SUPA Physics Scotland

SUPA IAC – 11th May 2017

Particle Physics

Theme Leader: **Victoria Martin** (Edinburgh) (since October 2016)
previously Paul Soler (Glasgow)

Institutes: University of Glasgow & University of Edinburgh

Funding: **STFC**: consolidated grants, project grants, fellowships
plus: EPSRC, ERC, Intel, Royal Society, EC Horizon 2020 …

Particle Physics: Current Research Overview

Experiments:

- **Large Hadron Collider at CERN**: ATLAS and LHCb
- **Quark flavour physics:** LHCb and NA62 (CERN)
- **Neutrino physics:**
  - ➡ Neutrino Factories and MICE at RAL
  - ➡ DUNE (Fermilab & South Dakota) & proto-DUNE (CERN)
  - ➡ Hyper-Kamiokande (Japan), ANNIE (Fermilab)
- **Dark Matter** (LUX,LZ) in Homestake mine, South Dakota
- **Future colliders** (ILC, CLICdp, FCCpp)

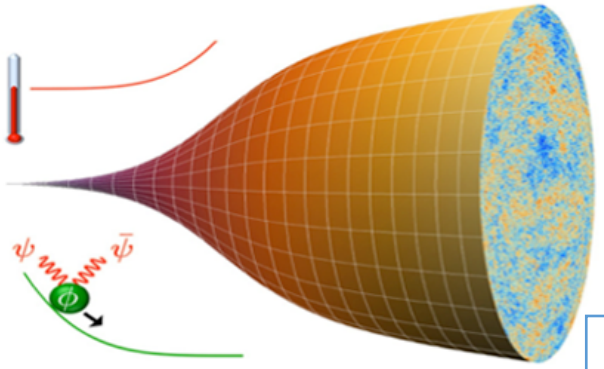
Theory:

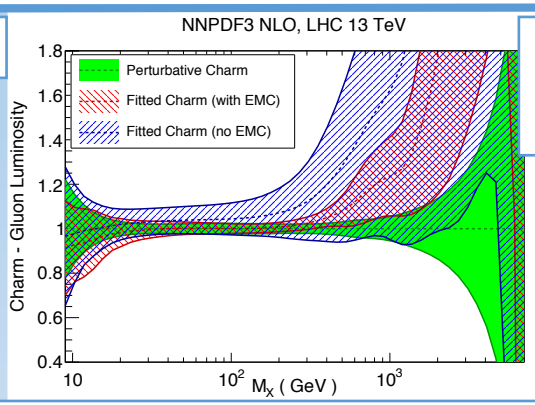
- **Lattice field theory for LHC, g−2, flavour physics** at DiRAC facility & elsewhere
  - ➡ Working with HPQCD, QCDSF and RBC/UKQCD collaborations
- **Phenomenology for LHC, cosmology & beyond**: nnPDF, HEJ, flavour anomalies, warm inflation, TopFitter
- **Formal theory:** little Higgs, Supersymmetry, extra dimensions
- Turbulence, links to condensed matter

Computing & Data Analysis

Particle Physics Theory
2016/17 Research Highlights

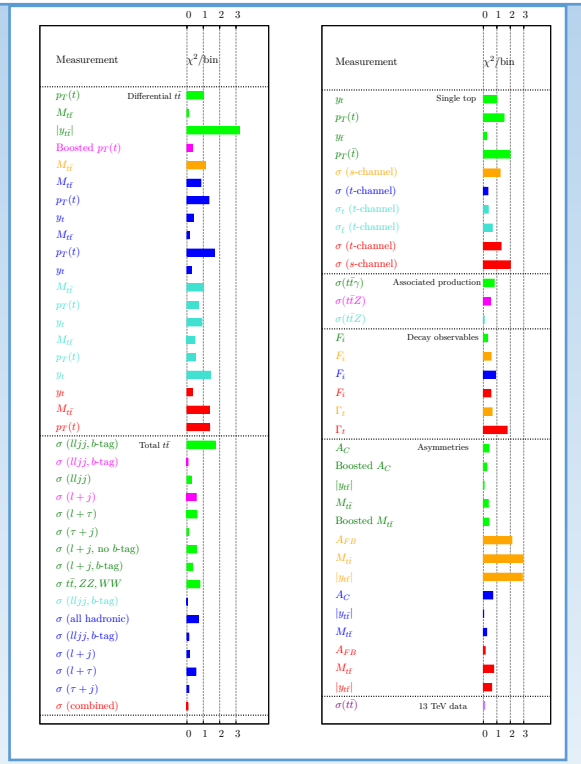
Little Higgs in warm inflation (PRL**117**, 151301)



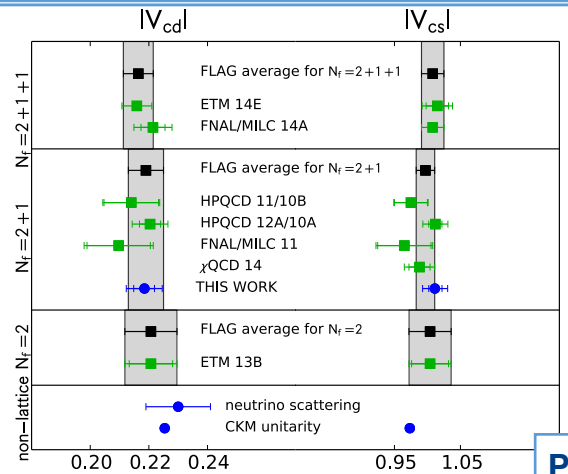


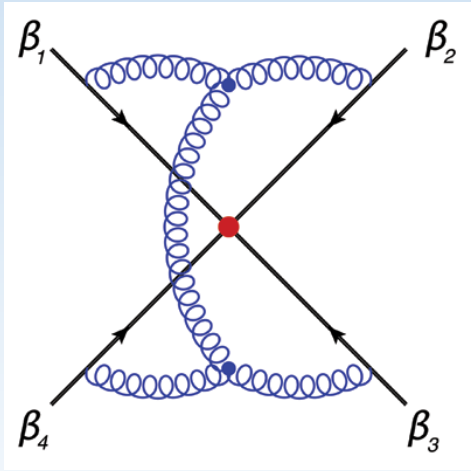
NNPDF, e.g. charm component of the proton
arXiv:1605.06515

Precision predictions & interpretation for top quarks & Higgs boson physics at **LHC**, e.g. arXiv:1702.01930, JHEP1604 (2016) 015

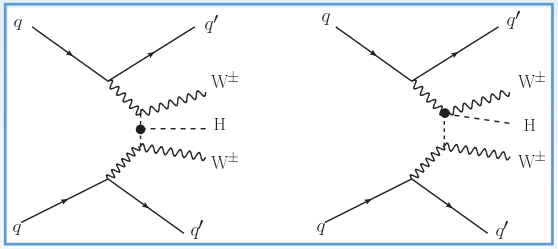


Lattice results for flavour physics & g–2
e.g. arXiv:1701.02644



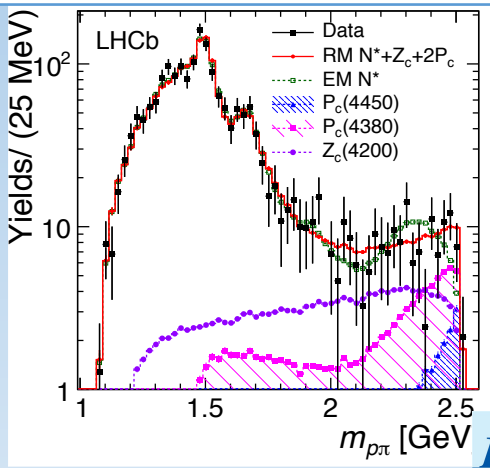


Perturbative calculations e.g. complete 3-loop soft anomalous dimension PRL**117**, 172002

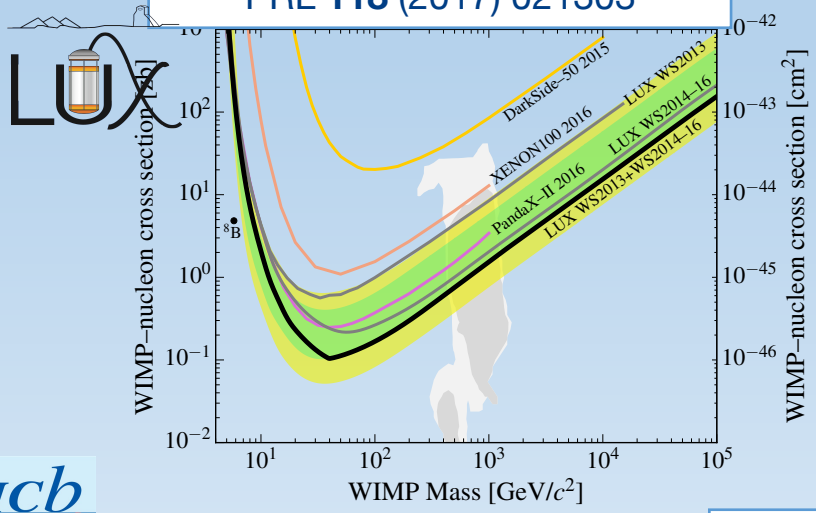


Particle Physics Experiment 2016/17 Research Highlights

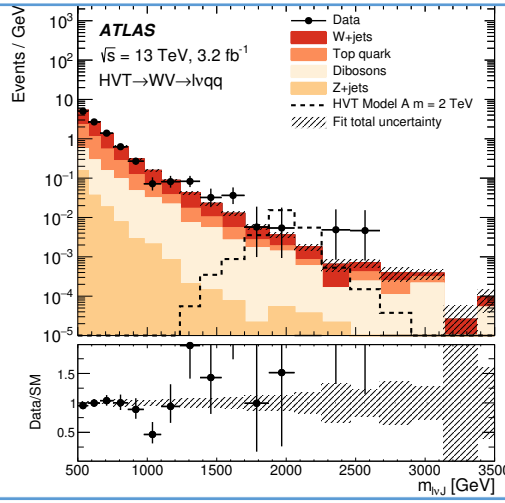
Confirmation of two **pentaquarks** (PRL**117** 082003)



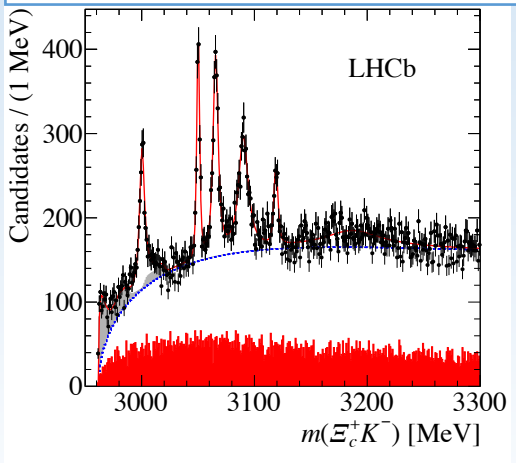
Full exposure results from LUX PRL **118** (2017) 021303



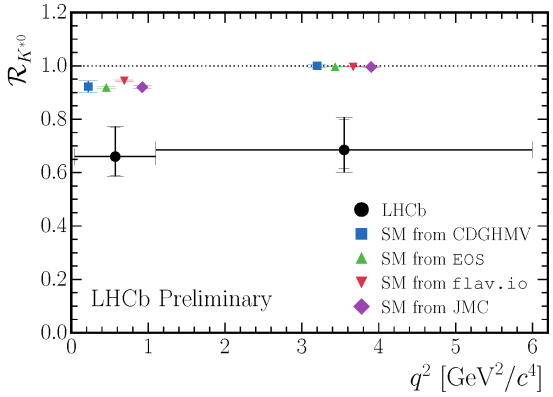
limits on exotic new particles (JHEP (2016) 2016: 173)



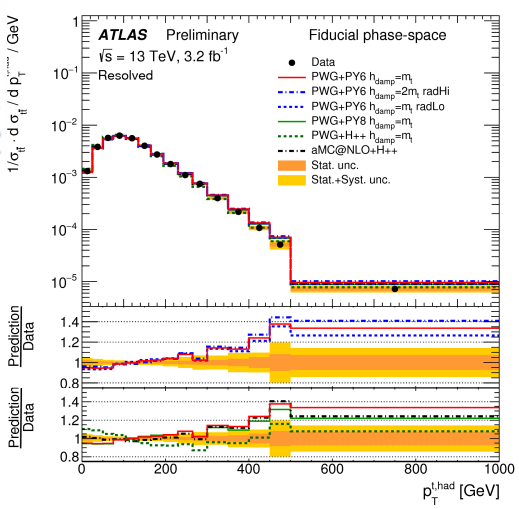
Five new baryon Ω_c states discovered (arXiv:1703.04639)



Hints at lepton non-universality **in B*→K*ℓℓ** (https://indico.cern.ch/event/580620/)

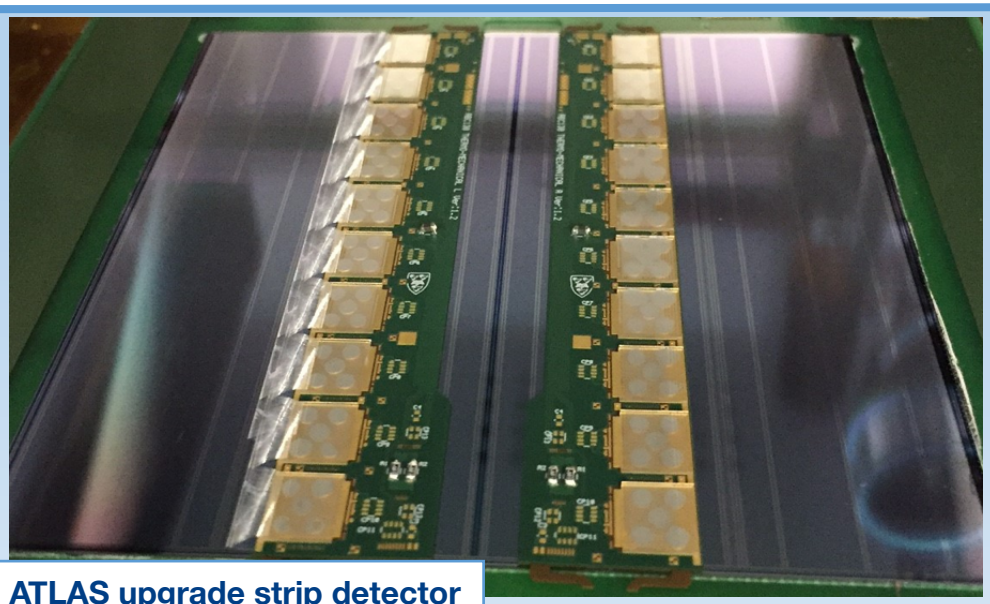


Precision tests of top quark physics at 13 TeV (ATLAS-CONF-2016-040)

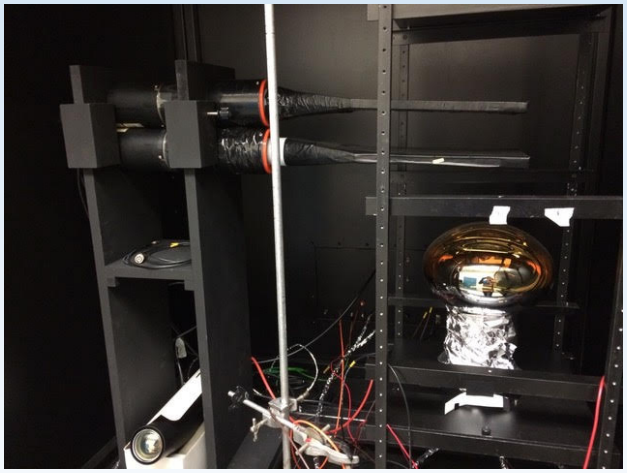


Particle Physics Experiment 2016/17 Detector Developments

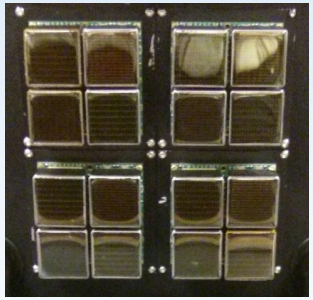
babyMIND detector at CERN, collaboration including Glasgow

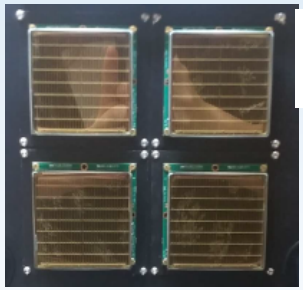


ATLAS upgrade strip detector prototype in Glasgow

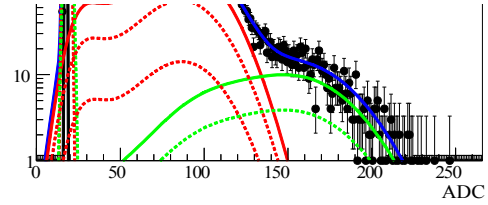


Hyper-K and LHCb phase 1a upgrade photon detectors in Edinburgh





~1000 MaPMTs delivered (of 3600 orde
testing on schedule



Particle Physics: Beyond Research

Medipix3 silicon pixel detector developed at CERN with Glasgow participation. Glasgow collaborator on demonstration of Medipix3 for electron microscopy.

National Museum of Scotland, Edinburgh: NEW Particle Physics gallery with Edinburgh & Glasgow physicists featured plus ongoing engagement with NMS with teachers & pupils.

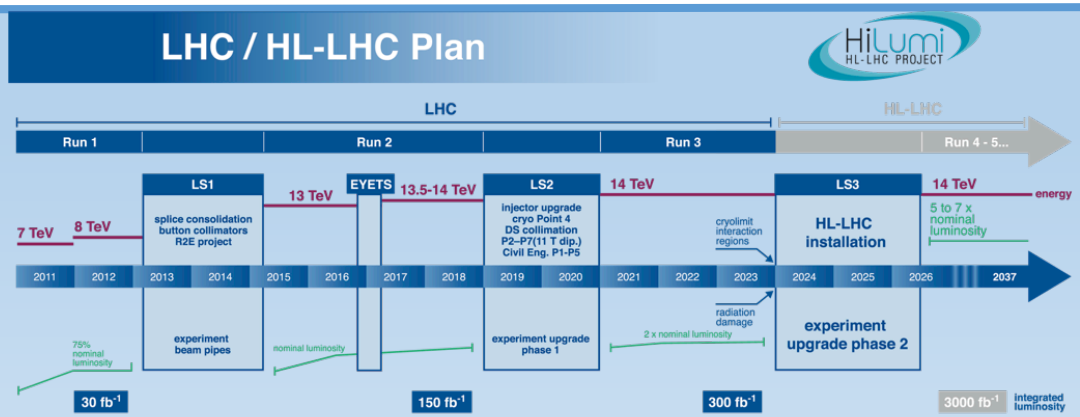
Destination: Space
co-authored by Christoph Englert
Shortlisted for Blue Peter Book Award

http://www.nms.ac.uk/explore/stories/science-and-technology/cern-accelerating-cavity/
http://www.booktrust.org.uk/news-and-blogs/news/1437
http://www.gla.ac.uk/schools/physics/news/headline_515843_en.html

Particle Physics Experiments: Active Developments

ATLAS & LHCb upgrades for 10x nominal luminosity starting 2027

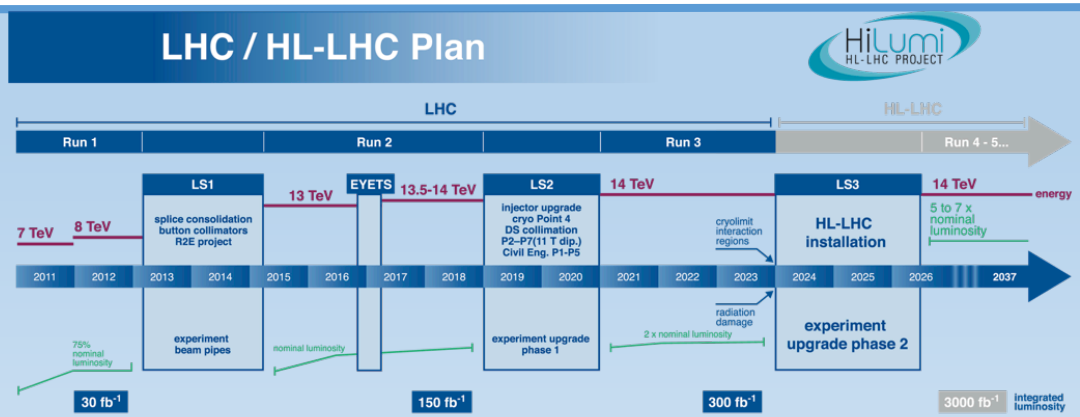
- **ATLAS**: STFC grant process ongoing
- **LHCb**: phase 1a upgrade funded and in construction, future phases being discussed



Particle Physics Experiments: Active Developments

ATLAS & LHCb upgrades for 10x nominal luminosity starting 2027

- **ATLAS**: STFC grant process ongoing
- **LHCb**: phase 1a upgrade funded and in construction, future phases being discussed

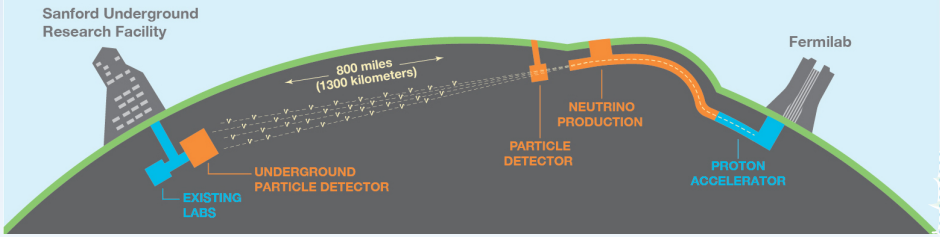


Long baseline neutrino experiments: fire neutrinos underground to determine precision measurements of neutrino properties, with data taking starting ~2026

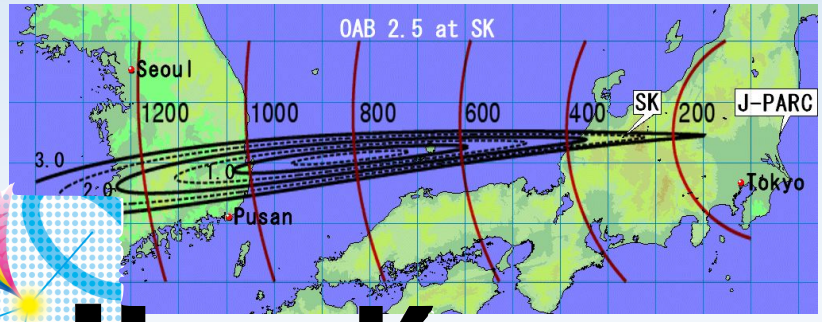
- **DUNE** (Fermilab to South Dakota)
- **Hyper-K** (Japan, maybe to Korea)

Both experiments both in *preconstruction* phase with SUPA involvement

STFC could fund *construction* grants starting ~2020



DEEP UNDERGROUND NEUTRINO EXPERIMENT



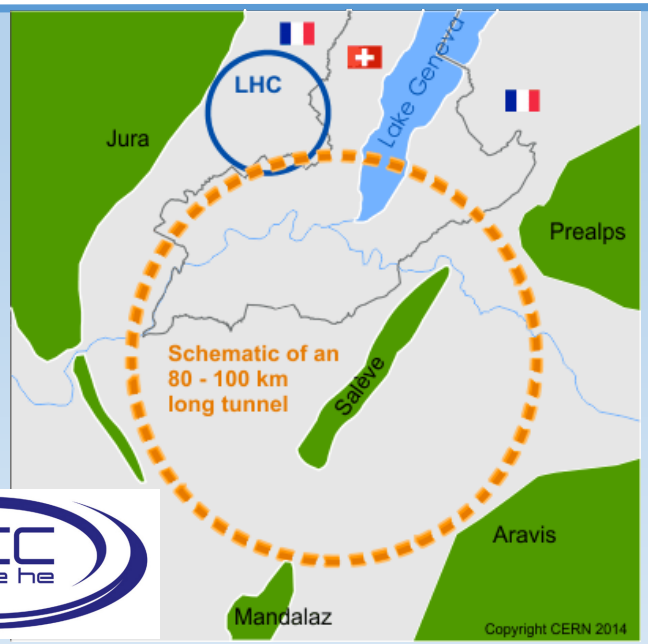
Hyper-Kamiokande

Particle Physics Experiments: Potential Areas for Development

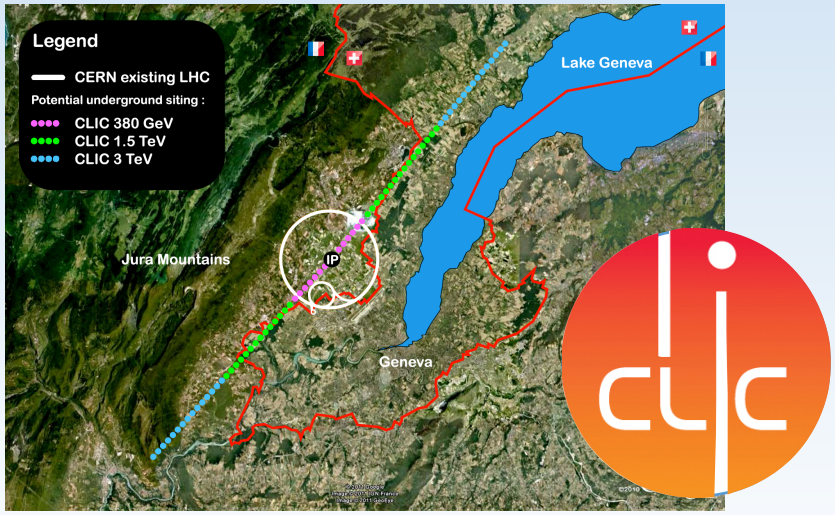
Possible future colliders:

- **CLIC** e^+e^- 450 GeV, 1.5 GeV & 3 TeV, at CERN
- **ILC** e^+e^- 500 GeV and 1 TeV, in Japan
- **FCC** e^+e^- 250 GeV & pp ~100 TeV & ep at CERN

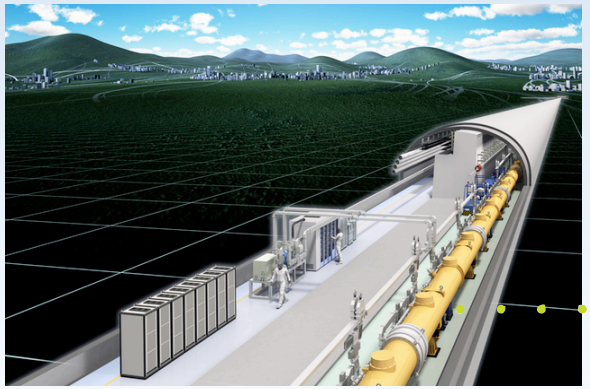
- No decisions likely to be made before ~2020.
- 5-10 year to build
  - High energy LHC (28 TeV) is another option



FCC hh ee he



CLIC



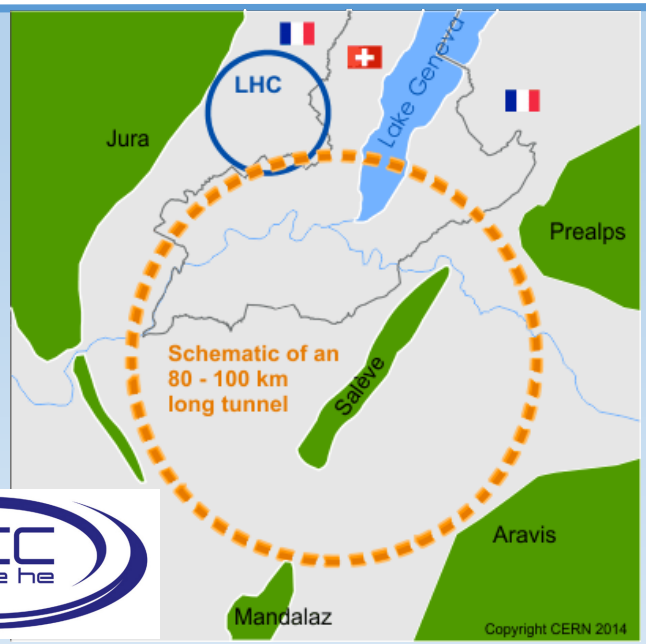
ILC

Particle Physics Experiments: Potential Areas for Development

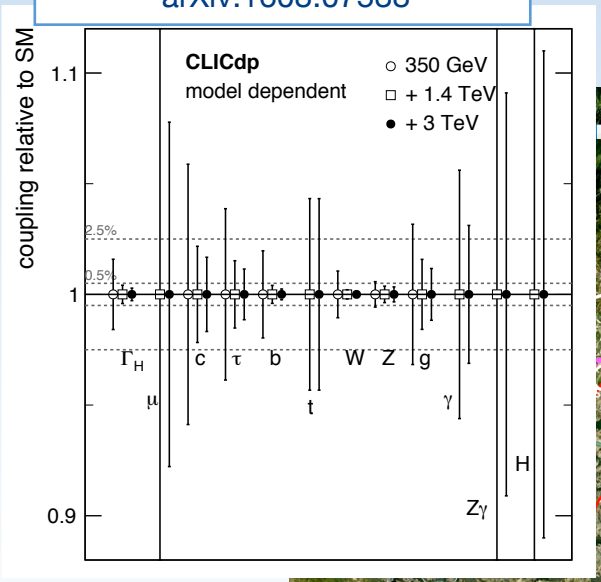
Possible future colliders:

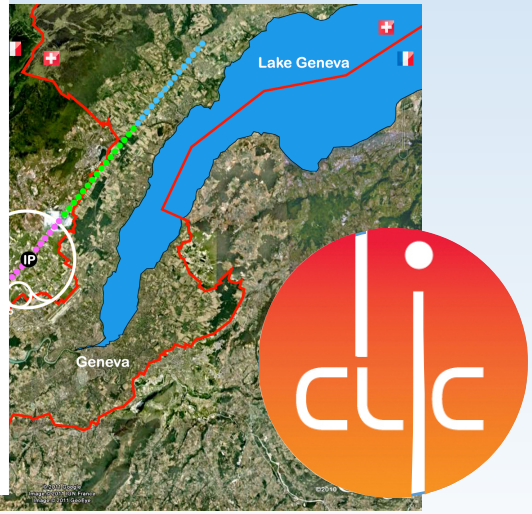
- **CLIC** e^+e^- 450 GeV, 1.5 GeV & 3 TeV, at CERN
- **ILC** e^+e^- 500 GeV and 1 TeV, in Japan
- **FCC** e^+e^- 250 GeV & pp ~100 TeV & ep at CERN

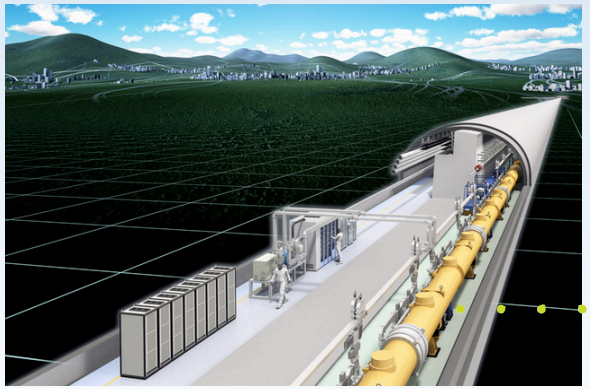
- No decisions likely to be made before ~2020.
- 5-10 year to build
  - High energy LHC (28 TeV) is another option



CLIC Higgs Physics Prospects
arXiv:1608.07538







Particle Physics Theory: Potential Areas for Development

Theoretical exploitation of LHC and future experiments

- Phenomenology beyond the SM
- Parton Distribution Functions for the LHC
- Precision lattice QCD results (g−2, flavour, fundamental parameters of the QCD Lagrangian)
- Strong interacting Beyond the Standard Model (BSM) and lattice (composite Higgs models)
- Theoretical tools for perturbative computations at higher orders (amplitudes, new methods in Quantum Field Theory)
- Lattice QCD: adding QED effects, development of algorithms and super-computing hardware

Interdisciplinary applications:

- Innovation in theoretical methods
- Algorithms
- Development of hardware architectures
- Spin-offs in other fields: mathematics, informatics/data science and exascale programmes

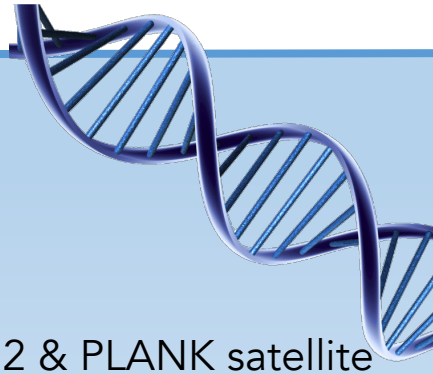
Particle Physics: Potential Areas for Development

Higgs Centre for Innovation

CDT in Data Intensive Science: Glasgow, Edinburgh, St Andrews in particle, astro and nuclear physics

- Research Council reorganisation
- UK government's industrial strategy
- European Strategy for Particle Physics 2020 process
- Review of the PP courses delivered by SUPA
- Edinburgh is planning a new MSc in data analysis in particle & nuclear physics to start in 2018

Concluding Remarks



- LHC exploitation - **experimental and theoretical - remains top priority**
  - **Phenomenology and Parton Distribution Functions**
  - **Detector operations and data analysis**
  - **Detector upgrades**
  - Exploitation and interpretation of other experiments: NA62 & MICE, g−2 & PLANK satellite

- Developments for the future
  - Installation of LZ for dark matter searches
  - Future long-baseline neutrino experiments are a major new priority for STFC: we are already engaged in Hyper-K and DUNE
  - SUPA physicists are leading efforts in future colliders collider - both in theory & experiment - we will be prepared if these facilities are chosen
  - Developments in precision lattice QCD & formal theory
  - Detector technology

- Collaboration is in the DNA of particle physicists - particle physics does not happen without collaboration.
  - But we need to work more to bring our collaborative skills outside our research to further our impact e.g. in medical & industrial applications, data science, education …

Particle Physics: Awards & Major Roles

- Awards in 2016/17:
  - Peter Boyle: Royal Society Wolfson Research Merit Award
  - Greig Cowan: IPPP Durham associateship
  - Christine Davies: APS Fellowship
  - Tony Doyle: RSE/Lord Kelvin Medal
  - Peter Higgs: Royal Commission for the Exhibition of 1851 Medal
  - Victoria Martin: CERN associateship
  - Franz Muheim: IPPP Senior Experimental Fellowship
  - Jennie Smilie: ERC starting grant
  - Alan Walker: honorary degree (D. hc), University of Edinburgh
- Major Roles:
  - Craig Buttar: ATLAS UK PI, 2019-2021 (Deputy, 2016-2018)
  - Christine Davies: member, STFC Science Board
  - Christine Davies: Project Management Board for DiRAC HPC Facility
  - Richard Kenway: appointed to STFC council
  - Victoria Martin: Chair, STFC Project Peer Review Panel 2016-17
  - Alex Murphy: Chair, LUX Executive Committee
  - Alex Murphy: Experiment advisory committee for SNOlab
  - Aidan Robson: Chair, CLICdp Institute Board
  - Paul Soler: MICE UK PI