Update on the Analysis of GSI1 ^{16}O (200 MeV on C_2H_4)

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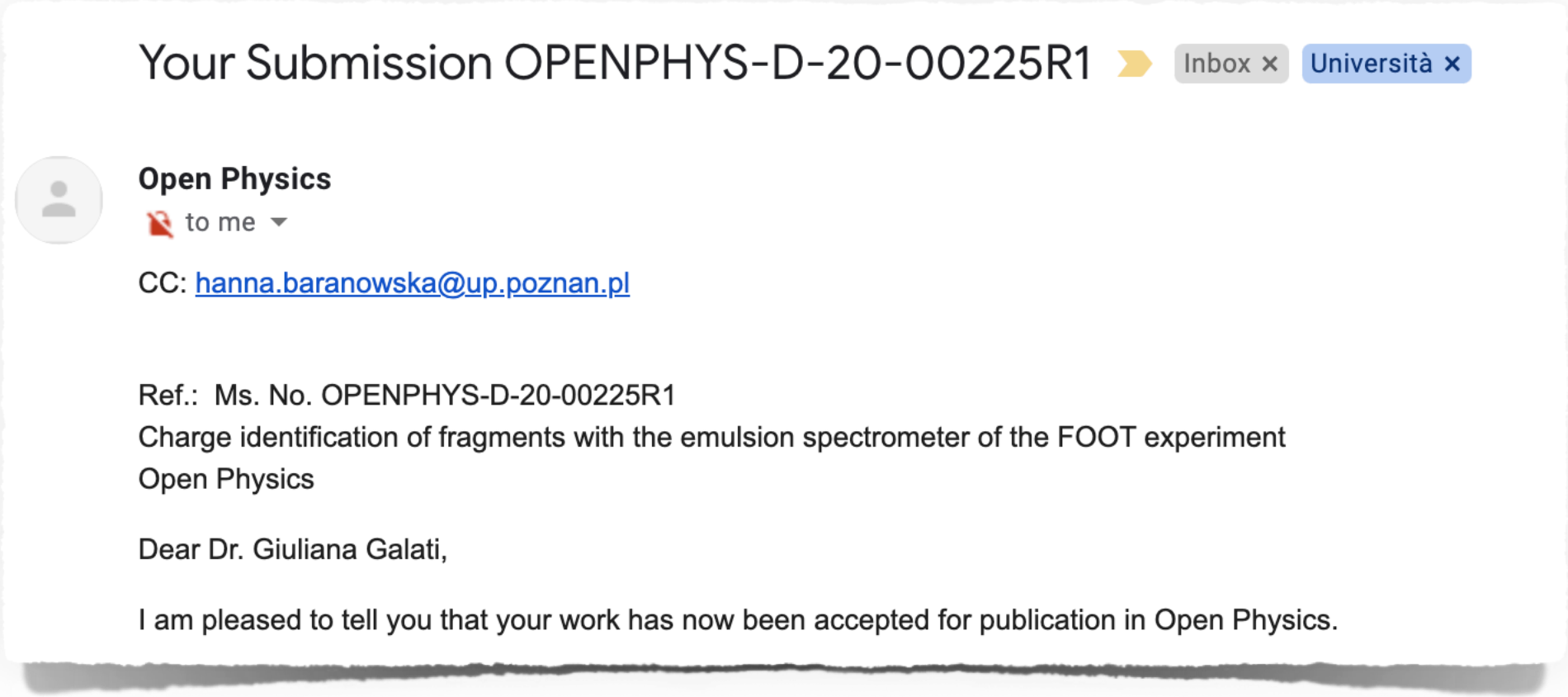
Physics Meeting, ZOOM, 05/05/2021

Outline

- Status of the paper submitted on OPEN PHYSICS
- Status of the analysis
  - Scanning Progresses
  - GSI1 Charge measurement and comparison with GSI2

Paper on OPEN PHYSICS

- The paper has been accepted for publication!
- We are proceeding with fee payment



Your Submission OPENPHYS-D-20-00225R1 Inbox × Università ×

Open Physics
to me

CC: hanna.baranowska@up.poznan.pl

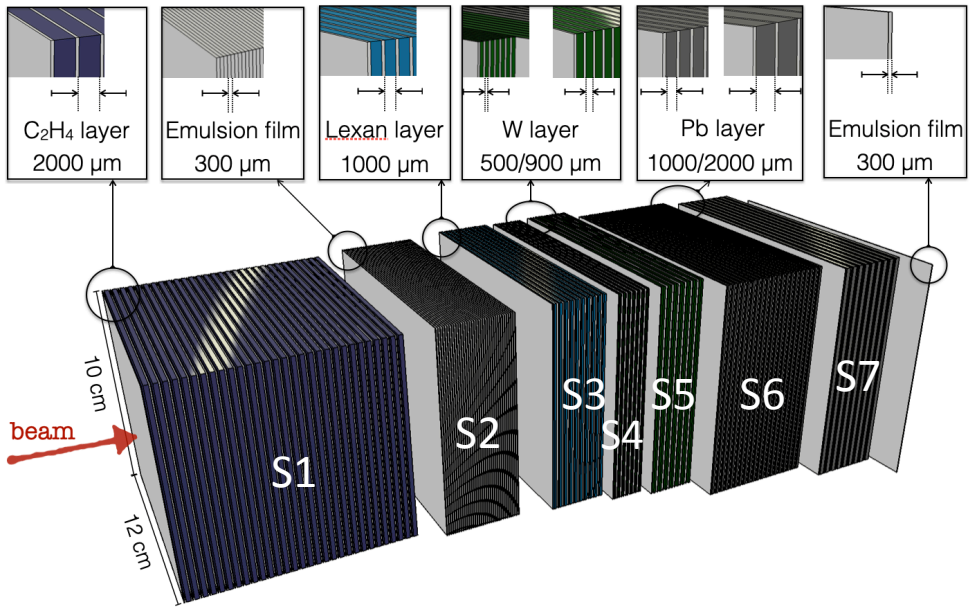
Ref.: Ms. No. OPENPHYS-D-20-00225R1
Charge identification of fragments with the emulsion spectrometer of the FOOT experiment
Open Physics

Dear Dr. Giuliana Galati,

I am pleased to tell you that your work has now been accepted for publication in Open Physics.

Scanning Progress

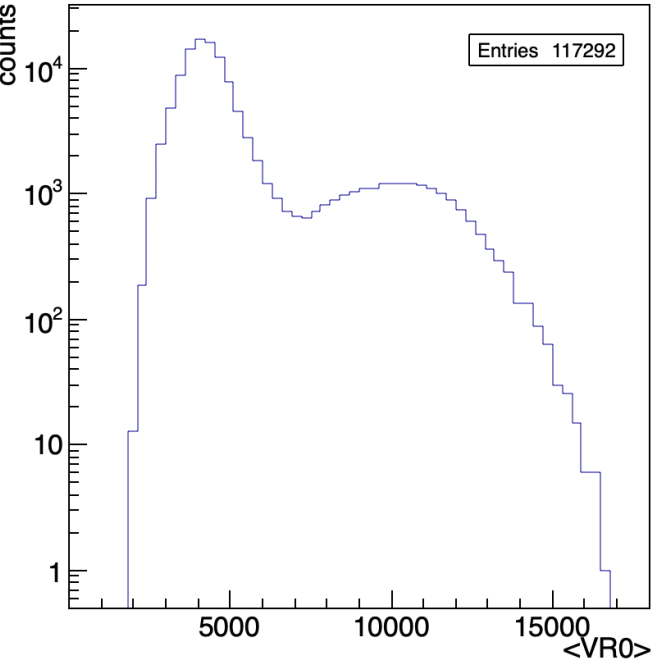
TARGET \ BEAM	2019 Oxygen 200 MeV/n	2019 Oxygen 400 MeV/n	2020 Carbon 700MeV/n
Carbon	GSI1	GSI3	GSI5
Polyethylene	GSI2	GSI4	GSI6

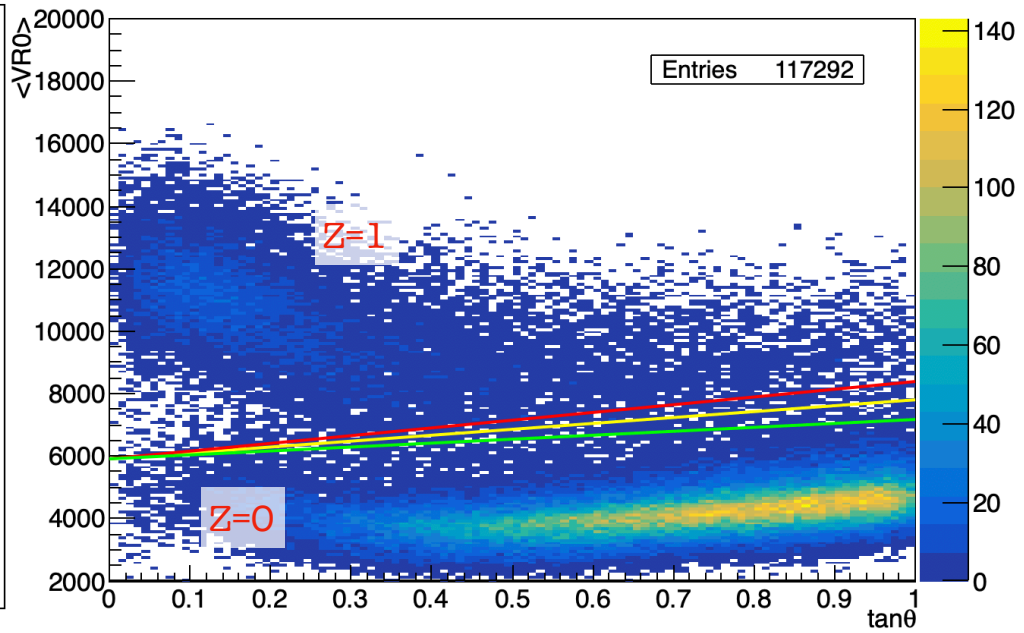


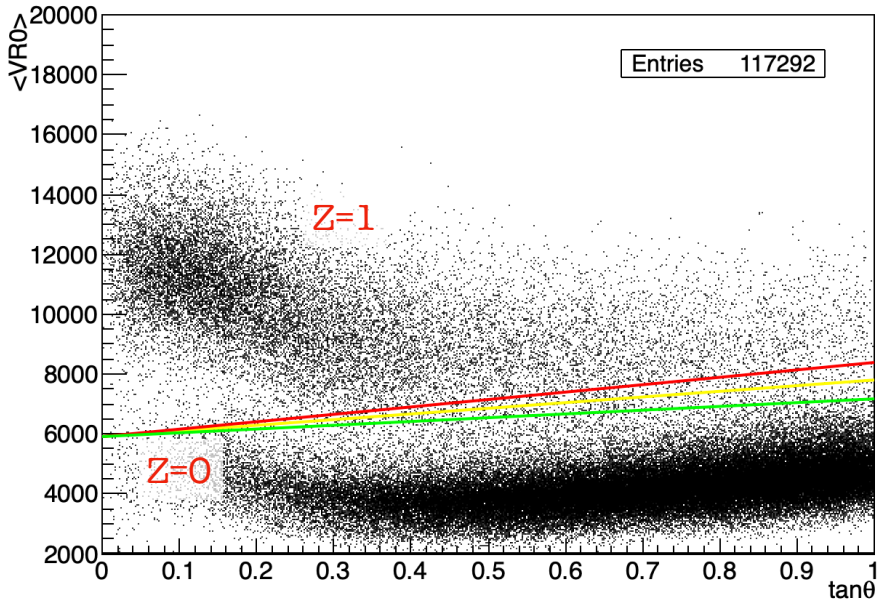
- 2019 (GSI1, GSI2, GSI3, GSI4):
  - scanning: 100%
  - alignment:
    GSI1: 100%
    GSI2: 100%
    GSI3: 47%
    GSI4: 34%
  - tracking:
    GSI2: S1+S2 completed, S3 (=S3+S4+S5+S6+S7) started
    GSI1: S1 quality checks ongoing
    S2 completed
- 2020 (GSI5, GSI6):
  - scanning: 328/328 (100%)

GSI1 Charge Measurement

Cosmic Rays and High Energy Z=1

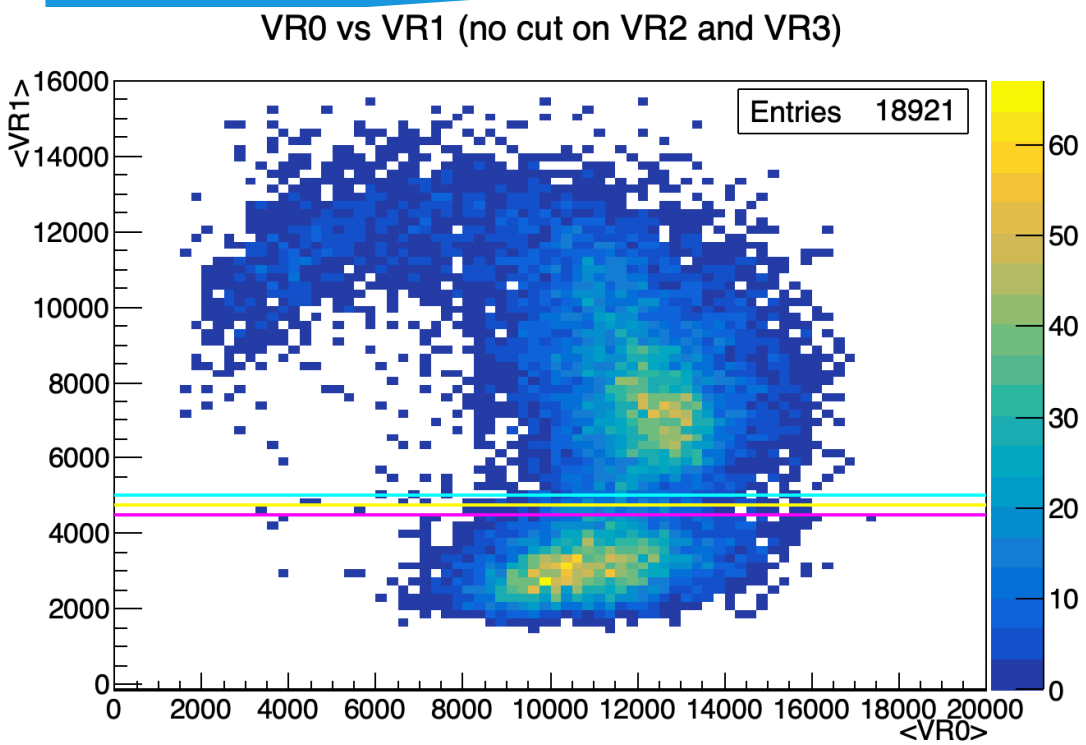


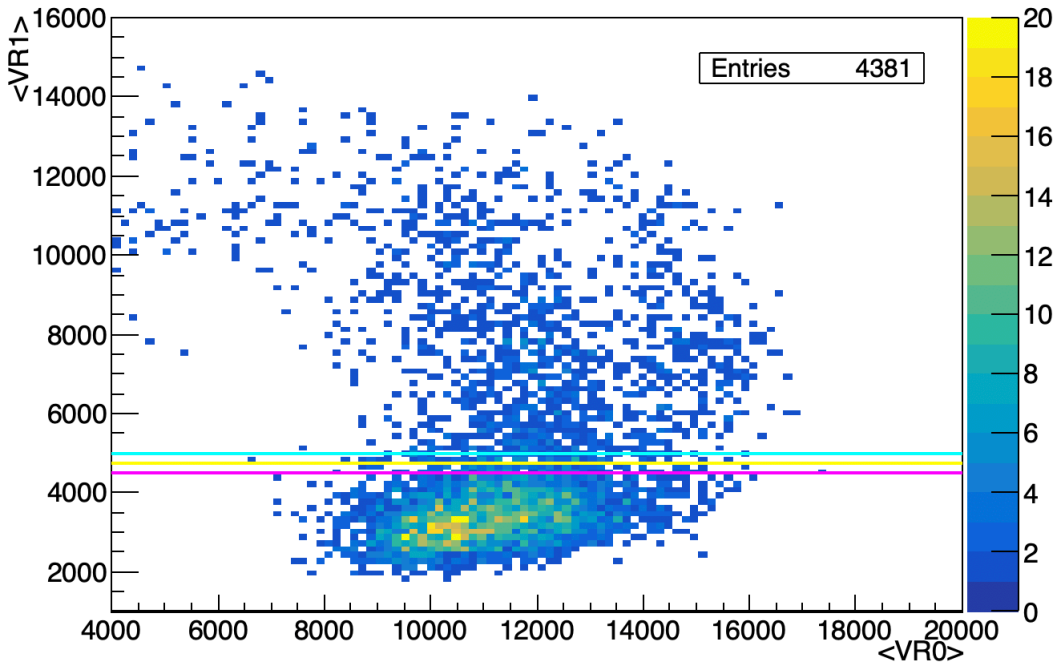




- **Cosmic Rays:**
  - **line0a:** ⟨**VR0**⟩ <1285.71*tanθ+5900 & ⟨VR0⟩!=0&nseg1<2&nseg2<0&nseg3<0
  - **line0b:** ⟨VR0⟩< 1892.86*tanθ+5900 & ⟨VR0⟩!=0&nseg1<2&nseg2<0&nseg3<0
  - **line0c:** ⟨VR0⟩< 2500*tanθ+5900 & ⟨VR0⟩!=0&nseg1<2&nseg2<0&nseg3<0
- **High energy Z=1**: ⟨VR0⟩≥line0* &&nseg1<2&&nseg2<2&&nseg3<2

Z=1 Low energy





- **Low energy Z=1:**
  - line1a: ⟨VR0⟩≥0&&0<⟨VR1⟩≤ 4500&&nseg2<2&&nseg3<2
  - line1b: ⟨VR0⟩≥0&&0<⟨VR1⟩≤ 4750&&nseg2<2&&nseg3<2
  - line1c: ⟨VR0⟩≥0&&0<⟨VR1⟩≤ 5000&&nseg2<2&&nseg3<2
- **High energy Z=2**: ⟨VR1⟩≥line1*&&nseg2<2&&nseg3<2

Error Evaluation for Sharp Cuts

line0a / line1a

Z	# trks	% on total
Cosmic	96462	79.3%
1	23594	19.4%
2	1617	1.3%
Tot	121673	

line0c / line1a

Z	# trks	% on total
Cosmic	97752	80.3%
1	22304	18.3%
2	1617	1.3%
Tot	121673	

line0a / line1c

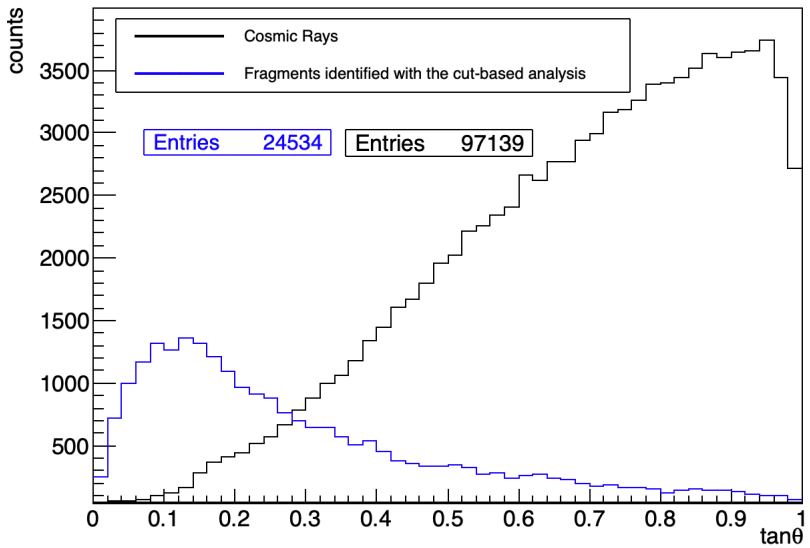
Z	# trks	% on total
Cosmic	96462	79.3%
1	23835	19.6%
2	1376	1.1%
Tot	121673	

line0c / line1c

Z	# trks	% on total
Cosmic	97752	80.3%
1	22545	18.5%
2	1376	1.1%
Tot	121673	

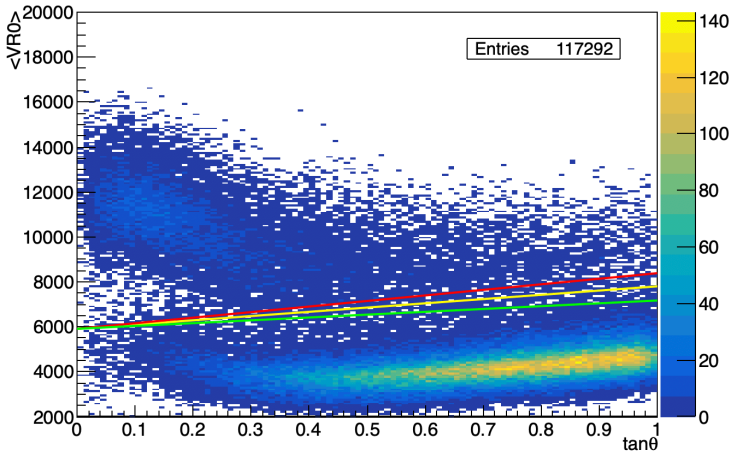
Results

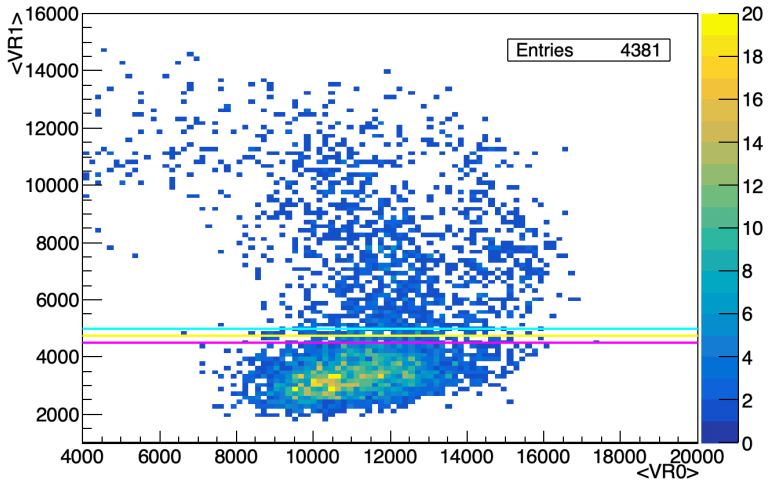
	MEAN line0b / line1b		ERROR (Max-Min)/2	
Z	# trks	% on total	# trks	% on total
Cosmic Rays	97139	80%	645	1%
Z=1	23048	19%	766	3%
Z=2	1486	1%	121	8%
TOT	121673			



Comparison between GSI2 and GSI1

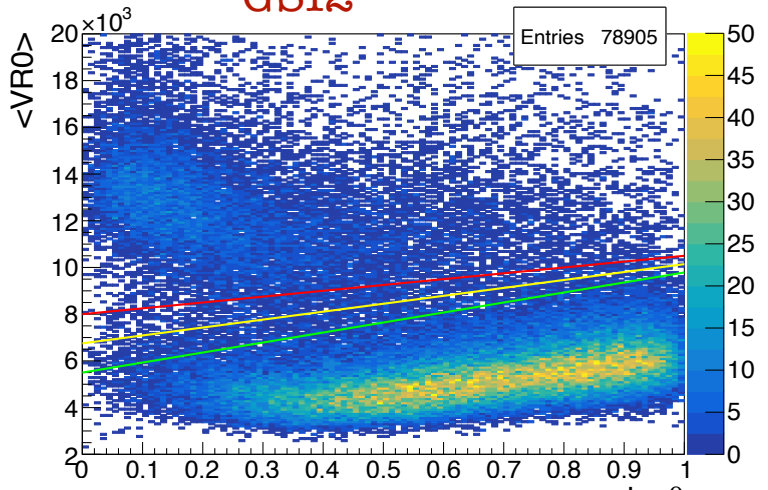
GSI1

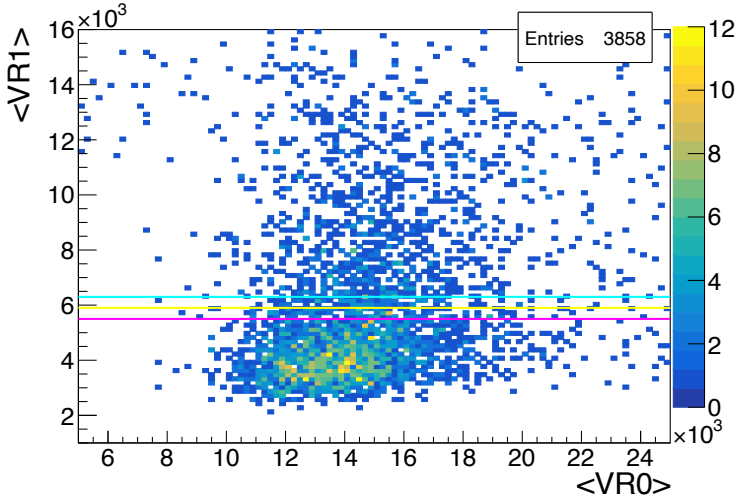




Z	#trks	Result	Systematic err
1	23048	94%	3.3%
2	1486	6%	8.1%

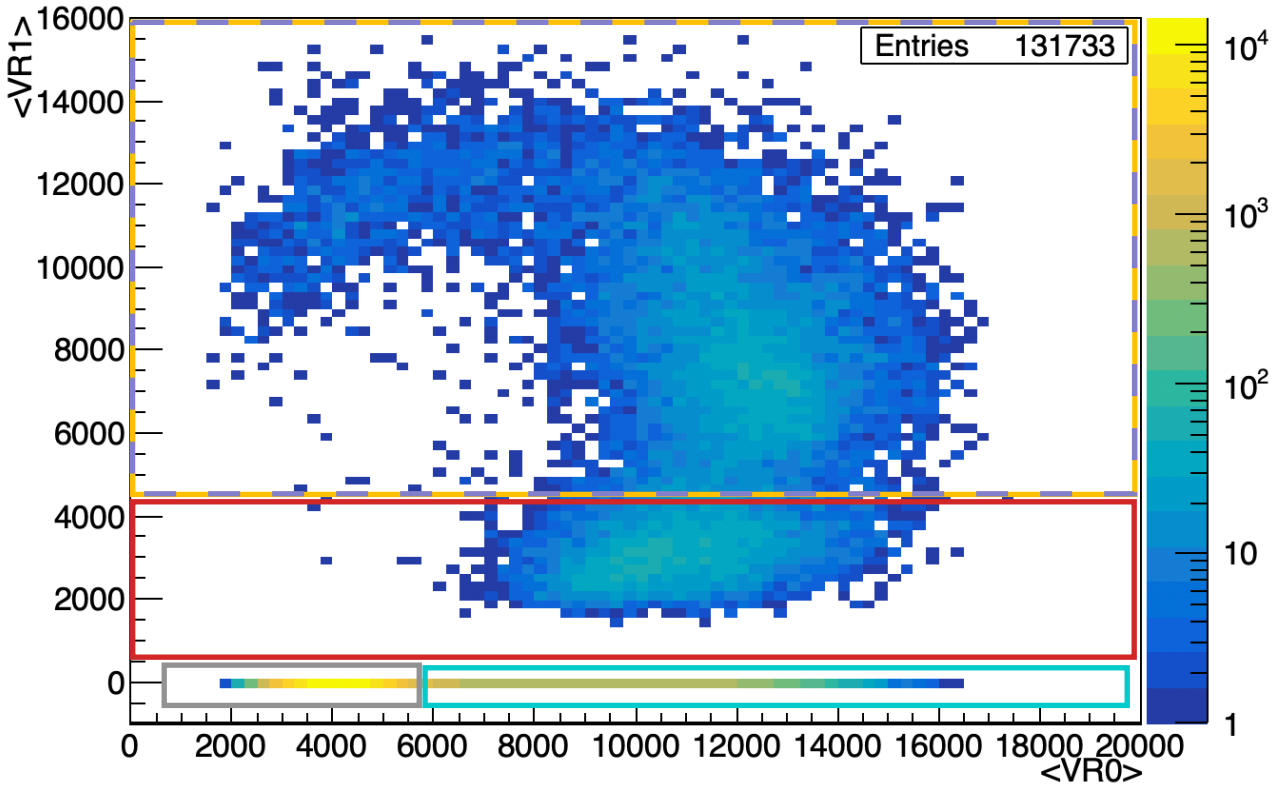
GSI2





Z	#trks	Result	Systematic err
1	21199	94%	7.8%
2	1438	6%	11.2%

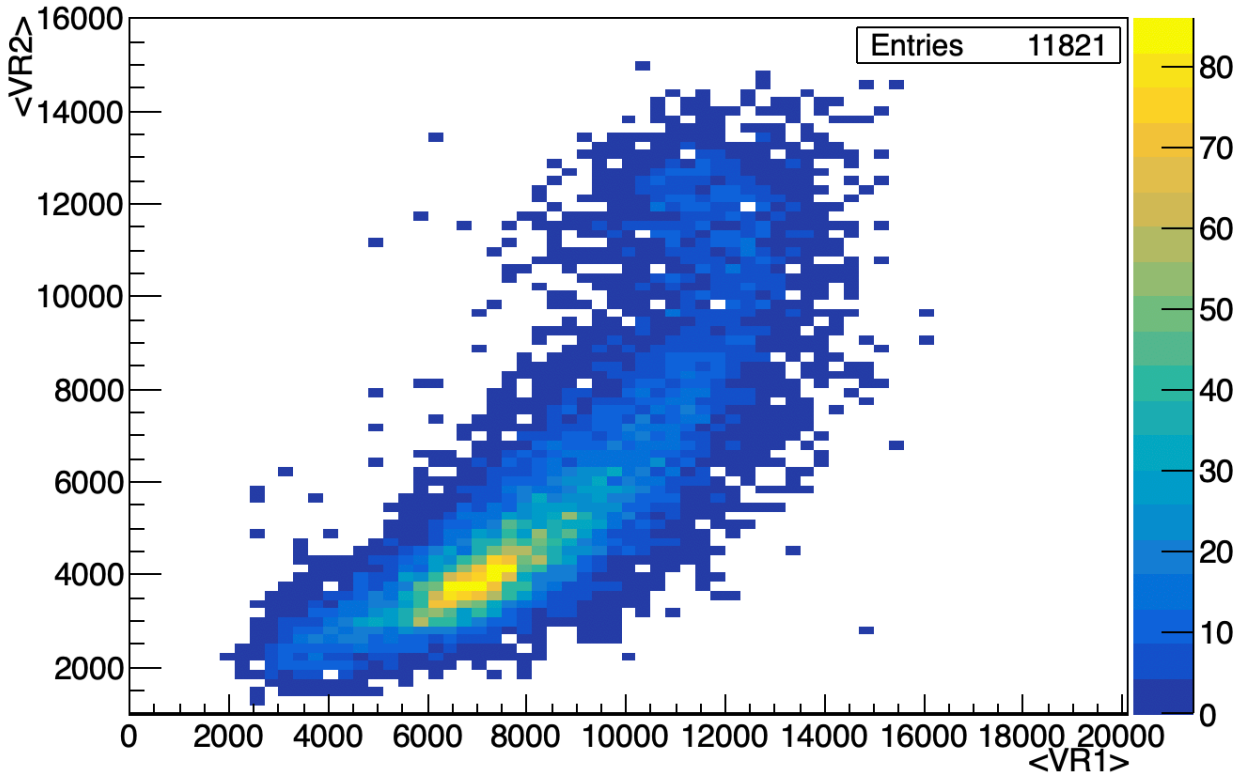
Summary Charge Measurement Z≤2

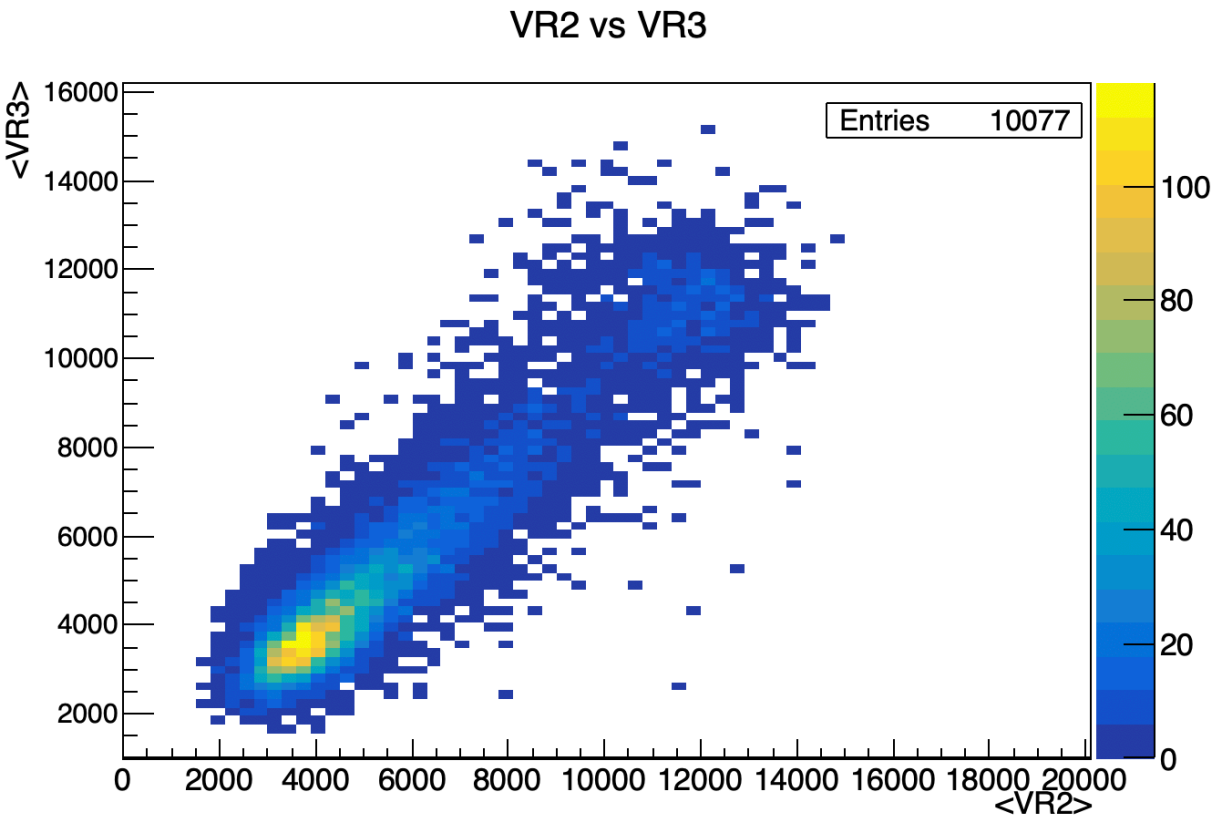


- **Z=0:** 0<⟨VR0⟩< 3392.86*tanθ+6750 & nseg1<2 & nseg2<2 & nseg3<2
- **High energy Z=1:** ⟨VR0⟩ ≥3392.86*tanθ+6750 & nseg1<2 & nseg2<2 & nseg3<2
- **Low energy Z=1:** ⟨VR0⟩≥0 & 0<⟨VR1⟩≤4750 & nseg2<2 & nseg3<2
- **High energy Z=2:** ⟨VR1⟩>4750 & nseg2<2 & nseg3<2

- **Z≥2: at least 3 VRx → Principal Components Analysis**

VR2 - VR3 Distributions





Principal Components Analysis (Pca)

Ref: https://root.cern.ch/doc/master/classTPrincipal.html

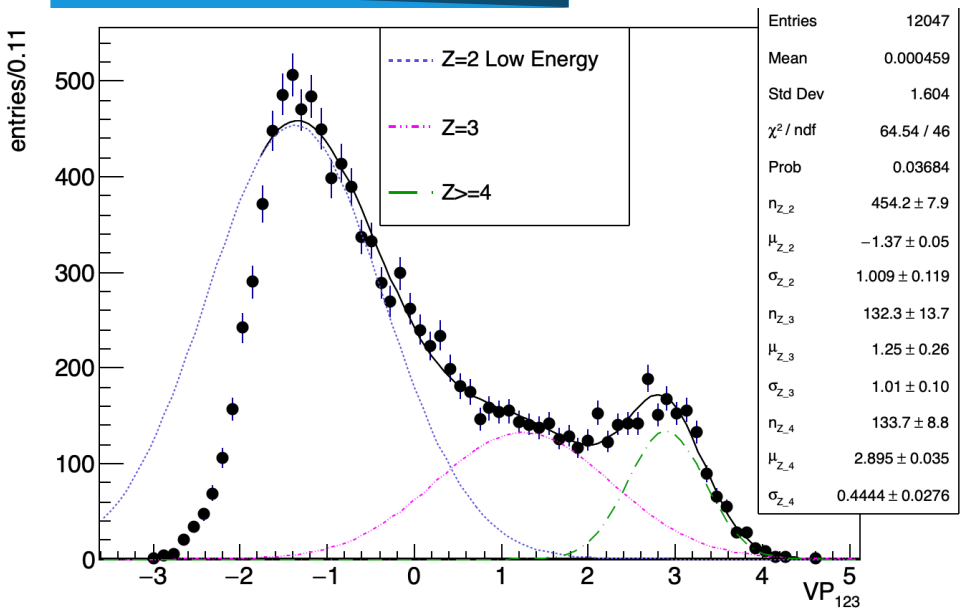
- Request: at least 3 ⟨VRx⟩
- Four different variables have been created:
  - VP_123 = a·⟨VR1⟩ + b·⟨VR2⟩ + c·⟨VR3⟩
  - VP_023 = d·⟨VR0⟩ + e·⟨VR2⟩ + f·⟨VR3⟩
  - VP_013= g·⟨VR0⟩ + h·⟨VR1⟩ + i·⟨VR3⟩
  - VP_012= l·⟨VR0⟩ + m·⟨VR1⟩ + n·⟨VR2⟩

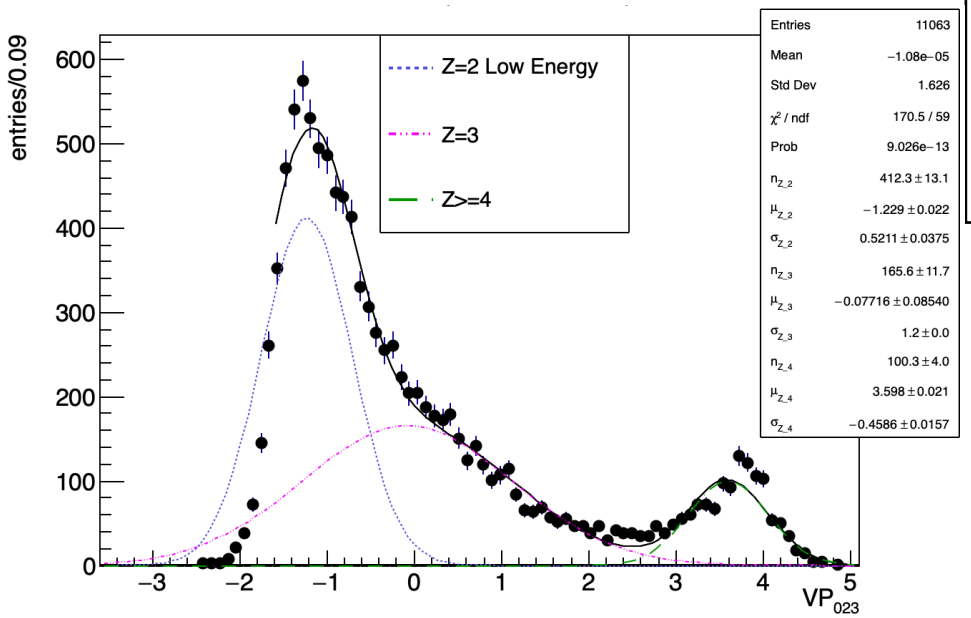
Given the value of VP_{xxx} we assign Z according to the probability provided by the three gaussian distributions (see next slide)

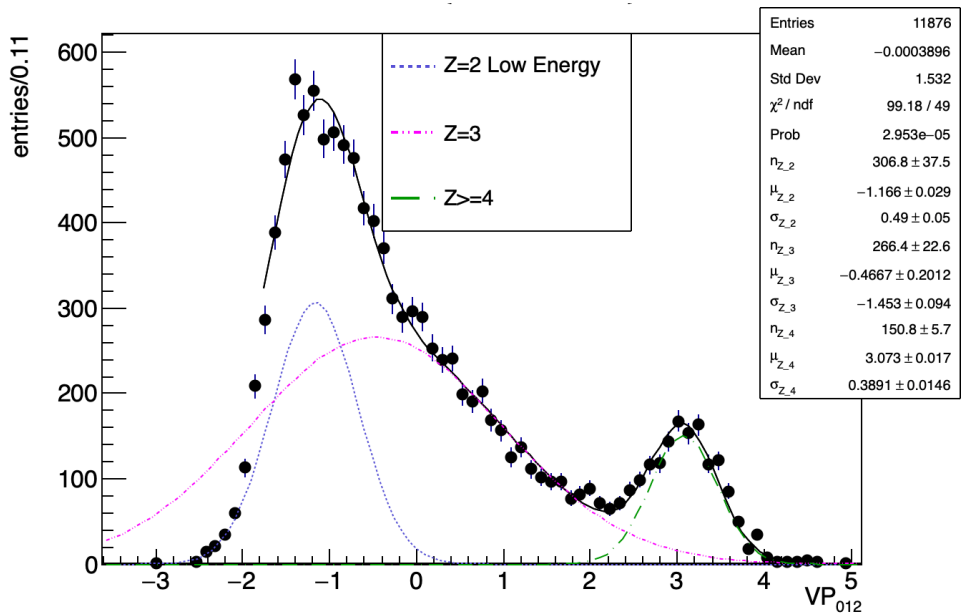
Assigned with PCA

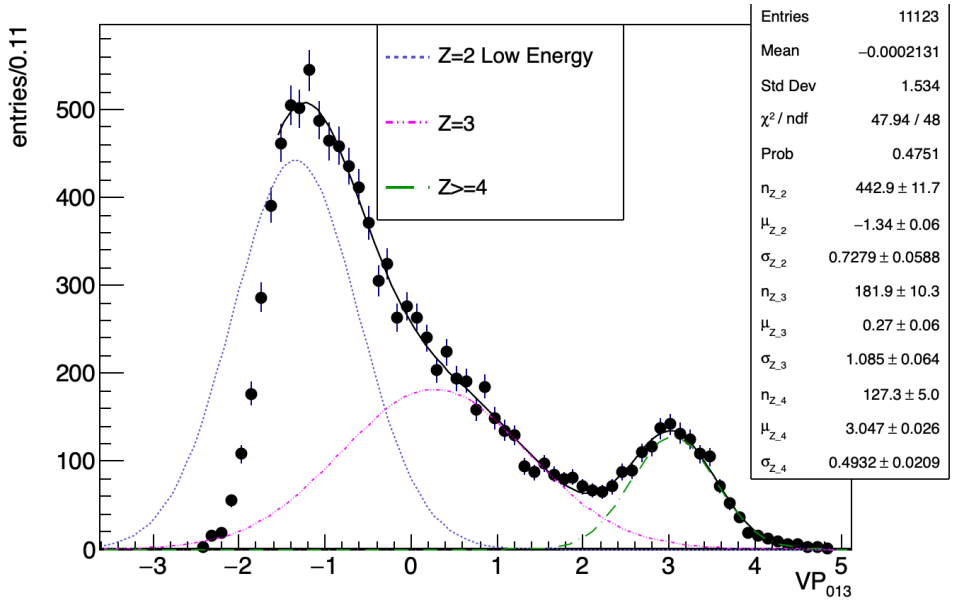
Z	#	%
VP_{123}	8772	88.4%
VP_{012}	840	8.5%
VP_{013}	182	1.8%
VP_{023}	134	1.3%

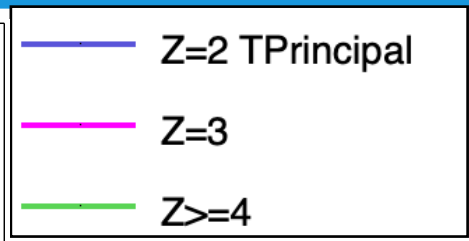
VP_xxx Fits


entries/0.11
Z=2 Low Energy
Z=3
Z>=4
VP123
Entries 12047
Mean 0.000459
Std Dev 1.604
χ² / ndf 64.54 / 46
Prob 0.03684
nZ_2 454.2 ± 7.9
μZ_2 −1.37 ± 0.05
σZ_2 1.009 ± 0.119
nZ_3 132.3 ± 13.7
μZ_3 1.25 ± 0.26
σZ_3 1.01 ± 0.10
nZ_4 133.7 ± 8.8
μZ_4 2.895 ± 0.035
σZ_4 0.4444 ± 0.0276

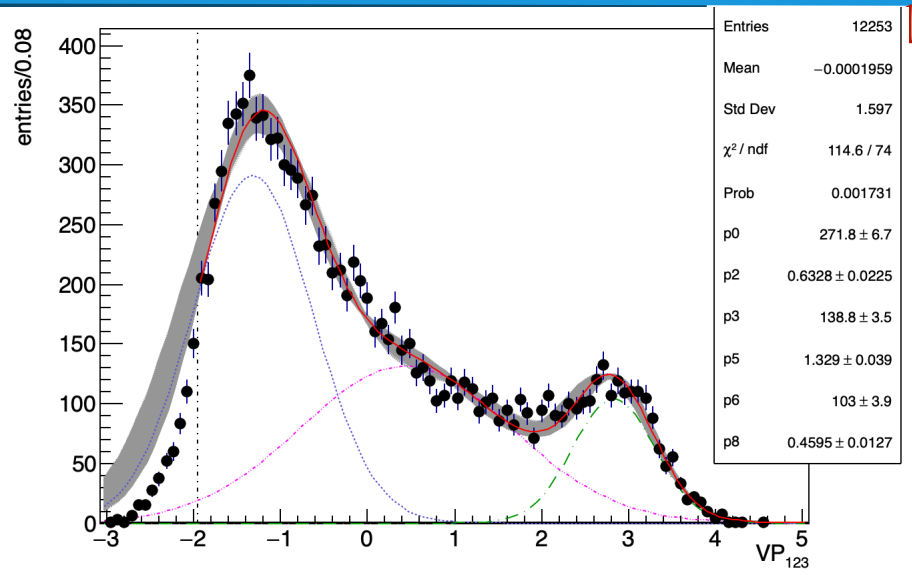

entries/0.09
Z=2 Low Energy
Z=3
Z>=4
VP023
Entries 11063
Mean −1.08e−05
Std Dev 1.626
χ² / ndf 170.5 / 59
Prob 9.026e−13
nZ_2 412.3 ± 13.1
μZ_2 −1.229 ± 0.022
σZ_2 0.5211 ± 0.0375
nZ_3 165.6 ± 11.7
μZ_3 −0.07716 ± 0.08540
σZ_3 1.2 ± 0.0
nZ_4 100.3 ± 4.0
μZ_4 3.598 ± 0.021
σZ_4 −0.4586 ± 0.0157


entries/0.11
Z=2 Low Energy
Z=3
Z>=4
VP012
Entries 11876
Mean −0.0003896
Std Dev 1.532
χ² / ndf 99.18 / 49
Prob 2.953e−05
nZ_2 306.8 ± 37.5
μZ_2 −1.166 ± 0.029
σZ_2 0.49 ± 0.05
nZ_3 266.4 ± 22.6
μZ_3 −0.4667 ± 0.2012
σZ_3 −1.453 ± 0.094
nZ_4 150.8 ± 5.7
μZ_4 3.073 ± 0.017
σZ_4 0.3891 ± 0.0146


entries/0.11
Z=2 Low Energy
Z=3
Z>=4
VP013
Entries 11123
Mean −0.0002131
Std Dev 1.534
χ² / ndf 47.94 / 48
Prob 0.4751
nZ_2 442.9 ± 11.7
μZ_2 −1.34 ± 0.06
σZ_2 0.7279 ± 0.0588
nZ_3 181.9 ± 10.3
μZ_3 0.27 ± 0.06
σZ_3 1.085 ± 0.064
nZ_4 127.3 ± 5.0
μZ_4 3.047 ± 0.026
σZ_4 0.4932 ± 0.0209


Z=2 TPrincipal
Z=3
Z>=4

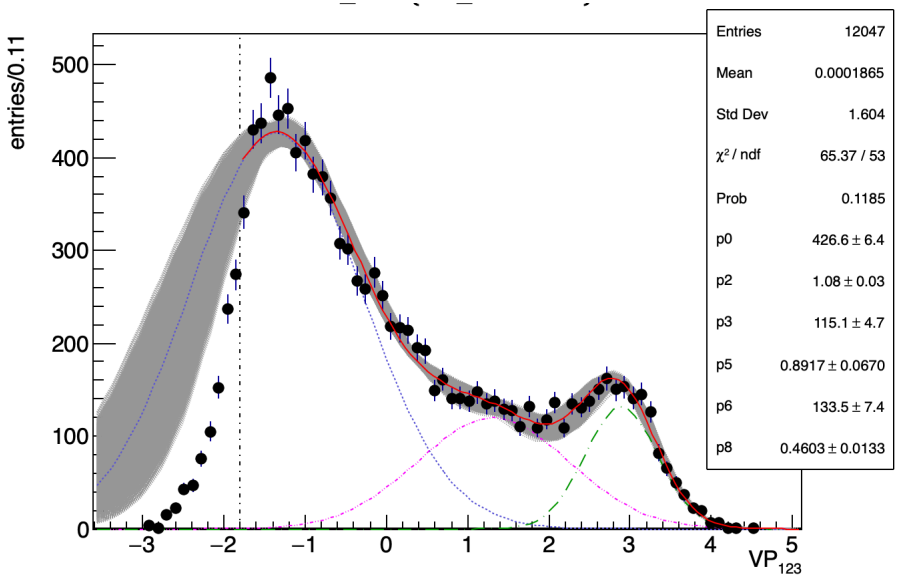
VP_{123} Fits - Error evaluation



1

N trials	13285

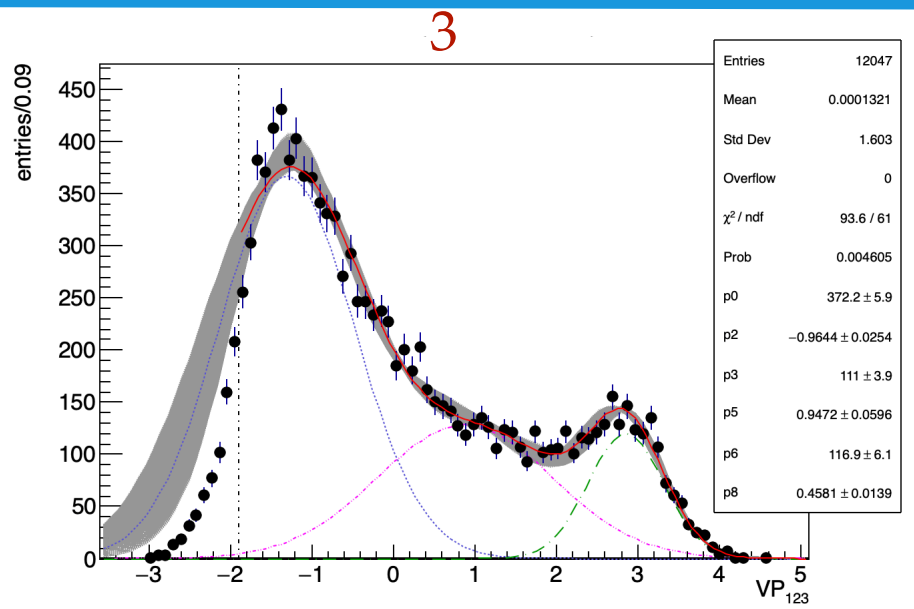
Z TPr	Mean	St. Dev
2	51.78%	5.85%
3	37.52%	5.90%
4	10.70%	0.49%



2

N trials	10230

Z TPr	Mean	St. Dev
2	72.25%	4.17%
3	17.98%	4.21%
4	9.77%	0.705%

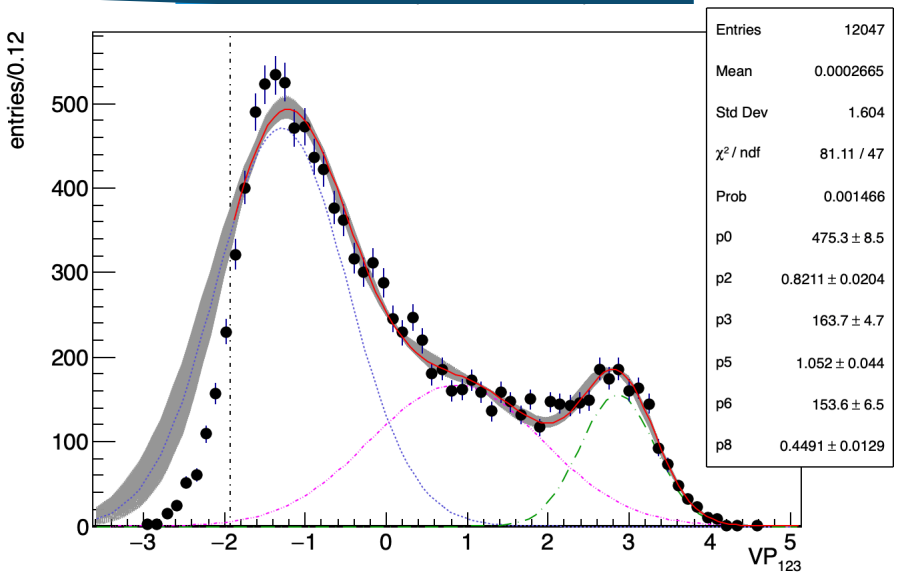


3

N trials	13162

Z TPr	Mean	St. Dev
2	63.46%	4.68%
3	26.19%	4.68%
4	10.35%	0.59%

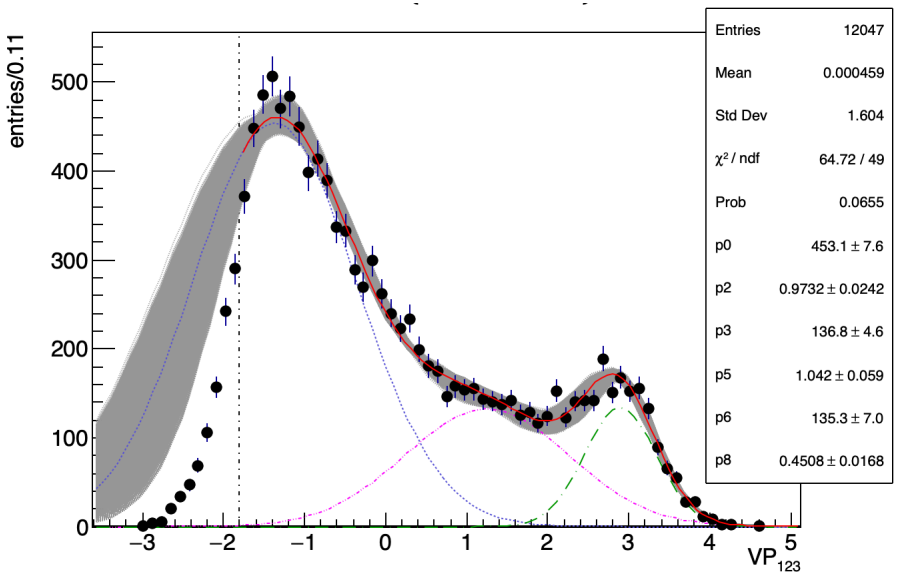
VP_{123} Fits - Error evaluation



4

N trials	34874

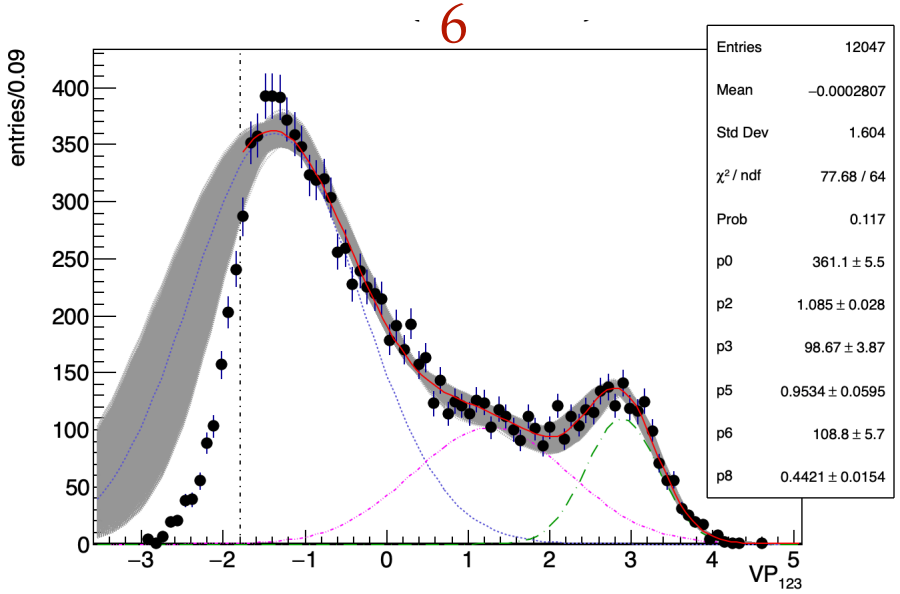
Z TPr	Mean	St. Dev
2	62.92%	3.25%
3	26.68%	3.16%
4	10.41%	0.39%



5

N trials	10453

Z TPr	Mean	St. Dev
2	70.23%	4.74%
3	20.45%	4.73%
4	9.33%	0.77%



6

N trials	10180

Z TPr	Mean	St. Dev
2	71.43%	4.39%
3	18.91%	4.44%
4	9.66%	0.73%

Fits - Gaus Par + Systematic ERROR

Tot trks VP_123	8772

Fit #	Z=2		Z=3		Z≥4	
	Mean	Dev.St	Mean	Dev.St	Mean	Dev.St
1	51.8%	5.9%	37.5%	5.9%	10.7%	0.49%
2	72.3%	4.2%	18.0%	4.2%	9.8%	0.71%
3	63.5%	4.7%	26.2%	4.7%	10.4%	0.59%
4	62.9%	3.3%	26.7%	3.2%	10.4%	0.39%
5	70.2%	4.7%	20.4%	4.7%	9.3%	0.77%
6	71.4%	4.4%	18.9%	4.4%	9.7%	0.73%

RESULT:

	Z=2			Z=3			Z≥4			TOT
	Mean	Syst	Gaus Par	Mean	Syst	Gaus Par	Mean	Syst	Gaus Par	
# trks	5675	898	154	2214	857	154	872	60	20	8762
%	64.7%	10.2%	1.76%	25.2%	9.8%	1.75%	9.9%	0.7%	0.228%	1

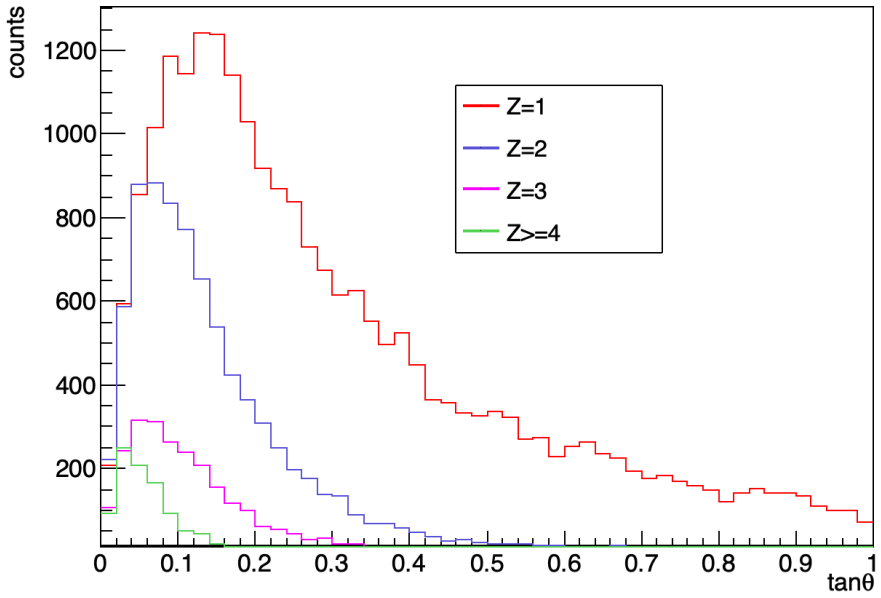
weighted average

(Max-Min)/2

Dev. st. on weighted average

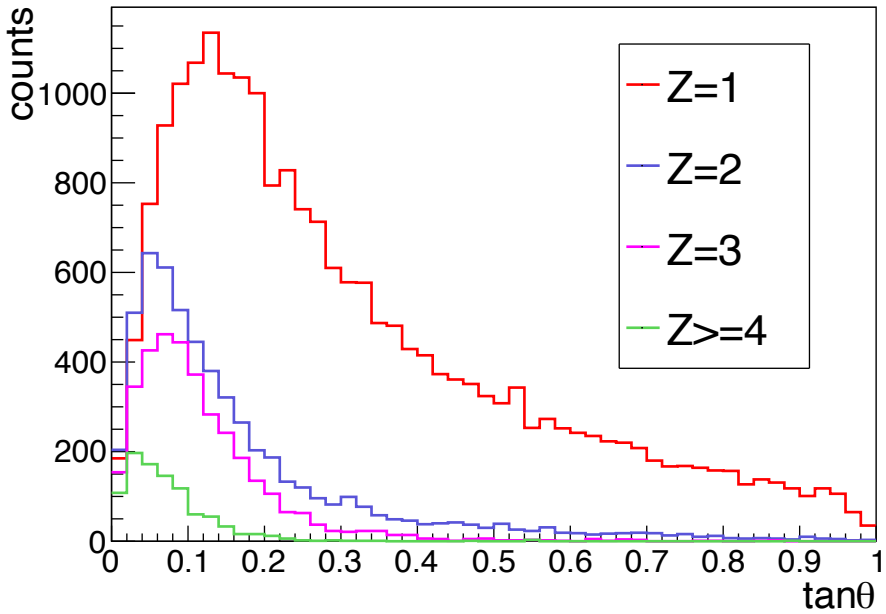
Distributions with Z Flag - Comparison with GSI2

GSI1



Z	Mean	RMS
1	0.31	0.23
2	0.15	0.13
3	0.12	0.10
≥4	0.06	0.04

GSI2



Z	Mean	RMS
1	0.32	0.23
2	0.17	0.17
3	0.11	0.09
≥4	0.08	0.07

GSI1 Results and comparison with GSI2

GSI1

Z	% on total charged			
	Result	Systematic err	Gauss Param err	Statistic err
1	67%	2%	/	1%
2	22%	3%	0%	1%
3	8%	2%	0%	2%
≥4	3%	0%	0%	3%

GSI2

Z	% on total charged			
	Result	Systematic err	Gauss Param err	Statistic err
1	70%	5%	/	1%
2	16%	2%	0%	1%
3	10%	2%	0%	2%
≥4	4%	1%	0%	3%

Conclusions

- The paper "Charge identification of fragments with the emulsion spectrometer of the FOOT experiment" has been accepted for publication on Open Physics
- First results for GSI1 charge analysis are compatible with GSI2 results

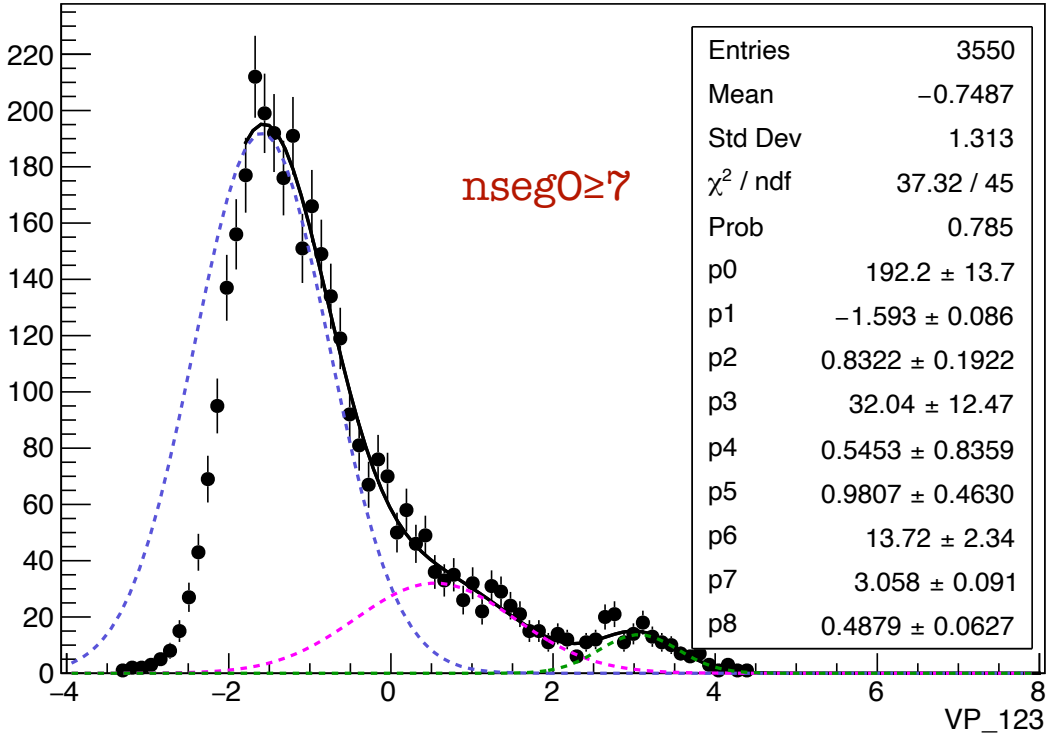
THANK YOU!

Back up slides

VP_xxx Fits

Our fit model is characterized by:

- 3 gaussians
- Z=2 gaussian is partially erased
- Mean of Z=2 gaussian > Mean of Z=3 gaussian > Mean of Z≥4 gaussian
- Heigh of Z=2 gaussian > Heigh of Z=2 gaussian ≥ Heigh of Z≥4 gaussian



Model was qualitatively inferred by the analysis with a "cleaner" sample (requirement of 7 nseg0)

(see Adele Lauria's presentation on 4/3/2020)

Error Evaluation PCA

- Systematic error: due to the chosen fit (fits can differ because of different binning, lower limit…)
- Gauss parameters error: due to the errors of fit parameters
  - ➡ Each gaussian has its "mean" value and its error
  - ➡ Random generation of 3 new gaussian means, normally distributed around the mean within 1 sigma
  - ➡ 3-gaussian fit fixing the 3 mean parameters
  - ➡ Evaluation of fit probability to describe data. If larger than 1% the fit is considered good
  - ➡ Charge assignment and evaluation of relative fractions for each Z ($Z \geq 2$)
  - ➡ Mean and Standard Deviation evaluated on 10000 good fits

We consider only the error on VP_123 (90% contribution)

Charge Measured (DATA)

Z	cut sharp		VP_{123}			other VP	TOT	% on total assigned				% on total charged			
	#trks	err max	#trks	err sys	err stat	#trks		Result	Err syst	Err par gaus	sample err	Result	Err sys	Err par gaus	sample err
Cosmic Rays	97139	645					97139	73.8%	0.5%	/	0.3%				
1	23048	766					23048	17.5%	0.6%	/	0.7%	66.9%	2.2%	/	0.7%
2	1486	121	5675	898	0.0	362	7523	5.7%	0.8%	0.00%	1.2%	21.8%	3.0%	0.00%	1.2%
3			2214	857	0.0	663	2877	2.2%	0.7%	0.00%	1.9%	8.4%	2.5%	0.00%	1.9%
≥4			872	60	0.0	131	1003	0.8%	0.0%	0.000%	3.2%	2.9%	0.2%	0.00%	3.2%
Total w/o	24534		8762			1156	34452								
Not assign							528								
Total assign	121673		8762	1815	0	1156	131591								
Total trks							132119								