Thesis Title

Thesis Subtitle

A thesis presented for the degree of
Doctor of Physics

Department Name
University Name

Abstract

The increased necessity of experimental proof of physics beyond Standard Model (SM) and Dark Matter theories leads us to develop new detectors for high energy experiments, like ATLAS with his upgrade (New Small Wheel project in particular) for the luminosity increase at LHC and a new experiment on SPS facilities at CERN called NA64; to search for Dark Matter on invisible(visible) decays of dark photons.
For this two experiments, detectors from our institute have been made to be part on such enterprise. Characterizations and tests have been done with the use of particles beam (electrons, pions, muons and gamma rays) from the Experimental Area at CERN.

Dedication

Acknowledgments

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1. Introduction

Let's see if this thing apppear as a introductio

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2.1. ATLAS Detector Upgrade

2.1.1. High Luminosity Large Hadron Collider - HL-LHC

The Large Hadron Collider (LHC), run by CERN at the Franco-Swiss border near Geneva, is a circular accelerator with 27 km of acceleration pipes, is the largest scientific instrument ever designed and built for scientific research. Successfully commissioned in March 2010 for proton-proton collision with a 7 GeV centre-of-mass energy.
The LHC is pusshing the limits of human knowledge, enabling physicist to go beyond Standar Model (SM): the enigmatic Higgs boson, mysterious Dark Matter and the world of supersymetry are just three of the long-awaited mysterous that the LHC will unveil. The announcement given by CERN on 4 July 2012 about the discovery of new boson at 125-126 GeV, almost certainly the long awaited Higgs particle, is the first fundamental discovery, hopefully the first of a series, that the LHC can deliver.
Such discovery was thanks to the different detectors located on the four interaction points; ALICE, LHCb, CMS and ATLAS. This last one is the detector where our university is taking part.

	Period	Energy $\sqrt{s}$	Upgrade on LS	L	Integrate L
Run I	2010-2012	7-8 TeV	-	$6\mathrm{x}10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	25 fb^{-1}
LS1	2013-2014	Go to design energy, nominal luminosity, bunch spacing 25ns			
Phase 0	2015-2018	14 TeV	-	$1\mathrm{x}10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	75-100 fb^{-1}
LS2	2019-2020	Upgrade muon spectrometer;NSW, LAr Calorimeter & FTK			
Phase I	2021-2023	14 TeV	-	$2\mathrm{x}10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	~350 fb^{-1}
LS3	2024-2025	New Inner Tracker and trigger architecture			
Phase II	2026-2030	14 TeV	-	$5\mathrm{x}10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	~3000 fb^{-1}

Figure 2.1: LCH Schedule

CONTINUE WITH LHC UPGRADE and GOALS

2.1.2. ATLAS Detector

The ATLAS detector it is a general-purpose detector, designed to explore proton-proton colissions at center of mass up to $\sqrt{s}$ =14 GeV. Looking for....
Such energy has been achived from 2015 and successfuly working with a luminosity of 1x10^{34}cm$^{-2}s^{-1}$ from 2016.

Describe ATLAS detector and its part, together with the problem faced by now.
ENDING WITH THE FAKE TRIGGERS AND PROBLEMS FOR LOW PT.

2.1.3. New Small Wheel

In manner to fullfill the LHC program (in fig.2.1), and in order to benefit from the expected high luminosity performance that will be provided by the Phase-I upgraded LHC, the first station of ATLAS muon end-cap system (Small Wheel, SW) will need to be replaced. The New Small Wheel (NSW) will have to operate in a high background radiation region (upto 15kHz/cm^2) while reconstructing muon tracks with high precision as well as furnishing information for the Level-1 trigger. These performance criteria are demanding. In particular, the precision reconstruction of tracks for offline analysis requires a spatial resolution about 100 μm, and the Level-1 trigger track segments have to be reconstructed online with an angular resolution of symroximately 1mrad. The NSW will have to chamber technologies, one primarily devoted to the Level-1 trigger function (small-strip Thin Gap Chambers, sTGC) and one dedicated to precision tracking (Micromegas detectors, MM). The sTGC are primarily deployed for triggering given their single bunch corssing identification capability. The MM detectors have exceptional precision tracking capabilities due to their small gap (5mm) and strip pitch (symroximately 0.5mm). Such a precision is crucial to maintain the current ATLAS muon momentum resolution in the high background environment of the upgraded LHC. The MM chambers can, at the same time, confirm the existence of a track segments found by the muon end-cap middle station (Big Wheels) online. The sTGC also has the ability to measure offline muon tracks with good precision, so the sTGC-MM chamber technology combination forms a fully redundant detector system for triggering and tracking both for online and offline functions. This detector combination has been designed to be ablo to also provide excellente performance for the eventual High Luminosity LHC upgrade.

2.2. Small-strip Thing Gap Chamber

The Small strip Thin Gap Chamber (a.k.a sTGC) detector it is a multi-wire proportional chamber (MWPC) working in a high gain mode with a cathode-anode pitch smaller than the anode-anode pitch, mostly based on the design of the Thin Gap Chamber[1], with thinner strips as the main improvement from the previous version. The TGC tecnology has been used since 1988 in OPAL experiment and currently are part of the the muon spectrometer in ATLAS.
This new chamber has the advantage of having a 3.2mm strip width compare to the 5-6

mm from the previous TGC, that is why it is called small strip Thin Gap Chamber. The size of the strips has been choosen to cope up with the precision resolution require for the NSW (explained before), where it has to be better than 100 μm and provide a reponse with a few nanoseconds. For this purpose, chambers with different strips sizes has been build and test under pion beams, chosed the 3.2mm has the best option[3].

The sTGC is made of two resistive cathods planes, one with csymer strips and the other with pads, each cathode plane is made of FR4 with 1.6mm of thickness, where 100 μm of csymer is etched for strips (pads) and then pressed with a 100 μm of FR4 over it and then sprayed with graphite to provide 100-200 k$\Omega/\square$ (1 M$\Omega/\square$ for TGC) so it can be treatead as a resistive cathode plane.
The anodes are golden tungsten wires of 50 μm diameter, distributed at 1.8 mm between each other. The gas gap (2.8mm) is filled with a mixture of carbon dioxide (CO_2) and n-pentane(C_5H_12) in proportion 55:45 respectively both strongly quenching gases that provide a high amplification factor and relatively low sensitivity to mechanical variations.[ref Mechanical variations]

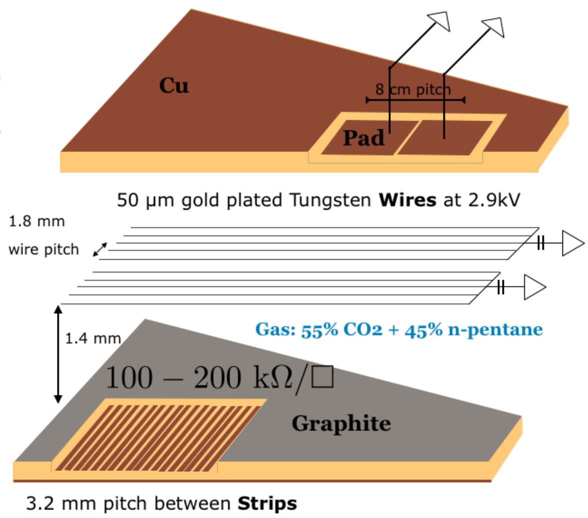

Figure 2.2: Single plane sTGC

A MWPC detector type is a relativetely old technology, its succesfuly introduction to detector system in 1968 gave the Nobel prize to George Charpak in 1992. This device has been a major ingrediente in detector systems since it can achieve spatial resolutions of 500 μm or less, and has typical time resolution of about 30 ns.
The TGC has been built as a MWPC with a thinner gas gap, its means, the distance from the anode-cathode is smaller than the anode-anode (wire to wire) to provide a fast time response, and at the same time giving a higher amplification, to achieve this smaller distance, precautions must be taken into account when the internal pieces are construct, for that a precision of 50 μm must be achieve.
To work with such geometry several test were made to find the proper gas mixture[2].

Find the most suitiable mixture of 55% well known carbon dioxide as a quenching gas, and a 45% of n-pentane, which for his nature can absorb energy in many ways of molecules degree of freedom, vibrational, rotational, etc.

- voltaje de operacion.
- resitividad del graphito y para que usamos grafito.
- Que es lo moderno de este detector...

2.3. Construction process

Cathode production and how we achieve the resolution requeride for this.
Clean cathode
Sprayed process
Achieve the proper superficial resistivity
glue internal parts
Winding wires, soldered and clean afterwards
test wires under hv
Close chamber and filled with CO_2, no sparks must found
glue chamber
Thickness measurments
Repeat process till get 4 modules
Overall thickness measurements and pin position check

2.4. Gain uniformity measurements

After the chambers are built it is important to know the response of the detector, es and a primivite way to do such thing without any electronic readout attach to strips or wires, is to measure the current draw from the power ssymly and see how it behaves to a radiation source.
There are two ingredients that can produce gain variations on wire detectors, the first one is the "nature" gain fluctuations from the charge production in proportional counters which follow Polya distribution, however is less pronounced in semi-proportional mode such as sTGC working region.
The second one is related to the mechanical tolerances, this part is very well known since 40 years as it is presented on Sauli book about drift chambers and tell us that for a diameter variations of the wire about 1% (fabrication precision) will result on a 3% change in the gain, where as about 100μ m difference in the gas gap thickness (2.7mm) results in about 15% chage of the gain. the effecto of a wire displacment of about 100μ m of a wire plane results in 1% int the charge of the two adjacent wires which with a gain of $\sim 10^6$

will give a $\sim 10\%$ change in the gain.
Taking all of this in consideration is expected to get a gain variation less than 20% as Quality Acceptance.
In this test the gain is considered as the current draw measured from the power ssymly and its need to test under two different working points (bias voltage), one when the chamber it is not in the limited proportional region, 2500 volts, a take it as a reference compare to the 2900 volts which is the operational voltage.

For such test the x-ray source is used due to the many advantages;

- Mostly monoenergetic photons.
- Variable current: which can provides diferent rates. [1μA - 200μA]
- Variable voltage: modifyng breaking voltage of electrons inside the x-ray gun. [10keV - 50keV]
- Different spot size: with a set of collimator it is posible to irradiate only interesting area.
- Portable, it is possible to move accross the sensitive area of the detector.

2.4.1. Setup

Provide explanation of setup and posterior details of instruments.

- X-ray source: Mini-X gun with photons of 50 keV and flux of 45 μA
- Collimator: 5^o.
- Distance from source: 2.5 ± 0.3 cm. Spot size: 2 ± 0.26 mm.
- KUKA arm; giving vertical steps:1.5 cm, horizontal steps: 5 cm.
- HV power ssymly: 50 nA resolution. Sampling rate: 1 sample/s.

2.4.2. Results

2.5. Test under high rate

2.6. Spatial resolution strips

2.7. Charge sharing between pads

2.8. summary

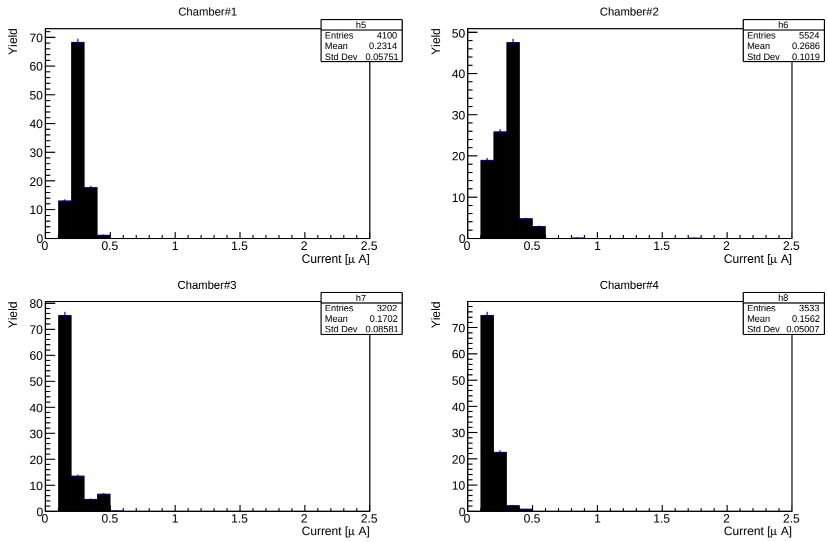

Figure 2.3: Current draw from power ssymly at 2500V

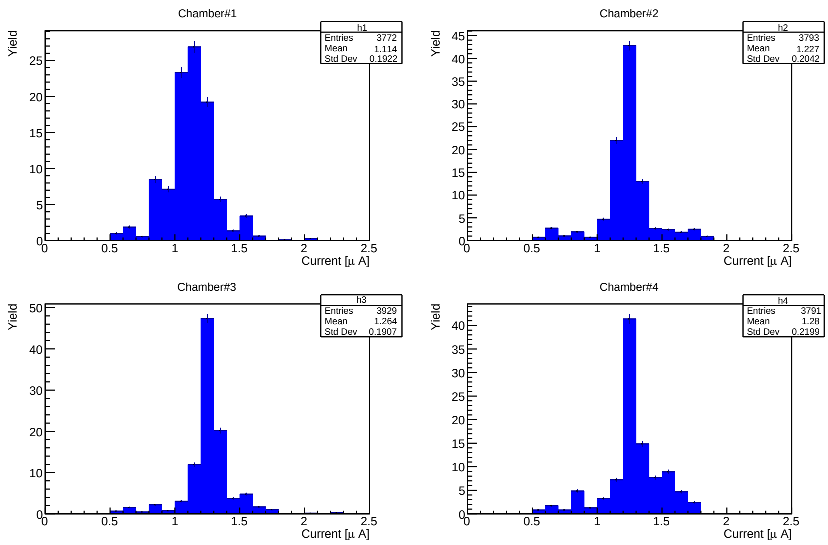

Figure 2.4: Current draw from power ssymly at 2900V

3. Brillance380 under high gamma rate

3.1. Scintilators counters

3.2. high count rates

3.3. Internal radiation

3.4. Experimental setup

3.5. Spectrum and rates under different attenuation filters

3.6. Data Analisys

3.6.1. Wavelets

3.6.2. Peak identification

3.7. Results

4. LYSO crystals array as SRD

4.1. NA64 experiment

The NA64 experiment is a fixed-target experiment at the CERN SPS combining the active beam dump and missing energy techniques to search for rare events.
A fully hermetic detector placed on the H4 beam line has been built with the primary goal to search for light dark bossons (Z') from dark sector that are coupled to photons, e.g. dark photons (A'), or sub-GeV Z' coupled only to quarks. In some cases the Z' is coupled only to μ or tau, so we call the Z' the dark leptonic gauge boson. The experiment is also capable to search for $K_L \rightarrow$invisible decay, which is complementary to $K+ \rightarrow \pi^+ + \nu\nu$, and invisible decays of π_0, η,η', K_S mesons.
The advantage of this approoc is that the sensitivity (or number of signal events) of the experiment is roughly proportional to the Z' coupling squared ε^2, associated with the Z' production in the primary interaction in the target/ While in a classical beam dump experiment, it is proporiotional to ε^4, one ε^2 came from the Z' production, and another ε^2 is either from the probability of Z' decays or their interactions in a detector located at a large distance from the beam dump.
The sensitivities of these two methods depend on the region under study in the (ε^2,m_Z) parameter space, background level for a articular process, available beam intesity, etc.[Beam intensity] In some cases, much less running time and primary beam intensity are required to observe a signal event with our approach.

4.1.1. Physics Motivation

4.1.2. Dark Photon signal

4.1.3. Setup

4.2. Synchroton Radiation Detector

4.2.1. BGO

4.2.2. Pb+Sc

4.2.3. LYSO

4.3. Calibration

4.4. Position and time resolution

4.5. Hadron rejection

4.6. Purity 100 GeV electron identification

4.7. Summary

5. Conclusion

A. Appendix

A.1. Mechanical Measurements sTGC Module 0

A.2. PMT RT7525 Data Sheet

A.3. Data Structure NA64 Experiment

A.4. DAQ system

Bibliography

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