Summary Readout-Electronics

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- introduction
- front-end electronics
- data transmission
- data processing
- slow control/calibration

input parameters*:

- $\sim 10^4$ photon detectors
- $50 - 100$ kHz background rate
- $\sim 5 - 10$ Byte per "hit"

$$\Downarrow$$

$$\text{total data rate} \approx 2.5 - 10 \text{ GB/s}$$

*cost $\Rightarrow$ sparse detector $\Rightarrow$ single photon detection

- digitalisation[†]:

  off-shore $\Leftrightarrow$ on-shore

  $\Downarrow$

  electronics
  clock system
  power
  mechanics

- data distribution:

  address $\Leftrightarrow$ time-domain

- data processing:

  software $\Leftrightarrow$ hardware

[†]original photon signal is digital!

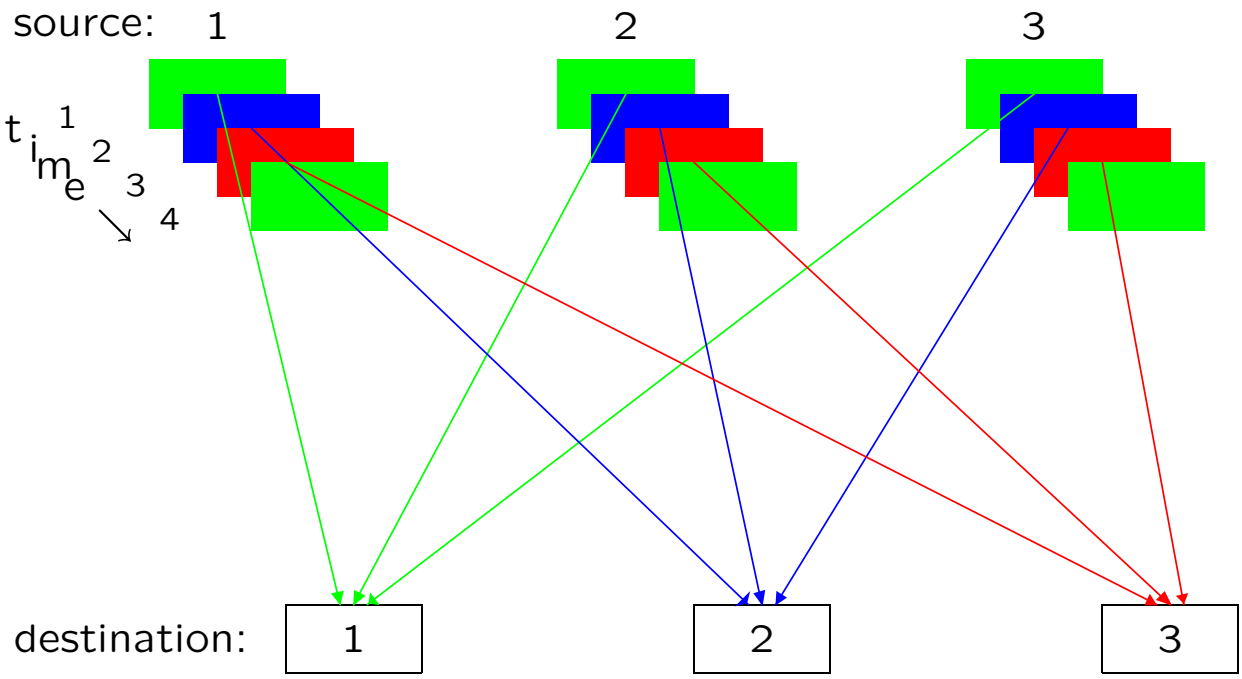
front-end electronics:

- analogue signal processing
  - Time-Over-Threshold
  - rise-time and decay-time
  - total charge
  - sampling (frequency $\sim 100 - 500$ MHz)
  - time accuracy?
  - dynamic range?

- front-end data processing
  - FPGA (= embedded processor)
  - VLSI

- optical modulation
  - 1 colour-fibre for each PMT
  - digital/analogue!
  - direct addressing (slow control)
- data transmission
  - CWDM (10 Gb/s $\times$ λ_{1-8} $\times$ 100 fibres)
  - DWDM (1 Gb/s $\times$ λ_{1-128} $\times$ 100 fibres)

Data distribution concept:



each destination gets all data of same time slice

data processing:

- comparison with CMS is encouraging
- cost/complexity $\Rightarrow$ fast algorithm(s)
- output ≤ 1 MB/s $\Rightarrow$ reduction $10^3 - 10^4$
- new physics $\Rightarrow$ flexible $\Rightarrow$ software
- efficiency $\Rightarrow$ complete data sample
- logic
  - democratic $\Leftrightarrow$ speed
  - hierarchical $\Leftrightarrow$ detector topology
  - $1 \leftrightarrow 2$ SPE $\Leftrightarrow$ photon-detector

- filter criteria:
  - causality (Čerenkov light)
  - slow motion (mono-poles)
  - (a priori) directional information
  - (a priori) time information

- slow control
  - embedded processor with local bus
  - each instrument as Ethernet node
  - remote fibre-optic sensoring
- calibration/instrumentation
  - what?
  - how often?
  - auto-calibration

calibration:

calibration	photon-detection
read/write	(mainly) read
slow IO	slow I/fast O
duty cycle $\leq 10\%$	duty cycle 100%
subset of nodes	all nodes

$\Downarrow$

separate physically the calibration and photon-detection systems

"Hybrid concept" :

- calibration units:
  - number of nodes $\sim$ 10% of total
  - "known" technology
  - redundancy
  - maintainability
  - low duty cycle $\Rightarrow$ low power
- photon-detection units:
  - number of nodes $\sim$ 90% of total
  - no maintenance $\Rightarrow$ very reliable
  - low power
  - if R&D completed $\Rightarrow$ "easy" to build

summary:

- workshop is a good start (to be continued)
- significant R&D work started on front-end electronics
- new ideas for data transmission
- data filtering:
  - software way ...
  - physics!
- calibration specifications?