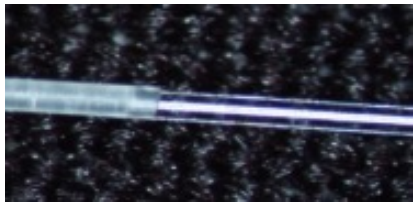
VXD Monitoring and Beam Abort Status

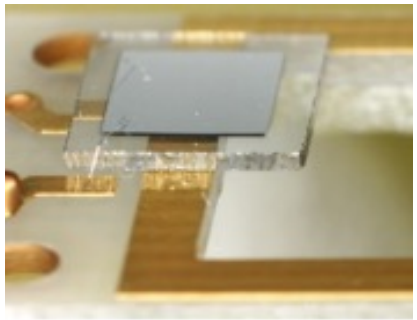
L. Vitale – Univ. & INFN Trieste

Belle2 remote meeting with INFN referees, 2021.09.08

1. Environmental monitors & Interlock status
   a) Temperature NTC & FOS
   b) VXD Interlocks VHLI
   c) Humidity sniffers + upgrade



2. Radiation monitoring and Beam Abort with diamonds
   a) Reminder and running status 2021
   b) Catastrophic beam loss events
   c) Short/medium term hardware work
   d) Plans for future upgrade



UNIVERSITÀ DEGLI STUDI DI TRIESTE
Dipartimento di Fisica
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Istituto Nazionale di Fisica Nucleare
SEZIONE DI TRIESTE

ENVIRONMENTAL MONITORS AND INTERLOCK IN BELLE2 VXD

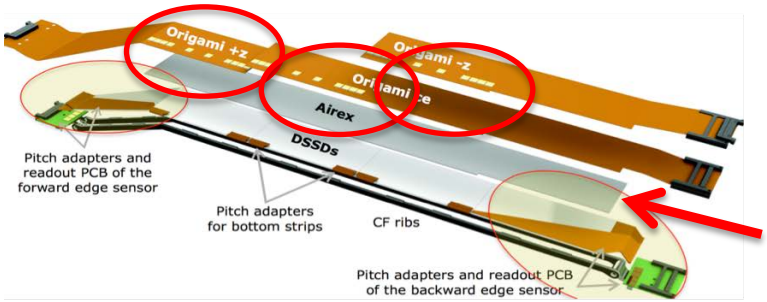
Status of VXD Temperature

Resp. Trieste

- NTC Temperature Monitor & Interlock

  64 NTC sensors mainly along the CO_2 cooling pipes and support rings @– 20°C

  Readout & interlocks: smooth operation, no problems



- FOS Temperature Monitor

  In total 260 FOS sensors on 44 fibers. FOS sensors along the L4-5-6 SVD ladders, close to SVD FE readout chips (origami), at the VXD outer cover and reading 4 PXD fibers.

  Smooth operation, no problems

Status of VXD Interlocks & Humidity

Resp. Trieste

- VXD Local Hardwired Interlock

  Smooth operation, no problems

  A back-up system completed in 2019,
  used in Trieste as Test Stand with small
  modifications to include the Humidity “box 2”

- Humidity Monitor & Interlock

  Smooth operation, no problems

  New Dew/Frost Point sensors with wider measurement
  range (down to -100°C) installed for Phase 3 in “box 1”
  at the end of 2018.
  Dew/frost points in VXD volumes
  around – 85°C

New Humidity System “box 2”

Resp. Trieste

- New Humidity Monitor & Interlock

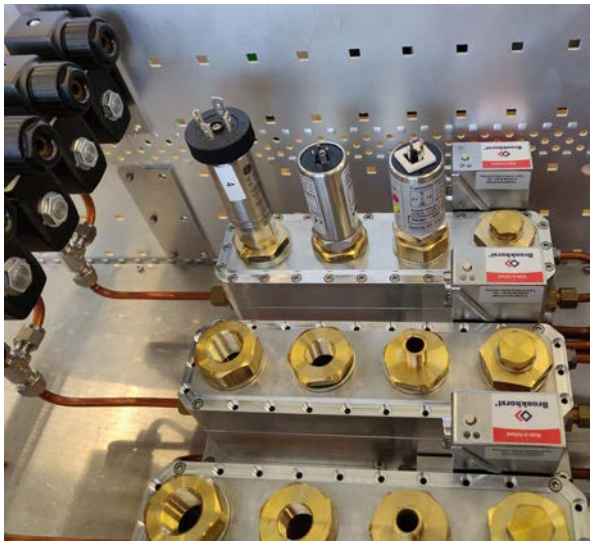
  Assembly of the upgraded “box 2”: completed and tested end of 2019

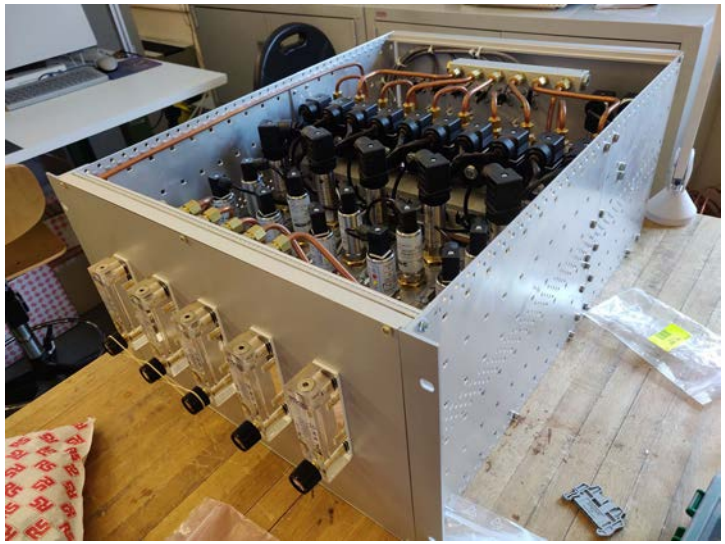
  Several redundancies and more robust readout (HW and SW)

  5 lines (for 4 sniffers) each with duplicated sensors

  It can/will be operated simultaneously with box 1

  Its shipping to KEK delayed; sensors need to be fluxed with N2 or dry air ~continuously (at least often) before installation; re-calibration ongoing now

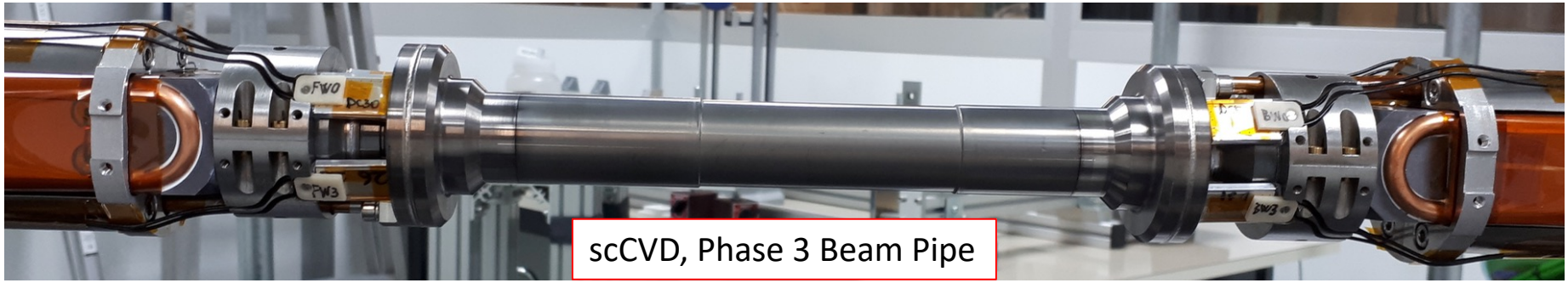




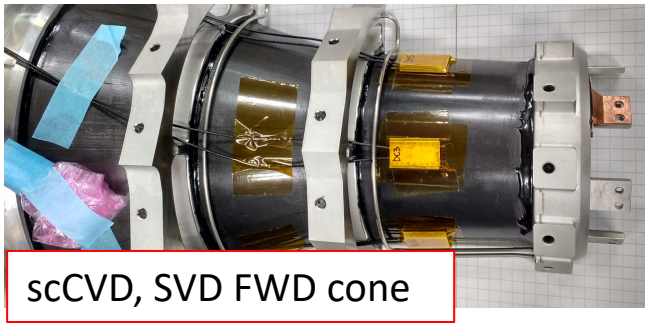
VXD RADIATION MONITORING AND BEAM ABORT

28 scCVD diamond detectors

Resp. Trieste

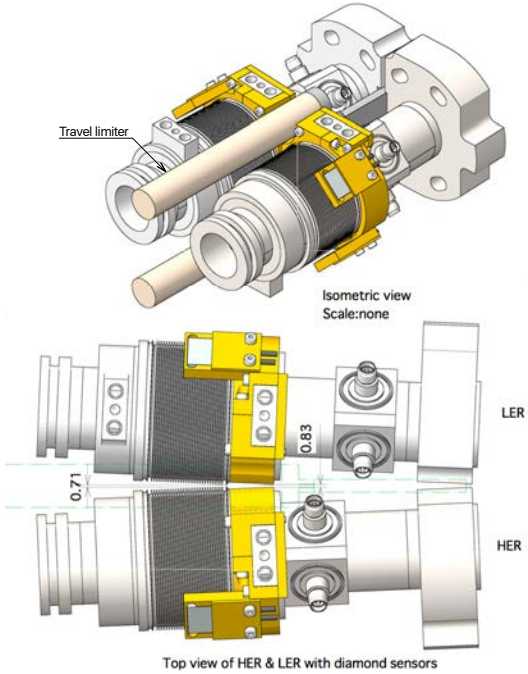


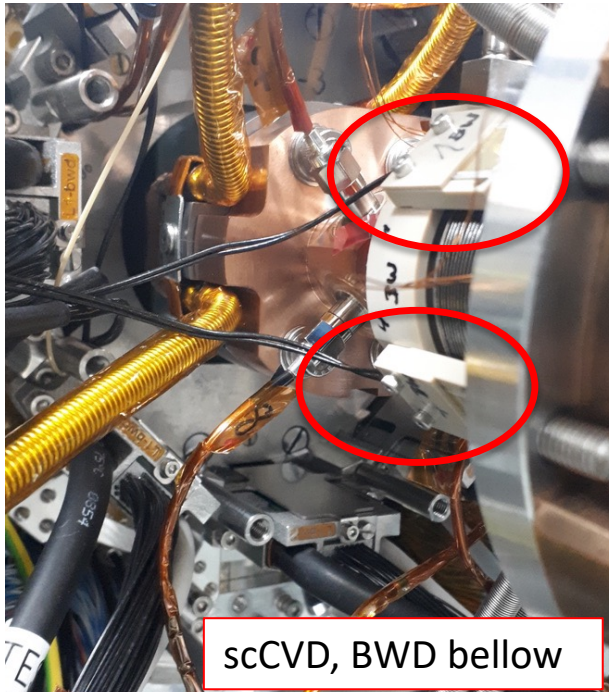
scCVD, Phase 3 Beam Pipe



scCVD, SVD FWD cone

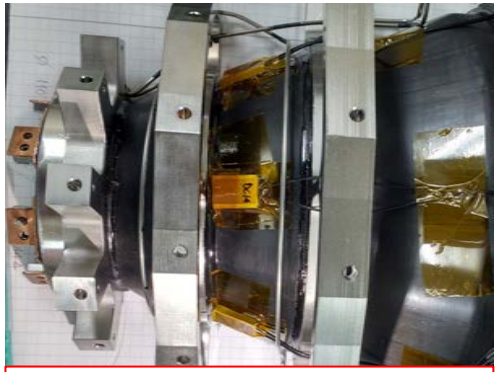
Moreover 8 (originally not foreseen) at z=±536 mm QCS Bellows





scCVD, BWD bellow

12 SVD
4 horiz
plane

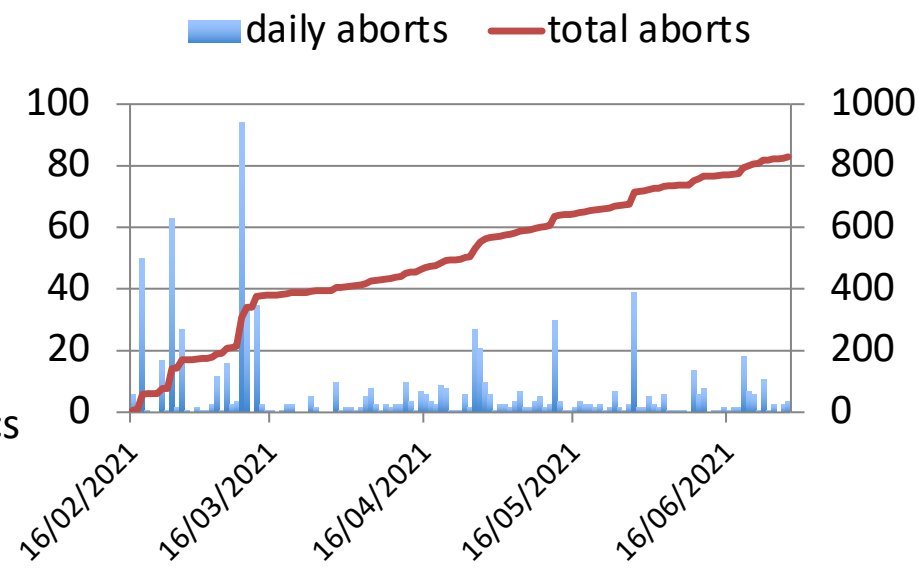


scCVD, SVD BWD cone

Monitor & beam abort in 2021ab

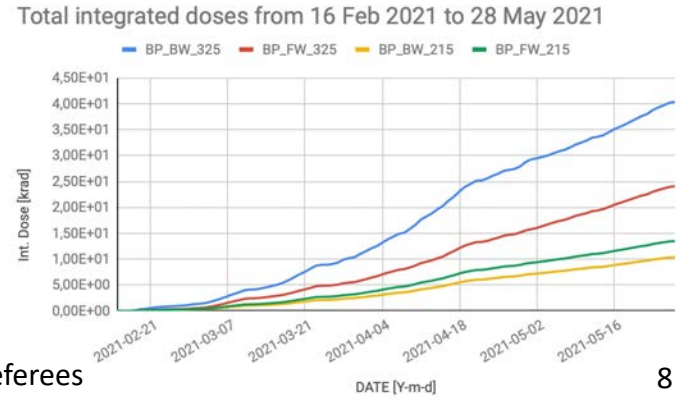
Overall operations: smooth!

- Beam abort
  - Since 2020 2.5 μs abort cycle (it was 10)
  - Same strict threshold as in 2020
  - In total ~800 aborts: ~10/hour during machine tuning, but only 1-2/day in physics
  - Increase of aborts large/huge beam losses
- One radiation accident on May 10
  - One analog channels damaged in DCU5
  - DCU immediately replaced with spare DCU
  - Damaged DCUs repaired by KEK colleagues
- Software and automatic procedures
  - Several improvements on the Python software by Yifan and Hao, (inhibit flag script, elastalert, etc)



Monitoring diamonds

- OK, except saturation on injection BG spikes
- Integrated dose available: daily online YJ, total offline CLL, new effort starting in IPMU TS



Possible improvements of present diamond system

Is there still some room for improvements in the present system?

1. Thresholds
   - Present values are “heuristic”
   - Beam conditions are evolving
   - Some ideas are under study
2. Usage of QCS bellows diamonds for abort
   - Requires long studies at range 2 (and 1) in order to accumulate patterns during QCS quenches and large losses
   - Cons: removing 4 monitoring sensors
3. ***Range 0 optimization
   - Mitigation of saturation effects during injection
   - Requires changing the resistors in the amplifier feedback loop
4. ***Common mode noise spikes
   - Ferrite clamps on the signal cables mitigate this noise

*** it requires onsite hardware work and several careful tests

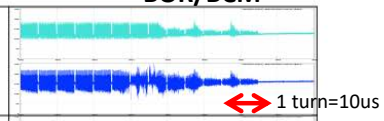
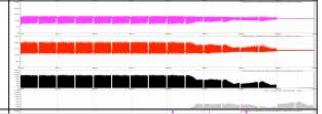
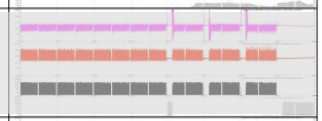
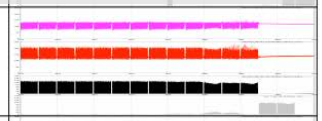
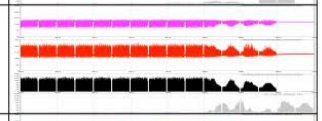
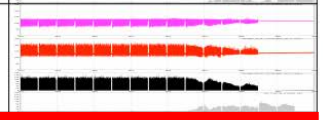
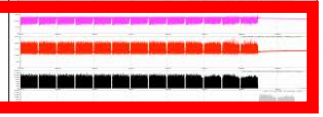
4 slides from H. Nakayama Sept. 1-2, 2021

The 25th KEKB Accelerator Review Committee

CATASTROPHIC BEAM LOSS ABORT EVENTS IN 2021

Catastrophic beam loss abort events in 2021b

(which caused QCS quenches)

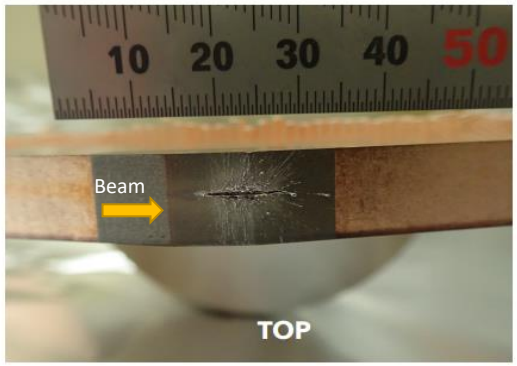
				BOR/BCM
4/19 (MO) Owl	1:07	QCS quench QC1LE	HER 820 mA	
5/10 (MO) Day	14:26	QCS quench QC1LP, QC1RP	LER 910 mA	
5/14 (FR) Owl	0:35	QCS quench QC1RP	LER 840 mA LER kicker trouble	
5/23 (SU) Owl	8:24	QCS quench QC1LP, QC1RP	LER 840 mA	
5/28 (FR) Owl	3:21	QCS quench QC1RP	LER 840 mA	
6/2 (WE) Swing	20:13	QCS quench QC1LP, QC1RP	LER 840 mA	
6/6 (SU) Day	16:06	QCS quench QC1LP, QC1RP	LER 840 mA	

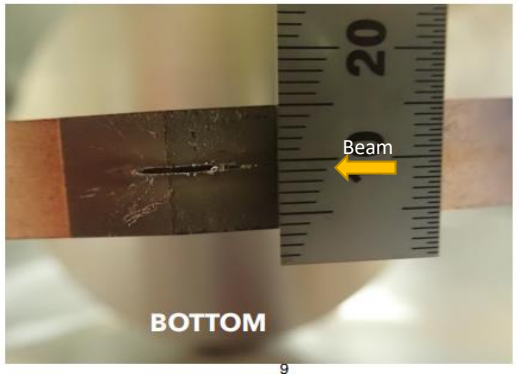
Most of them are caused by huge beam loss in LER, several turns before the abort.

Dangerous for Belle II inner sensors. In some cases, diamonds on IP beam pipes saw >1500mrad (saturated) and PXD was damaged

This event caused a severe damage on LER D2V1 collimator [19]

Severe damage on LER D02V1 collimator after the huge beam loss on June 6th





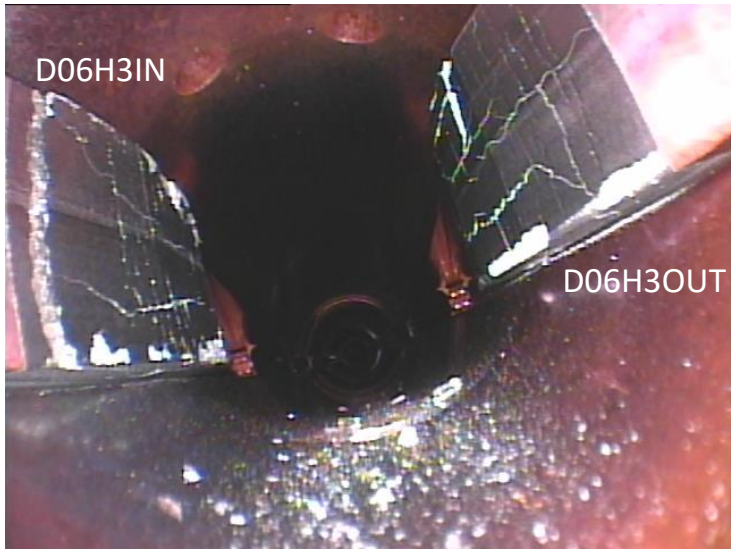
9

- After the huge beam loss event on June 6th, LER BG increased significantly
- D02V1 collimator jaws were severely damaged (deep scar on the bottom jaw)
- We lost 3~4 days for the collimator replacement work and the baking runs

Understanding the cause of huge beam loss events is essential for the stable operation at high beam currents. Where in the ring the beam abnormality initially occurs? Adding more sensors to the key collimators will help to understand the initial beam loss position.

20

Severe damage on D6H3 collimator, probably due to kicker misfire event on May 14th



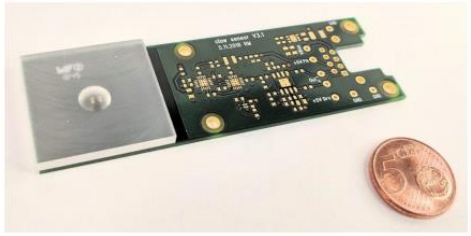
Terui-san's report on July 15th

- Kicker misfire happened on May 14th
- QCS quench occured
- Pressure burst at D6H3 was also observed
- However, we realized the severe damage only after the run end (in July), not just after the incident
  - Loss monitor PINs got easy saturated and can't tell if the beam loss is huge or moderate
- Dust particles falling off from D6H3 could be a cause of catastrophic events in LER?
  - Ikeda-san's post-mortem abort analysis using loss monitor data is ongoing
  - *If yes, why huge loss disappeared after D2V1 replacement?*

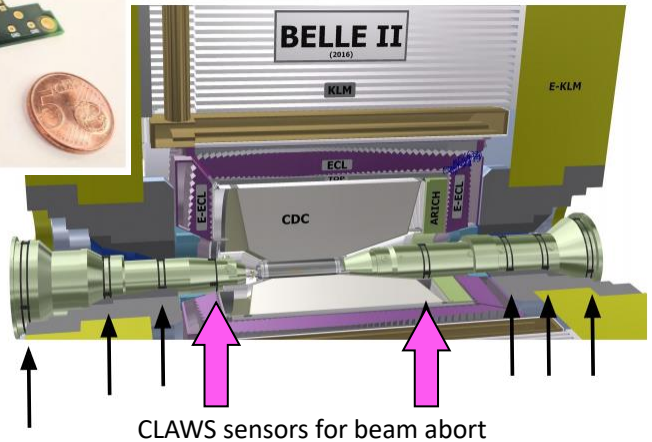
21

Even faster beam abort: CLAWS

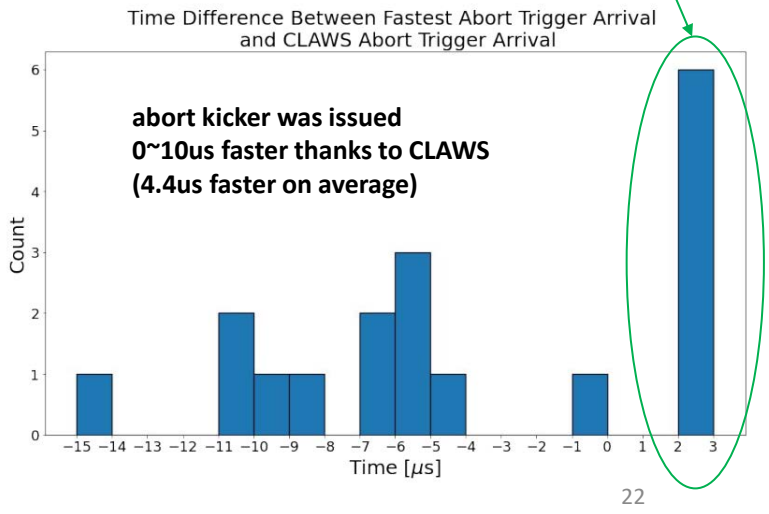
- 4+4 CLAWS sensors (on QCSL and QCSR) are used to issue beam aborts (since May 26th, 2021)
- **Thanks to CLAWS, abort kicker can be fired faster by ~4.4us on average**
  - For some LER aborts, CLAWS are outperformed by LER RF D5-F, which is located at better ring position
  - Adding new beam loss sensors (upstream of IP and downstream of initial beam loss) might be able to make abort even faster



3x3 cm^2 plastic scintillator
+ Hamamatsu SiPM



CLAWS sensors for beam abort



22

HARDWARE WORK
- RECENT OR PRESENT

2020: new diamond characterization, re-calibration and its impact

- During 2020 a remarkable effort was put to characterize the few remaining diamonds with α, β, x radioactive sources, comparing with a reference Si diode, and improving the Fluka simulation

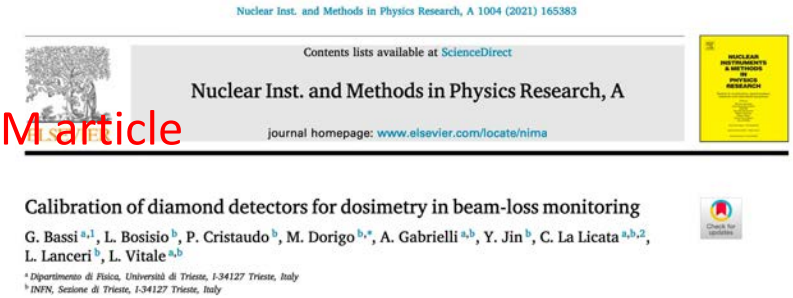
  Master thesis work by Alice Gabrielli with M. Dorigo, L. Vitale, L. Bosisio, L. Lanceri

  BELLE2-MTHESIS-2020-008 https://docs.belle2.org/record/2151 Alice Gabrielli

- Outcome (Alice PhD in Trieste since Nov 2020): for the calibration of new diamond detectors we can use a procedure that relies significantly less on the source activity and simulation, allowing to achieve 8% systematics for the calibration coefficients

- Using this procedure, we re-analyzed the old calibration data for the 28 installed diamonds; the current to dose-rate coefficients

- This work is now described and published in a NIM article https://doi.org/10.1016/j.nima.2021.165383


Nuclear Inst. and Methods in Physics Research, A 1004 (2021) 165383

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

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

Calibration of diamond detectors for dosimetry in beam-loss monitoring

G. Bassi [a,1], L. Bosisio [b], P. Cristaudo [b], M. Dorigo [b,*], A. Gabrielli [a,b], Y. Jin [b], C. La Licata [a,b,2], L. Lanceri [b], L. Vitale [a,b]

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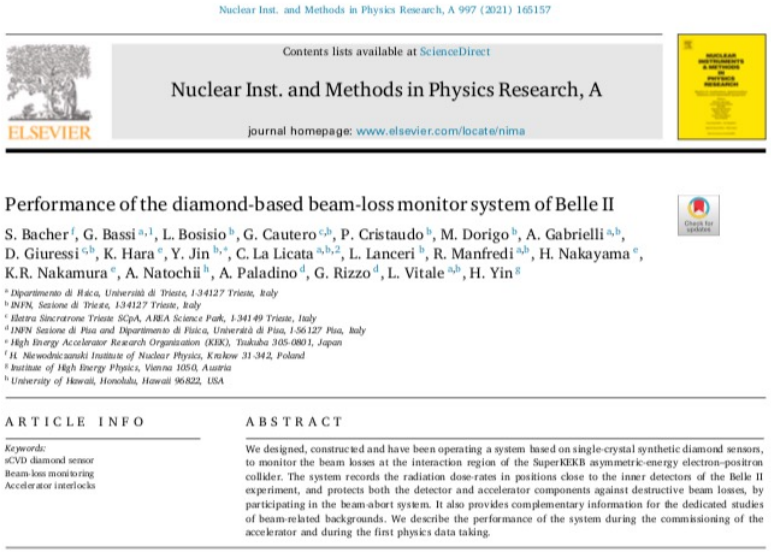
- New calibration factors can be applied off-line without changing the on-line part for the time being, at least for the 2021 runs.

Diamond papers

- Besides the calibration published paper
- We have recently published (Feb. 2021) a specific paper about diamond system performance in Phase2 and early Phase3



Nuclear Inst. and Methods in Physics Research, A 997 (2021) 165157

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

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

Performance of the diamond-based beam-loss monitor system of Belle II

S. Bacher [f], G. Bassi [a,1], L. Bosisio [b], G. Cautero [c,b], P. Cristaudo [b], M. Dorigo [b], A. Gabrielli [a,b], D. Giuressi [c,b], K. Hara [e], Y. Jin [b,*], C. La Licata [a,b,2], L. Lanceri [b], R. Manfredi [a,b], H. Nakayama [e], K.R. Nakamura [e], A. Natochii [h], A. Paladino [d], G. Rizzo [d], L. Vitale [a,b], H. Yin [g]

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ARTICLE INFO

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ABSTRACT

We designed, constructed and have been operating a system based on single-crystal synthetic diamond sensors, to monitor the beam losses at the interaction region of the SuperKEKB asymmetric-energy electron–positron collider. The system records the radiation dose-rates in positions close to the inner detectors of the Belle II experiment, and protects both the detector and accelerator components against destructive beam losses, by participating in the beam-abort system. It also provides complementary information for the dedicated studies of beam-related backgrounds. We describe the performance of the system during the commissioning of the accelerator and during the first physics data taking.

- Moreover there are devoted sections about environmental and radiation monitoring in two other papers in preparation SVD and Phase2

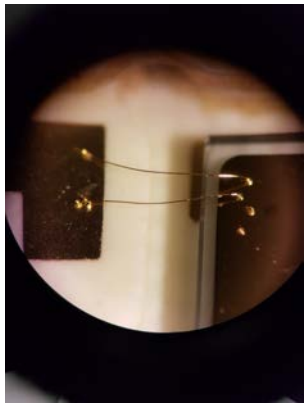
Hardware: work in winter/spring 2021

- Preparations for 2022 shutdown: construction and tests for 10 new diamond detectors (AG, LV, LB, MD, LL)
  - Directly mount these on new Beam Pipe to speed up the schedule 2-3 months without waiting the dismount of old ones
  - Work already started in Oct 2020 - with Covid difficulties

    Diamonds ordered at the end of 2020 (CSN1 budget advance)

    Feb-Apr 2021: all 10 diamonds glued & bonded on their PCBs with cable
  - As June 2021: first round of testing, characterization, stability, calibration - Alice Gabrielli (PhD) working full time on this task
  - July/September 2021: x-ray tests
  - Next: final assembly, retest
- Beam Test with 1 GeV electrons at Fermi TS

  High doses and transients response 1pC 1ps



WORK FOR ELECTRONIC UPGRADE

Electronic upgrade 1: RMBA work & EOI

- Electronic upgrade: RMBA Working Group, EOI, UWG recommendations

  End 2019: RMBA Working Group formed (chaired by L. Vitale)

  2020: Preliminary work with several remote meetings

  Jan-Mar 2021: EoI prepared with revisited requirements and specifications (summary in the next slides)*

  https://confluence.desy.de/display/BI/Upgrade+EOI+Submission

  Mar 2021: EOI discussed within the Belle II Upgrade WG

  April 2021: UAC recommendations received*

  https://confluence.desy.de/display/BI/Comments+to+EoIs%2C+questions+from+the+UAC

  *Both uploaded in the agenda of this meeting

Electronic upgrade 2: DCU limitations

Present electronics limitations

- Dynamic range

  → overall ok, with good resolution, but split in 3 ranges
- Common mode noisy spikes
- Memory read
- Synchronization with SKB

  → at present only SKB abort timing confirmation signal
- Injection-related dose rates
- HV control
- External Logics

Electronic upgrade 3: specifications

Future DCU upgrade:

- Starting point: keep same functions – same reliability

  Individual HV control, 2.5 µs cycle (400 kHz), programmable moving sums, logical combinations of abort signals and masks, read-out of read buffer memories, computation of 10 Hz monitoring data, initialization of abort thresholds, etc

Requirements to overcome previous limitations:

- Dynamic range

  → at least 180 dB, 9 orders of magnitude from 3 pA to 5 mA - conversion 35 (mrad/s)/nA
- Bandwidth and noise rejection

  → 1 MHz, optimization of grounding scheme, common mode
- Memory read

  → internal ring buffer can be shorter, but must be duplicated
- Synchronization

  → at least another, SKB injection timing
- Injection-related dose rates

  → dose in the injection veto time intervals

Electronic upgrade 4: technical solutions

Technical solutions

Keep same building blocks, modularity and form factors of the existing DCUs

External cabling is minimized

Major challenge: re-design of the analog front-end

Installation issues: Limited!

The DCUs of the present system are in E-hut, always accessible

Also arranging tests of prototypes is feasible.

Electronic upgrade 5: design

State of the art

survey of existing electronics for beam-loss monitoring and beam abort done in 2020 in RMBA meetings, see backup slides (summary table and meetings)

large dynamic range: CTF (current to frequency converters) + fast switch + FPGA controlling digitization

R&D steps

R&D required to investigate a viable solution for dynamic range of the analog front-end

Continuation of collaboration with Elettra (ongoing), they are interested

Plans for prototypes and tests

1-2 years from initial design to build and test prototypes

~1 year final production

Electronic upgrade 6: human resources

- Manpower issues:

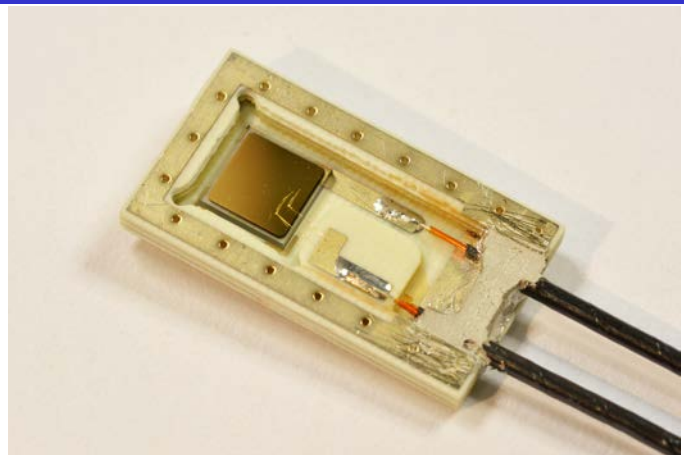
  As seen before we have been very busy with new diamond production and related items in 2020-2021

  Moreover Trieste group reduced (two senior retired),

  I'm looking for new manpower in Trieste (at least full time senior engineer) and/or possible participation from other Belle II groups

- Meanwhile: ongoing contacts with Elettra (and others) to develop key features. Very fast auto-range to increase dynamical range, dual port fast memory, etc

Summary



- VXD monitoring running smoothly in 2021
- Several HW activities ongoing

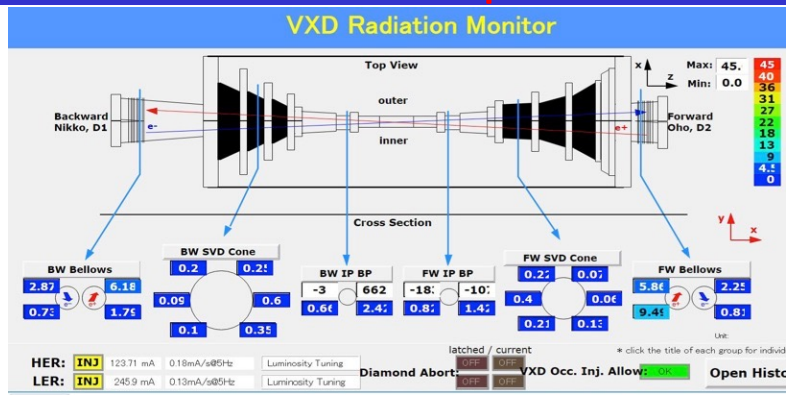
  Construction, tests and calibrations for 10 new diamond detectors

  2022 long shutdown (not only rad-mon)
- Path for the electronic upgrade

BACKUP

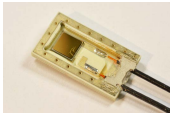
Diamonds and Beam Abort

Resp. Trieste



Improvements for 2020 run

- Faster beam abort
  - Old DCU firmware: 100 kHz abort cycle (10 µs)
  - New DCU firmware: 400 kHz abort cycle (2.5 µs)
- Software, automatic procedures and documentation
  - Pedestals, on-line integrated doses, post-abort files: all improved
- New optimized dose-monitor measurement range
  - Aim: reduce saturation on injection BG spikes
  - On hold: ongoing investigation to mitigate common-mode noise in 10 Hz data (new range, some channels)



28 diamonds installed

- 8: beam pipe (BP)
- 12: SVD cones (SVD)
- 8: QCS bellows (QCS)

read-out by 7 DCUs (Diamond Control Units)

- 4: VXD beam abort
- 24: dose rates monitors averaged 10 Hz

Present monitoring system: budget

INFN Trieste: Rad. Mon. system budget (up to now, approximate)

Initial R&D	25 k€	few sensors, broadband amplifiers for TCT, etc
Diamond sensors	100 k€	30 sensors + contacts with pre-test
Electronics	50 k€	7+2 RO modules - reduced by collaboration
Consumables	20 k€	rad-hard PCB + cables + connectors
	40 k€	extra specific tools for testing
Computers	8 k€	2 servers + console

(+ Travel money, shipping, irradiations, as needed)

INFN Trieste budget for the electronics upgrade:

10 k€ (s.j.) in 2020 for initial design/prototyping

INFN referees, about future budget requests:

positive attitude for the upgrade

expecting a detailed project in 2020 to discuss further funding

suggest to enlarge the collaboration

Present system: human resources

Human resources during 2015-2019: about 5 FTE/year

INFN and Univ.Trieste

Permanent staff/faculty: Luciano Bosisio, Livio Lanceri, Lorenzo Vitale, Benigno Gobbo

Post-docs (2 or 3 year contracts): Chiara La Licata, Yifan Jin

Undergrad students: Giovanni Bassi, Riccardo Manfredi

Technicians: Pietro Cristaudo, Giorgio Venier, mechanical workshop

Elettra (electronics)

Giovanni Cautero, Dario Giuressi + technicians

Kracow/Poland (online EPICS software)

Szymon Bacher

SVD group (discussions, reviews, other contributions)

Giuliana Rizzo, Hao Yin, Christian Irmler, …

Persone e responsabilità

L. Vitale (PI)	Staff UNITS	100%	Convener Radiation Monitor Beam Abort upgrade, Responsabile dei monitor ambientali e di radiazione VXD
M. Dorigo	Staff INFN	100% (da 90%)	Convener del B to charmless physics group
D. Tonelli	Staff INFN	90%	Physics coordinator da settembre 2021 per due anni Chair del comitato di statistica
B. Gobbo	Staff INFN	70%	
Y. Jin	PD	100%	Responsabile operazioni Radiation Monitor & Beam Abort
R. Manfredi	PhD	100%	
E. Ganiev	PhD	100%	Responsabile dei VLHI interlocks
S. Raiz	PhD	100% (new entry)	
A. Gabrielli	PhD	100% (new entry)	
L. Lanceri	ret	0% (da 100%)	
L. Bosisio	ret	0%	Responsabile sensori e microchip SVD
G. Cautero	Staff Elettra	10%	
D. Giuressi	Tec. Elettra	10%	

Totale 8.8 FTE (come lo scorso anno)

6

Belle II - Trieste

Preventivi 2021 per 2022

Missioni	163 k€ comprende responsabilità e long shutdown
Consumi	13 k€
Apparati	32 k€
Manutenzione	2 k€
Trasporti	2 k€

Richieste ai servizi

Elettronica:	9 m.u.
Meccanica:	2 m.u.

Full list of requests for SVD

	Sede	Capitolo	Categoria	Descrizione	Richiesta	Richiesta SJ	Anticipabile 2021?	Commenti	Proposta referee
SVD	TS	missioni	C	Installazione 8 diamanti sulla nuova Beam Pipe pre-shutdown	7			1 m.u. assumendo 2 persone per 2-3 settimane	
SVD	TS	missioni	C	Smontaggio/test/Rimontaggio monitoring SVD e sostituzione connettori diamanti durante shutdown 2022	48			8 m.u. (1 fisico + 1 tecnico) scablatura completa rimozione degli endcap, test monitoring, ricablatura monitoring	
SVD	TS	missioni	C	Turni di sotto-rivelatore (SVD)	3.5			SVD 1 local shifter (5 mesi: 4.5 running + 0.5 before start/ after stop) * frazione Trieste/All-SVD (~8%) = 0.4 m.u.	
SVD	TS	manutenzi	D	Contratto annuale di mantutenzione del sistema attuale di beam abort	2		no	Per modifiche HW e riparazioni delle 7 DCU (6% del valore complessivo)	
SVD	TS	apparati	A	Necessità immediata di ulteriore modulo DCU spare	7		sì	Causa nuovo incidente in maggio 2021 con sostituzione di una DCU con un canale danneggiato da eccessiva radiazione, è necessario avere un altra DCU spare	
SVD	TS	apparati	A	Studio su un prototipo per upgrade readout diamanti	10		no	Procurement di un prototipo in collaborazione con Elettra e studi delle prestazioni su specifiche e punti critici elencati nell'EOI	
SVD	TS	apparati	A	Four-Fold Programmable Logic Unit with remote control	15		sì	Due moduli logici NIM N1081B (uno più uno spare) con accesso e controllo remoto per sostituire vecchi moduli di concidenze, ritardi, contatori per i segnali di abort	
SVD	TS	missioni	C	Installazione e messa a punto del nuovo prototipo di Beam Abort	6			1 m.u. per installazione e test del nuovo prototipo	
SVD	TS	missioni	A	Irraggiamenti diamanti	2				
SVD	TS	trasporti	A	Spedizioni Elettronica radiation monitor e beam abort	2				

Replace several modules in a NIM crate with a remote programmable module CAEN N1081B

A pocketknife tool in your laboratory!