



# PPAP UK Community Meeting 2015

24-25 September 2015  
Imperial College London

# Phenomenology

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# Phenomenology

Phenomenology is a part of theoretical particle physics concerned with the applications of theory to particle physics experiments

two-way interactions: EXPERIMENT  $\leftrightarrow$  THEORY

Part of the [UK Theory effort](#) with its extraordinary tradition and record of scientific excellence

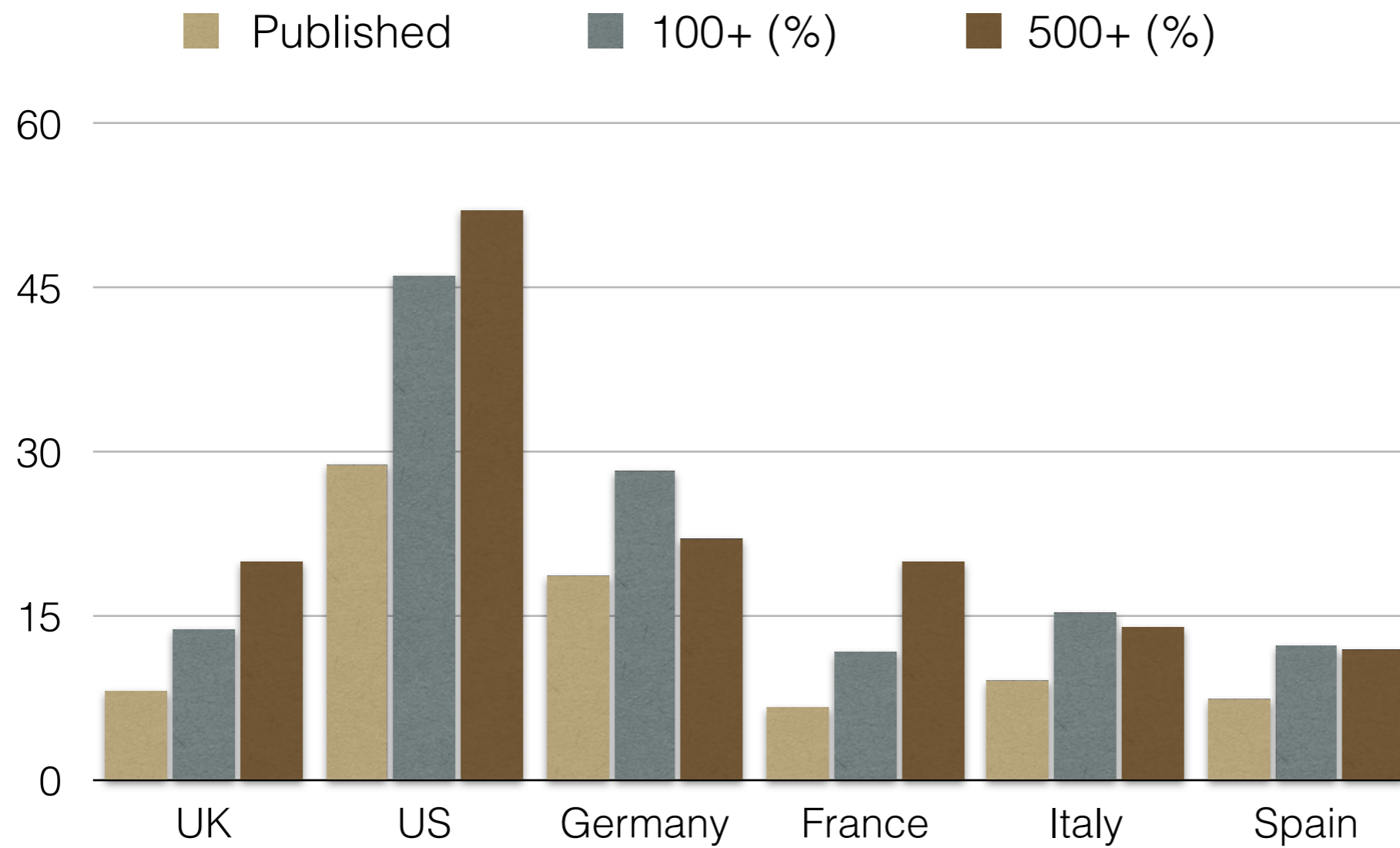
[UK Phenomenology](#) has a world-class reputation

strong UK activity in all areas - QCD (perturbative and non-perturbative), Electroweak & Higgs physics, Beyond the Standard Model, Neutrino and Astro-particle physics, hadronic Flavour, Monte Carlo event generation, PDFs and Computational tools.

[Focused phenomenology effort: \[requires maintaining critical mass!\]](#)

development of new theoretical ideas [Phenomenology & Formal theory close links]  
maintain and develop computational tools,  
and **strong links** between **Theory and Experiment**

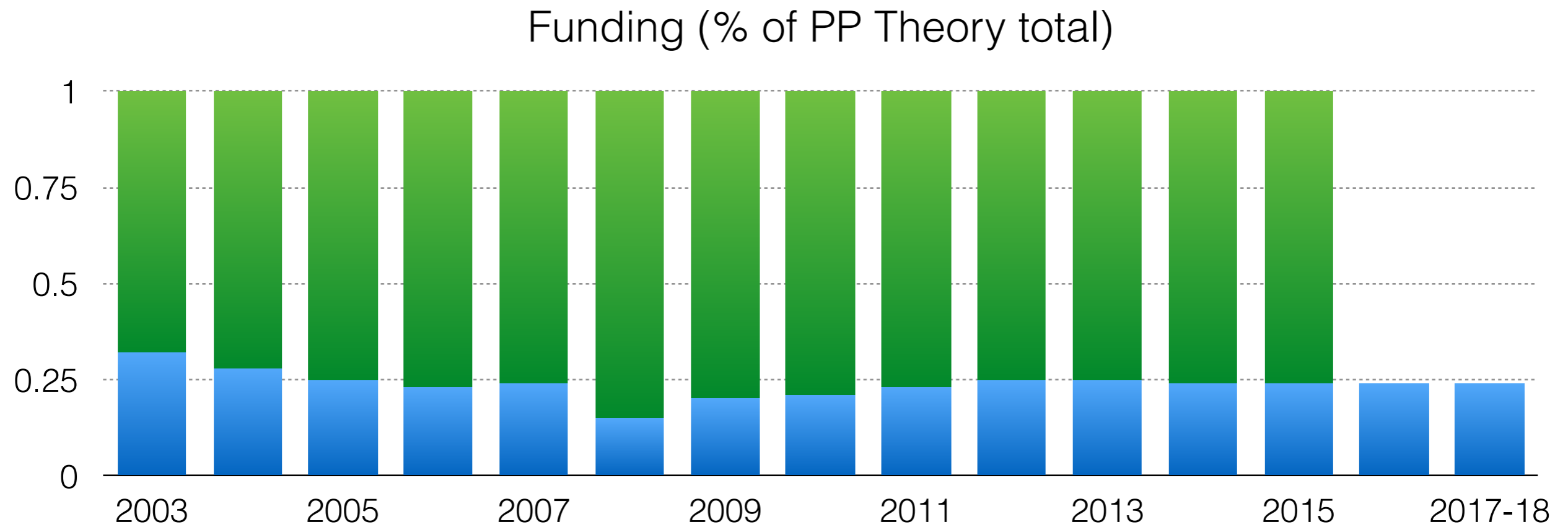
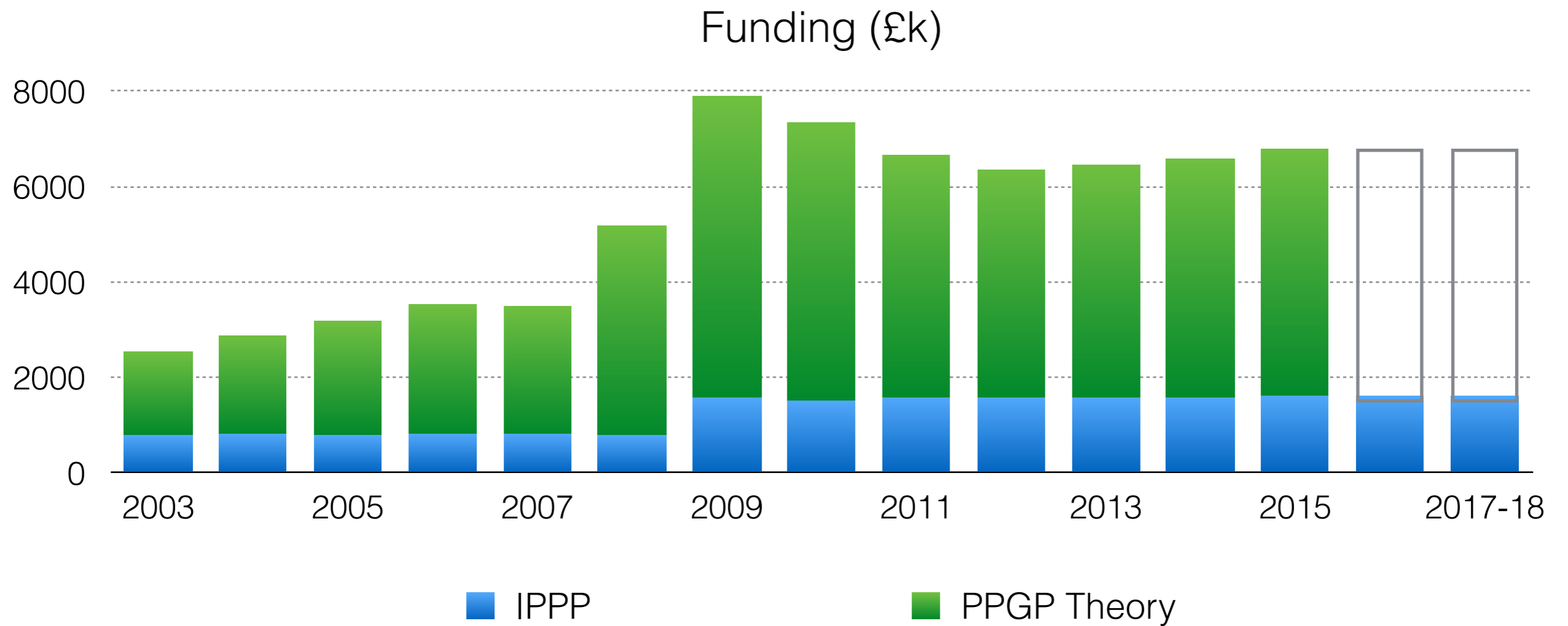
## Refereed Publications in Phenomenology since 2005



# Phenomenology

**Phenomenology research** in the UK is funded by STFC at:

- ◆ IPPP — a national phenomenology institute at Durham University  
[IPPP is a University-based group => IPPP academics teach]  
funded by direct grant from STFC & is a joint venture with Durham
- ◆ in University departments at Cambridge, Edinburgh, Glasgow, Kings College London, Liverpool, Manchester, Oxford, Royal Holloway, Southampton, Sussex and University College London  
funded by Theory Consolidated grants via PPGP(T)

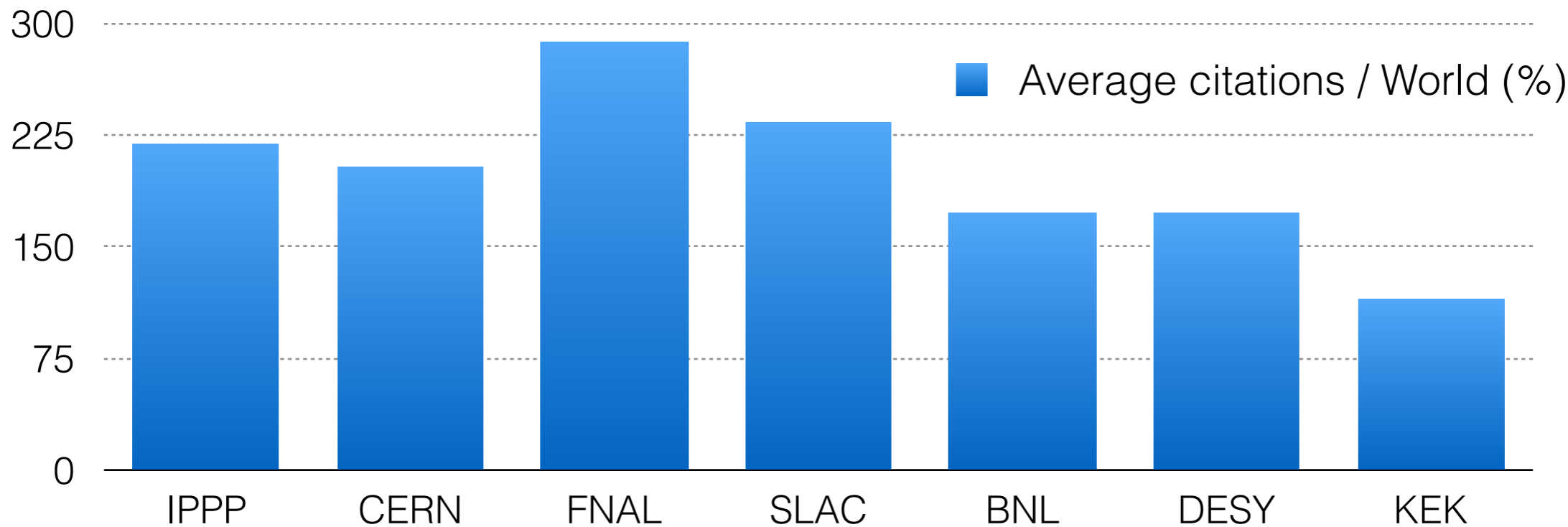
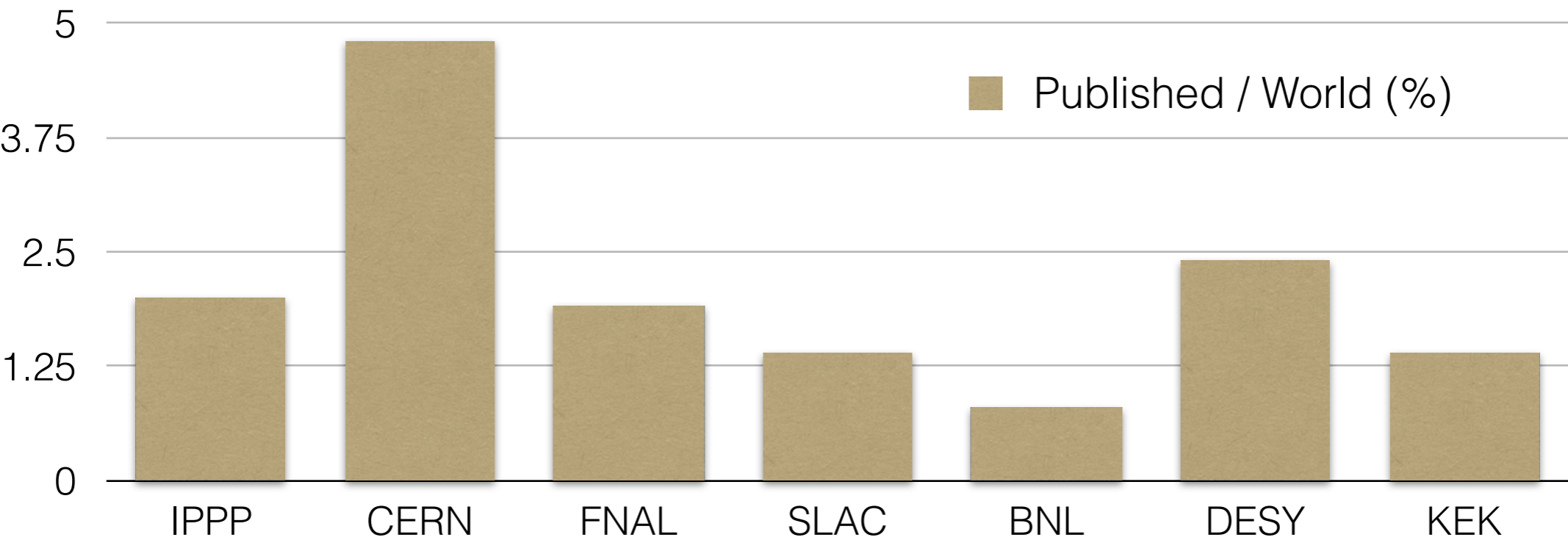


- University groups supported by Consolidated grants via **PPGP Theory** have seen a significant increase in numbers of academic staff.

PPGP(T)	2005	2008	2011	2013
A=Academics	122	155	163	185
<FTE>		20%	14%	16%
A x <FTE>	0	-31	-23	-30
PDRA <sub>s</sub>	41	35	29	28

- Large fraction of these STFC funds awarded goes to universities as Directly Allocated Staff costs, and cannot be used for PDRA posts!
- 
- For **IPPP** — thanks to its long-term funding — the number of FTE academic posts @ IPPP is fixed at the 2008 level — for the entire 2008-2018 period covered by the current grant.
  - Subsequent expansion of IPPP - post 2008, present and future - does not result in STFC funds being diverted -> number of PDRA posts is maintained and not adversely affected by the growth of the group.

# IPPP and International Labs: Refereed Publications in Phenomenology since 2005

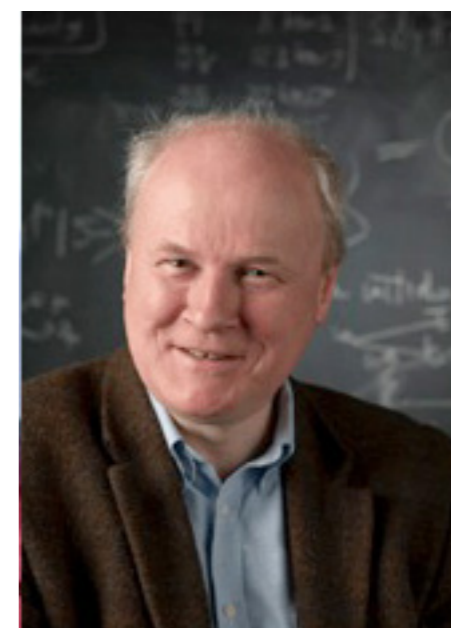


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Ogden Centre for Fundamental Physics ground breaking ceremony Martin Ward, Tom Ward (pVC Education), Carlos Frenk (ICG), Valya Khoze (IPPP)

Recent IPPP Preprints

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## IPPP Workshops

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Higgs Couplings 2015  
Mon, 12/10/2015 - Lumley Castle

UK HEP Forum: Anomalies and Deviations  
Thu, 05/11/2015 - The Cosener's House

Kavli-IPMU-DURHAM-KIAS workshop:  
New Particle searches confronting the LHC run-2 data

UK Annual Theory Meeting  
20-22 Dec 2015

YETI 2016

IBS-MultiDark Joint Workshop on Dark Matter  
Mon, 23/11/2015 - Madrid

## Recent IPPP Preprints

### Closing up on Dark Sectors at Colliders: from 14 to 100 TeV

Philip Harris, Valentin V. Khoze, Michael Spannowsky, and Ciaran Williams

### Higgs-Strahlung: Merging the NLO Drell-Yan and Loop-Induced 0+1 jet Multiplicities

Dorival Goncalves, Frank Krauss, Silvan Kuttimalai, and Philipp Maierhöfer

### WIMP-Search Results from the Second CDMSlite Run

R. Agnese et al.

### Forward $D$ predictions for $pPb$ collisions, and sensitivity to cold nuclear matter effects

Rhorry Gauld

### The Effect of Final HERA inclusive Cross Section Data on MMHT2014 PDFs

R.S. Thorne, L.A. Harland-Lang, A.D. Martin, and P. Motylinski

### Unitarity and the three flavour neutrino mixing matrix

Stephen Parke, and Mark Ross-Lonergan

## News

Previous news is available in our [archive](#)

### New IPPP Director - Prof. R. Keith Ellis, FRS

Professor Richard Keith Ellis will become the new Director of the Institute for Particle Physics Phenomenology (IPPP) starting in October 2015.

### The IPPP is inviting applications for a new round of IPPP Associateships

Open for members of permanent academic staff UK PP

Duration 1 year, start date October 2015.

Applications closing date: 18 September 2015

<http://www.ippp.dur.ac.uk/ippp-associateships>

### New round of Senior Experimental Fellowships at IPPP

To be awarded to small teams led by senior UK experimentalists.

Duration 1 year, start date 1 January 2016

Applications closing date: 18 September 2015

<http://www.ippp.dur.ac.uk/senior-experimental-fellowships>

### We are looking for nominations for new members for IPPP Steering Committee

The vacancies are for theorists and experimentalists.

<http://www.ippp.dur.ac.uk/steering-committee>

## Forthcoming Workshops

12/10/2015 to 15/10/2015

### Higgs Couplings 2015

05/11/2015 to 06/11/2015

### UK HEP Forum: Anomalies and Deviations

23/11/2015 to 27/11/2015

### IBS-MultiDark Joint Workshop on Dark Matter

11/01/2016 to 14/01/2016

### YETI 2016

## Forthcoming Seminars

Tuesday, September 22, 2015

### The Galactic Center excess in gamma rays

German Gomez-Vargas

Thursday, October 15, 2015

### TBA

Margarete Muehlleitner

Thursday, October 29, 2015

### TBA

Daniel Schmeier

Thursday, November 5, 2015

### Extradimensional origins of R- parity violation

Abhishek Iyer

# The era of the LHC

- The LHC is a QCD machine (it collides protons)
- It was built to discover New Physics
- It discovered the Higgs
- Direct searches found no New Physics beyond the SM
- BSM physics is pushed further away (for now)

that's just the beginning. The LHC Run 2 at 13 TeV has started and the expectations are high. LHC upgrades and future experiments are also of key importance and essential.

there is more to come

# The era of the LHC

- The LHC is a QCD machine

Our role is to provide tools and calculations covering all relevant phenomenological aspects of experimental programme.

Computational techniques & tools include:

- ❖ Parton distribution functions (NNPDF and MRST/MSTW/MMHT)
- ❖ Precision QCD Physics
- ❖ Jet algorithms and jet substructure, boosted objects.
- ❖ NNLO calculations
- ❖ [Very useful overlap with 'Scattering Amplitudes' in 'formal' theory]
- ❖ Monte Carlo event generators (Herwig++ and Sherpa)
- ❖ Monte Carlo tuning tools (Rivet & Professor)

UK leads in all these areas.

# After the Higgs: what next?

The LHC Higgs discovery was the crowning achievement of the SM. But at a more fundamental level it leaves fundamental key questions unanswered:

- SM accommodates  $v = 246$  GeV and  $m_h \simeq 125$  GeV as input parameters, but does not explain their origin and why  $\ll M_{\text{Pl}}$
- The SM Higgs potential is unstable (or meta-stable) at  $\mu_{\text{RG}} \gtrsim 10^{11}$  GeV
- Generation of the matter-anti-matter asymmetry of the Universe is impossible within the SM
- There is no Dark Matter in the SM
- Generation of the quark Flavour structure
- Neutrino masses and mixing
- Strong CP and axion or axion-like particles
- Particle physics implementation of Cosmological Inflation

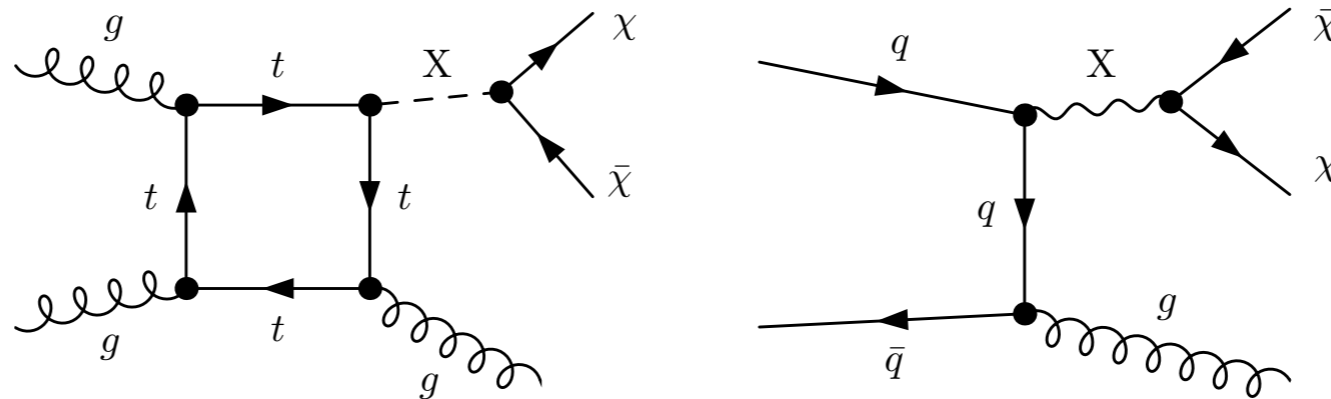
# After the Higgs: redouble the BSM effort

- Extended Higgs sectors: more scalars, some pseudo-scalars, Higgs portals to new physics...
- Dark Matter sectors in addition to the SM: new mediator particles: vector and/or axial-vector  $Z'$  bosons, new scalars, axions and ALPs; Dark Matter
- Baryogenesis, Leptogenesis, sterile neutrinos, flavour and CP, phase transitions (EW and beyond)...
- New structures/symmetries, e.g.: Supersymmetry [perhaps split SUSY with Higgs relaxation & GUT]; Classical Scale Invariance; ... ; Twin Higgs-like scenarios...
- in this very broad research area: **UK needs to increase its critical mass**

# One example in more detail:

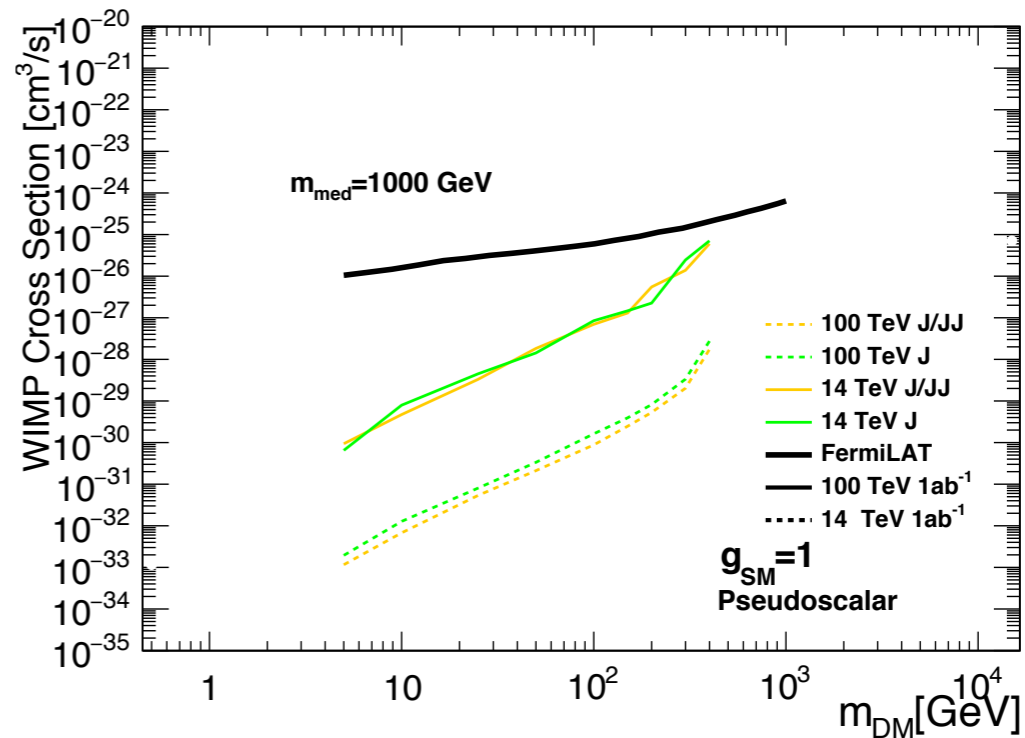
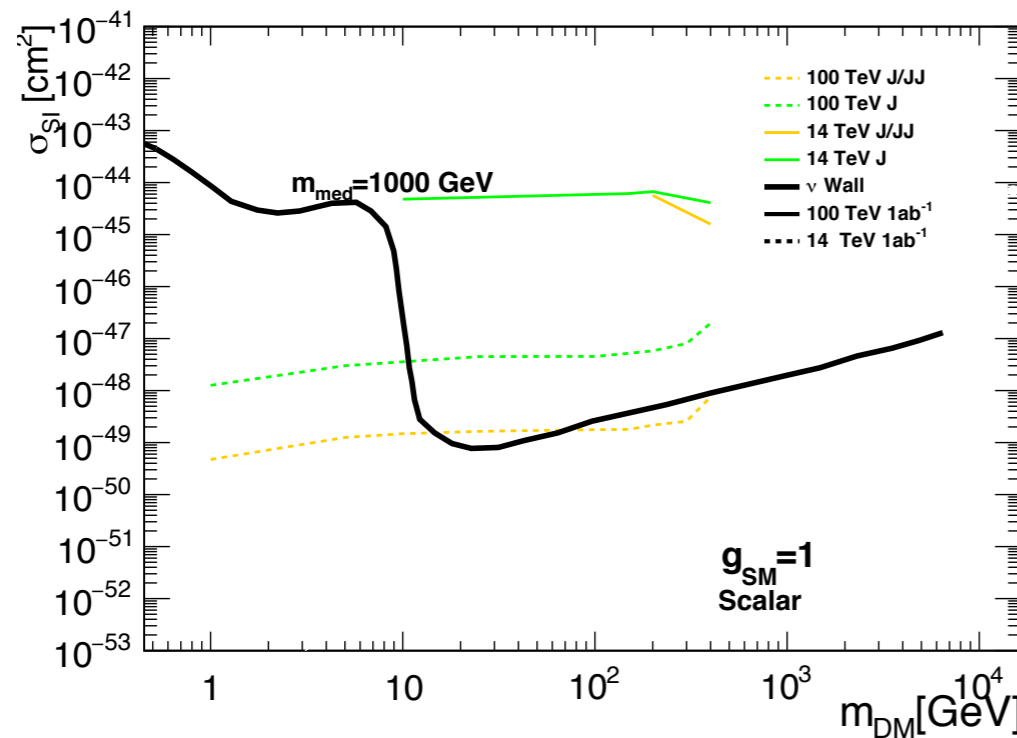
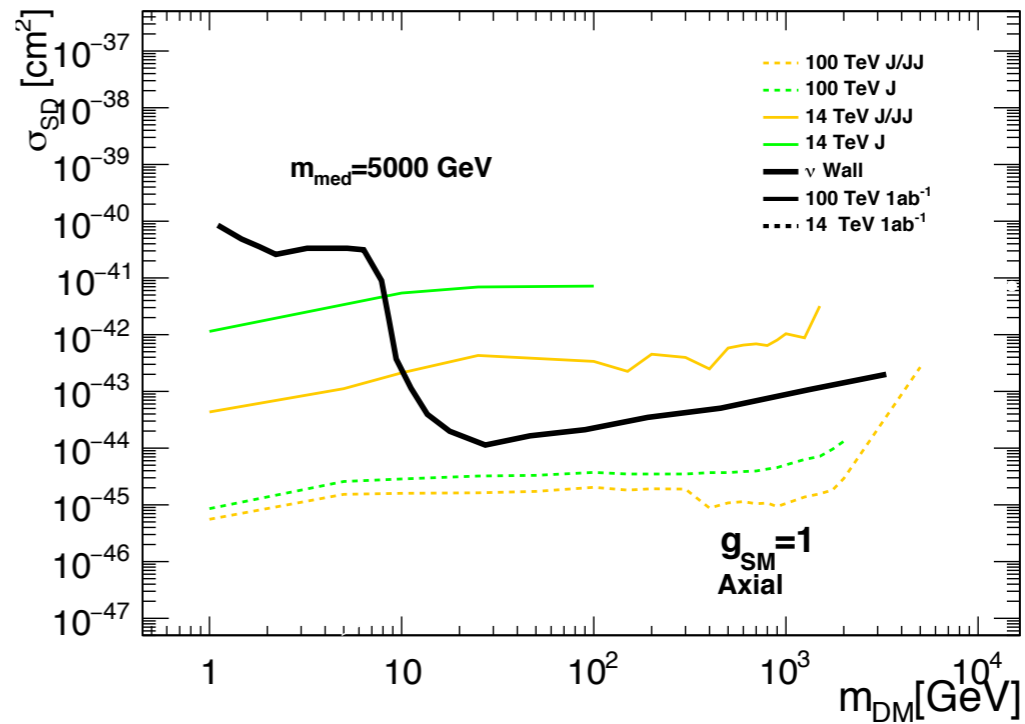
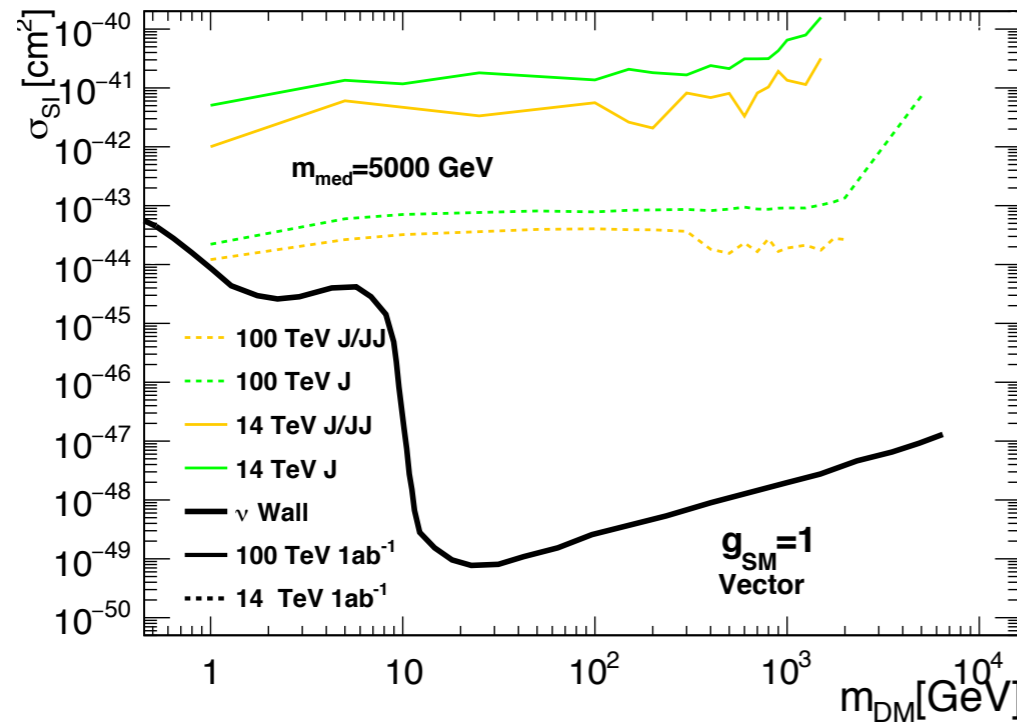
## Dark Matter Sectors at Colliders and in Direct Detection

- Dark Sector should contain Dark Matter (which is cosmologically stable) plus possibly other dark particles.
- At colliders dark sector particles produced in collisions would manifest themselves as missing transverse momentum (aka MET).
- Use SM jets to recoil, consider jets + MET signatures.
- Being stable on collider scales – is much less restrictive than the cosmological DM – i.e. can look for more than just DM in dark sectors.
- Dark Particles interact with the Standard Model by exchanging a *mediator* field  $X$ . Mediator particle is a key new physics d.o.f. at colliders.
- Four basic types of mediators: vectors, axial-vectors, scalars, pseudo-scalars (can be exchanged in  $s$ - or  $t$ -channel). Concentrate below on the  $s$ -channel models (colourless mediators):



Representative Feynman diagrams

# LHC 14 and FCC 100 TeV DM reach interpreted in terms of the spin-dependent and spin-independent cross sections vs DD and ID



# Main recommendations

- Critical to reverse the trend and increase the overall number of PDRA posts in Particle theory —specifically in phenomenology [for purposes of this talk].
- Aim to create — not shift around — postdoctoral positions. UK leadership, future of the field, and health of particle physics in the UK depends on this.
- Invest strategically: obviously the full exploitation of the LHC, also non-accelerator experiments, PLUS strategic investment into future post-LHC physics programme: UK needs to take a more prominent role in phenomenology/theory support of future colliders (all the way to FCC hh).
- STFC is strongly encouraged to continue with longer-term grants to support research areas where it has long-term strategic priorities.