Symposium 1

European Research Infrastructure (Neutron, Muon and Photon Sources, Low-Energy Ion Accelerators)

Convener:

Y. Petroff
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X-RAY SCIENCE AT THE EUROPEAN SYNCHROTRON RADIATION: RECENT RESULTS AND FUTURE CHALLENGES

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Third generation synchrotron radiation sources are presently reaching their full maturity. Their impact is very widespread, and many areas of science and technology are strongly benefiting from them. Fundamental research problems are regularly addressed, and typical examples are provided by: I) High pressure research, where equation of state, physical properties and new materials are investigated at very exotic conditions, ii) Highly correlated systems, which are studied with novel polarization dependent scattering and spectroscopy techniques, iii) time resolved studies, addressing microscopic processes in the sub-nanosecond range, iv) The extraordinary revolution in biology, which is fostered by the exploding field of structural studies of proteins. The present contribution will illustrate few examples in this respect. Moreover sometime will be devoted to new challenging possibilities, as the fields that may become available in the future thanks to expected instrumental achievements from new storage ring, extreme x-ray focusing, and exotic samples and sample environments.

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SCIENCE WITH VUV AND SOFT X-RAY SYNCHROTRON LIGHT SOURCES

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The development of « third-generation » synchrotron light sources of VUV and soft x-ray radiation has been particularly intense in Europe, but also in the US and in the Far East. These sources provide photon beams characterized by high brilliance, high degree of spatial coherence and also tunable polarization properties. They are particularly important in the determination of the electronic properties of matter, with techniques such as photoelectron spectroscopy, photoabsorption, resonant x-ray scattering and imaging. An important extension of the powerful photoemission techniques for the investigation of electronic states is obtained by the achievement of spatial resolution, from the sub-µm to the ~10nm scale, either by focusing the photon beam with suitable optical elements, or by imaging the photoelectrons by electron optics devices. These techniques have found applications as diverse as the study of catalytic action, the imaging of domains in magnetic nanostructures (exploiting the polarization properties), or the study of growth and deposition processes. The polarization properties are also useful in the study of magnetic and strongly correlated systems by absorption and/or resonant scattering techniques. The emergence of new techniques such as inelastic VUV scattering is also discussed.

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ANTIBIOTICS TARGETING RIBOSOMES

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Resistance to antibiotics is a major problem in modern therapeutics. Antibiotics are small chemical agents (m.w. 600-800 Dalton), designed to eliminate bacteria. Over 40% of the useful antibiotics interfere with translation of the genetic code into proteins; a fundamental life process, which, in rapidly growing bacterial cells consumes up to 80% of the cell's energy. Most of these antibiotics target the ribosomes, the universal cellular organelles catalyzing this process. Ribosomes are giant nucleoprotein complexes (m.w. 2.3 mega-Dalton in prokaryotes and 4.5 mega-Dalton in mammalian), built of two independent subunits that associate upon the initiation of protein biosynthesis. The larger subunit creates the peptide bonds and provides the path for emerging proteins and the smaller controls the fidelity, the initiation and the termination of the biosynthetic process.

We identified bacterial sources suitable to serve as pathogen models and used their ribosomes for crystallographic studies with bright synchrotron radiation. These led to the localization of clinically relevant antibiotics that were found to inhibit ribosome function by interfering with substrate binding, hindering the progression of nascent proteins or limiting ribosomal mobility. All bind primarily to ribosomal RNA and do not cause major conformational changes. Understanding their modes of action provide powerful tools for rational drug design.

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ESS: A QUANTUM LEAP IN RESEARCH OPPORTUNITIES

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Tremendous progress in neutron scattering research capabilities has been achieved over the past half century primarily by the development of the performance of the instrumentation, both in terms of new concepts and approaches and advances in components, such as detectors. Over the same period of time the brightness of neutron sources only increased by a modest amount. ESS will offer an unprecedented jump of some two orders of magnitude in a crucial source performance parameter, the instantaneous peak flux during the pulses compared to the leading continuous or pulsed neutron sources existing today, while in terms of time average flux it will equal the most powerful continuous sources. The pulsed character allows for a more efficient use of the total number of neutrons produced, and this efficiency differs from one application to another. The goal of the ESS project is to combine the vastly enhanced, unique source quality with the most advanced instrumentation concepts and techniques to achieve a quantum leap in neutron scattering research opportunities well beyond what could be achieved by concentrating only on enhancing the source performance or only trying to further develop instrumentation. The results of the combined effort as characterised by the sensitivity of observing small signals.(which is the main limitation in the use neutron scattering techniques in general) are found to amount to as much as three orders of magnitude in some unique core applications and more than two orders of magnitude in the majority of neutron scattering work. To achieve this huge step forward, well comparable to the progress expected from the realisation of large free electron laser in X-ray research, we need to vigorously advance neutron scattering instrumentation techniques together with the source performance. Extensive experience accumulated over the past 5 decades of using continuous reactor source and nearly 3 decades of progress with pulsed spallation. sources provides a solid and sophisticated basis for this effort. The utilisation of innovative concepts will further enhance the efficiency of using source power in the actual experiments. Examples include enhancement of the efficiency of extracting and transporting neutrons from the source to the sample by advanced neutron optical means, or sophisticated so called multiplexing techniques, which allow us to optimise the efficiency gains by the pulsed character of the source simultaneously for a large number of instruments with very different characteristics. As a result ESS will not only surpass all other neutron sources (existing or being built) by its higher neutron brightness achieved by more proton beam energy per pulse, but it will enhance this advantage by the more efficient use of the neutrons produced.

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MUON BEAM RESEARCH IN CONDENSED MATTER SCIENCE: ACHIEVEMENTS AND PROSPECTS

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The overriding strength of μSR, a generic acronym for muon spin relaxation, rotation and resonance techniques, is that it is a uniquely sensitive probe of extremely small magnetic fields and the distribution and dynamics of such magnetic fields within a sample, both in zero and applied magnetic field. Indeed the sensitivity of μSR is such that fields generated by nuclear moments are easily measured, whilst the dynamical response (10^{-12}-10^{-4} s) serves to bridge the gap that separates, for example, neutron spin echo methods from the bulk measurements of magnetization and susceptibility. The field dynamics measured by the muon can be related either to intrinsic internal field fluctuations, or to the apparent fluctuations caused by a muon diffusing through a lattice. The latter case is often of key interest, as the muon itself behaves like a light isotope of hydrogen (M_μ=1/9amu) and therefore can be used to probe hydrogen-like diffusion processes.

The unique sensitivity of μSR has secured its role as an indispensable and increasingly important tool in the armory of the condensed matter scientist. Over the last decade the extremely successful and often pioneering exploration of phenomena as diverse as spin glass dynamics, spin fluctuations in itinerant electron systems, magnetic ordering in ultra-small moment systems, critical dynamics, flux distribution in superconductors, hydrogen mobility, passivation in semiconductors, muonium formation and dynamics in proteins and, more recently surface and near surface effects, has provided a testimony both to the wide applicability of muon beam techniques and to the breadth of the muon beam user community.

Europe is particularly fortunate to host two major world-class muon facilities, namely PSI in Switzerland and ISIS in the UK. In this presentation I will briefly revue the impact of the muon beam research performed at these facilities, and also extrapolate beyond existing facilities and capabilities to what the proposed European Spallation Source might be able to offer muon spectroscopists in the future.

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ION BEAM ANALYSIS TODAY AND TOMORROW

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Ion Beam Analysis (IBA) is a general name of wide group of analytical methods, based on the observation and analysis of various particles emerging from the investigated sample under MeV energy ion impact. The most widespread IBA techniques are:

	name	*observed particle*
RBS	Rutherford Backscattering Spectrometry	elastically scattered ions
ERDA	Elastic Recoil Detection Analysis	elastically recoiled target atoms
NRA	Nuclear Reaction Analysis	nuclear reaction products (p, á, γ...)
PIXE	Proton Induced X-ray Emission	characteristic X-rays

RBS, the first IBA method, was introduced for thin film analysis in the field of semiconductor technology in the early 1960's. Since then, new IBA methods are continuously developed and applied in various fields of application. Today it is routine to determine the depth distribution of almost all the elements and isotopes in the first few ìm of the sample with sensitivities of a few tenths or hundreds of at% and with a depth resolution of a few nm (near to surface). The lateral size of the investigated spot in most cases is a few mm^2, but in microbeam facilities the beam size can be reduced to few ìm^2. IBA is not sensitive to chemistry, gives reliable information only on the elements existing in the sample.

To remain competitive with other surface sensitive analitical methods unique features of IBA have to be developed. In the years past some remarkable results have been achieved. The sensitivity of the method can be extremely good using coincidence detection methods (e.g. H detection with ERDA using H ions) or AMS (Accelerator mass spectrometry). Atomic scale depth resolution can be achieved using magnetic or electrostatic spectrometers. Application of time of flight energy determination forecasts also significant improvements. The lateral resolution of few hundred keV Focussed Ion Beam devices, applying electrostatic focusing, is now being to reach the few nm scale. The impurity lattice localisation by channelling with sub-angstrom spatial resolution still remains an attractive feature. New IBA setups using compact accelerators of 1 MeV energy are now available in the market.

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Symposium 7

High-Energy Accelerators and the Future of High-Energy Physics

Convener:

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THEORETICAL PERSPECTIVES OF PARTICLE PHYSICS

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The symmetries of the standard model of particle physics point towards a unified theory of all particles and interactions. This leads to the quest for supersymmetry and to the prediction of baryon- and lepton-number nonconservation, with important implications for particle physics and cosmology.

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WHAT HAVE EXPERIMENTS TAUGHT US?

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Recent results from neutrino oscillation experiments and cp-violation experiments are discussed together with a summary of the main successes achieved in the last years at the large colliders: LEP, HERA and TEVATRON.

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THE SCIENTIFIC ROADMAP OF PARTICLE PHYSICS IN THE COMING 20 YEARS

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The Large Hadron Collider, currently under construction at CERN, should be completed in 2007. It is likely to revolutionise our understanding of particle physics. There is an unprecedented world-wide consensus that the next major project in particle physics, which will complement and extend the research that can be done at the LHC, is the construction of a linear electron-positron collider with an energy of at least 400-500 GeV. My talk will explain why this is the case and put it in the context of other current or planned facilities. I will also discuss what other developments will be important in the longer-term future to ensure that progress in understanding the fundamental constituents of matter can continue.

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CHALLENGES FOR ACCELERATORS

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The major facilities implied by the present Roadmap for Particle Physics are outlined. They comprise an electron-positron linear collider, advanced neutrino beams and a very large hadron collider. The possible upgrade options for the Large Hadron Collider (LHC) under construction are also briefly reviewed. The outline emphasizes the most critical issues. The present global effort and the medium-term plan for accelerator R&D addressing these issues are presented

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PARTICLE PHYSICS WITHOUT ACCELERATORS

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The first elementary particles not present in normal matter were discovered in the 1930's using cosmic rays in a period before the development of accelerators. Following 60 years during which the majority of knowledge in particle physics came from accelerator based experiments, non-accelerator experiments have begun again to make major discoveries.

In this presentation the experimental developments in non-accelerator particle physics of the past decade will be described together with planned future projects. The subjects covered will range from searches for proton decay; measurements of neutrino mass differences with neutrino oscillations; searches for dark matter and high-energy astronomy with cosmic rays, gamma rays and neutrinos.

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CHALLENGES OF GOING GLOBAL NEW PARADIGMS FOR PARTICLE PHYSICS?

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Particle Physics, astrophysics and cosmology have advanced in parallel to produce what could be called a standard model of the Universe, but recent observations have raised very fundamental questions about the early stages of the Universe and its fundamental composition in terms of matter and energy. It is generally accepted that the next generation of accelerators and detectors required to probe physics 'beyond the Standard Model' will require a changed paradigm, from national or regional facilities exploited internationally to inherently global projects, fundamentally different in their basic organizational concepts. Global projects are not new to science, but building a major new facility which will be open to researchers on a global scale is a new undertaking which poses questions which can only be addressed at governmental level.

The OECD Global Science Forum (GSF) established the High Energy Physics (HEP) Consultative Group (CG) in June 2000 to exchange views on the future direction of HEP, particularly as regards large facilities, examine the rationale behind programme priorities and strategies, look at common or generic issues and approaches, and identify and discuss relevant organization and managerial issues. It reported to the GSF in June 2002.

The report states that "the Group was impressed by the range and depth of the studies carried out by the world-wide HEP communities in setting out the scientific and programme priorities over the next decade and beyond, and by the degree of unanimity between the communities in all regions" and that "the Group found the scientific arguments presented by the communities to be compelling. "

A wide range of organisational and managerial issues associated with the creation of a major new international facility were studied. These are all areas where work will be required of the proposers of such projects and the participating governments. Specific issues highlighted in the discussion included: legal structure, financial arrangements, managerial structure, reporting and accountability, host nation and host laboratory. A key issue that is already exercising the communities is the mechanism whereby international negotiations on the next steps towards a linear collider can be started. The Group looked at the ways in which community driven initiatives offering different technological approaches to common scientific objectives might be reconciled to converge on a global consensus and, ultimately, funding decisions.
The conclusions of the report will be described, as will proposed follow-up activities, and possible implications for other areas of science will be mentioned.

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