Test of the DIRC-like TOF prototype at SLAC CRT for SuperB project

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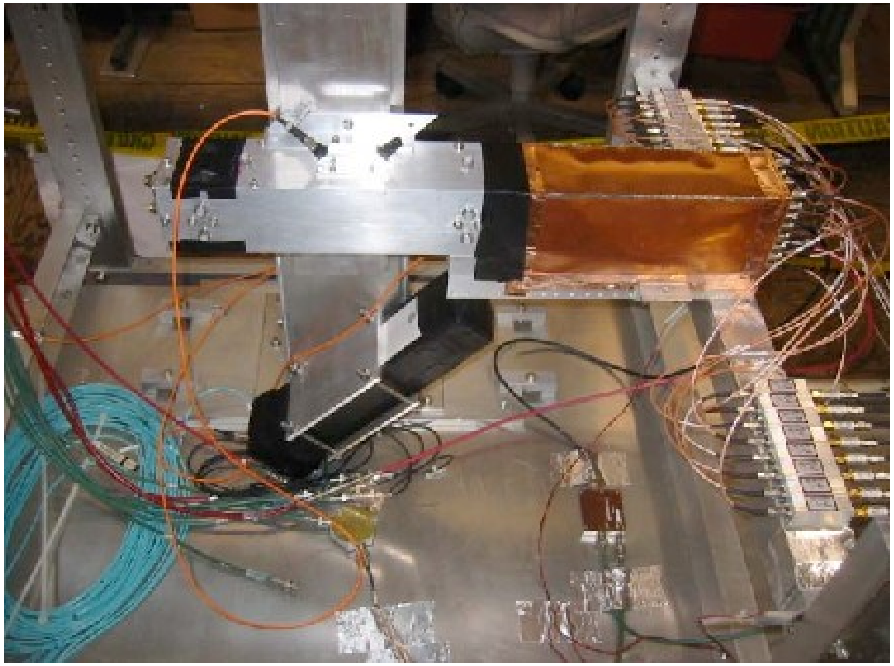
Frascati SuperB Workshop
April 4, 2011

Outline

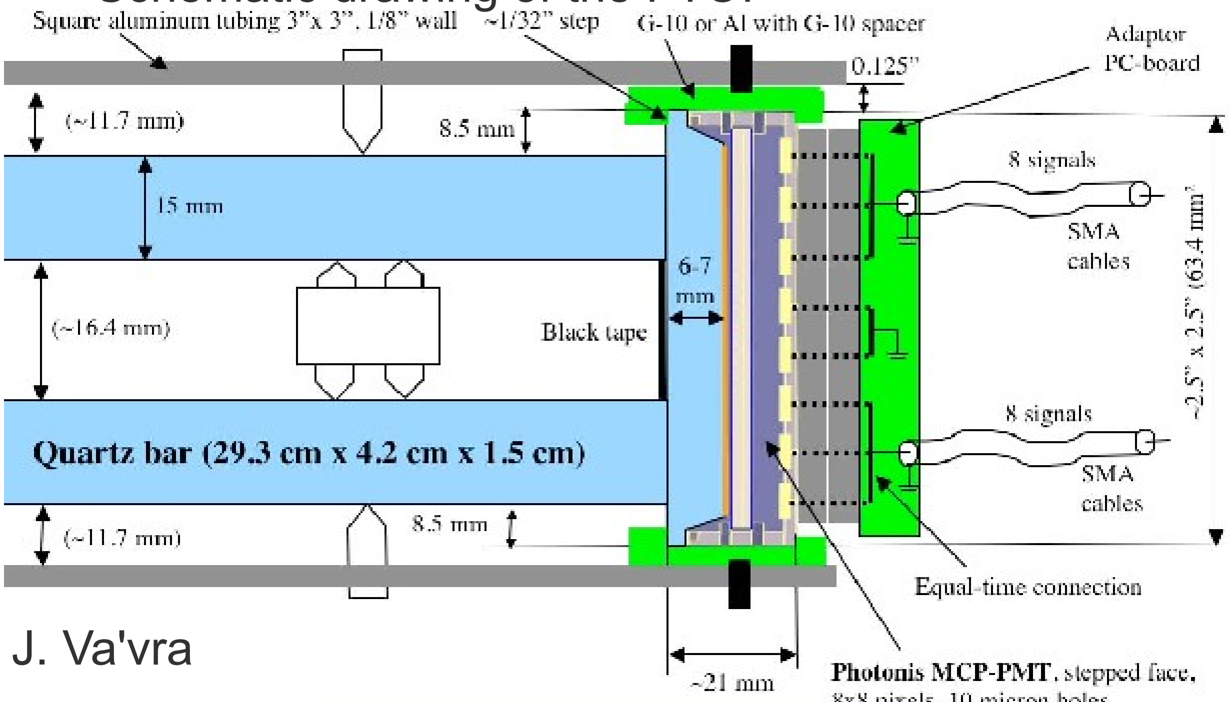
- The FTOF prototype
- Geant4 simulation of the FTOF prototype
- Analysis of the waveform. USBWC wavef. classification.
- Simulation of the MCP-PMT response
- Merging of the CRT and USBWC DAQs
- Muon track reconstruction with CRT
- Results from real data and comparison with simulations
- Conclusions

Prototype of the DIRC-like TOF detector

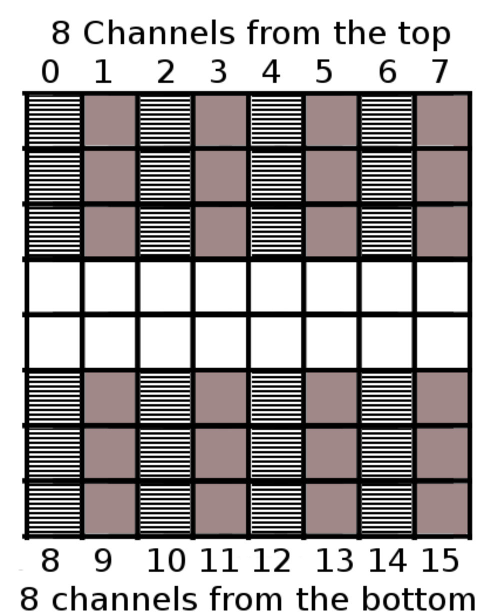


- Two quartz bars connected to one Photonis MCP-PMT (8x8 channels, stepped face, 10 micron holes).
- Tube operate at -2.7kV (gain ~ 7.0×10^5).
- 16 channels connected to the USBWC electronics developed by LAL and CEA/IRFU electronics team.
- Amplifiers (40dB).
- Filters (600MHz bandwidth).
- Installed at SLAC CRT in Fall 2010.

Schematic drawing of the FTOF



MCP-PMT pixel map



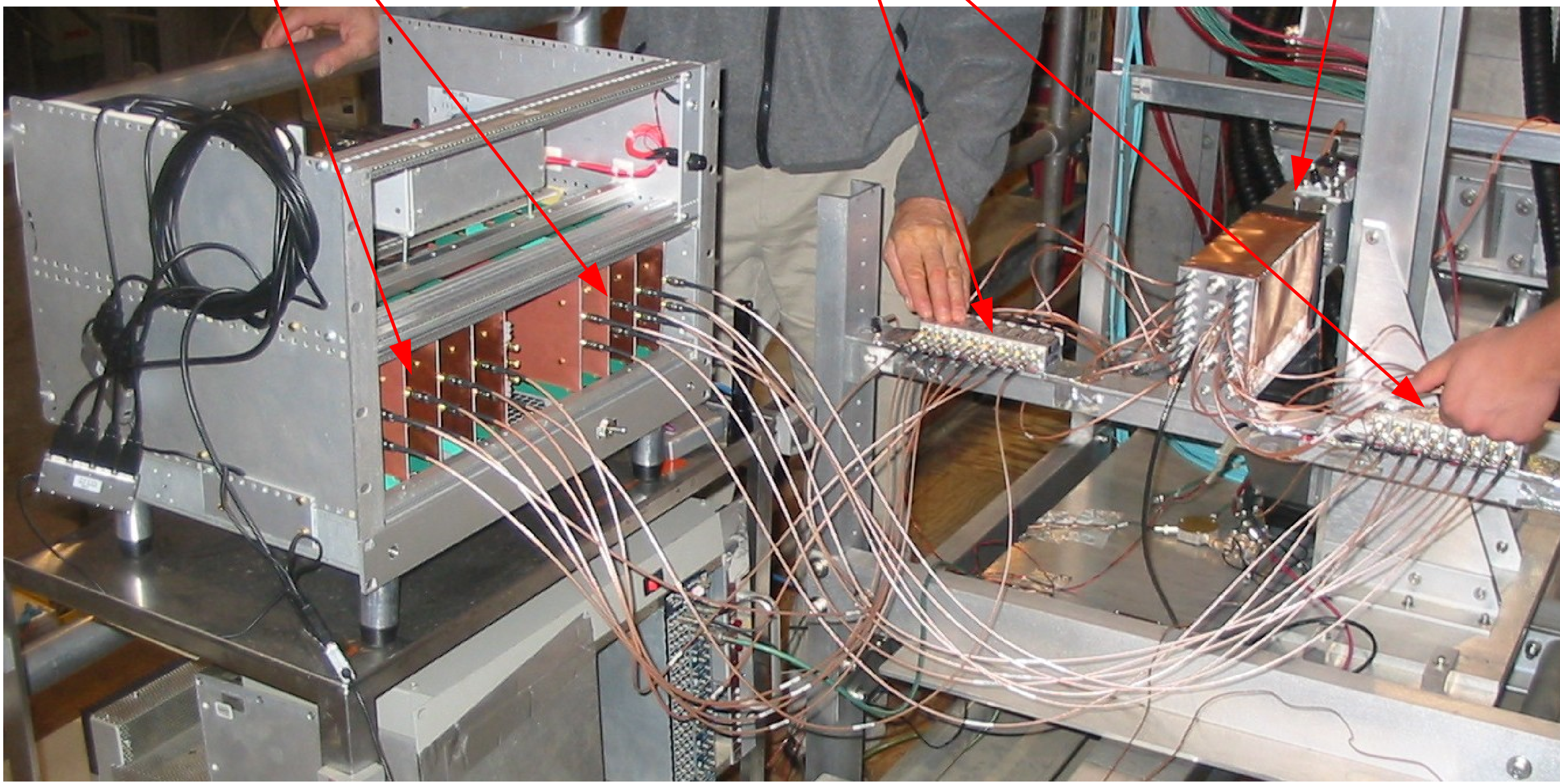
J. Va'vra

Experimental Setup

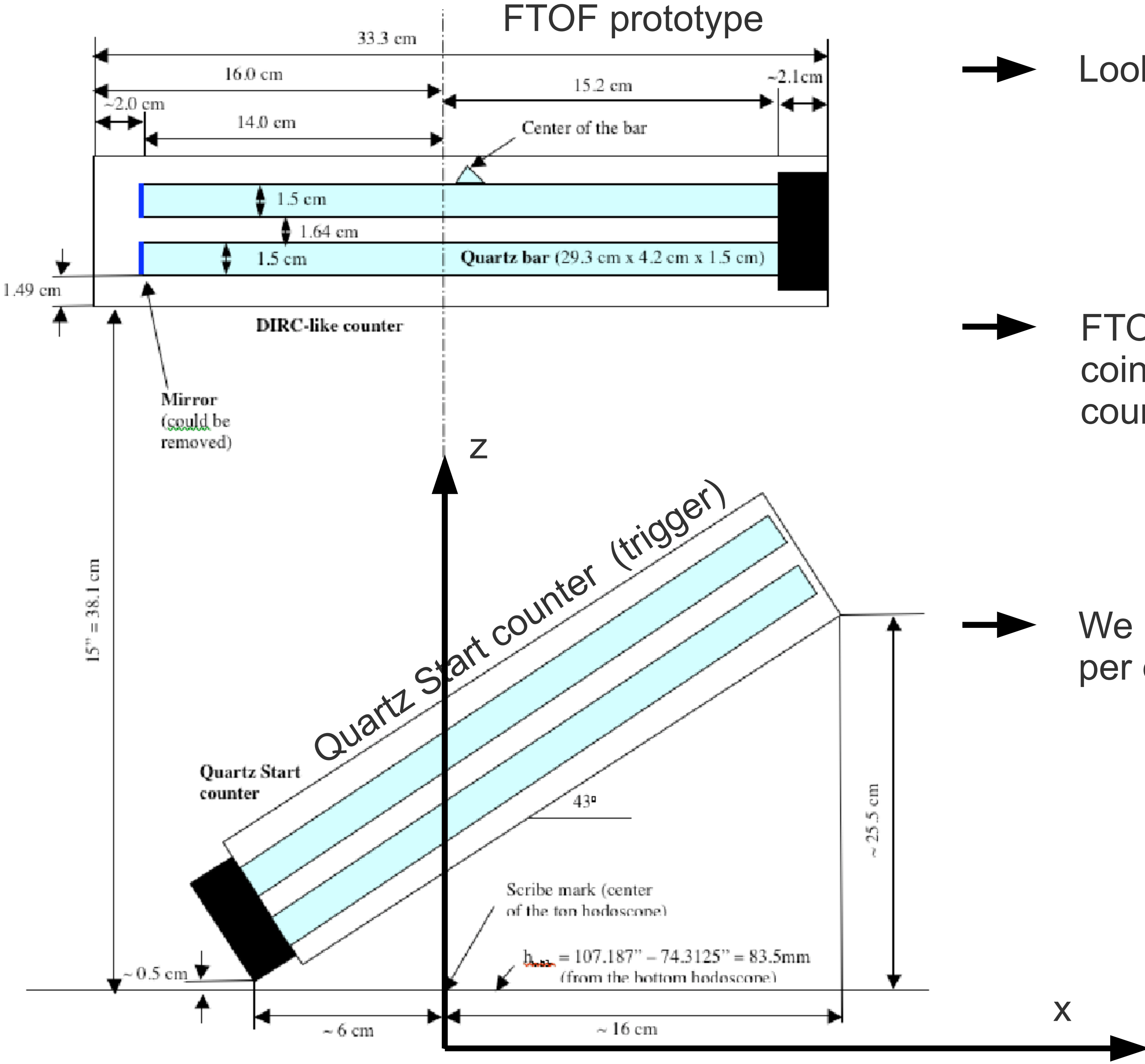
8 USBWC = 16 Channels

Amplifiers (40dB) and
Filters (600MHz bandwidth)

FTOF
prototype

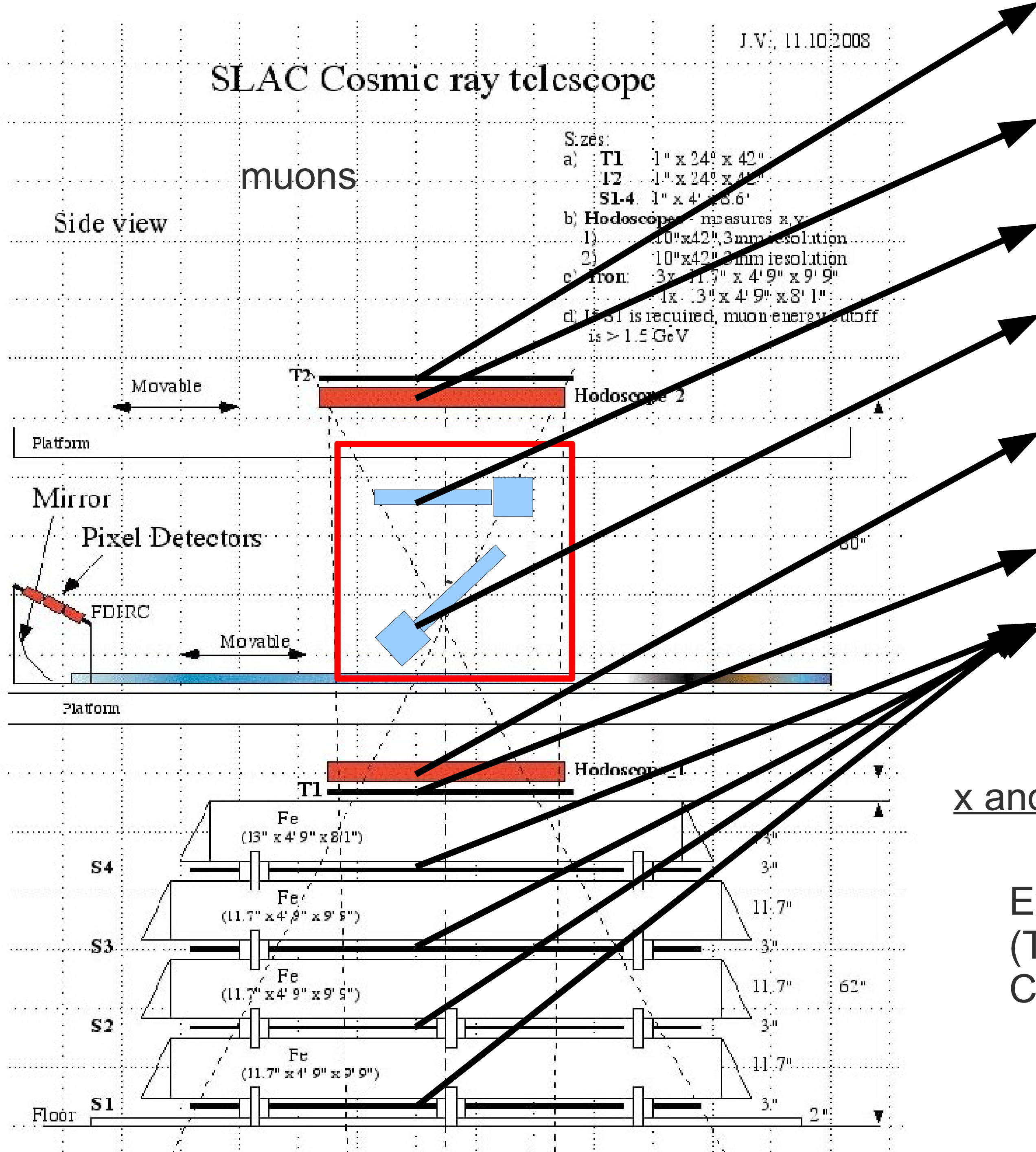


Geometry of the experiment



- Looking for cosmic muons
- FTOF prototype works in coincidence with Quartz Start counter.
- We record all 16 waveforms per event.

CRT



Top trigger counter (T2)

Top x and y hodoscopes(2)

FTOF prototype

Quartz start counter (QSC)

Bottom x and y hodoscopes(1)

Bottom trigger counters (T1)

Stack counters for momentum measurements

<u>x and y position resolution is ~ 3 mm</u>

Events with triple coincidence (T1 x QSC xT2) recorded by CRT DAQ.

All data taking period can be divided into 4 runs

RUN1	old setup	old software
RUN2	old setup	new software*
RUN3	new setup**	new software
RUN4	new setup	new software + channel 15 + new laptop*** + veto****

RUN1
total run time 1432 hours
Total number of entries USBWC 575164
GMT time START run : 5.10.2010 0:02:39
GMT time END run : 3.12.2010 16:10:34

RUN3
total run time 428 hours
total number of entries USBWC 163265
GMT time START run : 06.01.2011 18:36:31
GMT time END run : 24.01.2011 15:01:31

RUN2
total run time 719 hours
total number of entries USBWC 305677
GMT time START run : 7.12.2010 18:41:29
GMT time END run : 6.01.2011 17:56:36

RUN4
total run time 1414 hours
total number of entries USBWC 378347
GMT time START run : 28.01.2011 18:21:19
GMT time END run : **Ongoing**

* USB buffers purged every 500 events. To ensure synchronization between diff. boards.

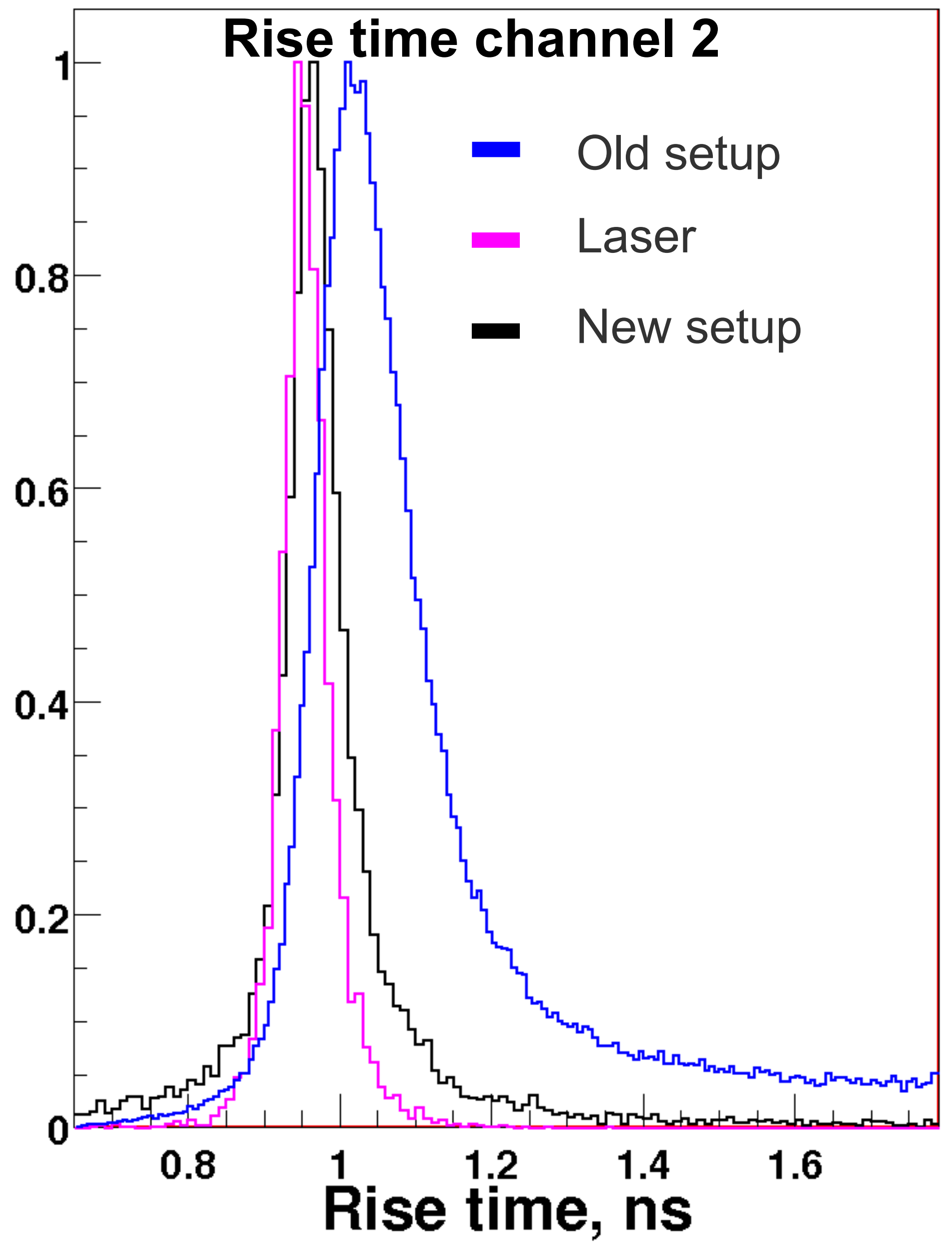
** **Insert two 0.005" mylar sheets between bars and MCP-PMT to reduce # of photo electrons (p.e.)**

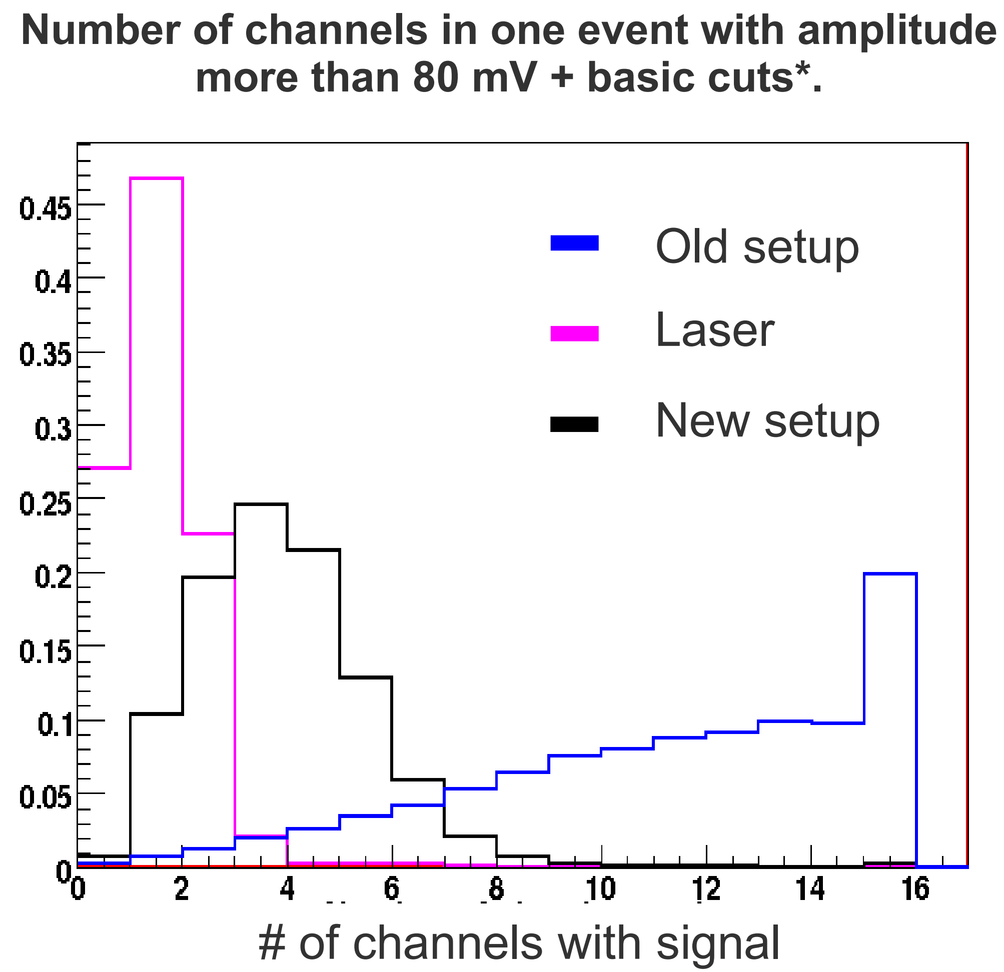
*** The DAQ laptop has also been upgraded. The new one is faster and logfiles don't show anymore USB errors (there were a few per day with the old PC)

**** CRT has a dead time around 1s; the veto allows us to stop USBWC DAQ during this time.

Effect of the mylar absorber. (Upgraded setup).

We add a mylar sheets between MCP-PMT and quartz bars. Thanks to that the number of p.e. should be reduced by a factor of ~5.

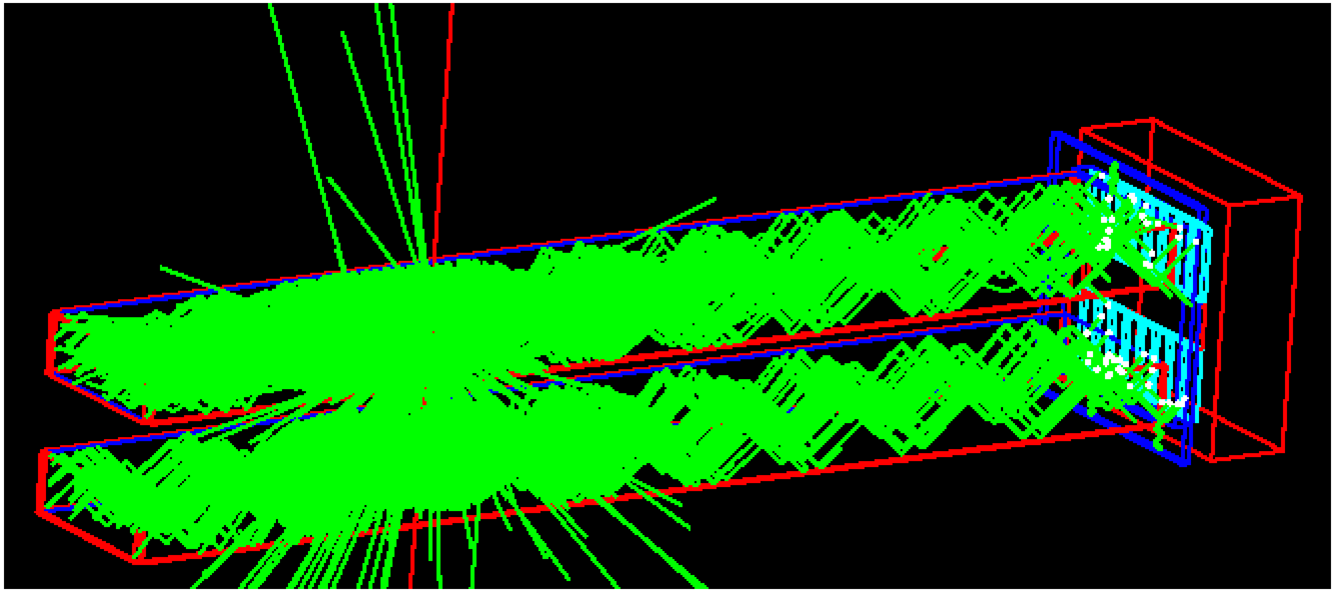




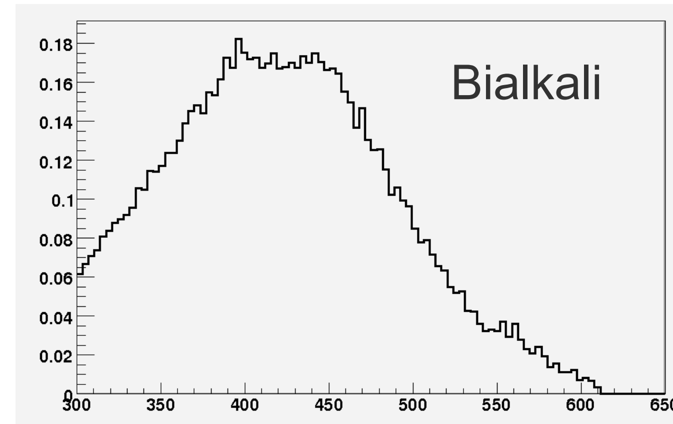
Average number of channels with signal is 4. This is good compromise between running the tube in "clean" conditions and have a reasonable statistic.

* definition of the basic cuts can be found on slide number 31

Geant4 Simulation of the FTOF prototype



QE + electron collection efficiency (14%)

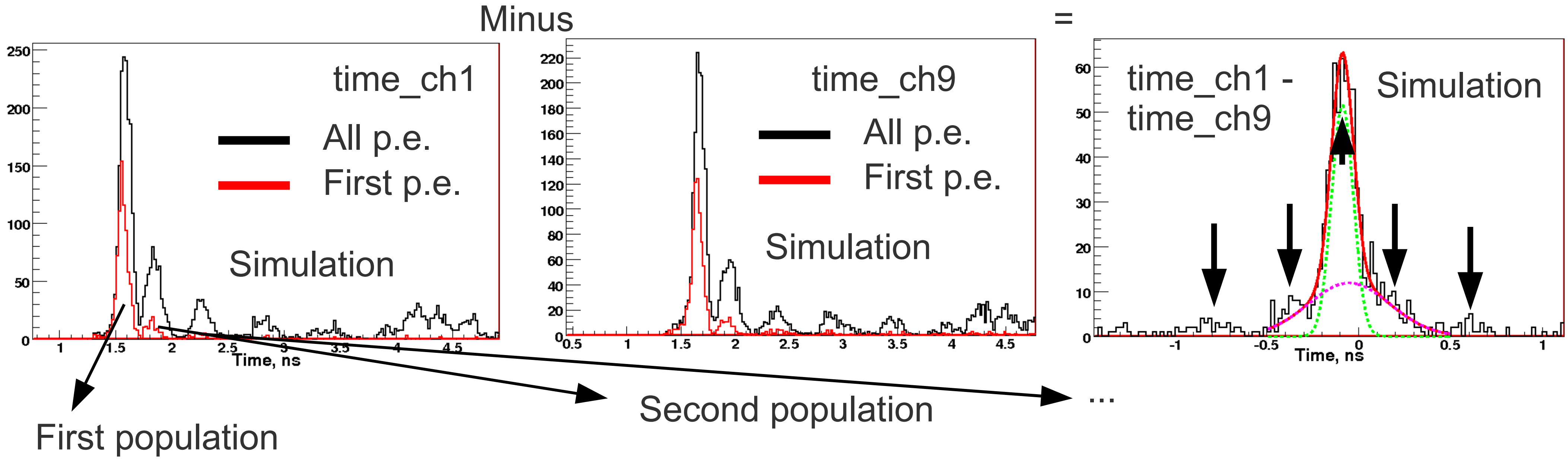


λ

- 16 channels 6 x 18mm each
- Transit Time Spread of the MCP – PMT (TTS) = 35 ps / channel
- Electronics resolution = 10 ps / channel
- Bialkali photocathode
- **electron collection efficiency 14% = 70.0%(coll eff of the PM) * 1/5(mylar sheets)**
- Time of first p.e. arriving is taken as a time measurement for a given channel.

  Simulation of the waveform based on the MCP-PMT response on single p.e. (laser run)
- Simple muon generator developed

Why do we fit with two Gaussian?



- Several possible paths exist to reach same channel => several different times measured (peaks on the histogram above).
- Definition: the p.e. which belongs to a given peak are from one population.
- Due to geometry of the prototype (bars with 29.3 x 4.2 x 1.5 cm) the time distances between different populations are small, unlike in the real FTOF detector.
- Time difference between two channels will have two components: narrow and wide. Narrow component corresponds to time difference between p.e. from same populations, while wide component corresponds to time difference between p.e. from different populations.
- **We consider RMS(of narrow component)/sqrt(2) as the time resolution per channel.**

Waveform analysis(1)

- Each waveform (wf) is made of 256 samples with 312.5 ps between two consecutive points.
- Offline we add 5 additional equidistant points in between two sampling points, which are then joined by a straight line.
- We use the first 6 sampling points to compute average base-line amplitude, which is then subtracted from the waveform.
- For each waveform we define 5 quantities which are used in the analysis.

Amplitude	Positive amplitude of the signal
CF – time (constant fraction)	time measured at given fraction of the amplitude (at rise / fall edge)
Rise time	CF-time between 10% and 90% of the amplitude (at rise edge)
Width	CF-time between rise and fall ages taken at 50% of the amplitude
Wf identification number (wfID)	integer number which correspond to a given shape of the wf

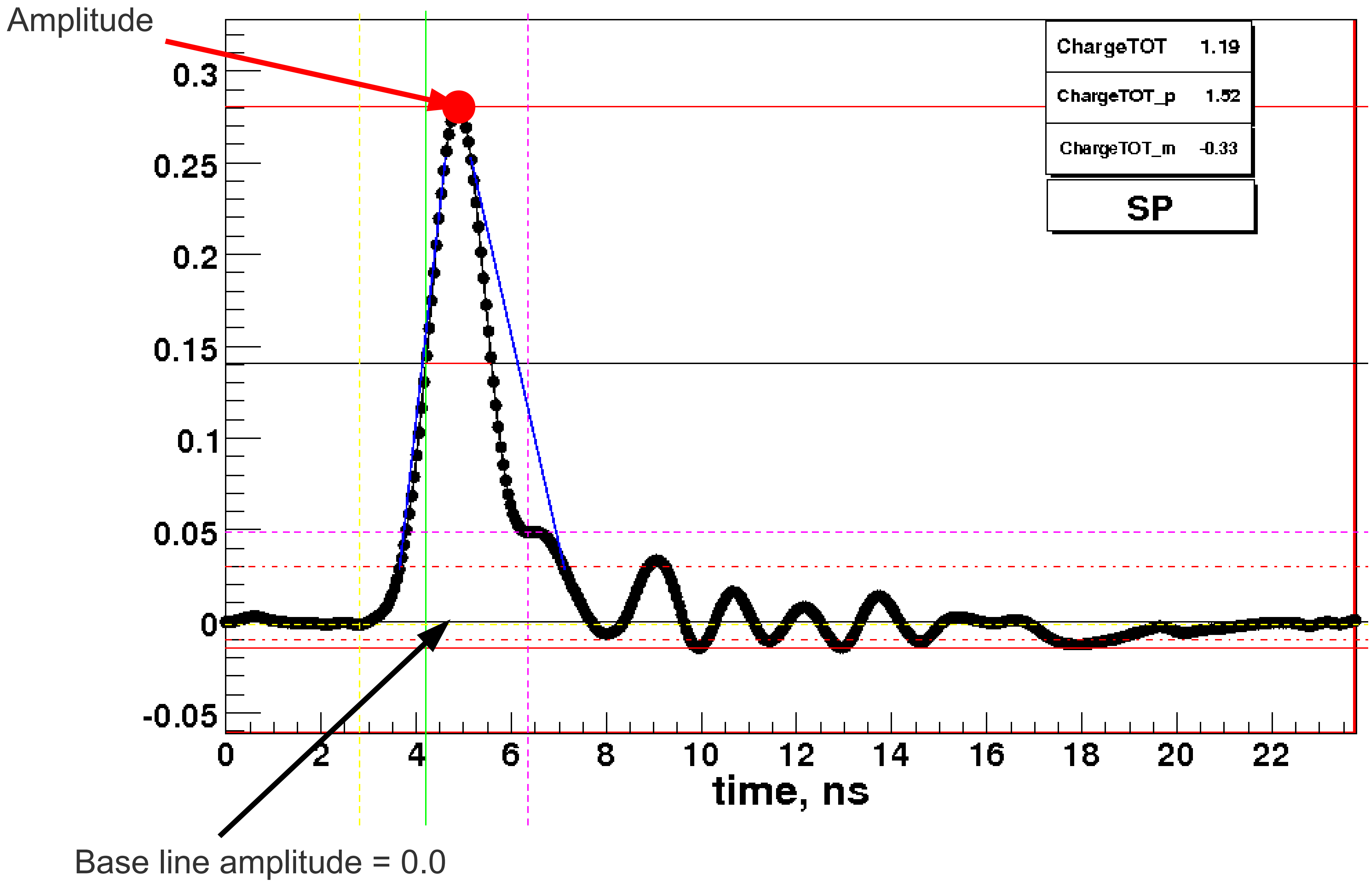
- We define three main shapes of the signal:

Shape	wfID
Crosstalk-like	0
Single peak- like	1
Multi peak	2

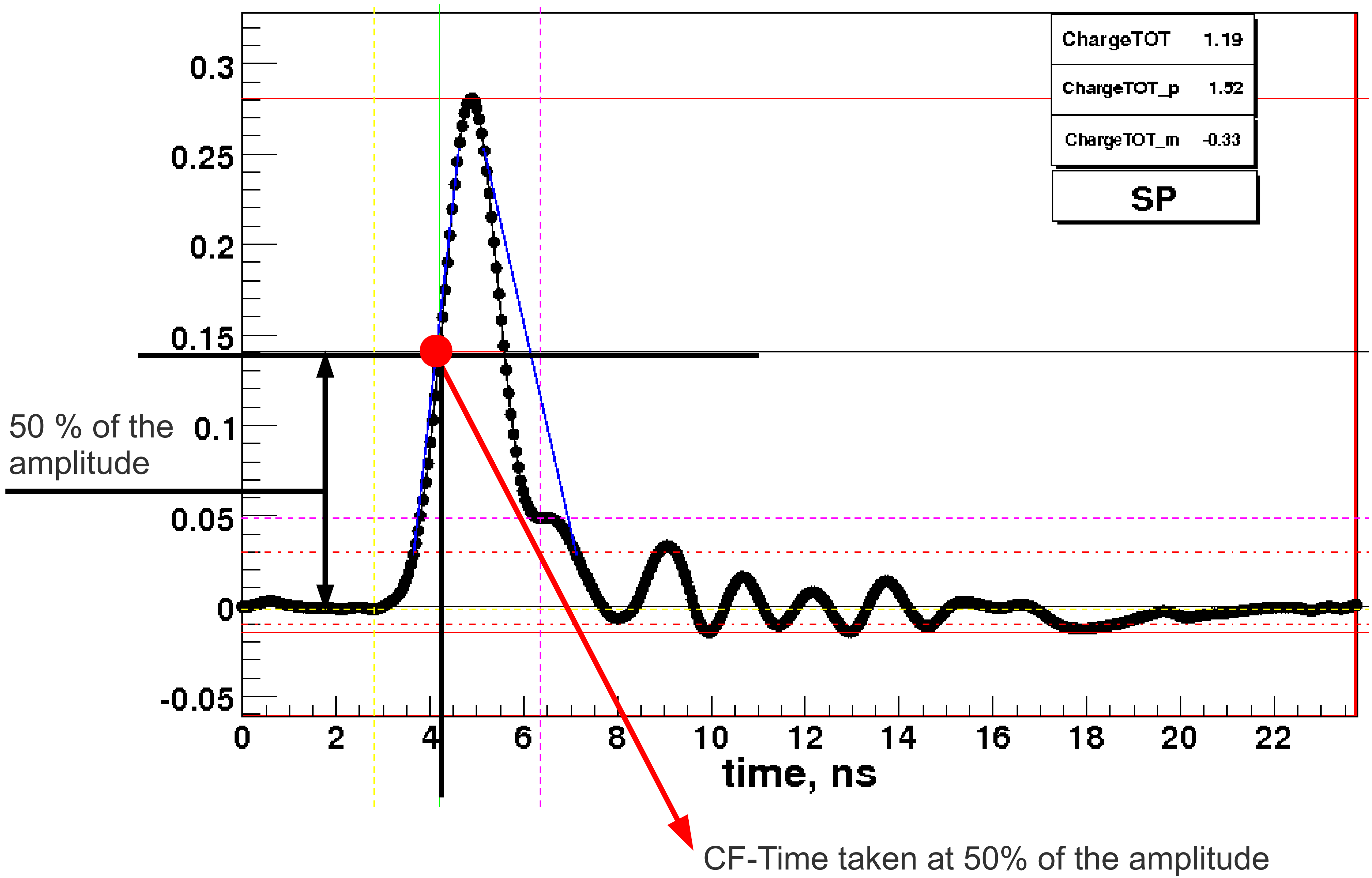
- Waveform analyzer uses three inputs:

Signal threshold = 30mV
Crosstalk threshold = -10mV
Multi peak fraction = 0.8

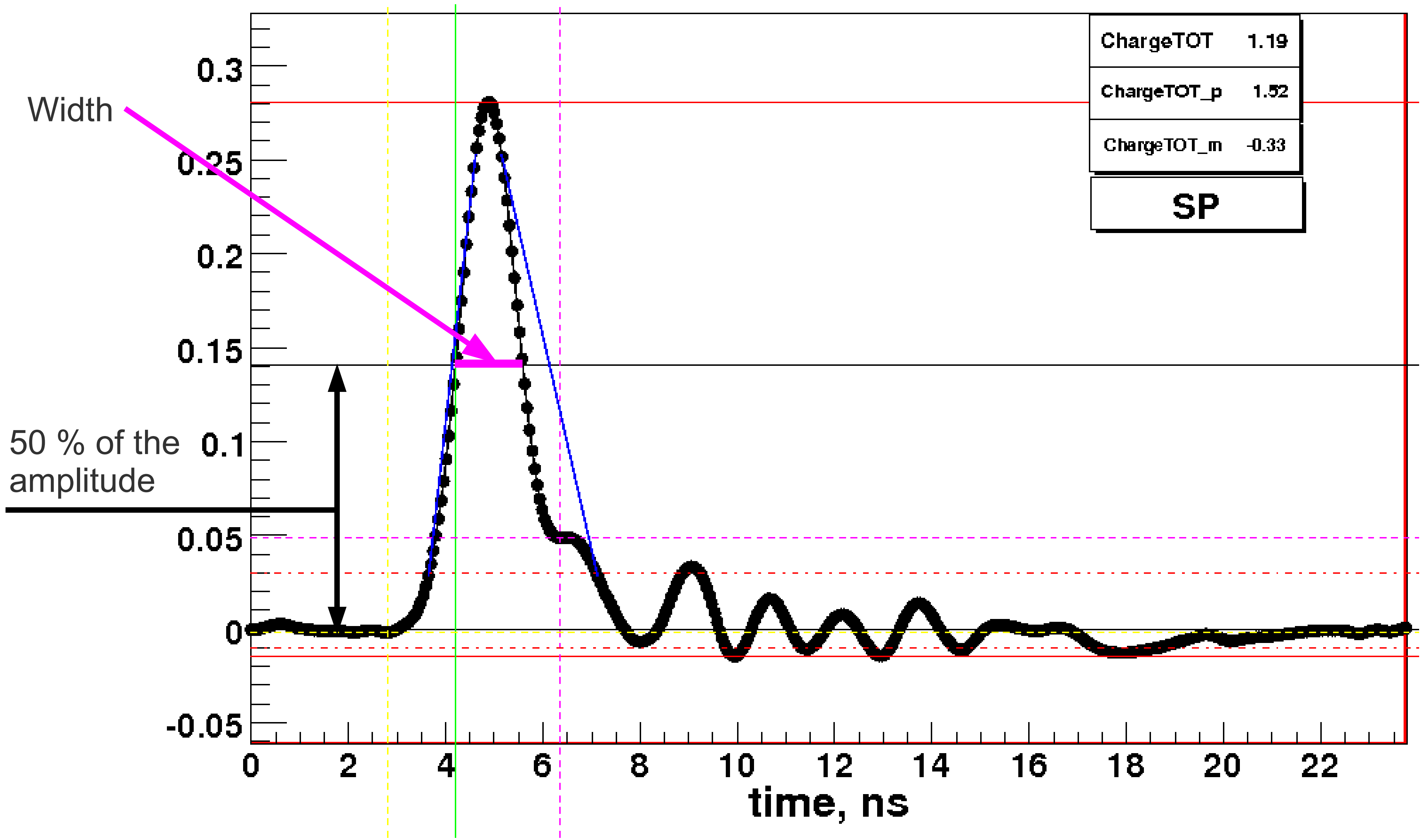
Quantities of the wf which we are using in our analysis



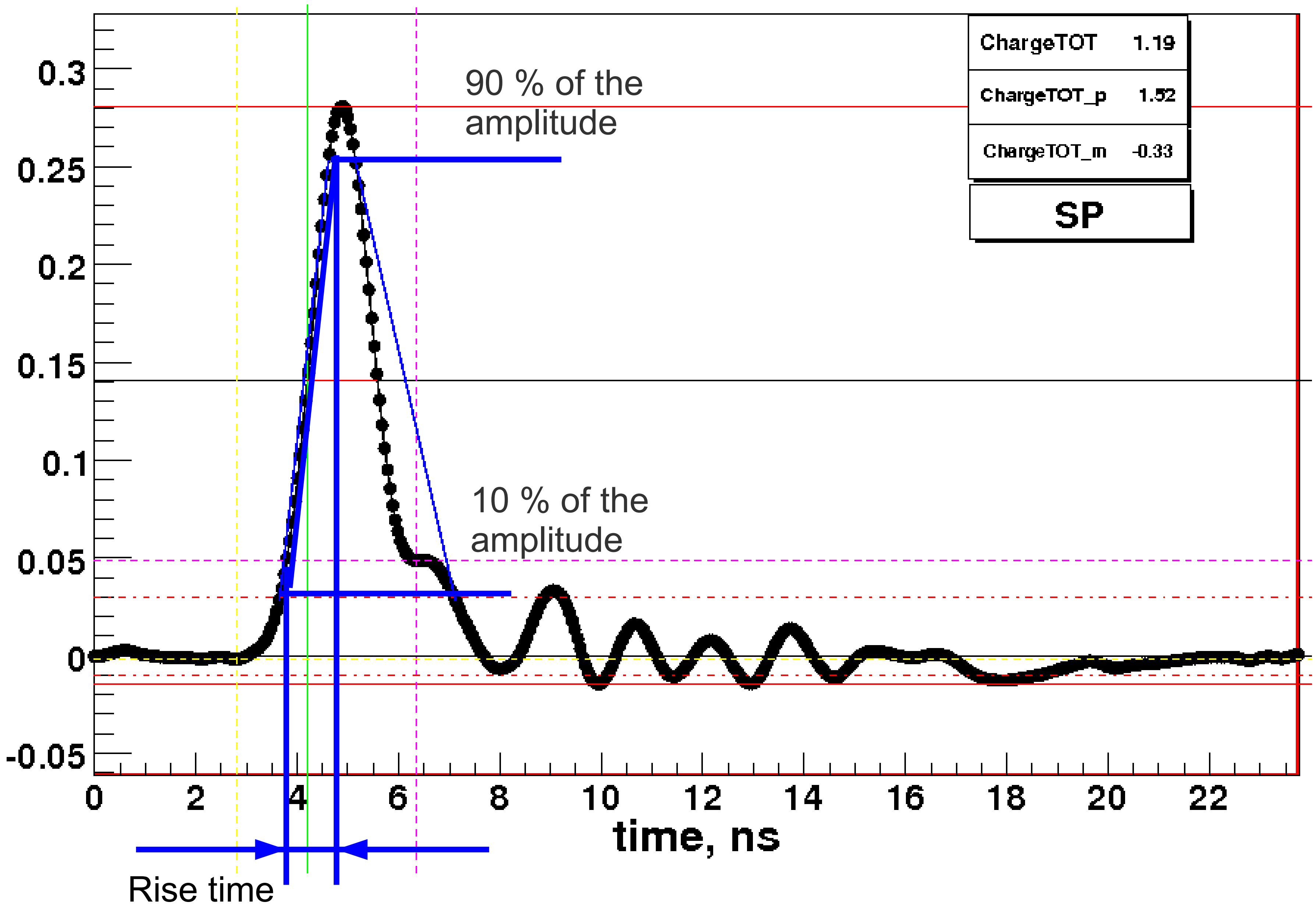
Quantities of the wf which we are using in our analysis



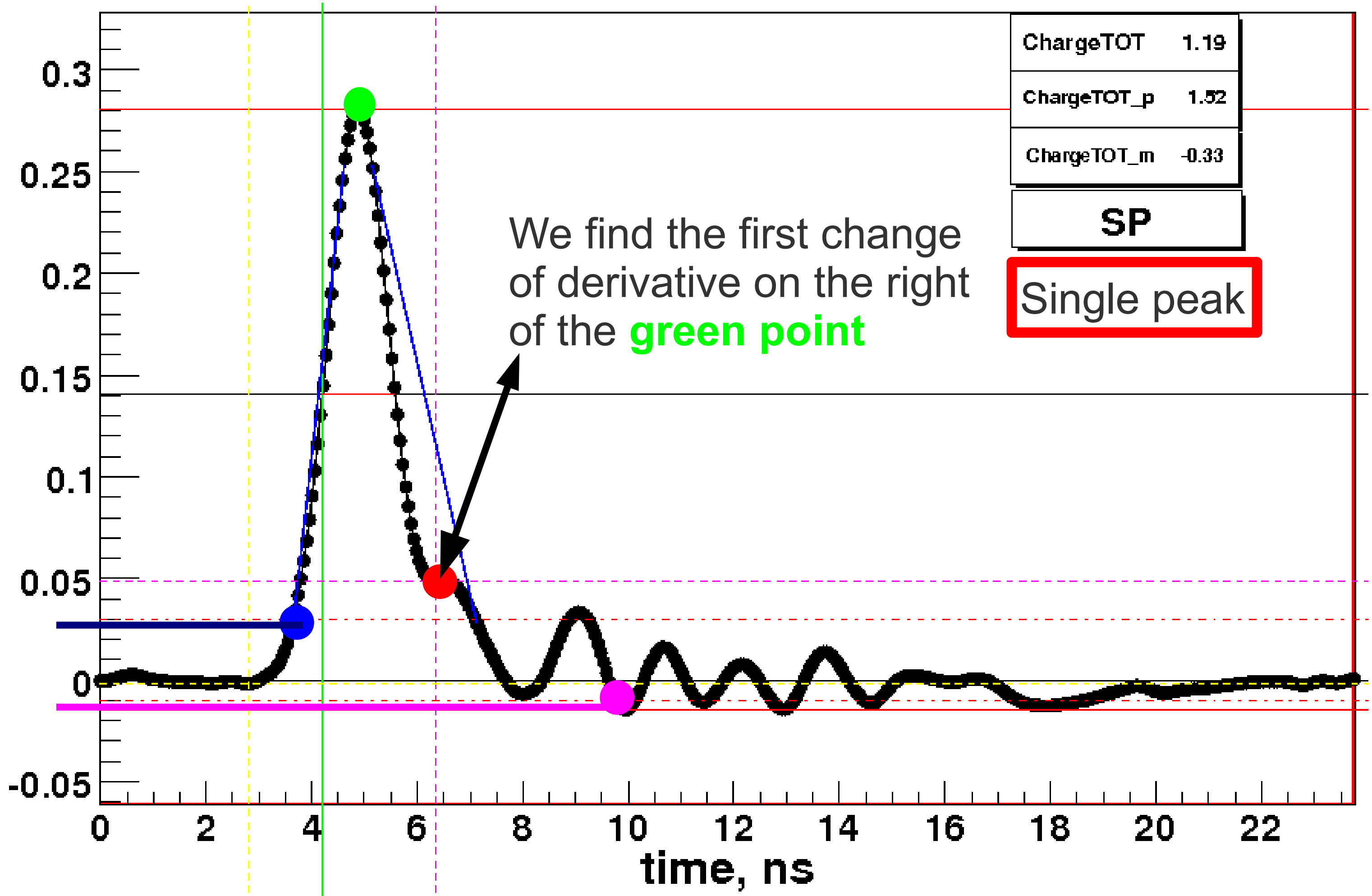
Quantities of the wf which we are using in our analysis



Quantities of the wf which we are using in our analysis



Waveform analysis algorithm



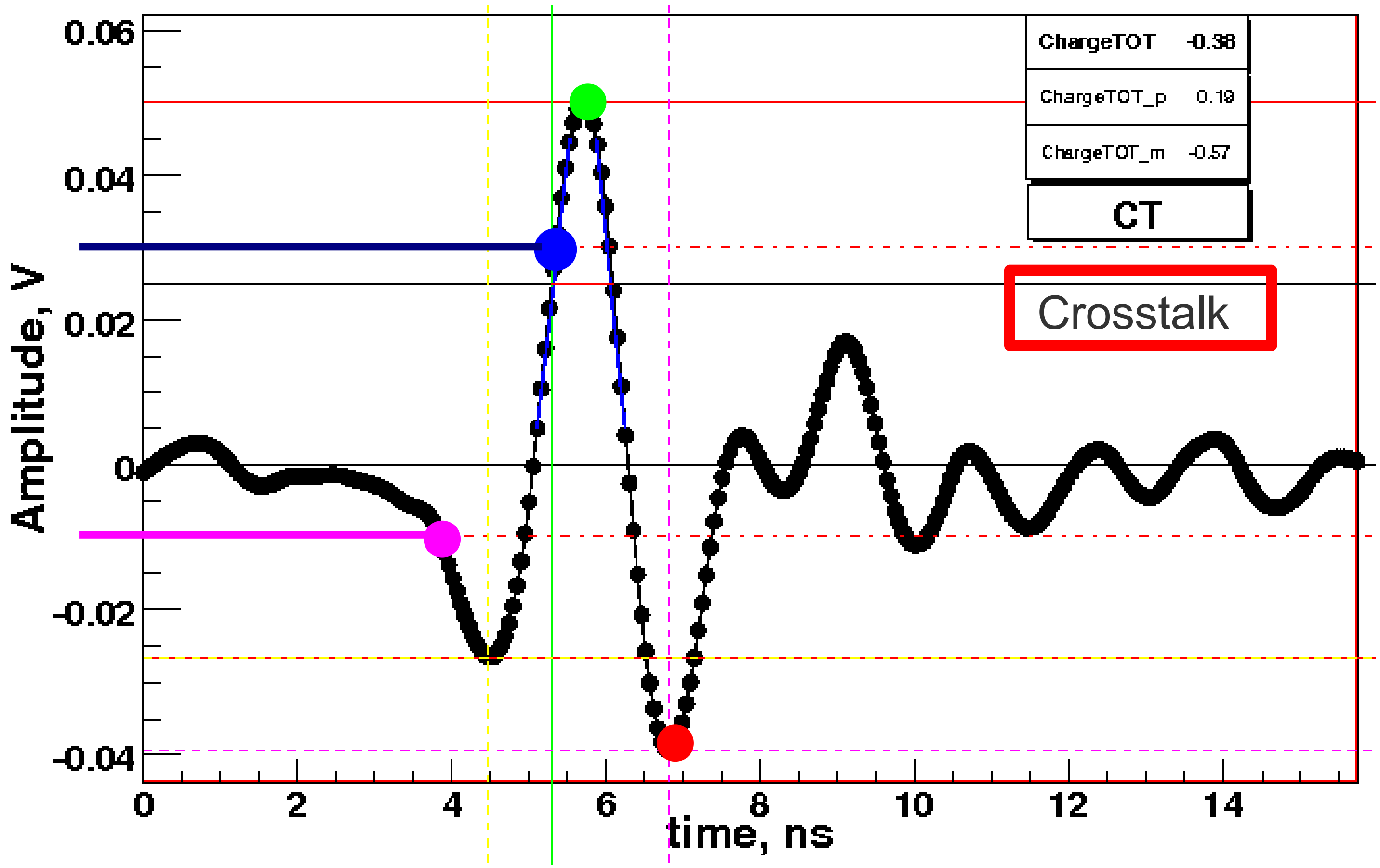
- **Signal threshold = 30mV**
- **Crosstalk threshold = -10mV**
- **Multi peak fraction = 0.8**

The definition of the single peak:

(Time of the Signal threshold < Time of the Crosstalk threshold) && (Not a multi peak*)

*Defined later

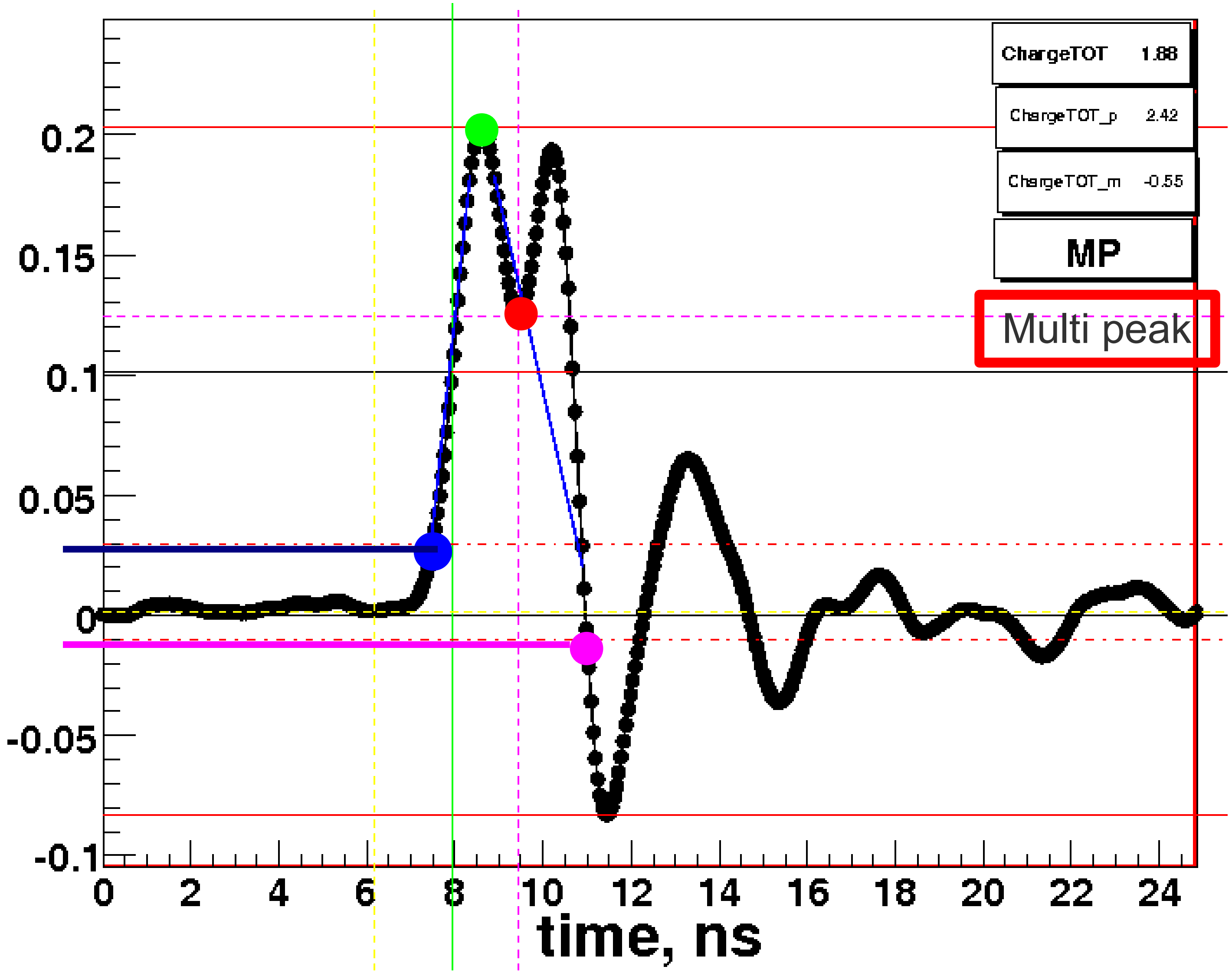
Waveform analysis algorithm



The definition of the Crosstalk :

(Time Signal threshold > Time Crosstalk threshold)

Waveform analysis algorithm



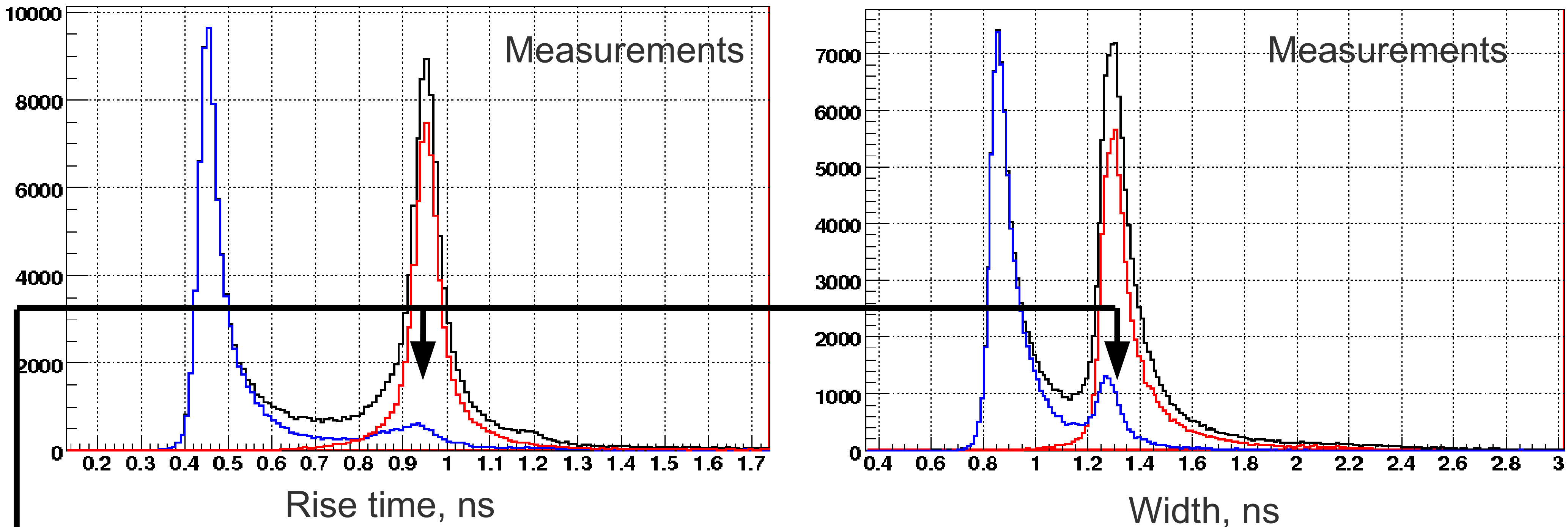
The definition of the Multi peak:

(if red point has amplitude bigger then 20% of the green point) && (not a crosstalk)

Test of the waveform analysis algorithm

- Signals with all shapes
- Crosstalk - like shape
- Single peak - like shape

- Signals with all shapes
- Crosstalk - like shape
- Single peak - like shape



Crosstalk - like and single peak - like signals have their own typical values of the rise time and width. As we can see from the histograms above these quantities can be used for distinguishing between Crosstalk - like and single peak - like signals.

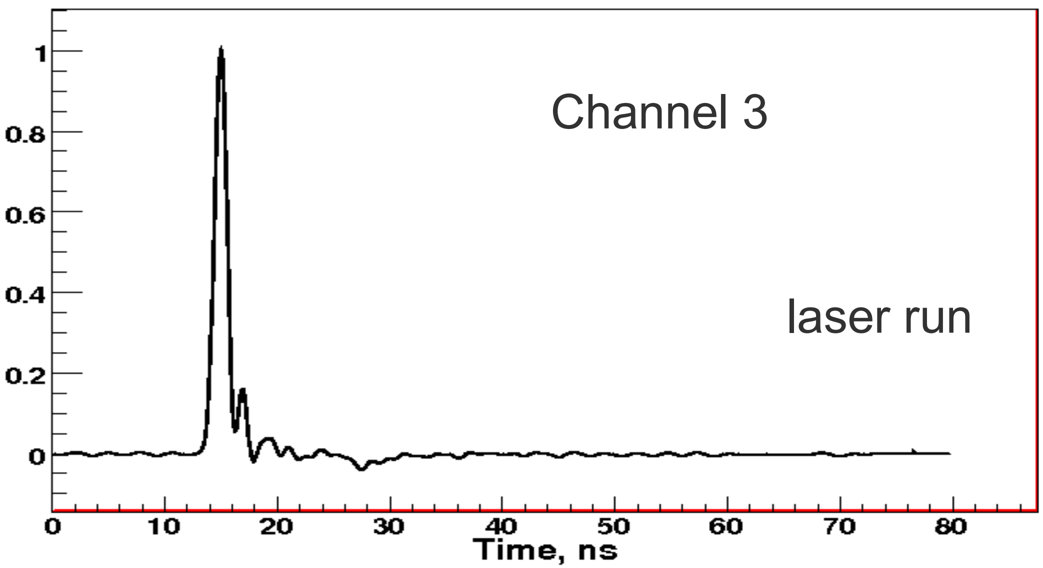
Signals with a normal rise time and width can have crosstalk ahead and so recognized as a crosstalk -like signals.

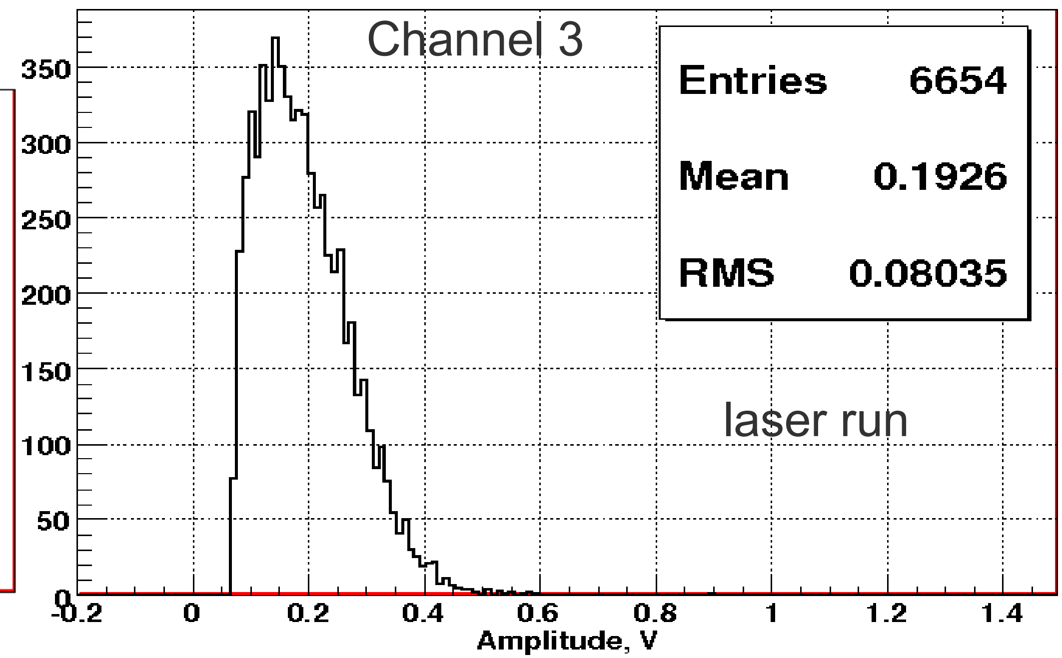
Waveform simulation

- From laser run we extract information about MCP-PMT response on single p.e. (average waveform shape and amplitude distribution)

Amplitude distribution of the signal from single p.e.

Average shape of the signal from single p.e





- Each p.e. in the simulation creates a signal with the shape and amplitude drawn above. The time of the p.e. defined by Geant4 ⊕ 35 ps (TTS) smearing. The total waveform (wf) is the sum of wf's from all p.e.

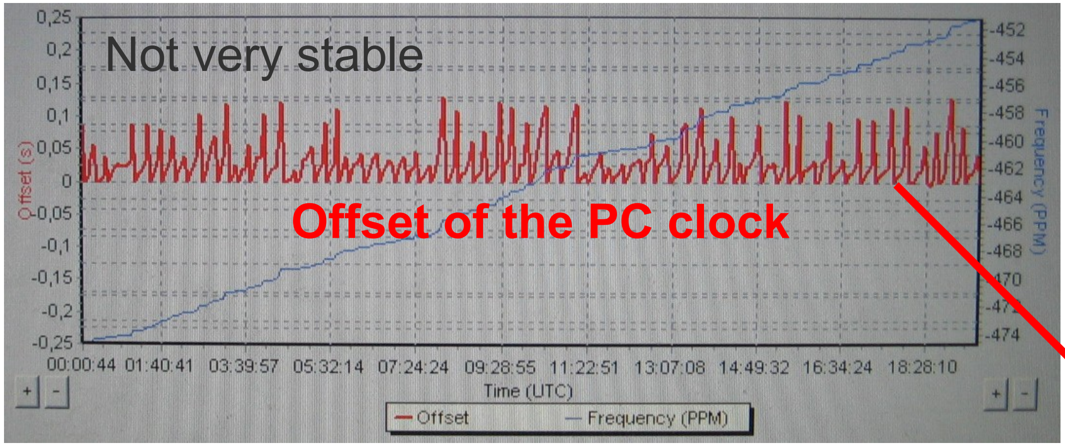
- White noise generated on top of the total wf. The amplitude of the noise is generated as a Gaussian with mean = 0, RMS 1.3- 1.5 mV (values taken from the data) .

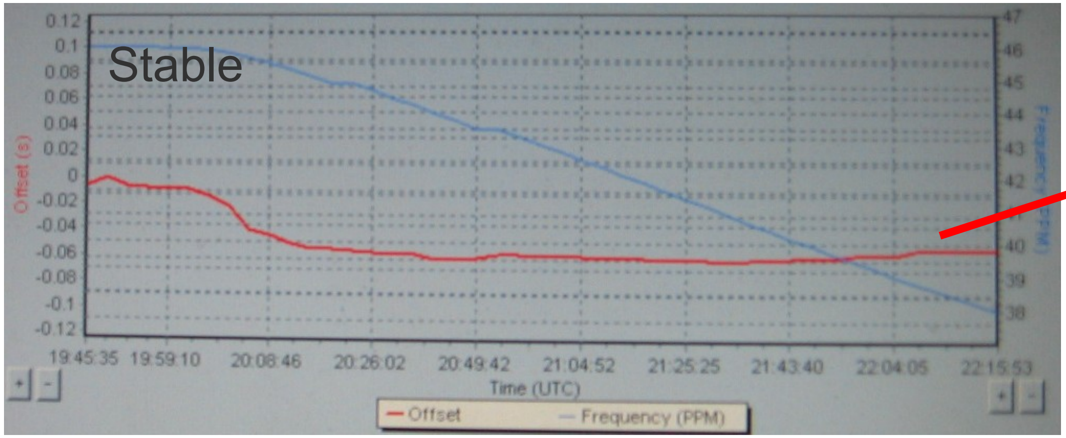
- Crosstalk and charge sharing are not taken into account (yet?).

Merging USBWC and CRT DAQ systems

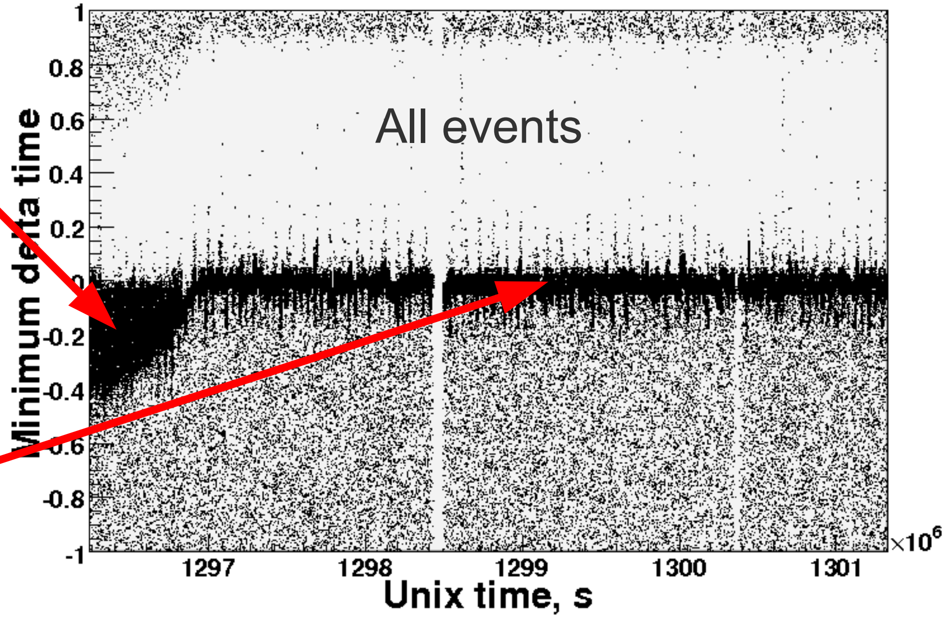
- USBWC and CRT DAQ systems are independent from each other.
- We use timestamps of the event to merge information from CRT and USBWC
- In order to have precise and stable timing both DAQs update their time from ntp server.
- We use NTP monitoring in order to control precision of the time.

NTP monitoring



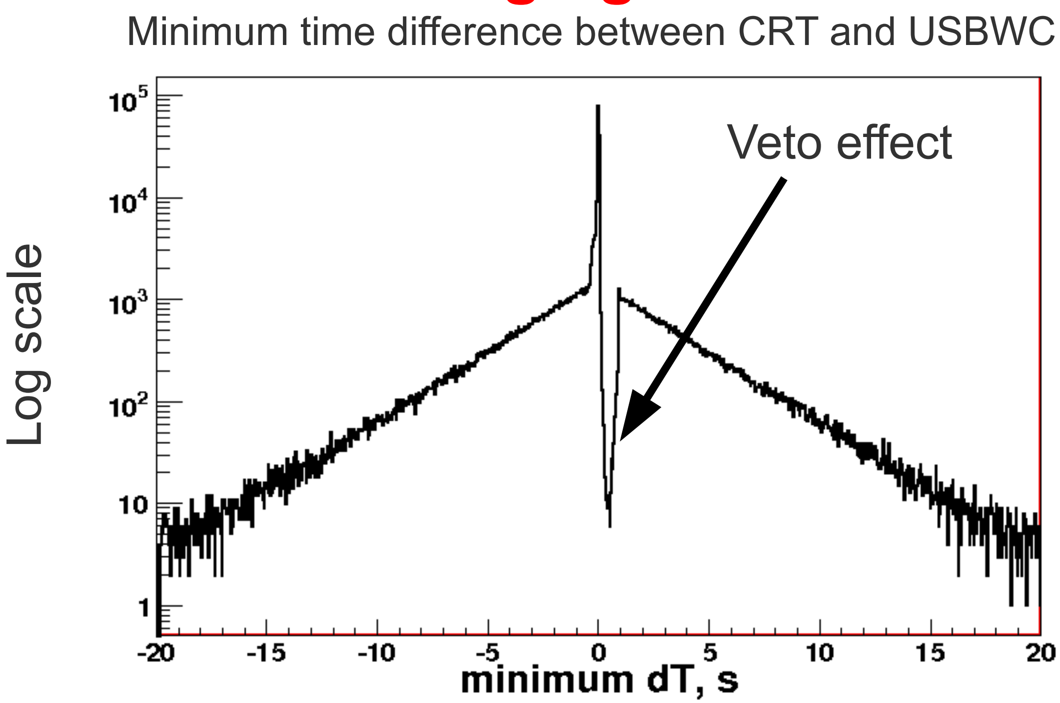


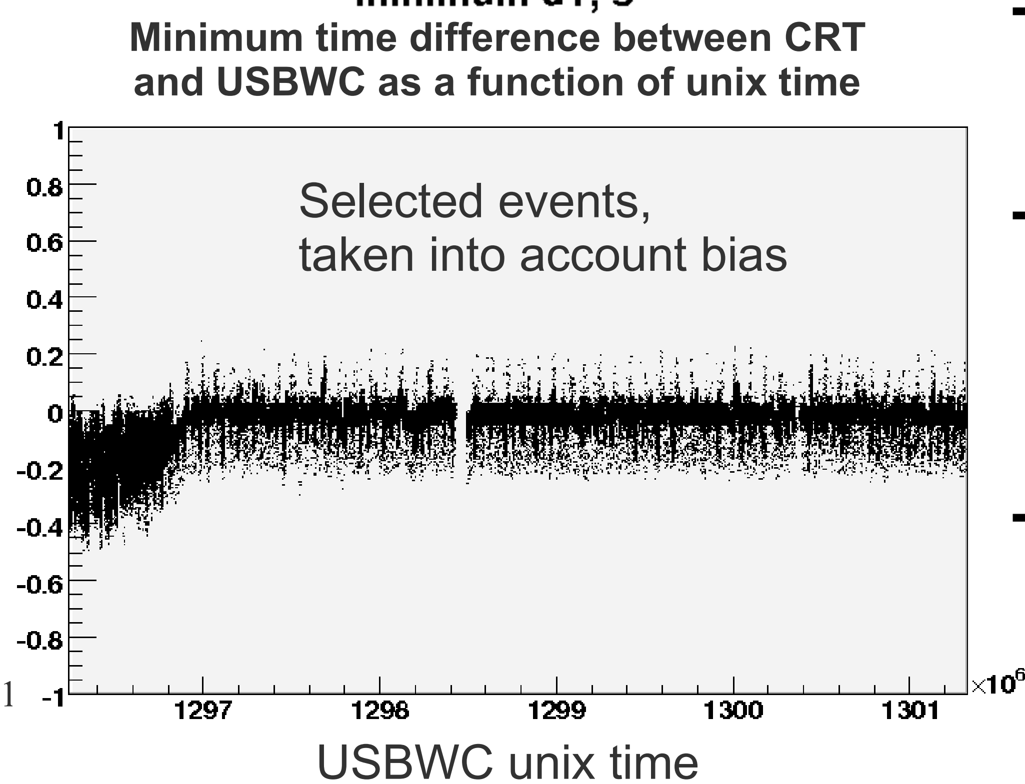
Minimum time difference between CRT and USBWC as a function of unix time



After some time of running the clock of the USBWC DAQ laptop stabilized.

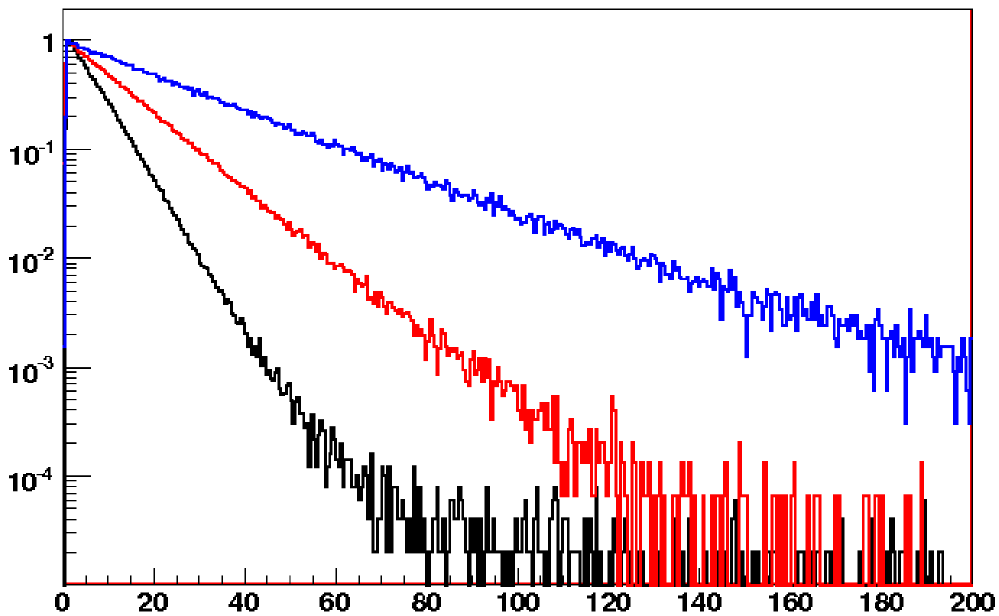
Merging USBWC and CRT DAQ systems



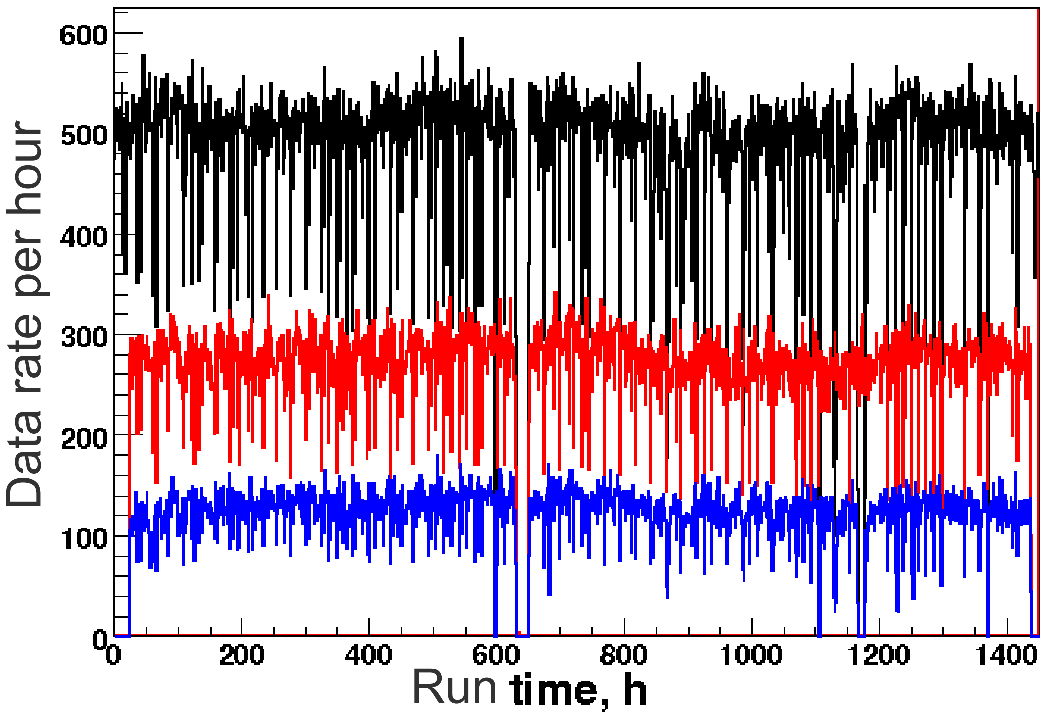


- The peak on this histogram correspond to the coincident events in the CRT and USBWC.
- The peak contain 50% of all the USBWC events.
- Long exponential tail correspond to events which are not in coincidence.
- The peak is broaden due to the PC time drift.
- Using information about mean time difference between CRT and USBWC as a function of time we can correct this bias.
- Taking into account the bias, unix time difference between CRT and USBWC should be less then 0.2 s.

Merging USBWC and CRT DAQ systems



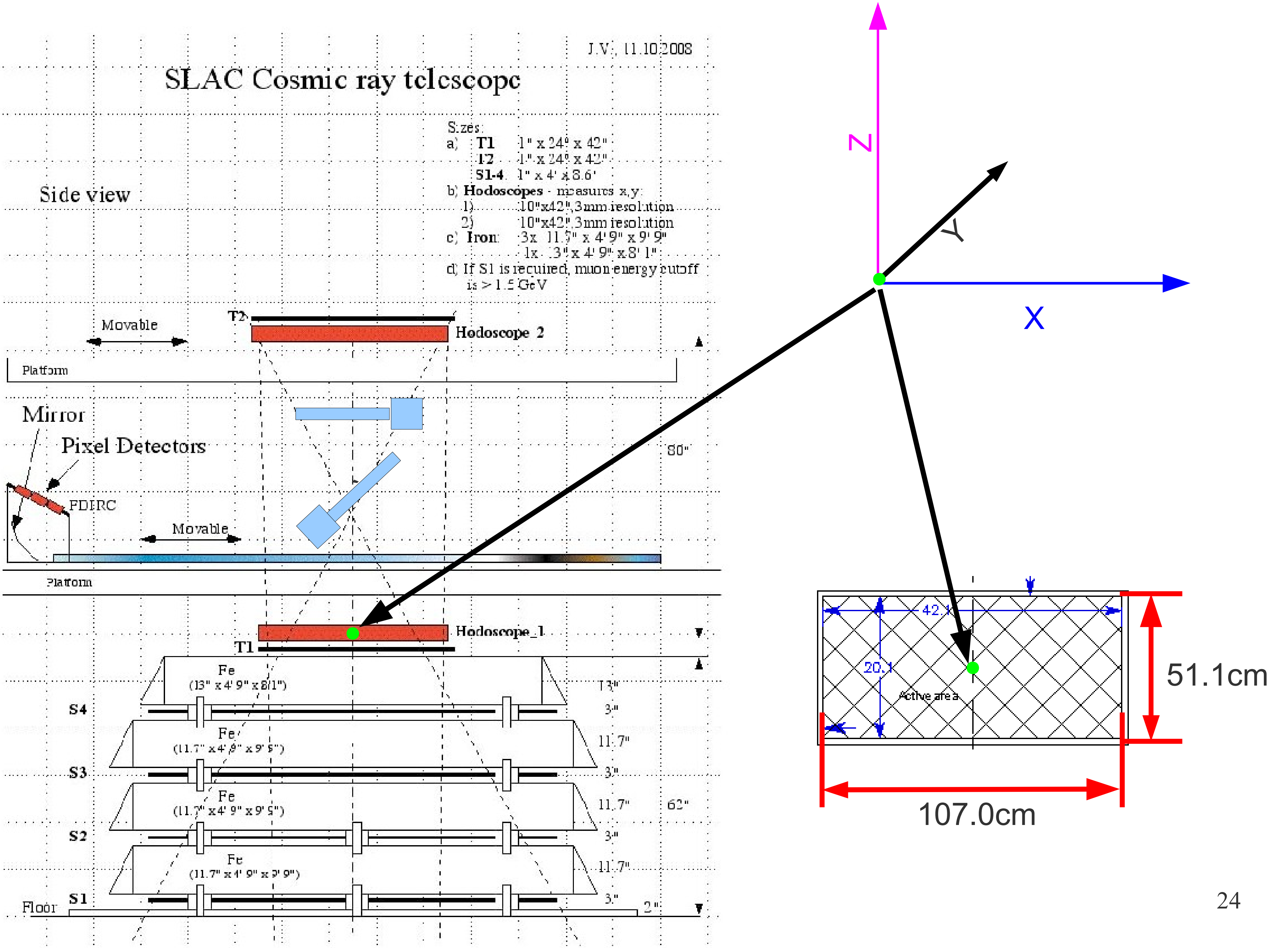
Time difference between two consecutive events, s



Color in the plots	System	Rate events/h
black	CRT	490
red	USBWC	275
blue	merged	130

For the moment we do not know why the rates are so different

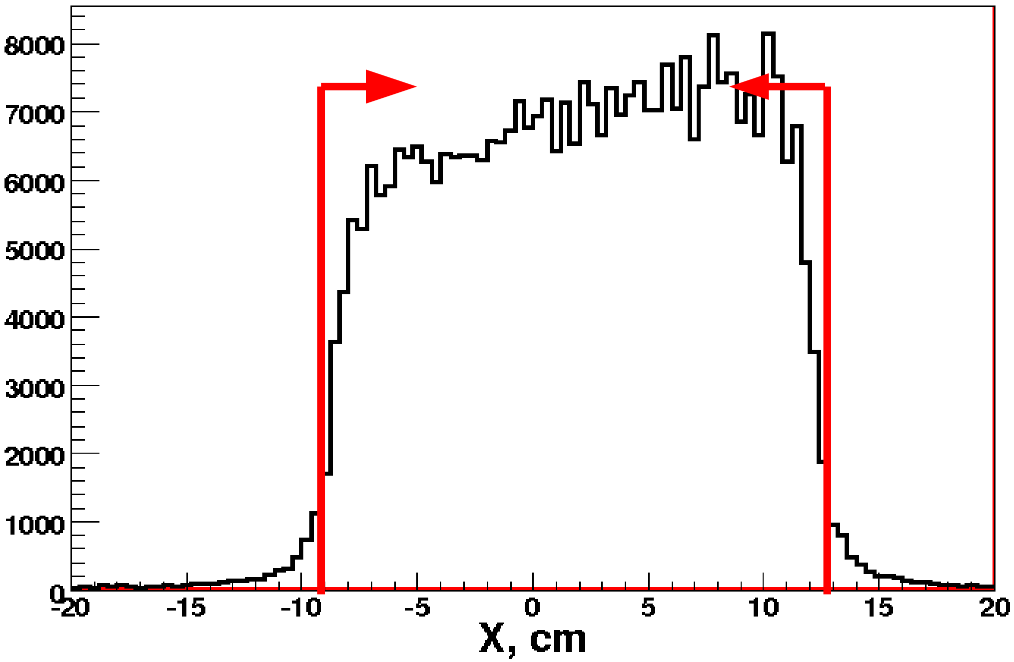
Definition of the coordinate system in the CRT

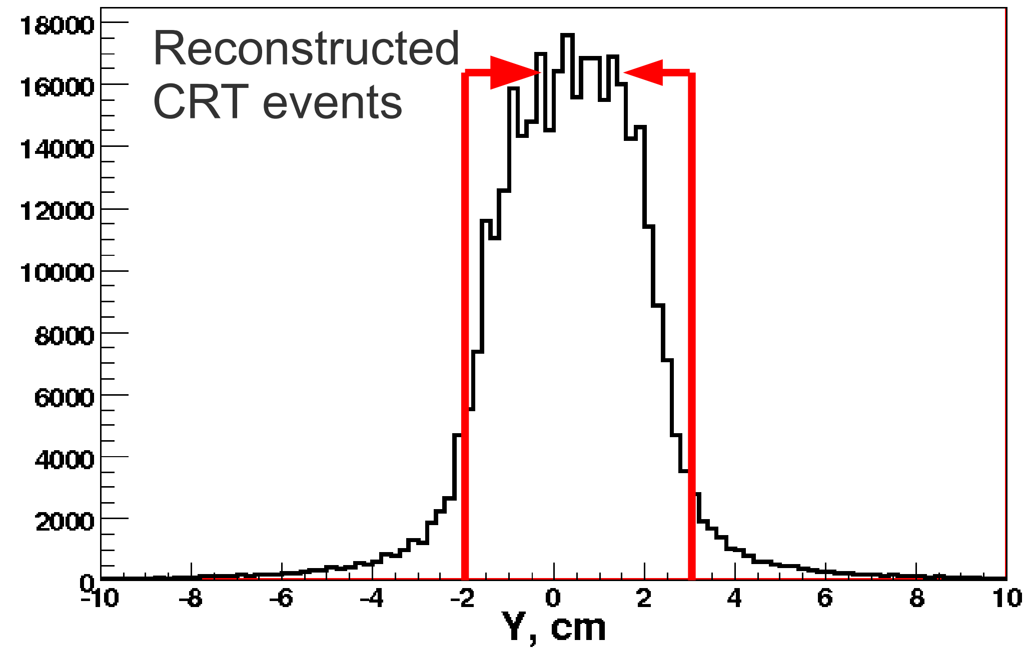


Muon track reconstruction with CRT

- Using hodoscopes we can reconstruct x and y coordinates of the muon from the top and bottom.
- Assuming that the trajectory of the muon is a straight line, one can find intersection points with quartz start counter and FTOF prototype.
- Efficiency of the track reconstruction is about 46%. Main reason of the loses is ambiguities in determination of the x, y coordinates due to noise signal in another hodoscope finger.

X_{QSC}, Y_{QSC} coordinates of the intersection with quartz start counter

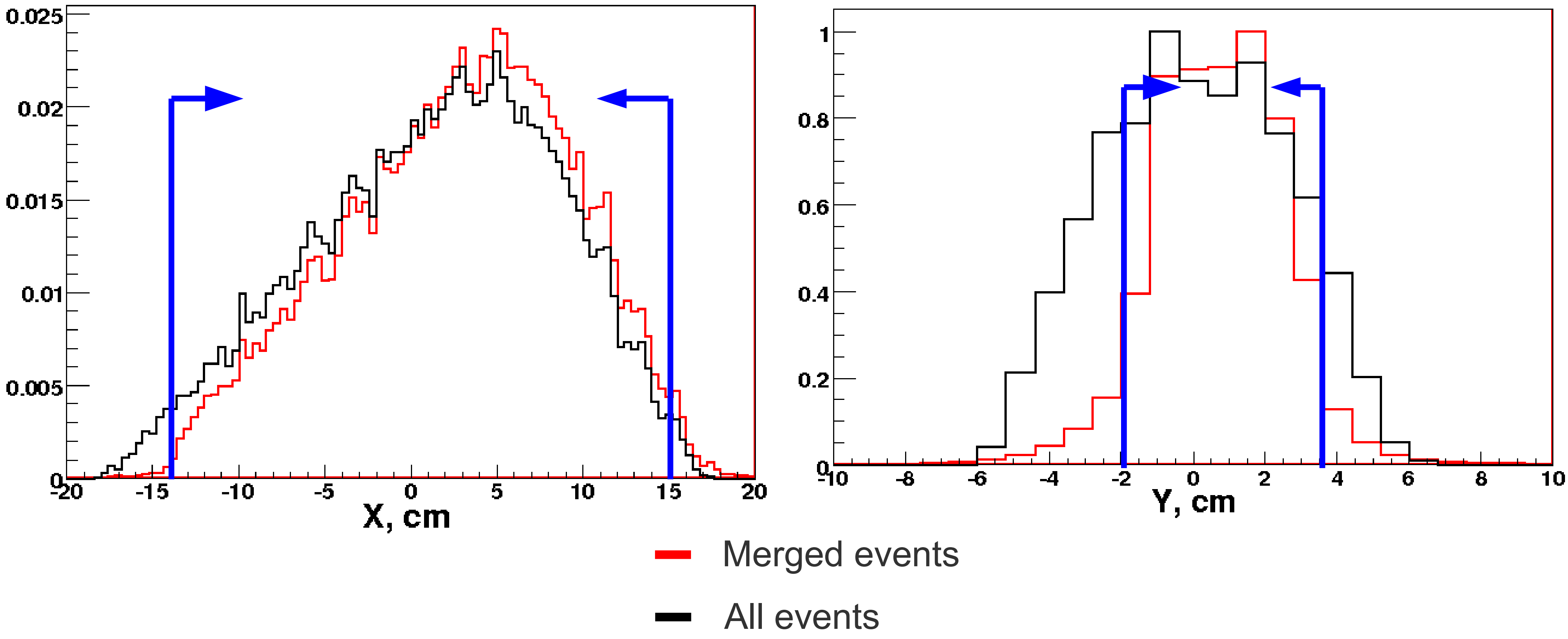




Additional sanity cuts are applied on X_{QSC} and Y_{QSC} coordinates:
-9 < X_{QSC} < 13 && -2 < Y_{QSC} < 3

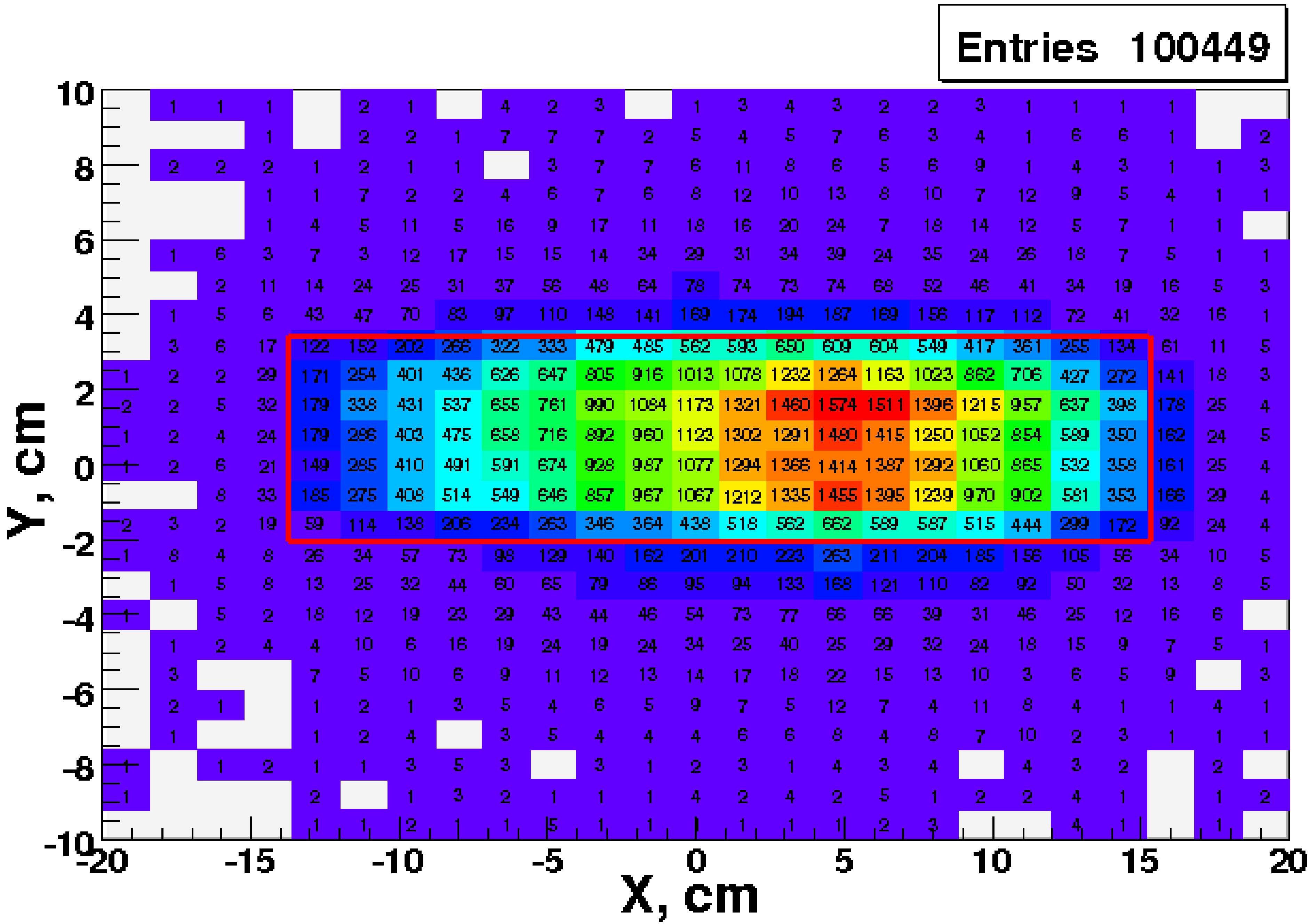
Test of the merging USBWC and CRT DAQ systems

X_{FTOF}, Y_{FTOF} coordinates of the intersection with FTOF prototype



Additional sanity cuts are applied on X_{FTOF} and Y_{FTOF} coordinates:
-14 < X_{FTOF} < 15 && -2 < Y_{FTOF} < 3.5

Map of the reconstructed muons



Basic Cuts per event

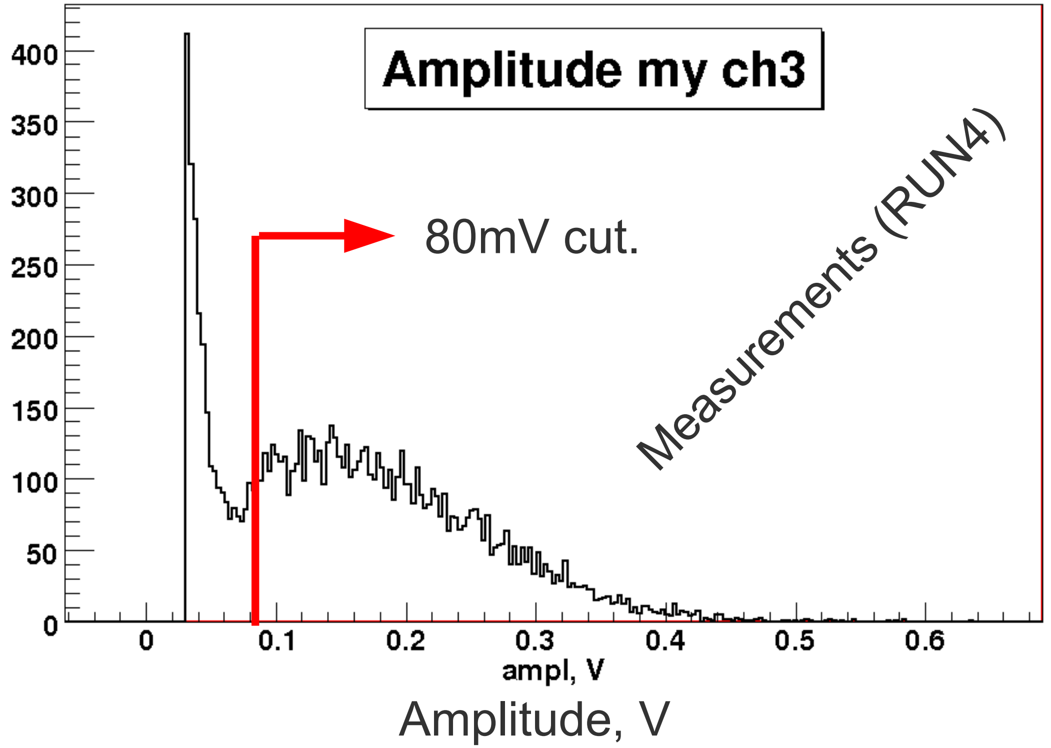
Cuts applied on the waveform

- Waveform to be single peak - like
- Have time measurement
  (Sanity check. In 99.9% of the cases the time measurements does exist.)
- Amplitude > 80mV (next slide for details)
- Number of channels with signal < 6
  (to reduce effects coming from crosstalk)

Cuts on date from CRT

- Merged with CRT (using time of the event)
- Have a muon track reconstructed
- $-9 < X_{QSC} < 13$ && $-2 < Y_{QSC} < 3$
- $-14 < X_{FTOF} < 15$ && $-2 < Y_{FTOF} < 3.5$

Cuts on amplitude

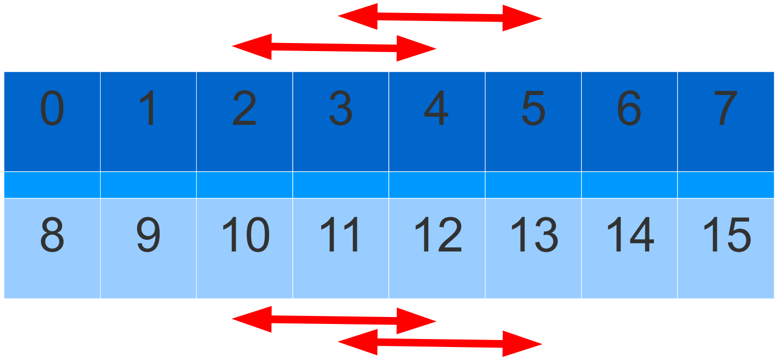


The signals with amplitude bigger than 80 mV are considered to be from p.e.

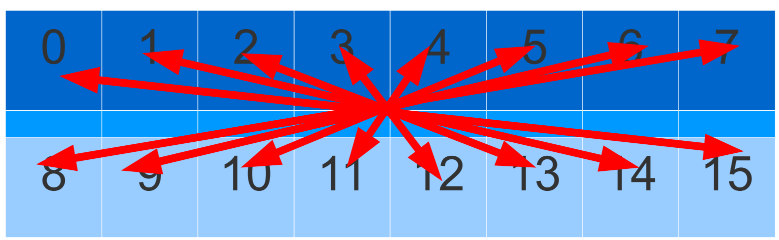
Minimum amplitude of the signals from real p.e. Is about 60-70 mV

The time resolution measurements of the FTOF prototype

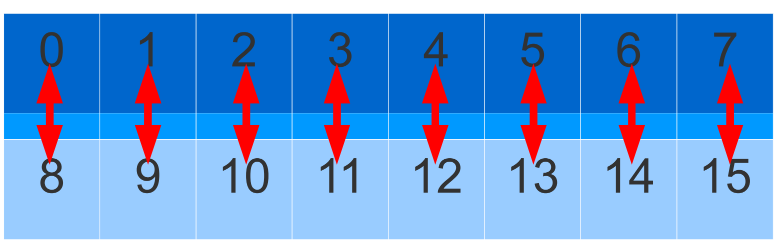
→ Time difference between channels are used in order to estimate resolution.



Type L3: not neighbor channels connected to same quartz bar



Type L4: not neighbor channels connected to different quartz bars

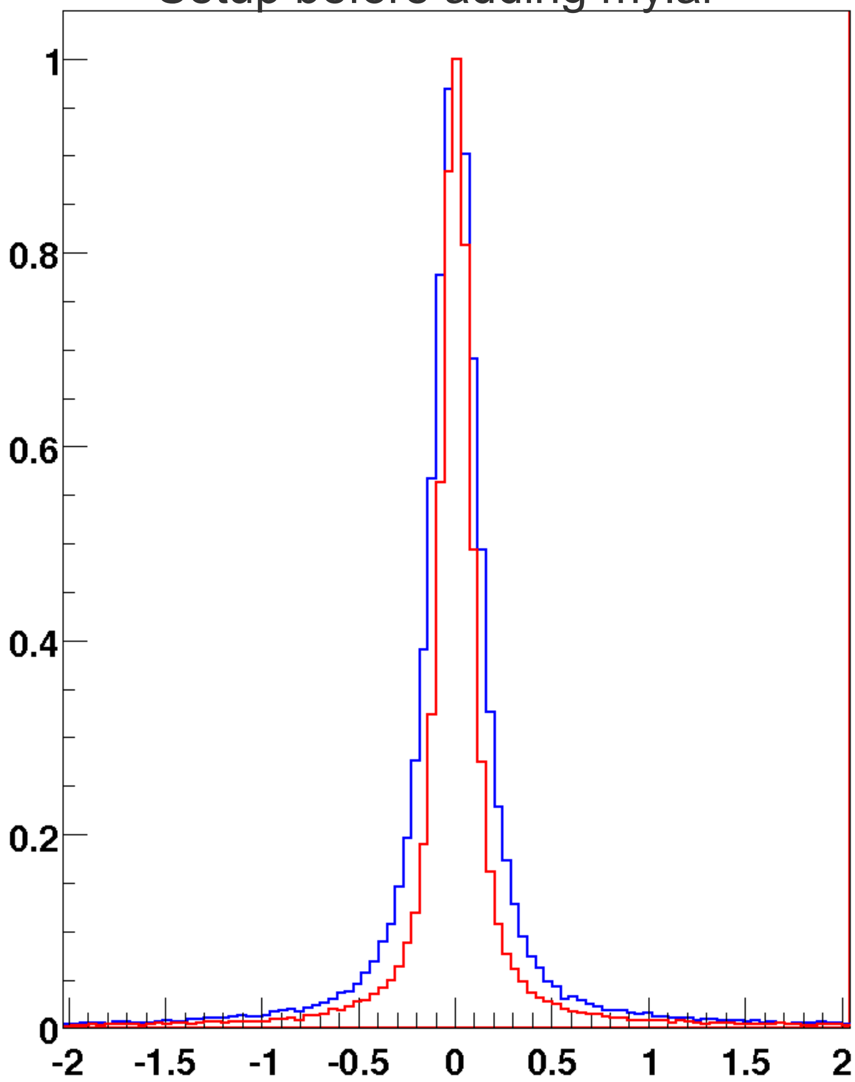


Type TtB: top to bottom time difference

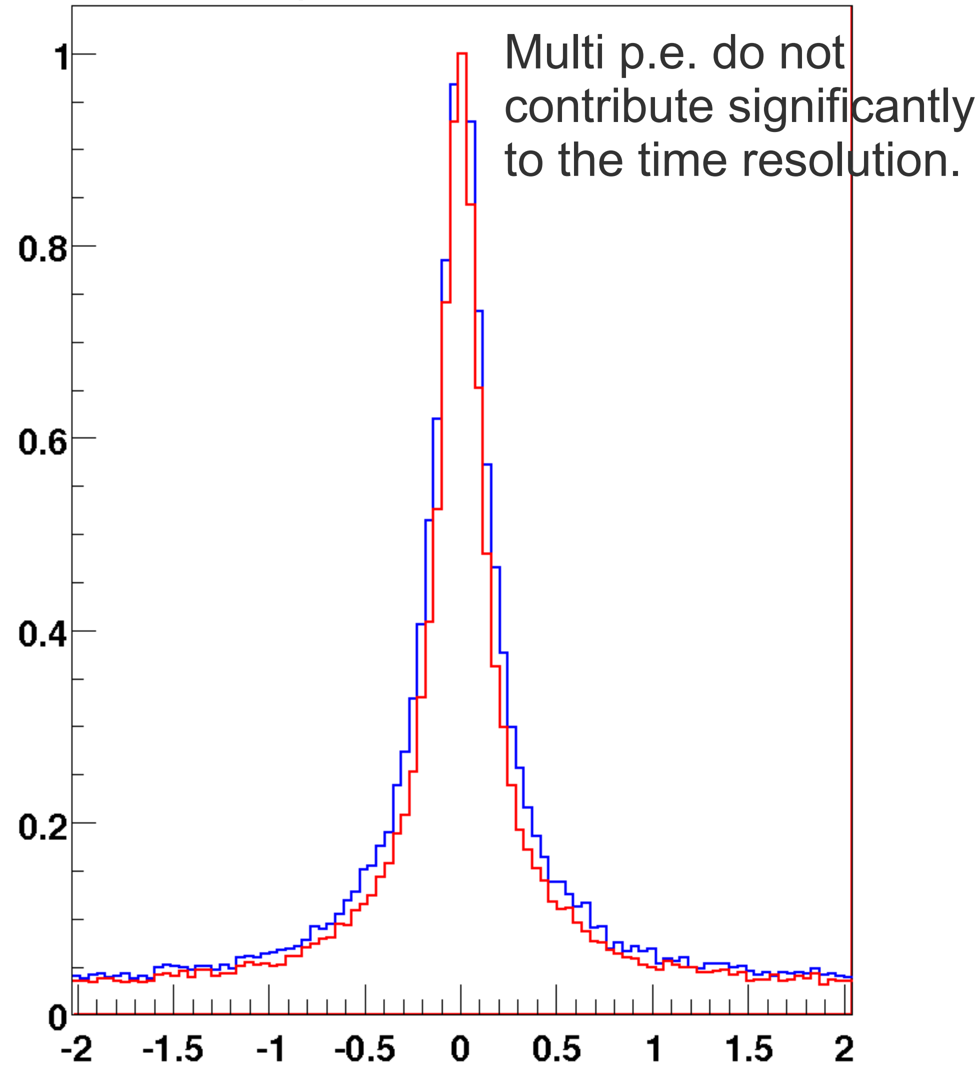
NOTE we do not use neighbor channels to estimate time resolution. Because we observe not negligible contribution from this effect: measuring time between signal and its own charge sharing.

Two simulated times

Collection efficiency 70%
Setup before adding mylar



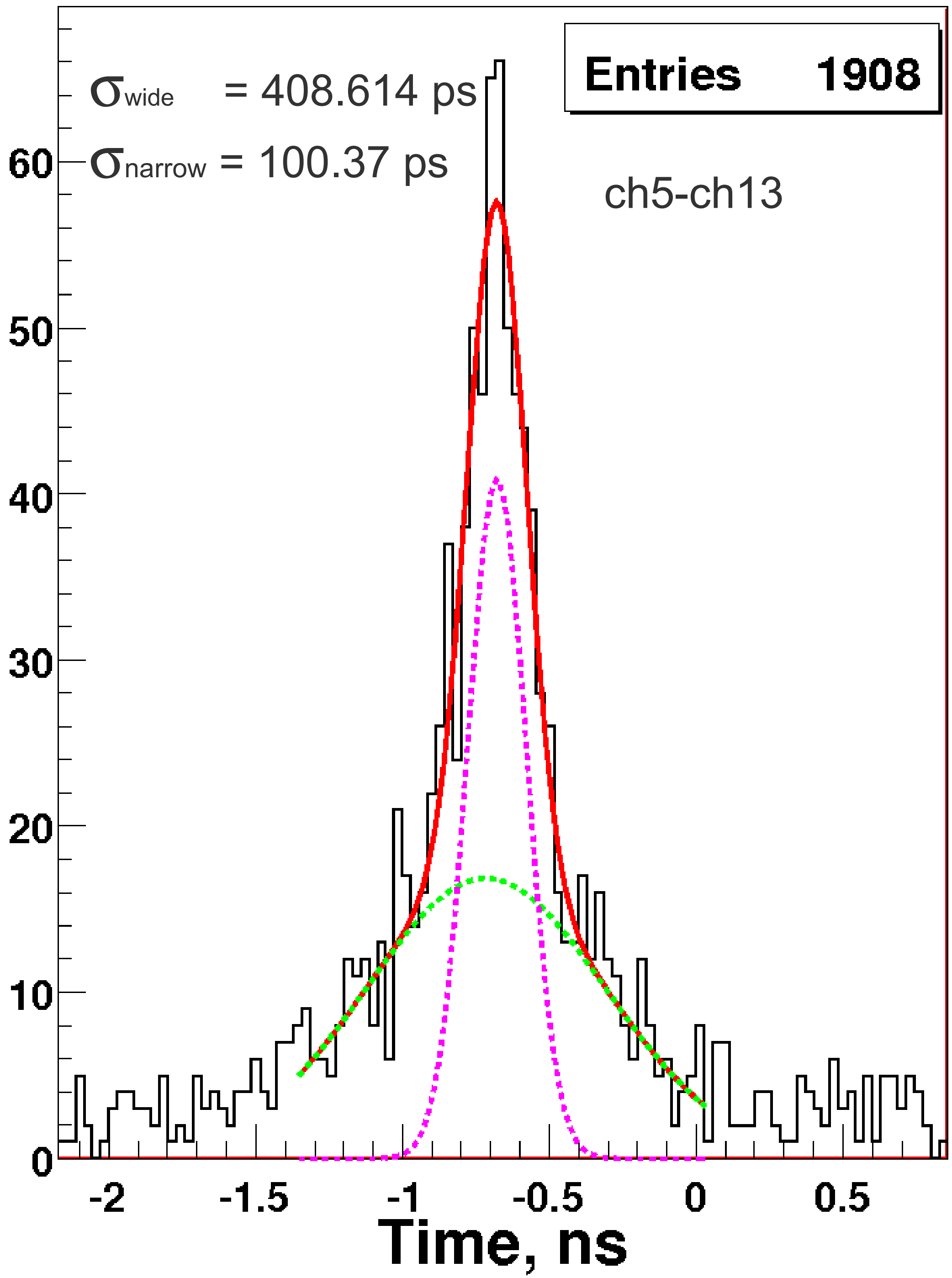
Collection efficiency 14%
Setup after modification



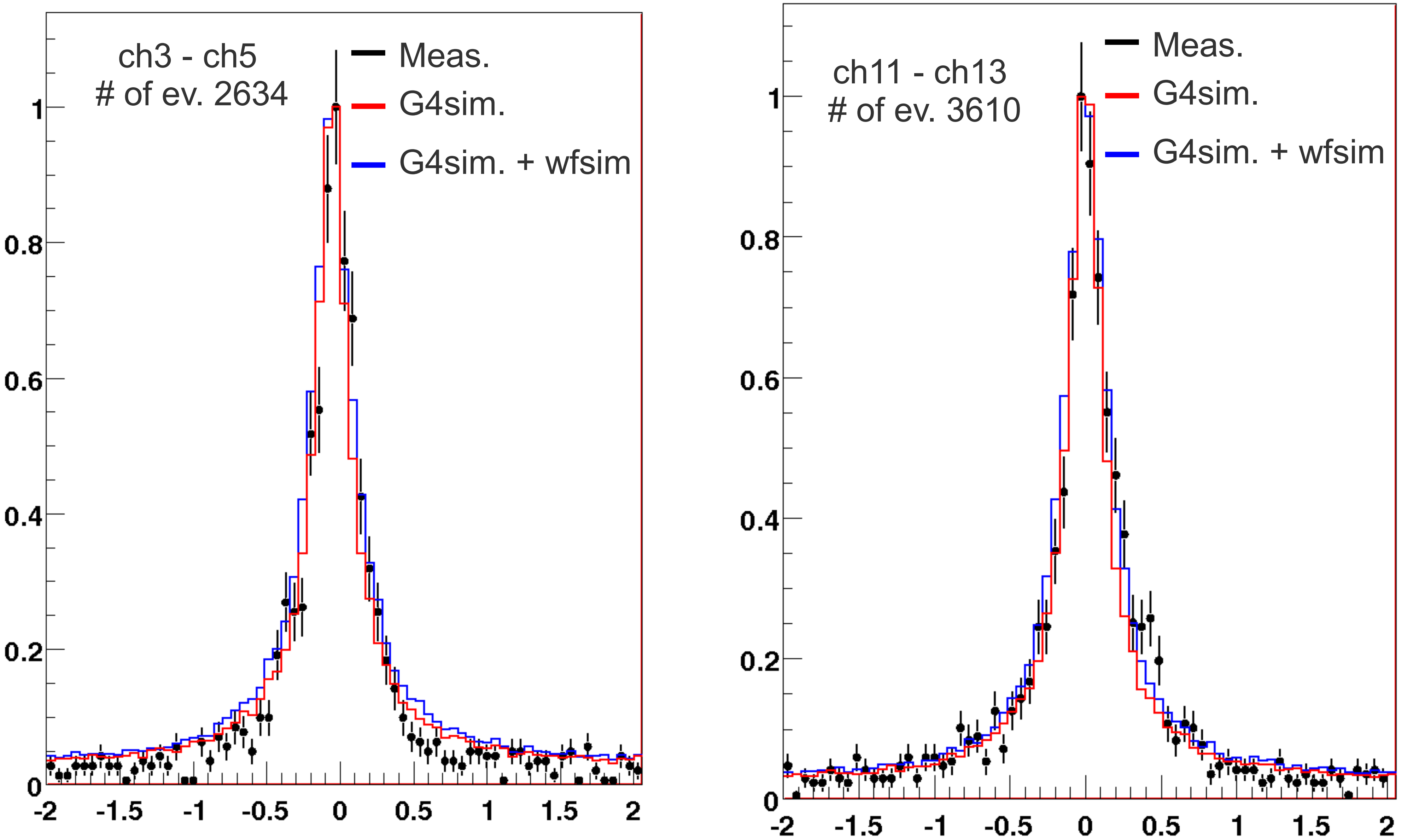
G4sim. - time of the first p.e. taken as a time measurements.

G4sim. + wfsim – we take in to account waveforms from all p.e.

Double Gaussian fit

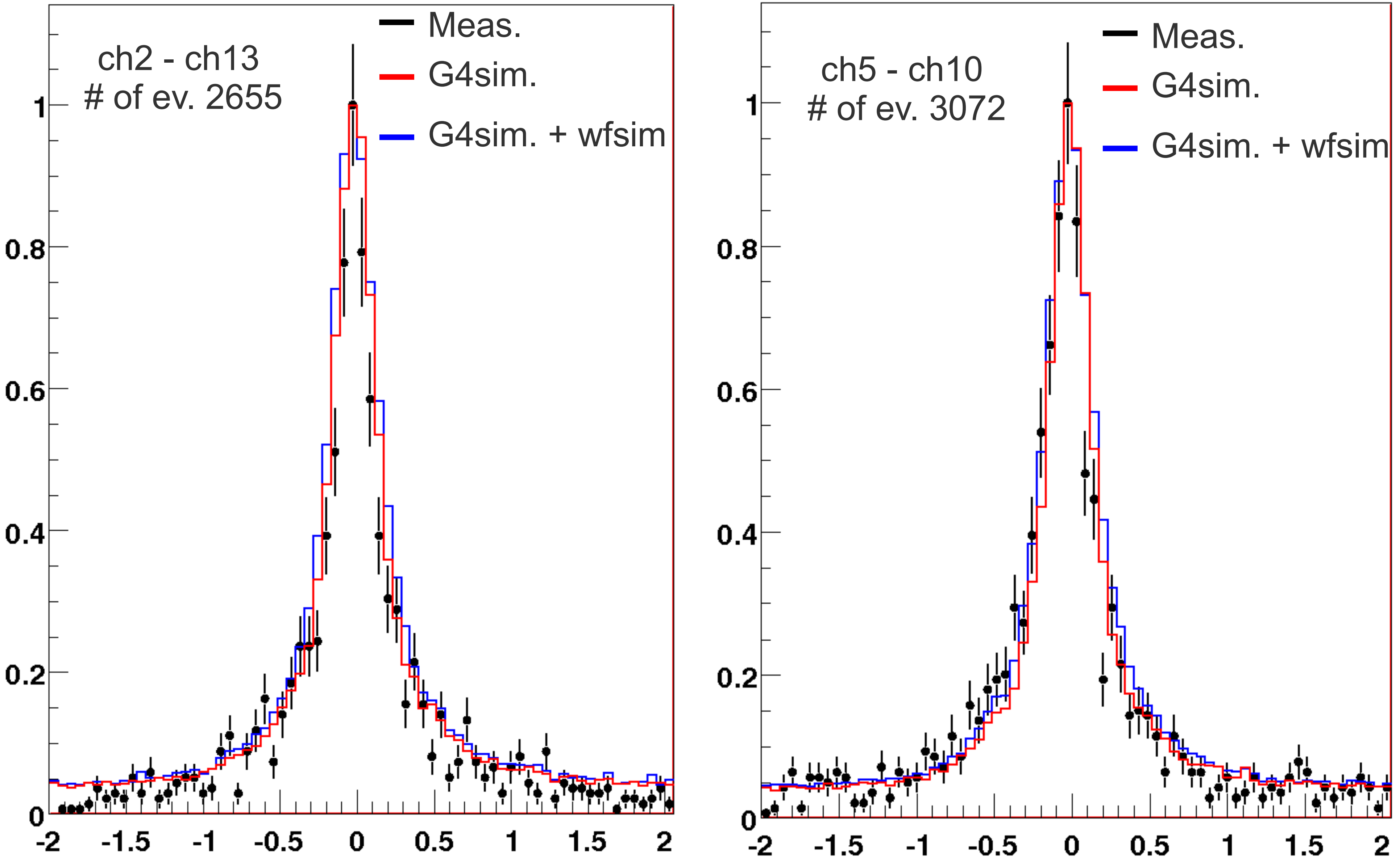


Time difference between not neighbor channels connected to same quartz bar. (type L3)



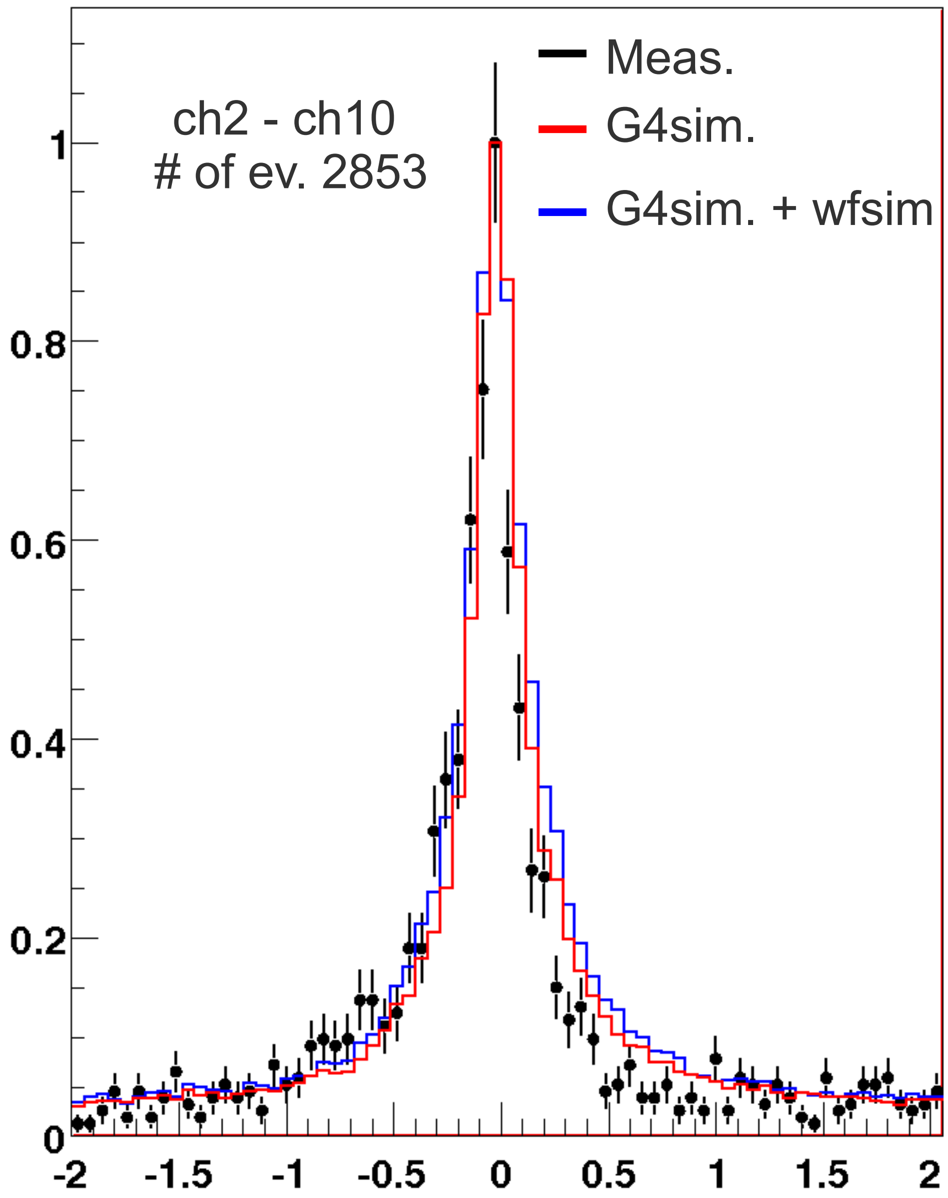
Average time resolution calculated using this type of time differences is ~110ps = **80ps/channel.**

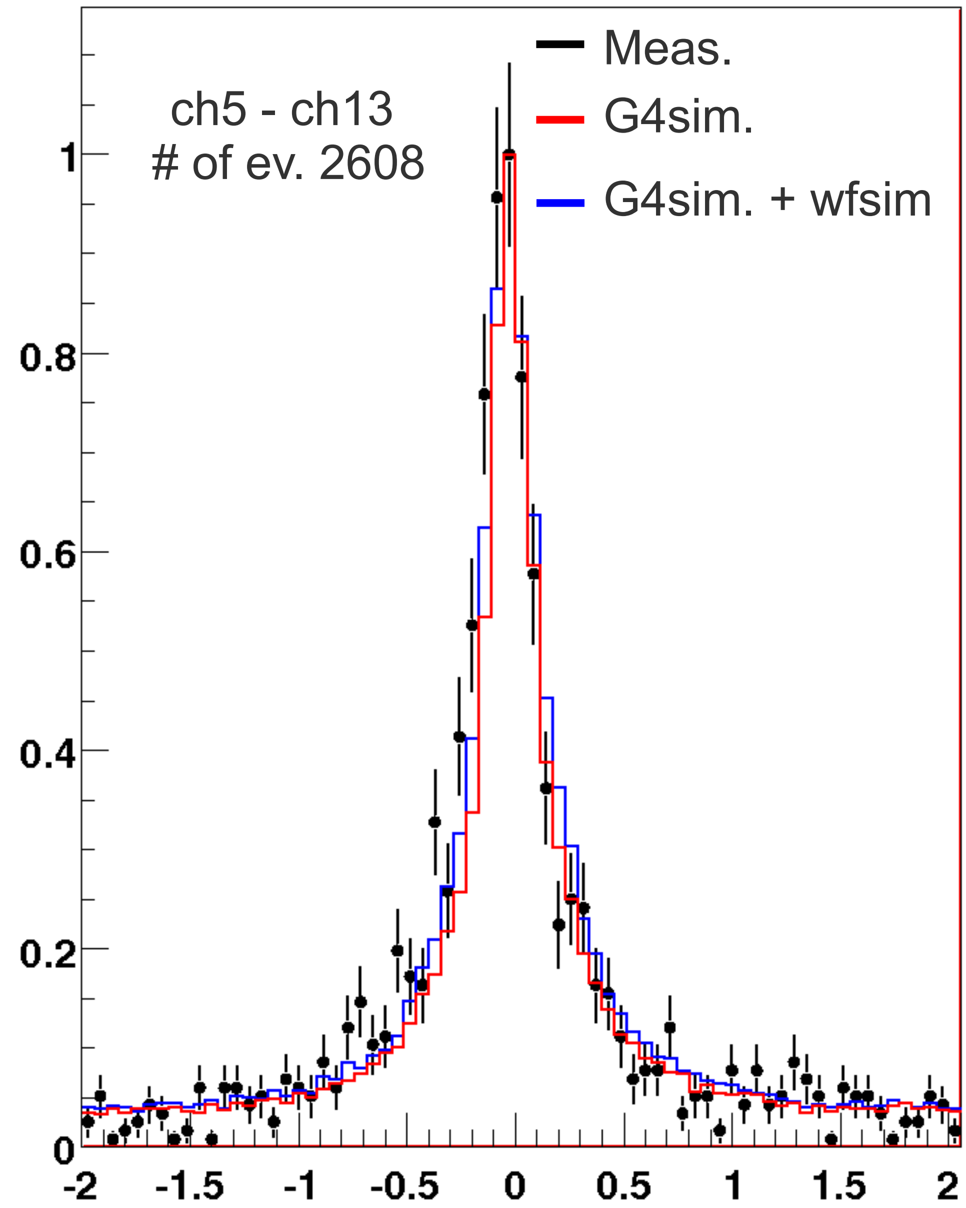
Time difference between not neighbor channels connected to different quartz bar. (type L4)



Average time resolution calculated using this type of time differences is ~100ps = **70ps/channel.**

Time difference between top and bottom channels. (type TtB)





Average time resolution calculated using this type of time differences is ~100ps = **70ps/channel.**

Conclusions

- New setup and software give results cleaner and easier to understand.

- Simulation is not final yet but already quite precise including geometry and waveform parametrization.

- Data/MC agreement is reasonable for all the time differences between channels studied so far.

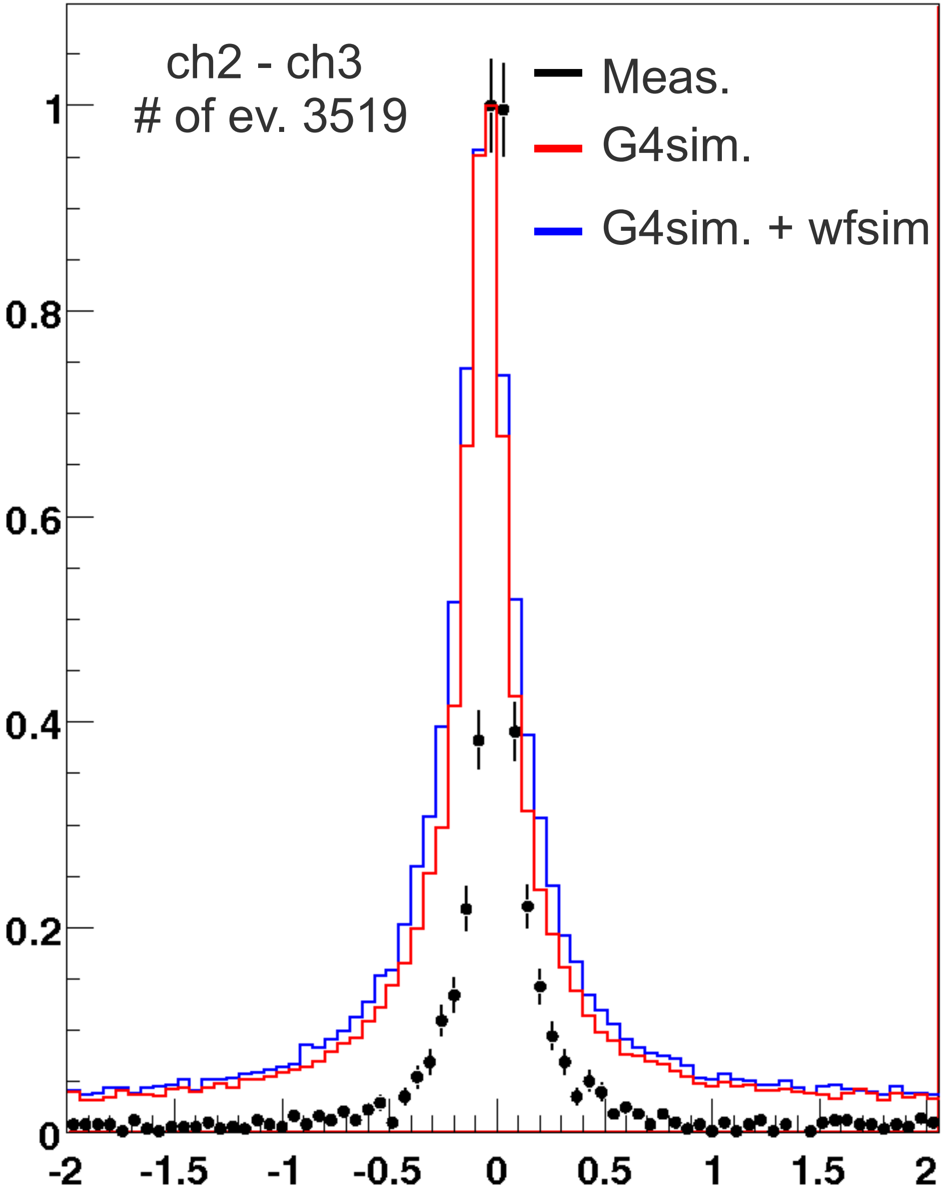
- We measure **70ps /channel** time resolution, to applying basic cuts of the waveform. Note with old setup we get 90ps/channel we were obliged to make a cut on rise time of the waveform.

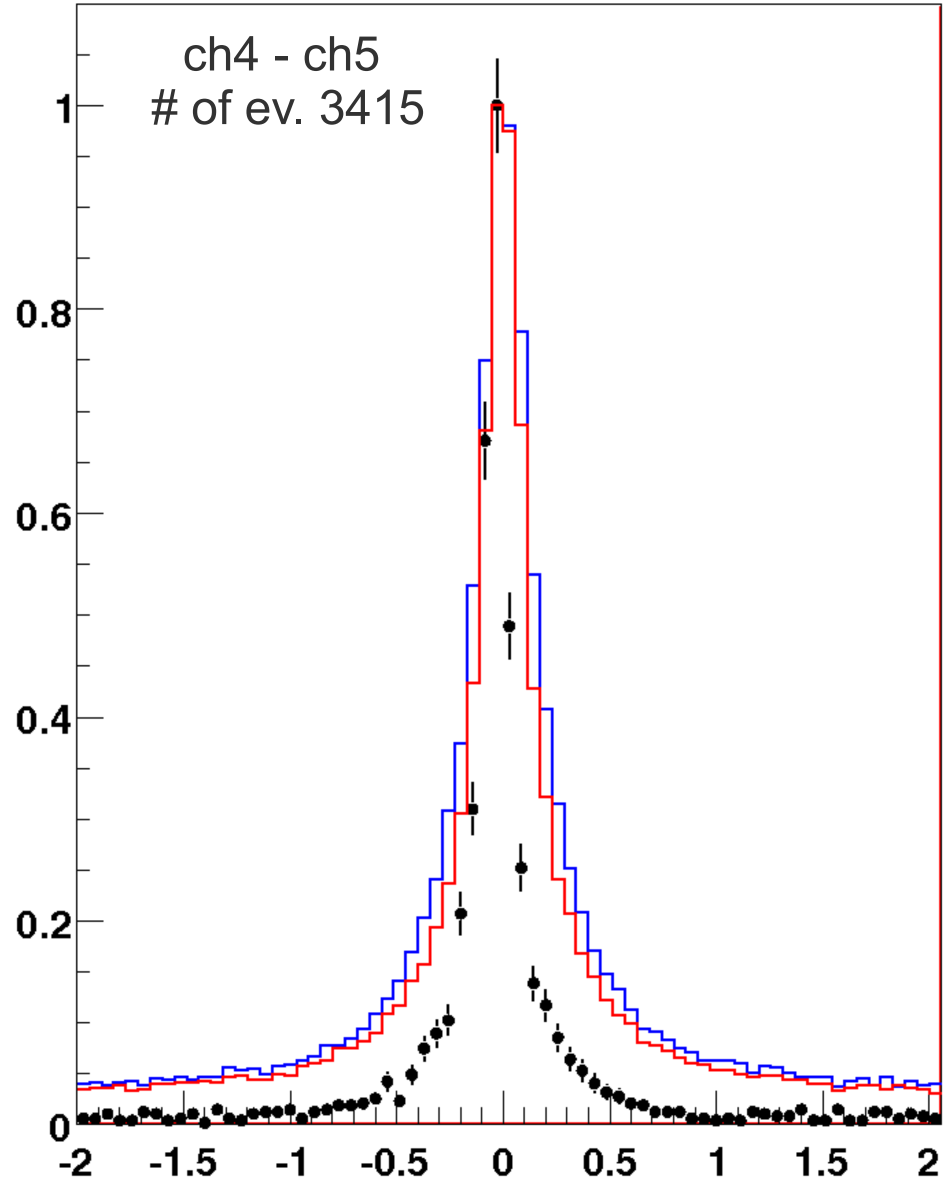
$$\sigma_{tot} = \sigma_{det} \oplus \sigma_{TTS} \oplus \sigma_{electronics} \oplus \sigma_{waveform}$$

- $\sigma_{det} \oplus \sigma_{waveform}$ ~60ps
- σ_{TTS} ~35ps
- $\sigma_{electronics}$ ~10ps

Backup

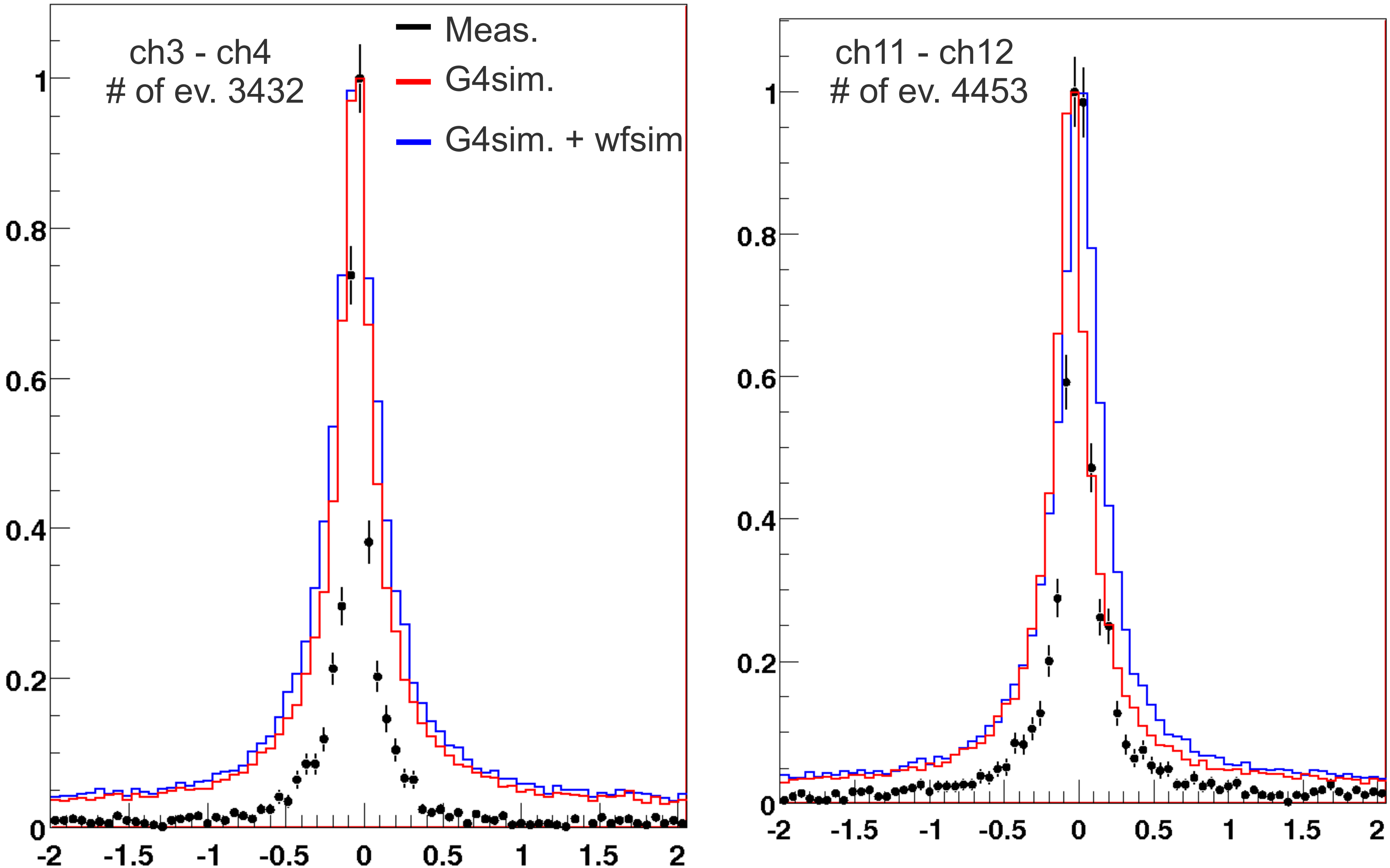
Time difference between neighbor channels from same board. (type L)





Average value of the RMS of the 2 Gaussian fit is ~ 50 ps while simulation give as 80 ps

Time difference between neighbor channels from different board. (type L2)



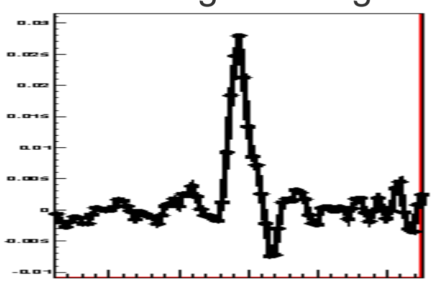
Average value of the RMS of the 2 Gaussian fit is ~ 50 ps while simulation give as 80 ps

Time difference between signal and its own charge sharing

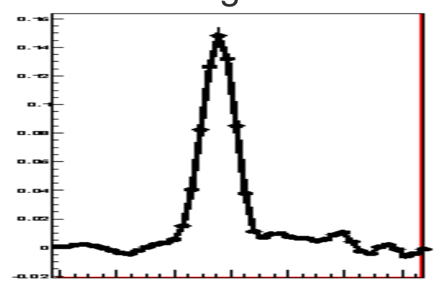
- We find very small timing between neighbor channels, which is not in agreement with simulations.

- **Possible explanation:**
From the run with laser (very low flux photons to reach a single p.e. level) we know that each time the channel gives a signal the neighbor channels have a smaller signals called charge sharing. Usually the amplitude of them is small ~ 10 – 40mV but in ~5 % of the cases the amplitude exceed 80mV threshold, so would be recognized as normal signal coming from another p.e..

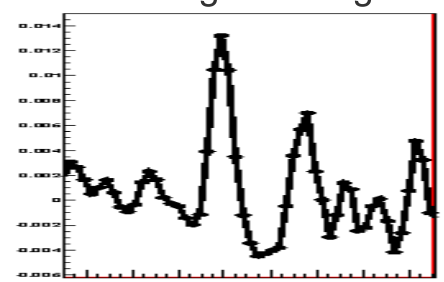
Charge sharing



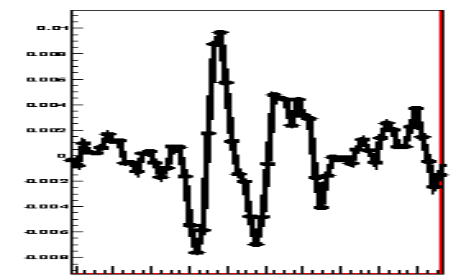
Signal



Charge sharing

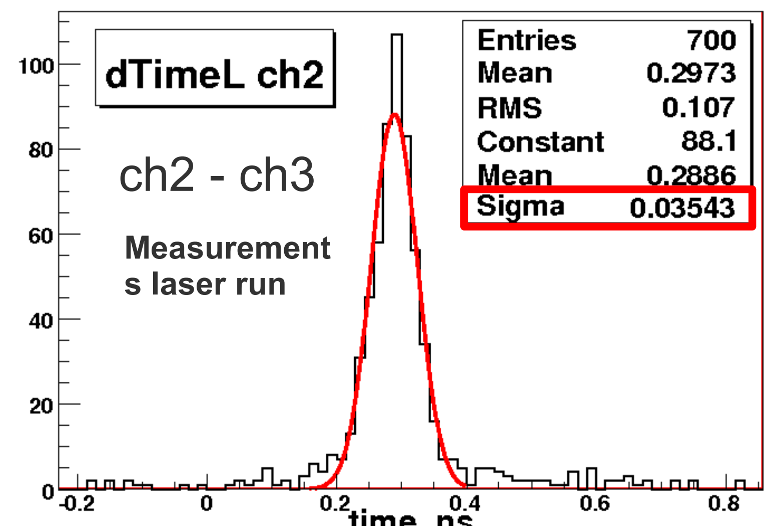


Crosstalk



- In order to check our hypothesis we did same analysis on run with laser. 35 ps time resolution have been find.

- Time difference between neighbor channels can not be used for time resolution measurements.



Proper simulation of the effect coming from mylar sheets

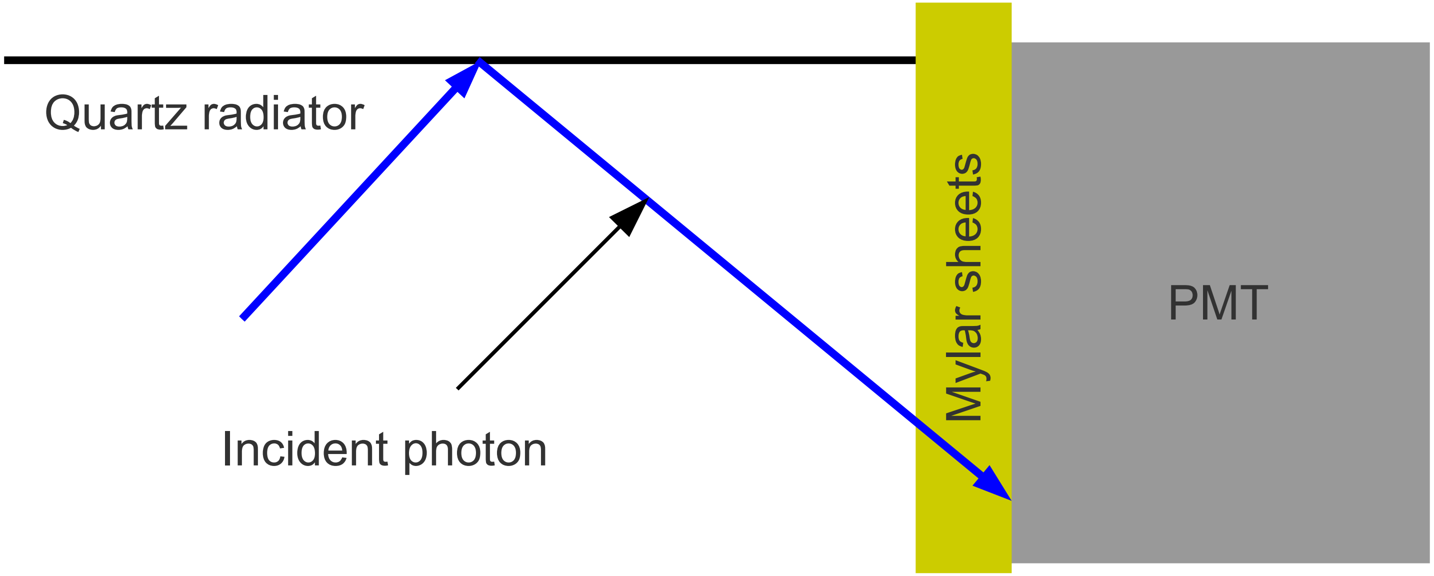
- Calibration done with photons which are perpendicular to the surface.
- In reality photons are not perpendicular so effective thickness of the absorber is bigger.

$$dN = -k \cdot N(x) \cdot dx$$

dN – number of the absorbed photons, *N(x)* – total number of photons as a function of mylar sheet thickness, *k* – absorption coefficient, *dx* – photon path length.

$$N(x) = N_0 \cdot e^{-k \cdot x}$$

N_0 initial number of incident photons



- For the moment this is not taken into account in the simulation.