Evolution of DAQ: Belle to SuperBelle

Ryosuke Itoh
KEK
on behalf of Belle DAQ group

RealTime 2009, Beijing, 5/14/09

Evolution of DAQ: Belle to ~~SuperBelle~~ Belle II

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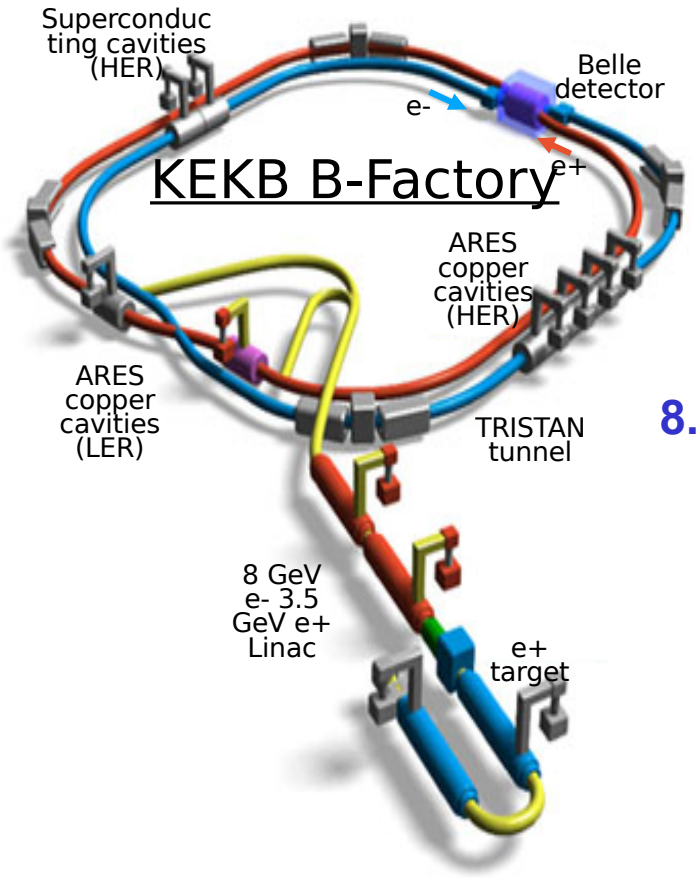
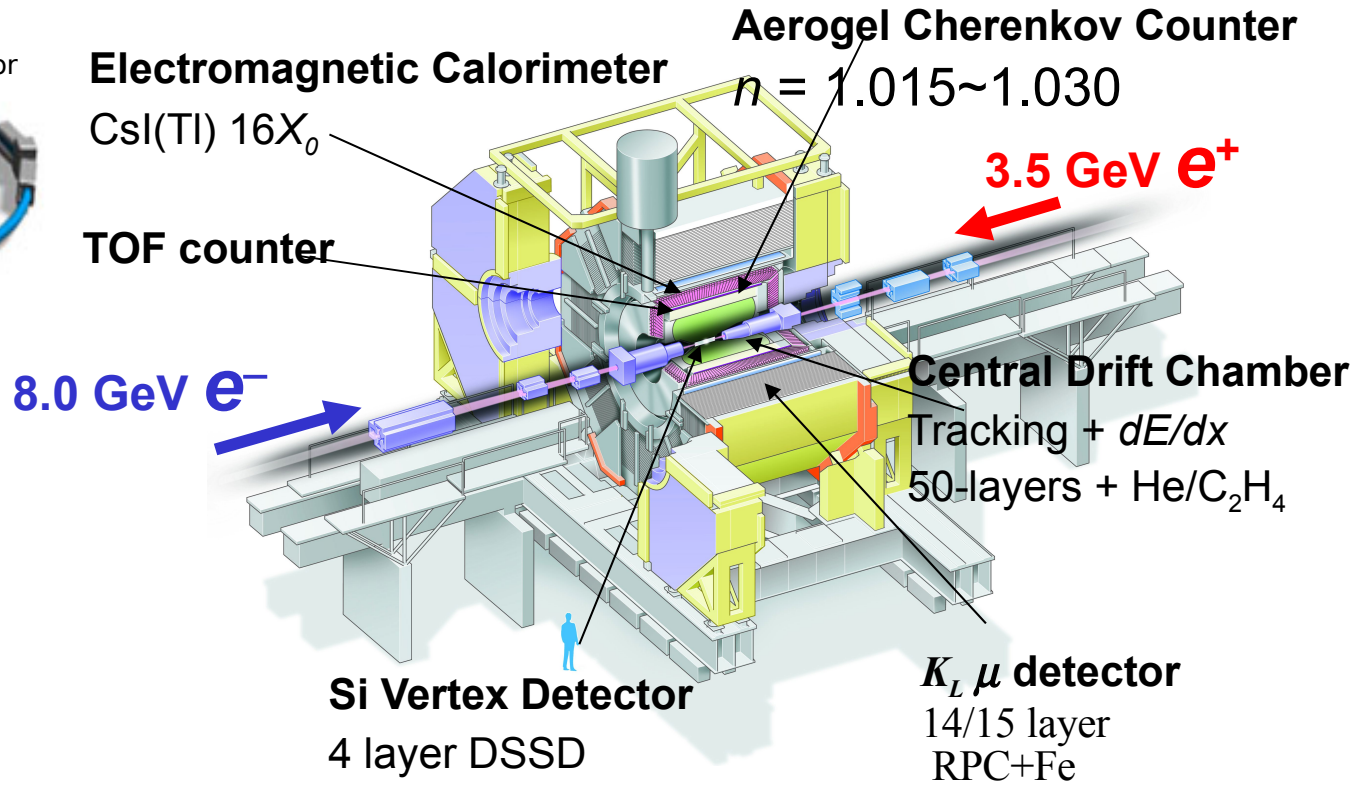
1. Introduction
2. History of Belle DAQ
   - DAQ system of early days(1999)
   - 2001 upgrade
   - 2003 upgrade
   - 2005 upgrade
   - 2007 upgrade and after
3. Go Beyond: SuperKEKB and Belle II
4. Concusions

1. Introduction

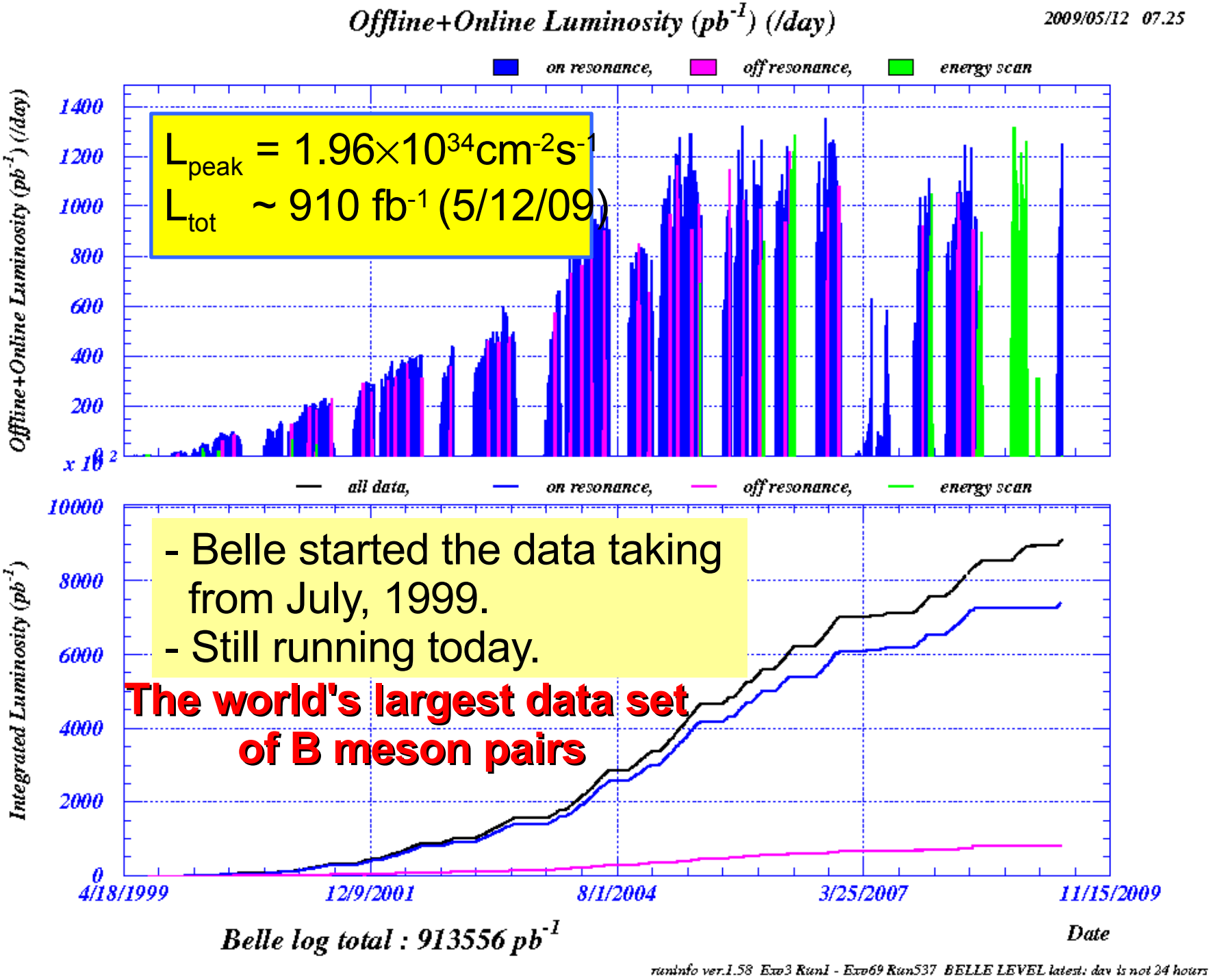
KEKB Accelerator



Belle Detector



- The primary goal of the Belle experiment is to study the CP violation in B meson decays produced by the KEKB accelerator
- Many physics results already.
  * Observation of CP violation in 2001 led 2008 Nobel prize to Profs. Kobayashi and Maskawa


Offline+Online Luminosity (pb-1) (/day)
2009/05/12 07.25
on resonance,
off resonance,
energy scan
Offline+Online Luminosity (pb-1) (/day)
1400
1200
1000
800
600
400
200
0
x 10 2
Lpeak = 1.96×10^34 cm^-2 s^-1
Ltot ~ 910 fb^-1 (5/12/09)
all data,
on resonance,
off resonance,
energy scan
Integrated Luminosity (pb-1)
10000
8000
6000
4000
2000
0
- Belle started the data taking from July, 1999.
- Still running today.
The world's largest data set of B meson pairs
4/18/1999
12/9/2001
8/1/2004
3/25/2007
11/15/2009
Belle log total : 913556 pb-1
Date
runinfo ver.1.58 Exp3 Run1 - Exp69 Run537 BELLE LEVEL latest: day is not 24 hours

Belle DAQ :10 year operation

- The key of the experiment is to collect as much as larger data set of B meson decays.
- Serious competition with PEP-II/BaBar

Continuous effort for
- Dead time reduction
- Stable operation over a long run period more than 10 years.

was required for DAQ.

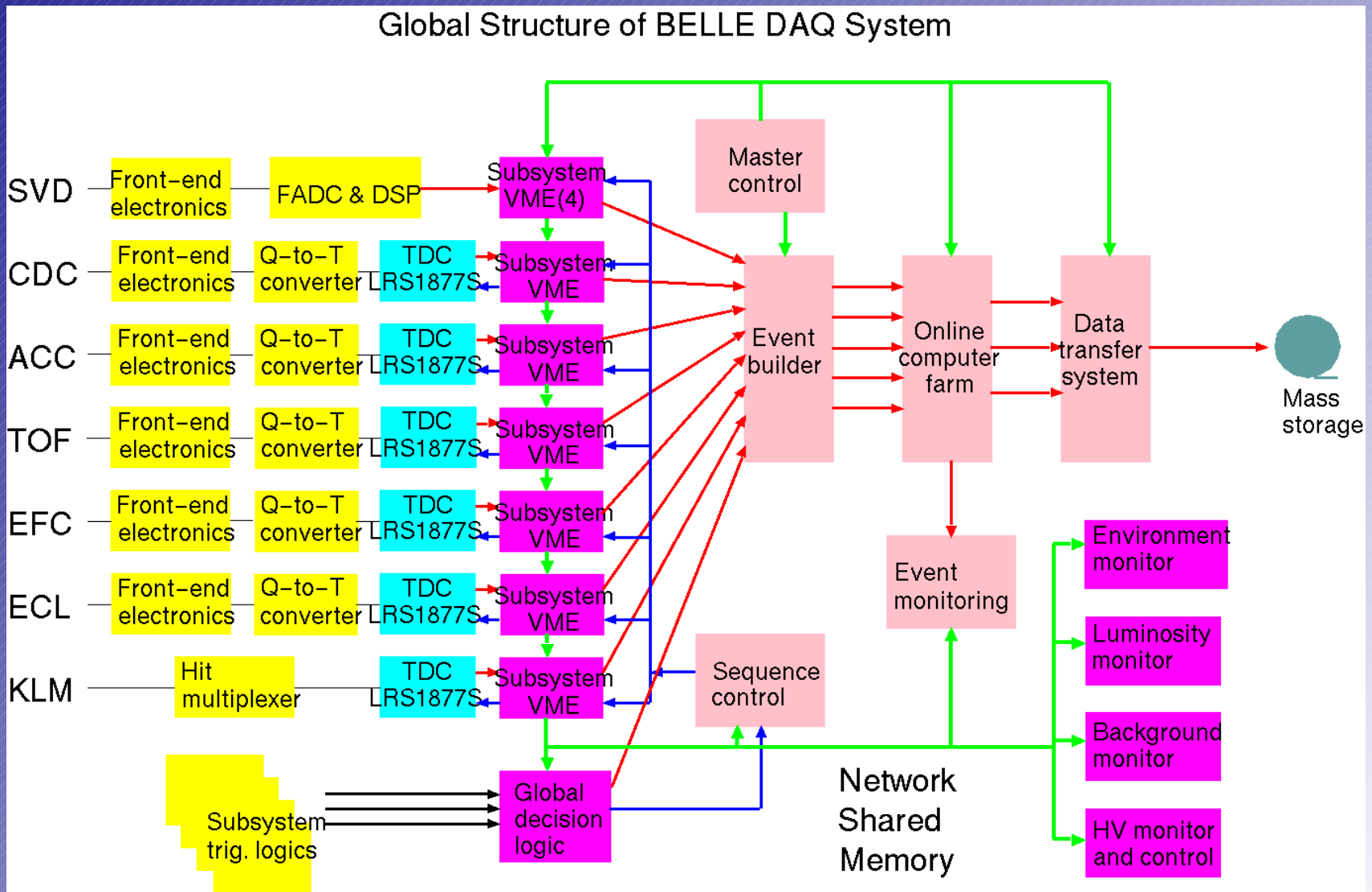
However,
* Original DAQ design was based on 90's technologies which were hard to maintain. -> unstable, large dead time ... at the beginning
* Long running time to accumulate statistics (up to 10 full months/yr)
  -> no long shutdown was allowed for the upgrade
* Need to keep up with the technology innovations over 10 years....

"Continuous" upgrade utilizing short vacations in summer and winter

2. History of Belle DAQ

2.1 Early days (1999)

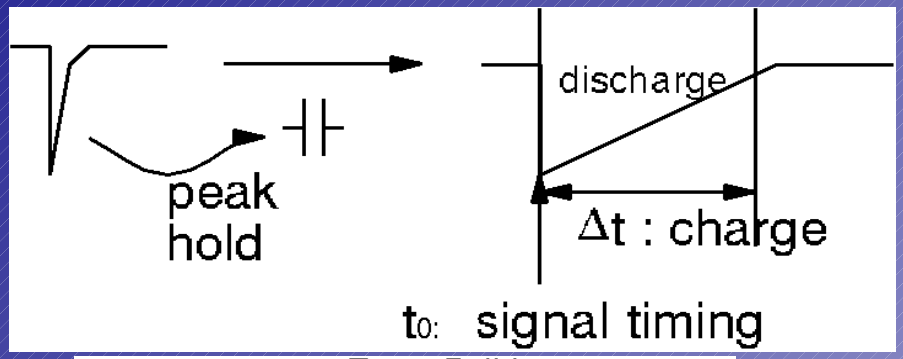
Initial requirements:
- L1 trigger rate : 200Hz (typical), 500Hz (max)
- Raw data size : 30KB/event

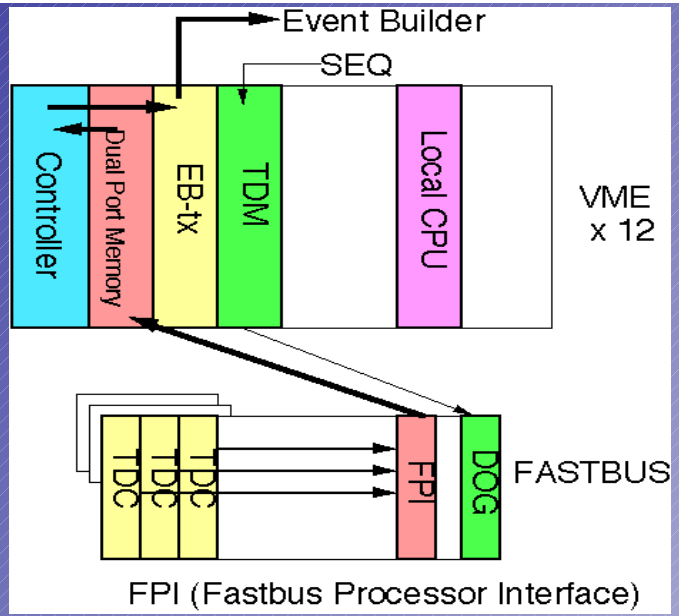


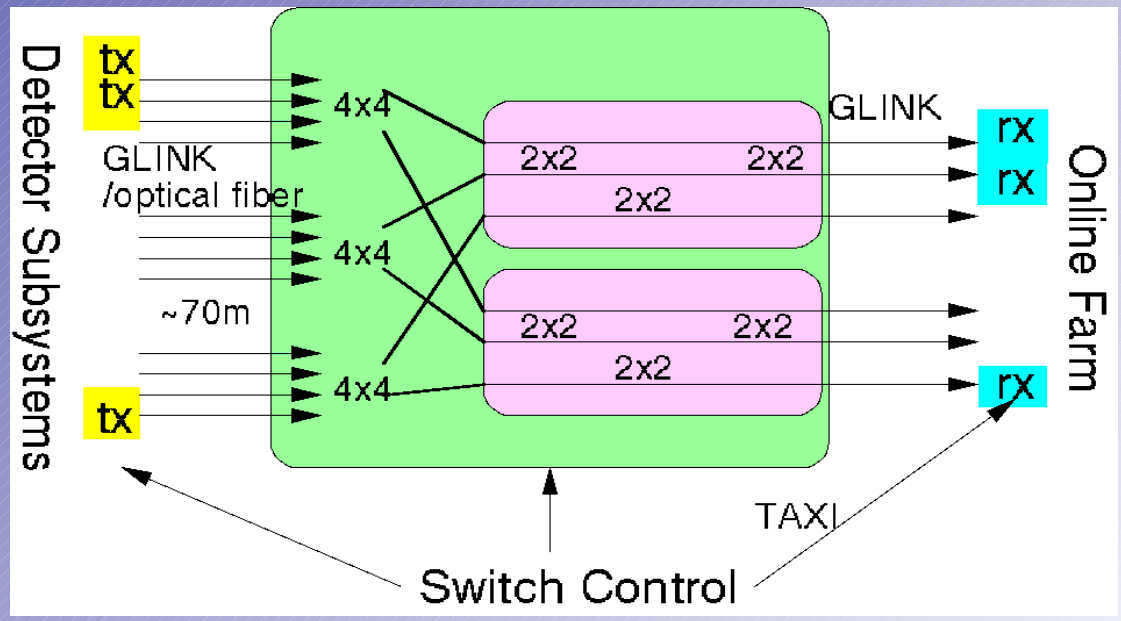
Used techniques : based on 90's technology – proprietary hardware

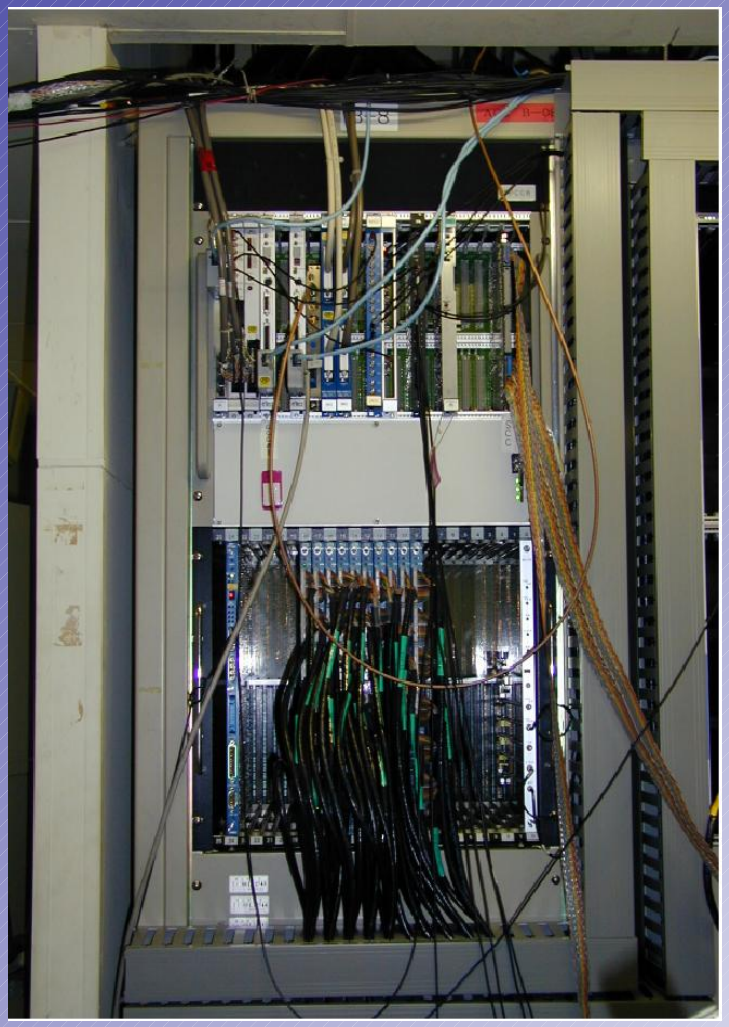
IT technologies were not available yet.

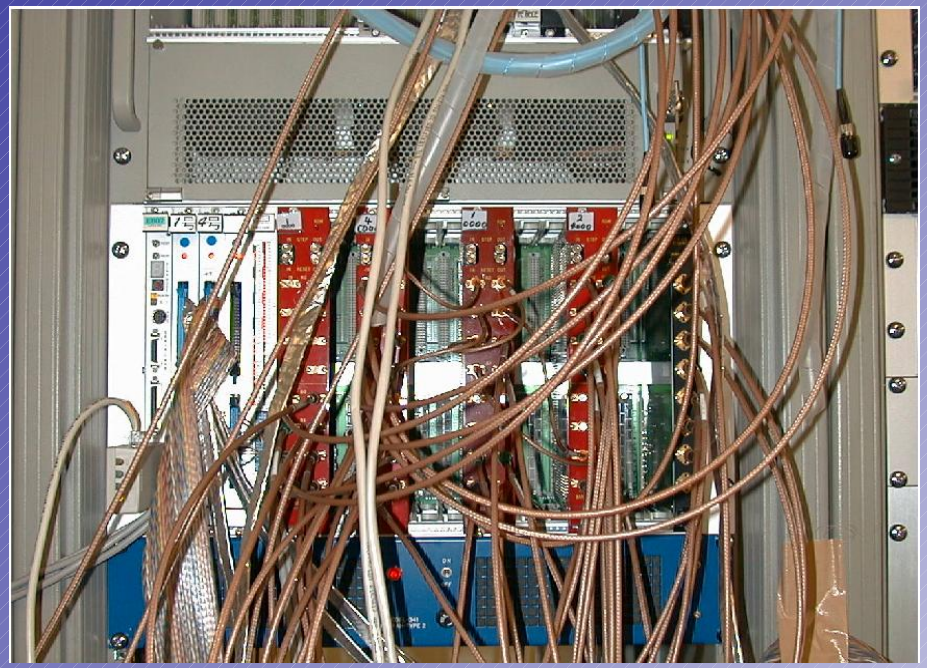
- Unified readout based on Q-to-T conversion + FASTBUS TDCs
- Readout was not pipelined
- Custom designed event builder (barrel switch +G-link)
- Level 3 trigger farm utilizing industrial VME CPU boards
- Data storage using digital video tape used for broadcasting

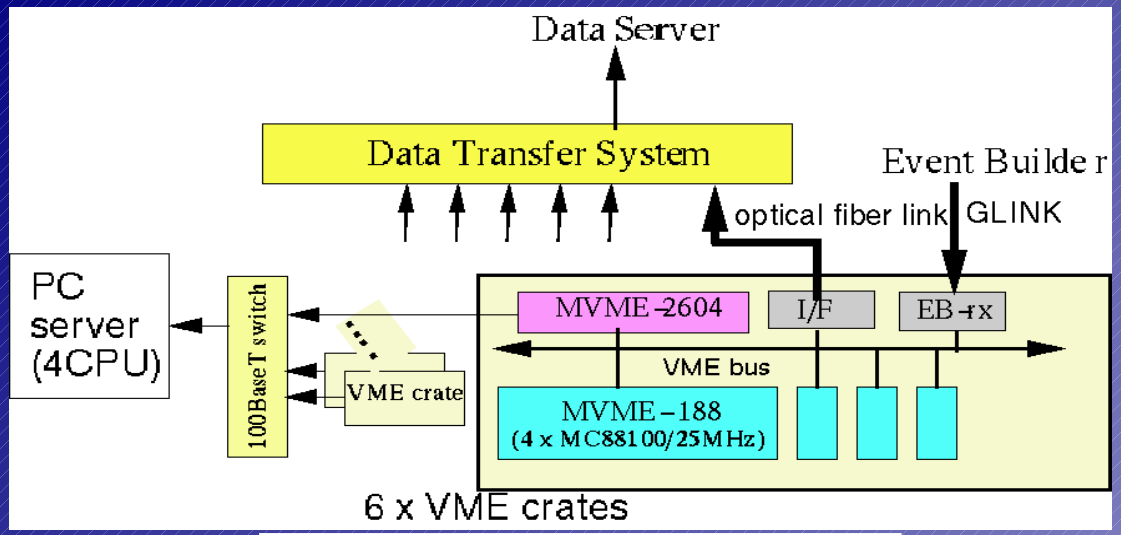




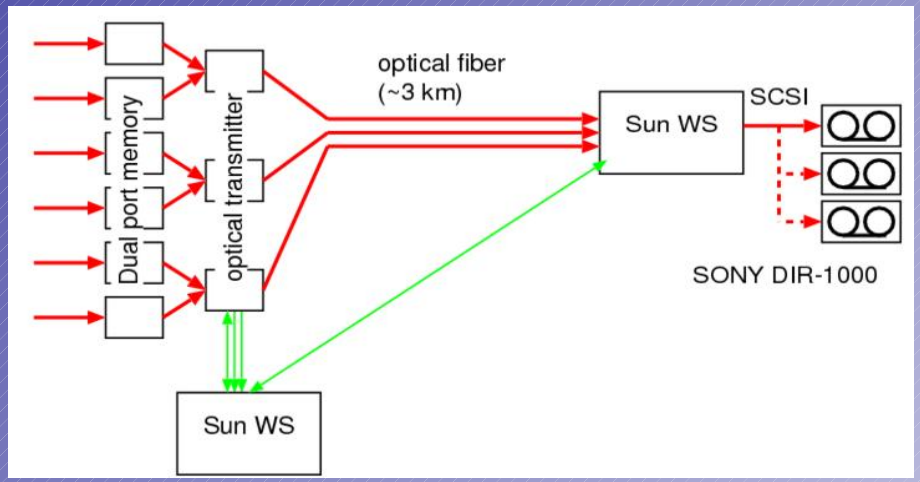


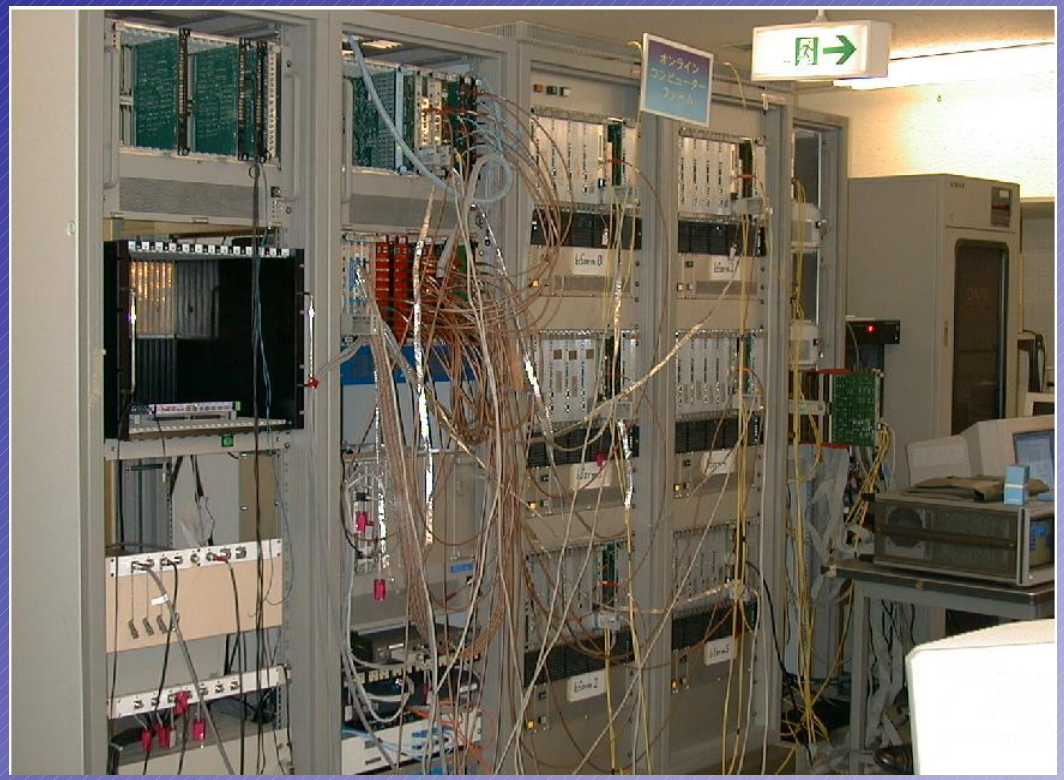


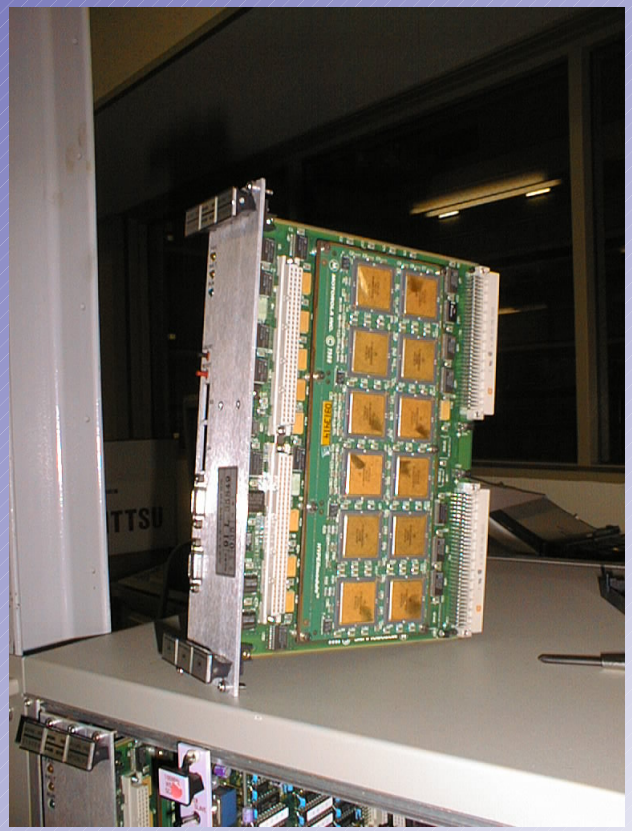




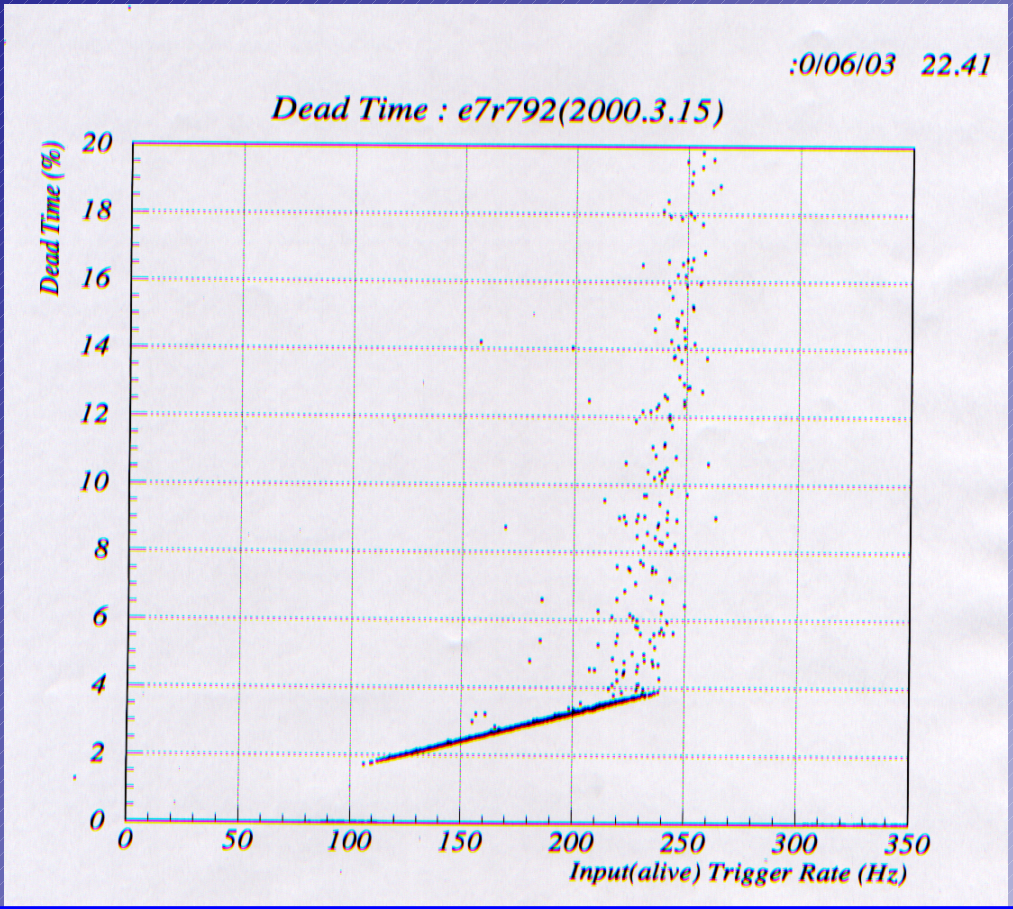
96 x MC88100 (~ 2000 MIPS)







Dead time fraction vs. L1 trigger rate in 2000

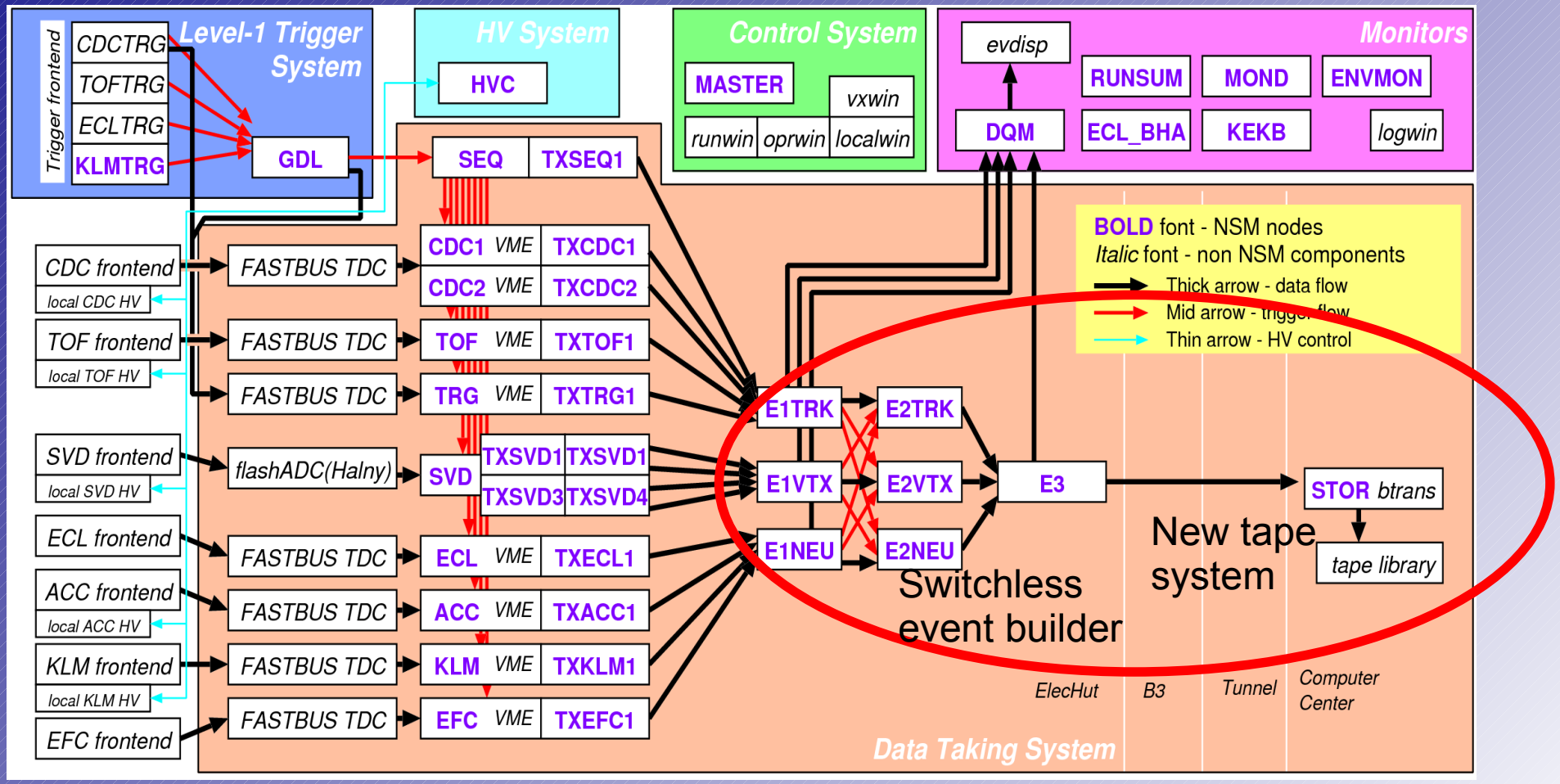


* DAQ dead time of ~ 3% at 200Hz.
* Performance saturation @ ~240 Hz due to a lack of processing power of online farm.
* Most of subsystems consisted of proprietary hardware
  -> difficult to maintain for a long period

→ Upgrade required!

2.2 2001 upgrade: transition to commodity

- Event builder, L3 farm and data transfer system were replaced with network-connected PC servers in 2001.
  <- Utilize commodity technologies (PC, 100BaseT,GbE....)



M.Nakao

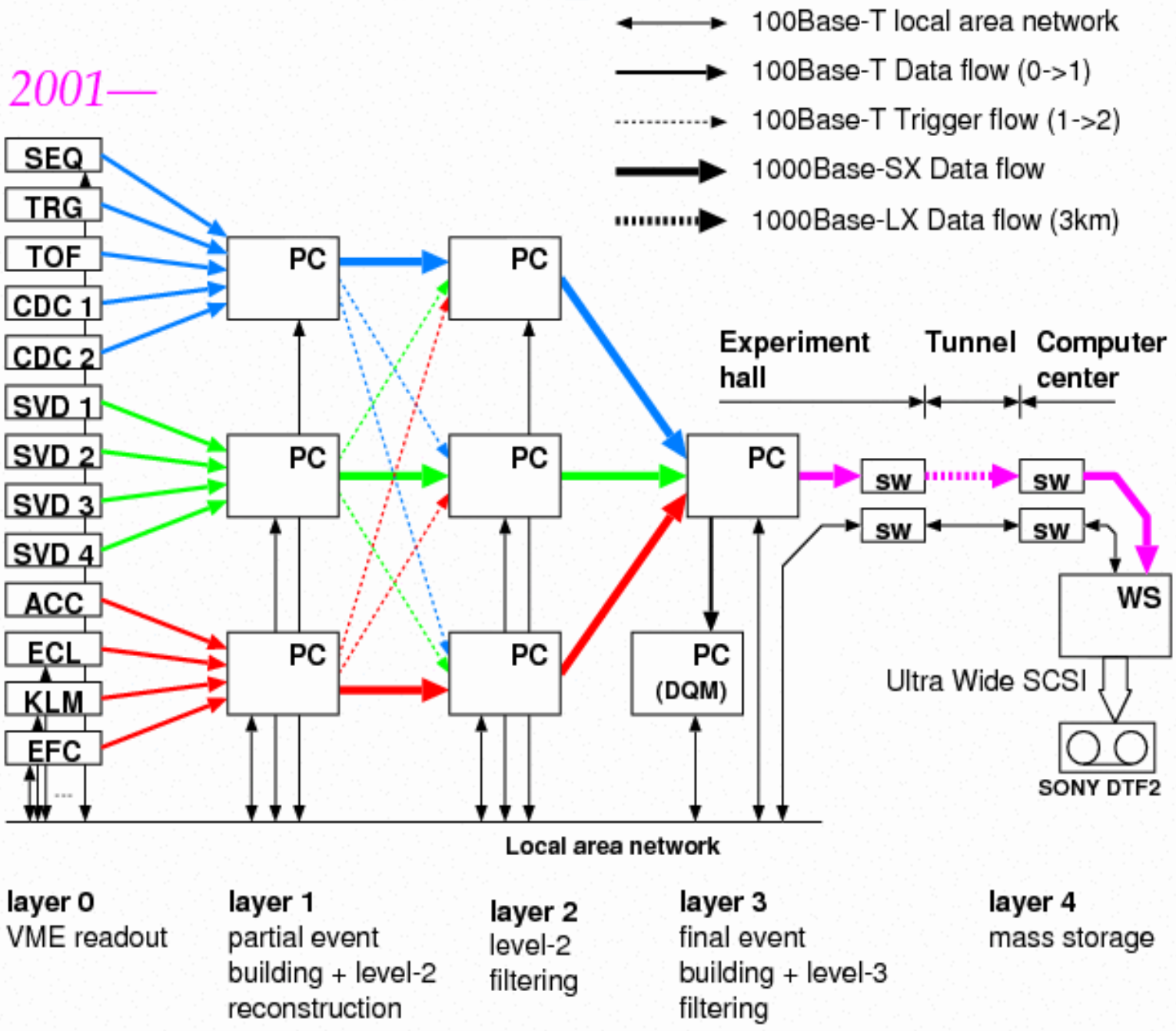
Switchless event building farm

Since Summer 2001—

Fast PC +
Fast network

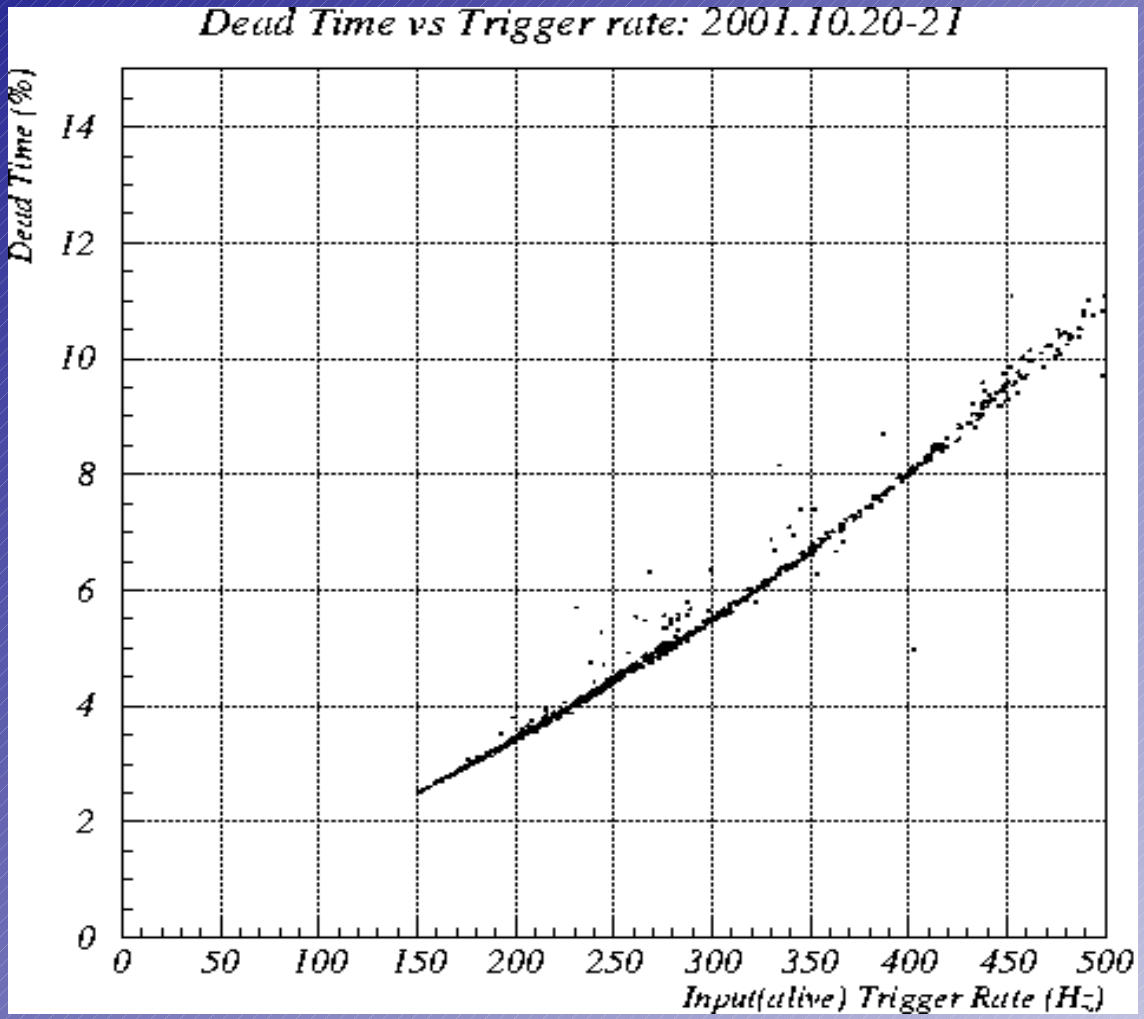
but

No switch!
point-to-point



PC: 700MHz Quad Xeon, L2.5 trigger software on layer 1 nodes.

Dead time fraction vs. L1 trigger rate in 2001



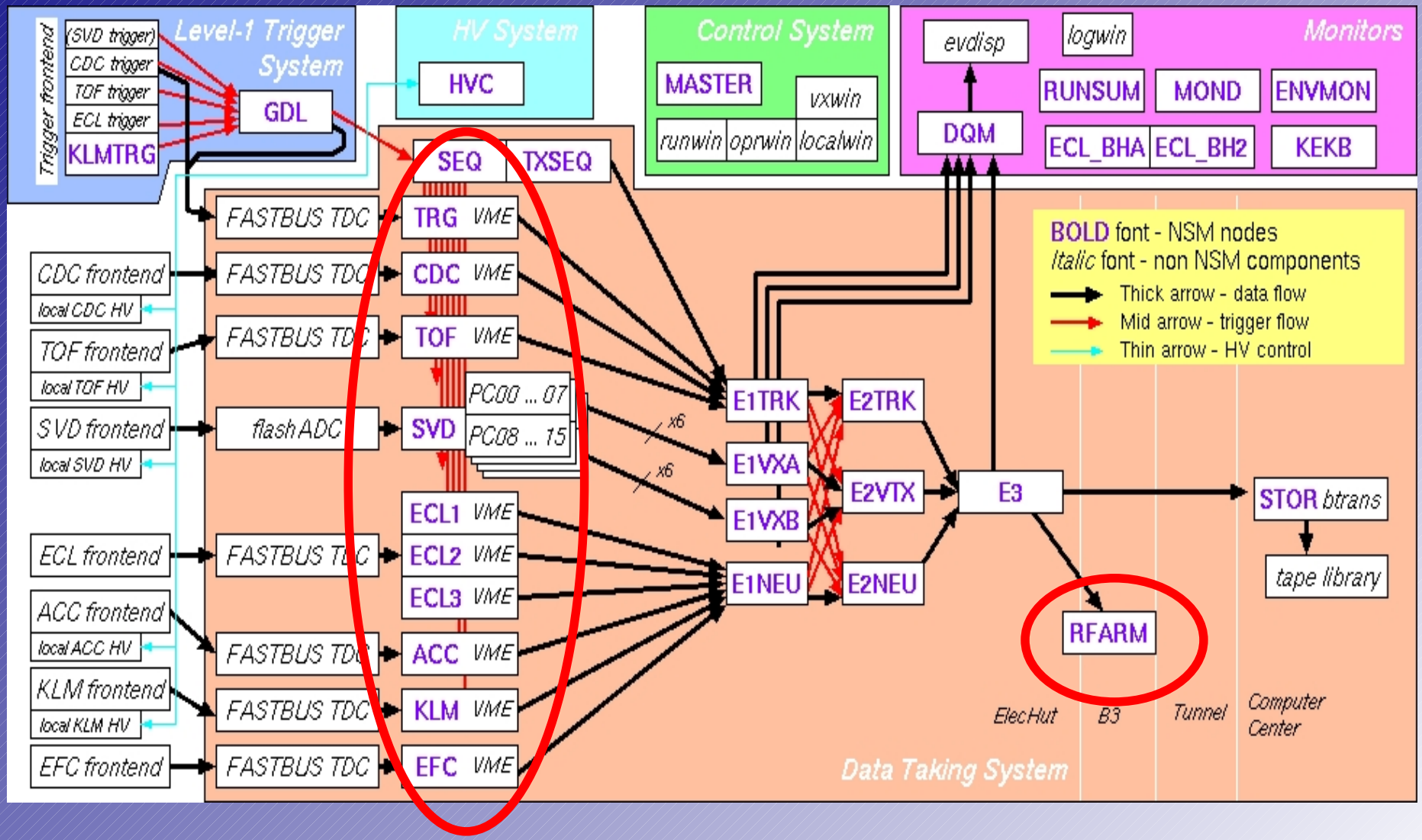
* No performance saturation up to 500Hz.
  -> Initial design performance was achieved

However,

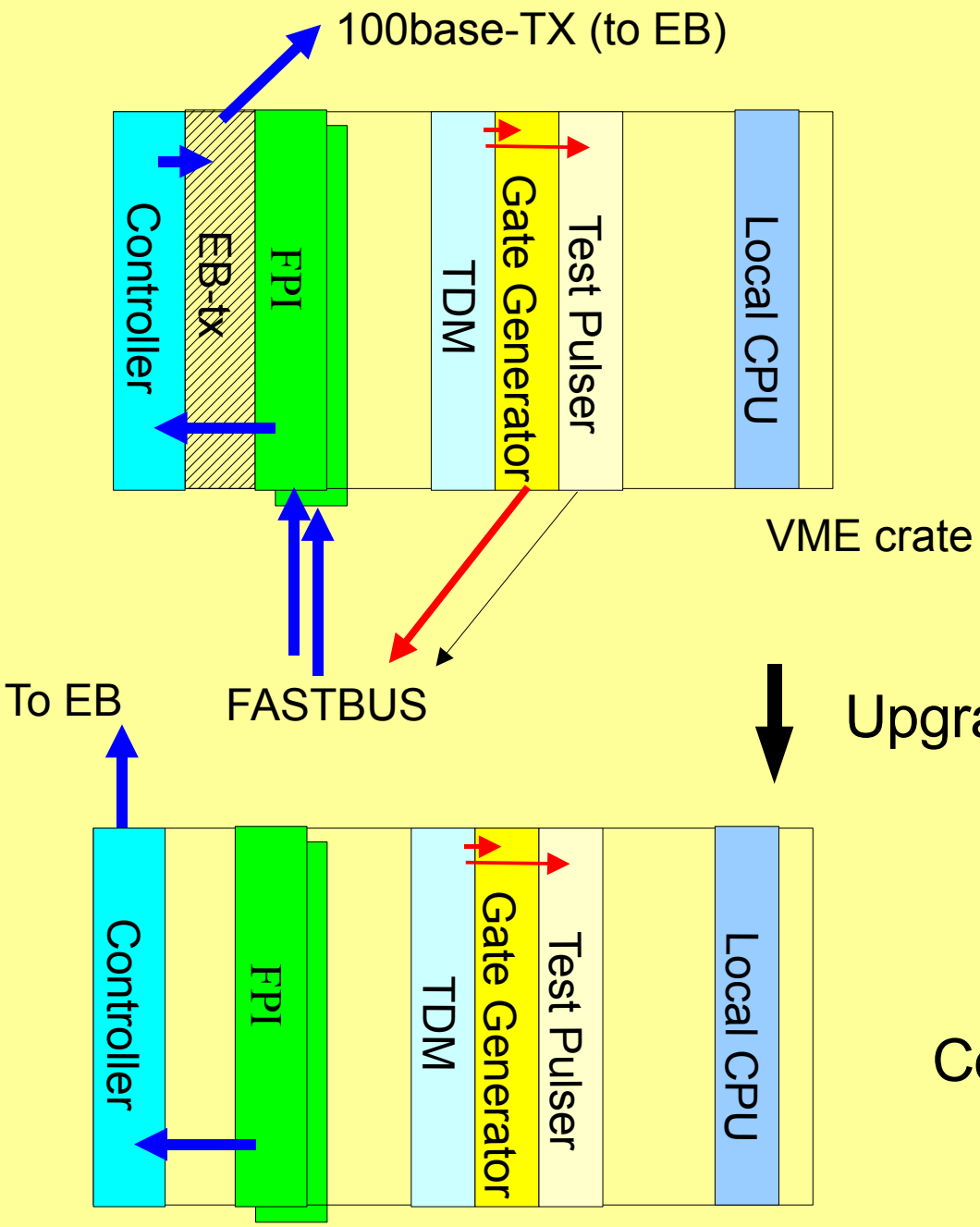
* Dead time is still large (>5%) at >300Hz.

2.3 2003 upgrade : faster and more intelligence

- Speed up of FASTBUS readout
- Addition of real-time reconstruction farm (RFARM)



“Faster FASTBUS Readout”



2-fold DMA:
FPI -> Controller
Controller -> EB-tx
(Event builder I/F)

↓

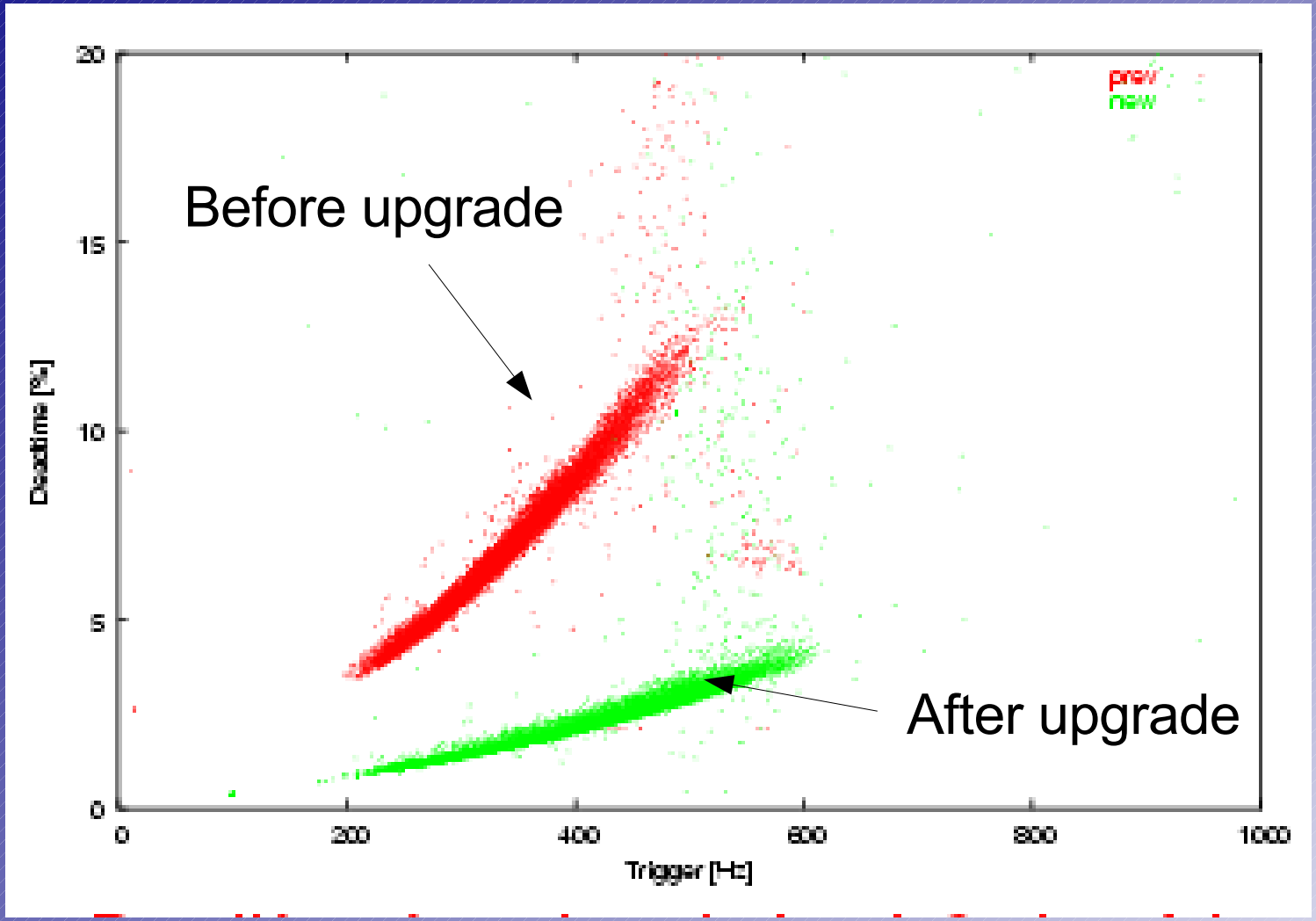
source of intrinsic readout time

Controller : MVME162
(MC68040@25MHz)

1-way DMA:
FPI->Controller

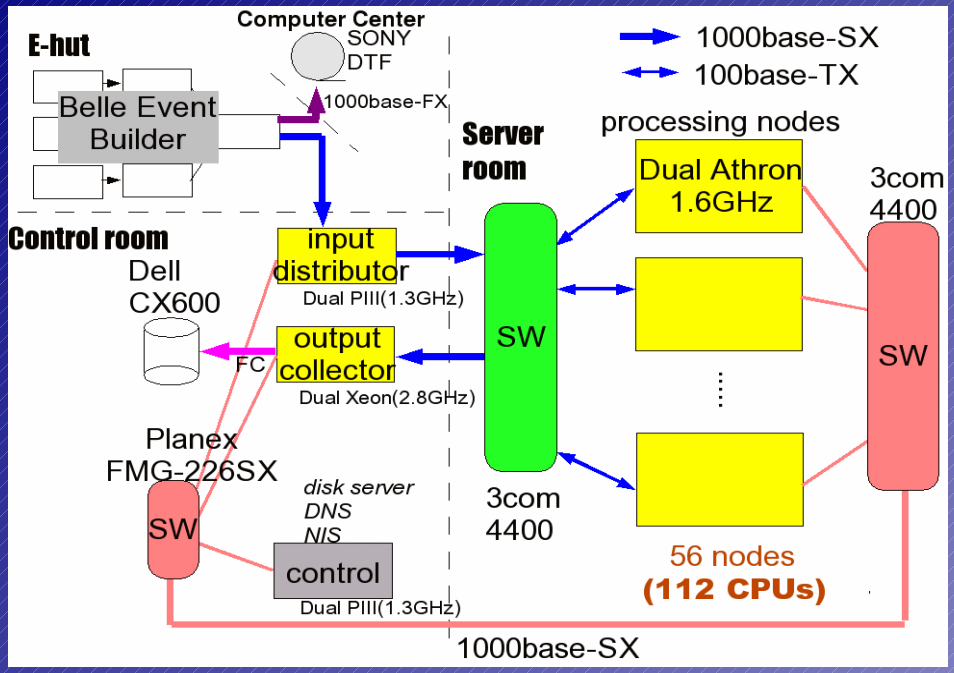
Controller : MVME5100
(PowerPC(MPC750) @300MHz)
w/ 100base-TX interface

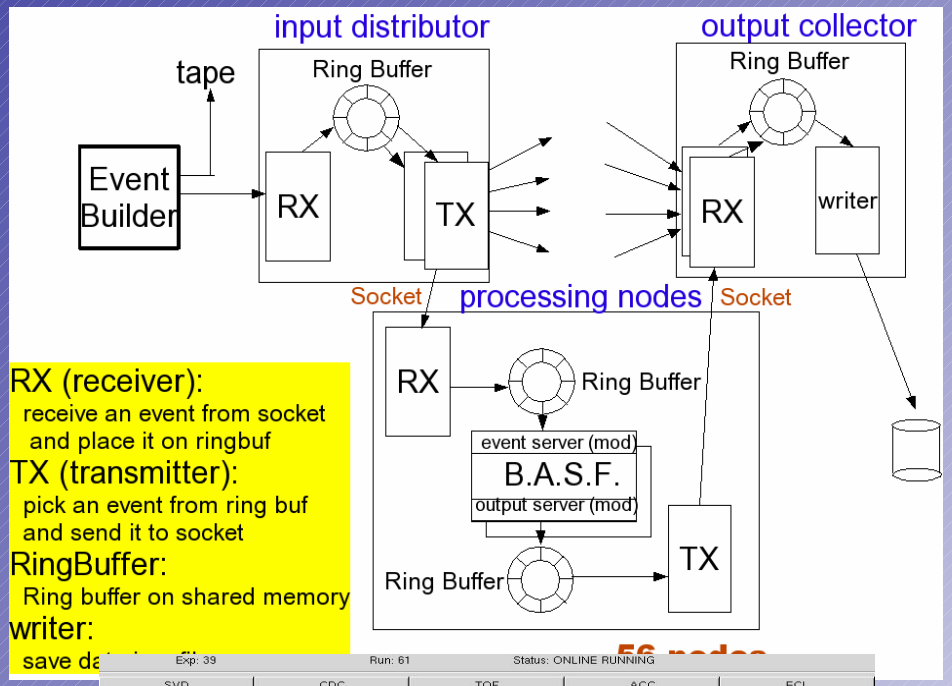
Dead time fraction vs. L1 trigger rate in 2003

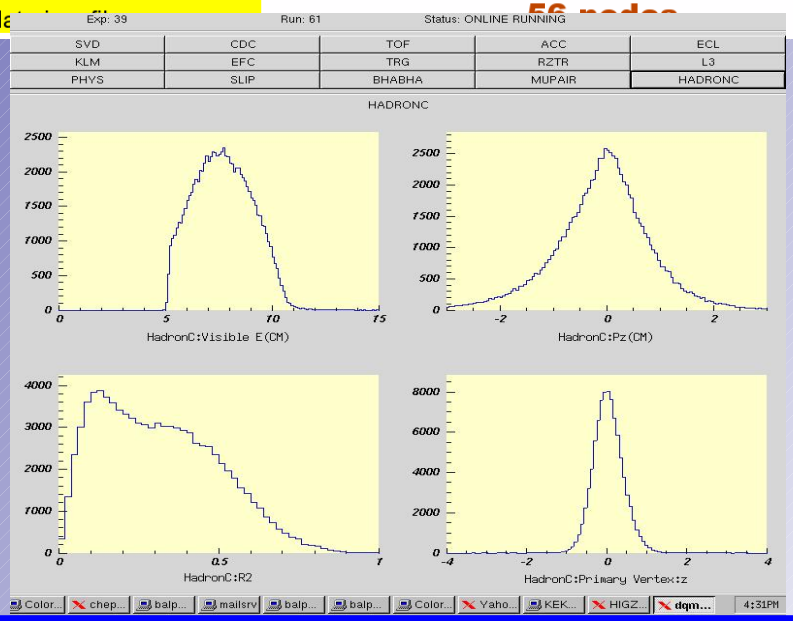


* Dead time fraction = 2% @ 300Hz, <5% @ 500Hz

RFARM





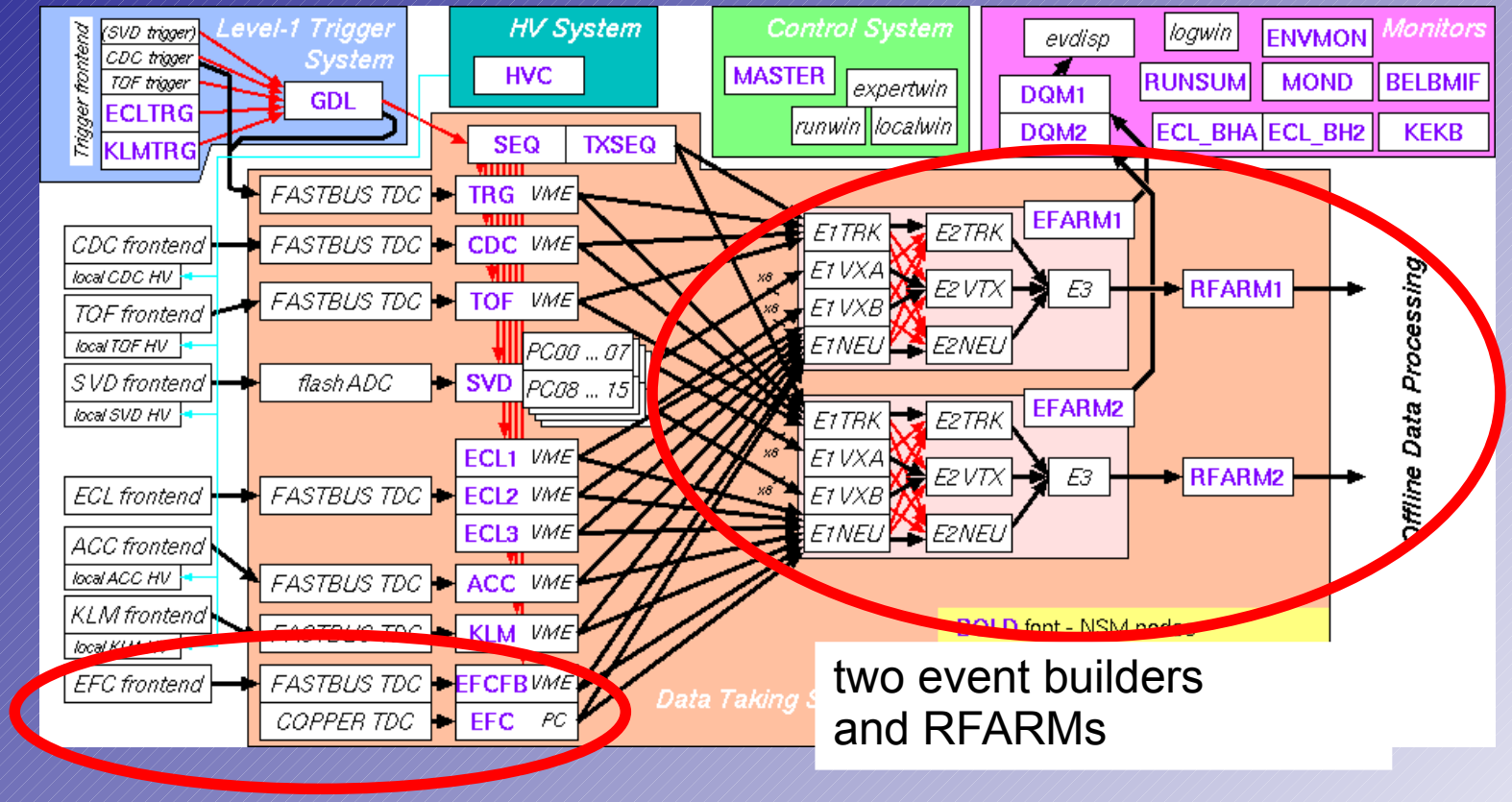


- The same offline event reconstruction for all taken events in real time -> real time feedback of event vertex to accelerator

=> greatly contributed to increase the luminosity

2.4 2005 upgrade : preparation for higher luminosity

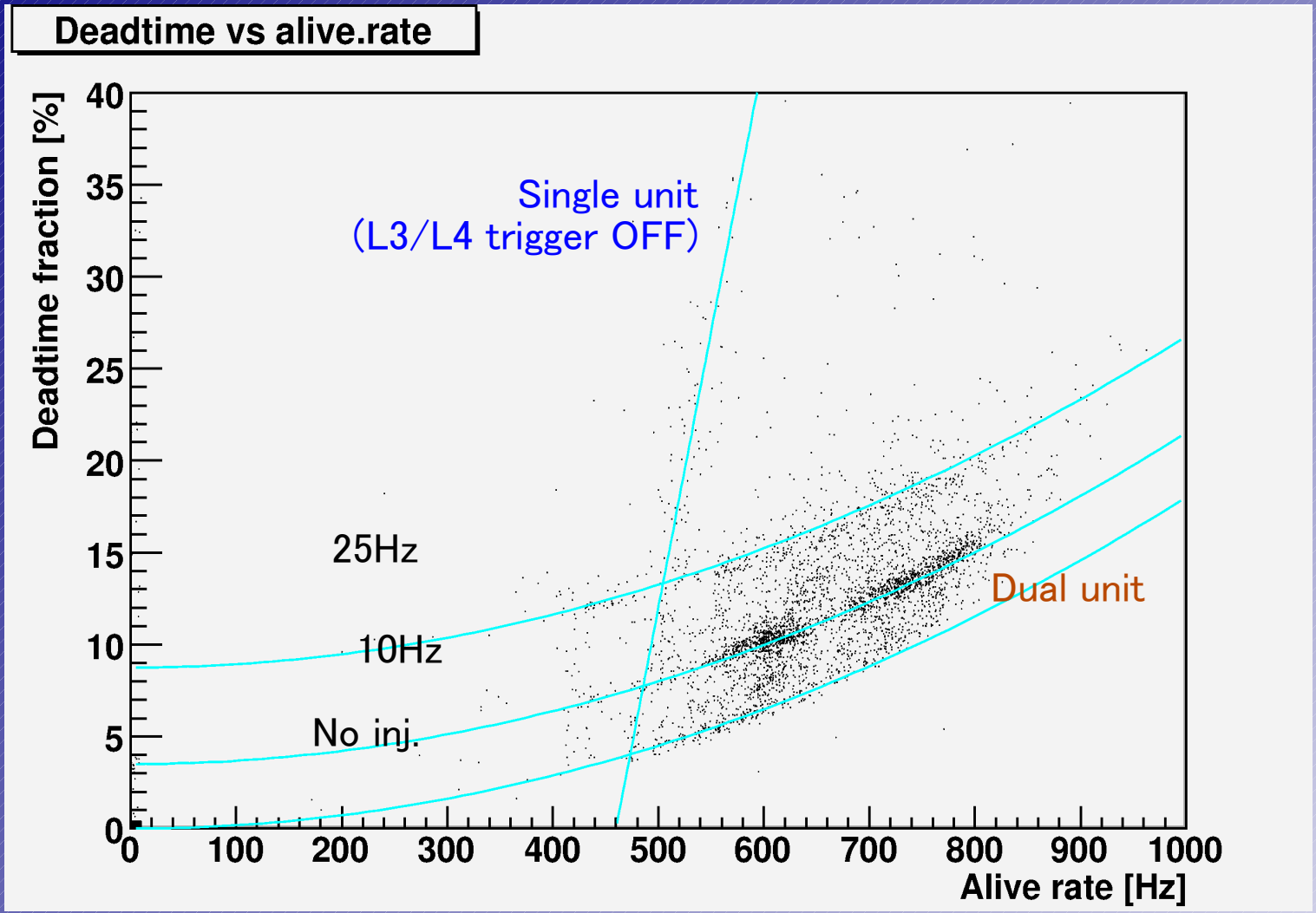
- Duplexing of event builder + RFARM for the preparation of higher trigger rate up to 1kHz
- Stop tape recording and switch to direct RAID recording
- Start testing of pipeline readout with COPPER



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

Transfer Network Matrix + Event Builder 1 and 2

Dead time fraction vs. L1 trigger rate in 2005



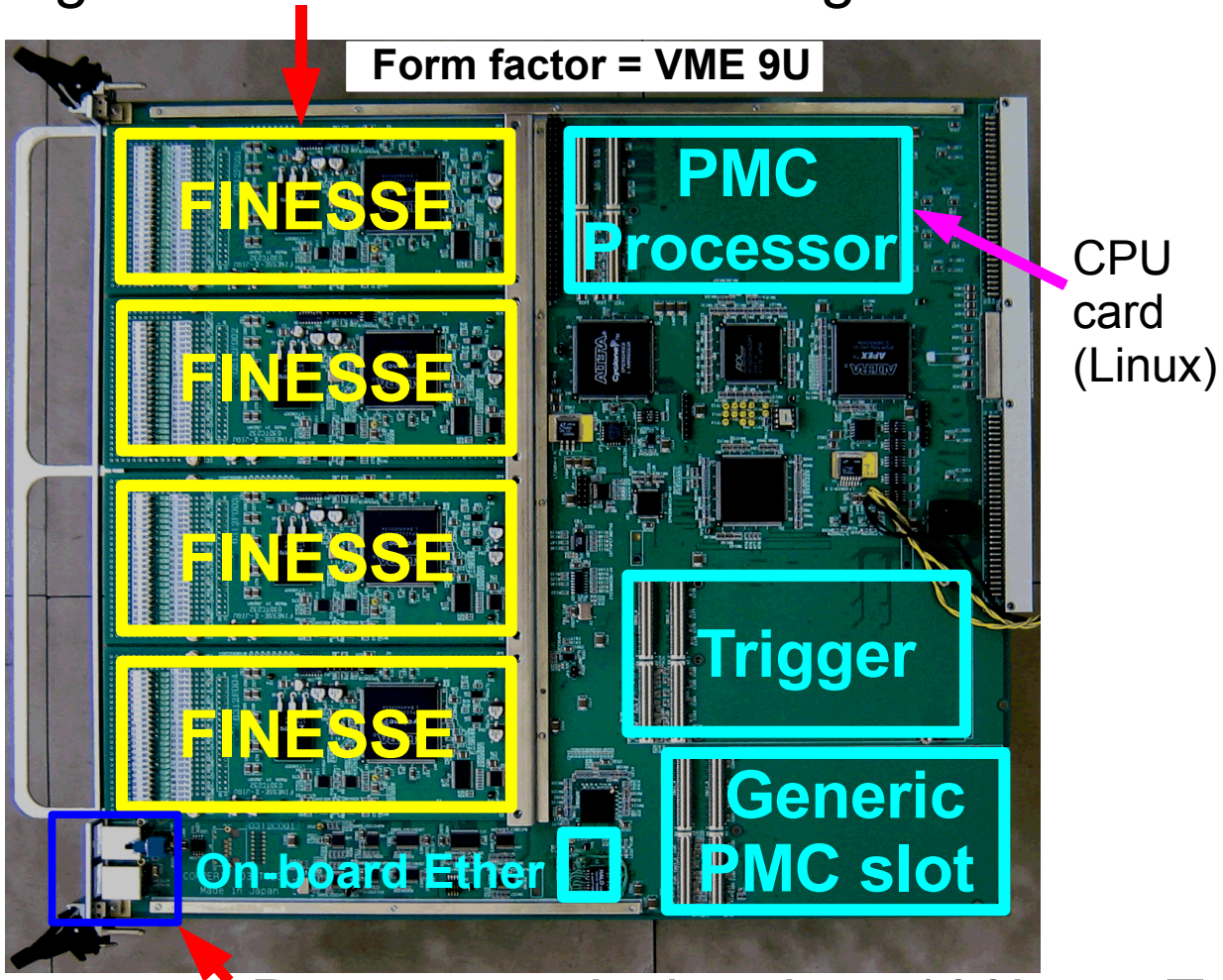
* Continuous injection : 3.5ms/injection deadtime -> +3.5%@10Hz
* Data taken on Y(2S) with loosened trigger condition

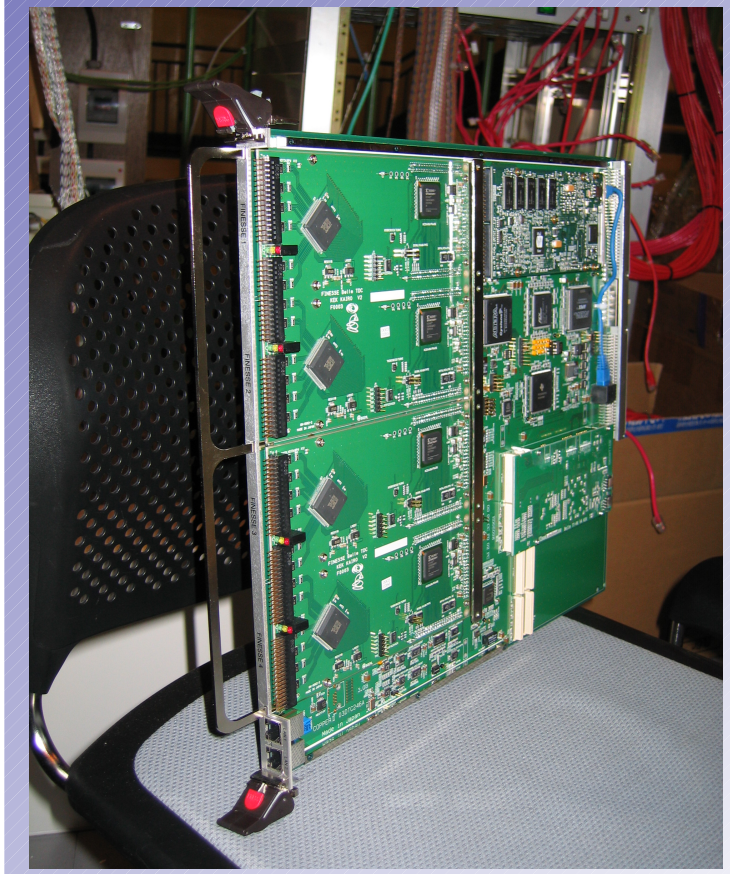
* “fault-torelent” operation of event builder and RFARM.

2.5 2007 upgrade and after : finally pipelined

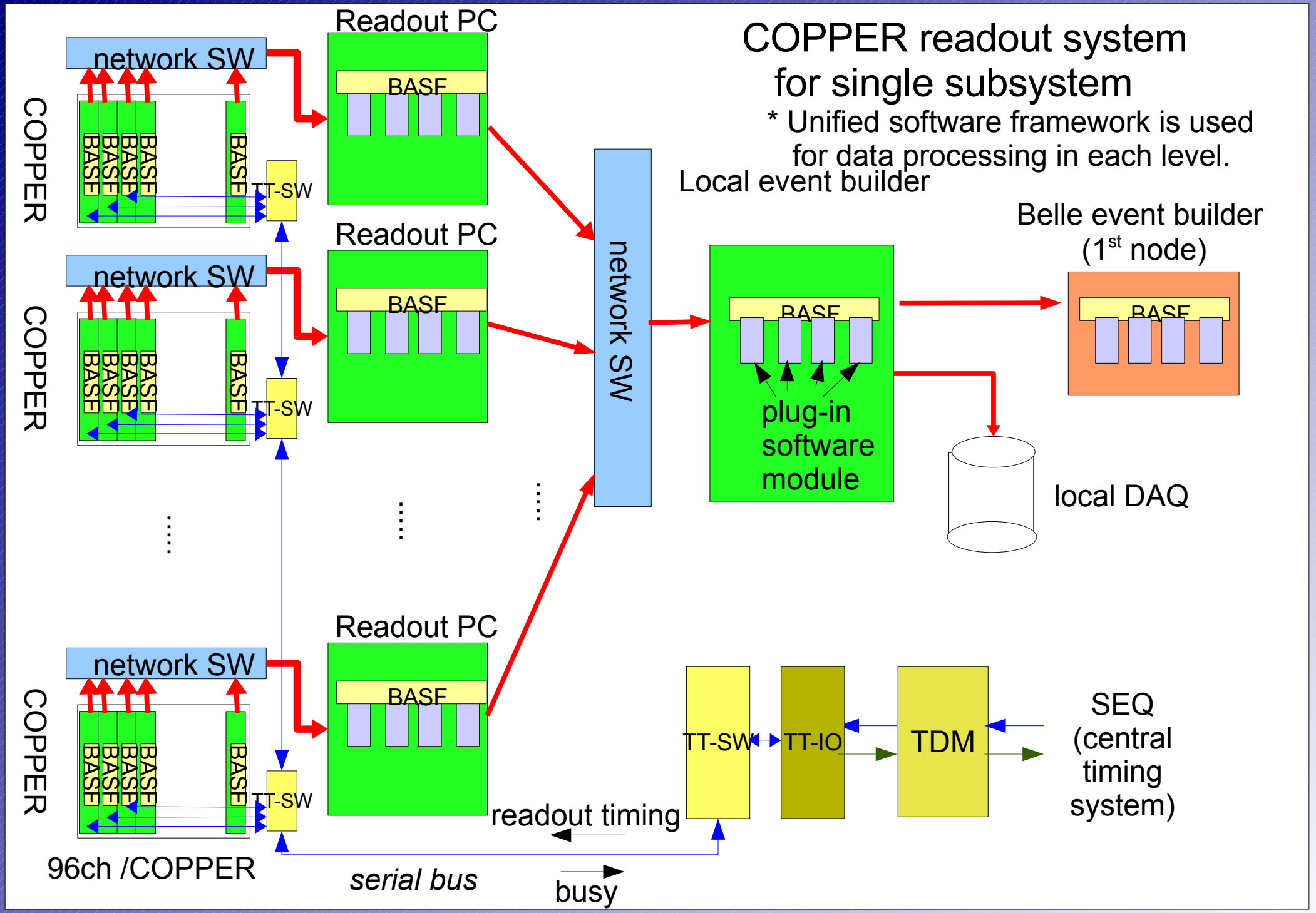
- Replacement of FASTBUS TDCs with pipelined ones.
- Pipeline TDC was developed based on “COPPER” platform which is a general purpose pipeline readout board developed at KEK.

digitizers are mounted as daughter cards

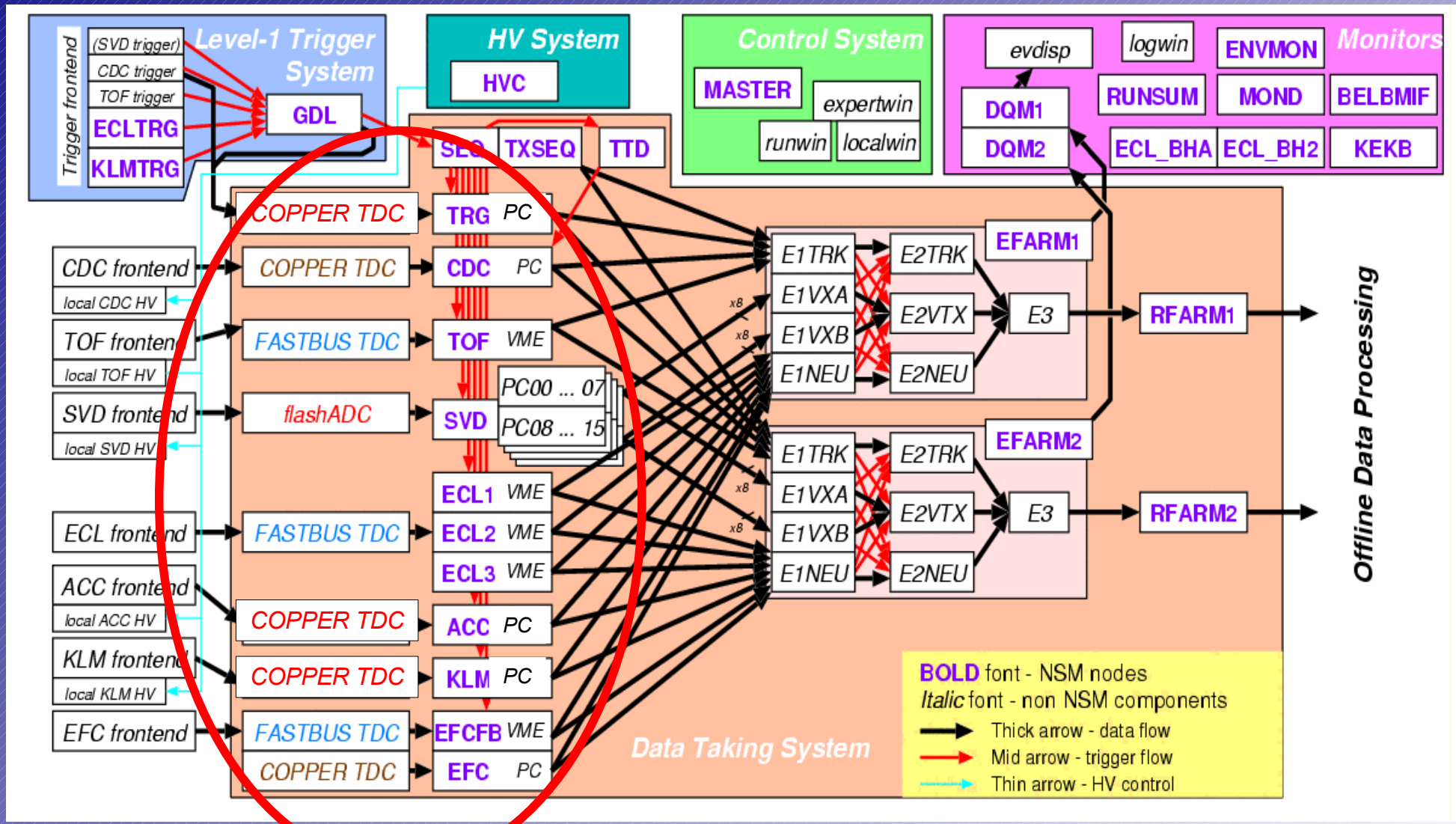




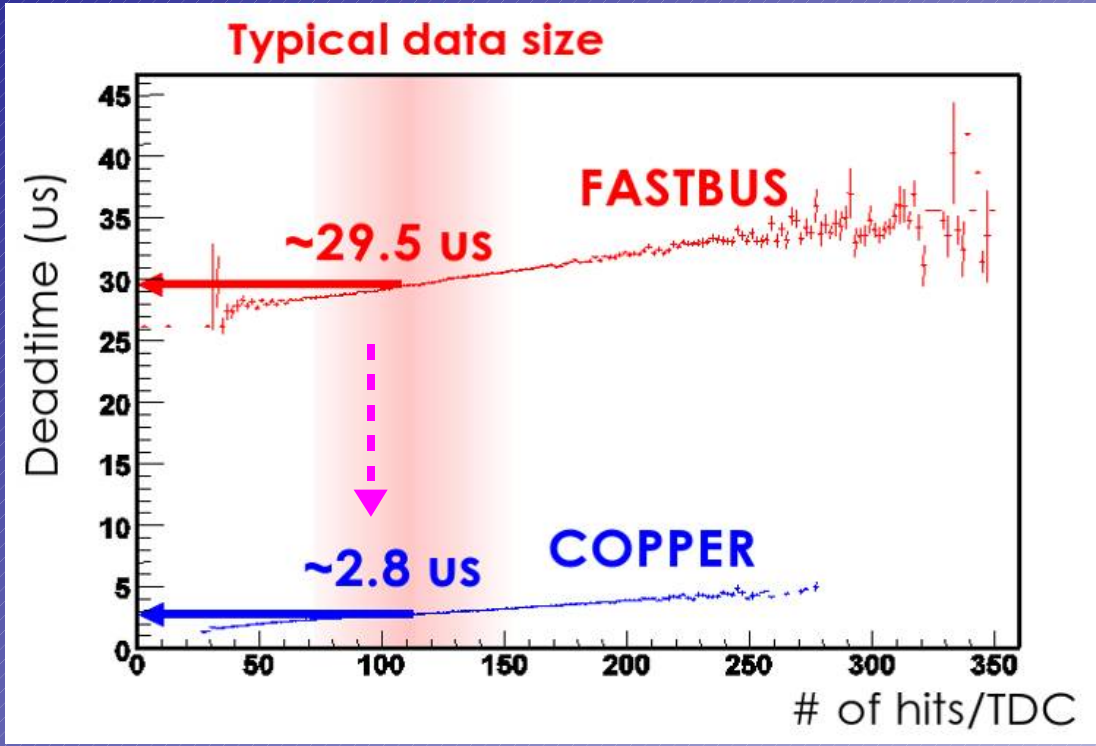
digitizer cards with AMT3 TDC chips


COPPER readout system
for single subsystem
* Unified software framework is used
for data processing in each level.
Readout PC
network SW
BASF
TT-SW
COPPER
Local event builder
Belle event builder
(1st node)
plug-in
software
module
local DAQ
TT-SW
TT-IO
TDM
SEQ
(central
timing
system)
readout timing
busy
serial bus
96ch /COPPER

* The replacement with COPPER TDCs was performed gradually subsystem by subsystem starting from CDC in Jan. 2007.
* 5 subsystems out of 8 have been already replaced .
-> ~150 COPPERs + 13 readout PCs



Readout “busy” time vs. data size (# of hits)

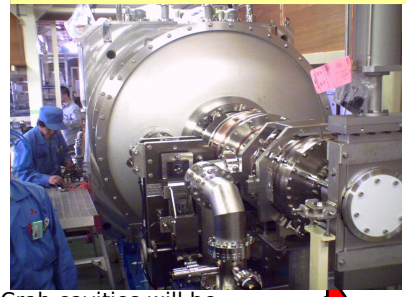


Dead time fracton of replaced systems has been reduced to < 1% @ 1KHz.

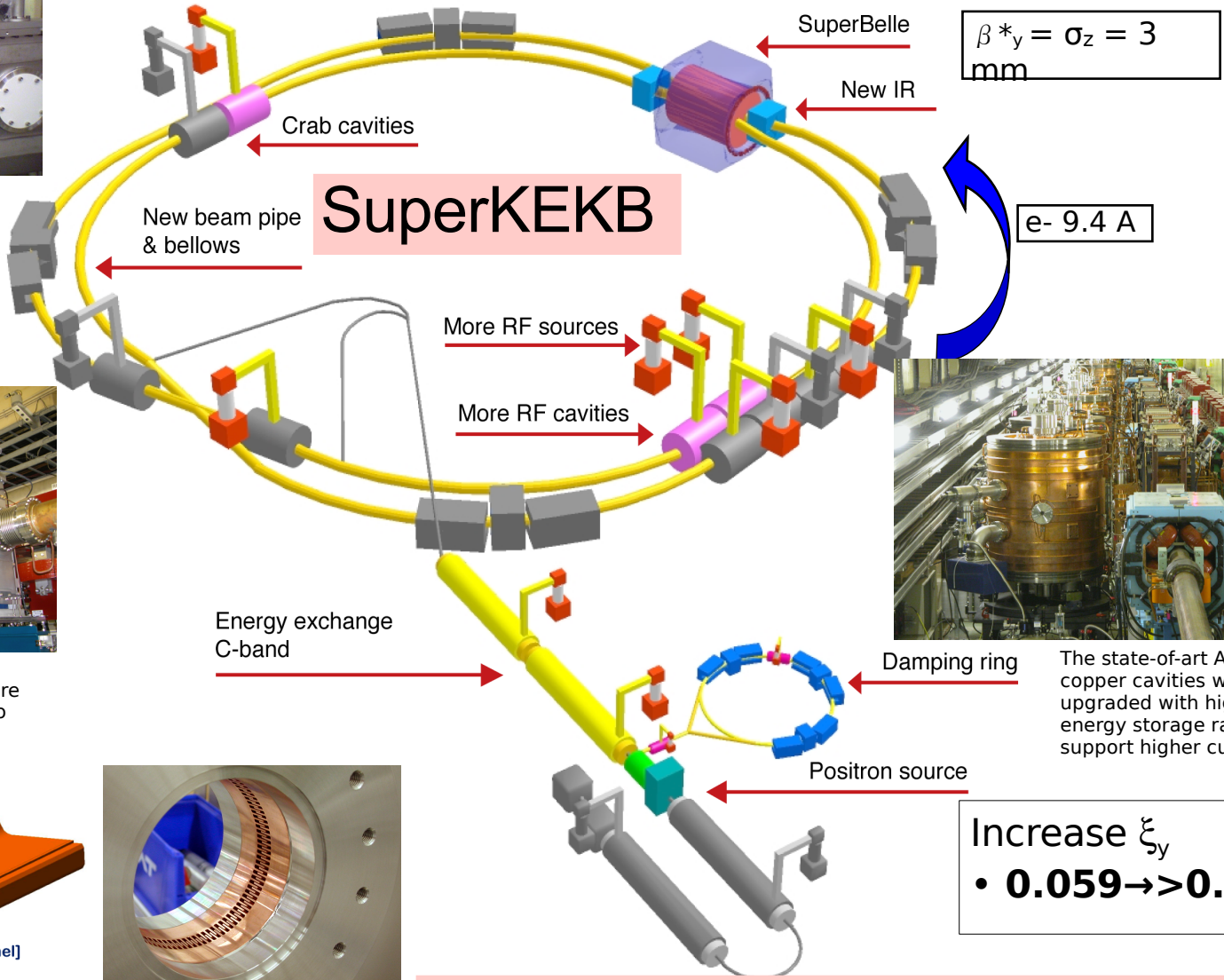
- FASTBUS readout still remains..... (TOF and ECL)
  -> planned to be replaced further, however.....

4. Go beyond: SuperKEKB and Belle II

The upgrade of current KEKB accelerator to SuperKEKB is being planned for the further studies of *B* and other flavor physics.



Crab cavities will be installed and tested with beam in 2006.



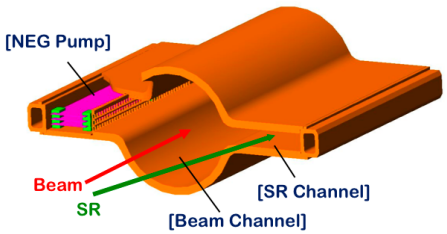
$\beta^*_y = \sigma_z = 3$ mm

e- 9.4 A

e+ 4.1 A

The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.

The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.

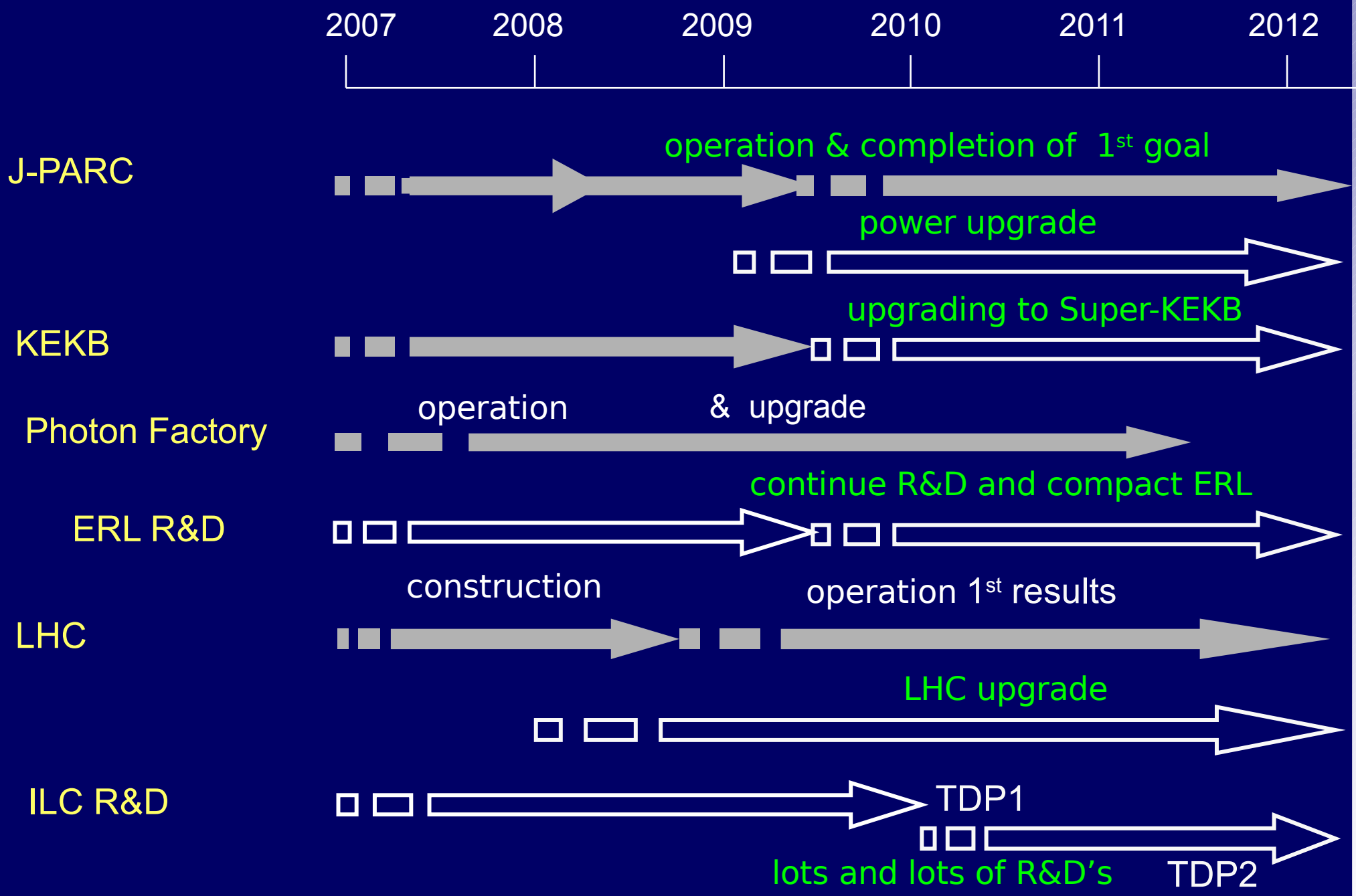


The beam pipes and all vacuum components will be replaced with higher-current-proof design.

Increase ξ_y
- **0.059→>0.30**

will reach 8×10^{35} cm^{-2}s^{-1}.

Summary of KEK Roadmap



Expected DAQ condition in Belle II

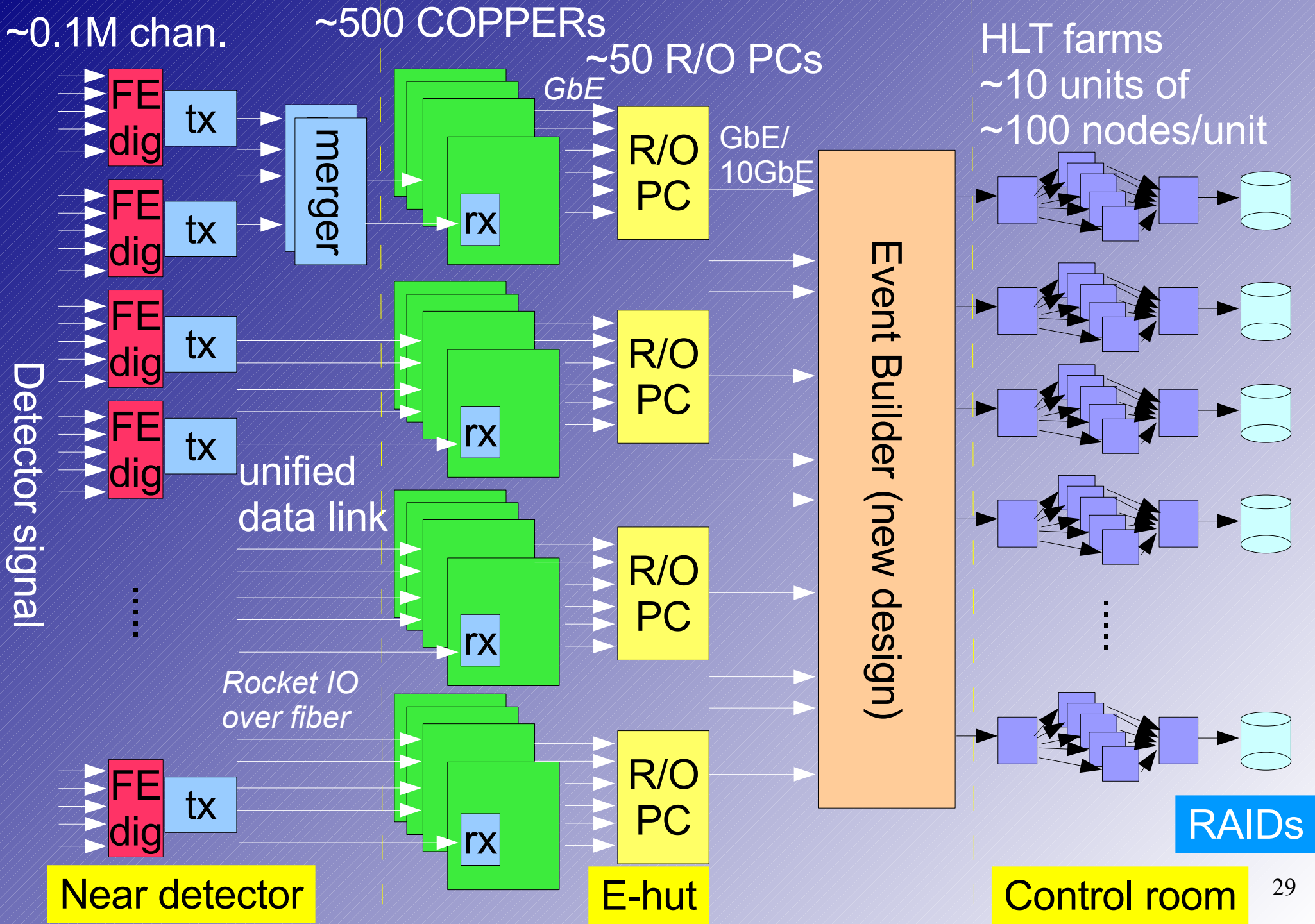
	Current Belle	Upgraded KEKB
Typical L1 rate	0.5kHz	20kHz
(Maximum L1 rate	~1kHz	~30kHz)
L1 data size(in)	40kB/ev	300kB/ev
flow rate(in)	20MB/sec	6GB/sec
L3+HLT reduction	1/2	~1/20 (physics skim)
Storage badwidth (raw data only)	20MB/sec	300MB/sec

DAQ design for Belle II

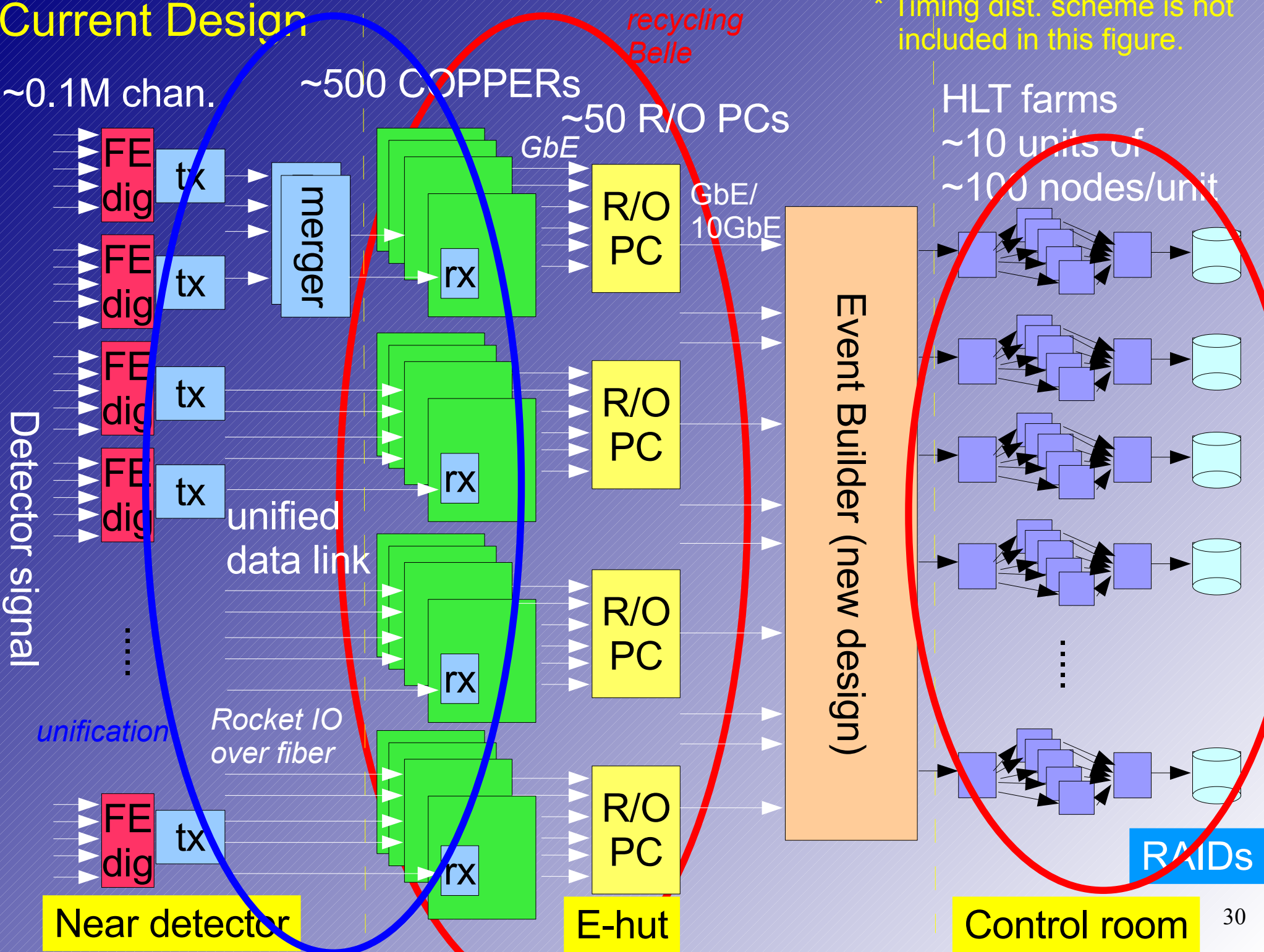
* Smooth transition from Belle DAQ
* Maximum use of Belle's legacy : We have only 3-4 years to go
  - COPPER based readout
  - HLT farms based on Belle's RFARM
* Readout unification again!
* Deadtime-less readout

Current Design

* Timing dist. scheme is not included in this figure.



Current Design



4. Conclusions

- KEKB/Belle has been running since 1999 without any big troubles and collected the world's largest data set of B meson decays. -> produced many physics results.

- Belle DAQ has been continuously upgraded to keep up with the increasing luminosity and technology innovations.

- The smooth and continuous upgrade strategy was quite successful for the long term stable operation without sacrificing any running time.

- The DAQ for Belle II will be constructed based on the concept of Belle's “continuous upgrade”.