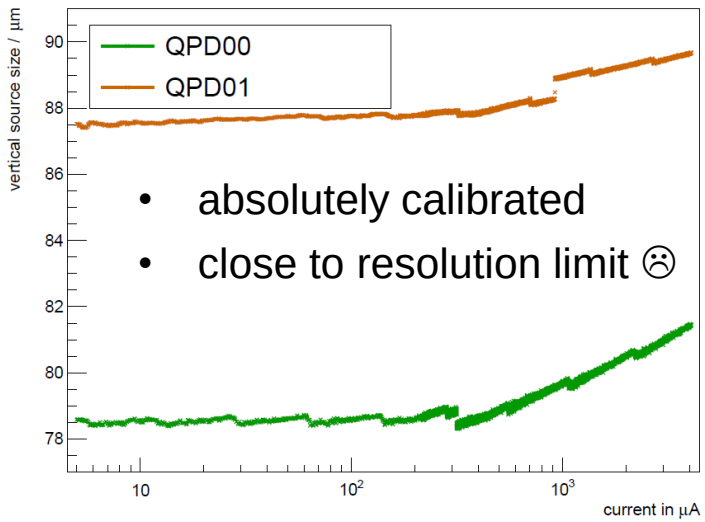
MOTIVATION: STUDY INTRABEAM SCATTERING ?? BESSY VSR

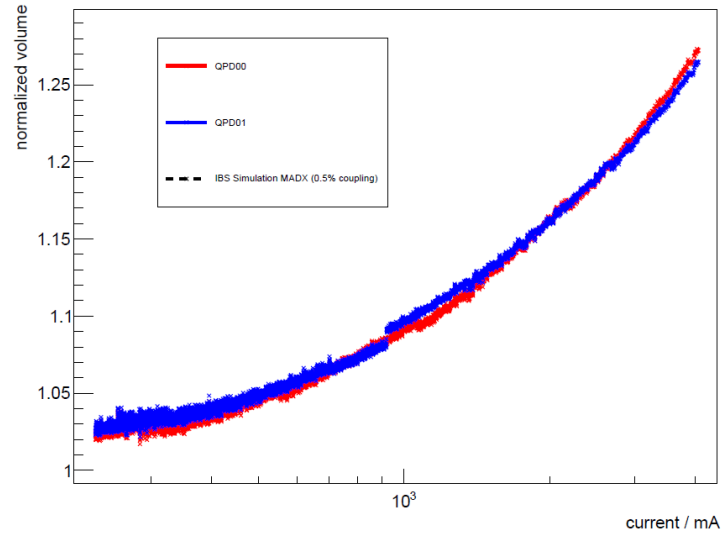




- lengthening vanishes on transverse blow up
- no bursting

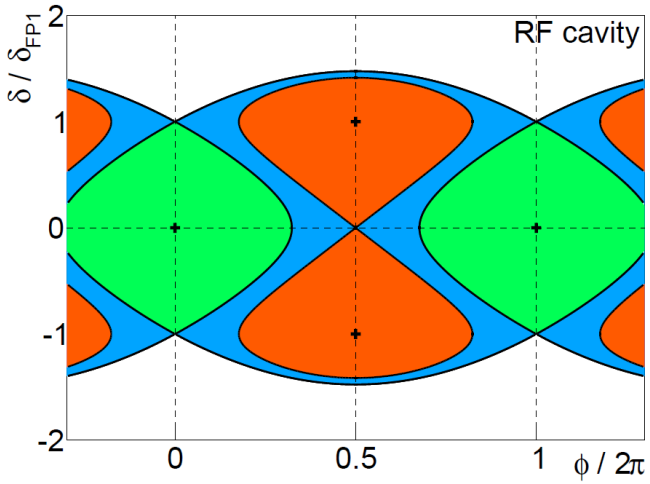


- absolutely calibrated
- close to resolution limit ☹

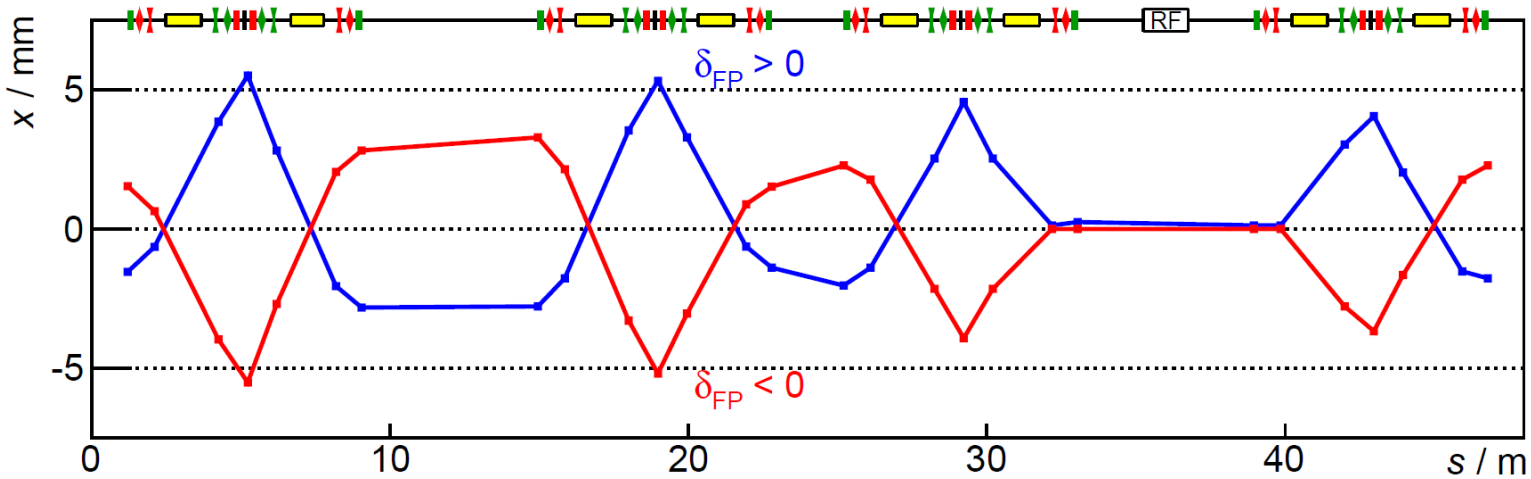


EXOTIC OPERATION MODES

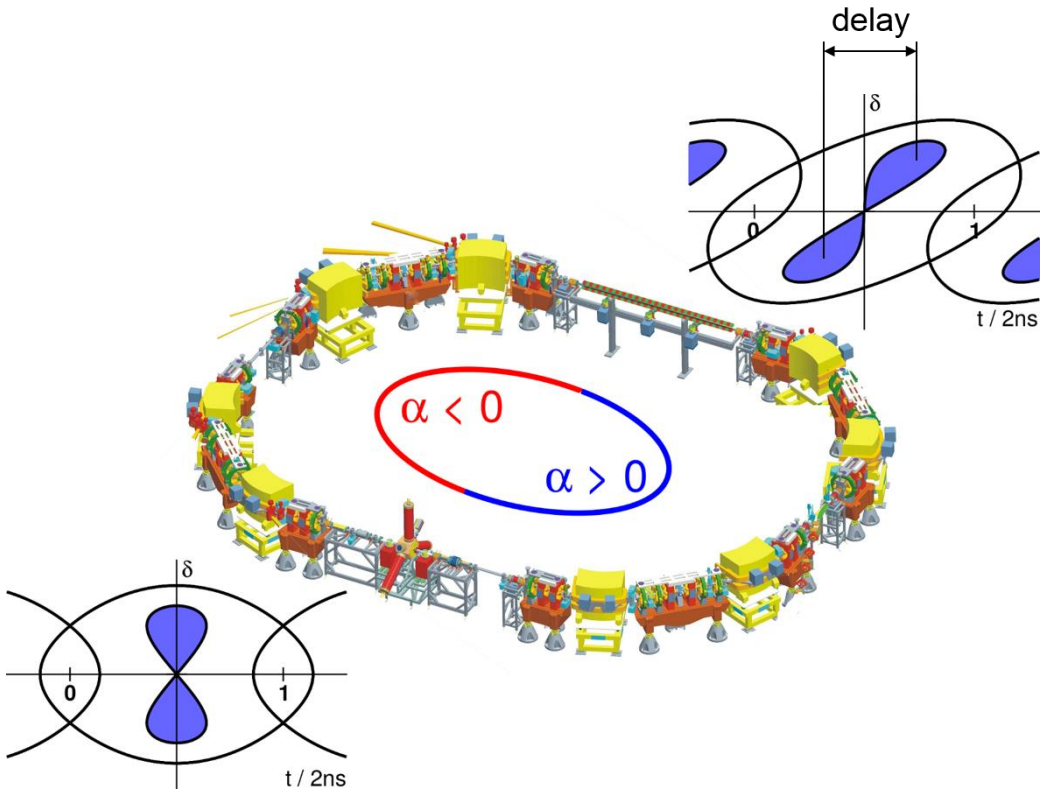
MOTIVATION: TICKLE & PROBE MEASUREMENTS

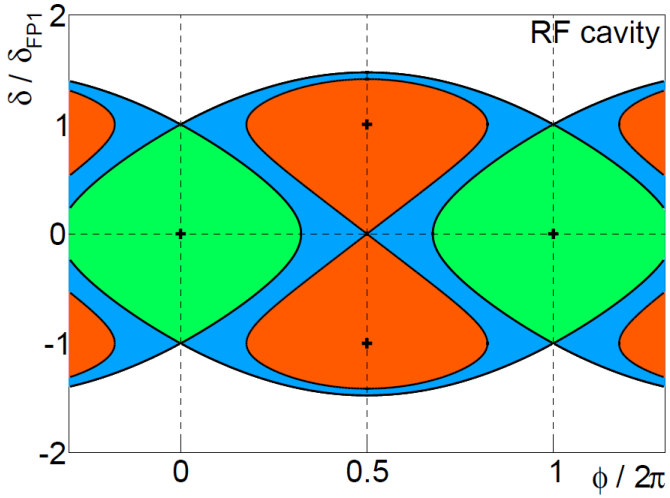


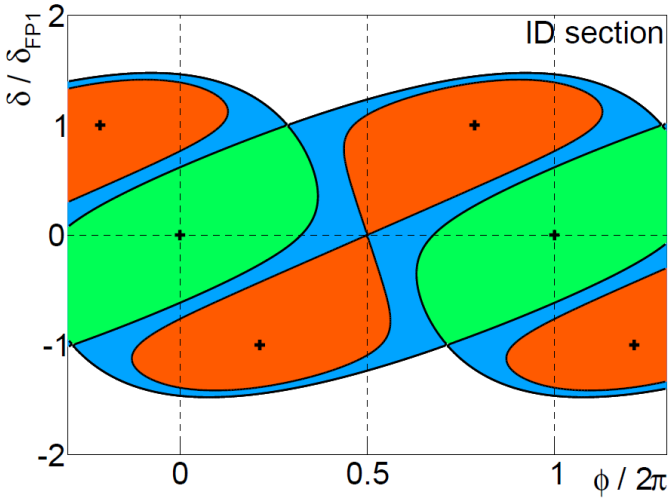
- based on alpha buckets / nonlinear longitudinal beam dynamics
- idea: make both buckets race each other
- alpha buckets need to be in the RF cavity at the same time (diff. energy loss negligible)
- breaking longitudinal symmetry of the ring



MOTIVATION: TICKLE & PROBE MEASUREMENTS



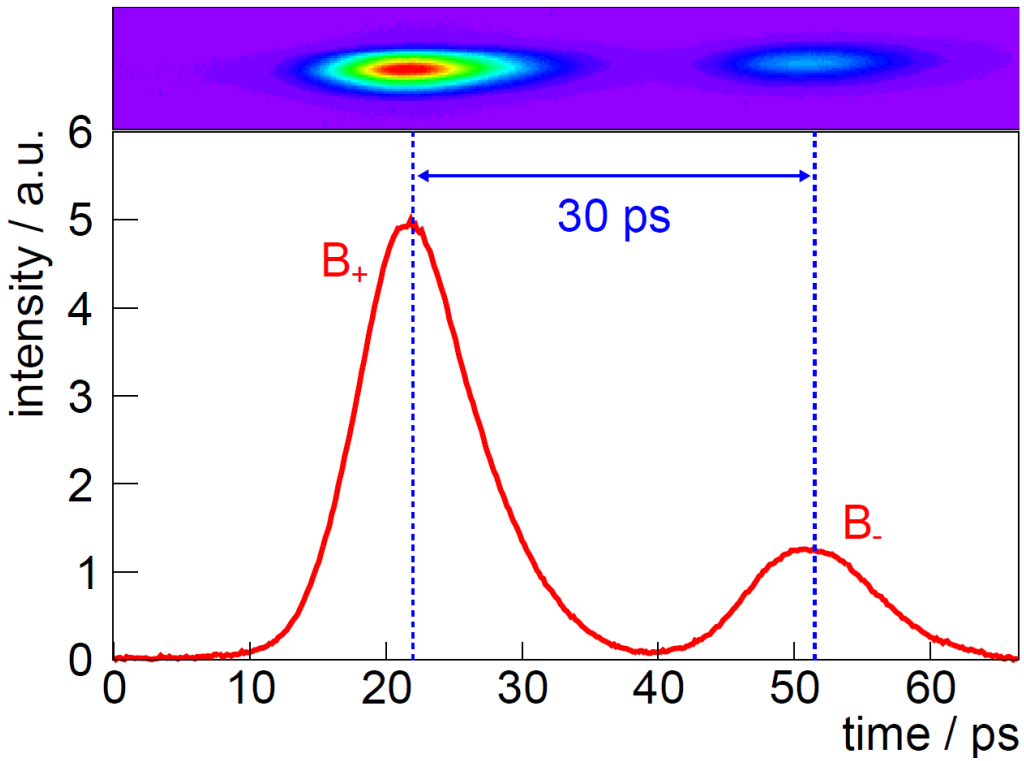




- low-α lattice (on average!)
- large partial momentum compaction of different signs in both halves of the ring (R56)

MOTIVATION: TICKLE & PROBE MEASUREMENTS

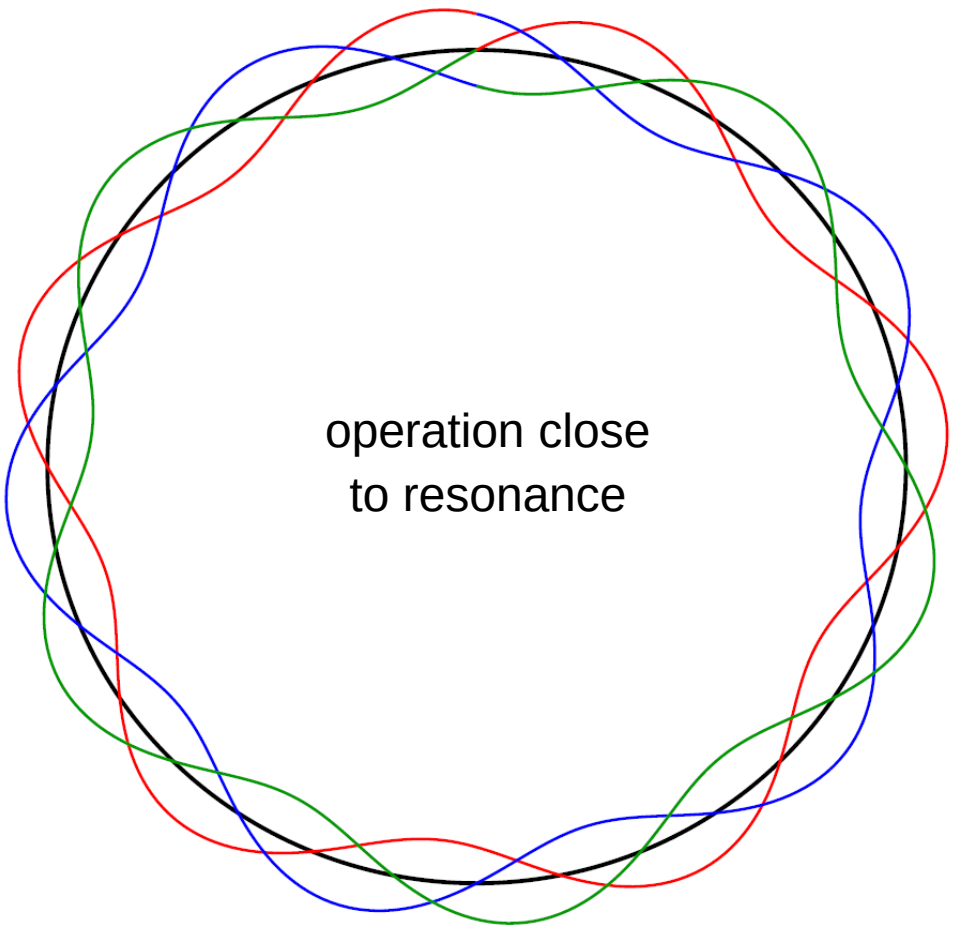
MOTIVATION: TICKLE & PROBE MEASUREMENTS

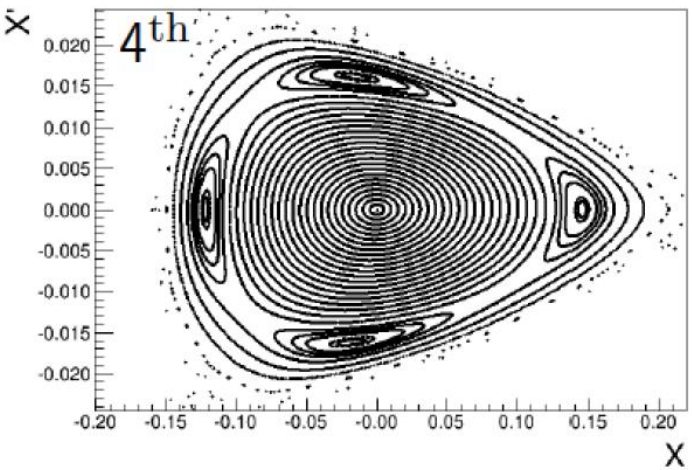


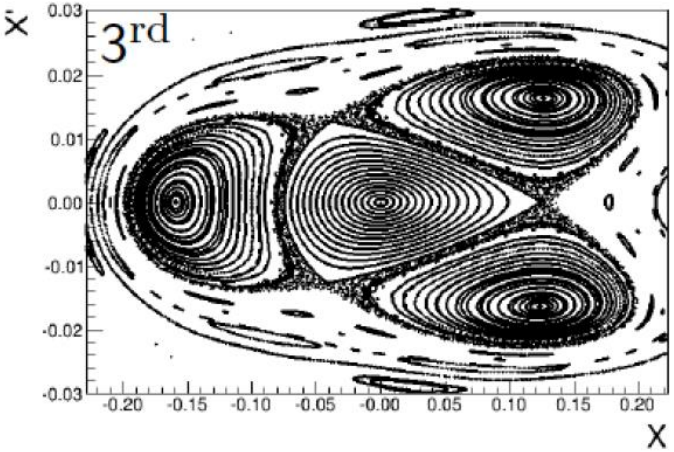
Streak measurement in ID straight

- accessible bunch length range corresponds to low-alpha range (factor $\sqrt{2}$ due to α-buckets)
- delay is tunable
- arbitrary current distribution
- horizontal emittance suffers due to dispersion manipulation
- only THz usage so far

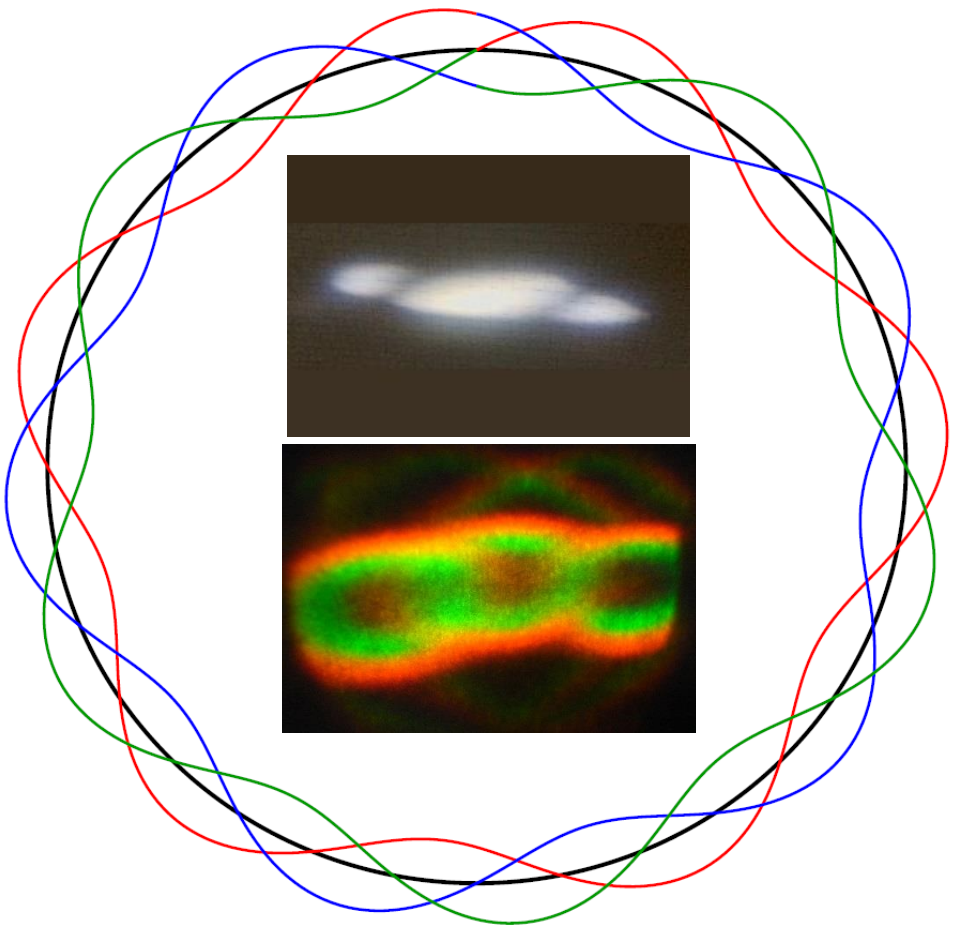
MOTIVATION: BEAM SEPARATION

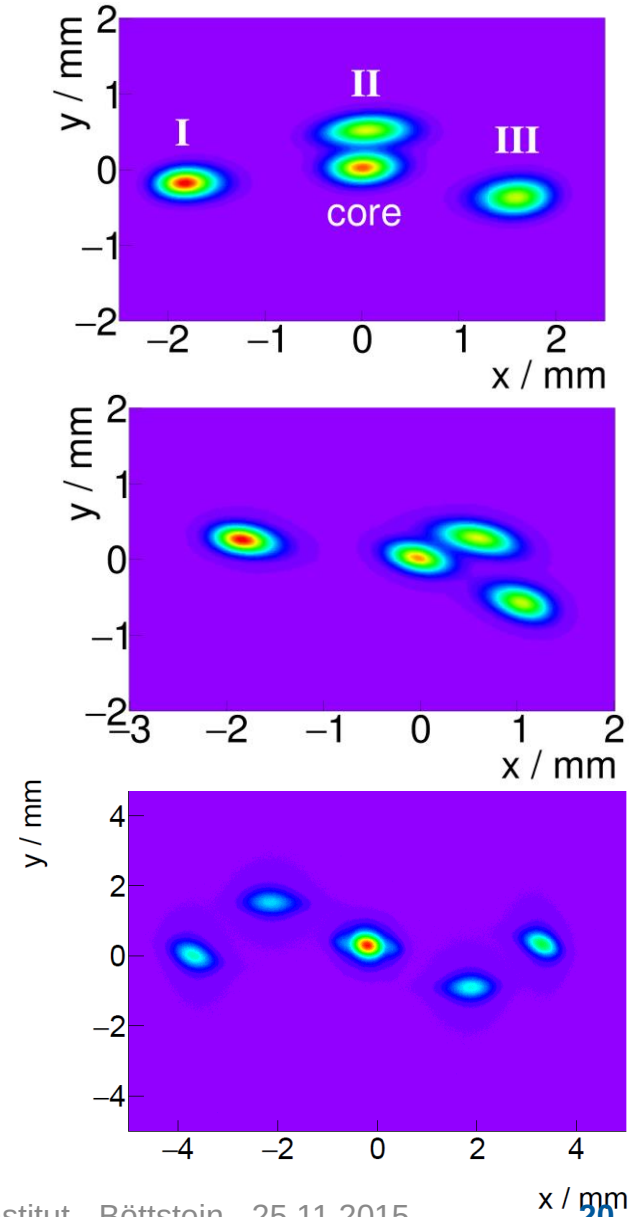






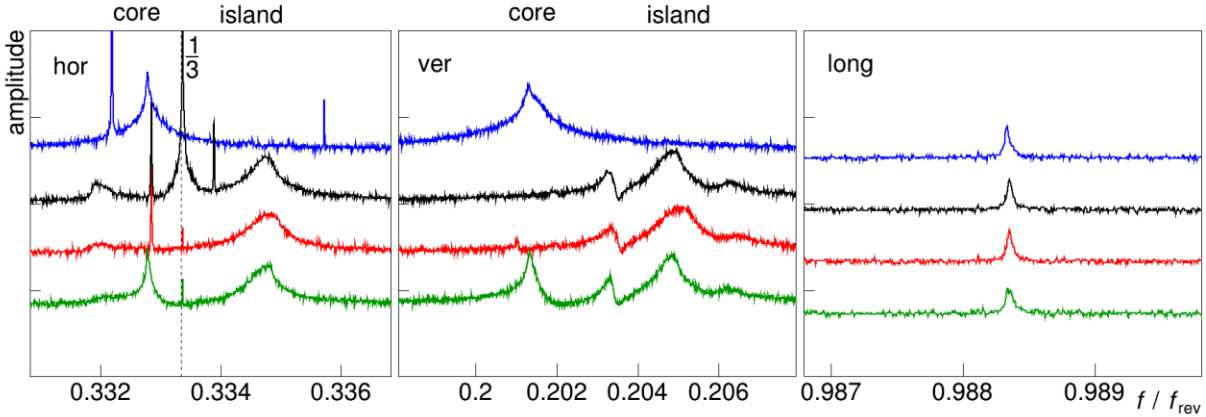
MOTIVATION: BEAM SEPARATION





HOW TO GET THERE?

- starting from DBA lattice
- setup optic ramp to cross coupling resonance, move working point near $\Delta Q_{hor} = \frac{1}{3}$
- correct transverse chromaticities
- use 3rd sextupole family to preserve lifetime while approaching the resonance
- carefully check diagnostics:
    - lifetime measurement or loss monitor
    - tune spectra
    - source point imaging system / emittance measurement
    - take care for strong IDs / machine protection

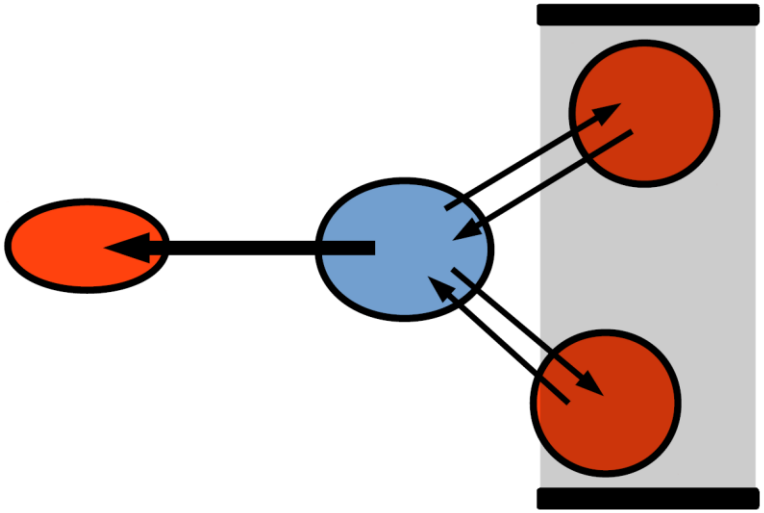


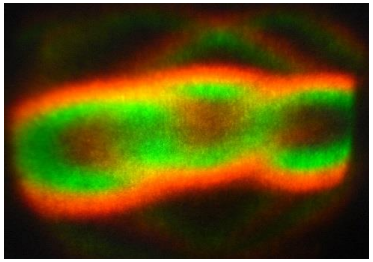
- only core populated
- only islands populated
- only “one island” populated
- core and islands equally

MOTIVATION: REVOLUTION DOWN CONVERSION

How to populate a single island?

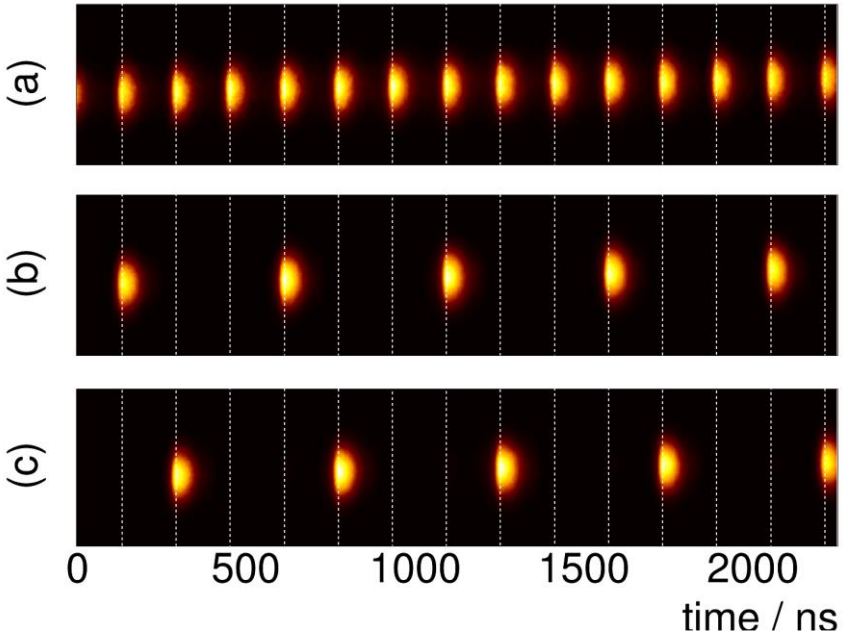
→ Nonlinear kicking (stripline)





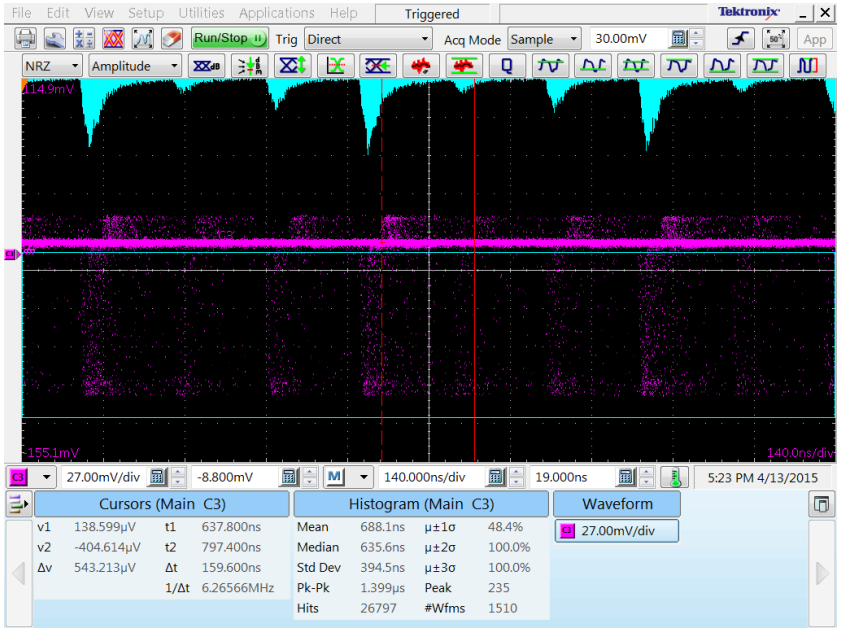
streak measurement

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



- (a) equally populated islands
- (b) + (c) single island populated

MOTIVATION: USER OPERATION



Commissioning together with users to optimize beam separation (rotation in phase space)

two user runs in decay mode with more than 10 h each for ARTOF experiments

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USER EXPERIENCE WITH ISLAND BUCKETS

- operational stability is suprisingly high
  → pushbutton implemation for the operator
- long term orbit stability is comparable to standard user operation
- beam lifetime is acceptable for decay operation
- scientific case is not very strong for the MLS as it is a very flexible machine anyway
  → apply to BESSY II or BESSY VSR
  see talk of P. Goslawski
- large emittance requires delicate tuning to minimize intra-bucket diffusion rates
- $\Delta Q_{hor} = \frac{1}{3}, \frac{1}{4}$ suitable resonances for operation
- dynamics were also investigated around $\Delta Q_{hor} = \frac{1}{2}, \frac{1}{5}$
- also works in the vertical plane at $\Delta Q_{ver} = \frac{1}{3}$

CONCLUSION

- user operation of the MLS is characterized by:
    - single standard user mode
    - many user-tailored modes making use of machine flexibility
    - close cooperation with users when developing new modes of operation
- CSR instability thresholds
- Ions dominating dynamics in several states
- MLS is a great machine to study nonlinear beam dynamics
    - Longitudinal plane → alpha buckets
    - Transverse plane → resonance island buckets
- experience gained is transferred between MLS and BESSY II
- realization of the Robinson wiggler project will be exciting

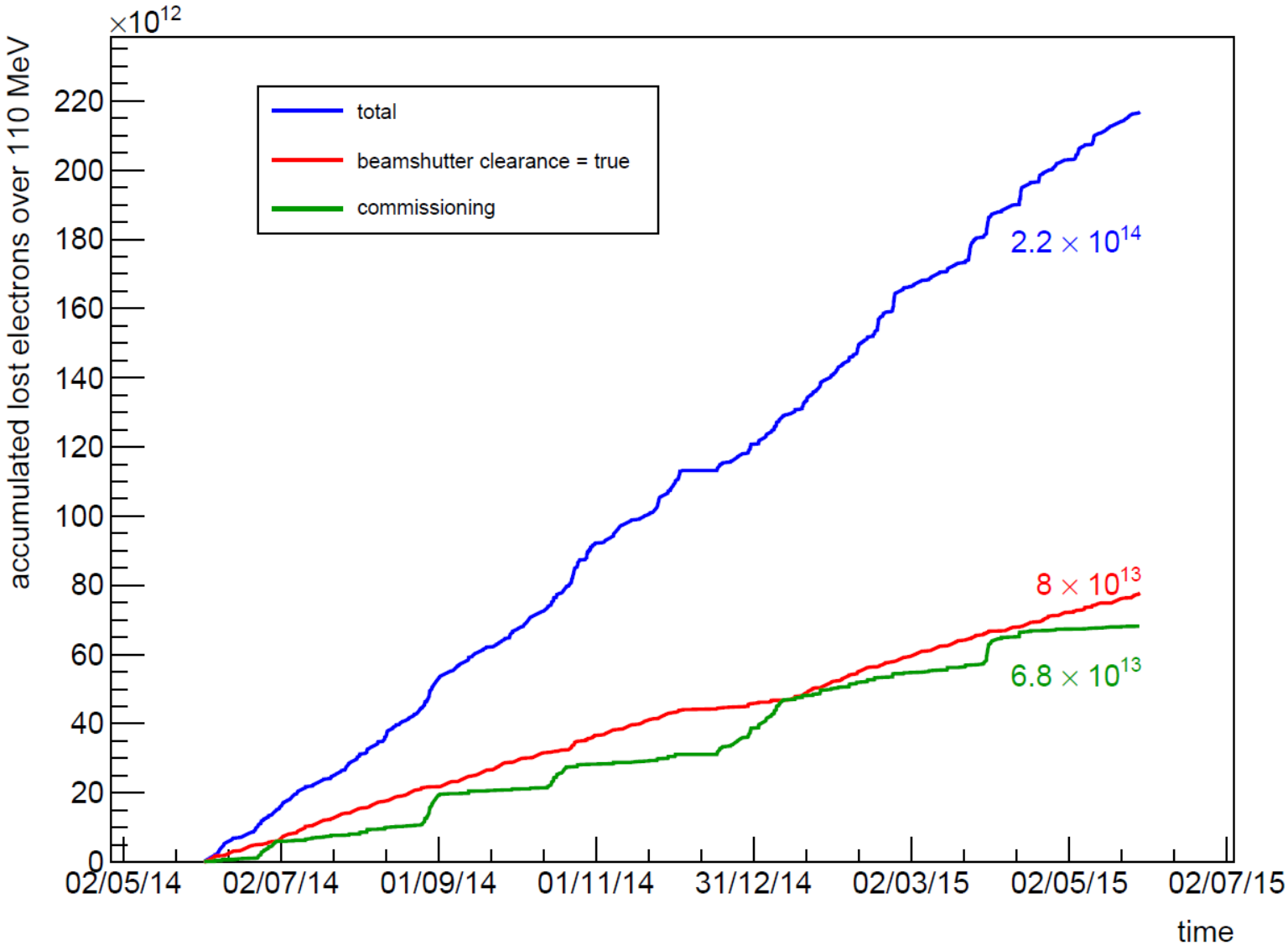
THANK YOU FOR YOUR ATTENTION

REFERENCES

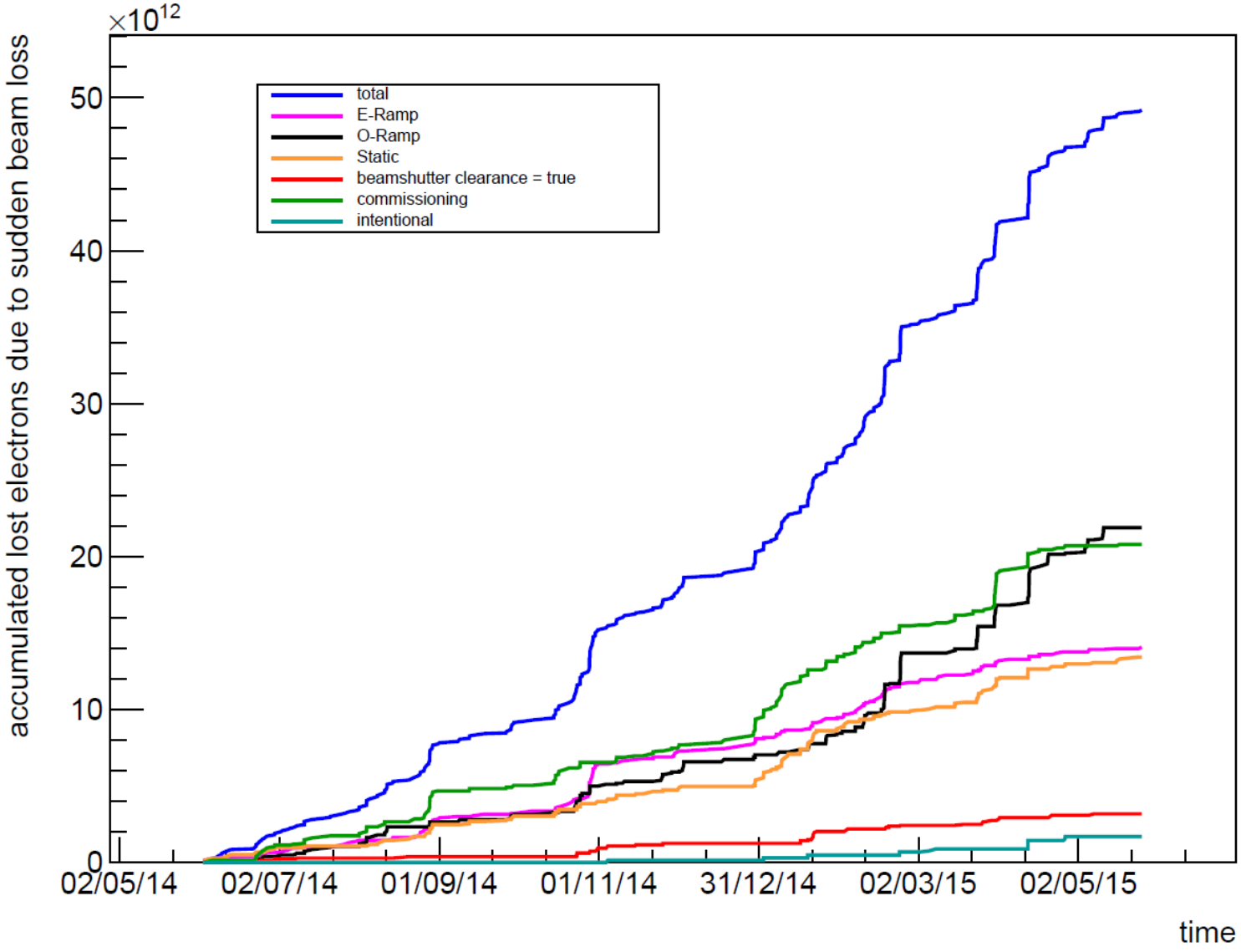
- Nonlinear Momentum Compaction and Coherent Synchrotron Radiation at the Metrology Light Source
- Survey of Beam Optics for the MLS Lattice
- BESSY VSR Technical Design Study
- Transverse Resonance Island Buckets at the MLS and BESSY II
- Status of the Robinson Wiggler Project at the Metrology Light Source

BACKUP SLIDES

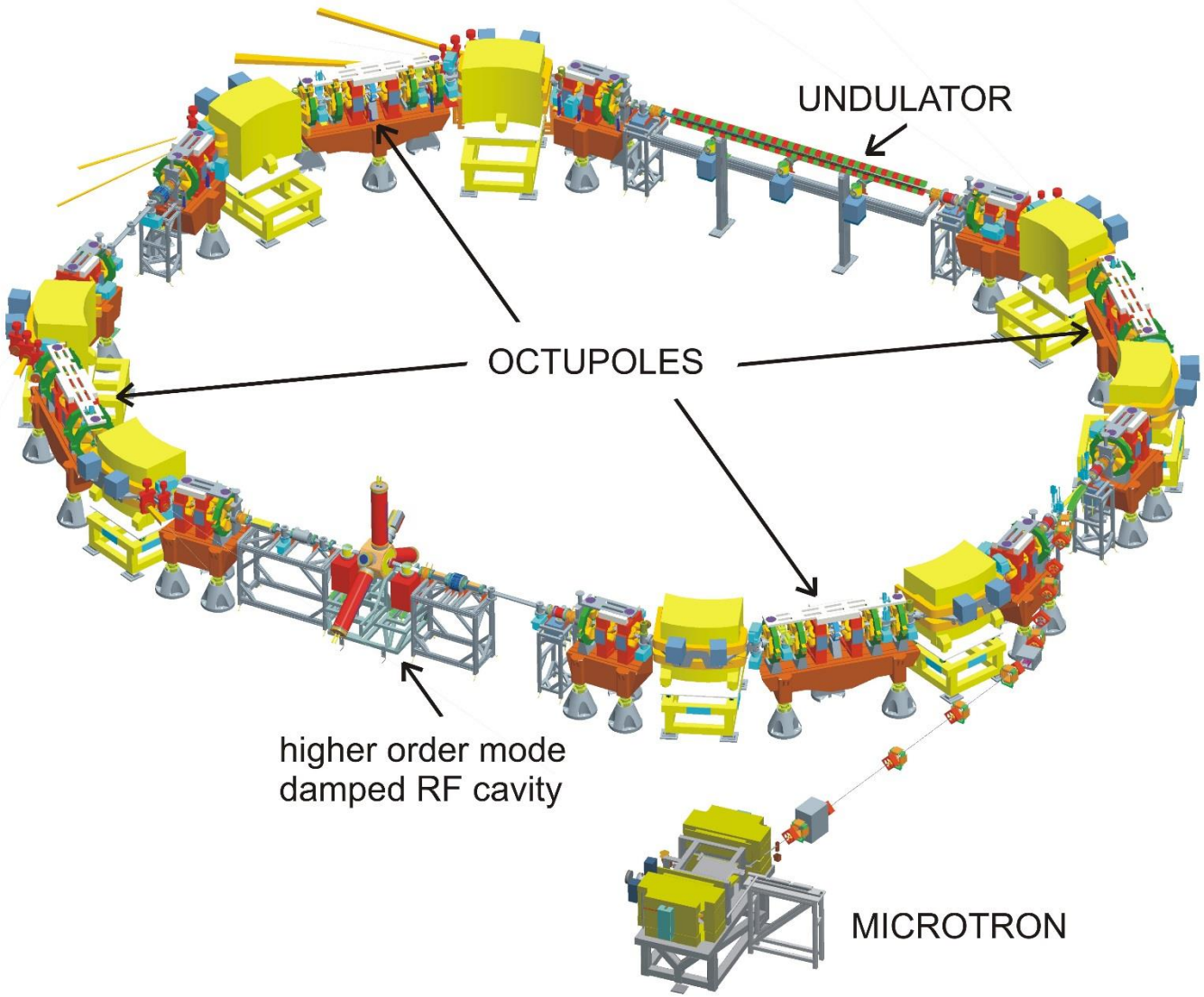
ELECTRON LOSSES



BEAM LOSSES

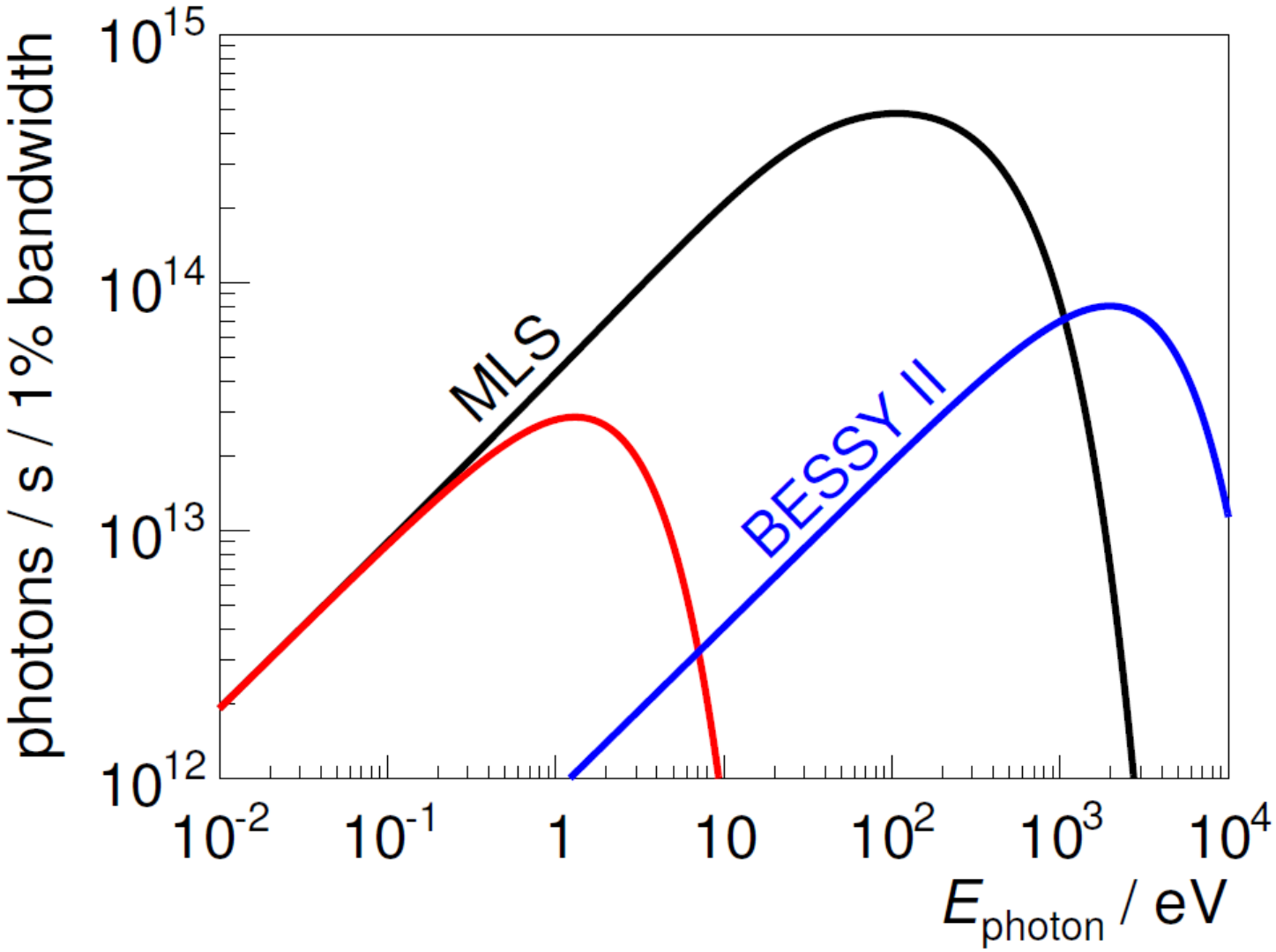

×10^12
accumulated lost electrons due to sudden beam loss
0
10
20
30
40
50
total
E-Ramp
O-Ramp
Static
beamshutter clearance = true
commissioning
intentional
02/05/14
02/07/14
01/09/14
01/11/14
31/12/14
02/03/15
02/05/15
time

METROLOGY LIGHT SOURCE: STATS

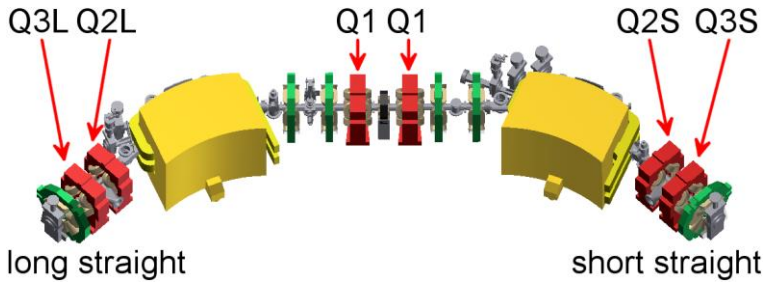


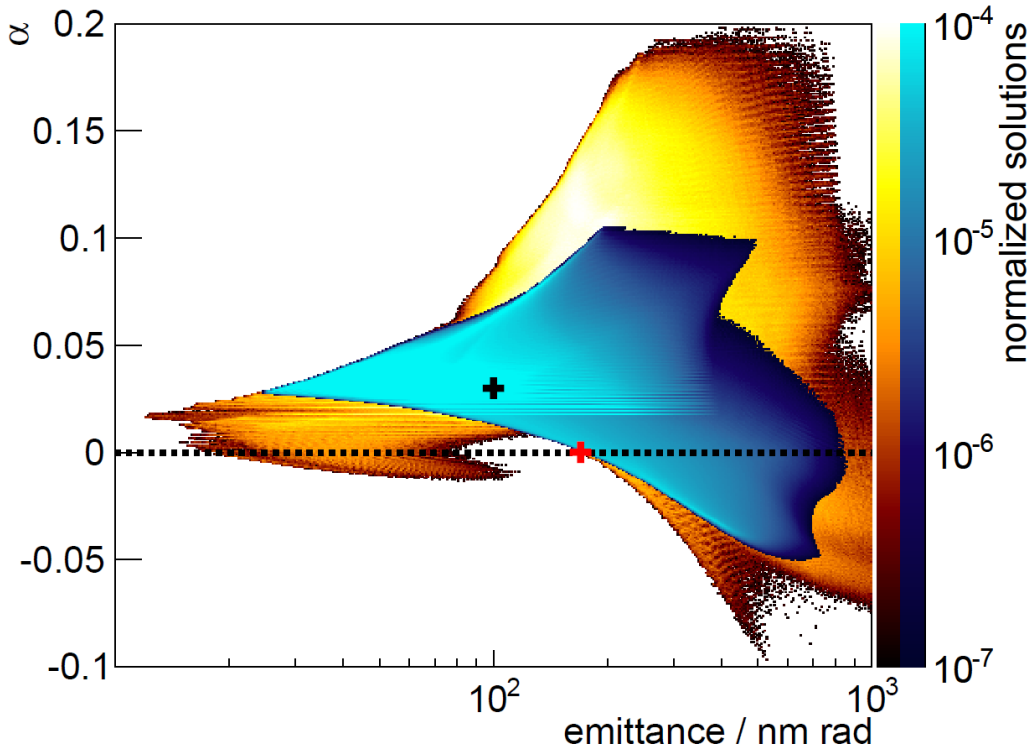
- $E = 50 \ \ldots \ 629$ MeV (105 MeV inject.)
- $C = 48$ m
- $R_{bend} = 1.528$ m
- $\delta_0 = 0.7e-4 \ \ldots \ 4.2e-4$
- $f_{rf} = 500$ MHz
- $U_{rf} = 500$ MV
- $\tau = 20$ s $\ldots 10$ ms
- $\alpha = -3e-2 \ \ldots \ 7e-2$
- $\sigma = 1$ ps $\ldots$ 100 ps
- $Q_{hor} = 3.18$
- $Q_{ver} = 2.23$

METROLOGY LIGHT SOURCE: SPECTRUM

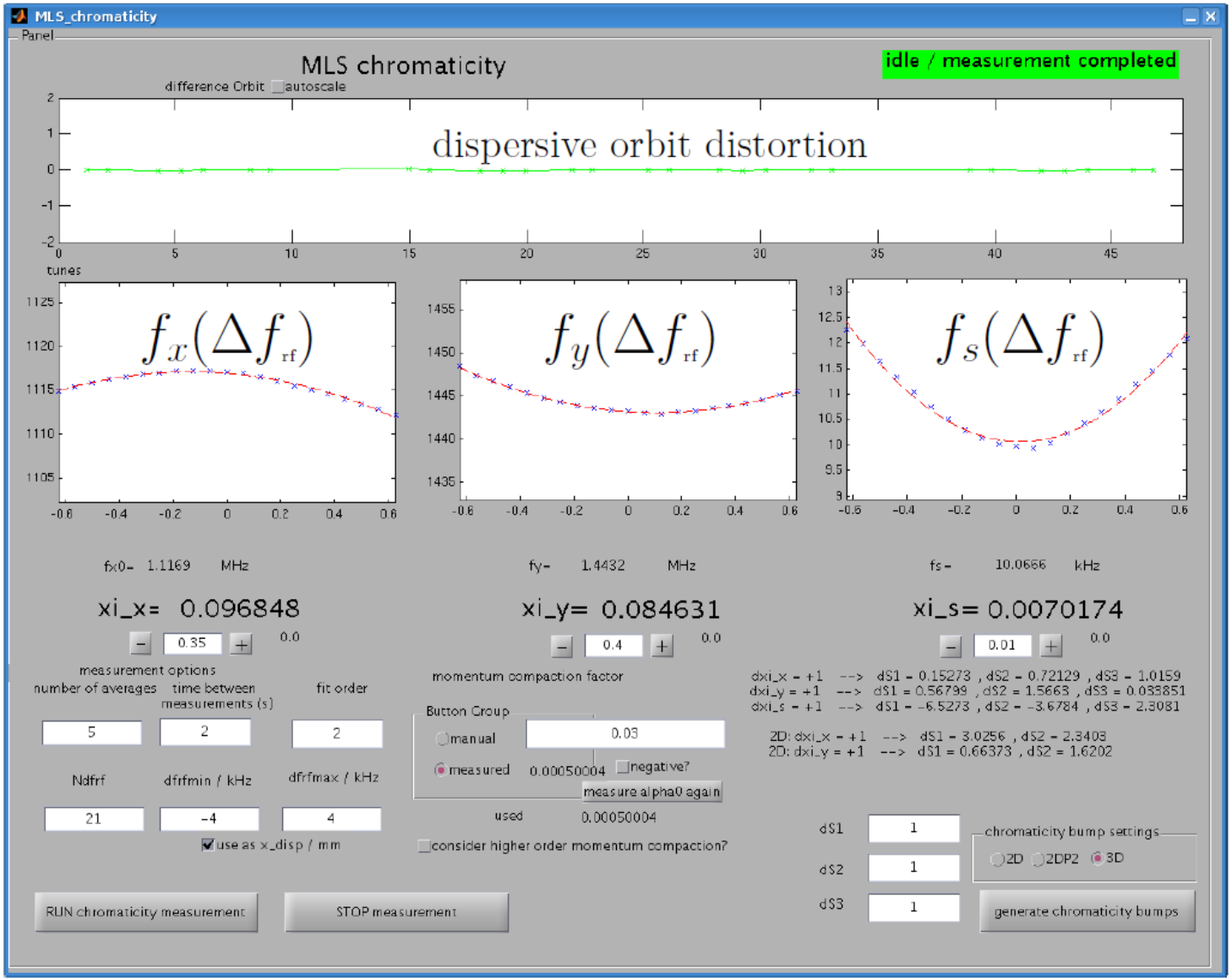


METROLOGY LIGHT SOURCE: ALPHA – EMITTANCE – RANGE

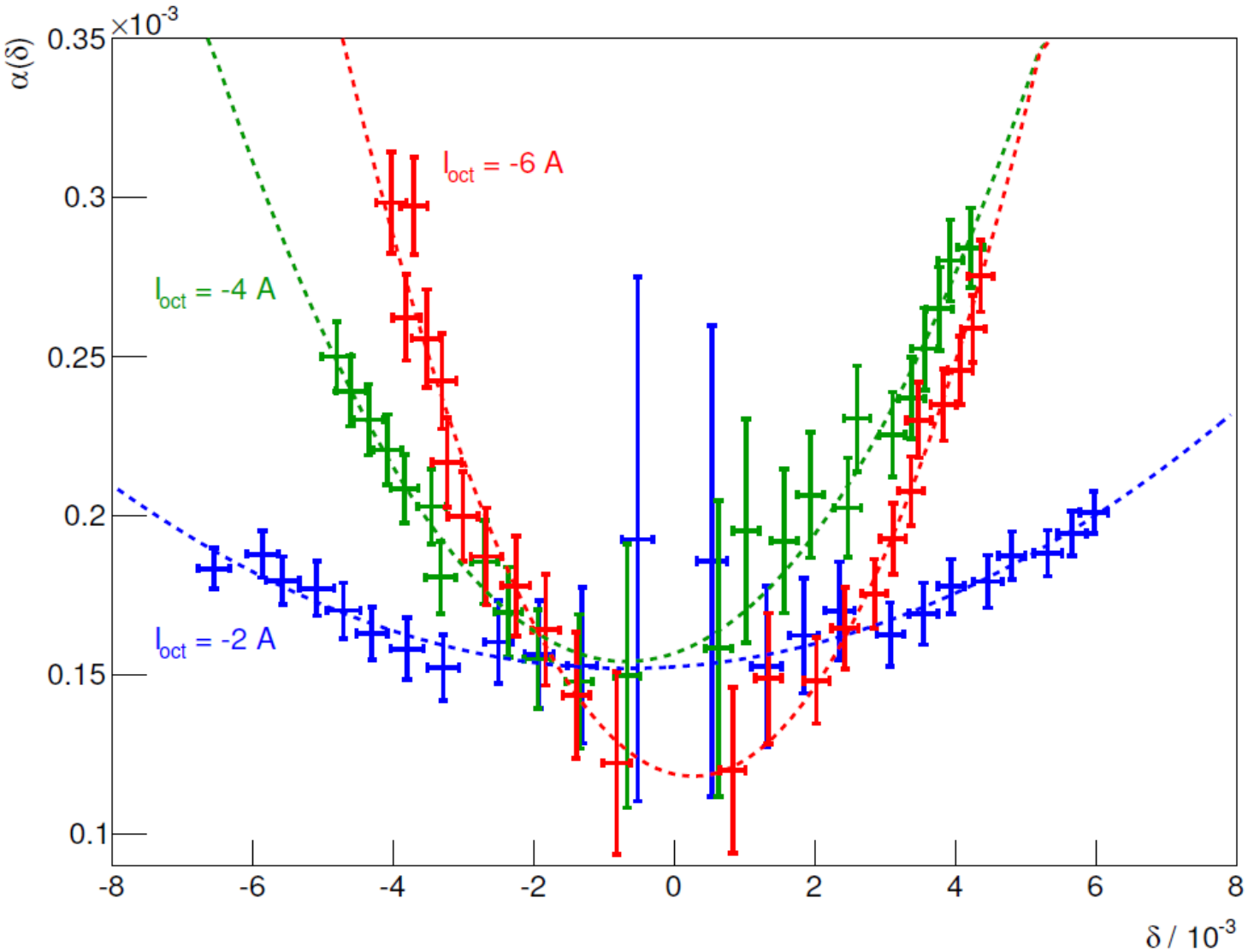




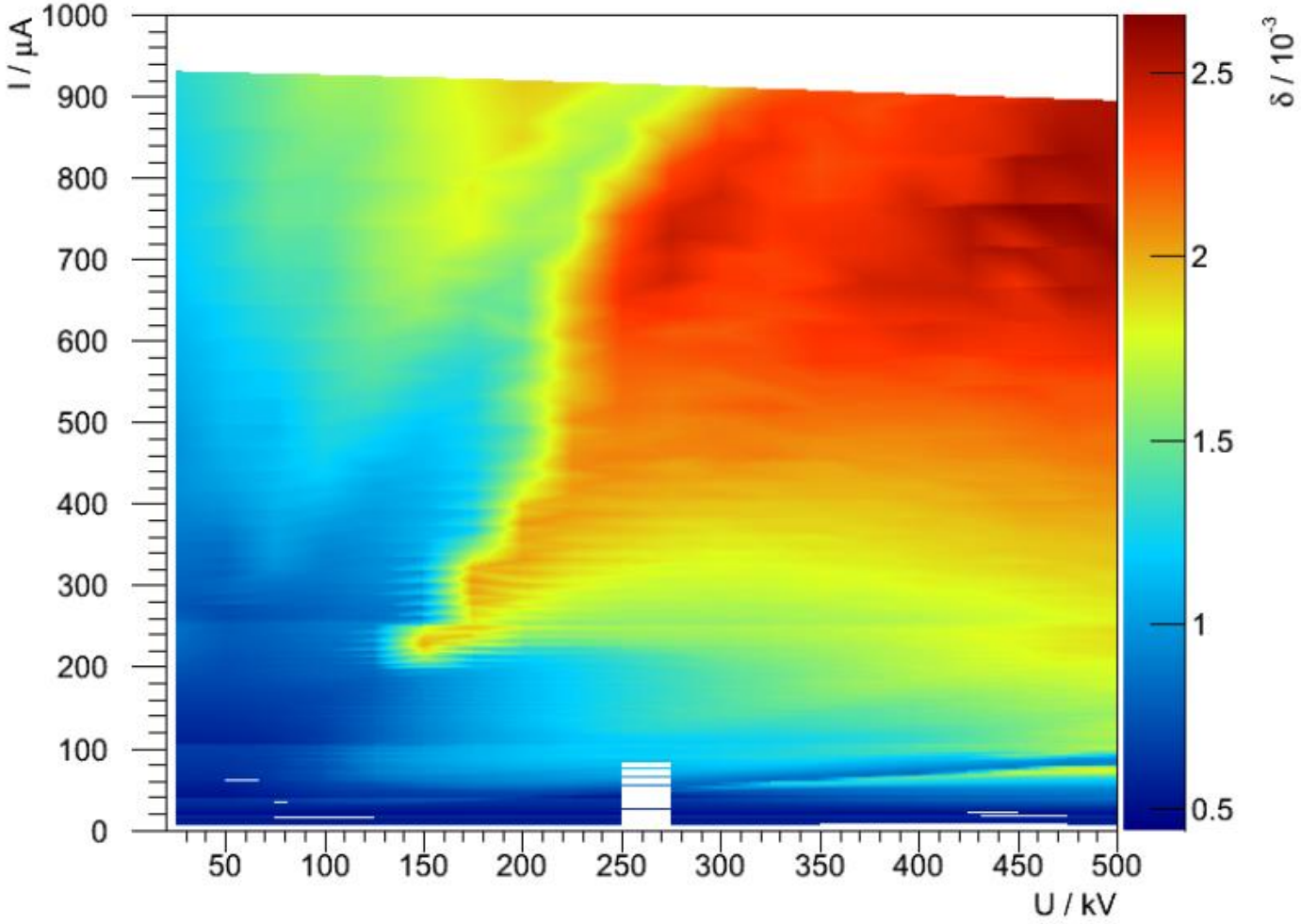
METROLOGY LIGHT SOURCE: ALPHA – EMITTANCE – RANGE



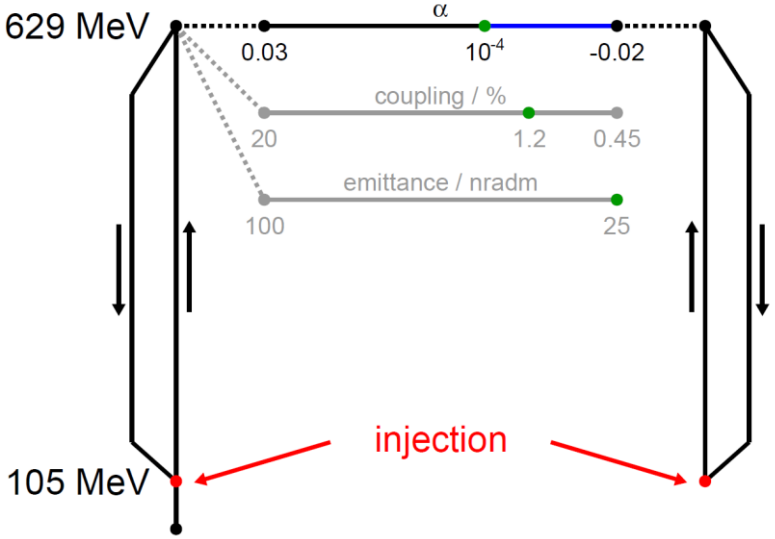
METROLOGY LIGHT SOURCE: ALPHA – EMITTANCE – RANGE



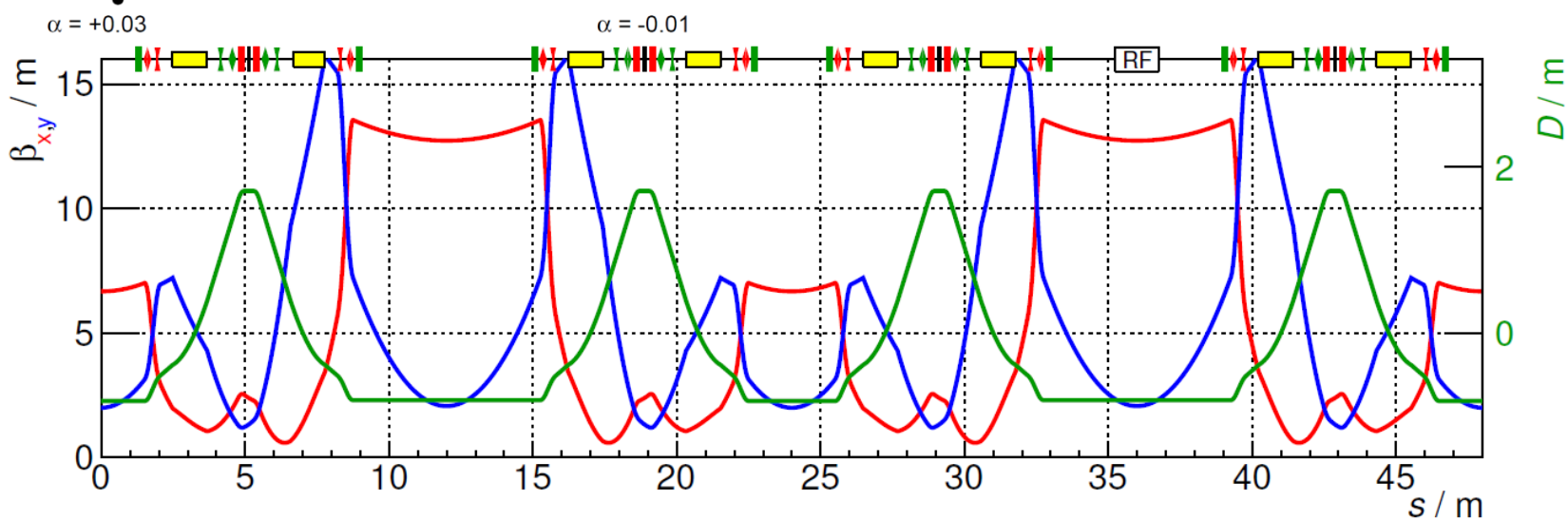
MOTIVATION: STUDY BURSTING THRESHOLDS



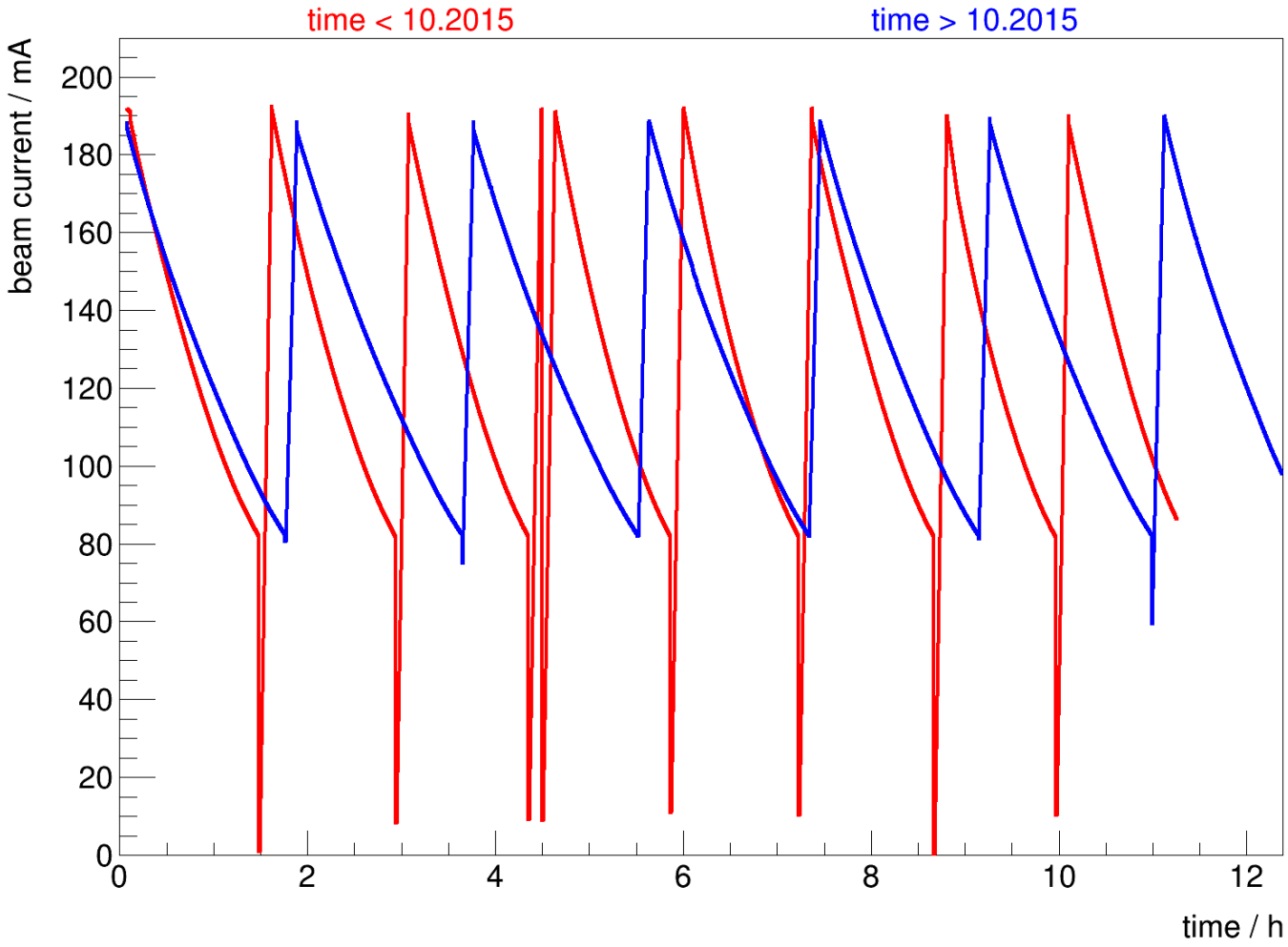
MOTIVATION: STUDY CSR BURSTING DYNAMICS



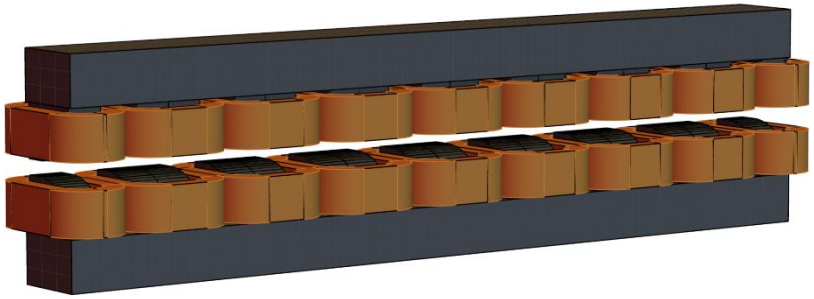
- low-α operation without octupole
- study differences near the bursting threshold for ±α

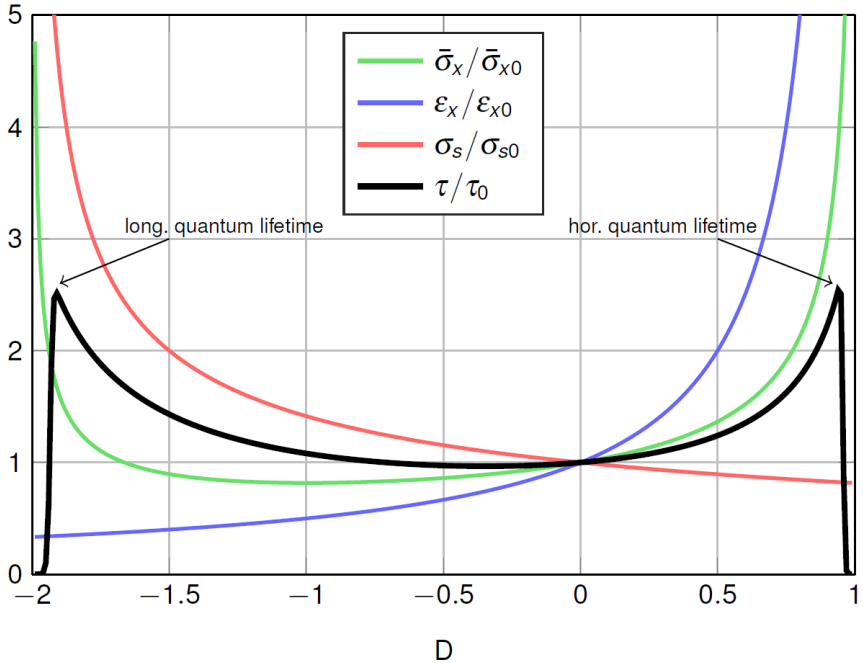


MOTIVATION: LOW EMITTANCE – RAMPING DOWN



MOTIVATION: REDISTRIBUTE DAMPING PARTITION





Principle of operation