NEWS*dm*

PLASMON ANALYSIS

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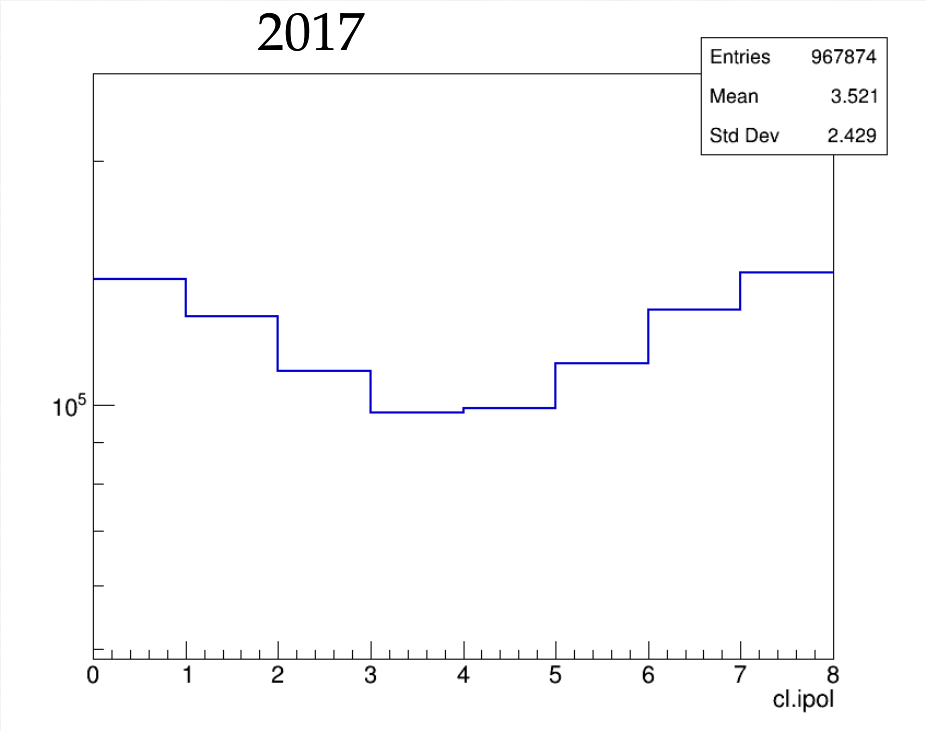
Summary

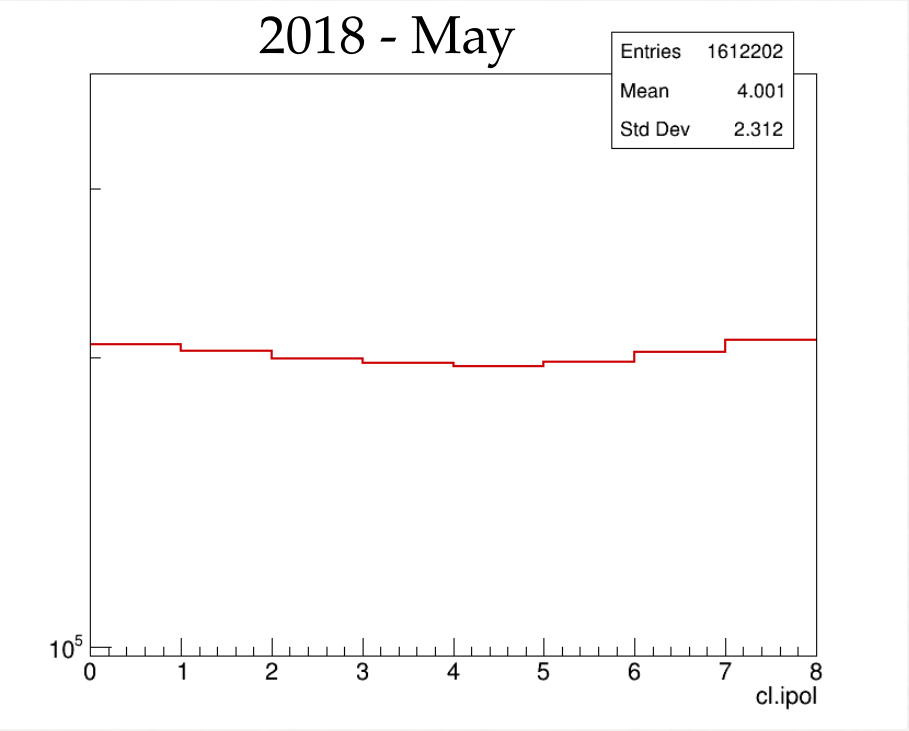
- Plasmon response with the current setup of the optical system
- Barycenter shift with Carbon Ion samples
- Study of brightness stability after the microscope optimization

NP40nm

Plasmon Analysis Updates

Microscope optimization in terms of brightness response for each polarization angle (T. Asada, A. Alexandrov)



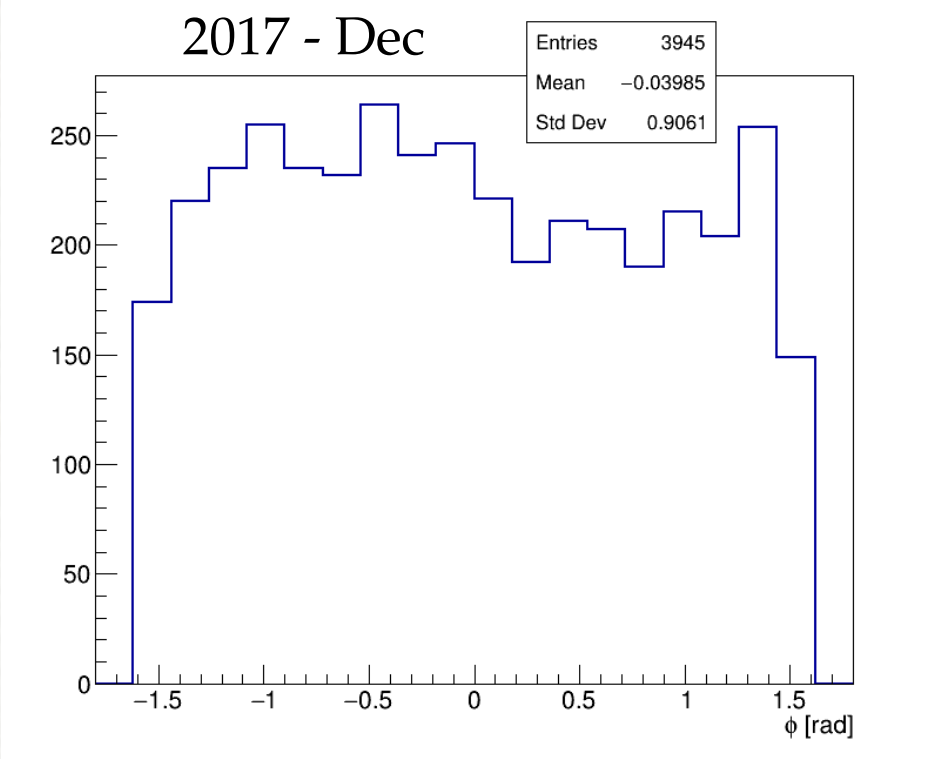


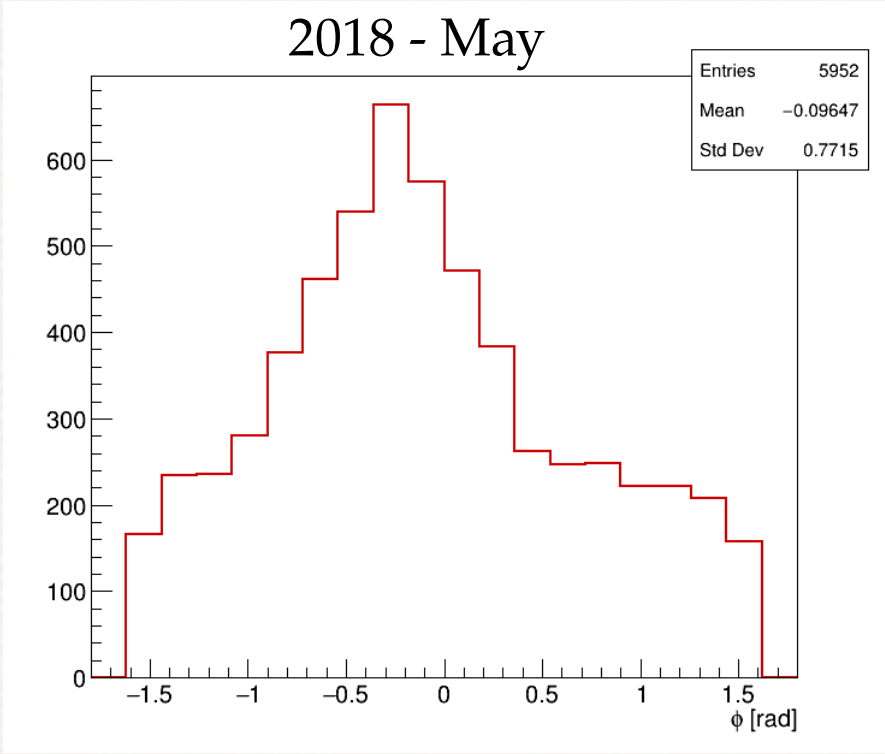
Number of clusters for each polarization angle (NP40nm)

Plasmon Analysis Updates

The current setup on the other side shows now a very large anisotropy

The source of this anisotropy has not been studied yet

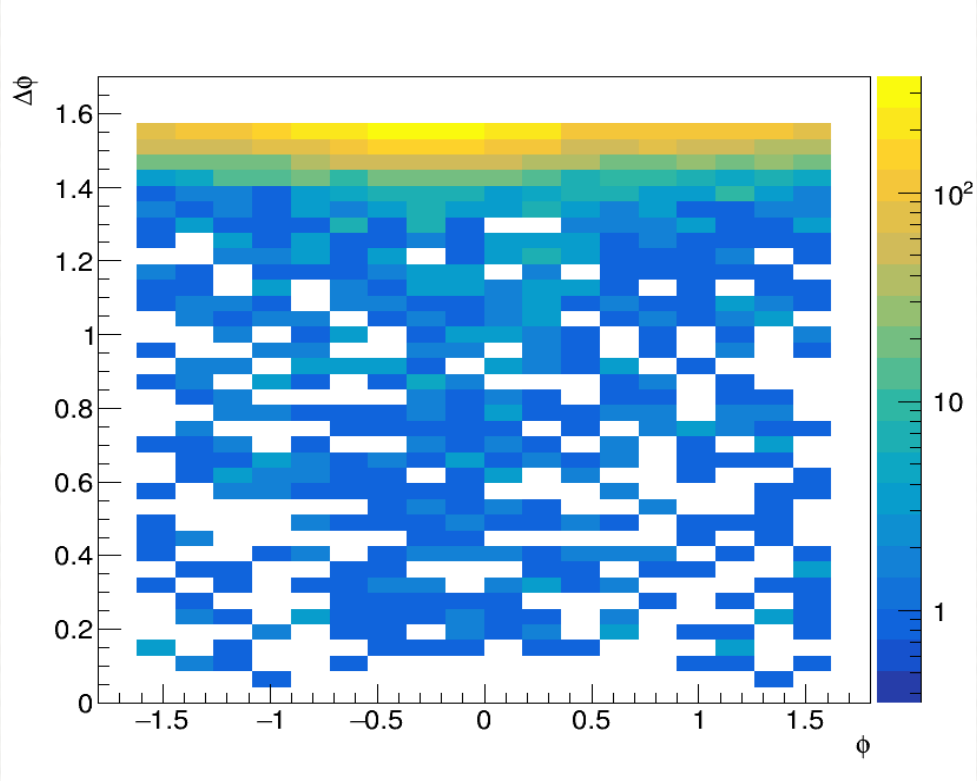




Phi angle distribution – Expected isotropic (NP40nm)

Plasmon Analysis Updates

Anisotropy affects mainly rotating grains, i.e. static grains without any preferred direction



ΔΦ versus Φ

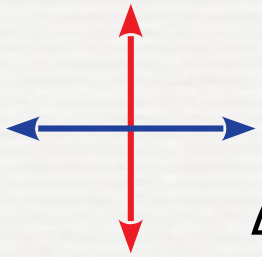
ΔΦ is the maximum angular distance between two polarizations of the same collection

ΔΦ = 30°

ΔΦ = 45°

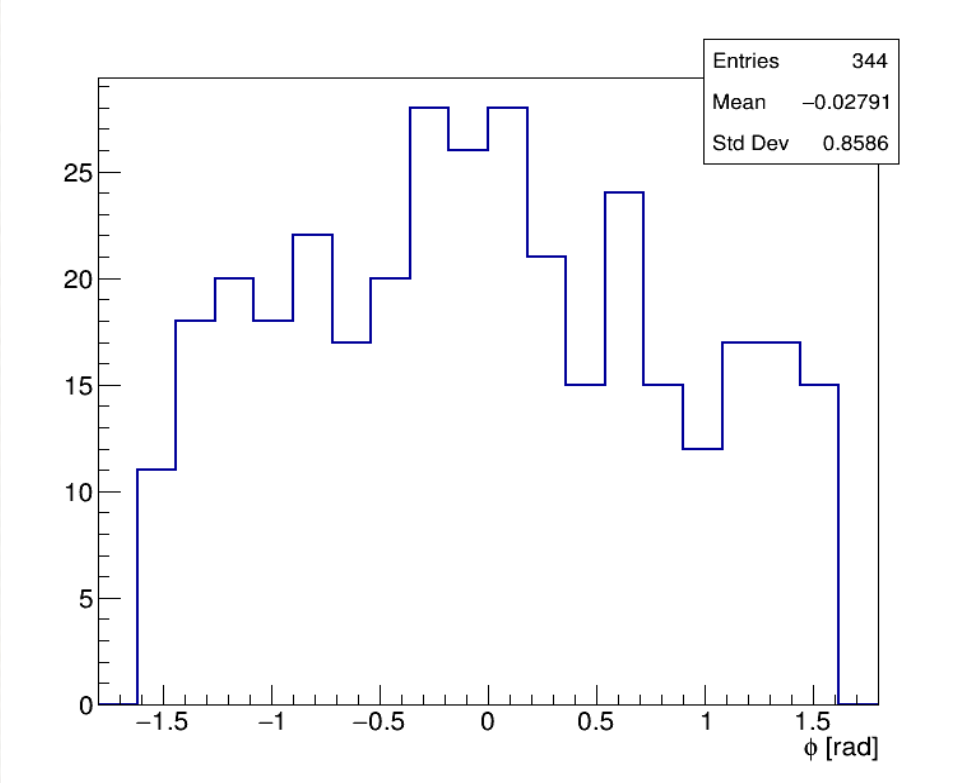
pol_i

pol_j



ΔΦ = 90°

Plasmon Analysis Updates



Reduction of the anisotropy with ΔΦ <1

Only 5.7% of dataset survives

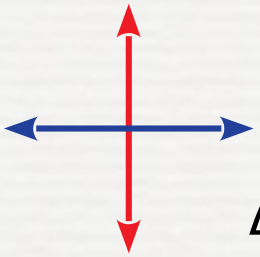
ΔΦ is the maximum angular distance between two polarizations of the same collection

ΔΦ = 30°

ΔΦ = 45°

pol_i

pol_j

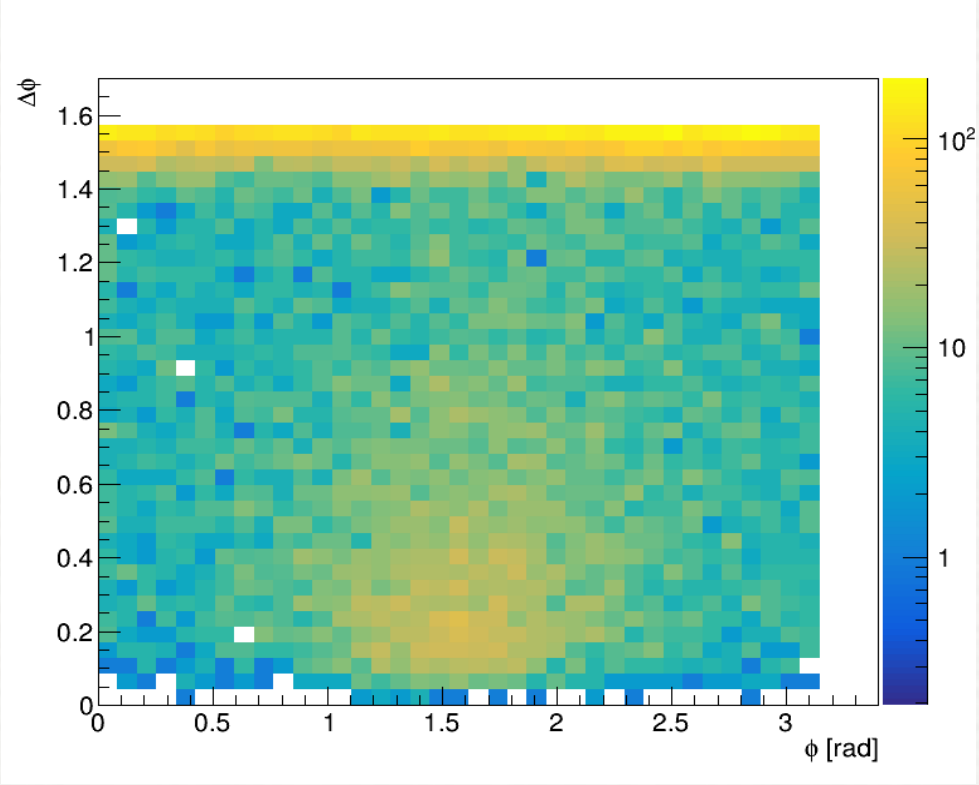


ΔΦ = 90°

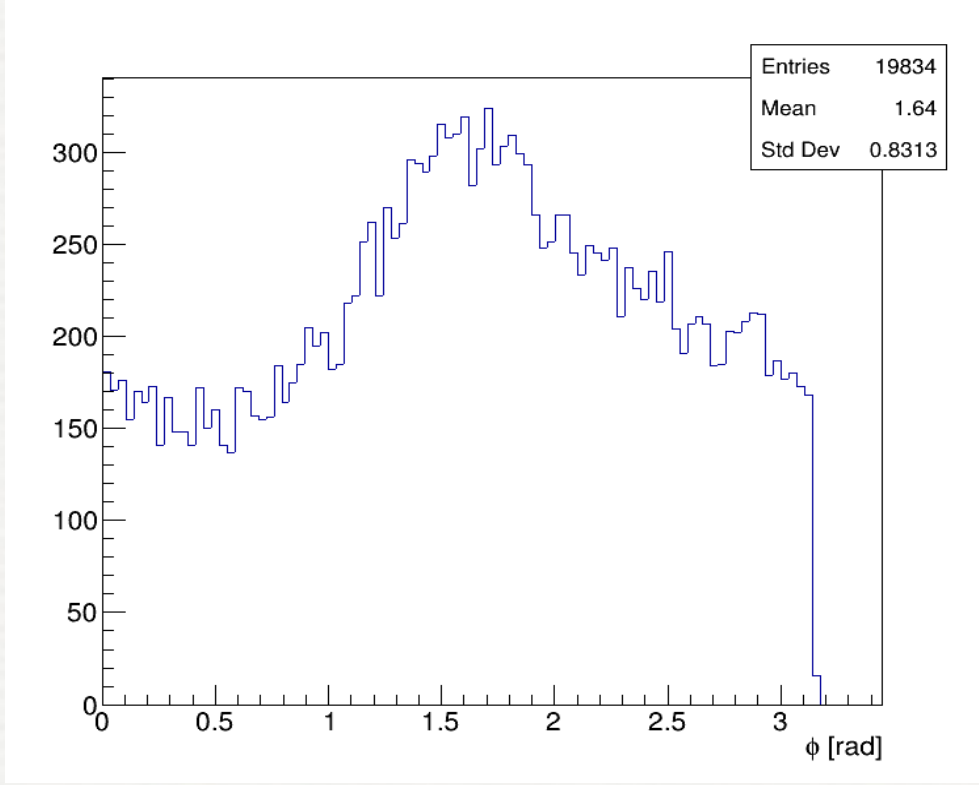
C 100 keV

Plasmon Analysis Updates

Signal is mainly contained in the $0 < \Delta\Phi < 1$ region



$\Delta\Phi$ versus Φ

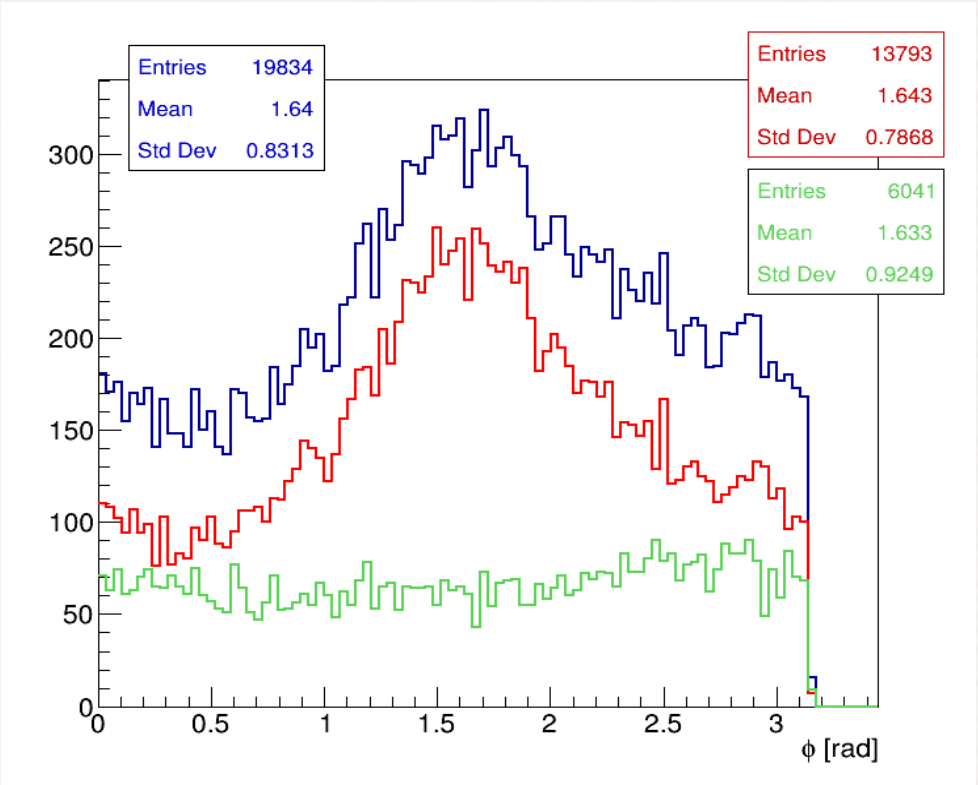


Phi angle distribution

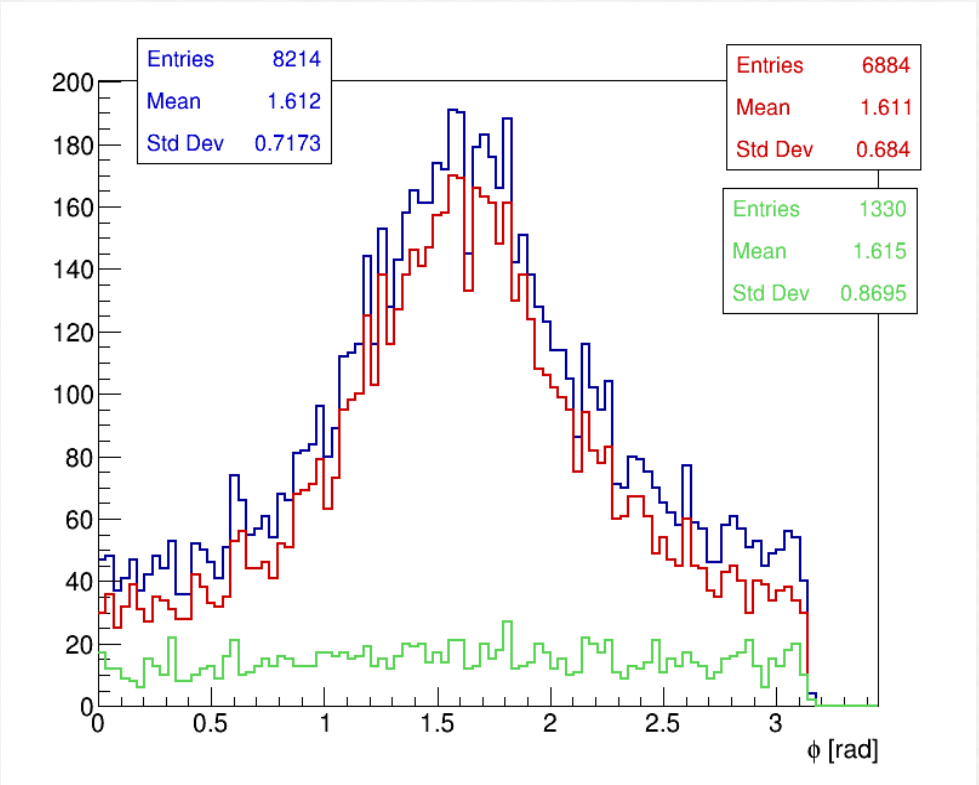
Plasmon Analysis Updates

No barshift cuts
Barshift > 30nm
Barshift < 30nm

No cut on ΔΦ



Cut on ΔΦ < 1

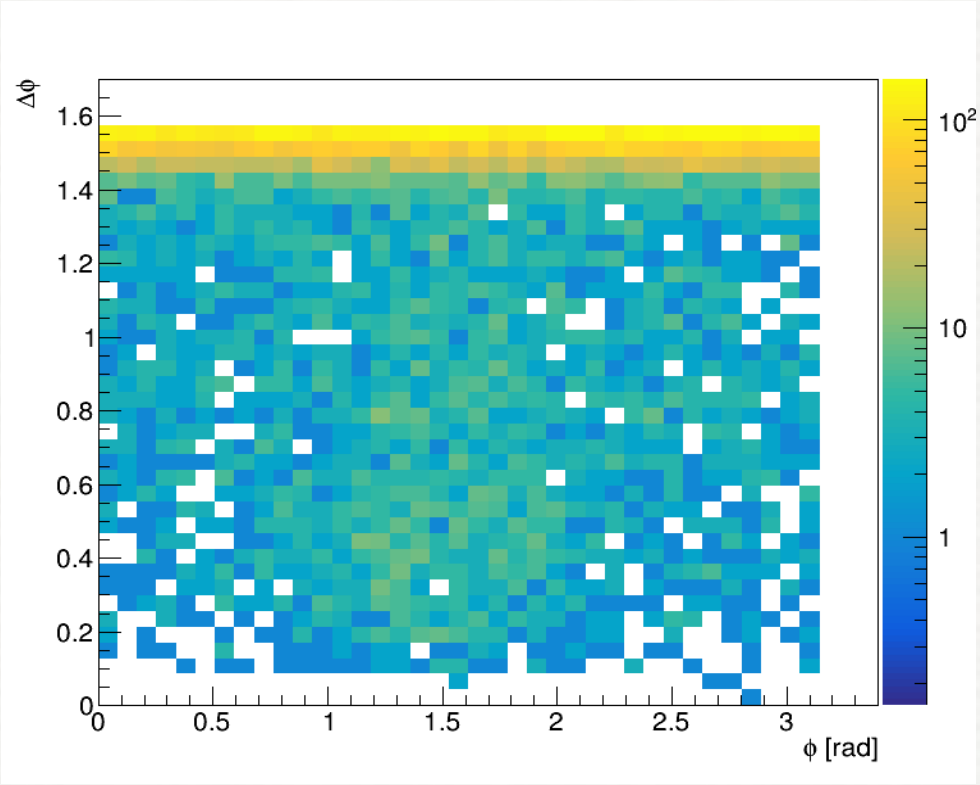


Phi angle distribution

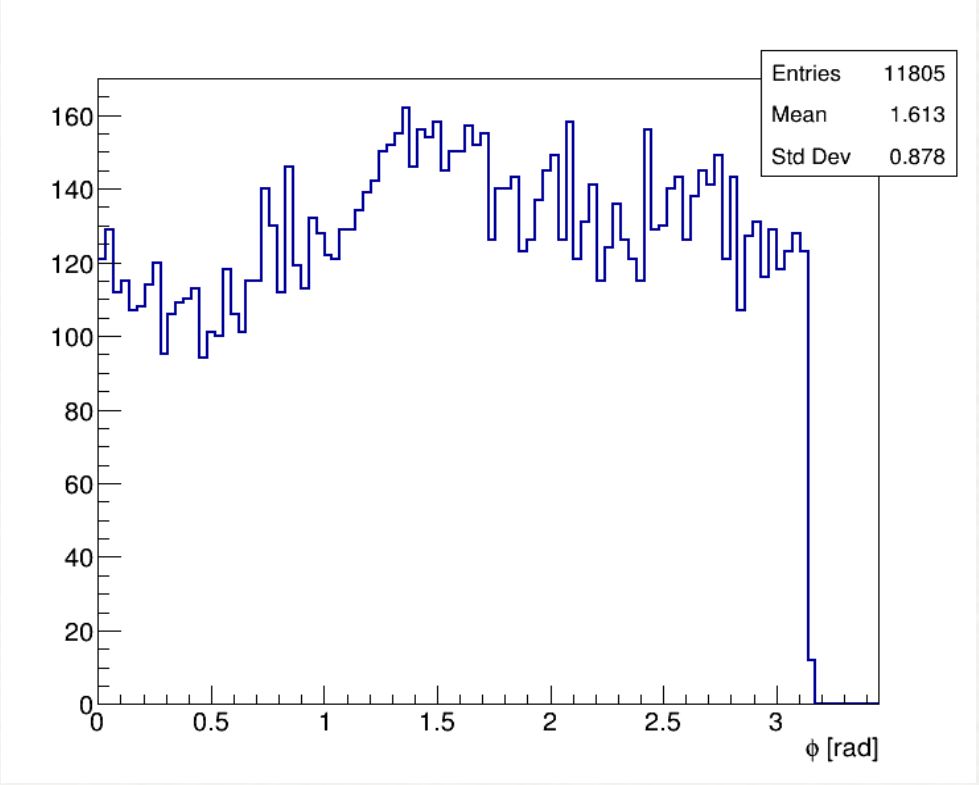
C 60 keV

Plasmon Analysis Updates

Signal is mainly contained in the $0 < \Delta\Phi < 1$ region



$\Delta\Phi$ versus Φ



Phi angle distribution

Plasmon Analysis Updates

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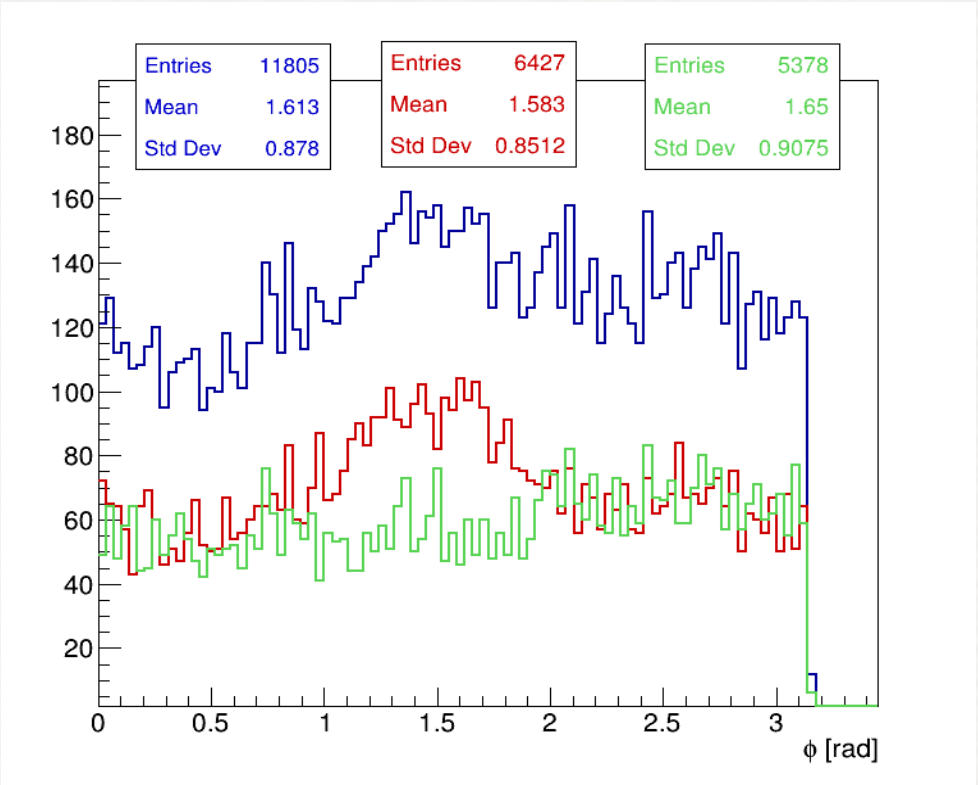
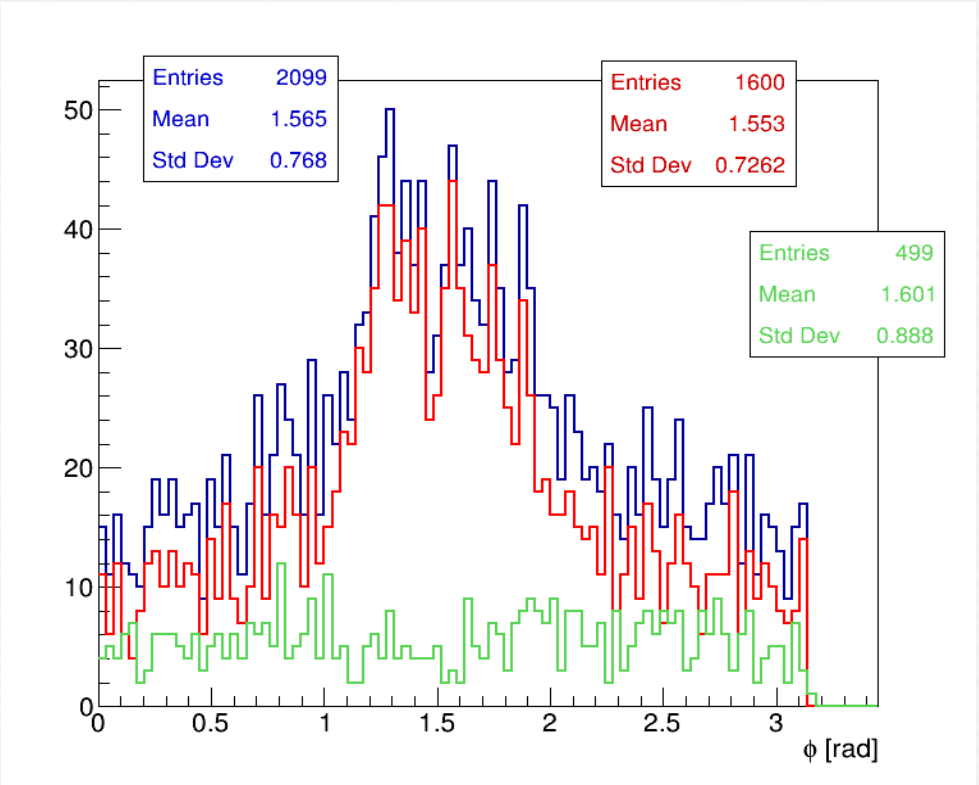


Cut on ΔΦ < 1



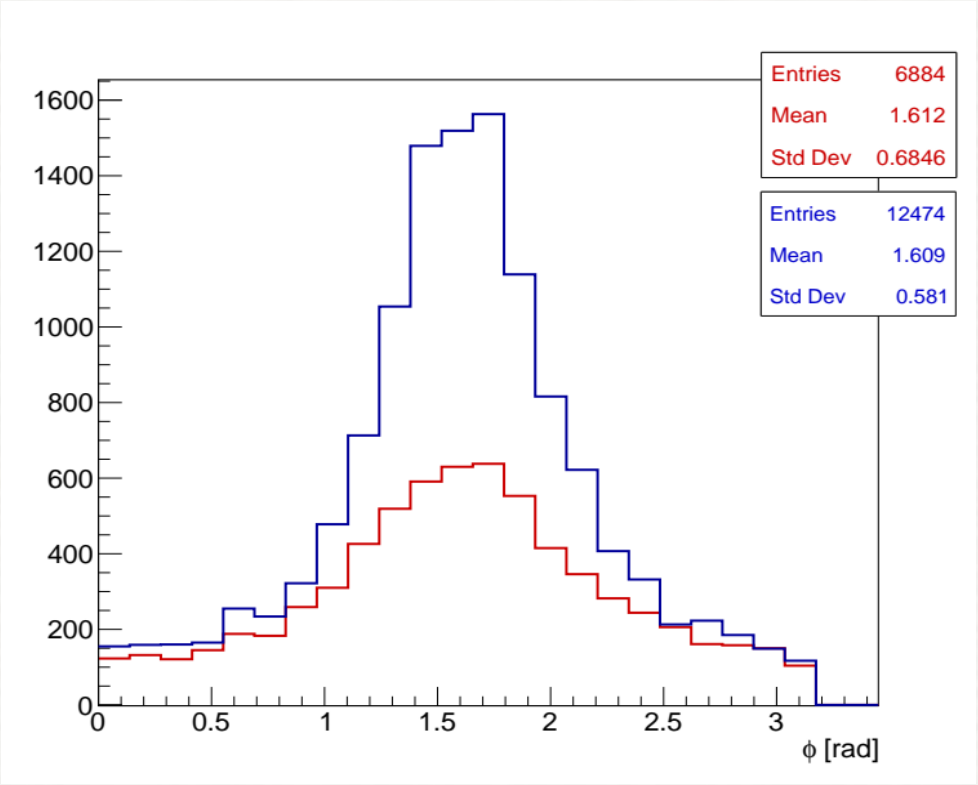
Phi angle distribution

Plasmon Analysis Updates

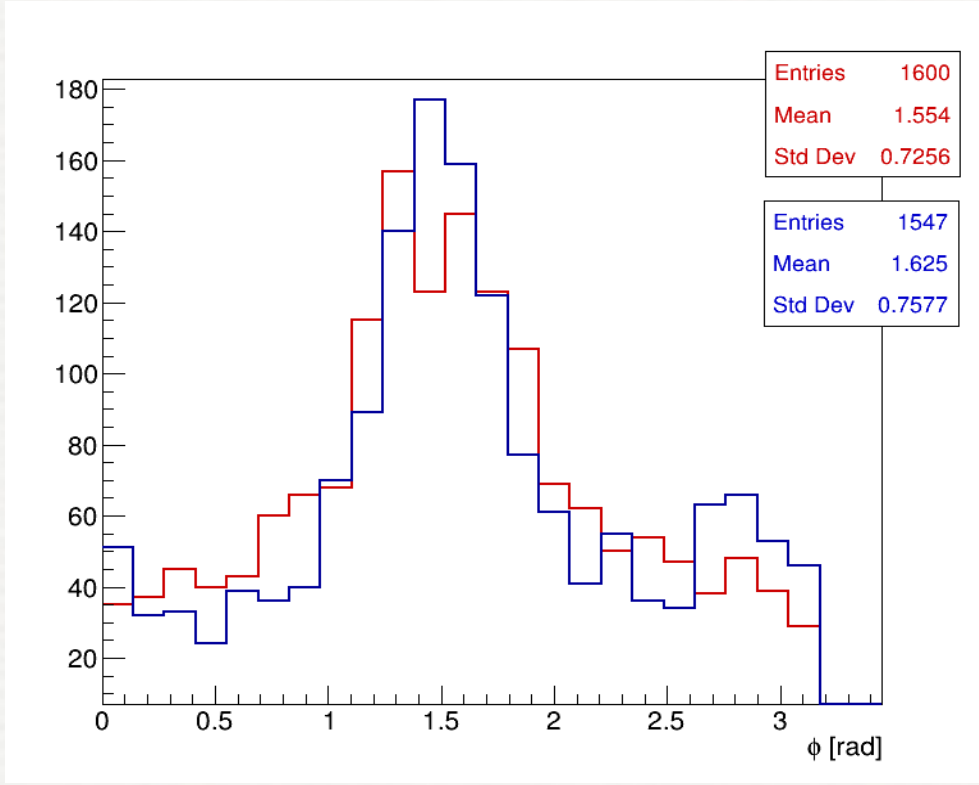
Microtracks

Nanotracks

C 100 keV



C 60 keV



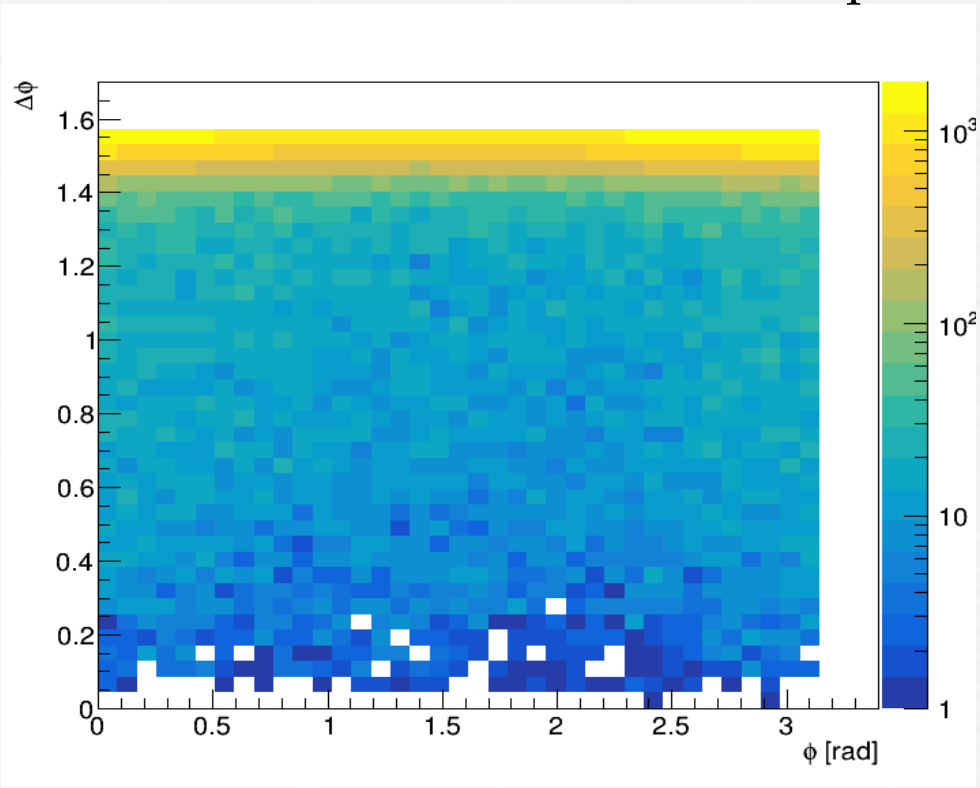
Phi angle distribution

C 30 keV Vertical

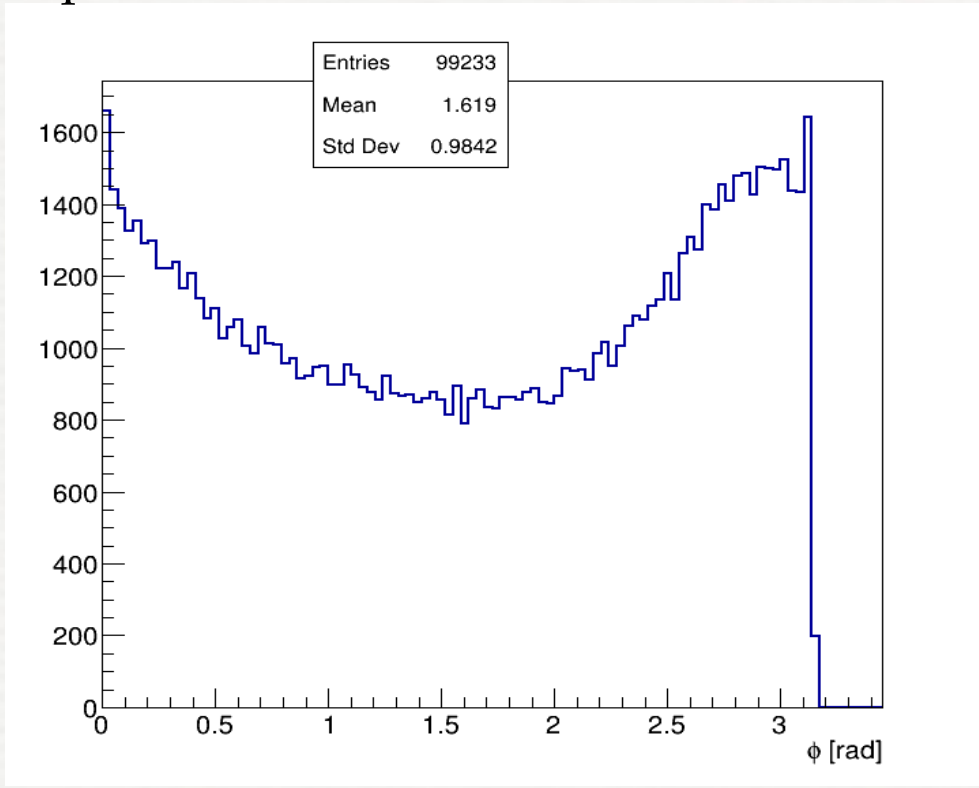
Plasmon Analysis Updates

No signal expected in the $0 < \Delta\Phi < 1$ region

A clear instrumental peak is present around 0 rad



$\Delta\Phi$ versus Φ

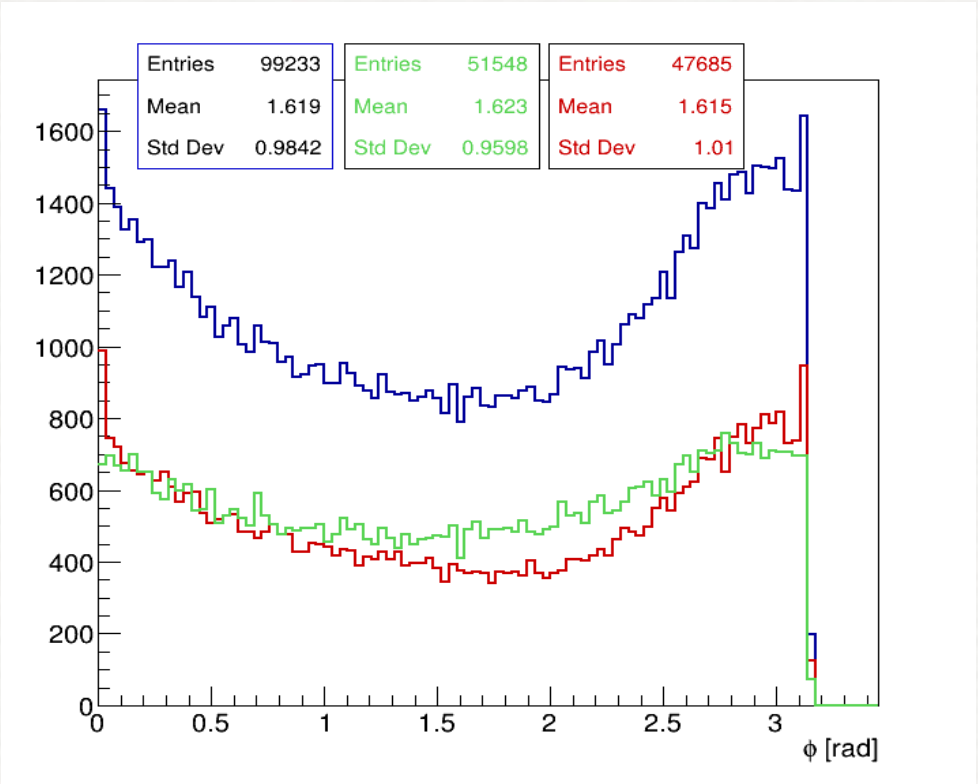


Phi angle distribution

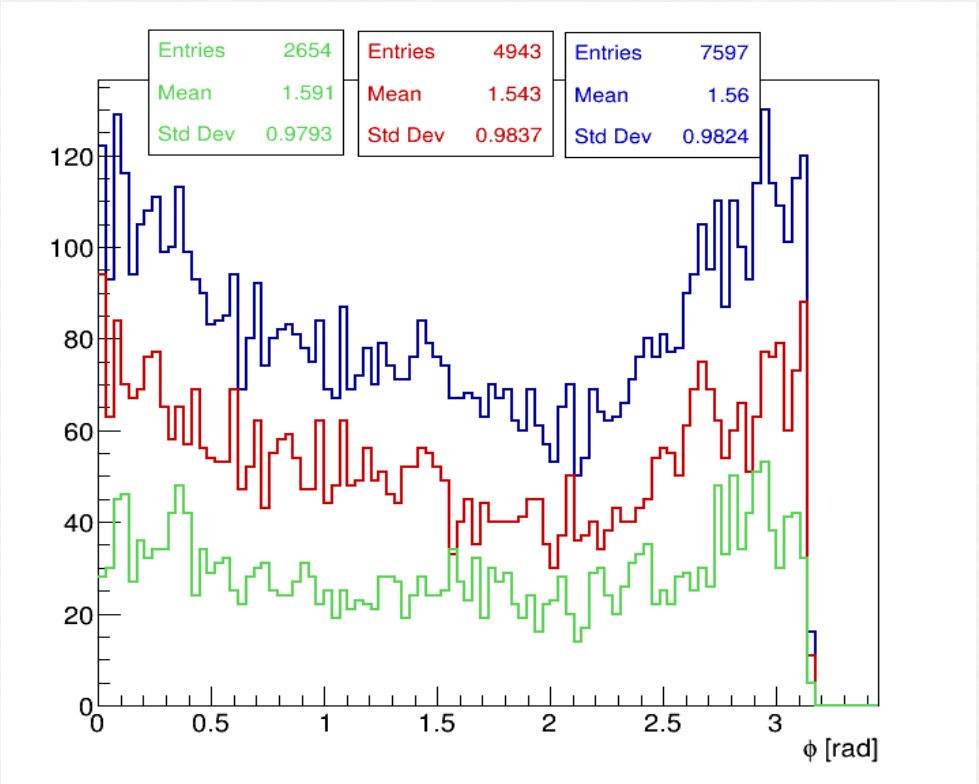
Plasmon Analysis Updates

No barshift cuts
Barshift > 30nm
Barshift < 30nm

No cut on ΔΦ



Cut on ΔΦ < 1



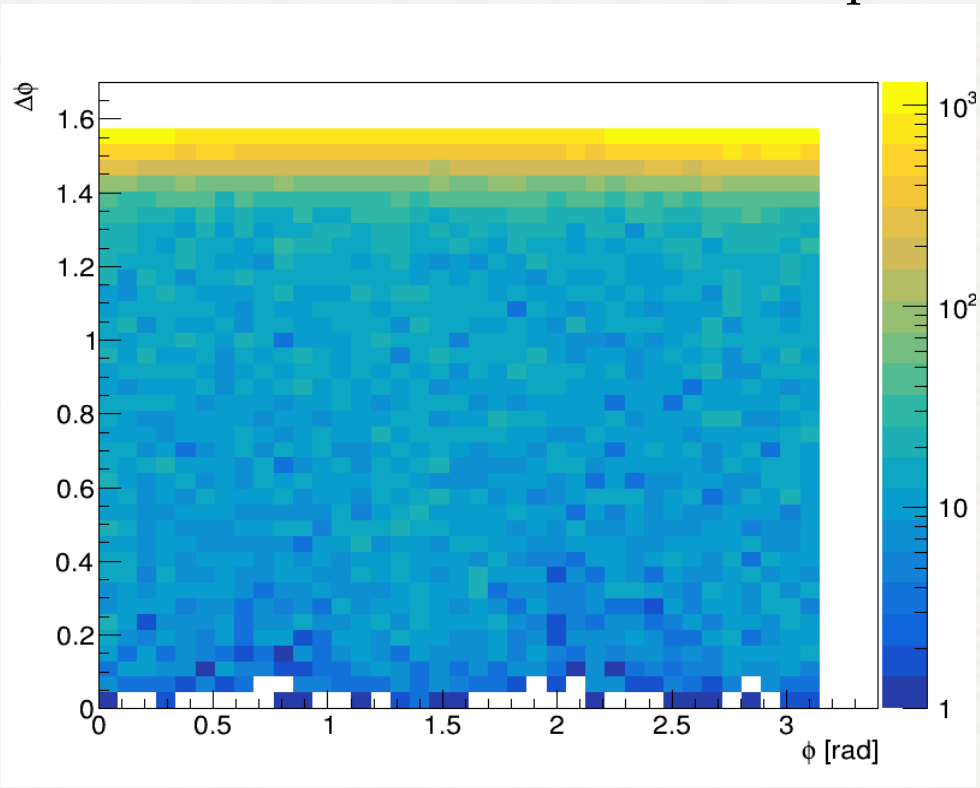
Phi angle distribution – Instrumental peak still present

C 30 keV
Horizontal
90°

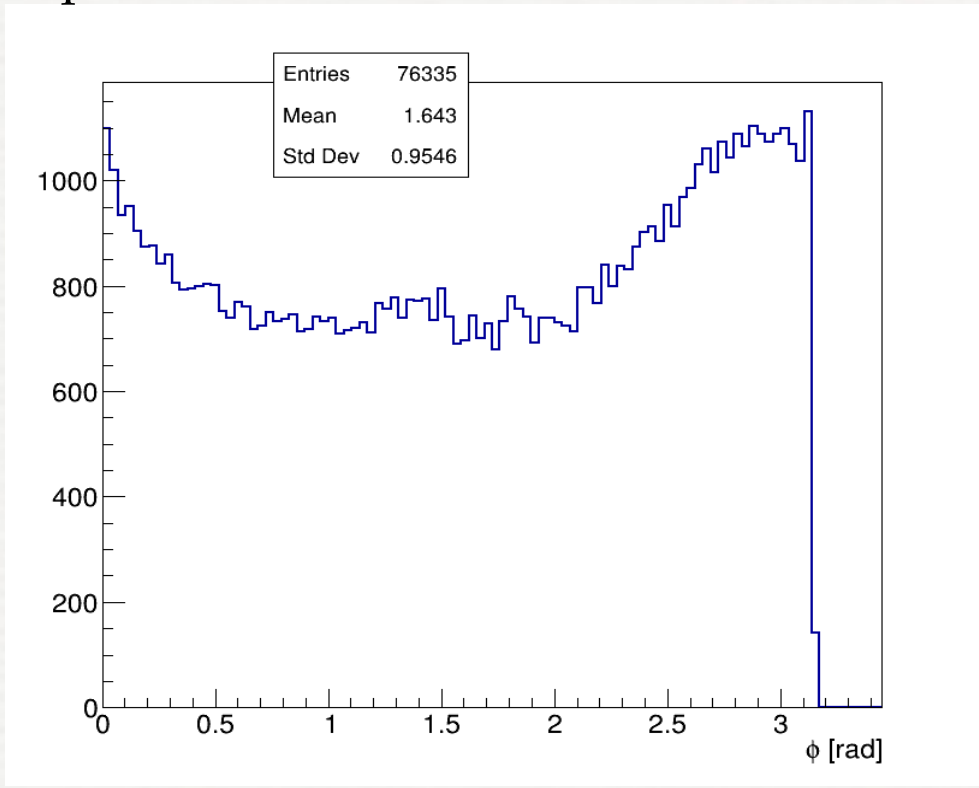
Plasmon Analysis Updates

Signal expected in the $0 < \Delta\Phi < 1$ region

A clear instrumental peak is present around 0 rad



$\Delta\Phi$ versus Φ

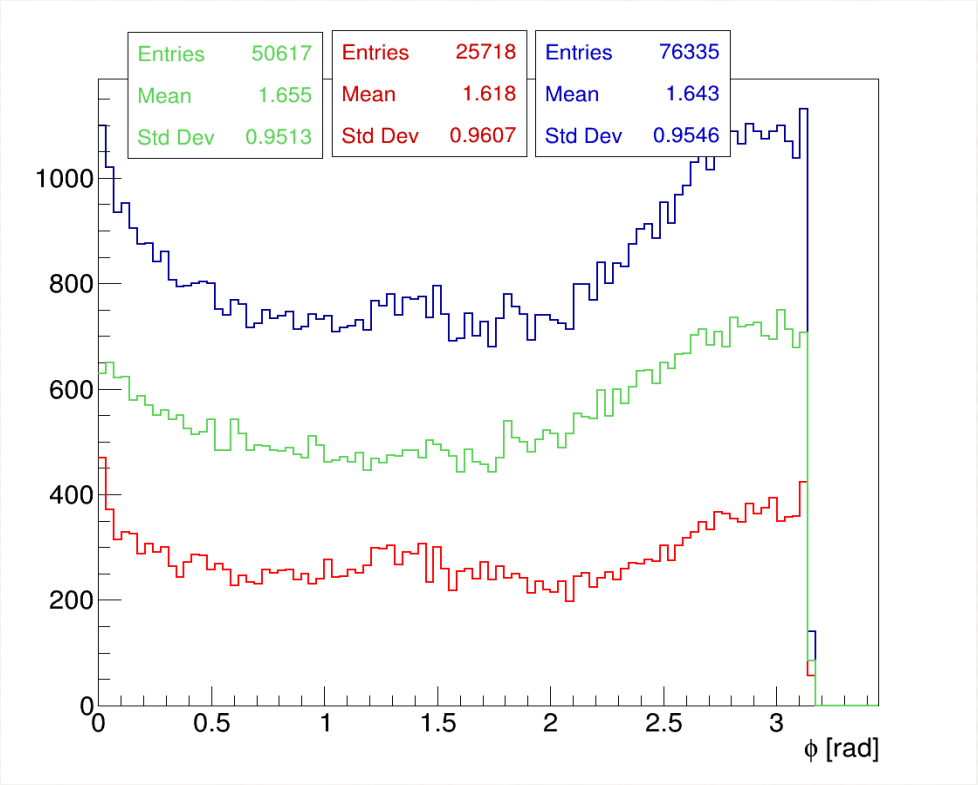


Phi angle distribution

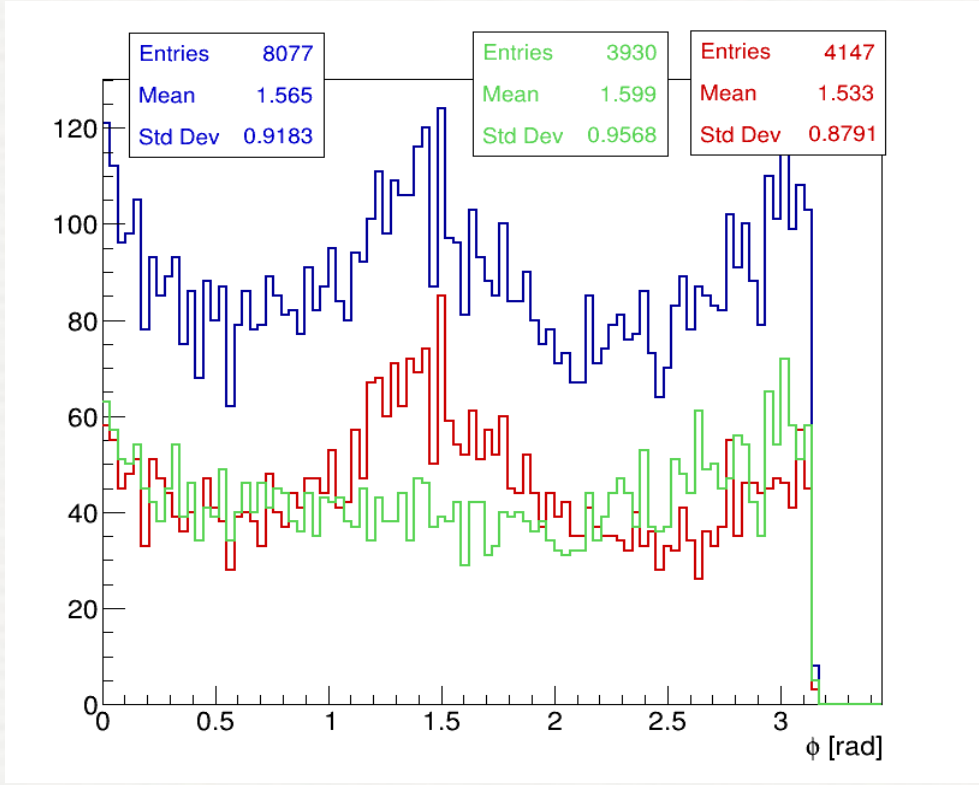
Plasmon Analysis Updates

No barshift cuts
Barshift > 30nm
Barshift < 30nm

No cut on ΔΦ



Cut on ΔΦ < 1



Phi angle distribution – Instrumental peak still present

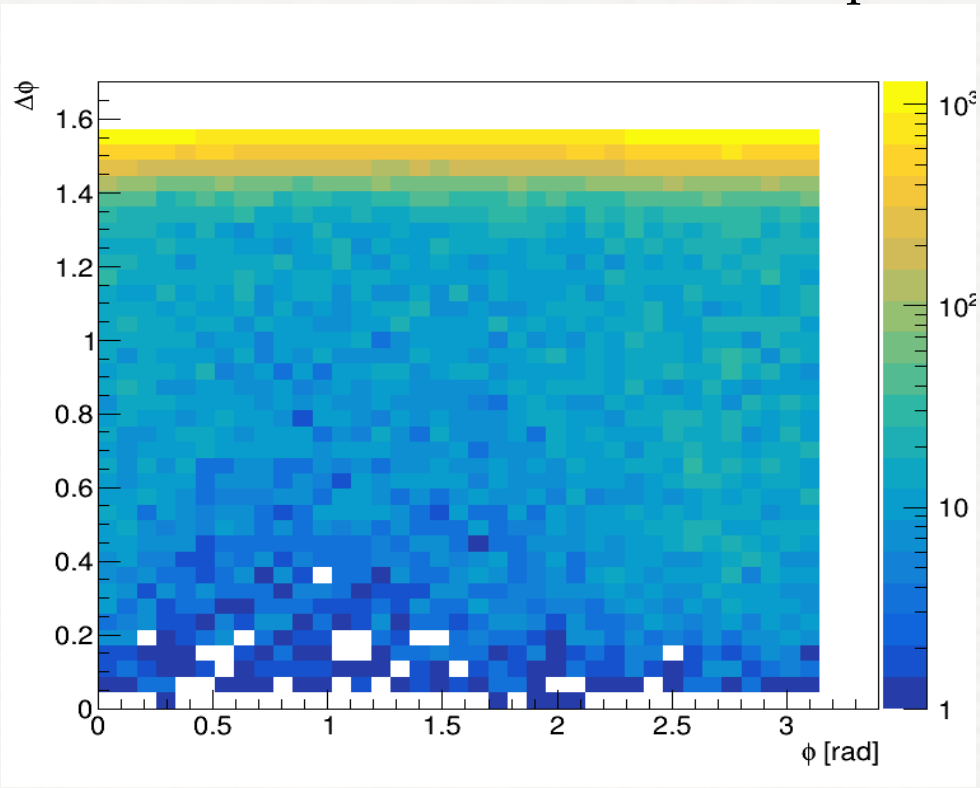
Signal peak evident after cut

C 30 keV
Horizontal
135°

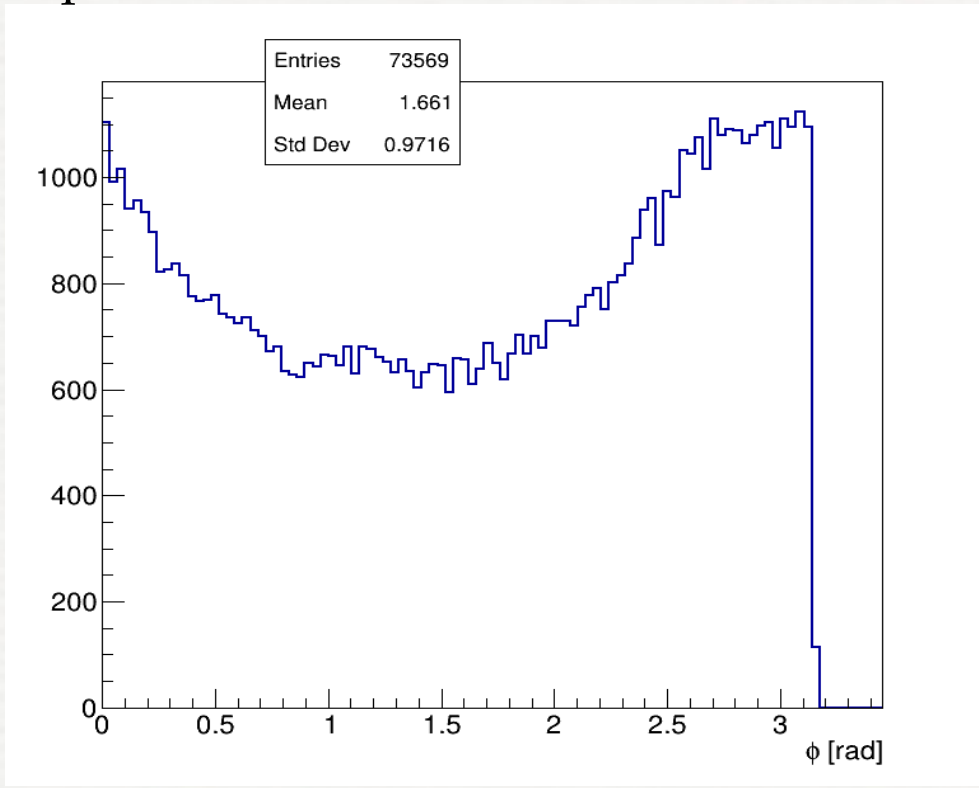
Plasmon Analysis Updates

Signal expected in the $0 < \Delta\Phi < 1$ region

A clear instrumental peak is present around 0 rad



$\Delta\Phi$ versus Φ



Phi angle distribution

Plasmon Analysis Updates

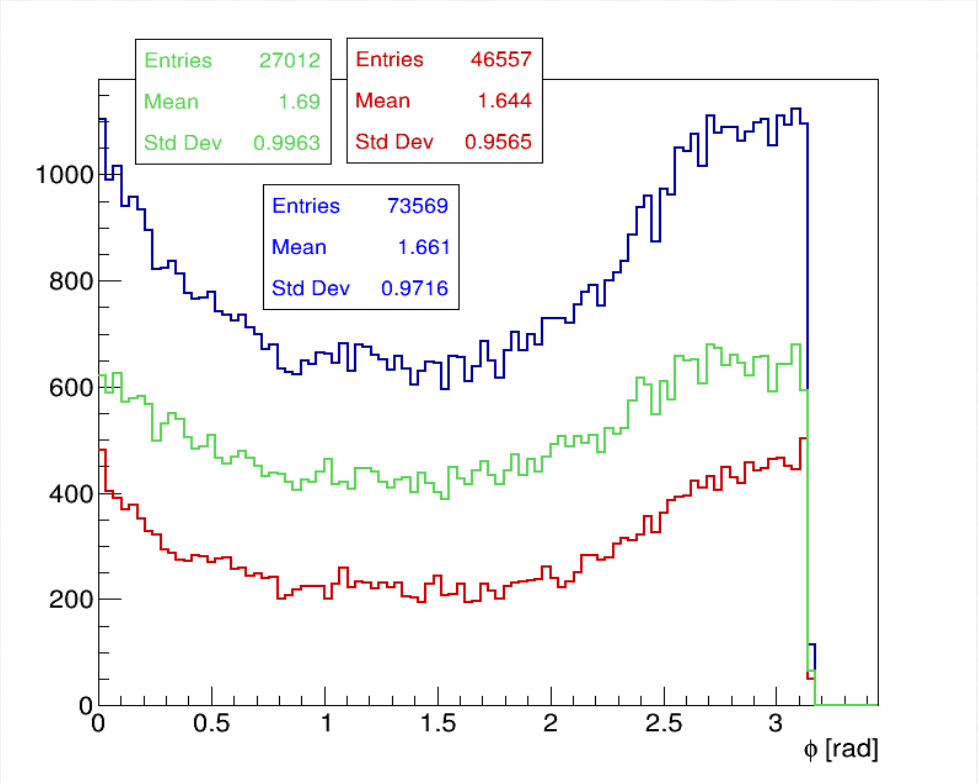
No barshift cuts

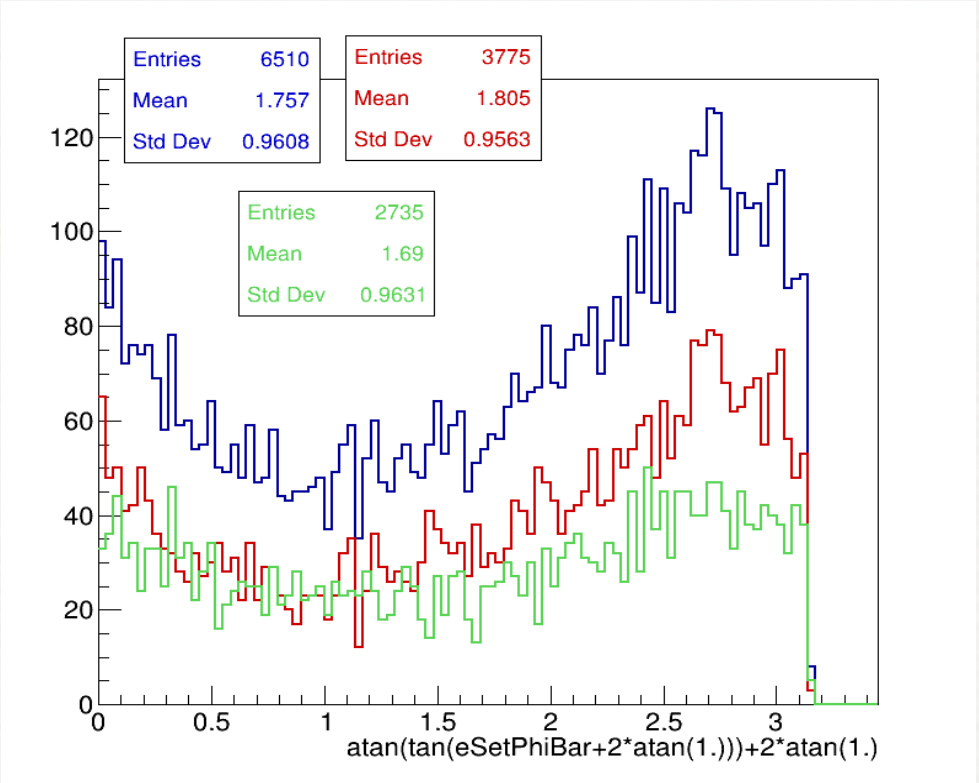
Barshift > 30nm

Barshift < 30nm

No cut on ΔΦ

Cut on ΔΦ < 1





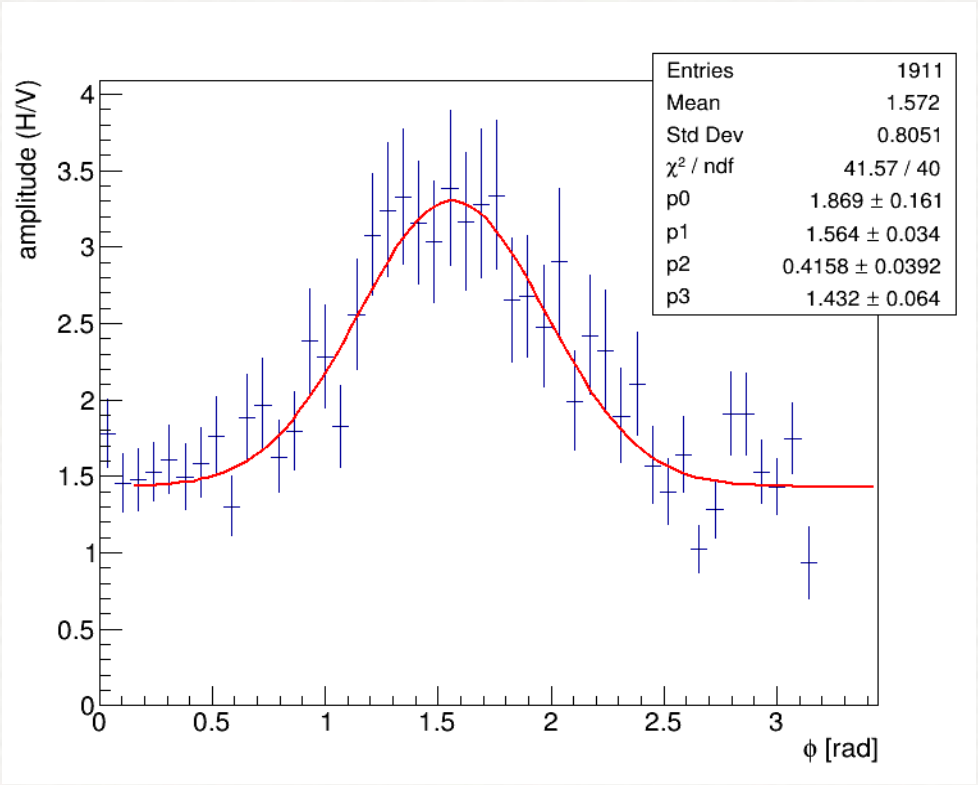
Phi angle distribution – Instrumental peak still present

Signal excess visible after cut

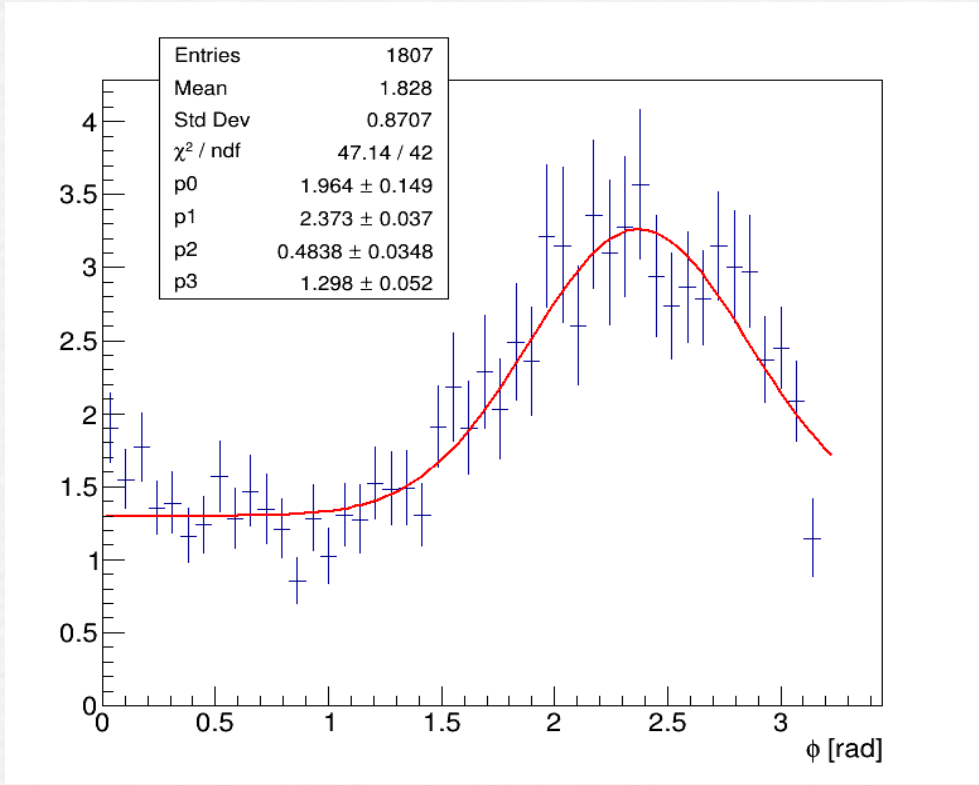
Plasmon Analysis Updates

PDF Ratio between C 30 keV ion horizontal samples and vertical sample

Expected: 90° - Measured: 90°



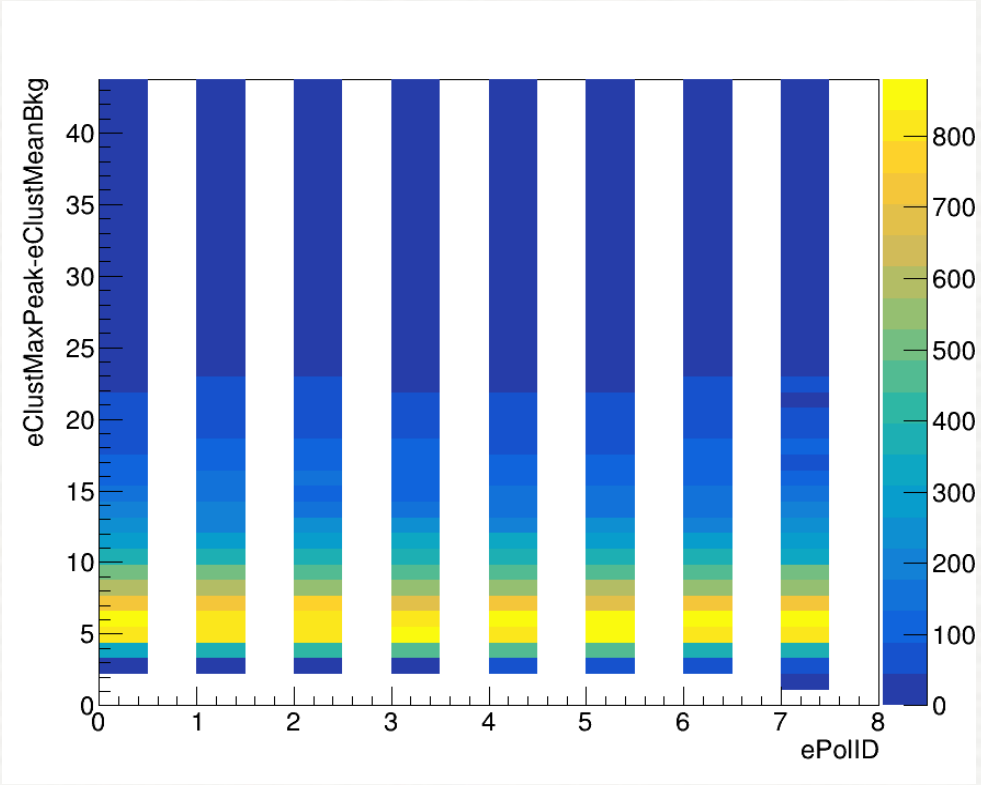
Expected: 135° - Measured: 136°



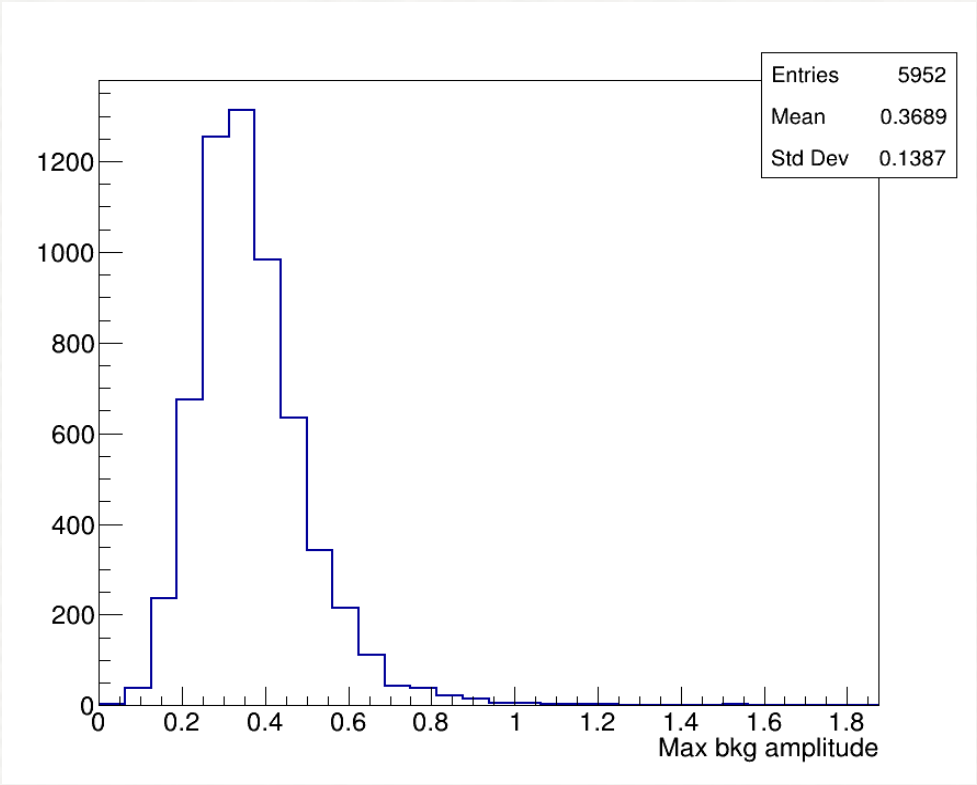
Preliminary study on brightness

Plasmon Analysis Updates

NP 40 nm



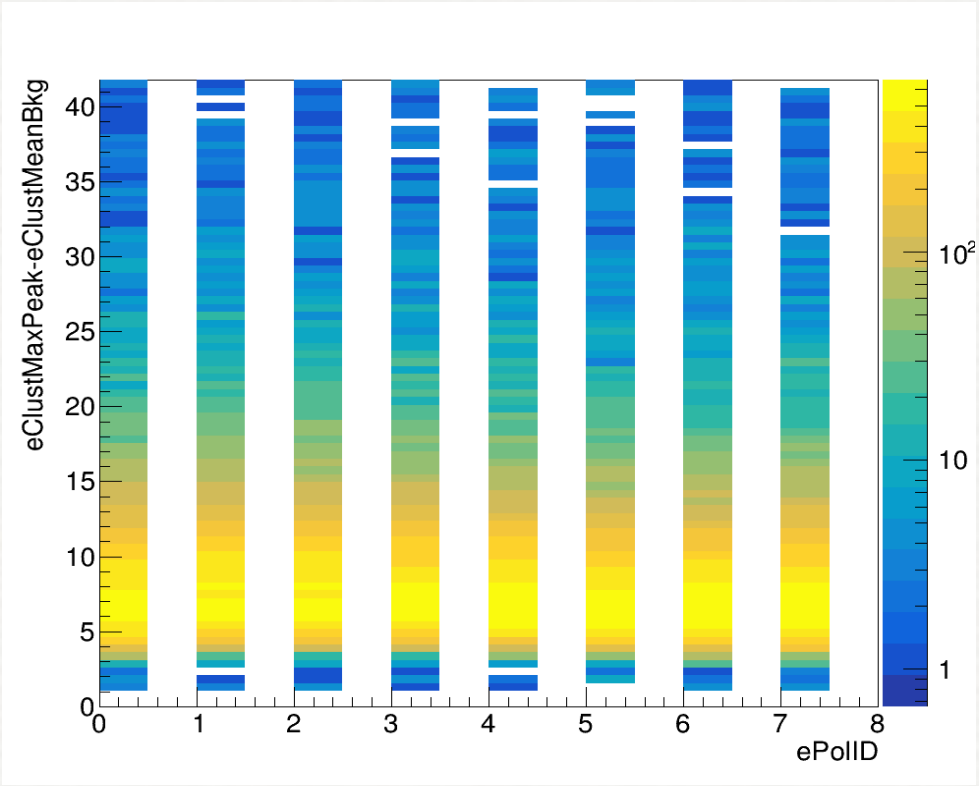
Brightness of the clusters over the mean background



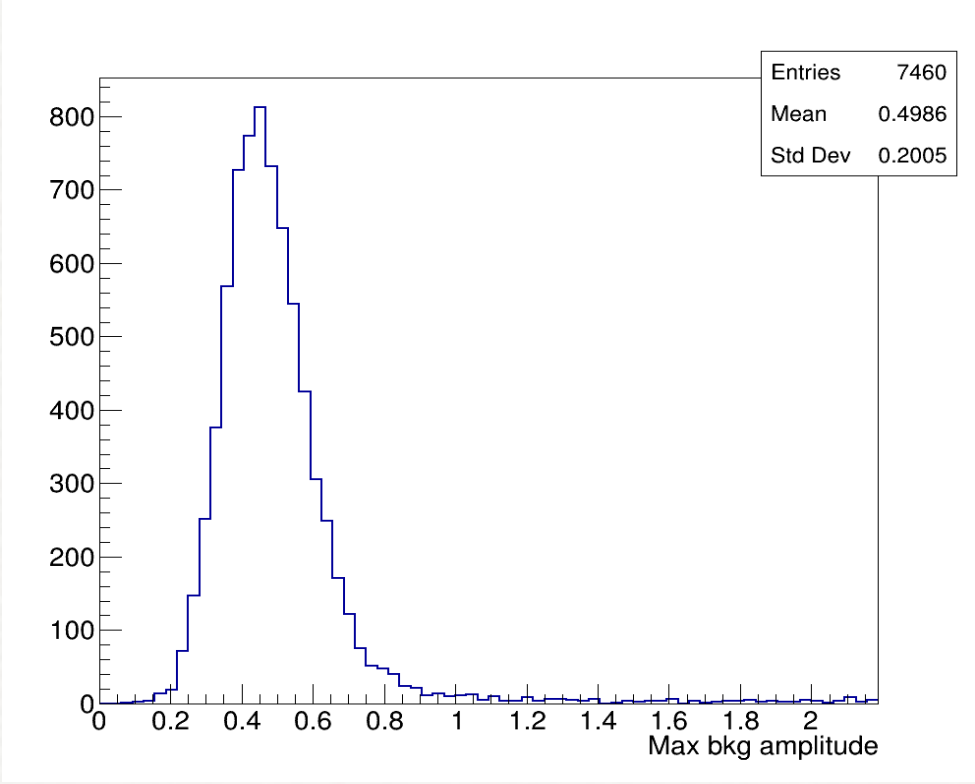
Maximum variation of the background for each collection

Plasmon Analysis Updates

10g Test sample



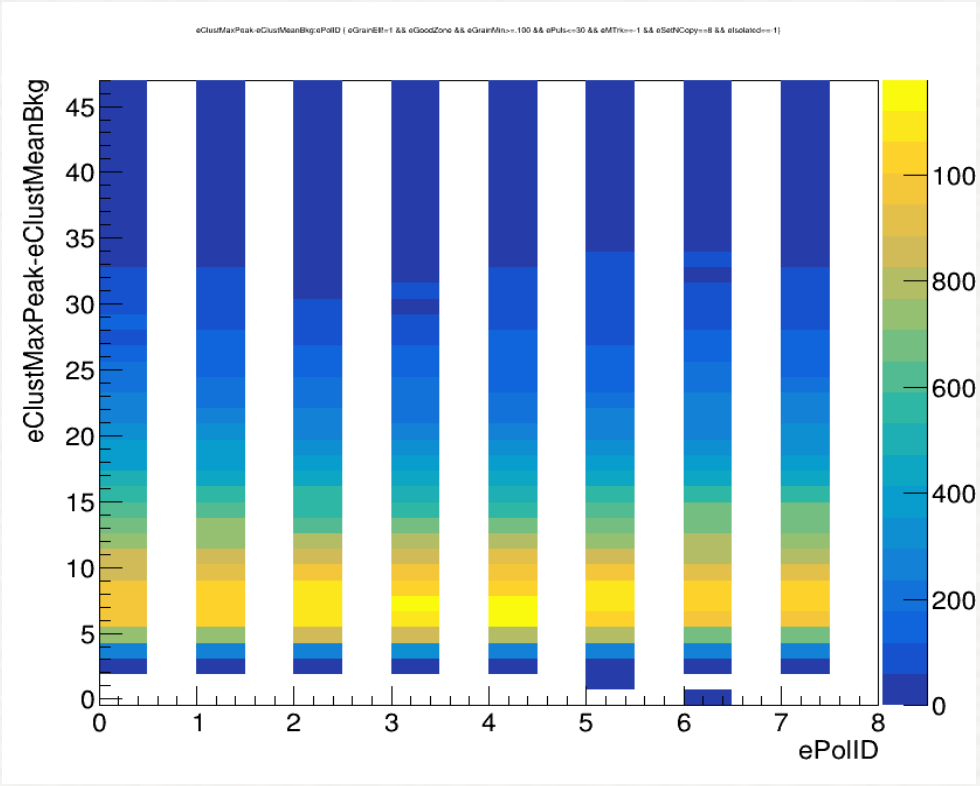
Brightness of the clusters over the mean background



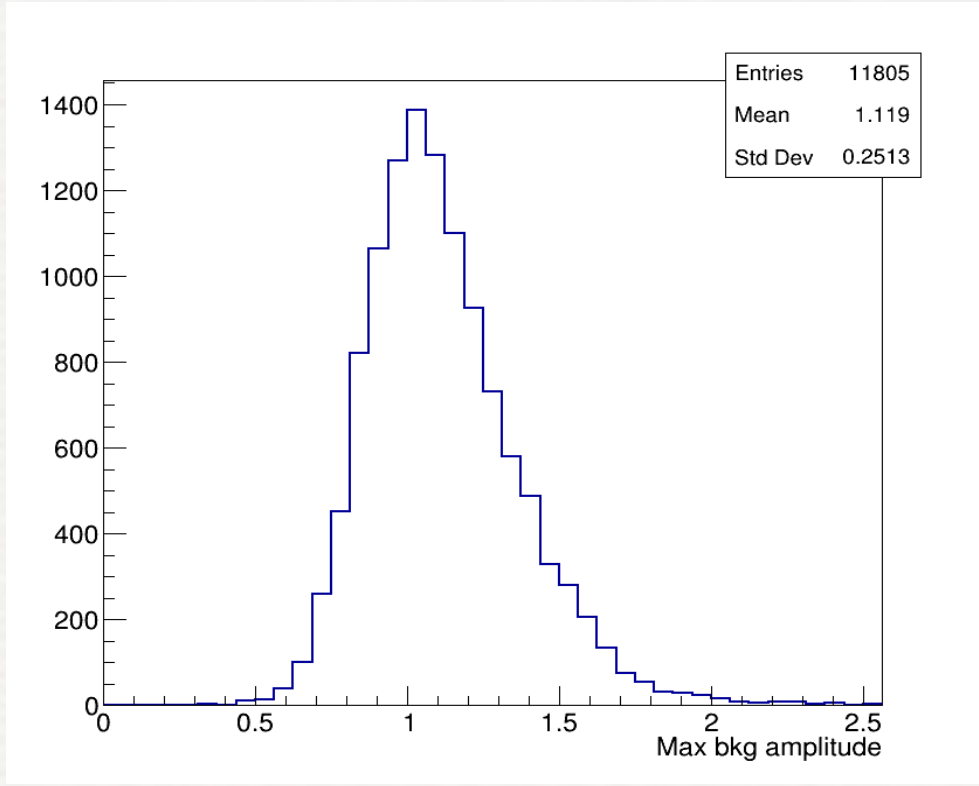
Maximum variation of the background for each collection

Plasmon Analysis Updates

C 60 keV



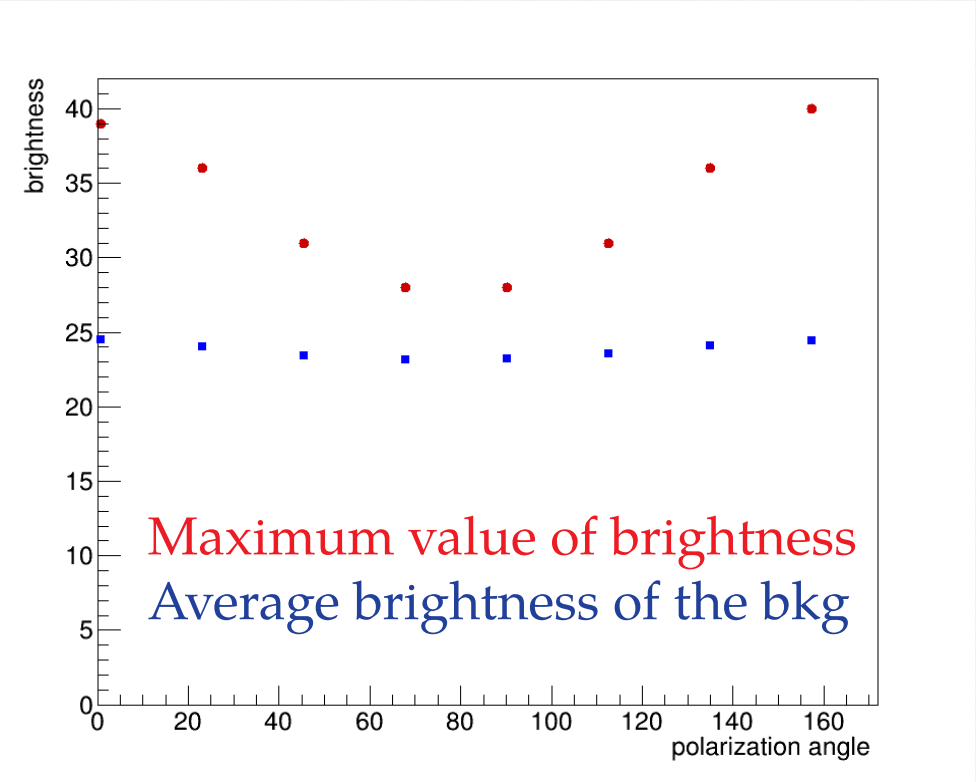
Brightness of the clusters over the mean background



Maximum variation of the background for each collection

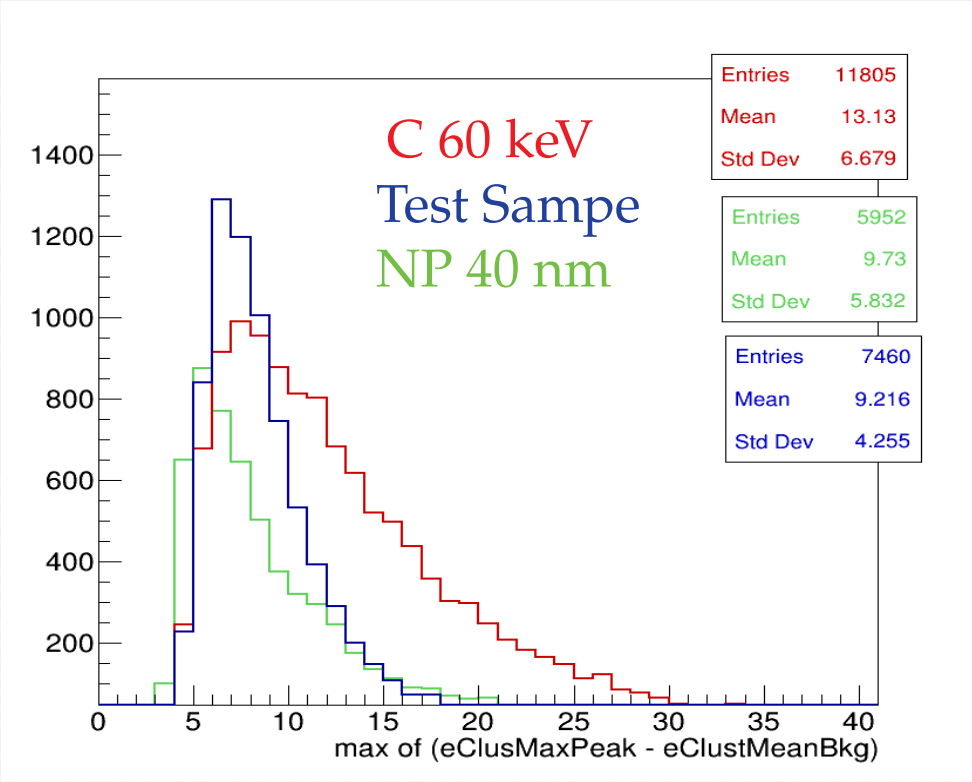
Plasmon Analysis Updates

Preliminary investigation of new variables to exploit the brightness information



Brightness versus polarization

Example of a C 60 keV collection



Distribution of maximum of the brightness over the mean background

Conclusions

- The optimization of microscope in terms of brightness stability makes it possible to include the brightness in the plasmon analysis
- On the other side, the new setup produces a new source of anisotropy that needs to be reduced since it affects the efficiency of the signal observation
- The amplitude of phi angle of the collection was used to reduce the anisotropy
- A signal observation for C30keV has been achieved

Perspectives

- Study of the brightness information (any ideas?)
- Comparison of brightness for candidates after ellipticity cut (TestSample) with Carbon ion sample
- Estimation of plasmon analysis power discrimination

BACKUP

Plasmon Analysis Overview

NEWSdm analysis strategy consists of a two-step approach:

1. Elliptical shape analysis for candidate selections (currently done in Nagoya)
2. Plasmon analysis for validation of candidates (currently done in Napoli)

Grains with track length about the optical resolution limit (~200 nm)
appear like a single cluster.

A single cluster therefore may consist of:

- one grain and would appear like spherical (fog-like)
- two grains inside and would have an elliptical shape (signal-like)

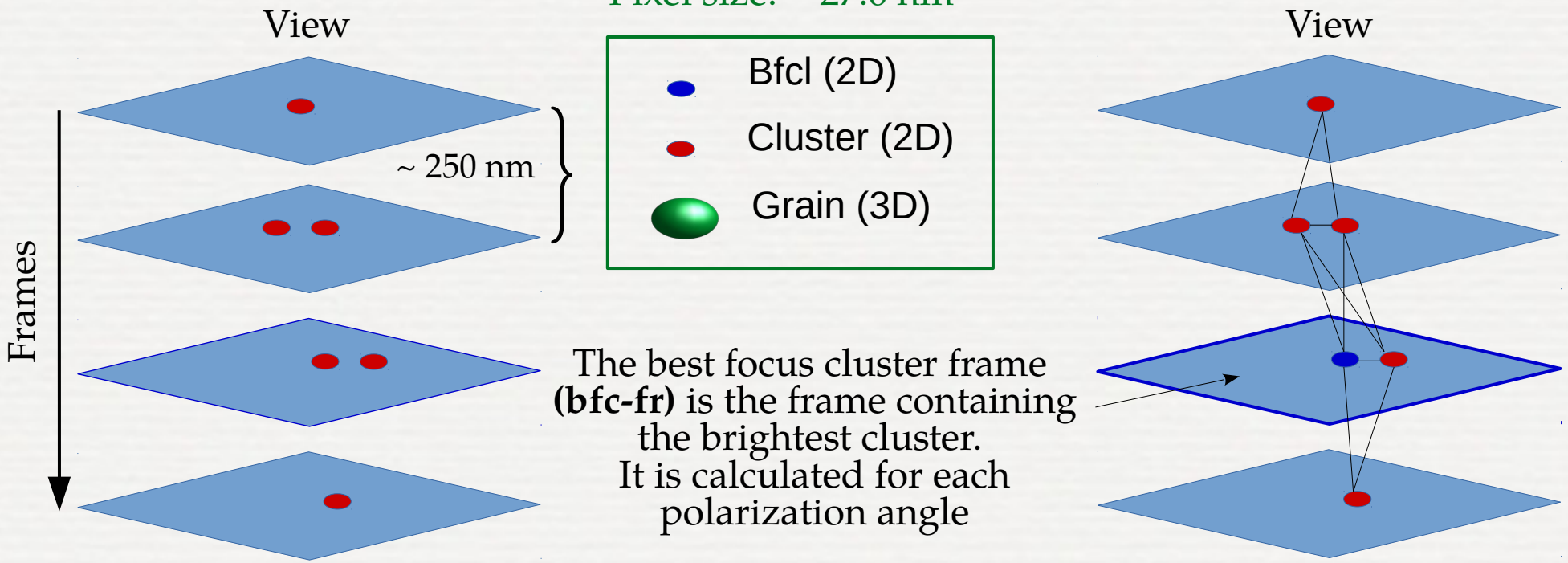
Elliptical shape analysis makes a selection exploiting the ellipticity of the clusters

Plasmon analysis validates the candidates looking at the cluster properties when observed with different polarization of incident light

Plasmon Analysis in Napoli

View dimension: 61 x 48 um^2

Pixel size: ~ 27.6 nm



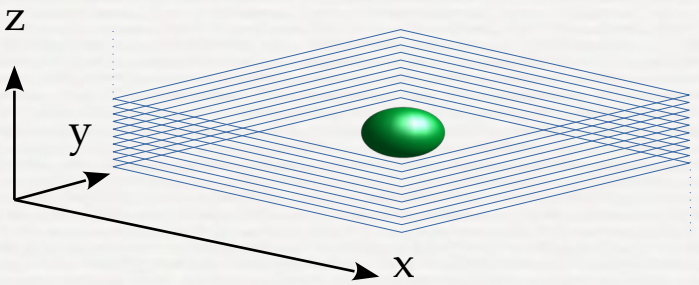
The best focus cluster frame **(bfc-fr)** is the frame containing the brightest cluster.
It is calculated for each polarization angle

For each candidate
8 measurement with different polarization angle

(0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135°, 157.5°)

Graining process

Max dist between clusters (XY) ~ 300nm



Plasmon Variables

Clusters (2D objects within the frame) → different polarization angles

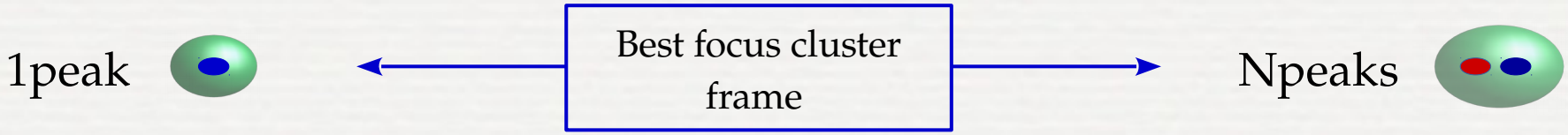
Grains (3D objects) → (obtained from linked clusters) :

x 8 Clusters → Best focus clusters → Best focus cluster frames

List of variables:

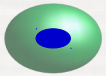
- Npol → Number of polarizations linked to the grain
- 1peak → Grains with one brightness peak in the bfc-fr
- Npeaks → Grains with two or more brightness peaks in the bfc-fr
- Barshift → Max displacement of the barycenter over all the best focus clusters

Npol = 8 (total number of polarization angles) is needed for a full and reliable analysis

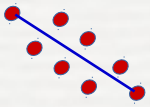


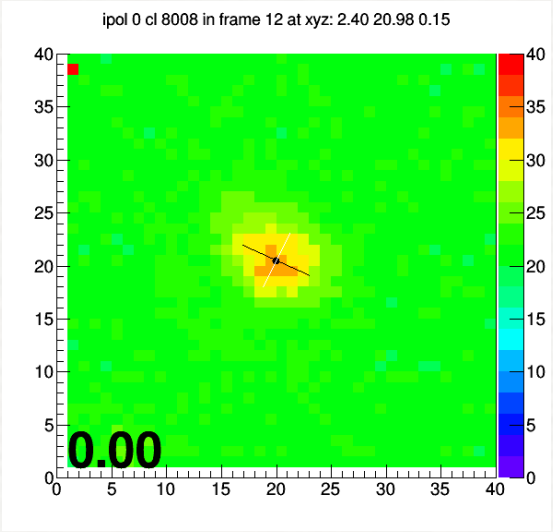
Plasmon Variables

1peak

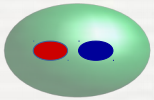


Look at the max shift of the barycenter (nanotracks)



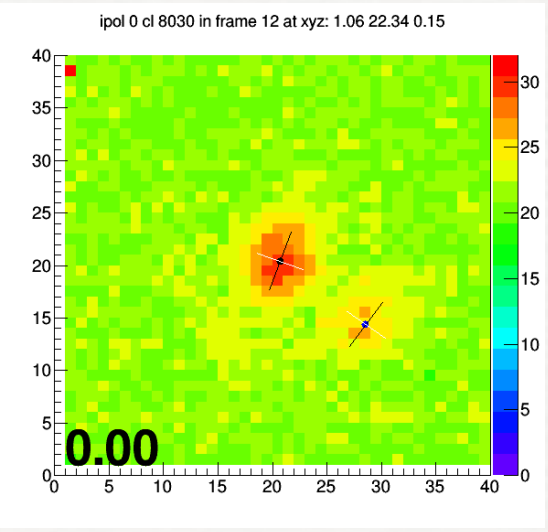


Npeaks



Two clusters very close and linked in one unique grain

Tagged as microtracks



Exploiting the resonance effect of polarized light:

- brightness variation;

  Useful to find clusters with two (or more) brightness peak

- displacement of the barycenter of the cluster;

  A large displacement means the presence of two or more grains within the cluster

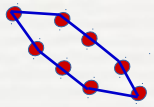
Topological Variables

List of variables:

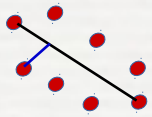
- Npol → Number of polarizations linked to the grain
- **1peak** → Grains with one brightness peak in the bfc-fr
- Npeaks → Grains with two or more brightness peaks in the bfc-fr
- Barshift → Displacement of the barycenter over all the best focus clusters

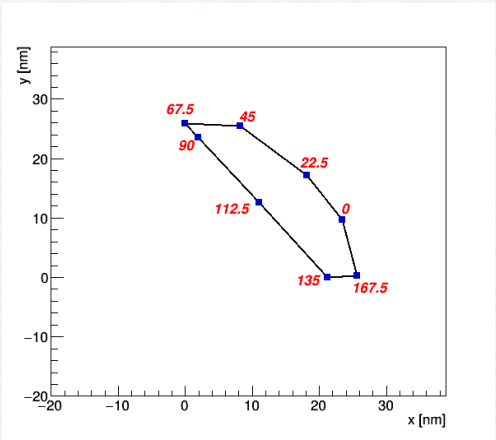
New topological variables:

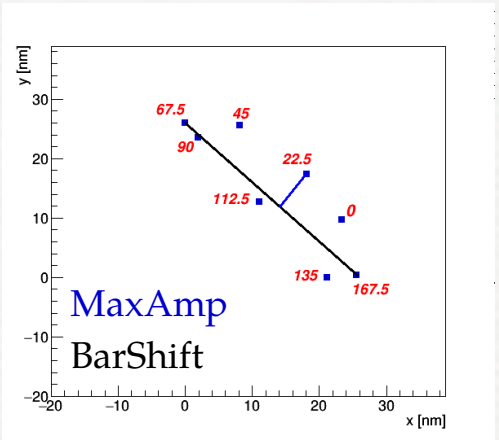
- PathLen → Path length of the barycenter from polarization 0°



- MaxAmp → Max distance from the Barshift line







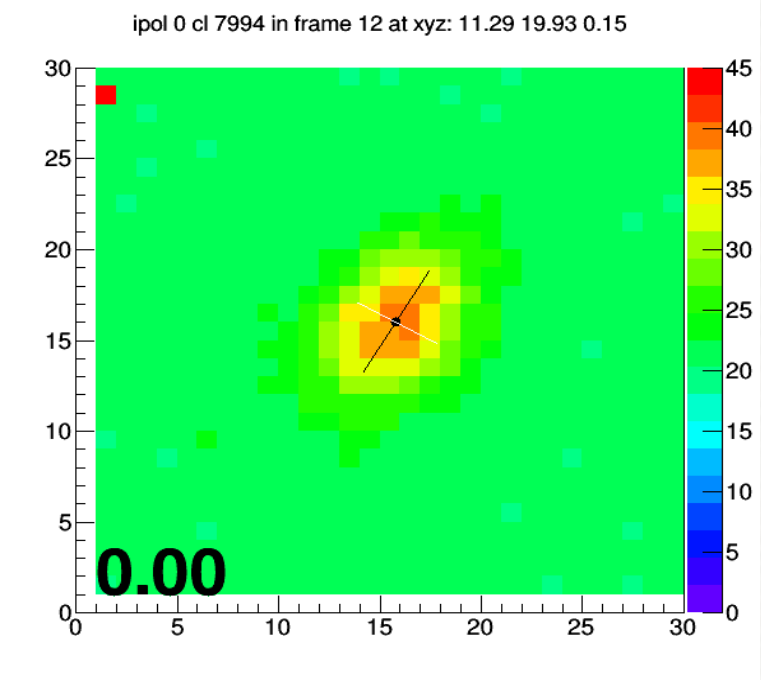
Barshift threshold is not enough to distinguish signal-like from fog-like events

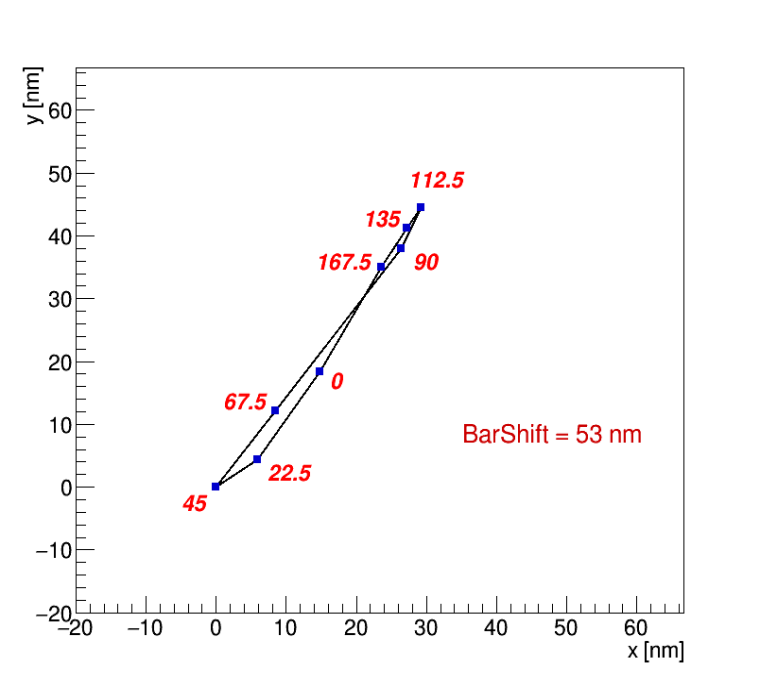
These new variables could improve the characterization of 1peak clusters

Plasmon Analysis in Napoli

- BarShift → Displacement of the barycenter over all the best focus clusters
- PathLen → Path length of the barycenter from polarization 0°
- MaxAmp → Max distance from the Barshift line

Regularity index: $\frac{\text{PathLen}}{\text{BarShift}}$

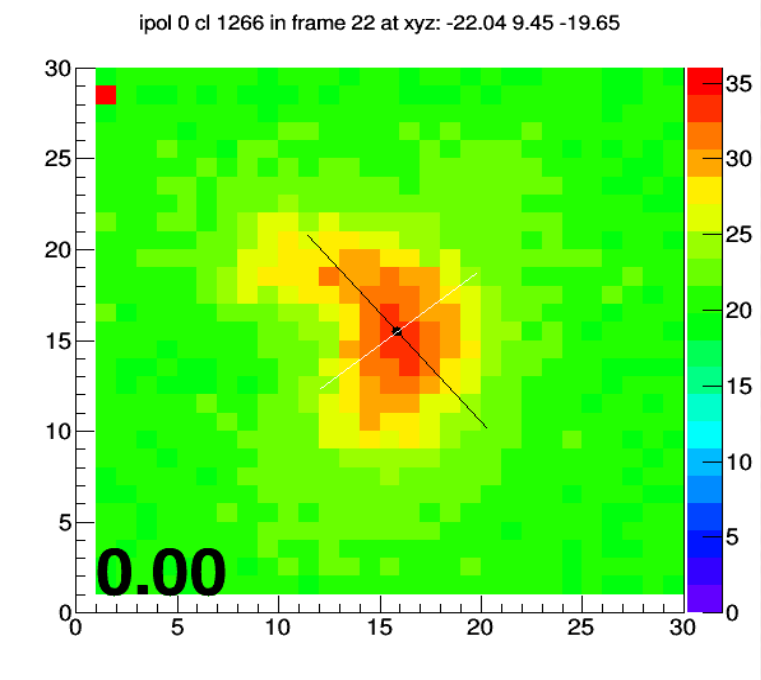


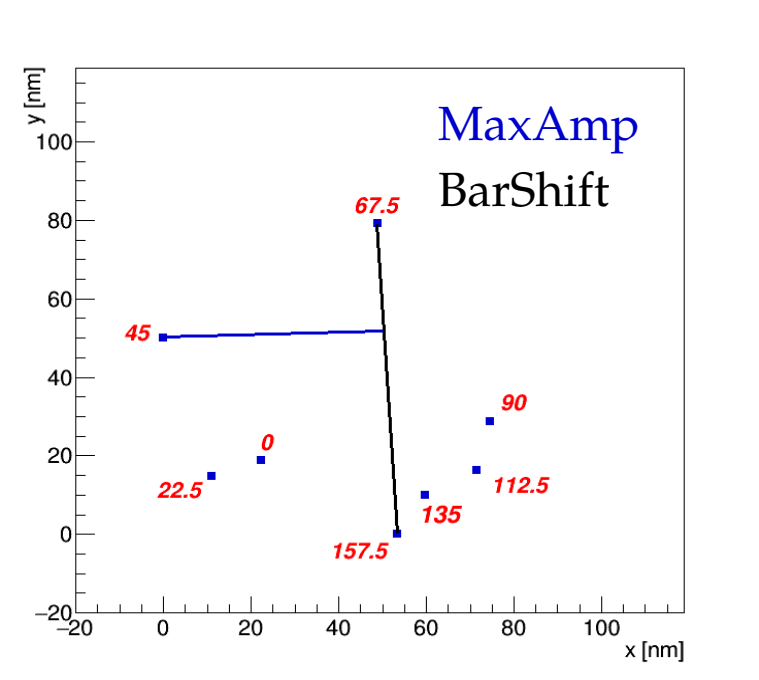


Plasmon Analysis in Napoli

- BarShift → Displacement of the barycenter over all the best focus clusters
- PathLen → Path length of the barycenter from polarization 0°
- MaxAmp → Max distance from the Barshift line

$$\text{Spread:} \quad \frac{\text{MaxAmp}}{\text{BarShift}}$$

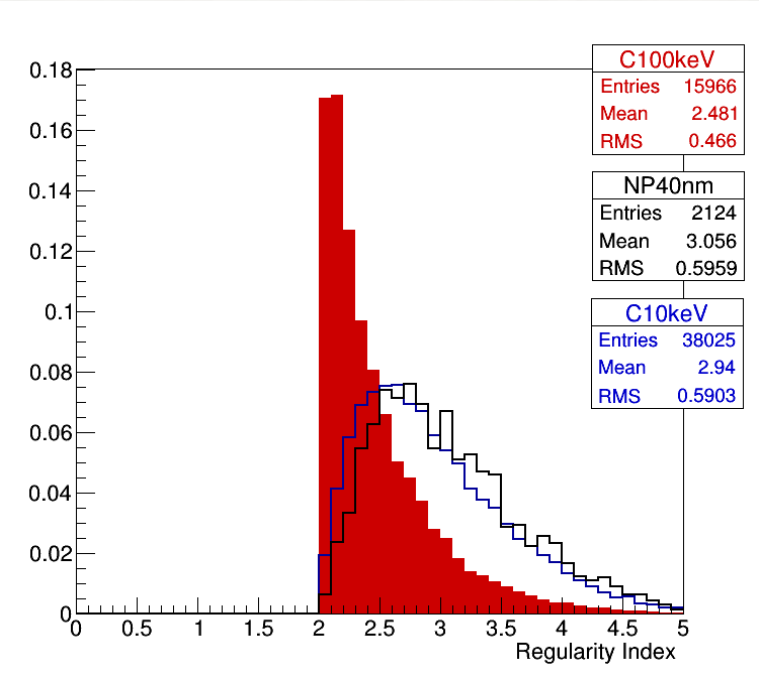


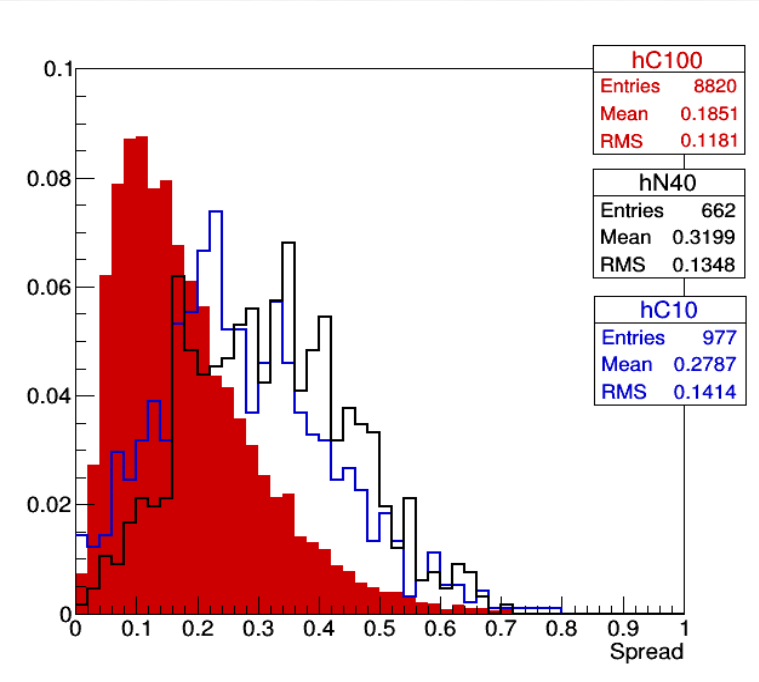


Plasmon Analysis in Napoli

Regularity index: $\frac{\text{PathLen}}{\text{BarShift}}$

Spread: $\frac{\text{MaxAmp}}{\text{BarShift}}$





Signal-like events have a Regularity Index peaked at 2 → Very regular path

Signal-like events have a Spread peaked around 0.1 → Deviations from BarShift direction are small

List Of Samples

- NP 40nm → Nanoparticles
- C10 keV → Carbon vertical ions

} Background studies

- C30 keV
- C60 keV
- C100 keV

Carbon horizontal ions

} Signal-like events

- C150keV → Carbon vertical ions

Gelatine layer on top surface

- 10gTS → 10g test sample

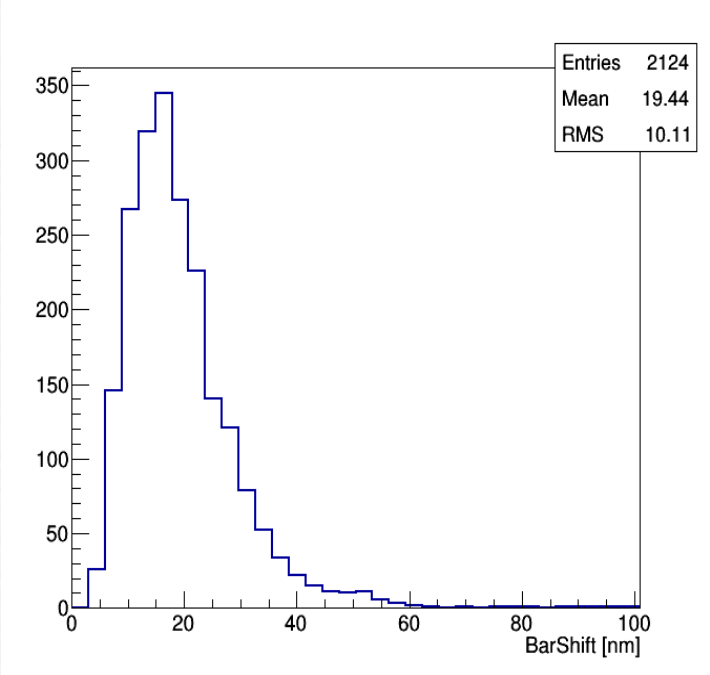
Rejection power of plasmon analysis on candidates

NP 40nm

1Peak clusters

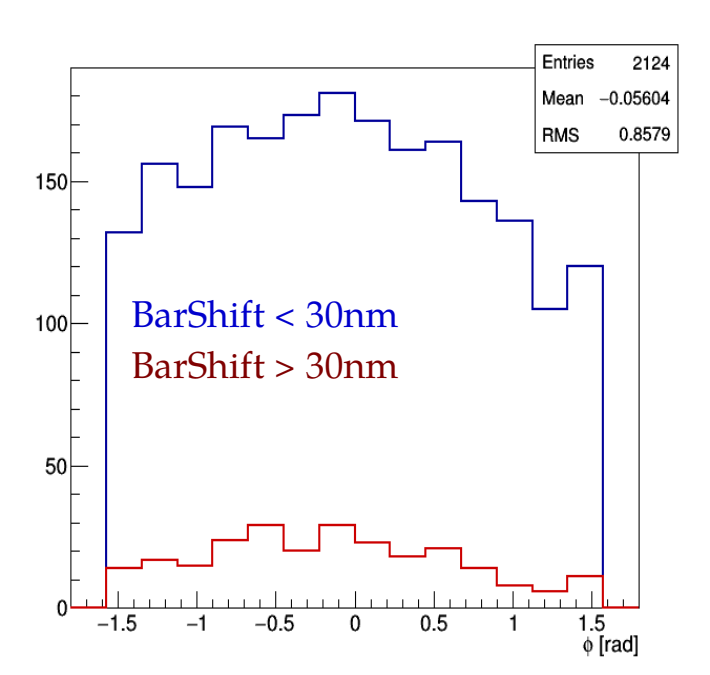
BarShift > 30nm : 11.72 %

Displacement of the barycenter



Mean BarShift ~ 20nm

Phi angle distribution



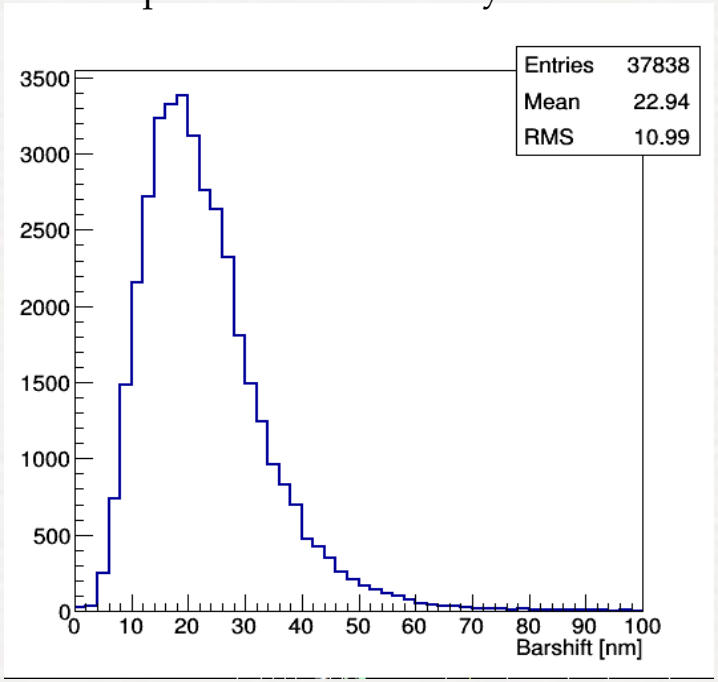
Not-physical anisotropy

C10keV

1Peak clusters

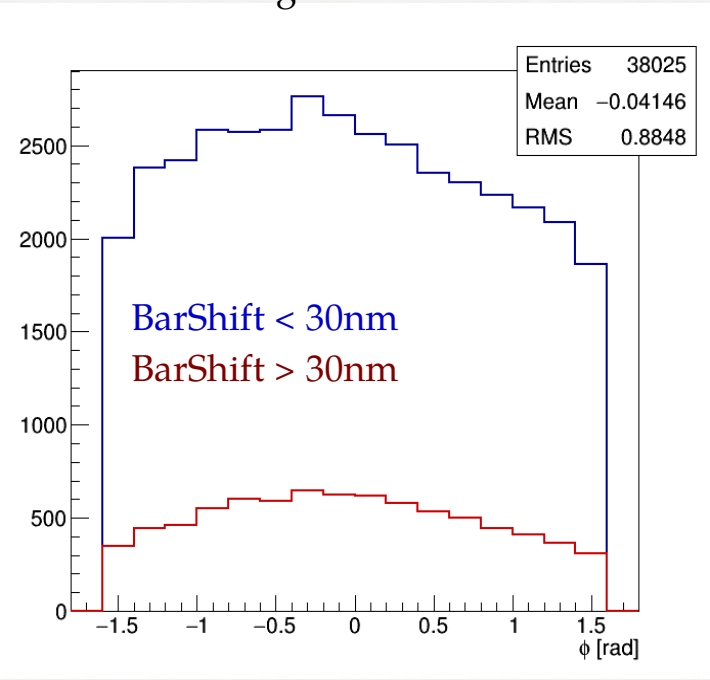
BarShift > 30nm : 21.14 %

Displacement of the barycenter



Mean BarShift ~ 23nm

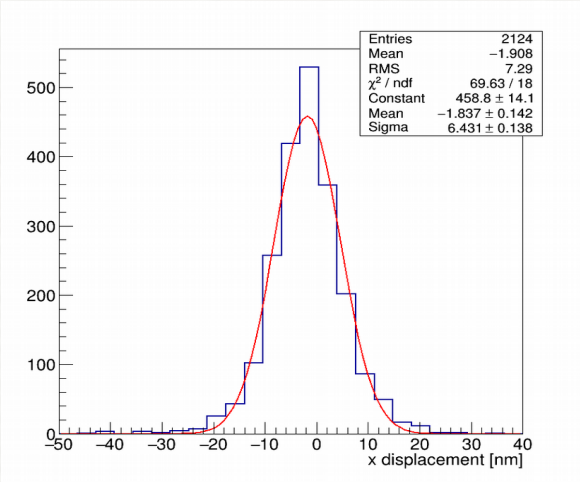
Phi angle distribution

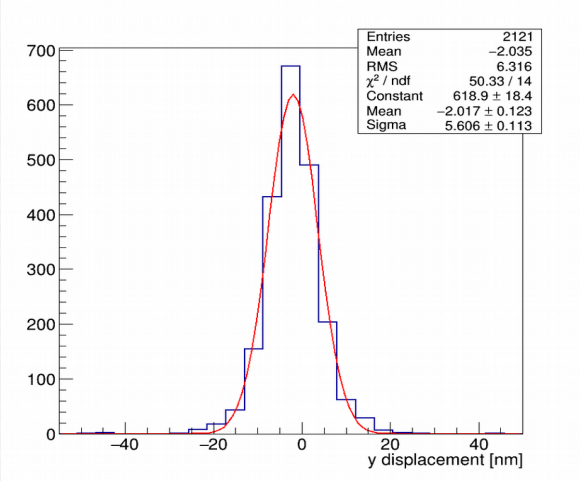


Not-physical anisotropy

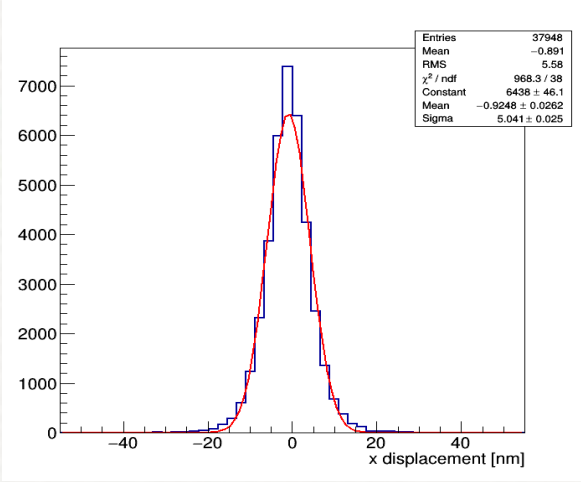
Position Accuracy

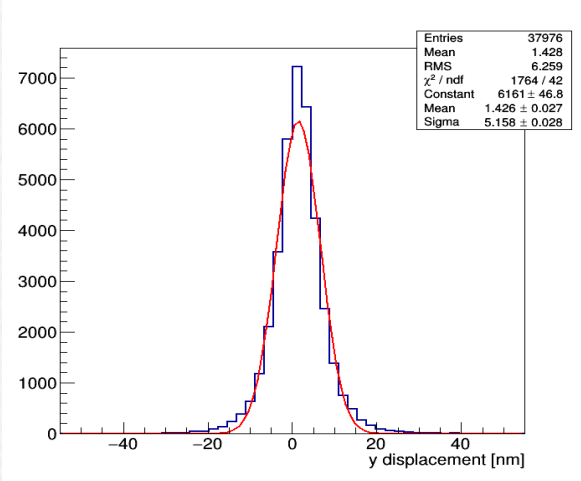
NP40nm





C10keV





Improvements in the position accuracy

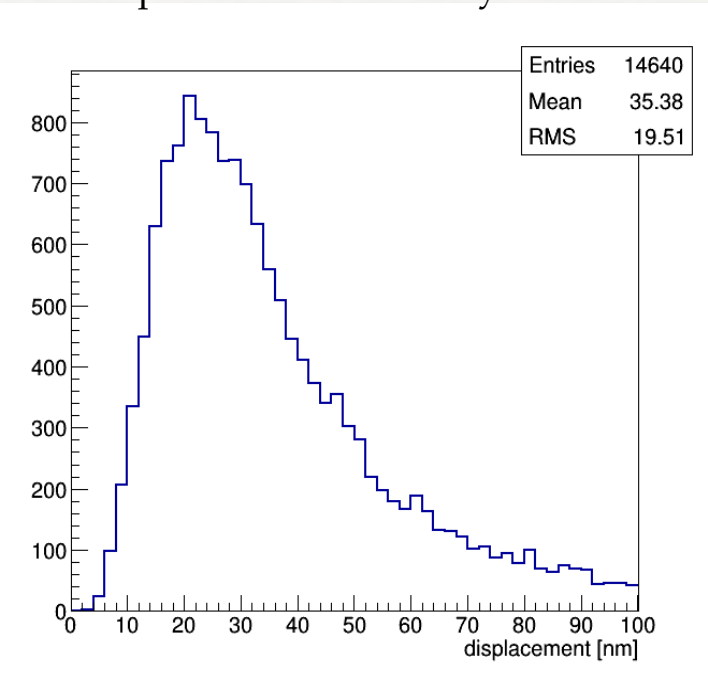
The accuracy achieved in the position of the grains is ~ 5nm

C100keV

1Peak clusters

BarShift > 30nm : 55.24 %

Displacement of the barycenter

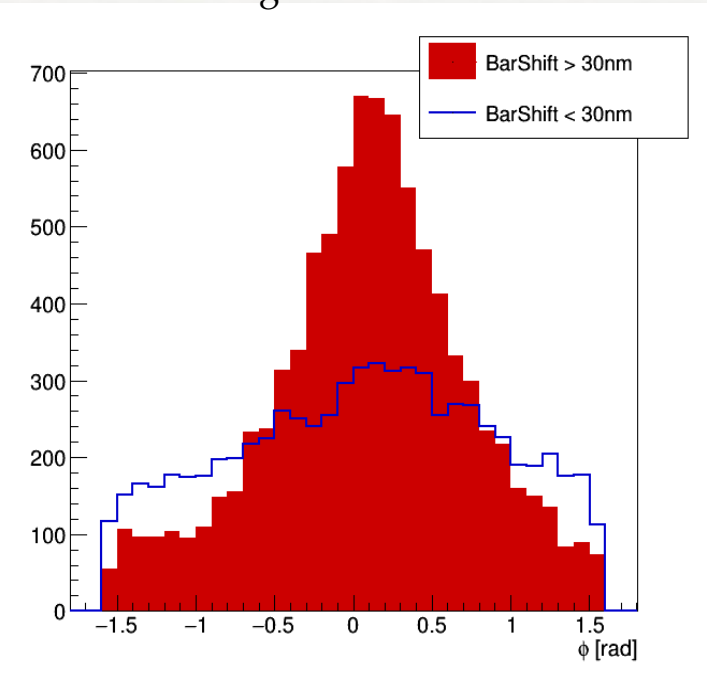


Mean BarShift ~ 35nm

FROM SRIM

Mean track length ~ 275nm

Phi angle distribution



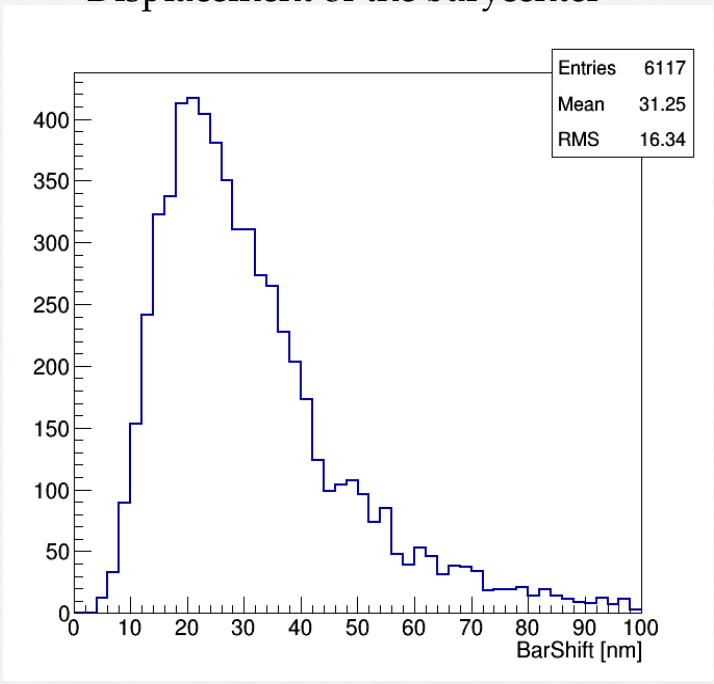
Peak at 0° degrees

C60keV

1Peak clusters

BarShift > 30nm : 46.67 %

Displacement of the barycenter

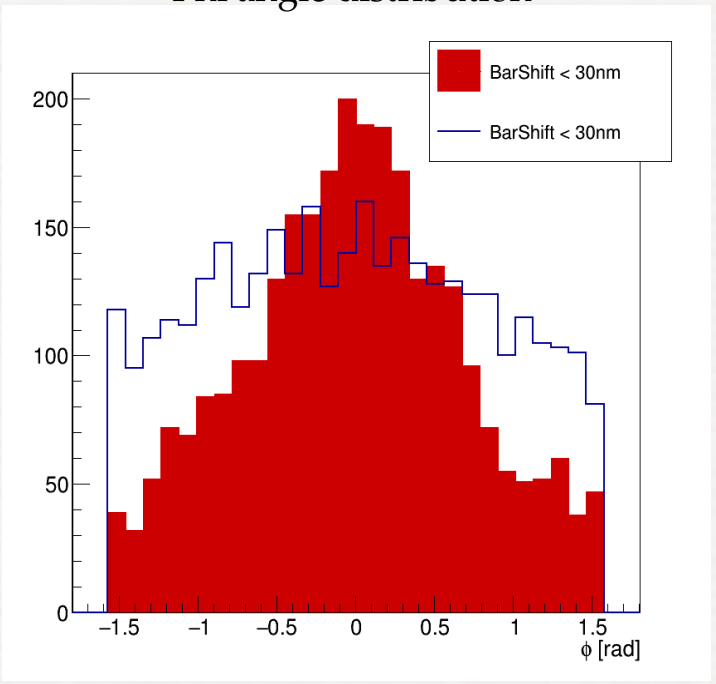


Mean BarShift ~ 31nm

FROM SRIM

Mean track length ~ 170nm

Phi angle distribution



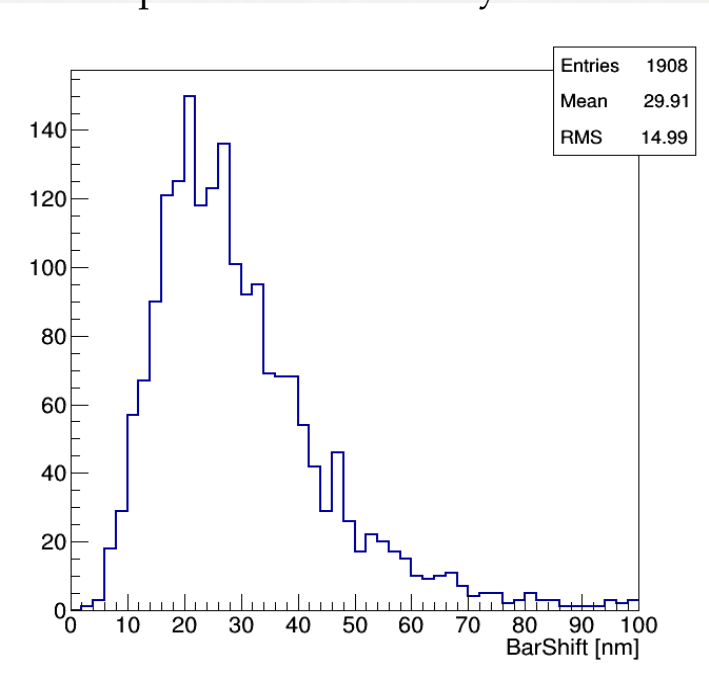
Peak at 0° degrees

C30keV

1Peak clusters

BarShift > 30nm : 39.90 %

Displacement of the barycenter

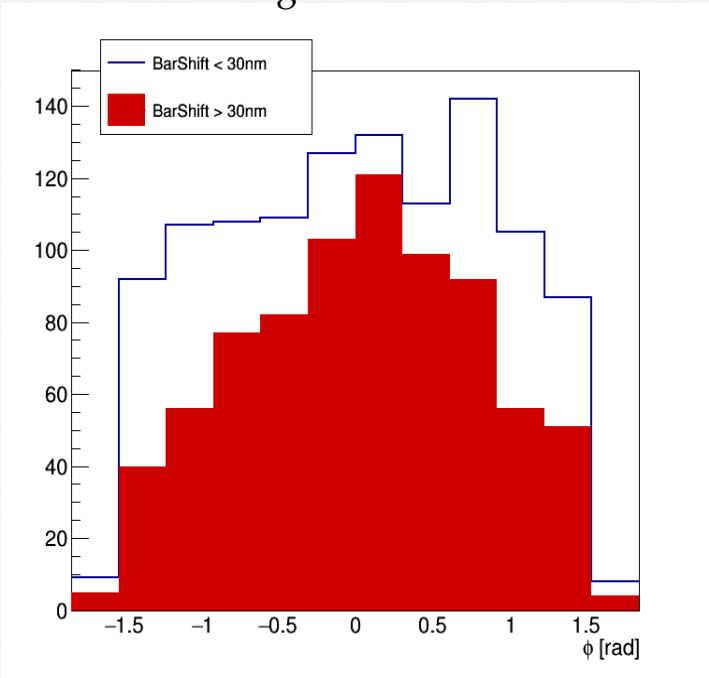


Mean BarShift ~ 31nm

FROM SRIM

Mean track length ~ 86nm

Phi angle distribution

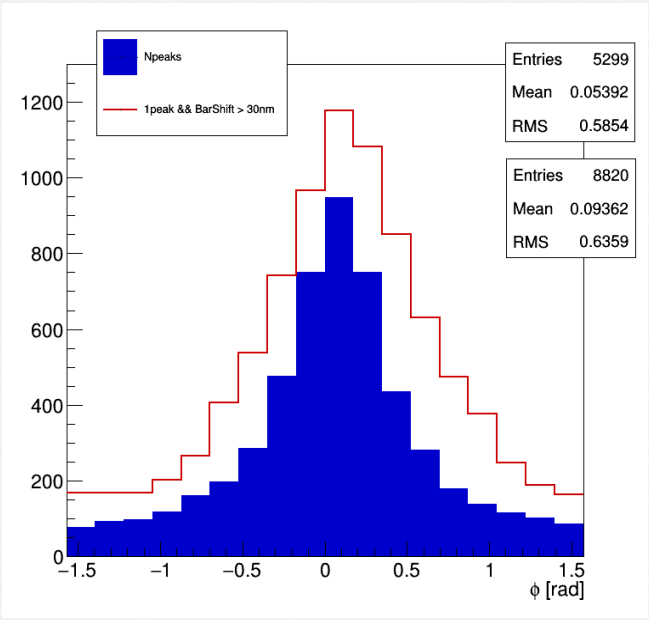


Small peak around 0° degrees

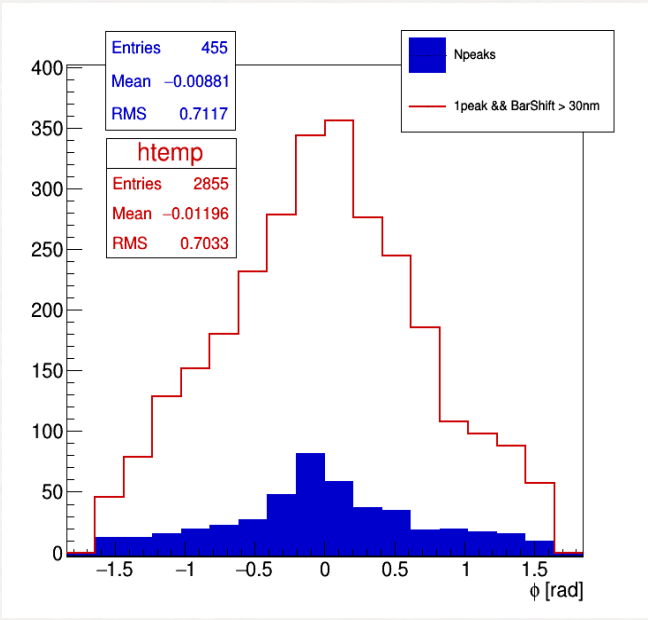
Nanotracks vs Microtracks

Nanotracks (BarShift > 30nm)
Microtracks

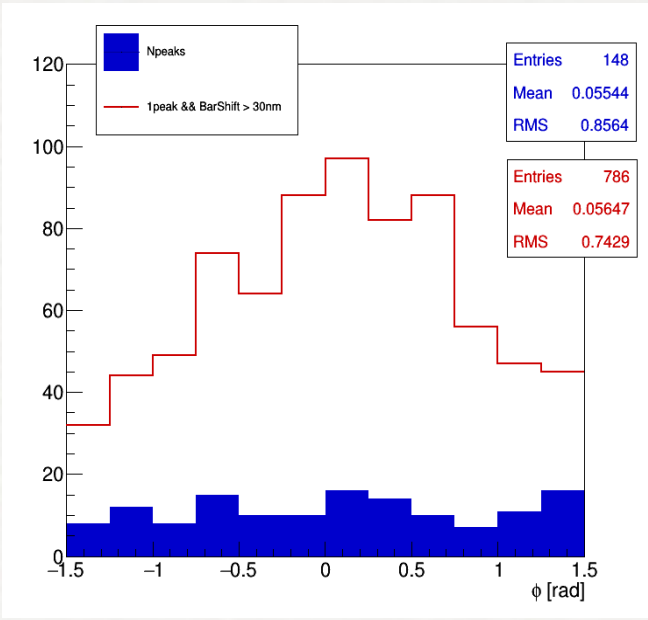
C100keV



C60keV



C30keV



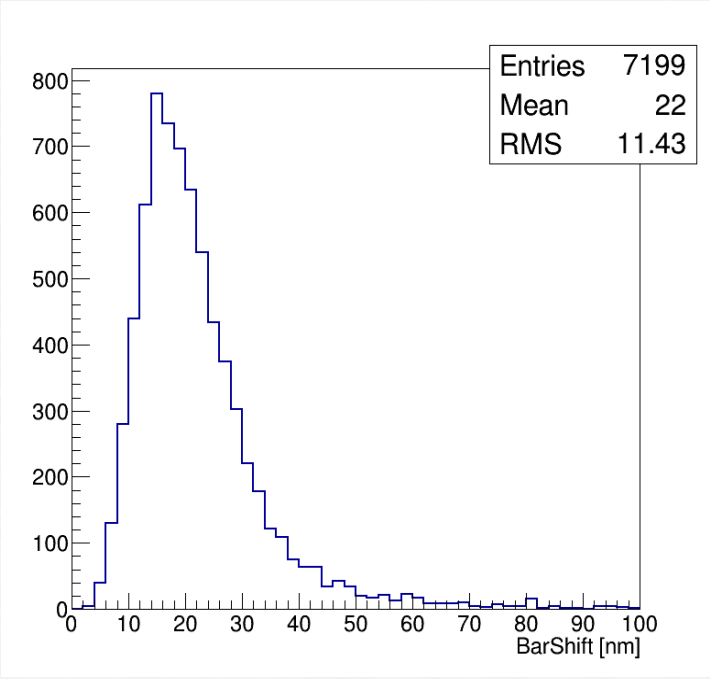
A larger fraction of microtracks is found for C100keV sample while the contribution of microtracks is not visible for C30keV sample, where the tracks are expected to be made of one grain only

Test Sample 10g

1Peak clusters

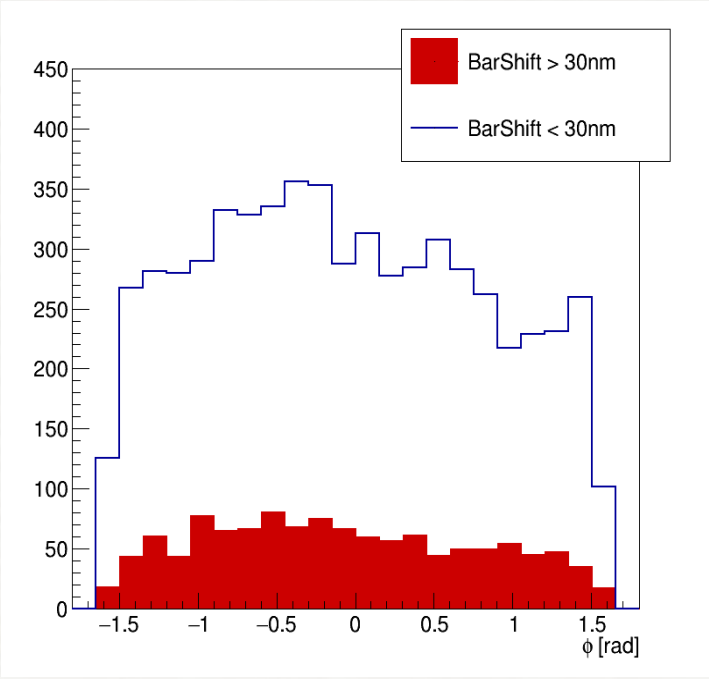
BarShift > 30nm : 16.66 %

Displacement of the barycenter



Mean BarShift ~ 22nm

Phi angle distribution



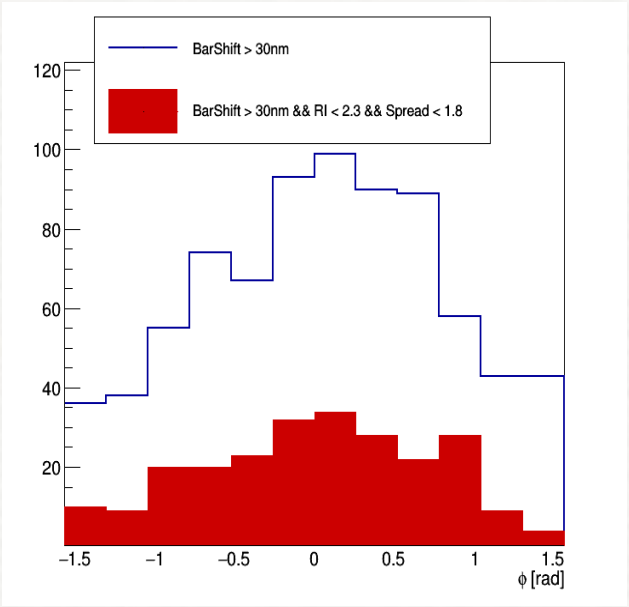
Not-physical anisotropy

Signal Selection (C30keV)

Regularity index and Spread cuts have been used to reduce the anisotropy

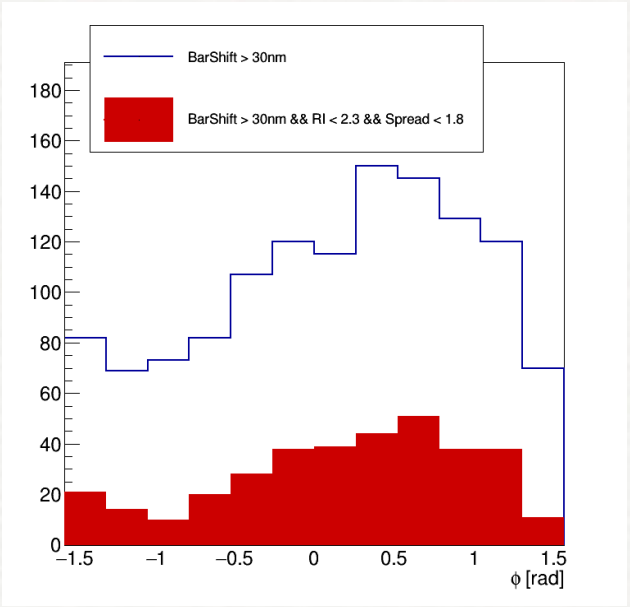
Regularity Index < 2.3
Spread < 0.18

Sample Orientation: 0°



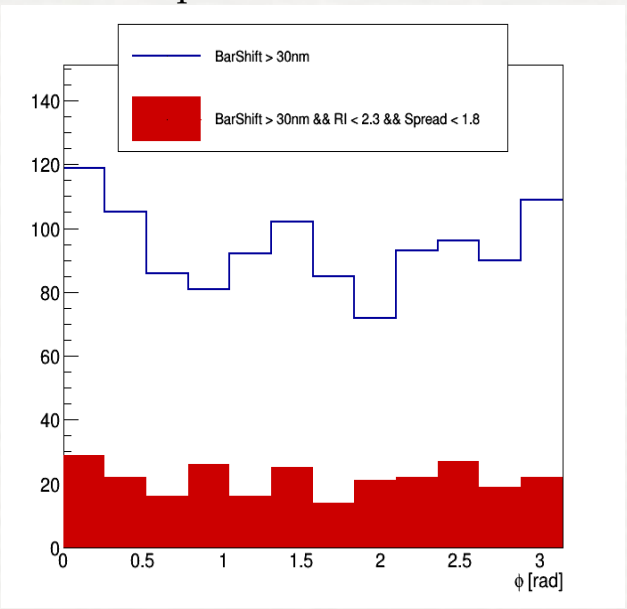
Clear peak around 0°

Sample Orientation: 45°



Small peak around 45° ?

Sample Orientation: 90°



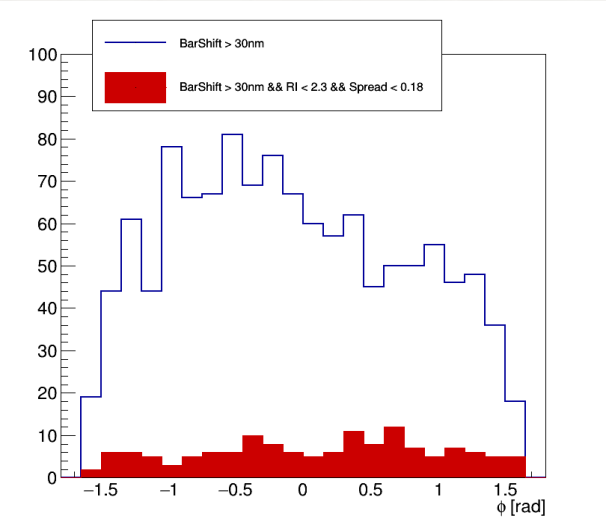
No peak

A signal can be observed in the 0° orientation and barely in the 45° orientation
At 90° the signal disappear → Anisotropy effect? , Low contrast?

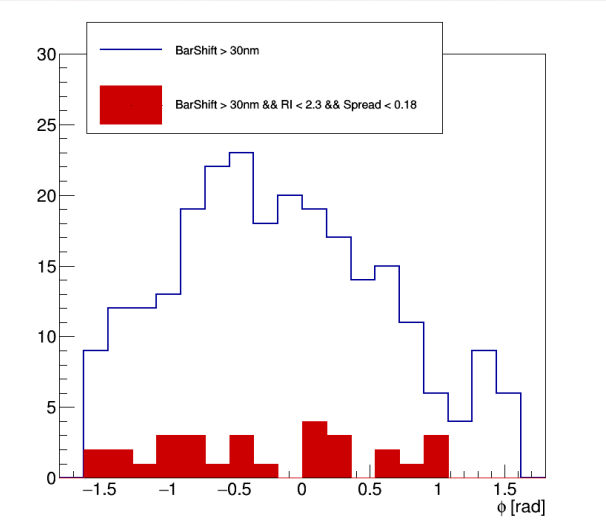
Signal Selection

Regularity Index < 2.3
Spread < 0.18

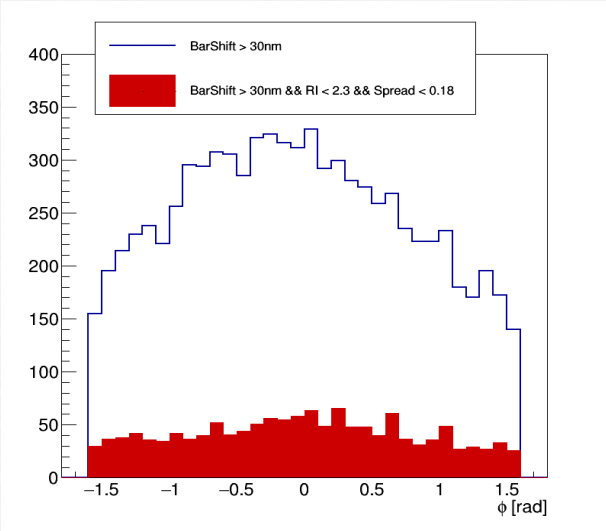
Test Sample



NP40nm



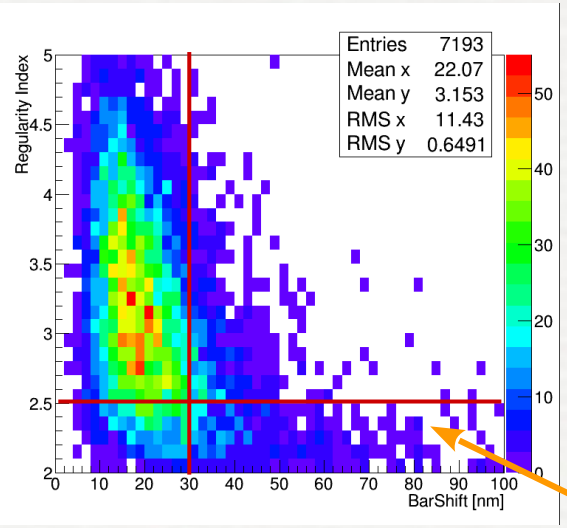
C10keV vertical ions



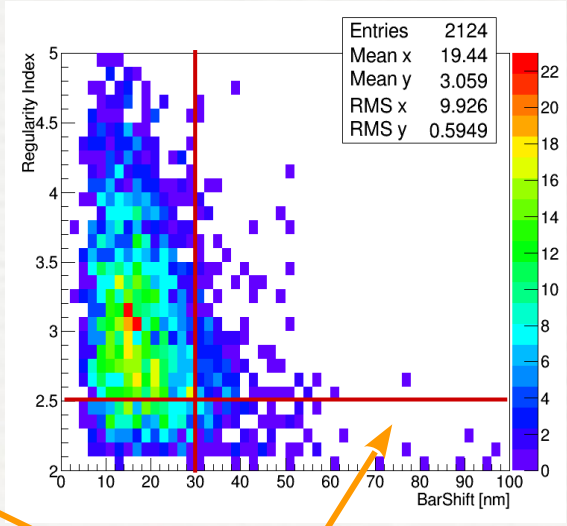
Anisotropy seems to be reduced after cuts on the topological variables

Regularity vs Barshift

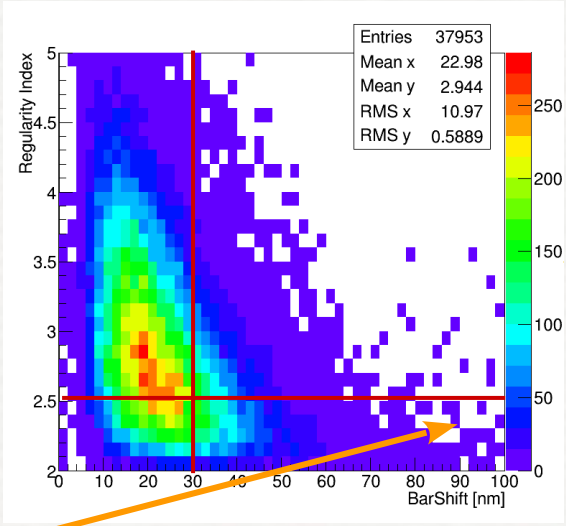
Test Sample



NP40nm



C10keV vertical ions

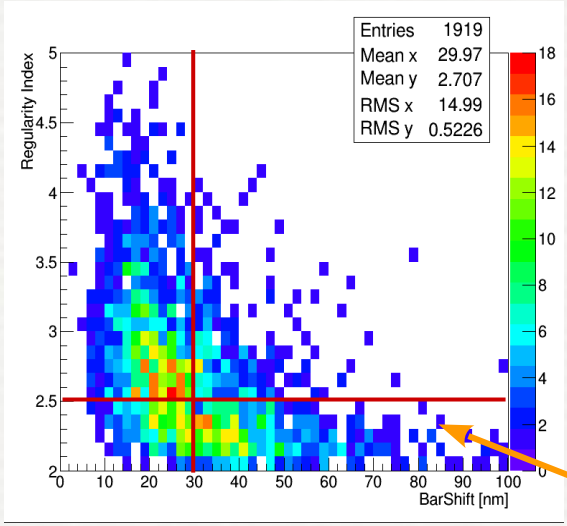


SIGNAL REGION

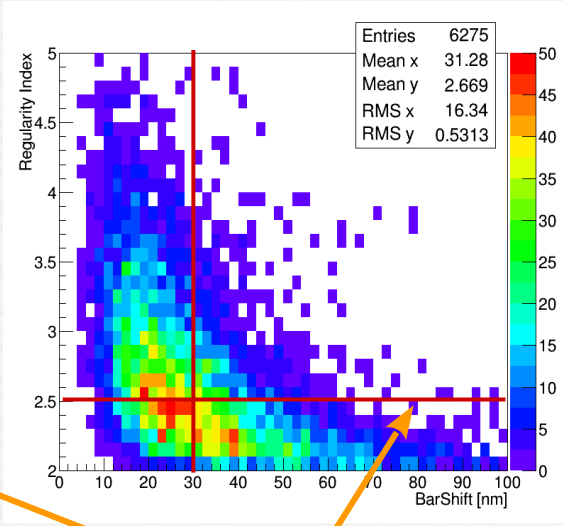
In order to reduce the background contamination several cuts should be applied
For example, in addition to BarShift > 30nm an upper cut at 2.5 on Regularity Index improve the background rejection

Regularity vs Barshift

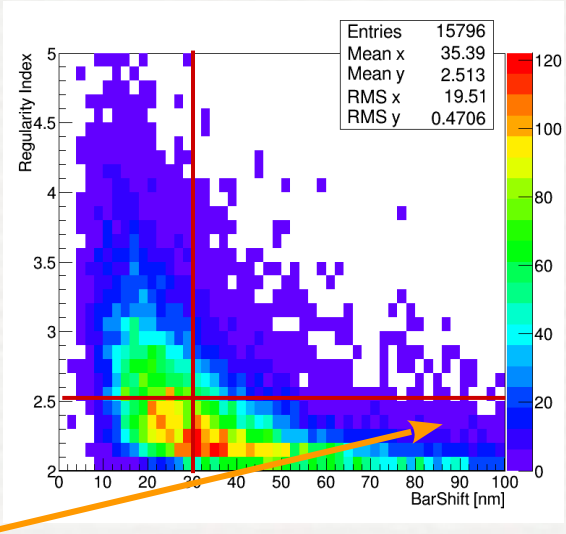
C30keV



C60keV



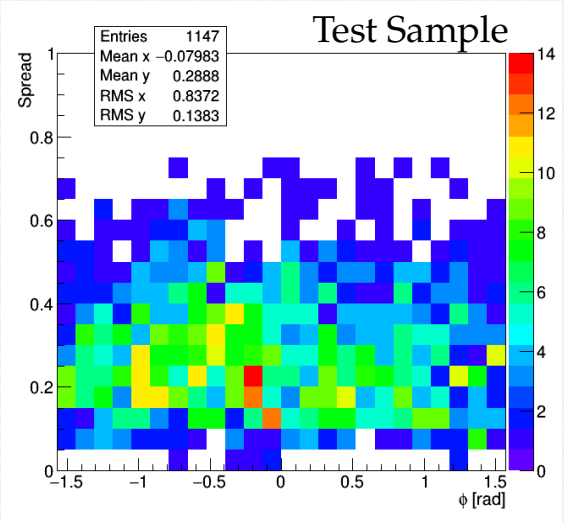
C100keV

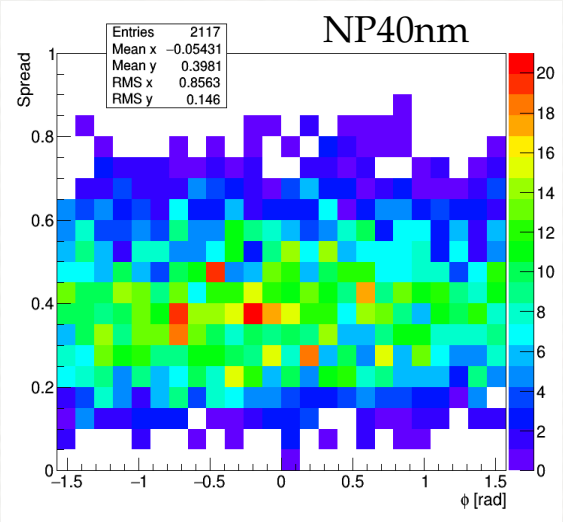


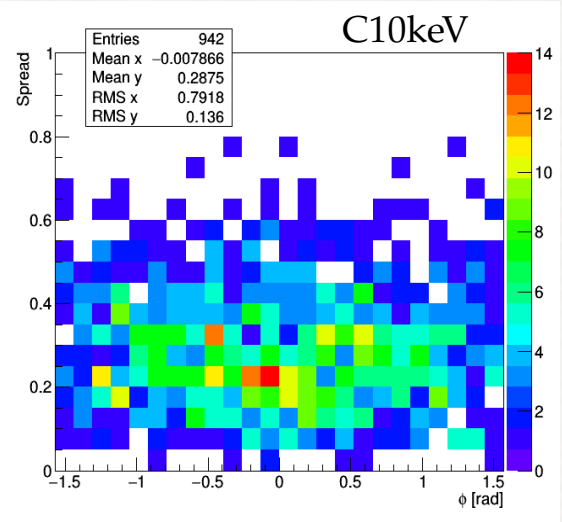
SIGNAL REGION

In order to reduce the background contamination several cuts should be applied
For example, in addition to BarShift > 30nm an upper cut at 2.5 on Regularity Index improve the background rejection

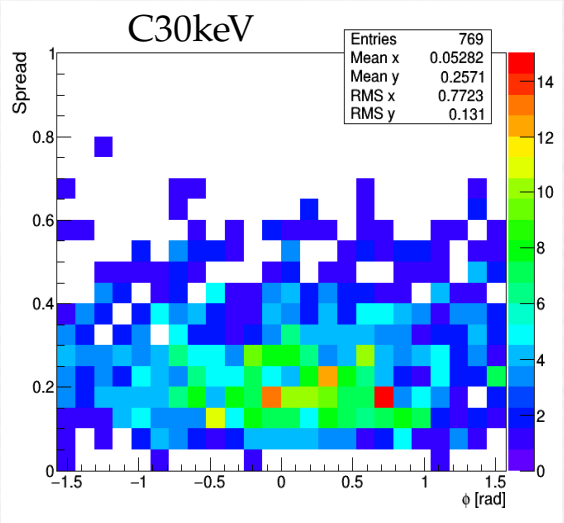
SPRED VS PHI ANGLE

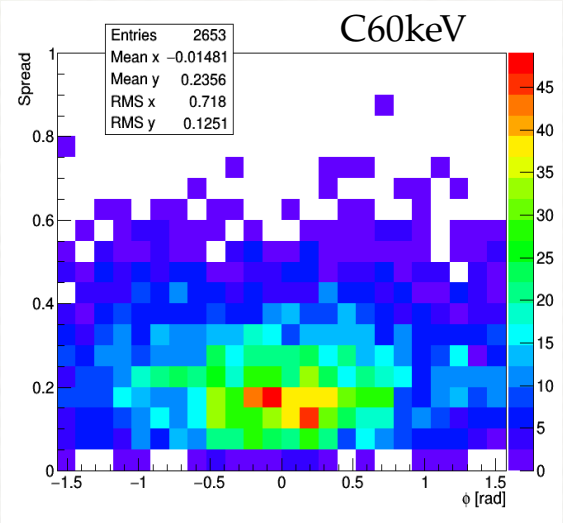


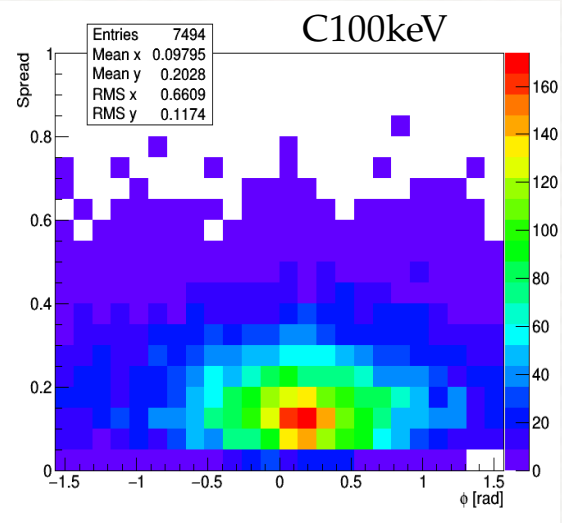




Samples with grains with preferred direction have a smaller Spread (~0.2)







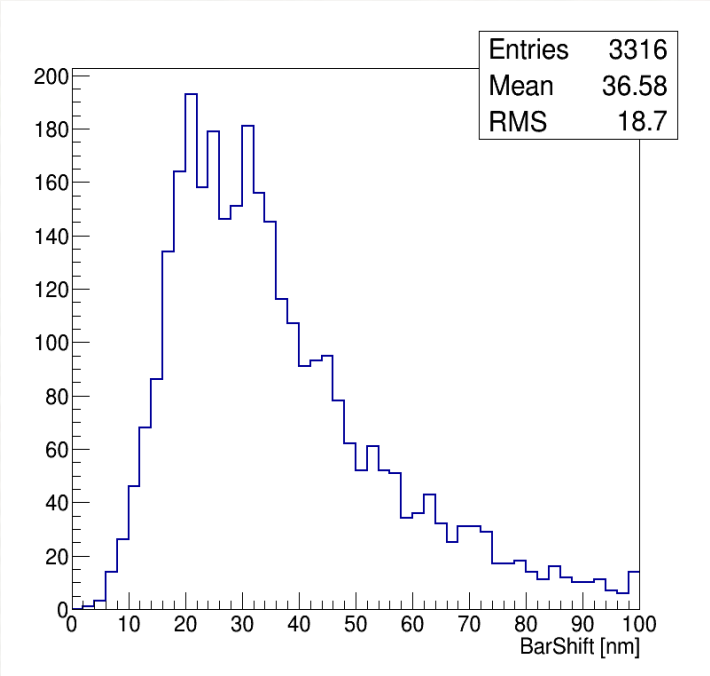
C150keV

- Gelatine layer on top surface
- Vertical ions exposure

1Peak clusters

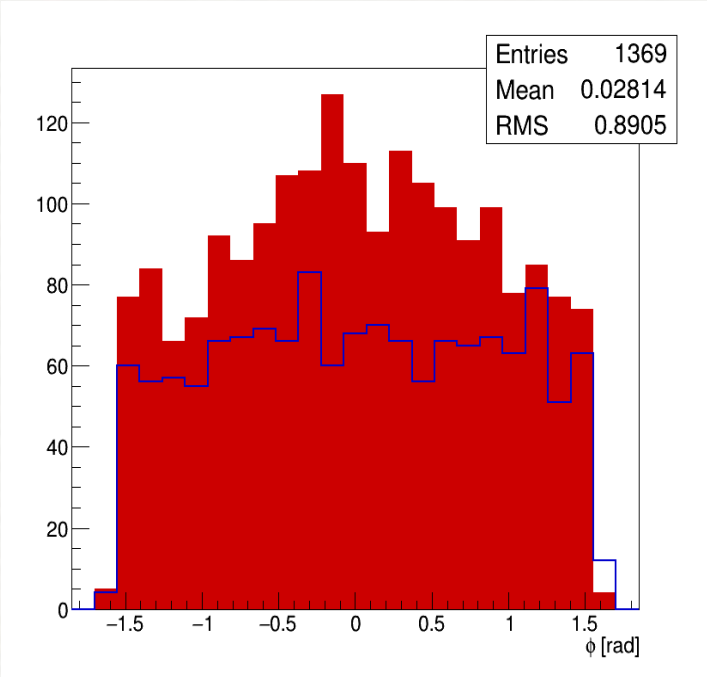
BarShift > 30nm : 58.71 %

Displacement of the barycenter

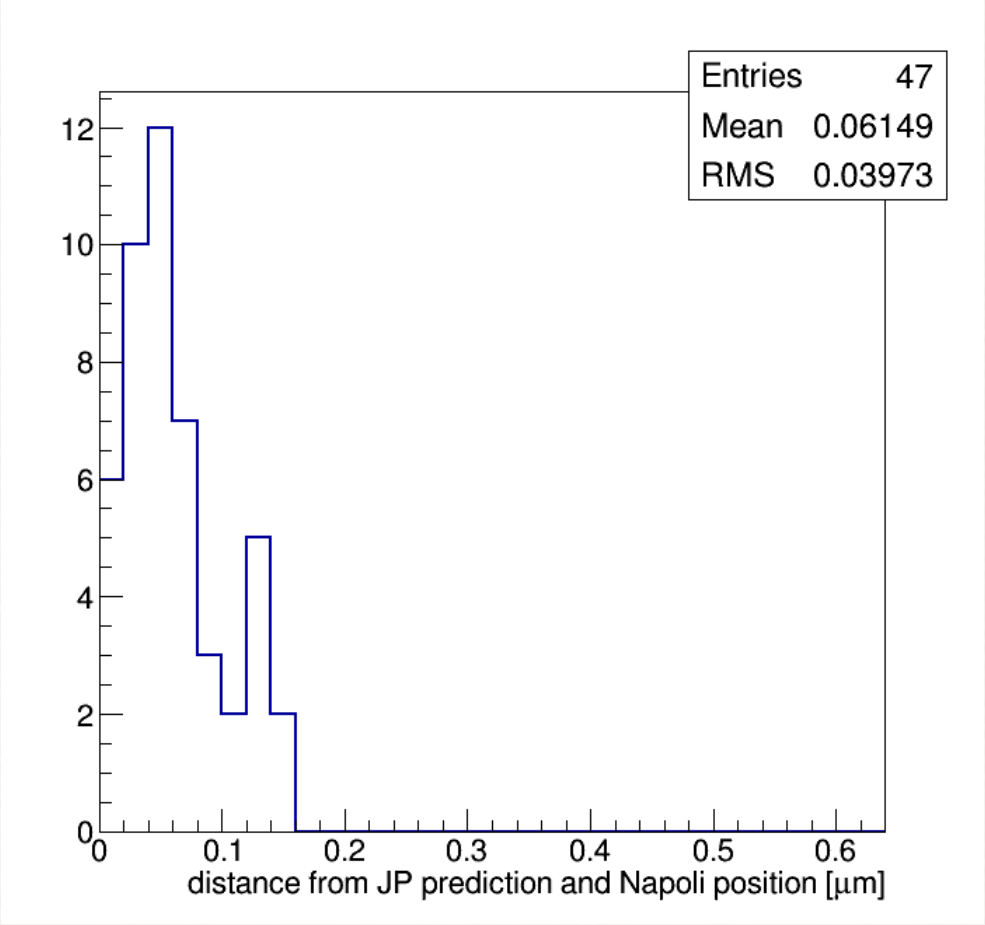


Mean BarShift ~ 37nm

Phi angle distribution



C150keV Matching



Japanese predictions allow to find the candidates from elliptical shape selection in Napoli scanning data with an accuracy less than 200 nm

Conclusions

- Position accuracy of 5 nm achieved with plasmon analysis
- Signal directional peak detected for C60keV
- Small directional peak observed also in C30keV

Perspectives

- Analysis of C40keV and C50keV useful to evaluate the detection track length threshold
- Study of topological variables for signal / background discrimination
- Identification of new topological variables
- Larger sample of candidates needed to test the different selection cuts
- Use of **electronic microscope** needed to find the correlation between the shift of the barycenter and the real track length

THANK YOU