Search for long distance correlations from multi-track events

Team: Paola La Rocca
Chiara Pinto
Silvia Pisano
Franco Riggi

EEE Meeting – March 5th, 2021

The new data set

The whole statistics (2015-2020) was reprocessed in order to:

- extend previous results using multi-track events to select EAS (before limited to 2015-2018)
- Add more information about the tracks to the tree with candidates

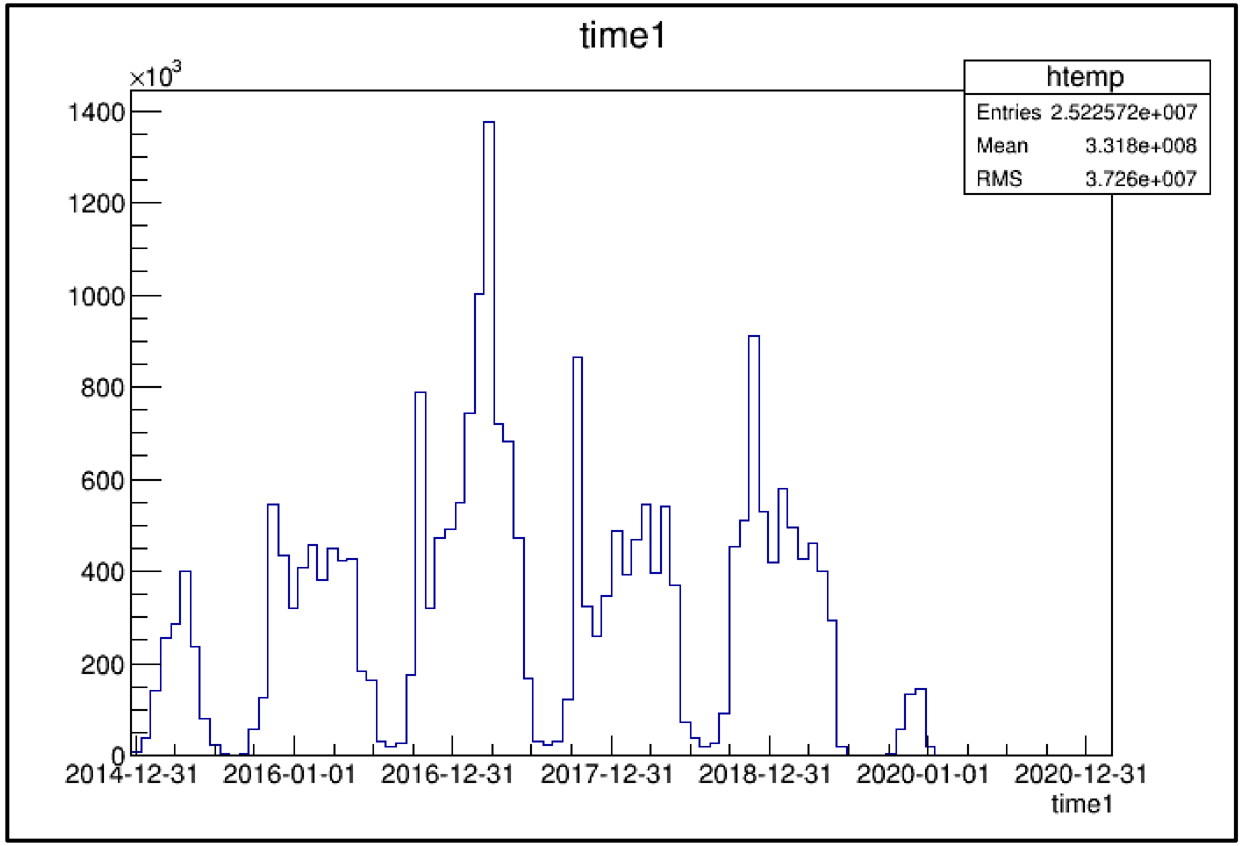
Dataset: Full available statistics: 2015-2020
all EEE telescopes (no clusters)
25M coincidence events (within ±2 s)

Info saved on ROOT file for further analyses:
Telescope code
Event time
Direction, **position** and $\chi 2$ of individual tracks
Sum of scalar products between tracks
(alignment between tracks)

Preselection cuts:
$\chi 2 < 10$
Rough alignment between tracks in the same telescope
Distance between telescopes > 5 km

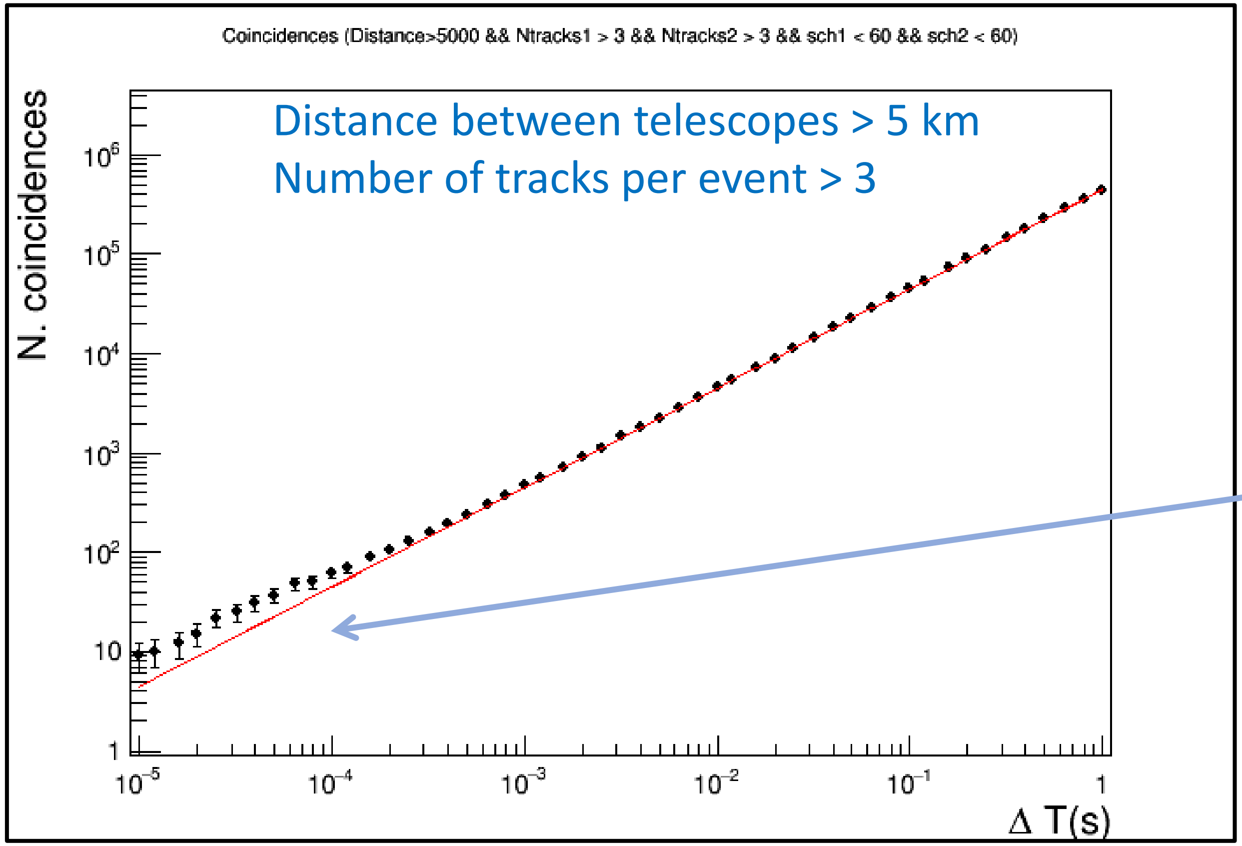
- The tree was available since Jan2021

The new data set



First look at the data

Analysis repeated on the new data applying the same cuts used on old data



Events excess observed for $\Delta T \approx 10^{-4}$ s

48 coincident events observed

(expected background ~ 29 events)

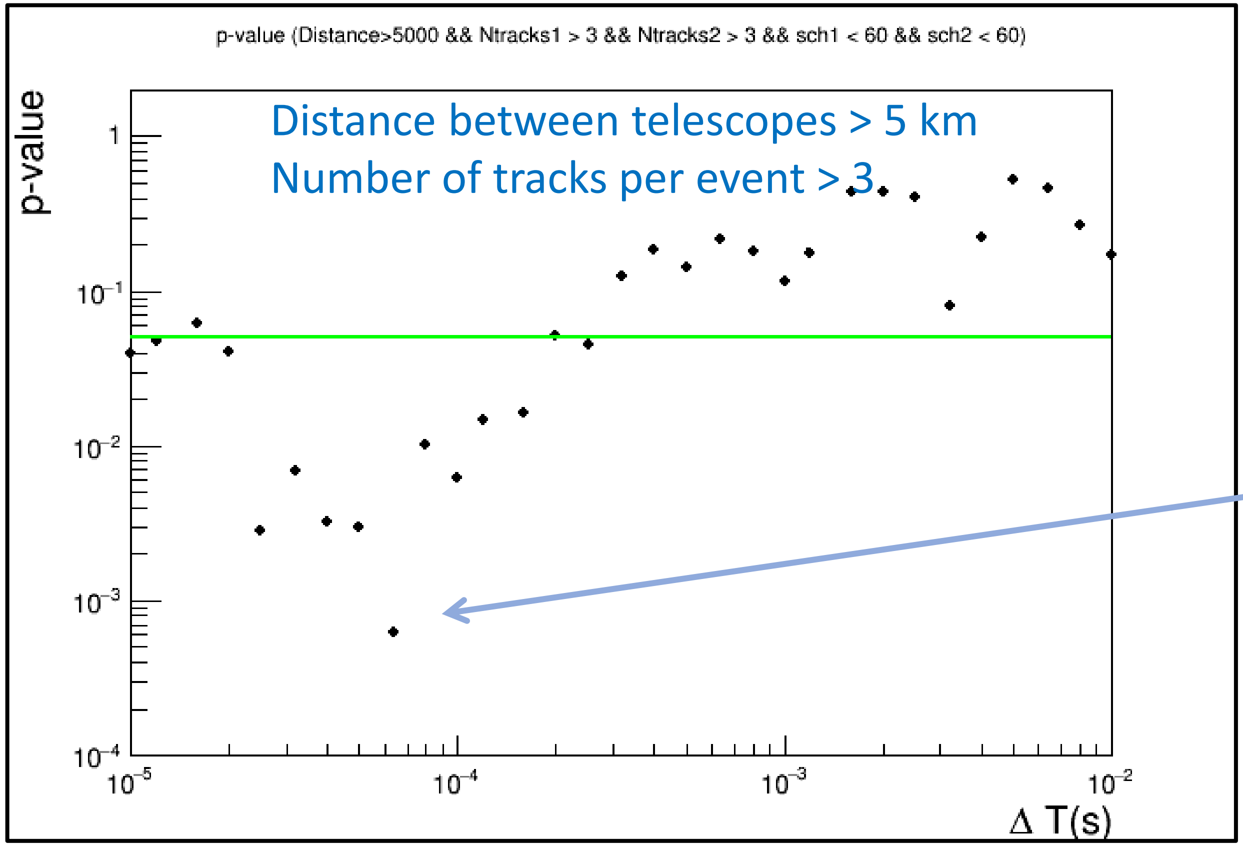
p-value ~ 10^{-3}

48 (total) – 29 (background) = 19 (signal) ± 9

Results similar to those obtained before

First look at the data

Analysis repeated on the new data applying the same cuts used on old data



Events excess observed for $\Delta T \approx 10^{-4}$ s

48 coincident events observed

(expected background ~ 29 events)

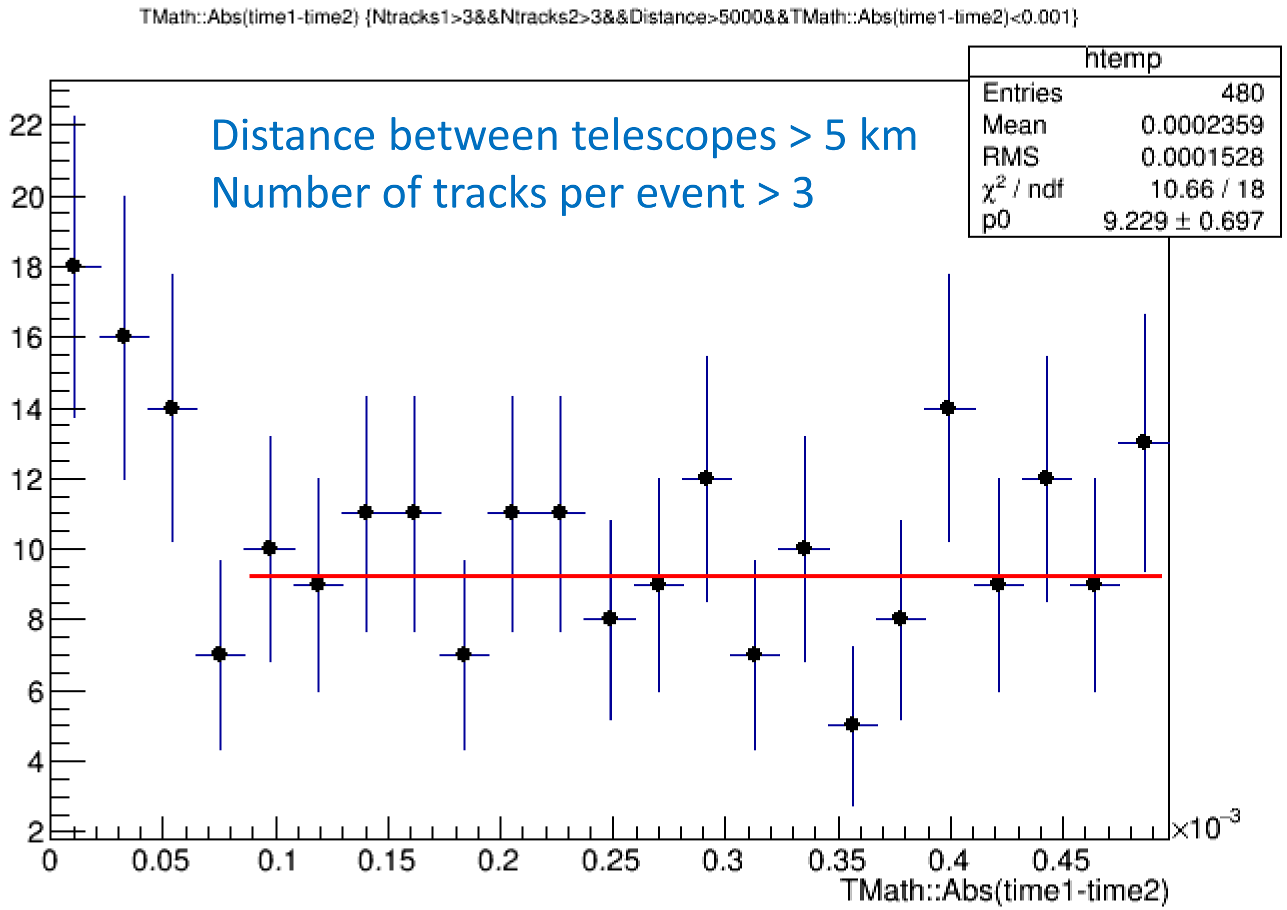
p-value ~ 10^{-3}

48 (total) – 29 (background) = 19 (signal) ± 9

Results similar to those obtained before

First look at the data

Alternative representation of the coincidence excess → absolute time difference spectrum



The absolute time difference exhibits a small excess for small coincidence time windows

Average background (estimated from a pol0 fit in the range > 0.1 ms)

~ 9 events/0.02 ms

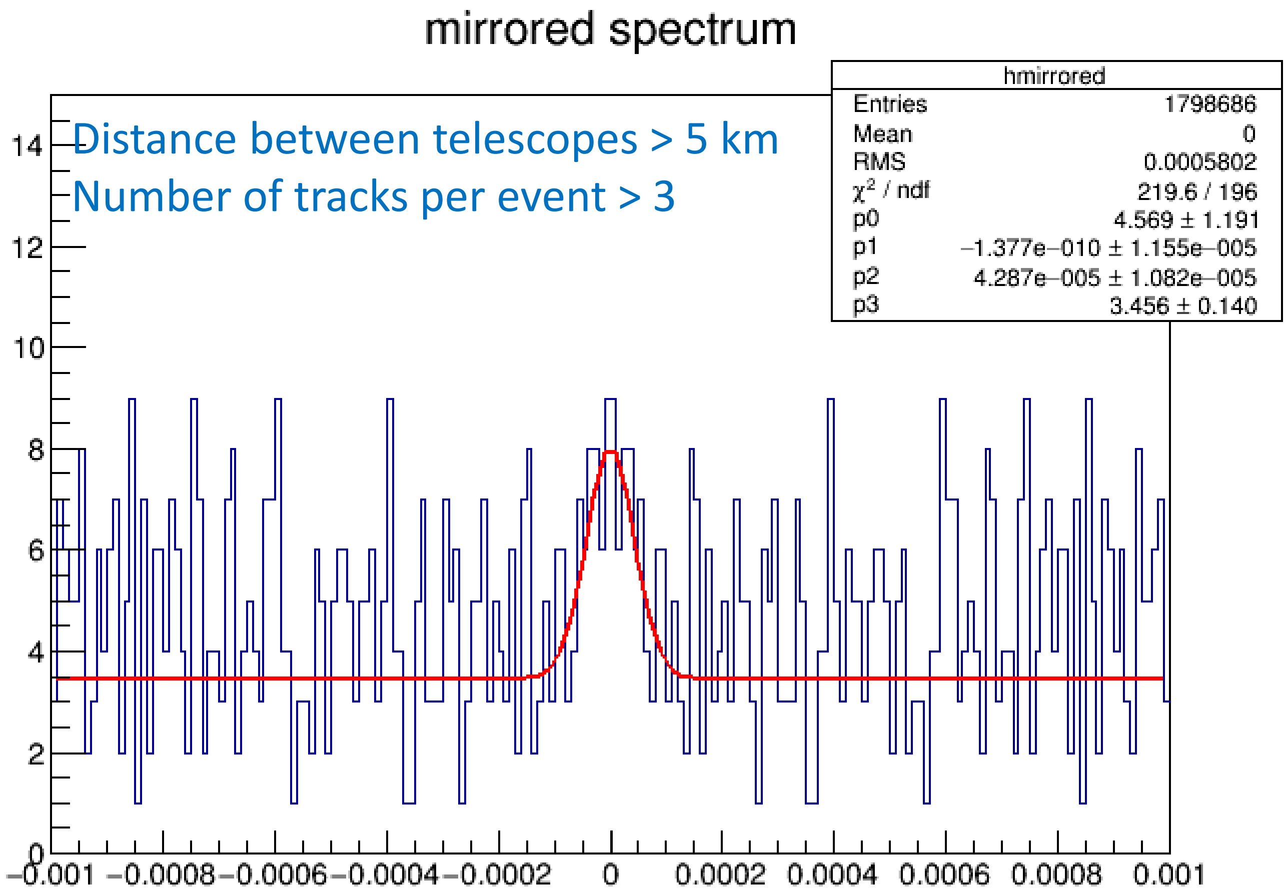
From the first 4 bins:

55 – 37 (background) = 18 (signal) ± 10

S/B = 0.49 **S/√B = 3**

First look at the data

Alternative representation of the coincidence excess → mirrored time difference spectrum



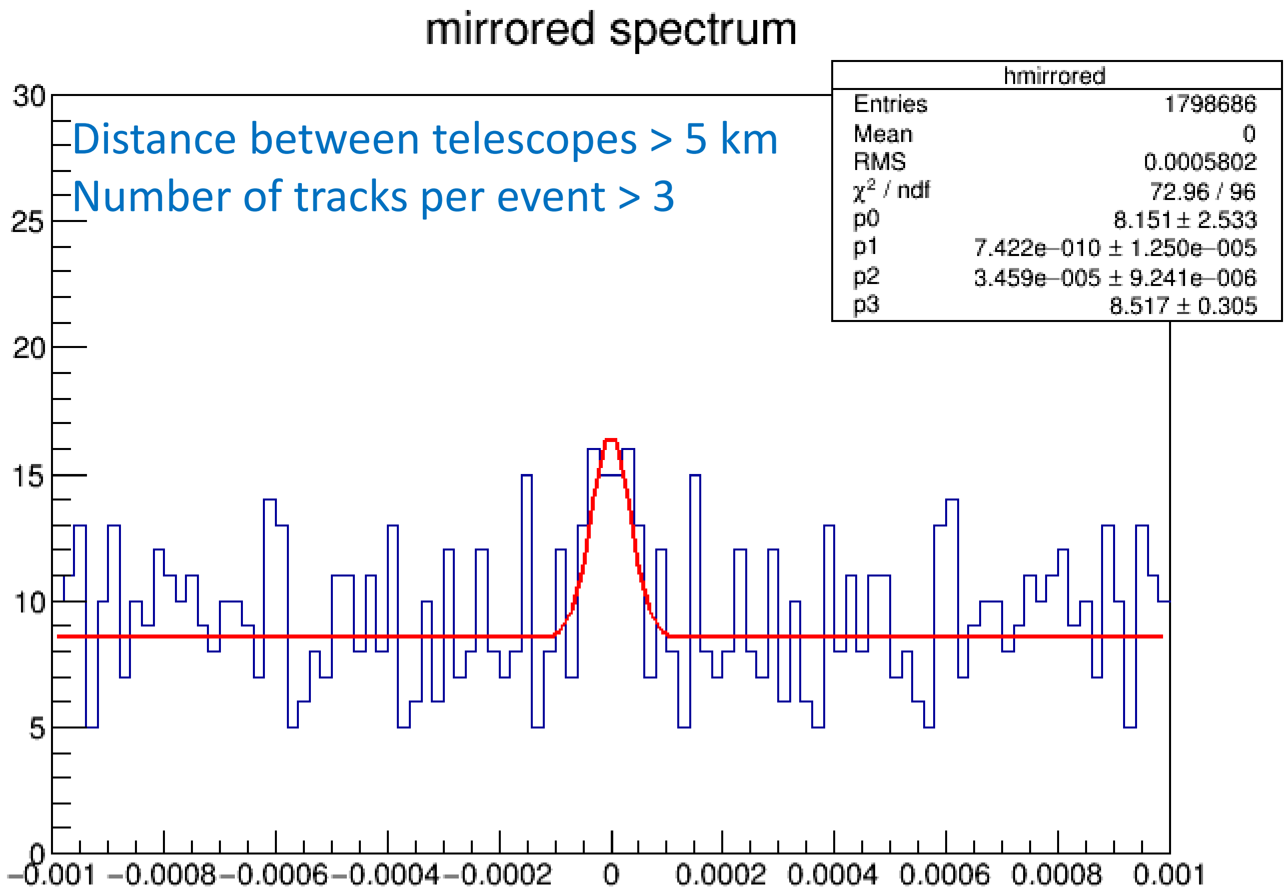
The absolute time difference is mirrored to negative values (producing a symmetric peak)

Bin width 0.01 ms

Fit gaus+pol0 → **25 ± 9**

First look at the data

Alternative representation of the coincidence excess → mirrored time difference spectrum



The absolute time difference is mirrored to negative values (producing a symmetric peak)

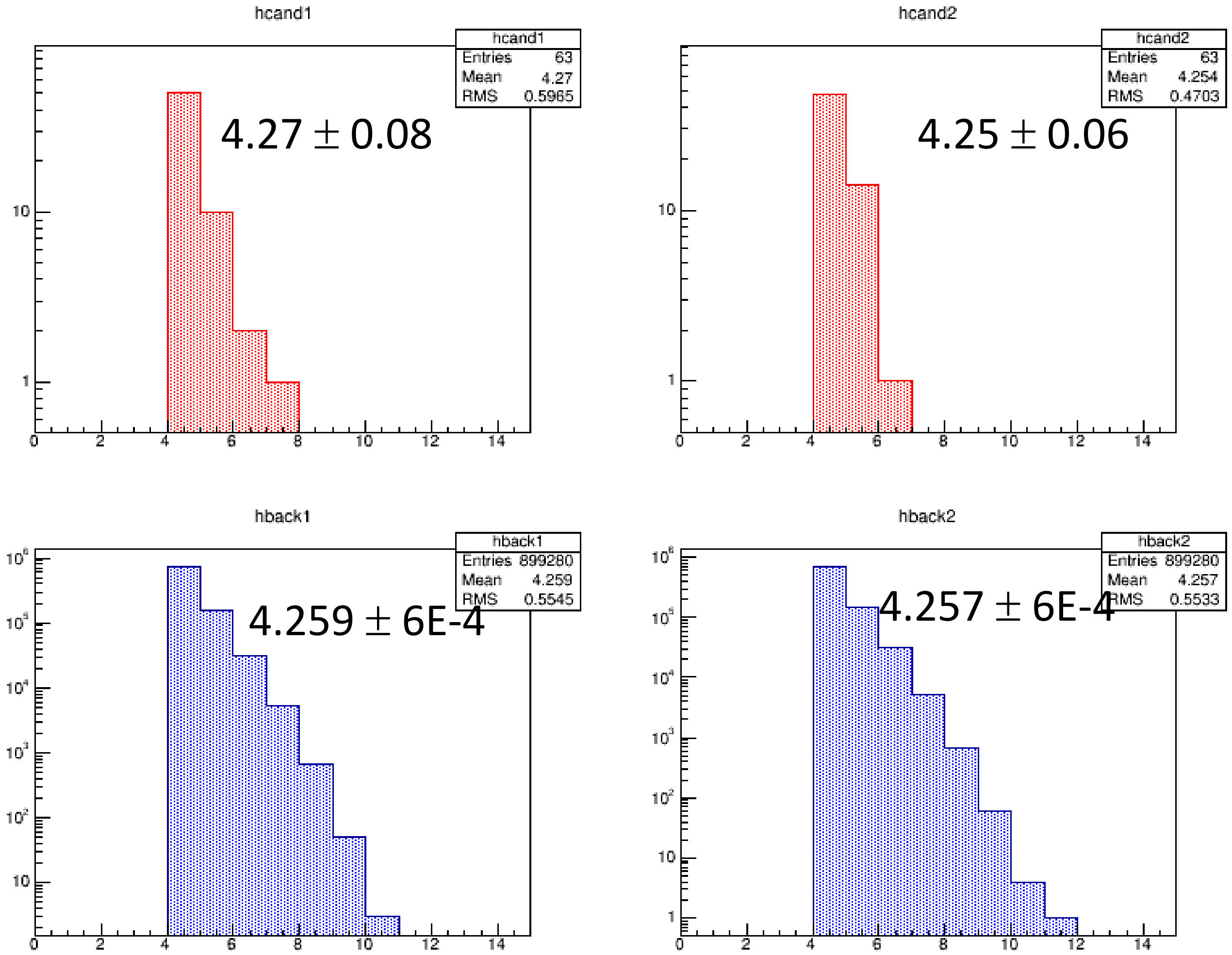
Bin width 0.02 ms

Fit gaus+pol0 → **18 ± 7**

Additional checks

- **Optimization of cuts on the number of tracks**
  - Coincidence excess less evident for cuts different from Ntracks>3
- **Average Ntracks similar for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-4 s)**

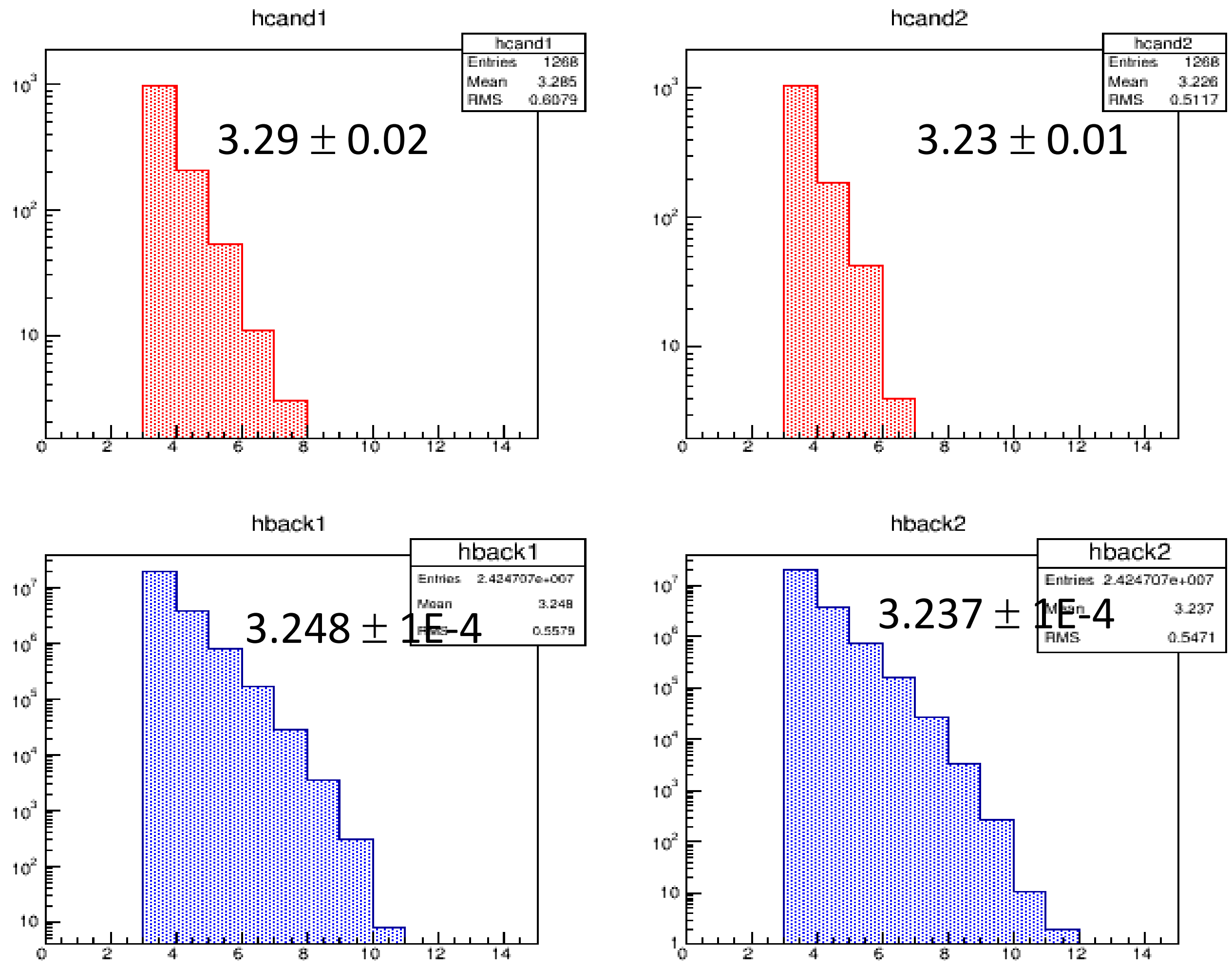
Ntracks > 3



Additional checks

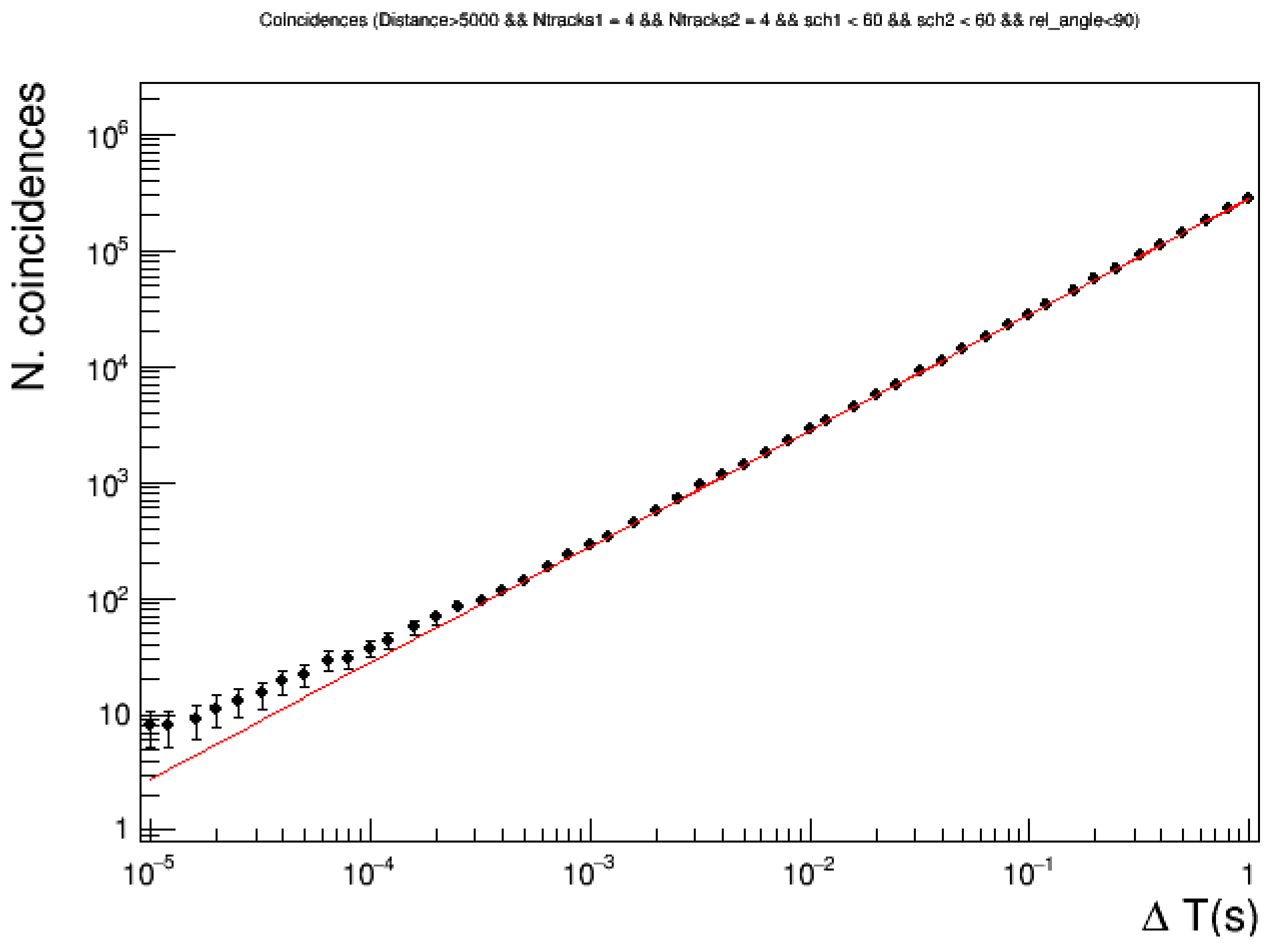
- **Optimization of cuts on the number of tracks**
  - Coincidence excess less evident for cuts different from Ntracks>3
- **Average Ntracks similar for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-4 s)**

Ntracks > 2



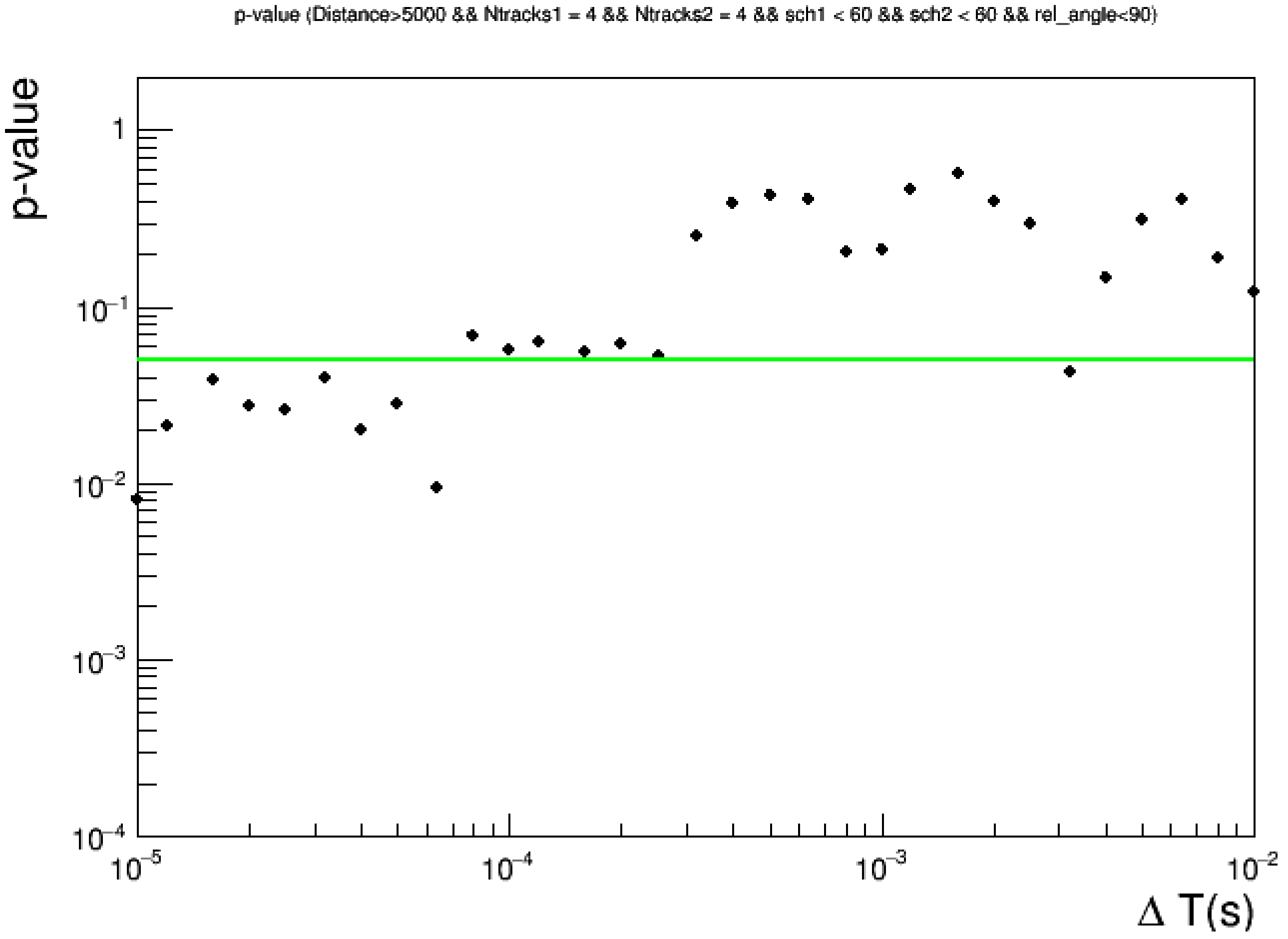
Additional checks

- **Optimization of cuts on the number of tracks**
  - Coincidence excess less evident for cuts different from Ntracks>3
- **Average Ntracks similar for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-4 s)**
- **Analysis repeated for Ntracks1 = Ntracks2 = 4**



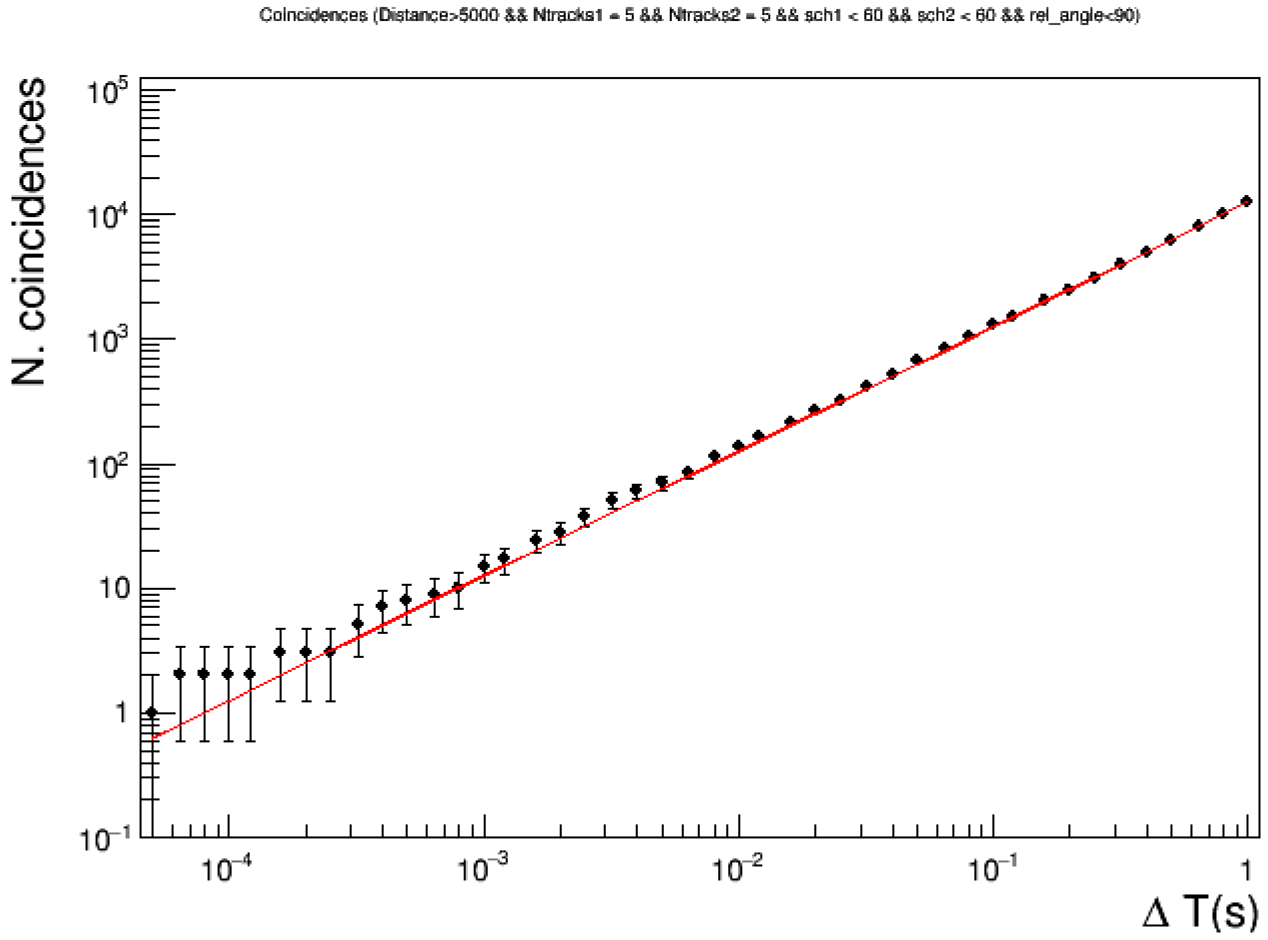
Additional checks

- **Optimization of cuts on the number of tracks**
  - Coincidence excess less evident for cuts different from Ntracks>3
- **Average Ntracks similar for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-4 s)**
- **Analysis repeated for Ntracks1 = Ntracks2 = 4**



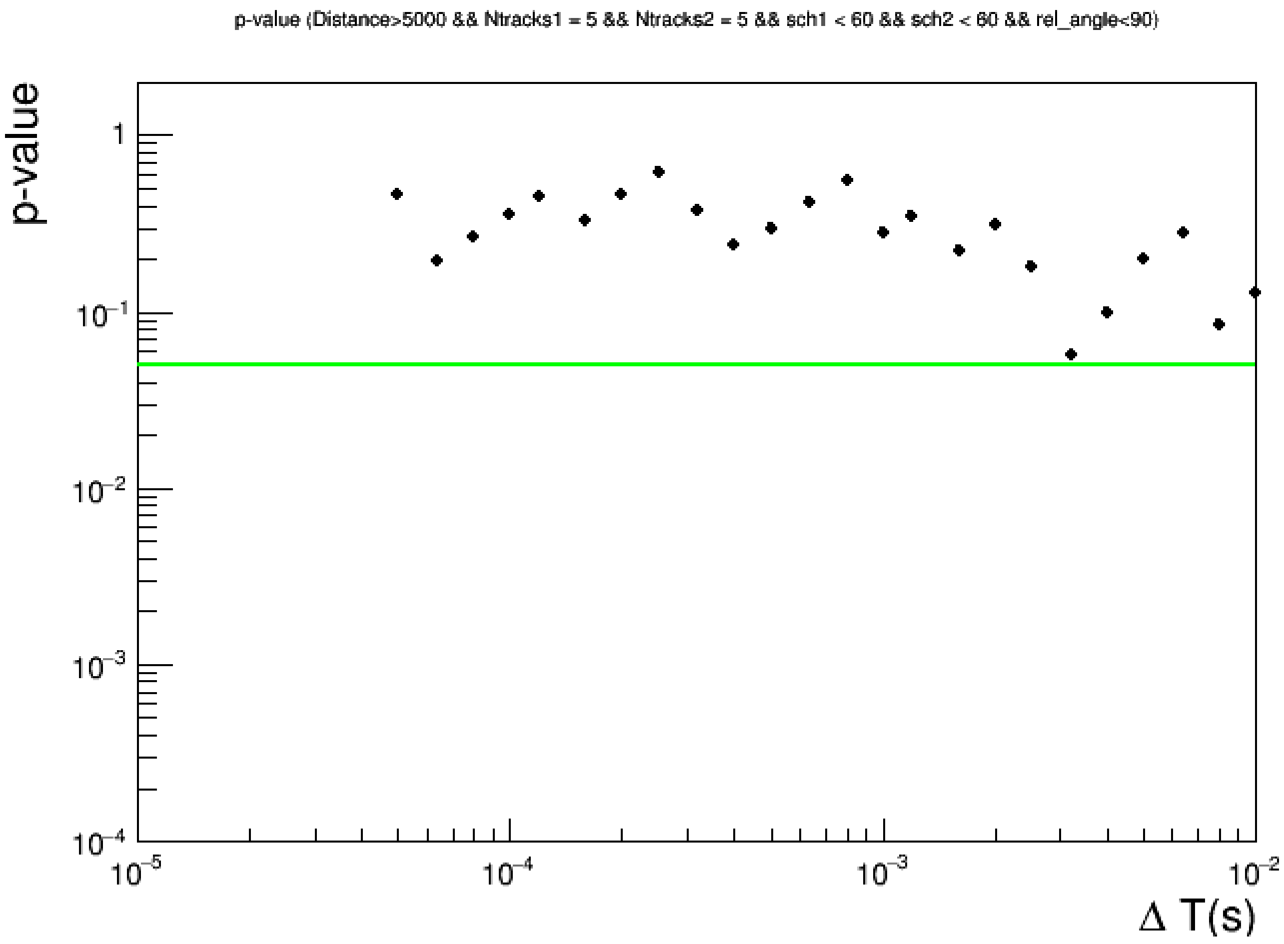
Additional checks

- **Optimization of cuts on the number of tracks**
    - Coincidence excess less evident for cuts different from Ntracks>3
- **Average Ntracks similar for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-4 s)**
- **Analysis repeated for Ntracks1 = Ntracks2 = 4**
- **Analysis repeated for Ntracks1 = Ntracks2 = 5**



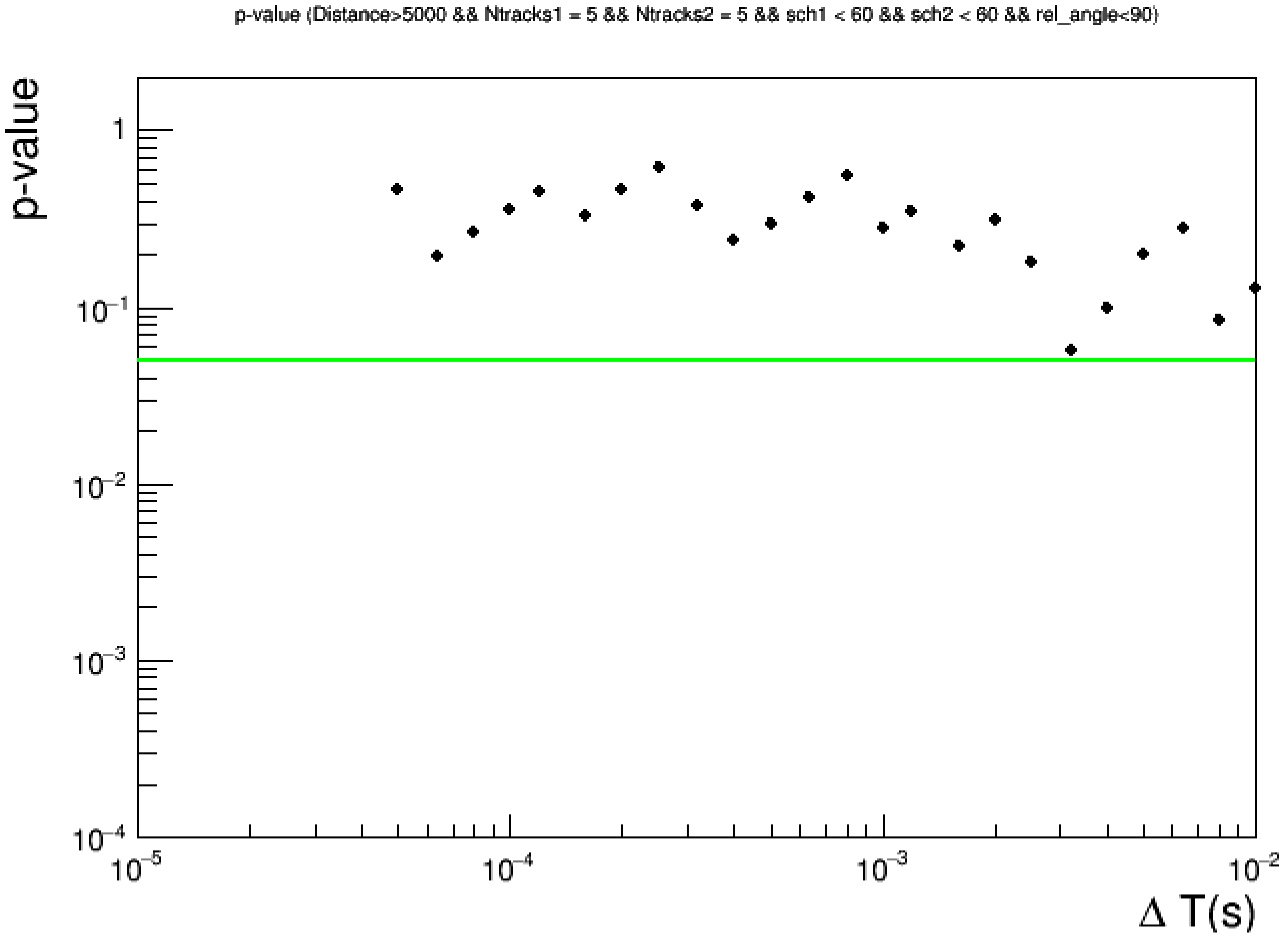
Additional checks

- **Optimization of cuts on the number of tracks**
  - Coincidence excess less evident for cuts different from Ntracks>3
- **Average Ntracks for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-4 s)**
- **Analysis repeated for Ntracks1 = Ntracks2 = 4**
- **Analysis repeated for Ntracks1 = Ntracks2 = 5**



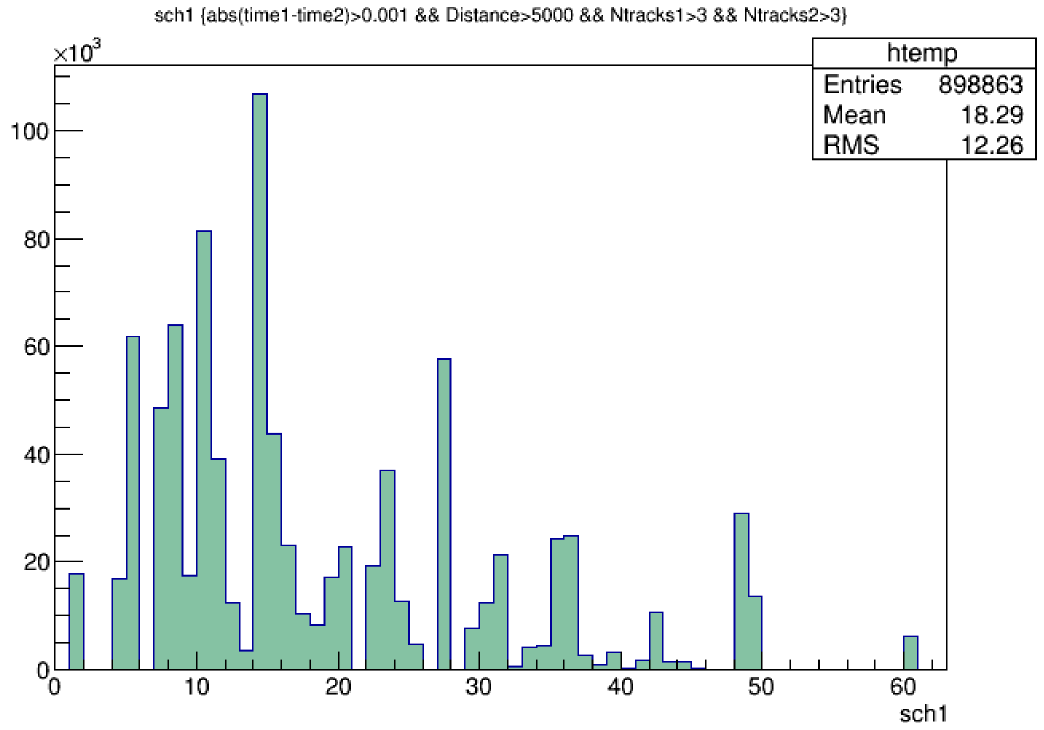
Additional checks

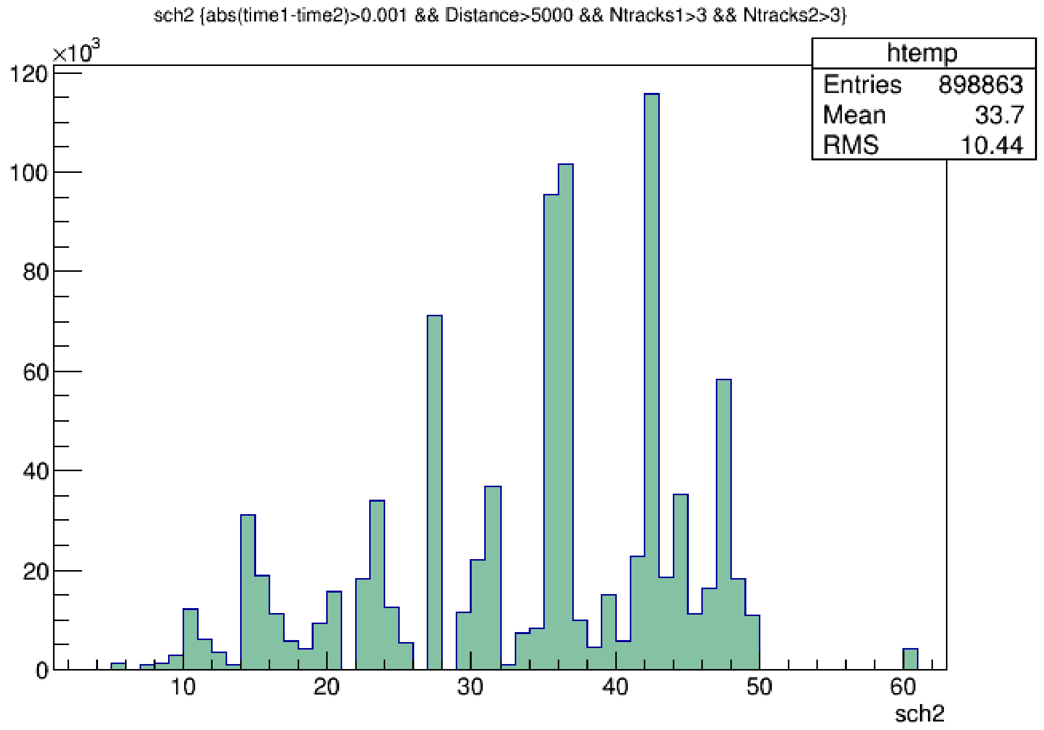
- **Optimization of cuts on the number of tracks**
  - Coincidence excess less evident for cuts different from Ntracks>3
- **Average Ntracks for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-4 s)**
- **Analysis repeated for Ntracks1 = Ntracks2 = 4**
- **Analysis repeated for Ntracks1 = Ntracks2 = 5**



Additional checks

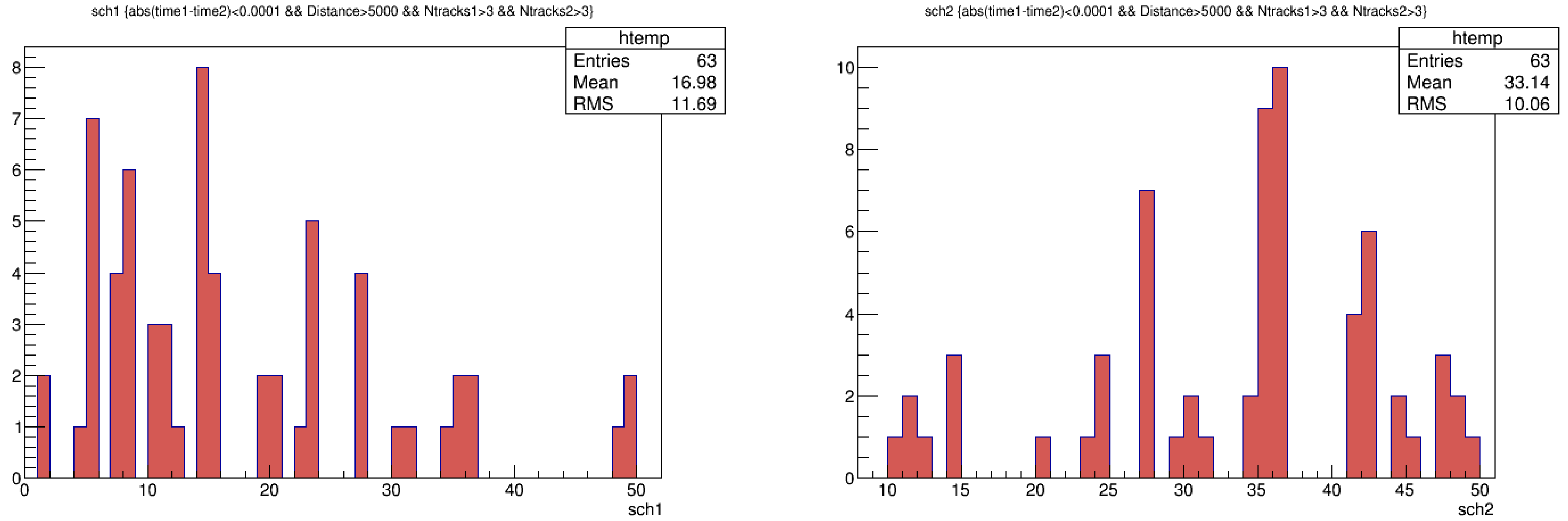
- **Site codes for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-3 s)**





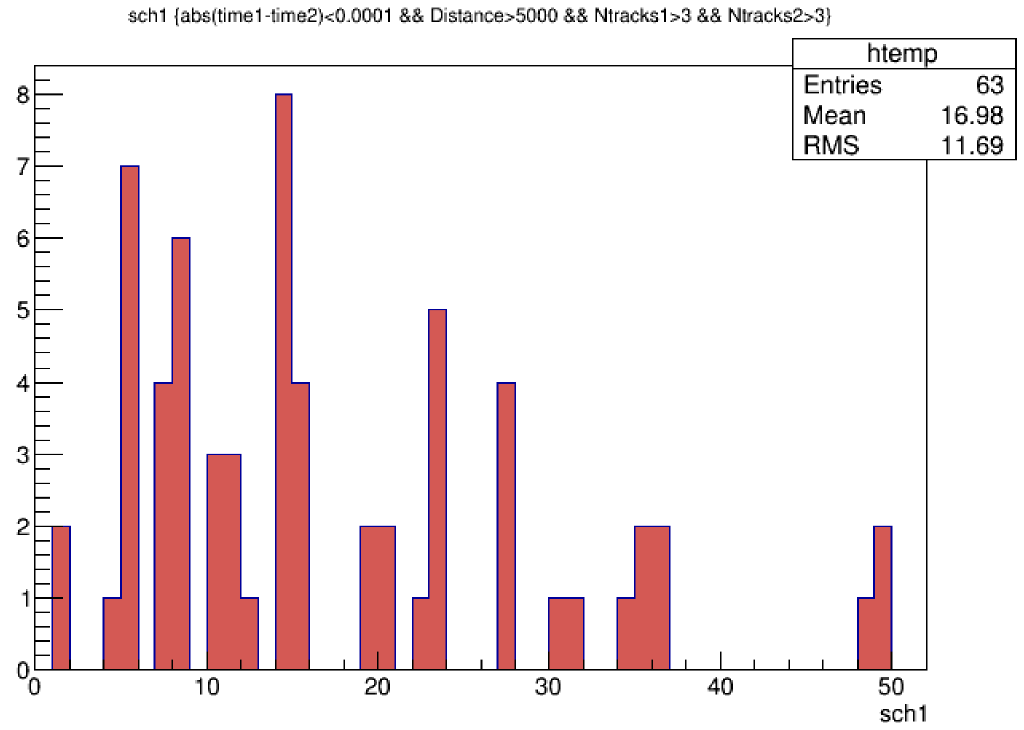
Additional checks

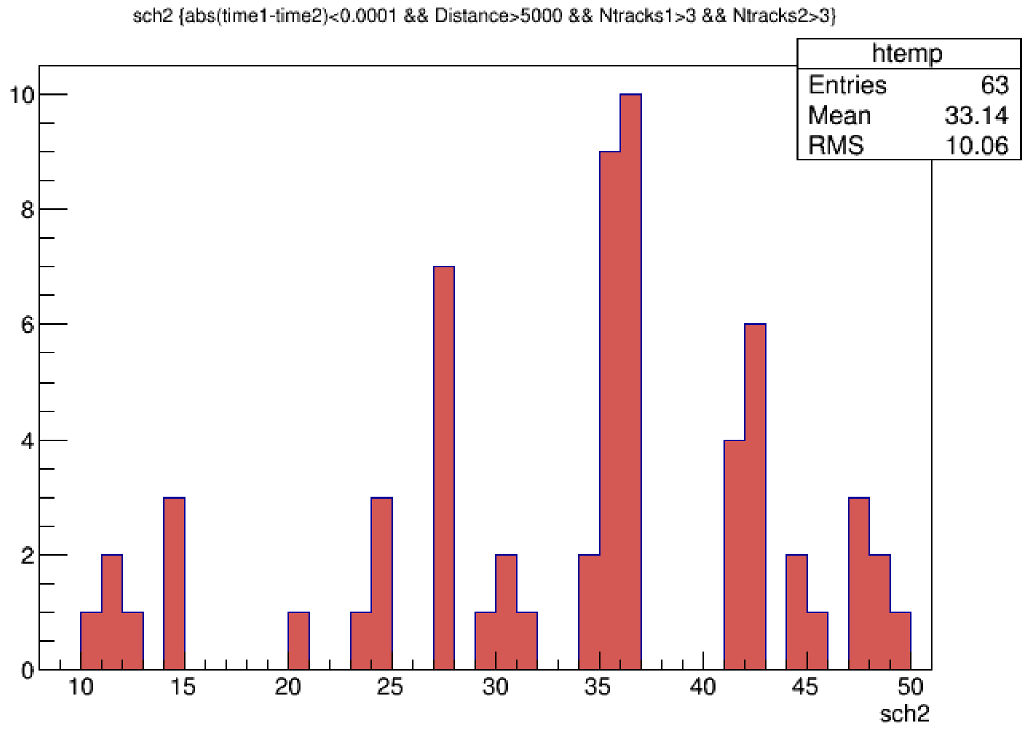
- **Site codes for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-3 s)**



Additional checks

- **Site codes for candidates (abs(DeltaT) < 1E-4 s) and background (abs(DeltaT) > 1E-3 s)**

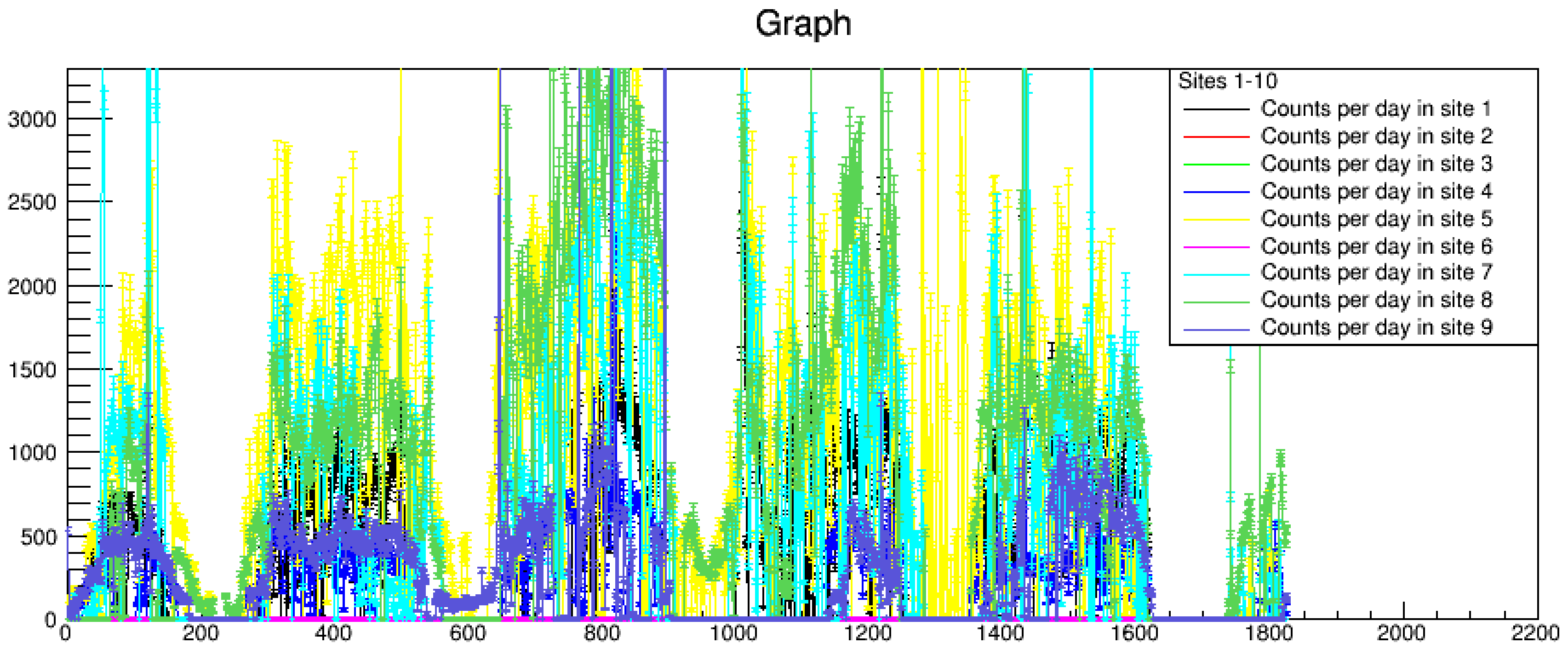




Conclusions: Some sites show a larger number of coincidences (due to higher single rate?)

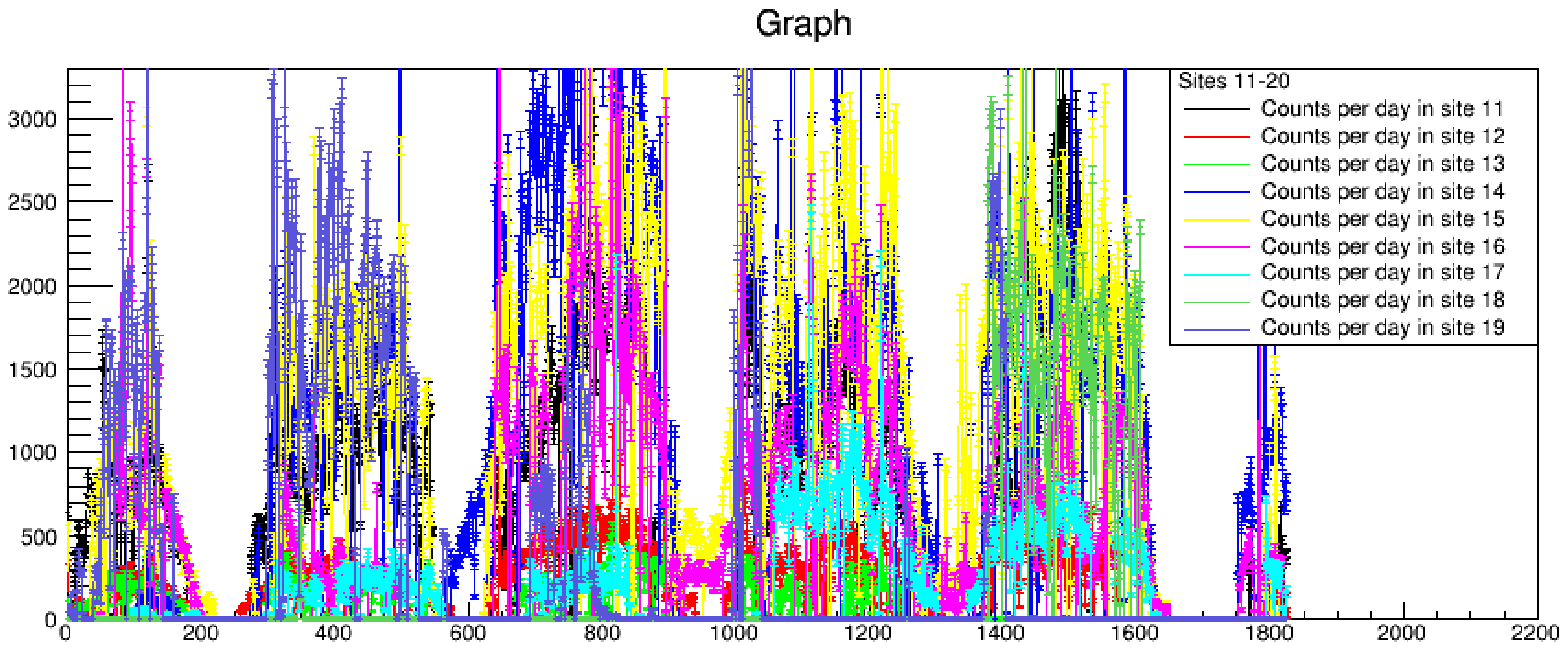
Additional checks

- **Daily number of coincidences (in $\pm$ 2 s) as a function of time for each site (1-9)**



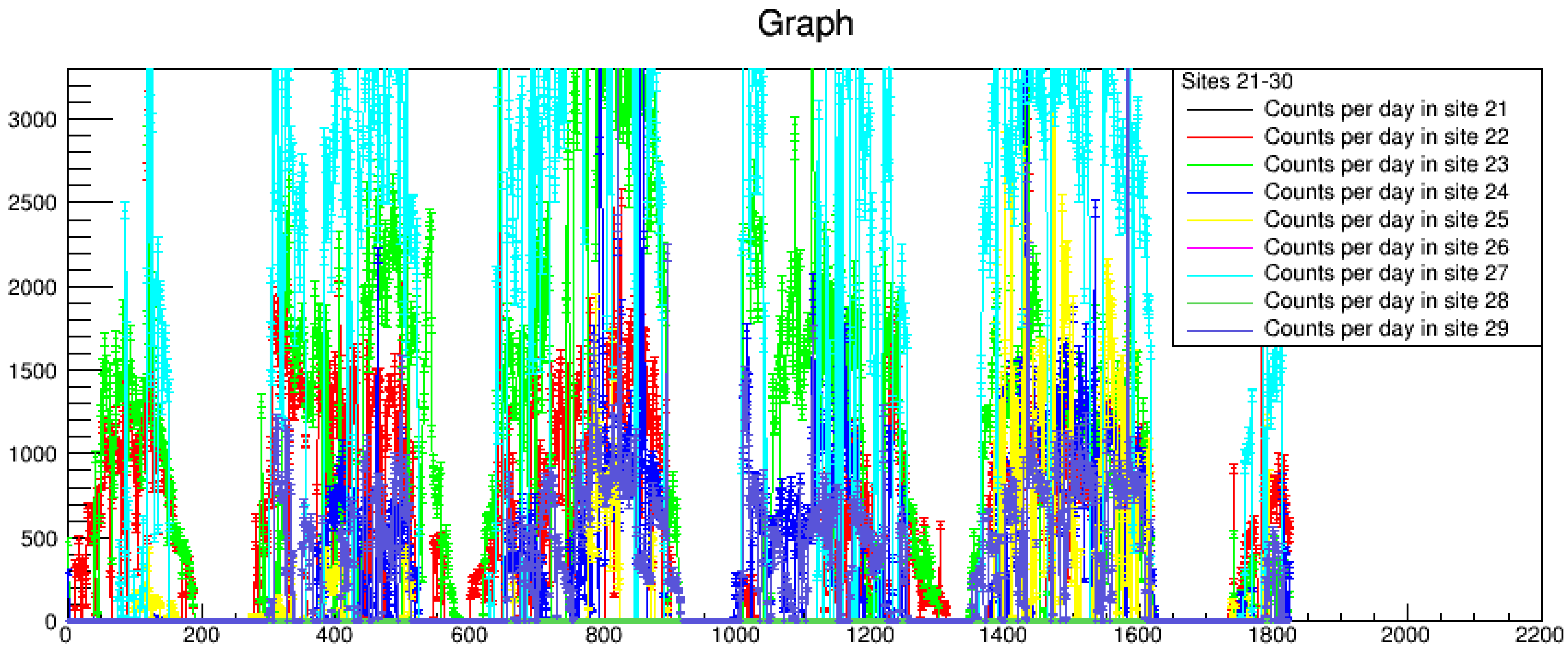
Additional checks

- **Daily number of coincidences (in ± 2 s) as a function of time for each site (11-19)**



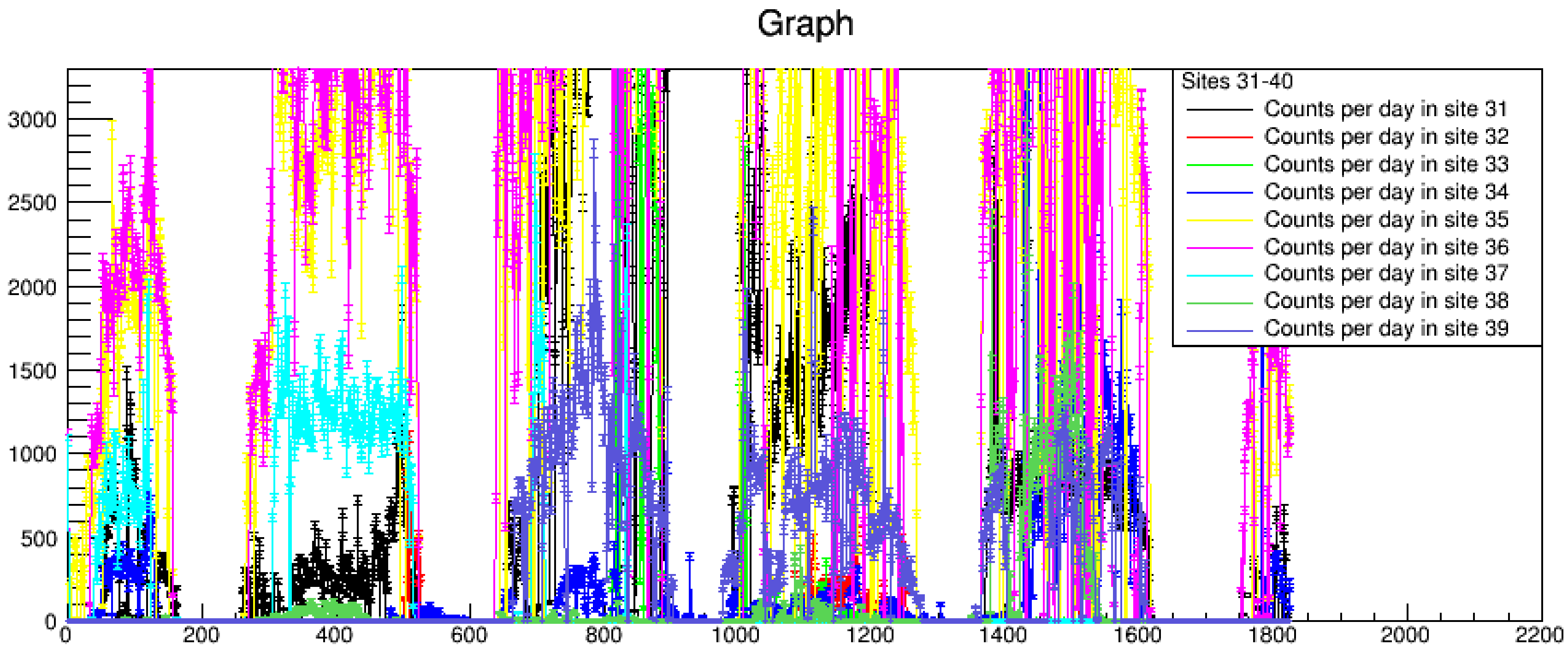
Additional checks

- **Daily number of coincidences (in $\pm$ 2 s) as a function of time for each site (21-29)**



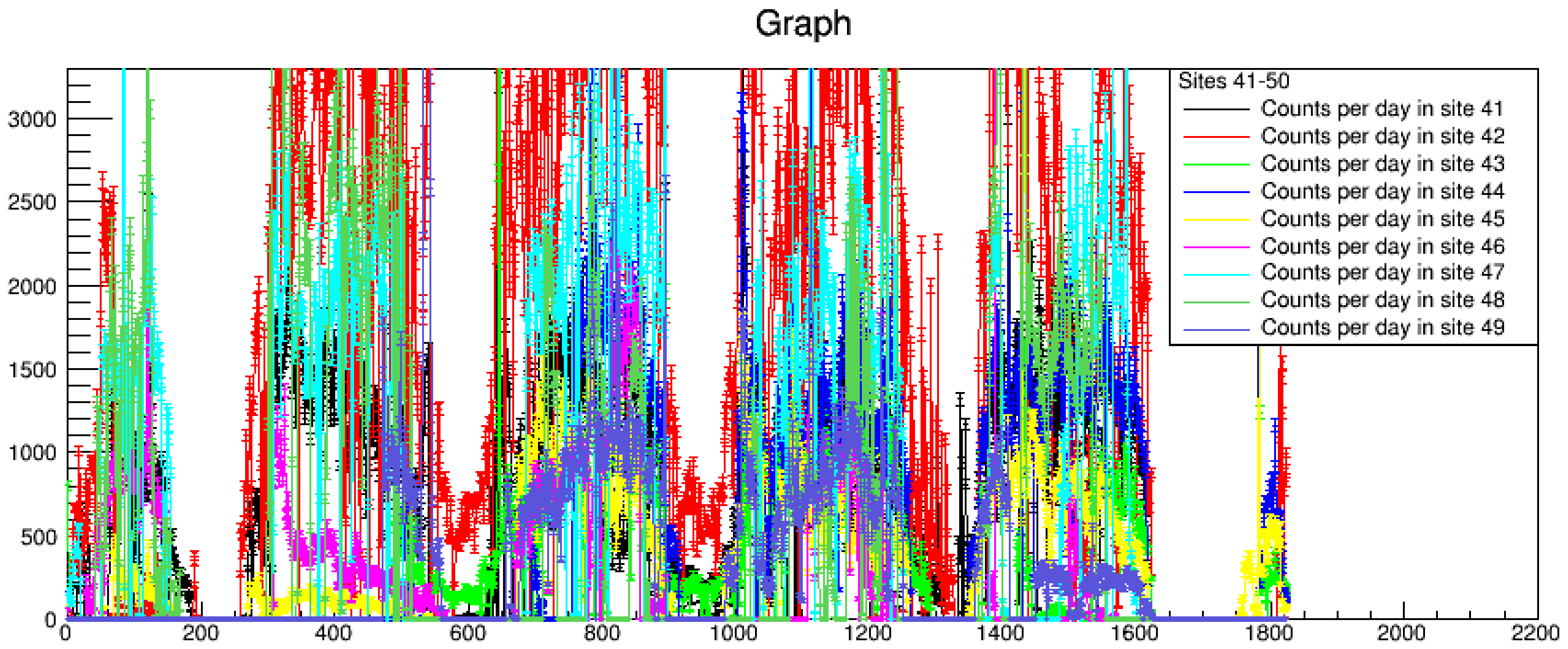
Additional checks

- **Daily number of coincidences (in ± 2 s) as a function of time for each site (31-39)**



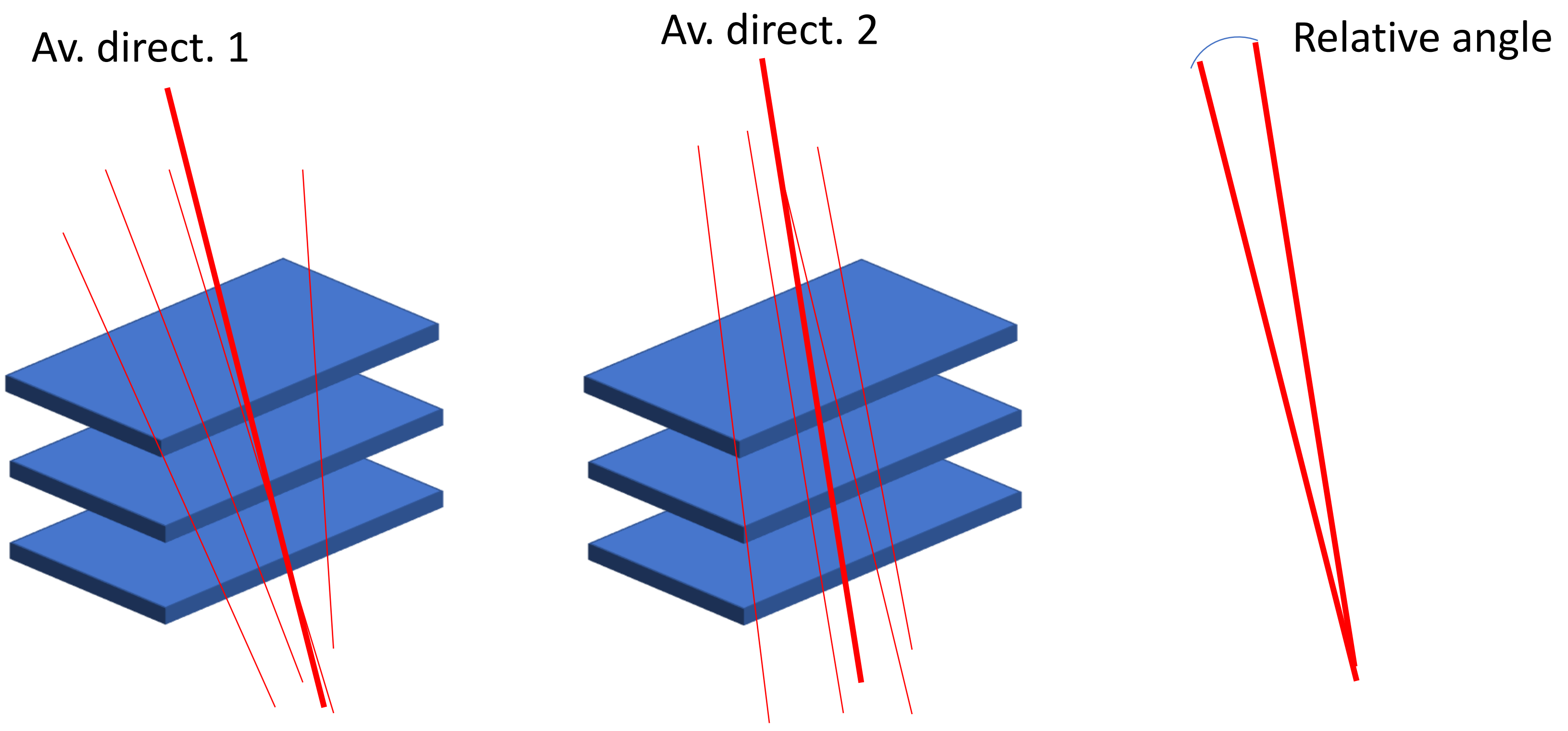
Additional checks

- **Daily number of coincidences (in ± 2 s) as a function of time for each site (41-49)**



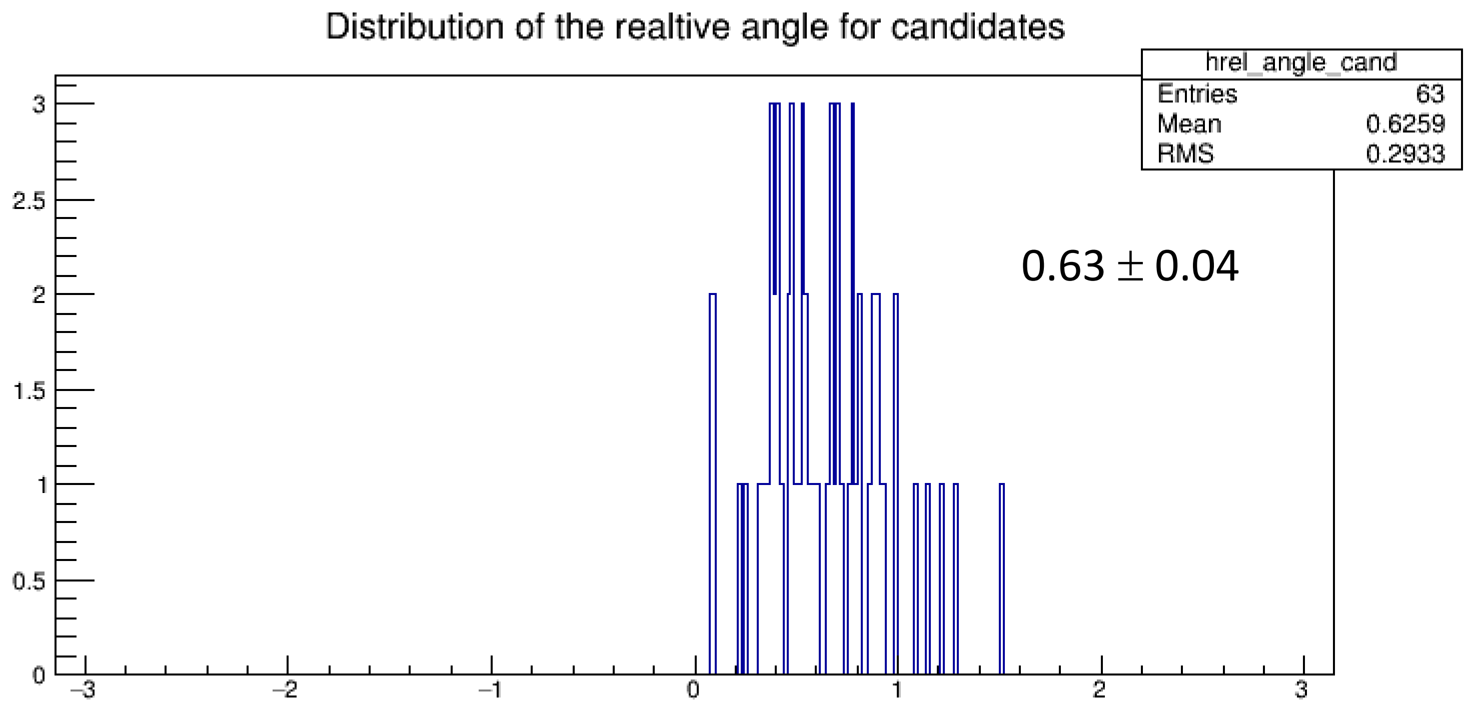
Additional checks

- **Cut on the relative angle between the average directions reconstructed in each site**



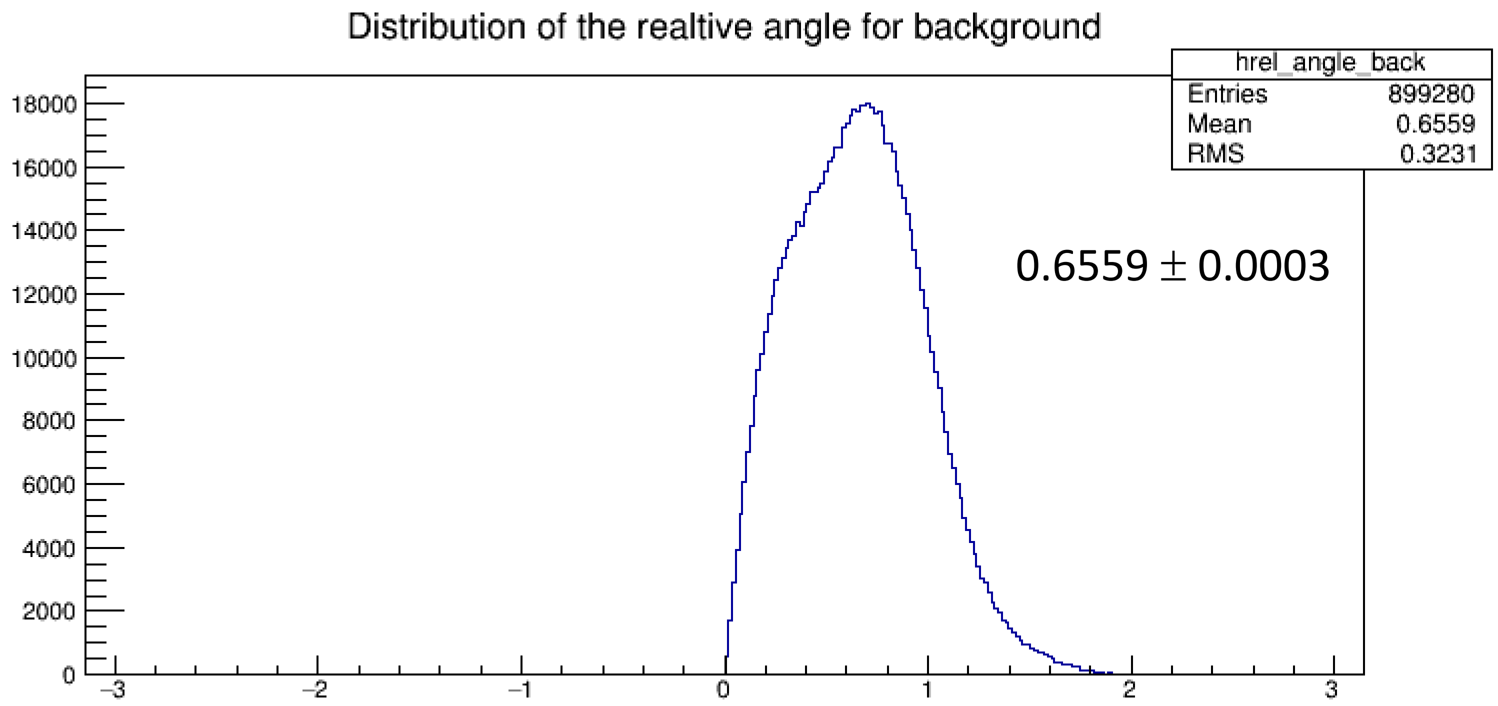
Additional checks

- **Distribution of the relative angle between the average directions reconstructed in each site for candidates**



Additional checks

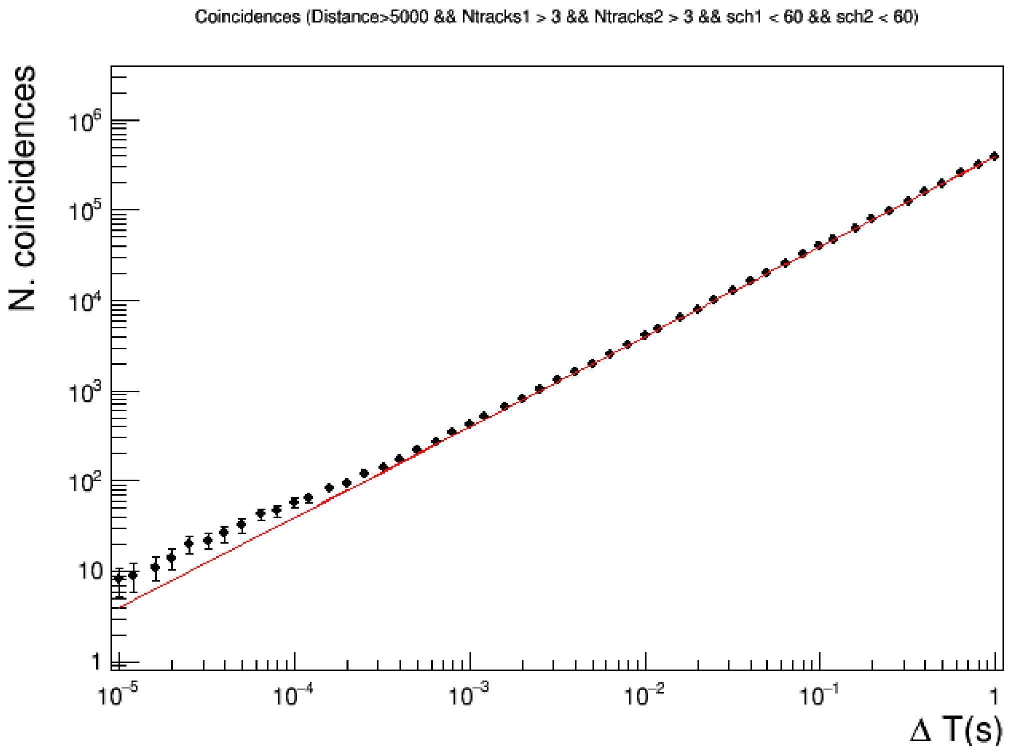
- **Distribution of the relative angle between the average directions reconstructed in each site for background**



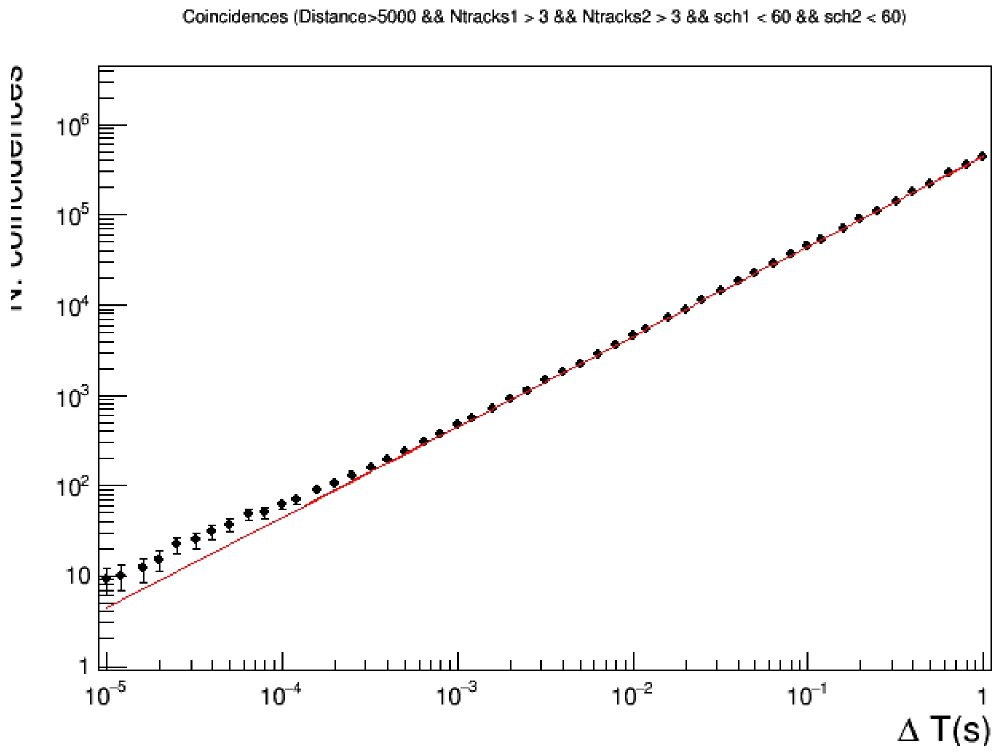
Additional checks

- **Cut on the relative angle between the average directions reconstructed in each site**

Relative angle < 60°



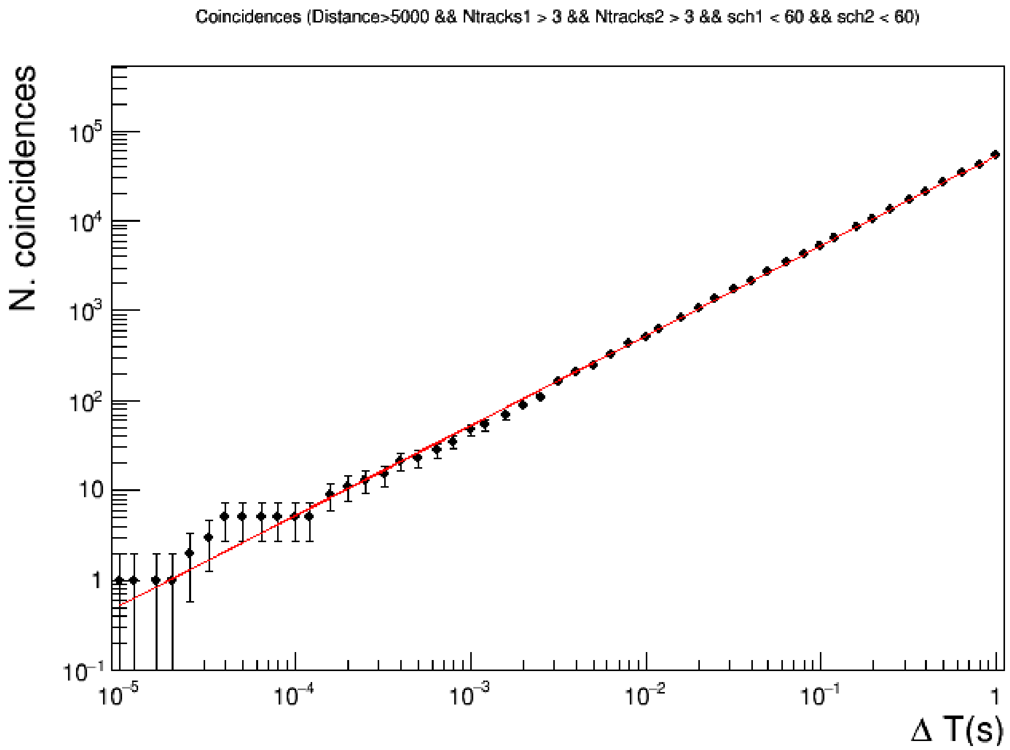
Relative angle < 90°



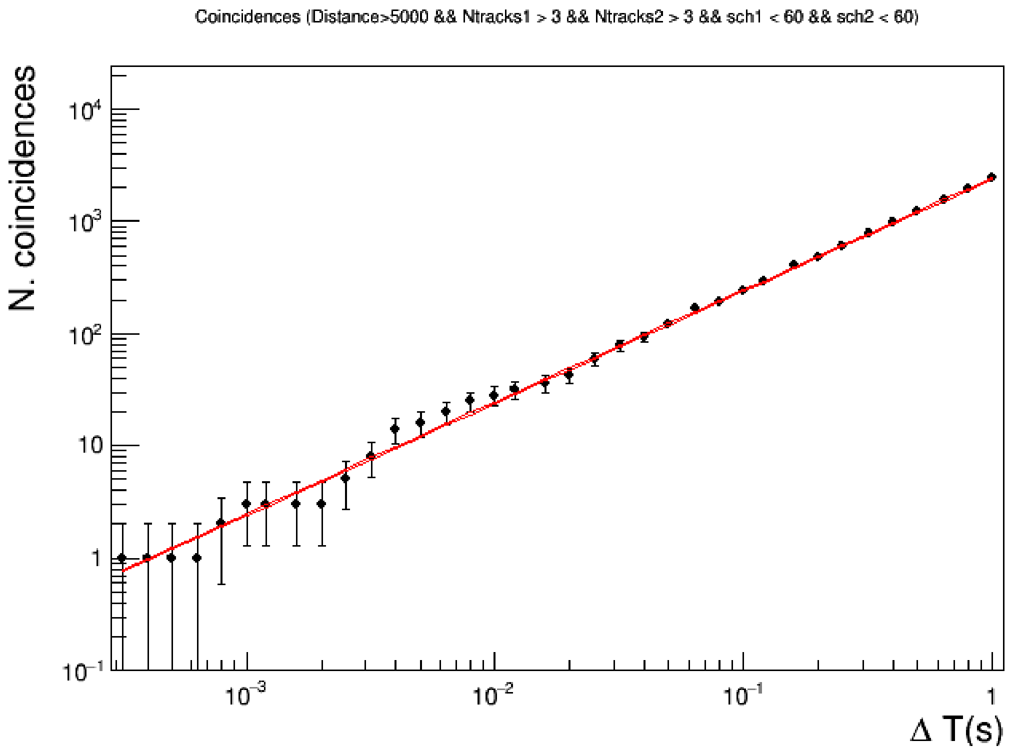
Additional checks

- **Cut on the relative angle between the average directions reconstructed in each site**

Relative angle > 60°



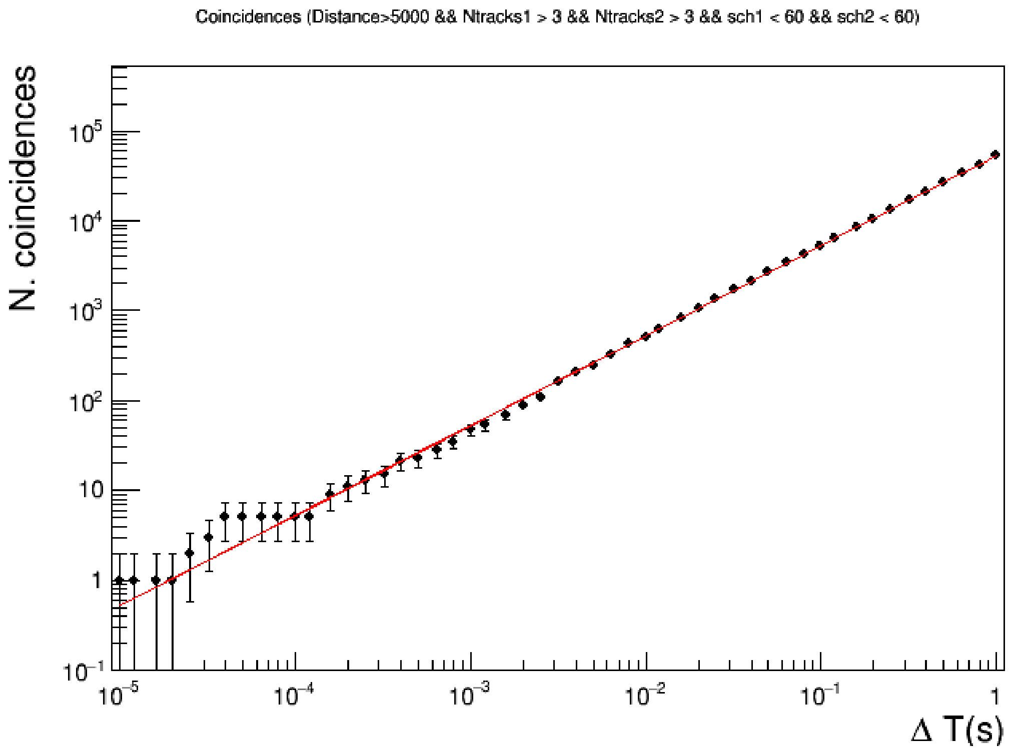
Relative angle > 90°



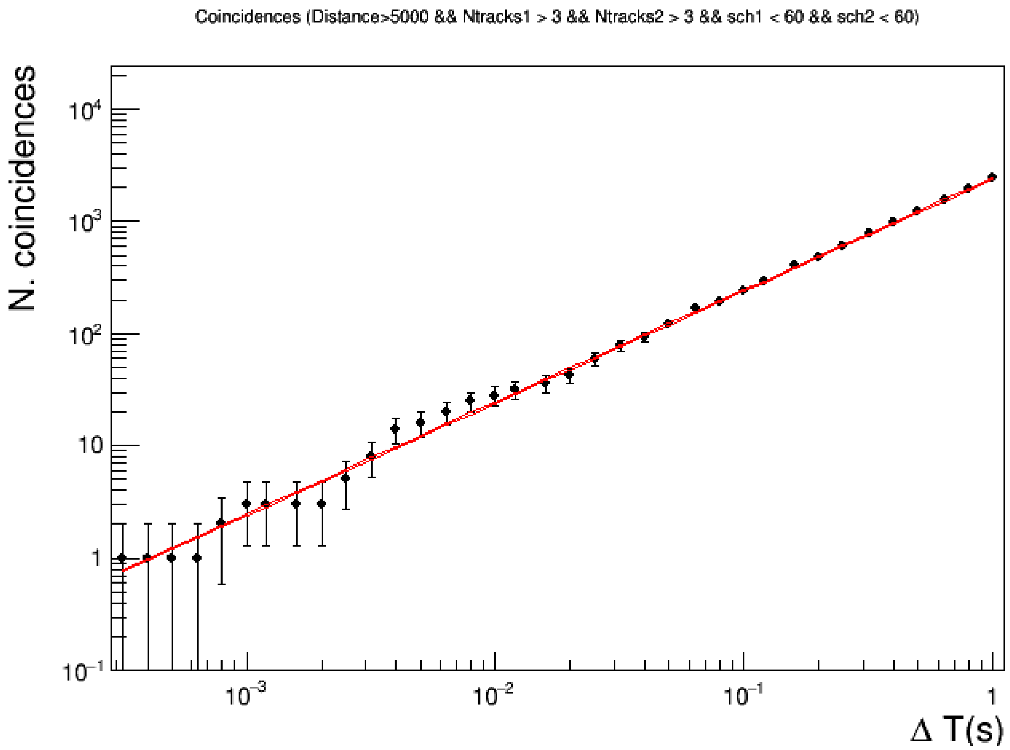
Additional checks

- **Cut on the relative angle between the average directions reconstructed in each site**

Relative angle > 60°



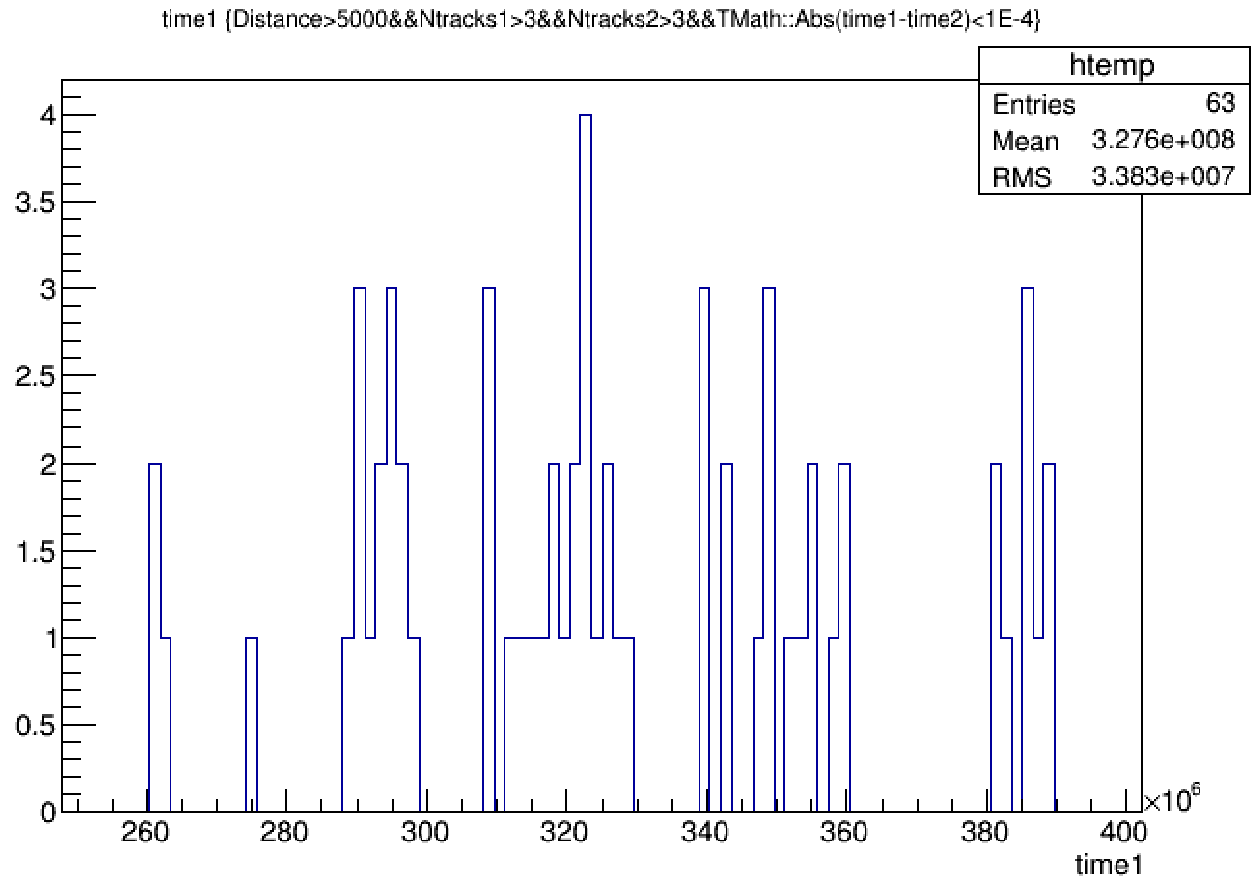
Relative angle > 90°



Conclusions: Events with larger relative angles are more likely related to background

Additional checks

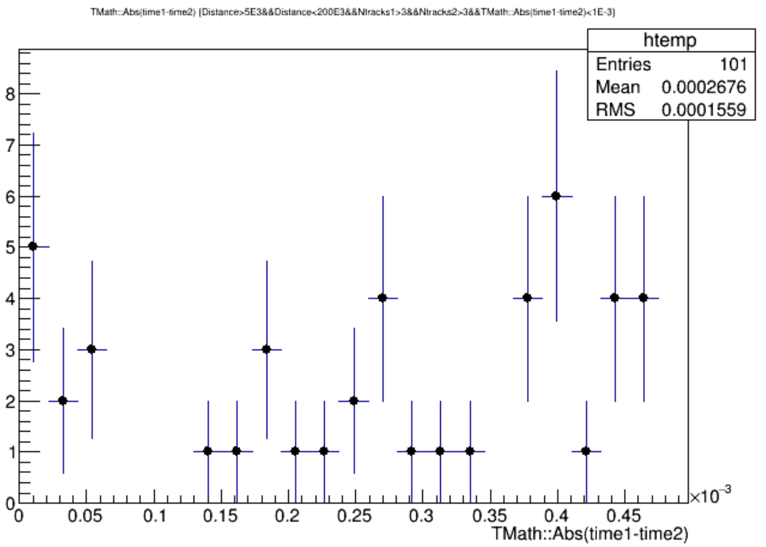
- **Time occurrence of candidate events looks almost uniform**



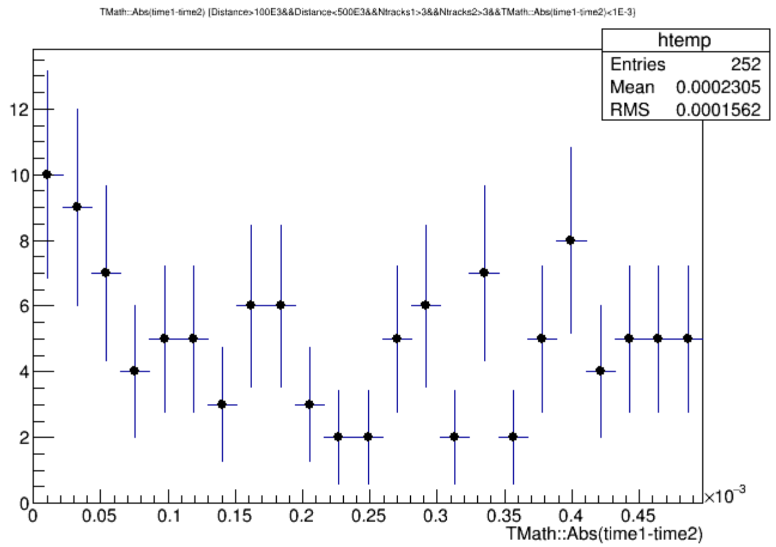
Additional checks

- **Cut on distance between sites**

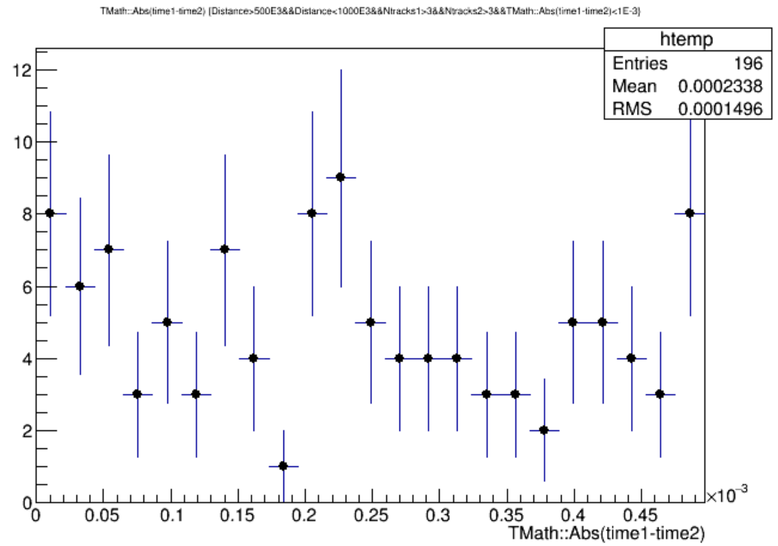
Distance 5 km - 200 km



Distance 100 km - 500 km



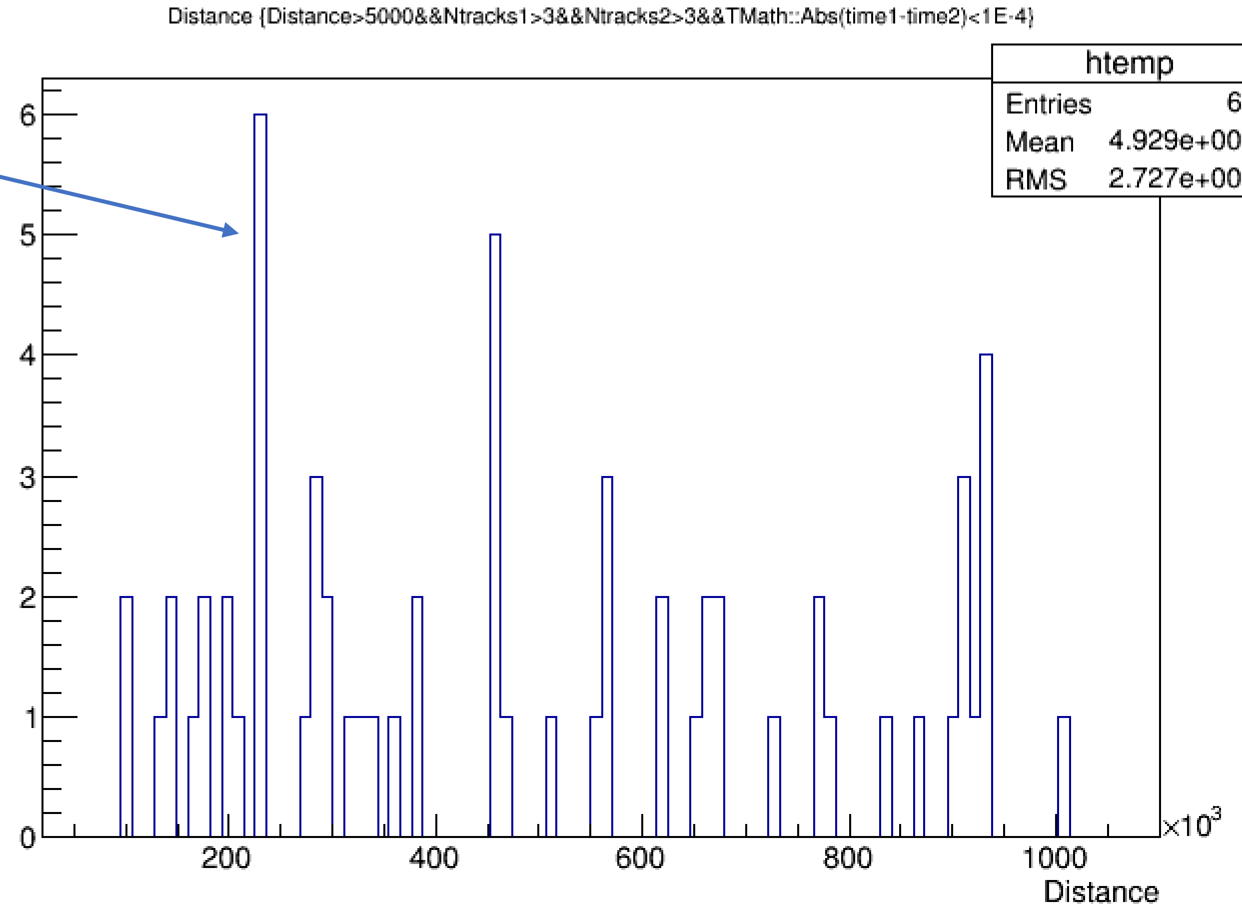
Distance 500 km - 1000 km



Additional checks

- **Distribution of the distance between sites for candidate events**

BOLO-01 – SAV0-01 (x2)
BOLO-01 – SAVO-02
BOLO-03 – SAVO-02
BOLO-04 – SAV0-01
BOLO-04 – SAVO-02
but different time occurance!



Additional checks

- Similar distributions of the average chi2 for candidate events and background
- Similar distributions of the SumScalarProducts for candidate events and background

Outlook

- **Investigation of the characteristics of the candidate events** (in terms of sites involved, site distance, time occurrence, relative angle, ntracks, chi2 of the tracks…)
- **Alternative approaches for the background estimation** (taking into account only those sites that detect candidate events)