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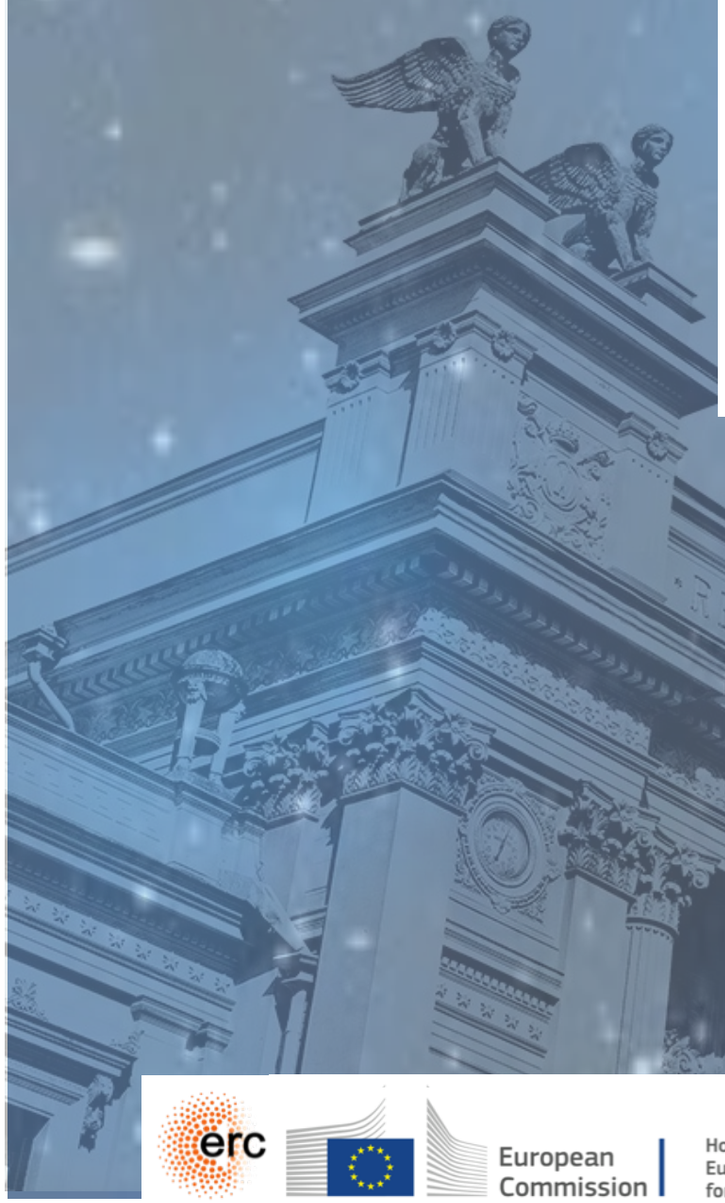
WITH INPUT (SLIDES) FROM: MONICA D'ONOFRIO, MICHELANGELO MANGANO, MICHAEL PESKIN

Future (hadron) colliders: discussion points



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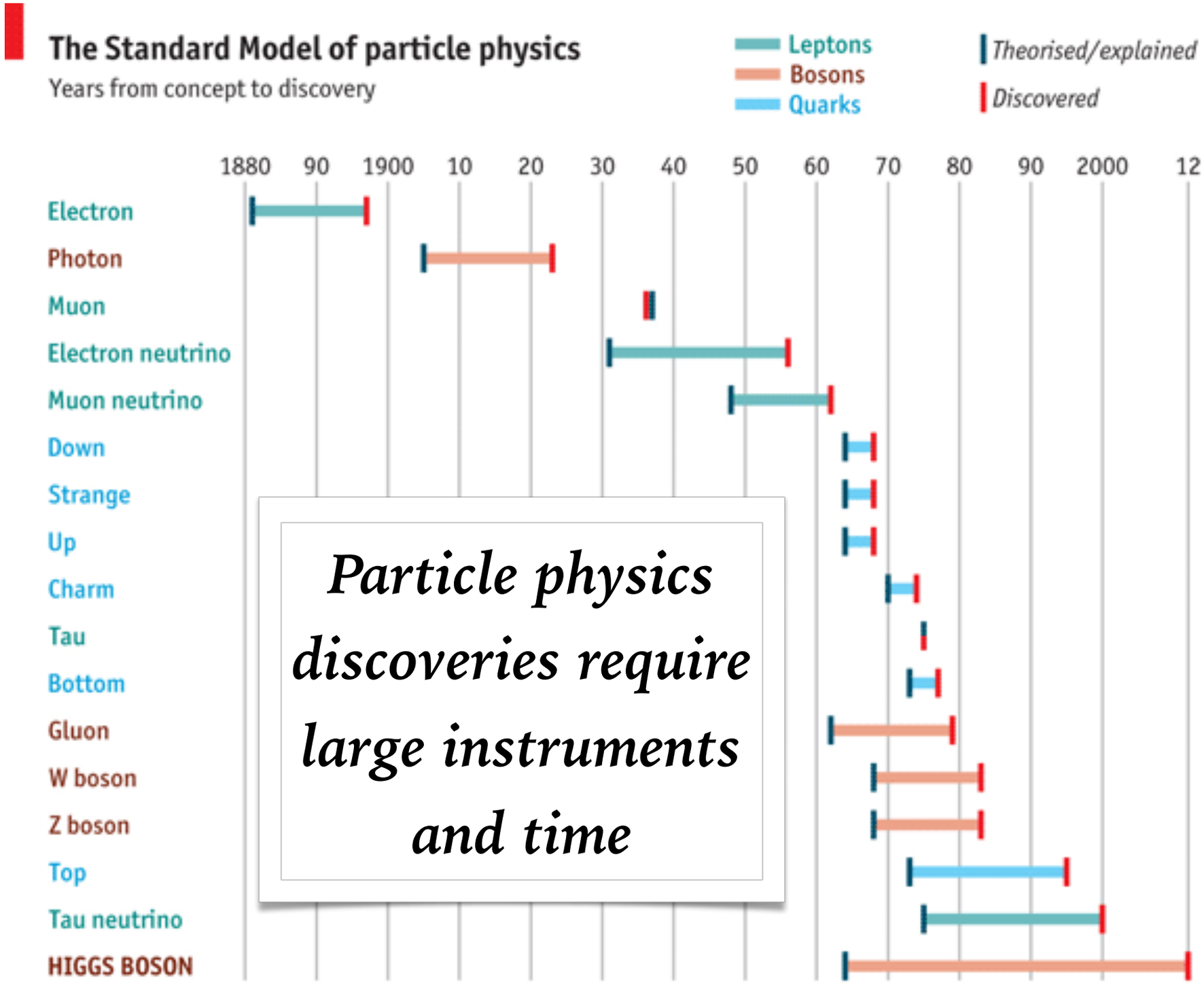
Remember the history of discoveries



Particle physics discoveries require large instruments and time

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Key question for HEP

M. Mangano's UVA colloquium, 2017

Key question for the future developments of HEP:
Why don't we see the new physics we expected to be present around the TeV scale ?

- **Is the mass scale beyond the LHC reach ?**
- **Is the mass scale within LHC's reach, but final states are elusive to the direct search ?**

These two scenarios are a priori equally likely, but they impact in different ways the future of HEP, and thus the assessment of the physics potential of possible future facilities

Readiness to address both scenarios is the best hedge for the field:
- *precision*
- *sensitivity (to elusive signatures)*
- *extended energy/mass reach*

The small print

Remark

the discussion of the **future** in HEP must start from the understanding that there is no experiment/facility, proposed or conceivable, in the lab or in space, accelerator or non-accelerator driven, which can ***guarantee discoveries*** beyond the SM, and ***answers*** to the big questions of the field

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Answers from a Future Circular Collider

The potential of a Future Circular Collider

M. Mangano's UVA colloquium, 2017

- Guaranteed deliverables:
  - study of Higgs and top quark properties, and exploration of EWSB phenomena, with unmatchable precision and sensitivity

- Exploration potential:
  - mass reach enhanced by factor ~ E / 14 TeV (will be 5–7 at 100 TeV, depending on integrated luminosity)
    - *statistics enhanced by several orders of magnitude for BSM phenomena brought to light by the LHC*
  - benefit from both direct (large Q^2) and indirect (precision) probes

- Questions to which firm Yes/No answers can likely be given:
  - is the SM dynamics all there is at the TeV scale?
  - is there a TeV-scale solution to the hierarchy problem?
  - is DM a thermal WIMP?
  - did baryogenesis take place during the EW phase transition?

This applies to hadron machines with energy beyond the LHC (for lepton machines, see David's talk)

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What is "future"? HE-LHC

Kick-off of HL/HE-LHC workshop: **E. Elsen's talk, M. Benedikt/F. Zimmermann's talk**

"Energy Doubler"

- high-field magnets to go to 2x the energy of the LHC
- "adiabatic approach to pp-collisions at higher energy"

possibly funded out of annual CERN budget

naturally following HL-LHC

currently: assessing the physics reach

timescales: after HL-LHC (2040)

HE-LHC physics parameters

27 TeV c.m. energy in *pp* collisions

>10 ab^{-1} over 20 years

pile up of up to ~800 at 25 ns spacing (~400 w 12.5 ns or w leveling)

excellent prospects for lepton-hadron & heavy-ion collisions

earliest technically possible **start of physics: 2040**

- this would require HL-LHC stop at LS5

What is "future"? HE-LHC/FCC

Kick-off of HL/HE-LHC workshop: **E. Elsen's talk, M. Benedikt/F. Zimmermann's talk**

hadron collider parameters (*pp*)

parameter	FCC-hh		HE-LHC	(HL) LHC
collision energy cms [TeV]	100		**27**	14
dipole field [T]	16		**16**	8.3
circumference [km]	100		**27**	27
beam current [A]	0.5		**1.12**	(1.12) 0.58
bunch intensity [10^{11}]	1 (0.5)		**2.2**	(2.2) 1.15
bunch spacing [ns]	25 (12.5)		**25 (12.5)**	25
norm. emittance $\gamma\varepsilon_{x,y}$ [μm]	2.2 (2.2)		**2.5 (1.25)**	(2.5) 3.75
IP $\beta^*_{x,y}$ [m]	1.1	0.3	**0.25**	(0.15) 0.55
luminosity/IP [10^{34} cm^{-2}s^{-1}]	5	30	**25**	(5) 1
peak #events / bunch Xing	170	1000 (500)	**800** (400)	(135) 27
stored energy / beam [GJ]	8.4		**1.4**	(0.7) 0.36
SR power / beam [kW]	2400		**100**	(7.3) 3.6
transv. emit. damping time [h]	1.1		**3.6**	25.8
initial proton burn off time [h]	17.0	3.4	**3.0**	(15) 40

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What is “future”? FCC

Kick-off of HL/HE-LHC workshop: **E. Elsen’s talk, M. Benedikt/F. Zimmermann’s talk**

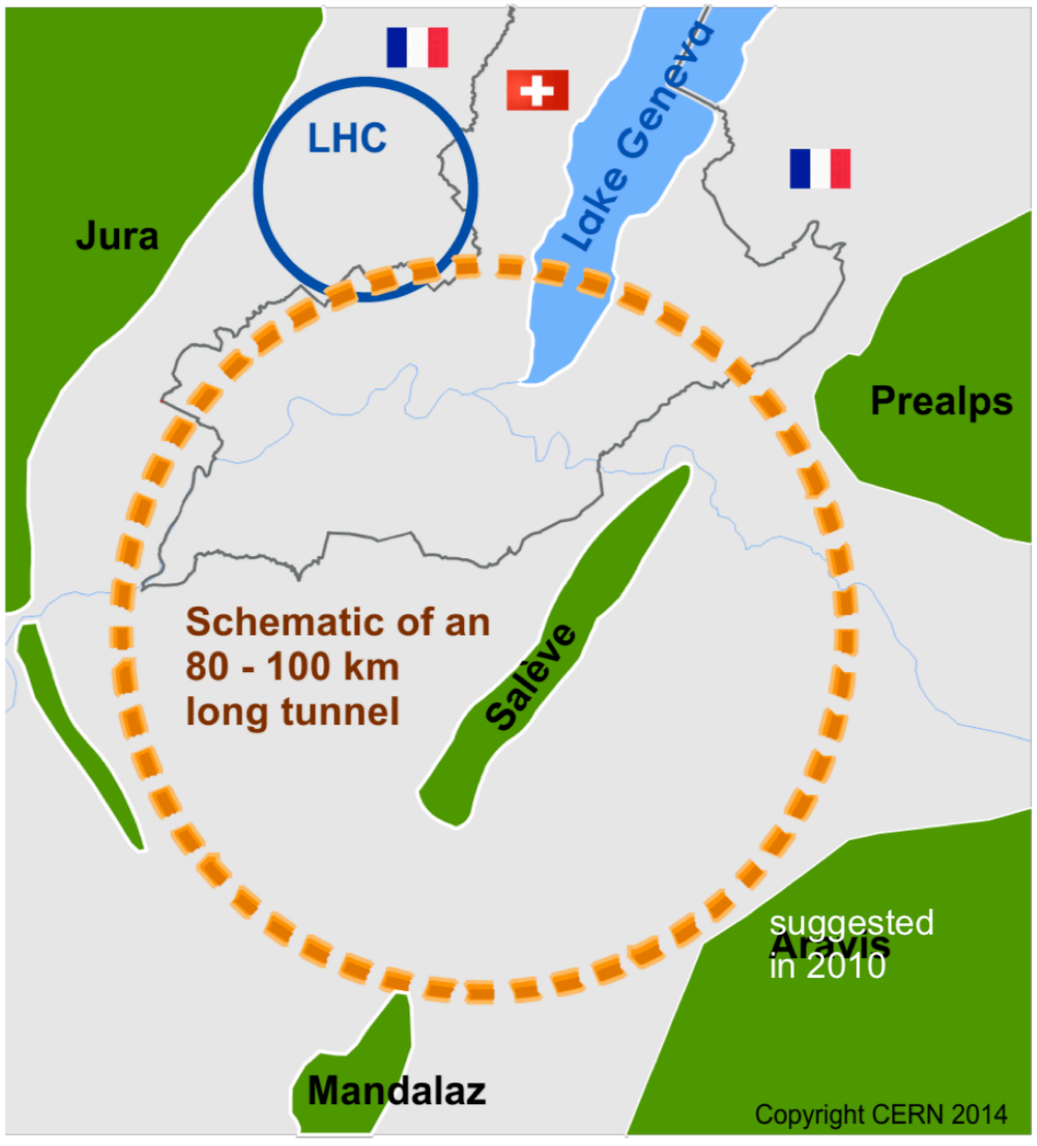
Future Circular Collider Study
CDR for European Strategy Update 2019/20

international FCC collaboration (CERN as host lab) to design:

- ***pp*-collider (*FCC-hh*)**
  → main emphasis, defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km

- **80-100 km tunnel infrastructure** in Geneva area, site specific
- ***e*$^+$*e*$^-$ collider (*FCC-ee*),** as a possible first step
- ***p-e* (*FCC-he*) option,** one IP, FCC-hh & ERL
- **HE-LHC** w *FCC-hh* technology



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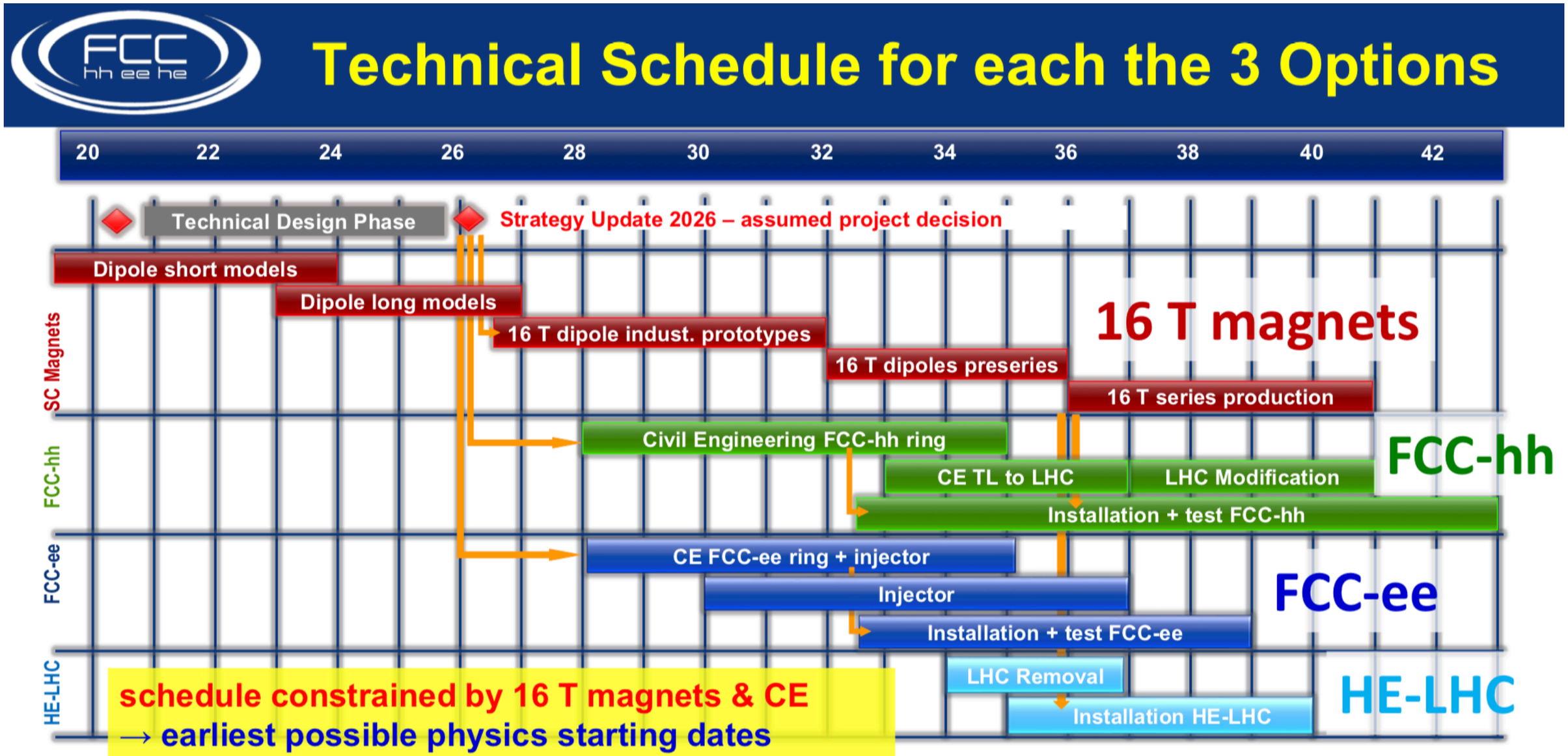
When is “future”? FCC/HE-LHC

Kick-off of HL/HE-LHC workshop: E. Elsen’s talk, M. Benedikt/F. Zimmermann’s talk

FCC Physics Workshop, M. Benedikt's talk FCC week Amsterdam (April 2018)

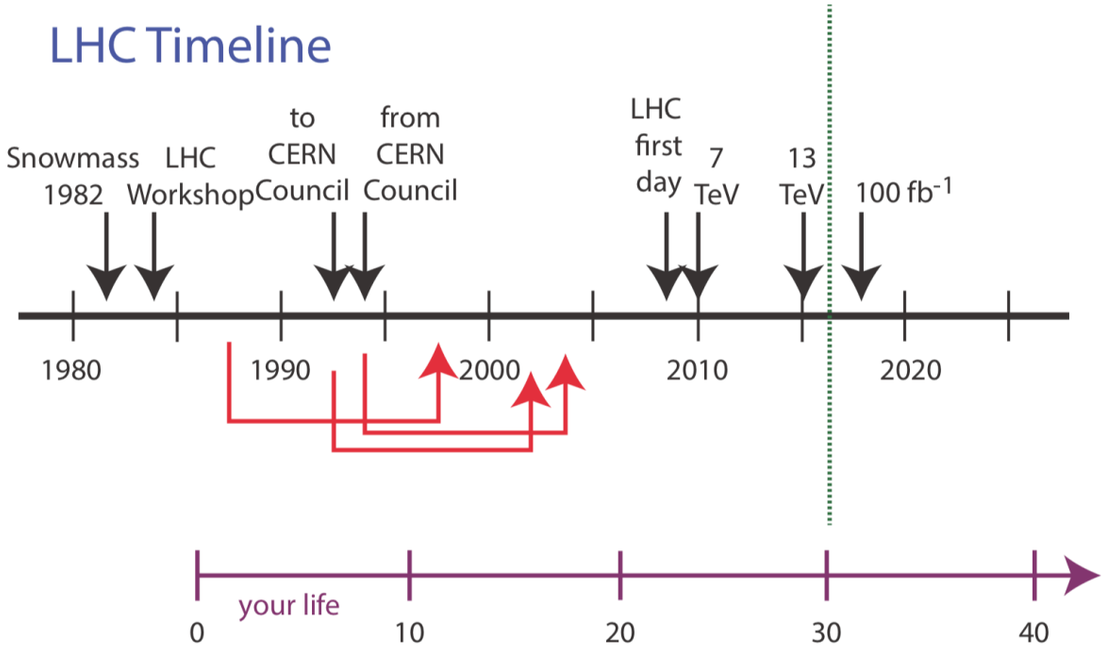


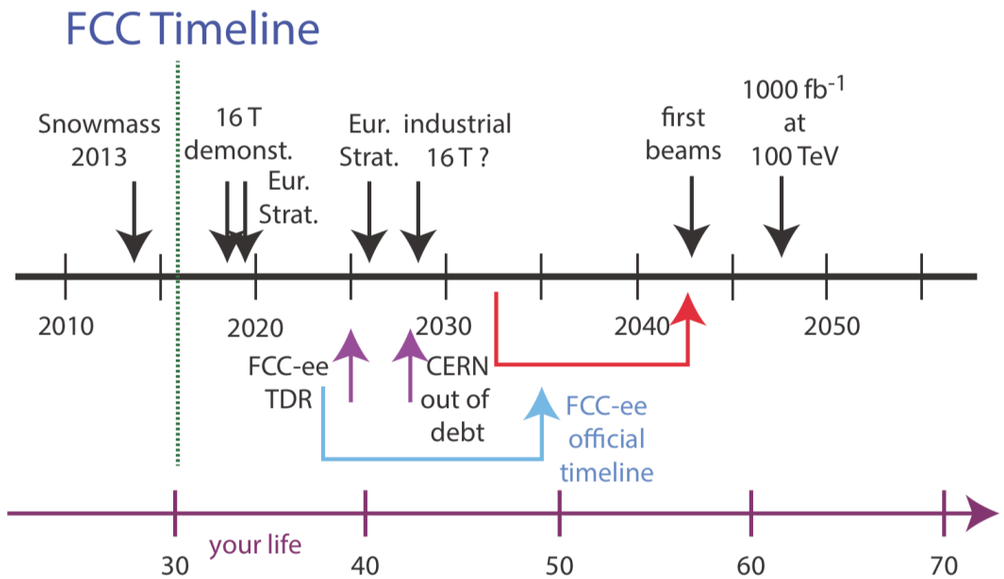
schedule constrained by 16 T magnets & CE
→ earliest possible physics starting dates

- **FCC-hh: 2043**
- **FCC-ee: 2039**
- **HE-LHC: 2040 (with HL-LHC stop LS5 / 2034)**

Worries by M. Peskin

Loss of expertise (interest) if community waits too long





M. Peskin, SEARCH 2016

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Discussion points

- *waiting for more LHC results? until when?*
- *costs vs benefits*
- *timescales*
- *perception of other fields ?*

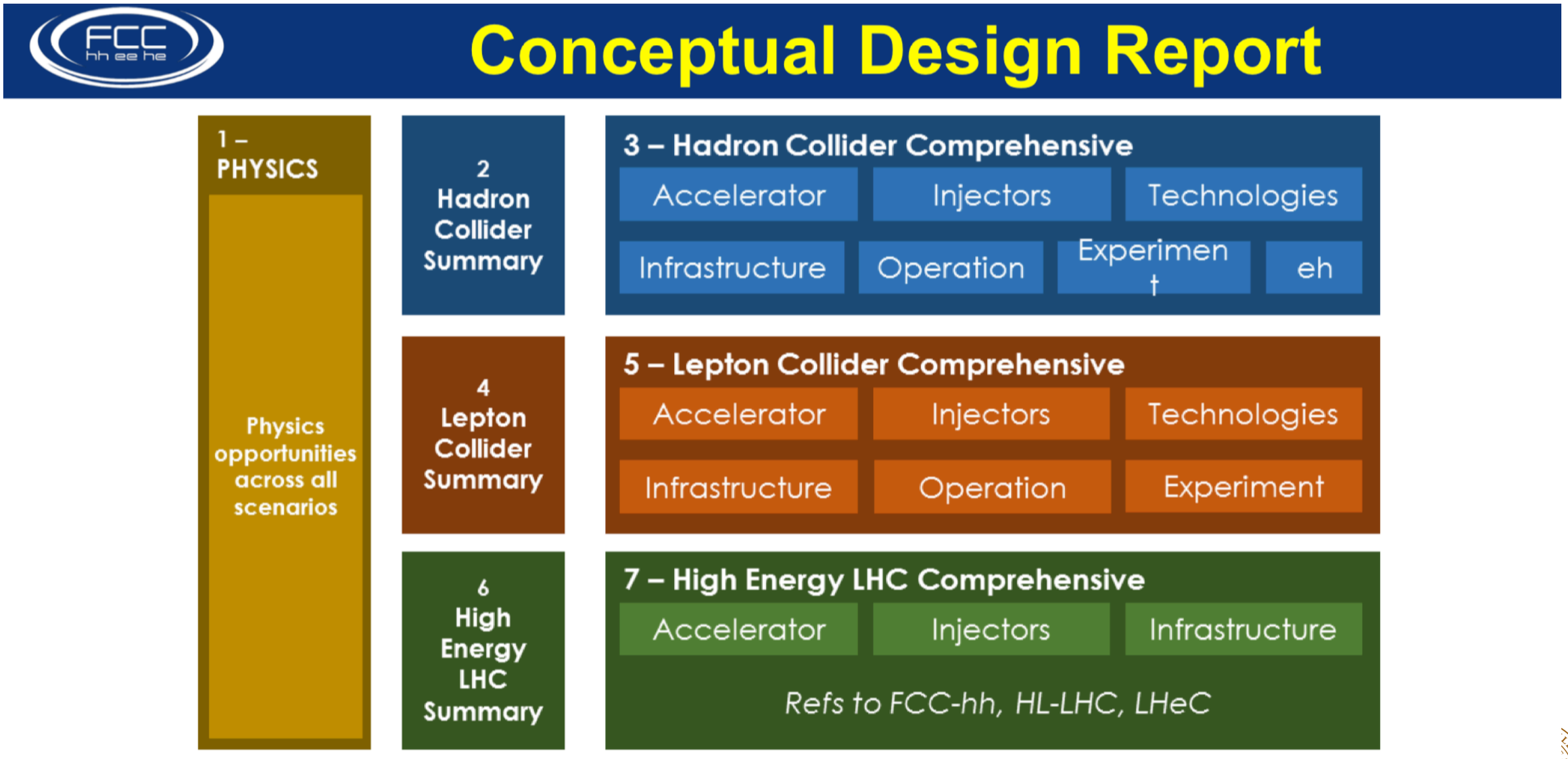
Dilbert comics

CATERINA.DOGLIONI@HEP.LU.SE
@CATDOGLUND

When is “future”? FCC

FCC week Amsterdam (April 2018)

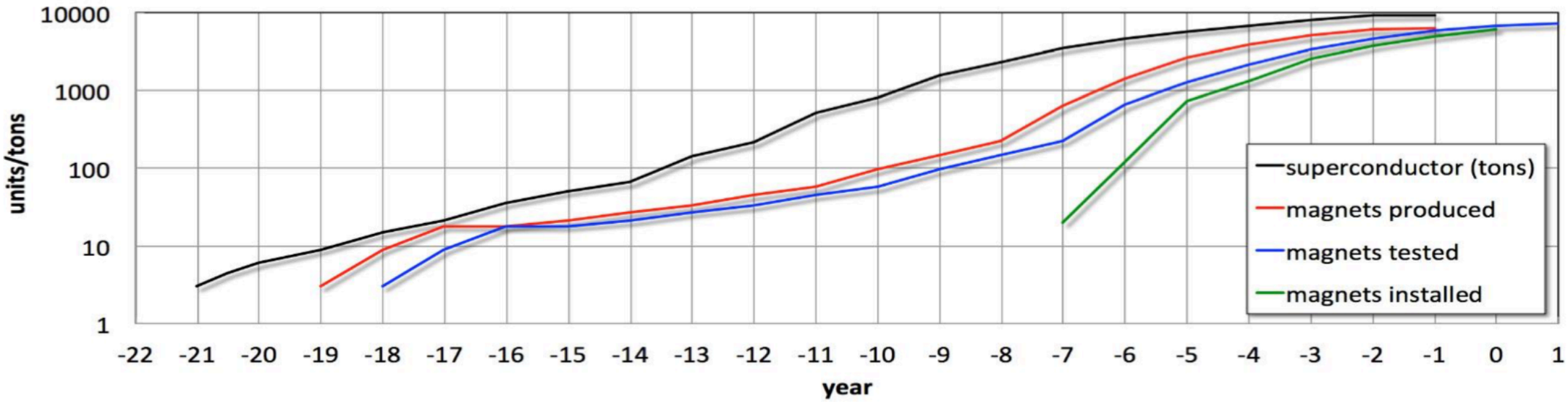
FCC Physics Workshop, M. Benedikt's talk

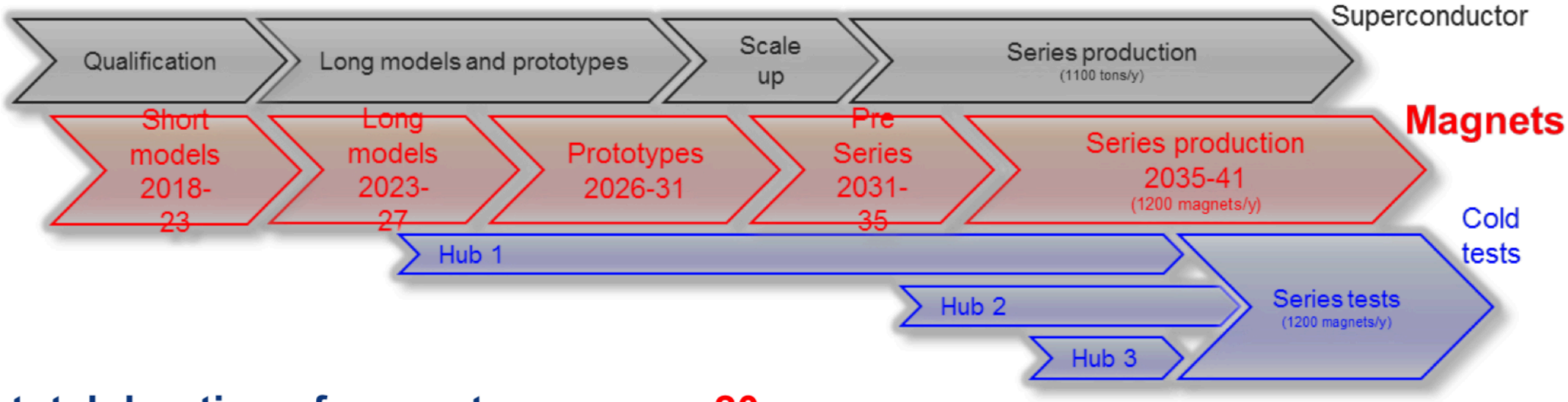


CDR summary volumes will be available by end 2018, as input for European Strategy Update 2019/20

Magnet timeline

FCC 16 T magnet R&D schedule





total duration of magnet program: ~20 years

would follow HL-LHC Nb_3Sn program with long models w industry from 2023/24

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