

New, proposed and still missing diagnostics

A. Topaloudis on behalf of SY-BI

Many thanks to:

- The (too many to list) BI colleagues
- All groups for feedback and support
- The conveners of the workshop preparation

Outline

Across Machines and General Items

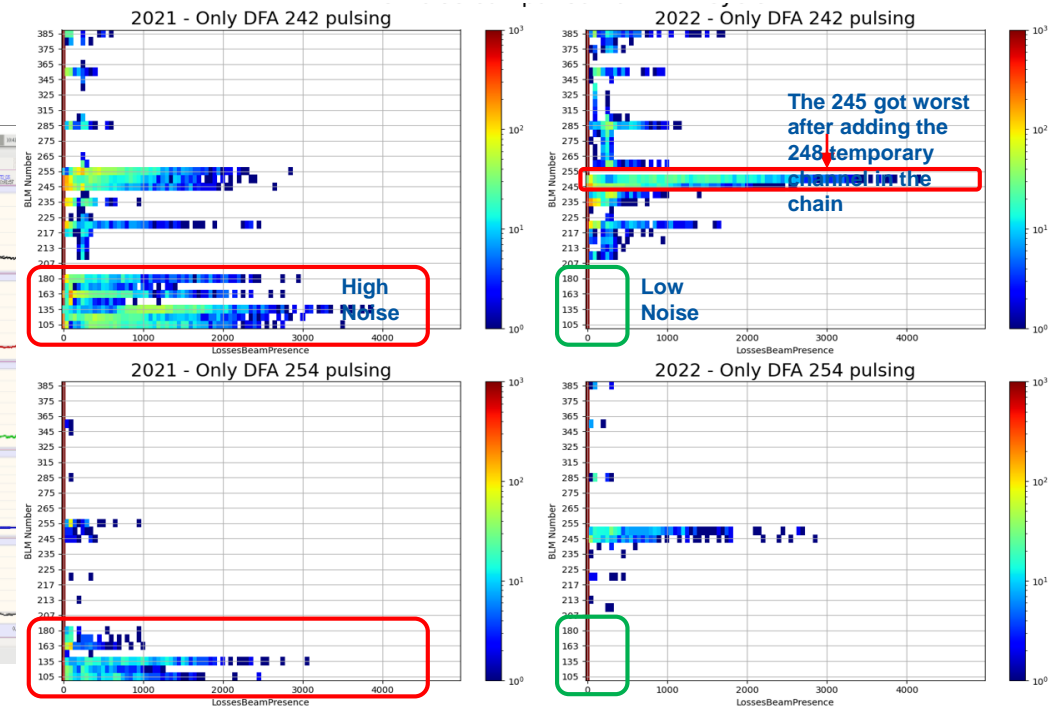
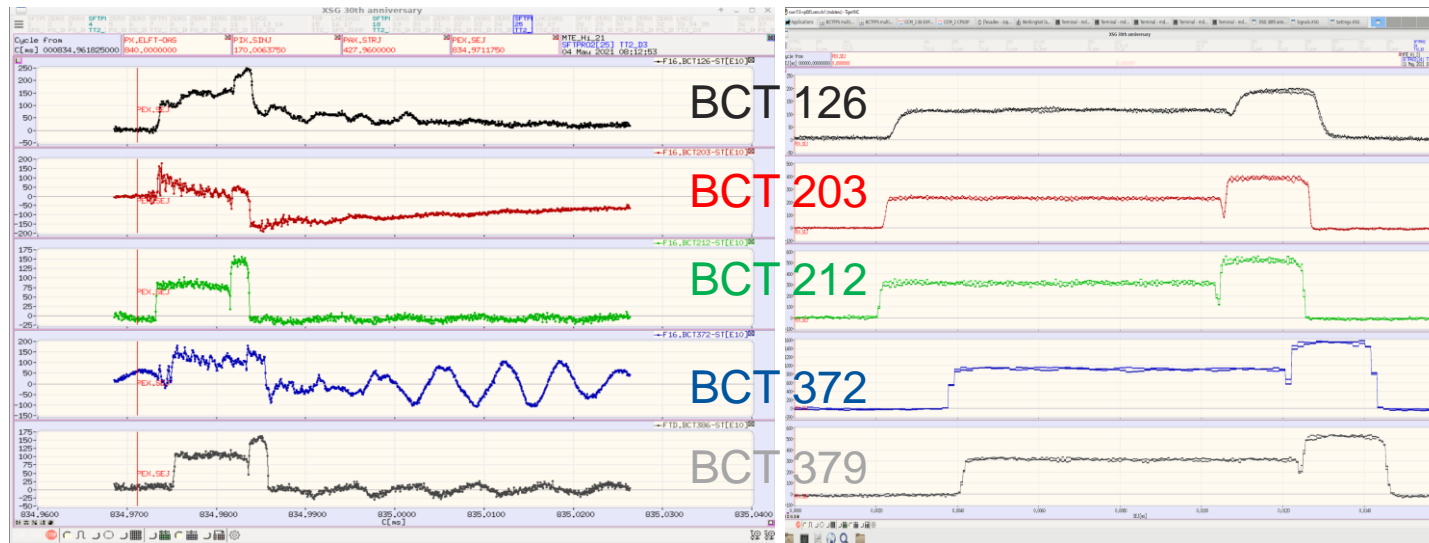
EMI and NOISE
Injectors BWS
Injectors fast BCTs

Machine Specific Items

LEIR
PSB
PS
Transfer lines
AD – ELENA
EA
SPS - NA
LHC

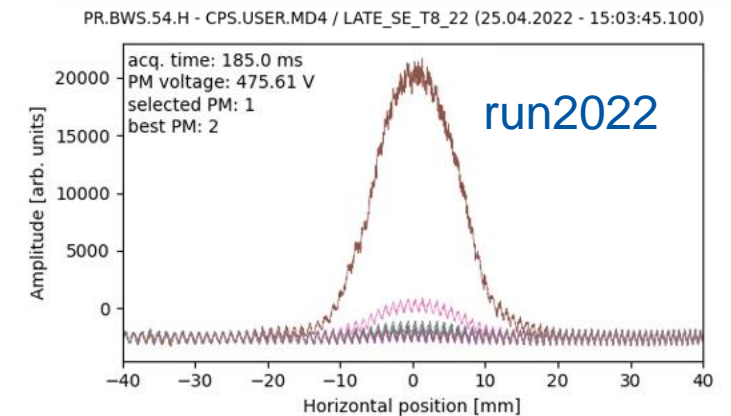
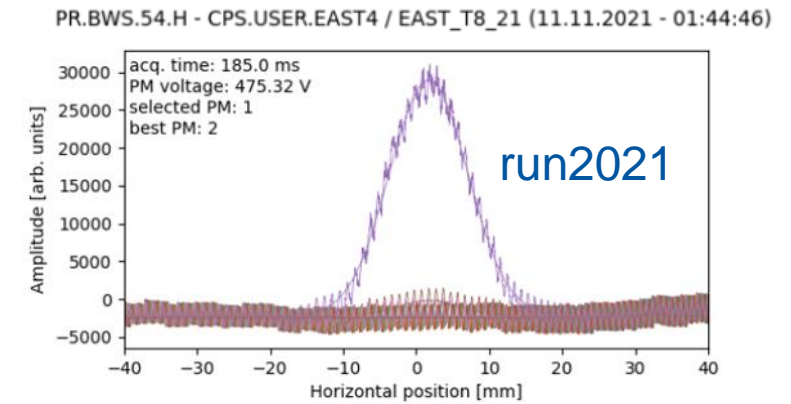
EMI and noise

- BLM: stable situation, no action pending (see [this presentation](#))
 - TT2 & TT10, recabling, shielding & ferrite addition
- BCT: stable situation, no action pending (see [this presentation](#))
 - TT2, new amplifier, better coax cables



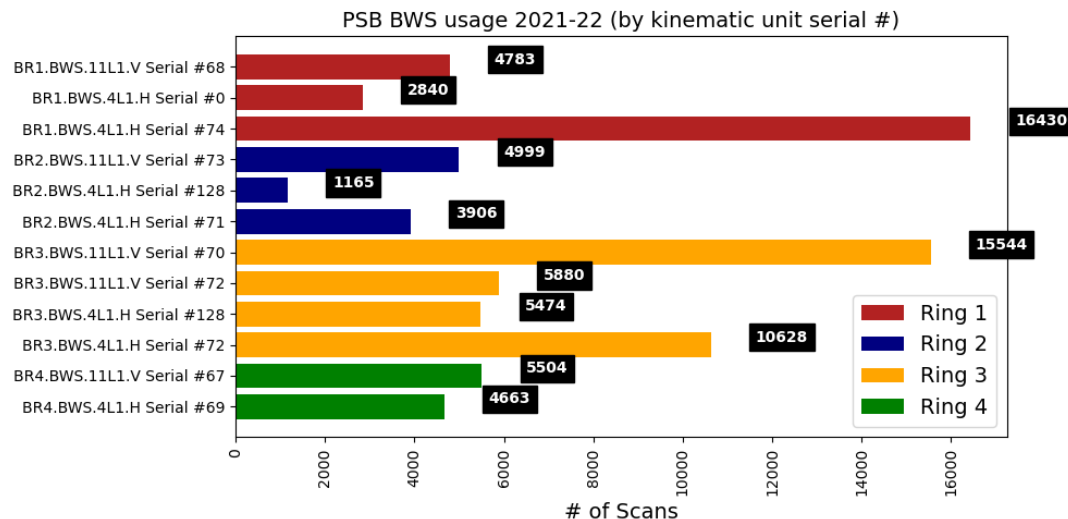
EMI and noise

- H0-H- noise problems mitigated in 2022.
 - OP feedback is positive == system ~reliable to track stripping efficiency and to re-adjust the injection position/angle
 - Plans for improvements (e.g. to better suppress pickup signal from circulating beam)
- BWS: stable situation, reduction of perturbations in the PS for the run2022 (see [this presentation](#))

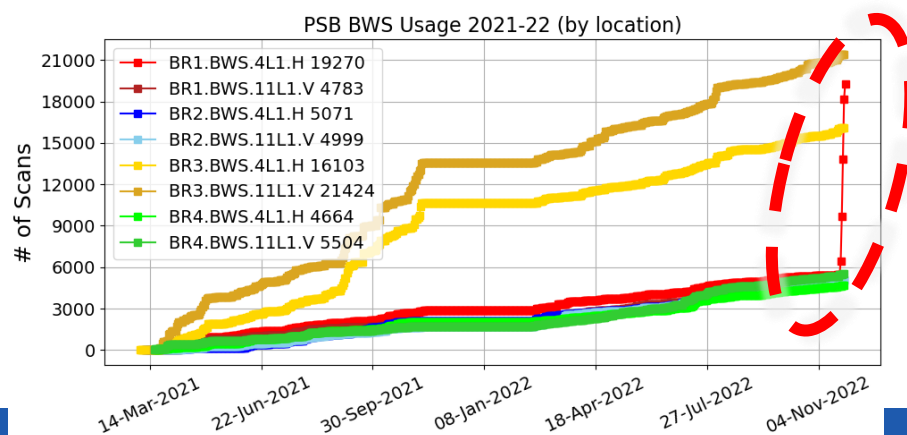


PS OP tool figures of 54H (A. Huschauer)

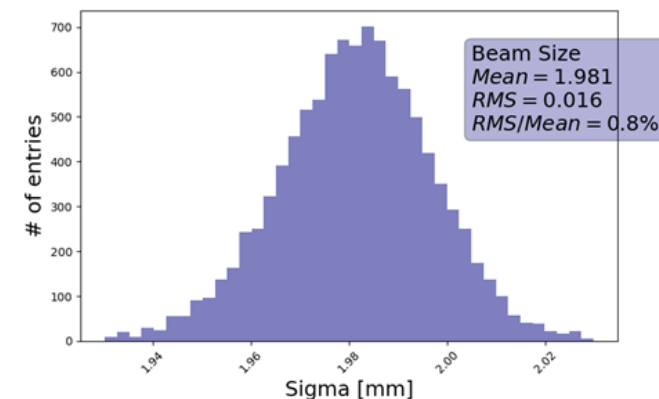
Injectors BWS



- 17 new scanners operational after LS2
- 125 kScans performed in 2 years, 1 wire broken + few issues
 - Baseline noise in PS (see previous slide)
 - ~all commissioning hiccups of 2021 fixed in 2022
- Missing features (ready, will be tested start of 2023)
 - Lower speed, multiple scans in a cycle, SPS automatic protection vs intensity/energy)
- YETS 22/23: change 1 scanner per machine
 - PSB R1H (inspection of fatigue test)
 - PS H65 (preventive maintenance, optical disk quality)
 - SPS 41678 (preventive maintenance, suspected friction)



- End of the run 2022: 14k scans in 3 days on R1 Horizontal
- Proved **system reliability** and **beam reproducibility**

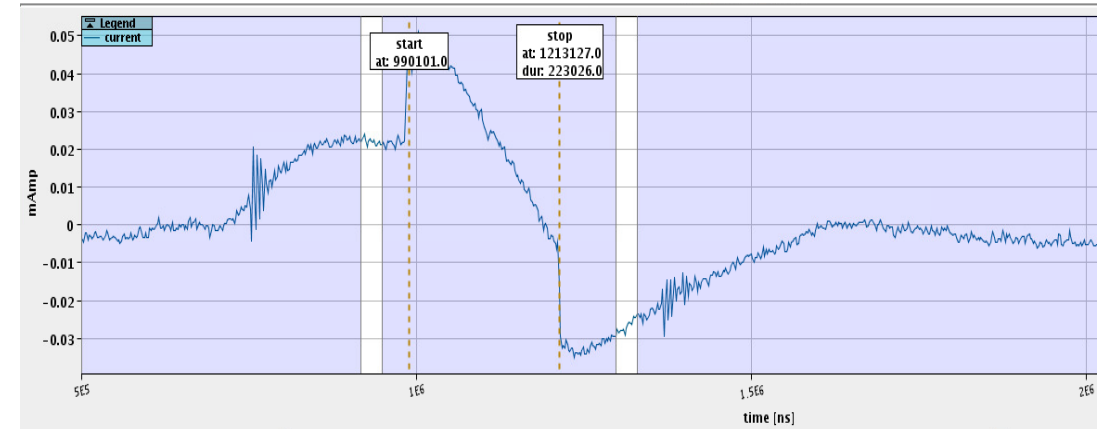


Average distribution of 10K out scans

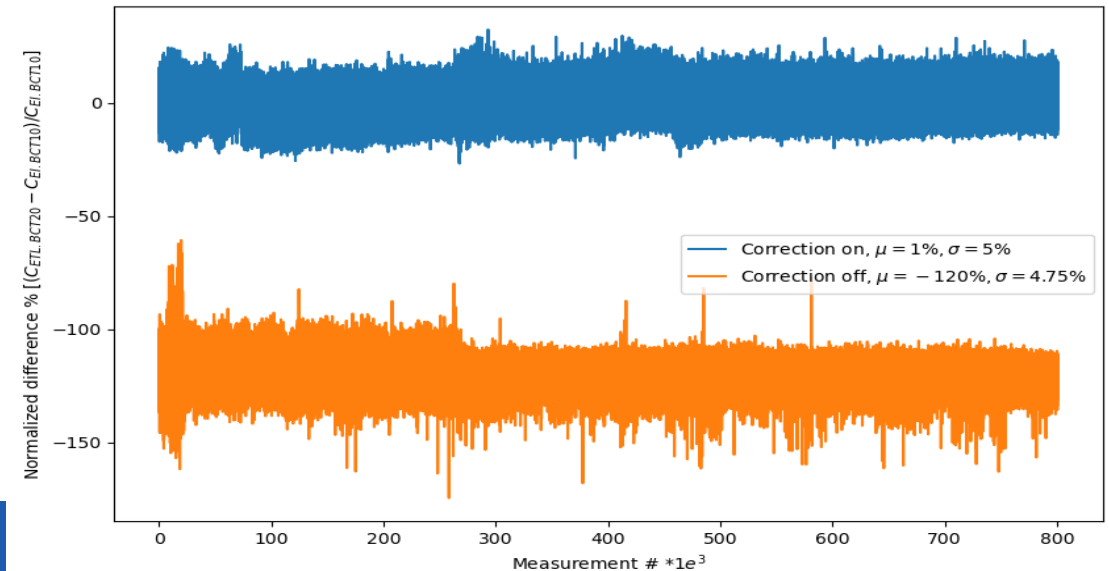
Injectors fast BCTs

- **Renovation of the fBCT acquisition electronics in the PS complex (EDMS No 2787895)** – pending consolidation project
- Measurement improvement on BCTs with linear or close to linear baseline instabilities
- Already tested in LEIR (mean difference between ETL.BCT20 and EI.BCT10):
 - Before correction: ~ -120%
 - After correction: ~1%
- Will be deployed more widely this YETS 22/23
- For more info, see this presentation

Intensity measurement with ETL.BCT20

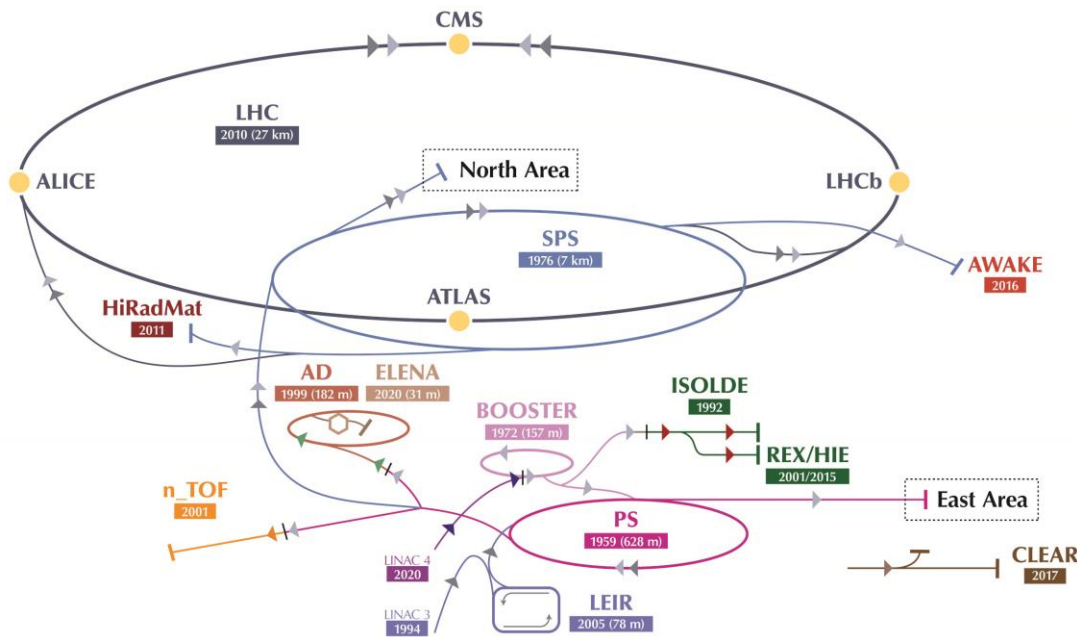


Normalized intensity measurement difference (ETL.BCT20 - EI.BCT10)



Machine Specific Items

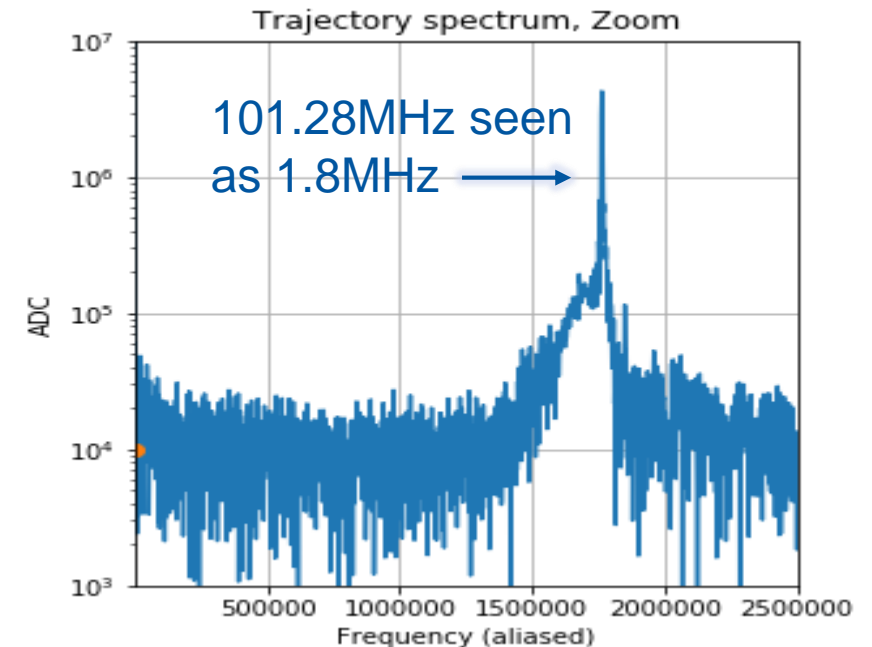
- LEIR
- PSB
- PS
- Transfer lines
- AD – ELENA
- EA
- SPS – NA
- LHC



SY-BI everywhere...

LEIR

- LEIR first turn measurement status – see [this presentation](#)
 - MD during 2022
 - Prototype production/test 2023
 - Installation EYETS 23/24
- Commission a new measurement correction algorithm on ETL.BCT20 and EI.BCT10



PSB

- 2 BPMs at BWS R1 for b function – YETS 22/23
- Problem with last BPMs in BI line
 - They don't work with de-bunched beam
 - Work in progress: Prototype able to measure position – *still missing a way to combine the bunched/de-bunched way of measuring*
 - Low priority since workaround exists by OP/ABT
- PSB ring 1 stripping efficiency increase as a comparative measurement
 - Malfunctioning cable/connection was changed in last YETS 21/22
 - DCBCT was not recalibrated, and stripping efficiency increased by 1%
 - Calibration during YETS 22/23 to verify if this is the source of the issue
- BTY grids refurbishment: ongoing, change planned for EYETS 23/24

PS

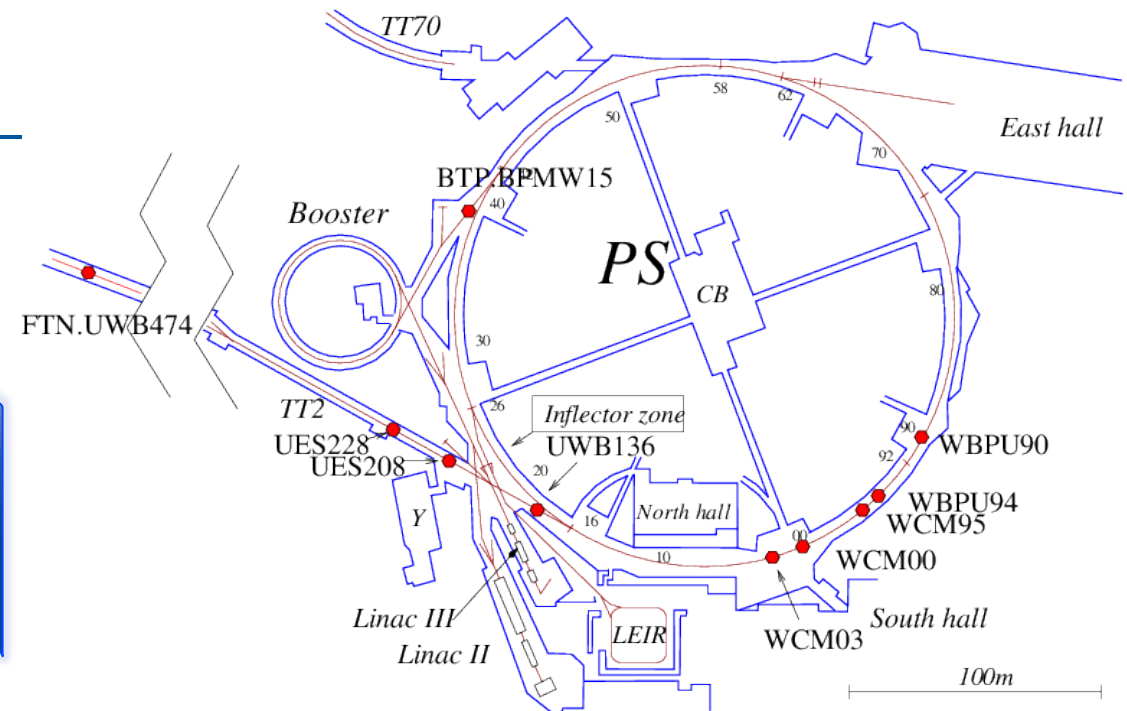
- New WCM98 during this YETS 22/23
- New request for bunch-by-bunch intensity measurement in the ring
 - to be included as a new spec for the current cons-request
- New BGI:
 - BGI-Horizontal (PR.BGI82) is fully operational – including bunch-by-bunch beam profiles
 - BGI-Vertical (PR.BGI84) had 2 issues

An extended BWS/BGI benchmarking campaign is needed in 2023 among BI, OP, ...

During 2022:

BGI-H: 2,049,174 profiles from 26,520 beam cycles

BGI-V: 488,076 profiles from 8,659 beam cycles

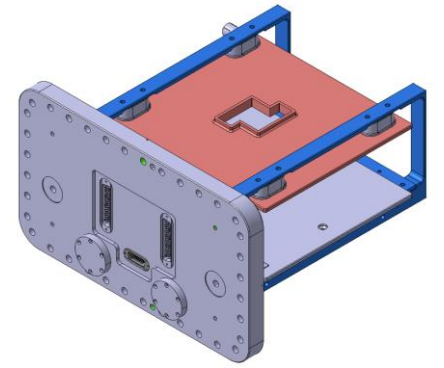


PS BGI

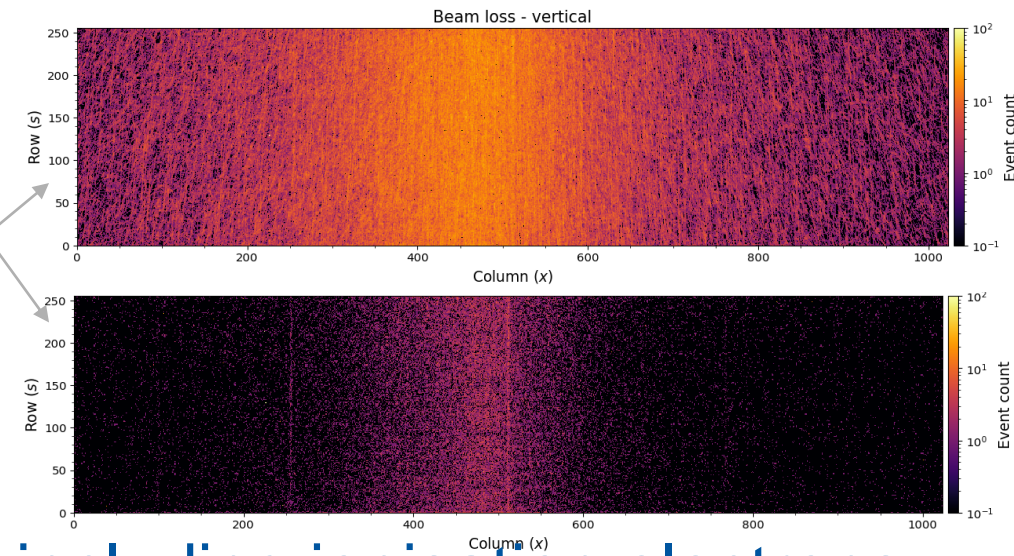
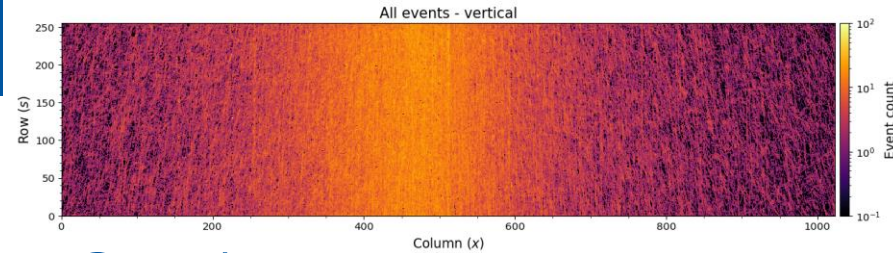
BGI-Vertical (PR.BGI84)

Problem #1) Beam position dependence

- Ionisation electrons are not detected when the beam position in the horizontal plane is close to the electron detector (located on the inside of the ring).
- Explanation = electron's don't gain enough kinetic energy from the field cage to be detected in the Timepix3 Hybrid Pixel Detector (min. detection energy = 2keV)
- Solution = increase the cathode high voltage from -23kV to -30kV. Requires upgrade to external high voltage components, which will be implemented during YETS 22/23.



PS BGI



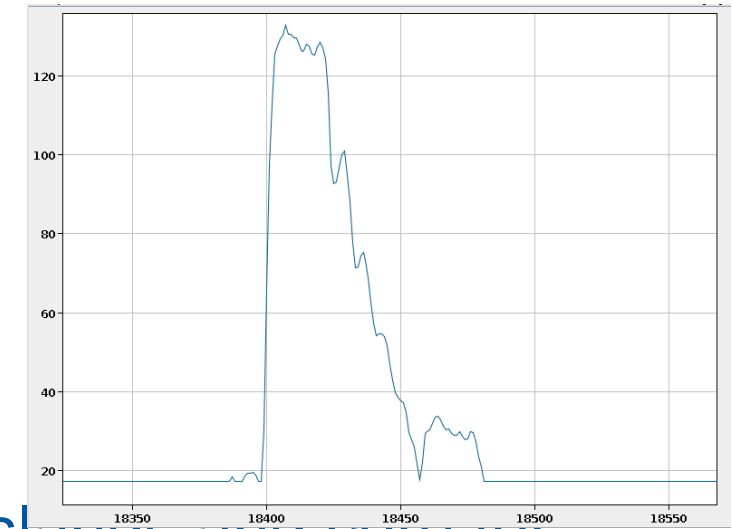
BGI-Vertical (PR.BGI84)

Problem #2) Beam loss:

- Timepix3-HPD detects all charged particles, including ionisation electrons, as well as the charged particles resulting from beam loss.
- (A) solution = Apply cluster finding algorithm and selection criteria to separate the ionisation electrons from the beam loss background e.g.
- Only possible offline (operation takes 10s of seconds)
 - However, if the beam loss $> \sim 10^7$ particles per second, the detector will saturate and no useful data can be recorded (i.e. instrument is not useable.)
- (B) reduce the beam loss at SS84 to avoid detector saturation and activation of the instrument (2 mSv/hr. at the instrument flange.)

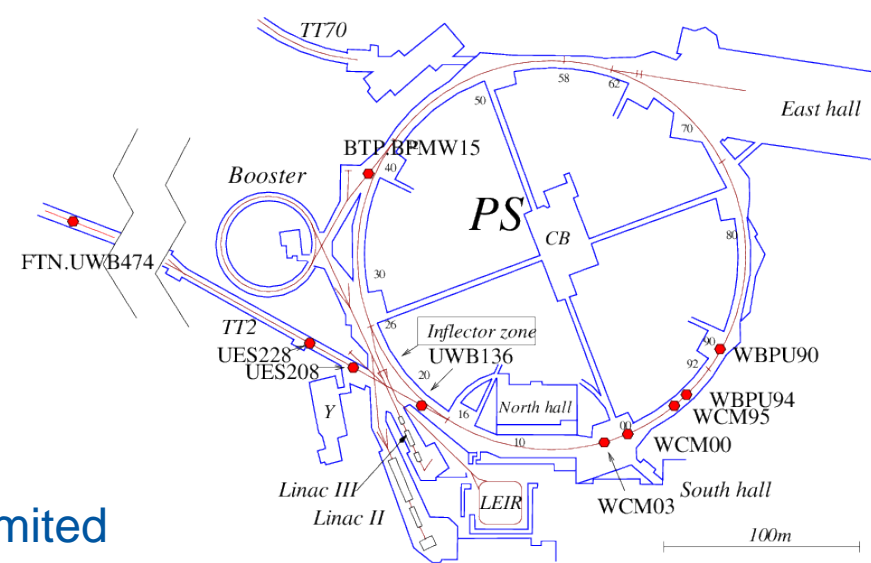
Transfer Lines

- Trajectory measurement renovation:
 - Old electronics, limited spares
 - TT10 – ALPS installation during YETS 22/23
 - FW/SW renovation needed if monitoring of the islands and core for the PS multi turn extraction is a requirement
 - TT2 – ALPS installation during 2023
 - additional filter design finalized in November, ongoing filter production
 - FW/SW renovation during YETS 22/23 or 2023
- Need to review the request of instrumentation in FTA and FTN
- Double extraction in the same cycle for nToF
 - Acquisition triggers changes in all instruments during this YETS 22/23



Transfer Lines

- TT2 WCMs
 - F16.UWB136 installed, but no cable exists
 - New cables during YETS 22/23
 - FTN.UWB474 installed with 462m cable -> bandwidth heavily limited
 - New (better and hopefully much shorter) cables during next EYETS 23/24



Functional Specification EDMS document
(under preparation): 2788492

- TT2 WBPU
 - UES208, UES228 measure only low intensity beams (SFTPRO), saturate for AD and nToF beams

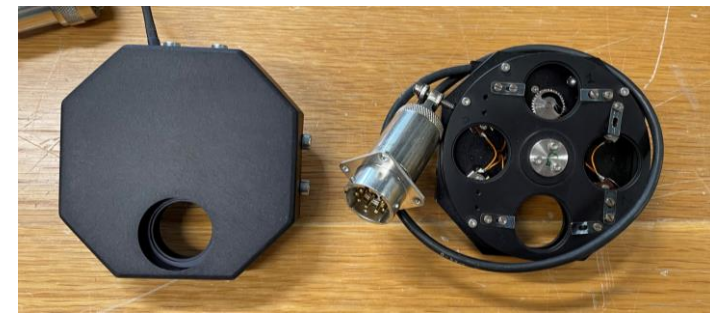
Proposal:

- UES208: Position for high intensity beams (AD, N_TOF) – under discussion (BI, OP)
- UES228: Position for low intensity (SFTPRO) – No change

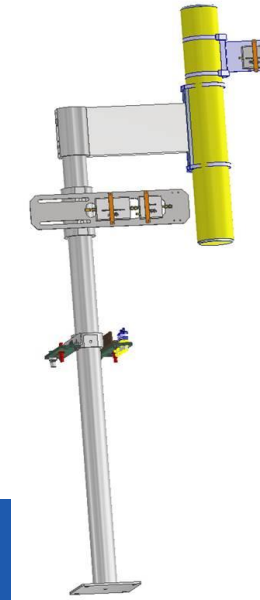
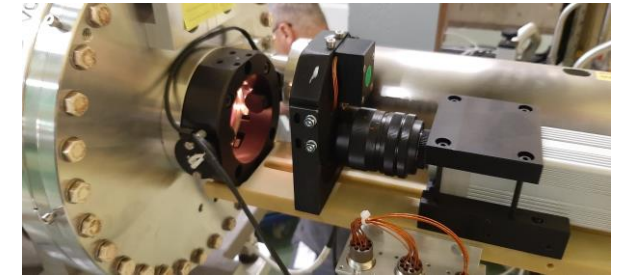
- Review of instrumentation in AD injection line (DI)
- IPM – Horizontal (transverse profile) in AD not working
 - Investigate with radiography during this YETS 22/23
 - removing/re-installing the device not before EYETS 23/24
- Issue with BCCCA during 2022
 - expert's investigation/maintenance during this YETS 22/23 in collaboration with manufacturer and other institutes (GSI & Magnicon)
- New intensity measurement in ELENA ring presented at IBIC'22
 - Challenging measurement ($\lesssim 0.5\mu\text{A}$) for traditional transformers
 - Ongoing studies to improve absolute calibration accuracy
- Accurate intensity measurement in ELENA ejection lines: joint effort among RF (PU), BI (DAQ), OP
- On going work to internalize the production of future SEM grids for ELENA transfer lines

East Area

- BTV filters
 - 2 filter wheels already used in 2022, will complete installation (additional 4) during this YETS 22/23
- Cross-calibration of T08.XSECs with Al-foil and BCT
 - useful calibration sets in 2022, thanks to IRRAD colleagues
 - details in spare slide
- T10 line : issues with Cherenkov Threshold (XCET) performance
 - Several actions taken. Investigations will continue during this YETS 22/23
- BLMs YETS 22/23:
 - 4 additional new IC channels to cover blind spots and help steer the line better
 - Moving the 2 channels from CHARM (currently in a legacy BLM system) to the common EA crate.
 - Adding a new dBLM at the beginning of the line to monitor the spill quality



BTV filter wheels

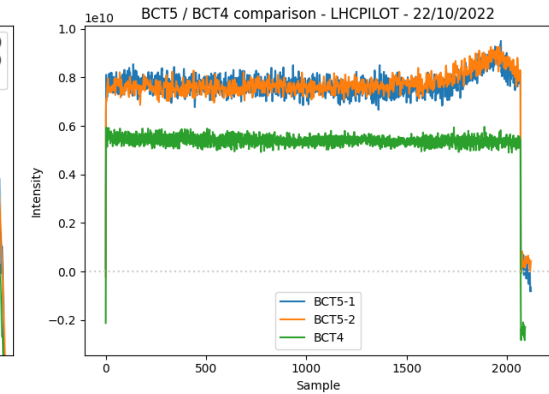
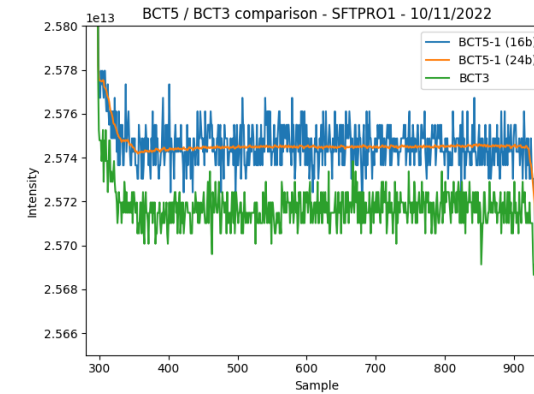


3D drawing of the support that hosts both an IC and a dBLM detector

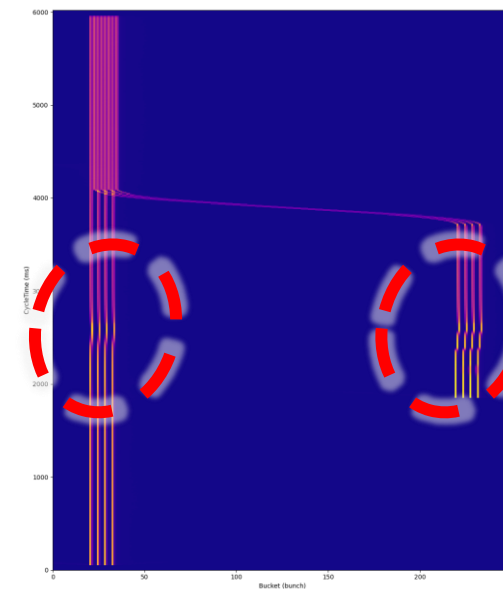
- ALPS – trajectory interlock still not operational. Dedicated tests during beam commissioning
- Continuous emittance measurement throughout the cycle
 - BWS
 - during MD end of the run , scanned at 450 GeV $\sim 4.4e13p$ (theoretical -conservative' limit $\sim 3.2e13p$)
 - Wire not broken, will be inspected during this YETS 22/23
 - still need to check precise emittance and wire speed during the test
 - BSRT
 - System operational (only at flat-top) but not really used!
 - Limitations due to high radiation of the dump and large horizontal dispersion
 - new BSRT tank installed at low dispersion location —> all the rest on hold (optics, camera etc)
 - SPS BGI's:
 - CONS project in progress to deliver new Timepix3-based BGI's for the SPS (BGI-Horizontal at 51634 & BGI-Vertical at 51694).
 - On track for installation during EYETS 23/24

SPS Intensity

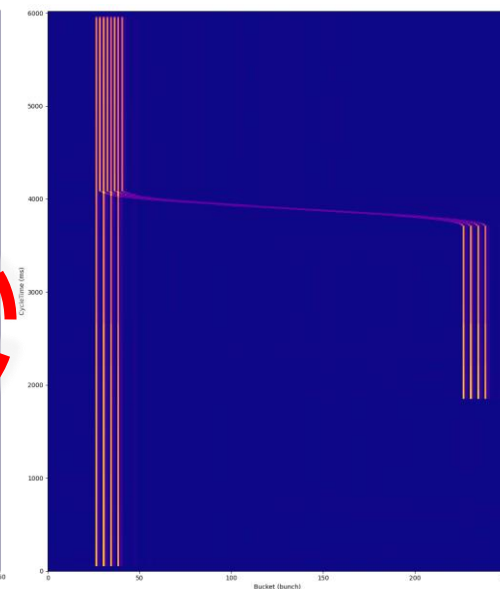
- New 24-bit acquisition system installed for SPS DC-BCTs in BA5 including dl/dt and direct SMP transmission
 - FESA class under development for deployment in 2023
- Issues with FBCT during ion operation as bunch positions not stable during acceleration
 - added a WR2RF to generate delay compensated clocks for the BCTFR.31450 (SY-RF and BE-CEM) during 2022
 - Will be installed in BCTW.31931 during this YETS 22/23



BCTW.31931 w/ BST



BCTFR.31450 w/ WR2RF



SPS NA

- **NA CONS:** SY-BI received a func. specs update (e.g.: >> # of beam size monitors and TBIU/Ds cons)
 - SEM as baseline technology. Will study special version of BGI (R&D) as a noninvasive measurement
 - **Reviewed plan at NA CONS C&S review end of January**
- **Beam intensity monitors (BSI) calibration** via ‘activation method’ (thanks to BE-EA and HSE-RP):
 - T10 only in 2022, Preliminary results ~confirm present calibration. Surely to be resurrected as ‘systematic’ measurement at all target station locations. Follow up at **ECN3 TF and BE-EA tech meetings**
- **Fast spill monitor studies**
 - OTR-PMT system: aim at operationally meas 50-100 Hz (and test Feed Forward to power converters as complementary meas to SERVO-spill BSI) and 200 MHz in 2023.
 - 800MHz and > GHz (for PBC) beam intensity harmonics == detectors and electronics R&D

Fast Spill Monitor Studies for the SPS Fixed Target Beams @ IBIC 22

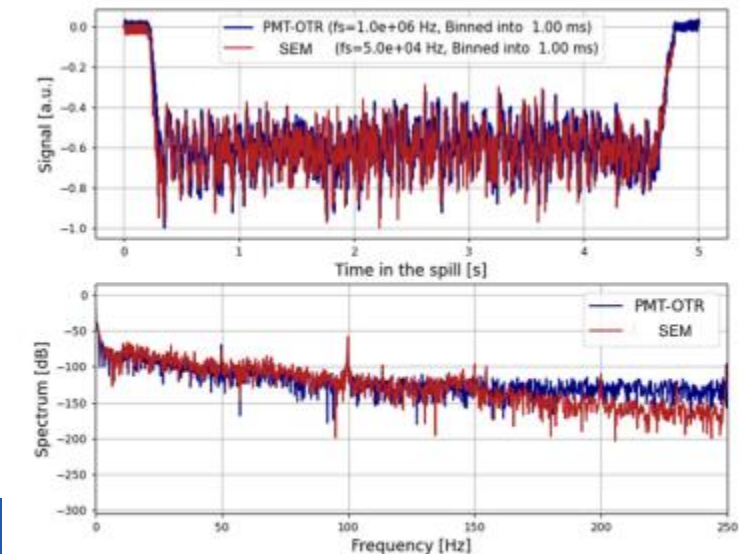


Figure 5: SEM and OTR-PMT detectors comparison in time and (low) frequency domain.

SPS NA beam instrumentation

- YETS 22/23:
 - **Servo spill BSI** has been noisy. New detector ready and exchange is in the schedule (we thank TE-VSC for their support)
 - **Within ECN3 TF:** Anticipated (w.r.t. NA cons) 3 new BSG and added 14 BLMs (<https://edms.cern.ch/document/2777729>) to P42 line
 - Installing test tank with sample tungsten and carbon wires as alternative to BSG Titanium bands
- Remaining plan & detector numbers needed to extend to the rest of the lines around ECN3 to be defined
- LS3: consolidate BLM at TDC2 (kapton cables, support with robotic interventions)
- LS3: oBLM system at TDC2; currently one instance for development at TT20



Servo spill BSI

LHC

- **BBQ saturation**

- Signal saturation due to the increased bunch intensity
- Few options how to fix it → trade off with sensitivity
- Not obvious which is the best

- **New di/dt**

- Two redundant systems per beam were optimized/tested during the 2022 run
- A version tested at the end of the run fulfils all the system requirements and this version will be fully deployed for the system commissioning during the 2023 startup

- **DOROS BPMs**

- During 2022 we have seen a few cases of DOROS front ends in the IPs affected by radiation. This should be mitigated with redundant front ends.
- Redundant front-ends are already installed in P1 and they will be installed also in for the Q1s of P5 during this YETS 22/23
- A new UCAP node is being developed with OP to consider the redundant pairs of points 1 & 5
- Also, few other issues (e.g. gain lock during VdM scans, commands for time constant optimization) will also be fixed during this YETS 22/23



LHC

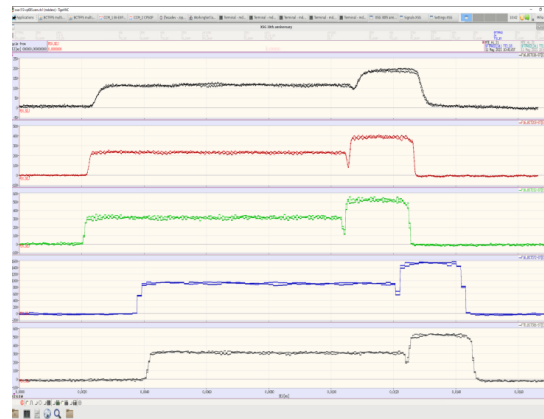
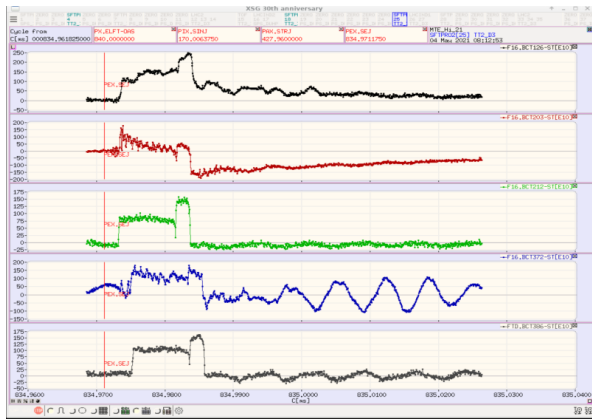
- Request for **halo monitoring** (transverse tails):
 - coronagraph is not expected to fulfil initial requirements according to latest simulations, to be confirmed after prototype tests during 2023
 - new BWS successfully used in injectors via ‘PMTs in saturation’ —> method will be available with CONS LHC scanners (tests in Run3, installation LS3). However will not full fill HL-LHC specs in term of contrast
 - alternative or complementary methods to be defined
- Reliable **emittance** measurement through the cycle
 - Currently, the only instruments are the BWS and BSRT
 - BWS: legacy systems limited in accuracy and reliability; CONS program ongoing
 - As of 2022, 2 BWS H spares refurbished as new system prototypes
 - BSRT: can’t measure during the ramp. Reliable relative measurements (incl. bunch per bunch), limited absolute accuracy, especially flat top, needs periodic cross calibration w.r.t. BWS
 - BSRT B2H large fluctuations observed in 2022 traced back to bad quality optical filter. Being changed during this YETS 22/23
 - HL-LHC BGV/BGI review committee (Oct 2022) recommends that the BGI should be the HL-LHC profile baseline

Thank you for your attention!

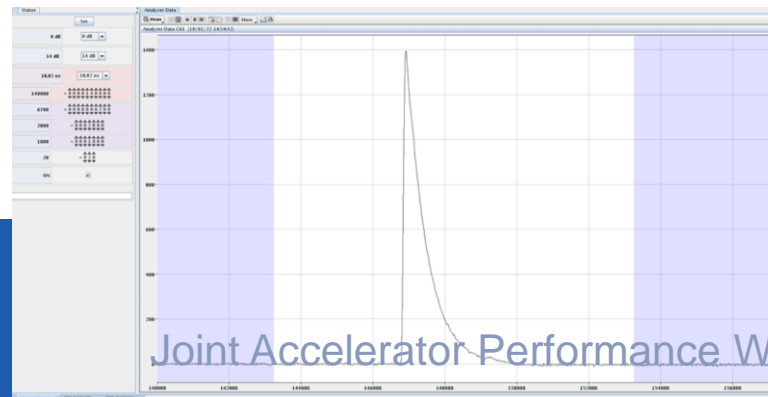
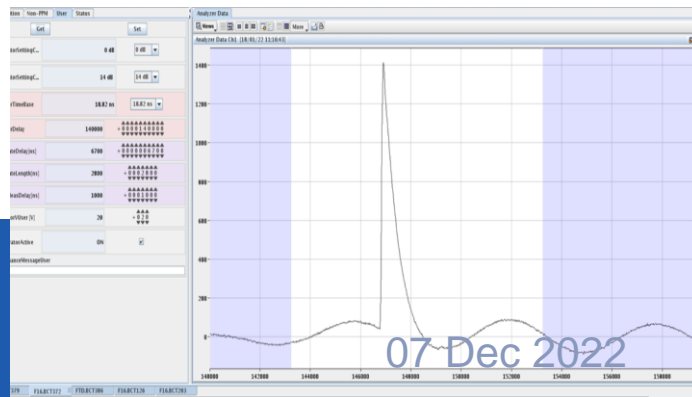


The production of amplifiers for the entire PS complex is underway.
Installation is planned for early 2022 the most disturbed detectors.
In parallel, measurements will be carried out on these amplifiers to optimise them for the general installation

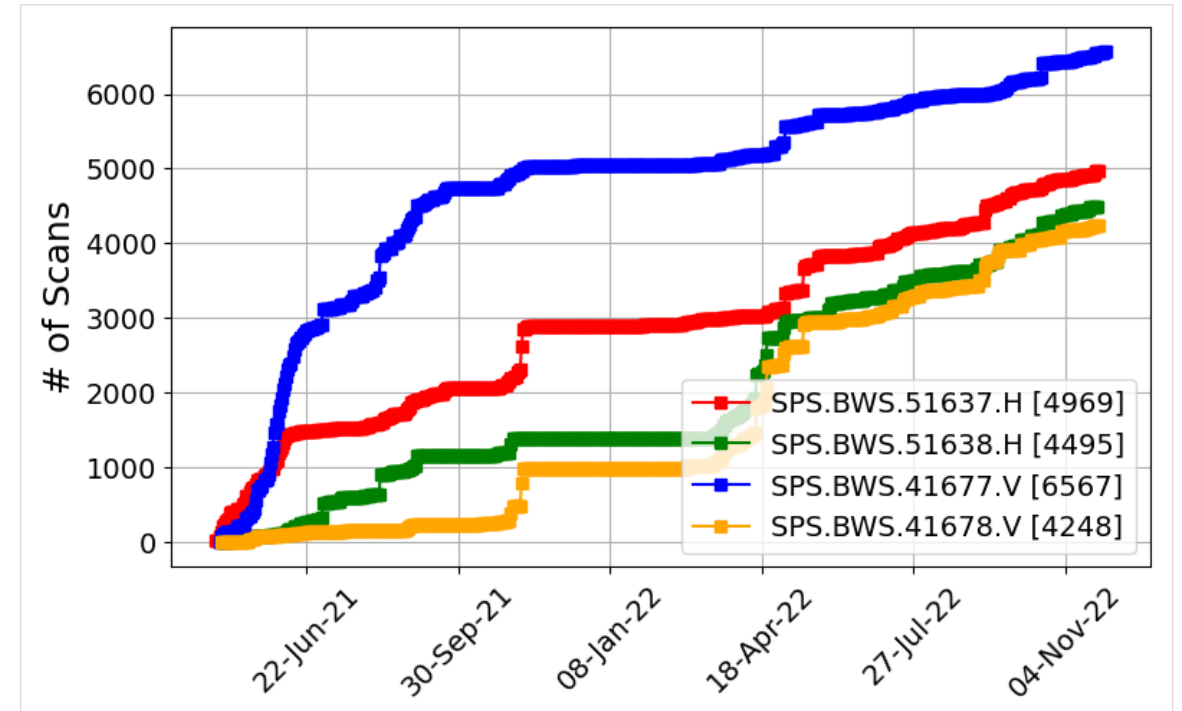
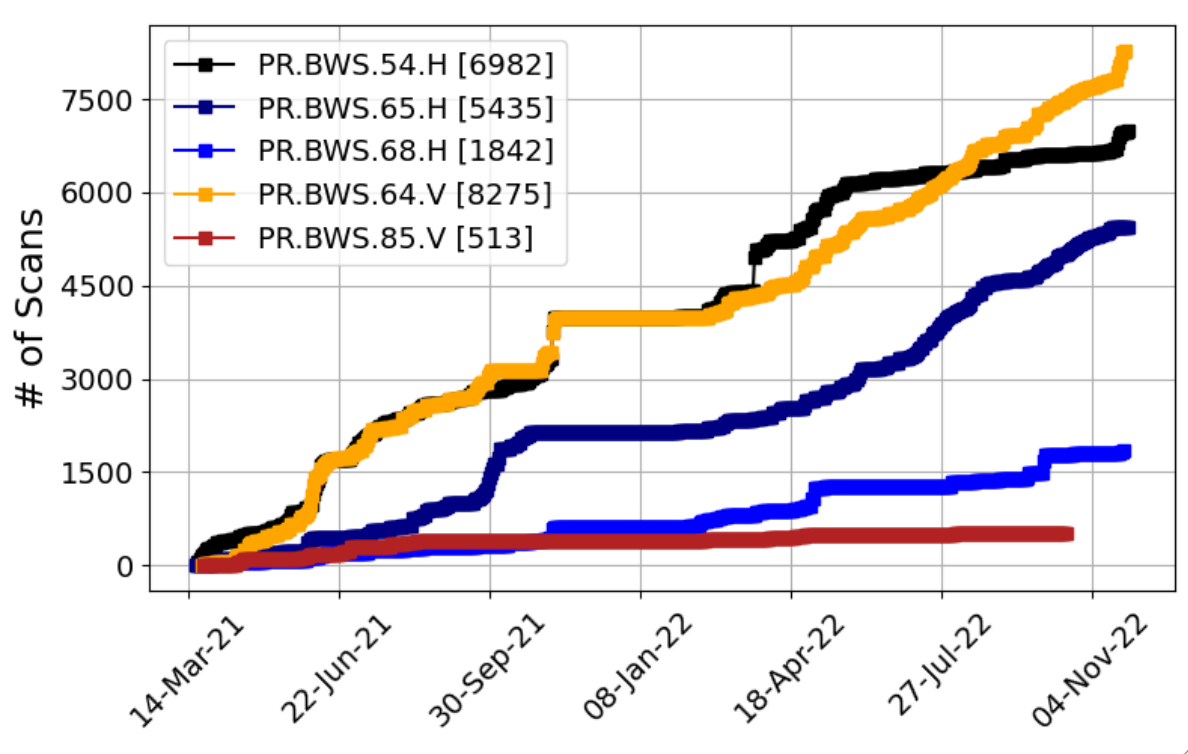
Following the disturbance problem encountered in TT2 the design and installation of the new amplifier has reduced the problem significantly



Residual disturbance that was still present on some BCTs has been corrected with the use of better quality coax cables in the acquisition rack



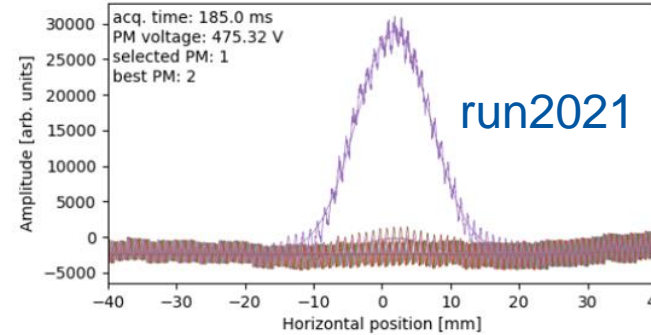
BWS PS and SPS usage



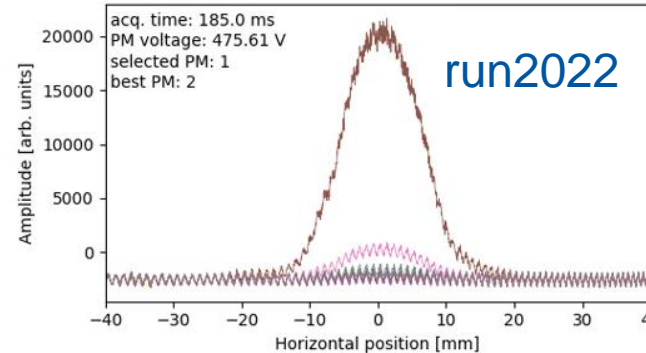
LIU BWS noise reduction in the PS

- Noise observed on the BWS acquisition in run2021
PS: 1.3% of acq full scale, SPS: 0.37%, PSB: 0.13 %.
Temporal evaluation in ADC bin see table 2 (N1)
- Main source $f=16\text{kHz}$, phase reproducible from scan to scan, one scanner motor can influence another scanner's acquisition.
Thanks to ABP & OP team for their help in investigating!
- BWS motor power stage cables cross-talk to acquisition cables is the source. Correlation between length and noise amplitude observed. Power stage EMI already minimized in the design: filtered & cable shielded.
- Mitigation: common mode noise suppressor at the surface acquisition inputs. Tested on 85V (run2021).
Deployed for run2022 on all 5 LIU-PS scanners.
- Encouraging results with positive feedback from OP.
Min. factor 10 improvement for the target frequency (table 2. N2 to N3). Some higher frequencies mode enhanced. But most of the stochastic noise is filtered by the gaussian fit.
- If further reduction is found necessary, more invasive and expensive solution can be envisaged (cables re-routing and extra shielding in collaboration with EN-EL)

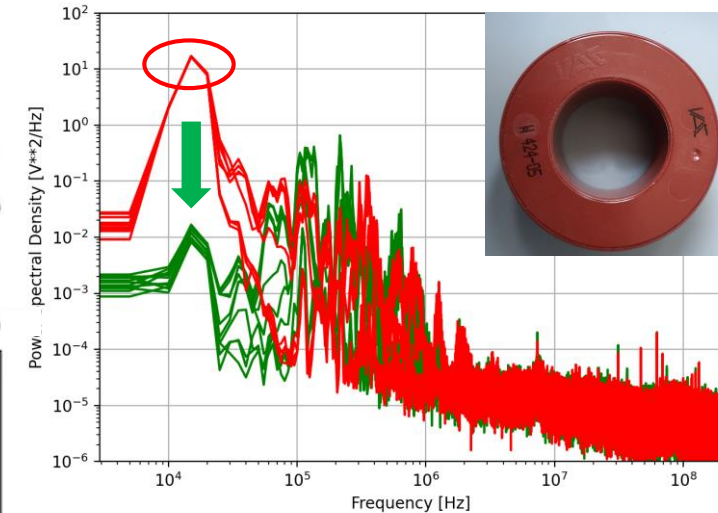
PR.BWS.54.H - CPS.USER.EAST4 / EAST_T8_21 (11.11.2021 - 01:44:46)



PR.BWS.54.H - CPS.USER.MD4 / LATE_SE_T8_22 (25.04.2022 - 15:03:45.100)



PS OP tool figures of 54H (A. Huschauer)

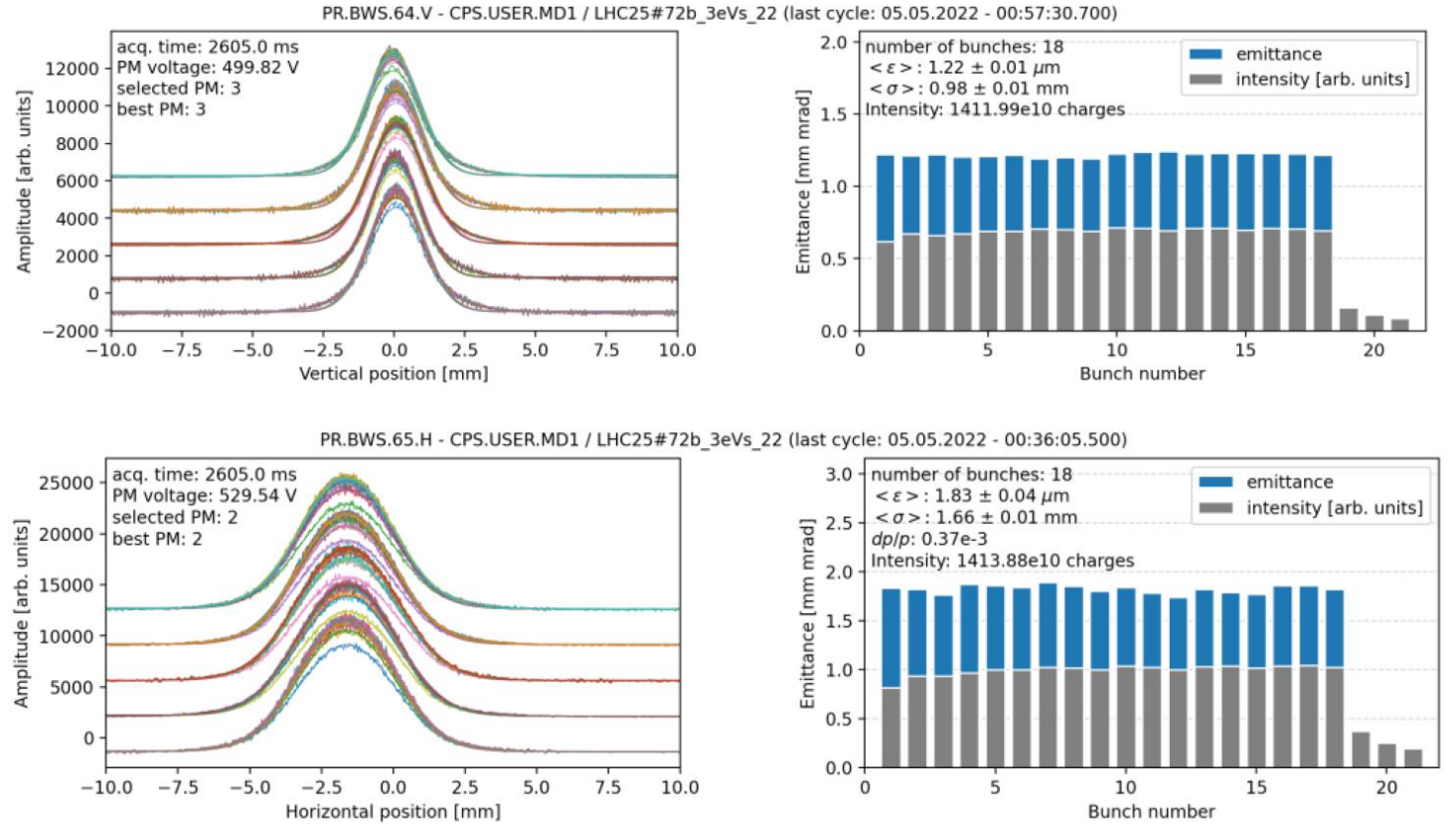


Effect of inserting Nanocrystalline toroidal ferrites from VAC on one acquisition channel (at the surface) of scanner 85V (run2021)

Table 2: Scanner name (N), accelerator (A), cabling length (L), trajectory reproducibility error (TRE1) in 2020 and 2022 (TRE2), PMT noise (N1), noise @16 kHz in May 2021 (N2) and noise @16 kHz in July 2022 after installation of noise limiter on the PS scanners (N3).

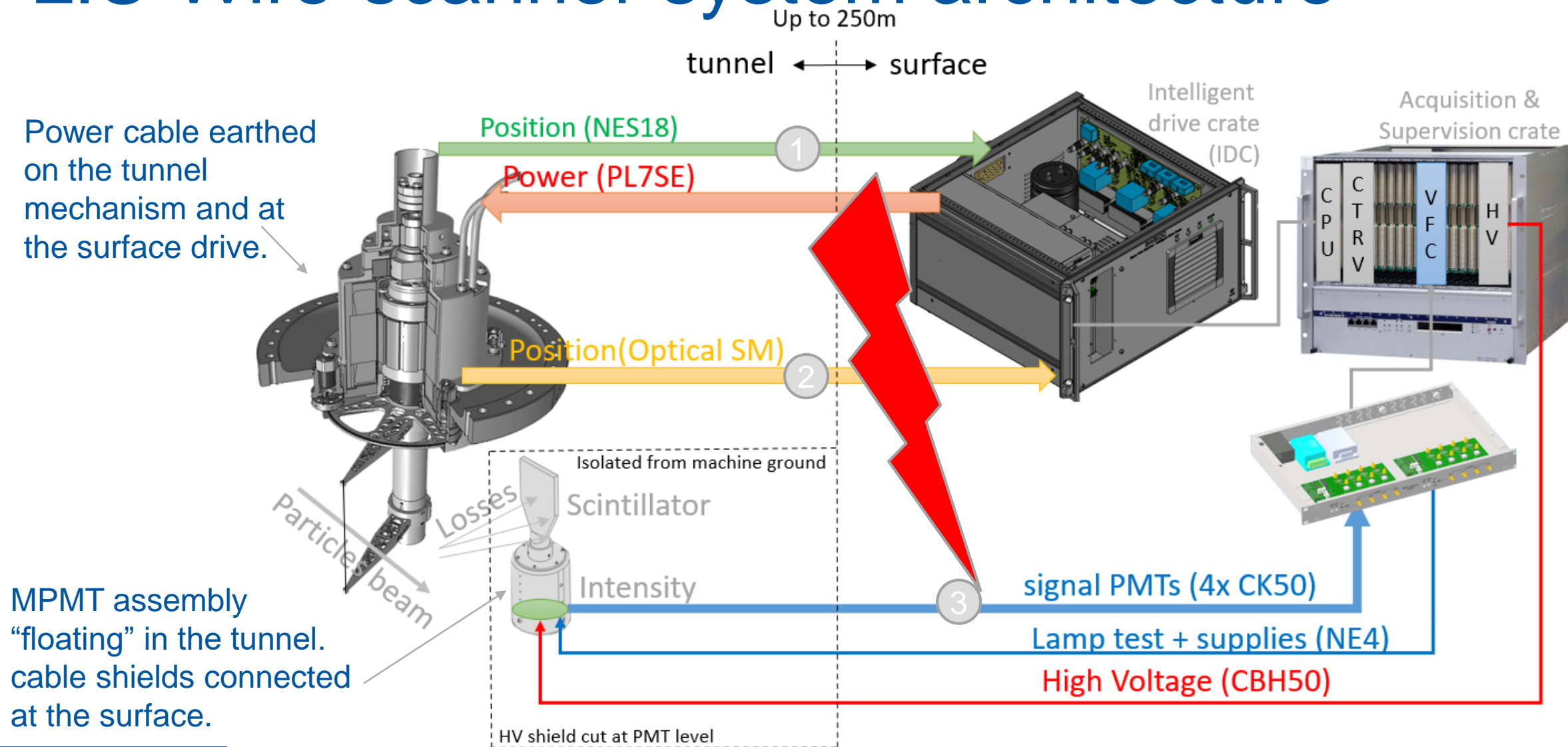
N	A	L [m]	TRE1 [mrad/s]	TRE2 [mrad/s]	N1 [bin]	N2 [V ² /Hz]	N3 [V ² /Hz]
54H	PS	185	63	-48	1706	44.1	0.013
64V		230	63	-79	901	8.04	0.940
65H		232	106	63	492	1.04	0.024
68H		215	21	0	522	2.15	0.014
85V		216	85	-32	1634	19.2	2.036

- LIU BWS was designed with EMC and EMI in mind (output driver filtering and shielded power cables)
- Today's perturbation levels does not limit system's operation
- Ferrites in place for all PS scanner since run2022
- Good feedback from OP



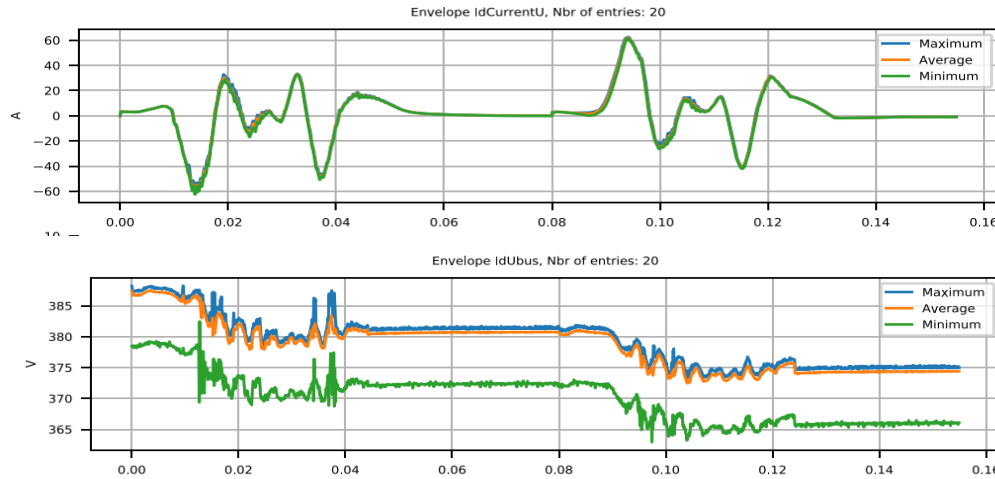
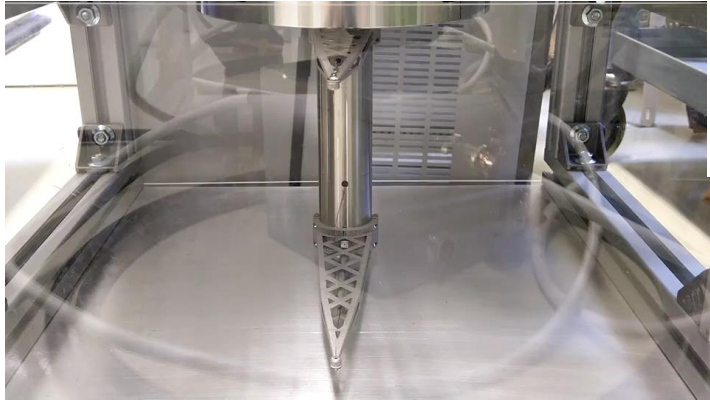
PS REPORT W18 (D. Cotte) with 64V & 65H

LIU Wire-scanner system architecture



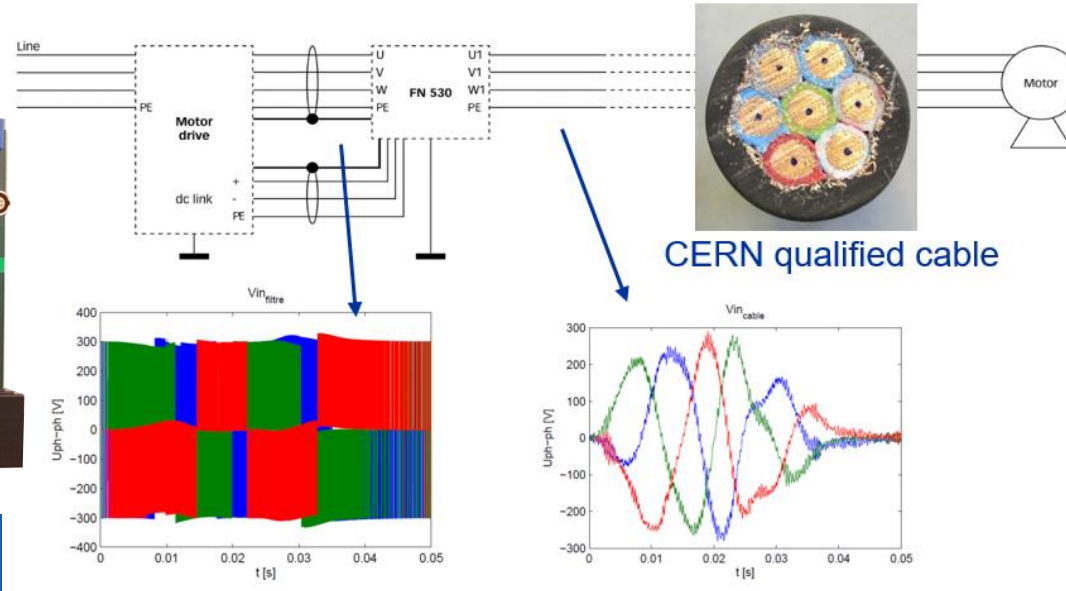
The PMT acquisition system is sensitive to external noise source as well as “internal” noise generated by the motor drive current switching (inverter)

PWM Motor driving technology



Output filter with post filter current sensing

IGBT based Three phase full bridge inverter



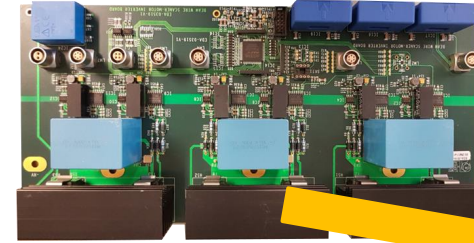
Minimization of motor drive EMI during design

- PMT signals (1mA - 1V on CK50)
Motor powering (400V, ~60A)
 - Signal and power cables routed together
 - Motor drive technology:
linear drive (legacy scanners – still in LHC and PSB)
Switch mode power stage for the LIU scanners
 - LIU power cable exclusively driven during on-demand scans lasting about 2x50ms with Pulse Width Modulation at 16kHz.
 - “EMC study for the control of Wire Scanner”, EDMS-1416465
Collaboration with Swiss University to validate this technology in the context of BWS (2013)
- Introduction of a large EMC filter at the output stage
---Recommendation to design a custom drive to integrate large EMC filter while ensuring high performance using “vector control technics”
---Validate our selection of the shielded power cable (CERN type “PL7SE”)

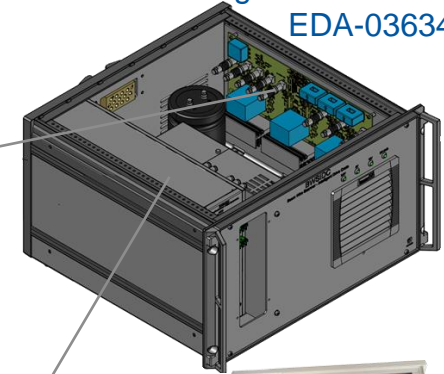


Cross-section
“PL7SE”
7 conductors of 6mm²
with outer shielding.
EMC connector
mounting procedure
EDMS-2172897

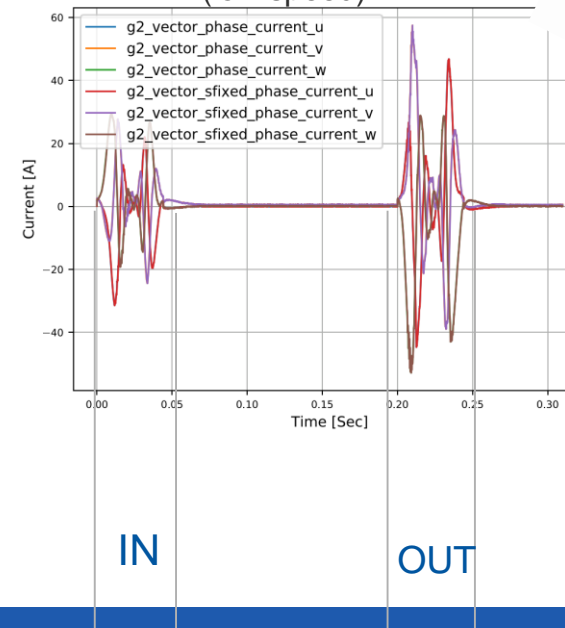
“Motion Inverter Board” EDA-03519



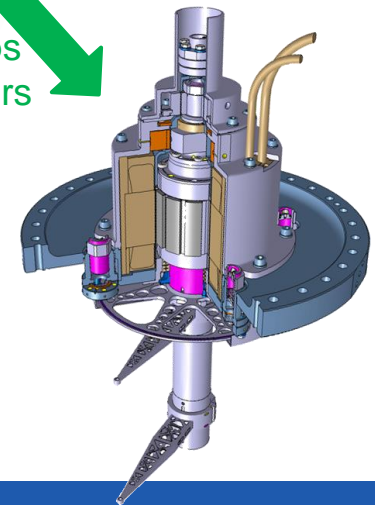
Intelligent drive crate
EDA-03634



Example of output currents
(low speed)



3 phases
~400V - 60 Amps
Up to ~230meters



PS BGI – Usage statistics

BGI vistar

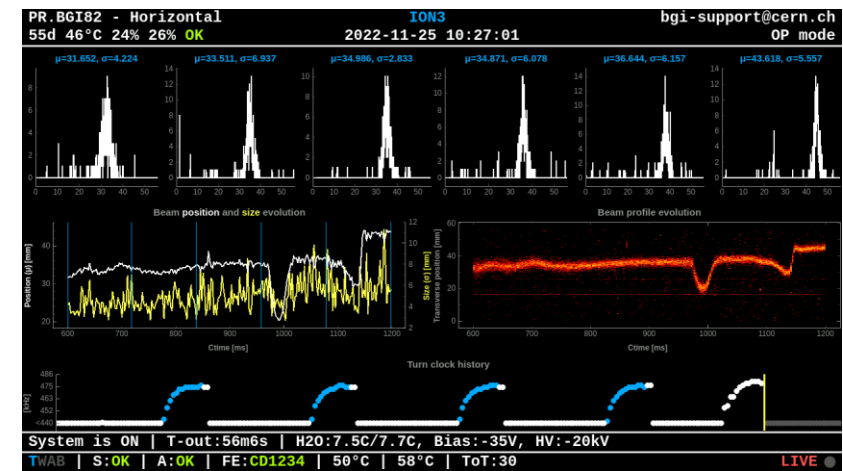
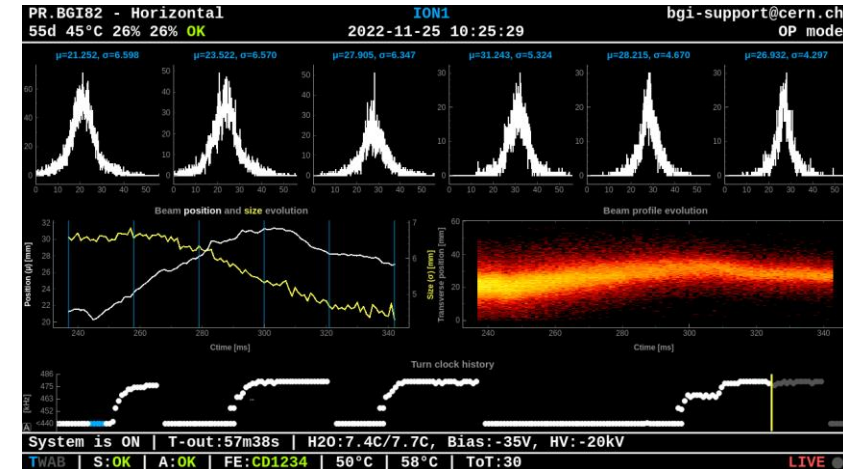
Beam profiles recorded to NXCALS in 2022

In the past month:

- BGI-H: 1,235,103 profiles from 14,821 beam cycles
- BGI-V: 137,038 profiles from 2,129 beam cycles

In the past year:

- BGI-H: 2,049,174 profiles from 26,520 beam cycles
 - BGI-V: 488,076 profiles from 8,659 beam cycles
- [Large dataset ready for exploitation!]



First turn trajectory in LEIR

Beam test:

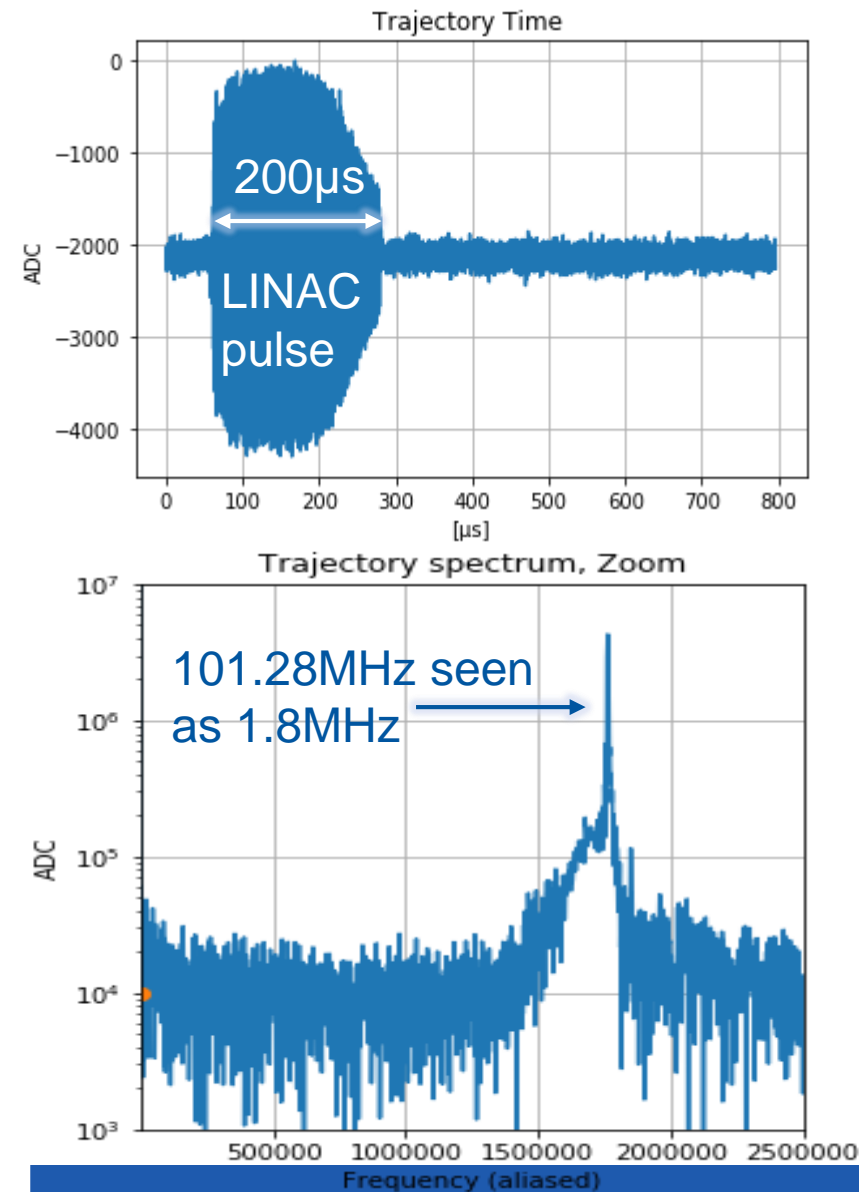
- The 101.28MHz RF modulation from the LINAC3 can be seen in the signal from a orbit PU in LEIR.

Using an amplifier with 20dB gain at 100MHz to observe an injected 30 μ A beam that is non circulating (stopped for this test). The under-sampled alias signal can be observed in the existing trajectory data. Estimated position resolution 1-4mm (depends on Pick-Up types)

Outlook:

- Proto type (with sum and delta) developed, *is* in the design office for finalization....
- Proto type produced / tested
- Update design / Production of amplifiers series
- Installation
-

Spring 2023
Fall 2023
YEST 2023/2024



101.28MHz Test

(possible first turn position measurement)

Data: LEI.BPM.RING-NOMINAL-TrajectoryOASIS-1/11-11-22/1668162312167.csv

Joint Accelerator Performance Workshop

33

Injectors

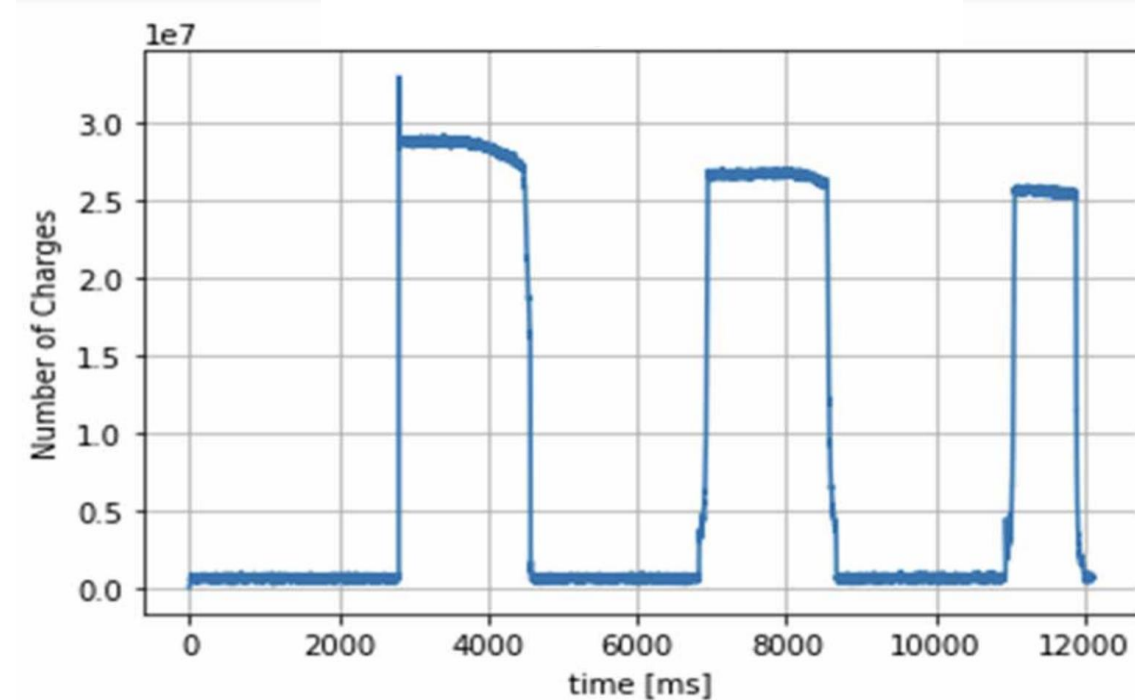
- LN4: BSM spare status policy
 - Procuring new spares today is not possible due to the current political situation
- PS and TL: Measurement of CHIMERA beams in PS ring
 - Extraction 10^6 – 10^9 charges limitation to BI have to be checked

Transfer Lines

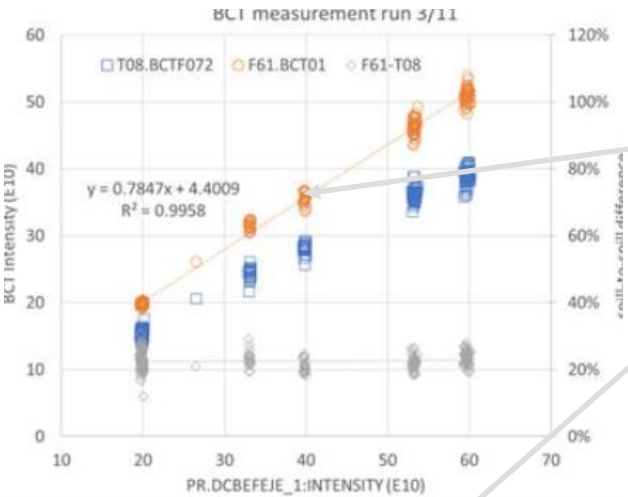
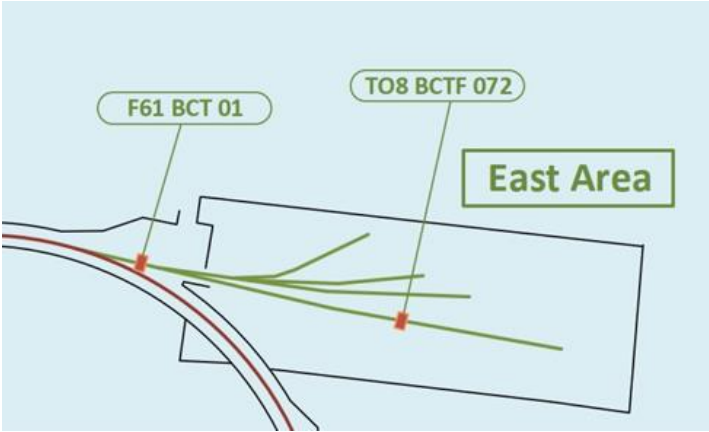
- nToF
 - Follow-up of discussions about SEM grid tank being source of losses:
 - The potential gain of increasing the aperture of the tank (flanges) and the vacuum window was considered small.
No change justified for the moment
 - A version of the system with larger detector acceptance and number of channels is in preparation. Could be ready for EYETS 23/24

New intensity measurement in ELENA ring

- Challenging measurement ($\lesssim 0.5\mu\text{A}$) for traditional transformers
- New intensity meas of bunched beams using an existing orbit PU
- Simulated in CST
- Presented at IBIC'22 ([TUP30](#))
- Ongoing studies to improve absolute calibration accuracy
- Cross-check not possible as no other instrument presently provides the same measurement



Cross-comparison of total intensity measured with Al-foil and BCT techniques with a fast beam performed with increasing intensity steps extracted from the PS to determine new calibration factors for the T08.XSECs



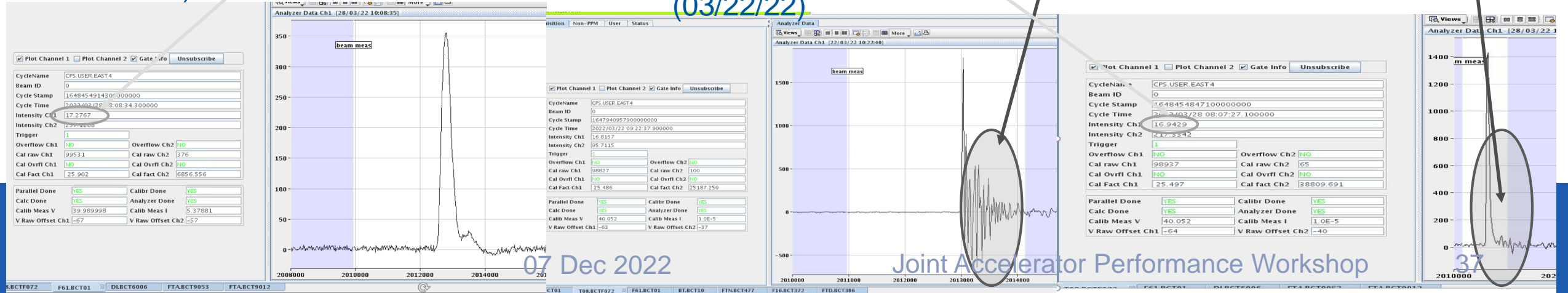
In comparison with the measurements carried out last year, we can already notice that the efficiency of the transmission has improved between 10 and 15% this year!

Beam tuning performed by OP allowed the reduction of residual disturbance on bct measurements

F61.BCT01(03/28/22)

T08.BCTF072 (03/22/22)

T08.BCTF072 (03/28/22)



CLEAR / AWAKE

CLEAR

- Migration to digital cameras in 2023

AWAKE

- 2 chBPMs installed in the tunnel
 - Acquisition electronics only for 1 for commissioning
 - Conclude the commission during 2023
 - Finalize the design and install to the other one
- 1 commercial high frequency BPM
 - Acquisition only with scope to evaluate the performance

New BCCM in the LHC

- The system measures beam intensity drops and triggers a beam dump if the intensity losses are above safety thresholds
- The system is a safety backup for the large and distributed BLM system
- Two redundant BCCM systems for each beam were optimized during the 2022 run
- The largest challenge was the longitudinal emittance RF blow-up, heavily perturbing the system operation during the ramp
- A few hardware and software versions were tested to find the optimal analogue and digital signal processing
- A version tested at the end of the run fulfills all the system requirements and this version will be fully deployed for the system commissioning during the 2023 startup