Fixed Target Secondary beamlines

Feedback from operations

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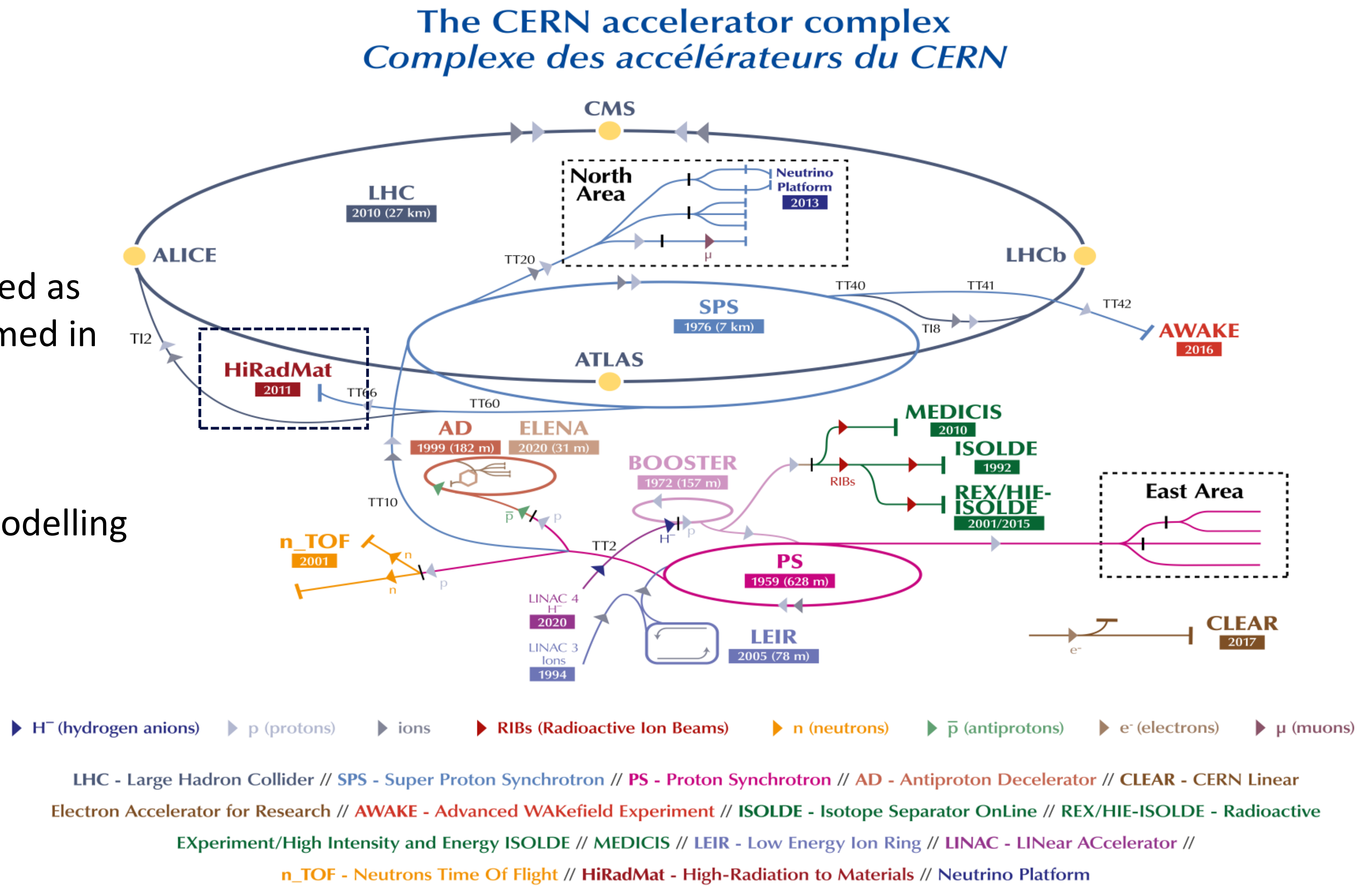
Date: 10.12.2024

Scope of the presentation

The slides are organised as per the four pillars aimed in the workshop.

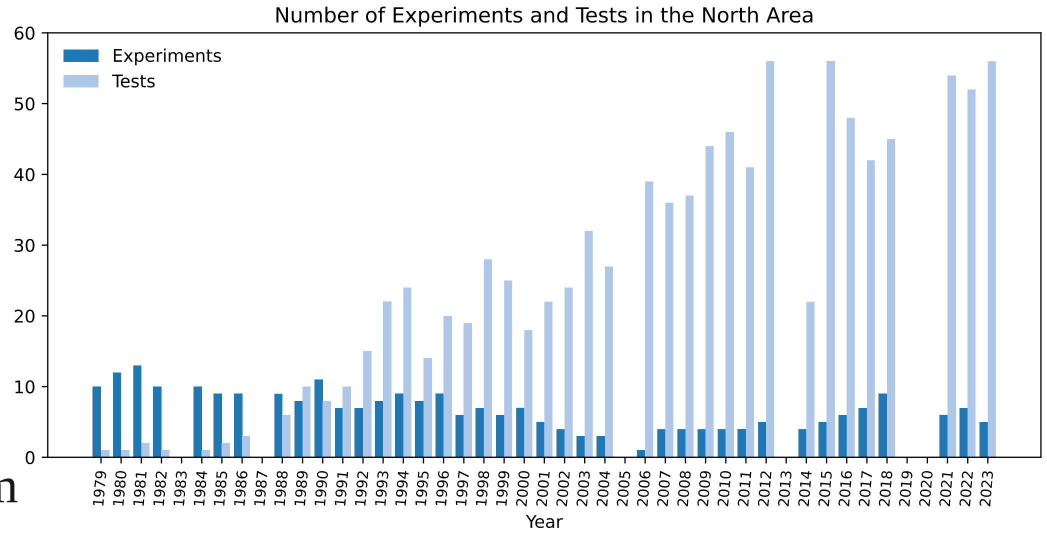
- Operation
- Equipment
- Beam Dynamics Modelling
- Controls, Data & Automation

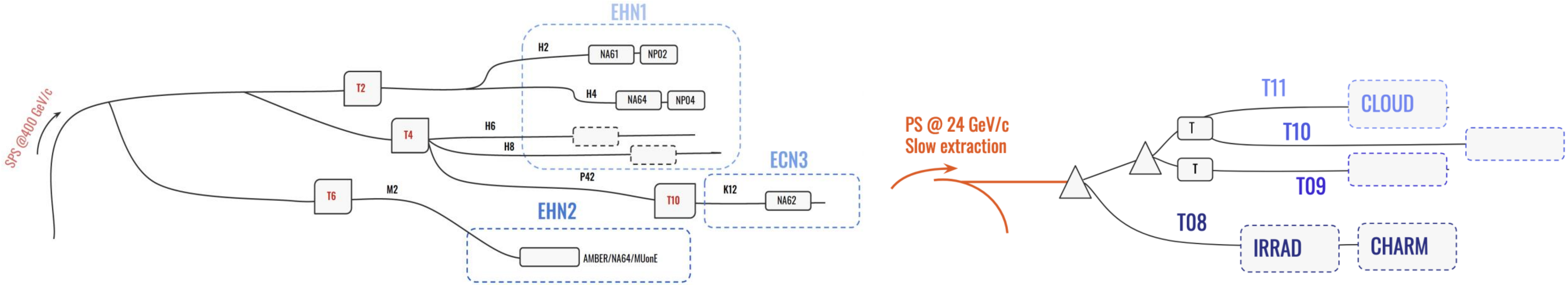


The North and East Area

- The SPS North and the PS East Area are one of the most diverse experimental facilities, serving **primary and secondary proton, hadron, electron, muon, and ion beams** to yearly over **200 user** teams for fixed target experiments (currently NA61, NA62, NA64e/μ, AMBER), the two large neutrino platform cryostats, to the GIF++, IRRAD/CHARM and CERF irradiation facilities, and to several experimental areas used for detector R&D.

- There are a total of seven beam lines in the North Area and 4 beam lines in the East Area with attached experimental areas for a combined more than **2000 users**.



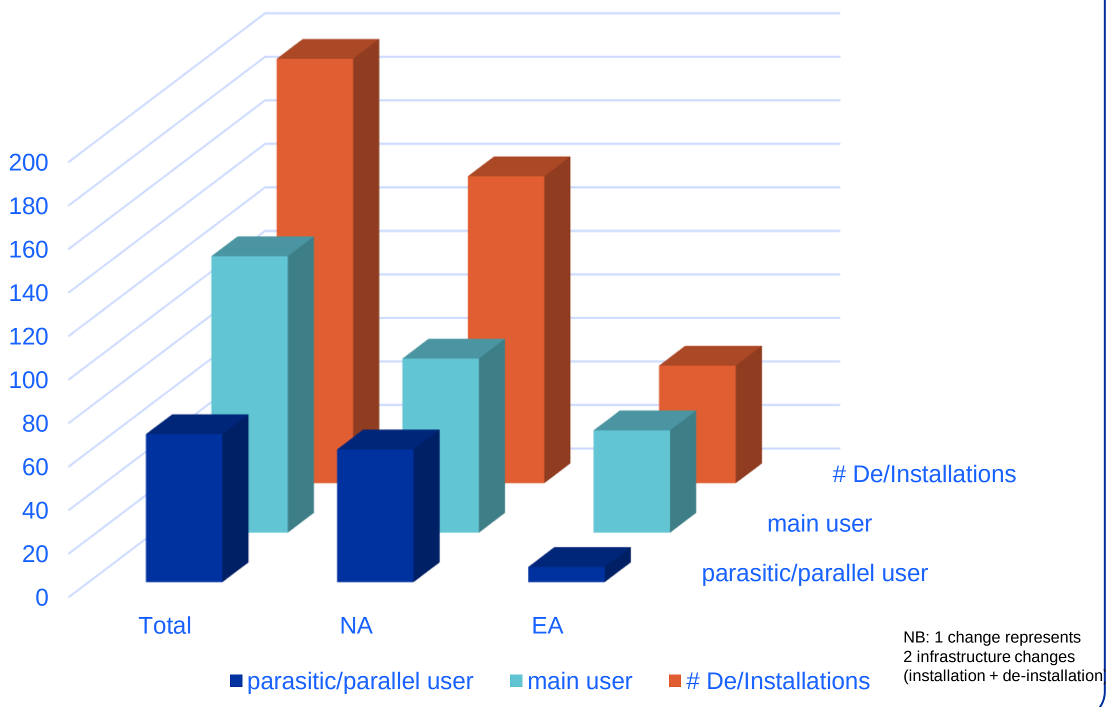


Operation

(Highlights)

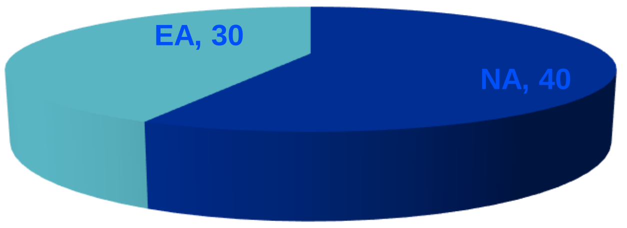
Beamline Users

2024 Run - # of infrastructure Changes



- **Record-high number of test beams and experiments** in the North and East Area in 2024.
- **High flexibility required**: About 10% of the users ask for substantial last-minute changes. In addition, new user additions and cancellations make life interesting!
- **Communication is key**: A strong collaboration between equipment teams, SPS/PS physics coordination, BE-OP, safety, and the beam physicists is essential for successful operation of such an amount of test beams.

# of distinct installation days



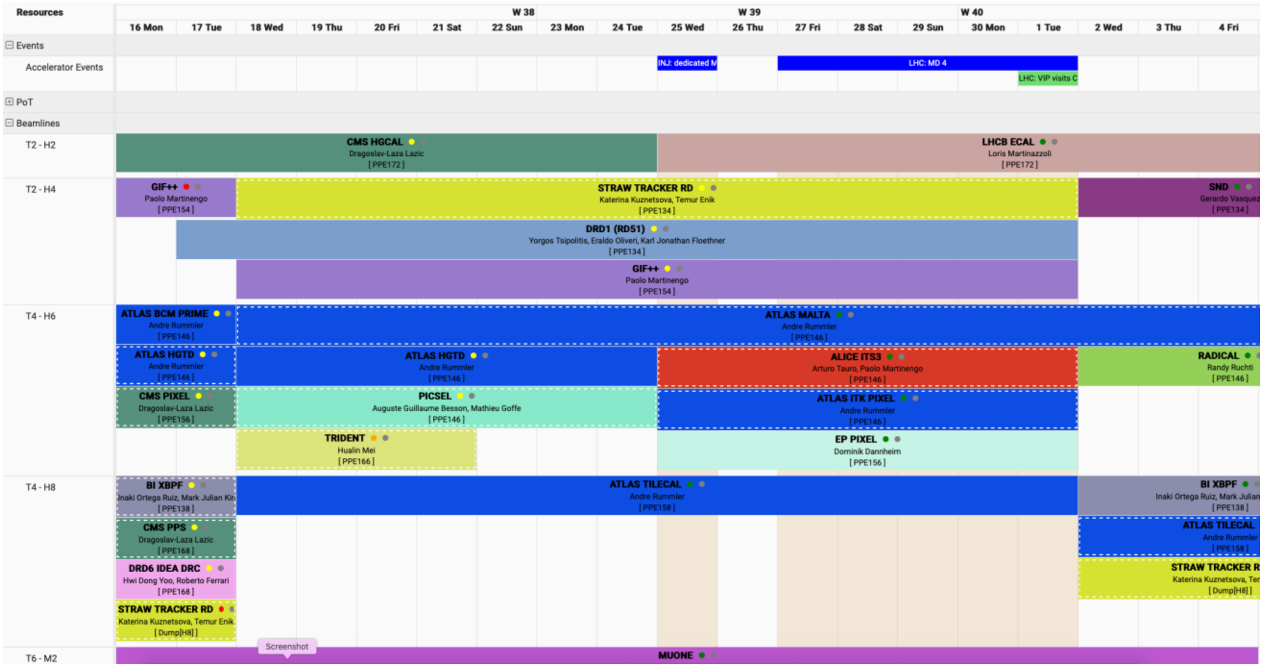
normally 1x/week (Wednesday),
some Friday, Saturday & Monday
exchanges were accommodated

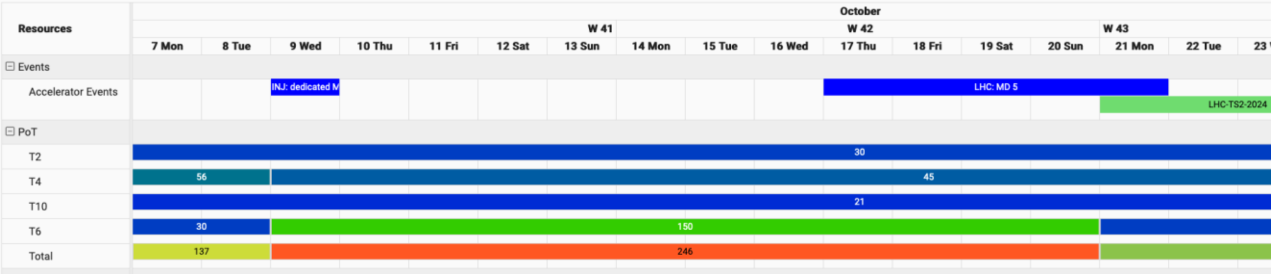
Process of Test Beam User Changes

Users Meeting: Thursday morning → SBA Meeting: Thursday afternoon → NA and EA Coordination Meetings: Monday morning → Implementation / User Changes: Wednesday

ASM – Accelerator Scheduling Management

- Extension of the ATS-wide scheduling tool towards all experimental areas, fully available since the 2024 run.
- The idea is to organize and streamline all aspects of all North and East Area infrastructure, user installations, and beam operation in one spot.
- The tool includes all experiment and test beam infrastructure needs, installation and de-installation tasks, allowing for storage of all user communication with the technical teams and the beam physicists
- A weekly overview of all configurations and tasks is available, including MDs.
- Management of requests for protons on target by beam physicists available, allowing for forecasts and coordination with the accelerator operators.
- **Very good collaboration with BE-CSS!!**

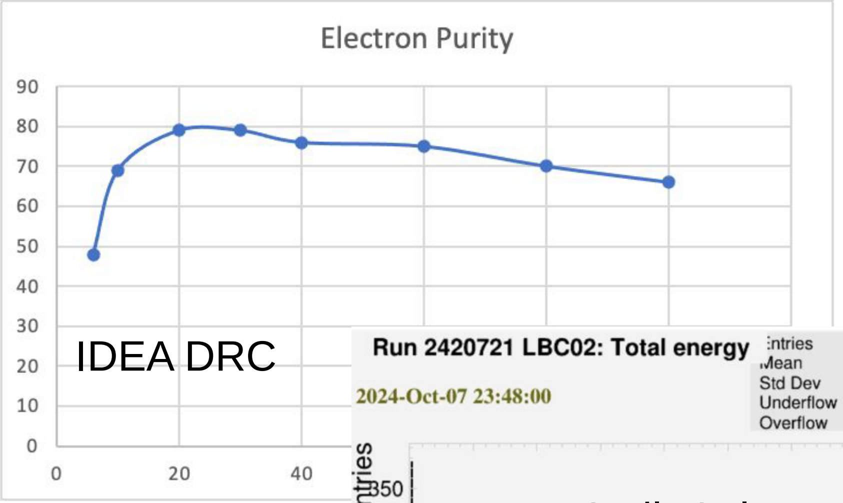


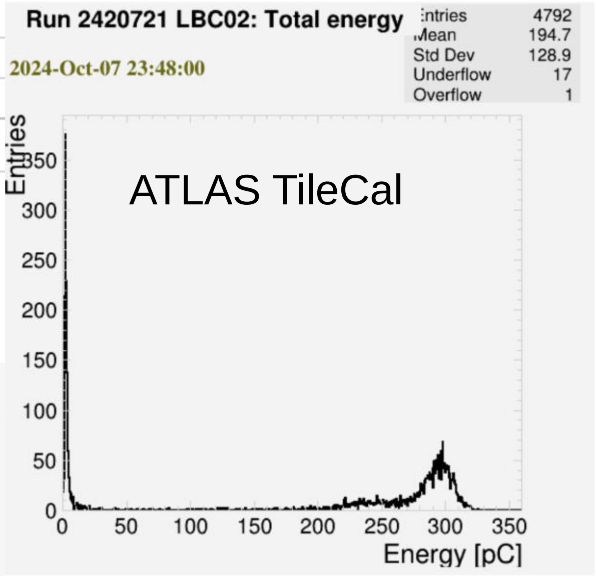


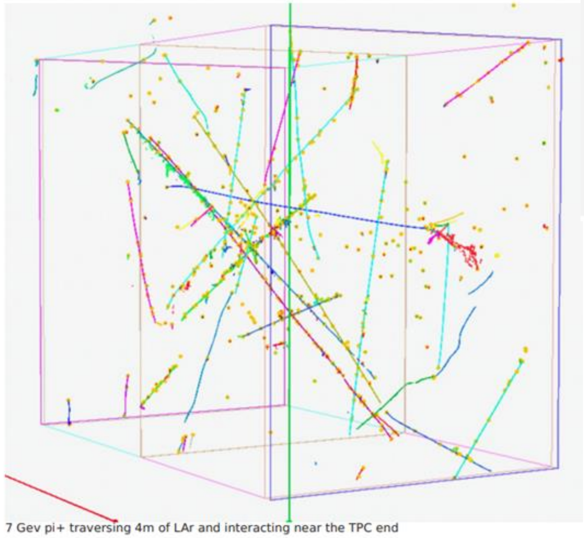
North Area Proton operation

- Electron beam users in H6 and H8:
  - Following the improvements in the electron beam qualities in H6 and H8, many electron users could be scheduled → helping in the overbooking of H2 and H4 beamlines.
  - Electron beam was provided between 10 and 300 GeV with very positive feedback!

- First operation of the H4 VLE line for NP04 after LS2.
  - NP04 reported good agreement with the MC performed by BE-EA in 2018, and first-time measurement of anti-proton cross-section with Argon done.



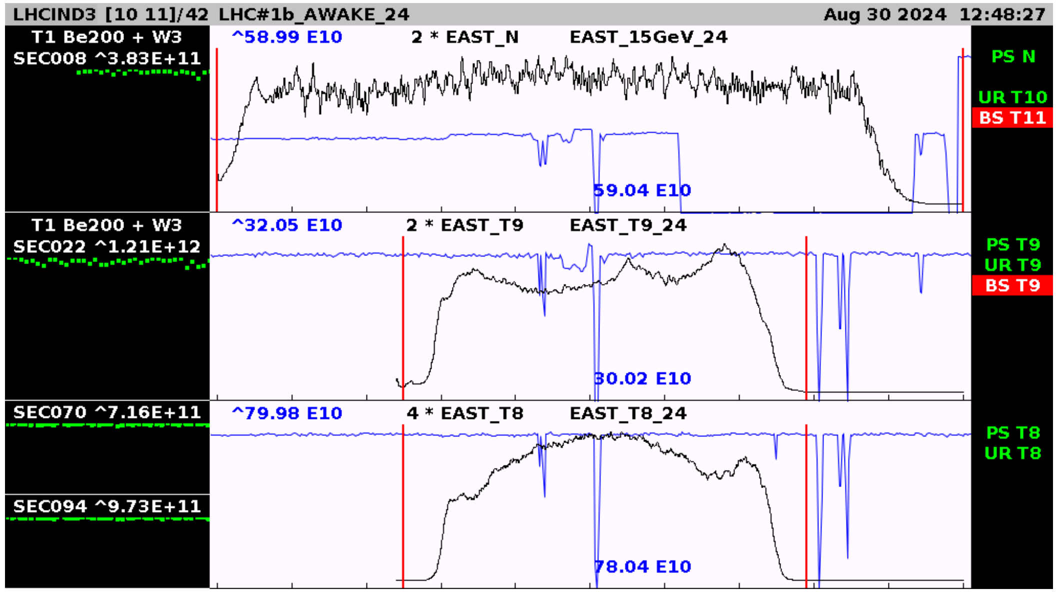


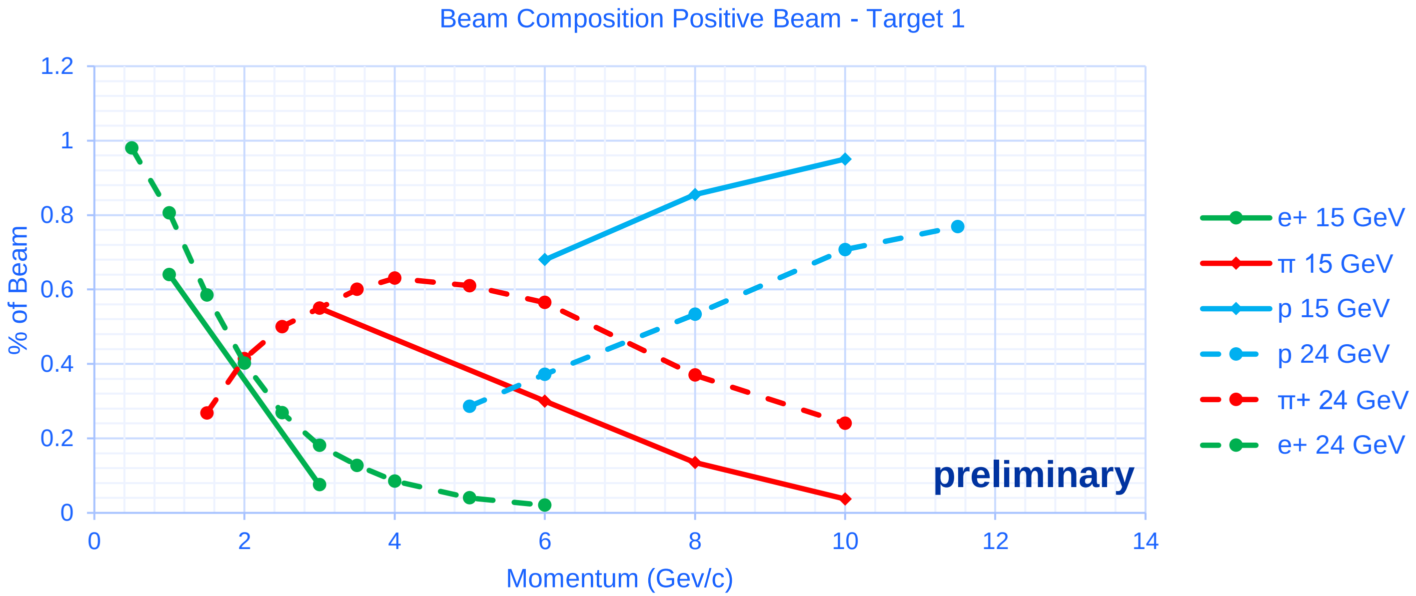


7 Gev pi+ traversing 4m of LAr and interacting near the TPC end

East Area Low momentum

- Request for low momentum primary proton and longer spills to the East Area.
  - 15 GeV primary proton beam with 0.8 s flat top tested in both T09 and T10. **Many thanks to BE-OP!**
  - Beam composition studies performed in T10 → Lower primary beam momentum helps in hadrons at lower momentum. A very important improvement in the flexibility of the lines.
  - Provided to users with positive feedback.





Higher intensity requests post-LS3

Category	Exp.	Beam line	Target(s)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
R&D	HL-LHC, FCC, DRDs, muon collider	H2	T2	30	30	30	30	30	30			30	30	30	30	30			30	30	30	30	30
		H4 & GIF++	T2	30	30	30	30	30	30			30	30	30	30	30			30	30	30	30	30
		H6	T4	30	30	30	30	30	30			30	30	30	30	30			30	30	30	30	30
		H8	T4	30	30	30	30	30	30			30	30	30	30	30			30	30	30	30	30
		H8 electrons	T4	30	30	30	50	50	50			50	50	50	50	50			50	50	50	50	50
		T09	East_T09	0.3	0.3	0.3	0.3	0.3	0.3			0.3	0.3	0.3	0.3	0.3			0.3	0.3	0.3	0.3	0.3
		T10	East_N	0.3	0.3	0.3	0.3	0.3	0.3			0.3	0.3	0.3	0.3	0.3			0.3	0.3	0.3	0.3	0.3
Dark Matter and FIPS	NA64-e	H4	T2	80	80	80	90	100	100			≥150	≥150	≥150	≥150	≥150			≥150	≥150	≥150	≥150	≥150
	NA64-h	NA/T09/T10	NA/East								Test	25	25	25	25	25							
	NA64-μ	M2	T6	50	50	50	50		50			100	100	100	100	100			150	150	150	150	150
	BDF/SHiP	P42	dedicated										Test	≤400	≤400	≤400			≥400	≥400	≥400	≥400	≥400
	MADMAX	H8, w/o beam, only YETS/LS			0	0	0		0	0	0												
Precision Physics	NA62	K12	T4/T10	75/40	75/40	56/30	40/22	40/22	40/22														
	MUonE	M2	T6		135	150	150	150	150			≥150	≥150	≥150	≥150	≥150							
	NA63	H4	T2	50	60																		
	DsTau	H2	T2	25	25	50																	
QCD	COMPASS	M2	T6	130	135																		
	AMBER Rp	M2	T6	Test	Test	Test	Test	100	100														
	AMBER DY	M2	T6			Test	150	150	150			≥150	≥150	≥150	≥150				*AMBER Phase 2 (in preparation)*				
	AMBER spectroscopy	M2	T6									100	100	100	100	100							
	NA61 & NA61++	H2	T2	35	35	50	50	50	50			50	50	50	50	50							
	NA60+	H8 prot. (x 1e8)	T4						Test			1	1	1	1	1			1	1	1	1	1
	NA60+	H8 ions (x 1e8)	T4			Test	Test	Test	Test			5	5	5	5	5			5	5	5	5	5
Neutrino-related Beams	ProtoDUNE-SP	H4	T2				50	50	50														
	ProtoDUNE-VD	H2	T2					50	50														
	WCTE	T9	T9				0.3	0.3	0.3														
	NA61 low energy	H2/H4	T2									50	50	50									
	SBN (ENUBET+NUTAG)	new	new																≤100	≤100	≤100	≤100	≤100
Others (astroparticle physics, atmospheric chemistry, …)	AMBER antip	M2	T6		50	50	50																
	NA61 antip	H2	T2					50	50			50											
	CLOUD	T11	T10/T11	0.3	0.3	0.3	0.3	0.3	0.3	0	0.3	0.3	0.3	0.3	0.3	0.3							

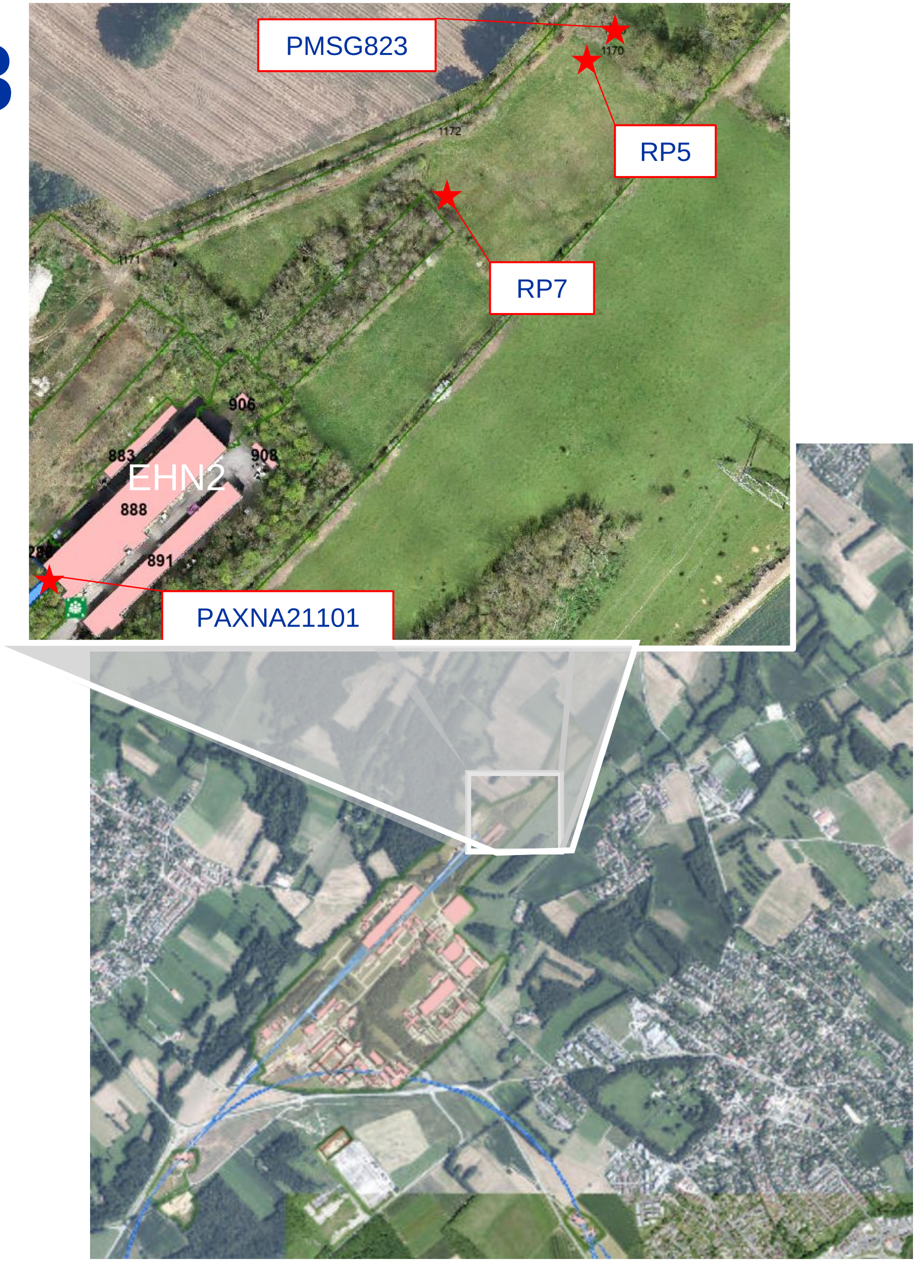
Numbers are needed units on target (= 1e11 protons). 0 = running without beam. More dark = more likely / approved experiment. Less dark = less likely / test. **This table is not official and not approved.**

Higher intensity tests for post-LS3

- Many users request high intensity beams post-LS3 including fixed target experiments like AMBER, MUonE and NA64.

- To potentially increase the muon intensity in M2 a high intensity test was conducted **successfully together with RP**:
  - Currently, the limitation comes from radiation protection at the CERN fence.
  - Unlike for COMPASS / AMBER and their required beam height, the M2 beam can be deflected slightly downwards for MUonE.
  - During the test, the beam was deflected downwards by about 5 mrad, concluding that deflection of the beam can reduce the dose rate due to the muon beam at the fence by almost a factor of three.
  - Further studies including optimising the transmission and acceptance of the beamline as well as location and integration of the magnet are planned for next year.

RP monitor locations



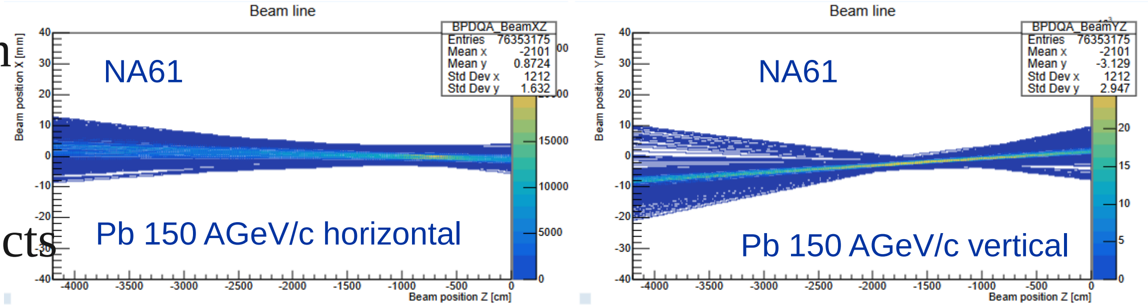
Higher intensity tests for post-LS3

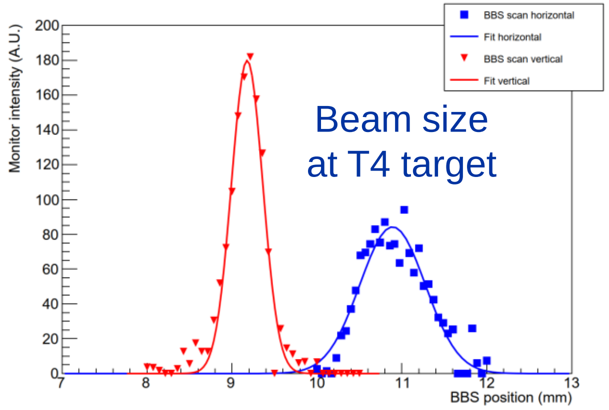
- Many users request high intensity beams post-LS3 including fixed target experiments like AMBER, MUonE and NA64.

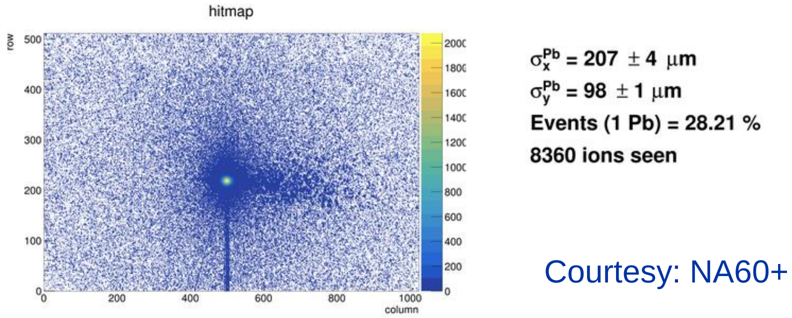
- To meet the request of NA64 to increase their statistics by more than an order of magnitude and continue Light Dark Matter searches with world leading sensitivities:
  - Tests performed to send high intensity up to 1.3×10^7 electrons / spill with 100 units on T2 by adjusting collimators.
  - **Upto 1×10^7 electrons/spill beam quality remained the same.**
  - **For higher intensities background and halo starts to increase.**
  - Increasing intensity on T2 will aid in better collimation and further reduction of beam halo.
- Beamline modifications for further reduction of the spot-size and improving the particle ID are being studied for implementation during run 4.

Ion Operation - 150 AGeV/c

- Quick ion beam commissioning allowed NA61 to start the ion run two days in advance.
- Still, ion beam users suffered for some time from transverse beam position fluctuations, in particular due to hysteresis effects when going to and coming back from LHC filling.
- Collimator settings had to be adapted frequently to keep a constant intensity for the NA61 experiment due to source fluctuations.
- For NA60+ measurements for beam size and divergence done at T4 which will serve as an input for H8 beamline simulation. **Many thanks to BE-OP!**
- The required ion beam intensity for 150 AGeV/c has been reached, with a good spot size for NA60+.
    - In 2023 2.4 x 10^6 Pb ions were reached while in 2024 10^7 achieved **in collaboration with RP**.





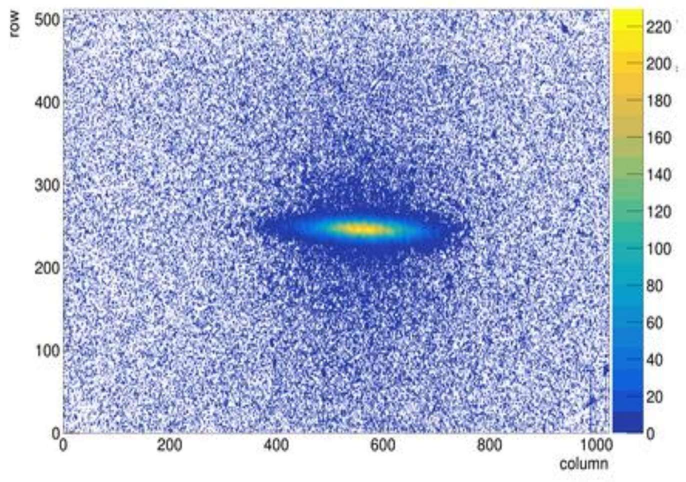


Courtesy: NA60+

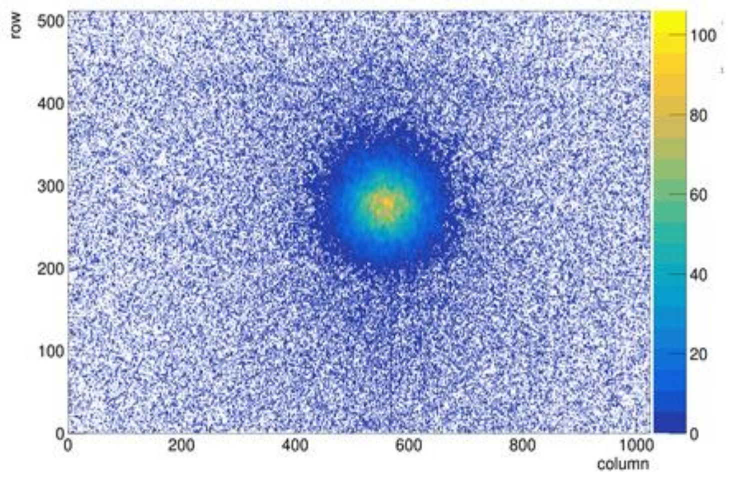
Ion Operation - 13.5 AGeV/c

- At low momentum, 13.5 AGeV/c, NA60+ request: beam spot σ <0.6mm in both planes
- Different optics tested at this momentum. Requires further development of optics, possibly movement or addition of a quadrupole, to be investigated.
- Minimisation of material critical for low momentum beam. Removal of a single scintillator and related vacuum windows (~1.8% X0) at a key point reduced the vertical beam size from 900 µm to 200 µm. Further improvement of vacuum (VXSS) would be beneficial.

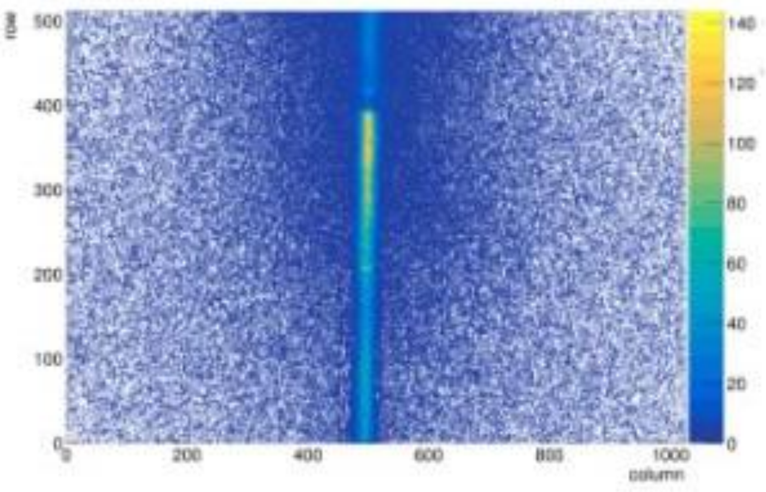
$(\sigma_x , \sigma_y) = (1.6, 0.18)$ mm



$(\sigma_x , \sigma_y) = (1.2, 0.75)$ mm



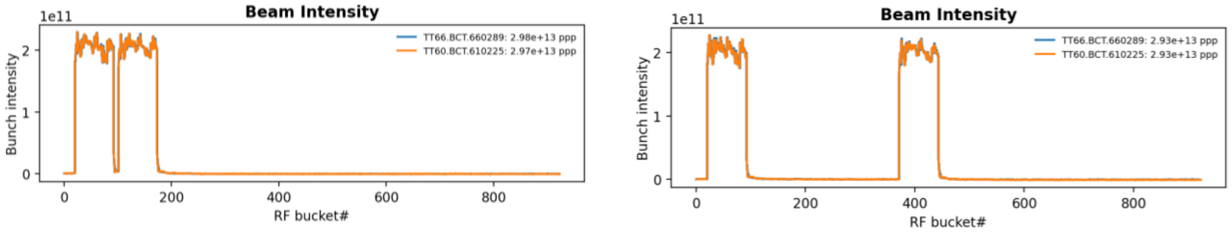
$(\sigma_x , \sigma_y) = (0.24, >2.3)$ mm



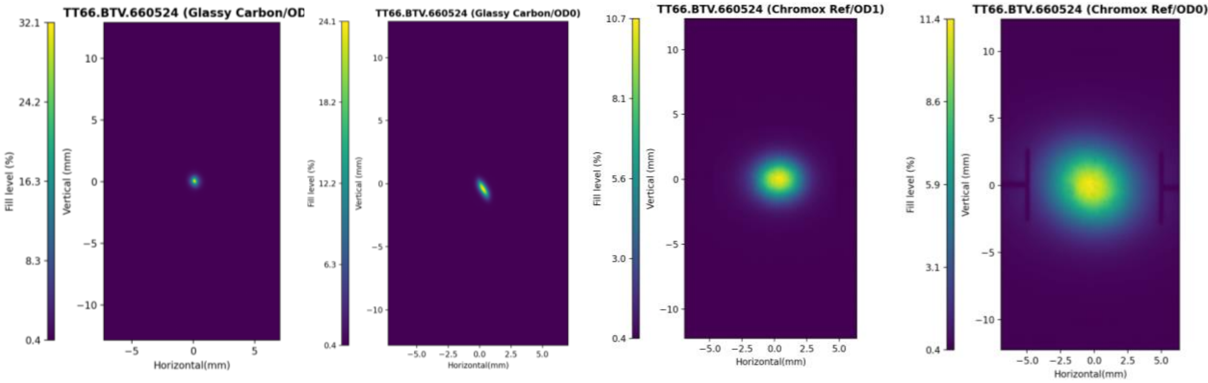
HiRadMat Operation

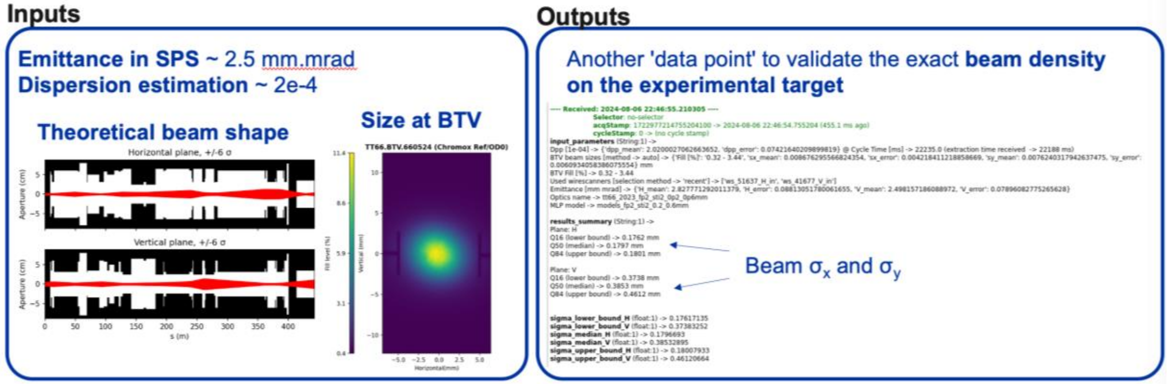
- HiRadMat operated 4 experiments.
  - **Running without parallel activities** favourable for everyone.
  - Pre-commissioning time slot a few days before actual physics time extremely beneficial.
  - All experiment finished before the end of the scheduled week, **all weekends returned to physics**. AWAKE and MDs also recuperated days from the HiRadMat weeks.
  - Nonetheless, stakes are high: experiments need to complete their program within one week and have no contingency.
- 288 bunches @ 1.9E11 ppb with a 0.25 mm x 0.25 mm beam size operated. Maximum density achieved so far. Versatile beam size and shape.
- **New live tool** developed by BE-OP and SY-ABT (F. Velotti & P. Zisopoulos) that provides a more realistic estimation of the beam size on the experiment based on parameters from the machine.
- BTV performance & optimisation to be studied further in 2025 in collaboration with SY-BI.

Usual batch spacing (225ns) | Maximum batch spacing (7 μs)

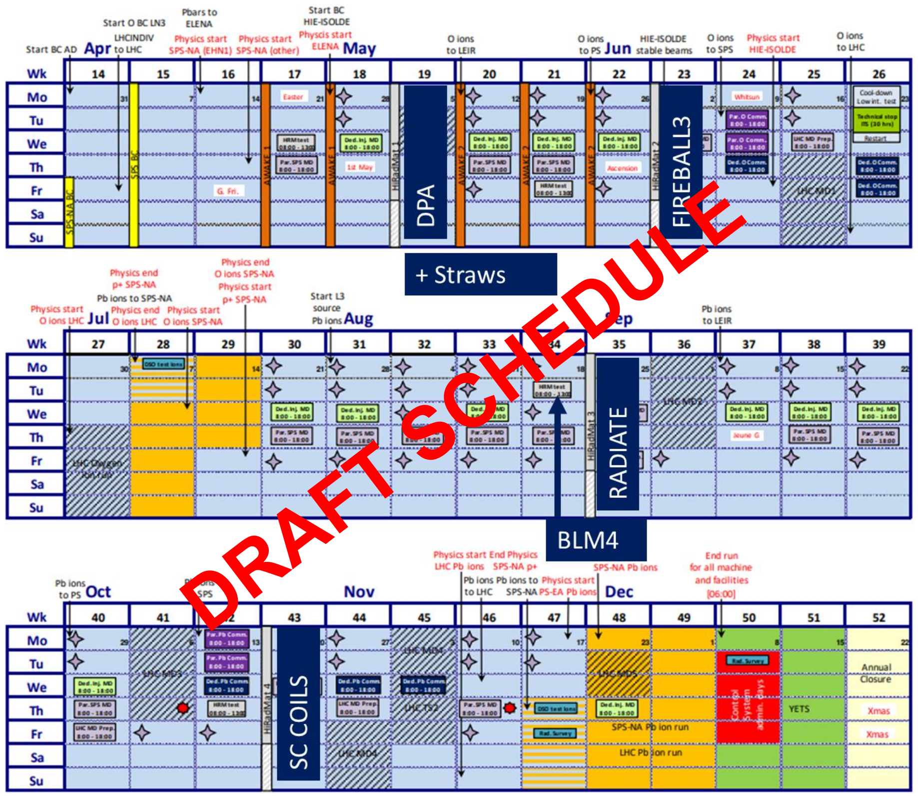


0.25x0.25 mm | 0.15x0.3 mm | 1x1 mm | 3x3 mm





HiRadMat Outlook for 2025+



- 6 experiments for 2025
  - HRMT63 DPA – JPARC
    - Measurement of displacement cross-sections.
  - HRMT69 StrawRad – SY/BI
    - Straw BPM devices in high radiation environments characterisation.
  - HRMT68 Fireball-III – Oxford University
    - Follow-up of measured instability with further improved setup.
  - HRMT67 RaDIATE-II – Fermilab (RaDIATE collaboration
    - Test of various materials for future target systems.
  - HRMT70 SCcoils-II – TE/MPE
    - Study of damage limit in SC coils for HL-LHC magnets.
  - HRMT71 BLM4 – SY/BI
    - Test and validate multiple types and production runs of BLMs.

ENLARGE THE POSSIBILITIES

- Letter of intent for ion beams in 2026 ; MD to prepare it to be requested for 2025
- MD to study lower momenta for HiRadMat (injection energy ?)
- New materials for the BTV (preparation of an experiment in 2026)

Equipment

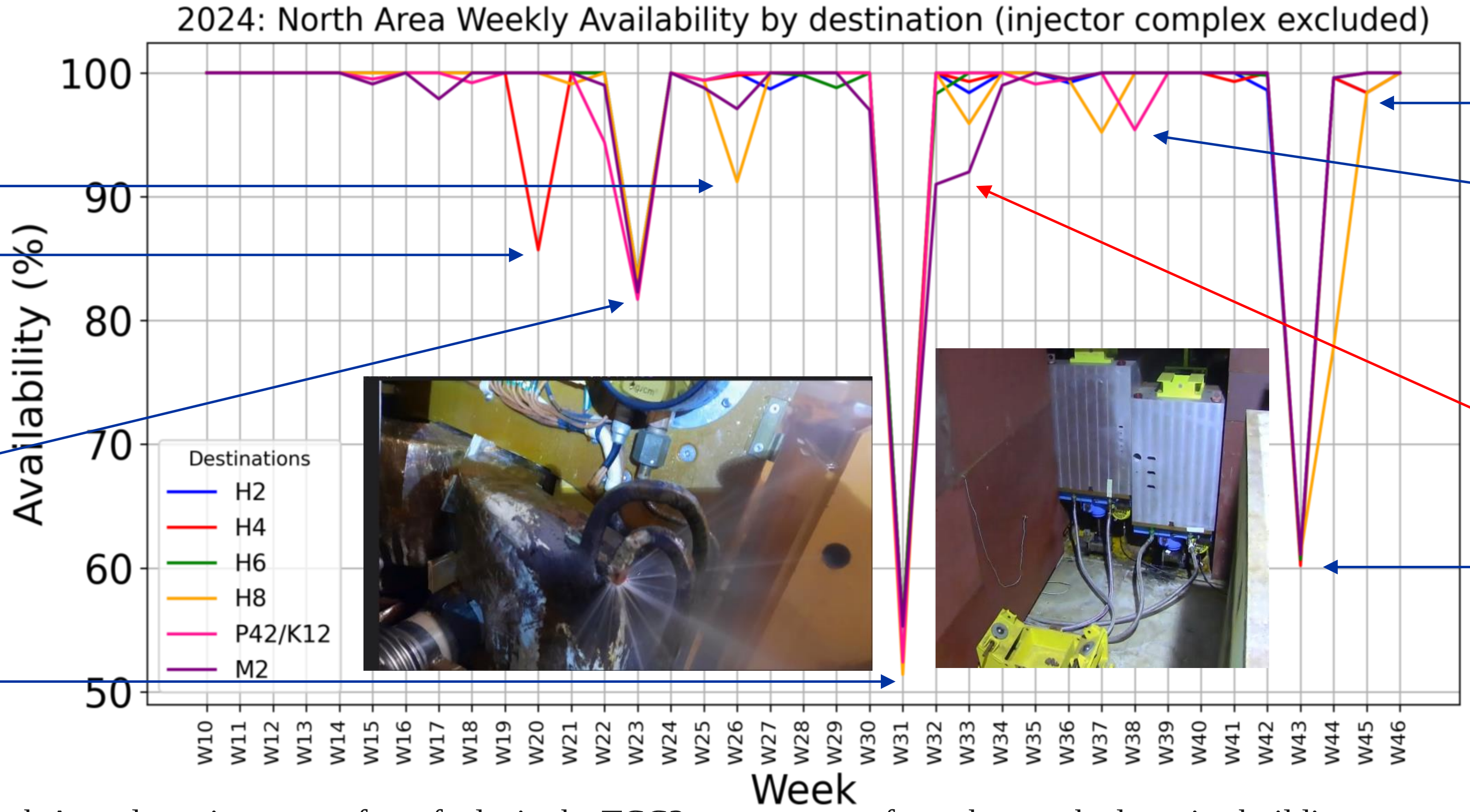
Availability 2024 (Automatic Fault Tracking)

Power converter issue quadrupole QSL.X0420033 (TCC2/BA80)

Power converter issue dipole MBN.X0220053 (TCC2/BA80)

Water leak quadrupole QNL.X0210049 (TCC2)

Exchange of QNL.X0210049 (TCC2)



H4 and H8 XTAX control issues (TCC2)

Power converter issues quadrupole QSL.X0420033 (TCC2/BA80)

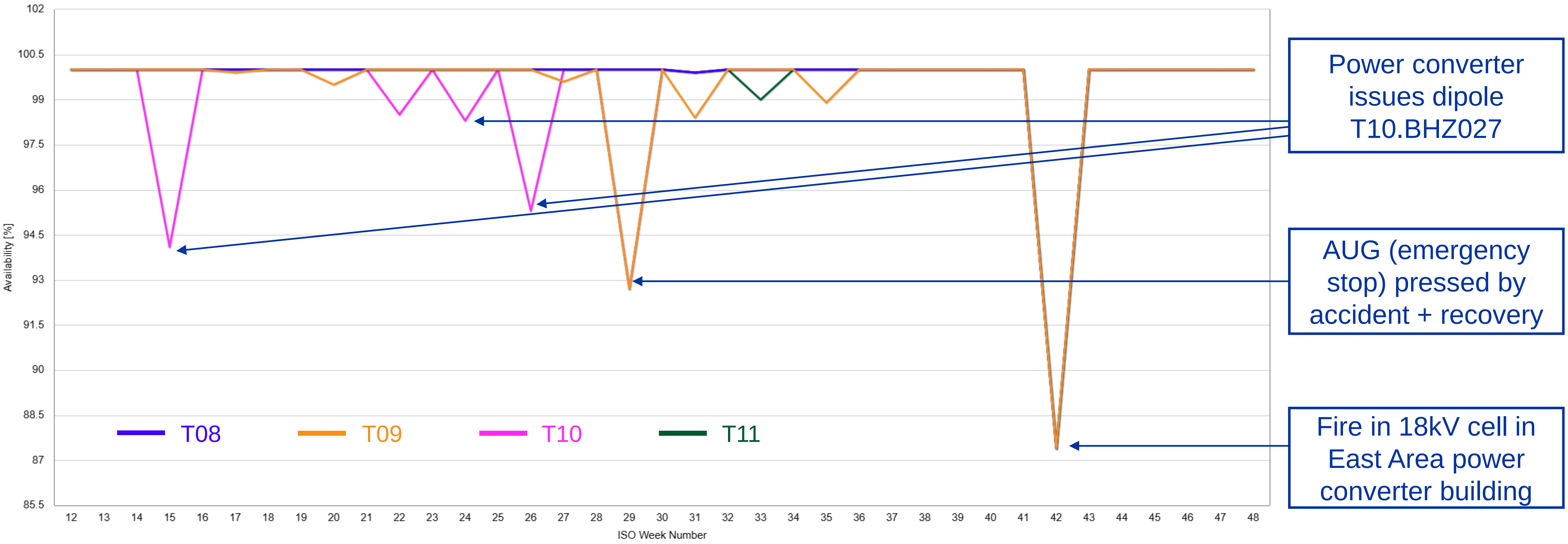
P42 and H8 XTAX moving issue (TCC2)

Leak on water circuit of dipole MTN.241128 (TCC2)

- This year, most of the North Area downtime stems from faults in the TCC2 target area or from the attached service building.
- Many faults will be addressed by the North Area Consolidation project, but due to the high activation levels in TCC2, we will have to survive at least until LS3 to get better reliability.
- The P42 XTAX fault nearly caused an extremely long downtime for the North Area, but thanks to the quick and **efficient reaction of all involved teams (BE-DSO, BE-CEM, BE-CSS, HSE-RP, BE-EA),** we were able to continue operation.

Availability 2024 (Automatic Fault Tracking)

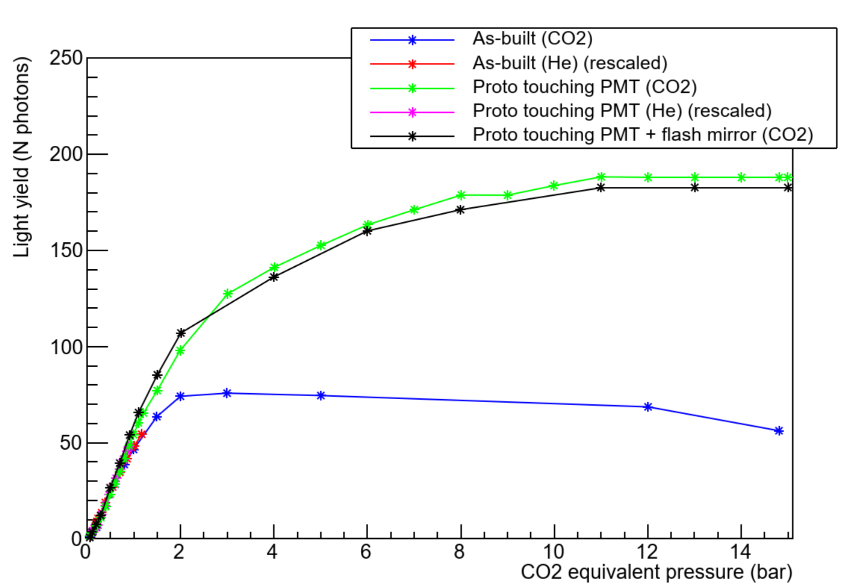
- Very good availability of East Area beams thanks to the LS2 renovation.



Particle ID detector improvements

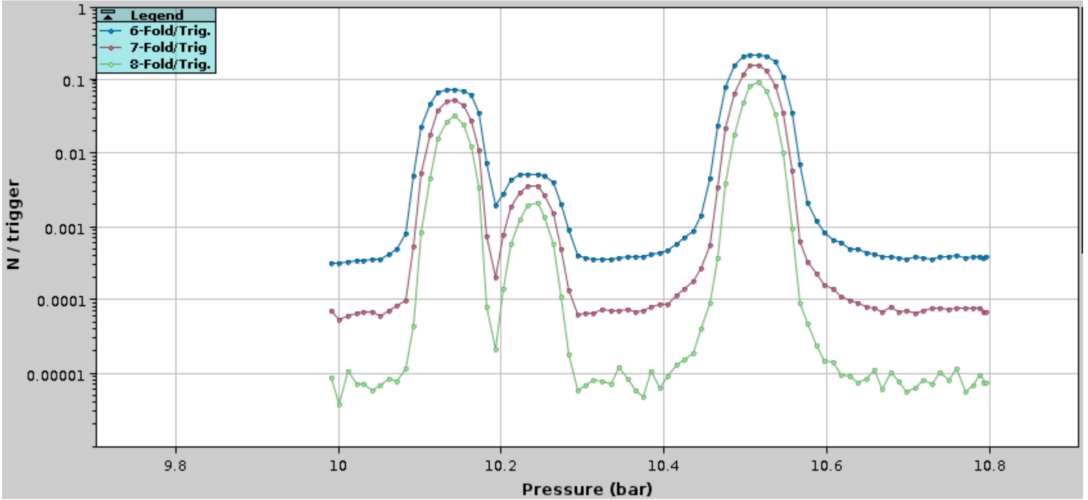
- Experiments and test beams rely heavily on particle identification cherenkov detectors (XCET, XCED).
- As part of NACONS many refurbishment efforts have been completed and many are still ongoing.
- New bodies and mirror have been manufactured and tested in the H8 beamline for the XCET detectors.
  - For the same 45-degree mirror, parabolic mirror prototype increases photon collection an extra 50% at 2 bar to 320% at 15 bar
  - The new XCET detector prototype has been designed, manufactured, inspected and tested according to the European standard EN-13445 (unfired pressure vessels)
  - HSE has validated the body, lifting access restrictions with new prototype

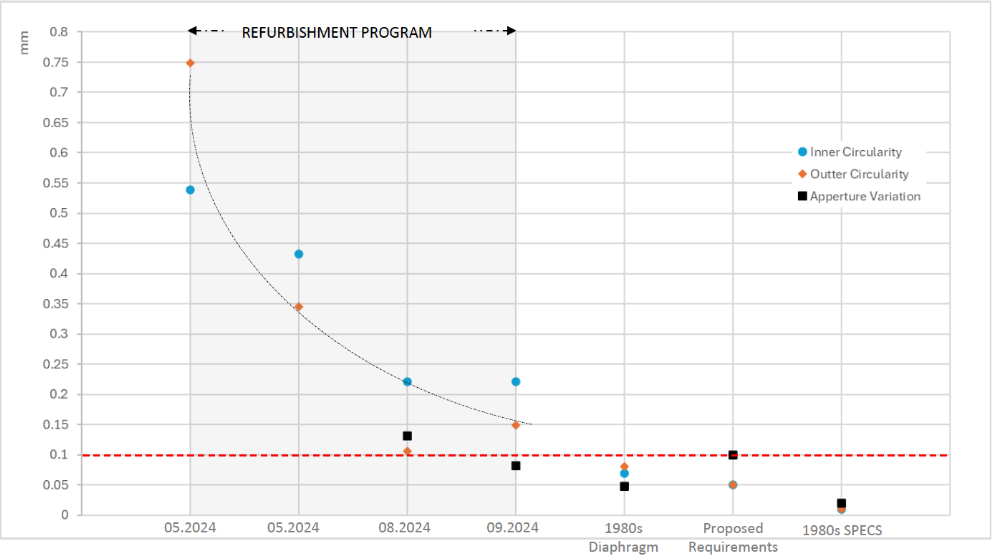
Successful collaboration with HSE, EN-MME, EP-DT, SY-STI and BE-EA!



Particle ID detector improvements

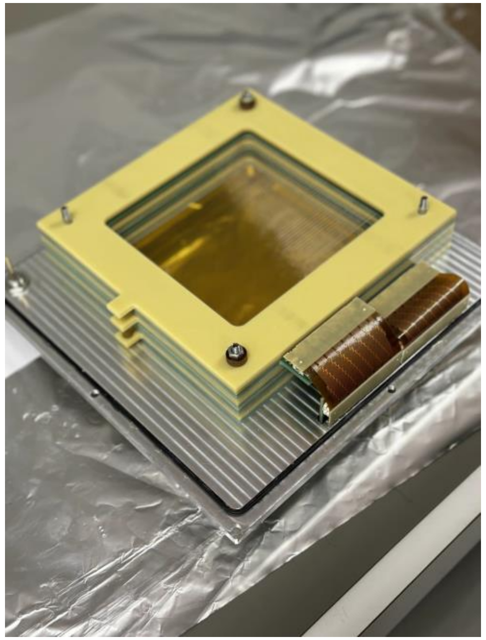
- Experiments and test beams rely heavily on particle identification cherenkov detectors (XCET, XCED).
- As part of NACONS many refurbishment efforts have been completed and many are still ongoing.
- Refurbished XCED detectors were installed in M2 for AMBER with improved motor control precision, diaphragm alignment and convergent algorithm for the motor controls in **collaboration between BE-EA and SY-BI**.
- Current performance still not according to the specifications but approaching the needed precision with each iteration.
- Procedure also being updated for the installation and commissioning.

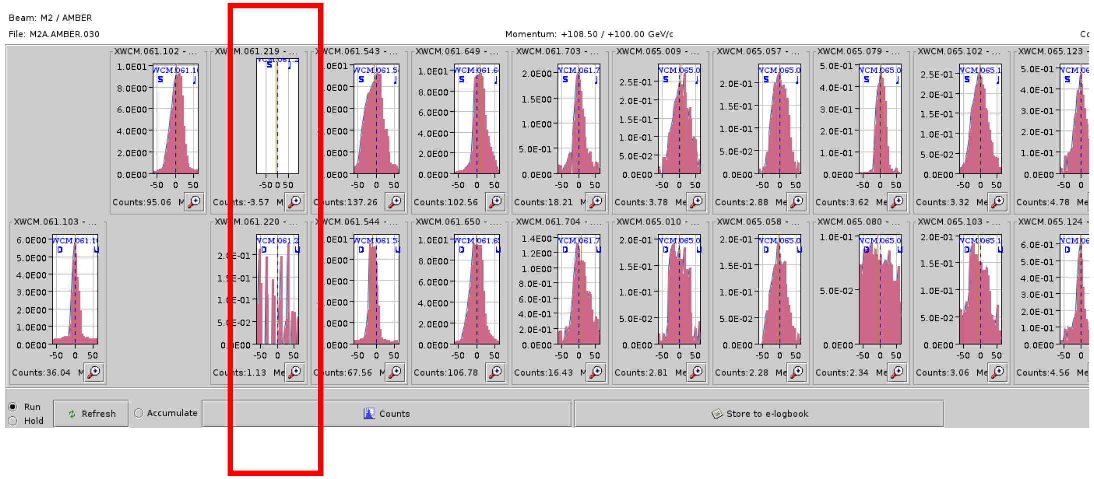




XWCM Critical Spares

- Spare situation critical for Large MWPCs (XWCM 20 cm x 20 cm) with only 1 spare available (recently repaired, although with a few dead channels) → M2, K12, CHARM operation depend on it.
- Spare situation for smaller chambers (XWCA 10 cm x 10 cm) is not critical with a few spares available and lower failure rates. They are not installed in high radiation areas.
- First 10 cm x 10 cm prototype (XWCA) tested in July 2024 with some unexpected delays with the weaving machine and other small problems with the prototype that were all solved.
- A second prototype is aimed for April 2025.
- During October already one XWCM found not working in M2. To be checked during YETS.
- **In case of any further faults and unavailability of spares, the 2025 and 2026 operation will be compromised.**





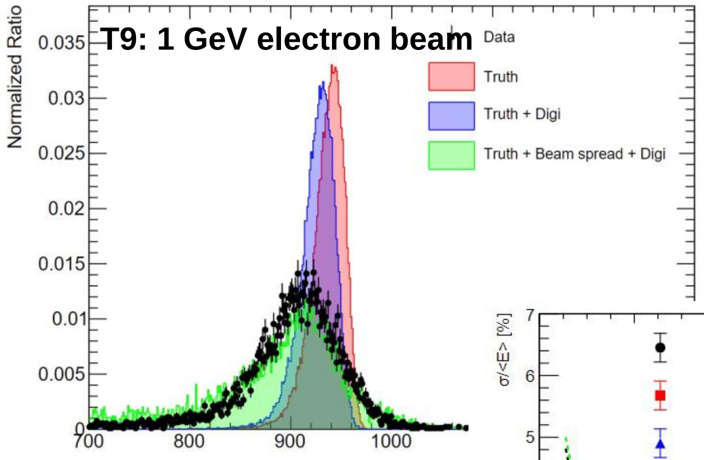
Future requests

- Critical devices like XCET and CEDARs are actively used for physics data taking by experiments. Faults can cause long downtimes and loss of physics if not treated quickly. Availability of experts outside working hours for such devices is critical.
- No spares available for the pressure sensor electronics for XCET/CEDARs.
  - NACONS was able to advance the money to buy new sensors with possible deployment planned for the YETS. This is critical for operation.
- BBS scans at target extremely difficult for low momentum ion beam with large beam size and small filament. Signal is very small and noisy.
  - Future requested upgrade to BSGs in target instrumentation is a likely solution.

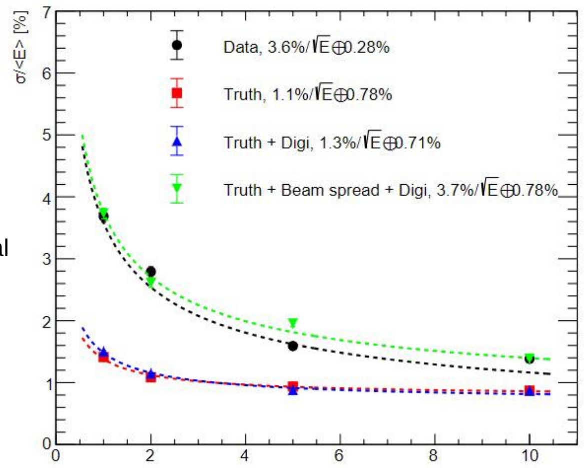
Beam Dynamics Modelling

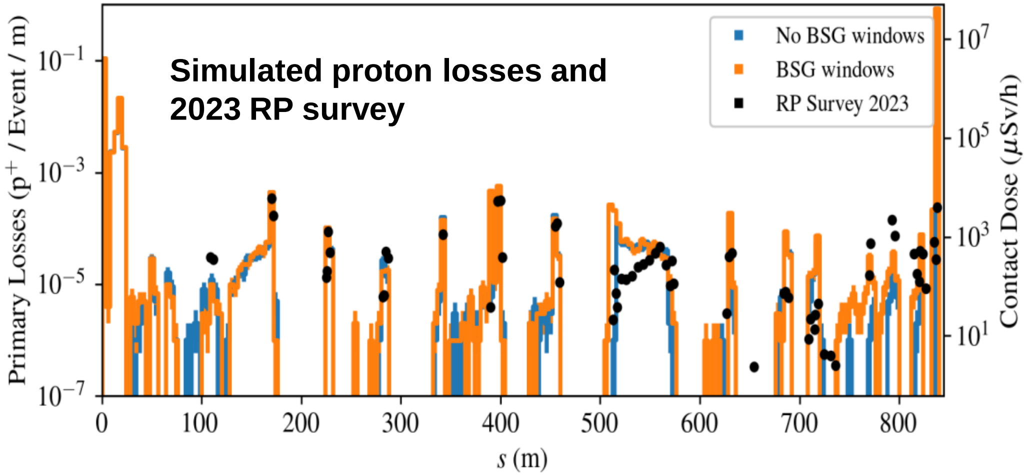
Beamline Modelling

- A lot of progress done to implement all beamlines in Geant4 based simulation package BDSIM as well as FLUKA.
- Ideal to share models and input for users for their simulations.
- Detailed simulation for T9 low momentum electron beam to validate detector response for CALICE/DRD6.
- P42 BDSIM model with all beamline material finalised
  - Validation with activation pattern. Very good agreement!
  - Verified with FLUKA model of XTAX region
  - Informing engineering decisions for the HI-ECN3 project.
  - To be used for muon background studies for SHiP.

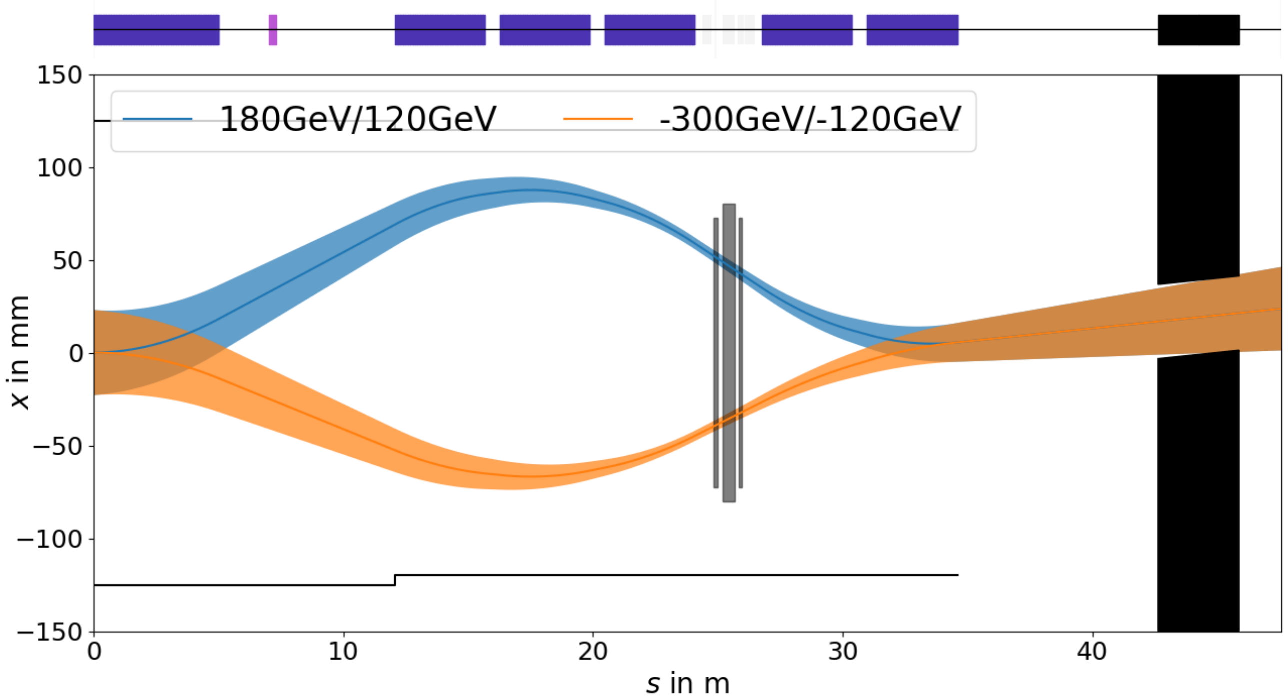


Energy resolution for CALICE crystal calorimeter

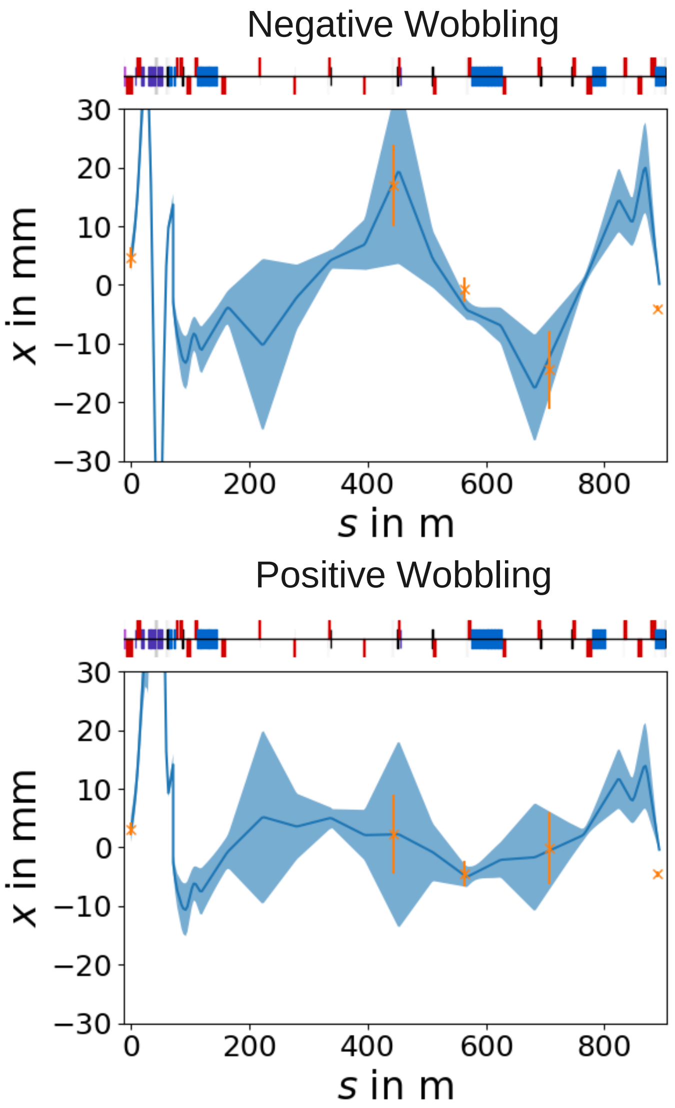




Beam Trajectory through T4 and along P42



Orange: Mean position with 1σ obtained from profile fit to grid data
Blue: SFTPRO optics in TT24; mean position with 1σ envelope obtained from fit of intial angle to match grid data



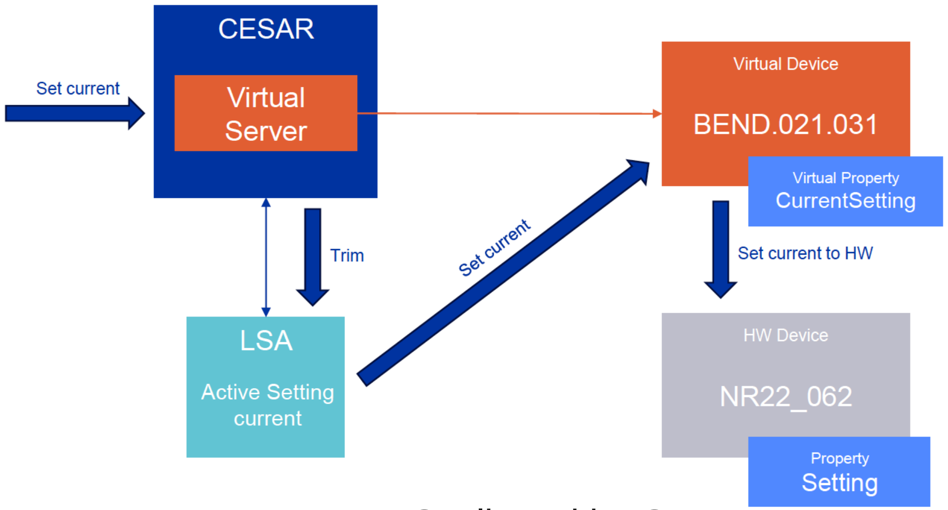
- Investigated impact of T4 Wobbling on beam trajectory in P42.
- Beam distributions measured with BSGs in TT24 and P42.
- Constrained mean position in TT24 through measurement. Horizontal angle obtained through fit to grid data
- Result is sensitive to auto-steering on T4
  - Important to move TBIU/D to horizontal position of split foils.
  - Test will be redone in 2025 with correct TBIU/D position and without auto-pilot and adding a degaussing of wobbling magnets between different wobbling settings.

Controls, Data & Automation

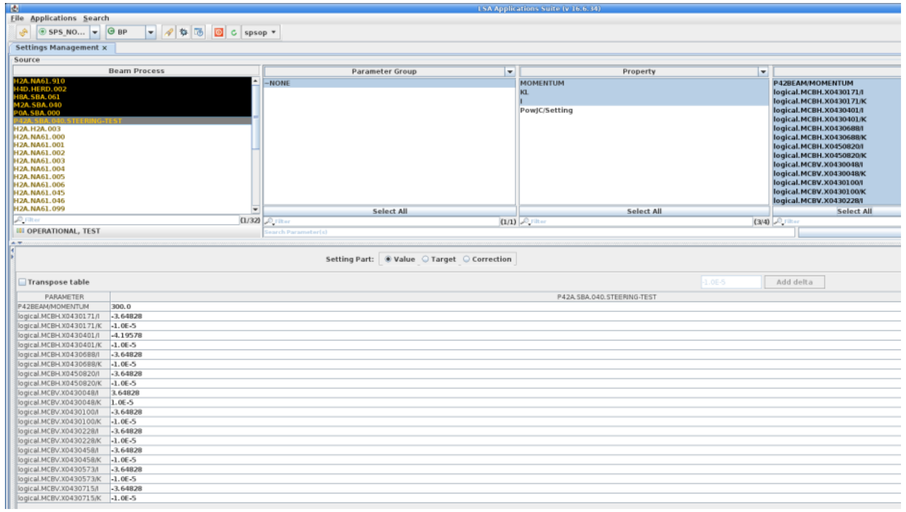
M. Peryt, T. Oliveira

CESAR-LSA Integration

- In frame of NACONS aim to bring CESAR closer to Accelerator Controls with possible introduction of high-level parameters.
- CESAR stays in maintenance mode until its end of life planned for LS3.
- Highlights of 2024:
  - LSA has been adapted to handle Experimental Areas settings management.
  - LSA for model-based controls, with the first model of North Area P42 (control of steerers tested).
    - Currents set and verified without beam. Set ±10μrad in all Trims.
    - Momentum scaling verified (important for NA)
    - Can now be used for steering MDs
  - InCA instances for East Area/North Area are in place.
  - Ongoing collaborative effort (**BE-CSS, SY-BI, BE-CEM, BE-EA**), to replace CESAR Virtual server with UCAP, https://edms.cern.ch/document/3095571.
  - Prototyping with Sequencer to automate LSA beam process loading and more.



Momentum Scaling with LSA



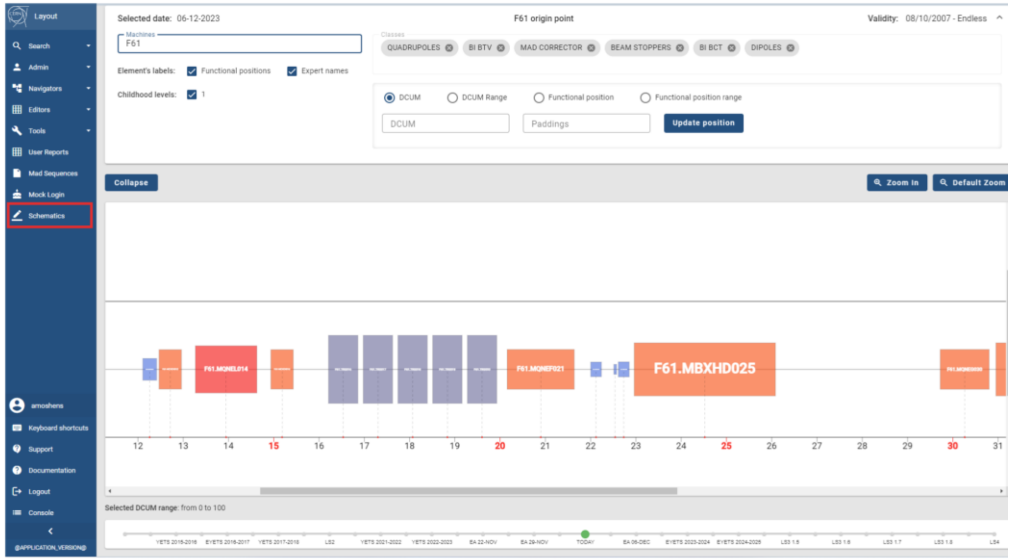
Experimental Areas Controls – next steps

M. Peryt, T. Oliveira

- Work on Accelerator Controls for EA is on track: data-driven Synoptics with WRAP + Controls services.
- End of Q3 2025: MVP* as initial version to validate with the expert users.
  - Data-driven (CCS and Layout).
  - LSA for model-based controls and settings management.
  - RBAC for authorization.
  - UCAP/FESA as device servers.
  - Sequencer integration for settings loading and access commands.
- End of 2025: first PRO version aimed at the end-user
- Staged deployment one beamline at a time
  - Progressively replacing CESAR instances
  - Careful deployment to be transparent to operation.
- YASP Steering to be tested in 2025:
  - Stitched TT24-P42 optics model now included in YASP.
  - Patched BSG names showed system worked correctly – awaiting full BSG name update.

Layout

Project Leader:
Pascal Le Roux



https://layout.cern.ch/beamline-schematics

Summary

- **A very productive and intense year with many highlights and challenges.**
- **A year full of excellent collaborations and achievements. Heartfelt thanks to all groups involved!**

Thank you

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