Karlsruhe Institute of Technology

Muon induced secondary electrons at the KATRIN experiment Detector installation and setup and data analysis

Diploma Thesis of

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I declare that I have developed and written the enclosed thesis completely by myself, and have not used sources or means without declaration in the text.

PLACE, DATE

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(**YOUR NAME**)

Contents

1. Introduction

1.1. The standard model

1.1.1.

1.2. Massive neutrinos

1.2.1. Neutrino Oscillations

1.3. The KATRIN experiment

1.3.1. Source Side and Transport Section

1.3.2. Pre-Spectrometer

1.3.3. Main Spectrometer

1.3.4. Focal Plane Detector System

1.3.5. Solenoids

1.3.6. Air coil system

1.3.7.

1.4. Cosmic air showers

1.5. Muon interaction with matter

1.6.

[BKR09] . . .

2. The muon detection system

The need for low background rates at the main detector requires for a good knowledge of background sources. Despite magnetic reflection and wire electrodes, cosmic ray and particularly cosmic muon induced background may be an issue for the KATRIN experiment. To gather and asess muon related data, scintillator modules have been installed at both the monitor spectrometer and the main spectrometer. While the monitor spectrometer is equipped with only two rather small modules, at the larger main spectrometer, 8 modules have been installed at different positions enabling the user to cover different regions of the vessel. This freedom is enlarged by installing the detection system on three independently movable trolleys.

2.1. Scintillator modules

The central part of the detection system are the eight scintillator modules. They are made of the synthetic material BC-412 which is utilized in applications requiring large area coverage [Cry05]. These have previously been used at **(From Where?)**. Every scintillator cuboid is read out by two sets of four photomultiplier tubes. Photons arriving at the short ends of the module are guided to the photomultiplier tubes via non-scintillating material which, away from that, exhibits similar optical properties. All other sides of the scintillator are covered in reflective foil to push detection efficiency to the maximum. Of the eight photomultiplier tubes per scintillator module installed, 4 are read out via one FLT channel. Only coincident signals should be recorded by the DAQ, though, on some occasions, quite a lot of single side signals occur. To account for those, every dataset is first analysed by a search algorithm to filter them.**(reference search algorithms)** **ToDo** **ToDo**

2.2. Photomultipliers

Each Photomultiplier tube is made up of a layer of **(of what)** where photons from scintillation ionize the layers' atoms leaving electrons with their initial Energy less the ionization energy **ToDo**

$$E_{e^-} = E_{phot} - E_{ion}$$

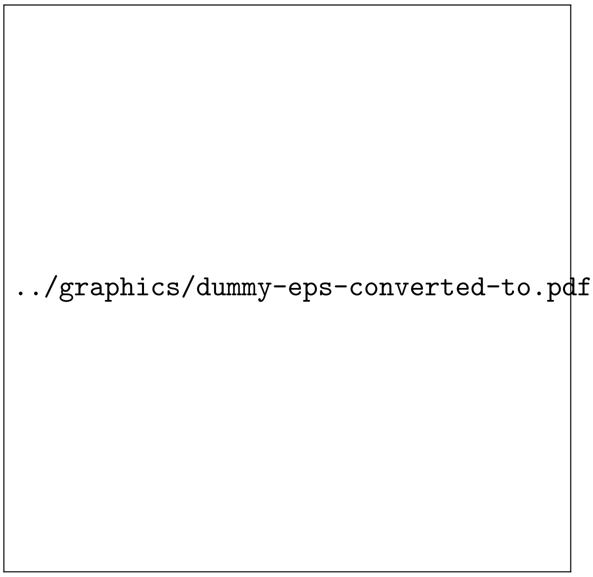
The electron is then accellerated and guided by the electric field from dynode to dynode, cascading to more and more electrons, as each electron's energy rises by $e \cdot U_{acc}$ between each pair of dynodes.

../graphics/dummy-eps-converted-to.pdf

2.3. Gains, Thresholds and Acceleration Voltages

To achieve the best possible event detection, the photomultipliers' acceleration voltages as well as the software gains and thresholds in Orca had to be adjusted. The focus here was to obtain landau peaks with equal heigt and width, as the rates throughout the modules can be considered equal. At first, the acceleration voltages were kept low to limit the signal peaks' heigts to aroud 2 V. Carefully setting the mentioned parameters, one achieved the following, well alligned curves:

Later in the comissioning process, it got clear form the handbooks that the photomultiplier tubes hat to be operated at accelleration voltages of 1.5 kV and above. To keep the singnals height as small as possible, most of the tubes were limited to this minimal voltage, wheras **ToDo** the sides **(which ones)** were set to 1.6 kV over showing lower rates than the others. Following this procedure, the tubes seemed much more stable and comparable, as all the gains and thresholds could now be set to the same values while still showing aligned peak positions: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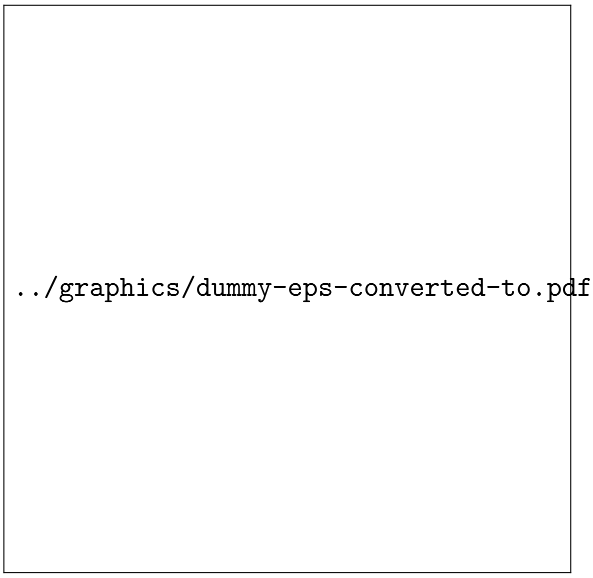
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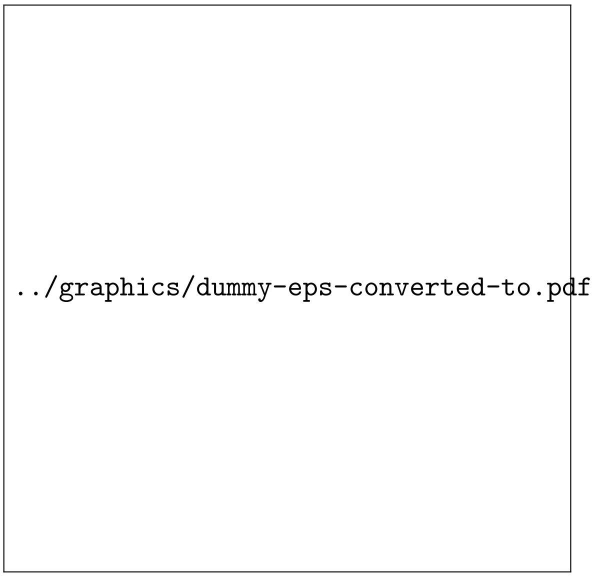
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3. Data aquisition crate

3.1. First level trigger cards

asdf

3.2. Second level triger cards

4. Orca control

4.1. Software Gains and Thresholds

4.2. Run control

4.3. File handling

4.4. Orca Fit

5. Analysis software

To analyse the data recorded by DAQ and ORCA software, completely new data structures fit to the needs of muon detection and coincidence analysis have been created. Methods have been implemented to further investigate data stored inside those structures.

5.1. Data structure

All data from the IPE-servers arrives converted from ORCA-specific formatting to .root files. Hence, ROOT Methods are used to extract data from these structures, while most of these methods are implemented as part of the KaLi package in Kasper, which constitutes for a complete and closed data transfer protocol. Through those structures, data will be cached locally and can be analysed.
Before heading to actual analysis, all data is stored in the runtime structures. Here, the newly written class **event** with the following members comes into play.

- fADCValue
- fTimeSec
- fTimeSubSec
- fPanel
- fSide

For each member, corresponding set- and get-methods have been implemented. Furthermore, the operators ”<”, ”<=”, ”>”, ”>=”, ”==”, and ”-” have been overloaded to compare the timestamps of the event class. This was useful especially since ADCValues are merely used for plausibility checking the data but not for quantitative analysis. Doing so, events and the classes derived from them can easily be compared and searching becomes cleaner and clearer.
Derived from the base event class are two more storage classes:
panelEvent storing the second ADCValue

- fADCValue2

and the common timestamp of events activating both panel sides and
coincidentEvent storing ADCValues of simultaneous events in multiple modules and the number of modules involved:

- std::vector fADCValues
- fnPanels

Every ORCA-run then utilizes the class **run** storing the data of the .root files in vectors of events. Recorded events should already be filtered - only simultaneously occurring events on the two sides of the same module should be recorded. As, under conditions not known, single sided events are recorded as well, a software workaround is needed. All events of one side of the modules are scanned to find whether a corresponding event with the same timestamp exists on the other side. If so, a coincidentEvent is created and pushed back into the run's vector of coincident events corresponding to the module it occured in. Now, the user can decide on which modules to analyse with the setPanels() function.

5.2. Search Algorithms

5.3. Module Stability

6. Analysis

6.1.

7. Simulation software

7.1. Geant4

7.2. Geometry setup

7.3. Muon generator

7.4. Hit counter

8. Conclusion

9. Outlook

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Appendix

A. First Appendix Section

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Figure A.1.: A figure

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