Random beam test analysis issues

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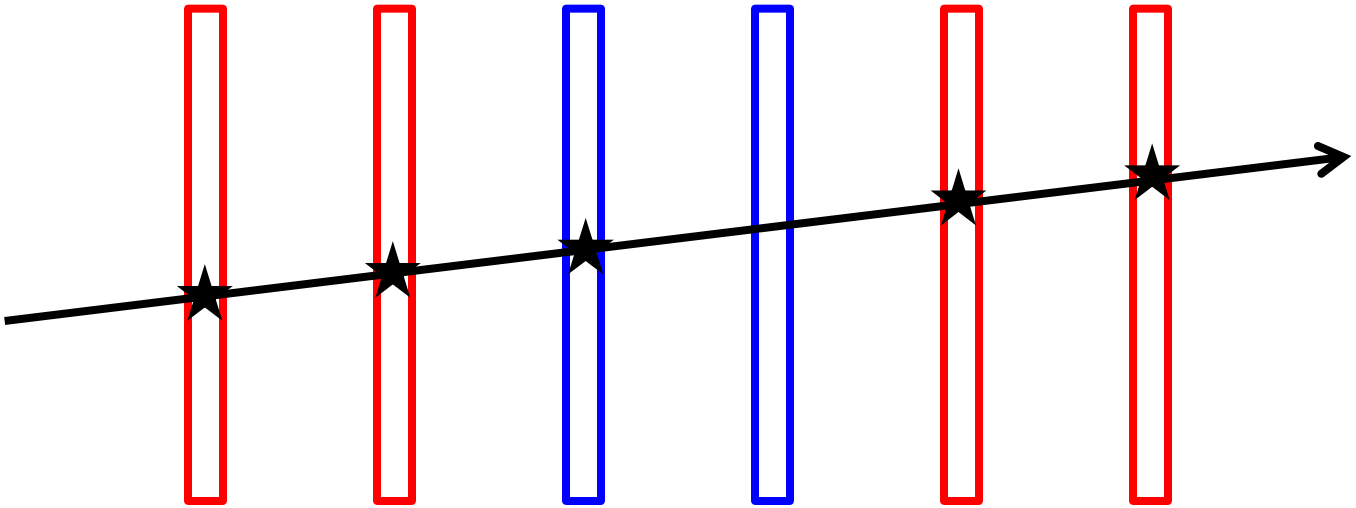
Basic aims of beam test(s)

- Verify performance of TPAC
  - Efficiency for MIPs, noise, number of hits...
- Match TPAC performance to simulation using tracks
  - Sensor simulation: compare different sensors (hi-res, deep p-well)
  - GEANT4 simulation: rates of hits, MIP efficiencies vs threshold
  - Can be done with pion or electron beams, without tungsten converter
- Measure number of hits (and other properties) of EM showers
  - Number of hits vs energy, shower width at various depths in X_0
  - Verify (or not) GEANT4 simulation of EM showers at very high granularity
  - Must have electron beams for this with tungsten converter to generate EM showers
- Must know efficiency from first part to do second part
  - This is the main point of the CERN beam test

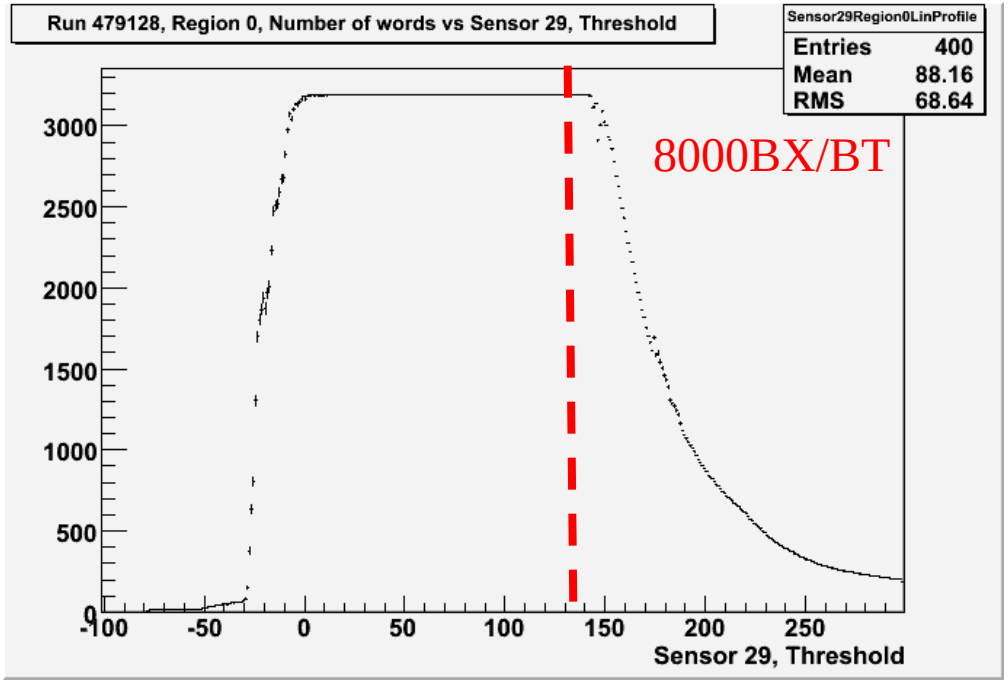
How do we measure efficiency?

- Five or six layers of sensors
  - Treat central one or two as “sensors-under-test”
  - Vary their parameters (threshold, masking, etc)
  - Keep outer two upstream and downstream sensors fixed
- Form tracks from outer sensors and project into inner sensors
  - Measure fraction of times a hit is found near projection to give efficiency
  - Easy, right?



Noise rate

- Average noise is ~7TU, so 5σ ~ 35TU
- Pedestal is fixed to 100TU by trimming
- Ideal threshold ~135TU but memory saturates at this threshold
- Due to few pixels with high noise
- Need to mask these, probably ~few % but direct impact on efficiency
- Assume hit rate ~5k per sensor per BT



Other efficiency effects

- Sensor has dead areas
  - Four 250μm-wide strips vertically
  - One 50μm-wide strip horizontally
  - Total active area 88.8% within nominal sensitive area
  - May also have tracks hitting outside sensitive area if sensors misaligned
  - Want to correct for this in efficiency, i.e. we want the efficiency for an active pixel, not of whole sensor
- Memory will saturate at 19 hits per row
  - Tracks at end of bunch train may have lower efficiency than at beginning
  - Can identify exactly when each row filled
  - Again, want to correct efficiency for this effect
- In all three cases (masking, dead areas, memory saturation)
  - Would need to know where hit was "supposed" to be if correcting at a track-by-track level
  - Masking needs us to know within a single pixel, memory a single row

Accuracy of track projection

- Resolution of projection ~ $\sigma_{outer}/2$
  - Assuming sensors equally spaced, negligible scattering
- If each hit in outer sensors located to one pixel
  - Implies σ_{outer} ~ 50μm/√12 ~ 14μm so projection resolution ~ 7μm
- But will in general have some nearest neighbours fire too
  - Do we set threshold in outer sensors much higher to cut down neighbour hits?
  - Reduces outer sensor efficiency and hence rate of usable four-hit tracks
  - Depends on (currently unknown) beam rate
- Even 7μm resolution is not ideal
  - If "definitely in a pixel" means 2σ from edge, then only ~20% of pixel surface will be used (and is a biased sample, not over whole pixel surface)
  - Cannot do a "per-track" hit efficiency correction easily
  - How do we correct for the "artificial" inefficiencies? Statistically?

Noise rate implications

- Noise rate likely to be ~5k hits/BT for each sensor
  - This is ~0.5hit for each BX during an 8000 BX train
- If PMTs work well, coincidences time-tag the beam particle
  - Need to look at hit maybe within ±1 (?) timestamp of PMT hits (plus potentially some fixed time alignment offset)
  - Will have ~1-2 noise hits within this time window in each sensor
  - Beam particle will give a similar number if sensor is efficient
- For making tracks in outer sensors
  - Need to do correlations also in space to identify real hits
  - Effectively track pattern recognition; need alignment at what level?
  - Do we allow tracks with only three of the four outer sensors included?
- For efficiency from inner sensors
  - Cannot just ask for any hit within time window
  - Probably always a hit somewhere so again need hit close to projection

Conclusions

- Main aim of CERN beam test is MIP efficiency measurement
  - Assuming no electron beam available
- Efficiency calculation is not trivial
  - Need to do full alignment of sensors
  - Need to have track pattern recognition and fit reconstruction code
  - Need to consider masking, dead areas and memory saturation effects
- Ideally would start on this before doing to the beam test
  - Can use MC data for this