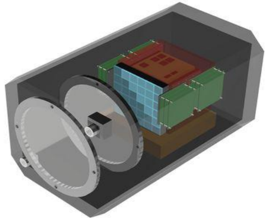
Search for high-speed events seen by Mini-EUSO : from meteors to nuclearites

Justine QUENTIN • 06/2022

Referent : Mario Bertaina
Co-referent : Dario Barghini

JEM-EUSO program

Mini-EUSO program

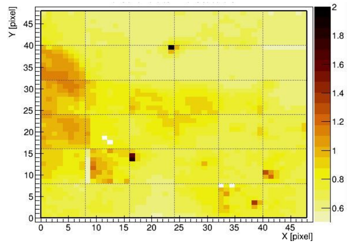


Meteors and nuclearities

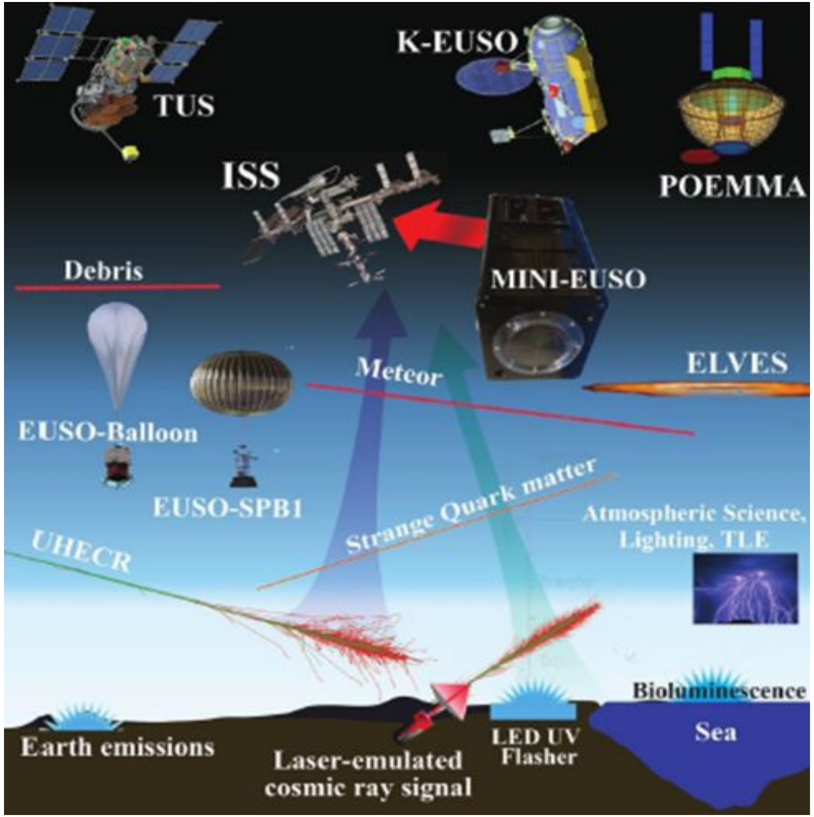
Events classification

Trigger efficiency

Conclusion



JEM-EUSO program :

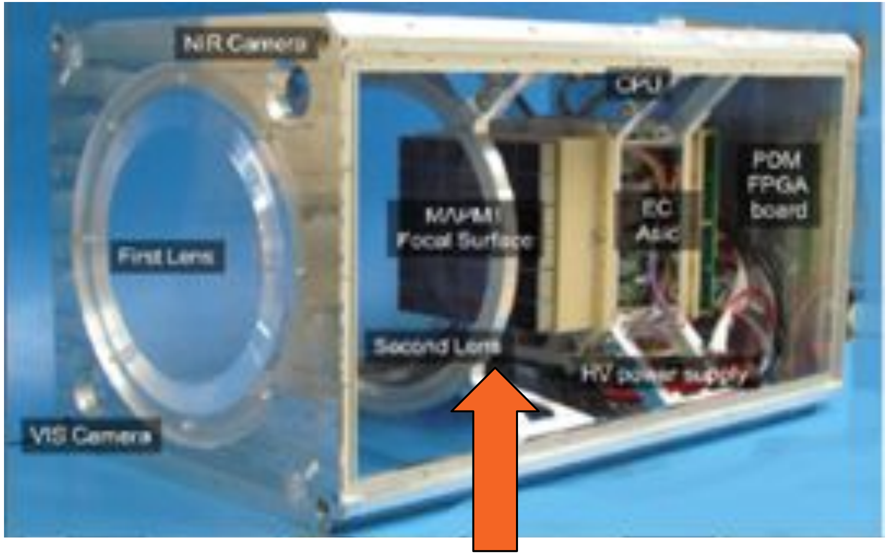


Joint Experiment Mission for Extreme Universe Space Observatory

- Scientific research for Extreme Energy Cosmic Ray (EECR) detection
- Observation of meteors, space debris, atmospheric events...

Mini-EUSO telescope :

On board of the International Space Station
Observing in the UV range



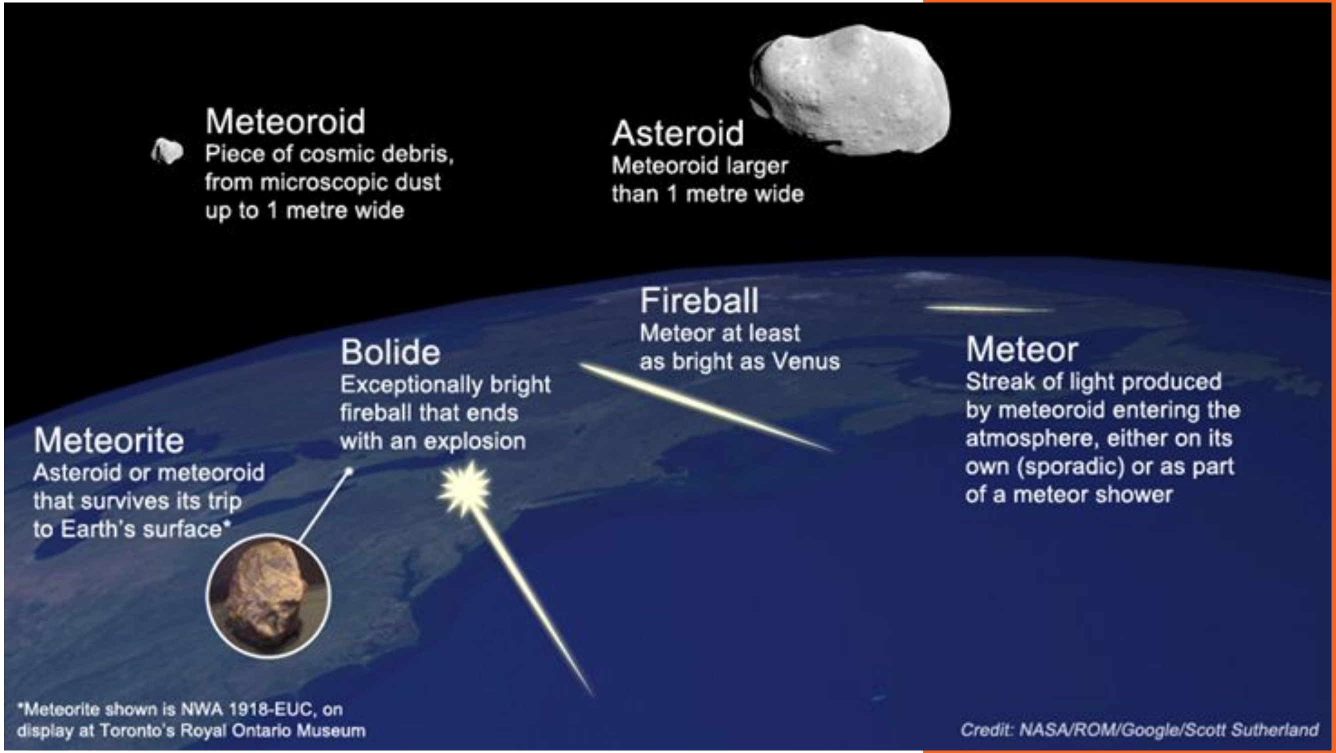
Multiwavelength Imaging New Instrument for Extreme Universe Space Observatory

- Measurement of UV emissions in the atmosphere and from ground sources

- 3 main sub-systems :
  - ❖ Fresnel-based system
  - ❖ Photo-Detector Module (PDM)
  - ❖ Data acquisition system

Mini-EUSO works with a 48 x 48 pixels matrix (PMD), considered independent with a field of view ~ 4.2km at 100 km (altitude of the meteors).

Common Meteors :



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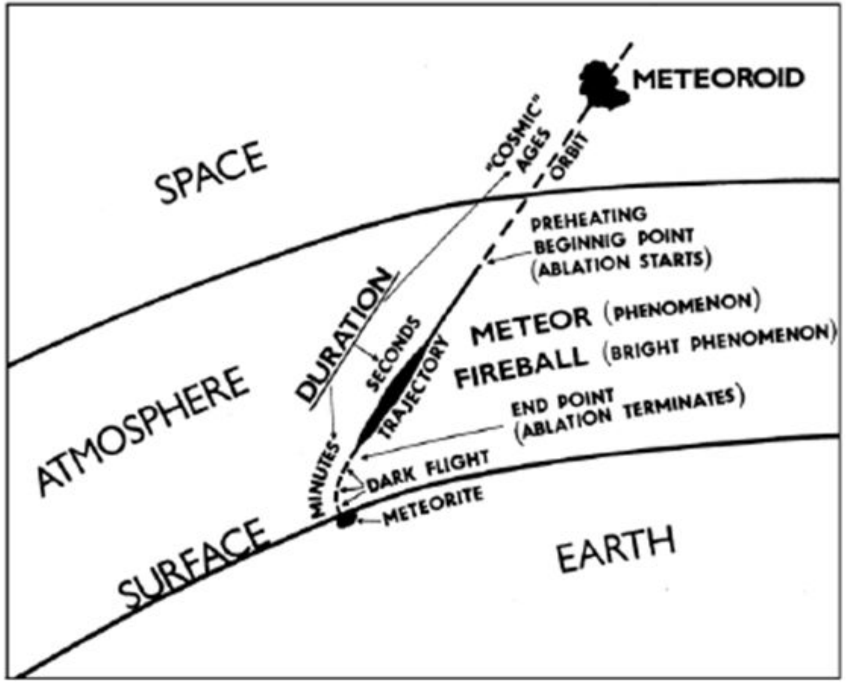
Hight speed events

Common Meteors :



Characteristics :

- Entry velocity : 11 - 72 km/s
- Ionization of elements + black body radiation = Light emission
- Possible phenomena : fragmentation and/or flares

Nuclearites :

up
down
strange

Nuclearites
=
Particles made of quarks up, down, strange
=
High speed atmospheric event
=
Hypothesized as possible macroscopic dark matter

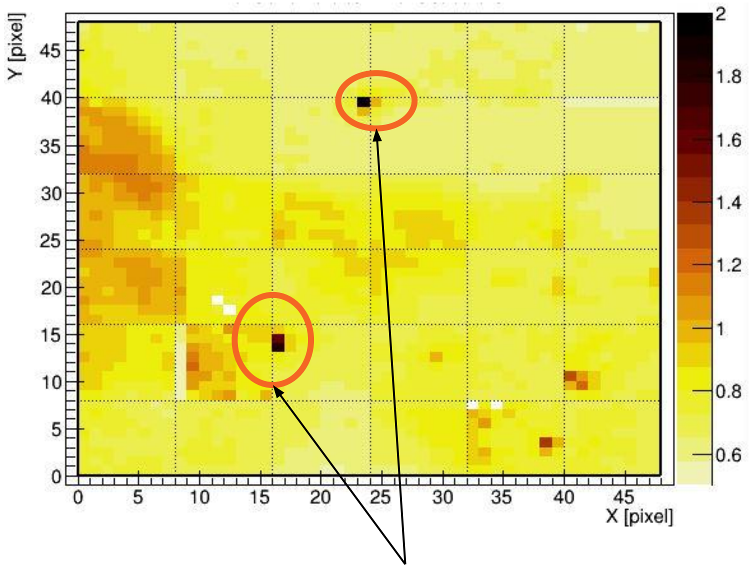
Characteristics :

- Entry velocity : >72 km/s
- Emit black body radiation
- Never seen yet

Prospects for macroscopic dark matter detection at space-based and suborbital experiments, Luis A. Anchordoqui et al, 2021, Europhysics Letters

Meteor trigger algorithm

Mini-EUSO datas :



Potentiel meteors

• The light takes ~ 20 µs to cross one pixel.

• Pixel signal is integrated over 8 consecutive Gate Time Units (1 GTU = 2.5 µs).

• The ground-level is determined by averaging over 128 GTU.

• If the signal is 16 σ over the background the event is triggered

Three different types of data acquisition stored :
• D1: 2.5 µs, timescale for EECR-like events.
• D2: 320 µs, timescale for fast atmospheric events.
• D3: 40.96 ms, 128 times D2.

Meteor trigger algorithm

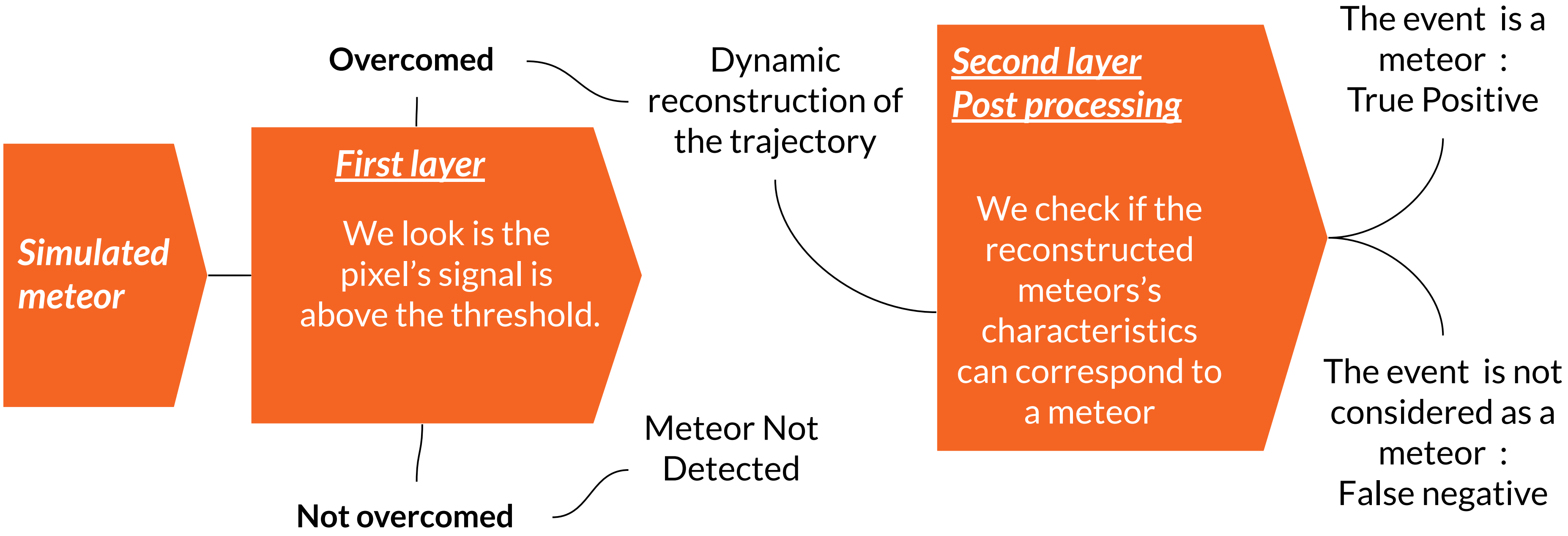
We simulate on IDL (Interactive Data Language), meteors with specific velocity and magnitude to check the trigger efficiency.

- Goal : developing an offline trigger logic to detect meteors to be possibly applied in the future JEM-EUSO missions
- The trigger tracks over-threshold pixels.
- We are testing it offline on Mini-EUSO datas

Meteor simulation

- ❖ The infinite speed (v_inf, in km/s) is the meteor's speed at the infinite distance. We will do the test with the ranges :
  - v_inf = [15., 20., 30., 40., 50., 60., 70.], corresponding to the common speed meteors
  - v_inf = [80., 100., 120., 140., 160.], corresponding to the high speed meteors
- ❖ The highest magnitude we attribute is 6 because it corresponded to a fainted event. The magnitudes will be :
  - mag = [0. , 2. , 4.]

The trigger is composed of 2 layers :



For this simulations, we generated 50 meteors for each speed and each magnitude :

so 50x12x3 = 1 800 meteor simulated

Quick explanation for the trigger analysis :

The trigger scan **neighbour pixels** to **reconstruct** the entire meteor track.

For each pixel : automatic gaussian fit + polynomial background on the light curve

At the end, we retrieve **relevant physical parameters** but we will only use the **projected velocity** for the analysis

We retrieve : duration, azimuth, horizontal speed and magnitude

Passing through the trigger, the simulated meteor lead to 3 possible analysis results

True positive (T_pos)

The simulated meteor is detected in the first layer and considered as a real meteor, regarding the reconstructed trajectory by the second layer.

False negative (F_neg)

The simulated meteor is detected but not considered as a meteor after the second layer.

Not detected (ND)

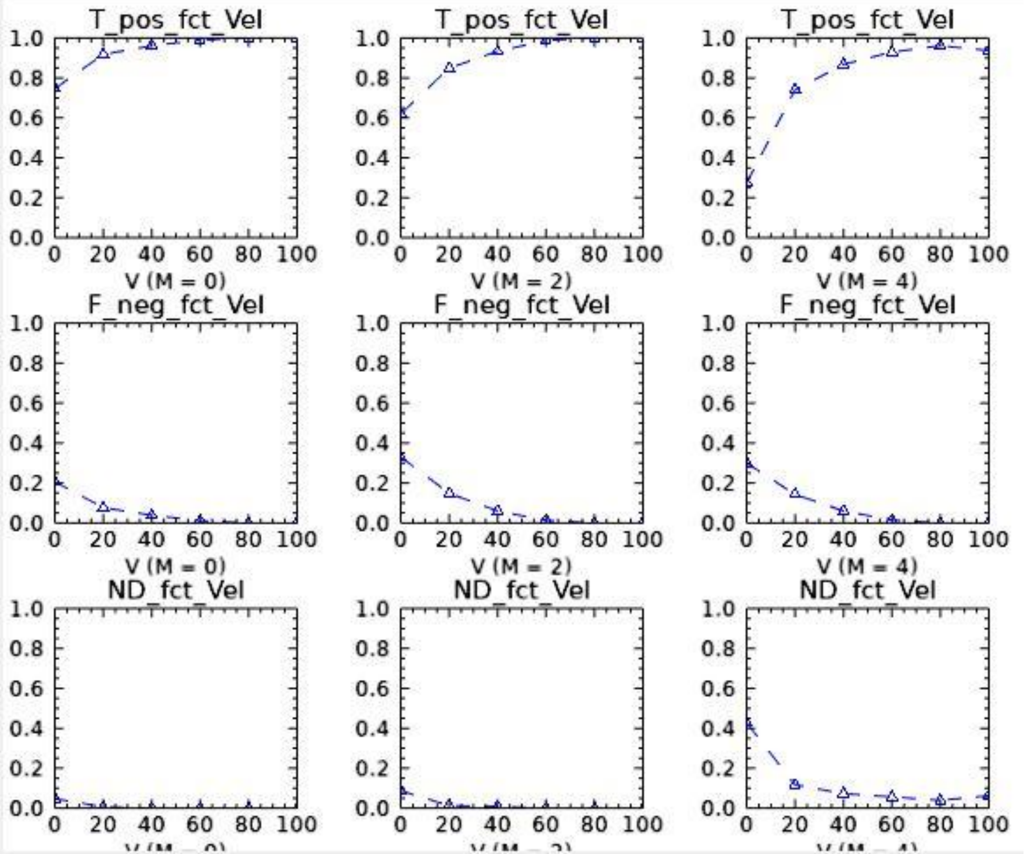
The simulated meteor's signal do not overcome the threshold, so the meteor is not detected from the first layer.

Meteors’ common speed results :

Here is the ratio of the meteor associated to each category (T_pos,F_neg, ND) in function of the reconstructed velocity.

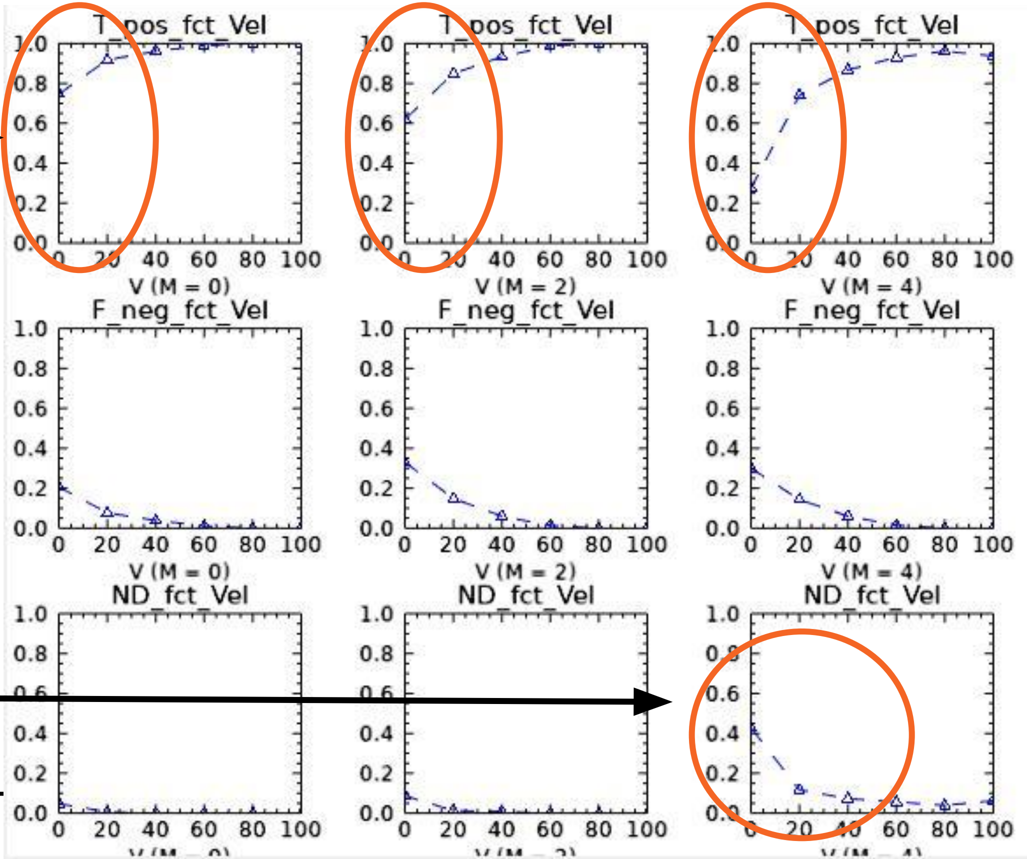
The speeds start from 0 and go to 100 km/s because the reconstructed velocity is a random speed always lower than the real speed because it is a projected one and we have practically no horizontal meteors.

Each column is associated to a magnitude.



Meteors’ common speed results :

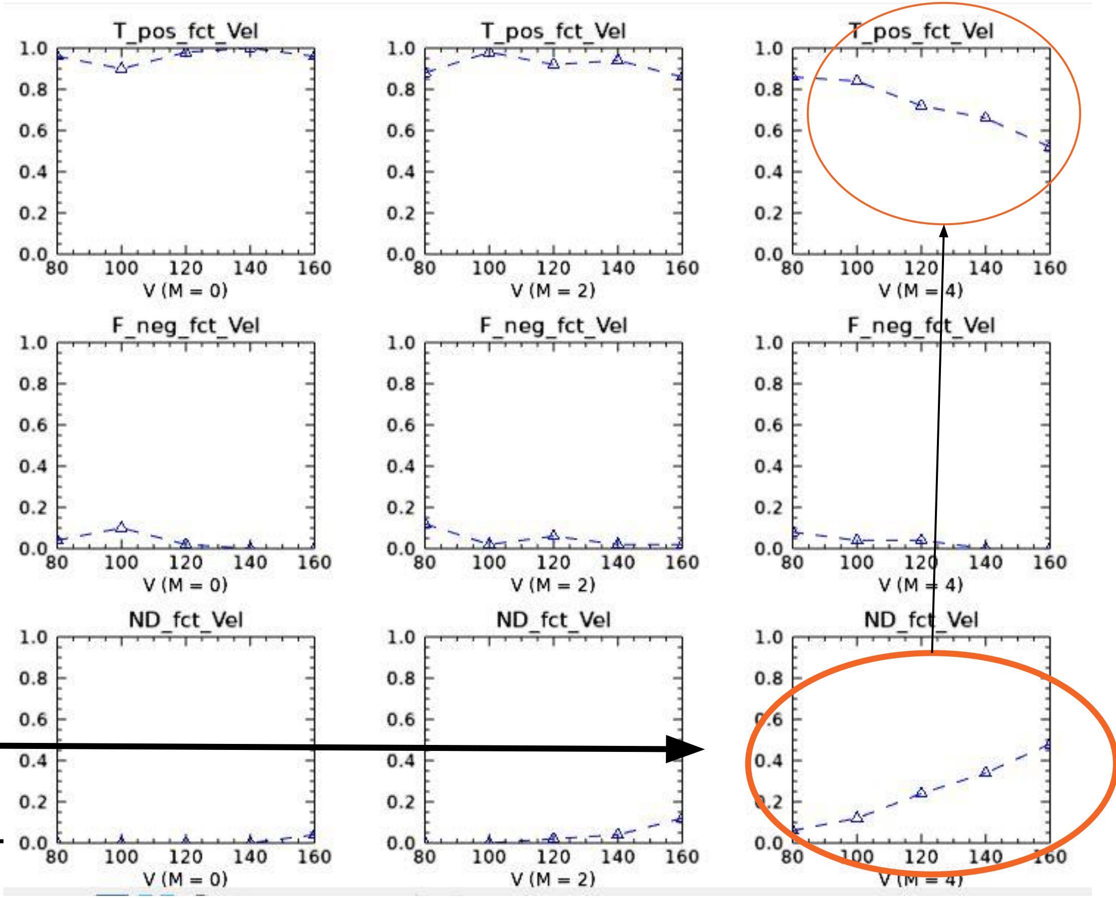
Low speed
=
Low efficiency
=
The signal lead to a stationary pixel that can be interpreted as noise.
Meteors are saw as fainted events



High magnitude
=
more not detected events

High speed meteors results :

For high speed meteors with magnitudes 0 and 2, most of the meteors are detected .



We can see that for the magnitude 4, the number of ND events increase.

Results :

The trigger has an efficiency higher then 80 % for speeds from 20 km/s to 160 km/s for all the magnitudes, except for mag = 4 for high velocities.

This low speed + high magnitude generate pixels that are not very bright over very short times which can be considered as noise.

Resume of the steps :

1. The first part of the work was to study and understand the characteristics of the meteors and the nuclearites.

2. Then I had to learn how to use the IDL programation and modify the pre-existing code to create a loop to simulate the meteors.

3. I had to analysis the plots of the number of meteors detected or not by the trigger. From them, we get the trigger efficiency.

4. Then, we will have to understand why we do not detect all the events and find the way to improve the trigger efficiency

Thank you for your attention

Thanks to professor Mr Bertaina and Dario Barghini and the other researchers for their support during this stage

Barghini_2021_EPSC_slides.pdf

Tesi-Rodrigues.pdf

Anchordoqui_2021_arXiv.pdf