Cosmics with ALPIDE

Bachelor Student Report

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September 22th, 2020

First Steps

- Started working in May
- Limited access to GSI
- Set up the telescope to be pointed towards the sky and record cosmics
- At first **no scintillators** available

Method of operation

- Use a NIM pulse generator to create artificial triggers for the chips.
- Trigger every ~100 μs (when not busy).
- When discriminator signal and STROBE are in coincidence, event is latched to memory
- That way no event should be missed

STROBE signal

Discriminator signal
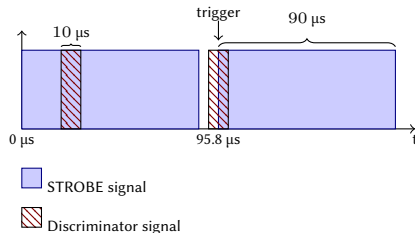
First Steps

PROs

- Running "without" external trigger possible
- Uptime is close to 100%
- Telescope can (and had) be operated **REMOTELY**
- Thin time slices makes it really unlikely to detect two muons at the same time, especially from similar angles.

CONs

- $> 10\,000$ Events per second (mostly empty)
- 4.4 MB per second of Data written to the disk
- EUDAQ 1 crashed often at filesizes > 5 GB $\rightarrow$ Runtime limited to ≈ 18 min

Taking Cosmics

Took 380 runs á 14-18 minutes in total over the course of several weeks

date	time started	time ended	time duration	participant	Runnumber	Event limit	moved to disk?	VCASN/VCASN2	ITHR	comments
	19:00:31	19:14:57	14min	David	429	9	yes	103/115	90	NO OUT OFF SYNC
	19:16:05	19:30:31	14min	David	430	9	yes	103/115	90	
	19:31:37	19:46:03	14min	David	431	9	yes	103/115	90	
	19:47:09	20:01:35	14min	David	432	9	yes	103/115	90	
	20:02:42	20:17:09	14min	David	433	9	yes	103/115	90	DAQ boards stay busy, no out of sync, still started run
	20:18:14	20:32:42	14min	David	434	9	yes	103/115	90	
	--	--	--	David	435	9	deleted	103/115	90	Stopped run manually, no crash
5/16/2020	9:58:11	10:12:37	14min	Felicitas	436	9	yes	103/115	90	
	10:13:41	10:28:04	14min	Felicitas	437	9	yes	103/115	90	
	10:29:10	10:43:31	14min	Felicitas	438	9	yes	103/115	90	
	10:44:37	10:58:59	14min	Felicitas	439	9	yes	103/115	90	
	11:00:05	11:14:25	14min	Felicitas	440	9	yes	103/115	90	
	11:15:32	11:29:52	14min	Felicitas	441	9	yes	103/115	90	NO OUT OFF SYNC (DAQ Boards stay busy -> reconfigure)
	11:30:58	11:45:17	14min	Felicitas	442	9	yes	103/115	90	
	11:45:40	11:59:57	14min	Felicitas	443	9	yes	103/115	90	NO OUT OFF SYNC
	-	-	-	Felicitas	444		deleted	103/115	90	
	12:45:39	12:59:54	14min	David	445	9	yes	103/115	90	
	13:00	13:15:08	14min	David	446	9	yes	103/115	90	
	13:16:14	13:30:22	14min	David	447	9	yes	103/115	90	
	13:31:27	13:45:36	14min	David	448	9	yes	103/115	90	
	13:45:59	14:00:06	14min	David	449	9	yes	103/115	90	NO OUT OFF SYNC
	14:01:14	14:15:23	14min	David	450	9	yes	103/115	90	DAQ boards stay busy, no out of sync, still started run
	14:16:28	14:30:36	14min	David	451	9	yes	103/115	90	
	14:31:41	14:45:47	14min	David	452	9	yes	103/115	90	
	14:46:53	15:00:57	14min	David	453	9	yes	103/115	90	
	15:02:03	15:16:08	14min	David	454	9	yes	103/115	90	
	15:17:14	15:31:19	14min	David	455	9	yes	103/115	90	

- 1.5 TB of Data
- First analysis showed only ~10 good tracks per run

Cosmic Analysis

- Corryvreckan fails to do analysis with just a few tracks per run
  (no way of combining multiple .raw files for alignment?)

- Used the [TextWriter] module to transform RAW data into .txt files.

    - Reducing filesize from ~4.5 GB to ~200 MB per run

Cosmic Analysis

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- Used the [TextWriter] module to transform RAW data into `.txt` files.

  - Reducing filesize from ~4.5 GB to ~200 MB per run

- Compression program stores only non-empty events.

  - Reduces size of `.txt` files to ~90 kB (Only non-empty events)

- Further analysis in Python

Cosmic Analysis

- First visualization attempts
- Plane alignment with testbeam data from 2019 → inaccurate (planes seem to have shifted)
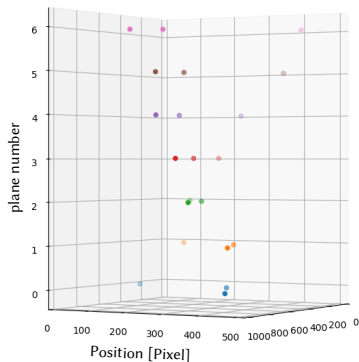
$\underset{\text{(align)}}{\rightarrow}$
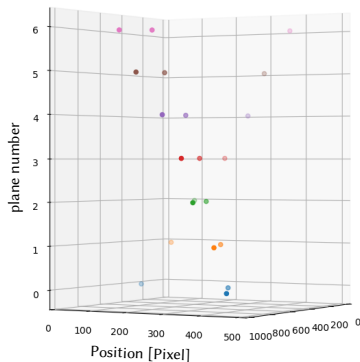
- Taking closer look at alignment

Cosmic Analysis
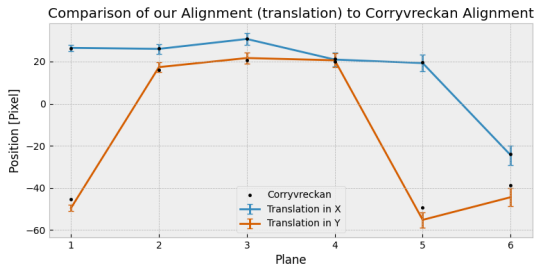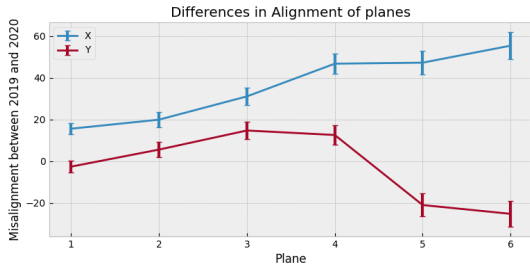
- First look at perpendicular tracks (testbeam)
- Disalignment of planes to over 1.5 mm (after transport)
- Generally, testbeam alignment from 2020 closer to cosmic setup than from 2019
- Simple translation algorithm and comparison with the alignment that Corryvreckan suggests (second figure)
- Goal: Do alignment with cosmic data

  (new complication: angles)

Cosmic Analysis

Implemented a 3D-Fitting algorithm in Python:
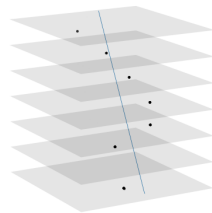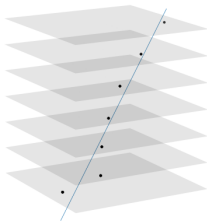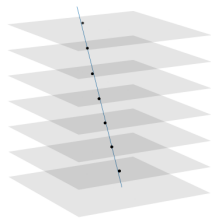

Using numpy's Singular value decomposition `np.linalg.svd`

$\rightarrow$ Calculating χ^2 (goodness of fit) "by hand"
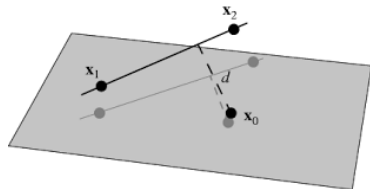
$$d^2 = \frac{|x_1 - x_0|^2 |x_2 - x_1|^2 - [(x_1 - x_0) \cdot (x_2 - x_1)]^2}{|x_2 - x_1|^2}$$

Event Analysis

- Calculation of measurable muon rate
  - Considering detector geometry,
    expected muon rate and angular distribution
- Distinguish events by the number of traversed detector layers (planes)
  - Event with n traversed planes: n-plane-event (npE)
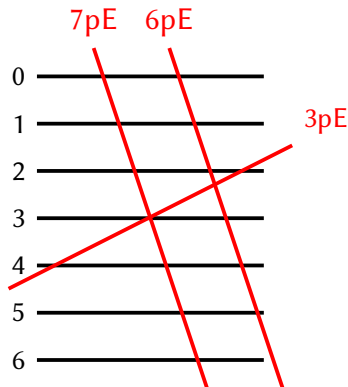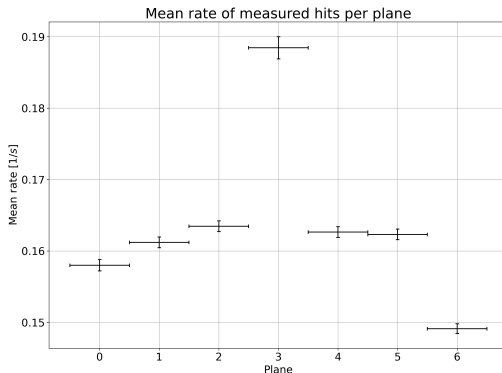
Event Analysis

- Comparison of evaluated data to expectation

Mean rate of expected and measured multi-plane-events
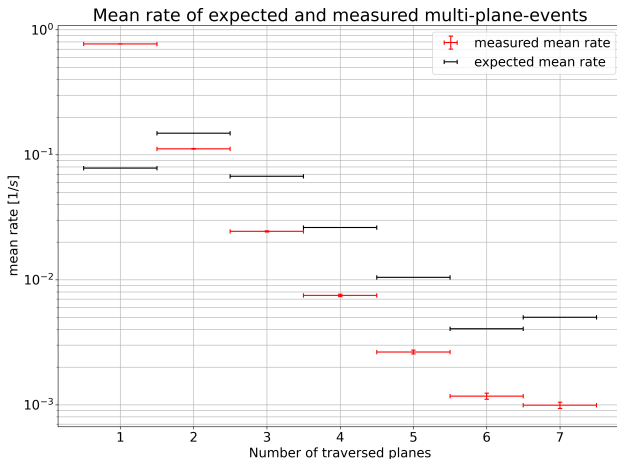
- What are the reasons for the overestimation?

Event Analysis

- Differences in measured mean hit rate per plane
- Dependency on thresholds

Mean rate of measured hits per plane

Plane	0	1	2	3	4	5	6
Threshold [*DAC*]	27.2(6)	31.3(6)	22.8(4)	12.7(5)	21.4(5)	16.1(6)	20.2(6)

Event Analysis

- Check for events with hits on not consecutive planes
  - (i.e. planes 1,2,3,4,5,7 registering a hit lead to false 6pE)
- Corrected mean rate by removing not consecutive plane events
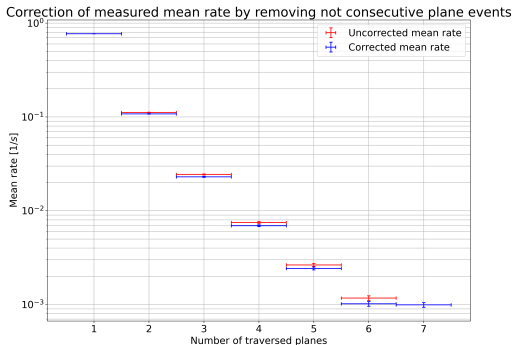- Further analysis with track information

Figure: Mean rate correction by not consecutive plane events

Track Analysis

- Track visualized with 2-dimensional projection
- Alignment with data of testbeam June 2020
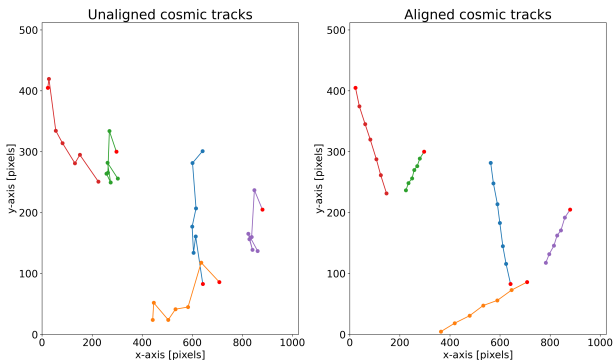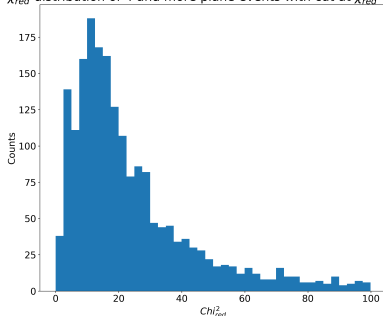- Possibility to classify events as valid or fake track

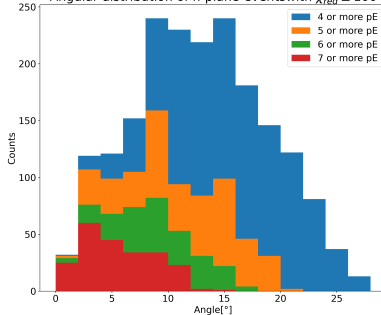Figure: Alignment with 2020 testbeam data

Track Analysis

- Linear fit on 2D-track projections
- Analysis of χ^2_{red}-distribution and angular distribution
- Open questions regarding the angular distribution (e.g. too few entries at small angles)

Outlook

Projects

- Alignment
    - Trying to achieve better alignment by iterative track fitting (similar to corryvreckan)

- Cosmic Analysis for Thesis
    - Comparing angular distribution and rate with theoretical calculations
    - Cluster sizes and cluster analysis

- The ALPIDE-Telescope
    - Now have scintillators again
    - Trying to revive the setup in triggered mode (now together)
    - As of right now: Eudaq not able to work with low particle rate (maybe you have some input?)
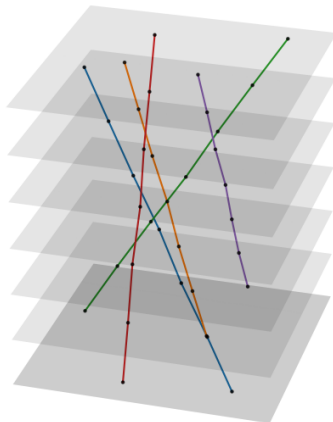
APENDIX

$$\chi^2_{red}$$

- $\chi^2_{red} = \frac{\chi^2}{dof}$
- dof = number of measurements - variables of the fit
- dof = number of traversed planes - 2 (linear fit)