Unified Software Framework for Upgraded Belle DAQ System

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Outline

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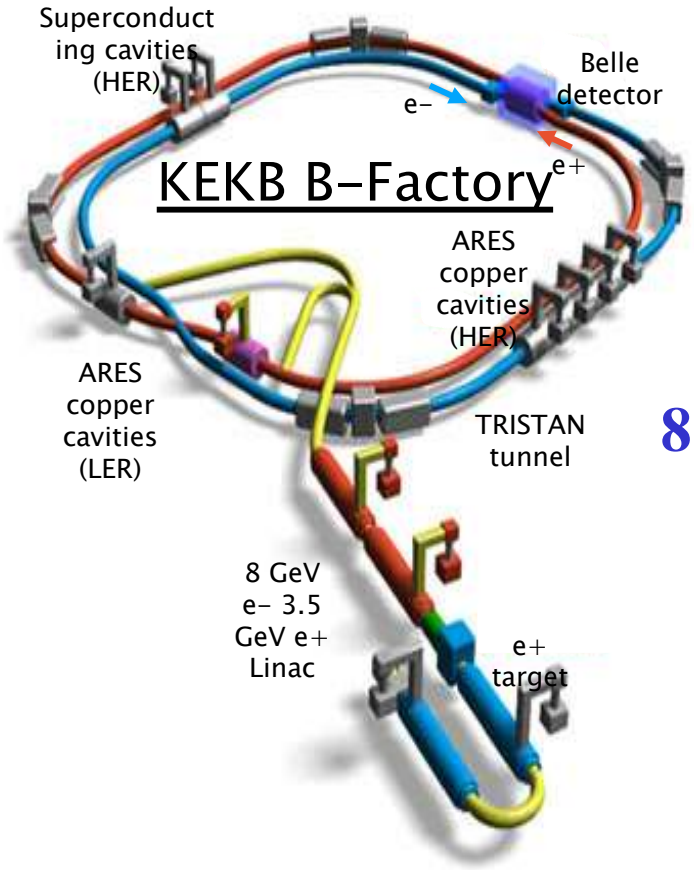
3. Software Design

4. Implementation
   - Frontend Readout Module
   - Readout PC
   - Event Builder
   - Reconstruction Farm

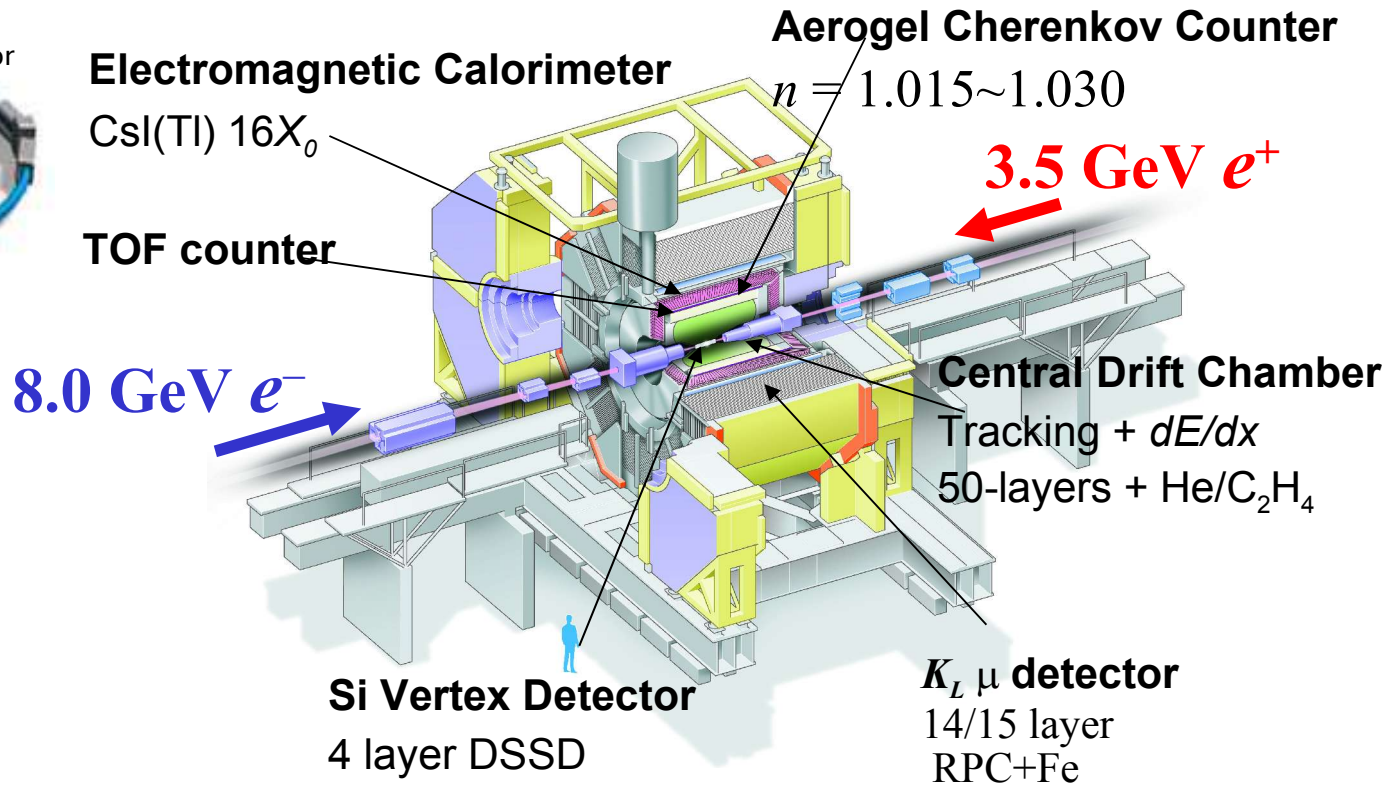
5. Summary

1. Introduction

KEKB Accelerator

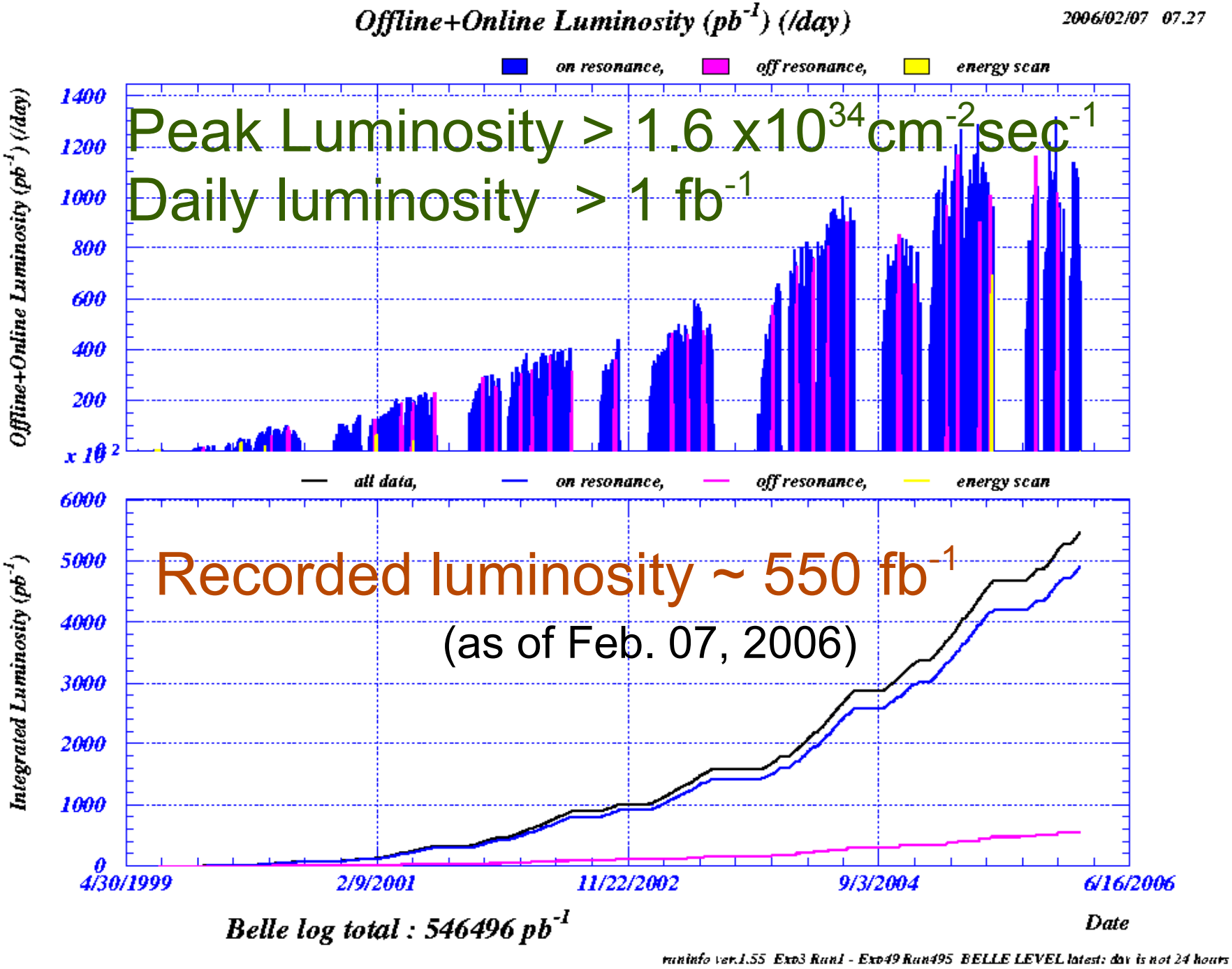


Belle Detector



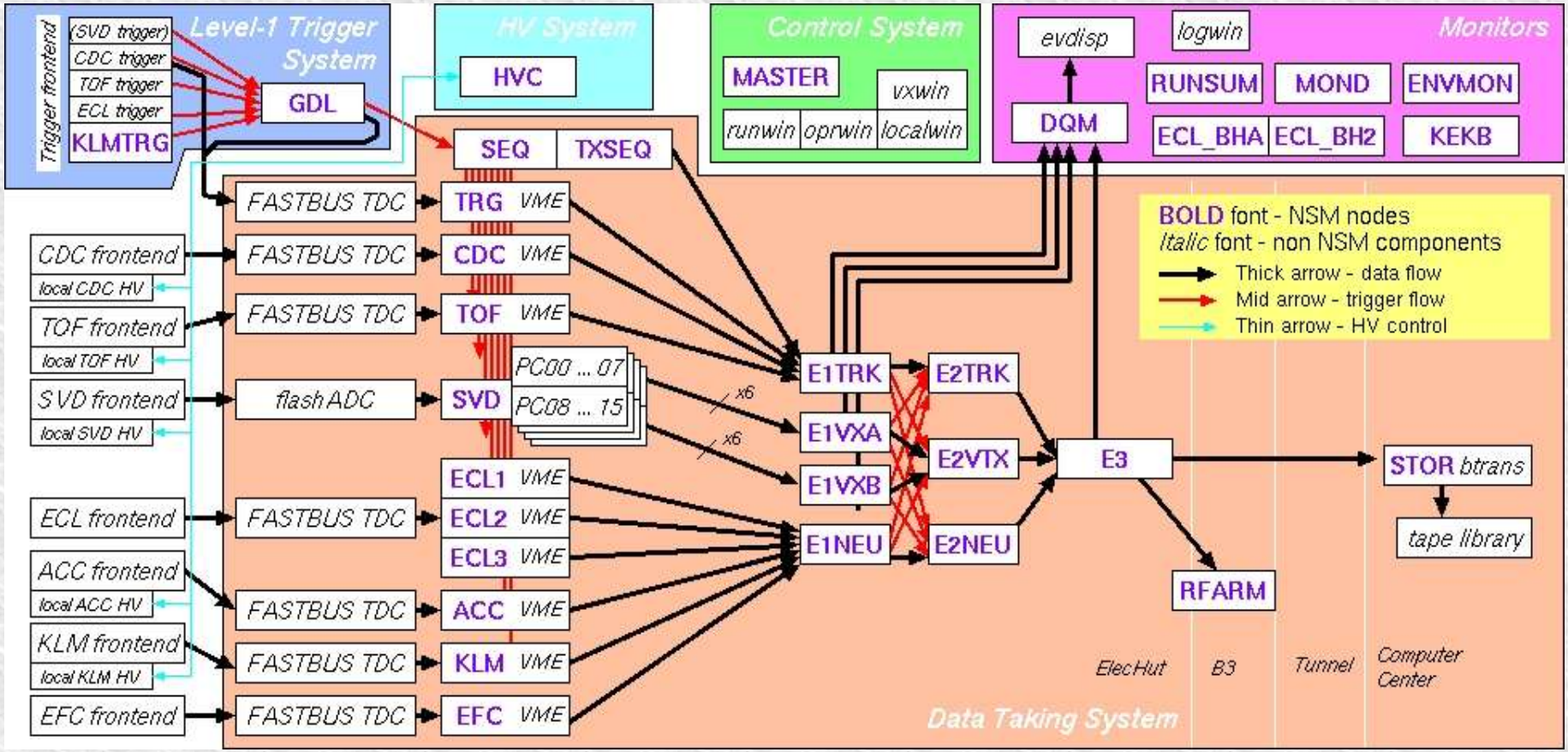
Belle Experiment: B-factory experiment at KEK in Japan to study CP violation in B meson decays.

- Precise determination of unitary triangle
- Discoveries of new particles: X(3872), Y(3940)
- New physics search in radiative decays : $B^0 \to K^* l^+ l^-$, $b \to d\gamma$


Offline+Online Luminosity (pb-1) (/day)
2006/02/07 07.27
on resonance,
off resonance,
energy scan
Offline+Online Luminosity (pb-1) (/day)
1400
1200
1000
800
600
400
200
x 10 2
Peak Luminosity > 1.6 x10^34 cm^-2 sec^-1
Daily luminosity > 1 fb^-1
all data,
on resonance,
off resonance,
energy scan
Integrated Luminosity (pb-1)
6000
5000
4000
3000
2000
1000
0
Recorded luminosity ~ 550 fb^-1
(as of Feb. 07, 2006)
4/30/1999
2/9/2001
11/22/2002
9/3/2004
6/16/2006
Belle log total : 546496 pb-1
Date
runinfo ver.1.55 Exp3 Run1 - Exp49 Run495 BELLE LEVEL latest day is not 24 hours

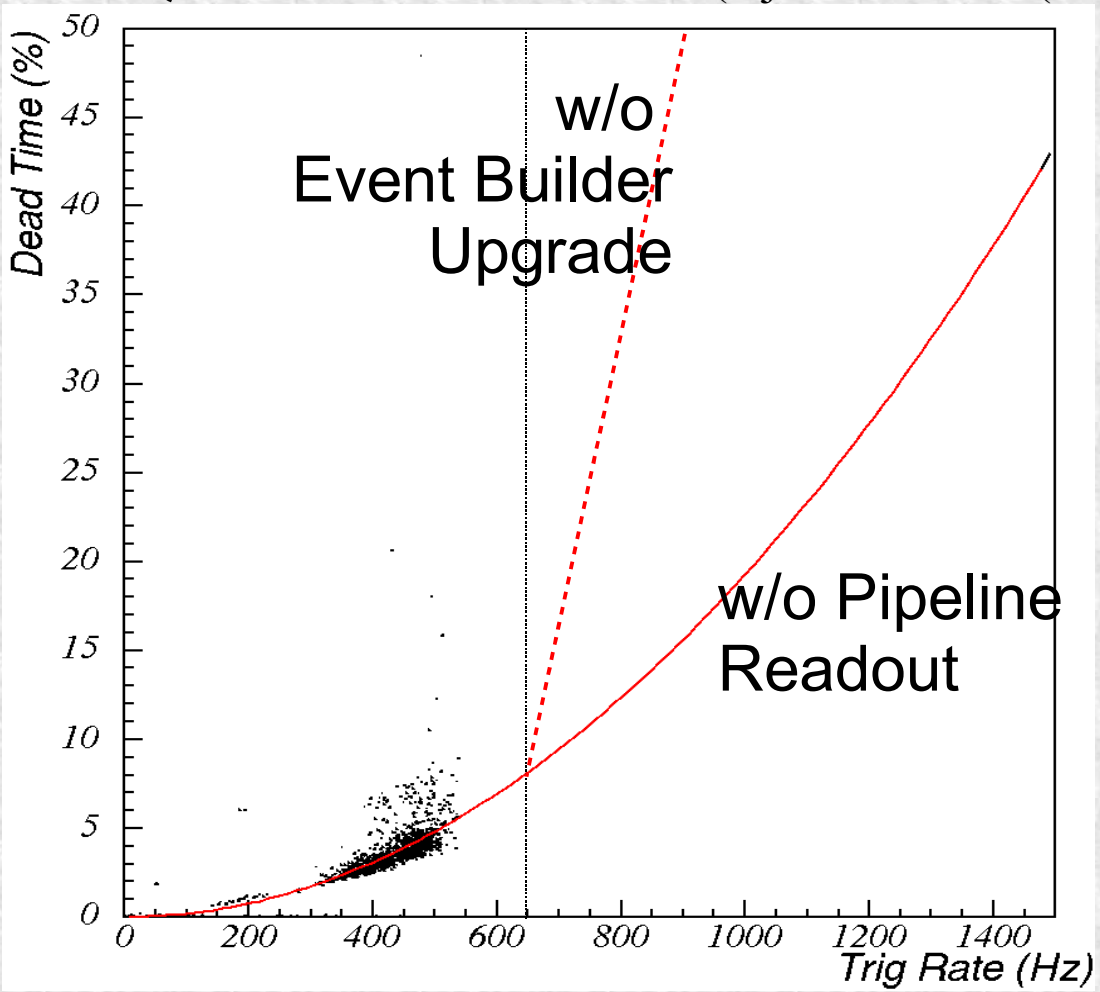
2. Belle DAQ Upgrade

Belle DAQ system until 2005 summer



* Q-to-T conversion + FASTBUS TDC, Switchless Event Builder
* Ave. Trigger Rate ~ 500Hz, Event Size ~ 40KB
  Intrinsic dead time ~ 4% (+ 3.5% due to injection VETO for continuous injection)
* RFARM for real-time event reconstruction

DAQ intrinsic deadtime (injection VETO(3.5%@10Hz) is NOT included)



Crab cavity installation is scheduled in Mar-Apr 2006.

L will reach > 2~3 x 10^{34} $cm^{-2}sec^{-1}$ in a few years

↓

Trigger rate > 1KHz

↓

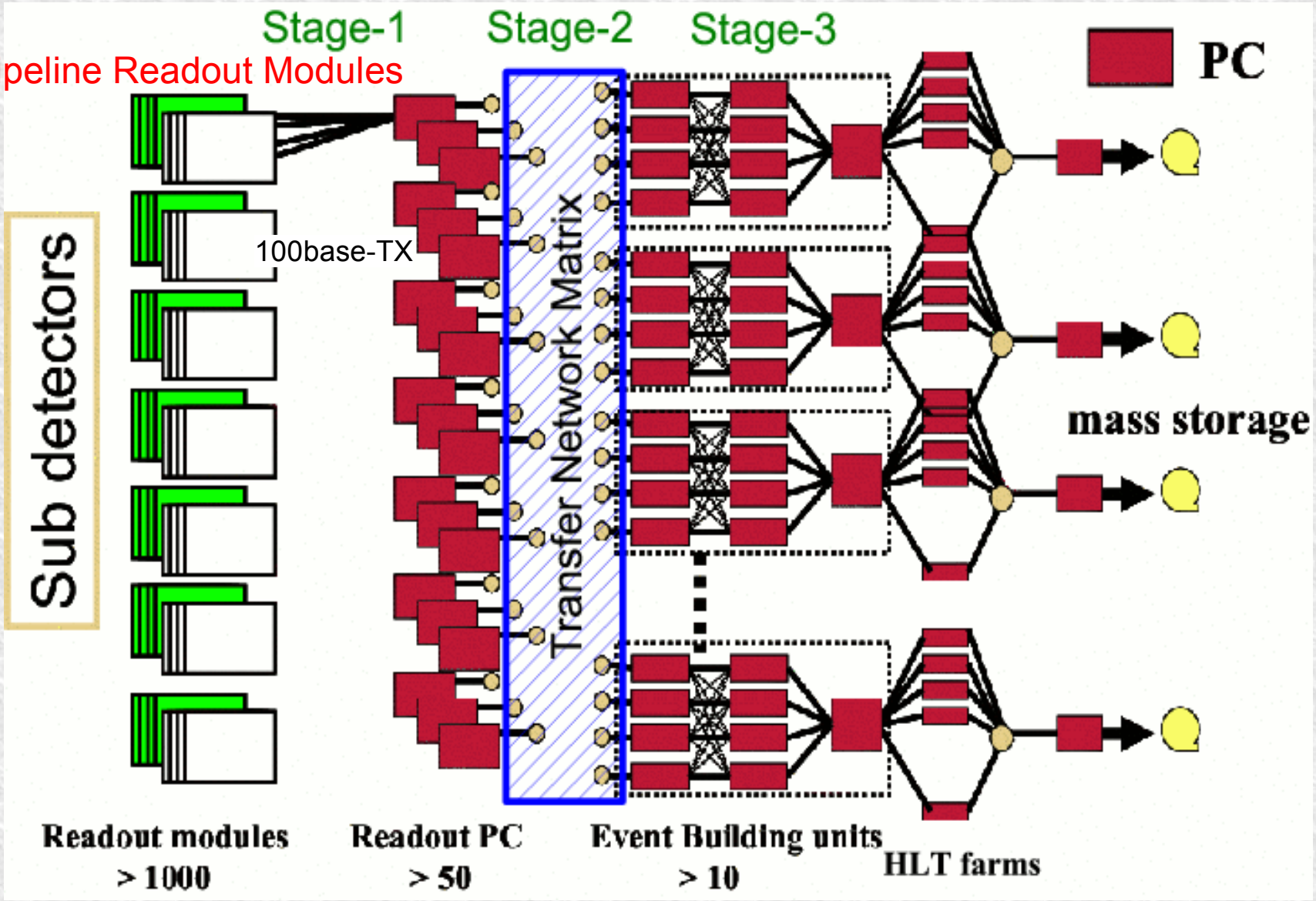
DAQ deadtime > 20%
which is unacceptable.

+ SuperKEKB upgrade
=> up to 30KHz!

1. Upgrade of readout system to pipeline-based system
   ** Unified pipeline readout module has been developed.*
2. Upgrade of Event Builder/RFARM also.
   ** To remove 650Hz barrier*

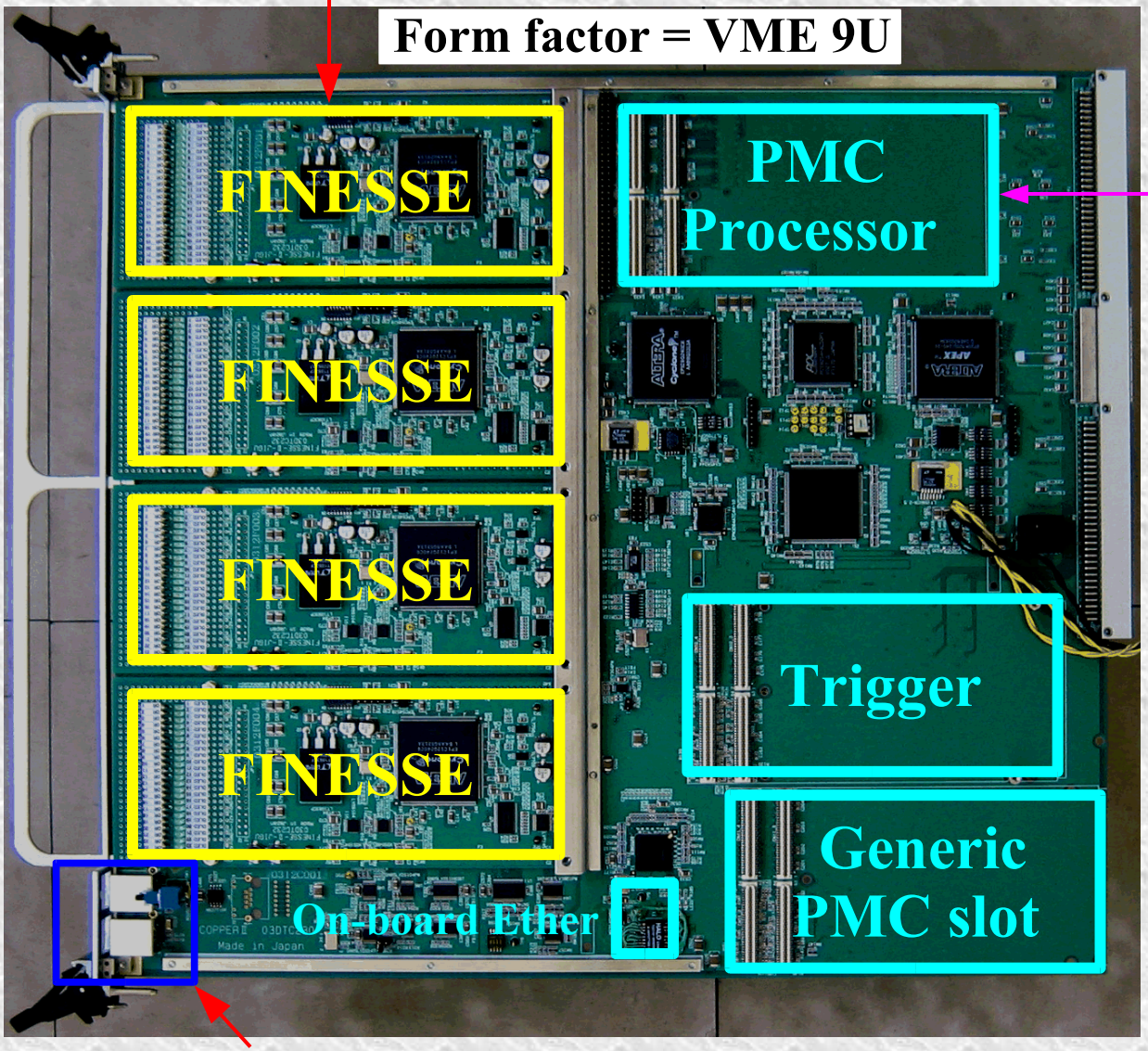
Global Design of DAQ upgrade (toward SuperKEKB)

3-stage event building



Unified Pipeline Readout Module (COPPER)

Digitizer cards (implemented as daughter cards)



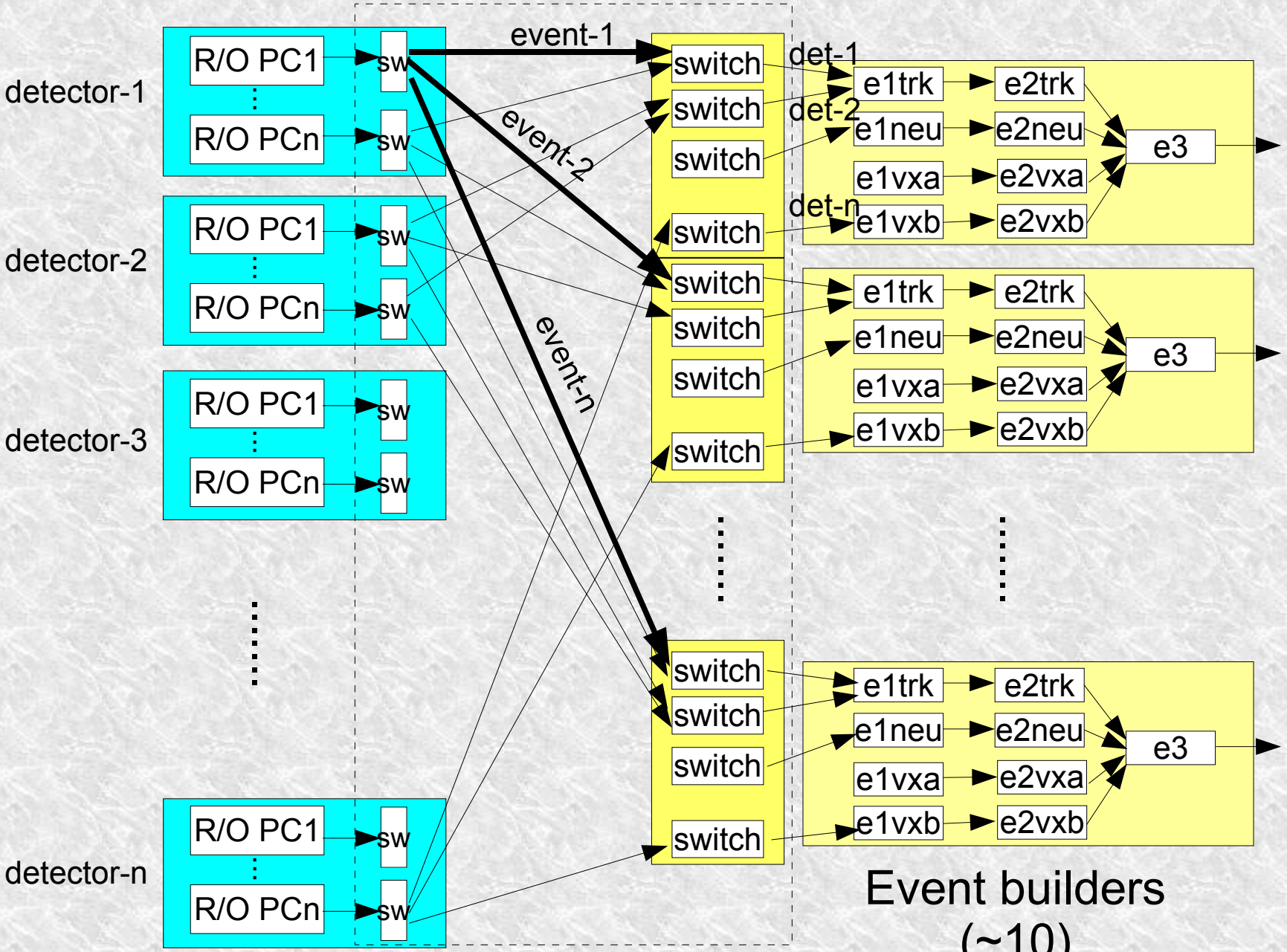
CPU card
(operated by Linux)

RadiSys EPC-6315

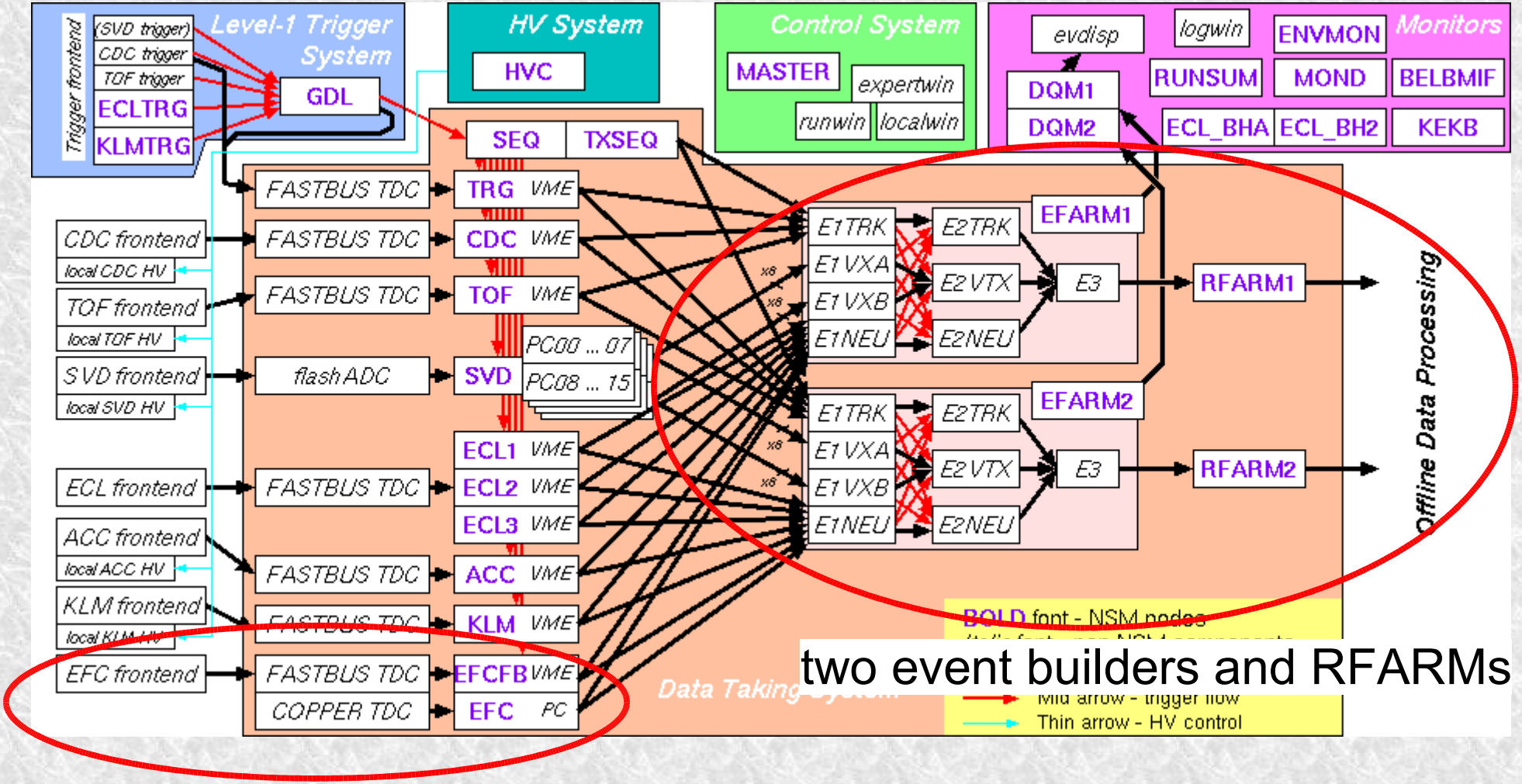
- **Intel PentiumIII 800 MHz** w/ **512 MB memory**.
- Network booted
- RedHat Linux 9

two100base-TX ports
(for control and data flow)

Transfer Network Matrix



Partially upgraded Belle DAQ (2005 fall -)



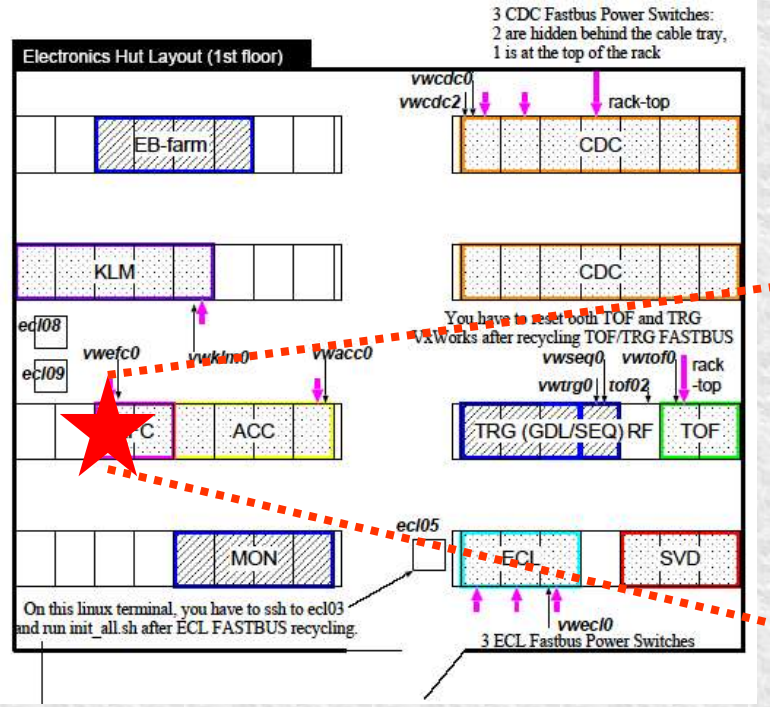
two event builders and RFARMs

COPPER readout for EFC
(for the system test in beam)

EFC COPPER crate

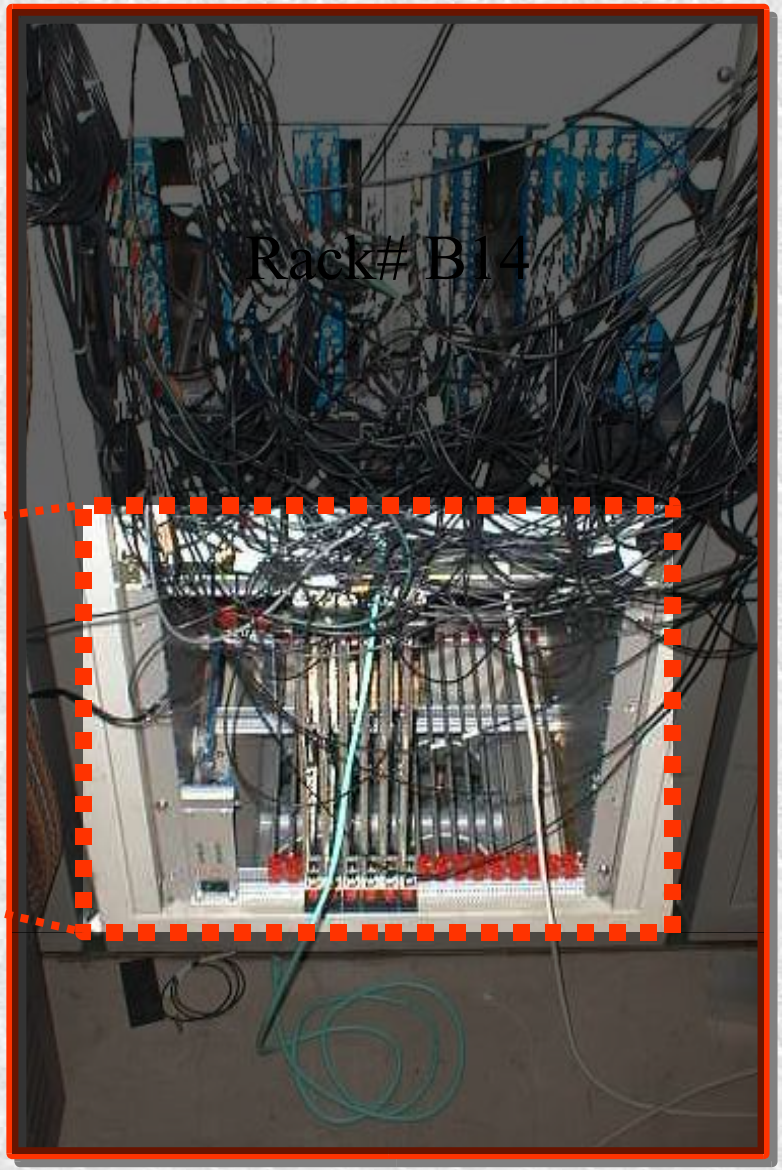
COPPER TDC :

made compatible with LeCroy 1877S
using FINESSE cards with AMT chips.



The COPPERs are already on operation from exp#45.

Rack# B14

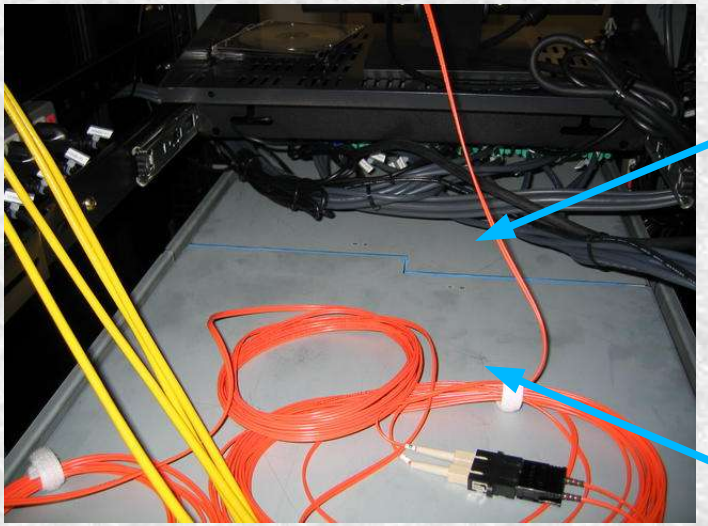


Before Q/T cabling

Transfer Network Matrix + Event Builder 1 and 2

2nd unit of RFARM

40 x Dual Xeon servers (3.4GHz)

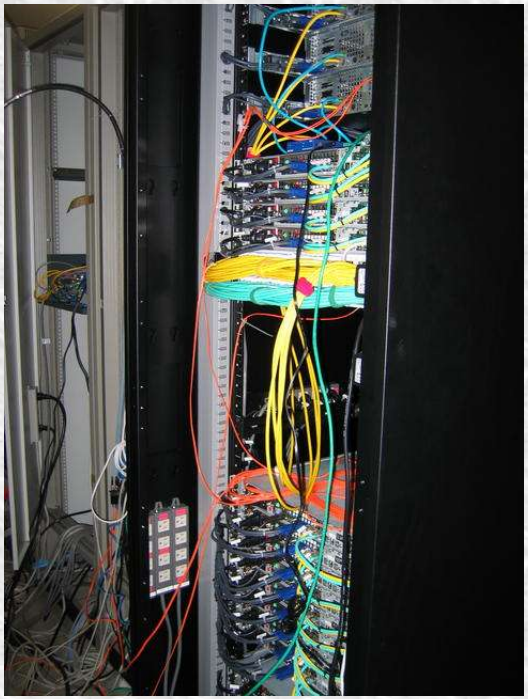


Front-side server

Back-side server

Each server houses dual Xeon in 1/2U

→ **4 Xeon CPUs in 1 U**



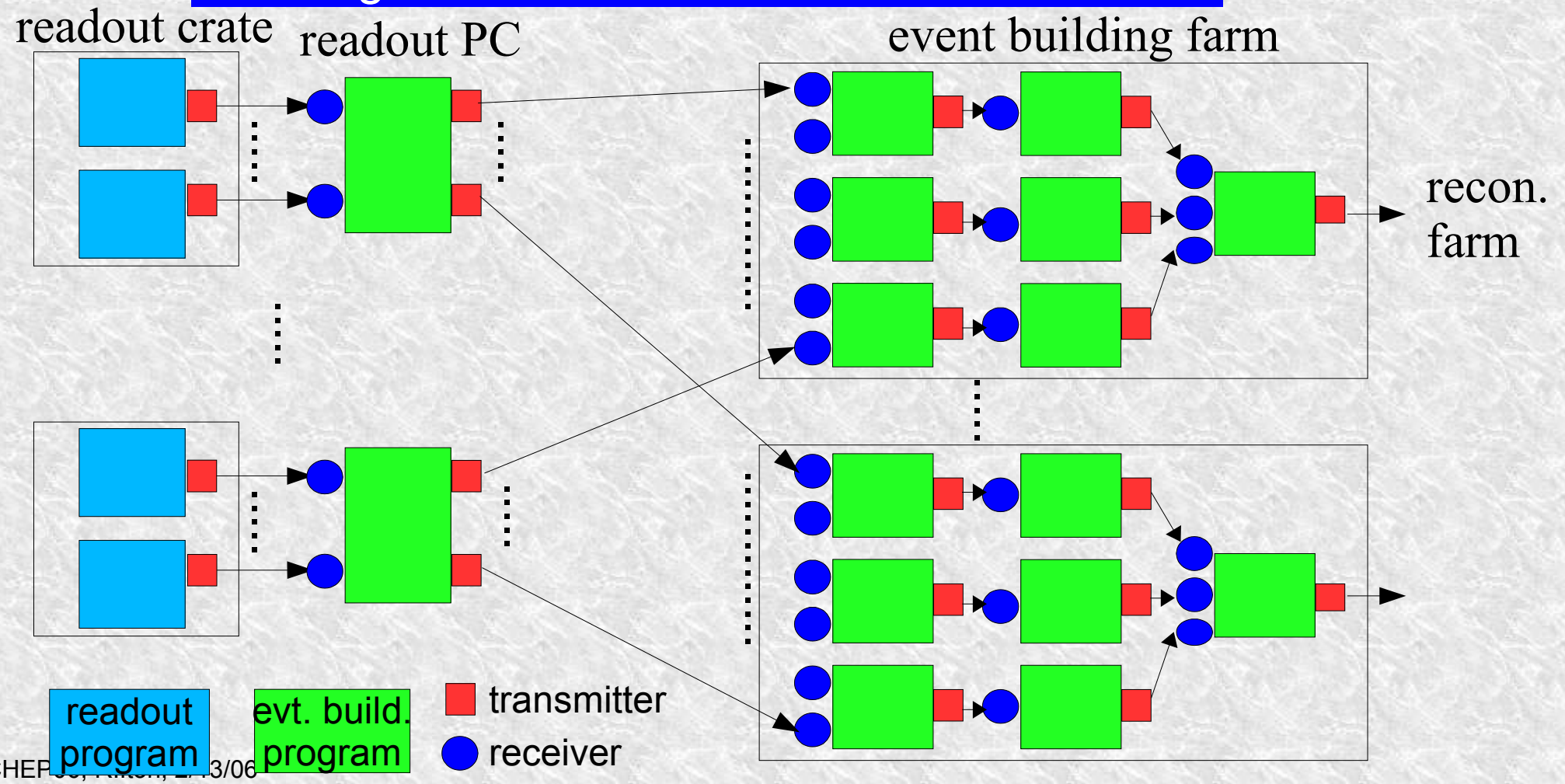
Backside

3. Software Design

[DAQ system from software viewpoint]

* point-to-point TCP/IP based data transfer everywhere.
* Linux operated PC is used in all DAQ components (inc. readout modules).
* 3-stage event building ... repeated use of similar processing

"Building block" construction of DAQ software



Considerations

Variety of complicated processing is performed on each node.

* Wave form sampling / feature extraction on readout modules.
* “Level 2.5” trigger on first nodes of event building farms.

.....

→Data reduction with node-by-node optimized algorithm on all nodes.

Readout program / Event building program:

→ Should be capable of accepting variety of data processing codes.

- Such codes are written by many people some of those are not familiar with DAQ software.

Needs an offline-like programming environment for DAQ which does not require DAQ-specific knowledge.

Idea: DAQ software based on offline analysis framework

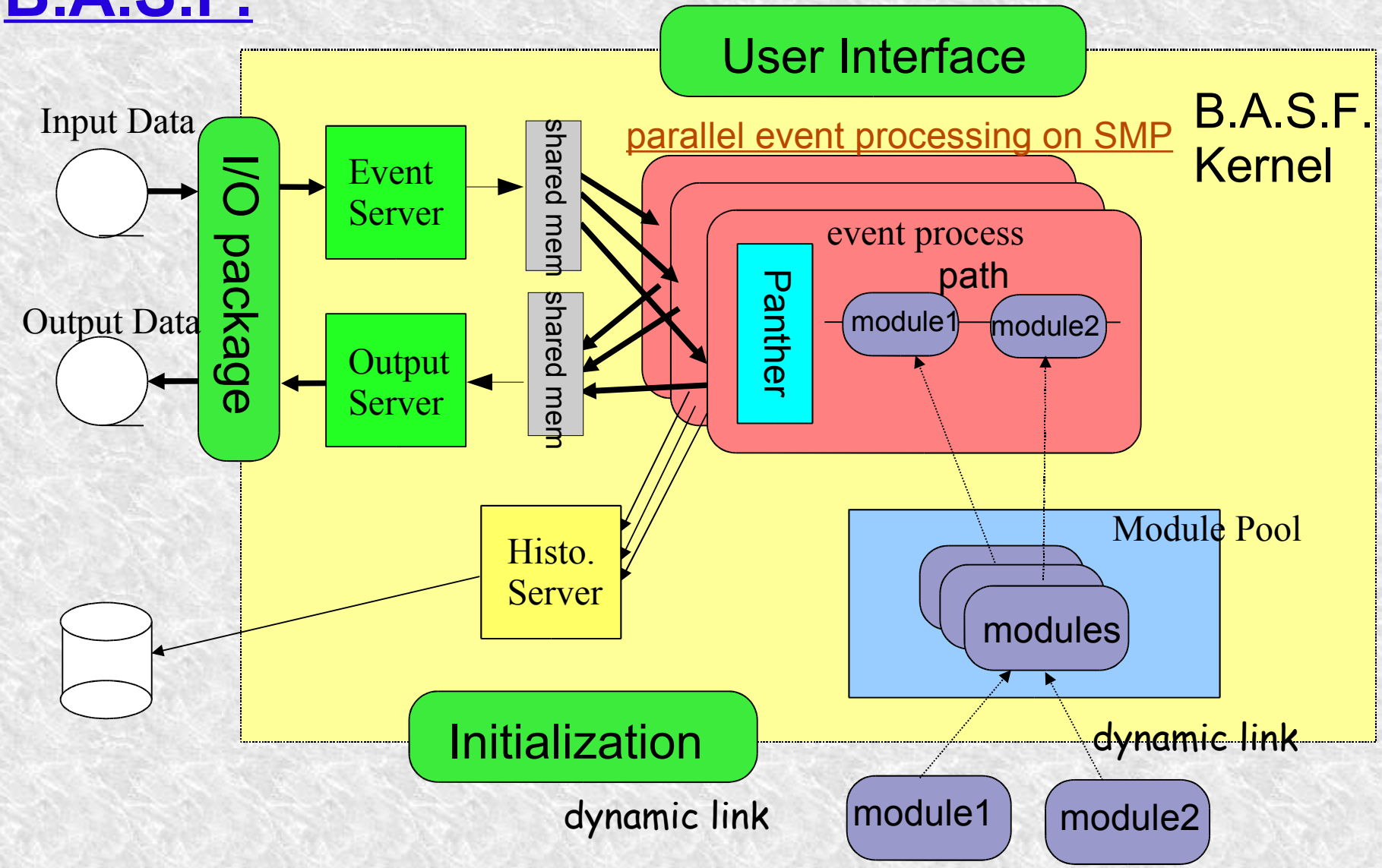
Offline analysis framework : B.A.S.F.
(Belle AnalysiS Framework)

* Well established in Belle and everyone is familiar with it.
* User code can be linked with the framework as modules by a dynamic link.
* Users don't have to take care of data I/O.
  ← data handling through data management package

Readout program / Event Building program :
* B.A.S.F. with DAQ modifications.

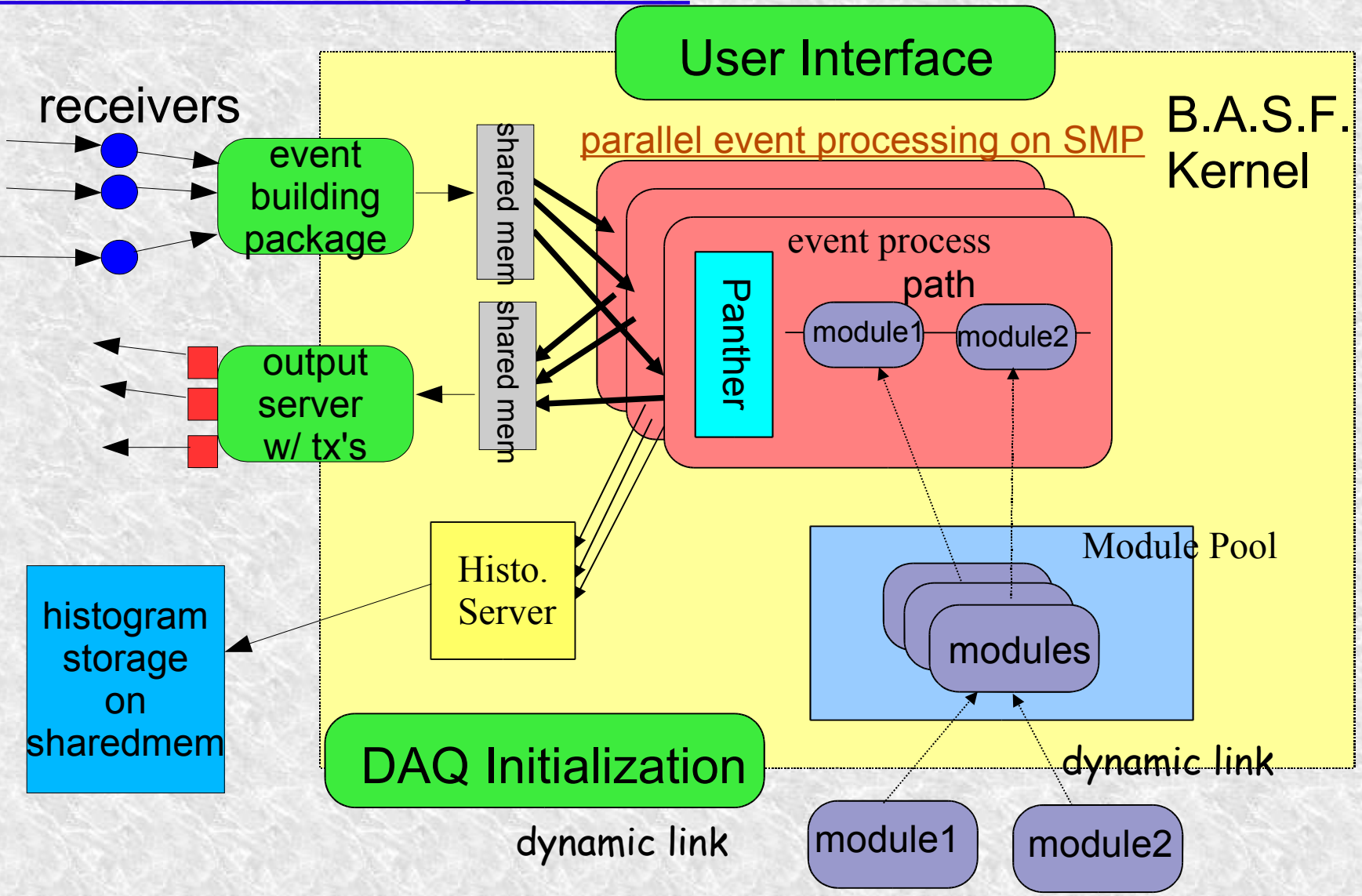
Data flow between nodes :
*Socket I/O implemented in B.A.S.F.

B.A.S.F.



* Green boxes are linked using dynamic link as well as “modules”.
* Data handling is done through “Panther” package.

B.A.S.F. with DAQ mods.

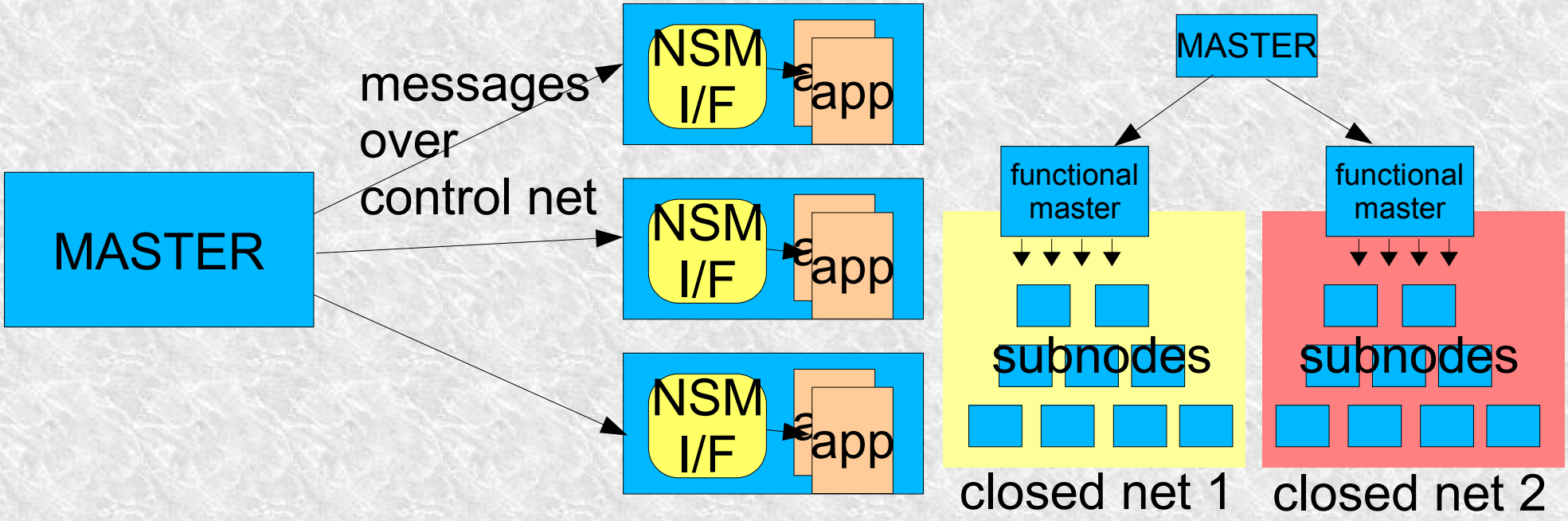


Socket I/O between nodes: based on unified “d2packet” protocol

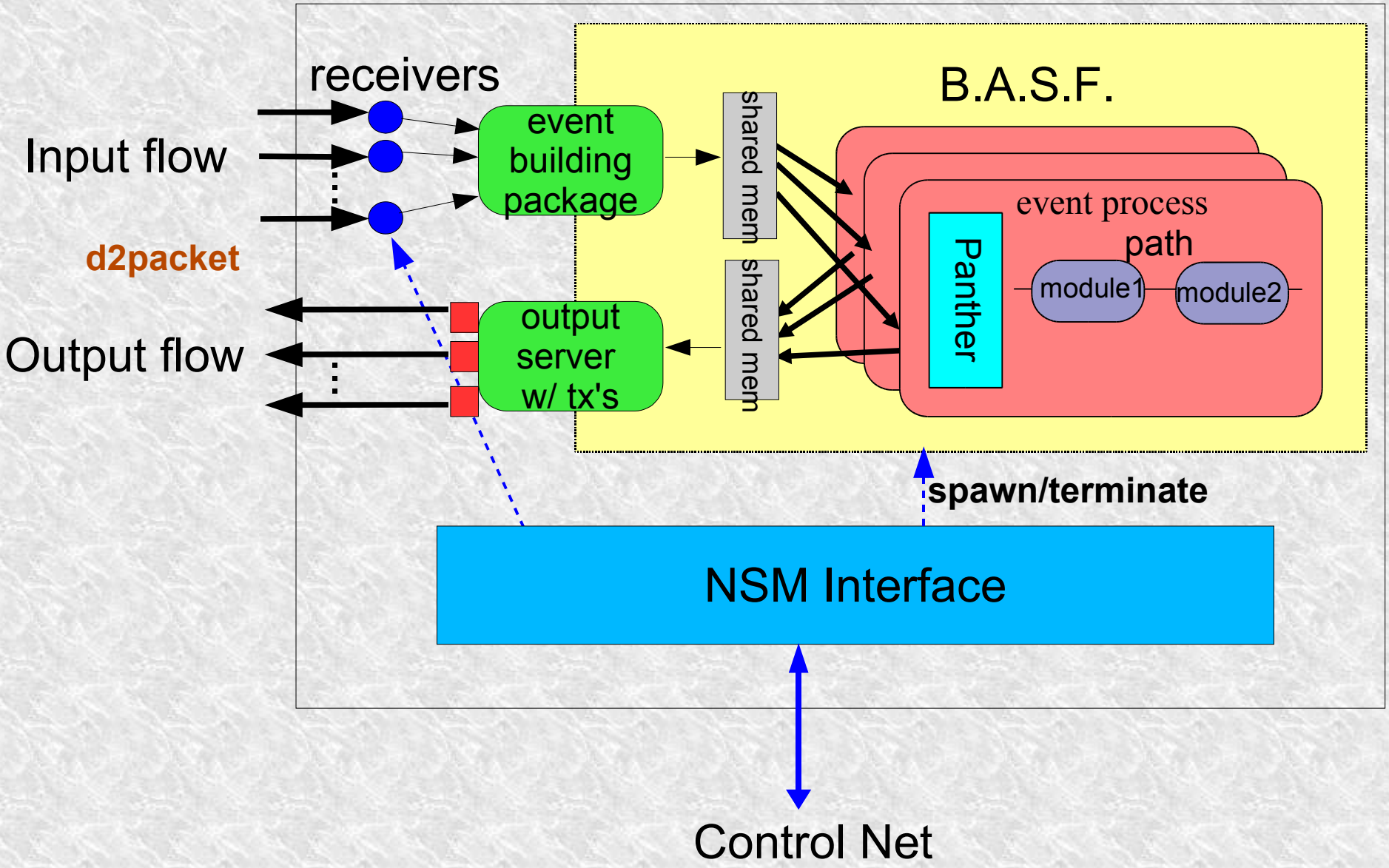
Slow control

NSM (Network Shared Memory) is used.

* Capable of
  - shared memory handling over network
  - message passing between nodes
    ← asynchronous handling by hooked-up action functions
* DAQ control is done through message passing from one MASTER node to many client nodes.
* Support for hierarchical network structure through functional master.



Unified DAQ Software Framework



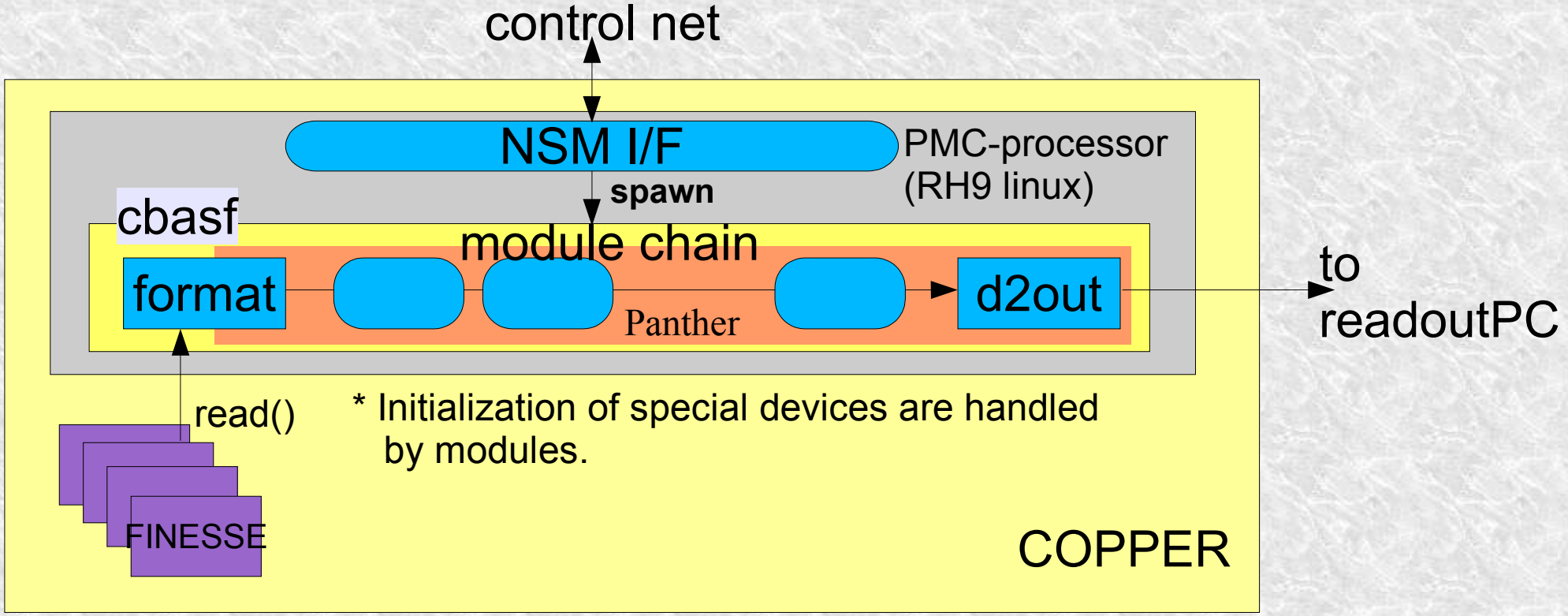
4. Implementations

a) Readout Module (COPPER)

- Special version of B.A.S.F. is used, “cbasf” : light-weight B.A.S.F.
  * parallel processing capability is removed.

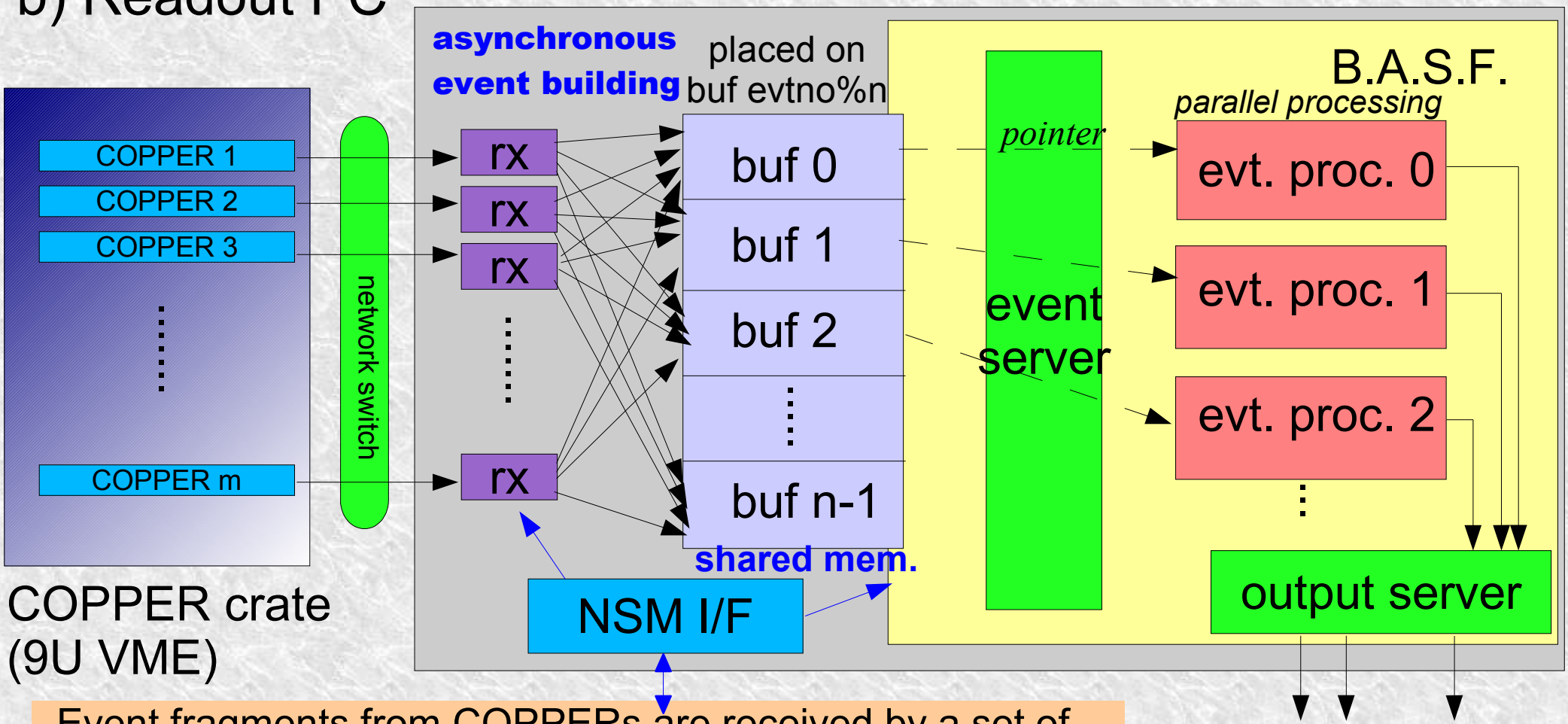
- FINESSE(digitizer) cards are accessed through a device driver with standard system calls (open(), close(), read(), write(), and ioctl()).

- Data from digitizers are formatted into Panther at the very beginning.



b) Readout PC

Dual Xeon server (RH9 Linux) → SMP with 4 CPUs



- Event fragments from COPPERs are received by a set of **rx** processes and placed in a buffer on a **shared memory** accoding to event nunber.

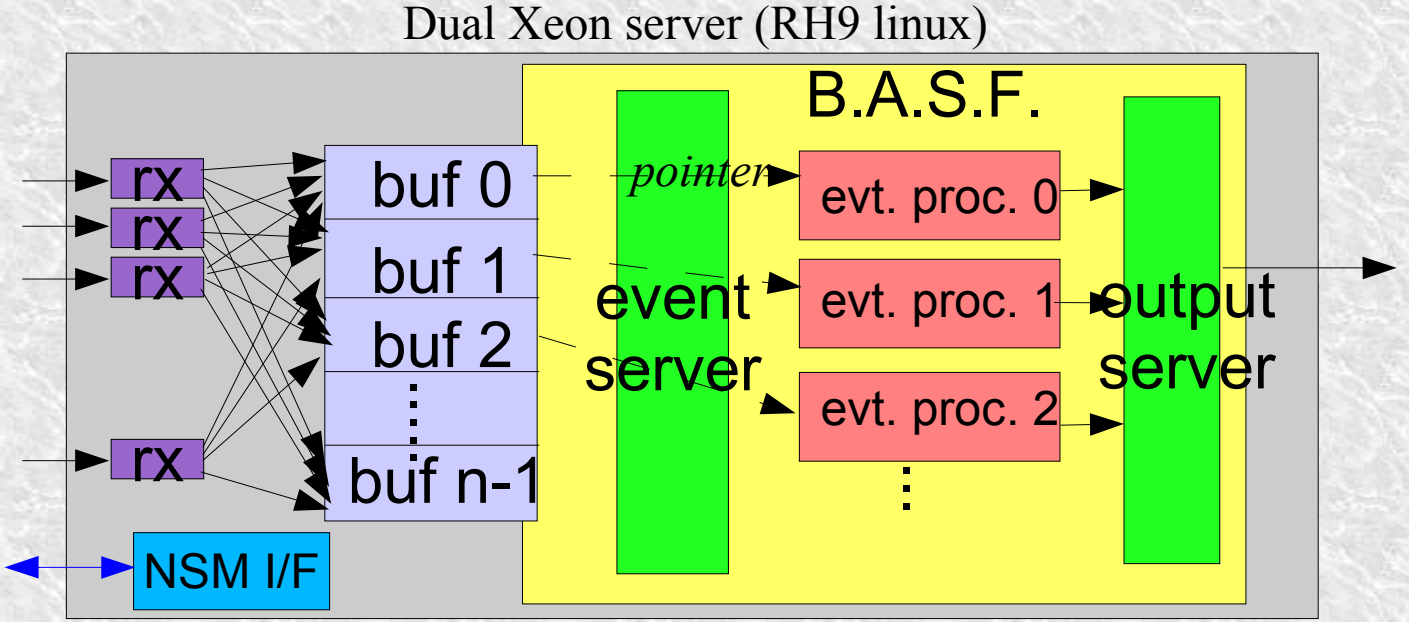
- Buffers with all event fragments filled are sent to event process by the "**event server**" by passing pointers.

- "**Output server**" sends processed outputs to event builders in turn through sockets.

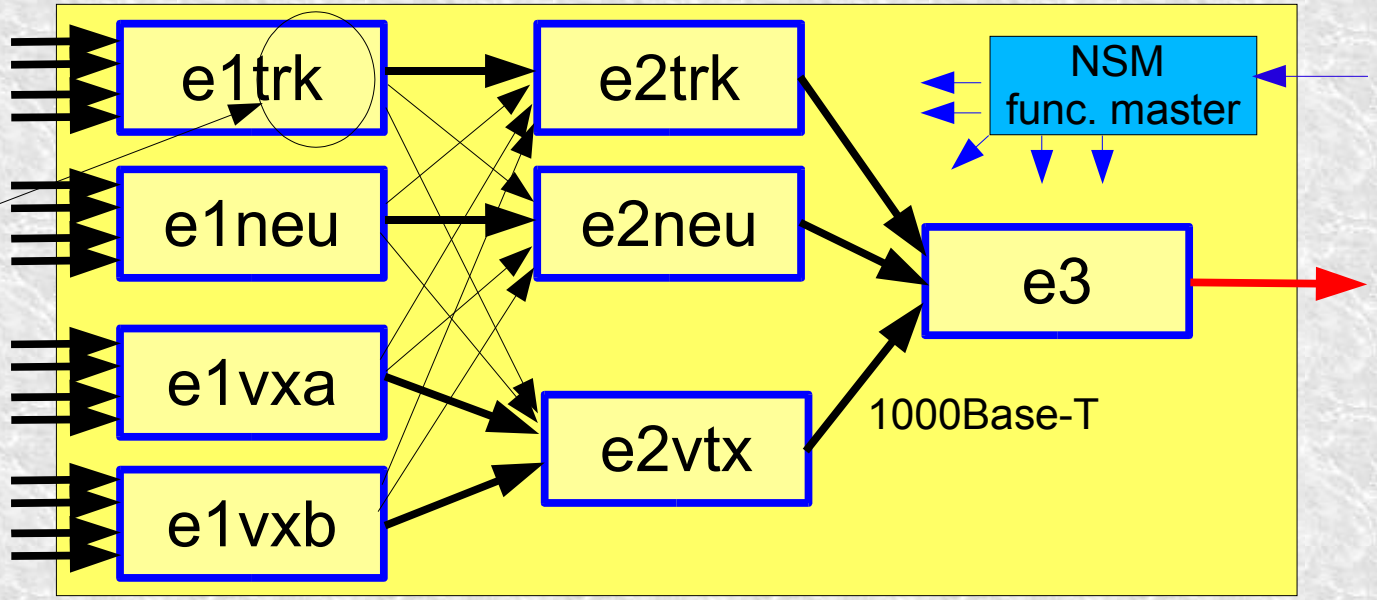
c) Event Builder

- Repeated use of software for Readout PC : Unified framework

Software
on single node



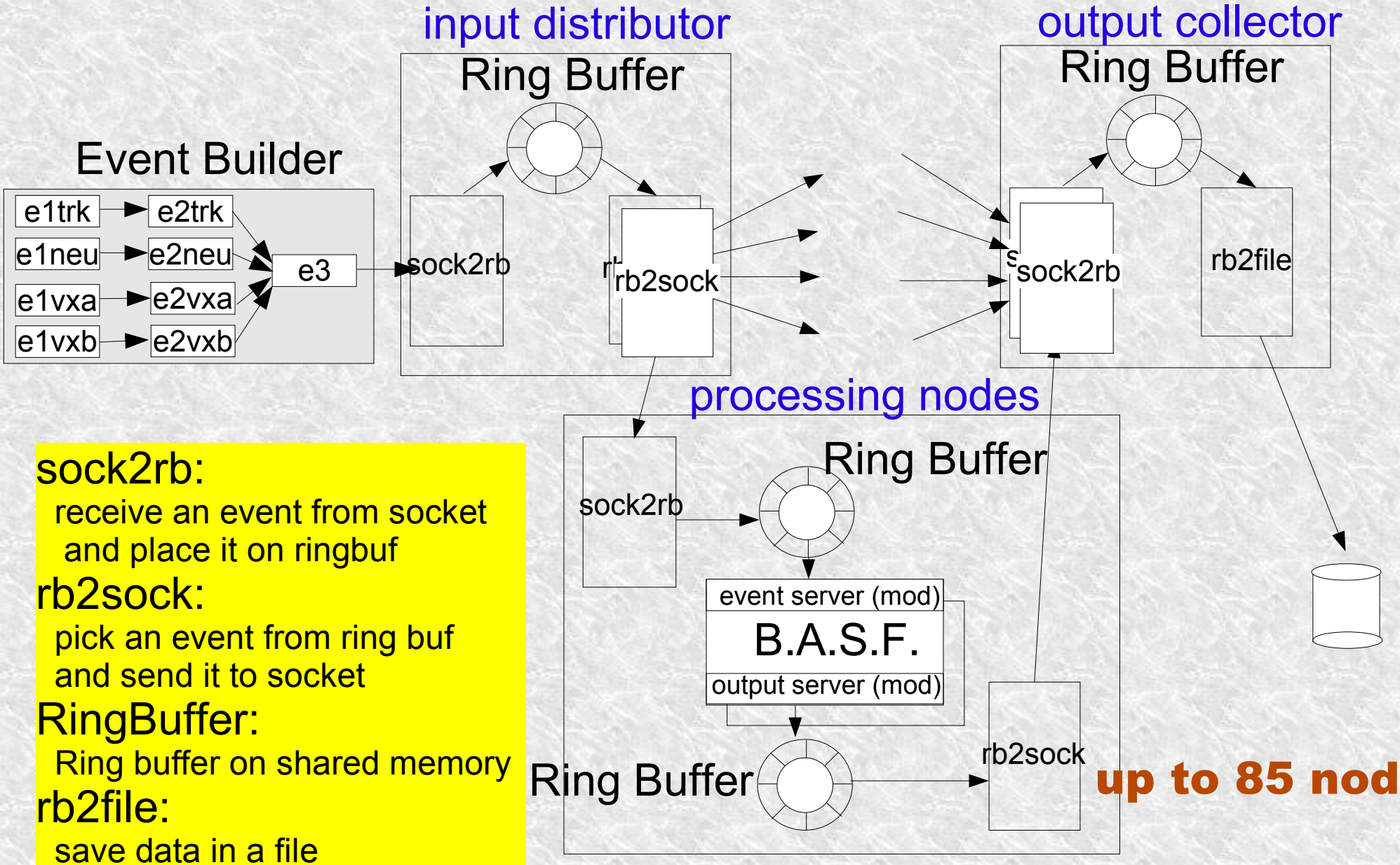
Event Builder Unit



Level 2.5 software trigger is implemented as a B.A.S.F.module

d) Reconstruction Farm

Nodes are dual Athron or Xeon servers oprated by linux(RH7.3/9 and WBL3)



sock2rb:
receive an event from socket and place it on ringbuf

rb2sock:
pick an event from ring buf and send it to socket

RingBuffer:
Ring buffer on shared memory

rb2file:
save data in a file

Each node : controlled by NSM in a closed net thru. functional master on a control node.

5. Summary

* Upgrade of Belle DAQ system is on going to keep up with a luminosity increase in coming years.

* A unified DAQ software framework is developed based on Belle's offline analysis framework combined with a socket I/O and event building package.

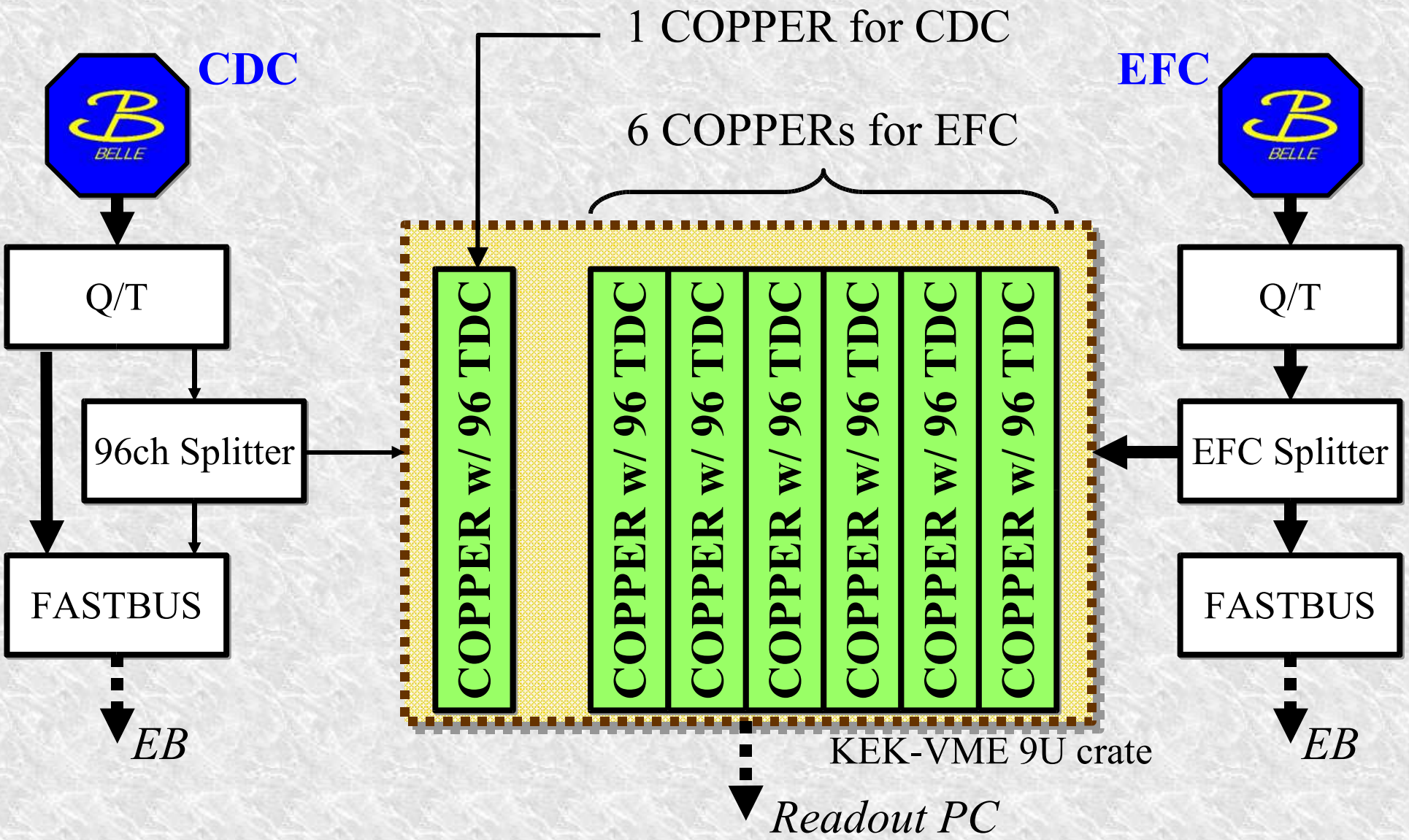
* The framework is used even on every front-end readout module.

provides easy and consistent environment for the development of DAQ software

* The partially-upgraded Belle DAQ system is now being operated with the unified software framework and is working stably.

Backup Slides

EFC COPPER Integration



Trigger Timing Distribution