Level 2 XFT Upgrade Overview

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L2 Upgrade Review
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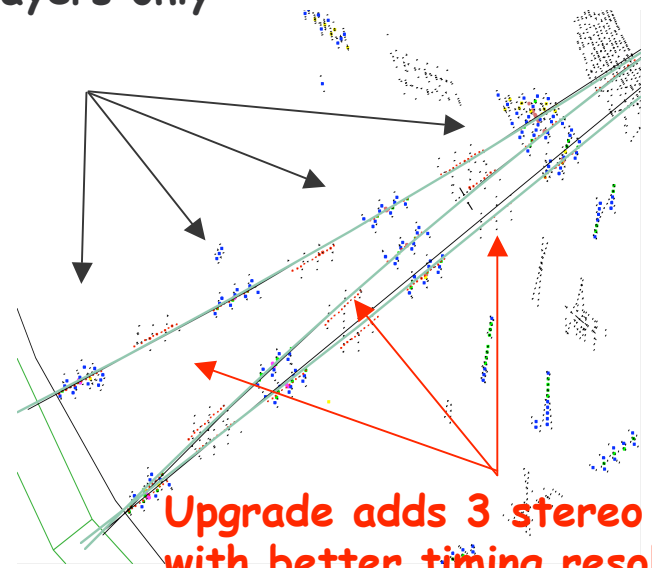
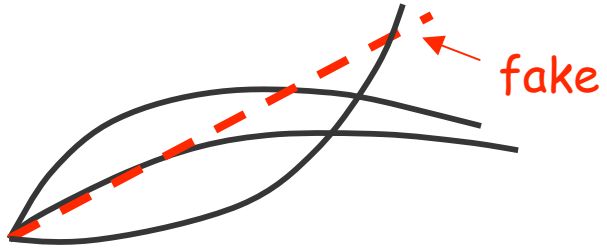
XFT Stereo Upgrade

Original XFT used 4 axial layers only



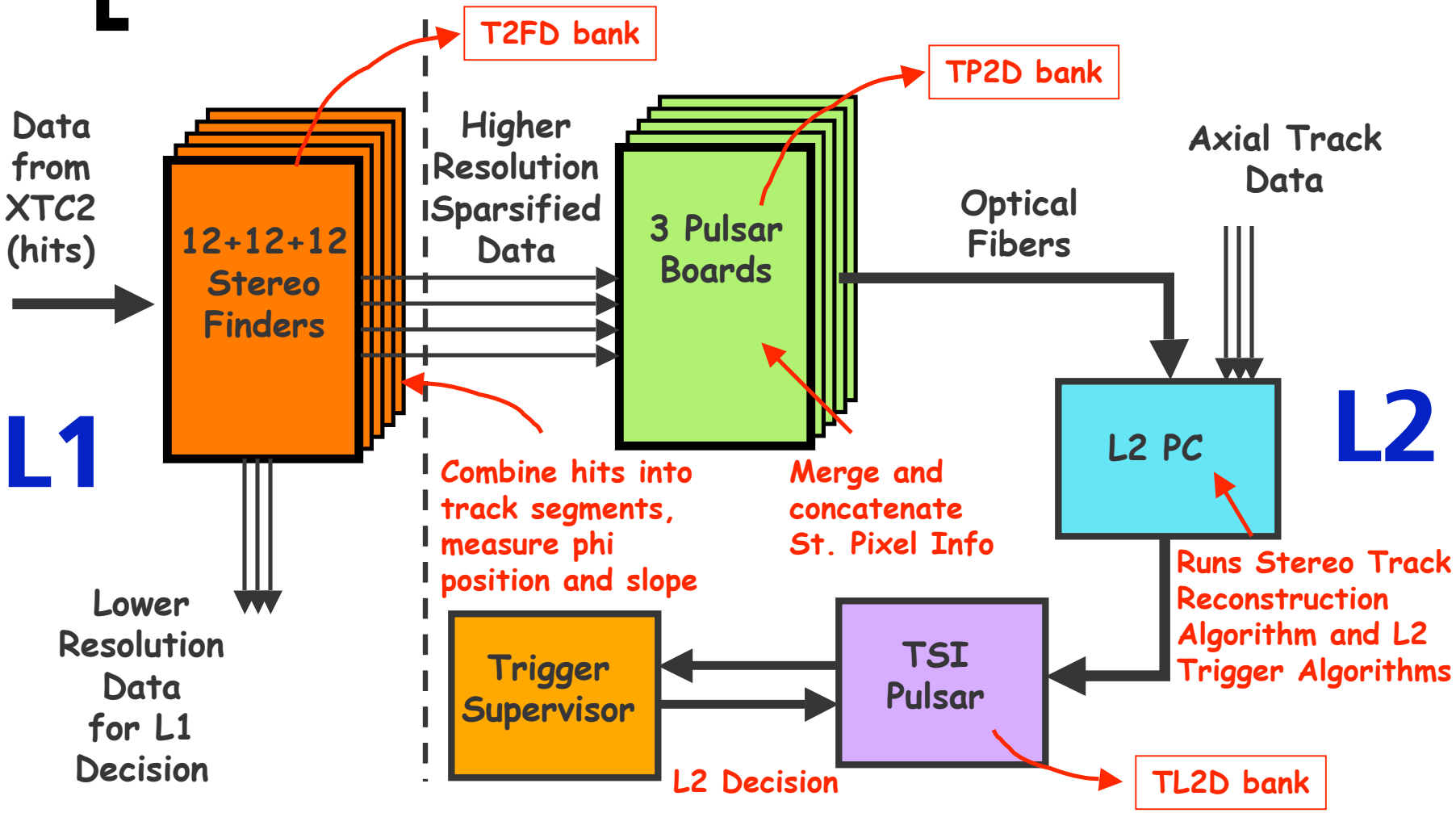
Upgrade adds 3 stereo layers with better timing resolution and higher precision tracking

- **XFT fake rates grow rapidly due to**
  - extra real tracks from multiple interactions per crossing
  - fake tracks from segments corresponding to different real tracks

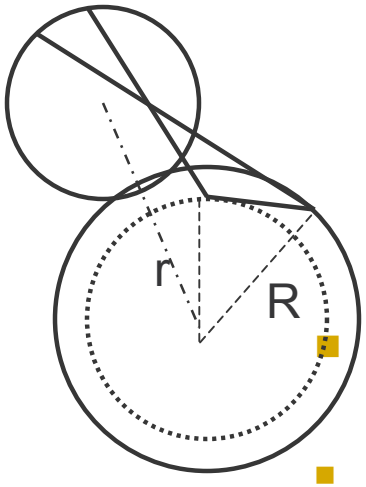


- **Associate axial tracks with stereo segments**
- **Confirm real tracks at Level 1/ reconstruct in 3D at Level 2**
- **Provides better fake track rejection**

L2 XFT Trigger Configuration



Stereo Geometry

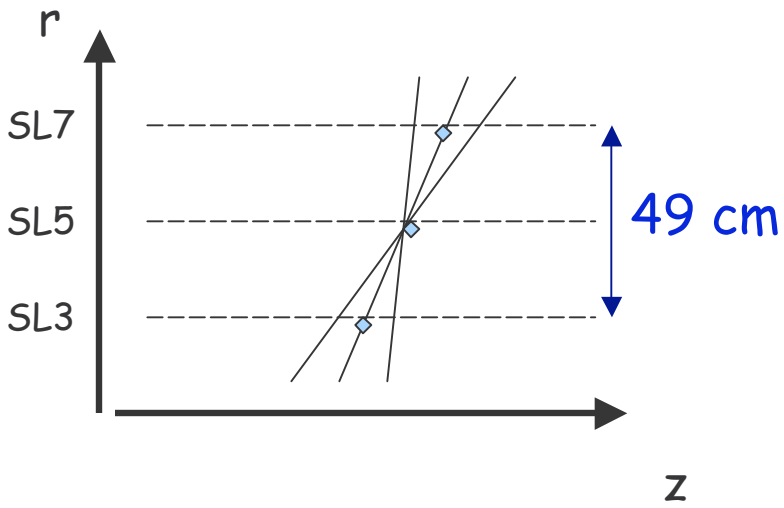


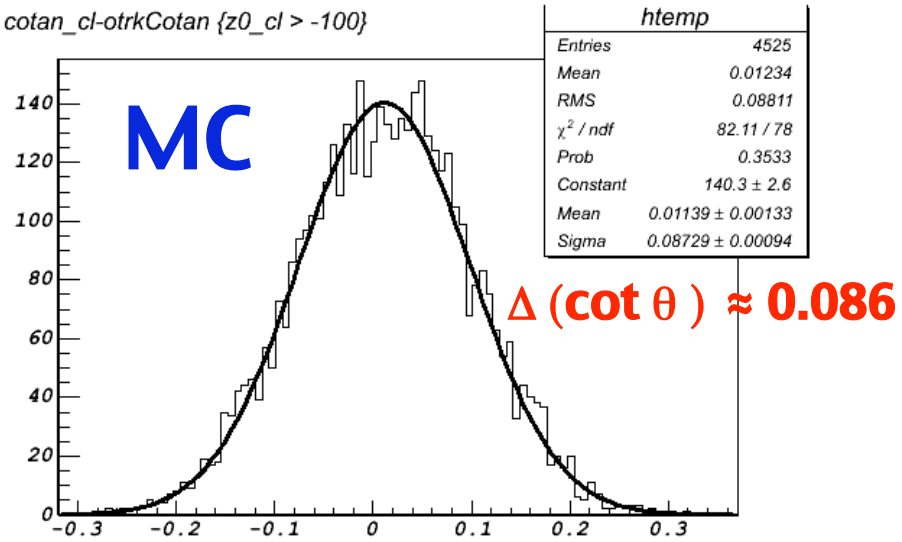
- Due to 2^0 stereo angle
  $z = \tan(\phi_{exp} - \phi_{obs})/S$
  - ϕ_{exp} – extrapolated position based on information from axial layers
  - ϕ_{obs} – measured position in the stereo layer

$N_{cells\ at\ SL3,5,7} = const * R_{SL3,5,7}$

- The maximum $\Delta\phi = \phi_{exp} - \phi_{obs}$ corresponds to 3 cells
- L1 pixel granularity: 1 cell = 6 ϕ pixels x 2 slopes (positive or negative curvature)
- L2 pixel granularity: 1 cell = 18 ϕ pixels x 5 slopes
- Better resolution and better fake rejection
- 3*18 pixels <–> 155 cm (a half of COT length)
- Shift by 1 ϕ -pixel corresponds to ~ 3cm in z at each stereo SL:
- $\Delta z_{3,5,7} \approx 3/\sqrt{2} \approx 2$ cm

Stereo Resolution





Δ (cot θ) ≈ 2*(3/ √ 2) cm / 49 cm ≈ 0.086

In absence of fake pixels:

$\Delta z_0 \approx R_5 * \Delta(\cot\theta) \approx 94$ cm * 0.086 ≈ 8 cm

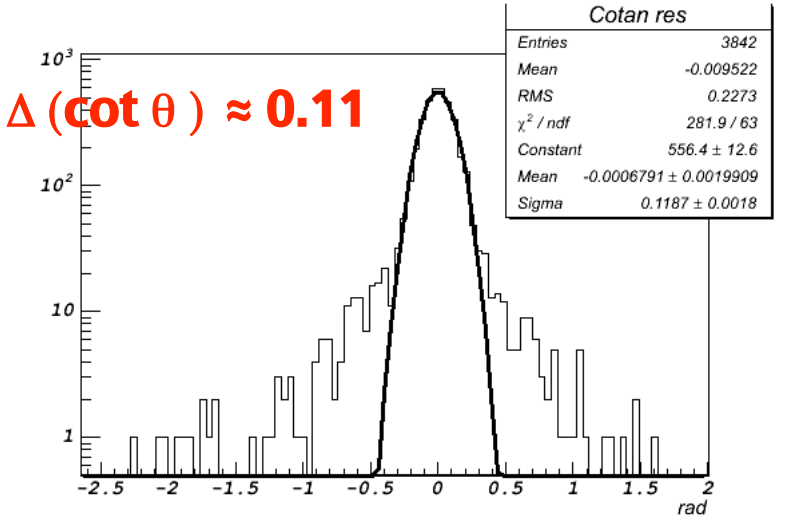
$\Delta z_{CEM} \approx (176 - 94) * \Delta(\cot\theta) \approx 7$ cm

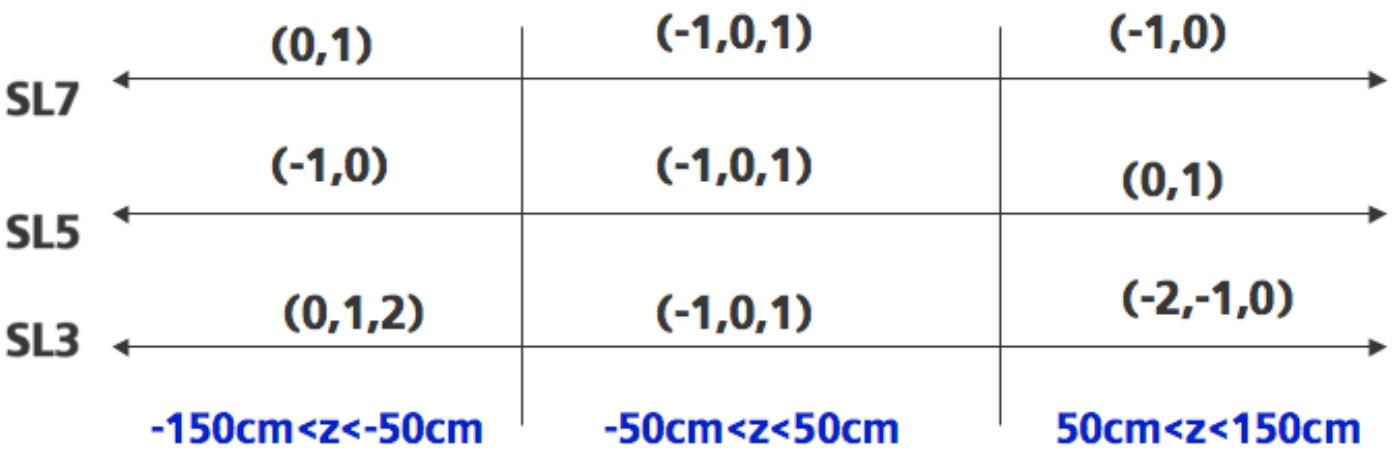
$\Delta z_{CMU} \approx (347 - 94) * \Delta(\cot\theta) \approx 22$ cm

Having only SL5 and SL7 information gives Δ (cot θ) ≈ 2* 0.086 ≈ 0.17

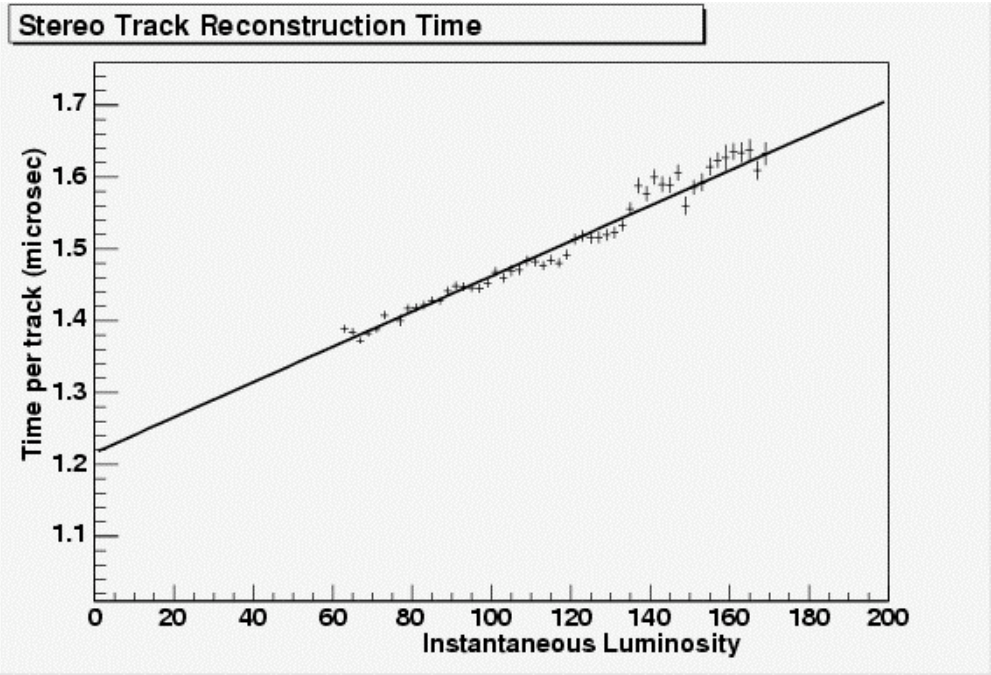
Resolution in data

- Resolution deteriorates due to high occupancy and a number of fake pixels:
  - Source of non-gaussian tails
- Most of them are removed by
  - a beam constraint: |z| < 90 cm
  - pixel alignment
  - Δ slope constraint:



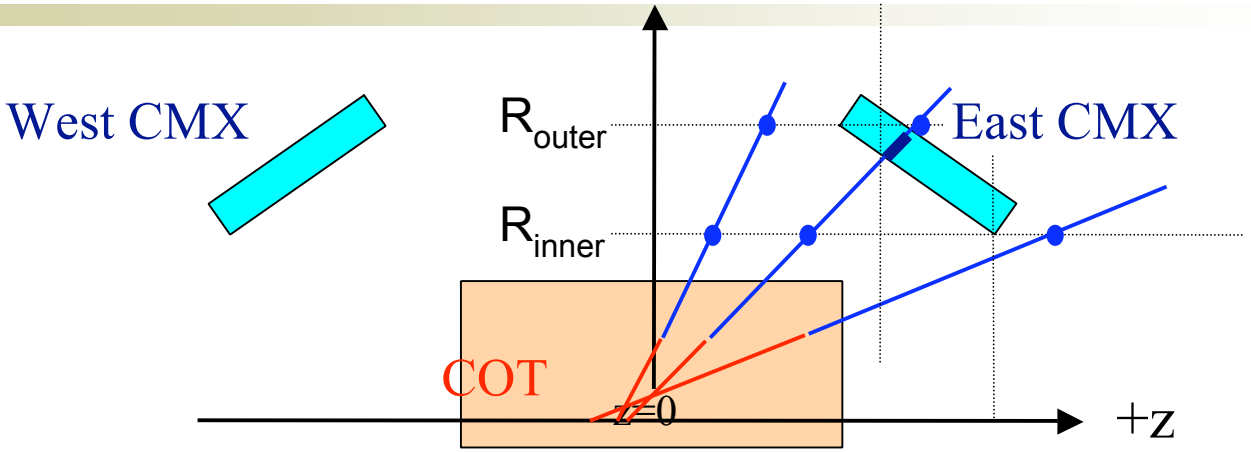


Stereo track reconstruction algorithm timing



- Stereo tracking algorithm has been validated online
- Ran in beam for several stores
- Gives an exact agreement with offline simulation based on L2 pixel banks
- The reconstruction time per track ~ 1.2–2.0 μsec
- Runs on demand, i.e. on top of what would be L2 Accept if only axial info is available

Stereo Trigger Development

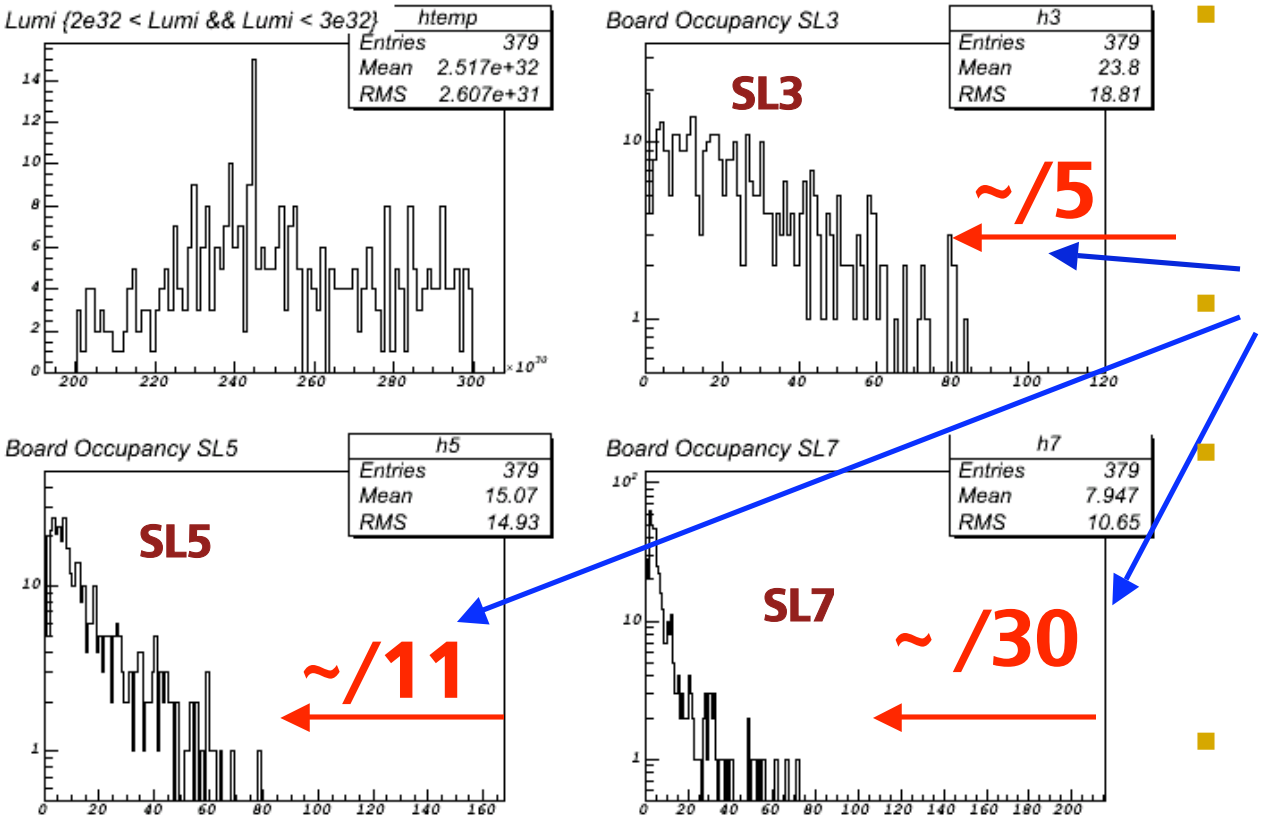


- CMX trigger with track stereo pointing is ready to be integrated into trigger table and tested in beam
- Cuts are selected are preserved to have high efficiency (99%) for CMX muons $z(R_{inner}) < N$ and $z(R_{outer}) > M$
- Stereo Track is pointed to East, West CMX chamber or neither
- Expect ~ 4 trigger rate reduction (preliminary)

- CMUP trigger is about to be ready – expect ~ 3 trigger rate reduction
- CEM trigger is under development to be available in ~1–2 weeks scale

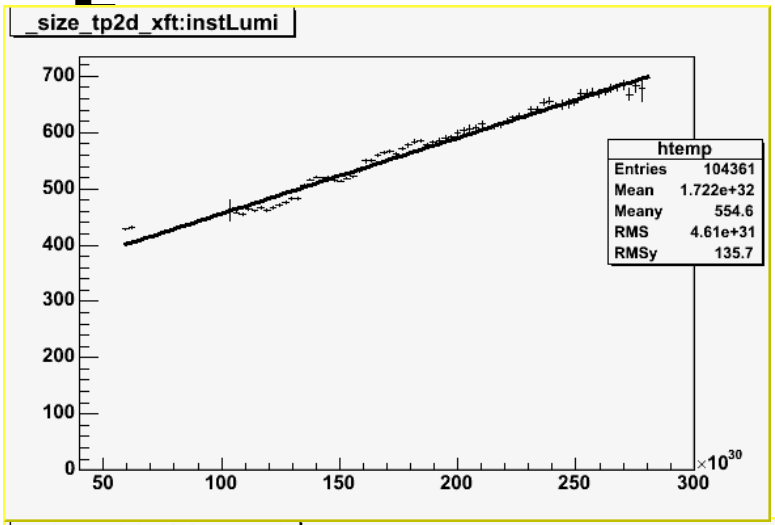
Data Sparsification

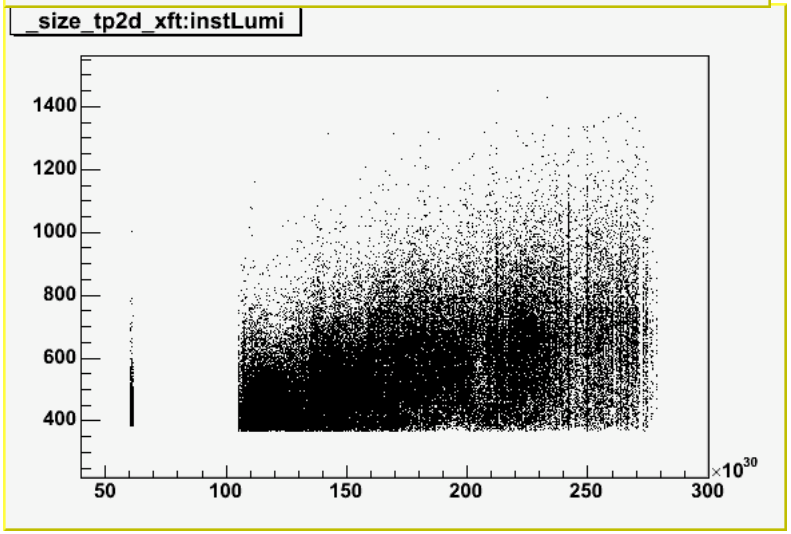
Finder Occupancies for Sparsified Data



- To provide high granularity stereo pixel data in time the XFT segments are sparsified with high factor in the data size reduction
- This step is implemented in the Stereo Finder firmware
- It took especially a lot of time to trace down and fix all the data errors due to L1 and L2 operating in the same FPGAs at different clocks
- The Finder->Pulsar Arrival time in ~ 2.5 μs
- Pulsar -> PC in ~7–9 μs

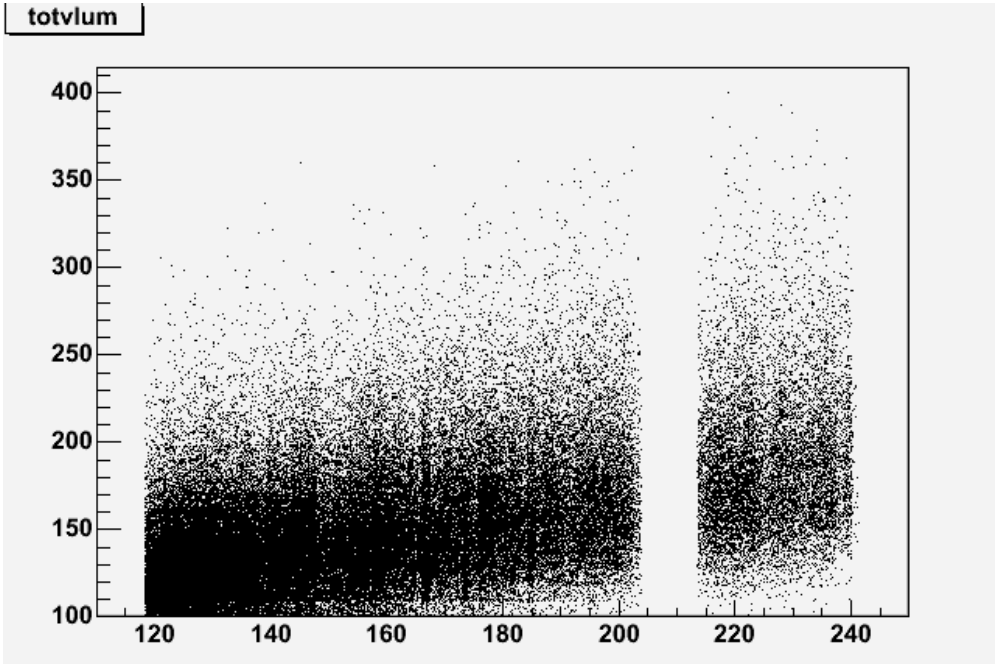
Sparsified XFT Data Volume





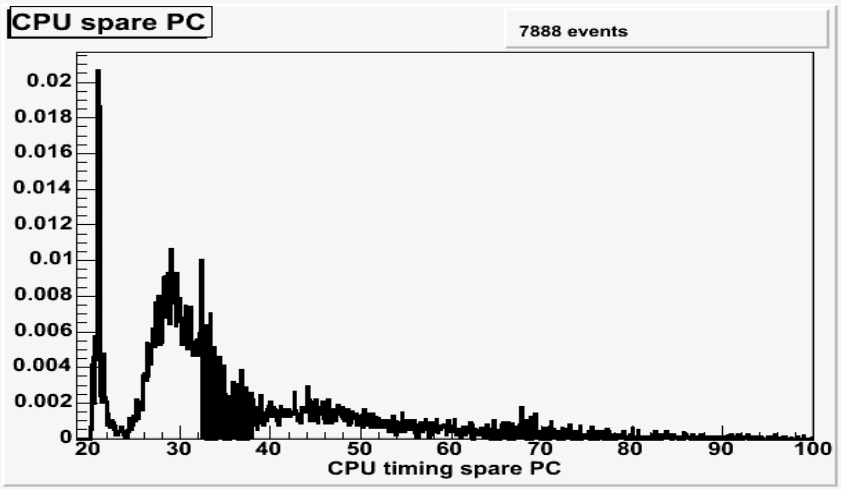
- **The XFT data format consists of**
- **1) the mask section – L1 granularity pixels with ORed slope bins – 360 SLINK words on every L1 Accept**
- **2) the sparsified data section - on average from 0 to 360 additional words for Luminosities up to $3x10^{32}cm^{2}s^{-1}$**
- **Single events can be as large as 1500 SLINK words**
- **The upper limit is 3000 words, but the SL3 will saturate earlier**

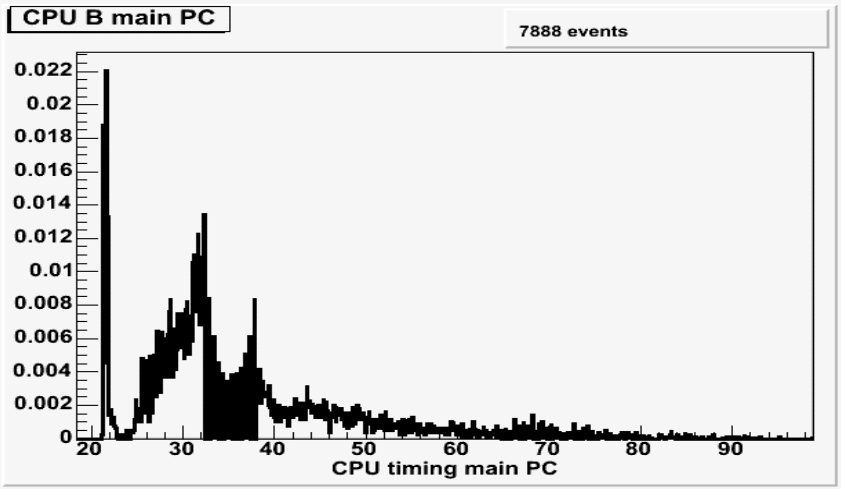
Non-XFT Data Volume

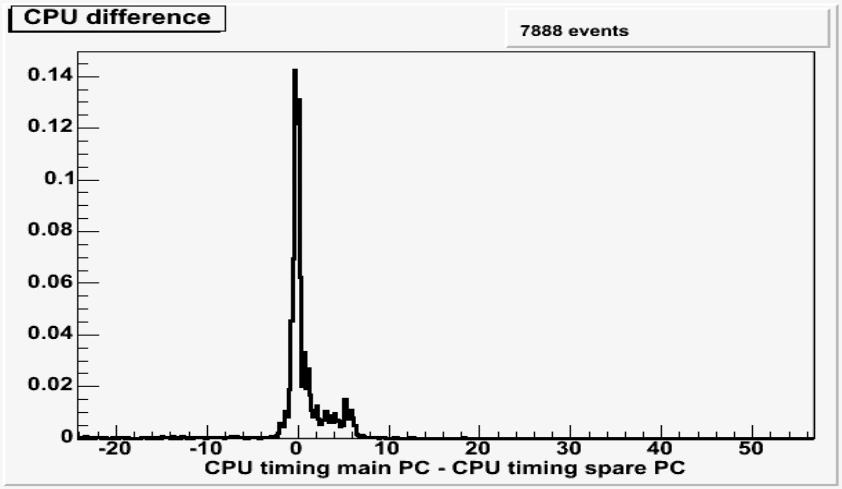


- Consists of Cluster, L1 bit, Muon, Track, CES and SVT information
- Average size ~ 150 SLINK word per L1 Accept
- The largest packet rising with luminosity is a Tracklist
- Packets arrive at different time after L1 Accept
- XFT commissioning was delayed with understanding the timing information
- FILAR PCI card operations were re-written to optimize into “first arrive-first serve “ basis

L2 Latency with XFT







- **As a result the L2 latency including the XFT data is the same as with old system**

Level 2 XFT in beam

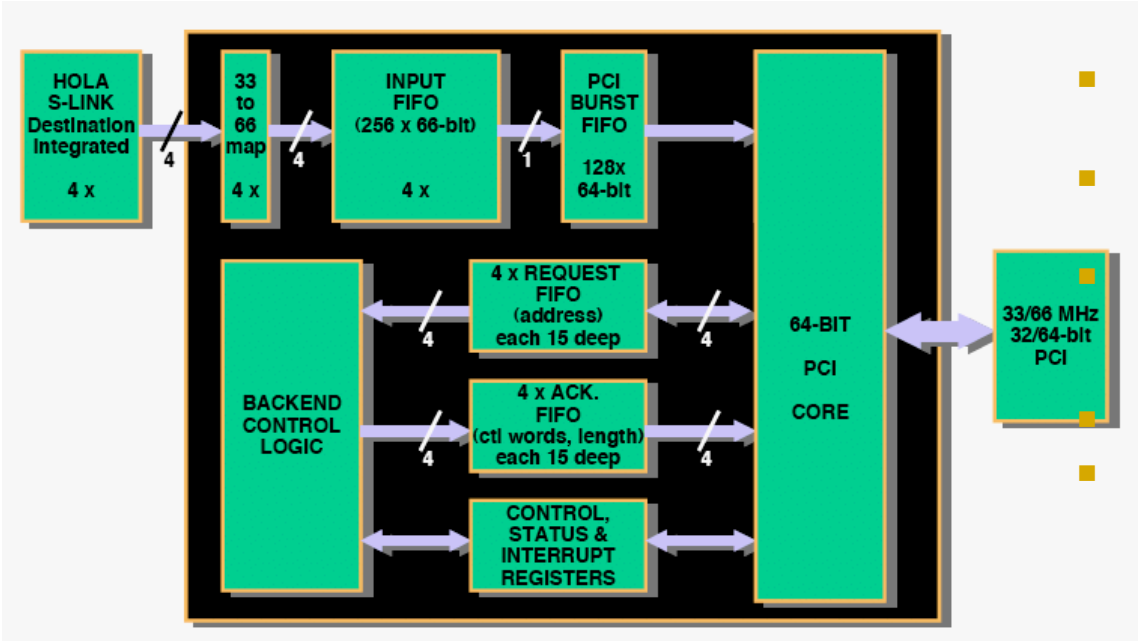
- Once timing problem solved for entire L2 system approved for parasitic running
- Has now been tested in beam up to luminosities $250 \times 10^{32} cm^{-2} s^{-1}$
- No operational problems observed
- System looks ready to commission as-is if only upgrade
- XFT error rates are under control, see next talk

Combining XFT and L2 CAL

What we have learned so far …

PCI Bus Transfer

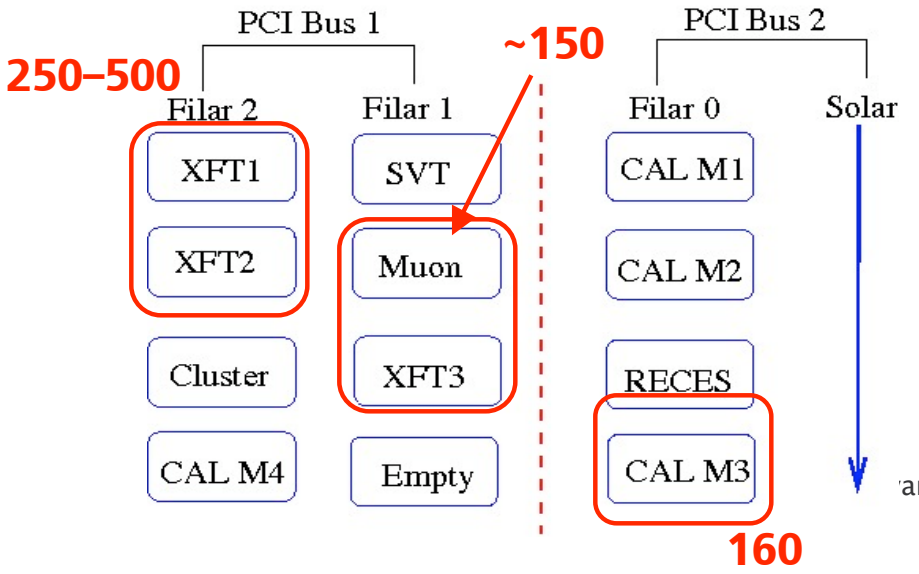
FILAR Block Diagram:



- First attempts in combining the system with L2 CAL as-is failed and exhibited themselves in data corruptions in FILAR
- Ted's theory on why that occurs has been proven in practice
- The Filar autonomously transfers data as soon as re-armed
- Due to multiple number of packets occupying a PCI bus arriving packets wait in the queue
- The INPUT FIFO = 512 SLINK words
- In the absence of back-pressure the large packets have greater chance not to get enough room in the FIFO
- Packets with sizes < 512/4 =128 will never have problems

Total Data Volume

- OLD existing paths ≈ 150 words with tails up to ~ 400 due to Tracklist
- L2 CAL = 460 – fixed data size
- XFT = 360+
- At luminosities of 3 x10^{32} $cm^{-2}s^{-1}$: XFT ≈700 with tails up to ~ 1500 words



Packets with sizes < 512/4 =128 will never have problems

Take advantage of 2 PCI buses

Need to re-balance the large packets: 3 XFT + 1CAL + MUON between PCI buses

Re-balancing studies

- To put the system into more stringent environment performed L2 torture tests with XTC patterns having two pixels per cell fired
- Each of three XFT data packets had the size = 500
- Re-balanced the system with 2 XFTs on one PCI bus and L2CAL3 + 1XFT on the other
- Ran L2 torture for ~12 hours with 50kHz L1 Accept and 1.2 kHz L2 Accept with no single problem
- Having two large packets per PCI bus does not seem to introduce data corruptions
- This configuration had been tested in beam and produced no errors up to Lumi = 190 x $10^{32}cm^{-2}s^{-1}$
- During the store with initial luminosity 240 x $10^{32}cm^{-2}s^{-1}$ problems with data corruptions appeared
- Detailed investigation of failed events showed that the MUON packet becomes big ~ 160 with 2 XFTs being on the same PCI bus

Further Approach

- At high luminosities the average size per one of the three XFT packets ~ 250 SLINK words
- We split XFT data into 6 input packets with ~120 on average which might be promising and solve the problem
- This configuration is running and being tested in beam right now
- So far proved to survive up to $240 \times 10^{32} cm^{-2} s^{-1}$
- This and other brilliant ideas discussed in the next talks

PCI Bus Transfer Time

Data Size	Time	(ms)
	1 link	2 links
5	2.1	2.5
47	2.4	3.0
97	2.8	4.0
120	2.9	4.1
147	3.2	4.6
197	3.5	5.3
253	3.8	6.0
297	3.5	6.2
347	2.7	5.6
397	3.1	5.2
447	3.4	5.2
497	3.8	6.1

- Measured by sending SLINK patterns of fixed size and measuring the latency of the system