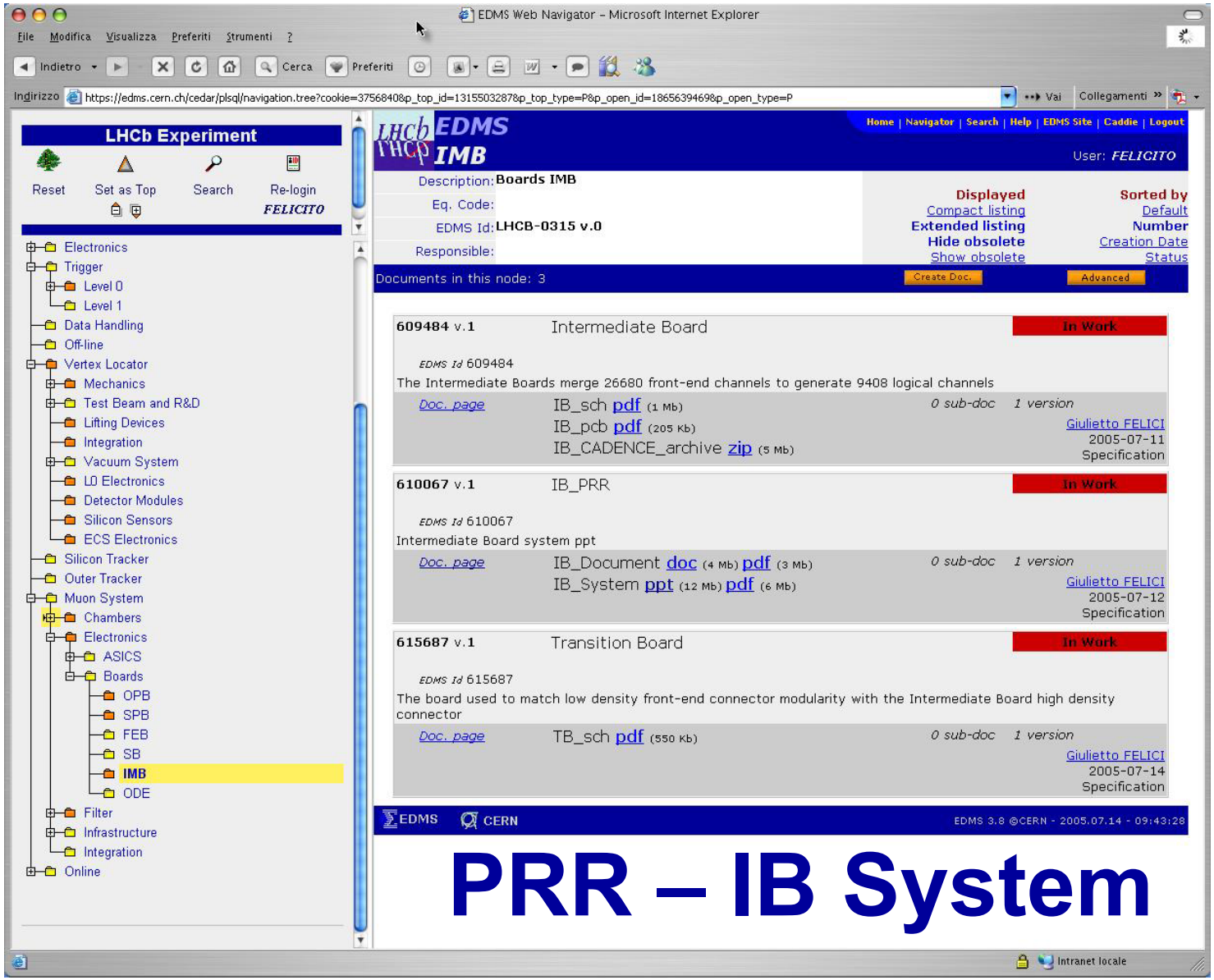
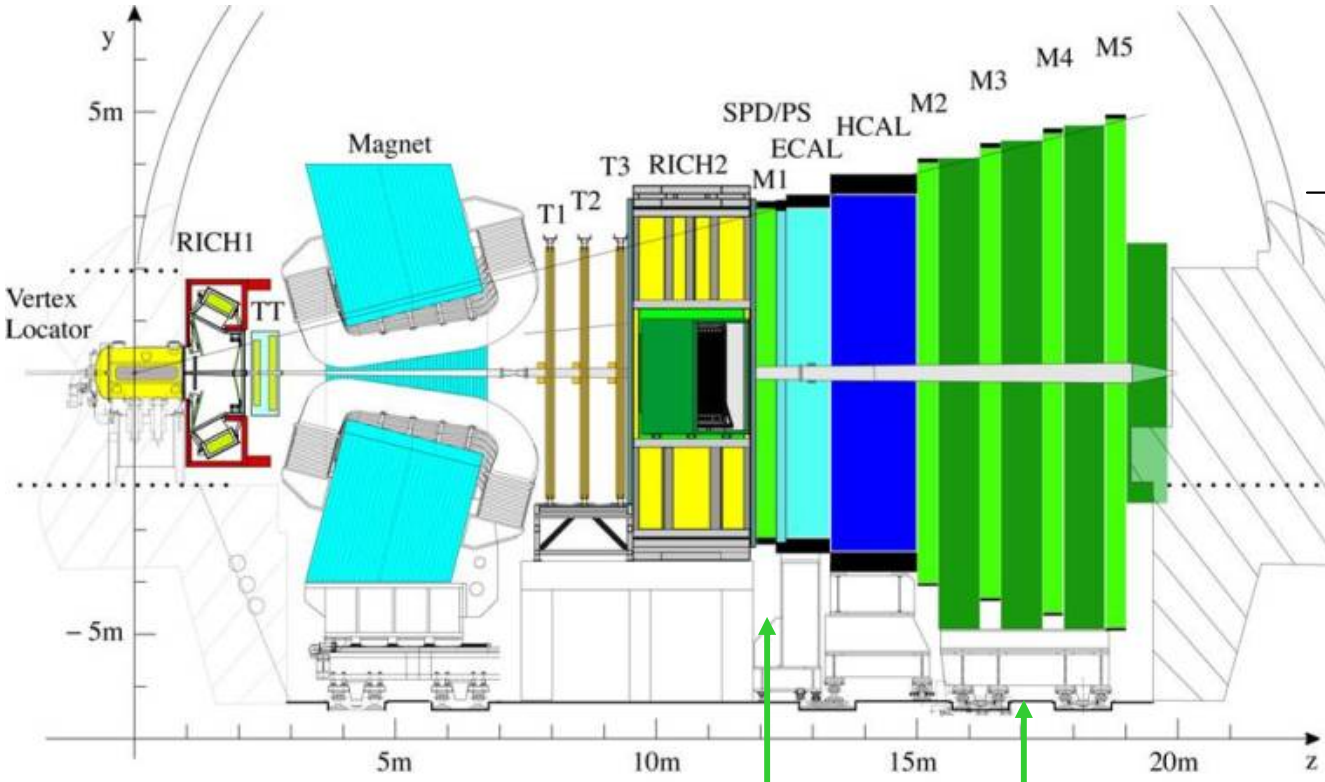


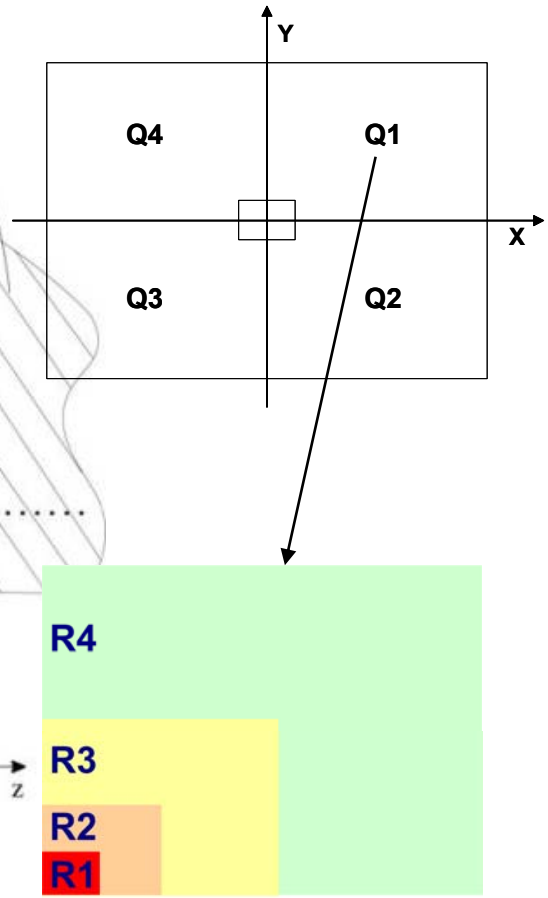
PRR – IB System

giulietto.felici@lnf.infn.it

- Why do we need the IB System ?
  - The apparatus
  - FEE Channels & Logical Channels
  - The FE chain
  - Station and Regions
- The IB System architecture
  - The IB and the TB boards
  - The IB and TB crate
- System qualification
  - Skew requirements
  - Skew measurements
  - Prototypes qualification test setup
  - Skew measurement results
  - Mass production test setup
  - Irradiation Test
  - Conclusions
  - Detector mapping example



Quadrants - Regions



Muon detector Station 1

Muon detector Stations 2-5

FEE channels & Logical Channels (Es: M3R3)

FEE channels

↓

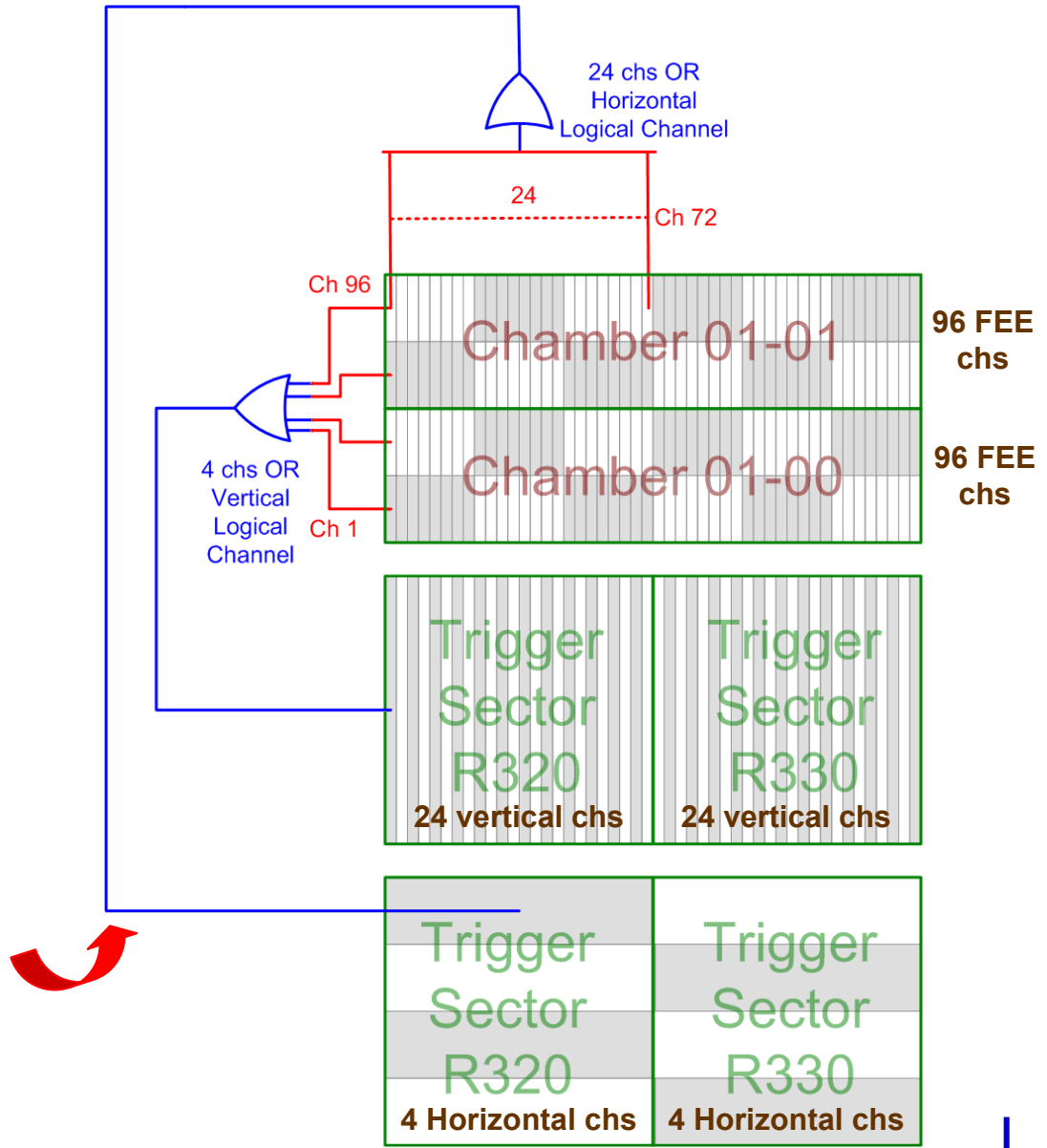
Logical channels

↓

Trigger Sectors

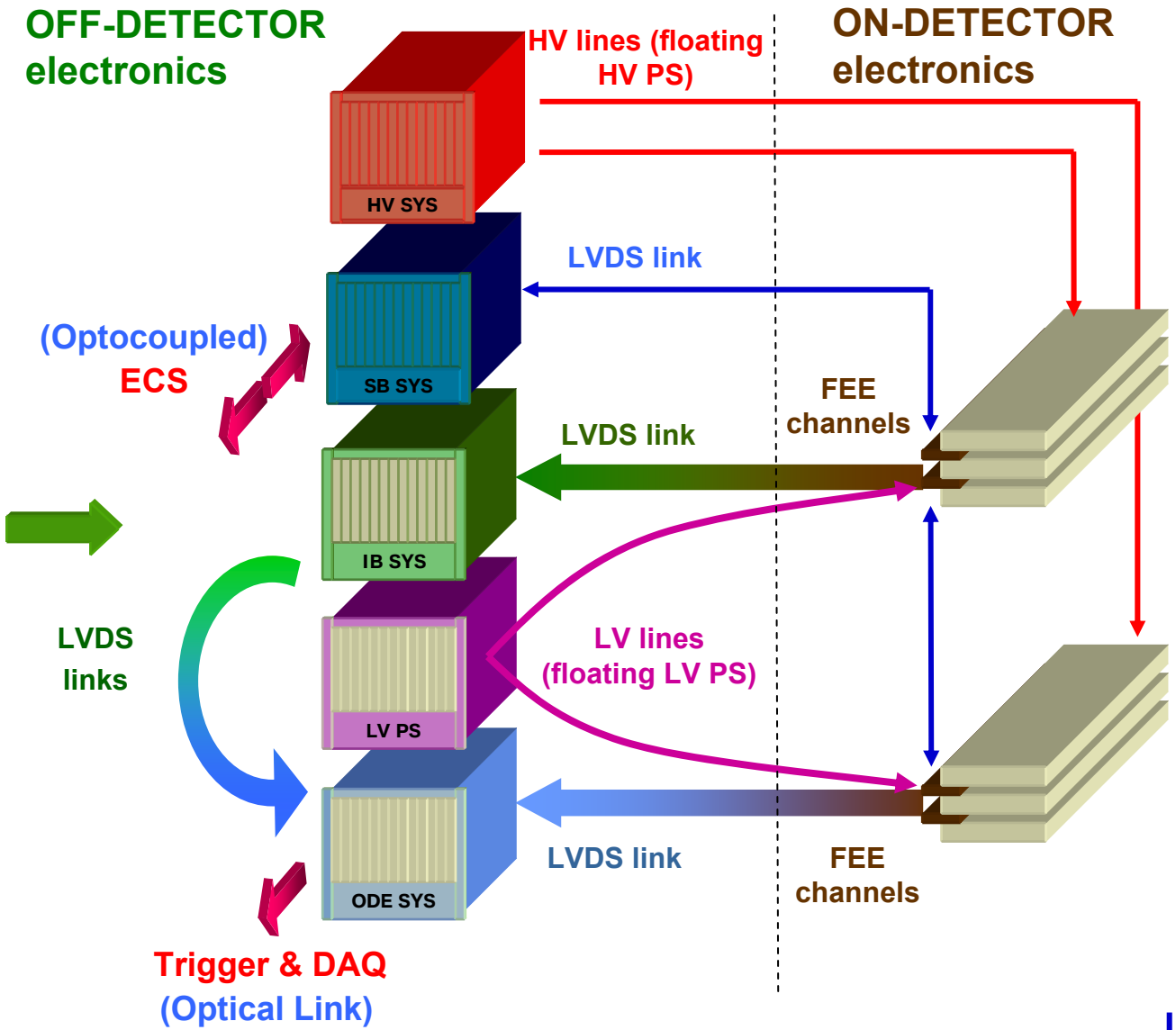
Because of single channel occupancy and electrode capacitance the detector segmentation for trigger propose is coarser than the physical one

An example : M2/M3 R3



The IB System is used to merge 26880 FE channels and to generate 9408 logical channels

Five different configurations are required to readout the muon detector

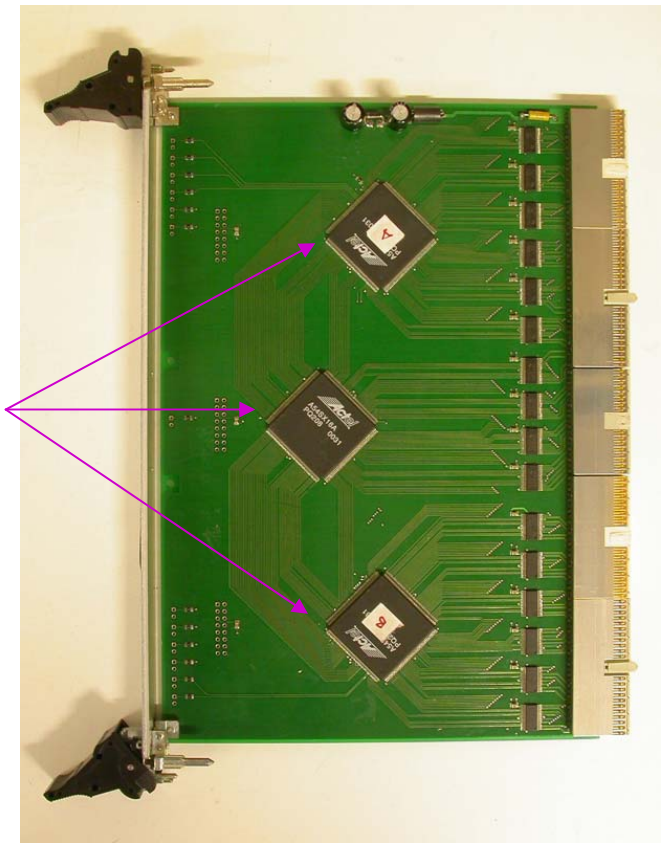


Stations and Regions

Station	Region	Number of optical links per quarter of region	Number of pads per optical links	Number of horizontal strips per optical link	Number of vertical strips per optical link	Total number of logical channels per link
M1	R1	24	24			24
	R2					
	R3					
	R4					
M2 or M3	R1	12		16	12	28
	R2	24		4	12	16
	R3	12		4	24	28
	R4	12		4	24	28
M4 or M5	R1	12	24			24
	R2	12		8	6	14
	R3	12		4	6	10
	R4	12		4	6	10

Six TS configurations → Six IB types

Single PCB
Six FPGA configurations

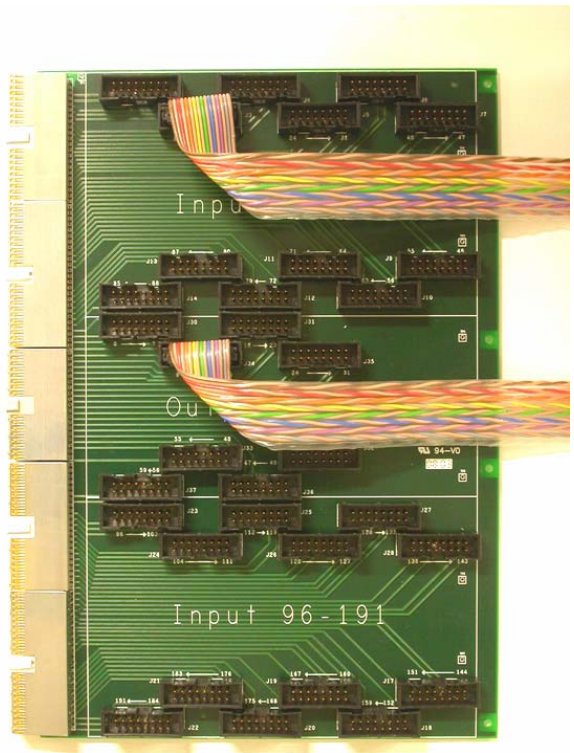


Up to 96 LVDS chs in

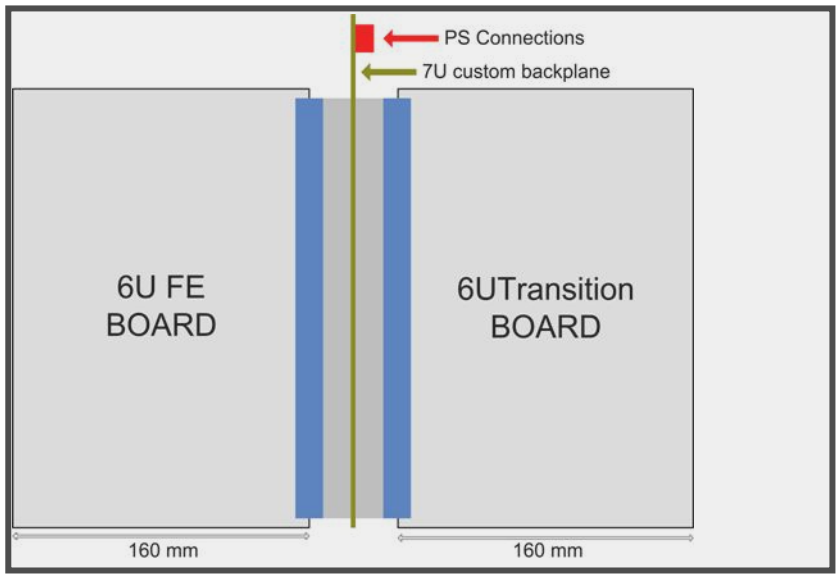
Up to 64 LVDS chs out

Up to 96 LVDS chs in

Single Transition Board
Six input cable configurations



7U crate instrumented with custom backplane



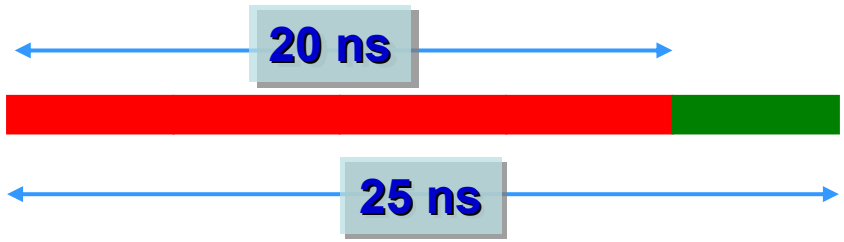
Input signals
(from on detector electronics)

Output signals
(to ODE boards)

→ **simplifies maintenance (IB can be easily replaced in case of failure)**
→ **simplifies cabling**

Skew requirements

skew between logical output channels must be minimized as much as possible to maximize efficiency

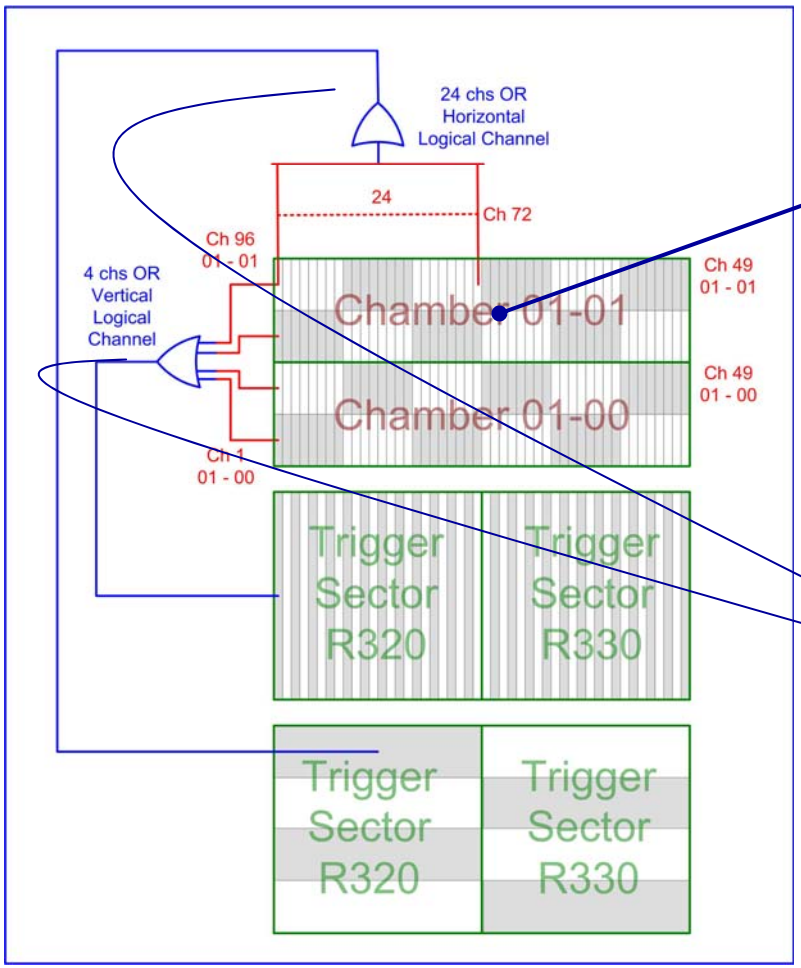


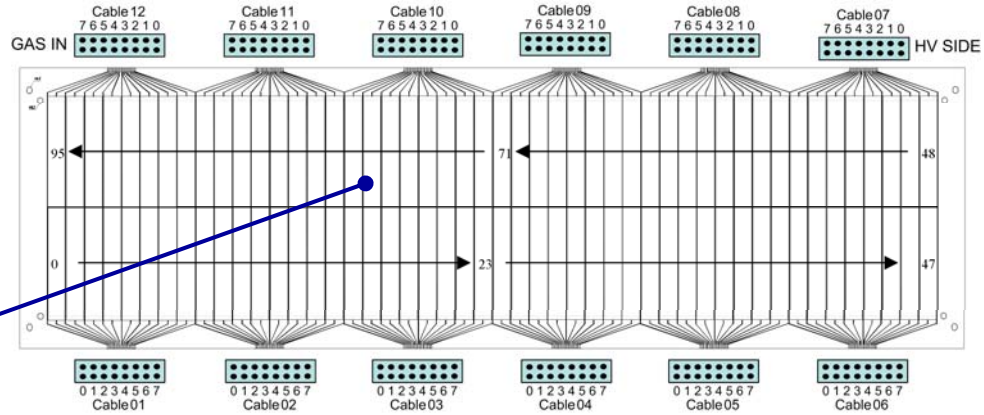
Front-End single channel delay adjustment capability : ~ 1.6 ns step (50 ns)

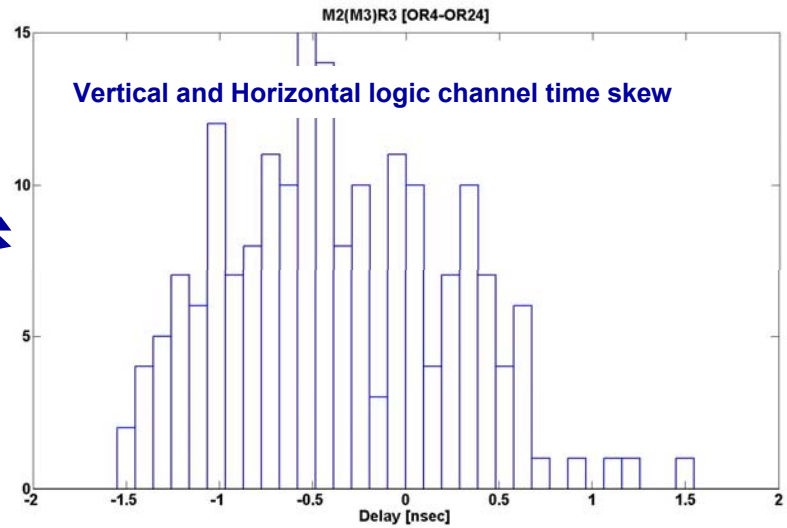
The electronics and cables contribution to jitter and skew must be less than 3 ns

Skew measurements

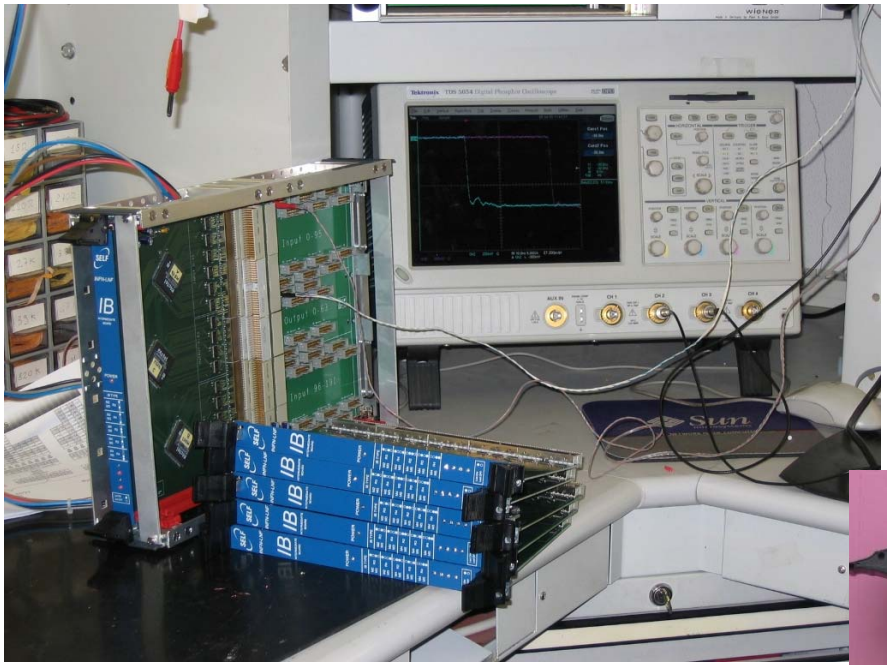
An example M3R3





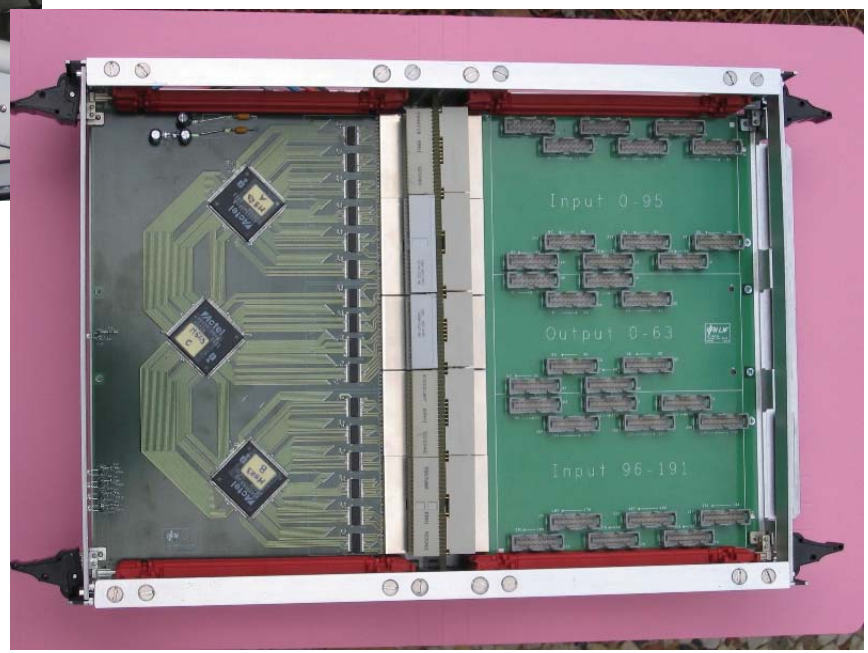


Prototypes qualification test setup

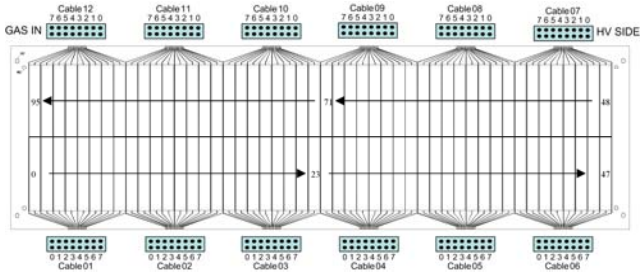


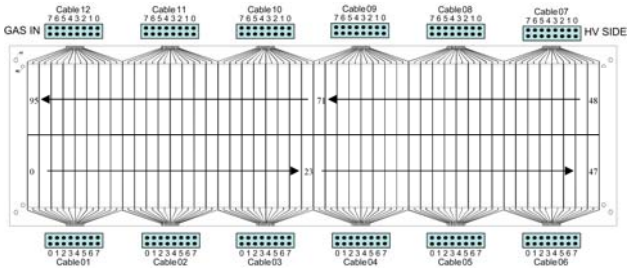
IB setup measurements
for skew measurements
(prototypes qualification)

Mini-crate for IB & TB test

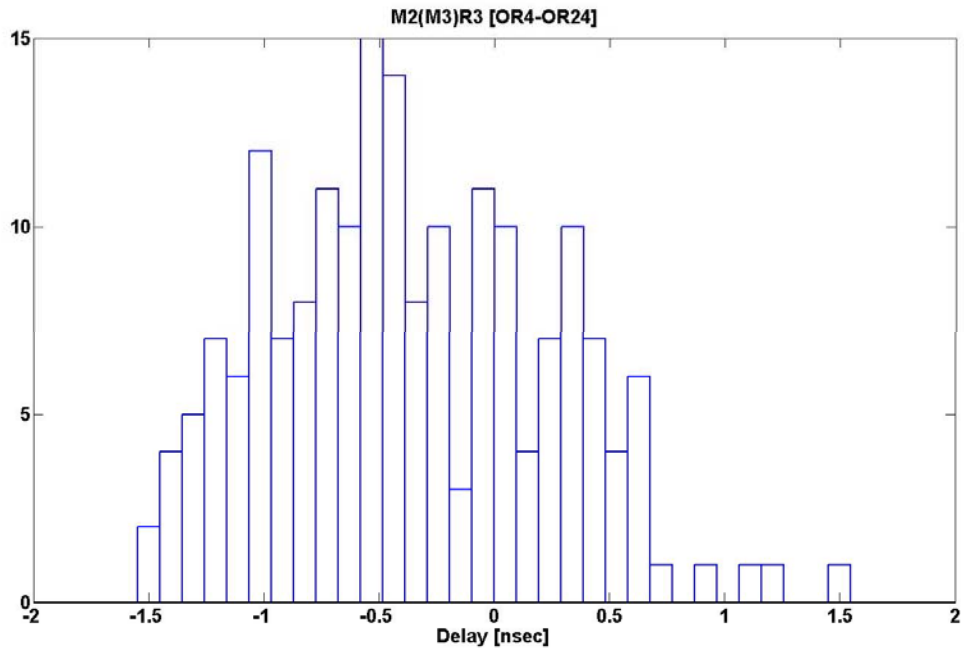


Skew measurements → M2(M3)R3



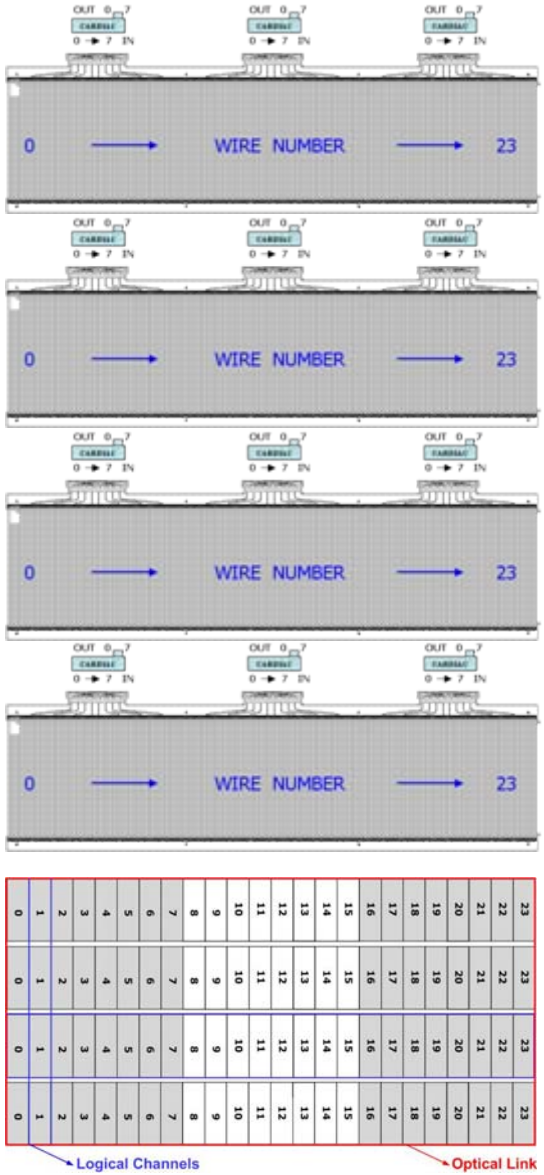


M2(M3)R3

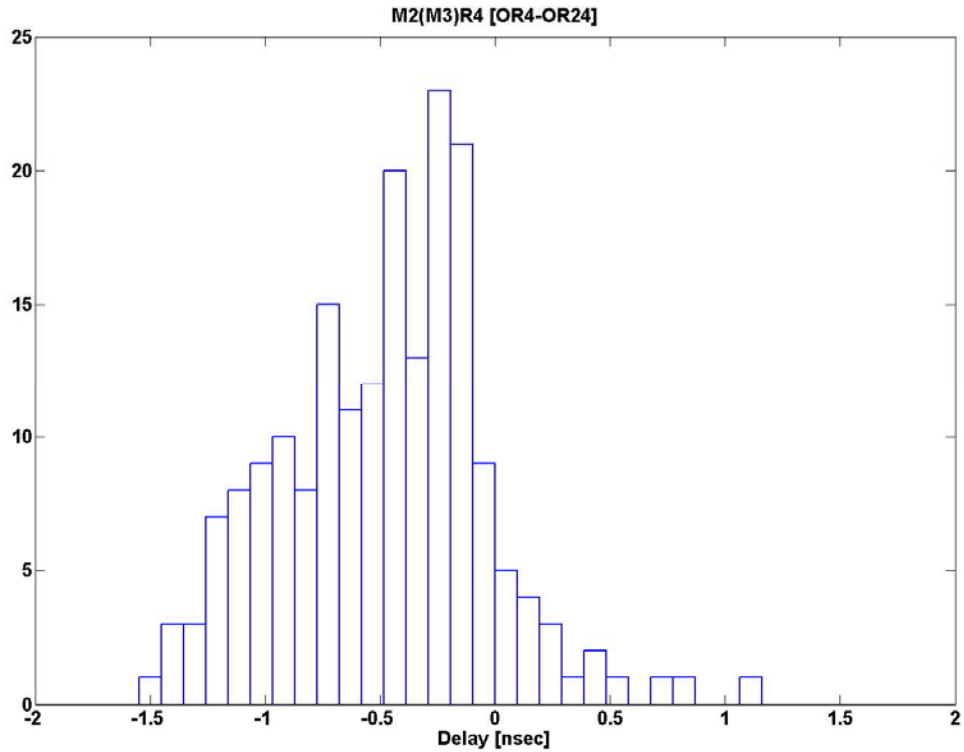


Trigger Sector → 24 Vertical strips + 4 horizontal strips

Skew measurements → M2(M3)R4



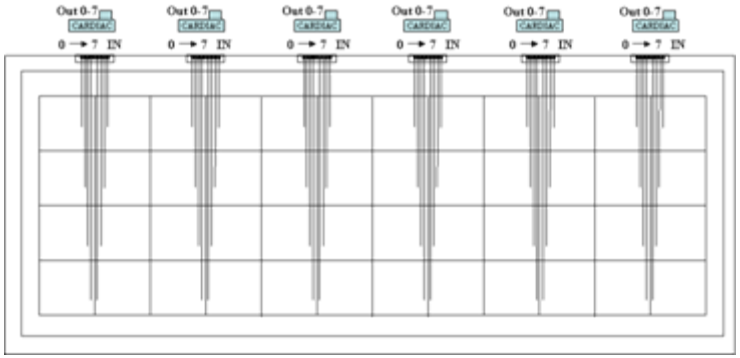
M2(M3)R4



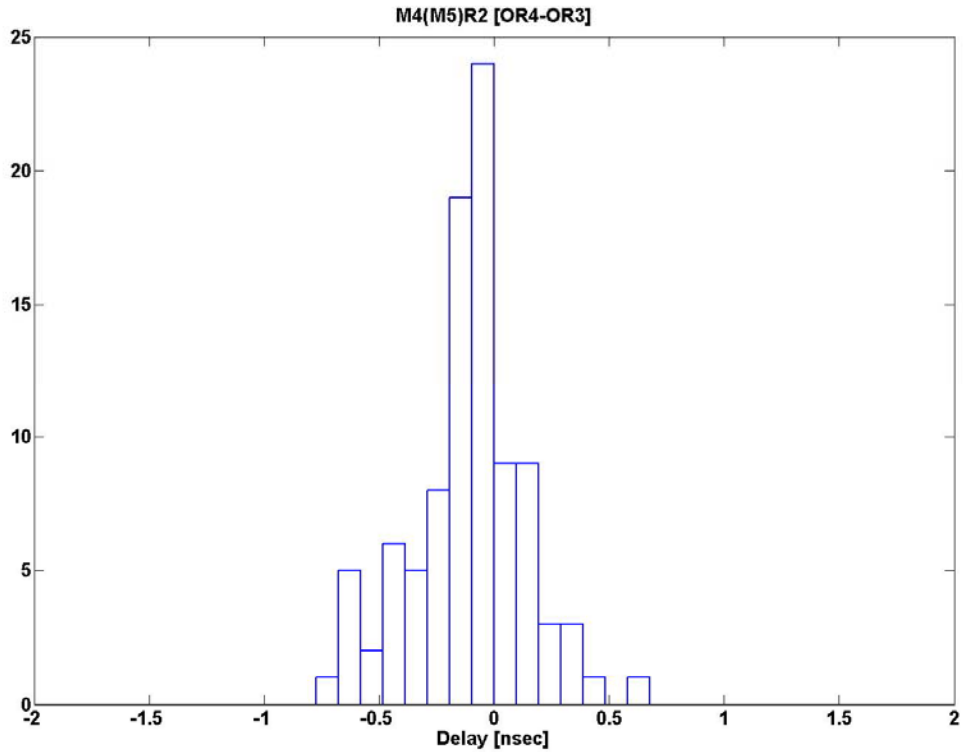
Trigger Sector → 24 Vertical strips + 4 horizontal strips

Skew measurements → M4(M5)R2

M4(M5)R2

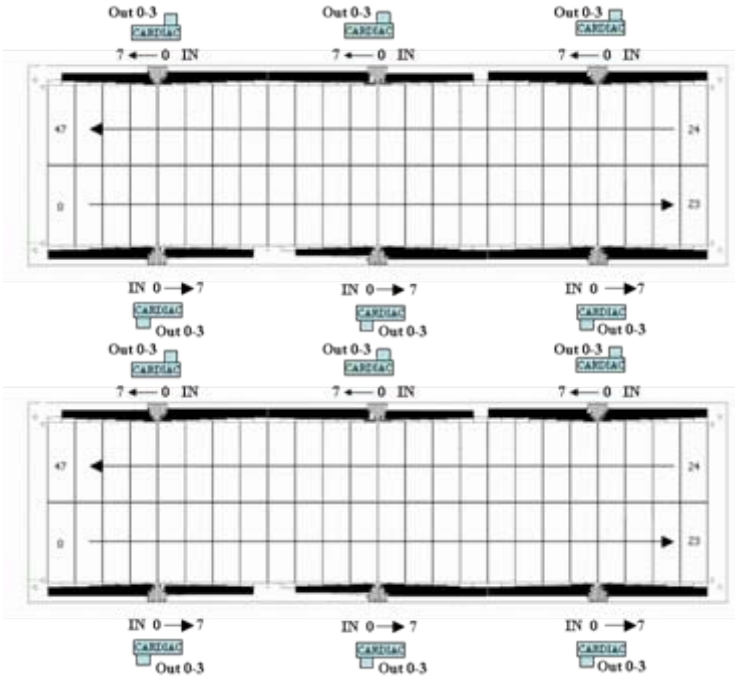


0	7	8	15	16	23	24	31	32	39	40	47
1	6	9	14	17	22	25	30	33	38	41	46
2	5	10	13	18	21	26	29	34	37	42	45
3	4	11	12	19	20	27	28	35	36	43	44



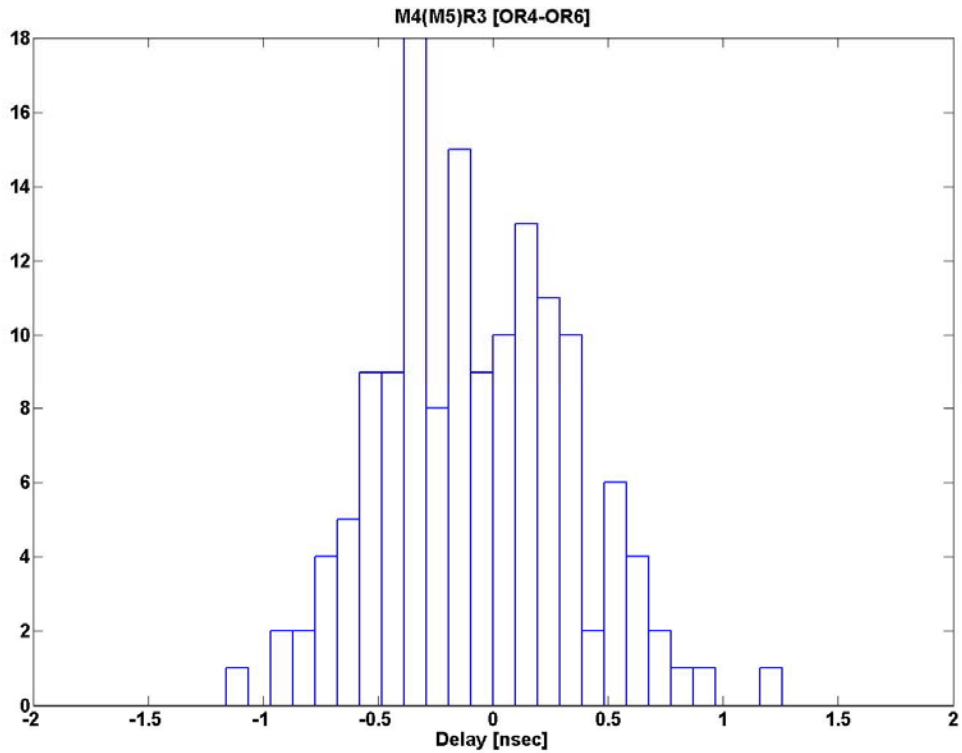
Trigger Sector → 6 Vertical strips + 8 horizontal strips

Skew measurements → M4(M5)R3



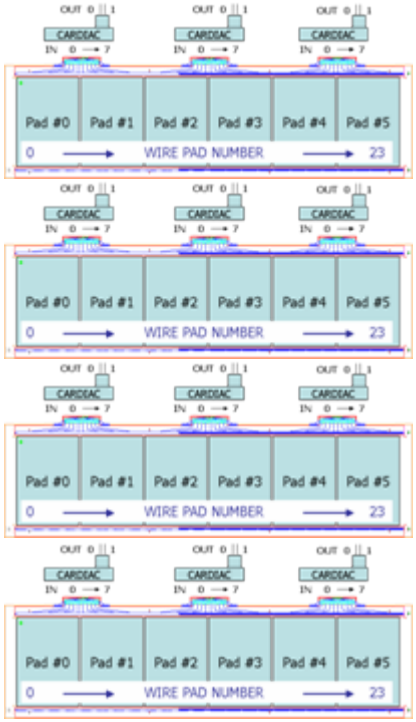
23	22	21	20	19	18	17	16	15	14	13	12
0	1	2	3	4	5	6	7	8	9	10	11
23	22	21	20	19	18	17	16	15	14	13	12
0	1	2	3	4	5	6	7	8	9	10	11

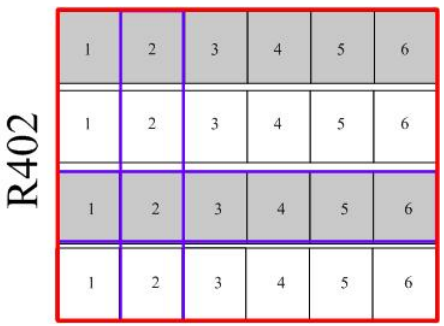
M4(M5)R3



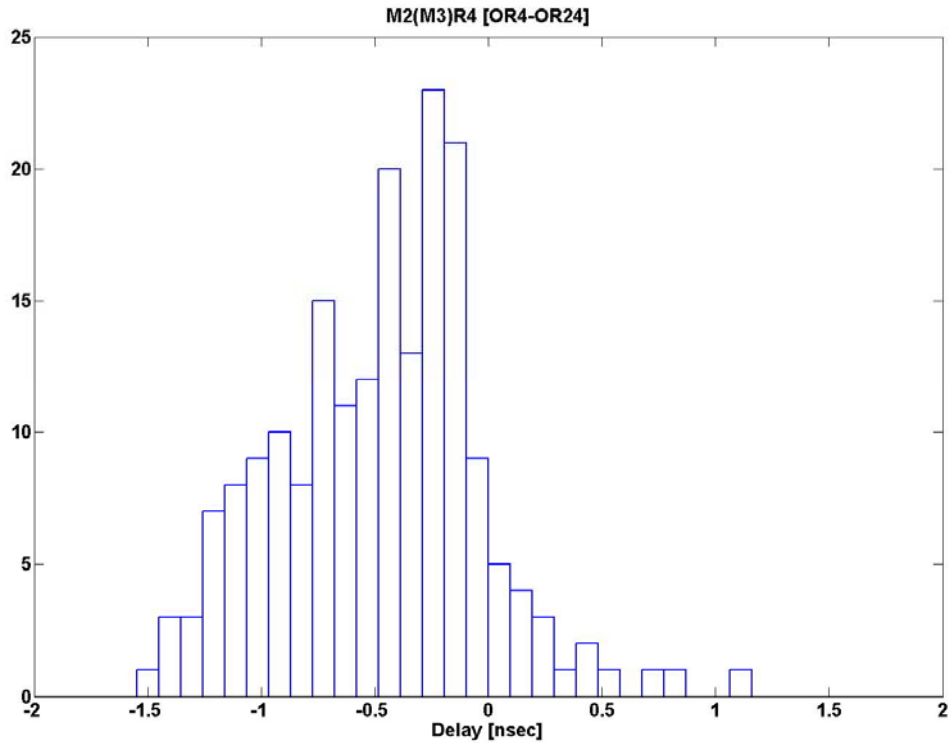
Trigger Sector → 6 Vertical strips + 4 horizontal strips

Skew measurements → M4(M5)R4





M4(M5)R4

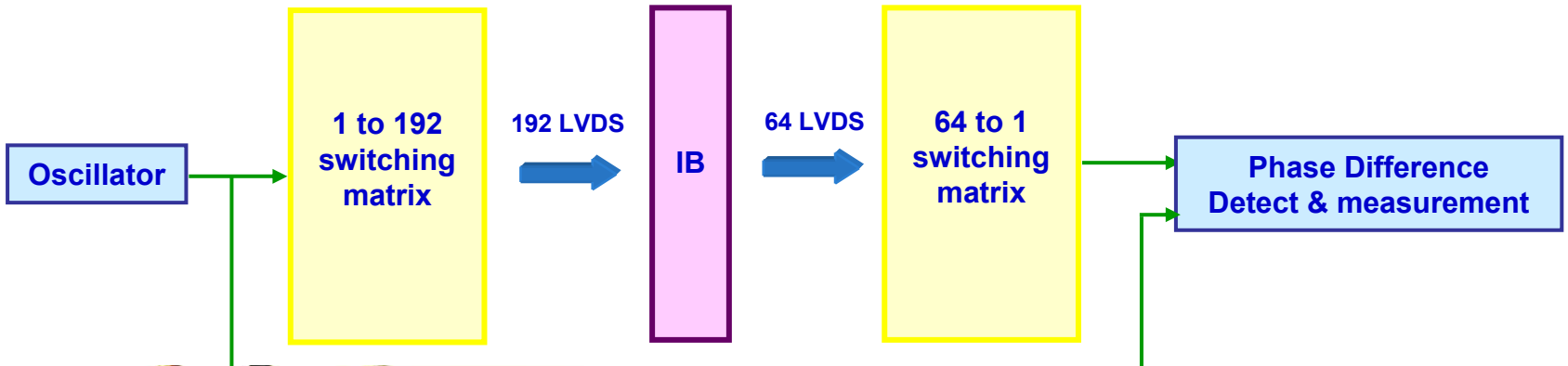


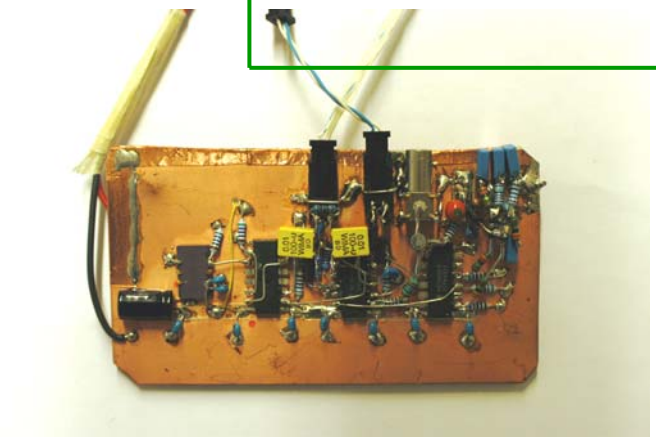
Trigger Sector → 6 Vertical strips + 4 horizontal strips

Mass production test setup

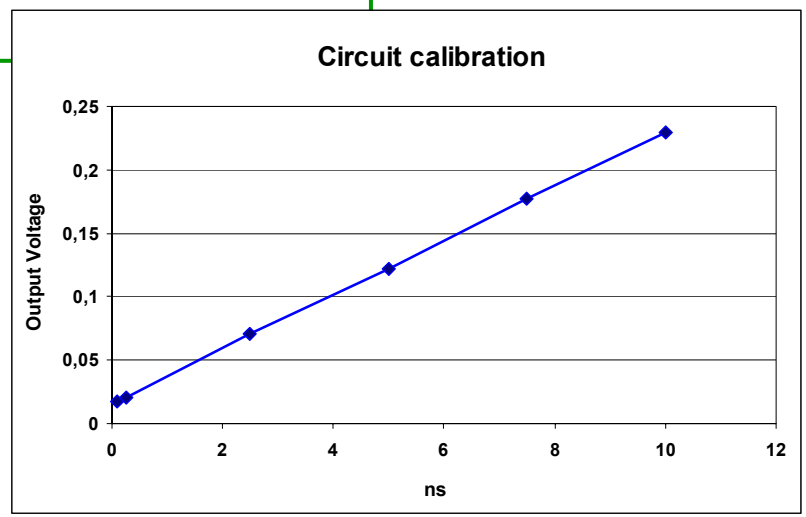
A measurement system has been developed for IB production test. The system features:

- a switching matrix for input/output delay measurement (192 differential inputs / 64 differential outputs)
- a new measurement method based on input/output signal phase measurement

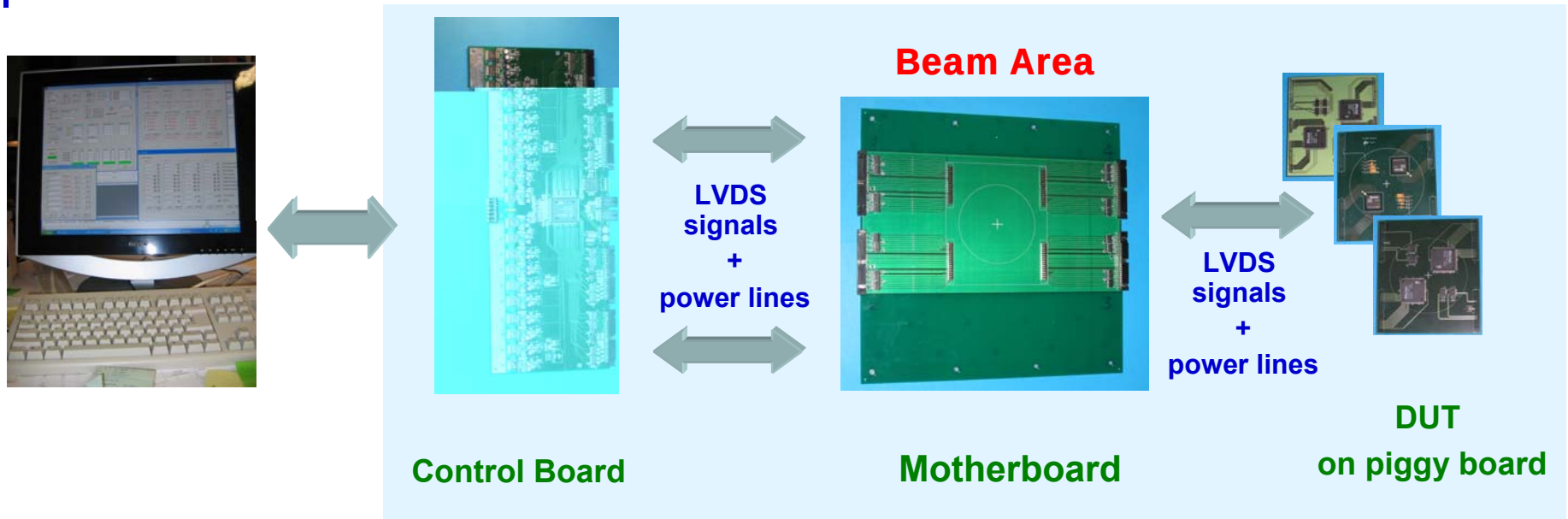




Delay measurement circuit prototype



Irradiation Test Setup → see ODE PRR



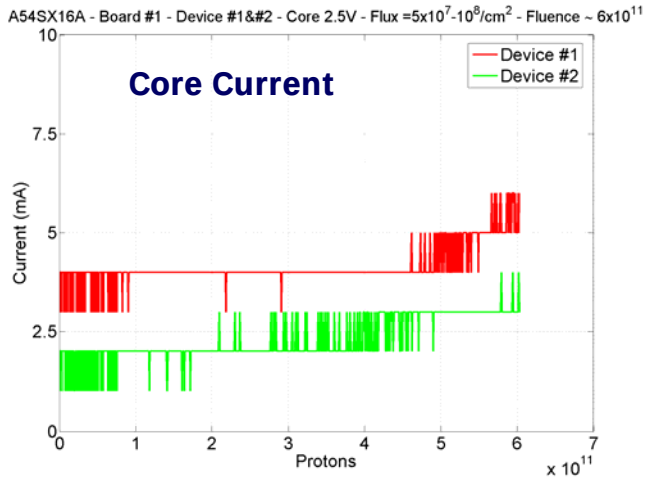
Proton beam at Louvain la Neuve Cyclotron

- Energy: ~ 70 MeV
- Nominal flux used
  - 5 x 10^{7} protons cm^{-2} s^{-1} up to 10^{11} protons cm^{-2}
  - 5 x 10^{8} protons cm^{-2} s^{-1} up to 6 x 10^{11} protons cm^{-2}
- Fluence of 6 x 10^{11} protons cm-2 correspond to:
  - ~ 6 x 10^{11} "energetic" hadrons (~ 120 years of LHCb muon life)
  - ~ 68.5 krad of TID (~ 86 years of LHCb muon life)
  - ~ 9 x 10^{11} neutrons cm^{-2} for NIEL (~ 10 years of LHCb muon life)

Irradiation Test → A54SX16A

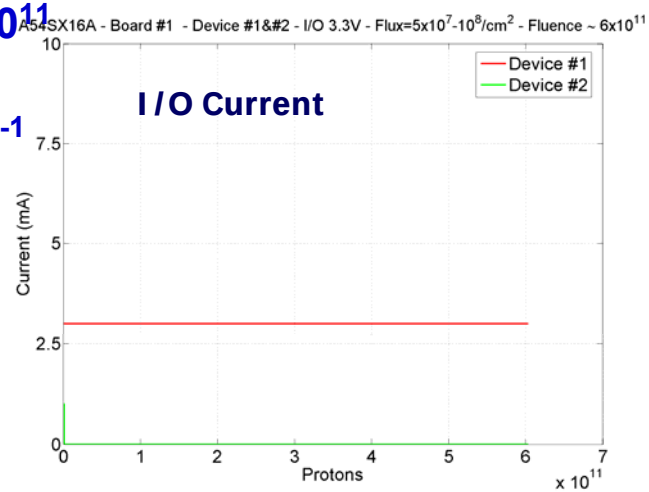
A54SX16A

- Anti-fuse based FPGA
- 0.22µm/0.25µm CMOS Process Technology
- 24000 (16000) system gates (typical gates)
- 924 combinatorial cells
- 528(990) dedicated flip-flops (maximum flip-flops)



Irradiation results

- No SEU observed in flip-flops up to a fluence of 6 x 10^{11} protons/cm^2
  - Cross section per bit < 2.1×10^{-14} cm^2 $protons^{-1}$ bit^{-1}
- No clock or control logic upset observed
- No SEL detected
- No change in I/O current @ 6×10^{11} protons/cm^2
- Small changes in Core current @ 6×10^{11} protons/cm^2



Irradiation Test → LVDS drivers/receivers

LVDS Drivers : SN75LVDS289

- No SEU observed in flip-flops up to a fluence of 6 x 10^{11} protons/cm^2
- No SEL detected
- No change in current @ 6 x 10^{11} protons/cm^2

LVDS Receivers : SN75LVDT288

- No SEU observed in flip-flops up to a fluence of 6 x 10^{11} protons/cm^2
- No SEL detected
- No change in current @ 6 x 10^{11} protons/cm^2

Conclusion (I)

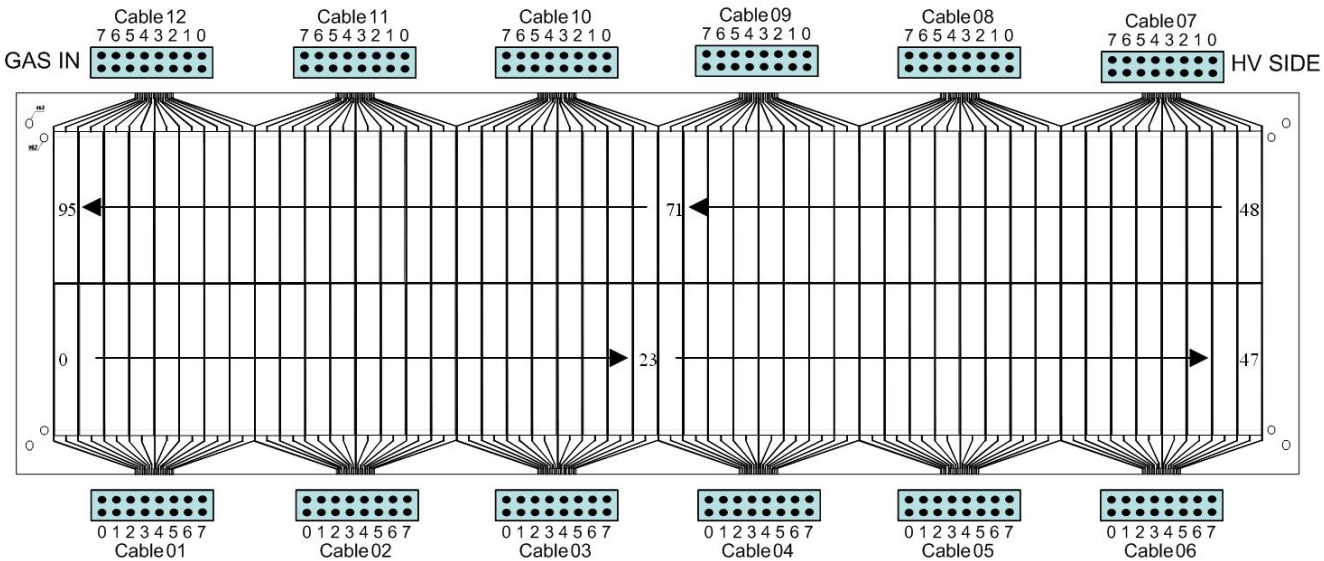
- ✓ The Intermediate Board system is used to match FEE granularity and Trigger logic requirements
- ✓ 6 different logic configurations are required to match the whole muon detector
- ✓ A single (halogen free) PCB board together with anti-fuse programmable logic has been used to implement the configurations.
- ✓ Six prototypes corresponding to the six required configurations have been produced and tested
- ✓ Skew measurements are within the design specs
- ✓ FPGA/Drivers/Receivers do not show any problem up to a fluence of 6×10^{11} protons/cm^2
- ✓ A test setup for IB mass production has been designed. The circuit features an input-output switching matrix allowing single channel delay measurement with a resolution less than 100 ps

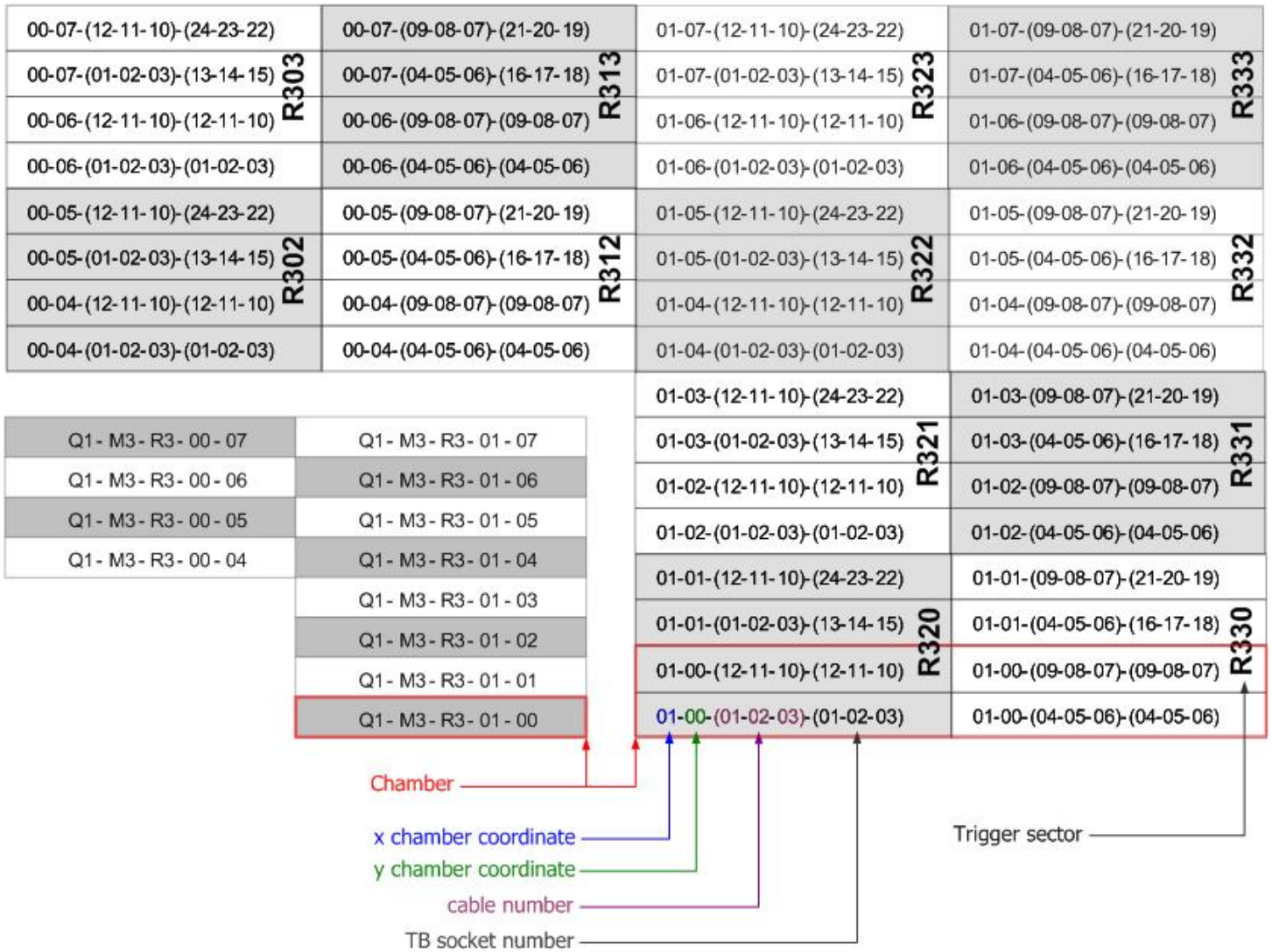
Conclusion (II)

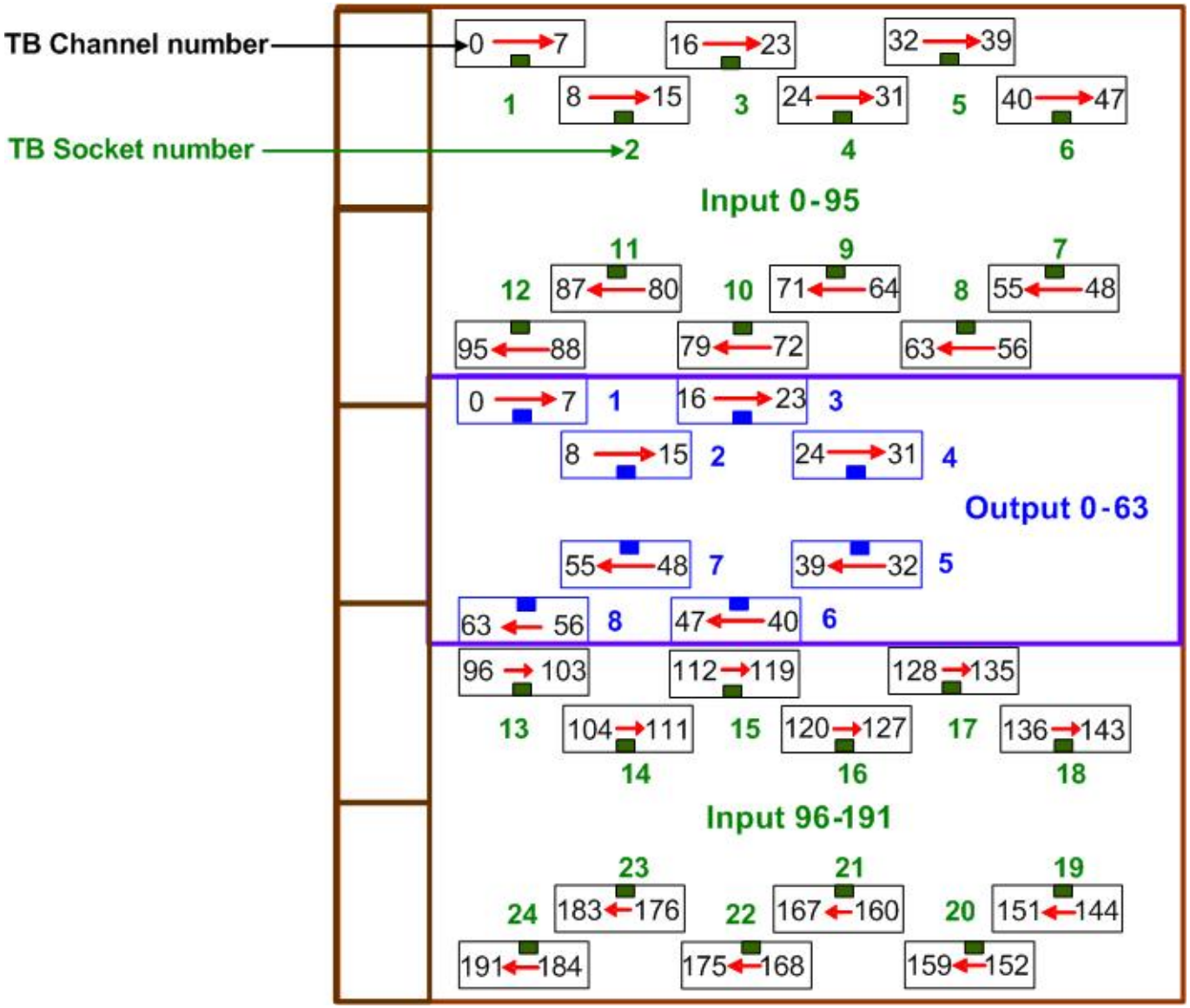
To design both the Transition Board and the Intermediate Boards the detector signal full path must be considered ...

The muon detector mapping for M2R2, M2(M3)R3-R4, M4(M5)R2-R3-R4 comes for free

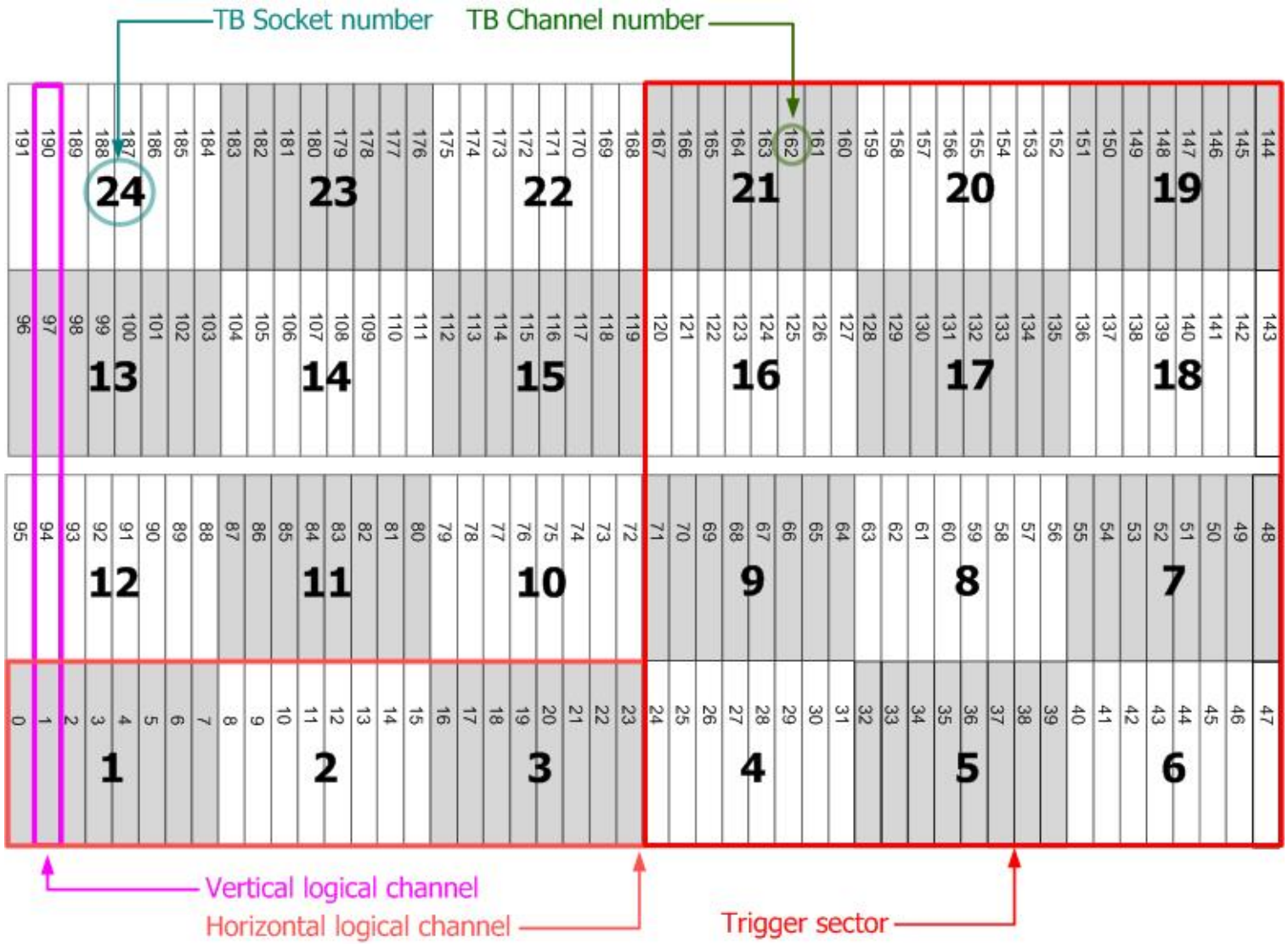
Mapping example
→ M3(M4)R3



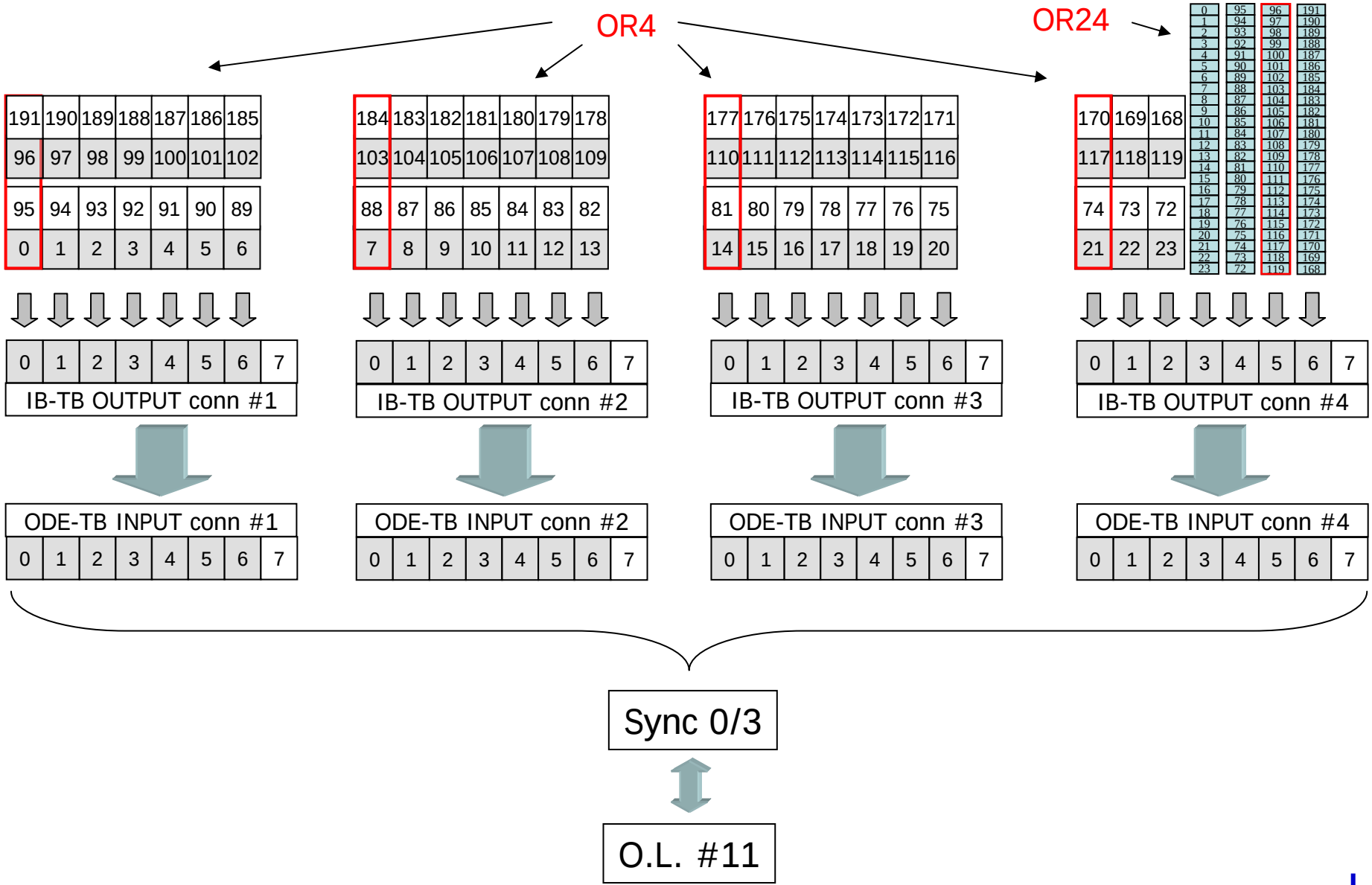

00-07-(12-11-10)-(24-23-22)
00-07-(01-02-03)-(13-14-15)
00-06-(12-11-10)-(12-11-10)
00-06-(01-02-03)-(01-02-03)
00-05-(12-11-10)-(24-23-22)
00-05-(01-02-03)-(13-14-15)
00-04-(12-11-10)-(12-11-10)
00-04-(01-02-03)-(01-02-03)
R303
R302
00-07-(09-08-07)-(21-20-19)
00-07-(04-05-06)-(16-17-18)
00-06-(09-08-07)-(09-08-07)
00-06-(04-05-06)-(04-05-06)
00-05-(09-08-07)-(21-20-19)
00-05-(04-05-06)-(16-17-18)
00-04-(09-08-07)-(09-08-07)
00-04-(04-05-06)-(04-05-06)
R313
R312
01-07-(12-11-10)-(24-23-22)
01-07-(01-02-03)-(13-14-15)
01-06-(12-11-10)-(12-11-10)
01-06-(01-02-03)-(01-02-03)
01-05-(12-11-10)-(24-23-22)
01-05-(01-02-03)-(13-14-15)
01-04-(12-11-10)-(12-11-10)
01-04-(01-02-03)-(01-02-03)
R323
R322
01-07-(09-08-07)-(21-20-19)
01-07-(04-05-06)-(16-17-18)
01-06-(09-08-07)-(09-08-07)
01-06-(04-05-06)-(04-05-06)
01-05-(09-08-07)-(21-20-19)
01-05-(04-05-06)-(16-17-18)
01-04-(09-08-07)-(09-08-07)
01-04-(04-05-06)-(04-05-06)
R333
R332
Q1-M3-R3-00-07
Q1-M3-R3-00-06
Q1-M3-R3-00-05
Q1-M3-R3-00-04
Q1-M3-R3-01-07
Q1-M3-R3-01-06
Q1-M3-R3-01-05
Q1-M3-R3-01-04
Q1-M3-R3-01-03
Q1-M3-R3-01-02
Q1-M3-R3-01-01
Q1-M3-R3-01-00
01-03-(12-11-10)-(24-23-22)
01-03-(01-02-03)-(13-14-15)
01-02-(12-11-10)-(12-11-10)
01-02-(01-02-03)-(01-02-03)
01-01-(12-11-10)-(24-23-22)
01-01-(01-02-03)-(13-14-15)
01-00-(12-11-10)-(12-11-10)
01-00-(01-02-03)-(01-02-03)
R321
R320
01-03-(09-08-07)-(21-20-19)
01-03-(04-05-06)-(16-17-18)
01-02-(09-08-07)-(09-08-07)
01-02-(04-05-06)-(04-05-06)
01-01-(09-08-07)-(21-20-19)
01-01-(04-05-06)-(16-17-18)
01-00-(09-08-07)-(09-08-07)
01-00-(04-05-06)-(04-05-06)
R331
R330
Chamber
x chamber coordinate
y chamber coordinate
cable number
TB socket number
Trigger sector


TB Channel number
TB Socket number
0 → 7
16 → 23
32 → 39
1
8 → 15
3
24 → 31
5
40 → 47
2
4
6
Input 0-95
11
9
7
12
87 ← 80
10
71 ← 64
8
55 ← 48
95 ← 88
79 ← 72
63 ← 56
0 → 7
1
16 → 23
3
8 → 15
2
24 → 31
4
Output 0-63
55 ← 48
7
39 ← 32
5
63 ← 56
8
47 ← 40
6
96 → 103
112 → 119
128 → 135
13
104 → 111
15
120 → 127
17
136 → 143
14
16
18
Input 96-191
23
21
19
24
183 ← 176
22
167 ← 160
20
151 ← 144
191 ← 184
175 ← 168
159 ← 152

Detector Mapping (III)



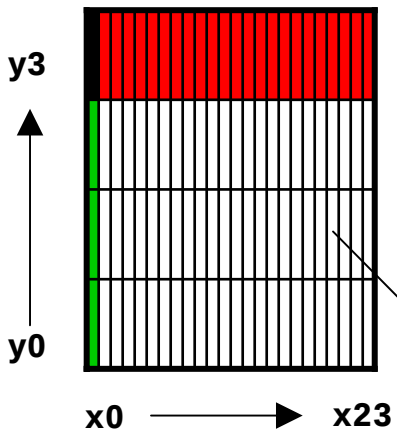
Detector Mapping (IV)



Detector Mapping (V)

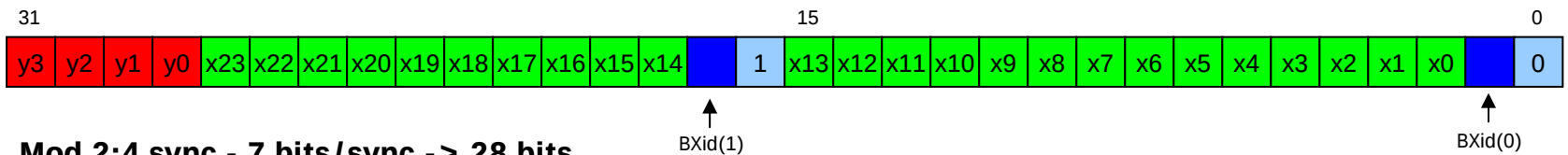
ODE 6TU #2 OL #9 R303	ODE 6TU #2 OL #11 R313	ODE 6TU #2 OL #5 R323	ODE 6TU #2 OL #7 R333
ODE 6TU #1 OL #9 R302	ODE 6TU #1 OL #11 R312	ODE 6TU #2 OL #0 R322	ODE 6TU #2 OL #3 R332
		ODE 6TU #1 OL #5 R321	ODE 6TU #1 OL #7 R331
		ODE 6TU #1 OL #0 R320	ODE 6TU #1 OL #3 R330

Trigger Sector



Legend	
E	Empty
x#	Vertical OR
y#	Horizontal OR

ODE-Optical Link Output Trigger Data Word



Mod 2:4 sync - 7 bits/sync -> 28 bits