Fixed Target Experiments Feedback from 2023 and Run 3 Outlook

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SPS and PS Physics Coordinator

Joint Accelerator Performance 23 Workshop (JAP23)
December 5th, 2023

https://indico.cern.ch/event/1337597/

Increased focus on the injector complex user beams in recent years – improve measurements, automatic corrections, reduce losses, improve stability, increase intensity (previous workshops, long lists of action items, new projects, working groups …)

→ in 2023 we have profited big time

→ users were full of praise for the beams received – availability and quality!

Input from ATS groups and users of PSB, PS, SPS and AD/ELENA

2021 IEFW https://indico.cern.ch/event/1194548/
2022 JAPW https://indico.cern.ch/event/1194548/

Communication Wishlist I

- Improve communication via **page 1 and OP logbooks**
  - Bring PS and SPS FT user info to the same **level of details and update frequency** as the one for LHC users
  - Add to the OP shut-down training explations what kind of information users need and why?
- Page 1 or other means: Improve **announcement of shorter-notice deterioration or unavailability** of user beams – and, **equally important, the end of the deterioration/beam unavailability**
  - **Communicate as soon as possible and keep information up to date**
  - e.g., dedicated or parallel LHC filling, MDs, other super-cycle changes.
  - → important for all users to plan their measurements accordingly (e.g., do not start a new measurement shortly before the conditions change, or the beam goes away, but rather continue with the ongoing run.)
- **PS and PSB vistar: add a page with a summary / statistics** of, e.g.: **number of cycles per user** (now and last 1 hour); **number of free cycles**. (Because the page 1 does not fit on one page especial via the web interface it is hardly possible to extract this info – page is not scrolling but jumping.)
  - Log to NXCALS

Communication Wishlist II

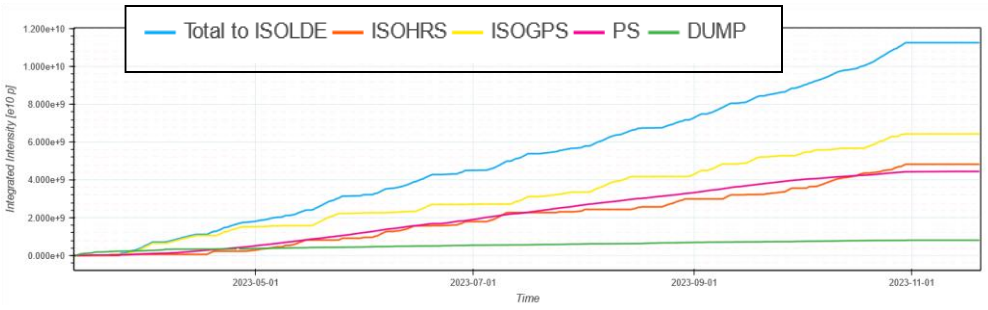
- Different technical solutions exist amongst the regular users to
  - Get **automatically informed when Page 1 changes** → make available to all the users?
  - **Log Page 1 messages** to be able to match them with the data recorded → centrally logged Page 1 messages for all the users? NXCALS?
- Make it easier to find a **beam-line summary table**, with **beam characteristics and estimation of the number of spills/week**. (Most of the information is already available but scattered on several web pages.)
- Numerous option available for **secondary beam parameters and compositions**. Some of them have been measured by different users.
  - Create **repository, where users can upload their results together with the secondary beam settings, target type, target intensity** etc.?

- **Quantify knock-on effects of future significant changes** (e.g. dedicated LHC filling) → improve communication to users across the accelerators (also between LHC and injector users)

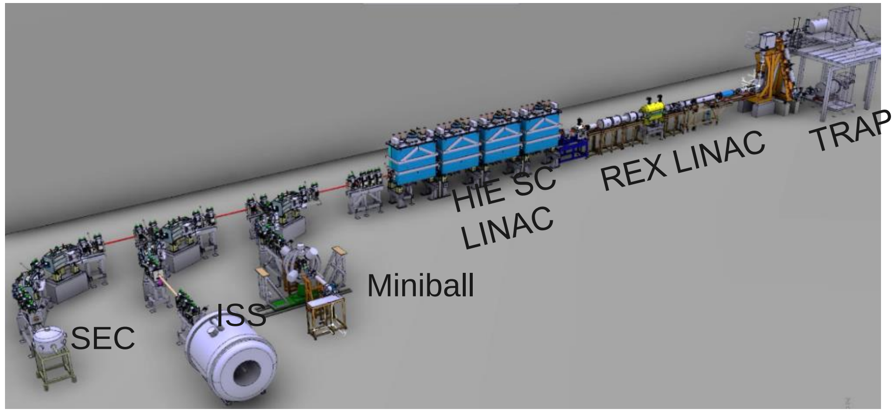
ISOLDE

ISOLDE

- Most of the protons to ISOLDE
- About 470 shifts in 2023, 122 of them for HIE ISOLDE
- About 40% of the shifts to be scheduled are for HIE ISOLDE
  → shorter physics period for HIE ISOLDE is problematic

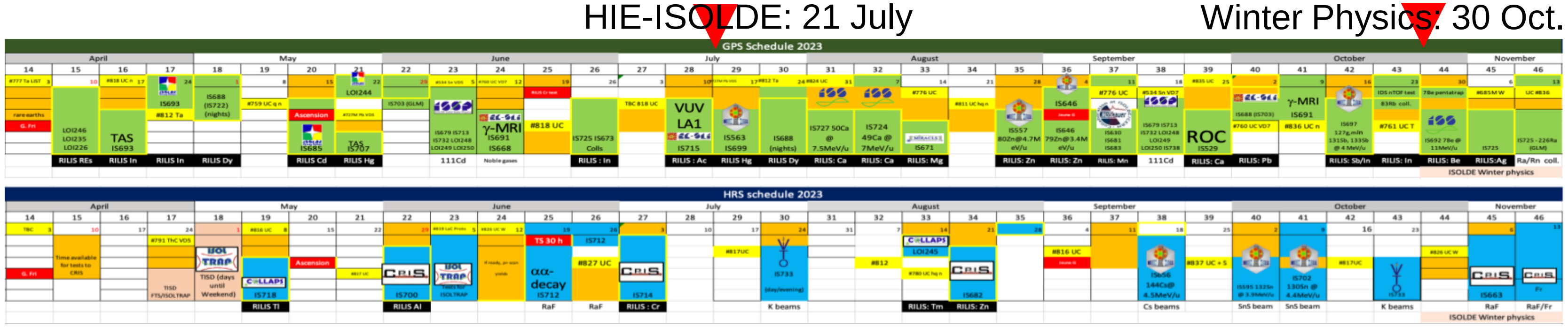


- Most runs were at least partly successful (few issues from machine and target side but also from experimental side)
- REX/HIE ISOLDE: Sever issues during the restart shortened the commissioning time. Despite many issues throughout the year, HIE ISOLDE managed to deliver beam according to schedule and physics requests.



HIE-ISOLDE: 21 July

Winter Physics: 30 Oct.



Article

Observation of the radiative decay of the ^{229}Th nuclear clock isomer

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Check for updates

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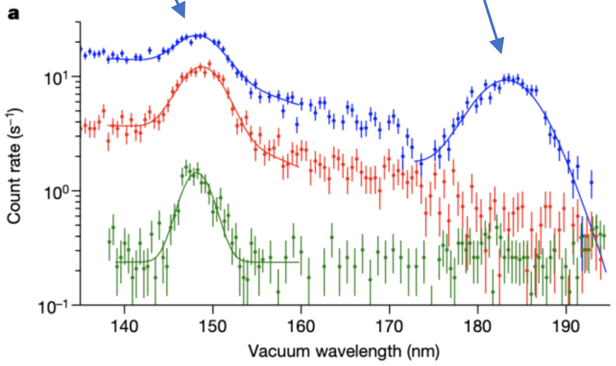
- **First direct evidence of very low-lying state in ^{229}Th** via measurement of the uv decay.
- More precise measurement of energy than indirect measurements, giving only 8.338(24) eV
- Measurement of $\tau_{1/2}$ for isomer embedded in MgF_2 670(102)s

Implantation of A=229 and 230 in three different hosts to search for and identify the uv transitions with ^{229}Th and to exclude artifacts.

Implantation of A=229

^{229}Th isomer decay

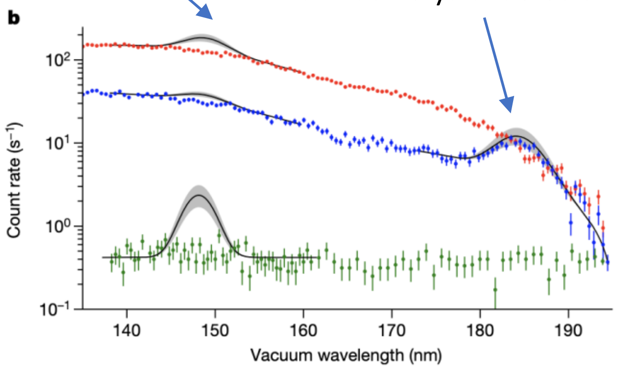
artifact: crystal defects



Implantation of A=230

no isomer

artifact: crystal defects

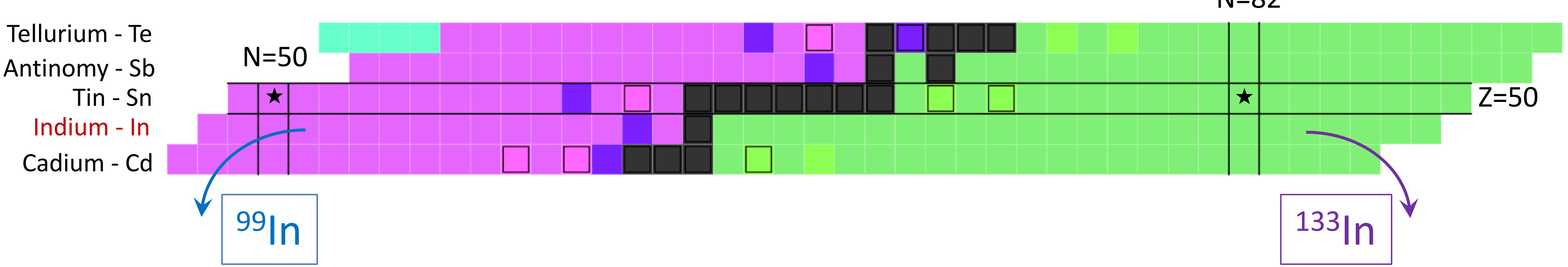


- **Nucleus exited state**: Low energy enables potential direct excitation by lasers and therefore use as a **nuclear clock.**
- Nuclear clock **much less sensitive to environmental effects than atomic clocks so more precise**.
- A nuclear clock would be a unique tool for many **precision tests of fundamental physics.**
- The observation of radiative decay in large band-gap crystal is a huge step forward in design of such a clock.
- Reduction in precision of energy significantly eases the search for direct laser excitation as lasers have narrow bandwidth compared to uncertainty in energy.

Slides from Sean Freeman

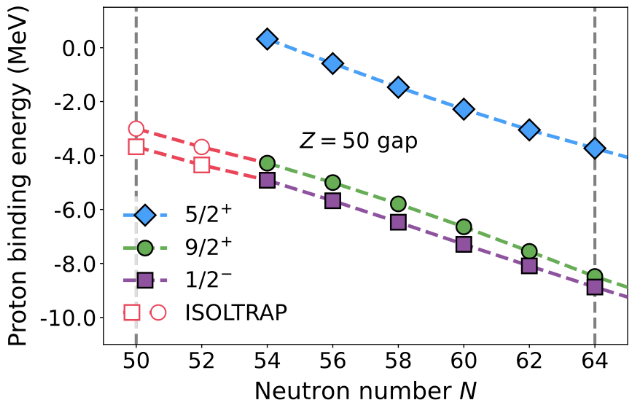
Indium – from one extreme to the other - *two back-to-back ISOLDE PRL's in July*

Part of nuclear chart with corner stones of doubly-magic Sn isotopes : ^{100}Sn and ^{132}Sn (★)



PHYSICAL REVIEW LETTERS **131,** 022502 (2023)

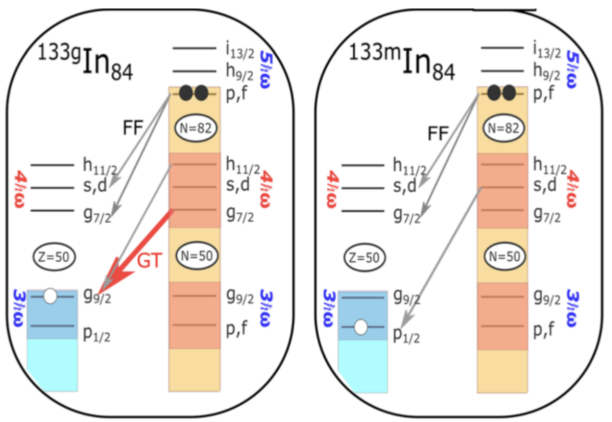
Isomeric Excitation Energy for ^{99}In^m from Mass Spectrometry Reveals Constant Trend Next to Doubly Magic ^{100}Sn



- Precision measurement of ground and isomeric state using ISOLTRAP.
- Excitation of isomer extremely constant across In
- In contrast to measurements of magnetic moment, which increases near N=50 - also ISOLDE experiment from 2022!
- Very difficult to reproduce with modern calculations and may point to missing physics.

PHYSICAL REVIEW LETTERS **131,** 022501 (2023)

^{133}In: A Rosetta Stone for Decays of *r*-Process Nuclei



- Measured β decays from ground and isomeric levels using ISOLDE DECAY STATION.
- Decays populate just a few unbound levels in ^{133}Sn.
- Measured resonance properties that are critical for benchmarking models of the *astrophysical r process* that manufactures many of the heavy chemical elements.

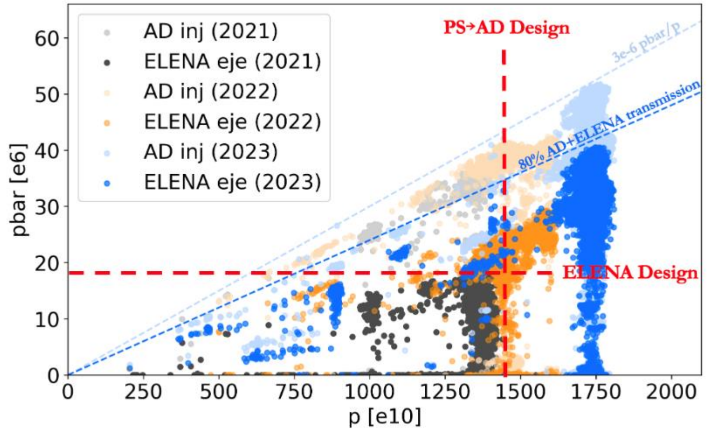
Good example of versatility of ISOLDE – precision studies of both neutron-rich and neutron-deficient exotic isotopes separated by 34 neutrons!

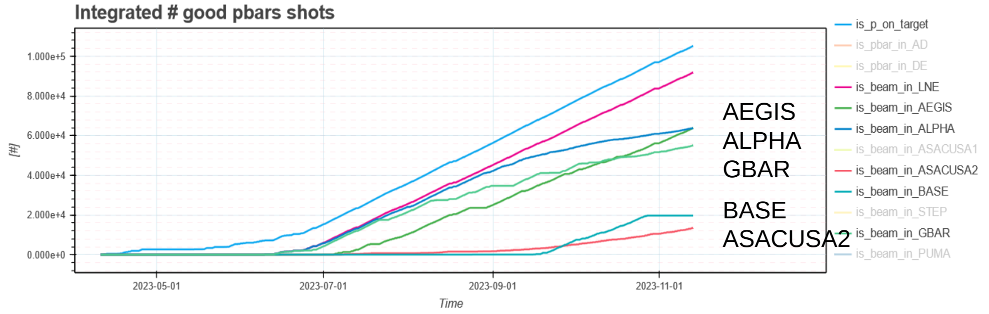
Slides from Sean Freeman

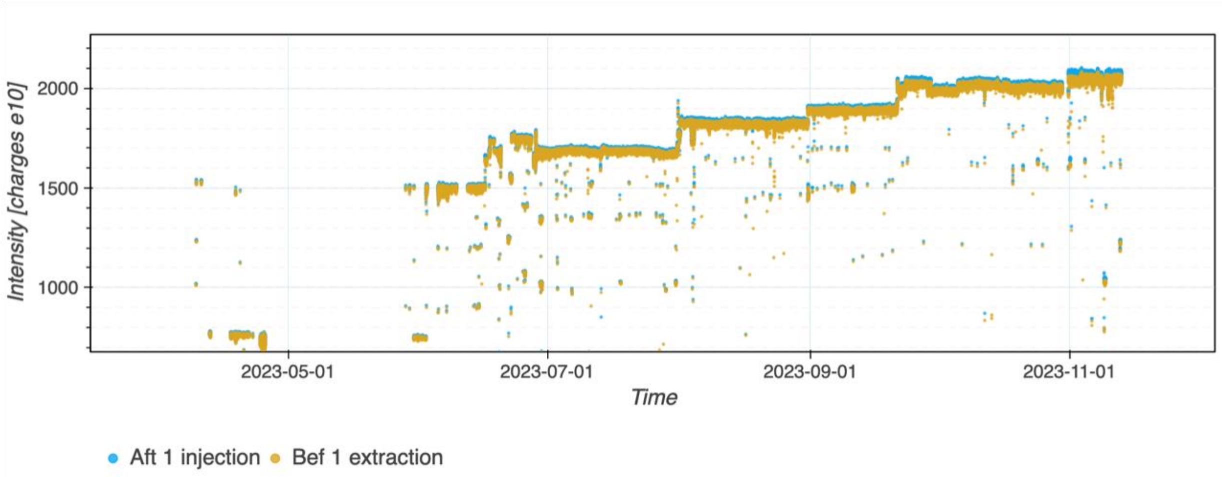
AD / ELENA

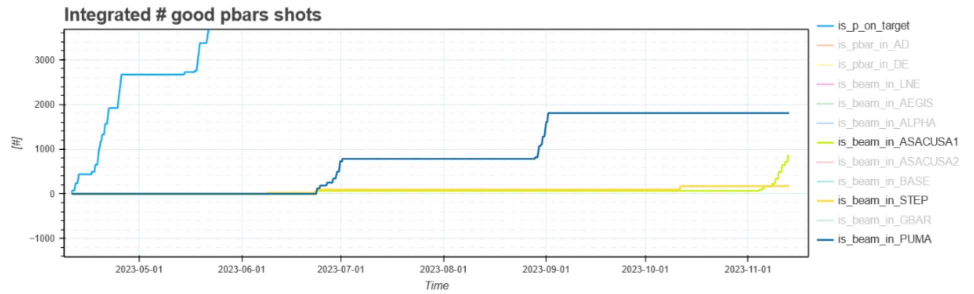
AD / ELENA

- **2023**: twice the ELENA design pbar / shot
  - Ad extraction increased to 2000e10 p (target limitation)
  - Optimisation of transmission efficiency in AD and ELENA allowed for **record bunch intensities of 1x10^7 pbars per bunch**
- **2024**: increase the shot-to-shot stability/reproducibility
- Users generally very happy with beam parameters and repetition rate
  - Experiments do not ask for higher repetition rate
  - GBAR requests to operate with **nominal emittance**









Antimatter Gravity - ALPHA

Article

Observation of the effect of gravity on the motion of antimatter

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E. K. Anderson[1], C. J. Baker[2], W. Bertsche[3,4], N. M. Bhatt[2], G. Bonomi[5], A. Capra[6], I. Carli[6], C. L. Cesar[7], M. Charlton[2], A. Christensen[8], R. Collister[6,9], A. Cridland Mathad[2], D. Duque Quiceno[6,9], S. Eriksson[2], A. Evans[6,9], N. Evetts[9], S. Fabbri[3,10], J. Fajans[8], A. Ferwerda[11], T. Friesen[12], M. C. Fujiwara[6], D. R. Gill[6], L. M. Golino[2], M. B. Gomes Gonçalves[2], P. Grandemange[6], P. Granum[1], J. S. Hangst[1], M. E. Hayden[13], D. Hodgkinson[3,8], E. D. Hunter[8], C. A. Isaac[2], A. J. U. Jimenez[6], M. A. Johnson[3,4], J. M. Jones[2], S. A. Jones[14], S. Jonsell[15], A. Khramov[6,9,16], N. Madsen[2], L. Martin[6], N. Massacret[6], D. Maxwell[2], J. T. K. McKenna[1,3], S. Menary[11], T. Momose[6,9,17], M. Mostamand[6,17], P. S. Mullan[2,18], J. Nauta[2], K. Olchanski[6], A. N. Oliveira[1], J. Peszka[2,18], A. Powell[12], C. Ø. Rasmussen[19], F. Robicheaux[20], R. L. Sacramento[7], M. Sameed[3,21], E. Sarid[22,23], J. Schoonwater[2], D. M. Silveira[7], J. Singh[3], G. Smith[6,9], C. So[6], S. Stracka[24], G. Stutter[1,26], T. D. Tharp[26], K. A. Thompson[2], R. I. Thompson[6,12], E. Thorpe-Woods[2], C. Torkzaban[8], M. Urioni[5], P. Woosaree[12] & J. S. Wurtele[8]

Einstein's general theory of relativity from 1915[1] remains the most successful description of gravitation. From the 1919 solar eclipse[2] to the observation of gravitational waves[3], the theory has passed many crucial experimental tests. However, the evolving concepts of dark matter and dark energy illustrate that there is much to be learned about the gravitating content of the universe. Singularities in the general theory of relativity and the lack of a quantum theory of gravity suggest that our picture is incomplete. It is thus prudent to explore gravity in exotic physical systems. Antimatter was unknown to Einstein in 1915. Dirac's theory[4] appeared in 1928; the positron was observed[5] in 1932. There has since been much speculation about gravity and antimatter. The theoretical consensus is that any laboratory mass must be attracted[6] by the Earth, although some authors have considered the cosmological consequences if antimatter should be repelled by matter[7–10]. In the general theory of relativity, the weak equivalence principle (WEP) requires that all masses react identically to gravity, independent of their internal structure. Here we show that antihydrogen atoms, released from magnetic confinement in the ALPHA-g apparatus, behave in a way consistent with gravitational attraction to the Earth. Repulsive 'antigravity' is ruled out in this case. This experiment paves the way for precision studies of the magnitude of the gravitational acceleration between anti-atoms and the Earth to test the WEP.

The weak equivalence principle (WEP) has recently been tested for matter in Earth's orbit[11] with a precision of order 10^{-15}. Antimatter has hitherto resisted direct ballistic tests of the WEP due to the lack of a stable, electrically neutral, test particle. Electromagnetic forces on charged antiparticles make direct measurements in the Earth's gravitational field extremely challenging[12]. The gravitational force on a proton at the Earth's surface is equivalent to that from an electric field of about 10^{-7} V m^{-1}. The situation with magnetic fields is even more dire: a cryogenic antiproton[13] at 10 K would experience gravity-level forces in a magnetic field of order 10^{-10} T. Controlling stray fields to this level to unmask gravity is daunting. Experiments have, however, shown that confined, oscillating, charged antimatter particles behave as expected when considered as clocks[14–16] in a gravitational field. The abilities to produce[17] and confine[18] antihydrogen now allow us to employ stable,

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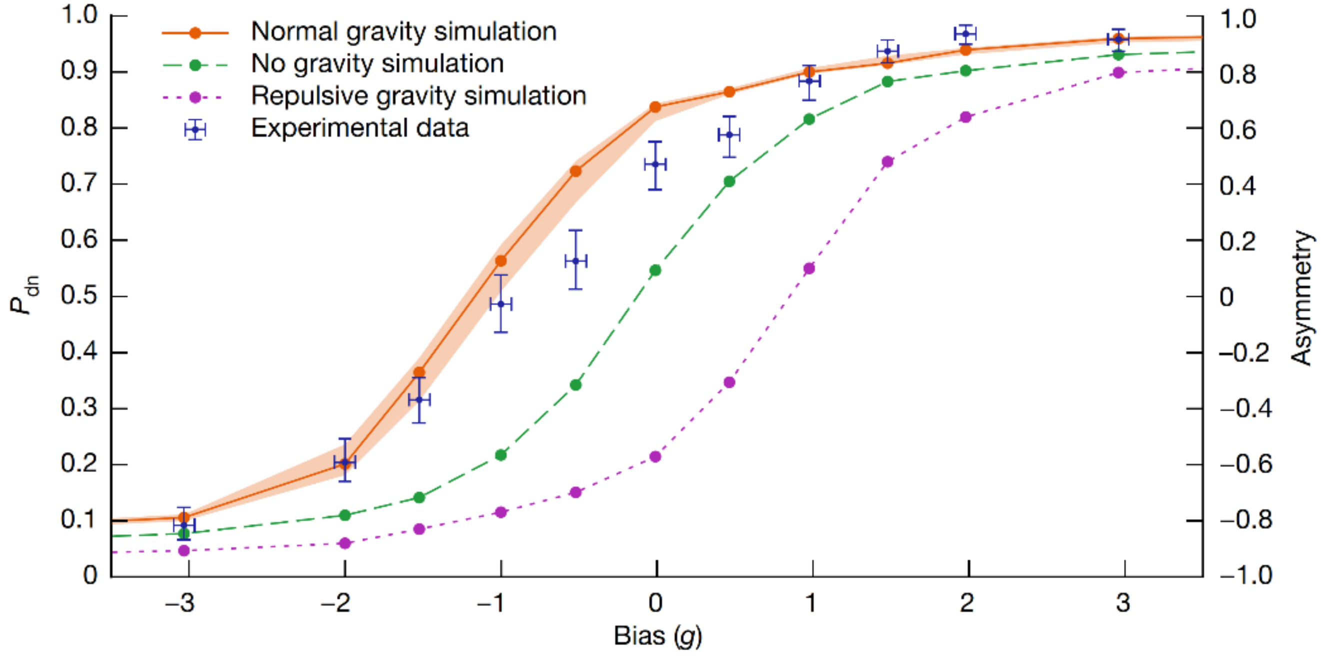
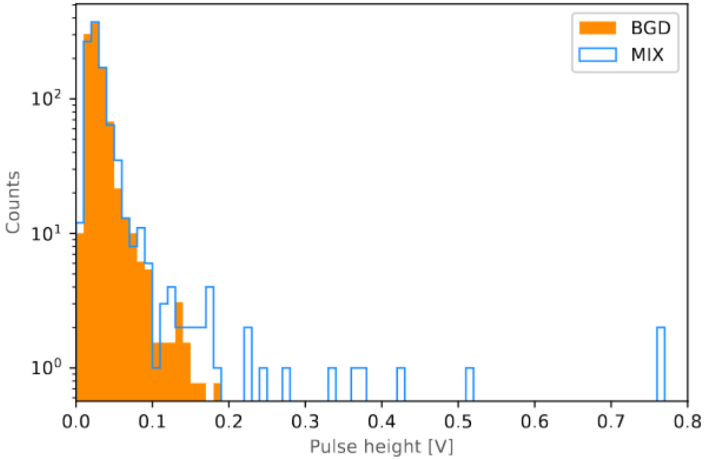
The escape curve



$$a = \Big(0.75\,(13)_{\text{stat,sys}}\,(16)_{\text{sim}}\Big) \times g$$

Further AD Physics Highlights

- **GBAR** published **production of antihydrogen atoms** by 6 keV antiprotons through a positronium cloud
  https://arxiv.org/abs/2306.15801

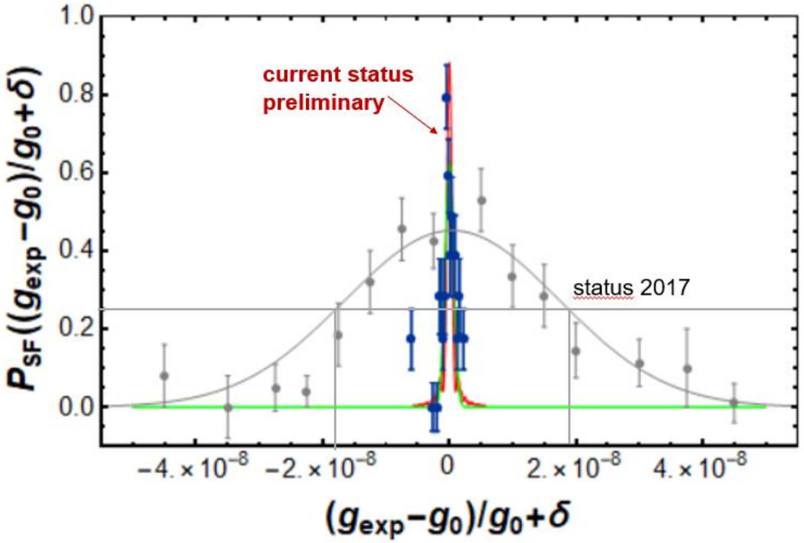


The European Physical Journal C

Regular Article - Experimental Physics

Production of antihydrogen atoms by 6 keV antiprotons through a positronium cloud

- **BASE** performed the **first ever coherent quantum spectroscopy with a single nuclear spin**, reducing g-Factor (magnetic moment) line width by more than a factor of 20.



Technical Highlights

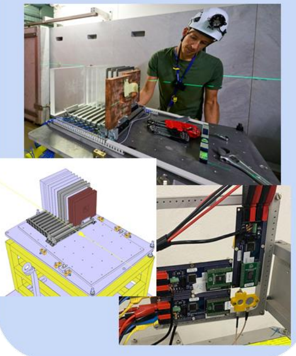
AD-3	ASACUSA	a) CUSP antihydrogen experiment; new Na22 positron source arrived / will arrive? **b) Antiprotonic helium experiment: successfully connected to ELENA; Induction decelerator under construction**
AD-5	ALPHA	• Fixed installation Helium transfer line for ALPHA-g almost complete
AD-6	AEGIS	• **First formation of highly charged ions in the AEgIS apparatus was observed** • Upgraded trap; intense measurement period at the end of the year • **low energy extraction beam line was commissioned** • New Na22 positron source arrived in November
AD-7	GBAR	ELENA team improved emittance of the beam: achieved nominal emittance for the nominal intensity + doubled intensity (1e7 $\bar{p}$/bunch)
AD-8	BASE	• **full reservoir trap (30 $\bar{p}$);** 1 $\bar{p}$ per month required, preparation of annual shutdown measurement campaign in progress. • BASE-STEP: transport routine established (3 hours without power); $\bar{p}$ trapping planned for 2024
AD-9	PUMA	Aim: Transport of $\bar{p}$ from ELENA to ISOLDE; measure charged pions from annihilation with low energy ions from ISOLDE → neutron-to-proton annihilation ratio • **Antiproton beam line (deceleration with PDT to 4 keV) validated with beam and ready for next year.** • First measurements at ELENA May 2024 • ISOLDE beam line final design; Requested to be ready before the end of 2024, for first experiments at ISOLDE in 2025.

PS East Area and nTOF

CHIMERA / HEARTS (Ion Run) in T8

- 2 weeks Pb ion beam with several **beam energies from 650 MeV/n to 3 GeV/n** in CHARM
- 2023 objectives largely achieved
  - beam commissioning and beam characterization (**regular BI + R2E detectors**)
    - including energy deposition measurements with diode in T8b (EA1/IRRAD)
  - Measurements for **detector characterization & calibration**:
    - including detectors from HEARTS EU project beneficiaries, partners & collaborators (GSI, Oldenburg Uni., PTW, Wollongong Uni.)
    - Single Event Effects testing

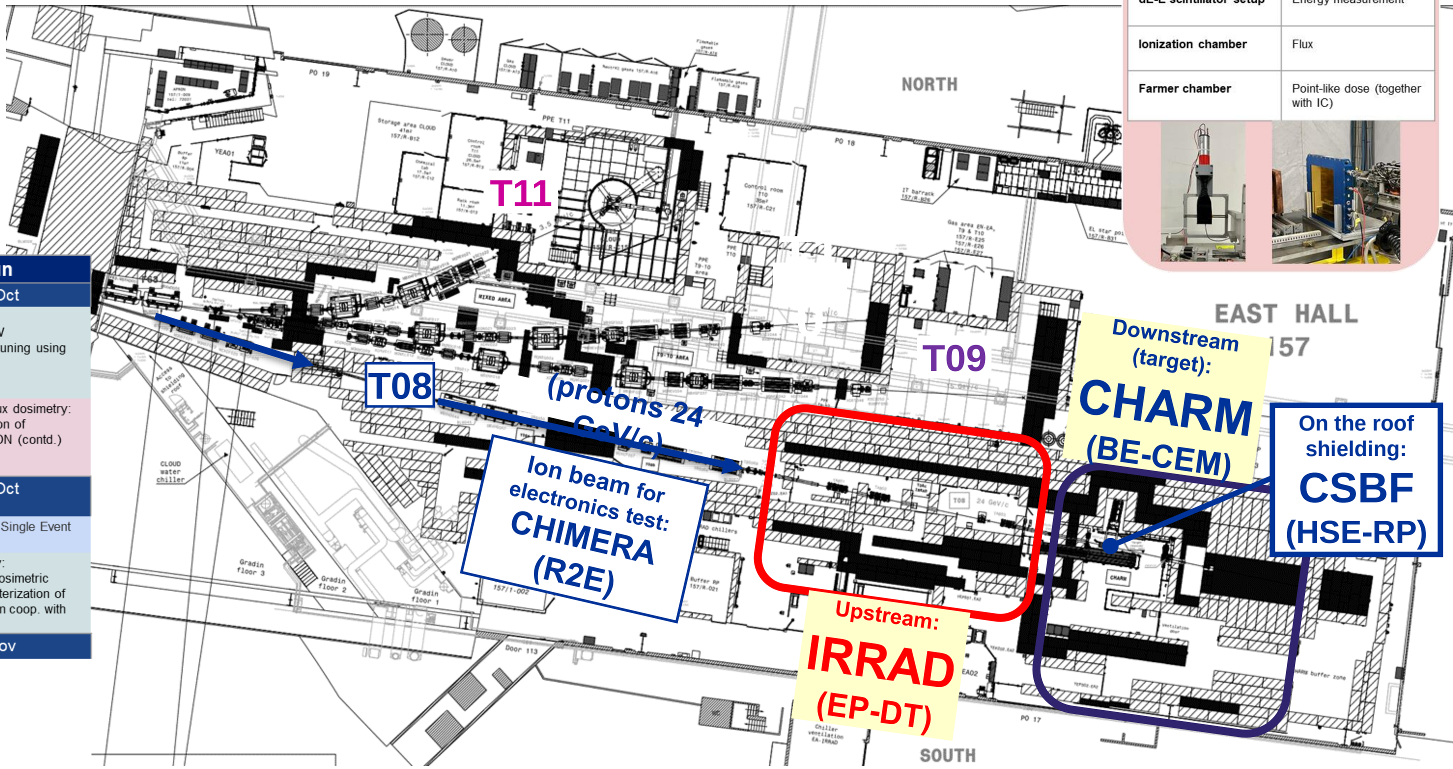
Beam exploitation



R2E diode in T8b

GSI

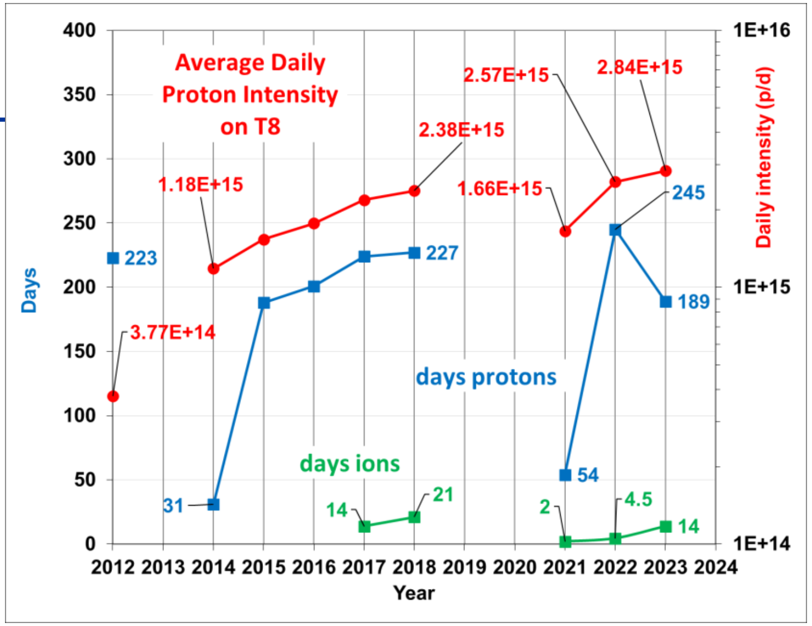
Transmission scintillator	Event-by-event particle counting
dE-E scintillator setup	Energy measurement
Ionization chamber	Flux
Farmer chamber	Point-like dose (together with IC)

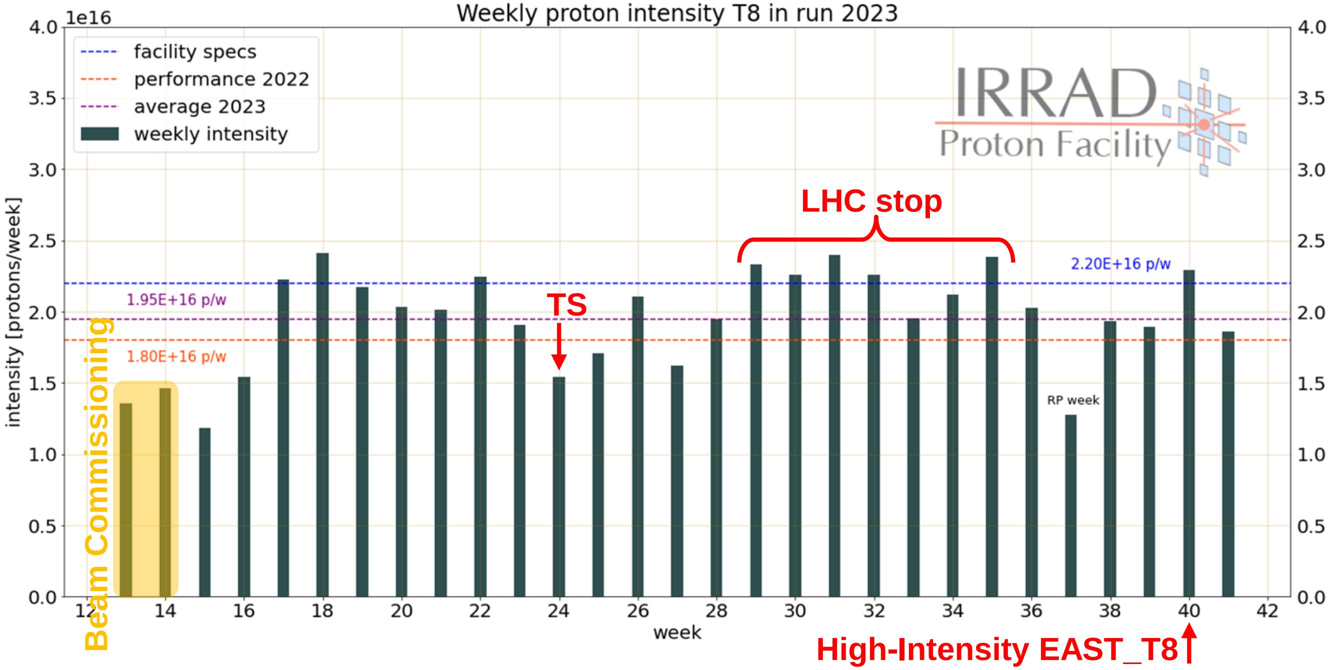


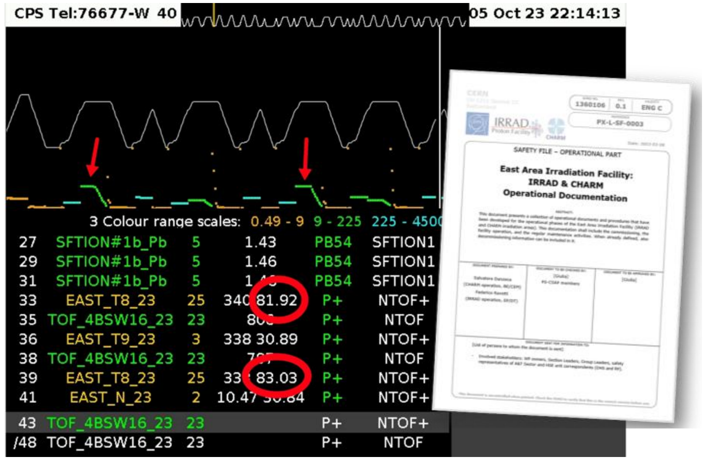
Mon	Tue	Wed	Thu	Fri	Sat	Sun
16 Oct	17 Oct	18 Oct	19 Oct	20 Oct	21 Oct	22 Oct
	Beam commissioning: control of spill duration and profile, energy, intensity, optics	Energy dosimetry: - Diode measurements in EA1 and CHARM		Energy dosimetry: - Microdosimetric characterization of beam in cooperation with UoW - Testing and exploitation of LET booster system for beam energy tuning using diode		
	Irradiation of SRAM electronic components: check against 2022 results	Beam flux dosimetry: Diode measurements for calibration of SEC/XION		Irradiation of SRAM electronic components: using LET booster		Beam flux dosimetry: calibration of SEC/XION (contd.)
23 Oct	24 Oct	25 Oct	26 Oct	27 Oct	28 Oct	29 Oct
HEARTS intercomparison CERN vs GSI using GSI beam monitoring devices: IC, Farmer chamber, scintillators	HEARTS characterization of beam profile in cooperation with UniOldenburg/PTW using detector arrays, gafchromic films and Farmer chamber, variation of beam optics		Direct beam and surrounding radiation field characterization using TimePix	Electronic component Single Event Burnout tests; Electronic component Single Event Latchup tests, SRAM tilt tests		
				Beam flux dosimetry: Diode measurements for calibration of SEC/XION using LET booster (contd.)	Energy dosimetry: - Diode measurements in CHARM (contd.)	Energy dosimetry: - Microdosimetric characterization of beam in coop. with UoW
30 Oct	31 Oct	1 Nov	2 Nov	3 Nov	4 Nov	5 Nov
Energy dosimetry: - Diode measurements in EA1 and CHARM	Electronic component Single Event Latchup tests, SRAM tilt tests	End of run at 6:00				
RP dedicated run with target overnight (either Mon or Tue)	Flash overnight, UniPD passive irradiation					

IRRAD / CHARM PS East Area T8 line

- Steady improvement of the average daily intensity
- Facility specification reached **~36% of the weeks** in 2023 (LHC stop)
- Tested **high intensity spill** 80E10 pps (was from 60E10)
  - CHARM Target operation validated (SY-STI)
  - HSE-RP: dedicated survey (EDMS 2965197) confirmed **no RP showstopper running within EAST_T* individual limits** per target
  - ECR to be completed during EYETS (EDMS 2825729)
- 2024: Run operationally with high-intensity EAST_T8 spill **to reach the facility specification**

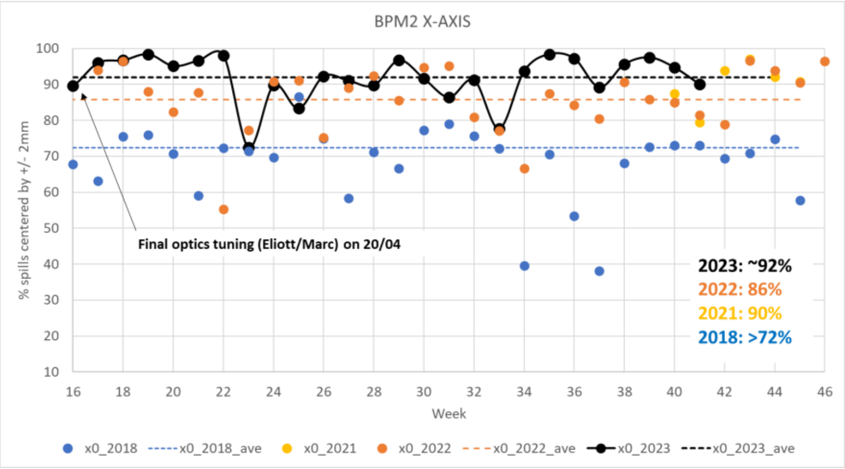


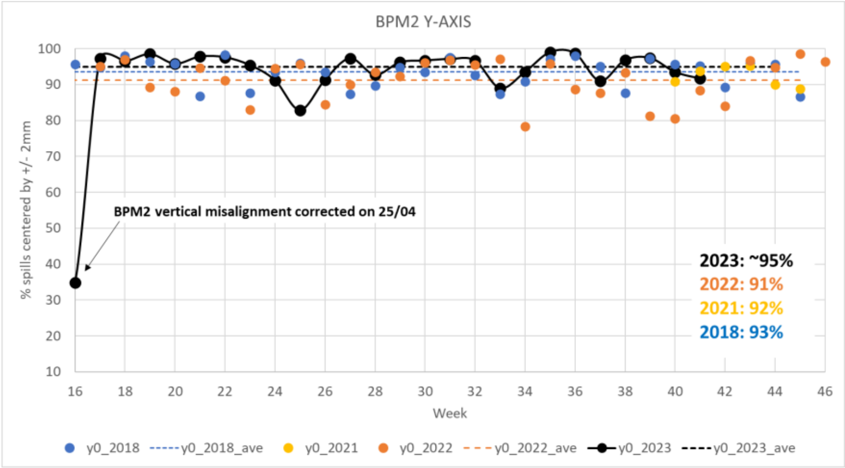




EAST_T8 Beam

- **2023**: Significant improvement of the beam center position >90%
- Very stable until week 22; Fluctuations from week 23 onwards:
  Cycle preceding EAST_T8? Extraction to AD?
- **2024**:
  - Understand and mitigate **beam center fluctuations**
  - Monitor and correct **fluctuation of transverse beam size**, fully exploiting IRRAD-BPM data
  - Add **protection against proton/ion beam wrongly sent to T8**:
    - external condition to T8 destination being implemented by BE-OP, BE-ICS and BE-CSS
  - Improve communication about MD activities on T8 proton/ion beams:
    - avoid unwanted (negative) feedback on the quality of the EAST_T8 operational beam
- **Further desiderata:**
  - For future (**CSBF -** CERN Shielding Benchmark Facility) runs: proton beams to T8 with **lower momenta, down to few GeV/c**
  - Ions runs (**CHIMERA**):
    - 1s spill duration (including beam instrumentation)
    - PS tune optimization as a function of energy
    - F61/T8 vacuum extension

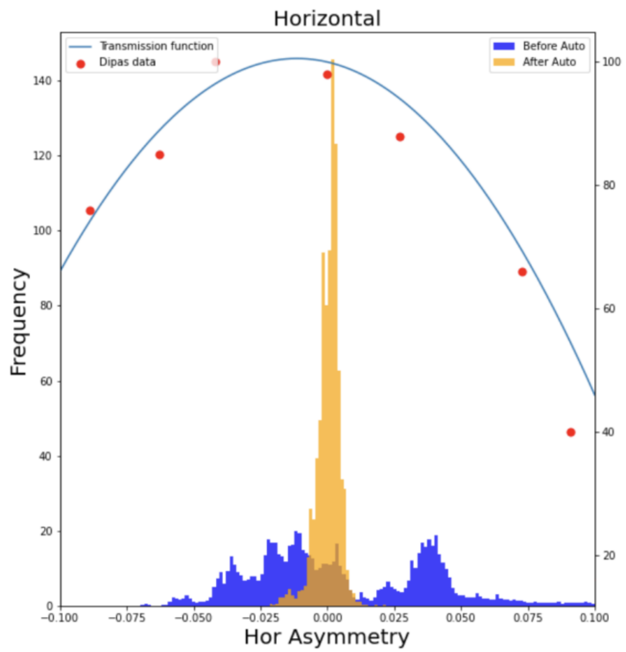




EAST_T9, EAST_N

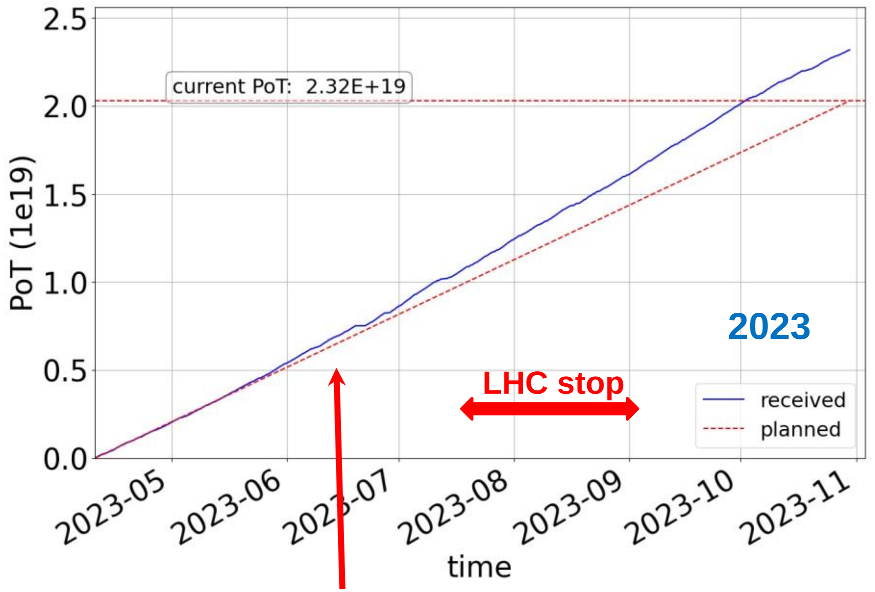
- Implemented **automatic beam steering on T9 and T10/T11 target** in collaboration with BE-EA during second part of the 2023 run
  - Based on beam asymmetry measurement from beam loss monitors around target

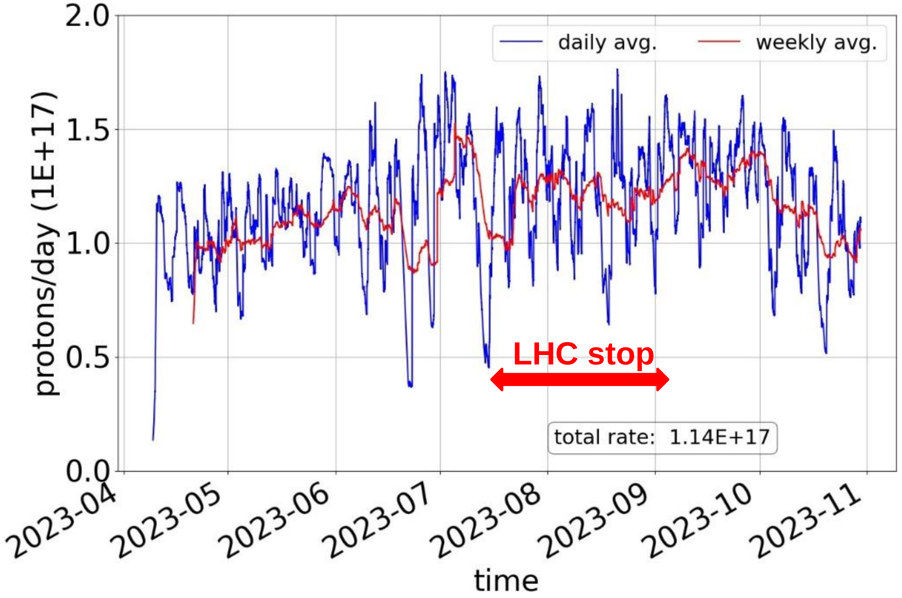
- **Requests 2024:**
- Users would **need more spills per super-cycle**: Can spills automatically be re-assigned when T9 or T10 opens the zone?
- **Infrastructure**:
  - Cherenkov counters in T10 not working properly
  - Some set-ups experienced **problems with sunlight** (through the windows) – set-ups usually not test for direct sunlight exposure in the lab
  - Roof tightness
  - Facilities not allowed inside a controlled zone – possible just outside? at least for **washing hands**?



Improvement in the horizontal beam asymmetry on the T9 target before (blue) and after (orange) automatic beam steering.

nTOF





Average proton beam intensity upper limit:
167E10 -> 220E10; 09.06.2023

2023 Highlights:

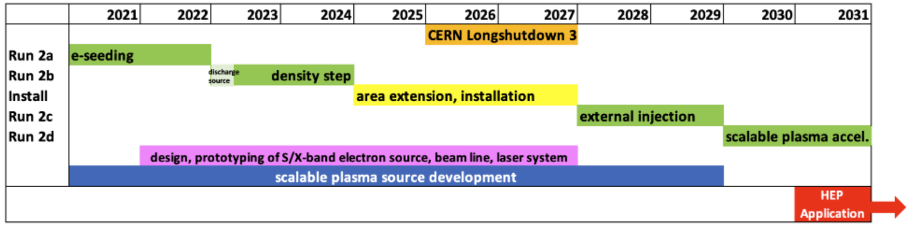
- Received **14% more protons than anticipated** (2.3E19 wrt 2.03E19). Average received: 1.14E17 p/day 😃
- All experimental campaigns received the approved number of protons
- **Flexibility on the pulse intensity**

2024

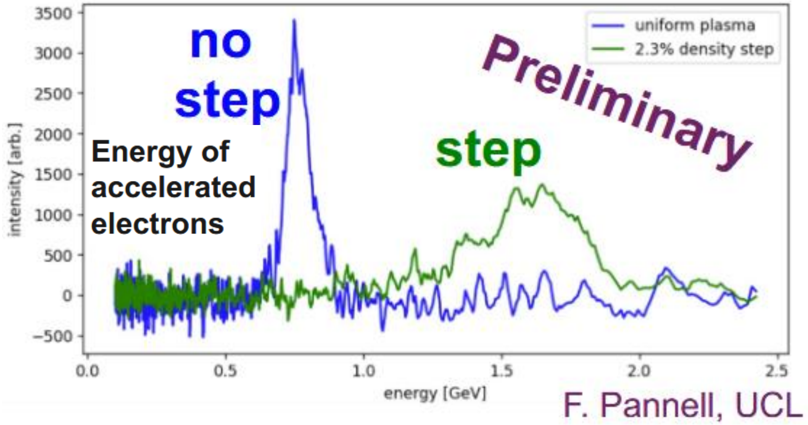
- **Keep 1E17 p/day as baseline average rate** (expect PS EA to be fully booked, LHC running etc.) but **hope for more**.

AWAKE and HIRADMAT

AWAKE

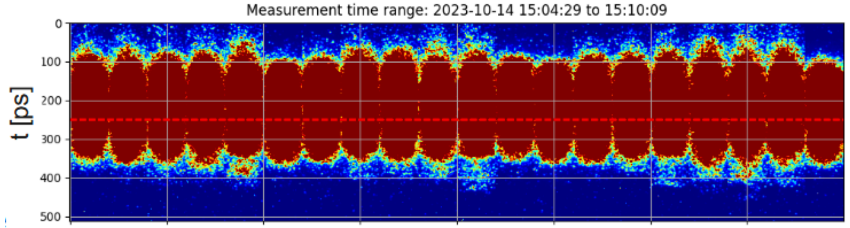


- **Highlights 2023**:
  - Operation of **new Discharge Plasma Source** – candidate technology for 2029 onwards
  - Operation of Rb source with **Density Step** to maintain large wakefield amplitudes over long plasma distances
- **2023 improvements**:
  - **Faster proton beam alignment**
  - Dedicated AWAKE operated when NA was in fault
  - Availability of laser and electron beams during EYETS. Added to official injector schedule.
  - **Issues**
    - Occasional event-to-event and day-to-day **changes in average bunch length and shape** (e.g., 20% in 3 days in November). SY-RF proposes improved monitoring for 2024 (https://indico.cern.ch/event/1349652/)
    - Continue dedicated data-taking for **proton beam jitter** measurements to pinpoint relevant power converters
- **2024**: need proton beam stability and reproducibility over multiple days
  - **Improve monitoring** of proton beam (in conjunction with OP) to immediately spot changes and react
  - Combined SPS+AWAKE effort to quickly spot know issues
- Baseline plan: **No beam in 2025** – dismantle CNGS



F. Pannell, UCL

Bunch z profile changing from event to event

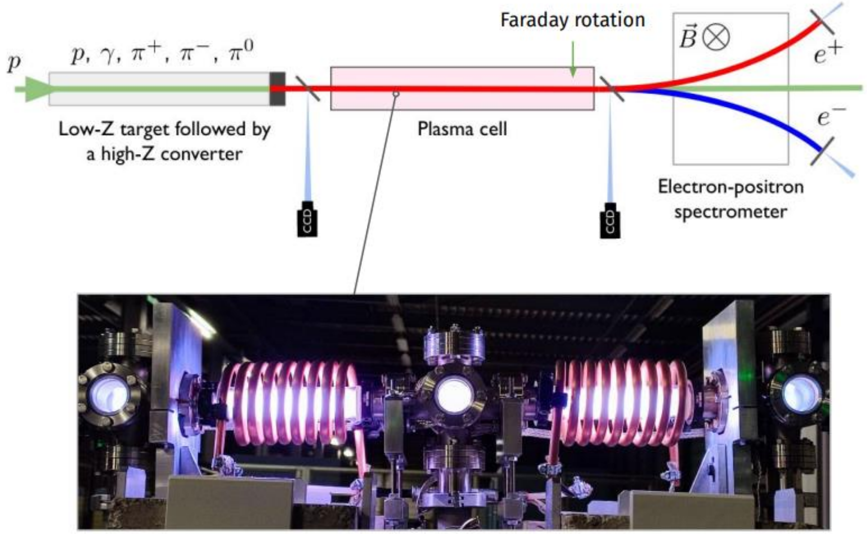


SPS Extraction

HiRadMat: Highlights and Requests

Experiment highlights

- **HRMT62 FIREBALL – Oxford:** Generate a **quasi-neutral e^-/e^+ pair beam** to reproduce an astrophysical jet in lab
Nature physics paper submission
https://home.cern/news/news/experiments/fireball-hiradmat



- **HRMT25 TPSG4 - SY/ABT:** MSE protection element & bending magnet tested under the LIU scenario successfully

Improvements

- AWAKE beam parameters achieved at HiRadMat: **1 bunch with 3×10^{11} protons** (1 ns bunch length)

- HiRadMat runs in 2023 **very smooth** (in comparison to 2021) thanks to
  - Excellent communication with OP (injectors and LHC)
  - Dedicated running time

- All experiments finished before the end of the week, **all weekends returned to physics,** AWAKE & MD also recuperated days from the HiRadMat Weeks

- HiRadMat Upgrade during this EYETS: **require 288 bunches of $2.3\text{x}10^{11}$ ppb in 2024**

Requests

- **Define in advance the KPIs** of the required beams (input from the experiments).

- **Pre-commission challenging beam configurations** during a couple of hours the week before the actual experiment.

- **Faster change-over** between HiRadMat cycles and faster SPS super-cycle changes in general

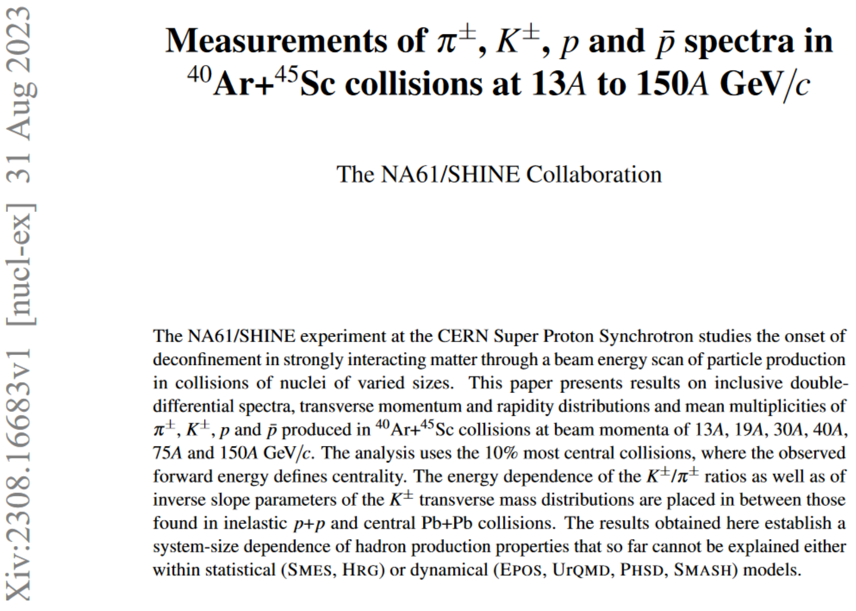
- **Extraction with momenta < 440 GeV/c** : A small taskforce has been established (BE-EA, SY-ABT & BE-OP) and tests are to be scheduled for end of 2024-25

SPS North Area

NA61/SHINE

- **2023**:
  - The **quality of the ion spill structure was significantly improved in 2023** - improvement was triggered by users' meeting discussions with machine experts
  - On top of known issues with **beam position stability**, a new thing was observed: **jumps in beam position for low momentum hadron beams - caused by interference when settings in neighbouring lines are changed.**
- **2024**
  - Addressing the **low momentum beam position jumps**.
  - Better **stability of ion beam intensity** and position

- Mayor paper on intermediate size system (Ar+Sc, 2015). https://inspirehep.net/literature/2692441



Xiv:2308.16683v1 [nucl-ex] 31 Aug 2023

Measurements of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ spectra in ^{40}Ar+^{45}Sc collisions at 13A to 150A GeV/c

The NA61/SHINE Collaboration

The NA61/SHINE experiment at the CERN Super Proton Synchrotron studies the onset of deconfinement in strongly interacting matter through a beam energy scan of particle production in collisions of nuclei of varied sizes. This paper presents results on inclusive double-differential spectra, transverse momentum and rapidity distributions and mean multiplicities of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ produced in ^{40}Ar+^{45}Sc collisions at beam momenta of 13A, 19A, 30A, 40A, 75A and 150A GeV/c. The analysis uses the 10% most central collisions, where the observed forward energy defines centrality. The energy dependence of the $K^{\pm}/\pi^{\pm}$ ratios as well as of inverse slope parameters of the $K^{\pm}$ transverse mass distributions are placed in between those found in inelastic p+p and central Pb+Pb collisions. The results obtained here establish a system-size dependence of hadron production properties that so far cannot be explained either within statistical (SMES, HRG) or dynamical (EPOS, UrQMD, PHSD, SMASH) models.

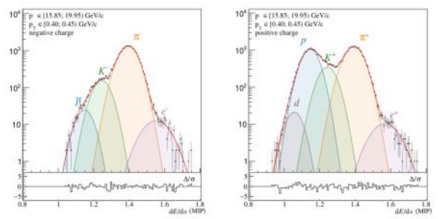


Figure 8: The dE/dx distributions for negatively (*left*) and positively (*right*) charged particles in a selected $p-p_T$ bin produced in *central* Ar+Sc collisions at 75A GeV/c. The fits by a sum of contributions from different particle types are shown by solid lines. The corresponding residuals (the difference between the data and fit divided by the statistical uncertainty of the data) are shown in the bottom plots. The absolute dE/dx scale is precise to 2%.

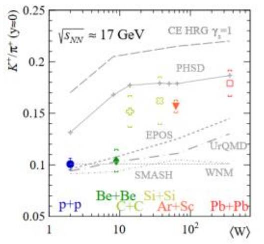


Figure 57: System size dependence of the K^+/π^+ ratio (at $y \approx 0$) in *central* nucleus-nucleus and inelastic interactions obtained at beam momenta of 150A GeV/c ($\sqrt{s_{NN}} \approx 17$ GeV) compared with dynamical (EPOS 1.99 PHSD 4.1 [20, 21] and UrQMD [78, 79]) and statistical (HRG [19]) models.

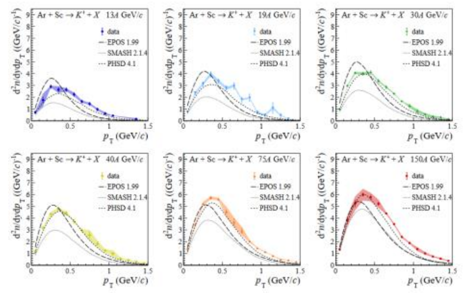
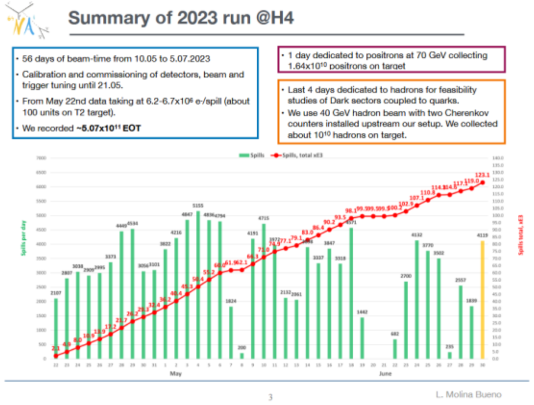
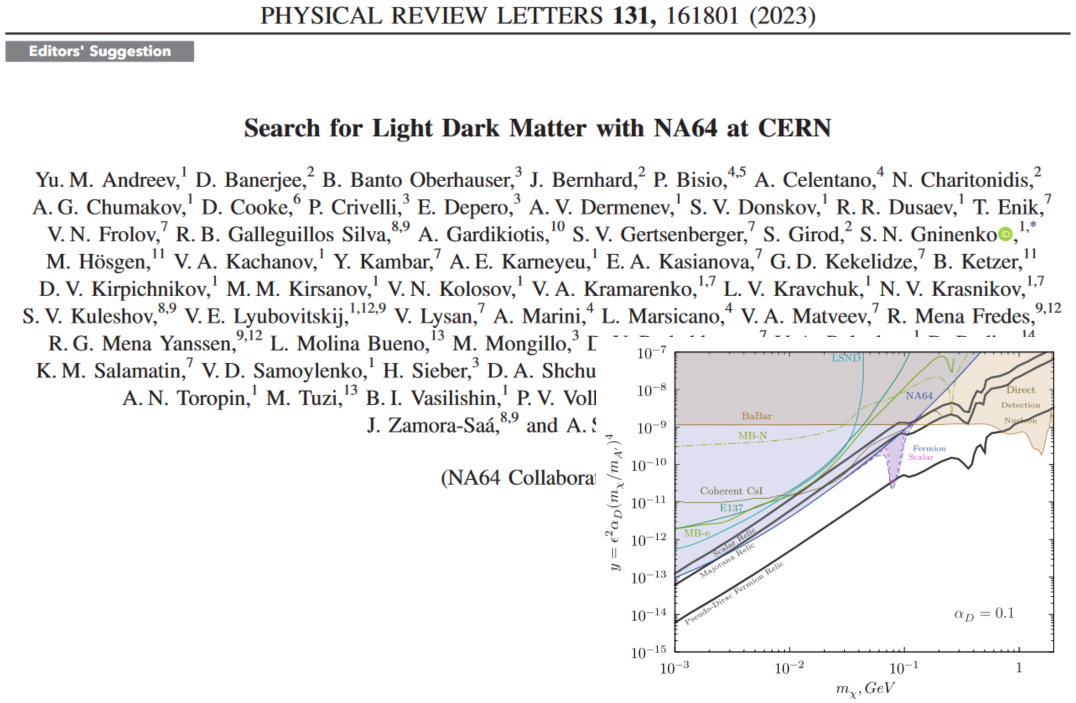


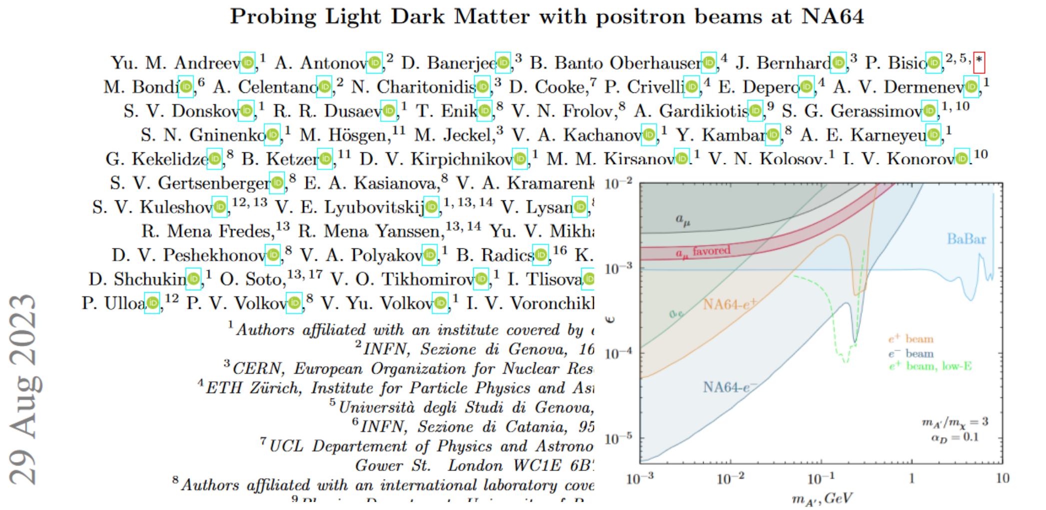
Figure 44: Mid-rapidity transverse momentum spectra of K^+ mesons produced in 10% most *central* Ar+Sc interactions at 13A, 19A, 30A, 40A, 75A and 150A GeV/c in comparison with models: EPOS 1.99 [73], PHSD 4.1 [20, 21] and SMASH 2.1.4 [74, 75].

NA64

- **2023**:
  - SPS H4 high purity electron beam:
    - **Improved overall beam quality, stability** of the spill and **consistent high intensity** electron beam reaching up to 6.8×10^6 e^-/spill (T2=100 units)
    - **Improved vacuum** of the beam line the beam quality was excellent with the **beam halo reduced from 5% to 3%** even at high intensities and the **hadron contamination was 0.3%.**
  - SPS M2 muon beam:
    Very good beam quality.
- **2024 / 2025**: same as in 2023







"Search for Light Dark Matter with NA64" **(PRL's Editor suggestion)**
https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.131.161801

"Probing Light Dark Matter with positron beams at NA64," *CERN-EP-2023-192, [arXiv:2308.15612 [hep-ex]] (submitted to PRL)*
https://arxiv.org/pdf/2308.15612.pdf

NA66 AMBER – M2 beamline - First physics data taking in 2023

- **2023**:
  - Beam quality and delivery very good - as far as we saw - but we are not really sensitive with the low intensity beams.
  - Problems with magnet regulation (**jumps in beam positions seen during 2022 most probably still exists but we were not sensitive** since we changed beam settings every few days.
  - The only problem was the **change in intensity every time the sharing on the primary targets changed –** due running at to beam low intensity
- **2024 – 2025:**
  - Better control about low beam intensity delivery
  - Review of the **beam instrumentation** we had problems with CEDARS but also with FISC and MWPCs in the beamline.
  - A beam component introduce quite high background rates on the top PMTs of both CEDARs. This was found by AMBER during the DY high intensity test. A second dedicated high intensity hadron test was performed by BE during PRM beam time to identify this component. → **Aperture of Bend 6 is hit by the beam, investigations are on-going.**
  - **Upgrade of beam-line vacuum before LS3** to make checks of the improvements before LS3

SPS North Area continued

- **NA62** – K12 beamline:
  - CEDAR-H fully operational and performing well
  - The work on the **spill structure** initiated in 2022 and **consolidated** in 2023 and the work of **re-alignment and fix of the extraction line in April** has **greatly improved the performance of NA62**
  - In 2024 and 2025: continue with the good spill quality.

- **MUONE** – M2 beamline:
  - Preparing their proposal for the SPSC (SPS Scientific Committee)
    - „An alternative evaluation of the leading-order hadronic contribution to the muon g-2 with MUonE", Phys. Lett. B 848 (2024), 138344; doi:10.1016/j.physletb.2023.138344 https://www.sciencedirect.com/science/article/pii/S0370269323006780
  - No changes in beam requested until LS3

Detector R&D Test Beam Users

- Numerous and diverse community
- New DRD collaborations being currently formed

General Remarks from Test Beam Users

- Many test beam users have only 1 or 2 weeks to perform their measurements. Substantial time for commissioning and set-up changes → even a relatively short beam unavailability can be problematic.
- **Maximal rate** during the spill is **usually defined by the DAQ (**few users limited by radioprotection)
  - Spill structure often hidden behind the low data-taking rate
  - The only way to improve statistics is by **increasing the number of collected spills** – increasing beam intensity would not improve statistics.

  →The best **KPI for a test beam is the number of delivered spills**
- Request to improve **announcements for shorter-notice super-cycle and beam changes:**
  - Examples
    - If users know that filling of the LHC will start in an hour, they can postpone their access to change their detector orientation until then.
    - When there is a beam stop, up to date (including reason of stop) information about the status should be communicated, **so that the people and equipment are ready when the beam comes back**, not scrambling out of the experimental area once the beam gets into the machine!

- User feed-back session test beams https://indico.cern.ch/event/1345699/

SPS NA Test Beams and CERF

CERF (CERN-EU high-energy Reference Field facility) - user facility in H6 https://cerf.web.cern.ch/	2023 beam very stable and highly available 2024: • **CERN-integrated solutions to perform beam monitoring** (e.g., centralized acquisition on NXCALS, etc.) could be studied with the support of BE and SY
RD51; micropattern Gas Detectors; up to 7 set-ups; 3x2 weeks; in H4 most of the time parallel to GIF++ → **Future DRD1** (gaseous detectors) → **Larger and more divers user group!**	2023: Improved purity of the muon beam; 2024: • pion beam: possibility to scan the rate densities (Hz/cm2) ? • Large number of set-ups: demanding installation and dismounting; resources on the limit (power sockets, IPs, gas, tables, …) • **Upgrade of the Beam instrumentations & environmental sensors** could bring to significant improvement in the measurements.
DRD6 Calorimetry	Large and challenging prototype setups even in early stages; Dedicated calorimeter test beam line requested
LHCb	Effort to move towards common runs with multiple subdetectors (e.g. VELO+RICH) Issue: **gas leak detection and gas bottle monitoring – service not available over the week-end; monitoring of the gas levels 24/7 is crucial;**

SPS NA Test Beams continued

EP R&D pixel sensors. • 5 weeks in H6 with high secondary beam rates. • All users requiring high rates run in parallel during these dedicated weeks.	• Require small beam size and/or high particle rates • Available rates are RP limited: up to $6x10^6$ / spill at 3 spills / 43.2 sec SC; **~ 2-3 times higher rate in 2023 than in 2022** – less upstream losses due to VXSS vacuum chamber material removal • User could take rates up to $\sim 8x10^7$ hits/s • Grafana monitoring of DAQ status and environmental conditions **Wishes:** • **Automatic adjustment of rate (collimator settings)** based on observed radiation levels →higher instantaneous rates during periods with fewer spills / longer super-cycles • Additional beam-profile monitors near H6B telescopes for easier beam tuning • **Possibility to run CESAR in monitoring mode on any non-Windows PC from remote** (for us it currently only runs on Windows Terminal Server machines) • **Documented API for CESAR monitoring data (zone access status, rates, ...)** **→Needed for integration in our Grafana monitoring**

Towards the unified CERN Controls Systems

Integration of the Experimental Areas Controls (CESAR) with the **Accelerator Controls is advancing.**

2023 Highlights

- **Technical design** of CESAR **based on Acc Controls**, endorsed by EATM and CTTB.
- **Development** work to **integrate CESAR with LSA** and **Controls Configuration.**
- **Progressing technical consolidation** of CESAR.
- **Ongoing study** of the future **CESAR GUI**.
- Ongoing analysis to **separate equipment-specific logic from CESAR** virtual server.

2024 Plans

- **EA settings management** based on **LSA** to be deployed this **YETS**.
- **CESAR Lite GUI** for the EA users, **based on standard Controls solutions** – release candidate by the end of 2024.
- Full integration of CESAR with **Controls Configuration**, leveraging CCDA.
- **Collaboration** with the **Equipment Groups** to improve CESAR and benefit from FESA.

The 2024 is a milestone year to bring the **Experimental Areas** operational procedures **closer to the Accelerators.**

Maciej Peryt BE-CSS

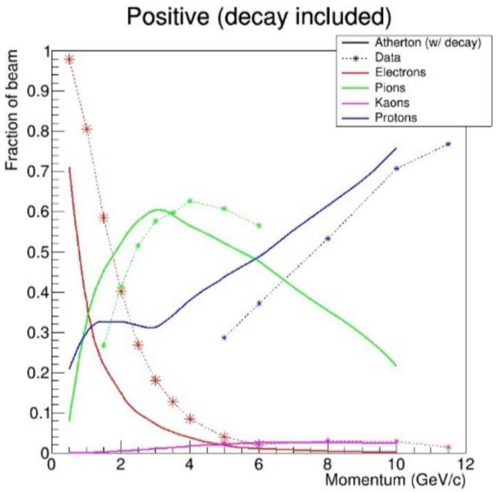
Secondary Beam Compositions

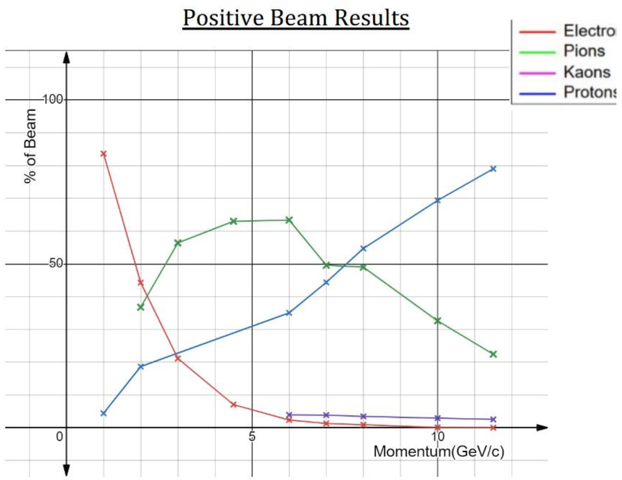
- Some experiments measure the secondary particle compositions

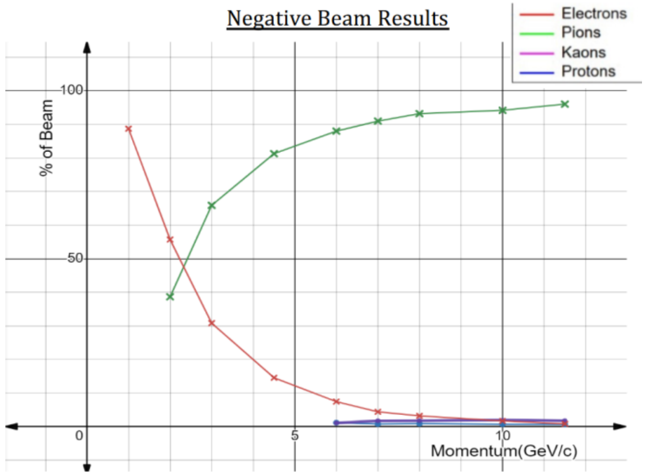
  Preliminary data during their beam time – final data would be available on request
- Also dedicated measurements by EA
- → Repository for secondary beam composition together with beam line settings, target type, target intensity?
- → trace possible improvements (or degradations)
- → Could be used by future users to plan their measurements

Preliminary Beam compositions

- PS EA T10 beam composition by **EA** (Maarten van Dijk) and **BL4S Pakistan Team** (https://indico.cern.ch/event/1233355/contributions/5512350/attachments/2722816/4731119/Team%20Particular%20Perspective%20Final%20Presentation.pdf)
- WCTE preparing paper on T9 beam composition





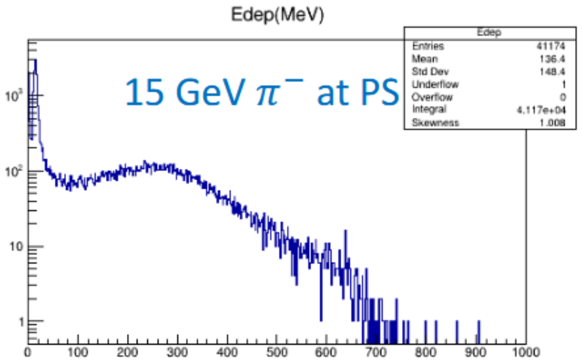


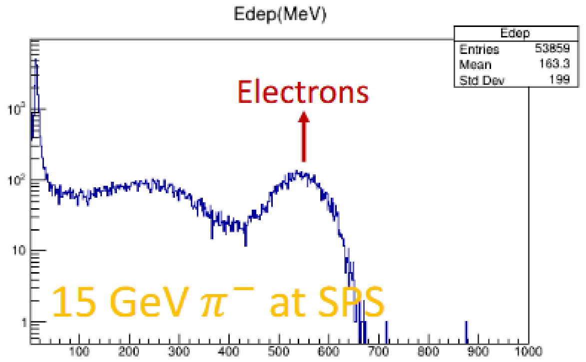
- **CALICE** (future DRD6): e.g. 15 GeV pions: less electron contamination at **PS T9** than at the **SPS H2**
- **ATLAS TILECAL** in H8 2023 wrt 2022:
  - Less electron contamination in hadron beam
  - Improved electron beam intensity and purity

- In the past Nov 22 TB:
  - - 10 GeV: ~71%
    - 20 GeV: ~37%
    - 30 GeV: ~21%
    - 75 GeV: ~3.1%

PRELINARY 2023

10 GeV: **85.8%**
20 GeV: **79.6%**
50 GeV: **64%**
80 GeV: **66.8%**
100 GeV: **66.9%**





Fragmented Ion Beams – 2023 test beam users

- Secondary ion beams created by nuclear fragmentation when the primary SPS Pb beam hits the target; rigidity selection of A/Z (mass/charge) ratio in the secondary beam line (H2, 2010, https://cerncourier.com/a/light-work-with-heavy-ions/)
- SPS H4, **HERD** test beam
- SPS H8, **VLAST** and **R2E** test beams

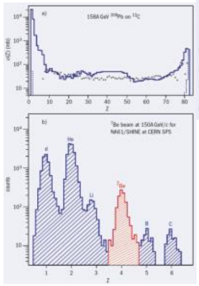
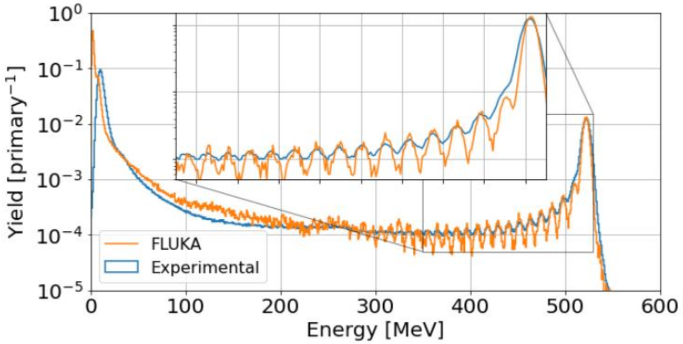
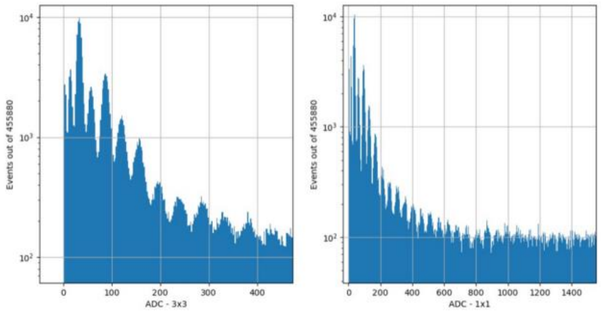
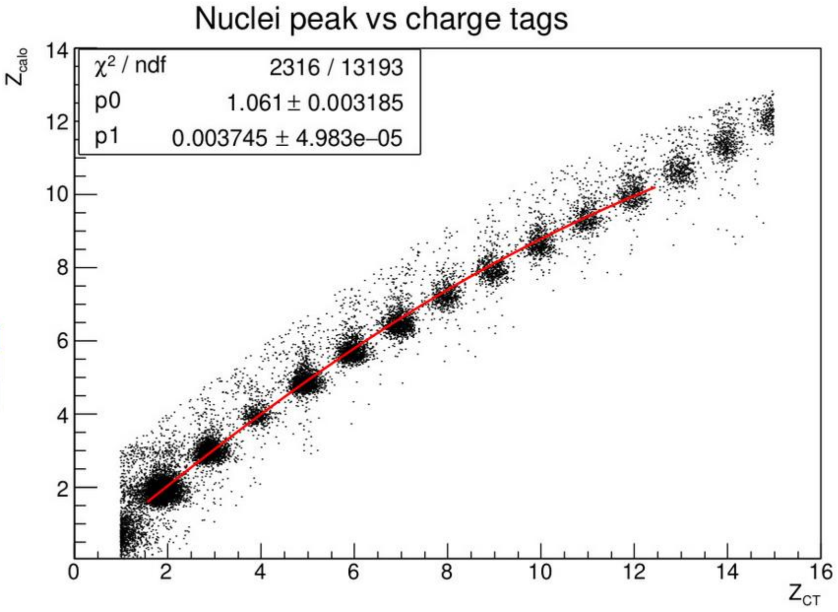


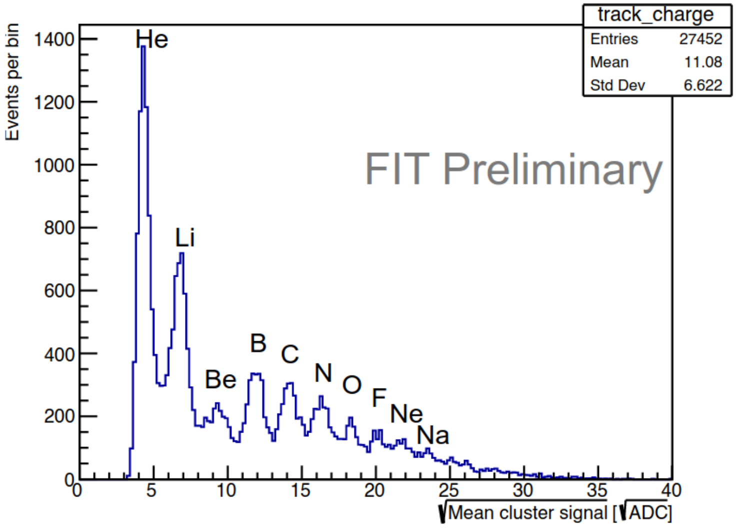
Fig. 1. a) Fragment cross-sections as a function of the charge Z of ions produced at CERN in Pb+C collisions at 158A GeV/c (Cecchini *et al.*). b) The measured ion rates in the H2 beamline for a selection in rigidity optimized for the transmission of ^{7}Be.

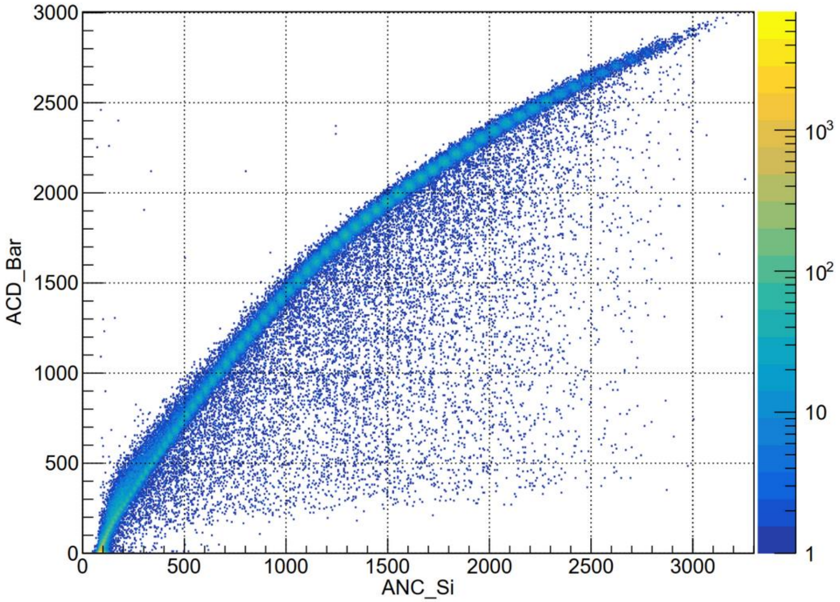
	Lead	Heavy fragments	Light fragments
Deposited energy [MeV]	> 500	100 < E < 500	< 100
Intensity [cm^{-2}/spill]	684	310	4100











Overview of Wishes and Expectations for 2024

- Topics for 2024 on beam quality
  - PS T8: continue to improve the position stability; measure (and correct) the shape stability
  - AD/ELENA:
    - shot-to-shot stability/reproducibility
    - Operate with nominal emittance
  - Reduce fluctuations in ion beam intensity
  - Improve position stability of the EHN1 beams
    - Pre-2023 position instability still present
    - Additionally in 2023 especially for low secondary low beam moment, setting changes in other EHN1 lines change the beam position in H2 and H4 for proton and ion beams
- NA62 is concerned about the EHN3 high intensity MDs. (Muon) beams reaching the experiment? Accident scenarios?
- Ongoing Study: Smaller spot size in H6 for pixel detector R&D

- More spills to everybody ;-)

Lots of praise from the users for the beam quality and availability and the phantastic responsiveness and support from all the teams!

Spare

Infrastructure Requests

- Additional DESY tables
- Counting room NA 443: minor updates requested from LHCb
- RD51 PPE134 and counting room: make it fit for even larger number of parallel users with DRD1
- Upgrade beam instrumentation and environment sensors, logged to NXCALS
- API for CESAR monitoring data (zone access status, rates, ...) for integration in Grafana monitoring

Overview 2023

- **Highlights 2023**
  - Removal of material in the SPS secondary beams → K12 and H6 / H8
    - Reducing losses, increasing beam quality
  - Increasing intensity to users
    - Increasing primary particle intensities (higher intensities in the accelerators)
      - nTOF
      - PS EA T8
      - ELENA bunch intensity
    - Secondary beam (RP limits, beam line improvements): SPS H6 test beams for pixel detector R&D (factor 2-3 to 6E6 particles/spill)
  - Improved quality of delivered beams
    - PS EA T8 – intensity stability ++, position stability +, shape stability - future
    - PS EA T9 and T10 targets – position stability ++
    - SPS NA – spill quality (reduction of frequency components, stability of the corrections):
      - Proton run: K12, H4, H2
      - Ion run: H2 (spill structure – initial problem was fixed by OP and spill flatness achieved was the best ever for NA61; intensity fluctuation -, position instability -)
  - Loss reduction
    - Empty bucket channeling and barrier-bucket operation covered in a later presentation
  - Quantification of secondary beam compositions by users and EA (PS EA, H8, fragmented ions)
- **Challenges 2023**
  - The LHC operated for the first time in the high luminosity ion scheme leads to a reduced beam availability for the SPS fixed target ion program due to the dedicated LHC filling and the higher filling frequency of the LHC (faster burn-off, many non-operator LHC dumps).
    → Quantify knock-on effects of significant changes early, to better inform the user community

Winter Physics during EYETS 2023/2024

Not to forget the measurements during the YETS 2023/2024

- ISOLDE: winter physics with 3 previously irradiated targets plus one external sample from PSI – 3 weeks (until Nov.20).
- GBAR: ELENA runs with H- beam from 13th November until 15th December: prepare for cross section measurement for the H+Ps —> H- + e+
- BASE winter physics
  - Filled reservoir trap (30 $\bar{p}$); typically require 1 $\bar{p}$ per month for their measurements
- GIF++ continues the gamma irradiations with its ^{137}Cs source
- CLOUD until December 4th
- AWAKE laser and e-beam
- MADMAX in 2024

Injectors: 2023 very good availability and beam quality

Facility	Destination	‘21/‘22 Overall [%]	Achieved 2023		Period
			Overall [%]	Per destination [%]	
LINAC4	PSB	**97.3/96.8**	**97.9**	**97.9**	03.03.2023 – 12.11.2023
PSB	PS	**94.5/94.8**	**96.1**	**96.4**	10.03.2023 – 12.11.2023
	ISOLDE			**96.6**	17.03.2023 – 30.10.2023
PS	SPS	**88.1/89.6**	**91.7**	**92.7**	17.03.2023 – 30.10.2023
	East Area			**93.5**	27.03.2023 – 01.11.2023
	nTOF			**92.8**	03.04.2023 – 30.10.2023
	AD			**93.9**	12.06.2023* – 12.10.2023
SPS	LHC	**73.4/74.1**	**86.6**	**94.8**	27.03.2023 – 30.10.2023
	North Area			**87.3**	24.04.2023 – 30.10.2023
	AWAKE			**98.4**	01.05.2023 – 22.10.2023
	HiRadMat			**99.0**	22.05.2023 – 27.08.2023
LHC	-	**- /76.3**	**51.1**	**51.1****	15.05.2023 – 30.10.2023

Revised AD start date following quadrupole water leak

***Includes RF finger module exchange & Cold mass to insulation vacuum repair*

Cumulative availability

In the injectors overall very good availability

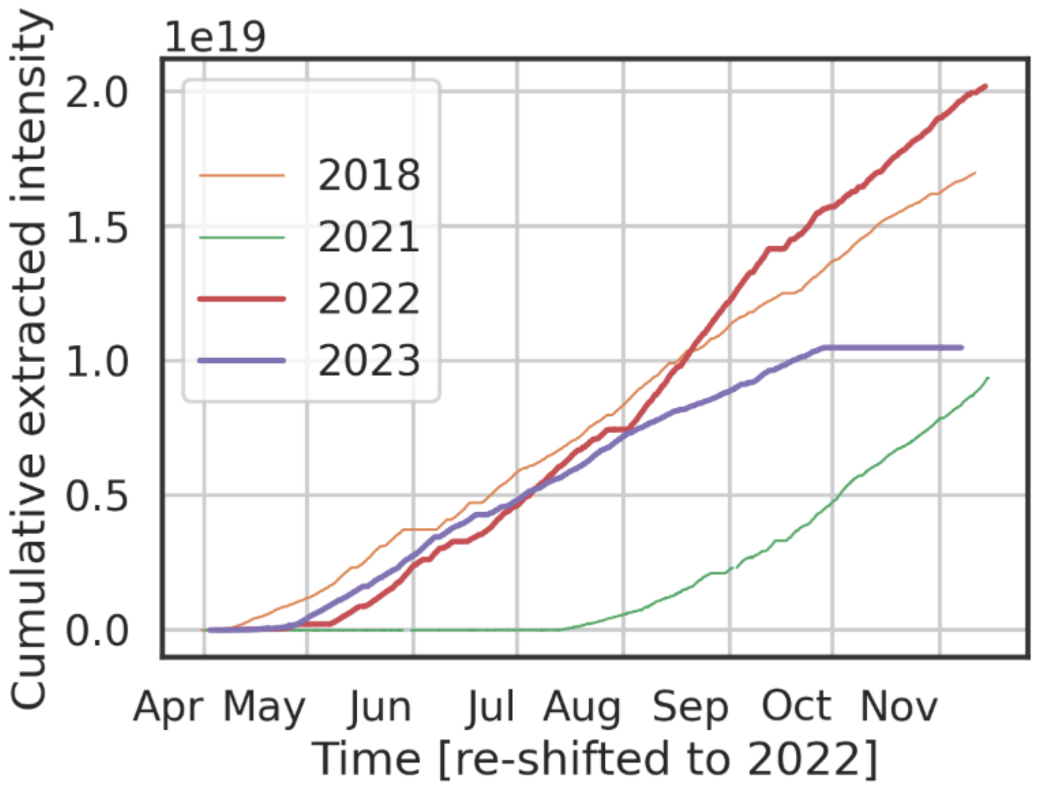
- *Better than in previous years*

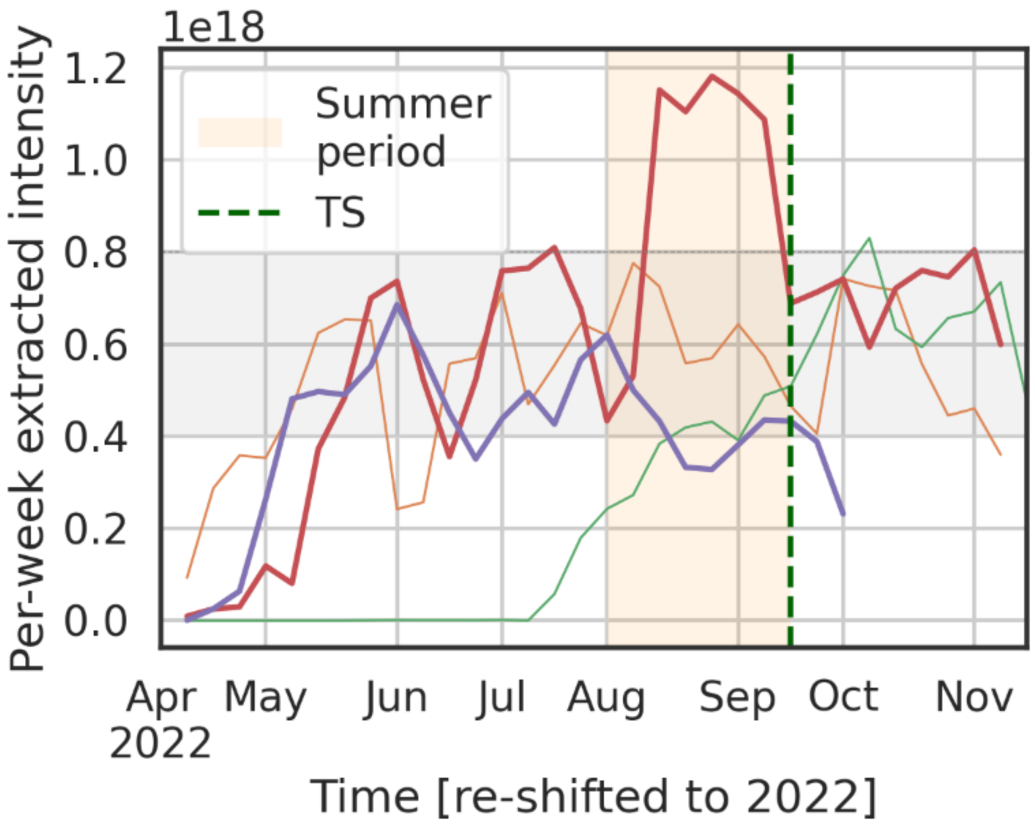
Overall includes the whole period and all other beams such as MD etc.

Very difficult year for the LHC

- *Overall machine availability only 51.1% with*

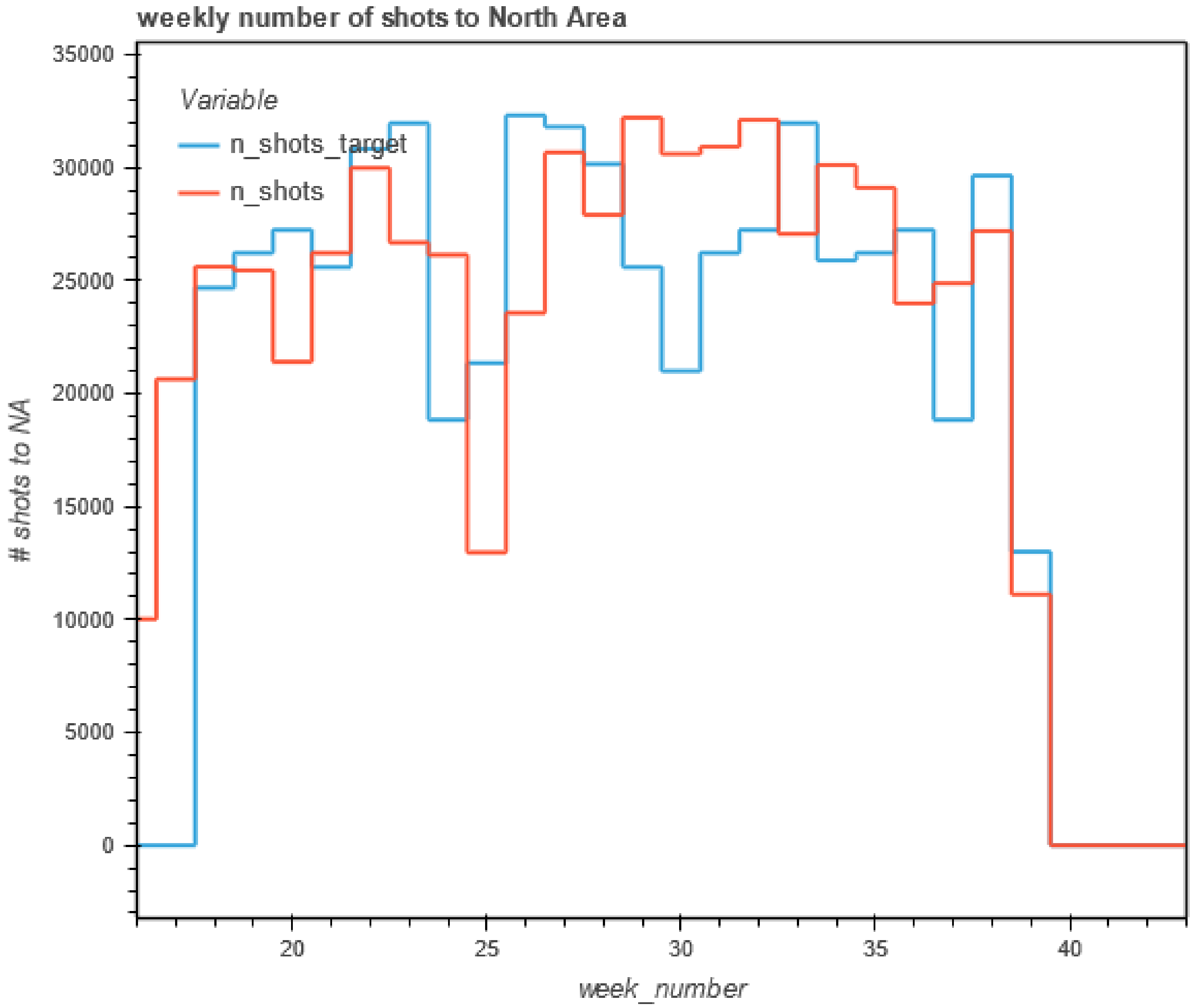
R. Steerenberg


1e19
2018
2021
2022
2023
Cumulative extracted intensity
2.0
1.5
1.0
0.5
0.0
Apr May Jun Jul Aug Sep Oct Nov
Time [re-shifted to 2022]


1e18
Summer period
TS
Per-week extracted intensity
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Apr 2022 May Jun Jul Aug Sep Oct Nov
Time [re-shifted to 2022]

SPS North Area 2023 Proton Spills Delivered

- Projected number of shots (in blue) depend on the program of the SPS
  - AWAKE, HiRadMat, MDs, special beam preparation for LHC, LHC physics,
- → big spread already in the planned number of spills per week
- Very good performance in 2023
  - some weeks below expectation
  - Others above, e.g. LHC not running in the middle of the year



https://bpt.web.cern.ch/sps/sftpro/2023/

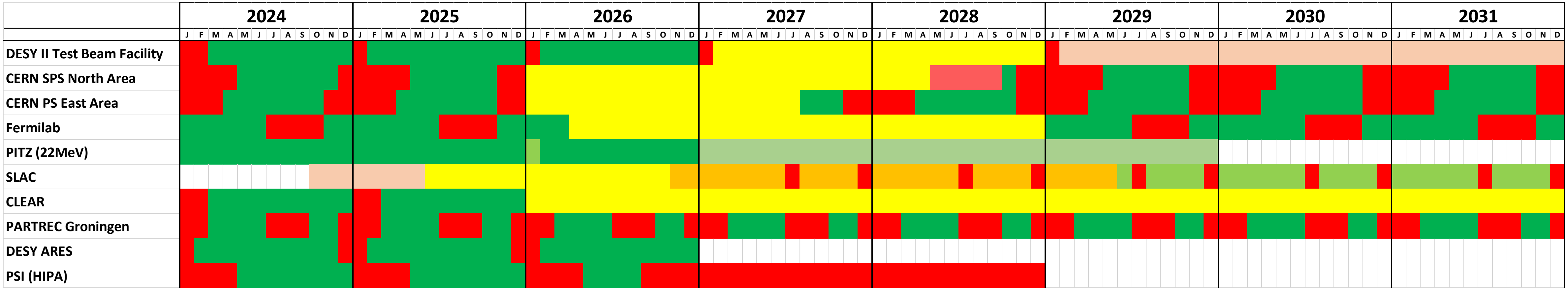
International Test Beam Schedule

- Compilation by the respective test beam coordinators https://cern.ch/international-facilities
- Aim: Rough estimate on available beam time to help the users with the planning of their test beams

- HEP detector R&D mostly performed at CERN, DESY and Fermilab
  → 2026 to 2028 will be difficult (future SPS/PS experiments, LS4 and LS5 upgrades, FCC, EIC)
- Update from DESY expected end of 2023

Last Update 16/11/2023

Running	1
Winter/Summer Shutdown	2
Longer Shutdown	3
Unclear	4
Likely	5
Pending Approval	6



- Removal of material (displaced vacuum tank) in the secondary beam line
  - Improved electron beam intensity and purity in H6 (not measured in 2023) and H8 (measured in 2023)
  - Reduction in primary protons on T4 for optimal K+ beam intensity for NA62
    - → allowed to use longer target (higher electron yield) for electron beam users in H6 and H8
  - Smaller beam size on T10
  - Factor 2 higher rate possible in H6 before hitting the radiation limit – less upstream losses?

- SPS NA heavily overbooked
- High number of user schedule change requests during the run (remained high during all of Run3 already – procurement problems, transport problems since COVID)