TRIDAS: a TRIggerless Data Acquisition System

Tommaso Chiarusi - INFN Sezione Bologna

Supported by Italian Ministry of Foreign Affairs (MAECI) as Projects of great Relevancy within Italy/US Scientific and Technological Cooperation under grant n. MAE0065689 - PGR00799
**TriDAS original constraints**

**Very small neutrino cross-sections**

\[
\sigma_{\nu N} \sim 7.8 \times 10^{-36} \left( \frac{E}{\text{GeV}} \right)^{0.36} \text{cm}^2 \quad \text{for } E > 1 \text{ TeV}
\]

**Very small expected fluxes**

\[
\frac{dN_\nu}{dE} \sim 9 \times 10^{-9} \left( \frac{E}{\text{GeV}} \right)^{-2} \text{[GeV}^{-1} \text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}] 
\]

\[ \downarrow \]

- O(km³) volume size detector
- many detector elements
- many years uptime

\[ \Rightarrow \]

- Time resolution of O(1ns)
- Positioning resolution O(10 cm)

**Astrophysical source searches**

with angular resolution < 1 deg over a km³ scale

**No bunch-crossing time info**

**Abyssal sites**

Undersea only: **40K and bioluminescence**

e.g.: > 50 kHz @ 10° PMT (0.3 p.e. threshold)

Signal (atm. μ) to noise ratio <10⁻⁴

**Note:** in nu-Tel, the S/N is < 1E-6 !!!
Neutrino Telescopes
PMTs inside the “scintillator”

Continuous signal sampling (e.g. one PMT channel)

- continuous,
- asynchronous
- channels streaming out of over-threshold (L0-skipping) samplings

The data are streamed out to the Trigger-less Data Acquisition System - TriDAS, implemented on the computing resources

Refer also to Marco Battaglieri talk on Wednesday
"on-shore" data processing

- Scan full TS - all channels for **Level 1 triggers** events

Event 1 Event 2 Event n-k Event n

- Event by event check for **Level 2 triggers**

- at least one L2 ?

- Drop No Yes Storage
A similar DAQ model is applied to both ANTARES and KM3NeT.

a) It exploits fixed latency electronics for clock distribution (different implementations).

b) The recorded type and number of information per each hit may be different.

c) It can be generalised for other applications, with the due dimensioning of resources.
TriDAS core written in C++ 11

Auxiliary technologies
BDX-1000 Crystals

A sketch of a KM3NeT-Italy tower

SiPM-CsI(Tl) chrystals hit (th: 0.5 p.e.)

10” PMT hit (th: 0.3 p.e.)
### Throughput comparisons

<table>
<thead>
<tr>
<th></th>
<th>BDX</th>
<th>KM3NeT (Towers)</th>
<th>Clas12 FT-ECAL (beam on/ high thresholds)</th>
<th>Clas12 TF-ECAL (no beam/low thresholds)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N. Channels</strong></td>
<td>1000 (only crystals) considered</td>
<td>672 (6 PMTs x 14 floors x 8 towers)</td>
<td>384 (crystals + flashADC w/o waveform)</td>
<td>384 (crystals + flashADC w/o waveform)</td>
</tr>
<tr>
<td><strong>Single rate/channel (Hz)</strong></td>
<td>5</td>
<td>50 x 10³</td>
<td>&lt;1 x 10⁵</td>
<td>&lt;5 x 10⁶</td>
</tr>
<tr>
<td><strong>Hit size (B)</strong></td>
<td>3 x 10³</td>
<td>46</td>
<td>12 B</td>
<td>12 B</td>
</tr>
<tr>
<td><strong>Global Throughput (Gbps)</strong></td>
<td>120</td>
<td>12</td>
<td>2</td>
<td>150</td>
</tr>
</tbody>
</table>

- **BDX-1000 Crystals**
- **SiPM-CsI(Tl) chrystals hit** (th: 0.5 p.e.)
- **10" PMT hit** (th: 0.3 p.e.)

A sketch of a KM3NeT-Italy tower
Interfacing TriDAS to Clas12 FT-ECal

User-defined Datacards

Coda-SRO Translator

by Sergey Boyarinov and Benjamin Raydo

TriDAS Core

Detector FT-ECal

4x sockets (1x half rack)

40x sockets (1:FADC board)

User

TSC

HM

TSV

TCPU

EM

Permanent storage

User-defined Datacards
TriDAS Control

TriDAS Hierarchical State Machine

State Machine

- Idle
  - Init
  - Standby

- Initiated
  - Stop
  - Configure

- Configured
  - Ready
  - Start
  - Running

TriDAS Core

Detector Electronics

- WebServer
- GUI

TriDAS

- TSC
- HM
- Data Flow (50Gbps)
- Command Flow (1Gbps)
- HFS (10Gbps)
- Permanente storage

Electronics

- TSV
- TCPU
- EM

TriDAS Control

Tommaso Chiarusi — INFN Sezione di Bologna

Streaming-readout Workshop VI - 15/05/2020
Notation:
TS: Time Slice
STS: Sector Time Slice, containing data from 12 x N channels
From Hit Manager to TriggerCPUs

**HM**: receives subsequent data from a fraction of the detector (the so called “sector”)

<table>
<thead>
<tr>
<th>Sector</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector 0</td>
<td>Sector 1</td>
<td>Sector 2</td>
<td>Sector 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HM0</td>
<td>HM1</td>
<td>HM2</td>
<td>HM3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T CPU0 with TS0</td>
<td>T CPU1 with TS1</td>
<td>T CPU2 with TS2</td>
<td>T CPU3 with TS3</td>
</tr>
</tbody>
</table>

**Notation:**
- **TS**: Time Slice
- **STS**: Sector Time Slice
- **TTS**: Total Time Slice

Detector

Electronics

HM: receives subsequent data from a fraction of the detector (the so called “sector”)

$\Delta T = 200$ ms

**Sector**

$N$ FADC-Boards = $N \times 16$ channels

**TCPU**: collects data from the full detector for a slice of time (i.e. the *Time Slice*)

$T S$
**What TriDAS can Do**

- **Time-slice \( i \)**

  - All channels \( N_{CH} \)

**What done with Clas12**

- HMs coherently slice the timeline, relying on time-synchronisation

  - TCPUs applies L1 + L2 filtering

  - One TimeSlice

  - With data from all Detector

**Triggering**

- L1 Trigger: \( Q_{th} \)

- L2 Trigger: Jana Plugin

**Post-trigger file**

- First integration of Jana in TriDAS by A. Celentano
- Support from Jana group: D. Lawrence, N. Brei

---

**Single-seed L1**

- \( \Delta t = 6\mu s \) (tunable)

**Multi-seed L1**

- \( \Delta t > 6\mu s \)
One **event is the collection of hits** which is supposed to describe the passage of neutrino induced muon or shower.

TCPUs **asynchronously process** independent Time Slices. The events are collected, but not time ordered, by the EM into a file.

High-level readout classes are prepared to parse the recorded file.
Aim of the tests:

- optimising the performance of data receptions (HM level)
- optimising the performance of data filtering (TCPU level)
- Studying memory + cpu consumption
- Studying online monitoring and coherence with recorded data

Number of hits: 1E8
Number of events (searched within 400 ns): 16E6

Data analysis ongoing:

S. Vallarino - Clustering
C. Fanelli - AI (see Cristiano’s talk, yesterday)

Courtesy of S. Vallarino and M. Bondì
Recent (ongoing) tests of TriDAS with Clas12
(no beam) - low thresholds

- **Situation:**
  - inhomogeneous distribution of many channels with large rates \(\Rightarrow\) stress test.

- **Inputs for revision:**
  Need of a revision of part of the TriDAS design for:
  - enhancing the flexibility and resilience;
  - focus to the used detector;
  - In particular, aiming to combine multiple sub-detectors, also the trigger-layering design must be expanded (possible evolution from HTC \(\rightarrow\) HPC).

Consider that with **nu-Tel, most of data are to be rejected.** In Clas12-like experiment, **most of data are good events.**

An implication is to invest in on-line reconstruction, and focus on computing resources.
Conclusions and Outlook

• Trigger-less approach derived from DAQ system of large scale neutrino telescopes in the Mediterranean Sea

• TriDAS design is modular and scalable with incoming throughput;

• Some constraints derived by nu-Tel assumptions imply to review TriDAS for JLab detectors (e.g. Clas12)

• Early 2020 tests @ JLab with Clas12 produced data for analysis (search for π0)

• Stress tests are ongoing with Clas12 FTCAL (although without beam)

• Improve the integration with auxiliary software developed @ JLab (JANA)

• Review (rethink) the trigger-layers model

• Interaction between TriDAS developers with JLab’s SRO team
Thank you!

Further readings


TriDAS web site: https://bitbucket.org/chiarusi/tridas.


R. Ammendola et al., NaNet3: The on-shore readout and slow-control board for the KM3NeT-Italia underwater neutrino telescope, EPJ Web of Conferences 116, 05008 (2016).

M. Favaro, et al., The Trigger and Data Acquisition System for the KM3NeT-Italia towers EPJ Web of Conferences 116, 05009 (2016)

M. Manzali, et al., The Trigger and Data Acquisition System for the KM3NeT-Italy neutrino telescope , Proceedings of CHEP 2016

BDX proposal: https://arxiv.org/abs/1607.01390
- Simulated Poissonian single rate per channel: **100 kHz**
- N. of TCPUs: 4 nodes  **(32 cores Intel(R) Xeon(R) CPU E5-2640 v2 @ 2.00GHz)**
- Concurrent TimeSlice processing: **20 TS in parallel/node**
- Time Slice duration: **200 ms**
- L1 event length: **6 μs**
- 1 Sector = **7 WaveBoards** (84 channels)

It means that for N>4 Sectors (336 channels at 100 kHz single rate!) additional TCPU nodes are needed (or more trigger threads, if allowed by the computing resources).

**Granny’s recipe:**

*add TCPU as much as it suffices!!*

...without affecting the DAQ design. Scalability is granted!