

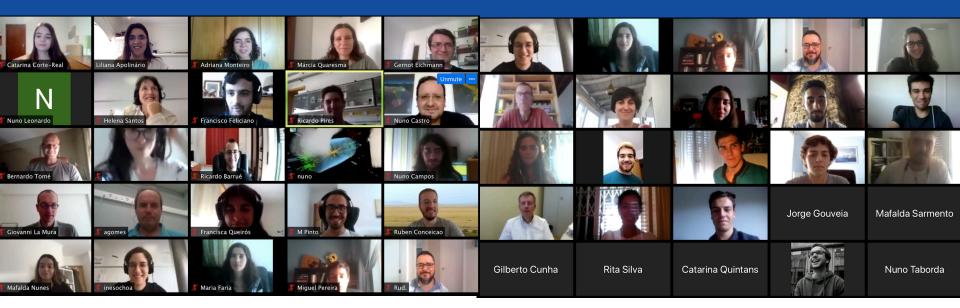
LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS partículas e tecnologia



IV LIP Internship Program / 2020 toward the end

Braga, Coimbra, Lisbon (Zoom!) — September 11th, 2020

... thank you for taking part !



and for making this edition of the LIP Internship Program another <u>great</u> <u>success despite</u> the exceptional global circumstance (pandemic) we're in



to the **student** participants

to the project supervisors

to LIP **researchers** in general for lectures, tutorials, topical chats, session convening, etc

to everyone who helped with the organisation

including Sofia (outreach), Ricardo (lectures), Liliana (workshop)

to the LIP support structures: IT (Hugo et al), Secretariat (Natalia et al), ECO (Catarina, Sonia, et al), directorate, ...

to everyone @ LIP

For this edition we needed to make some **adaptions** relative to past ones ...







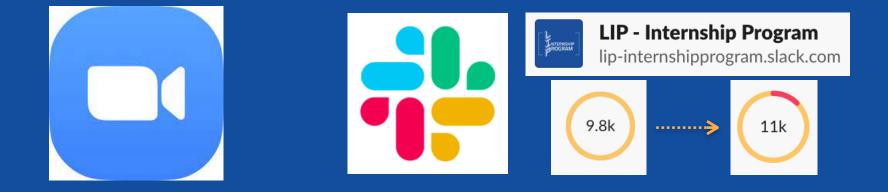








Successful transition to **online** format through **collaborative** apps





For this edition we needed to make some **adaptions** ...



Summaries

LIP NEWS Terapia com protões em Portugal



LIP NEWS

DATA IN (ASTRO)PARTICLE PHYSICS and COSMOLOGY SCIENCE

> When CP ones off beaten tracks R and the misteries of Quantum Chrome SHP: search for fidden particles iders and the EPPS upgrade

FORMAÇÃO AVANCADA

LIP Internship Program





2019 edition

bosons coupling to top pairs provide unique signatures at the LHC and we have used single lepton events collected by the ATLAS experiment to search for it. Machine learning techniques, namely deep neural networks, were used to distinguish this signal from the expected background. A statistical interpretation of the obtained results was also done

Kinematic reconstruction of ttbar events using the ATLAS open dataset

Student: Ana Alexandra Oliveira / Supervisors: Nuno Castro. Tiago Vale, Ana Peixoto, Emanuel Gouveia

Single lepton events were used to study the ttbar process. A cut-based analysis was developed to select these events and the full reconstruction of the ttbar system was performed using the

Search for Supersymmetry using September with a two-day long final workshc a Machine Learning tool where the students present their work. In be

LIP Internship Program is now a well establis

flagship event of LIP. Since 2018, the program

integrated all three LIP nodes, and has receiv

60 students each Summer. The programme in a preparatory week (lectures, thematic discu-

hands-on tutorials) in mid July, and ends early

the students carry out their research project:

proper. Thematic discussions in smaller group

and informal gatherings such as the "August c

"Churrasco" and "Coffee hour" allow student:

researchers to meet and discuss in a more inf

Yet another novelty, introduced in 2019. is th

possibility to describe the work in a scientific

(LIP note), following a prepared format, a cha-

that was readily taken by several students. It

worth stressing that the programme counts v

a broad and rather intense participation of LI

researchers, who serve as project supervisor

discussions, and take part in the discussion at

The programme of the 2020 edition - while

retaining the same underlying organization, f

and timings - moved entirely online. This po:

new challenges, which were met with needed

adaption, exploration of new tools, and some

inventiveness. The same level of participation

both students and researchers as in previous

AMBER - Physics simulations for a

AMBER is a project for a fixed target experiment at

CERN. One of its goals is to investigate guark and

gluon dynamics inside hadrons. Simulations were

process. Drell-Yan. Drell-Yan is a guarkantiguark

performed using Pythia8 in order to analyze a very r

annihilation where the resulting virtual photon deca

into a pair of muons. The starting point was to study

accompanying particles produced. We then focused on the kinematic variables associated to the muon pair (dimuon).

from the transverse momentum to the fraction of hadron momentum carried by the struck quark, Bjorken-x, The

acceptance of the detector was simulated by applying selection criteria on the muons' polar angle. Finally, we analyzed the effects of proton misidentification as a pion.

ABSTRACTS (2019 edition)

Student: Rita Silva / Supervisor: C. Ouintans

experiment at CERN

deliver tutorials and lectures, guide topical

way

final workshop.

was attained

Students: Artur Cordeiro, Timothée Cabos / Supervisors: P. Bargassa, Diogo de Bastos

We staved at LIP for only 5 weeks but we have developed a new Neural Network architecture to separate background from signal in the stop 4-body decays. The objective was to improve the performance compared to the BDT that was developed by our supervisor last year. We have achieved a significant improvement of performance (vet to be verified in detail). We learned a lot during this internship, we hope that our work might be useful for the lab. It was certainly useful to us

B mesons as novel probes of the QGP

Students: Alexandra Pardal, João Gonçalves / Supervisors: N. Leonardo, J. Silva

Quantum chromodynamics (QCD) predicts that under extreme conditions of temperature and/or density the Quark-Gluon Plasma (QGP) is formed. The QGP existed microseconds after the Big Bang and it is a state of matter formed by deconfined quarks and gluons. It can be recreated at the LHC by colliding heavy nuclei at the highest energies (Pb-Pb collisions). B mesons are composed of a bottom antiquark (b) bound to an up, down, strange or charm quark. In this experimental work we studied the B+ meson (bu) and the Bs meson (bs). Bottom quarks are created in the initial hard scattering stage and retain their identity while traversing the medium, thus recording information about its evolution. By comparing p-p collisions (vacuum medium) with Pb-Pb collisions (QGP), we can therefore use B mesons as probes to study the OGP properties. The goal of this internship was to measure the B mesons' crosssection in Pb-Pb collisions and to study how the QGP affects the hadronization of the b quark, using data collected by CMS in 2018 at the LHC. The raw signal yields were extracted by fitting the data, with an unbinned maximum likelihood implementation. The fits were validated using toy simulations. The detector and selection efficiency was calculated using simulated samples. These had to be validated against the data, which was achieved with sideband subtraction and SPlot statistical methods. Systematic uncertainties were calculated. Results were documented in a CMS internal note as part of the review materials of a CMS analysis.

Geant4 simulations on argon transparency to neutrons

Student: Leonardo S. R. Oliveira / Supervisor: S. Andringa

As the largest neutrino experiment to date, the DUNE experiment will have record-sized detectors, of which some will be liquid argon time projection chambers (LArTPC). One of the candidate calibration methods for these detectors is the pulsed neutron source (PNS) calibration, which relies on an anti-resonance neak in the cross section of argon-40. The upcoming Argon Resonance Transport Interaction Experiment (ARTIE) seeks to confirm the evistence of such anti-resonance neak and thus the feasibility of the PNS method. In this project. Geant4 simulation results for the ARTIE experiment are present lip news - edição n.17 Agosto

the upcoming experiment's rol Study of the Higgs couplings to methodology. quarks at ATLAS

P.Conde Measurement of J/w collisions at $\sqrt{s} = 8$ T Students: Francisco Albergari M. Araújo, P. Faccioli, J. Seixas

even with a 150 ns time smear

The polarization of prompt J/w proton collisions at data sampl at the LHC. The prompt polari from the dimuon decay angula The J/w results are obtained in 12<pT <70 GeV and in the rap of large polarization is seen in

Development of nove techniques for low-e showers

Students: Hugo Lóio, Luis Lou M Pimenta B Tomé The Southern Wide field-of-vie is a newly formed internationa a new observatory to be place. times bigger than the initially p being entirely composed of hyl provide the timing) and Water a WCD (1.5x1.5x1 m3) with a record the Cherenkov light pro particles.

The challenge of our work was reconstruct the shower geome well defined in time, but instea

The WCD signal time trace ha that hits the SiPMs directly; sc former has a sharp pulse that c the arrival of the shower parti-

Extending the functionality of a 3D graphic viewer of the Pierre Auger Observatory

Students: Leonardo Ramalho, Luís Neto / Supervisors: Henrique Student: Gonçalo Fernandes / Supervisors: R. Gonçalo, R. Pedro, Carvalho, Raul Sarmento

Since the discovery of the Higgs boson, the precise measurement of The 3D graphic viewer "Auger Visualizer" is a project for the its properties became a fundamental part of the ATLAS year as part of the LIP summer internships. This year new features between top and Higgs were found. In this project, the feasibility of simulating mixed-CP signals by interpolating CP-eyen and CP-odd simulated templates was demonstrated, which much

agreement with past results us Física Experimental de Partículas com os of this analysis are shown here detectores ATLAS, LUX e LZ. Students: André Filipe Silva, Ângelo Ferreira e Tiago Azevedo /

Supervisors: P. Bras, A. Lindote e F. Veloso As experiências ATLAS, LUX e LZ procuram dar resposta a várias

das questões que o modelo padrão da física de partículas deixa em abento. Desvios das previsões do SM relativas às propriedades. recem testes independentes de modelos específicos para nova la receita de matéria do Universo e do qual se sabe muito pouco. A deteccão da assinatura esperada das interaccões de matéria escura com matéria comum revelaria física nova, com fortes implicações para o SM e para a cosmologia. Neste estágio foram analisados

Machine Learning to improve the Higgs to b-quarks analysis in ATLAS Student: Dmytro Ostapchuk / Supervisors: P. Conde, R. Pedro

The approximation of the 1018 of the first observation of the Higs decay to b-quarks and of the associated production of Higgs and top guarks by ATLAS and CMS probed directly the coupling of the Higgs to quarks. The use of more advanced analysis techniques

We explored the possibility of improving the current ATLAS boson using Machine Learning techniques, not only to separate signal from background, but also to define the control regions different categories: signal. W+iets, top guark pair production. single top production, WZ and WW. The parameters of the NN

in the form of a graph, filters and event search, and also the implementation of the visualization of the extensive atmospheri shower. For this last task, the Heitler Model was used, with some simplifications to fulfill performance requirements, while maintaining a correct and appealing representation. Exploring the public data of the Pierre Auger Observatory Students: Osvaldo Freitas, Pedro Branco, Pedro Passos /

Supervisor: Raul Sarmento

During this summer internship we proceeded with the study of the public data given by the Pierre Auger Observatory. located in Argentina This observatory aims to study the cosmic rays which with energies of order of magnitude of 10°20 eV. Therefore, we analyzed the public data given by the observatory which anisotropies of the cosmic rays in large angular scales, where we drafted the spectrum in declination bands and maps with the aim to check for the existence of anisotropies. Finally, we proceeded with the analysis of the primary particle composition, where we intended and the energy which is associated with them.

Measurement of the ttbar cross-section in events with leptons using ATLAS open data

Students: Maria João Portela, Tomás Ferreira / Supervisors: Nuno Castro, Tiago Vale, Ana Peixoto, Emanuel Gouveia

In our internship at LIP Minho, we analysed events from ATLAS leptonic and dileptonic events. We did this using and improving our knowledge from quantum physics and python programming, to achieve the best outcome out of this work.

Search for Z'->ttbar events using machine learning techniques

Students: Maria do Céu Neiva Nuno Moruião / Supervisors: Nuno Castro, Tiago Vale, Ana Peixoto, Emanuel Gouveia

Despite the excellent experimental success of the standard mode be new physics phenomena beyond it. Models predicting new 2

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Research papers

LIP-STUDENT-20-33 made available from public database

B mesons as novel probes of QGP

João Goncalves^{1,a} and Alexandra Pardal^{2,1} ¹Instituto Superior Técnico, Lisboa, Portugal ²Faculdade de Ciências, Lisboa, Portugal

Project supervisors: N. Leonardo, J. Silva

Abstract. In this work we study B mesons as novel probes of the quark gluon plasma (QGP). We used PbPb data collected by the CMS experiment at the LHC in November 2018. The B+ and B1 production differential crosssections in PbPb collisions are measured. The cross sections of the two mesons and their ratios provide unique information about the properties of the OGP and how the hot and dense OCD medium affects the hadronization of the b quark. The B, meson is observed for the first time in heavy ion collisions

KEYWORDS: LHC, OGP, B mesons, production cross sections, energy loss, strangeness enhancement

2

6

8

Contents

- 1 Introduction
- 2 The CMS detector
- 3 Data, MC samples and signal selection
- 4 Extracting signals from busy ion collisions
- 4.1 Sideband subtraction 4.2 sPlot
- 5 Yield measurement
- 5.2 Yield results and significance 5.3 Fit validation 5.4 Systematic uncertainties from fit procedure 5
- 5.5 Systematic uncertainties from PDF modeling 6
- 6 Efficiency determination
- 7 Differential cross-section measurement 7.1 Data representation (abcissae) 7.2 Systematic uncertainties
- 8 Skills acquired

9 Summary and perspectives

1 Introduction

Ouantum chromodynamics (OCD) predicts that under extreme conditions of temperature and/or density the Quark-Gluon Plasma (QGP) is formed. The QGP existed microseconds after the Big Bang and it is a state of matter formed by deconfined quarks and gluons. It can be recreated at the LHC by colliding heavy nuclei (Pb) at the highest energies [1]

B mesons are composed by a bottom antiquark (\overline{b}) and an up, down, strange or charm quark. In this experimental

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work we study the B^+ meson ($\overline{b}u$) and the B_+ meson ($\overline{b}s$) 1.1 Components

of the b quark. The cross-section is given by $\sigma = \frac{..}{\varepsilon \mathcal{RBL}}$

where N is the signal yield, \mathcal{L} the luminosity, \mathcal{B} the branching fraction A the accentance and s the efficiency While N is measured from data, through the implementation of an unbinned fitting procedure in Section 5.1, s and A are determined from Monte Carlo (MC) simulation, that is validated through the methods of sideband subtraction and sPlot. in Section 4

The Compact Muon Solenoid (CMS) is one of the fou large experiments at the Large Hadron Collider (LHC). In Fig. 1 is represented a transversal slice of the detector and its lavers. When the particles travel through the detector they leave signatures (deposits of energy) in different layers, which allows their identification. In Fig. 1 it is possible to identify these layers from inward to outward the silicon tracker, which measures the positions of passing charged particles allowing their track reconstruction: the electromagnetic calorimeter (ECAL) and the hadronic calorimeter (HCAL), which measure the energy of particles): the solenoid with a magnetic field of 3.8 T that bends the trajectory of particles, allowing the measurement of their charge and momentum; and, the muon chambers, where the muons are detected, since they are able to

[2]. Bottom quarks are created in the initial hard scattering stage and retain their identity while traversing the medium they are in, thus recording information about its evolution By comparing pp collisions (vacuum medium) with PbPb collisions (OGP), we can therefore use B mesons as probes to study the QGP properties. The goal of this study is to measure the B meson's cross section in PbPb collisions at 5 TeV and to study how the OGP affects the hadronization

2 The CMS detector

Figure 1: Diagram of the SNO+ detector. The AV (Acrylic Vessel) in blue is supported by ropes (red and pink). The Green sphere is where the PMTs are enclosed 1.2 Goals of the experiment

penetrate dense materials. The most important subdetectors for this analysis are the silicon tracker and muon detectors, that are employed to trigger and measure the final

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Efficient Modelling of Optical Photon Propagation in SNO+

Samuel Filipe Azevedo Magalhães^{1.a} ¹University of Birmingham, Birmingham, United Kingdom Project supervisor: Nuno Barros

> Abstract, SNO+ is a liquid scintillator experiment that seeks to observe the neutrinoless double beta decay process. If seen, this docay can prove that neutrinos are their own antinarticles (Majorana Nature) and notentially also their effective mass. To characterise these events it is crucial to have a good understanding of the detectors response. In fact, the optical response of the experiment was affected by aging of some of its components. This work attempts to improve the PMT angular response model (efficiency in collecting light depending on the incident angle) by allowing the reflection model to vary the diffuse and direction reflection fractions as a function of the position in the light concentrators. An improvement in the match between data and simulation was verified

KEYWORDS: Optical model, SNO+, PMT, Concentrators, Optical calibration

1 Overview of the detector

The SNO+ detector [1] located in VALE's Creighton mine at a depth of 2 km is a remodel of the SNO experiment. It is comprised of the main following features: (a full description can be found in [11])

 Acrylic Vessel (AV): The AV is spherical and filled with liquid scintillator. The overall structure is positioned concentrically and all the operations are held in the deck level;

· PMT Support Structure: Steel sphere that encloses approximately 9000 Photomultiplier Tubes (PMTs).

SNO+ goal is to search for the neutrinoless double-beta

decay 0v66 of the 130 Te isotope [1].If observed it would

demonstrate that neutrinos are their own antiparticles (Ma-

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iorana Nature)

the AV and check the triangulation of the positions of the calibration sources inside the detector.[11] The laserball (mobile source diffuse sphere) is used for the efficiency of the PMTs and it also characterises the PMT and reflector assembly response. [11]

1.4 The Photomultiplier Tube (PMT)

1.3 Detector calibration

Light incident on a PMT [A-2] will produce a photoelectron. Subjected to a strong electric field the e accelerates and creates an electron shower that is interpreted as a pulse. This causes an accumulation of charge and subsequently the TAC slope of the pulse - time to amplitude alters the analog to digital counts into a time value. It is known as a PMT hit when the charge crosses a threshold. The PMTs read out times and charge values that are analysed to spot physics events.

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Bita Ataide da Silva^{1,8}

Project supervisor: C. Quintans

by a pion.

1 Introduction

11 AMPED

February 13, 2020

The experiment will be also home to measurements of

geo-neutrinos (how heat production works on Earth), reac-

position and energy) and to spot systematic uncertainties,

the optical sources certify the PMT response and measure-

ment of the optical properties of the detector. To guarantee

accuracy in the experiment there are 6 cameras that scan

nova explosions and low energy solar neutrinos.

The calibration of the detector will man

and optical sources. While radioactiv

check the energy scale, resolution, efficient

tor antineutrinos, neutrinos and antineutrinos from super-

urection.

¹Instituto Superior Técnico, Lisboa, Portugal

KENWORDS: AMBER PHYTIA Biorken x

The COMPASS++/AMBER (proto-) collaboration pro-

AMBER- Physics Simulations for a new experiment at CERN

LIP-STUDENTS-19-000

Abstract. AMBER is a new project for a fixed target experiment at CERN. One of its goals is to learn about

quarks and gluons dynamics inside hadrons. Physics simulations were performed using Pythia8 in order to analyze a very rare process. Drell-Yan. Drell-Yan is a quark-antiquark annihilation, where the resulting virtual photon decays to a pair of muons. The starting point was to study all the accompanying particles produced, and

then focus on the kinematic variables associated to the dimuon from the transverse momentum to the fraction of

hadron momentum carried by the struck quark. Biorken-x. The acceptance of the detector was also simulated.

by applying some cuts to the muons polar angle. Finally, it was analyzed the effects of proton misidentification

Francisco Albergaria^{1,a} and Henrique Borges^{1,b}

Project supervisors: Mariana Araújo, Pietro Faccioli and João Seixas,

¹Instituto Superior Técnico, University of Lisbon

Abstract.

For the dimuon: *n_x* : transverse momentum

p_{Abr} : absolute momentum;

from the dimuon decay angular distributions in the helicity frame. The June

Measurement of J/ ψ polarization in pp collisions at $\sqrt{s} = 8$ TeV in

The polarization of prompt J/ ϕ mesons is measured in proton-proton collisions at $\sqrt{s} = 8$ TeV, using a

data sample collected by the CMS experiment at the LHC. The prompt polarization parameter As is n

SNO+ accomodates approximately 9400 PMTs (Hamamatsu R1408) that were used in SNO as well, although some needed some tinkering or even total replacement. ~ 97.9 % are facing the PMT support sphere and detecting light that is created by particle interactions. There are extra PMTs in the neck of the AV and in the outer surface of the sphere (OWLs). OWLs are important to identify light from external sources such as cosmic muons

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February 13, 2020

Plastic in Particle Physics - Aging of WLS Optical fibers using the Fibrometer testbench of LOMaC

Ivan Panadero1, Hugo Miranda2, and Franscisco Laraniinha3 ¹Universidad Autónoma de Madrid, Spain ²Instituto Superior Técnico, Portugal ³ Faculdade de Ciências da Universidade de Lisboa, Portugal Project supervisor: A. Gomes, R. Gonçalo, J.G. Saraiva February 13, 2020

Abstract. The ATLAS barrel hadronic sampling calorimeter, uses scintillating plastic tiles as the sensitive medium and wavelength shifting (WLS) plastic optical fibres to guide the collected light to photodetectors. The same type of detection principle is one of the options for hadron calorimetry at future coliders. Regarding this type of detection systems and during the internship at LOMaC the following was studied: the natural aging of WLS fibres during 20 years. For the optical fibres, light yield follows the trend of the used reference fibers for the measurements taken during a period of 20 years. The optical fibres attenuation length decreases during this period of time. The ratio of light intensity at different points of the fibre over time remained constant.

KEYWORDS: LHC, Tile Calorimeter, Optical fibres, Aging

1 Introduction For this paper we have performed a 20 year old follow

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February 1

cement with pa

It is important to state that the r

even though all the coefficients give inde

tion [3]. In this paper (as well), we or

 $cos(\theta)$ distribution. However, correct of

ization measurements require information

gular distribution parameters, in at leas

motion of the colliding beams and of th

In this analysis, we considered an

with both J/ψ mesons in transverse

 $12 < p_T < 70$ GeV and in the rapidity

and a Monte Carlo simulation generate

larized production (uniform J/w decay

2 CMS detector and Data Pro

The CMS apparatus [5] was designed a

ement: a superconducting solenoid of 6

eter, providing a 3.8 T field. Within the

are a silicon pixel and strip tracker, a le

tal electromagnetic calorimeter, and a

hadron calorimeter. Muons are measured

detectors embedded in the steel return

solenoid and made using three technol

be found in the last reference cited.

oretical studies on 1/4 polarization

Characterization of Scintillators for the Future Circular Collider as a function of their dimensions

Rudnei Machado^{1,a} ¹Faculdade Anhanquera de Joinville Project supervisor: R. Gonçalo

February 13, 2020

Abstract. The calorimeters to operate in experiments at the hadronic Future Circular Collider - FCC-hh - will be one of the key pieces for the complete exploration collisions between hadrons. This is because the increase in energy in proton collisions will require detectors that can work in environments of severe radiation, with high energy rates, presenting a high resolution and low granularity. In this context, the choice of the hadronic calorimeter of the FCC detector - hh, the Hadronic Barrel (HB) and the extended barrel (HEB), will be inspired by the ATLAS Tile Calorimeter calorimeter (TileCal). The HB will have 10 layers, with scintillating tiles that will be separated through a reflective material (e.g. Tyvek) and read by wavelength displacement fibers (WLS) of 1 mm in diameter connected to silicon photomultipliers (SiPMs). Our study focuses on the comparison of the luminous signal intensity in the tile of the first layer of the HB and the tile in the last layer of HB, taking into account the dimensions of the tile. A study of the ontimization of the signal uniformity with a light-absorbine black strip deposited on the tile was made and results were compared with similar experiments performed at CERN. The procedure was performed in the Tilemeter, an ATLAS experiment.

KEYWORDS: Future Circular Collider, tile, Calorimeter, signal uniformity

1 Introduction 1.1 Particle detectors

The definition of a coordinate syste The development of particle physics is directly associated which the momentum of one of the tw with the use of particle detectors, whose operation is based is expressed in spherical coordinates, on the transfer of part of the energy emitted to the mass of measurement of the distribution under the detector [1], and the detection of these particles ocquarkonium measurements, the referen curs through the loss of energy of particles when they pass fixed with respect to the physical refer the directions of the two colliding beam through a certain material [2], thus enabling the detection of the most diverse particles. The detection occurs by the quarkonium rest frame. In this analysis, interaction of the particles with the detector, interaction helicity frame, HX, that is the opposite associated with the collision of the particle with the atoms motion of the interaction point (i.e. the of the medium, resulting in the loss of energy of the parthe quarkonium itself in the center-of-ma ticle. However, not all particles can be detected directly, beams) as stated in [4]. A formal and in some are detected indirectly through particles that arise of the three most used definitions of the from their interactions [3] z (decay reference frame) with respect t

Particle detectors can be divided into two large groups: detectors that function through ionization processes and detectors that function through excitation processes. Ionization detectors can also be divided into gas and emulsion detectors, in which the detection process is based on the trail of the electron-ion pair, which when subjected to an electric field, the charges can be collected. Electrons are collected in the anode, and ions in the cathode of a chamber, where the signal reading is performed by specialized electronics with the amplification of this signal. In semiconductor detectors (silicon, germanium and others), the working principle is based on particle interactions creating a trail of electron-hole pairs[4].

In scintillation detectors (such as the TileCal in the AT-LAS experiment), the principle of operation is directly associated with the energy "lost" by the particles that affect the scintillator, causing an excitation of the scintillator particles and, consequently, the emission of light in the visible ⁸e-mail: rudnei.cern2017@gmail.com

Plastic scintillators are currently one of the most economically viable options, and their light yield is associated with the interactions of the particle with the scintillator molecules. According to [5]: In a scintillating solution, usually composed of a solvent substance plus one or two substances canable of emitting light when dissipating energy, the charged particles and the secondary electrons release energy interact ing mainly with the molecules of the solvent. most of them in the scintillating solution, increasing the thermal energy of those who have undergone interaction. Part of the released energy will also be consumed in the creation

and ultraviolet (UV) ranges. These detectors can be of var-

ious types, but our study is based on organic scintillators

with a solid plastic solvent.

1.2 Plastic Scintillators

of ion pairs, free radicals and molecular fragments, making the luminous efficiency of the scintillating solution dependent on the way these products recombine. The concentration of these products will depend on the specific ionization of the radiation, being higher around the trajectory of the particle, mainly in its initial point of interaction, causing a reduction of the luminous efficiency every time this great quantity of ions and excited molecules react among themselves, instead of reacting with the molecules of the scintillators, a phenomenon denominated as extinction by ionization.

where the purely perturbative colour-singlet action is complemented by processes including possible non-perturbative transitions from colour octet states to the observable bound states. Therefore, it is crucial to analyze the most recent experimental data, which already reaches rather high quarkonium transverse momentum, p₁, (where the calculations are expected to be more reliable [1]), and compare it with the theory predictions. In fact, for high transverse momentum, the directly produced S-wave quarkonia are expected to be transversely polarized with respect to the direction of their own momentum. If inconsistencies between the predictions made by the theory and the experimental results are found, it is important to discover if those discrepancies are originated. from approximations and inaccuracies of the fixed-order perturbative calculations available at the moment or from

difficulties in the conceptual basis of the theory. Through the study of the angular distribution of the leptons produced in the JPC = 1- quarkonium states' $\mu^+\mu^-$ decay, we can measure their polarization, determined by the lambda parameters, from the expression provided

with φ and ϑ being, respectively, the azimuthal and polar angles of the u^+ , with respect to the z axis of the selected polarization frame [2].

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 $W(\cos \vartheta, \varphi) = \sum_{i=1}^{n} f^{(i)}W^{(i)} = (1 + \lambda_{\theta} \cos^2 \vartheta +$

 $\lambda_{\varphi} \sin^2 \theta \cos 2\varphi + \lambda_{\varphi\theta} \sin 2\theta \cos \varphi \frac{3}{4-(2+1+\lambda)}$, (1)

*e-mail: francisco.albergaria@tecnico.ulisboa.pt

tained by the CMS experiment in 201 by Quantum Mechanics:

Paper write-up

A **research paper** documenting the results obtained in your project Papers to be submitted as a LIP document shared in a **public** repository All students **strongly encouraged** to submit the report How much: 5 -10 pages When: by mid October

Consider writing in LaTex — a template in OverLeaf will be provided and is recommended for ensuring format uniformity. Other document formats may be also accepted. Message will be sent with instructions. You may contact us as always at estagios@lip.pt (and @slack).

Your Feedback

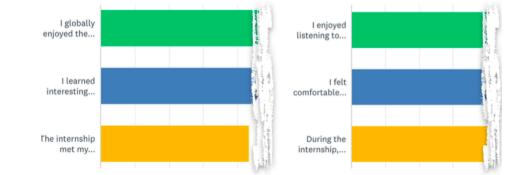
You shall receive an invitation to fill in a survey to share with us your feedback on the program

- what you think went well
- how it could be improved

Your feedback is important so we can improve on future editions of the program







Your LIP 'package'

