Abstract

In this thesis the global Standard Model (SM) fit to the electroweak precision observables is revisited with respect to newest experimental results. Various consistency checks are performed showing no significant deviation from the SM. The Higgs boson mass is estimated by the electroweak fit to be $M_H = 94\,^{+30}_{-24}$ GeV without any information from direct Higgs searches at LEP, Tevatron, and the LHC and the result is $M_H = 125\,^{+8}_{-10}$ GeV when including the direct Higgs mass constraints. The strong coupling constant is extracted at fourth perturbative order as $\alpha_s(M_Z^2) = 0.1194 \pm 0.0028\,(\text{exp}) \pm 0.0001\,(\text{theo})$. From the fit including the direct Higgs constraints the effective weak mixing angle is determined indirectly to be $\sin^2\theta^\ell_{\text{eff}} = 0.23147\,^{+0.00012}_{-0.00010}$. For the W mass the value of $M_W = 80.360\,^{+0.012}_{-0.011}$ GeV is obtained indirectly from the fit including the direct Higgs constraints.

The electroweak precision data is also exploited to constrain new physics models by using the concept of oblique parameters. In this thesis the following models are investigated: models with a sequential fourth fermion generation, the inert-Higgs doublet model, the littlest Higgs model with T-parity conservation, and models with large extra dimensions. In contrast to the SM, in these models heavy Higgs bosons are in agreement with the electroweak precision data.

The forward-backward asymmetry as a function of the invariant mass is measured for $pp \to Z/\gamma^* \to e^+e^-$ events collected with the ATLAS detector at the LHC. The data taken in 2010 at a center-of-mass energy of $\sqrt{s} = 7$ TeV corresponding to an integrated luminosity of 37.4 pb^{-1} is analyzed. The measured forward-backward asymmetry is in agreement with the SM expectation. From the measured forward-backward asymmetry the effective weak mixing angle is extracted as $\sin^2\theta^\ell_{\text{eff}} = 0.2204 \pm 0.0071\,(\text{stat})\,^{+0.0039}_{-0.0044}\,(\text{syst})$. The impact of unparticles and large extra dimensions on the forward-backward asymmetry at large momentum transfers is studied at generator level.

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Contents

CHAPTER 3

The Global Fit of the Electroweak Standard Model

Precision measurements, in line with accurate theoretical predictions, allow us to probe physics at much higher energy scales than the masses of the particles directly involved in experimental reactions by exploiting contributions from quantum loops. In case of the SM, unknown parameters of the SM (*e.g.* the Higgs boson mass) can be determined from multi-parameter fits. The analysis presented in this chapter relies on the Gfitter framework [1] and the presentation follows closely (though not identically) the presentation in the publications [1, 34]. This analysis has benefited from the enormous work in the past which has been done for the calculation of the electroweak precision observables. During this effort various software packages have been developed predicting the electroweak precision observables within the SM: ZFITTER [35, 36], TOPAZ0 [37, 38], LEPTOP [39, 40], and GAPP [41, 42] (see also the review [43]). Electroweak SM fits are also routinely performed by the LEP Electroweak Working Group [44] and for the electroweak review of the Particle Data Group [42].

This chapter is organized as follows. First, the statistical aspects of the fits as implemented in the Gfitter framework and the theoretical predictions of the electroweak observables are discussed. The experimental data used in the analysis is introduced. Especially, the treatment of the information from direct Higgs searches is explained in detail. The chapter concludes with the presentation of various fit results. Among them, constraints on the Higgs mass, a determination of the strong coupling, and indirect determinations of M_W, m_t, and $\sin^2\theta^{\ell}_{\rm eff}$ are shown.

3.1 Statistical Aspects

The statistical analysis is performed with the Gfitter framework, which adopts a least-square like notation. The test statistics is defined as

$$\chi^2(y_{\rm mod}) \equiv -2\ln\mathcal{L}(y_{\rm mod})\,, \tag{3.1}$$

where the likelihood function ($\mathcal{L}$) depends on the free parameter ($y_{\rm mod}$) of the physics model. The likelihood function of a parameter with its central measured value (x_0), positive (negative)

3.2 Standard Model Predictions

The SM predictions for the electroweak observables measured by the LEP, SLC, and Tevatron experiments are implemented as a function of the floating fit parameters M_Z, M_H, m_t, $\overline{m_b}$, $\overline{m_c}$, $\Delta\alpha^5_{\rm had}(M_Z^2)$, and $\alpha_s(M_Z^2)$. The predictions of the effective weak mixing angle and the W mass are the most important ones in order to constrain the mass of the Higgs boson. For the W mass eq. (6) and the coefficients of eq. (8) from [50] have been implemented. The calculation contains the full two-loop and leading beyond-two-loop corrections. The implementation of the effective weak mixing angle follows the full two-loop and leading beyond-two-loop computation of [51–53]. The asymmetry parameters can be computed by the effective weak mixing angle via

$$A_f = 2\frac{g_V^f/g_A^f}{1+(g_V^f/g_A^f)^2}\,, \tag{3.5}$$

where

$$\frac{g_V^f}{g_A^f} = 1 - 4|Q_f|\sin^2\theta^f_{\rm eff}\,. \tag{3.6}$$

The forward-backward asymmetry where the superscript '0' indicates that the observed values have been corrected for radiative effects and photon exchange, can be determined from the asymmetry parameters as follows

$$A_{\rm FB}^{0,f} = \frac{3}{4}A_e A_f\,. \tag{3.7}$$

Unlike the asymmetry parameters, the partial widths of the Z boson are defined inclusively, *i.e.* they contain all real and virtual corrections. They can be computed by[1]

$$\Gamma_Z^f = \frac{G_F M_Z^3}{6\sqrt{2}\pi}\left[(g_A^f)^2\left((1-4|Q_f|\sin^2\theta^f_{\rm eff})R_V^f + R_A^f\right) + \delta^f_{Im(\kappa^f)}R_V^f\right] + \Delta^f_{\rm EW/QCD}\,, \tag{3.8}$$

where G_F is the Fermi constant. For the analysis presented in this thesis, the vector and axial-vector couplings (g_A^f and g_V^f) are implemented using the parametrizations of [55–58], which are computed at one-loop level and partly at two-loop level for $\mathcal{O}(\alpha\alpha_s)$.[2] To account for a different Higgs mass dependence of the parametrizations and ZFITTER at large Higgs masses ($M_H \gtrsim 500$ GeV), a quadratic correction is added to $(\Delta T_Z)_{\rm SM}$ of eq. (23b) in [58] (for further explanation of the T parameter see chapter 4)

$$(\Delta T_Z)_{\rm SM,Corr} = \begin{cases} 0 & \text{if } M_H \le 200 \text{ GeV}, \\ 0.00764(x_h - x_{h,200}) - 0.112(x_h - x_{h,200})^2 & \text{if } M_H > 200 \text{ GeV}, \end{cases} \tag{3.9}$$

where $x_h = \log(M_H/100\text{ GeV})$ and $x_{h,200} = \log(200/100)$.[3] This correction factor does not affect the electroweak SM fit, but it slightly influences the constraints on new physics parameters (*cf.* chapter 4). The term $\delta^f_{Im(\kappa^f)}$ in eq. (3.8) represents the corrections from the imaginary part

[1] See for instance [54] and [55–58].

[2] The above mentioned Gfitter publications use the implementations from ZFITTER [35, 36], which contains up to two-loop electroweak corrections [35, 36, 43, 54, 59–66] and all known QCD corrections [35, 36, 67].

[3] The coefficients are determined by comparing the values of the T parameter computed with eq. (23b) of [58] and with the Fortran ZFITTER package [35, 36] (version 6.42 [68]).

Gaussian error $\sigma^+_{\rm Gauss}$ ($\sigma^-_{\rm Gauss}$), and positive (negative) theoretical error $\sigma^+_{\rm theo}$ ($\sigma^-_{\rm theo}$), for a given set of $y_{\rm mod}$ parameters and the theoretical prediction $f(y_{\rm mod})$ is given by[1]

$$-2\ln\mathcal{L}(y_{\rm mod}) = \begin{cases} 0\,, & \text{if: } -\sigma^-_{\rm theo} \le f(y_{\rm mod}) - x_0 \le \sigma^+_{\rm theo}\,, \\ \left(\frac{f(y_{\rm mod})-(x_0+\sigma^+_{\rm theo})}{\sigma^+_{\rm Gauss}}\right)^2\,, & \text{if: } f(y_{\rm mod}) - x_0 > \sigma^+_{\rm theo}\,, \\ \left(\frac{f(y_{\rm mod})-(x_0-\sigma^-_{\rm theo})}{\sigma^-_{\rm Gauss}}\right)^2\,, & \text{if: } x_0 - f(y_{\rm mod}) > \sigma^-_{\rm theo}\,. \end{cases} \tag{3.2}$$

Theoretical uncertainties are treated according to the *R*Fit scheme [45, 46], *i.e.* the theoretical prediction can freely vary within the range of the theoretical uncertainty without contributing to the χ^2 estimator. The final test statistics of the global fit is defined as the sum over all $-2\ln\mathcal{L}(y_{\rm mod})$ contributions from each observable. Correlations between measurements are considered properly in the likelihood function.

In addition, it is possible to introduce dependencies among parameters in Gfitter, which can be used to parametrize correlations due to common systematic errors, or to rescale parameter values and errors with newly available results for parameters on which other parameters depend (rescaling mechanism).

For the parameter estimation the offset-corrected test statistics is used

$$\Delta\chi^2(y_{\rm mod}) = \chi^2(y_{\rm mod}) - \chi^2_{\rm min}(y_{\rm mod})\,, \tag{3.3}$$

where $\chi^2_{\rm min}(y_{\rm mod})$ is the absolute minimum of the test statistics. The minimum value of $\Delta\chi^2$ is zero, by construction. This ensures that, consistent with the assumption that the model is correct, exclusion confidence levels (CL) equal to zero are obtained when exploring the $y_{\rm mod}$ space.[2] The CL is computed for a Gaussian problem by

$$\text{CL} = 1 - \text{Prob}(\Delta\chi^2, n_{\rm dof})\,, \tag{3.4}$$

where $n_{\rm dof}$ is the number of degrees of freedom of the offset-corrected $\Delta\chi^2$. In case of a non-Gaussian problem a toy Monte Carlo analysis is required to estimate the CL. For the electroweak SM fit no significant deviations between the toy Monte Carlo analysis and eq. (3.4) are observed [1].

The p-value is an estimator for the goodness of the fit. It quantifies the probability of wrongly rejecting the theoretical hypothesis. For a Gaussian problem the p-value is compute by $\text{Prob}(\Delta\chi^2, n_{\rm dof})$. In case of the electroweak fit, this naive p-value determinations have been confirmed with Monte Carlo toy experiments [1, 47].

In Gfitter the minimization of the test statistics is performed by TMinuit [48]. In addition, more involved global minima finders are used: Genetic Algorithm and Simulated Annealing, which are available with the TMVA [49] package in ROOT [2].

[1] The central value x_0 corresponds to the value with the largest likelihood, which is not necessarily equal to the arithmetic average in case of asymmetric errors.

[2] Throughout this thesis the term confidence level denotes 1 minus the p-value of a given $\Delta\chi^2$ (or χ^2) test statistics, and is hence a measure of the exclusion probability of a hypothesis. This is not to be confounded with a confidence interval, which expresses an inclusion probability.

[14] F. Englert and R. Brout, Broken symmmtry and the mass of gauge vector mesons, Phys. Rev. Lett. **13**, 321 (1964).

[15] WMAP Collaboration, E. Komatsu *et al.*, Seven-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Cosmological Interpretation, Astrophys.J.Suppl. **192**, 18 (2011), `1001.4538`.

[16] U. Baur, S. Keller, and W. K. Sakumoto, Qed radiative corrections to z boson production and the forward backward asymmetry at hadron colliders, Phys. Rev. D **57**, 199. 53 p (Jul, 1997).

[17] U. Baur, O. Brein, W. F. L. Hollik, C. Schappacher, and D. Wackeroth, Electroweak radiative corrections to neutral-current drell-yan processes at hadron colliders, Phys. Rev. D **65**, 033007. 39 p (Aug, 2001).

[18] ALEPH Collaboration, DELPHI Collaboration, L3 Collaboration, OPAL Collaboration, SLD Collaboration, LEP Electroweak Working Group, SLD Electroweak Group, SLD Heavy Flavour Group, Precision electroweak measurements on the Z resonance, Phys.Rept. **427**, 257 (2006), `hep-ex/0509008`.

[19] S. Bennett and C. E. Wieman, Measurement of the 6S –¿ 7S transition polarizability in atomic cesium and an improved test of the Standard Model, Phys.Rev.Lett. **82**, 2484 (1999), `hep-ex/9903022`.

[20] SLAC E158 Collaboration, P. Anthony *et al.*, Precision measurement of the weak mixing angle in Moller scattering, Phys.Rev.Lett. **95**, 081601 (2005), `hep-ex/0504049`.

[21] NuTeV Collaboration, G. Zeller *et al.*, A Precise determination of electroweak parameters in neutrino nucleon scattering, Phys.Rev.Lett. **88**, 091802 (2002), `hep-ex/0110059`.

[22] D0, V. M. Abazov *et al.*, Measurement of $sin^2\theta^{\rm lept}_{\rm eff}$ and Z-light quark couplings using the forward-backward charge asymmetry in $p\bar{p} \to Z/\gamma^* \to e^+e^-$ events with $L = 5.0$ fb^{-1} at $\sqrt{s} = 1.96$ TeV, (2011), `1104.4590`.

[23] CDF Collaboration, D. E. Acosta *et al.*, Measurement of the forward-backward charge asymmetry of electron positron pairs in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, Phys.Rev. **D71**, 052002 (2005), `hep-ex/0411059`.

[24] CMS Collaboration, Forward-backward asymmetry of di-lepton pairs and the weak-mixing angle, (2011), CMS-PAS-EWK-10-011.

[25] S. Drell and T.-M. Yan, Massive Lepton Pair Production in Hadron-Hadron Collisions at High-Energies, Phys.Rev.Lett. **25**, 316 (1970).

[26] S. Drell and T.-M. Yan, Partons and their Applications at High-Energies, Annals Phys. **66**, 578 (1971).

Bibliography

[1] H. Flacher *et al.*, Revisiting the Global Electroweak Fit of the Standard Model and Beyond with Gfitter, Eur.Phys.J. **C60**, 543 (2009), (note erratum http://www.springerlink.com/content/j0535mg347173up4/), `0811.0009`.

[2] R. Brun and F. Rademakers, Root: An object oriented data analysis framework, Nucl. Instrum. Meth. **A389**, 81 (1997).

[3] M. E. Peskin and T. Takeuchi, A New constraint on a strongly interacting Higgs sector, Phys. Rev. Lett. **65**, 964 (1990).

[4] M. E. Peskin and T. Takeuchi, Estimation of oblique electroweak corrections, Phys. Rev. **D46**, 381 (1992).

[5] T. Sjostrand, S. Mrenna, and P. Z. Skands, A Brief Introduction to PYTHIA 8.1, Comput.Phys.Commun. **178**, 852 (2008), `0710.3820`.

[6] Wikipedia, Elementary particle interactions, July, 2011, http://en.wikipedia.org/wiki/File:Elementary_particle_interactions.svg.

[7] H. Fritzsch, M. Gell-Mann, and H. Leutwyler, Advantages of the Color Octet Gluon Picture, Phys.Lett. **B47**, 365 (1973), Introduces the term 'color'.

[8] R. Ellis, W. Stirling, and B. Webber, QCD and collider physics, Camb.Monogr.Part.Phys.Nucl.Phys.Cosmol. **8**, 1 (1996).

[9] S. L. Glashow, Partial symmetries of weak interactions, Nucl. Phys. **22**, 579 (1961).

[10] A. Salam, Weak and electromagnetic interactions, Originally printed in Svartholm: Elementary Particle Theory, Proceedings Of The Nobel Symposium Held 1968 At Lerum, Sweden*, Stockholm 1968, 367-377.

[11] S. Weinberg, A model of leptons, Phys. Rev. Lett. **19**, 1264 (1967).

[12] P. W. Higgs, Broken symmetries and the masses of gauge bosons, Phys. Rev. Lett. **13**, 508 (1964).

[13] P. W. Higgs, Broken symmetries, massless particles and gauge fields, Phys. Lett. **12**, 132 (1964).

[42] J. Erler and P. Langacker (in: Review for Particle Data Group), Review of particle physics, J. Phys. **G37**, 075021 (2010).

[43] Electroweak working group, D. Y. Bardin *et al.*, Electroweak working group report, (1997), Prepared for Workshop Group on Precision Calculations for the Z Resonance (2nd meeting held Mar 31, 3rd meeting held Jun 13), Geneva, Switzerland, 14 Jan 1994, CERN-YELLOW-95-03A, `hep-ph/9709229`.

[44] LEP Electroweak Working Group (LEP EWWG), Status of July 2010, http://lepewwg.web.cern.ch/LEPEWWG/.

[45] A. Hoecker, H. Lacker, S. Laplace, and F. Le Diberder, A new approach to a global fit of the ckm matrix, Eur. Phys. J. **C21**, 225 (2001), `hep-ph/0104062`.

[46] CKMfitter Group, J. Charles *et al.*, CP violation and the CKM matrix: Assessing the impact of the asymmetric B factories, Eur. Phys. J. **C41**, 1 (2005), `hep-ph/0406184`.

[47] M. Goebel, A global standard model fit at the electroweak scale, Diploma thesis, University Hamburg, 2008.

[48] F. James and M. Roos, Minuit: A system for function minimization and analysis of the parameter errors and correlations, Comput. Phys. Commun. **10**, 343 (1975).

[49] A. Hoecker *et al.*, Tmva: Toolkit for multivariate data analysis, (2007), CERN-OPEN-2007-007, `physics/0703039`.

[50] M. Awramik, M. Czakon, A. Freitas, and G. Weiglein, Precise prediction for the W-boson mass in the standard model, Phys. Rev. **D69**, 053006 (2004), `hep-ph/0311148`.

[51] M. Awramik, M. Czakon, A. Freitas, and G. Weiglein, Complete two-loop electroweak fermionic corrections to $\sin^2\theta_{\rm eff}^{\rm lept}$ and indirect determination of the Higgs boson mass, Phys. Rev. Lett. **93**, 201805 (2004), `hep-ph/0407317`.

[52] M. Awramik, M. Czakon, and A. Freitas, Electroweak two-loop corrections to the effective weak mixing angle, JHEP **11**, 048 (2006), `hep-ph/0608099`.

[53] M. Awramik, M. Czakon, A. Freitas, and B. Kniehl, Two-loop electroweak fermionic corrections to $\sin^2\theta_{\rm eff}^{b\bar{b}}$, Nucl.Phys. **B813**, 174 (2009), `0811.1364`.

[54] D. Y. Bardin and G. Passarino, The standard model in the making: Precision study of the electroweak interactions, Oxford, UK: Clarendon (1999) 685 p.

[55] K. Hagiwara, S. Matsumoto, D. Haidt, and C. Kim, A Novel approach to confront electroweak data and theory, Z.Phys. **C64**, 559 (1994), Order of authors changed in journal, `hep-ph/9409380`.

[56] K. Hagiwara, Electroweak studies at Z factories, Ann.Rev.Nucl.Part.Sci. **48**, 463 (1998).

[27] H1 and ZEUS, HERA Combined Results, July, 2011, https://www.desy.de/h1zeus/combined_results/index.php?do=proton_structure.

[28] V. Gribov and L. Lipatov, Deep inelastic e p scattering in perturbation theory, Sov.J.Nucl.Phys. **15**, 438 (1972).

[29] G. Altarelli and G. Parisi, Asymptotic Freedom in Parton Language, Nucl.Phys. **B126**, 298 (1977).

[30] Y. L. Dokshitzer, Calculation of the Structure Functions for Deep Inelastic Scattering and e+ e- Annihilation by Perturbation Theory in Quantum Chromodynamics., Sov.Phys.JETP **46**, 641 (1977).

[31] E. Kuraev, L. Lipatov, and V. S. Fadin, The Pomeranchuk Singularity in Nonabelian Gauge Theories, Sov.Phys.JETP **45**, 199 (1977).

[32] I. Balitsky and L. Lipatov, The Pomeranchuk Singularity in Quantum Chromodynamics, Sov.J.Nucl.Phys. **28**, 822 (1978).

[33] A. D. Martin, R. G. Roberts, W. J. Stirling, and R. S. Thorne, Parton distributions and the LHC: W and Z production, Eur. Phys. J. **C14**, 133 (2000), `hep-ph/9907231`.

[34] M. Baak *et al.*, Updated Status of the Global Electroweak Fit and Constraints on New Physics, (2011), * Temporary entry *, `1107.0975`.

[35] D. Y. Bardin *et al.*, ZFITTER v.6.21: A semi-analytical program for fermion pair production in e^+e^- annihilation, Comput. Phys. Commun. **133**, 229 (2001), `hep-ph/9908433`.

[36] A. B. Arbuzov *et al.*, ZFITTER: A semi-analytical program for fermion pair production in e^+e^- annihilation, from version 6.21 to version 6.42, Comput. Phys. Commun. **174**, 728 (2006), `hep-ph/0507146`.

[37] G. Montagna, F. Piccinini, O. Nicrosini, G. Passarino, and R. Pittau, TOPAZ0: A Program for computing observables and for fitting cross-sections and forward - backward asymmetries around the Z0 peak, Comput.Phys.Commun. **76**, 328 (1993).

[38] G. Montagna, O. Nicrosini, F. Piccinini, and G. Passarino, TOPAZ0 4.0: A New version of a computer program for evaluation of deconvoluted and realistic observables at LEP-1 and LEP-2, Comput.Phys.Commun. **117**, 278 (1999), `hep-ph/9804211`.

[39] V. Novikov, L. Okun, A. N. Rozanov, and M. Vysotsky, LEPTOP, (1995), `hep-ph/9503308`.

[40] V. A. Novikov, L. B. Okun, A. N. Rozanov, and M. I. Vysotsky, Mass of the Higgs versus fourth generation masses, JETP Lett. **76**, 127 (2002), `hep-ph/0203132`.

[41] J. Erler, Global fits to electroweak data using GAPP, (1999), `hep-ph/0005084`.

[72] Tevatron Electroweak Working Group and CDF and D0 Collaborations, Updated Combination of CDF and D0 Results for the Mass of the W Boson, (2009), `arxiv:0908.1374`.

[73] Tevatron Electroweak Working Group, Combination of CDF and D0 Results on the Width of the W boson, (2010), `arxiv:1003.2826`.

[74] T. E. W. Group, Combination of CDF and DO results on the mass of the top quark using up to 5.8 fb-1 of data, (2011), * Temporary entry *, `1107.5255`.

[75] M. Davier, A. Hoecker, B. Malaescu, and Z. Zhang, Reevaluation of the Hadronic Contributions to the Muon g-2 and to alpha(MZ), Eur. Phys. J. **C71**, 1515 (2011), `arxiv:1010.4180`.

[76] The ALEPH, DELPHI, L3 and OPAL Collaborations, and LEP Working Group for Higgs Boson Searches, R. Barate *et al.*, Search for the standard model Higgs boson at LEP, Phys. Lett. **B565**, 61 (2003), `hep-ex/0306033`.

[77] T. CDF, D. Collaborations, t. T. N. Phenomena, and H. W. Group, Combined CDF and D0 Upper Limits on Standard Model Higgs Boson Production with up to 8.6 fb-1 of Data, (2011), * Temporary entry *, `1107.5518`.

[78] ATLAS Collaboration, G. Aad *et al.*, Limits on the production of the Standard Model Higgs Boson in pp collisions at sqrt(s) =7 TeV with the ATLAS detector, (2011), CERN-PH-EP-2011-076 (2011), `arxiv:1106.2748`.

[79] CMS Collaboration, S. Chatrchyan *et al.*, Measurement of WW Production and Search for the Higgs Boson in pp Collisions at sqrt(s) = 7 TeV, Phys. Lett. **B699**, 25 (2011), `arxiv:1102.5429`.

[80] ATLAS Colaboration, Update of the Combination of Higgs Boson Searches in 1.0 to 2.3 fb^{-1} of pp Collisions Data Taken at $\sqrt{7} = 7$ TeV with the ATLAS Experiment at the LHC, (Aug, 2011).

[81] CMS Colaboration, Combination of Higgs Searches, (Aug, 2011).

[82] Particle Data Group, K. Nakamura *et al.*, Review of particle physics, J.Phys.G **G37**, 075021 (2010).

[83] P. Skands and D. Wicke, Non-perturbative QCD effects and the top mass at the Tevatron, Eur. Phys. J. **C52**, 133 (2007), `hep-ph/0703081`.

[84] D. Wicke and P. Z. Skands, Non-perturbative QCD Effects and the Top Mass at the Tevatron, (2008), `arxiv:0807.3248`.

[85] A. H. Hoang, A. Jain, I. Scimemi, and I. W. Stewart, Infrared Renormalization Group Flow for Heavy Quark Masses, (2008), `arxiv:0803.4214`.

[57] G.-C. Cho and K. Hagiwara, Supersymmetry versus precision experiments revisited, Nucl.Phys. **B574**, 623 (2000), `hep-ph/9912260`.

[58] G.-C. Cho, K. Hagiwara, Y. Matsumoto, and D. Nomura, The MSSM confronts the precision electroweak data and the muon g-2, (2011), * Temporary entry *, `1104.1769`.

[59] A. A. Akhundov, D. Y. Bardin, and T. Riemann, Electroweak One Loop Corrections to the Decay of the Neutral Vector Boson, Nucl. Phys. **B276**, 1 (1986).

[60] D. Y. Bardin, S. Riemann, and T. Riemann, Electroweak one loop corrections to the decay of the charged vector boson, Z. Phys. **C32**, 121 (1986).

[61] R. Barbieri, M. Beccaria, P. Ciafaloni, G. Curci, and A. Vicere, Two loop heavy top effects in the standard model, Nucl. Phys. **B409**, 105 (1993).

[62] J. Fleischer, O. V. Tarasov, and F. Jegerlehner, Two loop heavy top corrections to the rho parameter: A simple formula valid for arbitrary higgs mass, Phys. Lett. **B319**, 249 (1993).

[63] G. Degrassi, S. Fanchiotti, F. Feruglio, B. P. Gambino, and A. Vicini, Two loop electroweak top corrections: Are they under control?, Phys. Lett. **B350**, 75 (1995), `hep-ph/9412380`.

[64] G. Degrassi, F. Feruglio, A. Vicini, S. Fanchiotti, and P. Gambino, Two-loop corrections for electroweak processes, (1995), `hep-ph/9507286`.

[65] G. Degrassi, P. Gambino, and A. Vicini, Two-loop heavy top effects on the mz-mw interdependence, Phys. Lett. **B383**, 219 (1996), `hep-ph/9603374`.

[66] G. Degrassi and P. Gambino, Two-loop heavy top corrections to the z0 boson partial widths, Nucl. Phys. **B567**, 3 (2000), `hep-ph/9905472`.

[67] B. A. Kniehl, Two Loop Corrections to the Vacuum Polarizations in Perturbative QCD, Nucl. Phys. **B347**, 86 (1990).

[68] ZFITTER Code (version 6.42), July, 2011, /afs/cern.ch/user/b/bardindy/public/ZF6_42.

[69] P. A. Baikov, K. G. Chetyrkin, and J. H. Kuhn, Order α_s^4 QCD Corrections to Z and τ Decays, Phys. Rev. Lett. **101**, 012002 (2008), `arxiv:0801.1821`.

[70] A. Czarnecki and J. H. Kühn, Nonfactorizable qcd and electroweak corrections to the hadronic z boson decay rate, Phys. Rev. Lett. **77**, 3955 (1996), `hep-ph/9608366`.

[71] R. Harlander, T. Seidensticker, and M. Steinhauser, Complete corrections of o(alpha alpha(s)) to the decay of the z boson into bottom quarks, Phys. Lett. **B426**, 125 (1998), `hep-ph/9712228`.

[102] R. Sundrum and S. D. Hsu, Walking technicolor and electroweak radiative corrections, Nucl.Phys. **B391**, 127 (1993), `hep-ph/9206225`.

[103] C. P. Burgess, S. Godfrey, H. Konig, D. London, and I. Maksymyk, Model independent global constraints on new physics, Phys. Rev. **D49**, 6115 (1994), `hep-ph/9312291`.

[104] N. G. Deshpande and E. Ma, Pattern of Symmetry Breaking with Two Higgs Doublets, Phys. Rev. **D18**, 2574 (1978).

[105] R. Barbieri, L. J. Hall, and V. S. Rychkov, Improved naturalness with a heavy Higgs: An alternative road to LHC physics, Phys. Rev. **D74**, 015007 (2006), `hep-ph/0603188`.

[106] L. Lopez Honorez, E. Nezri, J. F. Oliver, and M. H. G. Tytgat, The inert doublet model: An archetype for dark matter, JCAP **0702**, 028 (2007), `hep-ph/0612275`.

[107] M. Gustafsson, E. Lundstrom, L. Bergstrom, and J. Edsjo, Significant gamma lines from inert Higgs dark matter, Phys. Rev. Lett. **99**, 041301 (2007), `astro-ph/0703512`.

[108] E. Lundstrom, M. Gustafsson, and J. Edsjo, The Inert Doublet Model and LEP II Limits, Phys. Rev. **D79**, 035013 (2009), `0810.3924`.

[109] T. Hambye, F. S. Ling, L. Lopez Honorez, and J. Rocher, Scalar Multiplet Dark Matter, JHEP **07**, 090 (2009), `0903.4010`.

[110] S. Andreas, M. H. Tytgat, and Q. Swillens, Neutrinos from Inert Doublet Dark Matter, JCAP **0904**, 004 (2009), `0901.1750`.

[111] E. M. Dolle and S. Su, The Inert Dark Matter, Phys. Rev. **D80**, 055012 (2009), `0906.1609`.

[112] L. Lopez Honorez and C. E. Yaguna, The inert doublet model of dark matter revisited, JHEP **09**, 046 (2010), `1003.3125`.

[113] L. Lopez Honorez and C. E. Yaguna, A new viable region of the inert doublet model, JCAP **1101**, 002 (2011), `1011.1411`.

[114] B. Holdom *et al.*, Four Statements about the Fourth Generation, PMC Phys. **A3**, 4 (2009), `0904.4698`.

[115] B. Holdom, Approaching a strong fourth family, Phys.Lett. **B686**, 146 (2010), * Temporary entry *, `1001.5321`.

[116] W.-S. Hou, CP Violation and Baryogenesis from New Heavy Quarks, Chin. J. Phys. **47**, 134 (2009), `0803.1234`.

[117] K. Belotsky, M. Khlopov, and K. Shibaev, Stable quarks of the 4th family?, (2008), * Brief entry *, `0806.1067`.

[86] A. H. Hoang and I. W. Stewart, Top Mass Measurements from Jets and the Tevatron Top-Quark Mass, (2008), `arxiv:0808.0222`.

[87] D0 Collaboration, V. M. Abazov *et al.*, Determination of the pole and MSbar masses of the top quark from the ttbar cross section, (2011), `arxiv:1104.2887`.

[88] D0 Collaboration, V. M. Abazov *et al.*, Measurement of the top quark pair production cross section in the lepton+jets channel in proton-antiproton collisions at $\sqrt{s}$=1.96 TeV, (2011), `arxiv:1101.0124`.

[89] U. Langenfeld, S. Moch, and P. Uwer, Measuring the running top-quark mass, Phys. Rev. **D80**, 054009 (2009), `arxiv:0906.5273`.

[90] K. Hagiwara, R. Liao, A. D. Martin, D. Nomura, and T. Teubner, $(g-2)_\mu$ and $\alpha(M_Z^2)$ re-evaluated using new precise data, J. Phys. **G38**, 085003 (2011), `1105.3149`.

[91] M. Davier, S. Descotes-Genon, A. Hocker, B. Malaescu, and Z. Zhang, The Determination of alpha(s) from Tau Decays Revisited, Eur.Phys.J. **C56**, 305 (2008), `0803.0979`.

[92] CDF and D0 Collaborations, Combination of CDF and D0 Results on the Mass of the Top Quark, (2010), `arxiv:1007.3178`.

[93] G. Altarelli, R. Barbieri, and F. Caravaglios, Nonstandard analysis of electroweak precision data, Nucl. Phys. **B405**, 3 (1993).

[94] G. Altarelli, R. Barbieri, and F. Caravaglios, Electroweak precision tests: A concise review, Int. J. Mod. Phys. **A13**, 1031 (1998), `hep-ph/9712368`.

[95] C. P. Burgess, S. Godfrey, H. Konig, D. London, and I. Maksymyk, A Global fit to extended oblique parameters, Phys. Lett. **B326**, 276 (1994), `hep-ph/9307337`.

[96] R. Barbieri, A. Pomarol, R. Rattazzi, and A. Strumia, Electroweak symmetry breaking after LEP-1 and LEP-2, Nucl. Phys. **B703**, 127 (2004), `hep-ph/0405040`.

[97] C. P. Burgess, The Effective use of precision electroweak measurements, Pramana **45**, S47 (1995), `hep-ph/9411257`.

[98] S. Weinberg, Implications of Dynamical Symmetry Breaking: An Addendum, Phys.Rev. **D19**, 1277 (1979), (For original paper see Phys.Rev.D13:974-996,1976).

[99] L. Susskind, Dynamics of Spontaneous Symmetry Breaking in the Weinberg-Salam Theory, Phys.Rev. **D20**, 2619 (1979).

[100] J. R. Ellis, G. L. Fogli, and E. Lisi, Technicolor and precision electroweak data revisited, Phys.Lett. **B343**, 282 (1995).

[101] M. Golden and L. Randall, Radiative corrections to electrweak parameters in technicolor theories, Nucl. Phys. **B361**, 3 (1991).

[132] M. Bobrowski, A. Lenz, J. Riedl, and J. Rohrwild, How much space is left for a new family of fermions?, Phys. Rev. **D79**, 113006 (2009), `arxiv:0902.4883`.

[133] A. Soni, A. K. Alok, A. Giri, R. Mohanta, and S. Nandi, SM with four generations: Selected implications for rare B and K decays, Phys. Rev. **D82**, 033009 (2010), `arxiv:1002.0595`.

[134] A. J. Buras *et al.*, Patterns of Flavour Violation in the Presence of a Fourth Generation of Quarks and Leptons, JHEP **09**, 106 (2010), `arxiv:1002.2126`.

[135] H. Lacker and A. Menzel, Simultaneous Extraction of the Fermi constant and PMNS matrix elements in the presence of a fourth generation, JHEP **07**, 006 (2010), `arxiv:1003.4532`.

[136] J. Erler and P. Langacker, Precision Constraints on Extra Fermion Generations, Phys. Rev. Lett. **105**, 031801 (2010), `arxiv:1003.3211`.

[137] P. H. Frampton, P. Q. Hung, and M. Sher, Quarks and leptons beyond the third generation, Phys. Rept. **330**, 263 (2000), `hep-ph/9903387`.

[138] CDF and D0 Collaborations, T. Aaltonen *et al.*, Combined Tevatron upper limit on gg-¿H-¿W+W- and constraints on the Higgs boson mass in fourth-generation fermion models, (2010), `arxiv:1005.3216`.

[139] CMS Colaboration, SM Higgs Combination, (Jul, 2011).

[140] B. Holdom, Negative T from a dynamical left-handed neutrino mass, Phys.Rev. **D54**, 721 (1996), `hep-ph/9602248`.

[141] H.-J. He, N. Polonsky, and S.-f. Su, Extra families, Higgs spectrum and oblique corrections, Phys. Rev. **D64**, 053004 (2001), `hep-ph/0102144`.

[142] B. Holdom, The Discovery of the fourth family at the LHC: What if?, JHEP **0608**, 076 (2006), `hep-ph/0606146`.

[143] G. D. Kribs, T. Plehn, M. Spannowsky, and T. M. P. Tait, Four generations and Higgs physics, Phys. Rev. **D76**, 075016 (2007), `arxiv:0706.3718`.

[144] M. S. Chanowitz, Bounding CKM Mixing with a Fourth Family, Phys. Rev. **D79**, 113008 (2009), `arxiv:0904.3570`.

[145] M. S. Chanowitz, Higgs Mass Constraints on a Fourth Family: Upper and Lower Limits on CKM Mixing, Phys.Rev. **D**, 035018 (2010), `arxiv:1007.0043`.

[146] M. Hashimoto, Constraints on Mass Spectrum of Fourth Generation Fermions and Higgs Bosons, Phys.Rev. **D81**, 075023 (2010), `arxiv:1001.4335`.

[118] ATLAS Collaboration, Search for Fourth Generation Quarks Decaying to $W^+qW^-q \to l^+l^-\nu\nu qq$ in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS Detector, ATLAS-CONF-2011-022 (2011).

[119] CMS Collaboration, S. Chatrchyan *et al.*, Search for a Heavy Bottom-like Quark in pp Collisions at sqrt(s) = 7 TeV, Phys. Lett. **B701**, 204 (2011), `1102.4746`.

[120] CDF Collaboration, J. Conway *et al.*, CDF/PUB/TOP/PUBLIC/10395 (2011).

[121] CDF Collaboration, T. Aaltonen *et al.*, Search for heavy bottom-like quarks decaying to an electron or muon and jets in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, (2011), `arxiv:1101.5728`.

[122] C. J. Flacco, D. Whiteson, and M. Kelly, Fourth generation quark mass limits in CKM-element space, (2011), `arxiv:1101.4976`.

[123] C. J. Flacco, D. Whiteson, T. M. P. Tait, and S. Bar-Shalom, Direct Mass Limits for Chiral Fourth-Generation Quarks in All Mixing Scenarios, Phys. Rev. Lett. **105**, 111801 (2010), `arxiv:1005.1077`.

[124] L3 Collaboration, P. Achard *et al.*, Search for heavy neutral and charged leptons in e+ e- annihilation at LEP, Phys. Lett. **B517**, 75 (2001), `hep-ex/0107015`.

[125] A. Arhrib and W.-S. Hou, Effect of fourth generation CP phase on $b \to s$ transitions, Eur. Phys. J. **C27**, 555 (2003), `hep-ph/0211267`.

[126] W.-S. Hou, M. Nagashima, and A. Soddu, Large time-dependent CP violation in B_s^0 system and finite D^0 - $\bar{D}^0$ mass difference in four generation standard model, Phys. Rev. **D76**, 016004 (2007), `hep-ph/0610385`.

[127] W.-S. Hou, M. Nagashima, and A. Soddu, Enhanced $K(L) \to \pi^0\nu\bar{\nu}$ from direct CP violation in $B \to K\pi$ with four generations, Phys. Rev. **D72**, 115007 (2005), `hep-ph/0508237`.

[128] W.-S. Hou, H.-n. Li, S. Mishima, and M. Nagashima, Fourth generation CP violation effect on $B \to K\pi$, ϕK and ρK in NLO PQCD, Phys. Rev. Lett. **98**, 131801 (2007), `hep-ph/0611107`.

[129] A. Soni, A. K. Alok, A. Giri, R. Mohanta, and S. Nandi, The Fourth family: A Natural explanation for the observed pattern of anomalies in B^- CP asymmetries, Phys. Lett. **B683**, 302 (2010), `arxiv:0807.1971`.

[130] F. J. Botella, G. C. Branco, and M. Nebot, Small violations of 3 x 3 unitarity, the phase in B0(S) - anti-B0(S) mixing and visible $t \to cZ$ decays at the LHC, J. Phys. Conf. Ser. **171**, 012058 (2009).

[131] O. Eberhardt, A. Lenz, and J. Rohrwild, Less space for a new family of fermions, Phys. Rev. **D82**, 095006 (2010), `arxiv:1005.3505`.

[163] M. Shifman, LARGE EXTRA DIMENSIONS: Becoming acquainted with an alternative paradigm, Int. J. Mod. Phys. **A25**, 199 (2010), `0907.3074`.

[164] D. J. Kapner *et al.*, Tests of the gravitational inverse-square law below the dark-energy length scale, Phys. Rev. Lett. **98**, 021101 (2007), `hep-ph/0611184`.

[165] Particle Data Group, G. F. Giudice and J. D. Wells, Extra dimensions (in: Review of particle physics), J. Phys. **G37**, 075021 (2010).

[166] S. Hannestad and G. G. Raffelt, Stringent neutron-star limits on large extra dimensions, Phys. Rev. Lett. **88**, 071301 (2002), `hep-ph/0110067`.

[167] G. F. Giudice, R. Rattazzi, and J. D. Wells, Quantum gravity and extra dimensions at high-energy colliders, Nucl. Phys. **B544**, 3 (1999), `hep-ph/9811291`.

[168] T. Han, J. D. Lykken, and R.-J. Zhang, On Kaluza-Klein states from large extra dimensions, Phys. Rev. **D59**, 105006 (1999), `hep-ph/9811350`.

[169] J. L. Hewett, Indirect collider signals for extra dimensions, Phys. Rev. Lett. **82**, 4765 (1999), `hep-ph/9811356`.

[170] G. F. Giudice and A. Strumia, Constraints on extra dimensional theories from virtual graviton exchange, Nucl. Phys. **B663**, 377 (2003), `hep-ph/0301232`.

[171] R. Contino, L. Pilo, R. Rattazzi, and A. Strumia, Graviton loops and brane observables, JHEP **06**, 005 (2001), `hep-ph/0103104`.

[172] G. Landsberg, Collider Searches for Extra Spatial Dimensions and Black Holes, (2008), `arxiv:0808.1867`.

[173] S. Ask, Search for extra dimensions at LEP, (2004), `hep-ex/0410004`.

[174] CMS Collaboration, S. Chatrchyan *et al.*, Search for Large Extra Dimensions in the Diphoton Final State at the Large Hadron Collider, JHEP **05**, 085 (2011), `1103.4279`.

[175] ATLAS Collaboration, G. Aad *et al.*, Search for new phenomena with the monojet and missing transverse momentum signature using the ATLAS detector in sqrt(s) = 7 TeV proton-proton collisions, (2011), CERN-PH-EP-2011-090 (2011), `arxiv:1106.5327`.

[176] Muon G-2 Collaboration, G. W. Bennett *et al.*, Final report of the muon E821 anomalous magnetic moment measurement at BNL, Phys. Rev. **D73**, 072003 (2006), `hep-ex/0602035`.

[177] L. Evans and P. Bryant, LHC Machine, JINST **3**, S08001 (2008).

[178] O. S. Bruning *et al.*, LHC Design Report. 1. The LHC Main Ring, (2004).

[179] LHC Images, July, 2011, http://lhc-machine-outreach.web.cern.ch/lhc-machine-outreach/lhc_in_pictures.htm.

[147] N. Arkani-Hamed, A. G. Cohen, and H. Georgi, Electroweak symmetry breaking from dimensional deconstruction, Phys. Lett. **B513**, 232 (2001), `hep-ph/0105239`.

[148] N. Arkani-Hamed, A. G. Cohen, T. Gregoire, and J. G. Wacker, Phenomenology of electroweak symmetry breaking from theory space, JHEP **08**, 020 (2002), `hep-ph/0202089`.

[149] N. Arkani-Hamed, A. G. Cohen, E. Katz, and A. E. Nelson, The littlest Higgs, JHEP **07**, 034 (2002), `hep-ph/0206021`.

[150] C. Csaki, J. Hubisz, G. D. Kribs, P. Meade, and J. Terning, Big corrections from a little Higgs, Phys. Rev. **D67**, 115002 (2003), `hep-ph/0211124`.

[151] J. L. Hewett, F. J. Petriello, and T. G. Rizzo, Constraining the littlest Higgs. ((U)), JHEP **10**, 062 (2003), `hep-ph/0211218`.

[152] C. Csaki, J. Hubisz, G. D. Kribs, P. Meade, and J. Terning, Variations of little Higgs models and their electroweak constraints, Phys. Rev. **D68**, 035009 (2003), `hep-ph/0303236`.

[153] M. Perelstein, M. E. Peskin, and A. Pierce, Top quarks and electroweak symmetry breaking in little Higgs models, Phys. Rev. **D69**, 075002 (2004), `hep-ph/0310039`.

[154] T. Han, H. E. Logan, B. McElrath, and L.-T. Wang, Phenomenology of the little Higgs model, Phys. Rev. **D67**, 095004 (2003), `hep-ph/0301040`.

[155] H.-C. Cheng and I. Low, TeV symmetry and the little hierarchy problem, JHEP **09**, 051 (2003), `hep-ph/0308199`.

[156] H.-C. Cheng and I. Low, Little hierarchy, little Higgses, and a little symmetry, JHEP **08**, 061 (2004), `hep-ph/0405243`.

[157] J. Hubisz and P. Meade, Phenomenology of the littlest Higgs with T-parity, Phys. Rev. **D71**, 035016 (2005), `hep-ph/0411264`.

[158] J. Hubisz, P. Meade, A. Noble, and M. Perelstein, Electroweak precision constraints on the littlest Higgs model with T parity, JHEP **01**, 135 (2006), `hep-ph/0506042`.

[159] M. Asano, S. Matsumoto, N. Okada, and Y. Okada, Cosmic positron signature from dark matter in the littlest Higgs model with T-parity, Phys.Rev. **D75**, 063506 (2007), `hep-ph/0602157`.

[160] J. Casas, J. R. Espinosa, and I. Hidalgo, Implications for new physics from fine-tuning arguments. II. Little Higgs models, JHEP **0503**, 038 (2005), `hep-ph/0502066`.

[161] N. Arkani-Hamed, S. Dimopoulos, and G. R. Dvali, The hierarchy problem and new dimensions at a millimeter, Phys. Lett. **B429**, 263 (1998), `hep-ph/9803315`.

[162] I. Antoniadis, N. Arkani-Hamed, S. Dimopoulos, and G. R. Dvali, New dimensions at a millimeter to a Fermi and superstrings at a TeV, Phys. Lett. **B436**, 257 (1998), `hep-ph/9804398`.

[199] P. Bell *et al.*, CERN Report No. ATL-DAQ-PUB-2009-005, 2009 (unpublished).

[200] V. Lendermann *et al.*, Combining Triggers in HEP Data Analysis, Nucl.Instrum.Meth. **A604**, 707 (2009), `0901.4118`.

[201] ATLAS Collaboration, Atlas experiment - public results, July, 2011, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/WebHome.

[202] P. Waller, CERN Report No. ATL-DAPR-PROC-2010-001, 2010 (unpublished).

[203] ATLAS, G. Aad *et al.*, Luminosity Determination in pp Collisions at sqrt(s)=7 TeV Using the ATLAS Detector at the LHC, Eur. Phys. J. **C71**, 1630 (2011), `1101.2185`.

[204] P. Jenni and M. Nessi, CERN Report No. CERN-LHCC-2004-010. LHCC-I-014, 2004 (unpublished), revised version number 1 submitted on 2004-03-22 14:56:11.

[205] P. Jenni, M. Nordberg, M. Nessi, and K. Jon-And, *ATLAS Forward Detectors for Measurement of Elastic Scattering and Luminosity*, Technical Design Report (CERN, Geneva, 2008).

[206] H. Burkhardt and P. Grafstrm, Report No. LHC-PROJECT-Report-1019. CERN-LHC-PROJECT-Report-1019, 2007 (unpublished).

[207] W. Kozanecki *et al.*, Interaction-Point Phase-Space Characterization using Single-Beam and Luminous-Region Measurements at PEP-II, Nucl.Instrum.Meth. **A607**, 293 (2009).

[208] S. van der Meer, CERN Report No. CERN-ISR-PO-68-31. ISR-PO-68-31, 1968 (unpublished).

[209] CERN Report No. ATLAS-CONF-2011-011, 2011 (unpublished).

[210] M. Dobbs *et al.*, Les Houches guidebook to Monte Carlo generators for hadron collider physics, p. 411 (2004), Compiled by the Working Group on Quantum Chromodynamics and the Standard Model, `hep-ph/0403045`.

[211] A. Buckley *et al.*, General-purpose event generators for LHC physics, Physics Reports (2011), * Temporary entry *, `1101.2599`.

[212] M. Dobbs and J. B. Hansen, The HepMC C++ Monte Carlo event record for High Energy Physics, Comput.Phys.Commun. **134**, 41 (2001).

[213] HepMC, July, 2011, http://lcgapp.cern.ch/project/simu/HepMC/.

[214] B. Andersson, G. Gustafson, G. Ingelman, and T. Sjostrand, Parton Fragmentation and String Dynamics, Phys.Rept. **97**, 31 (1983).

[215] T. Sjostrand, Status of Fragmentation Models, Int.J.Mod.Phys. **A3**, 751 (1988).

[180] S. Catani *et al.*, QCD, (2000), `hep-ph/0005025`.

[181] ATLAS Collaboration, G. Aad *et al.*, The ATLAS Experiment at the CERN Large Hadron Collider, JINST **3**, S08003 (2008).

[182] A. Yamamoto *et al.*, Progress in ATLAS central solenoid magnet, IEEE-Trans.Appl.Supercond. **10**, 353 (2000).

[183] G. Aad *et al.*, ATLAS pixel detector electronics and sensors, JINST **3**, P07007 (2008).

[184] A. Abdesselam *et al.*, The barrel modules of the ATLAS semiconductor tracker, Nucl.Instrum.Meth. **A568**, 642 (2006).

[185] E. Abat *et al.*, The ATLAS TRT end-cap detectors, JINST **3**, P10003 (2008).

[186] ATLAS TRT Collaboration, E. Abat *et al.*, The ATLAS TRT barrel detector, JINST **3**, P02014 (2008).

[187] ATLAS Collaboration, ATLAS liquid argon calorimeter: Technical design report, (1996).

[188] A. Artamonov *et al.*, The ATLAS forward calorimeters, JINST **3**, P02010 (2008).

[189] The ATLAS Collaboration, G. Aad *et al.*, Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics, (2009), `0901.0512`.

[190] CERN Report No. ATL-PHYS-PUB-2011-006, 2011 (unpublished).

[191] W. Lampl *et al.*, CERN Report No. ATL-LARG-PUB-2008-002. ATL-COM-LARG-2008-003, 2008 (unpublished).

[192] ATLAS Collaboration, Electron performance measurements with the atlas detector in 2010 lhc proton-proton collision data, in preparation .

[193] ATLAS Collaboration, Performance of the atlas trigger system in 2010, in preparation .

[194] *ATLAS level-1 trigger: Technical Design Report*Technical Design Report ATLAS (CERN, Geneva, 1998).

[195] P. Jenni, M. Nessi, M. Nordberg, and K. Smith, *ATLAS high-level trigger, data-acquisition and controls: Technical Design Report*Technical Design Report ATLAS (CERN, Geneva, 2003).

[196] ATLAS Collaboration, CERN Report No. ATLAS-CONF-2011-114, 2011 (unpublished).

[197] T. Fonseca-Martin *et al.*, Event reconstruction algorithms for the atlas trigger, J. Phys.: Conf. Ser. **119**, 022022 (2008).

[198] A. Hocker *et al.*, Overview of the High Level Trigger Steering and Selection for the ATLAS experiment at the LHC, IEEE Trans.Nucl.Sci. **55**, 165 (2008).

[232] J. C. Collins and D. E. Soper, Angular Distribution of Dileptons in High-Energy Hadron Collisions, Phys.Rev. **D16**, 2219 (1977).

[233] ATLAS, CERN Report No. ATL-PHYS-PUB-2009-037. ATL-COM-PHYS-2009-099, 2009 (unpublished), CSC note.

[234] H. Yin, Measurement of the Forward-Backward Charge Asymmetry(A_{FB}) using $p\bar{p} \rightarrow Z/\gamma^* \rightarrow e^+e^-$ events in $\sqrt{s} = 1.96$ TeV, (2010), Ph.D. Thesis (advisor: Liang Han).

[235] H.-L. Lai *et al.*, New parton distributions for collider physics, Phys. Rev. **D82**, 074024 (2010), `1007.2241`.

[236] S. Alioli, P. Nason, C. Oleari, and E. Re, A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX, JHEP **06**, 043 (2010), `1002.2581`.

[237] G. F. Veramendi, A measurement of forward-backward charge asymmetry of electron-positron pairs in proton-antiproton collision at 1.8 TeV, (2003), Ph.D.Thesis (Advisor: Young-kee Kim).

[238] S. Ask, Simulation of Z plus Graviton/Unparticle Production at the LHC, Eur.Phys.J. **C60**, 509 (2009), `0809.4750`.

[239] S. Ask *et al.*, Real Emission and Virtual Exchange of Gravitons and Unparticles in Pythia8, Comput.Phys.Commun. **181**, 1593 (2010), `0912.4233`.

[240] J. Hewett and T. Rizzo, Collider Signals of Gravitational Fixed Points, JHEP **0712**, 009 (2007), `0707.3182`.

[241] H. Georgi, Unparticle physics, Phys.Rev.Lett. **98**, 221601 (2007), `hep-ph/0703260`.

[242] H. Georgi, Another odd thing about unparticle physics, Phys.Lett. **B650**, 275 (2007), `0704.2457`.

[243] A. Delgado, J. R. Espinosa, and M. Quiros, Unparticles Higgs Interplay, JHEP **0710**, 094 (2007), `0707.4309`.

[244] T. Kikuchi and N. Okada, Unparticle Dark Matter, Phys.Lett. **B665**, 186 (2008), `0711.1506`.

[245] S.-L. Chen, X.-G. He, X.-P. Hu, and Y. Liao, Thermal unparticles: A New form of energy density in the universe, Eur.Phys.J. **C60**, 317 (2009), `0710.5129`.

[246] H. Georgi and Y. Kats, Unparticle self-interactions, JHEP **1002**, 065 (2010), `0904.1962`.

[247] K. Cheung, W.-Y. Keung, and T.-C. Yuan, Collider Phenomenology of Unparticle Physics, Phys.Rev. **D76**, 055003 (2007), `0706.3155`.

[248] M. Kumar, P. Mathews, V. Ravindran, and A. Tripathi, Unparticle physics in diphoton production at the CERN LHC, Phys.Rev. **D77**, 055013 (2008), `0709.2478`.

[216] G. Marchesini and B. Webber, Simulation of QCD Jets Including Soft Gluon Interference, Nucl.Phys. **B238**, 1 (1984).

[217] B. Webber, A QCD Model for Jet Fragmentation Including Soft Gluon Interference, Nucl.Phys. **B238**, 492 (1984).

[218] T. Sjostrand, S. Mrenna, and P. Z. Skands, PYTHIA 6.4 Physics and Manual, JHEP **0605**, 026 (2006), `hep-ph/0603175`.

[219] S. Frixione and B. R. Webber, Matching NLO QCD computations and parton shower simulations, JHEP **0206**, 029 (2002), `hep-ph/0204244`.

[220] S. Frixione, F. Stoeckli, P. Torrielli, and B. R. Webber, NLO QCD corrections in Herwig++ with MC@NLO, JHEP **01**, 053 (2011), `1010.0568`.

[221] G. Corcella *et al.*, HERWIG 6.5: an event generator for Hadron Emission Reactions With Interfering Gluons (including supersymmetric processes), JHEP **01**, 010 (2001), `hep-ph/0011363`.

[222] GEANT4, S. Agostinelli *et al.*, GEANT4: A Simulation toolkit, Nucl.Instrum.Meth. **A506**, 250 (2003).

[223] J. Allison *et al.*, Geant4 developments and applications, IEEE Trans.Nucl.Sci. **53**, 270 (2006).

[224] M. Paterno, Calculating Efficencies and Their Uncertainties, May, 2003, http://home.fnal.gov/paterno/images/effic.pdf.

[225] Private communication with Michele Dieli (talk given in internal ATLAS meeting).

[226] M. Meyer, Untersuchung der Elektrontriggereffizienzen am ATLAS-Detektor mithilfe der Tag-and-Probe-Methode, (2011), Bachelor Thesis.

[227] Atlas, G. Aad *et al.*, Measurement of the $W \rightarrow l\nu$ and $Z/\gamma^* \rightarrow ll$ production cross sections in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, JHEP **12**, 060 (2010), `1010.2130`.

[228] A. D. Martin, W. J. Stirling, and R. S. Thorne, MRST partons generated in a fixed-flavour scheme, Phys. Lett. **B636**, 259 (2006), `hep-ph/0603143`.

[229] A. Sherstnev and R. S. Thorne, Parton Distributions for LO Generators, Eur. Phys. J. **C55**, 553 (2008), `0711.2473`.

[230] CERN Report No. ATL-PHYS-PUB-2011-008, 2011 (unpublished).

[231] P. M. Nadolsky *et al.*, ImpliFBcations of CTEQ global analysis for collider observables, Phys. Rev. **D78**, 013004 (2008), `0802.0007`.