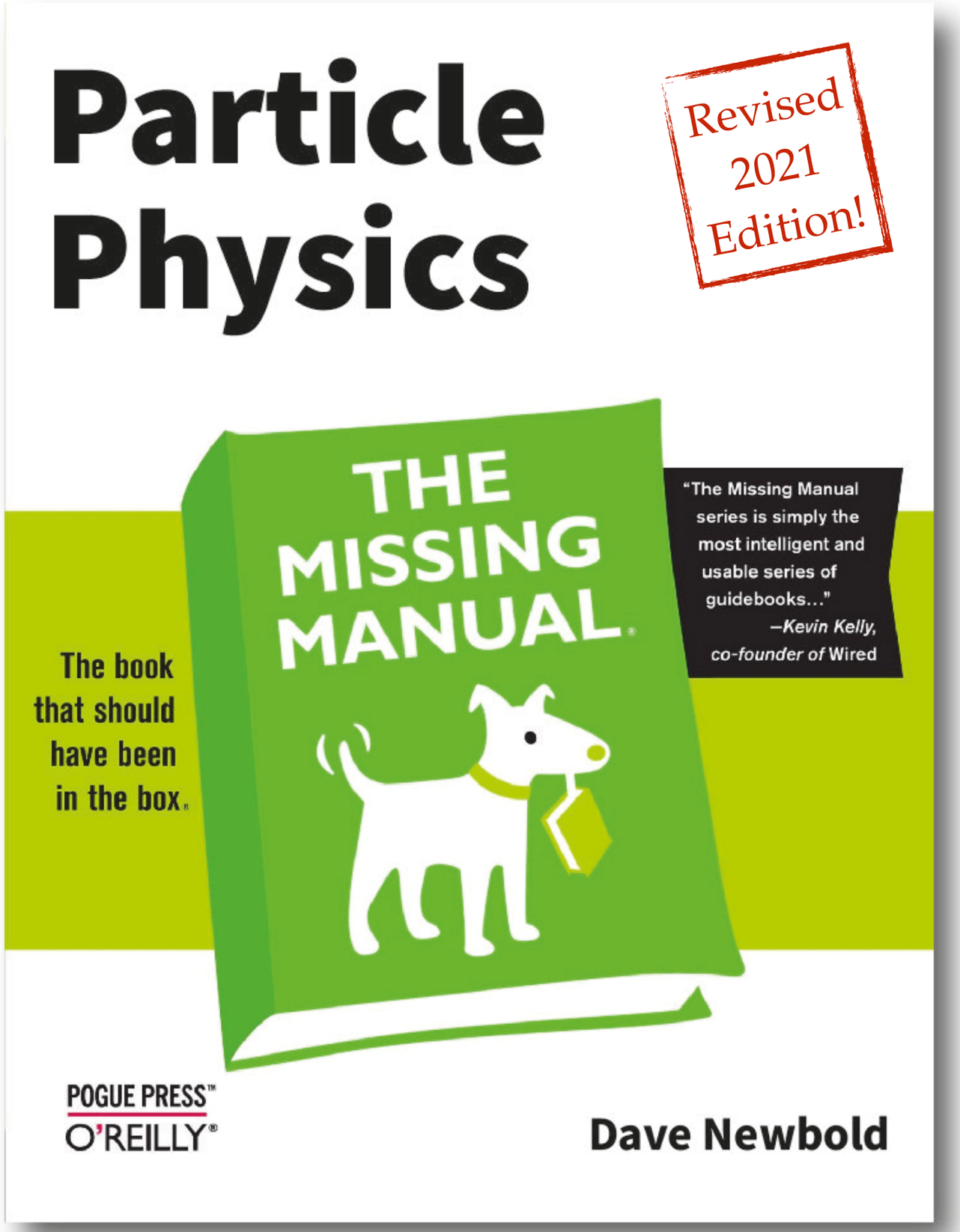

Introduction

- Comrades! Have you ever wondered…
  - How things really work?
  - What's going on *behind the scenes*?
  - Why interactions occur in the way they do?
  - Where it all *comes from*?

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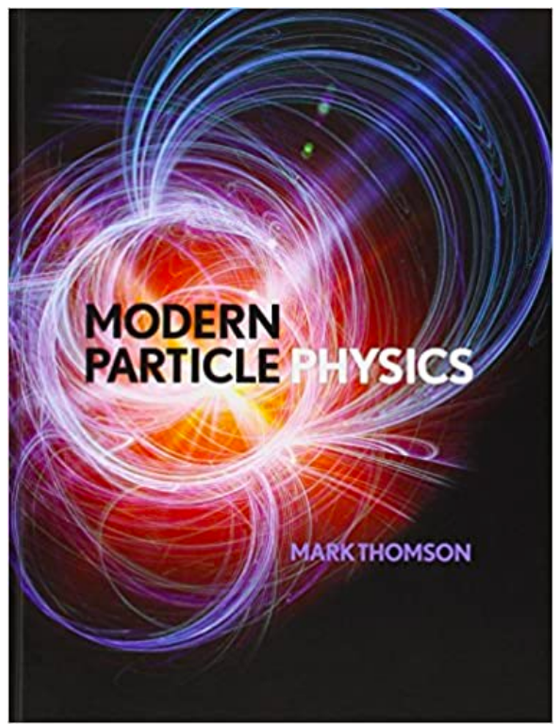
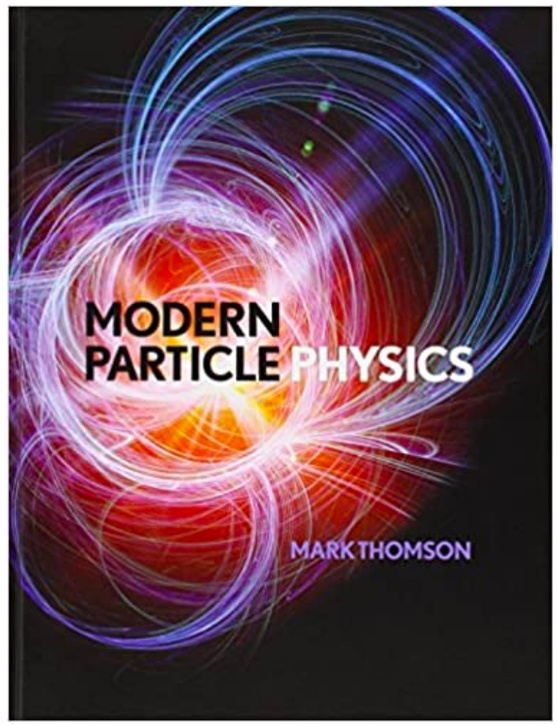
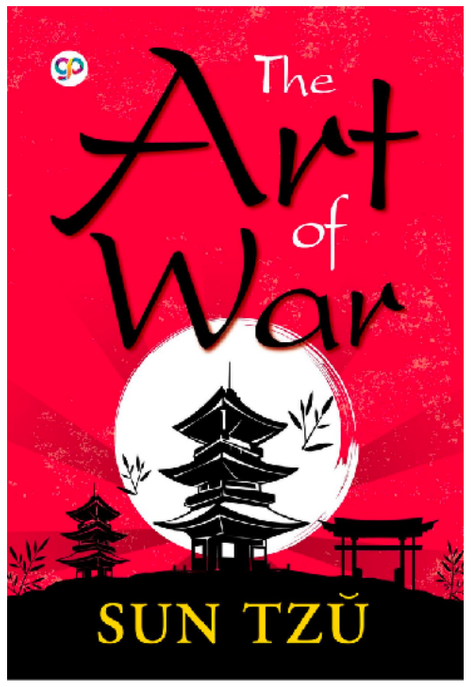


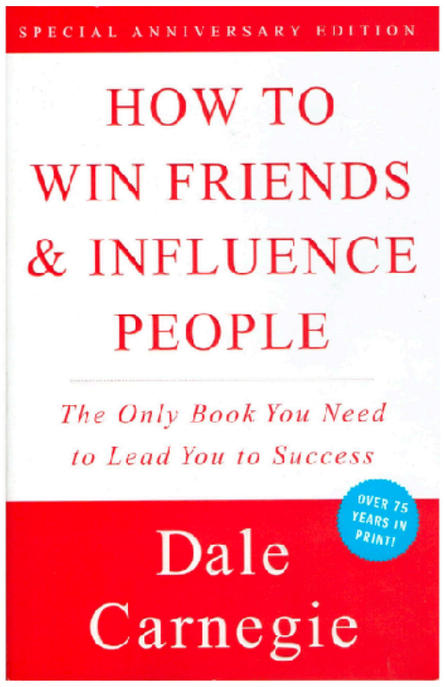
Introduction

- Comrades! Have you ever wondered…
  - How things really work?
  - What's going on *behind the scenes*?
  - Why interactions occur in the way they do?
  - Where it all *comes from*?
- Today we answer ~~all~~ ~~some~~ a few questions
  - Including some you didn't know you had



- To be covered
  - How particle physics gets done
  - How collaborations work
  - The machinery of particle physics
  - The UK field
  - Your career
  - Q&A





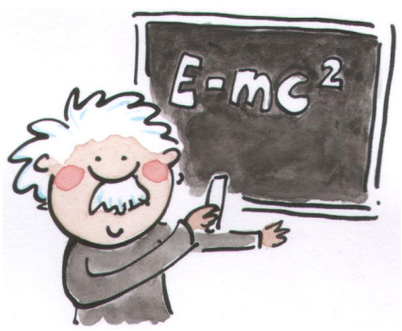
1. How Particle Physics Gets Done

"Don't let me catch anyone talking about the Universe in my Department" – Rutherford

Field Spotter's Guide

- PP theorists:
  - Think about Lagrangians
  - Particles = "field quanta"
  - (Can) work in small teams
  - Can rapidly play with new ideas
  - Admire elegance, simplicity (~ Dirac)
- But also…
  - Must invent new techniques
  - Interact with other fields
  - Get excited about new results

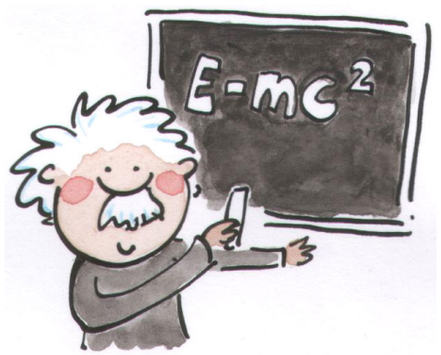
- PP experimentalists:
  - Think about measurements
  - Particles = "tiny charged blobs"
  - (Must) work in huge teams
  - New ideas take years to test
  - Admire ingenuity, effectiveness (~ Rutherford)
- But also…
  - Must invent new technologies
  - Interact with other fields
  - Get excited about new results



Real progress is only made when we work effectively together

How Science Works (Textbook Model)

Develop theoretical model with testable consequences



Devise experiment or observation to challenge model

Build and perform experiment

Unexpected results?

Scrap or further develop model

How Science Works (PP version)

Ongoing pursuit of interesting / fashionable / promising problems

Form consensus on phenomena that might be observable (today)

Form consensus on next required large facility, carry out R&D

~ 5 - 10 years

Finance (G$), plan facility

~ 5 years

Collaborations propose and design experiments (cash limited)

~ 5 - 10 years

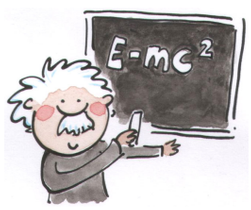
Perform experiments

~ 1 - 10 years

Discoveries / anti-discoveries (perhaps unexpected!)

Precision measurements of parameters

Scrap or further develop models



Why is PP Different and Special?

- All the easy experiments have been done
- Huge concentrations of resource and focus needed
  - Other disciplines think we 'get all the money'… do we?
- The tangible benefits are 'indirect'
  - But very substantial
- Broke 'normal rules' of {reproducibility, communication, organisation}
  - And then made up our own…
- Very hard to explain what we do to other scientists
  - But apparently easy to explain it to the public – discuss
- *Collaboration is the norm*, not the exception – indeed, essential
  - We all love each other very much…
  - Our culture does favour strong personalities – discuss
- Are we truly different and special?
  - No, not really – other fields now have the same problems we had 30 years ago

2. How Collaborations Work

"If your experiment needs a statistician, you need a better experiment" – Rutherford

Why Collaborate?

- Consolidate resources
  - And manage them effectively and professionally
- Organise operations
  - It really does take >2000 people build and operate a large experiment
- Manage communications
  - Internal – can have frank discussions, take risks
  - External – 'approved scientific statements', including publications
  - Upward – providing clear reporting to funders
  - Outward – to the public
- Bring together specialisms
  - 'Hardware people', 'software people', 'computing people', 'analysts'
  - Beware the cult of flag-planting
- Ensure continuity
  - Make sure vital knowledge is spread around and passed on
- Provide training and mentoring
- Ensure scientific good practice

The Challenges

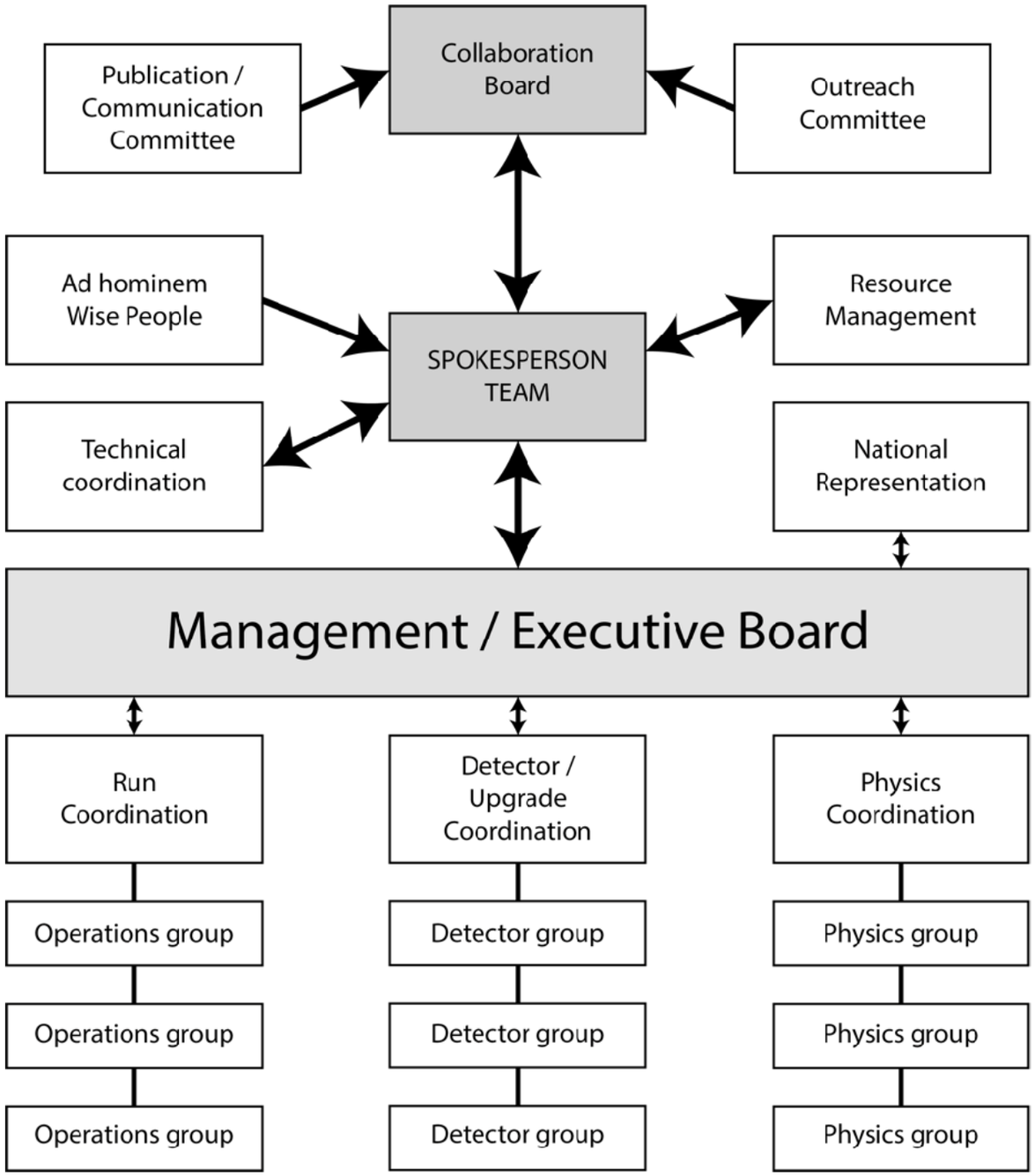
- Big collaboration equivalent to a multinational company
  - In size / complexity / budget

- Company
  - Run by (appointed) managers & accountants
  - Staffed by employees
  - CEO is in charge
  - Decisions top-down
  - Answerable to shareholders
  - Screw up or cheat, get fired
  - Competition in the market

- Experiment
  - Run by (elected) physicists
  - Staffed by volunteers
  - Nobody truly in charge
  - Decisions 'by consensus'
  - Answerable to funding agencies
  - Screw up or cheat, lose reputation
  - Competition in the market

- It's a wonder anything happens at all…
  - But of course it does
  - PP has developed a unique internal culture to cope with these challenges

Standard Model of PP Collaborations



- This means a LOT of meetings – you may have noticed

Meetings

ATLAS Meetings	342,166 events
BaBar	18 events
BASE	22 events
Belle II	150 events
BRAHMS meetings	270 events
CALET	75 events
CAST Meetings	131 events
CBM Meetings	13 events
CIMA Meetings	129 events
CLOUD	190 events
CMS meetings	180,868 events
COMPASS Meetings	2,465 events

- One meeting every 15 minutes for 20 years…

Standard Model of PP Collaborations

Upper House

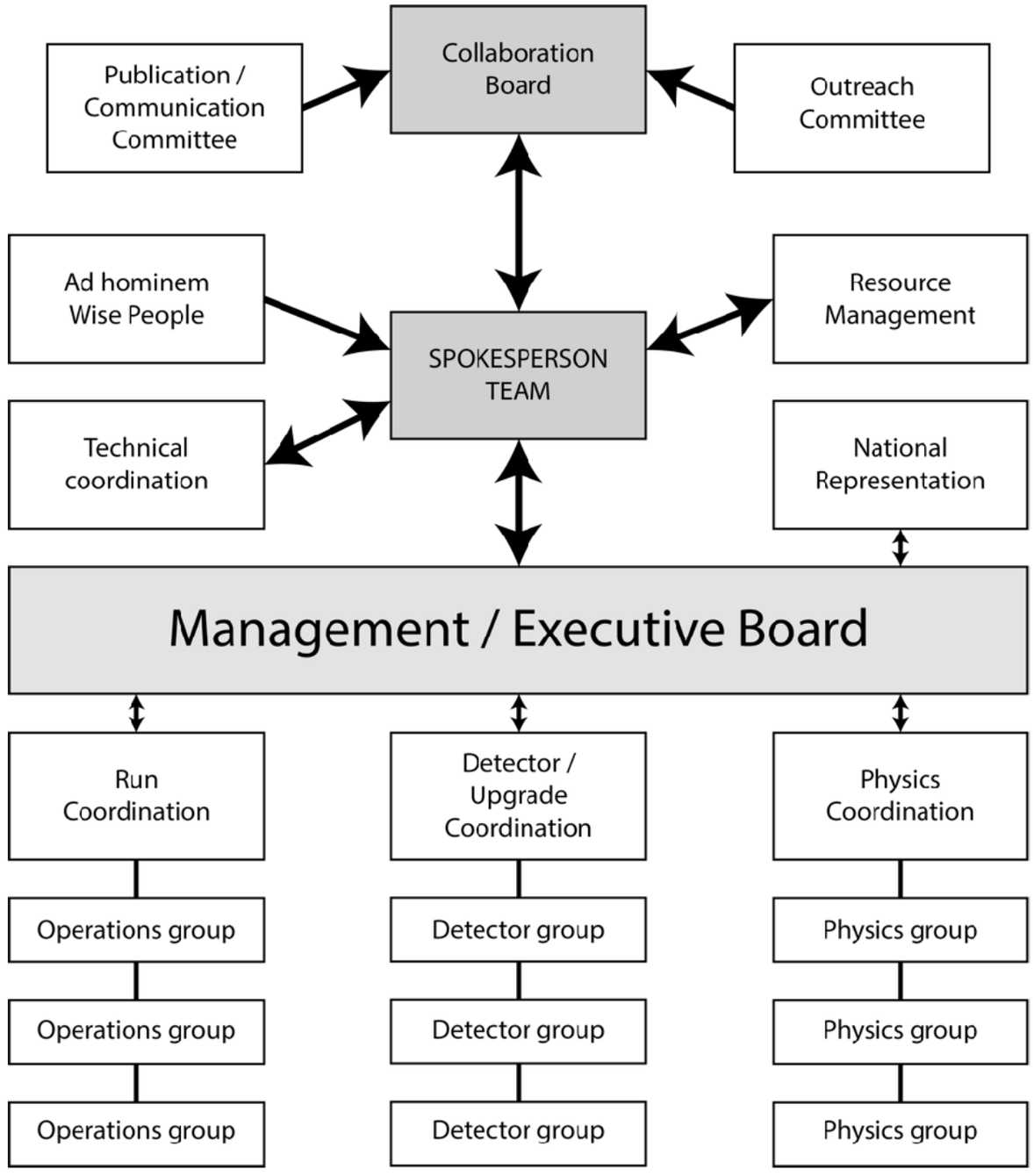
Prime Minister & Cabinet

Civil Service

President

Treasury

Lower House

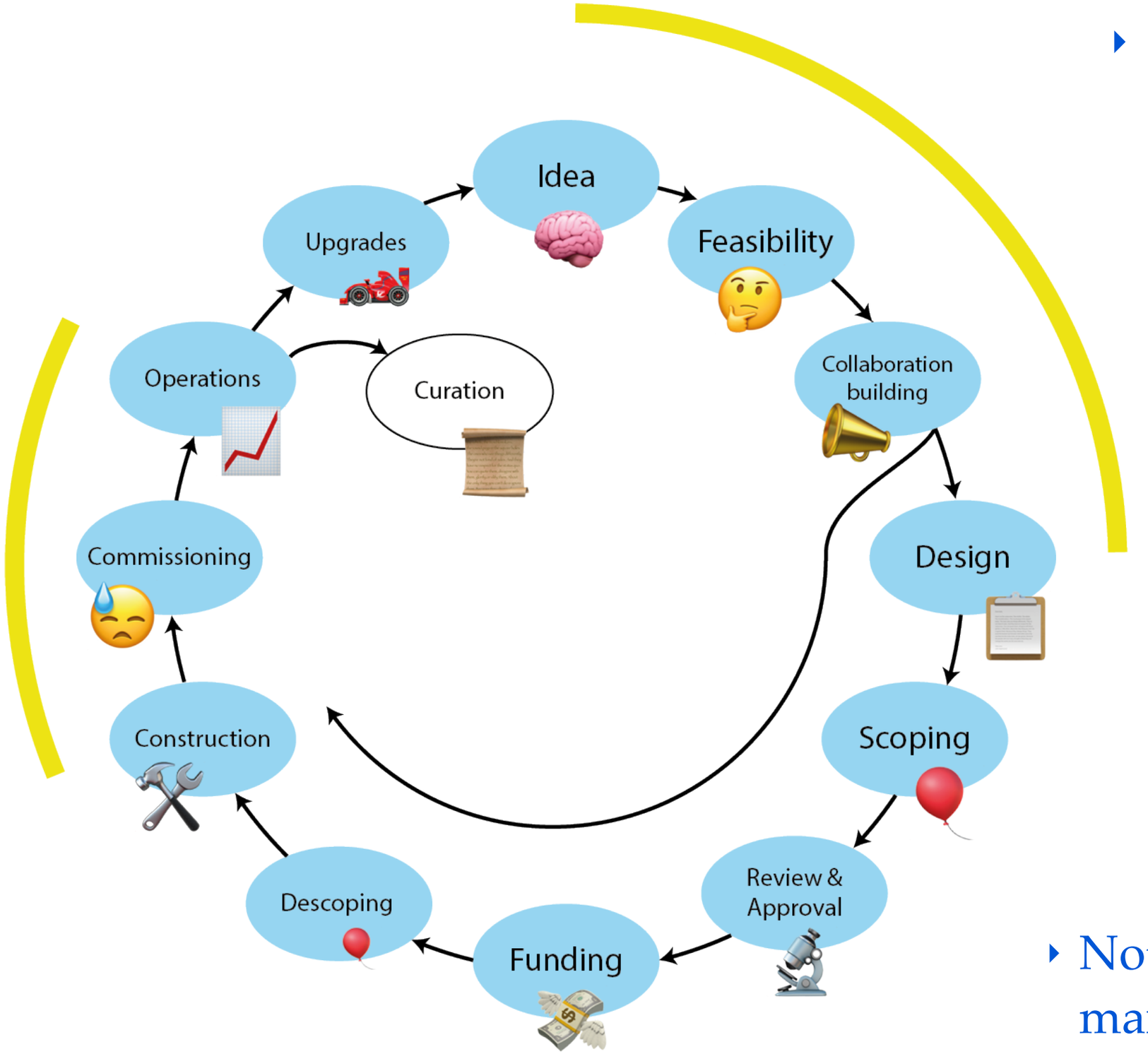


- Judiciary is along feudal system lines – ask me later

Scientific Integrity

- What's the problem?
  - Data analysis is complicated, subtle, error-prone, and pressured
  - Unconscious bias is a *proven* problem – you find what you are looking for
  - Must exclude possibility of gross mistakes, fabrication of data, mis-estimation of errors
- The usual solutions
  - Education, training and cultural expectation
  - 'Blind' analysis of data to avoid bias
  - Internal cross-checks at every level of data-handling
  - Peer review by 'independent' collaborators at every level
  - Collaboration ownership of all public results – everyone signs everything
  - Multiple experiments examining the same physics
- Being right is better than being first (being both is best of all)
- Isn't this all a bit old-fashioned? Why not just 'publish' the raw data?
  - Substantial resources needed to carry out all steps of data analysis
  - A culture of cross-checks and openness cannot be ensured
  - No incentive to contribute to design / construction of facilities

Collaboration Life Cycle



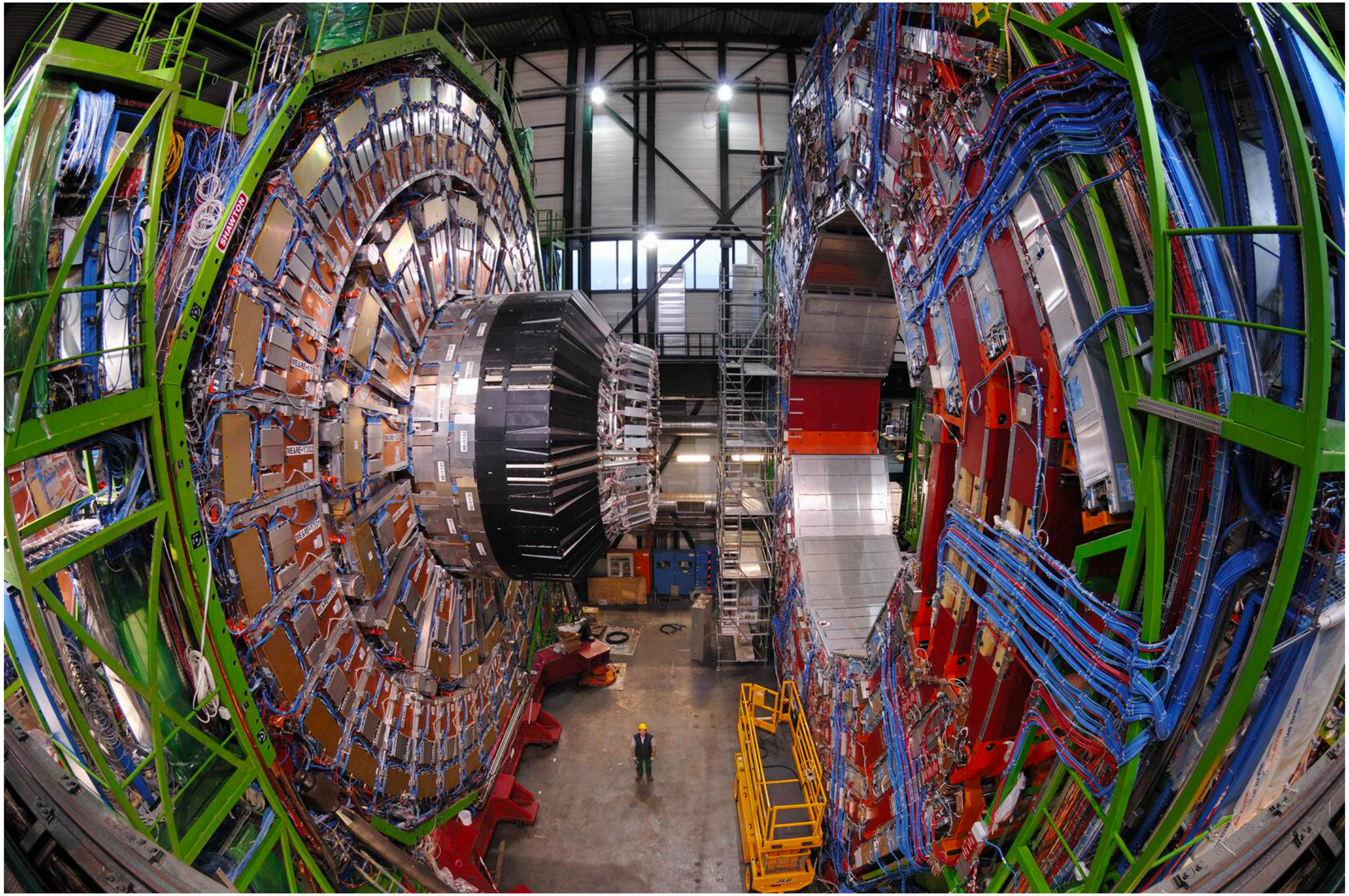
- Idea-to-curation now approaching a working lifetime…

- Note ‘golden periods’ of maximum intellectual return

3. The Machinery

"We've got no money, so we've got to think" – Rutherford

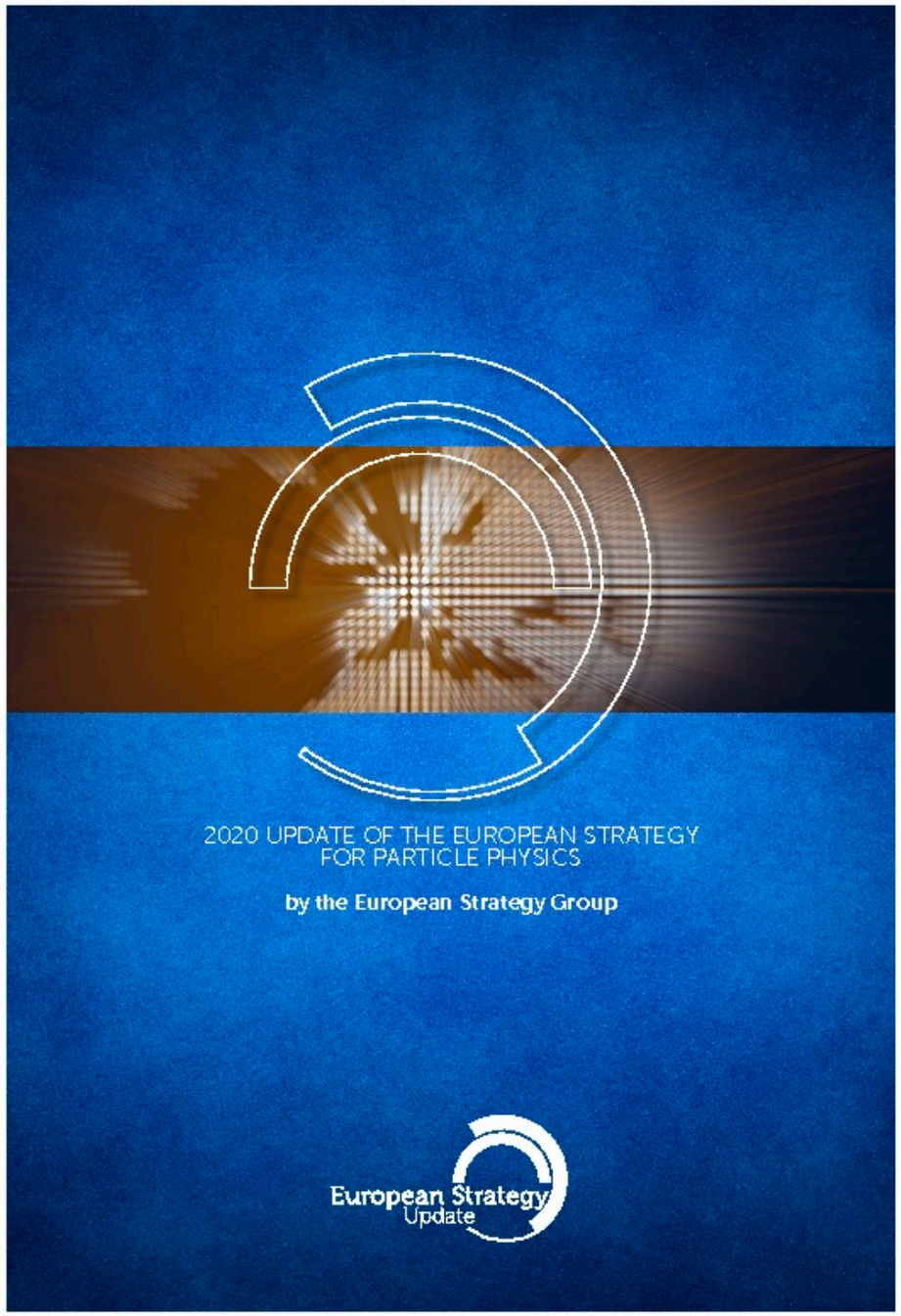
Not this kind of Machinery



Who Decides?

- How do we decide what experiments to do?
  - Long (decadal) process of forming consensus
- International level
  - Bodies like ECFA, LDG, CERN Council bring together senior physicists and funders
- European Strategy
  - CERN acts as the 'governing council' for European particle physics
  - Five-yearly European Strategy process to build consensus
    - Recommends actions on large projects both within and outside CERN
  - Other countries have similar things (e.g. Snowmass process in the US)
- National Strategy
  - STFC (UK funding agency), has semi-continuous gathering of scientific input
    - Expressed in regular 'programmatic review' documents
  - Note that the scientists decide, within funding constraints ('Haldane Principle')
    - Though considerations of feasibility, value-for-money and critical mass will always come into play
- Group and individual strategy
  - Senior physicists seek to join collaborations based on interests, experience, and needs
  - Proto-collaborations often hold a 'recruiting round' to form a nucleus of expertise

Who Decides?



https://cds.cern.ch/record/2721370

- Latest update to strategy: 2020
  - Culmination of two-year process
  - If you want to know what the future holds, it's in there – maybe
- Top priority projects:
  - HL-LHC (happening)
  - Neutrino platform (happened)
  - ILC / FCCee (didn't happen – yet)
  - Far future energy frontier (FCChh)
- Now in 'roadmapping phase'
  - Deciding what R&D to do for future experiments
  - Feasibility studies, optimisation, etc

Who Pays?

- The field is relatively well-funded
  - Global funding for PP over $10B per annum – most goes on researcher salaries 😁
  - CERN annual budget around 1GCHF, paid by 23 member states
- Origin of funds is almost exclusively national governments
  - CERN has a 'funding formula' based on national GDP
  - UK is second-largest contributor (after DE)
- Money comes in many flavours, e.g. in the UK:
  - Capital for building things vs recurrent funding ('resource') for operating the things
  - Staff vs equipment / travel / consumables / services funding
  - Project-specific vs 'portfolio' funding
  - Grants vs 'service level agreement' funding
  - Core (programmatic) funding vs national labs vs infrastructure
  - Research council vs QR funding
- Are you confused yet?
  - Ability to navigate the swamp of budgeting is a key skill later in your career
- All funding (regardless of country) subject to rigorous approval
  - Demonstration of need, peer review, feasibility assessments, project controls, etc
  - Making the case for a major new facility takes many years

Why do they Pay?

- Why on earth do governments spend this money?
  - The 'product' has no short-term economic value – right?
  - The costs are not small compared to national science expenditure
  - Long-term (pseudo-binding) commitments are needed
- The usual answers
  - National prestige
  - CERN as exemplar for international cooperation (the original motivation)
  - Maintaining a talent pool, and inspiring youth into STEM subjects
  - Technology spin-offs (into society, industry, other science)
- The answer often missed
  - Ensuring a supply of extreme-skill-set people with a 'can-do' approach
- Government frequently needs to be reminded of these arguments
  - One 'funding crisis' every ten years on average – watch this space
  - Not everyone in academia is 'entirely on our side' – tall poppy syndrome

Who Governs?

- The ‘standard model’ of PP governance
  - Scientists propose and conduct research
  - National and international labs facilitate, oversee and accommodate
  - National funding agencies approve, pay, monitor and govern
- What does ‘governance’ mean?
  - Defining the overall balance of scientific activities
  - Ensuring a proper assessment of the science
    - Usually through a system of anonymous peer-review
  - Defining standards for scientific practice and rigour
  - Allocating the ‘right amount’ of funding
  - Ensuring projects are properly managed and monitored
  - Preparation for and defence against against large scale risks and events
  - Overseeing international / inter-governmental agencies and agreements
  - Ensuring fair treatment and development of scientific researchers
  - Ensuring national policies for science are enacted
- Large national laboratories also have a governance function
  - Usually over the operation, conduct and technical coordination of collaborations

Who Hosts?

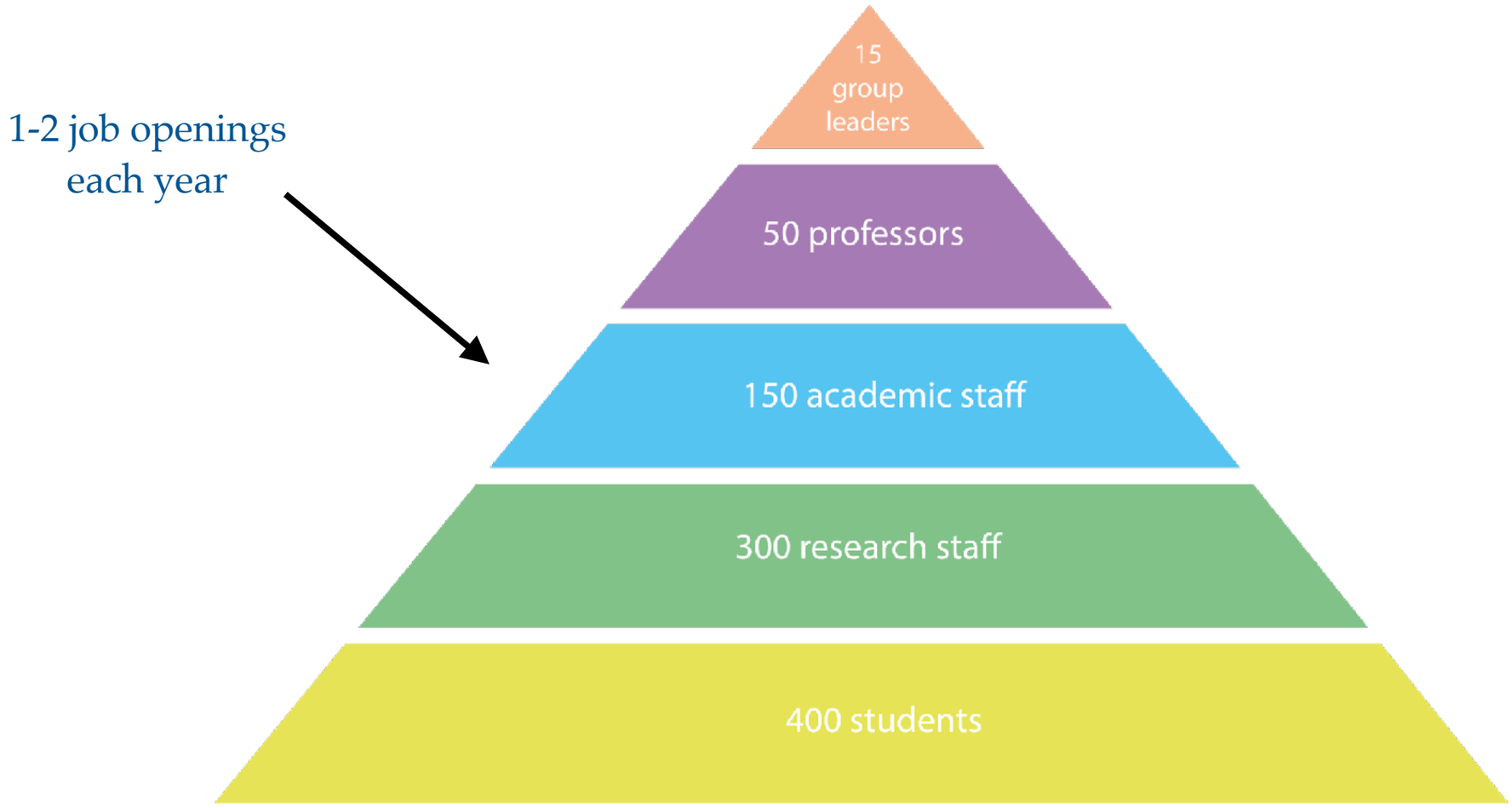
- UK's accelerator laboratory is CERN
  - Always remember that CERN is *our* lab!
- UK has major national laboratories
  - Rutherford Appleton Laboratory, Harwell
  - Daresbury Laboratory, Warrington
  - Boulby Laboratory, nr Whitby
  - Other institutes supporting astronomy

- CERN is special and unique, *by design and intention*
  - An extra-territorial entity by international agreement
  - (Very) long term funding support by member states
  - Huge technical infrastructure, unique capabilities
  - Able to act as a facilitator for large (global projects)
  - International centre for public and political interest in PP
- A handful of other PP accelerator labs exist (mainly in the US)

4. The UK Field

"Scientists are not dependent on the ideas of a single woman, but on the combined wisdom of thousands of women, all thinking of the same problem" – Rutherford

UK PP Demographics

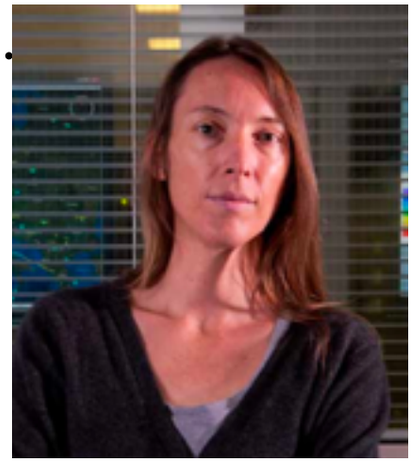


- Funding split between University group and national labs
  - Increasing work on the particle-astrophysics boundary
- UK participates in most major international experiments
  - LHC, short and long-baseline neutrinos, low background experiments
  - Around 15% of European particle physics community

Who's Who in STFC

STFC

(buy these people
beer and listen to them)



Prof. Tara Shears
Chair, STFC Science Board

Prof. Dave Newbold
Dir. Particle Physics, STFC

Prof. Mark Thomson
Executive Chair, STFC

Prof. Grahame Blair
Exec. Dir. Programmes, STFC

Prof. Matt Needham
Chair, STFC Particle Physics
Advisory Panel

Prof. Stephen Fairhurst
Chair, STFC Particle
Astrophysics Advisory Panel

Community

(these people will buy
you beer and listen)

Sarah Verth
Particle physics
programme manager

Science and Technology Facilities Council

Where STFC Funding Goes

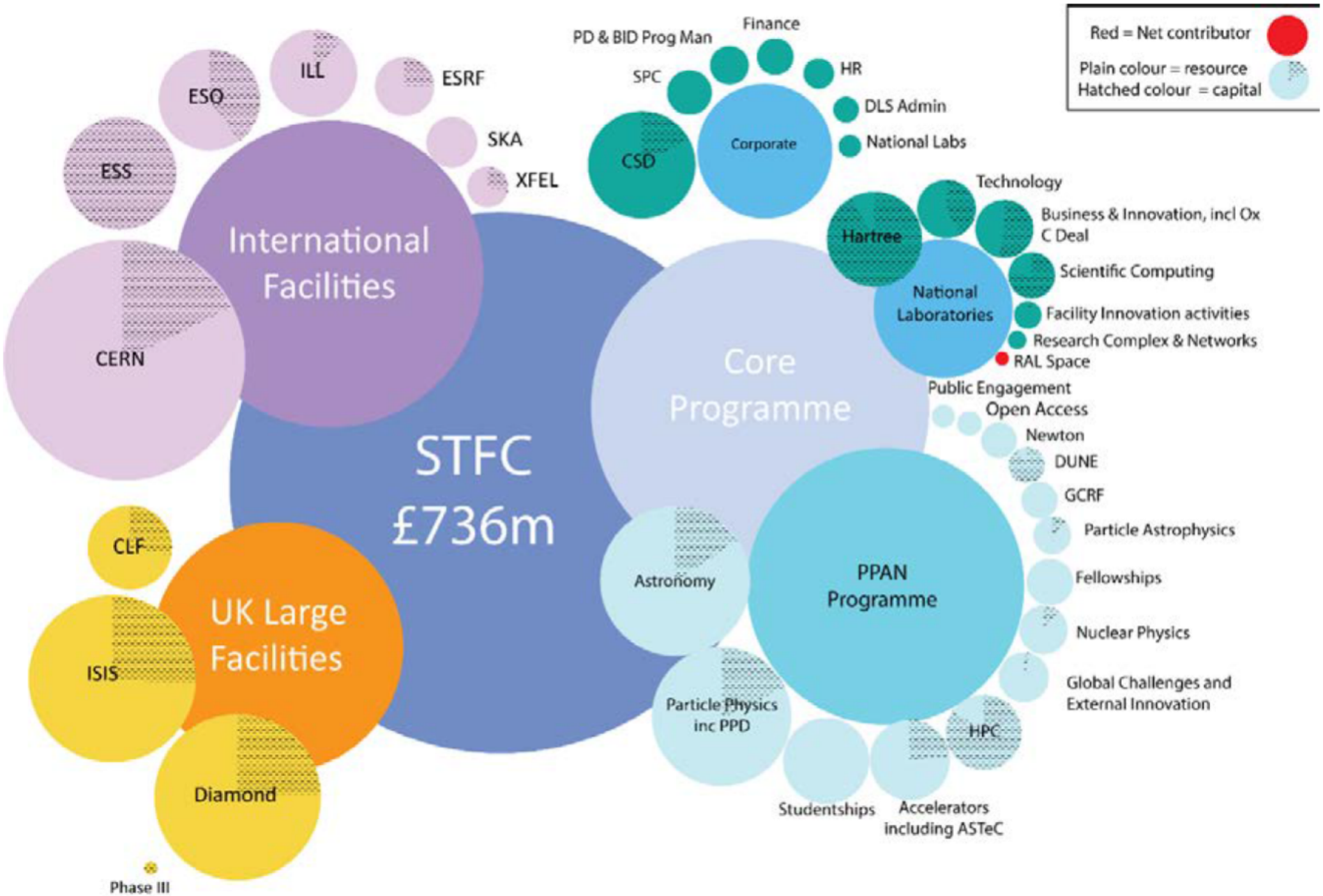


Figure 1: STFC's overall funding from BEIS in 2018-2019

UK Community Events

- National PP annual conference ('HEPP IoP meeting')
  - Next year at RAL! You may be called upon to help…
  - Includes a 'town meeting' with STFC executive
  - Student talks a (the?) major feature
- PPAP / PAAP responsible for convening community feedback
  - Collecting views on the research roadmap, reporting to Science Board
  - Typically two meetings per year
- 'HEP forum' workshop happens annually
- Many other ad hoc topical events and workshops
  - IoP 'half day meetings'
  - Workshops to discuss new projects
  - Training events in software, theory, etc
- STFC summer school for 1st year students in August / September
  - Upcoming school is the 50th. We may briefly go to the pub.
- UK news comes via the 'Hi-Phi' mailing list – subscribe! (No, really)

5. Your Career

"If you can't explain your physics to a barman it is probably not very good physics" – Rutherford

Climbing the Pyramid

- Postgraduate student
  - The training ground; learning the field
- First postdoc position
  - The first – and most difficult – step
  - Opportunity to specialise and get noticed
- Subsequent postdoc positions
  - Most people will hold a few 3-year positions before becoming ‘permanent’
  - This is where you consolidate your reputation
- Fellowships – lots, but a high bar
  - The first chance to hold your own funding and control your own future
  - Typically five years, and you may have students / postdocs working for you
- Permanent (aka academic) positions – the final destination
  - Typically in a University (as a lecturer)…
  - … or even more rarely as a staff member in a lab

Getting a Job

- What do we look for in postdoc employees?
  - Track record of getting things done
  - Breadth of experience; being a team player
  - *Appropriate level* of management experience for career stage
- What are not as important?
  - Personal characteristics (age / gender)
  - Your last boss or institute
  - How many publications you have
  - The contents of your thesis
- More senior positions
  - A (long-term) personal research strategy – your 'science story'
    - WHAT you'll do, WHY it's important, HOW you'll do it, and why YOU should do it NOW
  - For Universities, ability and track record in teaching
  - For labs, specific technical, organisational and leadership skills
- Important to recognise that not everyone stays for ever
  - And that a lot of people will not want to – many many opportunities out there
  - The 'product' is you!

Opportunities in the UK

- ‘Responsive RA’ positions
  - The majority of postdoc; carry out specific jobs on specific projects
  - Jobs last as long as the project, rotation expected
- ‘Core RA’ positions (or lab ‘core’ staff)
  - More experienced individuals, with specific skills
  - Work across a range of projects, more job security
- Fellowships
  - Ernest Rutherford Fellowship (STFC): 5 years, ~10 per year in STFC areas
  - Future Leaders Fellowship (UKRI): 7 years, ~40 per year
  - University Research Fellowship (RS), 5 - 8 years, ~40 per year
  - CERN Senior Fellowships, 3 + 3 years, ~40 per year
  - ERC / MCSA Fellowships (details to be determined…)
- All these positions have different criteria
  - You can actively monitor jobs lists via the ‘SPIRES jobs board’

Old Man Wisdom: How to Get Ahead

- Choose the right problems and positions
  - Work mostly on hard things
    - All the easy things have been done before, remember?
  - Move around, frequently and internationally
  - Learn something new in every new position – challenge yourself
    - What are you currently the best at the world at? What else? What next?
  - Exploit the 'golden periods' of experiments
    - Things move quickly at certain times, the rest is waiting
- Master your trade
  - Be the one to write things up (and publish them)
  - Serve, and serve diligently, on panels and committees
  - Find mentors, and stay in touch with them
    - These are the people who will write you all-important references
    - These people are more important than your boss as a source of guidance!
  - Learn as many different things as possible
    - Being a generalist is a hard (almost impossible) road, but you'll have more fun
- Keep rehearsing your 'science story'
  - Why do I seek to achieve in the long run? How does my current work get me there?

Old Man Wisdom: How to Get Ahead

- Communicate
  - Train yourself to speak, and to write
    - Some people are known for 'always giving a good talk' and 'always writing a good section'. Some are not.
    - This takes training and feedback, not just experience!
  - Actively seek outreach and teaching opportunities
    - Ancient truth: you don't understand anything until you teach it
    - You may find out that you don't really want to be a lecturer after all
- Learn to cope and to thrive
  - Build a network of your peers
  - Pace yourself
    - Look at the leaders in our field – how 'full on' are they? How 'full on' did they used to be?
  - Make collaboration (not competition) your first option
  - If you're not having fun, you're doing it wrong
- Be a good citizen
  - Mentor and train others
    - They might be your boss one day
  - Be scrupulous and generous in giving credit
  - Be nice – yes, it does get noticed. So does the opposite.

Further Reading

- *"You and your research"*, Richard Hamming, 1986
  - *https://homepages.inf.ed.ac.uk/wadler/papers/firbush/hamming.pdf*
- *"Microcosmographia Academica (being a guide for the young academic politician)"*, F. M. Cornford, 1908
- *"Beamlines and Lifetimes: The World of High Energy Physics"*, Sharon Traweek, 2009
- *"Anomaly! Collider Physics and the Quest for New Phenomena at Fermilab"*, Tommaso Dorigo, 2016
- *"Losing the Nobel Prize: A Story of Cosmology, Ambition, and the Perils of Science's Highest Honor"*, Brian Keating, 2018
- *"Lost in Math: How Beauty Leads Physics Astray"*, Sabine Hossenfelder, 2018
- Don't forget to read the European Strategy and CERN MTP:
  - *https://europeanstrategy.cern/home*
  - *https://cds.cern.ch/record/2631908/files/English.pdf*

Fin

Questions?