



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 great success despite the exceptional global circumstance (pandemic) we're in

Thanks

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**

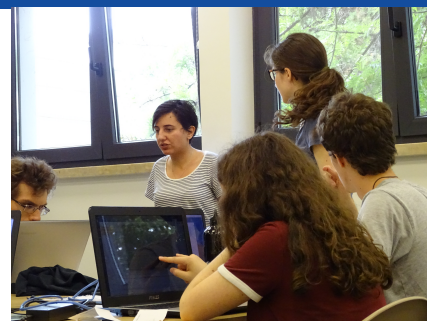
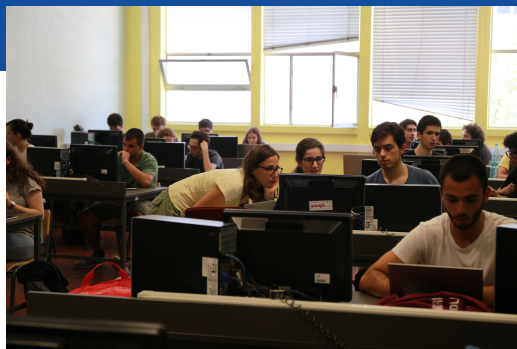
including Sofia (outreach), Ricardo (lectures), Liliana (workshop)

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** ...



COFFEE TIME



For next year's edition we hope and should aim at making up for the in-person **social** interactions and activities that we've (forcibly) lacked this time ...

LIP NEWS

Terapia com prótons
em Portugal

O Futuro da Física de Partículas
Roberto Salmeron 1922-2020

O LIP e a Pandemia
HEPérica 2020

ISSUE N. 16, JULY 2019

LIP NEWS

DATA IN (ASTRO)PARTICLE
PHYSICS and COSMOLOGY
SCIENCE

When CP goes off beaten tracks
AMBER and the mysteries of Quantum Chromodynamics
SABER: search for Higgs particles
Future colliders and the LHC upgrade
HISat/brantPET: high resolution medical imaging with RPC's

LIP Internship Program

A large group of approximately 40 people, including students and faculty, are posing for a group photo in front of a building. They are arranged in several rows, with some people kneeling or sitting in the front and others standing behind. The building in the background has a light-colored facade and a blue sky is visible above.

AMBER is a project for a fixed target experiment at CERN. One of its goals is to investigate quark and gluon dynamics inside hadrons. Simulations were performed using Pythia8 in order to analyze a very rare process, Drell-Yan. Drell-Yan is a quarkantiquark annihilation where the resulting virtual photon decays into a pair of muons. The starting point was to study accompanying particles produced. We then focused kinematic variables associated to the muon pair (differences 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 identification as a

The challenge of our work was to reconstruct the shower geometry as well defined in time, but instead of a trace.

The WCD signal time trace has a sharp peak that hits the SiPMs directly; so the former has a sharp pulse that marks the arrival of the shower particles.

We explored the possibility of improving the current ATLAS analysis of the $H \rightarrow b\bar{b}$ decay in associated production with a vector boson using Machine Learning techniques, not only to separate signal from background, but also to define the control regions. A multi-class Neural Net (NN) was used to classify events in six different categories: signal, $W+Z$, top quark pair production, single top production, WZ and WW . The parameters of the NN were varied to find the optimum network configuration. Signal events were correctly classified in 87% of the cases.

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

Despite the excellent experimental success of the standard model of particle physics we have strong indications that there might be new physics phenomena beyond it. Models predicting new Z

Research papers

LIP-STUDENT-20-33

made available from public database

LIP-STUDENTS-19-696

B mesons as novel probes of QGP

João Gonçalves^{1,*} and Alexandra Pardal²

¹Instituto Superior Técnico, Lisboa, Portugal

²Faculdade de Ciências, Lisboa, Portugal

Project supervisor: 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^0 and B^+ production differential cross-sections in PbPb collisions are measured. The cross sections of the two mesons and their ratios provide unique information about the properties of the QGP and how the hot and dense QCD medium affects the hadronization of the quark. The B meson is observed for the first time in heavy ion collisions.

Keywords: LHC, QGP, B mesons, production cross sections, energy loss, strangeness enhancement

Contents

1 Introduction	1
2 The CMS detector	1
3 Data, MC samples and signal selection	2
4 Extracting signals from busy ion collisions	2
4.1 Sideband subtraction	2
4.2 Δp_{eff}	2
5 Yield measurement	4
5.1 Likelihood model	4
5.2 Yield results and significance	4
5.3 Fit validation	4
5.4 Systematic uncertainties from fit procedure	5
5.5 Systematic uncertainties from PDF modeling	5
5.6 Differential yield	5
6 Efficiency determination	6
7 Differential cross-section measurement	7
7.1 Data representation (abscissa)	7
7.2 Systematic uncertainties	7
8 Skills acquired	8
9 Summary and perspectives	8

1 Introduction

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 (Pb) at the highest energies [1].

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

*e-mail: joaogoncalves@tecnico.ulisboa.pt
*e-mail: alexandrapardal@gmail.com

LIP-STUDENT- Project 52

Efficient Modelling of Optical Photon Propagation in SNO+

Samuel Filipe Azevedo Magalhães^{1,*}

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 decay can prove that neutrinos are their own antiparticles (Majorana Nature) and potentially also their effective mass. To characterize these events it is crucial to have a good understanding of the detector's response. In fact, the optical response of the experiment was affected by aging of some of its components. This work attempts to model 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

1.1 Components

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

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

2 The CMS detector

The Compact Muon Solenoid (CMS) is one of the four large experiments at the Large Hadron Collider (LHC). In Fig. 1 is represented a transversal slice of the detector and its layers. When the particles travel through the detector they leave signature (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, which measure the energy of the particles that 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

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

SNO+ goal is to search for the neutrinoless double-beta decay $0\nu\beta\beta$ of the ^{150}Nd isotope [11]. If observed it will demonstrate that neutrinos are their own antiparticles (Majorana Nature).

*e-mail: sam1347@studnet.bham.ac.uk

LIP-STUDENTS-19-696

AMBER: Physics Simulations for a new experiment at CERN

Rita Ataíde da Silva^{1,*}

¹Instituto Superior Técnico, Lisboa, Portugal

Project supervisor: C. Quintans

February 13, 2020

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 Pythia 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 if the accompanying particles produced, and then focus on the kinematic variables associated to the dimuon, from the transverse momentum to the invariant hadron momentum carried by the struck quark. Bjorken's. 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 by a pion.

Keywords: AMBER, PHYTIA, Bjorken's

1 Introduction

1.1 AMBER

The COMPASS++/AMBER (neutrino) collaboration, pro-

For the dimuon:

- p_T : transverse momentum;
- p_{miss} : absolute momentum;

LIP-STUDENTS-19-696

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

Francisco Alberga^{1,*} and Henrique Borges²

¹Instituto Superior Técnico, University of Lisbon

Project supervisor: Mariana Araújo, Pietro Faccioli and João Seixas.

February 13, 2020

Abstract. The polarization of prompt J/ψ 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 A_{FB}^{pol} is obtained from the dimuon decay angular distributions in the helicity frame. The A_{FB}^{pol} is obtained in the transverse momentum range $1.2 < p_T < 70$ GeV and in the rapidity interval $3.5 < y < 4.5$. No evidence of large polarization is seen in these kinematic regions. The results are in agreement with previous measurements. Preliminary results of this analysis are presented.

Keywords: QUARKonium, POLARIZATION

1 Introduction

The polarization of prompt J/ψ 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 A_{FB}^{pol} is obtained from the dimuon decay angular distributions in the helicity frame. The A_{FB}^{pol} is obtained in the transverse momentum range $1.2 < p_T < 70$ GeV and in the rapidity interval $3.5 < y < 4.5$. No evidence of large polarization is seen in these kinematic regions. The results are in agreement with previous measurements. Preliminary results of this analysis are presented.

The experimental will be also home to measurements of geo-neutrinos (how heat production from Earth), reactor antineutrinos, neutrinos and antineutrinos from supernova explosions and low energy solar neutrinos [11].

1.3 Detector calibration

The calibration of the detector will be made in the clock level and optical sources. While radioactivity sources are used to check the energy scale, resolution, efficiency, position and energy) and to spot systematic uncertainties, the optical sources are used to check the PMT response and measurement of the optical properties of the detector. To guarantee accuracy in the experiment there are 6 cameras that scan the AV and check the triangulation of the positions of the calibration sources inside the detector [11].

The laeserl (mobile source diffuse sphere) is used for the efficiency of the PMTs and it also characterizes the PMT and reflector assembly response. [11]

1.4 The Photomultiplier Tube (PMT)

Light incident on a PMT [A-2] will produce a photoelectron. Subjected to a strong electric field of the 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.

SNO+ accommodates approximately 9400 PMTs (Hamamatsu R1488) that were used in SNO as well as although some needed some tinkering or even total replacement - 97.9 % are facing the PMT support sphere and generating light 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.

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

*e-mail: henrique.joao.machado.borges@tecnico.ulisboa.pt

LIP-STUDENTS-19-696

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

Ivan Panadero¹, Hugo Miranda², and Francisco Laranjinha³

¹Universidad Autónoma de Madrid, Spain

²Instituto Superior Técnico, Portugal

³Faculdade de Ciências da Universidade de Lisboa, Portugal

Project supervisor: A. Gomes, R. Gonçalves, 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 fibers to guide the collected light to photodetectors. The same type of detection principle is one of the options for hadron calorimetry at future colliders. Regarding the type of detection systems and during the intership at LHC the following was studied: the natural aging of WLS fibers during 20 years. For the optical fibres, light yield follows the trend of the used reference fibres 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-

LIP-STUDENTS-19-696

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

Rudinei Machado^{1,*}

¹Faculdade Antargruppo de Juiz de Fora

Project supervisor: R. Gonçalves

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 experimental collision 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, providing a high resolution and low granularity. In this context, the choice of the hadronic calorimeter of the Future Circular Collider (FCC) will be a challenge. The ATLAS Tile Calorimeter (TileCal), the HB will have 10 layers, with scintillating tiles that will be separated through a reflective material (e.g. TiNy) and read by wavelength displacement fibres (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 optimization of the signal uniformity with a light-absorbing black wrap deposited on the life was made, and results were compared with similar experiments performed at CERN. The procedure was performed in the TileEmul, an ATLAS experiment.

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

1 Introduction

1.1 Particle detectors

The development of particle physics is directly associated with the use of particle detectors, whose operation is based on the transfer of part of the energy emitted to the mass of the detector [1], and the detection of these particles occurs through the loss of energy of particles when they pass through a certain material [2], thus enabling the detection of the most diverse particles. The detection occurs by the interaction of the particles with the detector, interaction associated with the collision of the particle with the atoms of the medium, resulting in the loss of energy of the particle. However, not all particles can be detected directly, some are detected indirectly through particles that arise from their interactions. [3].

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 ATLAS experiment), the principle of operation is directly associated with the loss of energy of particles when they pass through a certain material [2], thus enabling the detection of the most diverse particles. The detection occurs by the interaction of the particles with the detector, interaction associated with the collision of the particle with the atoms of the medium, resulting in the loss of energy of the particle. However, not all particles can be detected directly, some are detected indirectly through particles that arise from their interactions. [3].

*e-mail: rudinei.machado@ufjf.edu.br

2 CMS detector and Data Pro

The CMS apparatus [5] was designed as a superconducting solenoid of 6 m diameter, providing a 3.8 T field. Within it are a silicon pixel and strip tracker, a silicon strip calorimeter, a lead tungstate calorimeter, and a hadron calorimeter. Muons are measured by detectors embedded in the steel return solenoid and made using three technol-

and ultraviolet (UV) ranges. These detectors can be of various types, but our study is based on organic scintillators with a solid plastic solvent.

1.2 Plastic Scintillators

Plastic scintillators are currently one of the most economically viable options, and their light yield is associated with the interactions of the particles with the scintillator molecules. According to [5].

In a scintillating solution, usually composed of a solvent substance plus one or two substances capable of emitting light when dissipating energy, the charged particles and the secondary electrons release energy interacting 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 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.

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](#)).

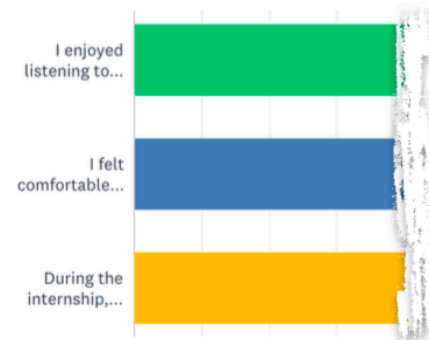
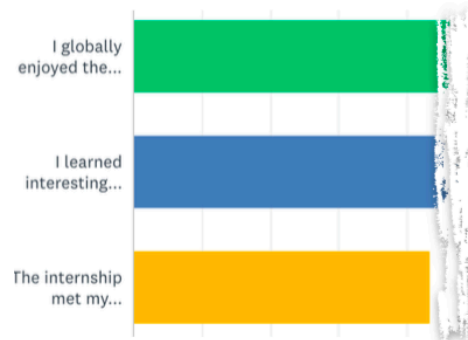
Your Feedback

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

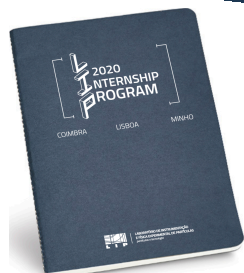
- what you think went well
- how it could be improved



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



Your LIP 'package'



some goodies available for you to pick up from your nearest LIP location!

**Thanks. Farewell.
Please stay all safe.**