EXP7: Muon Lifetime

Praktikum Review Day

Daniel Bick

Universität Hamburg

DER FORSCHUNG | DER LEHRE | DER BILDUNG

May 24, 2023

Scientific Content

- Muons
  - basic properties of leptons
  - weak interactions / π-decay
- Cosmic ray muons
  - primary and secondary cosmic rays
  - origin of cosmic ray muons
- Particle detection methods
  - interaction of particles with matter, Bethe-Equation
  - scintillators
  - PMTs
- Statistical processes
  - exponential decay
  - coincidental background

Aim of the Experiment

- Primary goal: measurement of the muon lifetime.
- Emphasis on
  1. having **fun** experimenting!
  2. building a **logical setup** with NIM electronics (hands-on experiment).
  3. data analysis: **fit muon lifetime** from a set of single lifetime measurements.
  4. consideration of **background**.
- Experimental method quite old, but still in use (NIM will be 60 next year!).
- Great to be able to *follow* logic pulses (with scope).
- Nowadays, the whole setup could easily be programmed to an FADC.
  (could be an Praktikum-experiment on its own?)

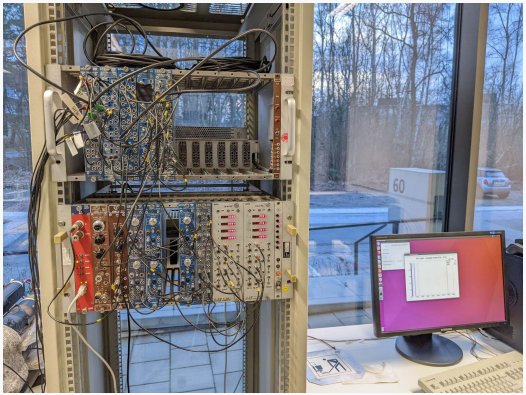
Experimental Setup

Detector

- Three layers of plastic Scintillators read out with PMTs.
- Detect muons that get absorbed in the middle layer.
- Detect $e^{\pm}$ from muon decay.

DAQ

- Mainly NIM modules for logic circuit.
- Single decay times measured by
  1. chained, gated counters.
  2. TAC-ADC combination.



Data Analysis Method

Two types of analyses:

(Gated) counters

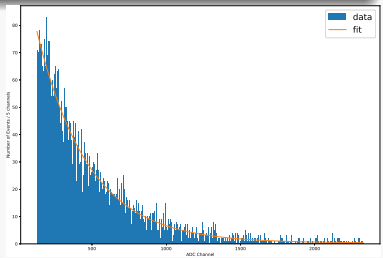
- weighted linear regression
- method explained in instructions
- spread sheet analysis

ADC Data

- list of decay times (channels)
- ▷ histogram
- ▷ fit
- (very basic) python-template (script and notebook)

x	y	dy	G	Gx	Gy	Gxx	Gxy	v	Gv	Gvv		
2	8,83433697	0,01206836	6866	13732	60656,5577	27464	121313,115	-0,0127699	-87,6783487	1,1196465	N=	337656600
4	7,84502442	0,01979131	2553	10212	20028,3473	40848	80113,3893	0,05836936	149,0169834	8,69802637	1/N=	2,9616E-09
6	7,01660968	0,02994764	1115	6690	7823,5198	40140	46941,1188	-0,0313892	-34,9989205	1,09858694	a=	-0,45908663
8	6,12468339	0,04677803	457	3656	2798,98031	29248	22391,8425	-0,0576361	-26,3397141	1,51811934	da=	0,00570533
			10991	34290	91307,4051	137700	270759,466	-0,0434259	-4,5169E-11	12,4343791	b=	9,73974031
										Chi^2	db=	0,02019433

U=	0,092	0,004										
x	y	dy	G	Gx	Gy	Gxx	Gxy	v	Gv	Gvv		
2	8,83432357	0,01206836	6865,99198	13731,984	60656,3948	27463,9679	121312,79	-0,0127565	-87,5862459	1,11729674	N=	337652607
4	7,84498838	0,01979134	2552,99198	10211,9679	20028,1925	40847,8717	80112,7698	0,0584054	149,1085168	8,7087425	1/N=	2,9616E-09
6	7,01652717	0,02994775	1114,99198	6689,9519	7823,37155	40139,7114	46940,2293	-0,0313067	-34,9066657	1,09281083	a=	-0,45910923
8	6,12448206	0,04677844	456,991984	3655,93587	2798,83921	29247,487	22390,7137	-0,0574348	-26,2472445	1,50750531	da=	0,00570536
			10990,9679	34289,8397	91306,7981	137699,038	270756,502	-0,0430926	0,368360759	12,4263554	b=	9,73977731
										Chi^2	db=	0,02019437



Key Scientific Results and Link to Modern Research

- Measured lifetime usually around $2\,\mu s$.
- Deviation from true lifetime due to muonic atoms.
- Different methods of background estimation (usually yielding the same results).
- Muons play a large role in every modern particle physics experiment.
- Detection with scintillators widely used (even NIM electronics still used).
- Data analysis methods: histogramming and fitting is a standard tool in many areas of physics.

Duration & Complexity

- Full day on Monday
  - 1.5 hours theory, focus on muons and detection
  - exercises to get to know (NIM)-electronics, oscilloscope, etc.
  - sometimes start of calibration (PMT thresholds, TAC time calibration)
- Most of the day on Tuesday
  - 1.5 hours of discussion, focus on exponential decays and analysis
  - rest of calibration, plugging together the experiment
- 2 hours on Friday
  - stopping the measurement, reading the counters, cleanup
  - start of python based analysis

Grade the complexity of the various aspects of your experiment; 1 is high and 5 low

Theory / preparation	Setup / experimental	Data taking	Analysis	Protocol
4 (1 w/o physics 5)	2	4	3	3 (usually 20+ pages)