Physics Studies for FCC-hh

Introduction

Filip Moortgat (CERN) and Heather Gray (LBNL)
Physics at the FCC-hh
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/FutureHadroncollider

- Volume 1: SM processes (238 pages) arXiv:1607.01831
- Volume 2: Higgs and EW symmetry breaking studies (175 pages) arXiv:1606.09408
- Volume 3: beyond the Standard Model phenomena (189 pages) arXiv:1606.00947
- Volume 4: physics with heavy ions (56 pages) arXiv:1605.01389
- Volume 5: physics opportunities with the FCC-hh injectors (14 pages)

- Study of Higgs and top quark properties and exploration of **EWSB phenomena**
- **Mass reach** enhanced by factor ~ E / 14 TeV
- Can we answer **Yes/No** questions like this?
  - Is DM a thermal WIMP?
  - Did baryogenesis take place during the EW phase transition?
  - Is the SM dynamics all there is at the TeV scale?
  - Is there a TeV-scale solution to the hierarchy problem?

**Physics case of the FCC-hh**
see M. Mangano, Wed morning

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**CDR, 2018**
Physics at the FCC-hh
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Performance assumptions discussed in M. Selvaggi’s talk on Wed

Experimental analysis effort began in mid-2014

Physics analysis studies coordinated by F. Moortgat and H. Gray together with software, detector (W. Riegler) and phenomenology (M. Mangano)

Monthly meetings (since February) announced on fcc-experiments-hadron e-group

References to FCC-hh, HL-LHC, LHeC
Studies from this group will contribute to two sections
Benchmarks

Superset of benchmarks established for the CDR, more details in M. Selvaggi’s talk on Wed

**Benchmarks serve one (or both) of these goals:**
1) illustrate sensitivity/reach for key physics channels
2) act as a benchmark for detector performance
   (calorimeter granularity, momentum resolution, …)

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**Higgs physics & Electroweak Symmetry Breaking**

**Higgs self-coupling** ($bb\gamma\gamma$, $bb\tau\tau$, $bb\text{leptons}$)
Top-Yukawa: $ttH, H \rightarrow \gamma\gamma, H \rightarrow bb$
Rare Higgs decays ($H \rightarrow cc, H \rightarrow \mu\mu, H \rightarrow Z\gamma$)
“Big Five”: Higgs decays ($H \rightarrow 4l, WW, \gamma\gamma, \tau\tau, bb$)
    WW scattering
    Other Higgs ($H^{+/0} \rightarrow tb$), $A \rightarrow tt$

**Top physics**
$tt\gamma/Z$
$tWb$ (single top s-channel)

**FCNCs**
rare decays

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**Strong SUSY**
gluinos, squarks: jets + MET, s.s dileptons + jets + MET
    stops: 0/1 leptons + jets + MET

**Weak SUSY**
EW-ino: 3/4 leptons + MET
**Higgsino (disappearing tracks)**
**Dark Matter**

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**Heavy Resonances**
$Z' \rightarrow tt, jj, ee/\mu\mu:
    M_{Z'} = 5, 30 \text{ TeV}$
$Diboson$
    $m(q^*) = 50\text{TeV}$

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See talks in this session by P. Harris, B. di Micco, M. Selvaggi, O. Cakir, R. Sawada
*Italics*: studies currently ongoing
(at least at a minimal level).
There are many opportunities for volunteers to join!
Reference Detector for the CDR

4T, 10m bore solenoid, 4T forward solenoids, no shielding coil

- 14 GJ Stored Energy
- Rotational symmetry for tracking and trigger!
- 20m Diameter (≈ ATLAS)
- 15m shaft

The performance of this reference detector has been implemented in DELPHES and will be used for the CDR studies

W. Riegler, Mon afternoon
Reminder: Getting started

• Pick a topic from the benchmarks or propose your favourite topic
• Follow the FCC Pythia + Delphes + Heppy tutorial (M. Selvaggi)
  • Note that v0.8.1 of the FCC software was just released
• Check the MC event database (C. Helsens, M. Selvaggi)
  • Les Houches events (many sample available)
  • FCC events (via Delphes) (in progress)

Produce $H \rightarrow ZZ$ plots from scratch within ~20 mins
Little software expertise needed
Very low threshold to contribute
Searches for Supersymmetry: Stop searches

Stop discovery up to ~8 TeV for 30 ab$^{-1}$ (exclusion ~ 9-10 TeV)

Plan: study boosted top reconstruction (calorimeter granularity dependence?) and consider also a muonic top tagger

Colegrove/Incandela (UCSB)

arxiv: 1406.4512
BSM Resonances

- High mass resonances are excellent benchmarks for physics object performance (muons, electrons, jets). Studies may include variations on the reference detector layout.

- (e.g. increase/decrease granularity) to understand potential gains/losses.

jj-resonance tt-resonance

- 2 bachelor students currently working on Z’ to ee and mumu

- 4 CERN summer students will work on FCC-hh physics studies
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