Extreme Energy Events Project @ ICD 2025
POLA-02 aboard of the Vespucci

Using the data acquired from the POLA-02 detector during the mission aboard the Vespucci (October 2022), we will study the variations in muon flux as a function of latitude.

The data
You have pre-processed data available from the POLA-02 detector covering both the period relating to the measurements aboard the Vespucci and the latest measurements during the car mission from Bologna to Tromso and back.

NB:

1. **For the ICD, ONLY data related to the mission aboard the Vespucci must be used**
2. **The data are available in csv format and in root format**
3. **Following instructions refer to analyses to be carried out in Excel (in English version)**
4. **Instructions represent a starting point to develop the analysis**

After downloading the file allfixed.csv

1- Make a copy adding the label orig (that is, original) to the name
2- At this point, open the file without that label, then

To open the file with Excel: **normally it is enough to double-click the file**. The file should appear as shown in the figure (if the data are not divided into columns, proceed to divide them manually from the Data menu -> Text to Columns):

	A	B	C	D	E	F	G
1	Run	Rate(Hz)	RateEffCorr(Hz)	pressure(mbar)	Tin(¬∞C)	Tout(¬∞C)	latitude(¬∞)
2	497621850	30.60	30.81	1023.74	32.50	25.75	45.65
3	497621850	31.78	32.00	1023.67	32.50	25.75	45.65
4	497621850	30.53	30.75	1023.13	32.56	25.75	45.65
5	497621850	30.32	30.53	1023.01	32.56	25.75	45.65
6	497621850	30.35	30.56	1021.16	32.62	25.81	45.65
7	497621850	30.60	30.81	1021.86	32.62	25.81	45.65
8	497621850	30.88	31.10	1022.25	32.69	25.88	45.65

Information carried in the file are:

Run: Number of Run, it is the number that identifies an acquisition file.
Rate (Hz): event rate measured during the Run
RateEffCorr (Hz): event rate corrected for the detector efficiencies.
pressure (mbar): atmospheric pressure measured in mbar
Tin (°C): Temperature inside the detector's electronics box
Tout (°C): external ambient temperature
Latitude (°): Latitude

Guide to the analysis

The first phase of the exercise concerns the selection of data (i.e., runs) useful for the analysis of the flux as a function of latitude. For this operation, we refer to the following summary table related to the data acquired when the Vespucci was not moving.

Run Iniziale	Run Finale
498897908	498942903
498396949	498431282
499232479	499279006

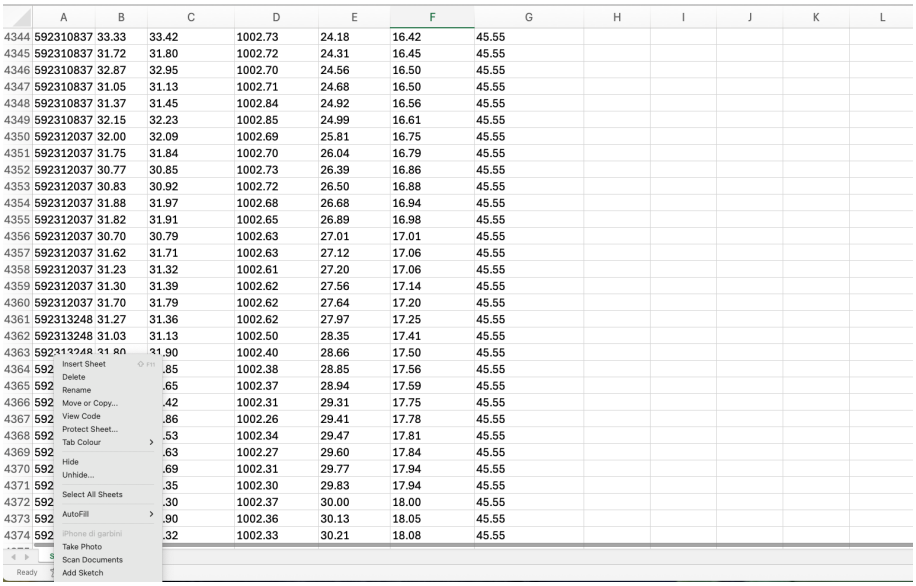
499342599	499380507
497949557	498003629
497621850	497651749

Table 1: Run's range ralted to measurments of fixed position

Based on this table, it will be necessary to select the runs in the file allfixed.csv corresponding to each fixed position.

SUGGESTED STRATEGY:

1. **Right-click on the tab name (Sheet1) and select Rename; suggested name: "fixed".**



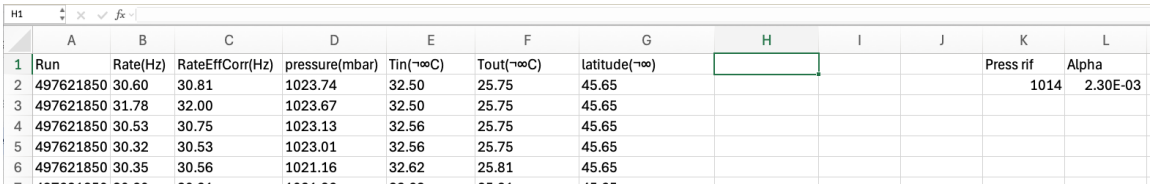
2. **Correction due to the barometric effect**

At this point, we move on to correct the rates for pressure effects: barometric effect. We will apply the correction for the barometric effect using the rate corrected for the detector efficiencies (column C). Recall that the formula for the correction is:

Rate_Corr = Rate_nonCorr* EXP(α*(Pmis-P_ref))

And we will use in this occasion the following unities:
α = 2.30E-03
P_ref = 1014 (mbar)

We then insert these values into two cells of the tab, as shown for example in the figure:



	A	B	C	D	E	F	G	H	I	J	K	L
1	Run	Rate(Hz)	RateEffCorr(Hz)	pressure(mbar)	Tin(¬∞C)	Tout(¬∞C)	latitude(¬∞)				Press rif	Alpha
2	497621850	30.60	30.81	1023.74	32.50	25.75	45.65				1014	2.30E-03
3	497621850	31.78	32.00	1023.67	32.50	25.75	45.65					
4	497621850	30.53	30.75	1023.13	32.56	25.75	45.65					
5	497621850	30.32	30.53	1023.01	32.56	25.75	45.65					
6	497621850	30.35	30.56	1021.16	32.62	25.81	45.65					

Now we will use Column H (which we rename RatePCorr) to calculate the barometric effect correction of the Rate in column C. So in cell H2 we enter the correction formula, considering that the Reference Pressure and a values will be constant.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Run	Rate(Hz)	RateEffCorr(Hz)	pressure(mbar)	Tin(¬∞C)	Tout(¬∞C)	latitude(¬∞)	RatePcorr			Press rif	Alpha
2	497621850	30.60	30.81	1023.74	32.50	25.75	45.65	=C2*EXP(L2*(D2-K2)			1014	2.30E-03
3	497621850	31.78	32.00	1023.67	32.50	25.75	45.65					
4	497621850	30.53	30.75	1023.13	32.56	25.75	45.65					
5	497621850	30.32	30.53	1023.01	32.56	25.75	45.65					
6	497621850	30.35	30.56	1021.16	32.62	25.81	45.65					

Pressing enter and then repeating for all the cells gives the corrected pressure values.

H2 =C2*EXP(L2*(D2-K2))

	A	B	C	D	E	F	G	H	I
1	Run	Rate(Hz)	RateEffCorr(Hz)	pressure(mbar)	Tin(¬∞C)	Tout(¬∞C)	latitude(¬∞)	RatePcorr	
2	497621850	30.60	30.81	1023.74	32.50	25.75	45.65	31.51	
3	497621850	31.78	32.00	1023.67	32.50	25.75	45.65		
4	497621850	30.53	30.75	1023.13	32.56	25.75	45.65		
5	497621850	30.32	30.53	1023.01	32.56	25.75	45.65		

To replicate the formula for the entire column H, you can drag it starting from the bottom right corner of cell H2 or alternatively, double-click the bottom right corner of the cell.

NB: we leave it to you to insert the units of measurement where necessary.

Let's proceed with finding the average rates for the run ranges related to measurements in fixed positions.

3. **Add a tab to the Excel sheet by pressing the "+" as shown in the figure and rename it (for example, Mean Rate) as shown previously.**

24	497623924	29.65	30.14	1020.95	33.90	26.56	45.65	30.63
25	497623924	29.92	30.40	1021.20	34.00	26.65	45.65	30.91
26	497623924	30.88	31.39	1021.82	34.03	26.69	45.65	31.96
27	497623924	28.83	29.31	1021.52	34.06	26.72	45.65	29.82
28	497623924	30.77	31.26	1021.12	34.06	26.75	45.65	31.78
29	497623924	30.33	30.82	1020.92	34.12	26.81	45.65	31.31
30	497623924	29.97	30.46	1020.41	34.12	26.84	45.65	30.91
31	497623924	30.53	31.02	1020.46	34.12	26.88	45.65	31.48

fixed + Enter Accessibility: Good to go

4. **Calculate the average values of the rate for the relevant run ranges.**

Now we need to use the information from the original tab with the average values per Run and extract the average information for each set of Runs. Meanwhile, let's create the column headers:

A2

	A	B	C	D	E
1	Run Min	Run Max	Rate (Hz)	ErrRate	
2					
3					

Using the information from Table 1.1, report the Run ranges in a table.

	A	B	C	D
1	**Run Min**	**Run Max**	**Rate (Hz)**	**ErrRate**
2	498897908	498942903		
3	498431282	498431282		
4	499232479	499279006		
5	499342599	499380507		
6	497949557	498003629		
7	497621850	497651749		

We now need to calculate the average rate within the run ranges of interest. We can use the function:

AVERAGEIFS(average_range, criteria_range1, criteria1, [criteria_range2, criteria2], ...)

which returns the arithmetic mean of a range of cells that satisfy multiple criteria. The meaning of the terms is:

Average_range – Required. One or more cells to average, including numbers or names, arrays, or references containing numbers.
Criteria_range1, criteria_range2, … – Criteria_range1 is required, while subsequent criteria ranges are optional. From 1 to 127 ranges in which to evaluate the associated criteria.
Criteria1, criteria2, … – Criteria1 is required, while subsequent criteria are optional. From 1 to 127 criteria in the form of a number, expression, cell reference, or text that defines which cells will be averaged. For example, criteria can be expressed as **32, "32", ">32", "apples",** or **B4**.

So, we can enter in cell C2 the function to calculate the average of column H in the "fixed" tab when the Run number (Column A) is greater than or equal to Run Min (column A in the MeanRate tab) and less than or equal to Run Max (column B in the MeanRate tab).

	A	B	C	D	E	F	G
1	**Run Min**	**Run Max**	**Rate (Hz)**	**ErrRate**			
2	498897908	498942903	=AVERAGEIFS(fixed!H:H,fixed!A:A,">="&A2,fixed!A:A,"<"&B2)				
3	498431282	498431282					
4	499232479	499279006					
5	499342599	499380507					
6	497949557	498003629					
7	497621850	497651749					

Repeating for the six ranges we obtain:

Run Min	Run Max	Rate (Hz)	ErrRate
498897908	498942903	30.74	
498396949	498431282	31.05	
499232479	499279006	31.22	
499342599	499380507	31.41	
497949557	498003629	31.62	
497621850	497651749	31.40	

5. Evaluation of the error

In column D, calculate the error on that average rate (**Suggestion:** Considering that there are N rate measurements for each range, the error can therefore be evaluated as the error on the mean of the measurements.).

6. Rate vs. Latitude graph

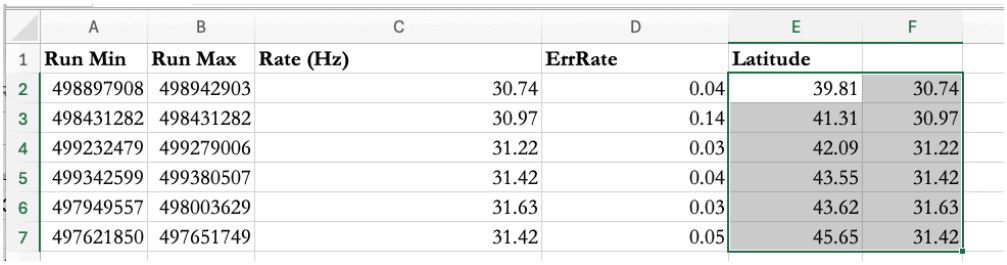
To build the graph of the rate variation as a function of latitude, add in column E of the MeanRate tab the latitude values (these can be extracted from the fixed tab by finding the average latitude in the run range of interest, as done for the average rate, using the AVERAGEIFS function).

	A	B	C	D	E
1	**Run Min**	**Run Max**	**Rate (Hz)**	**ErrRate**	**Latitude**
2	498897908	498942903	30.74	0.04	39.81

The quickest solution to insert the graph is to copy the rate values from column C into column F.
This can be done by selecting the data in column C, copying it, and pasting it into column F.

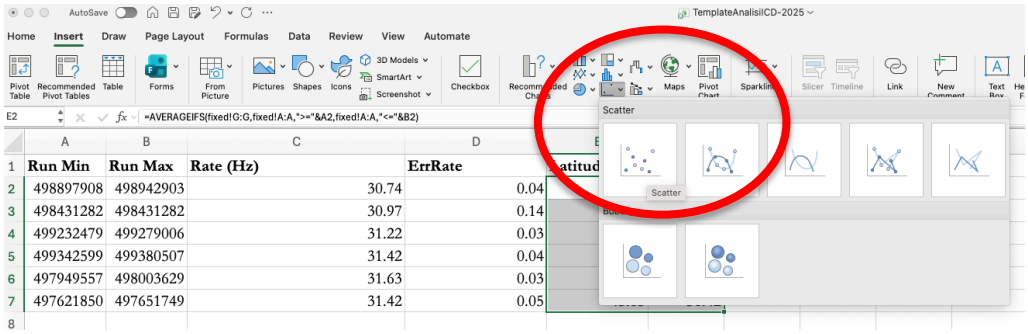
Run Min	Run Max	Rate (Hz)	ErrRate	Latitude	Rate
498897908	498942903	30.74	0.04	39.81	30.74
498431282	498431282	30.97	0.14	41.31	30.97
499232479	499279006	31.22	0.03	42.09	31.22
499342599	499380507	31.42	0.04	43.55	31.42
497949557	498003629	31.63	0.03	43.62	31.63
497621850	497651749	31.42	0.05	45.65	31.42

Select the data in column E (latitude), then while holding down the Ctrl key (or Command on MacOS), select column F in the MeanRate tab, as shown in the figure.

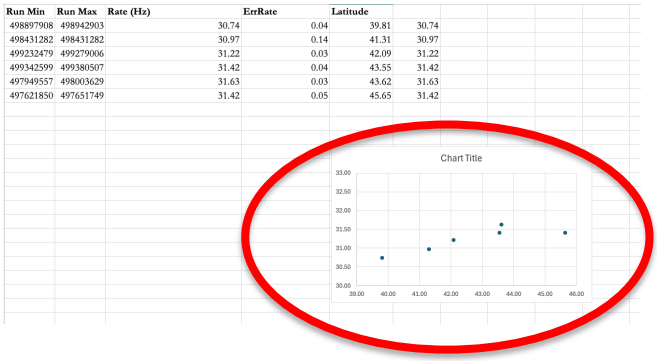


	A	B	C	D	E	F
1	Run Min	Run Max	Rate (Hz)	ErrRate	Latitude	
2	498897908	498942903	30.74	0.04	39.81	30.74
3	498431282	498431282	30.97	0.14	41.31	30.97
4	499232479	499279006	31.22	0.03	42.09	31.22
5	499342599	499380507	31.42	0.04	43.55	31.42
6	497949557	498003629	31.63	0.03	43.62	31.63
7	497621850	497651749	31.42	0.05	45.65	31.42

Once the two columns are selected (in the indicated order), go to the Insert menu and select the Scatter chart type, as shown in the figure, and press Enter.

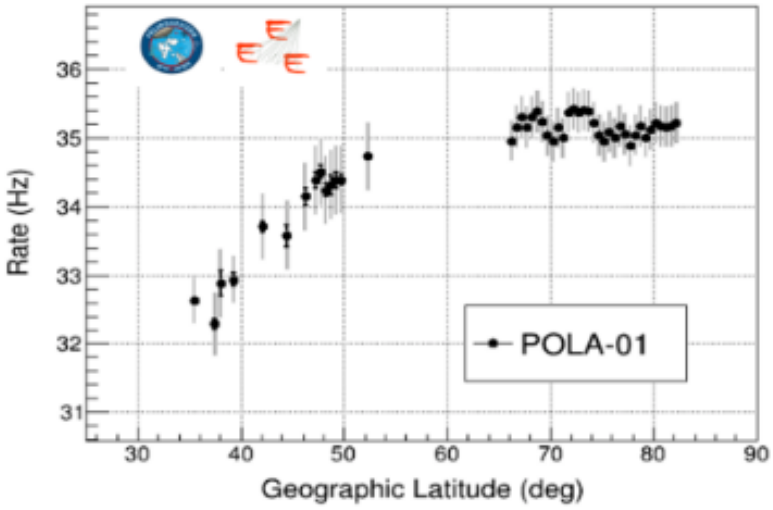


This will generate the chart shown in the figure (add error bars in y, and complete the chart by adding units of measure and other elements as needed).



Analysis suggestions

Briefly discuss the obtained result, also comparing it with what has been published: M. Abbrescia et al. (EEE Collaboration), "Measurement of the cosmic charged particle rate at sea level in the latitude range 35° ÷ 82° N with the PolarquEEEst experiment", Eur. Phys. J.C 83, 293 (2023). https://doi.org/10.1140/epjc/s10052-023-11353-w.



Download the data contained in the file allmoving.csv which includes measurements taken both during the mission aboard the Vespucci and during the 2025 car measurement campaign. Repeat the measurement using **EXCLUSIVELY** the runs related to the moving measurements on the Vespucci, referring to the table below to select the runs: for this analysis, the run selection must be based on both the run range and the latitude range where the Vespucci was at the time of measurement.

	Run Iniziale	Run Finale	**Latidue Min**	**Latitude Max**
V1	400000000	500000000	37.75	38
V2	400000000	500000000	38	38.25
V2	400000000	500000000	38.25	38.5
V2	400000000	500000000	38.5	38.75
V2	400000000	500000000	38.75	39
V2	400000000	500000000	39	39.25
V2	400000000	500000000	39.25	39.5
V2	400000000	500000000	39.5	39.75
V2	400000000	500000000	39.75	40
V2	400000000	500000000	40	40.25
V3	400000000	500000000	40.25	40.5
V4	400000000	500000000	40.5	40.75
V5	400000000	500000000	40.75	41
V6	400000000	500000000	41	41.25
V7	400000000	500000000	41.25	41.5
V8	400000000	500000000	41.5	41.75
V9	400000000	500000000	41.75	42
V10	400000000	500000000	42	42.25
V11	400000000	500000000	42.25	42.5
V12	400000000	500000000	42.5	42.75
V13	400000000	500000000	42.75	43
V14	400000000	500000000	43	43.25
V15	400000000	500000000	43.25	43.5
V16	400000000	500000000	43.5	43.75
V17	400000000	500000000	43.75	44
V18	400000000	500000000	44	44.25
V19	400000000	500000000	44.25	44.5

V20	400000000	500000000	44.5	44.75
V21	400000000	500000000	44.75	45

As the latitude value, use the arithmetic mean of the latitudes measured in the relevant range.