HEARTS 1st Annual Meeting: WP7

6 February 2024

https://indico.cern.ch/event/1314502/

Rubén García Alía,
Eliott Johnson
(CERN)
On behalf of HEARTS WP7

Funded by
the European Union

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Outline

- Introduction
- Readiness (both vs requirements and vs what is achievable with HEARTS@CERN boundary conditions) of:
  - Beam energy (and LET)
    - Including fragmentation
  - Beam intensity (and flux)
    (LET and fluence combined, i.e. SEE cross section benchmark)
  - Beam (spatial) profile
  - Physical access to experimental area
  - Yearly schedule
- Summary

Introduction

HEARTS WP7

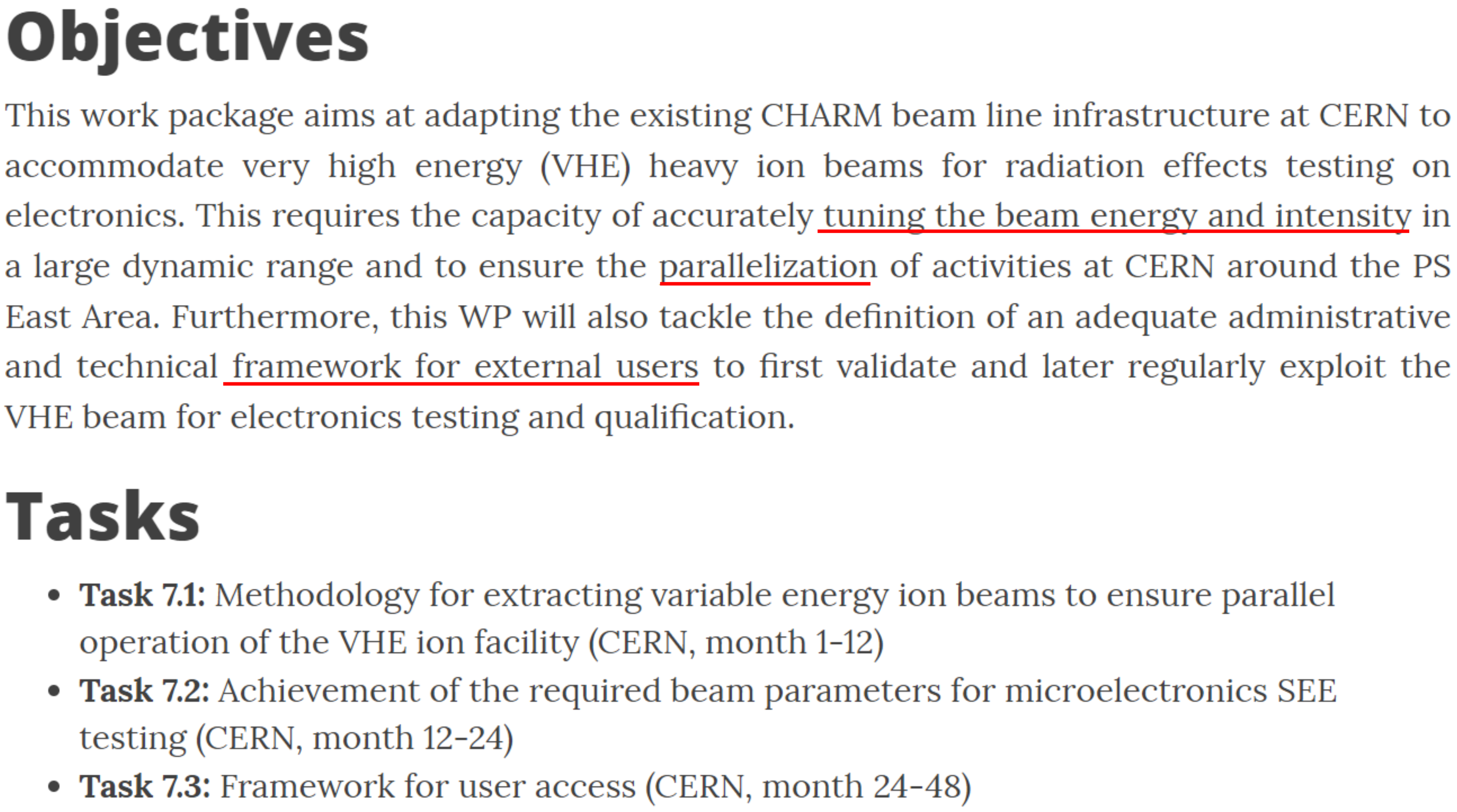
Work Package 7

Upgrade of CHARM beam line at CERN for VHE ion testing

Participants

- CERN

Objectives and tasks



Objectives

This work package aims at adapting the existing CHARM beam line infrastructure at CERN to accommodate very high energy (VHE) heavy ion beams for radiation effects testing on electronics. This requires the capacity of accurately tuning the beam energy and intensity in a large dynamic range and to ensure the parallelization of activities at CERN around the PS East Area. Furthermore, this WP will also tackle the definition of an adequate administrative and technical framework for external users to first validate and later regularly exploit the VHE beam for electronics testing and qualification.

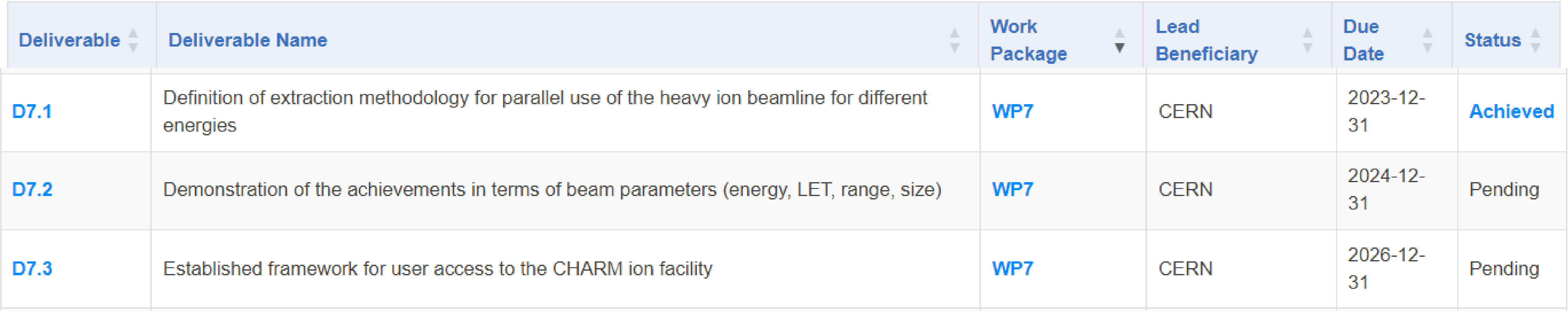
Tasks

- **Task 7.1:** Methodology for extracting variable energy ion beams to ensure parallel operation of the VHE ion facility (CERN, month 1-12)
- **Task 7.2:** Achievement of the required beam parameters for microelectronics SEE testing (CERN, month 12-24)
- **Task 7.3:** Framework for user access (CERN, month 24-48)

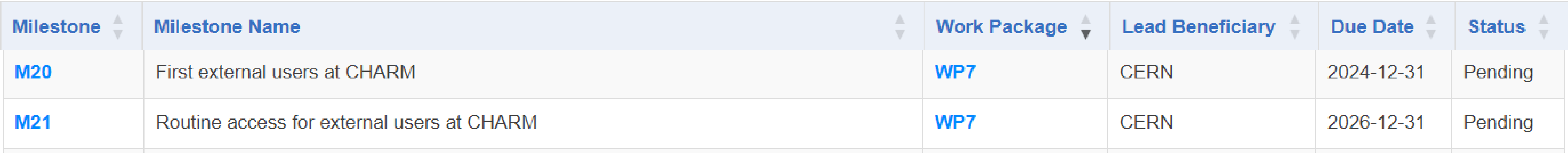
In other words…

- High-level objective: to be ready by the end of the project to provide **routine, reliable and user-friendly access to CERN's high-energy heavy ion beam for electronics testing**
- In order to achieve this, we need to:
  - Technically, be able to tune the beam energy (i.e. LET) and intensity (i.e. flux) in a large dynamic range and in an accurate manner (and do so in a way which minimizes the impact on other CERN accelerator users)
  - Define an administrative and technical framework for electronics users to regularly exploit the beam and facility for radiation effects testing
- And, yet in other words, what we want is to become a *competitive and attractive* facility for radiation effects testing

Deliverables and Milestones



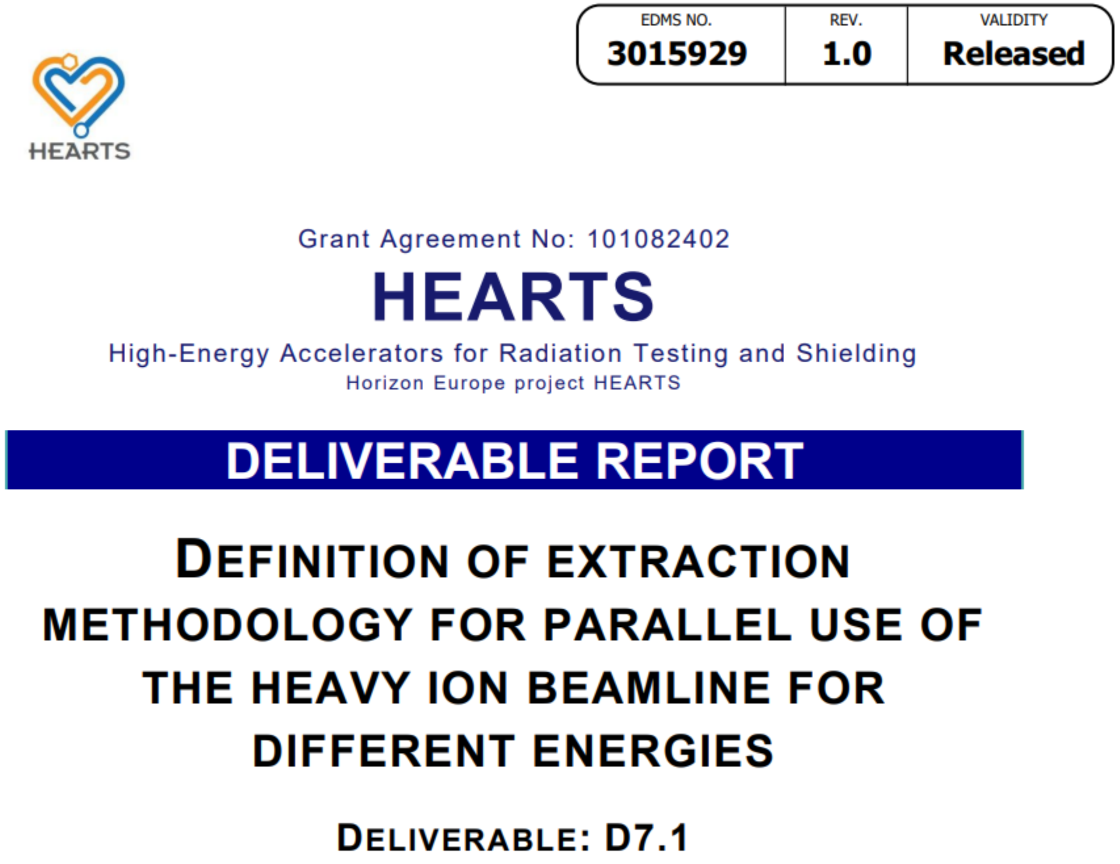
Deliverable	Deliverable Name	Work Package	Lead Beneficiary	Due Date	Status
D7.1	Definition of extraction methodology for parallel use of the heavy ion beamline for different energies	**WP7**	CERN	2023-12-31	**Achieved**
D7.2	Demonstration of the achievements in terms of beam parameters (energy, LET, range, size)	**WP7**	CERN	2024-12-31	Pending
D7.3	Established framework for user access to the CHARM ion facility	**WP7**	CERN	2026-12-31	Pending



Milestone	Milestone Name	Work Package	Lead Beneficiary	Due Date	Status
M20	First external users at CHARM	**WP7**	CERN	2024-12-31	Pending
M21	Routine access for external users at CHARM	**WP7**	CERN	2026-12-31	Pending

Main References

- Deliverable Report 7.1, *Definition of extraction methodology for parallel use of heavy ion beam line for different energies*
- JAPW presentation on *Slow extraction R&D and progress at the PS*
- EATM presentation on *HEARTS 2023 run and future prospects*
- November HEARTS WPL meeting, *W7 presentation with a focus on 2023 experimental campaign*
- *Presentation/discussion material during regular WP7 meetings*



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3015929	1.0	Released

Grant Agreement No: 101082402

HEARTS

High-Energy Accelerators for Radiation Testing and Shielding

Horizon Europe project HEARTS

DELIVERABLE REPORT

DEFINITION OF EXTRACTION METHODOLOGY FOR PARALLEL USE OF THE HEAVY ION BEAMLINE FOR DIFFERENT ENERGIES

DELIVERABLE: D7.1

WP7 members and interfaces (within CERN)

Accelerator operation (ion injectors, Proton Synchrotron)

Radiation to Electronics teams

Radiation environment and effects experts

Kacper Bilko
Andrea Coronetti
Natalia Emriskova
Luigi Esposito
Karolina Klimek
Daniel Prelipcean
Mario Sacristán Barbero
Andreas Waets

Accelerator beam physicists and operators

Marc Delrieux
Eliott Johnson
Matthew Fraser

CHARM and IRRAD teams

Beam Instrumentation

Radiation Protection

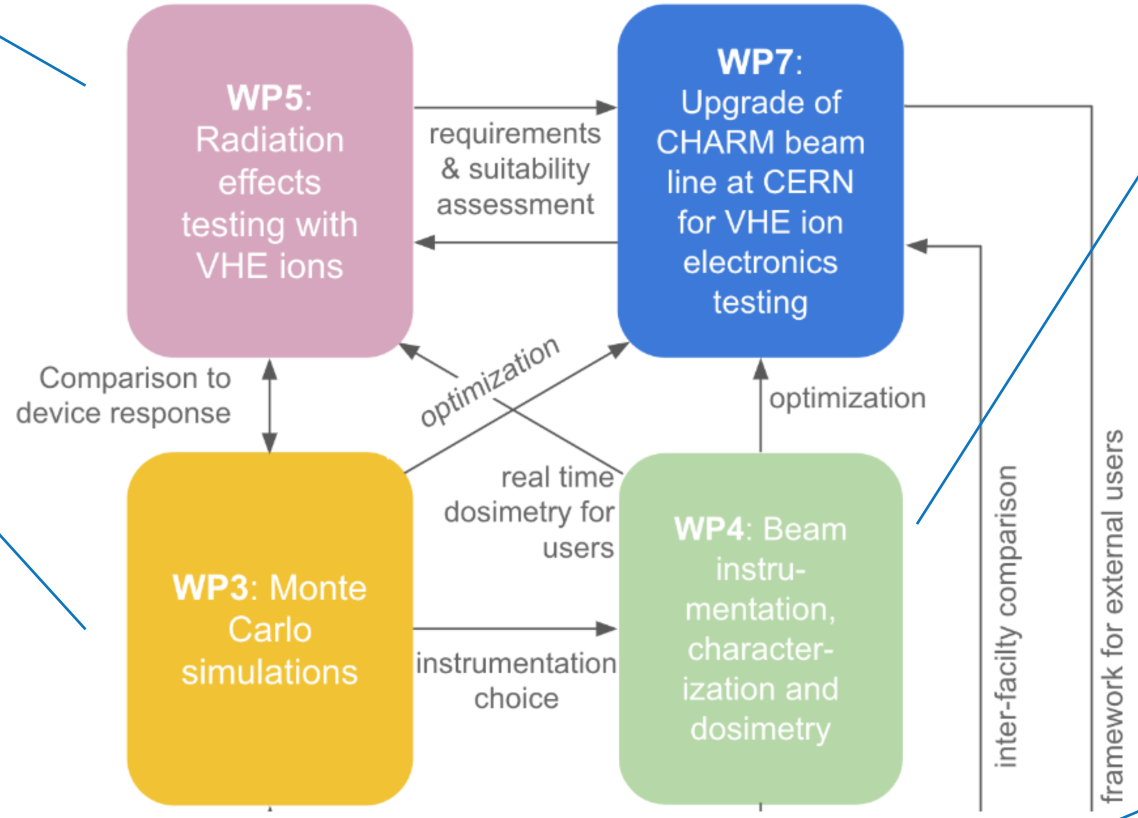
Targets, Collimators and Dumps

WP7 interfaces (within HEARTS)

Link to WP5: requirement definition set out in D5.1

Radiation effects user assessment to be performed during 2024 run

Link to WP3: critical Monte Carlo simulation input for beam optimization and characterization, implications of ion-matter interaction on SEE testing, etc.



WP5: Radiation effects testing with VHE ions

WP7: Upgrade of CHARM beam line at CERN for VHE ion electronics testing

WP3: Monte Carlo simulations

WP4: Beam instru-mentation, character-ization and dosimetry

requirements & suitability assessment

Comparison to device response

optimization

optimization

real time dosimetry for users

instrumentation choice

inter-facility comparison

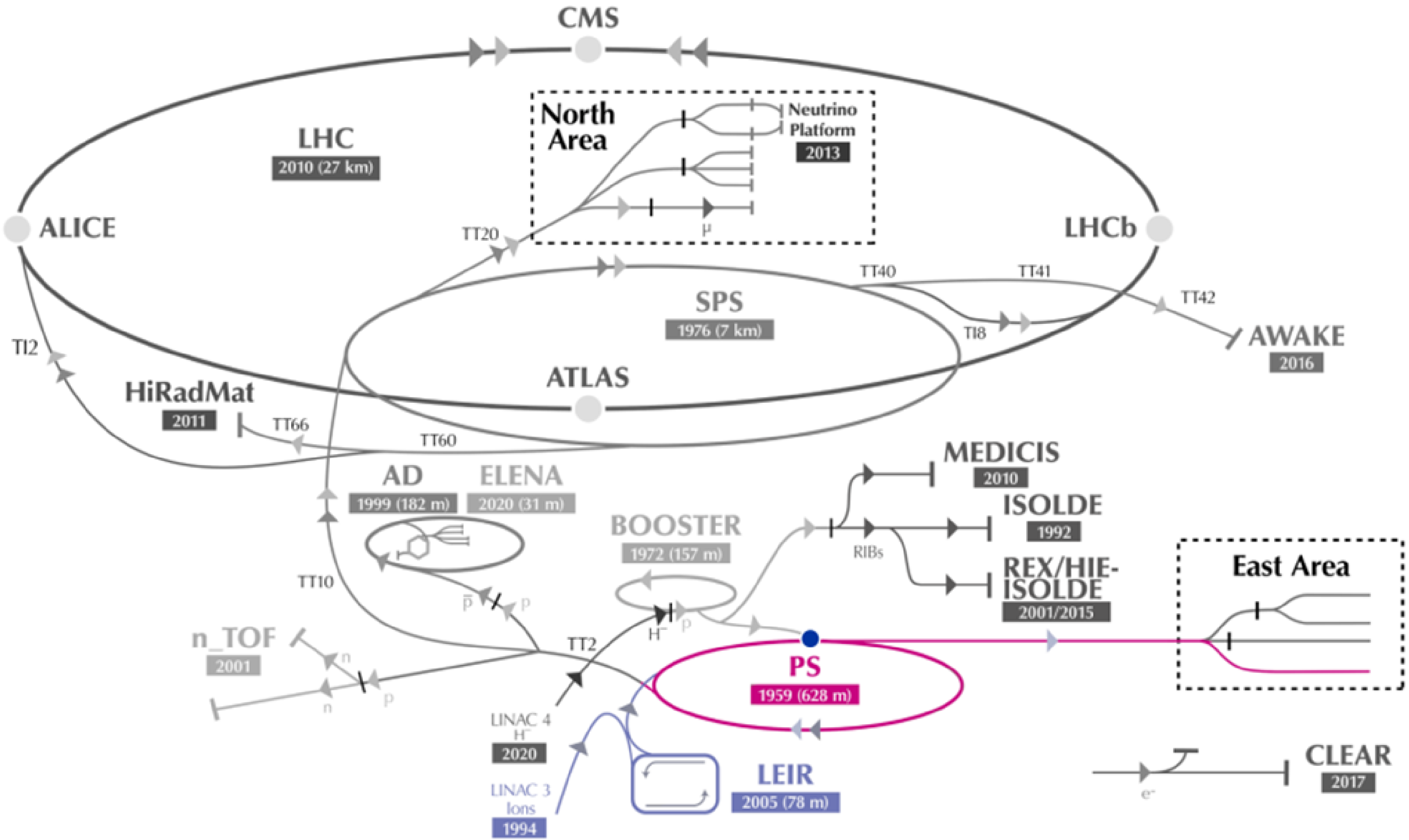
framework for external users

Link to WP4: a lot of discussions with GSI concerning beam characterization (and including dedicated visit and meeting at GSI)

Involvement of GSI, University of Oldenburg, University of Wollongong and PTW in 2023 HEARTS@CERN campaign, with broad variety of beam instruments

Links to WP6/8: facility SEE data intercomparison, harmonized access framework, etc.

Injector complex, PS, East Area and T8

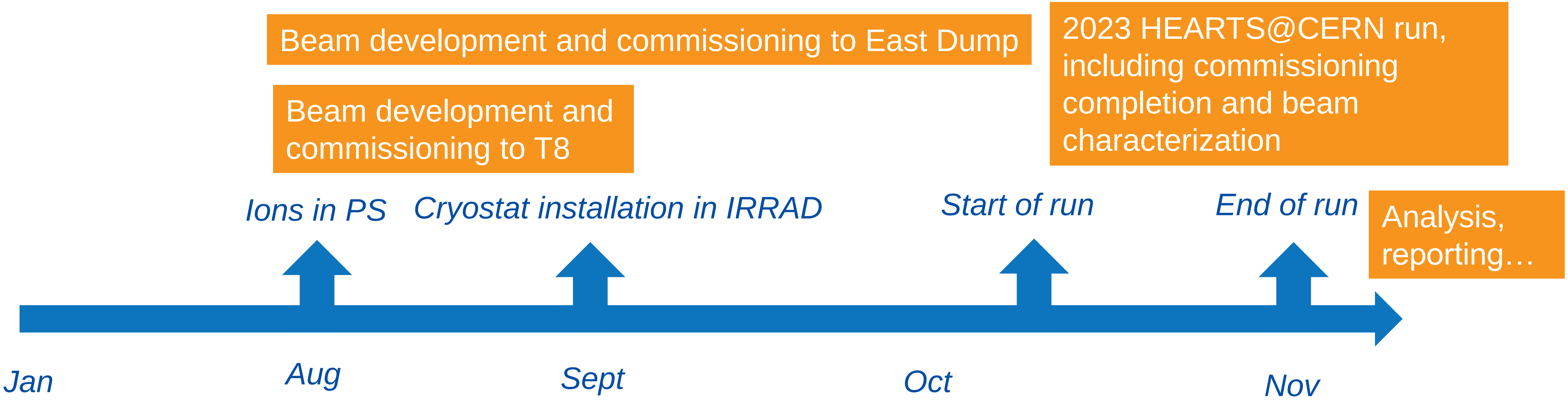


Ion Source + Linac 3 + LEIR = ion injectors

Injector complex, PS, East Area and T8

WP7 2023 timeline

Beam and FLUKA studies
Experimental area integration studies (including interface to external “users”)
Design and manufacturing of remotely movable degrader/mask system
Activity scheduling at many different levels (including interface to external “users”)



Beam development and commissioning to East Dump

Beam development and commissioning to T8

2023 HEARTS@CERN run, including commissioning completion and beam characterization

Ions in PS

Cryostat installation in IRRAD

Start of run

End of run

Analysis, reporting…

Jan

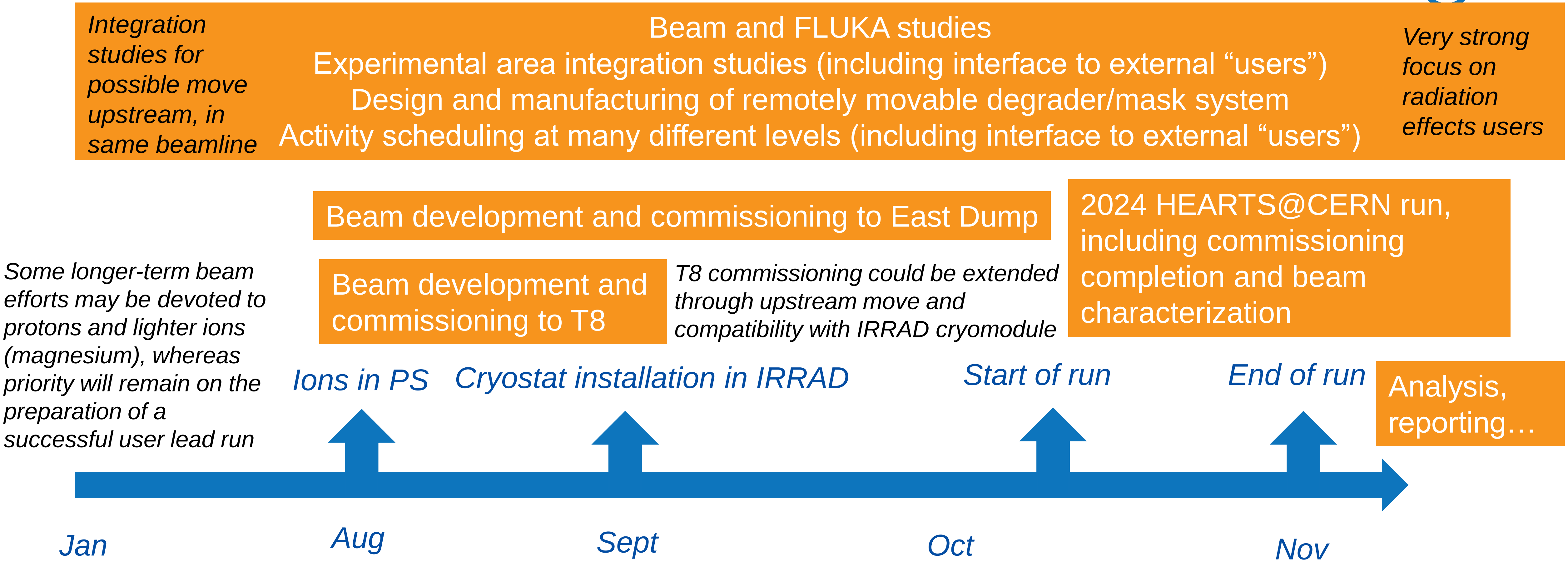
Aug

Sept

Oct

Nov

WP7 **2024** timeline – expected to be similar to 2023, but with some foreseen/possible changes



Integration studies for possible move upstream, in same beamline

Beam and FLUKA studies

Experimental area integration studies (including interface to external "users")

Design and manufacturing of remotely movable degrader/mask system

Activity scheduling at many different levels (including interface to external "users")

Very strong focus on radiation effects users

Beam development and commissioning to East Dump

2024 HEARTS@CERN run, including commissioning completion and beam characterization

Some longer-term beam efforts may be devoted to protons and lighter ions (magnesium), whereas priority will remain on the preparation of a successful user lead run

Beam development and commissioning to T8

T8 commissioning could be extended through upstream move and compatibility with IRRAD cryomodule

Ions in PS

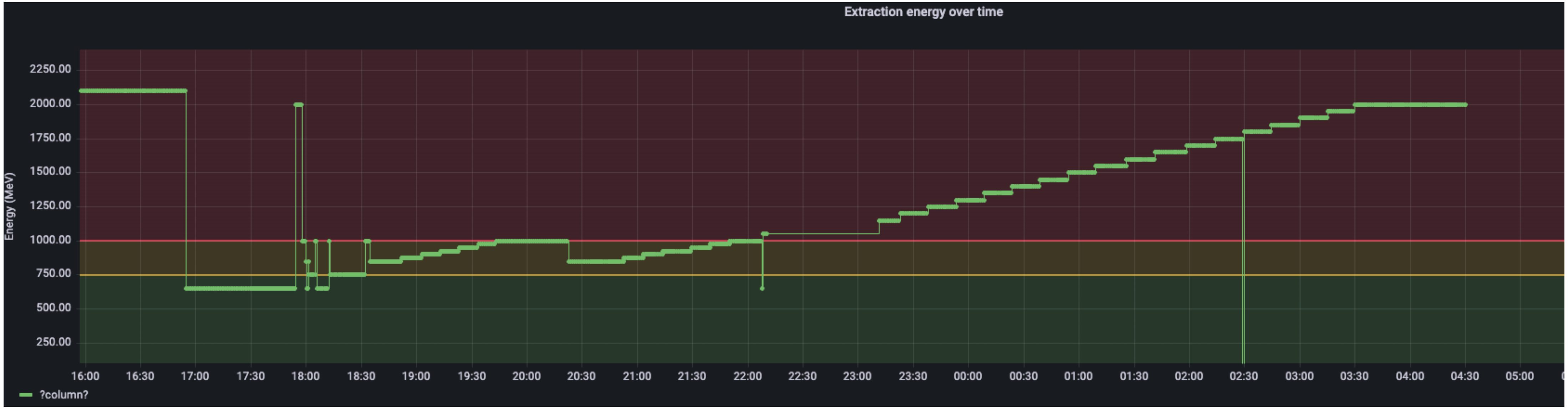
Cryostat installation in IRRAD

Start of run

End of run

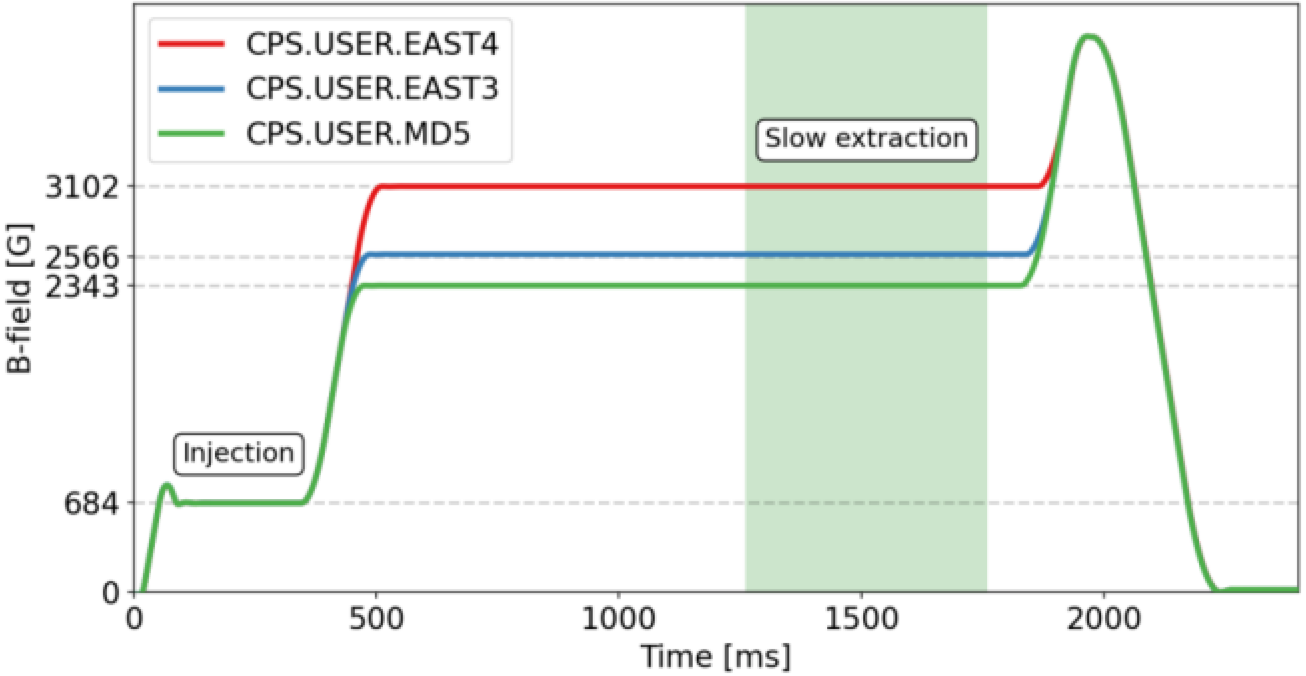
Analysis, reporting…

Beam Energy and LET



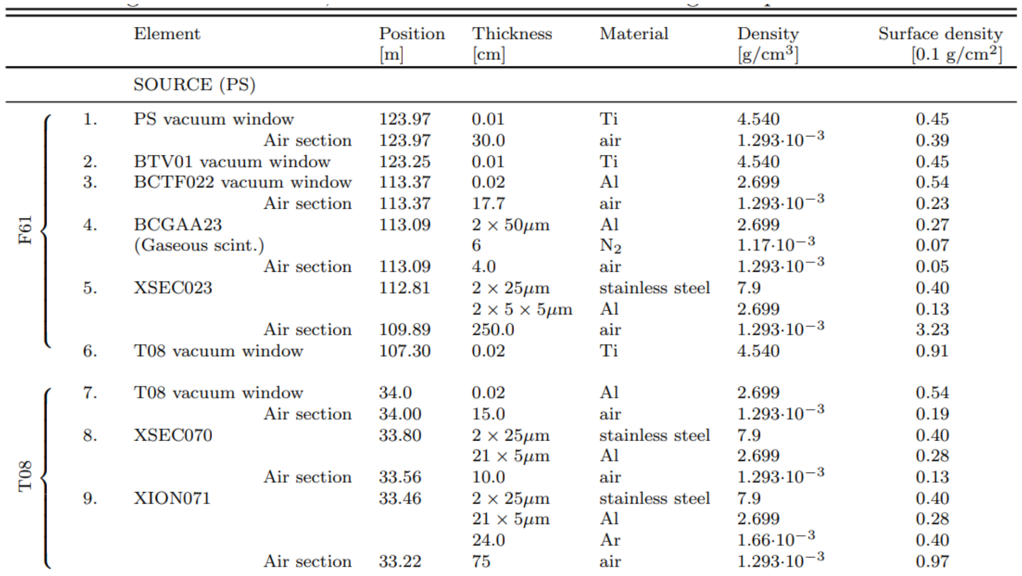
Beam Energy set through magnetic flat-top in PS

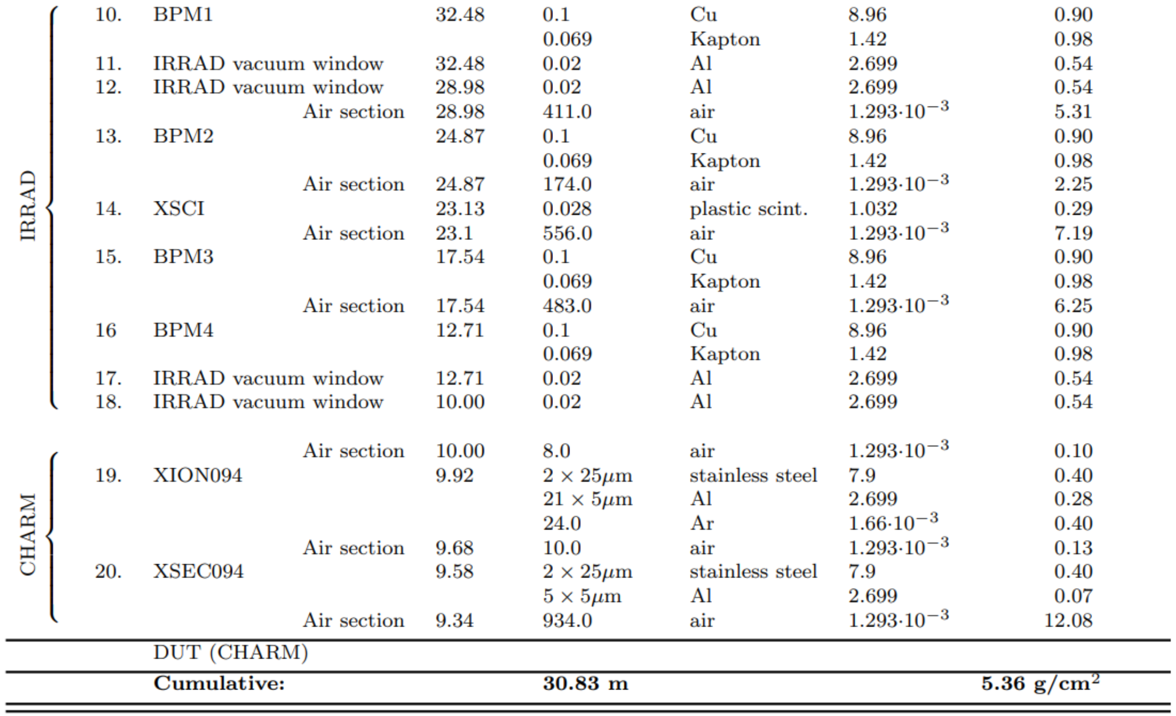
No need to tune any additional parameters(*), which simply “scale” with the magnetic field
(*) though, we may want to tune some, for further optimization (e.g. transmission, beam position, spill time profile…)



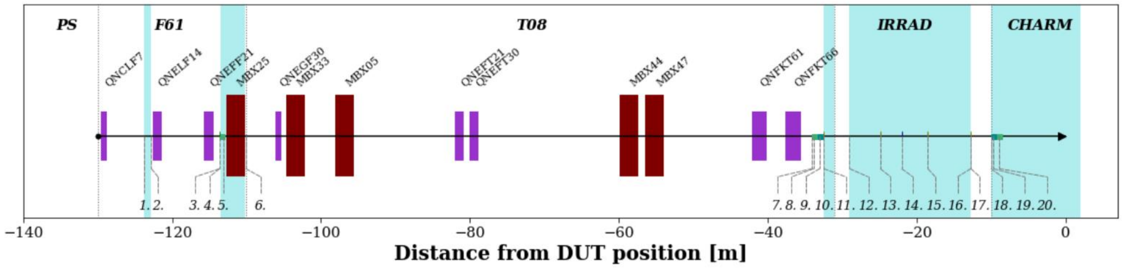
PS magnetic field at different energies, with injection plateau at 684 G and extraction plateau at varying B-field corresponding to different energy levels. In 2022, different USERs were used per energy.

PS beam energy vs. energy at DUT



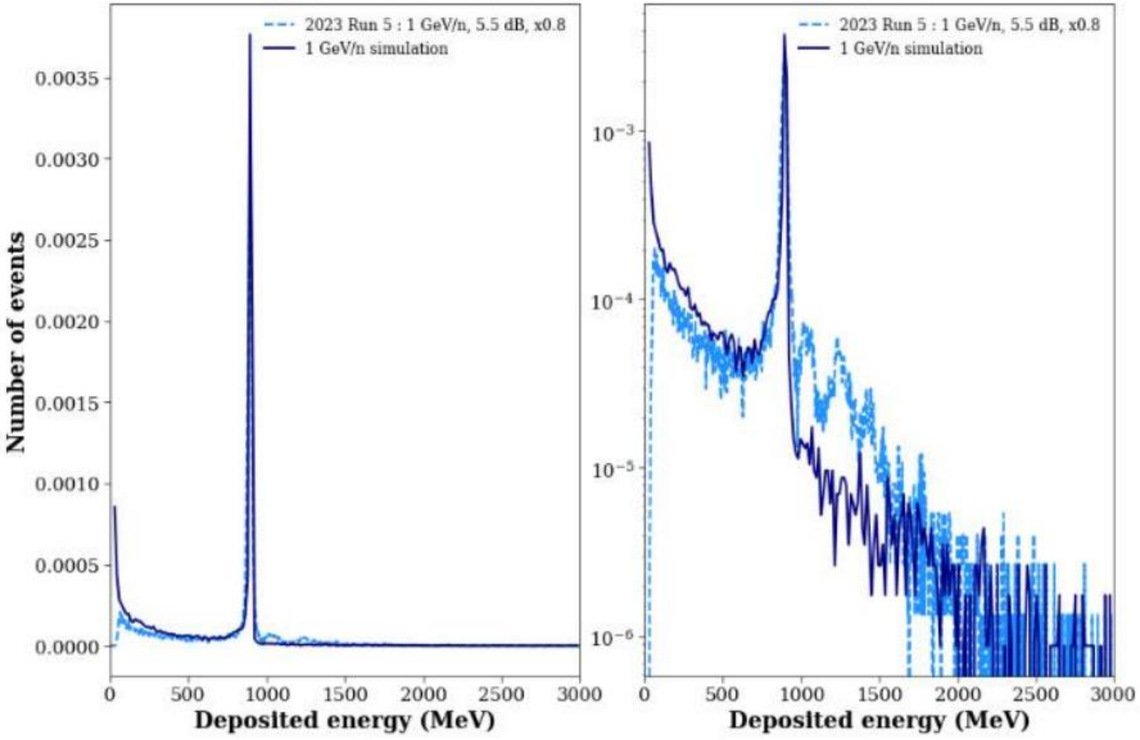


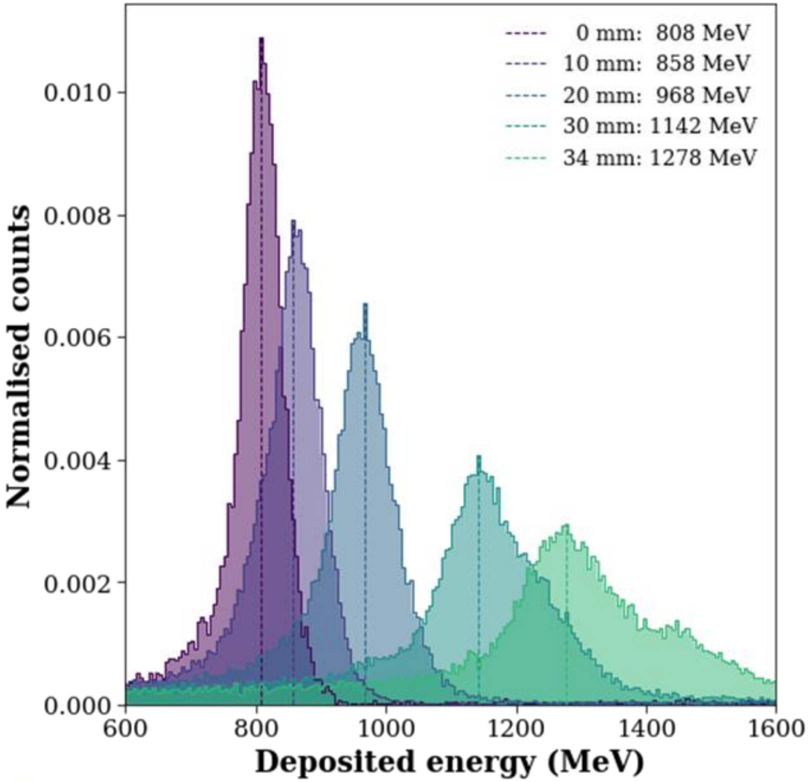
		Element	Position [m]	Thickness [cm]	Material	Density [g/cm^3]	Surface density [$0.1\ g/cm^2$]
		SOURCE (PS)					
F61	1.	PS vacuum window	123.97	0.01	Ti	4.540	0.45
		Air section	123.97	30.0	air	$1.293\cdot10^{-3}$	0.39
	2.	BTV01 vacuum window	123.25	0.01	Ti	4.540	0.45
	3.	BCTF022 vacuum window	113.37	0.02	Al	2.699	0.54
		Air section	113.37	17.7	air	$1.293\cdot10^{-3}$	0.23
	4.	BCGAA23	113.09	$2\times50\mu m$	Al	2.699	0.27
		(Gaseous scint.)		6	N_2	$1.17\cdot10^{-3}$	0.07
		Air section	113.09	4.0	air	$1.293\cdot10^{-3}$	0.05
	5.	XSEC023	112.81	$2\times25\mu m$	stainless steel	7.9	0.40
				$2\times5\times5\mu m$	Al	2.699	0.13
		Air section	109.89	250.0	air	$1.293\cdot10^{-3}$	3.23
	6.	T08 vacuum window	107.30	0.02	Ti	4.540	0.91
T08	7.	T08 vacuum window	34.0	0.02	Al	2.699	0.54
		Air section	34.00	15.0	air	$1.293\cdot10^{-3}$	0.19
	8.	XSEC070	33.80	$2\times25\mu m$	stainless steel	7.9	0.40
				$21\times5\mu m$	Al	2.699	0.28
		Air section	33.56	10.0	air	$1.293\cdot10^{-3}$	0.13
	9.	XION071	33.46	$2\times25\mu m$	stainless steel	7.9	0.40
				$21\times5\mu m$	Al	2.699	0.28
				24.0	Ar	$1.66\cdot10^{-3}$	0.40
		Air section	33.22	75	air	$1.293\cdot10^{-3}$	0.97
IRRAD	10.	BPM1	32.48	0.1	Cu	8.96	0.90
				0.069	Kapton	1.42	0.98
	11.	IRRAD vacuum window	32.48	0.02	Al	2.699	0.54
	12.	IRRAD vacuum window	28.98	0.02	Al	2.699	0.54
		Air section	28.98	411.0	air	$1.293\cdot10^{-3}$	5.31
	13.	BPM2	24.87	0.1	Cu	8.96	0.90
				0.069	Kapton	1.42	0.98
		Air section	24.87	174.0	air	$1.293\cdot10^{-3}$	2.25
	14.	XSCI	23.13	0.028	plastic scint.	1.032	0.29
		Air section	23.1	556.0	air	$1.293\cdot10^{-3}$	7.19
	15.	BPM3	17.54	0.1	Cu	8.96	0.90
				0.069	Kapton	1.42	0.98
		Air section	17.54	483.0	air	$1.293\cdot10^{-3}$	6.25
	16	BPM4	12.71	0.1	Cu	8.96	0.90
				0.069	Kapton	1.42	0.98
	17.	IRRAD vacuum window	12.71	0.02	Al	2.699	0.54
	18.	IRRAD vacuum window	10.00	0.02	Al	2.699	0.54
CHARM		Air section	10.00	8.0	air	$1.293\cdot10^{-3}$	0.10
	19.	XION094	9.92	$2\times25\mu m$	stainless steel	7.9	0.40
				$21\times5\mu m$	Al	2.699	0.28
				24.0	Ar	$1.66\cdot10^{-3}$	0.40
		Air section	9.68	10.0	air	$1.293\cdot10^{-3}$	0.13
	20.	XSEC094	9.58	$2\times25\mu m$	stainless steel	7.9	0.40
				$5\times5\mu m$	Al	2.699	0.07
		Air section	9.34	934.0	air	$1.293\cdot10^{-3}$	12.08
		DUT (CHARM)					
		Cumulative:		**30.83 m**			**5.36 g/cm^2**



Energy at DUT location calculated with FLUKA, and measured with silicon detector

Strong link to WP3

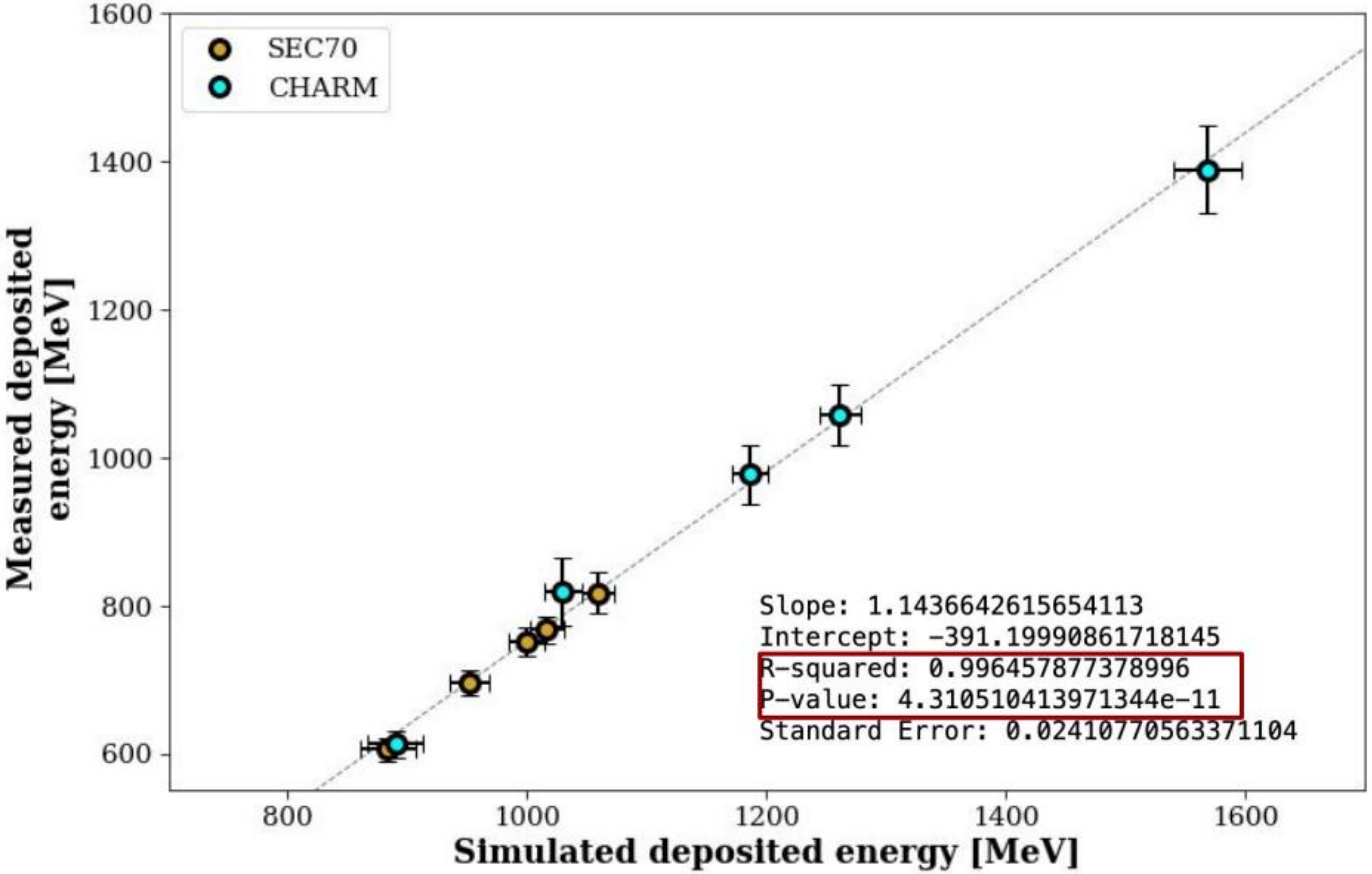




Comparison of energy deposition spectra obtained by Si diode measurements vs. FLUKA Monte Carlo simulation results for a 1 GeV/n Pb ion beam used at CERN.

Indirect energy measurement: through energy deposition (which does not scale linearly with energy)

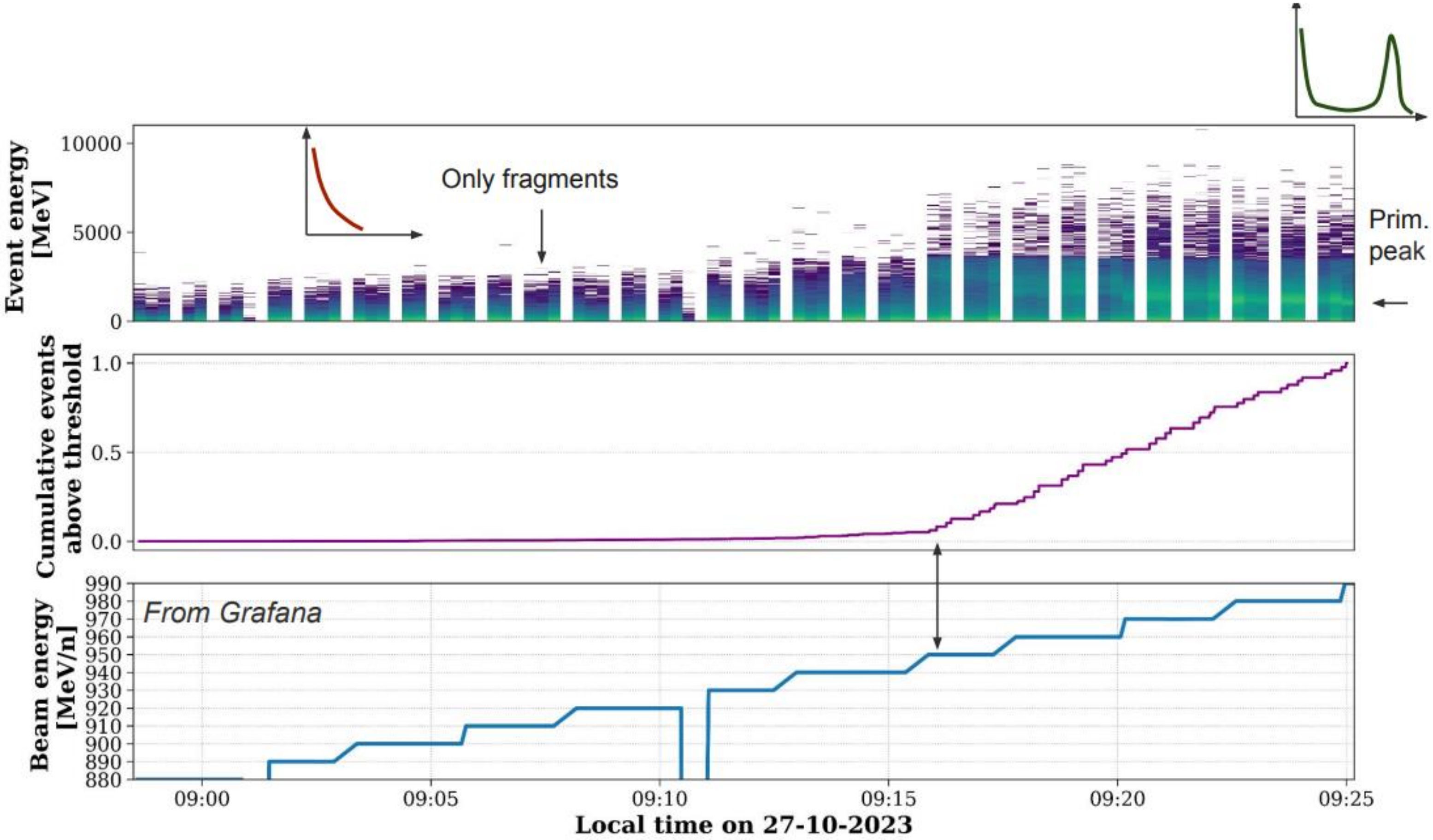
Strong link to WP3



```
Slope: 1.1436642615654113
Intercept: −391.19990861718145
R−squared: 0.996457877378996
P−value: 4.310510413971344e−11
Standard Error: 0.02410770563371104
```

Direct energy measurement: energy scan to determine amount of material needed to fully stop the beam

Strong link to WP3



Beam energy/LET summary

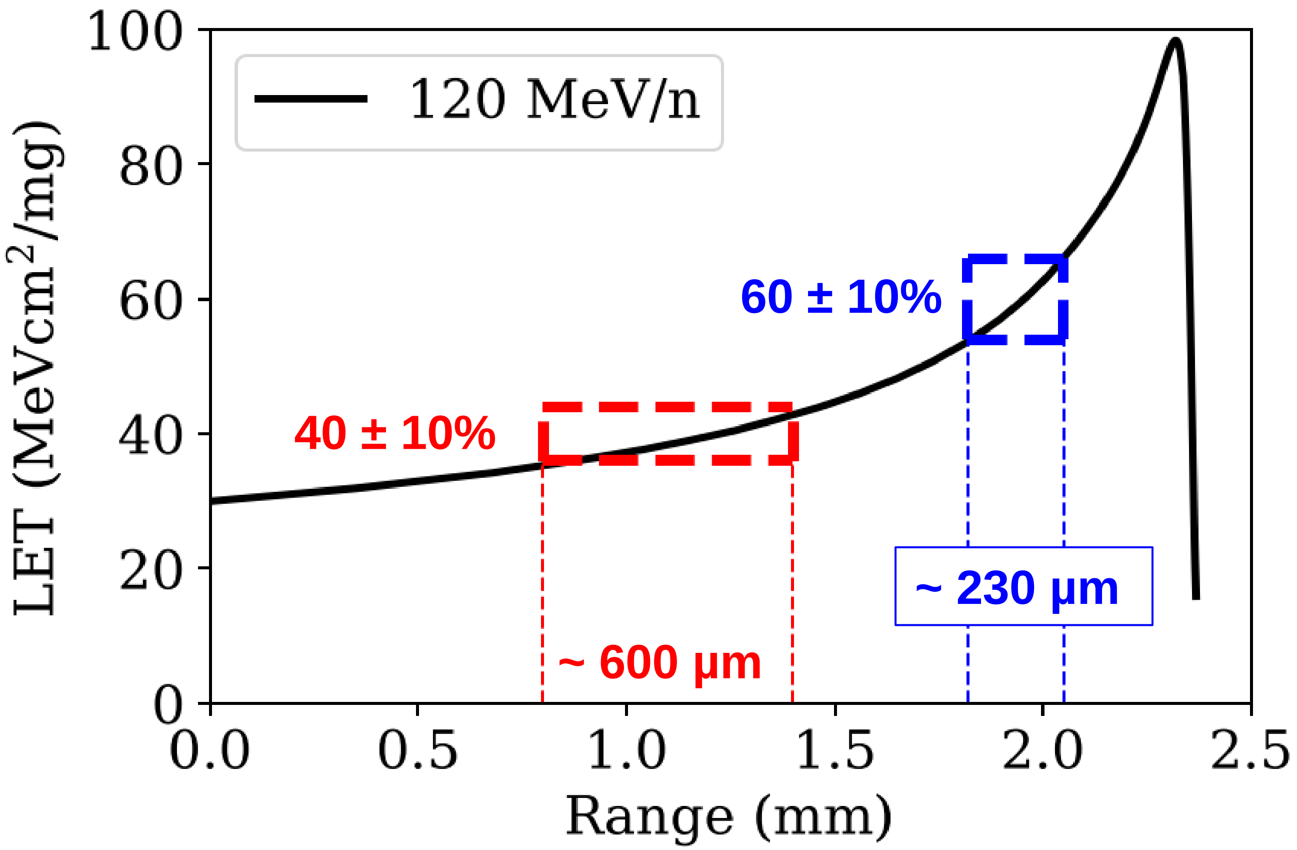
Already largely achieved

Not achieved, but in principle not critical (i.e. more of a “nice-to-have”) or achievable within HEARTS

High importance limitations not resolvable within HEARTS

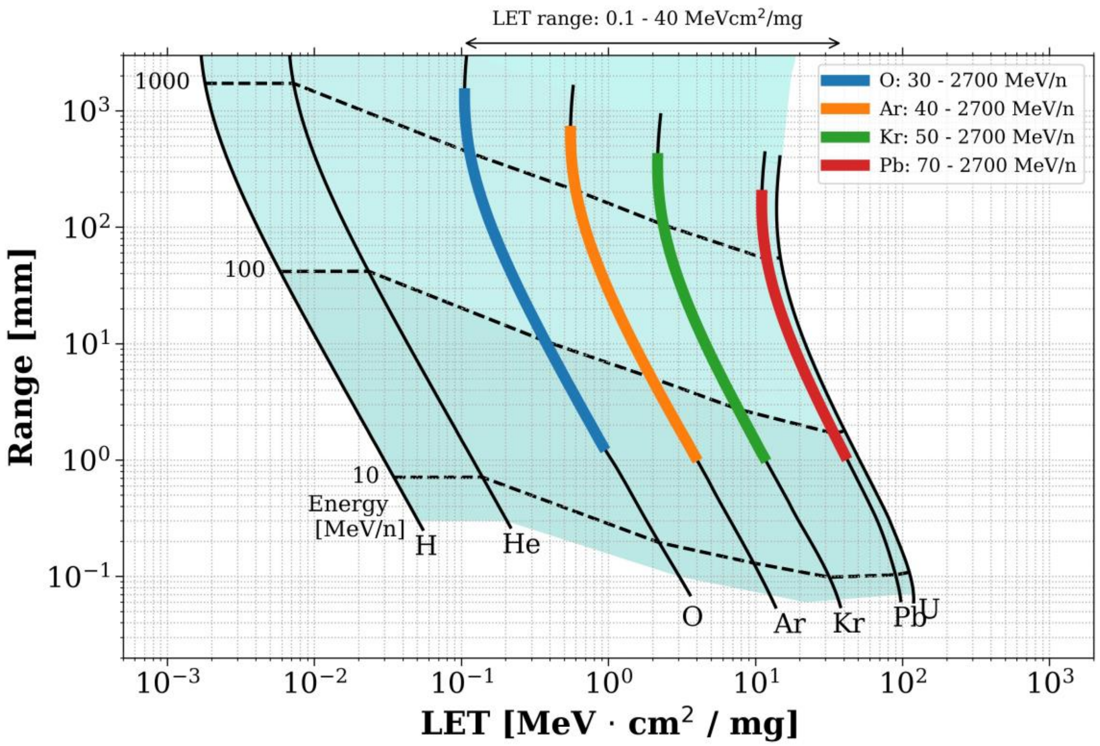
- **Excellent control and accuracy of beam energy/LET at DUT location**, being able to vary the LET between ~10 and **~40 MeVcm^2/mg** (and even beyond, at the cost of a reduced range in matter)
- The capability of rapidly and easily tuning the beam LET through the energy over a large range and despite the single ion species is **a key strongpoint of HEARTS@CERN**
- Limitations at the low and high LET ends are mainly physics related (i.e. hard to do better than lead, though uranium does offer some improvement)
  - High LET limit imposed by range requirement (i.e. larger LETs would be possible, but the beam would no longer be as highly penetrating)
  - **Low LET limit of 10 MeVcm^2/mg** imposed by large ion mass – ideally, levels down to 1 (or even 0.1 MeVcm^2/mg, see WP5 requirements) should be achieved to cover the full LET curve, and this would only be possible through lighter ions
  - Feedback from NSRL (through HEARTS Advisory Panel): users typically require around 5 MeVcm^2/mg as lowest LET point

LET vs penetration trade-off – lead on silicon

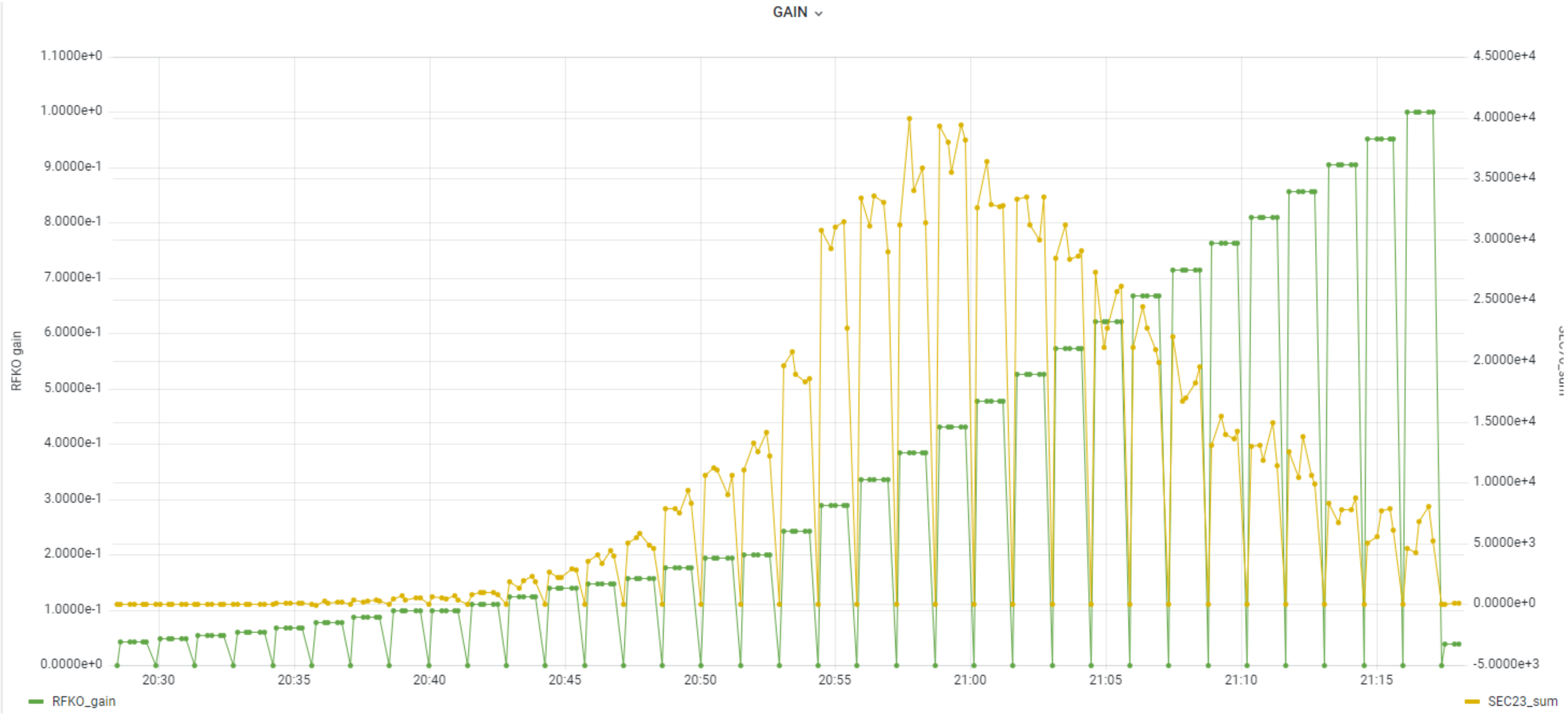


Lower LET ions

- Lighter ions are being integrated in the CERN physics program (i.e. for LHC and the SPS North Area). However, these would be used **sequentially**, as it takes several weeks to change between ions, which is not practical for radiation effects testing
- A **quick** (few hours max) **change between ions** would only be possible with a significant upgrade of the ion source and ion injector chain – synergies with other CERN activities for possible upgrade are currently being studied
- However, one could envisage **changing rapidly between ions and protons**, in such a way that users interested in performing both ion and proton testing “in one go”, with protons only being used in the case of low (~10 MeVcm^2/mg) LET sensitivity with ions
    - Possible development activities in this direction already in 2024

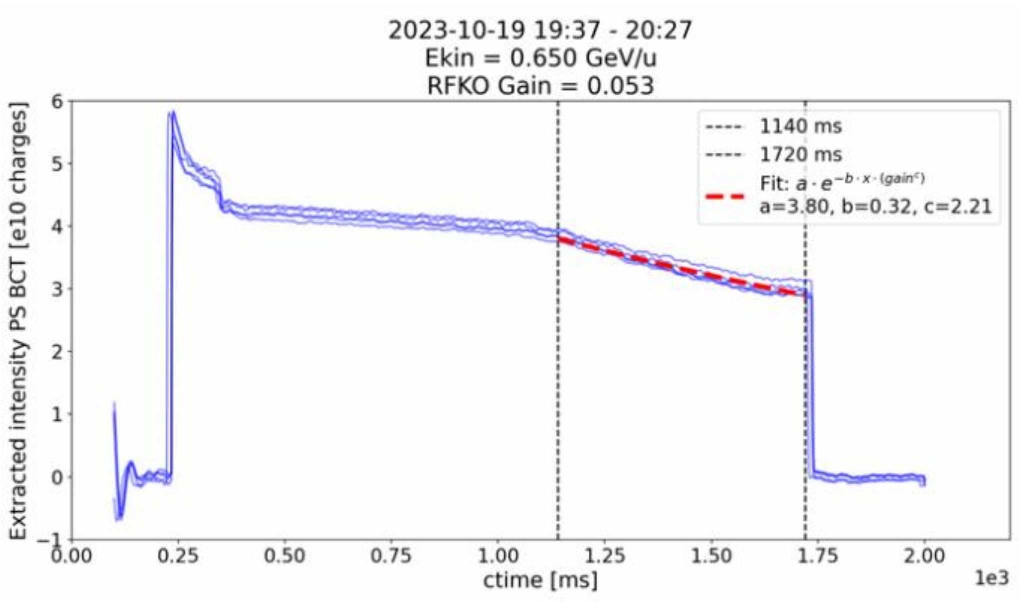


Beam Intensity and Flux

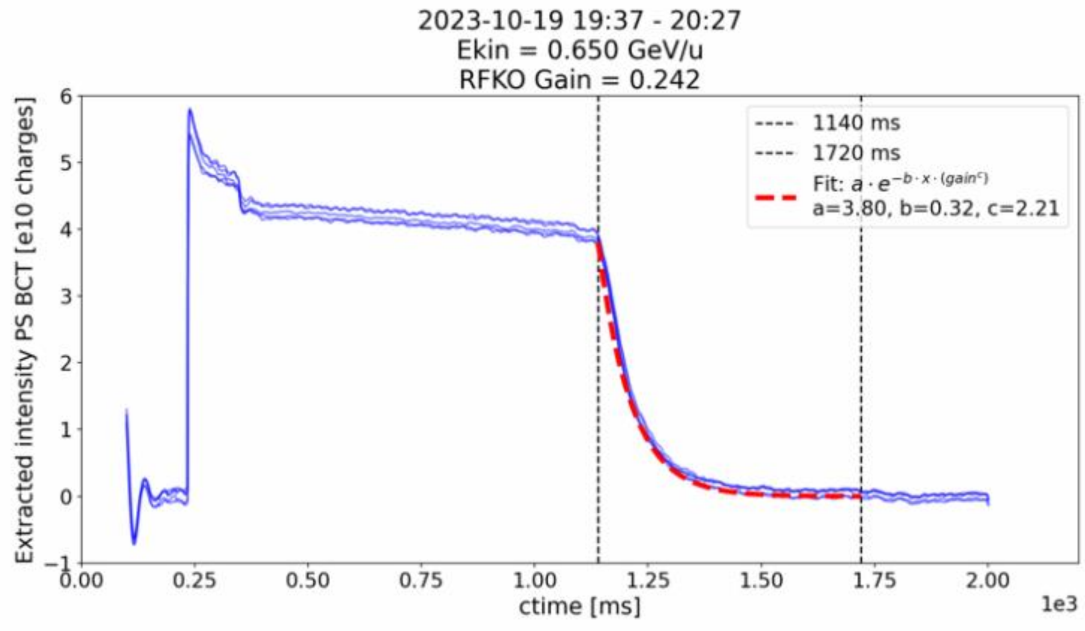


Amount of extracted beam controlled through RFKO gain

- *Initial ion intensity in PS is "fixed" to 1e10 or 7e10 charges, but fraction of extracted beam can be controlled through the RFKO knob*
- *Large dynamic range between min and max flux achievable with this technique, and accurately measurable by the beam instruments*
- *Knowing the dependency of the extracted intensity from the PS to the RFKO gain, a variable gain during the spill could help make the flux more uniform within the spill*



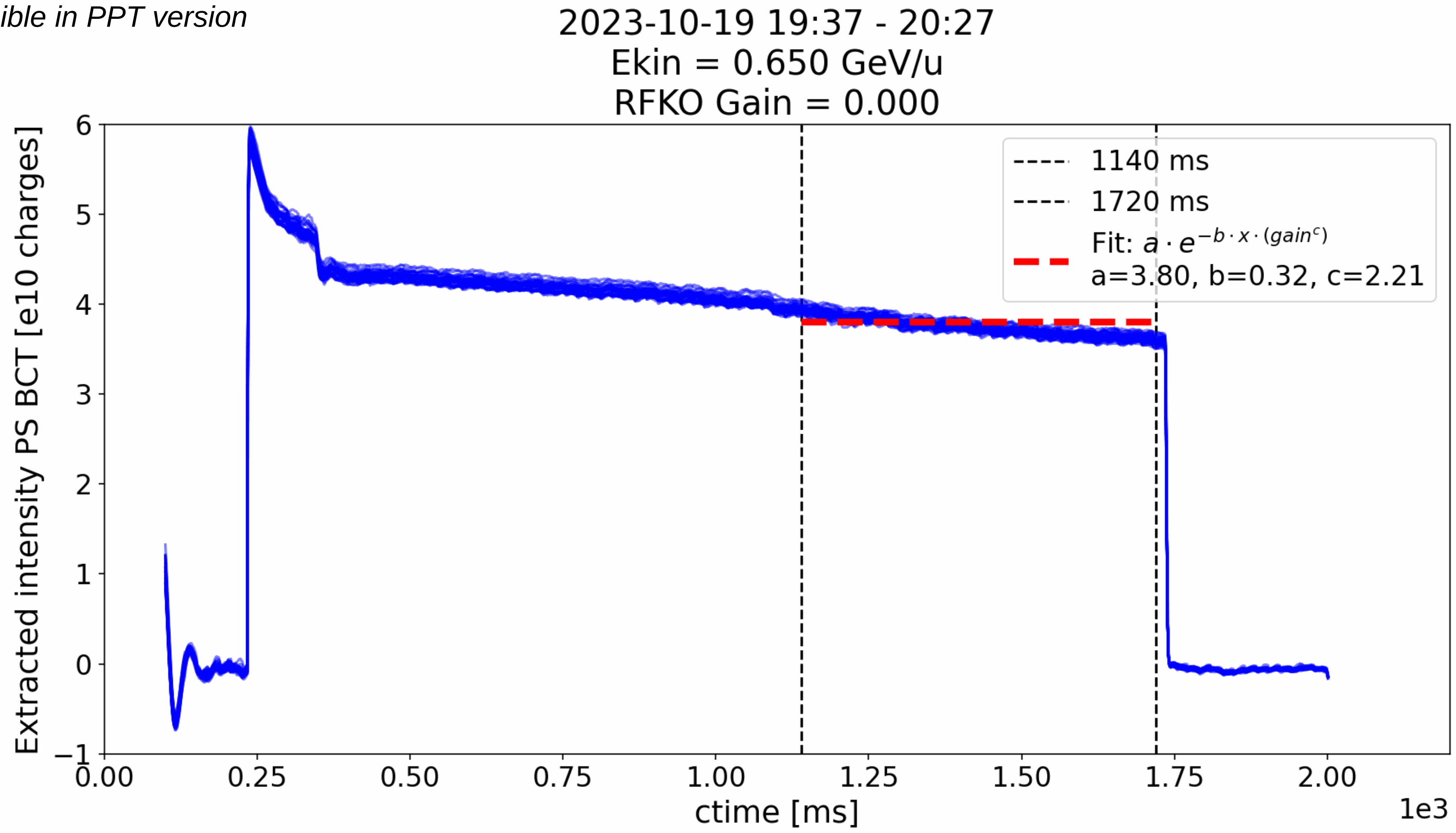
PS BCT trace with a low RFKO gain.



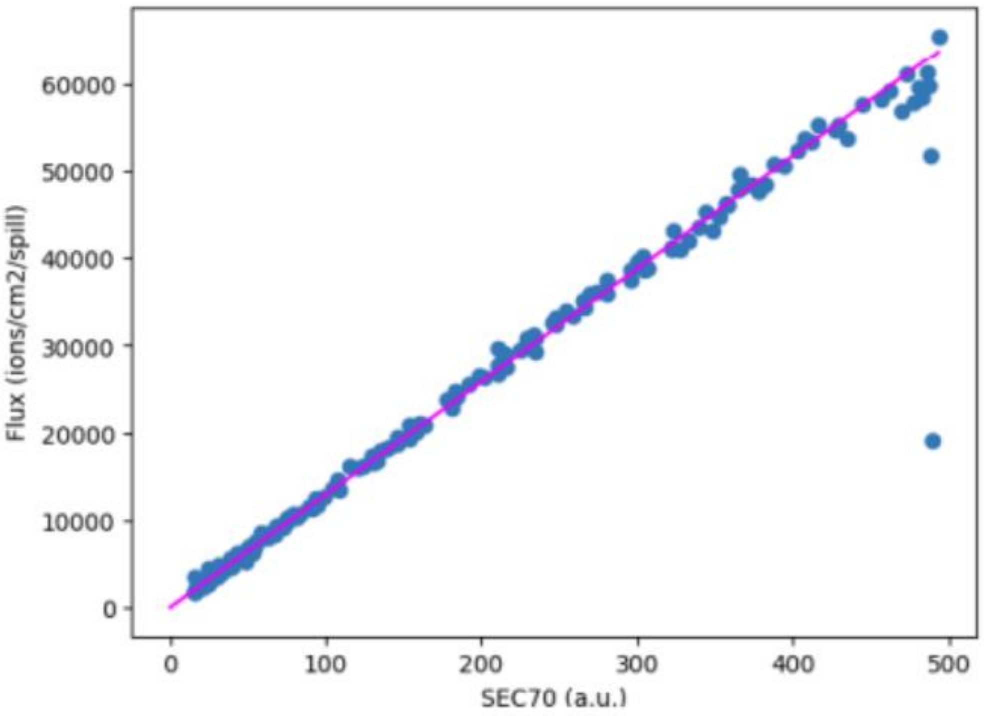
PS BCT trace with a high RFKO gain.

Amount of extracted beam controlled through RFKO gain

gif animation, only visible in PPT version

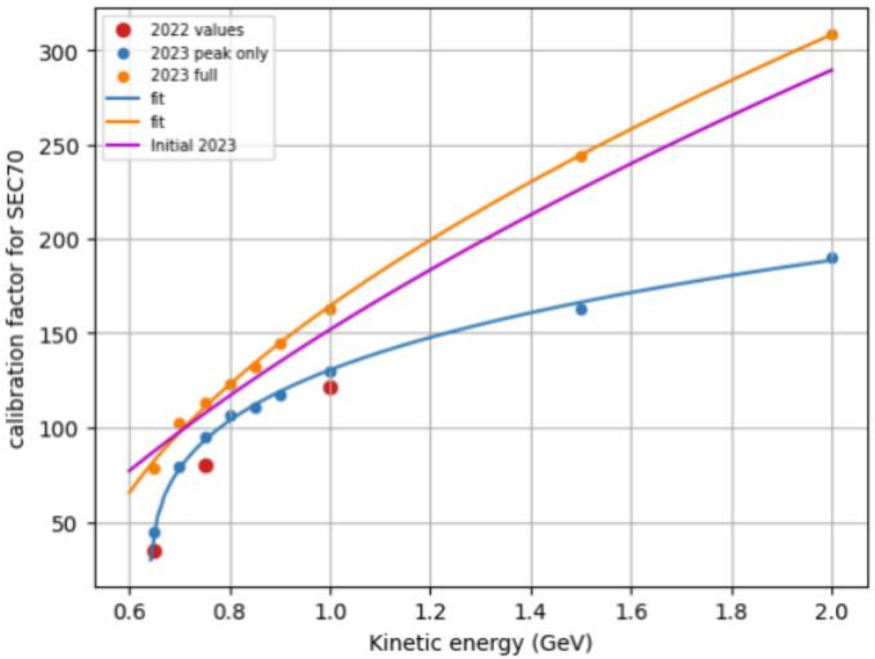


Flux calibration for different energies



Flux as a function of XSEC070 plot.

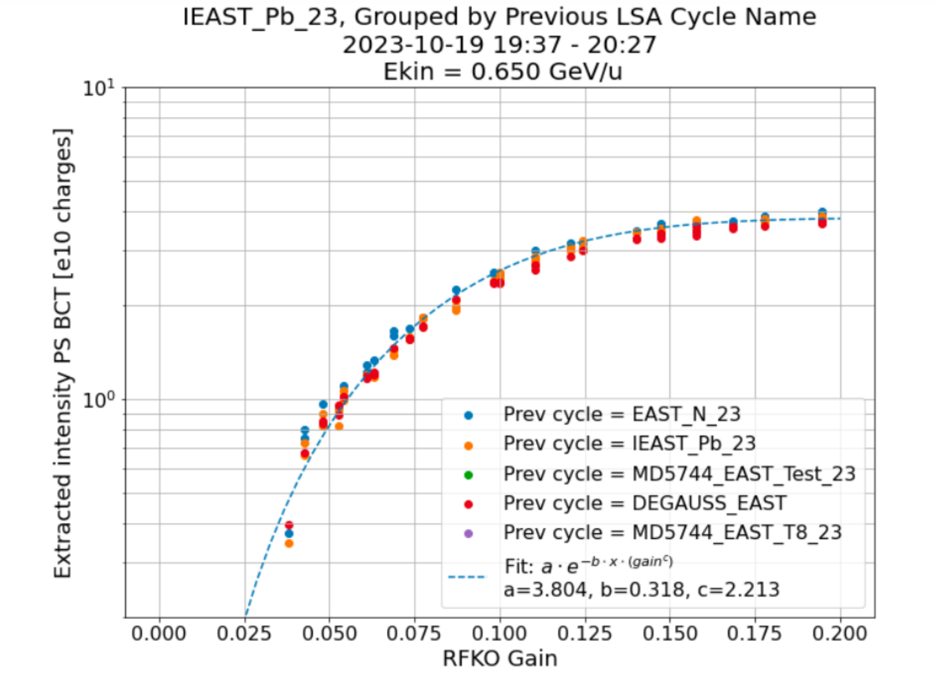
SEC70



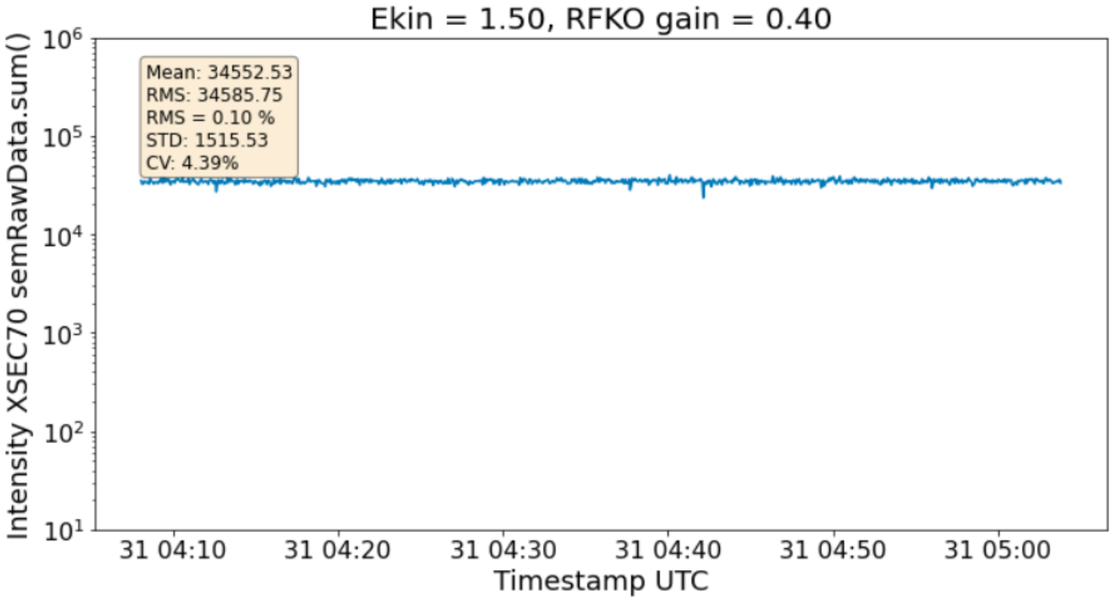
Calibration factor for XSEC070 as a function of kinetic energy.

Repeatability

Examples below are "good" cases of repeatable intensity versus RFKO gain independently of super-cycle composition, and low spill-to-spill variability within a run – not always the case in 2023 (also because it was not always considered as objective), but we are confident to achieve it more systematically in the future

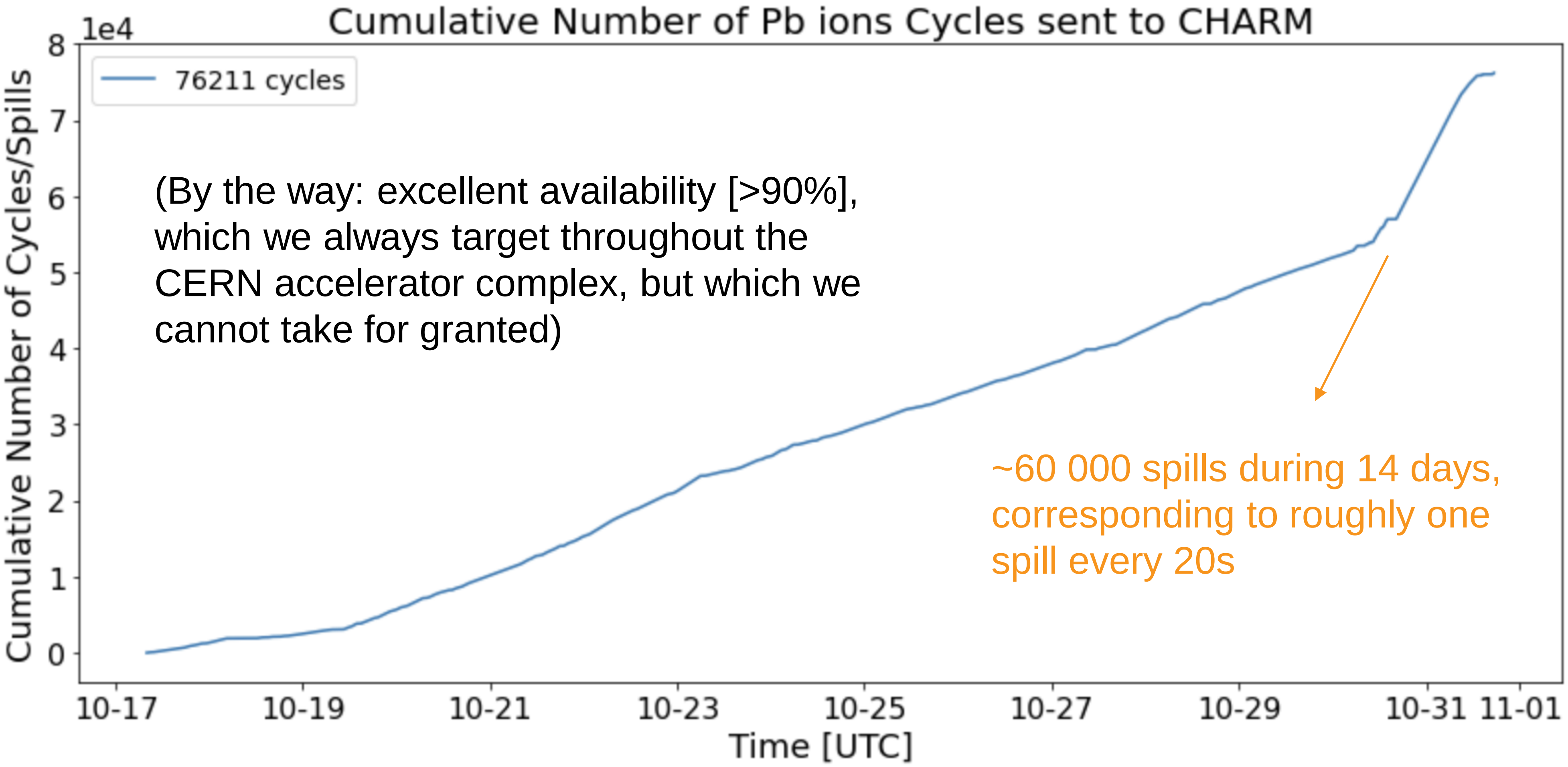


Extracted charges during a typical spill of 580 [ms]² as a function of RFKO gain.



Sum of the uncalibrated intensity measured on XSEC070. This figure shows the run ID with the lowest intensity variability during the 2023 HEARTS run.

Flux per spill x spill frequency = flux per unit time



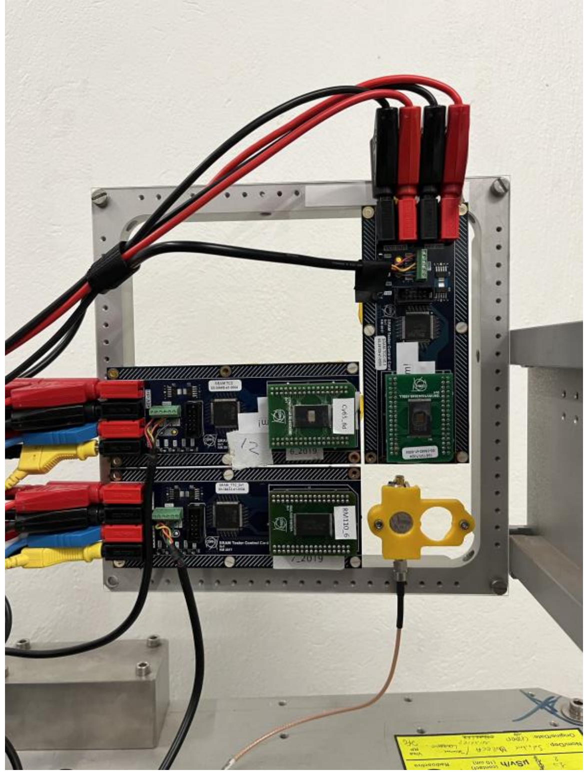
(By the way: excellent availability [>90%], which we always target throughout the CERN accelerator complex, but which we cannot take for granted)

~60 000 spills during 14 days, corresponding to roughly one spill every 20s

Intensity/flux summary

- Good **control and accuracy** of beam flux thanks to **RFKO extraction**, with RFKO gain as a knob
- Reasonably good spill-to-spill **repeatability** and predictable flux dependence on RFKO gain within given experimental campaign → some margin for improvement
- **Large dynamic range** of spill fluxes, from ~10^2 ions/cm^2/spill to few 10^5 ions/cm^2/spill
- This is obtained with a **relatively low transmission** (i.e. number of ions arriving at DUT plane vs. number of extracted ions from PS), estimated at around 5-10% - to be seen if this is intrinsic to the beam line and beam type, or if there is margin for improvement (possible sources of low transmission: BHZ02 not always degaussed; BHZ01 not in vacuum)
- Still, the spill duty cycle is quite short, as **we only receive one ~300ms spill every 10-20s**, which can be limiting, as the maximum average flux is lower than 10^5 ions/cm^2/s
- This is driven by the many PS destinations using beam during the same super-cycle
- One possibility for improvement could be to fit the slow extracted spill into one PS basic period, hence being able to significantly (to be quantified) increase the spills per super-cycle

LET and fluence combined → SEE cross sections



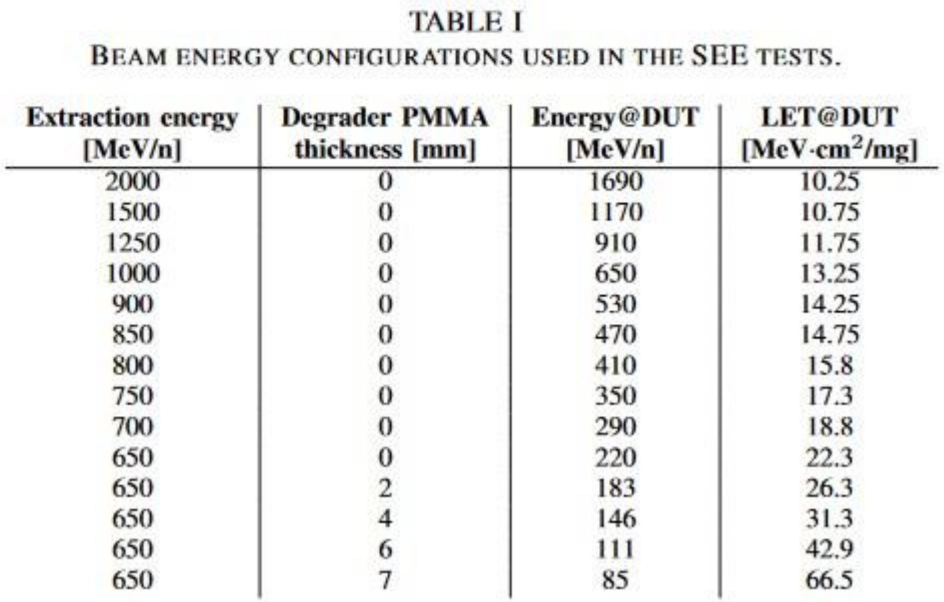


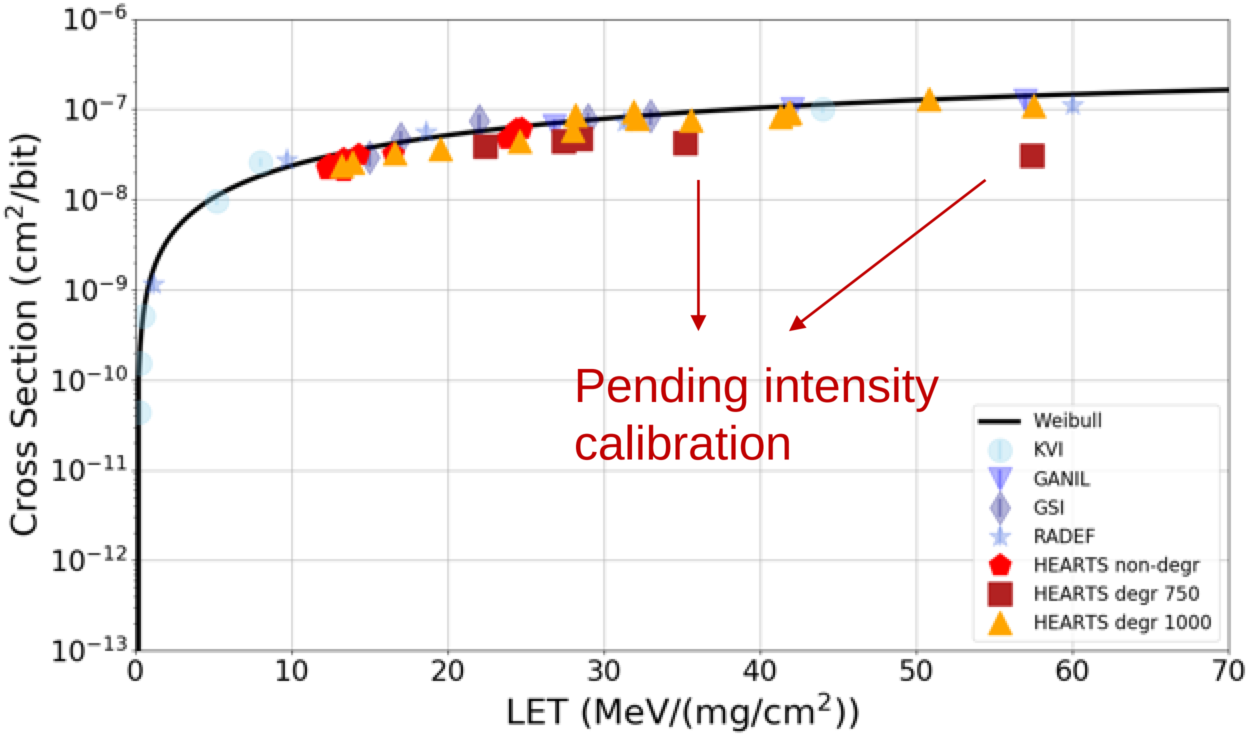
TABLE I

BEAM ENERGY CONFIGURATIONS USED IN THE SEE TESTS.

Extraction energy [MeV/n]	Degrader PMMA thickness [mm]	Energy@DUT [MeV/n]	LET@DUT [MeV·cm^2/mg]
2000	0	1690	10.25
1500	0	1170	10.75
1250	0	910	11.75
1000	0	650	13.25
900	0	530	14.25
850	0	470	14.75
800	0	410	15.8
750	0	350	17.3
700	0	290	18.8
650	0	220	22.3
650	2	183	26.3
650	4	146	31.3
650	6	111	42.9
650	7	85	66.5

LET and fluence validation: SEU cross sections

Degraded energies from 750 and 1000 MeV/n, Cypress

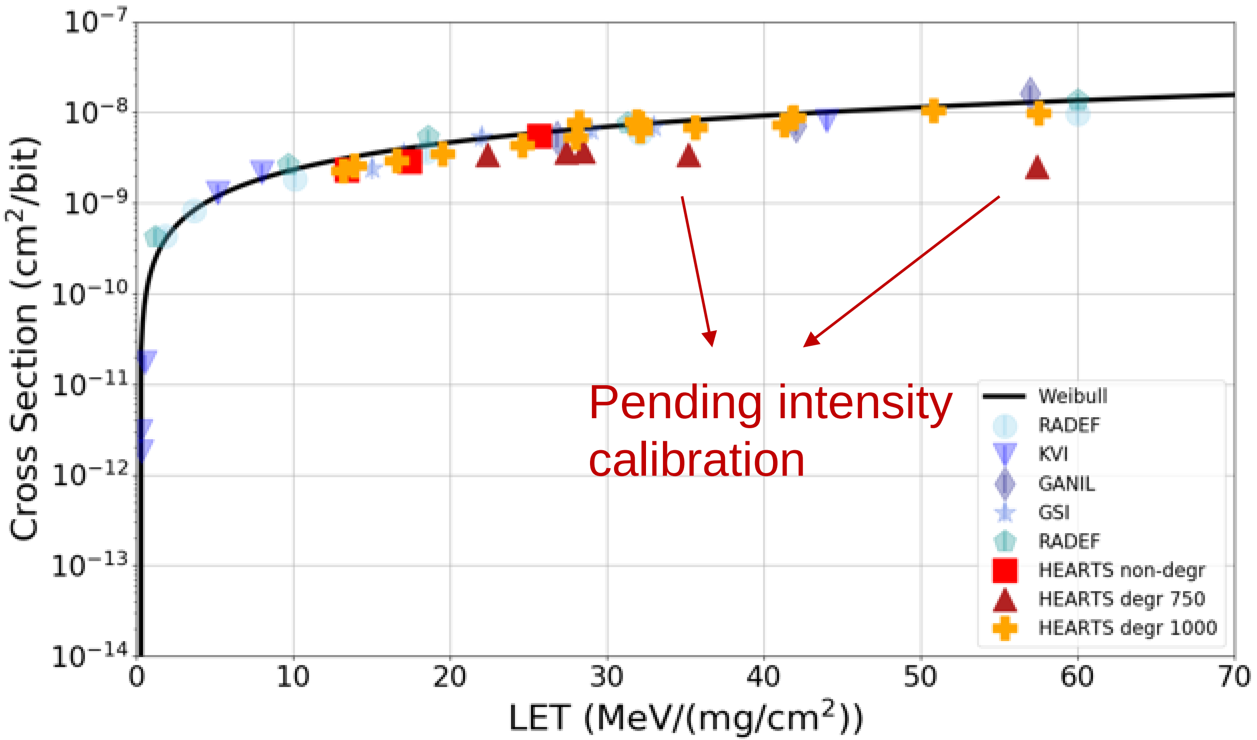


Pending intensity calibration

XSsat = 2.6 x 10^{-7} cm^2/bit
LETth = 0.1 MeV/(mg/cm^2)
s = 1.2
W = 70 MeV/(mg/cm^2)

LET and fluence validation: SEU cross sections

Degraded energies from 750 and 1000 MeV/n, ISSI

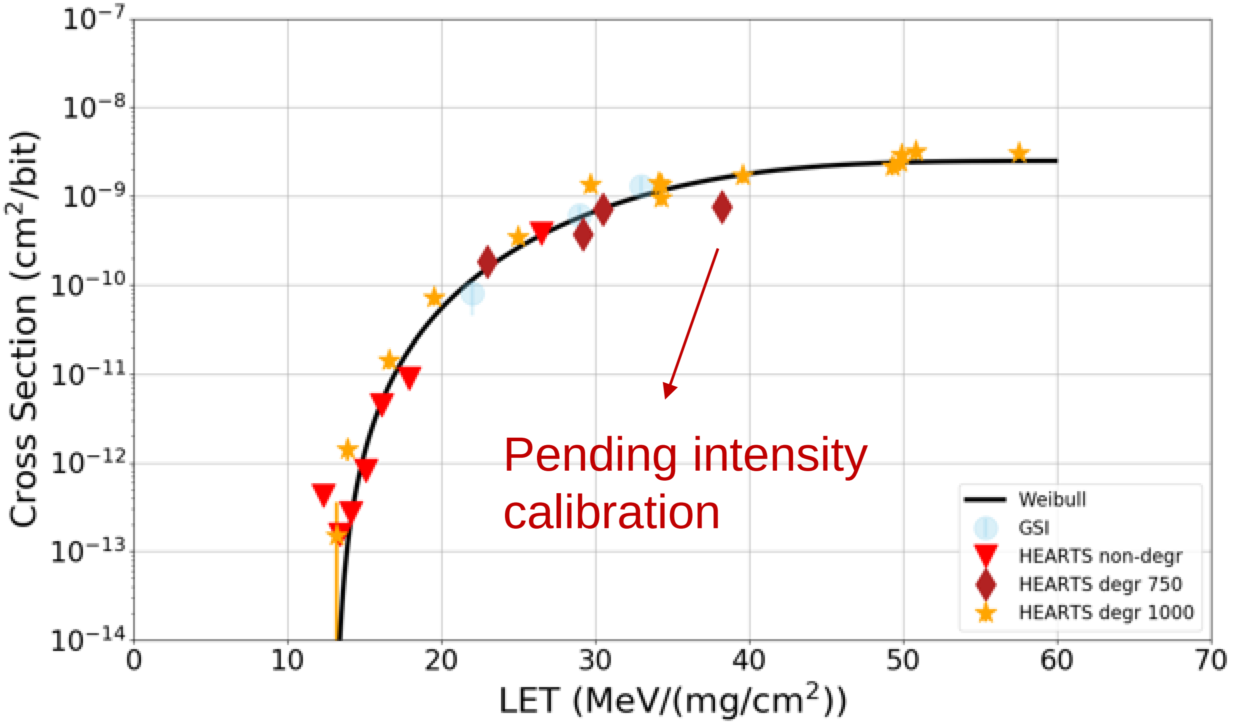


Pending intensity calibration

XSsat = 1.2 x 10^{-7} cm^2/bit
LETth = 0.2 MeV/(mg/cm^2)
s = 1
W = 500 MeV/(mg/cm^2)

LET and fluence validation: SEU cross sections

Degraded energies from 750 and 1000 MeV/n, Renesas

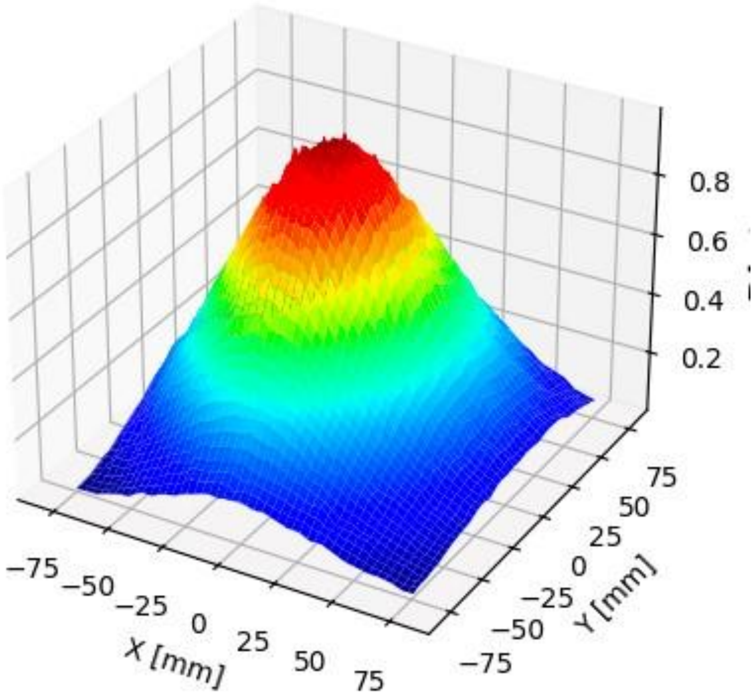


Pending intensity calibration

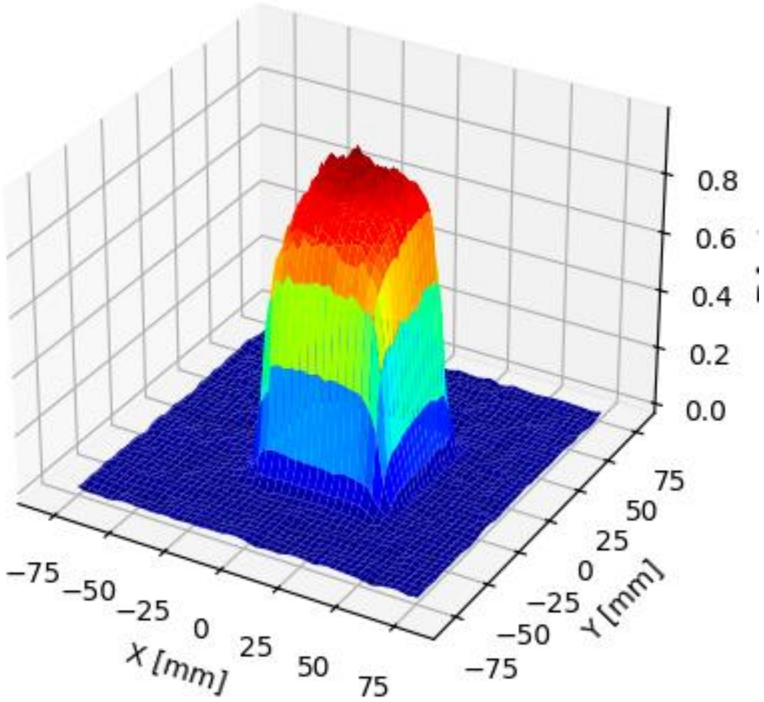
XSsat = 2.5×10^{-9} cm^2/bit
LETth = 13 MeV/(mg/cm^2)
s = 3
W = 25 MeV/(mg/cm^2)

Beam Profile

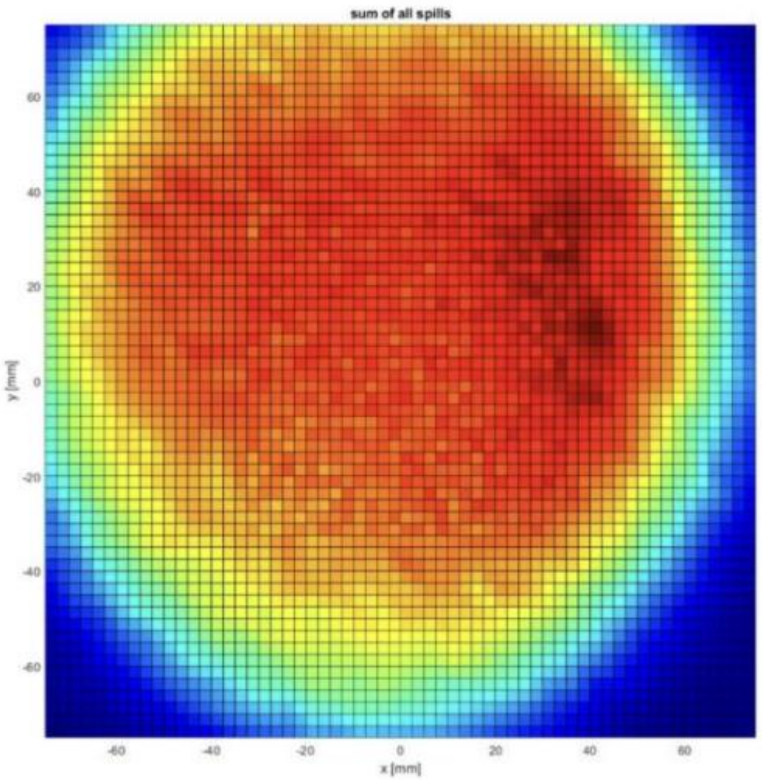
650MeV_0_070_mag_opt2_open
Start: 2023-10-25 10:53:06
End: 2023-10-25 10:55:14



650MeV_0_070_mag_opt1_5_cm
Start: 2023-10-25 10:22:00
End: 2023-10-25 10:25:47



Tunable beam size through beam optics



Beam size measurement on OCTAVIUS array with a large optics at 1 GeV/u.

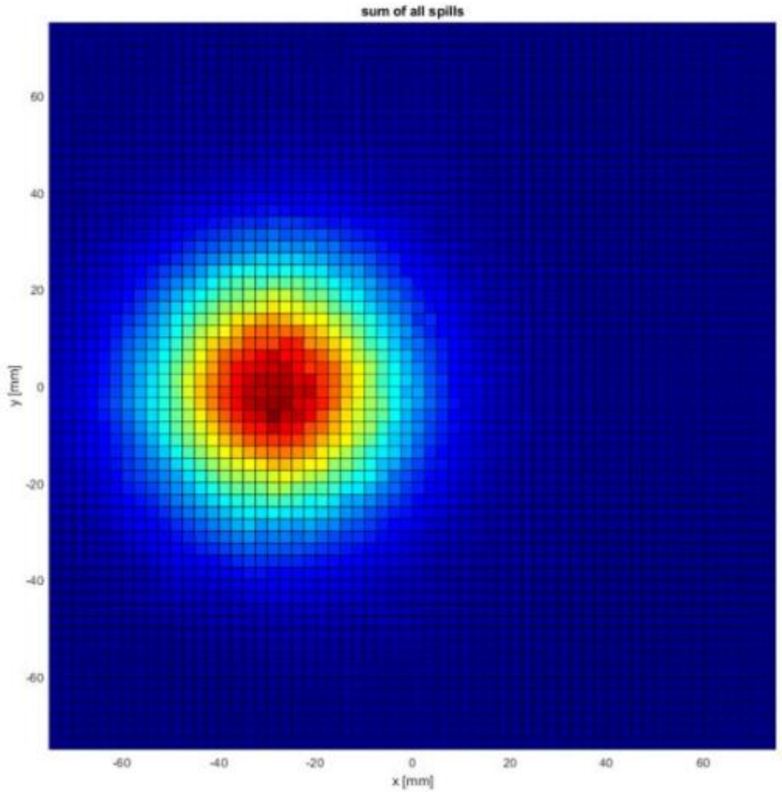
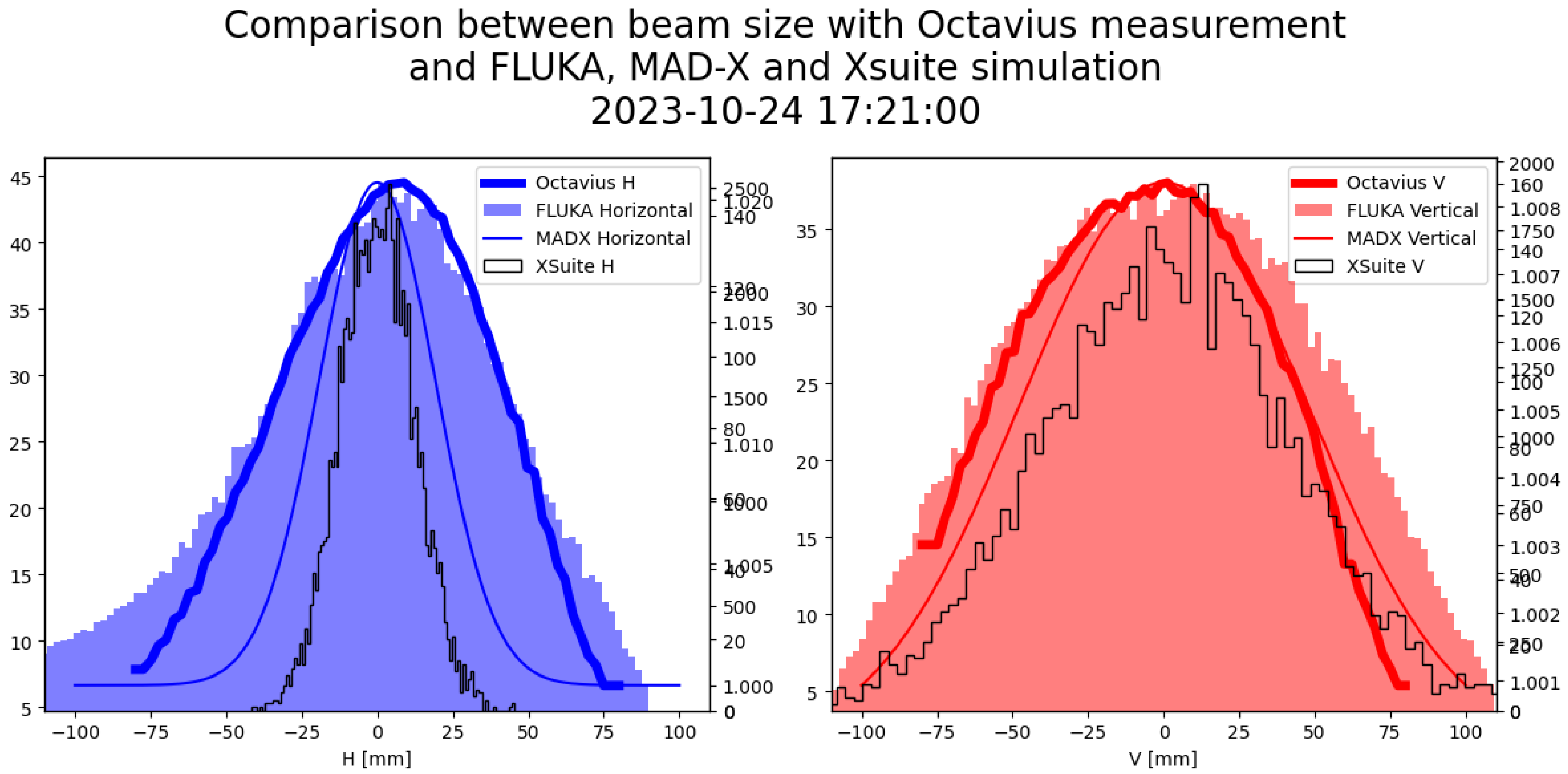


Figure 23: Beam size measurement on OCTAVIUS array using a small optics (no collimator) at 2 GeV/u.

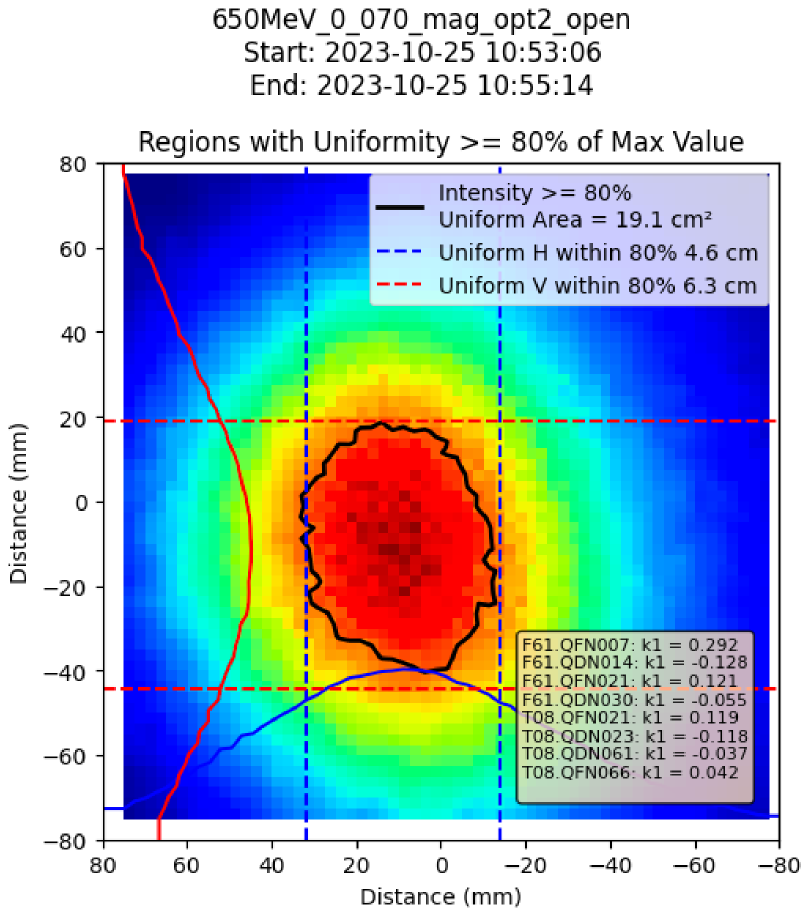
Good beam size agreement between measurements and simulations, which is important for further optimization

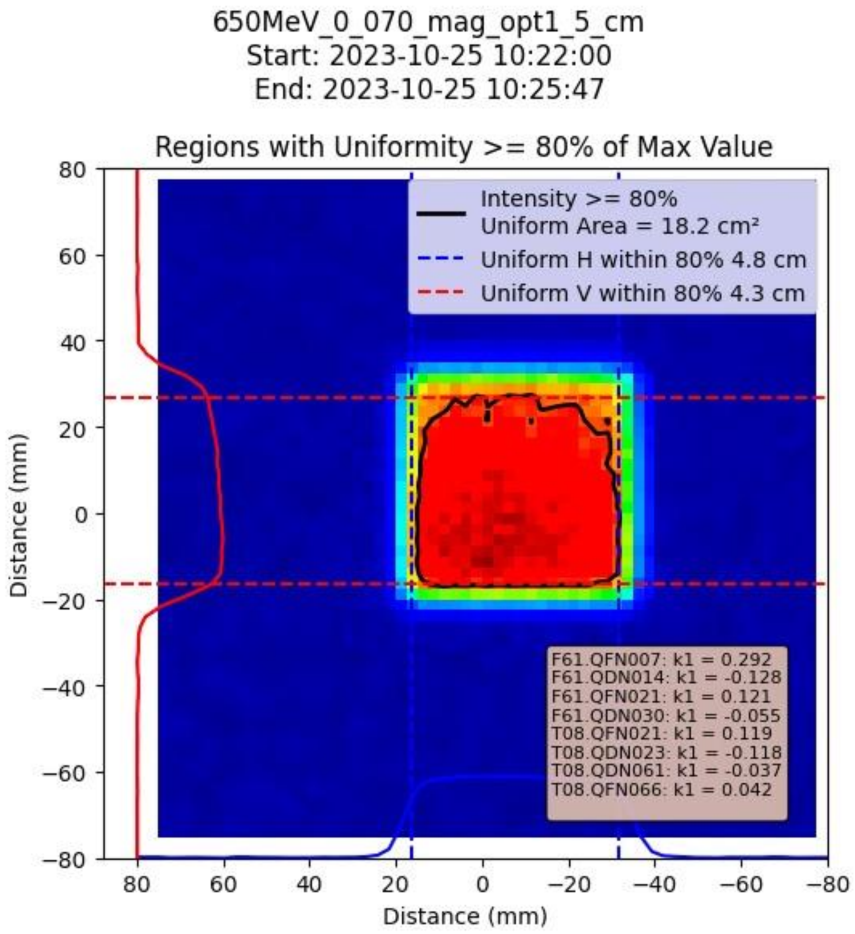
Strong link to WP3



Comparison between beam size with Octavius measurement and FLUKA, MAD-X and Xsuite simulation
2023-10-24 17:21:00

Our approach is to use large, Gaussian beams and cut off the edges with a mask near the DUT

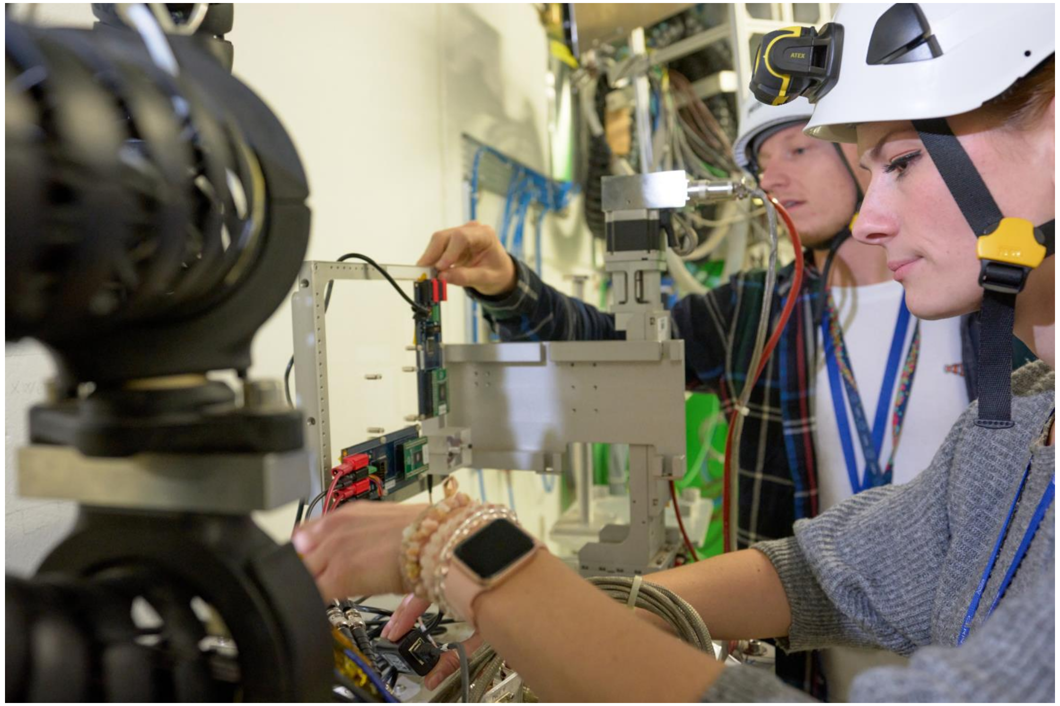


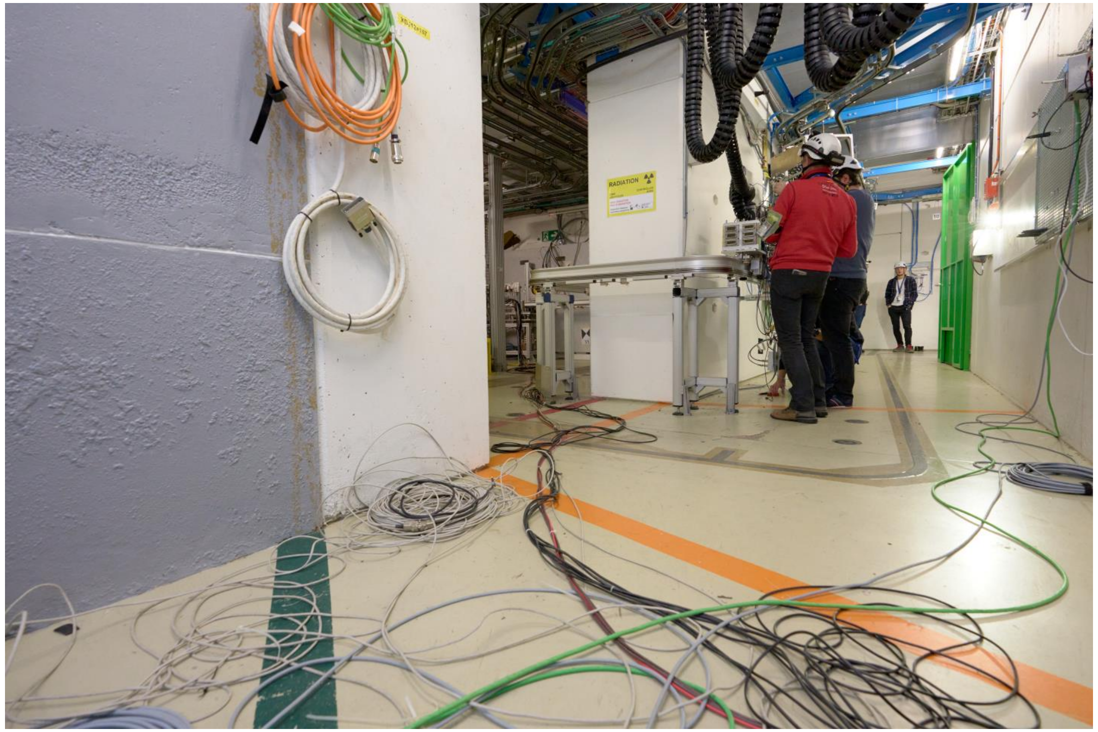


Beam profile summary

- The beams can be made **large**, but are **Gaussian**, meaning that the homogeneous flux region (e.g. within ±10%) is confined to the center of the beams
- The tails of the beam are not easily exploitable, as one would need to consider a flux and dosimetry as a function of the x-y position of the devices
- Therefore, the approach is rather to work with large Gaussian profiles, and cut the edges with a mask, **keeping only the central, homogeneous part**
- This is quite inefficient flux-wise, as we end up using only a small fraction of the beam (e.g. magnetic scanning [GSI] or octupole convolution of Gaussian into uniform beam [NSRL] are more efficient)
- Trade-off between homogeneity, beam size and flux, in which having large, homogeneous, high flux beam is not possible (nor is it foreseen to be within the HEARTS scope and timeframe)
- Still, we expect that a suitable working point can be found for *most* user tests

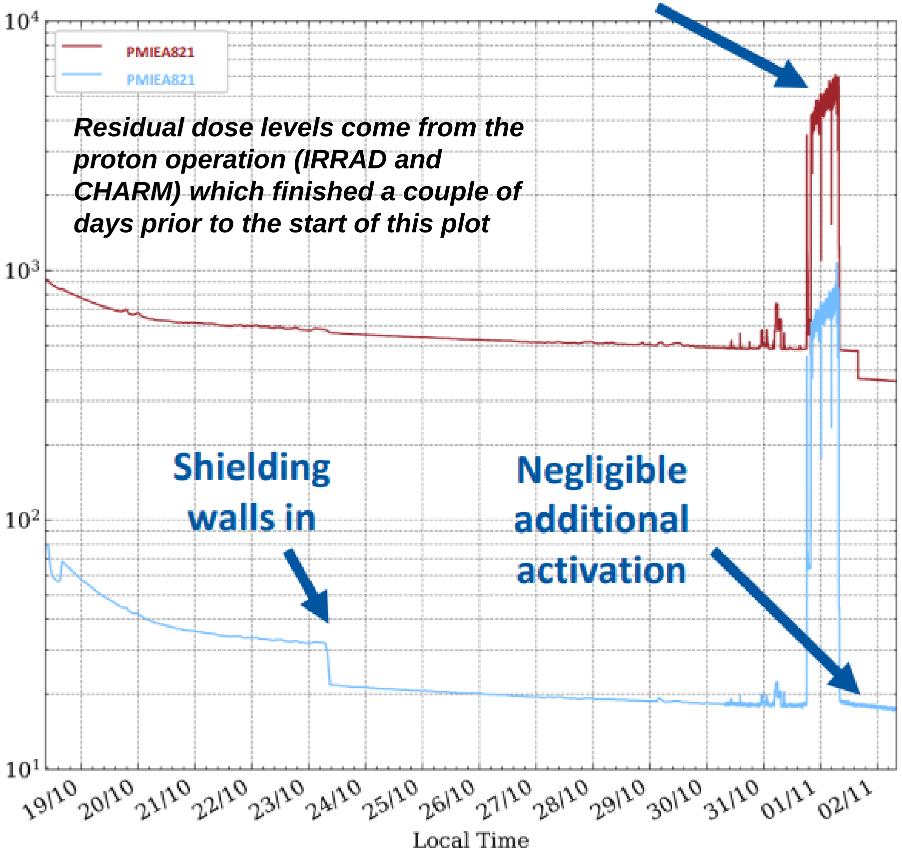
Physical access to experimental area





Residual dose levels

Prompt signal when beam is on target



Residual dose levels come from the proton operation (IRRAD and CHARM) which finished a couple of days prior to the start of this plot

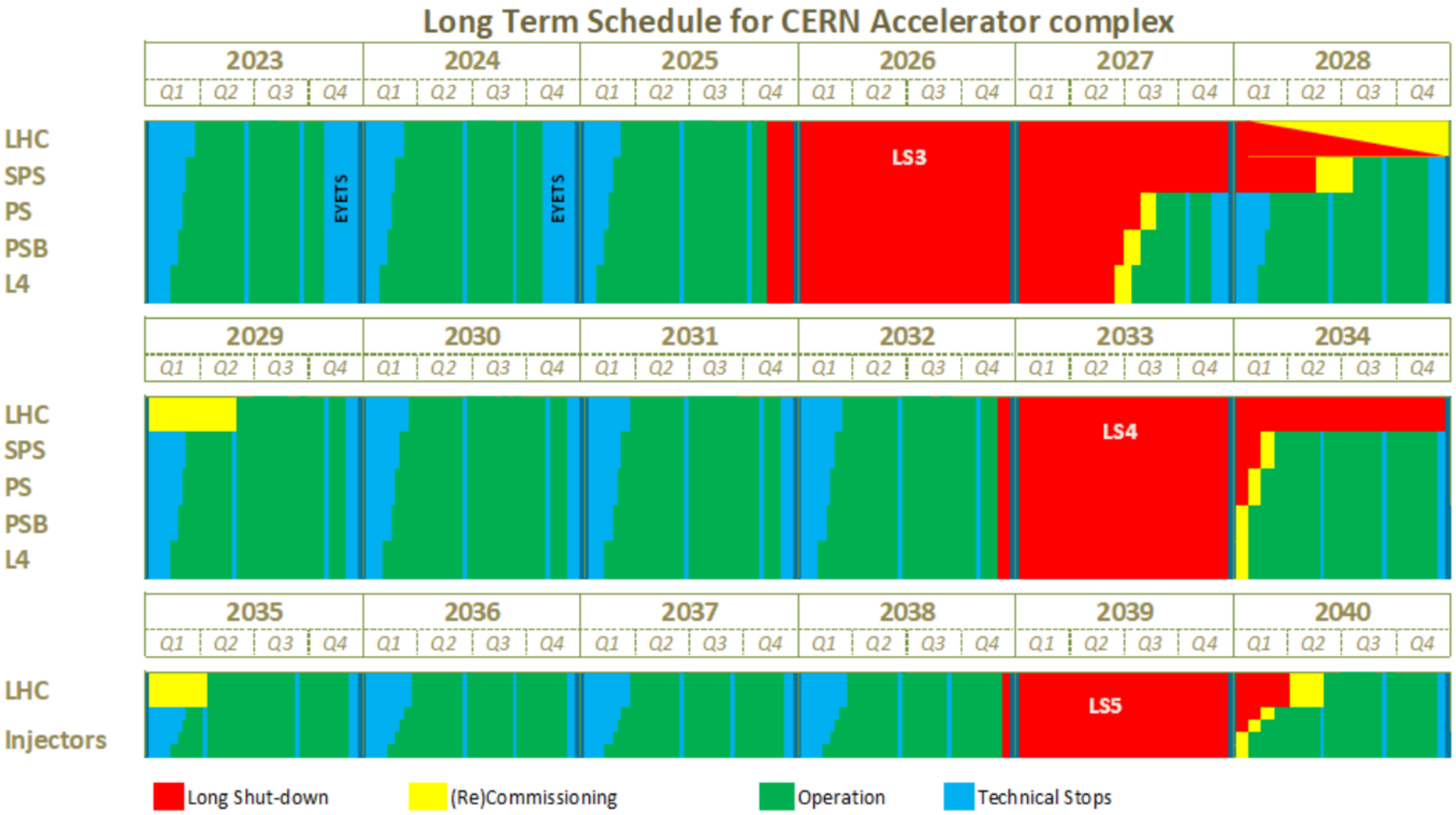
Shielding walls in

Negligible additional activation

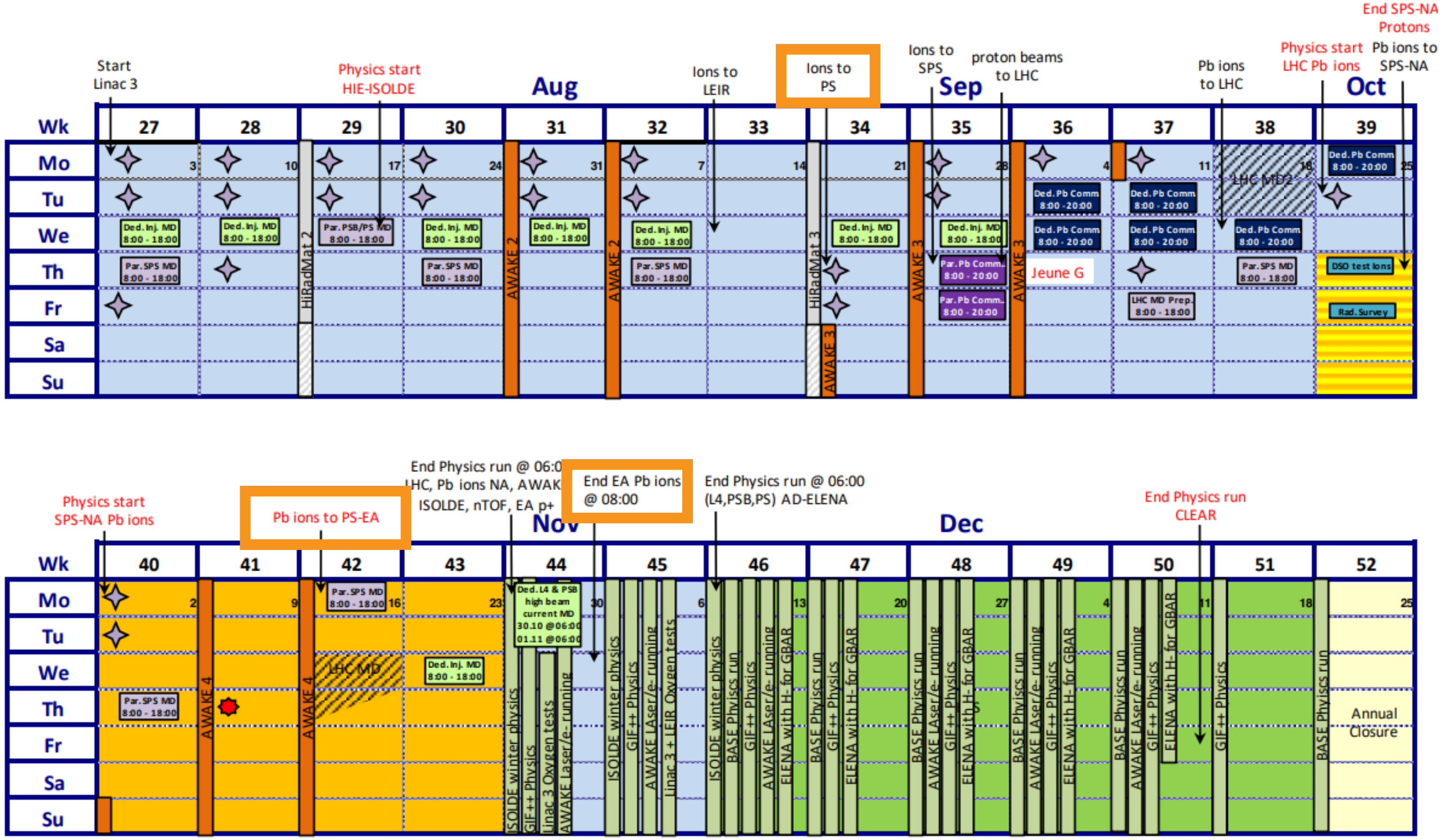
Summary of physical access to the experimental area

- HEARTS users can request the **start/stop of the beam** anytime, and independently to all other CERN users
  - Currently done by calling PS Control Room, but we are working on beam on/off button from user control room (as well as condition to stop beam after certain time or fluence)
- Reasonably **high activation levels in CHARM** due to proton-on-target operation and fact that ion run takes places at the end of the (operational) year
  - Hence the importance of working in low dose areas whenever possible, etc.
- These levels are not impacted by ion operation, therefore there is nothing to be gained by “waiting” after an irradiation, and the modification in the ventilation systems allows **for access just ~5 min after beam off**
- Access to internal area requires **1-day in-person controlled area Radiation Protection (RP) course** (valid for 3 years, renewable online), plus an **RP agent to join the access →** this presently limits accesses to working hours (and, “standard” user operation requires frequent access)

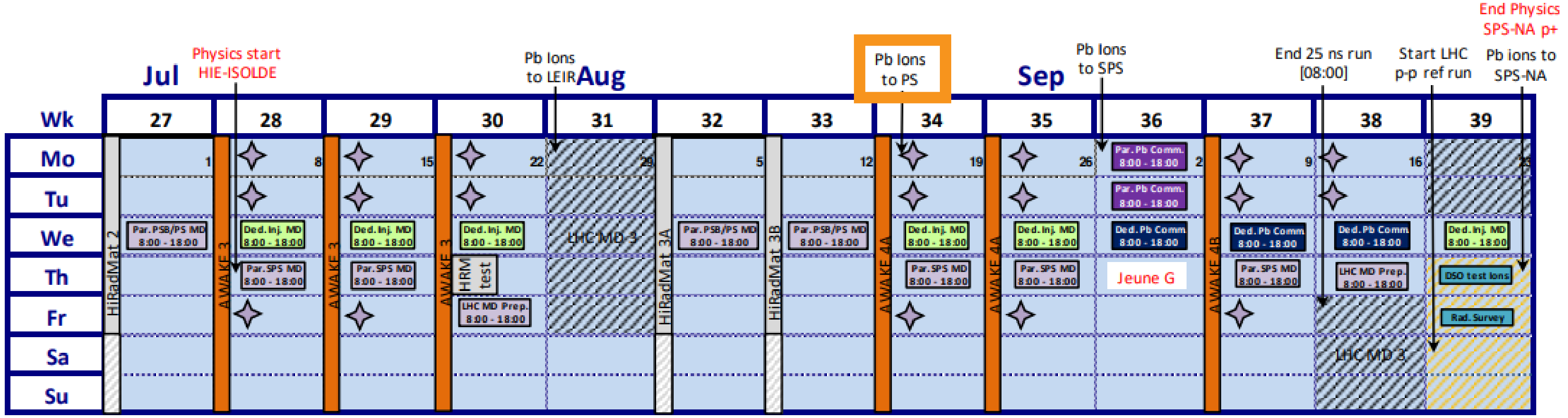
Yearly schedule



Injector schedule in 2023



Injector schedule in 2024



Jul

Physics start HIE-ISOLDE

Pb Ions to LEIR

Aug

Pb Ions to PS

Sep

Pb Ions to SPS

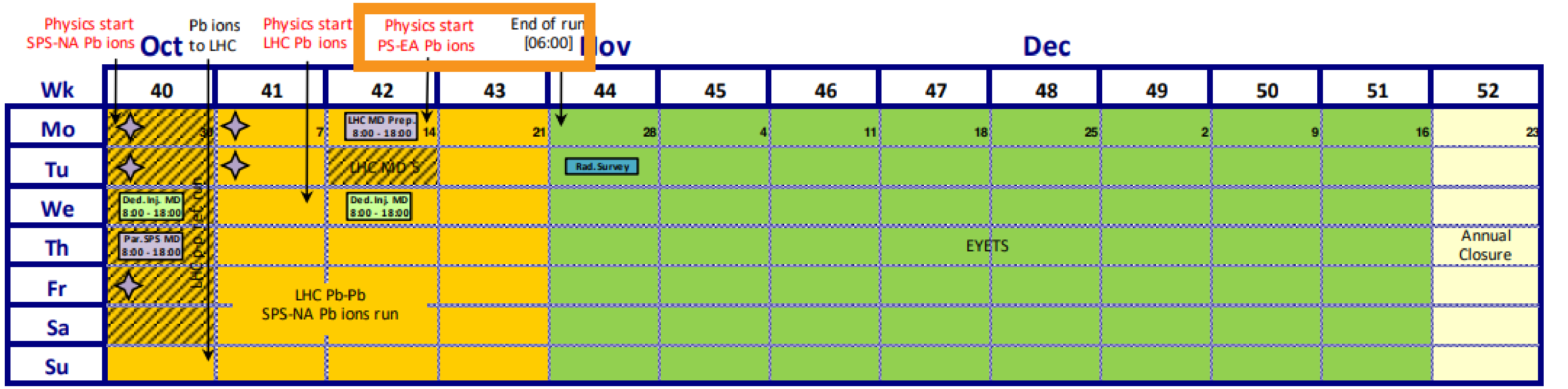
End 25 ns run [08:00]

Start LHC p-p ref run

End Physics SPS-NA p+

Pb ions to SPS-NA

Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	HiRadMat 2 1	AWAKE 3 ✦ 8	AWAKE 3 ✦ 15	AWAKE 3 ✦ 22	29	HiRadMat 3A 5	HiRadMat 3B 12	AWAKE 4A ✦ 19	AWAKE 4A ✦ 26	Par. Pb Comm. 8:00 - 18:00 2	AWAKE 4B ✦ 9	✦ 16	23
Tu		✦	✦	✦				✦	✦	Par. Pb Comm. 8:00 - 18:00	✦	✦	
We	Par. PSB/PS MD 8:00 - 18:00	Ded. Inj. MD 8:00 - 18:00	Ded. Inj. MD 8:00 - 18:00	Ded. Inj. MD 8:00 - 18:00	LHC MD 3	Par. PSB/PS MD 8:00 - 18:00	Par. PSB/PS MD 8:00 - 18:00	Ded. Inj. MD 8:00 - 18:00	Ded. Inj. MD 8:00 - 18:00	Ded. Pb Comm 8:00 - 18:00	Ded. Pb Comm 8:00 - 18:00	Ded. Pb Comm 8:00 - 18:00	Ded. Inj. MD 8:00 - 18:00
Th		Par. SPS MD 8:00 - 18:00	Par. SPS MD 8:00 - 18:00	HRM test				Par. SPS MD 8:00 - 18:00	Par. SPS MD 8:00 - 18:00	Jeune G	Par. SPS MD 8:00 - 18:00	LHC MD Prep. 8:00 - 18:00	DSO test Ions
Fr		✦	✦	LHC MD Prep. 8:00 - 18:00				✦	✦		✦		Rad. Survey
Sa												LHC MD 3	
Su													



Physics start SPS-NA Pb ions

Oct

Pb ions to LHC

Physics start LHC Pb ions

Physics start PS-EA Pb ions

End of run [06:00]

Nov

Dec

Wk	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo	✦ 30	✦ 7	LHC MD Prep. 8:00 - 18:00 14	21	28	4	11	18	25	2	9	16	23
Tu	✦	✦	LHC MD 5		Rad. Survey								
We	Ded. Inj. MD 8:00 - 18:00		Ded. Inj. MD 8:00 - 18:00										
Th	Par. SPS MD 8:00 - 18:00 LHC p-p ref run							EYETS					Annual Closure
Fr	✦	LHC Pb-Pb SPS-NA Pb ions run											
Sa													
Su													

Yearly schedule summary

- Ions are typically present in the PS for **~2 months per [operational] year** (September, October)
- As of the moment ions are setup in the PS, HEARTS@CERN ion **beam commissioning can start**, especially thanks to the option of sending ion beams to the East Area dump (i.e. no direct interference with T8)
- **Beams can also start to be sent to T8** during a few hours per week, which is very useful for the commissioning (and which relies on very strong coordination with IRRAD and CHARM)
- However, this is typically only the case for a few weeks, as the installation of the cryostat in IRRAD, which is incompatible with ion operation, typically takes place soon after the ions are setup → this constraint could be removed by moving the DUT location further upstream
- The IRRAD and CHARM facilities are heavily overbooked for detector and accelerator sensors and electronics, with **no margin to expand ion runs**
- In other words, substantially increasing the high-energy heavy ion beam time would require a dedicate ion beam line and experimental area (which would also significantly alleviate the RP – and related access - constraints)

In summary…

- We are, already at this stage, confident in being able to offer electronics testing users **LET and flux values** in a *large* enough range, and with the *necessary* level of accuracy
    - Still, we are somewhat limited on the high average flux end, mainly due to the low transmission and low repetition rate
    - The lowest LET might be too large for some applications – combining high-energy ions with high-energy protons in same experimental campaign could at least partially mitigate this, as fast changes between ions is not foreseeable in the near future
- Given the Gaussian **profile** of the beam and despite its large size (e.g. in terms of FWHM), the surface we can cover with a **homogeneous** flux (~5 cm side) is not enormous – larger areas will be investigated, at the cost of lower fluxes
- Exploitable beam time for user testing is currently quite limited, mainly due to **2 weeks of ion beams per year constraint**, but also due to accesses currently only being possible during working hours (we are in touch with RP about possible solutions to alleviate this second constraint)
- We are confident in providing users with clear and user-friendly procedures to register for CERN access, arrange the shipment of their equipment, prepare their setups in a way that complies with the facility mechanical and electrical interfaces, etc., though the **commercial access procedure** is still to be defined (also work in progress, with dedicated taskforce to be kicked-off early this year)
- **We very much look forward to 2024 and to having the points above assessed independently by external (to CERN) electronics testing users**

Many thanks for your attention!

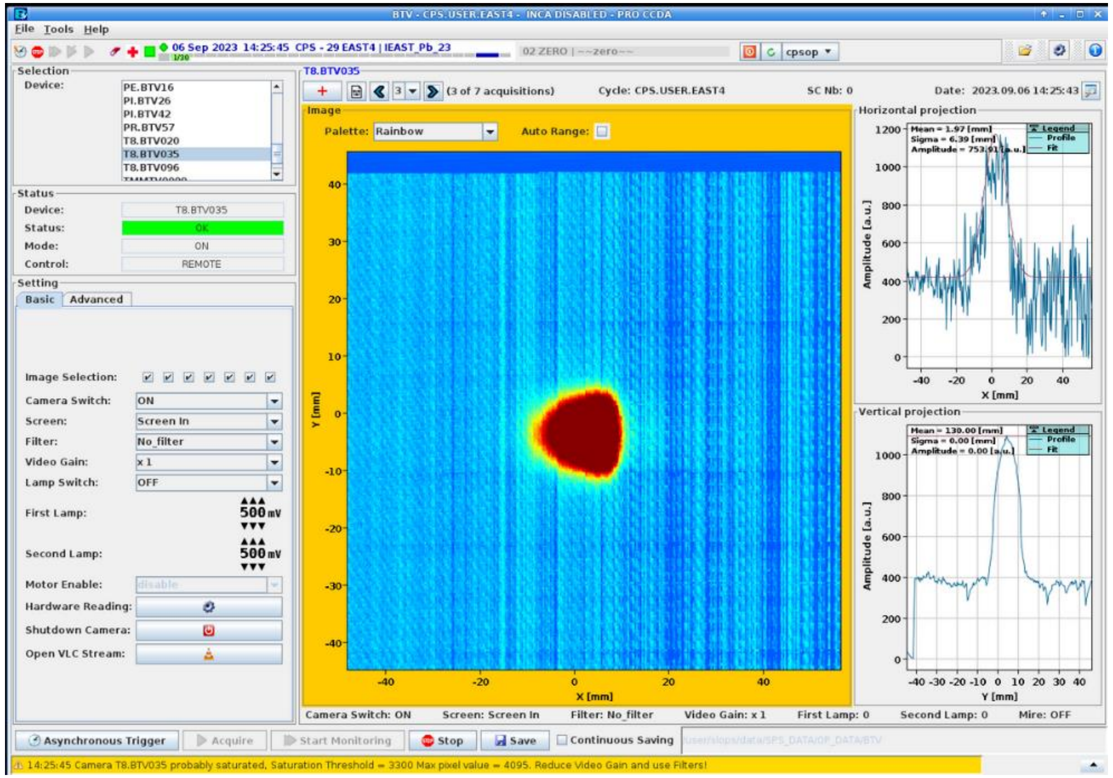
Funded by
the European Union

HEARTS is a project funded by the European Union under GA No 101082402,
through the Space Work Programme of the European Commission.

HEARTS

Extra slides

Beam commissioning in T8 on Sept 6th, 2023



06 Sep 2023 14:25:45 CPS - 29 EAST4 | IEAST_Pb_23

T8.BTV035

3 (3 of 7 acquisitions) Cycle: CPS.USER.EAST4 SC Nb: 0 Date: 2023.09.06 14:25:43

Status — Device: T8.BTV035; Status: OK; Mode: ON; Control: REMOTE

Image Selection: ☑ ☑ ☑ ☑ ☑ ☑ ☑

Camera Switch: ON

Screen: Screen In

Filter: No_filter

Video Gain: x 1

Lamp Switch: OFF

First Lamp: 500 mV

Second Lamp: 500 mV

Motor Enable: disable

Palette: Rainbow Auto Range: ☐

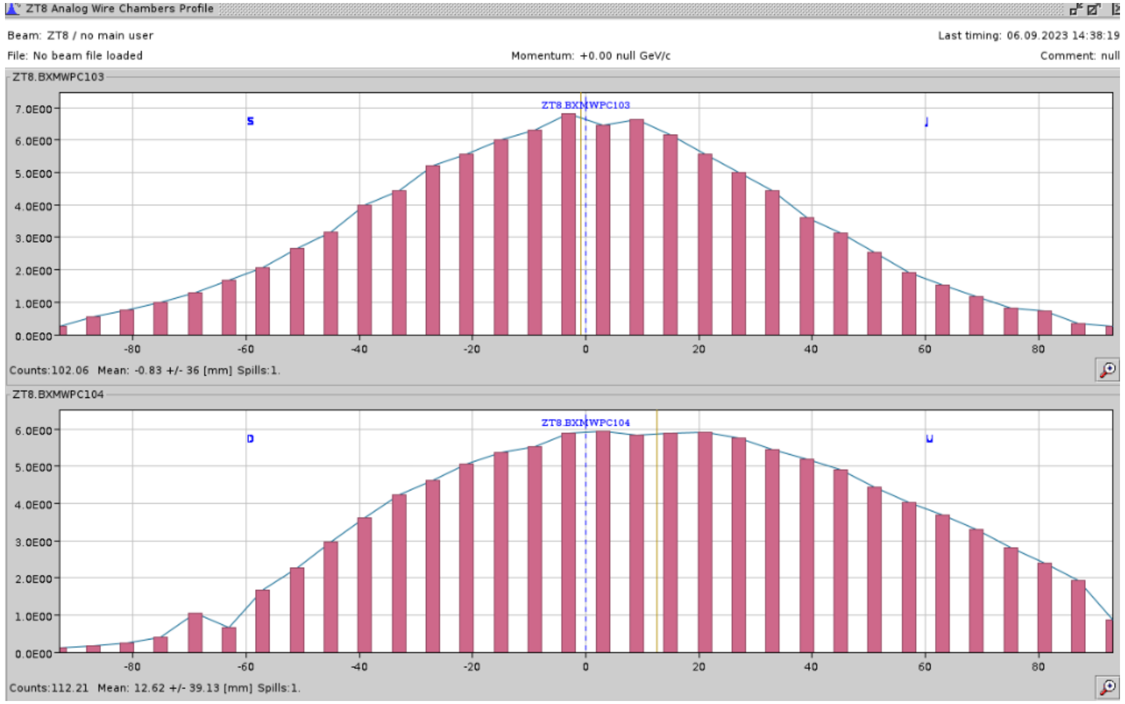
Horizontal projection: Mean = 1.97 [mm] Sigma = 6.39 [mm] Amplitude = 753.91 [a.u.]

Vertical projection: Mean = 130.00 [mm] Sigma = 0.00 [mm] Amplitude = 0.00 [a.u.]

Camera Switch: ON Screen: Screen In Filter: No_filter Video Gain: x 1 First Lamp: 0 Second Lamp: 0 Mire: OFF

☐ Continuous Saving /user/slops/data/SPS_DATA/OP_DATA/BTV

⚠ 14:25:45 Camera T8.BTV035 probably saturated, Saturation Threshold = 3300 Max pixel value = 4095. Reduce Video Gain and use Filters!



Beam: ZT8 / no main user

Last timing: 06.09.2023 14:38:19

File: No beam file loaded

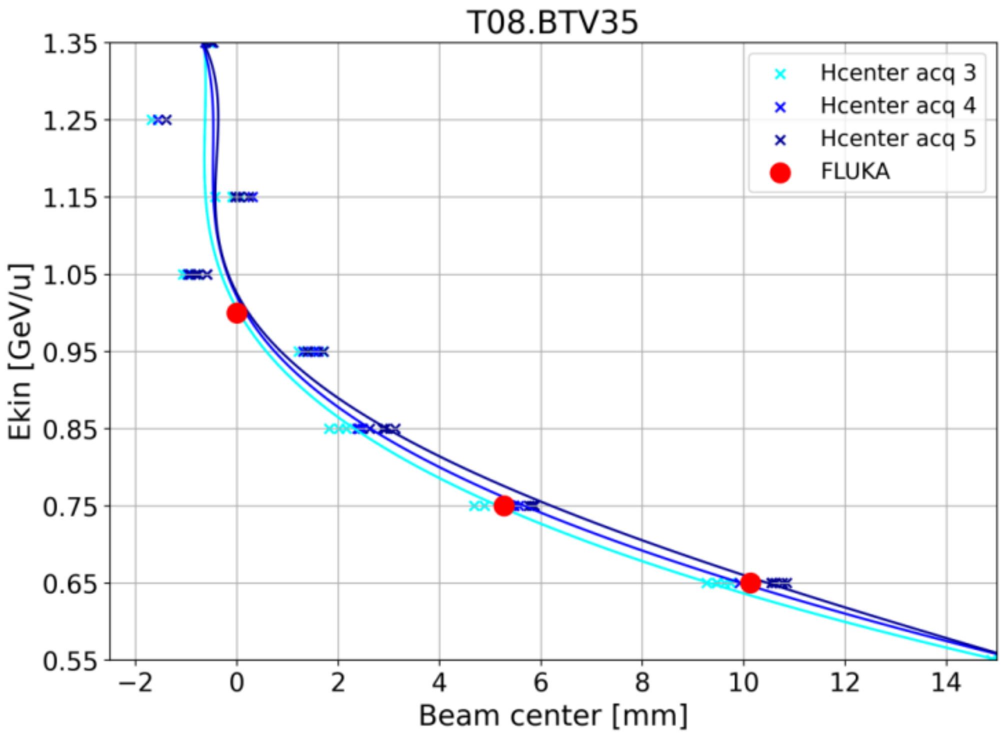
Momentum: +0.00 null GeV/c

Comment: null

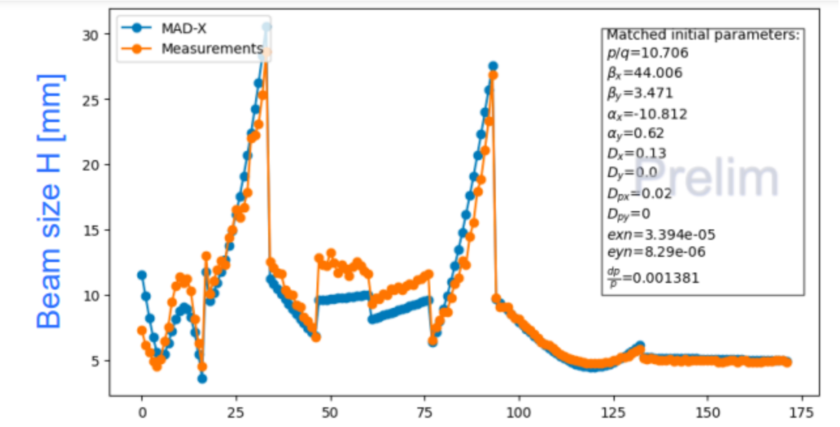
ZT8.BXMWPC103: Counts:102.06 Mean: -0.83 +/- 36 [mm] Spills:1.

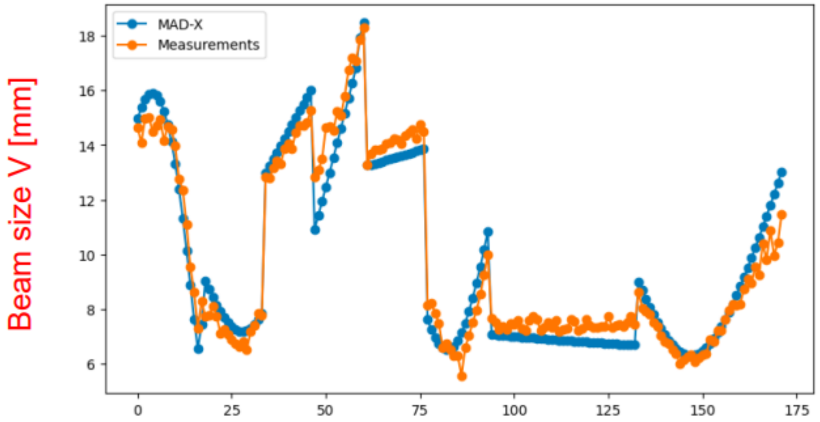
ZT8.BXMWPC104: Counts:112.21 Mean: 12.62 +/- 39.13 [mm] Spills:1.

Beam optics studies and measurements

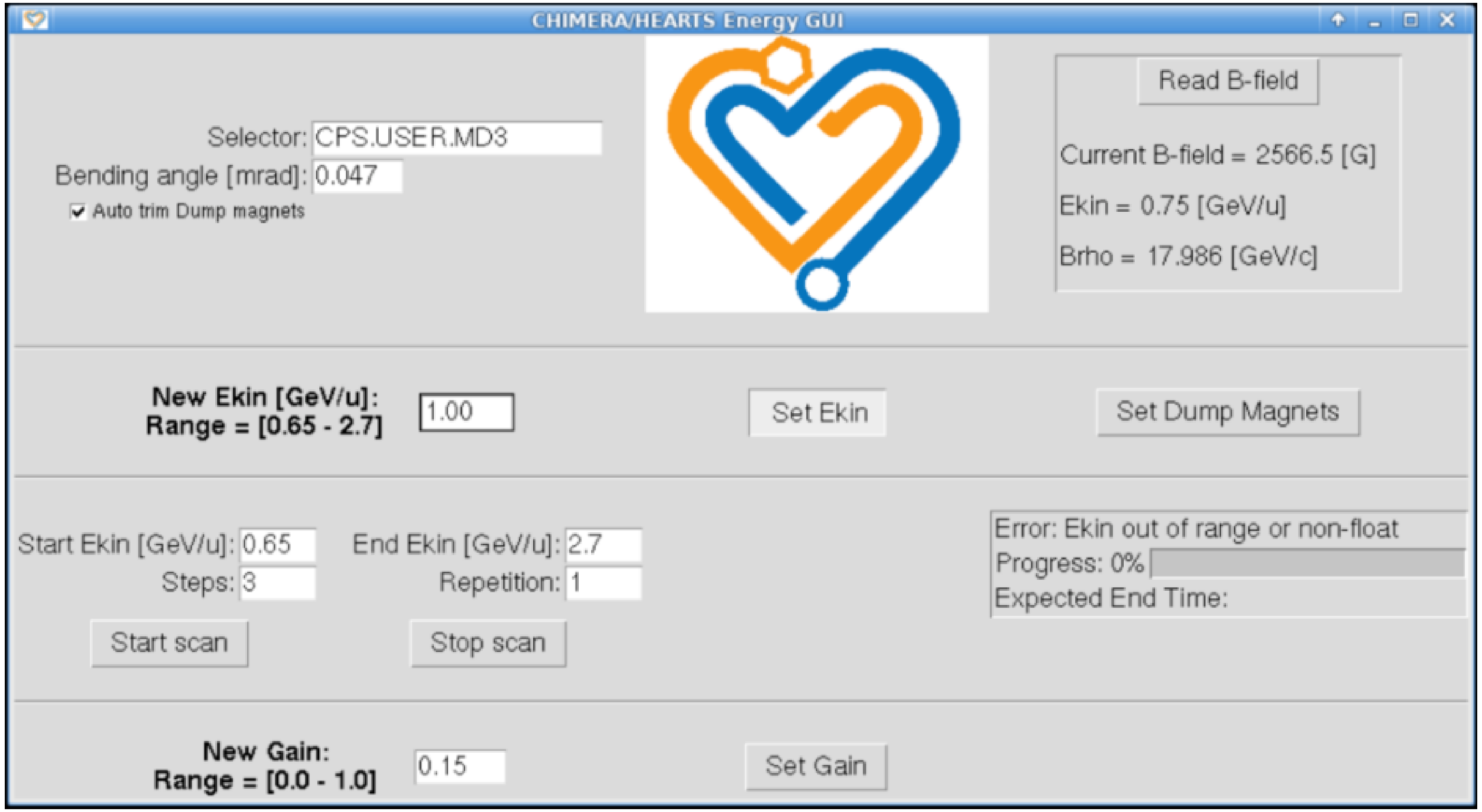


Energy straggling measurement and FLUKA simulation on T8.BTV035.





Beam energy and flux operator GUI



Selector: CPS.USER.MD3
Bending angle [mrad]: 0.047
☑ Auto trim Dump magnets

Current B-field = 2566.5 [G]
Ekin = 0.75 [GeV/u]
Brho = 17.986 [GeV/c]

New Ekin [GeV/u]:
Range = [0.65 - 2.7] 1.00

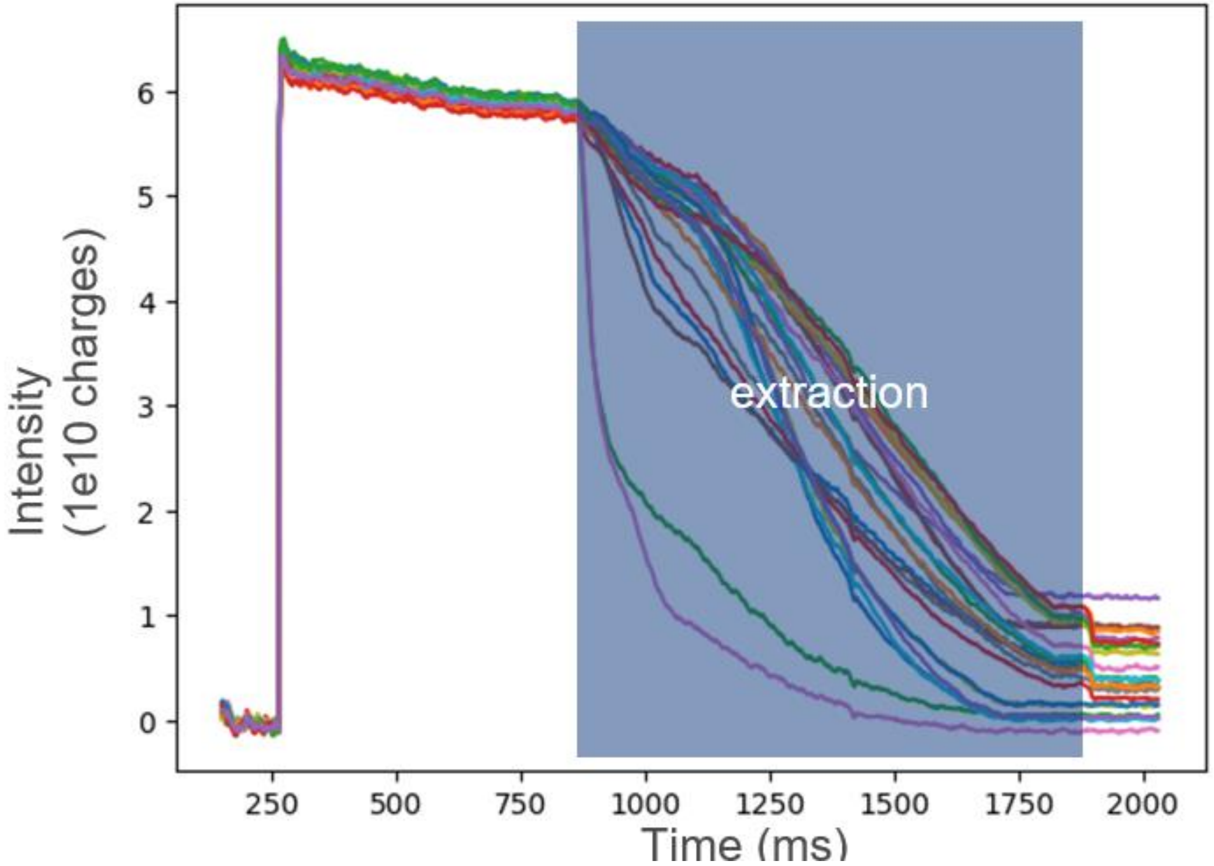
Start Ekin [GeV/u]: 0.65
End Ekin [GeV/u]: 2.7
Steps: 3
Repetition: 1

Error: Ekin out of range or non-float
Progress: 0%
Expected End Time:

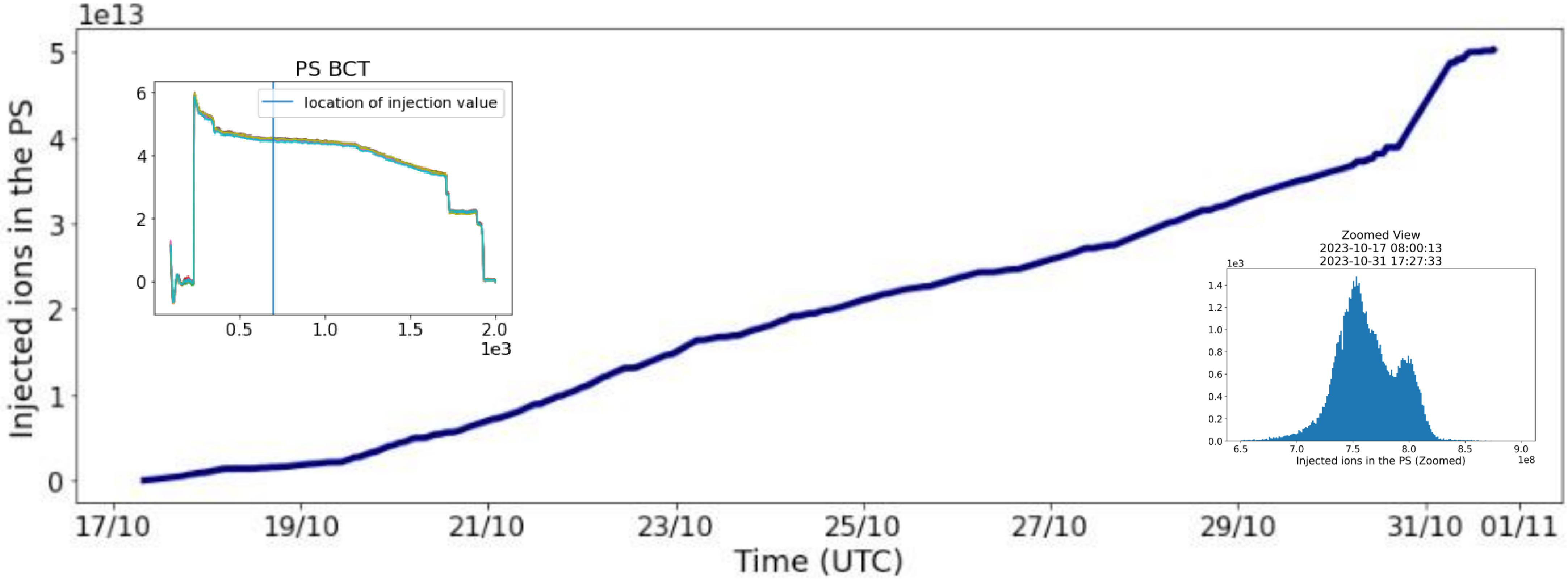
New Gain:
Range = [0.0 - 1.0] 0.15

HEARTS energy and flux GUI

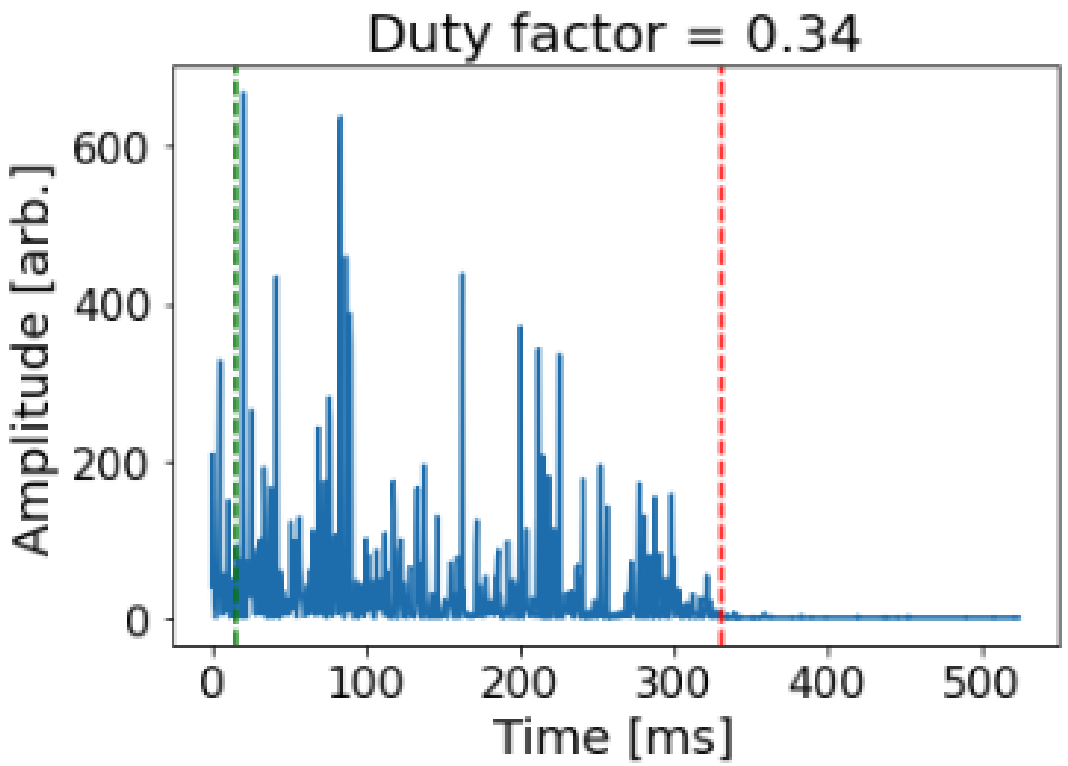
1000ms spill in development

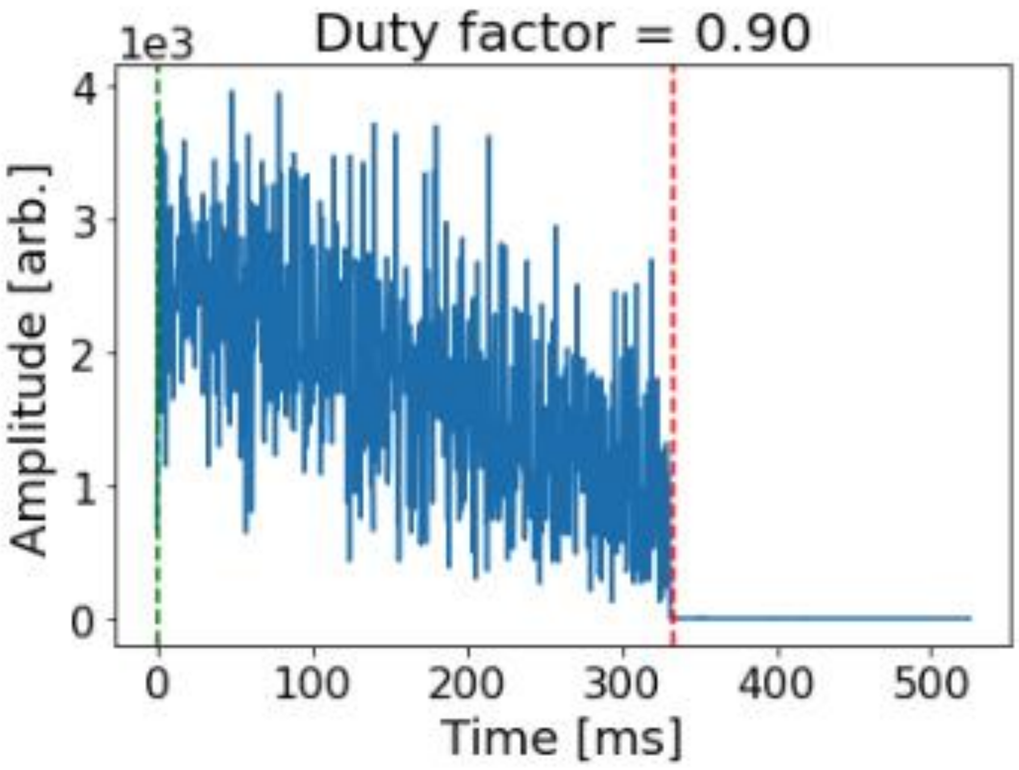


PS ion intensity before extraction

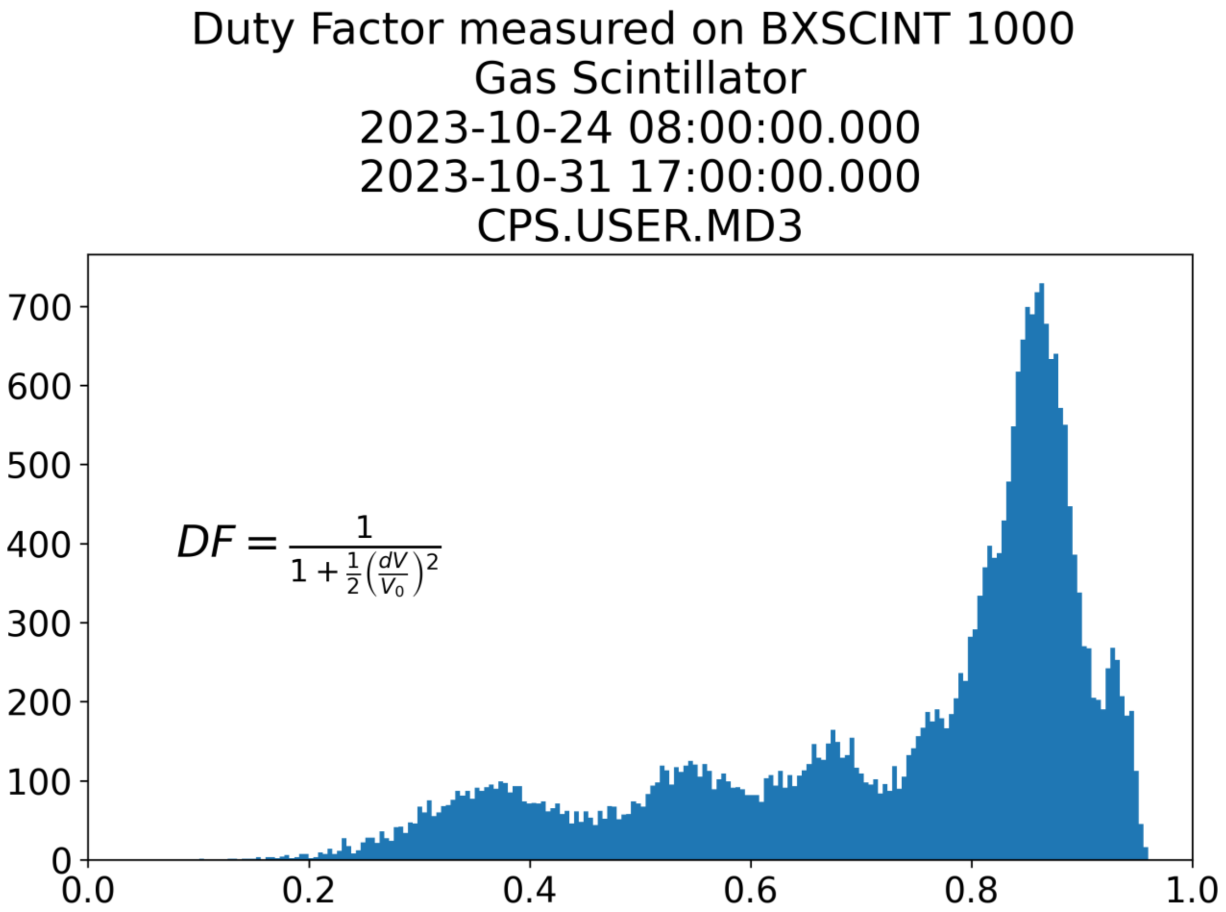


Spill time profile quality

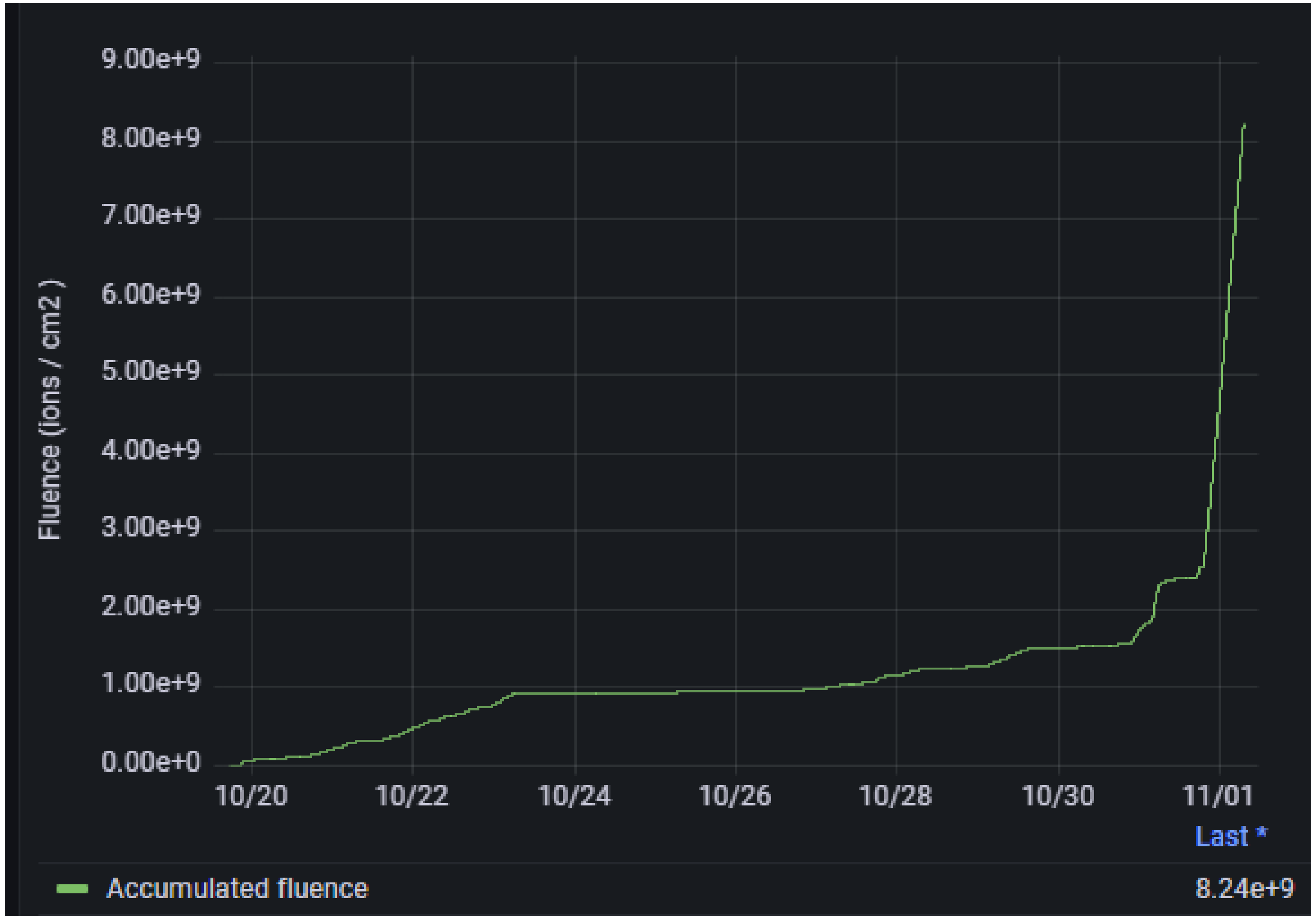

Duty factor = 0.34


Duty factor = 0.90

Spill time profile quality



Accumulated fluence at DUT location



SEE + detector setups, and degrader/mask system