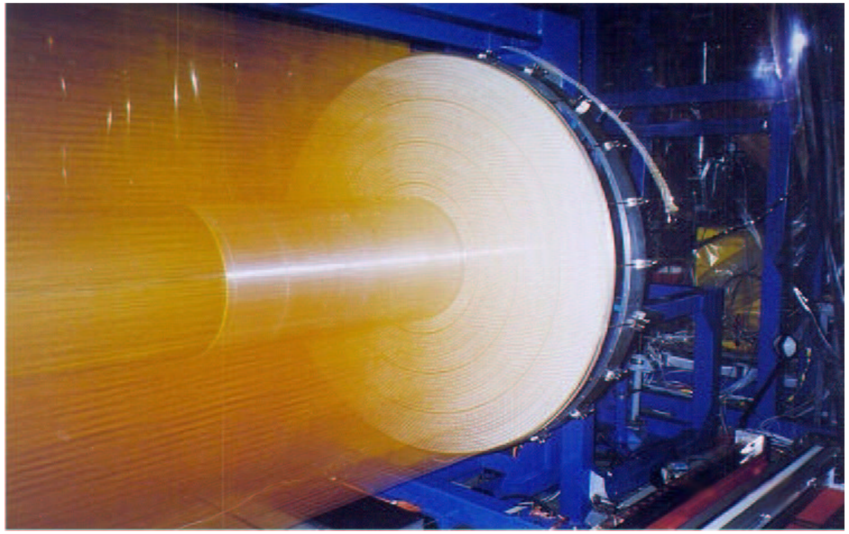
BaBar Level-1 Drift Chamber Trigger Upgrade



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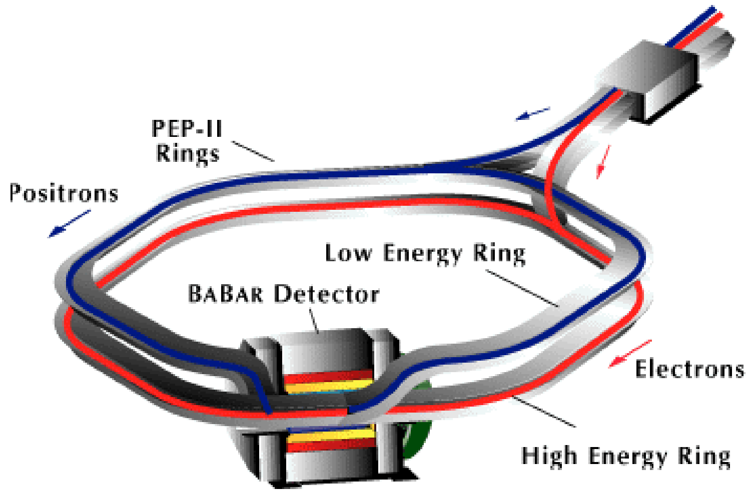
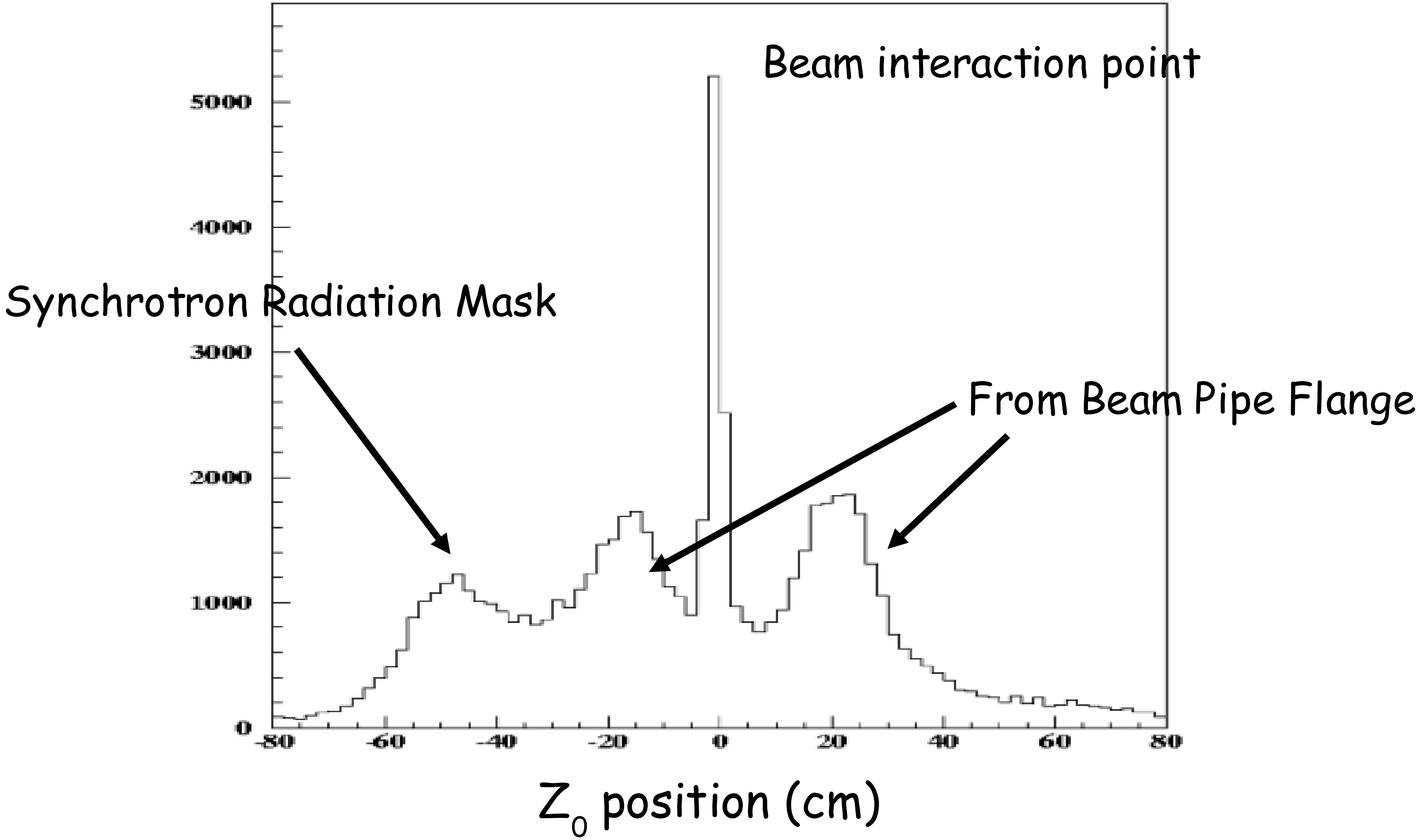
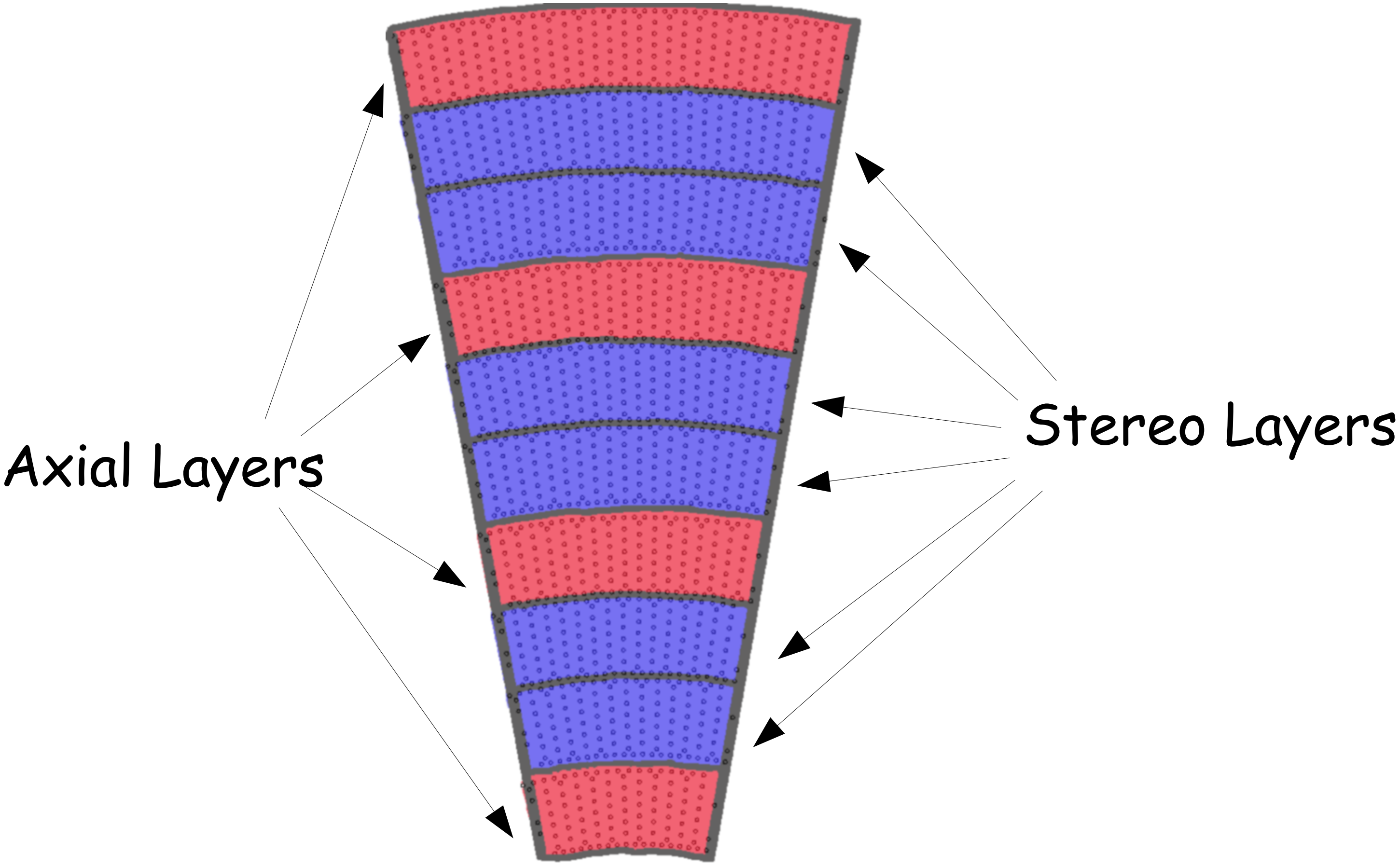


- PEP-II has now surpassed its initial design luminosity of 3×10^{33} cm^{-2} sec^{-1} by a substantial margin. Recently it has been running with $>7\times10^{33}$ cm^{-2} sec^{-1}
- Set to hit 10^{34} cm^{-2} sec^{-1} before the current physics run ends in the summer.
- BaBar Level-1 Hardware trigger rates have been hovering at or above 2kHz. An acceptable upper level is close to 3kHz before the data acquisition system becomes over stressed.
- Large proportion of triggers are caused by background events.

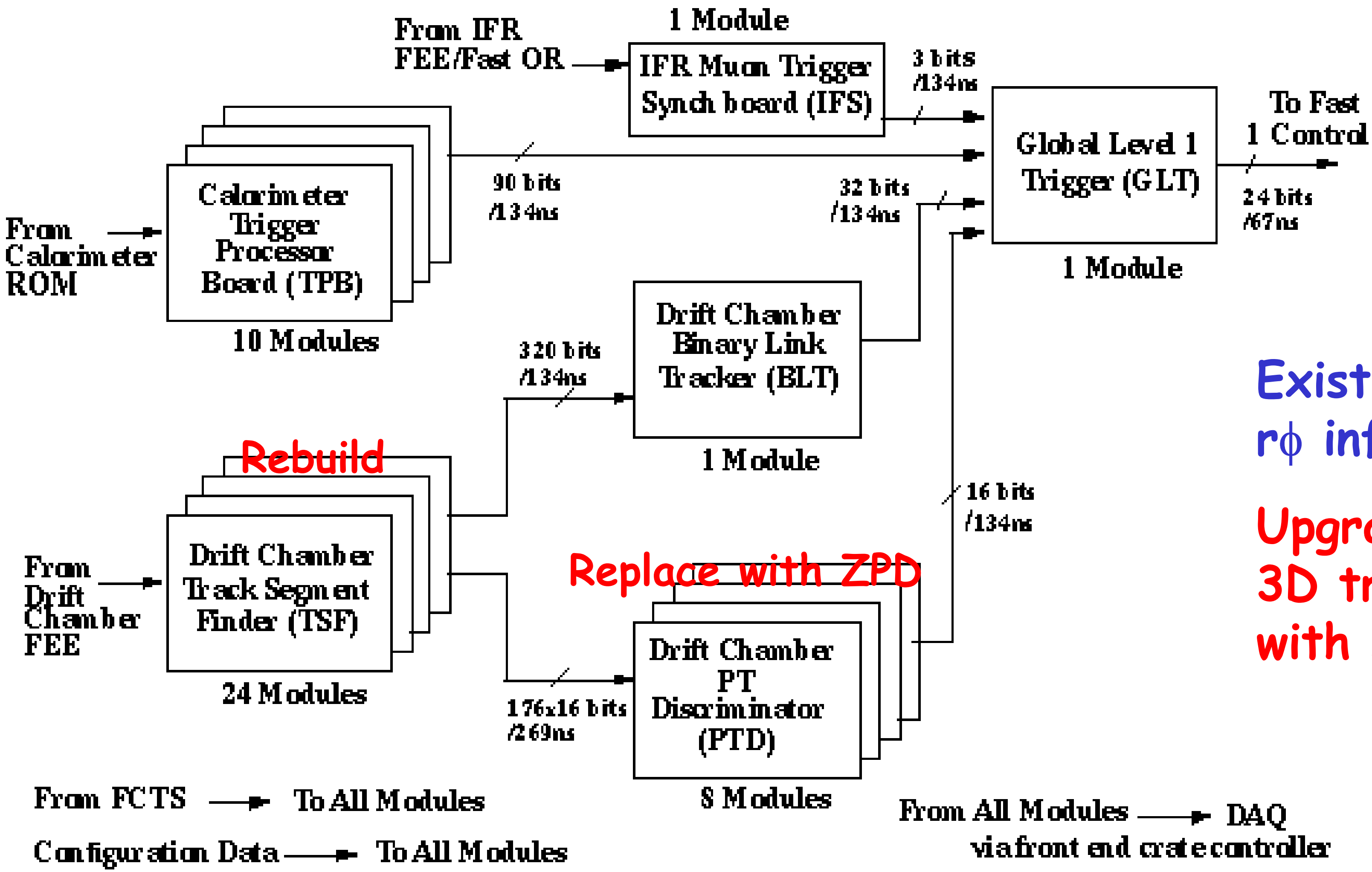
Distribution of Z_0 position of reconstructed tracks



Drift Chamber Layout of 1/16 Segment



- Drift Chamber has 40 layers grouped into 10 "SuperLayers"
- 4 of them are Axial.
- 6 are Stereo and form 3 Stereo Pairs.
- Trigger receives a complete frame of data at 4Mhz rate.



Existing system:
rφ info only

Upgrade:
3D track trigger
with stereo wires

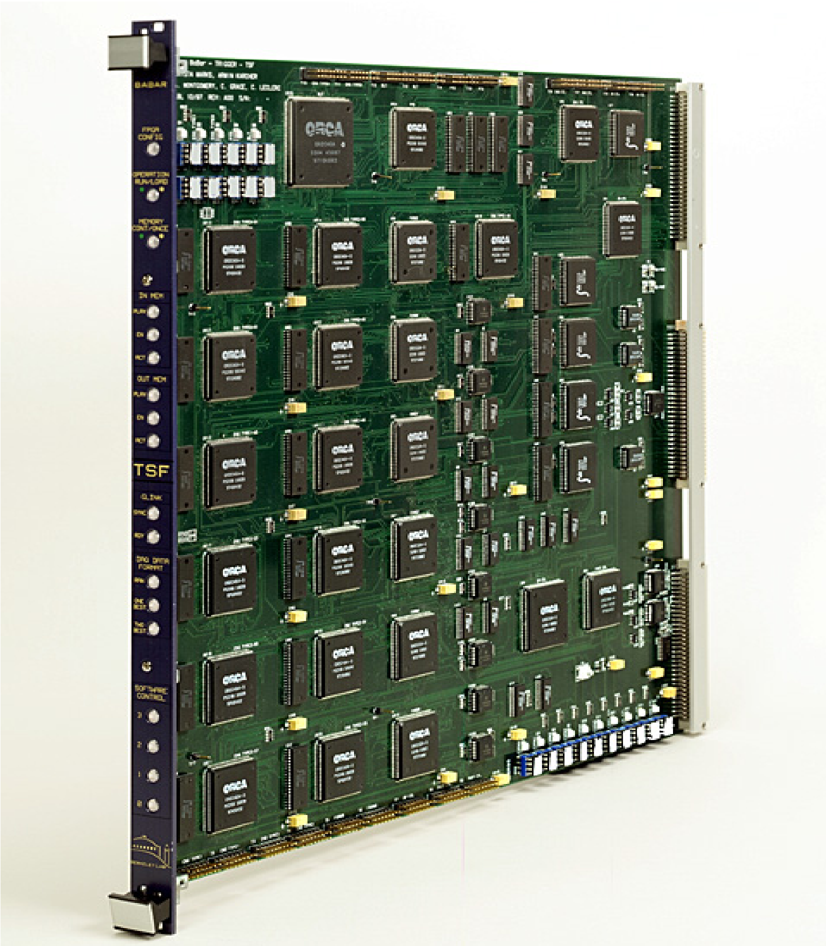
- A design upgrade to the original Drift Chamber Trigger (DCT) began being studied in 2001.
- The system was to use the Z position information that can be obtained from the stereo layers.
- From Monte Carlo studies it could give ~ 45% of background rejected with a Z_0 cut at 10cm from the Interaction Point.
- Still Retain ~98% of physics events at that cut level.
- System is tunable by on-line software to allow the cut level to be changed easily.

ZPD Board

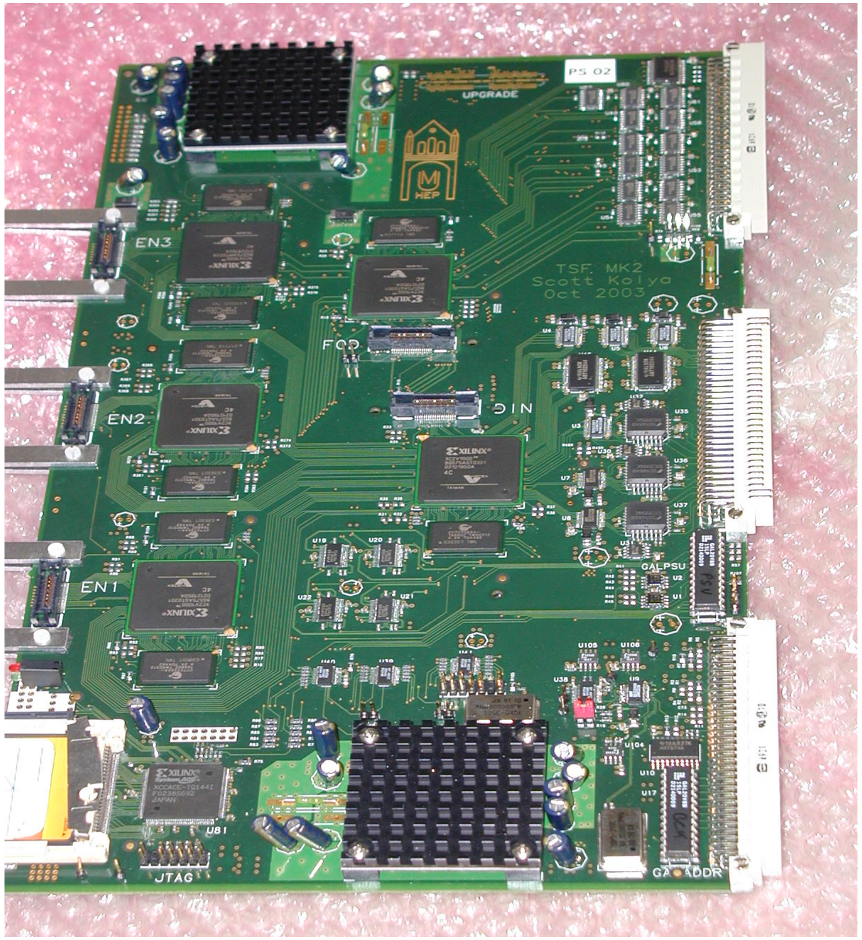
- A team from Harvard University undertook the design and production of the new ZPD which would perform the function of the old PT Discriminator and have the added Z Discriminator functionality.
- The updated Track Segment Finder (TSF) is a joint project involving in a Bristol & Manchester collaboration.

- Changes to the Track Segment Finder needed to support the ZPD were initially considered minor.
- Requires two main changes.
  - Output better phi resolution, an extra bit is used.
  - Output up to the best 3 segments found for a SuperLayer.
- Original plan to reproduce the LBNL design with changes was too costly in hardware terms. Contained 13 FPGAs!
- Total redesign of both Hardware and Firmware resulted in a new design containing only 5. At significant cost saving.

Original LBNL Design



New Manchester Design



Brief TSF overview

- 1 FPGA receives, formats and ships Drift Chamber data to 3 "Engine" FPGAs.
- An Engine handles up to 3 "SuperLayers" each between 6 and 16 segments.
- Segments occupancy converted into LUT address and values for Phi, delta-Phi and timing returned.
- Segments are processed and ranked. With the Position, Phi and delta-Phi for up to the 3 segments are sent to the ZPD.
- Final FPGA handles output formatting, DAQ and Control functions.

Brief ZPD overview

- Each ZPD takes segments from 9 TSF boards.
- These are built into a Pattern Recognition Matrix
- Seed tracks are made from highest ranking elements in this.
- These are then used to fit helical track paths to. From which various parameters can be extracted. Z_0 and Transverse Momentum (PT), curvature and dip angle for example.
- A trigger decision is then made based on the cut settings required.
- This is then sent to the Global trigger (GLT).

Testing of the system I

- Monte Carlo events from the C++ simulation were loaded into the input memories and the TSF used to play and record them into it's output memory.
- Very good agreement with simulation. 10K+ events played with a hand full of minor discrepancies, last of which was finally understood during the last week.
- Can Playback from TSF input to ZPD input memory to test interface chain for transmission errors. Can also play through to ZPD Output memory to check track finding of whole system.

Testing of the system II

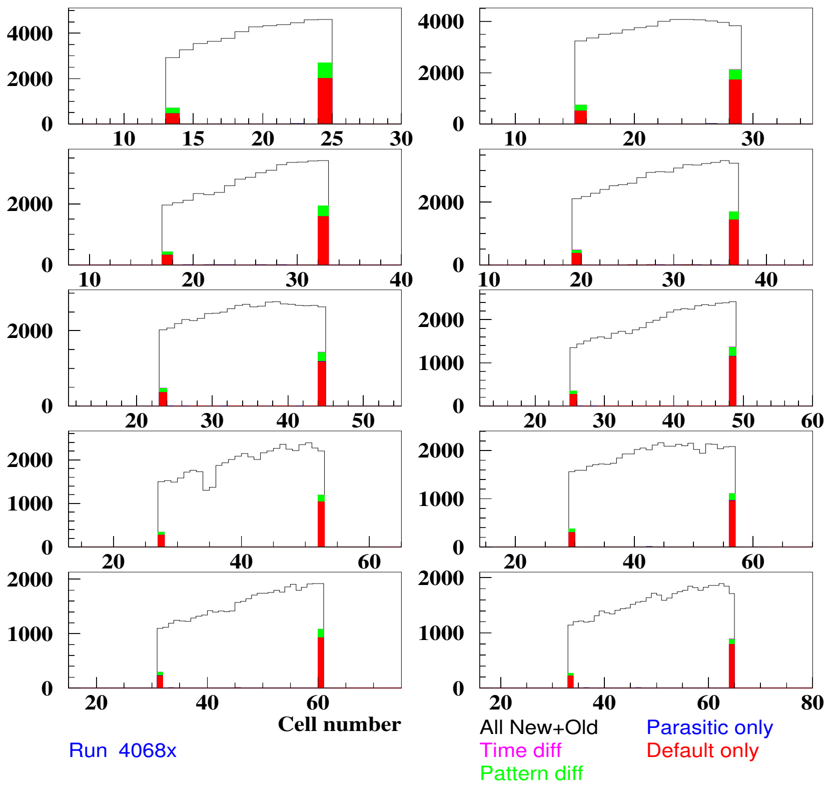
- Prototype wedge of the new trigger running in parallel to existing system.
- Drift Chamber signal is split and fed to both. BaBar uses old trigger and we get DAQ data from old + new for every event.
- TSF DAQ should match 100% between them with the exception of edge effect's caused by the prototype only being a wedge.
- ZPD can be compared to the Level 3 Trigger track reconstruction.

TSF DAQ Comparison

Coloured entries show discrepancy between old and new TSFs

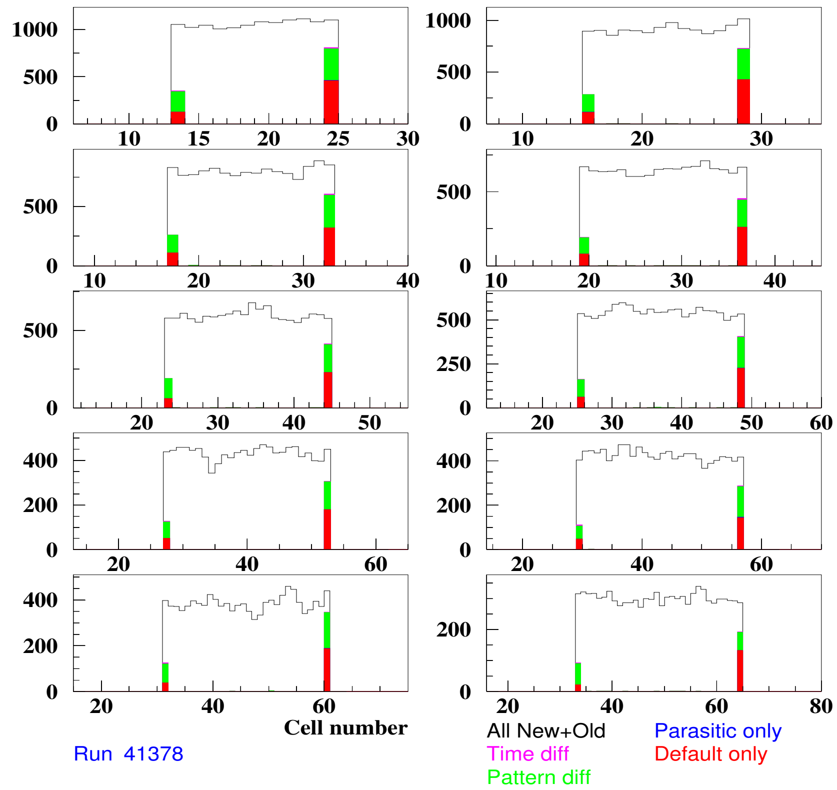
Cosmic Data

Segment Category by Superlayer



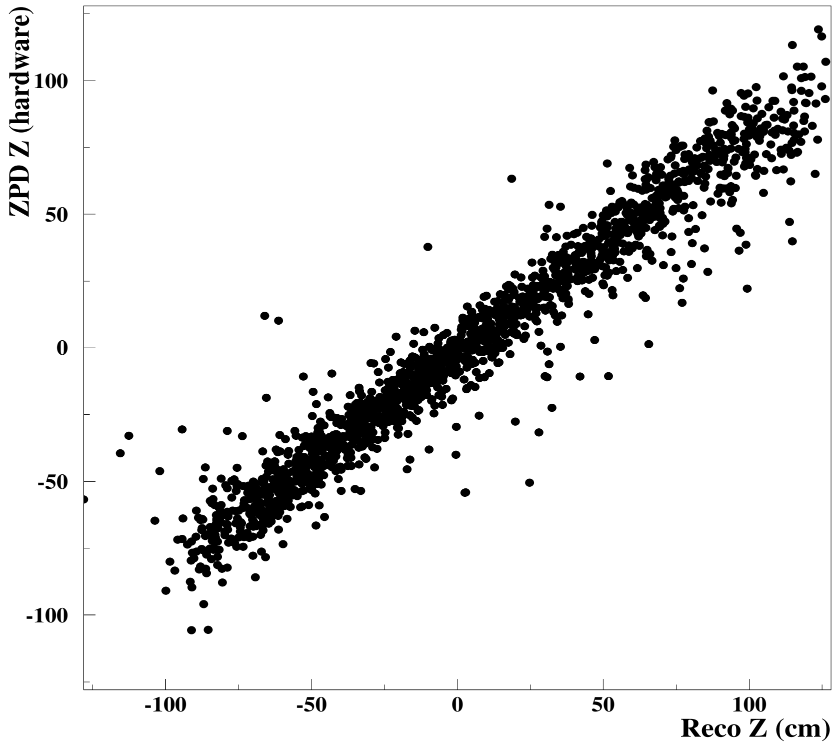
Colliding Beam Data

Segment Category by Superlayer



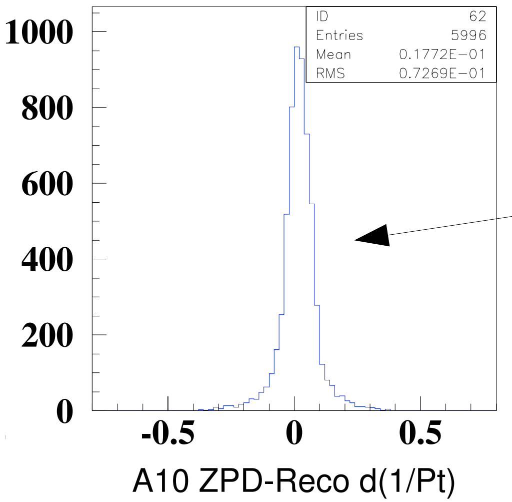
ZPD Track Comparison

Seed 0 ZPD vs Reco Track Z

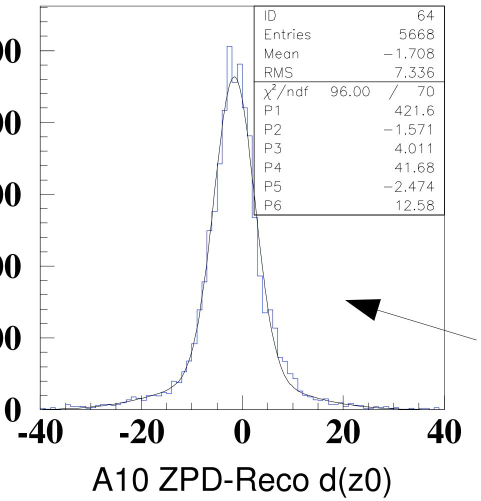


- Hardware results compared to Level 3 software reconstruction.
- In general shows good agreement
- Edge effects likely to be cause of errors as there were only 6 Prototype TSFs connected instead of the 9 needed.

Difference in track parameters between ZPD and Level 3



Transverse Momentum $^{-1}$



All important Z_0 value

- Shows the distributions of the difference when running with real Drift Chamber data.
- Mean slightly offset from zero due to a slight misalignment of the Interaction point inside BaBar from expected values.

Conclusions

- 24 Production TSF boards being made along with some spares. Will be tested at Manchester before shipment to SLAC.
- ZPD and interface boards already at SLAC.
- Online monitoring software installed and tested at BaBar.
- System to be tested with Monte Carlo and calibration data in the lab before installation into the electronics hut at BaBar.
- A period of full system parallel running and evaluation before switch over to new system.