Simulation

David Grellscheid
2015-04-2
What are the fundamental building blocks of Nature?
Elements

Hydrogen 1
Azote 5
Carbon 6
Oxygen 7
Phosphorus 9
Sulphur 13
Magnesia 20
Lime 24
Soda 28
Potash 42
Strontian 21
Barytes 68
Iron 56
Zinc 56
Copper 56
Lead 90
Silver 190
Gold 190
Platina 190
Mercury 167

Chemical Heritage Foundation
Опыт системы элементов.
Основанный на их атомном весе и химическом сходстве.

<table>
<thead>
<tr>
<th>Элемент</th>
<th>Атомный вес</th>
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<tbody>
<tr>
<td>Ti</td>
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<tr>
<td>Zr</td>
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<tr>
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Д. Менделеев
\[ L = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\varepsilon F_{\mu\nu} \Psi \Psi + \text{h.c.} \]
\[ L = -\frac{1}{4} F_{\mu \nu} F^{\mu \nu} + i \bar{D} \gamma^\mu D_\mu \psi + \text{h.c.} + x_i Y_{ij} x_j \Phi + \text{h.c.} + \overline{D}_\mu \Phi^2 - V(\phi) \]
$4\mu$ candidate with $m_{4\mu} = 125.1$ GeV

$p_T$ (muons) = 36.1, 47.5, 26.4, 71.7 GeV  
$m_{12} = 86.3$ GeV, $m_{34} = 31.6$ GeV  
15 reconstructed vertices
4e candidate with $m_{4e} = 124.6$ GeV

$p_T$ (electrons) = 24.9, 53.9, 61.9, 17.8 GeV  $m_{12} = 70.6$ GeV, $m_{34} = 44.7$ GeV

12 reconstructed vertices
\[ L = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\chi} D\chi + h.c. \\
+ \chi_i \gamma_\mu x_\mu + h.c. \\
+ |D_\mu \phi|^2 - V(\phi) \]
\[ \mathcal{L} = -\frac{1}{4} F_{\mu \nu} F^{\mu \nu} + i D \bar{\psi} \psi + h.c. + Y_i Y_{ij} X_3 \phi + h.c. + \Box \phi^2 - V(\phi) \]
Proton bunches 25 ns apart
$10^{11}$ protons per bunch
~25 collisions per crossing
~100 million readout channels, every 25 ns
After zeroes removed, 1.6 MB / event
After zeroes removed, 1.6 MB / event

* 40 M events / s = 64 TB / s?
After zeroes removed, 1.6 MB / event

* 40 M events / s = 64 TB / s ?

Can’t save everything
## Trigger system to keep only interesting events

<table>
<thead>
<tr>
<th>Level</th>
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<tr>
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<td>40 000 000</td>
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<tr>
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<td>100 000</td>
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200 events / s * 1.6 MB / event = 320 MB / s
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200 events / s * 1.6 MB / event = 320 MB / s

= ~ 3200 TB / year raw data
Trigger system to keep only interesting events

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200 events / s * 1.6 MB / event = 320 MB / s

= ~ 3200 TB / year raw data

Analysis is done offline,
~3000 collaboration members should have equal access to data worldwide
Overview and Motivation

July 4th 2012  The Status of the Higgs Search
J. Incandela for the CMS COLLABORATION

Results:

$m(4l)$ spectrum

164 events expected in [100, 800 GeV]
172 events observed in [100, 800 GeV]

$4l$ $m$

Events / 3 GeV

0 2 4 6 8 10 12

Z+X

$Z^*, ZZ$

$m_H = 126$ GeV

$\mu, 2e2\mu$, 2e2$\mu$

$\mu$, 2e2$\mu$

$8 \text{ TeV}$, $L = 5.26 \text{ fb}^{-1}$
$7 \text{ TeV}$, $L = 5.05 \text{ fb}^{-1}$

Selected diphoton sample

- Data 2011 and 2012
- $\sqrt{s} = 7 \text{ TeV}$, $\int L dt = 4.8 \text{ fb}^{-1}$
- $\sqrt{s} = 8 \text{ TeV}$, $\int L dt = 5.9 \text{ fb}^{-1}$

ATLAS Preliminary

Data - Bkg

$m_{\gamma\gamma} [\text{GeV}]$

100 110 120 130 140 150 160

-200 0 200 400 600 800

Events / GeV

2400 2000 1600 1200 800 400 0

Events / 3 GeV

2011+2012
Overview and Motivation

July 4th, 2012  The Status of the Higgs Search  J. Incandela for the CMS COLLABORATION

Results:

$m(4\ell)$ spectrum

164% events expected in [100, 800]GeV

172% events observed in [100, 800]GeV

Data

Z+X

Z

$H_m = 126$ GeV

$\mu, 2e2\mu$

$7 \text{ TeV}, L = 5.26 \text{ fb}^{-1}$

$8 \text{ TeV}, L = 5.05 \text{ fb}^{-1}$

$8 \mu e, 4\mu e$

$4\mu e, 4\mu$

$\pm 1.01$ $\pm 2.21 \pm 1.26$

$8$ reconstructed vertices

Selected diphoton sample

Data 2011 and 2012

$\sqrt{s} = 7 \text{ TeV}, \int dt = 4.8 \text{ fb}^{-1}$

$\sqrt{s} = 8 \text{ TeV}, \int dt = 5.9 \text{ fb}^{-1}$

Event yields for $m(4\ell) = 110..160$ GeV

2011+2012
Need to get theory predictions.
\[
\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\psi} \gamma^\mu \hat{D}_{\mu} \psi + h.c. \\
+ \chi \left( g_0 x_3 \phi + h.c. \right) \\
+ \mu_0^2 \phi^2 - V(\phi)
\]
\[ \mathcal{L} = -\frac{i}{2} F_{\mu\nu} F^{\mu\nu} \\
+ i\bar{\psi} \gamma^\mu \psi \ + \text{h.c.} \\
+ \chi_i g_i \chi_j \phi \ + \text{h.c.} \\
+ \mathcal{L}_\text{kin} - V(\phi) \]
Monte Carlo event generators

Results:

- $m(4l)$ spectrum
- 164 events expected in [100, 800 GeV]
- 172 events observed in [100, 800 GeV]

Data

- Z+X, ZZ
- $m =$ 126 GeV
- $H =$ 8 TeV, $L =$ 5.26 fb$^{-1}$
- 7 TeV, $L =$ 5.05 fb$^{-1}$

Monte Carlo event generators
Event generator

- Matrix element
- Parton shower
- Hadronization
- Decays

Monte-Carlo integration
Markov chain
book-keeping
Monte-Carlo integration
The structure of an event:

- Schematic only, everything simplified, nothing to scale.

- Incoming beams: $p$ and $p/\bar{p}$.
Hard subprocess: described by matrix elements.
Resonance decays: correlated with hard subprocess.
Initial-state radiation: spacelike parton showers.
Final-state radiation: time-like parton showers
Multiple parton–parton interactions.
with its initial- and final-state radiation.
Beam remnants and other outgoing particles.
Everything is connected by colour confinement strings.

Recall! Not to scale: strings are of hadronic widths.
The strings fragment to produce primarly hadrons
Man y hadrons are unstable and decaying further.
Many hadrons are unstable and decay further.
Simulated data sets of millions of events
Detector

Trigger

Reconstructed events

Nature

Analysis

Theory model

Event generator

Simulated events

need millions!

~15 s per event
Each event independent

Batch farms are OK, but typical university clusters not large enough

Connect all participants transparently:

Worldwide LHC Computing Grid
WLCG tiered structure
WLCG tiered structure
WLCG tiered structure
WLCG tiered structure
World Wide Web

The WorldWideWeb (W3) is a wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents.

Everything there is online about W3 is linked directly or indirectly to this document, including an executive summary of the project, Mailing lists, Policy, November's W3 news, Frequently Asked Questions.

What's out there?
Pointers to the world's online information, subjects, W3 servers, etc.

Help
on the browser you are using

Software Products
A list of W3 project components and their current state. (e.g. Line Mode, X11, Viola, NeXTStep, Servers, Tools, Mail robot, Library)

Technical
Details of protocols, formats, program internals etc

Bibliography
Paper documentation on W3 and references.

People
A list of some people involved in the project.

History
A summary of the history of the project.

How can I help?
If you would like to support the web..

Getting code
Getting the code by anonymous FTP, etc.