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letture serali

phenomenology

Spin Correlation Effects in Top Quark Pair Production

An analysis of the spin correlation effects in top quark pair production at hadron colliders is presented with special emphasis for the Large Hadron Collider (LHC). At the LHC top quark pair production is dominated by gluon-gluon fusion. For gluon-gluon fusion at high energies the production is dominated by unlike helicity gluon fusion which has the same spin correlations as quark-antiquark annihilation. At low energies the production is dominated by like helicity gluon fusion which imparts very strong azimuthal correlations on the di-lepton decay products in top quark pair decay. This production process is studied in detail and this suggest a new way to look for spin correlations in top quark pair production at the LHC.

Dalle conclusioni: "In summary, a new way to investigate spin correlations in top quark production and decay is presented for the LHC. The essences of this method is to look at the azimuthal angles between the two charged leptons in a sample of di-lepton quark pair events where the invariant mass of the tt system is constrained to be less than 400 GeV. Given the large top quark pair cross section at the LHC, it is estimated that there will be 1000 such events per fb−1 at 14 TeV."

Revealing the electroweak properties of a new scalar resonance

One or more new heavy resonances may be discovered in experiments at the CERN Large Hadron Collider. In order to determine if such a resonance is the long-awaited Higgs boson, it is essential to pin down its spin, CP, and electroweak quantum numbers. Here we describe how to determine what role a newly-discovered neutral CP-even scalar plays in electroweak symmetry breaking, by measuring its relative decay rates into pairs of electroweak vector bosons: WW, ZZ, \gamma\gamma, and Z\gamma. With the data-driven assumption that electroweak symmetry breaking respects a remnant custodial symmetry, we perform a general analysis with operators up to dimension five. Remarkably, only three pure cases and one nontrivial mixed case need to be disambiguated, which can always be done if all four decay modes to electroweak vector bosons can be observed or constrained. We exhibit interesting special cases of Higgs look-alikes with nonstandard decay patterns, including a very suppressed branching to WW or very enhanced branchings to \gamma\gamma and Z\gamma. Even if two vector boson branching fractions conform to Standard Model expectations for a Higgs doublet, measurements of the other two decay modes could unmask a Higgs imposter.

Higgs boson phenomenology in tau^+ tau^- final states at the LHC

We perform a detailed parton level study on the feasibility of the detection of a Higgs boson in the gluon fusion process $pp (gg+gq) \to h + jet \to \tau^+ \tau^- + jet$ at the Large Hadron Collider (LHC). The obtained results are applied to a few chosen Beyond the Standard Model (BSM) scenarios where the branching ratio of a Higgs boson decaying into a $\tau^+ \tau^-$ pair is enhanced as compared to the Standard Model (SM) case. We present the parameter space of the BSM scenarios that can be observed at the LHC and conclude that some regions of the parameter space can be probed with just a few fb^{-1} of integrated luminosity. Noticeably, our results are presented in a form which potentially allows their application to any generic model giving rise to a $pp (gg+gq) \to h + jet \to \tau^+ \tau^- + jet$ signature.

Searching for high speed long-lived charged massive particles at the LHC

The conventional way to search for long-lived CHArged Massive Particles (CHAMPs) is to identify slow (small β) tracks using delayed time of flight and high ionization energy loss. But at the 7-14 TeV center of mass energy of the LHC, a CHAMP may be highly boosted (high β) and therefore look more like a

minimum ionizing particle, while for high momentum muons (more than $\sim$500 GeV/c) the radiative effect dominates energy deposition. This suggests a new strategy to search for CHAMPs at the LHC. Using energy deposition from different detector components, we construct a boosted decision tree discriminant to separate high momentum CHAMPs from high momentum muons. This method increases substantially the CHAMP search potential and it can be used to distinguish possible di-CHAMP or CHAMP-muon resonance models from di-muon resonance models. We illustrate the new method using a mGMSB model and a recently proposed di-CHAMP model and we give updated CHAMP mass limits for these two models using the recent CDF CHAMP results. </>

Construction of a Kinematic Variable Sensitive to the Mass of the Standard Model Higgs Boson in H->WW*->l l nu nu-bar using Symbolic Regression

We derive a kinematic variable that is sensitive to the mass of the Standard Model Higgs boson (M_H) in the H->WW*->l l nu nu-bar channel using symbolic regression method. Explicit mass reconstruction is not possible in this channel due to the presence of two neutrinos which escape detection. Mass determination problem is that of finding a mass-sensitive function that depends on the measured observables. We use symbolic regression, which is an analytical approach to the problem of non-linear regression, to derive an analytic formula sensitive to M_H from the two lepton momenta and the missing transverse momentum. Using the newly-derived mass-sensitive variable, we expect Higgs mass resolutions between 1 to 4 GeV for M_H between 130 and 190 GeV at the LHC with 10 fb^-1 of data. This is the first time symbolic regression method has been applied to a particle physics problem.

Supersymmetric QCD and CP-violation effects in $t \bar t Z^0$ production at the LHC

We investigate the NLO QCD and the CP-violation effects in $t\bar{t}Z^0$ production at the Large Hadron Collider(LHC) in the minimal supersymmetric standard model(MSSM). Our calculation shows that the total NLO QCD correction in the framework of the CP-conserving MSSM significantly improves the scale uncertainty at the leading order, and the contribution from the pure supersymmetric QCD (pSQCD) correction can exceed -8% with the restrictions of $90~GeV < p_T^t < 120~GeV$ and $120~GeV < p_T^Z < 150~GeV$, where p_T^t and p_T^Z are the transverse momenta of the top-quark and Z^0 gauge boson, respectively. Our numerical results demonstrate that the pure SUSY QCD correction generally suppresses the total SM-like QCD correction in the CP-conserving MSSM, and tends to be a constant when either $\tilde{t}_1$ or $\tilde{g}$ is heavy enough. We find also that the CP-odd asymmetry ${\cal A}_{\Phi}$ can reach 2.17×10^{-3}, if the CP-phase angle really exists in the coupling of gluino-stop-top.

Boosting Higgs discovery - the forgotten channel

Searches for a heavy Standard Model Higgs boson focus on the 'gold plated mode' where the Higgs decays to two leptonic Z bosons. This channel provides a clean signature, in spite of the small leptonic branching ratios. We show that using fat jets the semi-leptonic ZZ mode significantly increases the number of signal events with a similar statistical significance as the leptonic mode.

Signals of single particle production at the earliest LHC

Based on simple phenomenological Lagrangians, fulfilling reasonable consistency conditions, we consider under which circumstances the production of a single particle might be an early signal of new physics at the LHC. Effective final states are $\gamma \gamma $ and $\gamma +jet$ already with tens of inverse picobarns of integrated luminosity at 7 TeV.

Optimisation of variables for studying dilepton transverse momentum distributions at hadron colliders

In future measurements of the dilepton (Z/γ^*) transverse momentum, \Qt, at both the Tevatron and LHC, the achievable bin widths and the ultimate precision of the measurements will be limited by experimental resolution rather than by the available event statistics. In a recent paper the variable \at, which corresponds to the component of \Qt\ that is transverse to the dilepton thrust axis, has been studied in this regard. In the region, \Qt\ $<$ 30 GeV, \at\ has been shown to be less susceptible to experimental resolution and efficiency effects than the \Qt. Extending over all \Qt, we now demonstrate that dividing \at\ (or \Qt) by the measured dilepton invariant mass further improves the resolution. In addition, we propose a new variable, \phistarEta, that is determined exclusively from the measured lepton directions; this is even more precisely determined experimentally than the above variables and is similarly sensitive to the \Qt. The greater precision achievable using such variables will enable more stringent tests of QCD and tighter constraints on Monte Carlo event generator tunes.

How well can the LHC distinguish between the SM light Higgs scenario, a composite Higgs and the Higgsless case using VV scattering channels?

A complete parton level analysis of ll + four jets l = e,mu and 3lv + two jets production at the LHC is presented, including all processes at order $\ordEW$, $\ordQCD$ and $\ordQCDsq$ when appropriate. The infinite Higgs mass scenario, which is considered as a benchmark for strong scattering theories and is the limiting case for composite Higgs models, and one example of a model incorporating a Strongly Interacting Light Higgs are confronted with the Standard Model light Higgs predictions. This analysis is combined with the results in the lv + four jets channel presented in a previous paper, in order to determine whether a composite Higgs signal can be detected as an excess of events in boson--boson scattering.

Extracting Higgs boson couplings from LHC data

We show how LHC Higgs boson production and decay data can be used to extract gauge and fermion couplings of Higgs bosons. We show that very mild theoretical assumptions, which are valid in general multi-Higgs doublet models, are sufficient to allow the extraction of absolute values for the couplings rather than just ratios of the couplings. For Higgs masses below 200 GeV we find accuracies of 10-40% for the Higgs boson couplings and total width after several years of LHC running. Slightly stronger assumptions on the Higgs gauge couplings even lead to a determination of couplings to fermions at the level of 10-20%. We also study the sensitivity to deviations from SM predictions in several supersymmetric benchmark scenarios as a subset of the analysis.

Bigger, Better, Faster, More at the LHC

Multijet plus missing energy searches provide universal coverage for theories that have new colored particles that decay into a dark matter candidate and jets. These signals appear at the LHC further out on the missing energy tail than two-to-two scattering indicates. The simplicity of the searches at the LHC contrasts sharply with the Tevatron where more elaborate searches are necessary to separate signal from background. The searches presented in this article effectively distinguish signal from background for any theory where the LSP is a daughter or granddaughter of the pair-produced colored parent particle without ever having to consider missing energies less than 400 GeV.

Vector-Vector scattering at the LHC with two charged leptons and two neutrinos in the final state

A complete parton level analysis of 2l2v2j and 4l2j, l = mu,e production at the LHC is presented, including all processes at order alpha^6, alpha^4*alpha_s^2. The infinite Higgs mass scenario, which is considered as a benchmark for strong scattering theories and is the limiting case for composite Higgs models, and one example of Strongly Interacting Light Higgs models are confronted with the Standard Model light Higgs predictions. This analysis is combined with the results in the lv4j, the ll4j and the 3lv2j channels presented in previous papers, in order to determine whether these alternative Higgs frameworks can be detected as an excess of events in boson--boson scattering.

Jet pair production in POWHEG

We present an implementation of the next-to-leading order dijet production process in hadronic collisions in the framework of POWHEG, which is a method to implement NLO calculations within a shower Monte Carlo context. In constructing the simulation, we have made use of the POWHEG BOX toolkit, which makes light of many of the most technical steps. The majority of this article is concerned with the study of the predictions of the Monte Carlo simulation. In so doing, we validate our program for use in experimental analyses, elaborating on some of the more subtle features which arise from the interplay of the NLO and resummed components of the calculation. We conclude our presentation by comparing predictions from the simulation against a number of Tevatron and LHC jet-production results.

We propose three ways to determine the CP eigenvalue of the Higgs boson at the hadron collider as follows: 1. We determine the Higgs CP eigenvalue from the production cross section which is affected by the CP eigenvalue of the Higgs boson. 2. We adopt the CP selection rules to determine the Higgs CP eigenvalue. 3. We determine the CP property by the momentum distribution of the decay products of the Higgs boson. Our methods can be applied for a wide range of the Higgs mass.

statistics and data analysis

Evaluation of three methods for calculating statistical significance when incorporating a systematic uncertainty into a test of the background-only hypothesis for a Poisson process

Hypothesis tests for the presence of new sources of Poisson counts amidst background processes are frequently performed in high energy physics (HEP), gamma ray astronomy (GRA), and other branches of science. While there are conceptual issues already when the mean rate of background is precisely known, the issues are even more difficult when the mean background rate has non-negligible uncertainty. After describing a variety of methods to be found in the HEP and GRA literature, we consider in detail three classes of algorithms and evaluate them over a wide range of parameter space, by the criterion of how close the ensemble-average Type I error rate (rejection of the background-only hypothesis when it is true) compares with the nominal significance level given by the algorithm. We recommend wider use of an algorithm firmly grounded in frequentist tests of the ratio of Poisson means, although for very low counts the over-coverage can be severe due to the effect of discreteness. We extend the studies of Cranmer, who found that a popular Bayesian-frequentist hybrid can undercover severely when taken to high Z values. We also examine the profile likelihood method, which has long been used in GRA and HEP; it provides an excellent approximation in much of the parameter space, as previously studied by Rolke and collaborators.

Trial factors for the look elsewhere effect in high energy physics

When searching for a new resonance somewhere in a possible mass range, the significance of observing a local excess of events must take into account the probability of observing such an excess anywhere in the range. This is the so called "look elsewhere effect". The effect can be quantified in terms of a trial factor, which is the ratio between the probability of observing the excess at some fixed mass point, to the probability of observing it anywhere in the range. We propose a simple and fast procedure for estimating the trial factor,

based on earlier results by Davies. We show that asymptotically, the trial factor grows linearly with the (fixed mass) significance.

Asymptotic formulae for likelihood-based tests of new physics

We describe likelihood-based statistical tests for use in high energy physics for the discovery of new phenomena and for construction of confidence intervals on model parameters. We focus on the properties of the test procedures that allow one to account for systematic uncertainties. Explicit formulae for the asymptotic distributions of test statistics are derived using results of Wilks and Wald. We motivate and justify the use of a representative data set, called the "Asimov data set", which provides a simple method to obtain the median experimental sensitivity of a search or measurement as well as fluctuations about this expectation.

Topics in statistical data analysis for high-energy physics

These lectures concern two topics that are becoming increasingly important in the analysis of High Energy Physics (HEP) data: Bayesian statistics and multivariate methods. In the Bayesian approach we extend the interpretation of probability to cover not only the frequency of repeatable outcomes but also to include a degree of belief. In this way we are able to associate probability with a hypothesis and thus to answer directly questions that cannot be addressed easily with traditional frequentist methods. In multivariate analysis we try to exploit as much information as possible from the characteristics that we measure for each event to distinguish between event types. In particular we will look at a method that has gained popularity in HEP in recent years: the boosted decision tree (BDT).

Finite detector resolution and limited acceptance require one to apply unfolding methods in high energy physics experiments. Information on the detector resolution is usually given by a set of Monte Carlo events. Based on the experience with a widely used unfolding program (RUN) a modified method has been developed. The first step of the method is a maximum likelihood fit of the Monte Carlo distributions to the measured distribution in one, two or three dimensions; the finite statistics of the Monte Carlo events is taken into account by the use of Barlow s method with a new method of solution. A clustering method is used before combining bins in sparsely populated areas. In the second step a regularization is applied to the solution, which introduces only a small bias. The regularization parameter is determined from the data after a diagonalization and rotation procedure.

A pedagogical introduction to the problem of unfolding probability distribu- tions in particle physics is given. Several of the most commonly used methods are reviewed and compared.

On hypothesis testing, trials factor, hypertests and the BumpHunter

A detailed presentation of hypothesis testing is given. The "look elsewhere" effect is illustrated, and a treatment of the trials factor is proposed with the introduction of hypothesis hypertests. An example of such a hypertest is presented, named BumpHunter, which is used in the recent ATLAS dijet resonance search, and in an earlier version in the CDF Global Search, to look for exotic phenomena in high energy physics. As a demonstration, the BumpHunter is used to address Problem 1 of the Banff Challenge.

physics objects reconstruction and kinematics

Kinematical variables towards new dynamics at the LHC

At the LHC, many new physics signatures feature the pair-production of massive particles with subsequent direct or cascading decays to weakly-interacting particles, such as SUSY scenarios with conserved conserved

R-parity or $H \to W(\ell\nu)W(\ell\nu)$. We present a set of dimension-less variables that can assist the early discovery of processes of this type in conjunction with a set of variables with mass dimension that will expedite the characterization of these processes.

Template Overlap Method for Massive Jets

We introduce a new class of infrared safe jet observables, which we refer to as template overlaps, designed to filter targeted highly boosted particle decays from QCD jets and other background. Template overlaps are functional measures that quantify how well the energy flow of a physical jet matches the flow of a boosted partonic decay. Any region of the partonic phase space for the boosted decays defines a template. We will refer to the maximum functional overlap found this way as the template overlap. To illustrate the method, we test lowest-order templates designed to distinguish highly-boosted top and Higgs decays from backgrounds produced by event generators. For the functional overlap, we find good results with a simple construction based on a Gaussian in energy differences within angular regions surrounding the template partons. Although different event generators give different averages for our template overlaps, we find in each case excellent rejection power, especially when combined with cuts based on jet shapes. The template overlaps are capable of systematic improvement by including higher order corrections in the template phase space.

CMS

Measurements of Inclusive W and Z Cross Sections in pp Collisions at sqrt(s)=7 TeV

Measurements of inclusive W and Z boson production cross sections in pp collisions at sqrt(s)=7 TeV are presented, based on 2.9 inverse picobarns of data recorded by the CMS detector at the LHC. The measurements, performed in the electron and muon decay channels, are combined to give sigma(pp to WX) times B(W to muon or electron + neutrino) = 9.95 \pm 0.07(stat.) \pm 0.28(syst.) \pm 1.09(lumi.) nb and sigma(pp to ZX) times B(Z to oppositely charged muon or electron pairs) = 0.931 \pm 0.026(stat.) \pm 0.023(syst.) \pm 0.102(lumi.) nb. Theoretical predictions, calculated at the next-to-next-to-leading order in QCD using recent parton distribution functions, are in agreement with the measured cross sections. Ratios of cross sections, which incur an experimental systematic uncertainty of less than 4%, are also reported.

other experiments

Evidence for an anomalous like-sign dimuon charge asymmetry

We measure the charge asymmetry $A\equiv(N^{++} - N^{--})/(N^{++} + N^{--})$ of like-sign dimuon events in 6.1~fb^{-1} of $p\bar{p}$ collisions recorded with the D0 detector at a center-of-mass energy $\sqrt{s}=1.96$~TeV at the Fermilab Tevatron collider. From A we extract the like-sign dimuon charge asymmetry in semileptonic b-hadron decays: $\aslb=-0.00957\pm0.00251\thinspace({\rm stat})\pm0.00146\thinspace({\rm sys})$. It differs by 3.2~standard deviations from the standard model prediction $\aslb({\rm SM})=(-2.3^{+0.5}_{-0.6})\times10^{-4}$, and provides first evidence of anomalous CP violation in the mixing of neutral B mesons.

Prospects for Higgs boson searches using the H W W ( ) l l decay mode with the ATLAS detector at √s = 10 TeV

The prospects for Higgs boson searches using the H W W ( ) l l (l = e, μ) decay mode at ATLAS are presented, including realistic detector effects and a discussion of meth- ods to estimate the backgrounds and systematic errors. Events are separated into three sets of analyses according to the hadronic jet multiplicity. The sensitivity of the ATLAS detector is computed for 10 TeV proton-proton centre-of-mass energy and assuming a data set of an integrated luminosity of 200 pb−1. With these conditions a Standard Model Higgs

boson with a mass in the range 160 – 170 GeV can be excluded with a 95% confidence level.

Comprehensive multivariate discrimination and the Higgs + W/Z search

A systematic method for optimizing multivariate discriminants is developed and applied to the important example of a light Higgs search at the Tevatron and the LHC. The Signficance Improvement Characteristic (SIC), defined as the signal efficiency of a cut or multivariate discriminant divided by the square root of the background efficiency, is shown to be an extremely powerful visualization tool. SIC curves demonstrate numerical instabilities in the multivariate discriminants, show convergence as the number of variables is increased, and display the sensitivity to the optimal cut values. For our application, we concentrate on Higgs production in association with a W or Z boson with H->bb and compare to the irreducible standard model background, Z/W + bb. We explore thousands of experimentally motivated, physically motivated, and unmotivated single variable discriminants. Along with the standard kinematic variables, a number of new ones, such as twist, are described which should have applicability to many processes. We find that some single variables, such as the pull angle, are weak discriminants, but when combined with others they provide important marginal improvement. We also find that multiple Higgs-candidate mass measures, such as from mild and aggressively trimmed jets, when combined may provide additional discriminating power. Comparing the significance improvement from our variables to those used in recent CDF and D0 searches, we find that a 10-20% improvement in significance against irreducible backgrounds is possible. Our analysis also suggests that the H+W/Z channel with H -> bb is also viable at the LHC, without requiring a hard cut on the W/Z transverse momentum.

SM Higgs boson searches in the early ATLAS data

ATLAS exclusion and discovery potentials of Standard Model Higgs boson searches at the LHC at 14 TeV, 10 TeV and 7 TeV center-of-mass energy are reviewed. For a LHC center-of-mass energy of 7 TeV and integrated luminosity of 1 fb^{-1}, contributions from the important decay channels $\Hboson \rightarrow \Wboson\Wboson^{()} **\rightarrow \ell\nu\ell\nu$, $\Hboson \rightarrow \Zboson\Zboson^{**}(){} \rightarrow \ell\ell\ell\ell$ and $\Hboson \rightarrow \gamma\gamma$ are considered, based on recent full Monte Carlo simulations at 14 and 10 TeV and the cross-section rescaling for the 7 TeV center-of-mass energy. First measurements of backgrounds to Standard Model Higgs boson search are also presented.

Observation of Single Top Quark Production

The field of experimental particle physics has become more sophisticated over time, as fewer, larger experimental collaborations search for small signals in samples with large components of background. The search for and the observation of electroweak single top quark production by the CDF and DZero collaborations at Fermilab's Tevatron collider are an example of an elaborate effort to measure the rate of a very rare process in the presence of large backgrounds and to learn about the properties of the top quark's weak interaction. We present here the techniques used to make this groundbreaking measurement and the interpretation of the results in the context of the Standard Model.

This note presents constraints on Standard Model parameters using published and preliminary precision electroweak results obtained at the electron-positron colliders LEP and SLC. The results are compared with precise electroweak measurements from other experiments, notably CDF and D\O\ at the Tevatron. Constraints on the input parameters of the Standard Model are derived from the combined set of results obtained in high-Q^2 interactions, and used to predict results in low-Q^2 experiments, such as atomic parity violation, M{\o}ller scattering, and neutrino-nucleon scattering. The main changes with respect to the experimental results presented in 2009 are new combinations of results on the width of the W boson and the mass of the top quark.

reviews & lectures

Elements of QCD for hadron colliders

The aim of these lectures is to provide (experimental particle physics Ph.D.) students with an introduction to some of the core concepts and methods of QCD that are relevant in an LHC context.

Parton distributions at the dawn of the LHC

We review basic ideas and recent developments on the determination of the parton substructure of the nucleon, in view of applications to precision hadron collider physics. We review the way information on parton distributions (PDFs) is extracted from the data exploiting QCD factorization, and discuss the current main two approaches to parton determination (Hessian and Monte Carlo) and their use in conjunction with different kinds of parton parametrization. We summarize the way different physical processes can be used to constrain different aspects of PDFs. We discuss the meaning, determination and use of parton uncertainties. We briefly summarize the current state of the art on PDFs for LHC physics.

Jets and QCD

The observation of quark and gluon jets has played a crucial role in establishing Quantum Chromodynamics [QCD] as the theory of the strong interactions within the Standard Model of particle physics. The jets, narrowly collimated bundles of hadrons, reflect configurations of quarks and gluons at short distances. Thus, by analysing energy and angular distributions of the jets experimentally, the properties of the basic constituents of matter and the strong forces acting between them can be explored. In this review we summarise the properties of quark and gluon jets and the impact of their observation on Quantum Chromodynamics, primarily the discovery of the gluons as the carriers of the strong force. Focusing on these basic points, jets in $e^+ e^-$ collisions will be in the foreground of the discussion. In addition we will delineate the role of jets as tools for exploring other particle aspects in ep and $pp/p\bar{p}$ collisions - quark and gluon densities in protons, measurements of the QCD coupling, fundamental 2-2 quark/gluon scattering processes, but also the impact of jet decays of top quarks, and $W^\pm, Z$ bosons on the electroweak sector. The presentation to a large extent is formulated in a non-technical language with the intent to recall the significant steps historically and convey the significance of this field also to communities beyond high energy physics.

conference proceedings

Multi-boson production

(conference proceeding) The studies of the diboson production in proton-antiproton collisions at 1.96 TeV performed by CDF and D0 collaborations at the Tevatron collider are reported in this paper. The diboson events are identified exploiting both leptonic and semi-leptonic final states. The presented results use different subsamples of the statistics collected by the Tevatron up to 4.8 1/fb. Measured production cross sections are in good agreement with Standard Model predictions and the limits on the anomalous triple gauge boson couplings are competitive with the ones measured by experiments at the LEP.

title

-- PietroGovoni - 03-Dec-2010

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