

# TRT Readout Document and Arising Readout Issues

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Hampton TRT Workshop Electronics Session 2

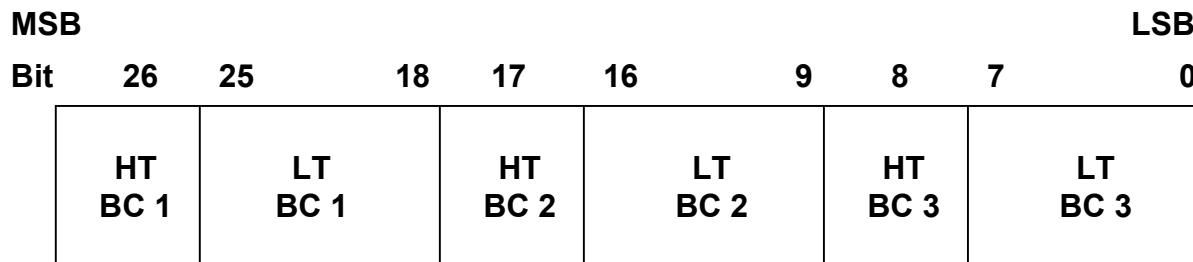
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# Introduction

- Daniel asked me write a document describing the read-out chain to facilitate writing software that simulates the byte stream that the TRT reads out.
- A draft note describing the TRT readout chain from the DTMROC through the ROD to the ROB is at:  
<http://hep.physics.indiana.edu/~luehring/readout.pdf>
- Please send me comments and corrections.
- No more simulation studies of the readout bandwidth have been done since Mogens' studies last summer.
  - Recent work with the latest GEANT3 simulation code indicates that his work should still be valid.

# DTMROC Data for a TRT Channel

- When a Level-1 trigger accept occurs, the DTMROCs transmit data for every channel in the TRT detector with the following characteristics:
  - There are a 27 total bits of data for each channel.
  - Twenty-four bits encode the low threshold state
  - Three bits encode the high threshold state.
  - The bits encodes for a total of 75 ns following bunch crossing causing the Level-1 accept.
- These bits are encoded as follows:



Earlier  Later

# ROD Data processing

- The ROD can run in four modes:
  - A fully transparent mode where all 27 bits for all channels are sent to the ROB. This mode is used for testing only.
  - A zero suppressed transparent mode where the full 27 bits are sent to the ROB but only for hit channels. Used at low luminosity.
  - A mode where the data is compressed to between 2 and 11 bits for each channel depending on whether it is hit. Used at high luminosity.
  - A mode where the data is compressed to between 6 and 15 for each channel and most of the empty channels are removed from the data stream. Proposed for use at intermediate luminosity.

# Zero Suppressed Transparent Mode

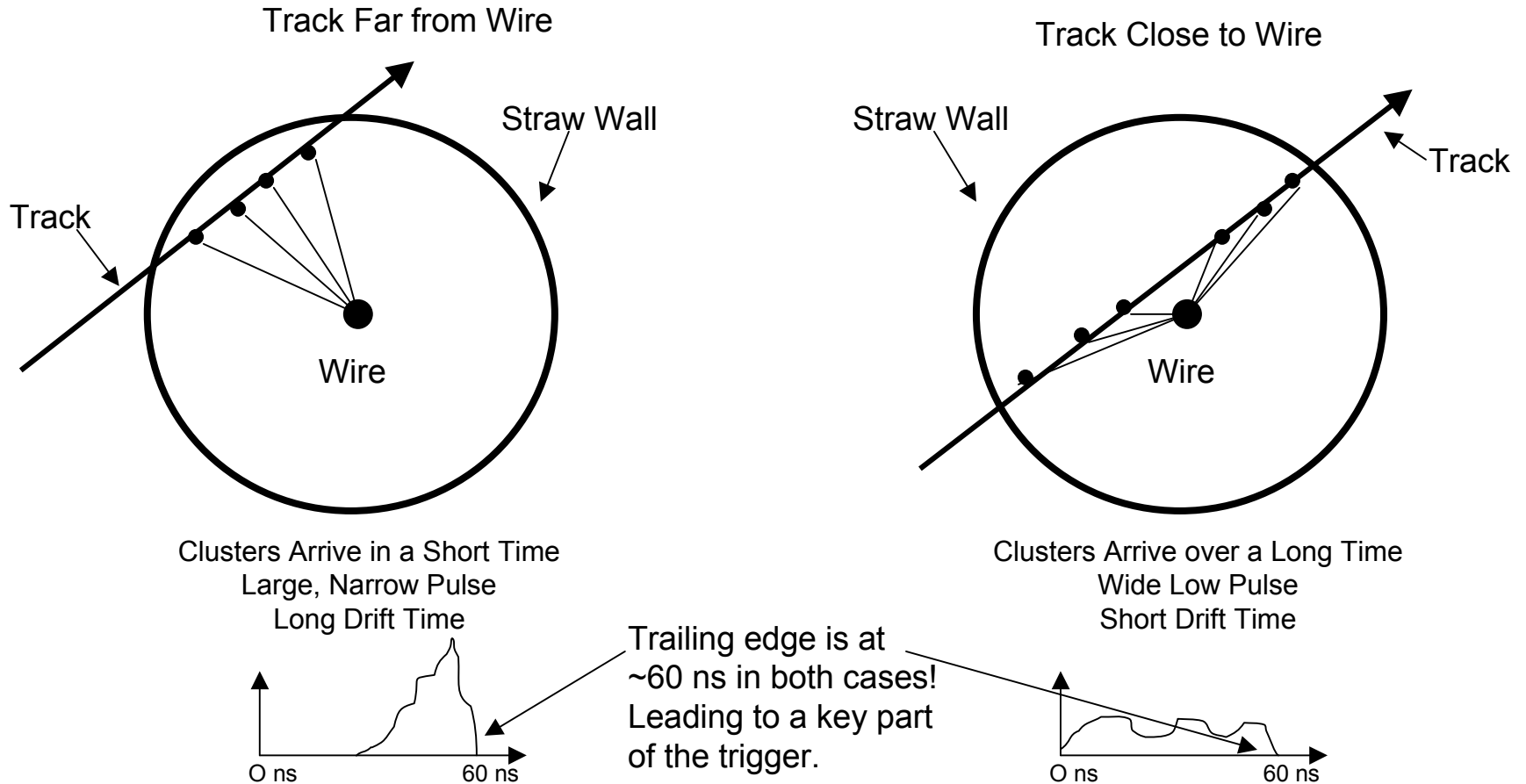
- Full information (27 bits) is kept for each hit channel.
- No data is transmitted for empty channels.
- The data is formatted into blocks containing information for up to 26 channels.
- Empty channels are dropped and five more bits are added the 27 data bits to identify the channel.
- Since 27 data bits + 5 address bits is 32 bits, this mode uses full 32 bit words for its buffer.

| Word | Bits 27-31 | Description       | Bits 0-26     | Description                                   |
|------|------------|-------------------|---------------|---|
| 1    | <11110>    | Start Block Code  | <0...0GGBBBB> | Group number (2 bits) & block number (4 bits) |
| 2    | <SSSSS>    | Channel ID (0-25) | 27 data bits  | 27-bit full encoding data for channel.        |
| :    | :          | :                 | :             | :   |
| N+1  | <SSSSS>    | Channel ID (0-25) | 27 data bits  | 27-bit full encoding data for channels.       |
| N+2  | <11111>    | End Block Code    | <0...0NNNNN>  | Number of hit channels in block (5 bits)      |

# ROD Data Compression

- The ROD divides the channels into three categories for compression purposes:
  - **Valid** channels with a hit that was probably caused by a stiff, in-time stiff track.
  - **Invalid** channels where it is unlikely that the hit was caused by a stiff, in-time track.
  - **Empty** channels with no hit.
- Hit channels are marked as valid or invalid using a 4 TDC bin gate near the hit trailing edge time.
- It may be necessary to widen this gate under real running conditions (the 4 bin gate width is determined from simulation only).

# Straw Tube Pulse Shape



The pulse width is highly correlated with drift time. Also the pulse trailing edge time is stable because all tracks deposit clusters near the straw wall.

# Compressed Modes

- The high luminosity compression mode generates data for every channel:
  - Valid hit channels generate the 2-bit code <10>, a 1-bit high threshold hit code, and two 4-bit edge times. Total of 11 bits.
  - Invalid hit channels generate the 2-bit code <01> and a 1-bit high threshold hit code. Total of 3 bits.
  - Empty channels generate the 2-bit code <00>. Total of 2 bits.
- The proposed lower luminosity compression mode skips generating data for empty channels:
  - Using 4 bits this mode records the number of empty channels preceding a recorded channel.

| Channel Type    | High Luminosity | Lower Luminosity (Nick Ellis) |
|-----------------|-----------------|-------------------------------|
| Valid Channel   | <10HLLLLTTTT>   | <10NNNHLLLLTTTT>              |
| Invalid Channel | <01H>           | <01NNNH>                      |
| Empty Channel   | <00>            | <00NNNN>                      |

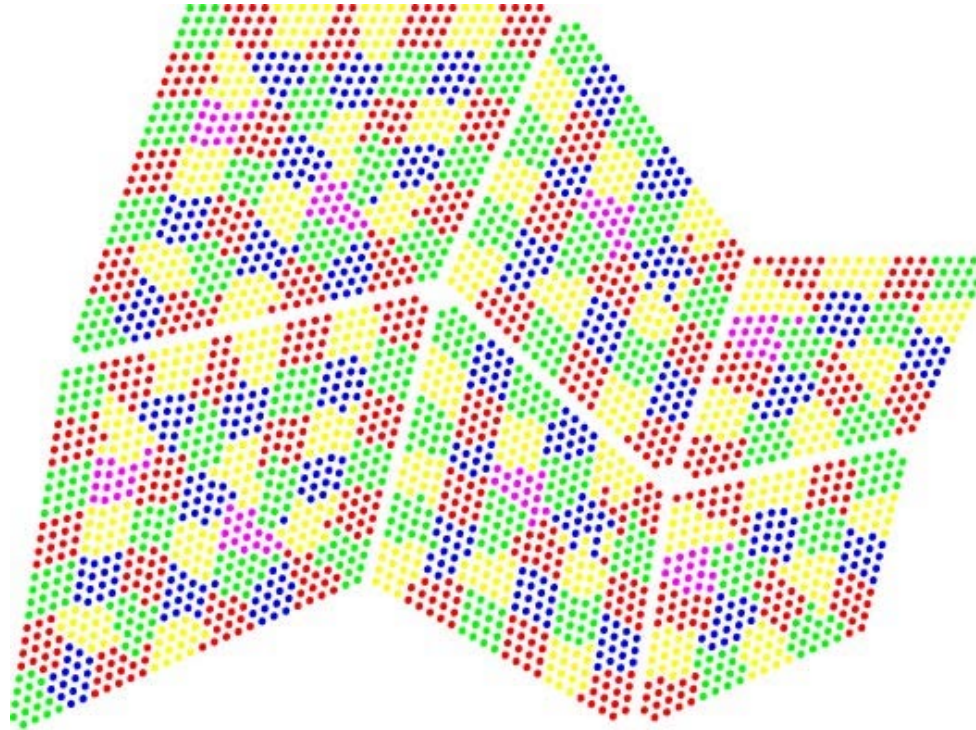
# Unresolved Issues and Questions

- In writing the note, a number of items were noted.
  - There were inconsistencies in how the physicists and engineers thought that the readout was being implemented.
- The rest of the talk will list these issues so that we can discuss them.

# Output Data Order

- The most important open question is how the ROD orders the data channels in its output buffer.
  - The higher level triggers (Level 2 and 3) and the offline would prefer that the channels follow the geometrical ordering of the straws in the detector (“offline identifier scheme”).
    - E.g. the first straw in a readout block should be the first straw in a layer, the next straw in the readout is the next straw in the layer, etc.
  - The readout currently generates an ordering in the output buffer that is complex and reflects several layers of hardware connections (“online identifier scheme”):
    - Straw connections to DTMROC channels.
    - DTMROC connections to the ROD.
    - The ROD blocking together 26 straws from 26 different DTMROCs.
    - Use of spare cables / channels.

# Output Data Order



- Paul made this mapping of DTMROCs onto barrel straws.
- The ROD combines one channel from 26 DTMROCs into a block.
- Data in this format will have to be reordered for use in offline and higher level trigger codes.
- The barrel is considerably more complex than the end-cap.

# Data Reordering

- Reordering the data treated by a single zero suppression engine (1/4 of a ROD) is “easy” and “cheap” because it can be done in the zero suppression engine (probably with a look-up table).
- Reordering the data for the whole ROD could be “hard” and “expensive” if it requires adding additional stages of electronics to the ROD.
- If new stages are added using a brute force approach the new stages would have to be:
  - added be after the existing stages.
  - very fast.
- Peter wants to try to think of a smarter approach.

# Compressed Output

- Which edges does Peter programs the ROD to record?
  - Keep two leading edges or a single leading edge.
  - Keep a leading edge and a trailing edge.
- What happens if one of the edges is missing?
  - Straw is coded as invalid (code <01>).
  - Four bits used to encode edge set to <0000> or <1111>.
- Exactly what is the validation gate?
  - Presence of a leading edge.
  - Level gate in four bins long near the trailing edge.

# ROI Definition

- Paul is trying to track down exactly how the global ROI maps onto the TRT.
  - It is certain that the ROI is about  $2\pi/30$  wide in phi to allow for overlap.
  - How this projects onto the TRT barrel with its zig-zagging boundaries in phi is not yet clear.

# Global TRT Data Structure

- How are blocks of data organized when the data is written out when a Level-3 accept occurs?
  - A possible order is -Z to +Z: -Z end-cap, -Z barrel, +Z barrel, +Z end-cap.
- The current document ends with describing the ROB format where the data is still being processed parallel.

# Type C Wheel Staging

- How are we going to connect end-cap channels to the ROD during the running periods where the Type C wheels are unavailable?
  - Lots of empty channels.
  - Fewer RODs.
- Staging the C wheels could have implications for the end-cap cabling.

# Other Questions Answered by Peter

- Is the data ordered same with compression on as it is with compression off? Yes
- Are there data blocks in the ROD output when compression is on? No (Yes NE scheme?)
- What happens when an entire block has no data?
  - Is an empty block with a header and trailer word generated?  
Yes
- What if an entire ROD has no hits?
  - Is an empty buffer with header and trailer generated? Buffer filled according to current compression or zero suppression scheme.