Analysis of FADC single-crystal data

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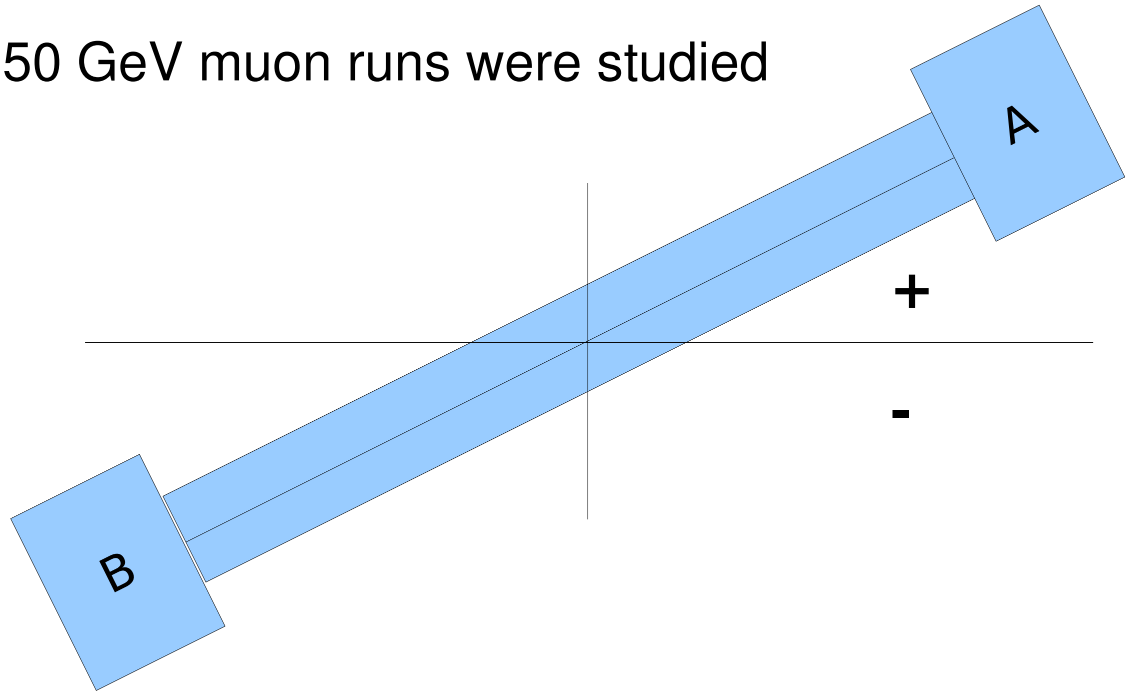
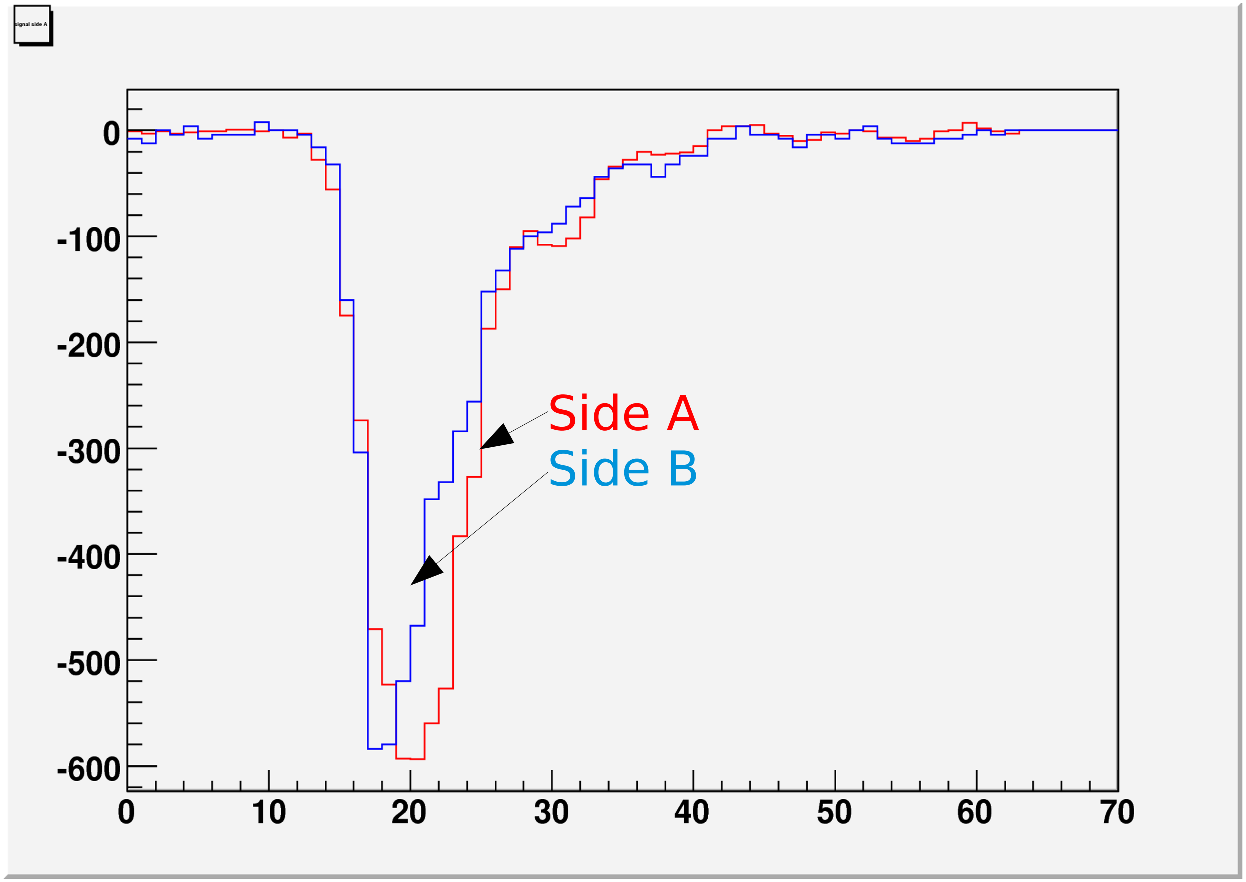
Aim of the study

- The presence of the Cherenkov component in the signal can be detected by studying its time characteristics:
  - Since the Cherenkov light is prompt, while the scintillation light is due to a secondary emission, an effect may be present in the signal arrival time
  - The Cherenkov component is faster than the scintillation one so the rise time of the signal is expected to decrease while the ratio of Cherenkov light to the total increases
- 10 GeV electron and 150 GeV muon runs were studied



The signals

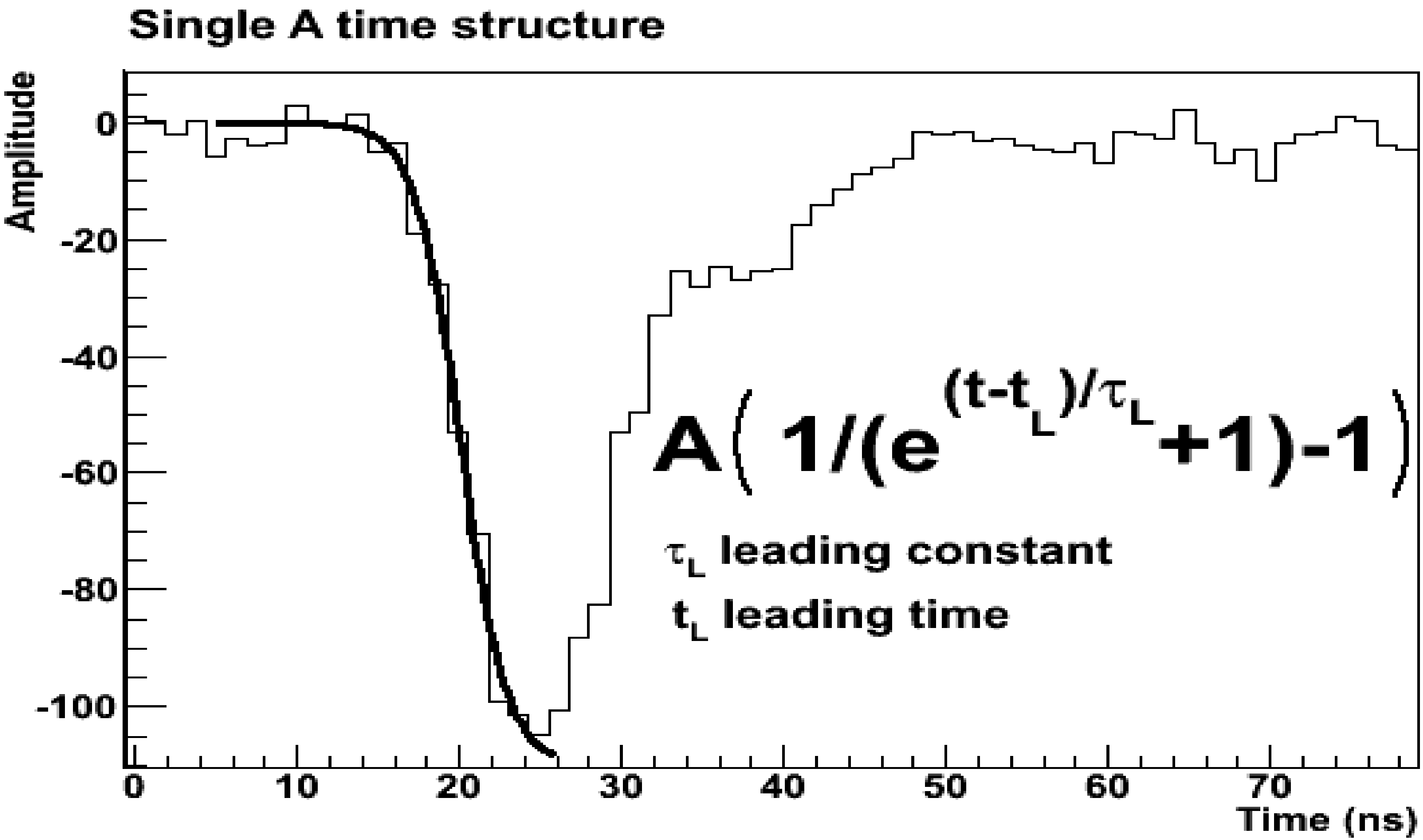
“Pseudo-analogue” signals are reconstructed by means of the FADC data on both sides (A and B in the following);



Evaluation of the temporal properties through:

- ✔ Leading edge fitting
  - ✗ e^-
- ✔ Threshold crossing study
  - ✗ e^-
  - ✗ μ

Leading edge fitting

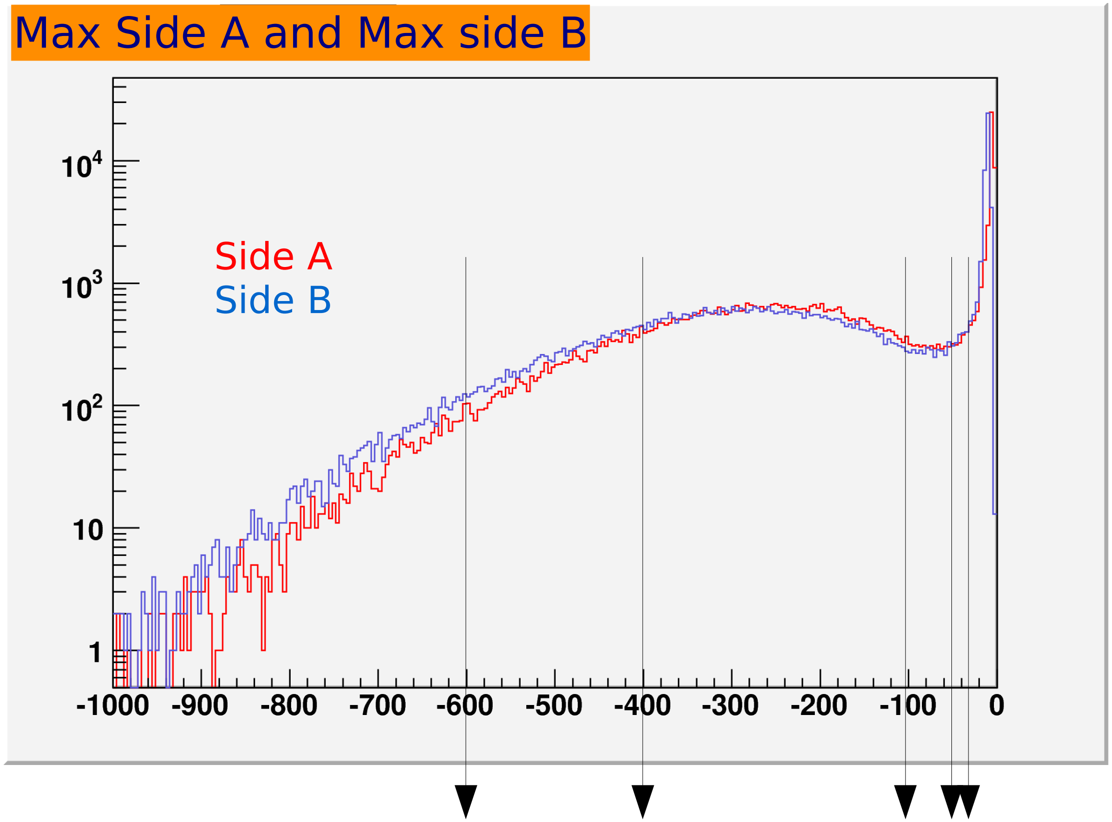


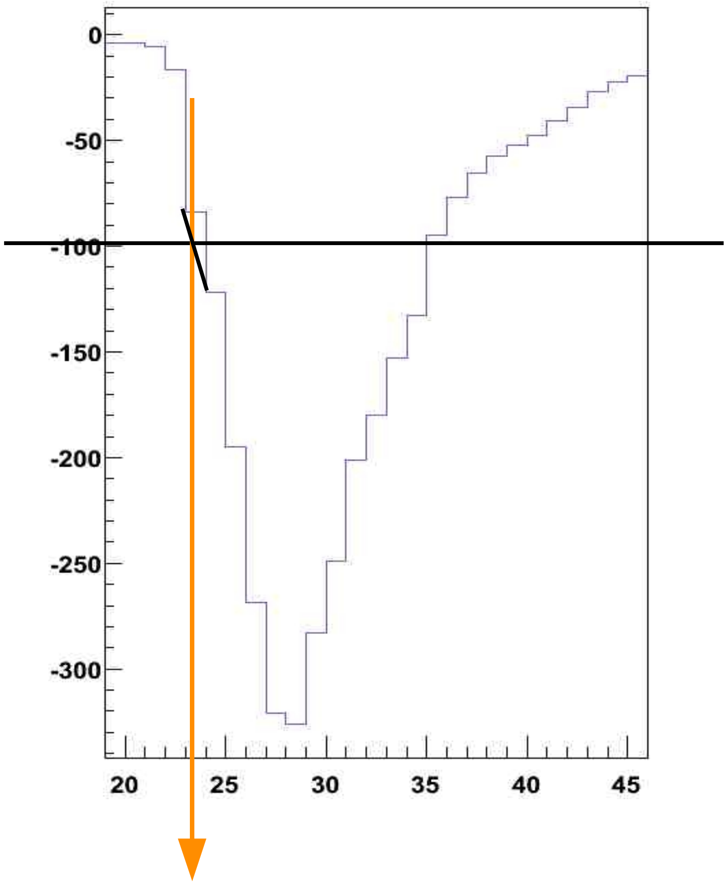
✔ Leading edge fitted with a Fermi-Dirac function

Threshold-crossing study

- We tried to evaluate what a TDC would have seen
- For each event, the crossing times for several threshold values (-30, -50, -100, -400 and -600) were recorded for the signals on both sides

Max Side A and Max side B



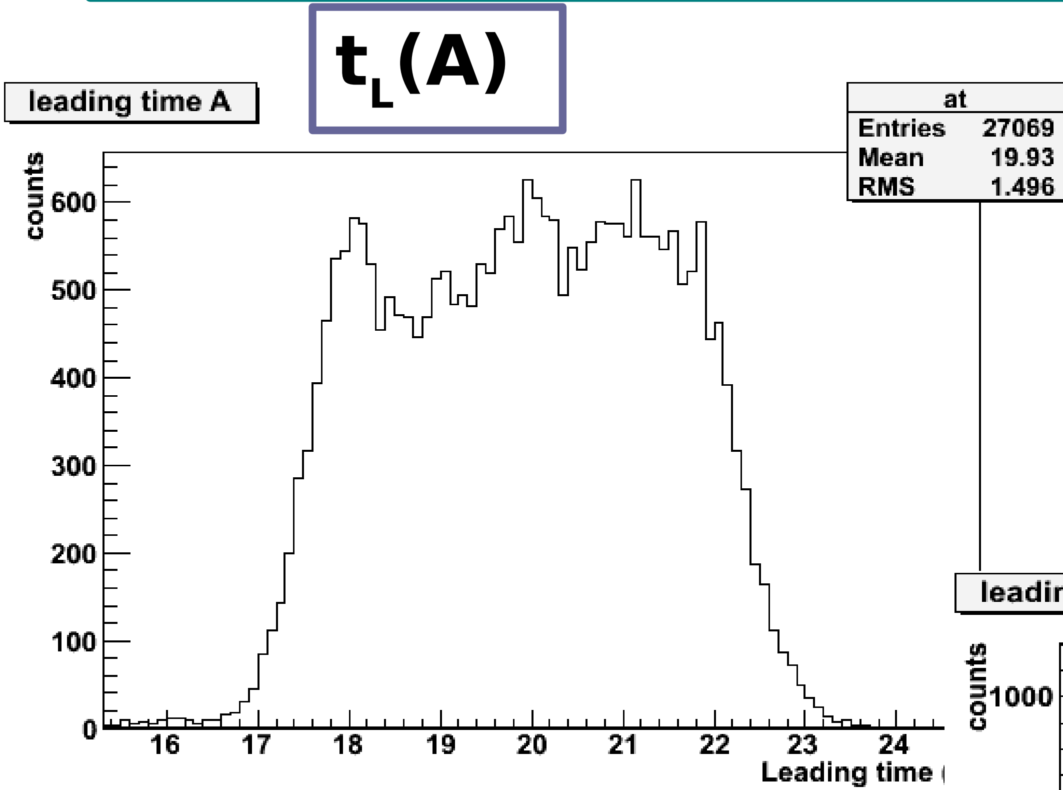


In runs with electrons, signals form B side are multiplied by a factor 4 in order to equalize the readout chain gains;

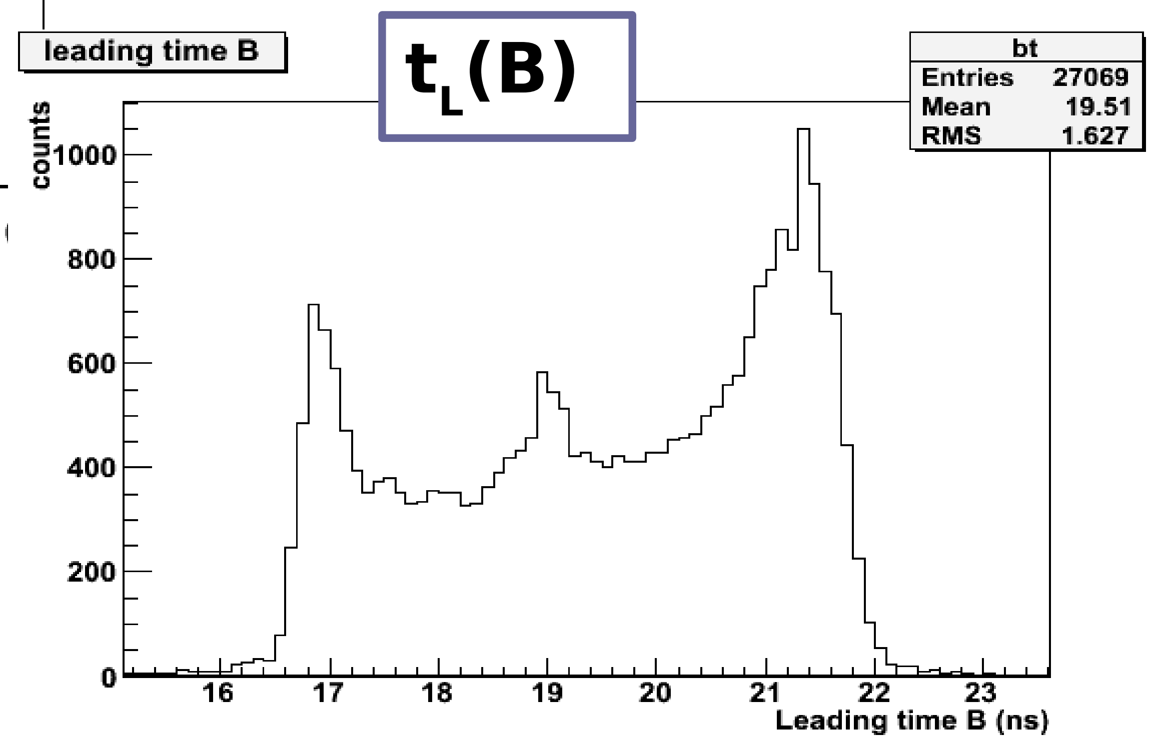
A linear interpolation is performed to get higher time resolution

Leading Time

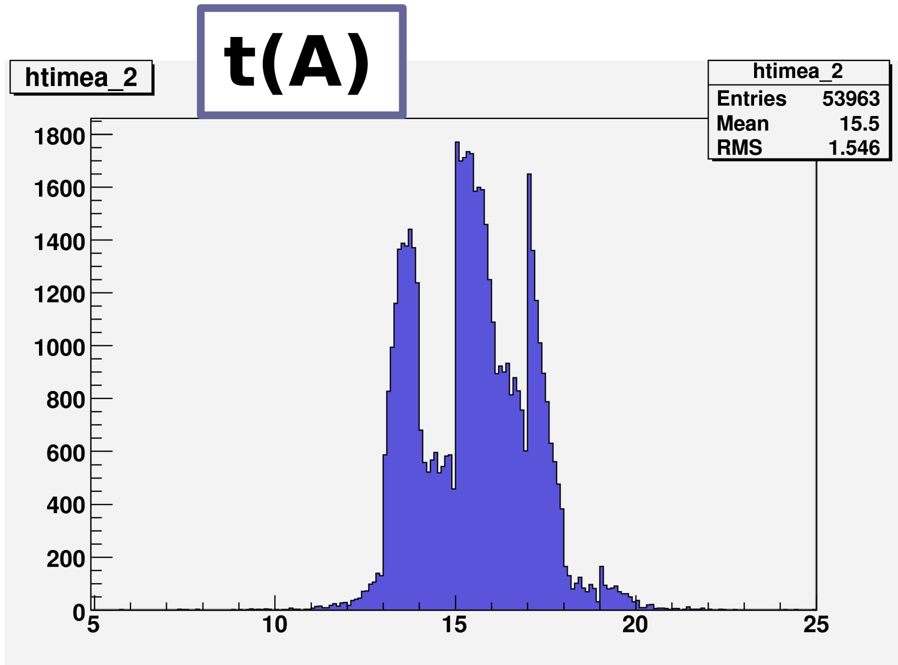
Leading edge time - Fitting

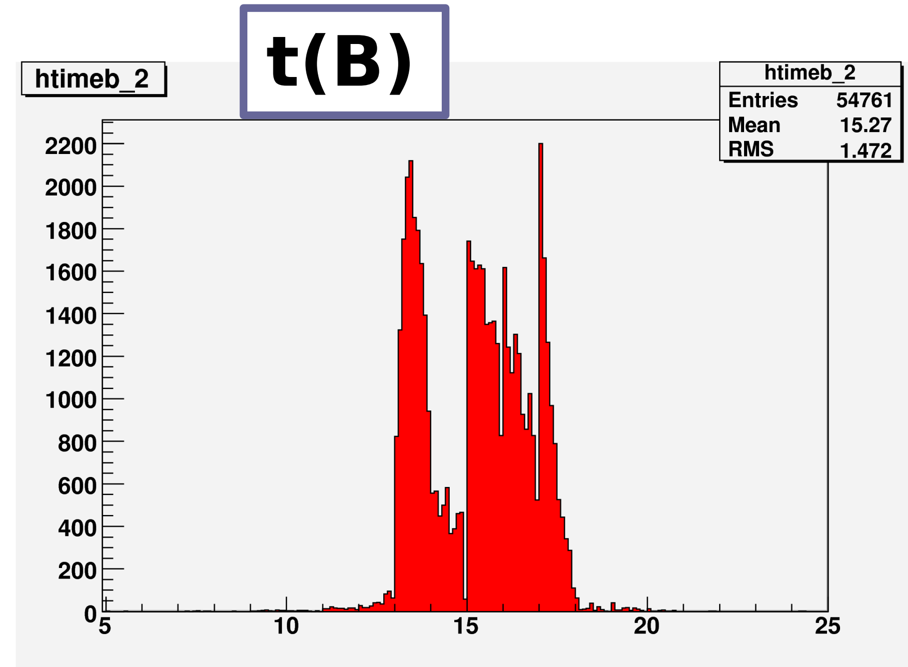


- ✔ Since the FADC clock is 200MHz and the trigger is asynchronous, structures narrower than 5ns should not be visible! (The FADC producers agree on that)



Leading edge time – Thr. cross.





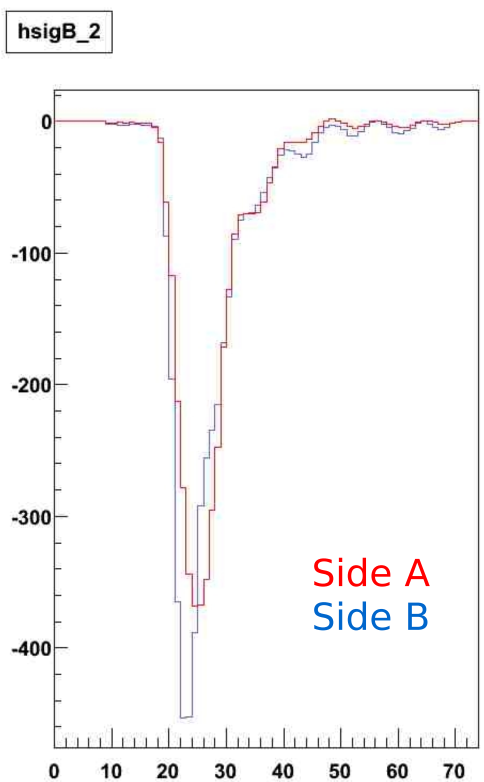
Plots show the time spectra for a threshold of -100;
On both sides, for all the threshold values, a distribution 5 counts wide and a strange structure is visible;

Average signals

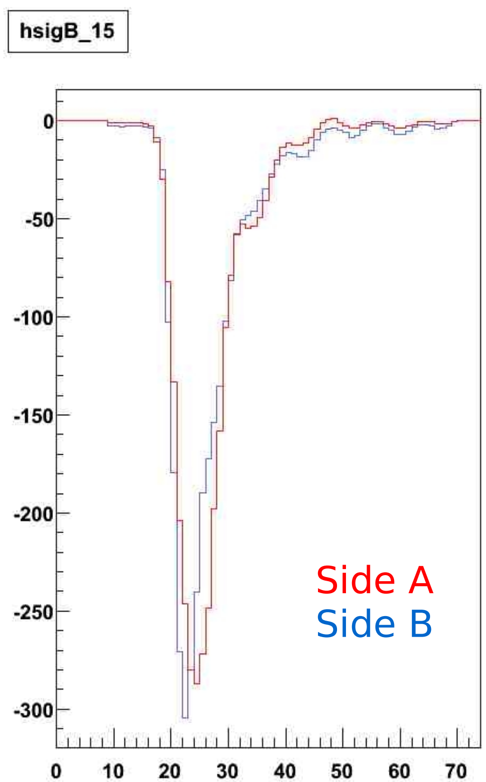
The shapes of the “average” signals from the two sides for each run have been reconstructed;

Signals have been synchronised asking for an amplitude of -30 at a time of 20 counts;

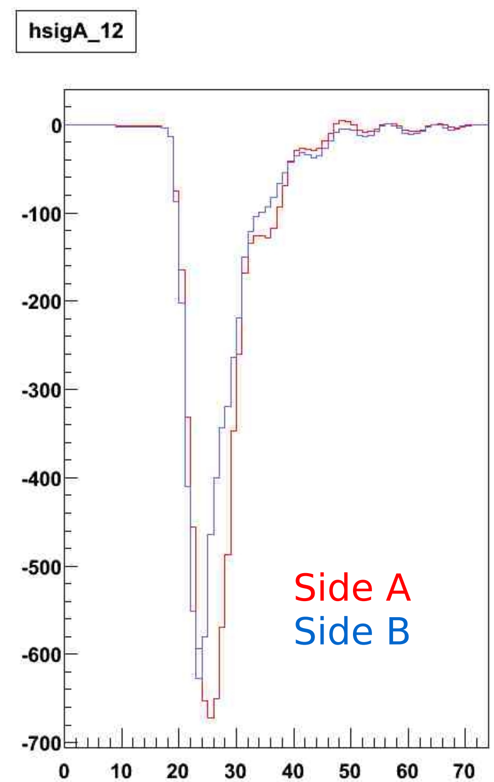
-30 degrees



0 degrees

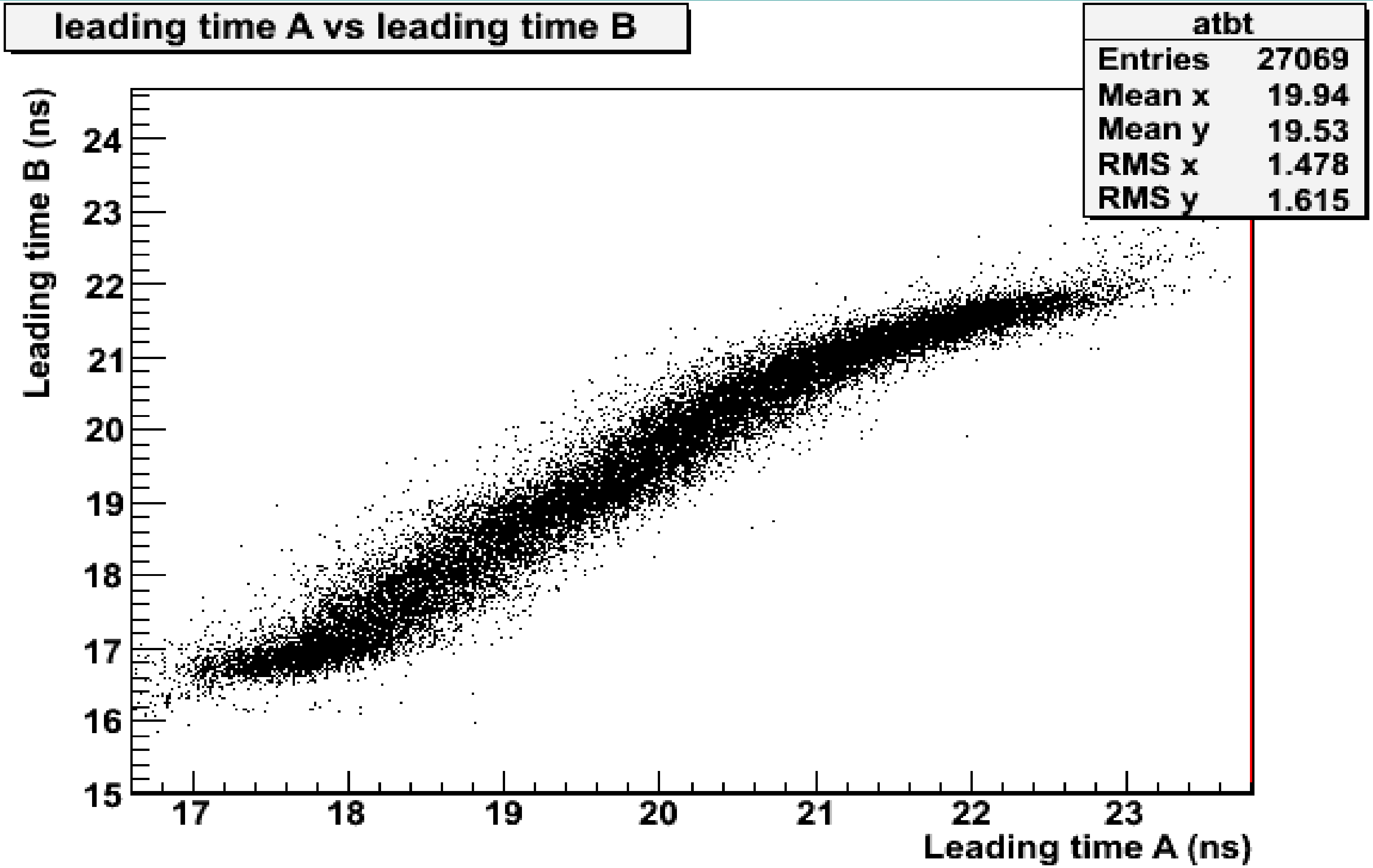


30 degrees



Side B seems always to be faster than side A

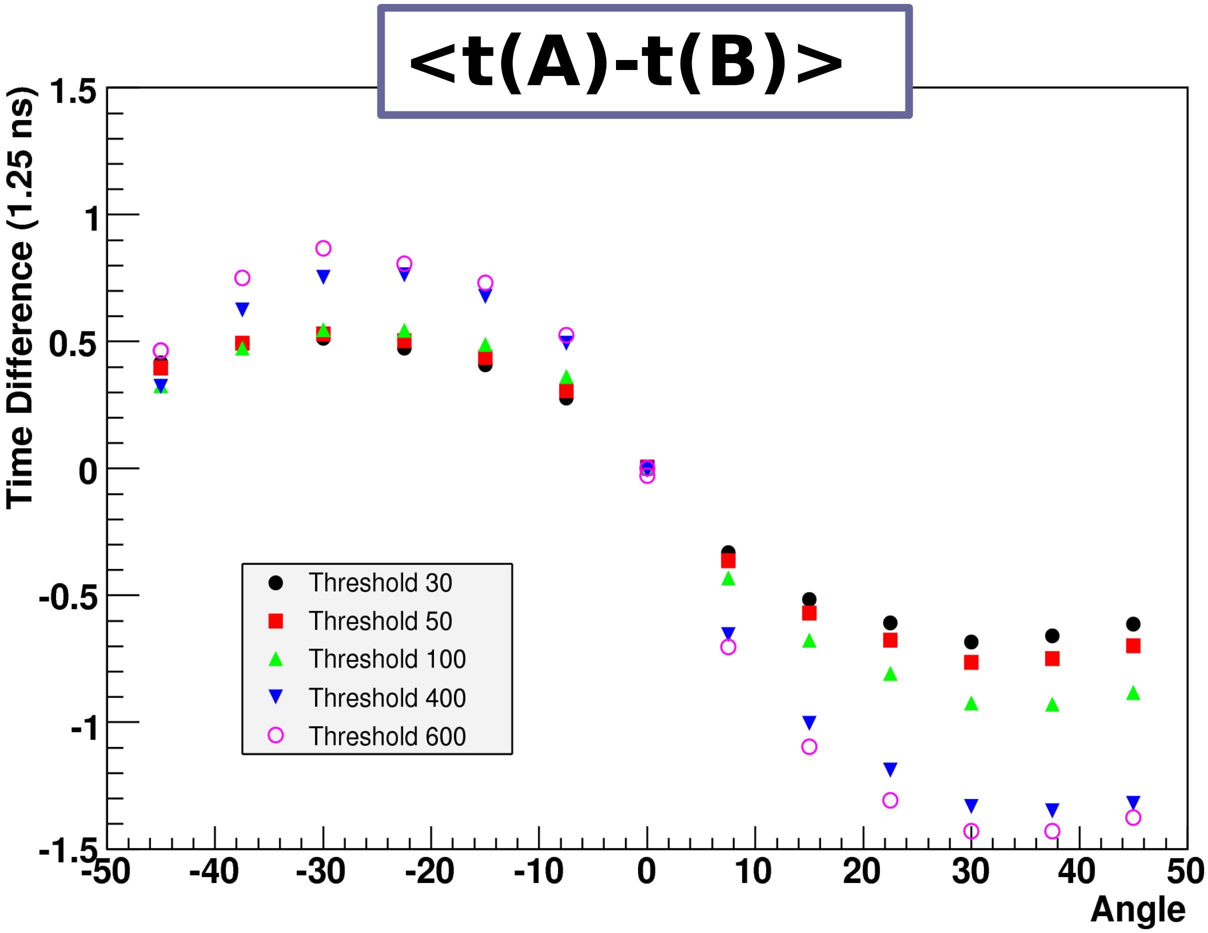
Leading time correlation



- Even if signals, event-by-event, are differently time shifted by the FADC, the A and B signals are well correlated for each event (i.e. the time shift is the same for both)
- Hence we can estimate an arrival time difference, which may give us information about the Cherenkov component

Time difference (A - B)

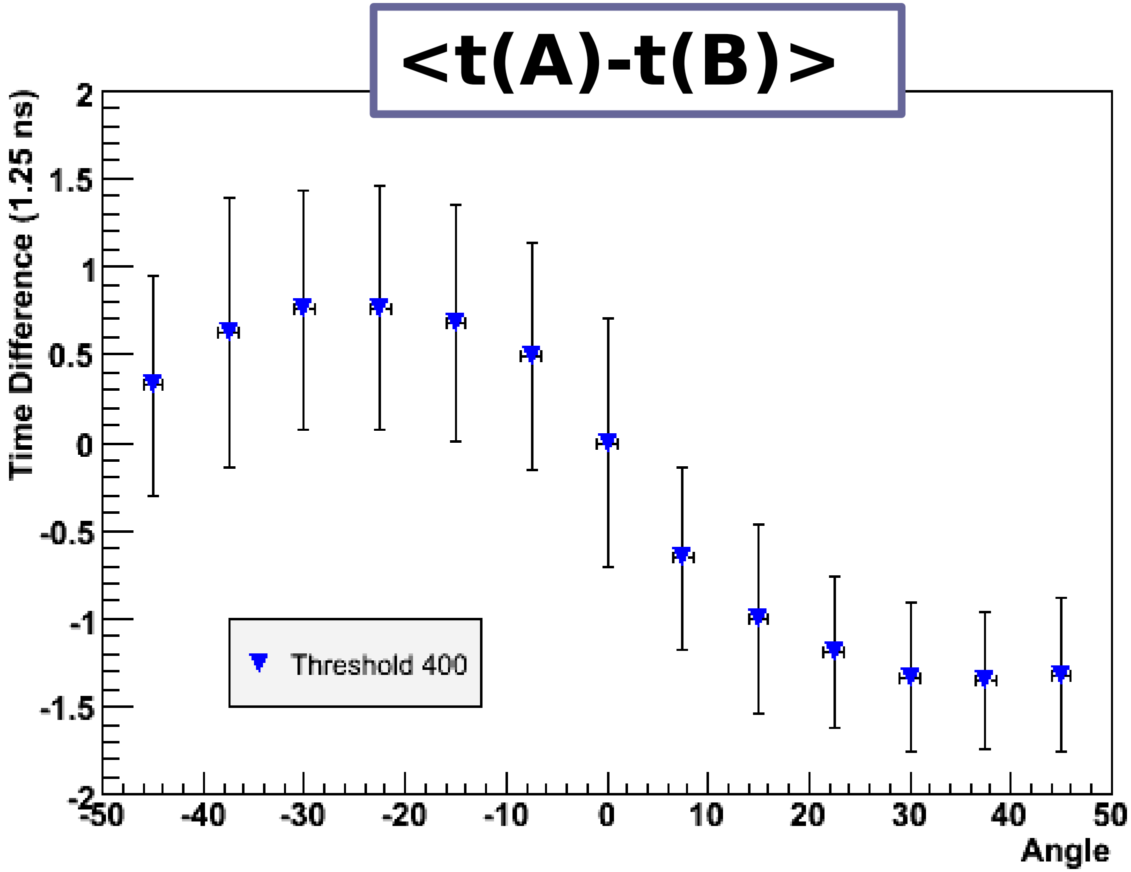
In the plot the results obtained with a simple linear interpolation is shown (once subtracted the value at 0 degrees)



- A clear dependence on the crystal angle is found with maximum and minimum at ± 30 degrees
- Higher thresholds correspond to higher effects
- For a threshold of 600 the time difference between +30 and -30 degrees reaches 3.1 ns

Time difference rms

- Error bands show the time-difference distribution rms
- Tell us if we can estimate, event by event, the Cherenkov fraction from the time difference



Rise time

Signal rise time – Thr. Crossing

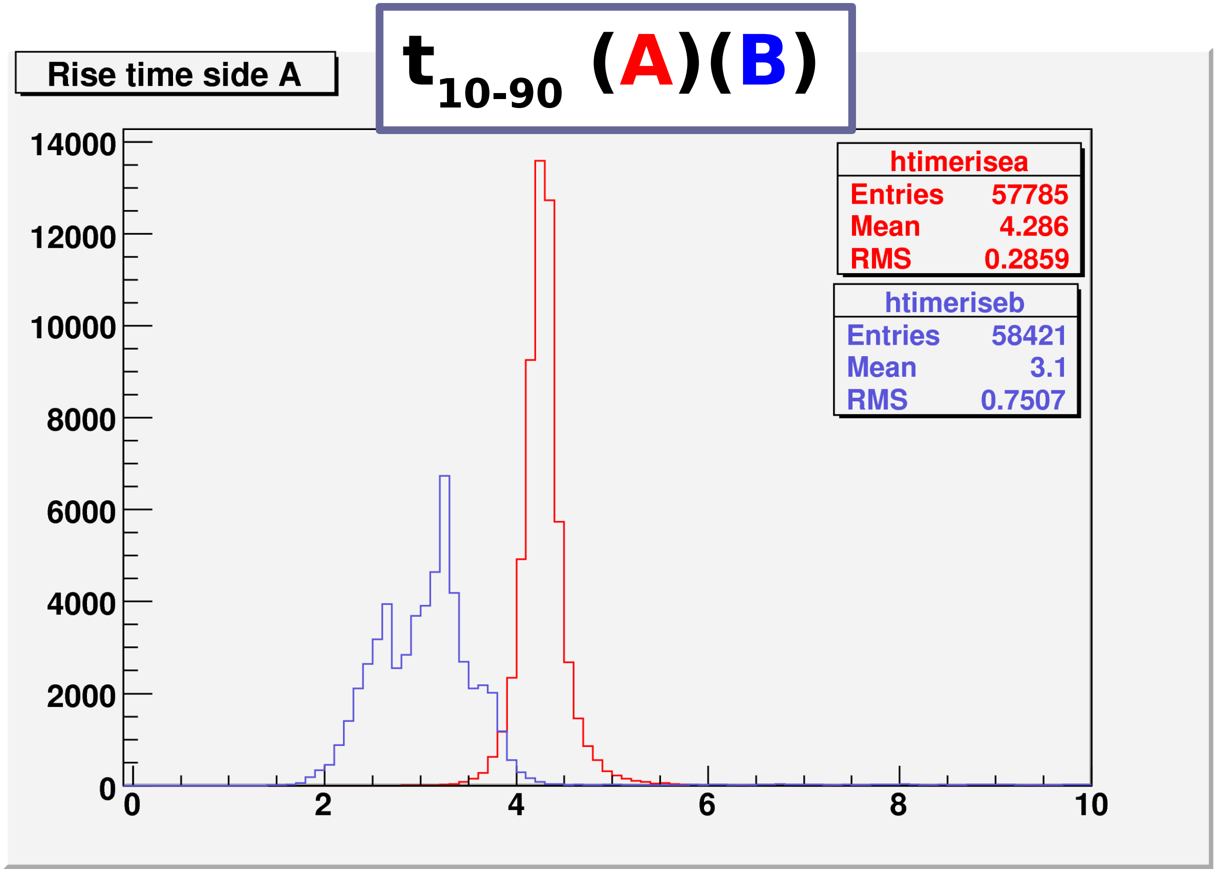
The signal rise time may provide information on the Cherenkov component just exploiting a single side signal.

We evaluated, event by event, the rise time $t_{10\text{-}90}$ of the signals from the 10% to the 90% of their amplitude.

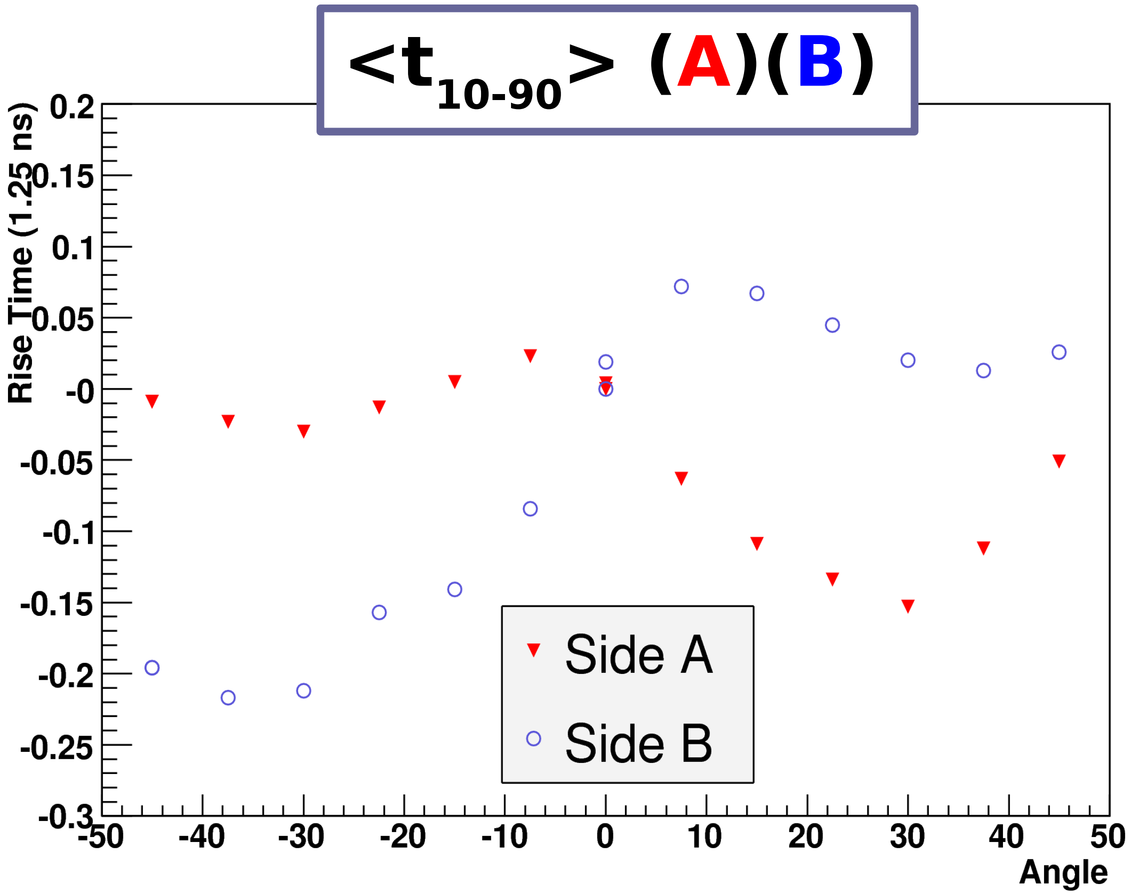
Two effects found:

(1) In average signals from side A are slower than the ones from side B

(2) While the rise time of the signals from side A behave as expected, a strange distribution is found for the rise time of signals form side B



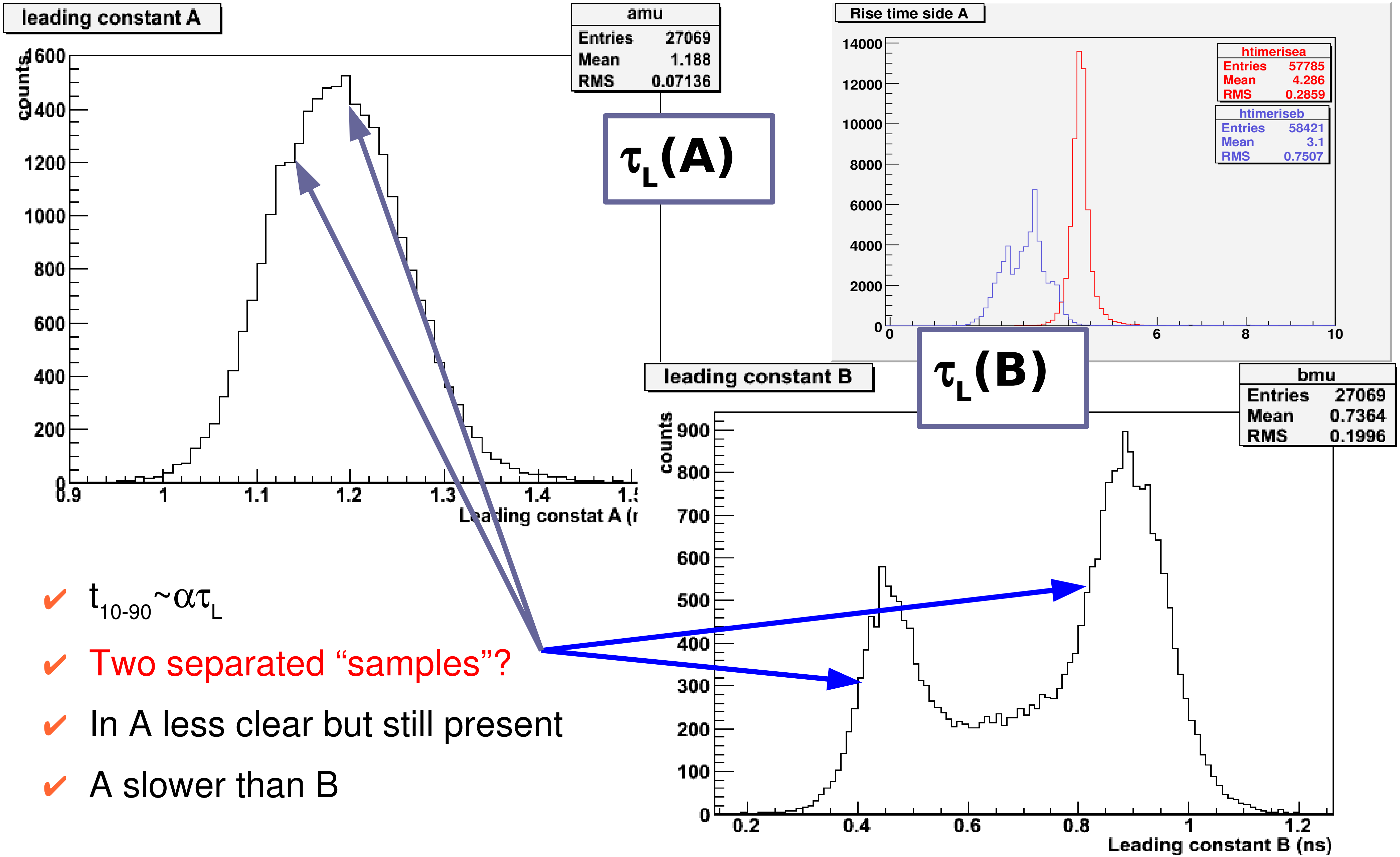
Signal rise time: results



A decrease of the rise time is found for angles allowing the Cherenkov light reach the PMs. Minima are found at ± 30 degrees

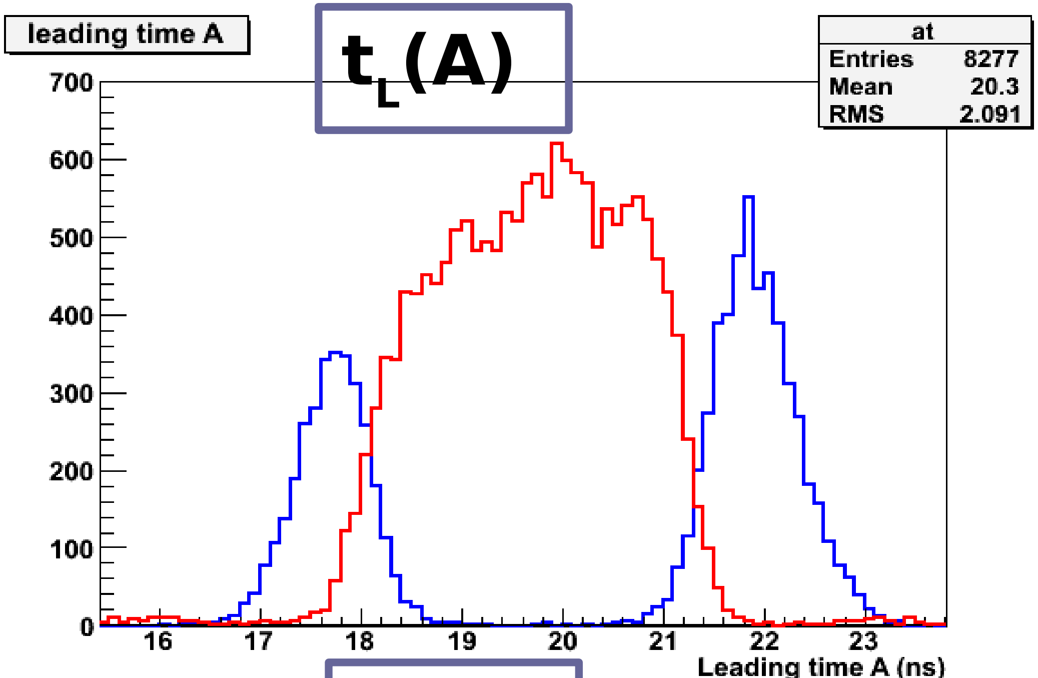
- Relative minima are also found at ∓ 30 degrees maybe due to the some minor effect
- Maybe little fraction of Cherenkov photons impinging normally to the inner crystal forward face are reflected and escape from the backward face

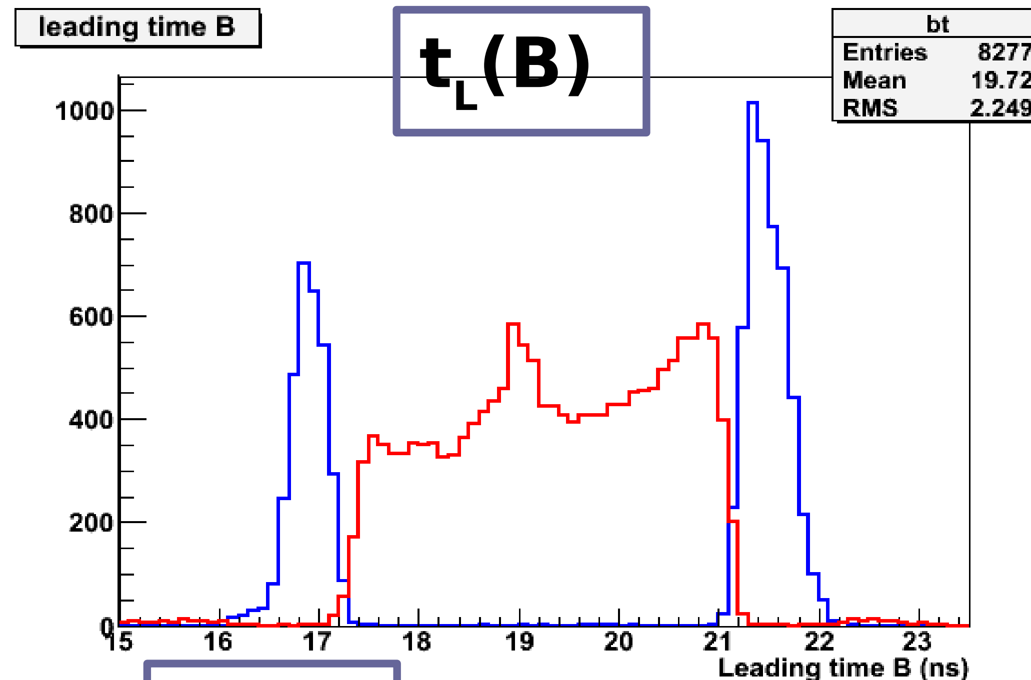
Signal rise constant - Fitting

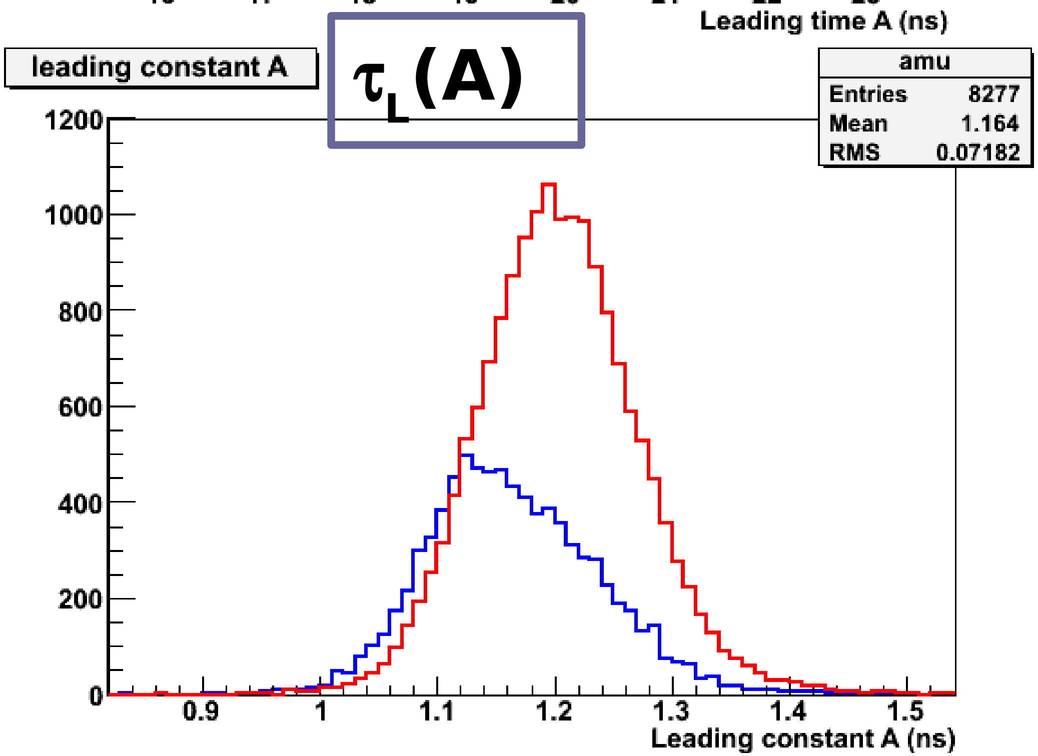


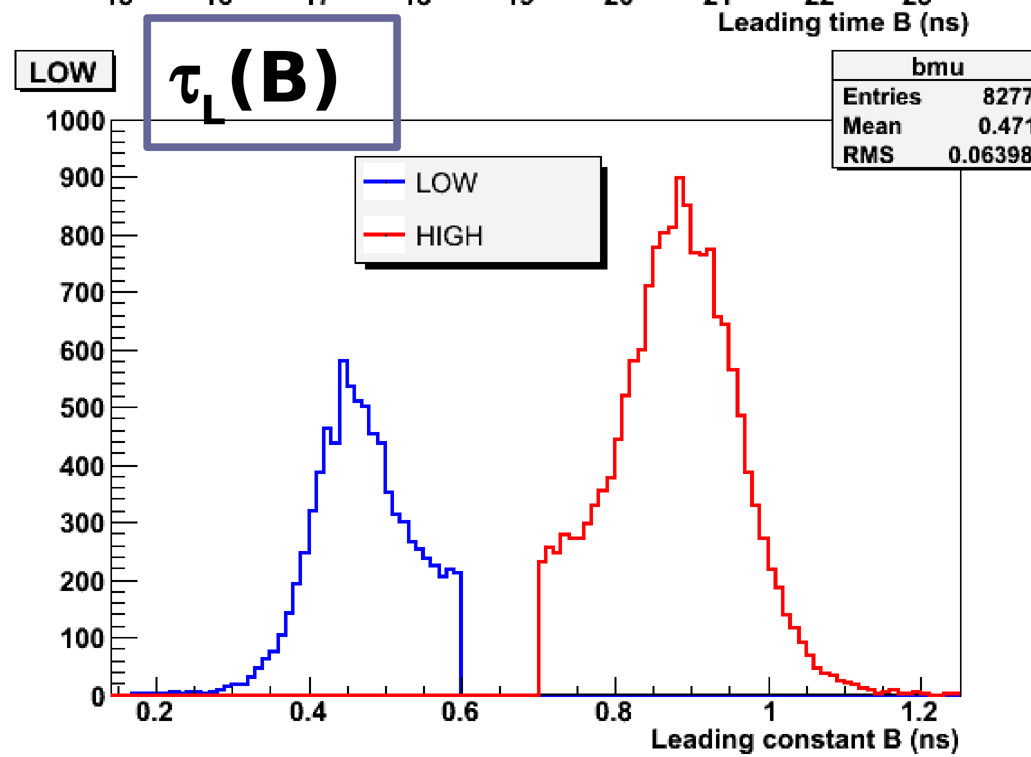
- ✔ $t_{10-90} \sim \alpha\tau_L$
- ✔ Two separated "samples"?
- ✔ In A less clear but still present
- ✔ A slower than B

Leading time vs Rise constant

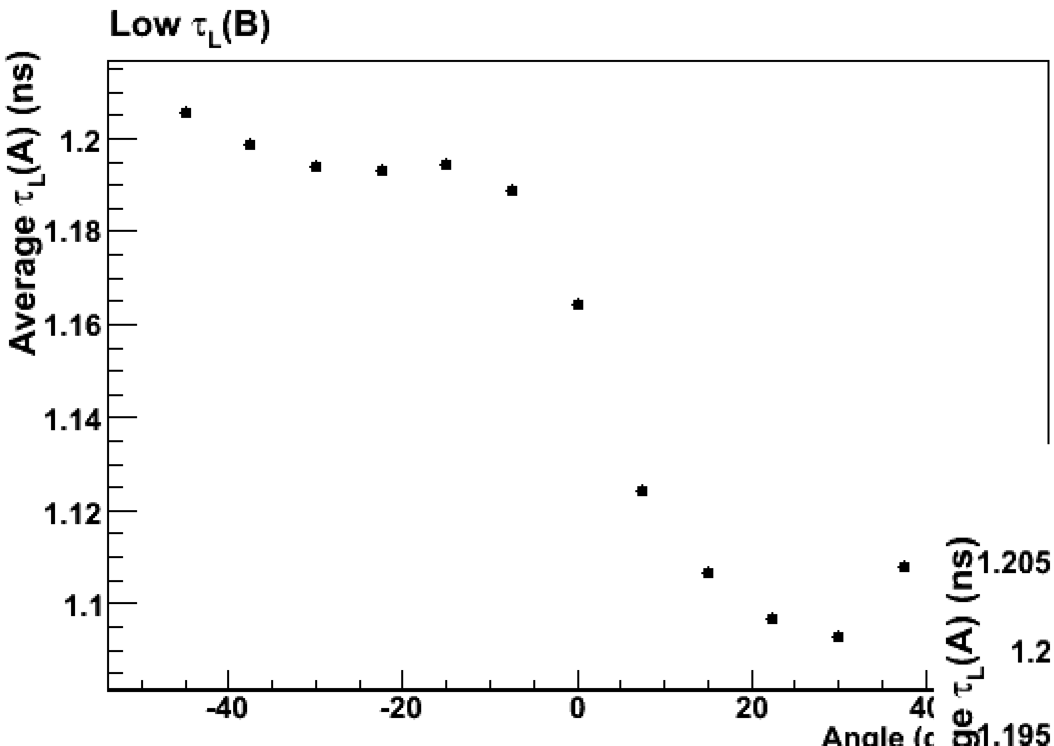


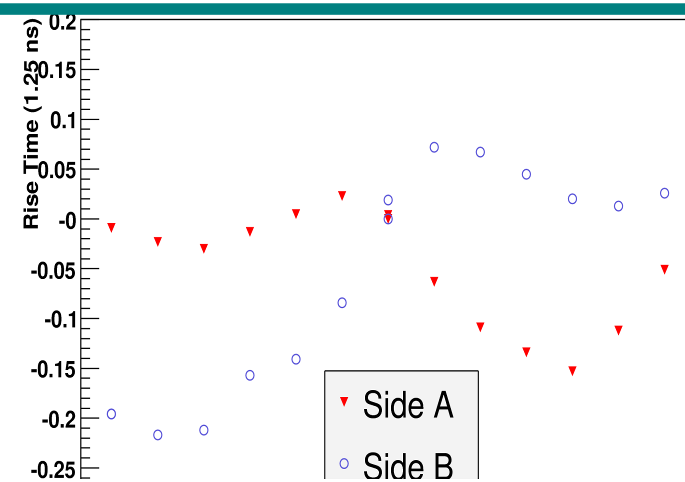


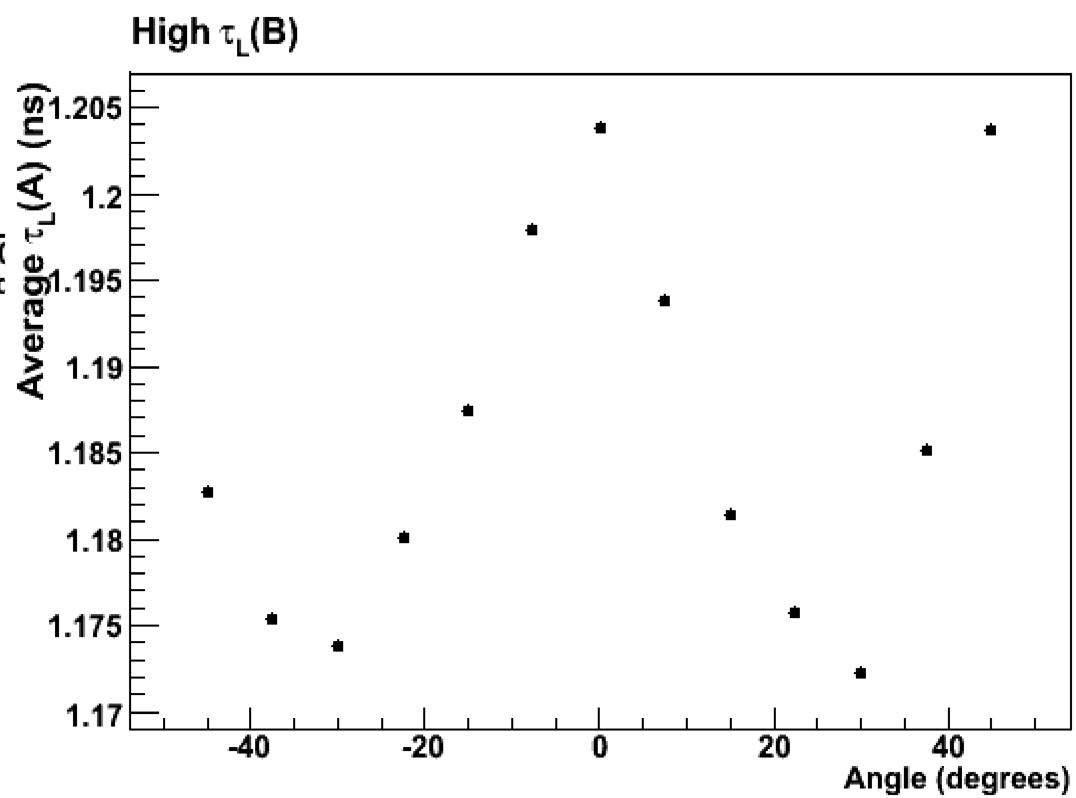




Rise constant – Side A

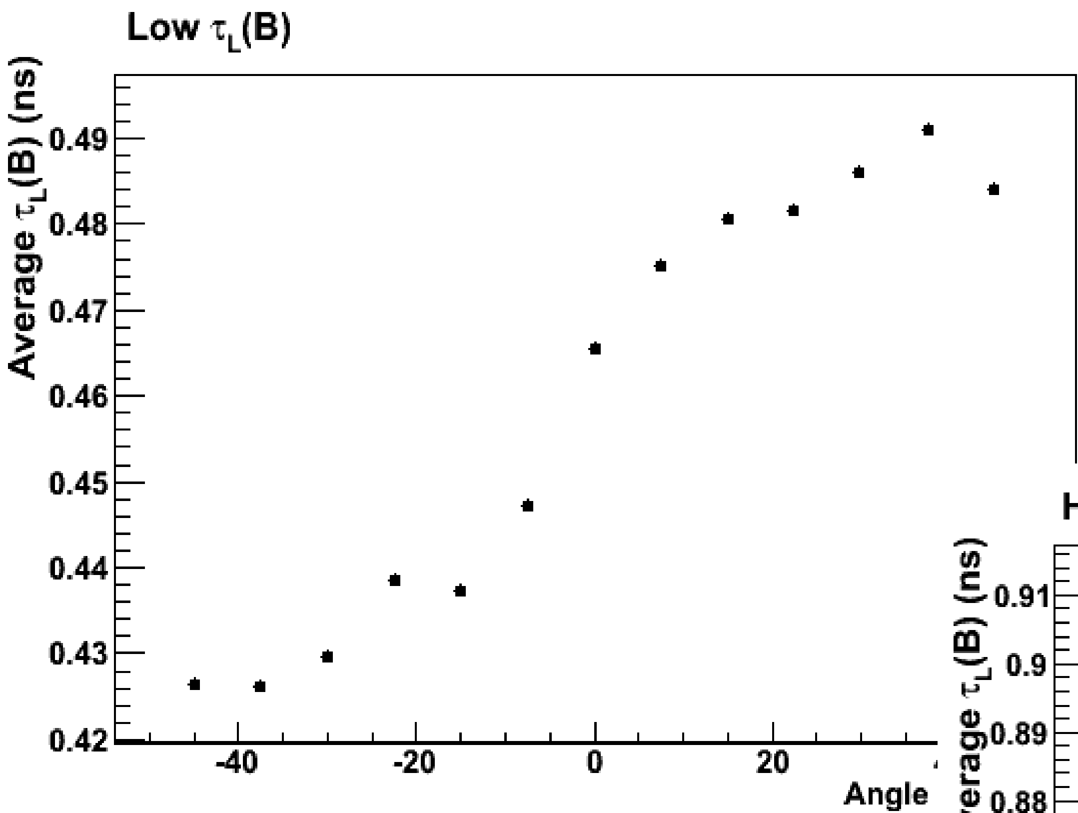


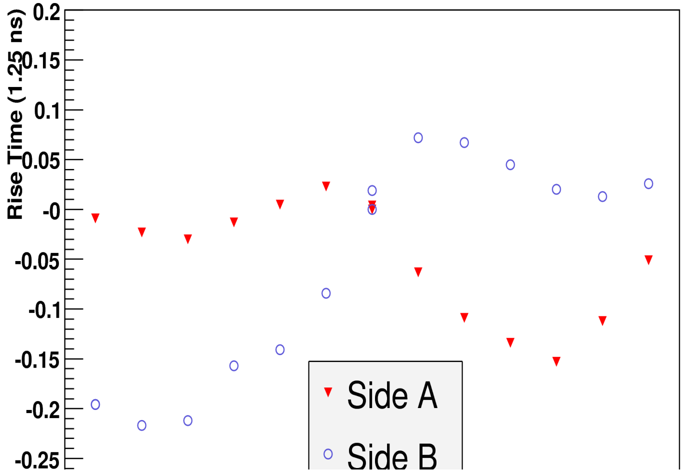


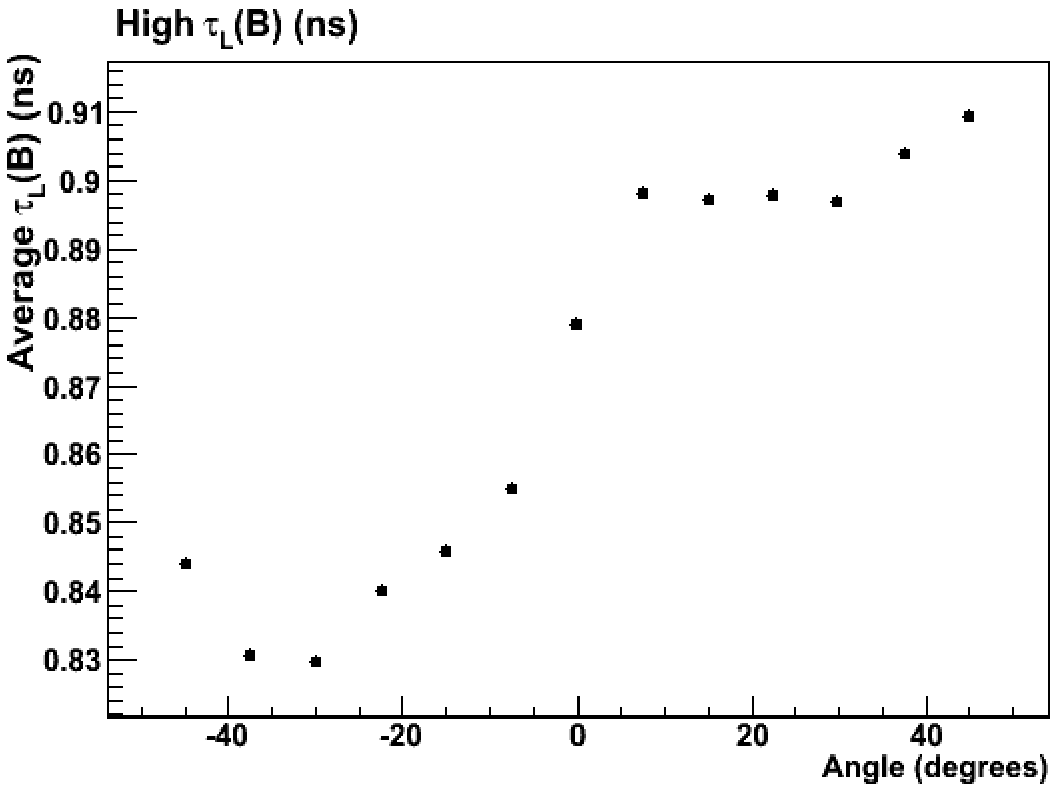


- Low τ component behaves as seen with the previous method
- High τ component behaves differently, but with smaller variations

Rise constant – Side B



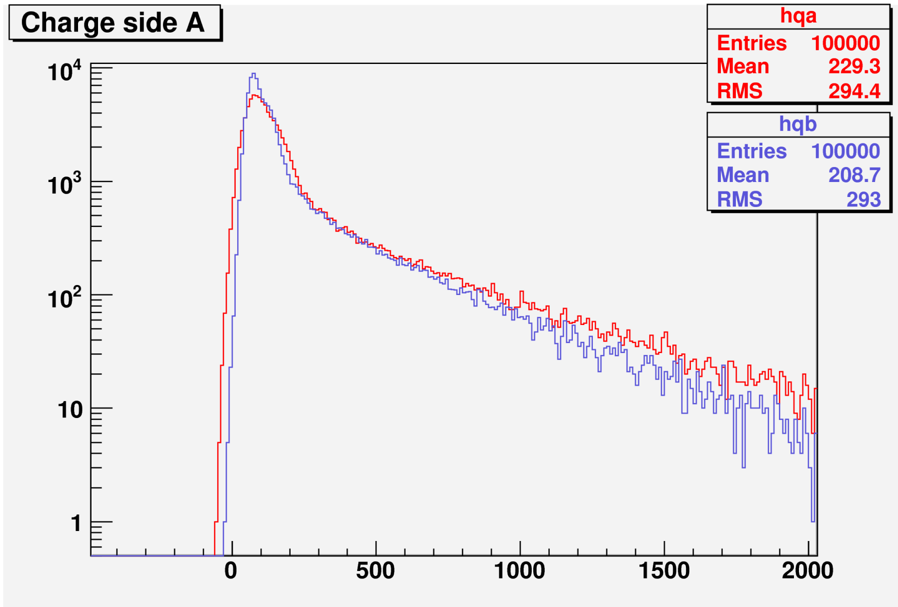


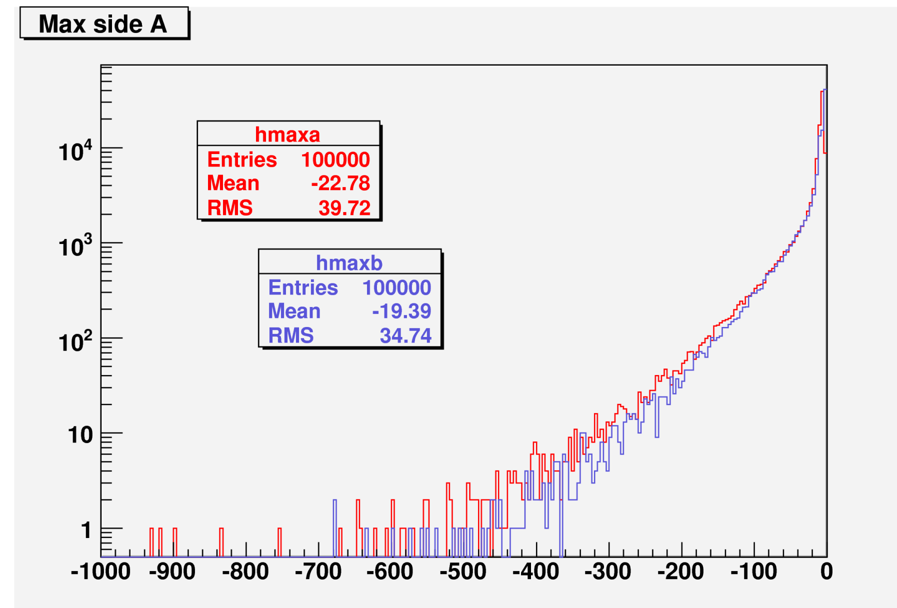


- ✔ Both Low τ and High τ components behave as seen with the previous method

The muon runs

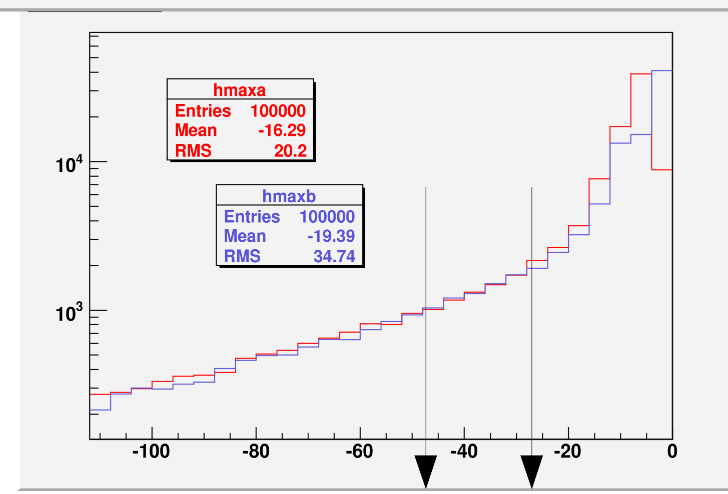
The same threshold-crossing studies were performed for the 150 GeV muon runs.





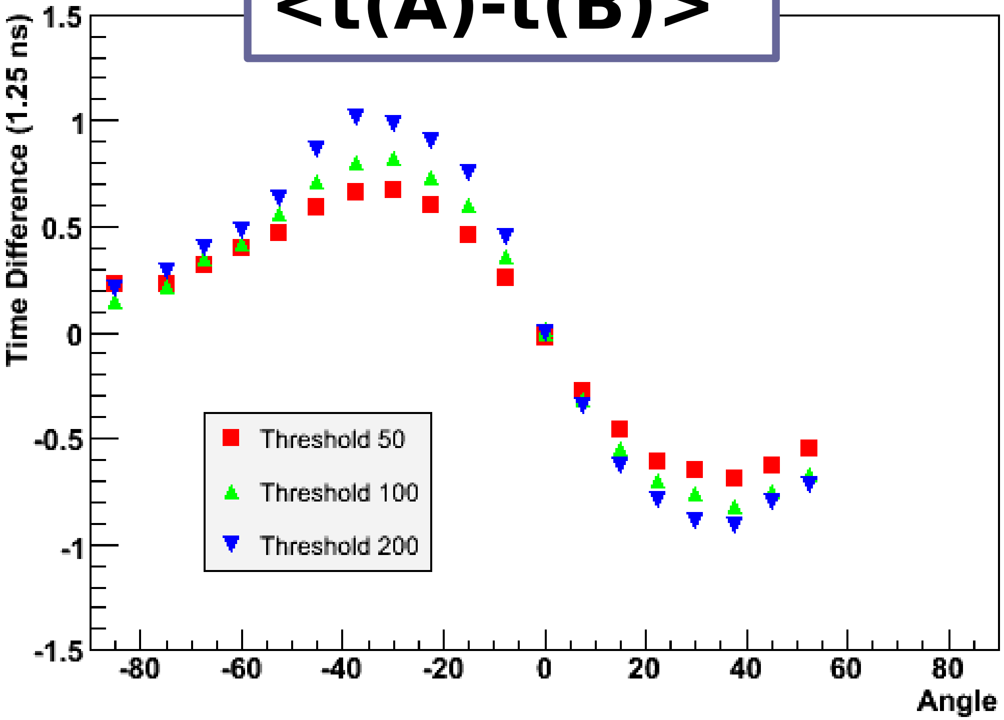
Charge from side A and B were equalised without the factor 4

Thresholds were set to -30, -50

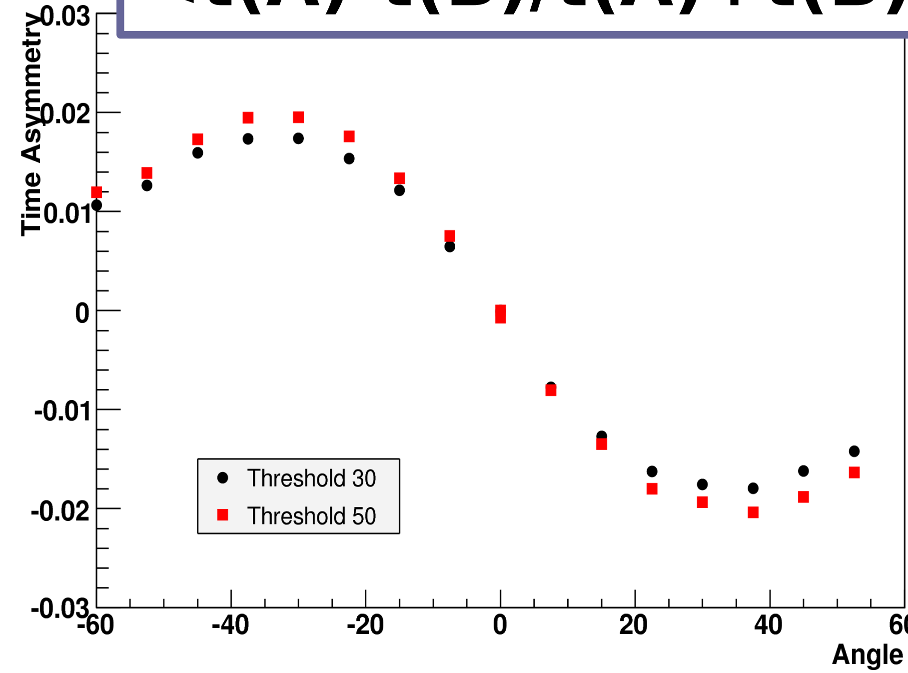


Muons: time difference and asymmetry

<t(A)-t(B)>



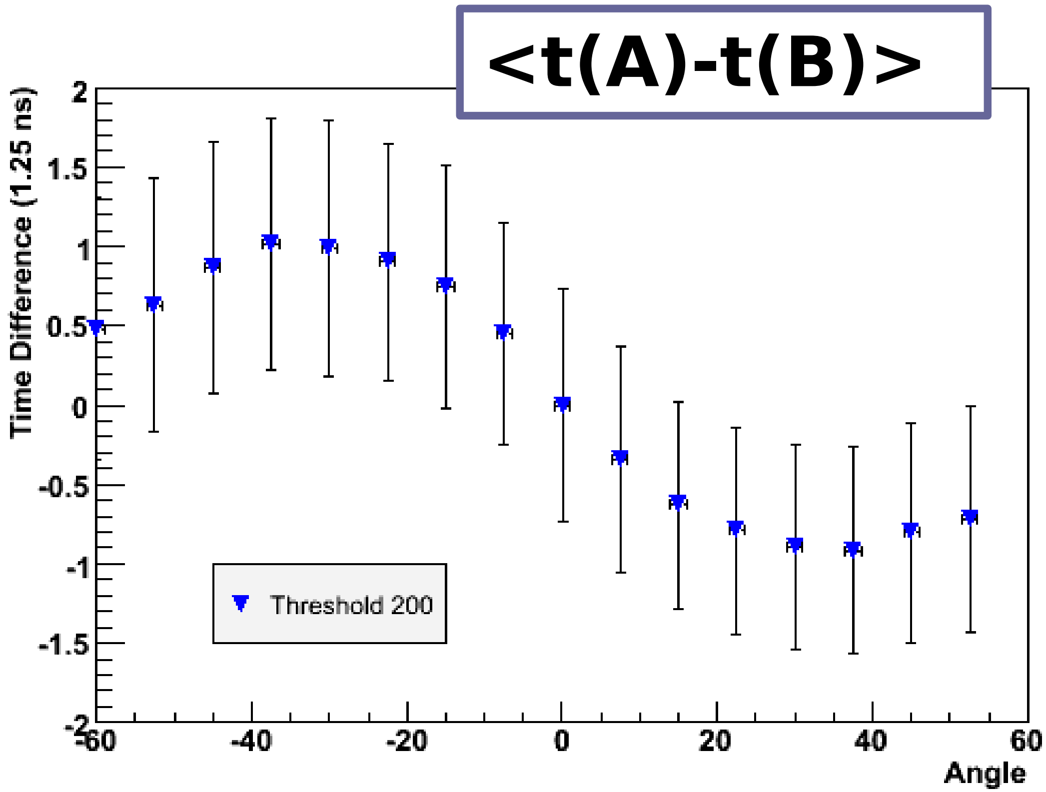
<t(A)-t(B)/t(A)+t(B)>



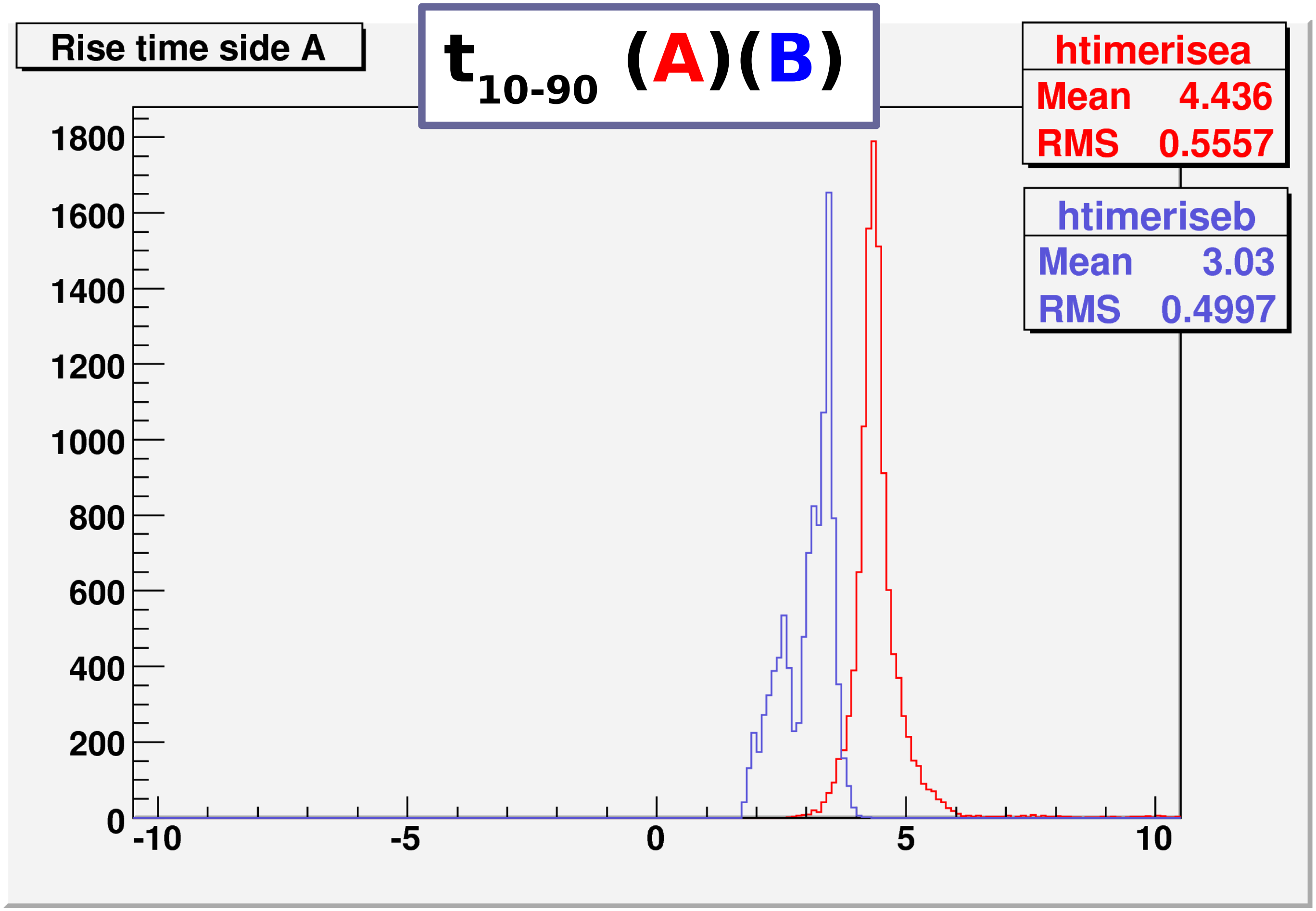
- Both, the time difference (A-B) and the time asymmetry (A-B)/(A+B) show a maximum and minimum at ± 30 degrees
- For angles close to 90 degrees the difference tends to zero

Time difference rms

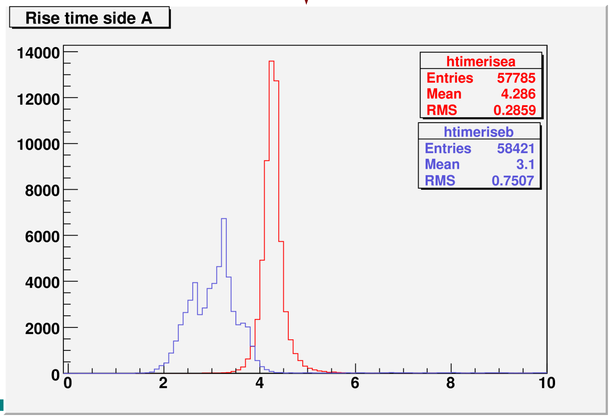
- Error bands show the time difference distribution rms
- Tell us if we can estimate, event by event, the Cherenkov fraction from the time difference



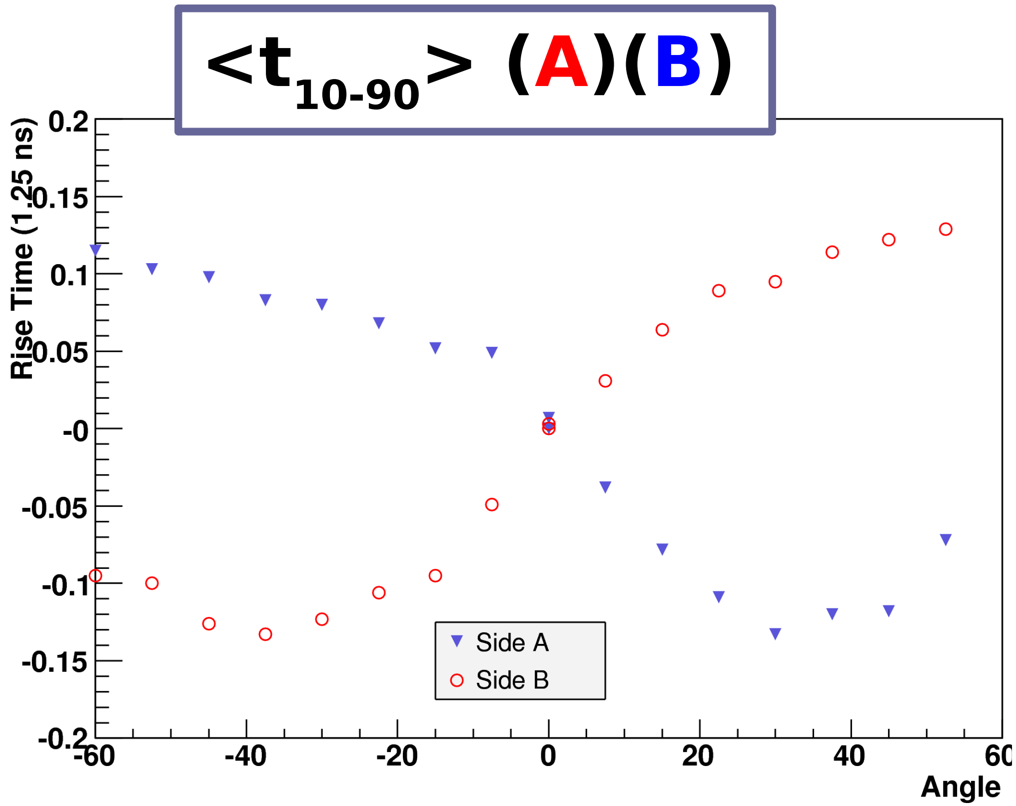
Muons: rise times (I)

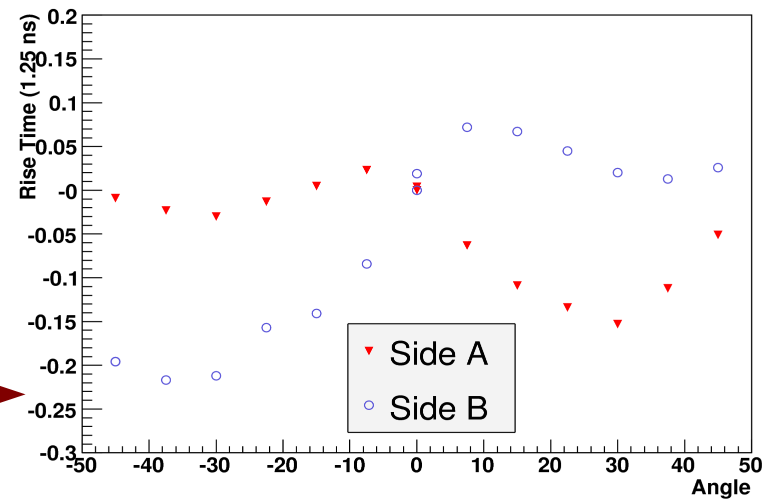


- Also for muons side B seems to be faster than side A
- Side B shows the same strange structure already seen for electrons



Muons: rise times (II)





- The rise times show minimum at (about) ± 30 degrees
- A quite flat zone is not as visible as it was for the electrons

Conclusions

(1) The time difference between side A and B has been studied as a function of the crystal angle for electrons and muons. Evidences of the fast collection of the Cherenkov light were found.

(2) The time structure of the signals on one side was also investigated by means of fitting and threshold crossing. In both cases we found:

I. Strange structures both in leading time and rise time distributions probably due to instrumental (FADC) effects.

II. A clear dependence of the signal rise times on the angle; this effect can be very interesting, allowing the detection of the Cherenkov light without needing information from both the crystal sides.

(3) The signal time structure seems to be able to provide useful information for the detection and the assessment of the Cherenkov light fraction.

I. Need to disentangle instrumental effects and signal properties