Extreme Energy Events
Science inside Schools

RUN MEETING

MAY 2, 2018

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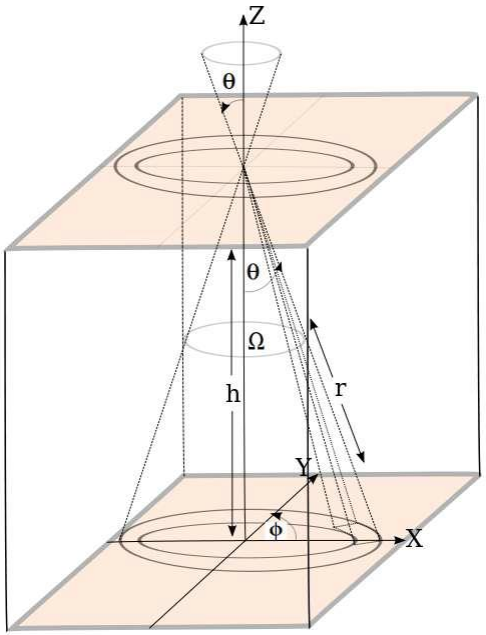
The Aim

- To measure the speed of cosmic ray muons analysing data collected by the Telescopes.



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Data Download

We downloaded data collected by two Telescopes: CERN-02 and ALTA-01

Request a subset of data, Page 2 of 22 — Logged in as "EEE1-04"

New | Find | Logout

Author: ee1-04

Full | Summary | Threaded | Hide attachments — -- All entries -- — Error: Attribute "Type" for quick filter not found — -- Type --

Goto page Previous 1, 2, 3 ... 20, 21, 22 Next All

ID	Date	Author	MC	Output format	Telescope ID	Start time	Stop time	RunNumber	Seconds	Nanoseconds	Theta	Phi	ChiSquare	TimeOfFlight	TrackLength	DeltaTi
1081	Wed Apr 18 01:33:31 2018	EEE1-04	☐	CSV	ALTA-01	03 February 2018	04 February 2018	☐	☐	☐	☐	☐	☐	☑	☑	☐
Data extraction succeeded																
Attachment 1: ALTA-01from2018-02-03to2018-02-04.csv.zip																
1080	Wed Apr 18 01:32:57 2018	EEE1-04	☐	CSV	ALTA-01	01 February 2018	02 February 2018	☐	☐	☐	☐	☐	☐	☑	☑	☐
Data extraction succeeded																
Attachment 1: ALTA-01from2018-02-01to2018-02-02.csv.zip																
1079	Wed Apr 18 01:32:21 2018	EEE1-04	☐	CSV	ALTA-01	03 February 2018	04 February 2018	☐	☐	☐	☐	☐	☐	☑	☑	☐
Data extraction succeeded																
Attachment 1: ALTA-01from2018-02-03to2018-02-04.csv.zip																
1078	Wed Apr 18 01:32:06 2018	EEE1-04	☐	CSV	ALTA-01	03 February 2018	04 February 2018	☐	☐	☐	☐	☐	☐	☑	☑	☐
1077	Wed Apr 18 01:31:33 2018	EEE1-04	☐	CSV	ALTA-01	01 February 2018	02 February 2018	☐	☐	☐	☐	☐	☐	☑	☑	☐
1076	Wed Apr 18 01:30:59 2018	EEE1-04	☐	CSV	ALTA-01	01 February 2018	02 February 2018	☐	☐	☐	☐	☐	☐	☑	☑	☐
Data extraction succeeded																

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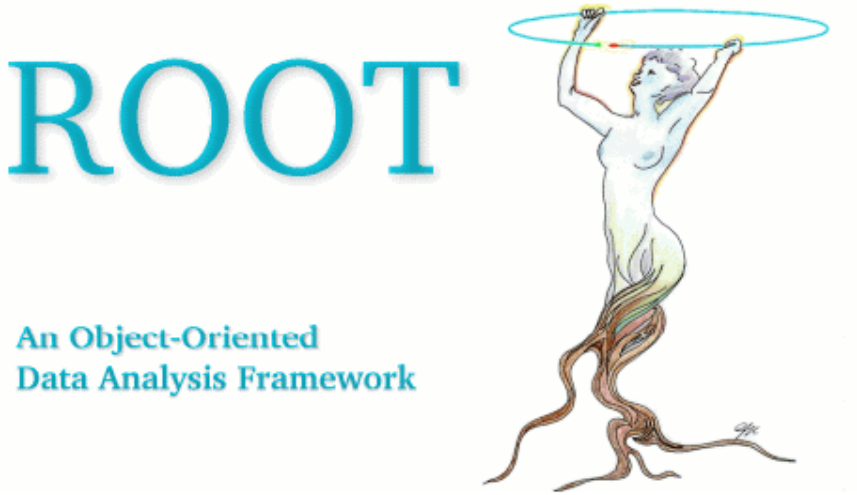
C++ Programming with Root

We started C++ programming using Root.

1) ROOT is a Framework developed at CERN
   (see the web site http://root.cern.ch)
2) It's completely developed in C++
3) It supports a collection of classes useful for data analysis
4) The IDE is based on the C++ interpreter, CINT



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Root for Windows

- Which Release we used? root_v5.34.36.win32.vc12

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C++: an introduction

- Our Teacher Mr. Ricchiuti explained, during our lessons, the basics of C++ programming:
- Data types;
- Declaring variables;
- Decision Making
- Loop Types
- Arrays
- Functions
- Classes and Objects

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Notepad ++

The Fields TimeOfFlight and TrackLength are separated in CSV files using "," , we have substituted each comma with \tab using the freeware software Notepad ++. In this way the file has a record layout ready to be read by root

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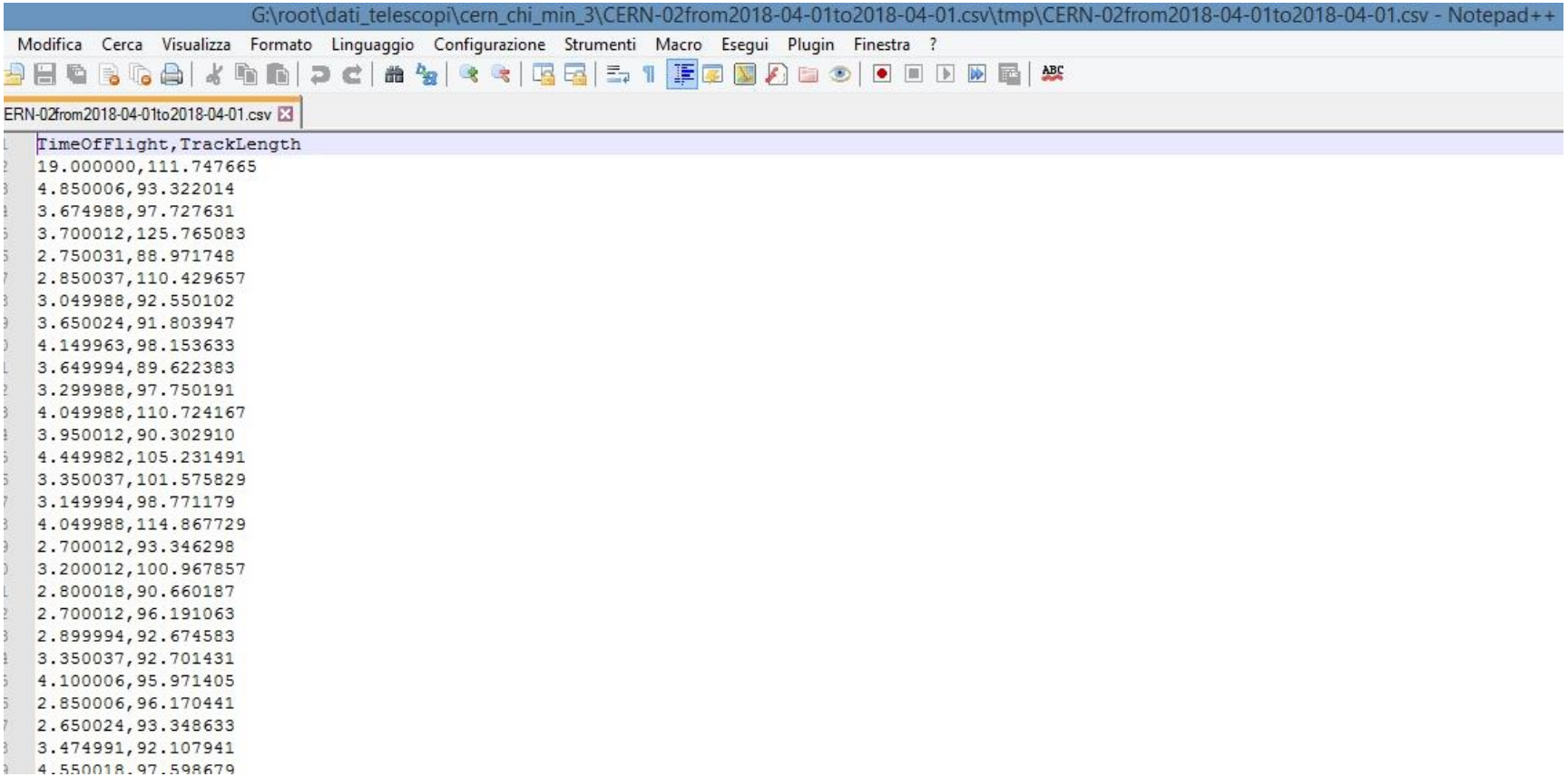
Notepad: importing data from a CSV file



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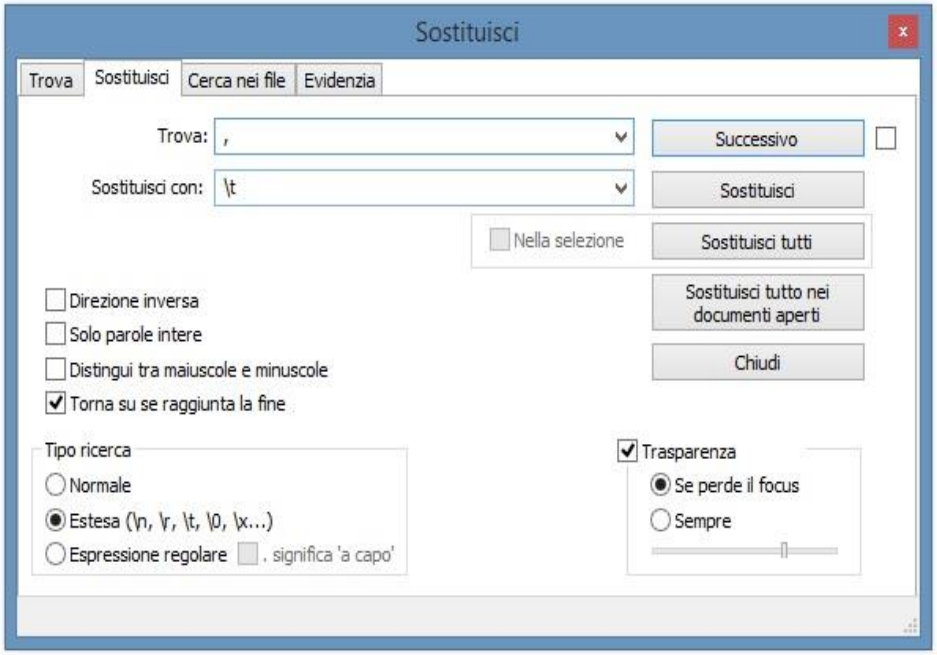
Notepad: replacement

G:\root\dati_telescopi\cern_chi_min_3\CERN-02from2018-04-01to2018-04-01.csv\tmp\CERN-02from2018-04-01to2018-04-01.csv - Notepad++

File Modifica Cerca Visualizza Formato Linguaggio Configurazione Strumenti Macro Esegui Plugin Finestra ?

CERN-02from2018-04-01to2018-04-01.csv

```
TimeOfFlight,TrackLength
19.000000,111.747665
4.850006,93.322014
3.674988,97.727631
3.700012,125.765083
2.750031,88.971748
2.850037,110.429657
3.049988,92.550102
3.650024,91.803947
4.149963,98.153633
3.649994,89.622383
3.299988,97.750191
4.049988,110.724167
3.950012,90.302910
4.449982,105.231491
3.350037,101.575829
3.149994,98.771179
4.049988,114.867729
2.700012,93.346298
3.200012,100.967857
2.800018,90.660187
2.700012,96.191063
2.899994,92.674583
3.350037,92.701431
4.100006,95.971405
2.850006,96.170441
2.650024,93.348633
3.474991,92.107941
4.550018,97.598679
3.149994,95.113045
```



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Histogram of the speed

- We calculated the speed of muons as the ratio TrackOfLength / TimeOfFlight, creating a frequency histogram about the distribution of the speeds

Gaussian Fitting: 10.000 events (1)

We obtained the gaussian fitting writing the line of code: `hist -> Fit("gaus");`

The centroid of the curve is the average speed of cosmic rays muons. We found a value very close to the speed of light, about 28,5 cm/ns. But the distribution is not perfectly a Gaussian function.

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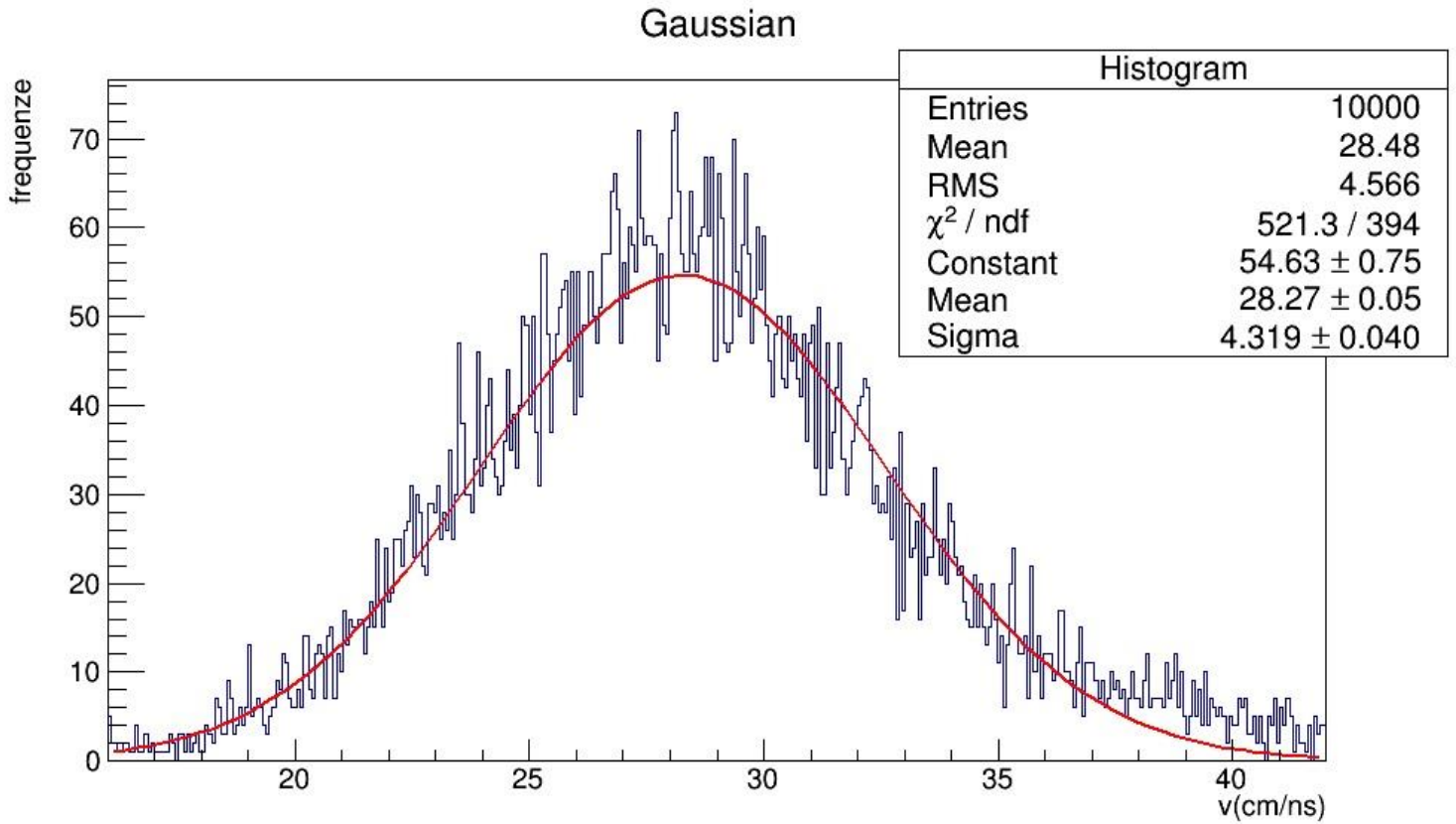
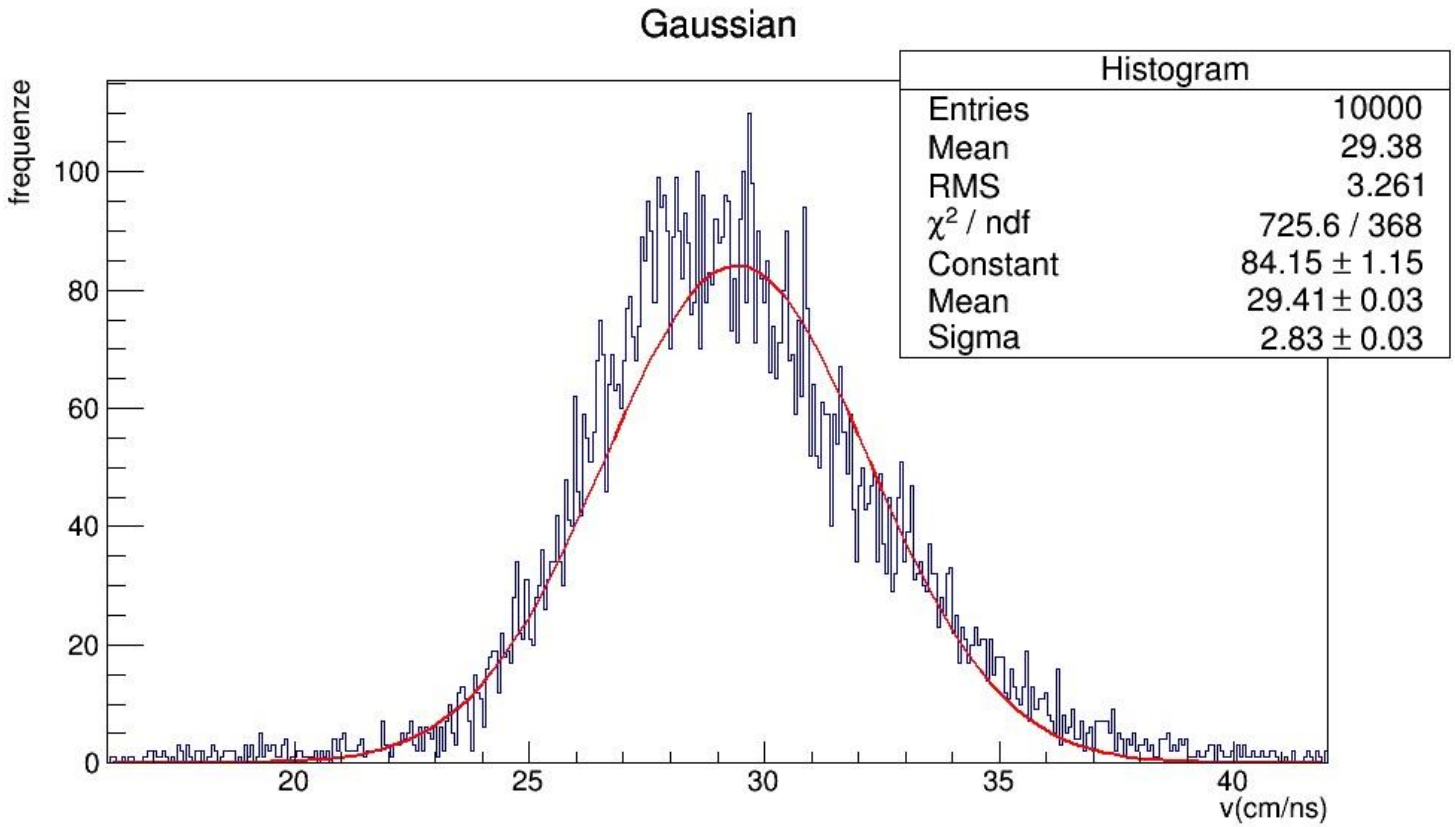
Gaussian Fitting: 10.000 events -CERN 02



Changing Telescope: Altamura



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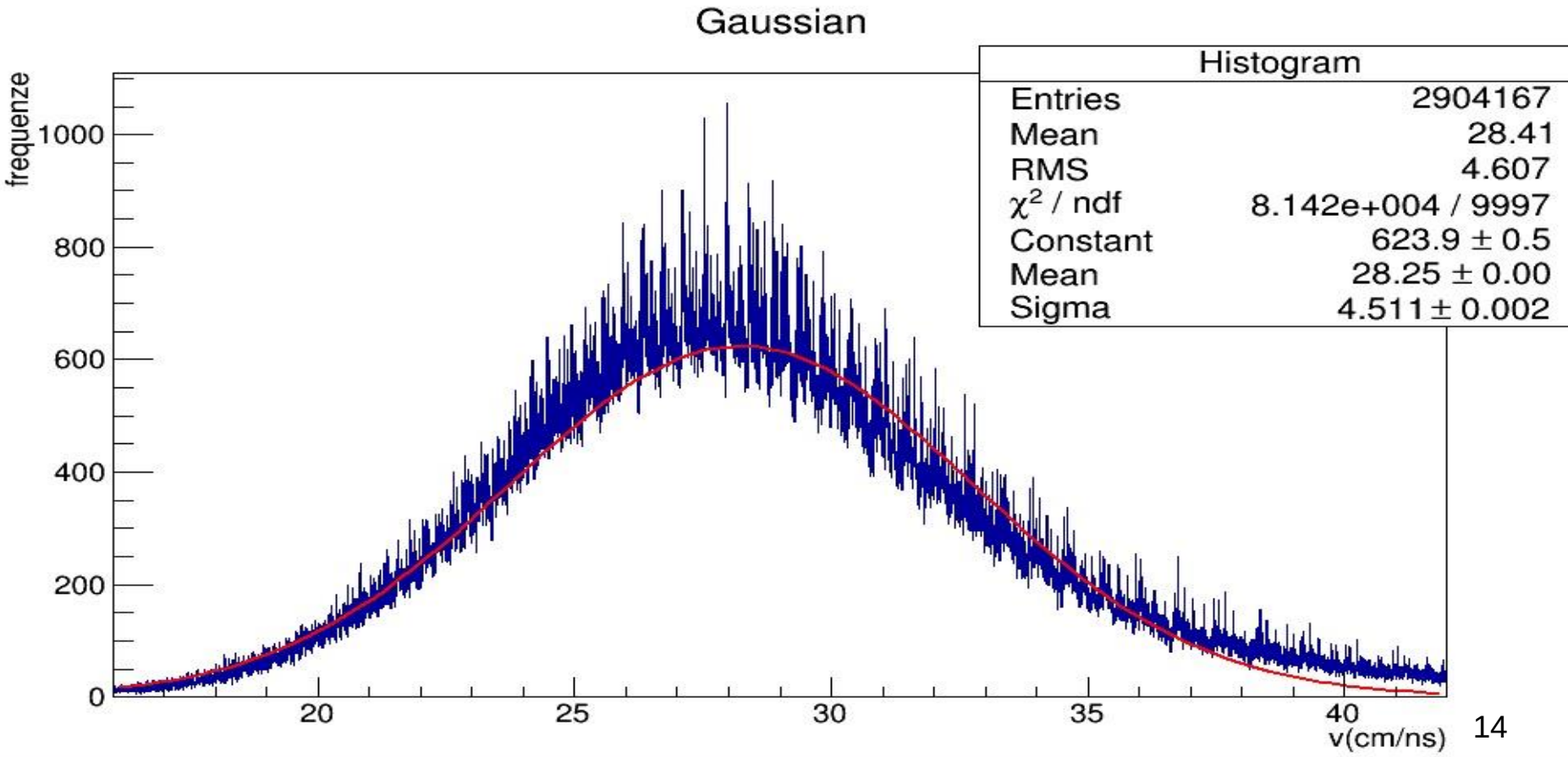
3 millions events – CERN 02

What happens? We have to increase the number of bins to reduce the ratio ChiSquare/ndf.



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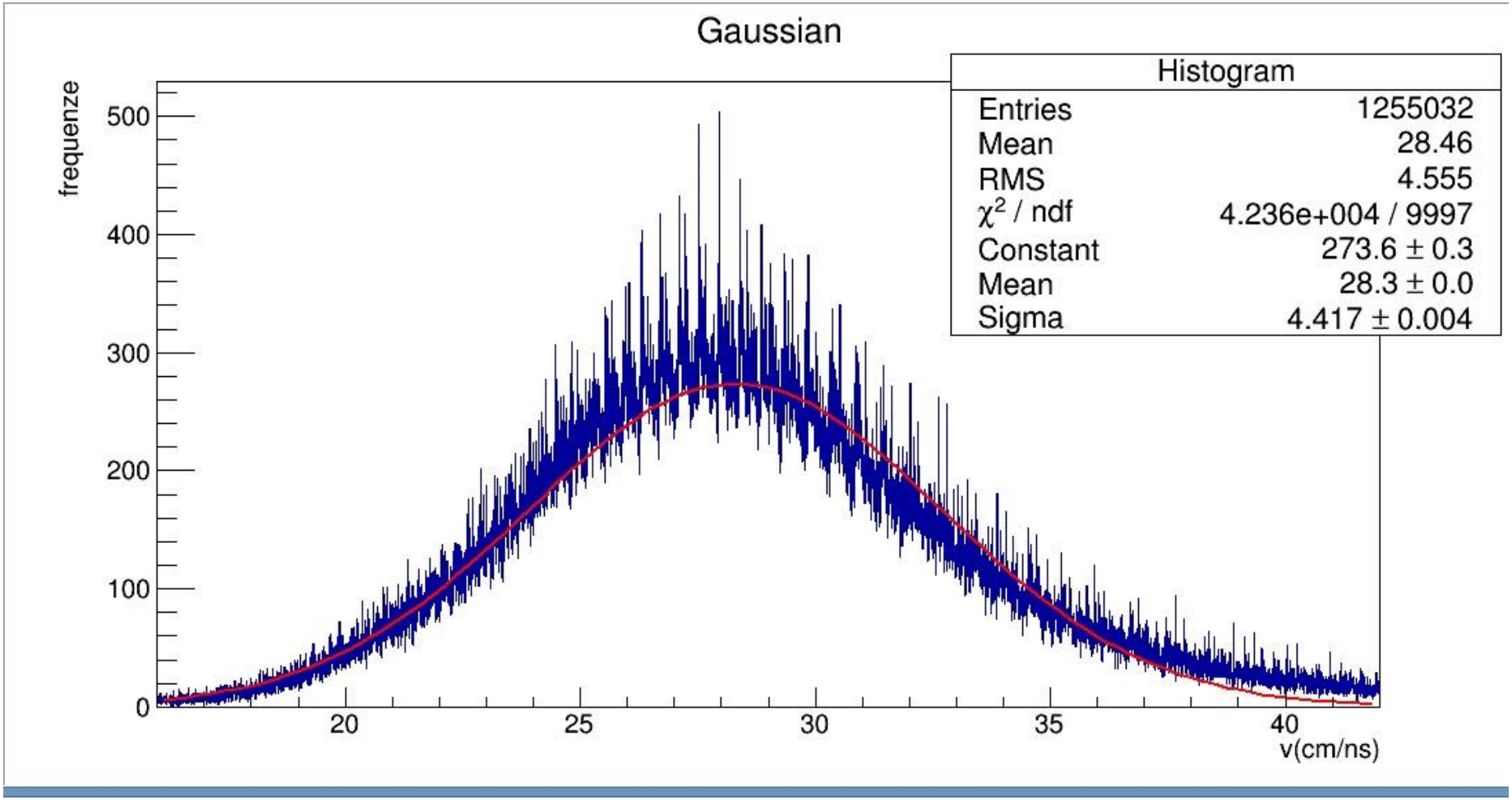
CUT ChiSquare <3



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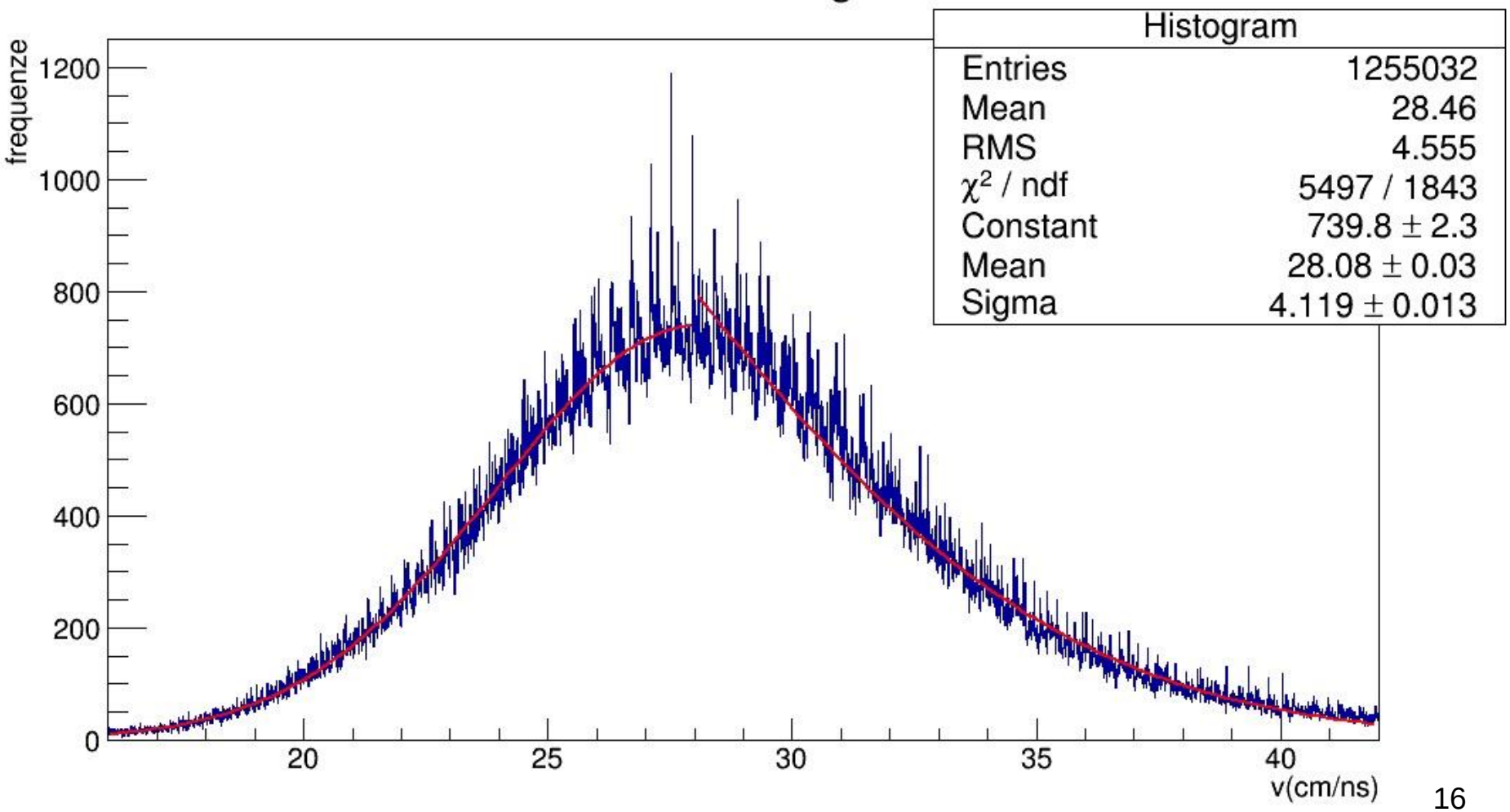
Multi-fitting



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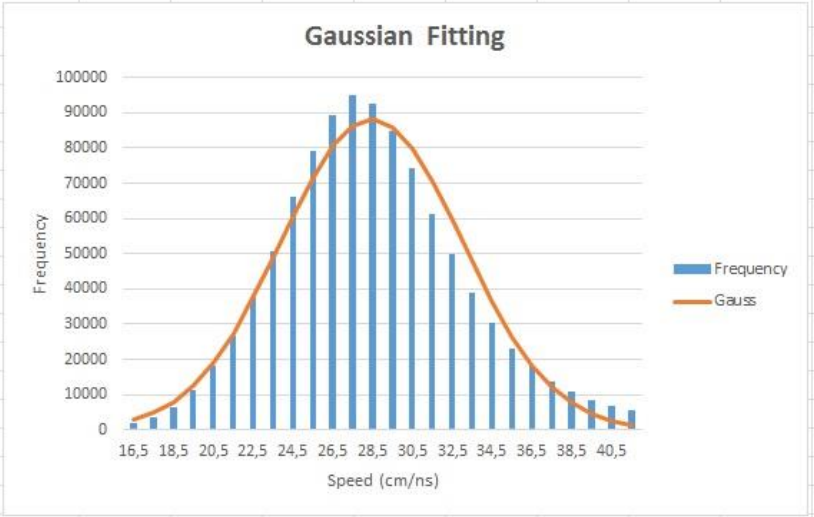
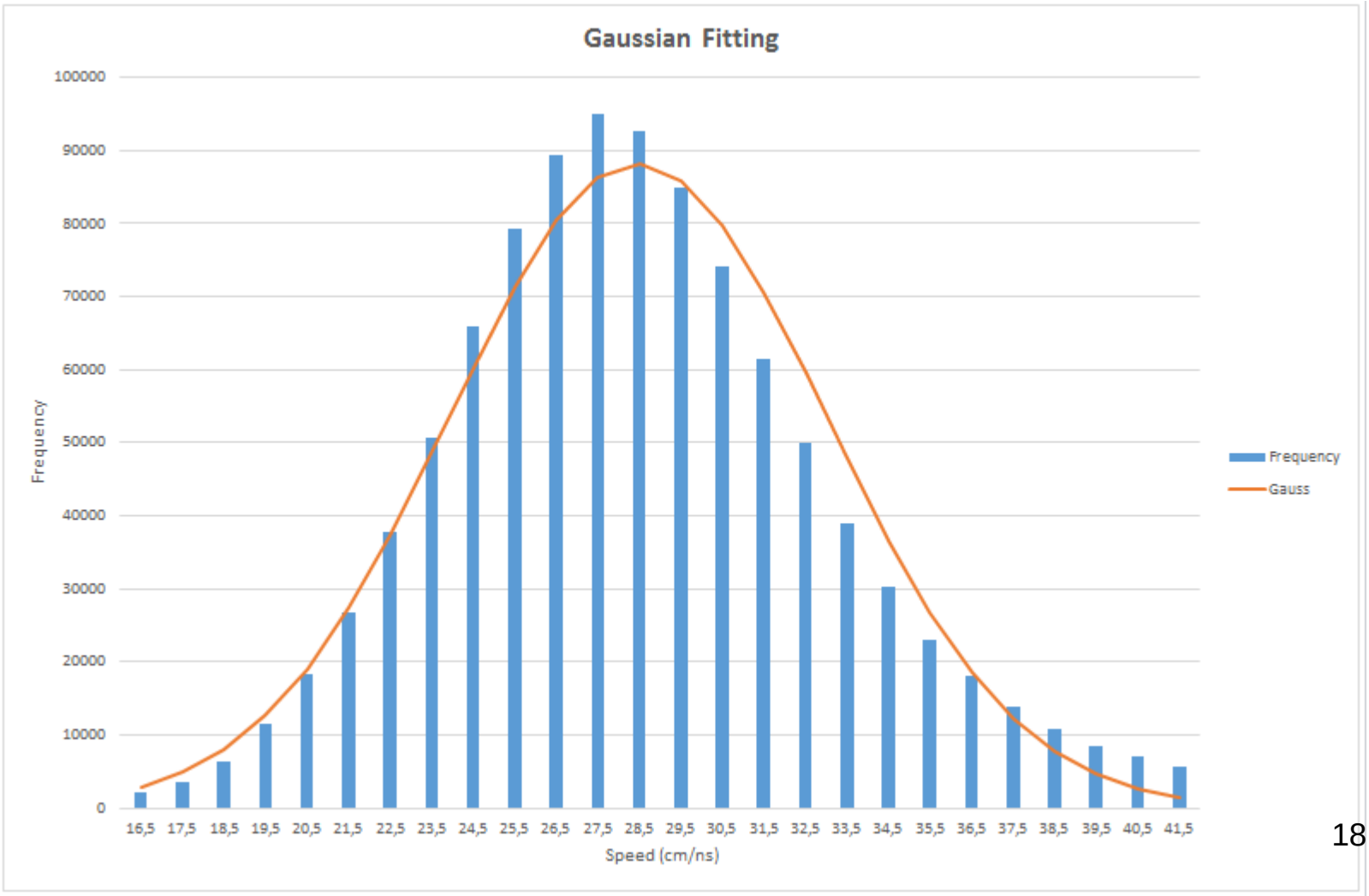
Data Analysis in Excel: CERN-02

A5 | 3.700012

	A	B	C	D	E	F	G	H	I	J
1	TimeOfFlight	TrackLength	Velocità	15,99<=vel<=42	*Classe*	Media Classi	*Frequency*	Media	Dev Stand	Gauss
2	19	111.747665	5.881456		15		6879	28.46127	4.547805	
3	4.850006	93.322014	19.24163	19.24162857	16		1554			
4	3.674988	97.727631	26.59264	26.59263949	17	16.5	2038			2776.858
5	3.700012	125.765083	33.99045	33.99045273	18	17.5	3535			4833.024
6	2.750031	88.971748	32.353	32.3529982	19	18.5	6405			8014.68
7	2.850037	110.429657	38.74675	38.74674504	20	19.5	11403			12663.55
8	3.049988	92.550102	30.34442	30.34441513	21	20.5	18398			19064.54
9	3.650024	91.803947	25.1516	25.15160092	22	21.5	26769			27346.33
10	4.149963	98.153633	23.65169	23.6516887	23	22.5	37835			37374.36
11	3.649994	89.622383	24.55412	24.5541179	24	23.5	50764			48668.77
12	3.299988	97.750191	29.62138	29.62137771	25	24.5	66001			60384.96
13	4.049988	110.724167	27.33938	27.3393815	26	25.5	79233			71385.34
14	3.950012	90.30291	22.86143	22.86142675	27	26.5	89437			80406.51
15	4.449982	105.231491	23.64762	23.64762172	28	27.5	94943			86292.93
16	3.350037	101.575829	30.32081	30.3208081	29	28.5	92562			88239.11
17	3.149994	98.771179	31.35599	31.35598957	30	29.5	85000			85970.39
18	4.049988	114.867729	28.36249	28.36248626	31	30.5	74219			79806.55
19	2.700012	93.346298	34.57255	34.57254931	32	31.5	61379			70587.86
20	3.200012	100.967857	31.55234	31.55233699	33	32.5	50057			59487.18



The fitting in Excel: about 1 million events



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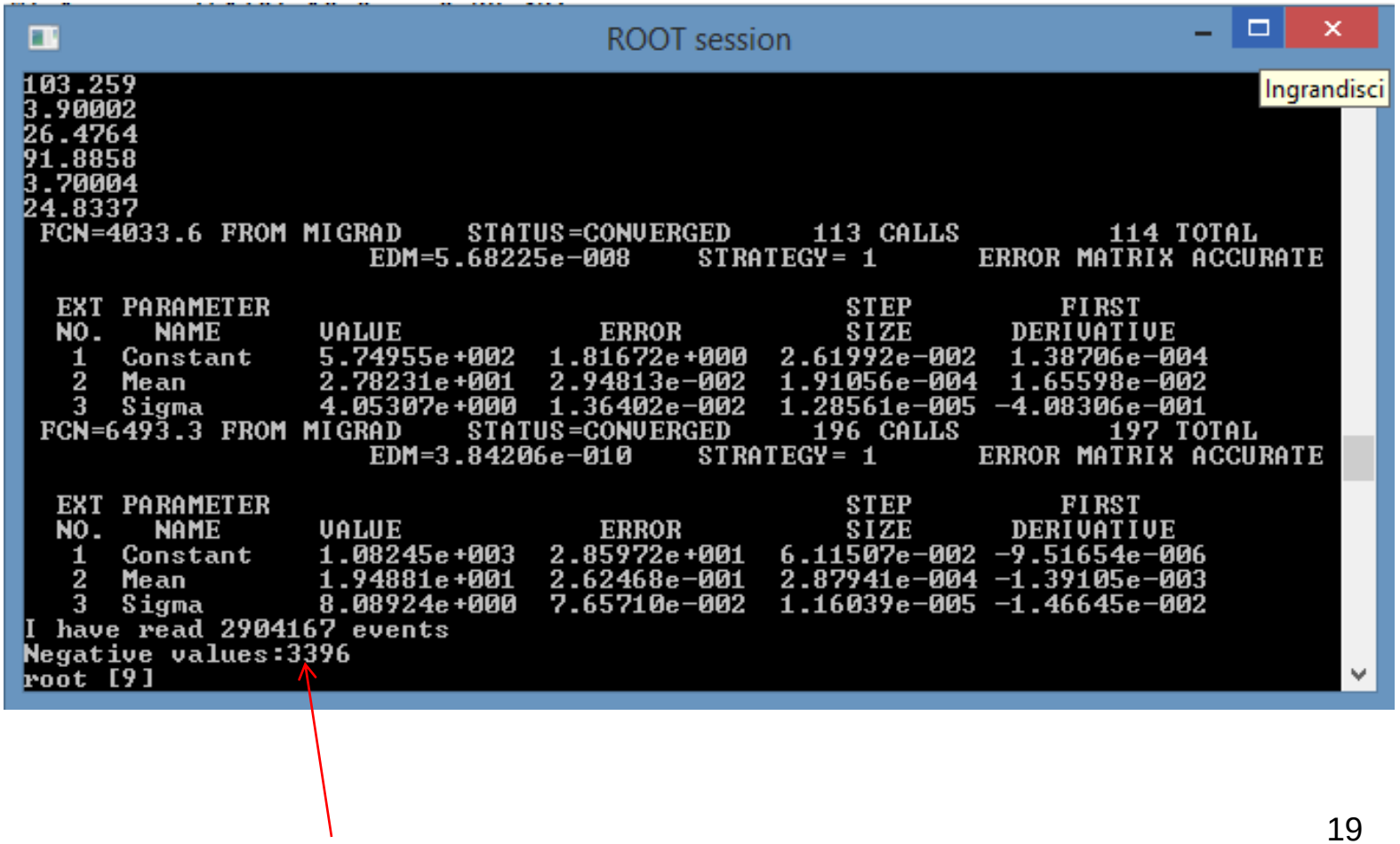
Counting Negative values of the speed: CERN02



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CONCLUSIONS

- The position of the centre of the peak in the distribution in velocity of muons is a value very close to the speed of light (we found about 29 cm/ns);
- Choosing a cut with ChiSquare <3, the fitting with a gaussian function slightly improves;
- Inside the data we found negative values of the velocity due to electrons produced as decay products of cosmic muons stopped in the ground;
- Probably the best fit for the distribution of the speeds is a double fitting with two gaussian functions.

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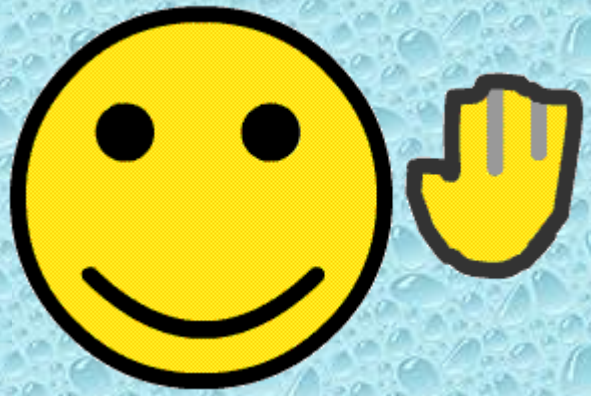
THANK YOU FOR YOUR ATTENTION!



Teachers involved in EEE Project:

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Francesco Cirrottola
Domenico Ricchiuti

Student Speakers

Maria Nicassio
Domenico Rinaldi

Classes

III A III B III C IIIASA
IV A IV B IV C IV ASA IV BSA
VB VC VD VE