

Towards the Next European Strategy for Particle Physics

UK HEP Forum: Future Colliders
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Overview

- A reminder of the previous european strategy update (2013)
 - The process
 - Main priorities identified
 - Some hard choices needed to be made
- What has happened since?
 - Science
 - Policy
- CERN budget realities
- Towards the next strategy update (some personal views)

The 2013 European Strategy: the Process

- Throughout 2012: Written submissions from HEP community
- September 2012: Community meeting in Krakow
- Strategy group decisions
 - ➔ Essentially final version for March 2013 CERN Council meeting
- A strategy cannot just be a list of all possible future projects
 - Priorities have to be set

The 2013 European Strategy: the Priorities

- Full exploitation of **LHC**, including the high luminosity upgrade (**HL-LHC**)
- Design studies and R&D towards ambitious **post-LHC** accelerator project **at CERN**
- R&D in preparation for contributions to accelerator-based **neutrino programmes in US or Japan**
- R&D towards possible European contributions to **ILC**, if it were to proceed in **Japan**
- Diverse and world-class programme of **non-LHC physics at CERN**, together with strong activity in **theory**

The 2013 European Strategy: Difficult Choices

Projects not identified as high priorities

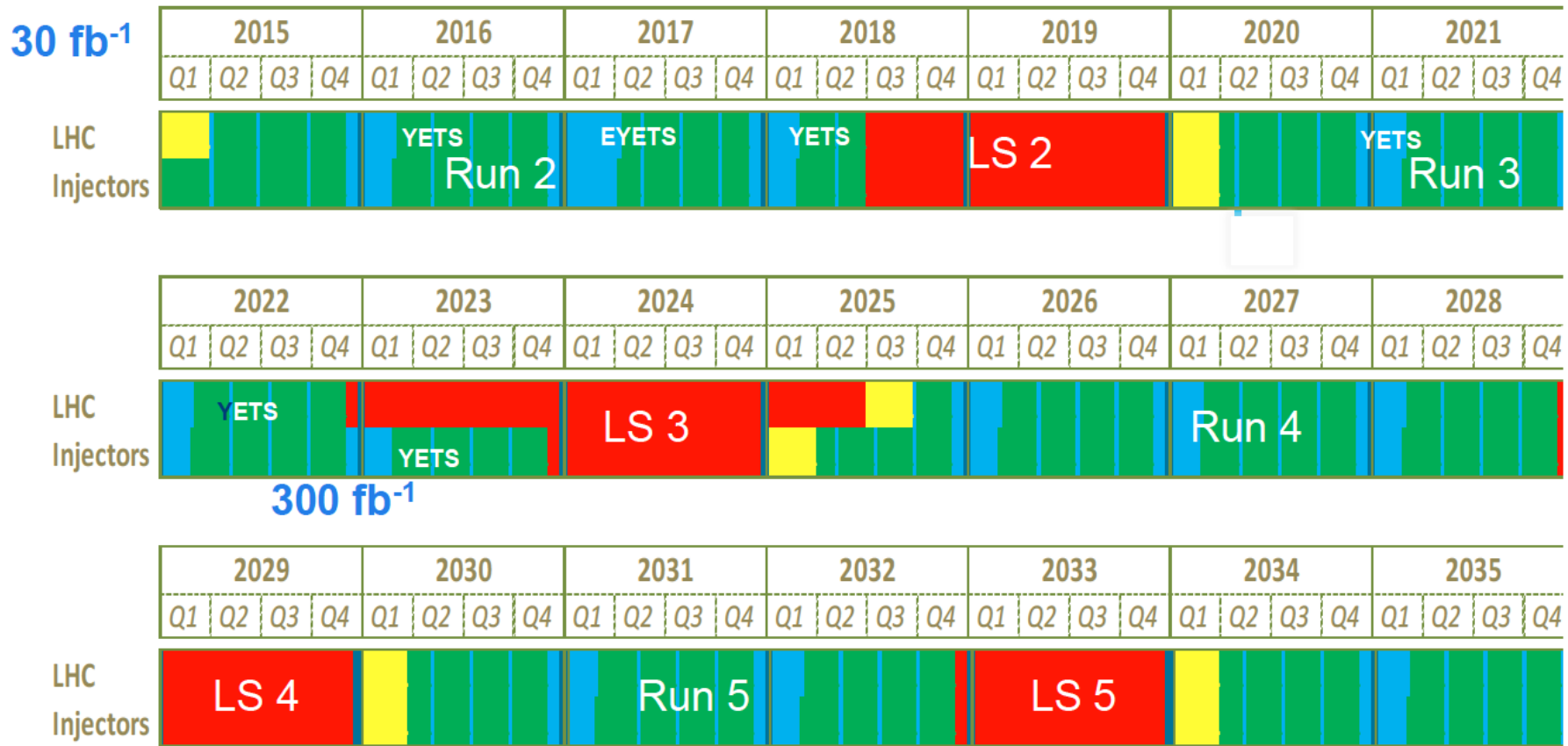
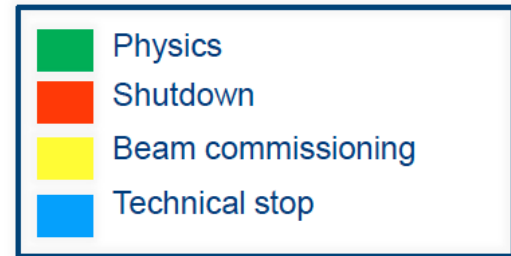
- Lepton-hadron or e^+e^- collider in LHC tunnel
- Photon-photon collider
- Neutrino beams in Europe
 - either for short- or long-baseline neutrino physics
- Muon storage ring R&D
 - as prelude to neutrino factory or muon collider

What have we learned since 2013 strategy update?

- The things we take for granted
 - LHC and experiments continued to perform extremely well
 - LHC accelerator successfully refurbished for ≥ 13 TeV
- Physics @ LHC
 - No strong hints of deviations from SM
 - Direct BSM searches, Higgs properties, SM & HF measurements
- Policy/politics
 - FCC @ CERN 80-100 km
 - h-h, e-e, h-e options
 - P5 in US
 - Support HL-LHC as the highest global priority
 - Long-term US-domestic accelerator-based particle physics programme
 - LBNF at Fermilab
 - China
 - Discussions of possible circular machine
 - 50-80 km?
 - current focus on 250 GeV e^+e^- Higgs factory

LHC schedule beyond LS1

LS2 starting in 2018 (July) => 18 months + 3 months BC
 LS3 LHC: starting in 2023 => 30 months + 3 months BC
 Injectors: in 2024 => 13 months + 3 months BC

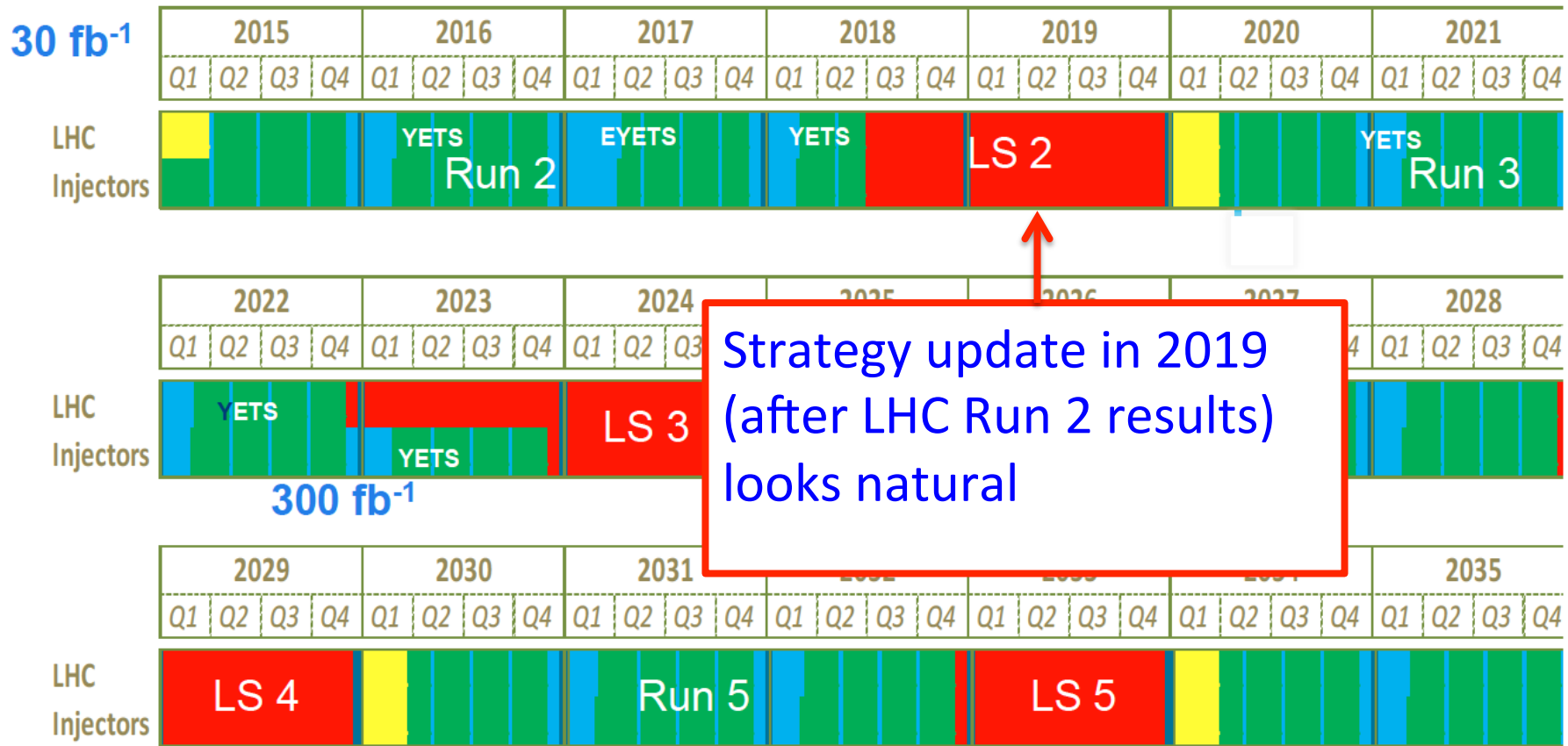
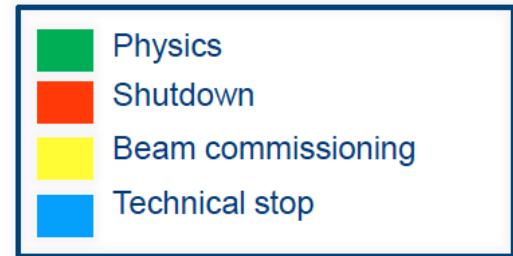


(Extended) Year End Technical Stop: (E)YETS

3'000 fb⁻¹

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Strategy update in 2019
 (after LHC Run 2 results)
 looks natural

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Economics of CERN budget

- CERN budget ~ 1.2 BCHF/year
- Running LHC and injector chain costs at least half of this budget

HL-LHC upgrade programme ~1 BCHF
~50%:50% accelerator:experiments

Running HL-LHC for
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CERN projected budget deficit (MCHF)

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
239	347	411	470	540	533	533	519	484	446	341	240

- Little scope for direct CERN contribution to ILC/LBNF construction
- Little scope for construction of next big CERN project until end of LHC operations

What will be know after LHC Run 2?

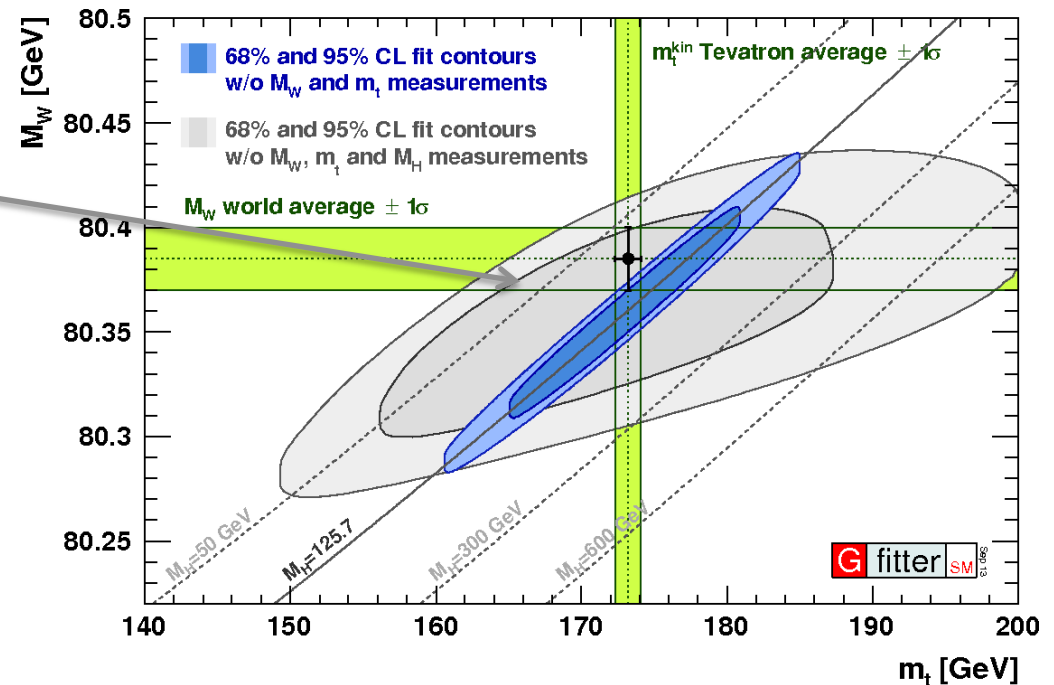
- If new physics found in LHC Run 2, it is likely to
 - point to best new accelerator to build
 - make it easier to get financial/political/societal support for this accelerator 😊
- Much greater challenge if no new physics found in LHC Run 2
 - Cannot continue indefinitely with R&D towards all possible future facilities
 - But it is impossible at the LHC to rule out (in a model-independent fashion) all possible new particles with masses < 1 TeV
 - Some very difficult and painful judgement calls will have to be made

Some Personal Views

- Very clear physics case for e^+e^- collider for $90 < E_{\text{cm}} < 350\text{--}500$ GeV
 - Precision Higgs and Electroweak physics

Precise EW measurements in the future

- $\sin^2\theta_W^{\text{eff}}$ starts to look like the poor relation in this plot!
 - Significant theoretical progress would be required in the interpretation of more precise experimental measurements in this area!



- $m_W, m_{\text{top}}, \sin^2\theta_W$, etc.
 - Unlikely at LHC to make huge gains relative to LEP/Tevatron
- New e^+e^- machines running at $\sqrt{s} = m_Z$, $\sqrt{s} = 2m_W$, $\sqrt{s} = m_Z + m_H$ and $\sqrt{s} = 2m_{\text{top}}$
 - Higgs properties
 - Could give order of magnitude or more improvements
 - e.g., $\sin^2\theta_W$ from polarization and forward-backward asymmetries
 - e.g., $\Delta m_W \sim 1 \text{ MeV}$, $\Delta m_{\text{top}} \sim 100 \text{ MeV}$, $\Delta m_H \sim 50 \text{ MeV}$

Some Personal Views

- Very clear physics case for e^+e^- collider for $90 < E_{\text{cm}} < 350\text{--}500$ GeV
 - Precision Higgs and Electroweak physics
- Much harder to make physics case for e^+e^- collider with $E_{\text{cm}} > 350\text{--}500$ GeV without clear evidence for accessible new particles
 - Need serious assessment of relative technical merits of ILC and circular e^+e^- as Higgs+precision EW machines
 - ILC: polarization, $WW \rightarrow H$, start 2030?
 - Circular e^+e^- machine: higher integrated luminosity, start 2045?
 - plus Realpolitik (new funding from Japan, etc, etc.)
- Hard to imagine next major investment in R&D for CLIC (cost ~ 300 MCHF) without clear evidence of new physics to study
- Exploration of energy frontier best done at a hadron collider (e.g., FCC-hh)

Some More Personal Views

- Will China be in a position to build an e^+e^- Higgs factory followed maybe by a hadron collider?
 - Financially, yes, but
 - size of community, expertise, scientific and organizational culture in both accelerator and particle physics
 - Difficulty of building accelerator complex on green field site
- Don't underestimate the value of CERN and its 60-year track-record (and treaty!) in comparison

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- Don't underestimate the value of CERN and its 60-year track-record (and treaty!) in comparison
- CERN should continue to expand geographically
 - but not diversify scientifically
 - e.g., into non-accelerator-based physics

Possible new associate member states	Minimum (10%) annual contribution (MCHF)
Brazil	14
Turkey	5
Russian Federation	11

- Can associate members be persuaded to contribute more than default 10%?
- Could China be persuaded to make a large in-kind contribution to accelerator?

Discuss!