Controls & Beam studies for protection
Highlights 2021

Daniel Wollmann

# New Post Mortem system for run 3
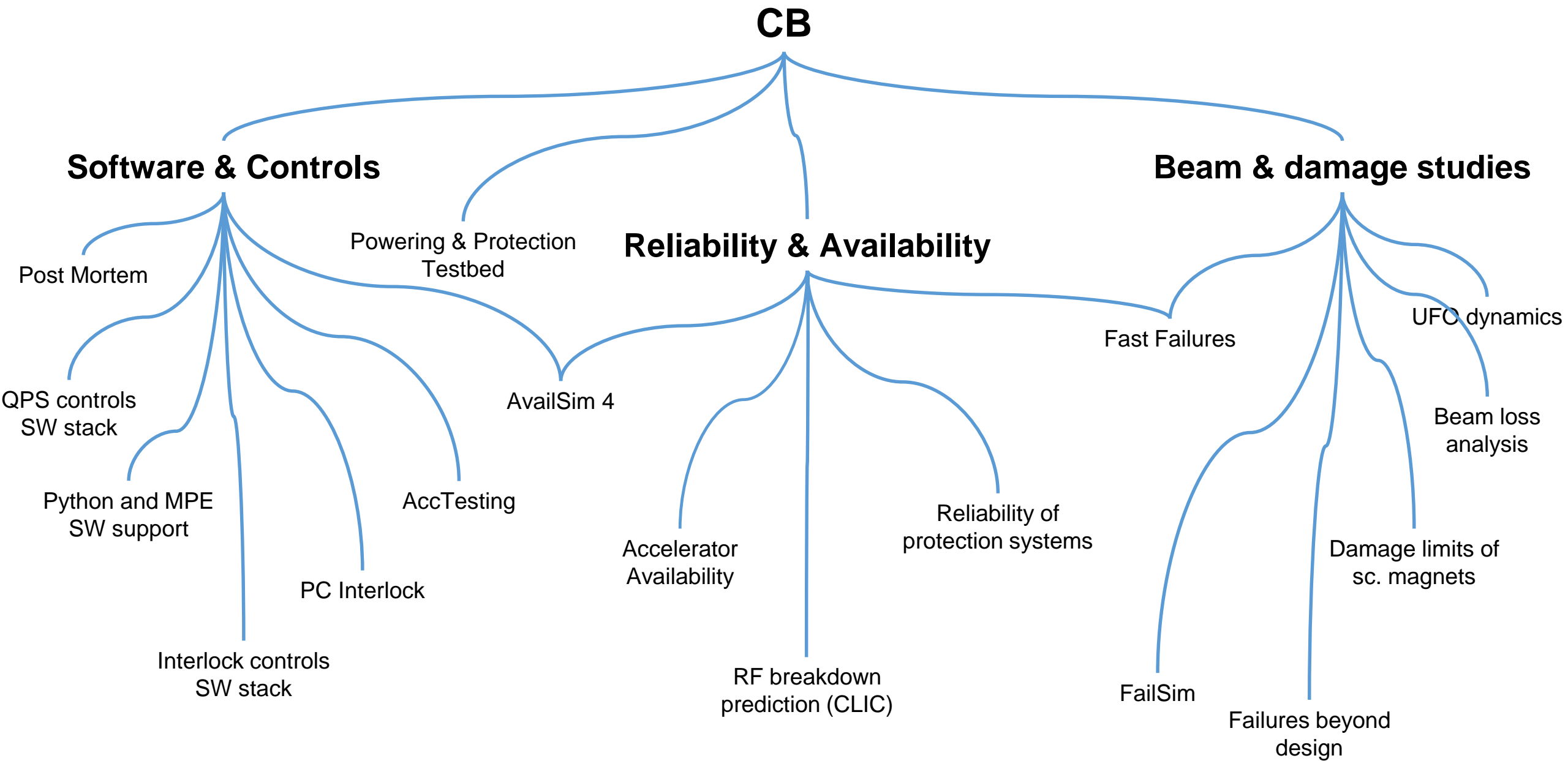
- Improved **scalability of data collection**
- New underlying **storage** (Oracle DB)
- Same API, same process, **minimum impact on users**
- Two instances:
  - **Post Mortem (LHC)**
    - Adaptation of 22 **PM analysis modules** to new Controls stack, development of 2 new ones
    - **Data migration** from pre-LS2
    - **Successful run** for the powering tests and the beam commissioning
  - **SPS Quality Check (SPSQC)**
    - Large amount of data to be processed cycle by cycle
    - Automatic **data cleaning**
    - Improvement and **scalability** of API
    - Improvements of **load balancing**
- The new PM system has **successfully** passed its first full reality check during operation in 2022
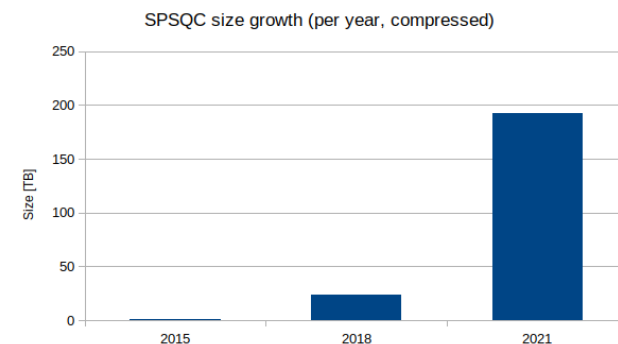
AccTesting and Powering Tests

- **Longest consecutive use** of AccTesting, with **two testing campaigns**, also exposing the limitations of the current AccTesting

- Valuable early validation in the Powering and Protection Testbed
  - Allowed for harmonisation of controls communication ahead of the powering tests

- Minimal maintenance, adapting of AccTesting to the new LS2 baseline controls software library
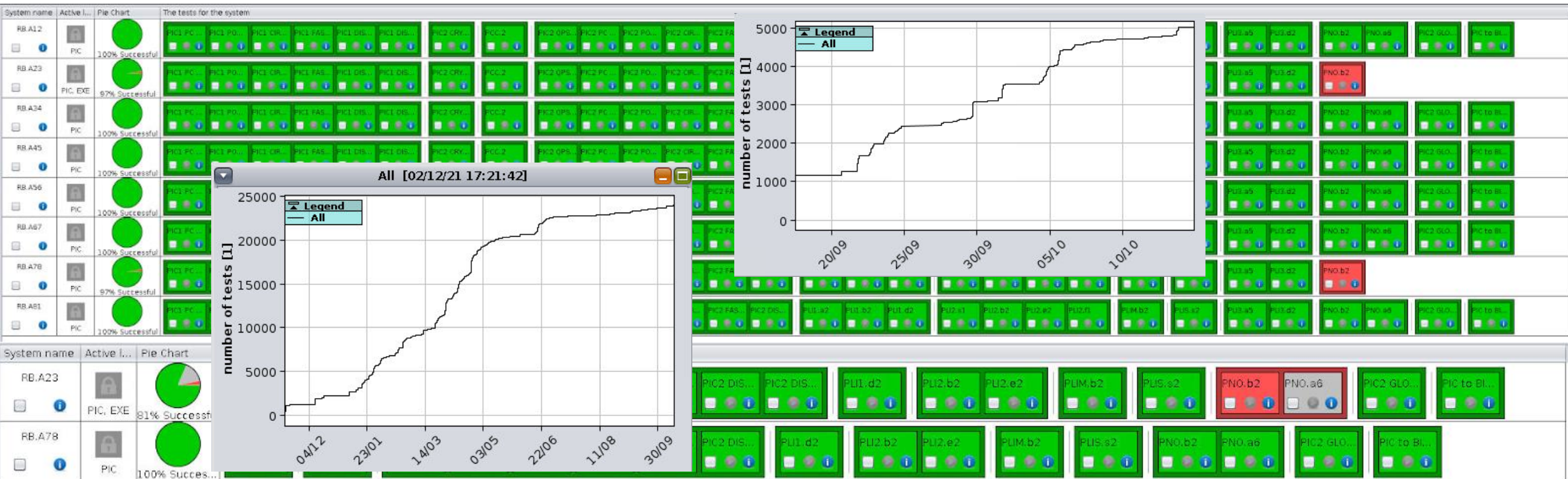
Sigmon

- Framework for unified **logging database access** (Post Mortem and NXCALS), **signal processing and execution of analysis modules** on the CERN computing cluster, strongly using SWAN to perform interactive data analysis in the cloud
- The new backbone for the **analysis of the powering tests**
- **67 notebooks** prepared, tested and maintained for the analyses of powering tests
- API has been **insourced** from the MPE-PE in 2021
- Work on Sigmon performed in **close collaboration** with the **MPE-PE and MP3**

RB	RQD/F	IT	IPQ	IPD	600A	80-120A	60A
PCC	PCC	PCC.T4	PCC.4	PCC.3	PCC	PCC.1	PCC.1
PIC2	PIC2	PIC2	PIC2	PIC2	PIC2	PIC2	
PLI1.a2/b2/d2	PLI1.b3/d2	PNO.d12/d13	PLI1.c3	PLI1.c2	PCS	PNO.d1	PNO.d1
PLI2.s1/b2	PLI2.s1/b3	PLI3.f6	PLI2.f3	PLI2.f2	PLI3.b1	PNO.a1	PNO.a1
PLI2.e2	PLI2.e2	PNO.d14	PLI2.e3	PLI3.c5	PNO.d3	PNO.e1	
PLI2.f1	PLI2.f1	PNO.d15	PNO.f4	PNO.a8/c6	PNO.b1*		
PLIM.b2	PLIM.b3	PNO.a9	PNO.a7		PNO.a3		
PLIS.s2	PLIS.s2	PNO.d16	PNO.c4		PNO.x1		
PLI3.a5/d2	PLI3.a5/b3	PNO.d17			PNO.x2		
PNO.b2/a6	PNO.b3/a6						
FPA/ FPA_SNAP	FPA	FPA	FPA	FPA	3xFPA-EE	FPA	FPA
QHDA	QHDA	QHDA	QHDA	QHDA			

Legend: Notebook (green) · No MP3 analysis (grey) · eDSL (yellow) · LabVIEW (blue)

SCOPE

The initial scope of the project is to develop signal monitoring applications for:

1. superconducting magnets and busbars;
2. circuit and magnet protection systems;
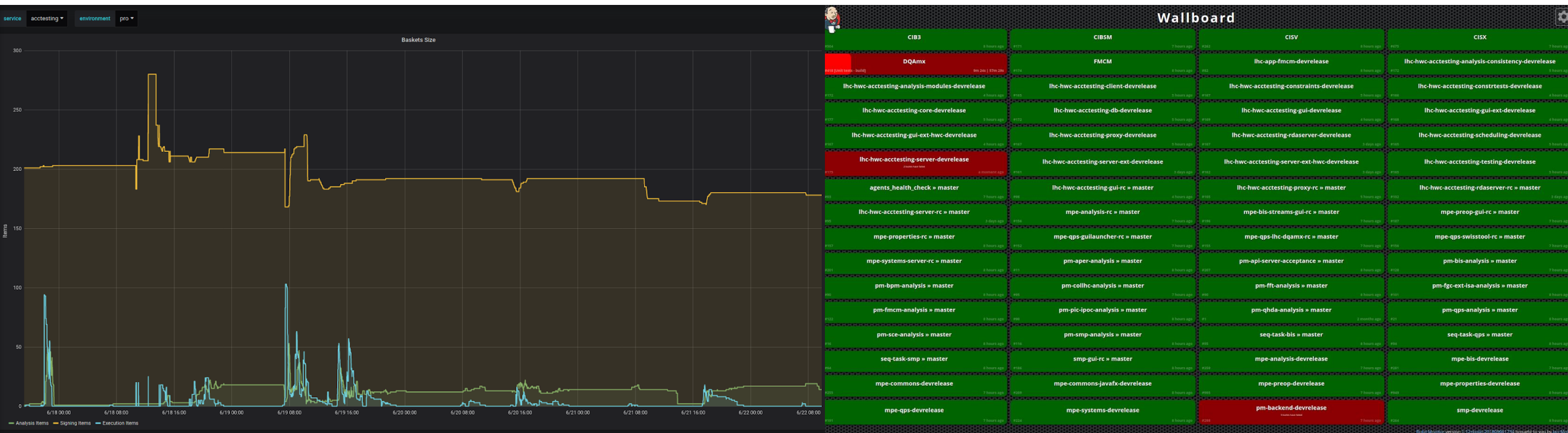3. grounding networks;
4. current leads
5. ...

The framework however is expandable to account for other systems of a superconducting circuit (e.g., power converters) as well as other types of hardware (e.g., cryogenics, beam instrumentation, vacuum, etc.).
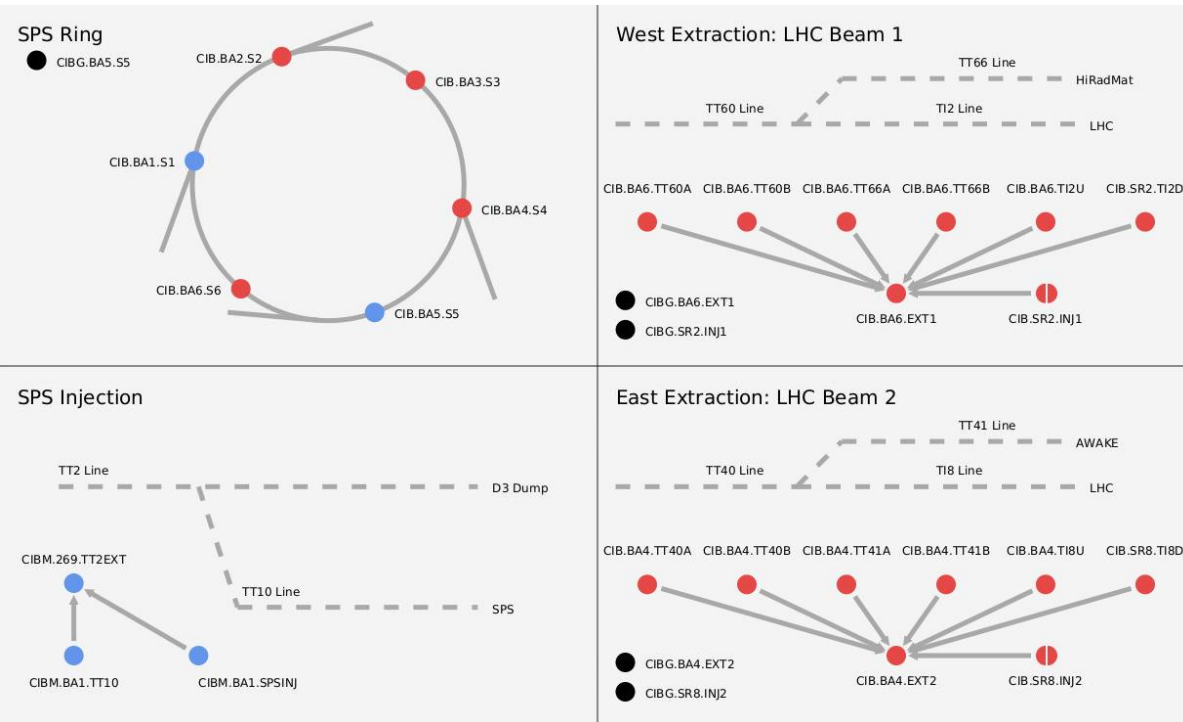
http://sigmon-docs.web.cern.ch
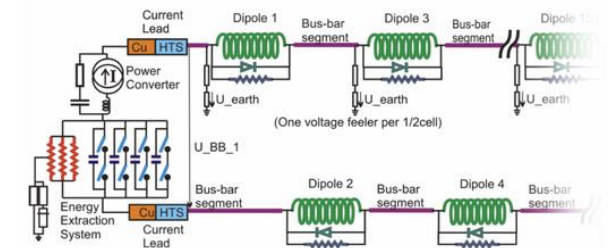
DevOps – Practises/tools for SW development and operation

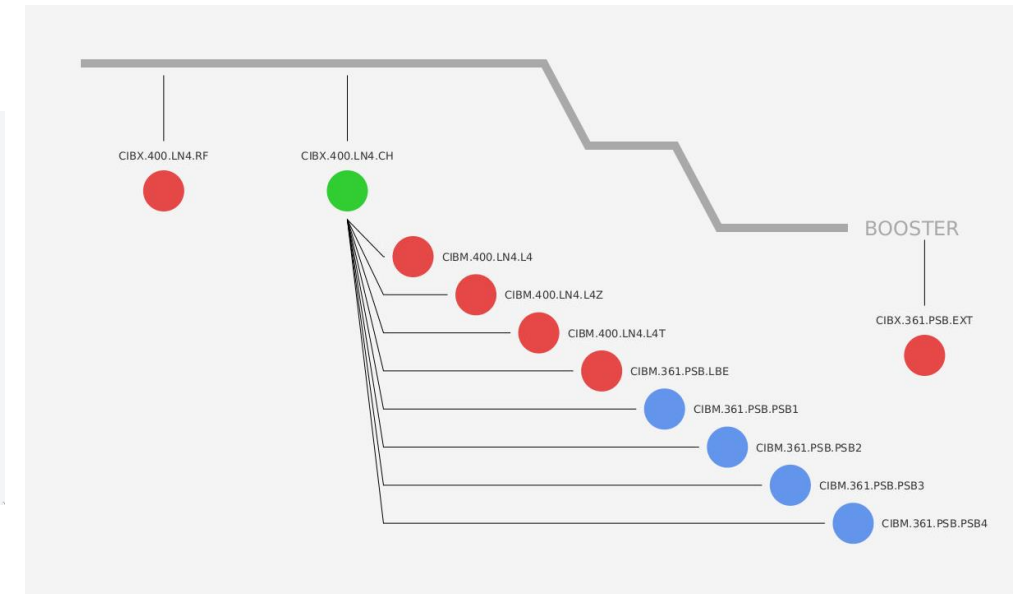- Implemented a whole **new Continuous Integration and Delivery service** tailor made to our needs using Jenkins and openstack from IT

- Upgraded SonarQube to support Java 11 – a service to manage & track SW quality and source code

- Preparing our entire software stack to a **new set of 3rd party dependencies** for January 2022

- New ElasticSearch and Grafana instances for storing of **logs and metrics**

Interlock Controls and Software

SPS Ring
- CIBG.BA5.S5
- CIB.BA2.S2
- CIB.BA3.S3
- CIB.BA1.S1
- CIB.BA4.S4
- CIB.BA6.S6
- CIB.BA5.S5

West Extraction: LHC Beam 1
- TT66 Line — HiRadMat
- TT60 Line — TI2 Line — LHC
- CIB.BA6.TT60A CIB.BA6.TT60B CIB.BA6.TT66A CIB.BA6.TT66B CIB.BA6.TI2U CIB.SR2.TI2D
- CIBG.BA6.EXT1
- CIBG.SR2.INJ1
- CIB.BA6.EXT1 CIB.SR2.INJ1

SPS Injection
- TT2 Line — D3 Dump
- CIBM.269.TT2EXT
- TT10 Line — SPS
- CIBM.BA1.TT10 CIBM.BA1.SPSINJ

East Extraction: LHC Beam 2
- TT41 Line — AWAKE
- TT40 Line — TI8 Line — LHC
- CIB.BA4.TT40A CIB.BA4.TT40B CIB.BA4.TT41A CIB.BA4.TT41B CIB.BA4.TI8U CIB.SR8.TI8D
- CIBG.BA4.EXT2
- CIBG.SR8.INJ2
- CIB.BA4.EXT2 CIB.SR8.INJ2

- Release 8.2.1 (2021/08)
- Release 8.2.0
- Release 8.1.1
- Release 8.1.0
- Release 8.0.2
- Release 8.0.1
- Release 8.0.0
- Release 7.3.1
- Release 7.3.0
- Release 7.2.0
- Release 7.1.0 - LN4 Baseline
- **Release 7.0.0 - LS2 Baseline**

- CIBX.400.LN4.RF
- CIBX.400.LN4.CH
- BOOSTER
- CIBM.400.LN4.L4
- CIBM.400.LN4.L4Z
- CIBM.400.LN4.L4T
- CIBM.361.PSB.LBE
- CIBX.361.PSB.EXT
- CIBM.361.PSB.PSB1
- CIBM.361.PSB.PSB2
- CIBM.361.PSB.PSB3
- CIBM.361.PSB.PSB4

Service Group
BISSystemServiceGroup
Open all check-results for service group "BISSystemServiceGroup" in Icinga

COSMOS Check Name	COSMOS Check Name
SwPermitTimeoutService	CibuMonitoringService
	Check CIBU power Supplies (CIBD)

Number of Failing FECs	Number of OK FECs	Number of Failing FECs	Number of OK FECs
5	37	15	27

| FECs with errors			FECs with errors		
Time	hostname	Status	Time	hostname	Status
2021-12-07 08:47:51	cfv-361-cibpsb12	UNKNOWN	2021-12-07 18:44:33	cfv-269-cibtt2ext	WARNIN
2021-12-07 02:37:32	cfv-361-cibpsb34	UNKNOWN	2021-12-07 05:46:27	cfv-361-cibpsb12	UNKNOWN
2021-12-07 08:37:36	cfv-ba1-cibinj	UNKNOWN	2021-12-06 22:56:25	cfv-361-cibpsb34	UNKNOWN
2021-12-07 00:27:26	cfv-ba1-cibs1	UNKNOWN	2021-12-06 20:43:49	cfv-361-cibpsbext	WARNIN
2021-12-07 06:28:50	cfv-ba5-cibs5	UNKNOWN	2021-12-07 04:31:22	cfv-ba1-cibinj	UNKNOWN
			2021-12-07 06:52:25	cfv-ba1-cibs1	UNKNOWN
			2021-12-07 07:58:50	cfv-ba4-cibext2	WARNIN

- BIS GUI:
  - Implemented improvements
  - New SPS overview
  - Support of LN4
- Continuous **service monitoring** based on COSMOS
- **Technical upgrades** of the controls & SW stack for all interlocks elements: BIS, SMP, FMCM, PICtoSIS, SISBox

QPS SW and controls

Heavy use of **controls and data storage infrastructure** by QPS equipment in the LHC & test facilities

- \> 130k QPS signals registered for continuous logging in NXCALS
- \> 3 x 10^8 data points per physic signals acquired by QPS
- \> 350k PM dumps from QPS equipment
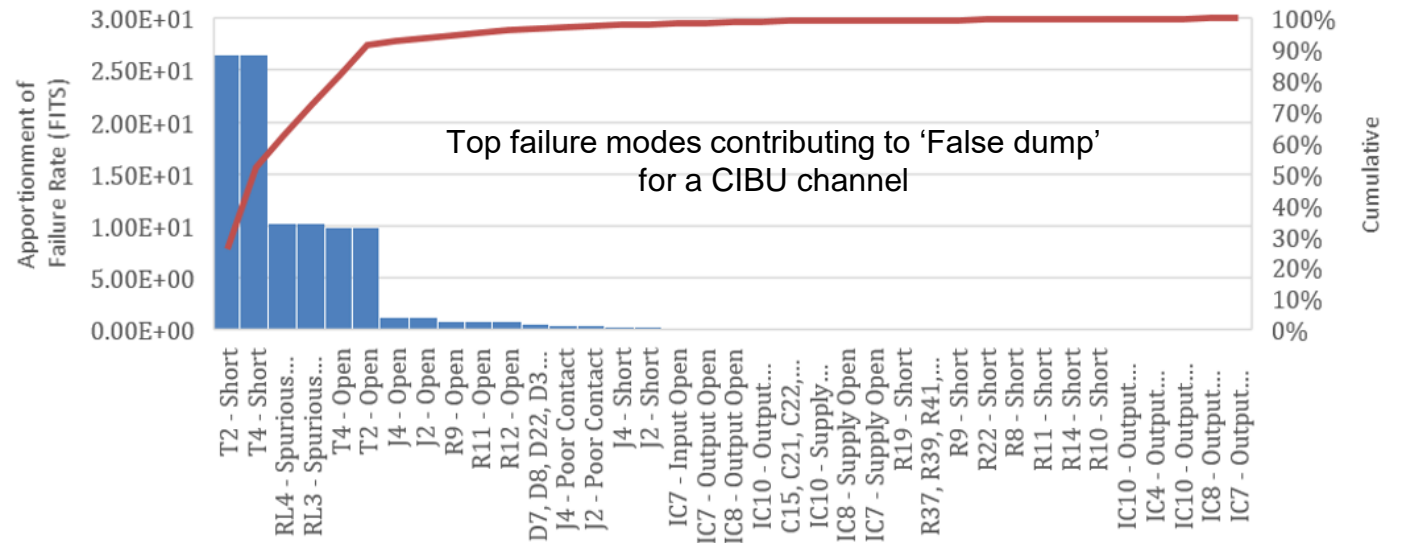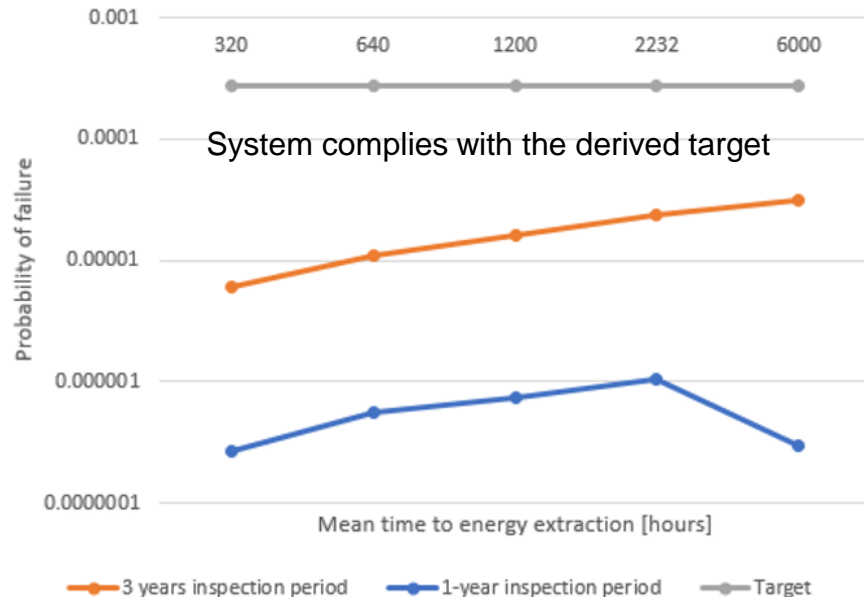

QPS PM dumps by day - 2020 vs.2021
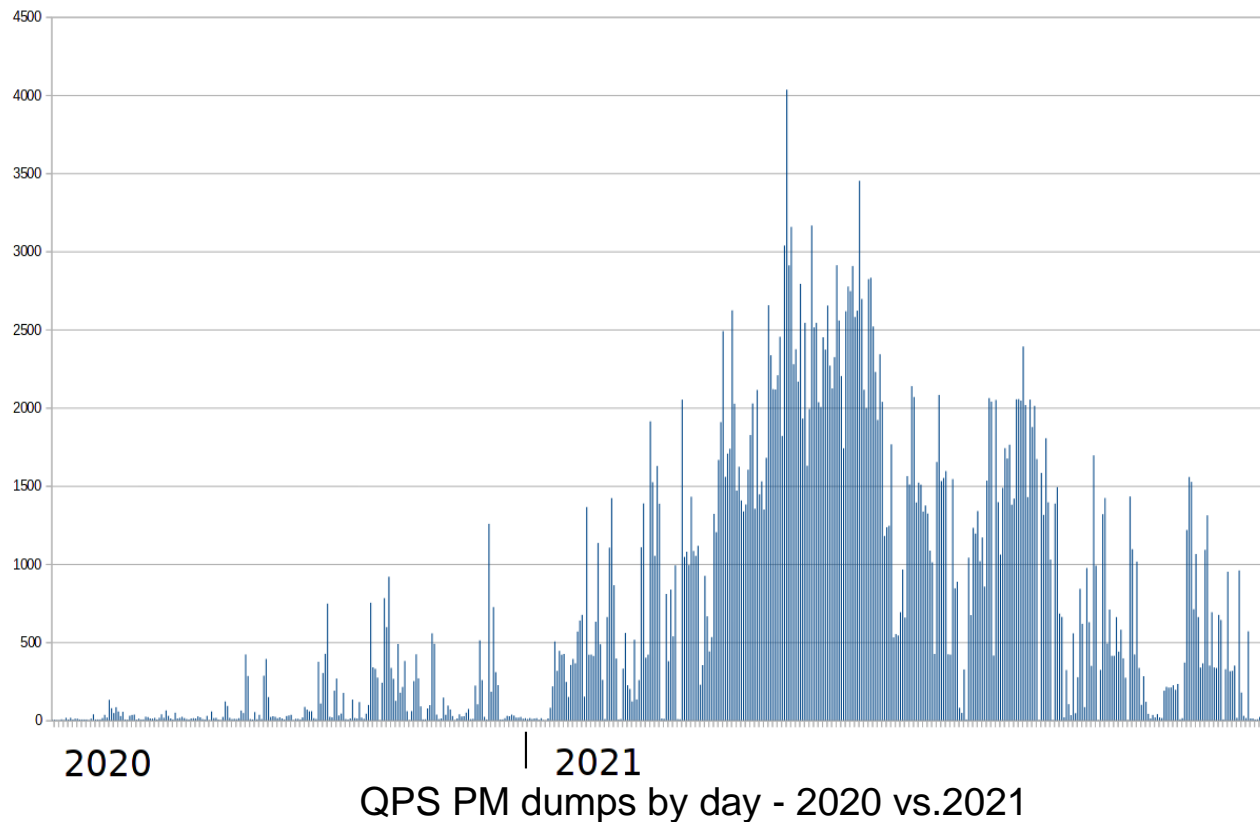
- Software services technical maintenance and upgrade for **EE switches**
- Continued support and maintenance for the QPS stack deployed in the **FAIR test facility**

- **Prototyping** the next generation QPS data acquisition system, with **high-through put** (Ethernet based field bus)
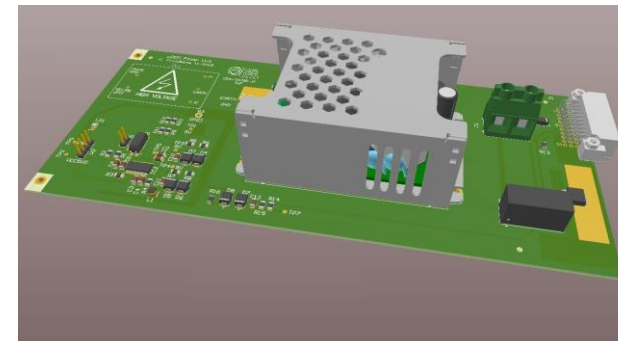
Reliability and Availability Studies

- First **release of AvailSim4**, the Monte Carlo tool developed in MPE for availability & reliability simulations

  - Simulation of LHC phases
  - Possibility to model complex repair strategies
  - Root cause analysis module

  - Custom-defined redundancy logic (MYRRHA use case with MPE-MI)
  - New simulation methods: Importance Splitting algorithm with x100 speed-up for rare event simulations

- Performed HL-LHC **Energy Extraction Systems reliability** study in collaboration with MPE-MP (AvailSim4)
- **BIS2 reliability study** ongoing in collaboration with MPE-MI: Analysis of CIBM and CIBU done, CIBFi ongoing (Isograph)
- Performed **CLIQ reliability study** in collaboration with MPE-MP

System complies with the derived target

Top failure modes contributing to 'False dump' for a CIBU channel

Machine Learning for protection

- Developed a generic **ML framework** for application to Machine Protection relevant use cases → **R&D** activities on Accelerator Failure Prediction with ML methods
- Focus on **Explainable AI** → promises to **ease the interpretation** of the ML results
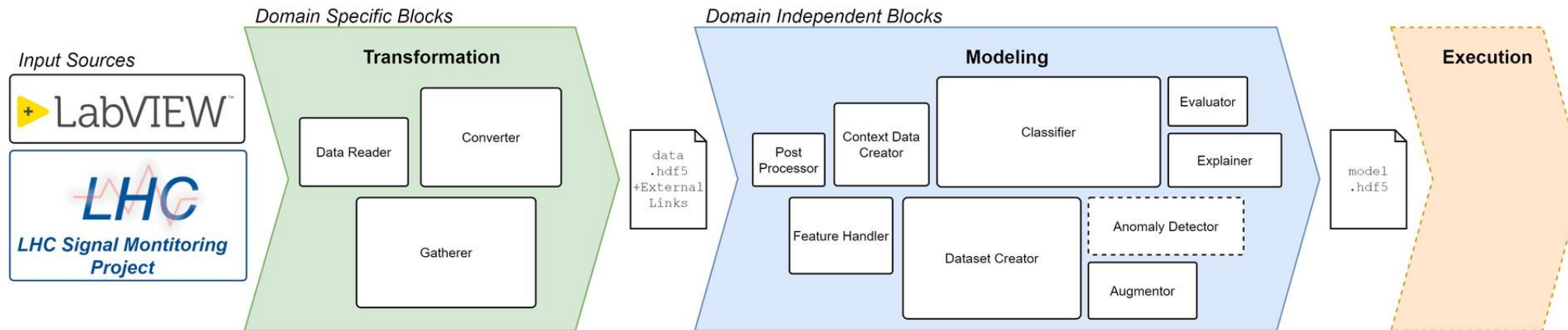
- RF breakdown **prediction** for CLIC:
  - Breakdown **precursor identified** (increase of vacuum pressure a couple of seconds before the breakdown) → publication under preparation

Machine learning for protection
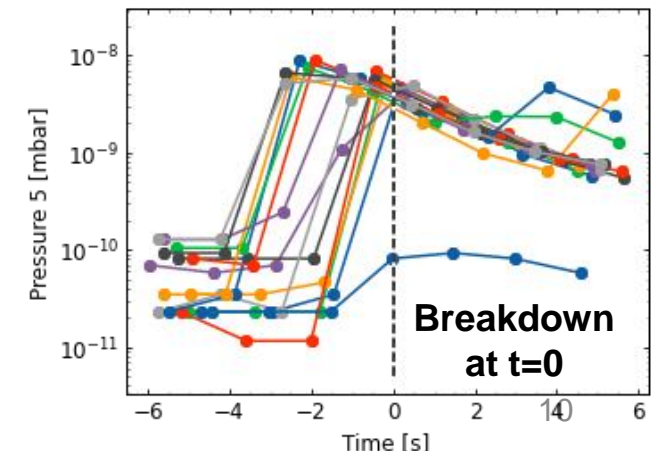
Fast Failure Studies for the LHC and HL-LHC

- Developed FailSim framework to efficiently perform **failure case simulations** for the LHC and HL-LHC
  - FailSim uses MadX and allows to perform full 6D **particle tracking** simulations
- Studied failure cases with and without depleted halo (hollow e-lens)
  - ADT coherent excitation: maximum 480b allowed to be excited at the same time
  - Spurious firing of CLIQ leads to critical loss level after only 5 turns due to strong skew octupole field components → **fastest failure in the HL-LHC**, interlocking required
  - Spurious QH firing: confirmed fast losses due to skew dipole kicks, interlocking required

https://fast-failures.web.cern.ch
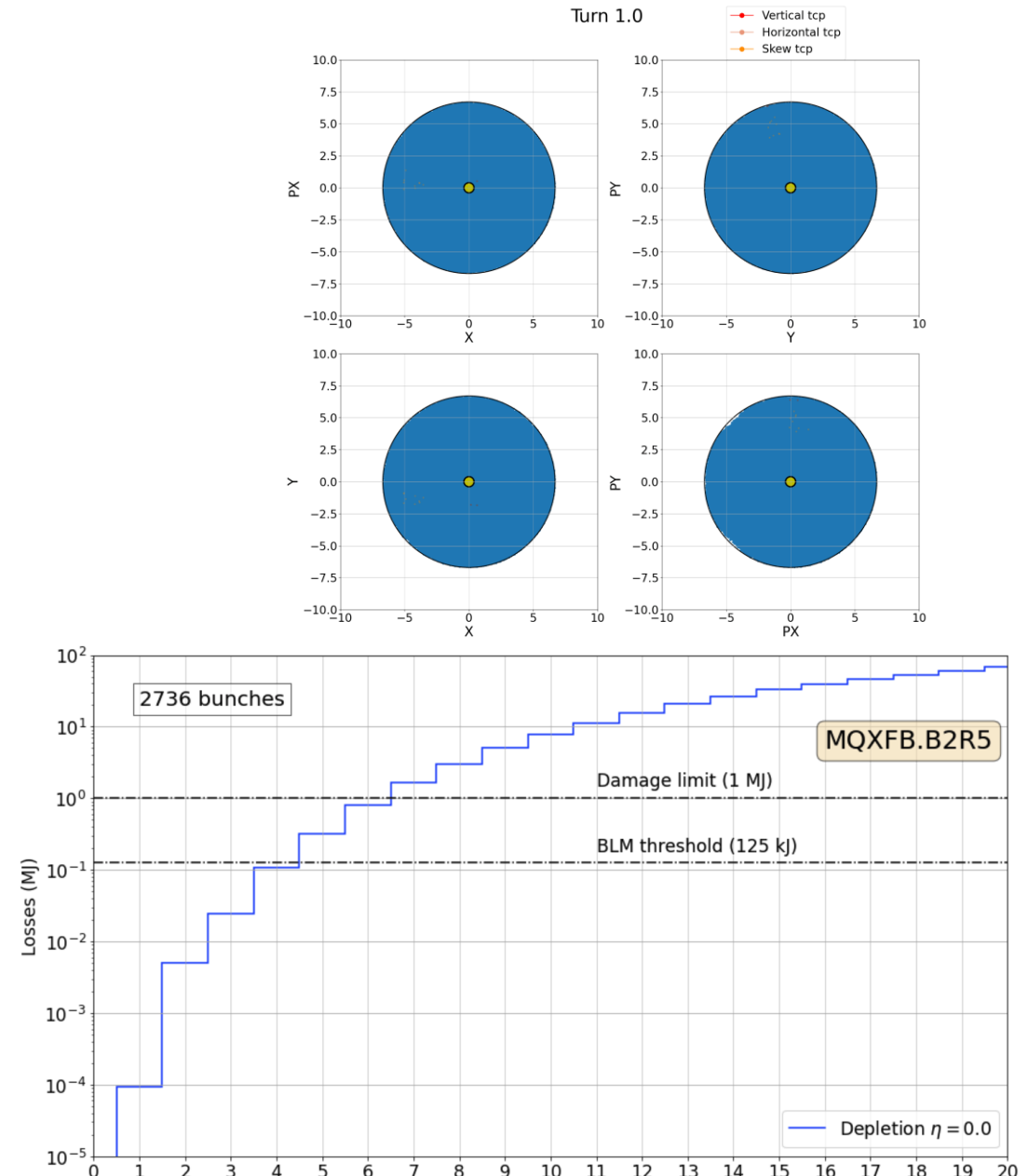
Quench heater effect on the beam

- New method for **reconstruction of quench-heater** fields from beam measurements gives consistent results regarding field levels and rise times

- New model provides significantly **improved understanding** of beam-screen shielding behaviour

Reconstructed QH fields inside the beam screen

Comparison of simulated and reconstructed QH field
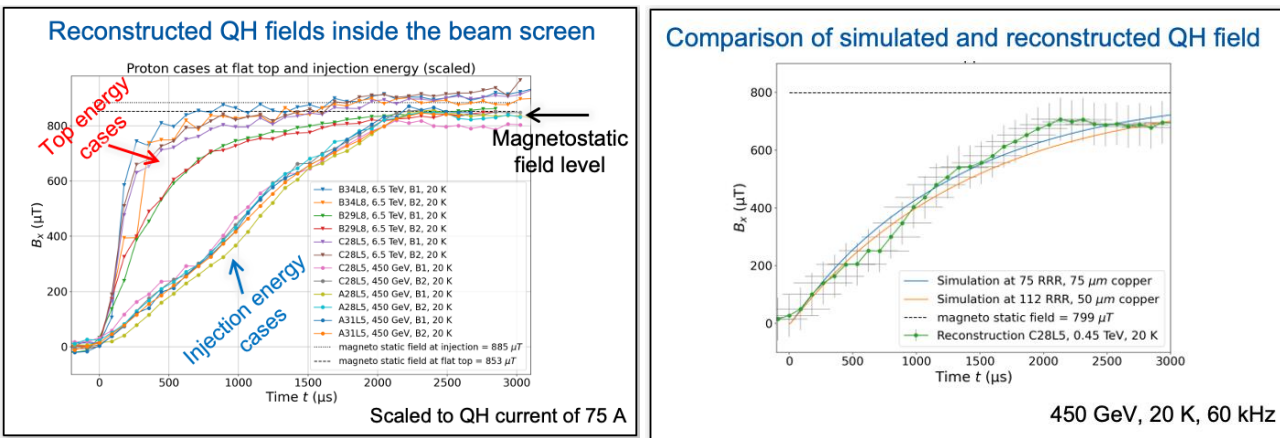
See L. Richtmann, M. Sc. Thesis (Sep. 2021), [CDS](#)

Hydrodynamic Tunnelling

- **Coupling** of FLUKA and Autodyn codes **established** in collaboration with EN-MME and SY-STI

- Ready for studies of hydrodynamic tunnelling and **beyond-design** failures

PM beam loss analysis of LHC high-energy dumps

- Classification of BLMs based on loss pattern

- Thresholds derived for >3500 BLMs based on ~1000 top-energy dumps from Run 2 → allows to **identify abnormal loss patters** during a beam dump

- To be implemented into **automatic loss analysis tool** inside the PM framework

Example of derived BLM thresholds

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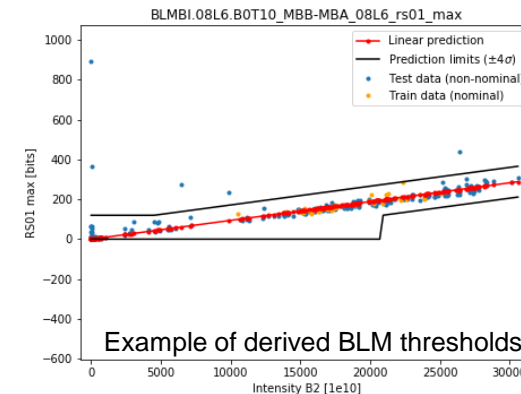
Reliability and Availability Studies Working Group (RASWG)

- **Combination and streamlining** of previous working groups (AWG, RASWG, MARP)
- **Revised membership list**, with representatives from AT Sector (+HSE and experiments)
- Synergies and **joint meetings** with other community forums for selected topics of interest (electronics production, formal verification methods,...)
- Chaired by A. Apollonio and B. Todd
- 5 meetings in 2021

Application Software Community Forum

- Bring together the application **software development community** to share and discuss
  - New requirements and ideas for improvements
  - Plans for the future
  - Progress and results
  - Needs for technical evolution
- Chaired by G. Kruk & J.C. Garnier

Courtesy to the BE-CSS newsletter - Issue 6

Machine Protection Panel

- 16 meetings in 2021 (11 LHC, 5 Injector related)
- Review of LHC HWC **procedures for the machine protection systems**
- Definition of commissioning needs for **beam test**
- **Review of specification**s of (new) interlock systems (SPS DI/dt, LHC BCCM, PSB-WIC, Linac4-BIS, PSB-BIS...)
- Definition of **interlock requirements** for new accelerator HW (SPS crystals)
- Linac4 RF breakdown protection, protection of LEBT settings, Linac4 source tests
- Issues with new LHCb velo wake field suppressor
- Proposed **LHC Intensity Ramp-up** for 2022

MPS System	MPP presentation	Procedure	Release date / Comments
Collimation System	21.05. ✓	889345 v.2.3	V2.3 under approval
Injection Protection System	23.04. ✓	889343 v.4.0	08.06.2016
Beam Interlock System	19.02. ✓	889281 v.3.0	21.04.2016
Powering Interlock System	19.02. ✓	896390 v.4.0	12.02.2016
Vacuum System	26.03. ✓	896391 v.1.0	03.06.2016
Beam Dump System	23.04. ✓	896392 v.3.0	02.06.2016
FMCM	19.02. ✓	896393 v.3.2	02.03.2018
BLM System	30.04. ✓	896394 v.3.4	Approval closed 13.03.2018
Warm Magnet Interlock System	19.02. ✓	896395 v.3.0	24.02.2016
Safe Machine Parameter System	19.02. ✓	1112187 v.1.0	01.08.2016
Software Interlock System	30.04. ✓	1062498 v.1.3	15.01.2020
TOTEM / CTPPS	21.05. ✓	No procedure	-
ARP	21.05. ✓	No procedure	-
UPS test	-	1773693 v.0.1	Version 31.03.2017, Approval closed 07.2019
Transvers damper (ADT)	Tbd	In work	Commissioning needs to be defined
Beam-Beam Compensator Wire	Tbd	2384198 v.0.1	Under approval 11.06.2020. To be finalized.
Beam Charge Change Monitor	19.11. ✓	Draft	(Note: not part of 2022 commissioning)
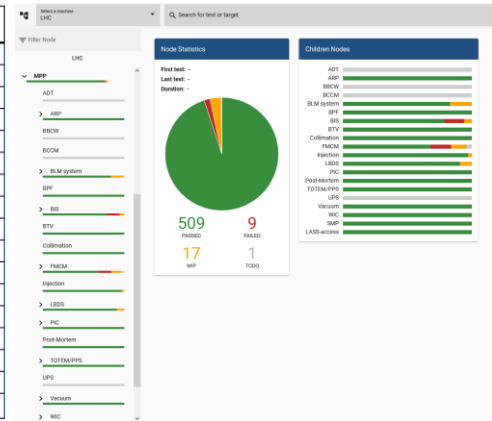
Powering and Protection Testbed

- Crucial for **testing** and validation of MPE **hardware and controls** deliverables
- Testbed status has been **reviewed and missing items identified**
- The **upgrade** to the full LHC Run3 configuration is ongoing and expected to be finished in Feb 2022

Newly installed FGClite controllers for IPQ circuit

CB in December 2021

Thanks a lot to the full CB team for an excellent year, your commitment and trust! 👏🎉 collaboration!

obermair christoph

Daniel Wollmann

Jonas

Christoph Wiesner

William

Jean-Christophe Garnier

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ola

Holger Severin Bovbjerg

Cedric

Ruediger

Thibaud

Jeppe Don

Thomas

Wojtek

https://mpe-cb.web.cern.ch
CB read the Docs

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