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We Begin to Look at the Microcosm, the Early Universe, and the Dark Universe

An interview with
Rolf-Dieter Heuer,
Director-General of CERN
– European Organization
for Nuclear Research

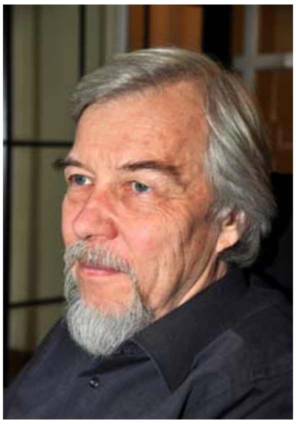

Photo: Andrew Kobos

Andrew Michael Kobos [**AMK**] – *Dr Heuer, how do you feel about being the director of CERN at the time it starts the regular use of the Large Hadron Collider (LHC) – the largest, most complicated, yet most promising research facility on this planet? Pride? Challenge? Burden?*

Rolf-Dieter Heuer [**RDH**] – I think, you characterize it very well. It is a challenge, a burden, and a pleasure. For me as a scientist, the pleasure is the largest part of it. Firstly, it is really a pleasure to see this machine coming up, and secondly it is the pleasure of seeing all these people working together, those not only from CERN and at CERN but also from other countries and other laboratories. It is certainly also some sort of burden to get everything running because the future of particle physics depends on the success of this machine.

AMK – *Frank Wilczek envisaged – I quote – "a new golden age in understanding the laws of Nature with the LHC".*

RDH – With this machine of the highest collision energy ever – to my mind – we'll change the view of the Universe. We are entering a very exciting phase of particle physics, astrophysics, and cosmology.

It is important to point out that the LHC not only hopefully opens new frontiers for basic research but it has also opened new frontiers for technology. For example, when the idea of the Large Hadron Collider came up 25 years ago there was no magnet technology existing which could serve this accelerator, i.e. no superconducting magnets of the type, which could give sufficient field to reach such energy of protons. The basic research drives innovations in technology and also in information technology.

AMK – *One is unable to predict what innovations will be driven by the LHC in several years…*

RDH – That's right. In this case, it always takes the foresight, imagination and vision of people who have specific needs in their research. At the LEP the basic research drove the World Wide Web. At the LHC it has already driven the [computer] Grid. These two innovations have been driving education and training.

AMK – *Are you confident beyond any reasonable doubts that a malfunction of a scale of the accident on September 19, 2008, will not reoccur at the LHC?*

RDH – I am confident. We've done all the things, introduced all the measures, we could. We have installed a lot of newly built equipment to make the machine better than before. The point is this: whenever you make a new project, usually the new technology is not so much failing. It is the old technology that fails because people think they know how to execute it.

AMK – *The LHC has been brought back to operation incredibly quickly. After the two space shuttle disasters, each time it took something like three years to get the space shuttle flying again. The Tevatron at FermiLab was being adjusted for several years. The job done within 14 months at the LHC is formidable, fantastic.*

RDH – Oh, yes. On Nov. 20, 2009, we restarted the LHC. Within four days we got it running very well.

The job, if we would not have changed anything, would still be quite faster. But we've changed a number of things because we wanted to avoid a problem like the one in 2008 in the future. For some people it was long but if one sees how much work was done, how many new things had to be done – then one can appreciate that indeed the job was done in a short time. Among other things, like replacing the magnets, connectors, cables, etc., one was kind of a miracle to me: over four kilometers of vacuum tube were cleaned so quickly.

AMK – *In the opinion of the many, you have personally "injected" a new optimism among the LHC staff.*

RDH – You see, the things had worked so well at the beginning. Then the accident happened. People are pulled down to a big depression when something like that happens. The first job was to bring people up and bring back the optimism. I'm a born optimist. I think I was able to transfer my optimism.

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AMK – *Yesterday, at the Cracow Epiphany Conference you said that, if everything goes well, in 2010 you would be running the LHC at 3.5 TeV each ring.*

RDH – 3.5 TeV x 2 means the proton collision at 7 TeV in the CM system. We'll get there this year. Then we'll have some work to do on the magnets. After that, we'll gradually ramp the energy up to 7 TeV x 2. I will be very cautious in doing that. Further, in the next few months we'll be brainstorming on how we could improve the luminosity of the LHC. With a new machine it will be easier than for a mature machine to improve the luminosity steadily.

AMK – *Please, let us talk a little bit about physics at the LHC. 7 TeV CM is one-half of the energy the LHC is designed for and expected to yield. So far, no one went significantly beyond the Tevatron energy (~2 TeV CM), but from theoretical predictions – is there much new physics up to 7 TeV CM?*

RDH – First of all, for the discovery of the Higgs boson the energy 7 TeV CM should be enough, but it will take time.

Higgs boson is the signature of the Higgs field, which is a scalar field, a field without any direction preference, i.e. everywhere in space. In the Standard Model the particles acquire their masses through an interaction with this field. The prime candidate for the mass acquiring mechanism is the Higgs boson; unfortunately it is not produced very often, and it decays because it is very short-lived. It may decay in different channels, depending on its mass. If it does exist, it will be found at the LHC. If it does not exist then something else has to be happening in the same energy range, which introduces the mass. And that something else would also be found at the LHC.

AMK – *In 2008 Peter Higgs said he believed the Higgs boson had been already detected at FermiLab but it's remained buried in the experimental data. If so, it would come down to algorithms and computing power to find it.*

RDH – Well, it might be true. But, you know, it's not only the question of computing power or algorithms. You have to find the needle in the haystack, many haystacks. And if the needle is very similar to the hay, it is very difficult to distinguish for it is in background and the background is large.

AMK – *And the physics – at the LHC – beyond the Standard Model?*

RDH – There must be such physics, another model that encompasses the Standard Model. The question is: Is it at the energy accessible to us with the LHC? And I believe it is.

If there exists a supersymmetric particle of the mass ~300 GeV/c^2, 7 TeV CM should also be enough. If we're lucky and Nature has supersymmetry in her pocket, we shall find it. It depends on the model; there may be a whole spectrum of supersymmetric particles. If I'm not mistaken, the mass of a supersymmetric particle of about 300 GeV/c^2 would explain dark matter.

The beam energy 3.5 TeV, i.e. 7 TeV CM, should open the window for discoveries. With the LHC energies we can look at the Universe 10^{-12} second after the Big Bang; we begin to look at the microcosm at the one hand and at the Early Universe at the other. This intrinsically means we can look at the connection between particle physics and the Early Universe. Extremely high energy density in the collisions makes the similarity to the Early Universe.

For example, the LHCb detector will study the origin of the matter–antimatter asymmetry. At the beginning of the Universe, matter and antimatter were created in equal quantity. If it would have stayed this way, we wouldn't be here. Shortly into the life of the Universe, a small asymmetry of matter and antimatter was introduced: one part in ten billion. This one part in ten billion is us.

AMK – *Dark matter and dark energy await explaning too…*

RDH – Ha! We are ready to enter the Dark Universe too. The future space telescopes can tell us more about dark matter in the Universe, its fraction, and how it is distributed, etc. However, only a particle accelerator can produce the dark matter in the laboratory to study it and tell what it is. The LHC might be the perfect machine to study dark matter.

The favoured candidate is the lightest supersymmetric particle (LSP). If supersymmetric particles do exist, the LHC will find their signature through the "missing energy" after they will have escaped the detector. But we have to understand our detector very well in order to prove the missing energy. It may take some time. With the LHC, and possibly a linear collider in later years, we can also measure the mass of the supersymmetric particle. Should this mass measurement correspond to the measurements of the dark matter fraction by space telescopes, then this particle would be responsible for the dark matter. If it wouldn't correspond, this supersymmetric particle would only be part of the dark matter and it would mean we have several species of dark matter particles. One way or another, particle physics and astrophysics together will explain the nature of the dark matter.

But this will explain only 25 percent of the missing mass of the Universe. Dark energy is supposed to inflate the Universe and be the cause of the expansion of the Universe in all directions. No direction is preferred. This is a scalar being 75 percent of the mass of the Universe.

There is a field predicted that is scalar: the Higgs field. It would be the first fundamental scalar ever detected. If we could measure this scalar, it might give us some hint also on dark energy. I'm not saying the Higgs is the dark energy. The question is: could the Higgs give us some handle on dark energy?

AMK – *Let's sidetrack a little bit. You've mentioned the LHCb detector. There are three more detectors at the LHC: ATLAS, CMS, ALICE.*

RDH – These are the most complex detectors existing today. They are indeed an engineering art. We will have 40 million collisions and 10^9 interactions within a second. Approximately 10^3 particles are produced per collision. This is an enormous challenge for the detectors and for data processing. Trough the Grid we are connected to 200 computing centres over the world, where the data will be distributed and stored.

It is not enough to find a new particle. In order to prove that the Higgs mechanism alone is responsible for the mass we have to measure its properties very precisely. Only then we could understand for the first time properties of a fundamental scalar. And if supersymmetry exists then there exist more than one Higgs boson. So, there is a whole plentitude of measurements awaiting to be done.

AMK – *However, one of the applications of the three detectors will be different than others, i.e. heavy ion collisions. Are you ready for the heavy ion beam too?*

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RDH – We did not have yet the heavy ion beam inside the LHC but such a beam was at the entrance to the LHC, passed the injectors and the transfer lines. The machine people do not expect big problems with the heavy ion beams; it should go relatively smoothly. Three of the detectors, ATLAS, ALICE and CMS, will also look after the experiments with heavy ion beams.

AMK – *Perhaps the LHC will take over from the Relativistic Heavy Ion Collider (RHIC) in the United States?*

RDH – It could well be so…

AMK – *Do you have any priorities for the experiments, or will all of them proceed simultaneously: search for the Higgs, the supersymmetric particles and thus the dark matter?*

RDH – All at the same time. The densities of the two beams are sufficient and the beams are immediately refocused after the collisions inside the detectors. These experiments are very big and many, many people are involved in them. Some people will study process "a", some process "b", etc.

AMK – *The next generation linear colliders like the ILC and/or the CLIC are close to the final design stage. You had worked on the ILC concepts. I know future decisions depend on the results from the LHC. How do you perceive the future for the ILC or the CLIC?*

RDH – Whatever we know on the Standard Model we do only because of the use of two types of colliders: proton colliders and lepton colliders. We do need input from both types of colliders, a synergy between them. Like in astronomy we need data in visible light, ultraviolet, infrared, radio wavelength, gamma rays. The same is the case with the types of colliders. I'm convinced that whatever the LHC finds, it will need to be complemented by results from a linear collider. The big question is: At what energy? Therefore we have to wait for the results from the LHC.

However, we have to have a concept that we have proven it can be built. The right moment to talk with politicians and funding agencies about the next linear collider would be when the LHC will have demonstrated exciting and amazing discoveries. Then we'll have a good justification for the next collider capable of still higher energies.

AMK – *It may come rather sooner than later…*

RDH – I can tell you my wishful thinking: I should like it comes before 2013 – because it is when my mandate at CERN ends – in order to determine the future of particle physics. It could be the ILC, it could be the CLIC – depending which energy we'll need at the new machine. Secondly, it will depend on how the technology is developing. Thirdly, perhaps most importantly, how much it would cost.

AMK – *The higher and higher beam energy will always be needed – but we'll never get with accelerators to the neutrino, GUT, and Planck scales.*

RDH – Of course not. But nonetheless, for any new project, one has to have a very good argumentation as to why a certain energy is better, sufficient, etc.

AMK – *There is another class of facilities particle physicists and astrophysicists want to expand: underground huge-mass detectors mostly for neutrino physics and astrophysics, and search for proton decay. People involved in this area in the USA, Canada, Japan, and Europe have big expectations. Currently, the LAGUNA Project makes feasibility studies for a pan-European underground laboratory with huge-mass detectors of three kinds. Do you consider it a complementary field?*

RDH – Definitely, it is complementary within the same field – it is particle physics, which looks into the microcosm and the Universe. It is necessary that one performs such experiments or observations but – clearly – it is also competition for funding. Therefore, one has to think carefully what one could do with one or two of such facilities in Europe. Can one do both neutrino physics and proton decay with a single large detector?

AMK – *Two days ago, at the Cracow Epiphany Conference, Dr. S. Parke from FermiLab talked about their plans for a muon collider and a neutrino factory that may be built at FermiLab.*

RDH – This is the field of particle physics the United States could take the lead. But don't forget Japan. They also have a very good program in neutrino physics.

AMK – *Yet there is an interest in such a program in CERN too.*

RDH – There is surely an interest. But, I reiterate, we have to carefully look at what we can do. With the LHC we have already a lot on our shoulders. CERN has to perform forefront science in a leading role. We have to carefully check out the CERN program to see how it can suite different tasks.

AMK – *If they find the proton decay – that would be the forefront science…*

RDH – Yes. But the question is who would be the first…

AMK – *Incidentally, in December 2009 there was an announcement from the Soudan mine facility in Minnesota that they had detected two events that might be attributed to the dark matter. Can one event be enough, if proved?*

RDH – Definitely, you need more than one event… You need a more general framework. Another group has to confirm it.

AMK – *Does CERN support other branches of physics and information technology?*

RDH – We at CERN can support only projects directly connected to our main program. However, we try to be more involved in some applications where we can help other facilities. One example is hadron cancer therapy. With our expertise we help developing hadron therapy centers.

AMK – *In your public lecture yesterday you brought up one generally unnoticed point: We have antimatter in the hospitals – positron emission tomography (PET).*

RDH – Yes. One has to realize that! That's antimatter, I simply spelled it out.

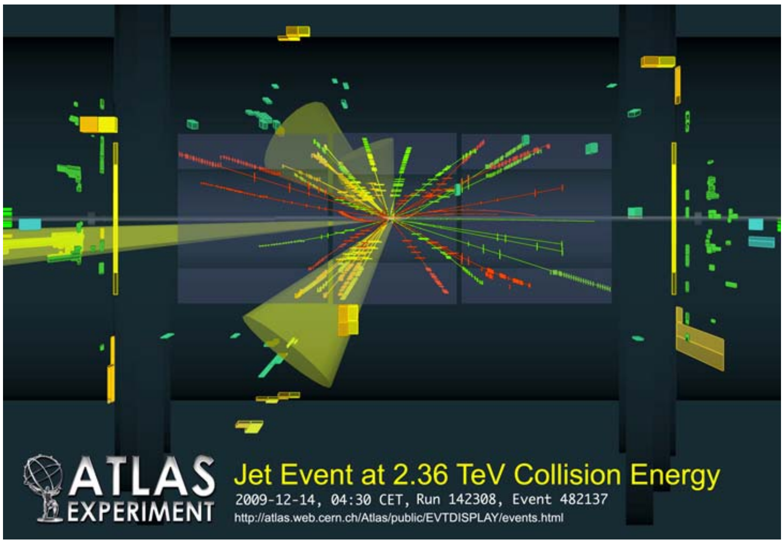
AMK – *You said at CERN people of 97 nationalities are registered.*

RDH – Science is a global language. Everybody can speak science. It should be open to everybody. Science, research and education are the bridge between nations.

AMK – *Good luck to you, Sir, with the LHC. It's been a privilege to me to talk to you.*

The interview held in Cracow, Poland, Jan. 8, 2010;
the text authorized by R.-D. Heuer at CERN, Jan. 12, 2010.

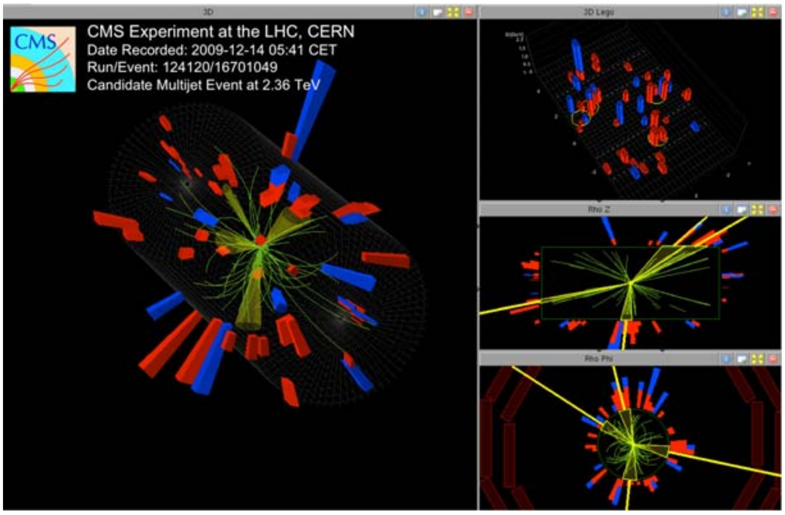
LHC – Photo gallery



CERN-EX-0912226 03

On Tuesday evening, 8th December, 2009, the LHC achieved for the first time 2.36 TeV collisions, and ATLAS detector recorded their first events at this record energy. More events at this energy were taken on 14th December in early morning. **© CERN**

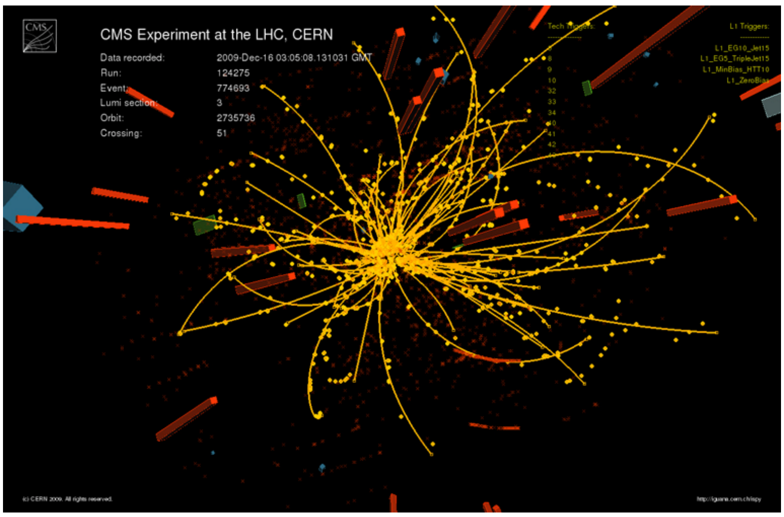
Photograph: ATLAS Collaboration
Date: 14 Dec 2009



CERN-EX-0912222 02

Some of the first candidate collisions in the CMS detector from 2.36 TeV run (1.18+1.18) of the LHC. Recorded on 14th December 2009. **© CERN**

Photograph: CMS Collaboration
Date: 14 Dec 2009



CERN-EX-0912231 01

Screen capture of a couple of proton-proton collision events in the CMS detector at a centre of mass energy of 2.36 TeV under "quiet beam" condition. 16th December 2009. **© CERN**

Photograph: CMS Collaboration
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