ALESSANDRO THEA

R&D TOWARDS THE FINAL SYSTEM

SYNCHRONISATION AND TIMING DISTRIBUTION

- FD2-VD Top and Bottom electronics use different technologies to achieve syncronisation and receive timing information
  - Bottom electronics: DTS (developed from "Single Phase")
  - Top electronics: White-Rabbit based
- Both timing systems independently meet DUNE DAQ timing requirements
- Non-negligible costs/effort would be required to completely switch to a single VD timing sytem
- DAQ and Top-electronics experts think that the two systems can conceptually interoperate and saitsfy the overall DUNE timing requirements

TIMING DISTRIBUTION HIGH-LEVEL REQUIREMENTS

All detector data structures are marked with a unique sample ID (SID)

- Formerly known as “timestamp”
- Most DAQ entities only see sparse data, and must align data from many sources

The SID is common across all subsystems in a module

The SID increases monotonically at the DUNE base clock frequency

- a 64b firmware counter clocking at a common clock frequency, initialised at a common time to a common value across all subsystems

SIDs are applied in FE electronics and are thereafter immutable

PRACTICAL REQUIREMENTS

Each FE system must be aligned to a common reference

- Where SIDS are applied

Common clock frequency

- Derived from common GPS
- Clocks locked everywhere in detector at nano-second

Common SID alignment

- An *initialisation event* is when the SID in an FE system is aligned with the current master SID
- All FE systems must be able to re-synchronise their SID at any point, to allow entering / leaving without a global restart

Data formats at DAQ input

- All data structures must be marked with the SID
- All packets should be marked with the SID to reserve the option to split or steer network data in future evolutions of the readout system

R&D TOWARDS AN INTEGRATED SYSTEM

- Discussion between DAQ and TDE timing experts ongoing
  - First meeting on June 14
  - Timing experts agree that inter-operating the two systems is (conceptually) possible
  - It’s possible to anticipate a combination of WR and DTS protocols

- Short term: configm relative stability of the two systems planned on a short timescale - outlined in previous talk
- Details of the integrated system to be worked out in follow-up meetings between experts
  - Targeting the second half of the VD coldbox test (Q1-Q2 2022) for complete demonstration
  - And NP02-VD for a full system test

FD2-VD DETECTOR READOUT

- 40G ethernet readout baseline for FD2-VD TDE readout
- FELIX 100 Gbps FULLMODE readout baseline for BDE readout
  - Data reception
  - On FPGA pre-processing (TP generation)
  - DMA to transfer host
- From the DAQ perspective
  - Ethernet is "just" a different data transport layer
  - No impact on the DAQ architecture, once proper abstraction is put in place
    - Standard data format, receiver architecture, etc.

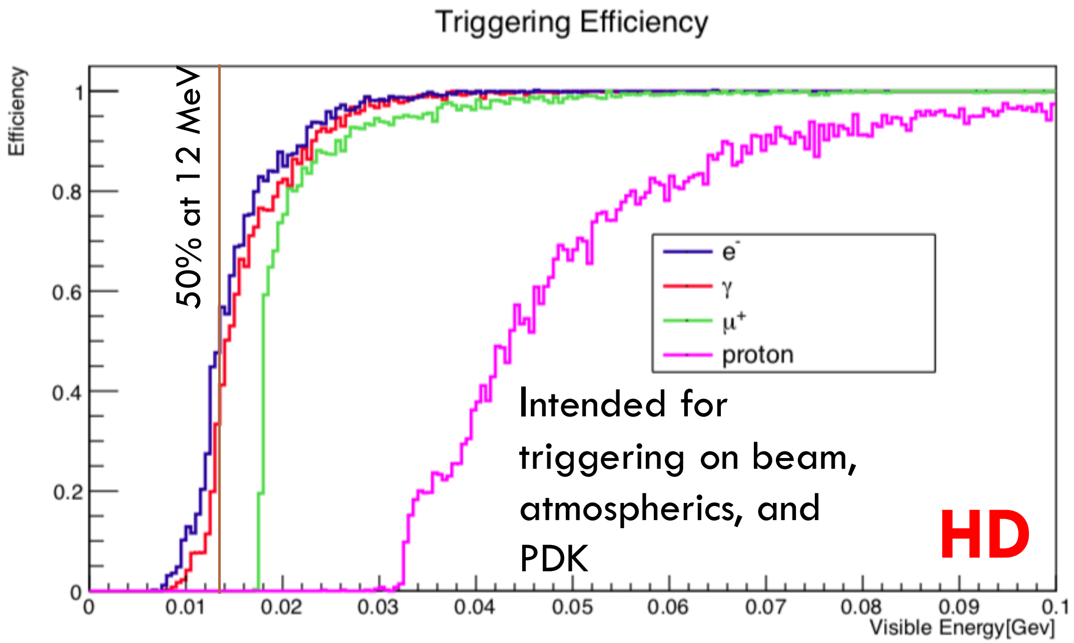
ETHERNET READOUT STRATEGY& PLAN

- Maximise the symmetry with FELIX-based readout
  - Maintain the capability for data-preprocessing and DMA
  - Investigate solution that maximise the code and tool re-use
- R&D Plans
  - Short term : establish dataflow with 40G/100G NIC
  - Medium term : identify viable FPGA-based solutions for 40G readout
    - And prototype key functions: reception, processing, DMA
    - Results presented by DP at the CERN collaboration meeting give confidence that this is doabe
  - Long term : re-implement the full upstream readout path based on ethernet
    - Target demonstration at NP02-VD

TRIGGERING - VD HIGH-ENERGY

Working right now on looking at existing HE algorithms on VD strips/geometry

1. Will depend on signal/noise model for VD strips
2. Radiological rates/channel may be different
3. Pitch of collection wires will have an impact



CAVEAT: quantitative results subject to availability of VD simulation samples

- VD simulation (including detector response) is still undergoing active development
- No reference configuration yet
  - Noise model, backgrounds, geometry need to be settled

Applies to following slide as well

TRIGGERING - MOVING LOWER IN E

Region-of-Interest (ROI) Readout

Can have a higher trigger rate if data/trigger is smaller size:

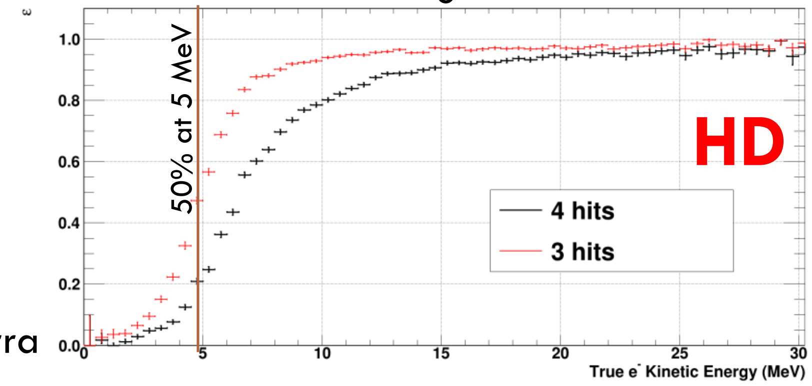
1. Halve readout window
2. Write out only CRPs with trigger activity (TA)
3. Use a much narrower readout (100 μs) window around hits ("zero suppression")
4. Fully localize TA and use 100 μs window for readout

Table 2:

Data Reduction Approach	Event Size (Uncompressed)	Max Trigger Rate	Enabled Physics
Nominal	6.075 GB	0.078 Hz	Beam, NDK, Atm.
2.7 ms Readout Snapshot	3.3075 GB	0.156 Hz	Unknown
APA-Localization (Cosmics)	0.243 GB	1.95 Hz	*hep* solar ν
APA-Localization (Low-E)	0.041 GB	11.7 Hz	^{8}B solar ν, neutrons,Rn
Zero Suppression	0.040 GB	12.0 Hz	^{8}B solar ν, neutrons,Rn
TA ocalization +Zero Suppression	14.6 kB	32.5 kHz	^{42}Ar, ^{40}Cl, *pep* solar ν?

HD

Threshold set so background rate ~ 10 Hz



Of course, ROI can depend on type of Trigger Candidate

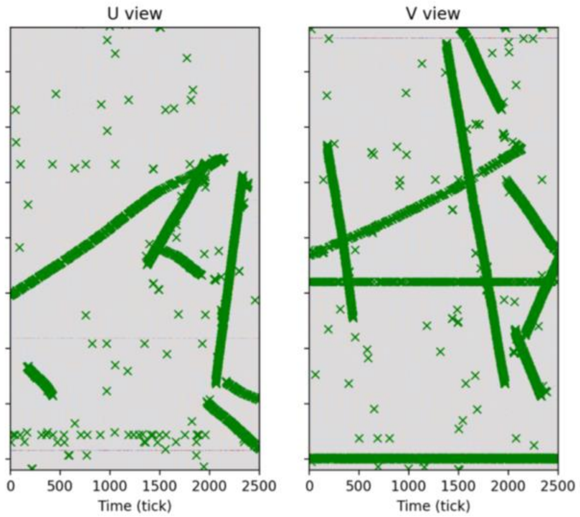
Need to examine impact of VD - Can apply existing algorithms to simulation, maybe 2 months

Thiago Bezerra

TRIGGERING - INDUCTION STRIP TPS

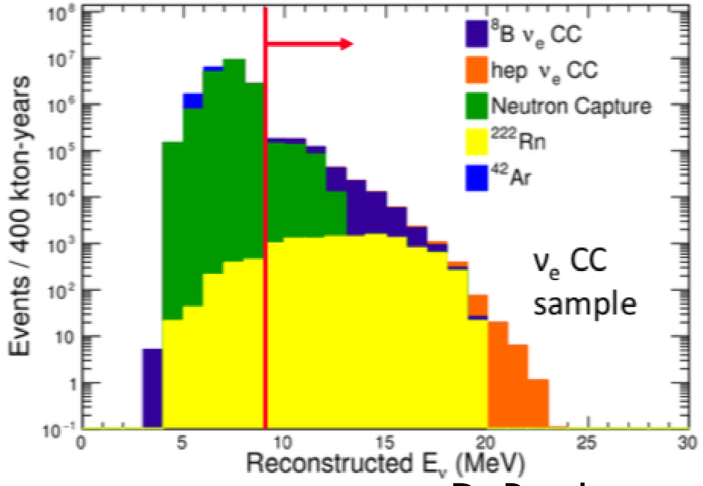
- Induction strips TPs will help with neutron/electron discrimination

HD



But noise level is about 20-30% higher than collection →

But helps in using topology



HD

D. Pershey

More complete "reconstruction" can be done in High-Level Filter

Need to examine impact of induction strip orientation on fiducialization, but fewer anode planes in VD should help with this

Effort not started yet

TRIGGERING- INCLUDING PDS

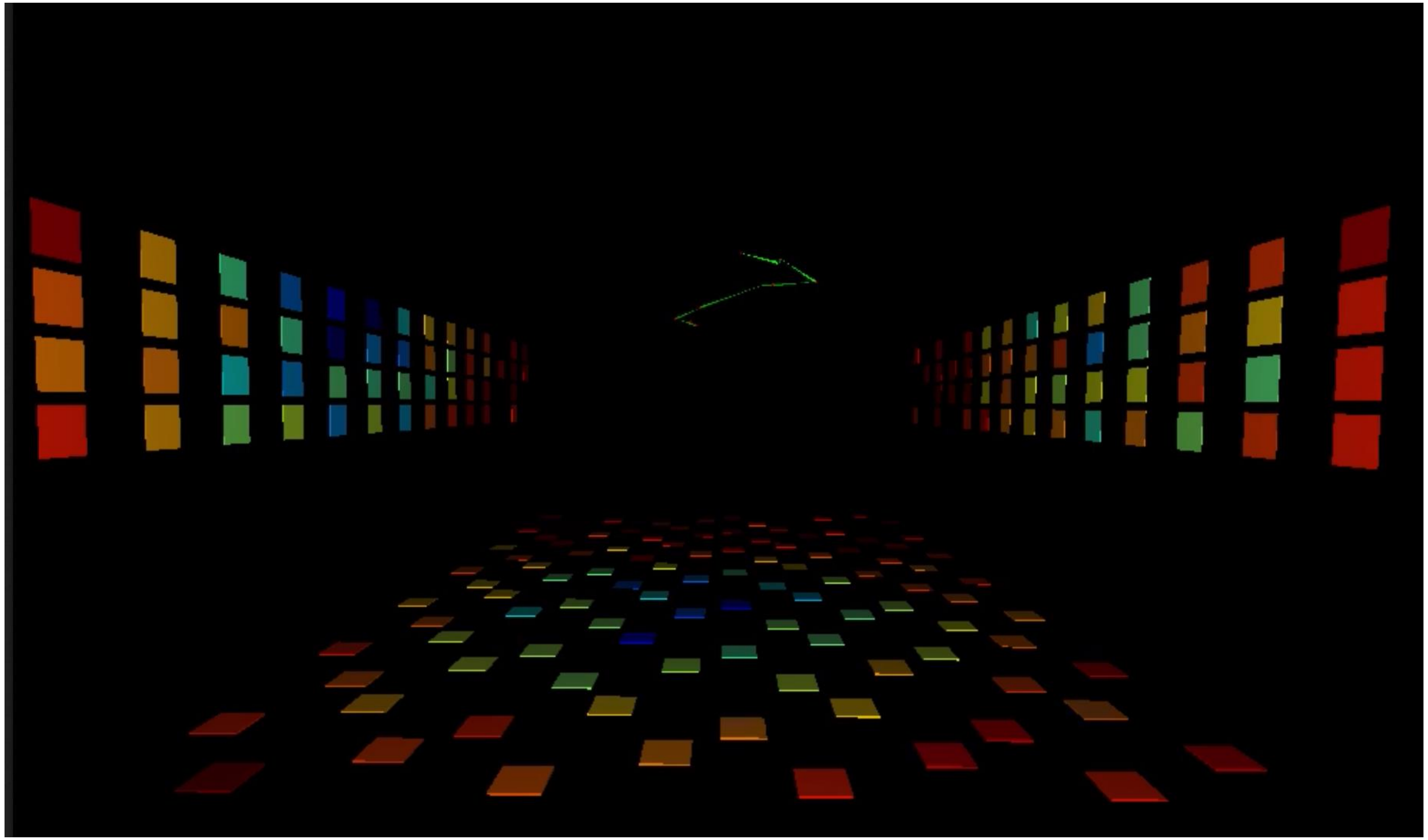
- Naturally inclusive trigger (e.g., Npe>threshold)
- Efficiency likely easy(-ier) to model and measure
- Can be fast
- Can reduce background rates via fiducialization
  - maybe in high-level filter
- Noise uncorrelated with TPC
- In principle singlet/triplet PID can reject αs for very low-E program with u/g Ar

Careful study of background rates needed - in progress

Requires TPC+PDS simulation with good background representation

INCLUDING PDS

New tool (Chroma) for PDS simulation may help



5 MeV single electron event

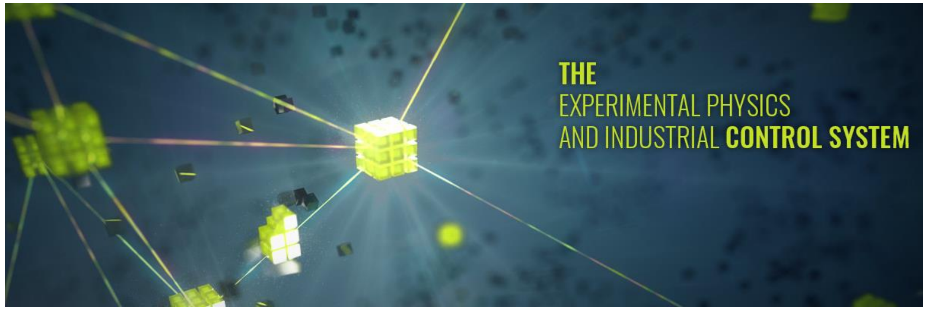
TRIGGERING-MOVING EVEN LOWER IN E

- Include induction strips trigger primitives
  - Very little pulse shape information at low energies
- Write all of them continuously
- Threshold is ~250 keV
- Can run “offline” algorithms as sophisticated as desired
- Data will be overwhelmingly ^{39}Ar

Requires TP definition from induction TP studies

DEVELOPMENT NEEDS TOWARDS FINAL SC

- Continue requirements capture & specifications
  - Coldbox
  - ProtoDUNE-II
  - Formal interface documents
- Choose the best suited SCADA tool based on
  - **Features**
  - Available experience
  - People committed to developing and maintaining the system



FEATURES REQUIRED

- **Reliable SCADA**
  - Mature product (all typical features ready: data collection, alerting, visualization, scripted logic and sequences, …)
  - Long term support and evolution
- **Support of all main industrial protocols, in particular OPC UA**
  - Extensibility to custom protocol connections
- **Scalability**
  - DUNE SC is large compared to many industrial plants
- **Multi-user and multi-developers support**
  - Essential for a scientific collaboration and not so common for industrial SCADA systems
- Interface to **powerful databases with effective data model** for data archival and retrieval

FACILITATING DEVELOPMENT

- The SC team will create the framework and architecture to be able to integrate all systems coherently
- The experts of the different consortia shall be able to contribute to the development of the SC for their subsystem
  - Available SCADA training/documentation is an important aspect
  - Exploring QUASAR as a tool to generate OPC UA servers (first discussions started with one CAL expert) to interface custom electronics
  - Centrally setup model for versioning, CI, etc. and a workflow to move from development to production versions

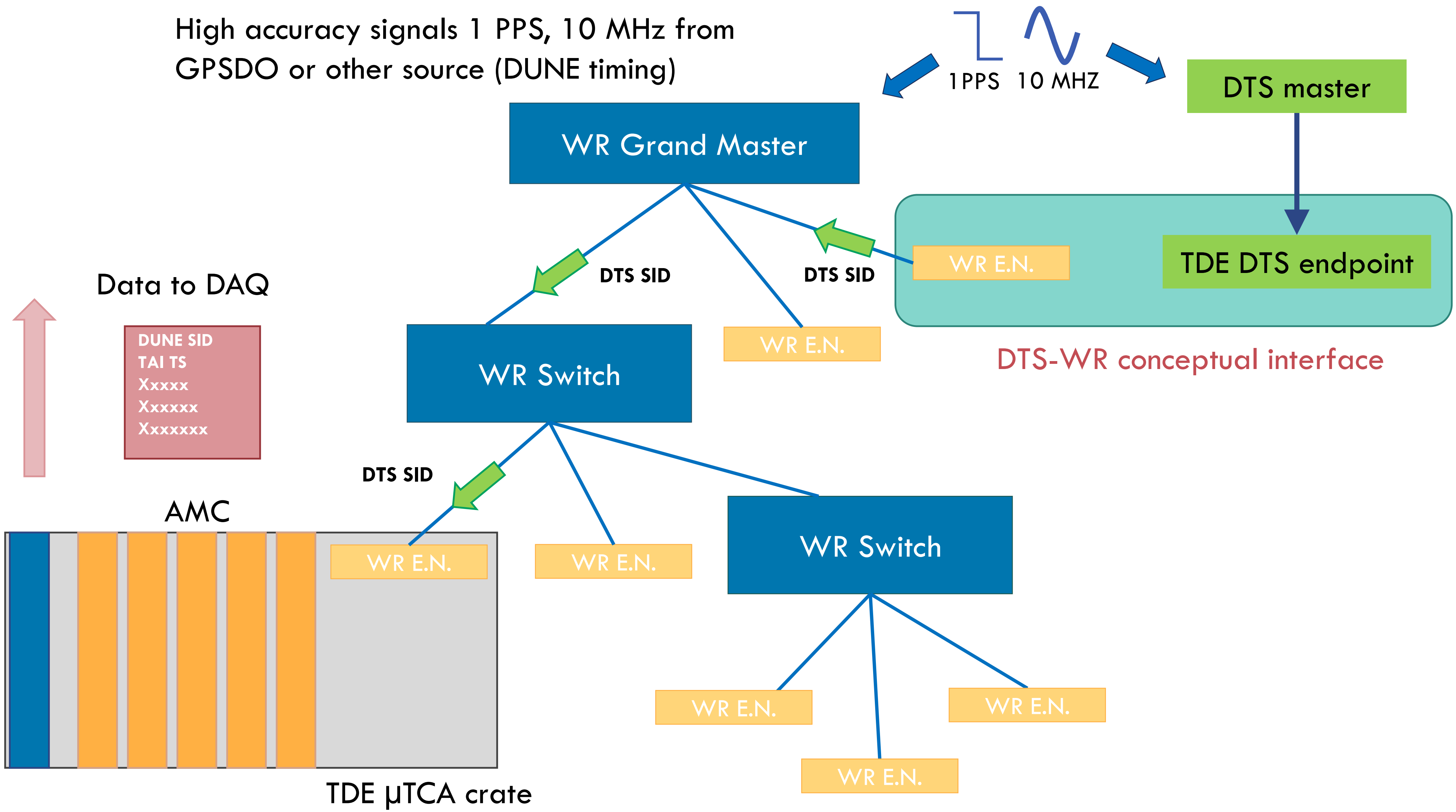
SUMMARY

- DAQ R&D is carried out in the DAQ consortium jointly for FD1-HD, FD2-VD and ND
- Areas where specific R&D effort will be required for FD2-VD are
  - Synchronisation and Timing Distribution
  - Ethernet readout integration
  - Trigger studies
  - Slow Control R&D
- The DAQ consortium has the expertise to carry out these developments, in collaboration with the relevant cosortia in DUNE
- The overall manpower remains a concern

BACKUP

CONTROL, CONFIGURATION & MONITORING

- Services and interfaces that allow the experiment to behave a coherent system
  - Services for configuring the experiment
  - Identifying and isolate faults, recover components, guarantee high uptime
  - Fine-granied monitoring to inspect behaviour of the system in details
- CCM still in early prototyping stage
  - Significat R&D required to bring it to maturity
- FD2-VD procedures to be developed ad-hoc


High accuracy signals 1 PPS, 10 MHz from
GPSDO or other source (DUNE timing)
1PPS
10 MHZ
DTS master
WR Grand Master
DTS SID
DTS SID
WR E.N.
TDE DTS endpoint
WR E.N.
DTS-WR conceptual interface
Data to DAQ
DUNE SID
TAI TS
Xxxxx
Xxxxxx
Xxxxxxx
WR Switch
DTS SID
AMC
WR E.N.
WR E.N.
WR Switch
WR E.N.
WR E.N.
WR E.N.
TDE μTCA crate