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Datum: 30 OCT 2019

UNIVERZITET CRNE GORE

Senat

U prilogu akta dostavljamo Predlog Odluke vijeća Prirodno-matematičkog fakulteta sa XXXVIII sjednice Vijeća održane 22.10.2019. godine, o imenovanju komisije za ocjenu podobnosti doktorske teze i kandidata Msc Jelene Mijušković, sa propratnom dokumentacijom.

Prilog:

- PD na crnogorskom jeziku
- PD na engleskom jeziku
- Potvrda o položenim ipsitima
- Potvrda o studiranju
- Biografije i bibliografije:
- Prof. dr Nataše Raičević
- Prof. dr Slobodana Backovića
- Prof. dr Ivane Pićurić

DEKAN
Prof. dr Predrag Miranović

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Datum: 2 8 OCT 2019

Na osnovu člana 64 Statuta Univerziteta Crne Gore i člana 34 Pravila doktorskih studija, Vijeće Fakulteta na XXXVIII sjednici održanoj 22.10.2019.godine, donijelo je

ODLUKU

Predlažemo Centru za doktorske studije i Senatu Univerziteta Crne Gore da imenuje Komisiju za ocjenu podobnosti doktorske teze i kandidata sa nazivom **"Od Z bozona do Higs bozona uz ograničenja na broj džetova nastalih pri produkciji bozona na LHC-u"** kandidata mr Jelene Mijušković u sastavu:

1. Dr Nataša Raičević, redovni profesor Prirodno-matematičkog fakulteta Univerziteta Crne Gore, mentor (naučna oblast: Fizika elementarnih čestica), mentor;

2. Dr Slobodan Backović, redovni profesor Prirodno matematičkog fakulteta Univerziteta Crne Gore u penziji, akademik CANU, (naučna oblast: Fizika elementarnih čestica) i

3. Dr Ivana Pićurić, redovni profesor Prirodno matematičkog fakulteta Univerziteta Crne Gore, član (naučna oblast: Fizika elementarnih čestica).

Obrazloženje

Jelena Mijušković podnijela je Vijeću Prirodno-matematičkog fakulteta Prijavu doktorske teze pod nazivom **"Od Z bozona do Higs bozona uz ograničenja na broj džetova nastalih pri produkciji bozona na LHC-u".** Vijeće Prirodno-matematičkog fakulteta je shodno članu 34 Pravila doktorskih studija utvrdilo Predlog Odluke za imenovanje komisije za ocjenu podobnosti doktorske teze i kandidata.

Dostavljeno:

- Senatu
- Centru za doktorske studije
- dosije

Dekan

Prof. dr Predrag Miranović

PRIJAVA TEME DOKTORSKE DISERTACIJE

OPŠTI PODACI O DOKTORANDU	
Titula, ime i prezime	Jelena Mijušković
Fakultet	Prirodno - matematički fakultet
Studijski program	Fizika
Broj indeksa	1/18
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Obrazovanje	Magistar u oblasti fizike, Prirodno - matematički fakultet, Univerzitet Crne Gore, 2018, B (10.00) Specijalista u oblasti fizike, Prirodno – matematički fakultet, Univerzitet Crne Gore, 2016, B(9.25) Bachelor u oblasti fizike, Prirodno – matematički fakultet, Univerzitet Crne Gore, 2015, (8.72)
Radno iskustvo	Jul 2017 – danas – Istraživač u CMS grupi Univerziteta Crne Gore (Evropska organizacija za nuklearna istraživanja) Oktobar 2018 – Predavač u okviru art@CMS programa na Otvorenim danima nauke 2018 (Ministarstvo nauke Crne Gore) Mart 2018 – Predavač i asistent na International Masterclass 2018 - Hands on Particle Physics (Ministarstvo nauke Crne Gore) Oktobar 2017 – Asistent na Otvorenim danima nauke 2017 Januar 2017 – Oktobar 2017 – Nastavnik u Gimnaziji "Stojan Cerović", Nikšić Mart 2017 – Asistent na Zimsko školi nauke (Fondacija za promovisanje nauke - PRONA) Mart 2017 – Predavač i asistent na International Masterclass Hands on Particle Physics (Ministarstvo nauke Crne Gore) Jun 2016 – Avgust 2016 – Polaznik Ljetnje škole CERN-a (Evropska organizacija za nuklearna istraživanja) Septembar 2015 – Asistent na CERN-ovoj izložbi u okviru Otvorenih dana nauke (Ministarstvo nauke Crne Gore)
Popis radova	(Podatke hronološki unositi od novijih datuma ka starijim)
NASLOV PREDLOŽENE TEME	
Na službenom jeziku	Od Z bozona do Higs bozona uz ograničenja na broj džetova nastalih pri produkciji bozona na LHC-u
Na engleskom jeziku	From the Z boson to the Higgs boson, constraining the number of associated jets in the production of a boson at the LHC

Obrazloženje teme

Higs mehanizam ili postojanje tzv. Higsova polja je temelj u teroji fizike elementarnih čestica, Standardnom modelu, kojim se opisuje proces u kojem sve fundamentalne čestice dobijaju svoju masu. Kao i svako fundamentalno polje i ovo polje ima svoju česticu koja ga kreira – Higs bozon. Postojanje Higs bozona je pretpostavljeno 70-ih godina prošlog vijeka a otkriven je dugo vremena posle toga na eksperimentima u CERN-u u julu 2012.

Fuzija gluona i fuzija vektorskih bozona su dominantni mehanizmi produkcije Higs bozona. Procesi sa fuzijom vektorskih bozona su osjetljivi na sprezanje tj. jačinu interakcije Higs bozona i vektorskih bozona dok je fuzija gluona osjetljiva na sprezanje sa fermionima iz fermionskog kruga koji se pri tome formira. Mjerenje jačine sprezanja tj. interakcije Higs bozona sa fermionima i vektorskim bozonima zahtjeva razdvajanje i raspoznavanje ova dva kanala za produkciju Higs bozona.

Pri produkciji Higs bozona kroz fuziju vektorskih bozona, dolazi do nastanka dva hadronska džeta (mlazovi hadrona koji se emituju u uskim konusima i nastaju u procesu hadronizacije kvarkova ili gluona). Ovako nastali džetovi su prilično razdvojeni (po rapiditetu) i ovo svojstvo predstavlja njihovo glavno obilježje po kojem su ovi procesi prepoznati tj. identifikovani. Pri mjerenju jačine sprezanja Higsa i drugih čestica, znatan doprinos grešci mjerenja daje greška mjerenja efikasnog presjeka koja potiče od rekonstrukcije samih džetova. Da bi se povećala preciznost mjerenja, u ovoj tezi će biti predlažen novi metod za razdvajanje navedenih kanala nastanka Higs bozona bez rekonstruisanja džetova. S ovim ciljem iz eksperiementalnih podataka dobijenih u CMS eksperimentu prvi put će se mjeriti varijabla nazvana N-džetnost (engl. N-jettiness) koja je povezana sa brojem džetova nastalih u proton-proton interakciji. Ova varijabla se računa direktno iz izmjerenih impulsa detektovanih čestica.

U ovom radu biće razvijen novi metod za mjerenje presjeka produkcije vektorskih bozona sa dežtovima u proton-proton interakcijama. Metod je zasnovan na mjerenju nove varijable, N-džetnost, i prvi put se koristi u analizama na CMS eksperimentu. Ovo će ujedno biti i prvo eksperimentalno mjerenje ove varijable u događajima u kojima dolazi do emisije vektorskih bozona i džetova. Primjenom ovog metoda očekuje se da se dobiju mjerenja efikasnog presjeka za procese u kojima dolazi do produkcije Z ili Higs bozona i džetova sa većom preciznošću u odnosu na prethodna mjerenja dobijena korišćenjem standardnih metoda. U radu će se mjeriti i konstante sprezanja Higs bozona sa fermionima i vektorskim bozonima. Eksperimentalne raspodjele vezane za produkciju bozona biće upoređene sa Monte Karlo simulacijom čime će se testirati teorijski modeli koji se koriste za opisivanje ovih procesa na LHCu.

Svi eksperimentalni rezultati biće dobijeni analizom događaja nastalih u proton-proton interakcijama sa energijom interakcije od 13 TeV koje nastaju ubrzavanjem protona na Velikom hadronskom sudaraču, LHC-u (engl. Large Hadron Collider) koji se nalazi u laboratoriji CERN u Ženevi. Eksperimentalni material dobijen je detektovanjem čestica nastalih iz proton-proton interkcija CMS (engl. Compact Muon Solenoid) eksperimentalnom aparaturom tokom tzv. LHC RUN II perioda rada LHC akceleratora.

Pregled istraživanja

Standardni model je kompleksna teorija koja sadrži čitav set matematičkih formula zasnovanih na kvantnoj teoriji polja i opisuje elementarne čestice i interakcije među njima. Ova teorija počela je da se razvija polovinom prošlog vijeka kroz rad velikog broja naučnika širom svijeta i zaokružena je 70-ih godina prošlog vijeka. Eksperimentalne potvrde mnogih aspekata ove teorije su dobijene nakon ovoga - top kvark je otkriven 1995, tau neutrino je detektovan 2000. a Higs bozon otkriven 2012. bio je posljednja kockica koja je nedostajala za eksperimentalnu potvrdu ove teorije. Više od 30 Nobelovih nagrada je dodijeljeno teorijskim i eksperimentalnim fizičarima čestica za rezultate dobijene u okviru Standardnog Modela. Za otkriće Higs bozona na CMS i

ATLAS eksperimentima u CERN-u 2013. dodijeljena je Nobelova nagrada teoretičarima koji su predvidjeli njegovo postojanje. Nakon otkrića nove čestice, veliki napori se ulažu u razumijevanje mehanizama njene kreacije i raspada kroz koje se proučavaju detaljno svojstva ove čestice. Takođe, što preciznija mjerenja svojstava Higs bozona, naročito jačine njegove interakcije sa elementarnim česticama, su od krucijalnog značaja ne samo za Standardni model kao teoriju, već i za nova otkrića do kojih se može doći samo ako postojeću teoriju razumijemo sa visokom preciznošću. Standardni model nije sveobuhvatna, niti zaokružena teorija koja vodi razumijevanju materije na fundamentalnom nivou i ne može objasniti mnoge fenomene čije je postojanje dokazano. Standardni model ne objašnjava mehanizme djelovanja gravitacione interakcije kao jedne od četiri fundamentalne interakcije. Standardni model ne opisuje niti može objasniti od čega je sazdano 95% Univerzuma, ne objašnjava šta je tamna energija, niti tamna materija. Standardni model takođe ne pruža odgovor zašto danas u Univerzumu postoji asimetrija između materije i anti-materije, niti predviđa postojanje mase neutrina. Dakle, mnogo je pitanja za koje se traže odgovori i mnogo je teorija koje pokušavaju da daju odgovor na ta pitanja. Takve teorije spadaju u domen Teorije izvan Standardnog Modela. Da bi se dobili odgovori i teorije dokazale ili opovrgle neophodan je eksperiment i mjerenja parametara Standardnog modela sa što većom preciznošću kako bi se uopšte o novim rezultatima moglo govoriti kao o eventualnim otkrićima koji izlaze iz domena Standardnog modela. Mjerenja konstanti sprezanja tj. interakcije Higs bozona sa što većom preciznošću su od izuzetnog značaja za što bolje razumijevanje strukture materije i davanje odgovora na mnoga neriješena pitanja. Varijabla N-džetnost, koja će se u ovom radu koristiti sa ciljem da dođemo do mjerenja produkcije vektorskih bozona na LHC-u sa što većom preciznošću, uvedena je 2010. godine sa ciljem da se identifikuju događaji sa džetovima i dobiju što preciznija mjerenja efikasnih presjeka za takve procese. Ova varijabla još uvijek nije eksperimentalno mjerena osim u slučaju kad je N = 0 i to u proton-proton interakcijama na energiji od 7 TeV u sistemu centra masa pri kojima nastaje Z bozon (ATLAS eksperiment).

Cilj i hipoteze

Cilj ovog rada je da se razvije novi metod za mjerenje efikasnog presjeka za produkciju vektorskih bozona uz emisiju džetova u proton-proton interakcijama. Prvi korak u radu biće mjerenje i testiranj nove varijable, N-džetnost, u događajima sa proton-proton interakcijama koje vode produkciji Z bozona i džetova. Z bozoni biće identifikovati kroz kanal raspada u dileptonski par. Ovo je uzorak visoke statistike sa vrlo jasnim signalom. Mjerenja ove varijable i varijabli korelisanih sa njom biće upoređena sa teorijskim modelima koji se koriste za simulaciju proton-proton interakcija uzimajući u obzir i efekte koji nastaju prolaskom čestica kroz eksperimentalnu aparaturu. Za ove procese sa kreacijom Z bozona, biće izmjeren diferencijalni efikasni presjek po novoj varijabli i procijeniće se preciznost njegovog mjerenja.
Nakon ovih mjerenja na uzorku sa produkcijom Z bozona ispitaće se potencijal N-džetnost varijable za razdvajanje ključnih procesa za produkciju Higs bozona, fuzije gluona i fuzije vektorskih bozona. Biće razrađena strategija analize produkcije Higs bozona korišćenjem N-džetnost varijable. U radu će se mjeriti efikasni presjeci za produkciju Higs bozona u procesima fuzije gluona i vektorskih bozona. Higs bozon će biti identifikovan kroz kanal raspada na dva fotona. Sva mjerenja će biti upoređena sa Monte Karlo simulacijom koja uključuje generisanje proton-proton interakcija i punu simulaciju detektorskog sistema.

H01 – Varijabla N-džetnost omogućava mjerenje efikasnog presjeka za produkciju Z bozona na LHC-u sa visokom preciznošću.
H02 - Varijabla N-džetnost ima potencijal za mjerenje efikasnog presjeka za produkciju Higs bozona sa visokom preciznošću.
H1 – Pravci osa džetova mogu se rekonstruisati korišćenjem nove varijable bez eksplicitne

rekonstrukcije džetova.
H2 – Eksperimentalne raspodjele za produkciju Z bozona dobijene korišćenjem nove varijable se mogu opisati nekim od teorijskih modela koji se koriste na LHC eksperimentu.
H3 - Eksperimentalne raspodjele za produkciju Higs bozona se mogu opisati nekim od teorijskih modela koji se koriste na LHC eksperimentima.
H4 – Nove analize daju mjerenje konstanti sprezanja Higs bozona sa vektorskim bozonima i fermionima sa visokom preciznošću.
* Pod mjerenjem visoke preciznosti podrazumjeva se mjerenje sa sistematskom greškom koja je manja od greške mjerenja koja je dobijena u prethodnima analizama ovih veličina.

Materijali, metode i plan istraživanja

U prvom dijelu ovog rada biće analizirani Drel –Jan procesi koji nastaju pri proton-proton sudarima u Velikom hadronskom sudaraču. Drel – Jan proces podrazumijeva anihilaciju kvark i antikvark parova iz hadrona, pri čemu nastaje Z bozon ili virtuelni foton koji se dalje raspada na lepton-antilepton par. Razumjevanje i analiza Drel-Jan procesa je veoma bitna, ne samo za testiranje i potvrđivanje Standardnog modela već i za dalje analize teorija izvan Standardnog modela, tako da je svako povećanje preciznosti mjerenja ovog procesa od velikog značaja . Takođe, Drel – Jan procesi su jedan od najznačajnih fonskih procesa za mnoge analize, kao sto su analize raspada Higsovog bozona.
U drugom dijelu rada, analiza ce biti fokusirana na Higsov bozon. Dominantan način produkcije Higsovog bozona, sa masom od 125 GeV, pri energiji interakcije 13 TeV je fuzija gluona. Fuzija gluona, za razliku od produkcije putem fuzije vektorskih bozona koja u finalnom stanju daje Higsov bozon sa dva kvarka od kojih hadronizacijom nastaju džetovi, u finalnom stanju sadrži samo Higsov bozon. Drugi načini produkcije koji se mogu posmatrati na LHC-u su produkcija Higsa sa vektor bozonom kao i produkcija sa top kvark-antikvark parom. Po teoriji Standardnog modela, Higsov bozon ima izuzetno kratko vrijeme života tako da se ovaj bozon nikad ne posmatra direktno vec se analiziraju produkti njegovog raspada. Najčešći način raspada Higsovog bozona je raspad na bb, ali zbog velikog hadronskog fona pri proton-proton sudarima, ovaj kanal raspada je vrlo teško eksperimentalno posmatrati. Kanali raspada koji imaju najveću osjetljivost, tj. najpogodnije ih je eksperimentalno posmatrati su raspad na dva fotona, koji će se posmatrati u ovom radu, i ZZ* raspad (Z* predstavlja virtuelni Z bozon, ili Z bozon izvan masene ljuske).
Podaci koji će se koristiti za izradu ovog rada biće podaci sa ekspreimenta CMS koji se izvodi u laboratoriji CERN u Ženevi. Radi se o eksperimentu koji se sastoji od velikog broja detektora pri čemu svaki ima svoju specifičnu funkciju. Centralni dio CMS-a čini superprovodljivi solenoid dužine 12.5 m i prečnika 6 m. Nominalna vrijednost magnetnog polja koje proizvodi ovaj solenoid je 4 T što je neophodna za ostvarivanje što veće zakrivljenosti trajektorija naelektrisanih čestica, a time i za bolju identifikaciju čestica visokih energija. Unutar solenoida se nalaze sistem za detekciju tragova, kao i elektromagnetni i hadronski kalorimetar. Izvan solenoida se nalazi gvozdena povratna sprega koja je ispreplijetana slojevima mionskih detektora.
Kombinacija informacija sa svih CMS subdetektorskih sistema, omogućava nam da rekonstruisemo i idetifikujemo različite vrste objekata nastale pri proton-proton sudaru. Algoritam koji u obzir uzima i kombinuje podatke sa svih subdetektorskih sistema naziva se PF algoritam (engl. Particle Flow), i pomoću njega osim fotona, neutralnih hadrona, naelektrisanih hadrona, elektrona i miona mogu se rekonstruisati i džetovi kao i proračunati transverzalna energija koja nedostaje. PF algoritam koristi podatke o tragovima iz sistema za detekciju tragova i mionskog sistema i informaciju o deponovanju energije iz elektromagnetnog i hadronskog kalorimetra. Čestice koje se koriste za analizu su rekonstruisane na sljedeći način:

- Mioni – trag čestice se dobija povezivanjem traga iz sistema za detekciju tragova i mionskog sistema, dok se informacija o energiji dobija iz zakrivljenosti traga.

- Elektroni – deponovana energija u elektromagnetnom kalorimetru se povezuje sa tragom u unutrašnjem sistemu za detekciju tragova, energija se mjeri kombinacijom deponovane energije u elektromagnetnom kalorimetru i transverzalnim impulsom traga.
- Fotoni – deponovana energija u elektromagnetnom kalorimetru postoji pri čemu ne postoji trag u u sistemu za detekciju tragova koji se može povezati sa njom, energija se mjeri samo kao deponovana energija u elektromagnetnom kalorimetru.

Kako bi se analizirali navedeni procesi, potrebno je ekperimantalne podatke uporediti sa simulacijom. Monte-Carlo simulacija interakcija dobiće se korišćenjem MADGRAPH5 AMC@NLO generatora pp interakcija. Ovako generisani događaji propuštaju se kroz simuliranu detektorsku aparaturu softverskim paketom GEANT4. Rekonstrukcija događaja kroz simuliranu detektorsku aparaturu vrši se na identičan način kao i u slučaju eksperimentalnih podataka. Analize koje će biti predstavljene u radu dobiće se korišćenjem programskih jezika C++ i Python u okviru CMS softverskog okruženja. Grafici raspodjela dobiće se korišćenjem softverskog paketa ROOT koji je opšte korišćeni softver u analizama u fizici čestica.

Plan istraživanja

Plan istraživanja može se podijeliti u dvije etape.

1. Mjerenje varijable N-džetnost.

- Prvo mjerenje varijable N-džetnosti za različite vrijednosti N tj. broja džetova koji nastaju u proton-proton interakcijama uz produkciju Z bozona;
- Upoređivanje eksperimentalnih raspodjela po varijabli N-džetnost sa Monte Carlo simulacijom koja obuhvata generisanje proton-proton interakcija i simulaciju cjelokupnog detektorskog sistema kroz koji prolaze čestice nastale u ovim interakcijama;
- Ekstrakcija diferencijalnog efikasnog presjeka u funkciji od varijable N-džetnost uz primjenu tehnika za dekonvoluciju detektorskih efekata;
- Upoređivanje izmjerenih vrijednosti za diferencijalni efikasni presjek sa analitičkim proračunima;
- Korišćenje dobijenih mjerenja za podešavanje parametara Monte Carlo generatora događaja koji se koriste za modeliranje partonskih kaskada i čestica koje ne pripadaju analiziranom događaju;
- Mjerenje varijable N-džetnost u procesima sa nastankom Z bozona van masene ljuske, a čija je masa bliska masi Higs bozona.

2. Mjerenje produkcije Higs bozona kroz kanal raspada na dva fotona.

- Ispitivanje potencijala varijable N-džetnost za razdvajanje proseca koji vode produkciji Higs bozona, fuzije gluona i fuzije vektorskih bozona;
- Razvoj strategije analize produkcije Higs bozona uz korišćenje varijable N-džetnost;
- Mjerenje efikasnih presjeka za produkciju Higs bozona kanalima za fuziju gluona i fuziju vektorskih bozona;
- Mjerenje konstanti sprezanja Higs bozona sa vektorskim bozonima i fermionima.

Očekivani naučni doprinos

Ovaj rad će dati doprinos razumijevanju i modeliranju radijacije gluona niskih energija („mekih" gluona) u proton-proton interakcijama na energijama pri kojima dolazi do produkcije Higs bozona. U radu će se mjeriti varijabla koja je definisana 2010. i koja je nedavno korišćena za dobijanje teorijskih proračuna efikasnih presjeka koji ukazuju na mogućnost mjerenja presjeka sa izuzetnom preciznošću za procese sa dva reda iznad vodećeg po konstanti jake interakcije α_S.

(engl. next-to next-to-leading order – NNLO) u kombinaciji sa dva reda iznad vodećeg po logarotamskim korekcijama (engl. next-to-next-leading logs - NNLL) koje opisuju radijaciju mekih gluona i partonske kaskade iz kojih oni nastaju. Partonska kaskada ili partonski tuš nastaje kada rasijani kvark ili gluon (parton) izrači nove gluone iz kojih zatim nastaju gluoni nižih energija, kvarkovi i antikvarkovi. Proračuni koji uključuju partonske kaskade su veoma važni sa eksperimentalne tačke gledišta jer omogućavaju simulaciju proton-proton interakcija uključujući odziv samog detektora što nije slučaj za proračune koji se dobijaju sa fiksiranim redom. Simulacija je od suštinskog značaja za samu strukturu i korišćenje podataka sa eksperimenata kakav je CMS. Prije uvođenja ove varijable, u teorijskim proračunima i pratećim tehnikama preciznost mjerenja partonskog tuša bila je ograničena na članove sa vodećim logaritamskim redom (dakle za dva reda manje nego što je to slučaj sa korišćenjem N-džetnost varijable) . N-džetnost varijabla je do sada mjerena samo za poseban slučaj kad je N=0 (0-džetnost). U ovoj tezi dobiće se prvo eksperimentalno mjerenje ove varijable za N≥1. Z bozoni kreirani u vrlo velikom broju pri proton-proton interakcijama na LHC-u biće korišćeni za razumijevanje mnogoređih procesa koji vode kreaciji Higs bozona i provjeru teorijskih procjenjena efikasnih presjeka. Takođe, ispitaće se mogućnost korišćenja nove varijable za razdvajanje procesa produkcije Higs bozona kroz fuziju gluona i produkcije Higs bozona kroz fuziju vektorskih bozona. Kroz ovo će se utvrditi potencijal nove varijabla za ove svrhe. U zavisnosti od ishoda ovih provjera, moglo bi doći do značajnog poboljšanja preciznosti mjerenja konstanti sprezanja Higs bozona sa fermionima i vektorskim bozonima.

Spisak objavljenih radova kandidata

Kandidat još uvijek nema publikovanih radova.

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2. CMS Collaboration, Measurements of Higgs boson properties in the diphoton decay channelin proton-proton collisions at √s= 13TeV, JHEP11(2018) 185.
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Bins, Phys.Rev. D85 (2012) 034011.
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SAGLASNOST PREDLOŽENOG/IH MENTORA I DOKTORANDA SA PRIJAVOM

Odgovorno potvrđujem da sam saglasan sa temom koja se prijavljuje.

Prvi mentor	Nataša Raičević	N. Raičević
Drugi mentor	Marc Dejardin	
Doktorand	Jelena Mijušković	Jelena Mijušković

IZJAVA

Odgovorno izjavljujem da doktorsku disertaciju sa istom temom nisam prijavio/la ni na jednom drugom fakultetu.

Podgorica,
18.10.2019.

Jelena Mijušković
Ime i prezime doktoranda
Mr Jelena Mijušković

966

25 APR 2019

Na osnovu člana 32 stav 1 tačka 14 Statuta Univerziteta Crne Gore, u vezi sa članom 29 Pravila doktorskih studija, Senat Univerziteta Crne Gore, u postupku razmatranja prijedloga Vijeća Prirodno-matematičkog fakulteta i na prijedlog Centra za doktorske studije, na sjednici održanoj 19.04.2019. godine, donio je sljedeću

O D L U K U

I

Dr Nataša Raičević, redovni profesor Prirodno-matematičkog fakulteta Univerziteta Crne Gore imenuje za mentora pri izradi doktorske disertacije kandidatkinje mr Jelene Mijušković

II

Dr Marc Dejardija, senior istraživač sa Instituta CEA, IRFU, SACLAY, Pariz, Francuska imenuje za komentora pri izradi doktorske disertacije kandidatkinje mr Jelene Mijušković.

III

Odluka stupa na snagu danom donošenja.

Broj: 03- 912/2
Podgorica, 19.04.2019. godine

PREDSJEDNIK SENATA

Prof. dr Danilo Nikolić, rektor

PRIJAVA TEME DOKTORSKE DISERTACIJE

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Popis radova	/
NASLOV PREDLOŽENE TEME (Title)	
Na službenom jeziku	Od Z bozona do Higs bozona uz ograničenja na broj džetova nastalih pri produkciji bozona na LHC-u
Na engleskom jeziku	From the Z boson to the Higgs boson, constraining the number of

	associated jets in the production of a boson at the LHC

Obrazloženje teme

The Higgs mechanism is the cornerstone in the particle physics theory, called the Standard Model, through which all fundamental particles acquire their masses. As for all fundamental fields, there is an associated particle for the Higgs field – the Higgs boson. The existence of the Higgs boson was predicted in the 1970s, but it was discovered long after that by experiments at CERN in July 2012. Gluon fusion and vector boson fusion are the dominant mechanisms of production of the Higgs boson. The process of vector boson fusion is sensitive to the coupling of Higgs to vector bosons while gluon fusion is sensitive to the coupling to fermions through the fermion loop. Measurement of the Higgs couplings to vector bosons and to fermions requires separation and identification of the two channels for Higgs production.
In the process of Higgs production via vector boson fusion, two hadronic jets are created (a jet - narrow cone of hadrons produced in the process of hadronization of a quark or gluon). Such jets are rather separated in rapidity, which is how such a process is recognized and identified. The dominant error in the Higgs couplings measurement comes from the jets reconstruction. To increase precision of the measurement, a novel method for separation of the two channels without explicit jet reconstruction will be proposed in this thesis. We aim to measure a new variable, termed N-jettiness, which is correlated with a number of jets created from a proton-proton collision. This variable is defined and calculated from particles' momenta.
In this work, a new method for measurement of the cross section for vector boson production in association with jets in proton-proton collisions will be developed. The method is based on the measurement of a new variable, N-jettiness, and this is the first time it is being used in CMS analysis. At the same time, this is the first measurement of this variable in events with vector boson and jets. It is expected that this method improves precision of the cross section measurements for Z or Higgs boson production in association with jets in comparison with previously used methods. The Higgs boson coupling constants with fermions and bosons will also be measured. To test theoretical models used for simulation of such processes at the LHC, the experimental distributions will be compared with Monte Carlo simulations.
All the experimental results will be obtained by analyzing proton-proton interactions at 13 TeV energy which occur in collisions of protons accelerated in the Large Hadron Collider (LHC) at laboratory CERN in Geneva. Experimental data is obtained by detection of particles created in the proton-proton collisions at the CMS (Compact Muon Solenoid) experiment during the RUN II period of the LHC work.

Pregled istraživanja

The Standard Model is a complex theory which contains a set of mathematical formulas based on quantum field theory and describing elementary particles and their interactions. It started to develop in the middle of the last century, through the work of many scientists all over the world, with the current formulation being finalized in the 1970s. Experimental confirmation of many aspects of this theory were obtained many years later - top quark was discovered in 1995, tau neutrino was detected in 2000, and the Higgs boson detected in 2012; the last piece of the puzzle to complete experimental evidence of the theory. More than 30 Nobel prizes have been awarded to theory and experimental particle physicists for the results obtained within the Standard model. For the Higs boson discovery by CMS and ATLAS experiments at CERN, the theoreticians who predicted its existence were awarded a Nobel prize in 2013. After the new particle was discovered, a lot of effort was put into investigating the mechanisms of its production and decays in order to understand its properties in more detail. High precision measurements of Higgs boson's properties, especially its coupling constants, are of crucial impact not only for the Standard Model, but also for the new discoveries which can be achieved if there are high precision measurements of the parameters of the existing theory. The Standard Model is not a completely comprehensive theory which provides understanding of the matter on a fundamental level and cannot explain some phenomena whose existence is proven. The Standard Model does not provide explanations of mechanisms of gravitational interaction as one of four fundamental interactions. The Standard Model cannot explain about 95% of our universe, nor does it explain so called dark matter and dark energy. The Standard Model does not explain why there is asymmetry between the matter and antimatter and why a neutrino would have mass. Therefore, there are a lot of questions left and there are many theories attempting to provide the answers. Such theories are theories beyond the Standard Model. To get an answer and to confirm or reject a theory, it is necessary to have an experiment and measurements of the Standard Model parameters with as high precision as possible. Only such precise measurements could confirm whether some new measurement go beyond this theory or not. The measurements of the Higgs boson couplings with high precision are of crucial importance for understanding the structure of matter and providing answers for many unsolved questions. The N-jettinnes variable will be proposed in this thesis with the aim to provide high precision measurements of vector boson production at the LHC. It was introduced in 2010 for identification of events with jets and to get as precise as possible measurements of the cross sections for such processes. This variable has not been experimentally measured yet except for the cases when N = 0 in proton-proton interactions at 7 TeV energy in the center of mass frame with the Z boson creation (ATLAS experiment).

Cilj i hipoteze

The aim of this work is to develop a new method for measurement of the cross section for boson production in association with jets in proton-proton collisions. As a first step, the new variable, N-jettiness, will be measured and tested for events with proton-proton interactions in which Z boson is created in association with jets. This is a high statistics sample with a very clean signature. In this analysis, the Z boson will be identified through its decay into a dilepton pair . The distributions of this variable and its correlated variables will be compared with theoretical models simulating proton-proton interactions with the detector effects included and simulated. For the processes with Z production, the differential cross section will be obtained with the new variable and the precision of its measurement will be estimated.
After the measurements with the Z boson sample have been made, a study of the potential of the N-jettiness variable to separate Higgs boson production processes, gluon and vector boson fusions, will be performed. An analysis strategy using N-jettiness variable for Higgs boson production measurement will be developed. The cross sections for Higgs boson production via fusion of gluons and vector bosons and Higgs boson coupling constants with fermions and bosons will be measured. In this analysis, the Higgs boson will be identified through its decay into two photons. All the measurement will be compared with Monte Carlo generated interactions and full simulation of the detector system.

H01 - N-jettiness variable provides high precision measurement of cross section for Z boson production at the LHC.
H02 - N-jettiness variable has a potential to be used for high precision measurement of cross section for Higgs boson production at the LHC.
H1 - The direction of jet axes can be reconstructed with the new variable without explicit jet reconstruction.
H2 - Experimental distributions for Z boson production obtained with the new variable are well described by the distributions obtained from Monte Carlo generator(s) used at the LHC experiments.
H3 - Experimental distributions for Higgs boson production are well described by the

distributions obtained from Monte Carlo generator(s) used at the LHC experiments.
H4 – The new analysis will provide high precision measurements of Higgs couplings to vector bosons and fermions.
* High precision measurement means that the systematic error of a measurement is smaller than the error of the same measurement obtained with previously used data and methods.

Materijali, metode i plan istraživanja

First part on this thesis will be devoted to analysis of Drell –Yan processes in proton –proton interaction at Large Hadron Collider. The Drell-Yan process consists in the annihilation of a pair of quark-antiquark into a virtual photon or neutral weak boson decaying into a pair of lepton-antilepton. Analysis of Drell-Yan processes are important not only for understanding and testing Standard Model processes but also for further analysis of theories Beyond the Standard Model, that is why having a good precision measurments is very important. Nevertheless, Drell-Yan process is the main background of many other processes such as decay of Higgs boson.
In the second part of the thesis, focus will be on Higgs boson. For collisions at centre-of-mass energy 13 TeV and a Higgs boson mass of around 125 GeV, gluon fusion is the dominant mode of production. Unlike the other modes, such as vector boson fusion which produces a Higgs boson together with two quarks that hadronise to form jets, the gluon fusion contains only the Higgs boson in final state. Other important production modes analyzed at LHC include vector boson-associated production and production in association with a top quark-antiquark pair. The Standard Model theory predicts that the Higgs boson has very short lifetime which means that the Higgs boson is never observed directly, but instead its presence is inferred from its decay products. The decay channel of Higgs boson with the largest branching fraction is bb, but because of the large hadronic background in proton-proton collisions at LHC this channel is very difficult to observe. The channels with the greatest sensitivity, that are most convinient to observe experimentally, are the diphoton ($\gamma\gamma$) and ZZ* decays (where Z* is a virtual, or off mass-shell, Z boson). In this thesis diphoton decay channel of Higgs boson will be observed.
The data used in this thesis is obtained by using CMS detector at CERN in Geneva. This detector has a compact structure with a lot of subdetectors systems. Central part of CMS detector is a large superconducting solenoid with a length of 12.5 m and a radius of 6 m. The nominal value of magnetic field that it can produce is 4T. Inside the solenoid the tracking detector, the electromagnetic calorimeter (ECAL) and the hadron calorimeter (HCAL) are all installed. Outside the solenoid is the iron return yoke of the magnet, interleaved with layers of muon detector.
In order to reconstruct and identify particles CMS uses algorithm called Particle Flow algorithm (PF). The goal of PF is to combine the information of all the CMS subdetectors, enabling the best possible identification and energy measurements for all types of objects. PF algorithm uses information about tracks from the tracker and muon system, and calorimeter clusters from the ECAL and HCAL. This algorithm allows us to reconstruct photons, neutral hadrons, charged hadrons, electrons and muons and it also provide us jet reconstruction and missing transverse momentum determination. Some of the particles used in this analysis are reconstructed in the following way:

- Muons - a path extrapolated from the tracker is consistent with a muon track, information about the energy is from the curvature of the track.
- Electrons - an ECAL super-cluster is present and associated with a track from the inner tracker, the energy is measured using a combination of the track and the super-cluster energy.
- Photons - an ECAL super-cluster is present and no track is associated with it, the energy is measured using the ECAL super-cluster only.

For analysis of the processes mentioned above, it is necessery to compare experimental data with the simulation. Proton – proton interaction is generated using the MADGRAPH5 AMC@NLO generator and the CMS detector itself is modelled using GEANT4. Reconstruction of simulated events will be done in the same way as for the experimental data. In order to analyse both experimental and simulated data,the programing languages C++ and python in CMS softver enviroment will be used. The analysed distributions will be ploted in ROOT which is widely used software package in particle physics.

Research plan

Research plan can be divided in two stages.

1. Measurement of the N-jettiness

- First measurement of the N-jettiness variable at CMS for different values of N i.e. number of jets which are produced in association with Z boson;
- Comparison of the experimental N-jetiness distributions and distributions related to it with theoretical predictions which include generation of proton-proton interactions and simulation of the detector material and passage of particles trough it;
- Extraction of the differential Z boson production cross section as a function of the N-jettiness with application of techniques for deconvolution of detector effects;
- Comparison of the measured differential cross section with analytical calculations;
- Use of the obtained measurements for tuning of Monte Carlo generator events which are used for modeling of parton showers and particles which do not belong to the analysed event;
- Measurement of N-jettiness in processes with production of virtual Z boson with the mass close to the Higgs boson mass.

2. Measurement of Higgs boson production in two-photon channel.

- Study of the potential of the N-jettiness variable to separate Higgs boson production processes: gluon fusion and vector boson fusion;
- Development of an analysis strategy using N-jettiness variable for the analysis of Higgs boson production;
- Measurement of the cross sections for Higgs boson production via fusion of gluons and vector bosons;
- Measurement of the Higgs boson coupling constants with fermions and vector bosons.

Očekivani naučni doprinos

This work will contribute to the understanding and modeling of soft gluon radiation in the proton-proton collisions at the energy scale involved in the production of the Higgs boson. It will provide a measurement of a variable, introduced in 2010 and which has been recently used in cross-section calculations and brought them to an unprecedented accuracy, next-to-next-to-leading order (NNLO) in α_s combined to next-to-next-to-leading logs (NNLL) and parton shower. Calculations including parton shower are extremely important for the experiment point of view because they allow the simulation of the proton-proton collisions including the response of the detector, which is not the case of fixed-order calculation. The simulation is essential in the design and the data exploitation of experiments like CMS. Before the use of this variable in the calculation and the associated techniques, the parton shower accuracy was limited to leading-log (therefore, two order less). This variable has been measured so far only in the special case of N=0 (0-jettiness). This thesis will be its first measurement for N≥1. The Z boson, produced abundantly at the LHC, is used as a proxy to understand the rarer production of the Higgs boson and validate the cross section calculations. In addition, the usage of this variable to discriminate gluon and vector boson fusion production modes of the Higgs boson will be explored. This study will assert the potential of this variable for this use. Depending on the outcome, it could lead to a significant improvement of the accuracy of the measurement of the couplings of the Higgs boson to fermions and vector bosons.

Spisak objavljenih radova kandidata

There has not been a publication yet. There are several preprints in which the candidate is a coauthor.

Popis literature

1. CMS Collaboration, Observation of a New Boson at a Mass of 125 GeV with the CMS Experiment at the LHC - Phys.Lett. B716 (2012) 30-61.
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SAGLASNOST PREDLOŽENOG/IH MENTORA I DOKTORANDA SA PRIJAVOM

Odgovorno potvrđujem da sam saglasan sa temom koja se prijavljuje.

Prvi mentor	Nataša Raičević	N Raičević
Drugi mentor	Marc Dejardin	[signature]
Doktorand	Jelena Mijušković	Jelena Mijušković

IZJAVA

Odgovorno izjavljujem da doktorsku disertaciju sa istom temom nisam prijavio/la ni na jednom drugom fakultetu.

Podgorica,
18.10.2019.

Jelena Mijušković
Ime i prezime doktoranda
MSc Jelena Mijušković

UNIVERZITET CRNE GORE
PRIRODNO-MATEMATIČKI FAKULTET
FIZIKA
Broj dosijea: **1/2018**

Na osnovu člana 165 stava 1 Zakona o opštem upravnom postupku ("Službeni list RCG", broj 60/03.), člana 115 stava 2 Zakona o visokom obrazovanju ("Službeni list CG", broj 44/14.) i službene evidencije, a po zahtjevu studenta Mijušković Dragan Jelena, izdaje se

UVJERENJE O POLOŽENIM ISPITIMA

Student **Mijušković Dragan Jelena**, rođena **14-12-1993** godine u mjestu **Nikšić**, opština **Nikšić**, Republika **Crna Gora**, upisana je studijske **2018/2019** godine, u I godinu studija, kao student koji se **samofinansira** na **doktorske akademske studije**, studijski program **FIZIKA**, koji realizuje **PRIRODNO-MATEMATIČKI FAKULTET** - Podgorica Univerziteta Crne Gore u trajanju od **3 (tri)** godine sa obimom **180** ECTS kredita.

Student je položio ispite iz sljedećih predmeta:

Redni broj	Semestar	Naziv predmeta	Ocjena	Uspjeh	Broj ECTS kredita
1.	I	EKSPERIMENTALNE METODE U FIZICI VISOKIH ENERGIJA	"A"	(odličan)	10.00
2.	I	METODOL.NAUČNOG RADA I PREDSTAVLJANJE EKSPERIM.REZ	"A"	(odličan)	10.00
3.	I	VIŠI KURS FIZIKE ELEMENTARNIH ČESTICA	"A"	(odličan)	10.00
4.	I	VIŠI KURS KVANTNE MEHANIKE	"C"	(dobar)	10.00

Zaključno sa rednim brojem **4**.

Ostvareni uspjeh u toku dosadašnjih studija je:

- srednja ocjena položenih ispita **"A" (9.50)**
- ukupan broj osvojenih ECTS kredita **40.00** ili **66.67%**
- indeks uspjeha **6.33**.

Uvjerenje se izdaje na osnovu službene evidencije, a u svrhu ostvarivanja prava na: (dječji dodatak, porodičnu penziju, invalidski dodatak, zdravstvenu legitimaciju, povlašćenu vožnju za gradski saobraćaj, studentski dom, studentski kredit, stipendiju, regulisanje vojne obaveze i slično).

Broj:
Podgorica, 25.10.2019 godine

M. P.

SEKRETAR,

UNIVERZITET CRNE GORE
PRIRODNO-MATEMATIČKI FAKULTET
FIZIKA
Broj dosijea: **1/2018**

Na osnovu člana 165 Zakona o opštem upravnom postupku ("Službeni list RCG" br. 60/03) i službene evidencije, a po zahtjevu Mijušković Dragan Jelena, izdaje se

POTVRDA O STUDIRANJU

Student **Mijušković Dragan Jelena**, rođena **14-12-1993** godine u mjestu **Nikšić**, opština **Nikšić**, Republika **Crna Gora**, upisana je studijske **2018/2019** godine, u **I** godinu studija, kao student koji se **samofinansira** na **akademske doktorske studije**, studijski program **FIZIKA**, koji realizuje **PRIRODNO-MATEMATIČKI FAKULTET** - Podgorica Univerziteta Crne Gore u trajanju od **3 (tri)** godine sa obimom **180** ECTS kredita.

Studijske **2018/2019** godine prijavila je *da sluša* **5** predmeta sa **60.00** (šezdeset) ECTS kredita.

Po prvi put iz **I** (**prve**) godine, prijavila je *da sluša* **5** predmeta sa **60.00** (šezdeset) ECTS kredita, što iznosi 100.00% od ukupnog broja ECTS kredita u **I** godinu.

Saglasno Statutu Univerziteta Crne Gore, **Mijušković Dragan Jelena** je po prvi put prijavila *da sluša* **više od 2/3**, odnosno **66,67% (šezdesetšest 67/100 %)**, od ukupnog broja ECTS kredita sa **I** godine i studijske **2018/2019 ima status redovnog studenta** koji se **samofinansira**.

Uvjerenje se izdaje na osnovu službene evidencije, a u svrhu ostvarivanja prava na: (dječji dodatak, porodičnu penziju, invalidski dodatak, zdravstvenu legitimaciju, povlašćenu vožnju za gradski saobraćaj, studentski dom, studentski kredit, stipendiju, regulisanje vojne obaveze i slično).

M. P.

Broj:
Podgorica, 25.10.2019 godine

SEKRETAR,

Curriculum Vitae

Lični podaci

Ime i prezime: Nataša Raičević

Datum i mjesto rođenja: 12.08. 1970, Srbija

Djevojačko prezime: Saveljić

Strani jezici: engleski – aktivno znanje
ruski – dobro razumjevanje i čitanje

Kontakt

Adresa: Univerzitet Crne Gore, Prirodno-matematički fakultet, Džordža Vašingtona BB, 81000 Podgorica, Crna Gora

E-mail: natasar@ucg.ac.me

Obrazovanje

1993 **Diplomirani fizičar,** Univerzitet Crne Gore, Prirodno-matematički fakultet
(prosječna ocjena na studijama 9.90)

1997 **Magistar fizičkih nauka,** Univerzitet u Beogradu, Fizički fakultet
(prosječna ocjena na studijama 10.0)

2000 **Doktor fizičkih nauka,** Univerzitet u Beogradu, Fizički fakultet

Studentske nagrade i priznanja

1990 Decembarska nagrada za najboljeg studenta Prirodno-matematičkog fakulteta

1993 Nagrada Univerziteta Crne Gore za najboljeg studenta završne godine Prirodno-matematičkog fakulteta Univerziteta Crne Gore za školsku 1992/93. godinu

Profesionalne pozicije

1993–1997 **Saradnik u nastavi** na Prirodno-matematičkom fakultetu Univerziteta Crne Gore u Podgorici, Crna Gora

1997–2000 **Asistent** na Prirodno-matematičkom fakultetu Univerziteta Crne Gore u Podgorici, Crna Gora

2000–2005 **Docent** na Prirodno-matematičkom fakultetu Univerziteta Crne Gore u Podgorici, Crna Gora

2005–2010 **Vanredni profesor** na Prirodno-matematičkom fakultetu Univerziteta Crne Gore u Podgorici, Crna Gora

2010–danas **Redovni profesor** na Prirodno-matematičkom fakultetu Univerziteta Crne Gore u Podgorici, Crna Gora

Nastava

Vježbe na matičnom i nematičnim fakultetima (u zvanju saradnika i asistenta)

Elektromagnetizam, Optika, Statistička fizika, Fizika čvrstog stanja, Nuklearna fizika (PMF), Eksperimentalne vježbe na nematičnim fakultetima

Predavanja na predmetima (u zvanju docenta, vanrednog i redovnog profesora)

Elektromagnetizam – osnovne studije na Prirodno-matematičkom fakultetu

Fizika elementarnih čestica – specijalističke studije na Prirodno-matematičkom fakultetu

Računari i programiranje – osnovne studije na Prirodno-matematičkom fakultetu
Teorijska elektrodinamika - osnovne studije na Prirodno-matematičkom fakultetu

Viši kurs fizike elementarnih cestica 1 - magistarske studije na Prirodno-matematičkom fakultetu

Eksperiment u savremenoj fizici čestica - magistarske studije na Prirodno-matematičkom fakultetu

Viši kurs fizike elementarnih čestica - magistarske studije na Prirodno-matematičkom fakultetu

Biofizika na Medicinskom fakultetu

Poglavlja iz fizike u okviru predmeta Fiziologija na Medicinskom fakultetu

Oblast istraživanja

Eksperimentalna fizika elementarnih čestica

1995 – 1999 Član međunarodne istraživačke kolaboracije eksperimenta CERES u laboratoriji CERN u Ženevi (akcelerator SPS)

1995–1996 Testiranje performansi trigera prvog nivoa na eksperimentu CERES
Ujedinjeni institut za nuklearna istraživanja u Dubni, Rusija

1996-1997 Unapređenje softvera za analizu događaja sa eksperimenta CERES – rekonstrukcija verteksa za interakciju jezgara olova sa segmentisanom metom od zlata
Ujedinjeni institut za nuklearna istraživanja u Dubni, Rusija

1996–1999 Proučavanje emisije e^+e^- parova u interakcijama teških jona
Fizički institut Univerziteta u Hajdelbergu, Njemačka
Univerzitet Crne Gore

2002– Član međunarodne istraživačke kolaboracije eksperimenta H1 u laboratoriji DESY u Hamburgu, Njemačka (akcelerator HERA)
Ova istraživanja realizovana su na Univerzitetu Crne Gore i kroz veći broj višemjesečnih boravaka godišnje na institutu DESY u Hamburgu i Berlinu.

2002-2005 Analiza podatataka za mjerenje efikasnog presjeka za duboko neelastično rasijanje elektrona (pozitrona) na protonu pri malim i srednjim vrijednostima kvadrata predatog kvadri-impulsa

2004-2005 Rad na unapređenju softverskog rješenja za simulaciju kaskada čestica u kalorimetru H1 eksperimenta koji detektuje elektrone sa malim uglom rasijanja

2005-2007 Analiza podatataka za mjerenje efikasnog presjeka za duboko neelastično rasijanje elektrona (pozitrona) na protonu pri velikim vrijednostima neelastičnosti interakcije

2006-2007 Učešće u priprema seansi za e^+p interakcije sa redukovanim energijama protona sa HERA akceleratora (kroz analizu tada postojećih eksperimentalnih podataka)

2007-2011 Mjerenje longitudinalne strukturne funkcije protona

2017- Član međunarodne istraživačke kolaboracije eksperimenta CMS u laboratoriji CERN u Ženevi, Švajcarska (akcelerator LHC)

2017 – Analiza produkcije Drell-Yan parova u proton-proton interakcijama.

Projekti (sa rukovodećom ulogom)

2004–2007 Učesnik na međunarodnom projektu finansiranom od strane DFG-a (Deutsche Forchungsgemeinschaft): **„Präzisionsmessungen und Analyse der Elektron-Quark-Wechselwirkung bei höchsten Energien sowie suche nach Phänomenen außerhalb des Standardmodels"**, broj **GZ:436JUG113/3/0-1**, odobren 2007. godine (partnerske strane: Univerzitet Crne Gore, institut DESY u Hamburgu, institut DESY-Zeuthenu u Berlinu i institut Max Planck u Minhenu).

2007–2010 Produžetak prethodnog projekta od DFG, pod brojem **GZ:436JUG113/3/0-2**

2005–2007 Rukovodilac naučno-istraživačkog projekta odobrenog od Ministarstva prosvjete i nauke Crne Gore **„H1 eksperiment na HERA akceleratoru"**

2008–2011 - Rukovodilac naučno-istraživačkog projekta odobrenog od Ministarstva prosvjete i nauke Crne Gore **„Duboko neelastično rasijanje elektrona (pozitrona) na protonu"**

2012-2015 - Rukovodilac naučno-istraživačkog projekta odobrenog od Ministarstva nauke Crne Gore **„Završna faza analiza H1 kolaboracije"**.

2019 – 2023 – Ključni partner u projektu odobrenog u program **HORIZONT2020 „The strong interaction at the frontier of knowledge: fundamental research and applications".**

Učešće u radu upravljačkih struktura velikih kolaboracija

2004–2012 učešće u radu Upravnog odbora H1 kolaboracije koji donosi najvažnije odluke za kolaboraciju

2007–2009 član Izvršnog odbora H1 kolaboracije

2012-2014 član Upravnog odbora H1 kolaboracije

2017- član Upravnog odbora CMS kolaboracije

Učešće u radu tijela/centara čiji je rad povezan sa obrazovanjem

2015-2017 – član Nacionalnog savjeta za obrazovnje Crne Gore

2015-2017 – član Odbora za obrazovnje Crne Gore

Od 2015 – član Centra za studije i kontrolu kvaliteta Univerziteta Crne Gore

Od 2015 – član Odbora za monitoring magistarskih studija Univerziteta Crne Gore

Od 2016 – član Vijeća za prirodne i tehničke nauke Univerziteta Crne Gore

Informatička pismenost

Operativni sistemi: UNIX i WINDOWS

Programski jezici: fortan, C, python

Nataša Raičević

Bibliografija

Odabrani radovi

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2. H1 and ZEUS Collaborations (H. Abramowicz,..N. Raičević *et al.*),Combination of measurements of inclusive deep inelastic $e^{\pm}p$ scattering cross sections and QCD analysis of HERA data, Eur.Phys.J. C75 (2015) no.12, 580.

3. N. Raičević, Recent Results from HERA on the Proton Structure, Acta Phys.Polon.Supp. 7 (2014) 3, 439. **

4. N. Raičević, Precision Tests of QCD at HERA, Acta Phys.Polon.Supp. 6 (2013) 3, 985. **

5. N. Raičević, A. Glazov and A. Zhokin, Shower library technique for fast simulation of showers in calorimeters of the H1 experiment., Nucl.Instrum.Meth. A718 (2013) 104.

6. N. Raičević, Measurement of the diffractive DIS cross section at the H1 experiment, Rom. Rep. Phys. 65 (2013) 427. **

7. N. Raičević, Precision measurement of the proton structure at HERA, Rom.Rep. Phys. 65 (2013) 103. **

8. H1 Collaboration (F. D. Aaron,..N. Rajčević *et al.*), Measurement of the Inclusive ep Scattering Cross Section at High Inelasticity y and of the Structure Function FL, Eur. Phys. J. C71 (2011) 1579.

9. A. Glazov, N. Raičević and A. Zhokin, Fast simulation of showers in the H1 calorimeter, Comput. Phys. Commun. 181 (2010) 1008.

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Proc. Suppl. 207-208 (2010) 125. **

11. N. Raičević, HERA results and their impact for LHC, Nucl. Phys. Proc. Suppl. 198: (2010) 75. **

12. N. Raičević, Measurement of proton structure and parton density functions from HERA, AIP Con. Proc. 1203 (2010) 85. **

13. N. Raičević, Measurement of the proton structure function F_L(x, Q**2) with the H1 experiment, AIP Con. Proc. 1203 (2010) 79. **

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15. N. Raičević, Proton structure and QCD dynamics at low x, Nucl. Phys. Proc. Suppl. 181-182 (2008) 57. **

16. N. Raičević, Measurement of the neutral current DIS cross section at H1, J. Phys. Con. Ser. 110 (2008) 022042. **

17. H1 Collaboration (F. D. Aaron,..N. Raičević *et al.*), Measurement of the Proton Structure Function $F_L(x, Q^2)$ at Low x, Phys. Lett. B665 (2008) 139.

18. N. Raičević, Measurement of the longitudinal structure function from e p collisions with the H1 detector at HERA, AIP Con. Proc. 899 (2007) 575. **

19. N. Raičević, Measurement of the inclusive e p deep inelastic scattering cross section at low Q^2 with the H1 detector at HERA, AIP Con. Proc. 899 (2007) 217. **

20. CERES/NA45 Collaboration (G. Agakichiev,..N. Saveljić et al.), e+e- pair production in Pb-Au collisions at 158-GeV per nucleon, Eur. Phys. J. C41 (2005) 475.

21. CERES/NA45 Collaboration (G. Agakichiev,..N. Saveljić et al.), Recent results from Pb - Au collisions at 158-GeV/c per nucleon obtained with the CERES spectrometer, Nucl. Phys. A 661 (1999) 23.

22. CERES/NA45 Collaboration (G. Agakichiev,..N. Saveljić et al.), CERES results on low mass electron pair production in Pb Au collisions, Nucl.Phys.A638 (1998) 159.

23. G. Agakishiev,.. ,..N. Saveljić *et al.*, A New robust fitting algorithm for vertex reconstruction in the CERES experiment, Nucl. Instrum. Meth. A 394 (1997) 225.

Odabrani radovi u zbornicima međunarodnih konferencija

24. N. Raičević, High y DIS cross section measurement with H1, Procedings of 15th International Workshop on Deep-Inelastic Scattering and Related Subjects, Munich, Germany, April 2007, vol. 1, 293, editors: G. Grindhammer, K. Sachs. ISBN 978-3-935702-23-2. **

25. N. Raičević, Structure functions and extractions of PDFs at HERA, Proceedings of 41st Rencontres de Moriond: QCD and Hadronic Interactions, La Thuile, Italy, 18-25 March 2006, 181, editors: Etienne Auge and Jean Tran Thanh. e-Print: hep-ex/0605050. **

** Radi se o publikacijama koje obuhvataju najzapaženije rezultate kolaboracija koji su predstavljani na međunarodnim konferencijama, a koje je N. Raičević predstavljala u ime jedne ili više kolaboracija.

Svi navedeni kolaboracioni radovi su radovi sa preko 100 citata tzv. **TOPCITE:100+** u bazama podataka.

Kompletna lista od oko 140 referentnih radova u kojima je N. Raičević autor ili koautor nalazi se u bazi podataka na web-stranicama

https://inspirehep.net/search?ln=en&ln=en&p=find+a+n.+raicevic&of=hb&action_search=Search&sf=earliestdate&so=d&rm=&rg=25&sc=0

https://inspirehep.net/search?ln=en&ln=en&p=find+a+n.+saveljic&of=hb&action_search=Search&sf=earliestdate&so=d&rm=&rg=25&sc=0

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Датум, 28.10.2010 г.

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Природно-математички факултет
Број 2948
Подгорица, 11.11.2010 год.

Ref: ____
Date, ____

Na osnovu člana 75 stav 2 Zakona o visokom obrazovanju (Sl.list RCG, br. 60/03 i Sl.list CG, br. 45/10) i člana 18 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore, na sjednici održanoj 28.10.2010. godine, donio je

ODLUKU
O IZBORU U ZVANJE

Dr NATAŠA RAIČEVIĆ bira se u akademsko zvanje **redovni profesor** Univerziteta Crne Gore za predmete: Elektromagnetizam i Fizika elementarnih čestica, na **Prirodno-matematičkom fakultetu.**

REKTOR

Prof.dr Predrag Miranović

SLOBODAN BACKOVIĆ

Rođen je 3. septembra 1946. godine u Nikšiću gdje je završio osnovnu školu i gimnaziju. Prirodno-matematički fakultet, Odsjek za fiziku, završio je u Beogradu. Od 1969. do 1972. godine radio je u gimnaziji u Nikšiću kao profesor fizike. Na postdiplomske studije, na PMF-u u Beogradu (Odsjek za fiziku – smjer Eksperimentalna nuklearna fizika), upisao se 1973. godine, kada je počeo i da radi u Institutu za fiziku Univerziteta u Beogradu (Laboratorija za fiziku visokih energija). U to vrijeme radio je honorarno kao asistent-pripravnik Odsjeka za fiziku PMF-a i Farmaceutskog fakulteta. Magistarski rad "Multiplicitet naelektrisanih čestica nastalih u interakciji protona od 200 GeV sa jezgrima nuklearne emulzije" odbranio je u januaru 1976. godine, poslije čega odlazi na naučnu specijalizaciju u Ujedinjeni institut za nuklearna istraživanja (Laboratorija za fiziku visokih energija), u Dubnu (Rusija).

Na specijalizaciji je radio u međunarodnoj grupi fizičara u oblasti visokoenergetske fizike (visokoenergetske interakcije čestica i jezgara sa jezgrima). U Dubni ostaje do avgusta 1978. godine. Doktorsku disertaciju "Interakcija p–mezona impulsa 40 GeV/*c* sa jezgrom ugljenika" odbranio je 1979. godine na PMF-u u Beogradu. U Titograd prelazi 1. oktobra 1979. godine gdje počinje da radi u Institutu za matematiku i fiziku. Iste godine je izabran u zvanje docenta. U zvanje vanrednog profesora izabran je 1985. godine, a redovnog 1991. godine.

U Institutu za matematiku i fiziku više godina bio je šef Odsjeka za fiziku (1980–1986. i 1994–1996), a od 1986. do 1990. i od 1998. do 2002. godine direktor Instituta, odnosno dekan Prirodno-matematičkog fakulteta. Od 1990. do 1994. godine bio je prorektor za nastavu Univerziteta Crne Gore. Od 2003. do 2008. godine godine bio je ministar prosvjete i nauke u Vladi RCG.

Naučnoistraživački rad posvećen je visokoenergetskim interakcijama čestica i jezgara i jezgara sa jezgrima i odvijao se u okviru međunarodne kolaboracije koja radi na višegodišnjem projektu "Izučavanje kvark-hadronske strukture nuklearne materije, nalaženje i izučavanje svojstava egzotičnih pojava u sudarima relativističkih jezgara". Bio je rukovodilac višegodišnjeg naučnog projekta "Nuklearna fizika sa primjenama" (1987–1990. i 1991–1995), a tema na kojoj je radio bila je uključena u jugoslovenski projekat "Eksperimantalna fizika elementarnih čestica, srednjih energija i teških jona u međunarodnim centrima". Rukovodio je projektom "Visokoenergetske interakcije jezgara" (1997–1998) kao i međunarodnim projektima koje su finasirali UNESCO"High energy nucleus-nucleus interactions" (1998–1999) i WUS "High energy nucleus-nucleus and hadron-hadron interactions" (1999). Radio je u evropskoj kolaboraciji H1 (DESY Hamburg). Na ovim projektima pod mentorstvom S. Backovića urađene su četiri doktorske disertacije i četiri magistarska rada.

Autor i koautor je preko 100 naučnih radova koji se mogu vidjeti u elektronskim bazama: http://inspirehep.net/search?ln=en&p=find+a+s+backovic&of=hb&action_search=Search;http i http://scholar.google.com/citations?user=fXGhNVwAAAAJ&hl=en i https://www.researchgate.net/profile/S_Backovic/contributions?ev=prf_act.
Bibliografija radova može se vidjeti i na:
http://vbcg.vbcg.me/cobiss/bibliografije/Y20141102154659-00001.html.

Koautor je zbirke zadataka i jednog udžbenika za srednje škole, koautor je prevoda fakultetske zbirke zadataka iz fizike „Zadaci iz opšte fizike" (I. E. Irodov) i autoruniverzitetskogudžbenika „Fizička mehanika".

Od 1980. do 1985. godine, kao sekretar Nacionalnog odbora za fiziku, bio je član Predsjedništva Saveza društava matematičara i fizičara Jugoslavije. Bio je: predsjednik Društva matematičara i fizičara Crne Gore (1986–1998), predsjednik Prosvetnog savjeta Crne Gore, član Savjeta za nauku Crne Gore, član Izvršnog odbora RSIZ-a za naučne djelatnosti Crne Gore. Bio je član Savezne komisije za sigurnost nuklearnih objekata. Učestvovao je u organizaciji republičkih i saveznih takmičenja iz fizike za učenike srednjih i osnovnih škola (Društvo matematičara i fizičara i pokret „Nauka mladima"). Član je DANU, bio je ekspert Saveznog ministarstva za razvoj, nauku i životnu sredinu u oblasti fizike. Dobitnik je republičke nagrade „Oktoih" za 1999. godinu. U toku 2002. godine koordinirao je poslovima na reformi obrazovanja u Crnoj Gori i bio predsjednik Komisije za reformu osmogodišnje škole.

U periodu 2008–2011. bio je ambasador Crne Gore u Ruskoj Federaciji. Od oktobra 2011. do oktobra 2014. godine bio je rektor Univerziteta „Mediteran".

Za vanrednog člana CANU izabran je 12. decembra 2003. godine, a za redovnog 29. novembra 2011. godine.

Živi i radi u Podgorici.

<u>**SPISAK RADOVA**</u>

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O D L U K U

O POTVRDJIVANJU IZBORA Dr SLOBODANA BACKOVIĆA

U ZVANJE REDOVNOG PROFESORA UNIVERZITETA CRNE GORE

ZA PREDMETE Fizika I i Nuklearna fizika

ZA RAD NA NEODREDJENO VRIJEME SA PUNIM RADNIM VREMENOM NA Prirodno-matematičkom fakultetu u Podgorici.

PRAVNA POUKA: Protiv ove Odluke lica koja smatraju da su im povrijedjena prava imaju pravo žalbe Naučno-nastavnom vijeću Univerziteta Crne Gore u roku od 15 dana.

R E K T O R,

PROF. DR BOŽIDAR NIKOLIĆ

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PRIRODNO-MATEMATIČKI FAKULTET
Broj: 651
Titograd, 21.o5.1991. godine

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O D L U K U

Dr SLOBODAN BACKOVIĆ, bira se u zvanje redovnog profesora za predmete FIZIKA I i GRUPU PREDMETA IZ NUKLEARNE FIZIKE na Odsjeku za fiziku, za rad na neodredjeno vrijeme sa punim radnim vremenom.

- SAVJET PRIRODNO-MATEMATIČKOG FAKULTETA -

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2012-2016 Završna faza analiza H1 kolaboracije

Reference **2000-2019**:

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