SUPA Physics Scotland

SUPA IAC Meeting – 26th May 2016

Particle Physics Theme

Theme Leader: Paul Soler, University of Glasgow, since 2014

SUPA Particle Physics: University of Edinburgh, University of Glasgow (Strathclyde University for MICE)

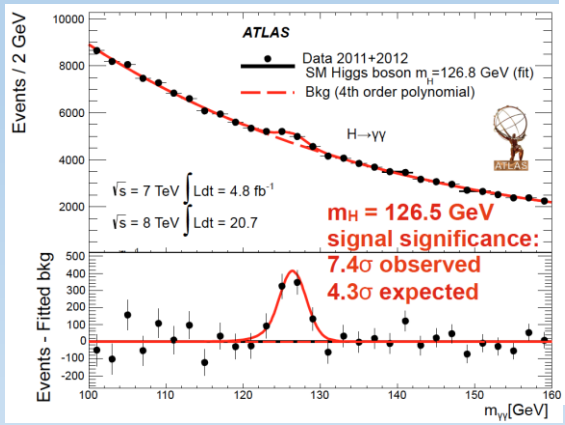
- Particle Physics Experiments: Large Hadron Collider at CERN (ATLAS and LHCb), NA62 at CERN, Neutrino Factories and MICE at RAL, Hyper-Kamiokande (Japan), Dark Matter (LUX,LZ) in USA, Linear Collider (ILC and CLIC)
- Particle Physics Theory: lattice QCD at the DIRAC facility and elsewhere, LHC phenomenology, formal theory

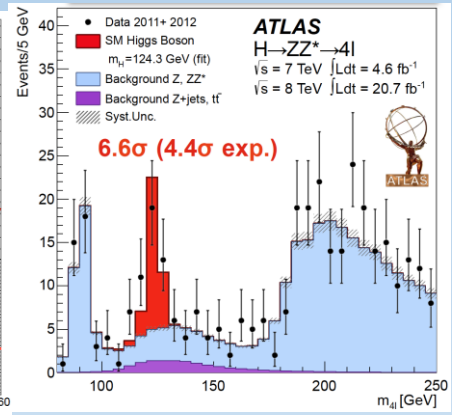
Existing Scope SUPA Particle Physics

- Particle Physics Experiments (PPE): exploitation current experiments and preparation for new experiments
  - Leading contributions to ATLAS and LHCb detectors at CERN
  - Discovery Higgs boson and search of new physics at ATLAS
  - World-best measurements CP violation, pentaquark discovery at LHCb
  - Preparation high-luminosity ATLAS and LHCb upgrades
  - World leading searches for dark matter at LUX, preparations for LZ
- Particle Physics Theory (PPT):
  - Lattice QCD: world's most accurate quark mass and nucleon mass predictions, muon g-2, nucleon form factors, EDM neutron
  - World leading Higgs phenomenology and new physics effects
  - Scattering amplitudes and theoretical duality QCD and gravitation
- Impact of Particle Physics research
  - Medical and industrial applications of detector technology
  - E-Science: Particle Physics Grid led to Cloud computing and applications to other fields of science

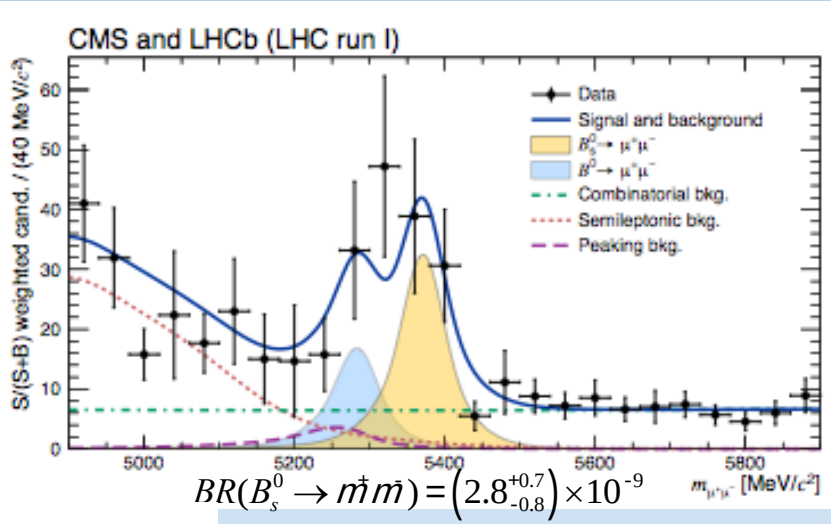
Illustrative Examples (PPE)

ATLAS Higgs Mass measurements

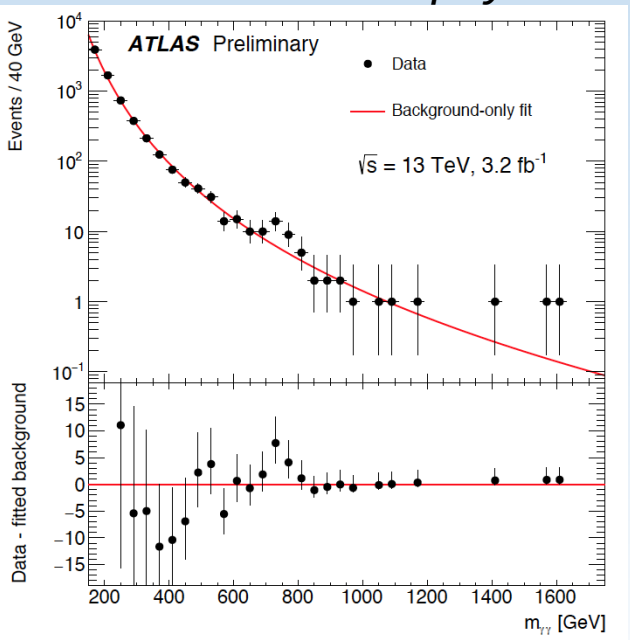




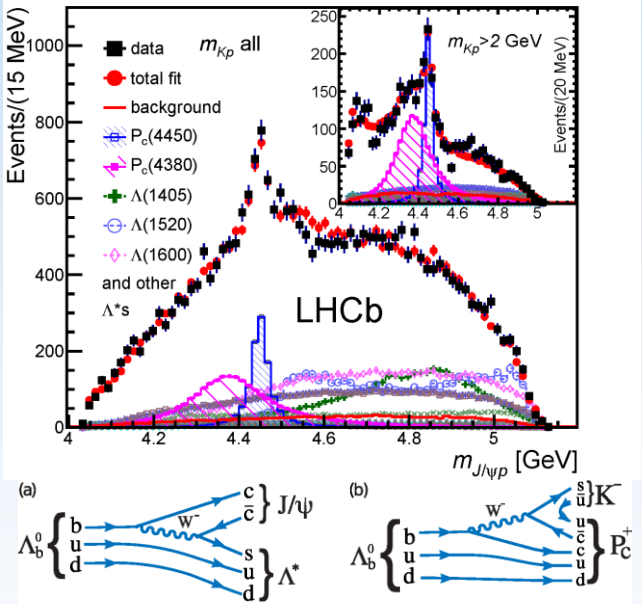
LHCb Bs➔$\mu^+\mu^-$



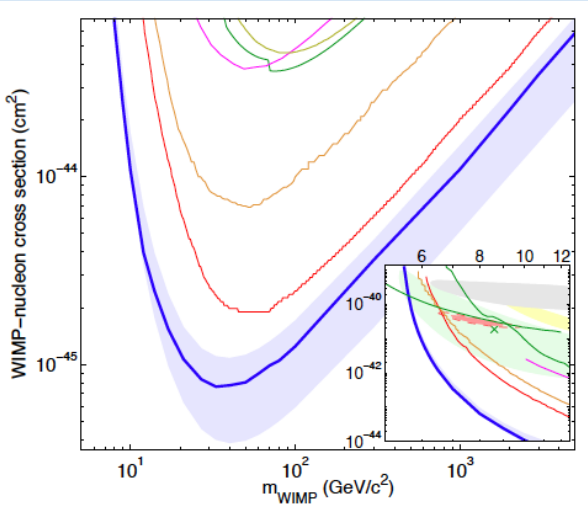
ATLAS search new physics



LHCb Pentaquark

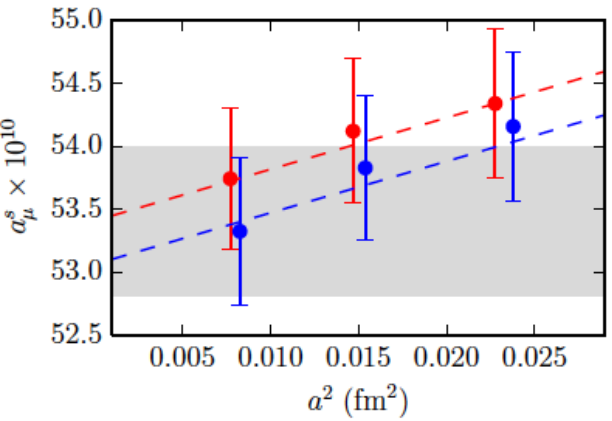


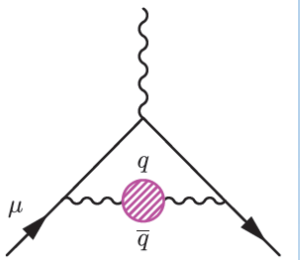
LUX Dark Matter search



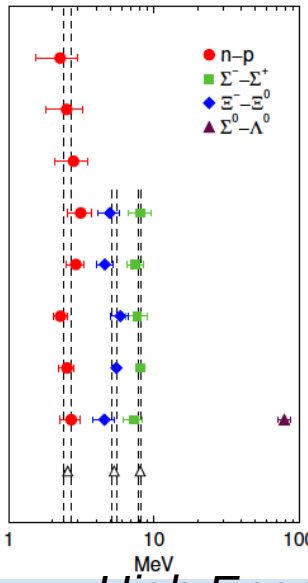
Illustrative Examples (PPT)

Lattice QCD calculation g-2





Lattice QCD baryon mass splittings



NPLQCD [arXiv:hep–lat/0605014]

Blum et al [arXiv:1006.1311]

RM123 [arXiv:1110.6294]

QCDSF–UKQCD [arXiv:1206.3156]

Shanahan et al [arXiv:1209.1892]

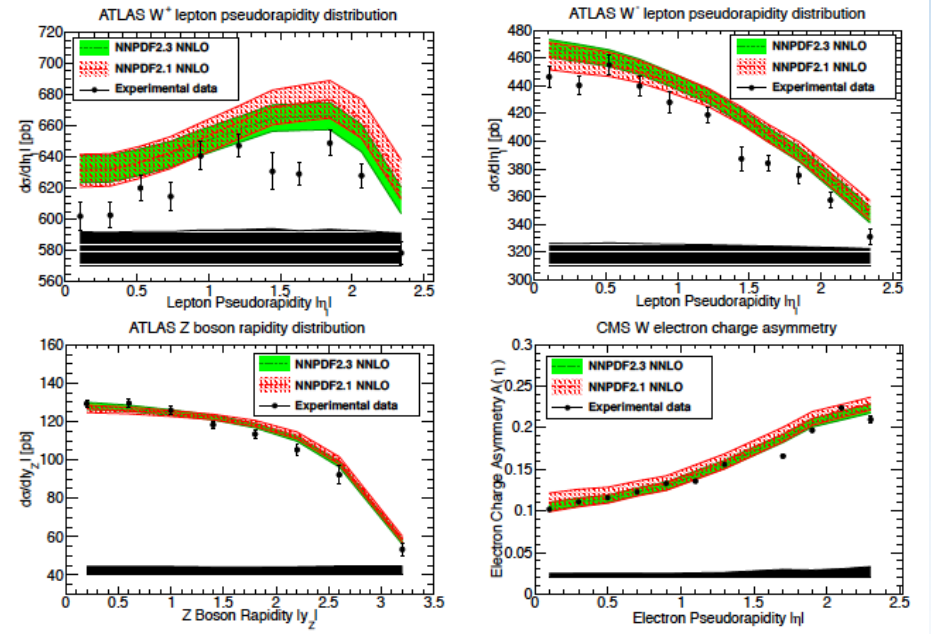
BMW [arXiv:1306.2287]

BMW [arXiv:1406.4088]

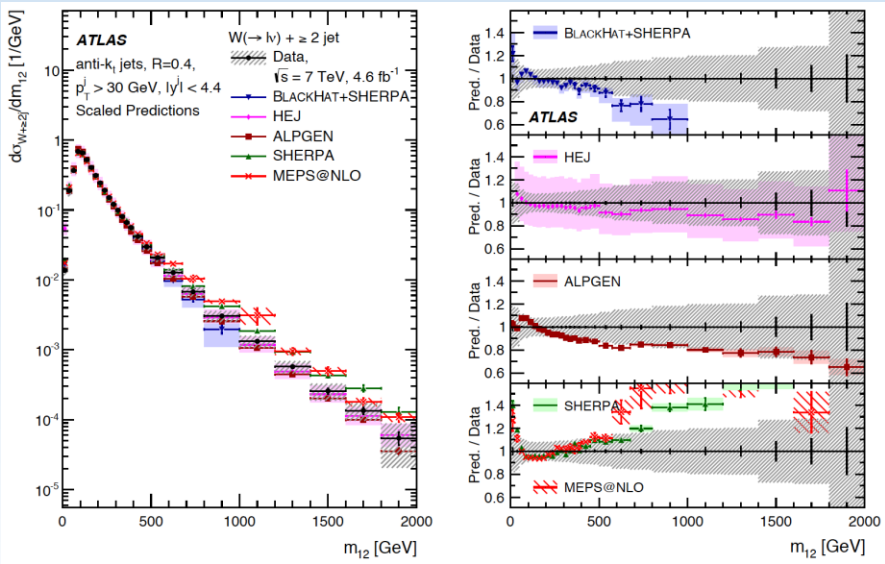
QCDSF–UKQCD [arXiv:1411.7665]

Weighted average

NLO and NNLO Parton Distribution Functions



High Energy Jets (HEJ) predictions



Potential Areas for Development (PPE)

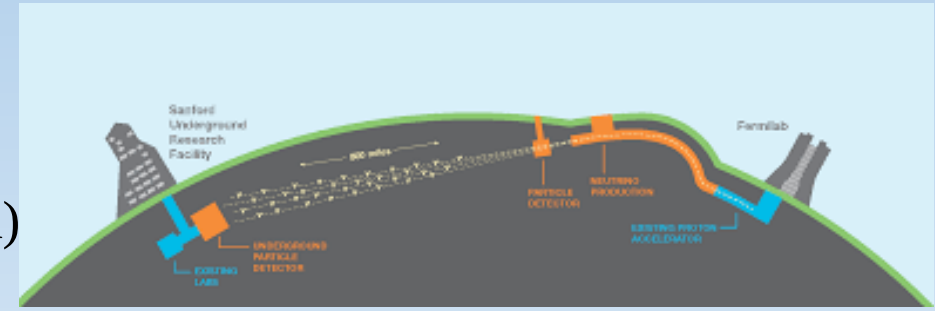
- ATLAS upgrade (Edinburgh, Glasgow): STFC grants awarded
  - Development pixel and strip detectors for upgrade
  - Computing and trigger
- LHCb upgrade (Edinburgh, Glasgow): STFC grants awarded
  - RICH upgrade (Edinburgh): leading photon detection testing
  - VELO upgrade (Glasgow): opto-electronics and data tapes
- NA62 exploitation (Glasgow): search for rare kaon decays
- Complete Muon Ionization Cooling Experiment (Glasgow/Strathclyde): STFC award 2016-2020 currently under negotiation
- Preparations for LUX-Zeplin (LZ) dark matter experiment (STFC funded)
- Future Long-baseline Neutrino Oscillation Experiments (HyperK/DUNE): STFC priority but to decide funding for one or both experiments ~2017
- Linear collider (Edinburgh, Glasgow): small effort, waiting for political decisions of funding in Japan
- Impact of particle physics technology (detectors and e-science): GridPP funding from STFC, STFC industrial awards, EPSRC awards …

Future Neutrino Opportunities

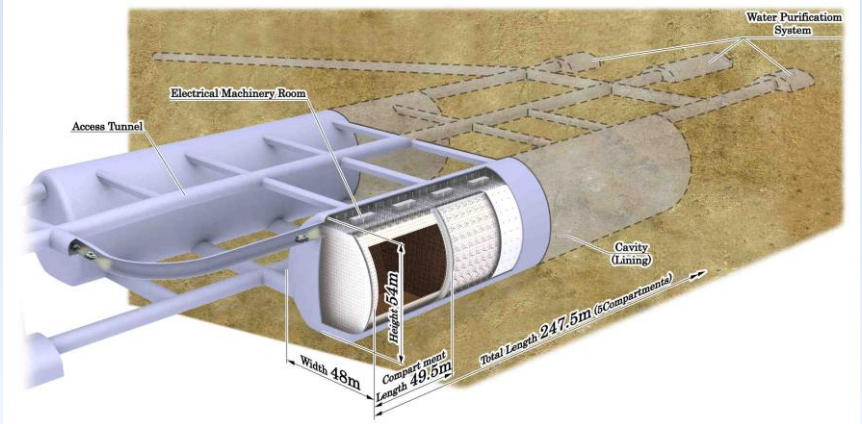
Two large international collaborations for Long Baseline Neutrino from 2025

DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

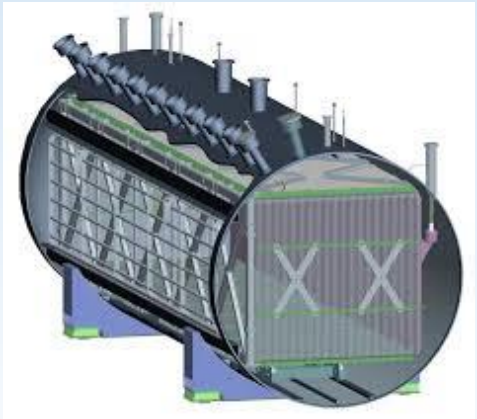
Hyper-Kamiokande



Beamline Tokai – Kamioka in Japan (295 km)
Successor to SuperK/T2K
Megaton water Cherenkov detector



Fermilab to Sanford mine in USA
Large liquid Argon TPCs

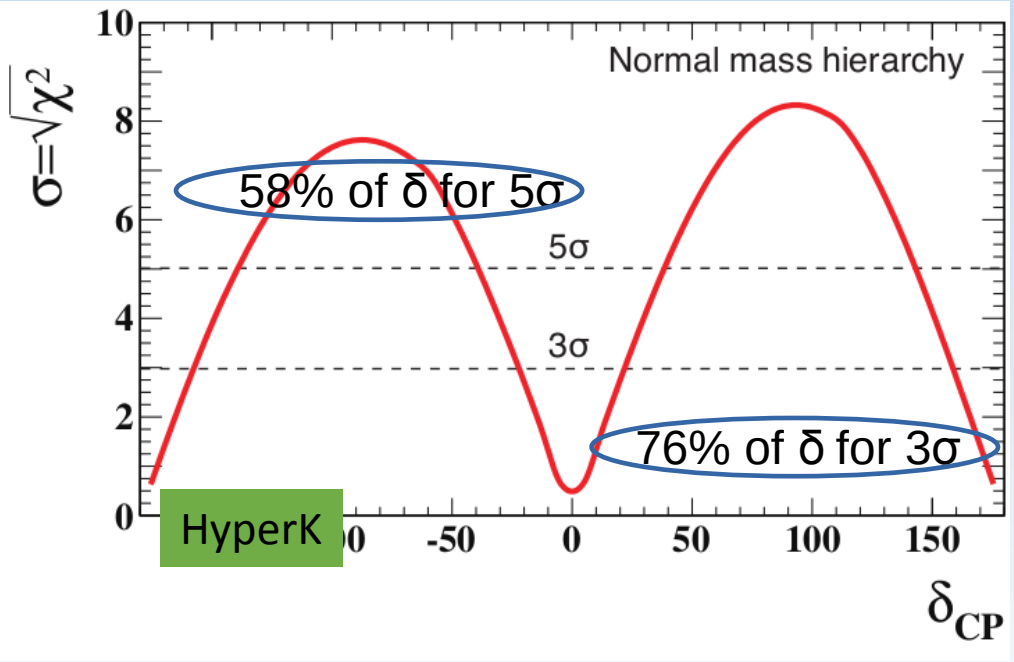


Future Neutrino Opportunities

Wide physics program probing range of fundamental physics

Multi-purpose experiments with much greater sensitivity than previous experiments

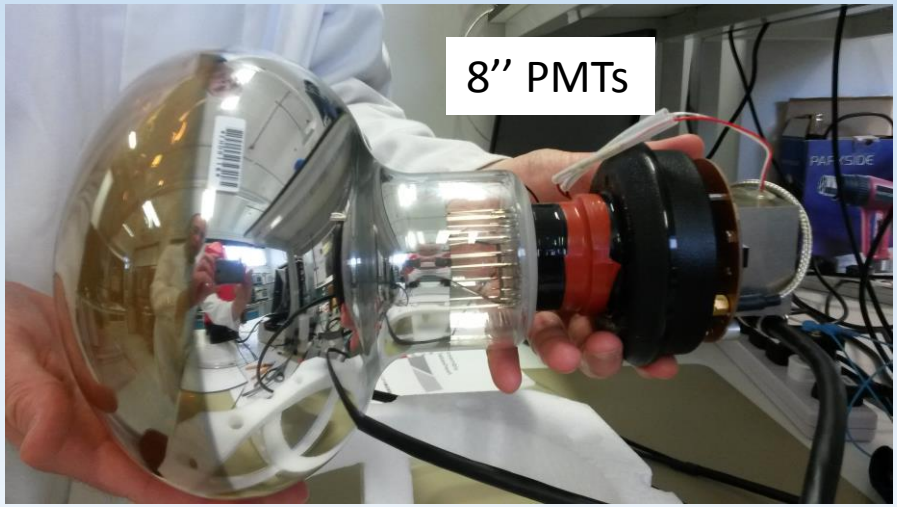
- Long baseline neutrinos: CP violation in lepton sector
- Atmospheric and solar neutrino measurements
- Supernova bursts (10, 000 neutrinos for supernova in Large Magellenic cloud)
- Neutrino geophysics
- Proton decay
- Dark matter….

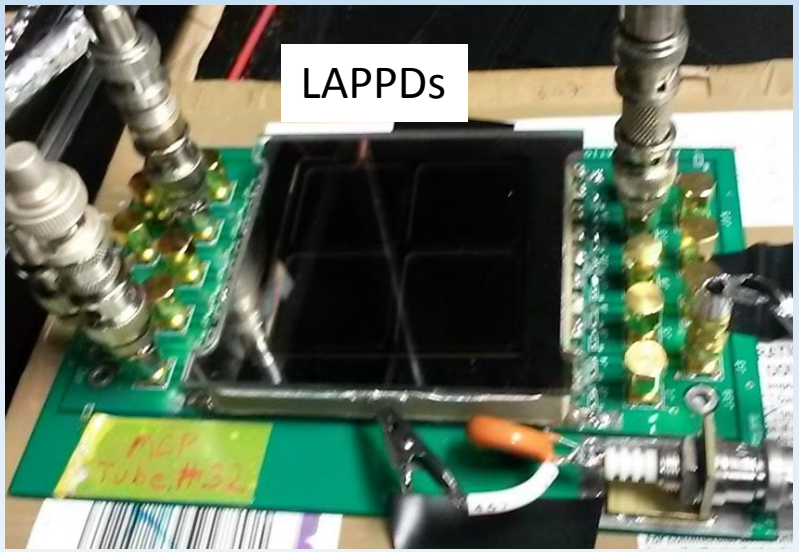


Future Neutrino Opportunities

Edinburgh in HyperK

- Edinburgh joined HyperK along with other UK groups in 2014
- UK groups focussed on detector optimization studies in particular for the Near and Intermediate detectors
- Edinburgh has small but growing effort: fraction of 2 Academics, 2 Fellows and a postdoc
- Working on detector optimization and simulation and photodetectors





Looking to expand our efforts: watching brief on DUNE, looking at joining running experiment such as T2K

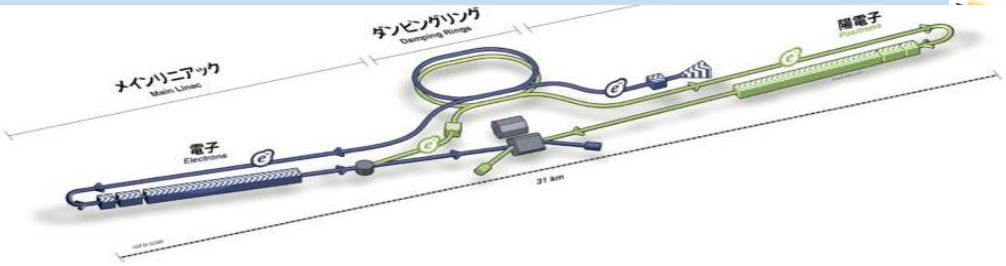
Linear Colliders

electron–positron colliders provide clean experimental environment

Pillars of physics programme:
- precision Higgs physics
- precision top-quark physics
- beyond-standard model physics

Two machines in advanced state of development:

International Linear Collider (ILC)



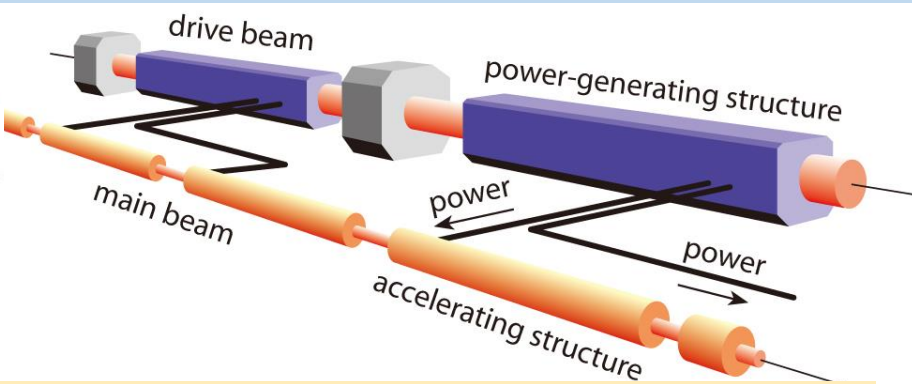
Conventional superconducting linacs

Baseline centre-of-mass energy 500GeV with low-energy stages and possible 1TeV extension

Site chosen: Kitakami, northern Japan

Site-specific technical design report is with Japanese government; high-level inter-government talks ongoing, expect decision in 2018; construction would take ~9-years

Compact Linear Collider (CLIC)



Room-temperature two-beam acceleration scheme

Staged programme: centre-of-mass energies 380GeV, 1.5TeV, 3TeV

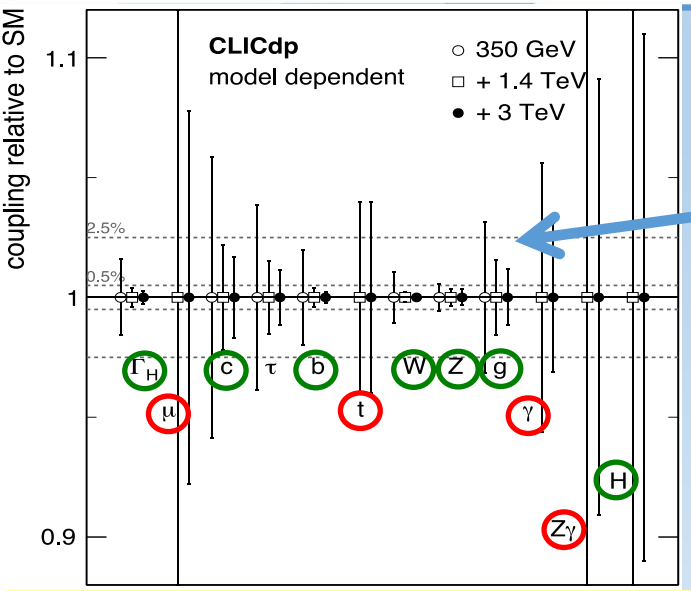
Site is CERN

Conceptual design report completed in 2012

Currently developing Project Plan for CERN decision at next European strategy (~2020)

Construction could start ~2025 and take ~6 years for 380GeV

Linear Colliders

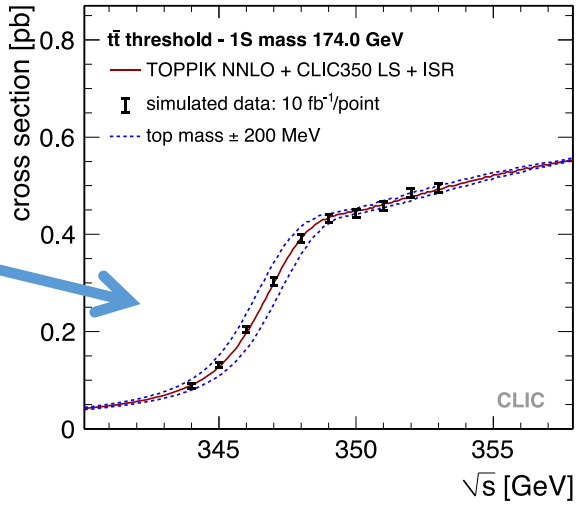


Example physics reach: precision Higgs physics
- measure Higgs couplings to O(1%)
- potential to reveal new physics at high energies

Precision significantly better than HighLumi-LHC

Precision comparable to HighLumi-LHC

Example physics reach: precision top-quark physics
- measure well-defined top-quark mass through threshold scan to ~50MeV



ILC: Two detector collaborations: ILD and SiD

CLIC: 62 institutes from 28 countries in accelerator collaboration
27 institutes from 17 countries in Detector & Physics collaboration (CLICdp)

SUPA activities:

ILC:

Glasgow co-leading simulation and reconstruction software effort for the SiD detector collaboration

CLIC:

Dundee participates in accelerator design

Chair of CLICdp collaboration board is from ***Glasgow*** ; ***Glasgow*** & ***Edinburgh*** are doing physics studies ; ***Glasgow*** contributing software

ILC & CLIC: Silicon sensor and structure design studies (***Glasgow*** + possible ***Edinburgh*** interest) ongoing as part of wider UK effort

Potential Areas for Development (PPT)

- Theoretical exploitation of LHC run 2 and experiments at the intensity frontier
  - 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: 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

Concluding Remarks

- Collaboration is in the DNA of Particle Physicists
- LHC exploitation and upgrade remains top priority
- Exploitation of other experiments: NA62 and MICE
- World-leading dark matter searches: LUX, LUX-ZEPLIN
- Future long-baseline neutrino oscillation experiments (HyperK or DUNE) – STFC physics priority
- SUPA physicists also leading efforts in linear collider
- Impact particle physics: medical and industrial applications, E-Science
- Theoretical exploitation of LHC run 2 and experiments at the intensity frontier
  - Phenomenology and Parton Distribution Functions for the LHC
  - Precision lattice QCD
  - Formal theoretical developments