T0 online algorithm using TOF counters

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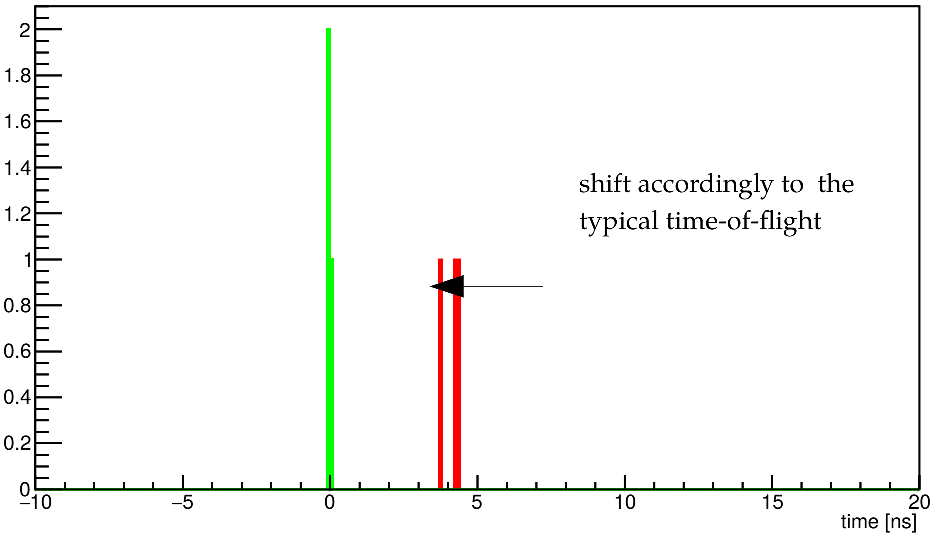
Motivation

- Decent time information of pbar annihilation with target (=t0) is necessary
  - for TOF, PID, pattern recognition, event sorting, ..
- T0 is needed online even with a limited precision for an event selection
- TOF counters (SciTil and FTOF) have the best time resolutions hence they have a high potential to play an indispensable role to deduce (online) t0.

Basic principle

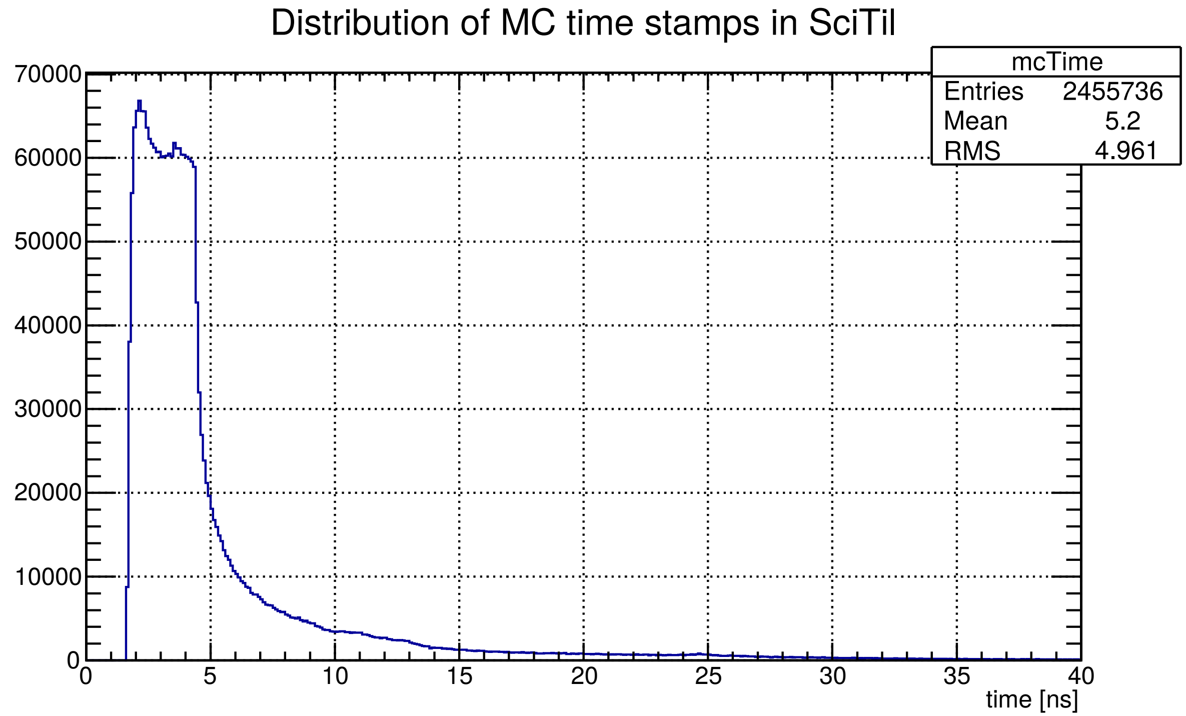
- For calculation of t0 it needs:
  - tracking information, PID, mass and momentum
- Assuming average values
  - Δt0 ~ 1 ns
- Calculating t0 using the most typical path length and momentum is equivalent to shifting the time stamp distribution by a typical time-of-flight to t0.
  - SciTil
    - Flight path ~ 0.5 - 1.5 m
    - Flight time ~ 2 - 6 ns



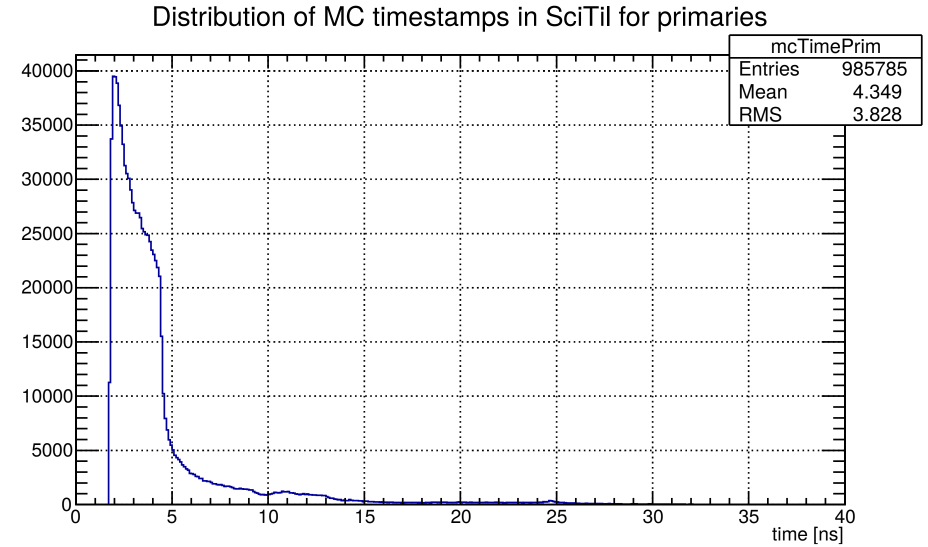
We study the potential performance of the online t0 calculation using TOF counter, also taking into account the influence of secondary particles

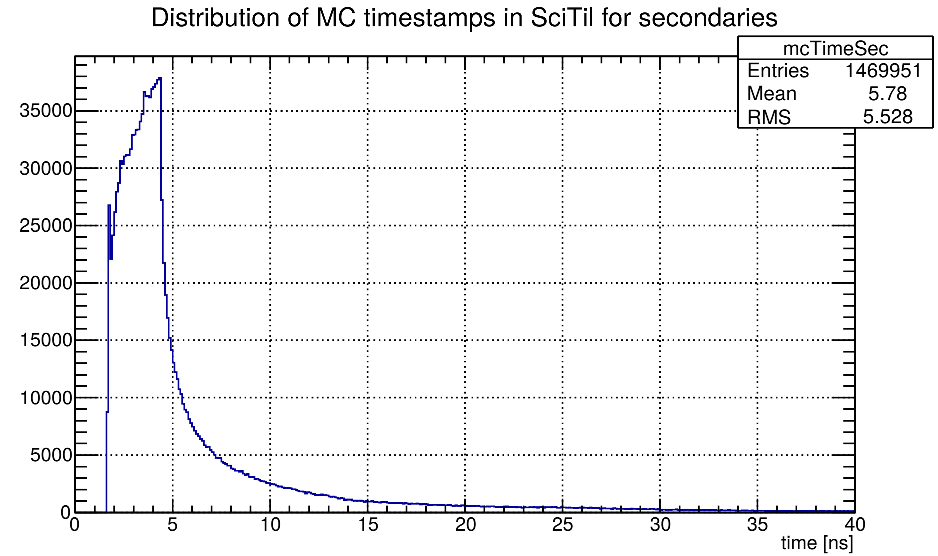
Time stamp distribution of SciTil

- For this study the MC data were generated using
  - Pandaroot, trunk 28975
  - DPM generator (beam momentum = 6.2 GeV/c)
  - Full geometry
- The right sided plot shows the distribution of the MC time stamps in the SciTil
  - Mean = 5.2 ns, σ = 5.0 ns, FWHM = 2.9 ns
  - 80% of the time stamps are located in the interval from 1.8 to 6 ns
  - Slow primaries and secondaries cause a long tail down to > 30 ns



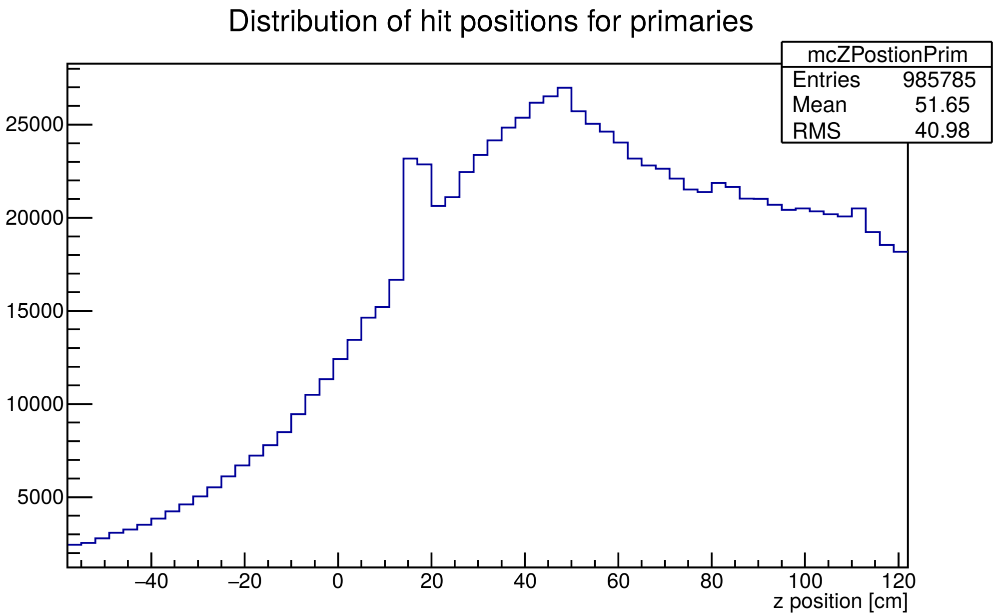
Time stamp distribution of primaries and secondaries

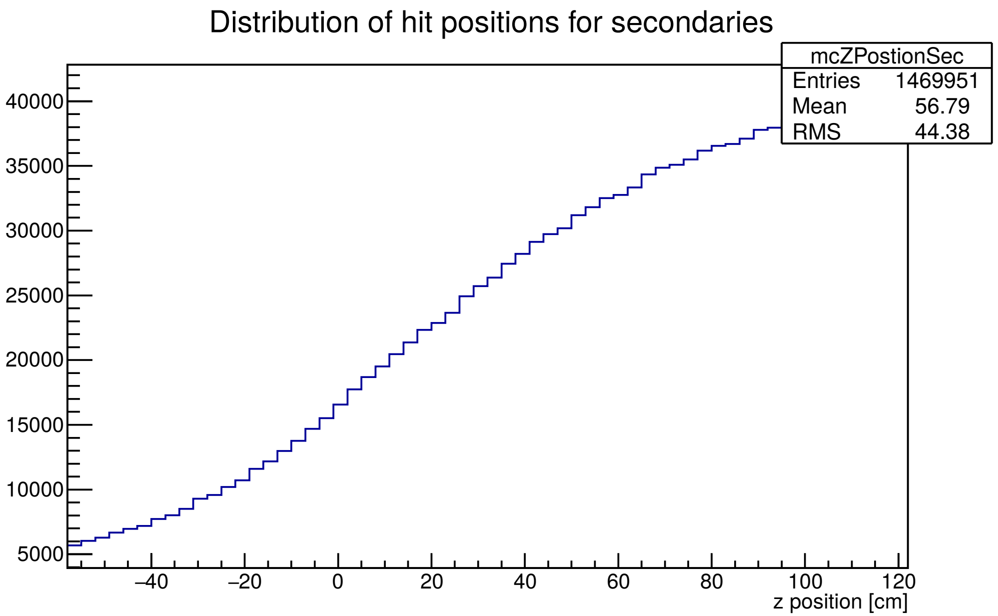




- Time stamp distribution for primary particles
  - Mean = 4.3 ns, σ = 3.8 ns, FWHM = 2.6 ns
  - Slow primaries also cause a long tail
- Time stamp distribution for secondary particles
  - Mean = 5.8 ns, σ = 5.5 ns, FWHM = 3.0 ns
  - ~ 50 % more secondaries then pimaries due to the tail
  - Nevertheless the dominant part of the secondaries is also located at 1.7 – 6 ns
- Secondary particles will be useful rather then disturbing for t0 calculation
  - Major part are “fast secondaries”
  - Provide a higher statistic per event

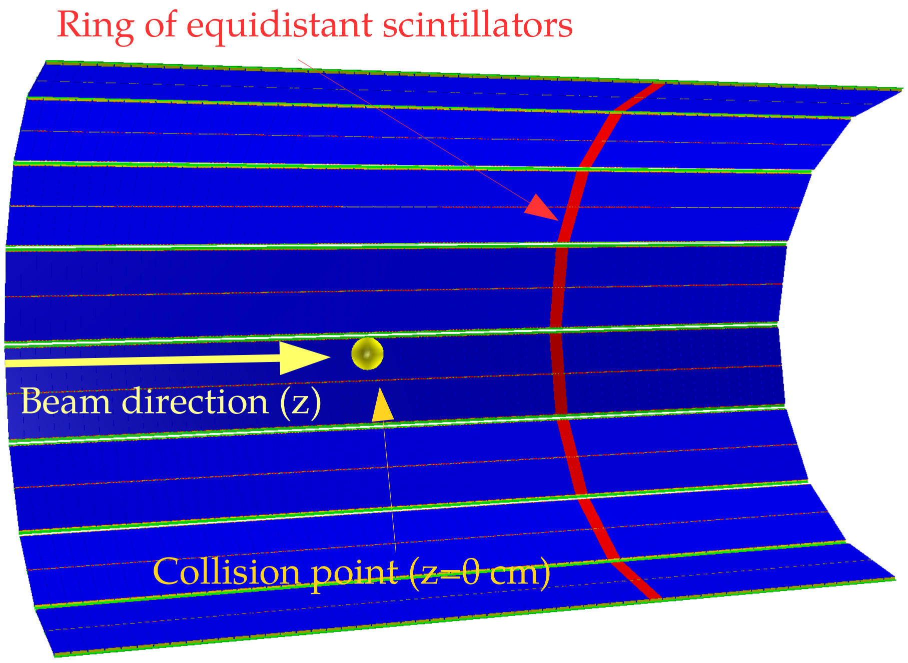
- The difference in the time stamp distribution originates in the different hit position distribution of the particle types.
- Secondaries have a higher probability to hit a SciTil tile located in a more forward position.





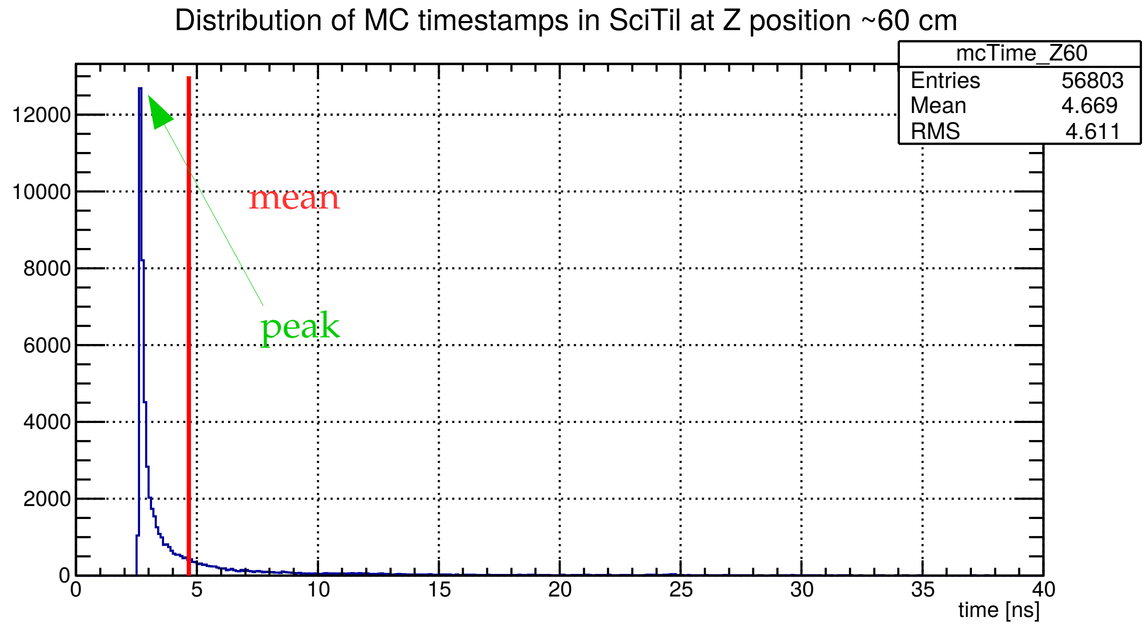
Time stamp distribution for equidistant tiles

- Typical time-of-flight is correlated with the production theta angle at the collision point
  - corrected shift on the time stamps respective to z-position of the hit
- Evaluate the typical time-of-flight for every z-position
  - Detector is sliced into 60 rings of equidistant scintillating tiles
  - The time stamp distribution for every ring was simulated to receive the typical time of flight

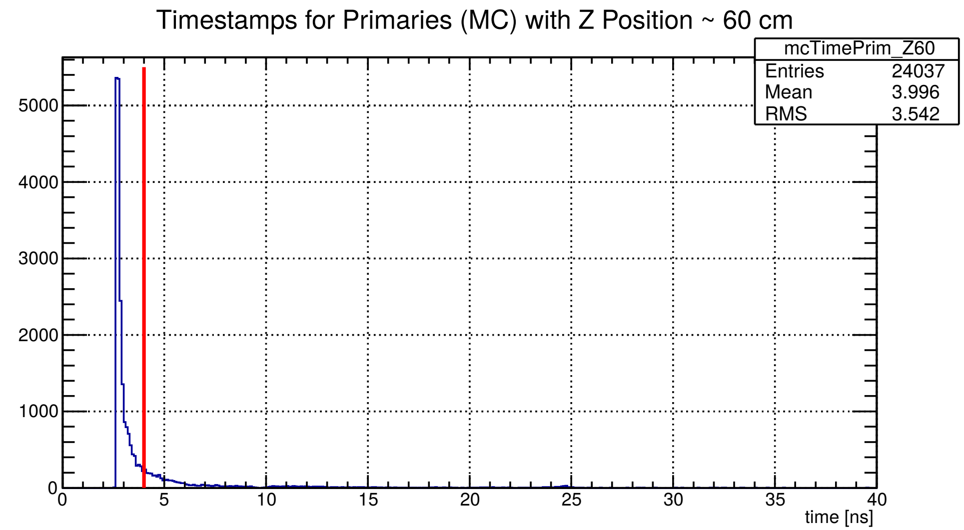


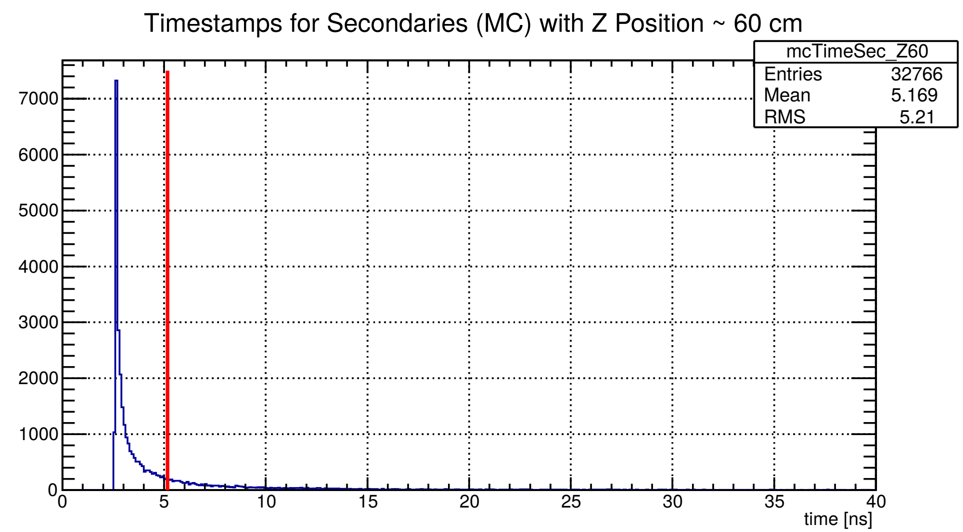
Time stamp distribution for equidistant tiles

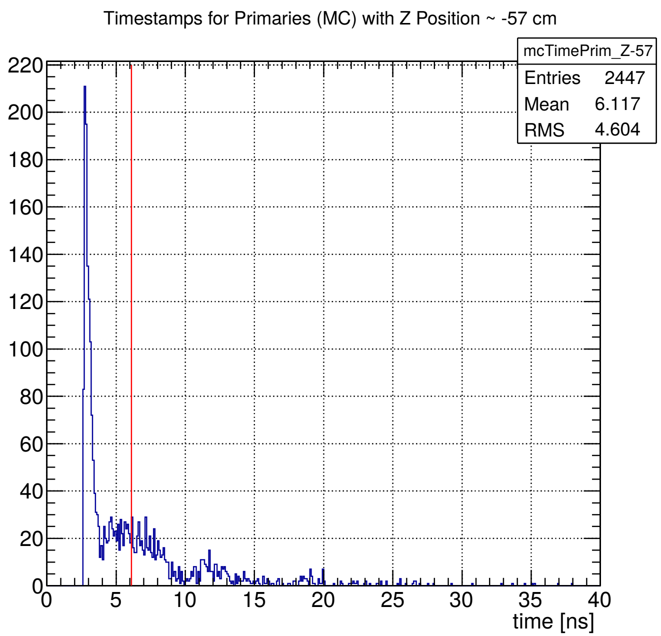
- Typical distribution for an equidistant ring
  - Mean = 4.7 ns, Peak = 2.6 ns
  - σ = 4.6 ns, FWHM = 0.3 ns
- For the T0 calculation subtract a defined value from the time stamp accordingly to this z position
  - Mean, Peak position

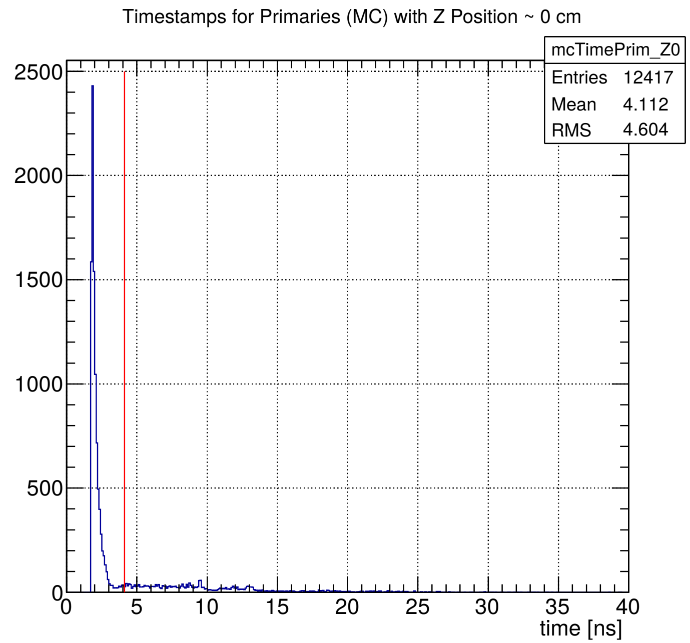


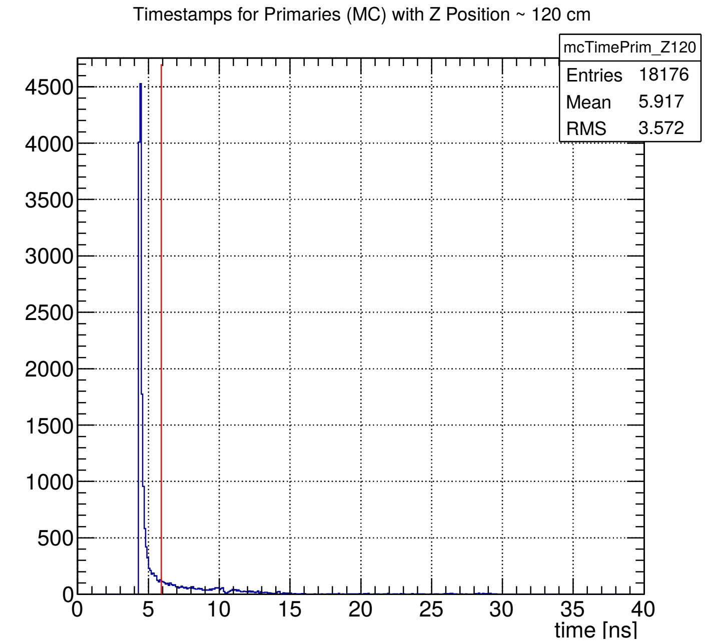
- Primaries
  - Mean = 4.0 ns, Peak = 2.6 ns
  - σ = 3.5 ns, FWHM = 0.2 ns
- Secondaries
  - Mean = 5.2 ns, Peak = 2.6 ns
  - σ = 5.2 ns, FWHM = 0.2 ns
- Identical Peak positions
- The secondary distribution is influenced by a higher amount of slow particles
  - The majority of the particles is fast and can support an t0 algorithm

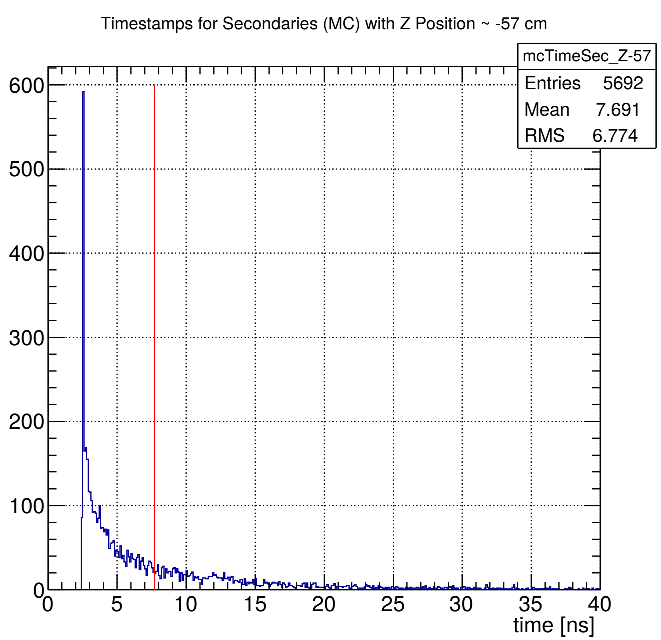


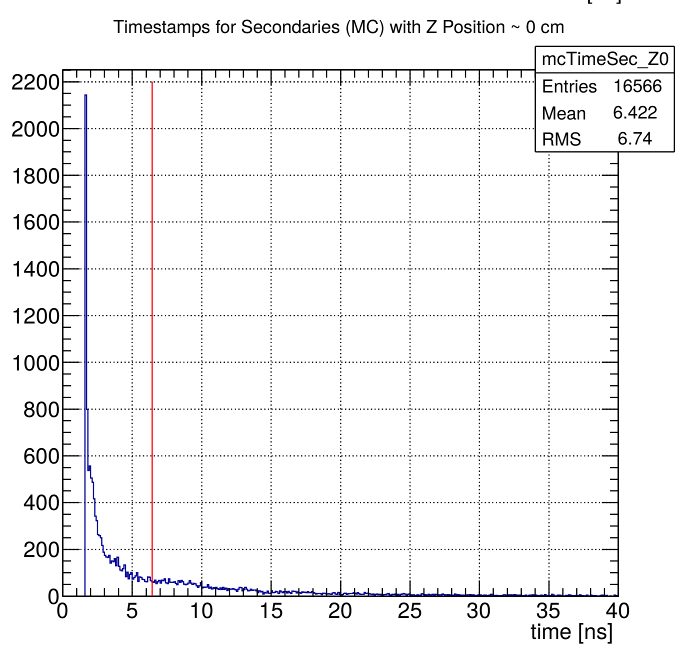


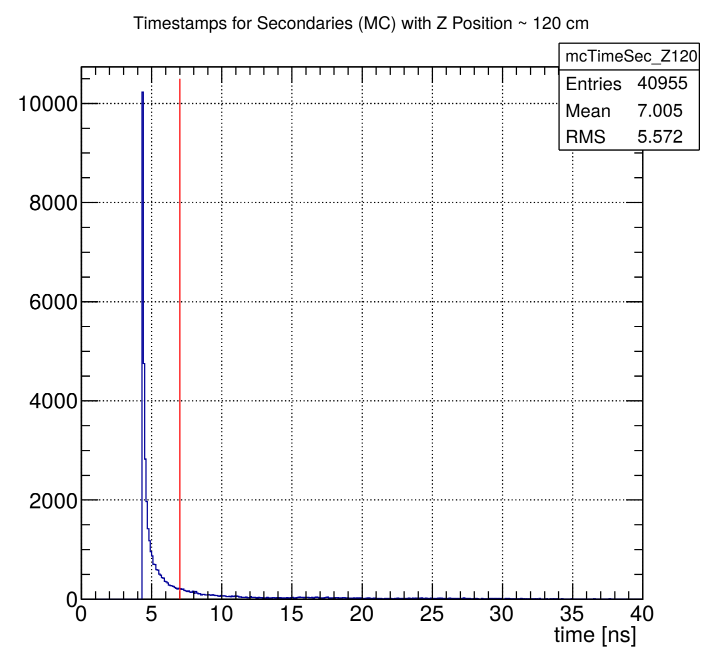

Timestamps for Primaries (MC) with Z Position ~ -57 cm
mcTimePrim_Z-57
Entries 2447
Mean 6.117
RMS 4.604
time [ns]


Timestamps for Primaries (MC) with Z Position ~ 0 cm
mcTimePrim_Z0
Entries 12417
Mean 4.112
RMS 4.604
time [ns]


Timestamps for Primaries (MC) with Z Position ~ 120 cm
mcTimePrim_Z120
Entries 18176
Mean 5.917
RMS 3.572
time [ns]

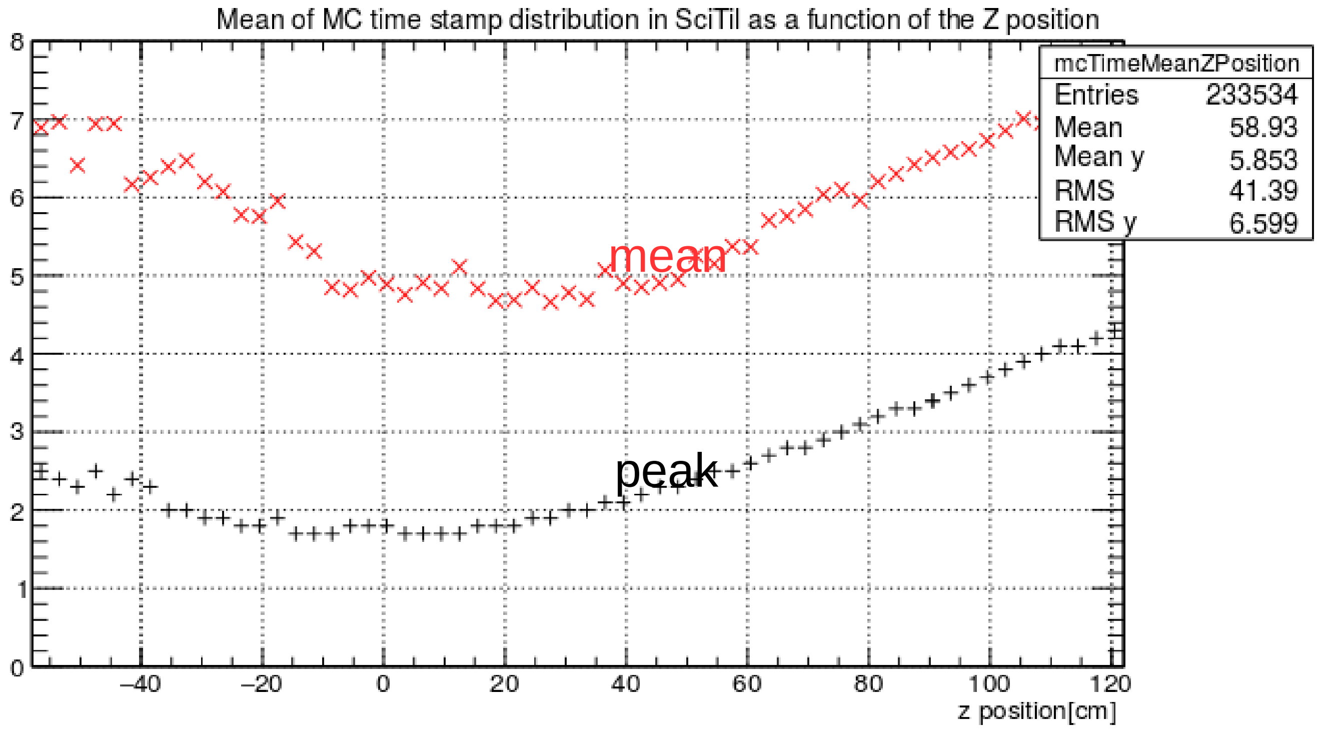

Timestamps for Secondaries (MC) with Z Position ~ -57 cm
mcTimeSec_Z-57
Entries 5692
Mean 7.691
RMS 6.774
time [ns]


Timestamps for Secondaries (MC) with Z Position ~ 0 cm
mcTimeSec_Z0
Entries 16566
Mean 6.422
RMS 6.74
time [ns]

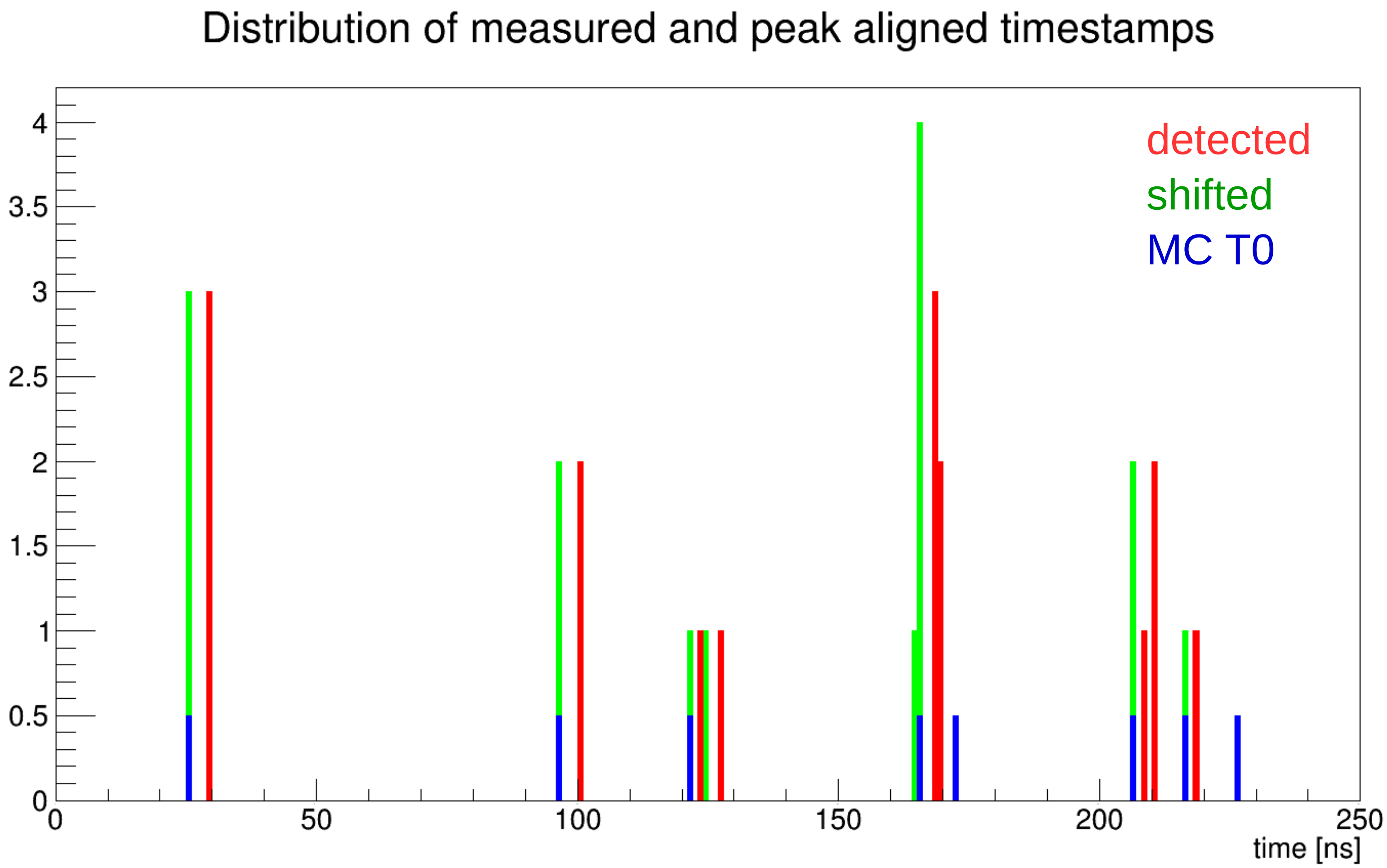

Timestamps for Secondaries (MC) with Z Position ~ 120 cm
mcTimeSec_Z120
Entries 40955
Mean 7.005
RMS 5.572
time [ns]

Time shift parameters

- Mean and peak position as a function of the z position
- The used value of central tendency must be chosen accordingly to the used algorithm to determine t0

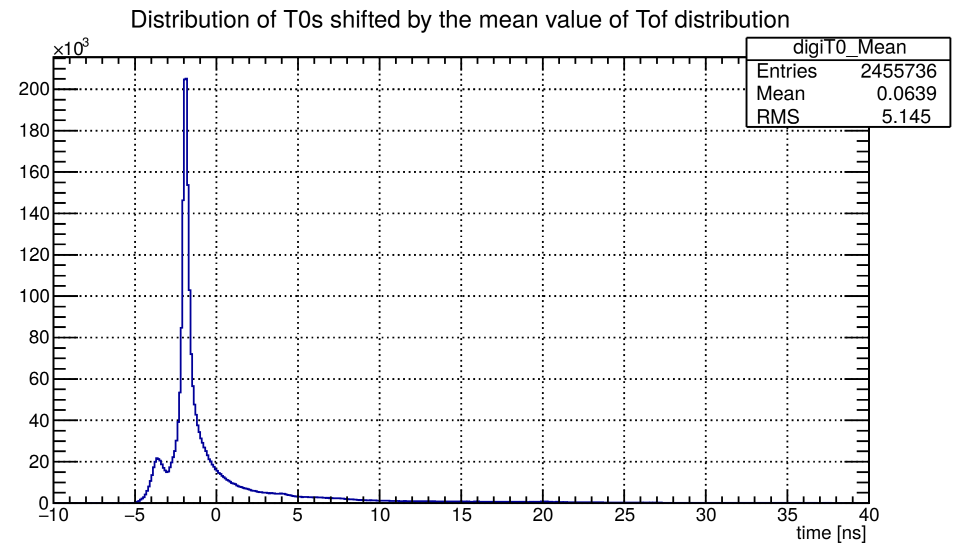


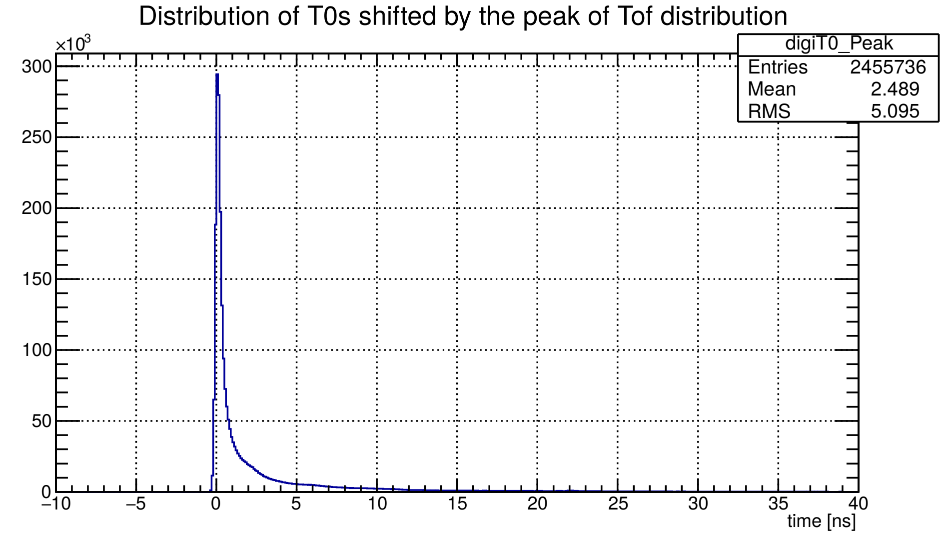
Time based simulation



Shifted time stamp distribution

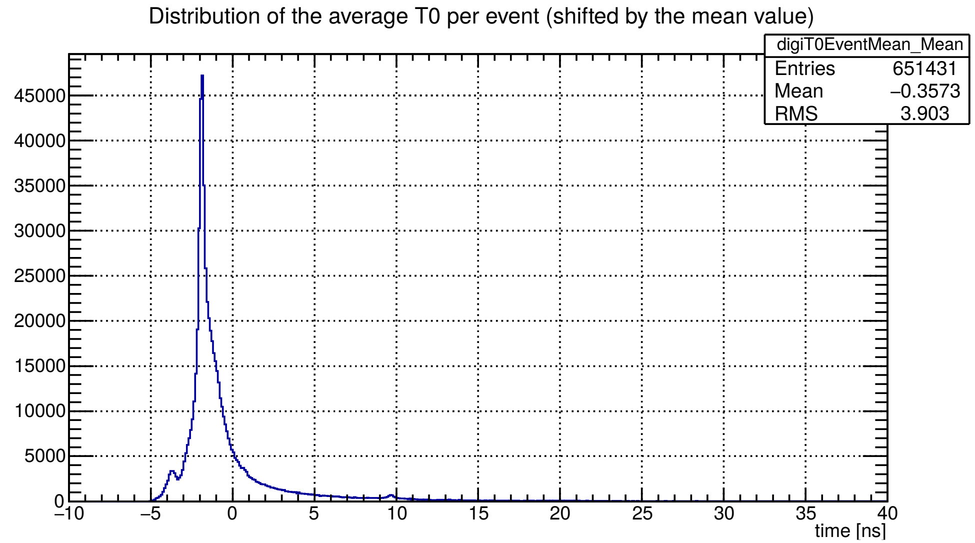
- "Mean-aligned" distribution
  - Mean = 0.06 ns, Peak = -1.9 ns
  - σ = 5.1 ns, FWHM = 0.4 ns
- "Peak-aligned" distribution
  - Mean = 2.5 ns, Peak = 0.0 ns
  - σ = 5.1 ns, FWHM = 0.4 ns

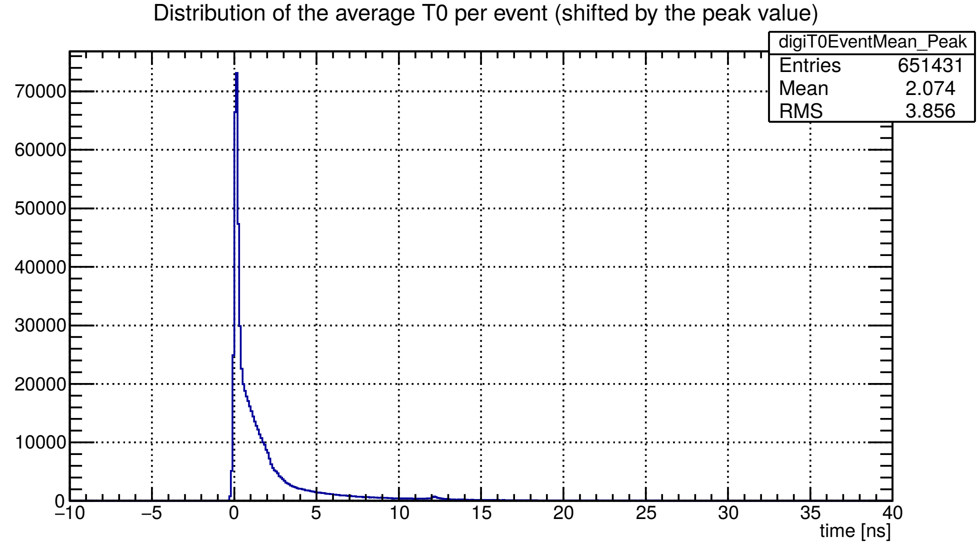




Average t0 per event

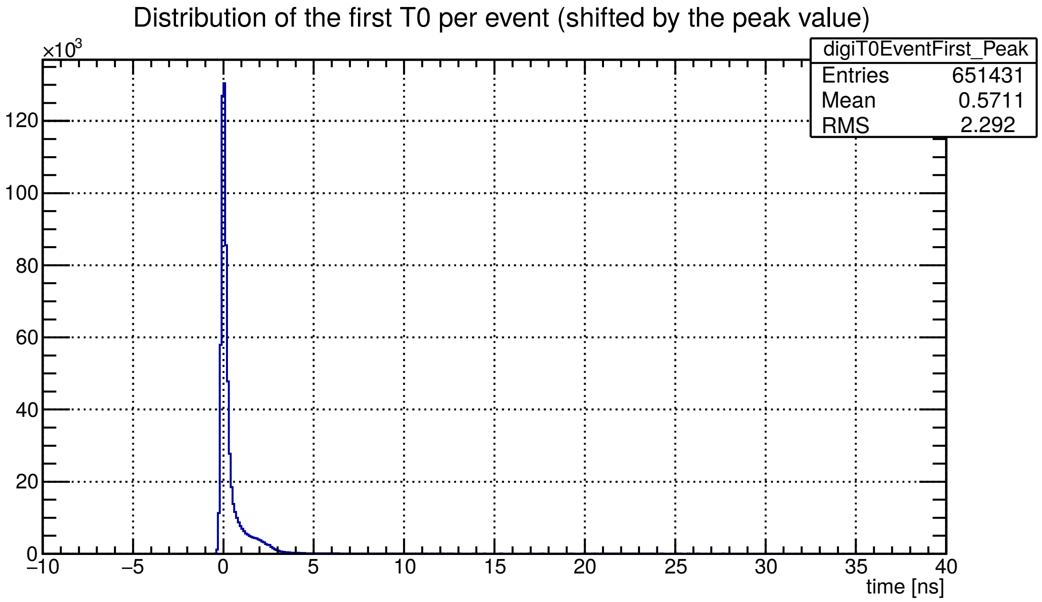
- combine shifted time stamps of one event to t0
  - mean-aligned
    - Mean = -0.35 ns, Peak = -1.9 ns
    - σ = 3.9 ns, FWHM = 0.5 ns
  - peak-aligned
    - Mean = 2.1 ns, Peak = 0.1 ns
    - σ = 3.9 ns, FWHM = 0.3 n
- the parameter used to shift time stamps has to be related to the algorithm used to calculate the final t0
- So far only by using the SciTil and a very simple algorithm we achieve a t0 time resolution of σ = 3.9 ns





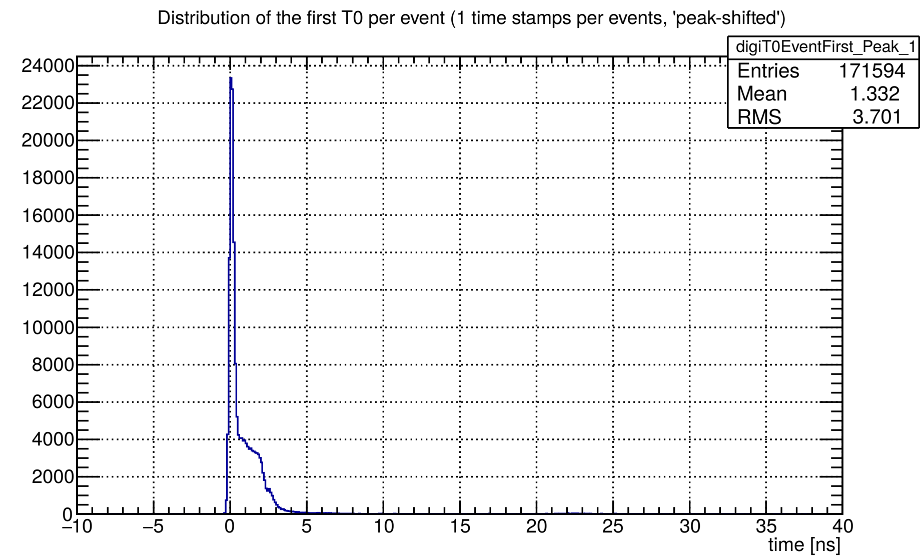
First time stamp method

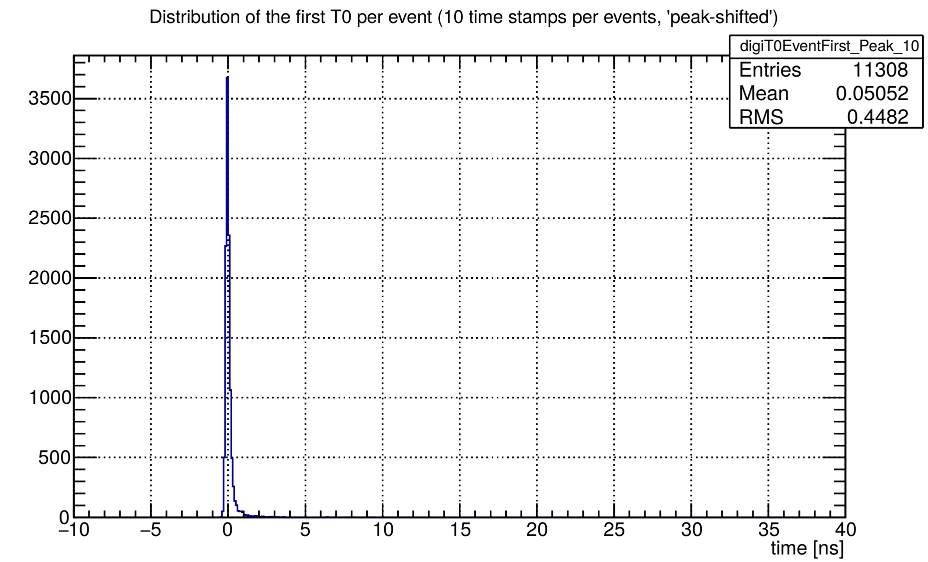
- Estimate t0 using first "peak-aligned" time stamp per event
  - Mean = 0.6 ns, Peak = 0.0 ns
  - σ = 2.3 ns, FWHM = 0.3 ns
- σ = 2.3 ns is achieved



Influences of particle multiplicity in SciTil

- Accuracy is strongly correlated with the particle multiplicity
- First time stamp method
  - $\sigma_1 = 3.7$ ns => $\sigma_{10} = 0.4$ ns
- Including time stamps of the FTOF (and other detectors) increase the accuracy further

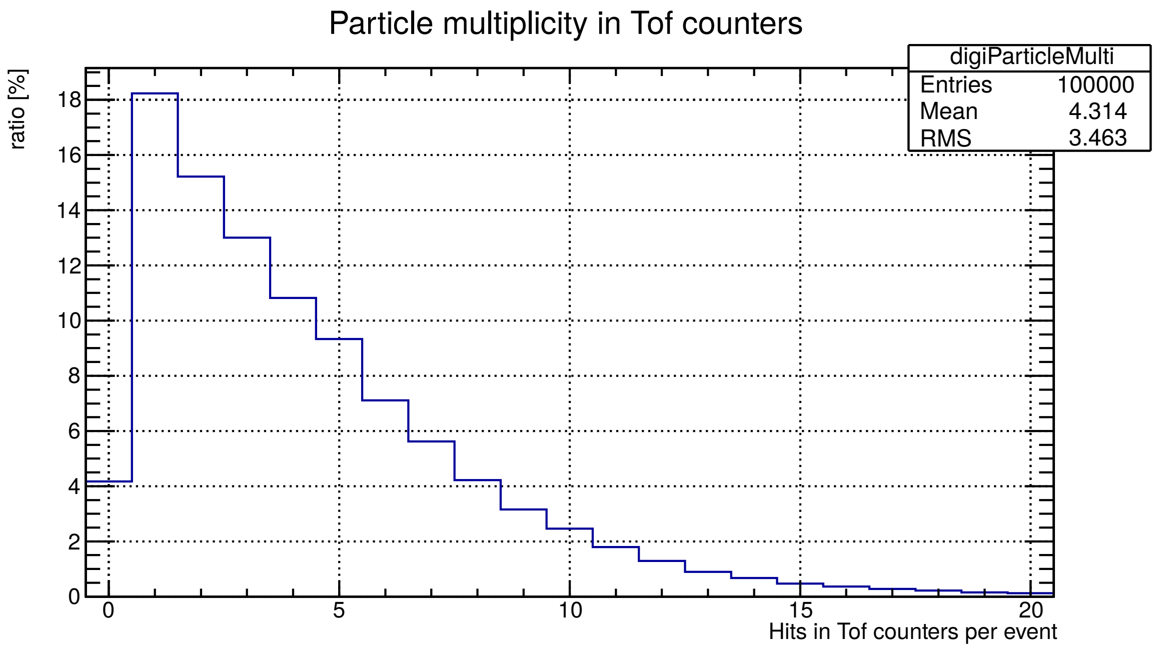




Time stamp multiplicity in TOF counters

- For ~ 4% of the events no time stamps
- For about 1/3 of the events 1 to 2 hits in the TOF counters
- For 2/3 of the events 3 or more Hits are registered

- For this study the DPM generator was used
  - The particle multiplicity for wanted events may differ from the background
  - Interesting events may have a higher particle multiplicity
    - $p\bar{p} \rightarrow p\bar{p}$



Half sample mode

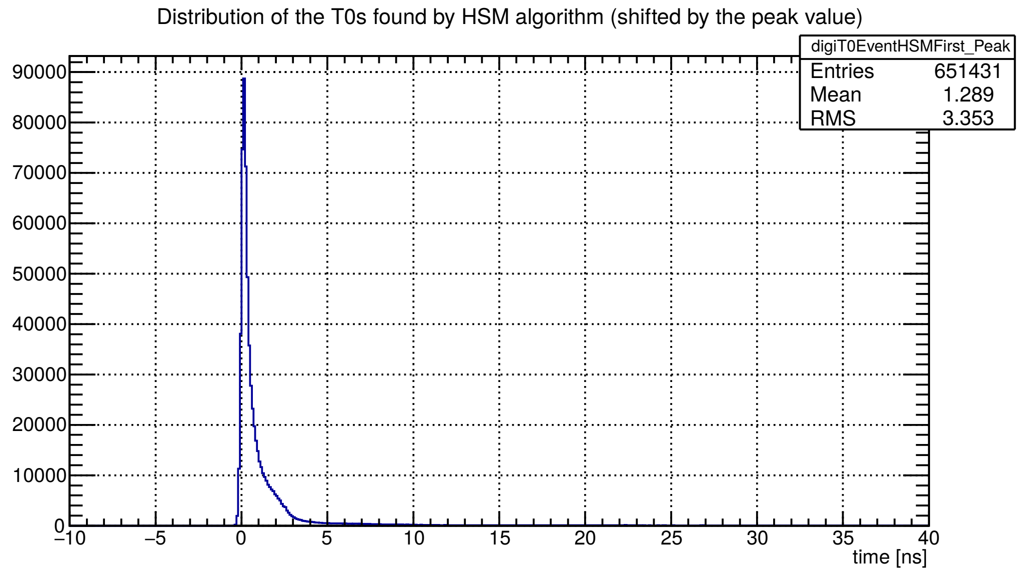
- No previous event separation in online reconstruction
- Exploiting the Peak structure
  - deliver good results
  - Weakly effected by event mixing effects
- "half sample mode" (HSM)
  - Simple cluster finding algorithm
  - Search for the shortest interval which is containing half of the timestamps in a defined interval
  - Iteratively repeat on the so found intervals till only 2 time stamps are left
  - The first one is chosen as T0 for the event

Half sample mode

HSM for single events

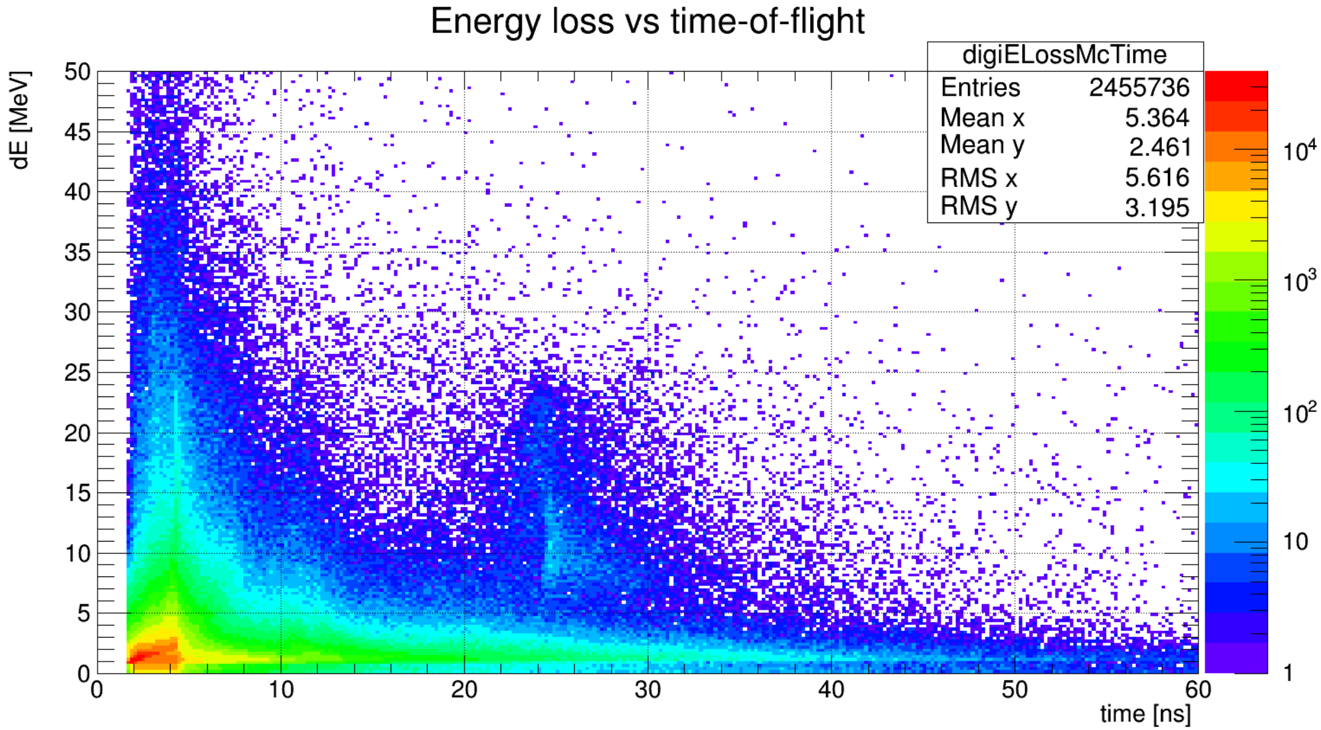
- Mean = 1.3 ns, Peak = 0.1 ns
- σ = 3.4 ns, FWHM = 0.4 n

- Performance located between average and first time stamp method
- Advantage of HSM (and similar) is the functionality in a continuously read out



Suppress slow particles

- Distinguish between fast and slow particles by energy loss in SciTil
  - No correlation between the energy loss and the flight time of the particles is observed



Summary

- We studied an simple and fast algorithm to estimate t0 based on the timing information of the TOF counters
  - Due to the limited scope of this study only the SciTil was taken into account
- It is evident that the secondaries provide an additional and useful information for the t0 estimation
- It was shown that T0 can be calculated by using the position information of the SciTil and the corresponding typical time of flight
  - Using the "first time stamp method" a t0 resolution of σ = 2.3 ns was achieved.
- Using the additional energy loss information provided by the SciTil lead to no enhancement so far
- Increase in accuracy is expected once the FTOF information is taken into account

Thank you for your attention