Trends in Particle Physics

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Eighth Annual Large Hadron Collider Physics Conference, LHCP2020, virtual, 25-30 May 2020
10 years of Experimental Physics at the LHC

We celebrated the 10th anniversary of the first collisions @ CMS

from P McBride
Initial Goals at the LHC

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  • access to TeV scale was expected to quickly reveal the SUSY sector *(for large couplings)*

• Discovery of the Higgs Particle

  • In the Standard Model its couplings are well understood

• Precision Tests of the Standard Model

  • QCD and more

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  - light Higgs
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$\rightarrow$ HL-LHC
Experimental Requirements

- Must maintain *low scale* capability even at the highest luminosity
- Concept of simply raising trigger thresholds not viable
- Need to separate all vertices of a collision (4d-reconstruction)
- Spectroscopy feasible at the LHC
- **MeV-scale** precision physics viable at a **multi-TeV** collider
- Heavy Ion physics richer and more quantitative
- variety of ion species and configurations

Progress in experimental techniques supports such a programme
Experimental programme at the LHC

- European Strategy update 2013 already identified the full exploitation of the LHC as the primary goal
  - HL-LHC was approved in 2016
  - Phase II upgrades of ATLAS and CMS were proposed and a cost envelope was acknowledged by Funding Agencies
    - Most Technical Design Reports have been presented; MoUs are being signed
    - upgrades well under way
  - ALICE and LHCb are both proposing upgrades on an LS3 and LS4 time scale
LHC is the Flagship on the European Strategy Update 2020

- Operation will extend far into the 2030ies
- ATLAS and CMS Phase II upgrades to be completed in LS3
- ALICE ITS3 and more scheduled for LS3 (still needs approval)
- Major upgrades of ALICE and LHCb planned for LS4

LHC will continue to be the work horse for precision physics at the energy frontier for many years to come.
Near term schedule
Reminder of Run 3 schedule as of November 2019

- Key conclusions at the time
  - extend LS2 by 2(3.5) months
  - delay LS3 by one year (to then start in 2025)

Brian Petersen and Filip Moortgat
...and then
Progress during lock-down

• Limited progress with sub-detectors wherever possible including in remote institutes

• Teleworking has been used everywhere

  • Analysis unhindered thanks to availability of IT infrastructure

  • Design – access to CAD software (incl. remote licence usage)

  • ASIC development

    • design requires access to licensed software
Logistics is a challenge

- Delivery of components from other institutes (or companies)
  - Production halted
  - Delivery chain broken
- Availability of foreign experts is a major uncertainty
  - Varying travel restrictions
    - entry to France and Switzerland
    - departure from home country and uncertainty of returning home (quarantine)
    - permission from some countries for work at CERN still needs to be granted
- Progress is very difficult to predict
Priority: completion of Phase 1 and preparation of Phase 2 upgrades

ALICE

- HCAL barrel (last phase I): install SiPM+QIE11-based 5Gbps readout
- Pixel detector:
  - replace barrel layer 1 (guideline 250 fb⁻¹ max lum)
  - replace all DCDC converters

Muon system (already phase II):
- install GEM GE1/1 chambers
- Upgrade CSC FEE for HL-LHC trigger rates
- Shielding against neutron background

MAGNET (stays cold!)
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CMS

ATLAS

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- New beam & forward systems:
  - BRL/BCM/FLT/GE1
  - New TOTEM T2 Tash del
  - PPS: RP det & mechanics upgrade

LHCb

- Civil engineering on P5 to prepare for Phase-2 assembly and logistics

Coarse schedule:
- 2019: Muons and HCAL interleaved
- 2020: beam pipe installation, then pixel installation
- Some Phase 1 and maintenance improvements
- Many activities already related to Phase 2 detector upgrades and related services and infrastructure

Operations
Spectroscopy
CP violation
Heavy ions
Upgrade LHCb upgrade I
LHCb-TDR-12
Emilie Maurice (LAL, LLR) LHCb status report 16/26

ALICE

CMS

ATLAS

LHCb
Re-start of Experiments depends on Availability of Users (experts)

- Practicing work under COVID-19 rules
- T0: Begin of gradual re-start
- June 8, LHC experiments and Accelerator: LS2 and Run 3
- CERN all open
- User presence depends on travel restrictions

2020
Impact on Schedule (preliminary)

- LHC faces a linear delay of 3-4 months (see presentation of M Jiminez on Monday)
  - extended training of dipole magnets for operation at the highest energy (14 TeV?) conceivable
- Delays for experiments less well predictable e.g. because of travel restrictions for experts
  - Opportunities to advance some activities to allow for more efficient Run 3?
    - CMS neutron shielding
    - ATLAS NSW-C
    - ...

Discussion has started; meeting June 8 to decide on a plan.
Preliminary Observations for Run 3

- LS2 will have to be extended
- Machine expected to be commissioned at the highest energy
- Aim for shorter interruptions than originally planned during Run 3
  - Position of LS3 will not be affected
  - Integrated luminosity for Run 3 essentially maintained (double Run 1 and 2 statistics)
- Luminosity in 2021 will be small or zero; time profile of Run 3 will change
Other elements of the Update of European Strategy for Particle Physics 2020
LHC and its injector chain

- LHC
  - operation at 13++ TeV
- Injectors supporting
  - Fixed target programme
  - ISOLDE (isotopes)
  - n-ToF
- AD-programme

\[
\text{75}\% \text{ of all p}
\]
Initial Fixed Target Programme (and more)

- PS and SPS beams will be available on 2021
- The initial Programme of 2021 has been approved by the Research Board
  - NA61, NA62, COMPASS, NA64
  - Feasibility Studies for MUonE with a test beam
- ISOLDE
- AD (Antimatter)
Recommendations of the Physics Beyond Collider Study

• COMPASS++/AMBER

• MUonE, if feasible

• ShiP requires a Beam Dump Facility (not before LS3; Decision depends on the future large scale facilities at CERN)

• eSPS

• pEDM

• BabyIAXO, etc.

\[ \text{external} \]
Neutrino platform

- has been established following ESPPU 2013
- tremendous success for LArTPC technology
  - Single Phase protoDUNE, comfortable e-lifetime; would support large drifts (simplified construction)
  - Double Phase protoDUNE - first attempts; needs to be optimised
- CERN contributes one of the DUNE/LBNF cryostats
Update of European Strategy for Particle Physics 2020 scheduled to be released during June 2020 Council Session
Community Input (Granada)

• Precision Higgs Physics in $e^+e^-$

• Need for Accelerator Technology Development
  • High Field Magnets

• Need for a future Energy Frontier machine

• Broad theoretical and experimental interest in axion-like particle searches.

Dark matter remains an enigma
Summary

- Experimental Programme of LHC extremely rich; long range experimental programme guarantees a broad physics return
  - by exploring the highest energies and the Higgs properties
  - by searching for violations of the SM in (highly sensitive) rare decays
- European Strategy for Particle Physics about to be released
  - LHC and HL-LHC
  - Vibrant physics programme beyond colliders
- Future Facilities at the energy frontier…