

Digital electronics for Hyperball Ge detectors

Digital Hyperball (DHB) initiative

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Tohoku University: A. Sasaki, K. Sugihara, Y. Yamamoto,
and N. Ichige, and the Hyperball collaboration

JAEA: K. Hosomi

Seoul National University: S. Yang

Argonne Natl. Lab. (U.S.A): M. Carpenter and P. Wilt The

RCNP: The CAGRA collaboration

Outline

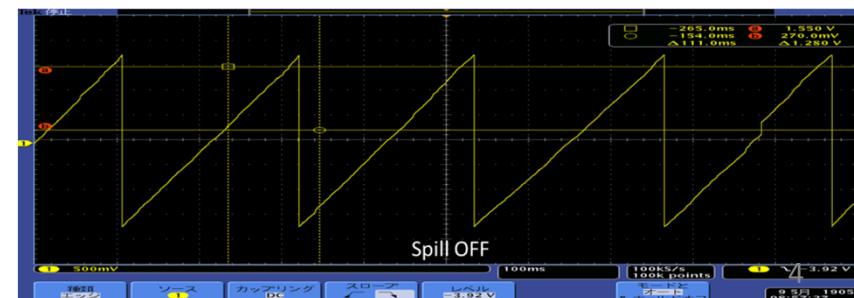
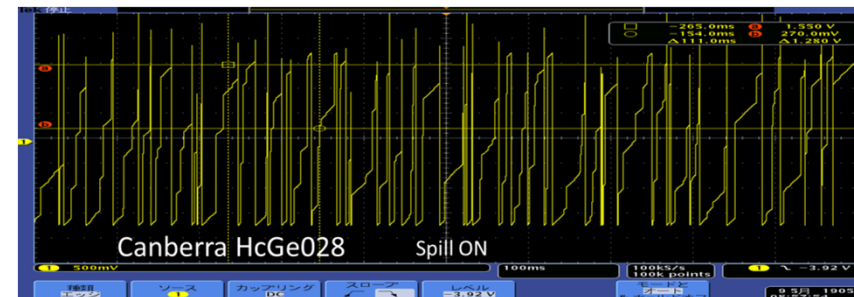
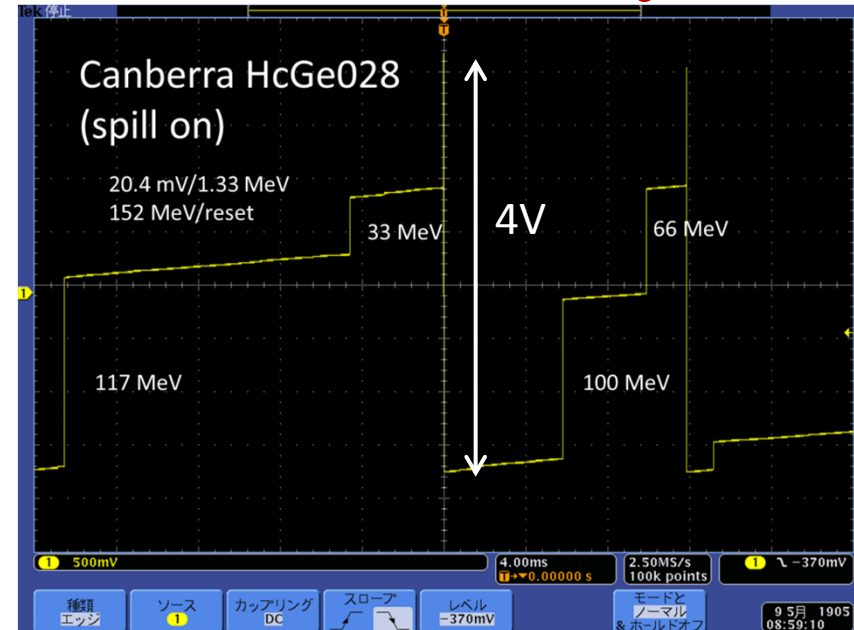
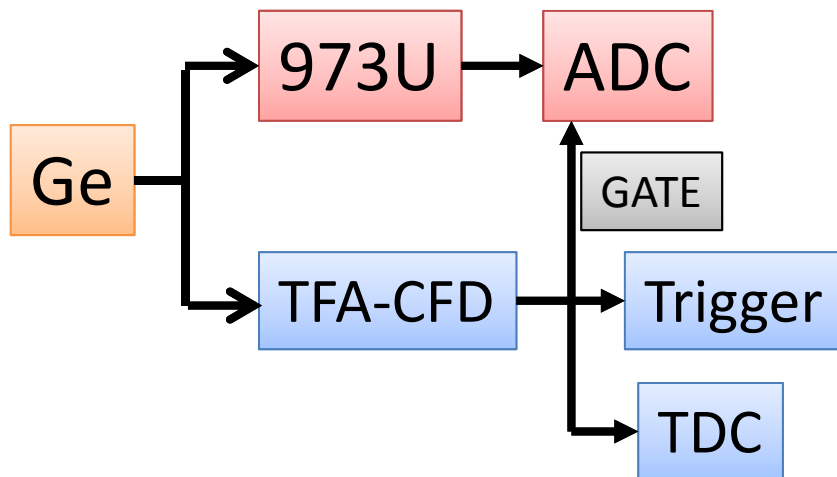
- Why go digital?
 - Measurement of through put ratio: T44 at the J-PARC K1.1 beam line
- GRETINA digitizer + ANL firmware
- Test experiment of digital Clover Ge array at CYRIC
- Summary

Why go digital?

Ge detector for Hyperball and its readout system

High energy deposit rate

- transistor-reset type preamp. for Ge
- Low gain: 20mV/MeV
- Reset threshold: 150MeV
- Gate Integrated Ultra High Rate Shap. Amp. (ORTEC 973U)



Dead time sources in the present readout system

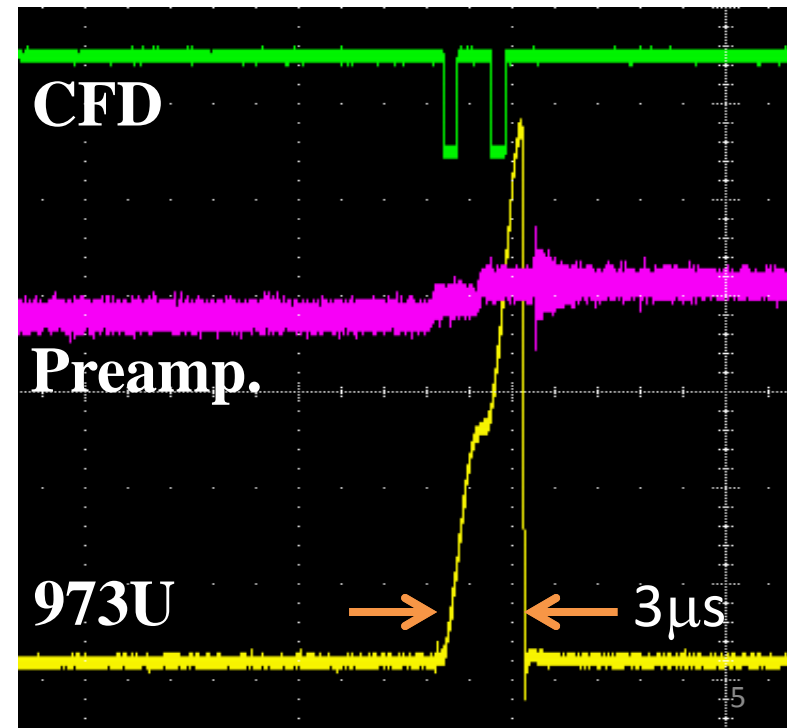
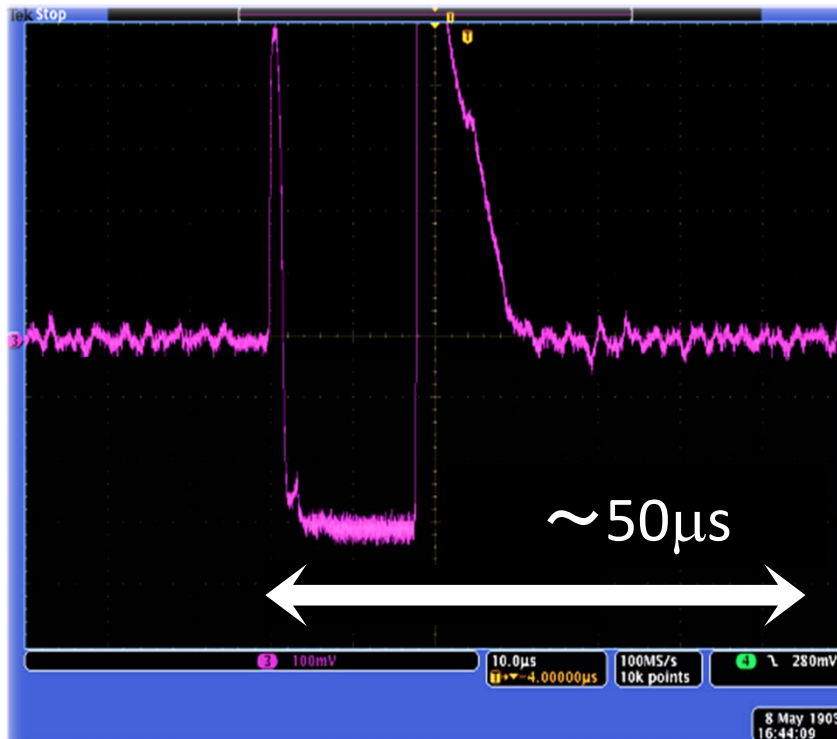
$$Det. \text{ Effi.} = \varepsilon(E_\gamma) \cdot \frac{\Omega}{4\pi} \cdot \underline{\text{(Trough Put Ratio)}} \cdot \varepsilon(DAQ)$$

Recovery from reset

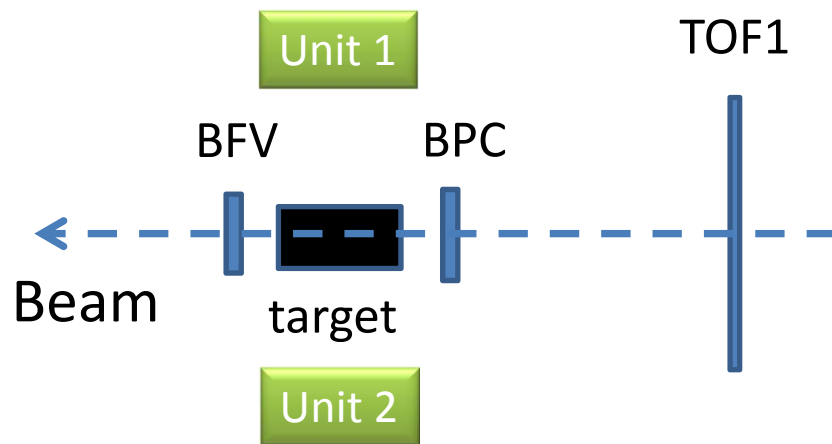
$$\tau_{rst} \approx 50 \mu s$$

Pile up

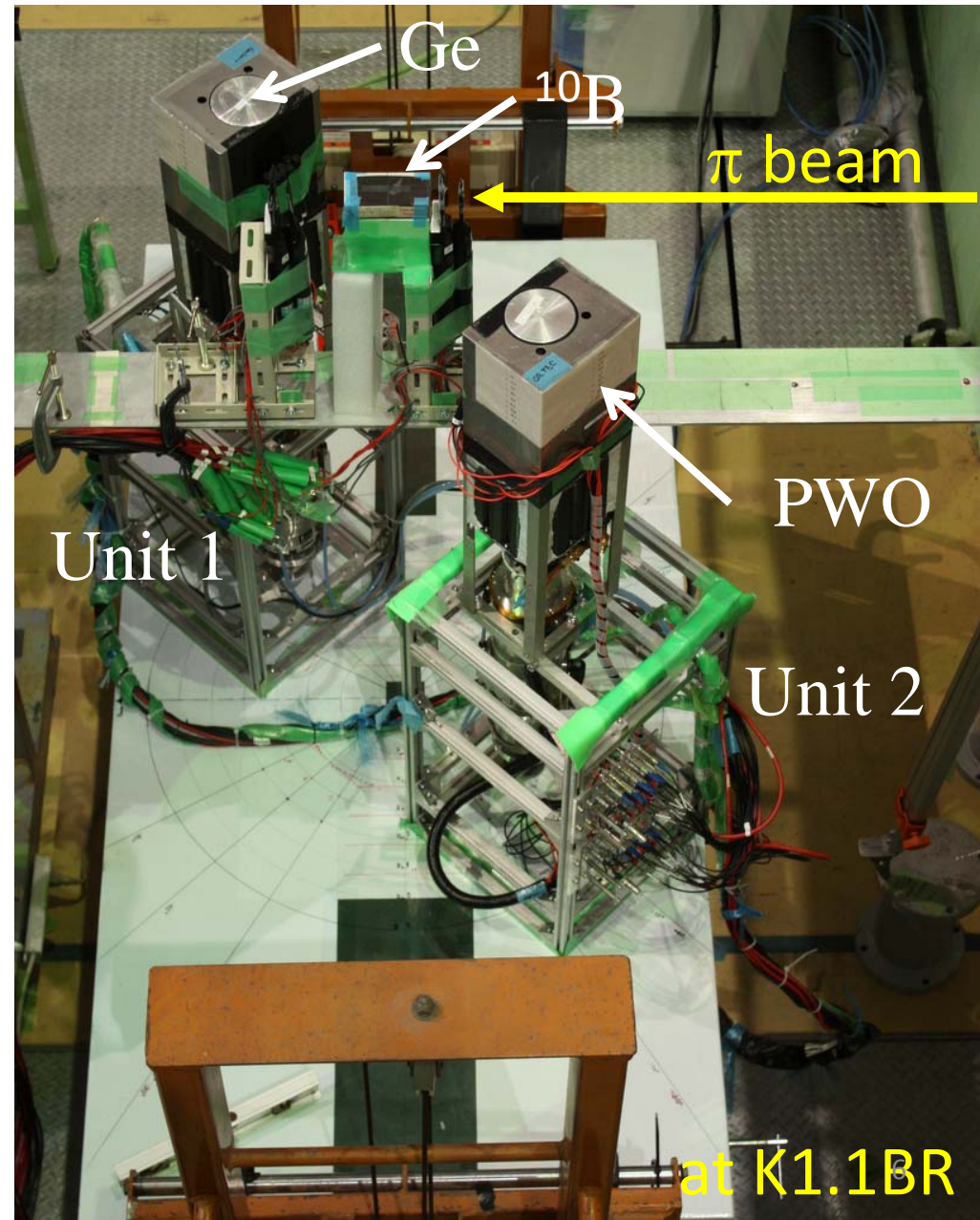
$$\tau_{pu} = 3 \times 2 \mu s$$



Measurement of Through Put ratio: T44 at K1.1BR



Beam time: 6/26 –7/2, 2012
Target: $^{10}\text{B}14.2\text{g}/\text{cm}^2$
Beam rate: **200kHz ~ 2MHz**
Two HBJ units (Ge, PWO, LSO)



Measurement of TPR with a test pulse

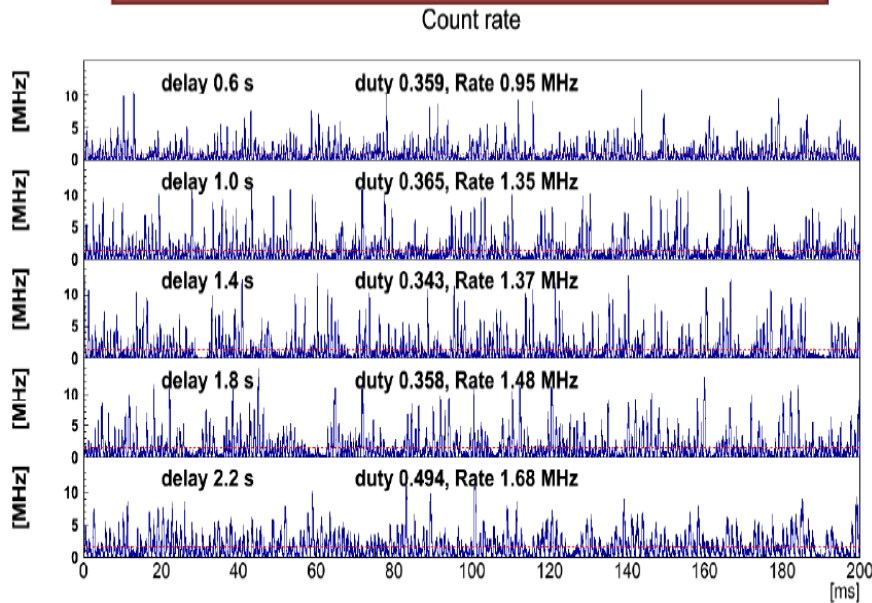
Two trigger types

Clock: 10kHz NIM signal
 BEAM: TOF1 ⊗ BPC
 (pre-scaled to 4kHz)

TPR =

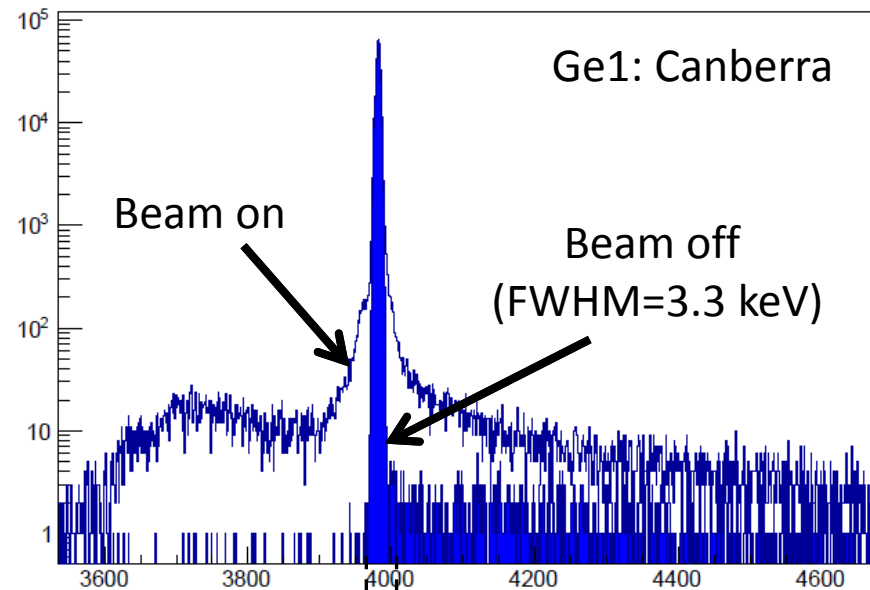
$$\frac{S(\text{low}, \text{high})}{\# \text{ of test signal acpt. by DAQ}}$$

TPR with micro structures of beam

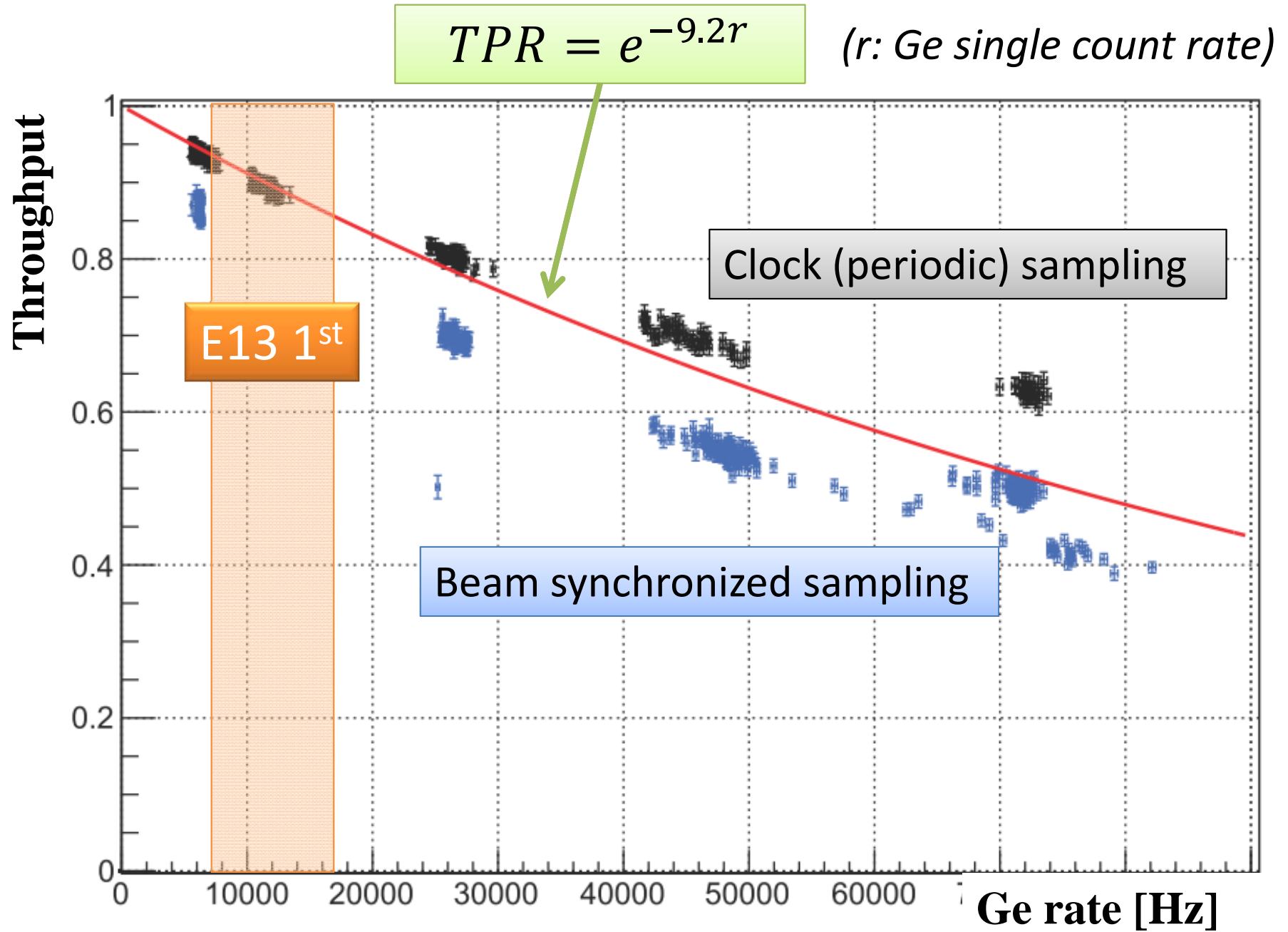


from E19, Feb., 2012, by K.Miwa

Test signal spectrum

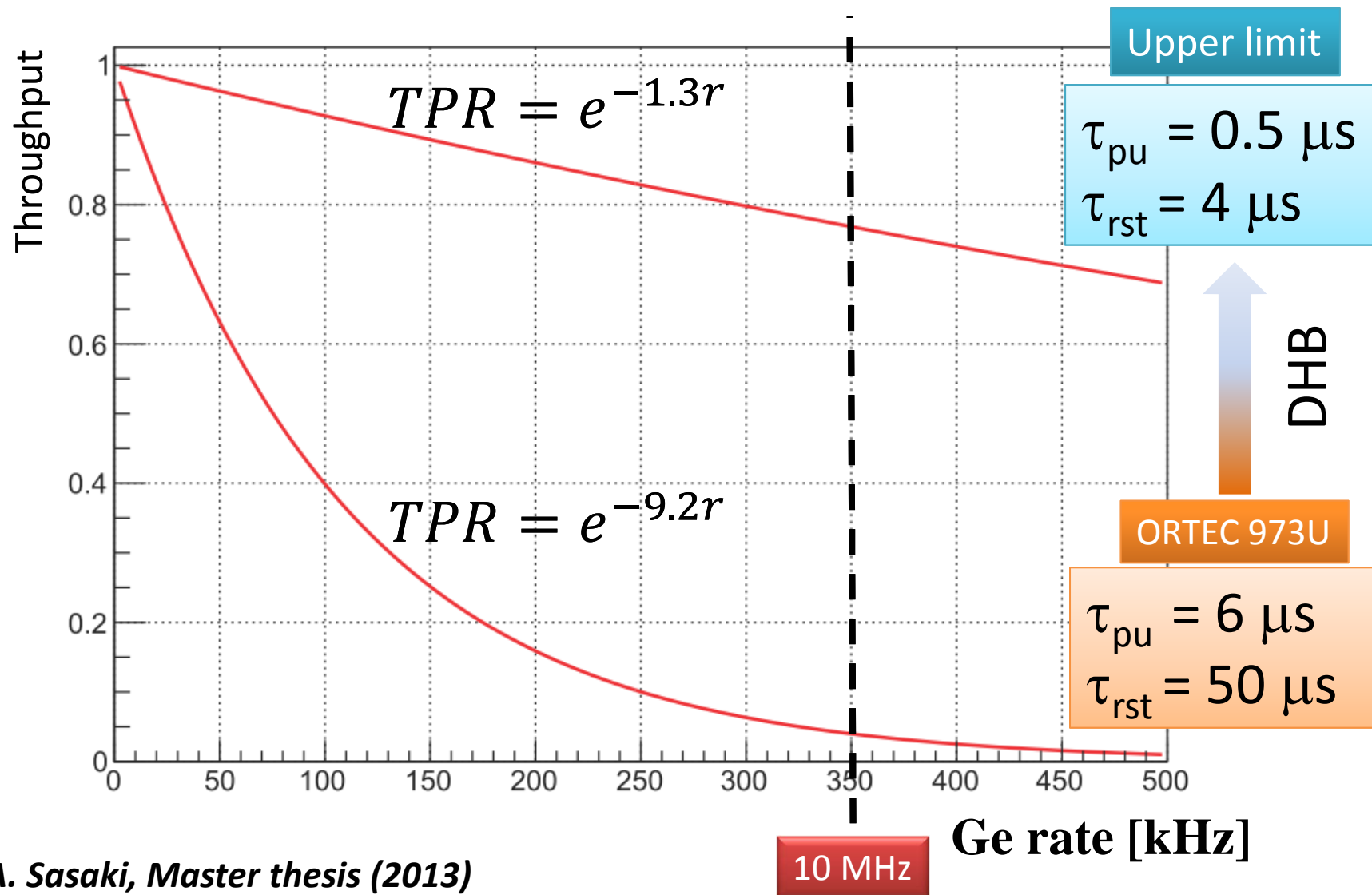


low → ← high



$$TPR = \exp\left[-\left(2\tau_{pu} + \tau_{rst} \frac{\varepsilon}{E_{rst}}\right)r\right]$$

$\varepsilon = 9.6 \text{ MeV}$ (ave. energy deposit)
 $E_{rst} = 152 \text{ MeV}$ (reset energy)



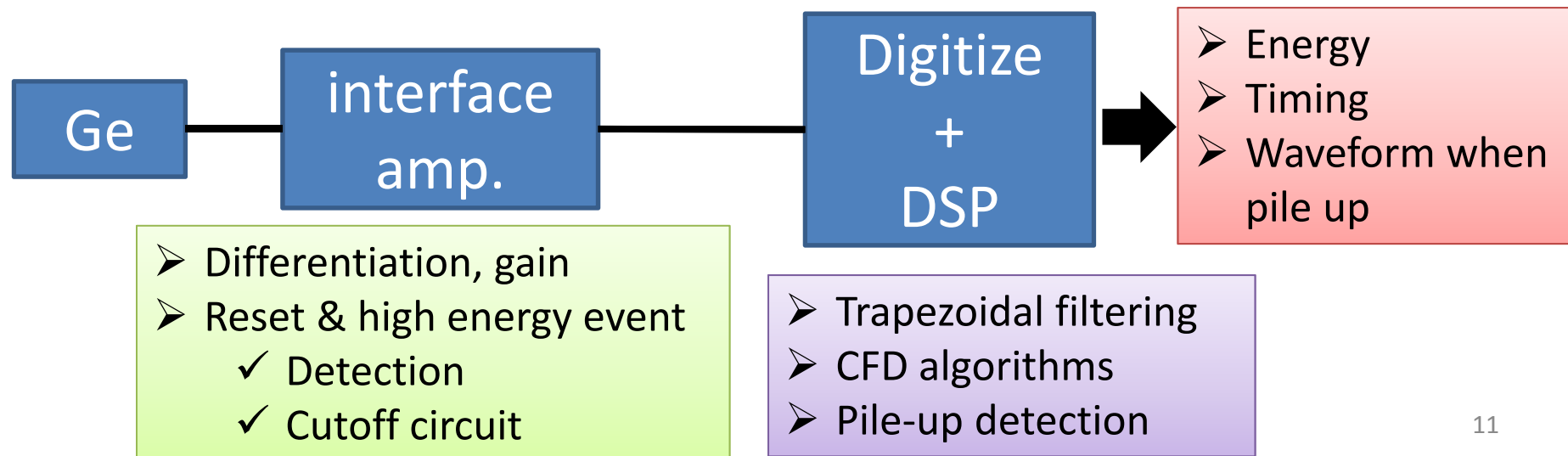
***GRETINA digitizer
+ ANL firmware***

Digital Hyperball (DHB): two approaches

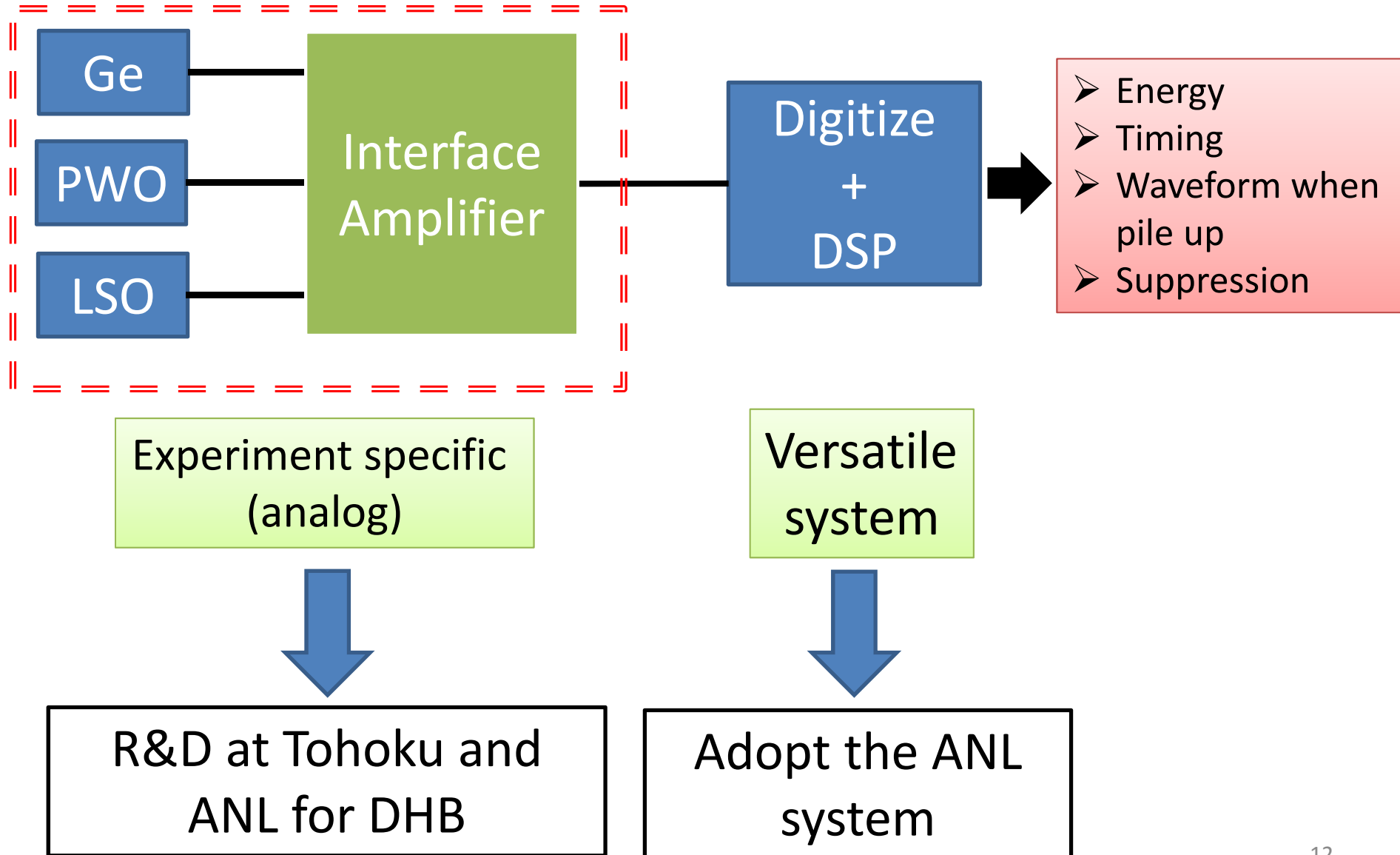
Tanida-Hosomi method



Argonne, Sugihara, and Yamamoto method



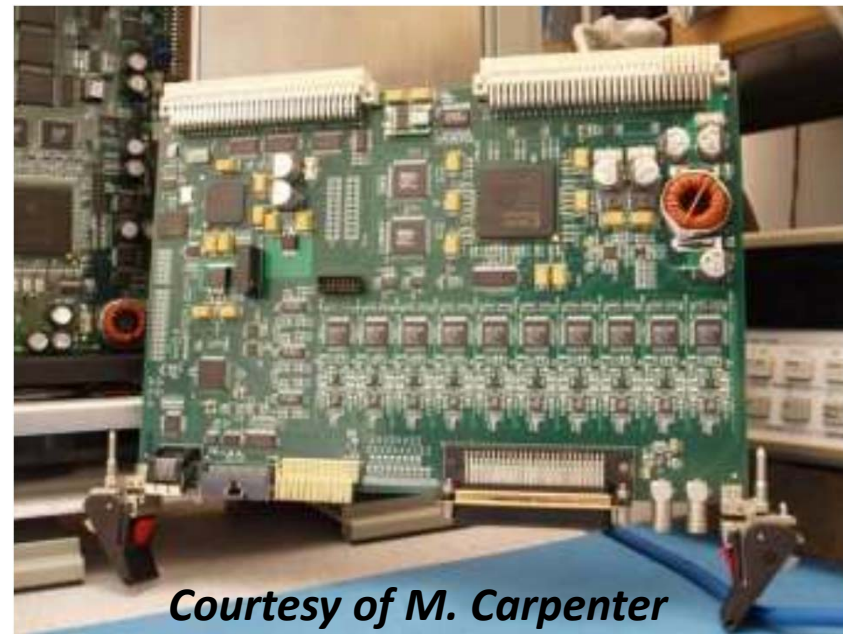
Digital Hyperball (DHB)



GRETINA digitizer (LBNL)

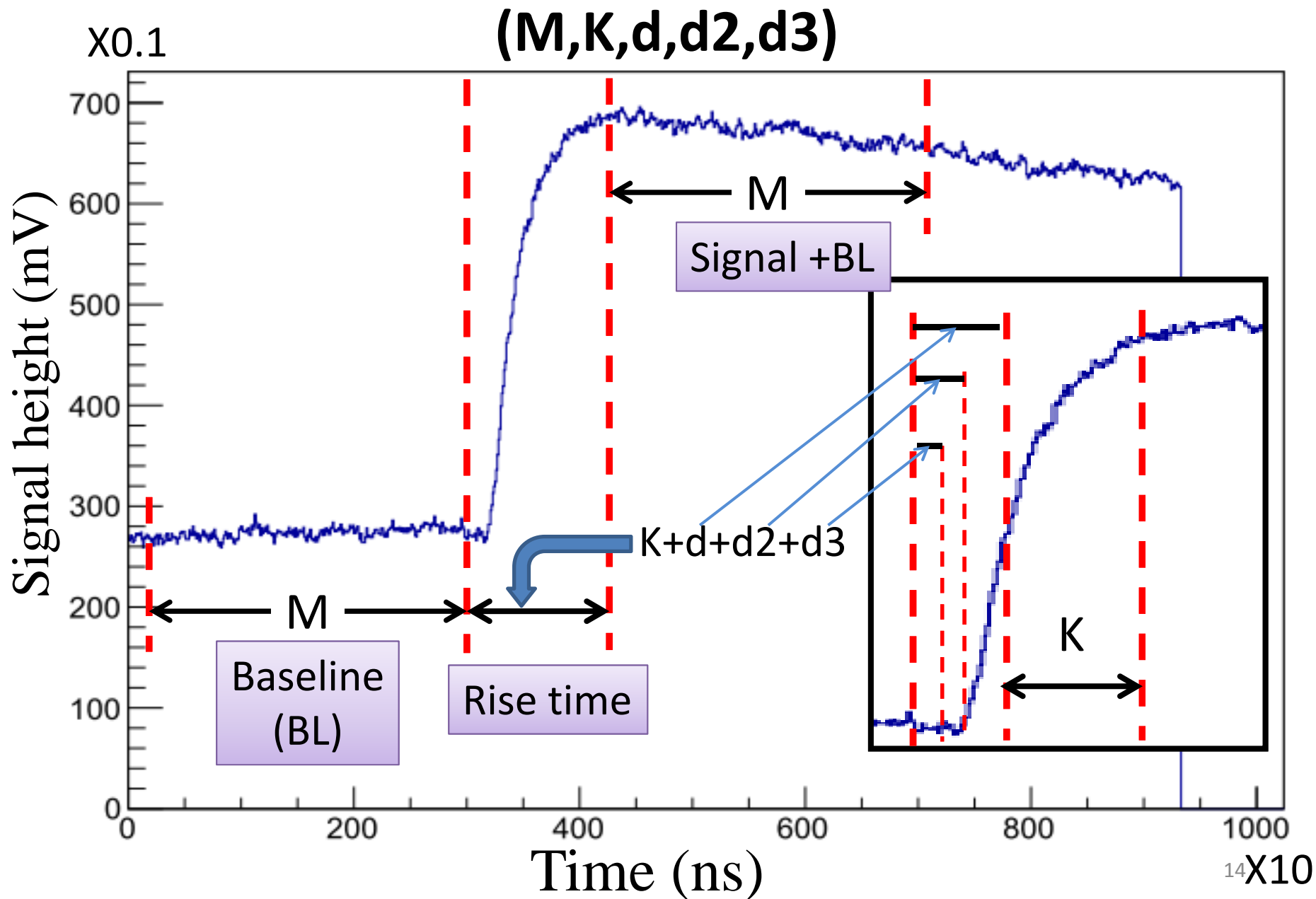
- 10 ch. (differential input)
- 14 bit, 100 MHz
- $\pm 1V$ dynamic range
 - for good linearity
- FPGA (Firmware)
 - Individually pipelined with memory buffers
 - Energy (Trapezoidal filter)
 - Leading Edge
 - Constant Fraction Disc.
 - Pile-up detection
 - Waveform (max. $10\mu s$)

- Developed for tracking Ge array, GRETINA by LBNL
- Firmware developed for Gammasphere by ANL (digital GS initiative)



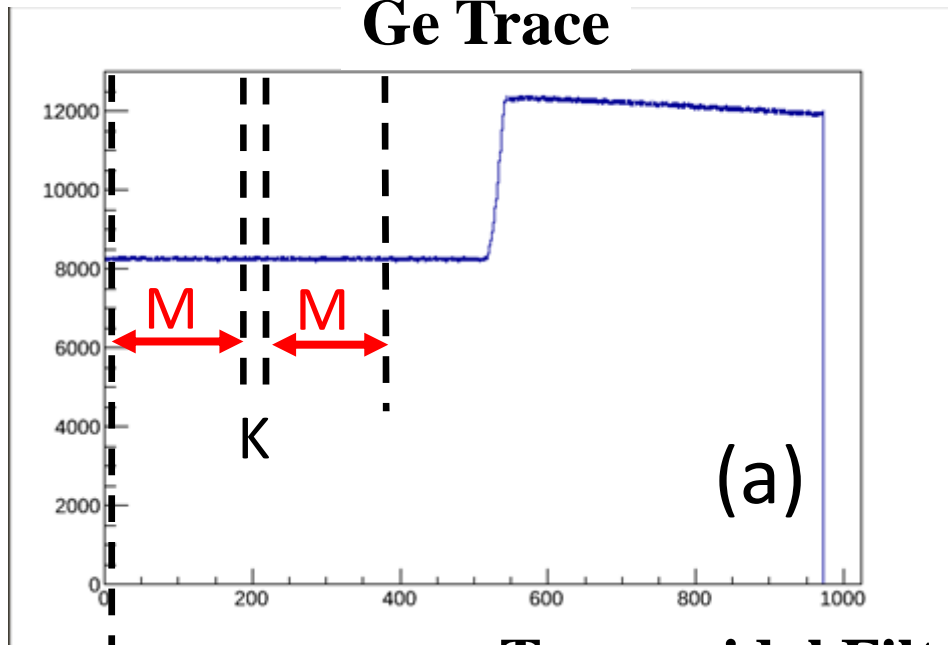
Courtesy of M. Carpenter

Digitizer firmware parameters (ANL)



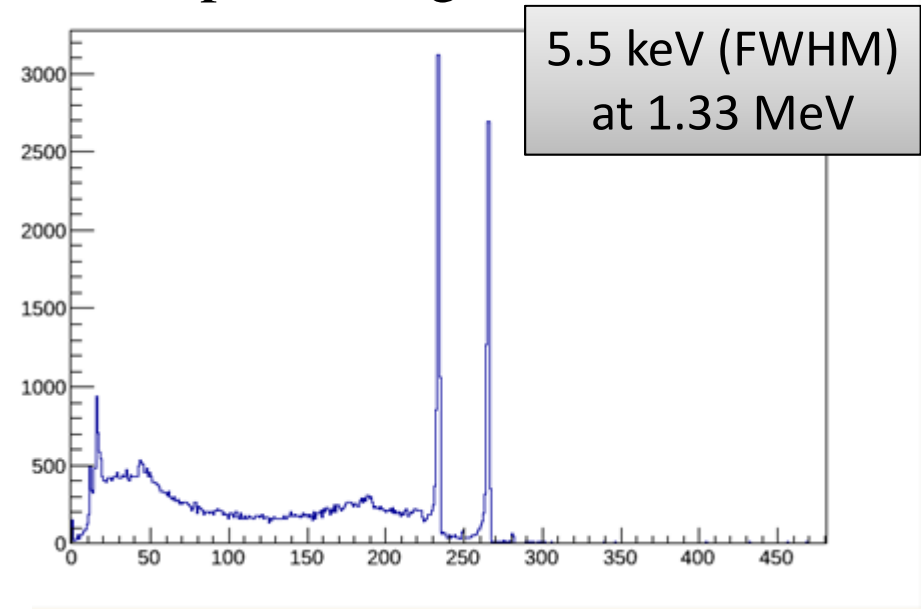
Waveform analysis

Ge Trace

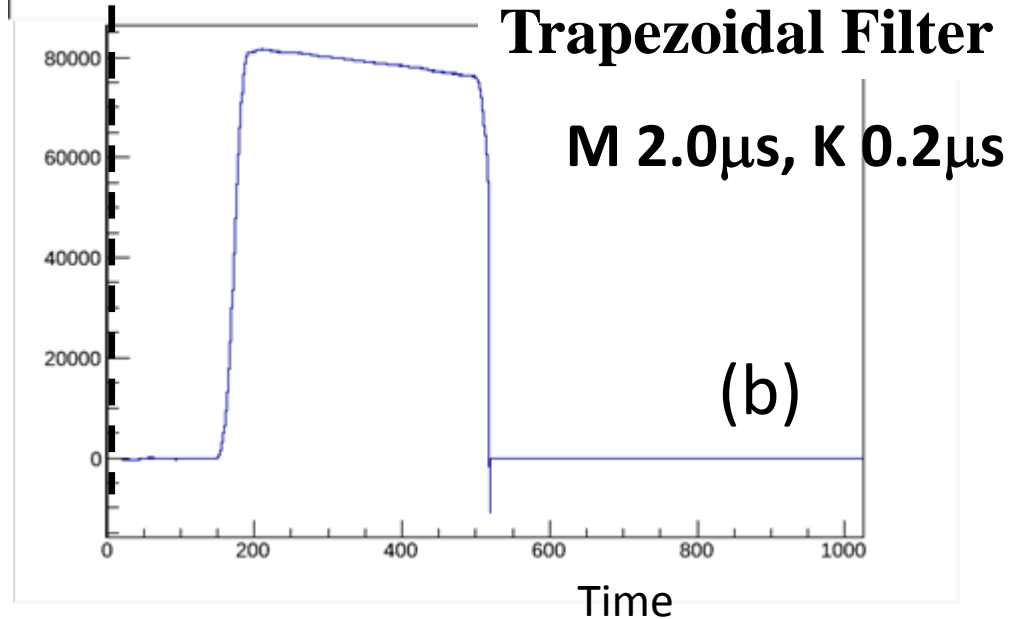


Energy Spectrum

pulse height of (b)

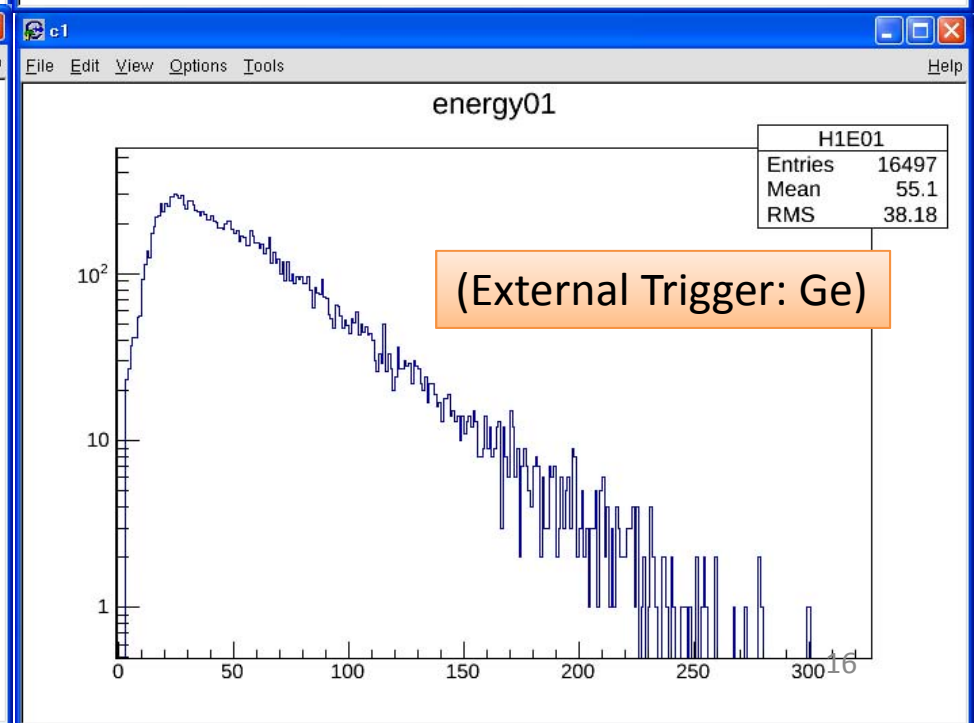
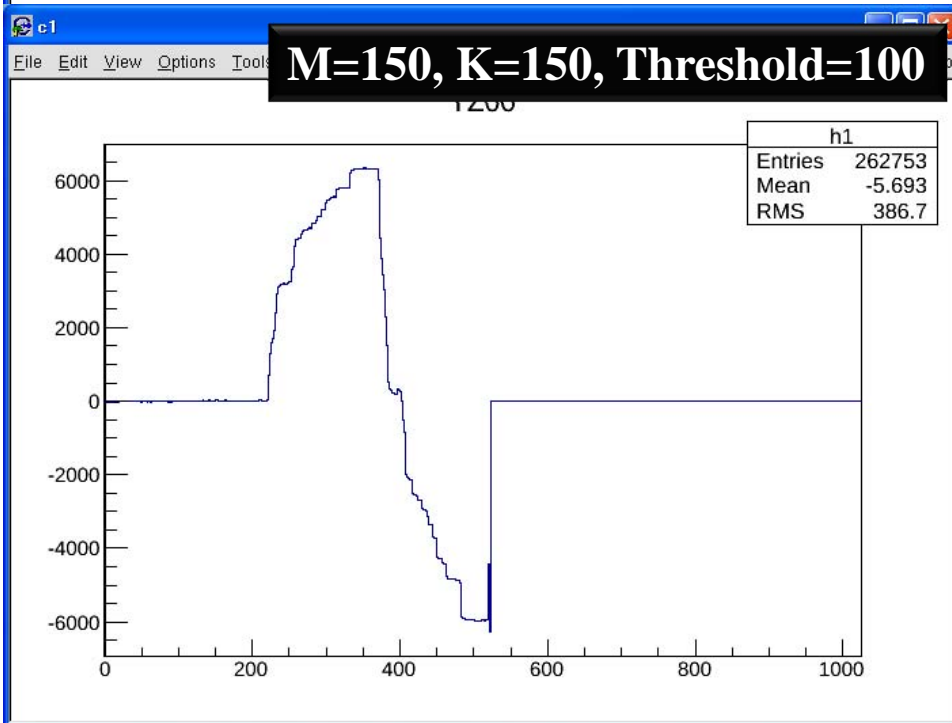
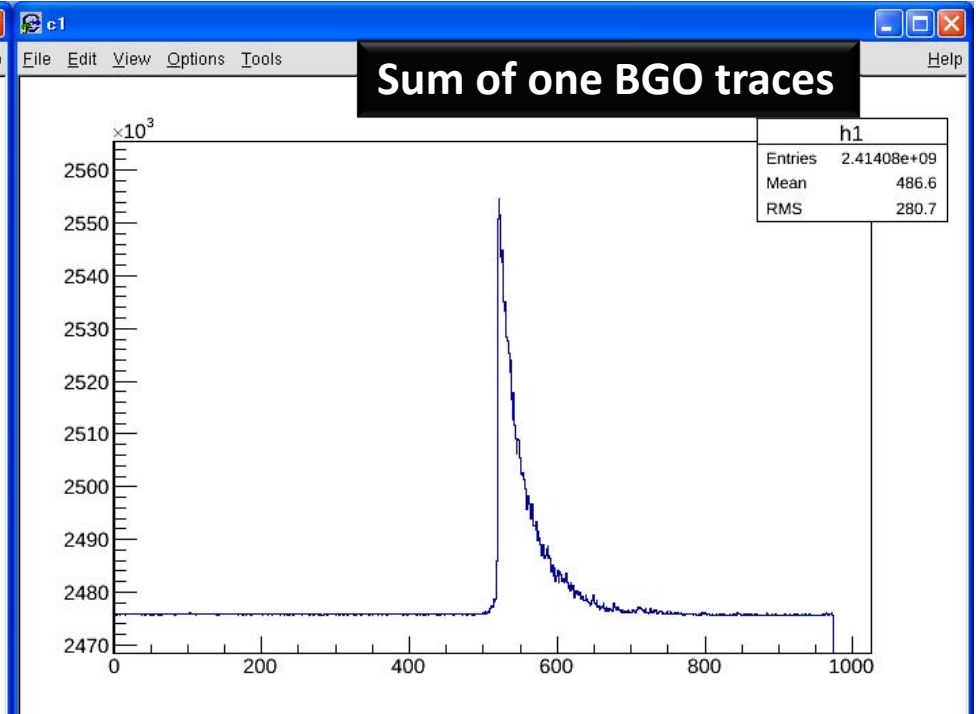
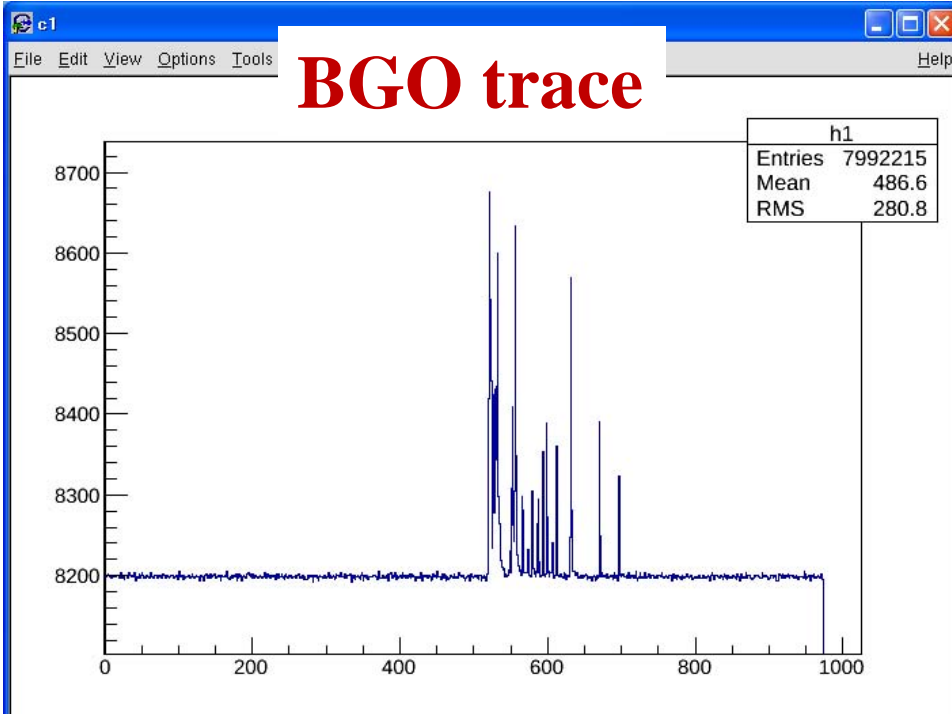


Trapezoidal Filter

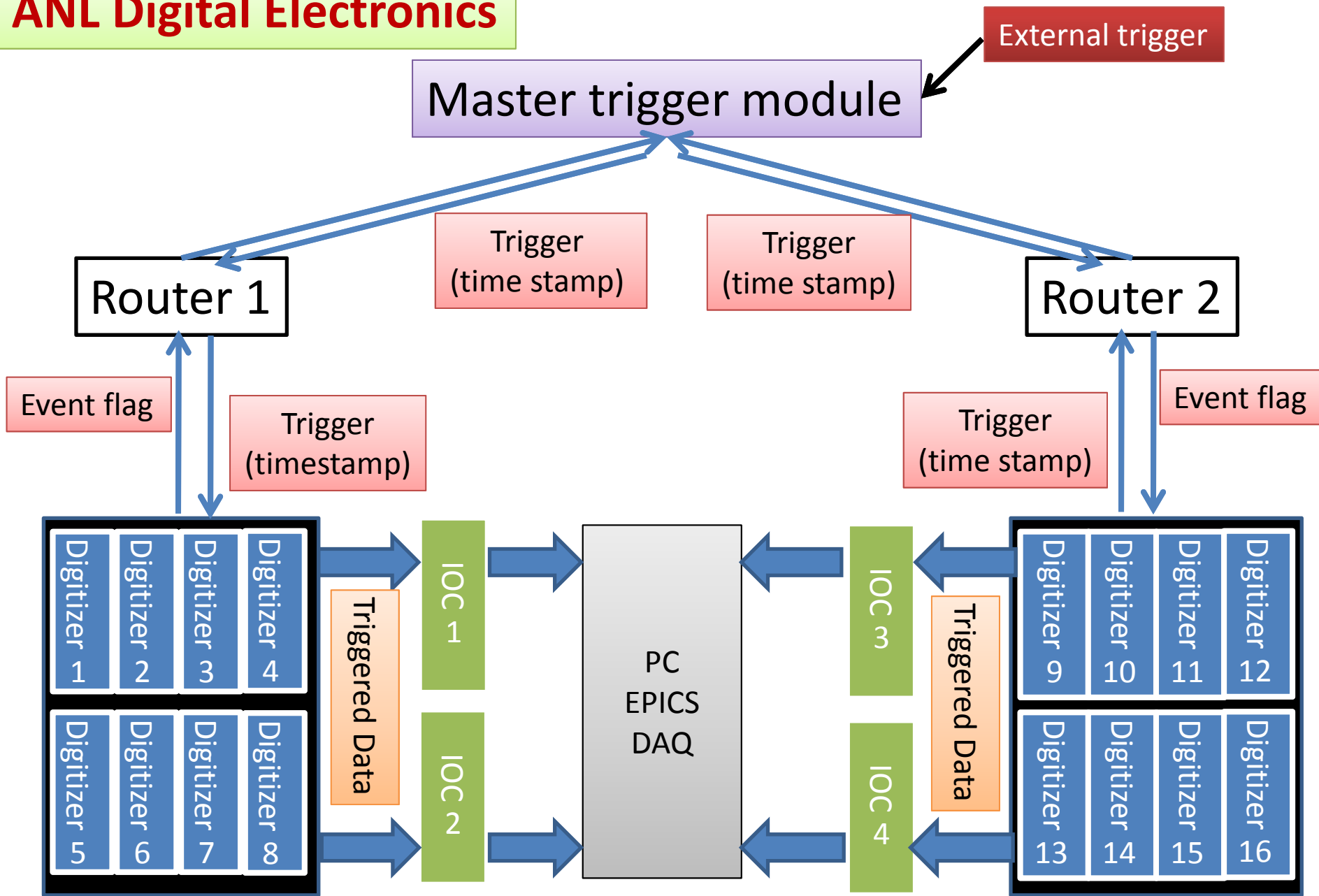


$$E = \frac{TZ_{max}}{M}$$

$$TZ = \sum_{i=0}^T \sum_{j=i}^M \{tr(j+K) - tr(j)\}$$

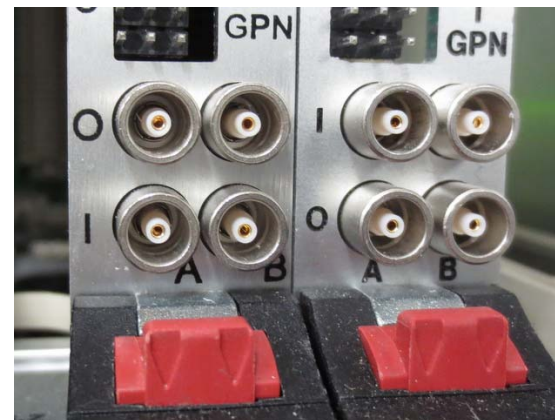
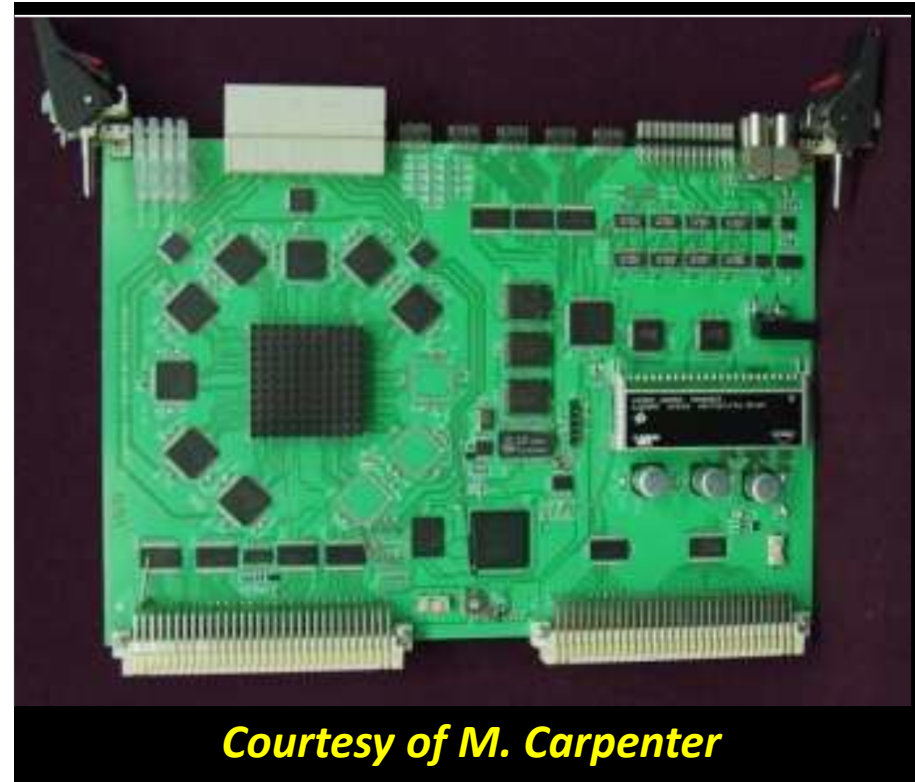


ANL Digital Electronics



Trigger timing and control module

- 1 Master, 1 Router/8 Digitizers
- Synchronize all digitizer clocks
- Trigger logics
 - programmable
 - Multiplicity
 - Hit pattern
- NIM external trigger



Tohoku CYRIC experiment



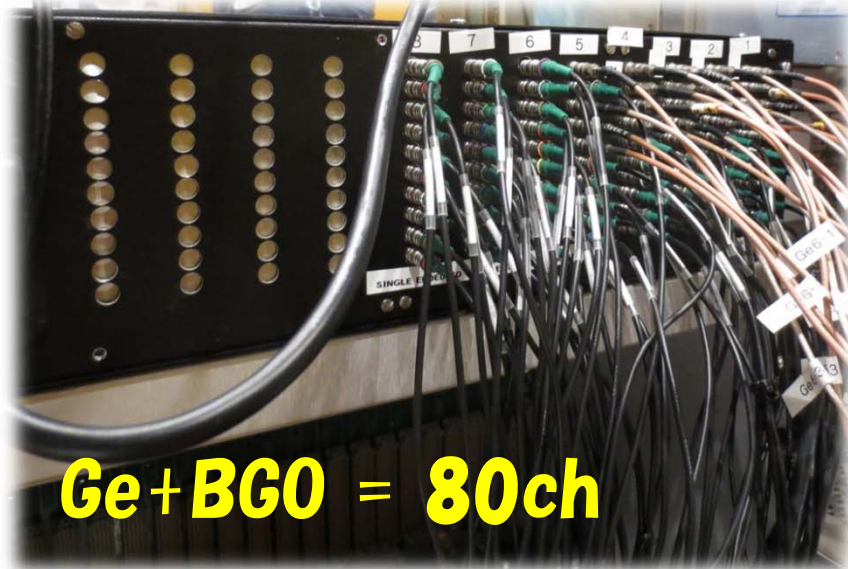
Experimental summary

- (Clover Ge + BGO ACS unit + Pb collimator) X 5
 - 20 Ge + 60 BGO = 80 ch
- Feb. 3 and 4, 2014, 36 hrs
- $^{120}\text{Sn}(^{20}\text{Ne}, 4n)^{136}\text{Nd}$
 - ^{20}Ne beam at 87 MeV, 1-6 pA
 - $1\text{mg}/\text{cm}^2$ ^{120}Sn
- Internal self-trigger
 - Ge multiplicity=1,2,3,4,5
 - Trigger rate ~80kHz
- 250 GB data/day

E07 Ge dets.

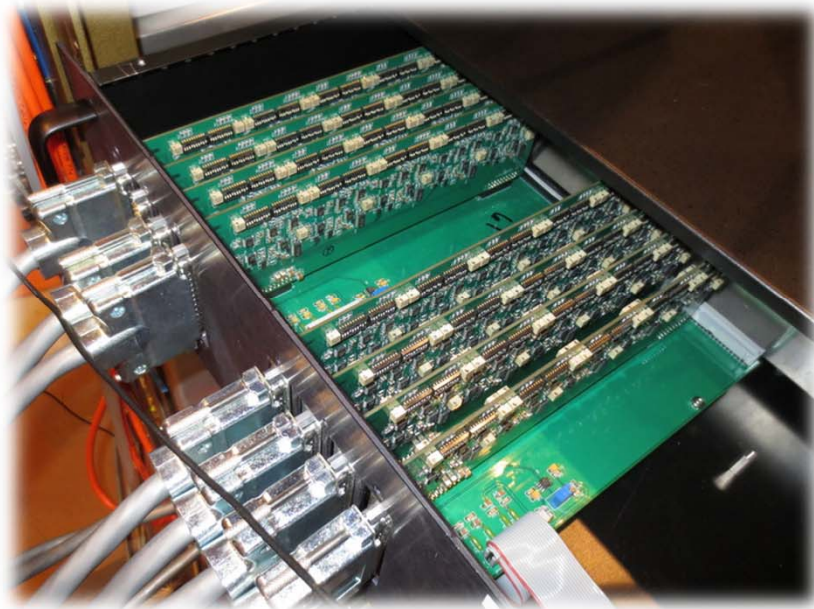


Interface box input

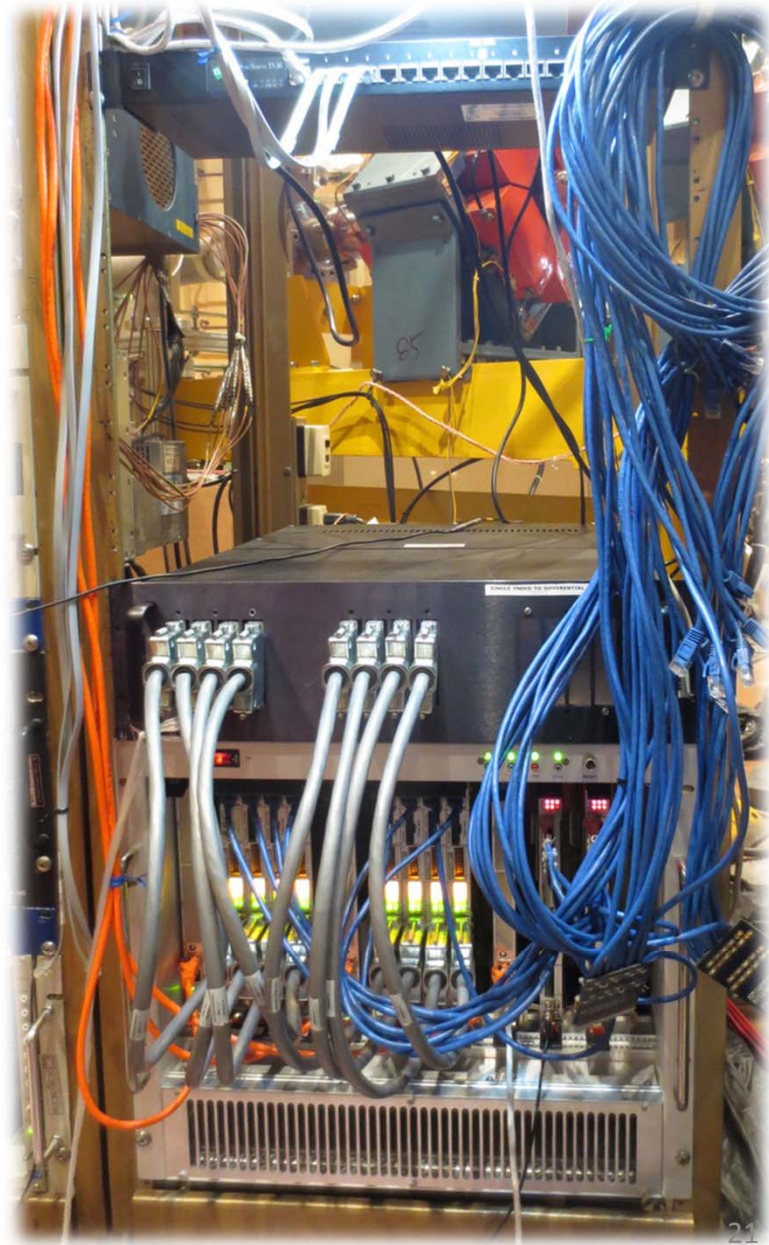


Ge + BGO = 80ch

Interface box inside + output



Very compact system!!



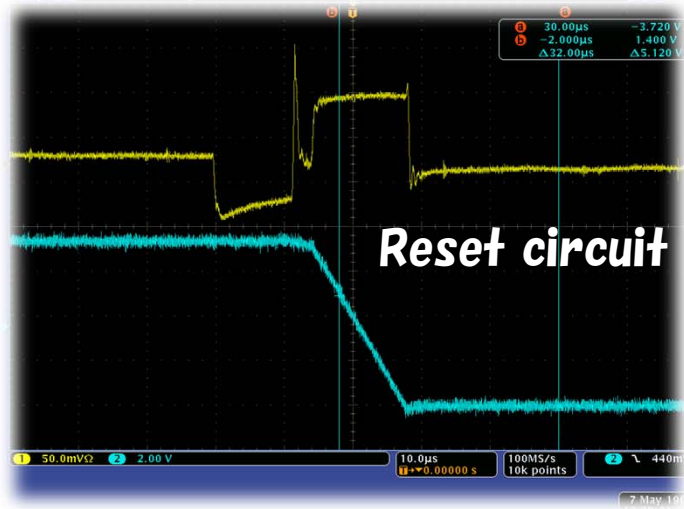
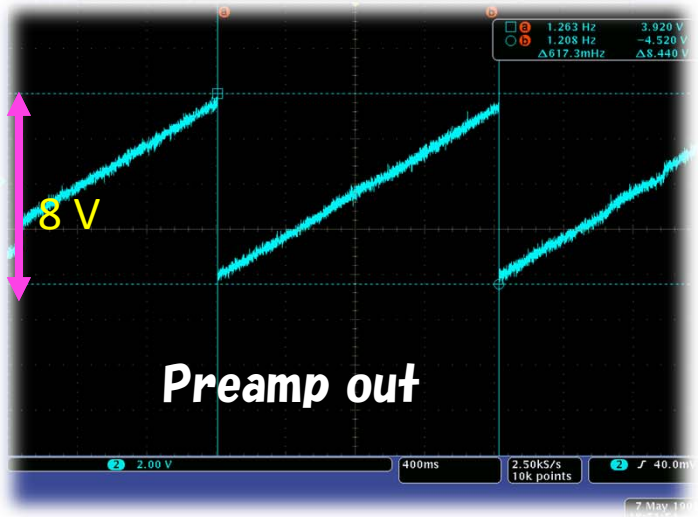
Ge



Interface Amp.



digitizer



DAQ: EPICS based

Experimental Physics and Industrial Control System

/global/devel/systems/edm/screens/CAGMrunControl.edl

CAGRA-mini Main Controller

Run Control

Start/Stop

Start Trigger Global Control Terminals

Save/NoSave

Save Digitizers VME Status Digitizer Enable

Copy/Sort

Sort Detector Rates Live Time Stamps Scripts

Digitizer and Trigger Control

```

dgs@dgs5:~
ファイル(E) 編集(E) 表示(V) 端末(T) タブ(I) ヘルプ(H)
CA.Client.Exception.....
Warning: "Identical process variable names on multiple servers"
Context: "Channel: "GLBL:DIG:raw_data_window", Connecting to: dgs5:5064, Ignored
192.168.253.234:5064"
Source File: ../cac.cpp line 1209
Current Time: Mon Feb 03 2014 22:56:49,087485530
.....
dgs@dgs5 ~] $ xterm&
[2] 13019
dgs@dgs5 ~] $
    
```

/global/devel/systems/edm/screens/dgs_Master2.edl

Control

Misc Stat

Misc Control

DGS Trigger 0

Revision Code and Date

0x2541 0x1206

LRU Control

Trigger Select

Input Link Mask

U R L H G F E D C B A

0 1 0 1 1 1 1 1 1 0 1

Output Control

Output Data

1 Sync

2 CPLD

Diag Counters

Trigger Settings

/global/devel/systems/edm/screens/cloGlobal2.edl

DGS Global Controls

Polarity: RiseEdge

Pileup Mode: Accept

Trig Mode: ExtTTCL

Channel Enable: Enabled

Min Overlap Win: 9.00 us

Max Overlap Win: 7.00 us

Disc. Width: 25.00 us

Peak Sensitivity: 3

Baseline Delay: GLBL.DIG.ba

Baseline Start: GLBL.DIG.ba

D Window: 0.30 us < 1.28 us

K Window: 1.20 us < 1.28 us

M Window: 3.50 us < 10.24 us

D2 Window: 0.20 us < 0.32 us

LED Thresh: 50

CFD fraction: GLBL.DIG.CF

Raw Delay: 1.00 us

Raw Len: 0.32 us > 0.28 us

/global/devel/systems/edm/screens/clocounterRates.edl

Disc Hit	Accept Hit	Accept Evt	Drop Evt	Disc Hit	Accept Hit	Accept Evt	Drop Evt
0 3207	3161	1633	0	0 4014	3942	1986	0
1 3538	3495	1685	0	1 3911	3843	1924	0
2 4701	4590	2253	0	2 4278	4205	2111	0
3 3657	3571	1843	0	3 4010	3934	1982	0
4 10673	9234	1285	0	4 14953	12064	1844	0
5 12621	9885	1433	0	5 9777	7708	1388	0
6 9253	8183	1306	0	6 11051	9298	1568	0
7 10589	9456	1668	0	7 17732	13258	1835	0
8 9224	7805	1412	0	8 14629	10655	1266	0
9 16145	13013	2017	0	9 32877	12098	1286	0

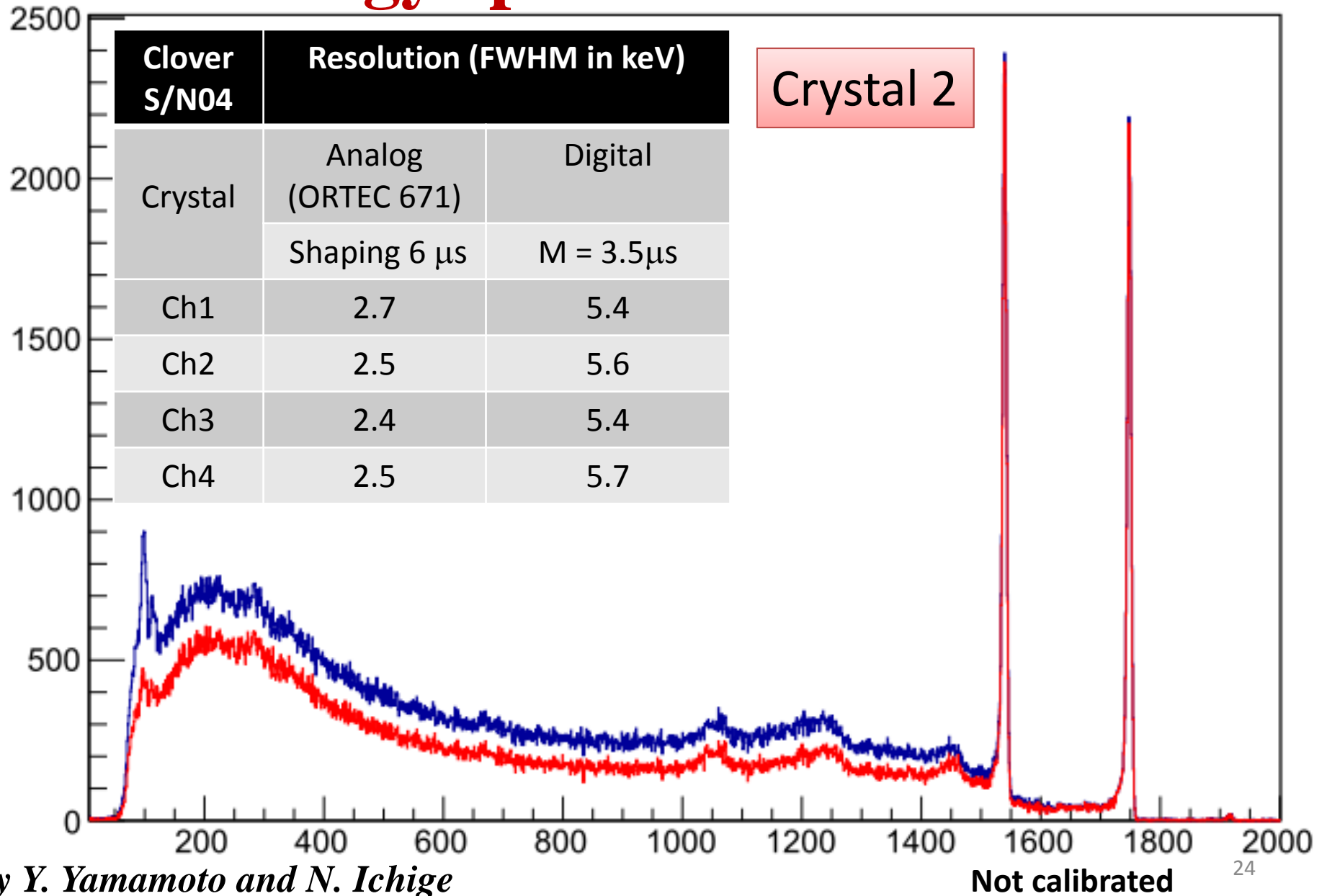
Digitizer 3

Disc Hit	Accept Hit	Accept Evt	Drop Evt
0 3542	3480	1816	0
1 4523	4408	2224	0
2 4224	4144	2129	0
3 3967	3892	1872	0
4 10235	8268	981	0
5 10449	7701	916	0
6 5949	5568	237	0
7 10774	8627	1094	0
8 12128	9089	1167	0
9 14127	7869	1095	0

Digitizer 4

Disc Hit	Accept Hit	Accept Evt	Drop Evt
0 3912	3778	1955	0
1 4176	4050	2061	0
2 3815	3739	1926	0
3 3528	3477	1760	0
4 7087	6001	1035	0
5 8828	6517	1133	0
6 8102	6547	1191	0
7 5600	4927	825	0
8 5162	4249	741	0
9 8175	6933	931	0

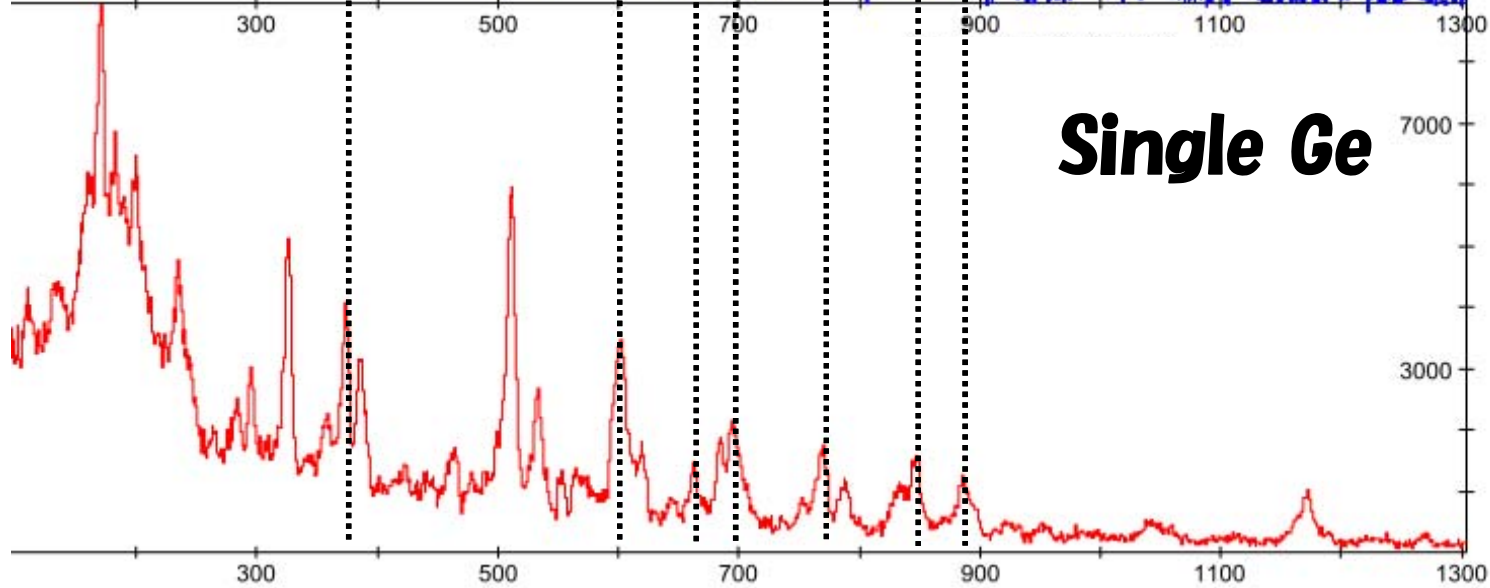
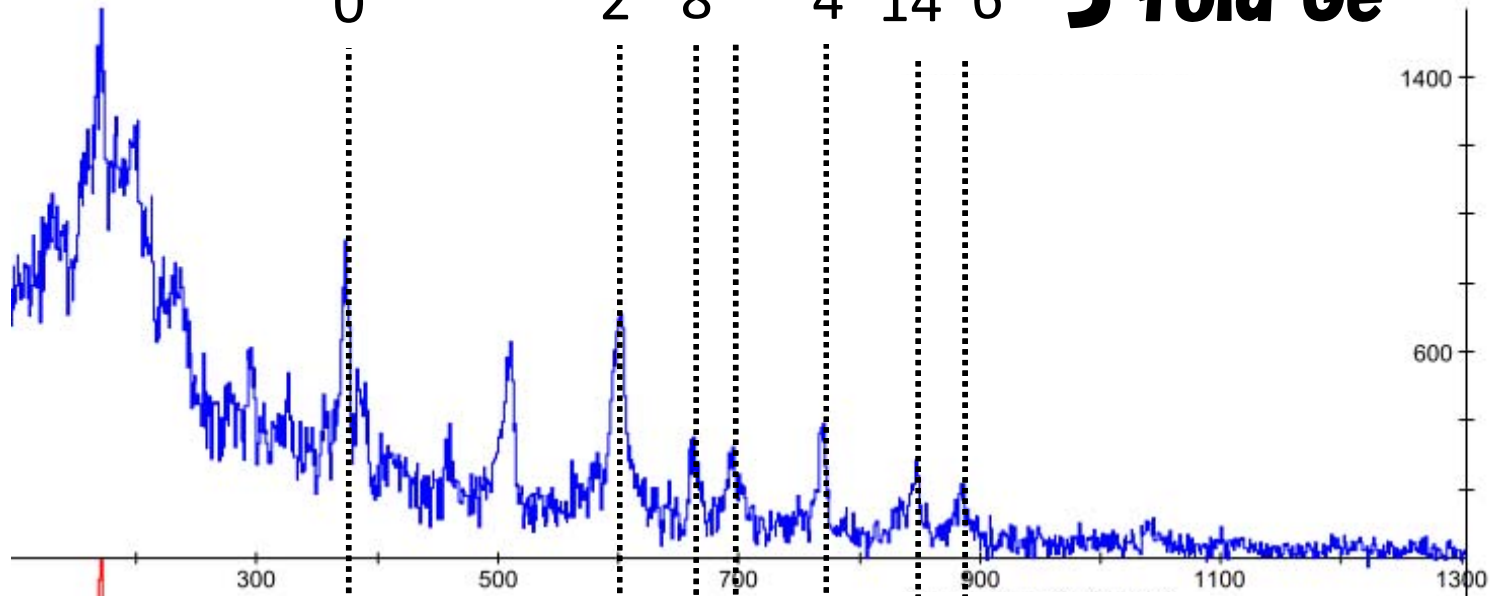
Energy spectrum with ^{60}Co



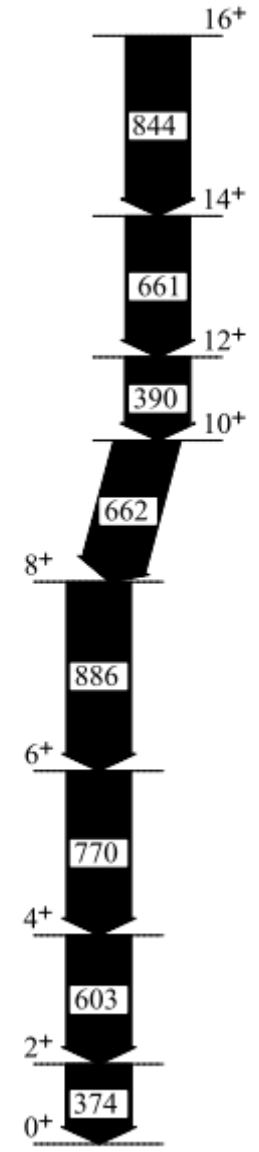
^{136}Nd

2	4	10	6	16	8
↓	↓	↓	↓	↓	↓
0	2	8	4	14	6

5 fold Ge



Single Ge



Summary

- Through put ratio measured at J-PARC T44
 - TPR= $\sim 80\%$ at $\sim 500\text{k/spill}$ beam rate
 - acceptable for the E13 1st experiment
 - Estimated TPR $< 0.5\%$ at 10MHz beam rate
- The Digital HyperBall (DHB) initiative
 - Interface board + ANL digital electronics (digitizer+ FPGA firmware+ EPICS DAQ)
- First test experiment of DHB with 5 (Clover Ge + BGO) at Tohoku CYRIC
 - Data taken with internal logic trigger (fully digital system)
- Future goals
 - Improvement of Ge resolution with the DHB system
 - Completion of the interface board
 - TPR measurement of the DHB system
 - Implementation to the E07 experiment