The LHC is restarting

The LHC, last among all of CERN’s accelerators, is resuming operation with beam while this issue goes to press. The year-end technical stop (YETS) started on 14 December 2015. During the 11 weeks of scheduled maintenance activities, several interventions have taken place in all of the accelerators and beamlines. They included the maintenance of the cryogenic system at several points; the replacement of 18 magnets in the Super Proton Synchrotron (SPS); an extensive campaign to identify and remove thousands of obsolete cables; the replacement of the LHC beam absorbers for injection (TDIs) that are used to absorb the SPS beam if a problem occurs, providing vital protection for the LHC; and 12 LHC collimators have been dismantled and reinstalled after modification of the vacuum chambers, which restricted their movement.

The YETS also gave the experiments the opportunity to carry out repairs and maintenance work in their detectors. In particular, this included fixing the ATLAS vacuum-chamber bellow and cleaning the cold box at CMS, which had caused problems for the experiment’s magnet during 2015.

Bringing beams back into the machine after a technical stop of a few weeks is no trivial matter. The Electrical Quality Assurance (ELQA) team needs to test the electrical circuits of the superconducting magnets, certifying their readiness for operation. After that, the powering tests can start, and this means about 7000 tests in 12 days – a critical task for all of the teams involved, which will rely on the availability of all of the sectors. About four weeks after the start of commissioning, the LHC is ready to receive first beams and for them to circulate for several hours in the machine (stable beams).

The goal of this second part of Run 2 is to reach 2700 bunches per beam and $\beta^*$ (~2.5 km) running period, therefore reducing the time needed to perform ramping and squeezing at the same time, therefore reducing the time needed between two successive injections.

In addition to several weeks of steady standard $\sqrt{s}$ TeV operation with 2/300 bunches per beam and $\beta^*$ ~40 cm, the accelerator schedule for 2016 includes a high $\beta^*$ (~2.5 km) running period for TOF/ALFA dedicated to the measurement of the elastic proton–proton scattering in the Coulomb–nuclear interference region. The schedule also includes one month of heavy-ion run. Although various configurations (Pb–Pb, p–Pb) are still under consideration, the period – November – has already been decided. As usual, the heavy-ion run will conclude the 2016 operation of the LHC, while the extended year-end technical stop (EYETS) will start in December and will last about five months, until April 2017. Several upgrades are already planned by the experiments during the EYETS, including installation of the new pixel system at CMS.

The goal for the second part of Run 2 is to reach $3\times10^{34}\text{ cm}^{-2}\text{s}^{-1}$ of luminosity, which with about 2700 bunches and 25 ns spacing is estimated to produce a pile-up of 40 events per bunch crossing. This should give an integrated luminosity of about 25 fb$^{-1}$ in 2016, which should ensure a total of 100 fb$^{-1}$ for Run 2 – planned to end in 2018.

* = 40 cm, $\beta^*$ = 2.5 km

News
Anisotropic flow in Run 2

Exploiting the data collected during November 2015 with Pb-Pb collisions at the record-breaking energy of √sNN = 5.02 TeV, ALICE measured for the first time the anisotropic flow of charged particles at this energy. Relativistic heavy-ion collisions are the tool of choice to investigate quark–gluon plasma (QGP), a state of matter with a hydrodynamic geometry and properties that are different from those of hadrons. Anisotropic flow, which measures the anisotropy of final-state particles, is sensitive to the one hand to the initial density of the QGP and to the geometry fluctuations of the overlap region, and on the other hand to the transport properties of the QGP. Flow is quantified by the Fourier coefficients, v_n, of the azimuthal distribution of the final-state charged particles.

The dominant flow coefficient, v_2, referred to an elliptic flow, is related to the initial geometric anisotropy. Higher coefficients, such as triangular flow (v_3) and quadrangular flow (v_4), can be related primarily to the response of the produced QGP to fluctuations of the initial energy density profile of the participating nucleons. Figure 1 shows the centrality dependence of flow coefficients, both for 2.76 and 5.02 TeV Pb-Pb collisions. Compared with the lower-energy results, the anisotropic flow v_2, v_3 and v_4 increase at the newly measured energy by (3.0±0.6%, (4.3±1.4%) and (10.2±3.8%), respectively, in the centrality range 0–50%.

The transport properties of the created matter are investigated by comparing the experimental results with hydrodynamic model calculations, where the shear-viscosity to entropy density ratio, η/s, is the dominant parameter. Previous studies demonstrated that anisotropic flow measurements are best described by calculations using a value of η/s close to 1/4, which corresponds to 300–500 GeV.

ALICE exploited the optimised boson tagging in the search for heavy resonances decaying into a pair of two electroweak gauge bosons (W, Z) or a Higgs boson and a gauge boson (H, WH, ZH) at 13 TeV collisions. Events are categorised into different numbers of charged/neutral leptons, and all possible combinations are considered except for fully leptonic and fully hadronic H or WH decays. For the Higgs boson, the only dominant decay into 4 quarks is considered. Figure 1 shows the results of WZ searches with a 2015 data set corresponding to 3.2 fb⁻¹, presented as the lower limits on the production cross-section times branching fraction for a WZ boson with certain mass. No evidence for new physics has been found with these preliminary searches.

The boosted techniques have evolved into a fundamental tool for beyond SM searches at high energy. ALICE foresees that the search will be greatly enhanced by the techniques, and seeks opportunities to adapt them in uncharted territory for the upcoming LHC run.

CMS hunts for supersymmetry in uncharted territory

The CMS collaboration is continuing its hunt for signs of supersymmetry (SUSY), a popular extension to the Standard Model that could provide a weakly interacting massive-particle candidate for dark matter, if the lightest supersymmetric particle (LSP) is stable.

With the increase in the LHC centre-of-mass energy from 8 to 13 TeV, the production cross-section for hypothetical SUSY partners rises; the first searches to benefit are those looking for the strongly coupled SUSY partners of the gluon (gluino) and quarks (squark) that had the most stringent mass limits from Run 1 of the LHC. By decoding to a stable LSP, which does not interact in the detector and instead escapes, SUSY can leave characteristic experimental signatures of a large imbalance in transverse momentum.

Searches for new physics based on final states with jets (a bundle of particles) and large transverse-momentum imbalance are sensitive to broad classes of new-physics models, including supersymmetry. CMS has searched for SUSY in this final state using a variable called the “transverse mass”, M_T2, to measure the transverse momentum imbalance, which strongly suppresses fake quark flavour, extending our Run 1 limits by more than 300 GeV. We are also sensitive to squarks, with our constraints summarised in figure 1. We set limits on bottom-squark masses up to 880 GeV, top squarks up to 800 GeV, and light-flavour squarks up to 600–1200 GeV, depending on how masses are degenerate in mass.

Even though SUSY was not waiting for us around the corner at 13 TeV, we look forward to the 2016 run, where a large increase in luminosity gives us another chance at discovery.

CMS-15-003, 0-lep (MT2) HVT model A, g_v = 1

Further reading

CMS awards physics prizes for its Kaggle competition

Machine learning, also known in physics circles as multivariate analysis, is used more and more in high-energy physics, most visibly in data analysis but also in other applications such as trigger and reconstruction. The community of machine learning data scientists organises “Kaggle” competitions to solve difficult and interesting challenges in different fields.

With the aim being to develop interactions with the machine-learning community, LHCb organised a competition, featuring the search for the lepton-flavour violating decay, \( \nu_{e} \rightarrow \nu_{\mu} e^{-} \), with the lowest limits for a quantum fluid. It is observed in figure 1 that the magnitude and the increase of flow measured at the higher energy remain compatible with hydrodynamic predictions, favouring a constant value for η/s going from v_2=2.76 to 5.02 TeV Pb-Pb collisions.

It is also observed that the results of the p_T differential flow are comparable for both energies. This observation indicates that the unique opportunity to test the validity of the hydrodynamic picture, and the power to further discriminate between various possibilities for the temperature dependence of the shear-viscosity to entropy density ratio of the produced matter in heavy-ion collisions at highest energies.

Further reading

Further reading
CEP-2016-067.
Anisotropic flow in Run 2

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The transport properties of the created matter are investigated by comparing the experimental results with hydrodynamic model calculations, where the shear-viscosity to entropy density ratio, η/s, is the dominant parameter. Previous studies demonstrated that anisotropic flow measurements are best described by calculations using a value of η/s close to 1/4π, which corresponds to the lowest limits for a quantum fluid. It is observed in figure 1 that the magnitude and the increase of flow measured at the higher energy remain compatible with hydrodynamic predictions, favoring a constant value for η/s going from v_2 = 2.76% at 2.76 TeV Pb–Pb collisions. It is also observed that the results of the p_T-differential flow are comparable for both energies. This observation indicates that the increase measured in the integrated flow (figure 1) reflects the increase of the ratio of the mean transverse momentum. Further comparisons of differential-flow measurements and theoretical calculations will provide a unique opportunity to test the validity of the hydrodynamic picture, and the power to further discriminate between various possibilities for the temperature dependence of the shear-viscosity to entropy density ratio of the produced matter in heavy-ion collisions at highest energies.

Further reading

https://cds.cern.ch/record/2398524

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With the increase in the LHC centre-of-mass energy from 8 to 13 TeV, the production cross-section for hypothetical SUSY partners rises; the first searches to benefit are those looking for the strongly coupled SUSY partners of the gluon (gluino) and quarks (squark) that had the most stringent mass limits from Run 1 of the LHC. By decaying to a stable LSP, which does not interact in the detector and instead escapes, SUSY can leave signatures characteristic experimental signature of a large imbalance in transverse momentum. Searches for new physics based on final states with jets (a bundle of particles) and large transverse momentum imbalance are sensitive to broad classes of new-physics models, including supersymmetry. CMS has searched for SUSY in this final state using a variable called the “transverse mass”, MT2, to measure the transverse momenta imbalance, which strongly supresses fake quark flavours, extending our Run 1 limits by more than 300 GeV. We are also sensitive to squarks, with our constraints summarised in figure 1. We set limits on bottom-squark masses up to 880 GeV, top-squark masses up to 800 GeV, and light-flavour squarks up to 600–1200 GeV, depending on how many states are degenerate in mass. Even though SUSY was not waiting for us around the corner at 13 TeV, we look forward to the 2016 run, where a large increase in luminosity gives us another chance at discovery.

Further reading

https://cds.cern.ch/record/1379723

LHCb awards physics prizes for its Kaggle competition

Machine learning, also known as data science, has become a key tool in the analysis of particle physics. In this context, LHCb has been involved in several Kaggle competitions, which are data science competitions that are run on a platform called Kaggle. These competitions are open to anyone, and participants compete to find the best solution to a given problem.

LHCb has recently won a Kaggle competition, which involved the analysis of data from the LHCb experiment. The competition was focused on the analysis of particle trajectories in the LHCb detector, and participants were asked to identify the most interesting events.

LHCb has also been involved in a competition called the LHCb–Kaggle competition, which was run during the 2016 year of the LHCb experiment. This competition was a collaboration between LHCb and Kaggle, and it involved the analysis of data from the LHCb experiment. The competition was focused on the analysis of particle trajectories in the LHCb detector, and participants were asked to identify the most interesting events.

The LHCb collaboration is continuing its hunt for supersymmetry (SUSY), a popular extension to the Standard Model that could provide a weakly interacting massive-particle candidate for dark matter, if the lightest supersymmetric particle (LSP) is stable. With the increase in the LHC centre-of-mass energy from 8 to 13 TeV, the production cross-section for hypothetical SUSY partners rises; the first searches to benefit are those looking for the strongly coupled SUSY partners of the gluon (gluino) and quarks (squark) that had the most stringent mass limits from Run 1 of the LHC. By decaying to a stable LSP, which does not interact in the detector and instead escapes, SUSY can leave signatures characteristic experimental signature of a large imbalance in transverse momentum. Searches for new physics based on final states with jets (a bundle of particles) and large transverse momentum imbalance are sensitive to broad classes of new-physics models, including supersymmetry. CMS has searched for SUSY in this final state using a variable called the “transverse mass”, MT2, to measure the transverse momenta imbalance, which strongly supresses fake quark flavours, extending our Run 1 limits by more than 300 GeV. We are also sensitive to squarks, with our constraints summarised in figure 1. We set limits on bottom-squark masses up to 880 GeV, top-squark masses up to 800 GeV, and light-flavour squarks up to 600–1200 GeV, depending on how many states are degenerate in mass. Even though SUSY was not waiting for us around the corner at 13 TeV, we look forward to the 2016 run, where a large increase in luminosity gives us another chance at discovery.

Further reading

https://cds.cern.ch/record/1602-01119
The Keplerian decay of \( \Lambda^c \) into \( \pi^+ \nu \) had been observed at Fermilab in 1976. Now, 40 years later, the Beijing Spectrometer (BESIII) experiment at the Beijing Electron–Positron Collider II (BES) has measured the absolute branching fraction of \( \Lambda^c \rightarrow pK^-\pi^+ \) at threshold for the first time.

The decay of \( \Lambda^c \) to hadrons proceeded only through the weak interaction, their branching fractions are key probes for understanding weak interactions inside a baryon. In particular, precise measurements of the decays of the \( \Lambda^c \) will provide important information on the final-state strong interaction in the charm sector, thereby improving the understanding of quantum chromodynamics in the non-perturbative energy region. In addition, because most of the excited baryons of the \( \Lambda^c \) and \( \Sigma^c \) types, as well as the b-flavoured baryons, eventually decay into a \( \Lambda^c \); studies of these baryons are directly connected to understanding the ground state \( \Lambda^c \).

Most decay rates of the \( \Lambda^c \) are measured relative to the decay mode \( \Lambda^c \rightarrow pK^-\pi^+ \), but there are no completely model-independent measurements from \( \pi^+ \) to \( pK^-\pi^+ \) for this decay mode. Moreover, most measurements of the ground-state \( \Lambda^c \) were made more than 20 years ago.

\[ \Lambda^c \rightarrow pK^-\pi^+ \]

**Further reading**

- BESIII collaboration measurements of hadronic branching fractions at the \( \Lambda^c \) threshold using a double-tagging technique that relies on fully reconstructed \( \Lambda^c \) decays. This technique obviates the need for knowledge of the luminosity or the \( \Lambda^c \) production cross-section. To improve precision, BESIII combines 1200000 event samples of decay channels and implements a global least-squares fit by considering their correlations. This leads to a result for the branching fraction for \( \Lambda^c \rightarrow pK^-\pi^+ \) of (5.84 ± 2.24 ± 2.3)%.

This is the first measurement of the absolute branching fraction of the decay \( \Lambda^c \rightarrow pK^-\pi^+ \) at threshold, and it has the advantage of incorporating an optimal understanding of model uncertainty. In addition, BESIII has made significantly improved measurements of the other 11 Cabibbo-favoured hadronic-decay modes.

In 2015, based on the same data set, BESIII also measured the absolute branching fraction of the semi-leptonic decay \( \Lambda^c \rightarrow \pi^+ e^-\nu \), using a missing-neutrino technique. In future, a larger \( \Lambda^c \) threshold sample will help to further understanding of the properties of the \( \Lambda^c \).

- **New facilities**

  - **‘First turns’ for SuperKEKB**

  On 10 February, the SuperKEKB electron–positron collider in Tsukuba, Japan, succeeded in circulating and storing a positron beam moving close to the speed of light through a narrow tube around the 3 km circumference of its main ring. And on 26 February, it is succeeded in circulating and storing an electron beam around its ring of magnets in the opposite direction.

  The achievement of “first turns”, which means storing the beam in the ring through many revolutions, is a major milestone for any particle accelerator.

  SuperKEKB, along with the Belle II detector, is designed to search for new physics beyond the Standard Model by measuring rare decays of elementary particles such as beauty quark, charm quark and tau leptons.

  Unlike the LHC, which is the world’s highest-energy machine, SuperKEKB/

- **CHARM DECAYS**

  BESIII makes first direct measurement of the \( \Lambda^c \) at threshold

  SuperKEKB’s detector, which is designed to search for new physics beyond the Standard Model by measuring rare decays of elementary particles such as beauty quark, charm quark and tau leptons, unlike the LHC, which is the world’s highest-energy machine, SuperKEKB/

  **Further reading**


  - **Further reading**


  - **Further reading**


  Belle II is designed to have the world’s highest luminosity—a factor of 40 higher than the earlier KKEKB machine, which holds many records for accelerator performance.

  SuperKEKB will therefore be the leading accelerator on the “luminosity frontier.”

  The Belle II detector at SuperKEKB was designed and built by an international collaboration of more than 600 physicists from 23 countries. This collaboration is supervised by an International Advisory Committee, which is responsible for all scientific and technical matters.

  At the same time as first turns were achieved, the BEAST in its cave at Tsukuba Hall was approved for its slumber. The BEAST II detector is a system of detectors designed to measure the beam backgrounds of the SuperKEKB accelerator experts to optimise the machine performance.

  When operating the new accelerator, these beam backgrounds must be well understood.

  Belle II and the BEAST II detector share the same data processing system. The PARASIT parasitic radiation produced by electromagnetic showers when the beam collides with the walls of the vacuum pipe not only obscure the signals that we wish to observe, but can also damage the detector. Therefore, when operating the new accelerator, these beam backgrounds must be well understood.

  BEAST II detector will collect data in the unique environment produced by SuperKEKB’s first beams, allowing Belle II to safely roll into the beam in 2017.

- **Further reading**


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  **Further reading**


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Another important step for the AWAKE experiment

AWAKE’s 10m-long plasma cell in the experiment tunnel.

By harnessing the power of wakefields generated by a proton beam in a plasma cell, the AWAKE experiment at CERN (CERN Courier November 2013 p17) aims to produce accelerator gradients that are hundreds of times higher than those achieved in current machines.

The experiment is being installed in the tunnel that was previously used by the CERN Neutrinos to Gran Sasso facility. In AWAKE, a beam of 400 GeV protons from the CERN Super Proton Synchrontron will travel through a plasma cell and will generate a wakefield that, in turn, will accelerate an externally injected electron beam. A laser will subsequently ionise the gas in the cell to become a plasma and seed the self-modulation instability that will trigger the wakefield.

The project aims to prove that the plasma wakefield can be driven with protons and that its acceleration will be extremely powerful – hundreds of times more powerful than that achieved today – and eventually to provide a design for a plasma-based linear collider.

The AWAKE tunnel is progressively being filled with its vital components. In its final configuration, the facility will feature a clean room for the laser, a dedicated area for the electron source and two new tunnels for two new beamlines: one small tunnel to hold the laser beams, which ionises the plasma and seeds the wakefields, and a second, larger tunnel that will be home to the electron beamline – the "witness beam" accelerated by the plasma. At the beginning of February, the plasma cell was lowered into the tunnel and moved to its position at the end of the proton line. The cell is a 10 m-long component developed by the Max Planck Institute for Physics in Munich (Germany). A first prototype successfully completed commissioning tests in CERN’s North Area in the autumn of 2015. The prototype allowed the AWAKE collaboration to validate the uniformity of the plasma temperature in the cell.

AWAKE is a collaborative endeavour with institutes and organisations participating around the world. The synchronised proton, electron and laser beams provided by CERN are an integral part of the experiment. After installation of the plasma cell, the next step will be installation of the laser, the vacuum equipment and the diagnostic system for both laser and proton beams.

Beam commissioning for the proton beamline is scheduled to start this summer. The programme will continue with installation of the electron line, with the aim of starting acceleration tests at the end of 2017.

Further reading
https://doi.org/10.1016/j.cub.2016.04.001

The three middle “spikes” are signals from CLAWS, a subsystem of the BEAST II detector triggered by the SuperKEKB Injection signal.

Belle II is designed to have the world’s highest luminosity – a factor of 40 higher than the earlier KEK-B machine, which holds many records for accelerator performance. SuperKEKB will therefore be the leading accelerator on the “luminosity frontier.”

The Belle II detector at SuperKEKB was designed and built by an international collaboration of more than 600 physicists from 33 countries. This collaboration is supported by the Japanese Ministry of Education, Culture, Sports, Science and Technology, and through the participation of the United States, Russia, and South Korea, and the contributions of many institutes and organisations.

At the same time as first turns were achieved, the BEAST II in its cave at Tsukuba Hall was being slumber. The BEAST II detector is a system of detectors designed to measure the beam backgrounds of the parasitic radiation produced by electromagnetic showers when the beam collides with the walls of the vacuum pipe not only obscure the signals that we wish to observe, but can also damage the detector. Therefore, when operating the new accelerator, these beam backgrounds must be well understood.

BELLE II will be commissioned this year. It will collect data in the unique environment produced by SuperKEKB’s first beams, allowing Belle II to safely roll into the beam in 2017.

Further reading
PT026 NMR Precision Teslameter
Reach new heights in magnetic field measurement

The Metrolab PT026 sets a new standard for precision magnetometers. Leveraging 30 years of expertise building the world’s gold standard magnetometers, it takes magnetic field measurement to new heights, measuring higher fields with better resolution.

The PT026 offers unprecedented flexibility in the choice of parameters, interfacing and probe placement, as well as greatly improved tolerances for inhomogeneous fields. And with Ethernet & USB interfaces and LabVIEW software, it fits perfectly into modern laboratory environments.

DZero discovers new four-flavour particle

Scientists from the DZero collaboration at the US Department of Energy’s Fermilab have discovered a new particle – the latest member to be added to the exotic species of particles known as tetraquarks. In 2003, scientists from the Belle experiment in Japan reported the first evidence of quarks hanging out as a foursome, forming a tetraquark. Since then, physicists have glimpsed a handful of different tetraquark candidates, including now the recent discovery by DZero – the first observed to contain four different quark flavours.

DZero scientists first saw hints of the new particle, called X(5568), in July 2015. After performing multiple cross-checks, the collaboration confirmed that the signal could not be explained by backgrounds or known processes, but was evidence of a new particle. And the X(5568) is not just any new tetraquark. While all other observed tetraquarks contain at least two of the same flavour, X(5568) has four different flavours: up, down, strange and bottom.

Four-quark states are rare, and although there is nothing in nature that forbids the formation of a tetraquark, scientists do not understand them nearly as well as they do two- and three-quark states. This latest discovery comes on the heels of the first observation of a pentaquark – a five-quark particle – announced last year by the LHCB experiment at the LHC.

The next step will be for DZero scientists to understand how the four quarks are put together. Indeed, the quarks could be scattered together in a tight ball, or they might be a pair of tightly bound quarks revolving at some distance from the other pair. Scientists will sharpen the picture of the quark quartet by making measurements of properties such as the way that X(5568) decays or how much it spins on its axis. As with previous investigations of the tetraquarks, studies of the X(5568) will provide another window into the workings of the strong force that holds these particles together.

Seventy-five institutions from 18 countries collaborated on this result from DZero.

Further reading

http://www.umd.edu/375988

DUNE scientists are also paying special attention to the prototype’s wire planes – pieces that hold the thin wires strung across the detector to pick up electrons. To ensure the frames will fit down the narrow mineshaft at SURF and avoid having to stretch the wires across the long DUNE detector, risk-taking scientists plan to use a series of independent 6-m-long and 2.3 m-wide frames. These wire planes should measure tracks in the liquid argon, both in front of and behind them, unlike other detectors.

Engineers have also moved some of the detector’s electronic parts inside the cryostat, which holds liquid argon at –0.84°C. Much like the full detectors, development of the components of the 35-tonne prototype depends on teamwork. For the prototype, Brookhaven and SLAC national laboratories in the US provided much of the electronic equipment. Indiana University, Colorado State University, Louisiana State University and Massachusetts Institute of Technology worked on the light detectors; and the universities of Oxford, Sussex and Sheffield helped to make special digital cameras that can survive in liquid argon, and wrote the software to make sense of the data. Fermilab was responsible for the cryostat and cryogenic support systems.

Scientists will use what they learn from this small prototype version to build one of the full-scale modules for a larger, 400-tonne prototype currently under construction at the CERN Neutrino Platform. A second 400-tonne module using dual-phase technology will also be built at CERN. These will be the final tests before installation of the four huge detectors at SURF for the actual experiment, which is scheduled to start in 2021/2022.

Testing of DUNE tech begins

The planned Deep Underground Neutrino Experiment (DUNE) CERN Courier December 2015 p19) will require the installation of the four huge detectors at CERN. These will be the final tests before installation of the four huge detectors at SURF for the actual experiment, which is scheduled to start in 2021/2022.

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Scientists will use what they learn from this small prototype version to build one of the full-scale modules for a larger, 400-tonne prototype currently under construction at the CERN Neutrino Platform. A second 400-tonne module using dual-phase technology will also be built at CERN. These will be the final tests before installation of the four huge detectors at SURF for the actual experiment, which is scheduled to start in 2021/2022.

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TPS exceeds design goal of 500 mA stored current

In December last year, the 3 GeV Taiwan Photon Source (TPS) of the National Synchrotron Radiation Research Center (NSRRC) stored 520 mA of electron current in its storage ring, and gave the world a bright synchrotron light as the International Year of Light 2015 came to an end. This is the second phase of commissioning conducted after the five-month preparation work set to bring the electron current of TPS to its design value of 500 mA (CERN Courier June 2010 p16 and April 2015 p22).

After the first light of TPS shone on 12 December, the beam injection stored an electron current greater than 100 mA with the efficiency of the booster to storage ring exceeding 75% using Petra cavities. To overcome the instability of the electron beam, high chromaticity and a vertical feedback system were applied to damp the vertical instability at a high current, in this case close to 100 mA, whereas the longitudinal instability appeared when the beam current reached around 85 mA. Subsequently, the dynamic pressure of the vacuum conditioning reached $10^{-10}$ Pa at 100 mA after feeding 35 amps per-hour beam dose. At this stage, the TPS was ready for the upgrade implementation scheduled for the remainder of 2015.

Several new components were installed during this phase, including new undulators and superconducting cavities, while the cryogenic and control systems were completed. The upgrade activities also involved the injection system and the transfer line between booster and storage, to improve the injection efficiency and the stability of the system. In addition, 96 fast-feedback corrector magnets were placed at both ends of the straight sections, as well as upstream of the dipole magnets.

After several tests runs in the fourth quarter of 2015, an unusual and unfamiliar phenomenon began to emerge, preventing the electron current from progressing beyond 250 mA. The pressure of the vacuum chamber located in the first dipole of the second arc section in the storage ring repeatedly surged to more than 100 times the normal value of $10^{-10}$ Pa when the beam current increased to 190 mA. A small metal-plastic pellet that contaminated the vacuum environment was removed and the staff performed flange welding on the spot. After the vacuum problem had been solved, commissioning of TPS went smoothly, ramping from 0 to 520 mA in 11 minutes on 12 December.

While the TPS was ramping up to its stored-current target value, two beamlines – the protein microcrystallography beamline (TPS-05) and the temporally coherent X-ray diffraction beamline (TPS-09) – were in the commissioning phase. The TPS beamlines will be open for use in 2016.
A new approach to incandescent bulbs promises to beat LEDs for efficiency. Oggen Illic and colleagues at MIT replaced the traditional light bulb filament with a flat tungsten ribbon. They then coated glass sheets with a photonic crystal made of alternating layers of tantalum oxide and silicon dioxide, with thicknesses determined by computer modelling, and sandwiched the tungsten between the two. The photonic crystals are transparent to visible light but reflect infrared photons back onto the filament so that they reheat it instead of being radiated. The efficiency so far is 6.5%, triple that of conventional light bulbs, but 40% may be reachable, which would far outstrip compact fluorescent bulbs (7% to 13%) and LED’s (5% to 15%).

The brightest supernova

A new supernova is more than twice as luminous as any seen before, at its peak being brighter than 570 billion suns. Subo Dong of Peking University in Beijing, China, and colleagues found the supernova – dubbed ASASSN-15lh – at a redshift of 0.2326, apparently in a luminous galaxy with little star formation. The power it has radiated in the first four months post-detection strains conventional models for its power source, so in addition to breaking a record, it poses an astrophysical puzzle.

Further reading
S Dong et al. 2016 Science 351 257.

When trees break

Data suggest that trees break at a critical wind speed of about 42 m/s, regardless of the characteristics of any given tree. This has now been explained by Christophe Clanet of LadHyX, of the Ecole Polytechnique in Palaiseau, France, and colleagues, using Hoek’s law, the Griffiths criterion for cracks, and tree allometry and modelling trees as fragile rods. The maximum wind speeds on Earth are about 50 m/s, so this may be part of why trees are so long-lived.

Further reading

A plant that counts

Remarkably, the Venus flytrap can count to five. Erwin Neher of the Max Plank Institute for Biophysical Chemistry in Göttingen, Germany, and colleagues, recorded electrical impulses from the plant in response to one to 60 touches. Two touches close the trap, but after only five touches the plant starts to make the enzyme that digests its prey, and to increase production of a sodium transporter used to absorb nutrients.

Further reading

First castes

Social insects have castes – queens, workers, and soldiers – and the origin of this structure has been tracked back to ancient termites. Michael Engel of the University of Kansas in Lawrence and colleagues found six termite lineages from at least 100 million years ago. The previous oldest caste soldiers were just 17 million years old.

Further reading