SUPA Physics Scotland

SUPA IAC – 7th June 2018

Particle Physics

Theme Leader: **Victoria Martin** (Edinburgh)
Presenter: **Ben Wynne** (Edinburgh)

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

Experiment:

- **Large Hadron Collider at CERN**: ATLAS and LHCb
- **Quark flavour physics:** LHCb and NA62 (CERN)
- **Neutrino physics:**
  - ➡ Neutrino Factories and MICE at RAL
  - ➡ Long-baseline: DUNE (USA) proto-DUNE (CERN), T2K (Japan)
  - ➡ WATCHMAN in Boulby Mine (detecting neutrinos from nuclear reactors)
- **Dark Matter** (LUX,LZ) in Homestake mine, South Dakota
- **Future colliders** (ILC, CLICdp, FCCee)

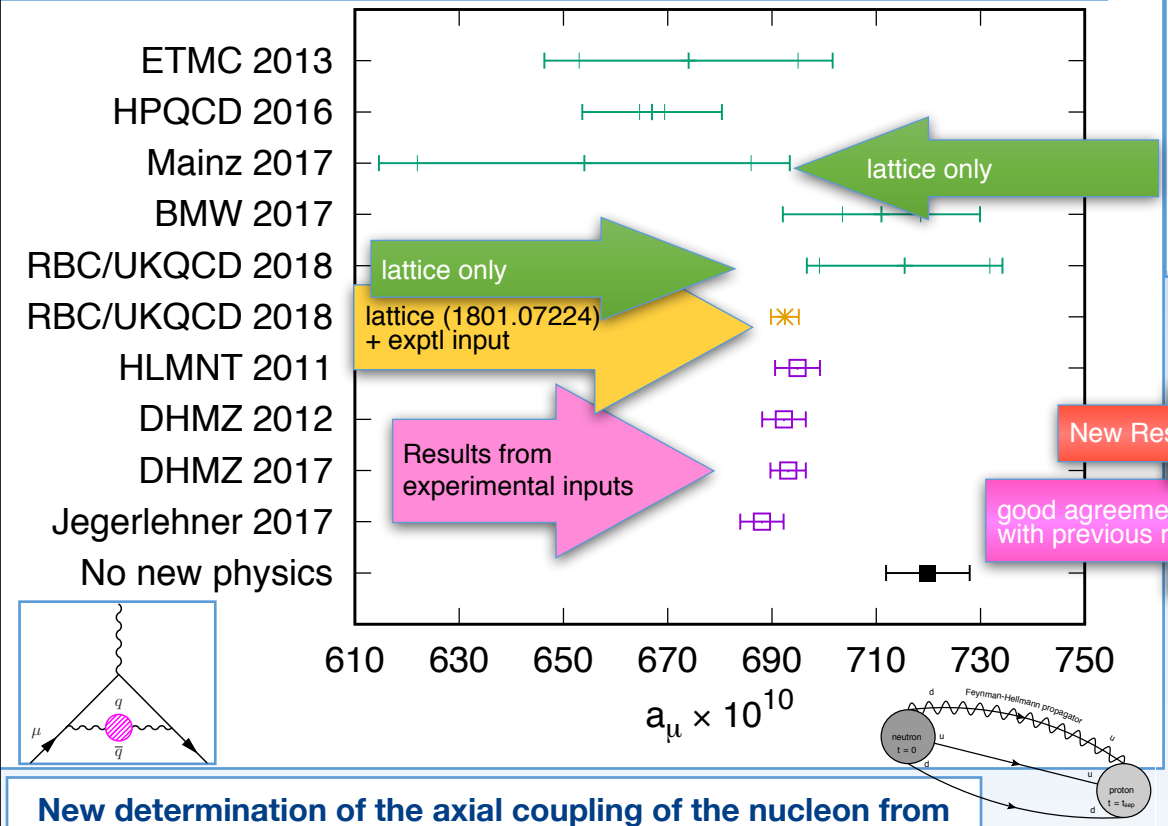
Theory:

- **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
- **Scattering Amplitudes calculations**
- **Formal theory:** little Higgs, Supersymmetry, extra dimensions
- Turbulence, links to condensed matter

Computing & Data Analysis aka **Data Science & AI**

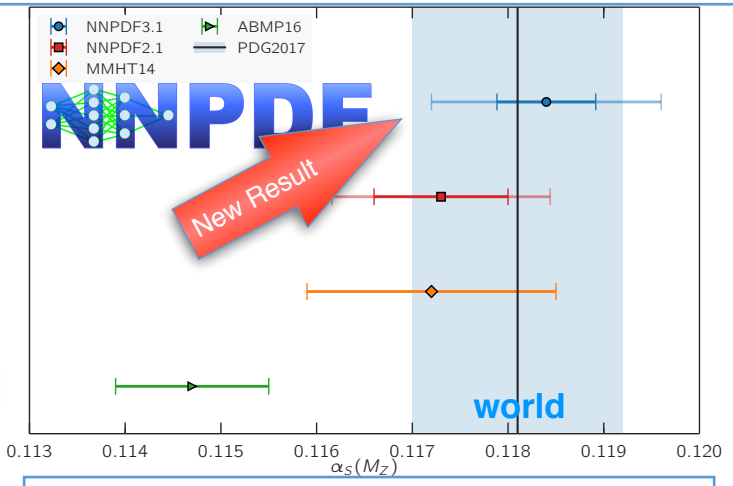
Particle Physics Theory
2017/18 Research Highlights

Calculations of hadronic vacuum polarisation contribution to anomalous magnetic moment of the muon, $a_\mu = (g_\mu - 2)/2$. Lattice QCD & experimental inputs - including separate masses for up & down quarks
arXiv:1801.07224, arXiv:1601.03071 arXiv:1710.11212
Combining lattice & experimental results suggest new physics is needed to account for a_μ!

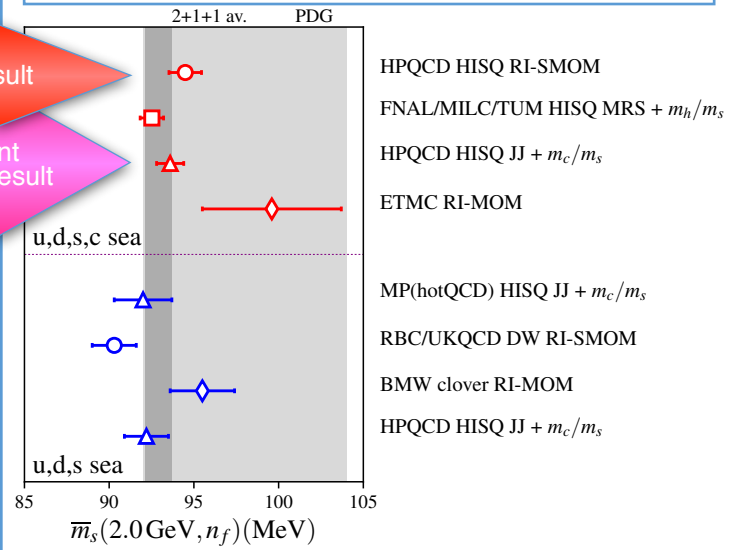


New determination of the axial coupling of the nucleon from lattice QCD: *for decay of neutron to proton; a ~1% measurement that agrees with experiment* arXiv:1805.06225

Improved determination of strong force coupling, α_S
agrees with experiment! arXiv:1802.03398

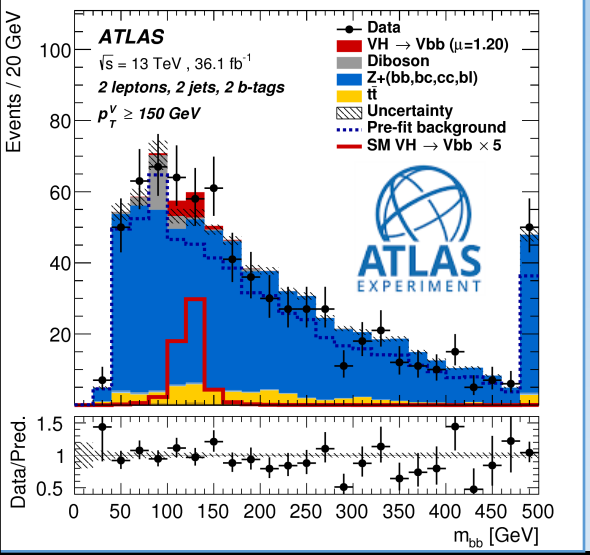


Determination of the strange quark mass with Lattice QCD arXiv:1805.06225

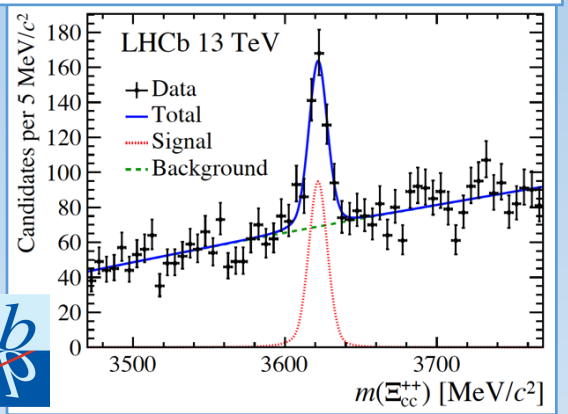


Particle Physics Experiment 2017/18 Research Highlights

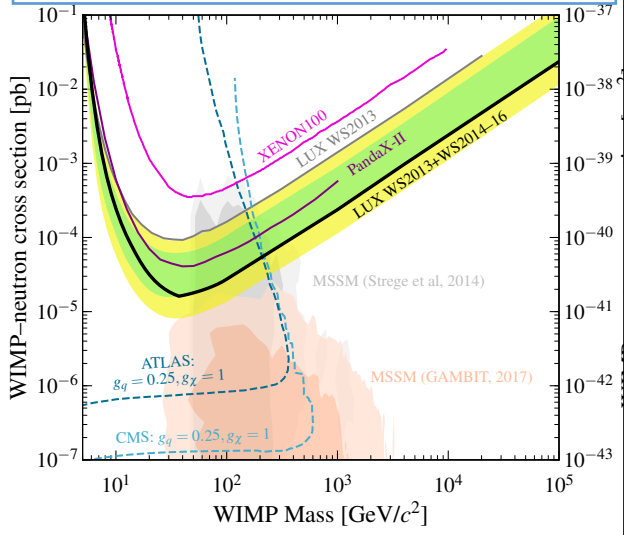
Observation of Higgs boson decaying to bottom quarks JHEP12(2017)024



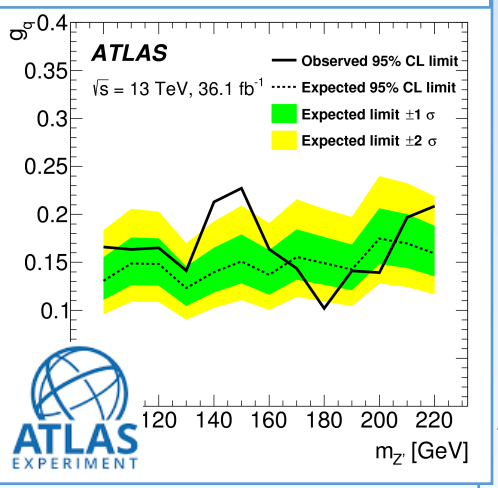
Observation of doubly-charmed baryons PRL 119, 112001 (2017)

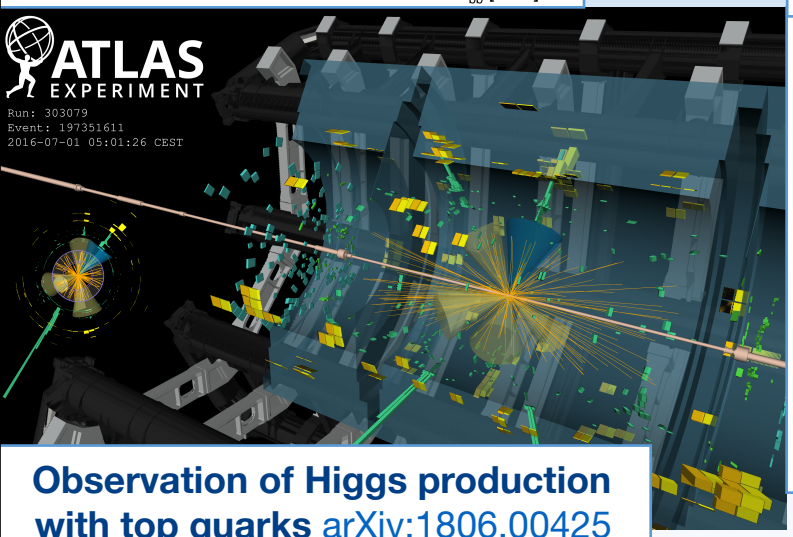


Spin-dependent limits on dark matter from LUX arXiv:1705.03380

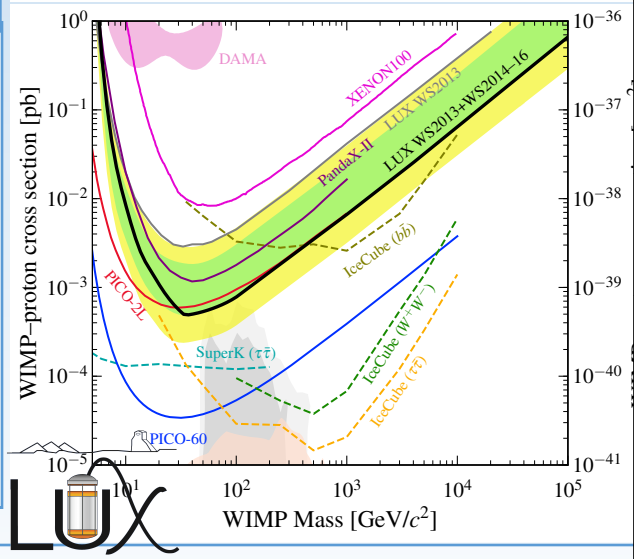


Hints of new particles in new topologies at the LHC?? arXiv:1801.08769

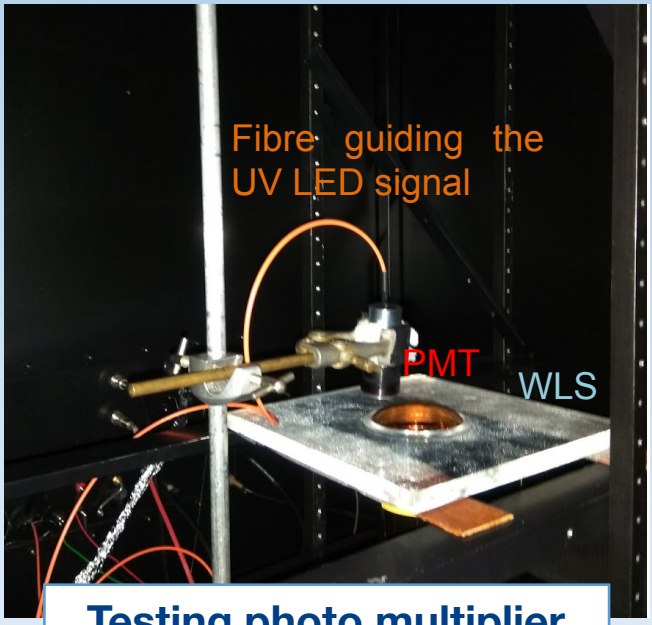




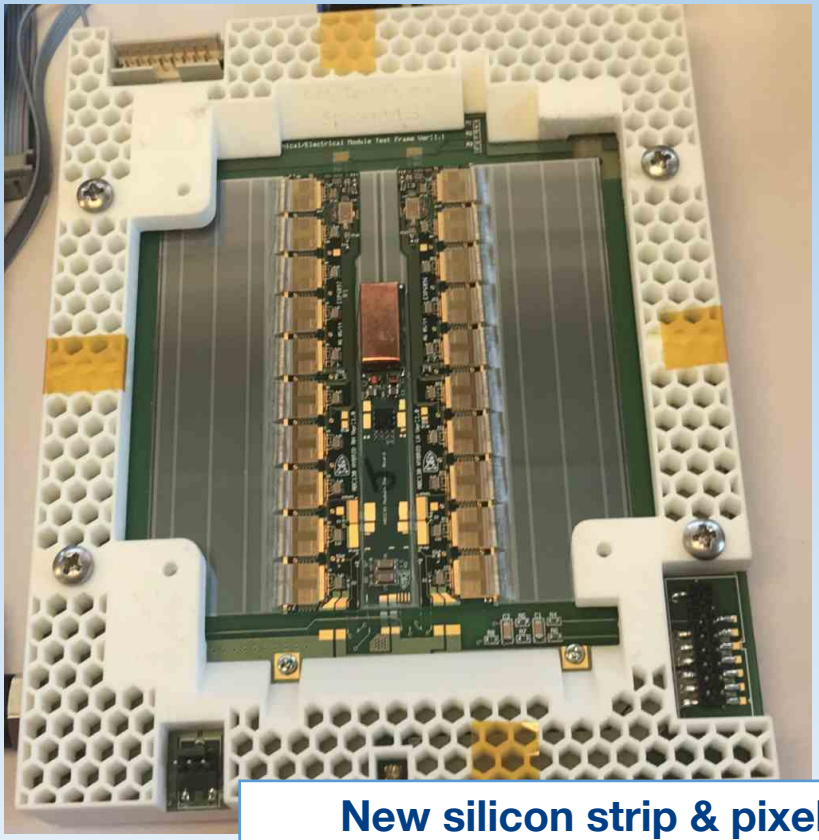
Observation of Higgs production with top quarks arXiv:1806.00425



Particle Physics Experiment 2017/18 Detector Developments



Testing photo multiplier tubes with wavelength shifting plate for Hyper-K



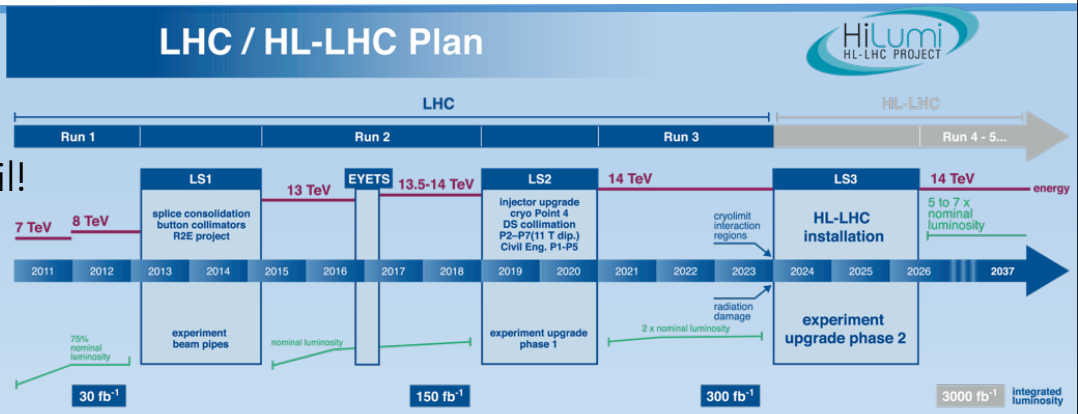
Electronics produced by ZOT, Musselburgh

New silicon strip & pixel detectors & associated electronics for ATLAS upgrade, developed in Glasgow & Edinburgh

Particle Physics Experiments: Active Developments

ATLAS & LHCb upgrades for 10x nominal luminosity starting 2027

- **ATLAS**: funding approved by STFC council!
- **LHCb**: phase 1a upgrade funded and in construction, future phases being discussed



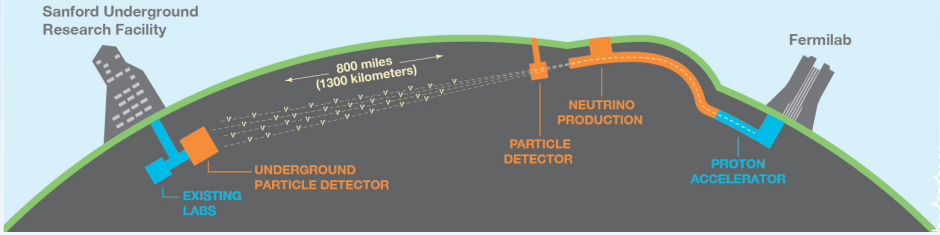
Long baseline neutrino experiments: neutrinos beams through the ground for precision measurements of neutrino properties; data taking starting ~2026

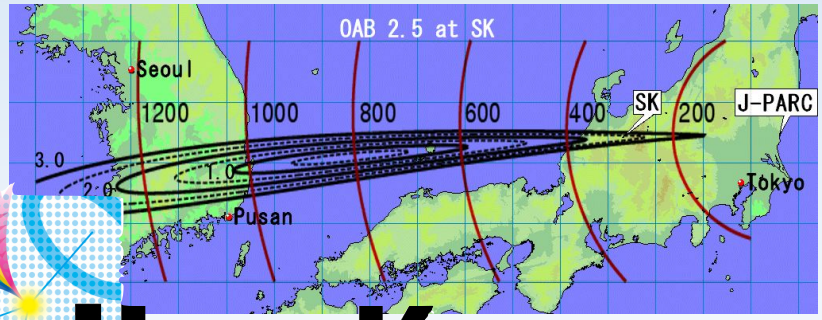
- **DUNE** (Fermilab to South Dakota): £65M investment from UKRI announced in September 2017
- **Hyper-K** (Japan, maybe to Korea)

[Jo Johnson signing the deal in Washington]

Both experiments both in *preconstruction* phase with SUPA involvement

STFC could fund *construction* grants starting ~2020





DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

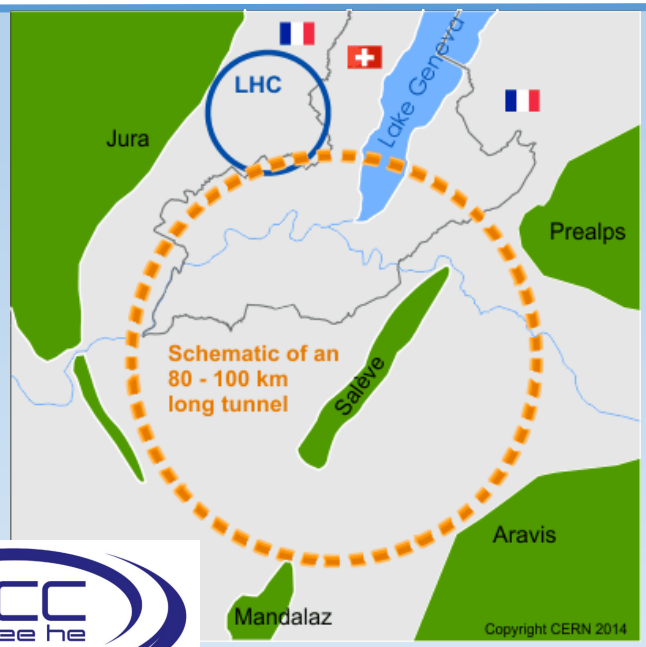
Hyper-Kamiokande

Particle Physics Experiments: Potential Areas for Development

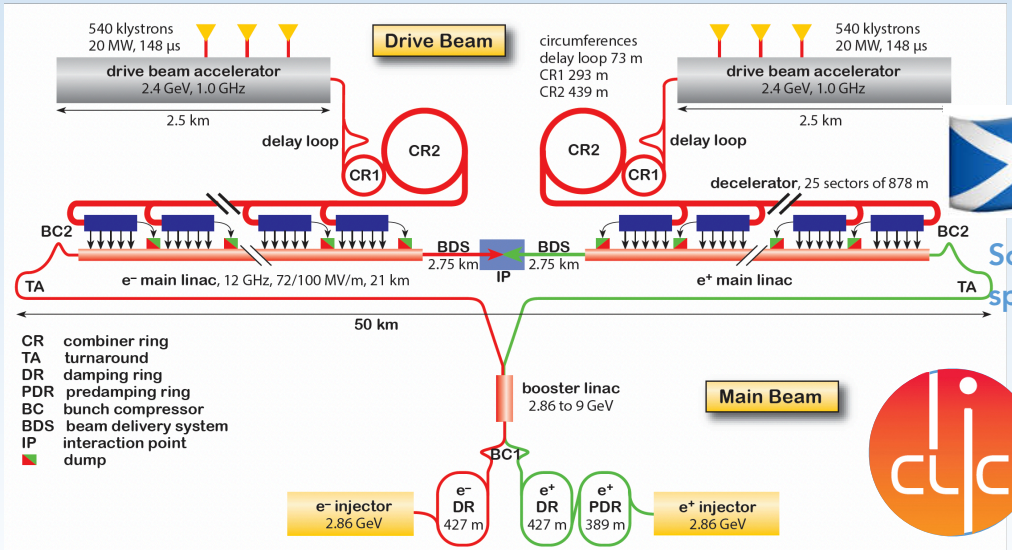
Possible future colliders:

- **CLIC** e^+e^- 380 GeV, 1.5 GeV & 3 TeV, at CERN
- **ILC** e^+e^- 250 GeV(++) in Japan
- **FCC** e^+e^- 90-350 GeV & pp ~100 TeV at CERN
- **High-Energy-LHC:** pp ~ 27 TeV: replace current LHC magnets with 16 Tesla NbSn)

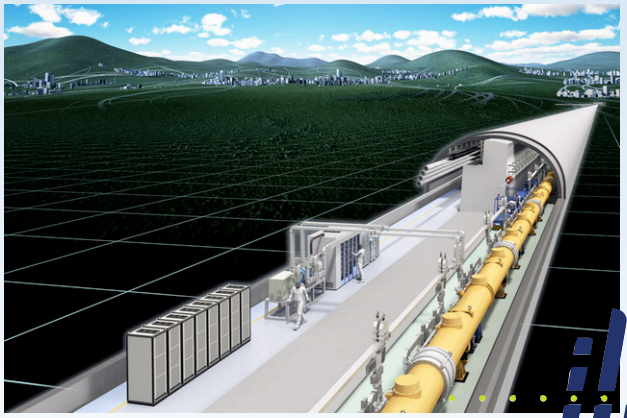
- **CERN council are now consulting for an update European Strategy for Particle Physics - to be published in 2020**



FCC hh ee he



Scottish spokesperson!



CLIC

ILC

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: CERN spin-off space!

- STFC has been subsumed into UKRI … can we keep a distinctive voice?
- European Strategy for Particle Physics Update process
- New MSc in particle & nuclear physics in Edinburgh starting September 2018
  - Need to think about SUPA teaching in the context of this
- SUPA Particle Physics courses:
  - Problems with students attendance at the core SUPA particle physics courses as they think the 40 hours is the only requirement
  - Overlaps w/ CDT Data Science courses: challenging for students with placements at CERN

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 T2K (currently running) and Hyper-K & DUNE (for the 2020s)
  - SUPA physicists are leading efforts in future collider physics - both in theory & experiment - we will be prepared if any of these facilities are approved
  - Developments in precision lattice QCD & formal theory
  - Detector technology

- **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 …

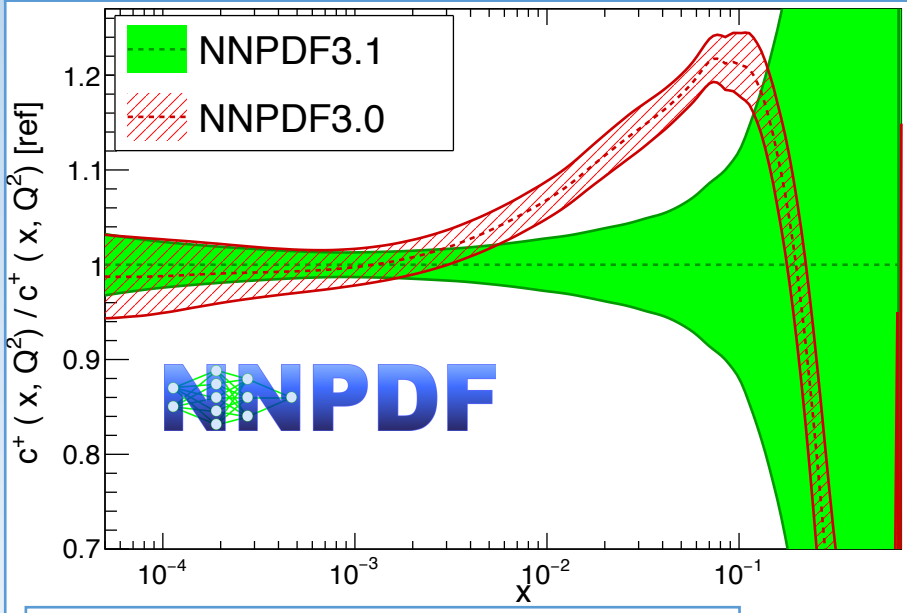
Backup: Major Roles & Awards

- **Personal Chairs in 2017 for**
  Lars Eklund, Aidan Robson (Glasgow); Roman Zwicky, VJM (Edinburgh)

- **Major Collaboration & Community Roles:**
  - Richard Ball: member, STFC Particle Physics Grants Panel
  - Craig Buttar: ATLAS UK PI, 2019-21 (Deputy, 2016-18)
  - Pete Clarke: member, STFC Science Board
  - Christine Davies: member, STFC Science Board
  - Lars Eklund: Deputy Chair, STFC Project Peer Review Panel 2018-19 (Chair, 2020-21)
  - Christos Leonidopoulos: member, STFC Particle Physics Grants Panel
  - Richard Kenway: member, UKRI STFC Council
  - Victoria Martin: Chair, STFC Project Peer Review Panel 2016-17
  - Victoria Martin: Chair, CLICdp Institute Board
  - Alex Murphy: Chair, LUX Executive Committee
  - Alex Murphy: Experiment advisory committee for SNOlab
  - Alex Murphy: REF Panel member
  - Aidan Robson: Chair, CLICdp Spokesperson, 2018-2019
  - Paul Soler: MICE UK PI
  - Paul Soler: member, STFC Particle Physics Grants Panel
- **Plus … many, many internal collaboration leadership roles for postdocs + students!**

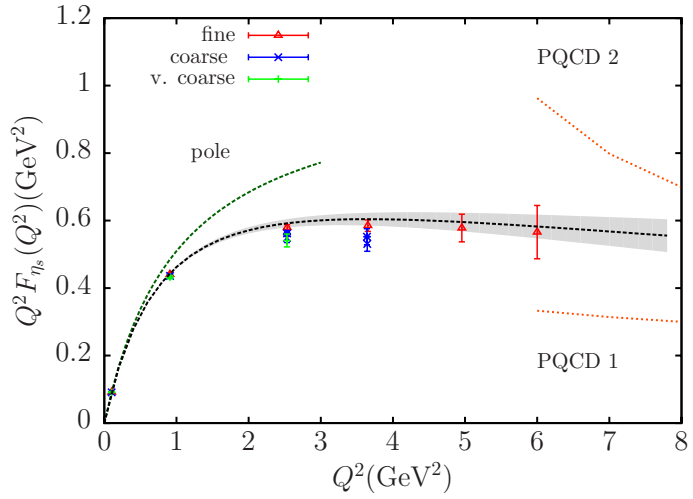
Backup: Particle Physics Theory 2017/18 More Research Highlights!

Updated proton PDF functions (content of the proton at high-energy) now including all LHC Run 1 data!
Indications that low-x dynamics are not fully captured by naïve (DGLAP) partonic picture
(this plot shows charm quarks in the proton)
arXiv:1706.00428



Light meson electromagnetic form factor from Lattice QCD: *suggests perturbative QCD techniques always not always good enough ⇒ implications for many results from mesons!*

PRD.96.054501



Interpreting top-quark LHC measurements in the standard-model effective field theory
arXiv:1802.07237
Parameterising where any new particles/ interactions can be found in LHC collisions
(As mentioned by Andy Buckley yesterday.

More complications in determining coupling between the charm and bottom quark V_{ub} - **as presented by C. Davies at Gathering 2017**
PRD.97.054502