

Abstract

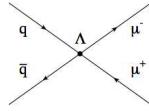
Are quarks and leptons fundamental particles, or composed of smaller constituents?

This question can be addressed at the Large Hadron Collider, CERN, Switzerland using the ATLAS experiment.

A search is conducted for deviations from Standard Model expectation in invariant mass and, for the first time, also the angular distribution, in dielectron and dimuon final states. The latest results are presented, using the full LHC 2012 proton-proton collision dataset recorded by the ATLAS detector, corresponding to 20 fb⁻¹ at $\sqrt{s} = 8$ TeV. [1]

Theory

- Quark-lepton compositeness and
- a new interaction with a massive mediator



can be described a contact interaction (CI).

CI Lagrangian [2]:

$$\mathcal{L} = \frac{g^2}{\Lambda^2} [\eta_{LL} (\bar{\psi}_L \gamma_\mu \psi_L) (\bar{\ell}_L \gamma^\mu \ell_L) + \eta_{RR} (\bar{\psi}_R \gamma_\mu \psi_R) (\bar{\ell}_R \gamma^\mu \ell_R) + \eta_{LR} (\bar{\psi}_L \gamma_\mu \psi_L) (\bar{\ell}_R \gamma^\mu \ell_R) + \eta_{RL} (\bar{\psi}_R \gamma_\mu \psi_R) (\bar{\ell}_L \gamma^\mu \ell_L)],$$

where: energy scale Λ corresponds to the binding energy between fermion constituents
 η_{ij} defines the chiral structure of the interaction where i and j are L or R (left or right)
 sign of η dictates if interference is constructive (-) or destructive (+).

CI cross-section:
$$\sigma_{\text{tot}} = \sigma_{\text{DY}} - \eta_{ij} \frac{F_I}{\Lambda^2} + \frac{F_C}{\Lambda^4}.$$

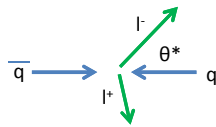
has a Drell-Yan (DY) component, interference (F_I) and pure CI (F_C) terms.

Search Method

- Search for 2 high energy e or μ .
- Require opposite sign & invariant mass ($M_{ee}/M_{\mu\mu}$) > 80 GeV.
- Search for deviations from Standard Model expectation in search region.

Search Region

Invariant mass $M_{ee}/M_{\mu\mu}$ in range 400-4500 GeV
 in forward/backward events, defined by $\cos\theta^*$.

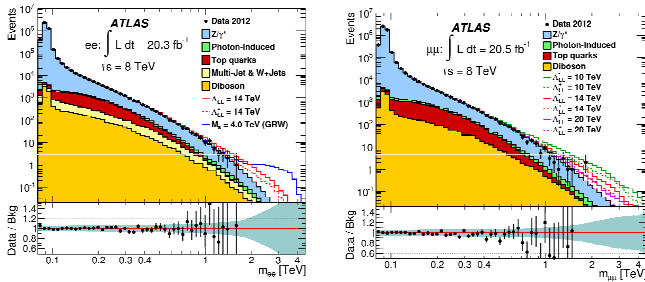


Also:
 Forward-Backward Asymmetry:

where $N_F : \cos\theta^* > 0$ and $N_B : \cos\theta^* < 0$

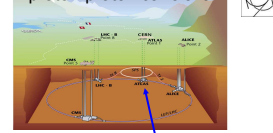
$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}.$$

Results: Invariant Mass

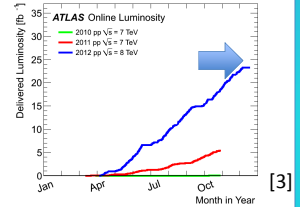


Detector

Large Hadron Collider
 proton-proton collisions



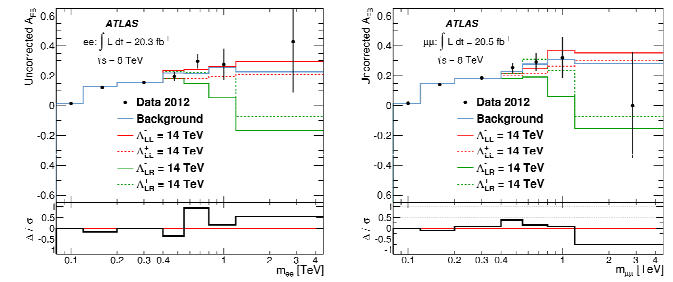
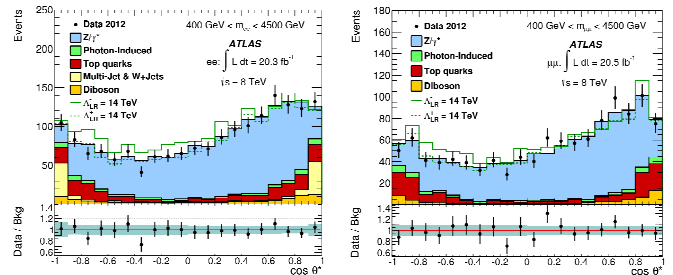
Dataset



Standard Model Expectation

Backgrounds simulated using Monte-Carlo (MC), except Multi-jet and W-jets in e-channel, estimated by data-driven method. MC is normalized to data $M_{ee}/M_{\mu\mu}$ in region 80-120 GeV.

Results: Angular



Systematic Uncertainties

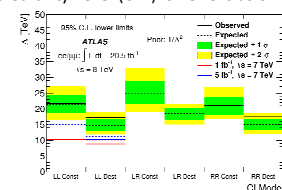
Mass-dependent systematic uncertainties can affect the shape of the discriminating variables. These are as a function of invariant mass for forward and backward events.

At relevant
 invariant masses
 of 1 (2) TeV:

Source	Dielectrons		Dimuons	
	Signal	Background	Signal	Background
Normalization	4.0% (4.0%)	N/A	4.0% (4.0%)	N/A
PDF Variation	< 0.1% (0.2%)	3.0% (11.0%)	< 0.1% (< 0.1%)	5.0% (12.0%)
PDF Choice	N/A	1.0% (7.0%)	N/A	1.0% (6.0%)
as	N/A	1.0% (3.0%)	N/A	1.0% (3.0%)
EW Corrections	N/A	1.0% (2.0%)	N/A	1.0% (3.0%)
Photon-Induced	N/A	7.0% (12.0%)	N/A	6.5% (9.5%)
Efficiency	1.0% (2.0%)	1.0% (2.0%)	3.0% (6.0%)	3.0% (6.0%)
Scale/Resolution	1.2% (2.4%)	1.2% (2.4%)	1.0% (4.0%)	1.0% (4.0%)
Multi-Jet & W-Jets	N/A	3.0% (5.0%)	N/A	N/A
Beam Energy	1.0% (3.0%)	1.0% (3.0%)	1.0% (3.0%)	2.0% (3.0%)
Charge Misidentification	1.2% (2.0%)	1.2% (2.0%)	N/A	N/A
MC Statistics	3.0% (3.0%)	0.5% (0.5%)	3.0% (3.0%)	0.5% (0.5%)
Total	5.5% (6.9%)	9.5% (19.4%)	6.0% (9.3%)	9.2% (18.7%)

Limits

- No significant deviations from expectation observed.
- So 95% Credibility Level (C.L.) lower exclusion limits on Λ set.



Conclusion & Outlook

- So far, quarks & leptons appear to be fundamental particles.
- Future 2015/2016 13-14 TeV datasets will enable further tests.

References:

- [1]: arXiv: 1407.2410.
- [2]: E. Eichten, I. Hinchliffe, K. D. Lane, and C. Quigg, Rev. Mod. Phys. 56 (1984) 579-707.
- [3]: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResults#Multiple_Year_Collision_Plots