Trigger and Data Acquisition
at colliders

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EVENT BUILDING

Network technologies

- Examples:
  - *The telephone network*
  - *Ethernet (IEEE 802.3)*
  - *ATM (the backbone for GSM cell-phones,*
  - *small fixed sized packets)*
  - *Infiniband (point-to-point bidirectional serial links)*
  - *Myrinet (high-speed LAN designed by Myricom)*
  - *many, many more*

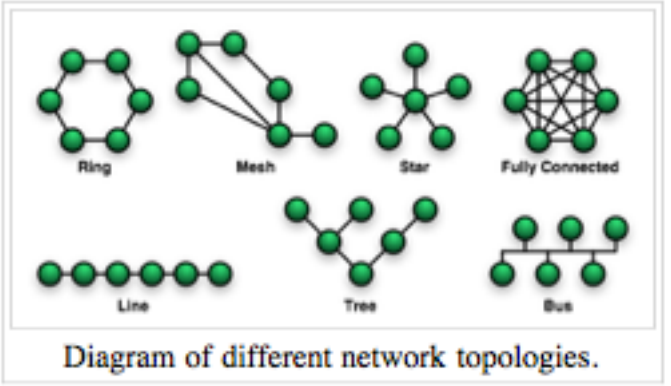
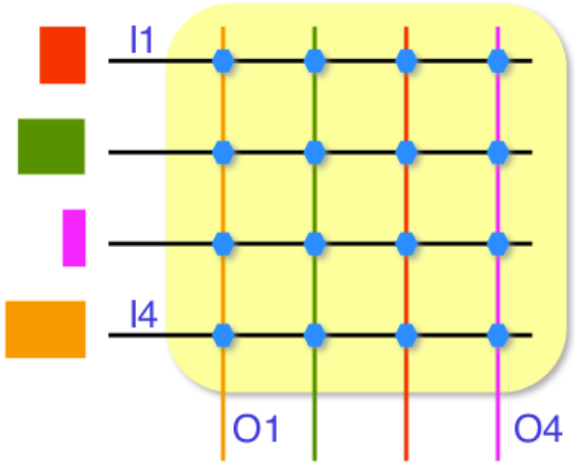


Diagram of different network topologies.

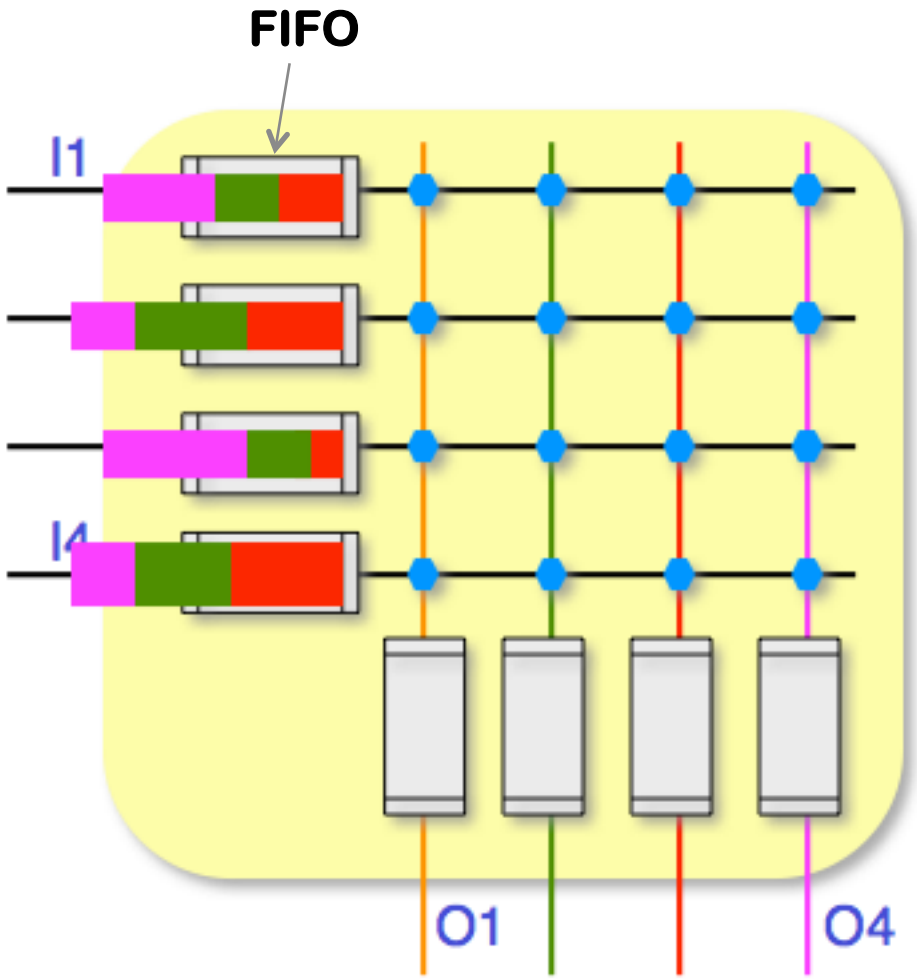
- Note: some of these have "bus"-features as well (Ethernet, Infiniband)
- Network technologies are sometimes functionally grouped
  - *Cluster interconnect (Myrinet, Infiniband) 15 m*
  - *Local area network (Ethernet), 100 m to 10 km*
  - *Wide area network (ATM, SONET) > 50 km*

Network switch: crossbar

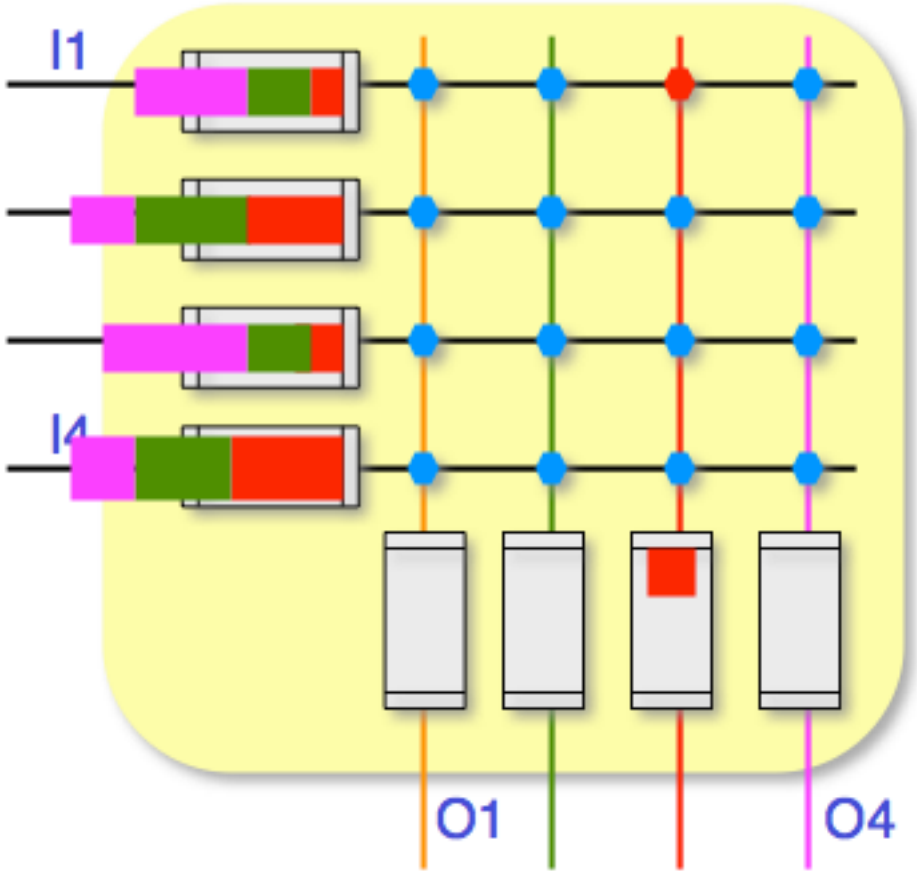
- *Each input port can potentially be connected to each output port*
- *At any given time, only one input port can be connected to a given output port*
- *Different output ports can be reached concurrently by different input ports*
- *→ Ideal situation:*
  - All inputs send data to different outputs
  - No interference (congestion)
  - All input ports send data concurrently



Example



Example



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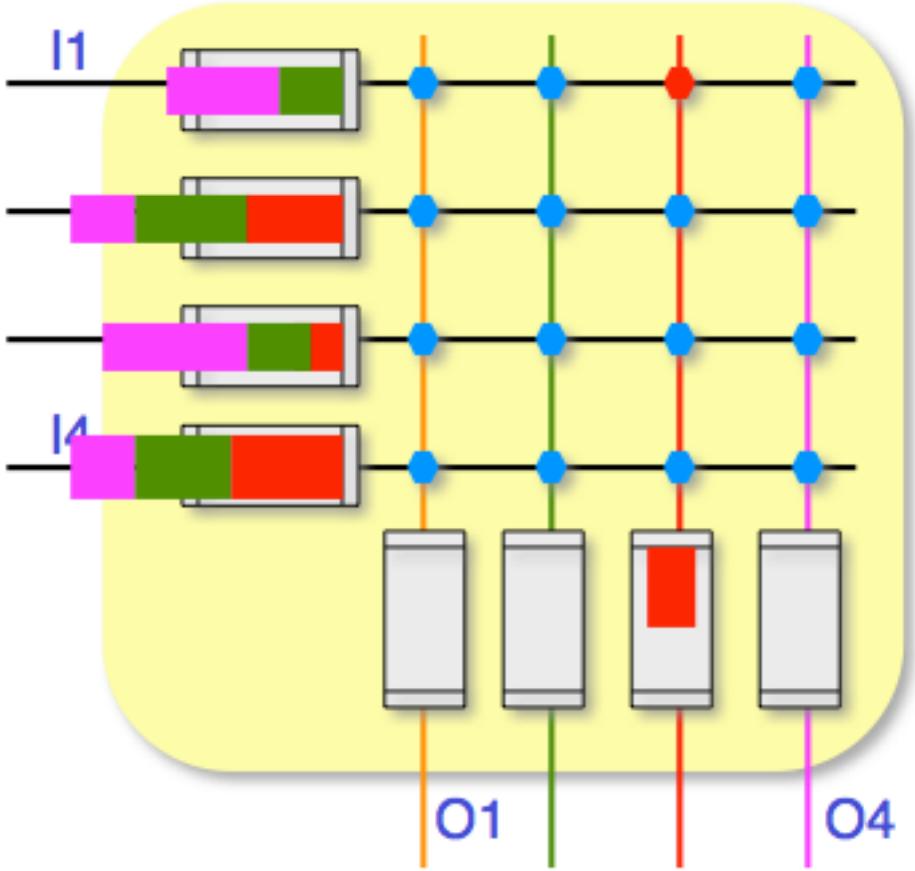
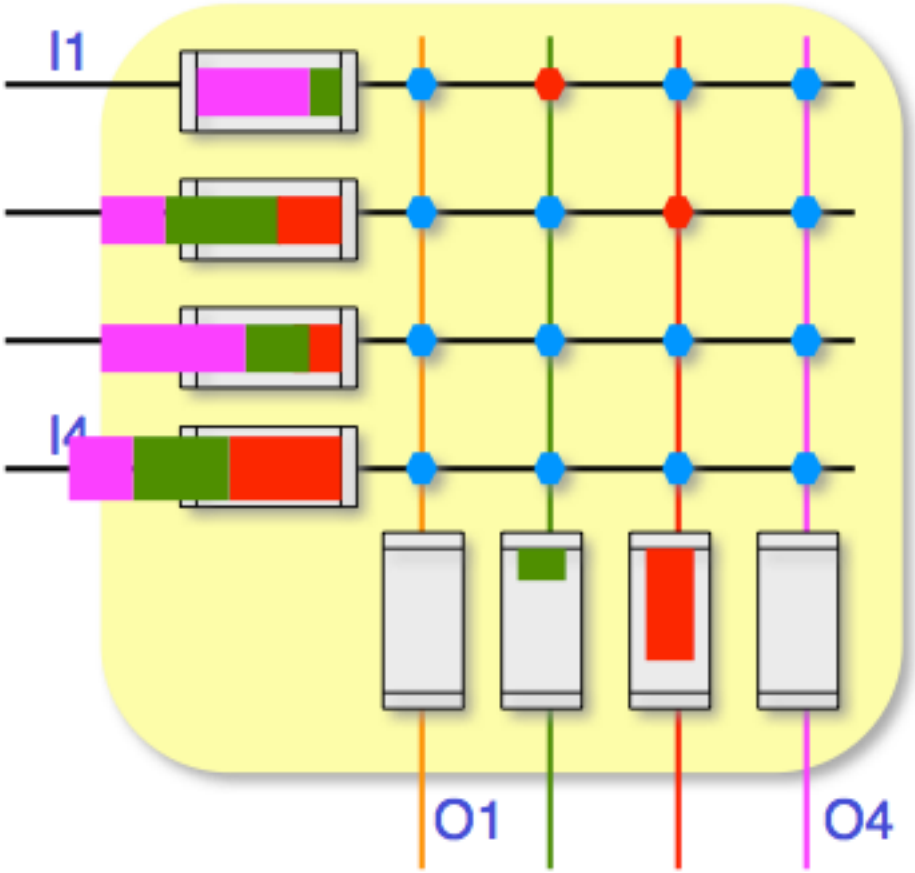
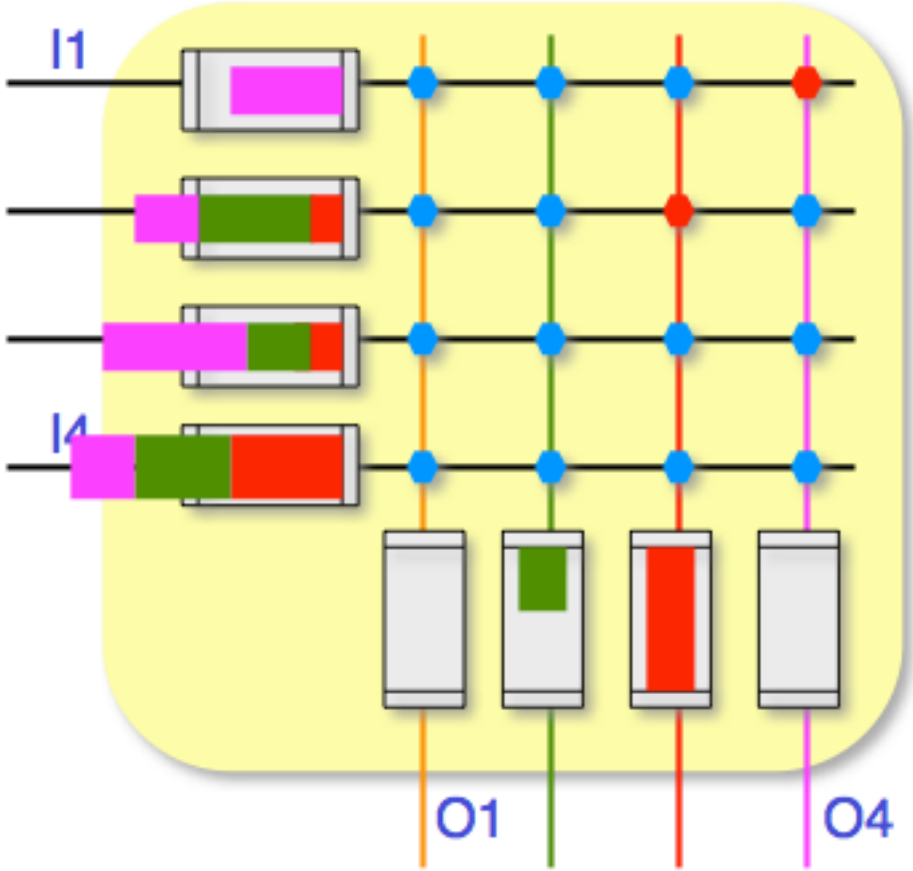


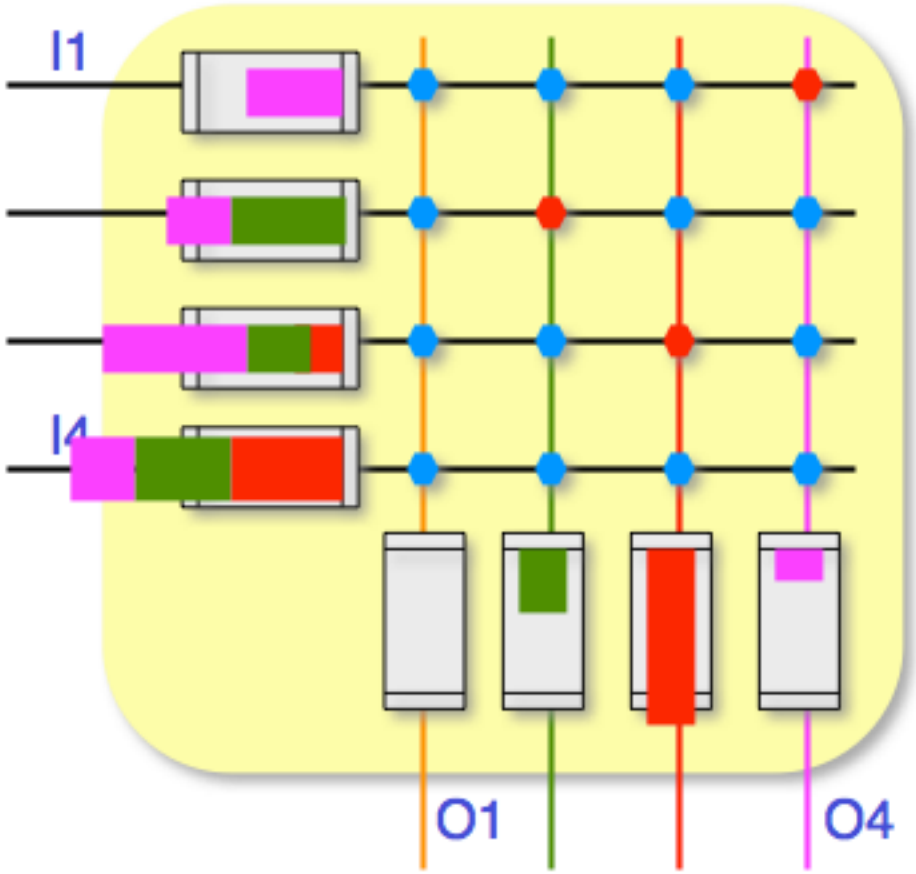
Example



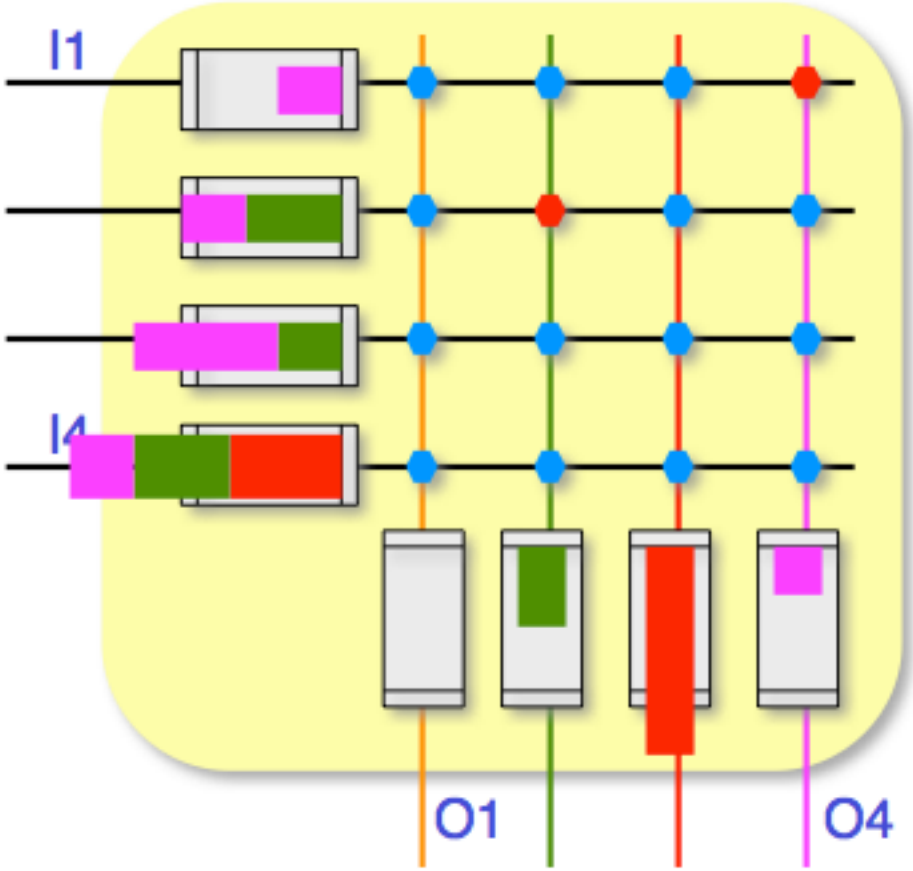
Example



Example



Example



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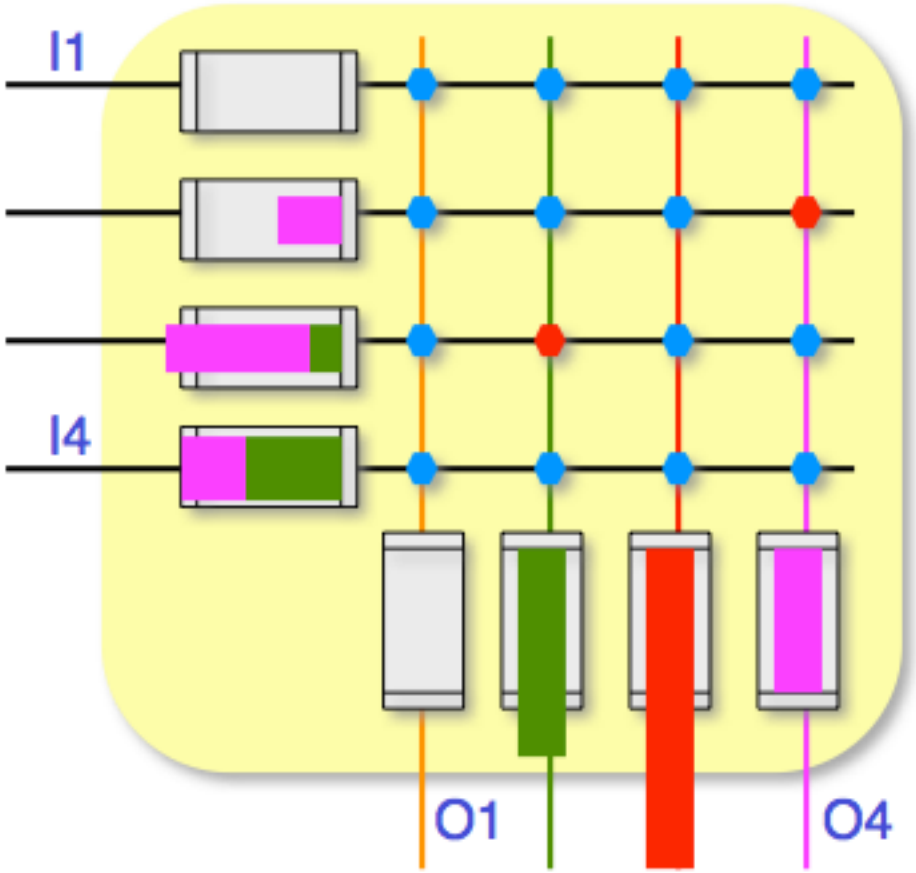
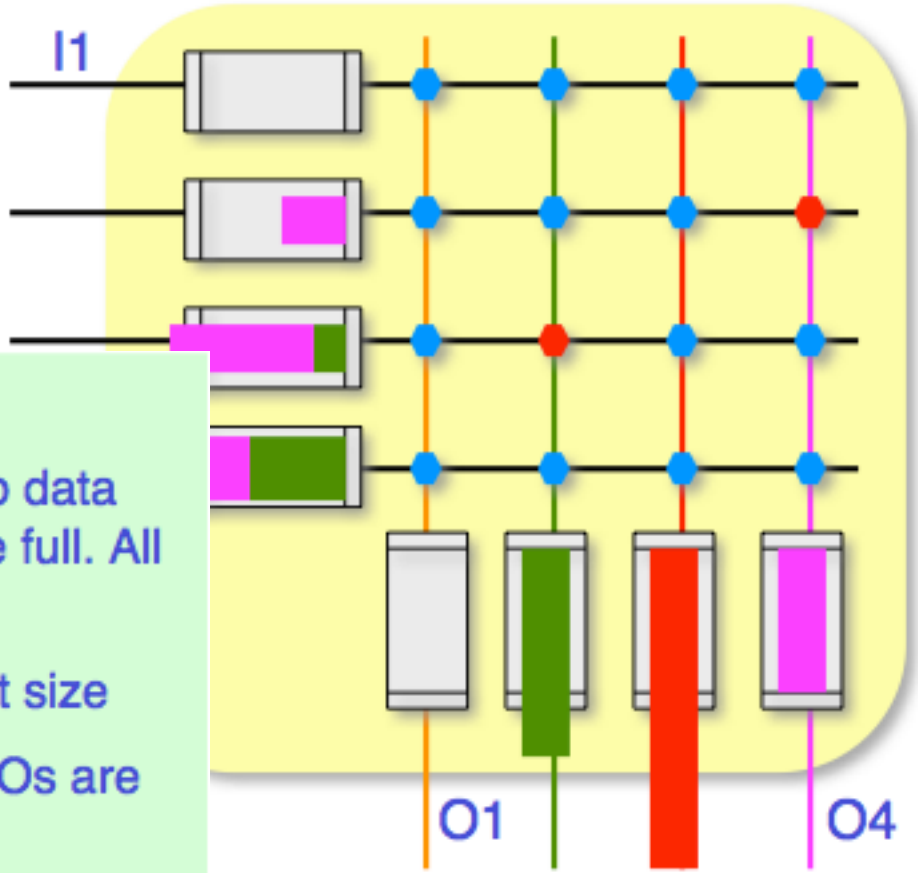




Problematic:

Input Fifios can absorb data fluctuations until they are full. All fine if:

Fifos capacity > event size

In practice: sizes of FIFOs are much smaller!

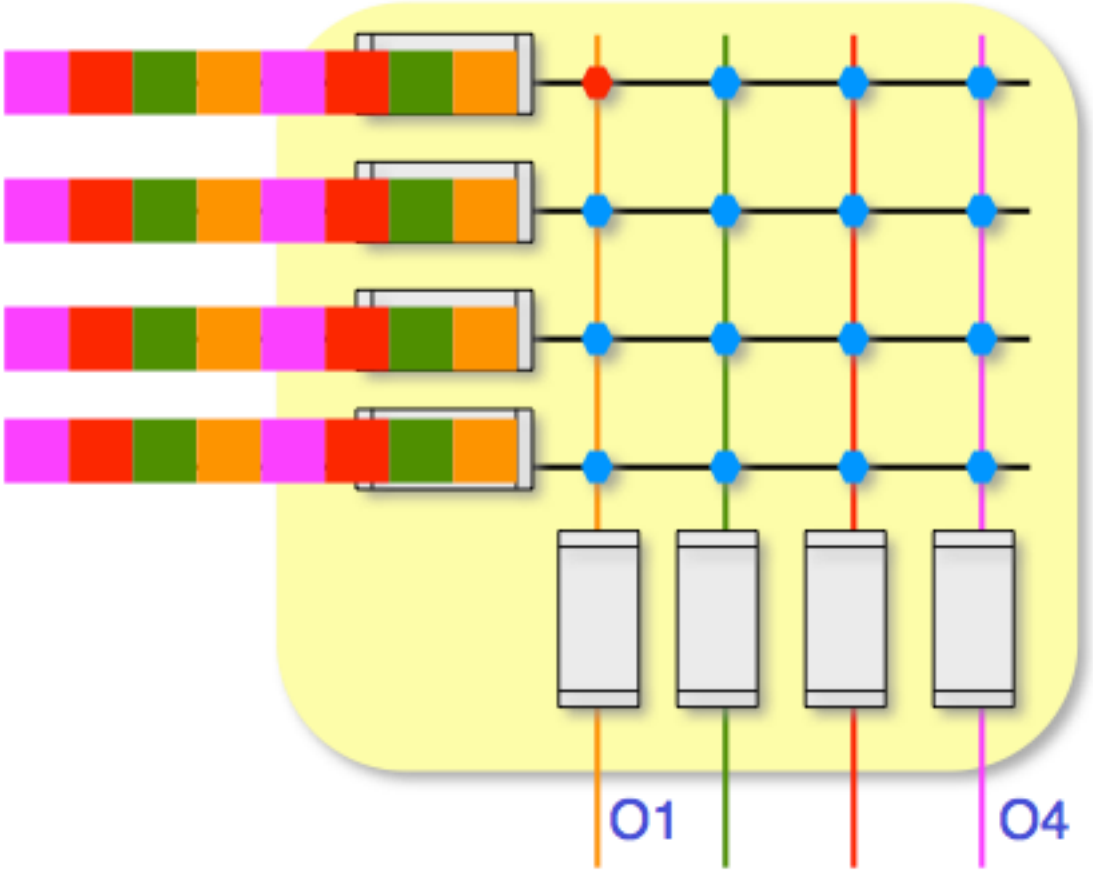
EVB traffic: switch will partially block

Avoid Congestion

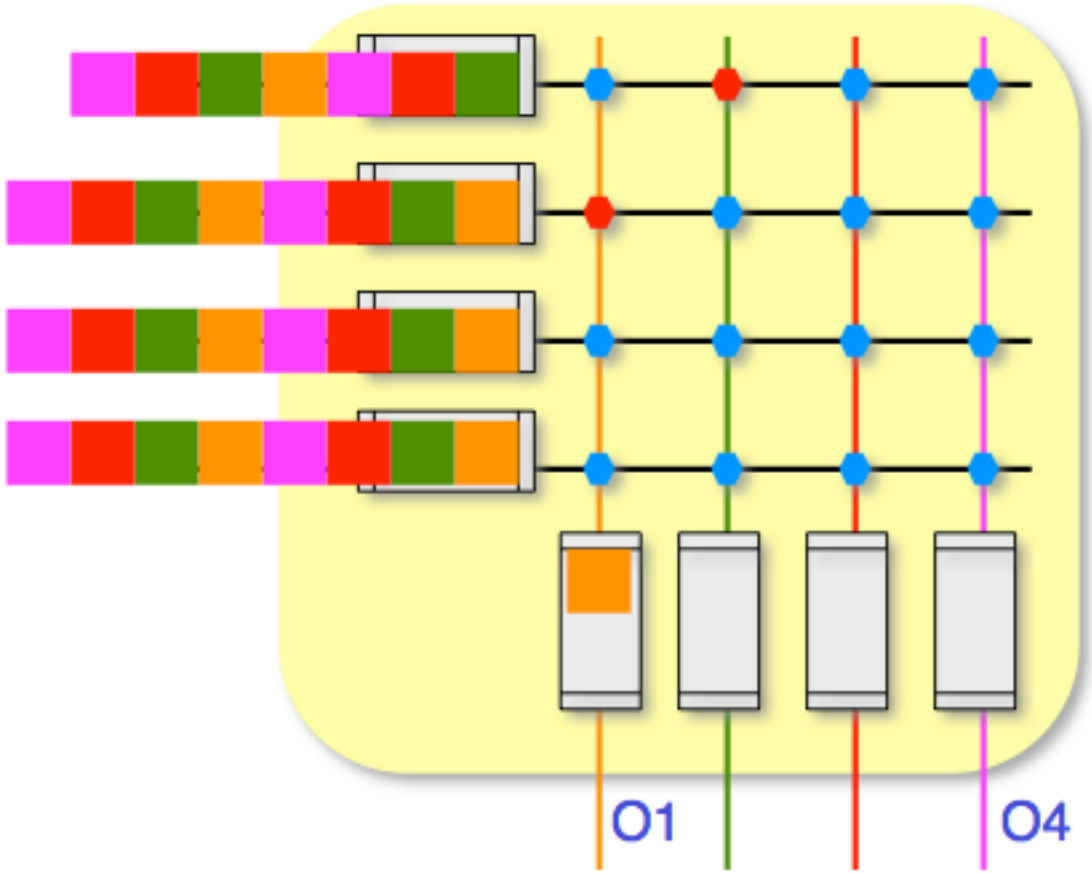
- → oversize the system or do traffic shaping…

Traffic shaping

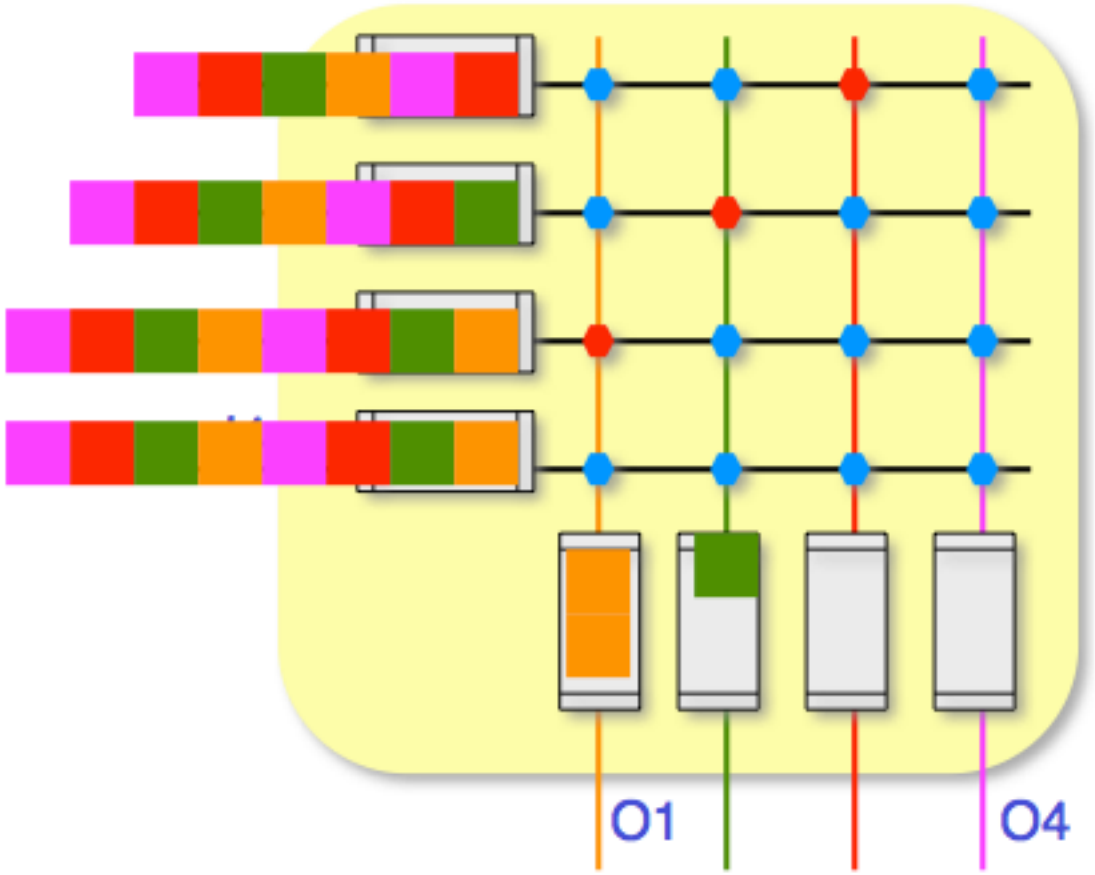
- If you don’t want to oversize your system: Barrel shifter



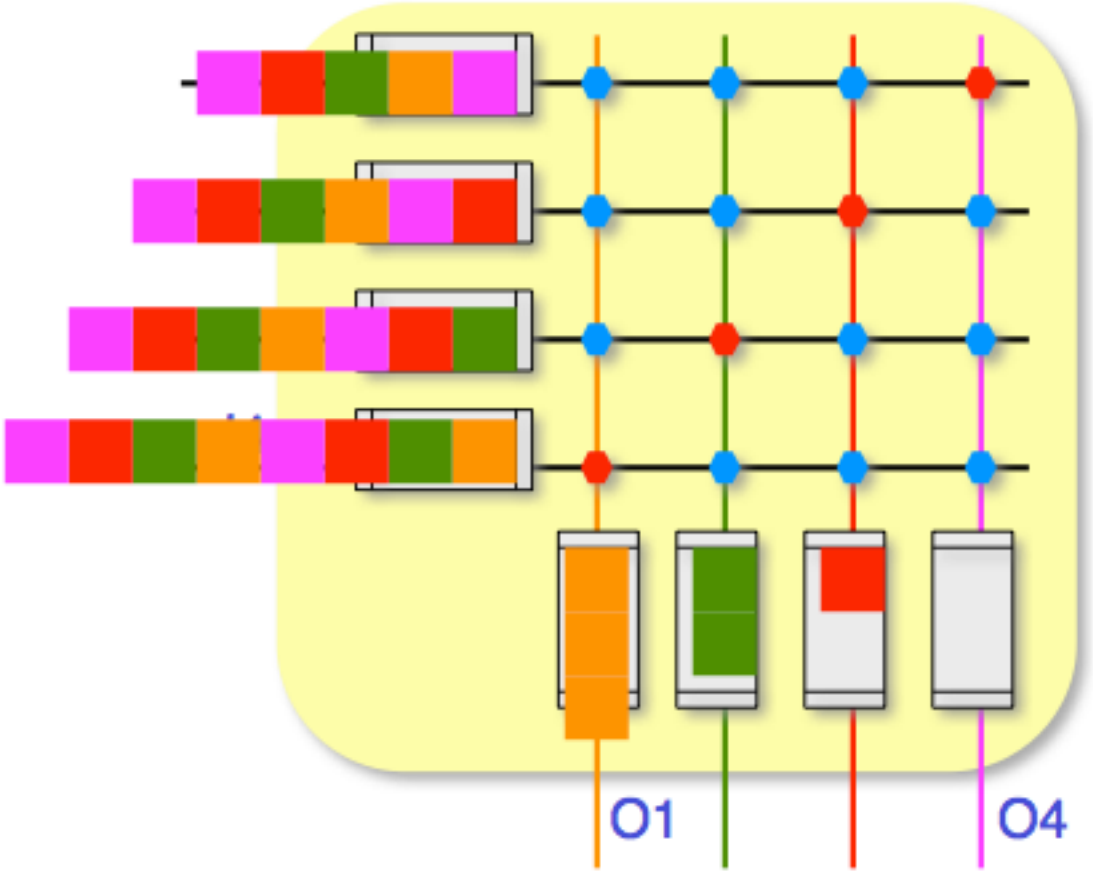
Traffic shaper



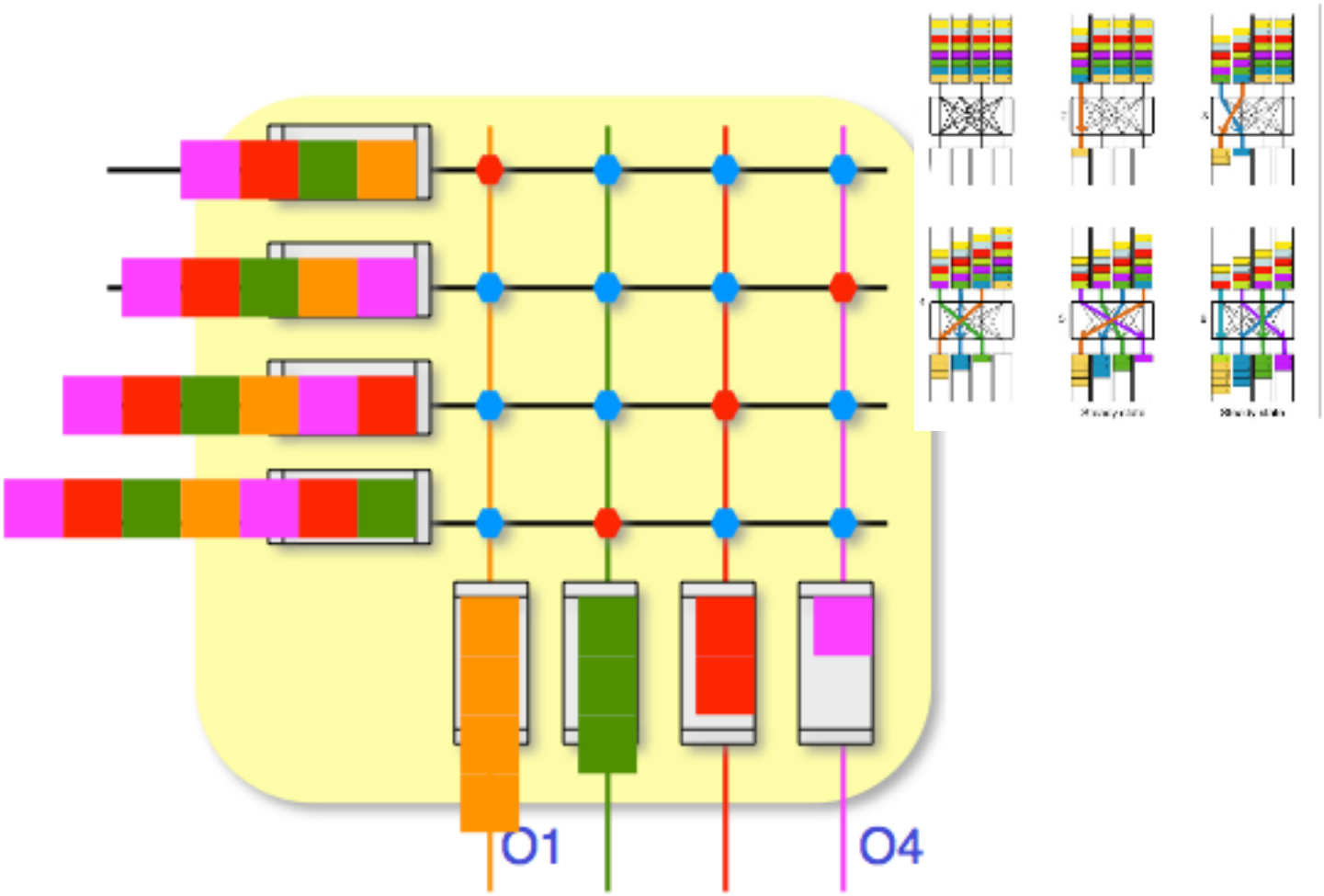
Traffic shaper



Traffic shaper

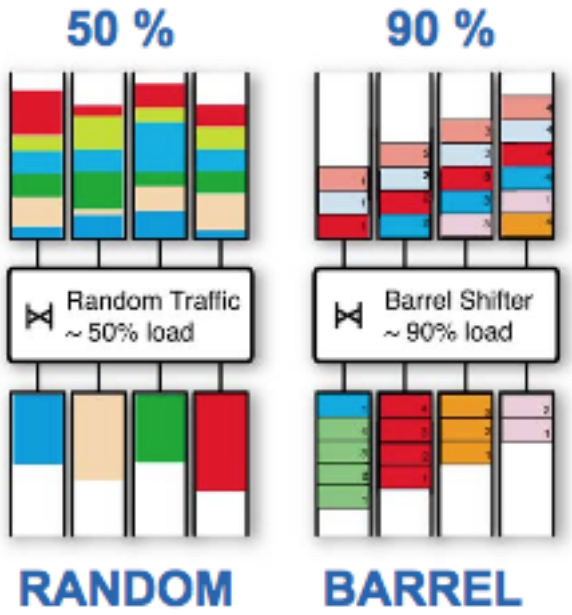


Traffic shaper

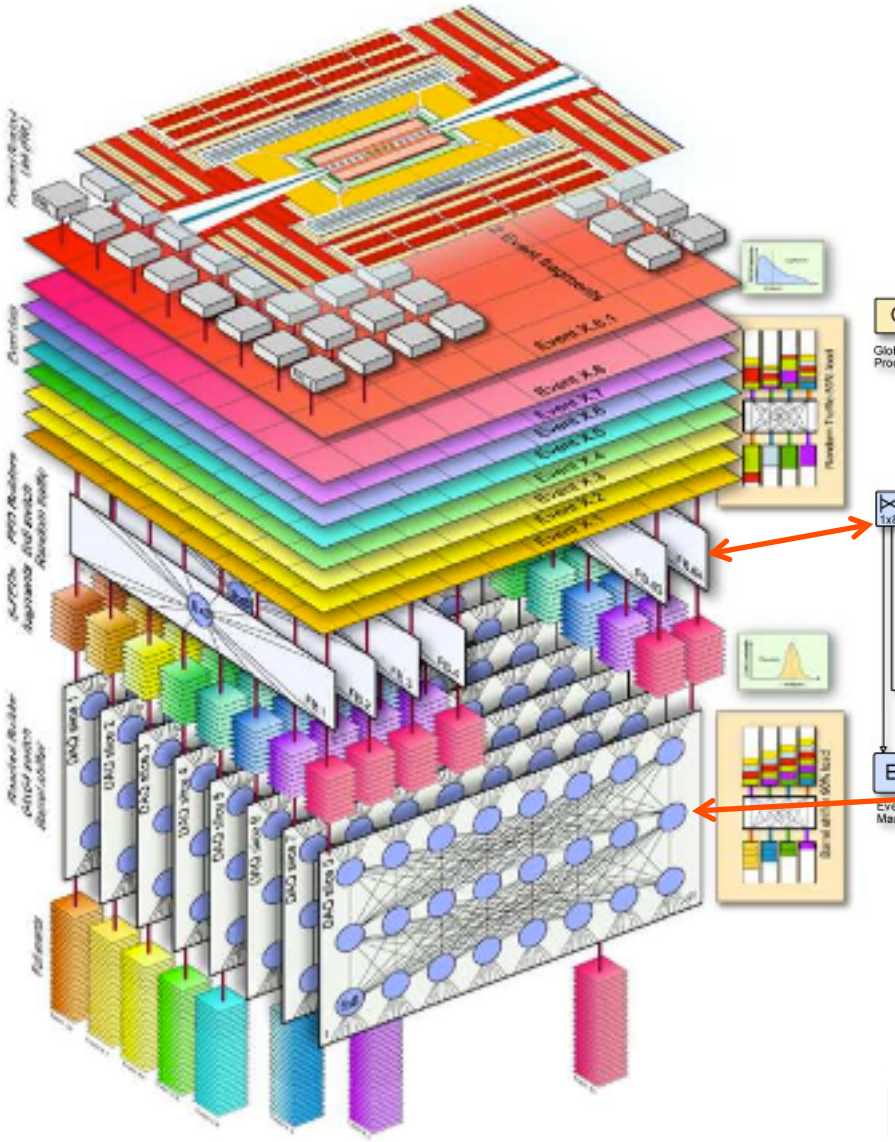


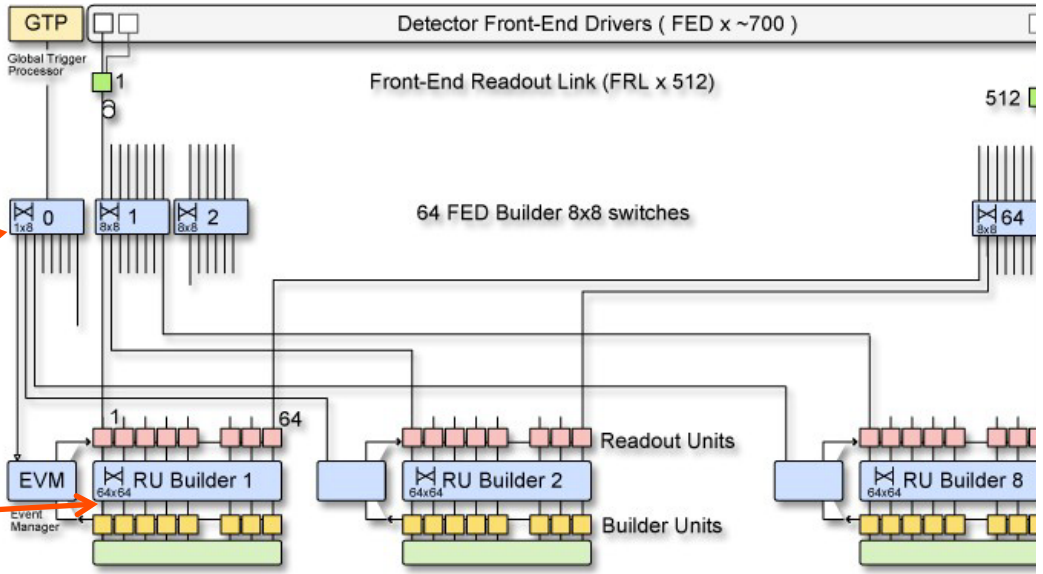
EVB Summary

- Random traffic: needs switch with factor 2 more bandwidth than throughput needed
- Barrel: can work with ~90% efficiency

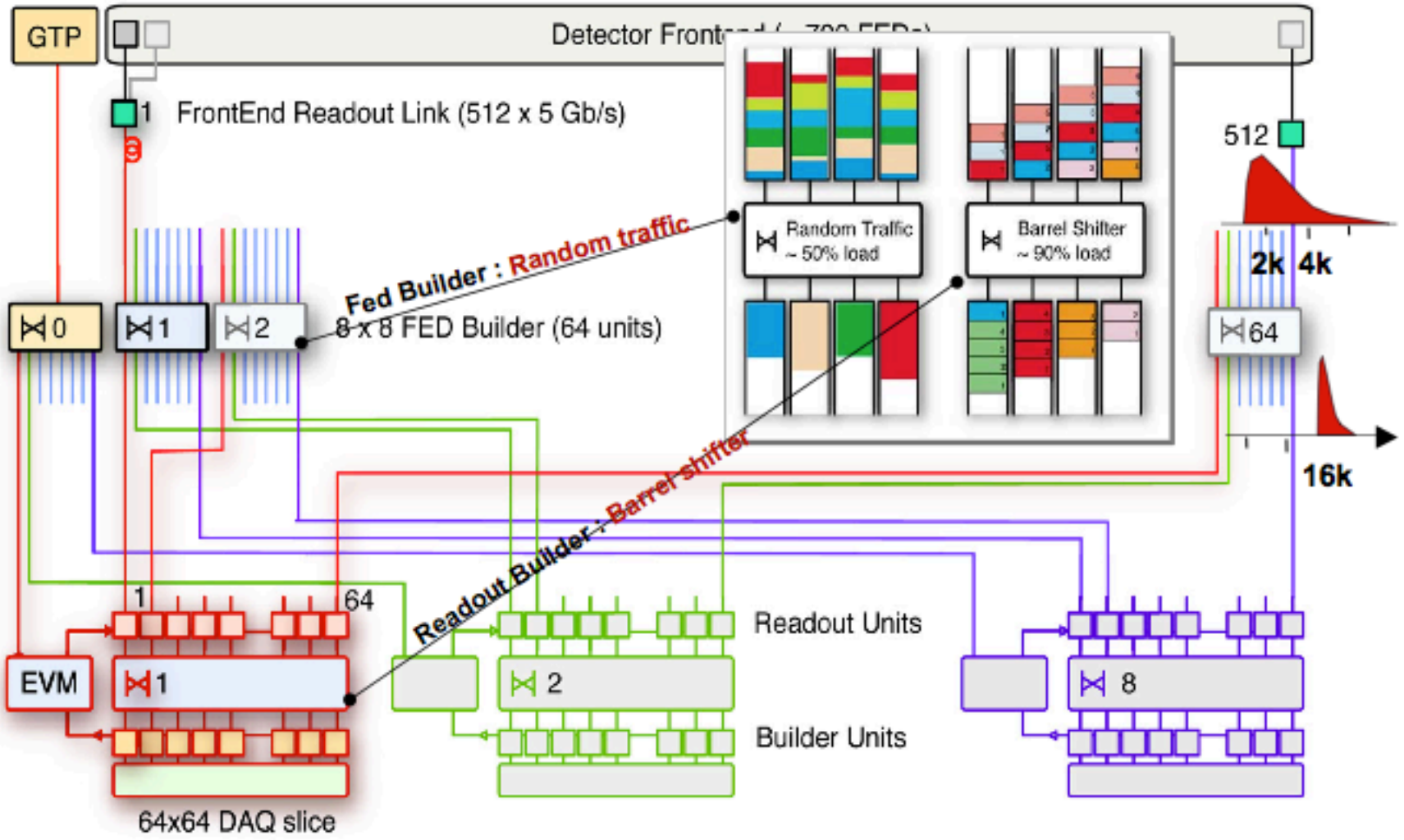


2 stages CMS EVB





Two stages CMS EVB

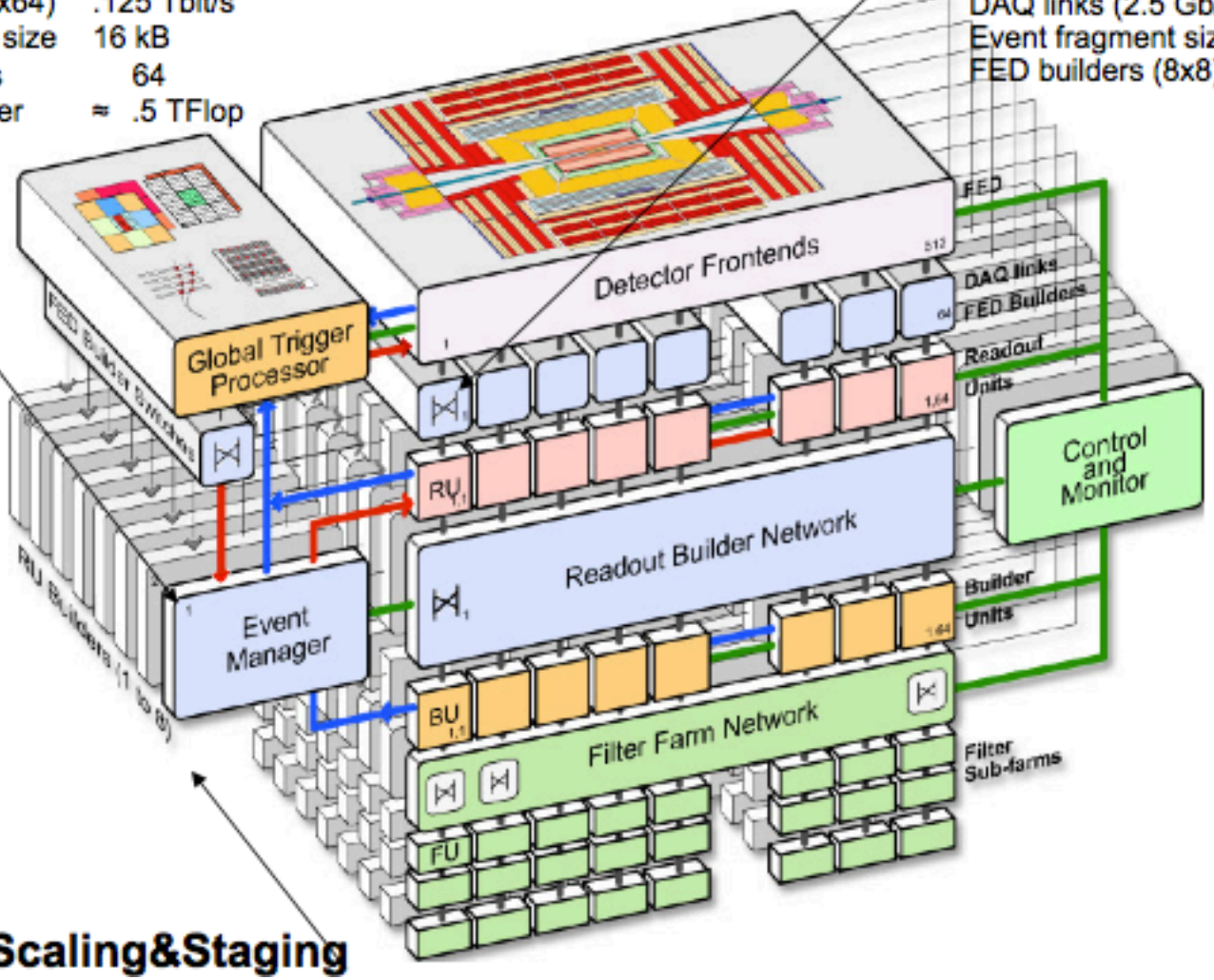


In 3D

DAQ unit (1/8th full system):

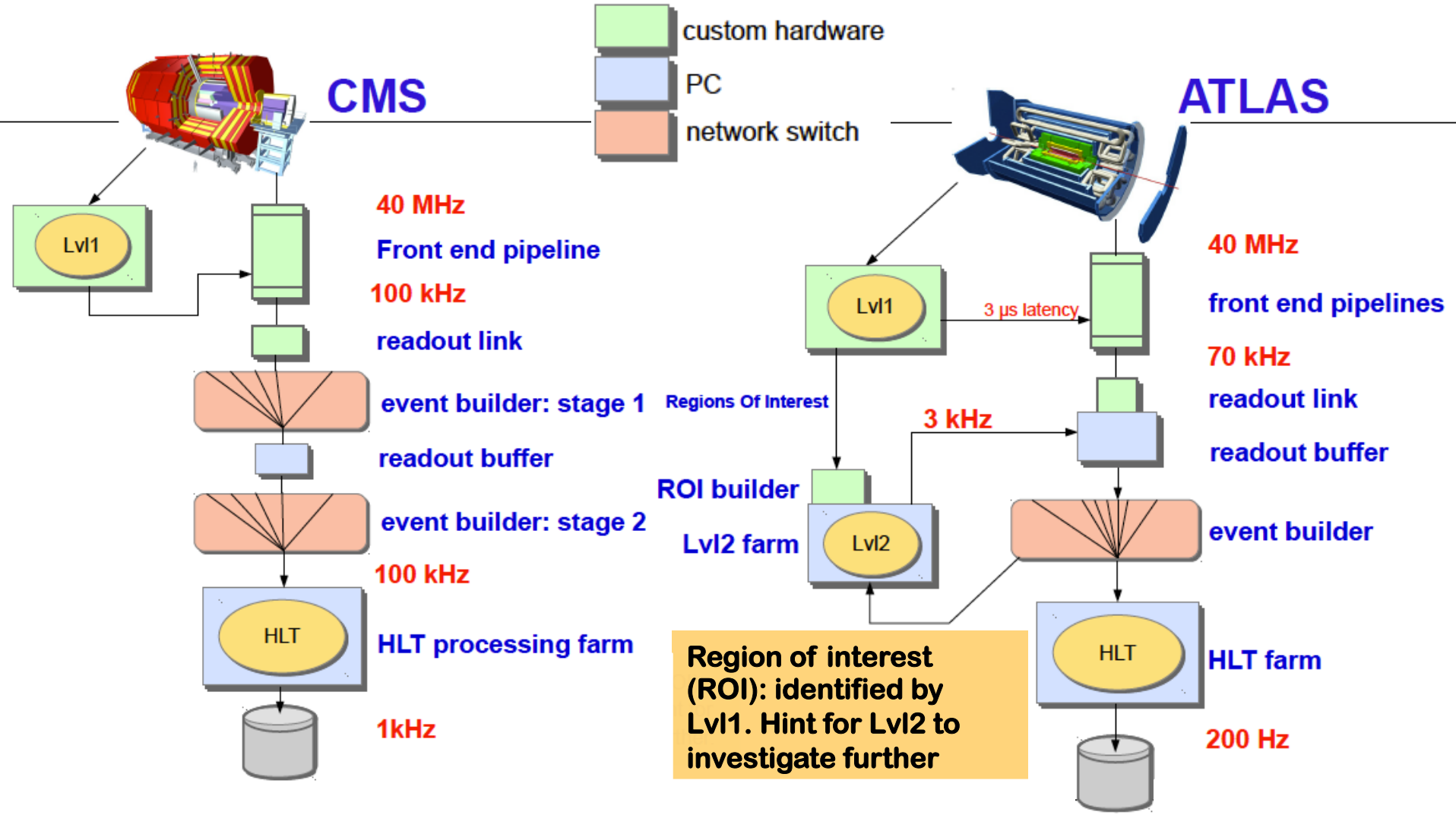
Lv-1 max. trigger rate	12.5 kHz
RU Builder (64x64)	.125 Tbit/s
Event fragment size	16 kB
RU/BU systems	64
Event filter power	≈ .5 TFlop

Average event size	1 Mbyte
No. FED s-link64 ports	> 512
DAQ links (2.5 Gb/s)	512+512
Event fragment size	2 kB
FED builders (8x8)	≈ 64+64



DAQ Scaling&Staging

CMS VS. ATLAS DAQ



The Filter Farm

- The final stage of the filtering process: almost an offline quality reconstruction & selection
  - *Very cost effective*
    - Linux is free
    - Interconnect : Ethernet (inexpensive & performant)
  - *Despite recent growth it is mature:*
    - The basic elements are mature: PC, Linux, Network

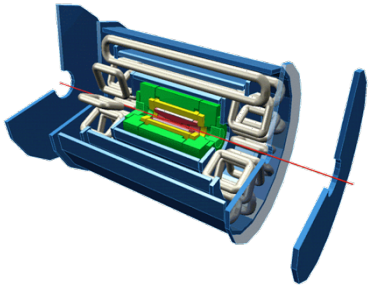
Algorithms & operation

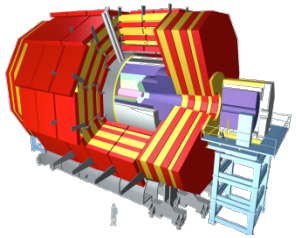
- **Strategy/design guidelines**
  - *Use offline software as much as possible*
    - **Ease of maintenance, but also understanding of the detector**
- **Boundary conditions:**
  - *Code runs in a single processor, which analyzes one event at a time*
  - *HLT (or Level-3) has access to full event data (full granularity and resolution)*
  - *Only limitations:*
    - **CPU time**
    - **Output selection rate (~10^2 Hz)**
    - **Precision of calibration constants**
- **Main requirements:**
  - *Satisfy physics program (see later): high efficiency*
  - *Selection must be inclusive (to discover the unpredicted as well)*
  - *Must not require precise knowledge of calibration/run conditions*
  - *Efficiency must be measurable from data alone*
  - *All algorithms/processors must be monitored closely*

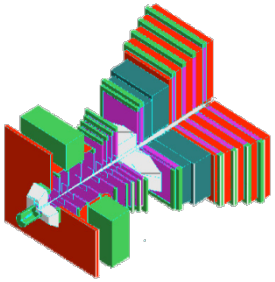
LHCb & ALICE DAQ

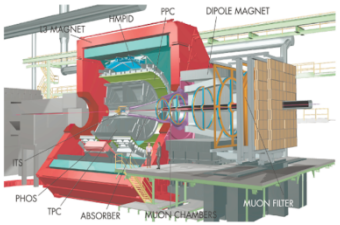
- LHCb
  - *Optimized to study B-hadron in p-p collisions*
  - *Level-0 output rate: 1MHz ($L=10^{32}cm^{2}s^{-1}$)*
  - *Event size = 40 kB*
- ALICE
  - *Optimized for heavy-ion collisions (Pb-Pb)*
    - Low collision rate (<10 kHz @ $L=10^{27}cm^{2}s^{-1}$)
    - But very high multiplicity (dN/deta ~ 8000)
      - Event size ~25 MB

LHC experiments DAQ



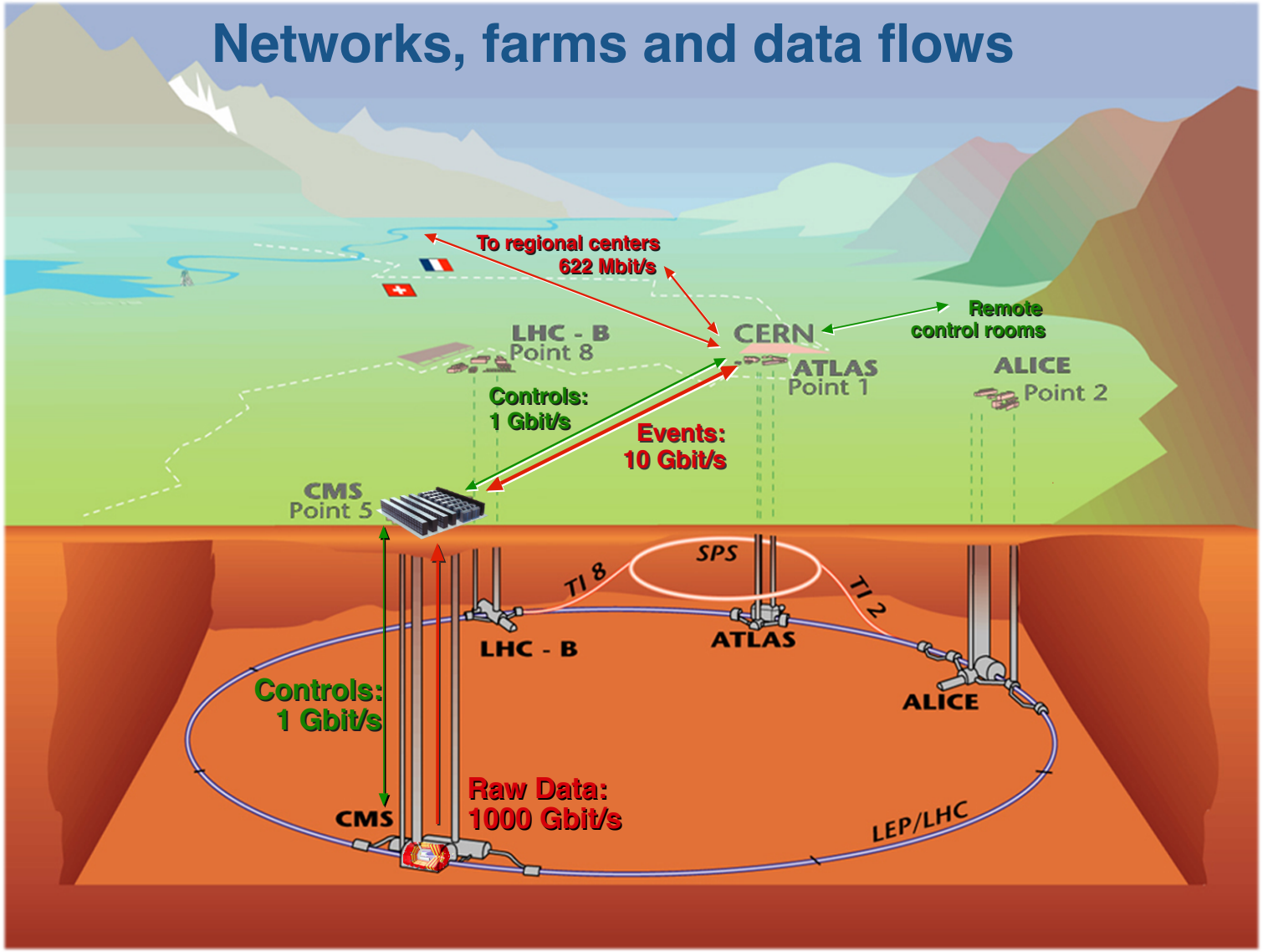






	Level-1 kHz	Event MByte	Storage MByte/s
ATLAS	100	1	100
CMS	100	1	100
LHCb	1000	0.04	80
ALICE	1(p-p) 0.2 (Pb-Pb)	25	1250

On to tape… and the GRID



Conclusions

- We have seen an overview of each step (from the detector to the filter farm) making the trigger/data acquisition system of an HEP experiment.
- Each topics would need a lecture for itself
- I had no time to discuss:
  - *Bus architectures (VME)*
  - *Control & Monitoring*
  - *DAQ software*
  - *LHC DAQ upgrades, future HEP exp. DAQ & new technologies*
  - *…*

Biblio

- *Lectures of W. Vandelli, CERN Summer Student progr. 2013*
- *Lectures of N. Neufeld, CERN Summer Student progr. 2010*
- *Lectures of J. Christiansen, CERN Summer Student progr. 2009*
  - And their predecessors
- *The Technical Design Reports of CMS, ATLAS, LHCb & ALICE*
- *Electronics lecture from Ch. de La Taille*

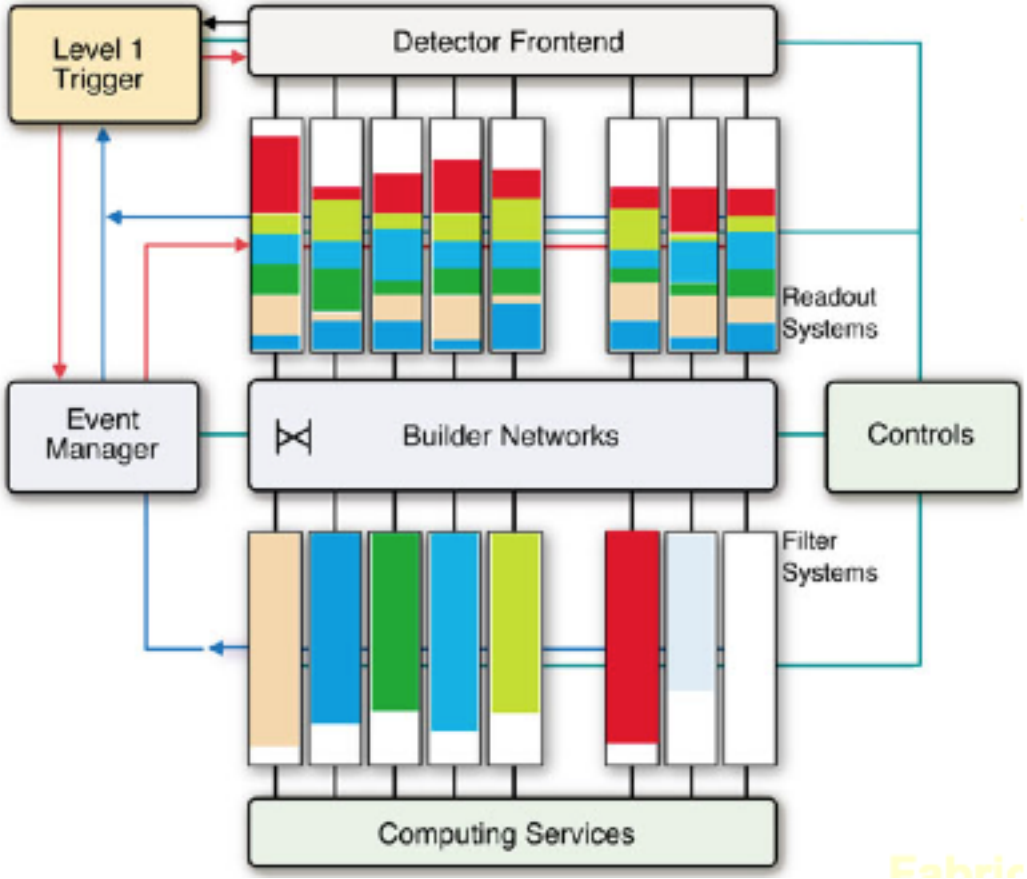
- *See also program of **International School of Trigger and Data Acquisition***

  http://indico.cern.ch/conferenceDisplay.py?confId=209985

BACK-UP

Event Building

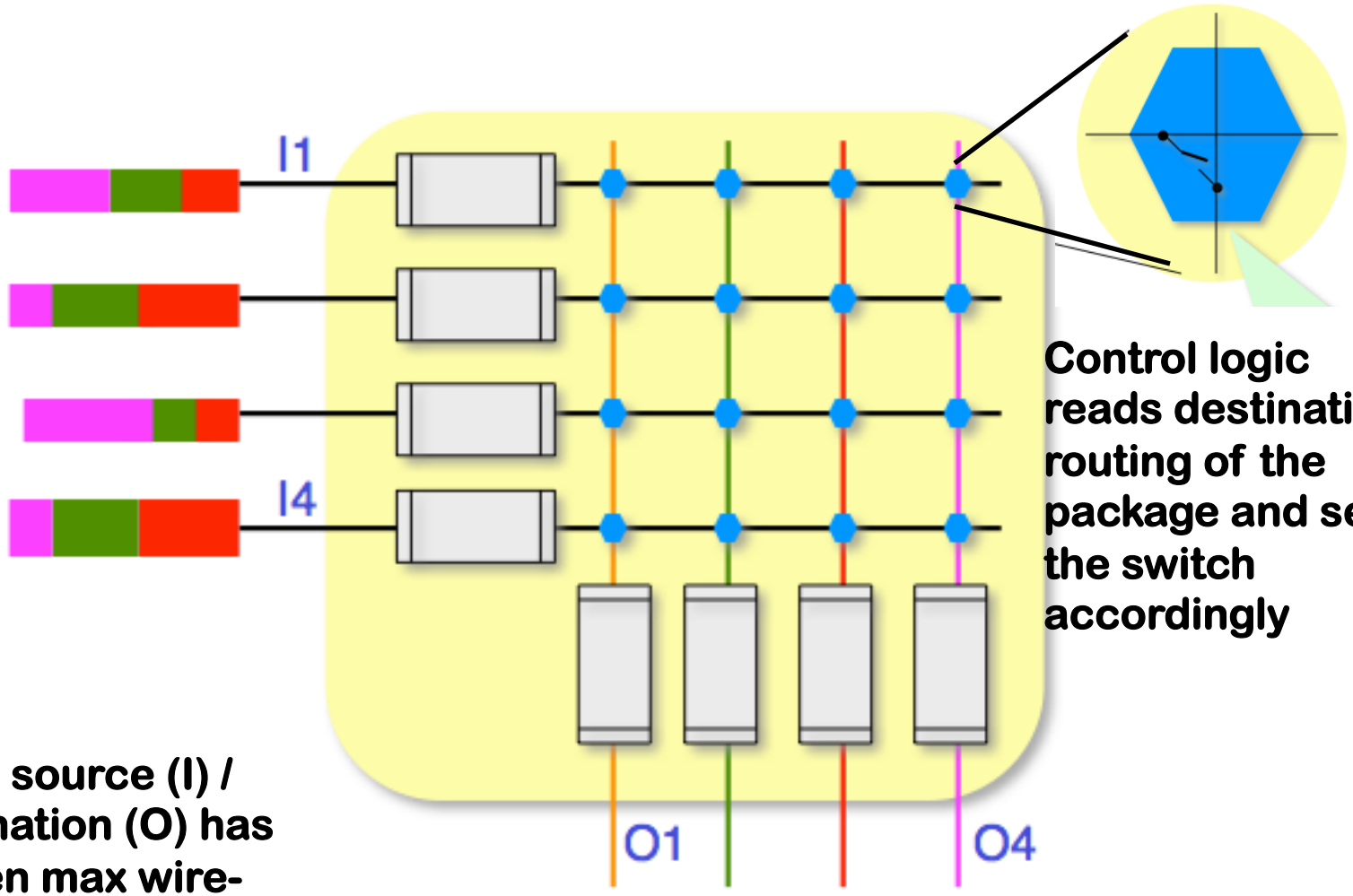
- Form full event data buffers from fragments in the readout
  => must interconnect data sources to destinations



**Data fragments are stored
In separated physical memory systems**

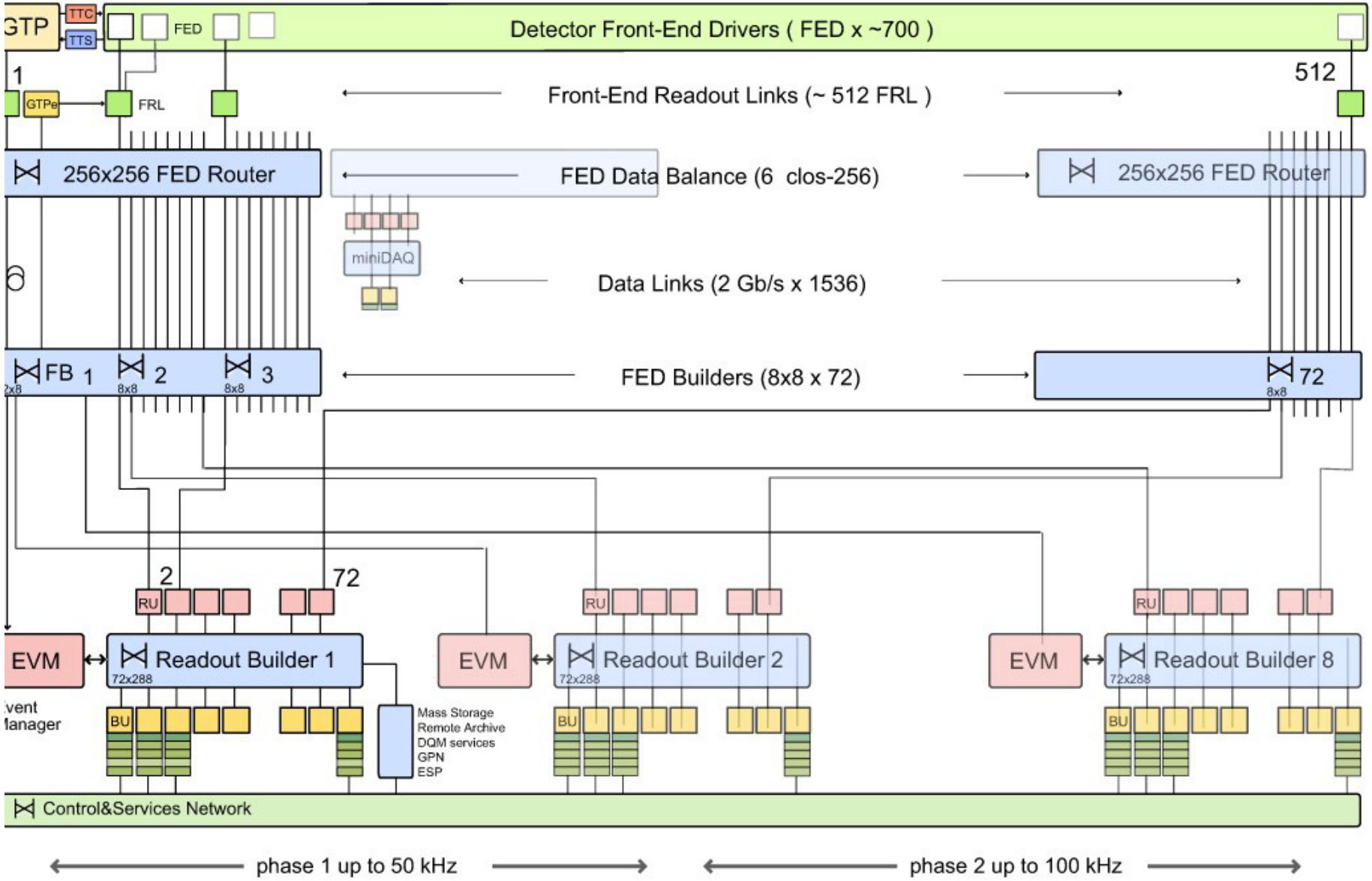
**Full event data are stored
Into one physical memory system
Associated to one processor unit**

Example



Control logic reads destination routing of the package and sets the switch accordingly

Every source (I) / destination (O) has a given max wire-speed (~2Gb/s)


GTP
TTC
TTS
FED
Detector Front-End Drivers (FED x ~700)
1
512
GTPe
FRL
Front-End Readout Links (~ 512 FRL)
256x256 FED Router
FED Data Balance (6 clos-256)
256x256 FED Router
miniDAQ
Data Links (2 Gb/s x 1536)
FB 1
2
3
FED Builders (8x8 x 72)
72
8x8
2
72
RU
EVM
Readout Builder 1
72x288
BU
Mass Storage
Remote Archive
DQM services
GPN
ESP
Readout Builder 2
Readout Builder 8
Control&Services Network
phase 1 up to 50 kHz
phase 2 up to 100 kHz

ATLAS DAQ

- After L1, L2 looks for Region of Interest (RoI)
- If L2 Accepts then all the event is sent to the next step