Improving Oxygen Reconstruction in Emulsions

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Outline

- Challenges in oxygen reconstruction with the «standard» emulsion scanning approach

- Overview of possible approaches to improve oxygen reconstruction
  - Reconstruction from clusters instead of micro-tracks
  - Design of a new high-pass filter for oxygen counting

- Results for 2019 GSI data
  - GSI1 = 200 MeV/n ^{16}O on carbon
  - GSI2 = 200 MeV/n ^{16}O on polyethylene

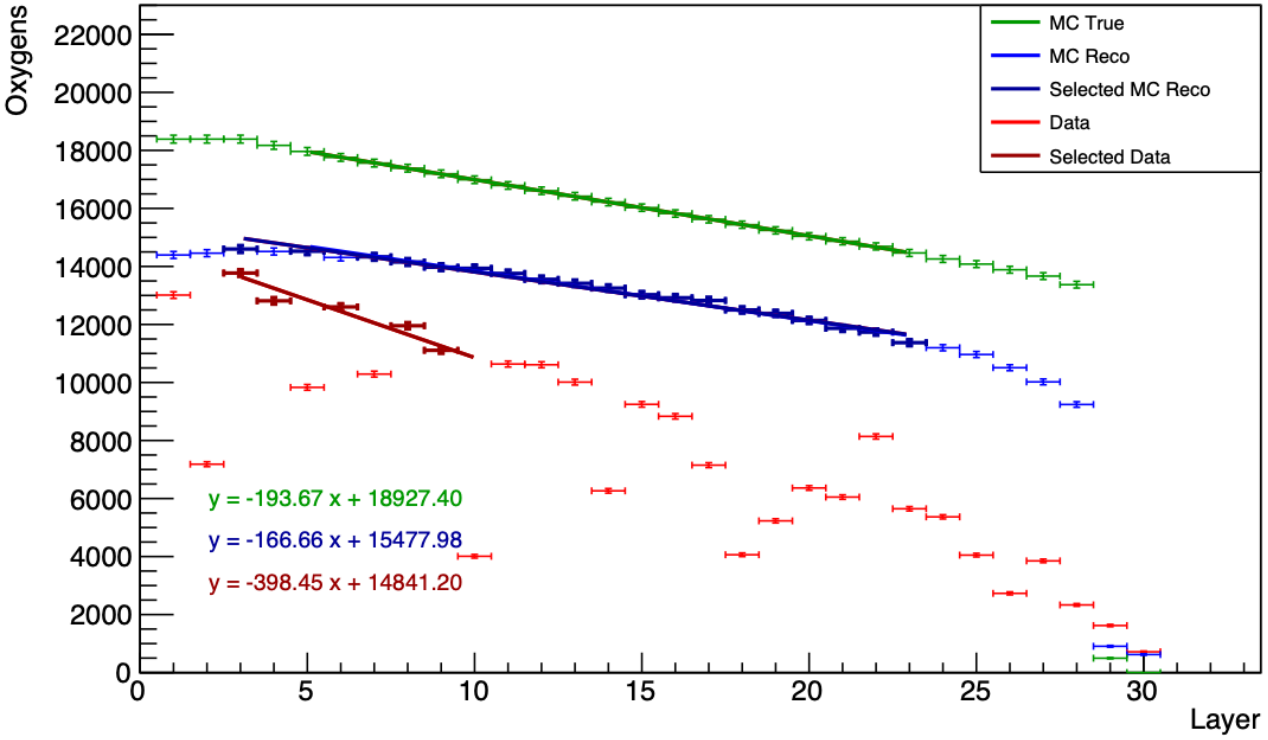
- Next steps

The problem of N_B evaluation

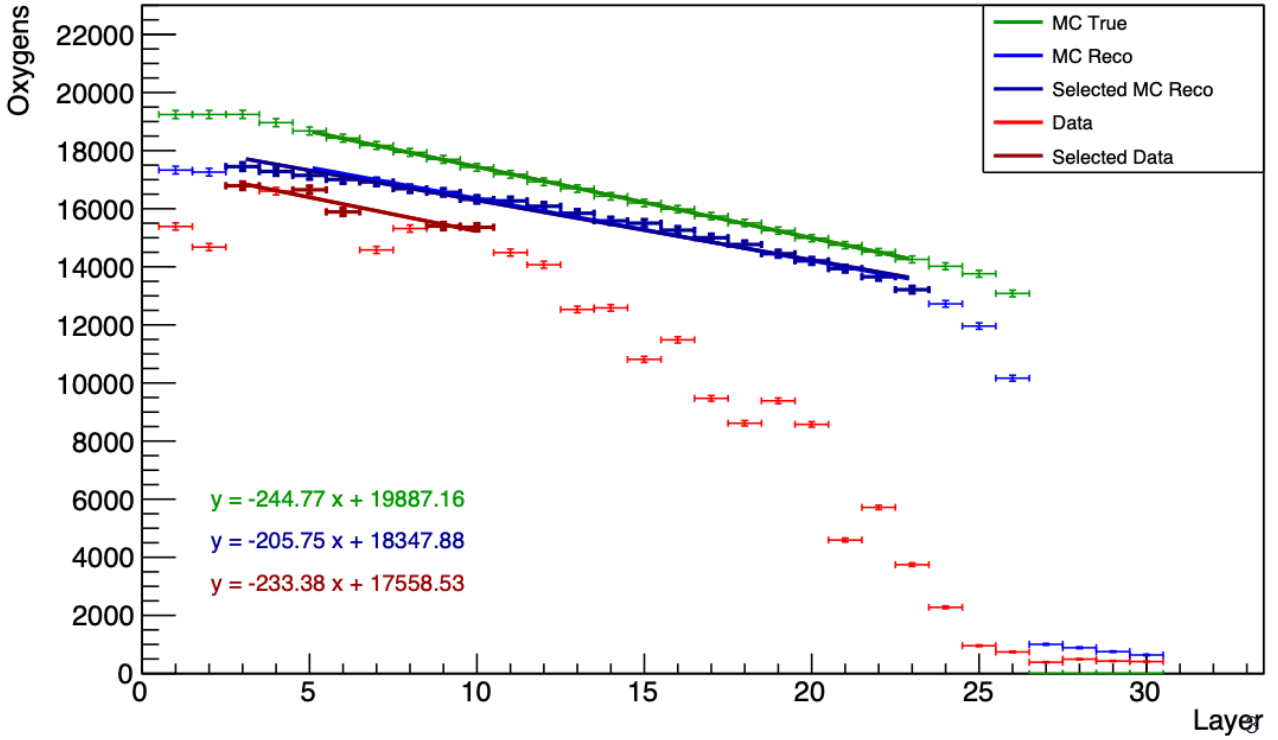
G.Galati, June 2024 FOOT General Meeting

- Cross section measurement sensitive to N_B
- New attempts on-going for improving (only) oxygen reconstruction
- If successful, it will be a double check for cross section evaluation!

C Target

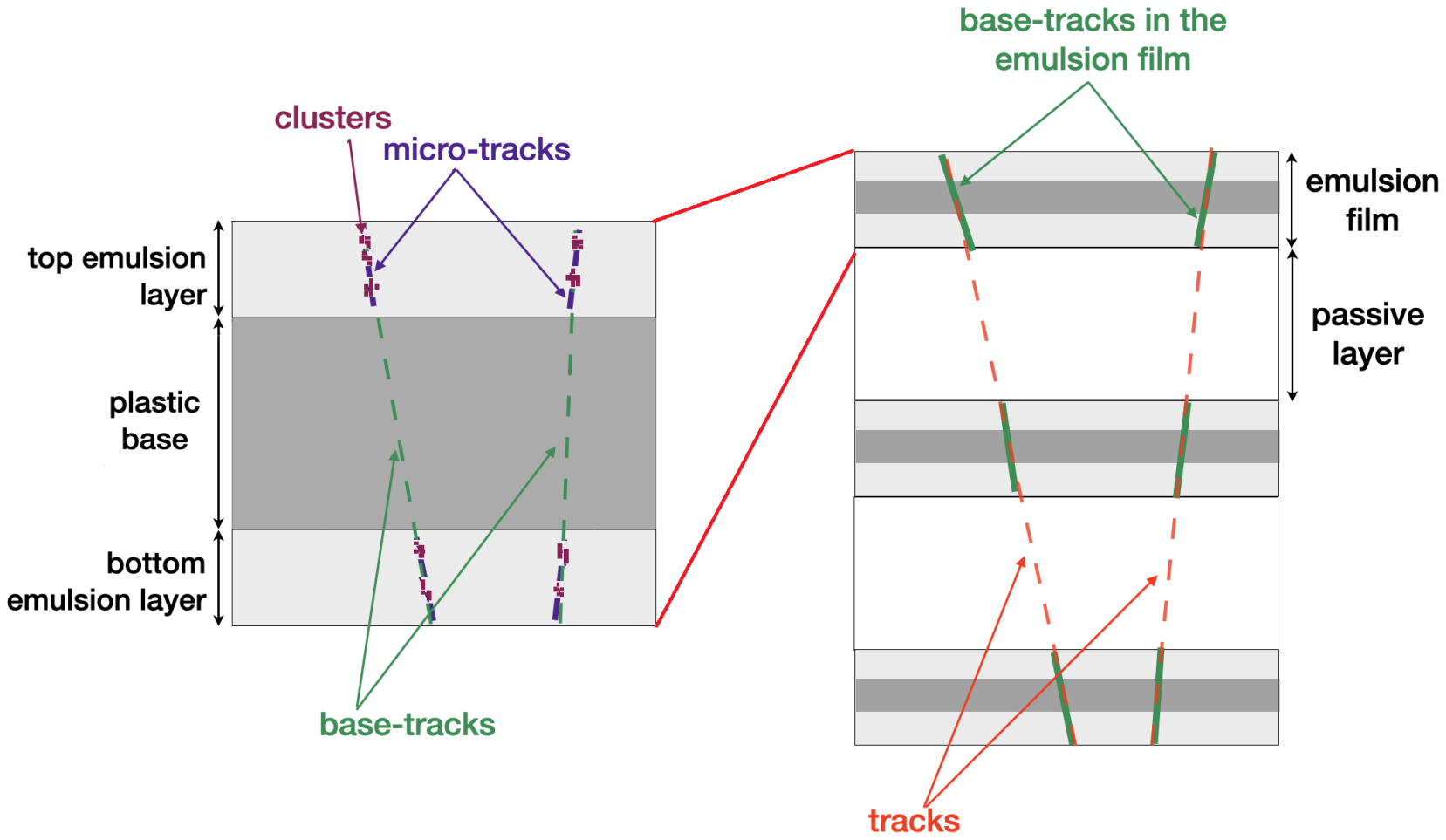


C_2H_4 Target



Emulsion Reconstruction Workflow (1)

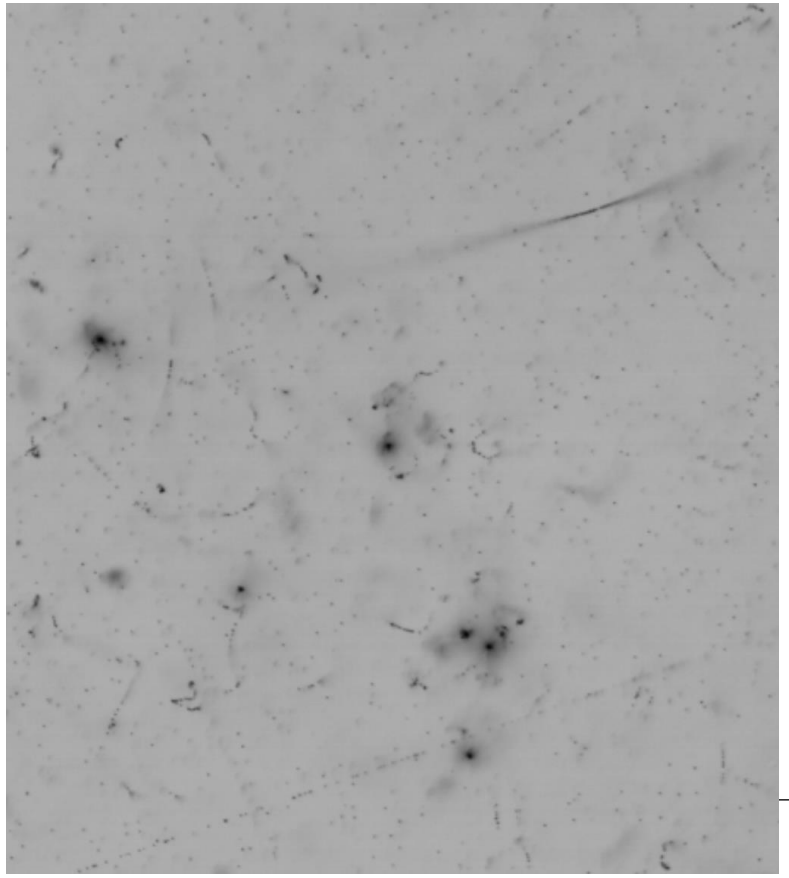
- During scanning, the emulsion surface is divided into views ($800 \times 600\ \mu m^2$) and several images («frames») are collected with a step along the Z axis equal to $1.75\ \mu m$



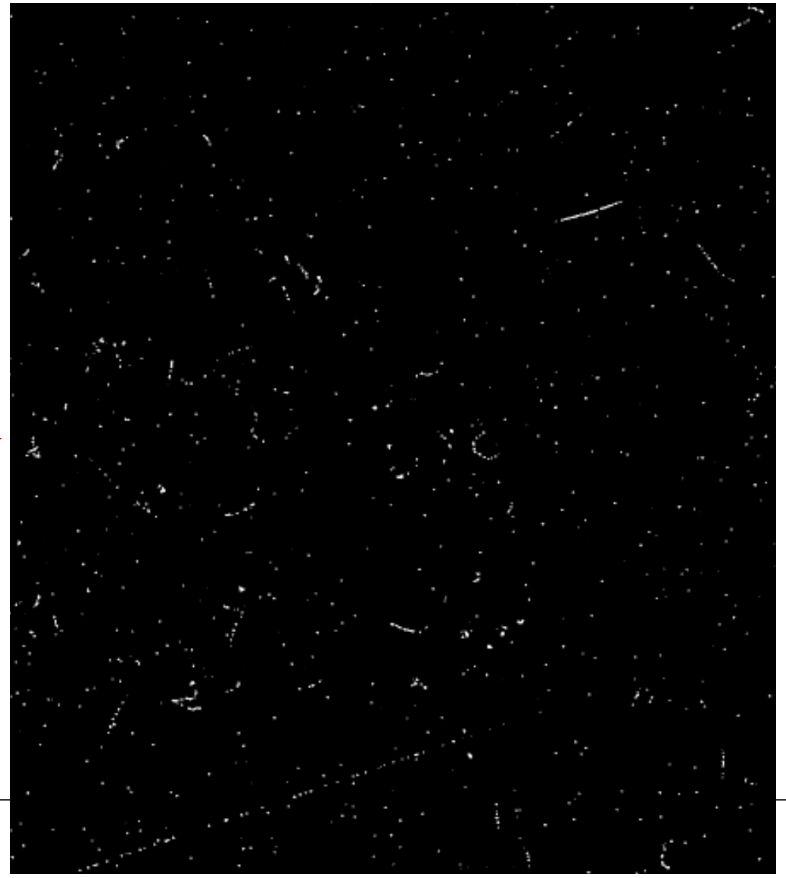
Emulsion Reconstruction Workflow (2)

- Convolution with a high pass filter is performed to reduce background
  - The size of the «standard» filter is 5x5 pixels and it was optimized for MIP reconstruction
- A shift (division by power of 2) is applied so that the final pixel values fall between 0 and 255
- All pixels with values greater than a given threshold are used for cluster reconstruction

Original Image

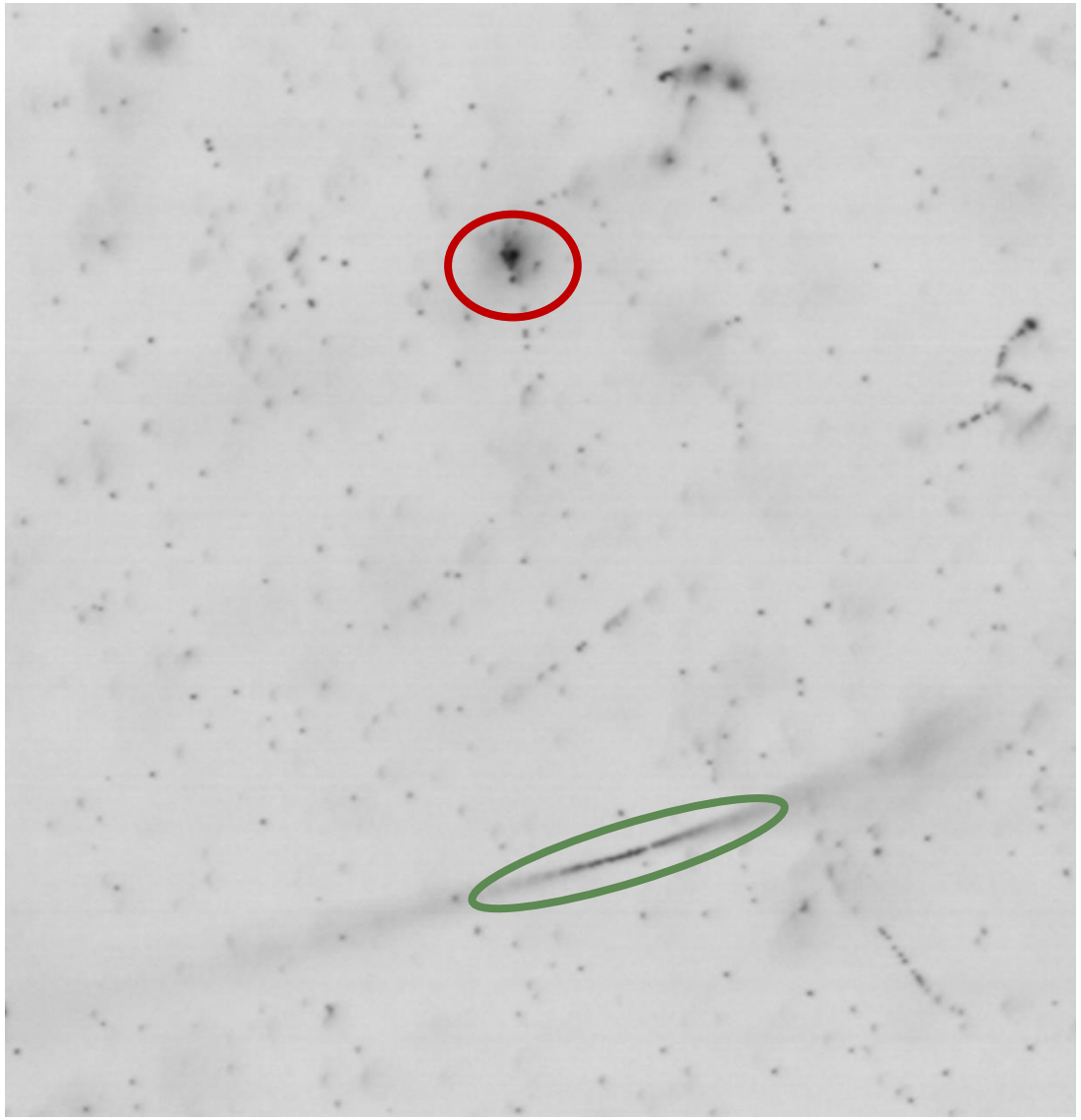


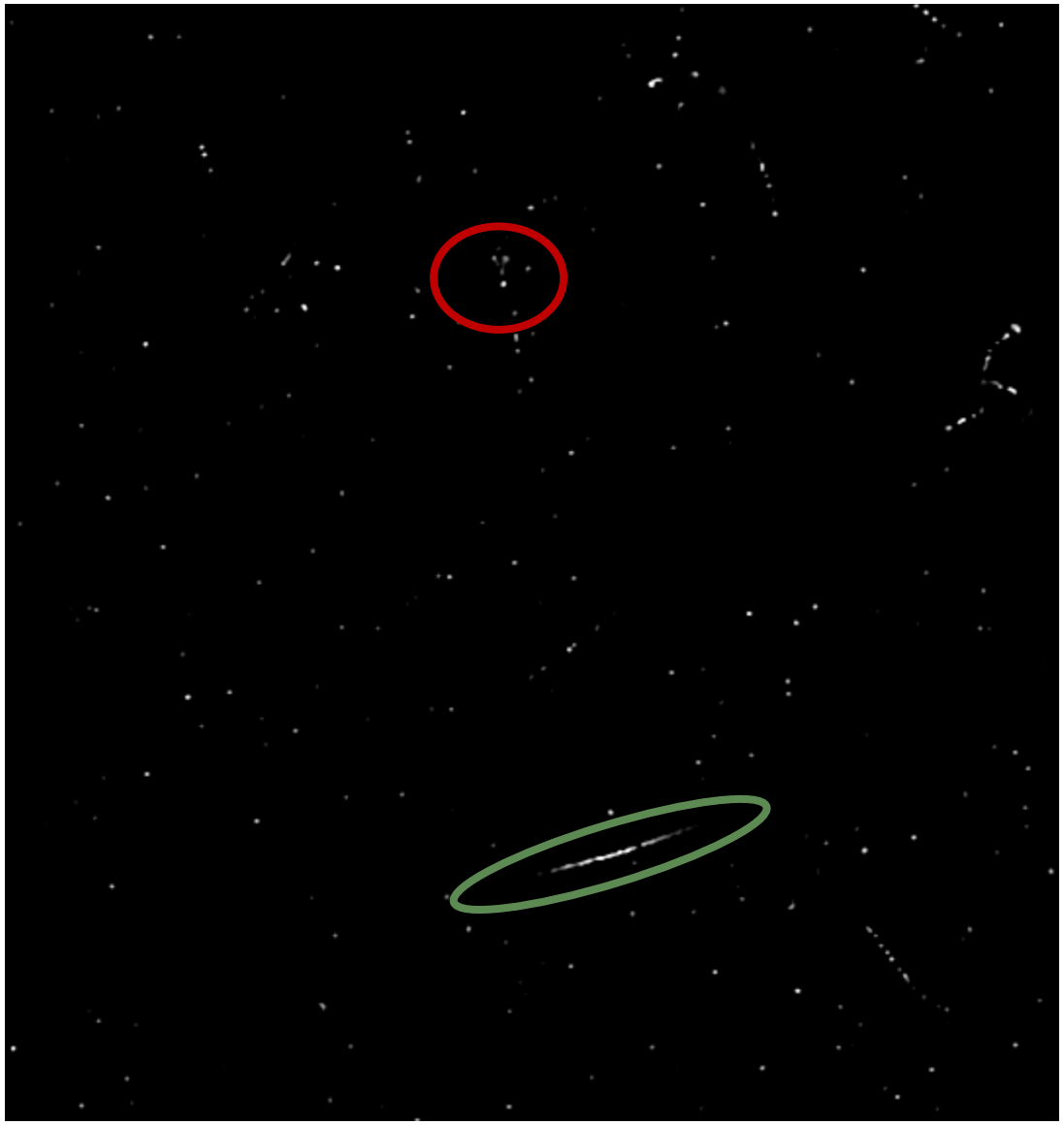
5x5 filter + shift + threshold



Cluster reconstruction

Effect of 5x5 Filter on Oxygen Clusters (1)

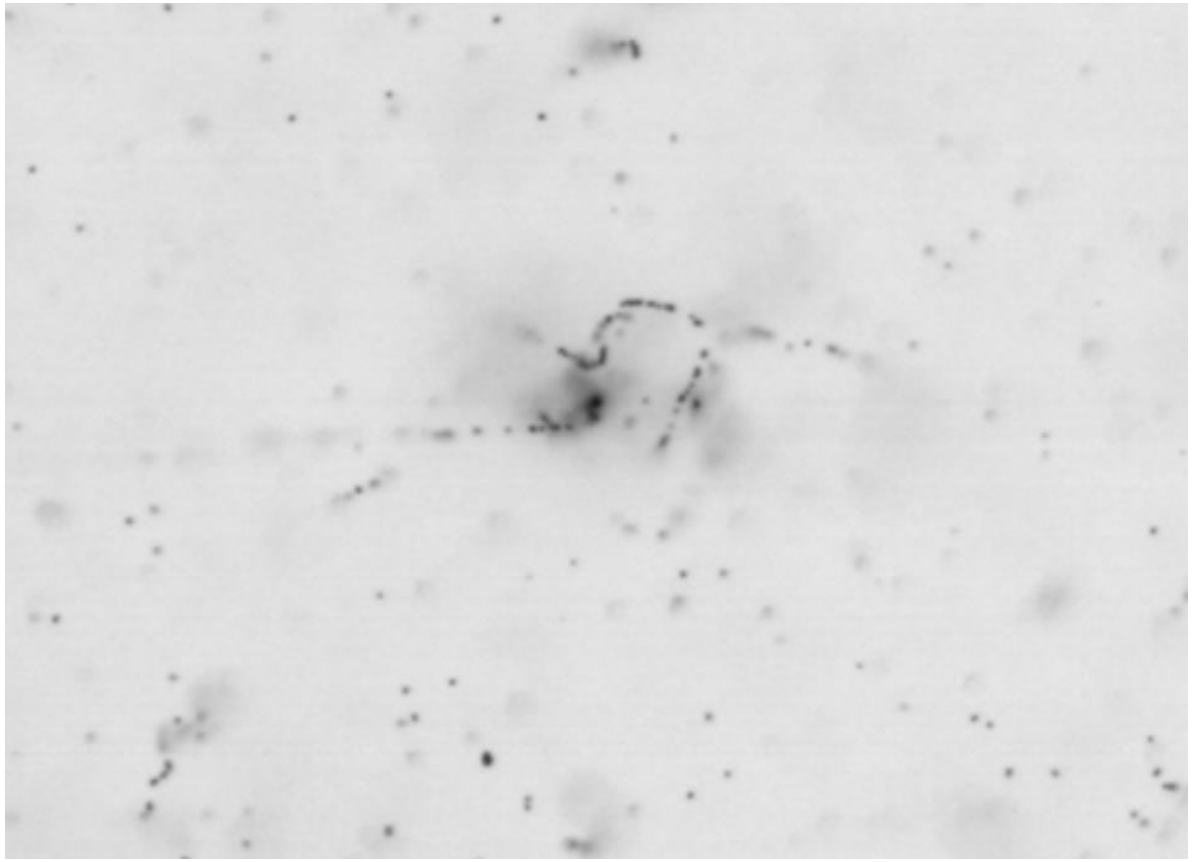




Original Image

5x5 filter + shift + threshold

Effect of 5x5 Filter on Oxygen Clusters (2)



- Smaller objects are highlighted while larger objects (such as oxygens) are split into smaller clusters
- The 5x5 filter leads to additional position and angular smearing and an overall loss of efficiency in oxygen reconstruction

Strategies

- The 5x5 kernel breaks oxygen clusters into smaller structures, which are later identified as separate clusters

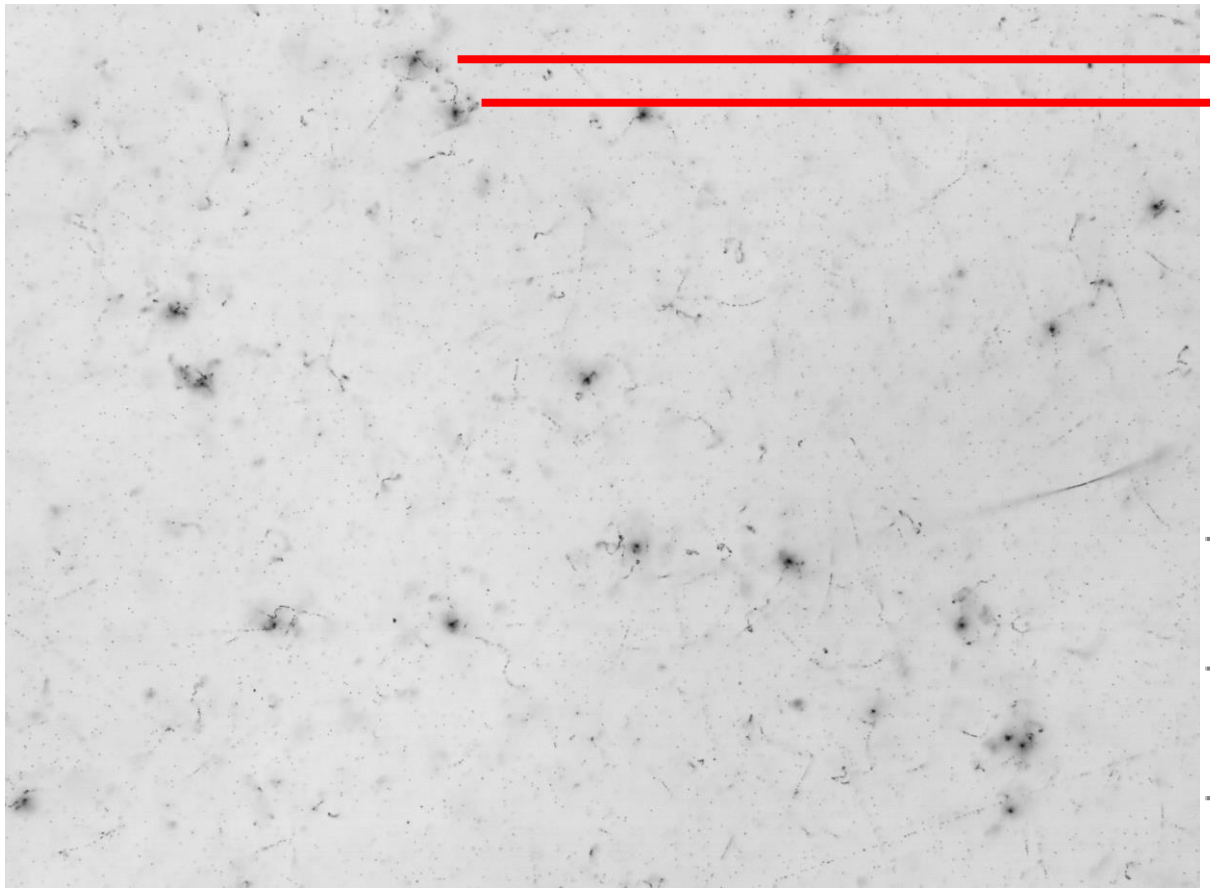
- Two main approaches possible, each with pros and cons

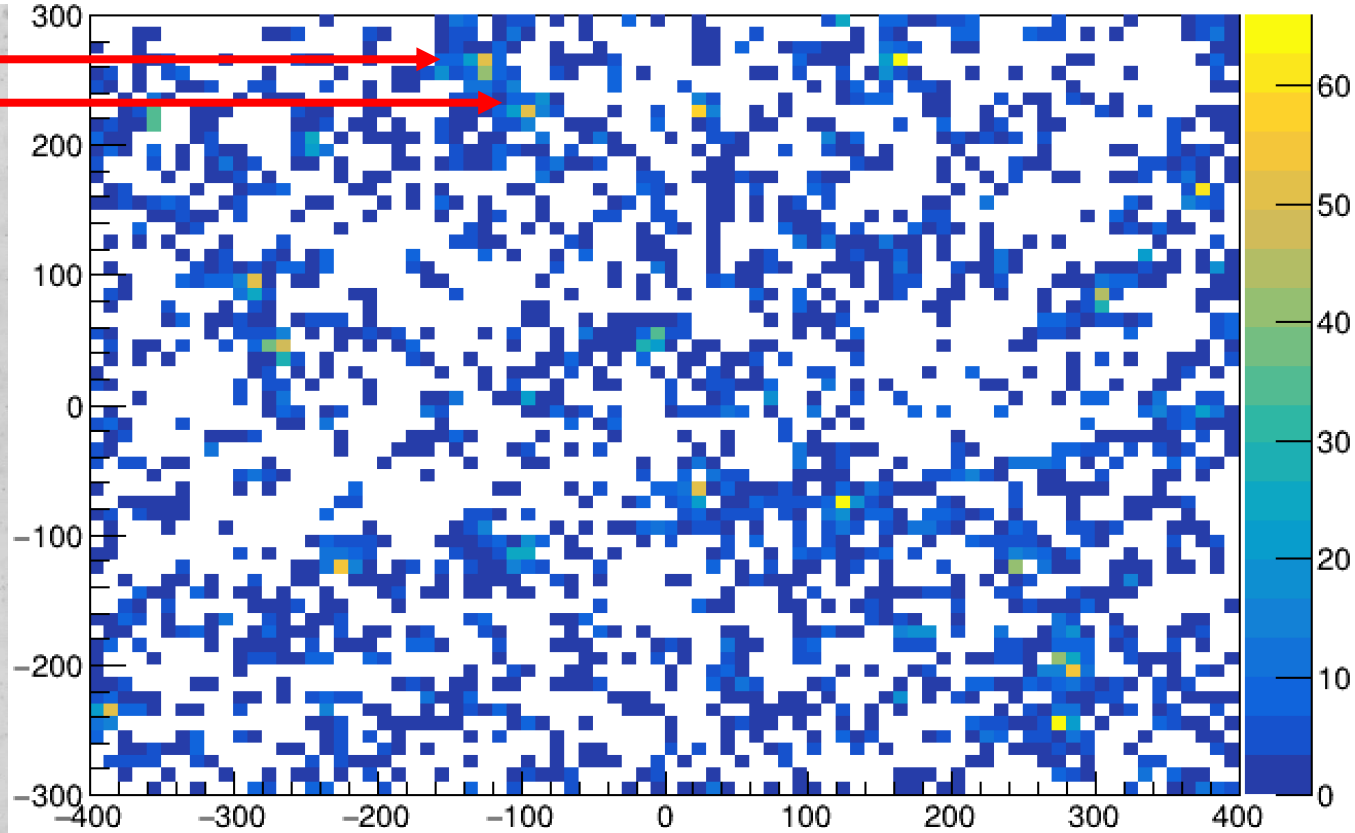
    1. Keep using the same filtering kernel to preserve the reconstruction of secondaries and identify oxygens from large number of clusters close to each other
    2. Design new filtering kernel optimized for the identification of oxygens (low efficiency for secondary tracks)

- In principle, a 2 kernel logic can be implemented in the scanning software

Oxygen Identification from Clusters

- Small area scans were performed with the 5x5 filter to understand whether it is possible to identify oxygens from clusters, without performing linking

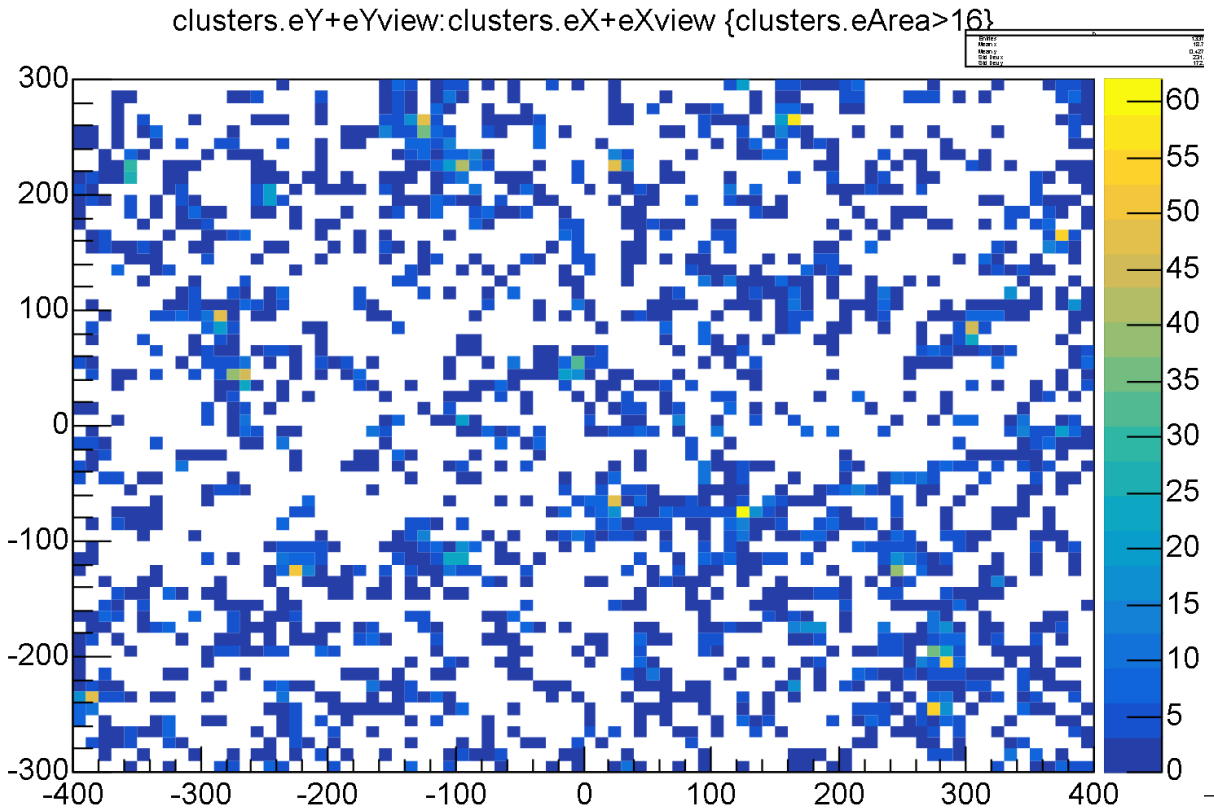


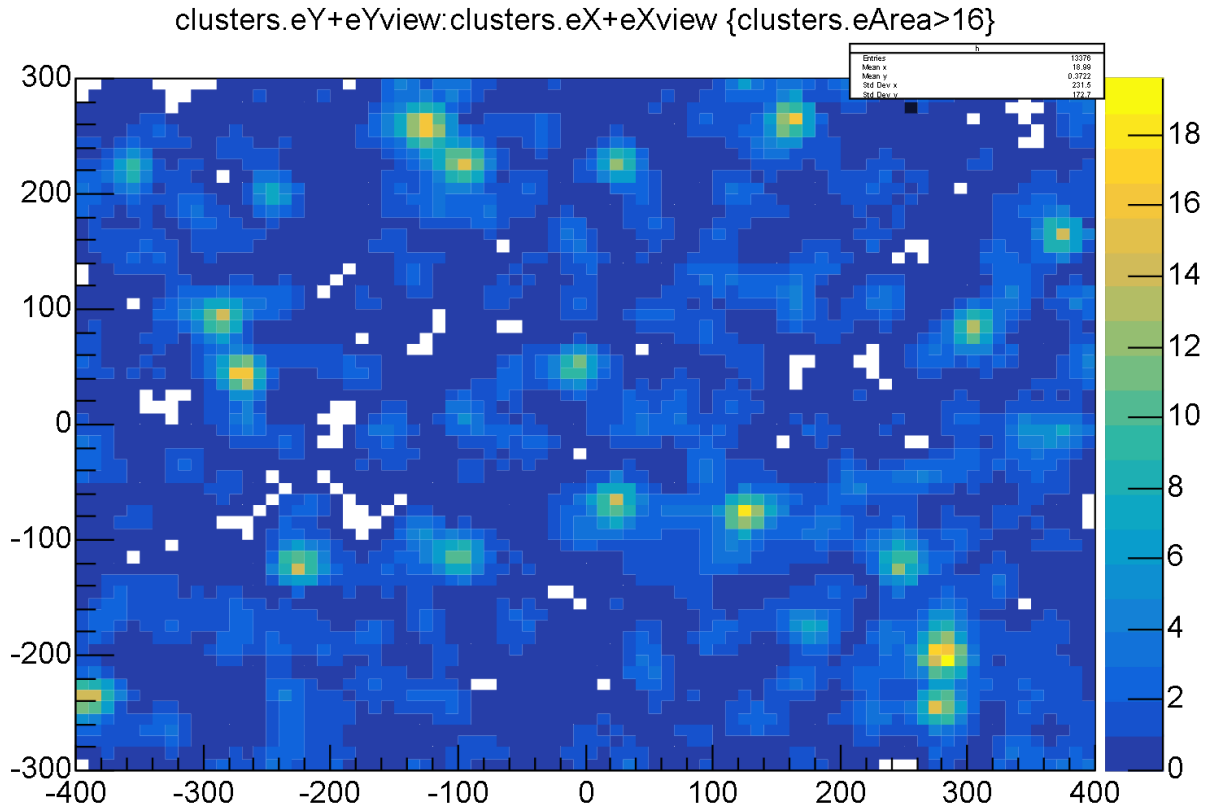


Possible to find oxygens with large binning ($10\ \mu m$)

Simple Algorithm to find oxygens (1)

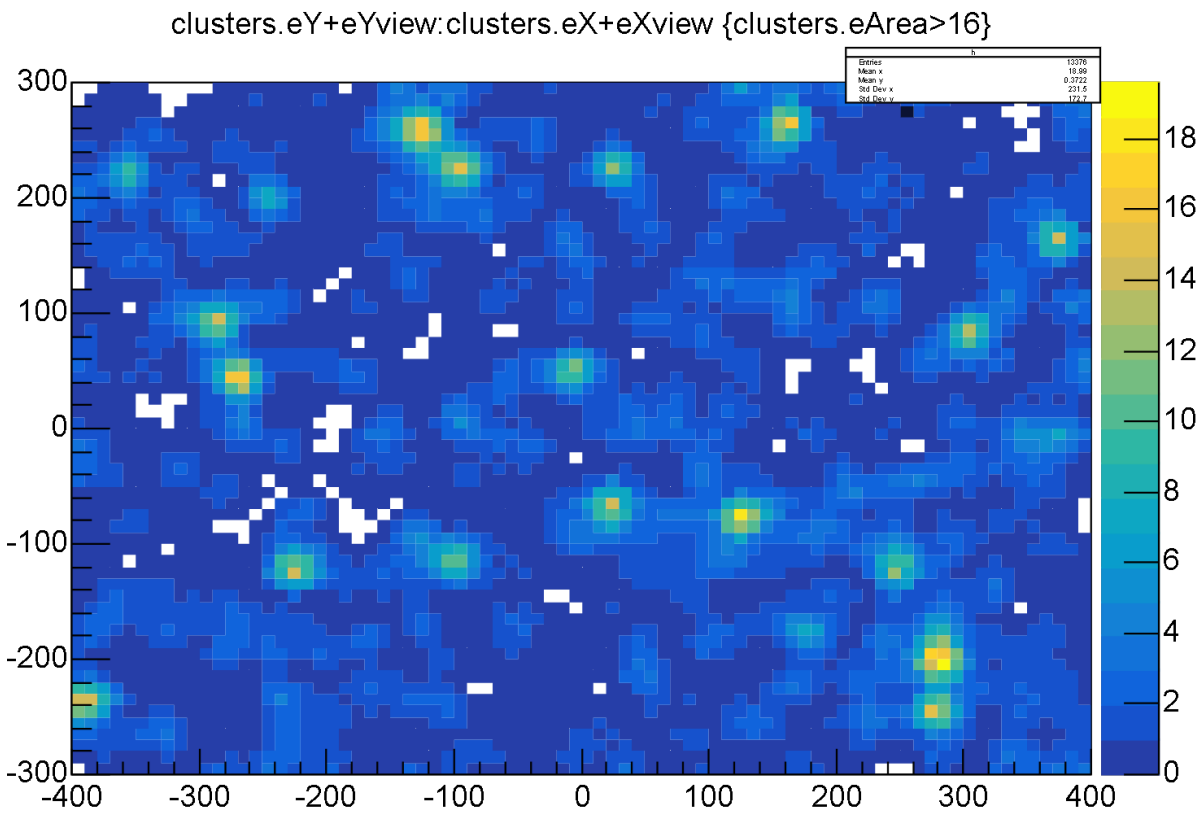
- Perform offline scanning (meaning without online grain and micro-track reconstruction) and save clusters
- Convert clusters to ROOT format and organize them into a 2D histogram
  - Binning defines spatial resolution and must be a compromise (these test used $10\ \mu m$ bins)
- Apply 5x5 smoothing filter (ROOT default)

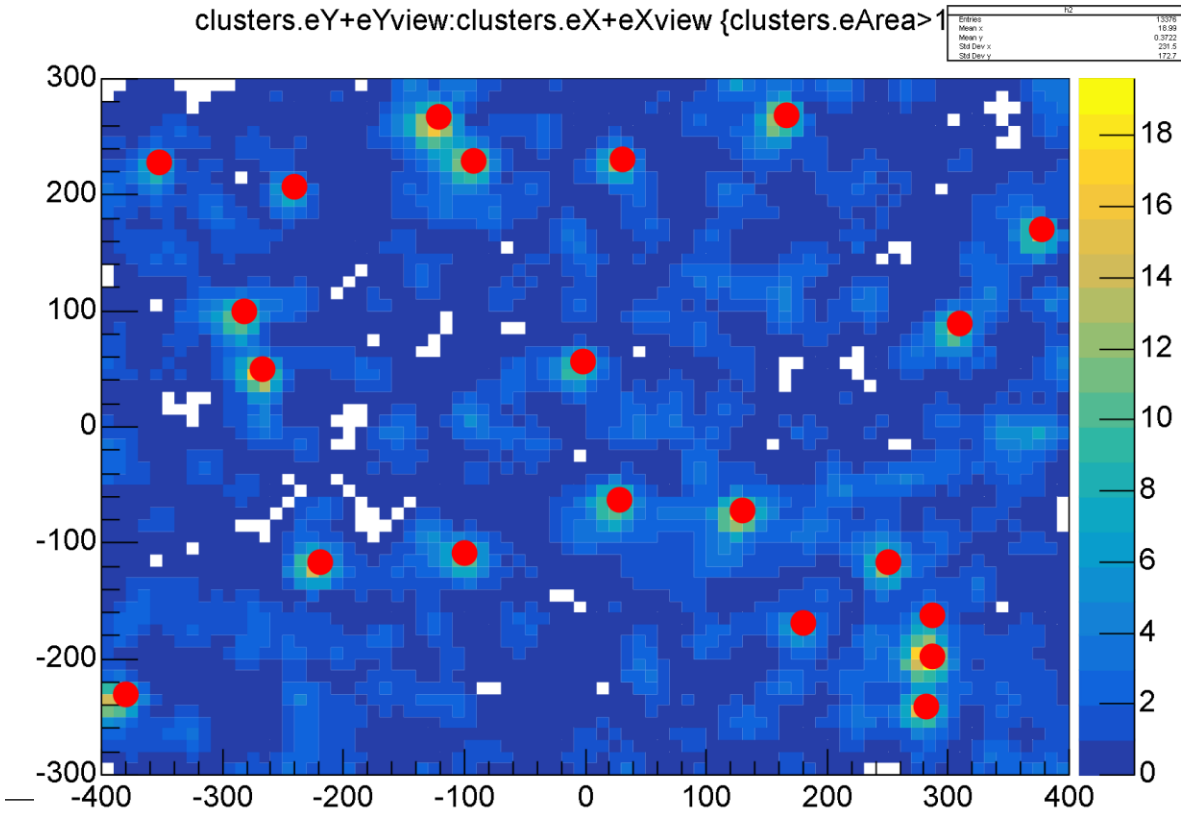




Simple Algorithm to find oxygens (2)

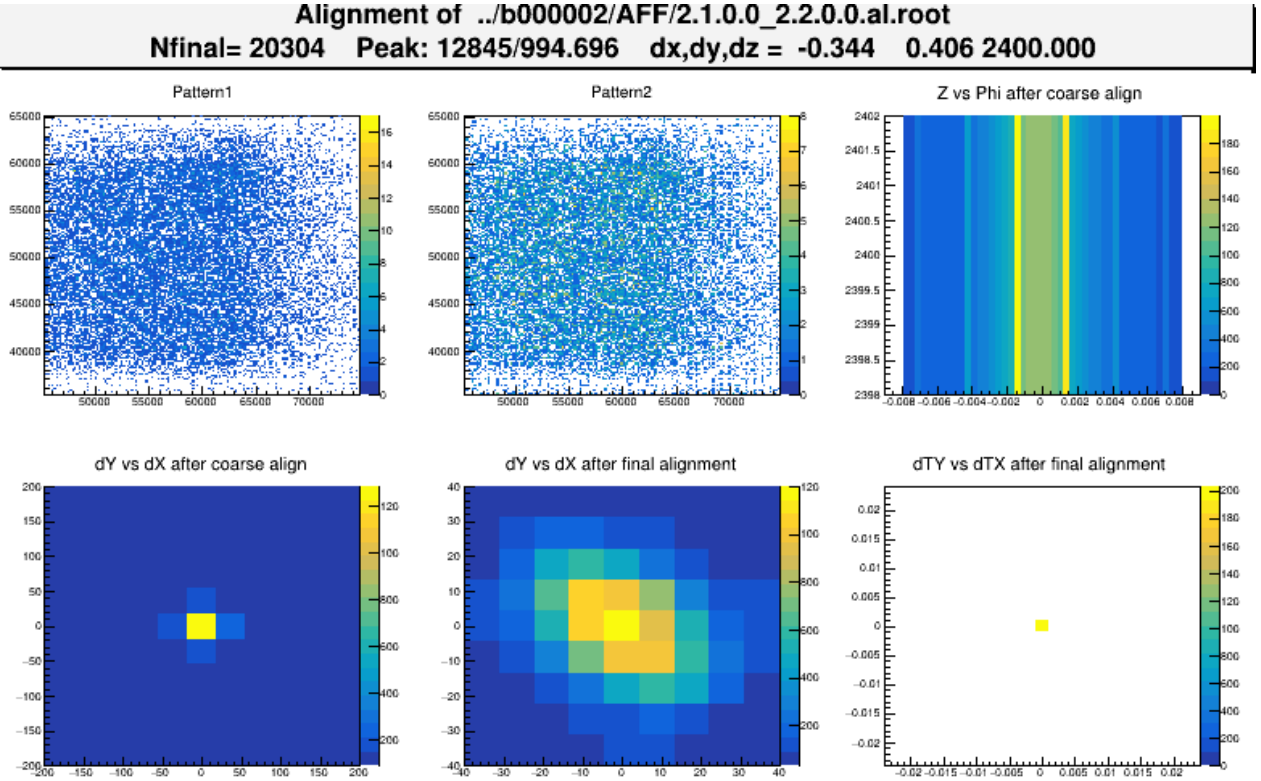
- Algorithm to identify clusters:
  - Define a threshold (minimum number of entries for peak, 7 in this case)
  - Find maximum bin → assume 5x5 cluster and evaluate centroids, total number of entries
  - Set pixel values in the 5x5 cluster equal to 0 and repeat

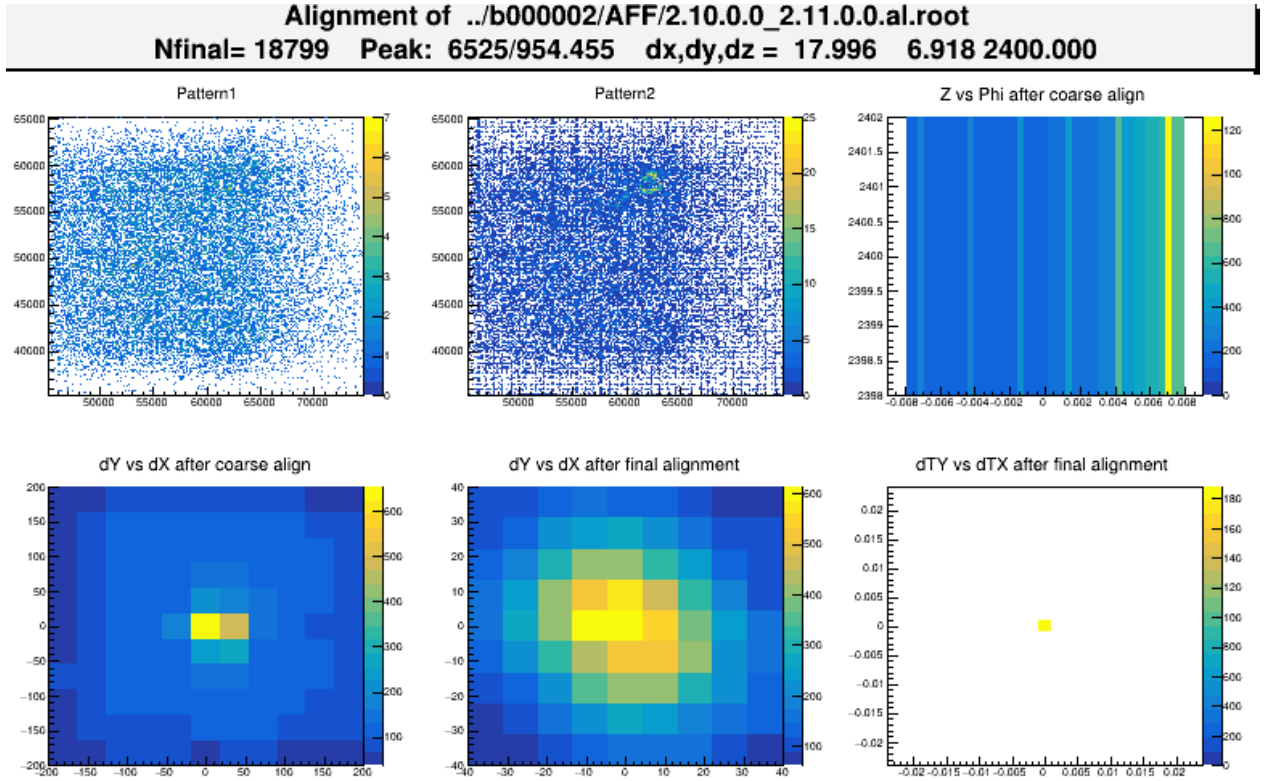




First Results: Alignment

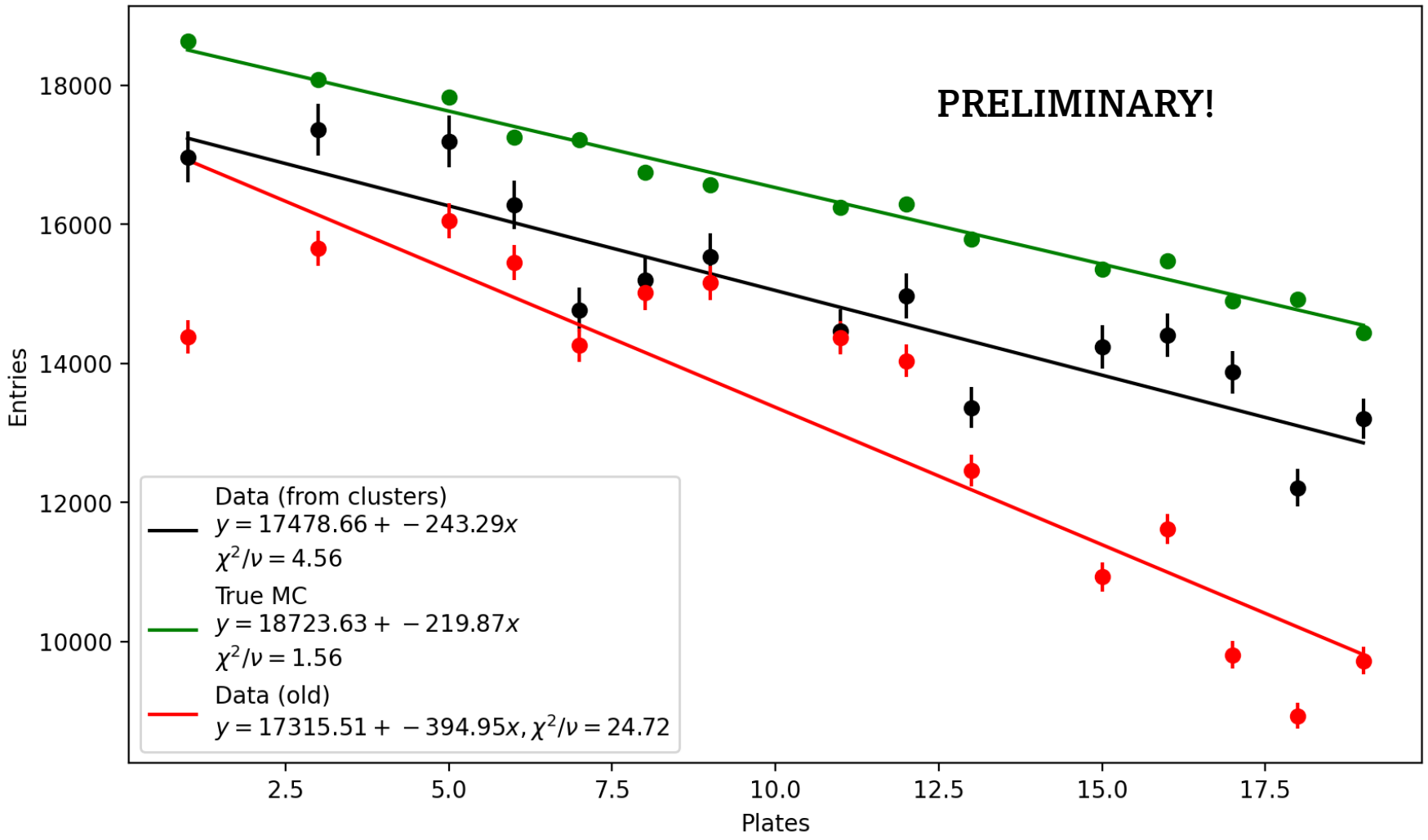
- Small area scans of the first 26 emulsions of the GSI2 2019 dataset were performed
- Oxygen positions were identified with the approach described so far, while the angles were set to 0
- Alignment with only oxygens is possible, but with lower accuracy than usual
- DZ cannot be aligned





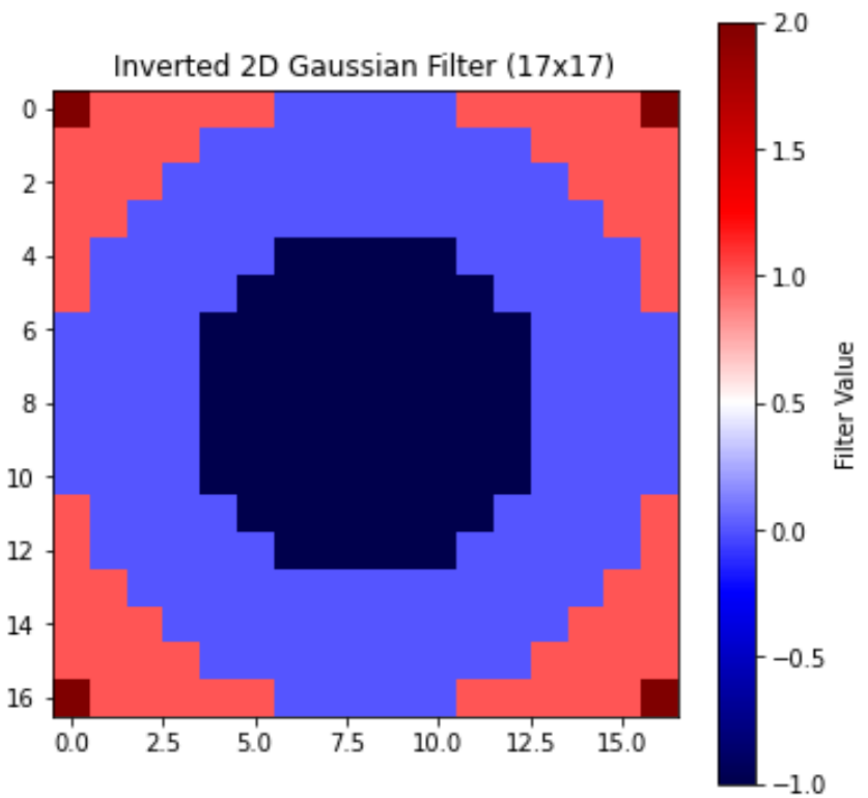
First Results: Number of Oxygens

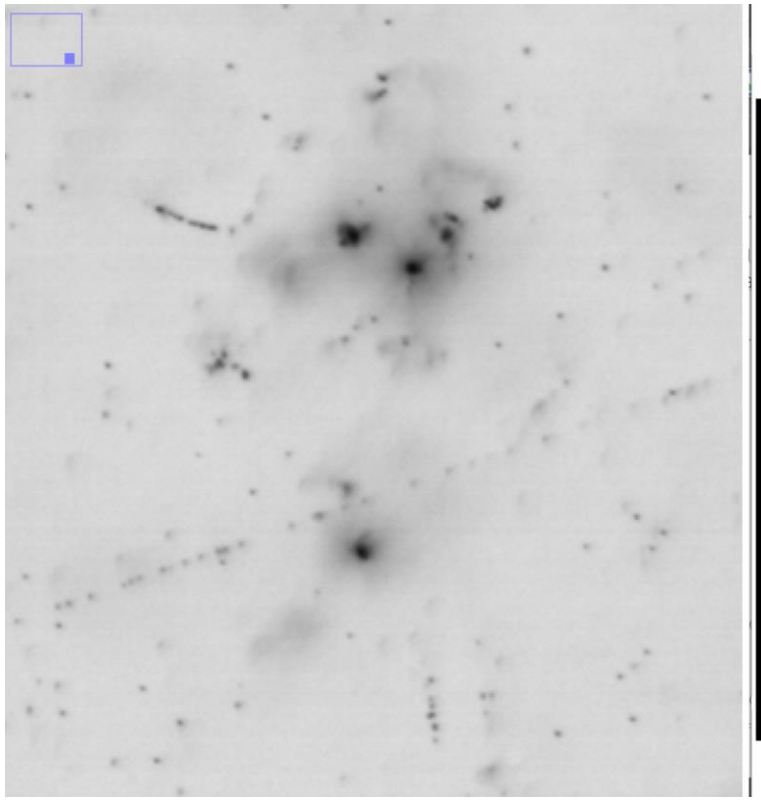
- For this test, only require a minimum amount of clusters in top and bottom layers
- Use alignment only qualitatively (confirm that they are true clusters and alignment can be found)
- Improvement with respect to standard reconstruction but still <u>too much fluctuation</u>



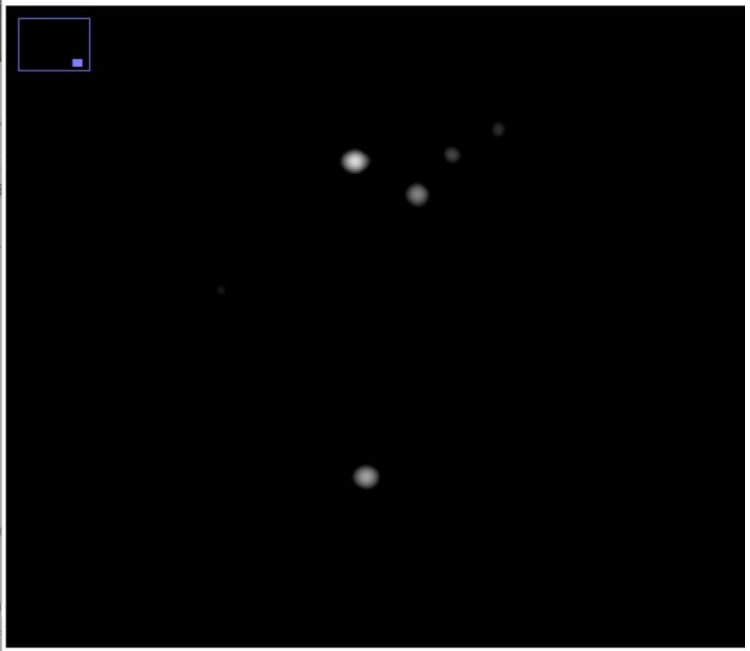
Second Approach: New High Pass Filter

- A cleaner solution is to use a larger filter, purely dedicated to oxygen reconstruction
- After the analysis of oxygen clusters, a Gaussian filter of 17x17 pixels and $\sigma = 11$ pixels was selected
- The acceptable range for the values inside the filter is fixed by the need to avoid overflow beyond 16 bit immediately after convolution (LASSO framework)
- Implementation in LASSO + tuning of threshold and normalization completed





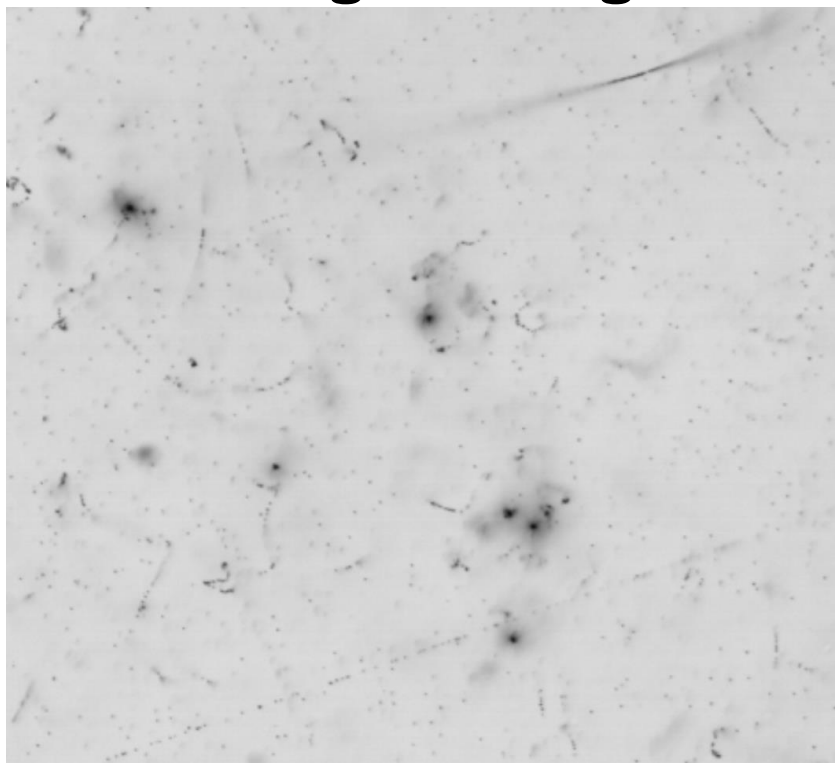
Original Image



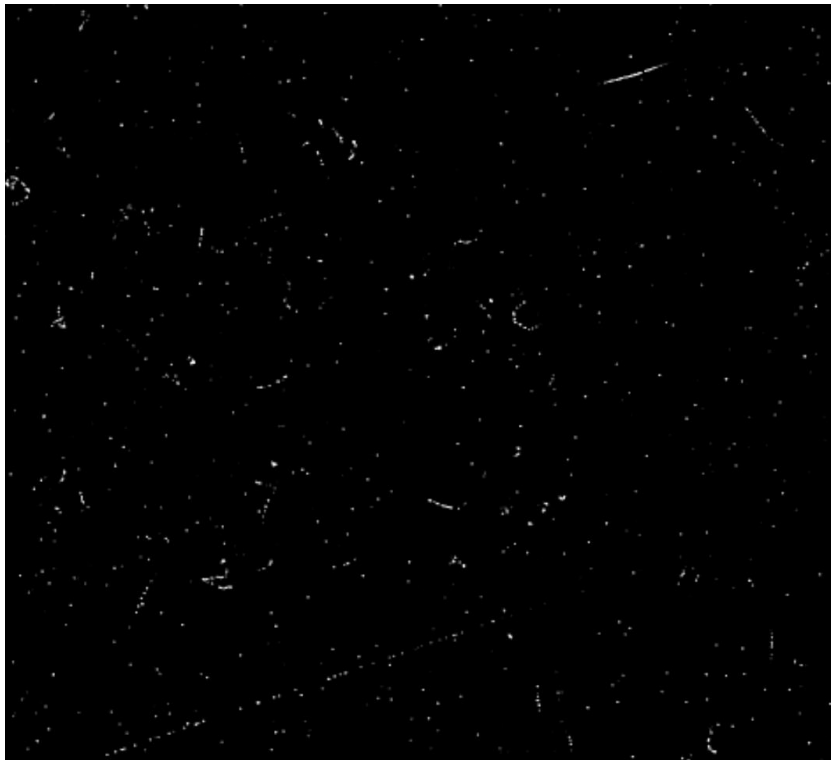
17x17 Filter

Comparison between 5x5 and 17x17 Filters

Original Image



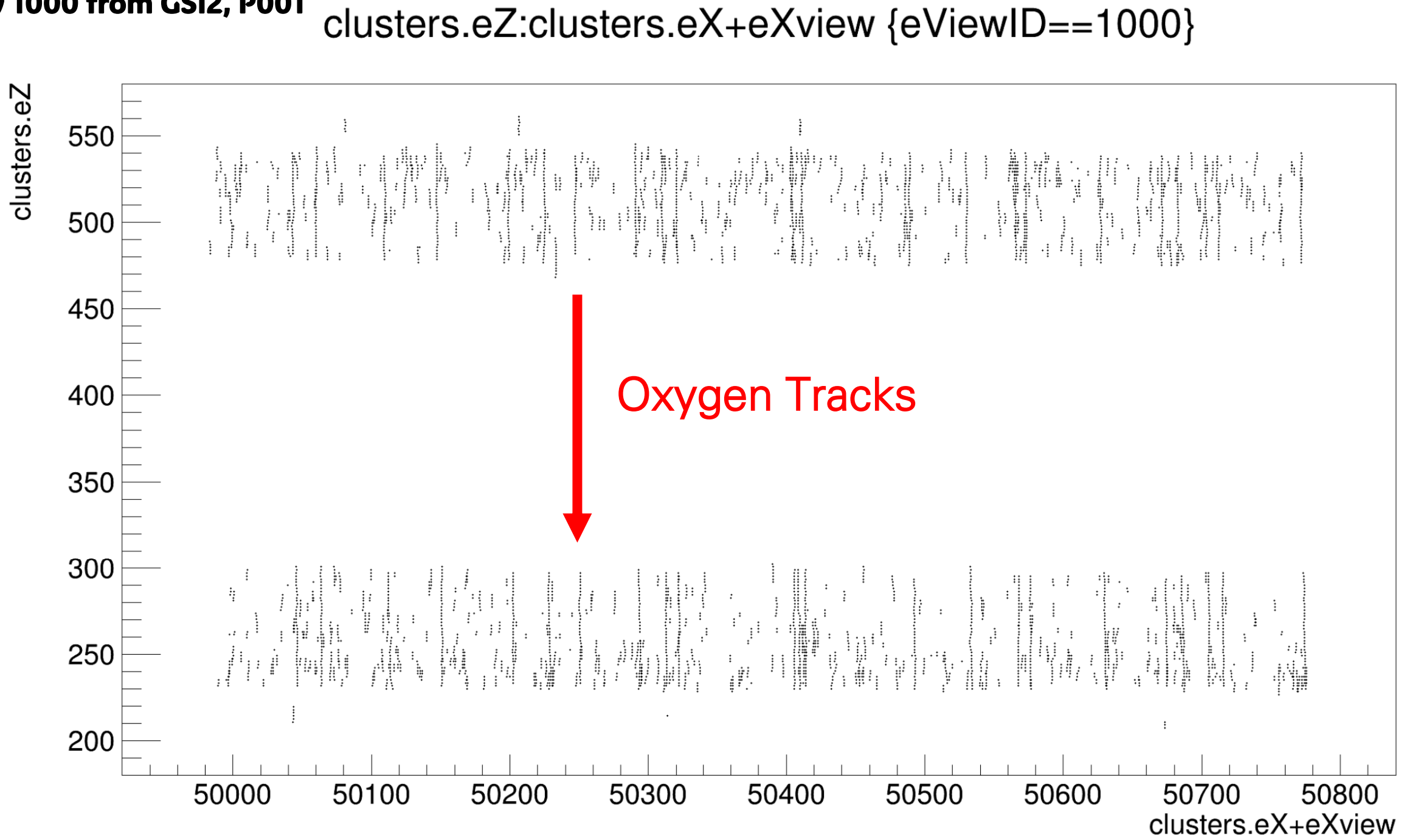
5x5 Filter



17x17 Filter

- The same image was filtered with the 5x5 filter and an 17x17 high pass Gaussian filter
- The latter seems well suited for the reconstruction of oxygens (low efficiency for secondaries)
- Promising results → scanning of all S1 films for GSI1 and GSI2 already perfomed with new filter

View 1000 from GSI2, P001

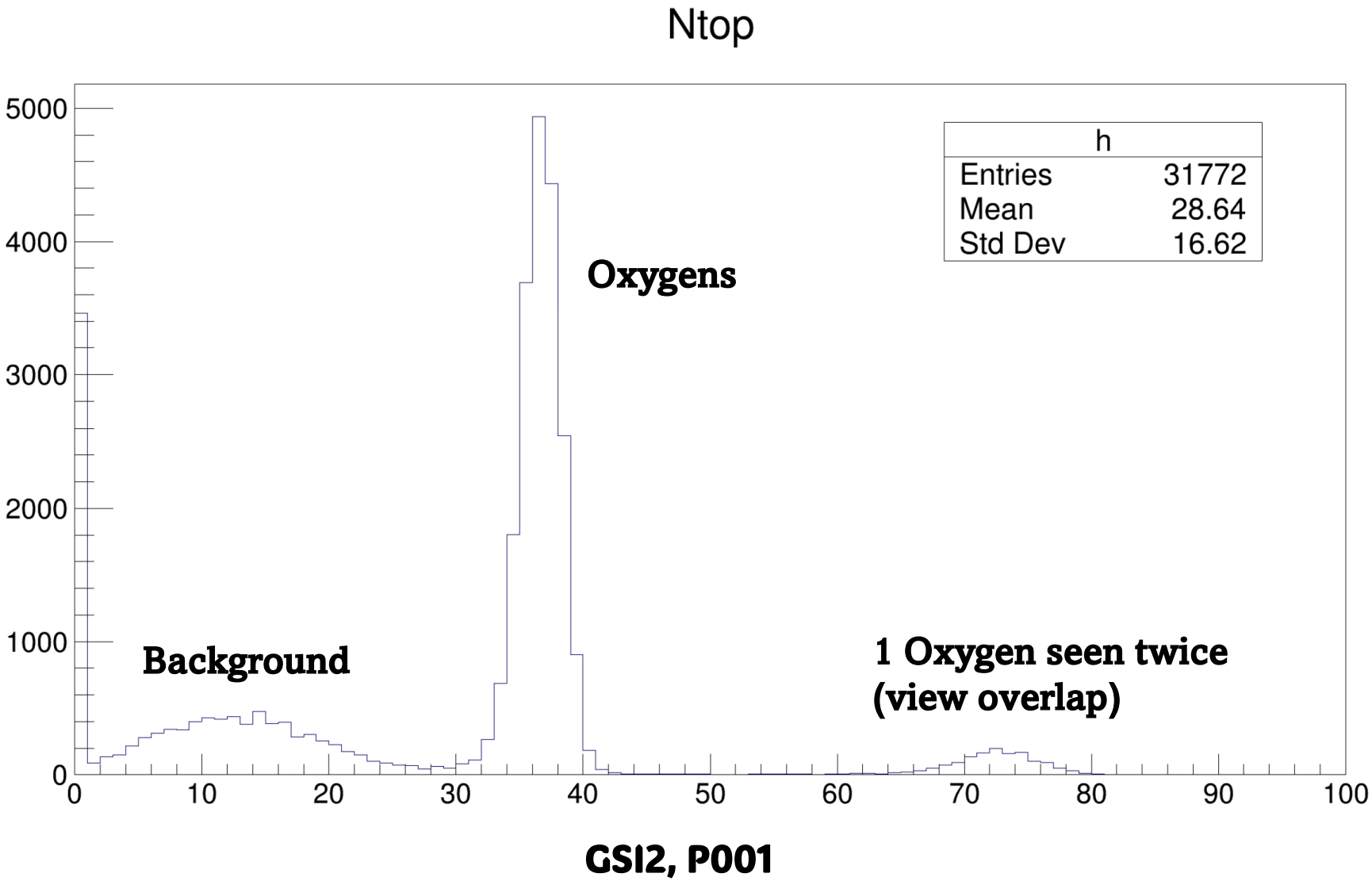


New Counting Method (1)

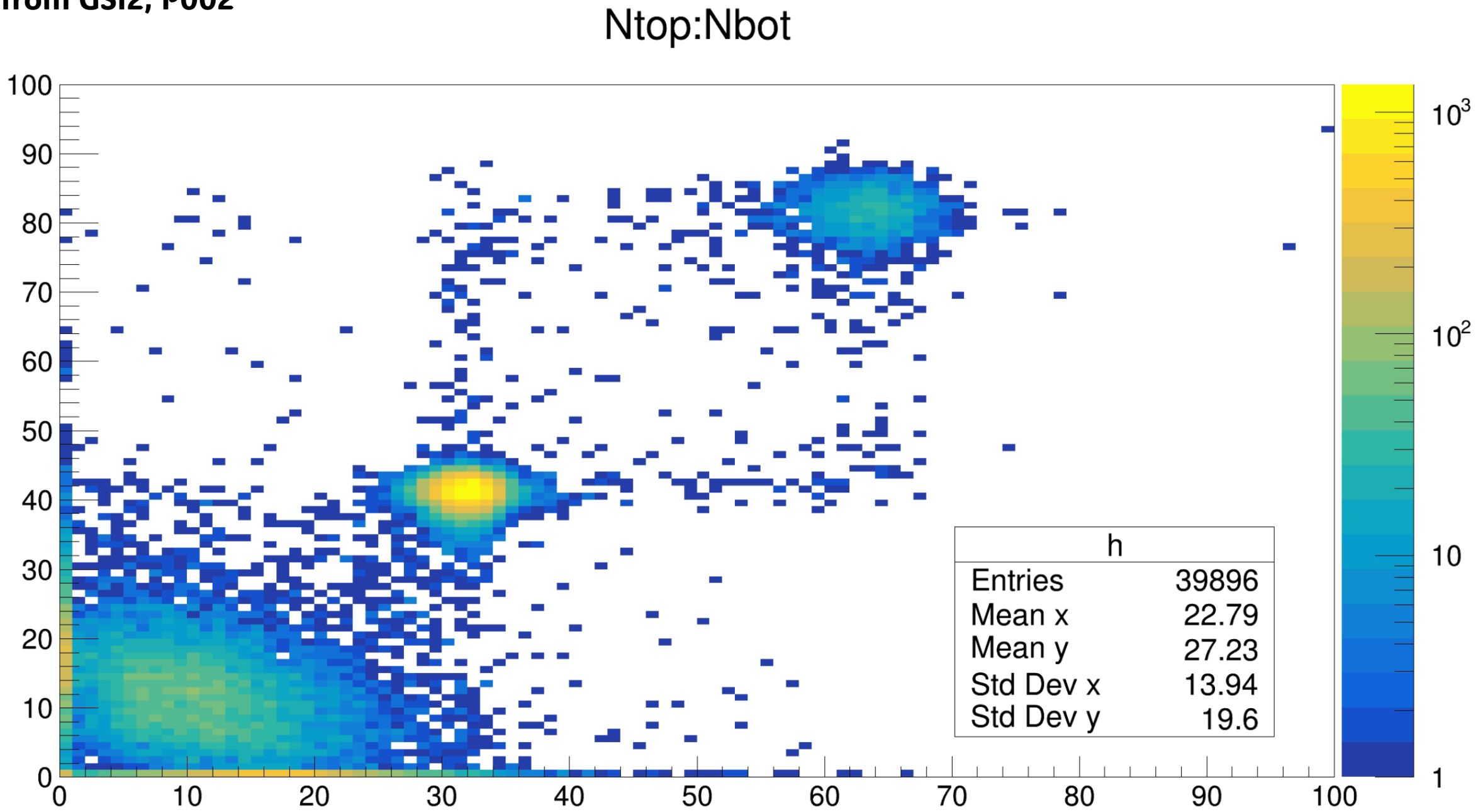
- As shown by visual inspection, oxygen tracks are now easy to find through clusters

- Current strategy for counting:
  1. Find rough position of oxygens based on XY cluster distributions

  2. Count number of clusters in top and bottom sides for each «candidate»

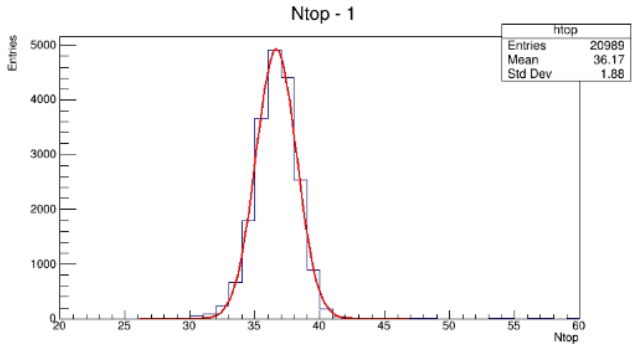


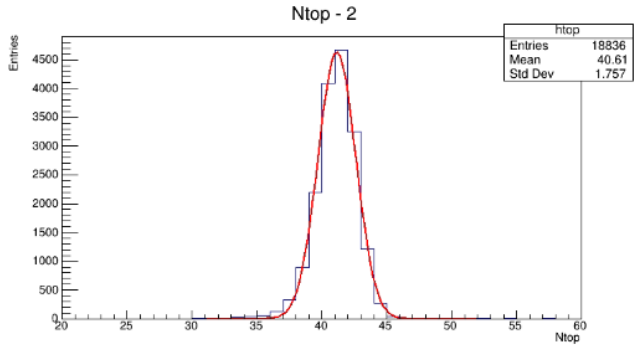
from GSI2, P002

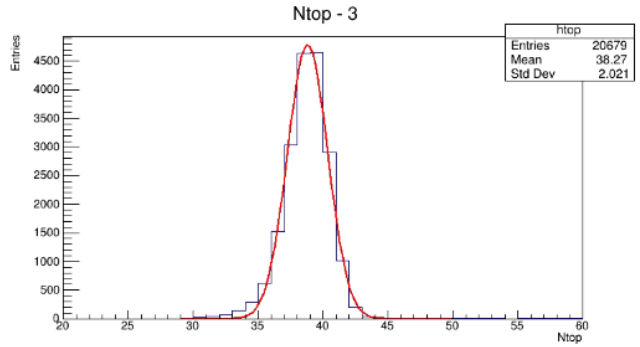


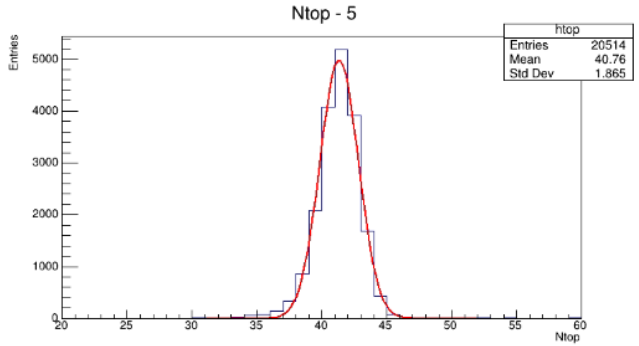
New Counting Method (2)

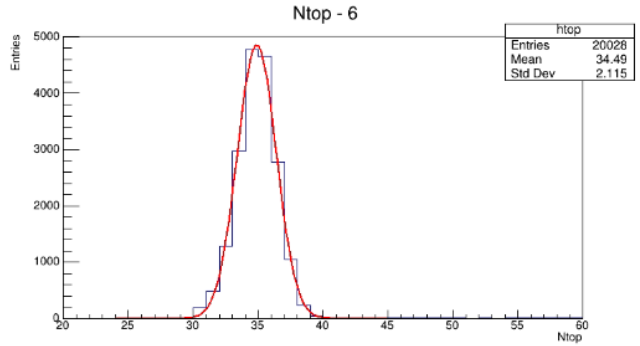
- To count the number of oxygens a Gaussian fit is performed on the main peak
- The final cut on the entries requires Nbot and Ntop to be within 3 sigmas of their peak (or 2 times that for the second peak due to view overlap)

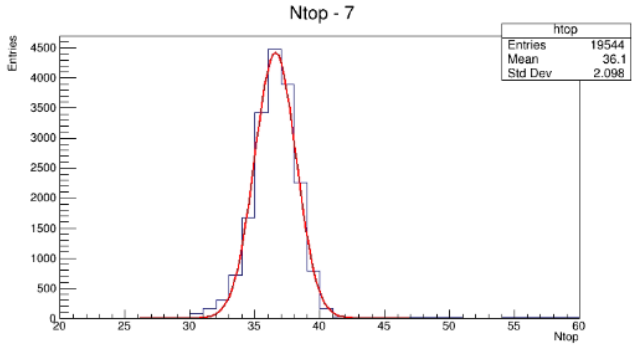


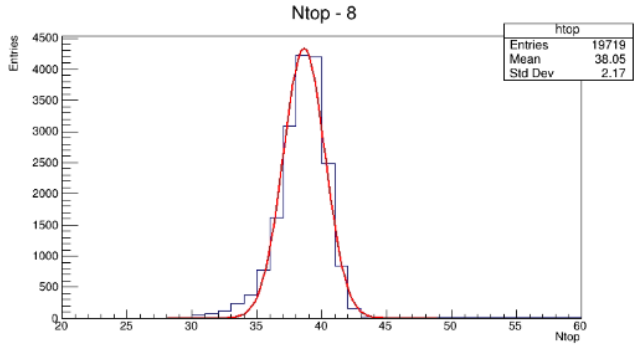


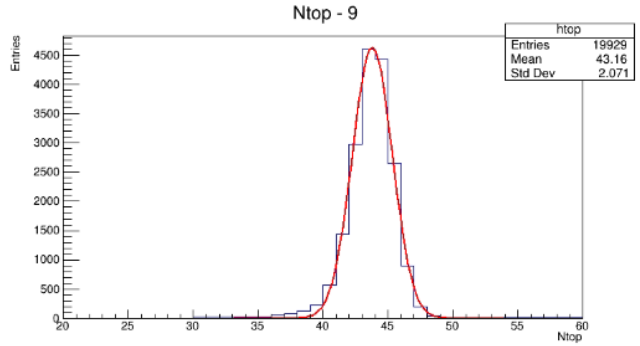








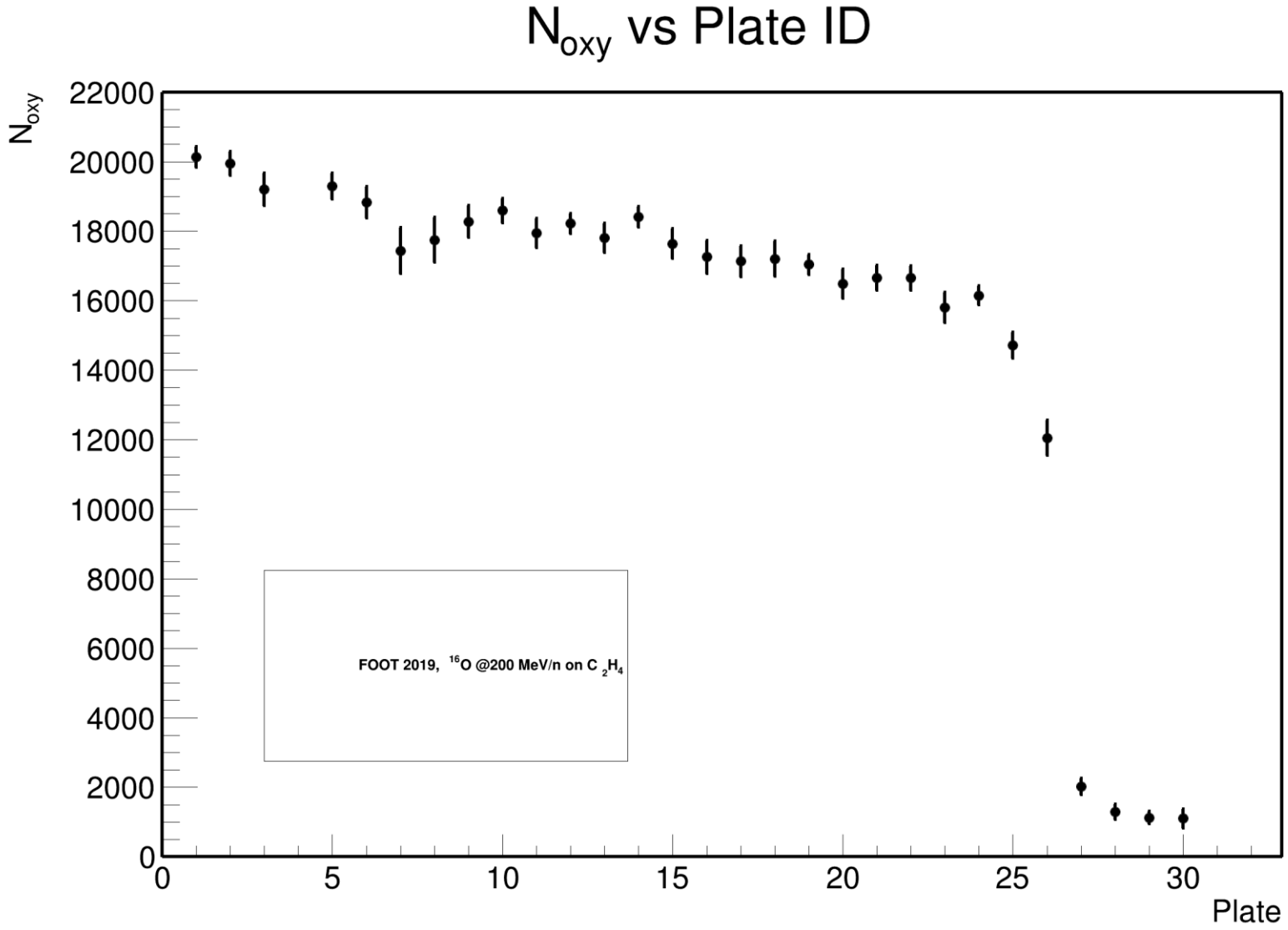




from GSI2, P001 to P009

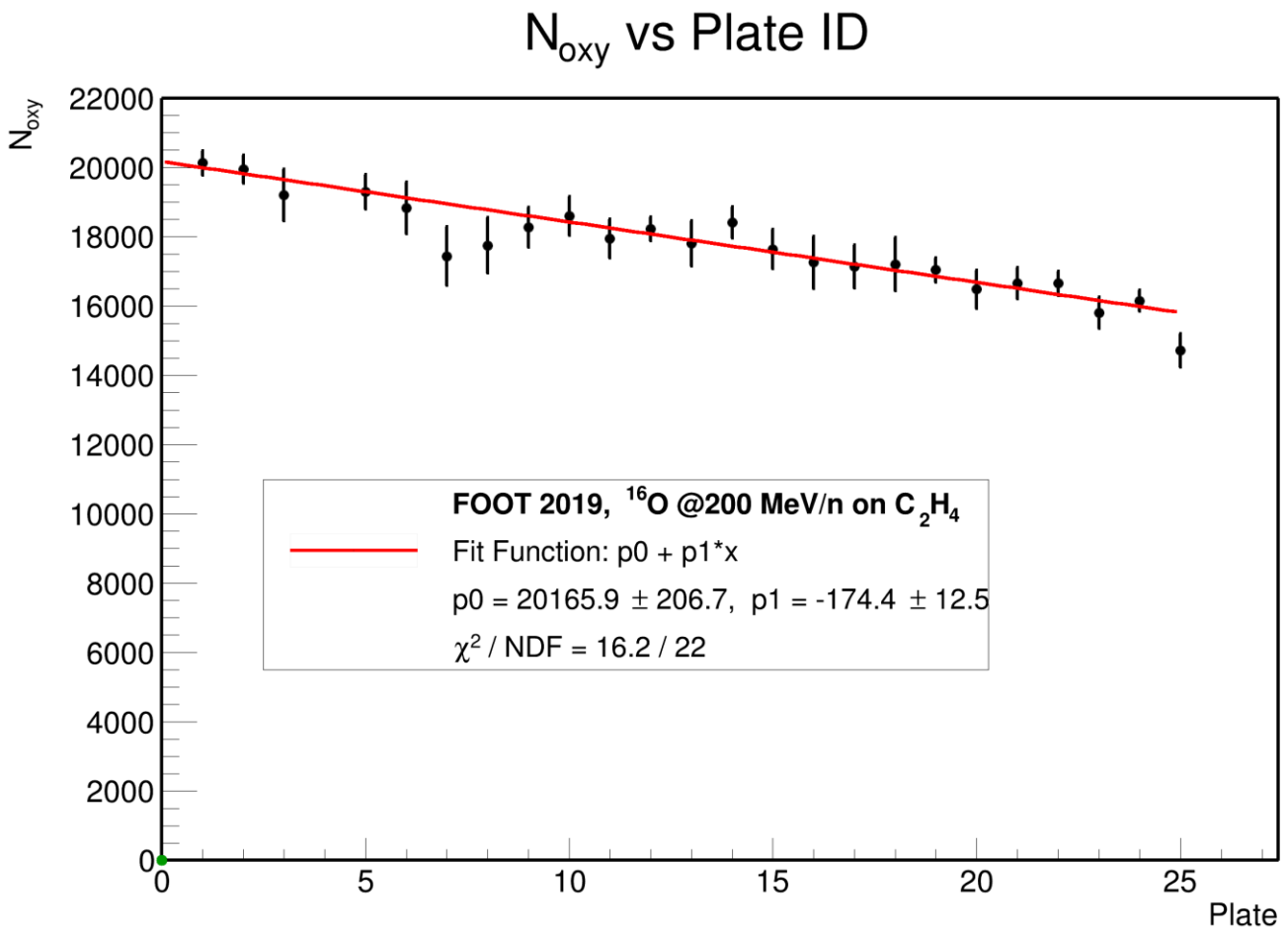
Scanning Results (17x17 filter)

- The number of oxygens in each plate is evaluated by a cut on the number of clusters in the top and bottom layers of each emulsion
- Robust measurement of the number of oxygens (each plate is independent from the others)
- Errors in the plot include a statistical component as well as a systematic component (here evaluated as difference between cut at 3 σ and 4 σ)



Oxygen Counting for Total Cross Section

- In order to evaluate the total cross section, the slope obtained by the fit must be corrected to take into account contamination coming from the heaviest secondary fragments



- To estimate the contamination, we assume that all tracks that are left after the Bragg Peak were uniformly produced up to plate 25
- By using the last three plates to estimate the background one gets 1173 ± 130
- The correction to the slope would be 46.9 ± 5.2
- Final value would be -221.4 ± 11.5

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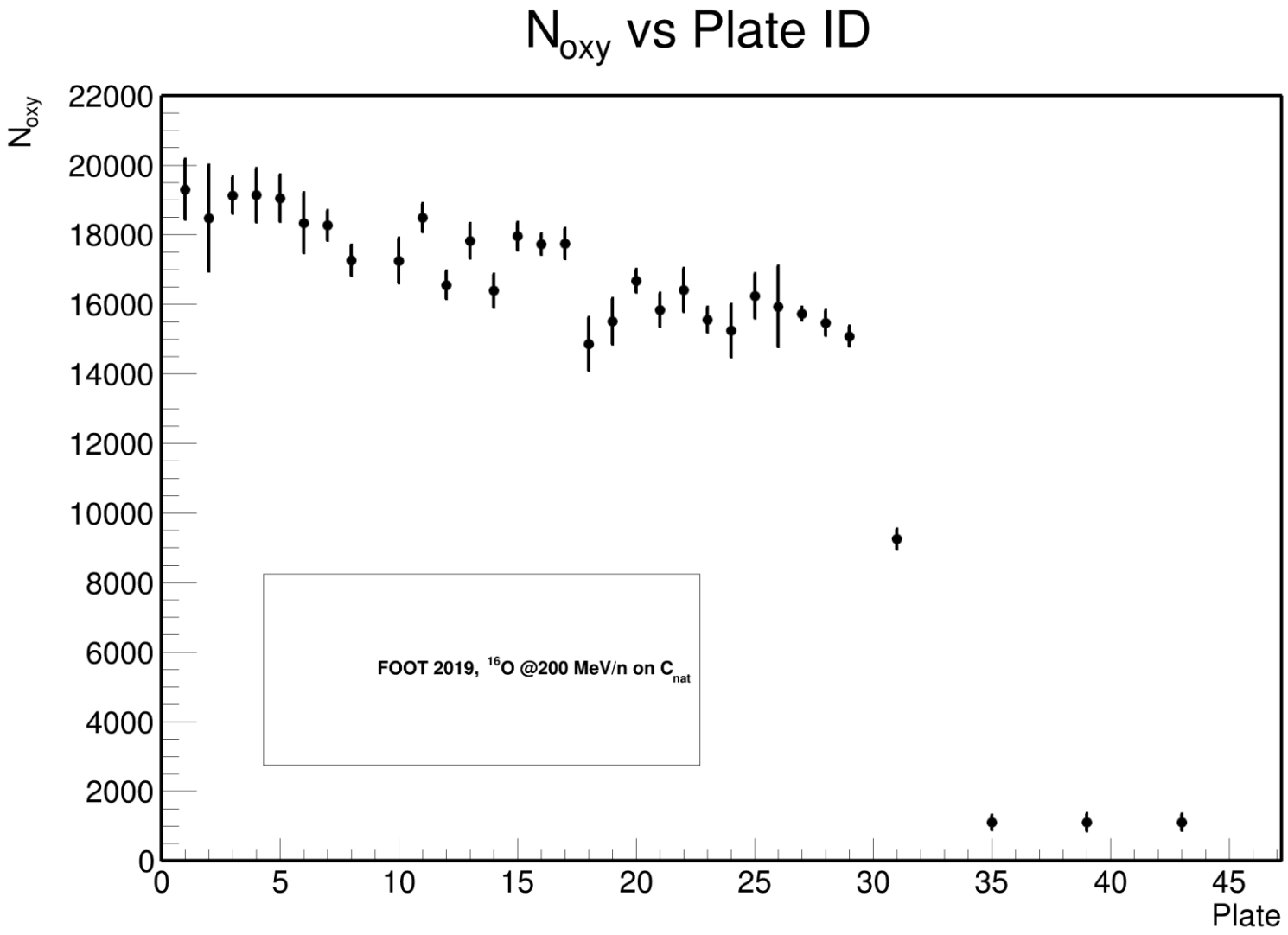

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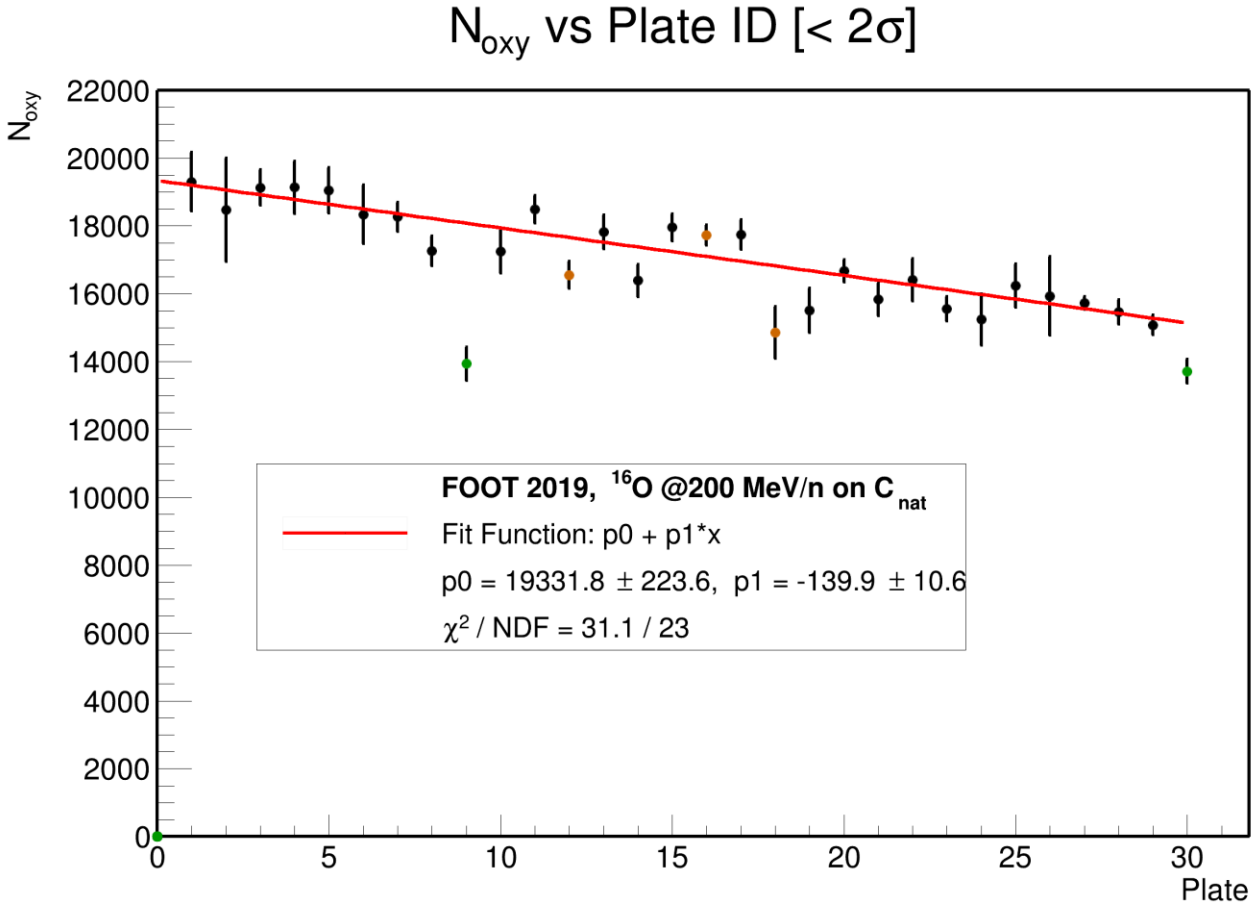

- To estimate the contamination, we assume that all tracks that are left after the Bragg Peak were uniformly produced up to plate 30
- By using the last three plates to estimate the background one gets 1092 ± 117
- The correction to the slope would be 36.4 ± 3.9
- Final value would be -184.0 ± 10.5

Conclusions

- Many efforts to improve oxygen reconstruction efficiency
- First approaches have shown that keeping the 5x5 filter was not the optimal solution, despite being a marked improvement with respect to the previous reconstruction attempts
- A new image filter for oxygen reconstruction has been designed and tested
  - Quite good results for both datasets
- Inclusion of these developments in the cross section measurement on-going

MIP Reconstruction with 17x17 Filter

- In order to estimate the background due to MIPs, scanning with areas larger than the extension of the beam were performed
- The reconstruction shows that background coming from out of beam areas (cosmics) is negligible