Benefits to Society of Particle Physics

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23/11/07

- Overview PP2020 KE Panel
- Accelerator Science
- Sensor Technology
- Electronics and Readout
- Computing, Software and Analysis Tools
- Special Skills and Competencies

The PP2020 Knowledge Exchange Panel

Aim of the Panel

To provide input into the IoP PP2020 Panel Chaired by Mark Lancaster on issues relating to KE and to help prepare the associated text and web-based back-up documentation

Membership and Expertise

Phil Allport (Liverpool)
Barbara Camanzi (RAL PPD)
Mike Poole (Director ASTeC, STFC)
Tim Short (Ex-Particle Physicists)
Marcus French (Head of RAL Microelectronics)
Jason McFall(Ex-Particle Physicist)
Val O’Shea (Glasgow)
Steve Lloyd (QMUL)
Stephen Watts (Manchester)

By invitation: Mark Lancaster (UCL), Nathan Hill (QI3) Victoria Wright (STFC)

The PP2020 Knowledge Exchange Panel

<u>Different KE Routes</u>

1) Directly funded intentional knowledge transfer to industry including setting up of spin-outs, Research Council schemes, industry/university initiated collaborations

2) Knowledge transfer via serendipity, industrial applications of ideas developed by particle physicists primarily for particle physics

3) Collaboration with industry to achieve major orders from large international particle physics tenders (many multi-£M contracts at leading international labs)

4) Know-how and technical skills acquired meeting demanding particle physics orders (possibly working with relevant scientists) leading to enhanced capability and prestige for delivery in other sectors

5) Acquisition by industry of personnel trained in particle physics techniques and with experience of competing in this state of the art international science arena

Indirect Benefits of Research in Particle Physics to Society

Phil Allport, Barbara Camanzi, Marcus French, ,Nathan Hill, Mark Lancaster, Steve Lloyd, Jason McFall, Val O'Shea, Mike Poole, Tim Short, Stephen Watts, Victoria Wright

In what follows I pick out highlights and some useful web references from this (still very rough) draft which I hope provide ammunition to anyone who may be engaging with decision makers of opinion formers.

Accelerator Science

CATEGORY OF ACCELERATOR	NUMBER IN USE*
High Energy (E > 1 GeV)	~ 120
Synchrotron Radiation Sources	> 100
Medical Isotope Production	~ 200
Radiotherapy Centres	> 7,500
Research Acc. (includes biomedical research)	~ 1,000
Acc. for Industrial Processing & Research	~ 1,500
Ion Implanters and Mills	> 7,000
TOTAL	> 17,500

(*) W. Maciszewski and W. Scharf, Int. J. of Radiation Oncology, 2004

Accelerators

Cyclotrons: radio-isotope production GE (Amersham) - Health/Industry

Synchrotrons: Photon science, … http://www.diamond.ac.uk/default.htm

Linacs: Proton drivers -> neutron spallation, ISIS, Oak Ridge, ESS

transmutation – energy amplifier – sub-critical reactors

industrial radiography linacs

Clatterbridge Centre for Oncology http://www.ccotrust.nhs.uk/index.asp

NS-FFAG: Neutrino Factory→ CONFORM (http://www.conform.ac.uk/) next generation hospital-based clinical accelerators for proton and carbon ion beam treatment of cancers, and fields from archaeology to zoology. (see Rob Edgecock and the EMMA Collaboration, "Introduction to the Non-scaling Electron Model FFAG EMMA", Nuclear Physics B - Proceedings Supplements, Volume 155, Issue 1, 2006, p321) CONFORM: Basic Technology grant (£8.2M)

Technologies for Accelerators

Magnets – superconductivity – Rutherford wire

Oxford Instruments (Martin Wood, Clarendon, Oxford) → MRI, Tesla

Fusion programme: IFMIF, ITER

RF High Power: (Magnetron → Klystron at SLAC) e2v, Toshiba, Varian, Thorn → Thorn Microwave Devices

Precision Engineering

Power supply stability, XFEL/ILC tolerances. LICAS. Control systems.

Health physics, shielding and nuclear power

Geant4 simulation, Fluka

Sensor Technology

Silicon microstrips: dosimetry, biomedical radiography, radioscopy (NIM A525 p294)

Hybrid pixel detectors: eg Pilatus at PSI SLS. Spin out company (http://www.dectris.com/sites/dectris.html)

Medipix: (licensed to Panalytical plc for X-ray diffraction, NDT, dosimetry (See http://medipix.web.cern.ch/MEDIPIX/)

CCDs; scientific demands coming from astronomy, space science and particle physics are helping to push the envelope of what is technically achievable in terms of readout speed, quantum efficiency, integrated functionality, pixel dimensions and array size. Examples of widespread use include digital cameras, including video cameras, and digital X-ray systems (http://e2v.com/introduction/app_dental_imaging.htm)

Other solid-state photon sensors: Silicon-PM, APDs,

Scintillators:

Institute for Cancer Research: "*only the large mass scale production of fast scintillators required by HEP experiment allowed the price of such scintillators to drop making them accessible for the medical physics community*" ,

eg Hilger Crystals Ltd CsI(Tl) for BaBar ECAL

Gas Ionisation Detectors:

Ionisation chambers, multi-wire proportional chambers (MWPCs) and Gas Electron Multipliers (GEMs). CERN applying GEMs to medical physics applications, eg X-ray, nuclear scattering radiography (Spin out: Oxford Positron System Ltd)

PET: *See* http://www.petrra.com/ and D. G. Darambara (ICR) "State-of-the-art radiation detectors for medical imaging: demands and trends" NIMA 569 (2006) p153 "*The significant advances achieved during the last decades in material properties, detector characteristics and high-quality electronic system played an ever-expanding role in different areas of science, such as high energy, nuclear physics and astrophysics. and had a reflective impact on the development and rapid progress of radiation detector technologies used in medical imaging.*" and from the conclusions

"*The requirements imposed by basic research in particle physics are pushing the limits of detector performance in many regards, the new challenging concepts born out in detector physics are outstanding and the technological advances driven by microelectronics and Moore's law promise an even more complex and sophisticated future*".

New frontiers in medical applications are: PET/MRI requiring APDs and SiPM for PET useable in the high magnetic fields, new scintillators for the higher granularity small animal PET (pharmaceutical applications), fast scintillators for ToF - whole body PET imaging.

Electronics and Readout

Instrumentation of bio-sensors by RAL microelectronics using developments out of particle physics has included: neural imaging for advances in brain science, Vision prosthesis, Finger print scanning Dosimetry for radiology, new methods in 3-d tomographic imaging of dose delivery in cancer treatment.

The Microplex ASIC in use in flat panel X-ray imagers developed by Varian and Thales
(see http://www.varian.com/xray/digital_radiography.html).
Similar designs used in X-ray line-scan systems by food industry, baggage handling and fright scanning.
See http://www.senstech.co.uk/xray/xdas.html

Other microelectronics collaborations with industry include:
DpiX - Xerox spinout exploiting microplex technology for X-ray imaging;
ETL - development of linescan systems;
Hitachi - Low noise instrumentation for Quantum electronics used ASICs at low temperatures to form embryonic computation devices;
Oxford Instruments – Low noise electronics.

Another examples of extending the capability of UK companies include Exception EMS who built the CMS Front End Driver (http://www.te.rl.ac.uk/esdg/cms-fed/qa_web/) and Cemgraft Ltd (ATLAS Read-Out Buffers)

See also the MI-3 Consortium: MRC (LMB), radiation physics (UCL), genetics (Liverpool), cancer research (ICR), STFC and 5 other University groups (2 PP) exploiting MAPS technology first developed for ILC
Their goals, stated in http://mi3.shef.ac.uk/ are:

- "***To significantly extend the effective spectral response of APSs from high-energy gammas and ionising particles to the infra-red (including the increasingly important soft x-ray/EUV regions) through integrating CMOS technology with novel substrates, micro-engineered electro-optical structures, etc.***
- ***To develop on-chip "intelligence" down to the pixel level, through adaptive signal processing/pattern recognition, to extent the limits of detectability and applicability, and mitigate the problems of data overload.***
- ***To provide a continuing responsive export core to meet the future imaging challenge within the UK science base; to ensure through building upon existing links with industry the future availability and exploitation of APS devices and systems.***"

Computing, Software and Analysis Tools

Word Wide Web http://www.internetworldstats.com/stats.htm 1.24 billion users worldwide

LHC data deluge stimulated "Grid Computing" which uses the internet and highly sophisticated management tools ("middleware") to harness together large numbers of CPUs and data storage facilities across the globe.
This has led to the LHC Computing Grid LCG becoming the largest academic Grid, being developed to cope with the unprecedented (15 million Gigabytes/year) data rate. (UK contribution: equivalent 10^4 PCs (10% of the total) to LCG).
Spin-outs (see http://www.gridpp.ac.uk/news/-1186485671.785221.wlg) include:

- WISDOM Malaria project see http://www.gridpp.ac.uk/news/-1170422779.710671.wlg
- Avian Flu see http://www.gridpp.ac.uk/news/-1146834257.668058.wlg
- Finance QMUL/Econophysics MiniPPIPS project
- Web security see http://www.gridpp.ac.uk/news/-1127720092.933501.wlg

Internationally, (see http://proj-openlab-datagrid-public.web.cern.ch/proj-openlab-datagrid-public/) Openlab provides collaboration directly between CERN and key industrial partners: Hewlett-Packard, Intel Corporation and Oracle
Also international training programme

Particle Physics Analysis Techniques

Early example, from http://www.iop.org/EJ/article/0305-4624/17/2/301/ptv17i2p56.pdf use of pattern recognition developed for particle physics tracking for applications in: measurement of meteorological records at Oxford; scanning for malignant cells in cervical smears at Nijmegen, cartography and computer-controlled drafting at Cambridge.
Particle Physics Generated Software
GEANT4 has become widely used in a number of areas including modelling radiation effects in space (ESA: Integral, NASA: GLAST) and medical physics (PET) (http://geant4-tt.web.cern.ch/geant4-tt/).

See also deltaDOT see http://www.deltadot.com/ : Direct monitoring of unlabelled biomolecules: faster, higher quality, lower costs for: protein science, chemistry, pharmacy, biopharmaceutical QA/QC, plant science, forensics

Special Skills and Competencies

In the USA, concern about the funding priorities can be found in the 2005 "Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future" by Norman R. Augustine (Retired Chairman and CEO Lockheed Martin Corporation), Craig Barrett (Chairman of the Board Intel), Charles Holliday (Chairman of Board and CEO DuPont), Lee Raymond (Chairman of the Board Exxon Mobil) and 16 others, presented before the Committee on Energy and Natural Resources of the U.S. Senate.

PPARC 2003 study: most taking PP PhD do so for "love of subject" but half take jobs in industry of which 38% found careers in IT, software or management consultancy while a further 25% became financial professionals.

Christos Danias (Head of CDOs - Europe, BNP Paribas):

"*In my experience, while science graduates are always useful in the City, physicists and most importantly particle physicists stand out I think this is because of the communication skills they have which complement the numerical skills but are sometimes in short supply when one meets PhDs in other parts of physics or science*."

Mark Tagliaferri (Chairman aAIM Group Plc):

"*We have employed a number of PhDs in particle physics at aAIM and we have found them to be highly flexible and numerate, with an analytic mindset and the type of international experience which enables them to make a significant contribution very quickly. We would definitely like to see more people with this background becoming available for employment in the City*."

Tim Short (2000-2006 Vice-President, Asset Finance, Credit Suisse First Boston) and 1992 PhD (Bristol):

" *Significant strengths in communications skills, developed in the course of frequently presenting results to demanding groups of scientific peers*

International experience gained very early in their careers, leading to flexibility, a wide network of multi-country contacts and often language skills

An understanding of large-cost budgeting because of the major experimental and equipment costs involved

Diversity leveraging from the already high prevalence of PhDs with this background in industry and business proof of "team playing self-starter" capacities demonstrated by taking responsibility for production of thesis within research group environment"