First results from the ATLAS experiment at the LHC

1. Particle Physics – Theory and Experiment
2. Construction and preparation activities
3. First results from 2009 run
4. Physics perspectives for 2010 and beyond

W. Verkerke
High Energy Physics Intro – Theory

- Aim to describe all matter and forces in terms of fundamental particles and interactions
  - Working model: ‘the Standard Model’

Quantum Field Theory

**Lagrangian**

\[ \mathcal{L} = \mathcal{L}_{\text{free}} + \mathcal{L}_{\text{int}} + \mathcal{L}_{\text{source}} + \mathcal{L}_{\text{vertex}}. \]  

**Particles**

- Constituents of ordinary matter
  - Quarks (u, c, t, d, s, b)
  - Leptons (e, μ, τ)
  - Bosons (W, Z, γ)

'Feynman rules' for the Standard Model:

1. **Parton model**
2. **Semi-leptonic**
3. **Quark-antiquark annihilation**
4. **Quark-antiquark fusion**
5. **Quark-gluon fusion**
6. **Quark-gluon annihilation**
7. **Gluon-gluon fusion**
8. **Gluon-gluon annihilation**

**Perturbation Theory**
The standard model has many open issues

- Gravity is not part of Standard Model
  - Unification of Gravity and SM physics $\rightarrow$ String Theory

- Requires existence of Higgs Boson $\rightarrow$ But not seen so far
  - Mechanism to generate particle masses through ‘Higgs mechanism’

- Other open questions
  - Why are quark masses so different?
  - Why does matter dominate over anti-matter?
  - What are the constituents of Dark Matter?

- Several reasons to believe that they may be interesting physics phenomena at energy scales of 1 TeV
  - SM Theory *without* Higgs breaks down around this energy
  - Many extensions of the SM predict new phenomena on this scale
Experimental particle physics

- Scattering experiment = Fundamental concept to most experiments in the past 100 years:

1909  Rutherford scattering: \( \alpha \) particles on target  
\[ E = \sim 1 \text{ MeV} \]

1947  Cosmic ray on target: discovery of \( K_S \) meson  
\[ E = \sim 100 \text{ MeV} \]

1954  First circular proton accelerators  
\[ E = 6000 \text{ MeV} \]

1989  Large Electron-Positron collider  
\[ E = 200,000 \text{ MeV} \]

2009  Large Hadron collider  
\[ E = 14,000,000 \text{ MeV} \]

Higgs boson?
The LHC machine

The Large Hadron Collider is a 27 km long collider ring housed in a tunnel about 100 m underground near Geneva.
The Large Hadron collider

The most challenging components are the 1232 high-tech superconducting dipole magnets

Magnetic field: 8.4 T
Operation temperature: 1.9 K (pressurized superfluid helium)
Dipole current: 11700 A
Stored energy: 7 MJ
Dipole weight: 34 tons
7600 km of Nb-Ti superconducting cable
High Energy Physics intro -- Experiment

Collisions at LHC

- **Proton-Proton**
  - Protons/bunch: $10^{11}$
  - Beam energy: 7 TeV ($7 \times 10^{12}$ eV)
  - Luminosity: $10^{34}$ cm$^2$ s$^{-1}$

Event rate:

- $N = L \times \sigma (pp) \approx 10^9$ interactions/s
- Mostly soft (low $p_T$) events
- Interesting hard (high-$p_T$) events are rare

Selection of 1 in
$10,000,000,000,000,000$

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The ATLAS experiment – Overview
The ATLAS experiment – Overview

Measure $p$ of muons
Tracking

Measure $E$ of all particles
Calorimeters convert absorbed energy in light

Measure $p$ of charged particles
Silicon & gas based tracking detectors in B field
Commissioning ATLAS – Plan of work

199x - 2008 • Construction

2008 - 2009 • Cosmic ray data taking
   – Understanding and Calibrating detector

end of 2009 • Low E Collision data
   – Understanding and Calibrating detector
   – Observing known physics

2010 onwards • High E Collision data
   – Observing known (and new?) physics

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The ATLAS experiments – Cosmics commissioning

- In absence of beam, can test particle detection performance using cosmic particles (25 Hz → 500 MeVt)

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The ATLAS experiment – Results from 2009 run

- LHC time line, starting at moment of first injection
  - Start of circulation of both beams (Day 1 - Nov 20 18.15 / 22.15)
  - Collisions at energy of 900 GeV (Day 4 - Nov 23)
  - Collisions at energy of 2.36 TeV (Day 24 - Dec 13)
  - Winter shutdown (Dec 16)
The ATLAS experiment – Results from 2009 run

Collision Event with 2 Jets

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The ATLAS experiment – Results from 2009 run

Collision Event with 2 Muon Candidates


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Results from 2009 run – Medium Energy Physics

\[ K_S \rightarrow \pi^+ \pi^- \] (Tracking)

\[ \pi^0 \rightarrow \gamma \gamma \] (Calorimeter)
Results from 2009 run – High Energy Physics

- Properties of pp collisions at 900 GeV beam energy
- Formation of particle jets
  - Distribution in transverse $E$
  - Distribution in azim. angle
- Compare with simulation
  - Physics sim. + detector sim.
Challenges and activities for next year(s)

• Higher beam energy: \( (0.9/2.36) \rightarrow 7 \rightarrow 10 \text{ TeV} \)

• Higher intensity
  (all of 2009 data = 1 second of data at *design* intensity)
  - High performance preselection of events will be very important

• Computational challenges in dealing with data volume

• Physics analysis on high energy data
  - Understand what known physics processed look like at this energy
  - Start looking for events that don’t look like SM (known physics)
GRID computing

- Computing facilities distributed around the world
  - 10 large ‘Tier-1’ centers (centralized reconstructed and simulation)
  - O(50) smaller Tier-2 centers (physics analysis and simulation)
  - Many more small Tier-3 centers

- Connection and organization through GRID technology
  - ‘World-wide batch system’
  - ‘World-wide file catalogue’

- Current cumulative capacity
  - 100,000 CPUS available
  - Storage space: 10 Pb
Exercising data distribution

Current situation

- Event count low,
- But event size 100x final size (data reduction disabled)

Can already exercise data management system with realistic data volumes