Antiproton Physics Workshop @QWG 2010

DAQ Ideas for a New $\bar{p}$ Experiment at the FNAL AA (E986)

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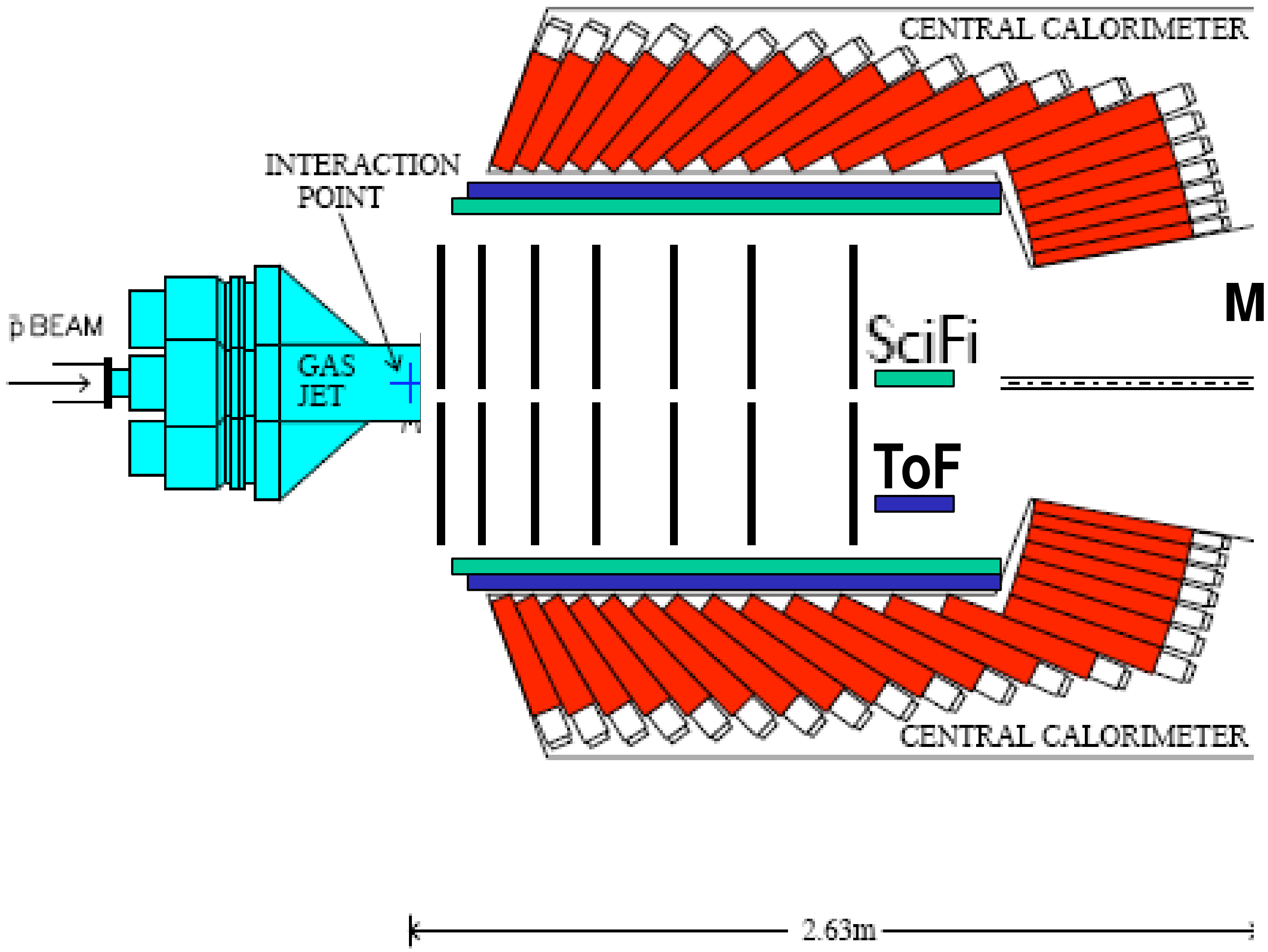
Preliminary Assumptions

- E986 Detector as Dan presented earlier
  - Charged particle tracking by means of scintillating fiber planes similar to MICE
  - Utilize the E760/E835 Crystal Calorimeter (CCAL)
  - Fast TOF detectors just inside the inner diameter of the CCAL for particle ID
  - Utilize a thin solenoid for insertion into the CCAL bore (inside the TOF) for track momentum measurement
- Physics targets also as Dan presented
  - Running at the AA with beam momentum between 5 and 9 GeV/c
  - Goals to study charm, charmonium and charmonium-related states, hyperon pair production,etc.

Potential Detector



Main systems:
- **CCAL**
- **SciFi**
- **TOF**

General Ideas

Keep everything as simple as possible… but not simpler **Einstein**	**The ideal of beauty is simplicity and tranquility** **Goethe**

- **We're aiming for some reasonably small cross sections in many cases**
- **Aim for effectively deadtime-less operation**
  - **Sampling and reading out all detectors on a continuous cycle provided by a global clock , rather than using a detector-based trigger to start readout**
  - **Parallelization of event streams and significant use of buffers for holding events and/or event fragments while various trigger or physics signature filter decisions are made**
  - **Very similar in nature to the plan of PANDA @ GSI**

Estimates for Trigger Rates

- At 2 x 10^{32} cm $^{-2}$ s $^{-1}$ we can expect a total interaction rate of order 15MHz, which is simply scaled up from E835 rates observed at a luminosity of 2 x 10^{31} cm $^{-2}$ s $^{-1}$
- This scaling estimate is consistent with the a total pp cross section of 75mb (at 5 GeV/c, this is more or less what is observed)
- Interesting cross sections are pb to tens of nb (charmonium, hyperons) or about 1 μb for charm meson pairs (D*D)
- **At our interaction rate, we're looking at 200Hz for every** μb of cross section. We'll aim for an overall trigger rate of something in the vicinity of 10kHz.

Readout & Trigger Requirements

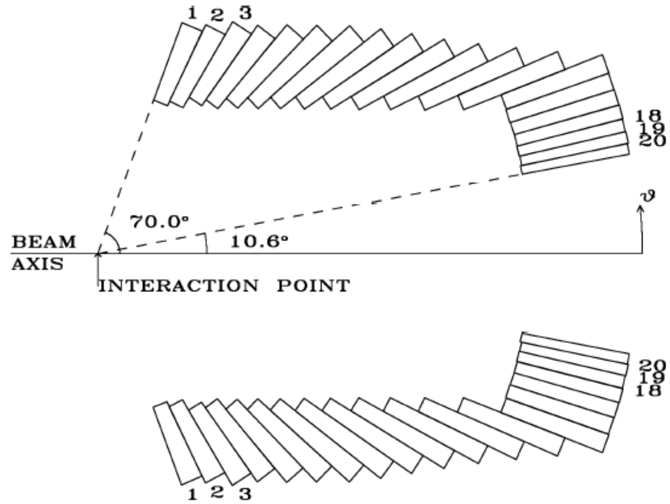
- Given the detector designs being discussed, we'll have to read out < 100k channels
  - ~ 90,000 Sci Fi
  - 128 (?) TOF (x2 if double-ended readout)
  - 1280 CCAL
- Expectations for reading these out include
  - VLPCs & AFE-II for SciFi
  - Sampling ADC for CCAL
- Trigger to be produced using
  - TOF + SciFi track combinations (charged)
  - Back-to-back Energy / Total Energy in CCAL (neutral)
  - General plan involving L1 hardware trigger + L2/3 software levels for further filtering
  - Writeout perhaps 10kHz?

Trigger Plans

- Triggering will require both charged and neutral triggers (perhaps not both simultaneously) based on the Sci Fi & ToF, and CCAL, respectively.
- L1 trigger formed from
  - CCAL via a scheme similar to that used in E835
    - Back-to-back clusters
    - Total CCAL energy > some threshold % of cm energy
  - Sci Fi and ToF via Lookup tables in FPGAs (?) for various track numbers and topology
- L2/L3 filtering done by additional compute nodes
- Utilize custom L1 Buffer boards and (?) Compute nodes from Giessen

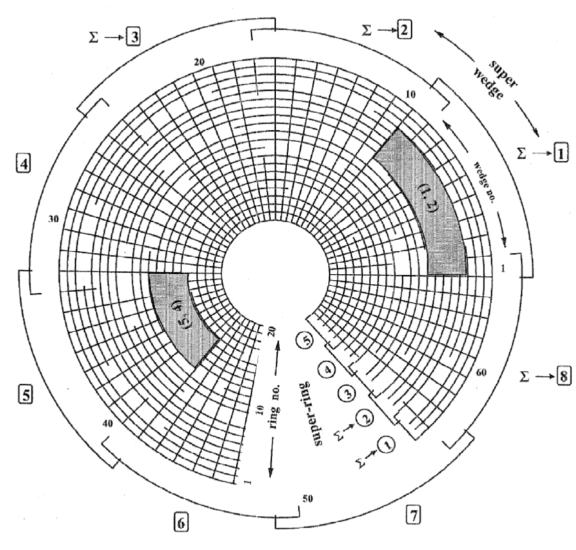
CCAL Notes

- In E760/E835, readout of the CCAL involved 320ns of delay cable to allow for the trigger decision to be made – this also introduced significant broadening of the signals (which, in E835 required shaping circuits to reduce pileup)

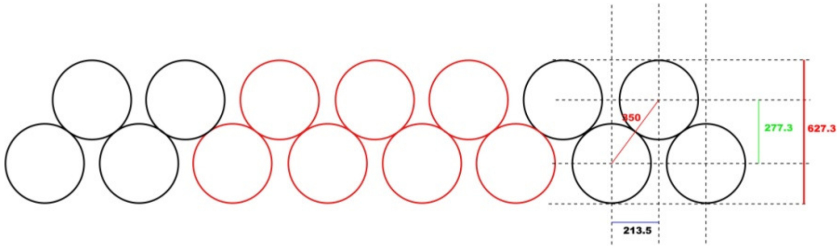


- We'll read out completely differently, so we expect much narrower signals

- For frontend we may use Fermilab sampling ADC modules (200MS/s) giving 4 samples per 50MHz clock cycle (see later discussion) to help catch pileup



Sci Fi Notes – also see Rubinov Talk

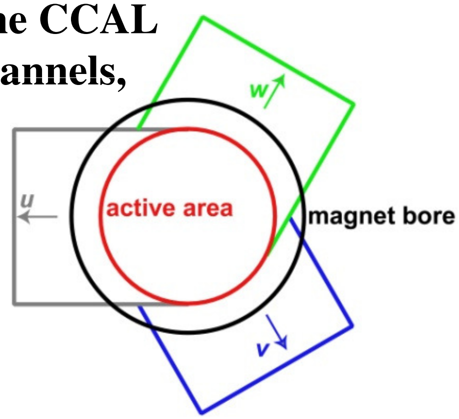


Existing MICE uses:

- **0.35 mm Scintillating fibers**
- **Five stations along the length of the solenoid**
- **Two overlapping layers per coordinate**
- **Combine 42000 signals in groups of 7**
- **Resolution ~0.5 mm per 2-layer plane**

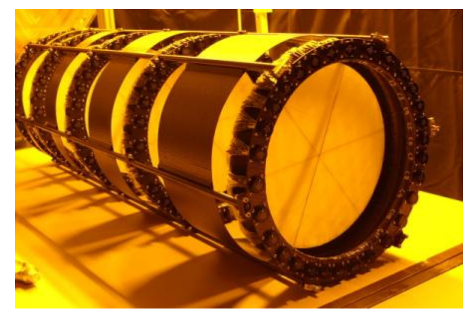
For our purpose,

- **0.25 mm fibers in overlapping layers for each of u,v,w**
- **Eight stations along the interior of the CCAL**
- **Estimate of approximately 90,000 channels, singly read out**

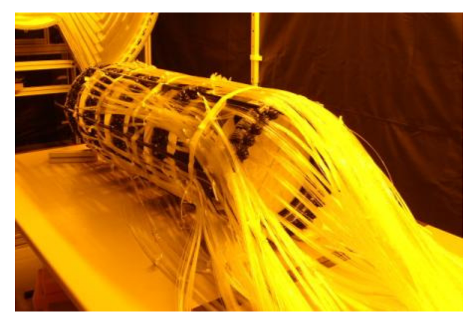


Use front-end essentially equivalent to the existing MICE readout:

VLPCs and Fermilab D0 AFE-IIt



5 tracker stations



Waveguide fibers attached

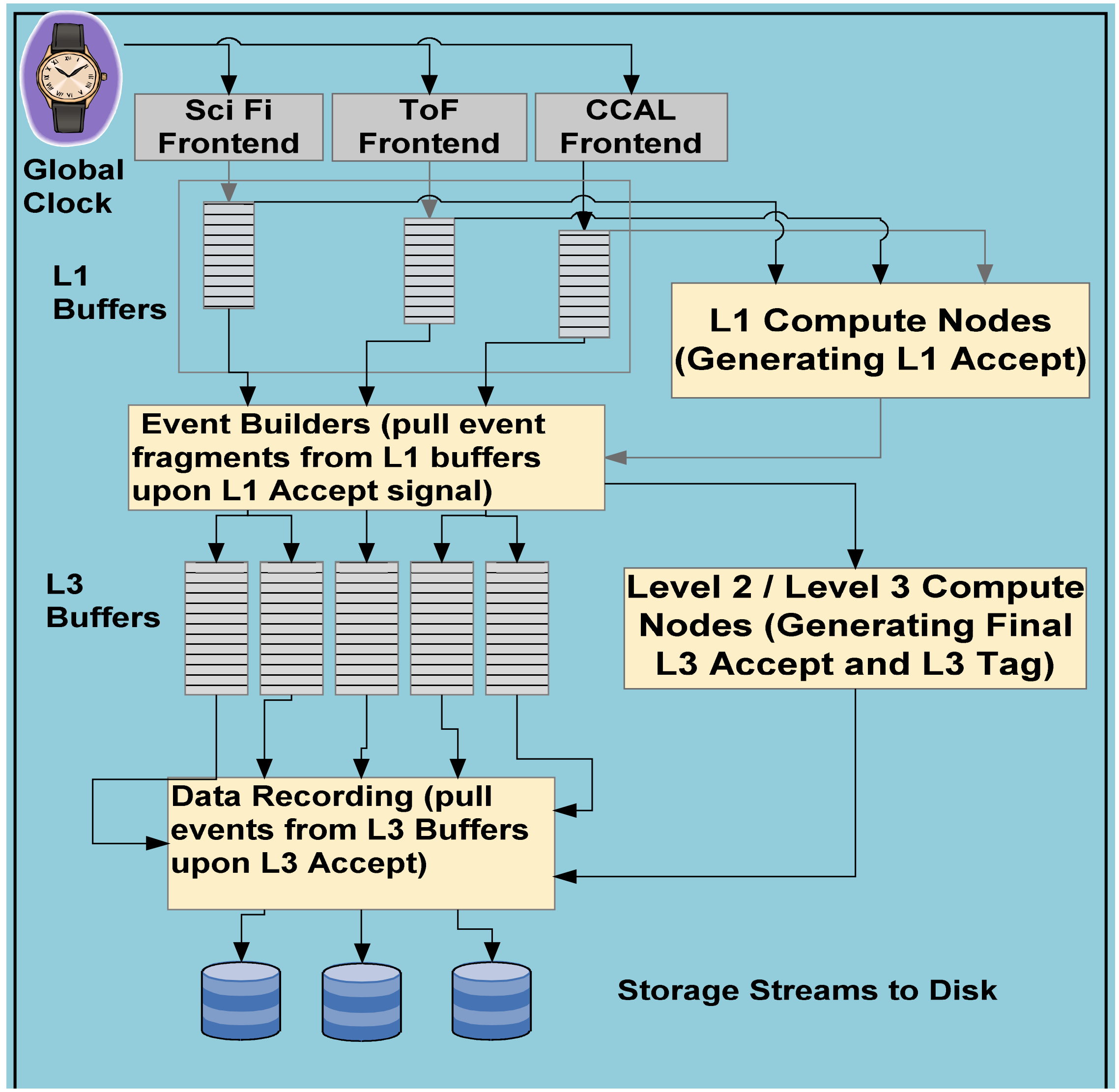
ToF Notes

- For particle ID, a thin and fast ToF system is proposed – perhaps 64 or 128 segments distributed azimuthally in a barrel geometry
- For good K-π separation at the expected momenta, will need ~10ps timing resolution for a detector ~60cm tangentially from the beamline. Systems under study by Frisch et al should do the trick
- ToF signals also will be used to form part of the charged trigger (topological combinations, e.g. 2 hits roughly back-to-back, or 4 total hits, or …)

Broad Strokes of DAQ Plan

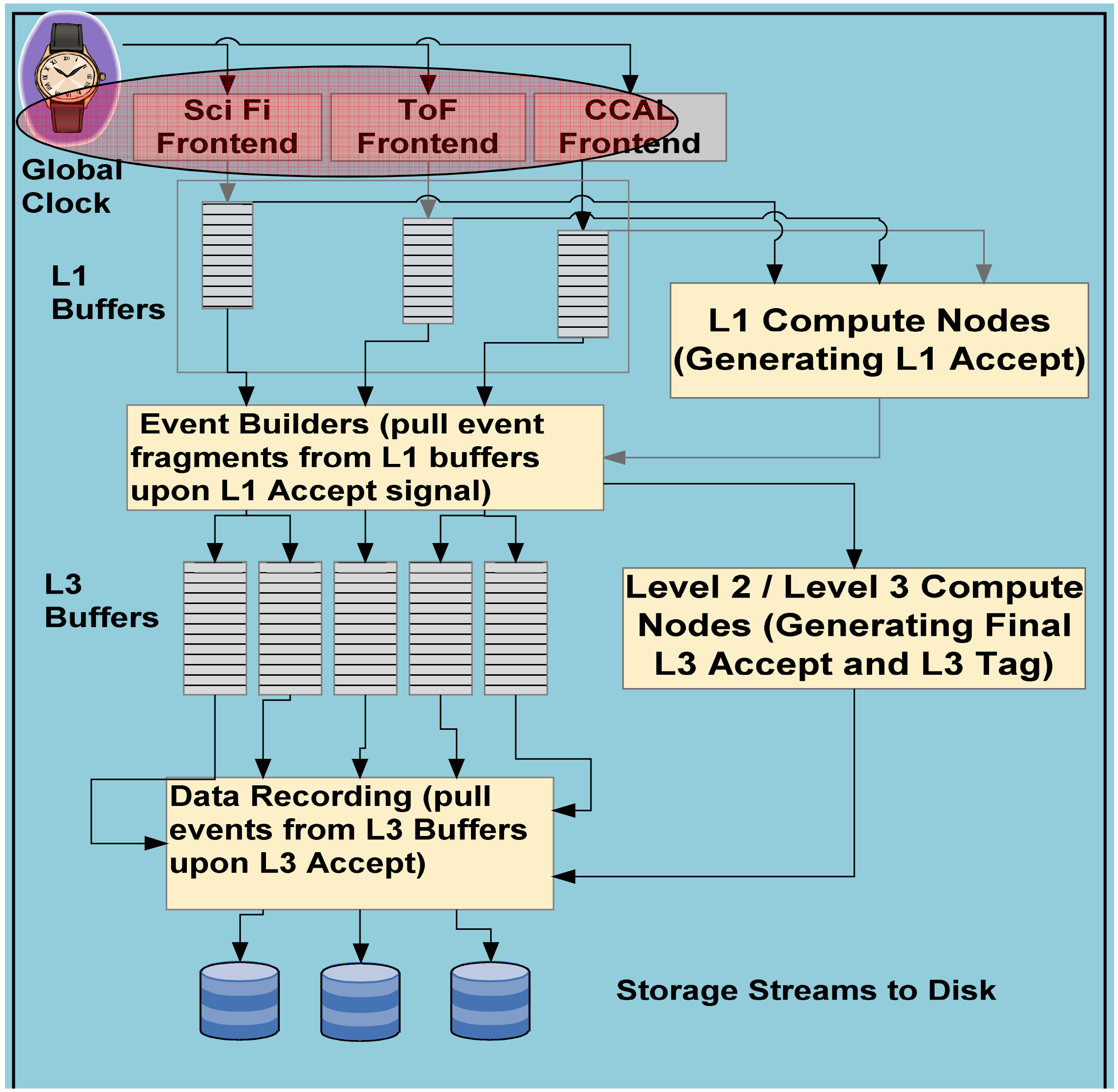
- The aim: Zero deadtime

- Full-detector Readout on 50MHz clock rather than on a hardware trigger provided by detector signals.



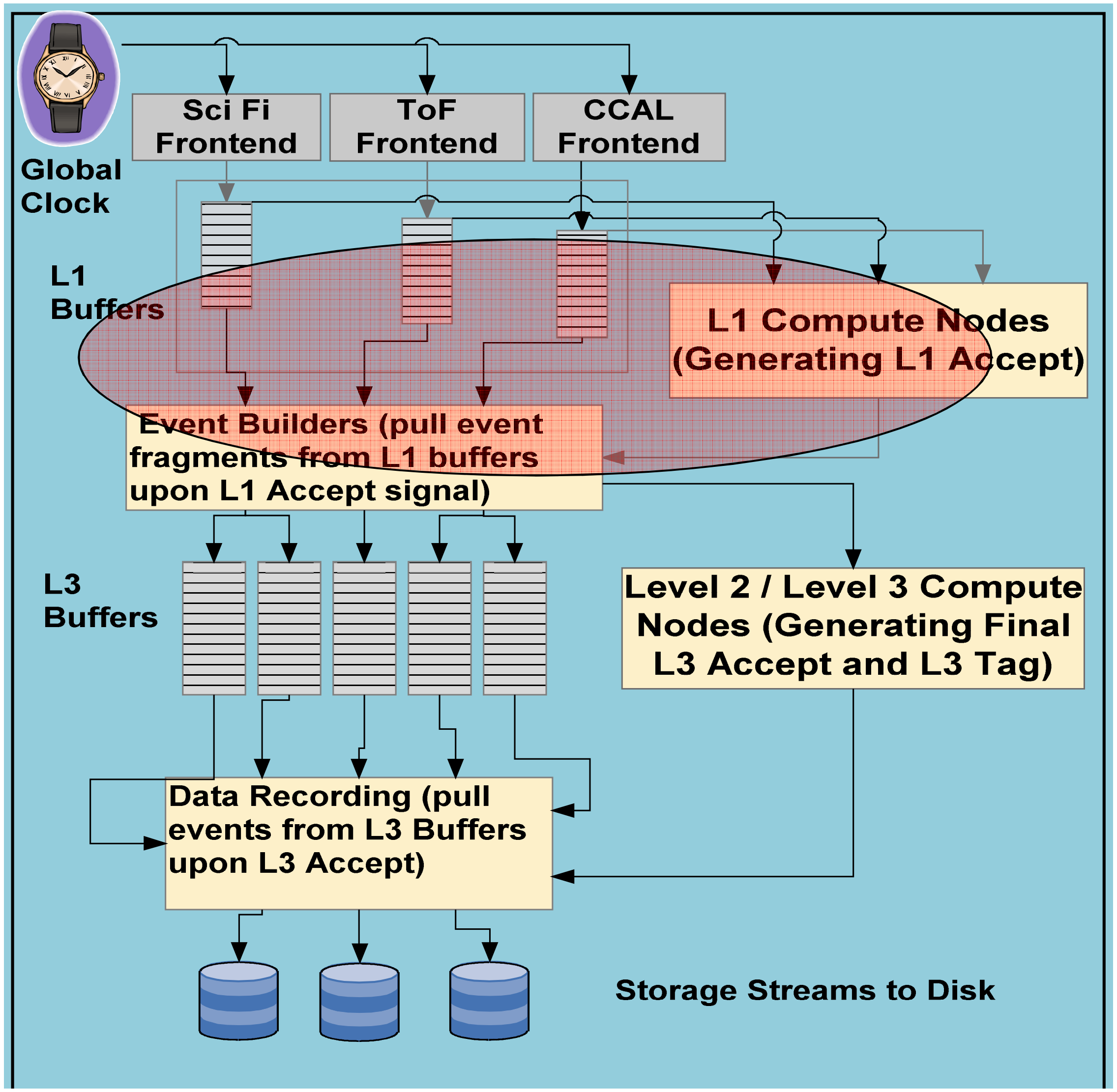
Broad Strokes of DAQ Plan

- Digitize CCAL signals via custom SADC, 4 samples per clock cycle
- Sci Fi readout via D0 AFE-IIt
- ToF readout via custom developed electronics



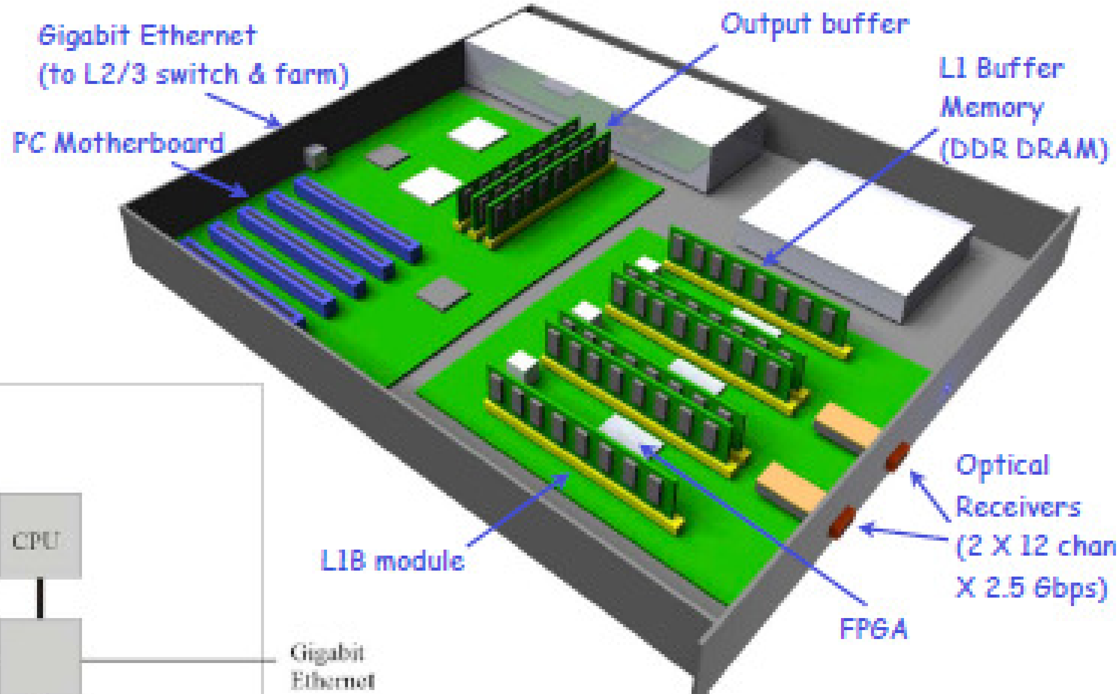
Broad Strokes of DAQ Plan

- All channels read out every clock cycle, with sparsified event fragments buffered in custom L1 buffer boards
- 'push' event fragments to L1 CPU nodes, and await L1 trigger decision. ('busy' can be sent when buffer reaches a threshold percentage)
- L1 trigger decision made on the basis of a subset of event fragments in FPGA/on-board CPUs

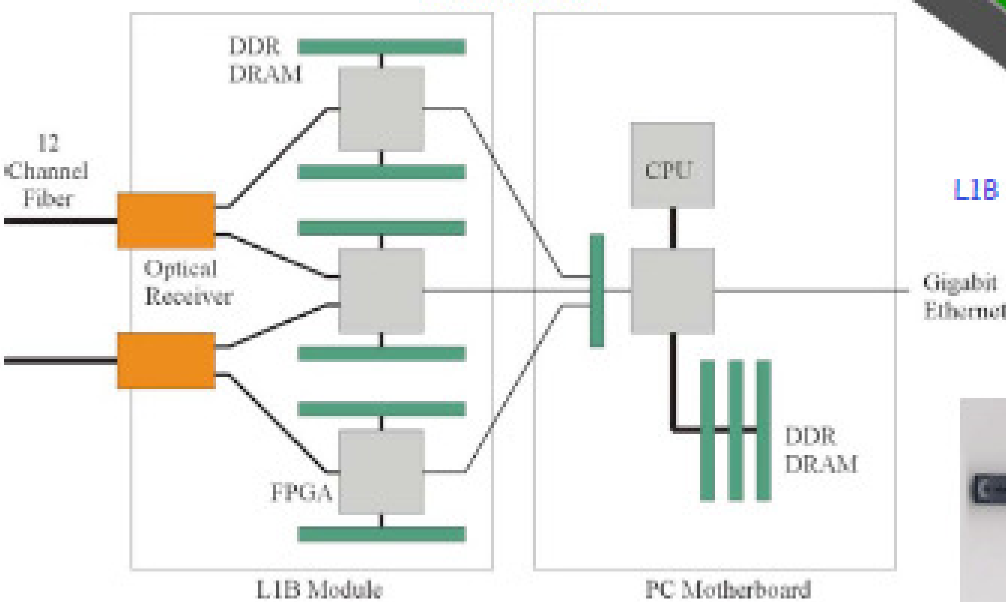


L1 Buffer Modules

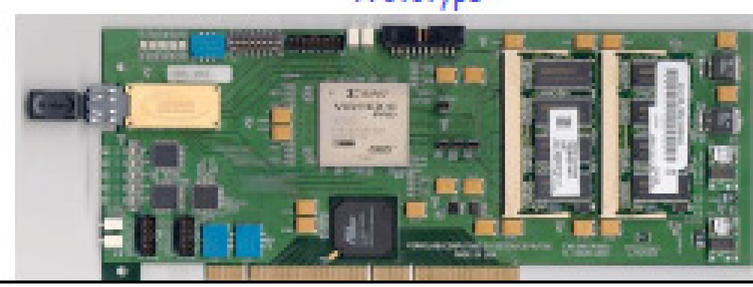
- Level I Buffer



Block diagram

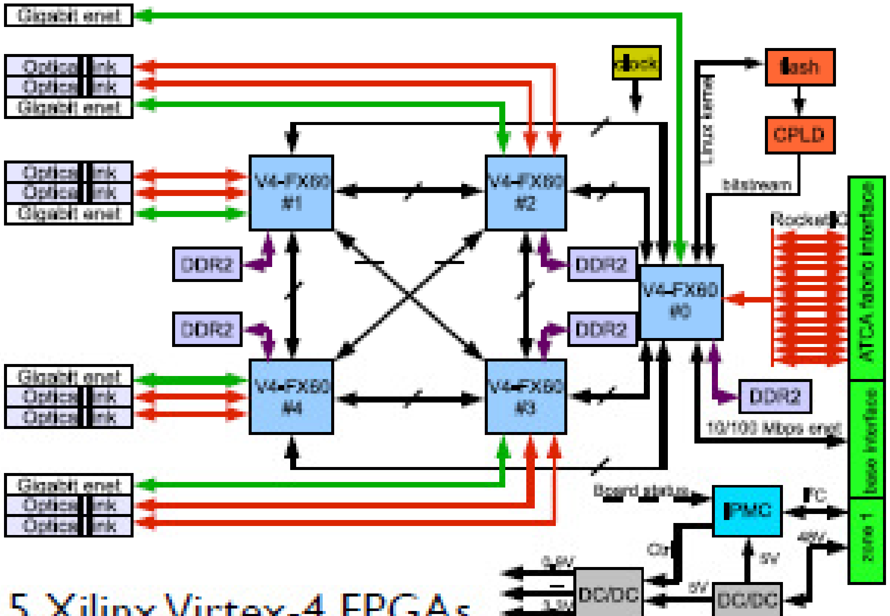


Prototype

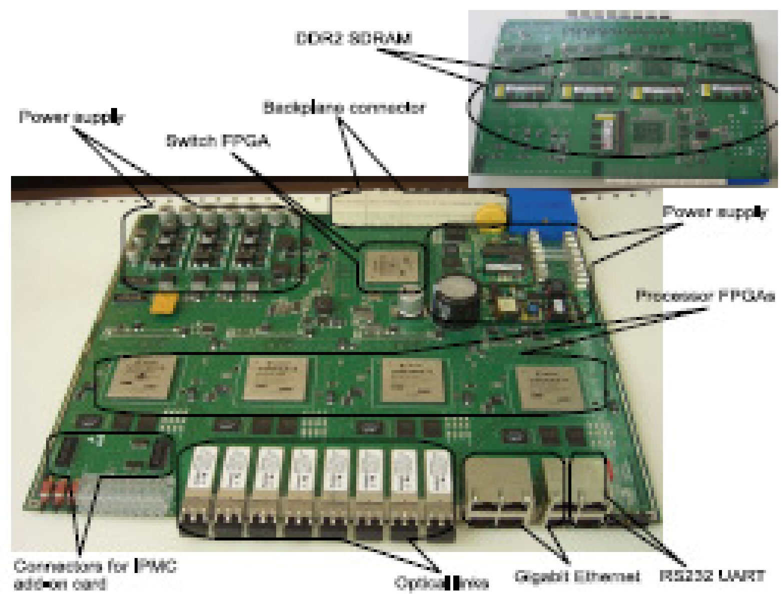


Possible Compute Nodes for L1/L2-3 Decisions: Giessen/RIT/IHEP

- Compute Node block diagram



- Prototype

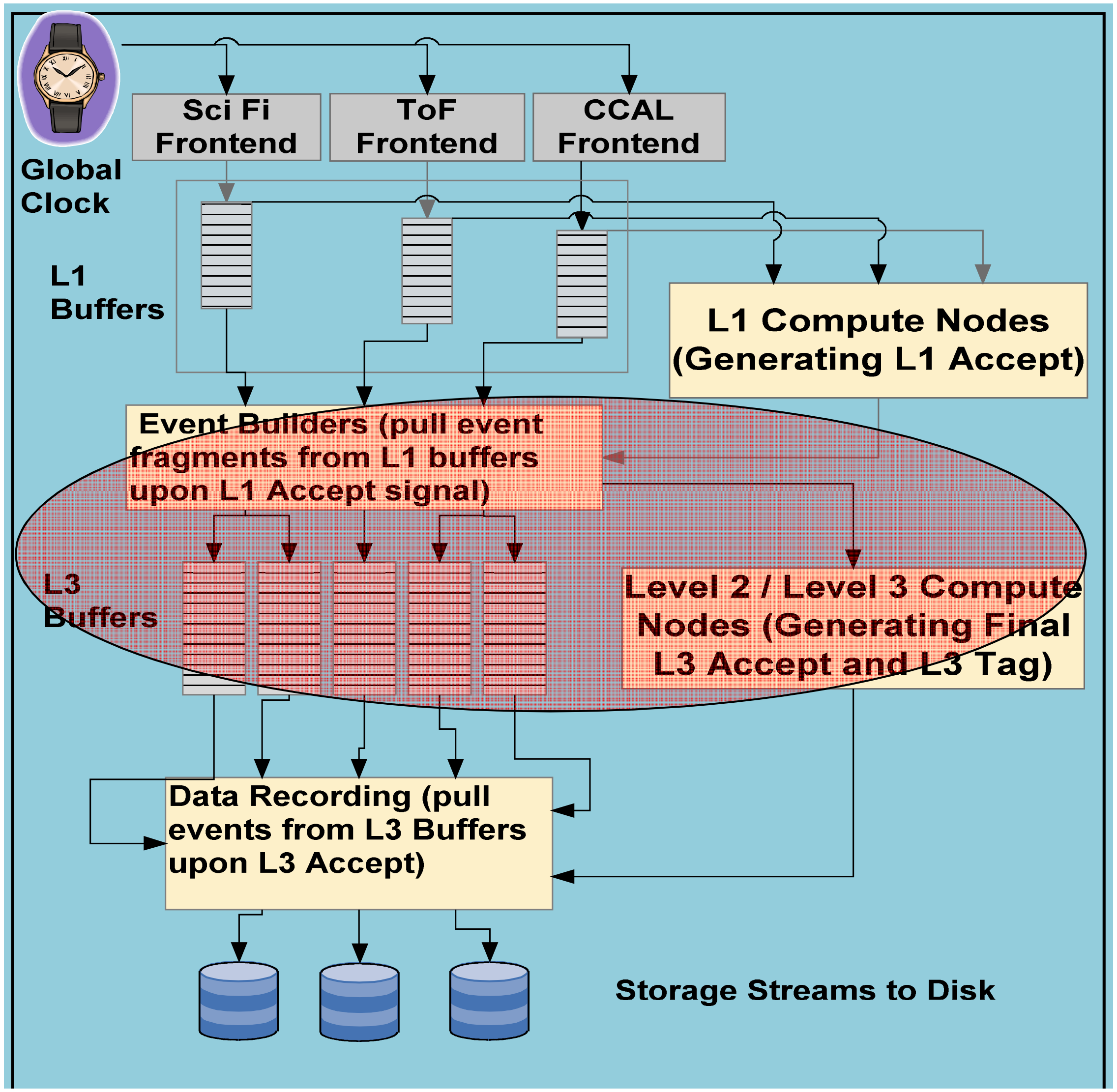


5 Xilinx Virtex-4 FPGAs, (4 workers + mgr) each with

- 2 GB RAM
- GB Ethernet
- 2 optical links (workers)

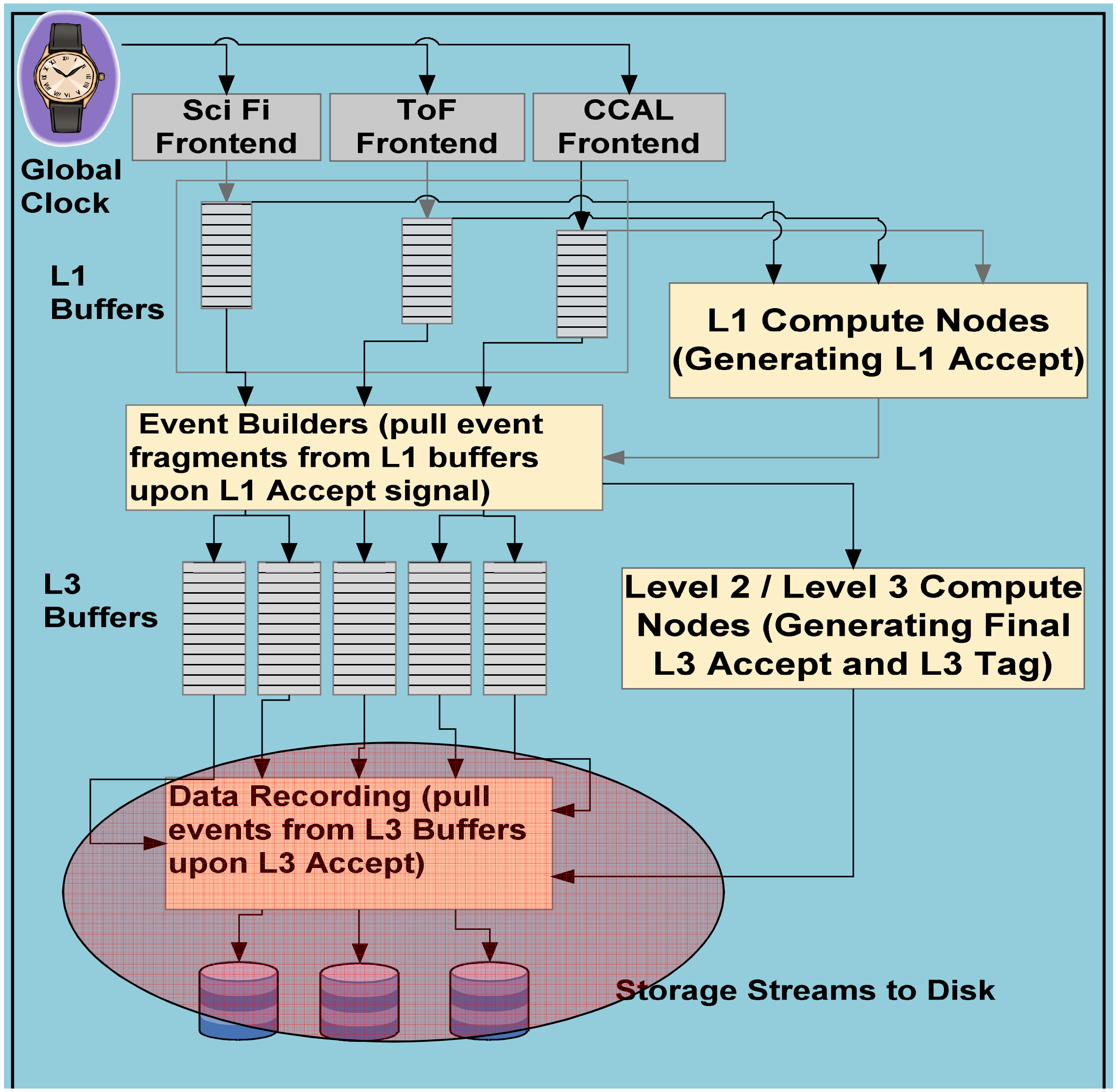
Broad Strokes of DAQ Plan

- L1 accept sent to Event Builders, which 'pull' requested events from the L1 FIFO buffers.
- Event Builders assemble event fragments and send to L2/L3 buffers, and to L2/L3 processor farm which makes further filtering and characterization of events and produces L3 Accept and an ID tag word for the filter type



Broad Strokes of DAQ Plan

- Positive L3 decision sent to CPUs governing writeout stream
- Data Recorders ‘pull’ corresponding events from the L3 buffers.
- Events from L3 buffers augmented with L3 Tag Words, and passed on to storage



How much data can we expect?

Some thoughts on data output

- Estimate average of 3 charged pions, 3 neutral pions per annihilation: 3 tracks, 6 CCAL clusters
- Rough (conservative) estimates of event size follow:
  - CCAL:
    - 6 clusters, 10 blocks each: 60 hits
    - 2 32-bit words per hit: 120 words
  - Sci Fi:
    - 3 tracks, 6 stations, 3 views, both layers at each station hit: 108 hits
    - 4 32-bit words per hit: 432 words
  - TOF:
    - both ends of each struck bar (assume 3) register pulses: 6 hits
    - 2 32-bit words per hit: 12 words
- At 10 kHz written out, 564*4 = 2.256 kB * 10000/s = 22.56 MB/s or 225.6 TB per year (assuming live time ~ 10^7 sec)
- Long-term archival storage (DVD-R) for such a data sample is increasingly cheap (approx. $0.10/GB for DVDs including jewel cases today)

Work To Do and in Progress

- Simulations of 3-4 GeV c.m. energy antiproton annihilation for detector studies
- Simulations of trigger algorithms and specific electronics choices
- Develop specifications for CCAL readout electronics
- Continue to pursue connections/synergy with PANDA