A READOUT SYSTEM-ON-CHIP FOR A CUBIC KILOMETER SUBMARINE NEUTRINO TELESCOPE

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TWEPP-11, Vienna, Austria,

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The KM3Net Detector

Digital
Optical
Module
(DOM)

31
PMTs/DOM

12800
DOMs

320 lines
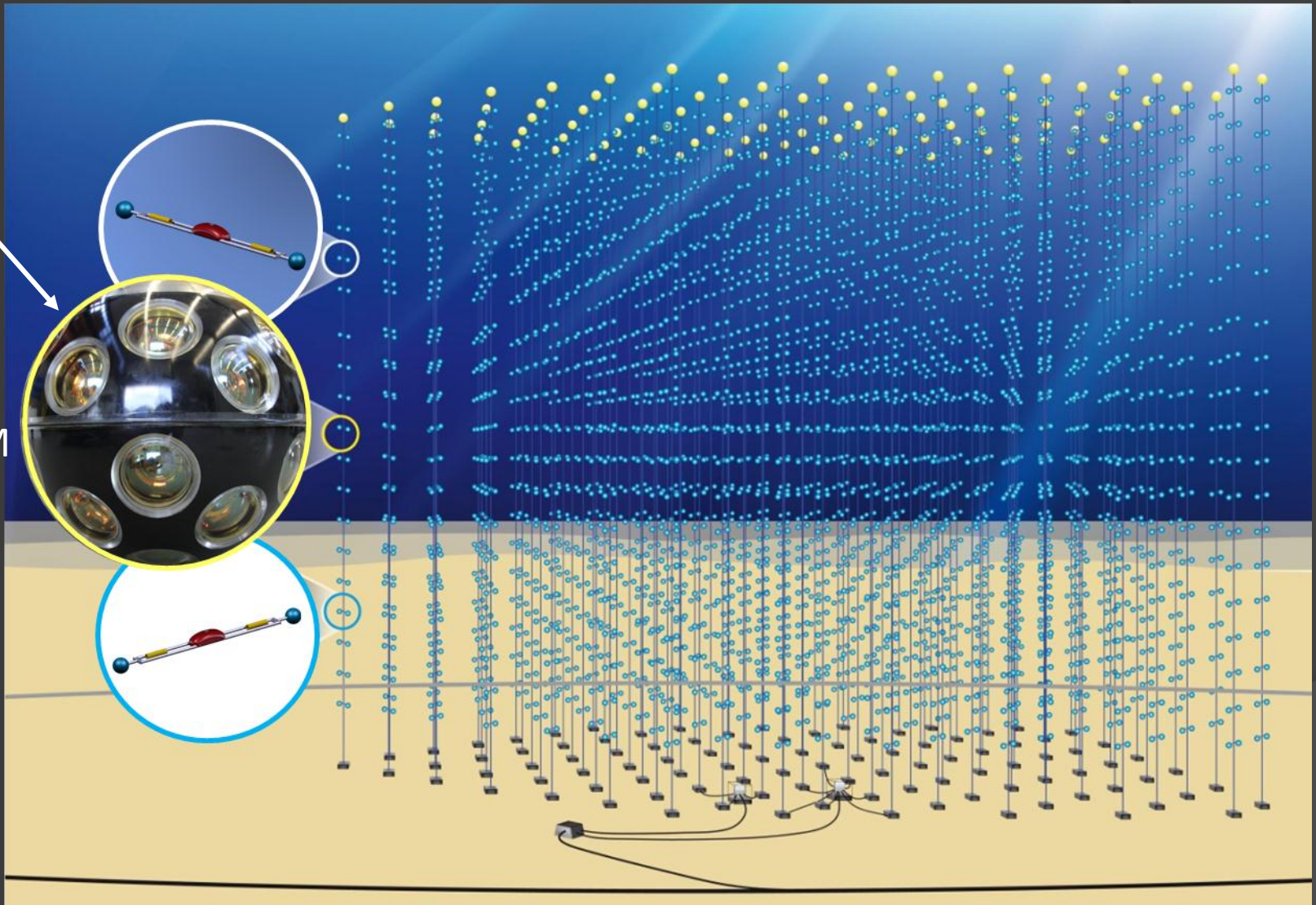
The DOM processor board

Heat conductor

Power conversion board

PMT

Processor board & Software designed at CEA-IRFU

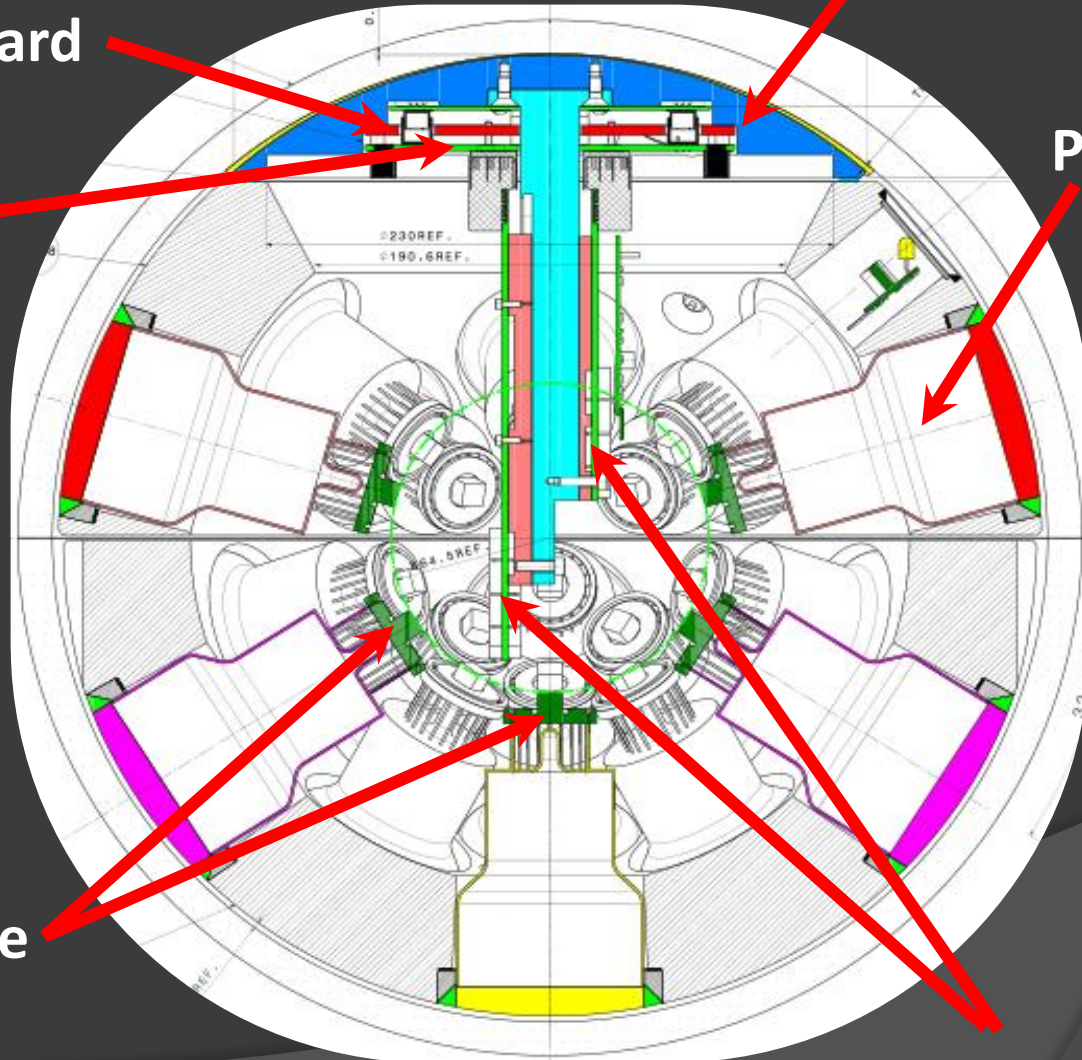**DOM designed at NIKHEF institute (Amsterdam, Netherlands)**
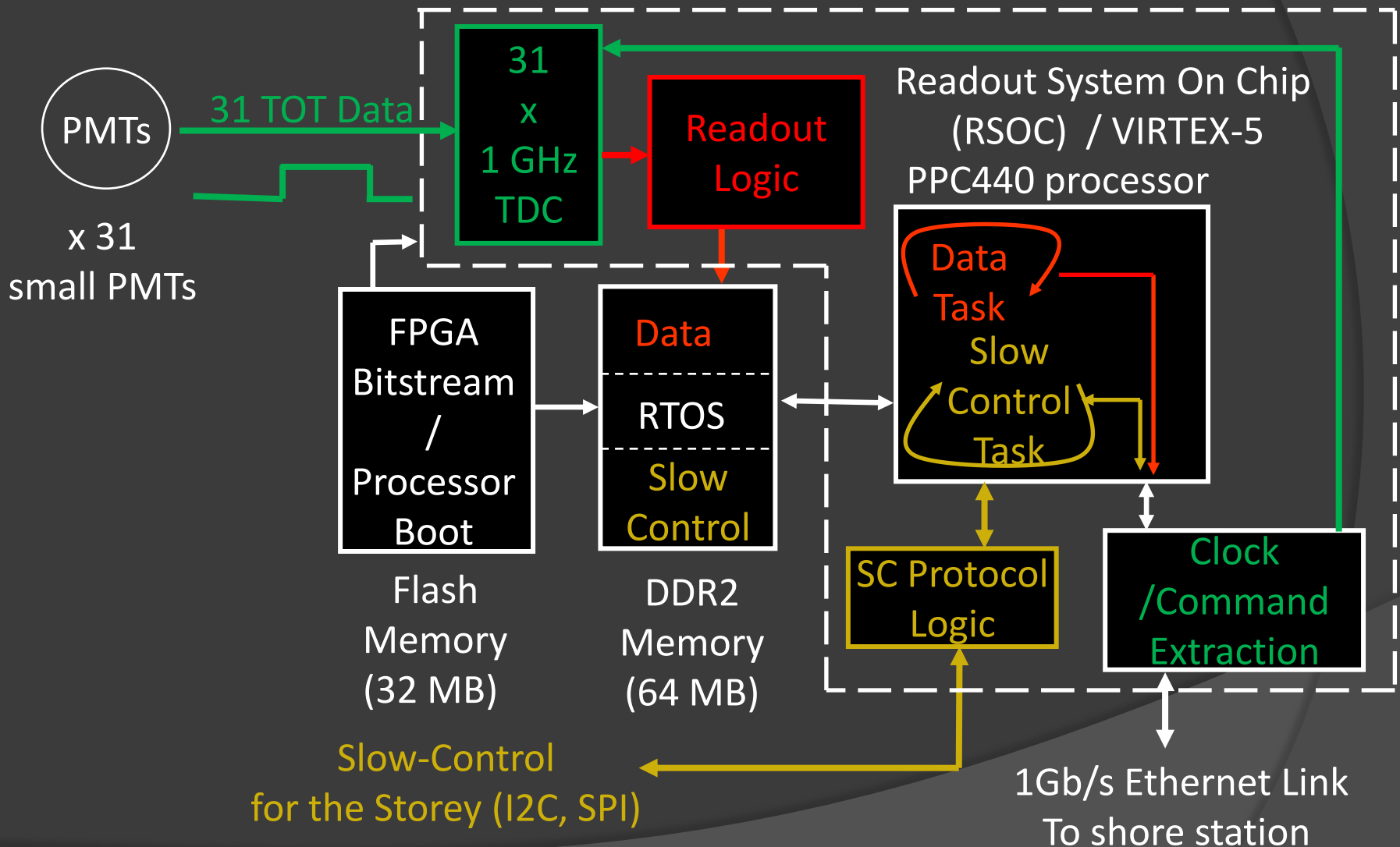
HV PMT base

Signal collection board

The KM3Net prototype Offshore Processor Board

PMTs

31 TOT Data

x 31 small PMTs

31 x 1 GHz TDC

Readout Logic

Readout System On Chip (RSOC) / VIRTEX-5 PPC440 processor

Data Task
Slow Control Task

FPGA Bitstream / Processor Boot

Flash Memory (32 MB)

Data
RTOS
Slow Control

DDR2 Memory (64 MB)

SC Protocol Logic

Clock /Command Extraction

Slow-Control for the Storey (I2C, SPI)

1Gb/s Ethernet Link To shore station

Firmware TDC Development

Packetized and Sent over ETHERNET

Event type/TDC number	Coarse Time Stamp #24-bit	TDC #16-bit

`0 0 0 1 1 1 0 0`

TOT LVDS PMT asynchronous input

XILINX VIRTEX-5 ISERDES

8-bit

1 GHz Sampling

0
0
0
1
1
1
0
0

Recovered ETHERNET Clock @125MHz

PLL
500 MHz

/500 MHz

125 MHz

Readout Logic @125 MHz

'1' Detection & Coarse Time Stamping

[Originally designed by A.Zwart (NIKHEF) / small PMTs test bench for ALTERA]

KM3NeT

Irfu   cea

Clock distribution

On Shore VIRTEX-6 Board

Command (CMD) insertion

Transmit Reference Clock @62.5 MHz

STANDARD 1000BASE-X ETHERNET

Custom Logic

Phase and Latency Measurements

Embedded 62.5 MHz

IDLE CMD DATA

1.25 Gbps

Off Shore VIRTEX-5 RSOC

Command(CMD) extraction

PPC440 Bus

CMD

Custom Logic

DATA

IDLE

Event Time Stamping

Recovered Clock @62.5 MHz / Bit slice analysis (known latency)
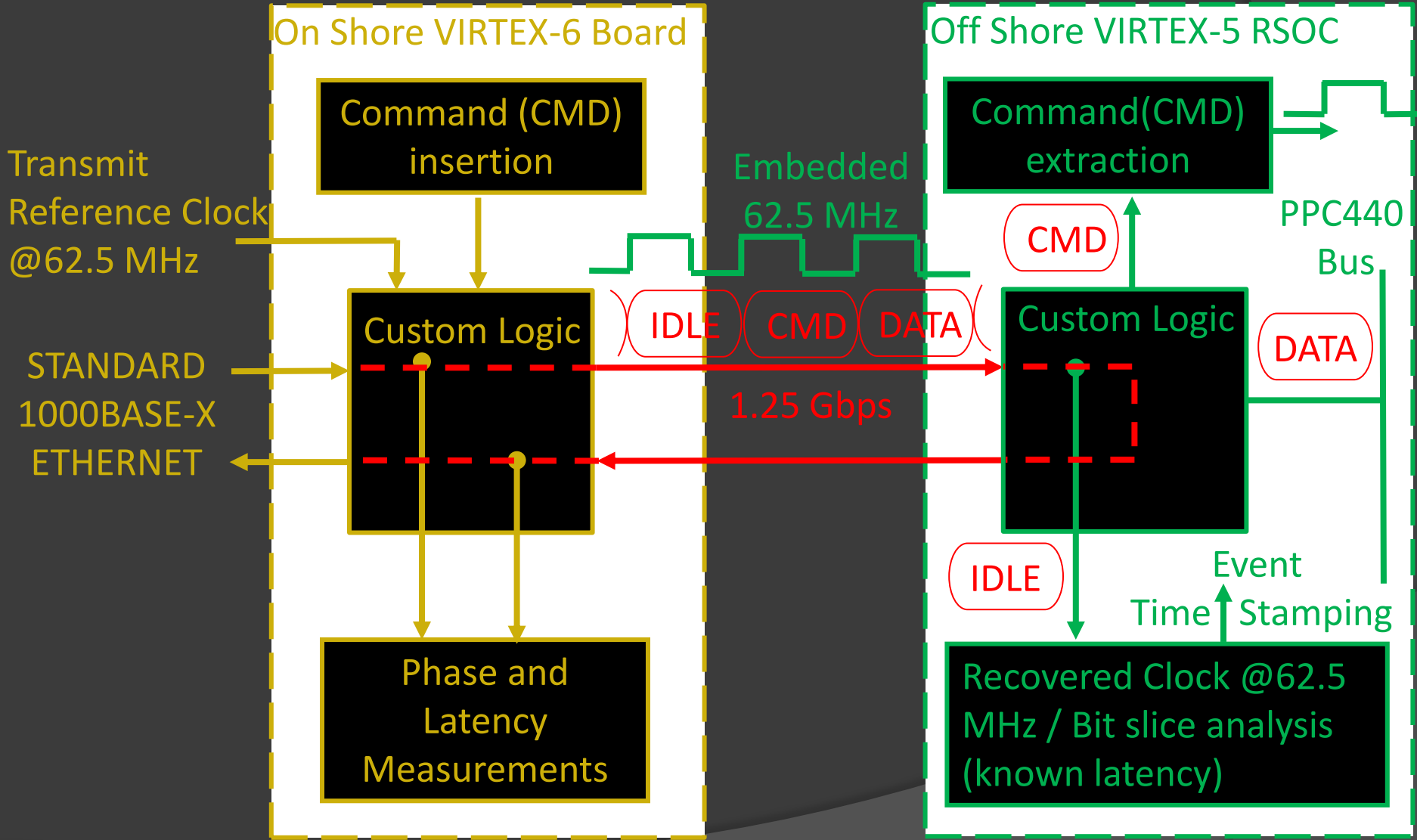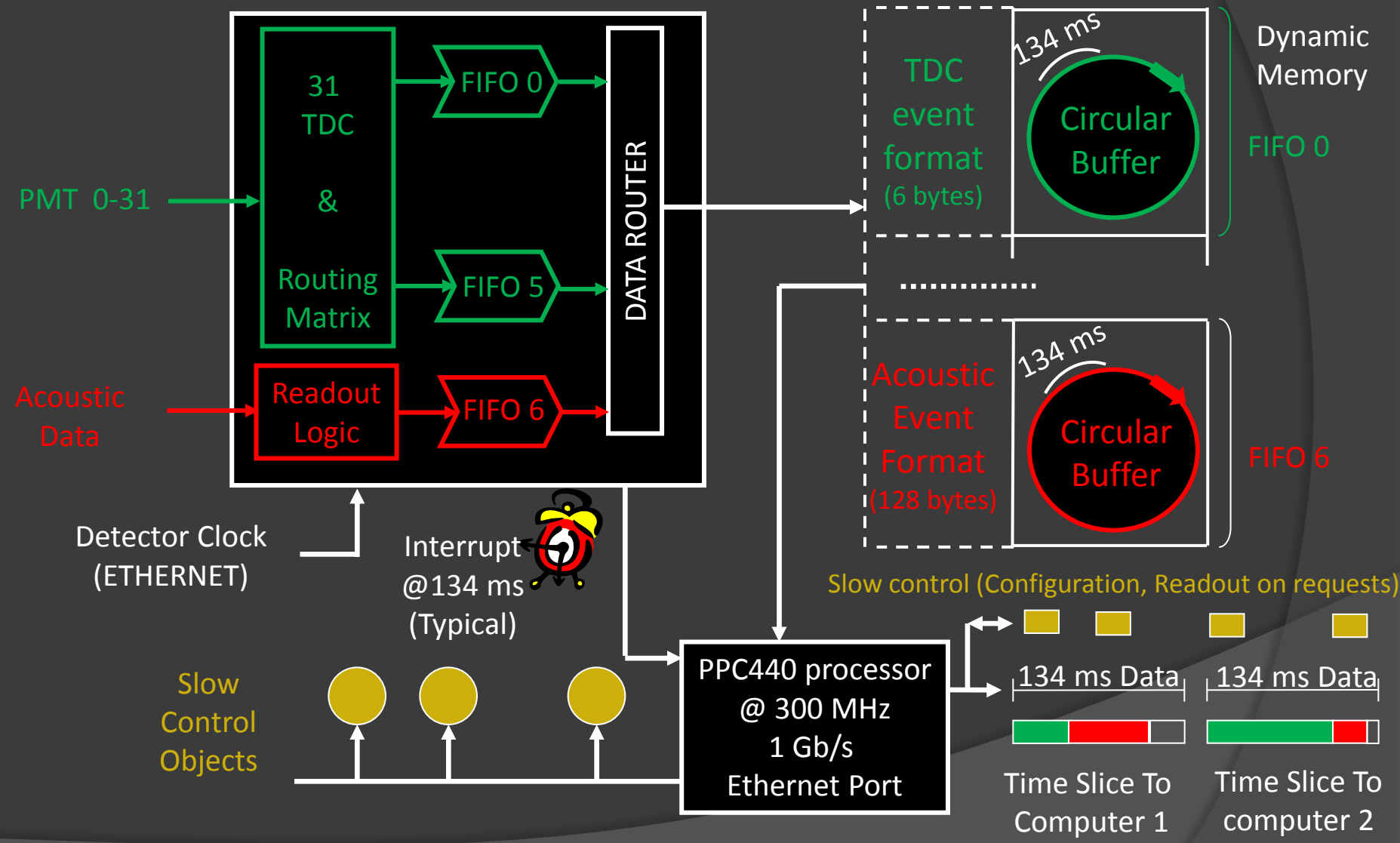
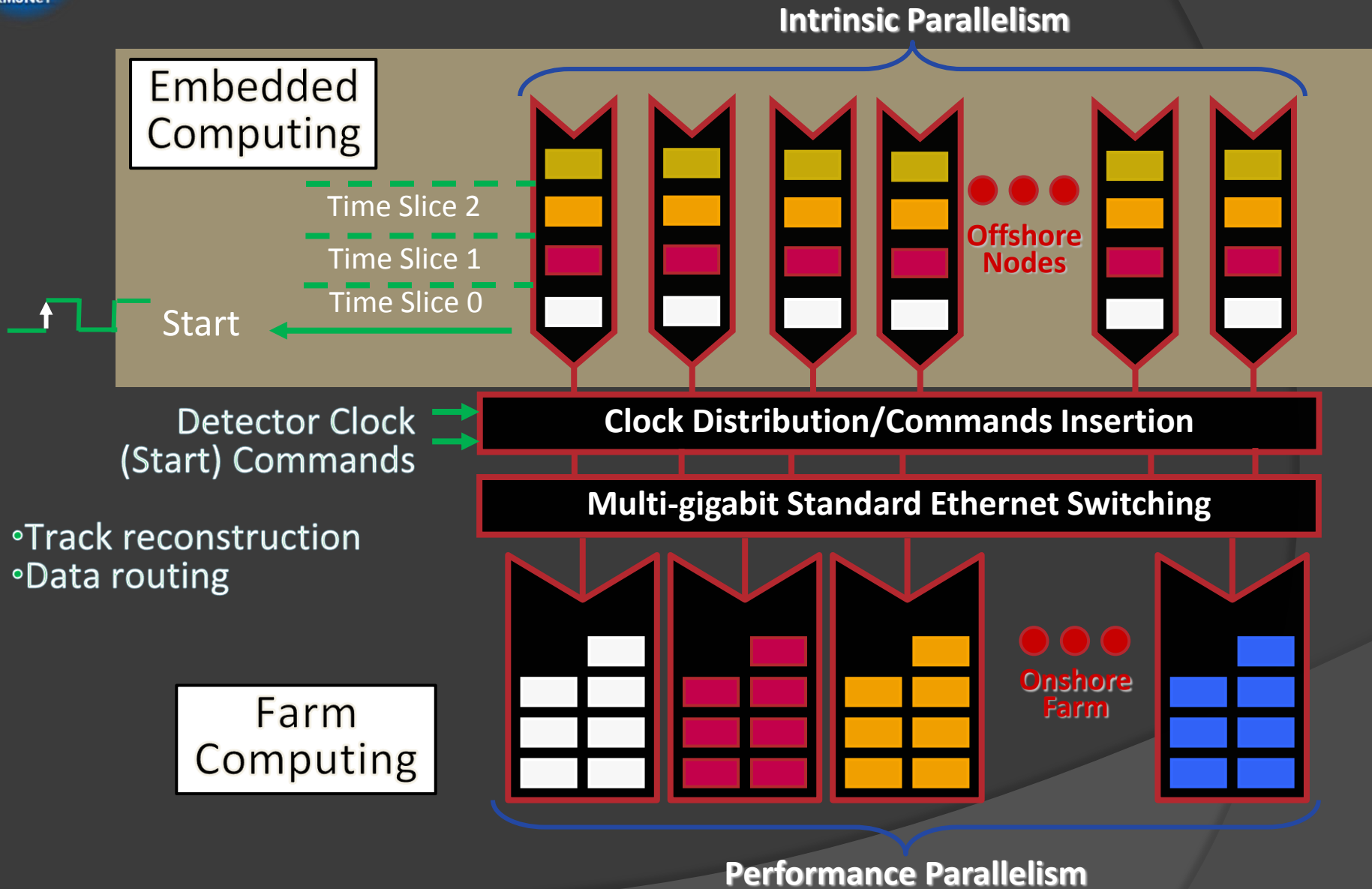# Transmit/Receive clock skew

DMTD (Dual Mixer Time Difference)
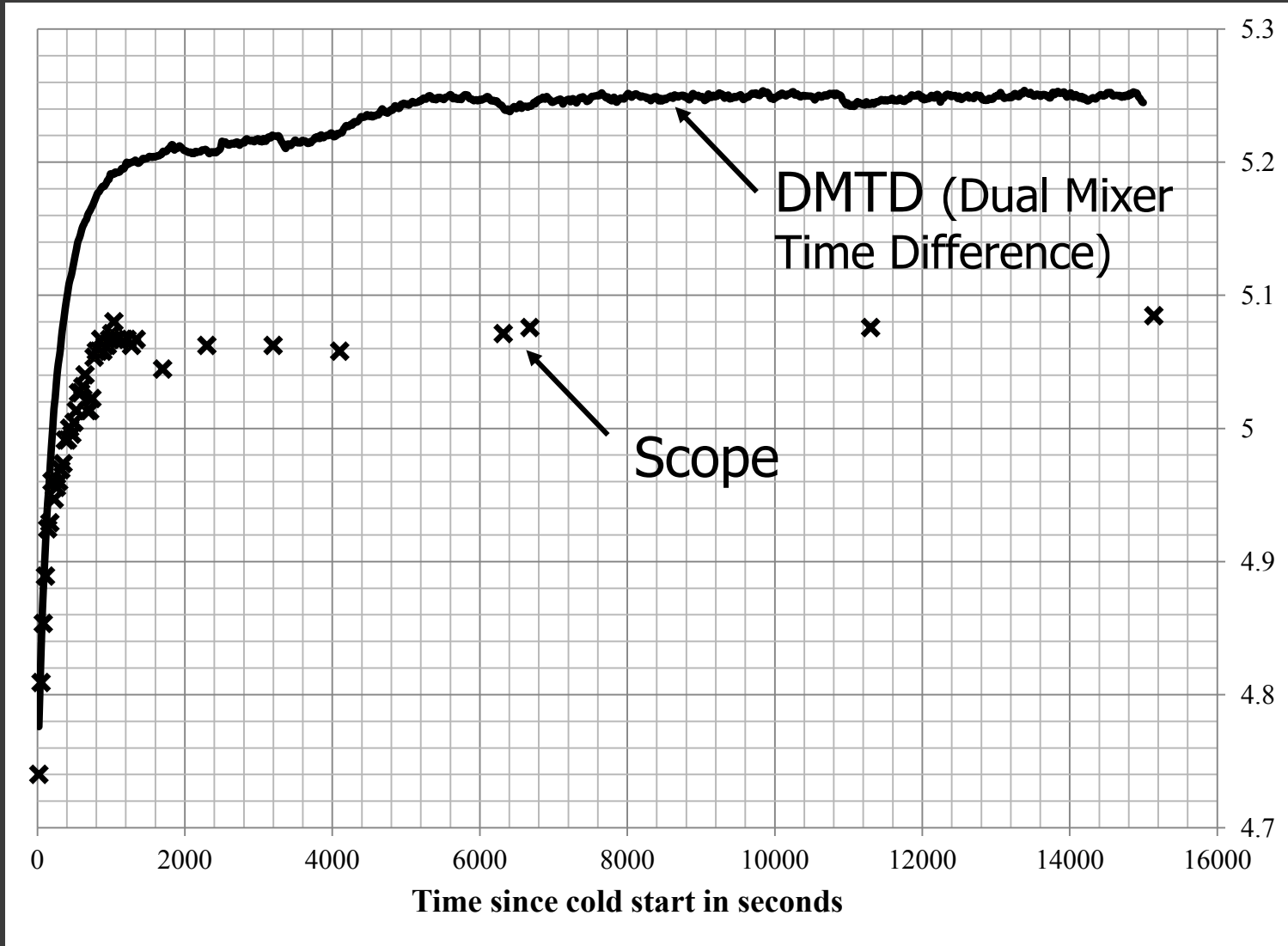
Scope

Tx/Rx clock skew measured on shore with DMTD and oscilloscope (ns)

Store & Forward Acquisition model

Time Slice Building

Intrinsic Parallelism

Embedded Computing

Time Slice 2

Time Slice 1

Time Slice 0

Offshore Nodes

Start

Detector Clock (Start) Commands

Clock Distribution/Commands Insertion

Multi-gigabit Standard Ethernet Switching

° Track reconstruction
° Data routing

Farm Computing

Onshore Farm

Performance Parallelism

Electronics control & config

Network

Embedded

Target SC Server

Embedded

Target SC Server

Communication middleware (ICE)

Electronics Control & Config (SC & Elec. RC)

Run Control

Communication middleware (ICE)

Data routers / writer

Data acquisition setup

KM3NeT

Irfu **cea**

Host PC

- Run Control
- Target Configuration
- Data acquisition
- vxWorks RTOS boot server

Pulse generator

Synchronous 1000BASE-X ETHERNET

On Shore VIRTEX-6 Board

STANDARD 1000BASE-X ETHERNET

RSOC VIRTEX5FX-70
- vxWorks RTOS
- 1 TDC Channel
- 1 dedicated TDC ASIC channel
- PPC440@300 MHz Bus@75 MHz

Start Command

Reference Clock @62.5 MHz

KDaq Run Control

Configuration

Site Config... | SiteCConfig/KoalaBench.xcfg

Data Path... | DataNode/AcqData

[X] Data Storage Enabled
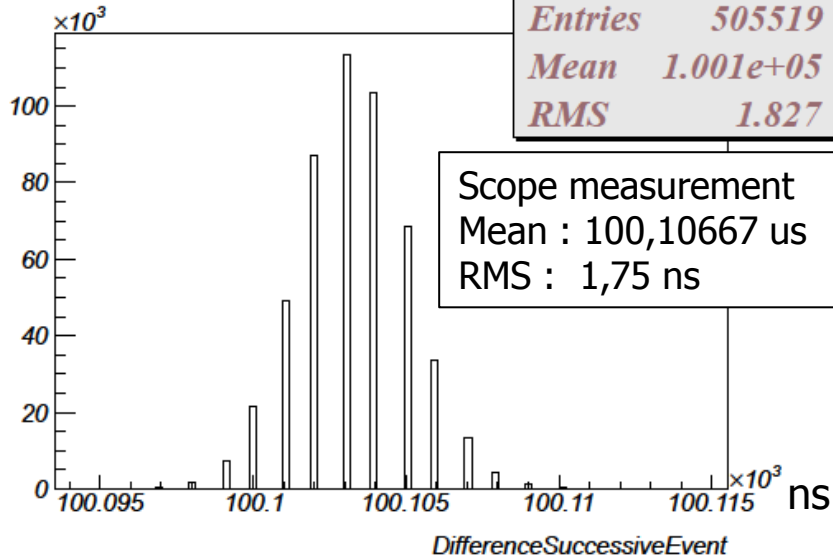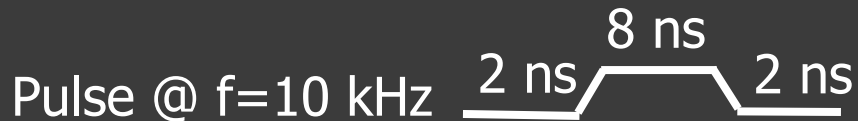
Console

```
>>> Init event from state IDLE: Done
>>> Reset event from state STANDBY: Done
>>> Start event from state READY: Done
>>> Stop event from state RUNNING: Done
>>> Reset event from state STANDBY: Done
>>> All active nodes connected
>>> Init event from state IDLE: Done
>>> Reset event from state STANDBY: Done
>>> Start event from state READY: Done
>>> Stop event from state RUNNING: Done
>>> Reset event from state STANDBY: Done
>>> Init event from state IDLE: Done
>>> Reset event from state STANDBY: Done
>>> Start event from state READY: Done
>>> Stop event from state RUNNING: Done
>>> Reset event from state STANDBY: Done
>>> Start event from state READY: Done
>>> Stop event from state RUNNING: Done
```
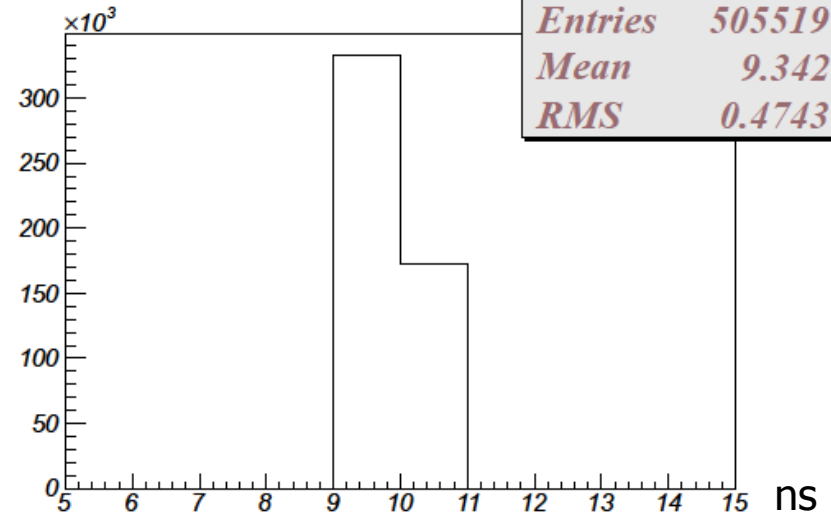
Acquisition Control

Disconnect

STANDBY

Reset | Init

Configure | Start

Stop

[ ] Automatic Runs

Run Monitor

Run time | 00:01:23
Data (MB) | 89.8
Events | 3171

Run ID

Run Site | KoalaBench
Run Number | 00037
Date & Time | 11.03.25@18:06:35

Acquisition results

Scope measurement
Mean : 100,10667 us
RMS : 1,75 ns

Pulse @ f=10 kHz

2 ns   8 ns   2 ns

Power : 7 W

Current acquisition setup (Source limitation): 60 Mb/s

Standalone measured TCP/IP throughput
PPC440@400 MHz / Bus@100 MHz /WindRiver Zero Copy buffer
/Jumbo frames : 988 Mb/s

CONCLUSION

- Common Readout system functions integrated in a single component (RSOC):
  - Event Time stamping @ 1 GHz
  - Clock and command distribution
  - Slow-control and data acquisition performed in a RTOS multi-tasking embedded system

- RSOC is a node designed to be plugged in a complete Data acquisition System
  - Server/Client topology (ICE)
  - Scalable system