Update on Charge Identification in Nuclear Emulsions (GSI 2019 Data Taking)

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04/05/2022, PHYSICS FOOT MEETING - ZOOM

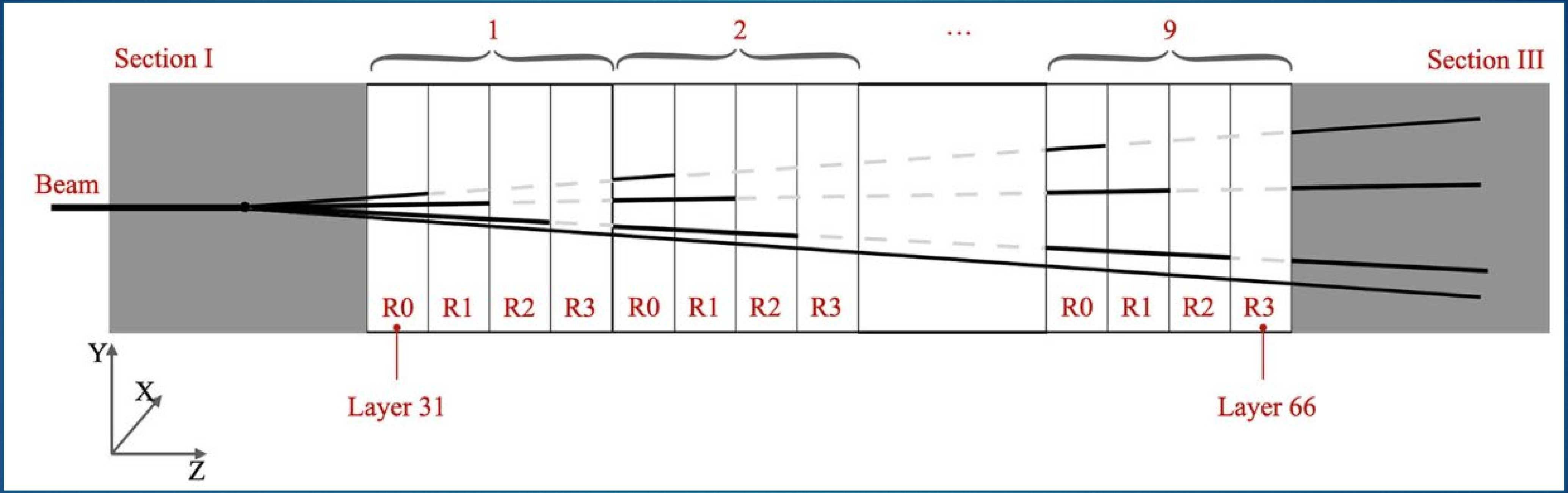
Outline

- Brief review of Section 2 for the charge identification analysis;
- Analysis of GSI1 and GSI2 data (reproduction of previous results + improvements);
- Status of the on-going charge ID analysis for GSI3 data;
- Future Steps.

TARGET \ BEAM	Oxygen 200 MeV/n	Oxygen 400 MeV/n
Carbon	GSI 1	GSI 3
Polyethylene	GSI 2	GSI 4

Charge Identification in Section 2 (S2)

- Section 2 is divided into nine cells, each one consisting of four emulsion films that underwent different thermal treatments.



Ref: [“Charge identification of fragments with the emulsion spectrometer of the FOOT experiment”]

- **R0**: Not thermally treated
- **R1**: 24 h at T1=28°C and RH = 95%
- **R2**: 24 h at T2=34°C and RH = 95%
- **R3**: 24 h at T3=36°C and RH = 95%

Charge Identification in Section 2 (S2)

- The thermal treatments arise totally or partially the track's segments, depending on its ionization.
- The charge ID analysis employs the following variables:
  - $\tan(\theta)$ -> the tangent of the inclination of the most upstream fitted track segment w.r.t. the Z axis;

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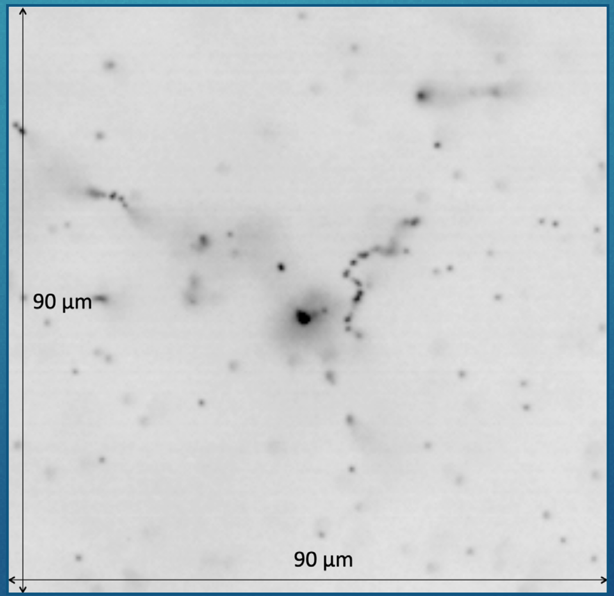

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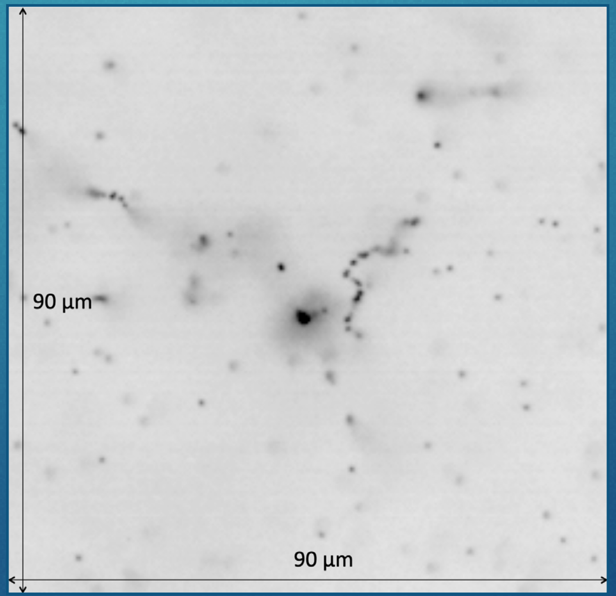

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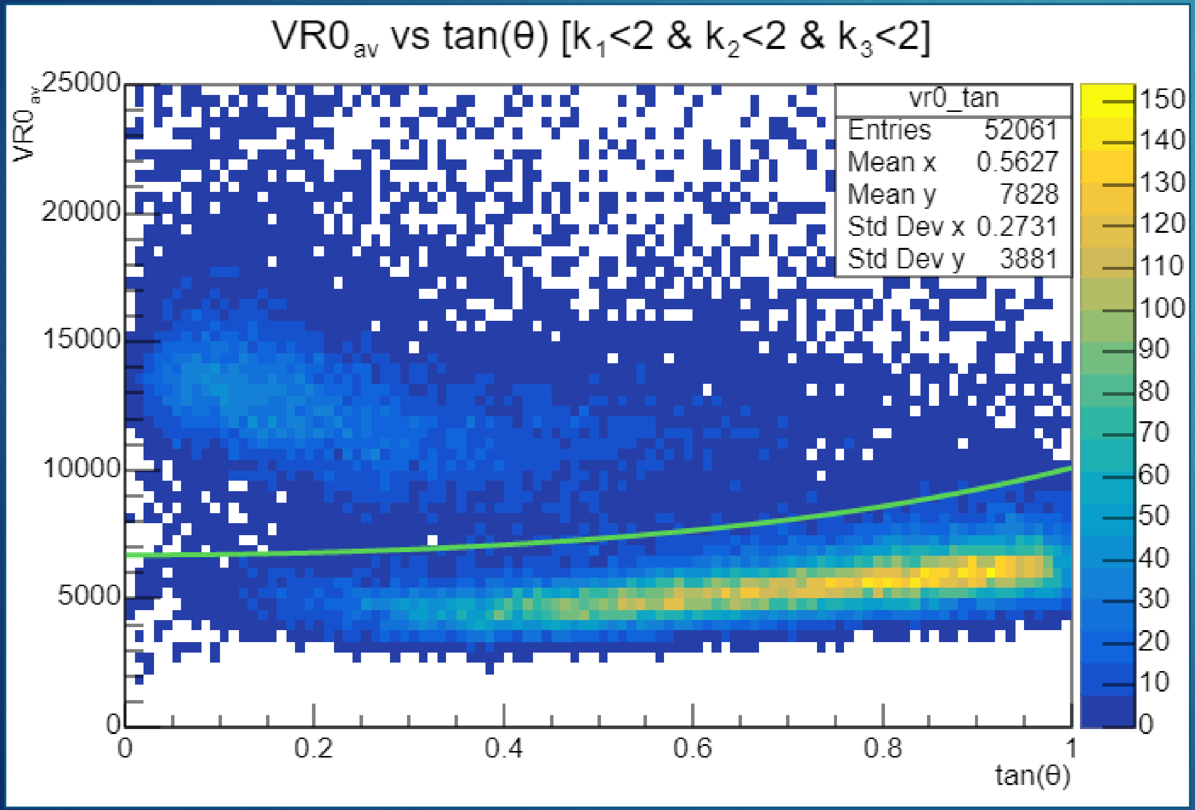
Particle's charge is identified either by **sharp cuts** on $VR0_{av}, \tan(\theta)$ and $VR1_{av}$ (Z<=2) or by combining the information of the different volume variables with the **Principal Component Analysis** (PCA)

GSI2: Identification of Cosmic Rays

- Cut $k_0 \geq 4$ for all plots;
- Optimized alignment between emulsion plates;
- Improved tracking procedure (as discussed in the FOOT Physics Meeting in February);



- Cut improved by the use of a non linear function;

The combination of $VR0_{av}$ and $\tan(\theta)$ makes it possible to distinguish the cosmic rays from the fragments.

«Frag Cut»: $VR0_{av} \geq a \cdot \left(1 + e^{b \cdot \tan^2 \theta}\right)$,

$a = 3350, b = 0.7$

GSI2: Identification of Cosmic Rays

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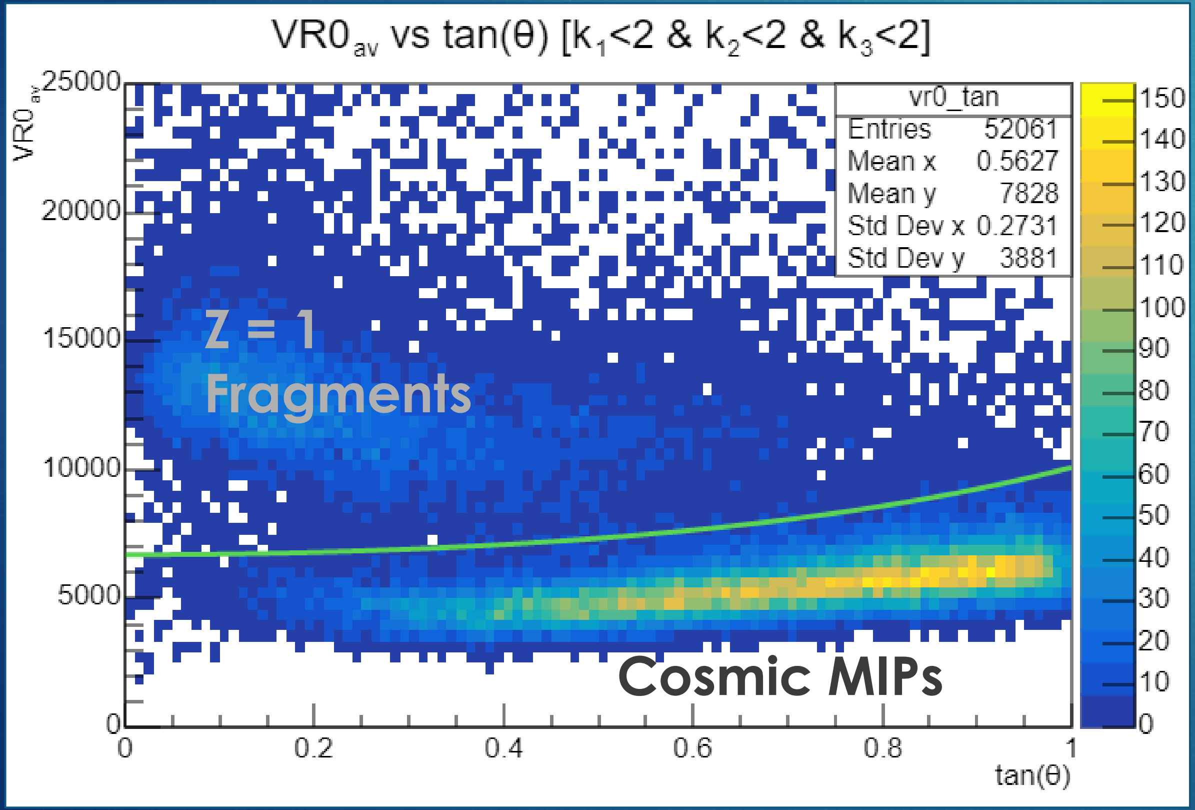

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GSI2: Identification of Z = 1 Fragments

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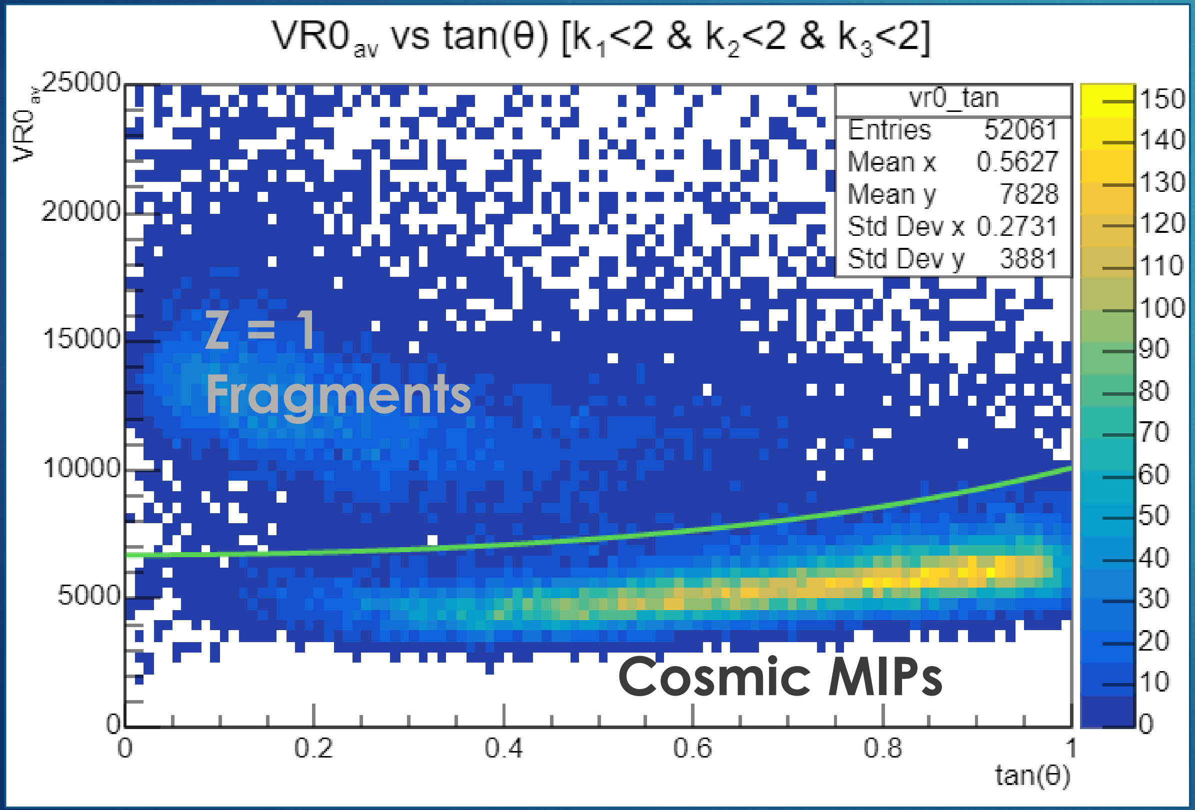

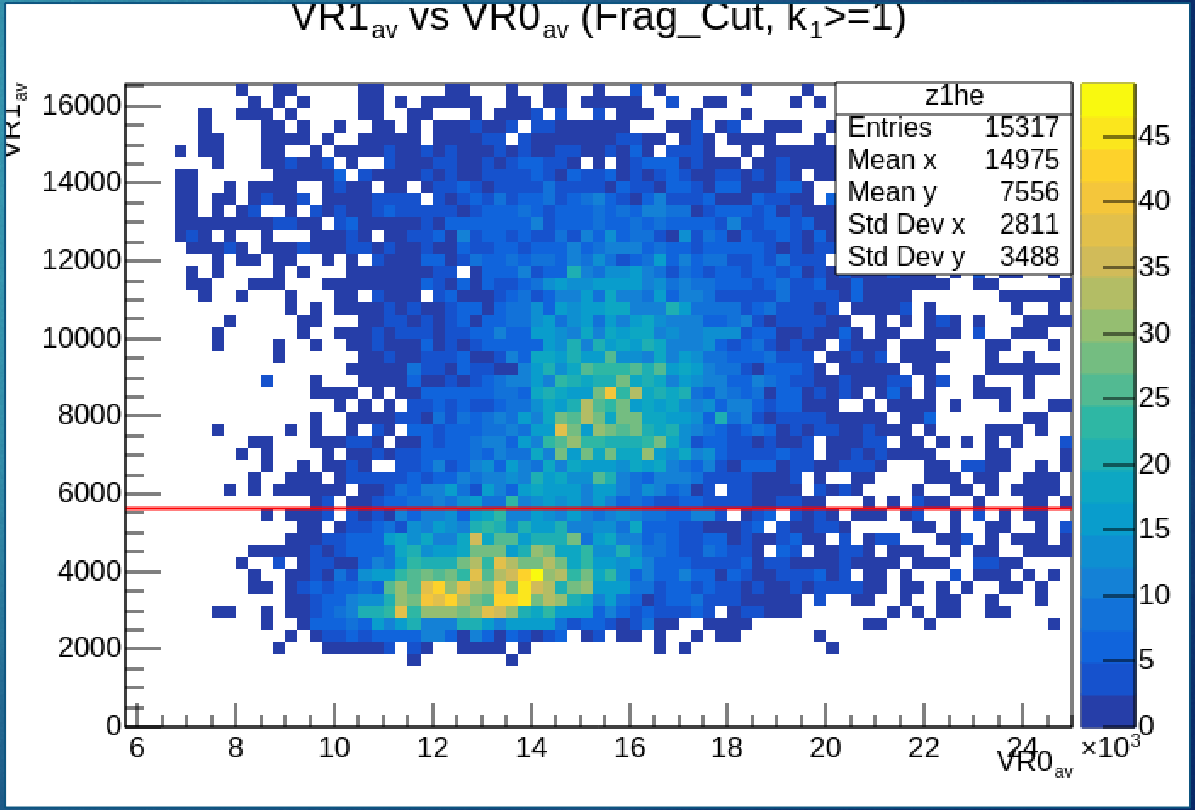

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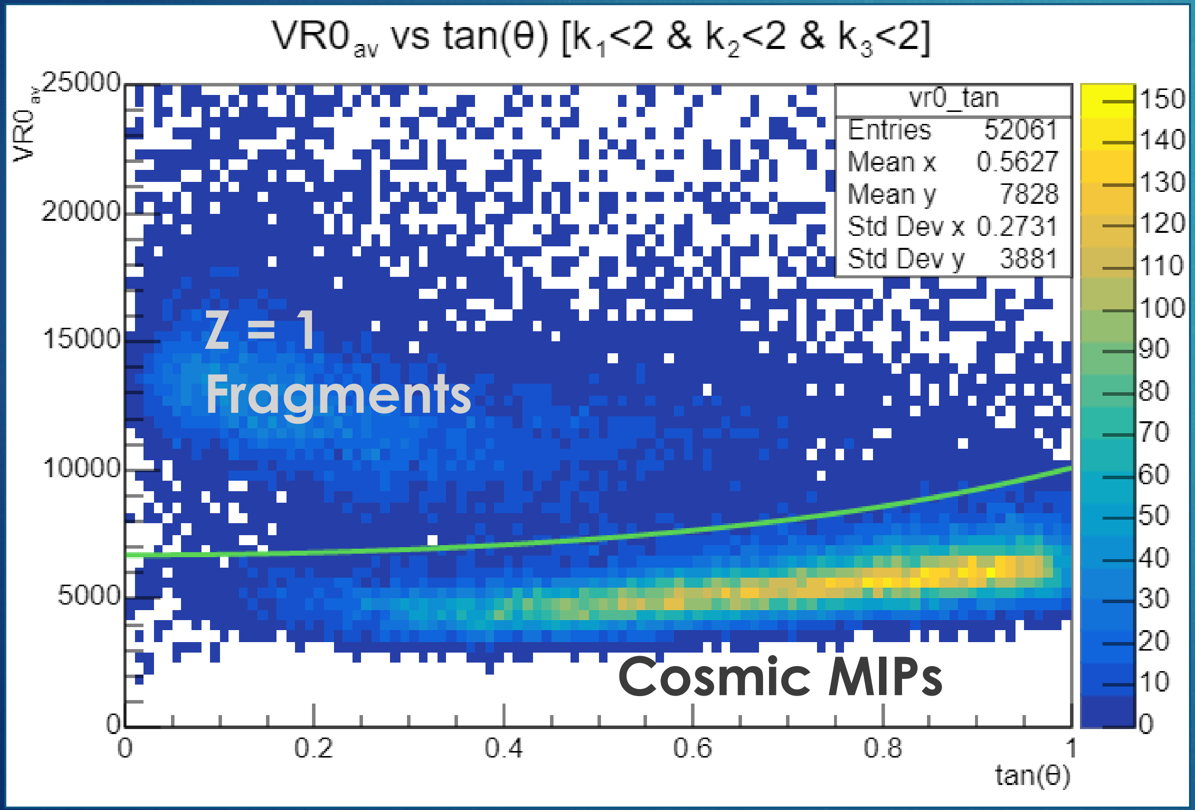
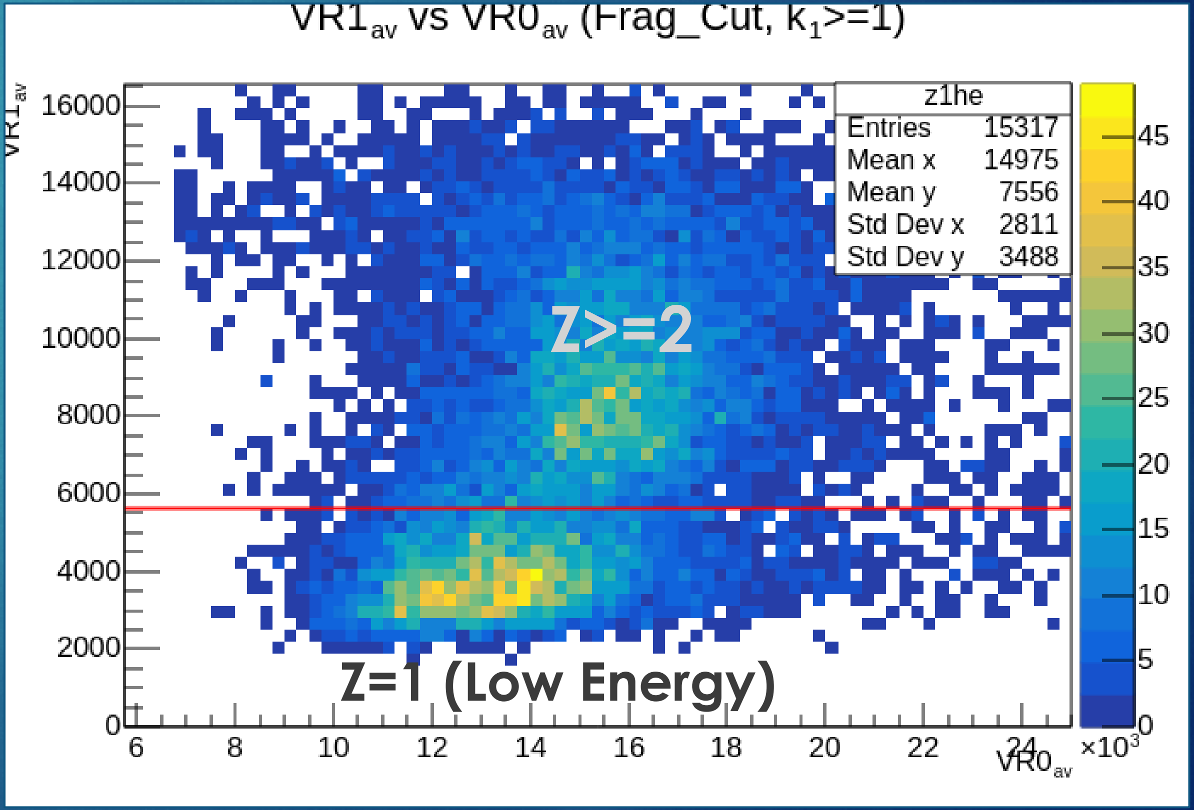
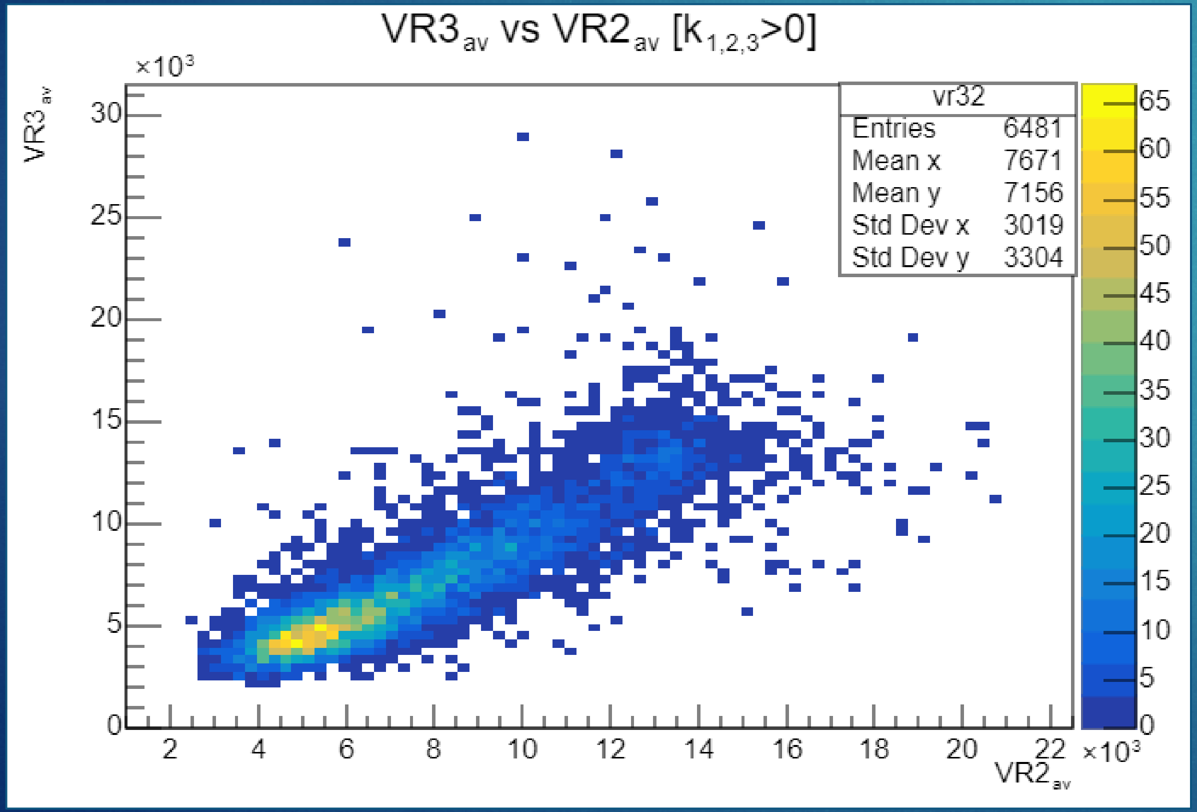
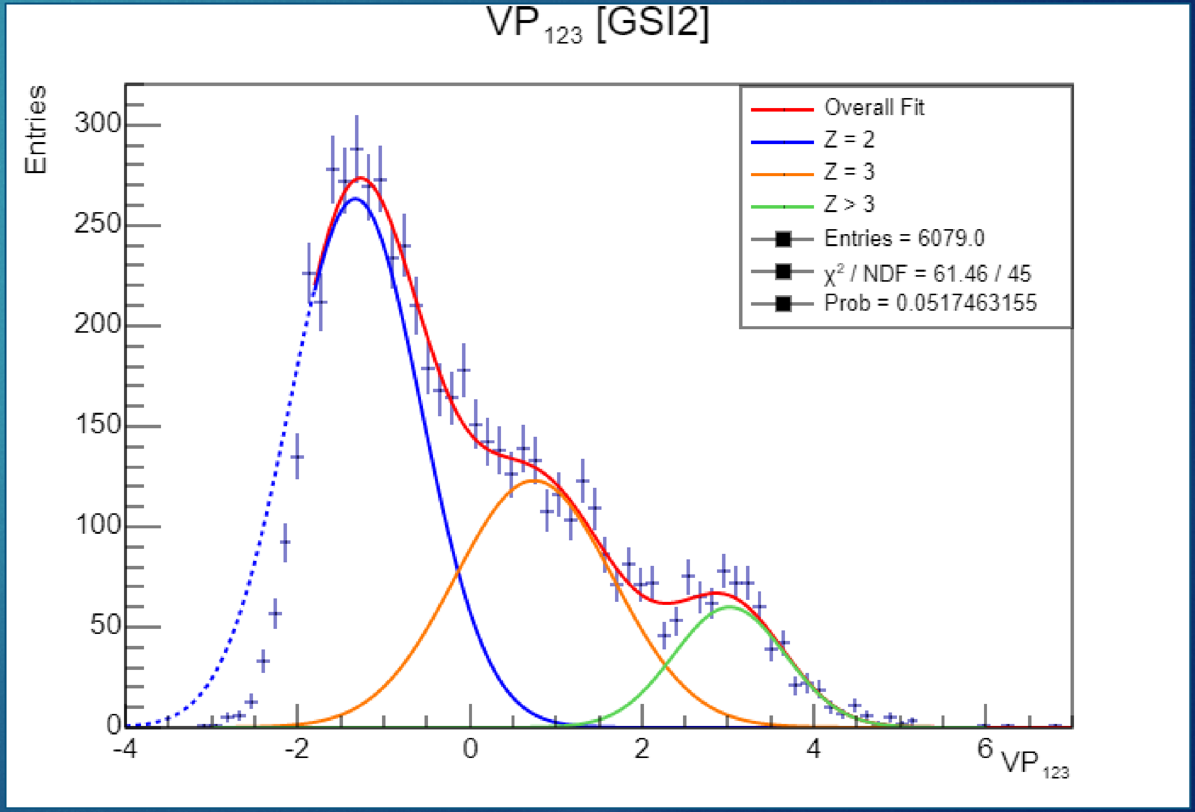




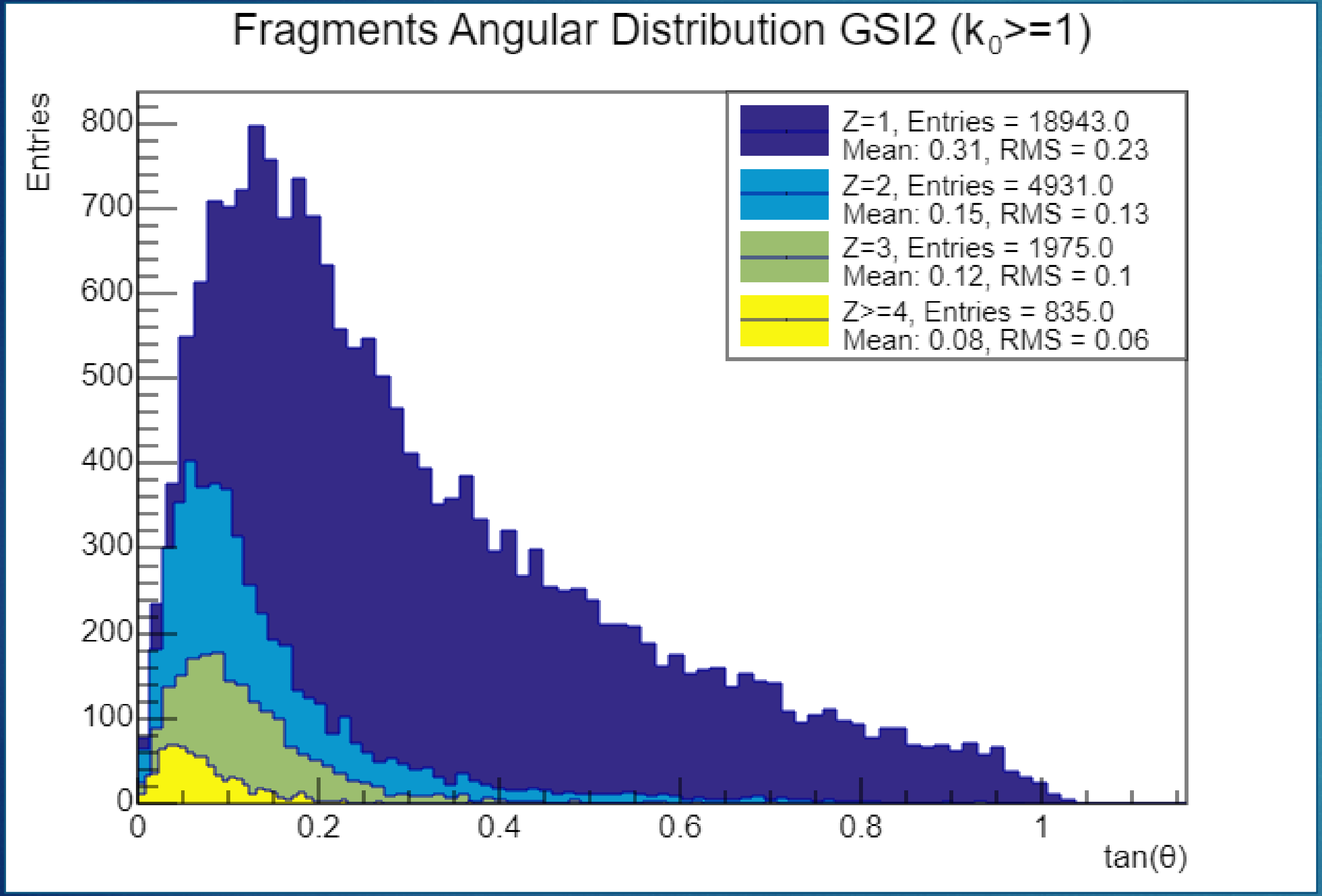
GSI2: Identification of Z >= 2 Fragments

- It is not possible to identify other populations by the use of sharp cuts
- The remaining volume variables are combined via the PCA to obtain new variables (denoted as VPxyz);





GSI2: Results



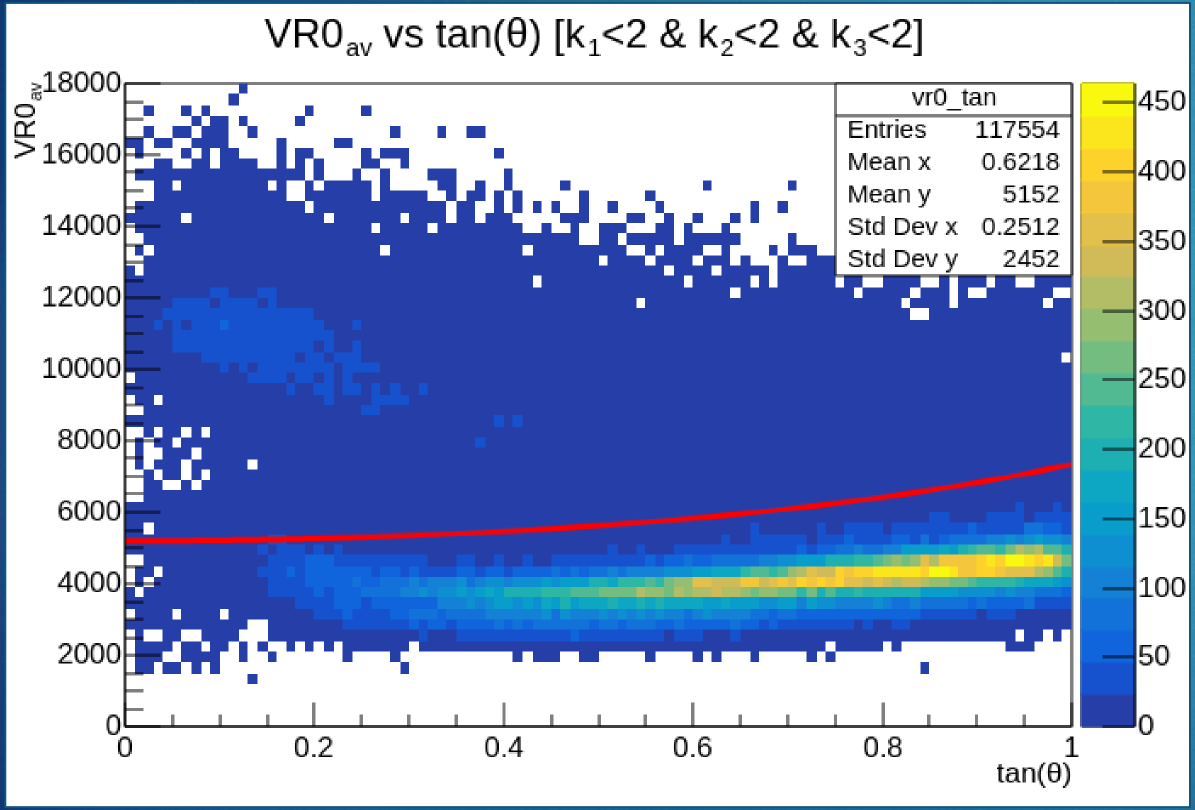
Z	Total	%	Stat.Err. (%)
1	18943	70	1
2	4931	18	1
3	1975	9	2
> 3	835	3	3

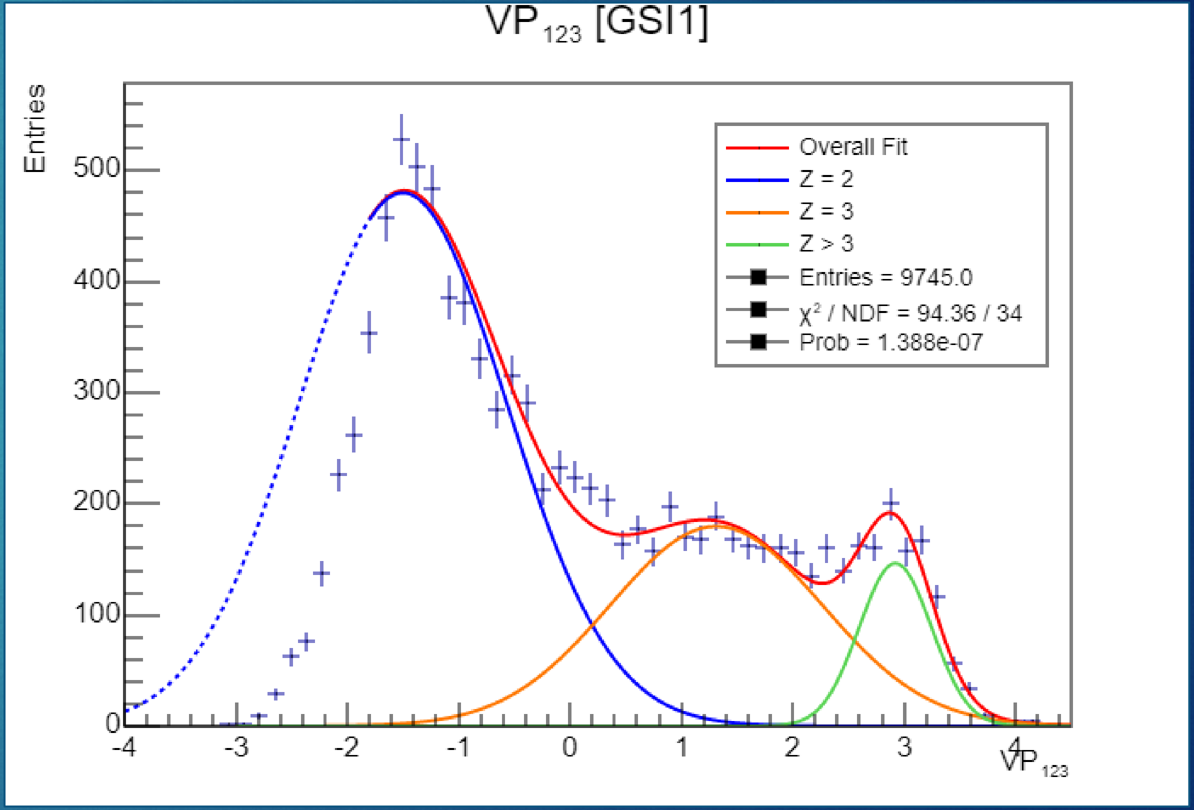
Z	Fragments classification					
	CB	PCA	Total	%	Syst. Err. (%)	Stat. Err. (%)
1	21,199	/	21,199	70	5	0.7
2	1,438	3,506	4,943	16	2	1.4
3	/	2,915	2,915	10	2	1.9
≥4	/	1,108	1,108	4	1	3.0
Total	22,637	7,529	30,166			

The results are compatible with the ones published in *Charge identification of fragments with the emulsion spectrometer of the FOOT experiment, Giuliana Galati et al.*

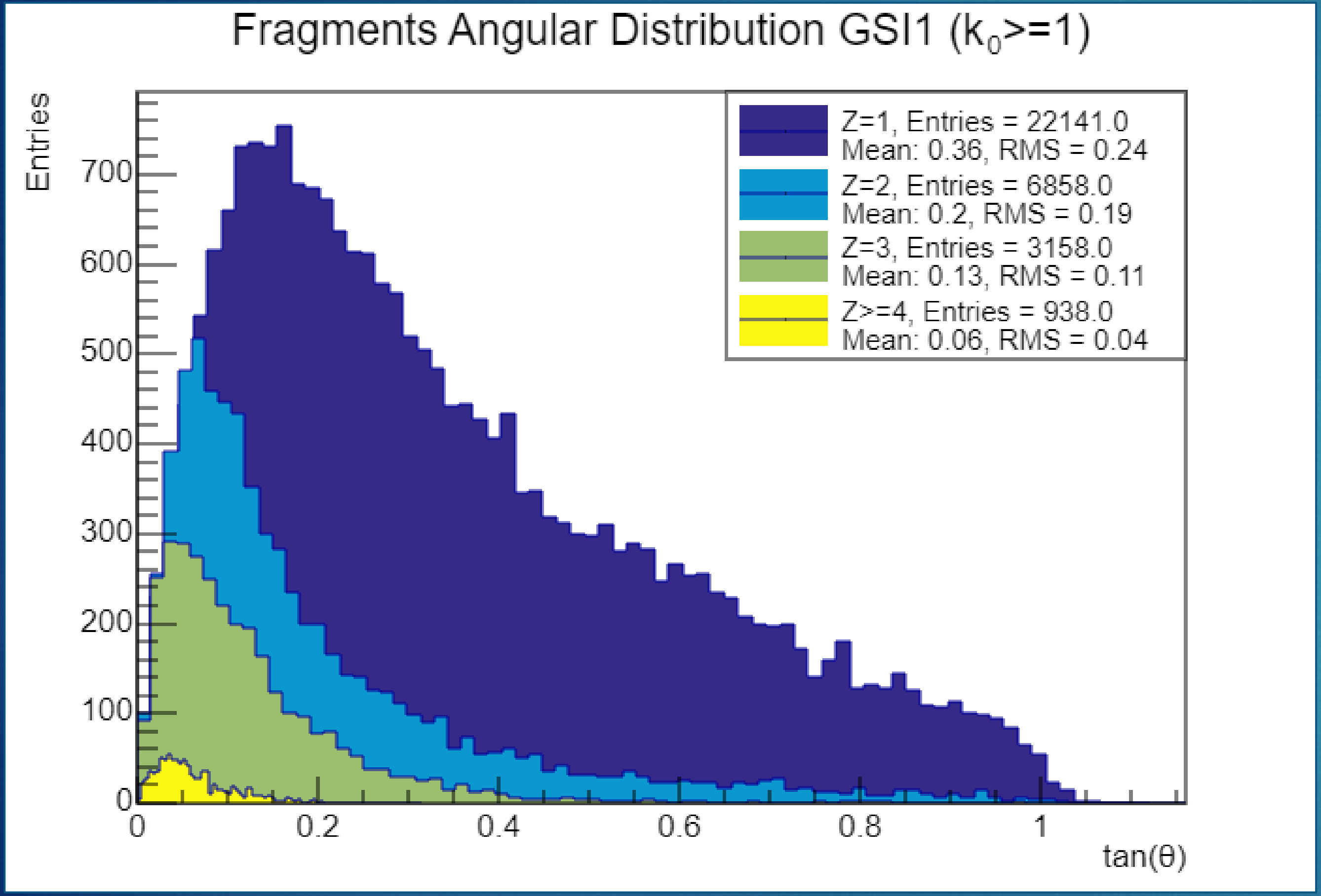
GSI1: Summary

- A similar analysis has been carried out for the GSI1 dataset;





GSI1: Results



Z	Total	%	Stat. Err. (%)
1	22141	67	1 %
2	6568	20	1 %
3	3158	9	2 %
> 3	938	3	3 %

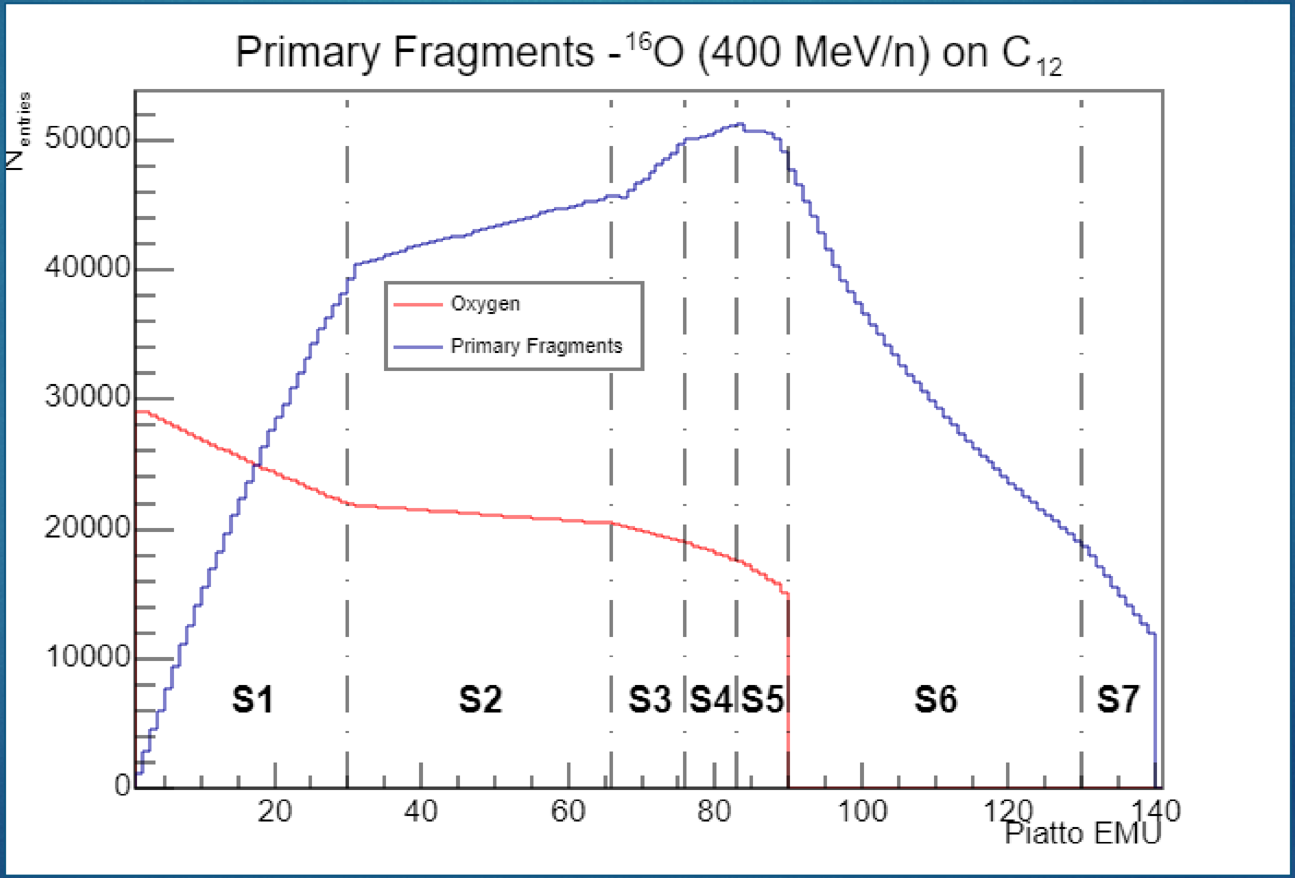
GSI1

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%

The results are compatible with the analysis shown at the FOOT General Meeting (26/05/2021) (Update on the Analysis of GSI1, *Giuliana Galati et al.)*

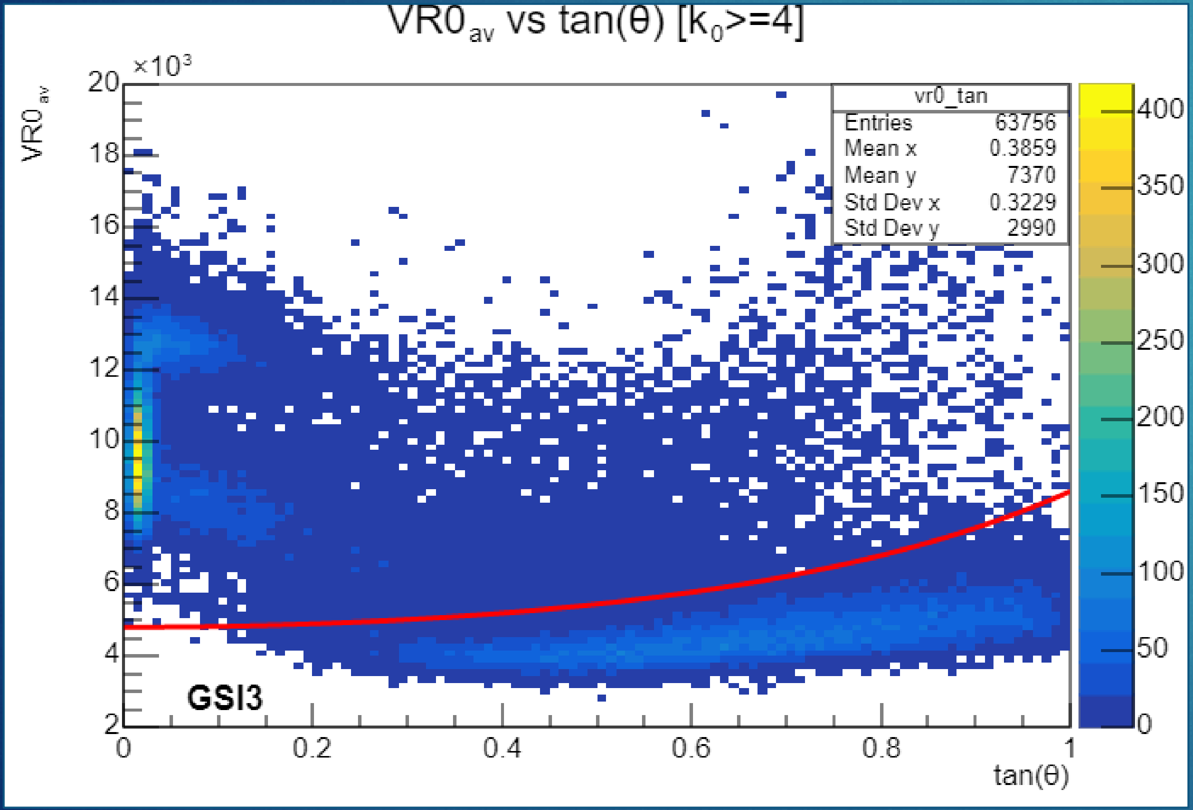
GSI3: *Differences with GSI1 & GSI2*

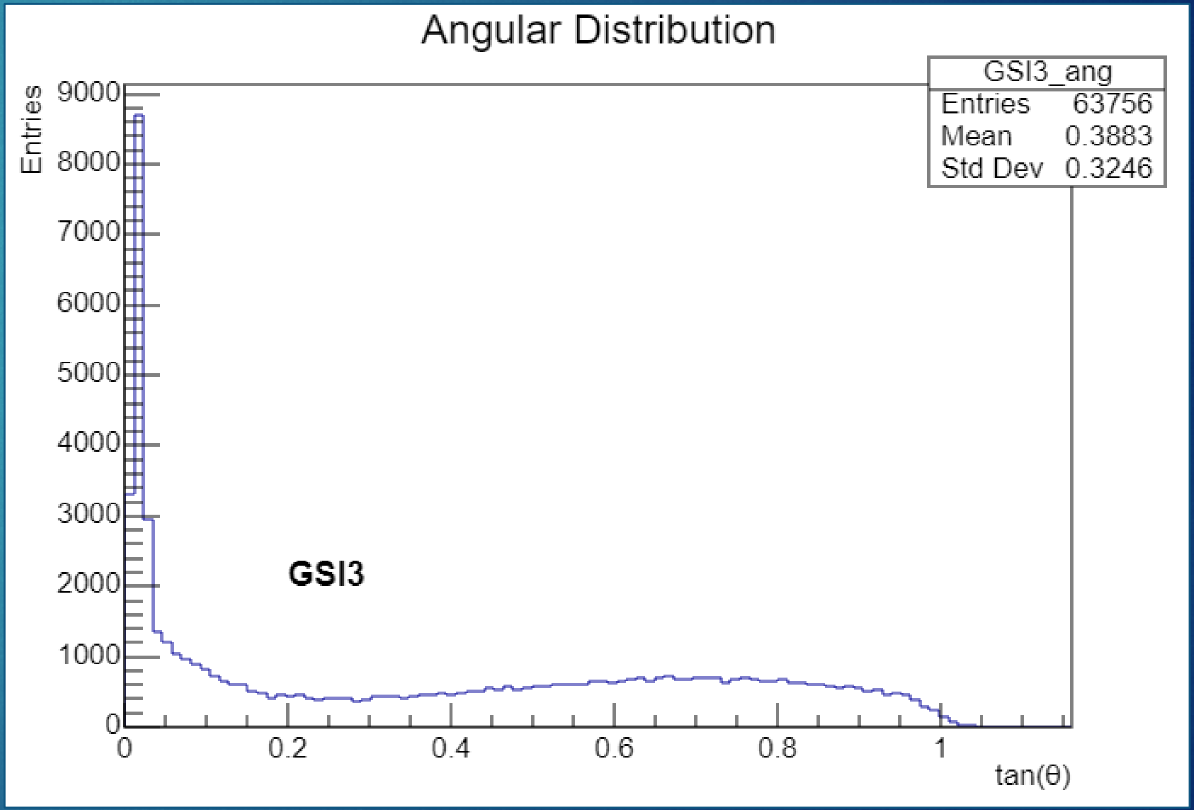
- The main differences with previous datasets are the initial kinetic energy (400 MeV/u ^{16}O beam) and the position of the Bragg Peak w.r.t. Section 2;



GSI3: *Identification of Cosmic Rays*

- Cut $k_0 \geq 1$ for all plots;
- The highly populated bins at low angles are linked to the presence of the primary beam in S2;

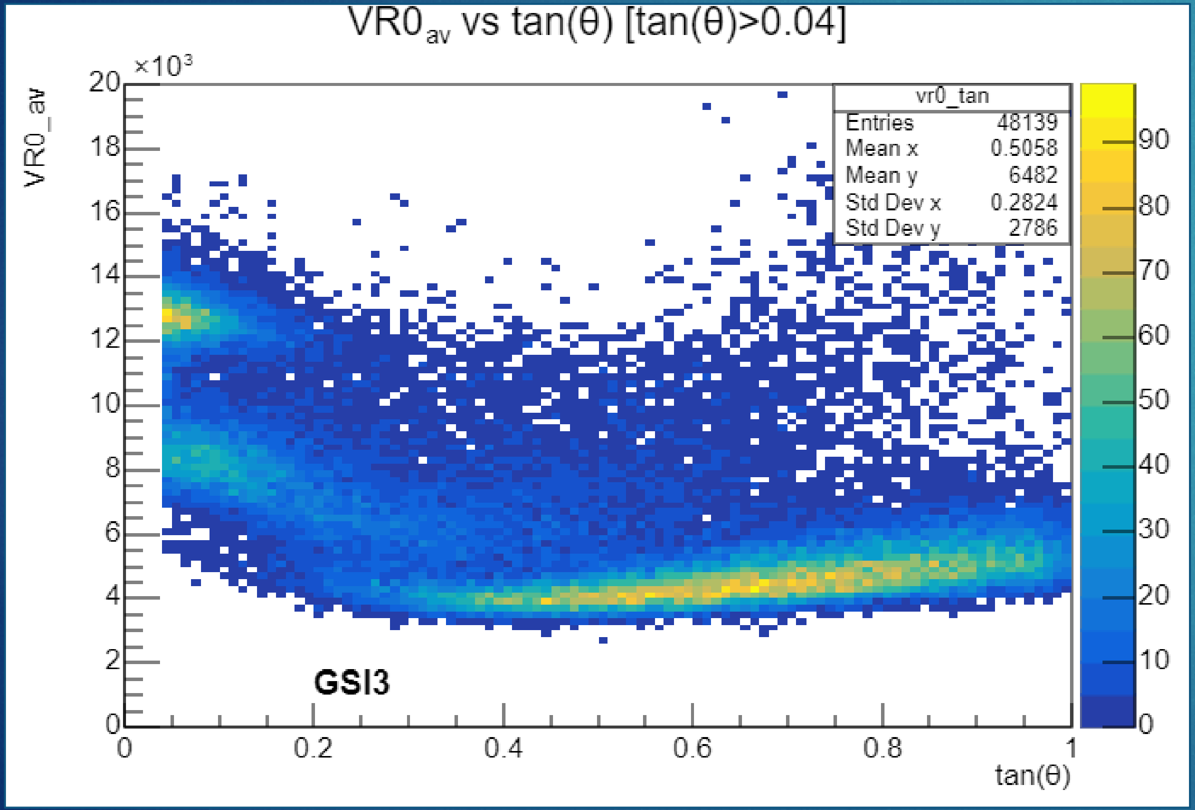




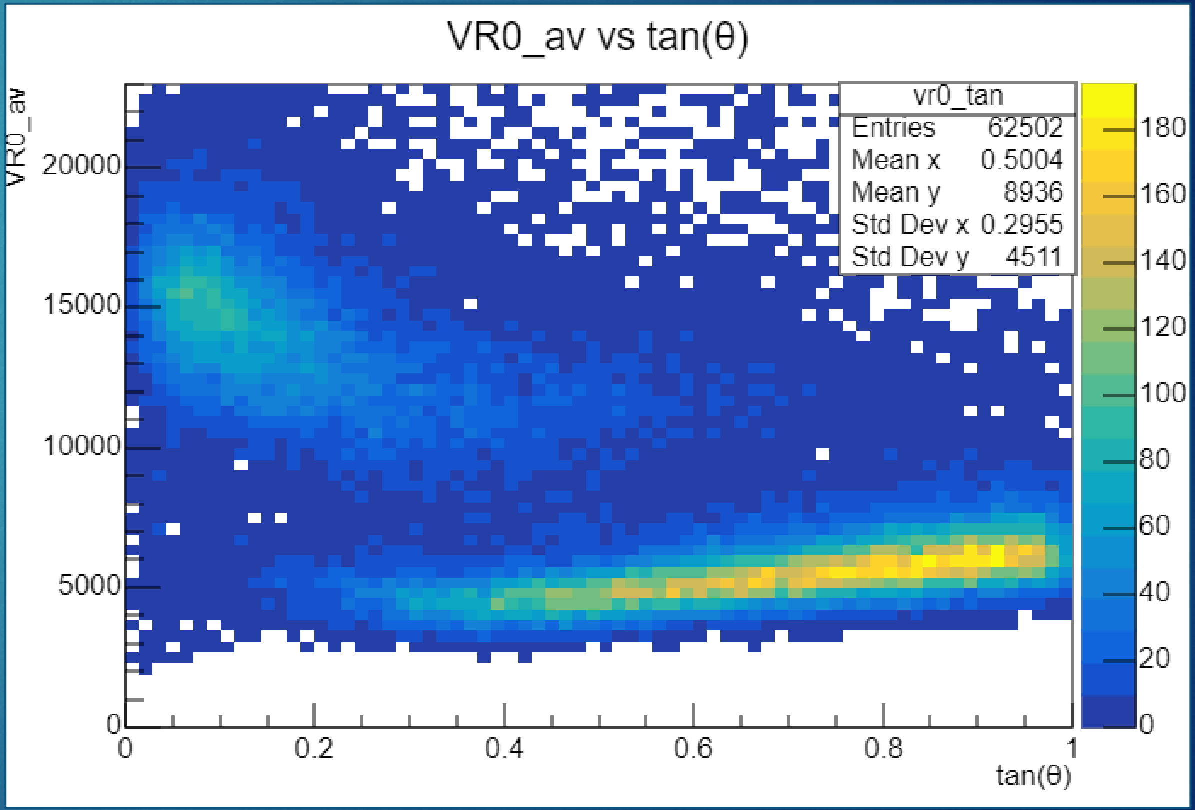
Cut: $VR0_{av} >= a_2 \cdot \left(1 + e^{b_2 \cdot \tan^2(\theta)}\right), a_2 = 2400, b_2 = 0.95$

Comparison between GSI3 and GSI2

- In GSI3 it is possible to identify two populations besides the cosmic MIPs;
- Checks still needed to understand this phenomenon and its link with the different energies involved;



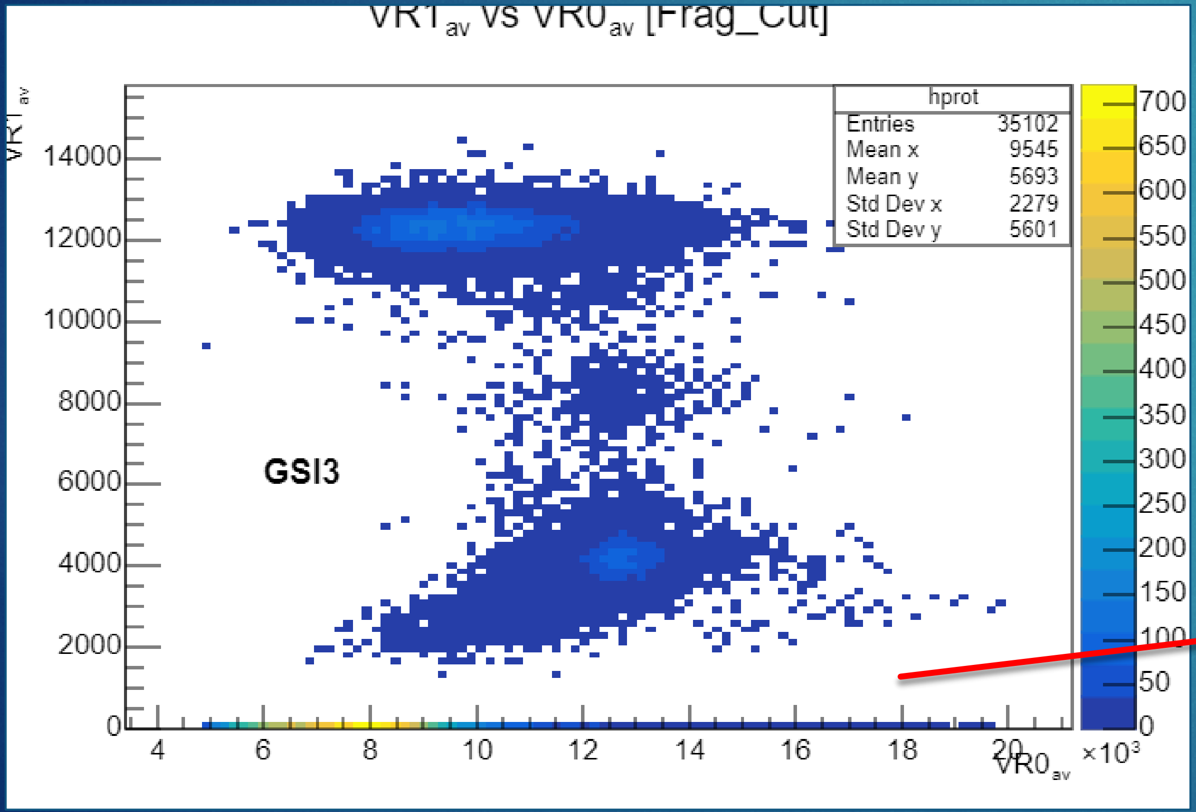
GSI3

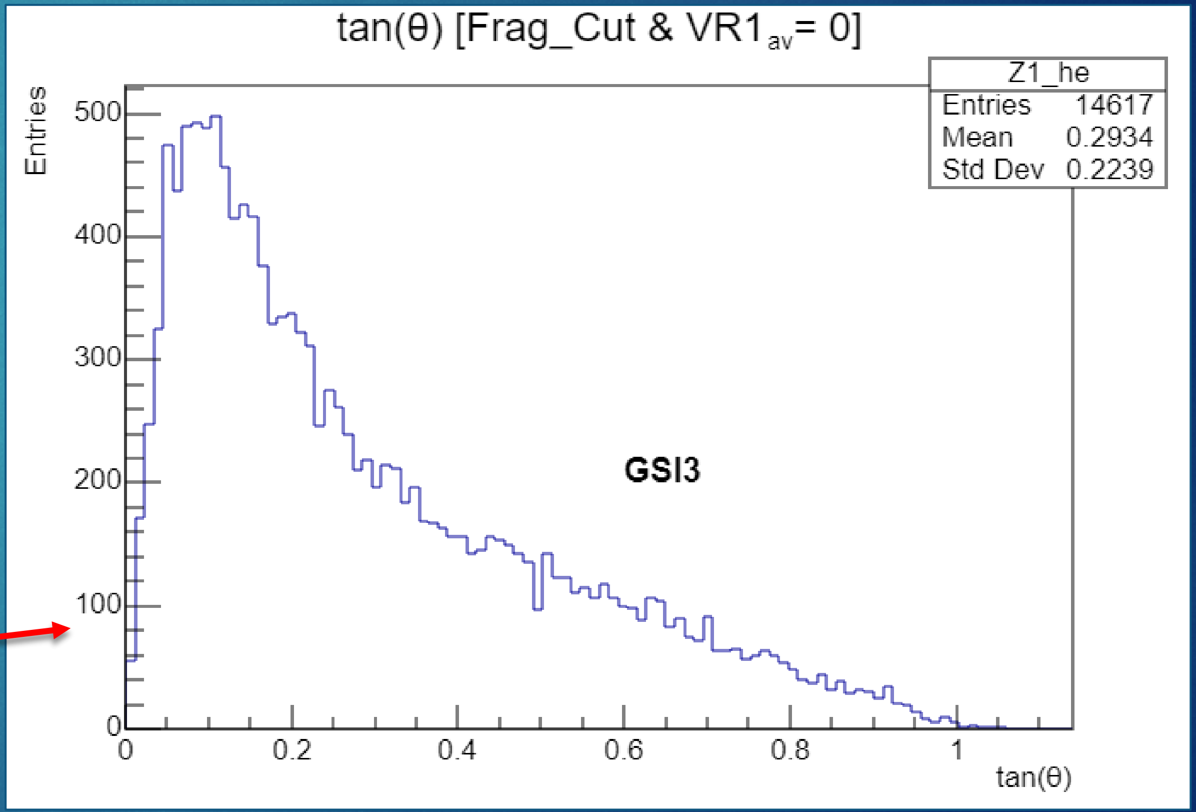


GSI2

GSI3: *Identification of Z = 1 Fragments*

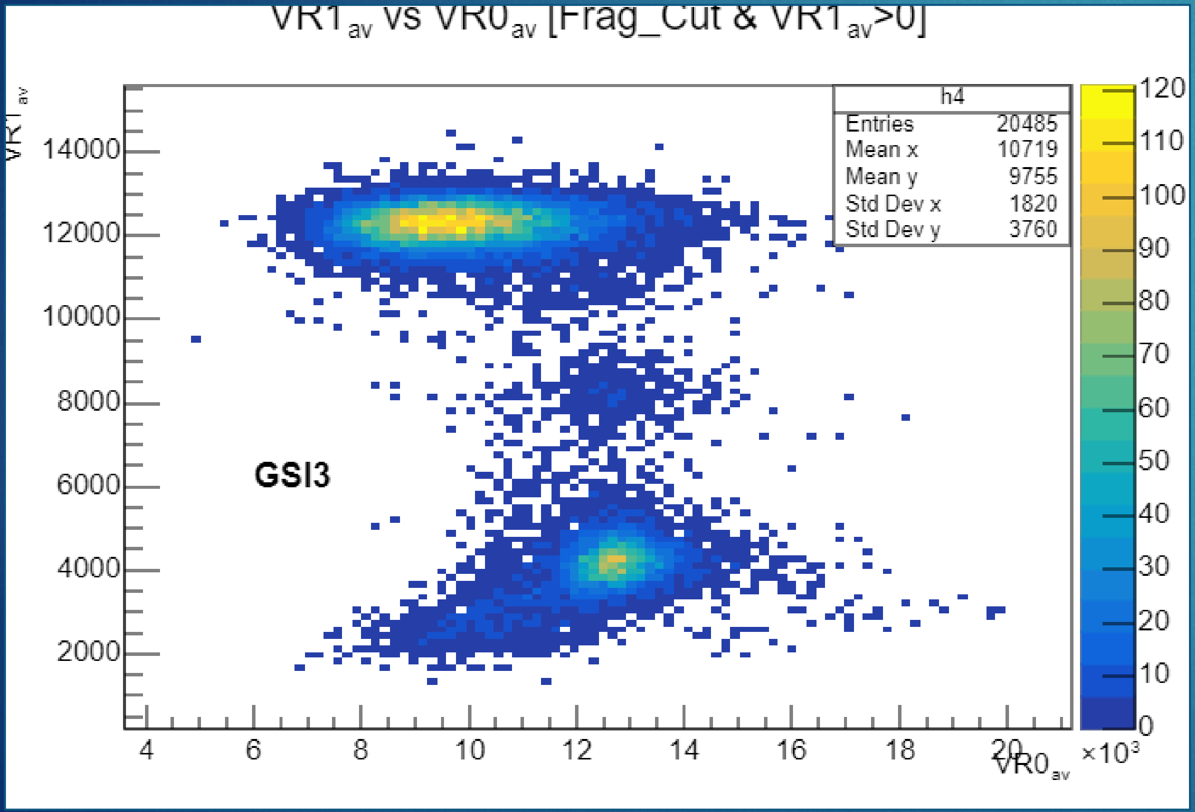
- The tracks that do not survive R1 treatment are identified as Z = 1 fragments;





GSI3: $VR1_{av} vs\ VR0_{av}$ distribution

- The presence of the primary beam and the different initial kinetic energy modifies the shape of the distribution w.r.t to the previous datasets;



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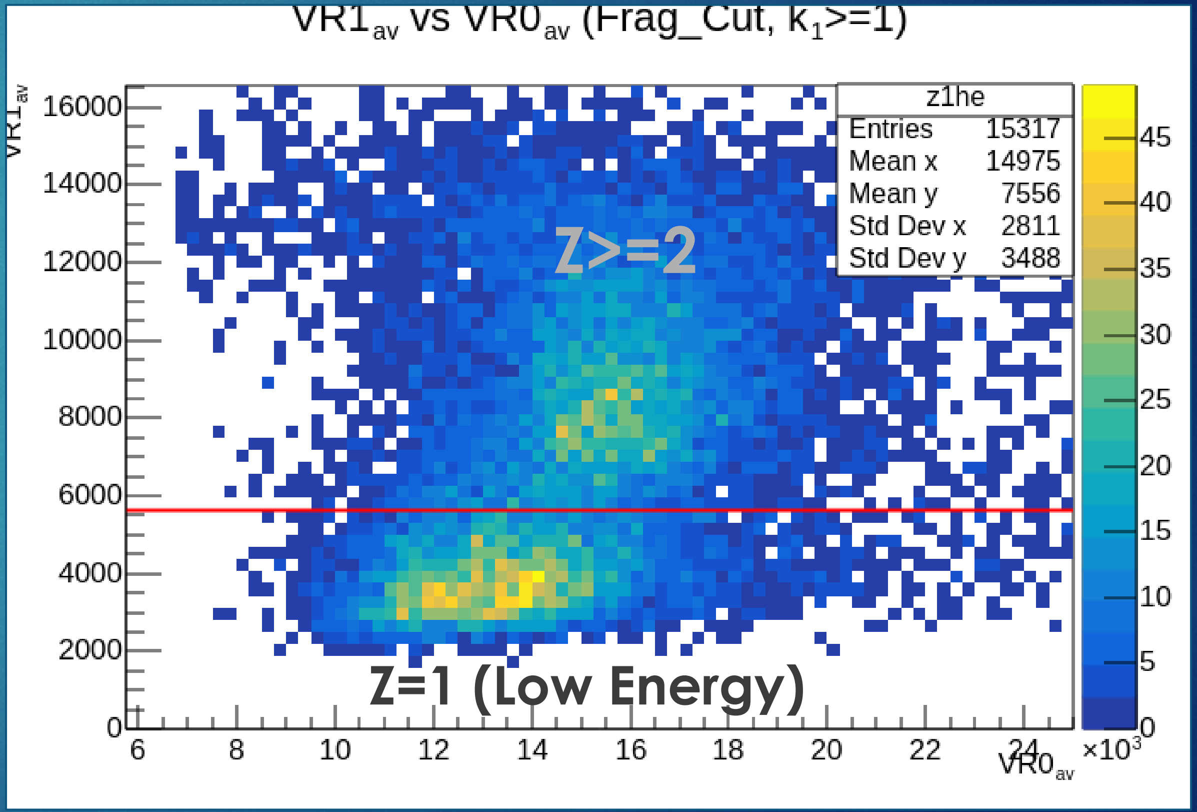
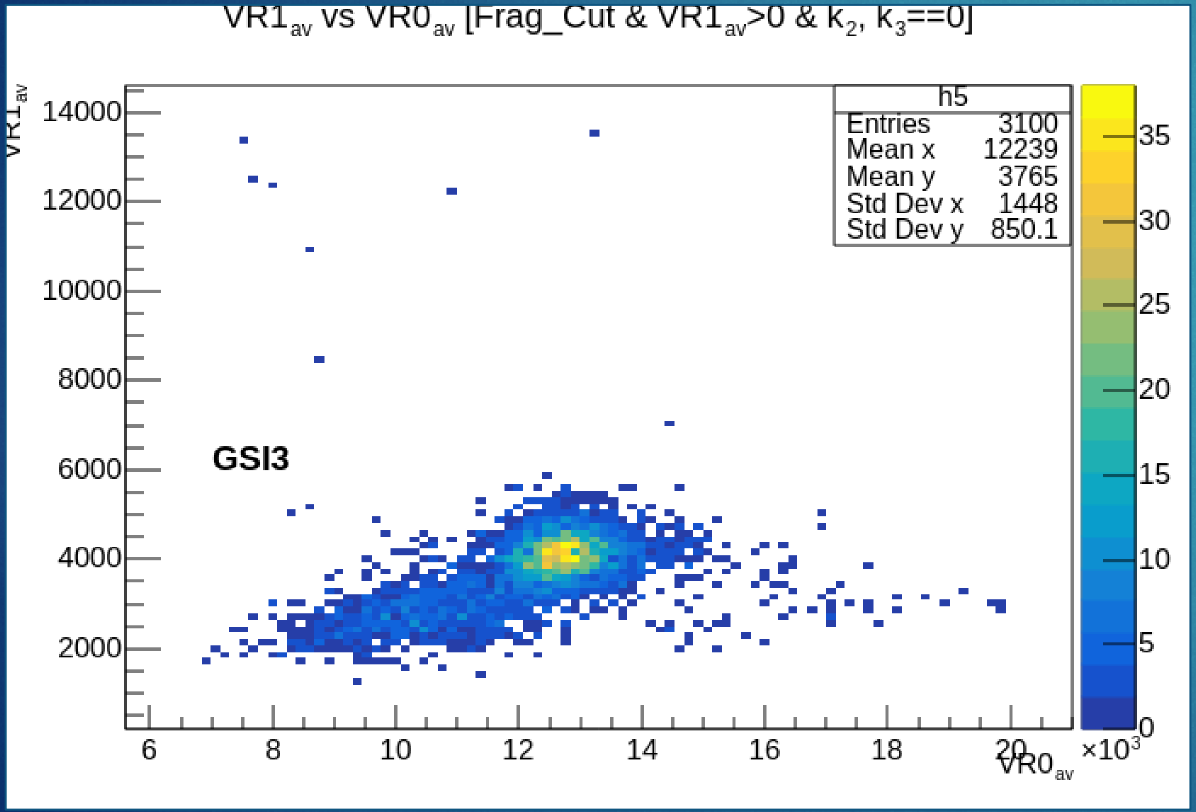
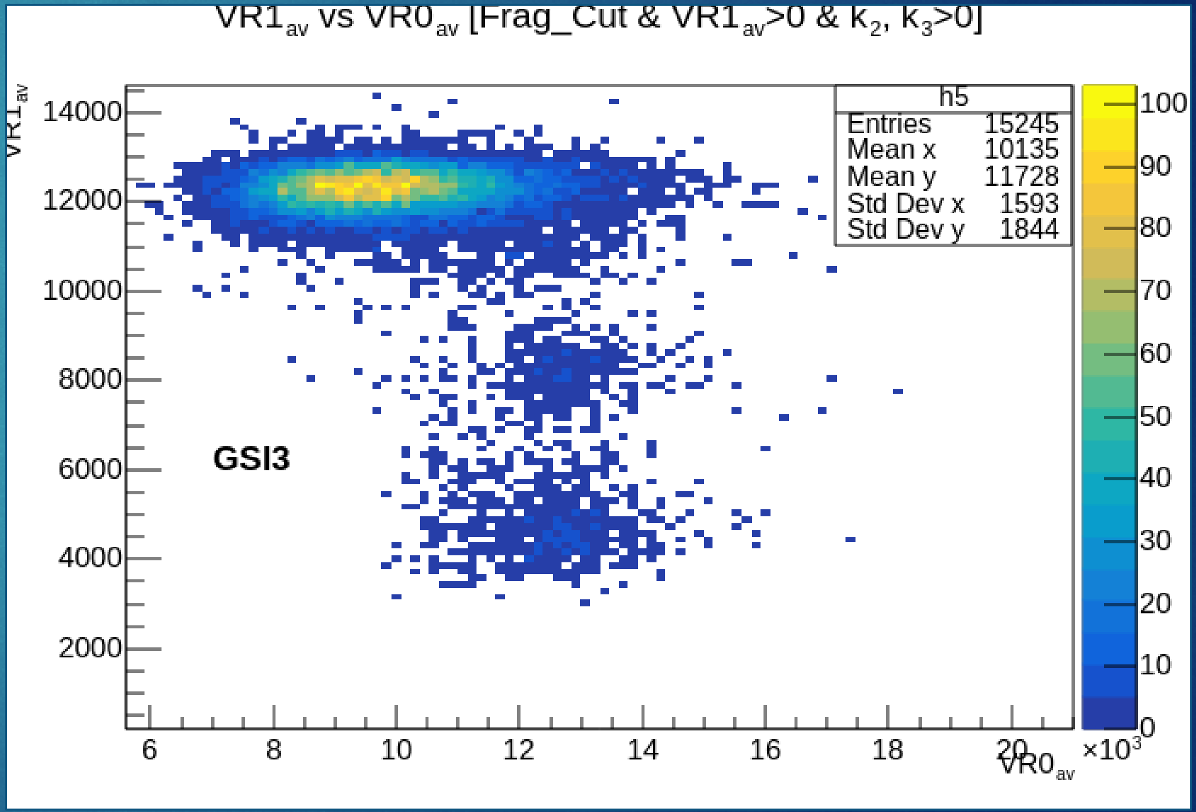


GSI2

GSI3: $VR1_{av} vs\ VR0_{av}$ distribution

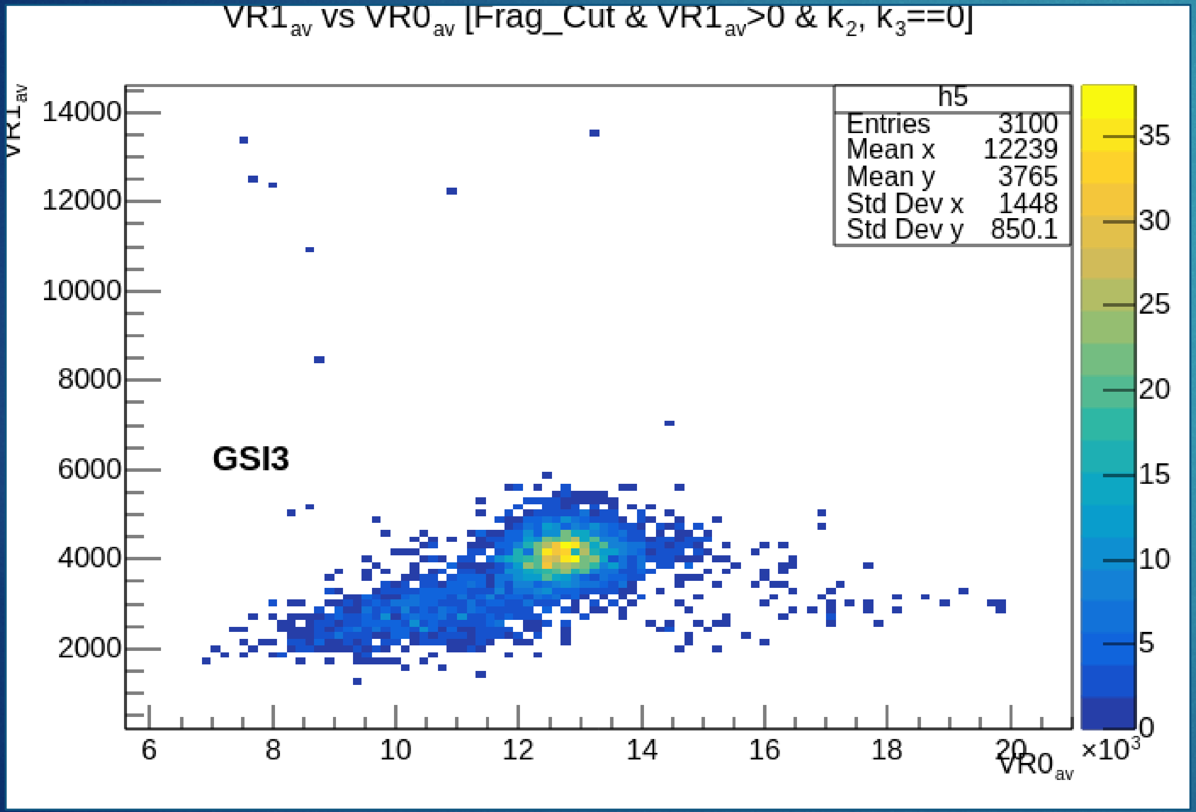
- Most of the tracks in the population with $VR1_{av} \sim 4000$ do not survive in R2 and R3;

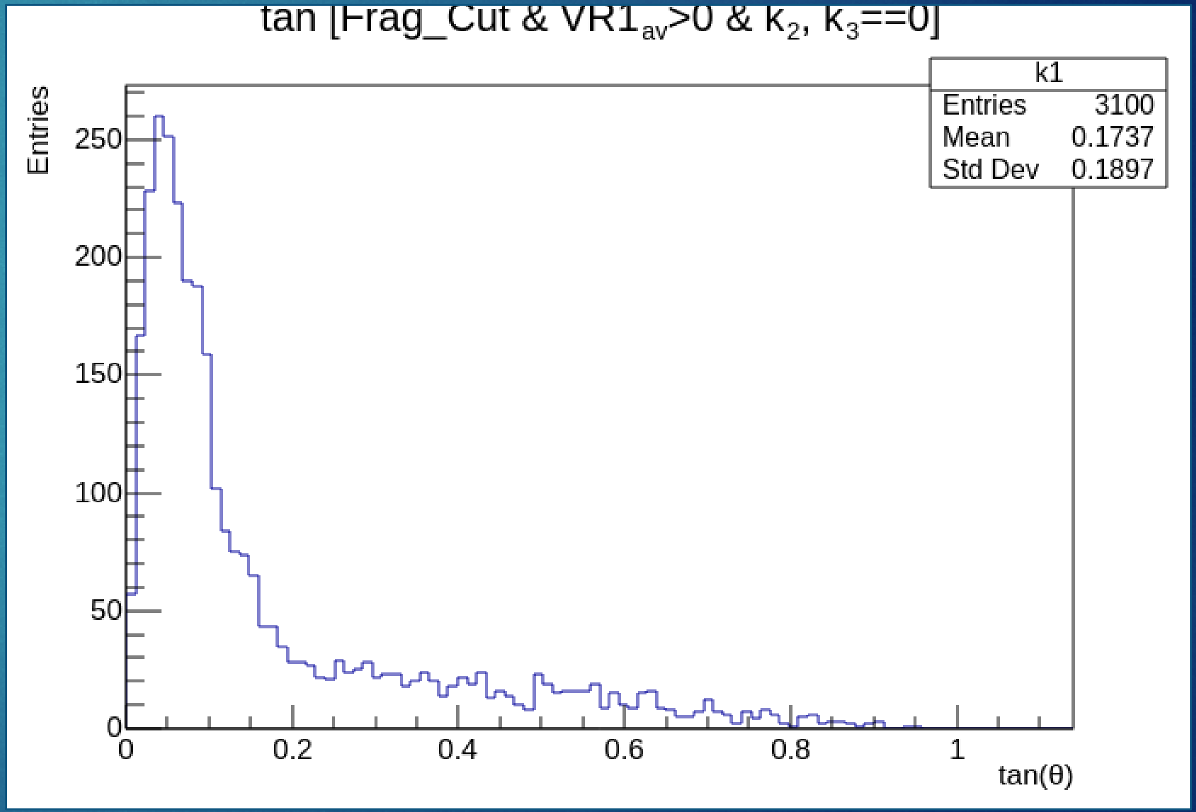




GSI3: $Z = 2$ *Fragments*

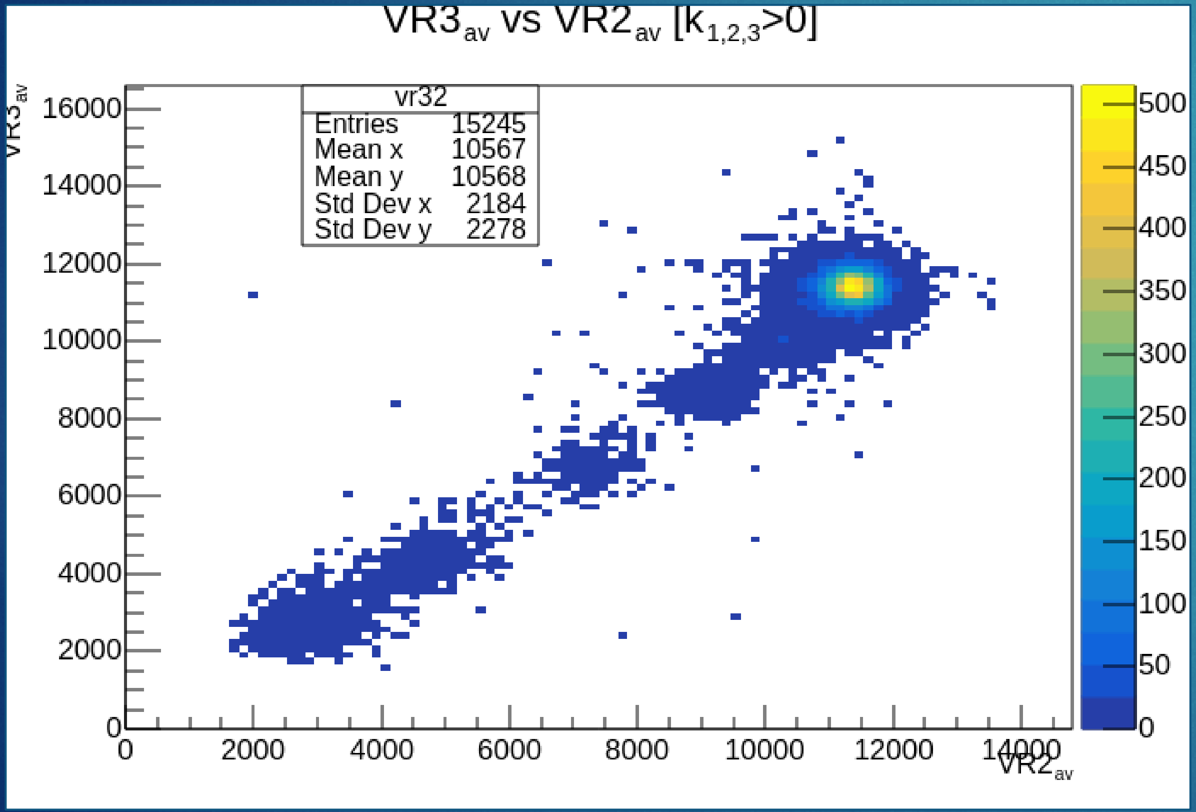
- Low number of segments in R2 and R3
- Higher ionization and narrower angular distribution w.r.t protons → $Z = 2$





GSI3: *Identification of Z>2 Fragments*

- Because of the different energies involved, in GSI3 it is possible to identify different populations when looking at the volume variables relative to the R2 and R3 regions;



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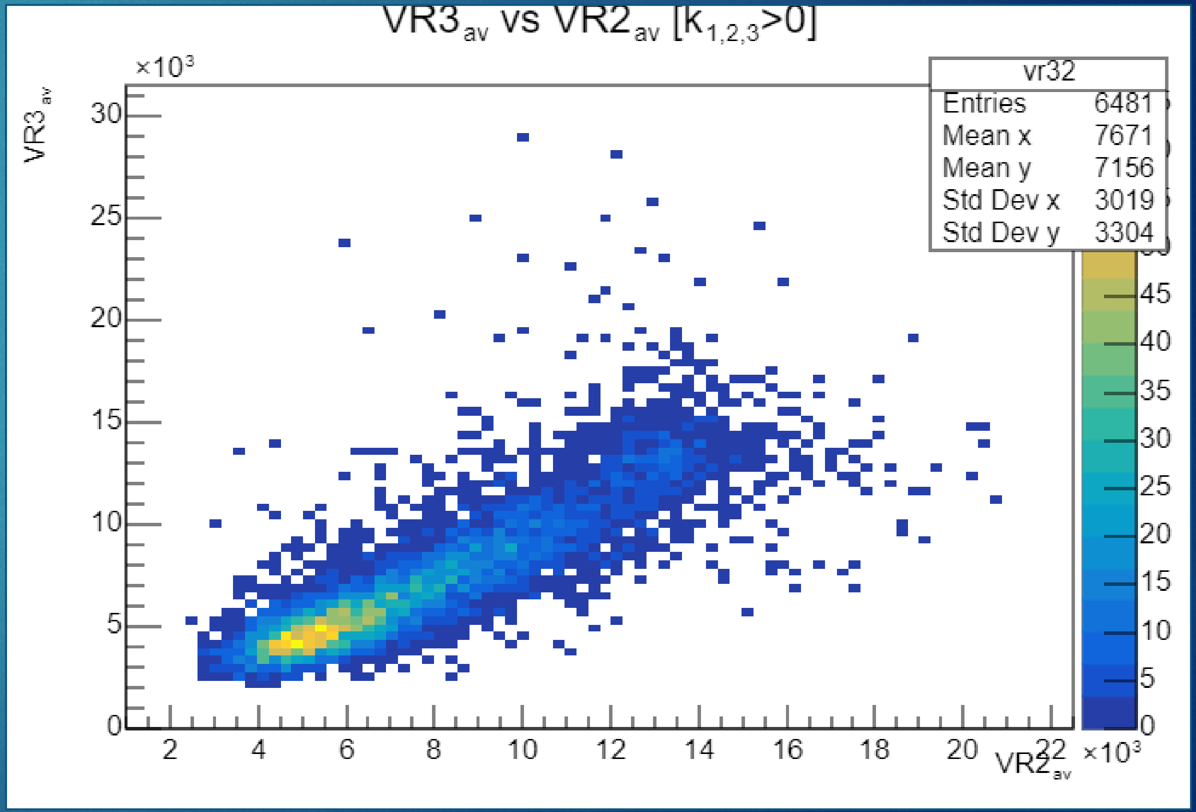

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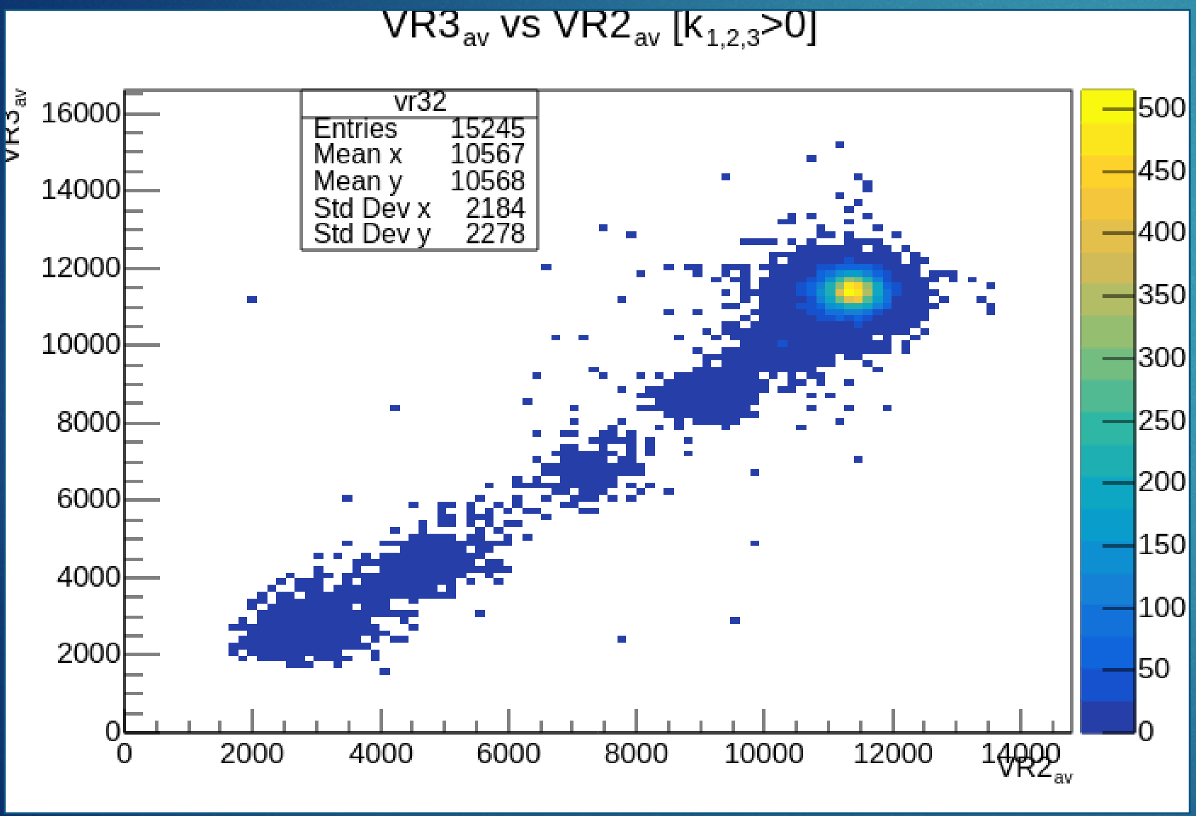

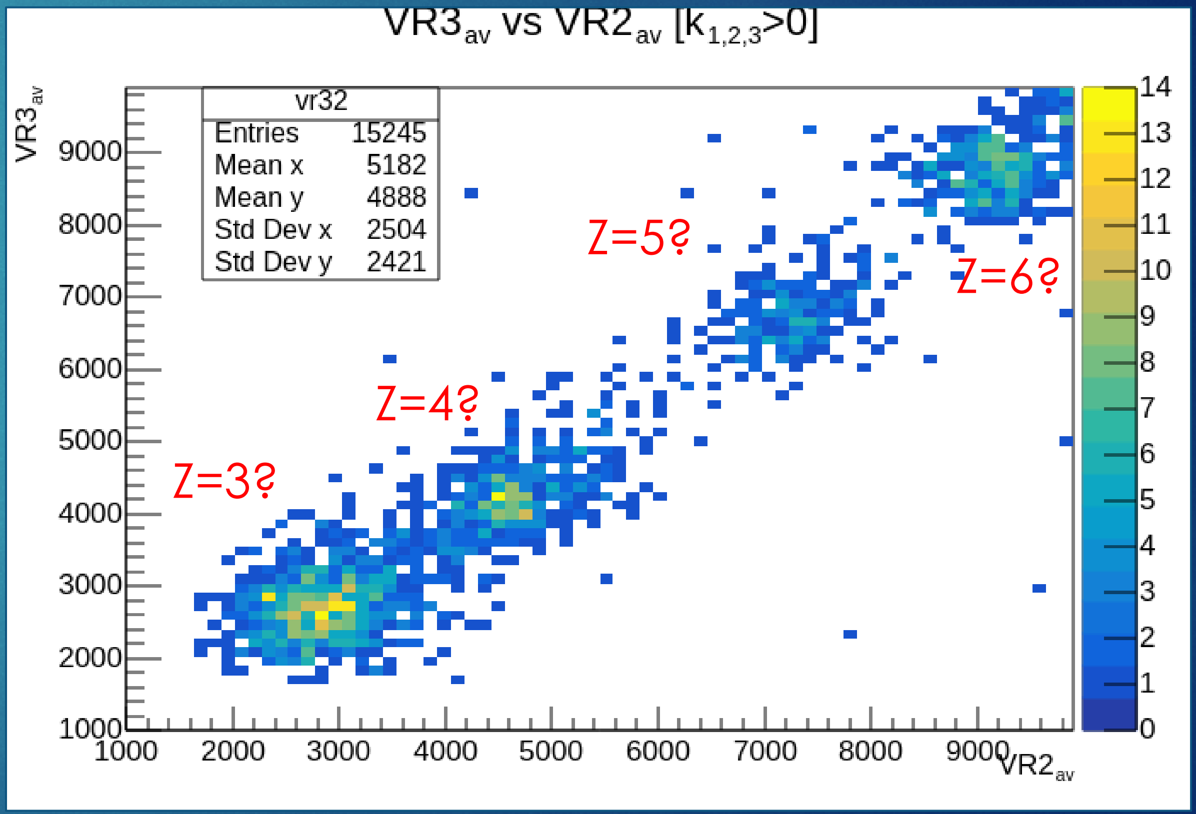

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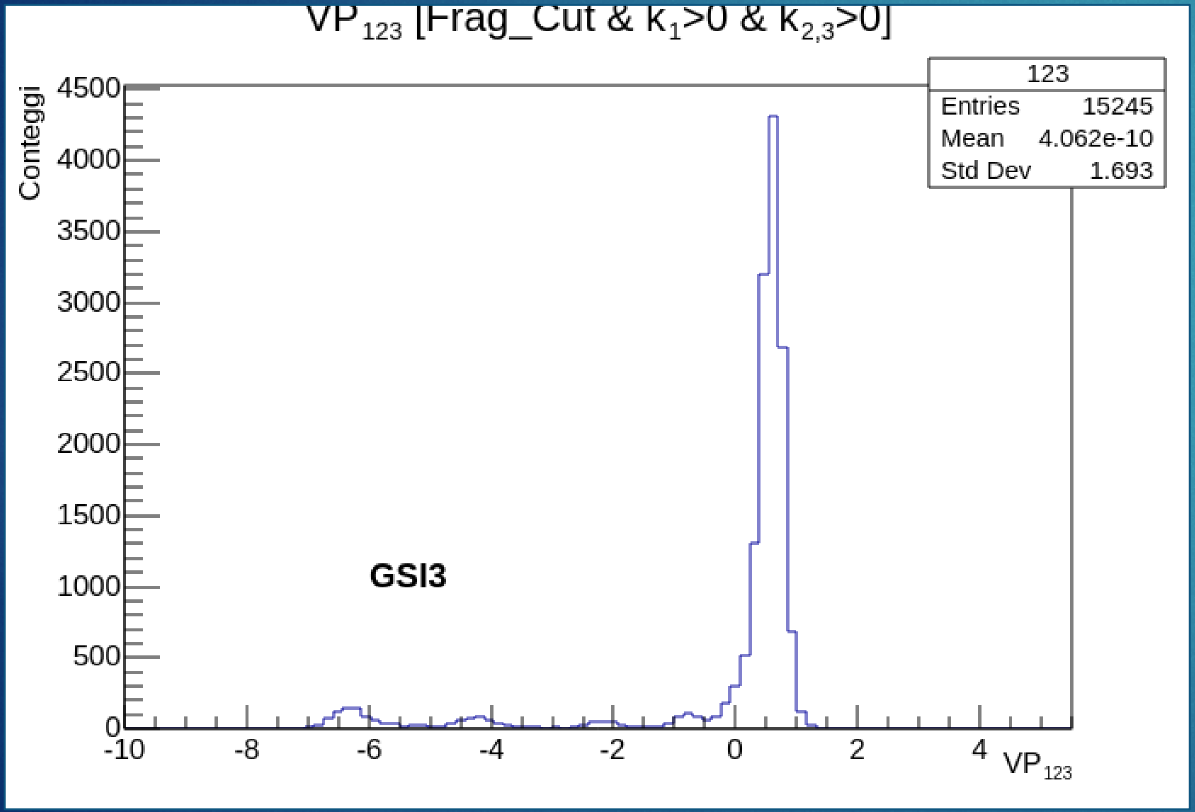
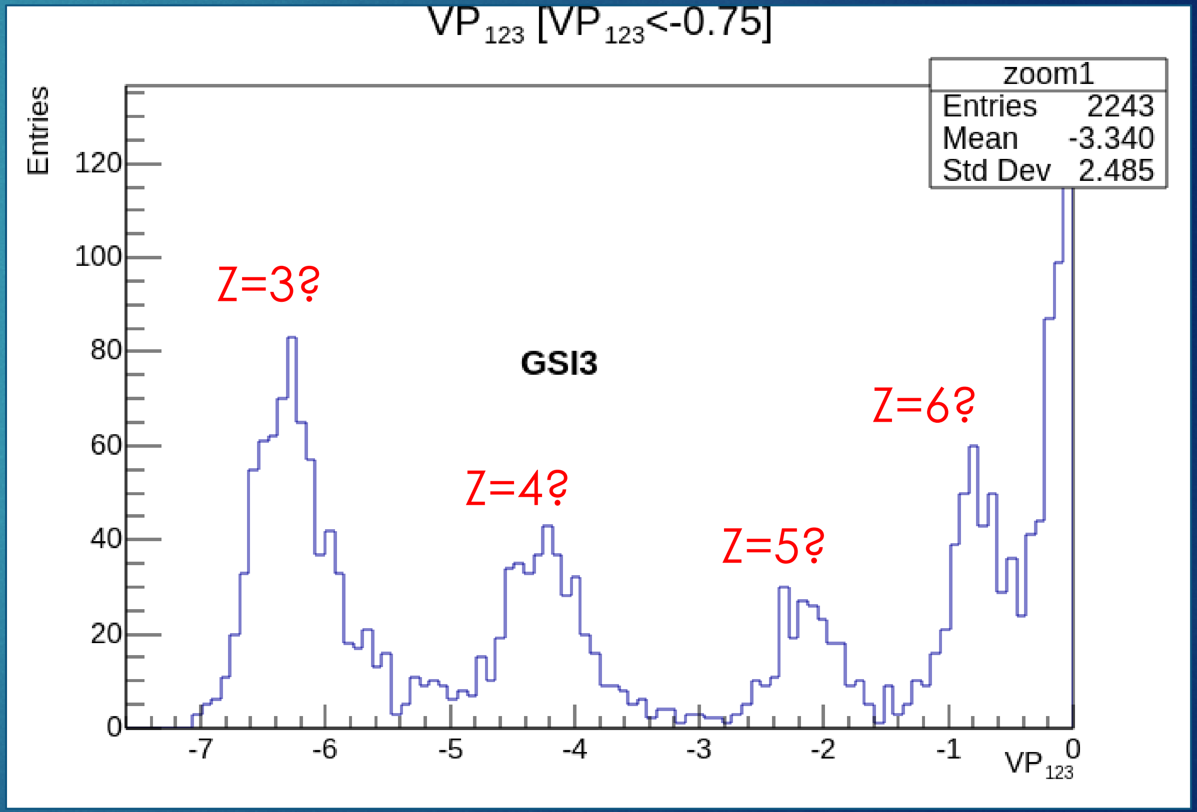
- The Principal Component Analysis highlights these populations more clearly;





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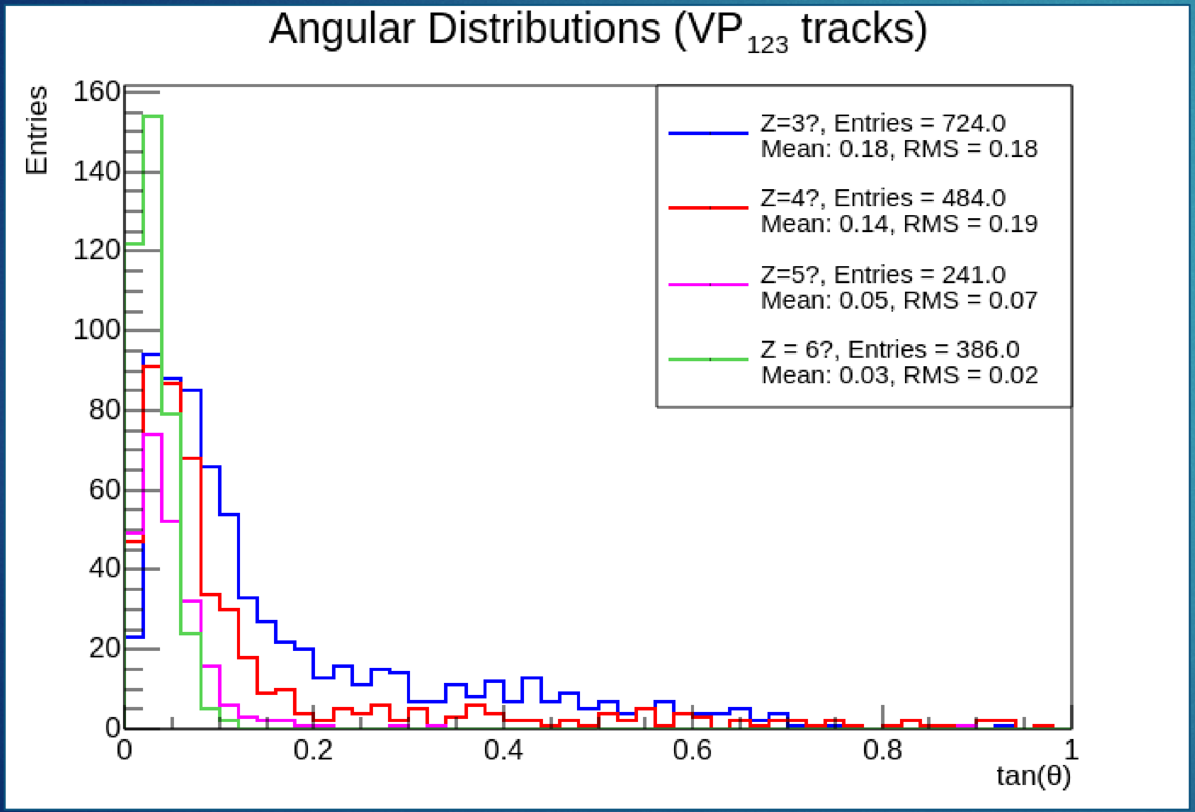

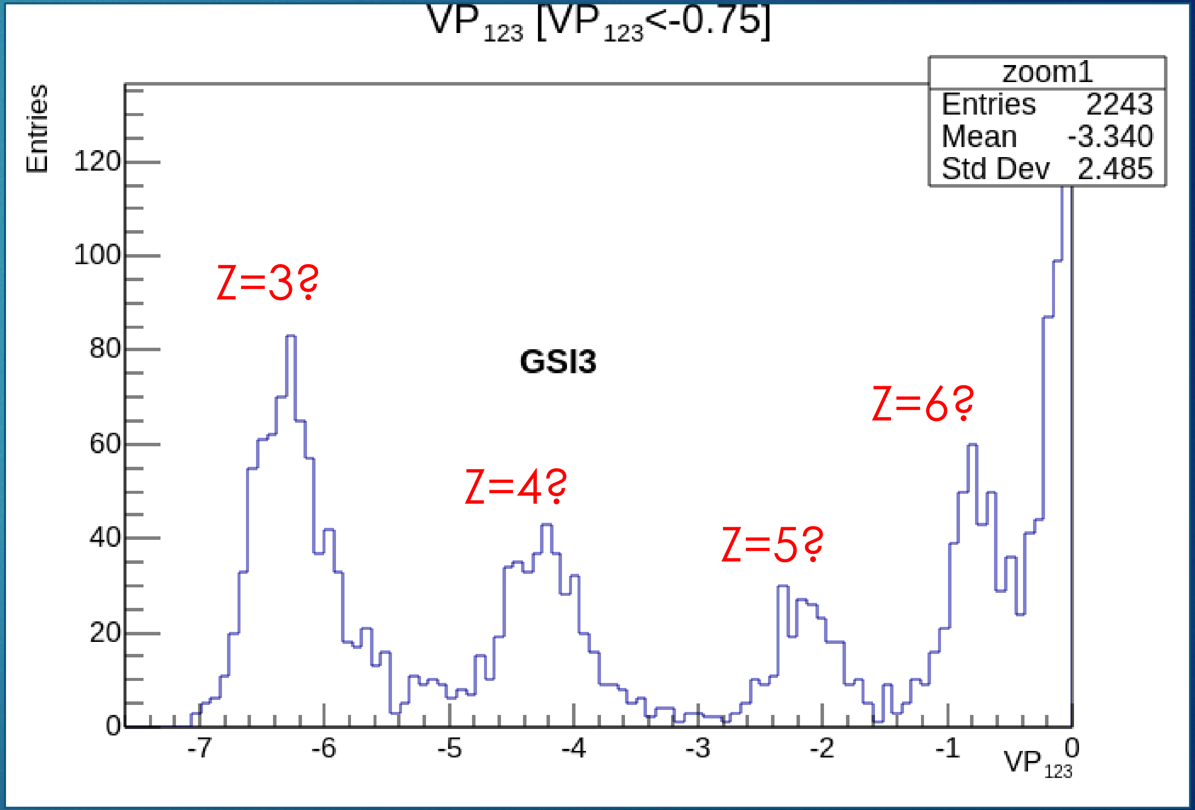

Next Steps

- Comparison with MC (True and Reconstructed) simulations;
- Inclusion of the vertex information to improve the classification;