

Machine Detector Interface (MDI)

MDI group structure

MDI group

Leader: Hiro Nakayama

MDI group includes not only **Belle II collaborators** but also several experts from **SuperKEKB** vacuum, monitor, control, commissioning, injection, RF groups, as well as from **LINAC** group.

Beam background subgroup

Leader: Andrii Natochii
(10 staff, 7 postdoc, 7 students)

- **BKG simulation**
 - simulate storage and injection background
 - Find optimal collimator settings
- **BKG machine studies**
 - validate BKG simulation based on machine study data
 - understand and improve injection BG duration which causes DAQ downtime
- etc..

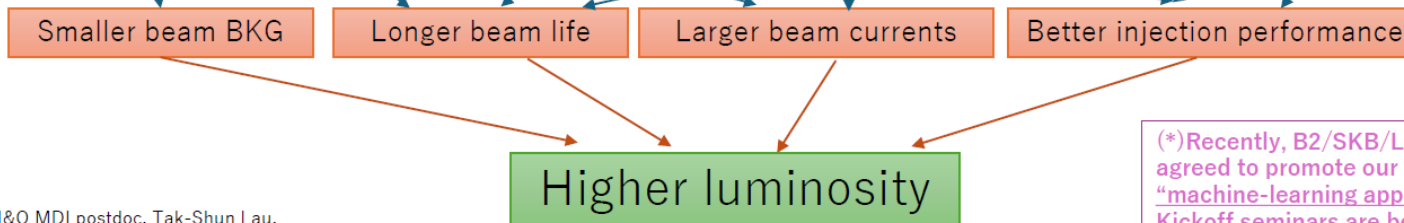
Beam loss monitor subgroup

Leader: Kenta Uno → TakShun Lau
(8 staff, 3 postdoc, 7 students)

- **Sudden beam loss (SBL)**
 - beam loss monitors with fast readout
 - acoustic sensors
 - post-mortem abort timing analysis
 - BOR timing analysis
- **Faster Abort delivery**
 - NLC CLAWS as a new abort source
 - Abort delivery using laser transmission in air
- etc..

Other efforts which are directly reported to the MDI meetings

There also exist other MDI-related topics which are not covered by these two subgroups, such as **machine-learning application to accelerator tuning (*)**, **beam injection**, **collimator R&D**, **diamond abort system**, etc...



KEK's new M&O MDI postdoc, Tak-Shun Lau, is expected to contribute to Beam loss monitor group and machine learning taskforce

(*)Recently, B2/SKB/LINAC management has agreed to promote our further collaborations on **"machine-learning application to accelerator tuning"**. Kickoff seminars are being held to recruit (remote) Belle II collaborators.

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(4 staff, 1 postdoc, 2 students)

from B2GM MDI session <https://kds.kek.jp/event/52430/> (← need KEK KDS account)
see also Run Coordinator's talk at B2GM

https://indico.belle2.org/event/13003/contributions/80750/attachments/30756/45438/B2GM_Runco_kuno_2024.10.07.pdf

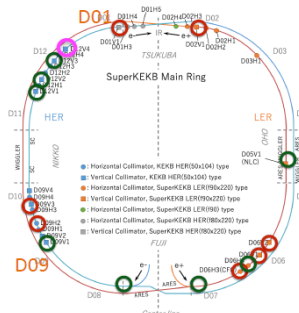
Sudden Beam Loss (SBL)

Adding more monitors help to understand the problem.
Faster beam abort.

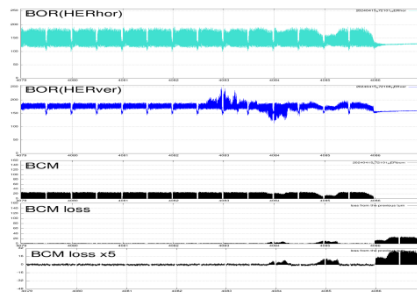
Sudden Beam Loss in 2024c

HER SBL: Not understood yet (no clearing electrode in HER)

- Need fast beam abort to protect our system against HER SBLs
 - Result of loss monitors: initial loss on all HER SBL is D9V1/D9V3
 - Installed optical fiber around the collimators for beam aborts
- Add Monitors to understand HER SBLs Expectation ~5 us earlier (preliminary)
 - Acoustic sensors around collimators to check electric discharges
 - PMT/EMT around HER collimators to understand feature of HER SBL
- Continue analyzing HER SBLs by combining info of all monitors

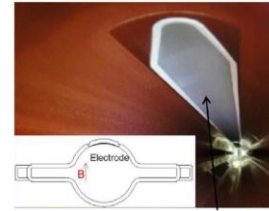


Installation in LS1
Installation before LS1

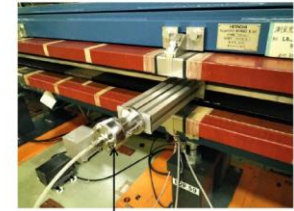


Knocker studies

- knocked beam pipes on D10 wiggler with clearing electrodes (with beams at 600-1000 mA)

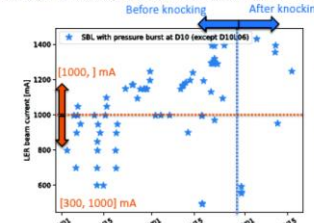


clearing electrode



Knocker machine

- ⇒ SBL events can be artificially produced by knocking beam pipes !!
- knocked beam pipes at D10 several times without beams

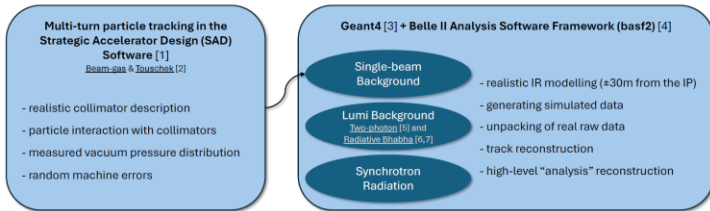


	I_{LER} [mA]	[900, 1000]	[1000,]
Before knocking	#SBL	24	42
	Operation-time [h]	633.77	350.32
After knocking	#SBL	4	4
	Operation-time [h]	98.5	162.3
	#SBL/time [1/h]	0.038 ± 0.008	0.12 ± 0.02
	#SBL/time [1/h]	0.041 ± 0.020	0.025 ± 0.012

⇒ frequency at $I_{\text{LER}} \geq 1 \text{ A}$ is reduced: $0.12 \pm 0.02 \rightarrow 0.025 \pm 0.012$!! ("knocking effect")

Beam Background

Background Simulation Software



[1] Y. Ohnishi, et al., "Computer program complex code for accelerator design, simulation and commissioning", Proceedings of the 16th Annual Meeting of Particle Accelerator Society of Japan (PAS2016), WEO-IP04, 2019
 [2] Y. Ohnishi, et al., "Accelerator design at SuperKEKB", Progress of Theoretical and Experimental Physics, Volume 2015, 2015, Pages 03A011
 [3] Geant4 (www.geant4.org)
 [4] A. Moll, The software framework of the Belle II experiment, J. Phys. Conf. Ser., 2013 (5)02024, 2011
 [5] F. A. Berends, et al., "Complete lowest-order calculations for two-photon final states in electron-positron collisions", Nuclear Physics B, Volume 253, 1985, Pages 441-463
 [6] R. Knie, et al., "BIBEL: Monte Carlo simulation of radiative Bhabha scattering in the very forward direction", Computer Physics Communications, Volume 91, Issue 3, 1994, Pages 372-380
 [7] B. Anders, et al., "BIBEL: Monte Carlo simulation of radiative Bhabha scattering at wide angles for LEP/SLC and LEP2", Physics Letters B, Volume 390, Issues 1-4, 1997, Pages 298-308

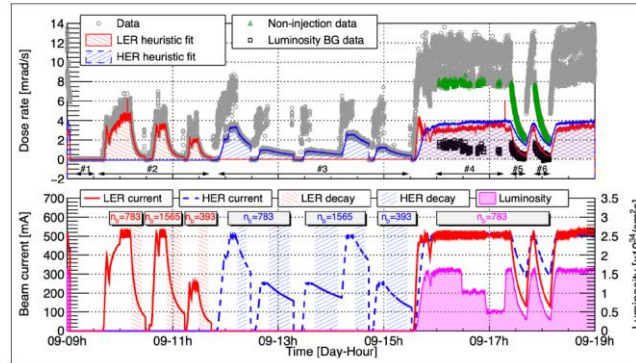
September 25, 2024

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Background Measurements

A dedicated beam-induced background measurement is performed to measure each background component separately, usually twice a year.



An example of dedicated beam background measurements in SuperKEKB.
 Top: typical measured detector background; bottom: measured machine parameters.

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Beam-gas

Elastic and inelastic particle scattering off of residual gas molecules

$$O_{\text{Beam-gas}} = B \times I P_{\text{eff}}$$

Touschek

Inelastic scattering of two particles in the same beam bunch

$$O_{\text{Touschek}} = T \times \frac{I^2}{n_b \sigma_x \sigma_y \sigma_z}$$

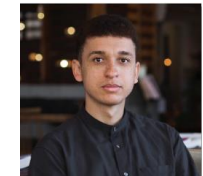
Luminosity

Radiative Bhabha and two-photon processes

$$O_{\text{Lumi}} = L \times \mathcal{L}$$

Background Composition

June 16, 2021 at the following beam condition: $I^{\text{LER/HER}} = 732.6/647.2 \text{ mA}$, $n_b = 1174$, $\sigma_x^{\text{LER/HER}} = 184.6/151.0 \mu\text{m}$, $\sigma_y^{\text{LER/HER}} = 60.7/36.2 \mu\text{m}$, $\sigma_z^{\text{LER/HER}} = 6.5/6.8 \text{ mm}$, $P_{\text{eff}}^{\text{LER/HER}} = 88.7/24.3 \text{ nPa}$, and $\mathcal{L} = 2.6 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$. Beam-



Andrii Natochii, PhD in Physics

E-mail: natochii@bnl.gov

- Dominant backgrounds
 - LER single-beam
 - Luminosity
- HER single-beam background ~10%
- SR is of no concern for the PXD
- We start to see SEUs due to EM shows and neutrons
- In 2022, due to beam current increase and high beam background after injection (<10 ms) we start seeing detector performance degradation (e.g. CDC dE/dx resolution drop)

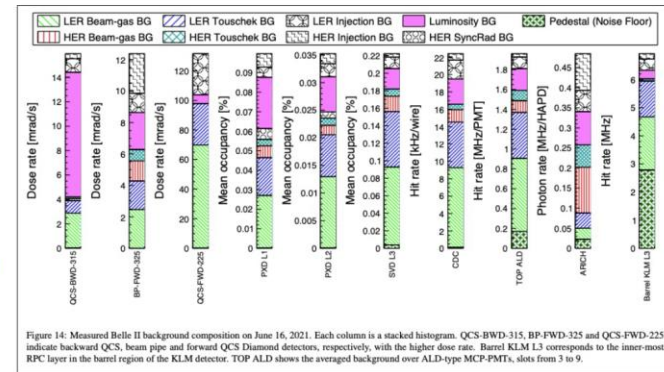


Figure 14: Measured Belle II background composition on June 16, 2021. Each column is a stacked histogram. QCS-BWD-315, BP-FWD-325 and QCS-FWD-225 indicate backward QCS, beam pipe and forward QCS Diamond detectors, respectively, with the higher dose rate. Barrel KLM L3 corresponds to the inner-most RPC layer in the barrel region of the KLM detector. TOP ALD shows the averaged background over ALD-type MCP-PMTs, slots from 3 to 9.

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Anomaly Detection, Correlation Studies

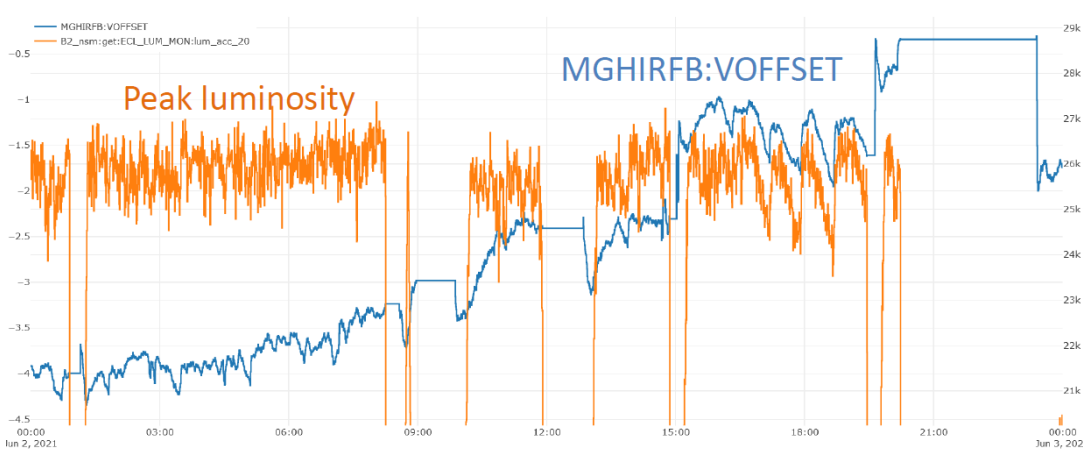
- EPICS was selected as the base of the KEKB/SuperKEKB/Linac control system.
 - About 140,000 PVs archived for SuperKEKB ([SuperKEKB archiver viewer](#))
 - About 190,000 PVs archived for Linac ([Linac archiver viewer](#))
- These archived PVs could contain some important information that we have missed.
- The strategy of the analyses is to **go through all the PVs to find out such information without any bias.**

PV (Process Variable): various measured values recorded in EPICS (e.g. temperature, currents, voltages etc.)

- 1) Correlation of a PV in question with other PVs.
- 2) Anomalies in PVs that coincide with an event.



→ Such analyses will help understand the machine, which is quite important at this stage.



Correlation with the luminosity

```

May 11, stable
.B2_nsm:get:ECL_LUM_MON:lum_acc_20
CG_OPT:CAP:SIGMAY.0.9539593838409346
CG_OPR:SpecificLuminosity.0.95340081189522
B2_nsm:get:NONZDUMINT_ZDUM_INTERVAL.value.0.7323845639724574
CO_KIKAI:ANM013.0.618919426592101
CO_KIKAI:ATU022.0.6140406611947532
CO_KIKAI:ATU094.0.613565996173172
RFDKPS:DRAB:CATH:V.0.612212645892594
MGHPS:ZVADRNE.1:IMON.0.6007335659806405
RFHNG:DO4H:DFEONT:KLYPLL_LR_THETA.0.5917577592616801
RFHFKPS:D1103:BBIV:V.0.592692326571776
RFHFKPS:DO4:AFG:HEAD:EX1_WTR.0.596440950117708
REFLNC:DO5B:1PPS1:VOL.0.585022905447053
CO_KIKAI:ANK557.0.5844086656511095
MGLPS:ZHWRNLP:IRB.0.5828148983260628
MGLPS:ZHWRNLP:CREG.0.5828148983260628
MGLPS:ZHWRNLP:NRB.0.5828148983260628
MGHPS:ZHOF2E.14:IMON.0.5825703152043628
CO_KIKAI:ANK501.0.5825582691703176
REFLNC:DOTA:KPLL:OUT.0.5817426863720431
MGLPS:ZHOF2P.33:KDIR.0.5789501736505192
CO_KIKAI:AFJ002.0.578686344286353
CO_KIKAI:ANK587.0.578129548285235
MGLPS:ZHWRNLP:IMON.0.575563190828042
MGHPS:ZVQDSC.36:REQVAL.0.57171874493983489
CO_KIKAI:ANK551.0.5762953079449577
MGLPS:ZHOT4FOP.2:IMON.0.57611171382022856
CO_KIKAI:ANM021.0.5749461365845326

June 2, zig-zag
.B2_nsm:get:ECL_LUM_MON:lum_acc_20
CG_OPT:CAP:SIGMAY.0.9539216946156772
CG_OPR:SpecificLuminosity.0.9524602477964494
MGHPS:VOFFSET.0.837344982809665
VAHOCG:DO2:H2Z:PRES.0.8023006597214472
VAHTMP:DO2_272:BC1RE:IR.0.7950271476802423
CGHOB:PMO01H1:Y.0.7902590114295769
BY:PID:Y:BI:Photoplate:RATE_curr.0.7828115550149469
BMH:MDL3LE:POS:PYP.0.773851502989451
VAHOCG:DO2:H2Z:PRES.0.7592883757536777
BMH:MDF2E14:POS:PYP.0.749308349812423
BMH:MD01E1:POS:PYP.0.7483174157658071
BMH:MDLY3LE:POS:PYP.0.7476312673899168
BMH:MD03E3:POS:PYP.0.7457808461325243
BMH:MDLA3LE:POS:PYP.0.7419381320409151
BMH:MDFAE5:POS:PYP.0.7411529768294762
BMH:MD05E14:POS:PYP.0.7367528431746776
BMH:MDF2E2:POS:PYP.0.73298963614115777
BMH:MDF2E1:POS:PYP.0.732881128547994
BMH:MD03E4:POS:PYP.0.7297643598709952
BMH:MD03E5:POS:PYP.0.7246581150761181
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BMH:MD05E6:POS:PYP.0.7213829602292965
CGHOPF:IP:SIGMAY.0.7156394309325419
BMHCRM:BEAM:SIGMAYatIP.0.7156394309325419
BMHCRM:BEAM:SIGMAY.0.7156394309322618
BMH:MDT2NEZ:POS:PYP.0.71501914238688437
BNL:MD04P15:POS:PYP.0.7147008146015309
    
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K. Matsuoka

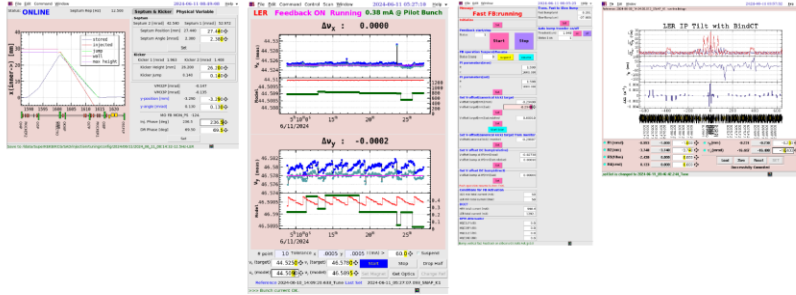
Machine Learning

How many parameters are we handling?

Injection bunch orbit

Betatron tune

Beam orbit and coupling at IP



2-6 parameters

2 parameters

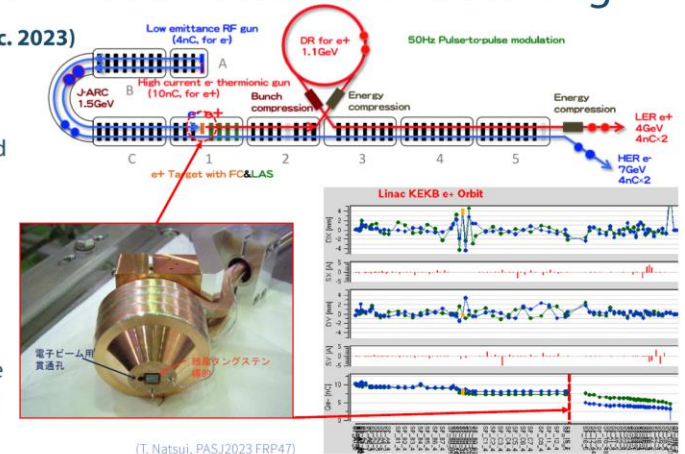
20 parameters

KCG shifters need to "watch" or "optimize" ~20-30 parameters (experts handle more.)

Black-box optimization-assisted Linac tuning

Study items (Nov. 2022 – Dec. 2023)

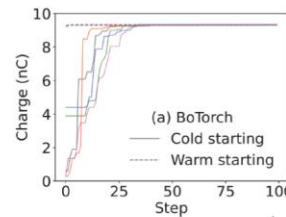
1. Improve the amount of KBP charge just before the e^+ target by changing the applied current of the pulsed steering magnets upstream of J-ARC (equivalent to reducing the beam loss at J-ARC).
2. Improve the e^+ yield by changing the applied current of the pulsed steering magnets just before the e^+ target (equivalent to hitting KBP beam with the e^+ target efficiently).



(T. Natsui, PASJ2023 FRP47)

H. Nakayama

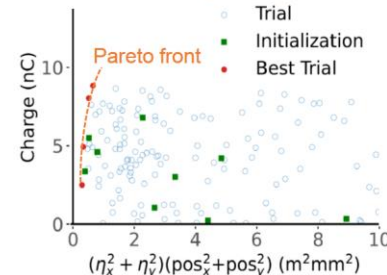
Black-box optimization-assisted Linac tuning



We use the "Optuna" framework for black-box optimization. [<https://optuna.org/>]

Bayesian and evolution-strategy-based optimizations with enqueued initial parameters

Multiobjective optimization



S. Kato (U. Tokyo), in data taking at KEK Linac on Jun. 2023

Many Belle II members (Nakazawa, Uno, et. al.) join beam studies.

PHYSICAL REVIEW ACCELERATORS AND BEAMS 27, 084601 (2024)

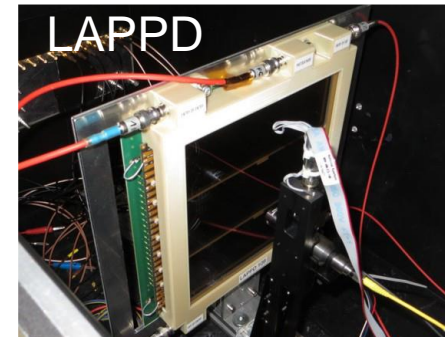
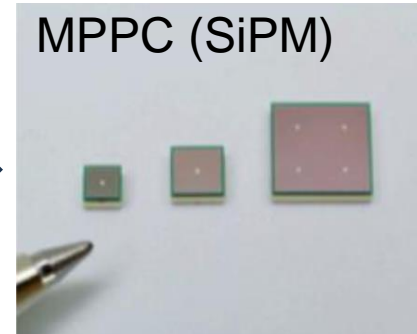
Machine-learning approach for operating electron beam at KEK electron/positron injector linac
Gaku Mizusaka,^{1,2*} Shimonosuke Kawabuchi,¹ Naoko Iida,^{1,2} Takaya Natsui,^{1,2} and Masanori Saitoh^{1,2}
¹KEK, Oho, Tsukuba, Ibaraki 305-0851, Japan
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(Received 28 January 2024; accepted 8 August 2024; published 26 August 2024)
In current accelerators, numerous parameters and monitored values are to be adjusted and evaluated, respectively. In addition, fine adjustments are required to achieve the target performance. Therefore, the conventional accelerator-operation method, in which experts manually adjust the parameters, is reaching its limits. We are currently investigating the use of machine learning for accelerator tuning as an alternative to expert-based tuning. In recent years, machine-learning algorithms have progressed significantly in terms of speed, sensitivity, and application range. In addition, various libraries are available from different vendors and are relatively easy to use. Herein, we report the results of electron-beam tuning experiments using Bayesian optimization, a tree-structured Pareto estimate, and a covariance matrix adaptation evolution strategy. Beam-tuning experiments are performed at the KEK e^+/e^- injector Linac to maximize the electron-beam charge and reduce the energy-dispersion function. In each case, the performance achieved is comparable to that of a skilled expert.

DOI: 10.1103/PhysRevAccelBeams.27.084601

(10.1103/PhysRevAccelBeams.27.084601)

PID (Photo detector)



Replacement of photodetectors are under consideration (long-time project)

For ARICH:

- **HAPDs are discontinued (no more production).**
- MPPC (SiPM) has better performance (PDE) but **has large concern on the dark count and radiation damage** ($>10^{12}$ n / cm² @ 1 MeV equiv. is expected.)
 - ✓ Cooling ($\sim -40^{\circ}\text{C}$?) is necessary.
 - ✓ Readout electronics with fast timing capability (fastIC chip developed for LHCb ARICH is a candidate)
- LAPPD looks a promising option, but it is still at development.

SVD service tasks

- Open tasks in SVD software, from **Luigi's presentation** at the SVD parallel:
 - **BIISVD-449**, Study offline performance of 3-sample acquisition mode
 - **BIISVD-464**, SVD reconstruction improvements towards 3-sample use
 - **issue-874**, Automate the production of SVD performance and validation plots
 - **issue-879**, Automate calibration of SVD Hot Strips
 - **Software coordinators cannot replace supervisors for helping with technical skills, prerequisite test to be passed by newcomers before requesting for a service task!**
- PI supervision and guidance essential to help students ramp up and have positive results
 - Regular attendance to SVD meetings is essential to be aware of what's going on and discuss with all experts possible issues
- New milestones/uncovered issues might require to find new people for service tasks in SVD software
- **Any interest in covering the open tasks?**