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Search for bosonic resonances decaying via a vector-like quark into the all-hadronic final state and bumpbonding interconnection technology for Phase-I Uprade of the CMS experiment

PHD-Thesis

submitted by

Simon Kudella

to Prof. Dr. U. Husemann
Institute for Data Processing and Electronics (IPE)

Second examiner Prof. Dr. U. Husemann
Institut für Experimentelle Kernphysik (IEKP)

Department of Physics
Karlsruhe Institute of Technology

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Dissertation

vorgelegt von

Simon Kudella

Prof. Dr. U.Husemann

Institut für Experimentelle Teilchenphysik (ETP) Korreferent Prof. Dr. M. Weber

Institut für Prozessdatenverarbeitung und Elektronik (IPE)

Fakultät für Physik

Karlsruher Institut für Technologie

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Chapter 4

Object identifcation

- for every bunch crossing, a huge number of particles is generated and tracked by the detector
- only a small fraction originates from the interesting initial interaction process
- CMS uses particle flow approach
- PF candidates get assigned to leptons, hadrons or photons
- charged particles get assigned to primary and pile-up vertices
- particles from pile-up vertices are removed
- number of neutral particles from pile-up have to be estimated
- here the CHS algortithm used - some words to CHS

4.1 Jet clustering

- every color charged particle creates shower of particles among which its energy is distributed
- observed object jet, initial object particle
- jet clustering algorithms to cluster particle flow particles into jet object
- here anti-k_T algorithm
- link for more detail

4.2 Jet-identification

- in general: showering of jet smears up all information about initial particle so much, no information about initial particle is possible
- in recent years, many developments on using as much jet information to give indicators on original particle

4.2.1 b-jet tagging

- widely used in high energy physics
- picture of secondary vertex
- bottom-quark decay supressed by CKM-matrix –¿ long life-time of B-mesons
- looking for secondary decay vertices
- established process included in MVA-methods considering impact parameter particle distribution within jet etc.
- Here: Combined Secondary Vertex (v2)

4.2.2 Boosted heavy object jet-identification

- higher center-of-mass energies -¿ more strongly boosted objects
- stronger boost −¿ decay products clustered into fat jet
- bild von boost
- large mass of particle gives jet substructure
- use substructure to identiy jets arrising from decaying heavy objects
- typical substructures: jet-mass, number of subjets

4.2.2.1 Jet mass algorithms

- two algorithms here
- 1. Pruned jet mass
- 2. Soft-Drop jet mass

4.2.2.2 N-subjettiness

- whidely used in combination with jet mass algorithm
- calculate p_T weighted average of minimal angles between subjets and particles
- $\tau_N = 0$ would mean that all particles within the jet are perfectly aligned with the subjets
- τ_N as indicator for having at least N subjets or more
- $\tau_{N,N-1}$ for indicator of having exactly N subjets
- more detailled

4.2.2.3 W/Z/H-jet tagging

- heavy bosons are expected to decay into two stable particles and therefore to create jets with dominantly two subjets
- τ_{21} as discriminating variable - jet mass expected to be around the mass of the heavy boson ($m(W) = 80.3\,\mathrm{GeV}$, $m(Z) = 91.2\,\mathrm{GeV}$, $m(H) = 125.1\,\mathrm{GeV}$)
- additional b-tag requirements to subjets possible
- b-tag veto for W-subjets
- b-tagging of H-subjets
- this analysis, focus on W-tagging, but also remain senitivity for Z- & H-jets
- WP?

4.2.2.4 t-jet tagging

- expected to decay into bottom quark and W-boson
- three quarks in final state −¿ three subjets
- τ_{32} as discriminating variable
- jet mass expected to be around the top mass $m(t) = 173.3\,\mathrm{GeV}$
- additional b-tag requirement possible to increase purity
- WP

4.3 Lepton-identification

- this analysis focusing on full-hadronic final state
- veto on isolated leptons

- lepton identification important for veto and to ensure orthogonality to semi-leptonic analysis
- isolated muons: $p_T > 30\,\mathrm{GeV}$, $|\eta| < 2.4$, $> 80\,\%$ valid tracker hits, LOOSE Muon ID, +additional criteria
- isolated electrons: MVA-ID, $p_T > 30\,\mathrm{GeV}$, $|\eta| < 2.4$, MVA cut¿0.837

Chapter 5

Heavy bosonic resonances decaying via a vector-like quarks

5.1 Current scientific status

- many searches within CMS and ATLAS to look for physics BSM in pp-collisions at the LHC in form of Z' resonance decaying into qq or VLQ/VLQ
- exclusion plots and references to other searches
- depending on mass of Z' & T' and model, $Z' \rightarrow T't$ dominant
- this analysis focus on kinematic range of $Z' \rightarrow T't$

5.2 Theoretical models

- in general this analysis is supposed to be a model independent search
- use two different models as benchmark models
- ρ-model as composite higgs model, where Z's arise as gauge bosons from additional gauge symmetries
- created MC with $m(Z') = 1500 - 2500$ & $m(T') = 700 - 1500$ and narrow width
- G*-model as extra-dimensions modell, where Z's arie as Kaluza Klein bosons from extradimensions
- created MC with $m(Z') = 1500 - 4000$ & $m(T') = 900 - 300$ and narrow width as well as wide width

5.3 Physics of the $Z' \rightarrow tT'$ system

- introduction on the physics of the expected signal
- high center-of-mass energies –¿ depending on mass of T', decay products highly boosted
- drastically reduce combinatoricals by using boosted regime
- looking for tri-jet events with high center-of-mass energy and tagged jets

5.3.1 Basic event selection

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7.4 Flip-chip bonding

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7.4.4 Reworking

7.4.4.1 Void-studies

7.5 Bump bonding post-processing

7.6 Results

Chapter 8

Summary and conclusion

List of Acronyms

ACAB Anisotropic Conductive Adhesive Bonding
ADC Analogue-Digital Converter
ALICE A Large Ion Collider Experiment
APD Avalanche Photo Diodes
ASIC Application-Specific Integrated Circuit
ATLAS A Toroidal LHC ApparatuS
BCB Benzocyclobutene
BD Bump Diameter
BH Bump Height
BPIX Barrel Pixel Detector
BSH Bump Shoulder Height
C4 Controlled Collapse Chip Connection
CA Chamfer Angle
CERN Conseil Européen pour la Recherche Nucléaire
CD Chamfer Diameter
CMOS Complementary Metal-Oxide-Semiconductor
CMS Compact Muon Solenoid
CSC Cathode Strip Chamber
CV Contact Velocity
DAC Digital-Analogue Converter
DC Drift Cell
DESY Deutsches Elektronen-Synchrotron
ECAL Electromagnetic Calorimeter
EDX Energy-Dispersive X-ray
EFO Electric-Flame-Off
ESD Electrostatical Discharges
ETH Eidgenössische Technische Hochschule Zürich
FA Face Angle
FAB Free Air Ball
FODO Focussing, nOthing, Defocussing, nOthing
FPGA Field-Programmable Gate Array
FPIX Forward Pixel Detector
FST Force Sensor threshold
HD Hole Diameter
HCAL Hadronic Calorimeter
HDI High Density Interconnect
HEP High-Energy Physics
HLT High Level Trigger
HPD Hybrid Photo Diode

HPK Hamamatsu Hotonikusu Kabushiki kaisha
IEKP Institut für Experimentelle Kernphysik
IPE Institute for Data Processing and Electronics
KIT Karlsruhe Institute of Technology
L1 Level 1 Trigger
LED Light-Emitting Diode
LEP Large Electron-Positron Collider
LEIR Low Energy Ion Ring
LHC Large Hadron Collider
LHCb Large Hadron Collider beauty
LHCf Large Hadron Collider forward
LINAC Linear Accelerator
LS1 Long Shutdown 1
LS2 Long Shutdown 2
MIP minimum ionizing particle
MoEDAL Monopole and Exotics Detector at the LHC
Nd-YAG Neodymium-doped Yttrium Aluminum Garnet
POM Polyoxymethylen
PPS Pre-coated Powder Sheet
PS Proton Synchrotron
PSB Proton Synchrotron Booster
PSI Paul Scherrer Institute
PTFE Polytetrafluoroethylene
PUC Pixel Unit Cell
QCD Quantum Chromo dynamics
ROC Readout Chip
RPC Resistive Plate Chamber
RTI Research Triangle Institute
RWTH Rheinisch-Westfälische Technische Hochschule Aachen
SEM Scanning Electron Microscopy
SD Smooth Distance
SH Separation Height
SPS Super Proton Synchrotron
TBM Token Bit Manager
TEC Tracker EndCap
T Tip diameter
TIB Tracker Inner Barrel
TID Tracker Inner Disk
TIP Tool Inflection Point
TOB Tracker Outer Barrel
TOTEM Total Elastic and Diffractive Cross Section Measurement
UBM Under Bump Metallization
UHH University of Hamburg
USG Ultrasonic Generator
VPT Vacuum Phototriodes
VTT Valtion Teknillinen Tutkimuskeskus
WD Wire Diameter

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Erklärung

Hiermit versichere ich, die vorliegende Arbeit selbständig angefertigt, alle dem Wortlaut oder Sinn nach entnommenen Inhalte anderer Werke an den entsprechenden Stellen unter Angabe der Quellen kenntlich gemacht und keine weiteren Hilfsmittel verwendet zu haben.

Simon Kudella
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