Technical University of Denmark DTU

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CAMEA

Scientific Demand for CAMEA

Author:

P. G. Freeman

PAUL SCHERRER INSTITUT

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Scientific Demand for CAMEA

To document the enthusiasm for the CAMEA spectrometer, we provide in this document:

i) Letters of support from leading scientists representing several of the fields of science that will be enabled by CAMEA.

ii) A list of scientists who wished to be listed as supporters of CAMEA, because they are keen to see CAMEA built.

iii) Statistics from a survey to identify the need for CAMEA, and the demand for each of the advanced measurement capabilities CAMEA will enable.

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23 October 2013

To Whom It May Concern

I am writing to provide a letter of support for the CAMEA spectrometer which has been proposed as one of the instruments for the ESS.

My research interests encompass various aspects of the physics of novel superconductors and quantum magnets. For the last 25 years or so I have been interested in developing methods for studying the fluctuations that endow these materials with their unusual properties, most especially those based on neutron scattering. During this time I have developed an appreciation of the need to continually develop the sources and instrumentation in concert, as it is only by so doing that we can drive the science forward in the direction of addressing ever deeper questions on the nature of correlated electron states.

In my opinion, the CAMEA spectrometer at the ESS will open a new window on our understanding of the fundamental origin of the novel phases displayed by unconventional superconductors, quantum magnets, and other correlated systems. CAMEA, optimized as it is from the outset for extreme sample environment, and benefitting from the most intense neutron beams available, will allow radically new types of spectrometry to be performed. For example, studying the critical fluctuations at a pressure induced quantum critical point for pressures above 20 kbar. I therefore recommend selection of the CAMEA project in the highest possible terms.

Yours sincerely,

Des McMorrow

Professor of Physics
Deputy Director, London Centre for Nanotechnology
University College London

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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KAVLI INSTITUTE FOR THEORETICAL PHYSICS
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Dear Colleagues:

I am writing in support of the proposed Continuous Angle Multi-Energy Analysis (CAMEA) spectrometer project. I am a theorist working broadly in correlated electronic systems and with a particular interest in complex magnetic materials, and would like to comment on the suitability and promise of this new instrument for that field.

Neutron spectroscopy has been and continues to be the pre-eminent tool for studying magnetism of solids. From elastic measurements of static order to inelastic studies of spin waves, it has formed the basis of our understanding of canonical ordered magnetic systems. In these situations, the order and excitations manifest as sharp peaks in line cuts of energy versus frequency, or versus wavevector. The sharpness of these peaks is a consequence of well-developed long-range order and of simple, particle-like spin-wave or magnon excitations. Seeing just the peaks really suffices to understand most of the physics in such cases.

However, there are many other system in which the physics does not manifest as sharp peaks, and indeed the information lies *entirely* in continuum scattering. There is a huge amount of information there, capable of describe subtle intermediate-scale or power-law correlations, and of revealing exotic excitations which are not particle-like. Such properties are the hallmarks of many long-sought states of matter, most notably quantum spin liquids, which have gone from a fringe idea of Phil Anderson to a hot – and hotly contested – field of research. New neutron spectrometers that can capture the continuum scattering with fine resolution are really the ideal tools to probe and discover these novel states. They will also be helpful much more generally with magnetic materials with complex interactions and large fluctuation regimes.

The proposed CAMEA spectrometer not only will provide broad maps of the diffuse scattering over large regions of momentum space in a single experiment, allowing the rapid identification of key features, and revealing these subtle fluctuations and excitations, it will do so with high resolution in the low to intermediate energy range relevant for the most interesting magnetic problems. I am also heartened by the promise of CAMEA to provide this information on considerably smaller samples than is possible at present. The need to produce large crystals is particularly onerous for the most interesting low-spin materials with small magnetic moments, and often in the discovery stage any crystals at all are hard to come by. Any steps to make that requirement less stringent will greatly speed scientific progress. In summary, I am excited at the scientific prospects of CAMEA, and strongly support its development at the ESS.

Sincerely,

Leon Balents
Permanent Member, KITP and
Professor of Physics

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11 October 2013

Letter of support: CAMEA – the Continuous Angle Multiple Energy Analysis spectrometer

Dear Dr Freeman,

This is to express my strong support for your proposal for an instrument at the European Spallation Source.

The proposed CAMEA instrument will allow researchers to address a wide range of topics including our research area of strongly correlated electron systems. Tuning of strongly correlated electron systems can induce phase transitions and lead to the emergence of exciting material properties associated with quantum critical behaviour and with the formation of novel states of matter. At Royal Holloway we are for example interested in the formation of exotic and high-temperature superconductivity as found in iron-based compounds and the properties of magnetic quantum critical regimes in other d-electron systems.

In the past, hydrostatic pressure has proven to be a key tuning parameter in the exploration of strongly correlated electron systems as it provides highly controlled system tuning without externally induced symmetry breaking. Therefore, one of the particular attractive features of the proposed beamline is the envisaged high-pressure option and compatibility with Paris-Edinburgh large-volume high-pressure cells. This includes the design features of maximising count rates in the horizontal plane, having a well-defined flight path and sophisticated shielding, which will minimise background particularly from the pressure-cell sample environment. This will allow us to study the dynamics of tiny crystals down to $1 mm^3$ in a wide parameter range and dramatically increases the number of accessible model systems.

At Royal Holloway, we have developed and are improving thermodynamic and transport techniques for high-pressure/low-temperature studies and we are now adding high-pressure/low-temperature X-ray diffraction experiments at the Extreme Conditions beamline I15 at Diamond Light Source. We would in the future greatly benefit from the possibilities CAMEA offers. Inelastic neutron scattering at high-pressures/low-temperature would complement our in-house capabilities and other experimental techniques available at large-scale facilities. CAMEA would allow us to study spin dynamics in a wide range of pressure-tuned compounds. We hope to be able to make ample use of the proposed facility.

Yours sincerely,
Philipp Niklowitz

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

College of Liberal Arts and Sciences
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May 5, 2014

Dear Henrik,

I am very excited about the CAMEA concept and proposal. I support it very strongly. As I understand it, Continuous Angle Multiple Energy Analysis (CAMEA) will allow for rapid data collection of inelastic neutron scattering data (i.e. dispersion curves) on relatively small samples as a function of temperature, pressure, and magnetic field. This would allow for the incorporation of inelastic neutron scattering into the materials / states discovery process. This would be a distinct change from neutron scattering's current role as a "high end" experiment that takes place as part of the detailed characterization of well characterized systems requiring very large samples and months if not years of sample preparation.

As an example CAMEA could aid in the identification of classes of compounds that might support new examples of high temperature superconductivity. Currently the feeling in the field is that some sort of "fragile" transition metal magnetism, that can be suppressed with either pressure or substitution, is key to finding new examples of the high T_c superconductivity found in the the CuO- as well as the FeAs-based systems. The problem is that in order to identify promising systems we need rapid feed back about the magnetic fluctuations in potential systems, often as they are doped or as pressure is applied. CAMEA can provide these data in a real time setting, studying samples on the 1 mm^3 scale. It would be my hope to have CAMEA run through scores of samples at ambient and high pressure and use these data to screen promising systems for further detailed synthesis and characterization. This would mark a turning point in the use of inelastic neutron scattering in terms of its use as an exploratory tool for new materials / states discovery.

Superconductivity is not the only example. Cleary CAMEA will be of great use for other pressure based systems, I can think of materials that we use pressure on to induce quantum criticality (by suppressing either anti- or ferromagnetic states) that would greatly benefit from that data that CAMEA could collect as well.

To repeat, I think CAMEA concept is GREAT and I strongly endorse it and hope to use it as well.

Sincerely yours,

Paul Canfield
Fellow of the American Physical Society
Distinguished Professor of Physics and Astronomy
Robert Allen Wright Endowed Chair in Physics
Senior Physicist, Ames Laboratory
Iowa State University

Princeton University

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Robert J. Cava
Russell Wellman Moore Professor of Chemistry

September 4, 2013

Prof. Henrik M. Rønnow
Head of Laboratory for Quantum Magnetism
École Polytechnique Fédérale de Lausanne
Lausanne, Switzerland
henrik.ronnow@epfl.ch

Dear Henrik,

Thank you very much for explaining to me your proposed instrument project for the future ESS when we spoke at the MaNEP workshop earlier this year. I understand that the instrument would be designed with the goal of characterizing the magnetic excitations in new materials, including at high magnetic fields, high pressures, and low temperatures.

In my view, this instrument would have an extremely high impact in the international materials physics community, and I would like to lend a strong voice in support of your proposal. As you know, new physics is often found when looking from a new perspective at the characteristics of new materials. My role in the research community over the past 30 years has been to try to find the new materials that form the basis for that new physics. I think that many possible discoveries in physics have unfortunately been missed because new materials have not been available in sufficient size to support the neutron scattering measurements that are needed to characterize their magnetic excitations. This type of research is at the forefront on quantum materials, as recent work for example in characterizing the magnetic excitations in cuprate superconductors and pyrochlore magnets, performed on very large samples, has shown.

Your proposed instrument, which would be designed specifically with an eye towards the study of much smaller samples than can currently be used, will dramatically expand the number of new materials that can be studied, and thus dramatically impact the discovery of new physics. This is because very often the materials that have the potential to display exotic new physics cannot be grown as large crystals or high volume samples. I have very often been asked to provide a crystal of a new material for neutron scattering studies, but have not been able to do so because it was impossible for me to provide a sample of sufficient size to allow the experiments to be done; it happens all the time, and is very frustrating. It would be great for the international materials physics and chemistry communities if your proposed instrument can be built; I am sure that it would change the kind of research that can be done for a large number of researchers, and would result in the discoveries of many new phenomena. I strongly support your proposal.

Sincerely yours,

Robert J. Cava

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Paris, Octobre, 2013

To whom it may concern.

Letter of support: CAMEA

This letter is to support funding and construction of the CAMEA spectrometer intended to be installed at the future European Spallation Source ESS.

My motivation for this support letter is the following: I have been involved during more than two decades in neutron scattering, in particular the development of novel high pressure methods for which I have an international reputation. Such experiments allow only small sample volumes in the order of mm^3 if pressures up to 100 kbar or higher are aimed for, i.e. pressures which are relevant for material and Earth sciences. Whereas synchrotron sources can nowadays routinley collect data under these conditions, the much weaker flux of neutron sources severely hampers the study of matter under pressure using neutron radiation.

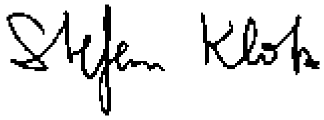
The CAMEA spectrometer is designed to overcome these limitations, thereby opening new directions in research under extreme conditions. CAMEA is optimized for the study of small samples in the mm^3 range. This is achieved by a clever combination of large detector coverage, a detector geometry allowing data collection at different final energies simultaniously, as well was a vastly improved signal-to-noise ratio. These are ideal conditions for high pressure measurements (potentially in combination with high temperatures) in the several 100 kbar range. This, in combination with the fact that ESS will have unprecedented neutron flux, will result in an instrument which will be unique in its kind. In addition, the horizontal scattering geometry of CAMEA is perfectly adapted to the geometry of high pressure cells which can reach 100 kbar and beyond.

In short: CAMEA has the potential of addressing fundamental questions on the dynamics and excitation of matter under extreme conditions, covering aspects of pure solid state physics (magnetism, highly correlated electron systems), material sciences (hydrogen in metals) and Earth sciences (diffusion and dynamics of hydrogen bearing rocks and minerals).

<u>I strongly encourage funding and construction of this instrument</u>. The team involved in the design of CAMEA are outstanding experts in neutron scattering with a strong interest in high pressure and extreme sample conditions in general. Having worked for decades in high pressure neutron scattering, I am delighted to see this team embarking in extending the frontiers of material research under extreme conditions.

Finally, I happen to be the current chairman of the European High Pressure Research Group (EHPRG, http://www.ehprg.org/), a more than 50 year-old organisation devoted to high pressure research and technology in Europe. In this function I wish to underline the importance of CAMEA for the European high pressure community. Most neutron activity worldwide is currently devoted to diffraction, in its own right. Probing dynamical properties under pressure using neutron has so far been neglected – for technical reasons – and CAMEA would fill a gap which is presently a ‘green field’. Funding agencies should realize that this is a unique chance to ensure the competitiveness of a large European science community covering very diverse research topics as listed above.

Sincerely,



Stefan KLOTZ
Head of the high pressure group
Chairman of the European High Pressure Group EHPRG
Editor in Chief of *High Pressure Research* (Taylor & Francis)

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To whom it may concern

N/réf. PG / cp

Ecublens, le 28 octobre 2013

Letter of support: CAMEA

This letter is to support construction of the CAMEA spectrometer intended to be installed at the future European Spallation Source ESS.

During my scientific carrier I have been involved in developing forefront methods for the investigation of systems of geophysical interest, and in particular I have, as first, developed the application of high-pressure methods (DAC) at synchrotron radiation facilities. Whereas synchrotron sources can nowadays routinely collect data under the extreme conditions relevant for Earth and Planetary Science, the much weaker flux of neutron sources still severely hampers this kind of studies. However neutrons are the ideal probe to investigate light elements which are scarcely visible to x-rays, and in particular hydrogen and hydrogen based systems, like water, methane, ammonia, which are basic constituents of earth and planets. In the last few years, a tremendous effort has been undertaken by several groups around the world to the determination of the structure of these systems up to very high pressures, a program in which my group has been actively involved. However, the knowledge of the dynamical counterpart lags far behind, due to the intrinsic technical difficulties linked to the necessity, for energy discrimination, of samples of large volume.

The CAMEA spectrometer is naturally designed to overcome this limitation as it is optimized for the study of small samples in the mm^3 range, thus providing the unique opportunity to develop neutron spectroscopy under extreme conditions. In particular, the combination of large detector coverage, simultaneous data collection at different final energies, and excellent signal-to-noise ratio, provide ideal conditions for high pressure measurements in the several 100 kbar range. This, in combination with the fact that ESS will have unprecedented neutron flux, will result in an instrument which will be worldwide unique.

CAMEA is perfectly suited, due to its horizontal scattering plane, to the new generation of large volume presses recently developed for dynamics studies, and will thus provide the most versatile solution for a broad community of users interested in both fundamental, and applied research in a wide field ranging from planetary interiors to the recovery to ambient conditions of non-equilibrium structures having novel functional properties.

Therefore, the access to dynamical properties under extreme conditions guaranteed by the CAMEA specifics will open new exciting prospective in the field and will provide an a unique chance to ensure the competitiveness of a large European science community.

For all these reasons I strongly encourage construction of this instrument.

Philippe Gillet

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Hamilton, October 30th, 2013

Prof. Henrik M. Rønnow
École Polytechnique Fédérale de Lausanne
Lausanne, Switzerland

Dr. Niels Bech Christensen
Technical University of Denmark
Department of Physics
Kgs. Lyngby, Denmark

Dear Henrik, Dear Niels,

I very enthusiastically support your proposal to build the novel Continuous Angle Multiple Energy Analyser spectrometer CAMEA at the future European Spallation Source ESS.

The determination of molecular dynamics in biological materials is certainly one of the greatest challenges in modern biology and biophysics. Few experimental techniques can access structural and dynamical properties on the nanometer scale. Advanced neutron scattering techniques have proven to be powerful tools to study dynamics and interactions in membranes and biomaterials down to nanometer length scales and up to the relevant picosecond and nanosecond times. However, sample sizes are typically small and the corresponding dynamical signals are further reduced by the intrinsic static and dynamic disorder in these materials, especially under physiological conditions.

Due to its design, CAMEA will be optimized for small samples and allow a fast data collection, thereby covering the relevant length and energy scales simultaneously. By aligning the materials, such as solid supported oriented membranes, spider silk or hag fish fibres, hair and chitin structures for instance, dynamics in the direction of interest can be measured fast, with a high resolution and a good signal to noise ratio. The high intensity of the machine should make it possible to study kinetics in these systems as well, which is very difficult to obtain with the current neutron instrumentation.

You and your project team, including Kim Lefmann, Christof Niedermayer, Fanni Juranyi , Marko Marton and Paul Freeman, have considerable experience in inelastic neutron instrumentation and are certainly in an outstanding position to tackle this challenge and successfully design and build CAMEA. I would envision that researchers who currently already use neutron diffraction in biomaterials will study dynamics in addition to structure using this novel instrument, especially in combination with dedicated sample environments that allow experiments under physiological conditions, such as body temperature and high humidity. The existing biophysical neutron community will welcome this new instrument as it opens up new possibilities and will enable exiting new science in the future.

I am very excited about this new instrument. Please do not hesitate to contact me if you have questions or need further information.

Sincerely,

Supporting Names for CAMEA

In addition to obtaining letters of support for CAMEA at the ESS we have asked known neutron scatterers if they wish CAMEA to be built.

The following names are a list of neutron scatterers who wish to see CAMEA built at the ESS:

Peter Svedlindh (Uppsalla University)
Alexander Komarek (Max Planck- Dresden)
Paolo Santini (University of Parma)
Andre Strydom (University of Johannesberg)
Andrew Boothroyd (University of Oxford)
Louis-Pierre Regnault (CEA, Grenoble)
Bella Lake (HZB)
Richard Mole (Bragg institute, ANSTO)
Toth Sandor (PSI)
Adroja Devishibhai (ISIS, STFC)
Tom Fennel (PSI)
Kirrily Rule (Bragg Institute, ANSTO)
Martin Boehm (ILL)
Oleg Petrenko (University of Warwick)
Simon Kimber (ESRF)
Markus Braden (university Of Cologne)
Pregelj Matej (Institut josef Stefan, Ljubljana)
Aziz Daoud-Aladine (ISIS, STFC)
Chris Stock (University of Edinburgh)
Tob Perring (ISIS, STFC)
Rob Bewley (ISIS, STFC)
Andrey Zheludev (ETHZ)
Takatsugu Masuda (University of Tokoyo)
Mogens Christensen (University of Aarhus)
Martin Rotter (Max Planck, Dresden)
Franz Demmel (ISIS, STFC)
Linda Udby (University of Copenhagen)
Collin Broholm (John Hopkins University)
Duc Manh *Le* (*Seoul* National University)
Oliver Stockert (MPG- Dresden)

Survey

Condensed matter neutron scatterers that may have an interest in CAMEA, were asked to complete a short survey. They were asked about what extreme environments they are interested in for neutron scattering, and what aspects of CAMEA are they particularly interested in.

Survey:

We wish to know if you are interested in performing neutron scattering experiments under:

1) High magnetic field (aim is 25 T assuming cuprate magnets become available)? Yes/No
2) High pressure (10 GPa range accessible with Paris-Edinburgh cells)? Yes/No
3) Simultaneously high pressure and high magnetic fields? Yes/No

What capabilities of CAMEA (see below for details) are you interested in:

A) Rapid mapping of excitations/parametric studies? Yes/No
B) Studying small samples? Yes/No
C) In-situ studies? Yes/No
D) Time resolved studies? Yes/No

The results of the survey are:

Question	Yes (%)	No(%)	Possibly
1) High Magnetic Fields?	91	9	0
2) High Pressures?	61	33	6
3) High Pressure and High Magnetic Fields?	39	58	3
A) Rapid Mapping?	97	3	0
B) Small Samples?	100	0	0
C) In-situ?	36	61	3
D) Time Resolved?	36	58	6

For performing neutron scattering under extreme conditions the highest demand is for performing experiments under high magnetic fields, the extreme condition that already has a significant user demand for inelastic neutron scattering. Despite the present strong limitations of performing inelastic neutron scattering under high pressures, there is a high demand for high pressure studies. As high pressure studies are severely limited with present neutron instrumentation it is of little surprise that going one step further for combining high magnetic fields and high pressures for experiments has a lower demand.

From the questions about what aspects of CAMEA are neutron scatterers most interested in we have a clear result. CAMEA's ability to perform rapid mapping, and CAMEA's ability to study small samples are the two most appealing aspects of the instrument.