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PPAP meeting

Report: Strategic Review of Particle Physics Theory

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using slides by VK

Members of the PPT Review Panel

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Prof Richard Brower	(Boston University)	Lattice, External
Prof Christine Davies	(University of Glasgow)	Lattice
Prof Antonella De Santo	(University of Sussex)	Experiment
Prof Nick Evans	(University of Southampton)	QFT
Prof Neil Lambert	(Kings College London)	Strings
Prof Arttu Rajantie	(Imperial College London)	Cosmology
Prof Kari Rummukainen	(University of Helsinki)	Cosmology, External
Prof Michael Seymour	(University of Manchester)	Phenomenology

Particle Physics Theory (PPT) programme in the UK consists of 5 themes:

Cosmology	particle cosmology and astro-particle theory
Lattice Field Theory	non-perturbative computations at strong coupling
Phenomenology	particle theory - bridge to - experiments incl. CERN
Quantum Field Theory	theoretical foundation of particle physics
String Theory	interconnects field theory, gravity, applied maths

All these PPT research areas are funded by STFC [supports entire PPT]

Background

The Panel was asked to undertake a strategic review of UK particle physics theory (PPT) programme and to advise the STFC executive on future STFC support for PPT.

A Review of funding mechanisms to support one PPT research theme - UK Phenomenology - was undertaken by STFC in 2015.

Review Process

The Panel reviewed the overall PPT programme including all five of its constituent research areas: Cosmo, Lattice, Pheno, QFT, Strings.

Requested and assessed:

1. Pro-forma submissions from all UK Theory Groups [24]
2. International Experiments consultation submissions [11]
3. International Theory Group submissions [6]

& background documentation: recent reports to Science Board, PPAP & PPGP reports.

The panel held a number of meetings, including a 2-day face-to-face meeting and 3 teleconference meetings.

Main Findings

1. The Panel found that the UK Particle Physics Theory (PPT) programme is **world leading**. All of the science themes have areas of strength. There is excellent linkage with the experimental PP programme.

2. The Panel emphasised that the programme **will not be internationally competitive** in the long term **if the constrained funding of PPT is not addressed**.

   In particular, the main threat is the **critically low number of PDRA posts** compared with other countries.

In more detail: world-leading

UK theoretical particle physics has a long history of international leadership and achievements, including the pioneering work of Paul Dirac, Jeffrey Goldstone, Abdus Salam, Peter Higgs, Tom Kibble, Steven Hawking, Michael Green and others, it forms the basis of our understanding of fundamental forces and interactions in nature.

This includes the foundations of quantum field theory, gauge symmetry, Higgs phenomenon, and on to gravitational waves, quantum gravity and string theory.

Crucial role in teaching in UK Physics and Mathematics departments; breadth of knowledge to explain complex subjects in undergraduate and postgraduate courses.

The international panel members commended the UK for the number of students studying Physics and Mathematics in the UK which **leads to a flexible and robust science base** (as compared to more narrowly specialised bases in some other countries).

These strengths as well as the **world class research** has led to the **growth by 50% in academic numbers in UK Universities in this area since 2005** (as measured by applications to STFC). **This growth represents a huge opportunity for the UK to broaden its world leadership in this research area.**

Currently 25 groups receiving funding through the PPT consolidated grants including the IPPP — a National Phenomenology Centre and a partnership between STFC and Durham University established in 2000.

Table 1 – Balance of PPGP(T) Programme by PDRA FTE excluding IPPP (Percentage of Programme)

Subject Area	**2005**	**2008**	**2011**	**2013**	**2016**
	Awarded	**Awarded**	**Awarded**	**Awarded**	**Awarded**
Cosmology	6 (18%)	4.7 (14%)	3.8 (13%)	3.1 (11%)	5.4 (17%)
Lattice	7 (21%)	5.3 (16%)	5.2 (18%)	4.2 (15%)	5.0 (16%)
Phenomenology	6 (18%)	10.5 (30%)	9.4 (32%)	9.4 (34%)	9.6 (30%)
QFT	5 (15%)	4.5 (13%)	5.2 (18%)	5.6 (20%)	6.7 (21%)
Strings	10 (28%)	9.3 (27%)	5.6 (19%)	5.7 (20%)	5.3 (17%)
Total	**34**	**34.3**	**29.2**	**28**	**32**

some overlap

The funding level for the entire PPT programme is approximately £6.6M per year.
Note the reduction in grants funding (by approximately 10%) from 2011 following STFC's 2009 Prioritisation exercise. Flat cash funding since 2011.
[2013 Programmatic Review recommended constant volume].

Based on the evaluation of the input from international experts, experimental collaborations, and the UK theory community; and their own assessment of research output in each of the theme areas; the Panel considered that the UK PPT programme was world-leading and showed a high level of international scientific leadership.

> "The UK particle theory community is a very strong contributor to the overall worldwide theoretical particle physics programme and with interactions with the experimental particle physics community."
>
> Experiment Response

> "Particle physics theory in the UK is internationally very visible and has a high reputation at a world-wide level."
>
> International PPT Institute Response

Table 2 – Summary of Publication Data for UK PPT Institutes

	Number of refereed publications		**Number of Citations**	
	Last 5 years	**Last 10 years**	**Last 5 years**	**Last 10 years**
Phenomenology	1,331	2,230	49,134	123,972
Strings	835	1,615	17,899	52,861
Quantum Field Theory	775	1,435	14,327	43,237
Cosmology	593	1,091	33,099	58,156
Lattice Field Theory	272	558	11,190	30,871
Total	**3,806**	**6,929**	**125,649**	**309,097**

UK strengths

Cosmology: particle physics theories of dark matter, inflation model building, baryo/leptogenesis, Higgs field dynamics in the early universe, modified gravity, cosmological field theory.

Lattice field theory: QCD calculations for experiments, e.g. LHCb, NA62, muon g-2 and Jefferson Lab; QCD parameters (quark masses and strong coupling), QCD at non-zero temperature and baryon density; non-perturbative physics of possible BSM theories.

Phenomenology: Parton distribution functions; Monte Carlo event generators; precision QCD (SM); Higgs physics (SM and BSM); neutrino physics (SM and BSM) ; flavour physics (SM and BSM); BSM model-building; particle dark matter.

QFT: amplitude calculations; exact solutions (SUSY); integrability; applications of AdS/CFT correspondence; solitons; speculative ideas such as Lorentz-violating theories.

strings: overlap with above along with foundation work in both perturbative (Green-Schwarz formulation and anomaly cancellation) and non-perturbative approaches to string theory (M-theory, U-duality)

In more detail: the main threat

The main threat to the UK PPT programme is the critically low number of PDRAs internationally.

The Panel considered that the UK has a significantly lower ratio of PDRAs (1:6 academics requesting funding; 1:4 funded academics) compared to other countries with leading PPT programmes.

> "Anecdotal evidence suggests that this number may be 1:2 for USA (NSF), (1:1) for Germany, 1:3 for Italy (INFN), and 1:2 (and falling) for the USA (DOE)."
>
> UK PPT Group Response

> "The UK has seen declining government support for fundamental theoretical physics in recent years, certainly compared to Switzerland, Germany and Nordic countries."
>
> International PPT Institute Response

In more detail: the main threat

The main threat to the UK PPT programme is the critically low number of PDRAs compared to other STFC programmes and internationally.

Concern about the level of PDRAs was stated by nearly all UK groups.
It was also supported by international theory group submissions.

> "The UK particle theory programme has historically been a world leader, and still has areas of world-leading strength, but in recent years its across-the-board leadership has declined some, perhaps related to a decline in postdoc and student support per principal investigator."
>
> International PPT Institute Response

> "Any further reduction in funding for RAs would be damaging for UK particle theory research and reduce international competitiveness."
>
> UK PPT Group Response

Up to now, the low level of PDRA support had been partially mitigated by the success of the UK PTT academics in attracting European funding. This amounts to 5million euros per year, a significant fraction of the STFC funding. But this of course raises another concern…

In more detail: the main threat

The Panel considered that if the critical level of PDRA support was not urgently addressed this would result in a loss of UK leadership and weaken the UK effort in PPT.

Support for PDRAs is critical in delivering the research programme and maintaining the international leading position of the UK.

The mobility of PDRAs ensures that the UK can join and maintain leadership in international collaborations.

PDRAs also play an important role in responding to new research areas and driving leadership in growth areas.

Additional support for PDRAs would allow the quality of the existing programme to be enhanced; therefore allowing the existing world class academic expertise and leadership in the UK to be more effective in carrying out world leading research.

Summary of Recommendations

The panel recommended that additional funding for PPT should be found to support additional PDRA posts. Increased support is essential to maintain international competitiveness.

How should we make the case for this?

The Panel recommended that STFC maintain the current timing of consolidated grant rounds, to allow alignment with recruitment timescales.

The Panel considered that it was important to maintain the breadth of the programme, especially in a constrained funding environment, as the programme areas are intimately linked and positively reinforce each other.

The Panel recommends that PPGP(T) continue to support a small amount of high risk, high reward research in theoretical particle physics as part of the broader PPT programme.

The Panel noted the importance of maintaining support for travel and visitor funds on consolidated grants especially where there are low PDRA numbers.

Summary of Recommendations

The panel considered the IPPP to be very successful in its mission as the National Phenomenology Centre and for its research programme.

To maintain the internationally leading strength of the QFT, Strings and Cosmology themes, the panel recommended the creation of a self-organising virtual QFT/String centre and a similar Cosmology centre which would act to bring these parts of the UK community together.

The Panel recommended that the DiRAC 3 upgrade is essential for the Lattice Field Theory community to remain competitive. The funding costs to support DiRAC 3 or PRACE should not be at the expense of core PPT programme as this would impact on numbers of PDRAs supported.

Summary of Recommendations

The Panel recommended that STFC consider appropriate mechanisms for research which falls across PPT and astronomy remits, to ensure that collaboration is encouraged and supported, e.g: cross-Panel membership, co-funding between programme areas; PPGP(T) to monitor the theoretical activity in gravitational waves that PPT aspects are included in UK gravitational wave research plans.

The Panel recommend that the UK PPT community should continue to be fully engaged with the forthcoming update of the European Strategy and planning for Particle Physics. Beyond that, STFC should support and encourage wider UK participation in future collider initiatives at CERN, or elsewhere, as well as other large scale or smaller scale innovative international experimental proposals.

Summary of Recommendations

The Panel encouraged STFC to consider how junior fellowships could be supported; for example, by alternating support annually for Postdoctoral Fellowships and Ernest Rutherford Fellowships.

The Panel welcomed the recent STFC supported Centres for Doctoral Training in Data Intensive Science and noted that some PPT groups were benefitting from this support. However, the Panel noted that the current studentship quota mechanism gives flexibility for academics and students to focus on scientifically excellent research and recommended that STFC maintain the existing studentship support mechanism and level of funding.

The Panel encouraged STFC to review the studentship allocations following the implementation of the revised algorithm to ensure that studentships are fairly distributed across the grants panel areas.

Summary of Recommendations

The Panel was concerned about the possible implications of Brexit and noted that the issue of long term sustainability in the UK programme would make it more difficult for the UK community to manage any detrimental impacts.

In particular, the potential loss of EU funding, especially European Research Council (ERC) funding, would have an unduly detrimental impact on the PPT programme.

The UK programme has a high level of international interactions both through the attractiveness of the UK for international researchers and the high volume of international collaborative activities. It is important that care is taken to maintain the world class UK PPT programme.

Need help from experimental community and PPAP in making the case for more funding for PPT, e.g. from balance of programmes exercise.

Relatively modest increases in RA numbers could yield large increase in theory output (within existing programme or new areas) given unsatisfied academic demand.

Future opportunities, beyond the existing programme, exist in every area: how to articulate these? Some will be untapped in the UK without additional RAs.

e.g. cosmology: exploiting info. from gravitational waves, lattice field theory: neutrino physics, ab initio PDFs, BSM phenomenology: Higgs physics, particle dark matter QFT/strings: modified gravity/dark energy, bootstrap methods.

Summary

1. The Panel found that the UK Particle Physics Theory (PPT) programme is **world leading**. All of the science themes have areas of strength. There is excellent linkage with the experimental PP programme.

2. The Panel emphasised that the programme **will not be internationally competitive** in the long term **if the low numbers of RAs in PPT is not addressed**.

A significant increase in UK particle physics output could be generated by tapping in to unsatisfied theory demand.

How should the case for this be made?