Od LHC do ery post-LHC

Nowe projekty i nowe inicjatywy w CERN
High Energy Physics Roadmap:

3 pillars: based on the 2013 European Strategy for Particle Physics

Full exploitation of the LHC:
- successful operation of the nominal LHC until end 2023
- construction & installation of LHC upgrades: LIU (LHC Injectors Upgrade) and HL-LHC

Scientific diversity programme serving a broad community:
- ongoing experiments and facilities at Booster, PS, SPS and their upgrades (HIE-ISOLDE, ELENA)
- participation in accelerator-based neutrino projects outside Europe (presently mainly LBNF in the US) through CERN Neutrino Platform
- new initiatives

Preparation of CERN’s future:
- vibrant accelerator R&D programme exploiting CERN’s strengths and uniqueness
  (including superconducting high-field magnets, plasma wakefield acceleration: AWAKE, etc.)
- design studies for future high-energy accelerators: CLIC, FCC (includes HE-LHC)
- future opportunities of diversity programme: Physics Beyond Colliders Study Group - PBC

Important milestone:
next update of the European Strategy for Particle Physics (ESPP) to be completed in May 2020
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.

HL-LHC from a study to a PROJECT

300 fb\(^{-1}\) → 3000 fb\(^{-1}\)

including LHC injectors upgrade LIU
(Linac 4, Booster 2GeV, PS and SPS upgrade)
The HL-LHC Project: $300 \text{ fb}^{-1} \rightarrow 3000 \text{ fb}^{-1}$

- New IR-quads $\text{Nb}_3\text{Sn}$ (inner triplets)
- New 11 T $\text{Nb}_3\text{Sn}$ (5.5 m dipoles)
- Crab Cavities
- Collimation upgrade
- Cryogenics upgrade
- Cold powering
- Machine protection
- …

Major intervention on more than 1.2 km of the LHC
LS2: (2019-2020), LHC Injector Upgrades (LIU)

LINAC4 – PS Booster:
- $\text{H}^-$ injection and increase of PSB injection energy from 50 MeV to 160 MeV, to increase PSB space charge threshold
- New RF cavity system, new main power converters
- Increase of extraction energy from 1.4 GeV to 2 GeV

PS:
- Increase of injection energy from 1.4 GeV to 2 GeV to increase PS space charge threshold
- Transverse resonance compensation
- New RF Longitudinal feedback system
- New RF beam manipulation scheme to increase beam brightness

SPS
- Electron Cloud mitigation – feedback system and partial coating of the vacuum system
- Impedance reduction, improved feedbacks
- Large-scale modification to the main RF system

These are only the main modifications and this list is far from exhaustive
Advanced Proton Driven Plasma Wakefield Acceleration Experiment

- Proof-of-concept experiment to **demonstrate a novel acceleration technique** that accelerates particles up to **three orders of magnitude** stronger than conventional methods.
  - Accelerate electrons of **several GeV/m**
- Use the **SPS proton beam** to generate powerful wakefields in a **10m long plasma**.
- Wakefields **accelerate externally injected electron** beam.
- Experiment has started end **2016**.

First proton beam sent to AWAKE for proton beam line tests (16 June 2016)
→ Facility considerably modified for the AWAKE experiment.
→ Proton and laser beam line installed and commissioned, matching all specifications.
→ Experiment diagnostics installed and tested.
→ Plasma cell installed and hardware commissioned.
→ Synchronization of SPS beam with AWAKE laser with 20 ps accuracy.
“to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update”

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.

HFM - FCC

HGA - CLIC
“CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines.”

Highest possible energy $e^+e^-$ with CLIC (CDR 2012)
Multi-lateral collaboration
The CLIC project

Main goal for the European Strategy update:
- Cost and power optimised 380 GeV machine (~11 km) (drivebeam and klystrons), upgradeable to 3 TeV

Key technical activities in the CLIC collaboration:
- X-band statistics and optimization for cost
- Work with FEL labs using their technology
- Permanent magnets (power)
- High Efficiency klystrons (power and cost)
- Stability and alignment (lumin. performance)
- Tests CTF3, CLEAR, ATF2, Low emittance rings
- Physics and detectors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>380 GeV</th>
<th>3 TeV</th>
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<tr>
<td>Centre-of-mass energy</td>
<td>TeV</td>
<td>0.38</td>
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<tr>
<td>Total luminosity</td>
<td>$10^{34}\text{cm}^{-2}\text{s}^{-1}$</td>
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<td>5.9</td>
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<td>Luminosity above 99% of $\nu$s</td>
<td>$10^{34}\text{cm}^{-2}\text{s}^{-1}$</td>
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<td>Repetition frequency</td>
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<td>Acceleration gradient</td>
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<tr>
<td>Site length</td>
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The **CLIC workshop 2018** covers Accelerator as well as the Detector and Physics studies, with their present activities and programme. Special focus of the workshop will go to the preparations for the European Strategy Update, for which the CLIC documentation is due by the end of 2018.

For the **Accelerator studies**, the workshop spans over 5 days: **22nd-26th of January**.

For **CLICdp**, the workshop is scheduled from **Tuesday afternoon 23rd to lunchtime on Friday 26th**.

**Programme**
International FCC collaboration (CERN as host lab) to study:

- **pp-collider (FCC-hh)**
  - main emphasis, defining infrastructure requirements
  - ~16 T \(\Rightarrow\) 100 TeV **pp** in 100 km ring

- ~100 km tunnel infrastructure in Geneva area, site specific

- **e^+e^- collider (FCC-ee)**, as potential first step

- **p-e (FCC-he)** option, integration one IP, FCC-hh & ERL

- **HE-LHC** with **FCC-hh** technology

**Future Circular Collider Study**

**Goal:** CDR for European Strategy Update 2018
16 T dipole design activities and options

Short model magnets (1.5 m lengths) will be built from 2017 - 2021
• CE & schedule studies: first sectors available after 4.5 to 5 years for Technical Infrastructure installation, total CE duration ~7 years
Technical Schedule for the 3 Options

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)
Meeting of Polish Community at CERN
Tuesday 12 Dec 2017
Physics Beyond Colliders Study was launched in 2016 with the goal of investigating all possible non-collider experiments. Several dozen proposals received so far.

PBC report to be submitted end 2018 as input to the next update of European Strategy for Particle Physics

PBC - Scientific goal

- The main goal of the Study Group is to explore the opportunities offered by the CERN accelerator complex to address some of today’s outstanding questions in particle physics through experiments complementary to high-energy colliders and other initiatives in the world.

- These experiments would typically:
  - ...exploit the unique opportunities offered by CERN's scientific infrastructure...
Gamma Factory

Presented by Mieczyslaw Witold Krasny,
CERN, BE-ABP, LPNHE–CNRS, Paris Sorbonne

- Accelerate and store beams of highly ionised atoms (Partially Stripped Ions – PSI) and excite their atomic degrees of freedom, by laser photons to form high intensity primary beams of gamma rays and, in turn, secondary beams of polarised leptons, neutrinos, neutrons and radioactive ions.

- Provide a new, highly efficient scheme of transforming the accelerator RF power (selectively) to the above primary and secondary beams trying to achieve a leap, by several orders of magnitude, in their intensity and/or brightness, with respect to the existing facilities.

Recent news: November issue of CERN Courier
NA61/SHINE program beyond 2020

Presented by Marek Gaździcki for NA61/SHINE
Frankfurt, Kielce

- Open charm production in heavy ion collisions
- Measurements for physics of galactic cosmic rays and neutrino experiments
  - Many requests for new data
  - Example: measurement of fragmentation cross sections

- What is the mechanism of open charm and \( J/\psi \) production?
- How does the onset of deconfinement impact open charm production?
- How does the formation of quark gluon plasma impact \( J/\psi \) production?
Dziękuję za uwagę!!

Jeśli nie zmienimy kierunku, to zapewne dotrzymy tam dokąd zmierzamy.

(przysłowie chińskie)
Acknowledgement

Frédérick Bordry
for slides presented during
7th HL-LHC Collaboration Meeting
CIEMAT - Madrid-Spain
13th November 2017
LHC operation in 2017

- ATLAS > 50 fb$^{-1}$, CMS a few pb$^{-1}$ below 50 fb$^{-1}$, LHCb 1.76 fb$^{-1}$, ALICE 16.6 pb$^{-1}$.

0.5 fb$^{-1}$/day on average since TS2
LHC operation in 2017

Integrated Luminosity [fb⁻¹]

Run 1
Long Shutdown 1
Run 2

Peak Luminosity [10^{34} cm²s⁻¹]

Run 1
Long Shutdown 1
Run 2

LHC Beam Intensity

Luminosity
LHC Run 2 and Run 3 goals

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
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<th>2018</th>
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<td>Dec</td>
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</table>

- **2015**: 4 fb\(^{-1}\)
- **2016**: 40 fb\(^{-1}\)
- **2017**: 90 fb\(^{-1}\)
- **2018**: >130 fb\(^{-1}\) (13 TeV)
- **2019**: 300 fb\(^{-1}\) (14 TeV)
- **2020**: 140 fb\(^{-1}\)
- **2021**: 140 fb\(^{-1}\)
- **2022**: 140 fb\(^{-1}\)
- **2023**: LS2

**Shutdown/Technical stop**
- Protons physics
- Commissioning
- Ions

Meeting of Polish Community at CERN
Tuesday 12 Dec 2017