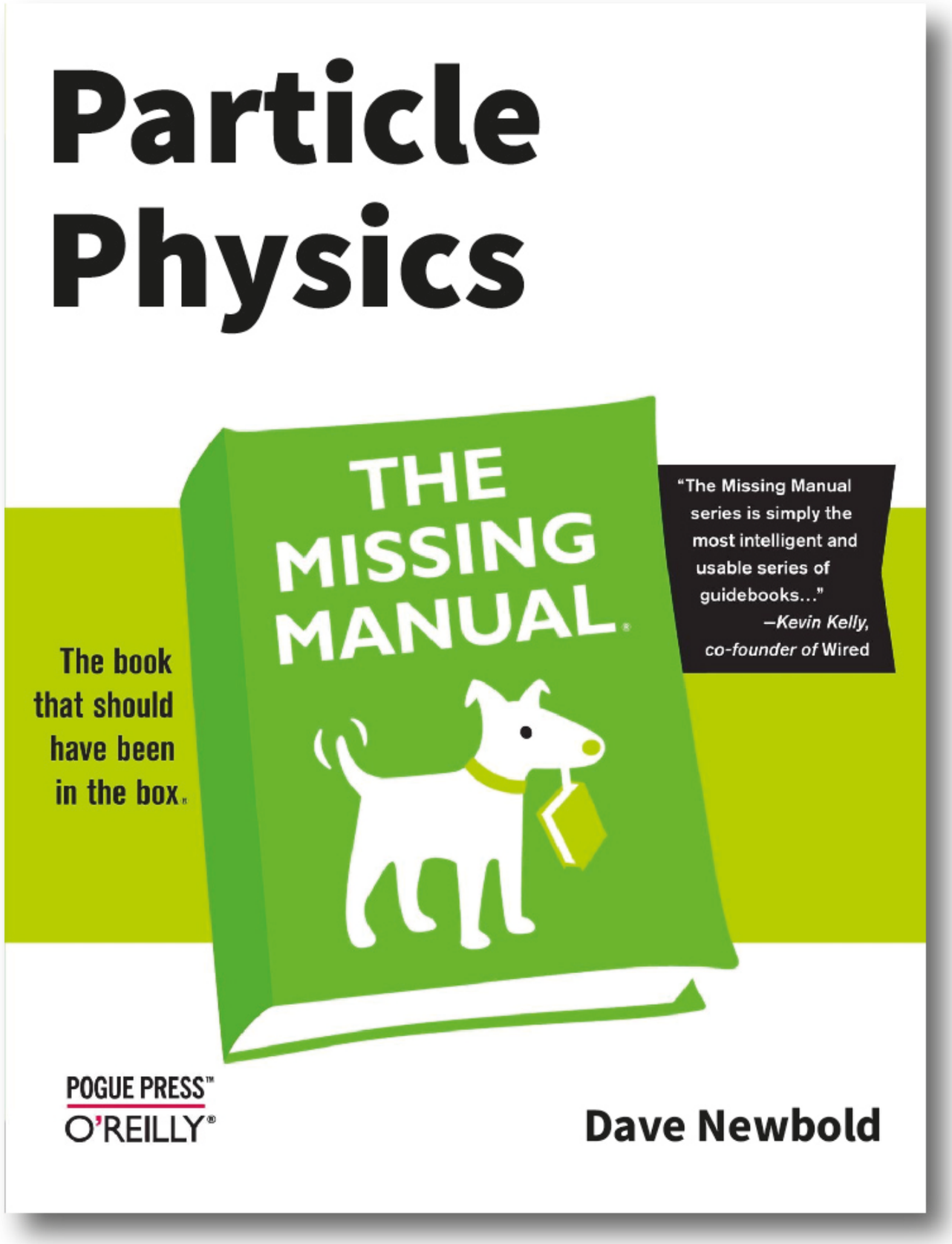

Introduction

- Colleagues! 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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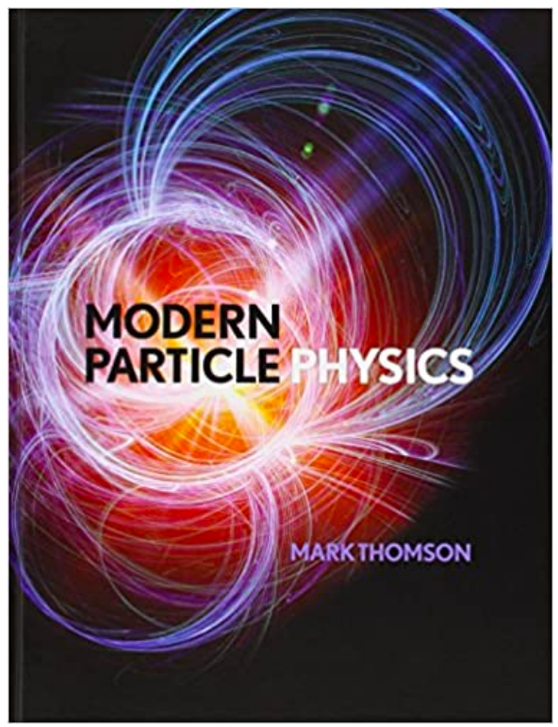
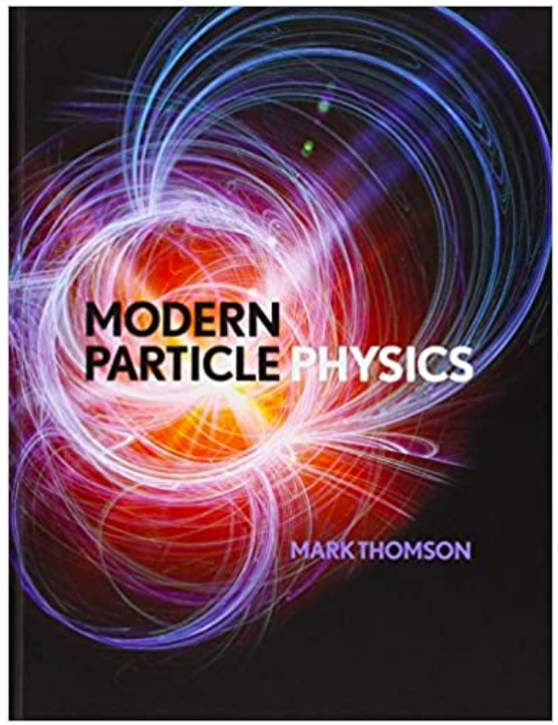
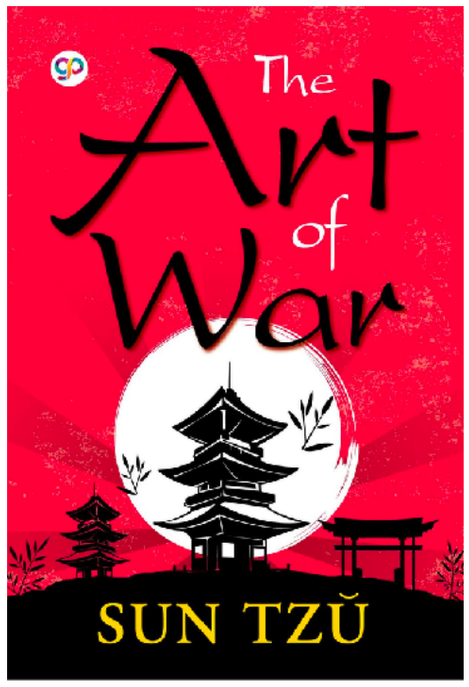


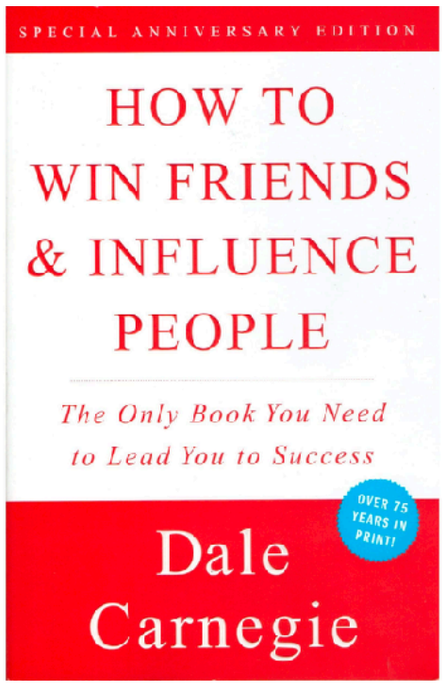
Introduction

- Colleagues! 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





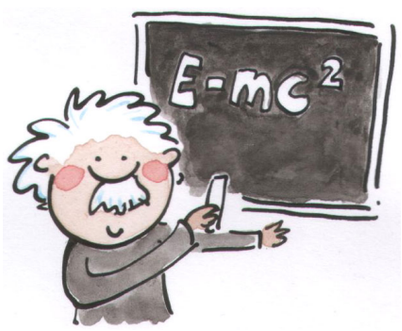
1. How Particle Physics Gets Done

"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

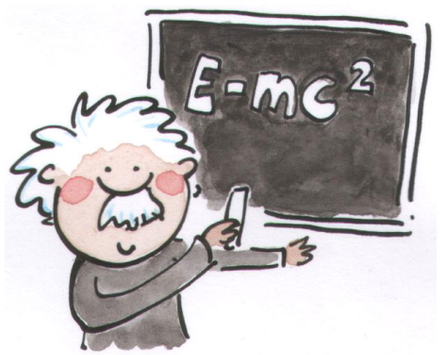
- PP experimentalists:
  - Think about measurements
  - Particles = "tiny charged blobs"
  - (Must) work in huge teams
  - New ideas take years to test
  - Admire ingenuity, effectiveness (~ Rutherford)
- But also…
  - Must invent new technologies
  - Interact with other fields
  - Get excited about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

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

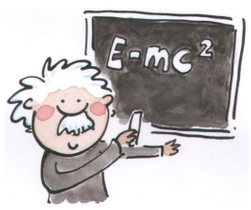
Perform experiments

~ 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
- *Collaboration is the norm,* not the exception – indeed, essential
  - We all love each other very much…
- 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'
- Ensure continuity
  - Make sure vital knowledge is spread around
- Provide training and mentoring
- Ensure scientific good practice

The Challenges

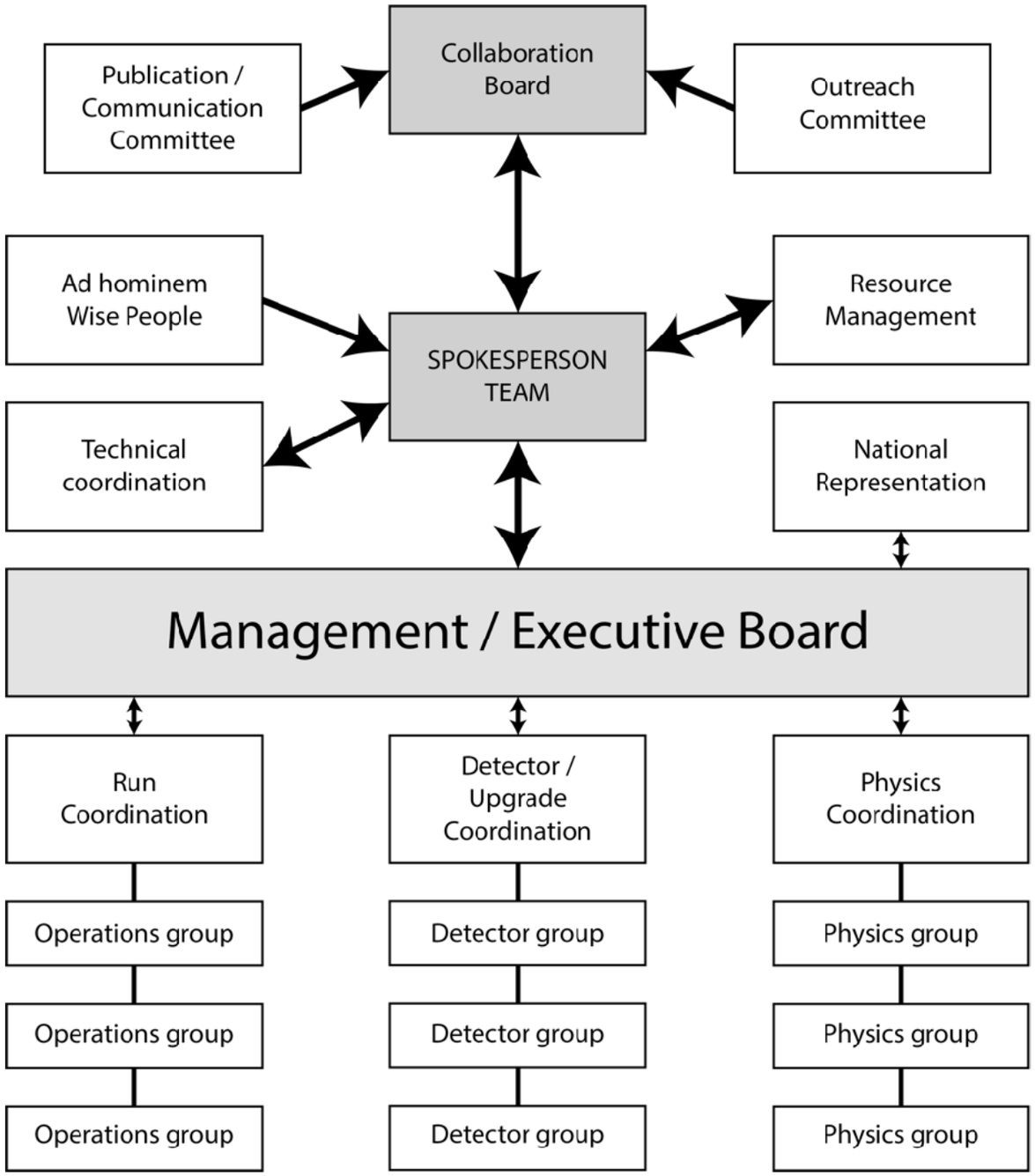
- Big collaboration equivalent to a multinational company
  - In size / complexity / budget

- Company
  - Run by (appointed) managers & accountants
  - Staffed by employees
  - CEO is in charge
  - Decisions top-down
  - Answerable to shareholders
  - Screw up, 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, 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

Standard Model of PP Collaborations

Upper House

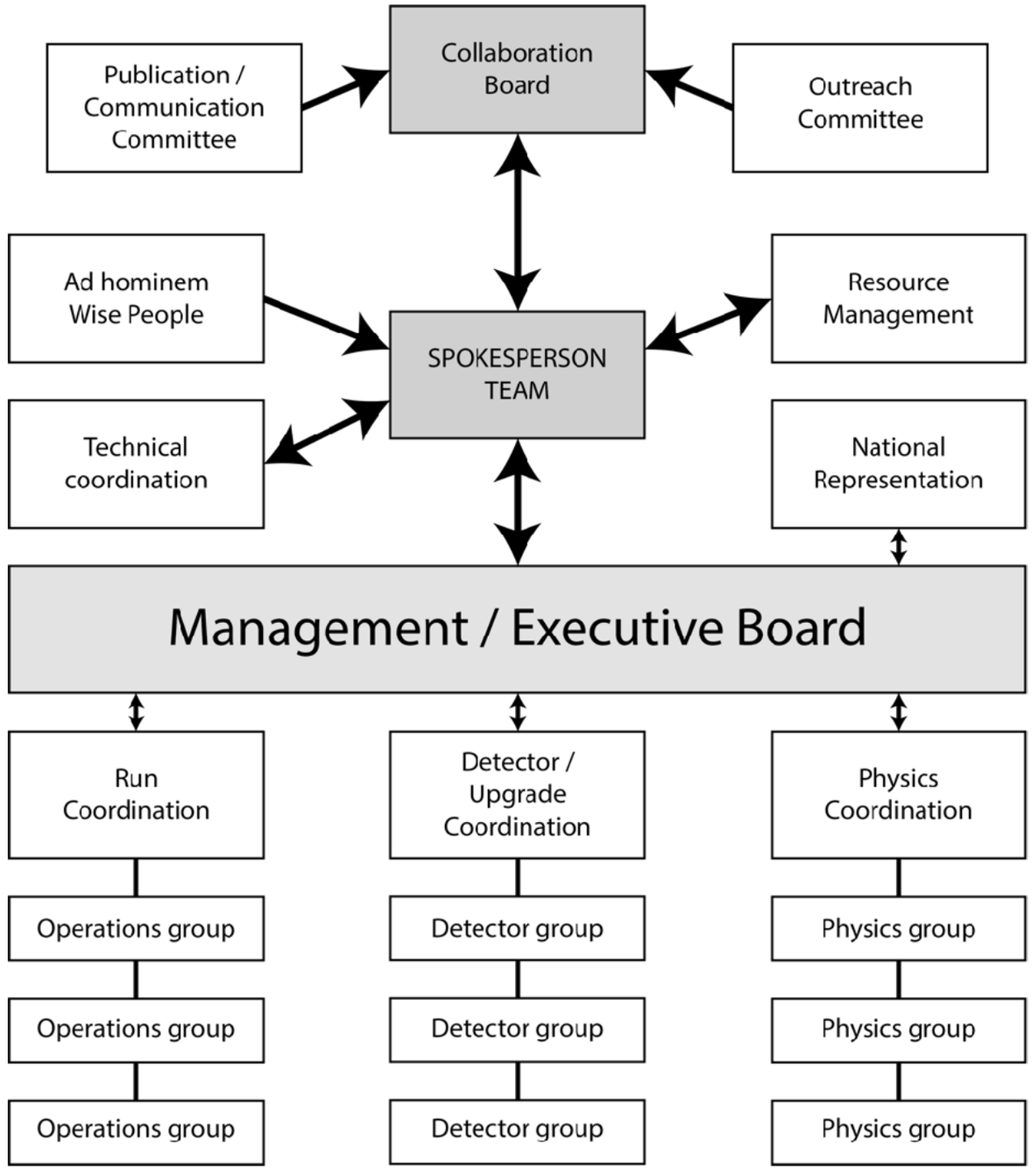
Prime Minister

President

Treasury

Lower House

Civil Service

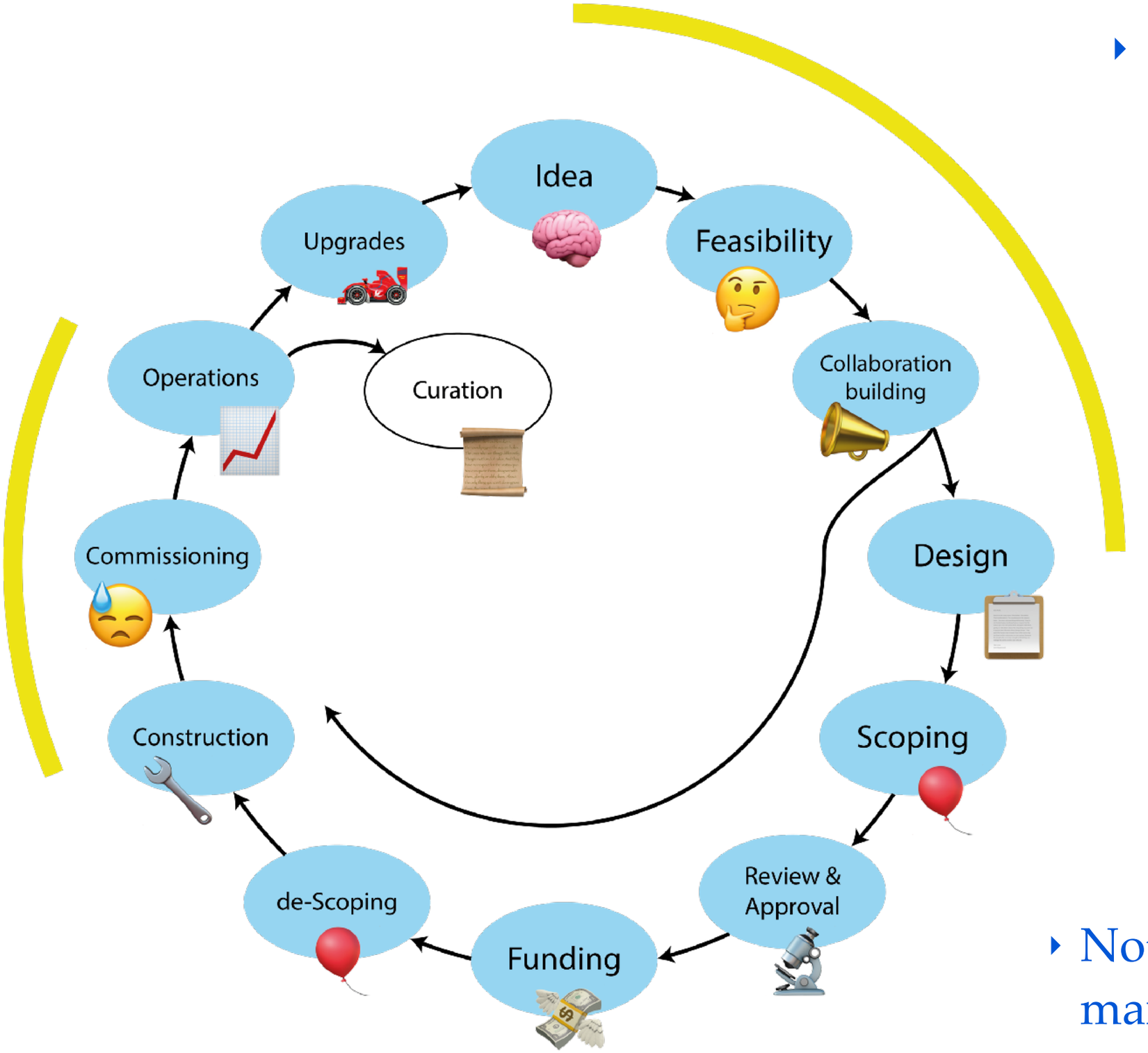


- Judiciary is on the feudal system – ask me later

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
  - Removal of incentives to contribute to design / construction of facilities

Collaboration Life Cycle

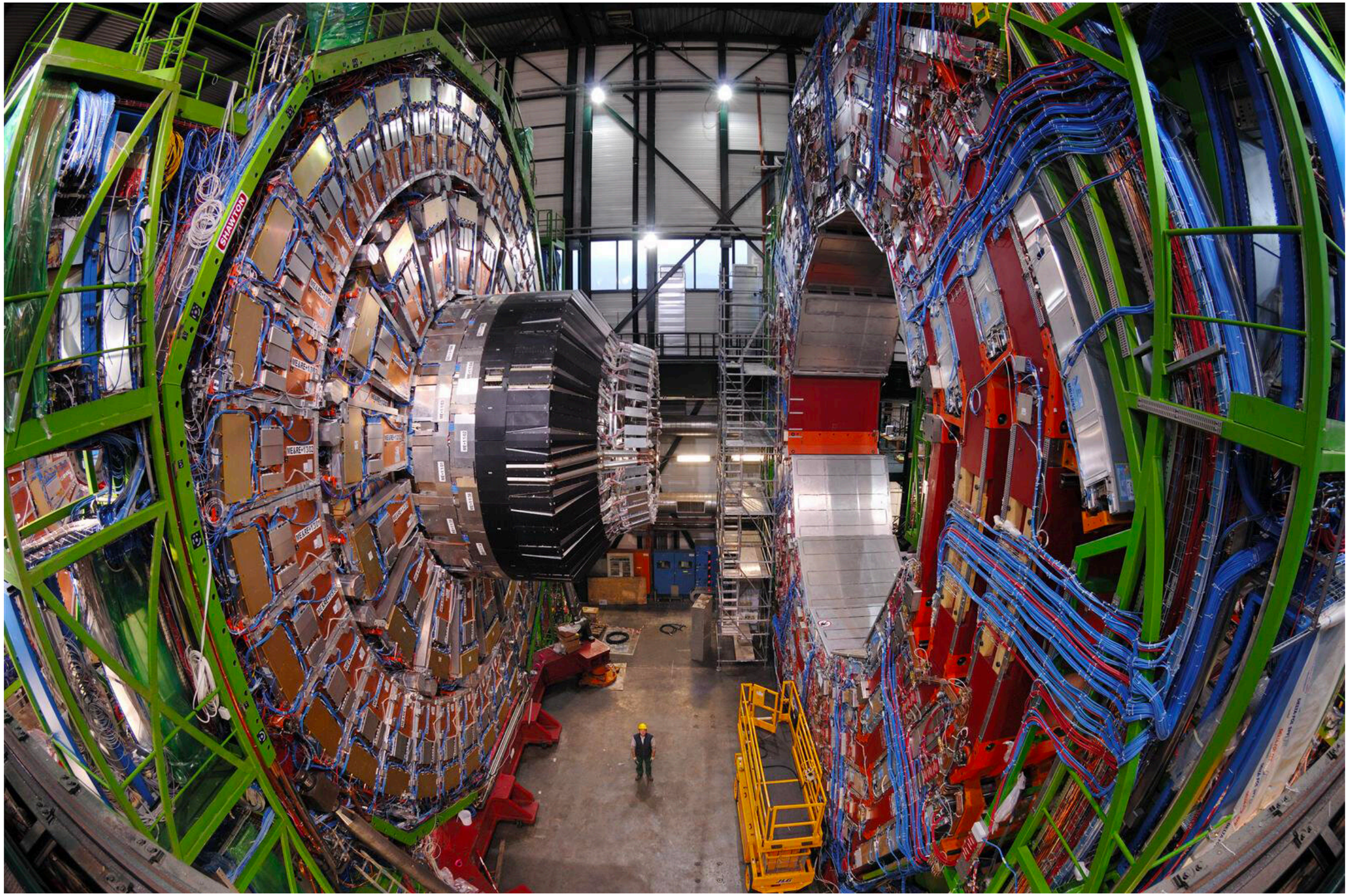


- Idea-to-curation now approaching a working lifetime…
- Note ‘golden periods’ of maximum intellectual return

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 ICFA and ECFA 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?

CERN-Council-S/106 1

The European Strategy for Particle Physics
Update 2013

Preamble

Since the adoption of the European Strategy for Particle Physics in 2006, the field has made impressive progress in the pursuit of its core mission, elucidating the laws of nature at the most fundamental level. A giant leap, the discovery of the Higgs boson, has been accompanied by many experimental results confirming the Standard Model beyond the previously explored energy scales. These results raise further questions on the origin of elementary particle masses and on the role of the Higgs boson in the more fundamental theory underlying the Standard Model, which may involve additional particles to be discovered around the TeV scale. Significant progress is being made towards solving long-standing puzzles such as the matter-antimatter asymmetry of the Universe and the nature of the mysterious dark matter. The observation of a new type of neutrino oscillation has opened the way for future investigations of matter-antimatter asymmetry in the neutrino sector. Intriguing prospects are emerging for experiments at the overlap with astroparticle physics and cosmology. Against the backdrop of dramatic developments in our understanding of the science landscape, Europe is updating its Strategy for Particle Physics in order to define the community's direction for the coming years and to prepare for the long-term future of the field.

General issues

a) The success of the LHC is proof of the effectiveness of the European organisational model for particle physics, founded on the sustained long-term commitment of the CERN Member States and of the national institutes, laboratories and universities closely collaborating with CERN. *Europe should preserve this model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.*

b) The scale of the facilities required by particle physics is resulting in the globalisation of the field. *The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.*

High-priority large-scale scientific activities

After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority.

c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

d) To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available. *CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous*

- Last European Strategy update in 2013
- Top priority projects:
  - HL-LHC (happening)
  - Neutrino platform (happened)
  - ILC (didn't happen – yet)
- 2020 update due in ~September
  - If you want to know what the future holds, it's in there
  - Maybe

Who Pays?

- The field is relatively well-funded
  - Global funding for PP around $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?
  - The ability to navigate this and understand budgets 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
  - Today, we have every reason to be optimistic in the UK (though COVID-19?)

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
  - Defence 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
- In PP, host laboratories also have a governance function
  - Usually over the operation, conduct and technical coordination of collaborations

Who Hosts?

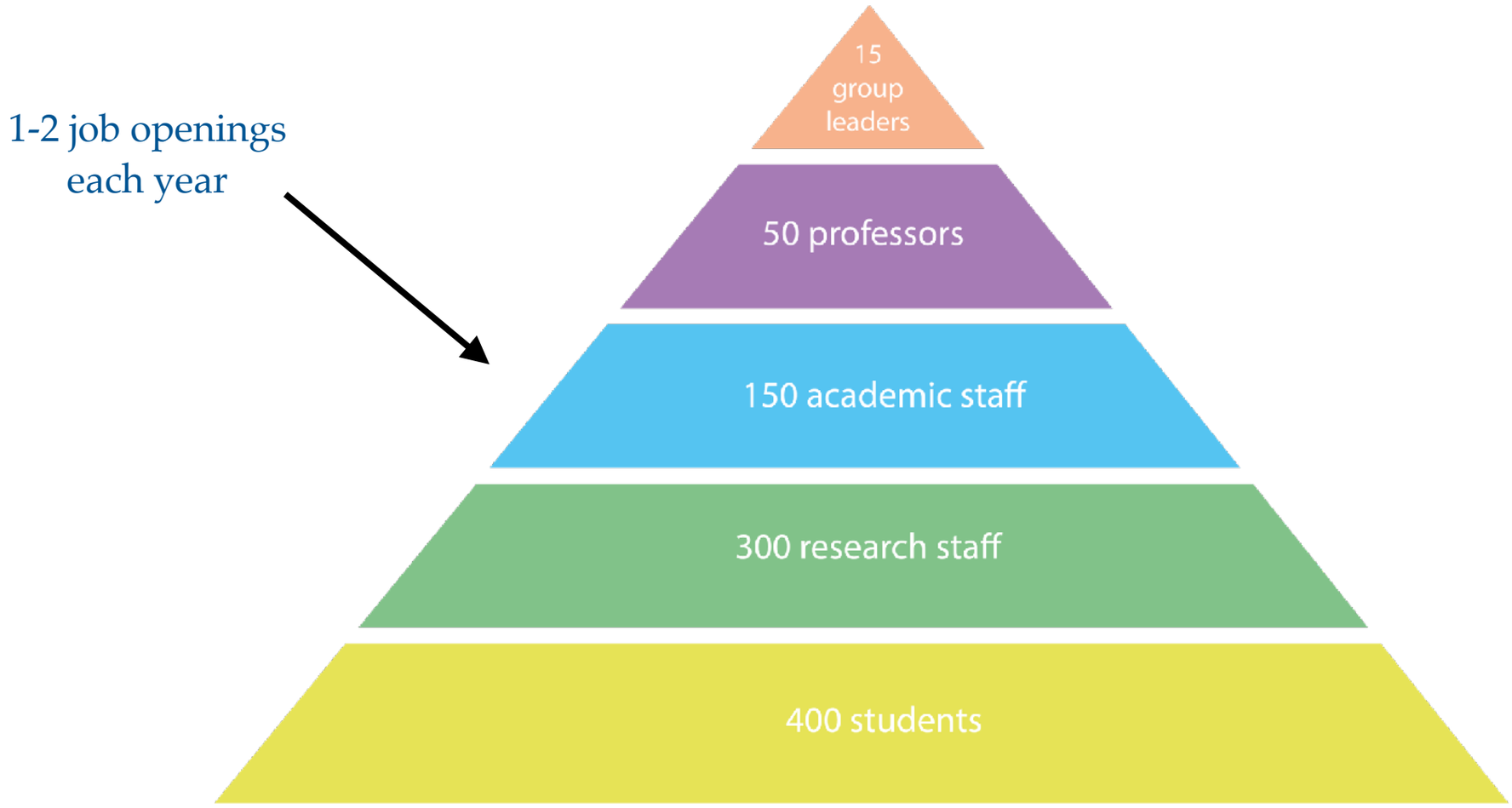
- UK's accelerator laboratory is CERN
  - Always remember that CERN is *our* lab!
- UK has major national laboratories
  - Rutherford Appleton Laboratory, Didcot
  - Daresbury Laboratory, Warrington
  - Boulby Laboratory, Whitby
  - Other institutes supporting astronomy

- CERN is special and unique, *by design*
  - 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 man, but on the combined wisdom of thousands of men, all thinking of the same problem" – Rutherford

UK PP Demographics

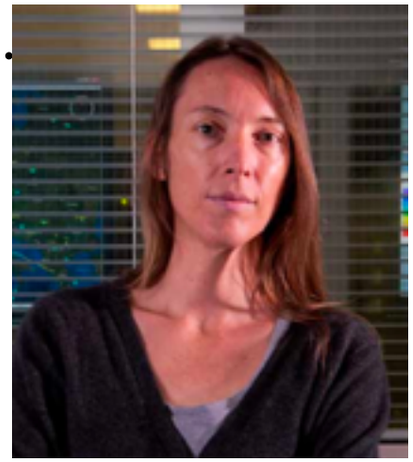


- Funding split between University group and national labs
  - Increasing work on the particle-astrophysics boundary
- UK participates in most major international experiments
  - LHC, short and long-baseline neutrinos, low background experiments
  - Around 10% of world particle physics community

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. Roger Jones
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

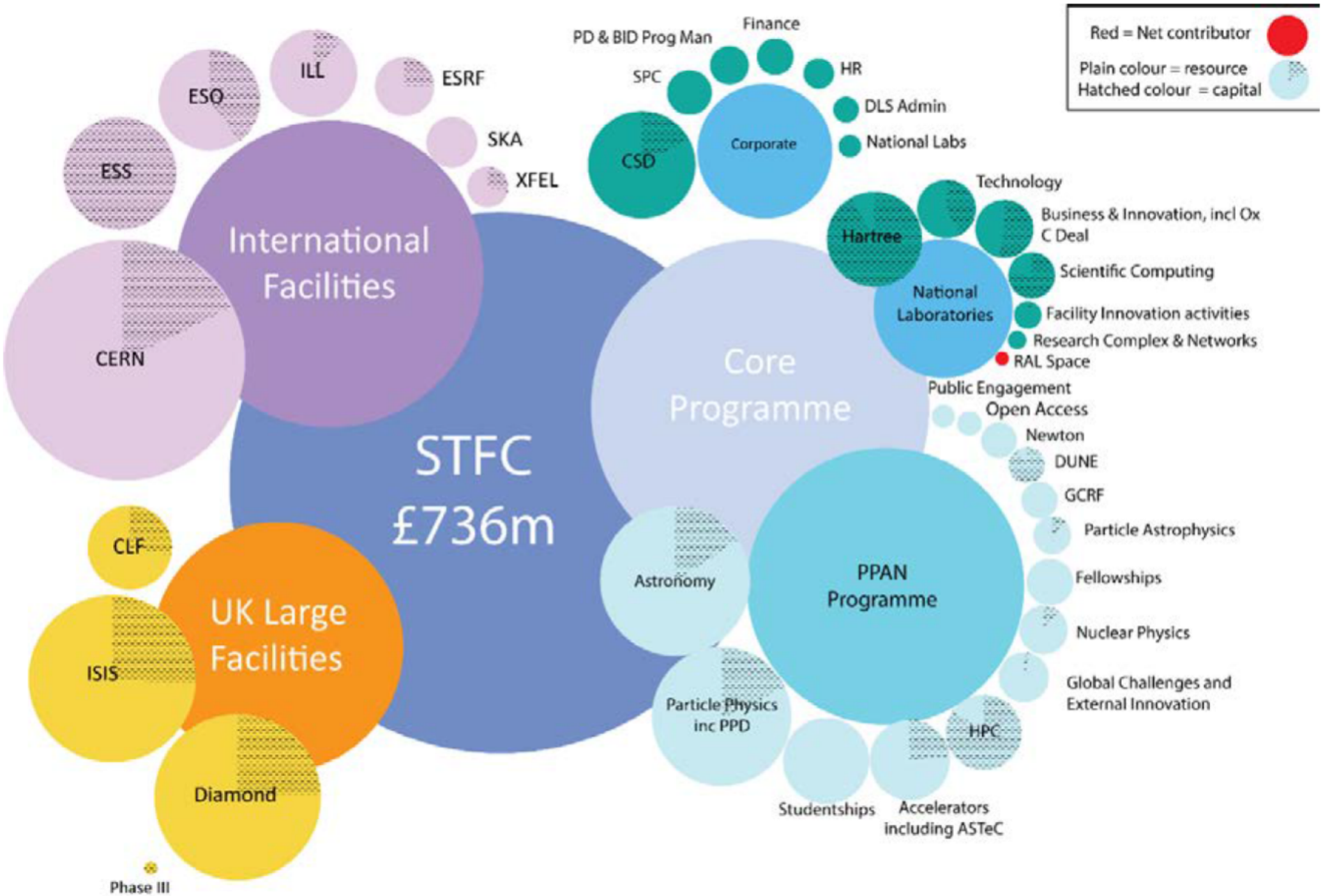


Figure 1: STFC's overall funding from BEIS in 2018-2019

UK Community Events

- National PP annual conference ('HEPP IoP meeting')
  - This year postponed - Edinburgh in 2021
  - Includes a 'town meeting' with STFC executive
  - Student talks a 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
  - Under review for this year
- UK news comes via the 'Hi-Phi' mailing list – subscribe!

5. Your Career

"If you can't explain your physics to a barmaid 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 postdocs working for you
- Permanent (aka academic) positions
  - Typically in a University (as a lecturer)…
  - … or 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 your level
- What is not important?
  - Personal characteristics (age / gender)
  - Your last boss or institute
  - How many publications you have
  - The contents of your thesis
- More senior positions
  - Need to see evidence of a (long-term) personal research plan
    - 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~~
- All these positions have different criteria
  - You can actively monitor jobs lists via the 'SPIRES jobs board'

How to Get Ahead

- Choose the right problems and positions
  - Work only on hard things
    - All the easy things have been done before, remember?
  - Move around, frequently, and internationally
  - Learn something new in every new position
    - What are you currently the best at the world at? What else?
  - 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
  - Do 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?

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 clearly’. 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?
  - 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

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?