Plan for TOF calibration

Main steps in TOF calibration procedure:

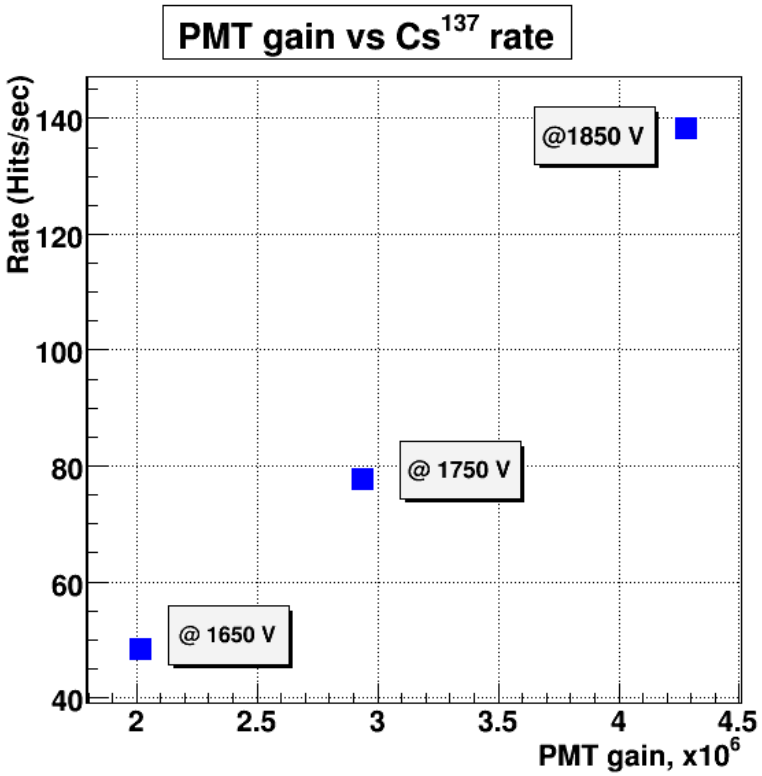
1. **ADC and TDC calibration and hardware monitoring**
2. **PMT gain-balancing through periodic HV adjustments**
3. **Determination of time-walk correction constants**
4. **Single-paddle adjustment of left/right relative timings**
5. **Paddle-to-paddle timing offsets determination**
6. **Fit of the final TOF timing constants to vertex (RF) time**

Step 1: TDC / ADC calibration

- Verify RC-delays calibration of VX1290A (*any random data but special TDC mode*)
- Check TDC counts to time conversion (*pulser run*)
- Verify Flash ADC offset calibration (*pulser run*)
- Monitor occupancy histograms for dead or inefficient channels (*normal runs*)

Step 2: PMT gain balancing and monitoring

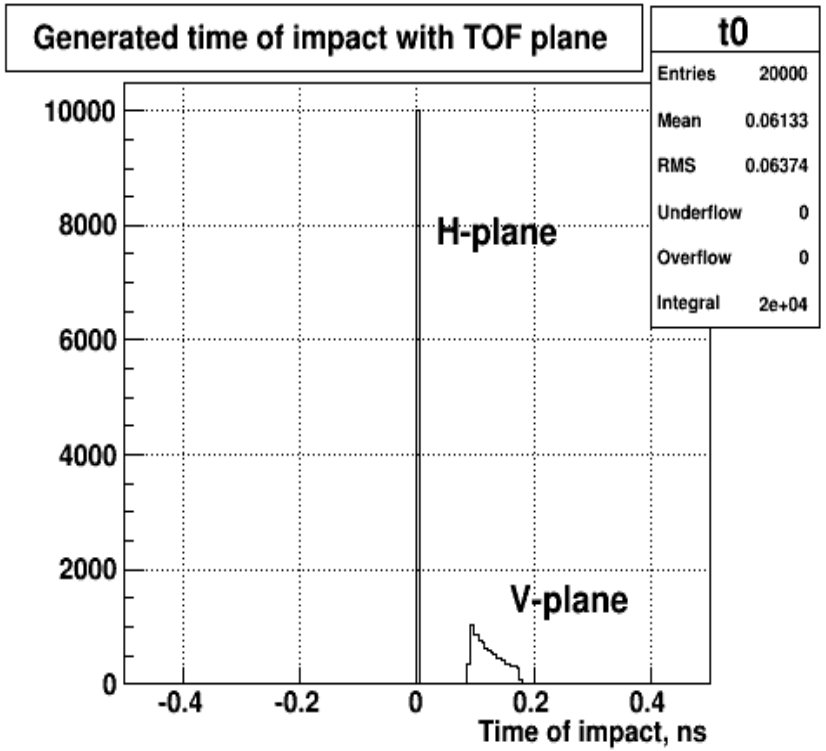
- Initial HV values are set during construction by normalizing PMT gains with ^{241}Am
- Due to expected PMT deterioration, gains need to be periodically re-measured and HV values adjusted
- One possible way to do this is to measure ADC position of minimum-ionizing peak in *normal runs*. This would require track reconstruction to select hits in the same location with the same angle (to avoid variations in path length and light attenuation)



- Alternatively, ^{90}Sr source can be mounted on a rail with a step motor and used during *downtime* to:
  - Measure flash ADC position of maximum β energy spectrum (2.28 MeV)
  - Or simply use a scaler to measure signal rate above 20mV threshold (minus background) to quickly adjust HV (^{90}Sr half life is 28.8 years)

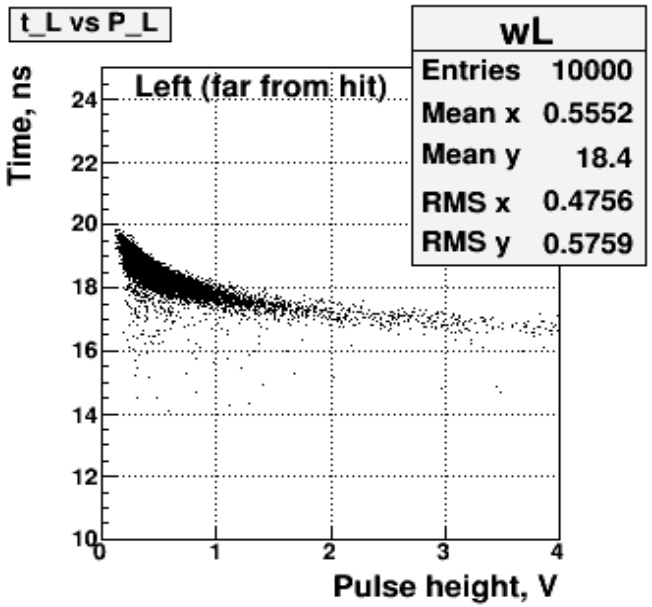
Step 3: Time-walk corrections

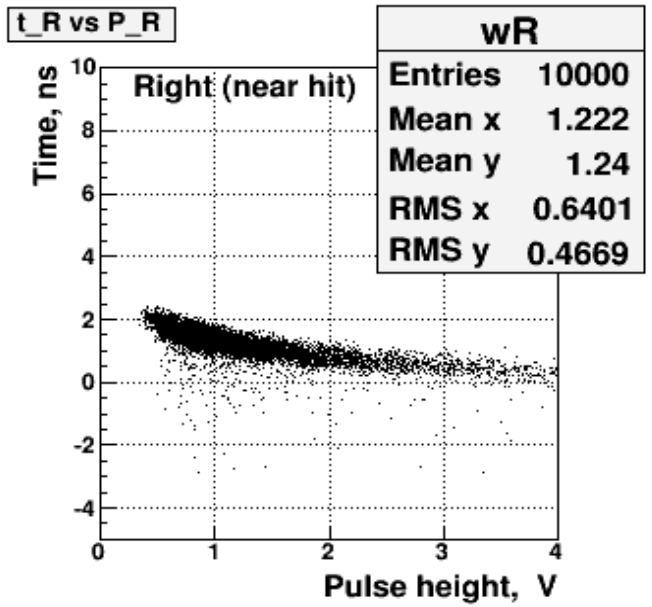
- General prescription is given by Elton Smith in GlueX-doc-1719
- Find a related pair of hits in 6x6cm^2 intersection area of two scintillator bars from H(orizontal) and V(ertical) planes (a *lower intensity run* seems to be preferred here). Determine time of hit in each plane as $t_H = (t_L + t_R)/2$ and $t_V = (t_T + t_B)/2$. Take difference $t_H - t_V$ to eliminate unknown t_o. Minimize it for these two times to coincide in order to find time-walk corrections.
- Elton developed a simple time-walk Monte Carlo to prove validity of such approach.

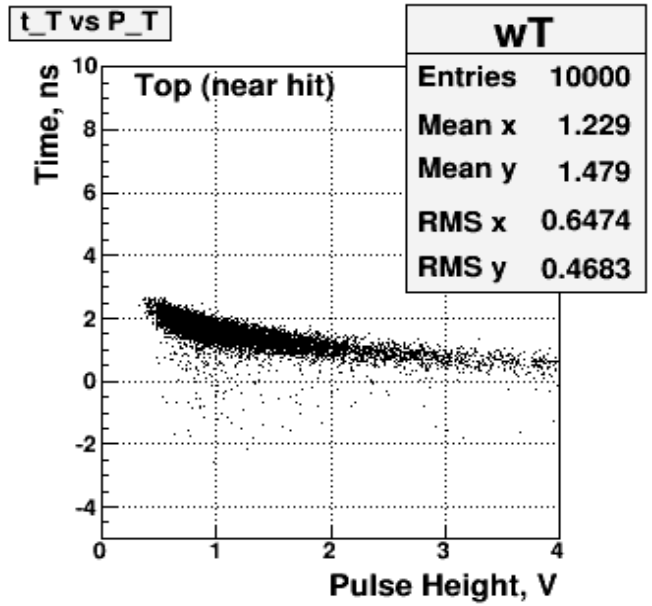


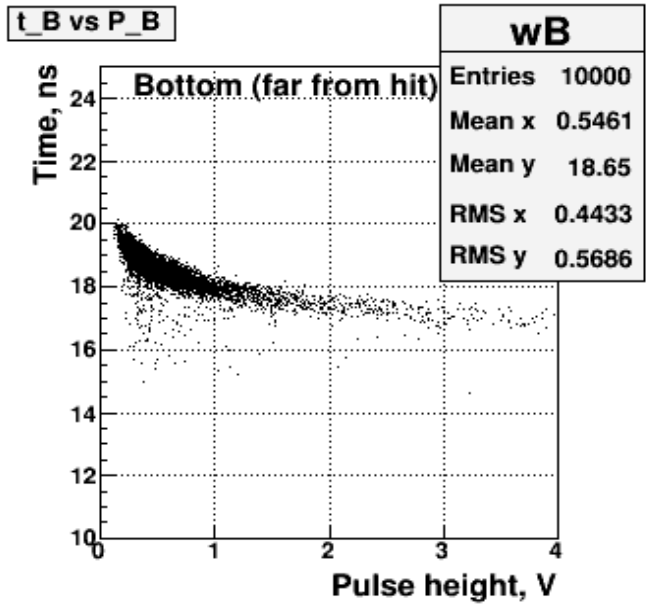
- The following effects have been now included in the next version of TOF hit generator:
  - 1" bar thickness (i.e., delay between H and V)
  - Angular distribution of tracks originating from target location
  - Variation in particle velocity β.
- Different approaches to account for these effects in the minimization function were studied

Example of generated time-walks for intersection in TOF top-right corner









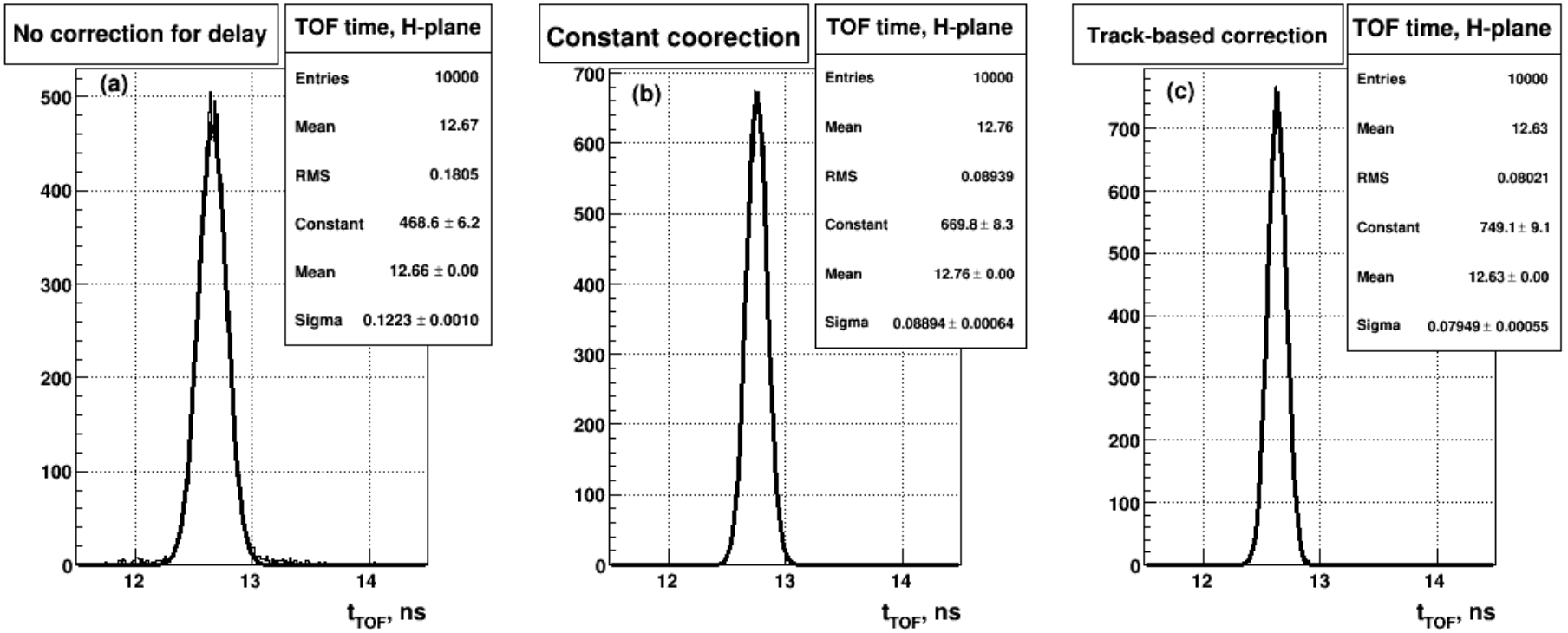
- Functional form of time-walk correction is

  $b_o / (1 + b_1\sqrt{P})$

- Hits are generated with 80ps timing resolution

- Without any time-walk corrections, timing distribution R.M.S. Is about 600ps

Reconstructed timing resolution for different minimization functions



- a) Do not account for delay between H and V planes → σ = 122 ps
- b) Assume constant predefined angle and β=1.0 → σ = 88 ps
- c) Use tracking info for event-by-event correction → σ = 80 ps

Conclusion: good time-walk correction can be found without tracking and later fine-tuned with tracking

Undecided yet: individual parameters for each of 1932 intersection regions, or just a pair of parameters per PMT from a single 344-parameter fit

Step 4: Single-paddle left/right adjustment

- To remove relative timing offsets between left and right channels of the same paddle, shift one of them so that $t_L - t_R$ (distributed over the whole paddle) is centered at zero
- This can be done either with *cosmic rays* or with *90Sr source* at both paddle's ends. Distribution from normal data can be skewed due to acceptance.

Step 5: Paddle-to-paddle timing offsets

- In each plane, find *cosmic rays* with hits in at least 3 neighboring paddles
- Use $(t_L - t_R)/2$ to determine hit location along each paddle
- Select only events with hits along a straight line (within resolution)
- In a minimization fit, adjust relative timing offsets of $(t_L + t_R)/2$ hit times to coincide with the expected propagation time from paddle to paddle

Step 6: Fit of TOF time to RF time

- Final production calibration is done with reconstructed tracks from *normal data* (perhaps, with some physics filter on pions or Kaons)
- Start with TOF time of a track. Swim it back from TOF to the vertex to determine its vertex time. Use start counter to find a proper RF bunch. Minimize difference between RF time and TOF vertex time to determine TOF timing calibration constants
- Multiple fit iterations of TOF time / ST time might be needed similar to current CLAS TOF calibration procedure

Current status of TOF calibration software

- VX1290A TDC RC-calibration is available but needs to be interfaced with VME access of GlueX DAQ
- Time-walk calibration software is currently being studied as described above
- Everything else still needs to be developed...