

Workshop Highlights

ARW 2024

Accelerator Reliability Workshop

MAX IV and ESS are Excited and Pleased to Announce their Joint Hosting

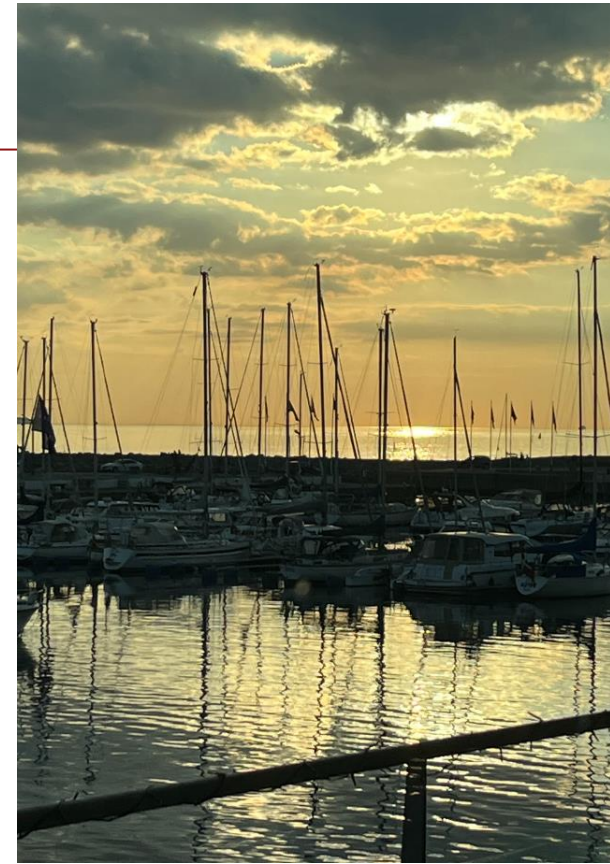
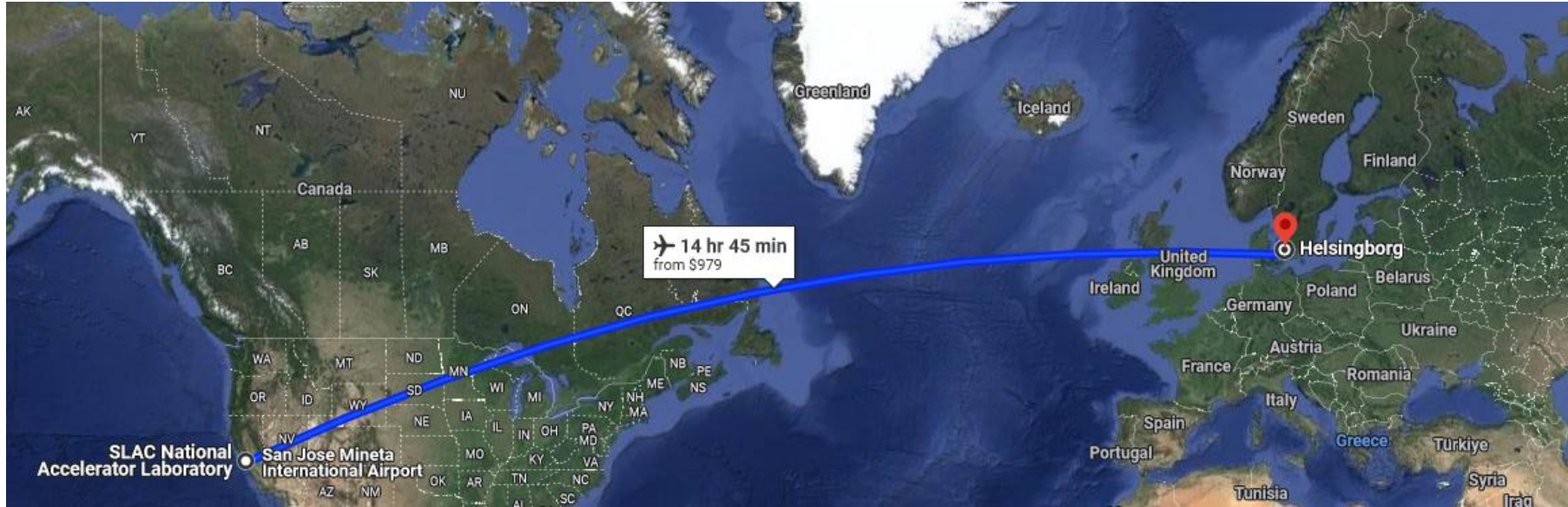
Establish or expand your network and gain valuable information and interesting insights from the ARW community – even if you are not a reliability or accelerator expert.

2024-06-23 until 2024-06-28
ARW2024 recap

Helsingborg, Sweden

SEA U conference centre

Long flight to beautiful northern city



Workshop overview

About 170 participants from all over the world

- Presentation sessions:
 - Reliability during procurement, installation, commissioning and upgrades
 - How to establish/ensure/maintain/evolve a reliability integrity culture
 - Machine learning & artificial intelligence & automatic prediction of failures
 - Failures / unintended consequences & analysis techniques
 - Maintenance methodologies (predictive, RCM, preventive)
 - Reliability of medical facilities
 - How to maintain and improve reliability during a facility lifetime
- Breakout sessions:
 - Fewer skilled experts: single source points of failure in personnel
 - Cultivating a reliability-centric culture
 - Issues on infrastructure and their effects on reliability
 - Effective preventative maintenance, balancing operations and projects
 - Reliability for legacy equipment, obsolescence, and eBay
 - Machine learning and AI
- Poster session with about 75 contributions



EED contribution

Presented on the LEMP modernization project

- Tasha Summers, James Bong, Jeff de Lamare, Joe DeLong
- Lots of good discussions, many labs are of the same vintage and working to update their equipment.



We won the best poster award!

Modernizing LINAC Equipment at SLAC

A process for identifying and prioritizing necessary upgrades

J. DeLong, J. de Lamare, J. Bong, T. Summers
SLAC National Accelerator Laboratory, Menlo Park, California, USA.

SLAC celebrated its 60th anniversary in 2022. The newly commissioned superconducting section of the LINAC was installed with modern equipment, but the remaining sections continue to operate with equipment that is a mix of technologies spanning many decades. Of particular concern are major systems such as LRF, BPMs, Vacuum, and others that rely on CAMAC and VME controls. The Electronics and Engineering Division is working on a plan to prioritize the modernization of this equipment with the goal of creating a more modern, modular, and reliable system to support the legacy accelerators for the foreseeable future.

BACKGROUND

The Linear Accelerator Facility at SLAC consists of 3 linacs, each 1 km long. The new LCLS-II is superconducting, FACET and LCLS-I are normal conducting. Electron beam from either LCLS-I or LCLS-II can be sent to either undulator line and the experiment end stations.



Geographical overview of SLAC facility and beamline schematic.

LEMP - LINAC EQUIPMENT MODERNIZATION PROJECT

Originally focused on planning for replacement of the oldest LRF equipment used in the normal conducting LCLS and the FACET accelerators, the LEMP project scope was expanded to include a risk assessment of all accelerator controls infrastructure.



Old CAMAC and new ATCA crates.

Old RF klystron and new solid-state subbooster station.

RISK ASSESSMENT PROCESS

1. Itemize all equipment at risk of obsolescence.
2. Rate failure impact to accelerator program.
3. Identify timeline of failure (e.g. out of spares).
4. Identify number of spares, and ease of repairing failed components or purchasing replacements.
5. Identify the amount of time and resources spent maintaining existing parts.
6. Determine number of failures in last 5 years.
7. Estimate the total cost, NRE, M&S, time to replace or upgrade system.

Project Element	Low = 1	Medium = 3	High = 5	Project LCLS IIRP	Priority grade: High
Project Cost	\$500K	\$200K to \$1000K	> \$5000K	Regulated by 3 Design, OCA, A-Review	High, Very High, Impact High, Critical/High
Project Duration	1 to 2 years	Well-Defined & New Requirements	> 2 years		
Project Scope and Requirements	Well-Defined	Well-Defined & New Requirements	Not Well-Defined		
Technical Complexity/Innovation	No New Requirements	Well-Defined	New Requirements		
Technical Complexity/Skills	Easy Manufacturer/Test	Medium Manufacturer/Test	Difficult Manufacturer/Test		
System/Environmental Complexity	No New Issues	No New Issues	New Issues		
Team Size	1 to 2	3 to 5	> 5		
Resource Availability	Highly Available	Scholar	Overstretched		
Collaboration	1-2 Groups	2-3 Groups	> 3 Groups		
Install/Upgrade/Time	Easy Installation/Test	Moderate Installation/Test	Difficult Installation/Test		
Team Stability	High	Medium	Low		
Formality Grade	Low	Medium	High		

These factors are compiled in a spreadsheet and graded to calculate overall formality and an operational consequence rating.

Item	Ranking	Project	Supplier	Material	Cost	Occupancy	Age	Reliability	Availability	Support	Complexity	Team	Collaboration	Install/Upgrade/Time	Team Stability	Formality	Overall	Operational Consequence	
1	1	LCLS-I RF High Power Sub-Booster	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI	RFI
2	2	LCLS-I Vacuum Valve Controllers	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC
3	3	LCLS-I Low Level RF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF	LRF
4	4	LCLS-I Vacuum Ion Pump Controllers	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP
5	5	FACET-II Vacuum Ion Pump Controllers	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP	VIP
6	6	Common Computing - Alpha & Micros	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM	COM
7	7	LCLS-I Vacuum Gauge Controllers	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC
8	8	FACET-II Vacuum Gauge Controllers	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC	VGC
9	9	LCLS-I Laser Power Meters	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM	LPM
10	10	FACET-II Vacuum Valve Controllers	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC	VAC

TOP 10 RESULTS

1. LCLS-I RF high power sub booster 10 year project \$2M
2. LCLS-I Vacuum valve controllers 2 year project \$1.5M
3. LCLS-I Low level RF 10 year project \$12M
4. LCLS-I Vacuum ion pump controllers 1.5 year project \$0.6M
5. FACET-II Vacuum ion pump controllers 1.5 year project \$0.6M
6. Common Computing - Alpha & Micros 4 year project \$8M
7. LCLS-I Vacuum gauge controllers 1.5 year project \$0.8M
8. FACET-II Vacuum gauge controllers 1.5 year project \$0.8M
9. LCLS-I Laser power meters 1 year project \$0.1M
10. FACET-II Vacuum valve controllers 10 year project \$1.5M

CONCLUSION AND NEXT STEPS

The list of highest risk items have been submitted for review and funding prioritization.

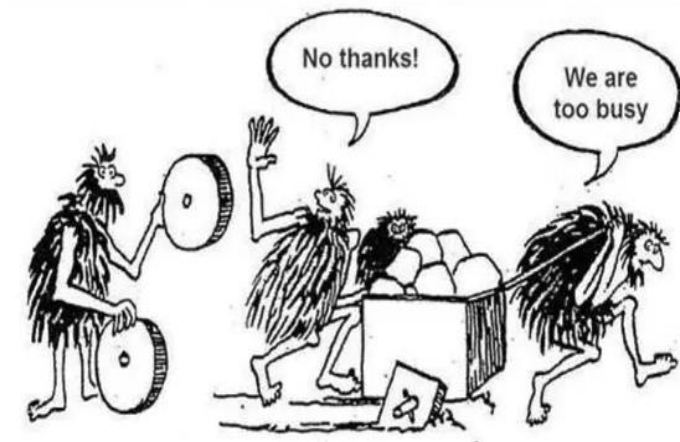
While these did not make the top-10 list, upgrading all remaining CAMAC and VME systems to modern equivalents is high priority and they are part of all the identified systems.

Of note is the entire Hard X-Ray undulator line, 32 undulators, are all running on VME. This system is complicated and time intensive to recover but it didn't achieve top-10 status because the failure rate is low and there is a high number of spares.


Big-picture themes



- Many labs are trying to move from reactive to strategic maintenance planning.
- Most labs find it challenging to find the right balance between spending money on maintenance and upgrades vs. new projects – no one has the ‘right’ answer.
- Several labs emphasizing system engineering, quality management, and environmental sustainability.
- Most labs feel understaffed and struggle with talent retention (many have the “bathtub curve”).
- Critical first step is frequent analysis of availability and failure data – this helps guide decisions.
 - SLAC has not prioritized this in recent years while focused on LCLS-II, but it is becoming important again!
- Identification of looming problems is key to prioritizing upgrades and reducing technical debt.
 - Think of our LEMP project and software modernization efforts.
- **Lack of high-level coordination leads to inefficiencies and duplicated effort (E.g. multiple SW groups across the lab)**
 - **One audience member commented that SLAC’s controls looked too disjointed to ever be reliable – ouch.**
 - Have to be willing to put in the time to make long-term improvements.



Interesting ideas and comments

- Building a Reliability Culture - Key is to disconnect the reliability of a system from blaming the staff.
 - Takes a paradigm shift from skilled-expert, single engineer ownership to one of team effort and responsibility – but not so far that no one feels any ownership at all.
- Be clear about what the reliability/availability metrics are and how we work to them, short & long term.
 - We'll look at this much more in the near future...
- “It takes a long time to recover from an upgrade.” 
- 4 parts to improving availability
 - Identify systemic issues with scheduling, project prioritization, resource skill and effort loading
 - Identify and minimize human factors with training, engineering practices and culture improvements
 - Work on continuous improvement with weekly reviews for immediate action, and run reviews for larger efforts
 - Make the necessary data easily accessible - real-time reporting, logbooks and equipment fault reports.
- Enterprise Asset Management (EAM) or Computerized Maintenance Management Systems (CMMS) are used by many labs for equipment management, technical documents, and maintenance scheduling.

Interesting Talk – FCC-ee Availability Challenge (CERN)

CERN's proposed 91 km Future Circular Collider!

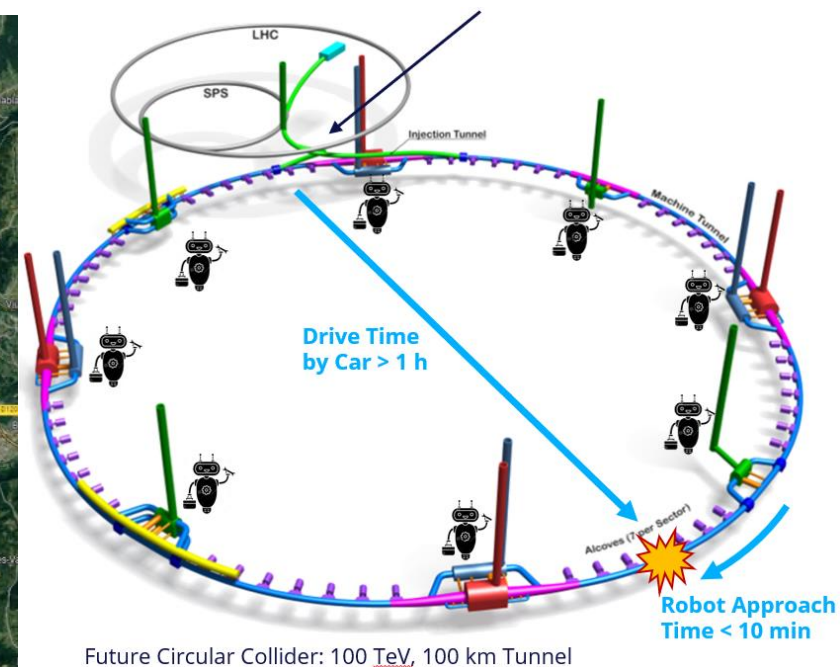
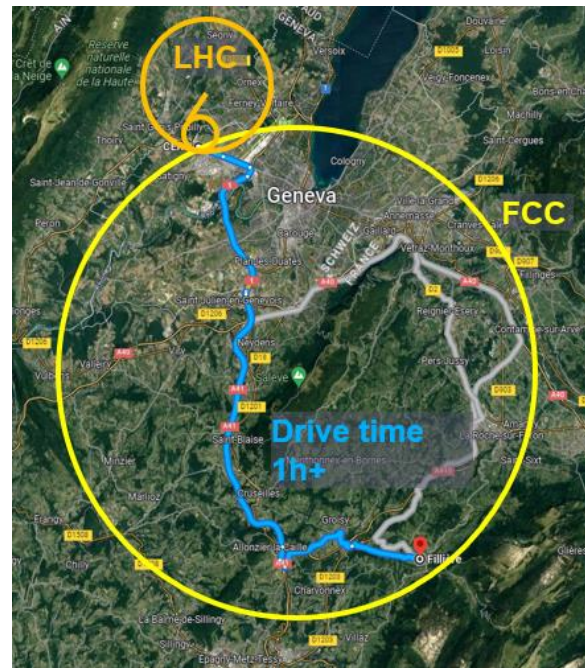


- Maybe start construction in 2030, running from 2044-2060 followed by an energy upgrade running from 2070-2095
- Goal for 185 delivery days, 80% availability: Infrastructure 97.1%, Injector 96.1%, Accelerator 85.8%
- Created simulation for relationship between availability and luminosity
 - William Colocho collaborated with ESS on AvailSim2



AvailSim4

- Start with availability target, determine reasonable forecasts, and identify shortfalls to focus on solving now
 - Considering robots to do initial repair while humans are in transit!



Interesting Talk – CERN's Robots

Robotic Service at CERN

- Infrastructure not designed to host robotics
- Need to adapt robots to environment
- Highly versatile systems / relatively low efficiency
- > 20 robotic systems operational in different configurations



KUKA



Telemax



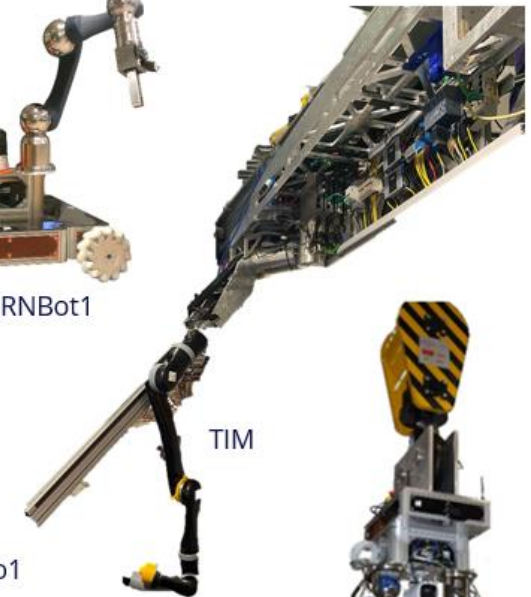
CERNBot1



Teodor



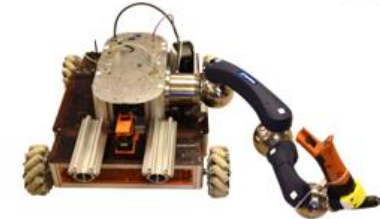
Unitree Go1



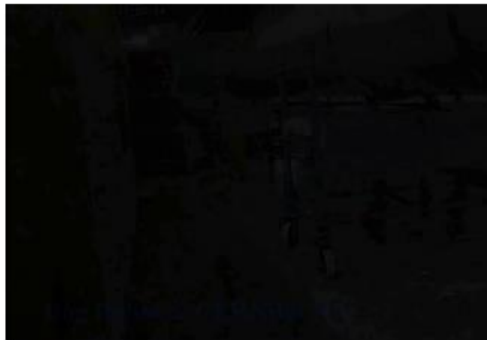
TIM



CERNBotCrane



CERNBot2



Unitree Go1



Train Inspection Monorail - TIM



Telerob Teodor X Schunk Arm



CERNBot1



Flyability Elios



CERNBot1

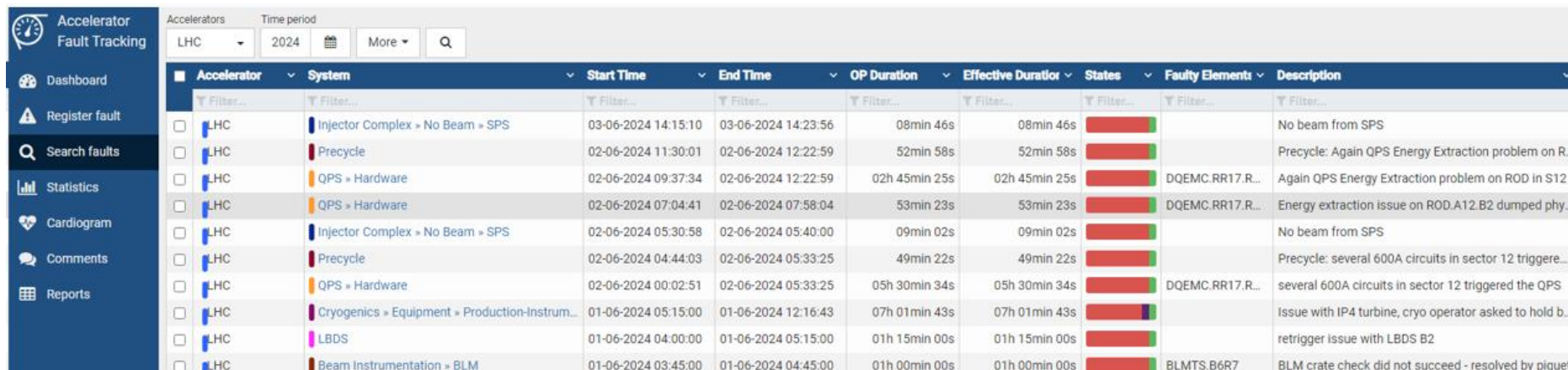


CERNBotSPS

Additional information on the service in academic training lectures: <https://indico.cern.ch/event/1055745/>

Interesting Topic – Automatic fault identification

- Distinction between the actual fault duration and the effective fault duration (subsequent faults, long recovery), as well as between direct cause (e.g. MPS) and root cause (e.g. temperature switch).
- Good fault tracking tools are essential, with as much automated post-mortem data recording as possible to identify root cause – enables intelligent and consistent review.
- Understand why systems fail (complexity, aging), emphasize what can be improved not what went wrong.

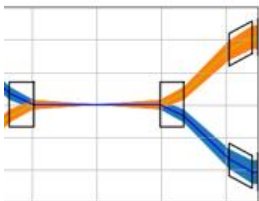
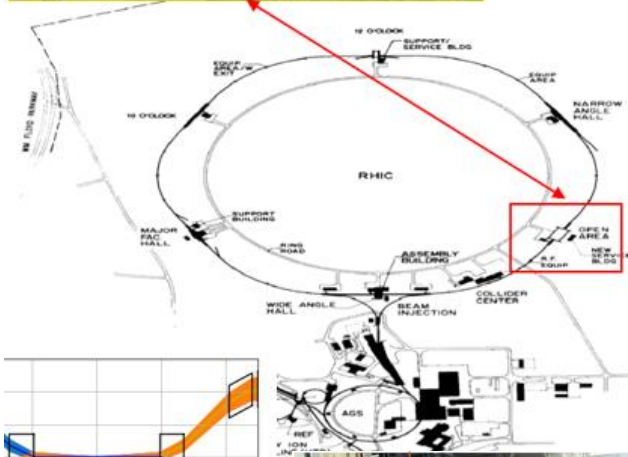
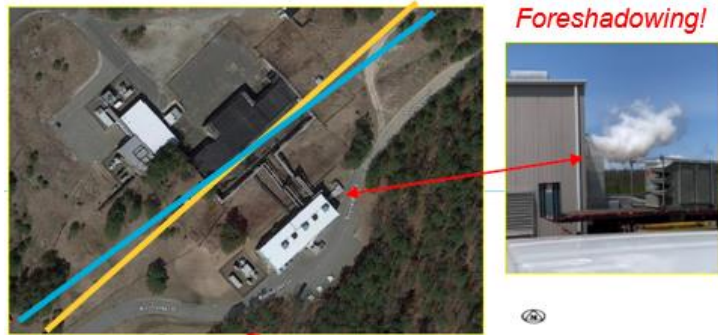


The screenshot displays the 'Accelerator Fault Tracking' interface. On the left is a navigation menu with options: Dashboard, Register fault, Search faults, Statistics, Cardiogram, Comments, and Reports. The main area shows a table of fault events for the LHC in 2024. The table has columns for Accelerator, System, Start Time, End Time, OP Duration, Effective Duration, States, Faulty Elements, and Description. Each row includes a checkbox, a small icon, and a color-coded bar representing the state.

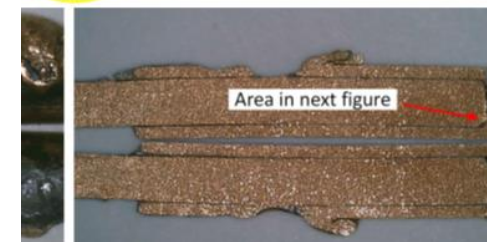
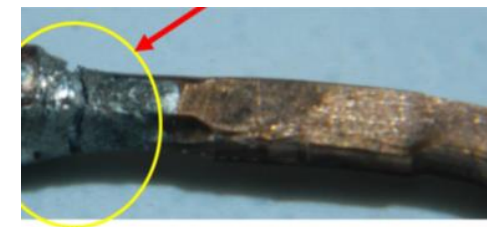
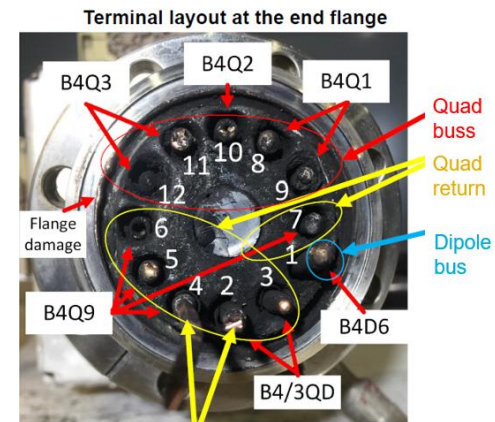
Accelerator	System	Start Time	End Time	OP Duration	Effective Duration	States	Faulty Elements	Description
<input type="checkbox"/>	LHC	Inject Complex > No Beam > SPS	03-06-2024 14:15:10	03-06-2024 14:23:56	08min 46s	08min 46s		No beam from SPS
<input type="checkbox"/>	LHC	Precycle	02-06-2024 11:30:01	02-06-2024 12:22:59	52min 58s	52min 58s		Precycle: Again QPS Energy Extraction problem on R...
<input type="checkbox"/>	LHC	QPS > Hardware	02-06-2024 09:37:34	02-06-2024 12:22:59	02h 45min 25s	02h 45min 25s	DQEMC.RR17.R...	Again QPS Energy Extraction problem on ROD in S12
<input type="checkbox"/>	LHC	QPS > Hardware	02-06-2024 07:04:41	02-06-2024 07:58:04	53min 23s	53min 23s	DQEMC.RR17.R...	Energy extraction issue on ROD.A12.B2 dumped phy...
<input type="checkbox"/>	LHC	Inject Complex > No Beam > SPS	02-06-2024 05:30:58	02-06-2024 05:40:00	09min 02s	09min 02s		No beam from SPS
<input type="checkbox"/>	LHC	Precycle	02-06-2024 04:44:03	02-06-2024 05:33:25	49min 22s	49min 22s		Precycle: several 600A circuits in sector 12 triggere...
<input type="checkbox"/>	LHC	QPS > Hardware	02-06-2024 00:02:51	02-06-2024 05:33:25	05h 30min 34s	05h 30min 34s	DQEMC.RR17.R...	several 600A circuits in sector 12 triggered the QPS
<input type="checkbox"/>	LHC	Cryogenics > Equipment > Production-Instrum...	01-06-2024 05:15:00	01-06-2024 12:16:43	07h 01min 43s	07h 01min 43s		Issue with IP4 turbine, cryo operator asked to hold b...
<input type="checkbox"/>	LHC	LBDS	01-06-2024 04:00:00	01-06-2024 05:15:00	01h 15min 00s	01h 15min 00s		retrigger issue with LBDS B2
<input type="checkbox"/>	LHC	Beam Instrumentation > BLM	01-06-2024 03:45:00	01-06-2024 04:45:00	01h 00min 00s	01h 00min 00s	BLMTS.B6R7	BLM crate check did not succeed - resolved by piquet

- At SLAC we have proposed PVs for the control system to track what state the accelerators are in – User delivery, Fault, Machine Development, Maintenance, Downtime.
- These can be used for automatic tracking and analysis as well as automatic alarm filtering.

Best disaster Story: BNL-RHIC SC Valve Box Failure

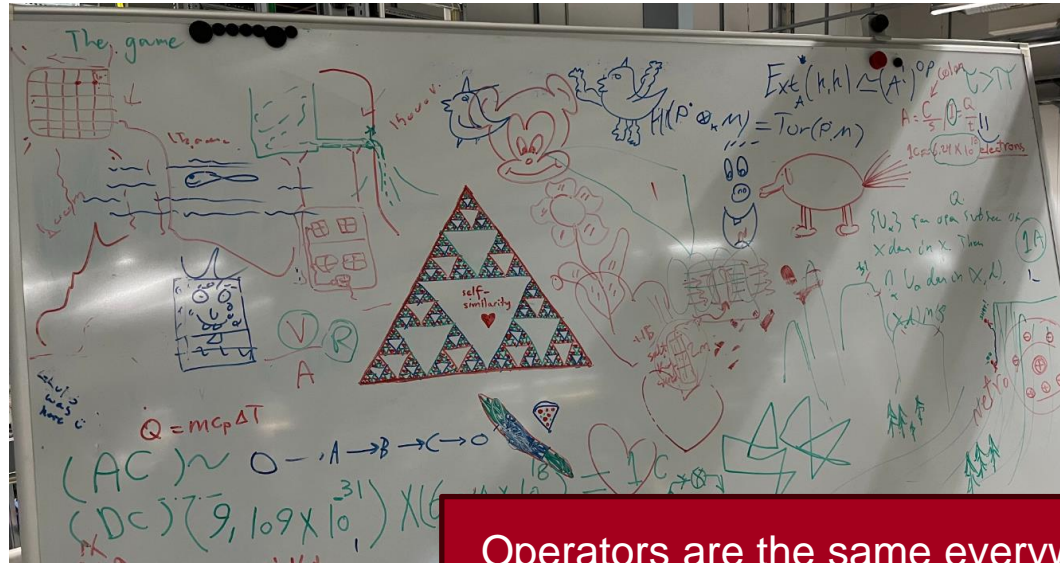


- 25 year old collider in NY - two rings, with big 'DX' magnets to bring the beams together at detectors.
- Cryogenic service buildings are where warm power supply leads are transitioned to the SC leads
- DX magnets have special heaters to flash helium in case of a quench to distribute the heat load
- Aug. 2023, 7 weeks before end of the run the one DX magnet quenched and the heaters fired...
- Original bad soldering was a time bomb!
- Repaired by Feb. 2024, machine running by May.



Host Facilities – Max IV and ESS

- MAX IV is a Swedish national synchrotron laboratory that has operated as a user facility since 2016. MAX IV offers access to 16 beamlines that provide modern X-ray spectroscopy, scattering/diffraction, and imaging techniques. MAX IV employs more than 300 people. MAX IV welcomes 1700+ users annually, expected to double in the coming years.
- The X-ray light at MAX IV is produced by an accelerator complex comprising a linear accelerator as well as 1.5 GeV and a 3 GeV storage ring for electrons. MAX IV is the first worldwide realization of a fourth-generation light source.

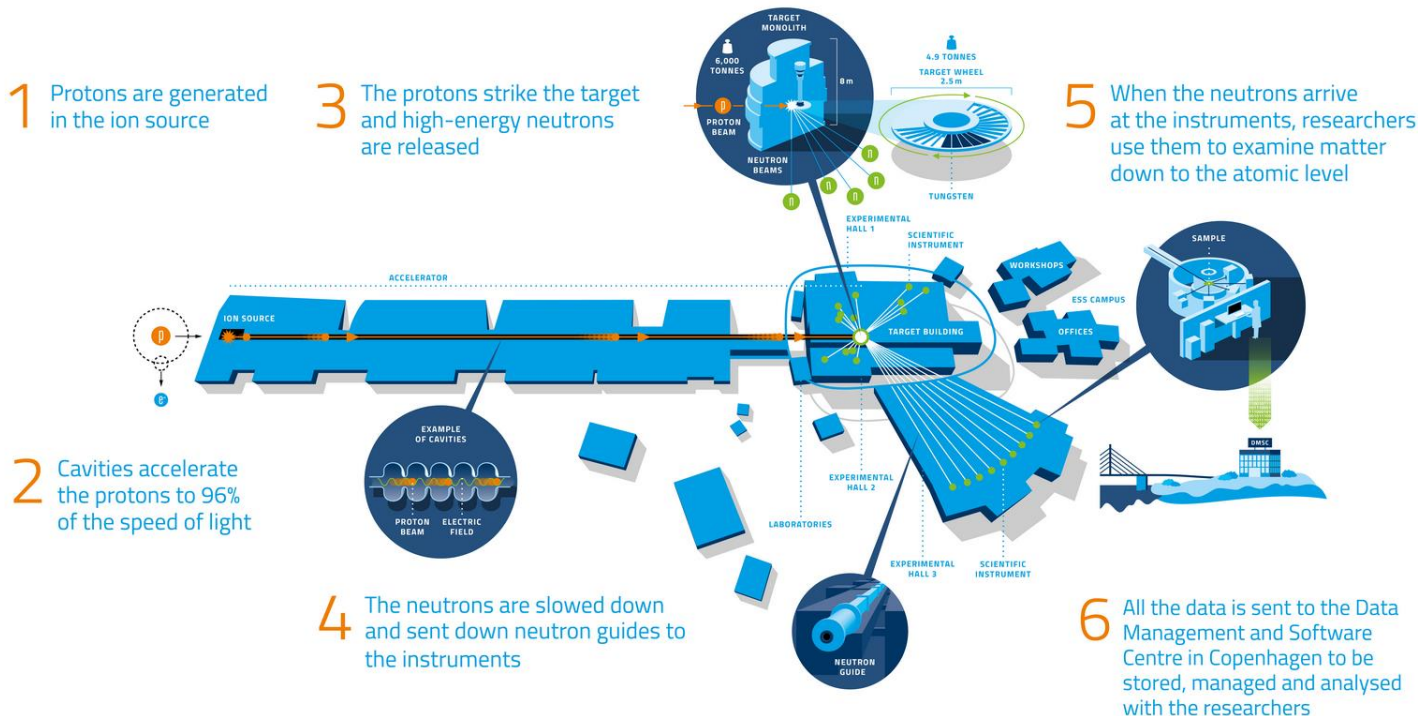
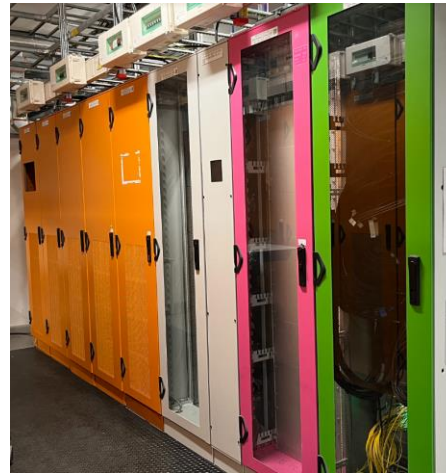


Operators are the same everywhere :)
Cooling water art, air-conditioned racks,
'new accelerator' clean!



Host Facilities – Max IV and ESS

- The European Spallation Source (ESS) is a European Research Infrastructure Consortium (ERIC), a multi-disciplinary research facility based on the world's most powerful neutron source. The facility began construction in 2014.
- Complications due to contributors from 60 countries speaking 60 versions of English!

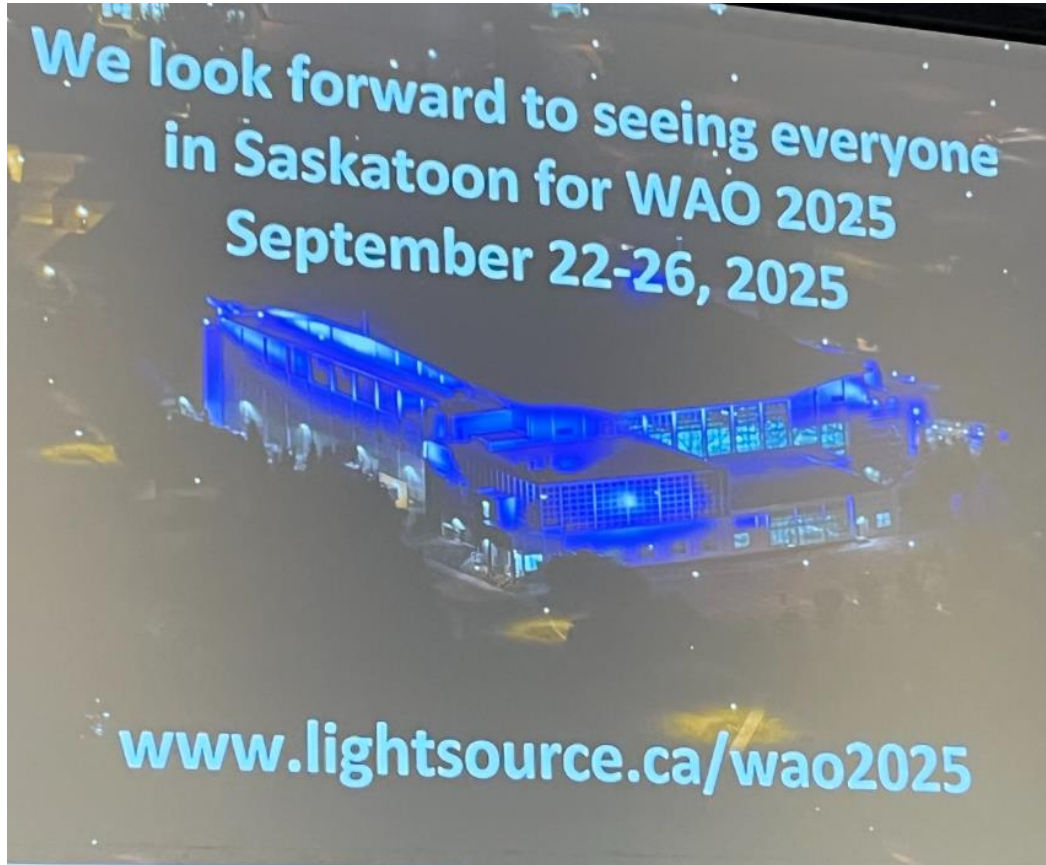


Color coded racks, shiny klystrons.
Fantastic chaos of a proton source front end!



The **Accelerator Reliability Workshop** alternates with the **Workshop on Accelerator Operations**

2025 WAO will be in Canada
2026 ARW will be in Japan





Helsingborg at 10 pm!

Excursion to Kronborg Castle, Denmark
UNESCO World Heritage Site

