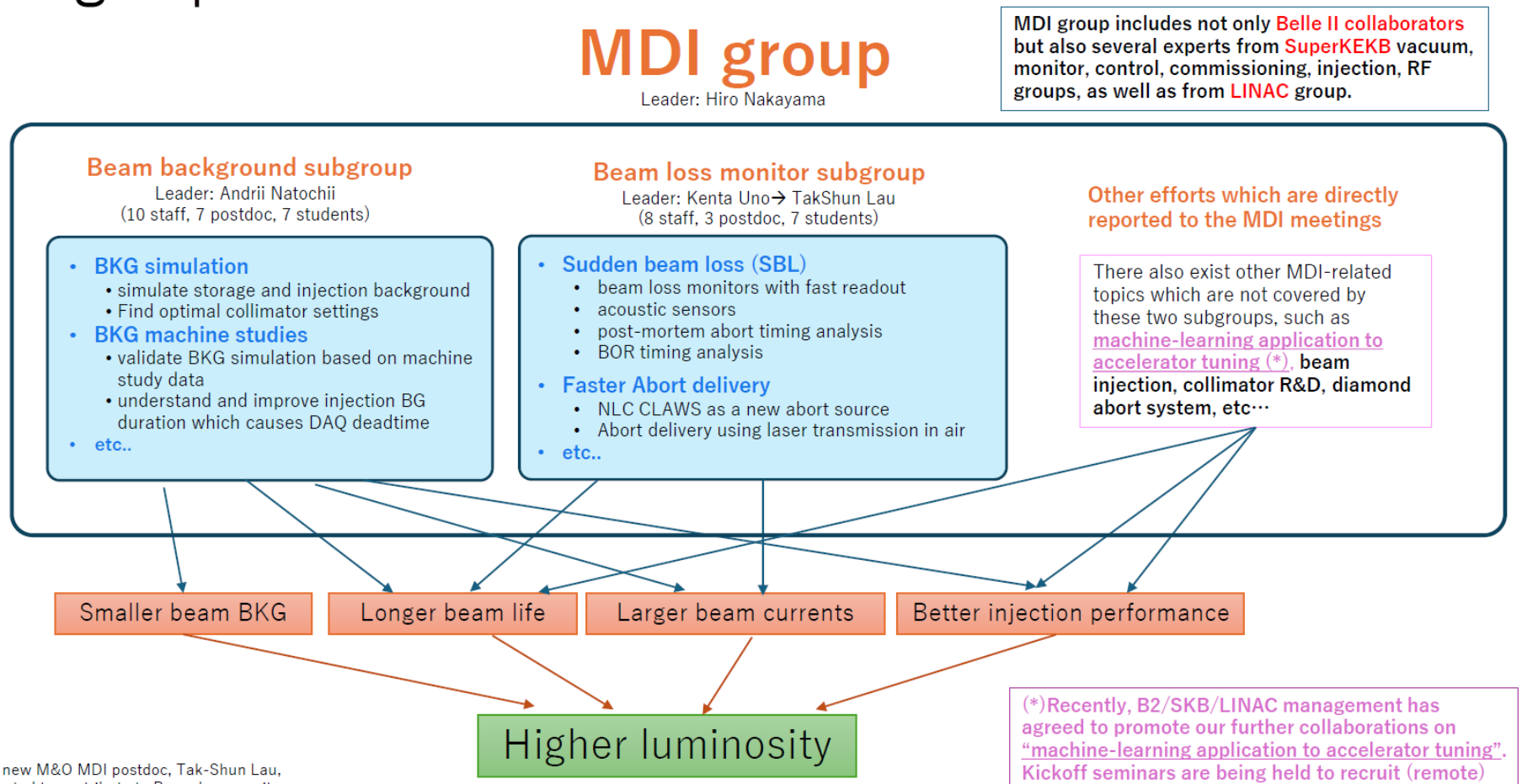
Machine Detector Interface (MDI)

MDI group structure



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

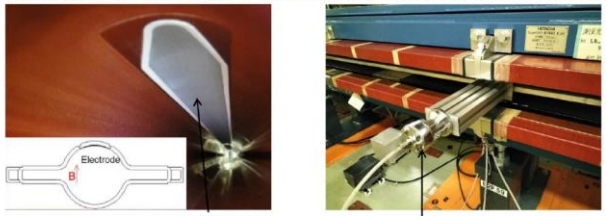
https://indico.belle2.org/event/13003/contributions/80750/attachments/30756/45438/B2GM_Runco_kuno_2024.10.07.pdf

Sudden Beam Loss (SBL)

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

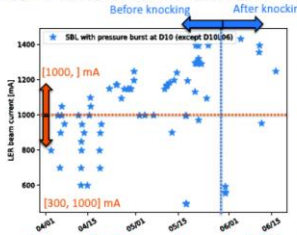
Knocker studies

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



⇒ SBL events can be artificially produced by knocking beam pipes !!

- knocked beam pipes at D10 several times without beams



I_{LER} [mA]		[300, 1000]	[1000,]
Before knocking	#SBL	24	42
	Operation-time [h]	633.77	350.32
	#SBL/time [1/h]	0.038 ± 0.008	0.12 ± 0.02
After knocking	#SBL	4	4
	Operation-time [h]	98.5	162.3
	#SBL/time [1/h]	0.041 ± 0.020	0.025 ± 0.012

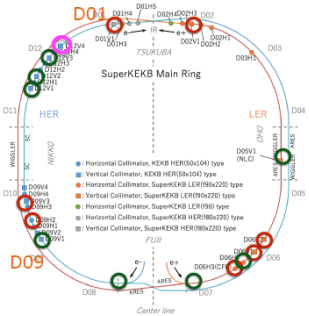
⇒ frequency at $I_{LER} \geq 1$ A is reduced : $0.12 \pm 0.02 \rightarrow 0.025 \pm 0.012$!! (''knocking effect'')

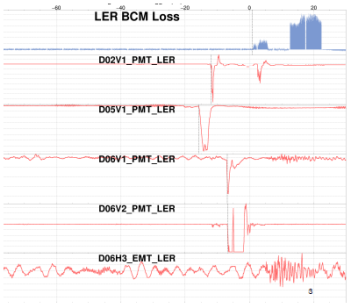
Sudden Beam Loss in 2024c

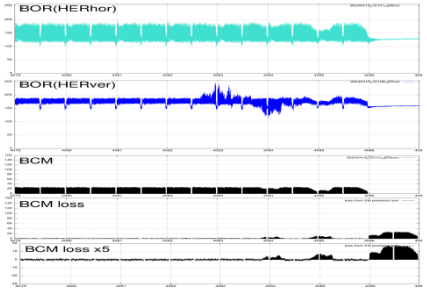
HER SBL: Not understood yet (no clearing electrode in HER)

- 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







Beam Background

Background Simulation Software

Multi-turn particle tracking in the Strategic Accelerator Design (SAD) Software [1]
Beam-gas & Touschek [2]

- realistic collimator description
- particle interaction with collimators
- measured vacuum pressure distribution
- random machine errors

Geant4 [3] **+ Belle II Analysis Software Framework (basf2)** [4]

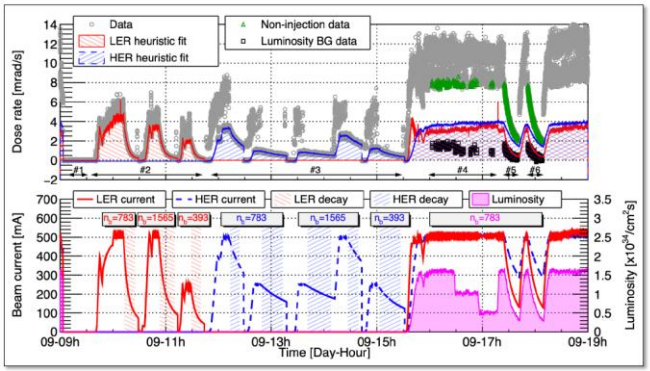
- Single-beam Background
- Lumi Background — Two-photon [5] and Radiative Bhabha [6,7]
- Synchrotron Radiation

- realistic IR modelling (±30m from the IP)
- generating simulated data
- unpacking of real raw data
- track reconstruction
- high-level "analysis" reconstruction

[1] Y. Ohnishi, et al., "Computer program complex sad for accelerator design, simulation and commissioning", Proceedings of the 16th Annual Meeting of Particle Accelerator Society of Japan (PASJ2019), WEOHP04, 2019
[2] Y. Ohnishi, et al., "Accelerator design at SuperKEKB", Progress of Theoretical and Experimental Physics, Volume 2013, 2013, Pages 03A011
[3] Geant4 https://geant4.web.cern.ch
[4] A. Moll, The software framework of the belle II experiment, J. Phys. Conf. Ser., 331 (3):032024, 2011
[5] F.A. Berends, et al., "Complete lowest-order calculations for four-lepton final states in electron-positron collisions", Nuclear Physics B, Volume 253, 1985, Pages 441-463
[6] R. Kleiss, et al., "BBBREM — Monte Carlo simulation of radiative Bhabha scattering in the very forward direction", Computer Physics Communications, Volume 81, Issue 3, 1994, Pages 372-380
[7] S. Jadach, et al., "BHWIDE 1.00: O(α) YFS exponentiated Monte Carlo for Bhabha scattering at wide angles for LEP1/SLC and LEP2", Physics Letters B,Volume 390, Issues 1–4, 1997,Pages 298-308

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.

Beam-gas
Elastic and inelastic particle scattering off of residual gas molecules

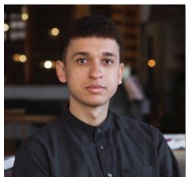
$$\mathcal{O}_{\text{Beam-gas}} = B{\times}IP_{\text{eff}}$$

Touschek
Inelastic scattering of two particles in the same beam bunch

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

Luminosity
Radiative Bhabha and two-photon processes

$$\mathcal{O}_{\text{Lumi}} = L{\times}\mathcal{L}$$



Andrii Natochii, PhD in Physics

E-mail: natochii@bnl.gov

Background Composition

- 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)

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-

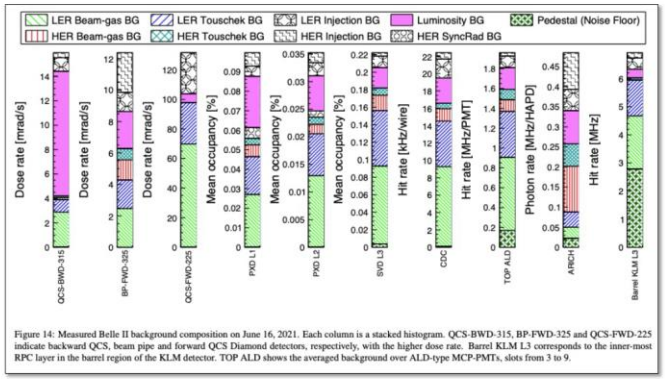


Figure 14: Measured Belle II background composition on June 16, 2021. Each column is a stacked histogram. QCS-BWD-315, BP-FWD-325 and QCS-FWD-225 indicate backward QCS, beam pipe and forward QCS Diamond detectors, respectively, with the higher dose rate. Barrel KLM L3 corresponds to the inner-most RPC 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.

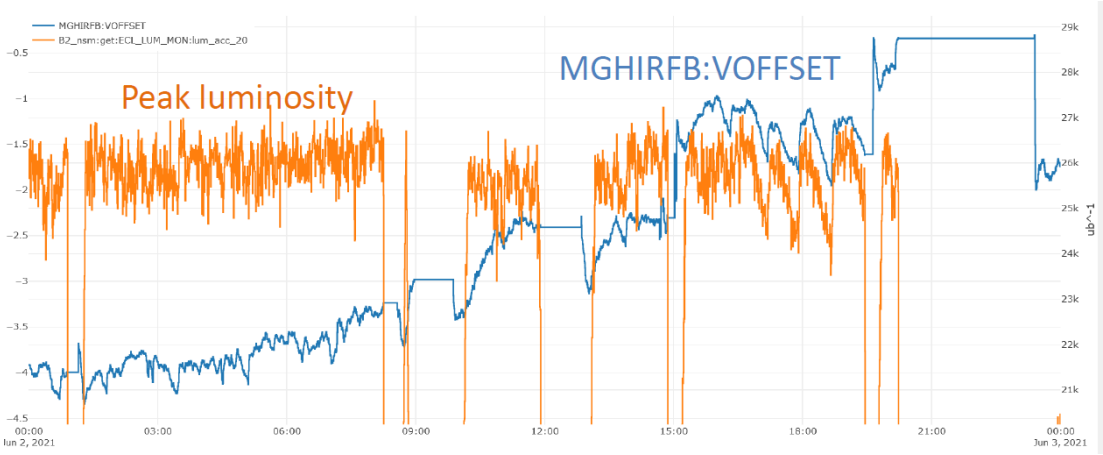
Anomaly Detection, Correlation Studies

- 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.

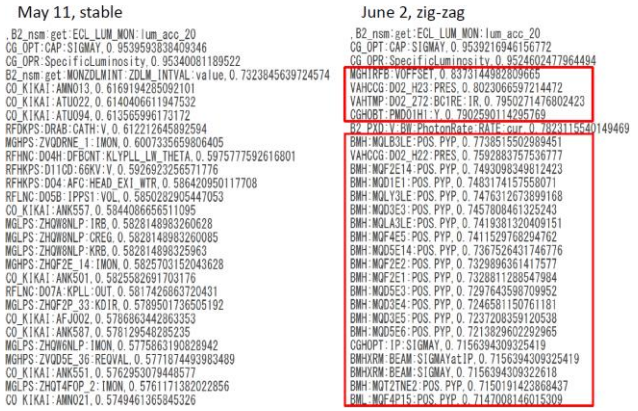
1) Correlation of a PV in question with other PVs.
2) Anomalies in PVs that coincide with an event.

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

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



Correlation with the luminosity

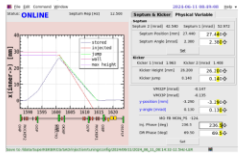


K. Matsuoka

Machine Learning

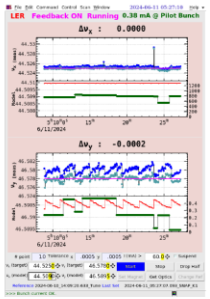
How many parameters are we handling?

Injection bunch orbit



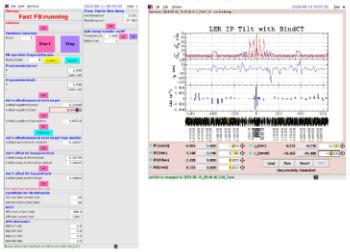
2-6 parameters

Betatron tune



2 parameters

Beam orbit and coupling at IP



20 parameters

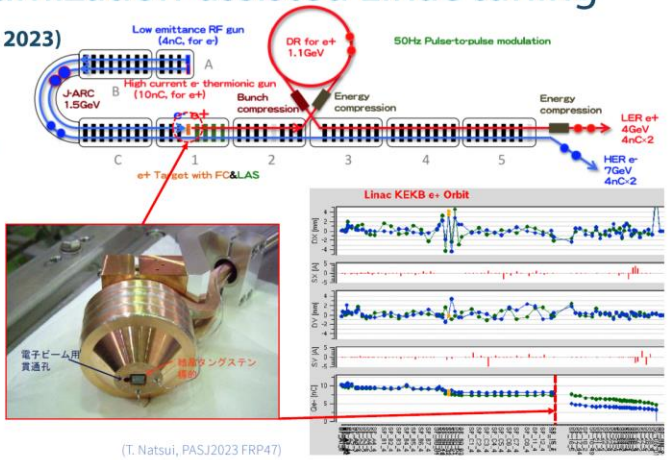
KCG shifters need to "watch" or "optimize" ~20-30 parameters (experts handle more.)

H. Nakayama

Black-box optimization-assisted Linac tuning

Study items (Nov. 2022 – Dec. 2023)

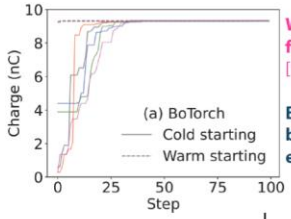
1. Improve the amount of KBP charge just before the e^+ target by changing the applied current of the pulsed steering magnets upstream of J-ARC (equivalent to reducing the beam loss at J-ARC).
2. Improve the e^+ yield by changing the applied current of the pulsed steering magnets just before the e^+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



(T. Natsui, PASJ2023 FRP47)

6

Black-box optimization-assisted Linac tuning



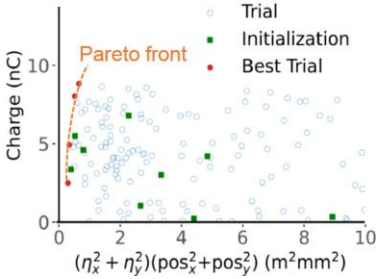
We use the "Optuna" framework for black-box optimization.
[https://optuna.org/]

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

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

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

Multiobjective optimization



PHYSICAL REVIEW ACCELERATORS AND BEAMS 27, 084601 (2024)

Machine-learning approach for operating electron beam at KEK electron/positron injector linac

Gaku Mitsuka,[1,2,*] Shinnosuke Kato,[1] Naoko Iida,[1,2] Takaya Natsui,[1,2] and Masanori Satoh[1,2]

[1]KEK, Oho, Tsukuba, Ibaraki 305-0801, Japan
[2]SOKENDAI, Shonan Village, Hayama, Kanagawa 240-0193, Japan
[3]The University of Tokyo, Bunkyo, Tokyo 113-0033, Japan

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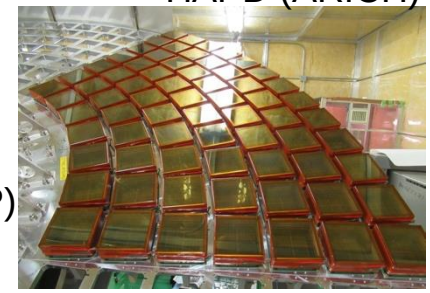
In current accelerators, numerous parameters and monitored values are to be adjusted and evaluated, respectively. In addition, fine adjustments are required to achieve the target performance. Therefore, the conventional accelerator-operation method, in which experts manually adjust the parameters, is 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 Parzen estimator, 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.

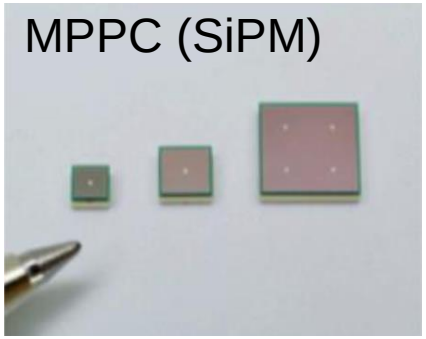
DOI: 10.1103/PhysRevAccelBeams.27.084601

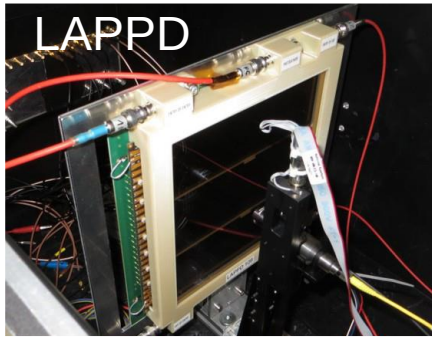
(10.1103/PhysRevAccelBeams.27.084601)

PID (Photo detector)

HAPD (ARICH)







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 / cm^2 @ 1 MeV equiv. is expected.)
  - ✓ Cooling (~ −40°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 performace 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?**