The Run IIb CDF Detector Upgrade Project

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Fermilab

Background

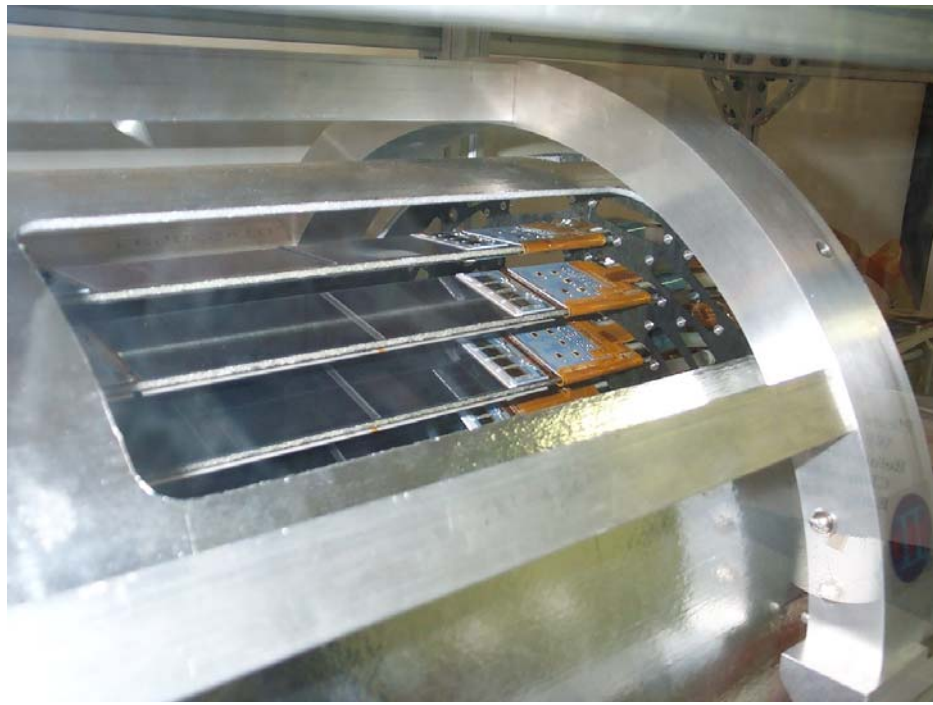
- The CDF Run IIb project exists to keep the experiment vital during high luminosity operation.
- Originally, the project the motivated by both high integrated and instantaneous luminosity - beyond the Run II specifications.
  - Reduced integrated luminosity projections reduced the motivation for the silicon detector, resulting in its cancellation.
- Design goal instantaneous luminosity projections are still ~$3\times10^{32}cm^{-2}s^{-1}$
  - Now at 396 ns crossing – higher occupancies than planned
- Portions of the project motivated by instantaneous luminosity are still needed and have been retained

Run IIb Project Scope

- Silicon Detector Replacement
- Calorimeter Upgrades
  - Preshower Upgrade
  - Electromagnetic Timing
- Data Acquisition and Trigger Upgrades
  - TDCs for the drift chamber
  - Level 2 Decision crate
  - Fast track trigger Upgrade
  - Event Builder Upgrade
  - Level 3 computer upgrade
  - Silicon Vertex Trigger upgrade

Silicon Detector Replacement

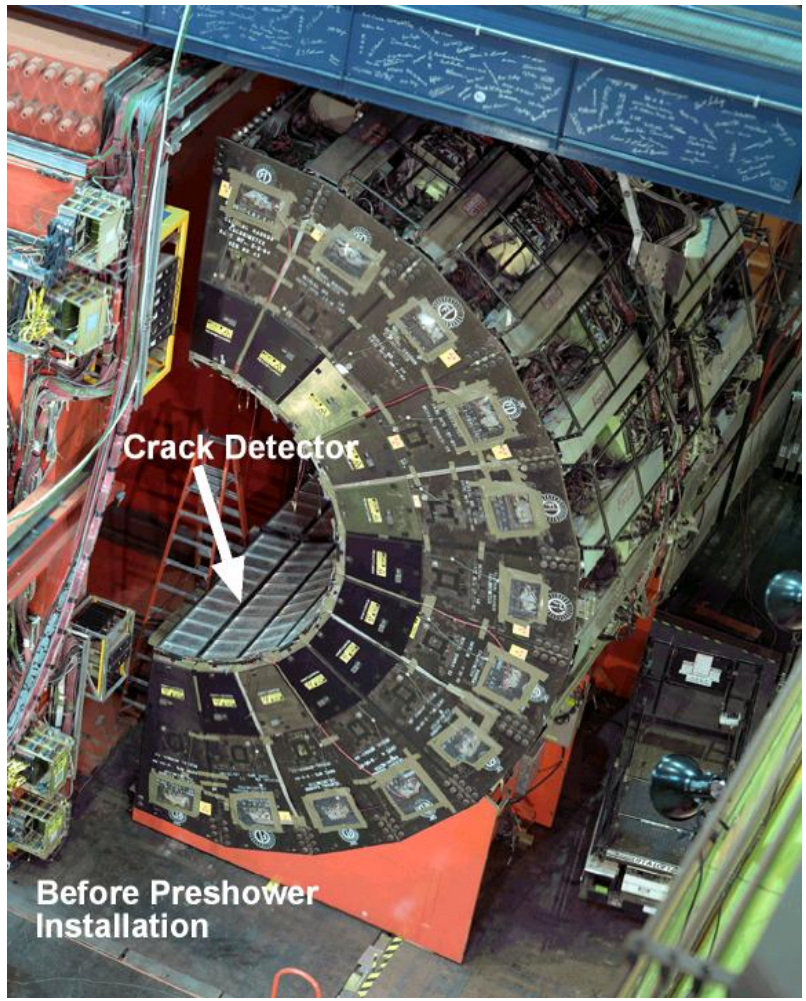
- Originally planned because the radiation damage lifetime of the current silicon detector was thought to be ~4 fb^{-1}.
  - Run IIb spec. was 15 fb^{-1}.
- New detector was much more rad. hard, optimized for high occupancy.
- Production was cancelled in Sep. 2003.



- 7% of the staves were built
- One ~15° section assembled and operated

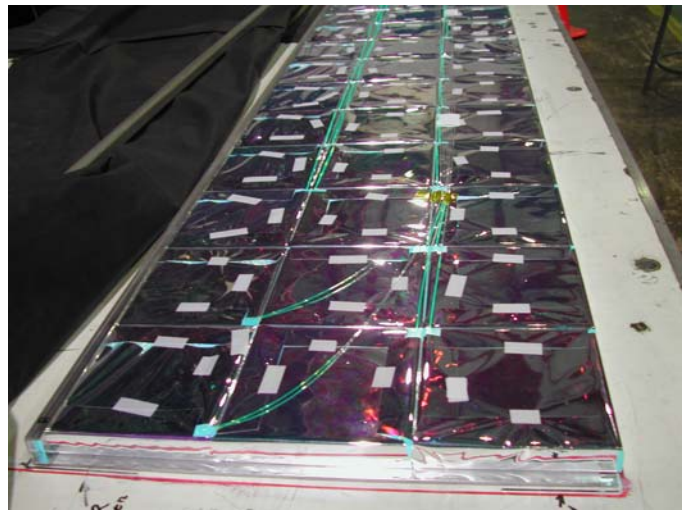
Preshower/Crack Detectors

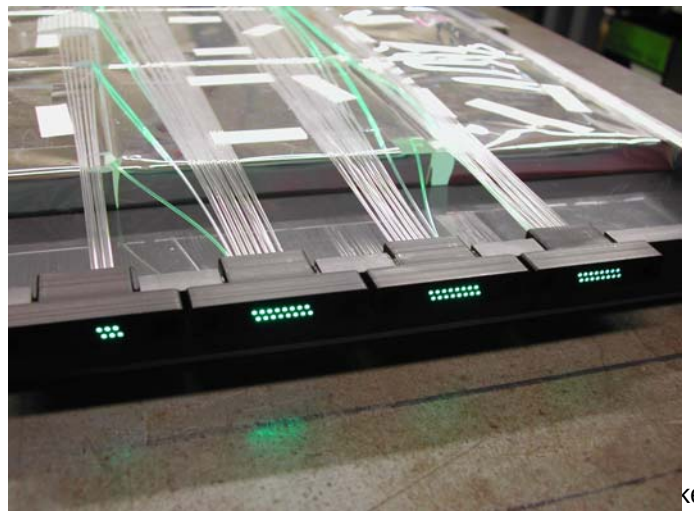
- The preshower upgrade replaces the older gas chamber system with scintillator.
  - Last accessible piece of gas calorimetry
  - Fiber/multichannel PMT readout – similar to what's used on the endplug.
- Significant foreign contribution here
  - PMT from Japan
  - Scintillator/fibers from Italy



Preshower Upgrade

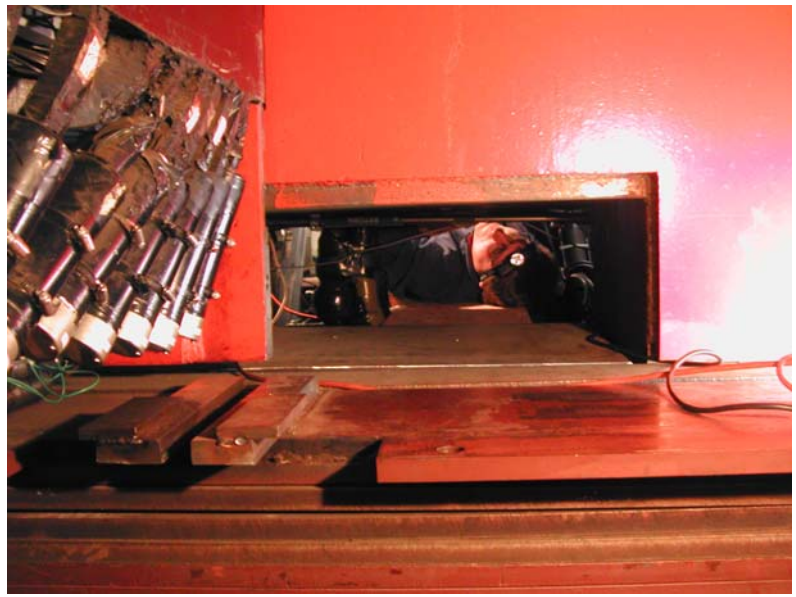
- System was planned for an assembly hall installation in FY 2006 (silicon shutdown)
- Schedule was adapted to accommodate accelerator shutdowns
  - Accelerated production of scintillator tiles, modules
  - Procurement of PMTs by Tsukuba was advanced
  - The project targeted Fall 2004





Calorimeter Installation

- Preshower installation involved detector installation on the inner surface of the calorimeter
  - Never serviced in the collision hall previously.
- Phototube and cables are located on the back.
- System installation was completed in Nov., 2004.

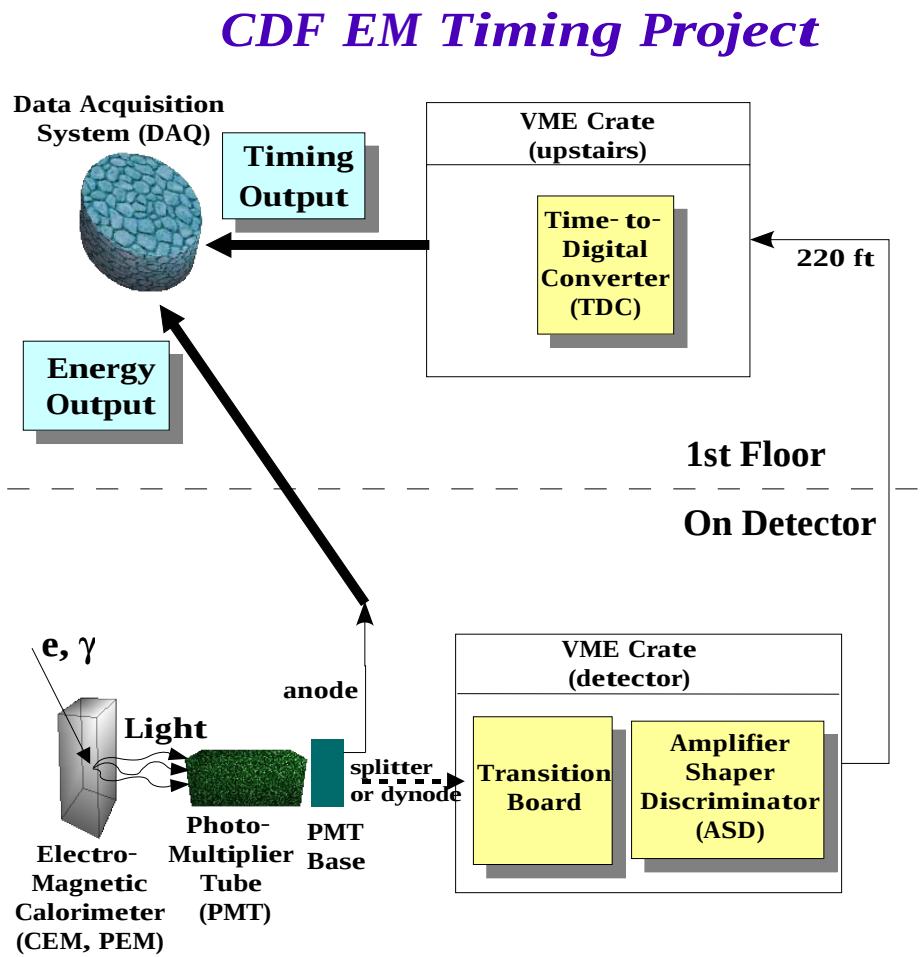


- All scaffolds, detector elements, people, passed through this opening.

Preshower/Crack Installation

EM Timing

- The electromagnetic timing upgrade splits a small portion of the phototube signal off for timing
  - Reduces cosmic ray or halo backgrounds for photons
- Entire system was installed during the fall 2004 shutdown.
- Has been included in the data since that time
  - (FERMILAB-PUB-05-54 3-E)



DAQ/Trigger Specification Run IIa vs IIb

	Run IIa Specification	Run II (2004) Achieved	Run IIb Specification
Luminosity	8.6×10^{31}	1×10^{32}	3×10^{32}
L1 Accept	45 kHz	25 kHz	30 kHz
L2 Accept	300 Hz	400 Hz	1000 Hz
Event Builder	75 MB/s	75 MB/s	500 MB/s
L3 Accept	75 Hz	80 Hz	100 Hz
Rate to Storage	20 MB/s	20 MB/s	40 MB/s
Deadtime Trigger	5%	10%	5% + 5% ÅÐ

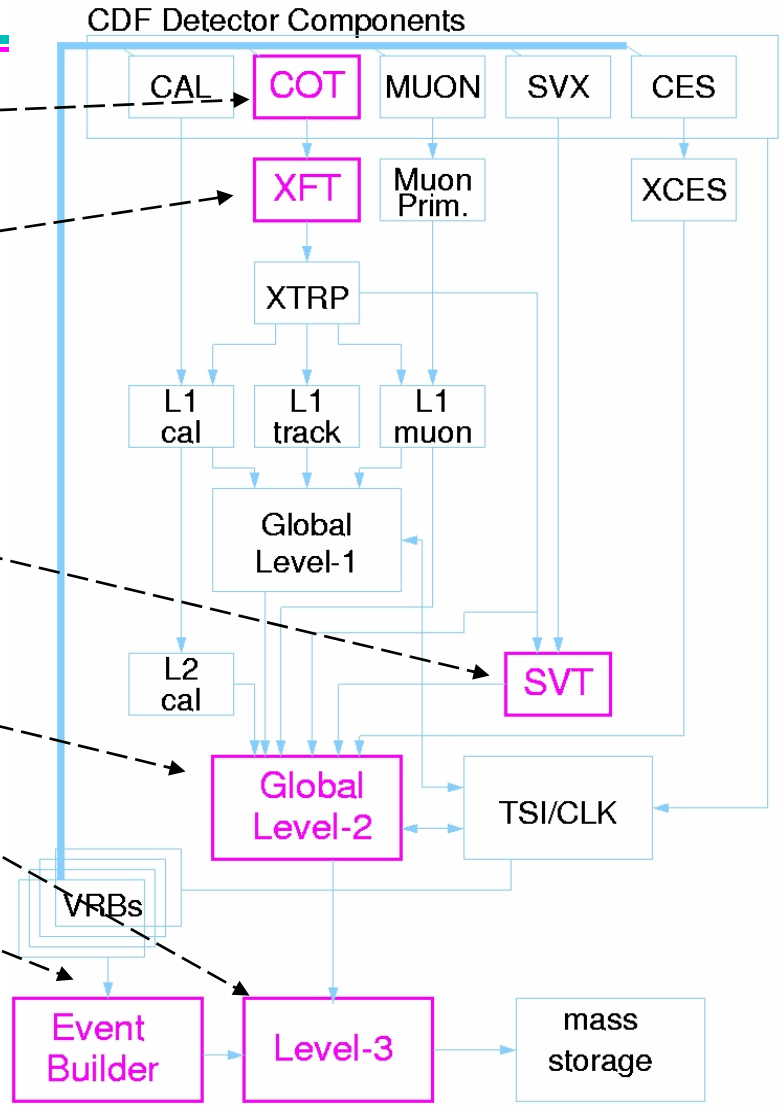
- Run IIb bandwidth needs are based on projections for the high P_T program only. B physics trigger are dropped for these purposes.

† Assume ~5% from readout and ~5% from L2 processing

- Reminder: IIb trigger & bandwidth rates estimated based upon Run IIa, significant underestimate possible (assumes linear growth in fake contribution)

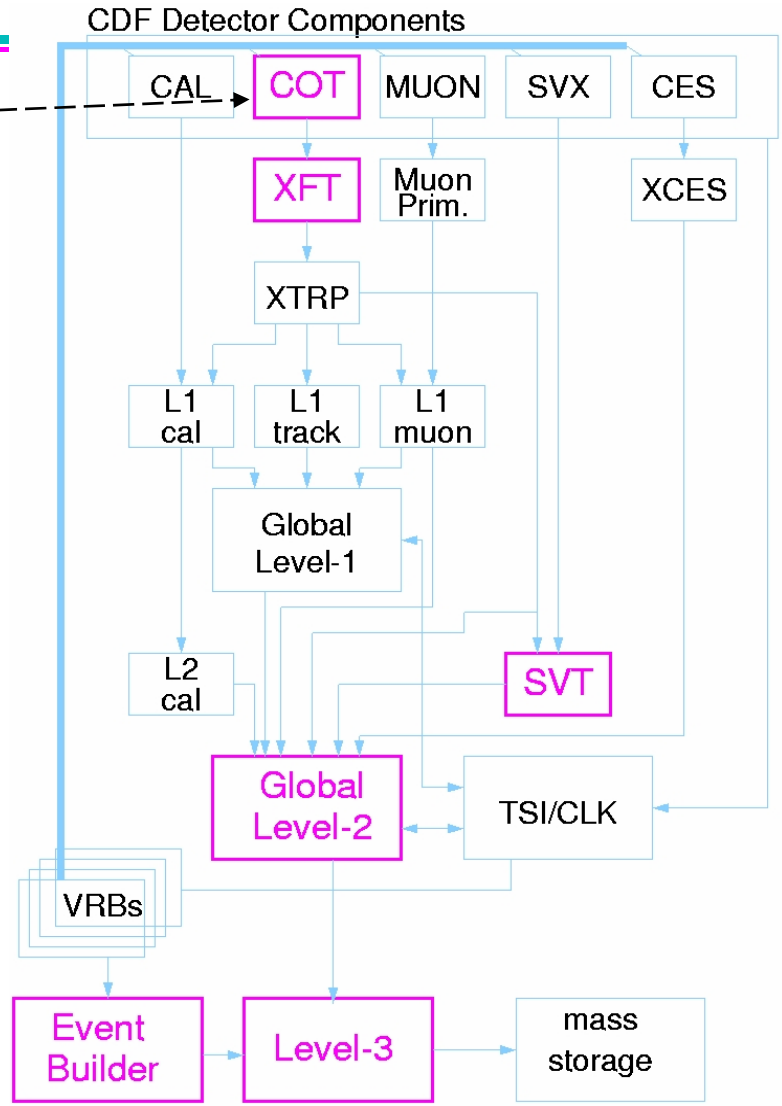
Trigger/DAQ Upgrades for Run IIb

- COT TDC upgrade
  - Original readout rate insufficient
- COT Track Trigger Upgrade
  - L1 trigger rate reduction needed
  - Complexity of events (occupancy)
- Silicon Vertex Trigger upgrade
  - Occupancy demands processing speed
- L2/L3 trigger upgrades
  - Processing speed/modernization
- Event builder upgrade
  - Processing speed upgrade needed
  - Level 2 accept rate is insufficient

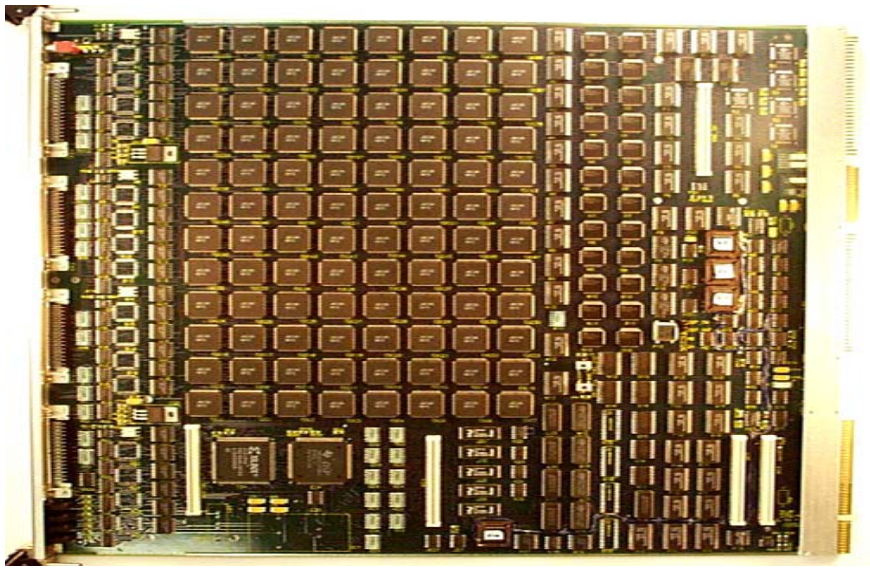


Trigger/DAQ Upgrades for Run IIb

- COT TDC upgrade
  - Original readout rate insufficient
- On-board processing (DSP) Time grows with # of hits
  - t = 1200μs/event for SL1 (4 hits/ch) at $4x10^{32}$ $cm^{-2}s^{-1}$
- VME Readout
  - Read sequentially by one block transfer (~14MB/s at high lum.)
- VME – Event builder link limited to 12 MB/s
- 2002 Internal review recommended replacement

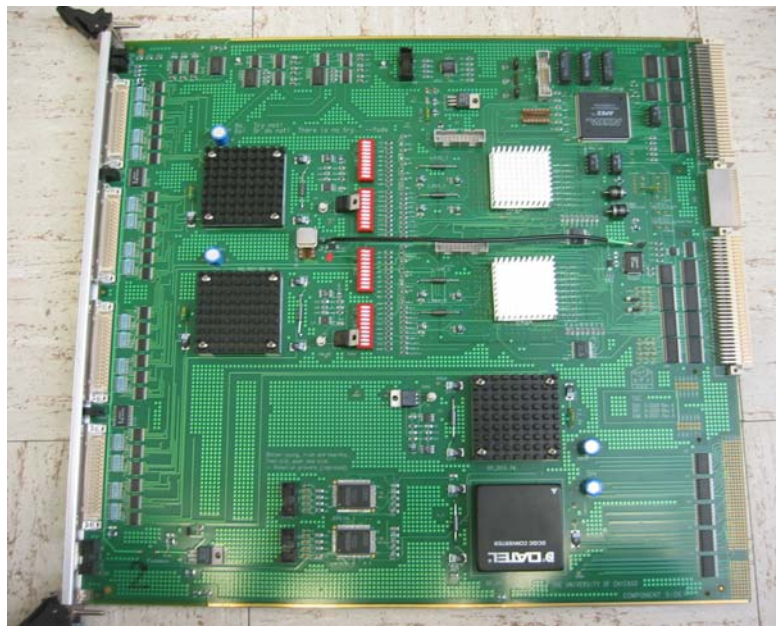


TDC Replacement



- CDF Run II, 96 channel TDC

- Run IIb TDC
- Far fewer components, functions all within an FPGA



TDC Performance Reviews

- Run 2b TDC
  - 5 preproduction boards received in Sept., 2004 pass tests
  - Implemented 64 bit VME transfer (was 32bit like rest of FE/Trig)
    - In bench tests 18MB/s (32bit VME) → 36MB/s
    - Can achieve 2kHz with less than 5% deadtime
  - **Exceeds all Run 2b specifications (NIM, A554:444-457, 2005)**
- However, from our Prod. Readiness Review –
  - "Commissioning would be smoother if the older TDCs were programmed to have the same data format as the newer ones."
  - "Yeah, but wouldn't that make them faster?"

TDC Modifications

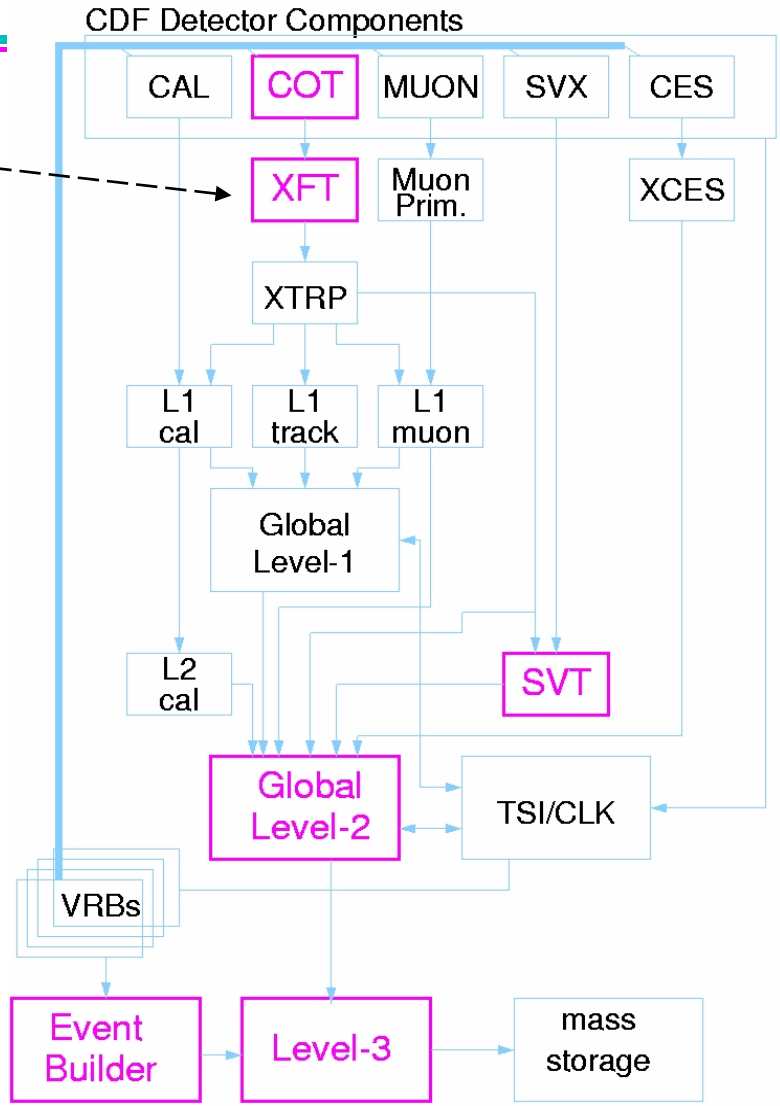
- After much hard work at night and on weekends by the Tevatron Department Head:
  - DSP execution now about factor of 2 faster than in 2002
  - New compressed data format (based in Run 2b TDC), halves the data volume.
  - Measured performance with 3 hits/channel of 5% deadtime at 1kHz
  - Need to implement Fast Clear on TDCs in SL5,6 (already on SL1-4) to keep these from taking longer than SL1
    - This is a hardware modification to the existing boards
  - **Meets the Run 2b readout specification**

New TDC Strategy

- The decision was made to retain the current TDCs for the remainder of the run
- Modifications of the current TDCs were needed (outer layer modules)
- These modifications were done in small batches throughout 2005, and were installed during access times of ~4 hours.
- Last crate was done in December.
  - The installed set is complete

The Track Trigger (XFT)

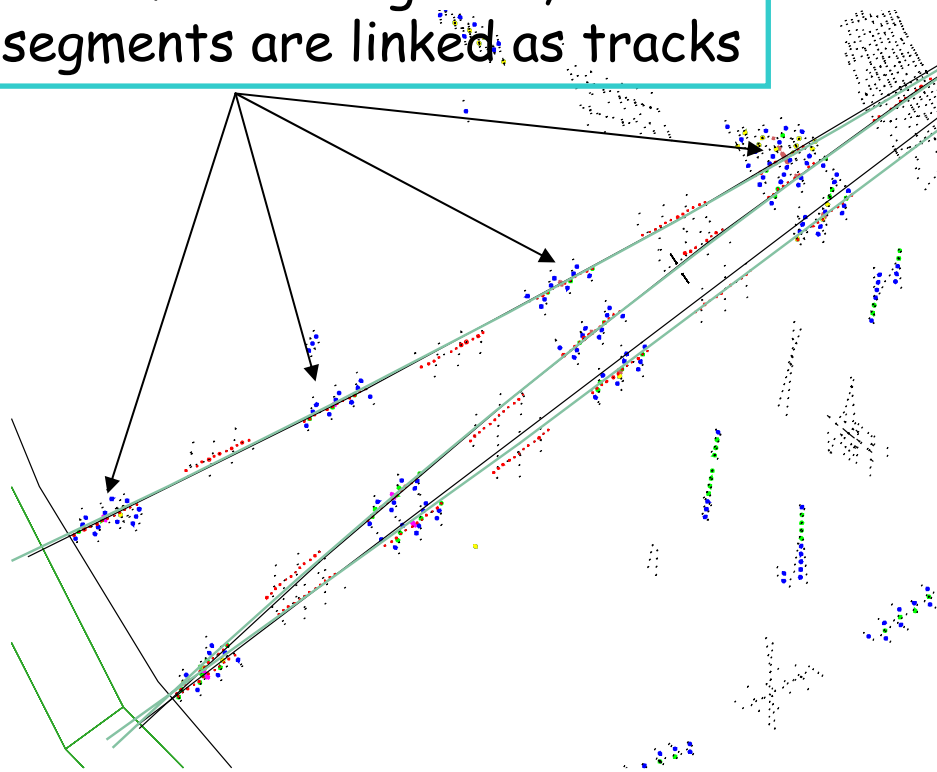
- The track trigger was designed with the expectation of ~1 interaction/beam crossing
- Higher instantaneous luminosities at 396 ns challenge this system with high occupancies.
  - Fake rates rise very quickly



CDF Track Trigger

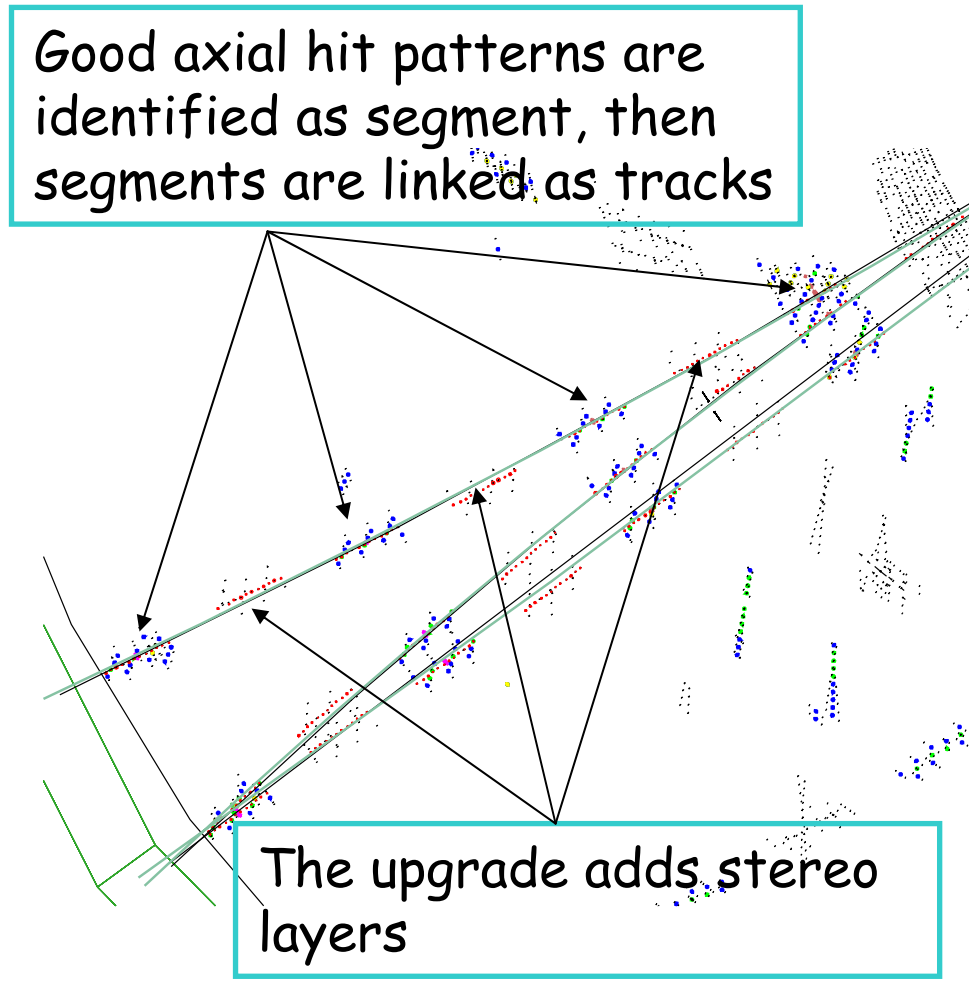
- Track trigger (XFT) uses the axial layers of the drift chamber to provide track information at level 1 in the trigger
- Critical to most of the CDF physics program.
- High hit occupancy in the tracking chamber creates fake trigger tracks
  - Processing time goes up

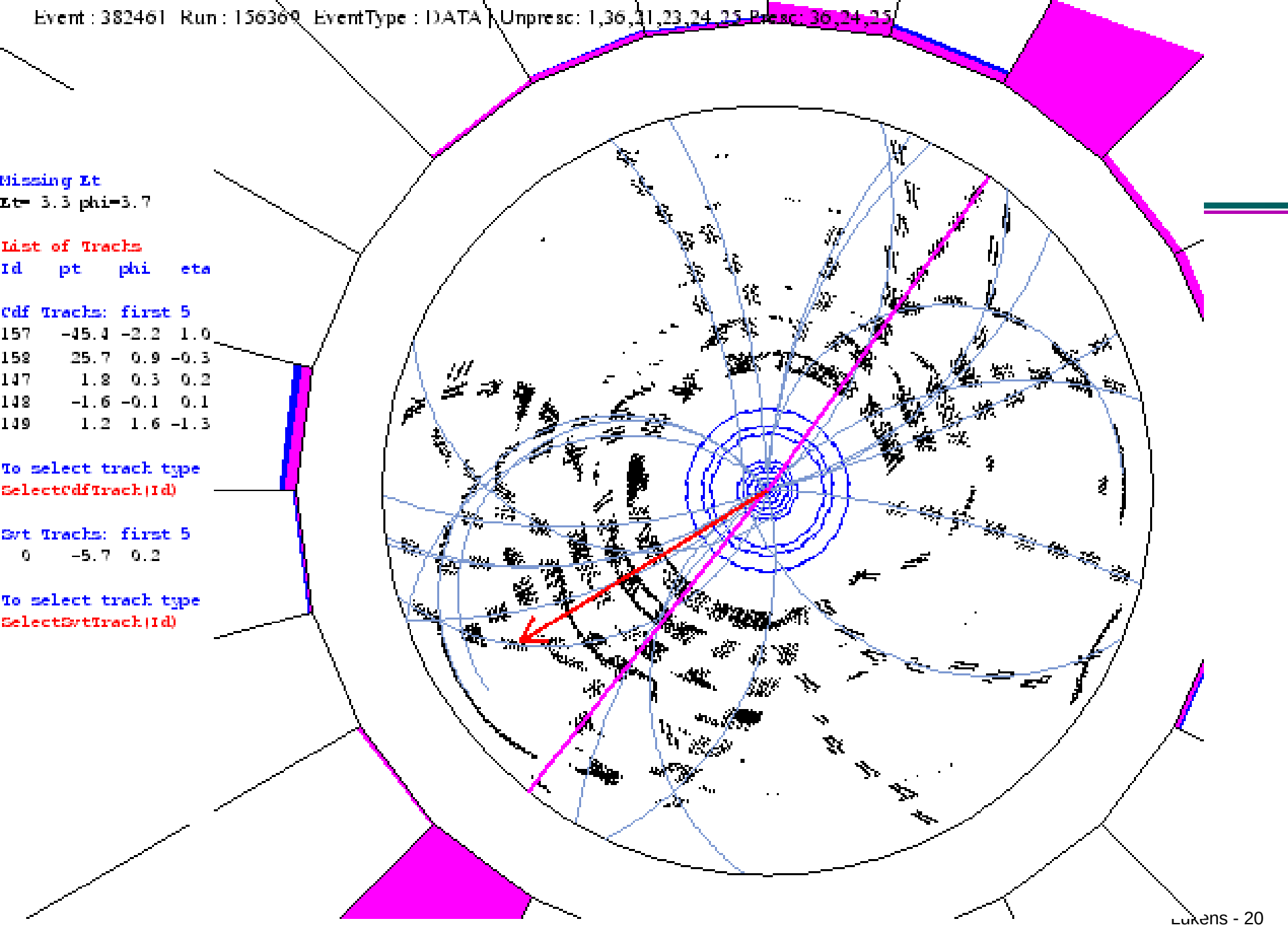
Good axial hit patterns are identified as segment, then segments are linked as tracks

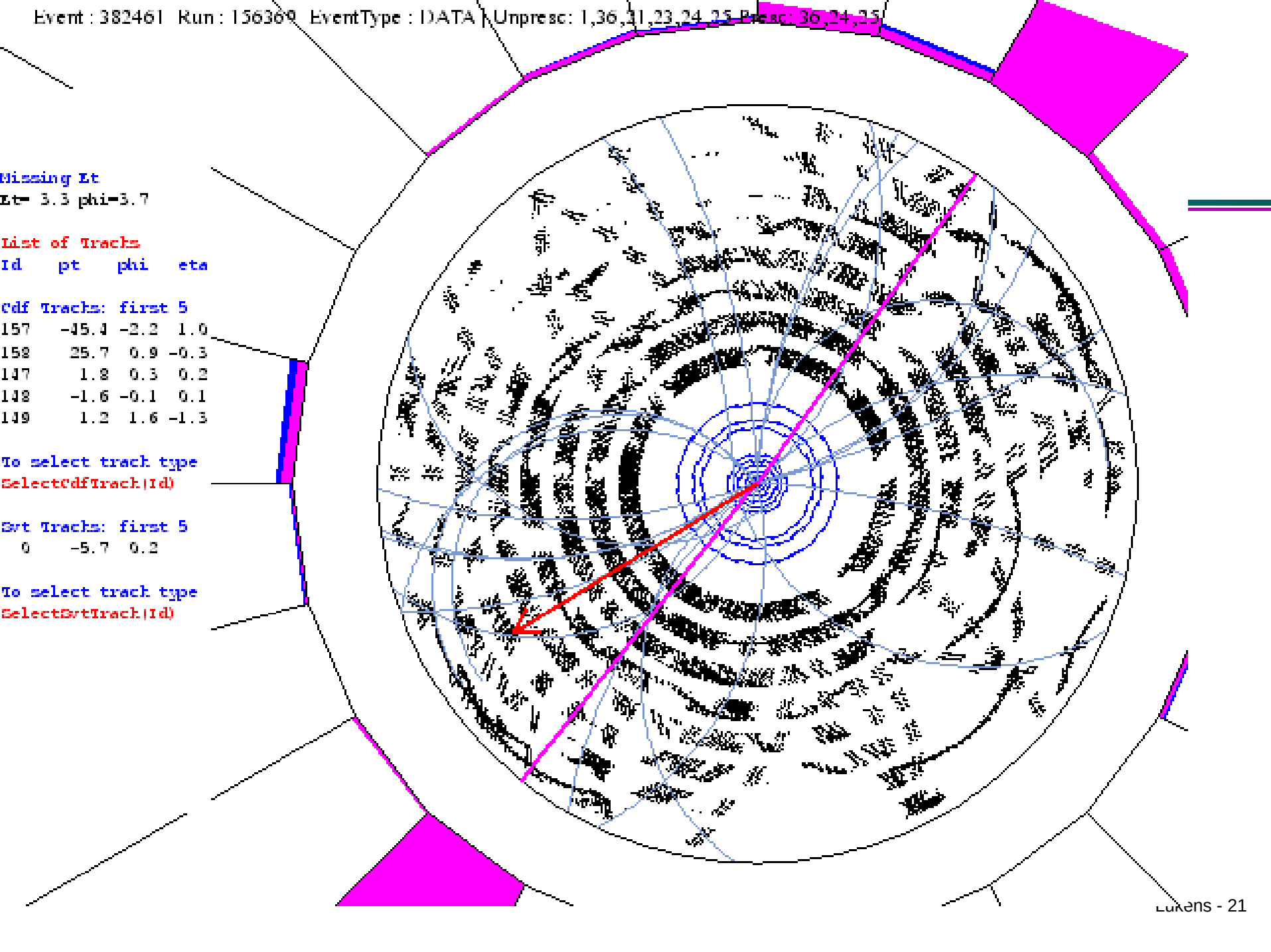


Track Trigger Upgrade

- The upgrade strategy will add information to the trigger tracks
  - Increased information provides greater selectivity
  - Rates will be reduced.
- Stereo layers will be incorporated.
- Simulations show significant improvements are possible




Event : 382461 Run : 156369 EventType : DATA | Unpresc: 1,36,31,23,24,25 Presc: 30,24,25
Missing Et
Et= 3.3 phi=3.7
List of Tracks
Id pt phi eta
Cdf Tracks: first 5
157 -45.4 -2.2 1.0
158 25.7 0.9 -0.3
147 1.8 0.3 0.2
148 -1.6 -0.1 0.1
149 1.2 1.6 -1.3
To select track type
SelectCdfTrack(Id)
Svt Tracks: first 5
0 -5.7 0.2
To select track type
SelectSvtTrack(Id)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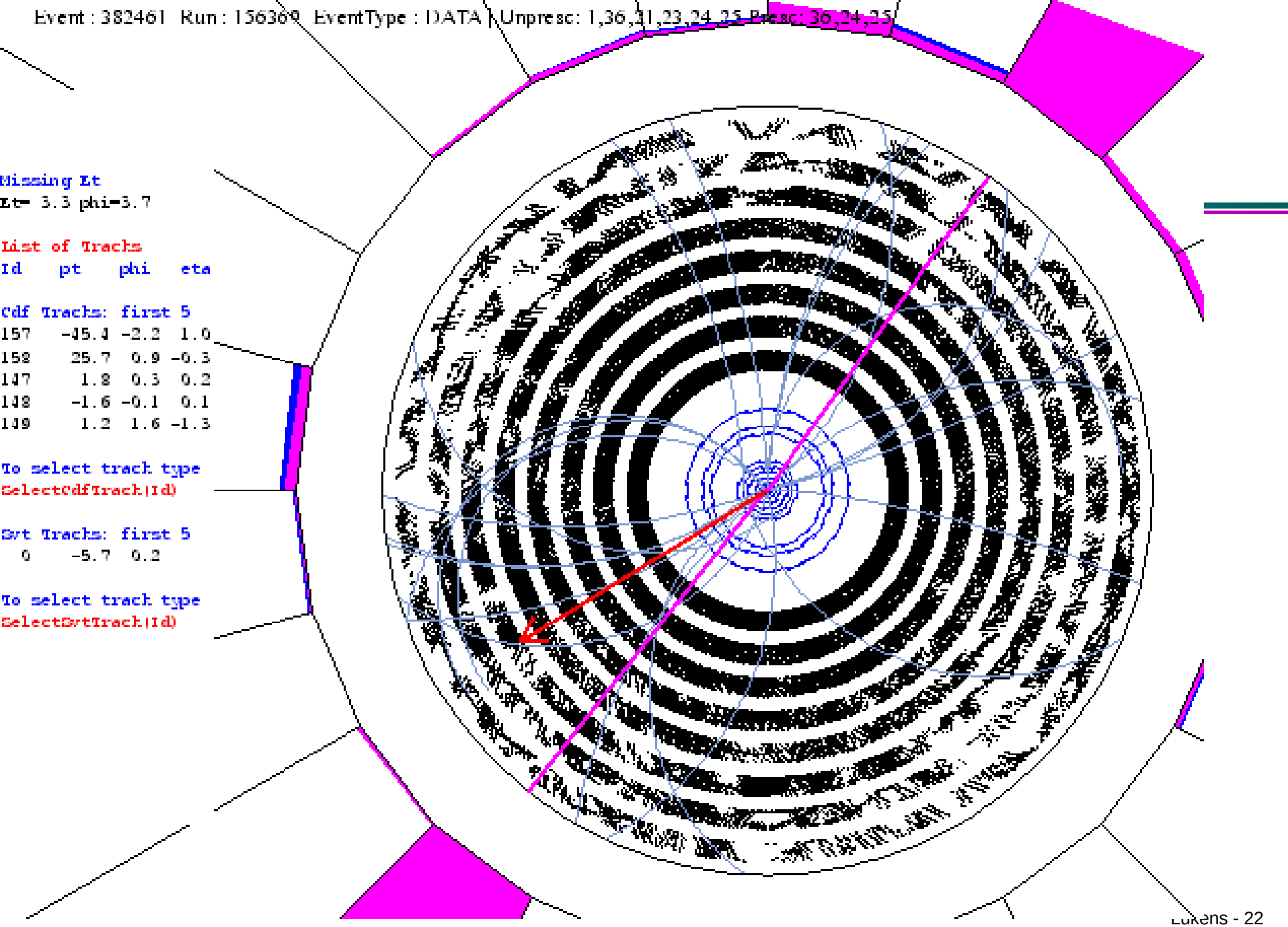
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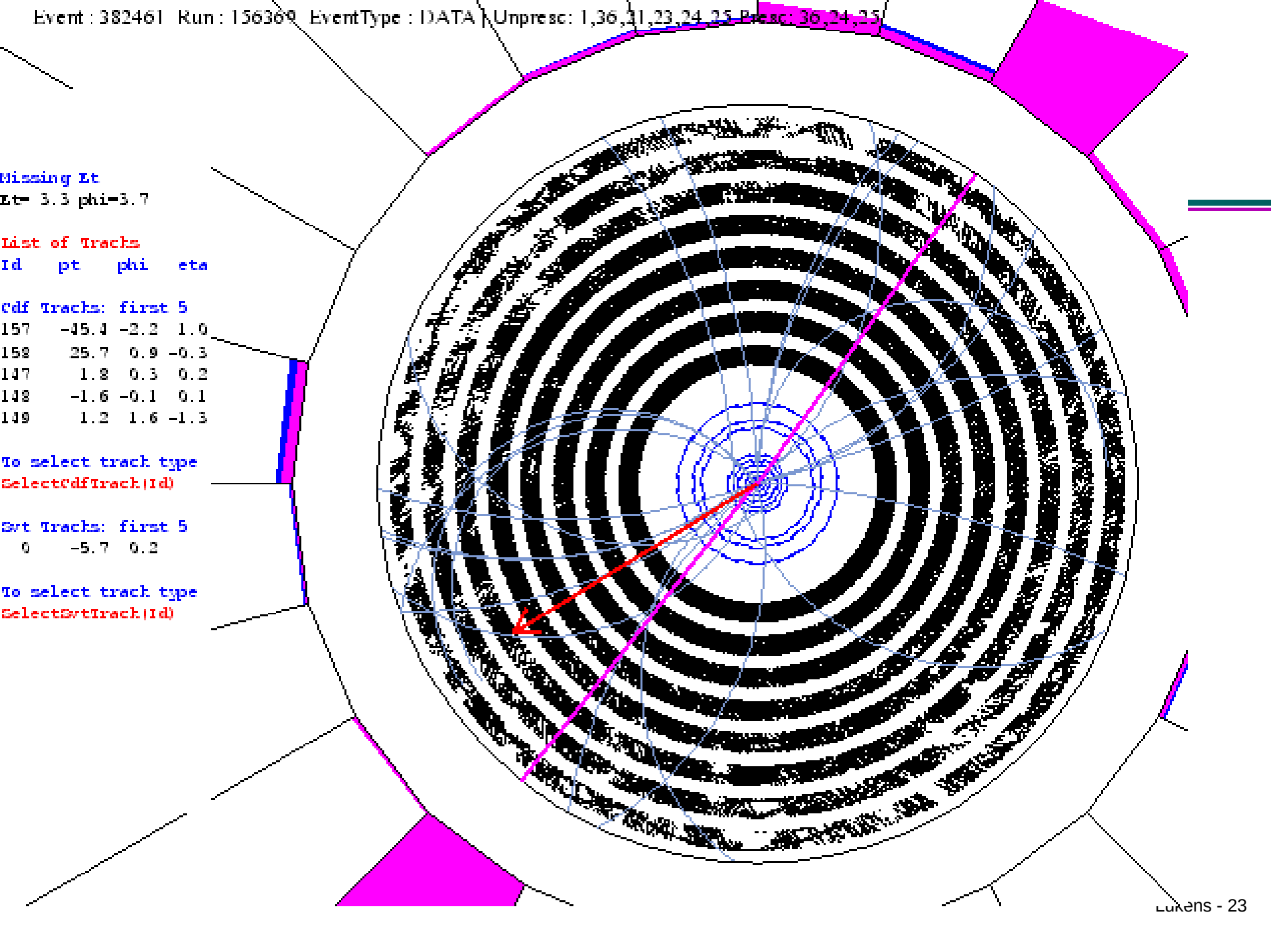
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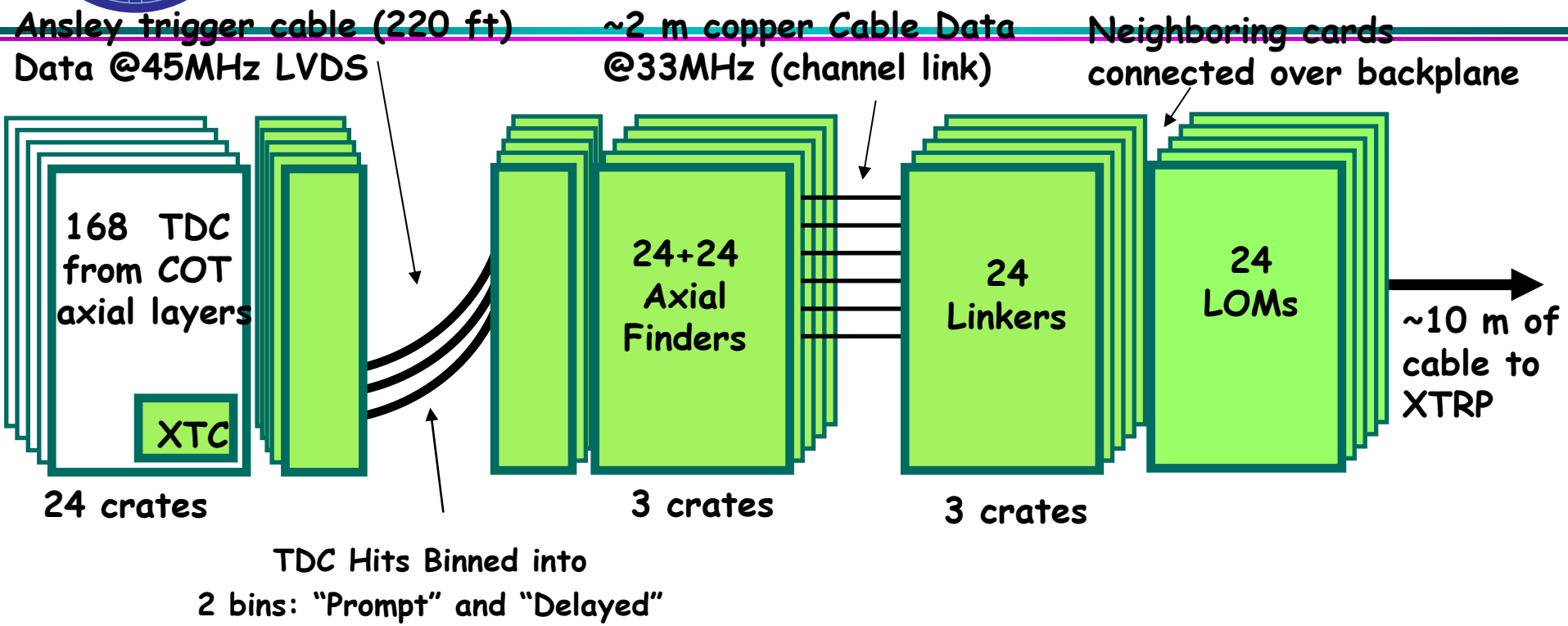
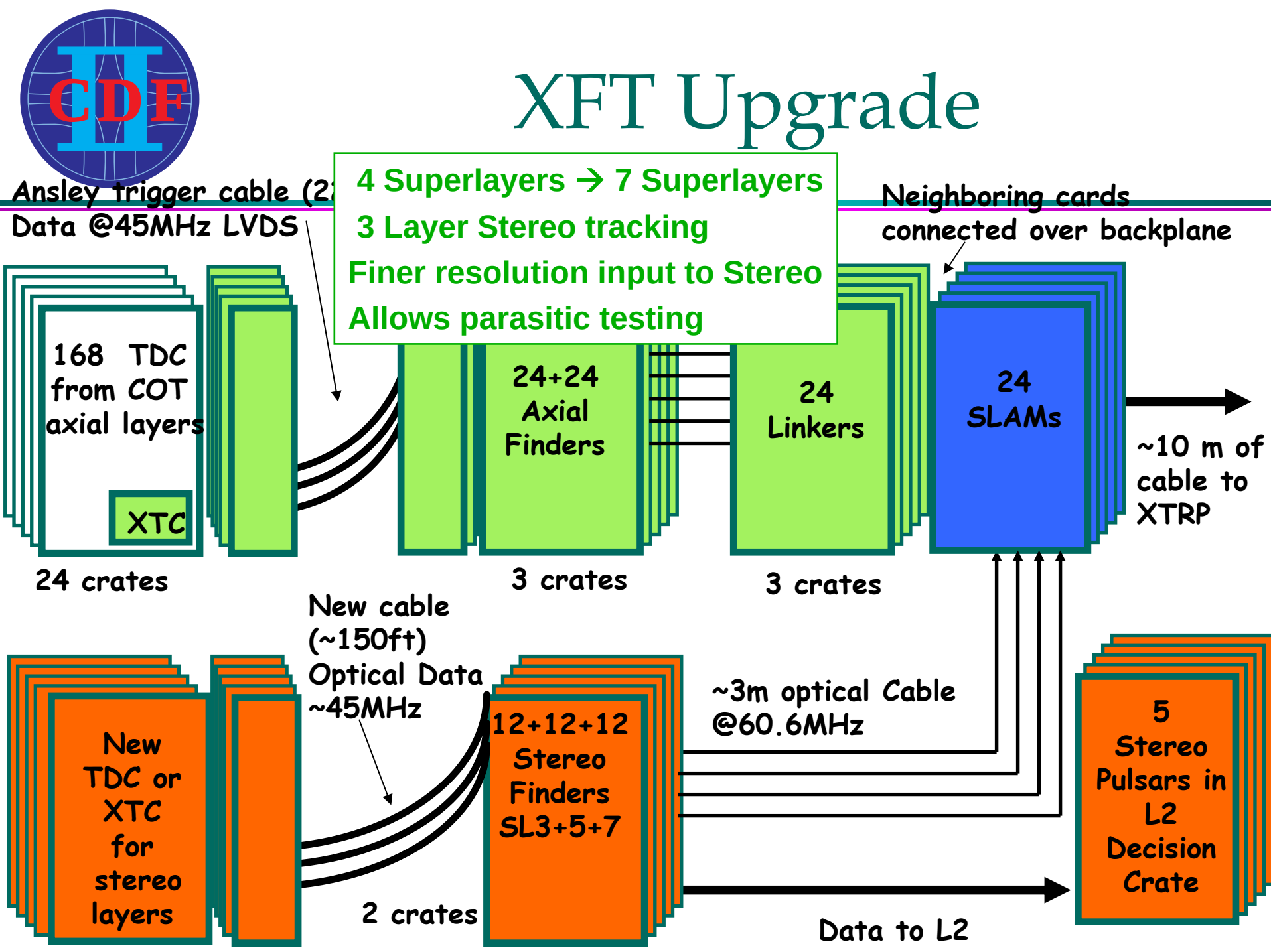
Run IIa XFT Configuration



XFT Upgrade

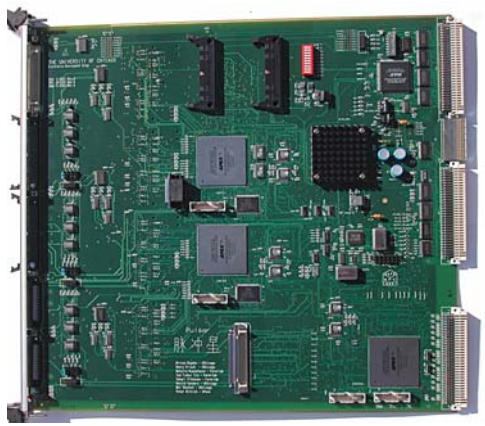

4 Superlayers → 7 Superlayers
3 Layer Stereo tracking
Finer resolution input to Stereo
Allows parasitic testing
Ansley trigger cable (2
Data @45MHz LVDS
Neighboring cards
connected over backplane
168 TDC
from COT
axial layers
XTC
24 crates
24+24
Axial
Finders
3 crates
24
Linkers
3 crates
24
SLAMs
~10 m of
cable to
XTRP
New cable
(~150ft)
Optical Data
~45MHz
New
TDC or
XTC
for
stereo
layers
2 crates
12+12+12
Stereo
Finders
SL3+5+7
~3m optical Cable
@60.6MHz
5
Stereo
Pulsars in
L2
Decision
Crate
Data to L2

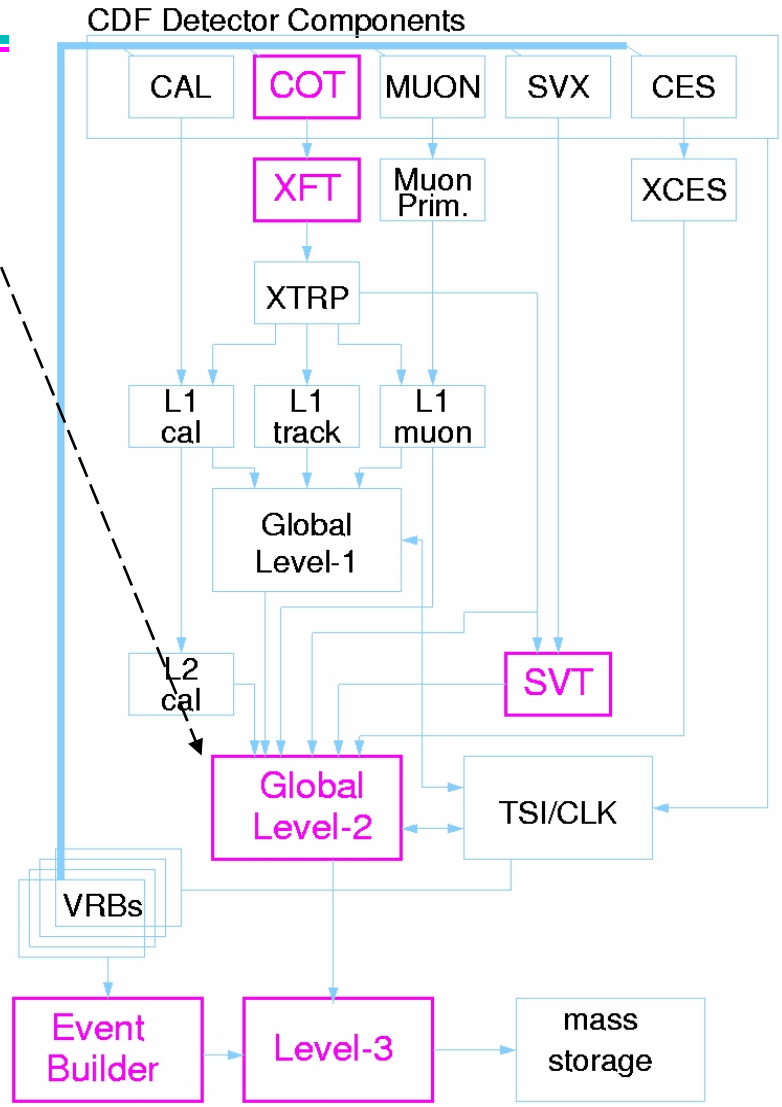
XFT Hardware Progress

- Collision hall installations
  - XTC2 cards – Installed with the TDC modifications
  - Transition cards and cables – Installed during the December downtime
- Trigger room installations
  - Stereo Finders installed Nov-Dec. – being commissioned
  - Stereo Linker Association Module - being commissioned
- Commissioning can be largely parasitic to operations.
  - Existing axial system will continue to run
  - Stereo upgrade will be fully operational in Summer, 2006

The Level 2 Decision Crate

- The Level 2 decision crate used
  - 6 different kinds of interface boards
  - Obsolete Dec α processors for the trigger decisions
- Replacement system is based on
  - Standard PCs for the trigger decisions
  - A universal interface board
  - Programmable “Pulsar”



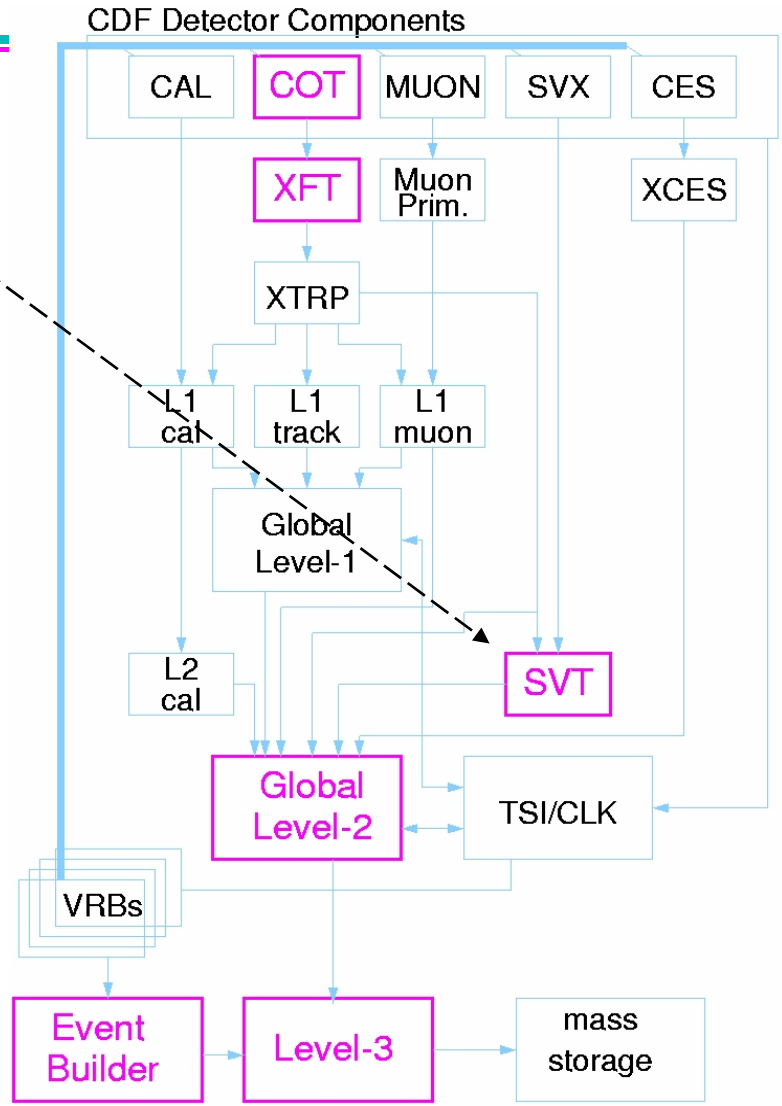


Level 2

- Extensive testing with beam occurred beginning in summer, 2004
- System was phased in during the winter 2005, and is now fully installed and used in operations.
  - Older, obsolete system was been removed (May 2005).
  - Reliability improvements have already been seen
  - Decisions made with common processors, speed improvements are substantial

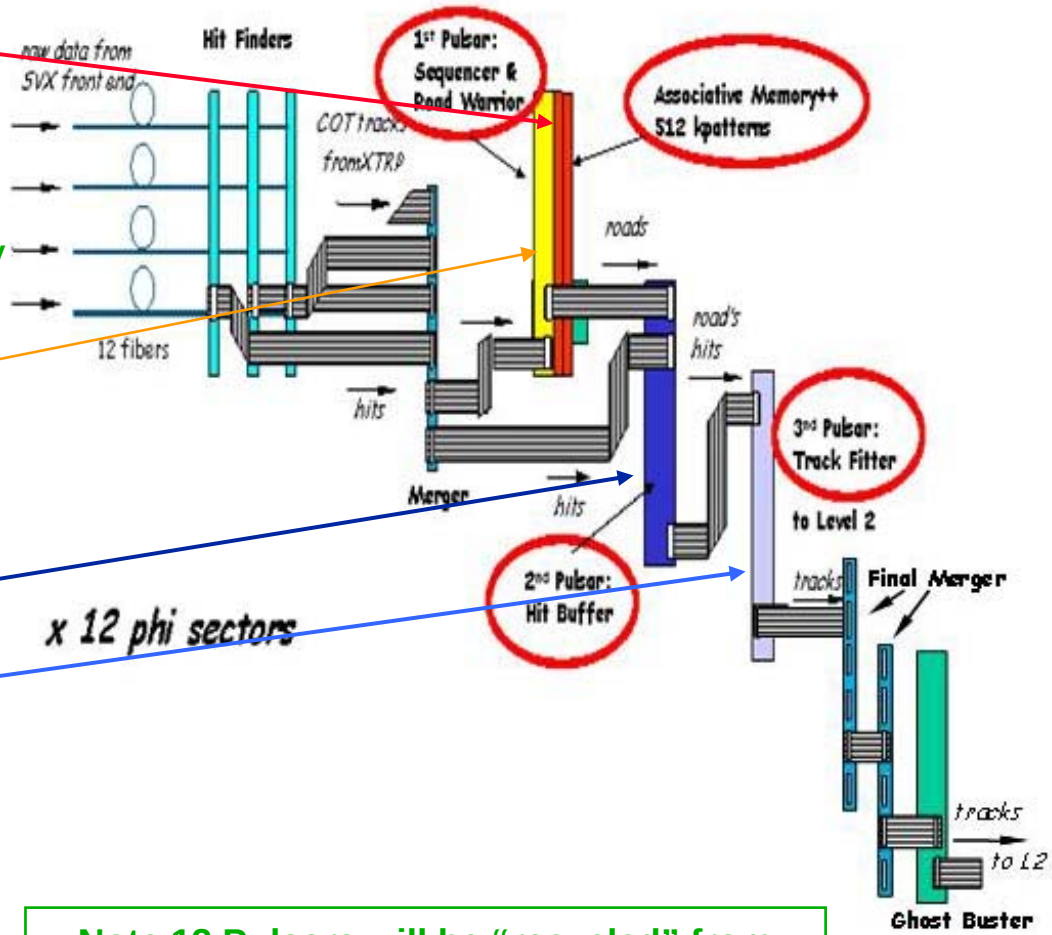
The Silicon Vertex Trigger (SVT)

- The Silicon Vertex Trigger has the same occupancy issues as the XFT
  - High occupancy → high fake rate
- Strategy
  - Add front end pattern memory for more patterns
  - Add processing power with Pulsar boards
    - Same hardware, different firmware



SVT Upgrade for SVXII

- New AM++ hardware with narrower roads (32K to 512K) reduces number of tracks to fit
  - Developed by Pisa, bought by INFN
- New AMSequencer/Road Warrior (12 Pulsars)
  - Interface for AM++
- New Hit Buffer (12 Pulsars)
- Faster Track Fitters reduce processing time on found roads (12 Pulsars)



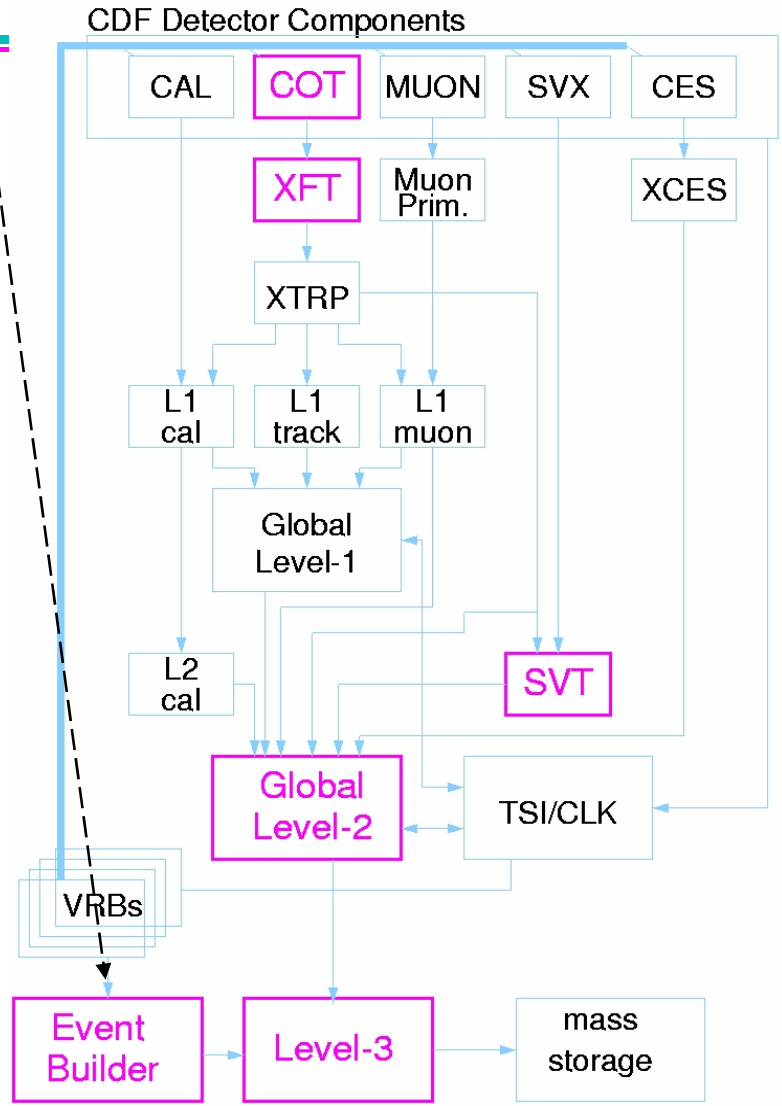
Note 12 Pulsars will be "recycled" from current use as "Road Warrior" boards

SVT Progress

- AM++ (not on project funds) at INFN
  - AM++ and the associated mezzanine boards have been installed and in operations since Sep., 2005
  - Immediate improvement in processing time was seen.
- Hardware :
  - All Pulsar boards have been built.
  - All Pulsar mezzanine boards have been built
- Track fitter units were commissioned in the fall, fully operational in Oct., 2005.
- Hit buffer is being commissioned now.

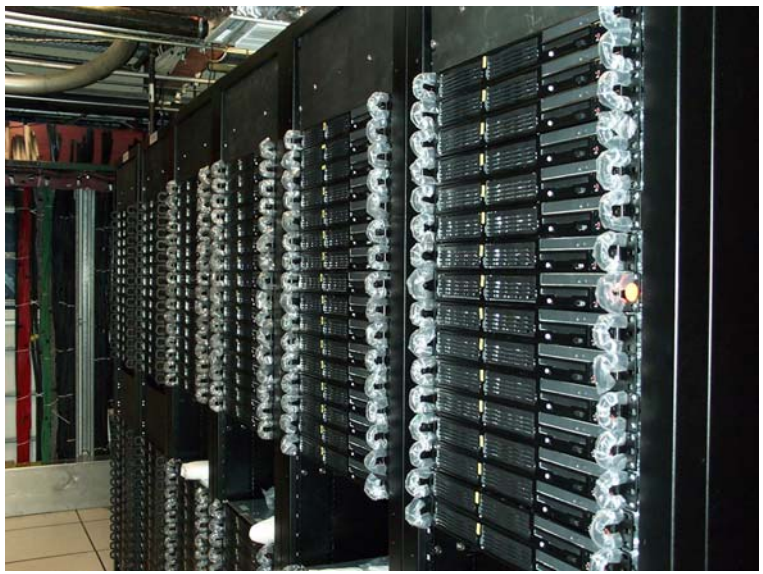
The Event Builder

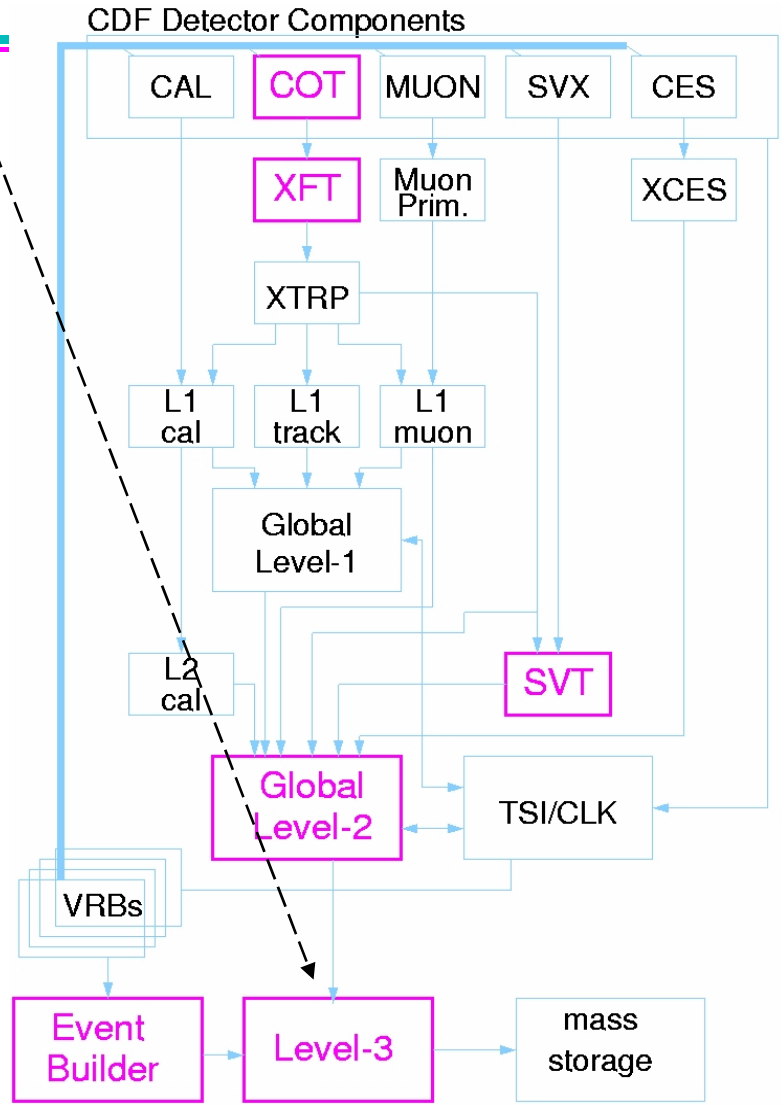
- The Event builder organizes data from the many different systems and build a single event record.
- Original system used an ATM switch, and was limited to 300 Hz.
- New system uses common ethernet, a switch commonly used at the lab.
- Commissioned in the summer, 2005. The new system went into full operations in August, 2005
- 800 Hz operations has already been achieved.



Level 3 Computing

- The Level 3 processing power has been increased to accommodate the event rate.
  - 1 THz→2.6 THz





CDF Upgrade Summary

- Silicon Detector
  - New design was prototyped and demonstrated
- Calorimeter
  - Both Preshower and Timing installed in Fall, 2004
- DAQ/Trigger
  - TDCs – modifications of older units is complete
  - XFT – commissioning is in progress
  - Level 2 – in operations since May, 2005
  - SVT – commissioning is in progress
  - Event Builder - in operations since August, 2005
  - Level 3 - commissioning is in progress

Project Completion

- With this, the Run IIb CDF Detector Project has met its technical baseline by its Level 1 completion Milestone, defined in its Project Execution Plan.
- We are formally able to state that we have met the schedule.
- Costs will continue for a couple of months, but the project will come in comfortably within its baseline ($8.2M).