CERN Bulletin

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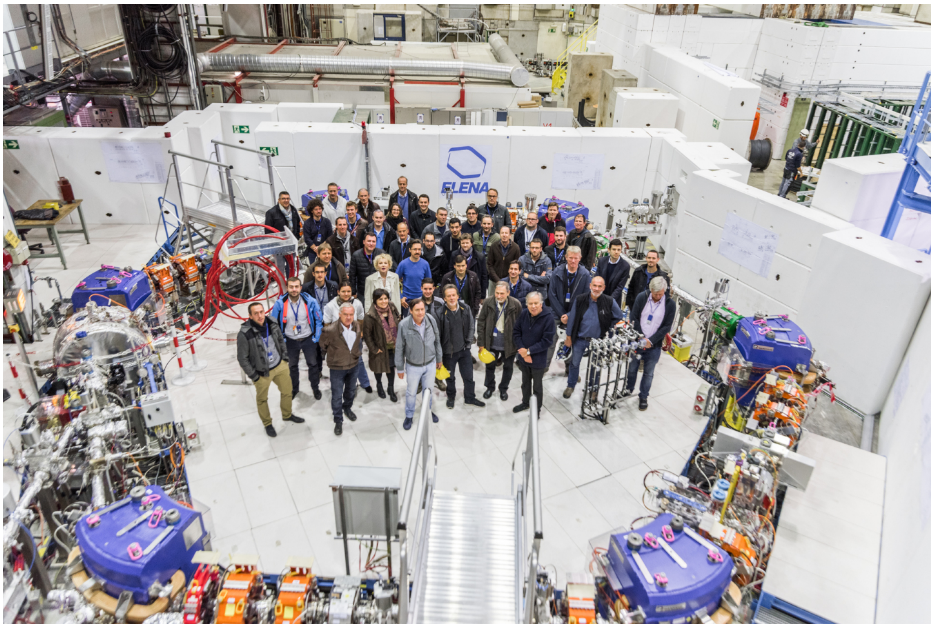
A NEW RING TO SLOW DOWN ANTIMATTER



The members of the ELENA project stand in front of the new decelerating ring (Image: Sophia Bennett/CERN)

With a circumference of just 30 metres, it looks a bit like a miniature accelerator. But don't be mistaken, ELENA has all the components of a bigger machine. Tests with beam of this brand-new accelerator for antimatter experiments began in mid-November. The first beam circulated on 18 November. "Starting the machine up with beam is an interesting and crucial phase of the project. The coming weeks will show us if everything is working as planned," explains Christian Carli, ELENA project leader.

The ELENA (Extra Low ENergy Antiproton) deceleration ring will be connected to the Antiproton Decelerator (AD) as of next year. The 182-metre-circumference AD supplies antimatter experiments with antiprotons at 5.3 MeV, the lowest energy possible in a machine of this size. The slower the antiprotons (i.e. the less energy they have) the easier it is for the experiments to study them or to manipulate them in order to produce antihydrogen atoms, for example. ELENA will reduce the energy of antiprotons from the AD by a factor of 50, to just 0.1 MeV. In addition, the density of the beams will be improved. The number of antiprotons that can be trapped will be increased by a factor of 10 to 100, improving the efficiency of the experiments and paving the way for new experiments.

To decelerate particles, you basically need the same tools as you need to accelerate them. So ELENA is equipped with a radio-frequency cavity to decelerate the bunches of antiprotons, with dipole magnets to keep them on a circular trajectory and with focusing magnets to keep them close together and to avoid the dispersion of particles. But at low energy and low intensity, other difficulties arise.

(Continued on page 2)

A WORD FROM ECKHARD ELSEN

THEORY AND EXPERIMENT - CLOSER TOGETHER BY BEING APART

One year ago, when the new directorate started to consider the idea of separating theory and experiment into two departments, the decision to do so was quickly made. While the new Theory Department may be small in terms of numbers, it is host to a large number of eminent scientists over the year. It seems inconceivable to me for a world-leading centre for fundamental physics not to have a vibrant, independent activity in theoretical physics. Creating a Theory Department has given us that. Perhaps paradoxically, it is also helping to bring theory and experiment closer together.

(Continued on page 2)

In this issue

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A WORD FROM ECKHARD ELSEN

THEORY AND EXPERIMENT - CLOSER TOGETHER BY BEING APART

One essential purpose of theory at CERN is to provide the bridge that makes theory testable by our experiments. Today that means enabling precision physics at a hadron collider: a task made all the more pressing by the superb performance of the LHC in 2016. One example, illustrating the vibrancy of the interplay between theory and experiment, came with the infamous 750 GeV bump. Much as we would all have liked it to develop into a discovery, rather than a statistical fluctuation, the tantalising excess seen by ATLAS and CMS nevertheless catalysed the theory community to examine just how flexible the margins of the Standard Model might be. Their numerous and imaginative attempts to accommodate the observation in extensions of the Standard Model has value for future experimental studies.

CERN's theorists work on many fronts. The LHC Physics Centre at CERN, LPCC, has for many years been our local primary interface between physics and experiment. As well as providing the day-to-day conduit between theory and experiment, it also allows new avenues to be thoroughly explored before detectors are put in place. A case in point is the expansion of forward physics at the LHC, which has seen major developments recently with the LPCC paving the way. The Physics Institutes that the Department regularly hosts provide another important contribution to the scientific life of CERN. They allow the intellectual firepower of the Department to be increased by addressing topical issues with eminent invited scientists from around the world. The upcoming meeting on neutron stars is just one example.

Recent developments in the Theory Department reflect the evolving nature of particle physics and the CERN research programme. One such initiative explores ways of exploiting the diversity of CERN's on-site facilities, looking at the potential for physics beyond colliders. Another has its sights set further afield: a neutrino activity, recently established with leading neutrino theorists spending extended periods at CERN. This complements the new neutrino group in the Experimental Physics Department: together their role is to survey the global neutrino physics landscape and act as a resource for CERN users wishing to engage with neutrino programmes wherever they may be. This is a clear example of the realignment taking place in our field to better coordinate and better make use of globally distributed facilities by a global physics community.

Our theory Department concerns itself not only with the very small, but also with the very large. While CERN makes resources available to collaborations in neighbouring fields through the recognised experiment programme, our theorists also engage with those researching fields such as cosmology. This makes CERN an attractive place for recognised experiments to hold their collaboration meetings, and it is good for CERN in exchange.

All this activity makes CERN's Theory Department an invaluable resource for an experimental laboratory and the community at large. It is by working hand in hand that theory and experiment advance human knowledge, as equal partners in a shared endeavour.

Eckhard Elsen
Director for Research and Computing

A NEW RING TO SLOW DOWN ANTIMATTER

"The beam is a lot more sensitive to external interference, such as the earth's magnetic field, which modifies its orbit," explains François Butin, the technical coordinator in charge of the installation.

To counteract these effects, the designers of ELENA worked on several technical parameters. The magnets were the subject of particularly intense studies, as at such low energies the magnetic fields are inevitably weak. The hysteresis of the iron in the magnet (in other words, the residual magnetism) can compromise the quality of the field. ELENA is therefore equipped with magnets that have been optimised to operate with very weak fields.

The circumference of the ring was a compromise between various constraints. It needed to be small enough to allow the magnetic fields to be more intense in order to counteract the effects of external interference, but also big enough to house all the necessary components. "The small size of the ring meant that we had to be particularly inventive as well as precise when fitting in all the components," says François Butin.

Time-lapse video of the installation of the components

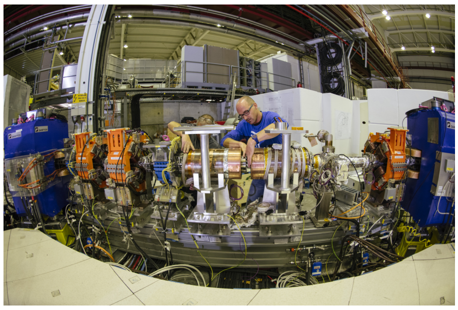
Another essential component of the decelerator will be its electron cooling system. When a beam is accelerated, its transverse size tends to decrease, but when it is decelerated, it increases. Electron cooling counteracts this effect by concentrating the particle bunches. The principle is to transfer transverse energy from the antiprotons to the electrons. The electron cooling system, which is in the final stages of development in the UK, will be delivered at the start of 2017.

Other challenges that had to be overcome included updating the beam instrumentation in order to be able to operate at low intensity and low energy. The vacuum system is also impressive, producing very low pressure, around 10^{-12} millibar.

The teams working on commissioning the machine will continue the tests with beam. In parallel, GBAR, the first experiment that will be connected to ELENA, is in the process of being assembled. GBAR will study the effect of gravity on antimatter, following in the footsteps of AEGIS and soon also ALPHA. The other experiments will be connected during the second long shutdown of CERN's accelerators in 2019-2020. ELENA will be able to supply antiprotons to four experiments in parallel.

360 °view of the 30-metre-circumference ELENA deceleration ring

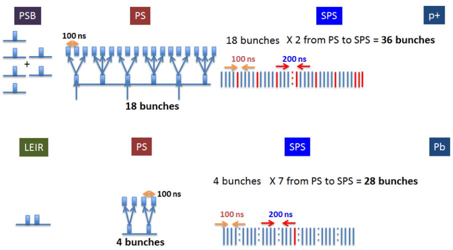
For more information you can read the CERN Courier article.



Members of the ELENA project install componants of the new decelerator in September 2016

Corinne Pralavorio

LHC REPORT: THE ROLE OF THE INJECTORS



The injection scheme for the proton beam (upper part of the picture) starts with the PSB, which first sends four bunches to the PS, followed by two more 1.2 seconds later. In the PS, the bunches are then split in three and are spaced by 100 ns. The 18 resulting bunches are accelerated to 25 GeV and delivered to the SPS. This operation is repeated and the second batch of 18 bunches is injected next to the first one in the SPS, with a spacing of 200 ns. After acceleration to 450 GeV, the 36-bunch train is transferred to the LHC.For the lead ion beam (lower half of the picture): LEIR accelerates the ion beam in two bunches to 72 MeV/nucleon, and sends it to the PS. In the PS, the bunches are split in two and their spacing is set to 100 ns using an RF technique known as "batch expansion". The accelerated beam is extracted towards the SPS and traverses a 1-mm thick aluminium foil, which strips the ions of their 28 remaining electrons. This operation is repeated six times, accumulating the seven four-bunch trains in the SPS with a spacing of 200 ns. The 28 bunches are sent to the LHC after acceleration to 177 GeV/nucleon.Due to the different bunch spacings, only the 27 blue bunches collide in each train. Each operation is repeated 20 times to fill both rings of the LHC.

For its last four running weeks of the year the LHC is colliding protons (p) with lead ions (Pb). This not only presents a challenge for the collider itself, but also for the six accelerators involved in producing the beams, which have to provide the bunches that will eventually collide in ALICE, ATLAS, CMS and LHCb. Two different injector chains boost and deliver the two different types of particles to the LHC. For the protons, the chain is Linac 2, the PS Booster (PSB), the Proton Synchrotron (PS) and the Super Proton Synchrotron (SPS), and for the lead ions, it's Linac 3, the Low Energy Ion Ring (LEIR), the PS and the SPS.

The challenge for the injector complex is twofold. Firstly, the injection pattern of the protons must match with that of the lead ions, in order to maximise the number of colliding bunches in the LHC.

The ideal situation would be to have the same number of bunches and the same bunch spacing for both protons and lead ions. However, the lead ion injection technique sets a constraint. LEIR and the PS can only provide the SPS with a lead ion beam consisting of four bunches spaced by 100 nanoseconds (ns), a different pattern than in normal p-p operations where the proton beam consists of 72 bunches spaced by 25 ns.

Secondly, the intensity of the proton beam must also be reduced to correspond that of the lead ions. For p-Pb operations, the proton bunches need to be five times less intense than usual.

The best possible match that the injector team has found is to inject a train of two batches each consisting of 18 bunches of protons and a train of seven batches consisting of four bunches of lead ions (see picture for more details).

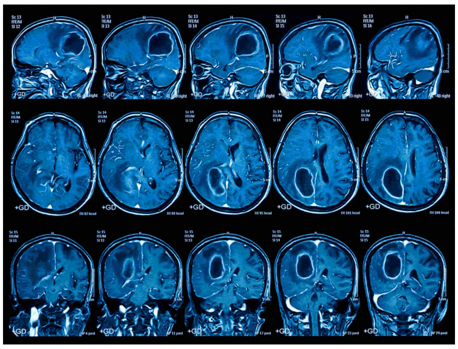
The injector chain is already benefiting from the results of the LHC Injector Upgrade (LIU) project, which aims to upgrade the beam performance of the injectors for the future High-Luminosity LHC. Since the beginning of the run, the Pb injectors have delivered an intensity three times greater than the original design value. This was a major contributor to reaching peak luminosity about six times greater than expected when the proton-lead programme was planned just a few years ago.

At the time of writing, the LHC is still on course to achieve all the physics goals of this run, in spite of all the technical mishaps encountered, such as a power cut last week and a quench on 24 November.

When not filling the LHC, the injector chain provides beams for lots of other users, including the Antiproton Decelerator, AWAKE, HiRadMat, and the North Area.

Django Manglunki for the injector team

HOW THE LHC COULD HELP US PEEK INSIDE THE HUMAN BRAIN



The LHC has been key in driving development of superconducting magnets – one of the most influential technologies to come out of accelerator research and development.

These magnets are needed for energy, transport, and medical technology, applications far beyond the field of high energy physics.

High Energy physics' thirst for superconducting magnets

At low temperatures, certain materials become superconductors. Superconducting wires can conduct 100 times the current of a traditional wire, and are at the heart of the LHC's powerful superconducting magnets, whose magnetic field steers the beam around the accelerator ring. Dedicated large-scale research and development (R&D) programmes like the LHC, spanning over decades, are determinant for this type of technology to develop and mature. Future advances in high-field magnets will benefit both CERN projects like High Luminosity LHC (HL-LHC) and Future Circular Collider study (FCC), and might also find application further afield, such as with imaging the human brain.

Magnets for neuro-imaging and beyond

Other disciplines are also keen on R&D for novel high-field magnets. They are an integral part of the technology behind cutting-edge Magnetic Resonance Imaging (MRI) and Nuclear Magnetic Resonance (NMR) spectroscopy.

At this time, Neurospin, a research centre near Paris set up by the French Alternative Energies and Atomic Energy Commission (CEA), is investigating applications of high-field magnets for imaging the brain – or neuro-imaging. These novel technologies open a new window into our understanding of how the human brain works – another scientific challenge for the 21st century.

Neuro-imaging studies can help understand what happens in the brain after a stroke, in ageing, and even for psychiatry and the study of mental health disorders. As our understanding of the brain evolves, advances in neuro-imaging could also contribute to developing new brain-machine interfaces, or "mind-reading technology", that could translate brain activity measured with neuro-imaging into thoughts.

The future of high-field magnets

High-field magnets have an enormous potential for neuro-imaging ttechnology, high energy physics and other industries, which means there is a strong incentive for collaborative R&D today. In January 2015, an ad-hoc working group called FuSuMaTech – for Future Superconducting Magnets Technology – was set up collaboratively between CERN and CEA to explore applications in high-field magnets, lower the technology barrier to make them more accessible to the market and identify potential synergies between CERN, other Academic partners, neuroimaging labs like Neurospin and European industry. For them, the HL-LHC and FCC offer an opportunity to push the European Superconducting Magnet Technology into the next decade. Together, twelve current partners are considering the Future Emerging Technologies (FET) programme of Europe's Horizon 2020 as an opportunity to continue exploring synergies together in close collaboration with Europe's cutting-edge superconducting magnet industry.

In the future, the HL-LHC aims to upgrade the LHC's eight Tesla (T) magnets with cutting-edge 13T ones. Further down the line, the FCC study is exploring different designs of circular colliders for the post-LHC era. The FCC requires magnets reaching 16T or even 20T depending on its design.

These high-field magnets would enable these future colliders to reach higher energies and unprecedented luminosities, allowing further exploration of the fundamental laws of nature.

Find out more at the next Knowledge Transfer seminar: "From the Proton to the Human Brain", 9 December 2016, by Prof. Denis Le Bihan, Director of Neurospin here (http://indico.cern.ch/event/574545/).

Anaïs Rassat

NA64 HUNTS THE MYSTERIOUS DARK PHOTON

An overview of the NA64 experimental set-up at CERN. NA64 hunts down dark photons, hypothetic dark matter particles. (Image: Maximilien Brice/CERN)

One of the biggest puzzles in physics is that 85 % of the matter in our universe is "dark": it does not interact with the photons of the conventional electromagnetic force and is therefore invisible to our eyes and telescopes. Although the composition and origin of dark matter are a mystery, we know it exists because astronomers observe its gravitational pull on ordinary visible matter such as stars and galaxies.

The NA64 experiment – which started operations earlier this year – uses a unique set-up to hunt down a specific type of dark matter particle called the dark photon.

Some theories suggest that dark matter consists of a family of new particles and forces, just like our visible world. In addition to gravity, dark matter particles could interact with visible matter through a new force, which has so far escaped detection. Just as the electromagnetic force is carried by the photon, this dark force is thought to be transmitted by a particle called the dark photon. It is predicted to have a subtle interaction (a "mixing", in particle physics jargon) with the regular photon and therefore act as a mediator between visible and dark matter.

"To use a metaphor, an otherwise impossible dialogue between two people not speaking the same language (visible and dark matter) can be enabled by a mediator (the dark photon), who understands one language and speaks the other one," explains Sergei Gninenko, spokesperson for the NA64 collaboration.

"Theories predict that dark photons could also explain the longstanding discrepancy observed in measurements with muons (known as the "g-2 anomaly"). Our experiment will be able to test this, and that's why we are so excited," continues Gninenko.

CERN's NA64 experiment looks for signatures of this visible-dark interaction using a simple but powerful physics concept: the conservation of energy. A beam of electrons coming from the Super Proton Synchrotron accelerator, whose initial energy is known very precisely (100 GeV), is aimed at a detector and the energy that it deposits is measured further downstream. Interactions between incoming electrons and atomic nuclei in the detector produce visible photons. If theories of dark forces are correct, however, these ordinary photons could occasionally transform into dark photons, which simply escape the detector and carry away a large fraction of the initial electron energy.

Therefore, the signature of the dark photon is an event registered in the detector with a large amount of "missing energy" that cannot be attributed to a process involving only ordinary particles, thus providing a strong hint of the dark photon's existence.

NA64 began operations in July for a period of two weeks, and the collaboration completed a second four-week run on 9 November. Although no signs of dark photons have been found so far, the results have already set new limits on the strength of the visible-dark-matter interaction. Significantly more data accumulated in the coming years will allow the team to narrow the search further.

If confirmed, the existence of the dark photon would represent a breakthrough in our understanding the longstanding dark matter mystery.

Stefania Pandolfi

PRESIDENT OF THE REPUBLIC OF POLAND VISITS CERN

The President of the Republic of Poland, Andrzej Duda, handing CERN Director-General, Fabiola Gianotti, a book about Marie Skłodowsk Curie, Polish and naturalized-French physicist and chemist.

President Andrzej Duda and his delegation were welcomed on 15 November 2016 by CERN's Director-General, Fabiola Gianotti, and the Representative of the French Republic, *sous-préfet* of Gex Benoît Huber.

During the visit, the President had the opportunity to visit the CERN Control Center, the ATLAS Control Room and the underground experimental area. At the end of the visit, President Duda took the time to sign CERN's guest book and to meet with a number of Polish members of personnel.

Stefania Pandolfi

COMPUTER SECURITY: DIRTYCOW BBQ-WELL DONE, CERN!

I had a big smile on my face on the evening of Friday, 21 October 2016, when I saw how quickly the CERN IT department, the LHC experiments, teams in the accelerator sector and many more individuals were rushing to secure their Linux systems against a new and highly critical vulnerability dubbed “DirtyCow” (i.e. CVE-2016-5195). ArsTechnica labelled this bug the "most serious Linux privilege-escalation bug ever", which stresses its severity nicely, and it was too risky to go into the weekend unprotected!

It seems that computer security problems tend to occur at weekends. “DirtyCow” was a particularly nasty one that, when exploited, allows any local user to inherit administrator privileges and, subsequently, become master of the corresponding Linux system. Although CERN’s SLC5 and 6 were said to be unaffected, a few brave members of the IT department spent the Thursday evening analysing the exploitation vector in depth and finally disproved this initial statement: it turned out that SLC5 and 6, as well as CentOS7, were very much affected... Unfortunately, a prompt patch was not immediately available, so the security risk was uncomfortably high for the CERN Data Centre, its interactive computing clusters – namely LXPLUS and LXBATCH – and many other interactive Linux services in the experiments and the accelerator sector. The risk was especially high as the weekend lay ahead.

Fortunately, however, the IT department was able to propose a mitigating workaround as a temporary protective measure. Intense hours were spent on Friday preparing new Linux “systemtap kernel modules” and proving that the impact on Linux systems was minimal (in fact, only debugging functions would be affected). Finally, at around 3 p.m., the green light was given for the massive roll-out to thousands of Linux LXBATCH servers and hundreds of LXPLUS servers in the CERN Data Centre. An official warning was sent out to all relevant stakeholders at CERN, including SWAN, ATLAS, CMS and others, who promptly applied the workaround to their systems. By late night, all critical services had been secured and were ready to run through the weekend. Great job, CERN! Congratulations to you all!

Addendum: The workaround is no longer needed. CVE-2016-5195 can be fixed by deploying the most recent kernel version available from CERN Puppet or the YUM repositories. Time to bring your system up to date!

For further information, questions or help, check our website (http://cern.ch/Computer.Security) or contact us at Computer.Security@cern.ch.

Do you want to learn more about computer security incidents and issues at CERN? Follow our Monthly Report (http://cern.ch/security/reports/en/monthly_reports.shtml).

The Computer Security Team

Official communications

MODIFICATION OF CERN SAFETY RULES

The CERN Safety Rules listed below have been published on the CERN website dedicated to the Safety Rules :

Safety Regulation SR-SO "Responsibilities and organizational structure In matters of Safety at CERN", v.2: *http://edms.cern.ch/ui/file/1389540/LAST_RELEASED/SR-SO_E.pdf*

This version 2 of the SR-SO cancels and replaces version 1 of the same document. The version 2 of the SR-SO takes into account the changes in the CERN management structure since the beginning of 2016 and in particular the changes to the structure of the HSE unit, which now includes the Medical Service and the Fire and Rescue Service.

The CERN Safety Rules apply to all persons under the Director General’s authority. They are available under the following link: *http://www.cern.ch/safety-rules*

114TH ACCU MEETING

Agenda for the meeting to be held on Tuesday, 6 December 2016 at 9:15 a.m. in Room Georges Charpak (Room F-60/6-015)

1. Chairperson's remarks
2. Adoption of the agenda
3. Minutes of the previous meeting
4. News from the CERN Management
5. Report on services from SMB Department
6. Report on services from IT Department
7. The Occupational Health & Safety and Environmental Protection unit HSE
8. eCars at CERN
9. Reports from ACCU representatives on other Committees: Housing Service Review
10. Matters arising
11. Any Other Business
12. Agenda for the next meeting

The **Advisory Committee of CERN Users (ACCU)** is the forum for discussion between the CERN Management and the representatives of CERN Users to review the practical means taken by CERN for the work of Users of the Laboratory. The mandate of ACCU is available on: *http://accu.web.cern.ch/content/mandate*.

There are one or two Delegates from each Member State (two Delegates from the large Member States), one Delegate from each of the Associate Members, four Delegates from non-Member States (NMS), and two from CERN. The list of ACCU members is available on: *http://accu.web.cern.ch/content/accu-members*.

ACCU meetings are attended by the Director General and members of the Directorate, other members of the CERN management and departmental representatives, the Head of the Users' Office and a representative of the CERN Staff Association. Other members of the CERN Staff attend as necessary for specific agenda items.

Chairperson: Dragoslav-Laza Lazic (Dragoslav.Lazic@cern.ch)

Secretary: Michael Hauschild (ACCU.Secretary@cern.ch)

Anyone wishing to raise any points under "Any Other Business" at the upcoming ACCU meeting is invited to contact the appropriate User representative, or the Chairperson or the Secretary.

CERN PENSION FUND: PENSION PAYMENT DATES IN 2017

- Friday 6 January
- Tuesday 7 February
- Tuesday 7 March
- Friday 7 April
- Monday 8 May
- Wednesday 7 June
- Friday 7 July
- Monday 7 August
- Wednesday 6 September
- Friday 6 October
- Tuesday 7 November
- Thursday 7 December

Announcements

ANNUAL CLOSURE OF THE CERN RESTAURANTS

- Restaurant 1 and the newspaper kiosk will close at 4.00 p.m. on Wednesday, 21 December 2016. The "Grab & Go" kiosk will be closed all day. Restaurant 1 and the newspaper kiosk will reopen at the usual times on Thursday, 5 January 2017. The "Grab & Go" kiosk will reopen at 8.00 a.m. on Monday, 9 January 2017.
- Restaurant 2 will close at 5.30 p.m. on Wednesday, 21 December 2016. On the same day, the snack bars will close as follows: in Building 6 at 4.00 p.m., in Building 13 at 4.15 p.m., in Building 30 at 4.30 p.m., in Building 40 at 5.00 p.m. and in Building 54 at 3.45 p.m. All outlets will reopen at the usual times on Thursday, 5 January 2017.
- Restaurant 3 will close at 4.00 p.m. on Wednesday, 21 December 2016. On the same day, the cafeterias in Buildings 864 and 865 will close at 4.00 p.m. and 10.45 a.m. respectively. All outlets will reopen at the usual times on Thursday, 5 January 2017.
- The cafeteria in Building 774 will close at 4.00 p.m. on Wednesday, 21 December 2016 and will reopen at 8.00 a.m. on Thursday, 5 January 2017.

WORK AND TRAFFIC DISRUPTION AT GATE B ON CERN'S MEYRIN SITE

Work will be carried out at Gate B (route Pauli) on the Meyrin site from 21 November to 7 December.

The purpose of the work is to install number-plate readers for both incoming and outgoing traffic in order to improve the access control system. A pedestrian turnstile will also be installed near Building 120.

Although every step has been taken to limit the inconvenience caused by the work, traffic disruptions are possible, particularly for incoming traffic. We therefore encourage you to use **Gates A (route Bell), C (route Maxwell) and E (route Karl Siegbahn)** while the work is in progress. The opening hours for these gates are available here (*http://smb-dep.web.cern.ch/fr/GS_News/cern-entrance-opening-hours*).

In addition, the CERN shuttles and visitor coaches **will all be required to use Gate A**. Goods vehicles **will enter the site via Gate D** (goods entrance, route de Meyrin), and access for Transport Service vehicles **will be via the tunnel.**

Thank you for your understanding.

SMB Department