Physics beyond the Standard Model at LHC

- Introduction (main parameters, machine, experiments …)
- Experimental challenges and techniques
- Examples of potential for physics beyond SM
LHC

- $\sqrt{s} = 14$ TeV    $L_{\text{design}} = 10^{34}$ cm$^{-2}$ s$^{-1}$
- $\sqrt{s}$ is 7 times higher and $L$ is $\sim 100$ times higher than Tevatron
- Heavy ions  (e.g. Pb-Pb at $\sqrt{s} \sim 1000$ TeV)

Start: summer 2007

TOTEM (integrated with CMS):
- pp, cross-section, diffractive physics

ATLAS and CMS:
- pp, general purpose

27 km ring (previously used for LEP $e^+e^-$ Collider)
- 1232 superconducting dipoles $B=8.3$ T

ALICE:
- ion-ion, p-ion

Here: mainly ATLAS, CMS

LHCb:
- pp, B-physics, CP-violation

F. Gianotti, Strings at CERN, 5/7/2004
The machine

First full LHC cell (~ 120 m long):
6 dipoles + 4 quads
Successfully tested at nominal current (12 kA)

~ 300 dipoles delivered
A few numbers ..... 

Rate of pp interactions at $10^{34} : 10^9$ events per second  
Weight of the CMS experiment: $\sim 13000$ tons (30% more than the Tour Eiffel)  
Amount of cables used in ATLAS : $\sim 3000$ km  
Data volume collected by CMS in 1 second: equivalent to 10000 Encyclopedia Britannica  
Machine temperature : 1.9 K (largest cryogenic system in the world)  
Total cost of machine + experiments : $\sim 5000$ MCHF  
Total number of involved physicists : $\sim 4000$  
Etc. etc.  

WHY ???

To explore in detail and directly the highly-motivated TeV-scale and say the final word about the SM Higgs mechanism and various TeV-scale predictions
The environment and the experimental challenges

1. Don’t know how New Physics will manifest → detectors must be able to detect as many particles and signatures as possible: $e, \mu, \tau, \nu, \gamma, \text{jets, b-quarks, ...}$

→ ATLAS and CMS are general-purpose experiments.

Excellent performance over unprecedented energy range: few GeV → few TeV

$t\bar{t} \rightarrow bW \bar{b}W \rightarrow bl\nu bjj$ event from CDF data
Event pile-up (consequence of high luminosity ...)

Event rate in ATLAS, CMS:
\[ N = L \times \sigma_{\text{inelastic}}(pp) \approx 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \times 70 \text{ mb} \approx 10^9 \text{ interactions/s} \]

Proton bunch spacing: 25 ns

\~25\text{ inelastic (low-}p_T\text{) events ("minimum bias") produced simultaneously in the detectors at each bunch crossing} \rightarrow \text{pile-up}
At each crossing: \(~1000\) charged particles produced over \(|\eta| < 2.5\) \((10^0 < \theta < 170^0)\)

However: \(< p_T > \approx 500\) MeV

→ applying \(p_T\) cut allows extraction of interesting events

\[\eta = -\ln \tan \frac{\theta}{2}\]

Impact of pile-up on detector requirements and performance:

-- fast response: \(~50\) ns
-- granularity: \(>10^8\) channels
-- radiation resistance (up to \(10^{16}\) n/cm²/year in forward calorimeters)
-- event reconstruction much more challenging than at previous colliders
• No hope to observe light objects \((W, Z, H?)\) in fully-hadronic final states \(\rightarrow\) rely on \(l, \gamma\)
• Fully-hadronic final states (e.g. \(q^* \rightarrow qg\)) can be extracted from backgrounds only with hard \(O(100 \text{ GeV})\) \(p_T\) cuts \(\rightarrow\) works only for heavy objects
• Mass resolutions of \(\sim 1\% (10\%)\) needed for \(l, \gamma\) (jets) to extract tiny signals from backgrounds
• Excellent particle identification: e.g. \(e/jet\) separation

\(\text{Huge (QCD) backgrounds (consequence of high energy ..)}\)
Length : ~45 m  
Radius : ~12 m  
Weight : ~ 7000 tons  
Electronic channels : ~ $10^8$  
... and 3000 km of cables ...

- **Tracking** ($|\eta|<2.5$, $B=2T$):  
  -- Si pixels and strips  
  -- Transition Radiation Detector (e/$\pi$ separation)

- **Calorimetry** ($|\eta|<5$):  
  -- EM : Pb-LAr  
  -- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)

- **Muon Spectrometer** ($|\eta|<2.7$):  
  air-core toroids with muon chambers
Length : ~22 m
Radius : ~7 m
Weight : ~ 12500 tons

• Tracking ($|\eta|<2.5$, $B=4T$): Si pixels and strips

• Calorimetry ($|\eta|<5$):
  -- EM: PbWO$_4$ crystals
  -- HAD: brass/scintillator (central+ end-cap), Fe/Quartz (fwd)

• Muon Spectrometer ($|\eta|<2.5$): return yoke of solenoid instrumented with muon chambers
Detector construction and performance: a few examples ....

ATLAS solenoid

CMS magnet yoke

ATLAS: coil components delivered, assembly started
Tracking and muon spectrometers

CMS tracker: 210 m² of Si sensors

Installation of CMS muon chambers

CMS end-cap system test

ATLAS end-cap Si wheel
Electromagnetic calorimeters

ATLAS barrel calorimeter inside cryostat

Module of 200 CMS crystals

ATLAS solenoid before insertion inside the cryostat
Modules of ATLAS barrel calorimeter being lowered in the pit

Hadronic calorimeters

CMS end-cap calorimeter assembled
Examples of expected performance

Heavy narrow resonances will likely be discovered in the $X \rightarrow e^+e^-$ channel (muon decay useful for couplings, asymmetry, etc.)

Electron E-resolution measured in beam tests of ATLAS EM calorimeter

Muon momentum resolution expected in CMS

$1 \text{ TeV} e^\pm : \sigma(E)/E \approx 0.5\%$

$1 \text{ TeV} \mu^\pm : \sigma(p)/p \approx 5\%$
Main asset of LHC physics potential: huge event statistics thanks to high $\sqrt{s}$ and $L$

Expected event production rates in ATLAS or CMS for representative (known and new) physics processes at the initial "low" luminosity of $L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

<table>
<thead>
<tr>
<th>Process</th>
<th>Events/s</th>
<th>Events per year</th>
<th>Total statistics collected at previous machines by 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W \rightarrow e\nu$</td>
<td>15</td>
<td>$10^8$</td>
<td>$10^4 \text{ LEP} / \sim 10^6 \text{ Tevatron}$</td>
</tr>
<tr>
<td>$Z \rightarrow ee$</td>
<td>1.5</td>
<td>$10^7$</td>
<td>$10^6 \text{ LEP}$</td>
</tr>
<tr>
<td>$t\bar{t}$</td>
<td>1</td>
<td>$10^7$</td>
<td>$\sim 10^4 \text{ Tevatron}$</td>
</tr>
<tr>
<td>$b\bar{b}$</td>
<td>$10^6$</td>
<td>$10^{12} - 10^{13}$</td>
<td>$10^9 \text{ Belle/BaBar} \ ?$</td>
</tr>
<tr>
<td>$H \quad m=130 \text{ GeV}$</td>
<td>0.02</td>
<td>$10^5$</td>
<td>?</td>
</tr>
<tr>
<td>$g\bar{g} \quad m=1 \text{ TeV}$</td>
<td>0.001</td>
<td>$10^4$</td>
<td>---</td>
</tr>
<tr>
<td>Black holes</td>
<td>0.0001</td>
<td>$10^3$</td>
<td>---</td>
</tr>
<tr>
<td>$m &gt; 3 \text{ TeV}$</td>
<td>$M_d=3 \text{ TeV}, n=4$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

→ LHC is a top factory, W/Z factory, Higgs factory, SUSY factory, etc....
→ mass reach for direct discovery of new particles up to $m \sim 6 \text{ TeV}$
Very broad physics programme, including:

-- precise measurements of SM particles (e.g. W mass, top sector) and CP-violation
-- SM Higgs searches
-- Physics beyond the SM

Goals:
• make sure that we don’t miss any relevant topology → detector robustness/flexibility, ability to cope with the unexpected
• go beyond assessment of discovery potential → attempt to characterize underlying model (fundamental parameters) through precise measurements

Here: a few examples (Higgs, SUSY, Extra-dimensions ....) to illustrate physics potential and experimental techniques
Where is the Higgs boson?

- Higgs mass:
  - $114.4 \text{ GeV} < m_H < 1000 \text{ GeV}$
  - from theory
  - from direct searches at LEP
  - from fit to the electroweak data (LEP, Tevatron, SLC, etc.):
    - indirect limit $m_H < 251 \text{ GeV}$ at 95% C.L. → present data favour a light Higgs
  - LEP “hint” ($\sim 2\sigma$ excess) for $m_H \sim 115 \text{ GeV}$?

- Higgs decay modes:
  - $g f \sim m_f / v$
  - $g m_W$
  - $W, Z$

Only unambiguous example of observed Higgs
Best channels at LHC:

- $m_H > 130$ GeV: $H \rightarrow ZZ(*) \rightarrow 4e, 4\mu$
  - Requires good lepton $E, p$ resolution and identification. *Gold-plated channel at LHC (~ background free ...*)

- $m_H < 150$ GeV: $H \rightarrow \gamma\gamma$
  - Requires excellent EM calorimetry (E-resolution, $\gamma/\pi^0$ separation)

ATLAS

CMS

100 $fb^{-1}$
• Higgs can be discovered over full allowed mass range in 1 year of LHC operation → final word about SM Higgs mechanism

• However: it will take time to understand and calibrate ATLAS and CMS ...

• In most difficult region $m_H < 130\text{ GeV} \geq 3$ different channels observable → robustness

• If Higgs found, mass can be measured to 0.1% up to $m_H \sim 500\text{ GeV}$
SUPERSYMMETRY

Present status ... from an experimentalist's point of view:

\[
m(\tilde{q}, \tilde{g}) > 200 \text{ - } 300 \text{ GeV} \\
m(\tilde{t}, \tilde{\chi}^+) > 90 \text{ - } 100 \text{ GeV} \\
m(\tilde{\chi}_1^0) > 46 \text{ GeV}
\]

from Tevatron Run 1

from LEP

\[
m(\tilde{p}) < \sim \text{ TeV}
\]

Sparticles (if exist ...) are heavy

BUT : to stabilize the Higgs mass need

LHC
Combining Collider searches with other constraints (cosmology, ...)

- Disfavoured by BR (b → sγ)
  from CLEO, BELLE
  BR (b → sγ) = (3.2 ± 0.5) • 10^{-4}
  used here

- Favoured by g_µ-2 (E821)
  assuming that
  δα_µ = (26 ± 10) • 10^{-10}
  is from SUSY (± 2 σ band)

- Favoured by cosmology
  assuming 0.1 ≤ Ω_χ h^2 ≤ 0.3

- Favoured by cosmology
  assuming 0.094 ≤ Ω_χ h^2 ≤ 0.129
  i.e. new WMAP results

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Ellis et al., hep-ph/0303043

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F. Gianotti, Strings at CERN, 5/7/2004 22
**SUSY searches at LHC**

- **Dominant processes**: $\tilde{q}\tilde{q}, \tilde{g}\tilde{g}, \tilde{q}\tilde{g}$ production
  - strong production $\rightarrow$ huge cross-section
  - e.g. for $m(\tilde{q}, \tilde{g}) \sim 1$ TeV $\sim 10^4$ events produced in one year at low L

- $\tilde{q}, \tilde{g}$ heavy $\rightarrow$ cascade decays
  - $\rightarrow$ spectacular signatures with many jets, leptons + missing $E_T$
  - $\rightarrow$ easy to extract SUSY signal from SM backgrounds at LHC

- **Lightest Susy Particle (LSP)** weakly interacting $\rightarrow$ not detected
  - $\rightarrow$ missing energy in final state

**R-parity conservation assumed**
Example:

\begin{align*}
LHC \text{ discovery reach} & \\
\begin{array}{|c|c|}
\hline
\text{Time} & \text{reach in squark/gluino mass} \\
\hline
1 \text{ month at } 10^{33} & \sim 1.3 \text{ TeV} \\
1 \text{ year at } 10^{33} & \sim 1.8 \text{ TeV} \\
1 \text{ year at } 10^{34} & \sim 2.5 \text{ TeV} \\
\text{ultimate (300 fb}^{-1}) & \text{ up to } \sim 3 \text{ TeV} \\
\hline
\end{array}
\end{align*}

\text{if nothing found at LHC, (low-E) SUSY is likely dead} \\
\rightarrow \text{ need another explanation for e.g. dark matter ...}
If SUSY is there ....

- ATLAS and CMS should be able to perform precise measurements of SUSY final states → determine sparticle masses and fundamental parameters of theory with precision ≈ 10% or better in many cases (studied in minimal models like mSUGRA)
- Method: measure end-points of reconstructed mass spectra at each step of (long) squark/gluino decay chains. End-points depend on involved masses → deduce constraints on combinations of masses
- LSP is not directly observable but its mass can be constrained indirectly from other measurements in final state → constraints on cold dark matter

Ex. : LHC “Point 5” : m_0 = 100 GeV, m_{1/2} = 300 GeV, A_0 = 300 GeV, tanβ = 2, µ > 0
m (q) ~ 700 GeV
m (g) ~ 800 GeV
m (χ^0_1) ~ 120 GeV
Example of a typical chain:

\[ \tilde{q}_L \rightarrow q \chi^0_2 \rightarrow l \chi^0_1 \]

- \( m(\text{ll}) \) spectrum end-point: 109 GeV
  - exp. precision \( \sim 0.3\% \)
- \( m(\text{ll})^{\min} \) spectrum
  - end-point: 552 GeV
  - exp. precision \( \sim 1\% \)
- \( m(\text{ll})^{\max} \) spectrum
  - threshold: 272 GeV
  - exp. precision \( \sim 2\% \)
- \( m(l^\pm j) \) spectrum
  - end-point: 479 GeV
  - exp. precision \( \sim 1\% \)

\[ m(\tilde{q}_L \chi^0_2 \tilde{t}_R \chi^0_1) = 690, 232, 157, 121 \text{ GeV} \]

ATLAS
100 fb^{-1}
LHC Point 5
Putting all constraints together:

\[ m(bb), m(ll), m(llj)_{\text{max}}, m(llj)_{\text{min}}, m(lj) \]

\[ \bar{q}_L \rightarrow q \chi^0_2 \]
\[ \bar{q}_L \rightarrow h \chi^0_1 \]
\[ \bar{q}_L \rightarrow \chi^0_0 \]
\[ \bar{q}_L \rightarrow l \chi^0_1 \]

Sparticle mass | Expected precision 100 fb\(^{-1}\)
--- | ---
squark left | ± 3%
\(\chi^0_2\) | ± 6%
slepton mass | ± 9%
\(\chi^0_1\) | ± 12%

Particles directly observable at Point 5:

\(\bar{q}_L, \bar{q}_R, \tilde{g}, \tilde{t}_1, \tilde{T}_R, \tilde{T}_L, h, \chi^0_2\)

From fit of mSUGRA to all experimental measurements can deduce:

-- fundamental parameters of theory
-- cold dark matter relic density:

\[ \Omega_\chi h^2 = 0.2247 \pm 0.0035 \quad \text{at Point 5} \]
**Expected precision on mSUGRA parameters for six “LHC Points”**

<table>
<thead>
<tr>
<th>Point</th>
<th>$m_0$ (GeV)</th>
<th>$m_{1/2}$ (GeV)</th>
<th>$\tan\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$400 \pm 100$ (25%)</td>
<td>$400 \pm 8$ (2%)</td>
<td>$2 \pm 0.02$ (1%)</td>
</tr>
<tr>
<td>2</td>
<td>$400 \pm 100$ (25%)</td>
<td>$400 \pm 8$ (2%)</td>
<td>$10 \pm 1.2$ (12%)</td>
</tr>
<tr>
<td>3</td>
<td>$200 \pm 5$ (2.5%)</td>
<td>$100 \pm 1$ (1%)</td>
<td>$2 \pm 0.02$ (1%)</td>
</tr>
<tr>
<td>4</td>
<td>$800 \pm 35$ (4%)</td>
<td>$200 \pm 1.5$ (0.8%)</td>
<td>$10 \pm 0.6$ (6%)</td>
</tr>
<tr>
<td>5</td>
<td>$100 \pm 1.3$ (1.3%)</td>
<td>$300 \pm 1.5$ (0.5%)</td>
<td>$2 \pm 0.05$ (2.5%)</td>
</tr>
<tr>
<td>6</td>
<td>$218 \pm 30$, $242 \pm 25$ (~10%)</td>
<td>$196 \pm 8$, $194 \pm 6$ (3.5%)</td>
<td>$44 \pm 1.1$, $45 \pm 1.7$ (~3%)</td>
</tr>
</tbody>
</table>

ATLAS 300 fb$^{-1}$

- Sign $\mu$ determined except Point 6
- $A_0 \sim$ unconstrained except Point 6
- $\tan\beta = 45$
- $\mu = +, -$
• These results are conservative because:
  only mass distributions used. Much more information will be available in the data:
  cross-sections, branching ratios, several distributions → will use everything
  → many more constraints.

• These results are optimistic because:
  constrained models like mSUGRA can artificially improve expected precision
  on model parameters because of high correlations between masses, etc. However:
  - impossible in practice to work in general MSSM (~ 100 parameters, not predictive enough)
    without experimental data to provide guidance
  - constrained models nevertheless provide useful benchmarks for study of LHC potential,
    detector performance, main analysis strategies
Experimental strategy towards understanding the underlying theory

1. **Inclusive searches → SUSY discovery** (must be as model-independent as possible ...)

2. **First characterization of the model, e.g.:**
   - First estimate of SUSY mass scale and cross-section (to 10-20%)
   - Measure h mass to 0.1%-1%
   - Look for general features: Is there large missing $E_T$ $(R_p$ violation $)$? Are there many leptons? Are there “exotic” signatures (many $\gamma$'s, heavy stable charged particles, etc.)? Are there many b-jets and taus (could indicate large tan$\beta$)? Is there an excess of top-quarks?
   - Look for / reconstruct semi-inclusive topologies, e.g.:
     - $h \rightarrow bb$ peaks
     - $ll^{-}$ peaks, edges, ...
     - $tt$ pairs and their spectra → may indicate stop, sbottom in final state
   - Explore Higgs sector: e.g. look for $\mu\mu$ and $\tau\tau$ peaks (from A/H decays)
   - More complicated signatures (e.g. involving combinations of jets) require more work ...

3. **Measure exclusive chains (masses, couplings, etc.) → try to determine theory parameters**

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At each step we should narrow spectrum of possible models and get guidance to go on ...
Joint effort theory/experiments will be essential!
Theories with Extra-dimensions

A few examples of the expected reach ...

“Why bastard? Wherefore base? When my dimensions are as well compact, my mind as generous, and my shape as true as honest madam’s issue?”

W. Shakespeare, King Lear, Act 1, Scene 2 (Edmund bastard son to Gloucester)
**Large Extra-dimensions (ADD models): direct graviton production**

Look for a continuum of Graviton KK states:

\[ q \rightarrow \text{topology is jet(s) + missing } E_T \]

- **Cross-section** \( \approx \frac{1}{M_D^{\delta+2}} \)
- **\( M_D \)** = gravity scale
- **\( \delta \)** = number of extra-dimensions

<table>
<thead>
<tr>
<th>( \delta = 2 )</th>
<th>( \delta = 3 )</th>
<th>( \delta = 4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_D^{\text{max}} )</td>
<td>9 TeV</td>
<td>7 TeV</td>
</tr>
<tr>
<td>( R_{\text{compact}} )</td>
<td>8 ( \mu )m</td>
<td>2 Å</td>
</tr>
</tbody>
</table>

Effective theory, valid only for \( \sqrt{S} < M_D \Rightarrow M_d^{\text{min}} \sim 5 \) TeV

To characterize the model need to measure \( M_D \) and \( \delta \)

Measurement of cross-section gives ambiguous results: e.g. \( \delta = 2, M_D = 5 \) TeV very similar to \( \delta = 4, M_D = 4 \) TeV

Solution may be to run at different \( \sqrt{s} \):

Good discrimination between various solutions possible with expected <5% accuracy on \( \sigma(10)/\sigma(14) \)

F. Gianotti, Strings at CERN, 5/7/2004
Warped Extra-dimensions (Randall Sundrum models):
production of narrow Graviton resonances

Best discovery channel: \( qq, gg \rightarrow G \rightarrow e^+e^- \)

CMS, 1 year at \( 10^{34} \)

ATLAS, 1 year at \( 10^{34} \)

Spin 1, e.g. \( Z' \)
Many other scenarios and topologies are accessible ....
Extended gauge groups: $Z' \rightarrow l^+ l^-$

- Reach in 1 year at $10^{34}$: 4-5 TeV
- Discriminating between models possible up to $m \sim 2.5$ TeV by measuring:
  -- $\sigma \times \Gamma$ of resonance
  -- lepton F-B asymmetry
  -- $Z'$ rapidity

**Dilepton invariant mass spectrum**

**Forward backward asymmetry measurement**

**Rapidity distribution**

LHC, $\sqrt{s}=14$ TeV

$M_{Z'} = 1.5$ TeV  $|y| > 0.8$

$Z'_{100 fb^{-1}}$

1.45 TeV $< M_{Z'} < 1.55$ TeV
Extended groups (l-q symmetry): leptoquarks

Production of pairs of scalar leptoquarks \( LQ \ LQ \rightarrow lq \ lq \rightarrow lj \ lj \)

Reach up to \( \sim 1.5 \) TeV
Mass resolution \( \sim 3\% \)
Compositeness: excited quarks and leptons

Reach: up to $m \sim 6.5$ TeV for $q^*$, $\Lambda = m^*$
up to $m \sim 4$ TeV for $e^*$, $\Lambda = 6$ TeV
Alternative approach to the hierarchy problem predicting heavy top T, new gauge bosons $W_H, Z_H, A_H$ and Higgs triplet $\Phi^0, \Phi^+, \Phi^{++}$

Arkani-Hamed et al., JHEP 207 (2002) 34

$V_H \rightarrow V h$
$m_h=120$ GeV

$T \rightarrow Zt \rightarrow ll blv$
Dirac Monopoles

ATLAS, 100 fb⁻¹ = 1 year at 10^{34}

\[ \mathcal{E}_T (\gamma_1) + \mathcal{E}_T (\gamma_2) \ (\text{GeV}) \]

Discovery reach up to ~ 20 TeV
The LHC and high-energy cosmic rays

$\sqrt{s} = 14$ TeV corresponds to $E \sim 100$ PeV fixed target proton beam

LHC studies most relevant to HECR:
- most energetic particles from the collisions
- pp (and pA, AA) cross-sections
both require detection in the forward region

Charged particle multiplicity and energy in pp inelastic events at $\sqrt{s} = 14$ TeV
Measurement of $\sigma_{\text{tot}}\,(pp)$

Curves are $\sim (\log s)^\gamma$

Goal of TOTEM: $\sim 1\%$ precision

TOTEM: 3 stations of detectors ("Roman Pots" RP1, RP2, RP3) at both sides of IP5 (integrated with beam pipe) to measure scattered proton in elastic interactions down to $\theta_{\text{scat}} \approx 20\,\mu\text{rad}$
Conclusions

LHC has very compelling and ambitious physics goals:

• Explore the highly-motivated TeV scale with direct discovery potential up to $m \approx 6$ TeV
• Say the final word about several TeV-scale predictions:
  - SM Higgs mechanism $\rightarrow$ origin of particle masses?, SUSY $\rightarrow$ dark matter ?, etc.
• Perform several measurements with unprecedented precision: e.g. W mass, top mass, CP-violation ($\rightarrow$ matter/anti-matter asymmetry, baryogenesis)
• Study heavy-ion collisions $\rightarrow$ quark-gluon plasma
• Measure $\sigma_{\text{tot}}$ (pp, pA and AA) and study very high energy products of pp collisions
  $\rightarrow$ relevant to high-energy cosmic rays

To achieve these goals, we are building challenging machine and detectors, of unprecedented performance and complexity.

Note: sensitivity of experiments to a huge number of signatures demonstrates their ability to cope with unexpected scenarios ...

LHC should add many crucial pieces to our knowledge of fundamental physics
$\rightarrow$ huge impact also on astroparticle physics and cosmology?
$\rightarrow$ in ~ 3 years particle physics may enter the most glorious epoch of its history ...