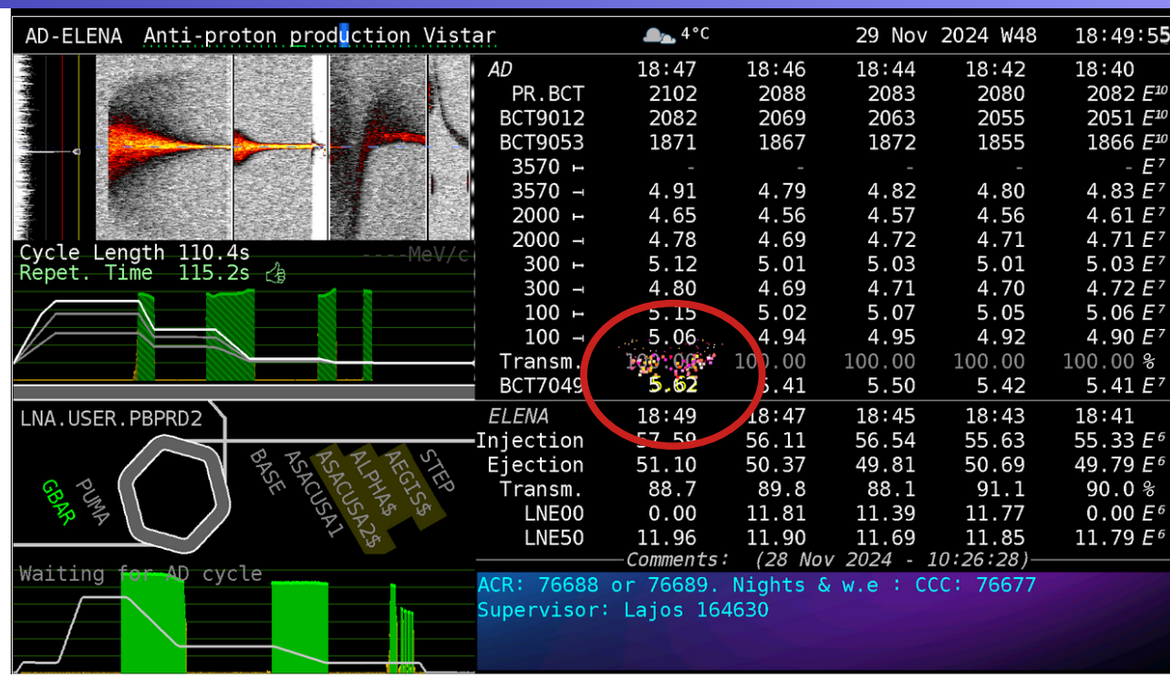
AD/ELENA performance in 2024 plans for 2025

Lauette Ponce

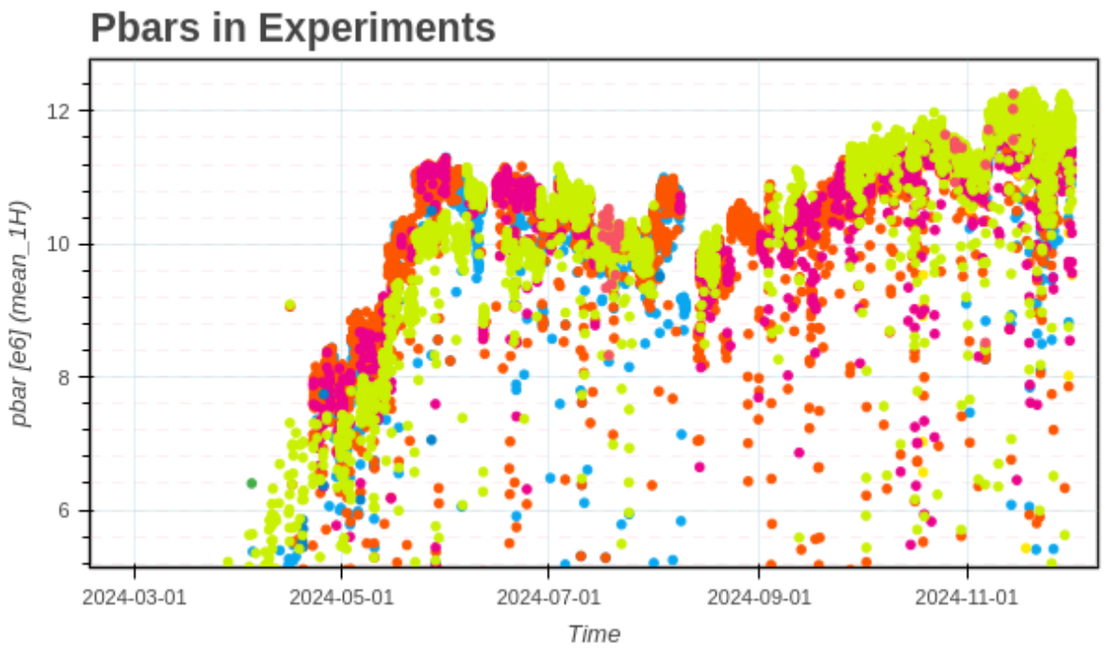
On behalf of AD/ELENA
operation and experts team

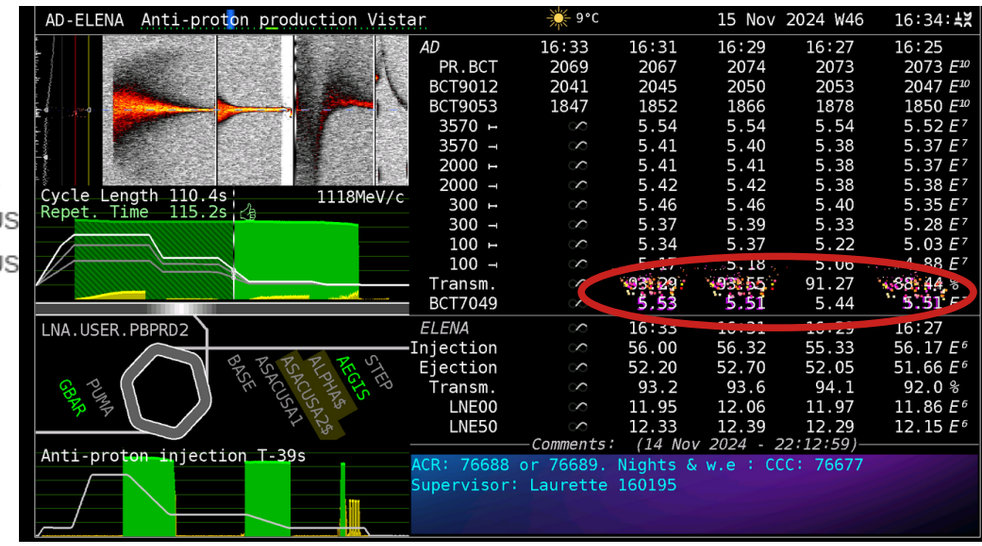
A record-breaking year for AD/ELENA

- New records:
  - More than 5.6e7 pbars injected in AD (previous record from 2000 with stacking of 3 batches of 3 bunches each)
  - Up to 5.6e7 pbars at AD extraction with deceleration efficiency above 90%
  - 1.2e7 pbars per bunch extracted to users



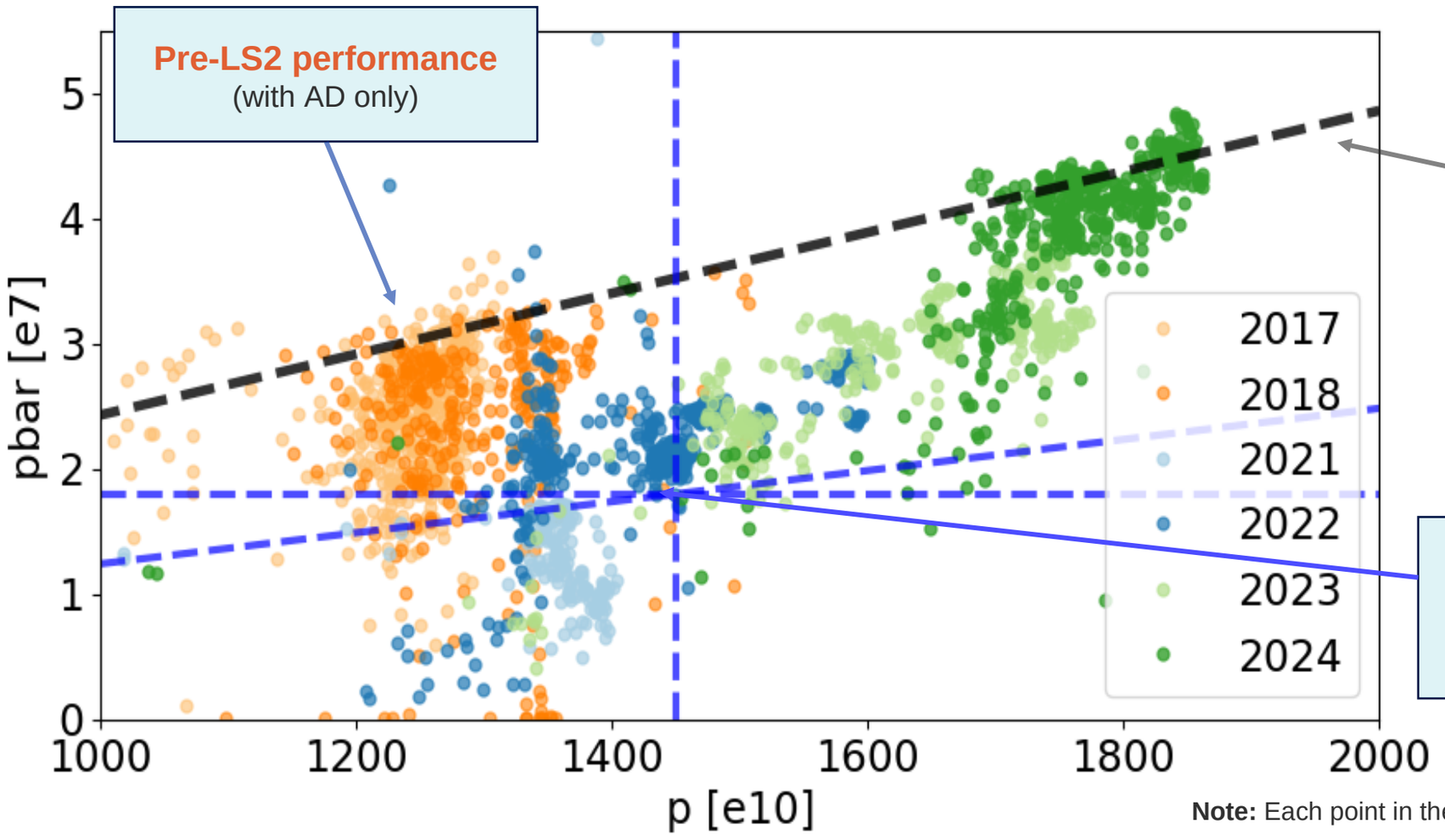
- Tedious and continuous optimization along the year to increase peak performance and improve reproducibility





Overview of AD/ELENA performances

- Enhancing reliability, operability and overall pbar flux:
  - Enabled by LIU upgrades (p intensity) and AD/ELENA investments (pbars yield and efficiency)



Time to define new KPI ?
3e-6 p-to-pbar yield
90% deceleration efficiency
in both AD-ELENA

ELENA Design Expectations:
1.45e13 ppp on target
1.8e7 pbars from ELENA

Note: Each point in the graph is the mean pbar/p intensity over 12 h periods

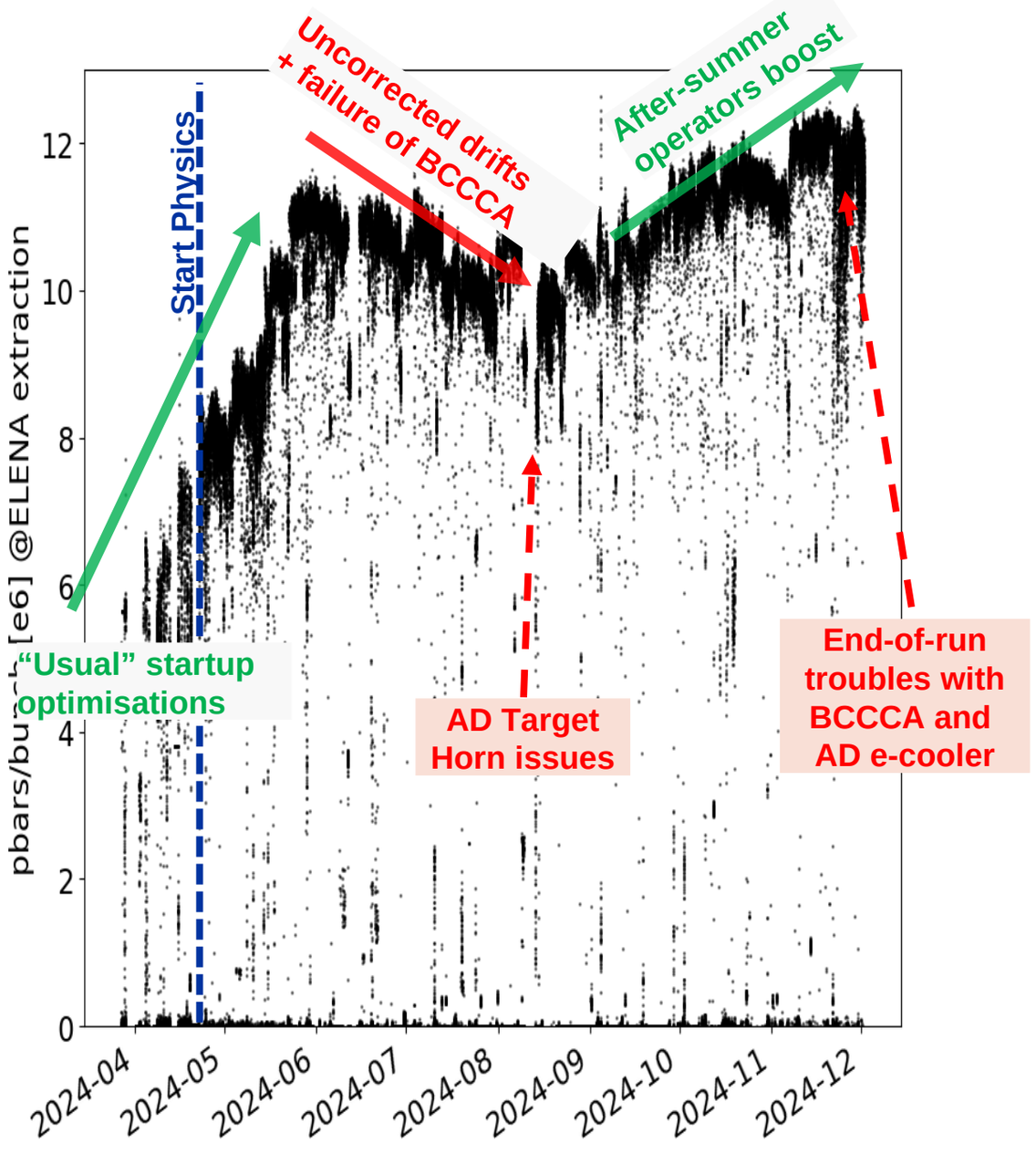
~2.7e18 p => ~6e12 pbars (10 pg of pbars!) in 1.5e5 shots => the highest integrated #pbars ever!

2024 run in more details

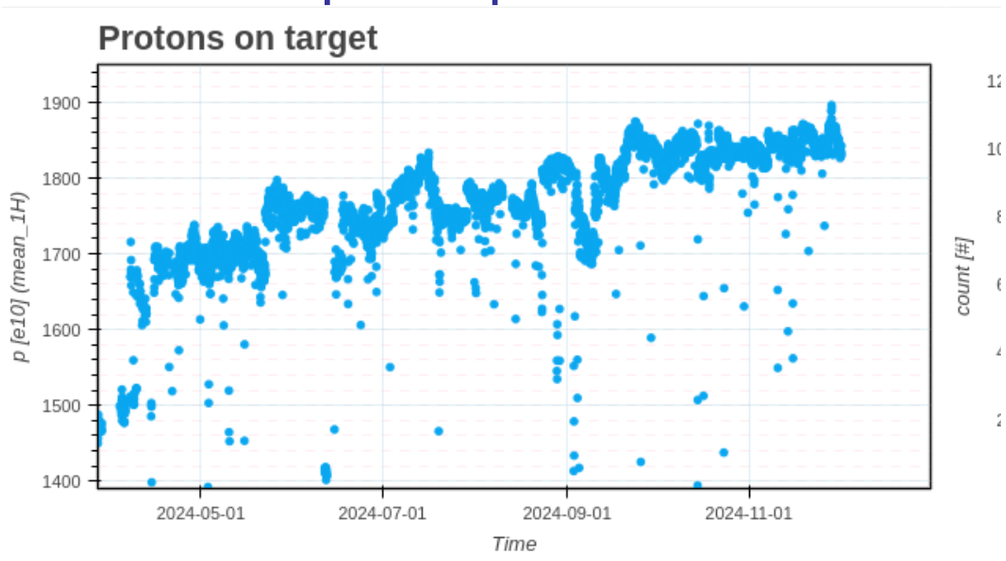
2024 Run at a glance

- Smooth restart after the YETS and quickly back to peak performance:
  - No major change compared to 2023 + repair of the horn
  - New working in ELENA to reduce transverse emittance for the users

  => First record intensities reached end of May: > 1e7 pbars per bunch to experiments

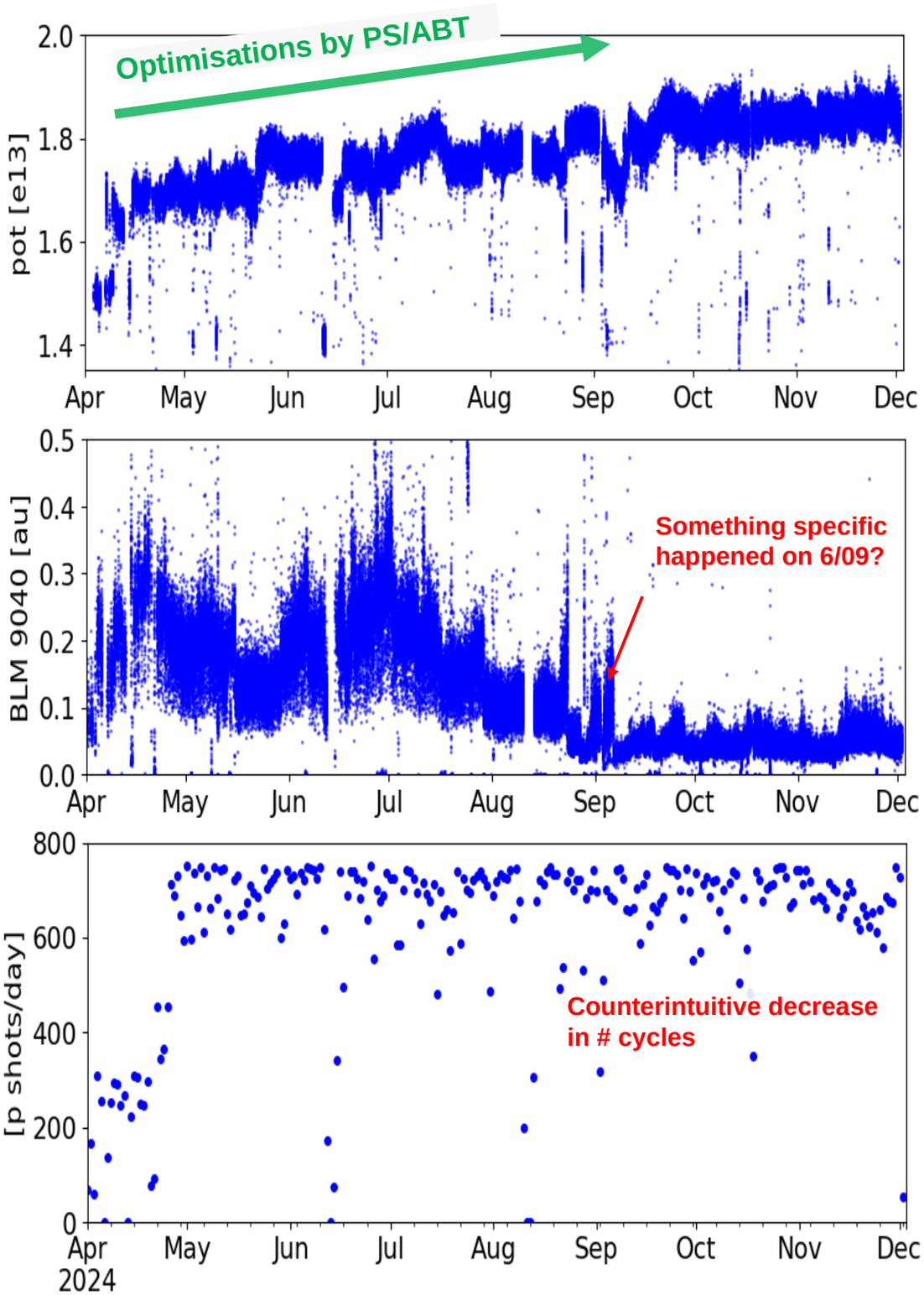


- Slow increase of number of protons on target to increase pbars production



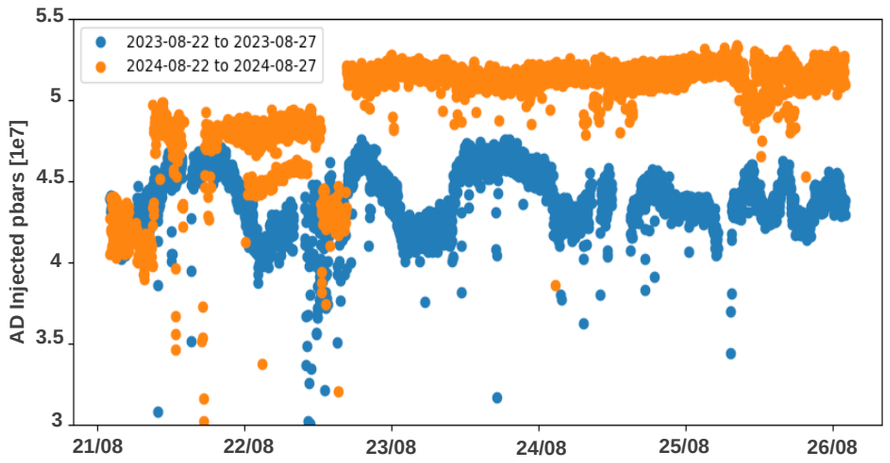
- Usual drift of peak performance over time:
  - Reliability issue of instrumentation limiting optimization of injection and deceleration efficiency in AD
  - Problem with magnetic horn
  - Instabilities around AD e-cooler
    - **OP struggling** to keep peak performance

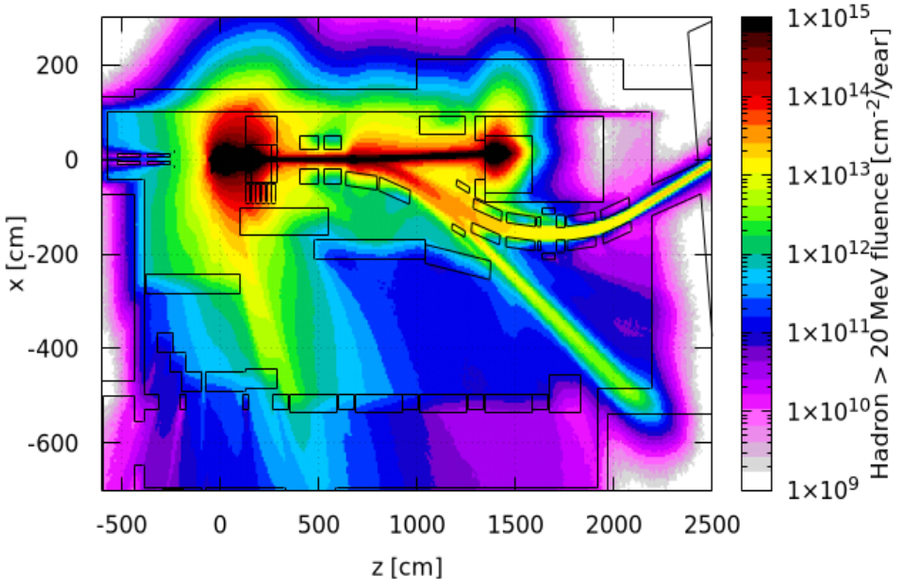
Proton beam production

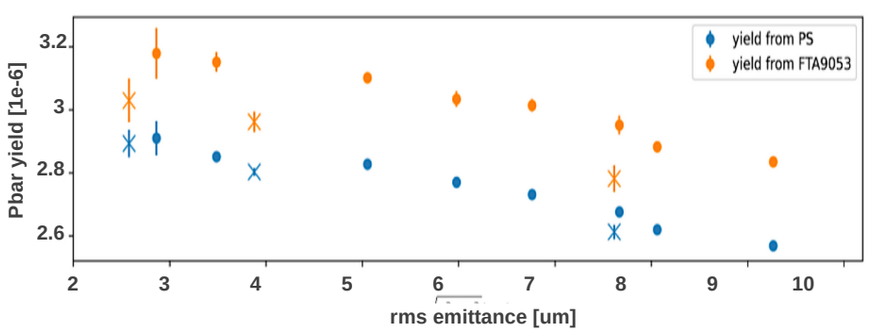


- Proton on Target intensity stability is translated one-to-one to Pbar
  - Invested on PS HW (mainly RF) and studies (working point, emittance control, …)
  - ~ 5% fluctuation intensity from injectors (LINAC4) over a week
  - Started looking into “debunched” beam in PS TT2 trajectory optimization/stabilisation
  - Improved transmission/p-on-target, which seems to be confirmed by less losses in TT2/FTA!
  - Also identified possible aperture restriction at AD target zone entrance caused by pre-LS2 wrong p beam size estimate
- Rep. rate/number of cycles variation remains a source of « unhappiness »
  - Non linear impact on user’s physics reach especially toward the end of the year
  - Shot to shot beam quality variation difficult to quantify
    - Looking forward for a dynamic sheduling after LS3

Pbar yield improvement



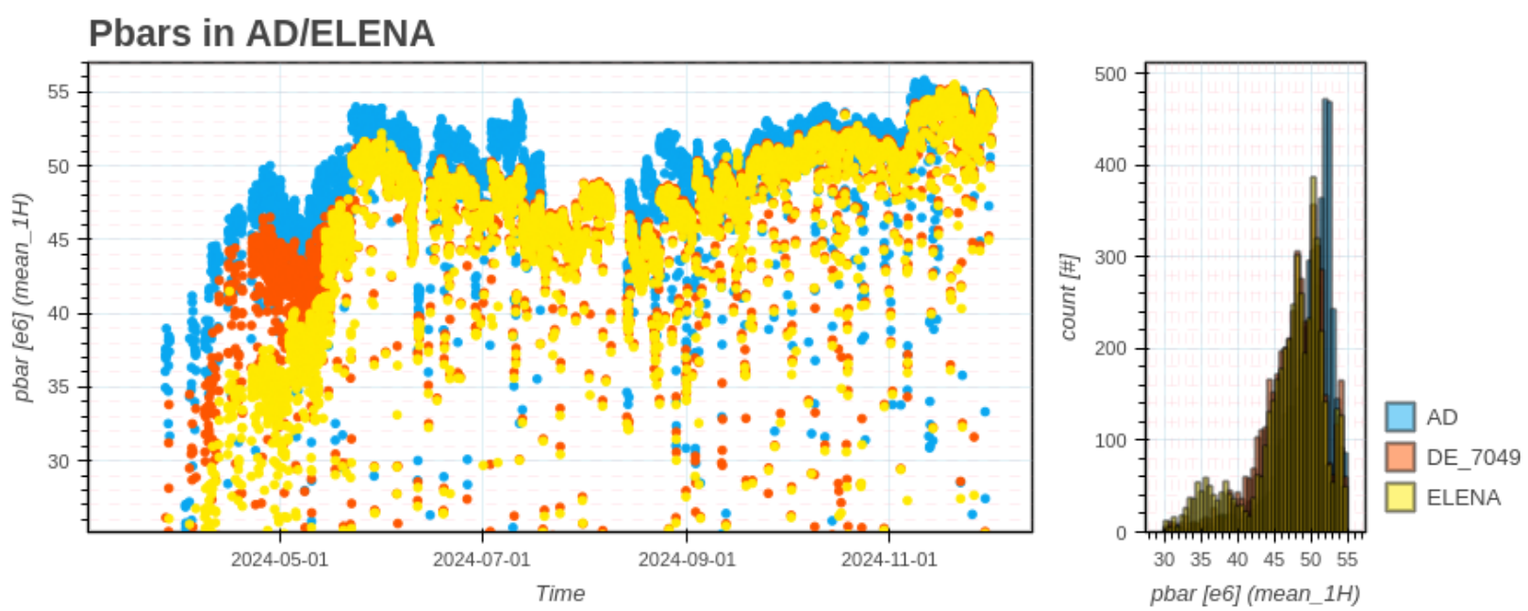




- Proton position on target stabilisation
  - feedback implemented using generic CERN framework *(thanks ABT)*
    - Initially fooled by BTV mirrors(?) moving with temperature(!?)
      - Requires custom ABT/BI procedure to stabilise the readings
      - A clear exemple of hardware-model-automation-operation challenge
- Finally refreshed efforts in FLUKA modelling of pbars yield *(thanks ABT/STI)*
  - Key ingredient to understand instrumentation along DI *(thanks BI)*
  - Allows to make more sense of pbar-yield vs p-emittance observations *(thanks ABT)*
    - (Also to start thinking about making antideuteron?!)
- Tackling several hardware-instability issues:
  - Identified instability in DI BHZ magnets *(thanks EPC/ABT/OP)*

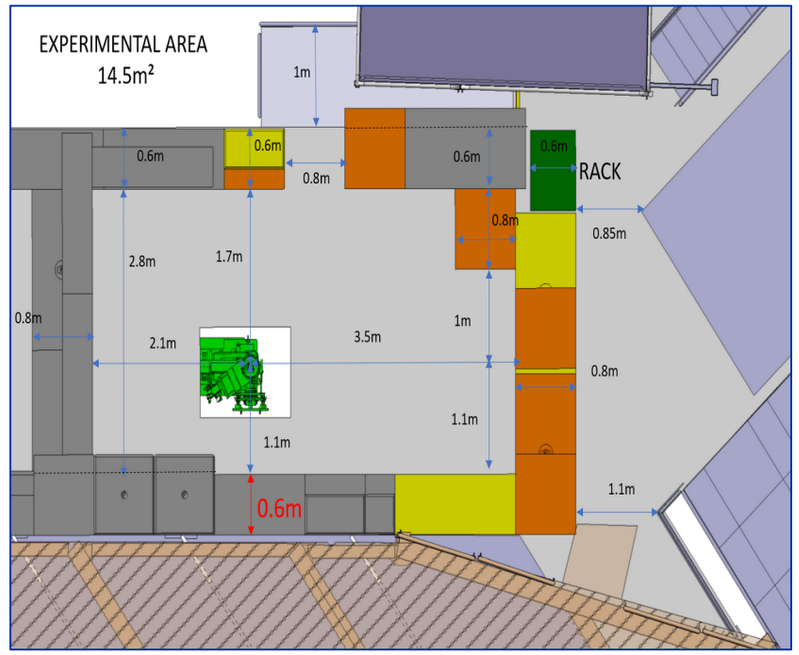
AD/ELENA deceleration improvement

- Regular sublimation of AD ring along the year:
  - Couple of hours every 6 weeks (during MD time) to gain 3-5% of deceleration efficiency
- Impressive work on s-cooling setup automatization *(thanks RF)*
  - Already saved several hours of physics after issues
  - Allowed to identified intermittent source of degraded performance (aging of equipement)
- Tackling several Hardware-instability issues:
  - Solved long lasting instability issue with AD ejection septum *(thanks OP/ABT)*
  - Identified and solved BBQ-indiced orbit jitter at AD extraction *(thanks OP/BI)*
  - Identified and solved source of larger injection oscillation variation with or without Hminus cycle for Pbars *(thanks OP/ABT)*



A new line in the AD Hall : TELMAX

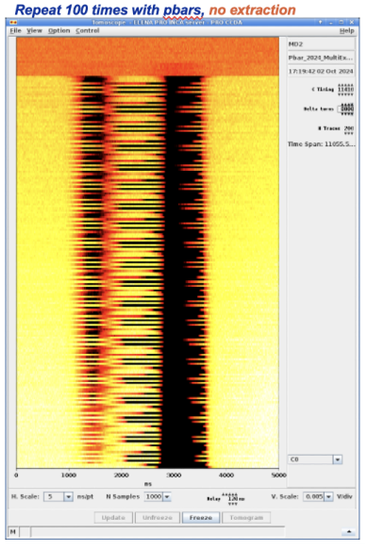
- The not used anymore ATRAP2 experimental area transformed into a test beamline for machine or experiments equipment tests:
  - Beam time requests managed with PS-SPS physics coordinator using standard SPSC beam time procedure as other facilities
- Refurbishment of the zone completed by the end of September:
  - Modification of the shielding and access system to increase usable surface



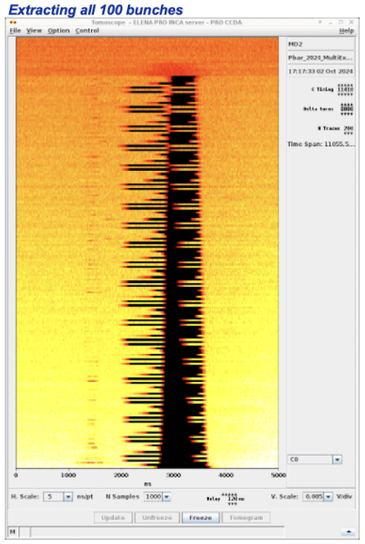
- First beam test with the PAX experiment using the new MMBE (Multi Mini Bunches Extraction) scheme developped in ELENA (thanks RF/ABP/OP)

Repeating multiple extractions with pbars

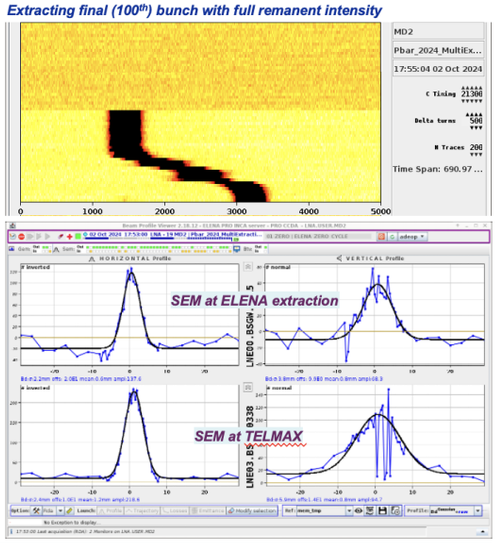
Repeat 100 times with pbars, no extraction

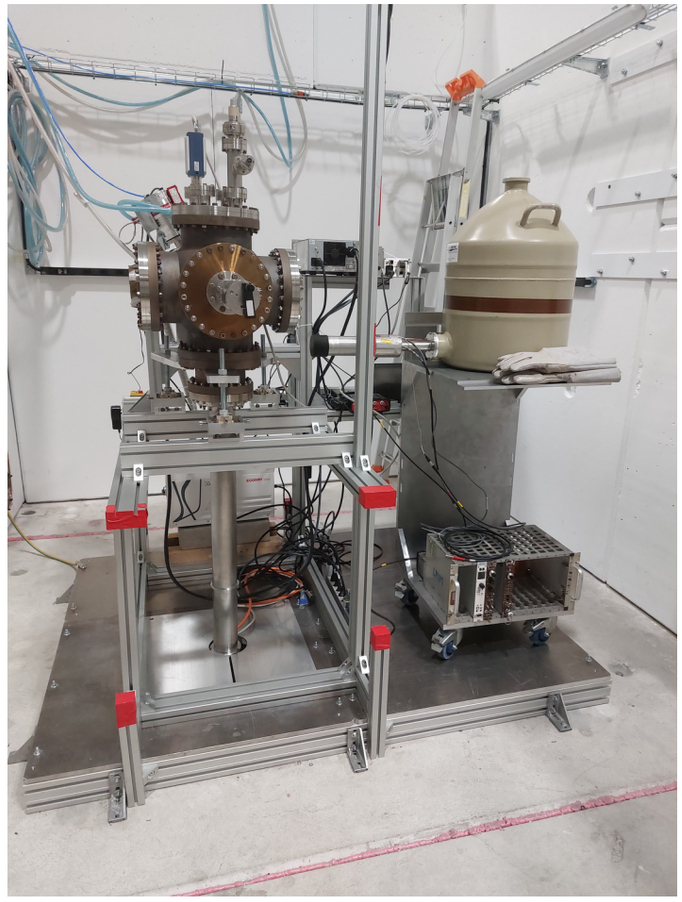


Extracting all 100 bunches

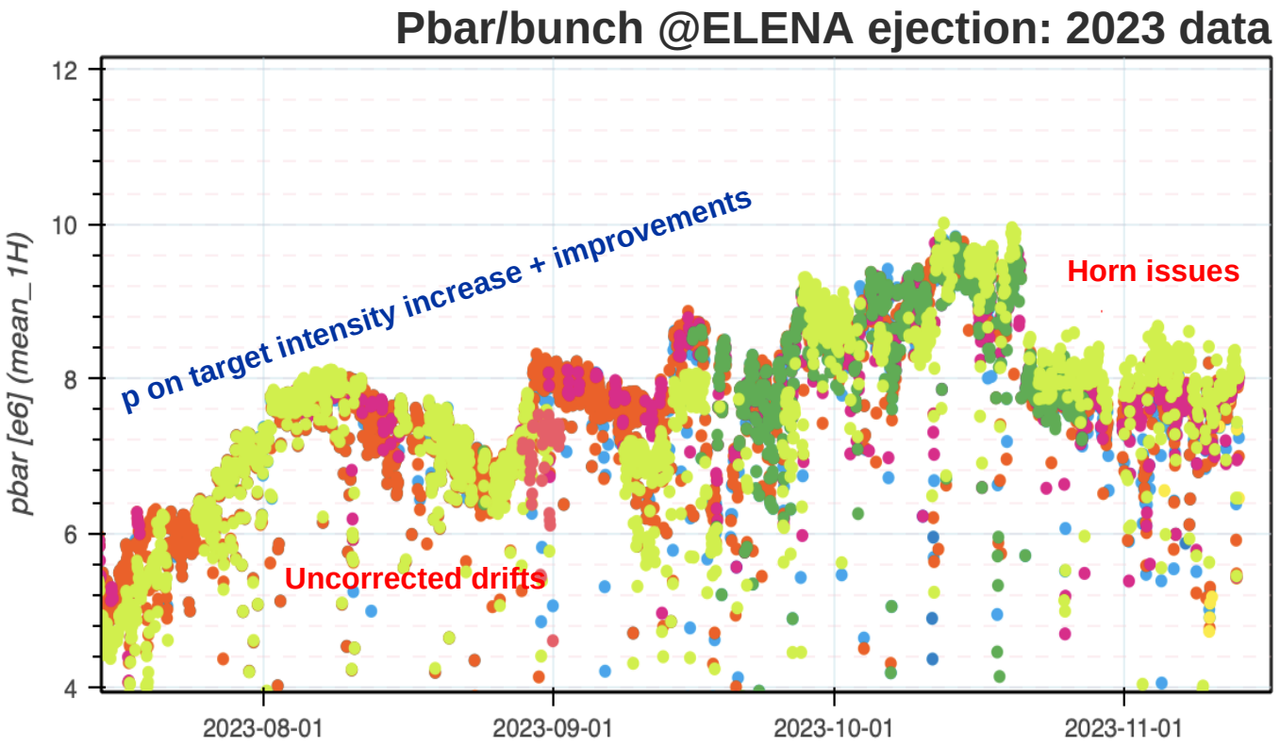


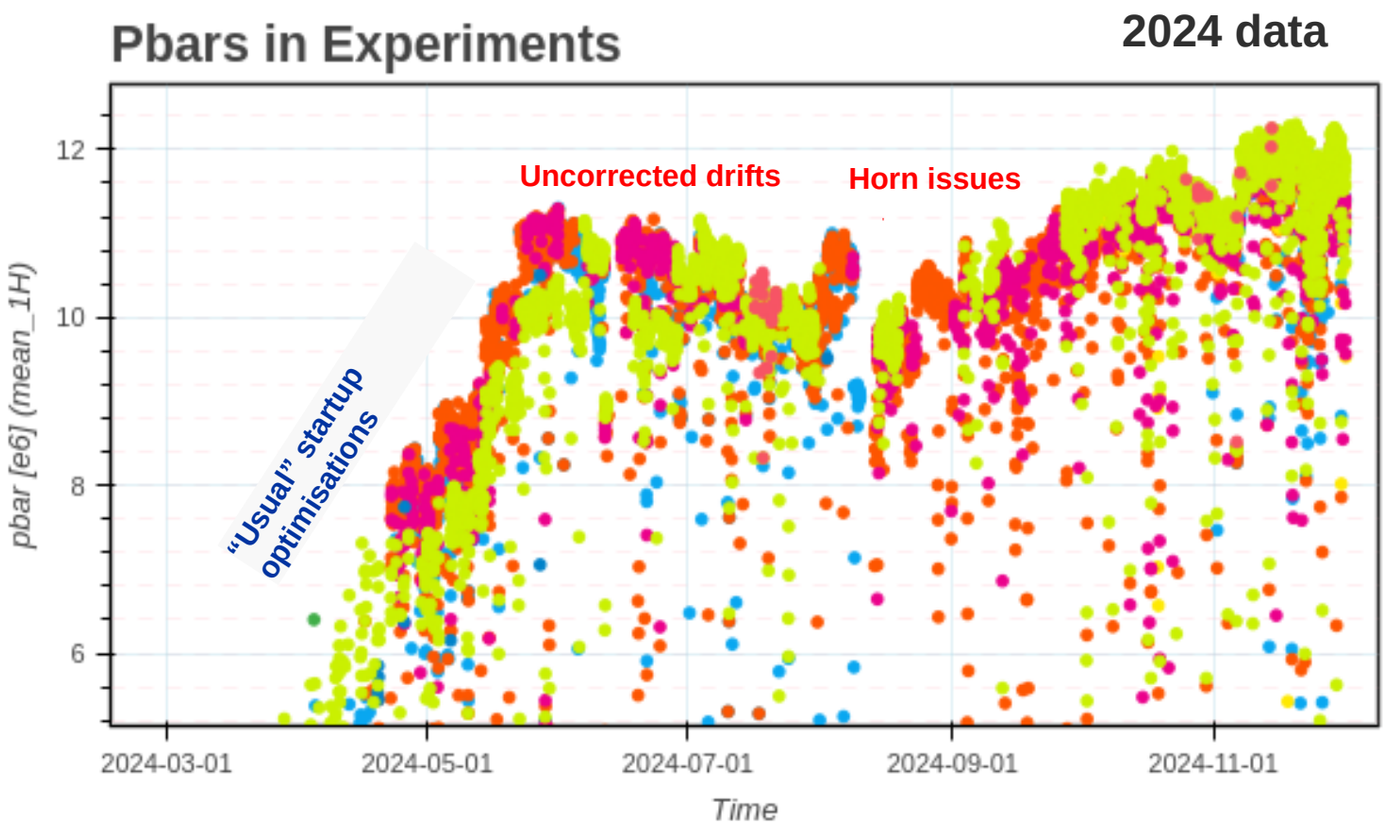
Extracting final (100th) bunch with full remanent intensity





Comparison of 2024 vs 2023 run





- Usual start-up optimization till summer period
  - Faster ramp-up in 2024
- Difficulty to maintain performance over summer period:
  - "Usual" issues with magnetic horn and instrumentation

Machines issues

Faults statistics

AD:

Issues not shown in statistics:

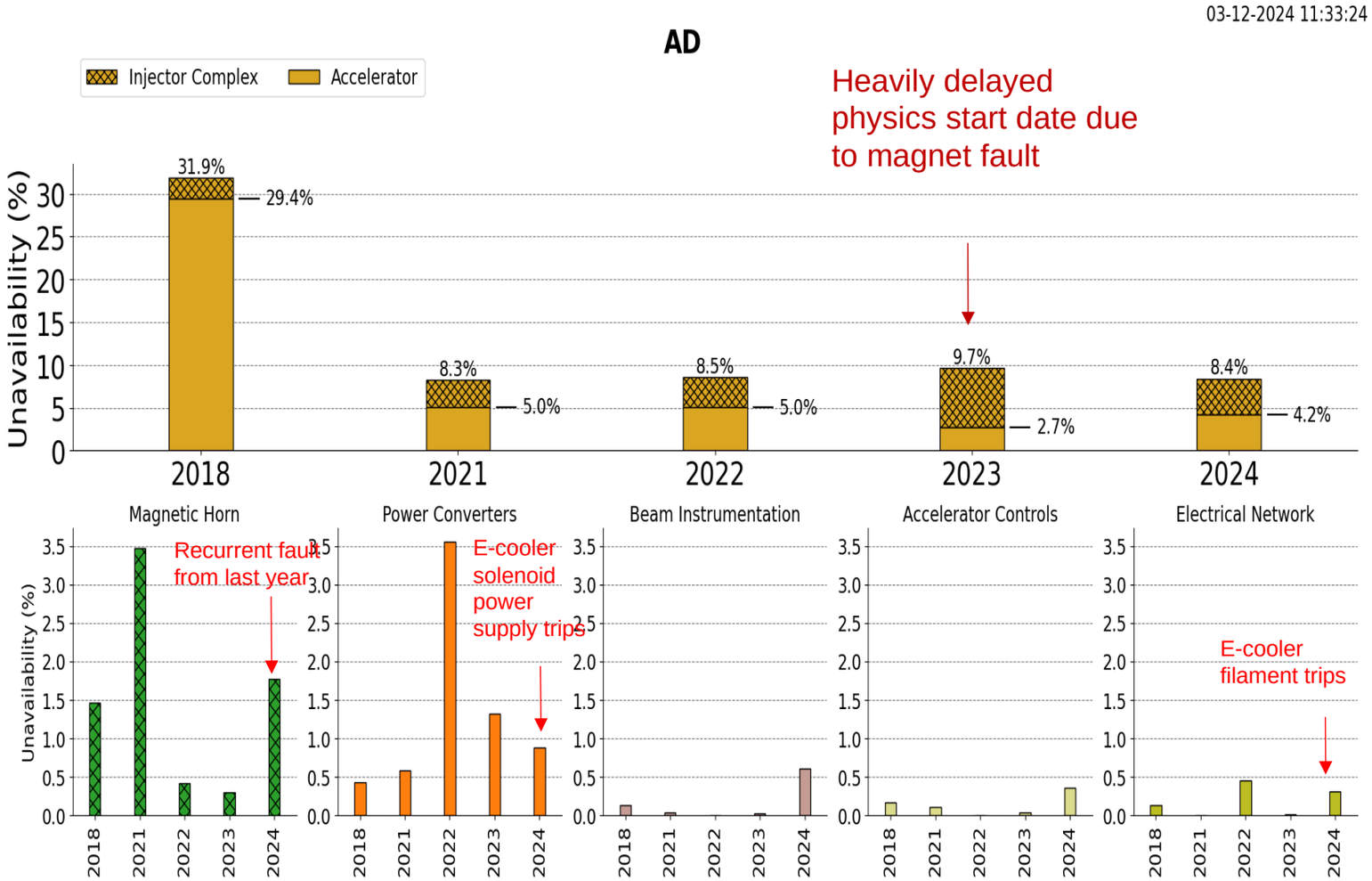
- Many systems in degraded mode: target, magnetic horn
- Non-blocking faults with stochastic cooling, instrumentation

<u>Recurrent issues from last year:</u>

- Spark in Magnetic horn,
- Cooling of the BCCCA (beam current monitor), 4h access needed to refill

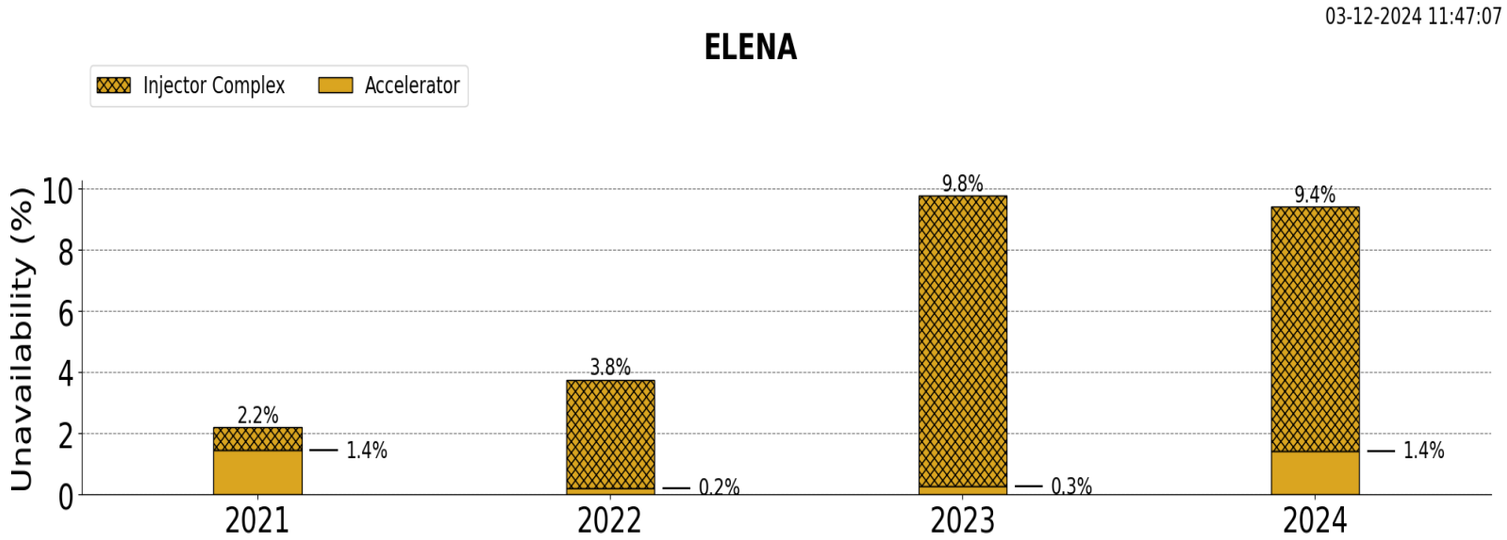
<u>PC & Elec. Net.:</u>

- Increasing number of trips of e-cooler solenoid PC
- Increased number of power cut inducing filament trips → long recovery time
- Still many trips of the main QUAD, but quick recovery compared to last year



ELENA:

- Most down time from upstream
- Most down time is destination dependent:
  - Communication problem with power converter in extraction lines

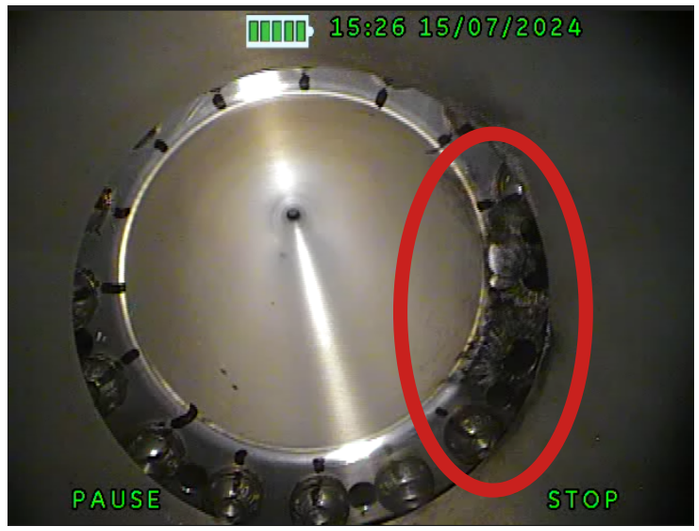


Note: No stand-by service for many equipement – specialist repair only in work hours

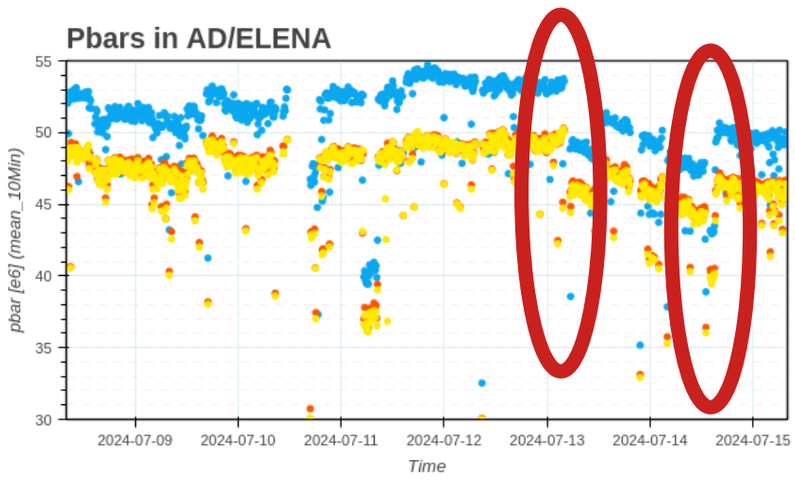
Difficult summer period

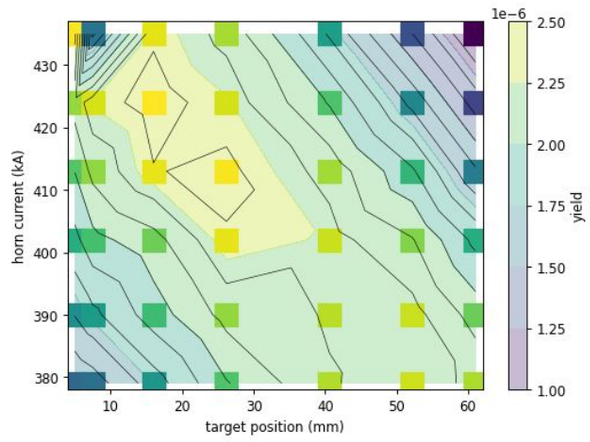
- Serie of flashovers in the AD magnetic horn:
  - Same issues as at the end of last year
  - Exchange of the horn during holidays period
  - Problem with the target longitudinal movement after the magnetic horn exchange

=> working in « degraded mode » for pbars production from end of summer till end of the run

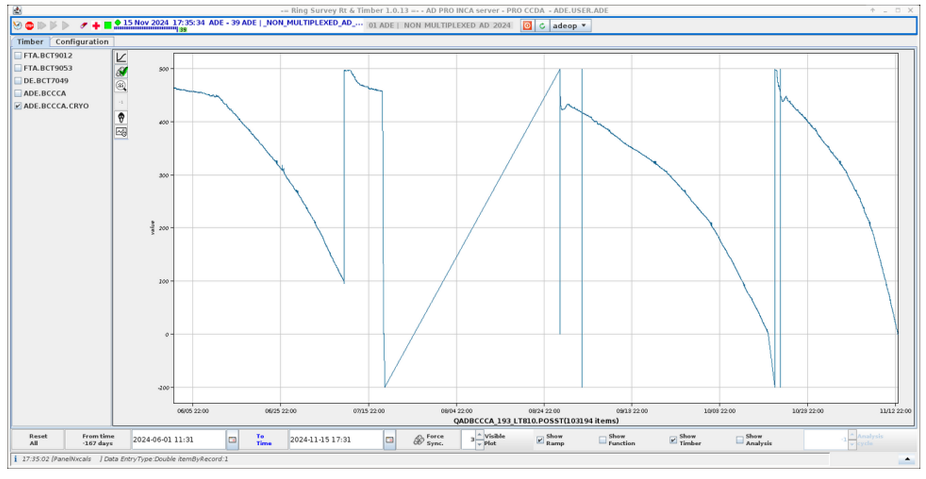


Sublimized screws inside magnetic horn





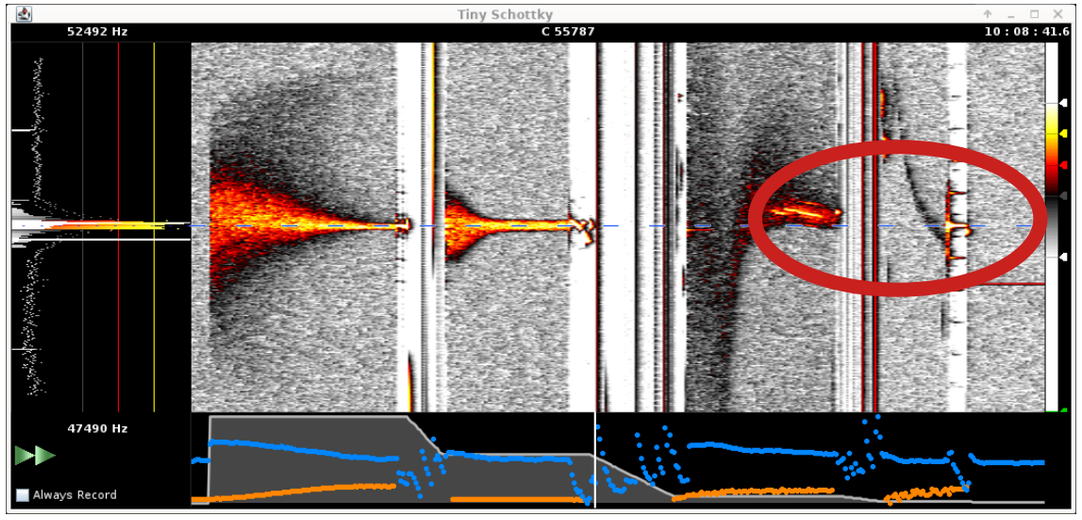
- Problem with the isolation vacuum of the BCCA (Beam cryogenic current comparator) in AD:
  - Crucial instrument for AD cmachine setting-up and optimization
  - Difficulty during the rest of the year to maintain LHe level,

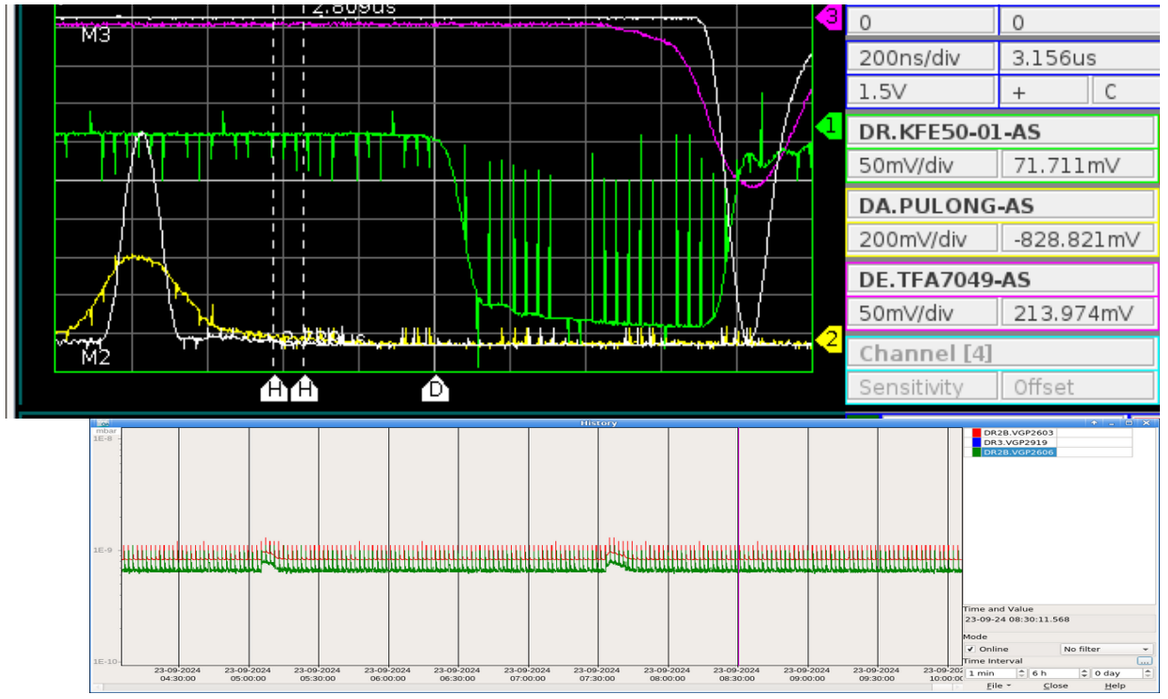


He level in the BCCA along the year

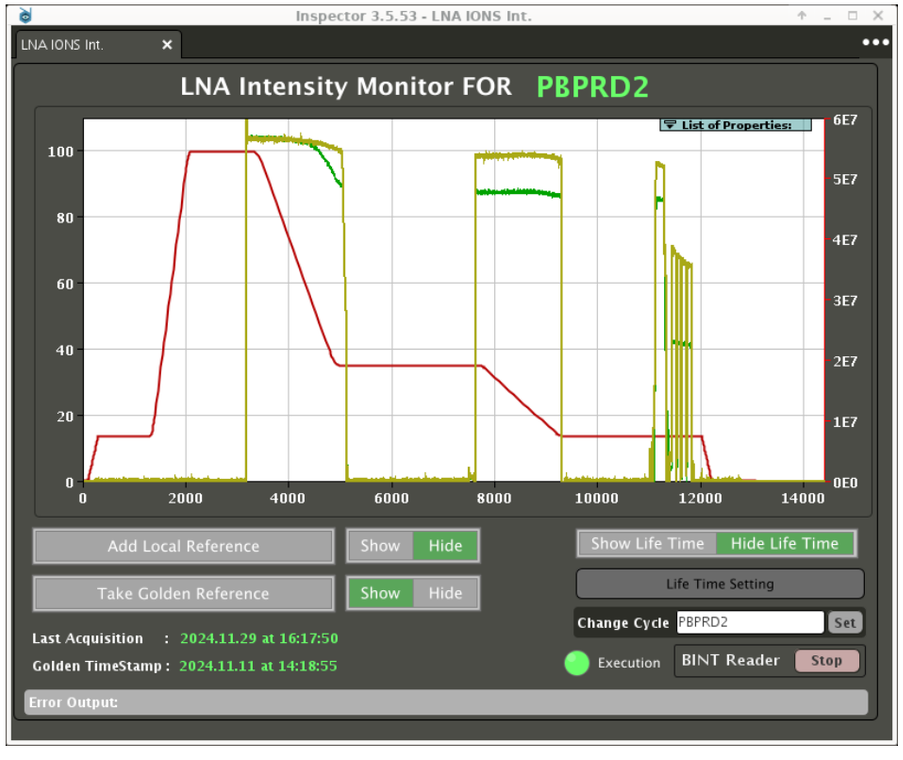
Issues still under investigation

- Periodic bad AD to ELENA transmission due to vacuum bump every 2.5 to 3 hours:
  - Change of electron energy or orbit bump leading to blow up and at AD extraction and losses in first ramp of ELENA
  - Will try to find a less sensitive setting





- AD e-cooler-related orbit reproducibility:
  - Recovery of power cuts (long standing issue!)
  - Big effect observed at the end of the run (New):
    - Orbit instability in AD creating emittance growth in ELENA and losses in first ramp

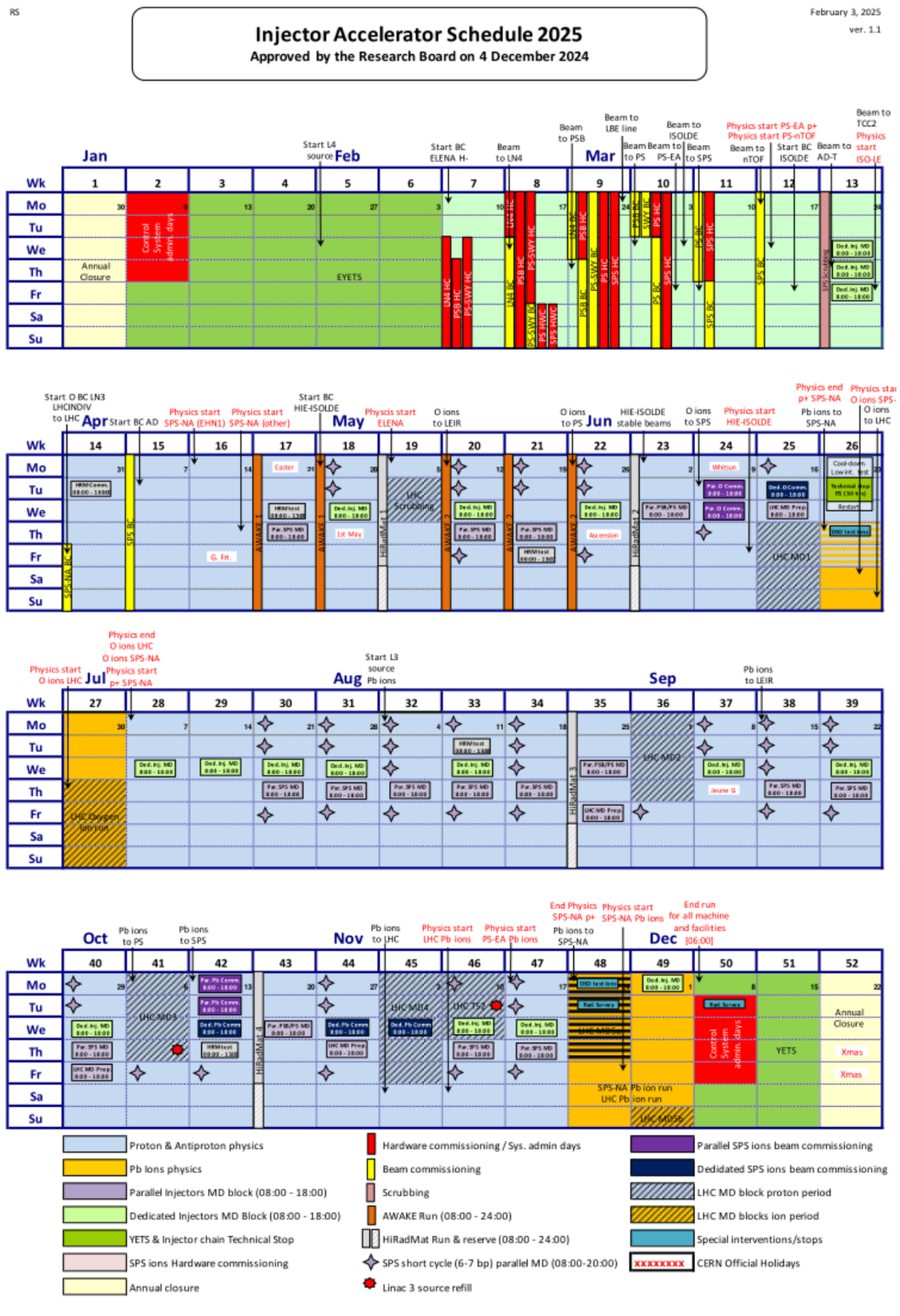


2025 run

2025 injector schedule

- Version 0.4 approved on 07/02

- Important dates:
  - ELENA H- from 04/03:
    => instrumental to start as soon as possible for efficient pbars commissioning
  - AD target + AD ring DSO test on 26/03
    => start of AD ring pulsing
  - First beam to ADT on 27/03
    => need AD ring closed
  - AD ring ready for beam on 08/04
    => end of C10 conditioning
  - Start of PHYSICS on 05/05
  - End of physics on 08/12



2025 Injectors Schedule in numbers

Experimental facility	Beam to	Start physics	End physics	Duration Version 1.0 [days]*	Duration Version 1.1 [days]*
ISOLDE	05.03	**28.03**	**08.12**	**241**	**241**
nTOF	17.03	**19.03**	**08.12**	**264**	**264**
PS East Area p^+	07.03	**19.03**	**08.12**	**264**	**264**
PS East Area Pb ions	-	**17.11**	**08.12**	**21**	**21**
SPS North Area p^+	28.03	**14.04**	**26.06**	**84**	**213**	**73**	**213**
	-	**07.07**	**24.11**	**129**		**140**	
SPS North Area O ions	07.07	**28.06**	**07.07**	**9**		**9**	
SPS North area Pb ions	24.11	**28.11**	**08.12**	**10 (+4)**		**10 (+4)**	
AD-ELENA	27.03	**05.05**	**08.12**	**224**		**217**	
HiRadMat	-	**05.05**	**21.09**	**20 (+8)**		**22 (+8)**	

*TS and MD time etc. not deducted

Beam commissioning initial planning

- Ambitious planning around Eastern period:
  - 1 week of target conditioning + FTA-DI transmission optimization in parallel of Main power supply HW test and C10 conditioning (AD ring closed)
  - 1 week for beam commissioning injected in ELENA
  - 2 weeks for fine tuning and extra studies

Main Activity	Activity	Details	Duration [working days]	From	To	Groups required	Notes
HWC							
	instrumentation check without beam	IPM gaz injection, scraper movement					
DSO test			1	25 March 2025			
AD target beam commissioning			4				
	First beam to AD target		1	26 March 2025	27 March 2025	OP, STI, ABT	1 day of intensity ramp up for target conditionning
	Nominal beam injected	Taget conditionning	1	27 March 2025	28 March 2025		
	DI commissioning		2	28 March 2025	01 April 2025		
Machine Check-out							
	Main power supply		5	26 March 2025	02 April 2025		
	C10 cavities conditioning		10	26 March 2025	09 April 2025		
	instrumentation check	scraper, tune meter, BPM					in parallell of AD target beam commissioning
	AD ring ready for beam			02 April 2025			
AD Nominal cycle setting-up			7				
	Nominal beam injected	C10 phasing, injection check	1	08 April 2025	09 April 2025	RF, OP	
	stochastic cooling	BTF on FT1 and FT2	2	09 April 2025	11 April 2025	OP, RF	AD in pause at 3.5 GeV/c and 2 GeV
	recapture and ramps	LLRF/longdiag, orbit…	1	11 April 2025	14 April 2025	OP, RF	
	E-cooling on both plateaus	E-beam pbars alignement	2	14 April 2025	16 April 2025	OP, BI	need IPM and scrapers
	Extraction	LLRF/longdiag…	1	16 April 2025	17 April 2025	OP, RF	
Eastern WE			2	17 April 2025	21 April 2025		
ELENA nominal pbars cycle	pbars operation						
	injection setting-up		1	21 April 2025	22 April 2025	OP, ABT	
	working point + emittance		1	23 April 2025	24 April 2025	OP	
	E-cooler extraction plateau		1	25 April 2025	28 April 2025	OP, ABP	
Extra Activities	IF time allows during beam commissioning						
	new SC deploiement	optical notch filter + filters	2	29 April 2025	01 May 2025		
	Orbit cleaning/IPM bump compensation		1	01 May 2025	02 May 2025		
	Transfer lines	Steering, Quad scan	1	02 May 2025	05 May 2025	OP, ABT	
ELENA Hminus operation				04/03/25			
	injection setting-up		1	04/03/25	05 March 2025		
	preparation of H=1, 2 cycle		6	04 March 2025	12 March 2025		
	LLRF test		2	12 March 2025	14 March 2025		
	scraper tests		1	14 March 2025	17 March 2025		
	E-cooler beam alignement		2	17 March 2025	19 March 2025		

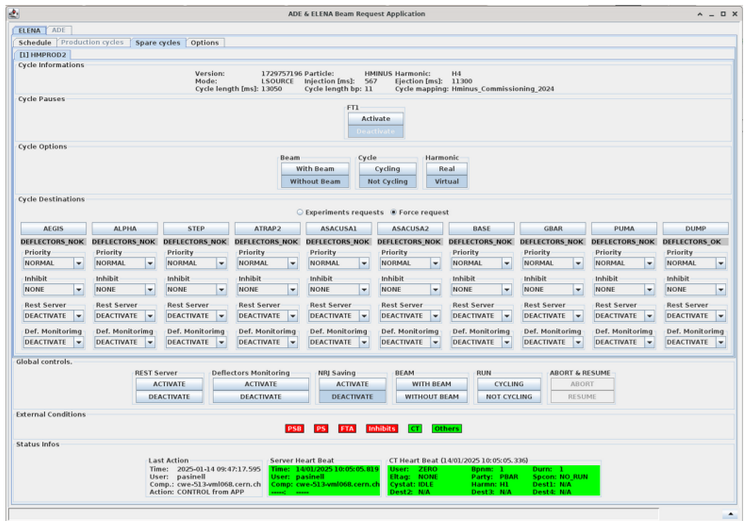
2025 configuration

- No major change for 2025 following discussions at the special User Meeting:
  - Same peak performances expected (same limitations on magnetic horn)
  - Stick to 4 bunches with PBPRD1 timing user name
    - We are exploring possibilities to get rid of the « hardcoded » timing user name
  - Preparation of single bunch extraction for dedicated test

- Physics run from 5/5 to 8/12:
  - Request for Wednesday Machine Development time as in the last 2 years:
    - Very important for performance reach and to prepare post LS3 operation

- New Beam Request server functionalities:
  - Consolidation of diagnostics and maintainability of the servers
  - REST disable per user + possibility to force the Inhibit status
  - Implementation of low priority destination (mainly thought for TELMAX) per destination

- MMBE (Multi mini bunches extraction) available only for TELMAX destination
  - Consolidation of the settings management



Last news on consolidation

PS-CONS & SPARES – Approved

Group	Description	EDMS	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	TOTAL
BE-ABP	Linac3 Source spare sub-parts microwave generators	3172700	80	100									180
EN-CV	Consolidation of East Hall ventilation	3172903			777	1,033							1,810
SY-EPC	PLC replacement for AD, LEIR, ISOLDE (S7-300 obsolete)	2788404		110	110	110	110	110					550
SY-RF	PS 200 MHz RF amplifiers	3161422	140	520									660
SY-STI	Consolidation of AD-target magnetic horn	3151259	120	180	180	140	100						720
SY-STI	ISOLDE laser ion source RILIS	2254500	415	550	500	440	340	310	100	180			2,895
TE-MSC	Replace dipole support polyurethane pads	3141539	152	165	165								482
TE-MSC	Replace power converters in magnet testing workshops	3141534	280	400									680
Group	**Description**	**EDMS**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**TOTAL**
SY-ABT	Spare for PS MTE fast bumper (BFA9P)	3104391	15	155	135	45							350
SY-BI	Mechanical spares for critical systems (PS, SPS, LHC)	2787852	200	200	100	100							600
TE-MSC	Consolidation PSB Multipole magnets	2962660	100	300	330								730

ADCONS & Over-cost – Approved

Group	Description	Comment	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	TOTAL
SY-EPC	AD consolidation phase 2	EDMS 2156024		50		400	450	200	400	400	300		2,200
TE-MSC	Replacement of AD electron cooler magnets (over-cost)	over-cost	149	-33	399								**515**

Summary

- Record performance for both AD and ELENA in 2024:
  - Keep pushing peak performance despite some Hardware limitations

- Some progress on performance stability:
  - Some of the long standing HW issues have been fixed
  - Some known issues will have to wait LS3 to be (potentially!) fixed
  - Some issued still to be investigated

- Ambitious restart planning for 2025 profitting of all the work invested on improving operational procedures and diagnostics:
  - Focus for 2025 moves now towards reproducibility

Many thanks to all the teams and let’s try to do even better in 2025