

Hough transform ESAF implementation

*J. Vasilko, M. Vrabel, E. Gajdoš, P. Bobik (bobik@saske.sk), B. Pastirčák
& Ke group*

15th International Meeting of the JEM-EUSO Collaboration
Palermo, Italy, 9. - 13. june 2014



- Hough method was applied and tested on fake pattern recognition/characterisation
- Different signal discrimination than for showers
- Conclusive results, moving with method to showers recognition
- First results from shower recognition (early phase of application to ESAF)
 - to discuss some problems



Signal discrimination for fake patterns characteristics determination

- So called **Summation method** used for 2D pattern reco (see E. Gajdos, JEM-EUSO general meeting, Tokio 2013 presentation)

Delete background condition

- If $pixel_{value} \leq 3$ then $pixel_{value} = 0$

Delete/reduce background from signal condition

- If $pixel_{value} > 3$ then $pixel_{value} = pixel_{value} - 2$
 $++number_{reduced\ pixel}$

Pattern recognition matrix $M36(i, j) = \frac{\sum_{k=1}^{31} pixel_{value}(i, j)}{number_{reduced\ pixels}(i, j)}$

Hough method

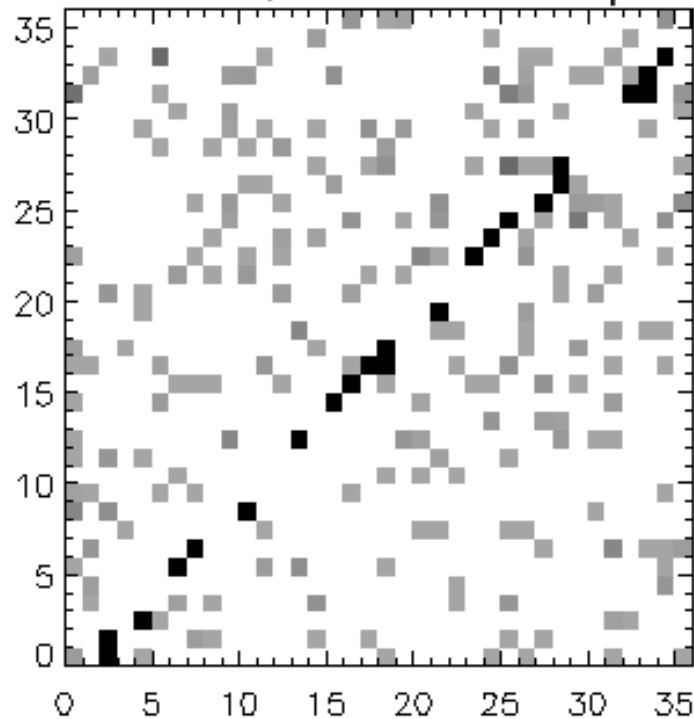
not continuous patterns / M36

Hough method parameters – not continuous patterns

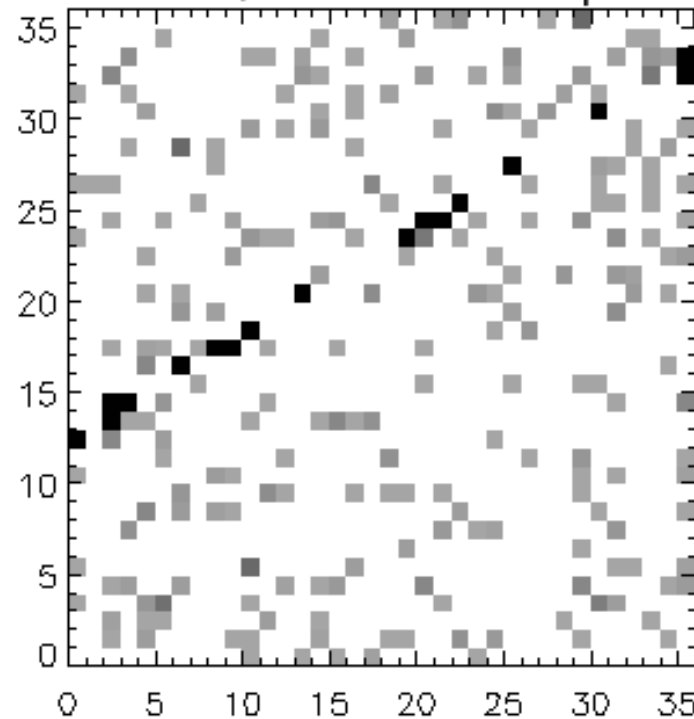
Number of directions **M**

Hough space division i.e. space element **dr = pixel_length / 2**

72 directions / not continuous pattern



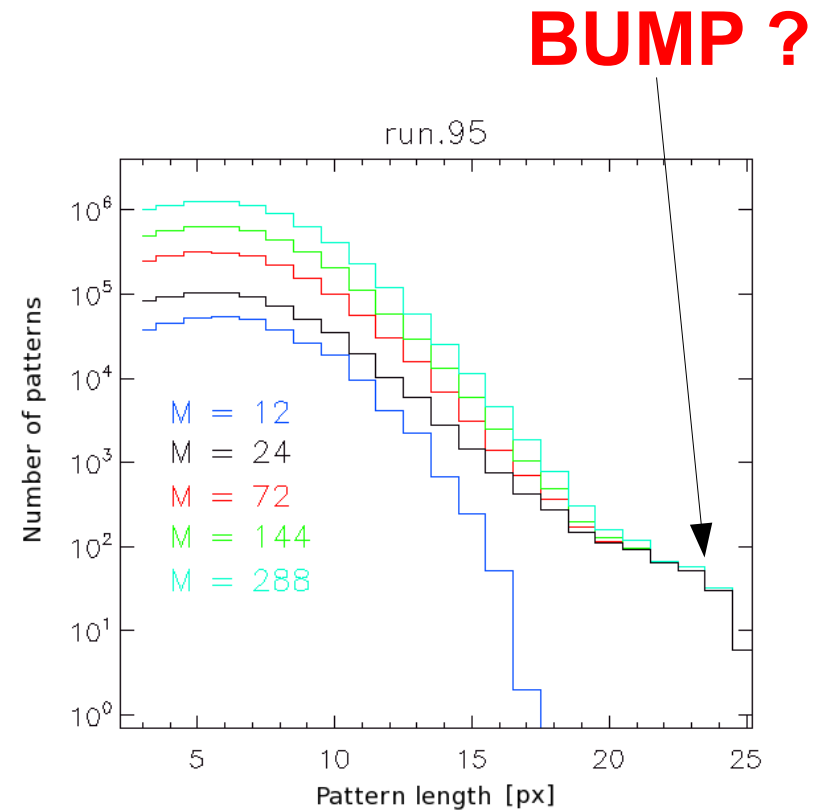
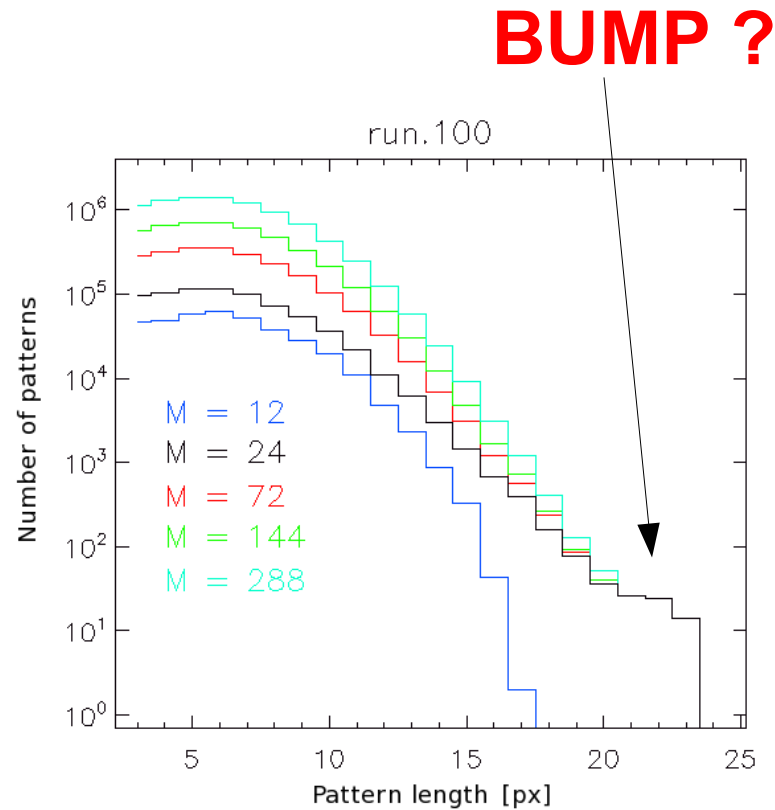
12 directions / not continuous pattern



“Summation method” + condition $T_{px} \geq 3$ i.e. pixel threshold ≥ 5 for noise + “shower” signal on M36

Hough method

not continuous patterns / M36

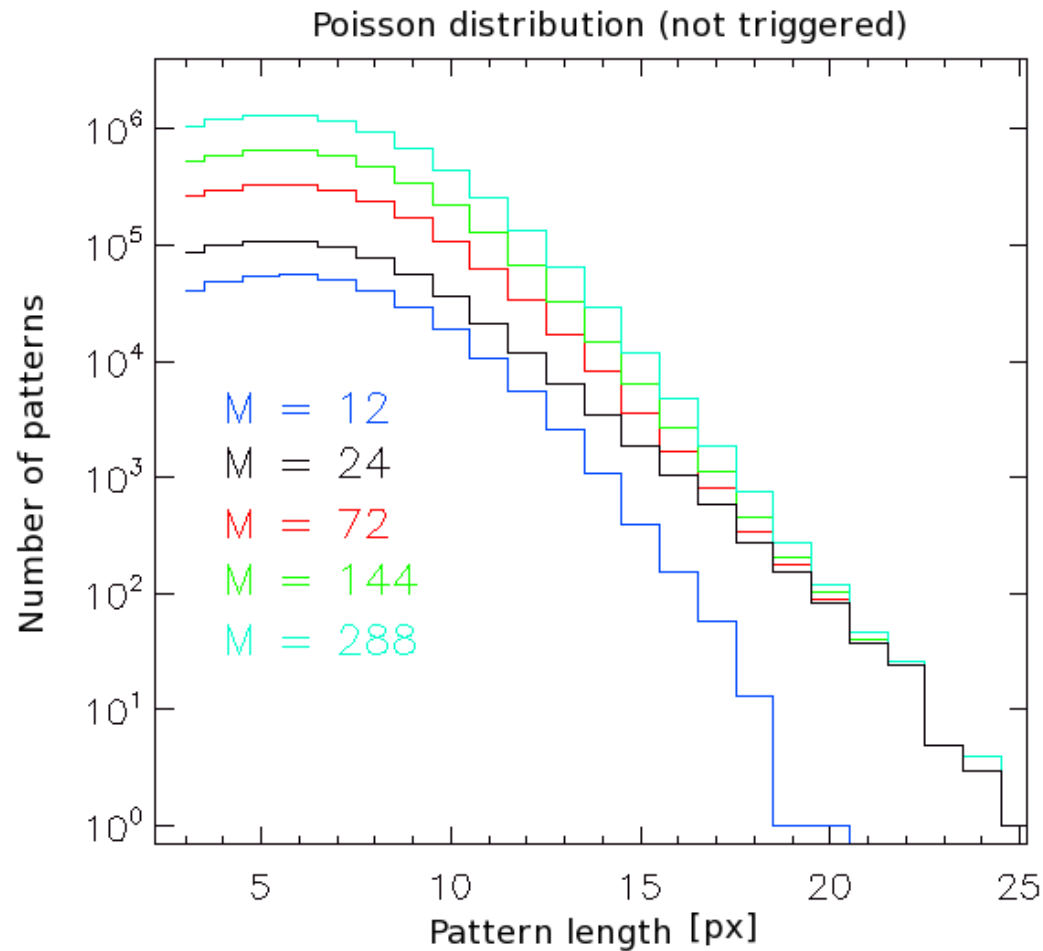


Two runs analysis, one run is 10^9 GTU = 2500 seconds, triggered ~two thousands events

$$dr = \text{pixel_length} / 2$$

Hough method

not continuous patterns / M36

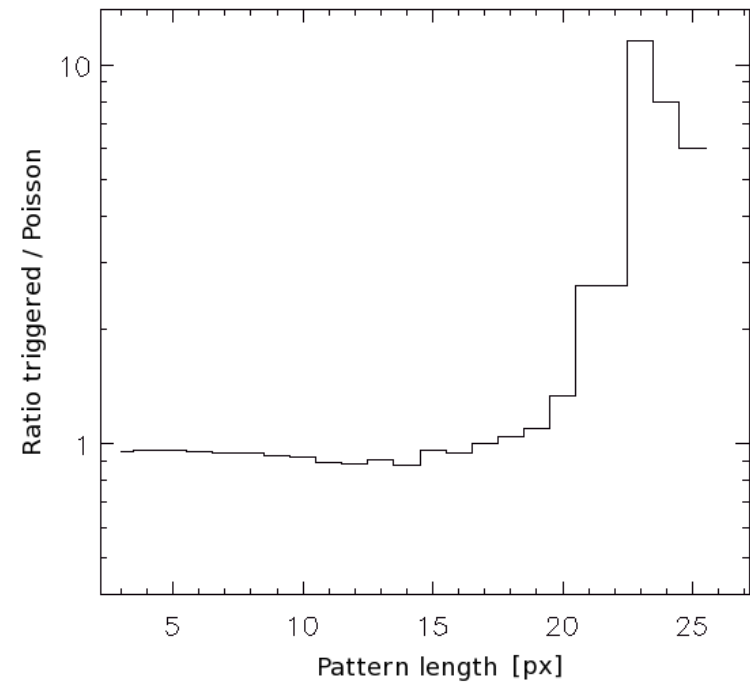
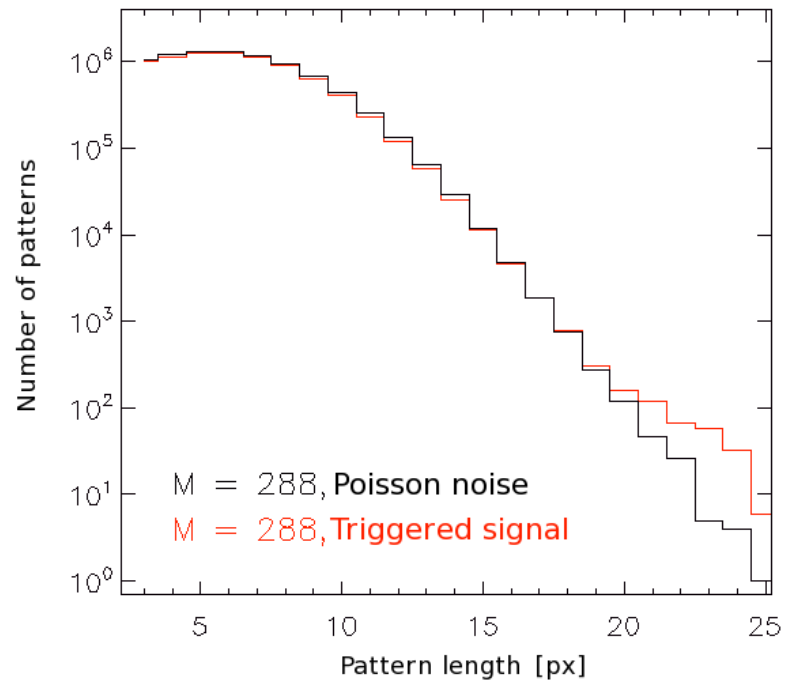


Two thousands generated events (i.e. 62 000 GTU) with Poisson noise analysis

$$dr = \text{pixel_length} / 2$$

Hough method

not continuous patterns / M36



Poisson noise analysis vs. triggered events analysis. Clearly visible sign of trigger scheme.

$$dr = \text{pixel_length} / 2$$

Hough method

continuous patterns / M36

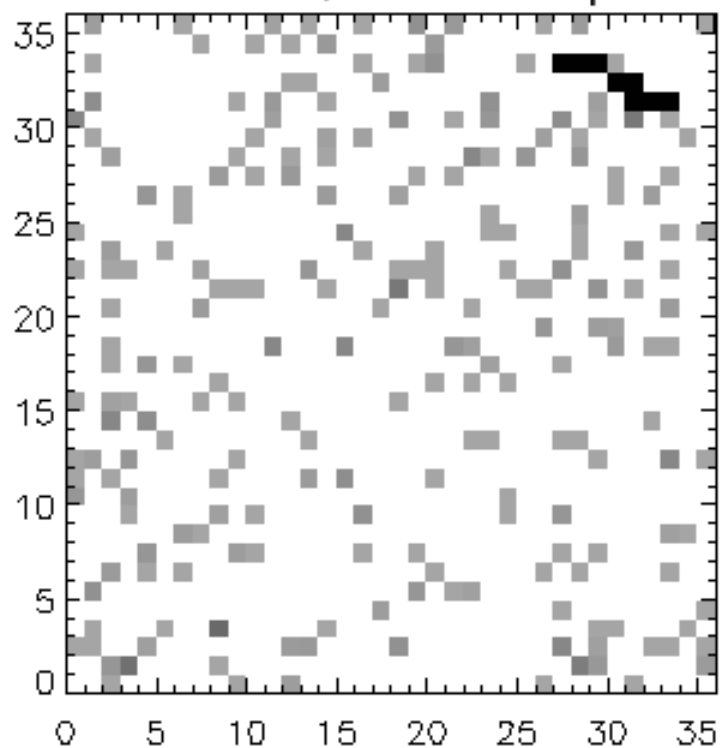
Hough method parameters – continuous patterns

Number of directions **M**

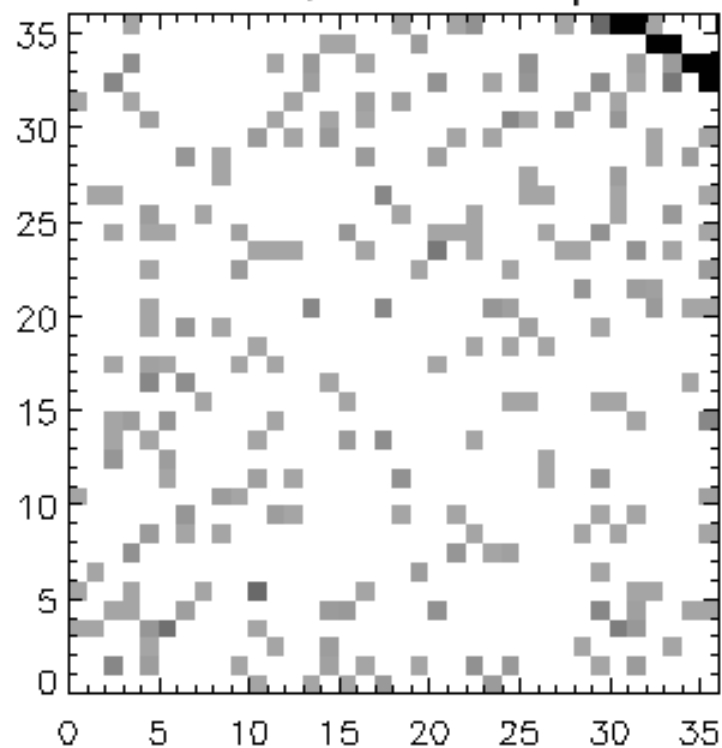
Hough space division i.e. space element **dr = pixel_length / 2**

Pattern continuity condition : **pixel centers max. distance < sqrt(2.0)**

72 directions / continuous pattern

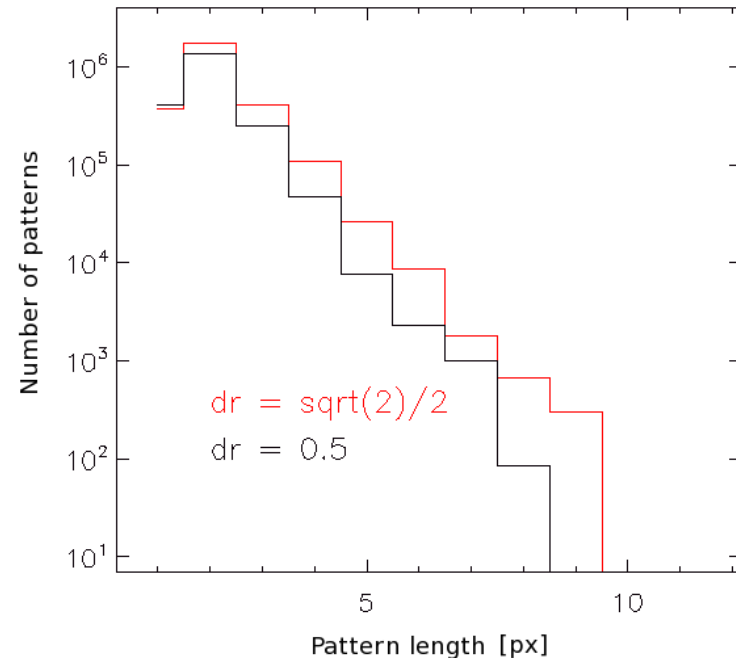
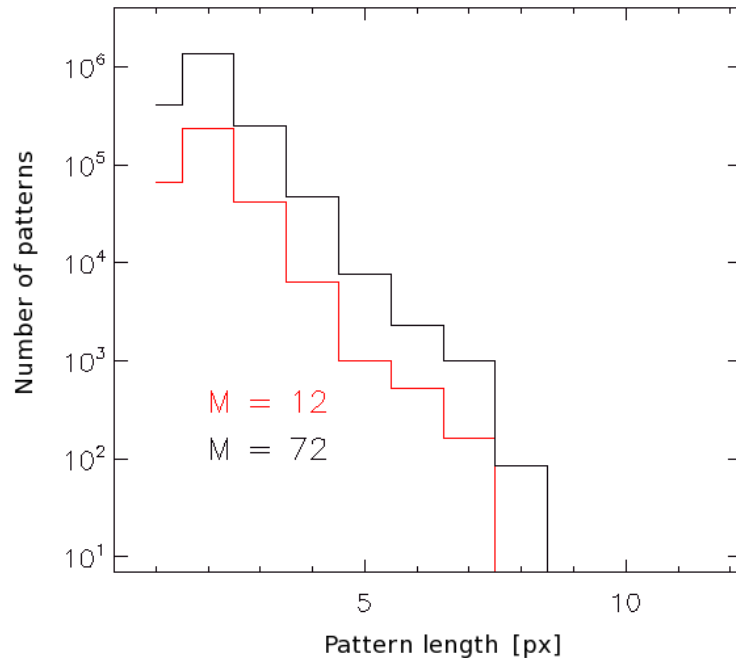


12 directions / continuous pattern



Hough method

continuous patterns / M36

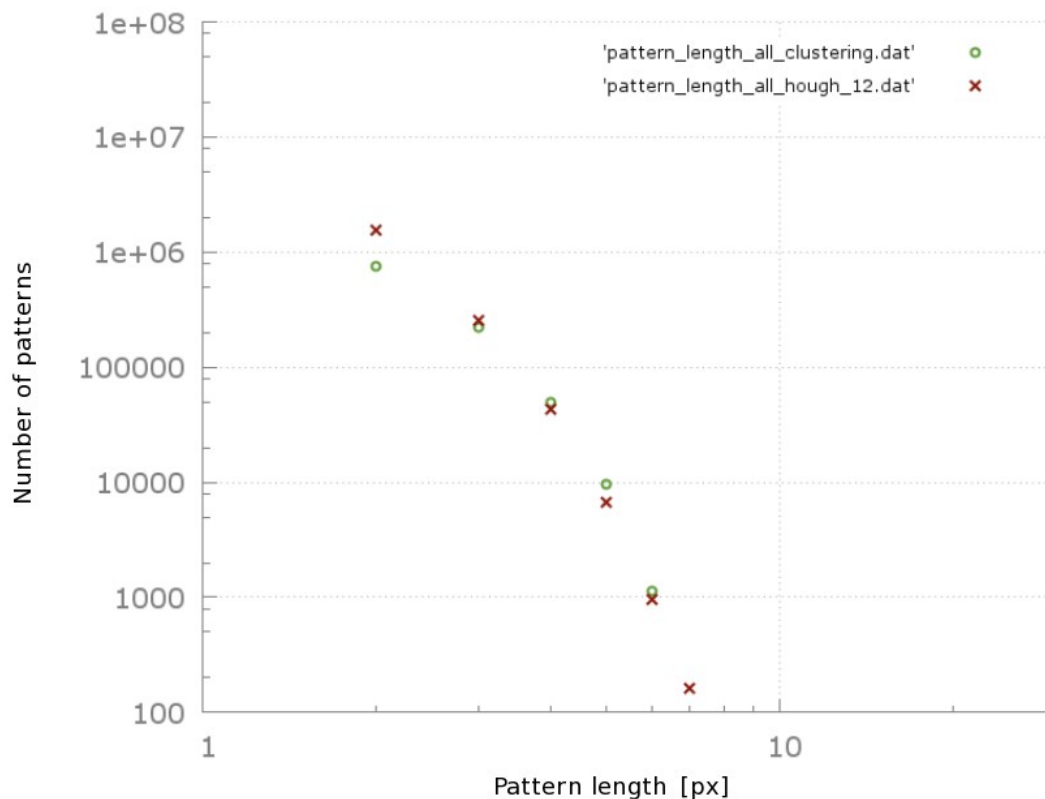


Two runs analysis, one run is 10^9 GTU = 2500 seconds, triggered ~two thousands events for $M = 12$ vs. $M = 72$, and $dr = \text{pixel_length} / 2$ vs. $dr = \sqrt{2 * \text{pixel_length}} / 2$

Results depend on pattern definition

Hough method vs. Clustering method

- E. Gajdos diploma work 2014, Clustering and Hough methods



Clustering and Hough gives basically same results. Similarity depend on patterns definition in both methods.

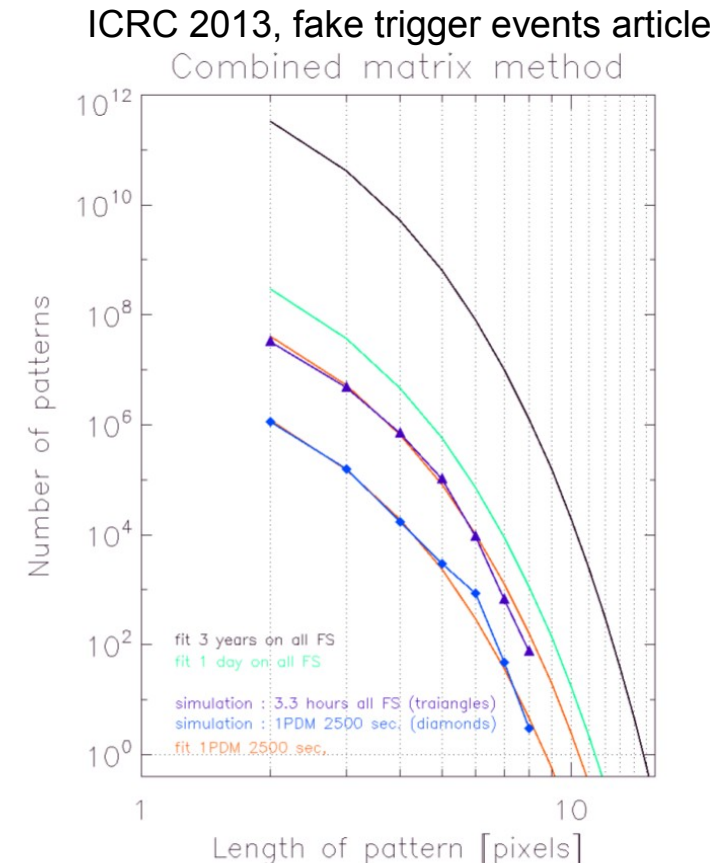


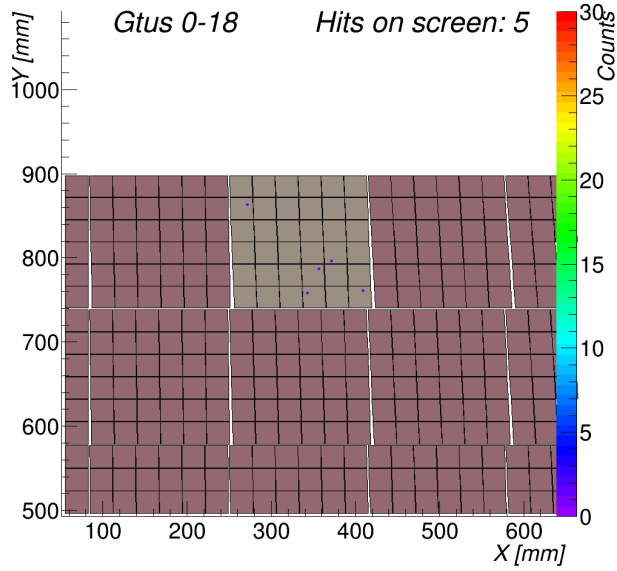
Fig. 5: Approximation to longer time periods of measurements for dependences the numbers of recognized patterns on their lengths

Fake triggers - Concluded

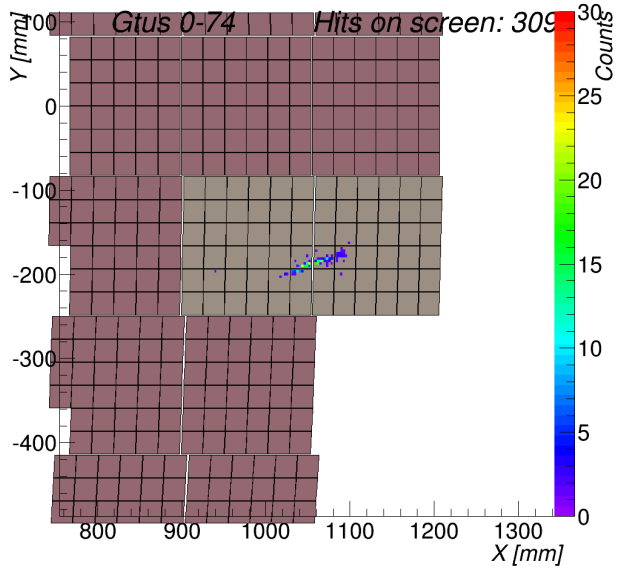
New starting activity – pattern recognition on showers

- Jozef Vasilko and Michal Vrabel, diploma students from Technical University in Kosice working on Hough method application to showers and method implementation to ESAF
- Dominik Imro, bachelor student at University of Pavol Jozef Safarik in Kosice, working on RANSAC method application to shower reconstruction (not described in this presentation)

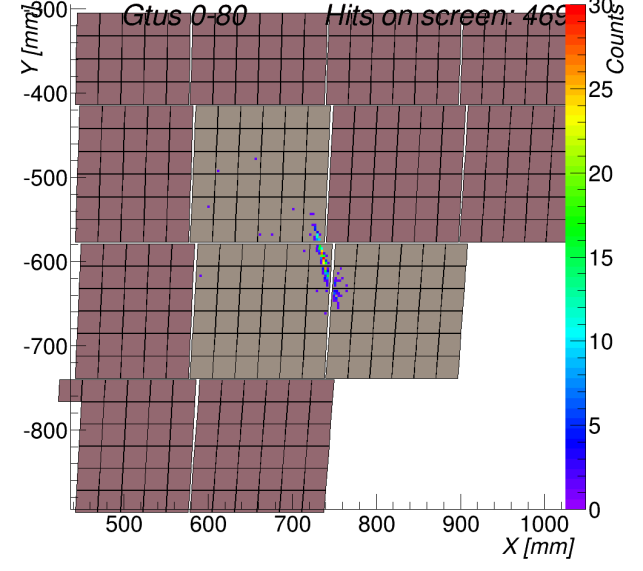
Event 0



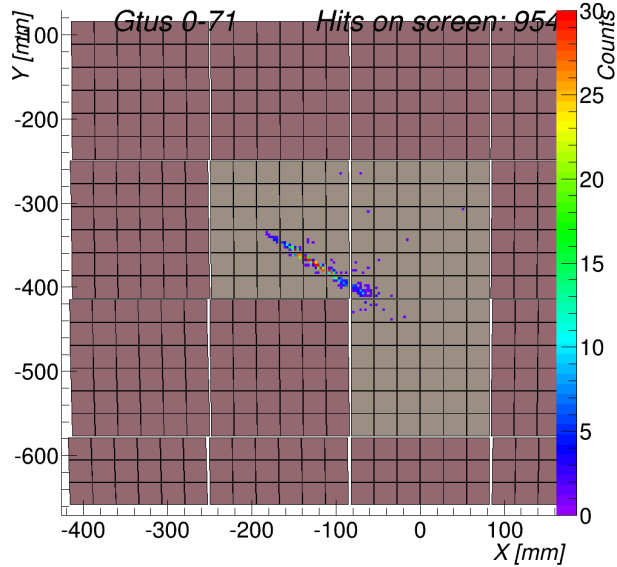
Event 2



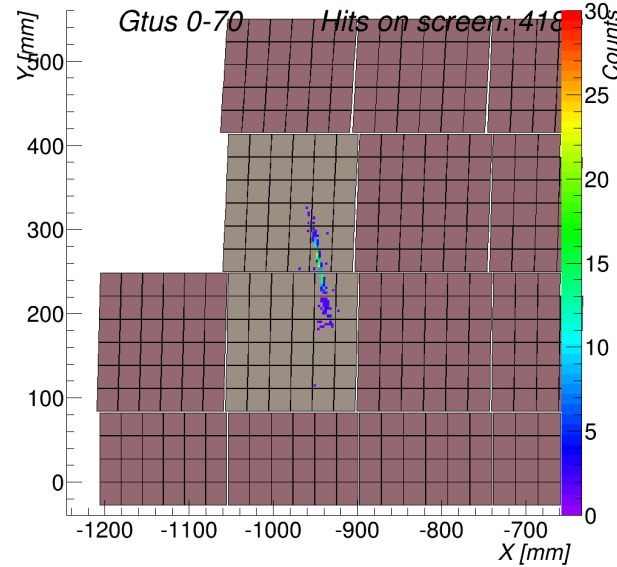
Event 3



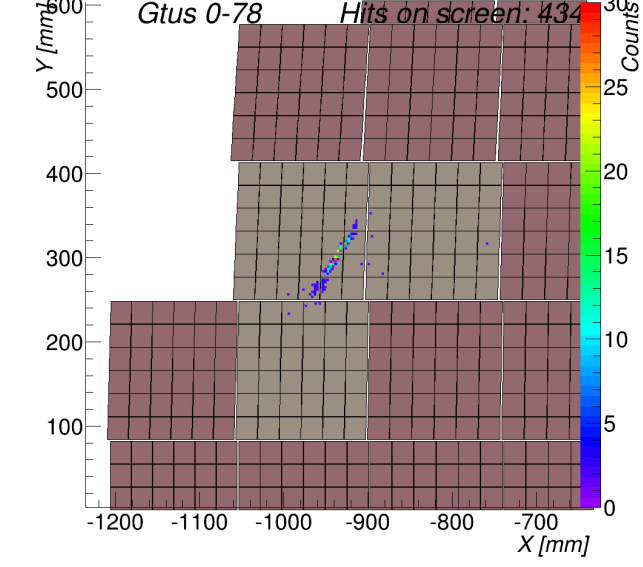
Event 4



Event 5

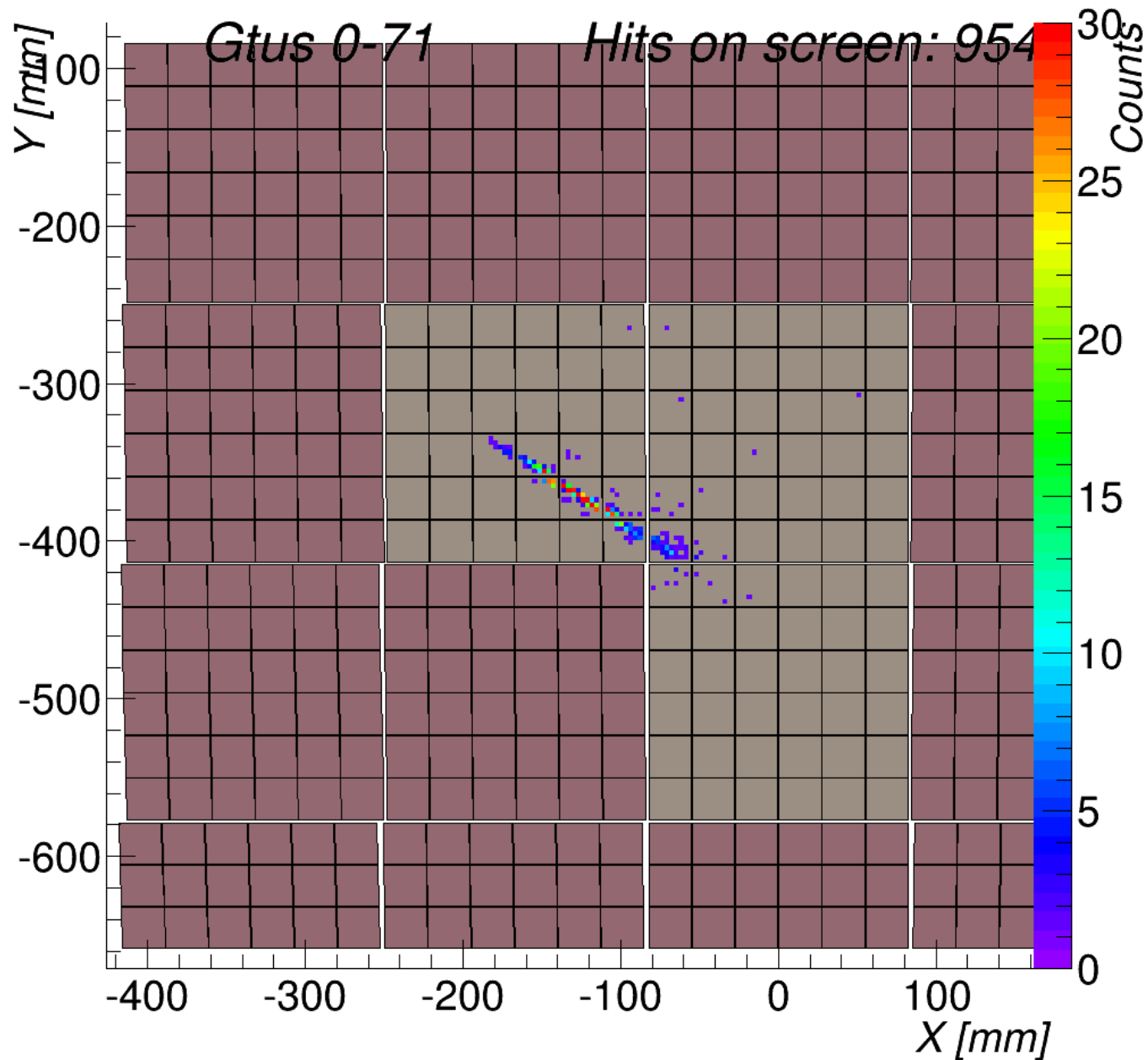


Event 6



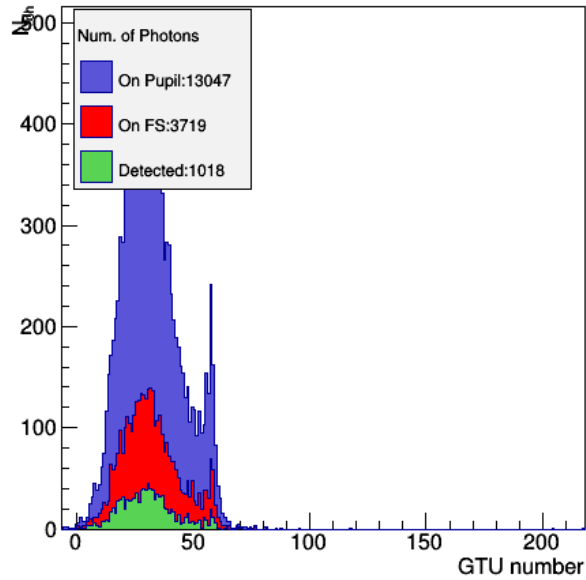
Examples of generated events

Event 4 : Energy = 1.00×10^{14} MeV, theta= 60.98 deg
varphi = 321.91 deg, $X_1 = 47.47$ g/cm², $X_{\max} = 892.47$ g/cm²

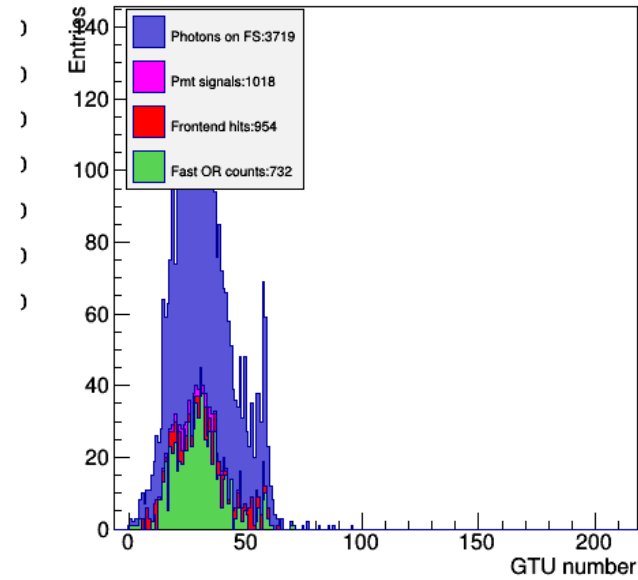


Event 4 : Energy = $1.00e+14$ MeV, theta= 60.98 deg
varphi = 321.91 deg, $X_1=47.47$ g/cm², $X_{max}=892.47$ g/cm²

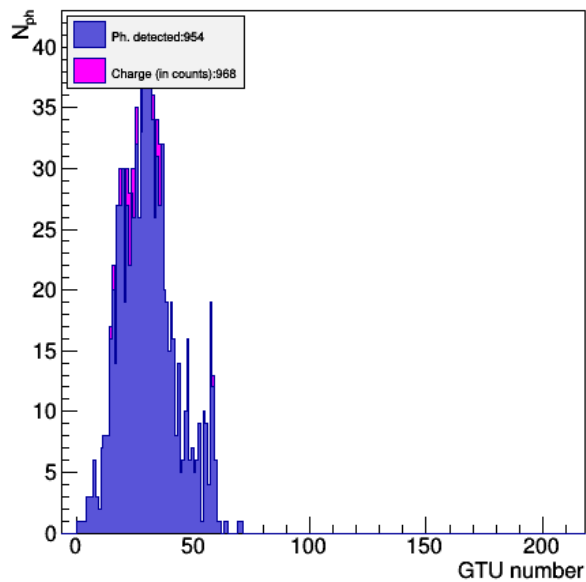
Photons vs GTU



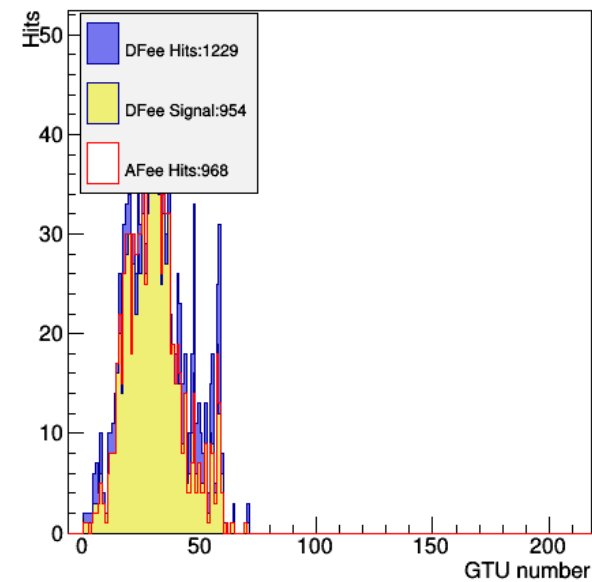
Photons vs GTU



Charge vs GTU

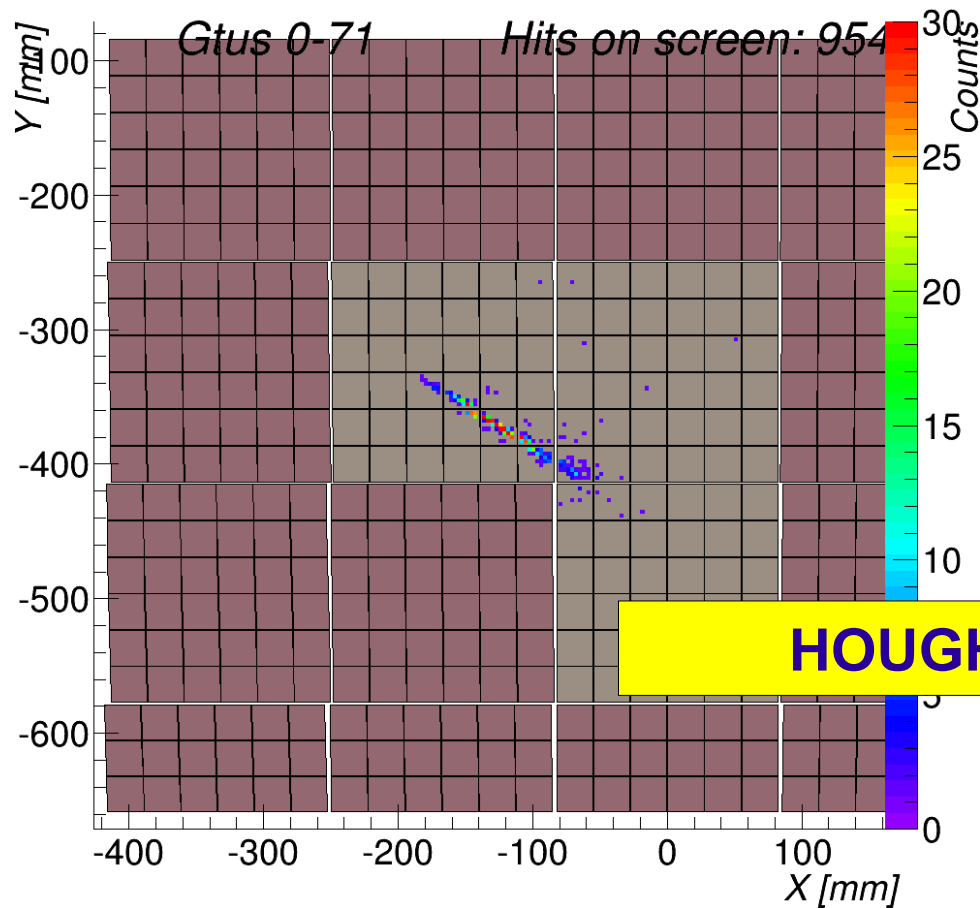


FrontEnd Hits

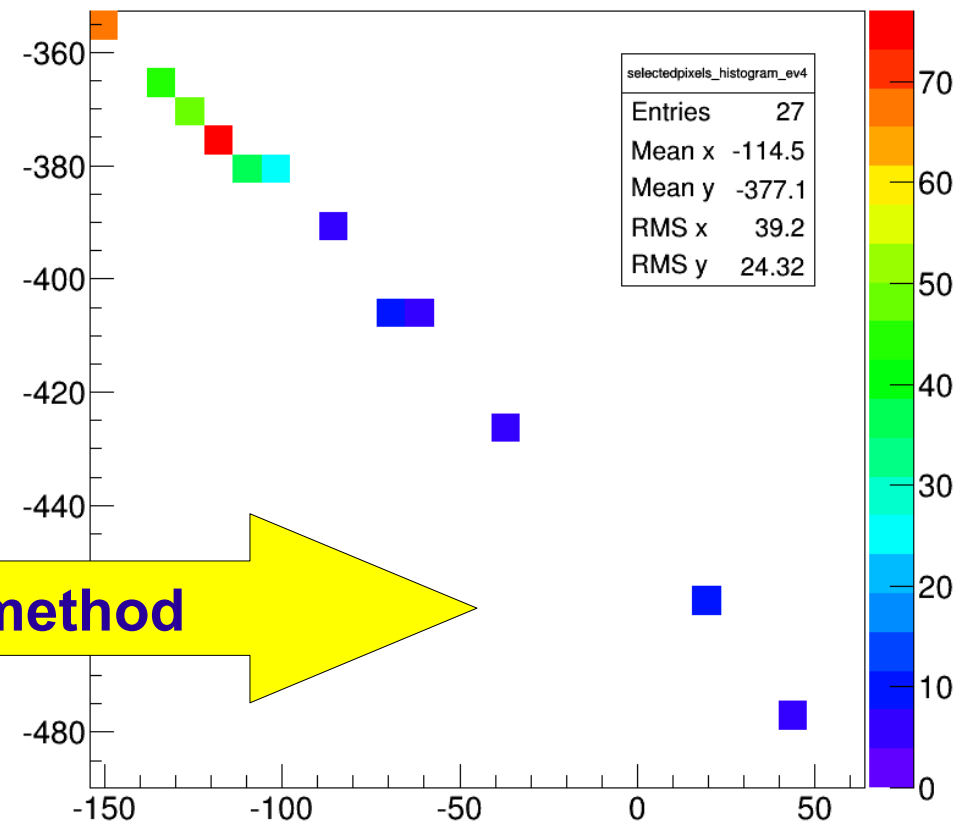


Event 4 : Energy = $1.00e+14$ MeV, theta= 60.98 deg
varphi = 321.91 deg, $X_1=47.47$ g/cm², $X_{\max}=892.47$ g/cm²

Reconstructed event

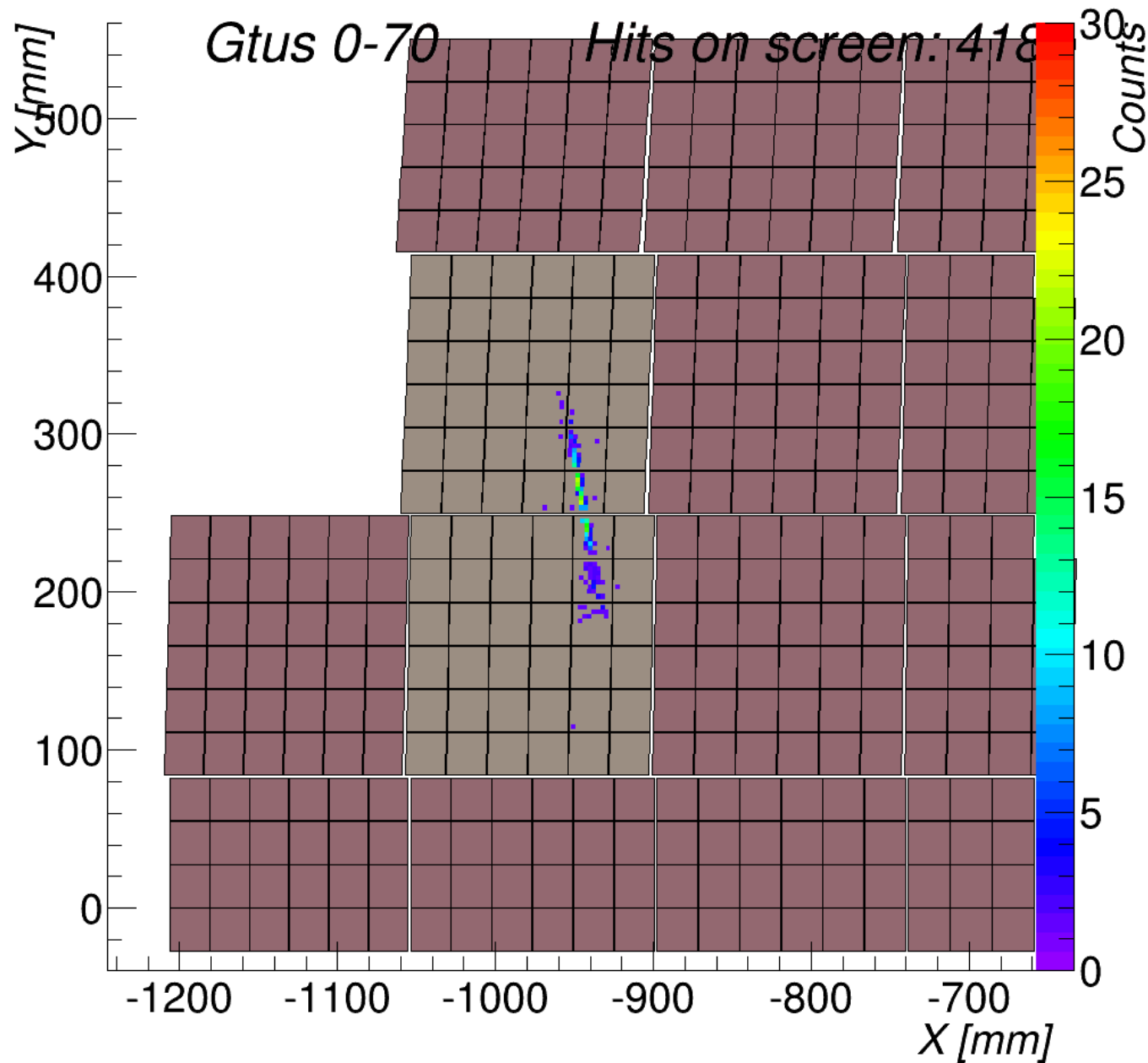


Selected pixels histogram event 4

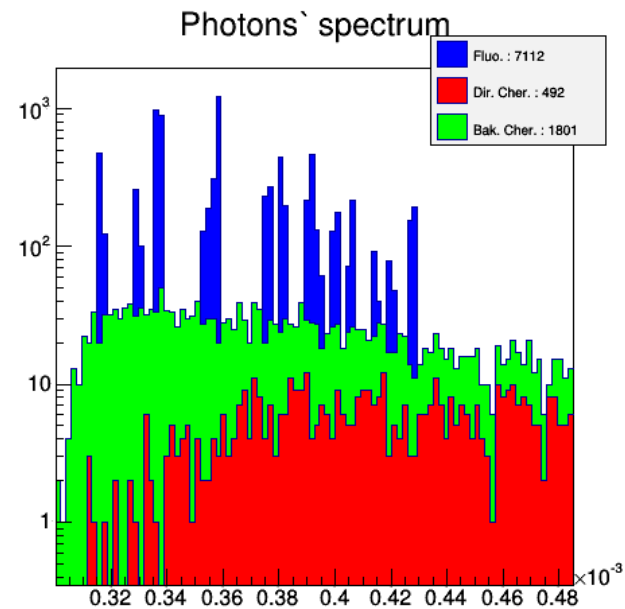
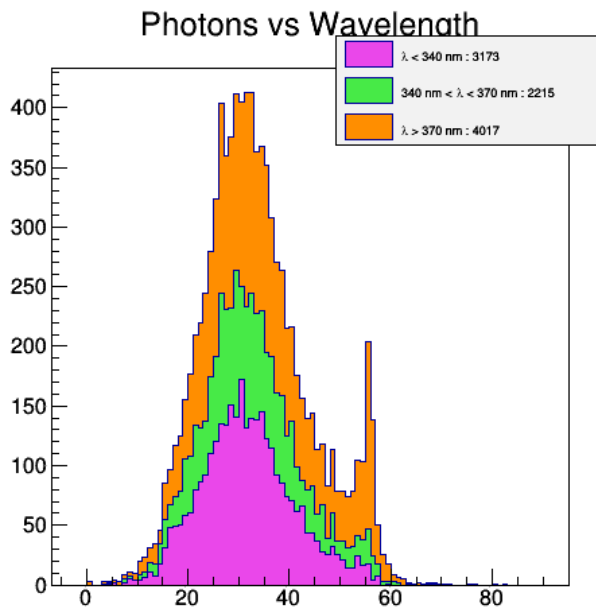
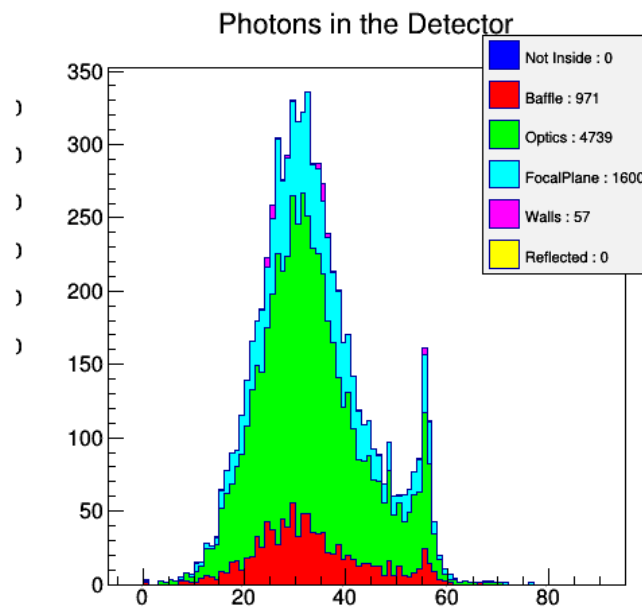
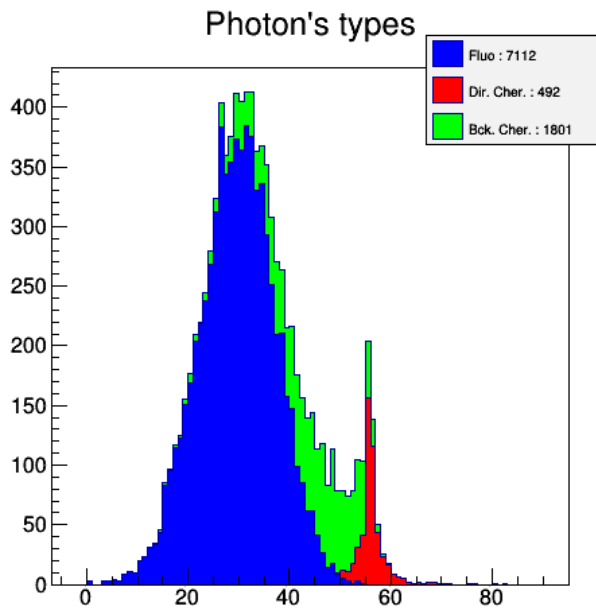


RECO: Event 4 : Energy: $1e+14$, Theta=62.20deg, Phi=322.63deg,
 $X_1 = 47.47$, $X_{\max} = 892.47$, Hmax = $6.97e+06$

Event 5, Energy 1.00×10^{14} MeV, $\theta = 60.17$ deg,
 $\varphi = 271.33$ deg, $X_1 = 7.51$ g/cm², $X_{\max} = 852.51$ g/cm²

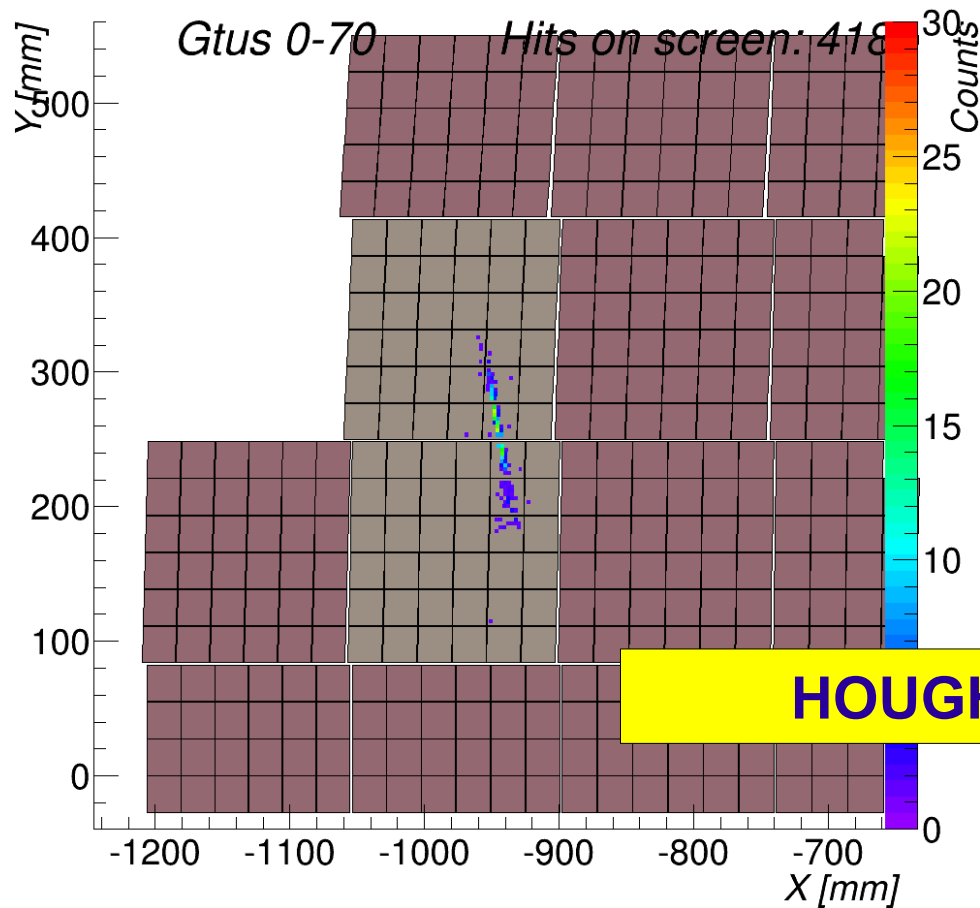


Event 5, Energy $1.00e+14$ MeV, $\theta=60.17$ deg,
 $\varphi=271.33$ deg, $X_1=7.51$ g/cm², $X_{\max}=852.51$ g/cm²

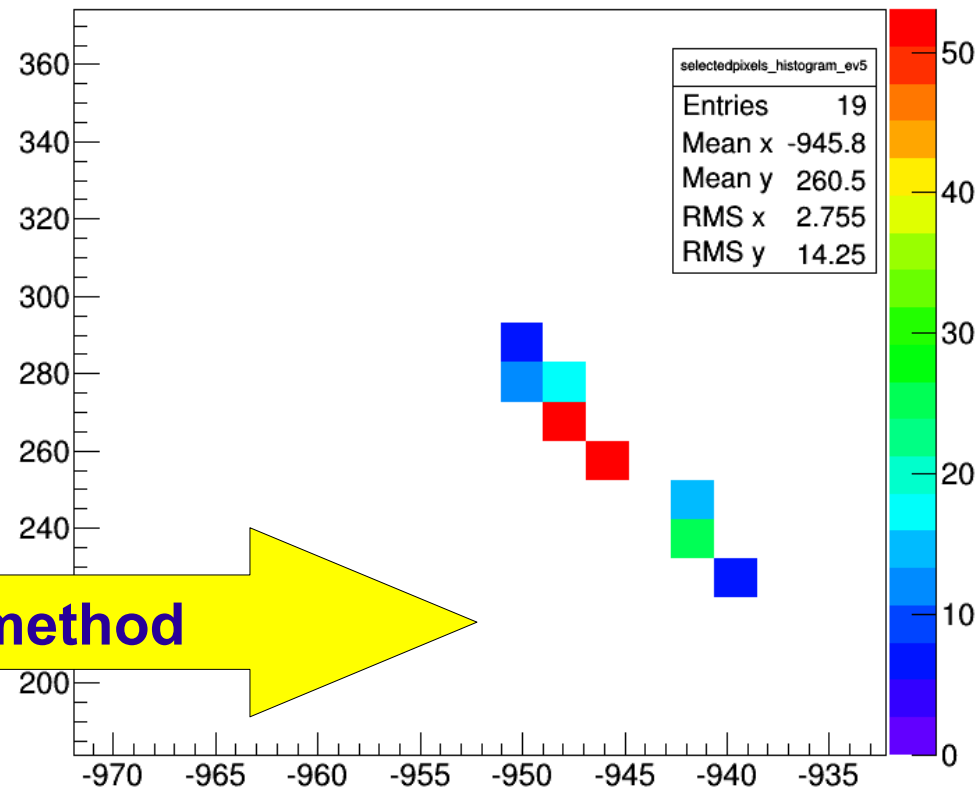


Event 5, Energy $1.00e+14$ MeV, $\theta=60.17$ deg,
 $\varphi=271.33$ deg, $X_1=7.51$ g/cm², $X_{\max}=852.51$ g/cm²

Reconstructed event



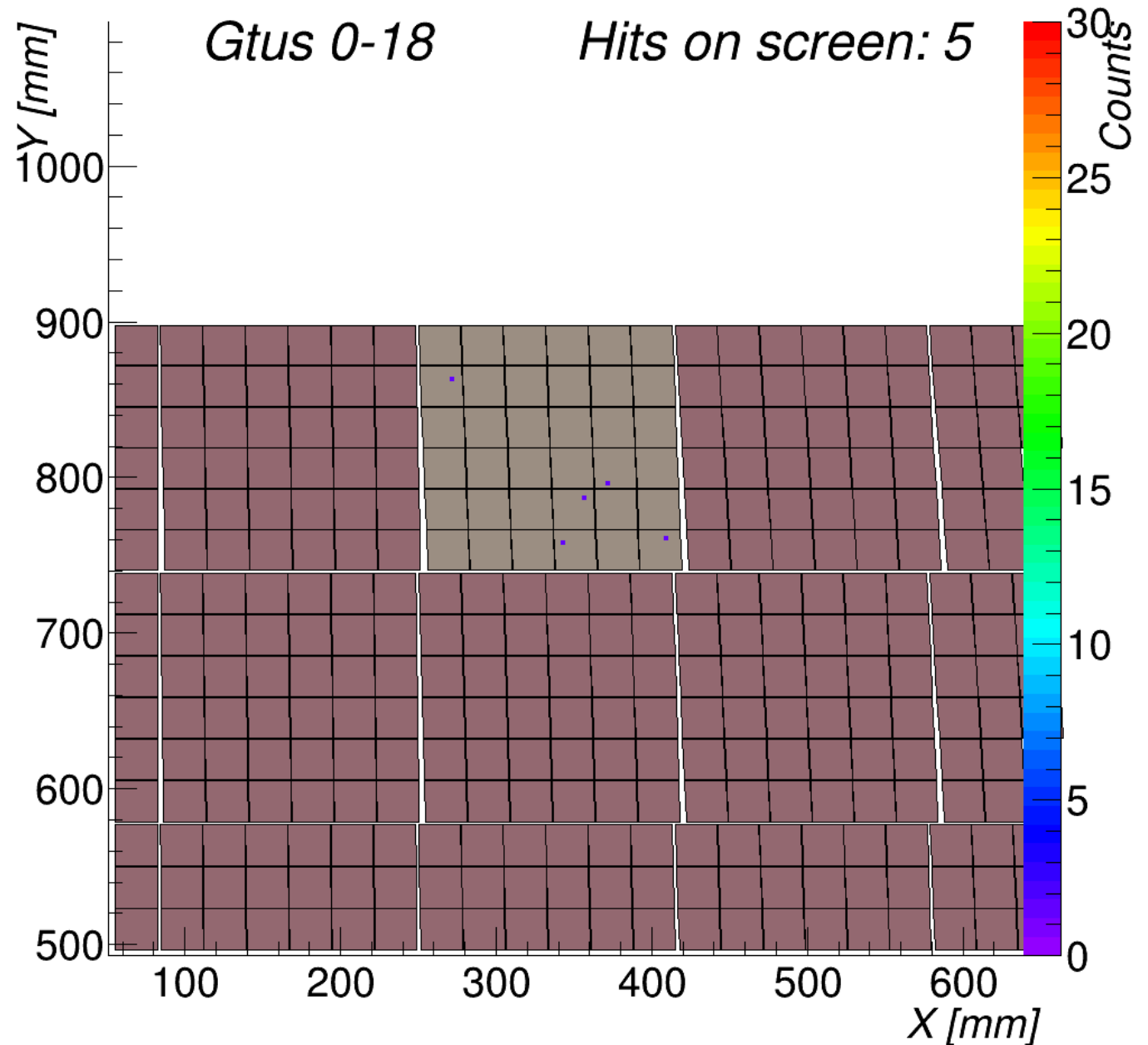
Selected pixels histogram event 5



RECO: Event 5, Energy: $1e+14$, $\theta=59.54$ deg, $\phi=271.44$ deg,
 $X_1=7.51$, $X_{\max}=852.51$, $H_{\max}=6.97e+06$

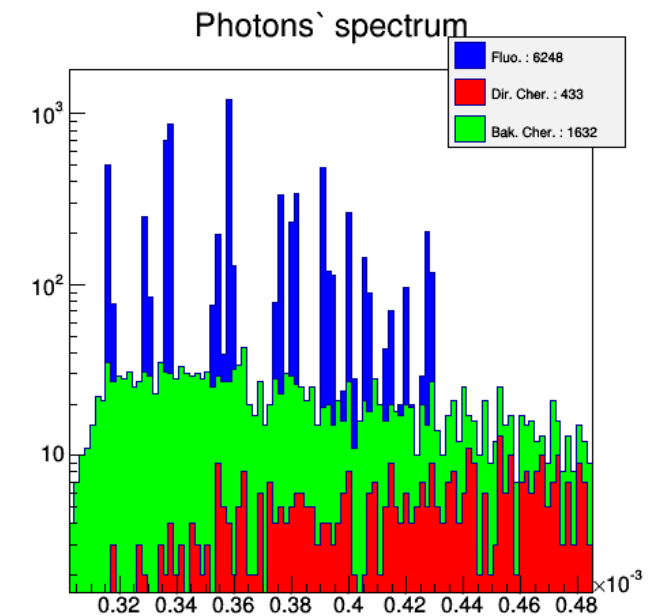
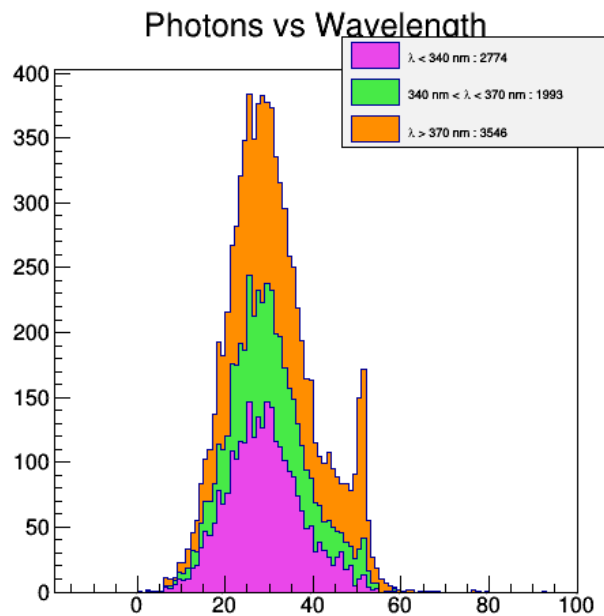
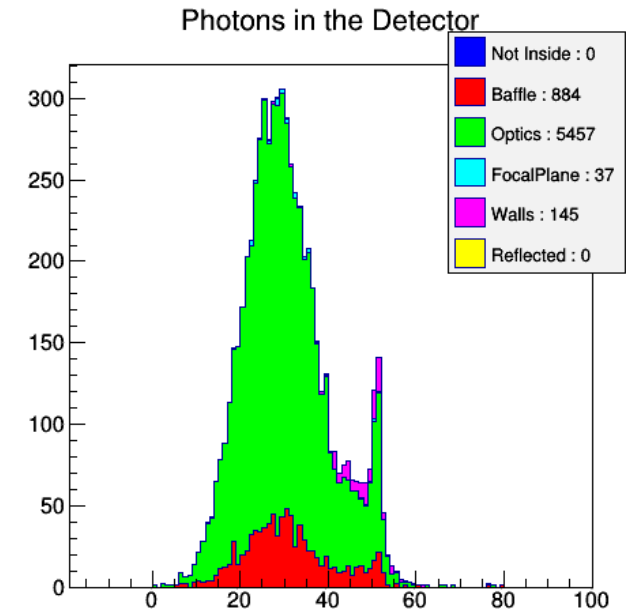
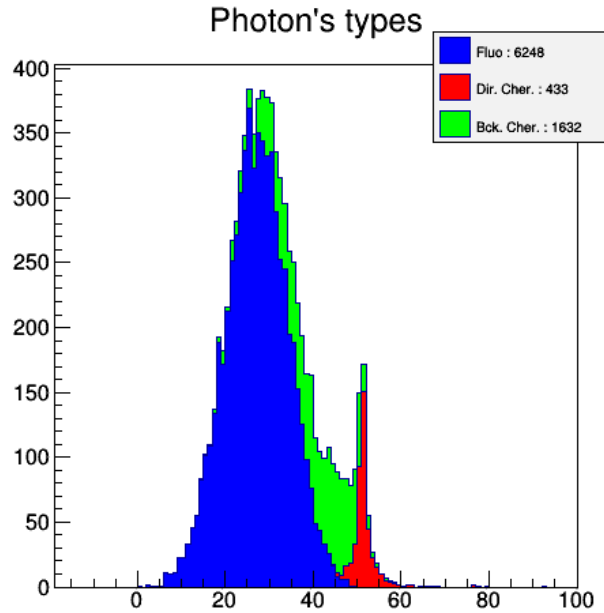
Event 0, Energy $1e+14$ MeV, Theta = 60.24 deg
Phi = 313.97 deg, $X_1 = 21.91$ g/cm², $X_{\max} = 866.91$ g/cm²

**Not
reconstructed
event**



Event 0, Energy $1e+14$ MeV, Theta = 60.24 deg
 Phi = 313.97 deg, $X_1 = 21.91$ g/cm², $X_{\max} = 866.91$ g/cm²

**Not
reconstructed**



Used commands

- Simu -b
--usrcfg=/home/michal/esaf_configs/simu.ConfigDumpTheta60.cfg --events=10
- Reco --usrcfg=config/config_ALL_last2
output/simu.2014-06-08-13h14m57s.root

Used configuration `simu.ConfigDumpTheta60.cfg` (rovnaké ako `simu.ConfigDump.cfg`
– Svetlana config but `GeneratorLightToEuso.ThetaRangeMax = 60` a
`GeneratorLightToEuso.ThetaRangeMin = 60`)
• with config `_ALL_last2` results are differen
Different parameters (first config `_ALL_last2`, second `configDumpTheta60.cfg`).

Created from Reco call

```
--usrcfg=config_ALL_last2 and from Reco call -  
usrcfg=simu.ConfigDump.cfg (Dump of configuration when Reco start)  
MacroCell.fTriggerType = 14336 | 10240  
PmtToShowerReco.fIterXmaxMin = 0.3 | 100  
LowtranAtmosphere.Lsup = 450.45 | 485  
PmtToShowerReco.fTestDebugMode = 0 | 1  
ShowerLightSource.fLambdaMin = 300 | 250  
PmtToShowerReco.fGapCorrection = 0 | 2  
PmtToShowerReco.fCorrectCher = 1 | 0  
SlastLightToEuso.WaveRangeMax = 400 | 485  
GeneratorLightToEuso.ImpactXmax = 205 | 270  
GeneratorLightToEuso.ImpactYmax = 5 | 190  
GeneratorLightToEuso.altitude = 430 | 400  
Euso.fAltitude = 430 | 400  
PmtToShowerReco.fIterXmaxMax = 0.3 | 100  
PmtToShowerReco.fRoughObscPrecis = 0.76 | 1  
TrackDirection2Module.fUseHoughwithselection = no | yes  
GeneratorLightToEuso.ImpactYmin = -5 | -190  
TrackDirection2Module.fSignalToNoise = 3 | 0.01  
TrackDirection2Module.fUseHough = no | yes  
EsafRandom.fSeed = 12345 | 3744  
ShowerLightSource.fLambdaMax = 450 | 485  
SlastLightToEuso.WaveRangeMin = 300 | 250  
TrackDirection2Module.fNumPointsMin = 5 | 10  
GeneratorLightToEuso.ImpactXmin = 195 | -270
```

Full comparison at:

https://www.dropbox.com/s/9c8ddw1hy8s7q3y/config_ALL_last2_vs__ConfigDumpTheta60.txt

Config comparison “almost” default vs. “oone from Svetlana”.

Different settings:

```
RootInputModule.FirstEvent = 8 | 0
MacroCell.fTriggerType = 14336 | 10240
LowtranAtmosphere.Lsup = 450.45 | 485
RootInputModule.LastEvent = 8 | -1
ShowerLightSource.fLambdaMin = 300 | 250
SlastLightToEuso.WaveRangeMax = 400 | 485
GeneratorLightToEuso.EnergyRangeMax = 5e+20 | 1e+20
GeneratorLightToEuso.ImpactXmax = 0 | 270
GeneratorLightToEuso.ImpactYmax = 0 | 190
GeneratorLightToEuso.altitude = 430 | 400
Euso.fAltitude = 430 | 400
GeneratorLightToEuso.ImpactYmin = 0 | -190
GeneratorLightToEuso.ThetaRangeMax = 90 | 60
EsafRandom.fSeed = 12345 | 3744
ShowerLightSource.fLambdaMax = 450 | 485
SlastLightToEuso.WaveRangeMin = 300 | 250
GeneratorLightToEuso.ImpactXmin = 0 | -270
```

Full comparison:

https://www.dropbox.com/s/o63vrm9712nxhed/default__vs__ConfigDumpTheta60.txt

How we call “almost” default config:

```
Reco --first=8 -last=8
--RecoFramework.ModuleFile=config/RecoModuleList_ALL_last2.cfg
output/simu.2014-06-08-13h14m57s.root
```

Ongoing activities

- Hough method to ESAF (P. Bobik, J. Vasilko, M. Vrabel)
- Clustering to ESAF (E. Gajdos, J. Vasilko, M. Vrabel)
- RANSAC⁽¹⁾ method (D. Imro, T. Horvath)

Ref.

(1) <https://en.wikipedia.org/w/index.php?title=RANSAC&diff=568355941&oldid=568355251>