Challenges of fundamental science: Ethics and International Collaboration

M. Doser, CERN

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and I'd like to remind you: scientists tend not to answer questions, but rather to raise new ones...

what are we talking about?

fundamental science: *curiosity driven*, exploration of the Universe (from smallest to largest scales), *not* application oriented, and *not* generally "goal-oriented" either (hope for the unexpected)

→ *outcome is better understanding or even new understanding*
(a different definition of ROI)

→ *a goal is not necessarily part of the process*

→ *the importance of serendipity*

but there are 'science ecosystem' boundary conditions for this to work

- assumptions may be challenged or even overthrown
- different / multiple / redundant approaches may be needed
- failure has to be part of the process
- acceptance of incompleteness/ambiguity of resulting knowledge
- acceptance of severity of (self-)evaluation by peers
- resource-limits mean promising approaches may be DOA; intellectual limits mean some answers may never be known

the result is an imperfect, halting, iterative attempt at better understanding ...

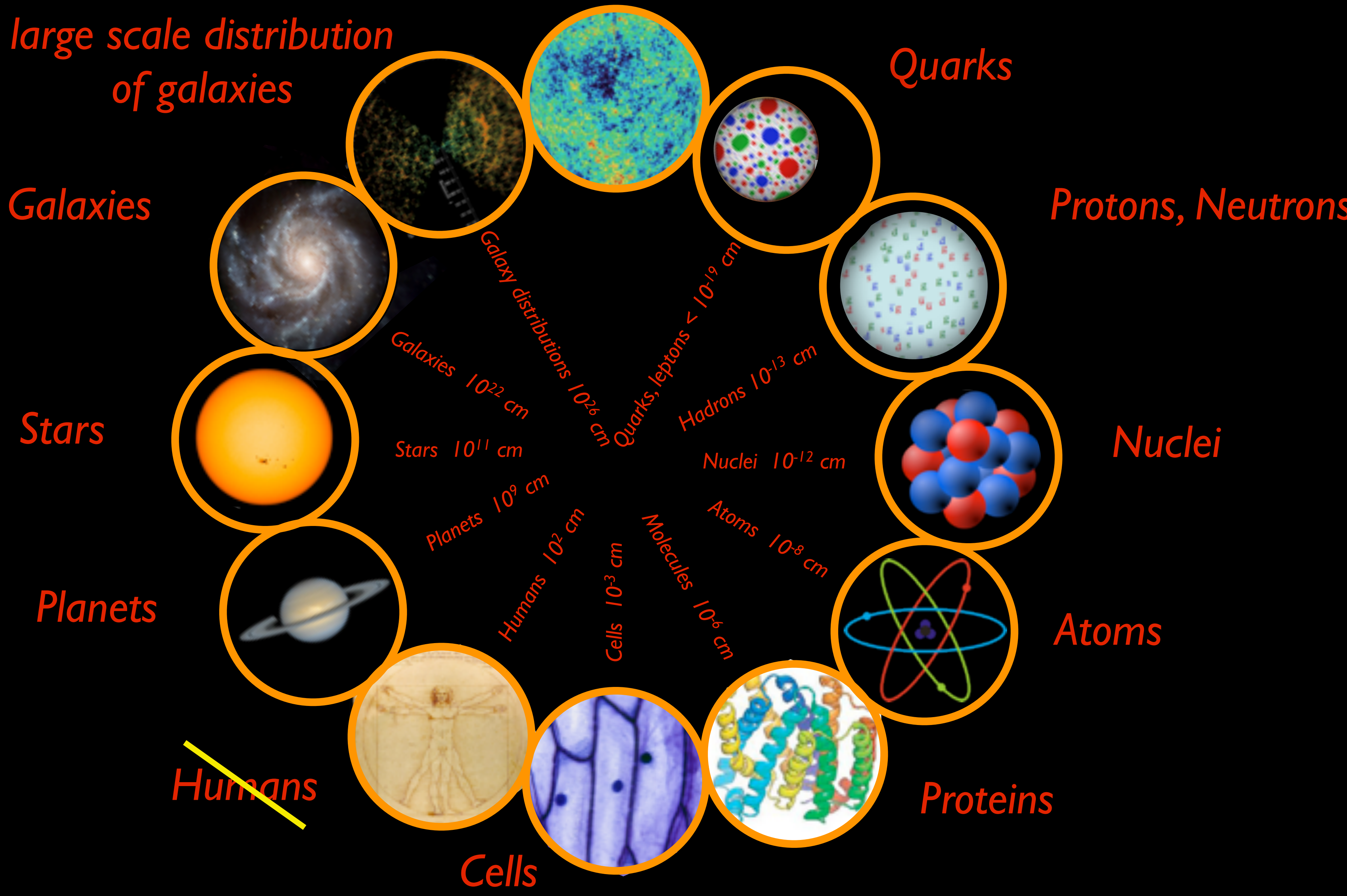
... a pretty good understanding:

google search:

“scientists explain”: 4700 million hits

“scientists baffled”: 1 million hits

so, yes, it works.
this is the “standard model”



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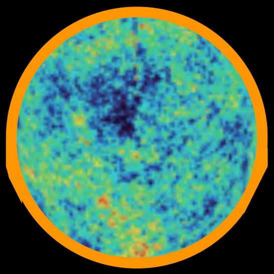


except when it doesn't:
dark matter & dark energy...
(as needed to understand the cosmic microwave background temperature patterns)

at the same time, we <u>know</u> it's deeply incomplete

a lot of the "easy" stuff has been done, and doing the "hard" stuff requires major resources

⟶ next steps go well beyond what an individual scientist / university / country can do

⟶ next steps go well beyond what an individual scientist / university / country can afford

⟶ next steps go well beyond what an individual scientist / university / country can justify

⟶ *global approaches to science, often <u>Big Science</u>*

What does Big Science entail?

- *major financial resources*
- *major manpower resources (expertise, motivation)*
- *major energy resources (climate impact)*
- *long term support / political & financial commitment & stability*

but also:

- *a focus on a small number of questions (so: what do we miss?)*
- *multi-generational planning (so: a different type of scientist?)*
- *targeted streamlined engineering (so: no table-top-tinkerers?)*
- *much enhanced public / political dialogue (so: no ivory towers)*
- *risk (so: how much is palatable?)*

democratic legitimacy (within science community but also towards national and global interests)

What does Big Science entail?

→ *need to focus on a small number of Big Science (>1 M€) projects*
example: grassroots plans à la Snowmass, European Strategy Group, Quantum sensing, NUPECC (https://indico.ph.tum.de/event/7050/contributions/)...

→ *large communities, many groups involved, thus not nimble*

example: organizational & sociological challenges of collaborations

→ *rich countries' pastime (linked to GDP and per capita income)*

example: membership fee to CERN
Austria: 20 M€/yr = "relatively modest" (but still ~ 100 k€/pp/yr)
which does not cover the cost of actually doing an experiment

→ *decadal timescales (Human Genome project, telescopes, accelerators)*

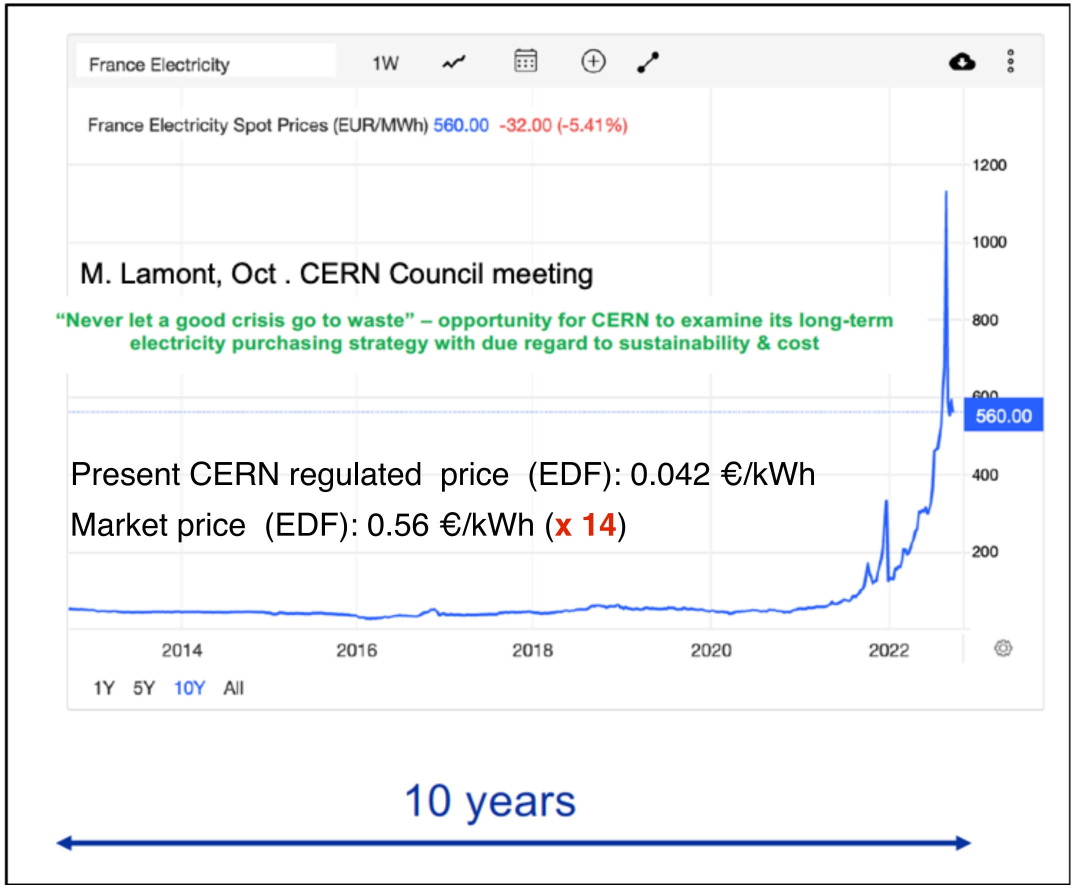
example: FCC-ee around 2045~2060, FCC-hh around 2060~...

What are the risks?

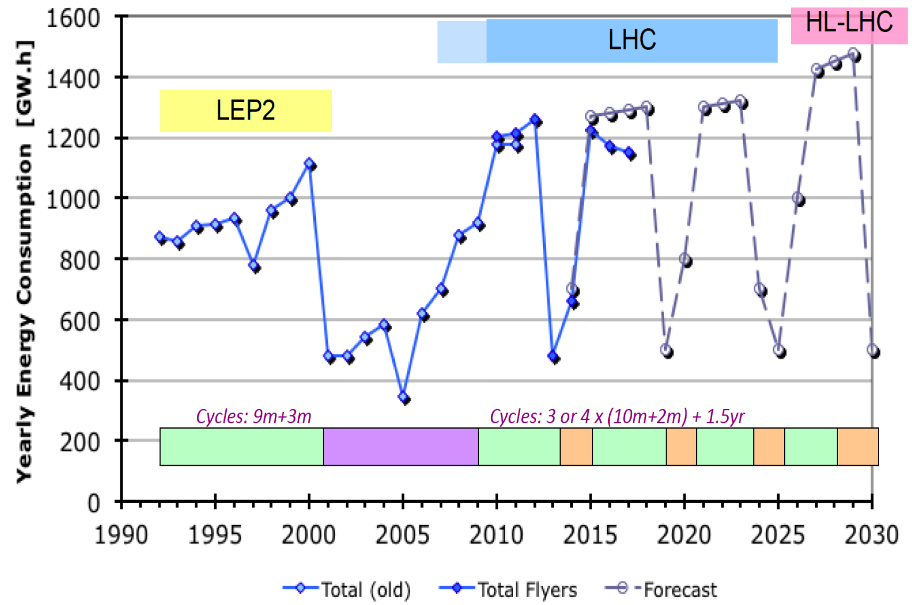
- *obsolescent technology (space exploration)*
- *rigidity (Human Genome project: consortium vs. Craig Venter)*
- *planning 50 years ahead: will it still be relevant then? (linear vs. exponential extrapolation, new fields, new techniques, ...)*
- *scientists vs. engineers / what keeps the next generation engaged ?*
- *failure*
- *need to focus on what is feasible (no grand questions à la "what is consciousness"; instead: "can we come up with a technology that allows us to sequence millions of base pairs in a short time"?)*
- *SDG compatibility?*

an example: energy cost of a future accelerator

CERN consumption 2022 ~ 1.4 TWh



FCC-ee, resp. FCC-hh entails another 1.4~2 TWh



Yardsticks(yearly electricity consumption):

- FCC-ee(240) ~ **2 TWh**
- FCC-hh ~ **3.8 TWh**
- Canton Geneva ~ **2.8 TWh**
- Mankind ~ **2 x 10^4 TWh**
- Mankind (total) ~ **2 x 10^5 TWh**

x 50'000

https://ourworldindata.org/energy-production-consumption

- *financial cost: CERN currently spends ~ 80 MCHF/yr on electricity; x14 largely exceeds CERN annual budget*
- *environmental cost: CERN ~ canton of Geneva; FCC-hh ~ 2 x canton of Geneva*

What's the alternative? (what keeps the next generation engaged ?)

An example of "small fundamental science": quantum sensing

- *many large countries / economic areas are investing "big science" budgets into numerous "small science" activities linked to quantum technologies (10-100 B€ over next 5-10 years)*

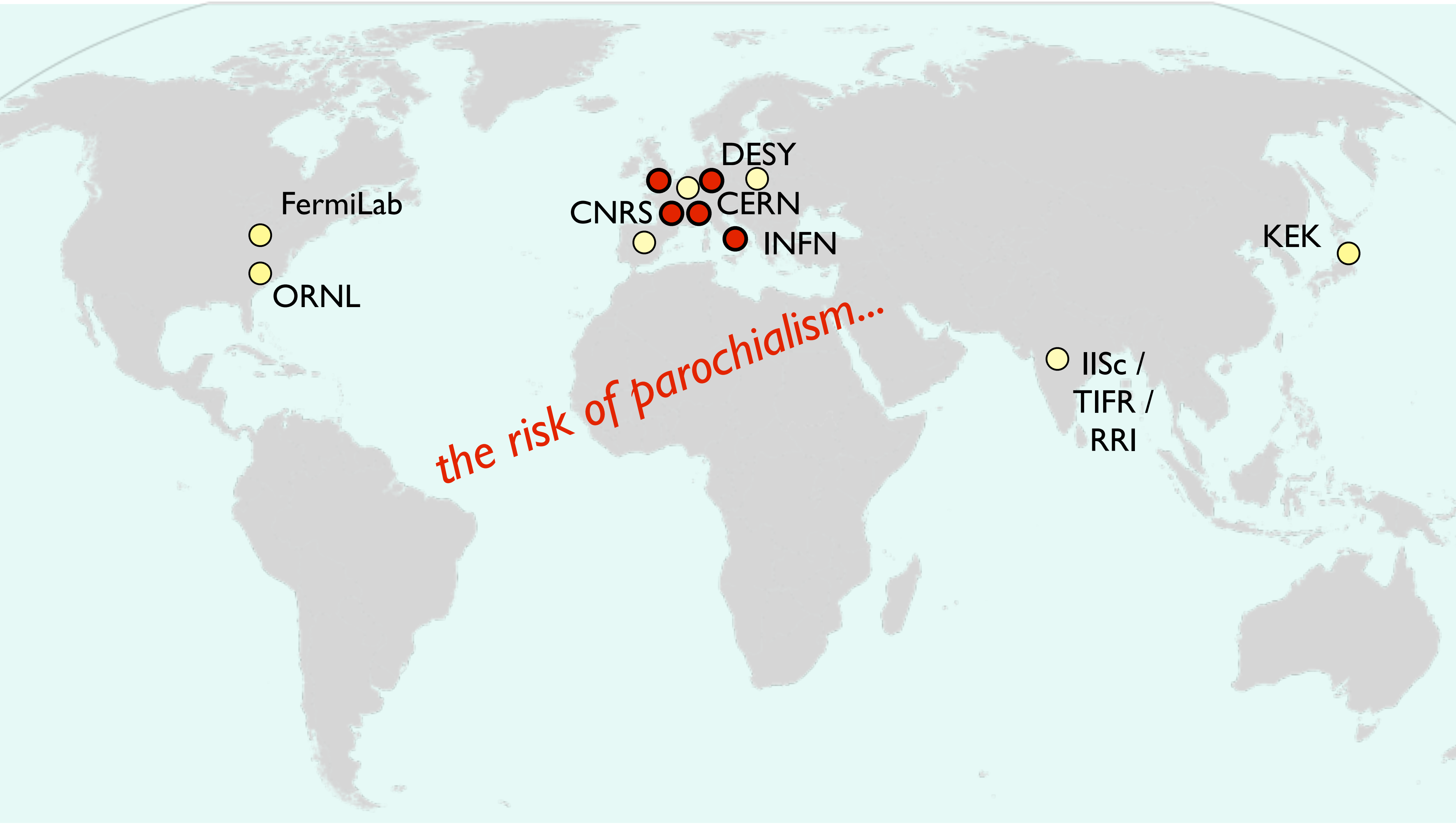
- *but: goal oriented (quantum computing), rapid societal impact!, sociological change (from table-top to international consortia) within the scientific community*

Benefits & Risks:

- *many affordable attempts, nimble, can rapidly grow new tech*

- *duplication of efforts, re-invention of the wheel, no scale effects*

possible platform hosting entities



- possible ECFA TF5 family platforms (6 families)
- HEP-related Quantum initiatives (involvement through Intl. Advisory Board)

What’s the alternative?

An example of “small fundamental science”: quantum sensing

- *embrace the change: build a network of related activities with a number of geographic hubs focusing on specific quantum technologies that leverages the existing initiatives*

- *dual approaches: fundamental research (foundations of quantum mechanics) + applied research (quantum internet)*

- *but: where is the rest of the world? “small science” should also be suited to South America, Africa, SE Asia!? Start-up & operation costs are nonetheless high (lasers, vacuum, cryogenics, ...)*

- *also: disparity of educational backgrounds; ramp up is slow...*

Necessity of collaboration increasing also within "small science"

- *complementary approaches: work on table-top fundamental physics while also being involved in long-term Big Science projects*
- *open networks by design!*
- *on-ramp for small institutions / economies*

What's a good mix?

optimum: 40% Big Science, 40% little science, 20% blue sky ?
optimum: 5% failure, 30% failure, 90% failure ?

personal view ...

attitude change: failure is good (depending on context ;)
attitude change: diversity is good (of approaches, but not only)

successful nations have a strong technologically-savvy population

successful nations have a very strong proportion of educated citizens

successful nations have appropriate planning certainty (legal, financial)

and vice versa (perhaps somewhat optimistically):

participating in research in concert with the global scientific community is a central component in educating a scientifically, and perhaps more importantly, technologically expert population that is central to all nations' development, but also has an impact on society more globally.

thus:

to remain attractive to technical as well as curious individuals, to foster creativity, and generally contribute to the welfare and cohesiveness of society, science must reflect societal changes, be open, be aware of the world in which it operates, be able and willing to build on scientists' eagerness to interact & to share their enthusiasm, but it also requires an understanding by society of what it can offer as well as what its limitations and needs are.

the same holds for global science; if anything, more so, since both collaborative (formal or informal) and cultural aspects need to be addressed flexibly, something that is simplified by the focus on fundamental, rather than applied, research.