# SBS tracking software update

**Eric Fuchey**
**University of Connecticut**

## SBS collaboration meeting
**Jefferson Lab, August 5-6, 2019**



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# Overview

*** Reminders: GEM digitization / analysis software**

*** Recent improvements of GEM clustering**
- **impact on GMn tracking efficiency**
- **next steps**

*** Summary**

# Reminder: GEM digitization software

Officially located in:
*https://github.com/JeffersonLab/libsbsdig*
Historically developped in standalone (for SoLID):
*https://github.com/JeffersonLab/libsolgem/tree/libsbsgem*
(NB: personally guilty of still using the latter rather than the former… need to quit that habit…)

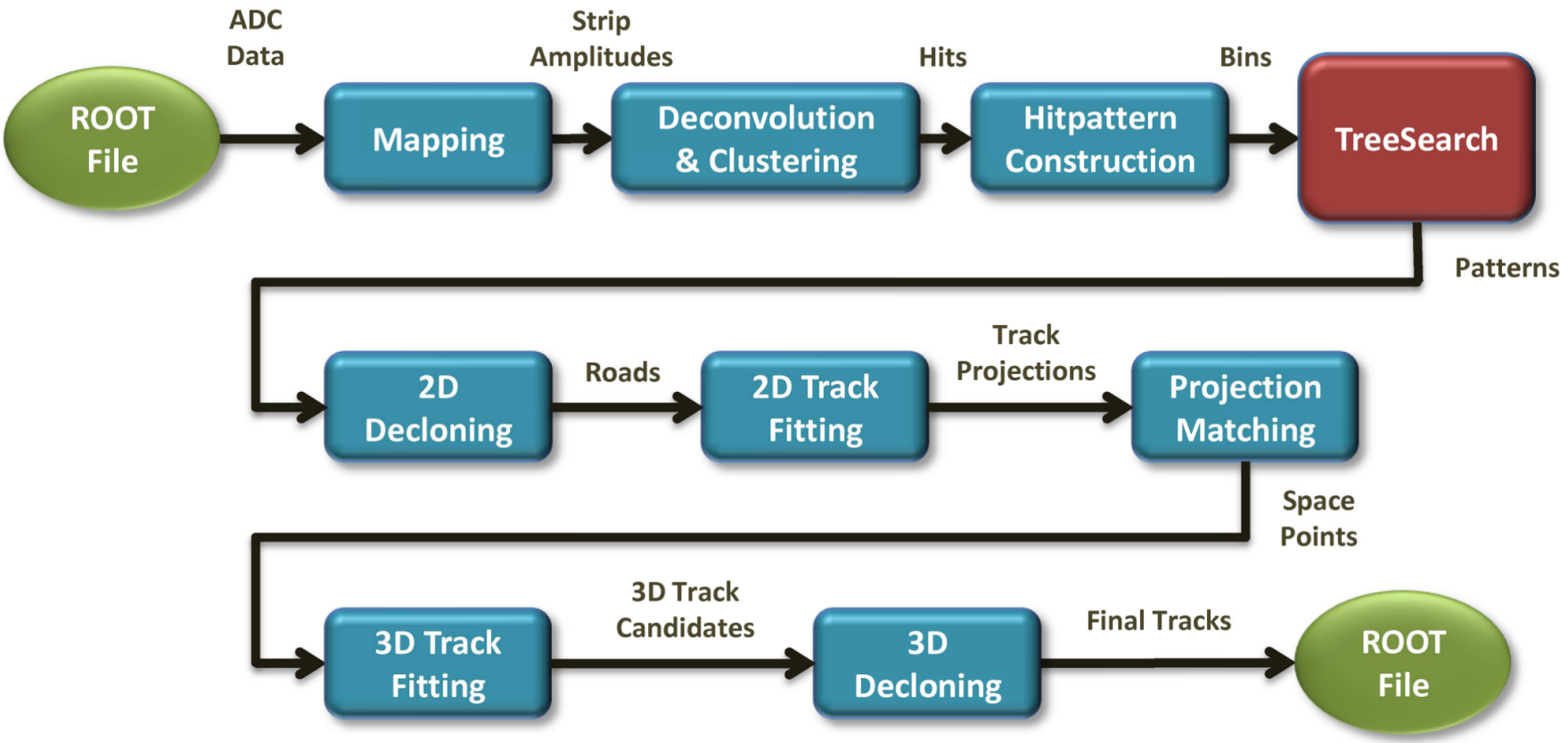
Digitization: takes g4sbs hit info to:
* simulate the number of ions formed in the drift;
* simulate the avalanche from these generated ions;
* spread the avalanche over the amplification layers (according to a Cauchy Lorentz distribution);
* integrate on each strip the fraction of spread avalanche landing on it, and then by sample of 25ns;
* converting this to ADC value, adding a pedestal with $\sigma$ = 20 ADC.

Manages background addition: add events from beam on background g4sbs simulations files

Documentation write-up underway with much detail at:
*https://github.com/efuchey/digtrk_doc/*
(report : file *GEpTracking.pdf*)

# Reminder: GEM analysis software

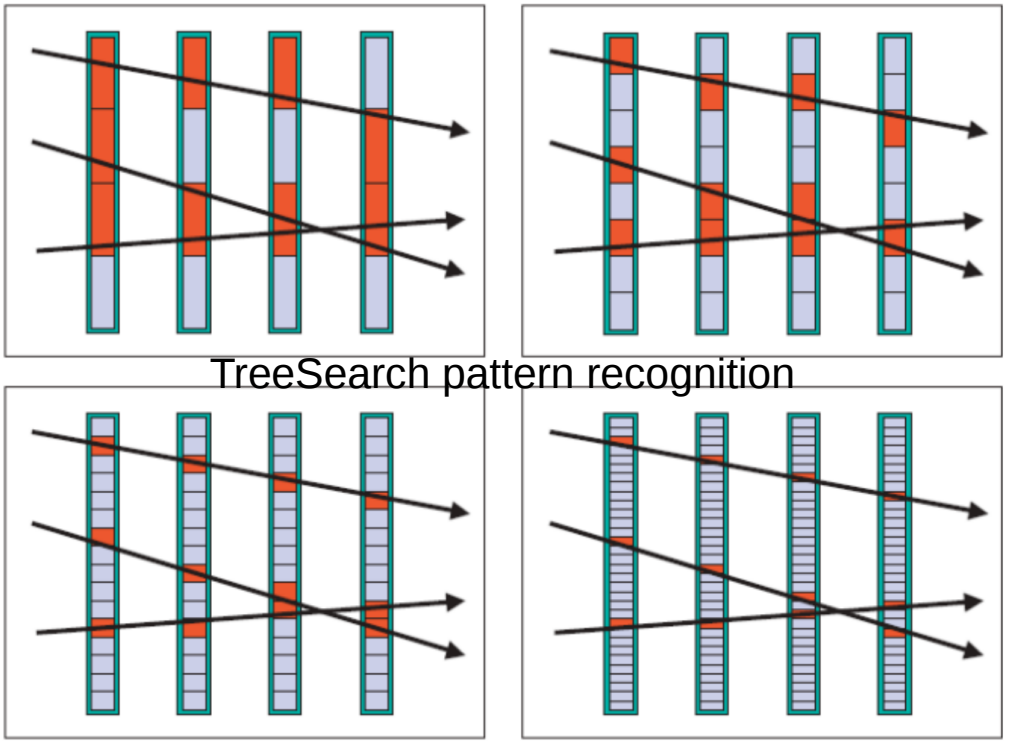
GEM simulation analyzed in TreeSearch located in:
*https://github.com/JeffersonLab/TreeSearch/tree/sbs*



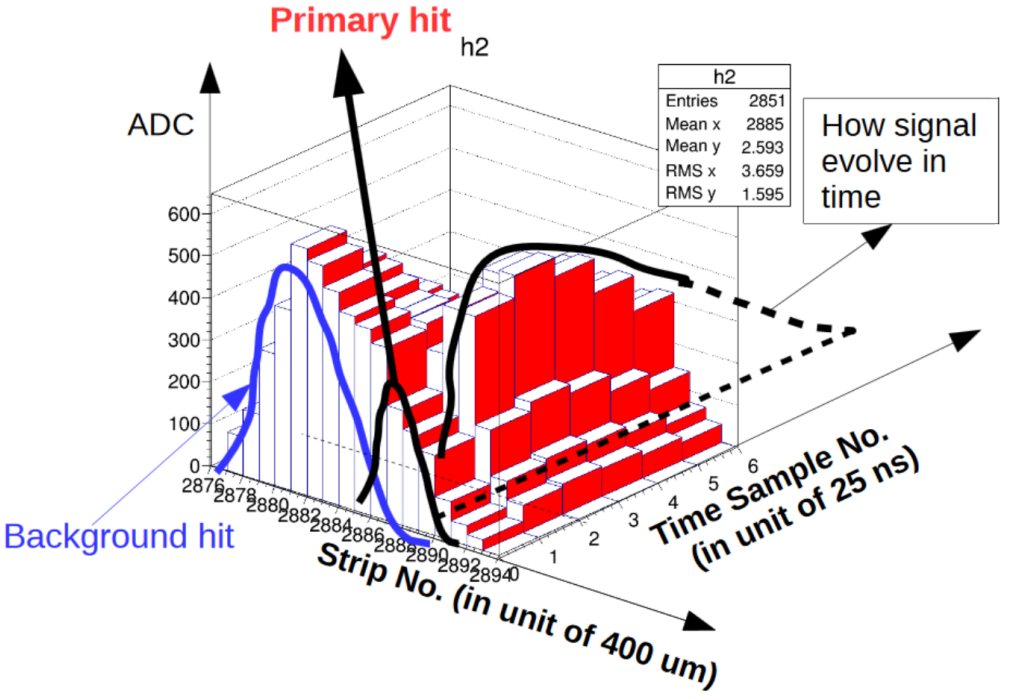

Documentation write-up underway at:
*https://github.com/efuchey/digtrk_doc/*
(report : file *GEpTracking.pdf*)

# Reminder: GEM analysis software

* Primary deployed algorithm using recursive TreeSearch
(raw combinatorics also employed for some analyses)
* GEMs provide six time samples over 25ns bins with jitter
* Hits are differentiated by fitting to spatial and temporal components
* Require amplitude matching between x-y components to obtain full 3D reconstruction
* General restrictions are placed on search areas based on other detector knowledge
* Basic multithreading implemented



TreeSearch pattern recognition




Plot credit :
Danning Di



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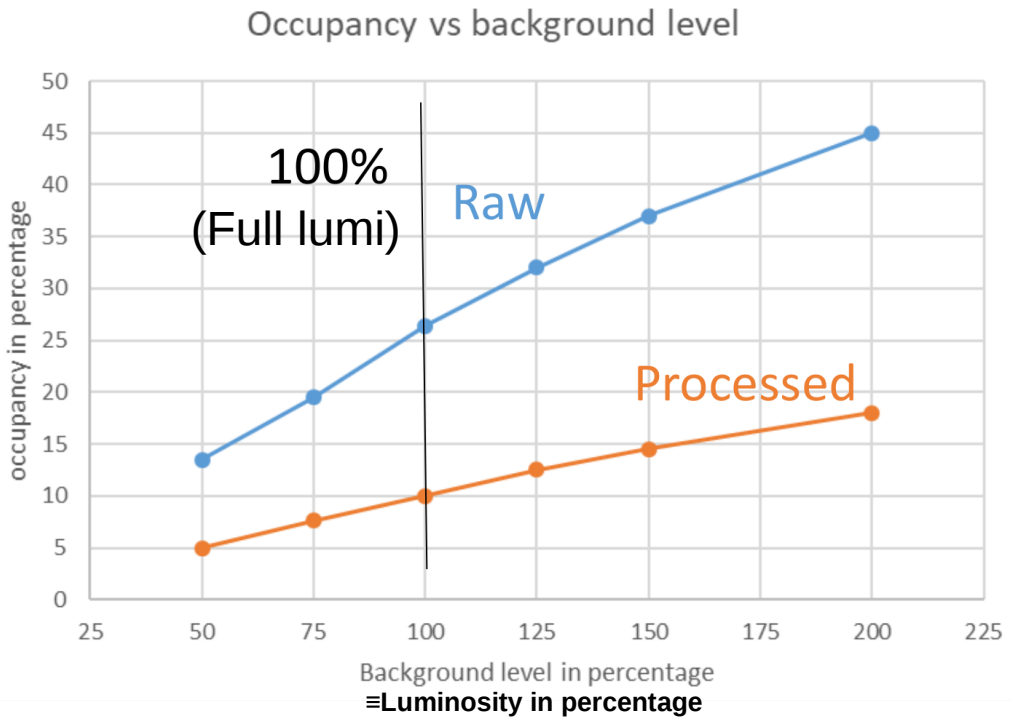
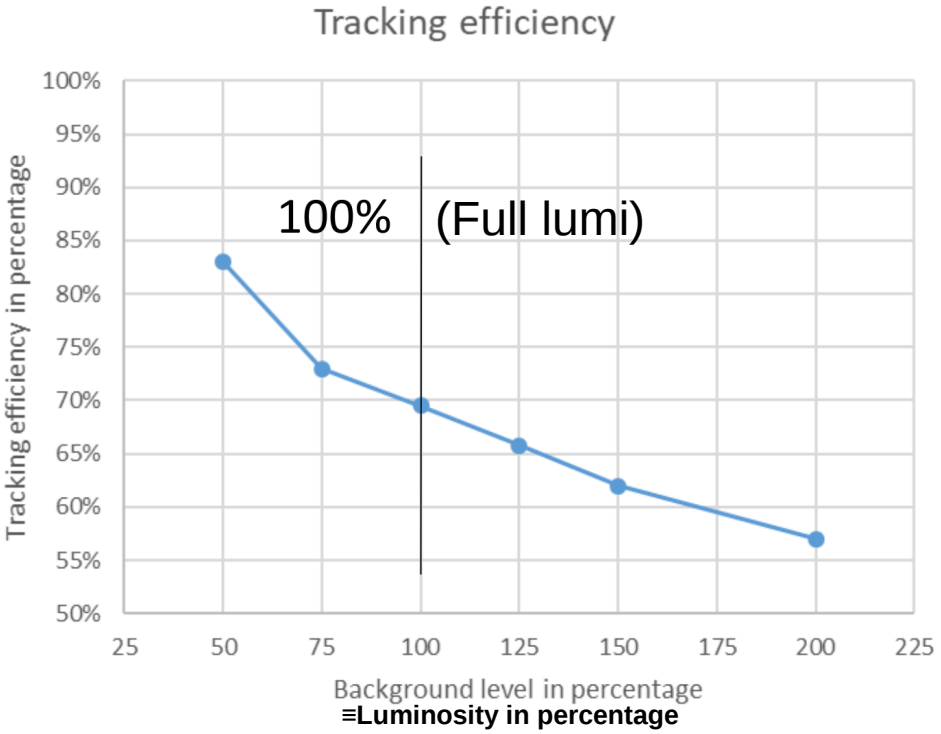
# Reminder: GEM analysis software

Since 2016:
* Improved simulated GEM response and validation based on data from constructed GEMs
* Observe larger and wider background response
* Event reconstruction at 70% tracking efficiency (2020 goal 80%)
=> processing speed 3 Hz (2020 goal 8Hz)



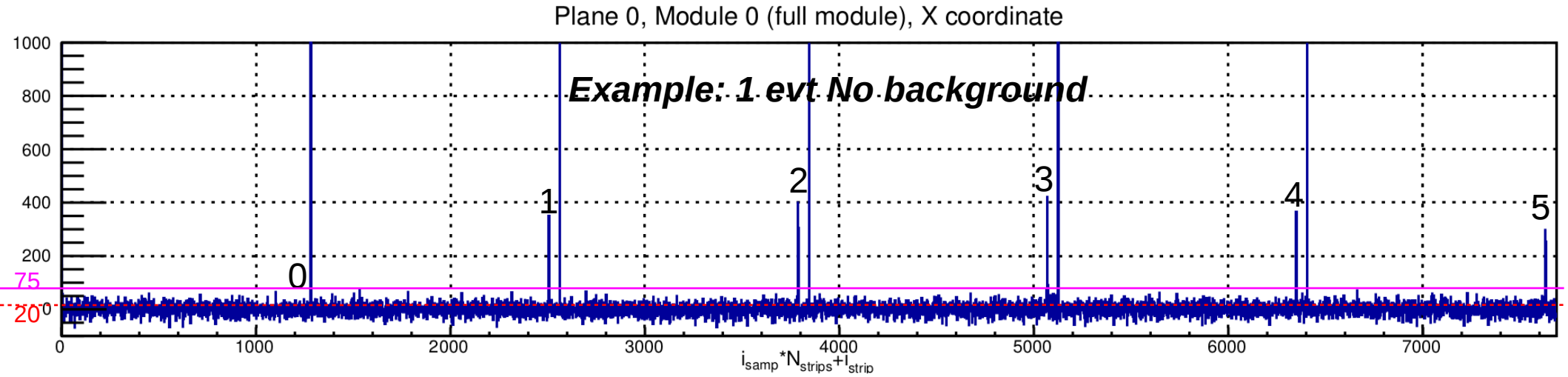

$G_M^n$ GEM background at full luminosity (10cm LD2, 45μA)
~100 kHz/cm$^2$

Plots credit :
Danning Di

# Recent improvements on GEM clustering:

Idea: *use the fact that the GEM hit shall be well described by a space-time* template function => optimized use of strip/sample info.
+Check ADC and time correlation for X/Y *before* doing the tracking

First step: scan *for each strip sample* a hit candidate: shoulder-peak-shoulder passing a low threshold at least 3 of the 6 samples to have one shoulder-peak-shoulder pattern
+ the peak passing a high threshold for at least one of the 4 middle samples.




Central strip hit candidate uses the same selection criteria as the one I have developed this spring:
* at least three shoulder-peak-shoulder samples with ADC≥20
* at least one of samples 1, 2, 3, 4 with ADC≥75
* strip ADC sum≥300
(values optimized for $G_E^p$)

# Recent improvements on GEM clustering:

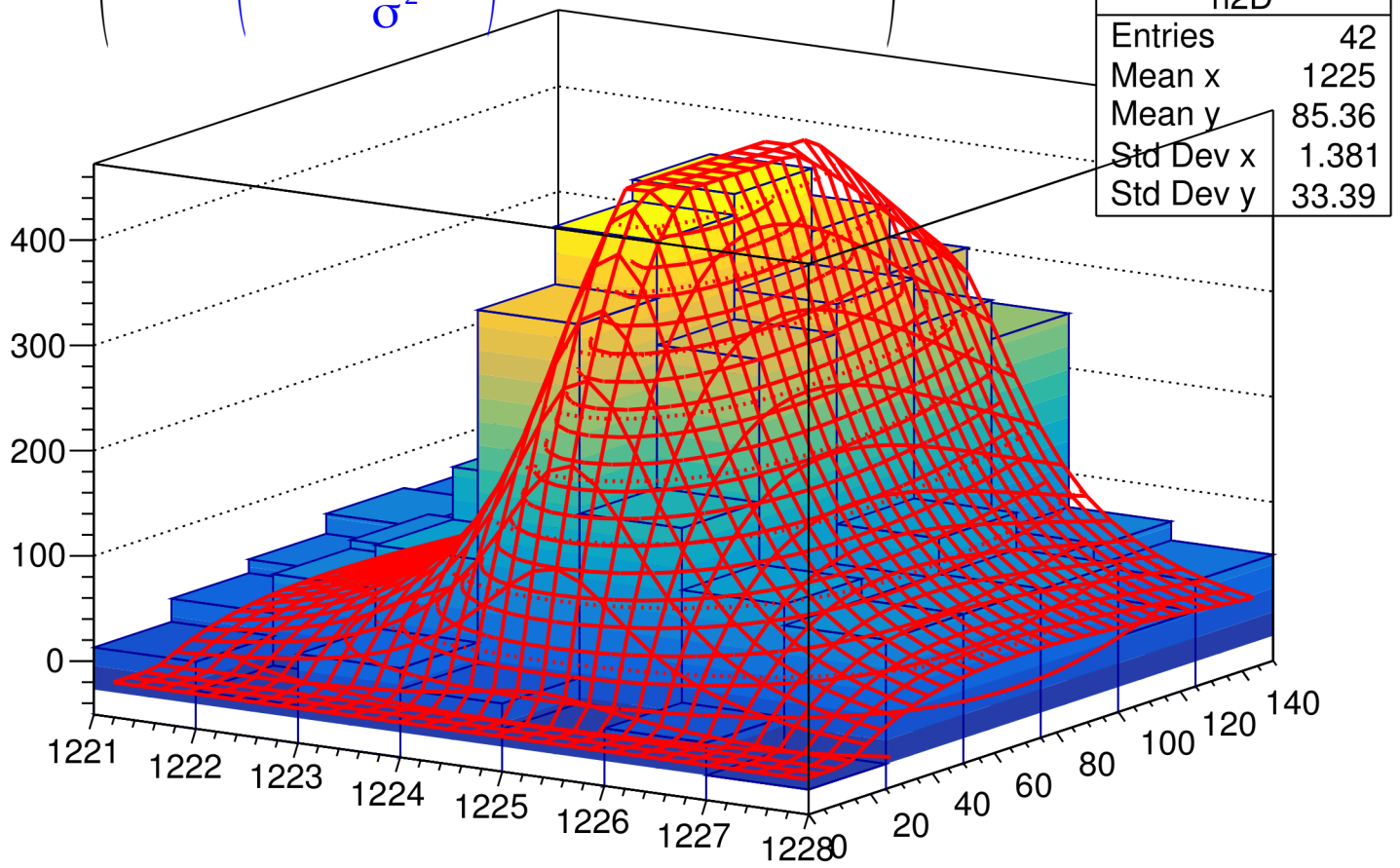
Idea: *use the fact that the GEM hit shall be well described by a space-time* template function => optimized use of strip/sample info.

=> Fit over the ± 2 strips around the central strip a hit template function of the form:

$$f(t) = Max\left(0, A \times \left(\frac{1}{1+\frac{(x_0-x)^2}{\sigma^2}}\right) \times \left(\frac{t-t_0}{\tau}\right)\exp\left(\frac{t-t_0}{\tau}\right)\right)$$

$\tau = 56\ ns$

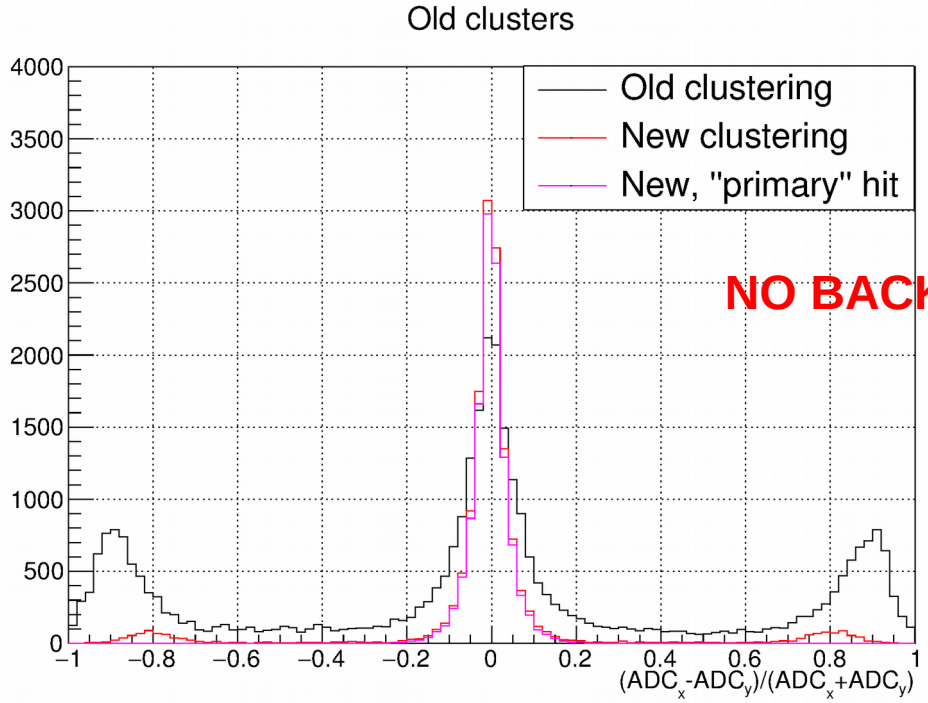
$\sigma = 1\ strip = 400\ \mu\ m$



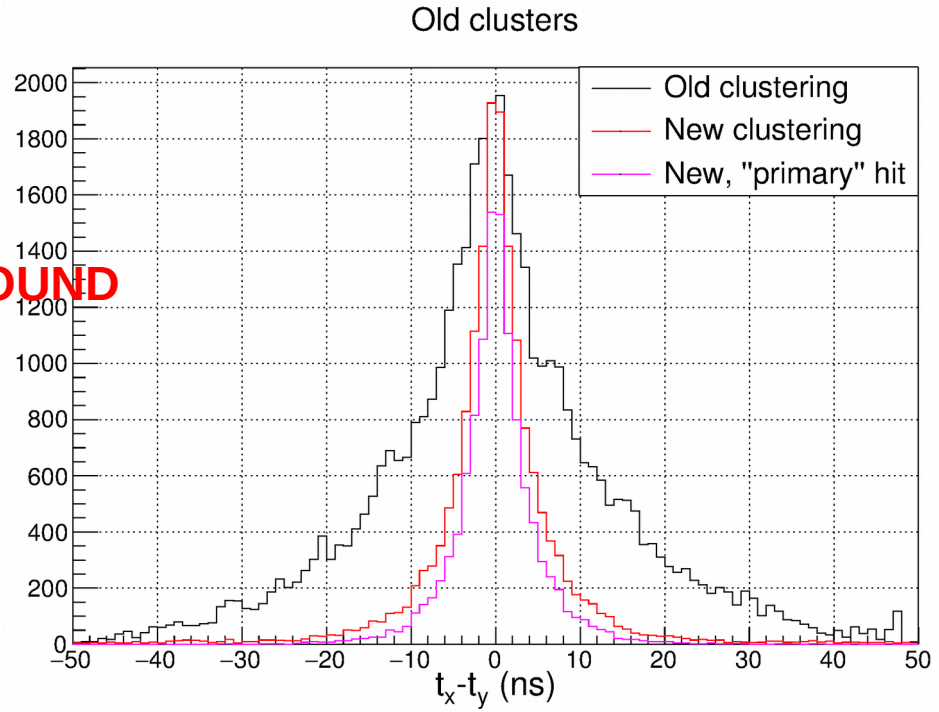
# Recent improvements on GEM clustering:

+Check ADC and time correlation for X/Y *before* doing the tracking

ADC asymmetry: |ADC asym| < 0.18 Time difference: |Δ*t*|<15ns
(3 standard deviations of distribution for "primary" hits - formed around max ADC sum primary strip)




**NO BACKGROUND**




98.8 % selection for new clustering
40 % selection for "old" clustering

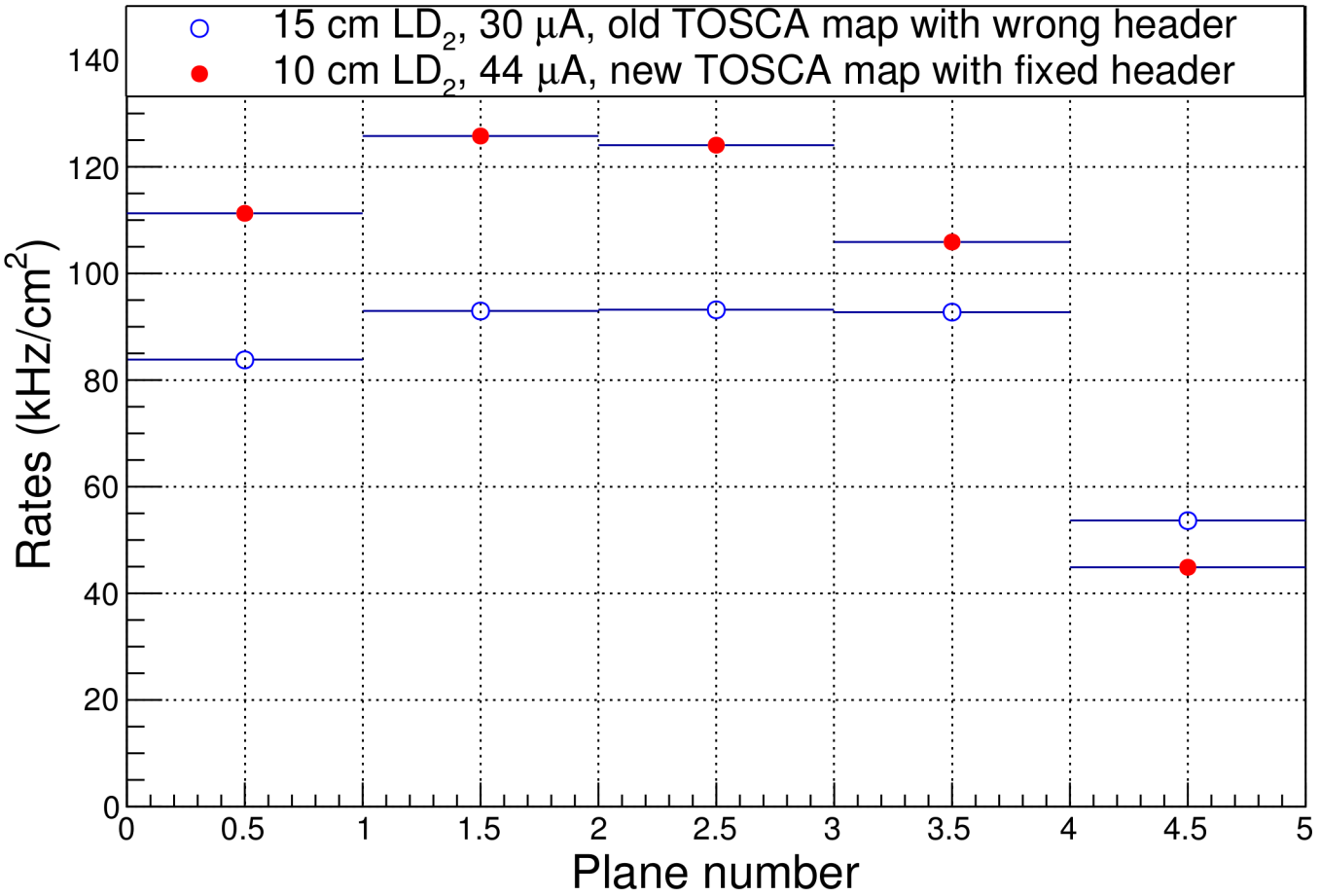
97.2 % selection for new clustering
72 % selection for "old" clustering

**Primary 2D hit selection efficiency after ADC and time difference selection: >85% for $G_E^p$**

Percentage of "fake" reconstructed hits: <4 % (mainly cross talk for large amplitude hits)
NB: >85% hit reconstruction efficiency at no background does not look impressive.
1D reconstruction efficiency with previous clustering method for $G_E^p$: ~95%; but would be *much less* after ADC / time correlation.

# **Reminder** (from yesterday)
# Update of GMn background (focus on GEMs)

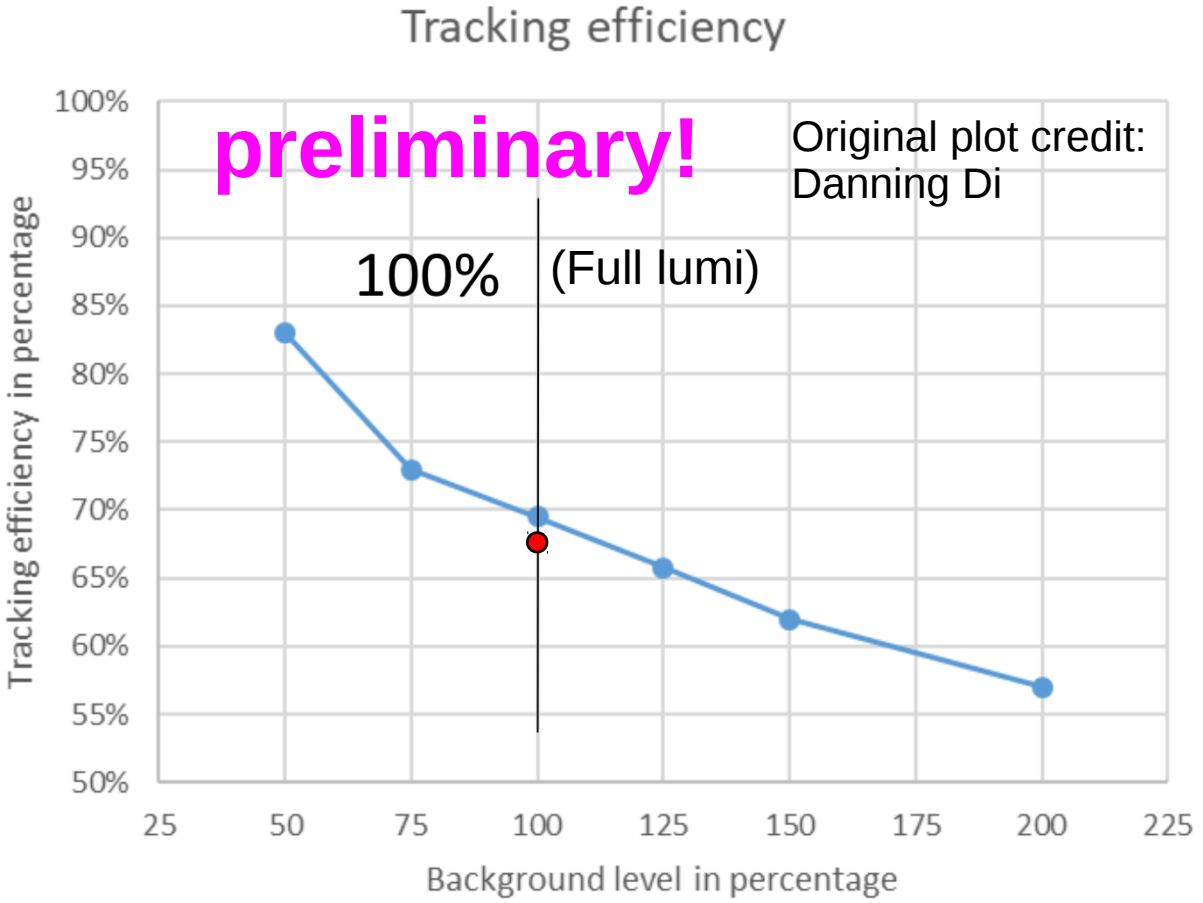
**Updates on rates:** "Slightly" worse background (10-40 % worse) for INFN GEMs, 20 % better for UVA GEMs than for previous estimations used for tracking.




Previous estimation slide 14 (made with design on iteration 3) in following link:
https://sbs.jlab.org/DocDB/0000/000012/001/EFuchey_SimuShieldpdate_20180722_edit.pdf

# Update of GMn background

## Impact on tracking $G_M^n$ efficiency




**Red**: new background estimation, previous clustering algorithm;

Damages the efficiency by ~5 %



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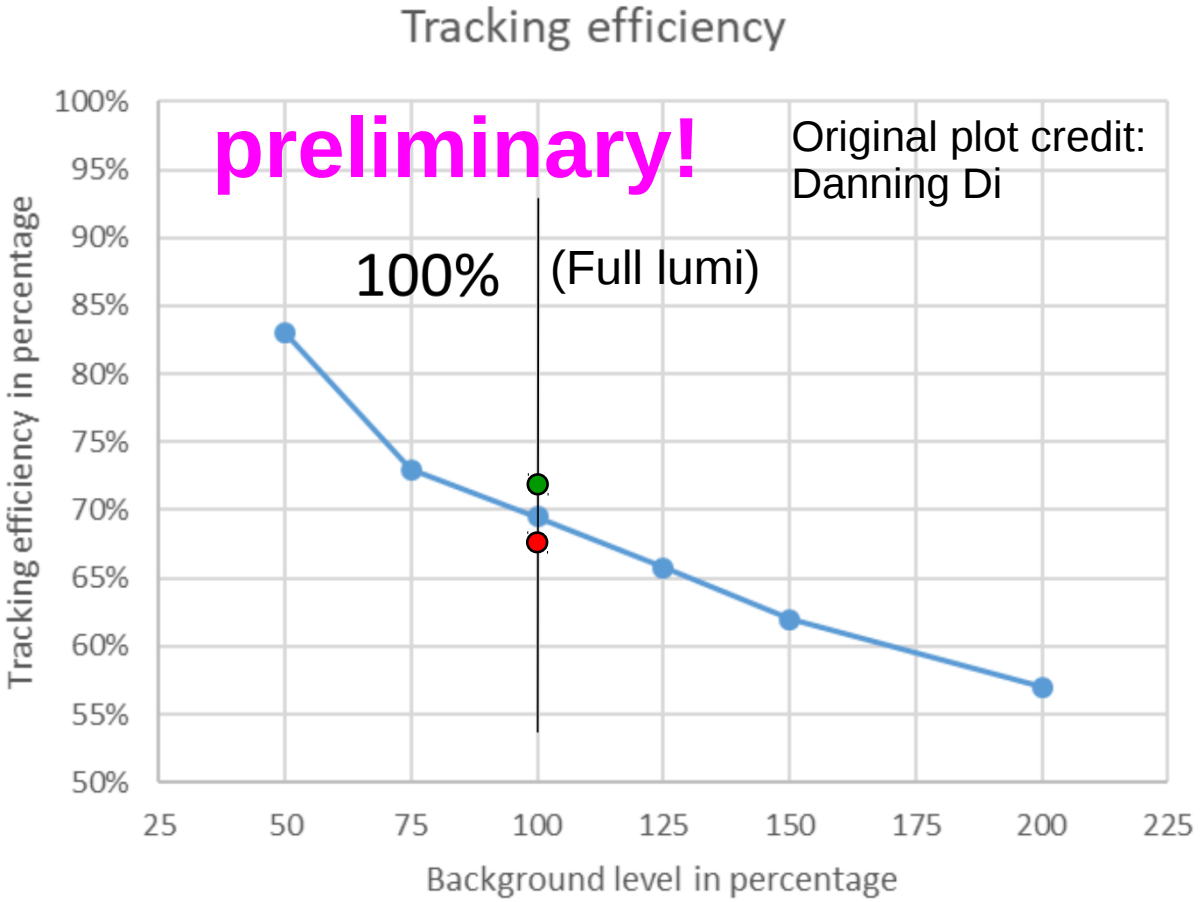
# Recent improvements on GEM clustering: *Preliminary* impact on $G_M^n$ tracking at full background




**Red**: new background estimation, previous clustering algorithm;
**Green**: new background estimation, new clustering algorithm
*/!\ does not include X/Y ADC and time correlation before tracking!*

Absolute values are not so important so far. What should be retained is that ***at $G_M^n$ background levels*, the template fit clustering algorithm under development seems to do, so far, a slightly better job than the previous algorithm.**
We expect this algorithm to do even better as we keep improving it.



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# Recent improvements on GEM clustering:
# Next steps :

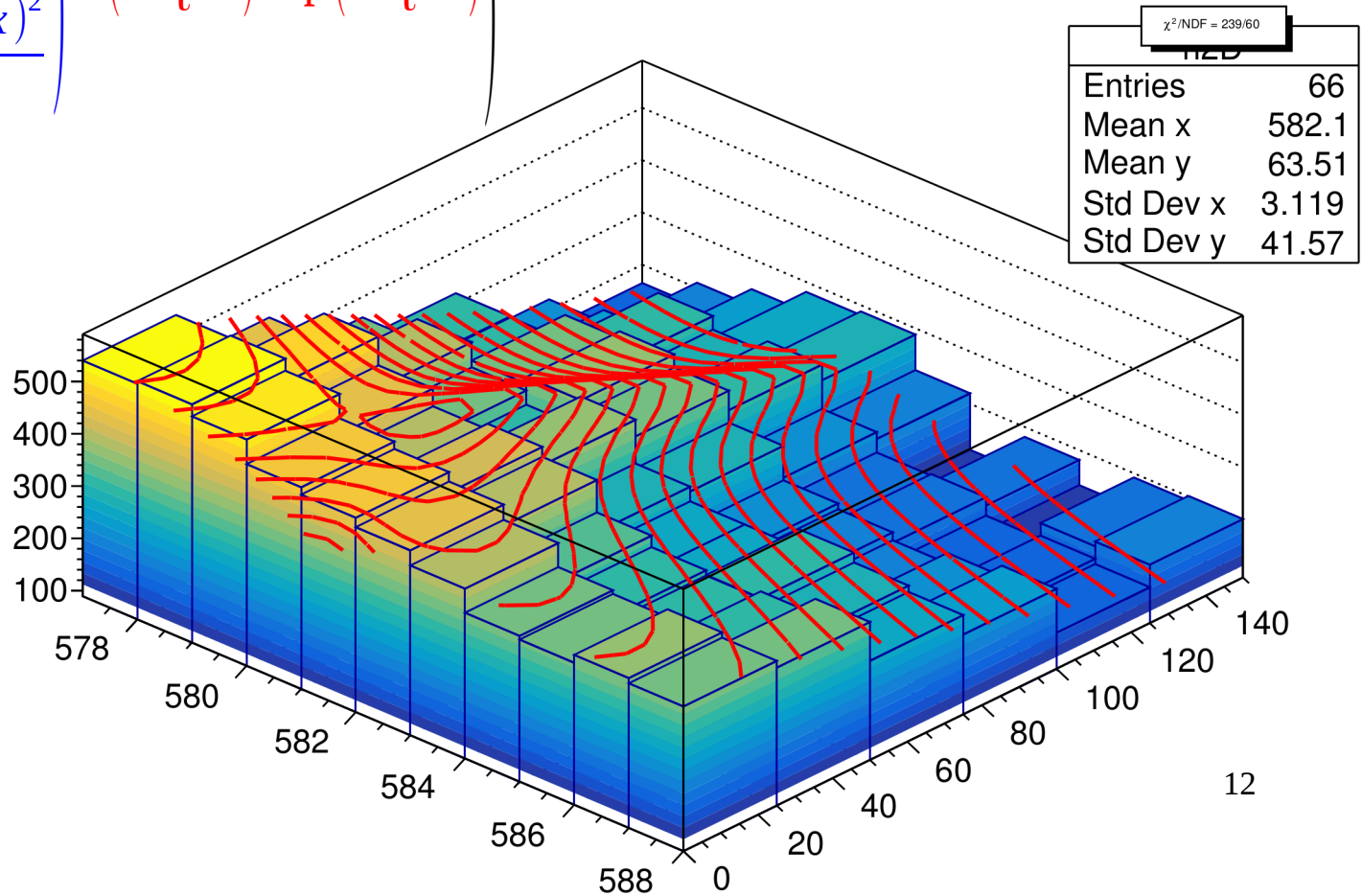
* Include X/Y ADC and time correlation before tracking

*** Include "multipeak" fit**

The identification of the actual, physical track at background levels higher than $G_M^n$ depends on our ability to efficiently deconvolute the hits of interest from background. A way to achieve this is to perform a fit of superimposed hit template functions

$$f(t) = Max\left(0, \sum_i A_i \times \left(\frac{1}{1+\frac{(x_{0,i}-x)^2}{\sigma^2}}\right) \times \left(\frac{t-t_{0,i}}{\tau}\right) \exp\left(\frac{t-t_{0,i}}{\tau}\right)\right)$$

Implementation of this is trivial, however **much attention needs to be paid on how to decide *in which case* the algorithm should do this.**



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# Summary

*** Efforts have been made to tackle tracking in high background environments with GEMs => *work in progress* but first results are encouraging**

*** We have yet to exploit the full information from the strips/samples to separate the signal hits from the background hits**

**TODO for UV**

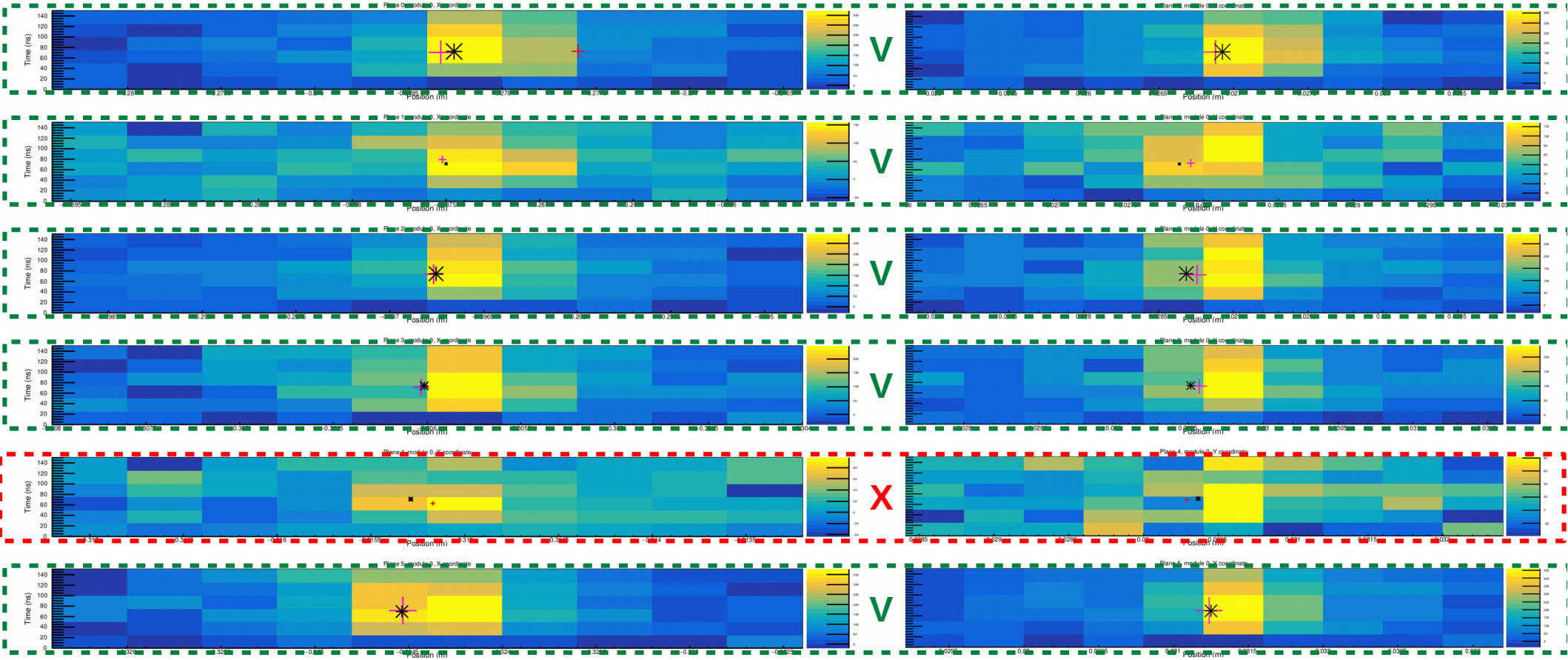
*** Digitization to produce U/V GEM data.**

*** Tree Search might not be most suited to mix in “pure” X/Y and U/V GEM**

**Thank you for your attention !**

# New*er* clustering analysis
## Comparison with previous method

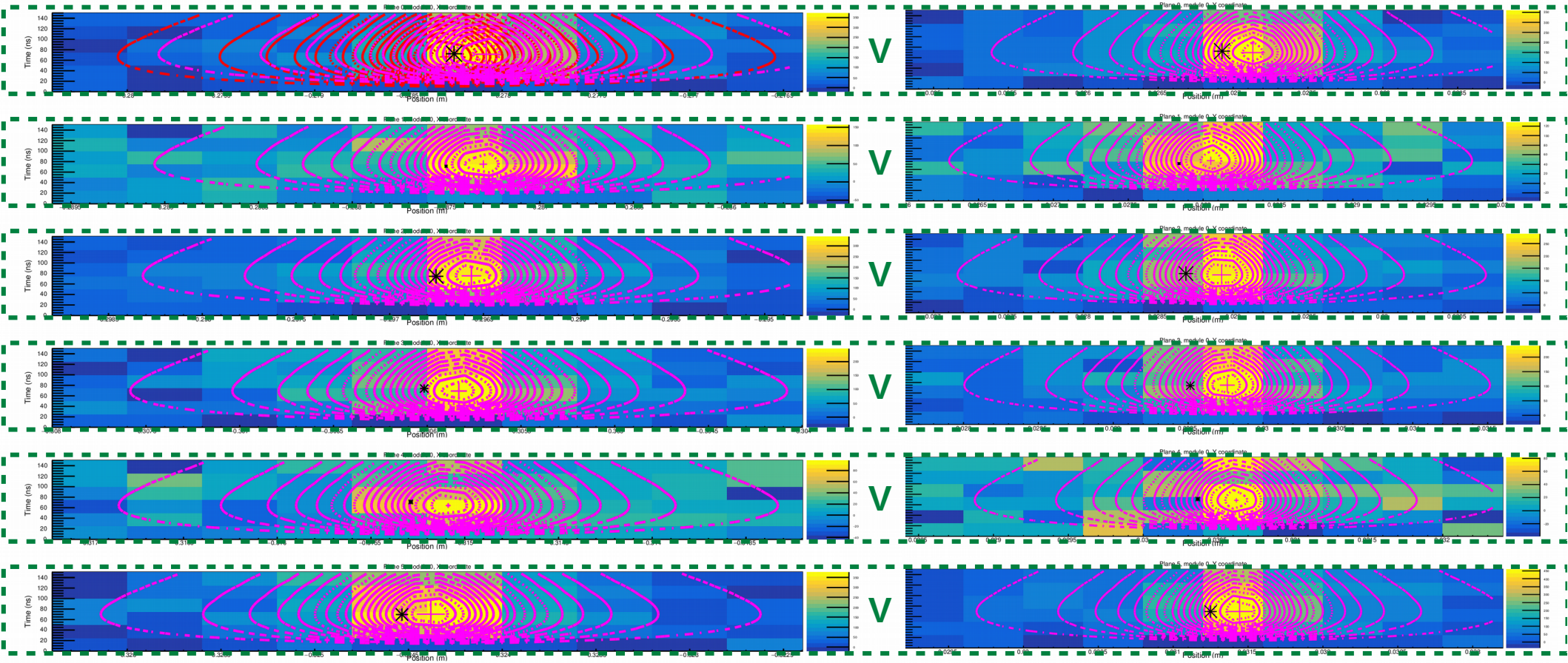
**Example:**
Evt display: Evt 1, 5th plane not reconstructed with method developed this spring
(I think it does not pass the $\Delta$t cut)




***/!\ No background***

# Newer clustering analysis
## Comparison with previous method

**Example:**
Evt display: Evt 1, all planes reconstructed with hit template fit function !!!




***/!\ No background***