News from the SY Department

Over the past months, the efforts of the teams in SY have helped to successfully restart the physics program in most of the injector complex, and to push the impressive commissioning progress with LHC. There have also been numerous issues to solve with equipment faults, failures and unexpected problems, but the tenacity and expertise of the different groups have been much in evidence as the problems have been rapidly understood, addressed and either completely solved or mitigated.

There have already also been many notable operational highlights – including ramping the LHC ramping beam to 6.8 TeV, reaching the LIU performance specification for LHC beam in both the PSB and PS, the dramatic improvement in the SPS spill structure in the beam delivered to the North Area and the increase of the number of bunches on the AD target (the latter topics described in detail in this Newsletter). A huge effort and attention goes into the operation of the machines and it’s very gratifying to see the progress and continuing development, based on the innovation and teamwork: across the sector and with the experiments themselves.

After the events and constraints of the past few years, the international developments continue to be pre-occupying and a source of concern to all. With the coming of summer, the chance for well-earned vacation is important to seize, to find time for ourselves and our families in order to maintain that all-important balance – not between ‘work’ and ‘life’, (because our work is invariably a big part of our life as another article in this Newsletter illustrates so well), but rather our internal balance and perspective, to let us keep things in context and to keep our energy and enthusiasm high.

So, enjoy the summer: both at work and away from it!

Brennan and Jean-Paul
Departmental Service Support (DSS)

In 2023, the majority of the Field Support Unit (FSU) contracts in the Accelerators and Technology (ATS) sector will end and the Accelerator Systems (SY) Department has anticipated this by re-tendering our needs in a new Departmental Service Support (DSS) contract. The DSS will replace these FSU contracts, for the SY Department, from the 1st July 2022 to provide technical support services for the operation, maintenance, consolidation and upgrade of CERN’s accelerator complex, test bench facilities and the technical infrastructure on the CERN site. The Services are divided into two distinct Competencies:

**Mechanical Departmental Service Support (M-DSS) including the Activities:**
- **Manufacturing;** machining, turning and milling with traditional and CNC machines, sheet metal work, welding and fitting of (stainless) steel, copper, brass and non-metallic materials;
- **Construction;** assembly, maintenance, and installation of a large variation of accelerator technical systems;
- **Other Activities;** logistics, inventory, test bench preparation and Ultra High Vacuum (UHV) related activities;
- **Supervision;** technical management and coordination of the M-DSS.

**Electrical/Electronic Departmental Service Support (E-DSS) including the Activities:**
- **Controls & Electrical systems;** assembly, electrical cabling, maintenance and installation of control chassis and racks; installation of electrical installations;
- **Electronics;** assembly, maintenance, installation, measurements and testing of electronics components and printed circuit boards;
- **Interventions;** lock-in and lock-out procedures and first line intervention of electrical installations;
- **Other Activities;** logistics, inventory, spare parts management, documentation and test bench preparation;
- **Supervision;** technical management and coordination of the E-DSS.

Detailed descriptions of all the Services supplied by the new DSS can be found on the SY webpages.

**Task Technical Managers (DSS-TTM)**
The DSS-TTM are the contact persons from the SY Groups for Job Requests, (short-long term) planning of the Services and will collaborate with the DSS-TEM (Contractor Technical Management) for the technical guidance and correct execution of the Services, as well as final quality control and Job Request acceptance.

**Service requests and Contact details**
Requests for both the M-DSS and E-DSS can be made via the “SY Departmental Technical Service Support (SY DSS)” Service in the CERN Service Portal.
Contract Manager: Wim Weterings
Assistant: Aikaterini Leventaki
Contact email: sy-dss@cern.ch
DSS requests: SY Departmental Technical Service Support (SY DSS)
Your group’s DSS-TTM can be found on this list.

Wim Weterings, SY-AR
Data privacy: Passports and CVs should be handled with care

How many times have you shared a copy of your passport, ID card or CV while working at CERN? Whether you are a member of the personnel, a contractor or simply a visitor, it is very likely that you have shared some of these documents in order to comply with the various administrative processes in place at CERN – but did you know that the information contained in these documents is considered personal data and is therefore owned by the data subject?

An article has been published in the Bulletin and is available on the following link: https://home.cern/news/announcement/cern/passports-and-cvs-should-be-handled-care

Hopefully, these simple tips are a helpful reminder of how to handle passports, ID documents and CVs with care.

Data Privacy Course

Impressive figures for SY concerning participation in the new mandatory data privacy course introduced in December 2021 (“Data Privacy Basics” – e-learning).

A total of 628 people completed the course in SY. The total number of participants who completed the course CERNwide was 15,007! (figures from 23.5.2022 by A. Kerhoas DPCC Chair)

Thanks for your participation!

Georgina
SY Departmental Privacy Coordinator
High heat and work wear: safety first!
Forte Chaleur et tenue de travail : la sécurité d’abord !

With the onset of summer and rising temperatures, new risks are emerging, both at home and in the workplace. What should you do? **Follow the basic rules of caution and remember to hydrate regularly!** You can find [here](#) a reminder of the good practices to adopt.

**In summary:**
- Protect yourself (**work in the shade, cover your body, wear PPE**)
- Keep cool (**use a ventilation system, have a misting device**)
- Drink regularly (**in small quantities without waiting to be thirsty**)
- Limit physical effort (**adapt your activities as much as possible in order to limit your efforts**)

Please note that high temperatures do **not exempt** you from wearing Personal Protective Equipment (PPE), please find [here](#) the General Safety Instruction (GSI) on wearing PPE.

If you feel a situation is at risk, make an EDH [Safety Incident declaration form](#)!

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Avec l’arrivée de la période estivale et la hausse des températures, de nouveaux risques émergent, à la maison comme sur le lieu de travail. Que faire ? **Respecter les règles élémentaires de prudence et pensez à vous hydrater régulièrement** ! Vous trouverez [ici](#) un rappel des bonnes pratiques à adopter.

**En résumé:**
- **Se protéger** (travailler à l’ombre, couvrir son corps, porter ses EPI)
- **Se rafraîchir** (utiliser un système de ventilation, disposer d’un brumisateur)
- **Boire régulièrement** (par petites quantités sans attendre d’avoir soif)
- **Limiter les efforts physiques** (adapter le plus possible vos activités afin de limiter vos efforts)

**Notez que des températures élevées ne dispensent pas du port des Equipements de Protection Individuelle (EPI), veuillez trouver [ici](#) l’Instruction Générale de Sécurité (GSI) relative au port des EPI.**

En cas de situation à risque, remplissez le [formulaire de déclaration d’Incident de Sécurité EDH](#).
Successful prototype validation of ultra-high precision current measurement devices for HL-LHC

The WP6B “Class 0” ultra-high precision current measurement devices, or DCCTs (direct current current transformers), are used for the accurate current measurement/regulation in the 14kA (D1: MBXF, D2: MBRD) and 18kA (Main Inner Triplet) power converters. Two prototype DCCTs, from the IT-4514 HL-LHC contract (PM Special Measurement Systems), have been fully tested at CERN and approval has been granted for the pre-series phase, another six units for the HL-LHC IT String in SM18.

All performance aspects of the detailed technical specification were verified. This included the very strict accuracy requirements, as well as EMC (electro-magnetic compatibility). The setup for EMC testing is shown in the image above. The unprecedented 12-hour stability requirements (±0.5 ppm) for HL-LHC could only have been achieved, and measured, by combining CERN’s “state of the art” measurement capabilities with industry’s manufacturing know-how. The chart below shows the spec-compliant 12h stability test, that could be repeated consistently, boding well for the next phase of the project: the integration of the DCCTs into the control system of the power converters.


Greg Hudson, SY-EPC
Antiprotons can be generated by sending a high-intensity proton beam on a target. At CERN this primary beam is delivered by the Proton Synchrotron (PS). The present Antiproton Decelerator (AD) has been built from bits of the Antiproton Collector (AC) ring which was part of the Antiproton Accumulator Complex (ACC) to accumulate the elusive antiparticles for the collider programme of the SPS. The AD circumference remained unchanged with respect to its predecessor, and today it is still the PS that provides the high-intensity proton beam producing the antiprotons. The harmonic number, the ratio between RF and revolution frequencies, of the radiofrequency (RF) system in the PS at extraction to the AD is yet the historical value of $h_{\text{PS}} = 20$, around which the PS had been initially designed in the late 1950s. The length of the AC had been chosen to receive beam from one quarter of the PS circumference. However, just one quarter of the PS ring would have been too short. An additional gap had to be kept for the injection kicker to guide the precious antiprotons into the AC and later the AD ring. Hence the design harmonic number at injection is $h_{\text{AD}} = 20/4 + 1 = 6$. The harmonic number ratio, $h_{\text{PS}}/h_{\text{AD}} = 20/6 = 3.3333$ implies that while the protons in the PS circulate three times, the antiprotons perform exactly 10 turns in the AD.

Originally each PS Booster ring delivered five bunches to the PS which were then combined by different RF manipulation techniques. Five high-intensity proton bunches in consecutive $h_{\text{PS}} = 20$-buckets were extracted and converted to antiprotons injected into the AC ring, leaving just one sixth of the circumference for the fall time of the injection kicker. With the upgrade of the PS Complex as LHC pre-injector during the 1997/98 shutdown these schemes had to be adapted. Seen that the PS Booster has four rings, they were resulting in only four bunches to the AD. In this case, two buckets out of six in the AD remain empty. Not an ideal situation, but difficult to imagine adding a fifth ring to the PS Booster.

With the connection of the PS Booster to Linac4 in the framework of the LHC Injector Upgrade (LIU) project, the beam brightness has become sufficiently large to deliver two bunches with the required longitudinal and transverse parameters from one single ring. This novel transfer scheme allows again to generate a chain of five bunches with only four rings, two from ring 3 and just one from the others.

However, since the bunches are nowadays injected at harmonic $h_{\text{PS}} = 8$, the chain of five bunches in the PS, spanning 5/8 of its circumference, would be more than twice longer than the entire AD ring and not suitable for a single turn transfer. After acceleration on $h_{\text{PS}} = 8$, a so-called batch-compression scheme is therefore applied at extraction energy in the PS. The principal harmonic of the RF system is gradually increased to $h_{\text{PS}} = 20$ in a sequence of intermediate steps. This RF manipulation moves the bunches closer together to fit the batch into the AD circumference. Compared to the 4-bunch batch compression the sequence of harmonic number steps ($h_{\text{PS}} = 8 \rightarrow 9 \rightarrow 11 \rightarrow 13 \rightarrow 15 \rightarrow 17 \rightarrow 20$) has been completely reviewed and reprogrammed for the new 5-bunch compression. With two additional intermediate harmonic number steps, the optimum sequence becomes $h_{\text{PS}} = 8 \rightarrow 9 \rightarrow 10 \rightarrow 11 \rightarrow 12 \rightarrow 14 \rightarrow 16 \rightarrow 18 \rightarrow 20$. The measured mountain range plot Fig. 1 illustrates how the five bunches are approaching each other within about 200 ms. The longitudinal beam profile measurements in the AD are initially blurred by the debris of particles generated at the conversion target. Only the antiprotons survive, and the five bunches are well captured in the AD (Fig. 2).
For the same total intensity accelerated in the PS, the 5-bunch scheme requires 20% less intensity per bunch and features lower losses in the transfer line between the PS and the target. The new beam was prepared and tested in the PS during the commissioning phase in March. It was successfully injected into the AD for the first time on April 5, more than 25 years after the last extraction of a 5-bunch batch to the ACC facility in the 1990s. After just one day of optimization, it was decided to keep the scheme for operation, and it has been reliably running since. With the upgraded longitudinal production scheme, the PS is now at the starting block to considerably increase the proton beam intensity. However, careful studies will be required to neither damage the target nor exceed radiation limits in the transfer line and in the AD hall. Back to the future with five bunches!

These achievements are a collaboration of many colleagues, and we would like to thank the PSB, PS and AD operations teams. The contributions of experts in ABT and RF were essential to commission the 5-bunch scheme.
Tomography-based RF voltage calibration and improvement of the slow extraction for the fixed-target beam

Tomography is a technique to reconstruct the distribution of a bunch in the longitudinal phase-space. The main inputs are the measured bunch profiles (Fig.1, left), the output is the phase-space distribution whose projections best match the ensemble of measured profiles (Fig.1, middle). The discrepancy parameter $D$ indicates the degree of matching between measured and reconstructed profiles. Tomography being an iterative process, the discrepancy typically decreases and reaches an asymptotic value $\bar{D}$ after a sufficiently large number of iterations, typically around 20 iterations. Tomography can only provide accurate results when certain accelerator and beam parameters are known. While parameters like beam energy are available with high precision, the actual (detected) voltage $V_d$ of the radiofrequency (RF) system acting on the beam and the phase position $\phi_s$ of the RF bucket center are difficult to measure. In particular, the actual RF voltage can be significantly different from the programmed one, due to uncertainties in electrical gap voltage measurements.

Longitudinal tomography can be used to find both, detected voltage and bucket center phase by determining which assumption leads to the smallest discrepancy (Fig.1, right). Tomography-based RF voltage measurements were performed with the SPS fundamental-harmonic RF system, which is composed of six accelerating travelling-wave structures operated at a frequency of 200 MHz. Each structure was measured separately, by injecting a single bunch of small intensity and longitudinal emittance. Bunch oscillations are essential for the voltage calibration (Fig.1, left).

To demonstrate the consistency and reliability, the obtained results were verified by directly examining the synchrotron oscillations of measured profiles, by applying beam-based voltage measurements to multiple cavities, and by using simulated bunch-profile data as input for voltage calibration.

In 2022, tomography-based voltage measurements were performed, after a campaign of electrical RF voltage measurements. The voltage error, defined as the relative difference between actual and programmed voltages, spanned from -4% to +5%, depending on the measured cavity. The phase values obtained from beam-based voltage calibrations allowed to verify that the six cavities are now perfectly aligned, within just 1 degree. While this confirmed the success of the electrical measurements, there is one application for which this voltage precision at the level of few percent was not sufficient. Currently, the optimization of the spill for the slowly extracted fixed-target beam (SFTPBO) requires the total RF voltage to be zero by adding single-cavity voltages with opposite phases. In this counter-phasing configuration, small errors in the phase and/or amplitude of the single-cavity voltages result in sufficiently large residual RF voltage (Fig.2, red and orange lines) to keep parts of the beam bunched.

Indeed, the North Area experiments could measure an important residual 200 MHz structure, and the quality of the extracted spill was not satisfactory. After the voltage setpoints per cavity were pre-corrected with the errors obtained from the tomography-based voltage calibrations, the residual 200 MHz structure was significantly reduced (Fig.2, green lines), small enough for the experimental data taking.
Figure 1. Left: bunch profiles measured at injection energy in the SPS. Only one of the six accelerating travelling-wave cavities is active, with constant programmed RF voltage of 0.9 MV. Middle: reconstruction of the longitudinal phase-space distribution at time zero, applying tomography to the measured profiles and assuming an RF voltage of 0.82 MV at zero phase. The measured (black) and reconstructed bunch profiles (red) agree very well. The discrepancy as a function of the iteration number is shown in the top right subplot. The asymptotic value is labelled with $D$. Right: voltage-calibration diagram, the pair of RF voltage and phase resulting in the lowest asymptotic discrepancy is the best assumption for the RF parameters acting on the beam. The voltage error is -4%.

Figure 2: Longitudinal beam profiles of the fixed-target beam observed with a BA3 wall current monitor in the middle of the spill, for 4 different cycles. The beam profiles without applying the pre-correction factors from voltage calibration are in orange/red and show strong 5 ns structure (i.e. 200 MHz). The beam profiles obtained with the correction factors applied are in green, and they feature a much reduced, albeit non-zero, 5 ns structure.
Digital LLRF for small circular machines: a long technical and human story

A look at the past: the first generation digital LLRF

I have been working as project leader on digital Low-Level RF (LLRF) systems for nearly 20 years. Over this period of great world evolution, my team and I radically changed the way LLRF systems are designed, developed and operated at CERN.

It all began in 2003 by a collaboration with BNL (Brookhaven National Labs).

At the time the CERN RF group was lagging behind in digital technology. So we got going in earnest with prototype hardware boards, beam tests on PSB Ring 4, taking, organising and teaching several training courses. All this we did with a good amount of resolve.

The CERN-BNL collaboration was cut short in early 2005 after a BNL internal reshuffle. Unruffled, we kept going on our own and the fall 2005 saw us deploying the first generation of our new digital LLRF in LEIR.

This was the very first digital LLRF system for circular machines ever deployed at CERN. It included the building blocks that we retained in further developments.

It was based on a motherboard and on three types of daughter cards: a Master Direct Digital Synthesizer (MDDS), a Digital Down Converter (DDC) and a Slave Direct Digital Synthesizer (SDDS). All of them were customized and in-house hardware.

The MDDS clocks the system, the DDC samples and filters input signals and the SDDS generates analogue outputs. On-board Digital Signal Processors (DSP) and Field Programmable Gate Arrays (FPGA) carry out the signal processing.

In LEIR, and for the first time, we used a new type of High-Level RF (HLRF) which then became an LLRF favourite companion.

Based on the Finemet® metal alloy, this wide-band, un-tuneable HLRF, was built in collaboration with our Japanese KEK colleagues. Flexible and compact, alas its transfer function varies substantially in amplitude and phase over the operational frequency range. This called for the LLRF to implement cavity servoloops, traditionally part of the HLRF for Meyrin machines. So indeed the LLRF became whole the brain of the RF system.

Last but not least, we also pioneered an innovative approach for timings generation, functions generation and observation channels, which were embedded in the LLRF and fully variable on a cycle-to-cycle basis (PPM). This approach is now routinely used in many machines. At that time however it appeared somehow way too innovative and required long discussions to get it widely accepted.
A long-term vision

Not a one-time project, developing the LEIR LLRF system was part of a long-term plan to provide a common and modular LLRF family for all small synchrotrons on the Meyrin site.

These machines are characterised by a large revolution frequency swing that the LLRF must cope with. Their synchrotron frequency being high the beam reacts quickly ... hence all beam-based feedback loops (phase, radial and synchronisation) must be fast, too!

Going fully PPM and digital has obviously many advantages: repeatability, remote access, extensive diagnostics and archival of all parameters. Additionally, having the same hardware, firmware and similar software in many CERN machines makes operational support and spare part management easier.

Following the success of the LEIR pilot project, the path for the consolidation and upgrade of the small Meyrin synchrotrons was established. A LLRF test system remained installed in the PSB and allowed testing and validating various RF gymnastics for several years.

The second generation digital LLRF family

In 2009 we began a collaboration with MedAustron (https://www.medaustron-technology.at/en) focusing on a second generation LLRF family. The aim was to develop a modern and more powerful family based on the previous one and on the operational experience we had accumulated. We succeeded and the new family was deployed in MedAustron [2014], PSB [twice! 2014 and 2020], LEIR [2016], ELENA [2017] and AD [2021].

The figure below shows the current installation in the PSB, where four LLRF systems control PSB Rings 1 thru 4. Since 2014 we also have one additional LLRF system we call Ring 0 LLRF, which controls in PPM the Ring 4 beam. This way we test new features with beam before their deployment on the operational LLRF systems.
The same hardware family and part of the firmware was also used by the Beam Instrumentation group for the orbit systems of LEIR, AD and ELENA. In these machines the LLRF and orbit systems exchange data in real time over optical fibers. The LLRF sends in real time the revolution frequency value to the orbit system so that it can acquire bunched beam data. The LLRF receives in real time the measured orbit that can be used as radial loop input, instead of the radial position calculated by the LLRF itself and based on a small pick-up subset.

This second generation family is powerful, flexible and upgradeable. In LEIR we could successfully operate at harmonics 3+6, which was not originally foreseen, to implement a fallback scheme for SPS slip-stacking operation. In ELENA a test feature of the LLRF has been replacing since 2021 the simulated Btrain, not yet available, for daily machine operation.

*Plans, plans and more plans*

This is not the end of the story. The same building blocks, repackaged in a different format, have been proposed for a compact medical synchrotron within the framework of CERN’s Next Ion Medical Machine Study (NIMMS) initiative.

We are also working on adapting the ObsBox systems (already used in SPS and LHC) to this LLRF family for longitudinal beam diagnostics. This will enable us to better monitor the beam characteristics and to implement additional alarms/warnings and slow controls of the system parameters. This could be the basis for automatic system optimization and reduction of the operational workload.

Last but not least, in LS3 we will likely start working on a third generation LLRF.

*A human story, not only a technical adventure*

I mentioned so far only technical aspects. The human component is however an important facet of the story.

I am the last member left of the original development team, whose composition changed over time as students, fellows, staff and external collaborators came and went, depending on their studies, their contract or their retirement date. I kept in touch with former team members, while others moved on into the rest of their lives - all stories I’ll never know the ending of.

I remember the many blocking problems we faced, the long hours and discussions to reach a solution or at least a workaround. The many successes, that always outnumbered the problems and that we celebrated with nibbles and drinks ...indeed, a successful LLRF can be heavy on one's liver!

Occasionally we even worked the whole night to meet a deadline - now fond memories but rather hard when actually experienced first-hand.

One example is the last night of beam before the Long Shutdown 1 (LS1): after recompiling and testing all night long, we installed the resulting hardware and software in the PSB BOR at 6 am. The start of LS1 was scheduled for 9 am but the PSB OP crew delayed it by half an hour, just for us. Thanks guys, you’re the best!
Another time MedAustron had a blocking problem at 10 in the evening and we found a workaround by 1 am through email “ping-pong”.

Certainly now you, faithful SY newsletter reader, will think we were extremely passionate - there were occasionally times of extreme efforts, but these were always consensual: discussed and agreed between us, with a spirit of flexibility and respect for our individual personal constraints.

I believe that this passion for our technology is a key ingredient to success when tackling such new and challenging projects. Indeed, would we really have the heart to start a new project if we knew in advance all the painful, unexpected problems we would have to solve to make it operational?

The examples above show how much we cared for our systems, something which cannot be just written into a work contract. I actually see the same attitude in many colleagues, in SY and outside, possibly more often at CERN than in industry. Really, it is this spirit that has allowed CERN to satisfy so many demanding deadlines, against all odds. It is also, I am afraid, what has often hidden the lack of workforce allocated to various projects.

Final wishes

As I slowly reach the end of this 20-year long work adventure and move on to other projects, I wish you all, young SY readers, similar highly fulfilling technical challenges and strong human interactions just as I had. May your data transfer always be fast and reproducible, may your on-board memory never get corrupted. May your mind remain forever young and open as time goes by.

Many thanks to past and present members of the Meyrin LLRF team.
Optimising CERN's energy consumption

This infographic provides food for thought about CERN's energy consumption and invites you to submit your ideas for its optimisation through an idea box. Take part!

This infographic is part of the series “CERN's Year of Environmental Awareness”
Have you heard of Le Jardin des Particules, the CERN Staff Association’s crèche and school?

It is a childcare facility for children from 4 months to 6 years old, but above all, le Jardin des Particules is a special place for children.

You have just arrived in the region? If you are looking for child-care, whether you work at CERN or not, don’t hesitate!

Our structure is open to all!

For us, taking care of your children is more than just a job: it is a passion.

Some places are still available for the school year 2022-2023.

We organise open days to present our structure, our educational project and answer all your questions.

Do not hesitate to contact us for an individual appointment, to visit and discover the structure.

Email: info.jdp@cern.ch Tel.: 0041 22 767 36 04

Le Jardin des Particules
https://nurseryschool.web.cern.ch
SY Contacts

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We are available for any questions that you may have.