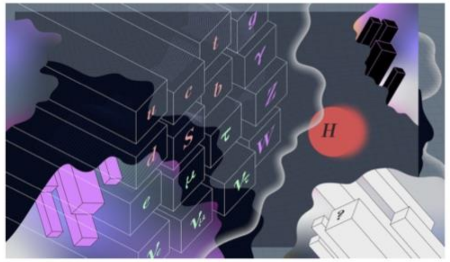
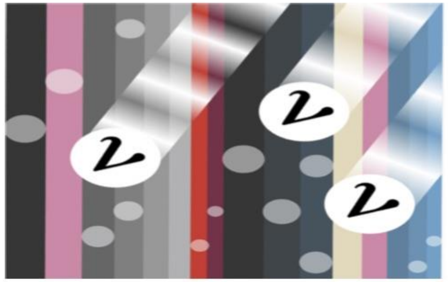
The Oxford PP Strategic Plan 2025-2035

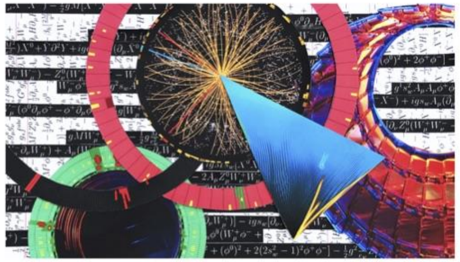


The Higgs as a tool for discovery

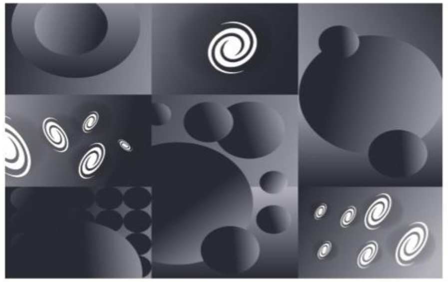
Understand the matter antimatter asymmetry of the Universe



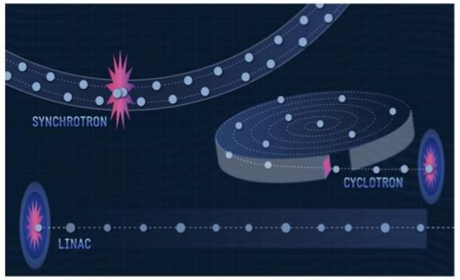
The physics of neutrinos



Explore the Unknown: New Particles, interactions, and physical Principles



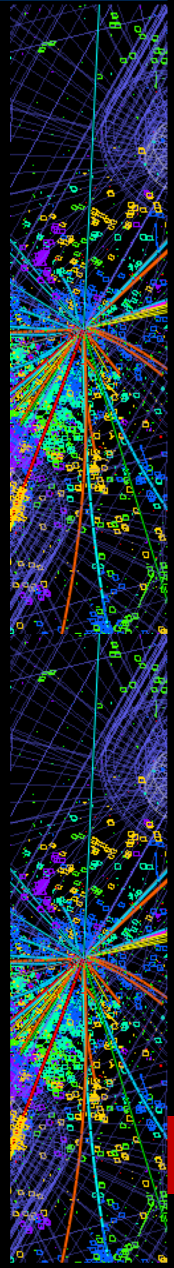
The new physics of dark matter and dark energy

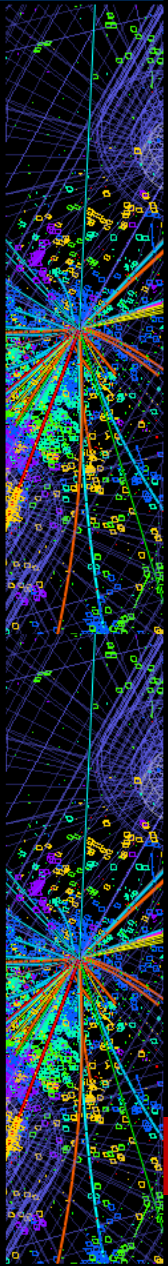


Develop new detectors and accelerator techniques

OXFORD PP in 2020

28 Academics





Oxford PP NOW if we had not implemented our strategic plan

18
Academics


Azfar

Barr

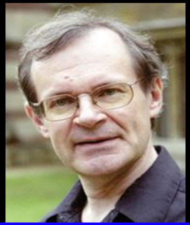
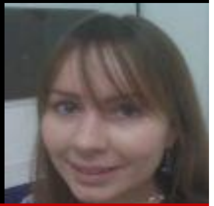
Barr

Biller

Bortoletto

Cooper-
Sarkar

Burrows


Foster

Gwenlan

Harnew

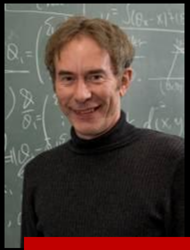
Hays

Huffman

John

Kraus

Nickerson


Reichold

Shipsey

Tseng

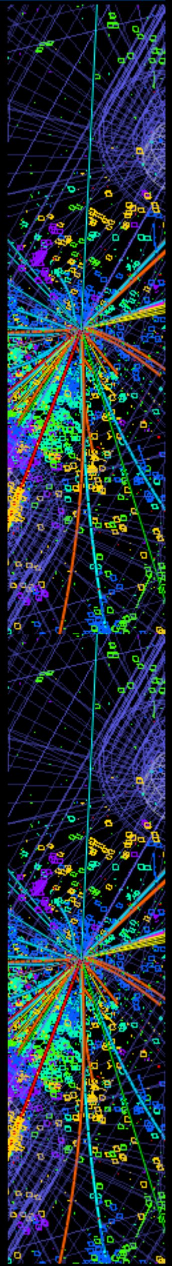
Viehhause
r

Walzac
k

Wark

Wilkinson

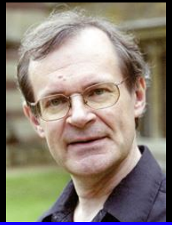
Weidberg



Oxford PP NOW

26 Academics


Cooper-Sarkar


Foster


Harnew


Nickerson


Walzack


Azfar


Barr


Barr

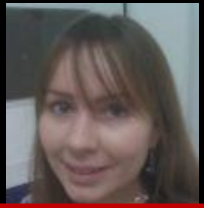

Biller


Bortoletto


Burrows


D'Arcy


Duffy


Gwenlan


Hays


Huffman


John


Kraus

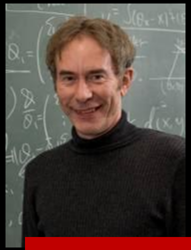

Oeftiger


Malde


Monroe


Palladino


Reichold


Shipsey


Tseng


Viehhauser


Wark


Wascko


Wilkinson

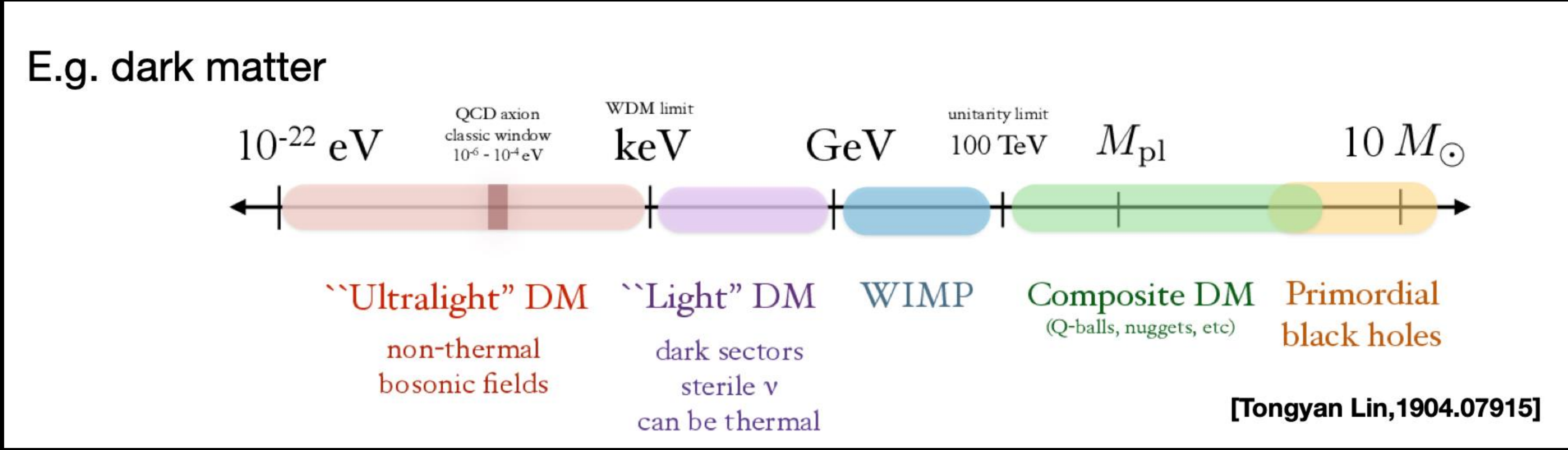

Weidberg


Withington

Planning for the future

- Major open questions
- No no-lose theorems
- Not even a dominant theoretical expectation

Exciting time for experimentalists!



Planning for the future

- We are in the middle of several exercises
  - ScienceBoard PPAN is working towards a prioritized UK road map
    - Funding is very tight until the completion of big construction projects (ATLAS, CMS, DUNE)
  - At the European level ESPPU
    - What will be next collider at CERN ?
    - Will CERN expand beyond accelerator physics ?

- We are dealing with the University monitoring hiring very closely and developing plans to reduce the size of the faculty across all disciplines
  - Carefully examining business cases
  - Expect STFC funding to be very tight
  - Dealing with only 4% academic contribution in STFC grants is very challenging and has caught the attention of the University
- Retirement age more uncertain than before

- Must have a compelling physics case for every hire
- Must look for opportunities

Evolution of the Oxford programme

- In 2020:
  - Energy frontier:
    - ATLAS/upgrade/ATLAS@HL-LHC
  - Flavor Physics: LHCb and Mu3e
  - Neutrino: T2K; DUNE; SNO+ for NDBD
  - Dark Matter: LZ
  - Dark Energy: LSST
  - QTFP: AION
  - Accelerator science and Detector programme

- In 2024:
  - Energy frontier:
    - ATLAS/upgrade/ATLAS@HL-LHC
    - Forward Physics Facility
  - EIC (IF)
  - Flavor Physics: LHCb/ LHCb Upgrade 2 (IF) and Mu3e (SOI for Mu3e Phase II)
  - Neutrino: T2K/HK (IF); MicroBoone/SND/DUNE; SNO+ for NDBD
  - Dark Matter: LZ/XLZD (activities to host XLZD at Boulby ongoing); DarkSide
  - Dark Energy: LSST
  - QTFP: AION, Quest DMC, QTNM, QSHS
  - We applied for new opportunities at Boulby – Waiting for the decision on which project will be chosen
  - Accelerator science and Detector programme

PP Hiring Timeline 2020

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy frontier				1			1		1			1
Intensity frontier		1										
Accelerator neutrinos					1	1	1					
0ν double beta decay		1								1		
Dark matter	1							1				
Dark energy												1
QSFP		1		1								
JAI		1	2									

Hiring plan and challenges

- Replacements of Tutorial Fellows is straightforward (displayed in green)
- Replacement of Statutory professorship are complex and require excellent candidates and compelling “business cases”- displayed in red
  - Note that Brian Foster, the D H Perkins Professor, who retired in September 2022 has not yet been replaced, but we were able to replace Neville, Richard, and Alfons (all APTFs).
  - We also took advantage of opportunities
- RS4 are personal (ad hominem) appointments (similar to personal chairs at other universities) – Cannot be refilled- Displayed in red if shown
- In 2022 we revised the plan in our 2020 strategy
  - Replace retiring academics before the submission of CG grants
  - The specific dates might change due to possible changes in EJRA policy

PP Hiring Timeline 2020 in 2022

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy frontier				1		1	1				1	1
Intensity frontier				1								
Accelerator neutrinos				1		1	1				1	
0ν double beta decay					1					1		
Dark matter		1						1				
Dark energy												1
QSFP					1	1						
JAI				1	2							

- Ian Retires
- Brian's Replacement
- Four hires critical for maintaining our leadership
- Neville's Replacement
- Weber's replacement
- Hires critical to have two academics in HK
- Jelley's replacement
- Hires critical to have two academics in these programs
- Replacement for Parra-Diaz in ALP
- Important to strengthening the JAI

PP Hiring Timeline 2020 in 2024

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy frontier	Brian's Replacement			1								
Intensity frontier			Malde	1								
Accelerator neutrinos				Wascko	1	1 Duffy						
0ν double beta decay					1							
Dark matter	Palladino	1		Monroe	1							
Dark energy												
QSFP				Withington	1							
JAI			D'Arcy	1	Oeftiger	L						

Hires critical for maintaining our leadership

Hires critical to have two academics in both of our neutrino programmes

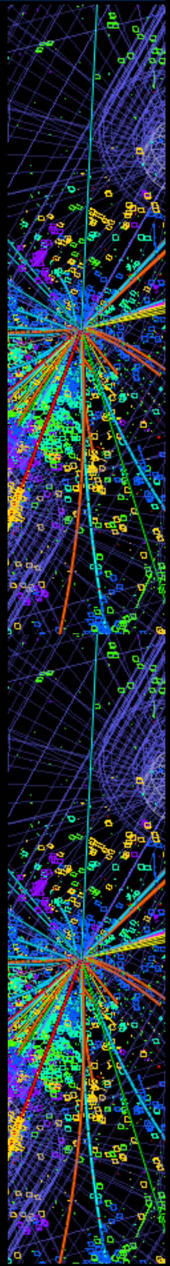
Hires critical to have two academics in these programs

One more hire needed to complete the JAI plan. Phil might also retire in 2034

Hires based on retirements and/or opportunities

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Energy frontier	1	Priority to fill the statutory chair		1					(0.5)	(0.5)		1		
Intensity frontier (q)	1							Fill 2nd statutory chair with non-accelerator Physicists ?						
Intensity frontier (mu) /EIC/ FPF									1	Opportunity?				
Accelerator neutrinos		1	1				1				1	0.5		
0ν double beta decay											1		0.5	
Dark matter		1							1					
Dark energy										0.5		0.5	Continue ?	
QTFP		1							1	Opportunity?				
JAI	1		1		1	Opportunity?							1.5	

But expect several retirements by 2035




Azfar


Barr


Barr

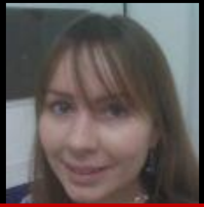

Biller


Bortoletto


Burrows


D'Arcy


Duffy


Gwenlan


Hays


Huffman


John


Kraus

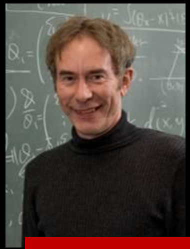

Oeftiger


Palladino


Monroe


Malde


Reichold


Shipsey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Wilkinson


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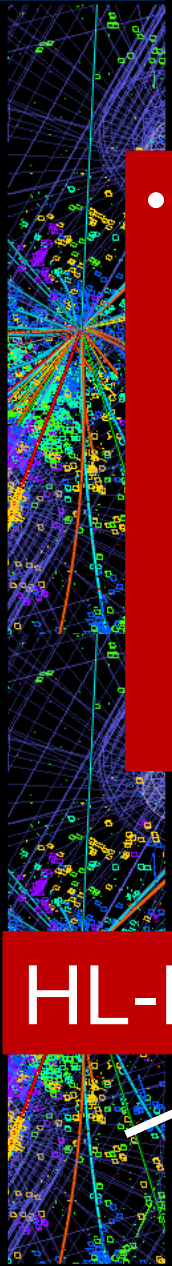
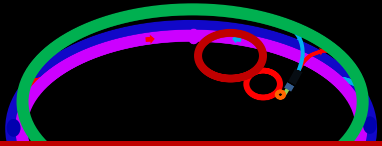
Possible Future Colliders



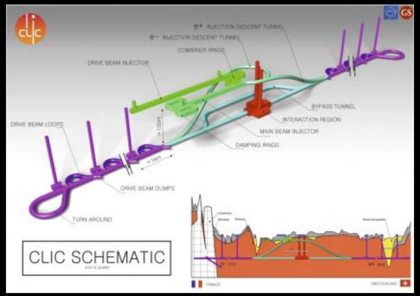


- Oxford well positioned for all options:
  - Bortoletto, Shipsey and Wilkinson (with Leonidopoulos of Edinburgh) set up 2020-21 group to catalyse UK interest in FCC
  - Wilkinson UK FCC-ee CoordinatorSecond CEPC European workshop in Oxford
  - Gwelan Convenor of: LHeC & FCC-eh;Gwenlan, Huffman, Viehhauser have joined in EIC UK
  - Foster and Burrows International Development Team (IDT) of ILC
  - Hays co-convenor of Future Colliders: ECFA Higgs-EW-Top convenor for future e+e- collider
  - Bortoletto, Harnew, Gwenlan, Monroe, Shipsey, Wilkinson played a role the ECFA Detector Roadmap
  - Burrows: ESPPU – accelerator physics - convener

HL-LHC

2030

2025



International Linear Collider (ILC) e^+e^- E_{cms} < 1 TeV

Future Circular Collider (FCC)

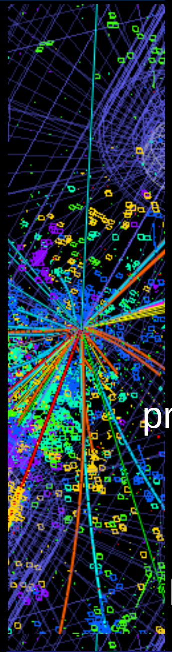
e^+e^- E_{cms} < 350 GeV

pp, E_{cms} ~100 TeV

AA E_{cms} ~40TeV

Oxford PP & the STFC Scientific drivers

UNIVERSITY OF OXFORD



General Purpose Detectors: ATLAS

Future colliders (not including muon collider), ee covers also ILC, CepC

precise muon & kaon physics experiments

Neutrino programme

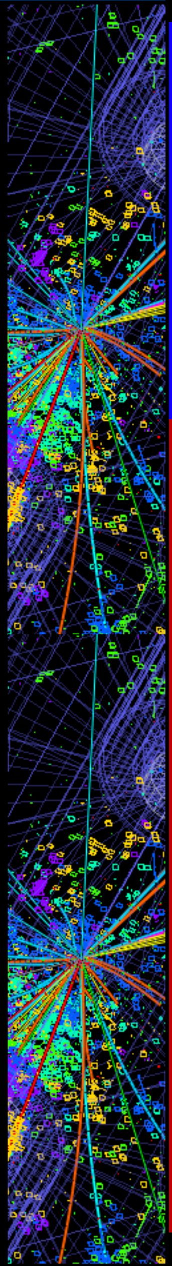
DM experiments and complementarities

	A1	A3	A7	A8	C1	C2	C3	C4	C5	C6	C7	C8	C9
HL-LHC (GPDs)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HL-LHC (LHCb)	✓	✓		✓	✓	✓	✓	✓	✓			✓	
Future e^+e^-	✓		✓		✓	✓	✓		✓			✓	✓
Future hh	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Future eh	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Non-collider flavour	✓	✓			✓	✓		✓	✓			✓	
ν osc.	✓	✓		✓	✓	✓	✓	✓				✓	
$0\nu\beta\beta/\nu$ mass	✓	✓			✓	✓	✓					✓	✓
e^-/n dipole moments						✓					✓	✓	
Direct dark sector	✓	✓		✓	✓	✓	✓	✓				✓	

CAUTION: the above table has been included in the 2021 roadmap. However, it is not meant to reflect the full breadth of the programme and is an oversimplification. More up to date/detailed versions exist

A1 What are the laws of physics operating in the early Universe?
A3 How is the universe evolving and what roles do dark matter and dark energy play?
A7 What is the True Nature of Gravity?
A8 What can gravitational waves and high-energy particles from space tell us about the universe?
C1 What are the fundamental particles and fields?
C2 What are the fundamental laws and symmetries of physics?
C3 What is the nature of space-time?
C4 What is the nature of dark matter and dark energy?
C5 How do quarks and gluons form hadrons?
C6 What is the nature of nuclear matter?
C7 Are there new phases of strongly interacting matter?
C8 Why is there more matter than antimatter?
C9 What will precision measurements of the Higgs boson reveal about the Universe?

PP Status



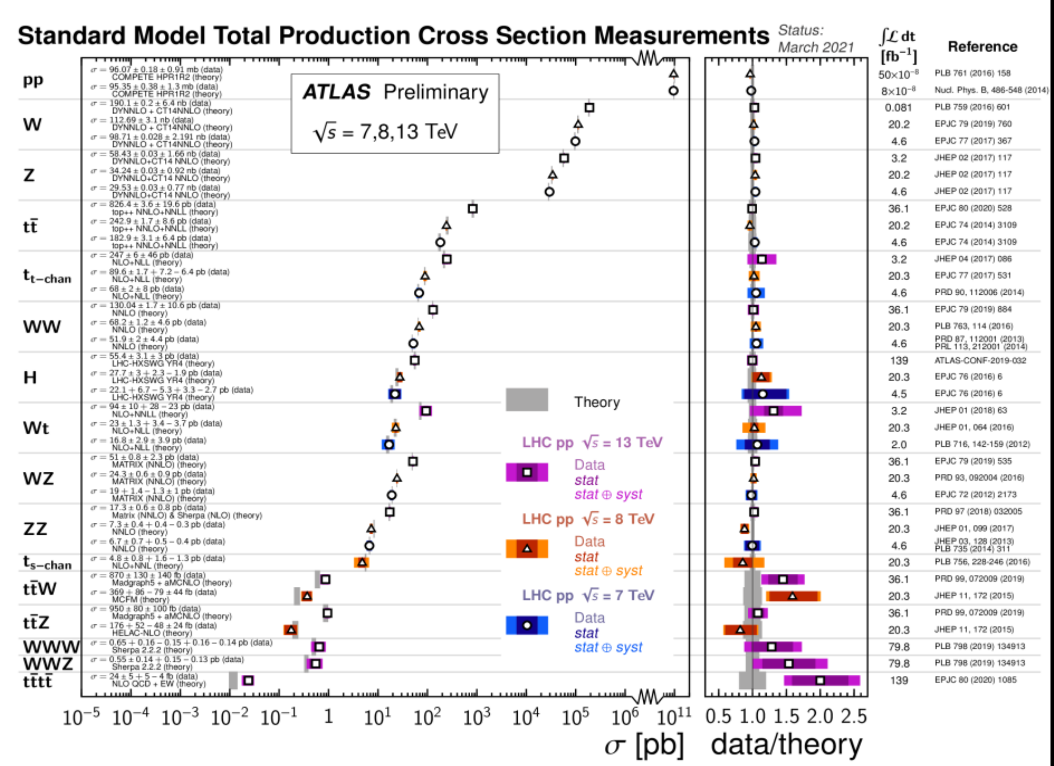
The success of Standard Model:

- particle spectrum experimentally completed
- very precise and extensive tests of predictions
- no significant deviations (but difficult to accommodate non-zero neutrino masses)

The outstanding questions remain:

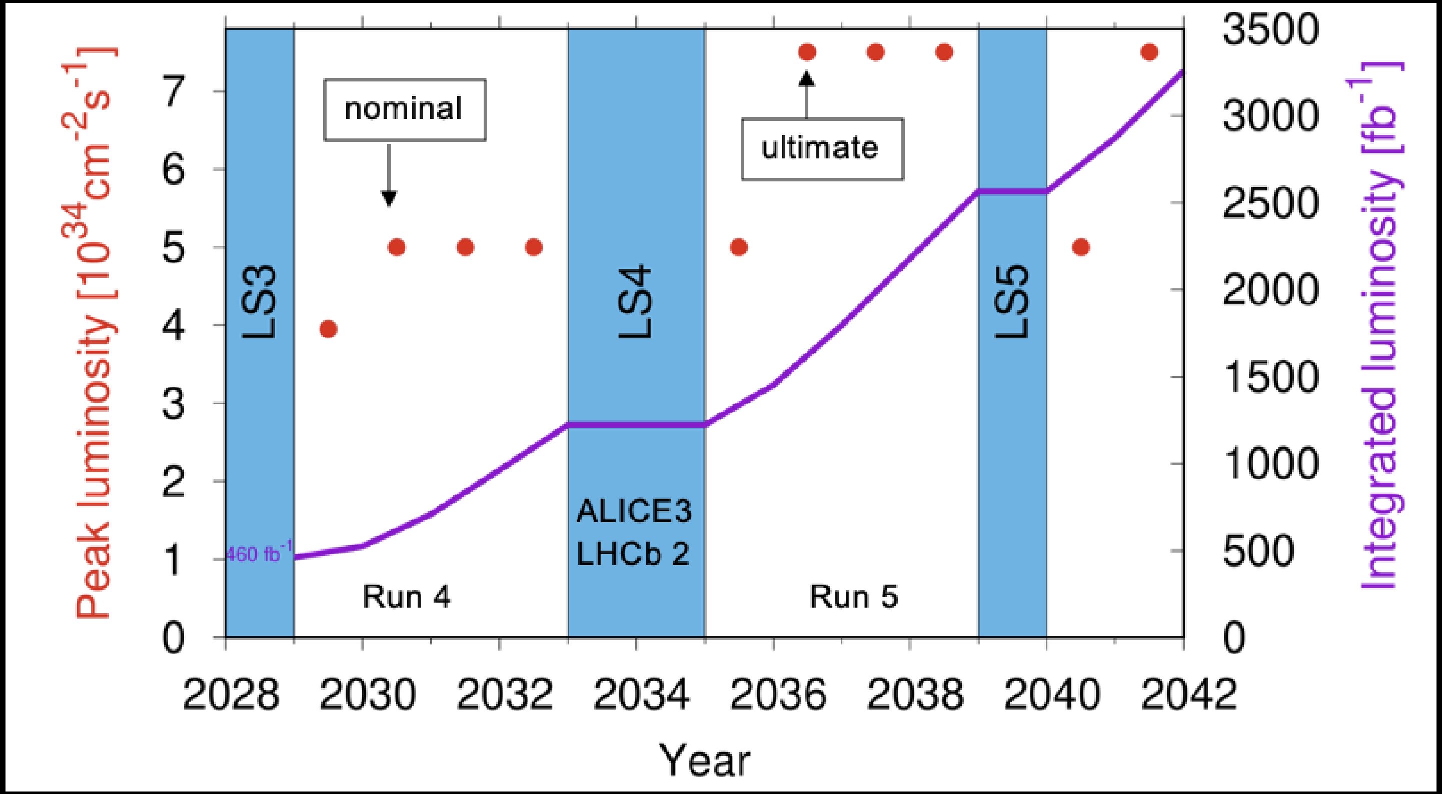
- Why is the Higgs boson so light (naturalness/hierarchy problem)?
- What is the origin of the universe matter-antimatter asymmetry?
- Why 3 fermion families ? Why do neutral leptons, charged leptons and quarks behave differently ?
- What is the origin of neutrino masses and oscillations ?
- What is the composition of dark matter?
- What is the cause of the Universe's accelerated expansion ?
- Why is Gravity so weak ?

New physics required but no clear indication of the E-scale



	High-E colliders	Dedicated high-precision experiments	Neutrino experiments	Dedicated searches	Cosmic surveys
H, EWSB	x	x		x	
Neutrinos	x (ν_R)		x	x	x
Dark Matter	x			x	x
Flavour, CP, matter/antimatter	x	x	x	x	x
New particles, forces, symmetries	x	x		x	
Universe acceleration					x

New HL-LHC Schedule in 2022



Fabiola- January 2022

LS4 extended from 1 to 2 years (in view of ALICE and LHCb upgrades)

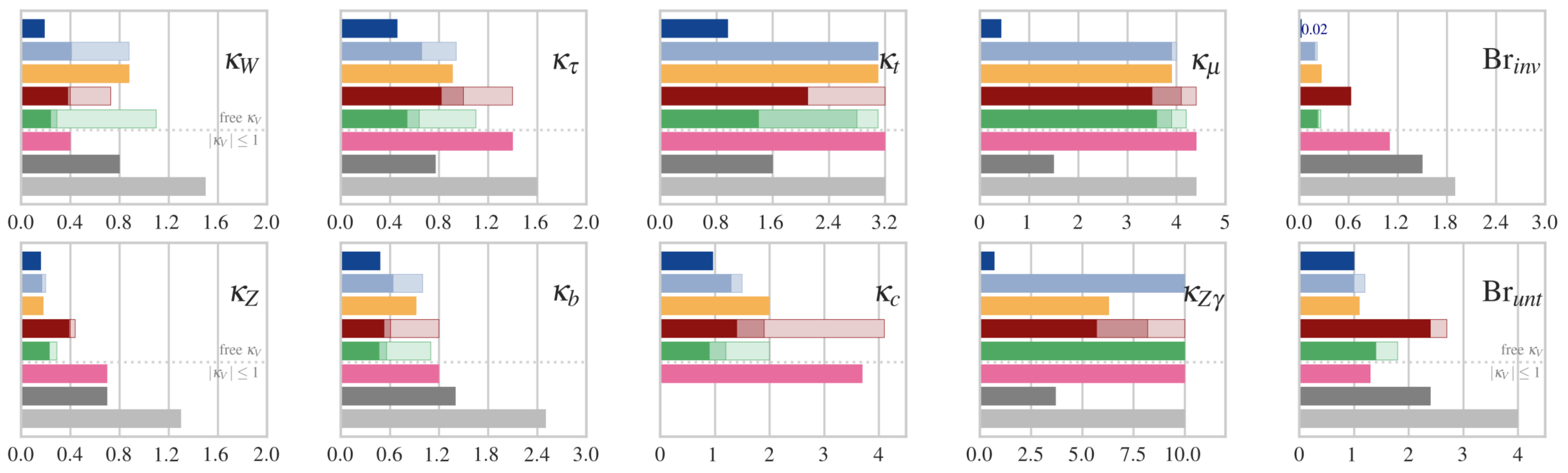
With proposed shift and extension of LS3, and inclusion of HI runs beyond LS3:

- 2500 fb^{-1} are expected by end 2038 (current end-date of HL-LHC)
- 3000 fb^{-1} (int. luminosity goal) would now be reached in ~ 2041
- Next collider cannot start before ~ 7 years from end of HL-LHC for technical and financial reasons

Note: it should not be assumed that future shifts of LS schedules, or new, ambitious upgrades of the experiments, entail an automatic shift/extension of HL-LHC end date, as this has an impact on the future of the field

Higgs Physics Prospects

Considerable progress on the determination of Higgs couplings

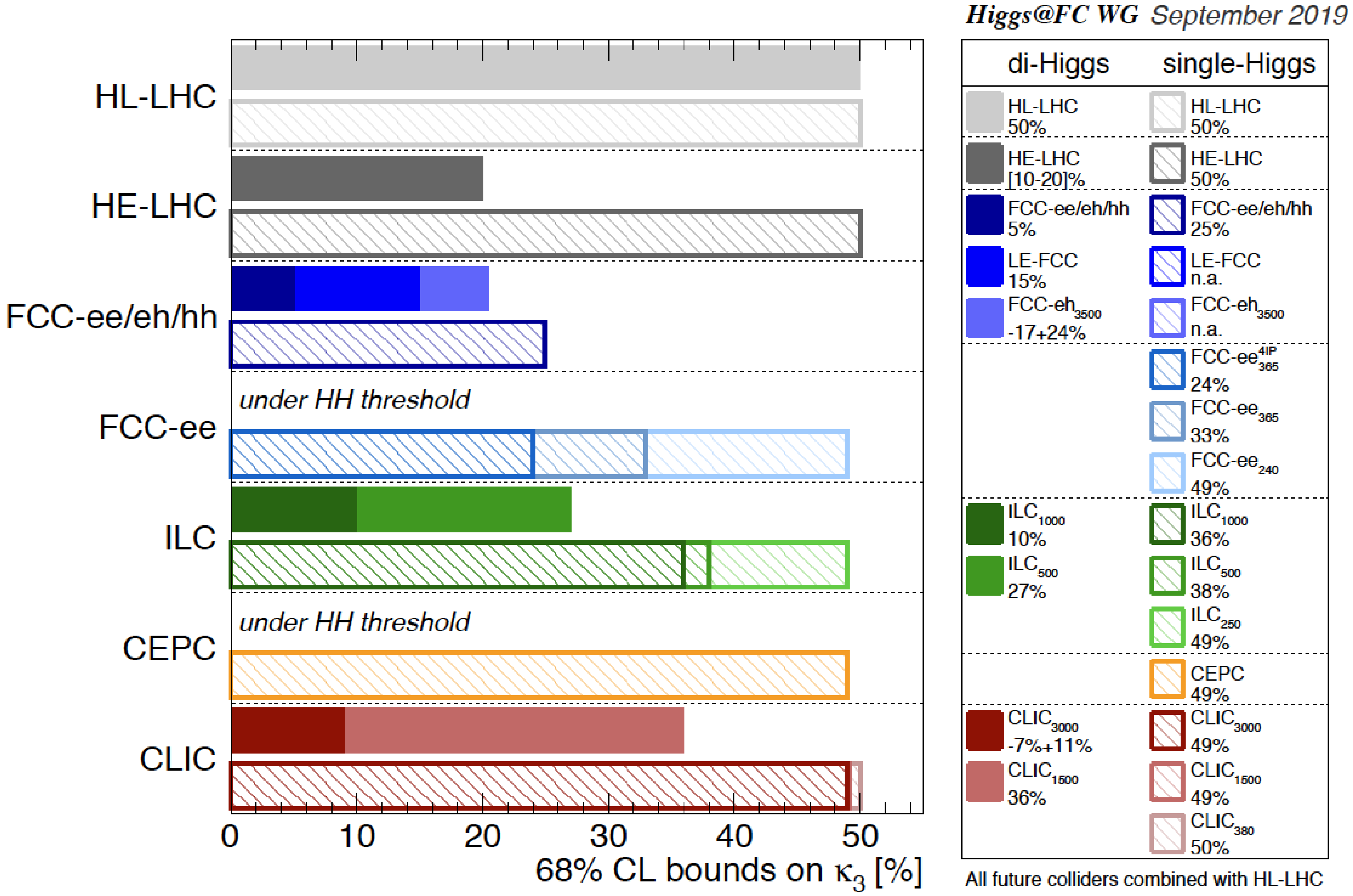


Future e^+e^- colliders allow:

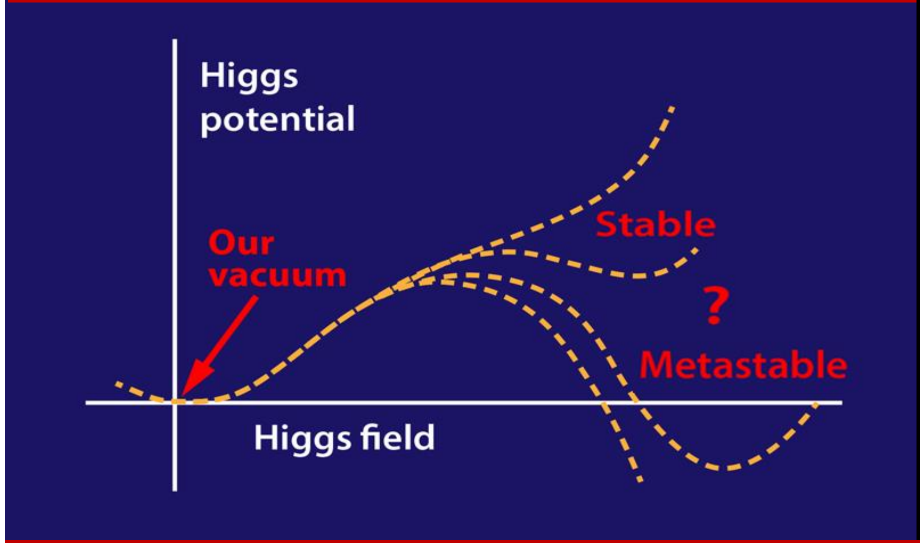
- measurement of k_c
- improve accuracy by factors 2-10, except for rare decay modes (k_μ, $k_{Z\gamma}$) where progress needs the FCC-hh

Higgs Physics Prospects

Determination of the Higgs self couplings



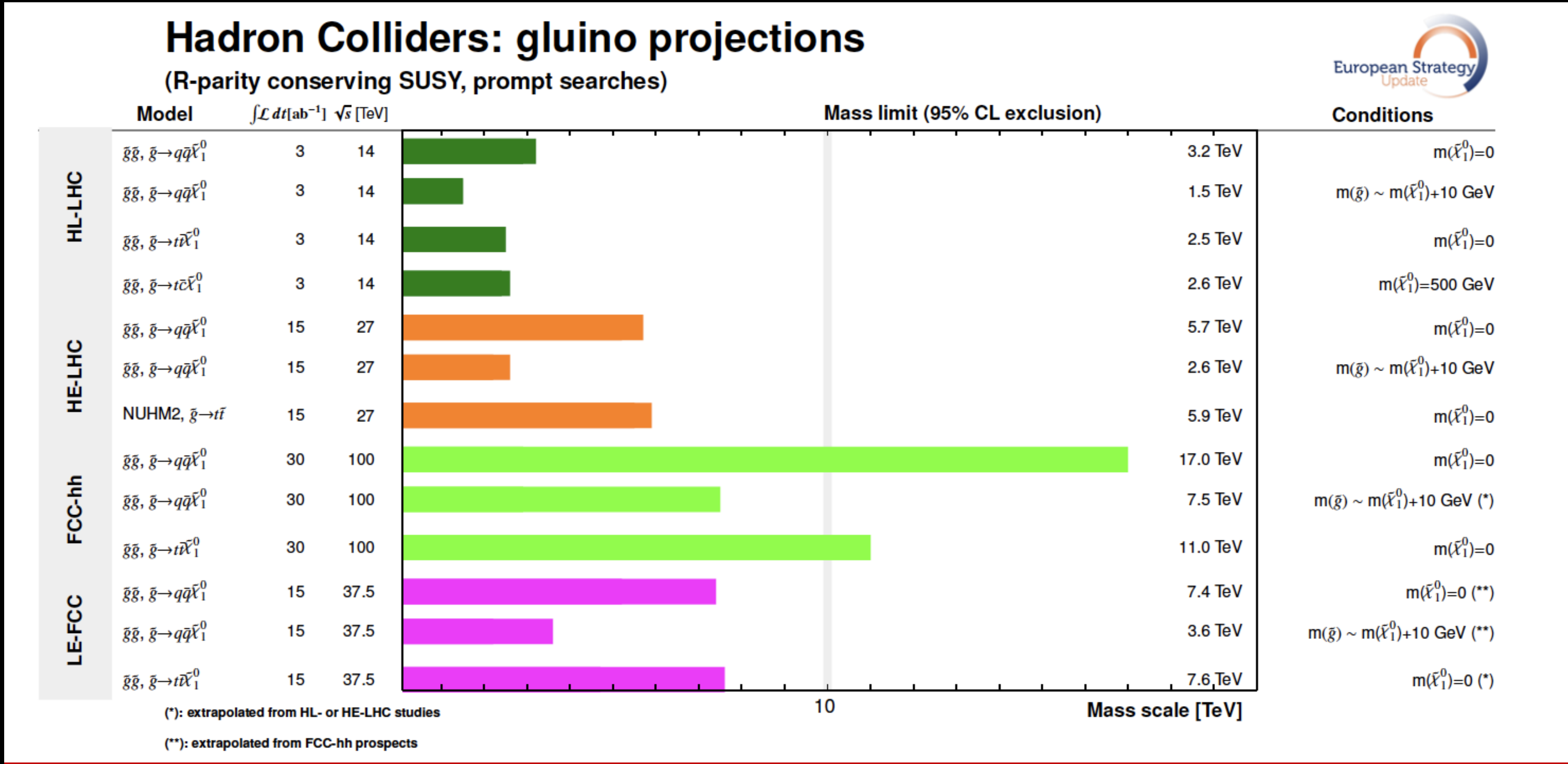
The shape of the Higgs potential



Higgs self-coupling deeply fundamental parameter:

- Affects shape of the Higgs potential and nature of EWPT
- Connected to cosmology (inflation, baryogenesis) and potential GW signals

Searches for new physics

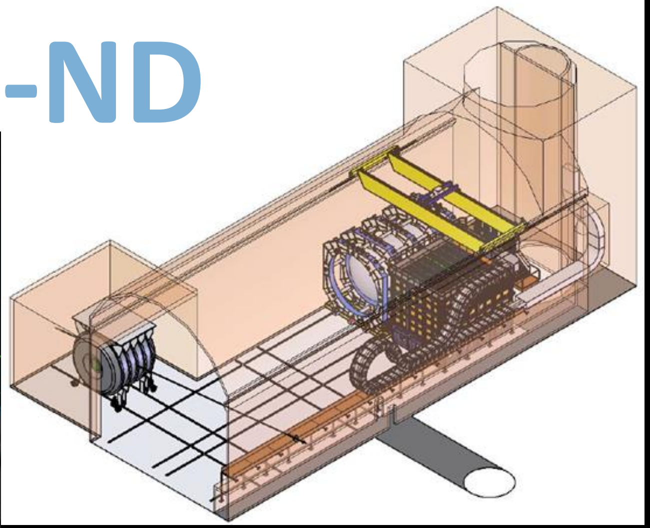


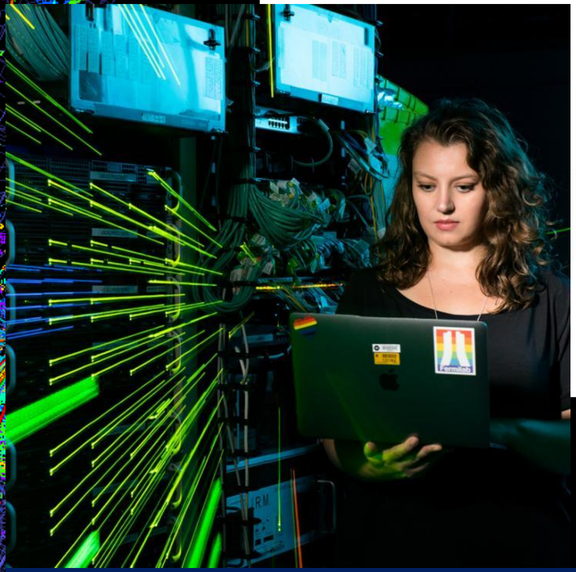
FCC-hh will reach mass scales X 3-5 HL-LHC

Opportunities in the neutrino programme

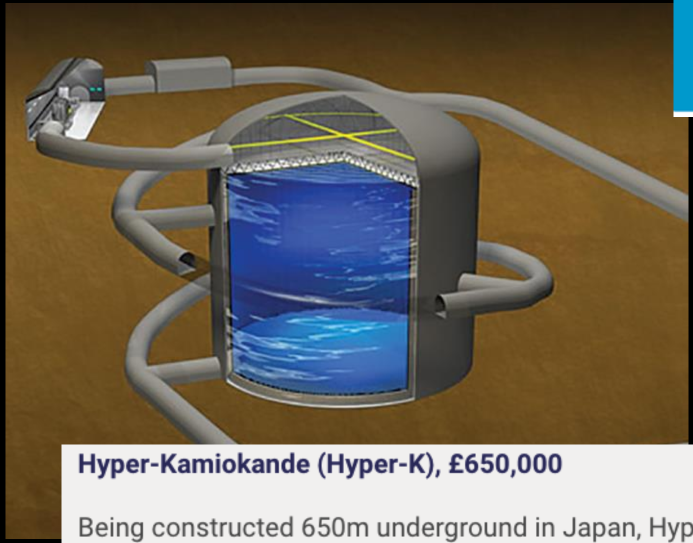
- UKRI/STFC investing > £65 M into LBNF/DUNE
  - Accelerator, neutrino beam, LAr TPC, readout/DAQ
  - A. Weber (Oxford) was UK PI of the program
- Further investments in DUNE Near Detector & HyperK are planned
  - Oxford can lead new activities with timely strategic hires

DUNE-ND





Kirsty Duffy – UKRI Future Leader



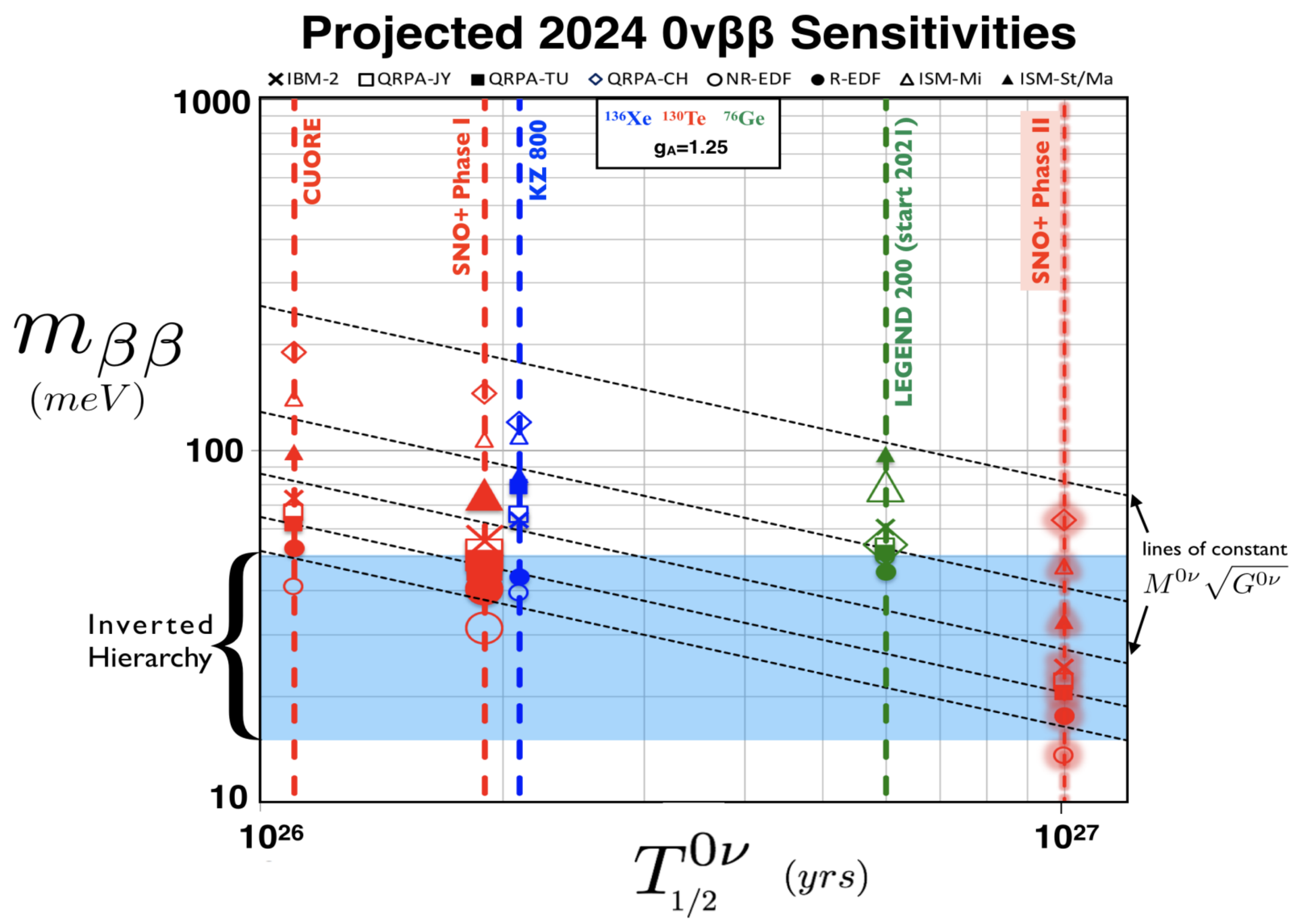
Hyper-Kamiokande (Hyper-K), £650,000

Wark- UK PI

Being constructed 650m underground in Japan, Hyper-K is an international science experiment to unlock the mysteries of the universe's evolution. It is both a microscope for measuring the properties of neutrinos and a telescope for observing the sun and supernovas.

This investment enables a collaboration of UK institutes to continue to engage with the project, with the possibility of becoming a partner in the experiment in the future.

- Neutrinoless double beta decay is a signature to understand if neutrinos are Dirac or Majorana particles
- The idea to load Te in SNO+ originated and was developed (Biller) in Oxford
- ^{130}Te is the most economically scalable isotope and Liquid scintillator is a scalable detector technology.



North America - Europe Workshop on Future of Double Beta Decay

29 Sep 2021, 14:00 → 1 Oct 2021, 21:30 Europe/Rome

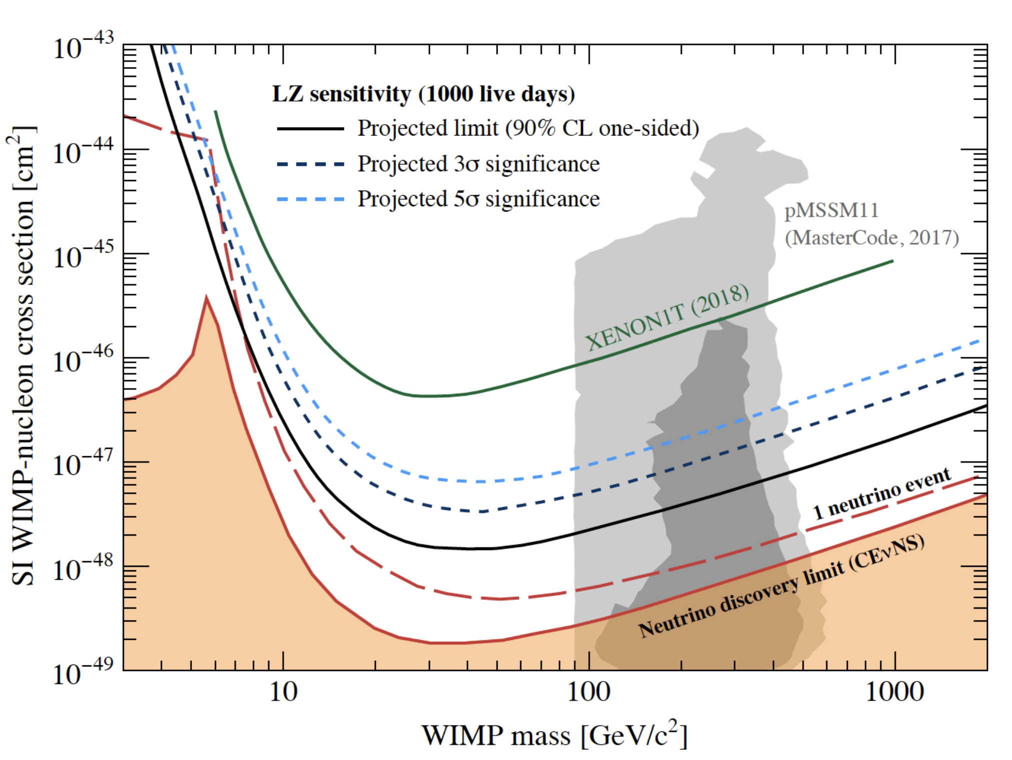
"E. Fermi" auditorium (Gran Sasso National Laboratory (LNGS))

Description

The Majorana nature of neutrino and the possible contribution of neutrinos to explain the matter-antimatter asymmetry in the universe are among the most challenging physics goals in the next decade. The purpose of the North America-Europe workshop on Double Beta Decay is to stimulate the discussion between the North American and European double beta decay community and the corresponding funding agencies to consolidate a strategy and define a path to the discovery of Majorana neutrinos. The discussion will focus on the upcoming generation of high sensitivity projects, their discovery potentials and the underground infrastructures.

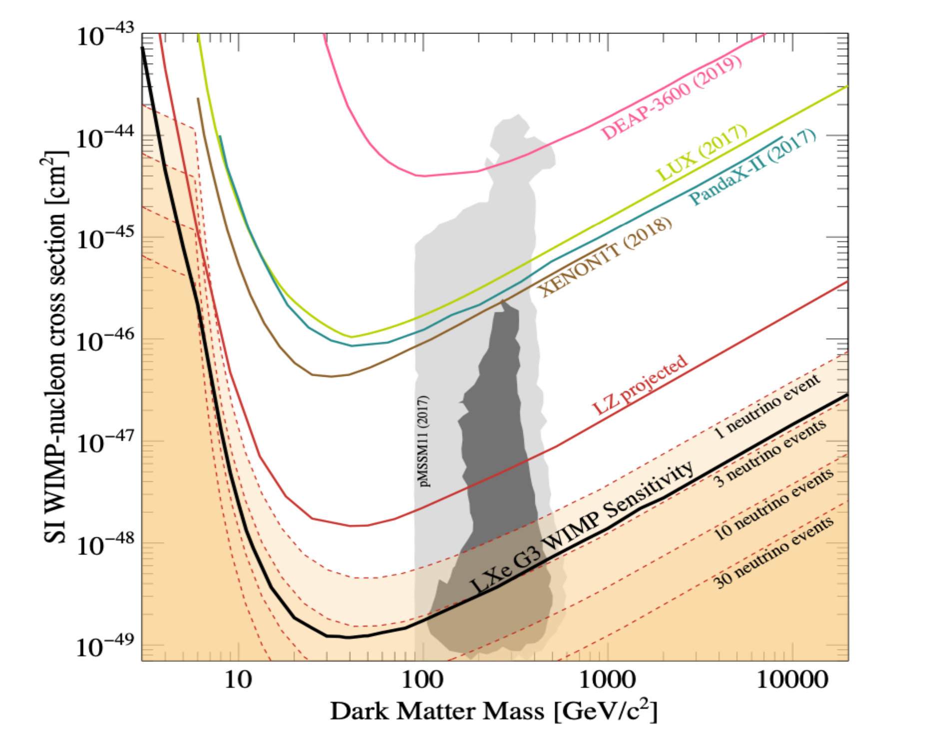
Joint meeting of INFN,DOE and APPEC Only CUPID, LEGEND, and NEXO invited

Dark Matter



Palladino

- SNOWMASS Cosmic Frontier
- UK STFC PPTAP and PPAP member
- APS CPAD Executive committee member



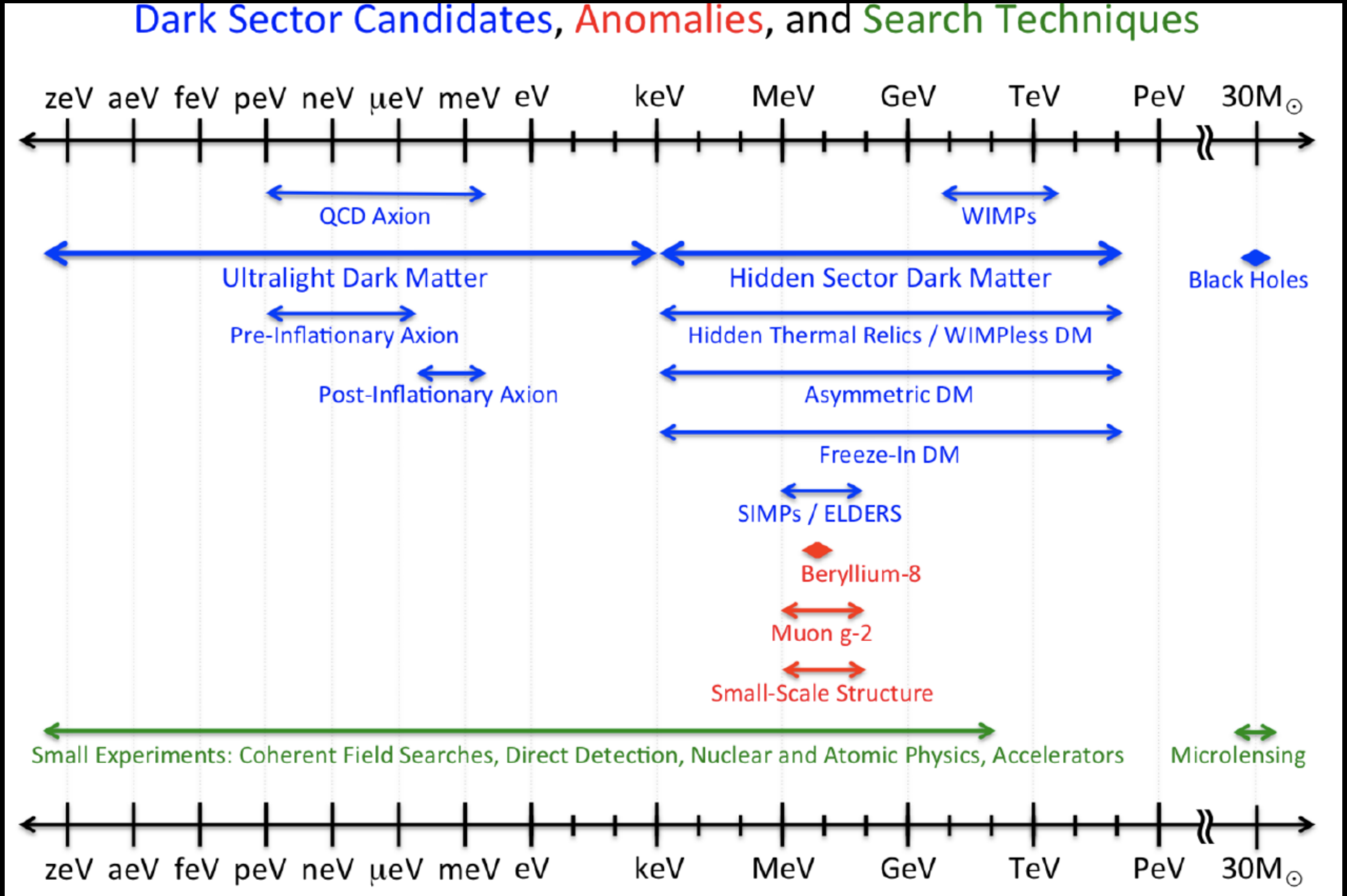
G3 experiment needed to reach the neutrino floor

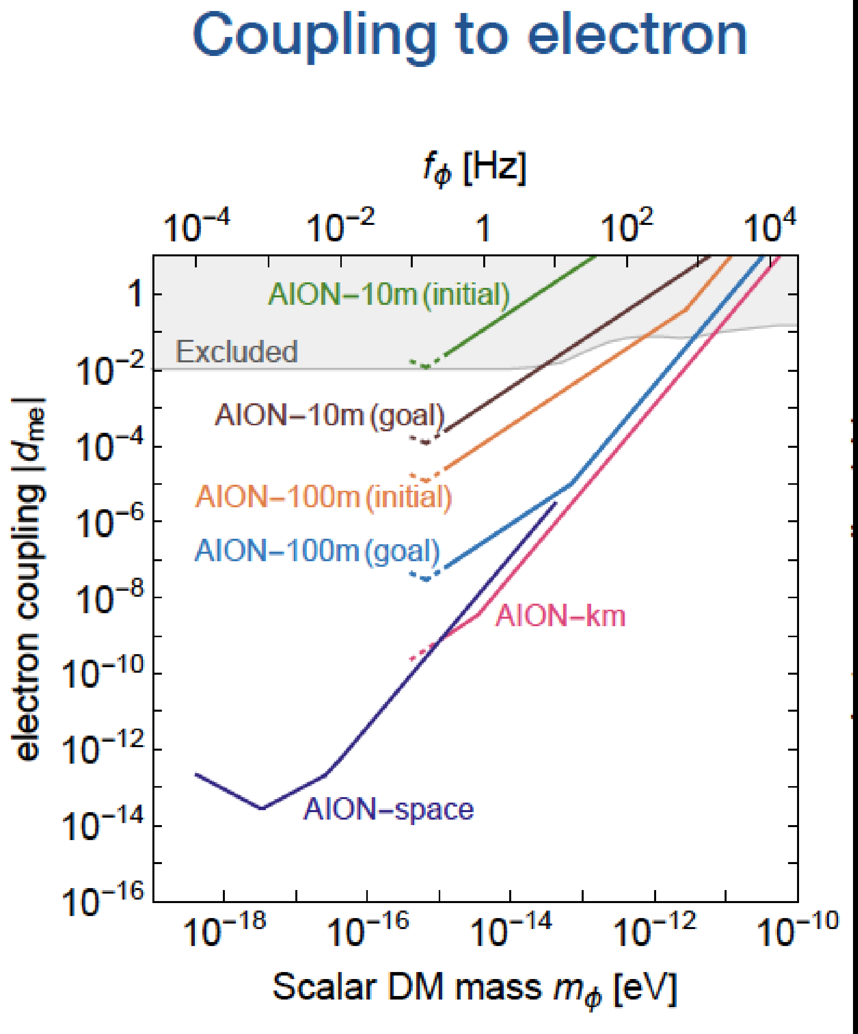
LZ and XENON/DARWIN collaborations have agreed to construct one Xe-based 'Generation-3' experiment and Oxford is playing a leading role:

- Palladino LZ Representative to Joint (with the DARWIN collaboration) Next Generation Steering committee
- Kraus: UK-PI of Xenon Future

Dark Matter: QTFP

- New experiments like AION can probe for "wider range" of possible dark matter candidates





PP in 2020

Two statutory professors: Shipsey and Foster

Energy frontier


Barr


Bortoletto


Cooper-Sarkar

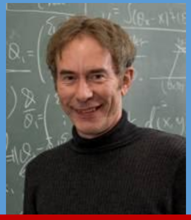

Gwenlan


Hays


Issever


Nickerson


Huffman


Shipsey


Viehhause
r


Weidberg

Intensity frontier


Harnew


John


Wilkinson

Non accelerator Physics and the dark universe


Biller


Tseng


Azfar


Kraus

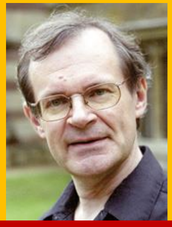
JAI


Burrows


Bartolini


Konoplev


Walzac
k


Foster


Reichold


Seryi

Accelerator Neutrino


Barr


Wark


Weber

PP in 2031

No statutory professors

Intensity frontier

John

Wilkinson

Energy frontier

Barr

Gwenlan

Hays

Loosing academics who are leading the HL-LHC upgrades

Viehhause
r

Non accelerator Physics and the dark universe

Tseng

JAI

Burrows

Bartolini

Reichold

Accelerator Neutrino

Weber

PP in 2031

No statutory professors

Energy frontier


Barr


Gwenlan


Hays

Loosing academics who are leading the HL-LHC upgrades


Viehhause

Intensity frontier


Malde


John


Wilkinson

JAI


Burrows


Negotiation ongoing


Reichold

Non accelerator Physics and the dark universe


Palladino


Tseng

Accelerator Neutrino


Negotiation ongoing

PRINCIPLES OUTLINED IN 2020

- Continued leadership at the energy and intensity frontiers where the LHC upgrade and new global facilities will bring high discovery potential
- Take advantage of the opportunity to hire two new statutory professorships to shape the future of the field
- Strengthen areas like accelerator neutrino, neutrinoless double-beta decay, and dark matter that will become unviable by 2030 unless new hires are made to take advantage of science opportunities
- Partner with other sub-departments to exploit the emerging area of quantum technology which offers new possibilities for experiments in fundamental physics (QTFP)
- Strengthen the JAI which is a UK centre of excellence for advanced and novel accelerator technology

PP STRATEGY

	Energy frontier	Intensity frontier	Accelerator neutrinos	0ν double beta decay	Dark matter	Dark energy	QSFP	JAI	SUM
Current strength (including Seryi and Issever)	10.5	3	2.5	2	1	2	0	5.1	26.1
Retirements before 2030 and recent faculty losses	6.5	1	2	1	1	1.5	0	3	16
Remaining in 2030 if no hires are made	4	2	0.5	1	0	0.5	0	2.1	10.1
Hires proposed before 2030	4	1	3	2	2	1	2	3	18
TOTAL 2030	8	3	3.5	3	2	1.5	2	5.1	28.1

PP Hiring Timeline 2020

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy frontier				1			1		1			1
Intensity frontier		1										
Accelerator neutrinos					1	1	1					
0ν double beta decay		1								1		
Dark matter	1							1				
Dark energy												1
QSFP		1		1								
JAI		1	2									

Conclusions

- We are delighted that we completed 4 faculty hires during the last 2 years
- Nonetheless, in PP we have a lot of upcoming retirements: APTFs, statutory professors (Foster, Shipsey), RS4 (Wark, Bortoletto) and non-APTF positions (Azfar by 2030)
- We have also many retirements between 2030 and 2035.
- We have to find a way to make a strong case for hires in HK. This is critical for neutrino physics, since HK is likely to start well before DUNE.
- The JAI position that we are filling is a good start but not enough for the JAI research scope.

If we continue to implement the hiring plan outlined in 2020 Oxford PP will continue shape the future of the field.