2023 UK Instrumentation Lectures

Lies, Damn Lies and Statistics

Daniel Hynds

Many many thanks!

Steering committee members:

- University of Birmingham - *Laura Gonella*
- University of Bristol - *Jaap Velthuis*
- University of Cambridge - *Bart Hommels*
- University of Glasgow - *Kenny Wraight*
- University of Edinburgh - *Stephan Eisenhardt*
- Imperial College London - *Alex Tapper*
- University of Lancaster - *Lingxin Meng*
- University of Liverpool - *Jon Taylor*
- University of Manchester - *Alexander Oh*
- University of Oxford - *Daniel Hynds (Chair)*
- Queen Mary University of London - *Peter Hobson*
- Rutherford Appleton Laboratory - *Giulio Villani*

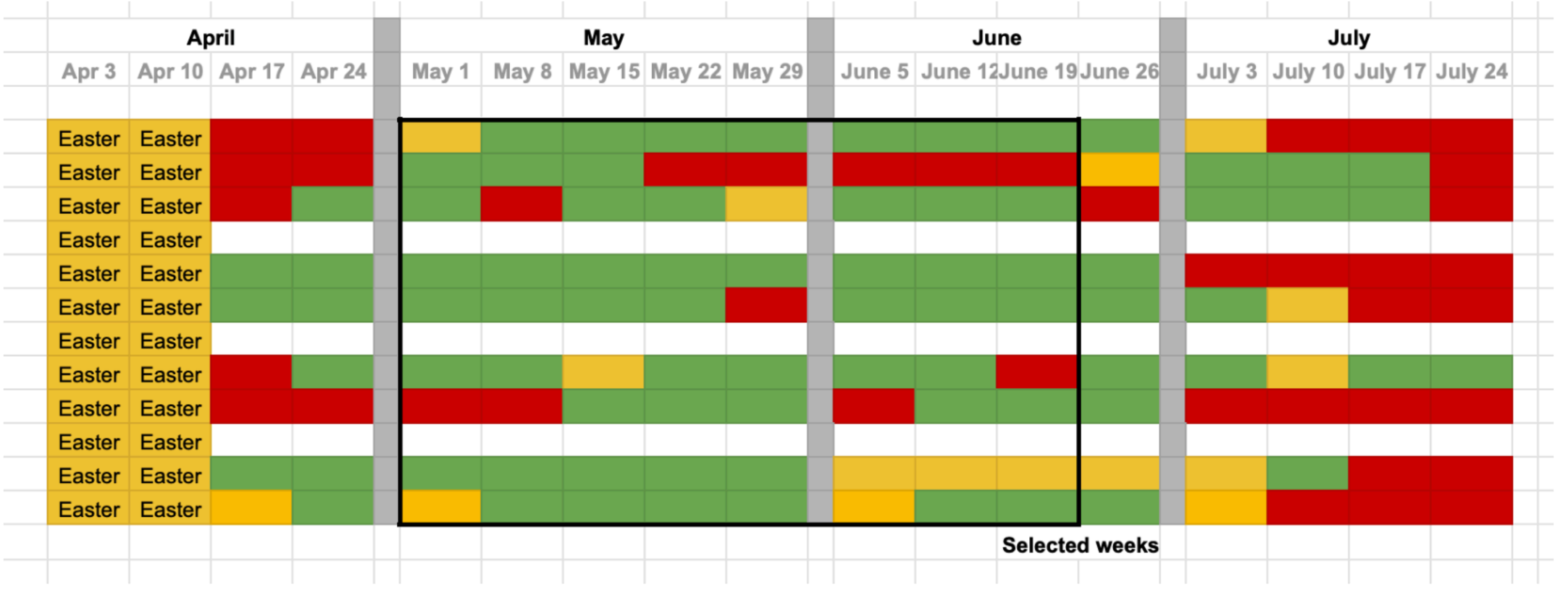
<u>Lecturers</u>

Alex Oh
Andrew Rose
Andy Blue
Bart Hommels
Dan Weatherill
Daniel Hynds
Eva Vilella
Georg Viehhauser
Giulio Villani
Jaap Velthuis
Jon Taylor
Kenny Wraight
Laura Gonella
Mike Booth
Nick Owen
Paki Munoz
Peter Hobson
Phil Allport
Philipp Windischhofer
Sneha Naik
Ulla Blumenschein (A)
Weida Zhang

Course programme

Course									
Semiconductors	Band theory 1	Band theory 2	Layout, guard rings, device calculations 1	Layout, guard rings, device calculations 2	Interaction of particles with matter 1	Interaction of particles with matter 2	Ramo-shockley theory	Radiation damage 1	Radiation damage 2
Electronics and DAQ	General electronics, simple circuit calculations	Circuit theory, common topologies	Circuit design, noise and grounding	Amplifier designs (fast amplifiers, TDC)	[cancelled] Typical ASIC architectures	PCB layout	Trigger + DAQ systems 1	Trigger + DAQ systems 2	FPGA overview
Mechanics and cooling	Mechanical structures 1	Mechanical structures 2	Thermal management 1	Thermal management 2	CAD and technical drawing	FE analysis tools	CAD walkthrough		
Fabrication and structures	Fabrication 1	Fabrication 2	Fabrication 3	Fabrication 4	Device structures: planar and 3D	Device structures: Gain layers (LGAD, SPAD, SiPM)	Device structures: Monolithic	Transistor layout, 250 - 28 nm, FinFETs	
Experimental techniques	Lab techniques: IV, CV, source measurements, x-ray measurements	Lab techniques: IV, CV, source measurements, x-ray measurements	Transient current techniques	Solid state techniques: DLTS, TSC, etc.	Testbeams 1	Testbeams 2	Irradiation 1	Irradiation 2	
TCAD	TCAD introduction, getting started	SProcess planar sensor	SDevice planar sensor	SProcess 3D sensor	SDevice 3D sensor	SProcess monolithic sensor	SDevice monolithic sensor	Advanced features	
Software tools	PCB design 1	PCB design 2	SPICE simulations 1	SPICE simulations 2	MC simulations 1	MC simulations 2	Testbeam reconstruction 1	Testbeam reconstruction 2	
Misc	Photon science applications	Non-silicon semiconductors: Diamond	Non-silicon semiconductors: Diamond II	Other silicon devices: CCDs, Depfets, imaging sensors	Applications: Dosimetry, medical uses				

Schedule


April
May
June
July
Apr 3
Apr 10
Apr 17
Apr 24
May 1
May 8
May 15
May 22
May 29
June 5
June 12
June 19
June 26
July 3
July 10
July 17
July 24
Easter
Selected weeks

Participation in a few numbers

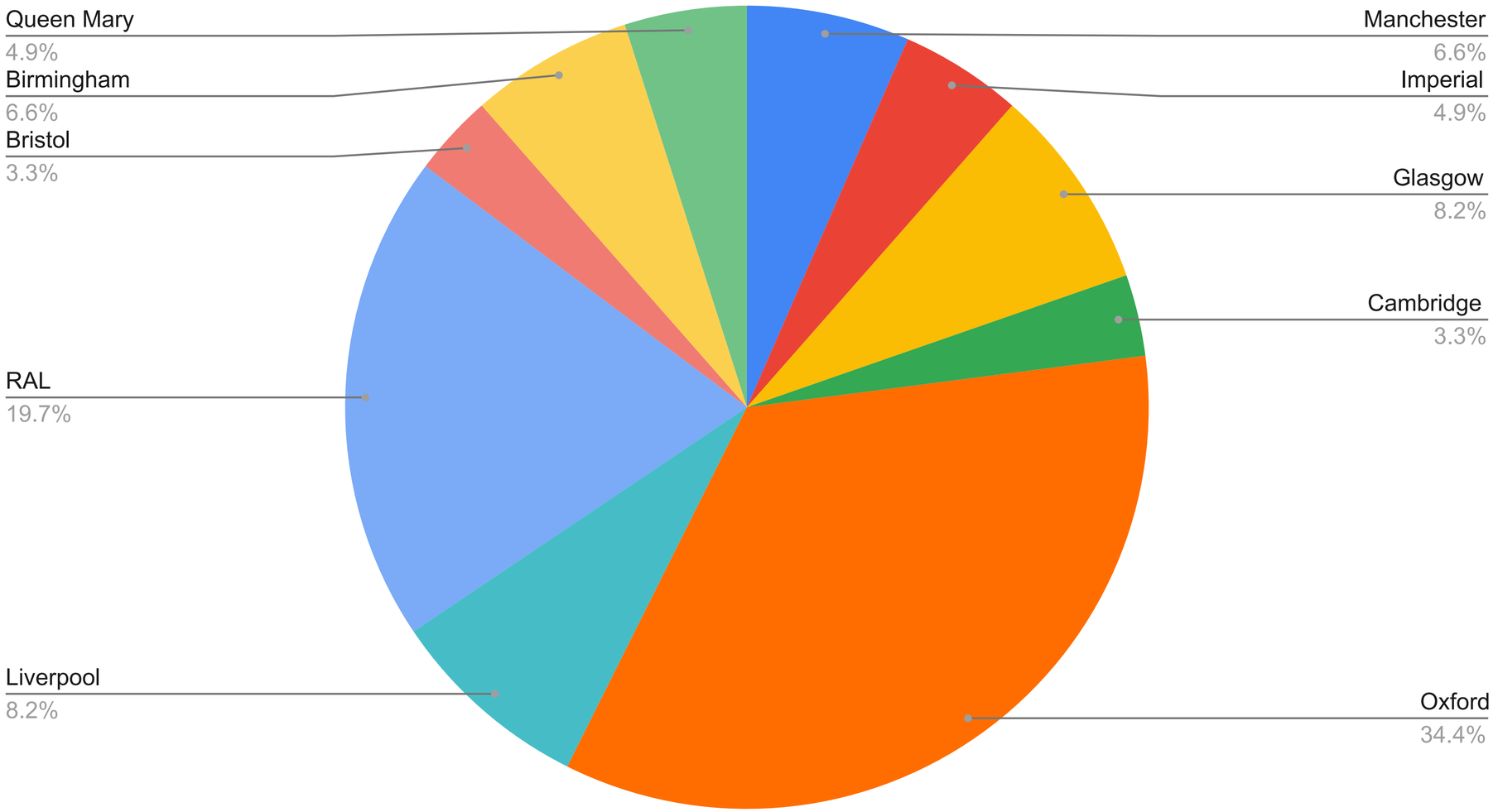
In total we gave **60 hours** of lectures over 8 weeks

- **22 lecturers** from **10 institutes** volunteered their time

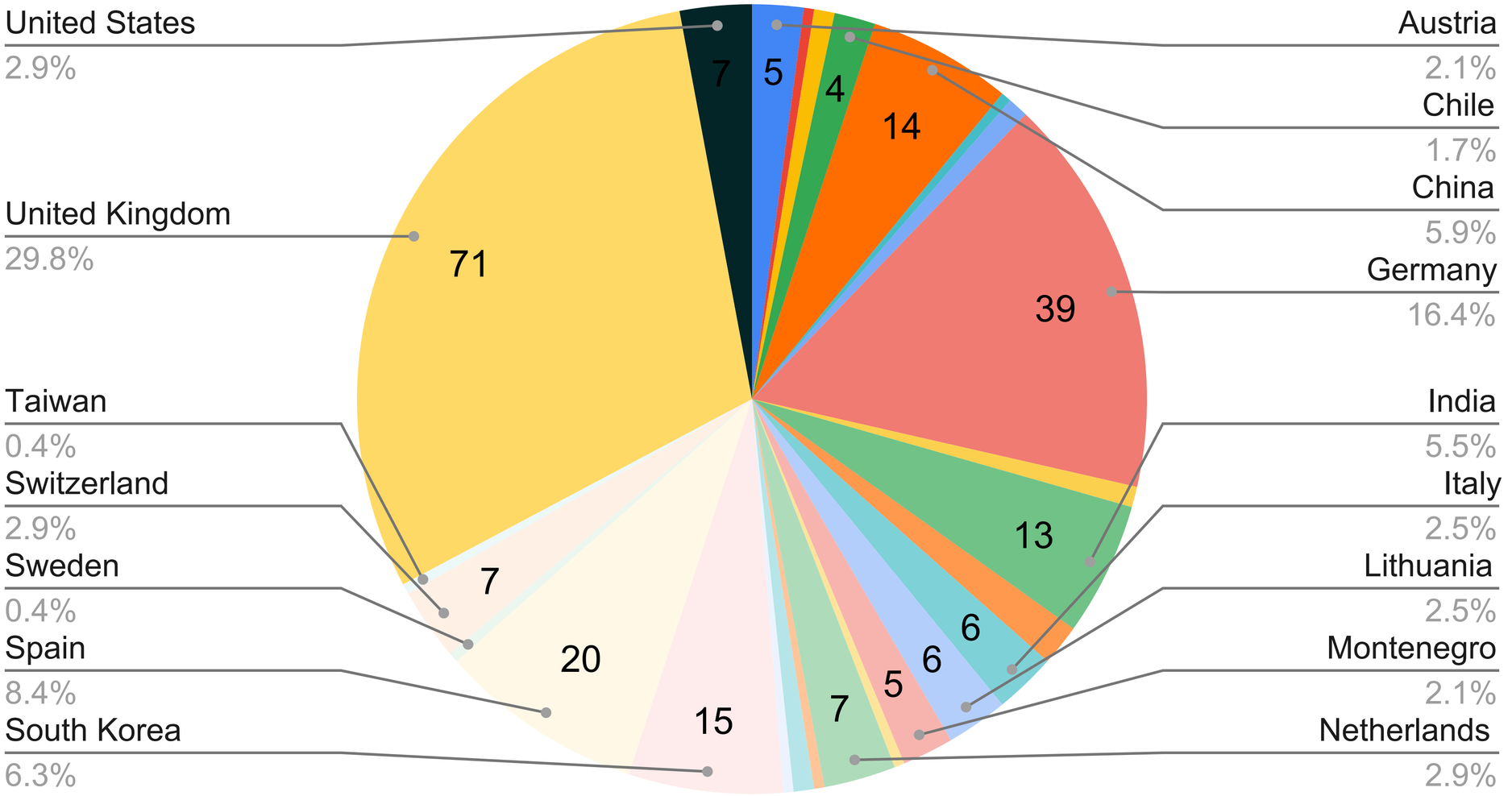
There were **238 registered attendees** from **26 countries**

- Participation started strong but tailed off as the courses progressed

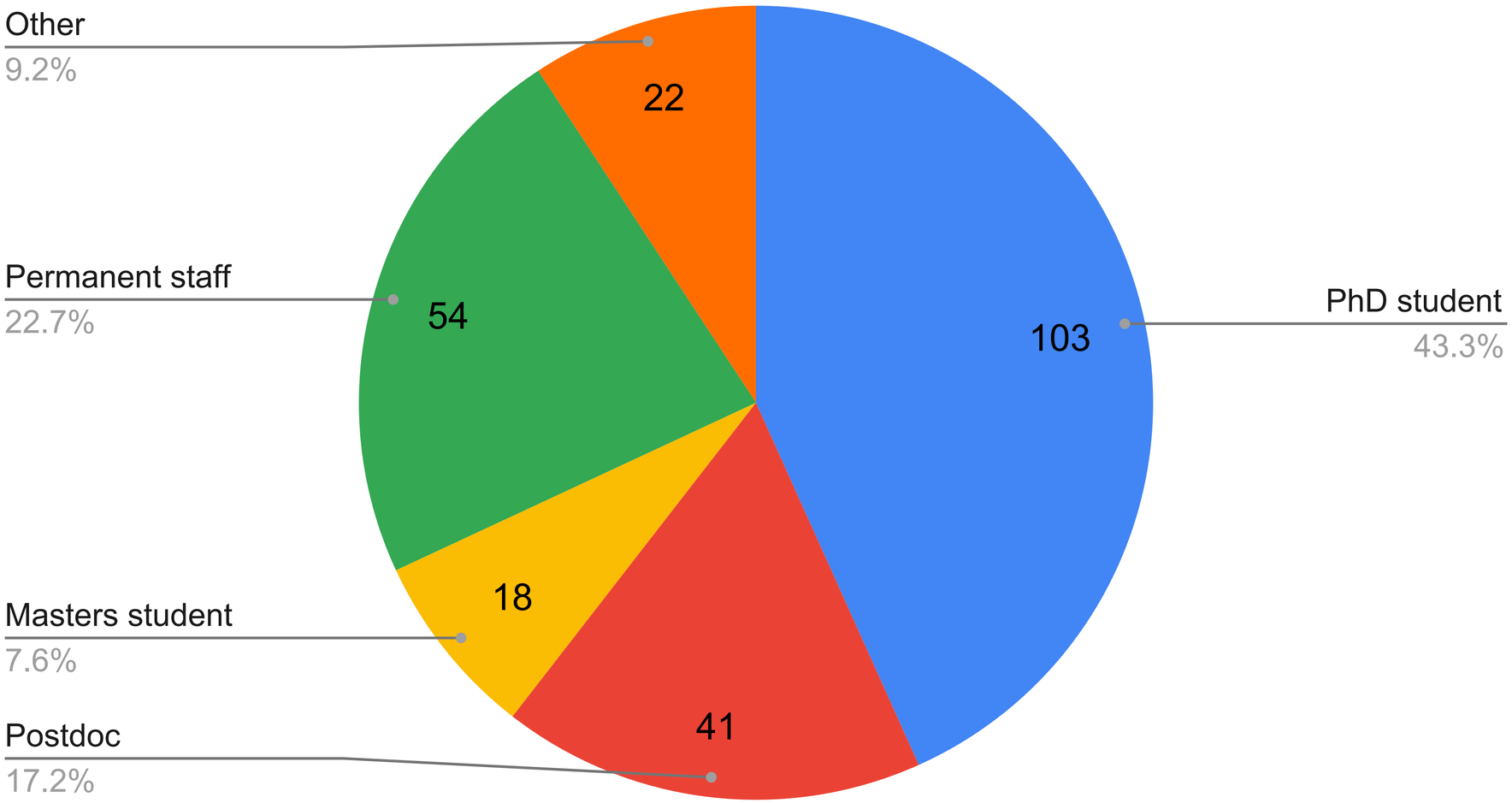
Lecturers


Queen Mary
4.9%
Birmingham
6.6%
Bristol
3.3%
RAL
19.7%
Liverpool
8.2%
Manchester
6.6%
Imperial
4.9%
Glasgow
8.2%
Cambridge
3.3%
Oxford
34.4%

Registrants - institute location

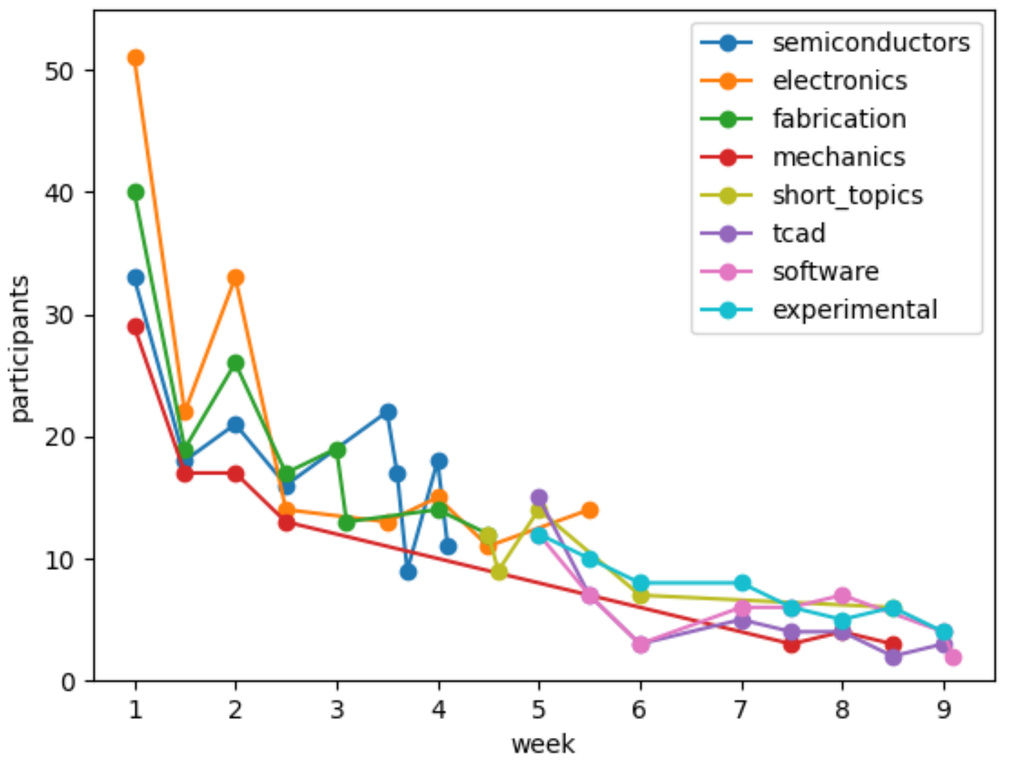


Registrants - career stage

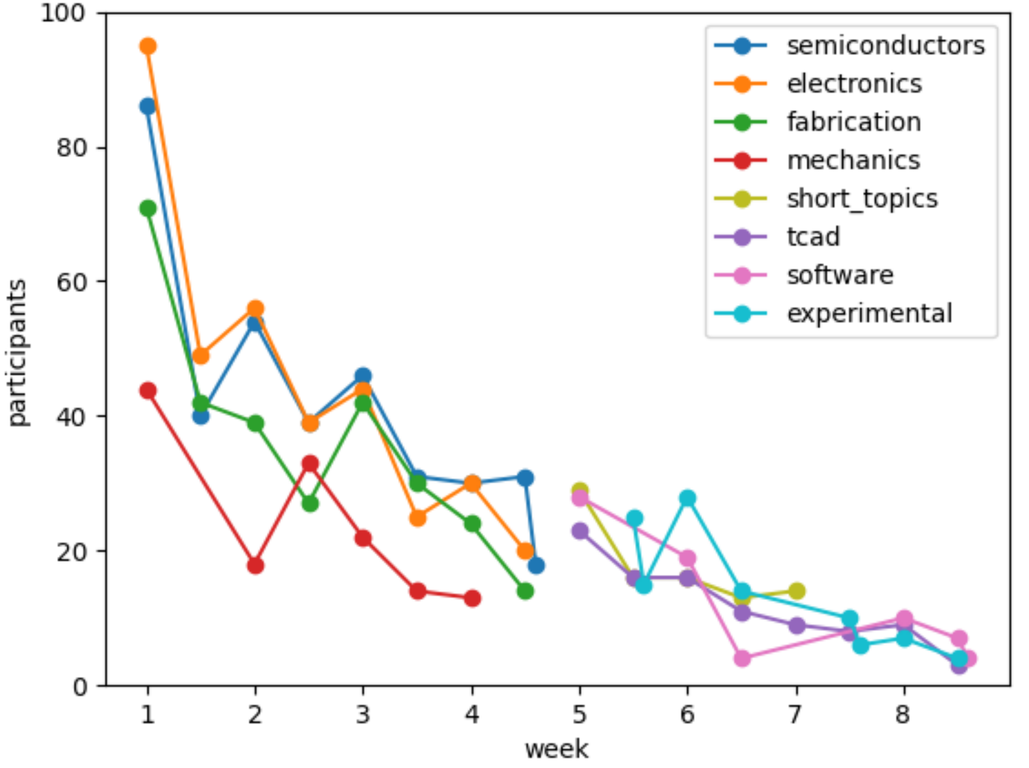


Attendance

2022



2023



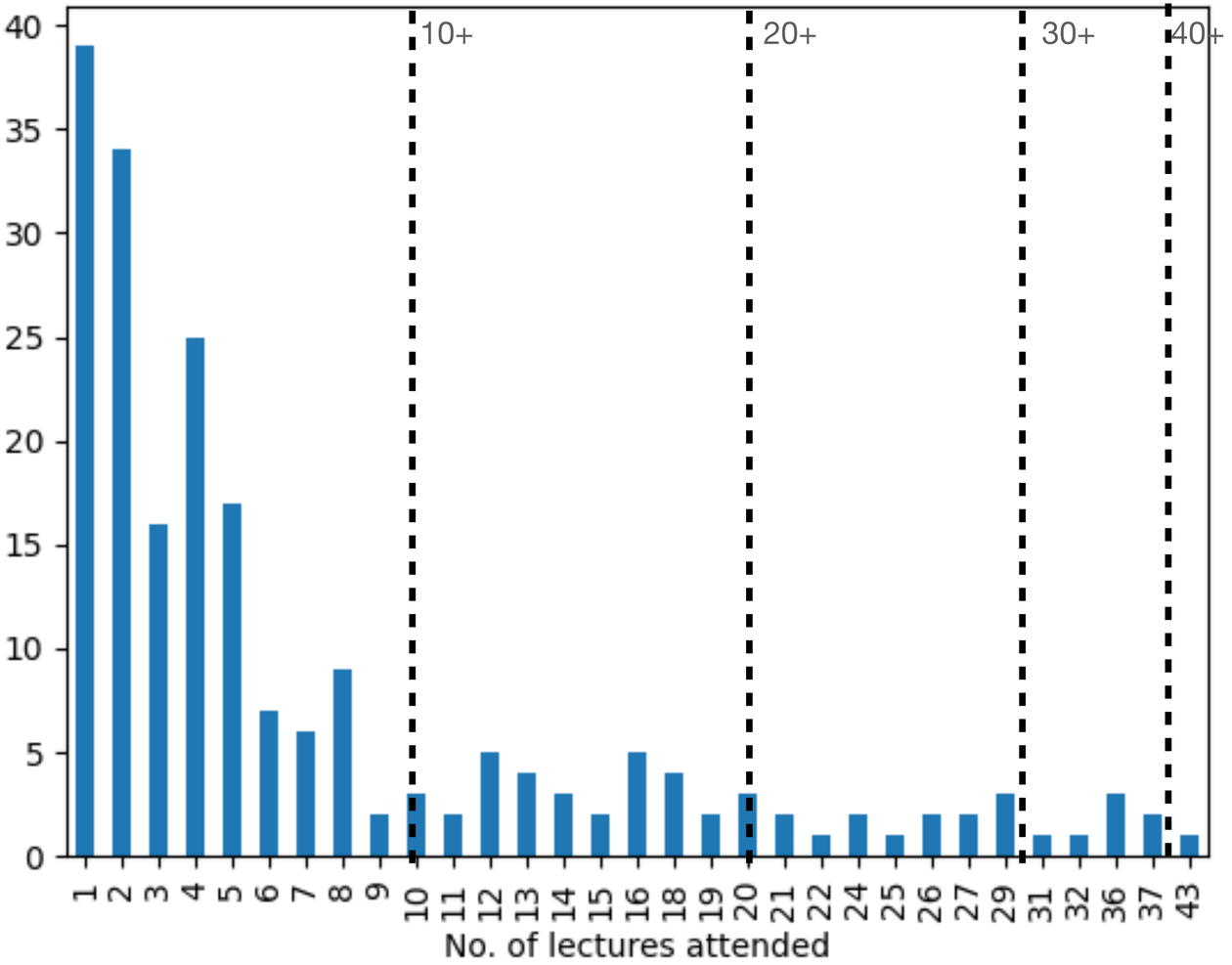
Attendance

Expected from previous iteration that participants would not join all lectures

- People join for courses which are more relevant

Lecture fatigue still an issue. This year versus last year:

- **54** (24) attended 10+ hours
- **24** (14) attended 20+ hours
- **8** (6) attended 30+ hours
- **1** (3) attended 40+ hours



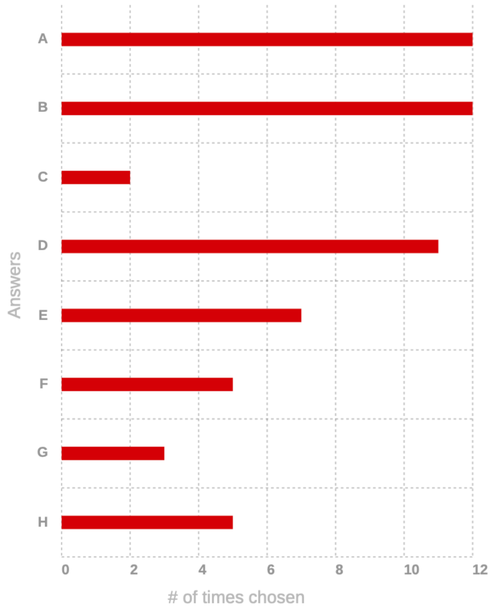
Participant feedback

Participant feedback - general questions

Which courses did you attend (fully or partially)?

Answered: *14*

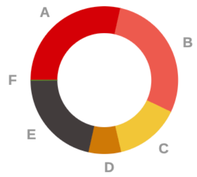
- **A. Semiconductor theory**: 12 (85.71%)
- **B. Electronics and DAQ**: 12 (85.71%)
- **C. Mechanics and cooling**: 2 (14.29%)
- **D. Silicon fabrication and structures**: 11 (78.57%)
- **E. Experimental techniques**: 7 (50.00%)
- **F. TCAD electric field and transport simulations**: 5 (35.71%)
- **G. Software tools**: 3 (21.43%)
- **H. Short topics**: 5 (35.71%)



Roughly how many lectures did you attend?

Answered: *14*

- **A. 1-10**: 4 (28.57%)
- **B. 11-20**: 4 (28.57%)
- **C. 21-30**: 2 (14.29%)
- **D. 31-40**: 1 (7.14%)
- **E. 41-50**: 3 (21.43%)
- **F. 51-60**: 0 (0.00%)



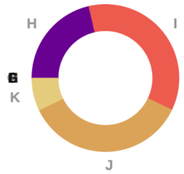
Participant feedback - general questions

How would you rate your general opinion of the programme?

Answered: 14

From 0 (awful) to 10 (amazing)?

- **A. 0**: 0 (0.00%)
- **B. 1**: 0 (0.00%)
- **C. 2**: 0 (0.00%)
- **D. 3**: 0 (0.00%)
- **E. 4**: 0 (0.00%)
- **F. 5**: 0 (0.00%)
- **G. 6**: 0 (0.00%)
- **H. 7**: 3 (21.43%)
- **I. 8**: 5 (35.71%)
- **J. 9**: 5 (35.71%)
- **K. 10**: 1 (7.14%)



Do you have any general comments on the programme?

Answered: 7

There will be specific questions on the course format and individual course content below

Seems well organised; the format is convenient for attending just the relevant sessions.

The course was very good for a PhD with respect to the content. But, some of the lectures were quite fast (some started with very basics) so it was not easy to follow.

I coudnt attemp all the classes I wanted because work and testbeam travels, but the one related to my topic were well explained and I could learn a bit more in my topic. Unfortunatelly I coudnt attemp the TDAQ lectures and the slides are not in the webpage it will be nice if they can uploaded! thanks!

A road map for all school lectures at the beginning may be help to show students how each part connected to each other.

For people outside Europe, the time change could be a problem to connect.

Firstly - thank you! I think the idea is brilliant: I appreciated the chance to learn from some of the best in the field, sharing the practical knowledge (otherwise trapped in their heads!) should definitely become a tradition. I especially liked the real-world minor but crucial detail examples. I also liked the usage of free tools such as KiCAD and LTSpice -- given the diversity of tasks in Physics experiments, it's often impractical to invest in a paid package. What could be improved is the content ratio, which is primarily textbook with some examples atm to mostly examples with reminders or references to theory or method description. It would be useful to maintain a repository of software tools and perhaps a UK community forum (could be part of a common platform) where particular problems could be dicussed. This would open up the overview of questions that people face in their work.

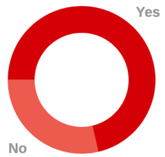
The programme overall was very well tuned to (at least) my schedule. There were times where due to conflicts, I had to skip one or two lectures that were really interesting. Here, I found it a great pity that we did not have recordings. In my opinion these are so useful in paying attention during the lecture and revisit parts later, or in the eventuality of missing one lecture. The caveat here is that people might stop attending altogether if they knew recordings will be provided :) ..

Participant feedback - format

Did your attendance drop over the course of the programme?

Answered: *14*

- **A. Yes**: 10 (71.43%)
- **B. No**: 4 (28.57%)



Do you think that there were too many lectures in total?

Answered: *14*

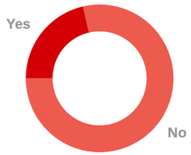
- **A. Yes**: 2 (14.29%)
- **B. No**: 12 (85.71%)

Do you think that there were too many lectures in a single block?

Answered: *14*

Reminder: lectures were scheduled during 2 days per week, with blocks of typically 4 lectures

- **A. Yes**: 3 (21.43%)
- **B. No**: 11 (78.57%)



Would you have preferred:

Answered: *14*

Assuming the same total number of lectures

- **A. More lectures per week over fewer weeks**: 1 (7.14%)
- **B. The same format**: 9 (64.29%)
- **C. Fewer lectures per week over more weeks**: 4 (28.57%)

Would you have preferred:

Answered: *14*

Assuming the same number of lectures per week

- **A. More lectures per block over fewer days**: 1 (7.14%)
- **B. The same format**: 10 (71.43%)
- **C. Fewer lectures per block over more days**: 3 (21.43%)

Participant feedback - format

What would have made you attend more of the lectures?

Answered: 7

I attended the lectures relevant to my interests, and the format was perfect for that.

Due to I am doing the PhD, I have to atttemp meetings and also work in my project. So, some of the lectures were not possible to be follow.

A possibility to listen to the lectures recording at a different time, as I had to skip some lectures due to other commitments and then next lecture was hard to understand. In addition, I would benefit from looking at some difficult parts of lectures later, even for the lectures I attended.

Assignments!!! If there is some followup/assignments people who want to follow it will be more into the course.

If I didn't have another workshop to attend towards the end of the training.

I am interested in the silicon detector and want to have more knowledge

I think the format was good, more lectures in one week would be too much, fewer too sparse. What I did not expect is the overall duration, which resulted in me missing the second half of the block due to a business trip. I would appreciate recordings of the lectures as I had to miss the ones that interested me the most.

Participant feedback - going forwards

Would you be keen to see this programme continue in the future?

Answered: *13*

A. Yes: 13 (100.00%)

B. No: 0 (0.00%)

Are there other topics that you would like to see included?

Answered: *3*

It would be great to have the following covered more in-depth: - designing a simple detector from scratch. eg: MAPS with 2x2 pixels. how to place transistors, metal lines, maybe with some available node for public on a MPW? (of course, I don't suggest a submission, just the design and what considerations about logic are needed). something like the TCAD course (a large number of lessons with us looking at the tutor doing the magic and we asking questions during the process; or, if time allows, follow along? -- but then all the software licensing problems..) - related to the first point, what to consider in the relation with the foundry. i remember them having some design rules or transistor designs that they send and only using those you can design (I think it's called PDK or DDK)... so something among these lines (sorry for not being specific). also, heard terms like: IP blocks, macrocells , DRC .. would be nice to maybe understand those :) or see a bit the workflow of the chip designers... - more inside stories from relation to foundries. what we are not aware of, what we should be aware of. - less known, but important facts that are not usually taught (eg: the sort of things you get from seniors during a beer talk). like for example, costs of producing detectors at the moment, problems in the field... - past mistakes from experiments / sensors (eg: faulty devices) and lessons learned? was it a design error, was it a foundry error. what can go wrong: eg: dicing, picking, bonding - more things related to foundry operation: how to go from sand to a pure silicon ingot. then how this is cut, how implantation is done (temperatures, doping levels, duration), how masks are used (how many masks are usually required, usual price ranges...); then all steps done: wafer processing, etching, etc. .. finally, how dicing is done, thinning, bonding, picking, and so on. i know some were touched during the fabrication lecture, however i would love to hear more! felt like the tutors wanted to say more but the time was not enough. - which steps (previously mentioned) are important for detector design (eg: maybe they need deeper doping or multi-well designs), which for consumer electronics, differences... - current trends in consumer electronics, what challenges are present in going sub-nanometer, what mosfet types

None

RF electronics, signal processing techniques, applications of machine learning AI in electronics design and signal processeing, some courses would be useful as hands-on

Would you be interested in attending an intense hands-on in-person school as part of this programme?

Answered: *13*

A. Yes: 12 (92.31%)

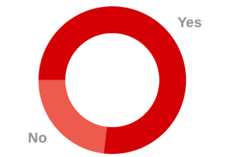
B. No: 1 (7.69%)

There have been suggestions of extending the UK training programme to include focussed hands-on courses in dedicated topics, such as GPU programming or vibration measurements and analysis. Would you be interested in attending such focussed training?

Answered: *13*

A. Yes: 10 (76.92%)

B. No: 3 (23.08%)



Participant feedback - going forwards

What kind of topics would you like to see covered there?

Answered: *5*

None

Perhaps a little higher-level material: communications with ZeroMQ/sockets, testing/integration of systems, principles of systems design for instrumentation monitoring/control.

In-person TCAD sessions

Interested in dedicated topics, although probably not the ones mentioned :) Personally interested in: - TCAD for monolithic pixel sensors (similar to what Nick did, but having the chance of doing it myself, or following along) - sensor design (probably not feasible due to the sheer complexity), but I would absolutely love to learn how to start from the design rules of a specific foundry and design a sensor myself up to the point of pending submissions - circuit design

As above + FPGA + DSP

Do you have any other suggestions for improvements?

Answered: *3*

None

It seems more and more that a shift towards MAPS designs is ongoing (even for rad hard experiments, although it might still be a few years before the technology is fully embraced). Having more dedicated material to MAPS would be great! On a different topic. I would always keep a component of remote participation to this conference, as some might not have the means to participate in person for extended periods of time.

Please, keep going, this is a multi-fauceted topic, hard to fully cover and satisfy all demands, but these courses were a step in the right direction!

2024 Programme

(Personal) Thoughts on the future - for discussion

A short list of personal opinions to kick-start discussion:

- I would continue the lectures again this year
- I would continue not to record the lectures, to try and maximise in-person participation
- I would ask for volunteers to help go through the slides and consider trimming/condensing the material to run the lectures over fewer weeks (maybe 6? 7?)
- I would ask for lecturers to provide a couple of worked examples and have a tutorial-style Q&A session
  - Not suggesting lecturers mark or grade students work
  - At Oxford, this could potentially count for our PhD students credited courses (we would have to mark ourselves)
- Any other suggestions?

UK DRD activities

(Personal) Interpretation of DRD-UK bid

As most people are aware, the UK detector community (particularly relevant: DRD3) have been discussing over the last year the prospect of reviving UK instrumentation R&D, to be tied in with the international DRD collaborations

At present an EoI covering all DRD areas with UK involvement has been submitted to STFC (PI: Chris Parkes)

- STFC do not seem willing to engage further at this moment
- The community has been told not to submit an SoI to Science Board

This programme is decoupled, but could eventually merge with this programme if it should get off of the ground

- There has been discussion on an instrumentation CDT
- We could already invite non-silicon areas to run their own lectures covering eg. Gaseous detectors, PID, etc.
- Contacts at present: Cristina Lazzeroni (Birmingham), Richard Bates (Glasgow)

(Personal) In-person summer school

Before this years programme we discussed the possibility of an in-person summer school, to complement the material covered

- I had planned to send this around to this group, but due to time constraints (mea culpa) this was submitted at the time of the STFC funding deadline on October 1

If funded, the plan would be to run the school in Oxford, with subsequent years rotating amongst interested groups in this community

- 2 week residential course for ~20 students covering simulation, assembly and measurements with silicon devices

	Monday	Tuesday	Wed.	Thursday	Friday	Weekend	Monday	Tuesday	Wed.	Thursday	Friday
Group 1	Intro.	Device simulation - TCAD		Electronics design and simulation		Free	Electrical characterisation		Radiation detection		Closeout
Group 2		Electronics design and simulation		Device simulation - TCAD			Radiation detection		Electrical characterisation		
Group 3		Electrical characterisation		Radiation detection			Device simulation - TCAD		Electronics design and simulation		
Group 4		Radiation detection		Electrical characterisation			Electronics design and simulation		Device simulation - TCAD		
Evening session	Poster session 1	Academic careers	UK infrastructure	Industrial careers 1	Public engagement		Poster session 2	Doing a PhD in detectors	College dinner	Industrial careers 2	

Many thanks again!

To all those who made this possible