Road to an update of the European HEP Strategy

Jorgen D’Hondt
Vrije Universiteit Brussel
ECFA chairperson
(https://ecfa.web.cern.ch)

Higgs Hunting
July 29 – 31, 2019
Paris
understand nature at the largest and the smallest scales
Particle Physics today

enormous success in describing matter at the smallest scales
Particle Physics today

enormous success in describing matter at the smallest scales
Particle Physics today

enormous success in describing matter at the smallest scales

describing ≠ understanding
Key open questions for particle physics?

Problems vs Mysteries

Problems:
- Dark Matter
- Baryogenesis
- Strong CP
- Fermion mass spectrum & mixing

Mysteries:
- Cosmological Constant
- EW hierarchy
- Black Hole information paradox
- very Early Universe

Plausible EFT solutions exist

Challenge or outside EFT paradigm
Need to agree on a long-term strategy for Particle Physics

- **Higgs discovery (2012)**
- **Start data taking at the LHC (2010)**
- **European Particle Physics Strategy (2006)**

**Organization (2006):**
http://council-strategygroup.web.cern.ch/council-strategygroup/

**UPDATE of the European Particle Physics Strategy (2013)**

**Organization (2013 update):**
http://europeanstrategygroup.web.cern.ch/europeanstrategygroup/
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.

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 accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.

Europe looks forward to a [ILC] proposal from Japan to discuss a possible participation.

CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.
1\textsuperscript{st} priority

LHC and HL-LHC
The impact of the LHC

a MORE PRECISE and more COMPLETE description

connection

our initial designs are not accepted by Nature

new physics
Taking into account innovative thoughts and research experience, what was optimistic in 2013 seems realistic in 2019.
2\textsuperscript{nd} priority

Future colliders at CERN
Concrete collider options studied at CERN

CLIC (ee), [http://clic-study.web.cern.ch/](http://clic-study.web.cern.ch/)
Concrete collider options studied at CERN


- **e⁺e⁻ collider** (*FCC-ee*) @ 90-365 GeV as potential first step
- **pp-collider** (*FCC-hh*) @ 100 TeV
- **p-e collider** (*FCC-he*)
- **HE-LHC** with FCC-hh magnets
- **μμ collider** (*FCC-μμ*) option
- AA, Ap, Ae options
Luminosity per facility

\[ L \propto P_{\text{synrad}} E_{\text{cm}}^{-3.5} \]

\[ L \propto P_{RF} E_{\text{cm}} \]

- FCC-ee
- CEPC
- ILC
- ILC-up.
- CLIC
- CLIC-up

Daniel Schulte @ Granada
Europe (European) Particle Physics Strategy Update

- Jan 2018: Call for proposals for venues for Open Symposium and Strategy Drafting Session
- Febr 2018: Call for scientific input
- March 2018: Call for nominations of PPG & ESG members
- June 14, 2018: Council decision on venues and dates
- Sept 27, 2018: Council launches the Strategy Update process & establish the PPG and ESG
- March 2019: Physics Briefing Book available
- May 13-16, 2019: Open Symposium Granada, ES
- May 20-24, 2020: Strategy Update Drafting Session Bad Honnef, DE
- May 2020: Council to approve Strategy Update

Physics results appearing after May 2019 will be taken into account in the process.
Open Symposium
Towards updating the European Strategy for Particle Physics
May 13-16, 2019, Granada, Spain
https://cafpe.ugr.es/eppsu2019/
The Granada themes

- Electroweak & Higgs
- Beyond the SM
- Strong Interactions
- Dark Sector
- Neutrino and astroparticle
- Flavour
The Granada themes

*Electroweak & Higgs*

- *Electroweak & Higgs*
- *Beyond the SM*
- *Strong Interactions*
- *Flavour*
- *Dark Sector*
- *Neutrino and astroparticle*
Potential to measure Higgs couplings

improvements wrt HL-LHC

EFT-framework

Beate Heinemann @ Granada
# of “largely” improved H couplings (EFT)

<table>
<thead>
<tr>
<th></th>
<th>Factor ≥2</th>
<th>Factor ≥5</th>
<th>Factor ≥10</th>
<th>Years from $T_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial run</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLIC380</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>FCC-ee240</td>
<td>10</td>
<td>8</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>CEPC</td>
<td>10</td>
<td>8</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>ILC250</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td><strong>2nd/3rd Run ee</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC-ee365</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>CLIC1500</td>
<td>10</td>
<td>7</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>HE-LHC</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td><strong>hh</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ILC500</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>CLIC3000</td>
<td>11</td>
<td>7</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td><strong>ee,eh &amp; hh</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC-ee/eh/hh</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>

13 quantities in total

NB: number of seconds/year differs: ILC 1.6x10^7, FCC-ee & CLIC: 1.2x10^7, CEPC: 1.3x10^7
Measuring Higgs couplings is perceived as one of the prime avenues in our search for new physics.

With the HL-LHC one can probe many Higgs couplings to the few percent level.

Additional to the HL-LHC sensitivity, all proposed first generation $e^+e^-$ colliders can achieve major and comparable improvements.

In a second stage, a higher energy $e^+e^-$ collider or hadron collider are important to reach the ultimate sensitivity.
There is new physics out there! and it should be our main objective to discover it

The exploration of the scalar sector is only one avenue to search for it
How precise do you want to know the Higgs couplings?

In the pursuit for new physics, from what Higgs coupling precision do you stop learning about for example the hierarchy problem, or about dark matter via the invisible Higgs width, etc.?

How precise do you want to know the trilinear Higgs self-coupling?

What precision is required to learn sufficiently about the EW phase transition, for example if it is related to baryogenesis, or to connect Higgs physics with gravitational physics, for example gravitational waves?