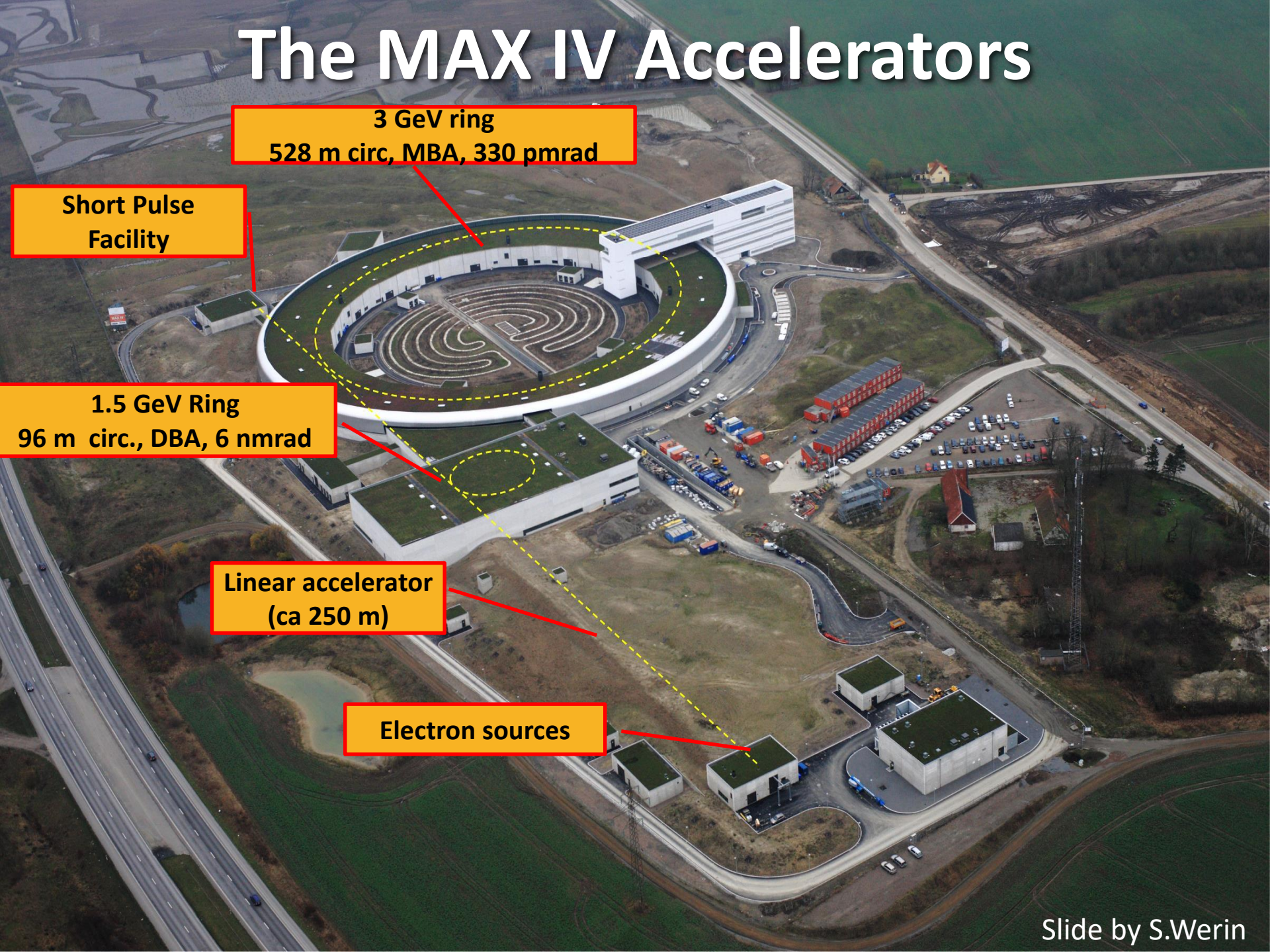
Status of the MAX IV storage rings

Å. Andersson on behalf of the MAX IV team

XXVII ESLS Meeting at ALBA, Barcelona 2019

The MAX IV Accelerators

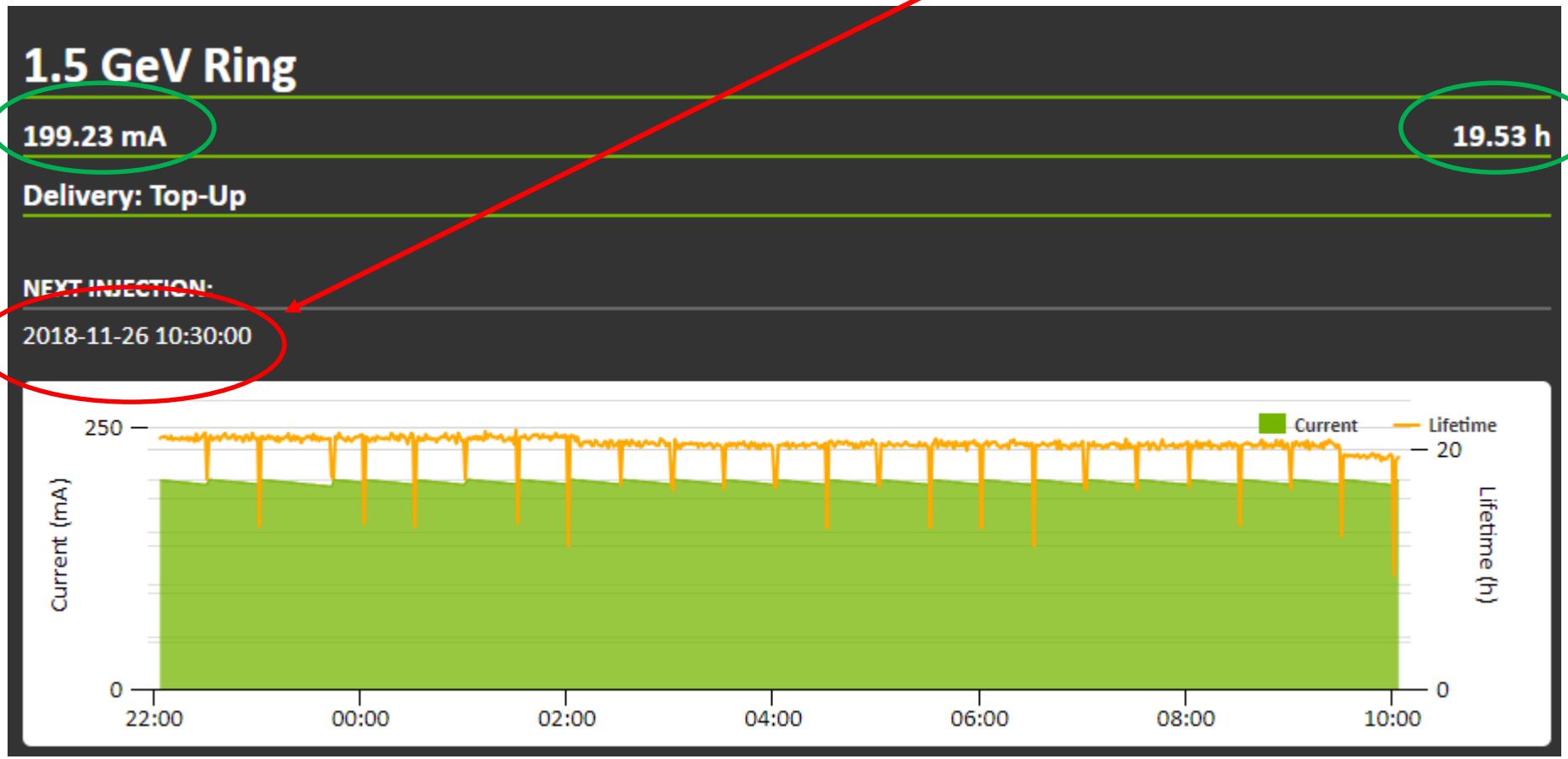


Slide by S.Werin

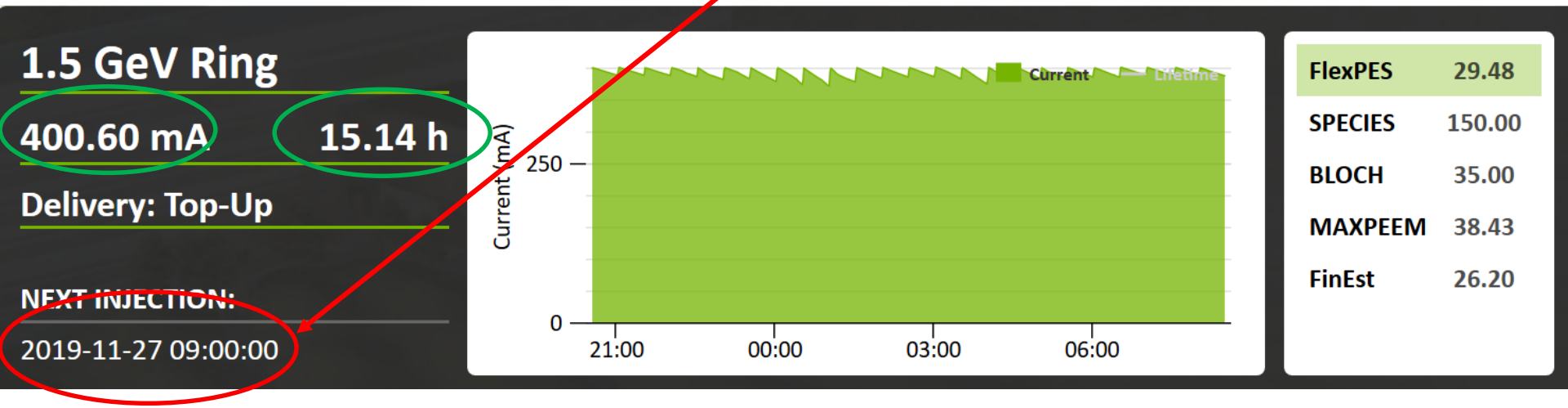
Outline

- Coarse Overview: What's new since last ESLS on the two storage rings.
- 2019 Statistics
- Some highlights

1.5 GeV Ring Delivery One Year Ago



1.5 GeV Ring Delivery Today



- **I = 400 mA**; **I*τ = 6 Ah** (friendly gaps/phases)
- No BbB feedback, Harmonic Cavities do the job
- 5 ID beamlines in user operation

1.5 GeV Ring – Achieved Performance

	1.5 GeV Ring		
	Design Goal	Achieved	Obs
☺ Energy [GeV]	1.5	1.5	
😐 Multi-bunch Current [mA]	500	500/400	500 mA delivery to beamlines first demonstrated in Spring 2018 . Regular delivery currently limited by request from beamlines at 400 mA
☺ Single-Bunch Current [mA]	16	90	Only Multi-bunch mode in normal delivery, single-bunch delivery starts oficially in winter 2020, Initial tests with beamlines in autumn 2019
☺ Horizontal Emittance (bare lattice, low current) [pmrad]	6000	6100 ±500	Estimated maximum systematic errors
☺ Vertical Emittance (bare lattice, low current) [pm rad]	60	15 ± 2	Estimated maximum systematic errors
☺ Orbit stability [% of beam size]	<10% RMS	< 2.3% RMS	**Does not include transients due to ID motion.**
☺ Top-up Mode	Yes	Yes	

☺ Achieved Design Goal

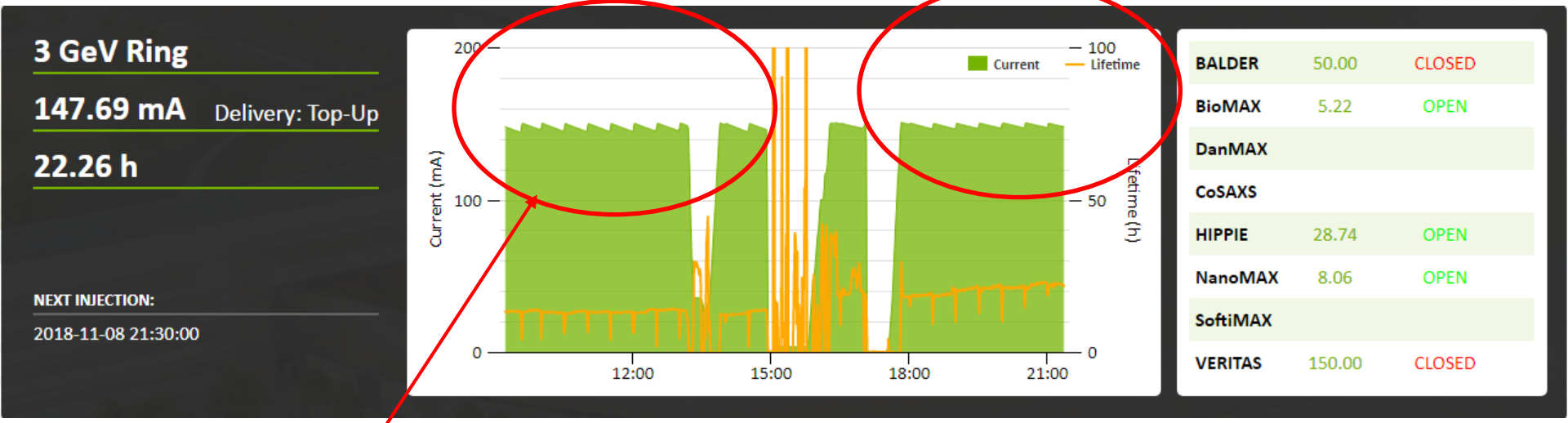
☺ Exceeded Design Goal

😐 Not Achieved Design Goal

MAX IV

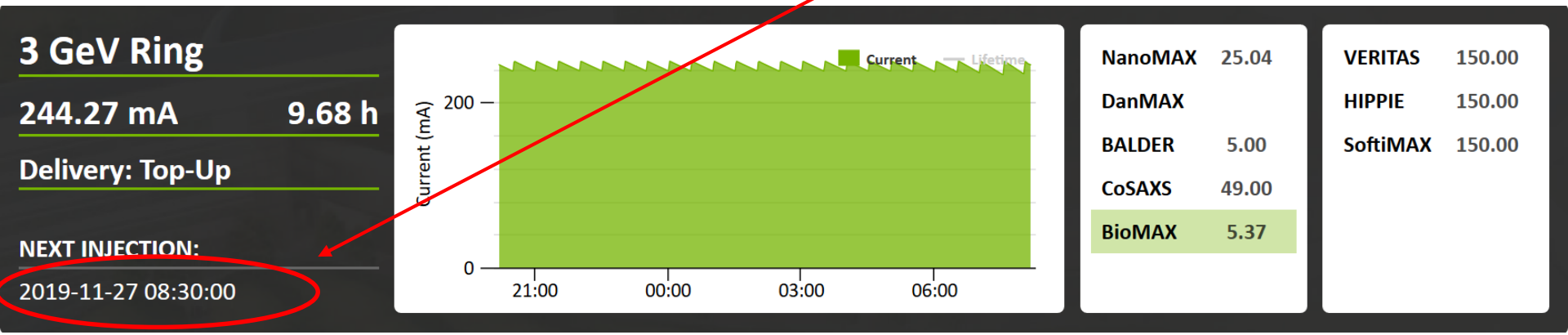
3 GeV Ring Delivery with HC, starting 8th Nov 2018

- Delivery shift: **150 mA** top-up every half hour, **I*Tau ~ 3 Ah with Harmonic Cavities**



- Earlier, we delivered with help of a BbB feedback system acting **longitudinally** against HOM driven Coupled Bunch Instabilities, **I*Tau ~ 2 Ah**
- 3 ID beam lines was in user operation

3 GeV Ring Delivery with HC, Today



- **I =250 mA**; I*τ = **3 Ah**
- We still deliver **without** help of a BbB feedback, but **with a separate Robinson-mode feedback** (implemented by David McGinnis**).**
- 6 ID BLs commissioned; 2 ID BLs awaiting rad. permit.

3 GeV Ring – Achieved Performance

	3 GeV Ring		
Parameter	Design Goal	Achieved	Obs
Energy [GeV]	3	3	
Multi-bunch Current [mA]	500	500/250	500 mA demonstrated in Autumn 2018 with undulator gaps open and HCs detuned. Limited to 250 mA for routine delivery by available RF power
Single-Bunch Current [mA]	2.8	9	Only multi-bunch mode in normal delivery, single-bunch used for accelerator experiments
Horizontal Emittance (bare lattice, low current) [pmrad]	330	320 ± 18	Estimated maximum systematic errors
Vertical Emittance (bare lattice, low current) [pm rad]	8	6.4 ± 0.9	Estimated maximum systematic errors
Orbit stability [% of beam size]	< 10 %	HOR < 2 % VERT < 5 %	Does not include transients due to ID motion.
Top-up mode	Yes	Yes	

- Achieved Design Goal
- Exceeded Design Goal
- Not Achieved Design Goal

Since we are in the IBS regime, Hor.Emitt. Vert. Emitt. & Rel. Energy spread are increased 10 to 15 % during delivery at 250 mA (depending on HC tuning).

MAX IV

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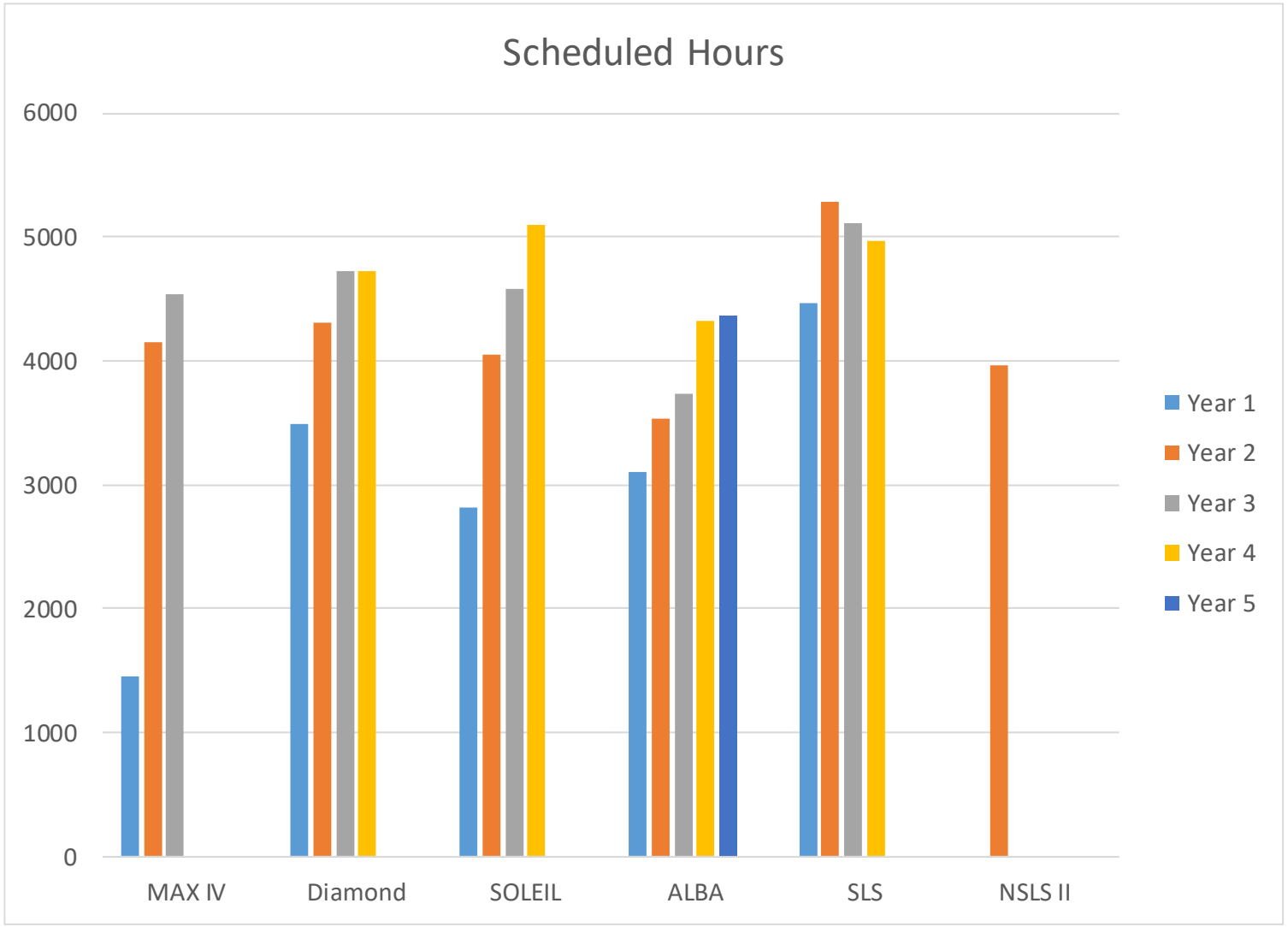
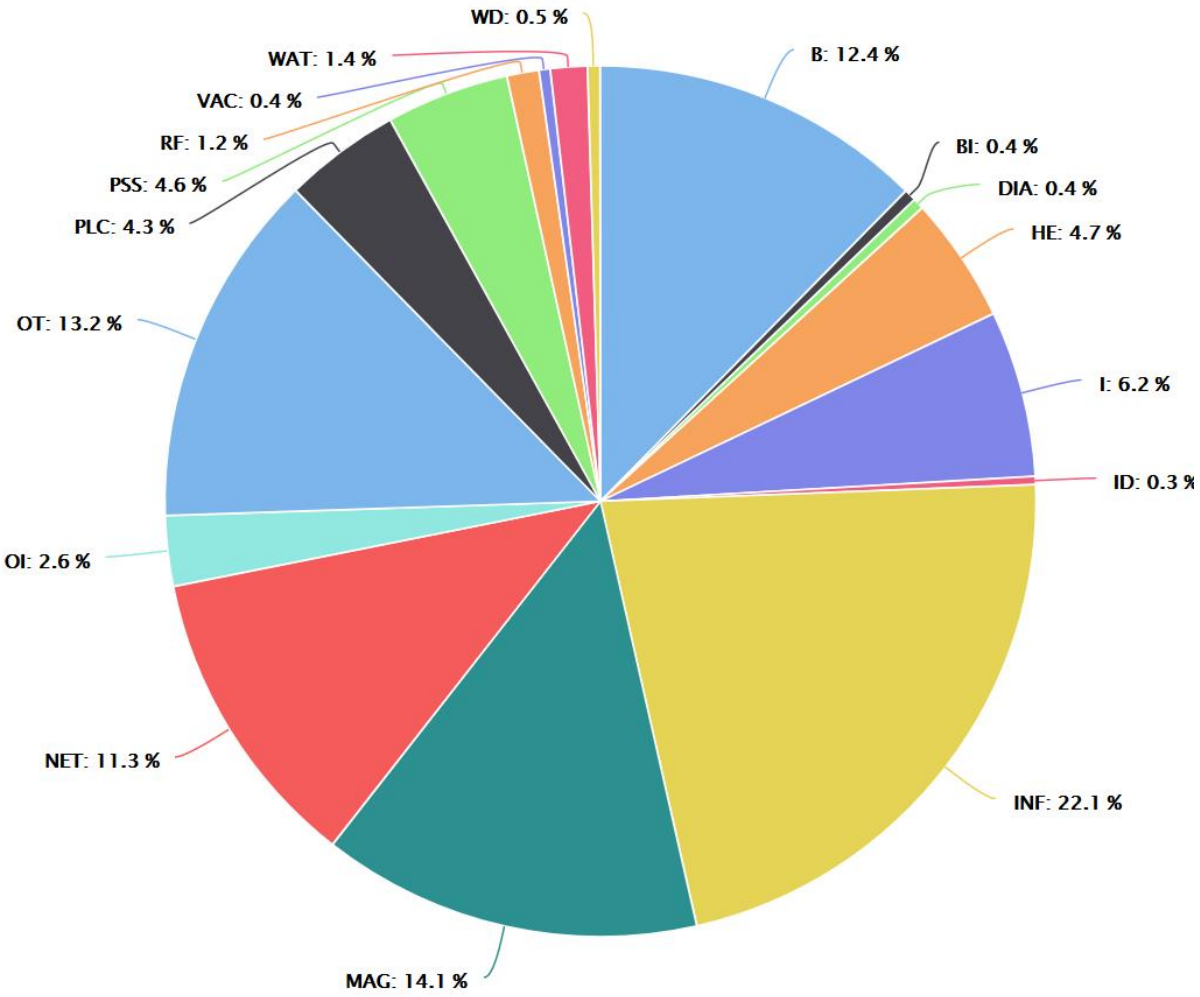
3 GeV Ring: Yearly Scheduled Beam Delivery Hours



Slide by Pedro F. Tavares

Year-to-date statistics: 1.5 GeV ring

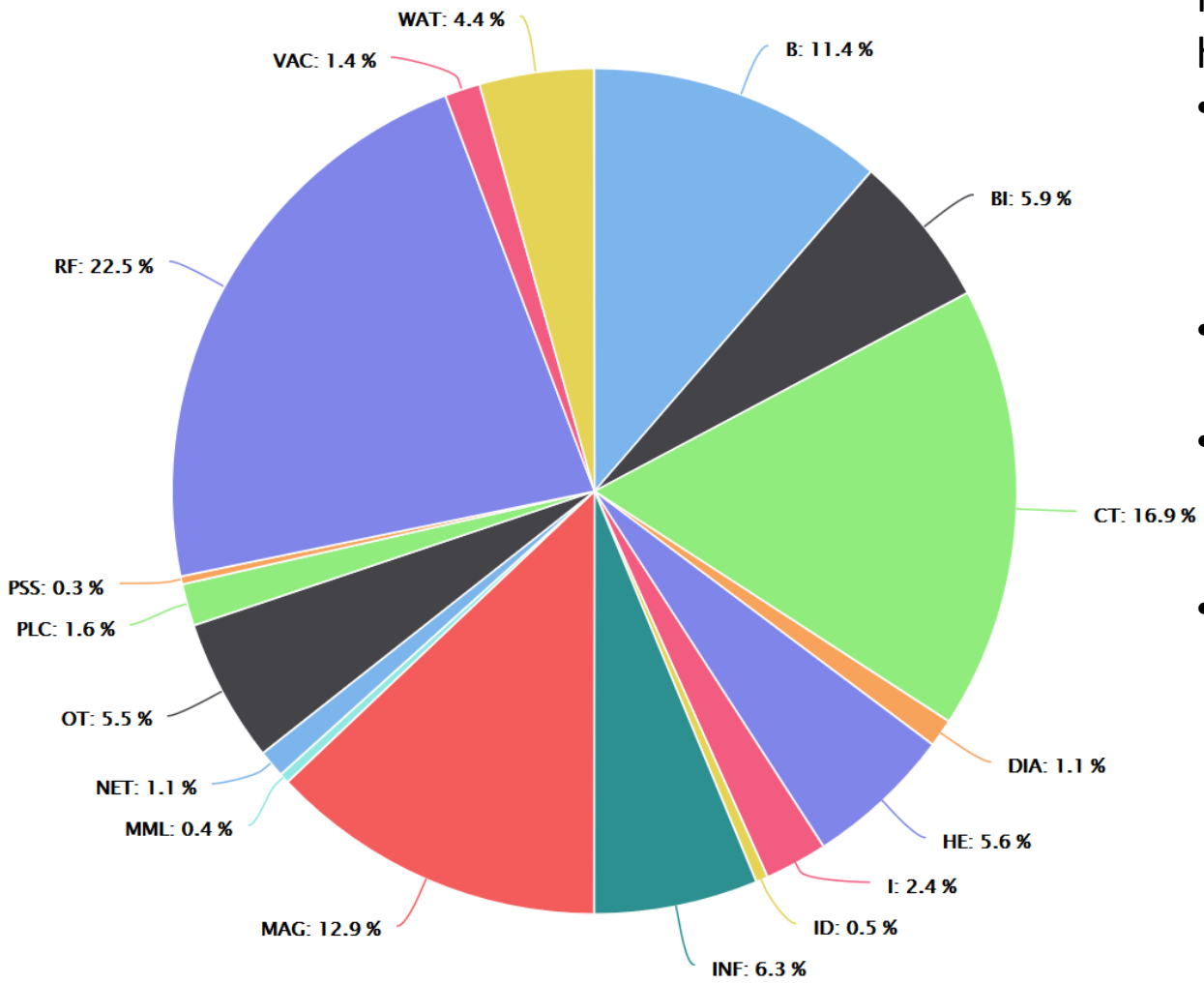


Most downtime (60 out of 82 hours) accounted for by:

- INFrastructure, water cooling circuits belonging to the site owner.
- MAGnets, PS failure of corrector magnets & a burnt main breaker (was flown from Stockholm and installed in the night).
- OThers, two unexplained successive beam losses killed the dose limit, wait 4 hours.
- Beamlines, while bringing new BLs online fast, BL issues triggers the RF dump & occationally the dose limit.
- NETwork, two instances of faulty cables.

UPTIME: 98.4 % MTTR: 1.1 h MTBF: 65.3 h

Year-to-date statistics: 3 GeV ring



Most downtime (71 out of 111 hours) accounted for by:

- RF, issues with L-cav running the wrong way (solved) & failures in individual modules in transmitters.
- ConTrols, critical servers becoming unreachable.
- MAGnets, PS failure of one sextupole. Difficult to find since PS reported output.
- Beamlines, while bringing new BLs online fast, BL issues triggers the RF dump.

UPTIME: 97.3 % MTTR: 1.1 h MTBF: 40.8 h

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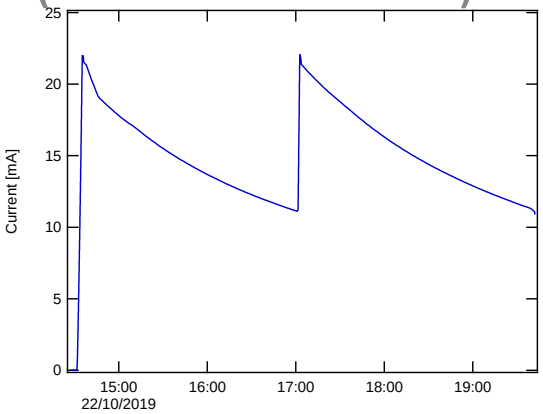
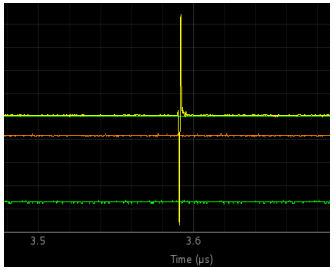
Highlights 1.5 GeV Ring

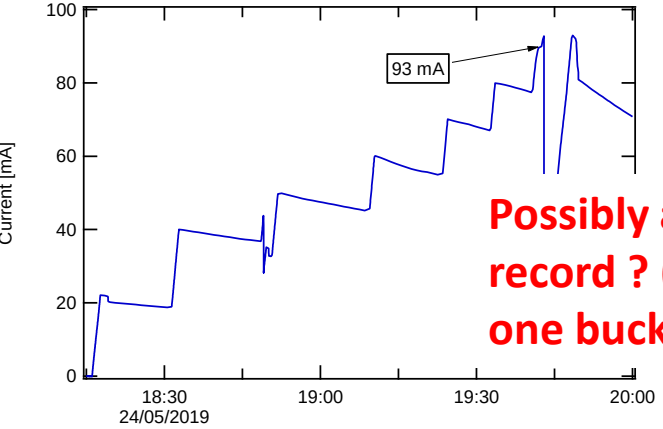
First Single-bunch delivery to beamlines (Francis Cullinan)



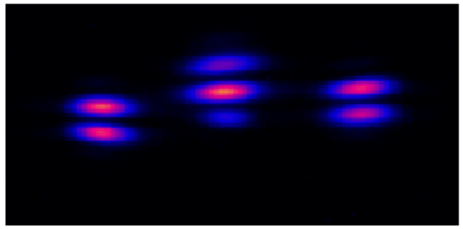


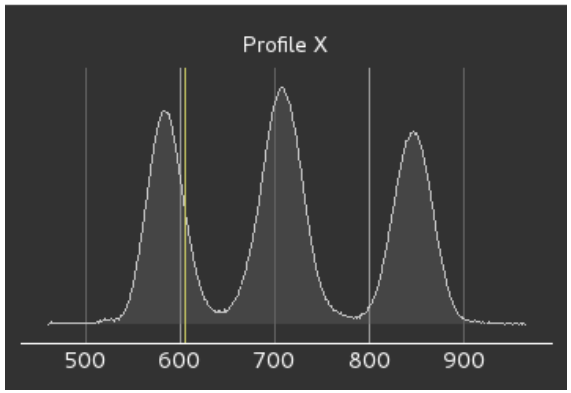
TRIBs
Thanks to Paul Goslawksi and the BESSY team

90 mA in a single-bunch (F. Cullinan, J. Breunlin)



Possibly a world record ? (29 nC in one bucket!)





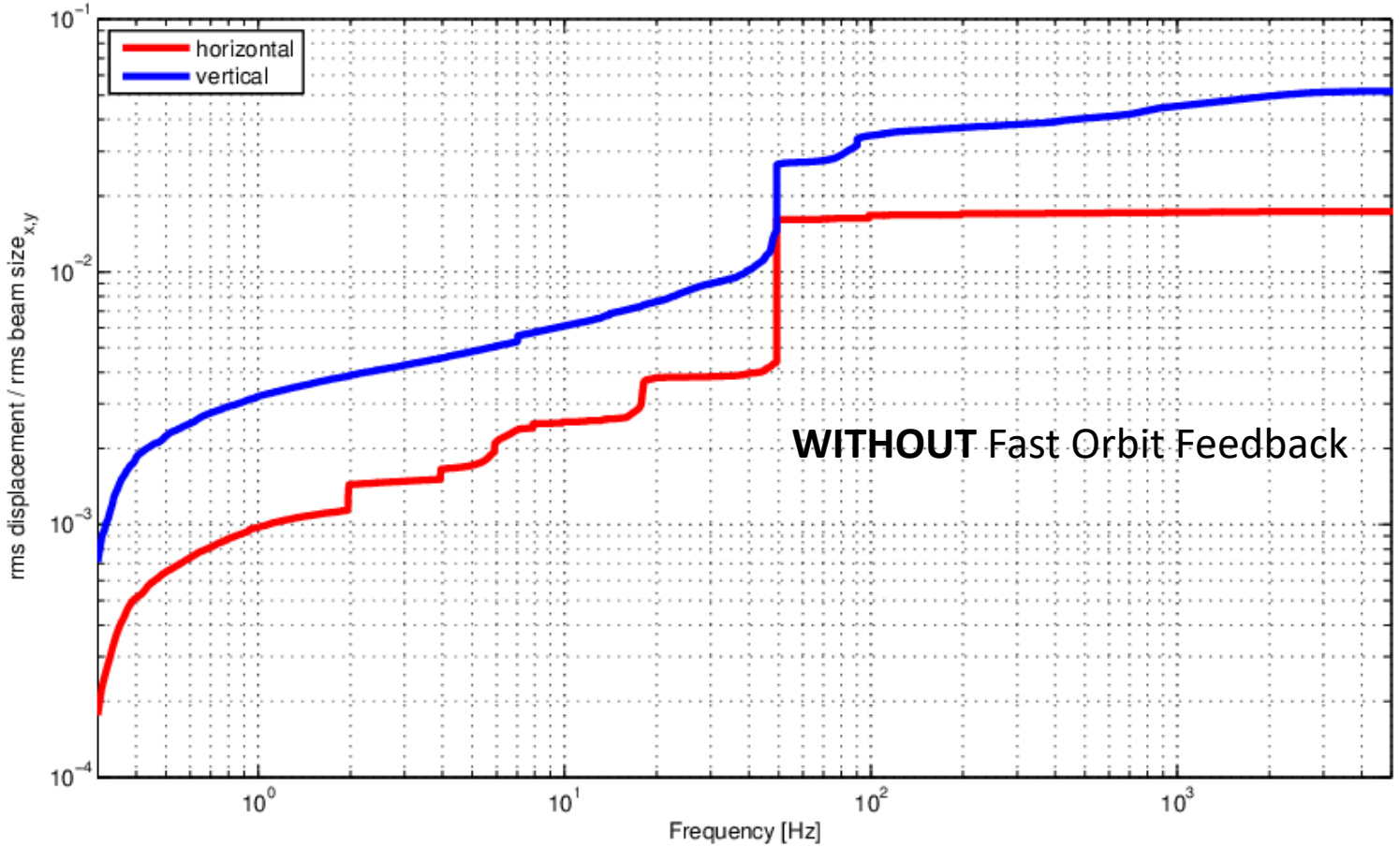
Presentation tomorrow by David K. Olsson

Pictures by D.K.Olsson

Highlights 3 GeV Ring: Orbit Stability

Average of 13 long straight flanking BPMs
April 2019, 250 mA beam current

Plot By Jonas Breunlin

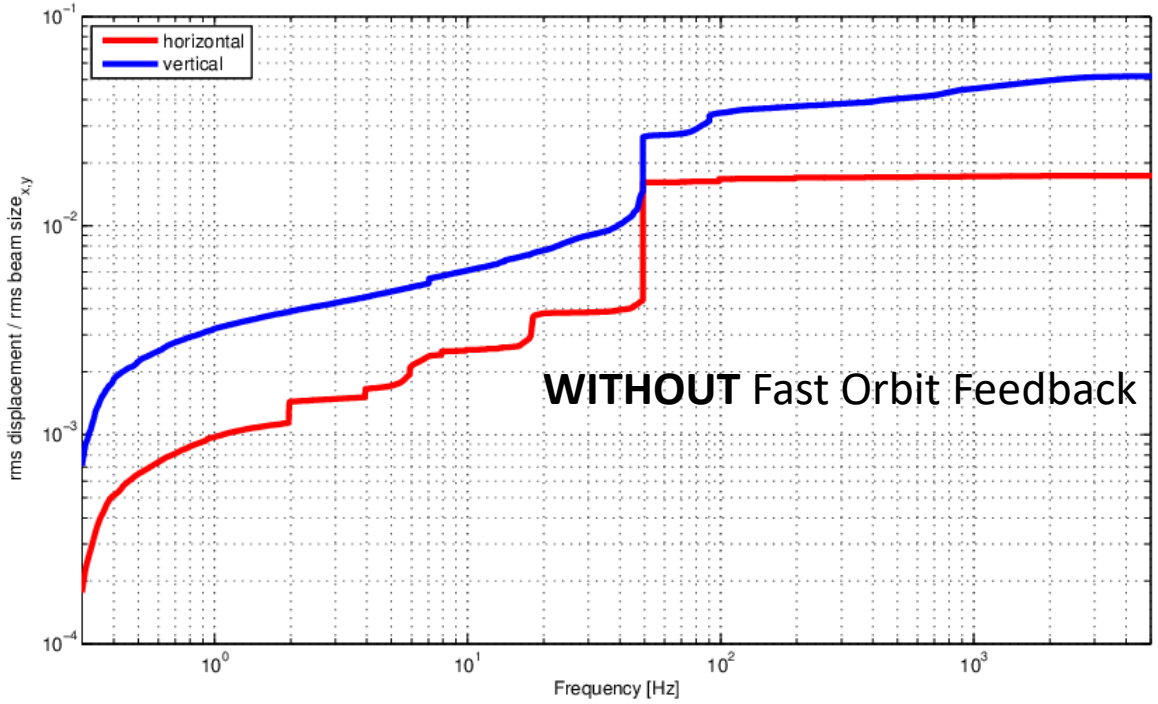


Integrated up to 5 kHz

- ❑ Horizontal RMS < 2.0 % of RMS beam size
- ❑ Vertical RMS < 5.0 % of RMS beam size

MAX IV

Highlights 3 GeV Ring: Orbit Stability

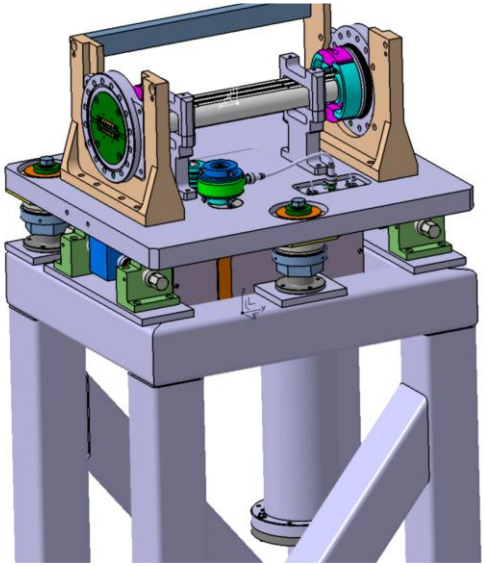


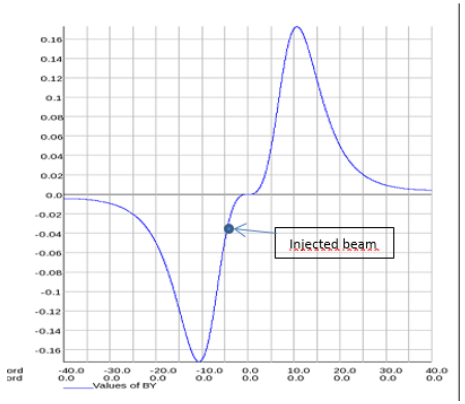
Despite the good results:

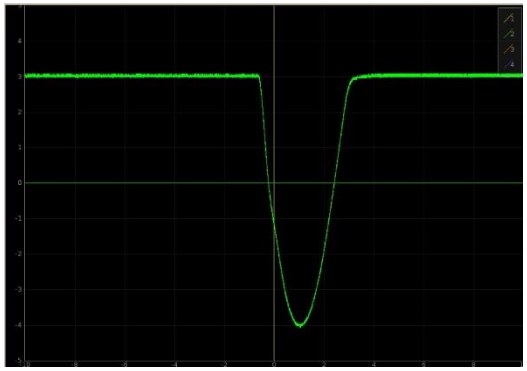
- A ”pilot” Fast Orbit Feedback System will be integrated to the SOFB, around one ID straight, during Christmas (**Magnus Sjöström**).
- Main goal is to eliminate orbit transients from ID gap movements.

Highlights 3 GeV Ring: Multipole Injection Kicker (MIK)

- Objective: achieve near transparent top-up injection.
- Joint project with **SOLEIL** based on original concept from **BESSY**.
- First prototype installed in summer 2017.
- Final device installed summer 2019.

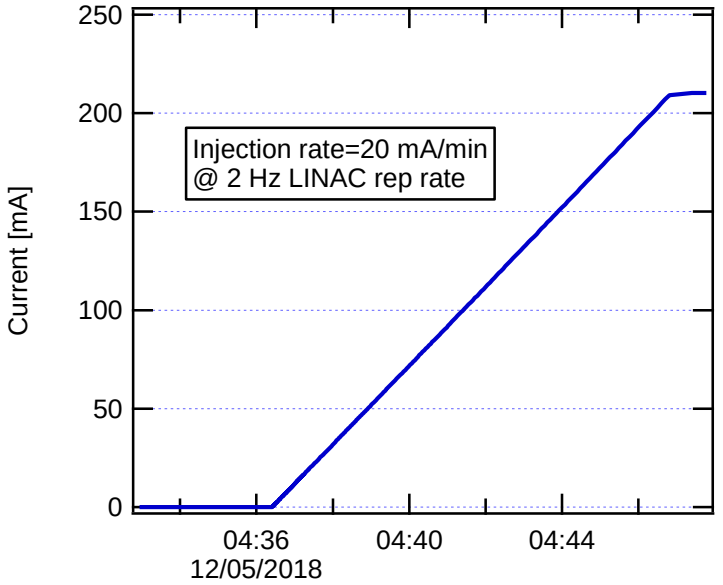






Engineering Design & Construction by SOLEIL
P.Lebasque
P.Alexandre

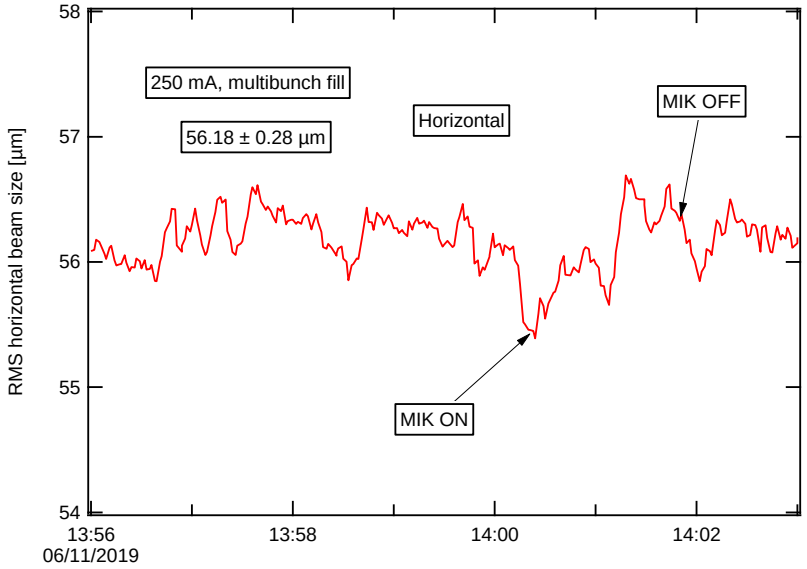
Injection with the MIK



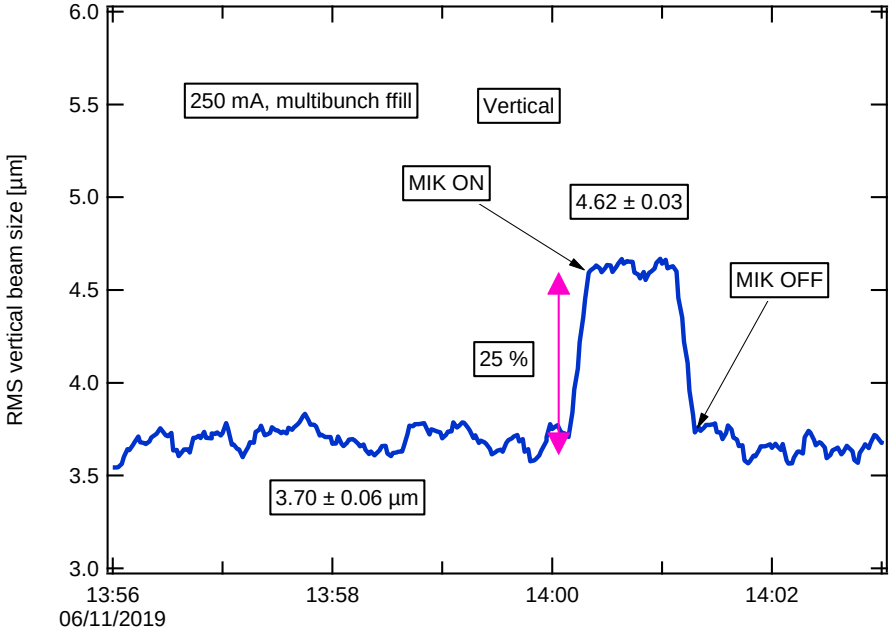
Residual Stored Beam Perturbations

Transverse beam profile measured at diagnostic beamline while pulsing the MIK.

Values scaled to the centre of the long straight



Horizontal transparency $\lesssim$ { **0.3 µm** / **0.5 % σ** }



Vertical transparency $\lesssim$ { **0.9 µm** / **25 % σ** }

Residual Stored Beam Perturbations

Transverse beam profile measured at diagnostic beamline while pulsing the MIK.

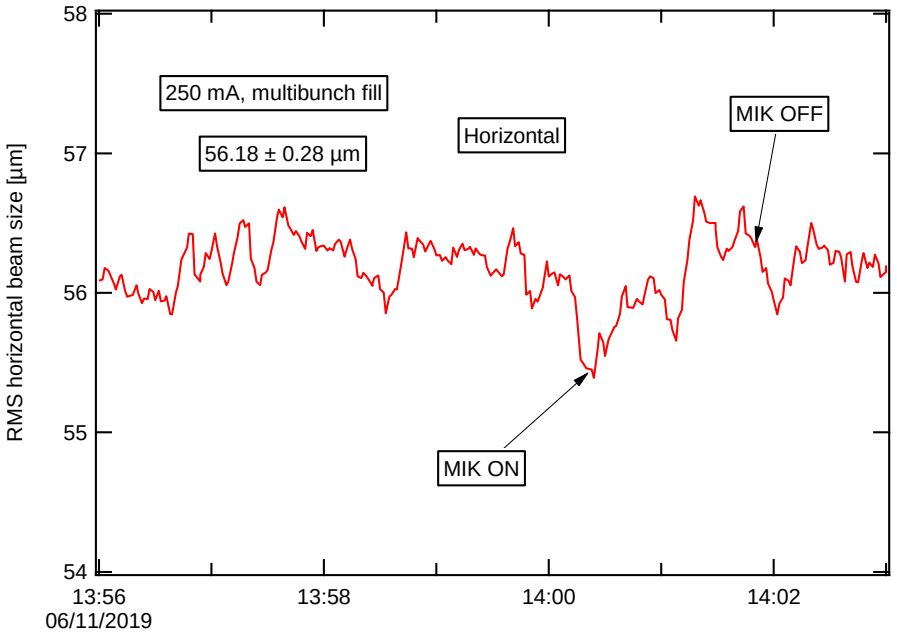
Values scaled to the centre of the long straight

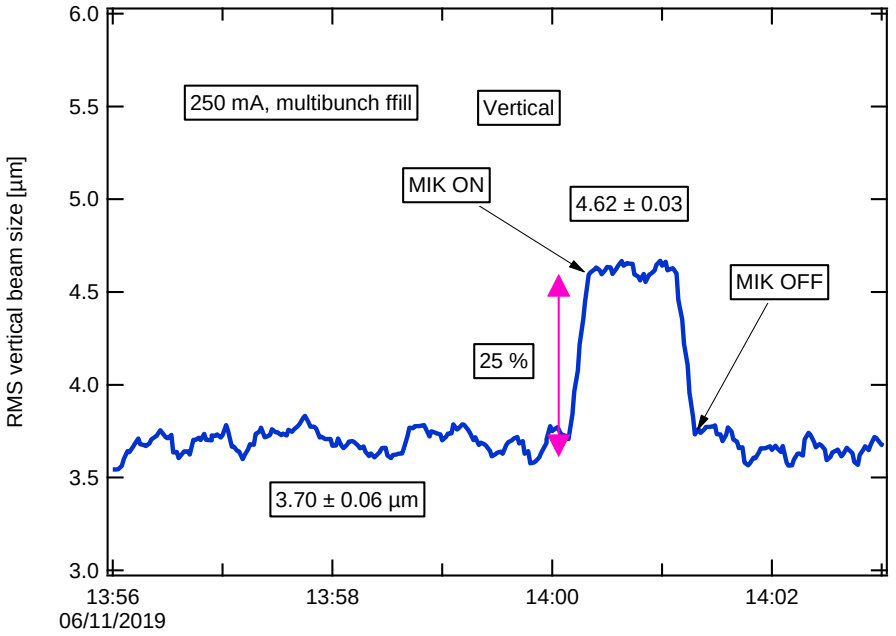
- The exposure of the cam is synchronized with the MIK pulse, duration 20 to 40 µs
- The vertical disturbance decays roughly with the vertical damping time 30 ms

➔ Effective disturbance less than 25 % during the top-up period

- Turn-by-Turn data, to follow the centroid motion, will soon be performed. It will reveal if a dipole kick is involved, or if the blow-up origins from quadrupole fields

Is this the most transparent top-up presently?





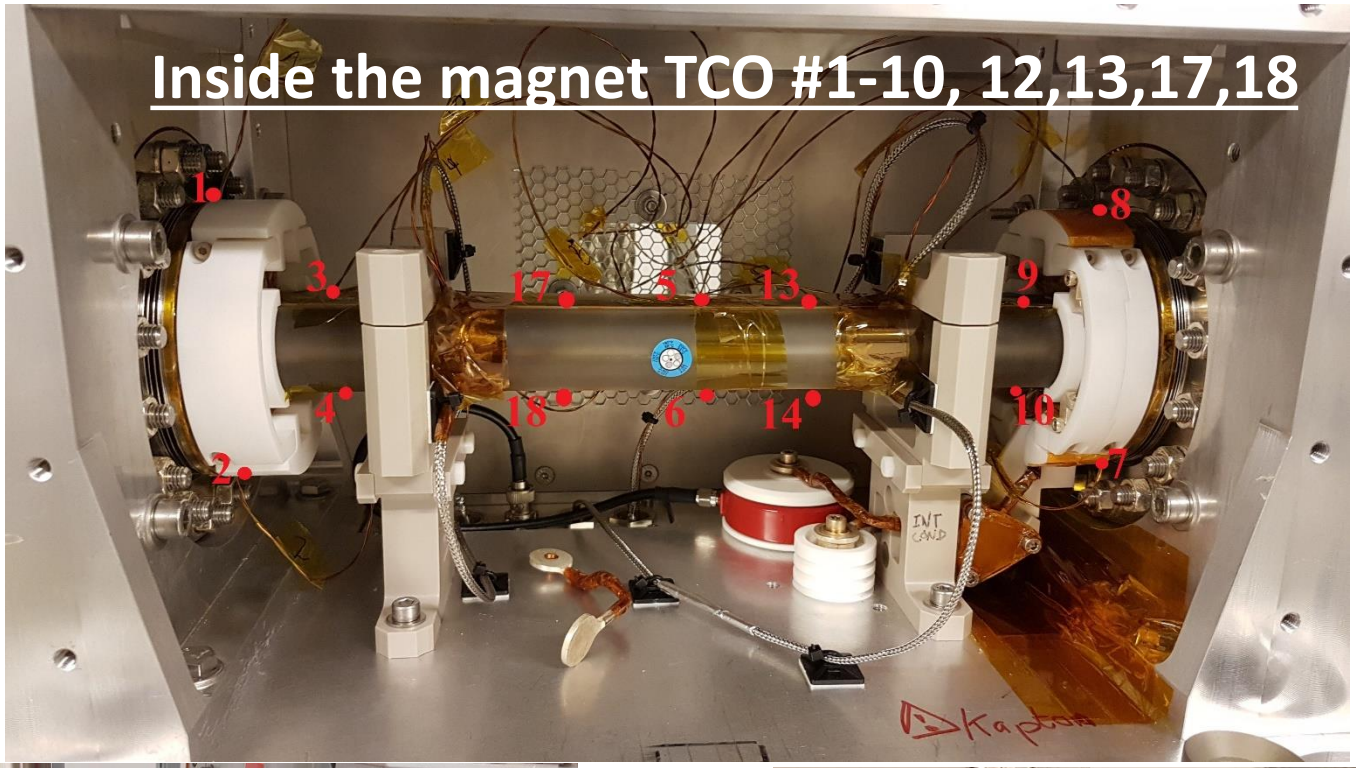
Thank you !

Back-up slides

Did we use this in MAX IV?

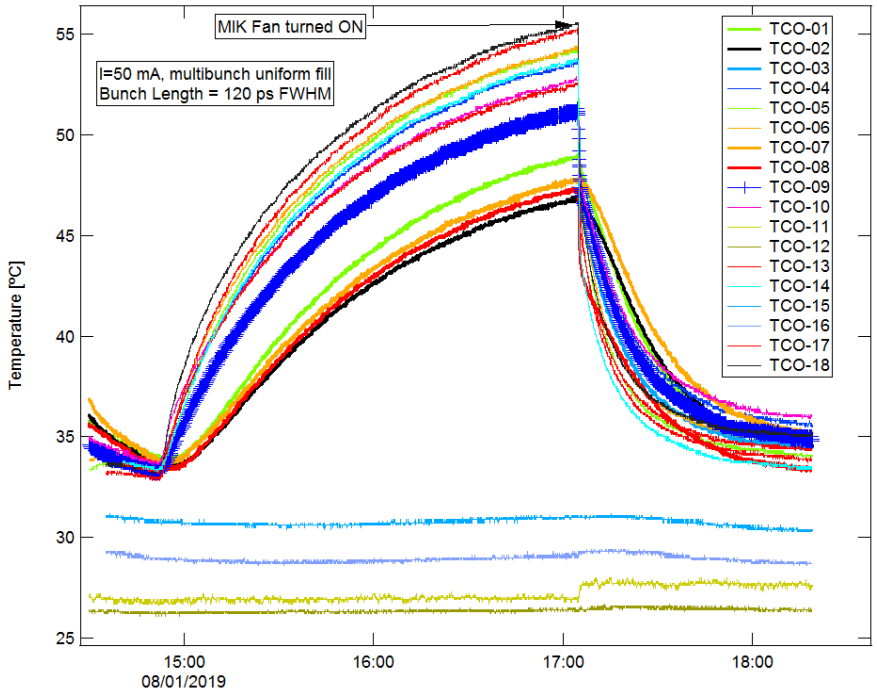
Temperature measurements on MIK chamber (Air fan on/off) @50 mA

TCO positions (09 Jan 2019)



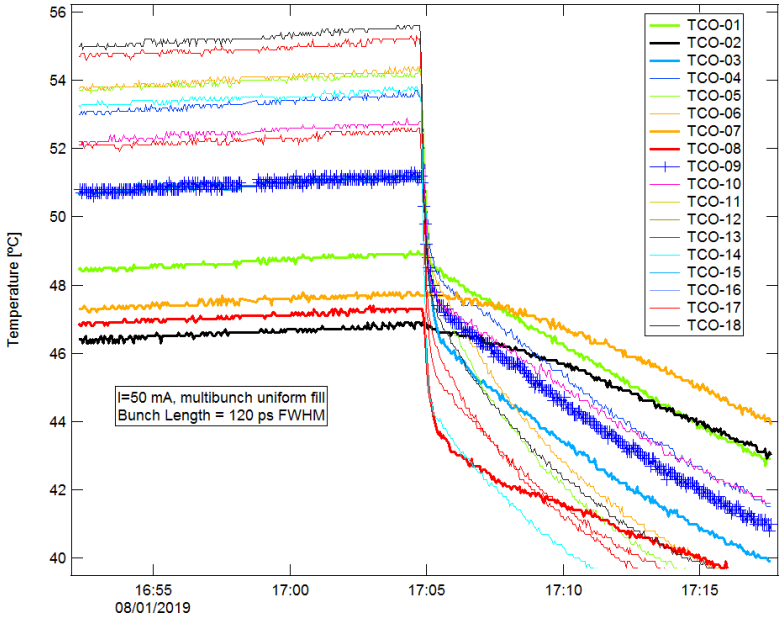
Courtesy of Alexey Vororozhtsov

Temperature measurements results (Air fan on/off) @50 mA

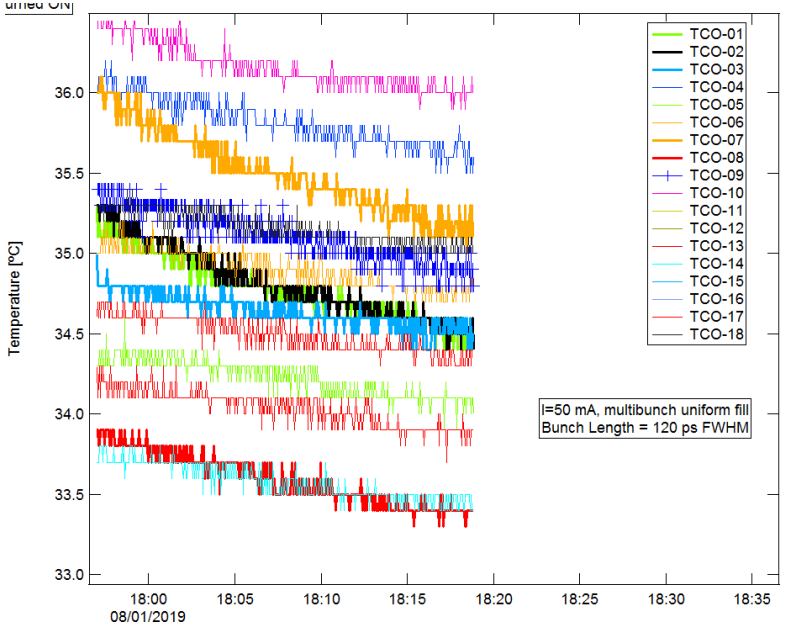


Courtesy of Alexey Vororozhtsov

Detailed view 1

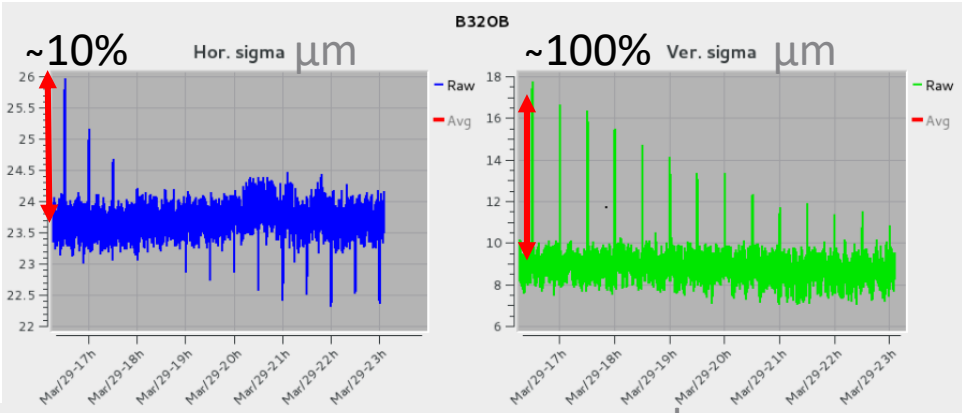


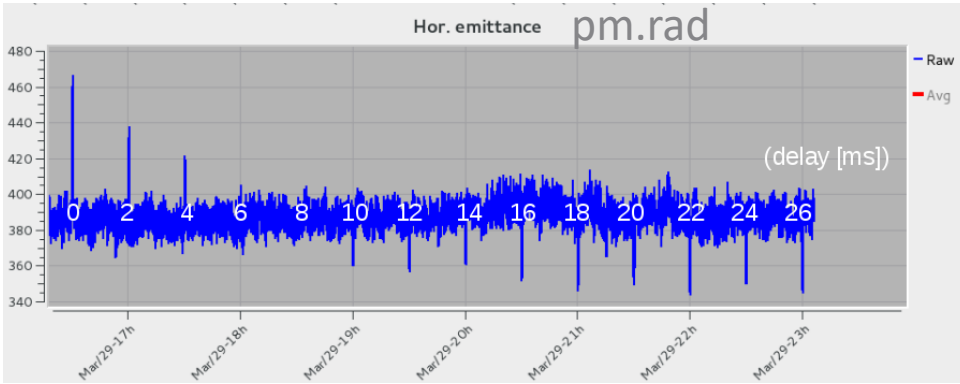
Detailed view 2

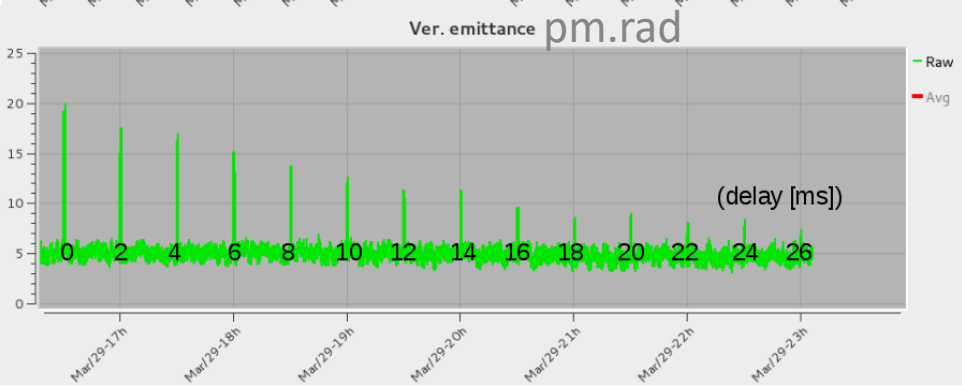


Delivery, 250 mA, top-up 2 Hz every ½ h, Old MIK

Measured beam sizes, 30 µs exposure time, synchronized with MIK.





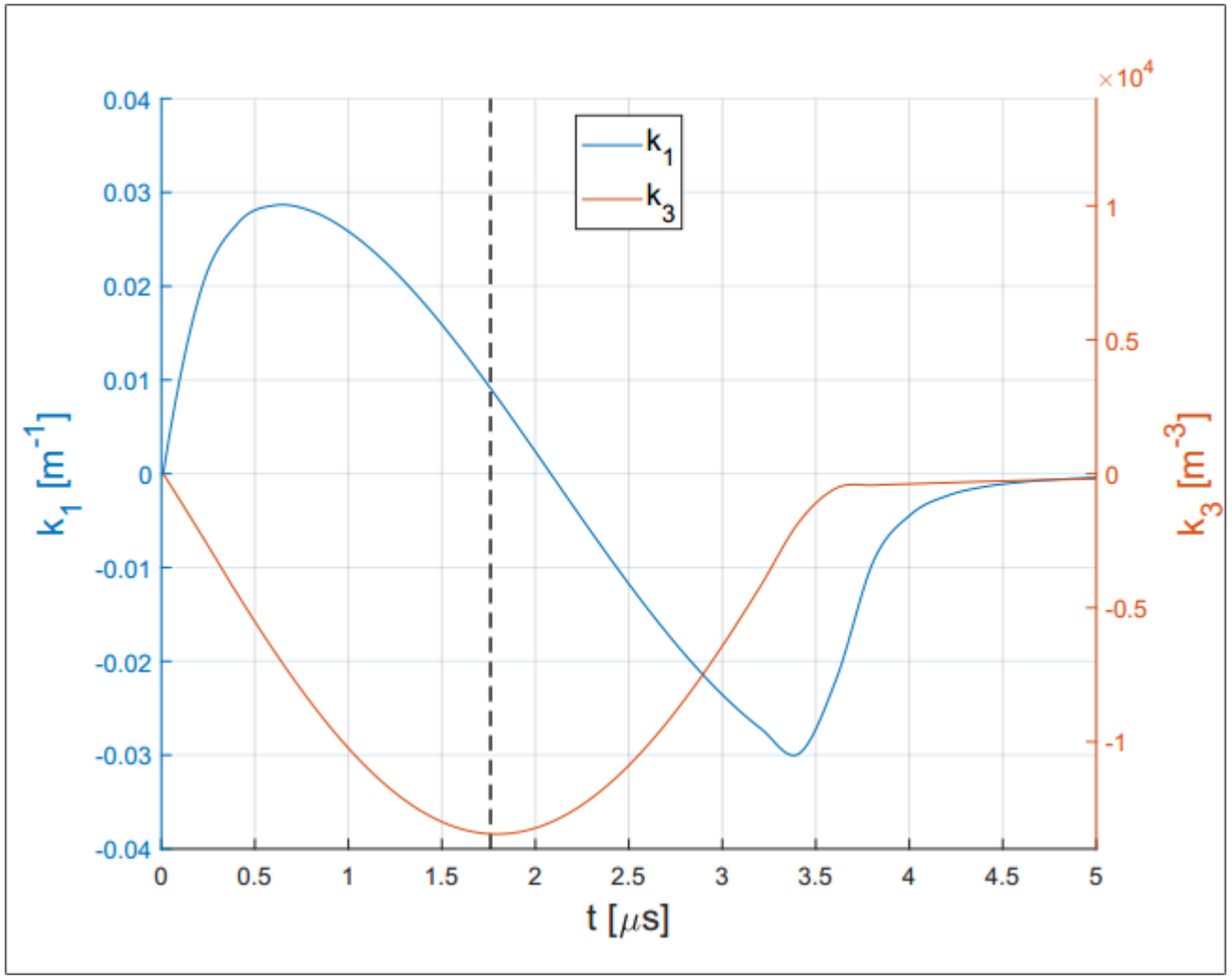


τ_x = 16 ms

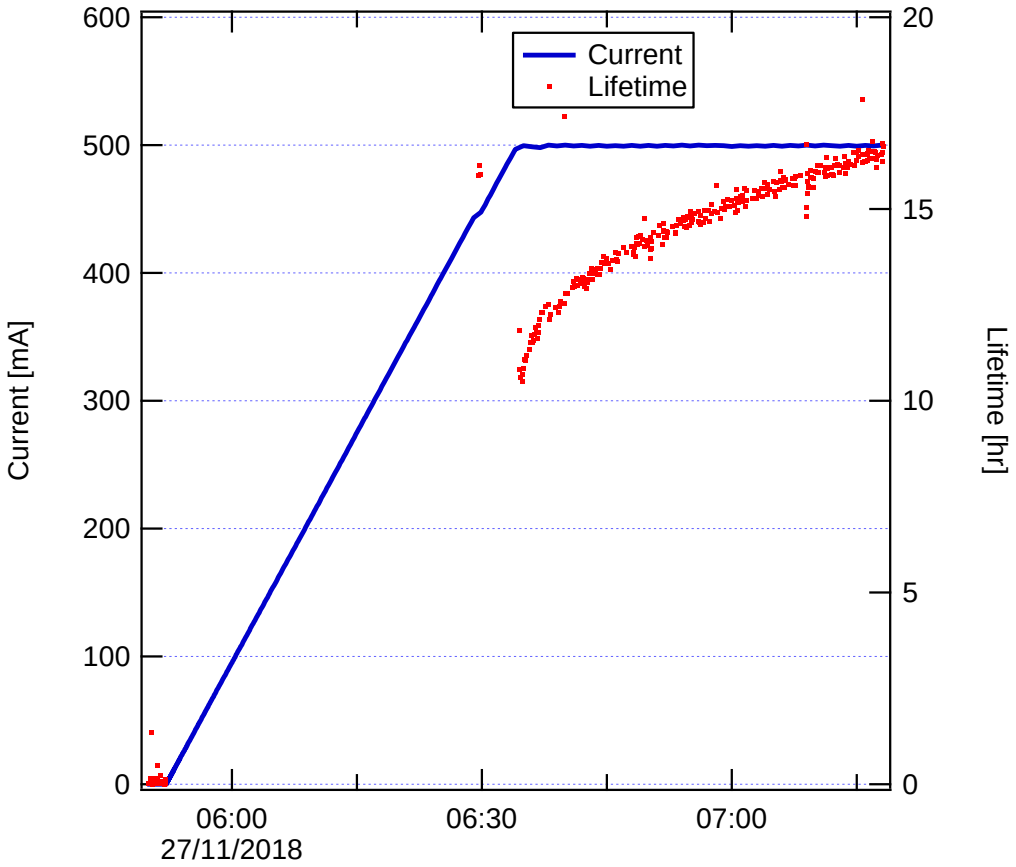
We believe this is an IBS effect.

τ_y = 30 ms

Back-ups


k1
k3
×10^4
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
1
0.5
0
-0.5
-1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
k1 [m^-1]
k3 [m^-3]
t [μs]

Back-up slides



Measured Energy Acceptance

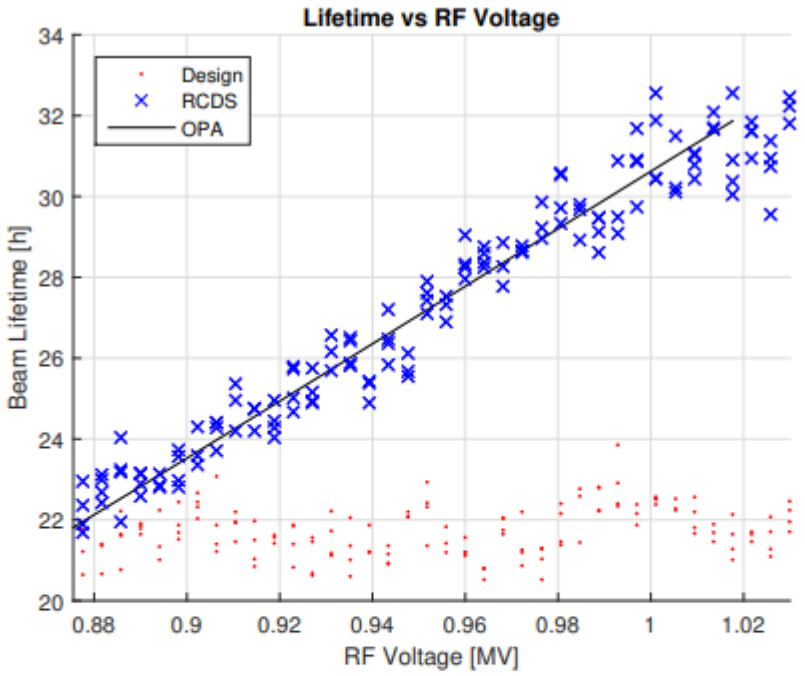


Figure 6: Result of momentum acceptance measurements for the two different non-linear optics. The measurements where taken at a beam current of 75 mA. The black solid line is the fitted results of a simulation in OPA corresponding to a gas lifetime of 95 h.