TOF calibration for HAND using elastic protons

In order to perform TOF calibration we used elastic proton into HAND. HAND was located at 50^0 deg and 15 m away from the target with no lead wall.
The best way to calibrate TOF is to take "left + right TDC" of HAND minus time of the reaction:

$$0.5*(TDC_L+TDC_R)-(REACTION\ TIME)+offset=TOF_{real}$$

Calculation of TOF_{real}

$$\frac{distance}{\beta*c}=\frac{15}{\frac{P*0.3}{\sqrt{P^2+0.938^2}}}$$

The proton momentum is assumed to be the value of the q vector. The difference in path for different paddle is negligible and less than 0.5 %.
The values for q vector were taken from Left HRS. q vector distribution is presented in fig 1:

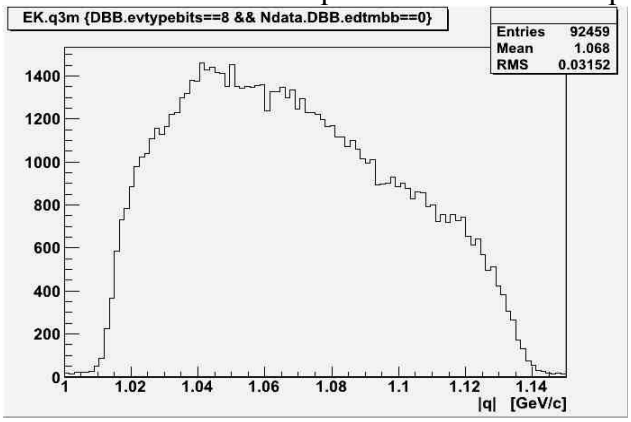

fig 1

The result for real TOF is around 67 ns. The purpose of elastic calibration is to calibrate the relative TOF between the different HAND paddles. The real value for the production will be found using the deuterium with X>1.
TOF distribution for ALL bars before the correction:

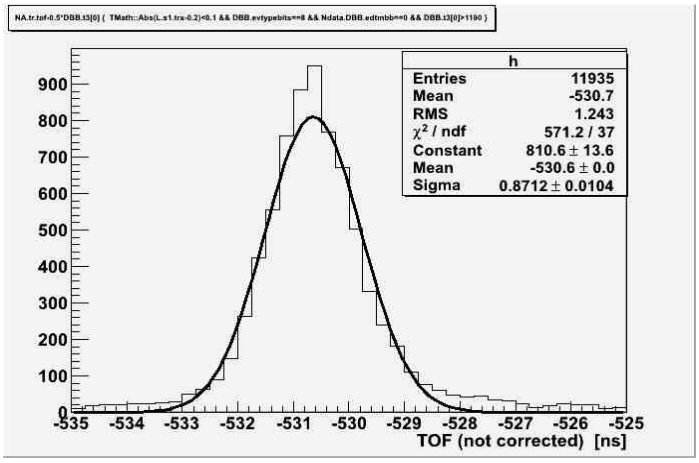

fig 2

During this calibration, I encountered a problem of finding the correct reaction time. This problem was due to the wrong installation / definition of 1877 TDCs. The original TDCs for HRS were 1875 that worked in "common start" mode but the 1877 TDCs work in "common stop" mode, so in the first week of the calibration period we had no TDC data from the S0, S1 and S2 planes of HRSs. (During the experiment Bob and Vince, looked on the raw data and their conclusion was that it's almost impossible to use it).
However, we still need to identify a reference point in order to calibrate the TOF for HAND. I can't just use the trigger time (hardware trigger) information because each event trigger originate from different paddle on the HRS (that I can't calibrate or use). Moreover, in the elastic scattering different paddles in HRS will correspond to different proton momentum in HAND. This mean that I still needed to find a way to lock on specific paddle.
The only reliable information from the left HRS is coming from VDCs. So, I used a calculated hit position on the HRS detector plane (I used plane S1) and than I looked on TOF of protons.

The cut was: $|\text{L.s1.trx} - 0.2| < 0.1$

The choice of these numbers is purely empirical. 0.2 I chose because there was a maximum in position distribution and 0.1 I chose because the width of each paddle on S1 plane is ~ 0.34 m. I chose less than half of the paddle because different paddles are overlapping.

The reference time for the reaction was the trigger time, stored by Trigger Supervisor (TS).

$$0.5*(TDC_L + TDC_R) - (DBB.t3) + offset = TOF_{real}$$

Here, we should be careful because the stop for FASTBUS crate for HAND TDC and stop for TS is different (they both originate from L1A but the later is re-timed with BB). However, it will add only some offset (same for all bars) that in any case should be found during the X>1 calibration.

HAND TDCs information is after the time walk correction. It should be mentioned that time walk correction in this case didn't affect the time because the energy deposit of these protons is high and lie in the almost flat region of time walk correction (see my report from 19-07-2011 on the analysis page).

Example of TOF for individual bar in HAND (plane 2 bar 7) with cuts:

- no EDTM
- elastic protons
- $|\text{L.s1.trx} - 0.2| < 0.1$
- DBB.t3[0] > 1190 (this cut ensure that the re-timing was done from two identical (but shifted) L1A signals that originated on Left HRS and not from the BB signal)

see Fig 3.

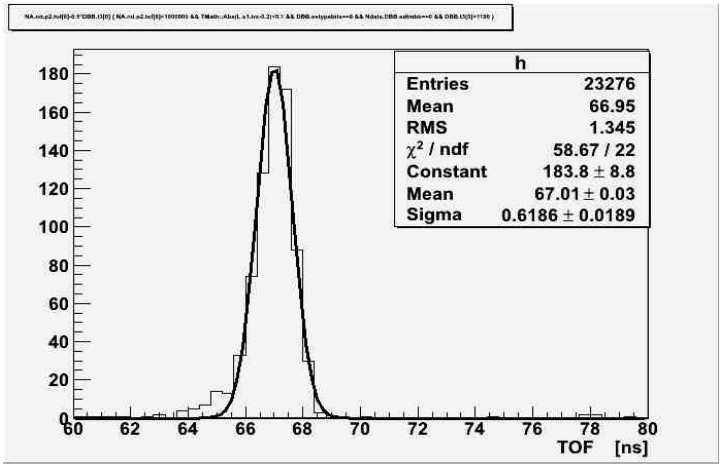

fig 3

The overall TOF for HAND after the alignment of all bars to 67 ns is:

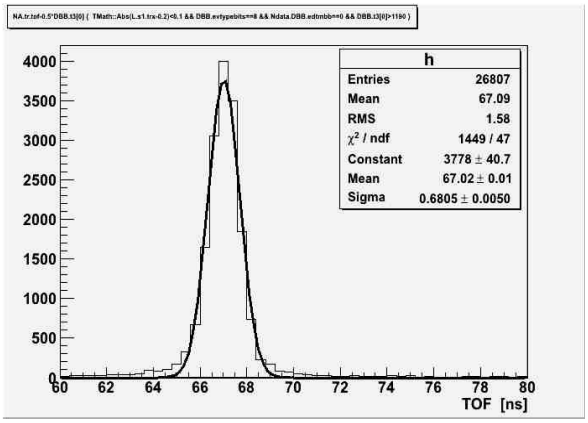

fig 4

From fig 4 we can see that sigma is 0.68 ns but it include the resolution of DBB.t3 that is 500 ps. So, TOF resolution for ALL HAND TOF is:

$$\sigma_{TOF} = \sqrt{0.68^2 - 0.5^2} = 0.46\,[ns]$$