

MAX-PLANCK-INSTITUT
FÜR PHYSIK



Run Coordination

Giovanni Zevi Della Porta

AWAKE Collaboration Meeting — October 4-6, 2023

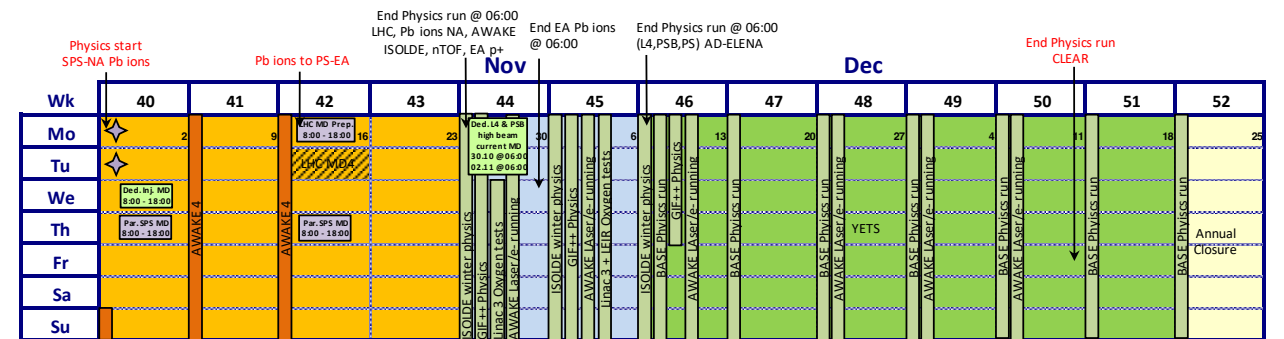
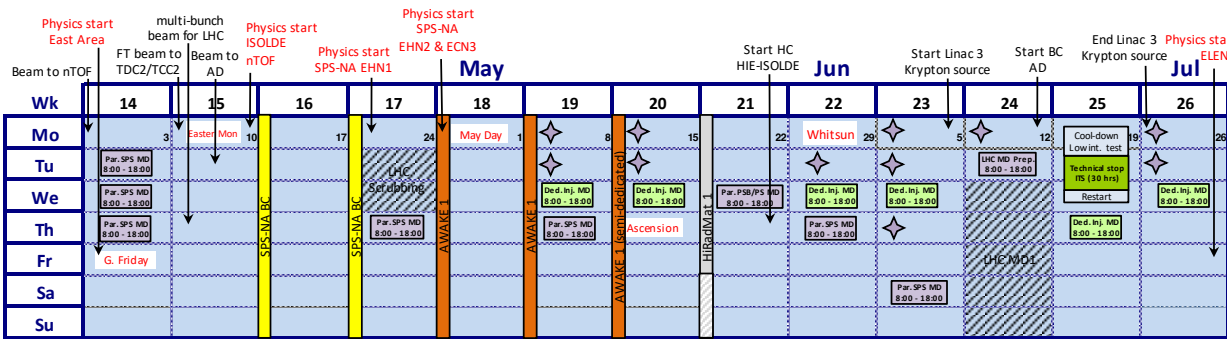
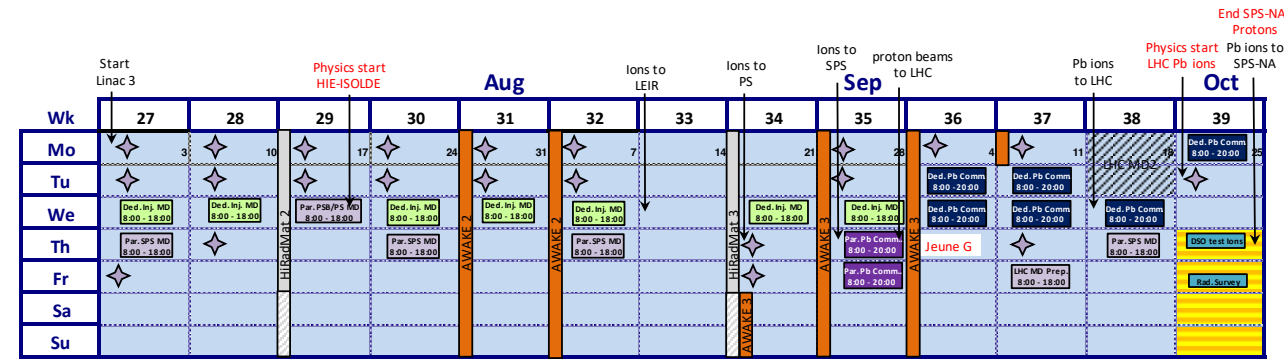
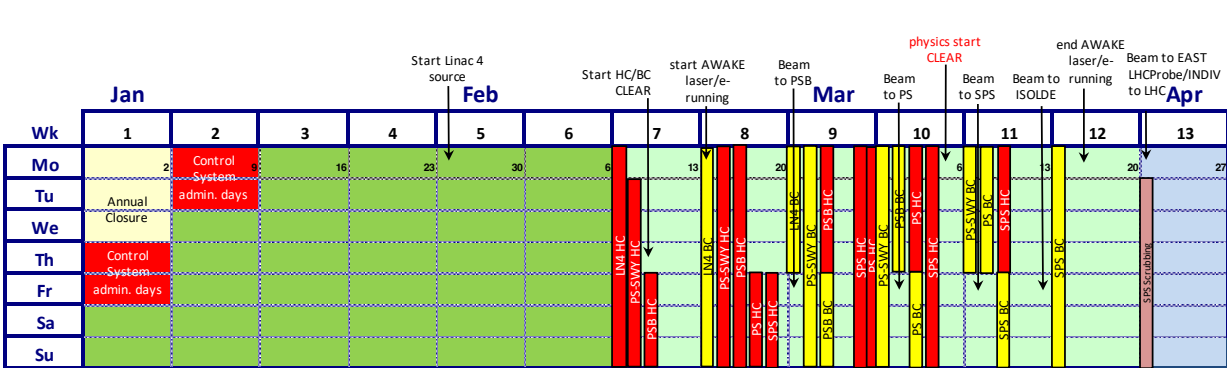
<https://indico.cern.ch/event/1329098>

Looking back since the last Collaboration Meeting



- 2023 has been a very challenging year: tunnel activities worthy of a long-shutdown, on top of ~10 weeks of protons
- 3 proton runs: May, July-August, August-September
- 2 plasma sources: Discharge and Density Step

- Proton runs:
 - ✓ • May 1-21
 - ✓ • July 31 - August 13
 - ✓ • Aug. 26 - Sept. 11
 - ⚠ • October 8-22

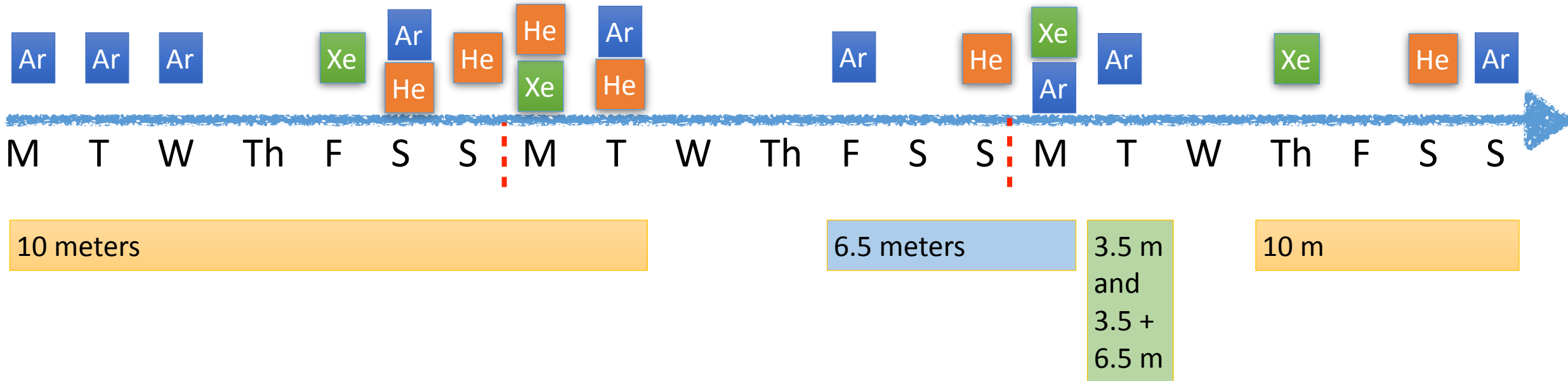


May 1-21: three weeks of DPS

1. May 1-9: Full physics program with 10 m single-plasma cell
 - Measure plasma frequency in Argon plasma at all densities, then Xenon and Helium
 - Ion motion (front/back of p+ bunch) and Filamentation (narrow/wide p+ bunch)
 - Plasma light with: PMTs, 1 μ s camera, spectral lines
2. May 12-15: Repeat program at 6.5 m: fewer scans, faster
3. May 16: Short test with 3.5 m and staged (3.5+6.5m) configurations
4. May 18-21: Return to 10 m to complete datasets and take delay scans with μ s cameras

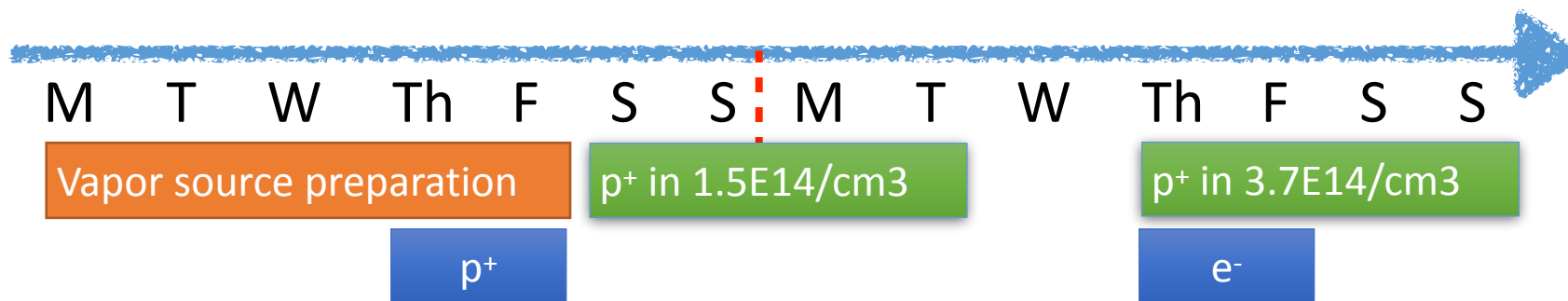


—> Long access periods used to reconfigure DPS and move Plasma Light diagnostics (PMTs, μ s cameras, grating camera) <—



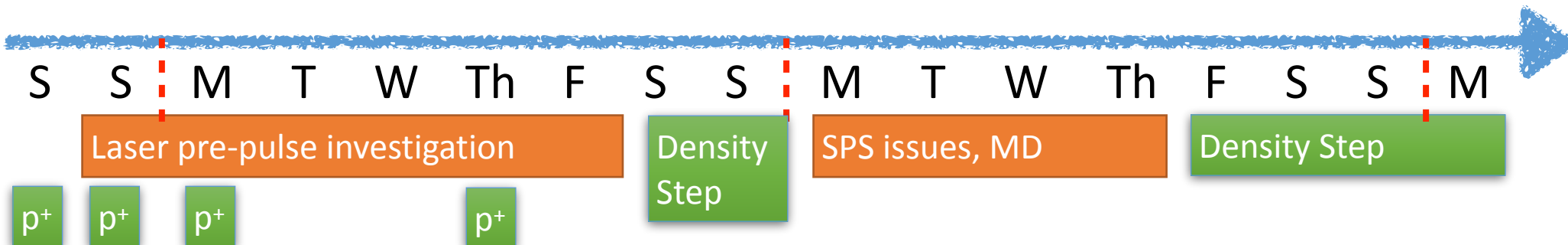
July 31 - August 13: First run with Density Step

- Vapor source filled and warming up by Friday August 4.
 - Protons in vacuum on August 3/4, first plasma on August 5
- Density-step tests starting on August 5th:
 - Begin every day with constant density to establish reference
 - Scan density step size and position
 - August 7-8: [0, 3, 6, 9] % steps at 1.25 m and 4.25 m, starting from $1.5E14/cm^3$
 - August 11-13: steps of 3% and 6% at [1.25, 2.25, 3.25, 4.25] m, starting from $3.7E14/cm^3$
- Electron + proton data for ChDR and HF BPM R&D on August 10-11
 - Parasitic: while changing temperature or at the end of the day
 - Good chance for training next generation



August 26 - September 11: Second run with Density Step

- First week spent understanding and solving a laser pedestal issue (unstable self-modulation)
 - Solved by tuning laser timing, but configuration prevented UV for photocathode (i.e.: no electrons)
- Commissioning and installation of plasma light diagnostics continued
 - Installed μs -exposure cameras (from DPS setup for plasma light)
 - Calibrated PMTs with Argon and Rb
- Starting on September 2nd, density-step studies:
 - Scan step size (%), since this showed larger effect than step position (m)
 - September 2-3: [0, 3] % steps at 1.75 m, starting from $3.7\text{E}14/\text{cm}^3$ and $6.2\text{E}14/\text{cm}^3$
 - September 7-10: [0, 1.5, 3, 3.5, 4.5, 6] % steps at 1.75 m, starting from $3.7\text{E}14/\text{cm}^3$
 - September 11: [-2, 0, 1.5] % steps at 1.75 m, starting from $6.2\text{E}14/\text{cm}^3$
 - Also scan proton-laser timing (i.e. RIF scans) and proton bunch intensity ($0.5\text{-}3\text{E}11\text{p}$)

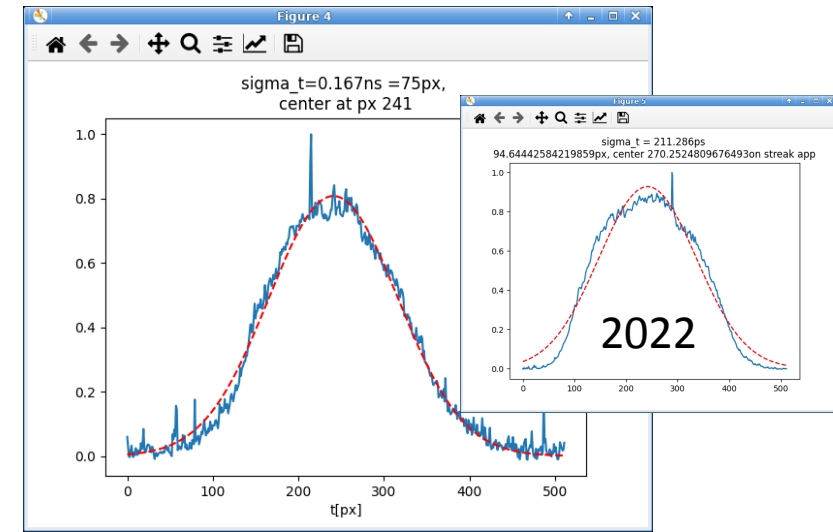


Proton Beam Performance and Issues

- Highlights from May and August runs:

- See backup and past Technical Boards for more details
- May: ~60% availability mainly due to LHC ramping up
- May: great use of narrow/wide-bunch optics, with focus at [0, 3.5] m
- August: great availability (no LHC)
- August: proton alignment moved completely to OTR screens. Very fast (<5 mins)

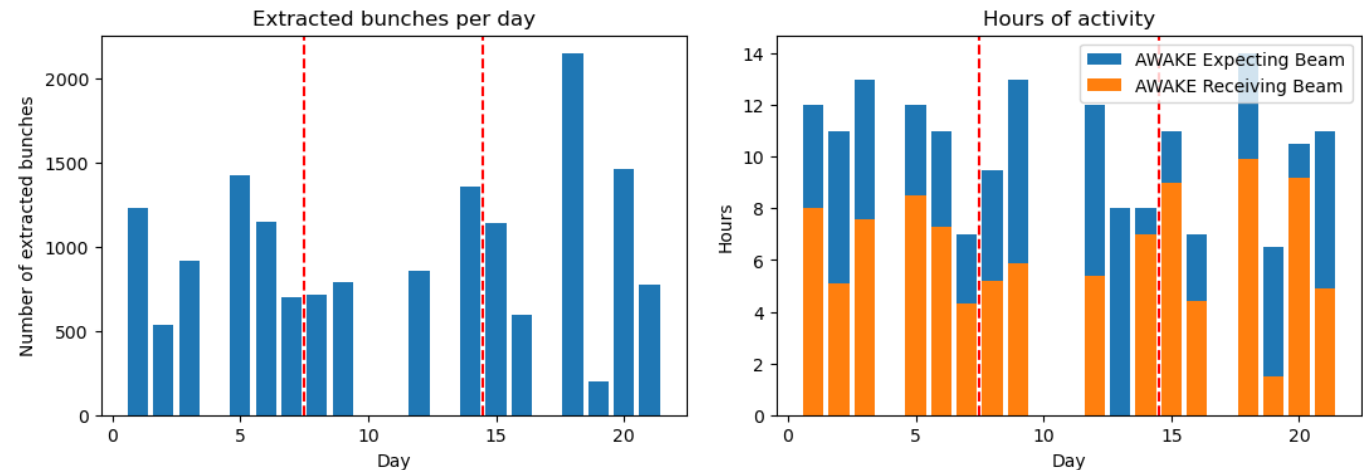
Bunch length: ~20% shorter and much more gaussian than 2022



- September run:

- 2 power supply issues on RBI.410010 (SPS-AWAKE transfer line)
- Fast Magnet Current Monitors (FMCM) for SPS septum (MSE)
- Instabilities on last Sunday/Monday: Losses during ramp and jitter in extraction time

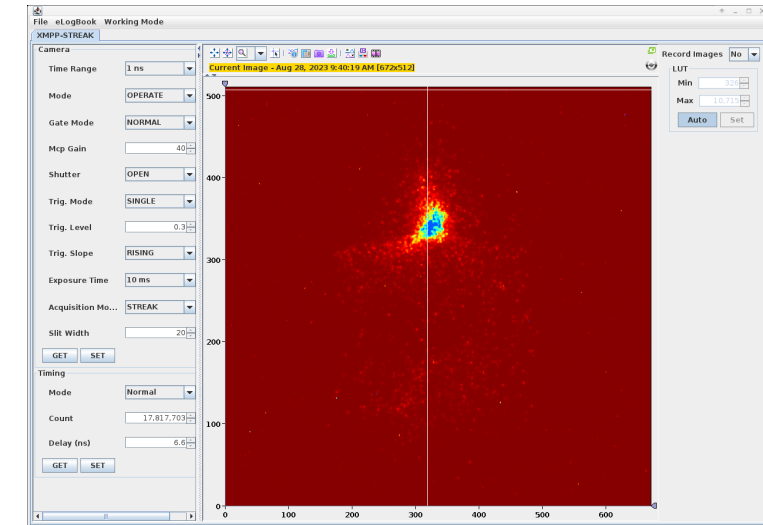
May Run: Proton Extractions and Hours of Beam



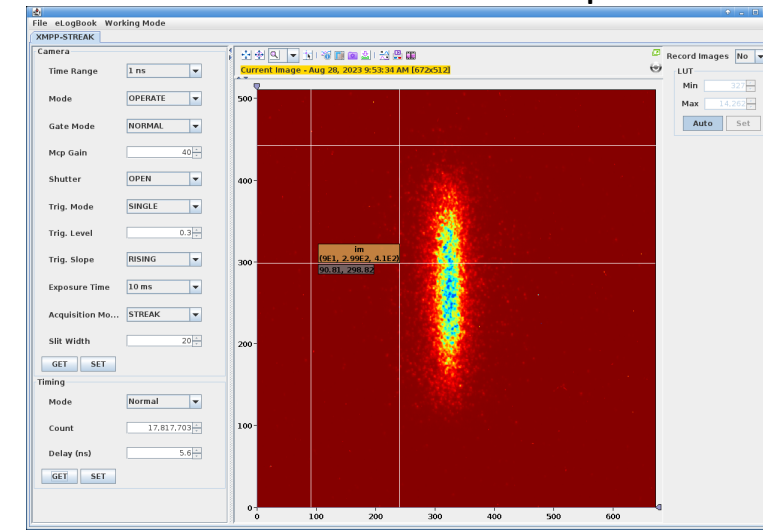
AWAKE Experiment Performance and Issues

Laser pedestal ahead of RIF

Bunch head focused/tilted



Entire bunch focused within pedestal



- Highlights from May and August runs:
 - See backup and past Technical Boards for more details
 - May: high radiation (due to DPS windows) resulted in many more remote reboots and dead PCs. Mostly remote, and occasional access
 - May: Digital camera FESA not fully commissioned: even more reboots
 - August: streak camera power supply short circuit (now replaced)
 - August: over-temperature controller (OTC) failures in Density Step vapor source
- September run:
 - Laser pedestal appeared: 1 week for investigation and (partial) solution.
 - Amplitude here today for full re-tuning
 - OTC failures in vapor source continued: ~1 per week, requiring access to resolve
 - Temperature probes in vapor source giving bad reading: masked
 - WDL here last week to solve both issues
 - Vacuum interlock due to malfunctioning gauge (replaced this Tuesday)

2023 Activities/Issues

Recent progress on the usual list

Run periods

- (laser) Align marker [and IR] on streak camera ✓
- (e) Estimate uncertainty from IN/OUT screen motion ✓
- **(e) Commission orthogonal steering with new corrector** ✓
- (p) Estimate position jitter on OTR screen ✓
- **(e) Test 4D tomography of beam** ⚠ ✓
- (e) Commission optimizer to match beamline to injector ⚠
- (e) Test cycling (vs de-gaussing) for hysteresis ✓

BTVs and Streak Camera

- **Complete commissioning of BI DAQ** ⚠ ✓ ✓ ✓
- Replace broken cameras: DMD1, 426.CORE ✓
- Move hardware IN position for CTR screen (avoid damage) ✓
- Align BTV lines ✓
- Align Downstream-to-Upstream line, marker laser line ✓
- Install OTR screen on BTV354 ✓
- Install new OTR screen at plasma exit ✓
- Improve imaging in optical line to upstream streak camera ✓
- **Estimate noise on Basler cameras before/after run** ⚠
- Install new server for additional cameras ✓

Rubidium

- Add automated warnings when Rb open

Other Instrumentation

- Fix BPM 412319 sending no data ✓
- Install additional channels to Oasis scope ✓
- Fix eBPM calibration signal
- Add proton/OTR light to DPS scope ✓
- Calibrate new BCT with pilot proton beam

Laser

- Replace Energy Meter 4 (no longer needed)
- Set up remote locking to RF ✓
- **Upgrade laser alignment**, add diode laser to virtual line ⚠
- **Reflective optics project** ⚠
- Enable LBDP2 automatic movement ✓
- Add protection for BTV 412442 in interlock ✓
- Shift delay stage in TCV4 ✓
- Repair UV line optics causing dark area in beam profile ✓
- Produce new spare cathode ✓

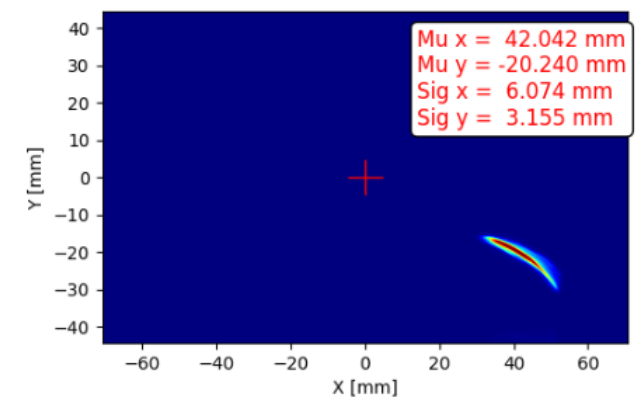
Data Acquisition / Data Quality

- Stabilize slit scan GUI for streak camera ✓
- Plasma light not recorded in 1Hz EventBuilder ✓
- Add ICT to Event Builder (check synch at 1 Hz)
- Automated frequency plot from streak camera ✓
- Check DPS+DAQ with calibration trigger ✓
- **Add PMT settings to Event Builder** ⚠

Preparation for October run

- Vapor source
 - WDL intervention for OTC and viewport probe issues: last week
 - Mu-metal installation to shield from Earth's B field: this week
 - Automated interlock to protect ExpVol screen from Rb contamination
- Plasma light
 - Re-align and calibrate existing 10 PMTs
 - Add 10 new digital cameras to capture plasma light from remaining ports
- Laser
 - Amplitude intervention to solve laser pedestal: this week
 - Trajectory drift measurements and automated warnings
- Electron beam commissioning
 - Commission "Steering 2.0": new final corrector and new degaussing procedure
 - Commission new injection optics: focus at [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10] m
 - Systematic measurements of Earth's B-field: different foci, different trajectories
 - Test effect of vapor source electrical heaters on electron trajectory

Electron beam propagated to spectrometer



Proposed program for October run

- 0. Start with diagnostics setup and beam alignment
 - Final diagnostics alignment takes place after mu-metal installation
- 0b. Complete electron commissioning in vacuum
 - Measure Earth's B field by comparing electron/proton trajectory
 - Measure effect of Heaters ON/OFF after mu-metal installation
 - Can take place in evenings, without protons/plasma
- 1. Plasma light commissioning
 - Understand differences between PMTs and Cameras
 - Measure plasma light as a function of proton bunch intensity for different configurations
- 2. Plasma light vs Density Step
 - Measure plasma light intensity without density step: expected to fall in last ~3 m
 - Find "best" density step: light intensity should be ~stable in last ~3 meters

RUN 2b GOAL

MAX-PLANCK-INSTITUT
FRIEDRICH-SCHILLER-UNIVERSITÄT
ERLANGEN-NÜRNBERG

AWAKE → WAKE →

Long term view:
◇ Demonstrate that a density step can make the wakefield amplitude constant and at high amplitude
◇ Operate with a density step
◇ Demonstrate that the amplitude of the wakefields is constant over the last x-meters of the plasma
◇ Demonstrate that the energy gain per meter of plasma by test electrons is constant over the last ...
◇ ...

Run 2b

© P. Muggli
P. Muggli, Collab. Meet. 10/04/2023

- 3. Demonstrate trajectory control with Electrons in Plasma
 - Set up for on-axis injection, then off-axis at 0, 1, 2 m
 - Measure light from electron-seeding: simulation predicts pinching in O(10) cm, wakefields for ~2 m
 - Use plasma light to demonstrate that electrons cross the plasma at known position: controlled injection
- 4. Electron acceleration
 - Pre-requisite (already shown with density gradient): demonstrate increased acceleration with density step
 - New-physics goal: demonstrate stable wakefields in last few meters, injecting at different positions, or with different hardware setup
- **We will see how far we get in the October run**

Next Steps

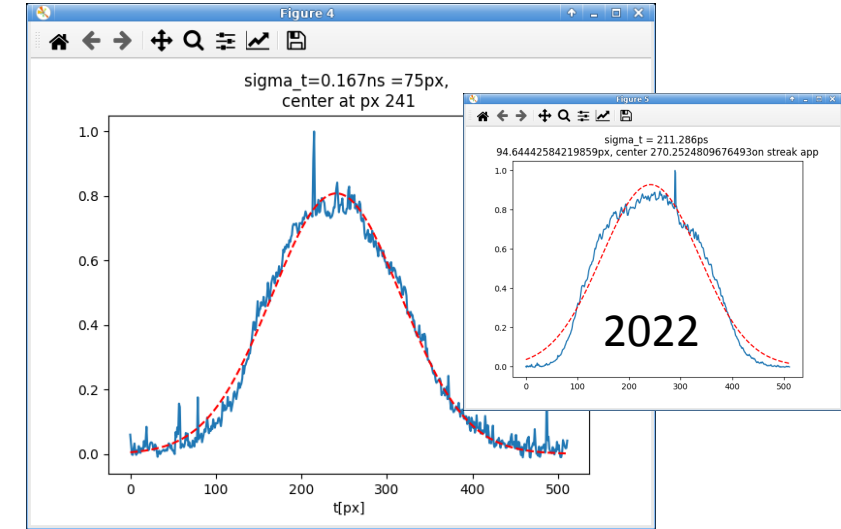
- Data-taking after the October run
 - Electron beam still possible for 1 week
 - Laser/Plasma experiments (with Wigner team) for 3 weeks
 - No more beams after November 17: YETS
- Restart laser and electrons in early 2024
 - Schedule still in flux. First proton beam expected in April 2024

Backup

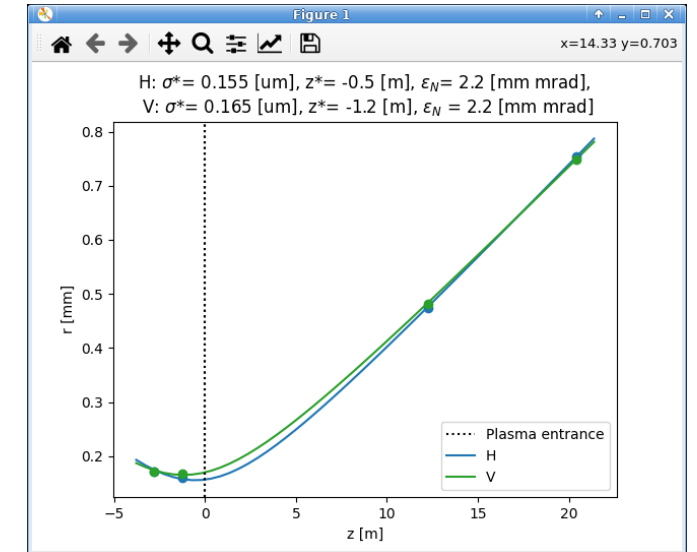
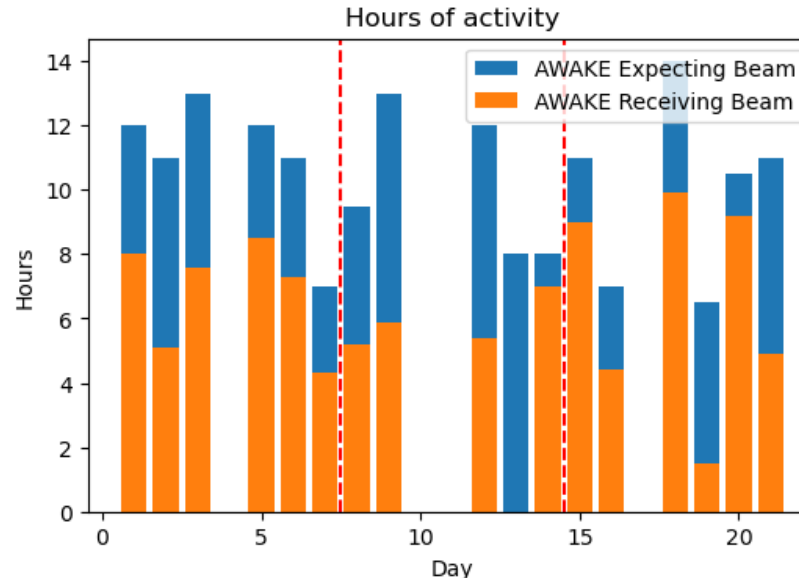
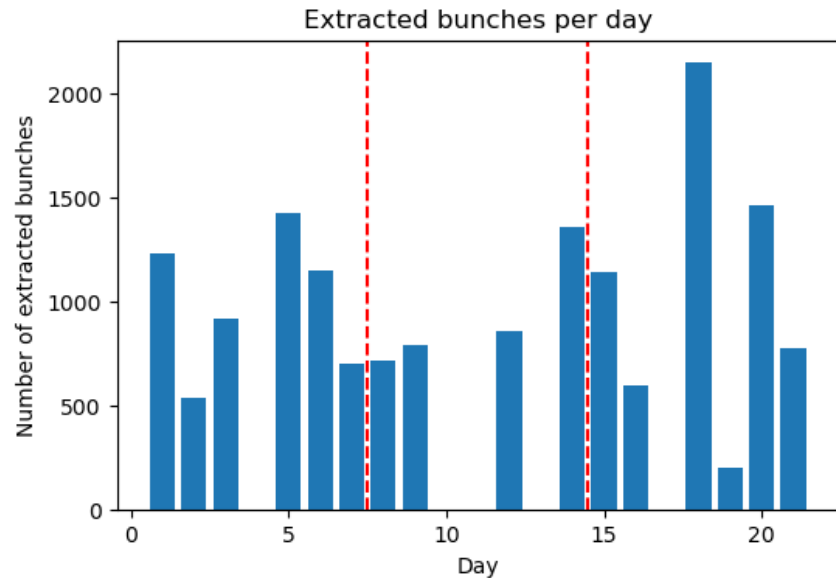
May run: Proton beam

- Proton bunch is shorter and more gaussian bunch than in 2022
- Beam almost every day, with large variations mainly due to LHC
 - Extractions per day (>0): 1000 ± 450
 - Hours per day: 10 ± 2 expecting beam, 6 ± 3 receiving beam
 - Availability: $57\% \pm 22\%$
- Narrow and wide-bunch optics, with focus at 0 m and 3.5 m
- Coped with unstable p⁺ beam thanks to simplified AWAKE setup (no laser, no e-)
 - LHC intensity still ramping up. Expect more stable conditions in Summer

Bunch length: ~20% shorter and much more gaussian than 2022



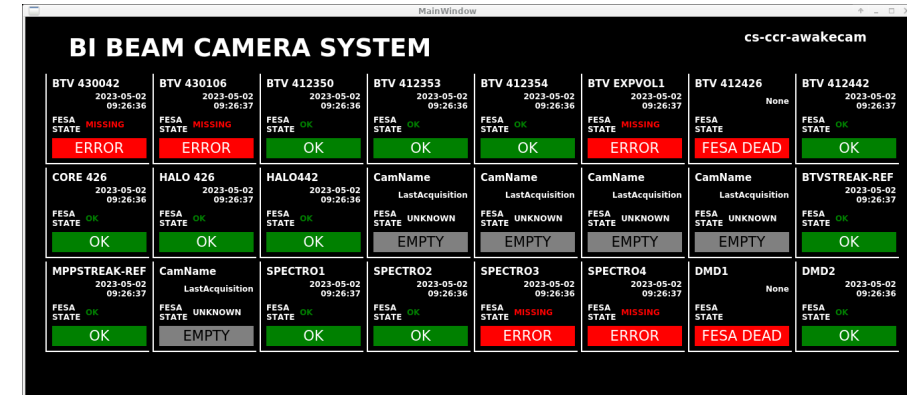
AWAKE emittance measurement (SPS wire scanners broken)



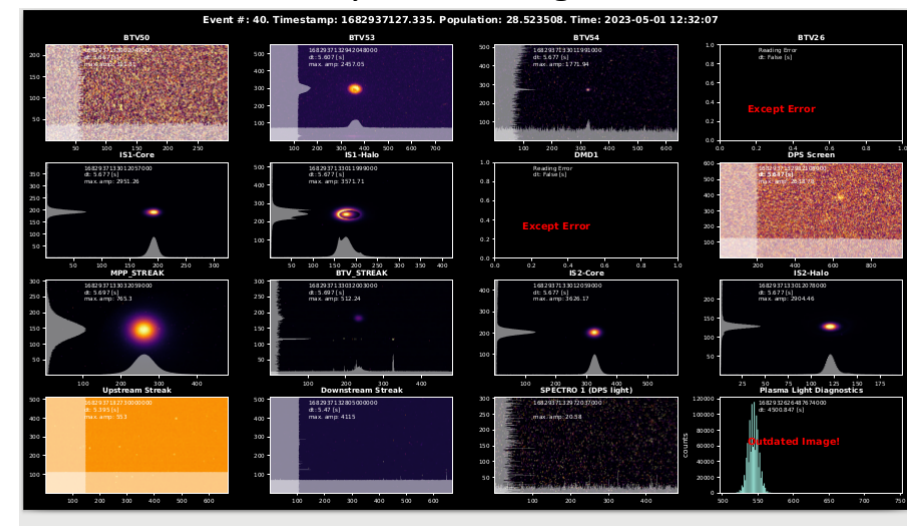
May run: Issues and accesses

- A couple of issues per week requiring access. Almost always planned on previous day
 - Also several remote reboots needed to crates and PC in TCC4
- Week 1
 - Digital camera FESA very unstable at beginning of run
 - Software fix solved overall issue (switched off AutomaticSynching)
 - Residual issues required O(10) manual resets per day
 - Two cameras (DMD1, BTV426) never fully functioning, even after replacements —> Possible causes: position/radiation/cabling
 - DPS power supply fuse broke when settings went beyond specs: replaced with spare
- Week 2
 - TCC4 PC connected to fast cameras died, replaced with spare PC
 - BTV filter detached, re-attached
- Week 3
 - Network reboot system for streak camera PCs stopped working, reconfigured
 - Access System team intervention required a new patrol

Digital Cameras Live Monitoring



Data Quality Monitoring on Event Files



August run: Proton beam

- In general: no LHC, few injector issues, reliable beam quality
 - Almost always had beam when we wanted it
 - Between 5 and 10 hours of data taking (allow time for density-step changes)
- Two notable exceptions:
 - First day (Thursday): AWAKE-SPS timing issue was preventing extraction: tracked down by Ben Woolley to new PLL board in AWAKE. Solved.
 - Second Thursday: Difficult beam conditions. Observed unexpected changes in proton bunch length (tracked down to SPS 800 MHz cavity being off) and bunch size (tracked to PS). Both solved by the end of the day.
- Update on alignments
 - Proton alignment moved completely to OTR screens, thanks to modified BTV54 and CTR setup. Very fast (<5 mins)
 - Laser alignment uses 2022 procedures, usually fast (<10 minutes) but twice took ~1 hour
 - Improvement in place for upcoming run: better centering on virtual line and streamlined fitting code

	M	T	W	Th	F	S	S	M	T	W	Th	F	S	S
SPS extractions				589	429	832	1272	749	870		1468	722	1286	1185
Hours of beam to AWAKE				4.5	2.7	5.2	7.8	4.6	6.3		9.0 (*)	5.2	8.0	7.3
Hours with no beam (**)				0	0.2	0	0	4.6	4.5		1.3	0.2	1.3	1.0

(**) “No beam” mainly due to AWAKE requests to stop beam during density-step changes

August run: Issues and accesses

- Few issues requiring access, always managed with RP or RPE help
- Week 1
 - SPS-AWAKE timing issue (see previous slide)
 - XMPP and YMPP Streak cameras and PCs died (entire power strip)
 - Tracked down to a power supply. Replaced with the one from Upstream Streak, which was then kept off. Spare has now arrived and been connected
 - Plasma light PMT trigger disconnected → Connected
- Week 2
 - Plasma light PMT filters added during Wednesday beam stop
 - Vapor source viewport heater shut down in the night, causing entire vapor source to cool down for safety. Tracked down to an over-temperature (OTC) controller. Solved within a day.
 - WDL team arrived yesterday at CERN to understand this issue and prevent future problems, since the system uses many OTC's
 - Laser Beam Dump 2 (LBDP2) often gets stuck while going IN/OUT. Likely a hardware issue, will need a replacement. Designed at MPP, need to find drawings and produce new parts. Potentially swap LBDP2-LBDP3 for short term if it becomes permanently stuck