
MAX IV

MAXIV Status and Development

Dr Stephen Molloy
Head of Accelerator Operations

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Operations Statistics: 2019 → 2020

Operation Statistics

Machine	Planned delivery (h)	total downtime (h)	uptime (%)	MTTR (h)	MTTF (h)	MTBF (h)
R1	5023	93.47	98.14	1.18	63.58	62.40
R3	4573	124.50	97.28	1.11	40.83	39.72
SPF	3889	71.12	98.17	0.74	40.51	39.77

2019

2020 (until 20/12/11)

Machine	Planned delivery (h)	total downtime (h)	uptime (%)	MTTR (h)	MTTF (h)	MTBF (h)
R1	4904	93.33	98.10	1.05	55.10	54.05
R3	4672	122.83	97.37	1.02	38.61	37.60
SPF	4384	195.52	95.54	0.68	15.22	14.54

- All three accelerators are meeting their uptime goals
  - >97% for the rings, & >95% for SPF
- Of note is the significant fall in the MTBF. Most extreme in SPF due to the shared linac.
- Although this is somewhat compensated for by MTTR improvements, I do not see this as sustainable
  - More on this later...

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COVID19 Impact

COVID19

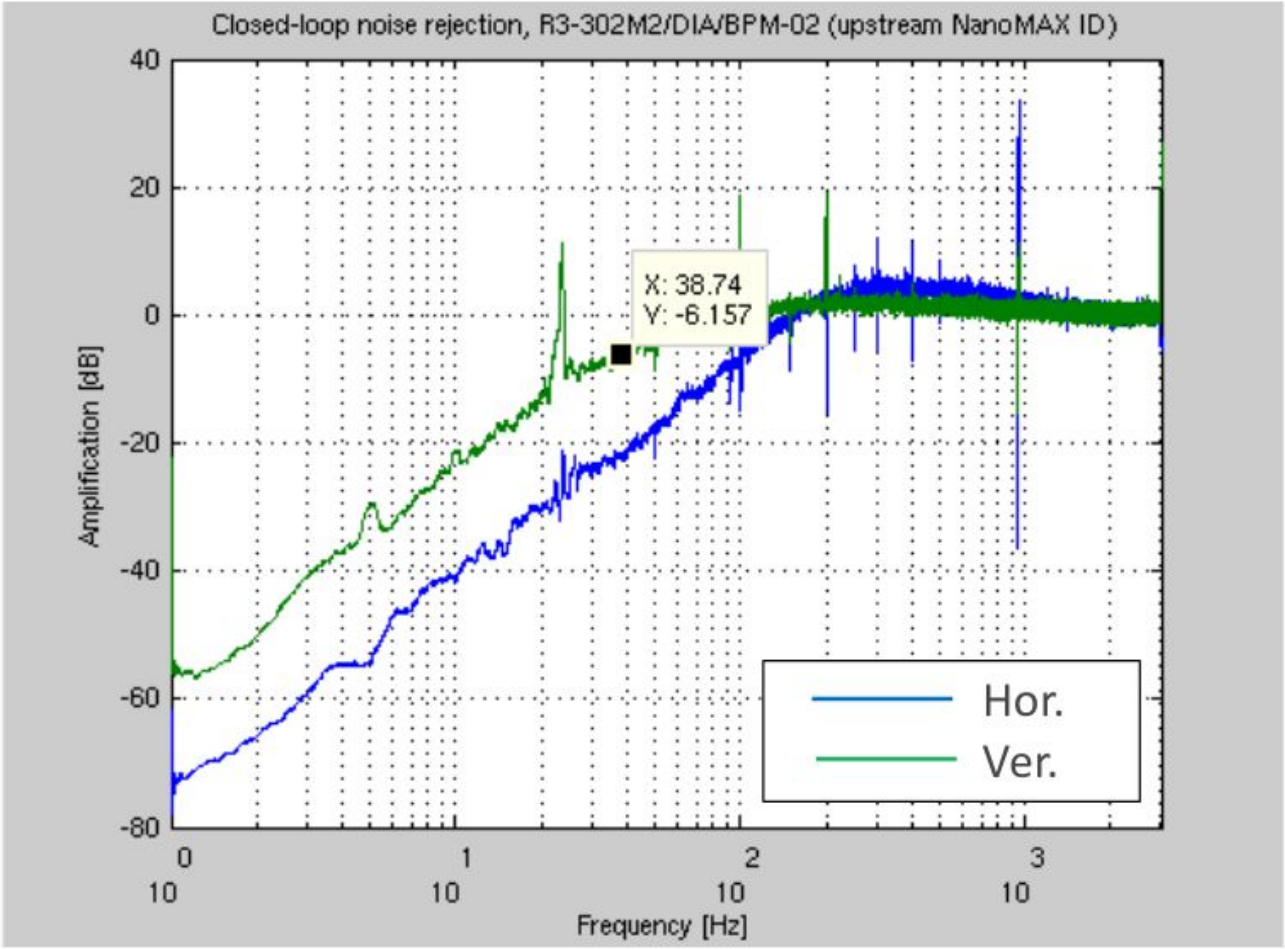
- No interruption to accelerator operation
  - On course to deliver ~5000 hours per accelerator
- Control room staff limited to max two people
  - AccDev group moved to remote participation in studies shifts
  - This transition had some friction
- Significant disruption to user visits
  - Many beamlines changing to mail-in, remote working, etc.

Results from 3 GeV Ring

Noise rejection w. global FOFB

Slide courtesy of Magnus Sjöström

Current closed loop performance as seen on a BPM flanking the NanoMAX ID straight.
It should be noted that the FOFB configuration is currently limited by FPGA bit-cutting, resulting in a closed loop BW of 100 Hz in the horizontal plane and ~40 Hz in the vertical. Plots based on 20 minutes of data collected at delivery conditions.



ID-induced transients

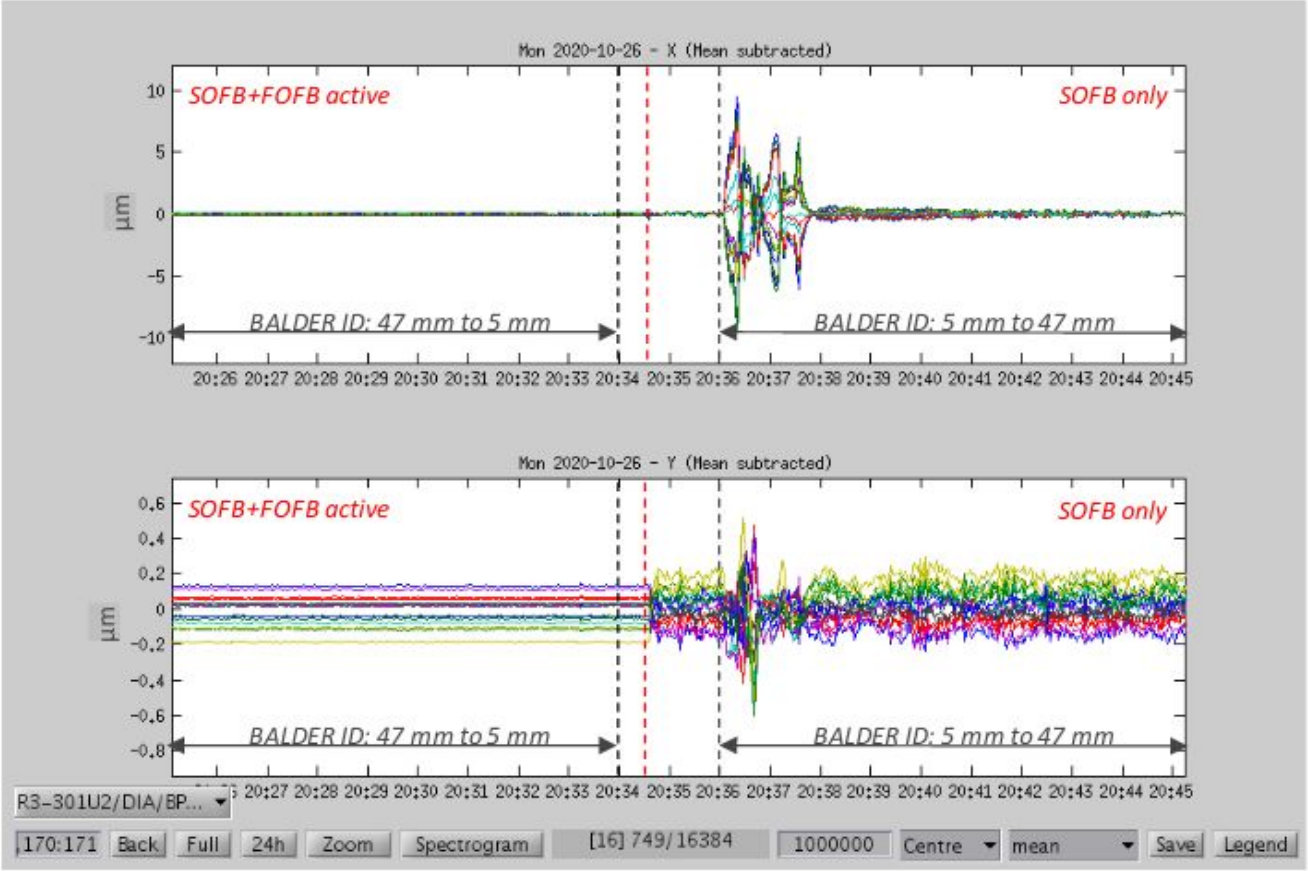
Slide courtesy of Magnus Sjöström

Looking at all BPMs flanking user IDs the combined SOFB+FOFB is able (even at more conservative settings with 30 Hz BW in both planes) to largely eliminate the orbit transients.

BALDER ID is an in-vacuum wiggler and has a very noticable orbit impact at low gaps.

Of note is that no fast correctors (+-10 µrad) ever exceed 10% of the strength.

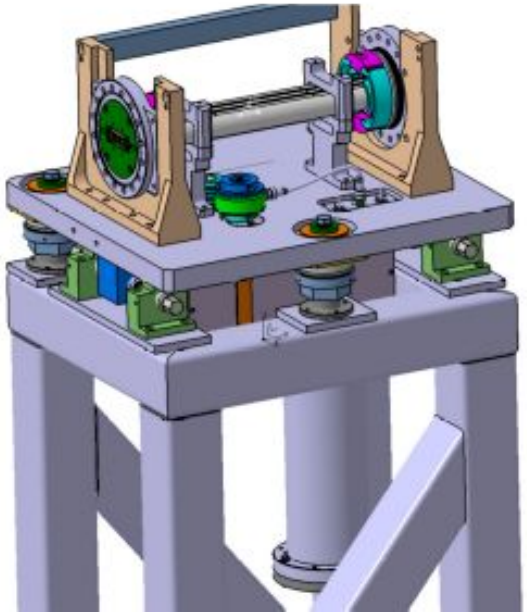
NB! Plot displays highly averaged 10 kHz data (16384 samples per point).

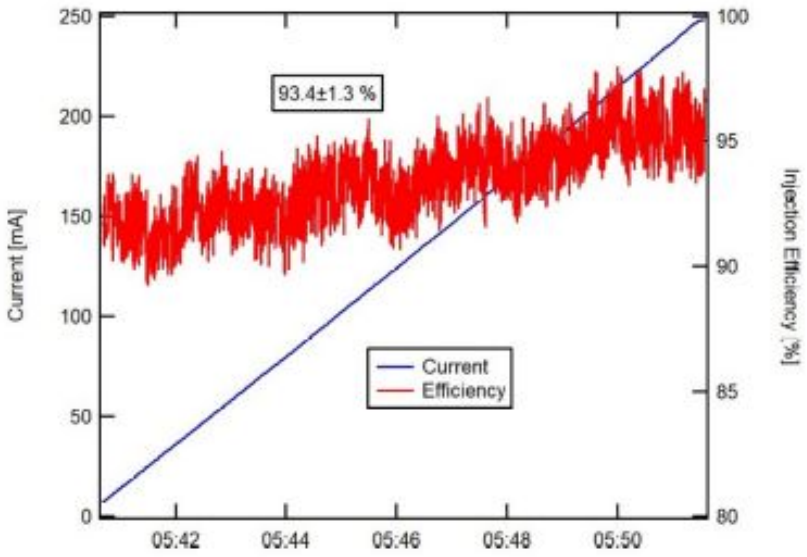


Transparent top-up injection

Slide courtesy of Magnus Sjöström

- 2nd version of Multipole Injection Kicker (MIK) chamber installed in summer 2019.
- Fine trimming and detailed scans with new MIK done **spring 2020**





HZB Helmholtz Zentrum Berlin

SOLEIL SYNCHROTRON

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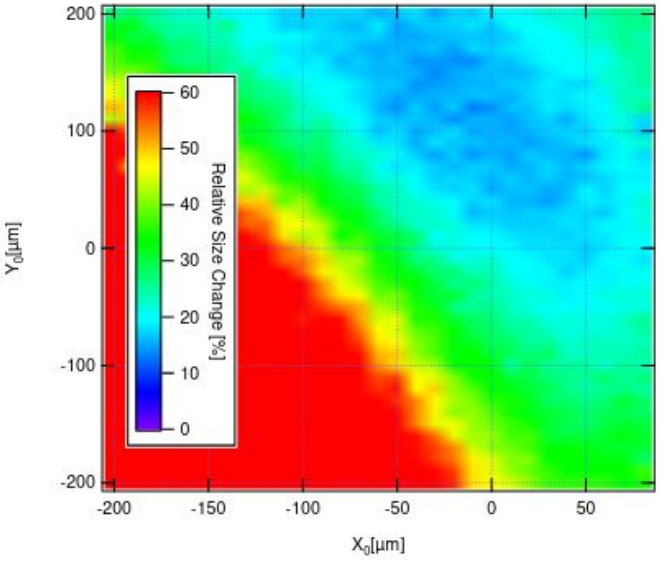
Residual Stored Beam Perturbations

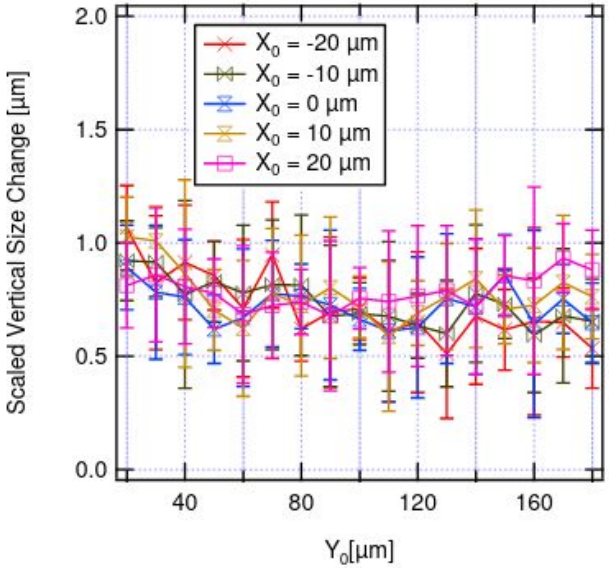
Transverse beam profile measured at diagnostic beamline while pulsing the MIK.

Transverse beam position at the MIK scanned on a 2D grid

Residual Perturbation Map



Vertical Size Change



Minimum

$$\delta\sigma_x = 0.5 \pm 0.7\ \mu m$$

$$\delta\sigma_y = 0.6 \pm 0.1\ \mu m$$

$$\delta(x_0, y_0) = \frac{\delta\sigma_x}{\sigma_x} + \frac{\delta\sigma_y}{\sigma_y}$$

Slide by Pedro F. Tavares

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Transparent top-up injection into a fourth-generation storage ring

Patrick Alexandre [a], Rachid Ben El Fekih [a], Antoine Letrésor [a], Serge Thoraud [a], José da Silva Castro [a], François Bouvet [a], Jonas Breunlin [b], Åke Andersson [b], Pedro Fernandes Tavares [b,*]

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[b] MAX IV Laboratory, Lund University SE22100, Lund, Sweden

Non-linear optics

Off-Energy Orbit Response Matrix

- Iterative method to correct chromatic sextupoles based on fitting a lattice to a measured off-energy orbit response matrix, analogous to LOCO
- Applying the sextupole corrections led to an increase in lifetime to 19 h from 11 h, after correcting coupling to produce same vertical emittance.
- Increase in lattice momentum acceptance and horizontal acceptance.

	Measured ξ_x/ξ_y	Fitted ξ_x/ξ_y
0th iteration	$+0.9233/+3.2345$	$+0.7873/+3.2507$
1st iteration	$+1.2167/+0.8254$	$+1.1884/+0.9677$
2nd iteration	$+1.0089/+0.9722$	$+0.9963/+0.9948$

Measured chromaticity and chromaticity from the NOECO fit with each iteration of applying correction to the sextupole circuits.

	A_x [mm mrad]	A_y [mm mrad]
Pre-symmetrization	3.7 ± 0.1	1.6 ± 0.2
Post-symmetrization	5.6 ± 0.2	1.9 ± 0.2

Change in transverse acceptance as determined by scraper measurements

Tables and data by D. K. Olsson

D. K. Olsson et al., "Nonlinear optics from off-energy closed orbits", Phys. Rev. Accel. Beams vol. 23, issue 10, Oct. 2020

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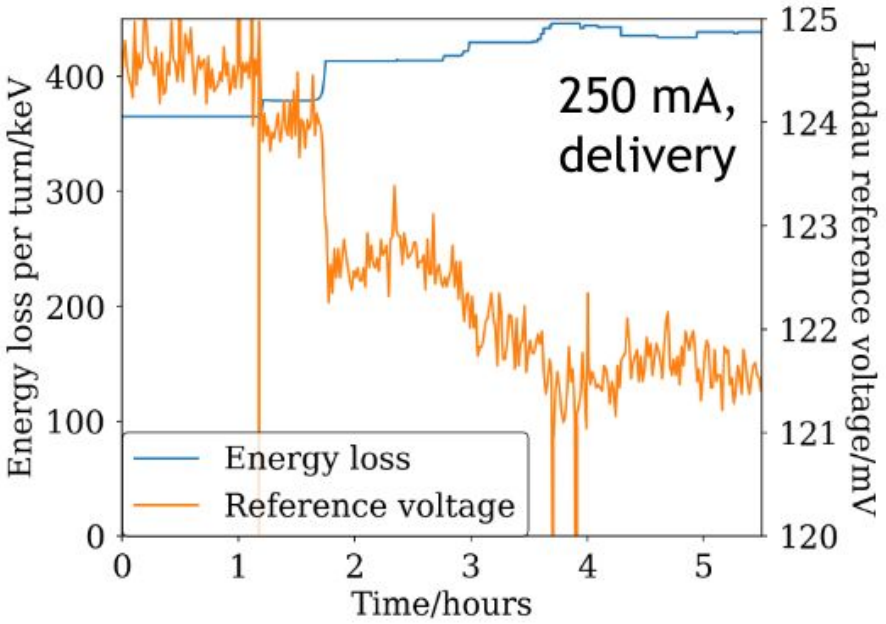
Feed-forward device for flat potential

Slide courtesy of Francis Cullinan

- Newly commissioned Tango device
- Maintain flat potential as IDs are closed (assuming evenly-spaced bunches with given form factor)
  - RF voltage with zero first derivative - Landau fields only
  - Zero first and second derivative - main and Landau fields
- Additional flexibility (current level, parked cavity, etc.)



Results from 1.5 GeV Ring

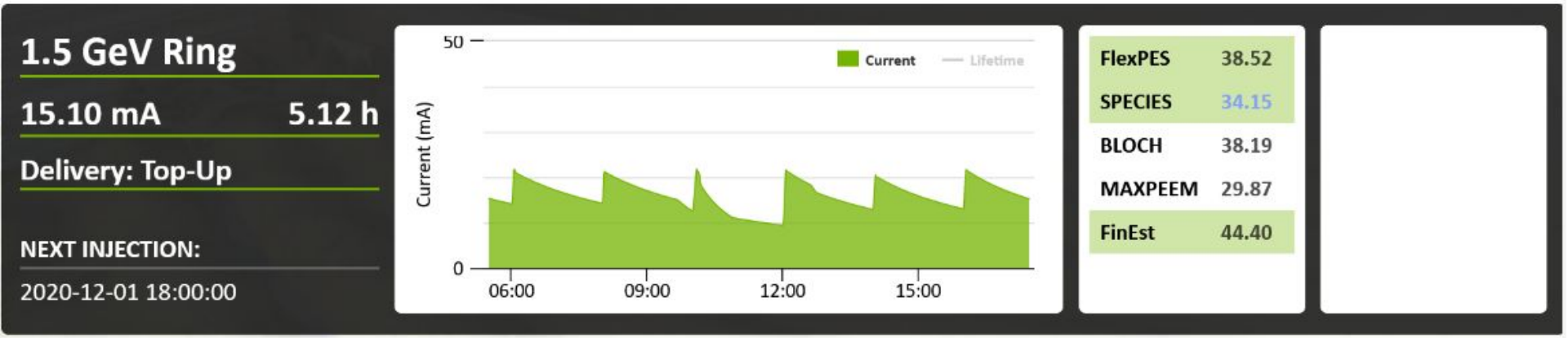
Slide courtesy of Åke Andersson

1.5 GeV ring, Single Bunch Delivery

- Single-bunch delivery to FinEst & FlexPES beamlines:
  - Two to three week runs, and several one-day runs in 2020

Method (developed by Francis Cullinan):

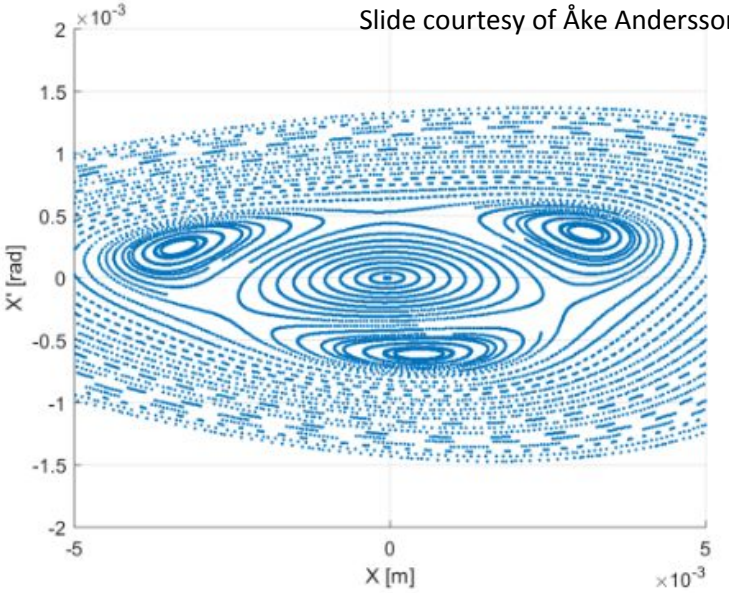
- Thermionic gun used for single-bunch injections:
  - TG delay decreased to clip end of bunch train
  - DC chopper delay increased to clip beginning of bunch train
- Scraper inserted and parasitic bunches excited using bunch-by-bunch system to clean them out
- Process now automated, injection every two hours



Slide courtesy of Åke Andersson

1.5 GeV Ring, Transverse Resonant Island Buckets (TRIBs)

Two, possibly three, BLs are interested in SB over substantial time of the yearly 5000 delivery hours. Also, interest in “fast swap” SB - MB.



- TRIBs would allow for simultaneous Single and Multi Bunch delivery.
- Operating the machine close to third order horizontal resonance at zero horizontal chromaticity.
- A secondary closed orbit appears and can be populated with one bunch:
  - Separated in x-x’ space from the core orbit.
  - Closes only every third turn.
  - **Both BLs have initially verified they may use one or two of the secondary orbit source points, while blocking the core orbit light.**

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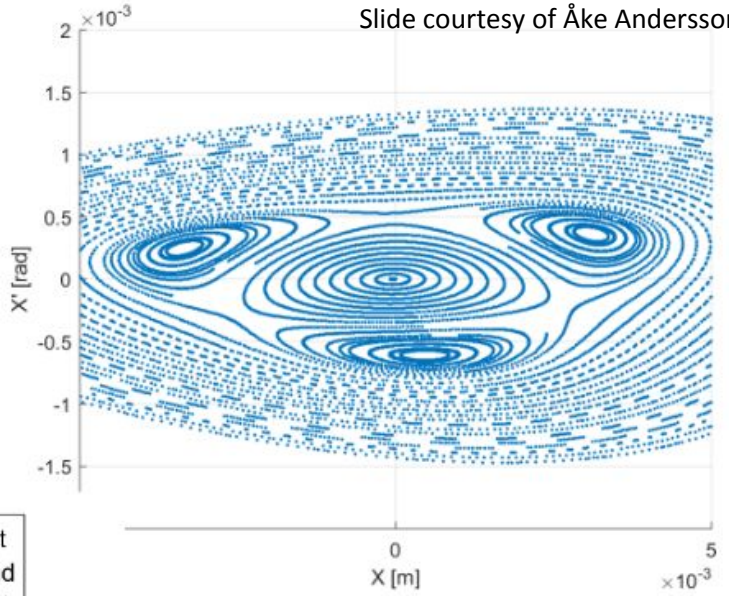
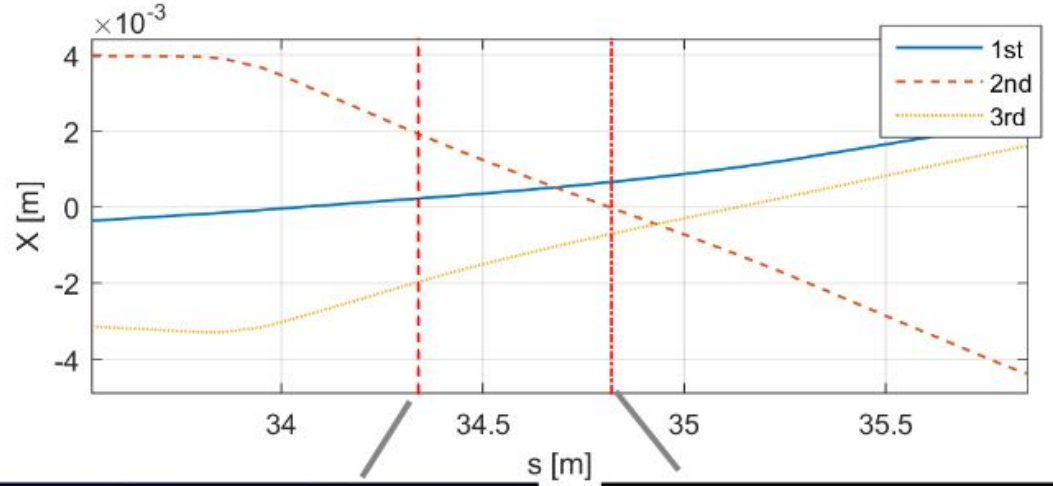
Slide courtesy of Åke Andersson

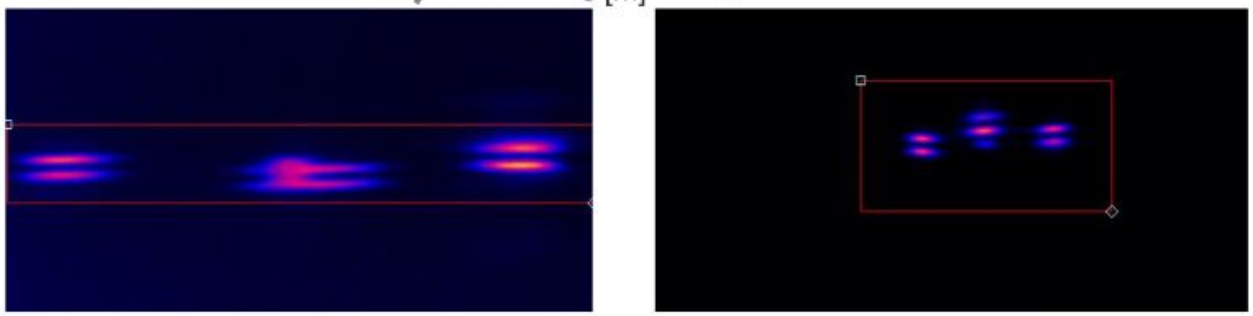
TRIBs Optics Characterisation

The LOCO fit corresponds well with what we see at the diagnostic beam lines.



Tracked island and core buckets at centre of first straight section (approximate position of BBB kicker).





Results from injector/SPF

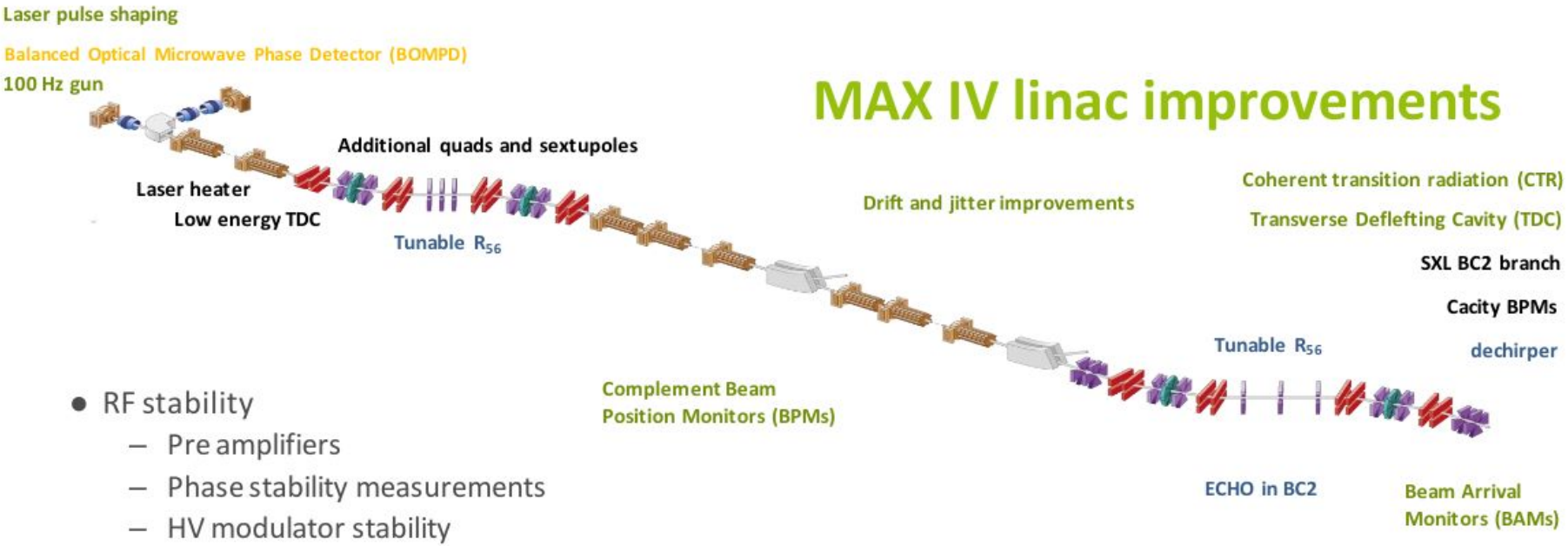
Slide courtesy of Erik Mansten

10 Hz operation

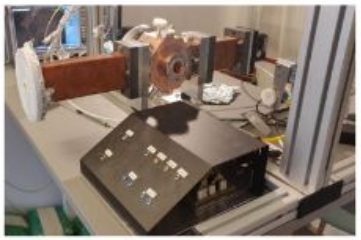
- Radiological commissioning week 47-week 48
  - Issues with chopper aperture heating was resolved
  - Dual repetition rate operation
- SPF, 100 pC, 10 Hz, from week 49 and onwards
- R1, up to 500 mA/min
- R3, up to 100 mA/min

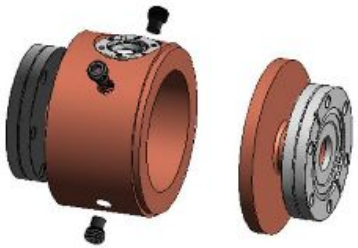
Slide courtesy of Erik Mansten

MAX IV linac improvements



- RF stability
  - Pre amplifiers
  - Phase stability measurements
  - HV modulator stability
  - Phase feedback
- Laser pulse shaper
- 100 Hz gun
  - Gun test facility
- Complement BPMs
- Transverse deflecting cavity
- BAM
- Cavity BPMs
- CTR – bunch length measurements





MTBF Working Groups

MTBF

- As shown in the statistics, MTBF is a significant concern
- Two large efforts have been put in place to tackle this
  - MTBF improvement project
  - Formation of a working group to streamline introduction of new beamlines

MTBF Improvement Project

1. Adjust FE & BL vacuum alarm levels
2. Prevent common mistakes
3. Reconfigure MPS actions (FE & BL vacuum protection)
4. Add redundancy to MPS sensors

1/ Adjust FE & BL vacuum alarm levels

- Review vacuum alarm levels in all beamlines
- Adjust if necessary
  - My belief is that these will be found to be overly conservative

2/ Prevent common mistakes

- To allow for certain work to be performed, beamlines PLC's are sometimes transitioned to "maintenance mode"
  - MPS is reliant on these PLC's, and so the beamlines needs to be shuttered off from the ring
    - We have had regular dumps due to this mode transition not being done correctly
  - A mechanism will be put in place to rule out a large class of these errors
- The ringside HA cannot handle ID light, and so the beam must be dumped if it is closed while the ID is not fully open
  - This leads to a common scenario whereby a mistake leads to a beam dump
  - A high-level software solution is already in place
  - A low-level solution is underway

3/ Reconfigure MPS actions

- Stakeholders agree that the MPS response to certain vacuum alarms is excessive
- Currently:
  - Close FE valves, generating a ring dump to protect them from ID light
- New idea:
  - Change the MPS action so that a vacuum interlock downstream of the triggering unit first closes the FE HA and then the downstream gate valves. If 5 s passes and the HA is not yet closed, then close the gate valves (thereby dumping the beam).
- Note, no changes are proposed for actions that trigger the fast valves.

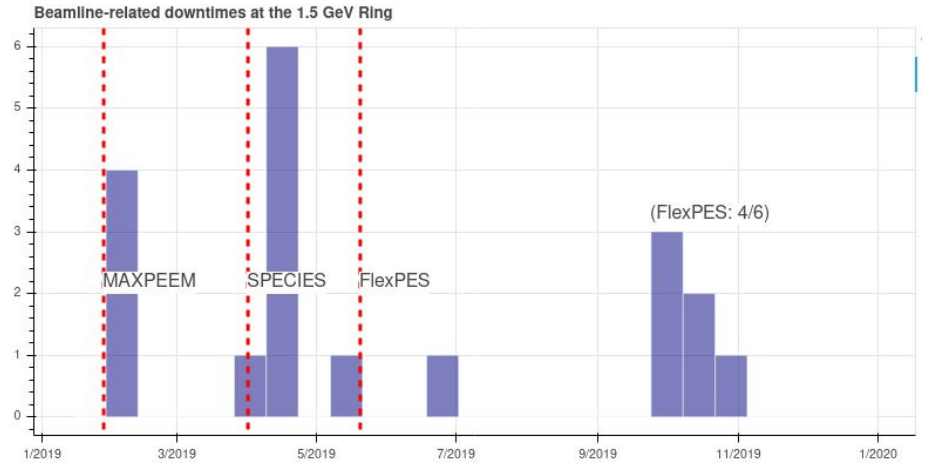
3/ Reconfigure MPS actions

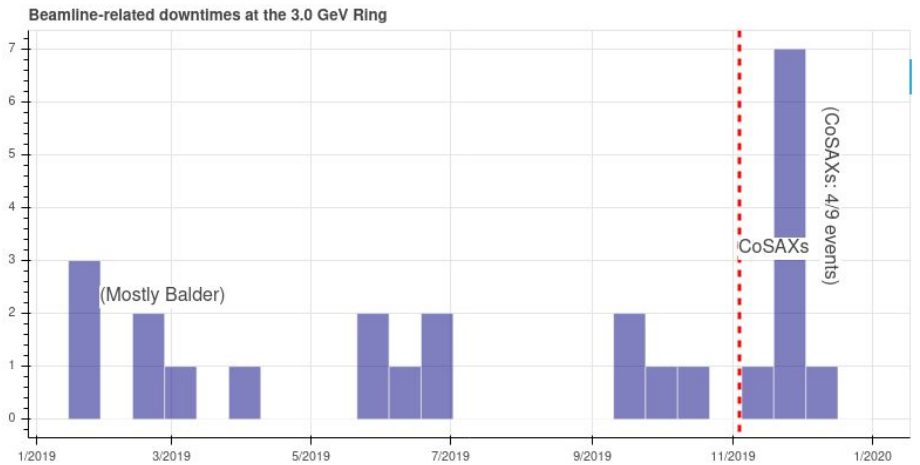
- Similar to the previous slide, the present actions for thermal events are considered to be too conservative
  - Perform the same actions as for a VAC alarm
- New concepts are still under discussion

6/ Add redundancy to MPS sensors

- Only trigger alarms in the case where two independent sensors agree
- Much more conceptual, and still under consideration by the vacuum team

New beamlines





- We have been bringing new beamlines online rapidly
- Each one comes with the challenge of integrating it into the suite of already-running beamlines
  - New surfaces exposed to undulator light
  - Misalignments
  - Etc.

Consistent plan for introduction of new beamlines

- Subdivide the beamline
  a. Insertion device
  b. Front-end (ID to monochromator)
  c. Beamline (downstream of the mono)
- Commission each subdivision in turn
  a. Planar-mode characterisation (one shift)
  b. FE vacuum commissioning (4-5 shifts)
  c. Remaining BL commissioning
- Detailed plan based on this template for each new beamline
  a. Authored by AccOps, RadSafety, ID, FE, BL, etc.

Time-limit the risks

- Limit “risky” activities to specific shifts when no users are present
  - Tuesdays from 0800 → 2400
- Temporarily increase vacuum limits (if appropriate)
  - Raise limits in FE & BL ion pumps during commissioning
  - X3 → X9
- Key tests to be passed before the new beamline runs outside these times
  - Accelerator performance
  - Vacuum & thermal robustness

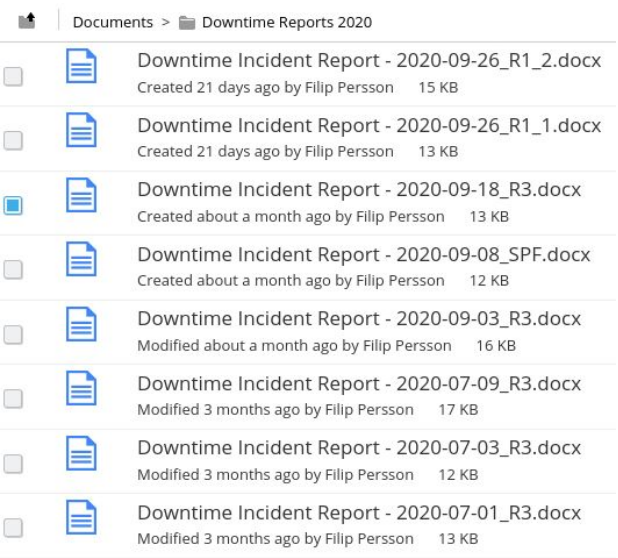
Thank you for your attention!

BACKUP SLIDES

Systematic approach to lessons learned

Accelerator Downtime Reports

- Formal documentation required for significant downtimes
  - >90 minutes



Downtime Incident Report

Author(s): Mathias Brandin

Date of report submission: 200918

Time and date downtime started: 03:47 200918

Duration of downtime: 1h 39 min

Description

The ICPUA R3-A110211/VAC/IPCUA-03 overheated and turned off its high voltage, generating a vacuum interlock. Valves were closed and RF turned off.

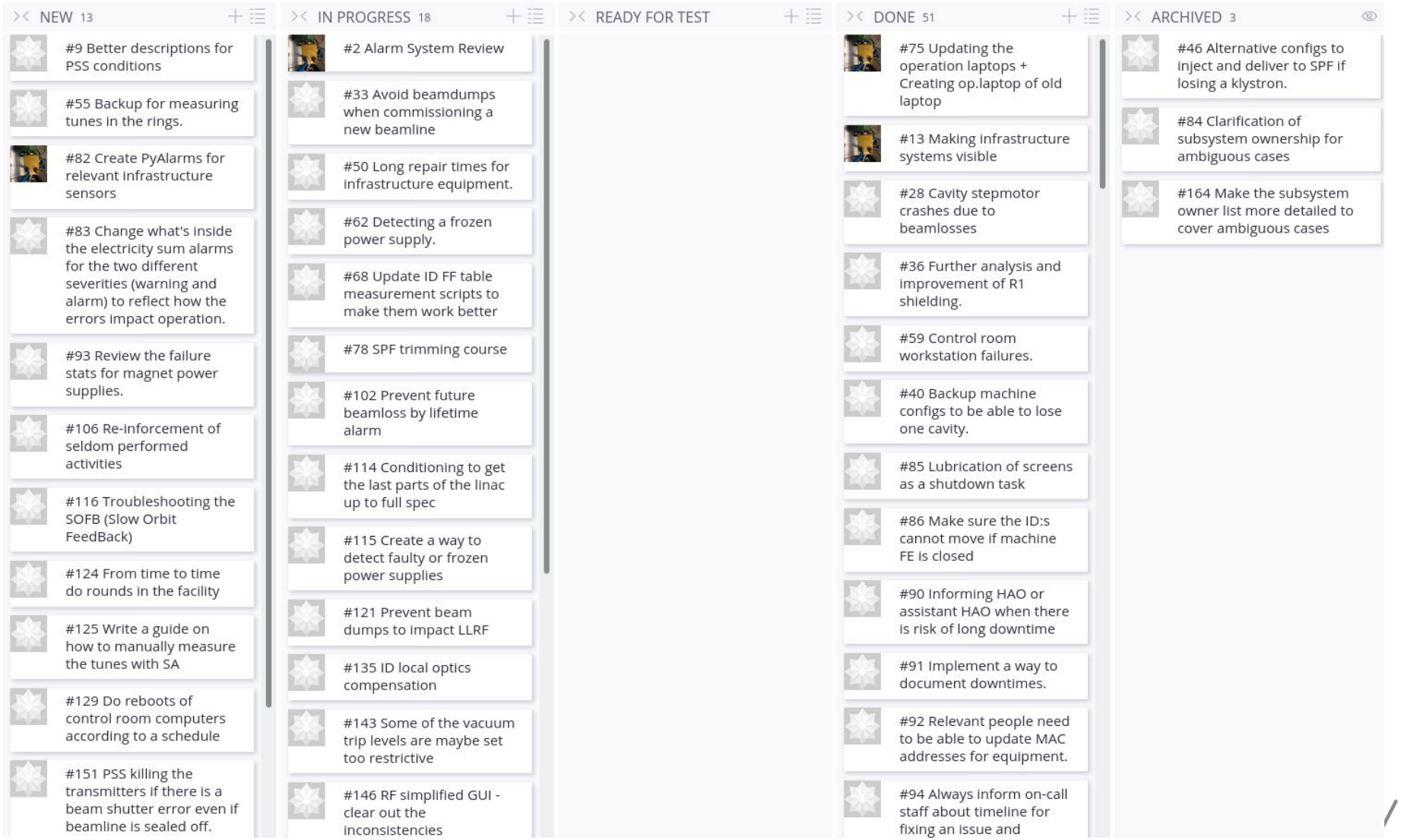
Causes

The ICPUA R3-A110211/VAC/IPCUA-03 overheated and turned off its high voltage, generating a vacuum interlock

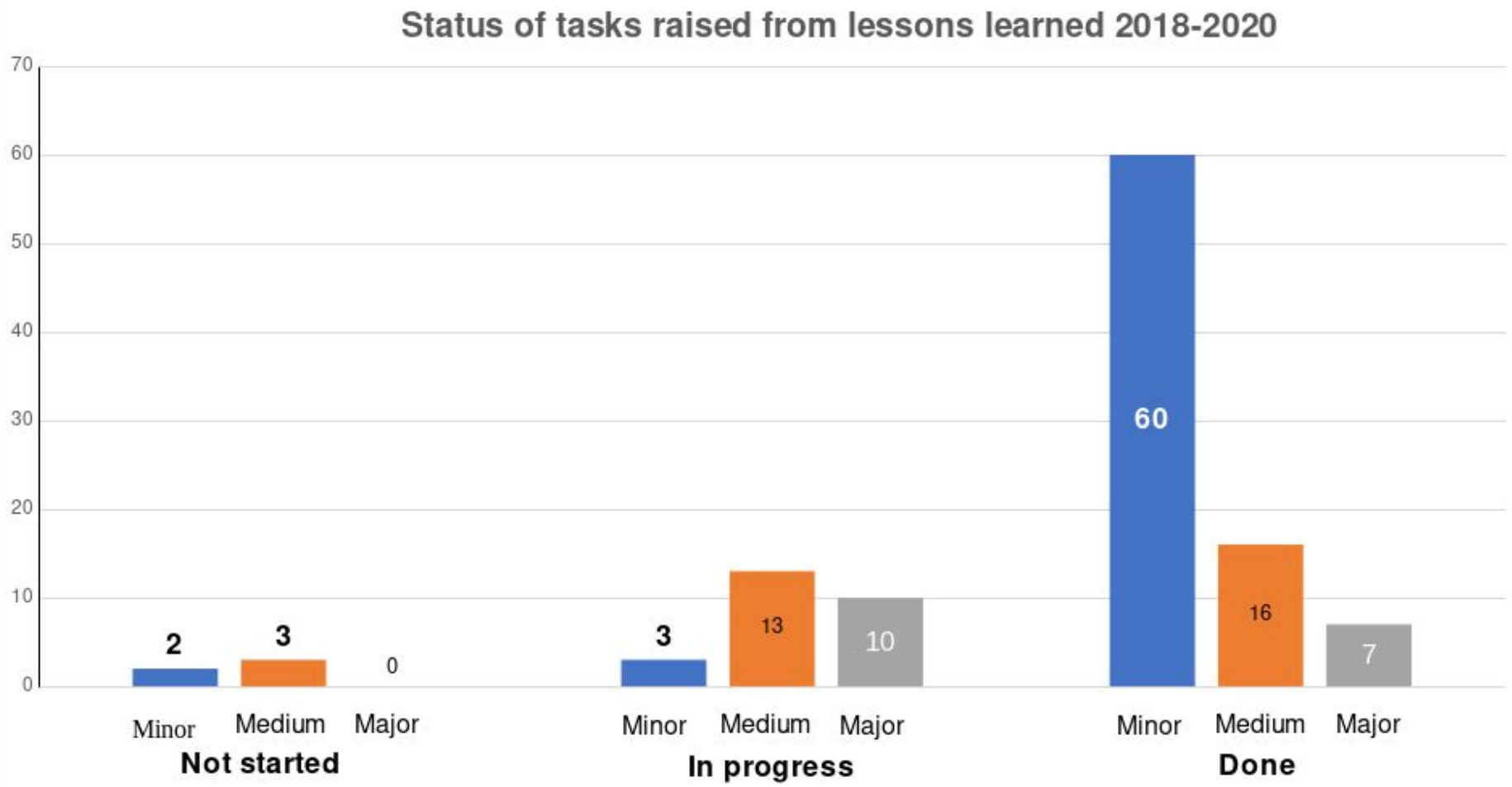
Lessons-learned

- Each downtime report contains lessons-learned
  - How to prevent this occurring in the future
- These have been gathered together by Filip Persson into an online planning application
  - Taiga -- typically used by IT to plan & track tasks

Taiga https://agile.maxiv.lu.se/project/filper-operations-lessons-learned/kanban



Progress


Status of tasks raised from lessons learned 2018-2020
70
60
50
40
30
20
10
0
2
3
0
3
13
10
60
16
7
Minor
Medium
Major
Not started
Minor
Medium
Major
In progress
Minor
Medium
Major
Done