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

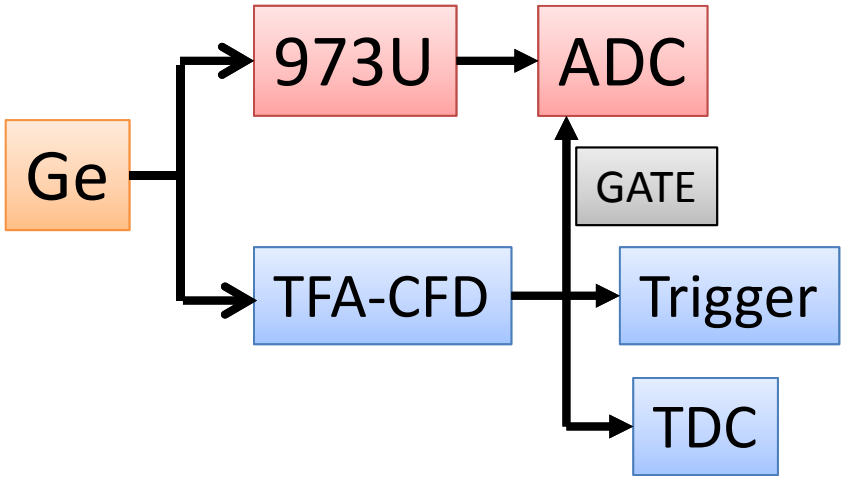
- Why go digital?
  - Measurement of through put ratio: T44 at the J-PARC K1.1 beam line
- GRETINA digitizer + ANL firmware
- Test experiment of digital Clover Ge array at CYRIC
- Summary

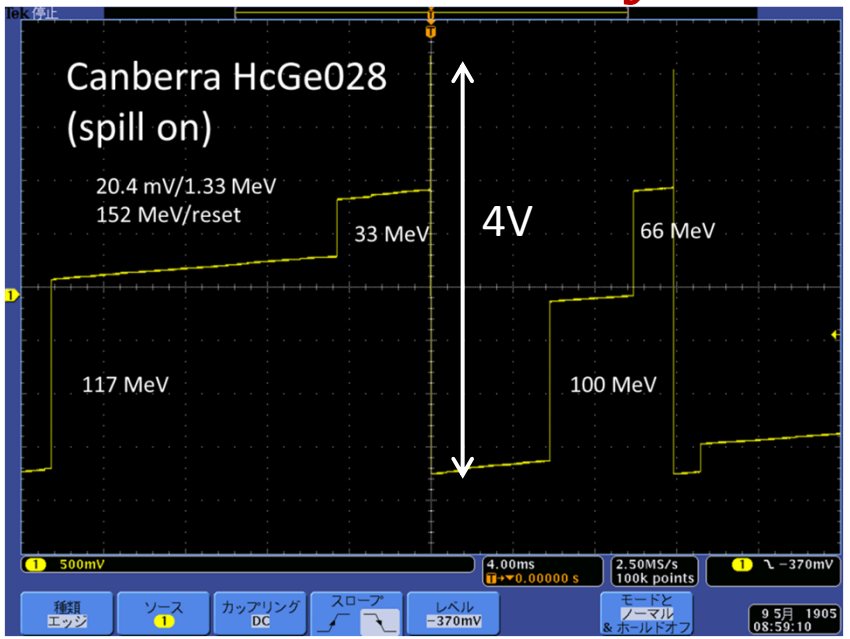
Why go digital?

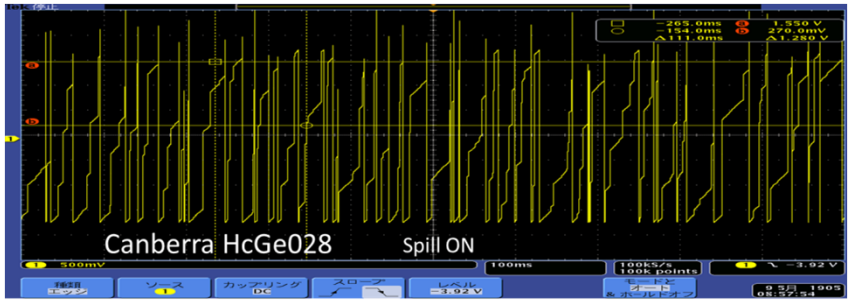
Ge detector for Hyperball and its readout system

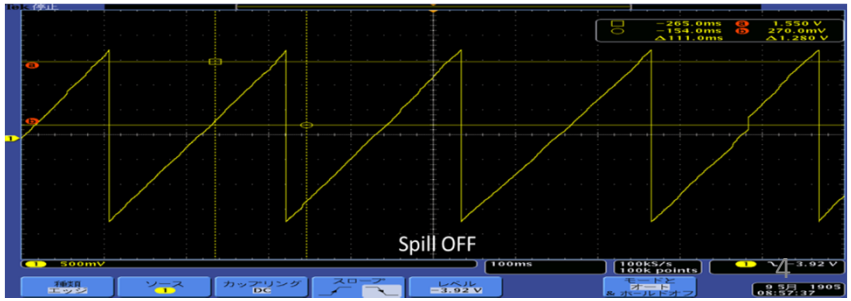
High energy deposit rate

- 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

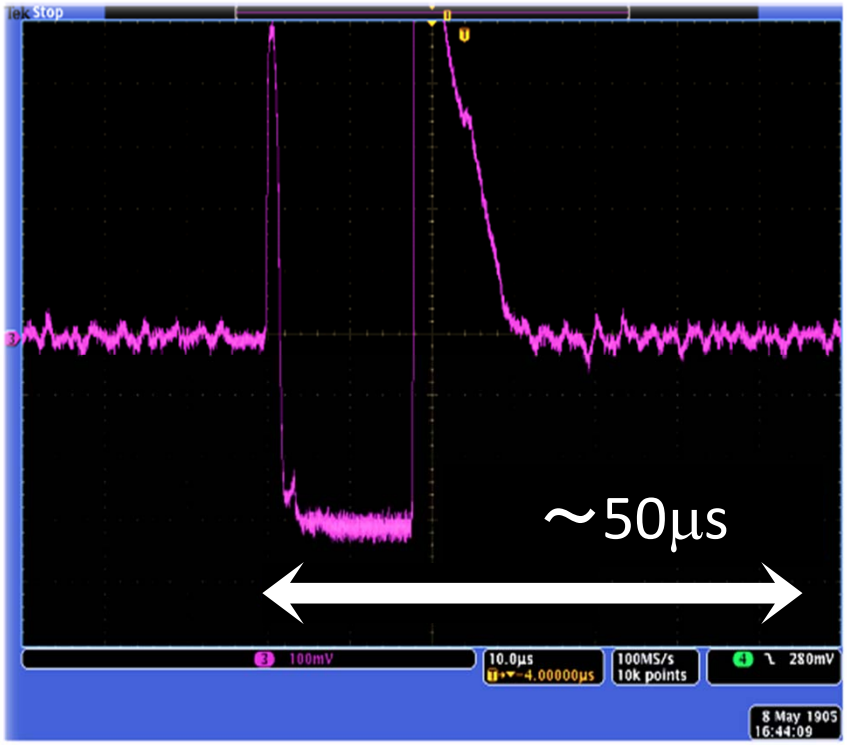
$$\textbf{Det. Effi.} = \varepsilon(E_\gamma) \cdot \frac{\Omega}{4\pi} \cdot (\textit{Trough Put Ratio}) \cdot \varepsilon(DAQ)$$

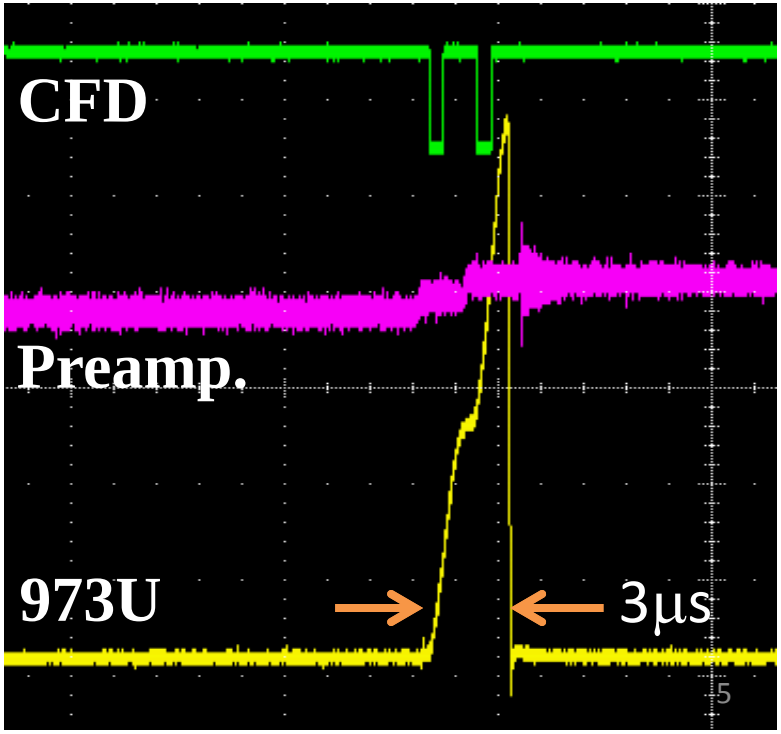
Recovery from reset

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

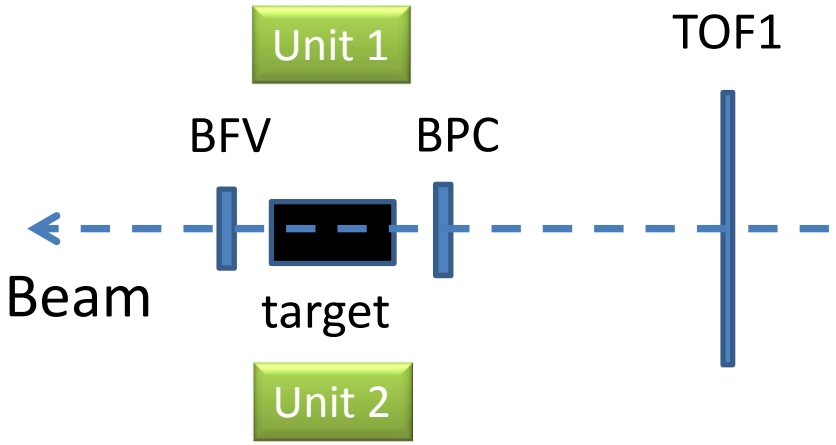
Pile up

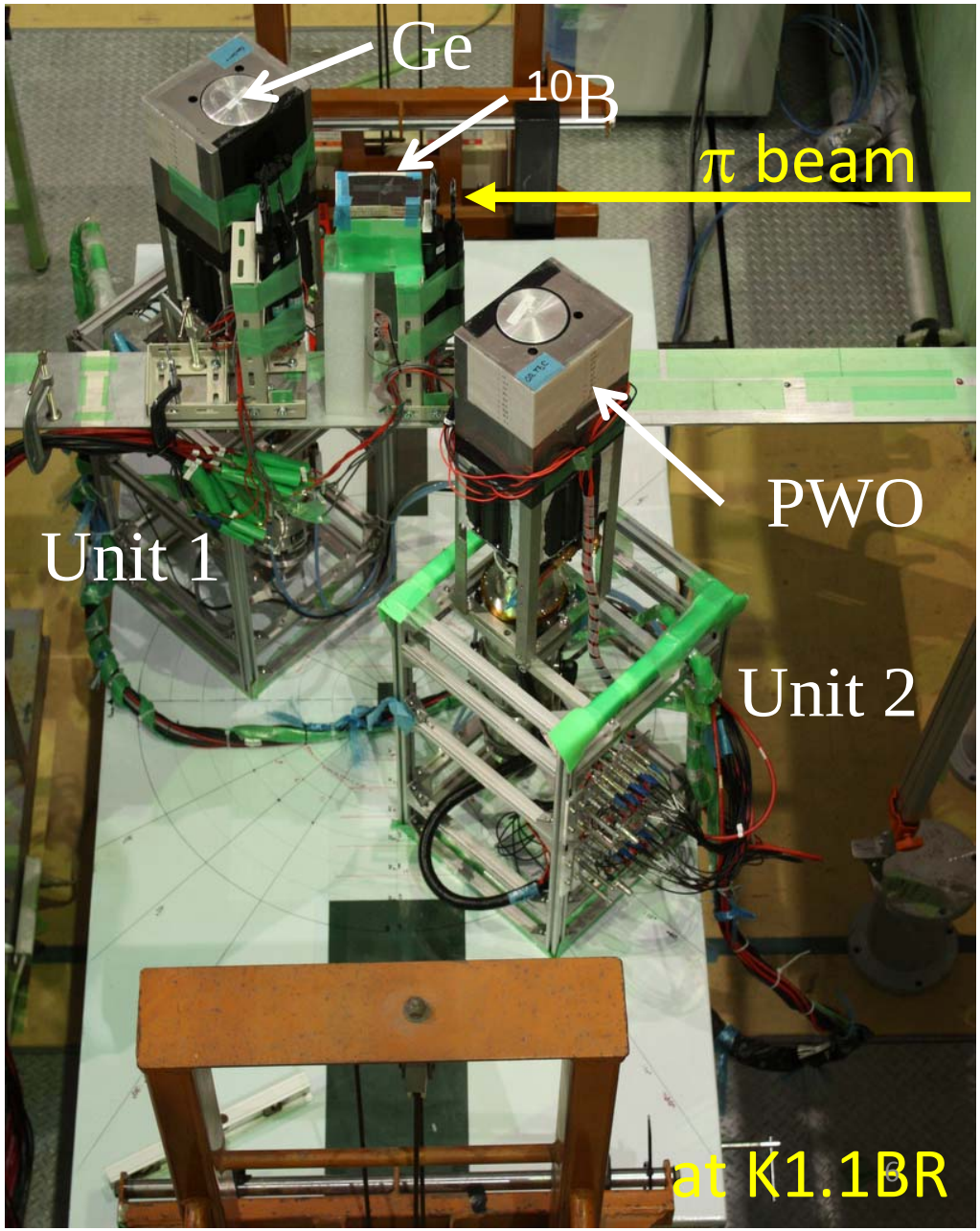
$\tau_{pu} = 3x2\ \mu s$





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





Beam time: 6/26 –7/2, 2012
Target: ^{10}B14.2g/cm^2
Beam rate: 200kHz ～2MHz
Two HBJ units (Ge, PWO, LSO)

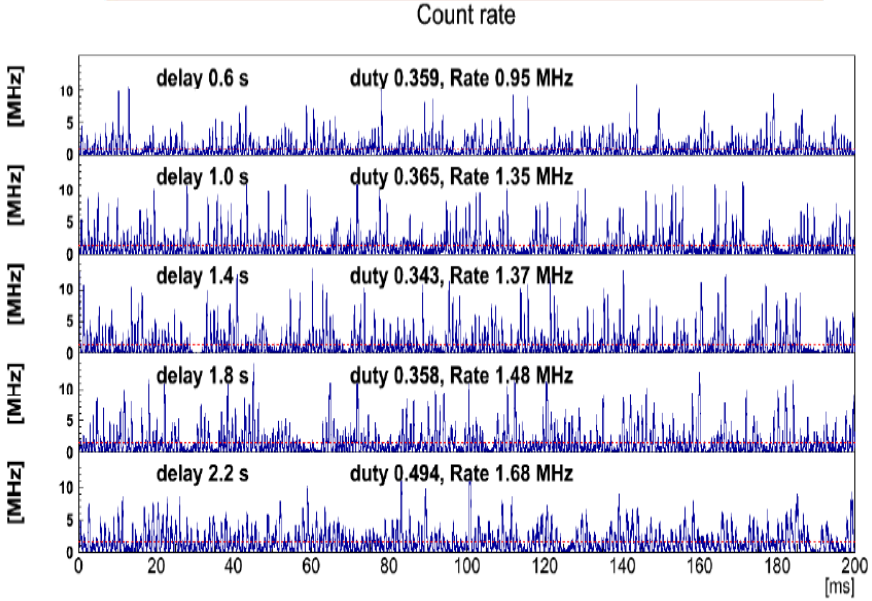
Measurement of TPR with a test pulse

Two trigger types

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

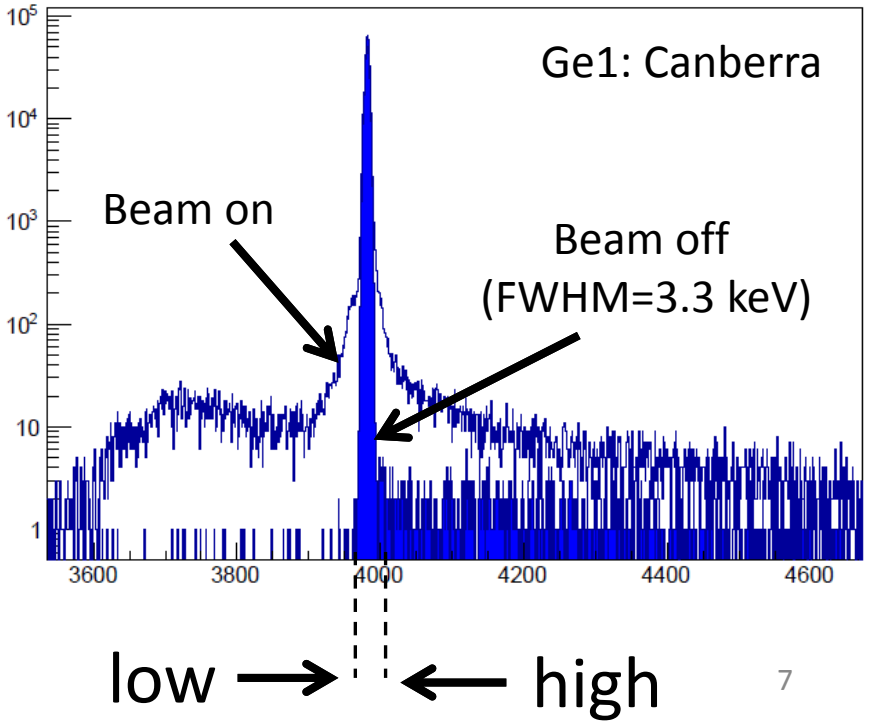
$$TPR = \frac{S(low,high)}{\#\ of\ test\ signal\ acpt.\ by\ DAQ}$$

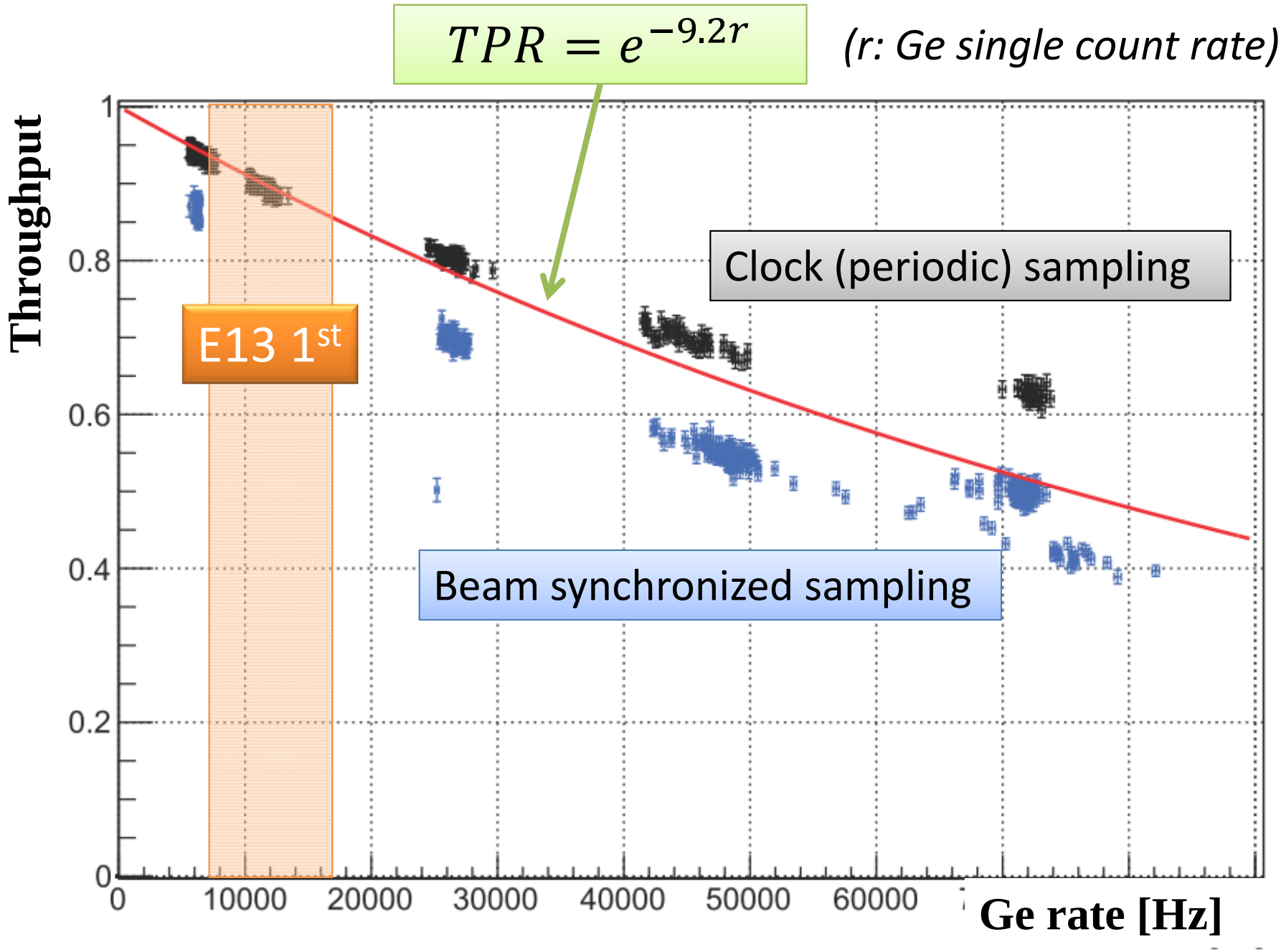
TPR with micro structures of beam



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

Test signal spectrum



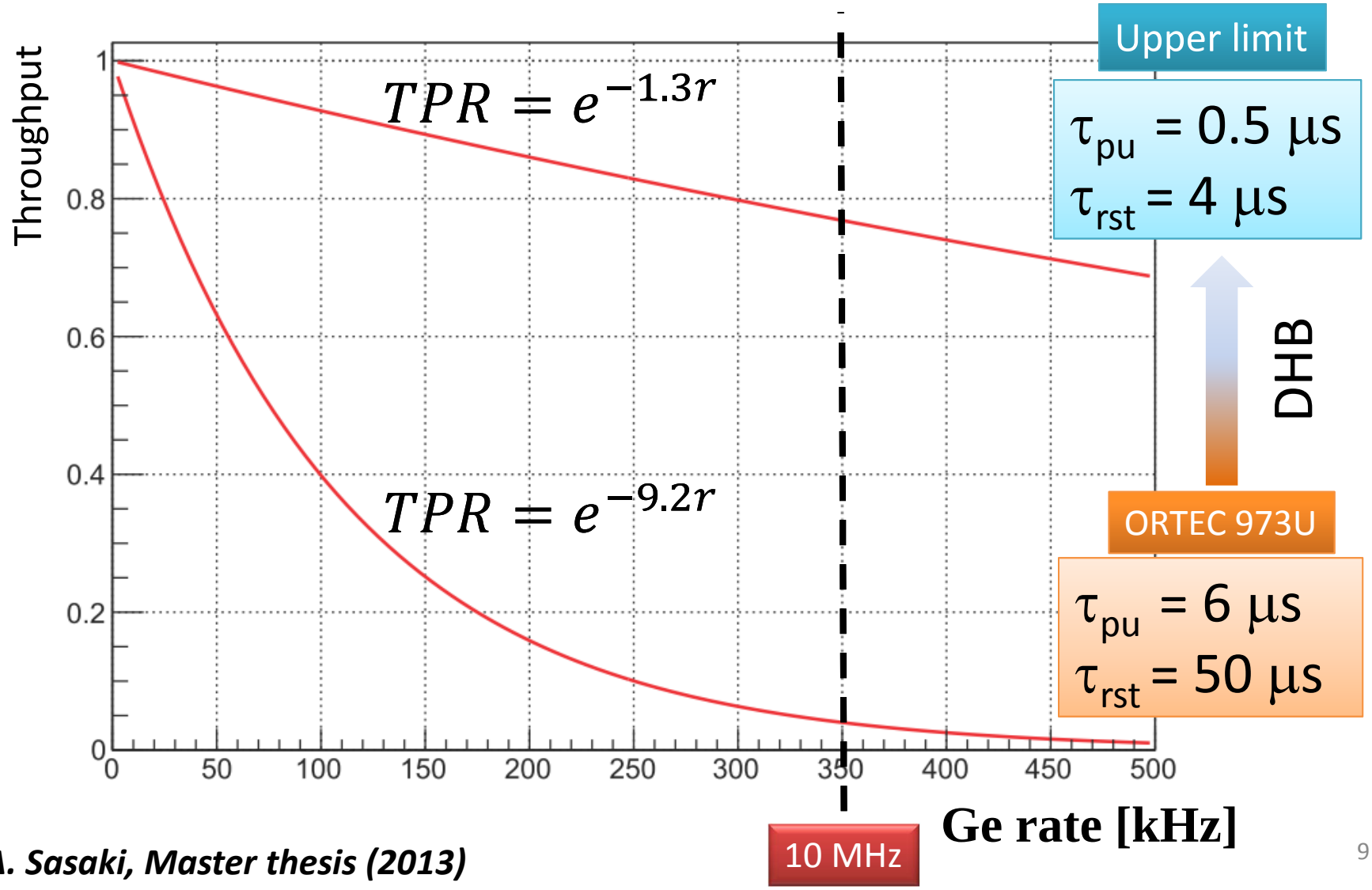


A. Sasaki, Master thesis (2013)

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

ε= 9.6 MeV (ave. energy deposit)

E_{rst} =152 MeV (reset energy)

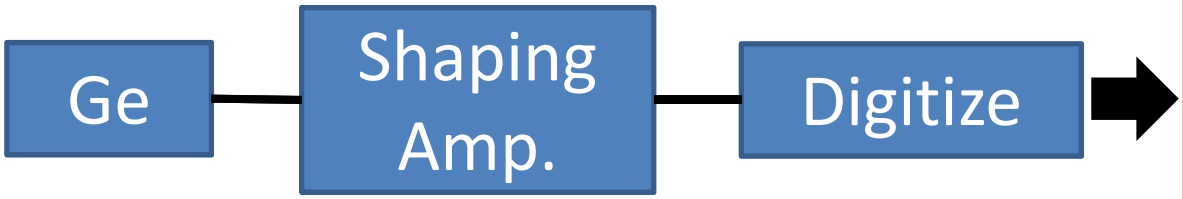


A. Sasaki, Master thesis (2013)

GRETINA digitizer + ANL firmware

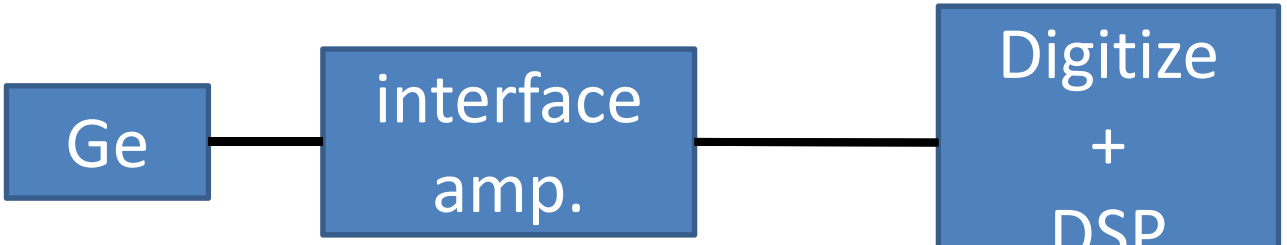
Digital Hyperball (DHB): two approaches

Tanida-Hosomi method



- Pile up separation
- Baseline fitting after rst.

Argonne, Sugihara, and Yamamto method

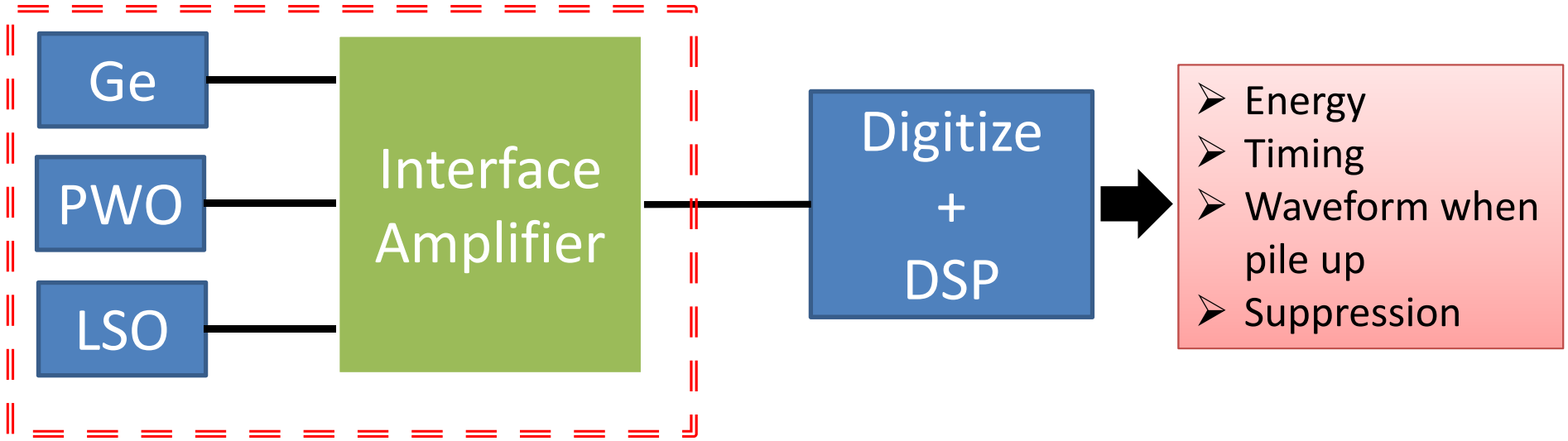


- Energy
- Timing
- Waveform when pile up

- Differentiation, gain
- Reset & high energy event
  - ✓ Detection
  - ✓ Cutoff circuit

- Trapezoidal filtering
- CFD algorithms
- Pile-up detection

Digital Hyperball (DHB)



Experiment specific (analog)

Versatile system

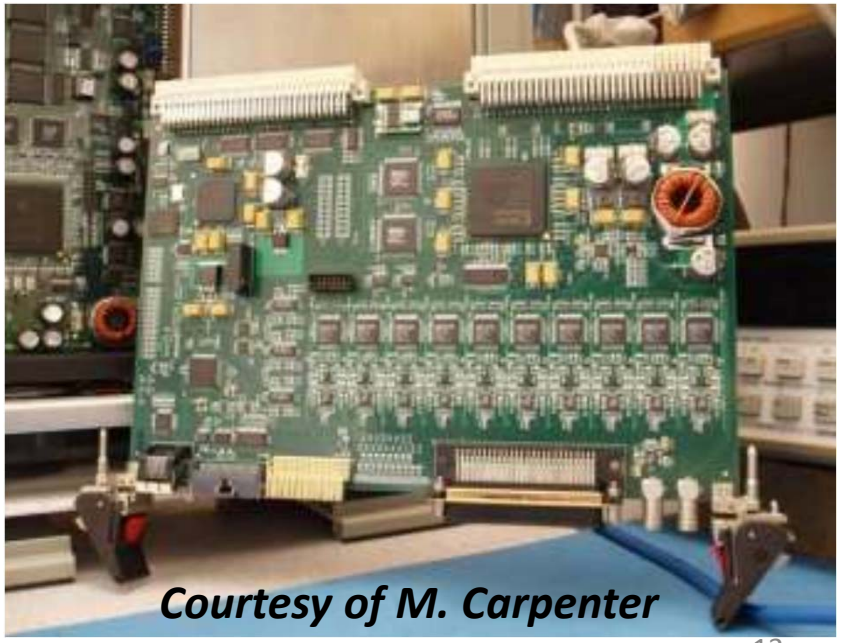
R&D at Tohoku and ANL for DHB

Adopt the ANL system

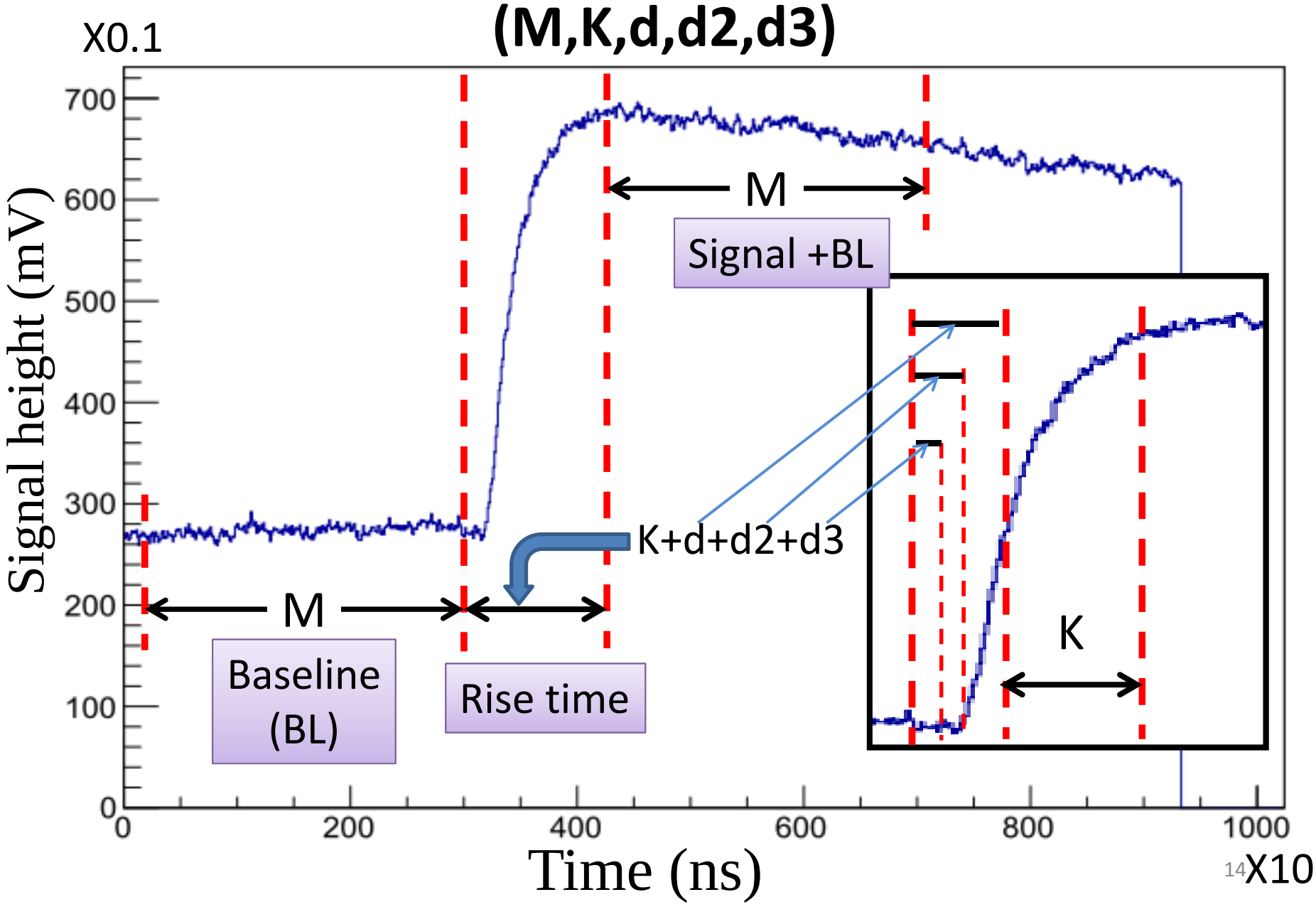
GRETINA digitizer (LBNL)

- 10 ch. (differential input)
- 14 bit, 100 MHz
- ±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. 10μs)

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

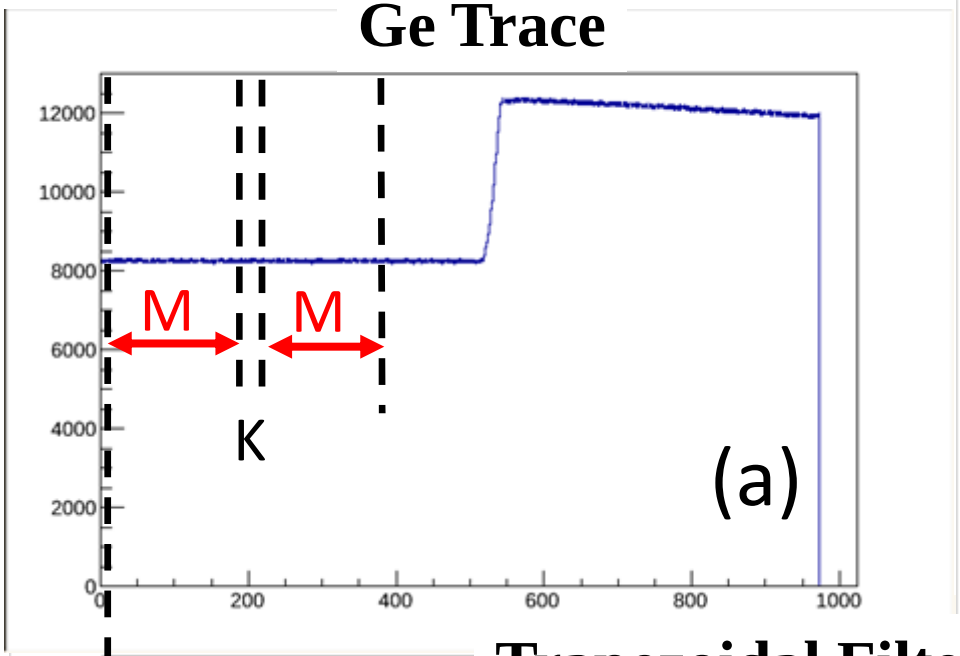


Digitizer firmware parameters (ANL)



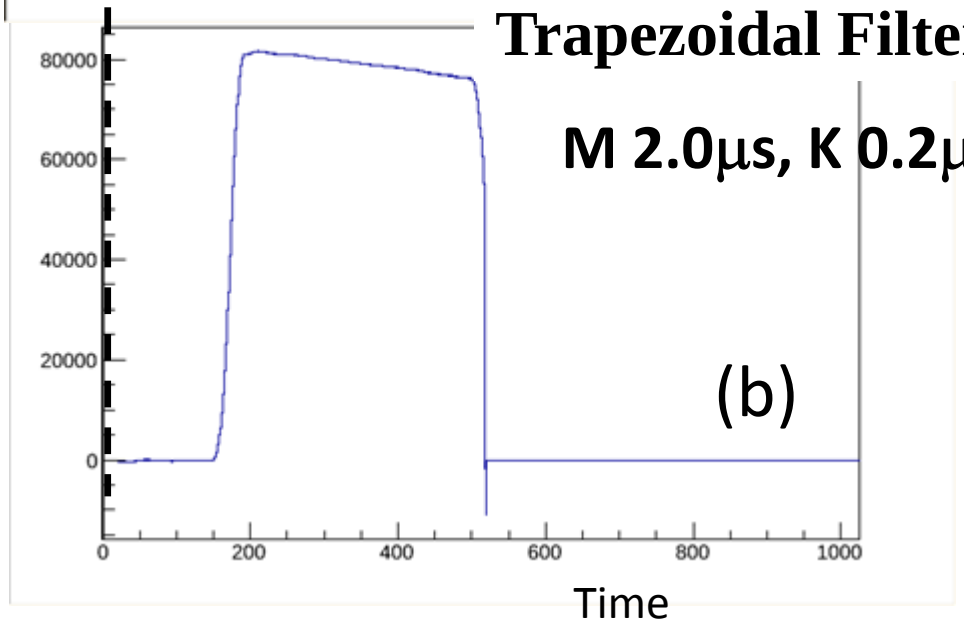
Waveform analysis

Ge Trace



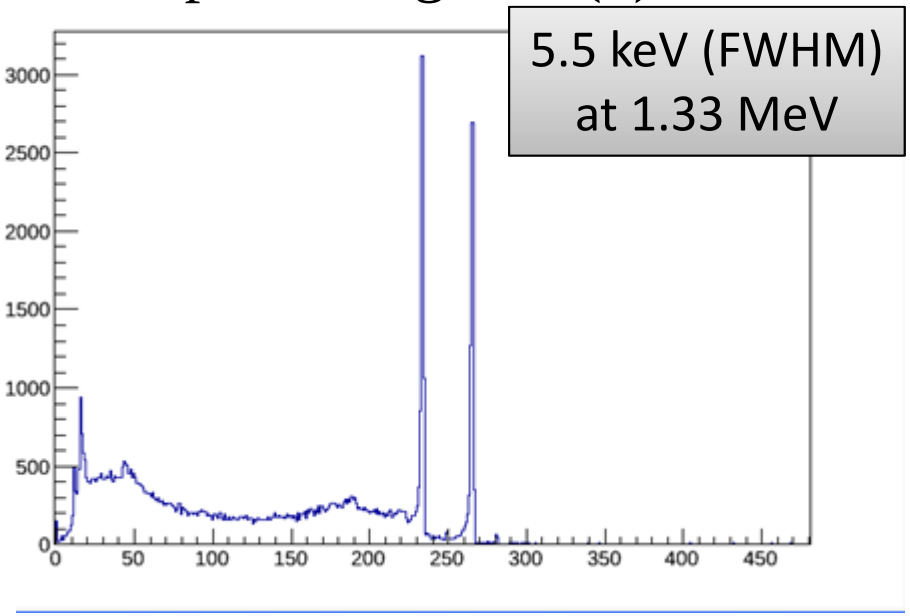
Trapezoidal Filter

M 2.0μs, K 0.2μs



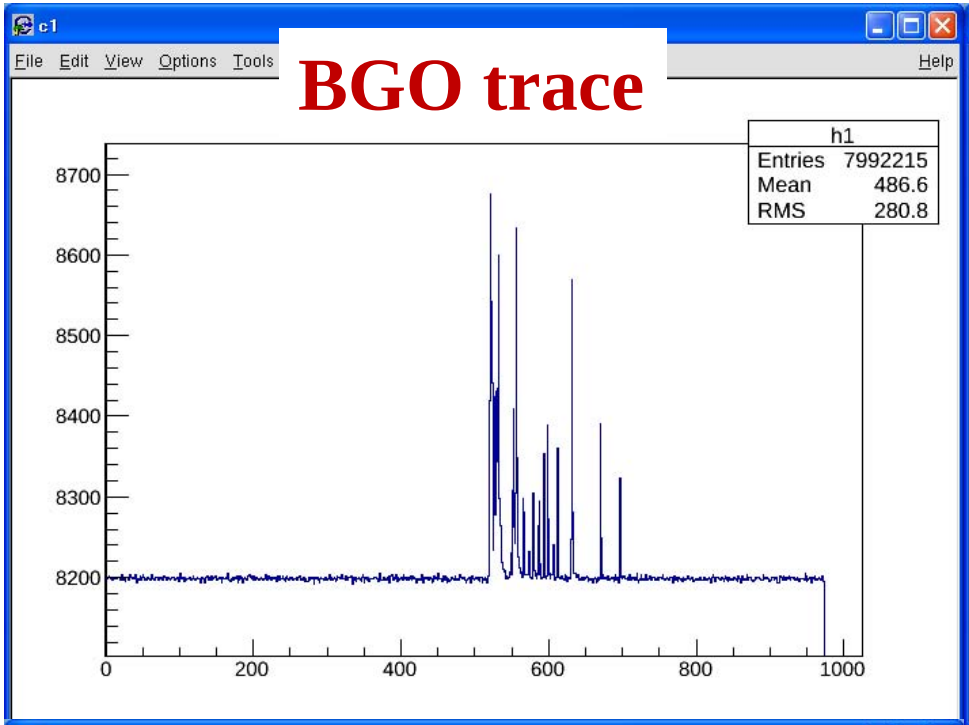
Energy Spectrum

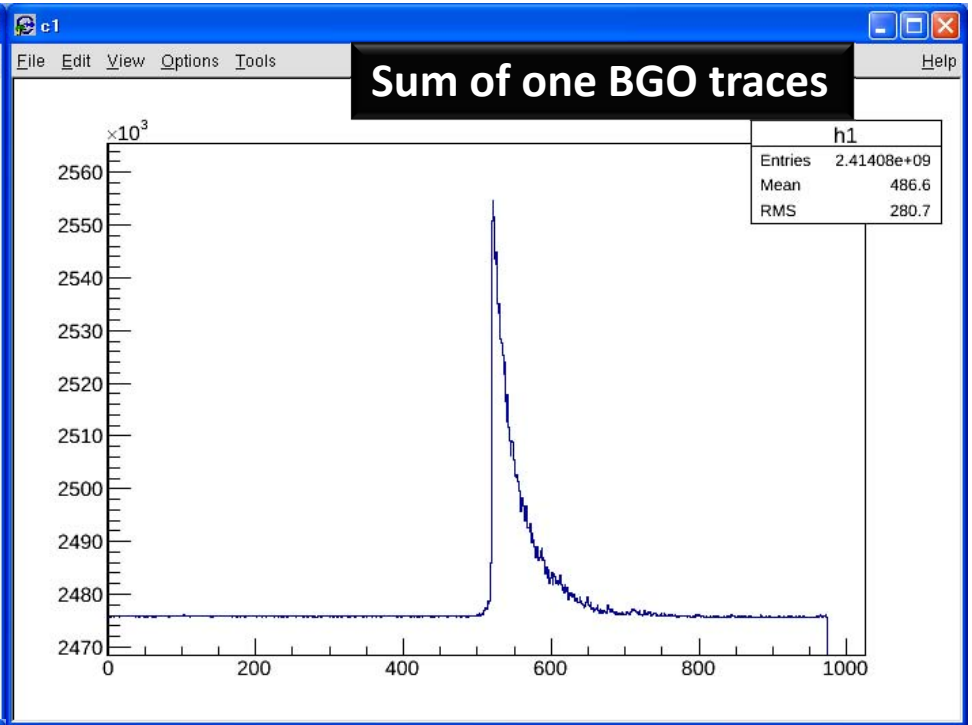
pulse height of (b)

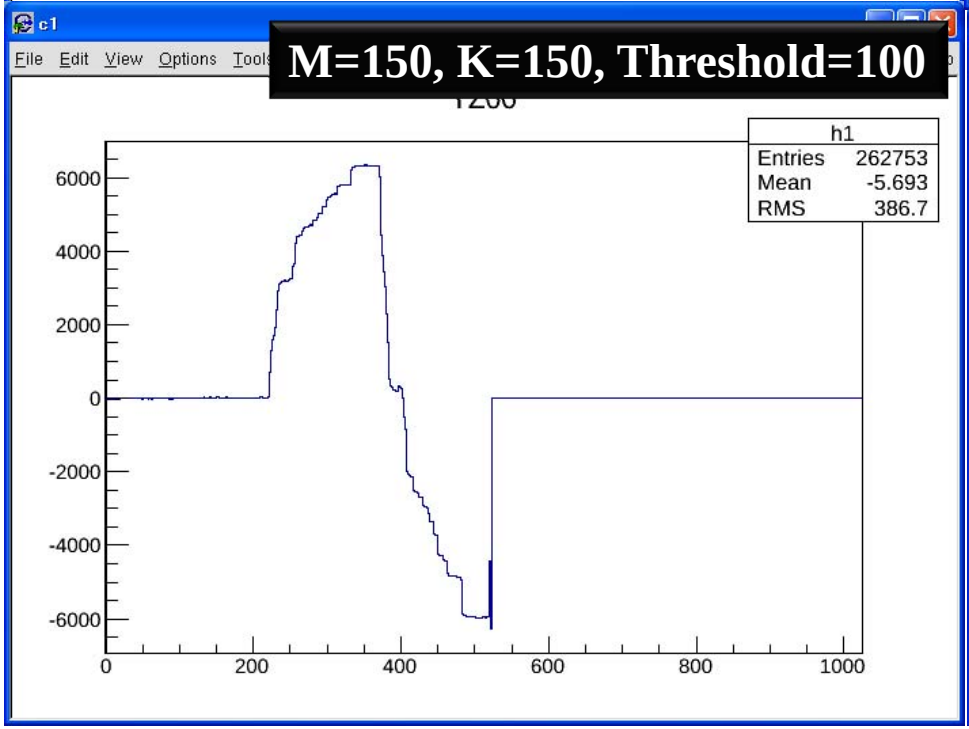


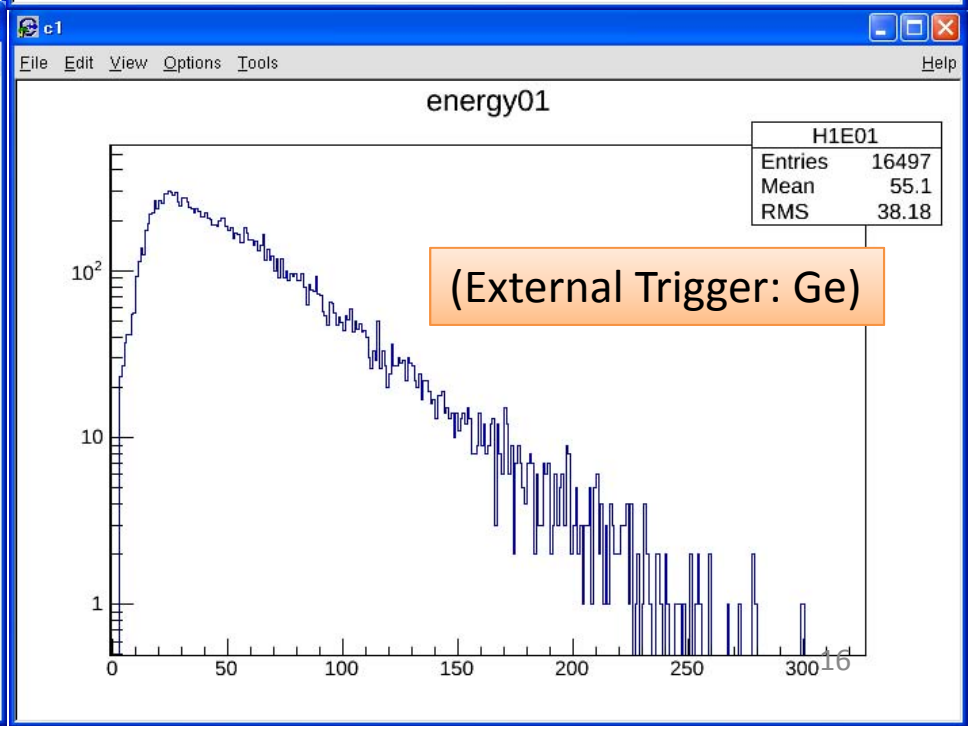
$$E = \frac{TZ_{max}}{M}$$

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

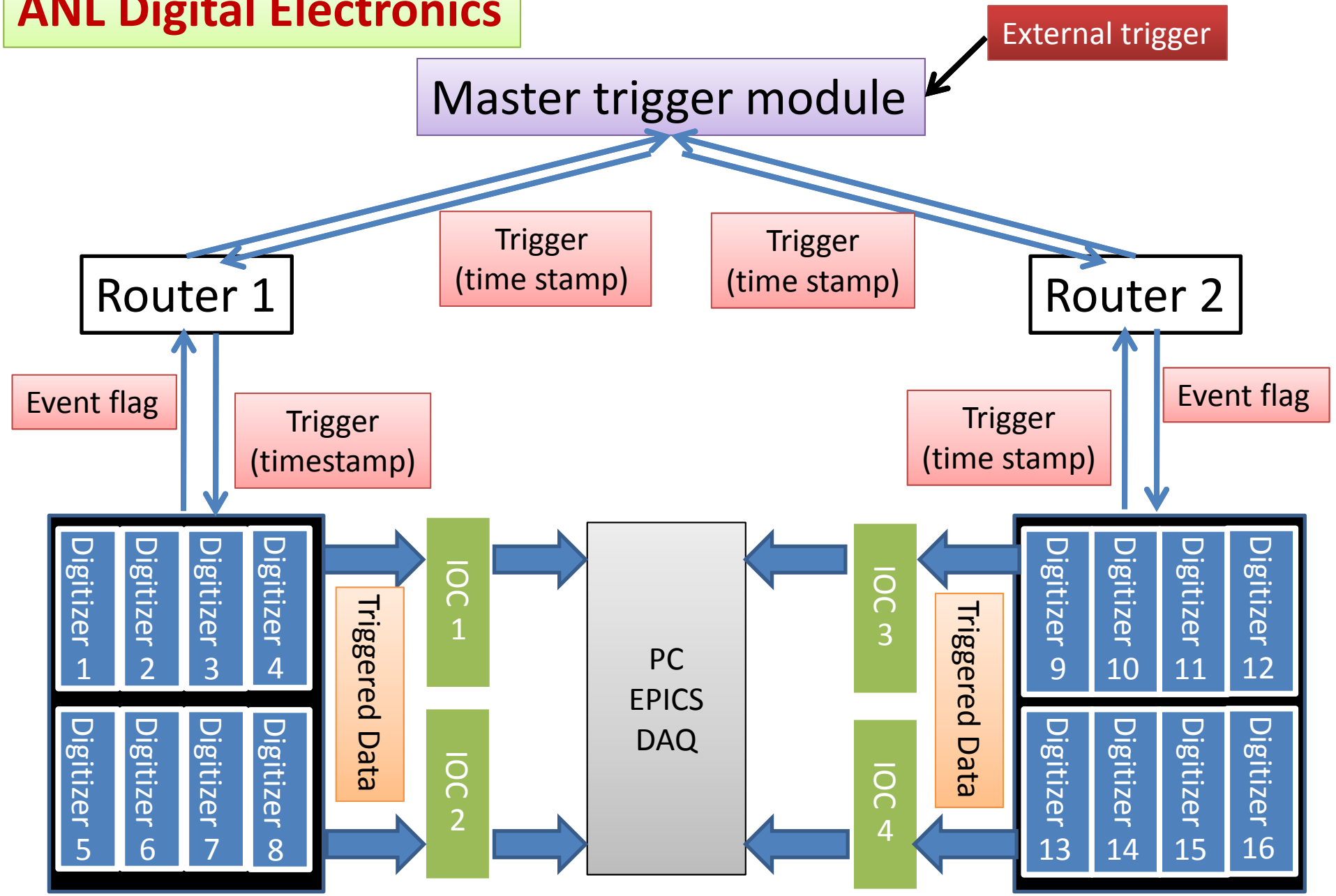

c1
File Edit View Options Tools Help
BGO trace
h1
Entries 7992215
Mean 486.6
RMS 280.8
8700
8600
8500
8400
8300
8200
0 200 400 600 800 1000


c1
File Edit View Options Tools Help
Sum of one BGO traces
×10^3
h1
Entries 2.41408e+09
Mean 486.6
RMS 280.7
2560
2550
2540
2530
2520
2510
2500
2490
2480
2470
0 200 400 600 800 1000


c1
File Edit View Options Tools
M=150, K=150, Threshold=100
h1
Entries 262753
Mean -5.693
RMS 386.7
6000
4000
2000
0
-2000
-4000
-6000
0 200 400 600 800 1000

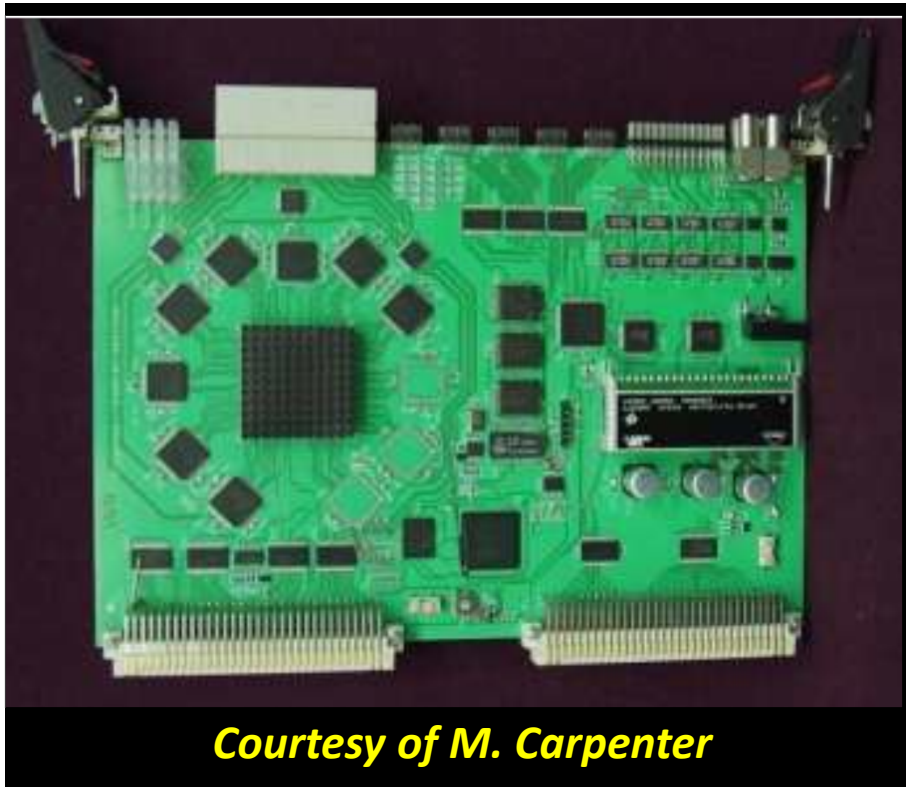

c1
File Edit View Options Tools Help
energy01
H1E01
Entries 16497
Mean 55.1
RMS 38.18
(External Trigger: Ge)
10^2
10
1
0 50 100 150 200 250 300

ANL Digital Electronics

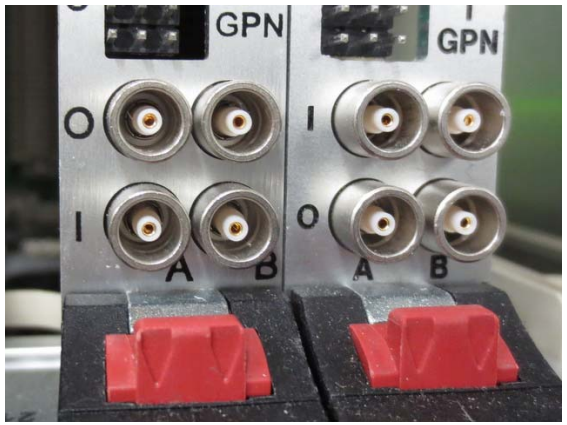


Trigger timing and control module

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



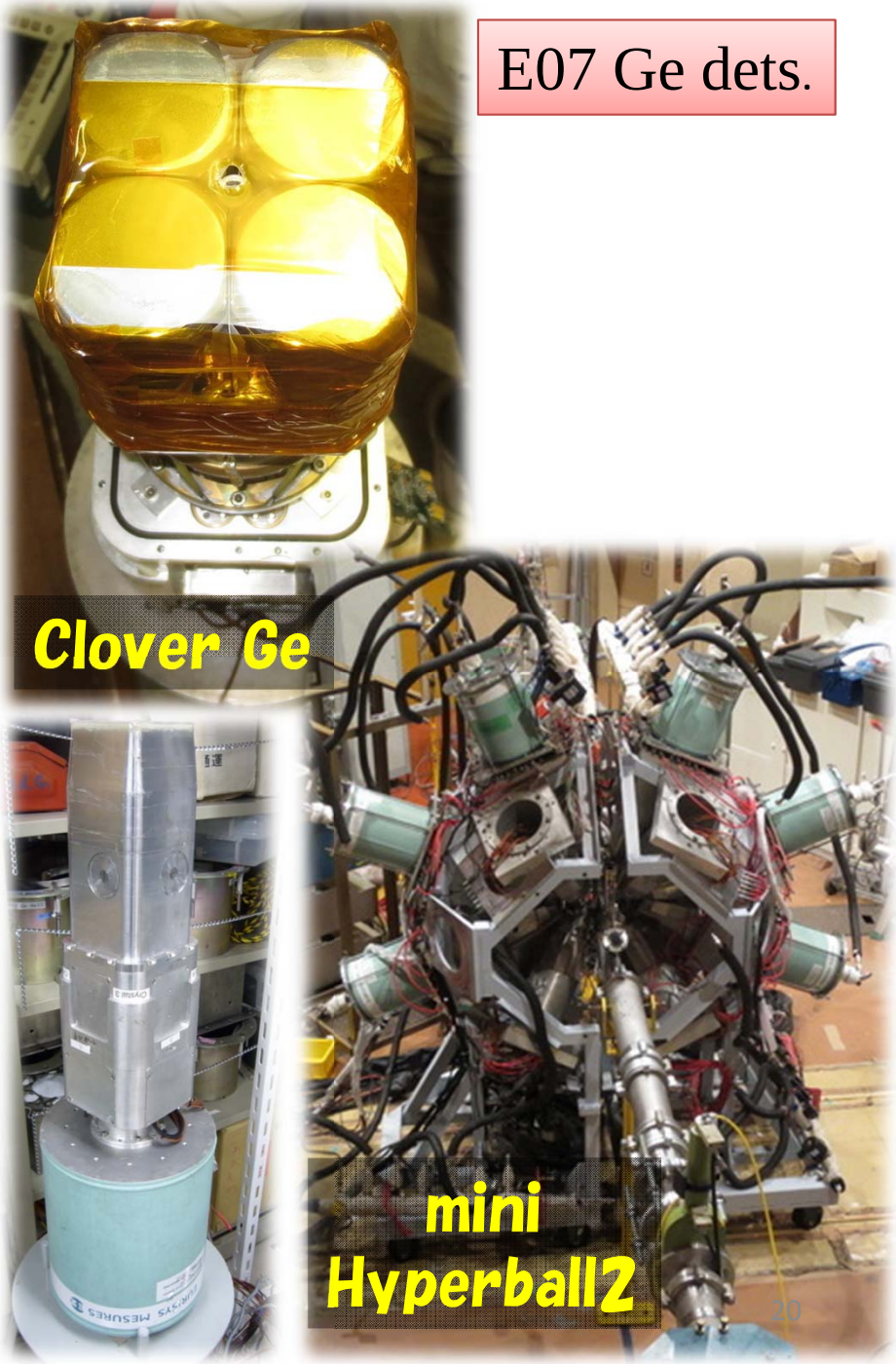
Courtesy of M. Carpenter



Tohoku CYRIC experiment

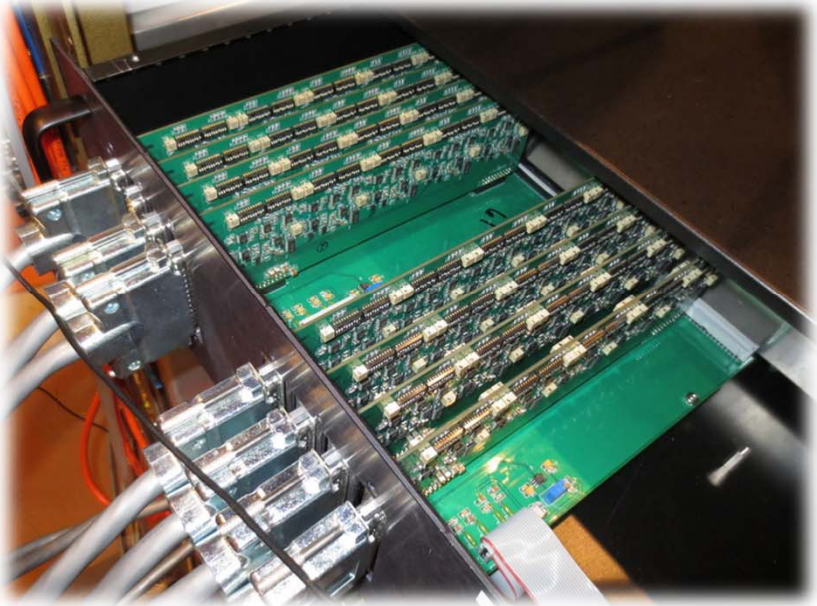
Experimental summary

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

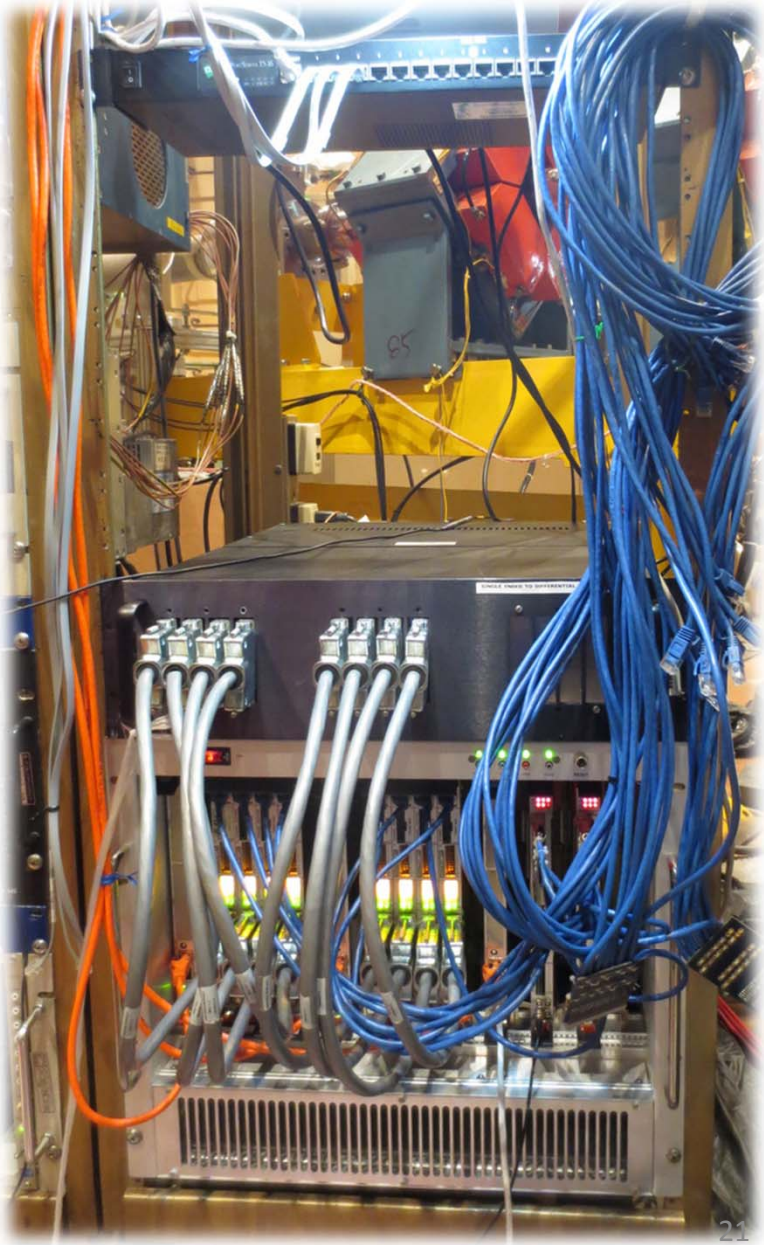


Interface box input

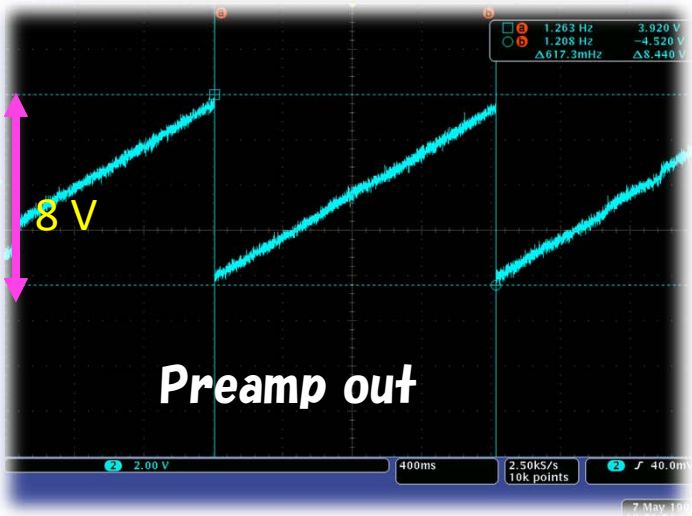
Interface box inside +output

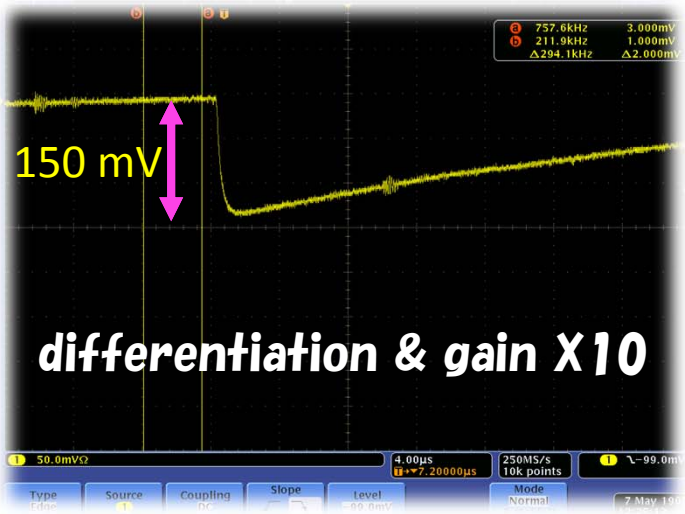


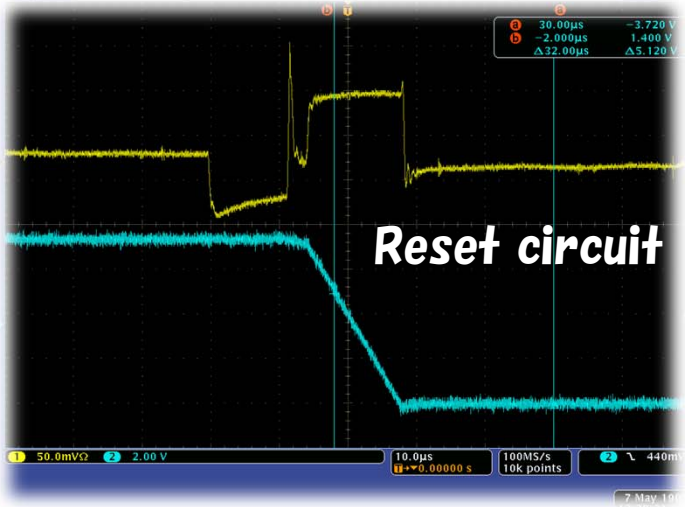
Very compact system!!



Ge → Interface Amp. → digitizer

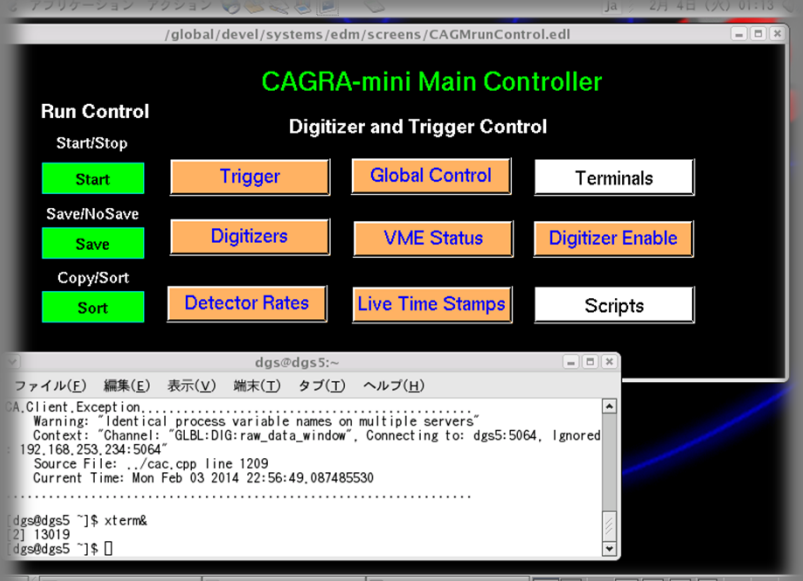


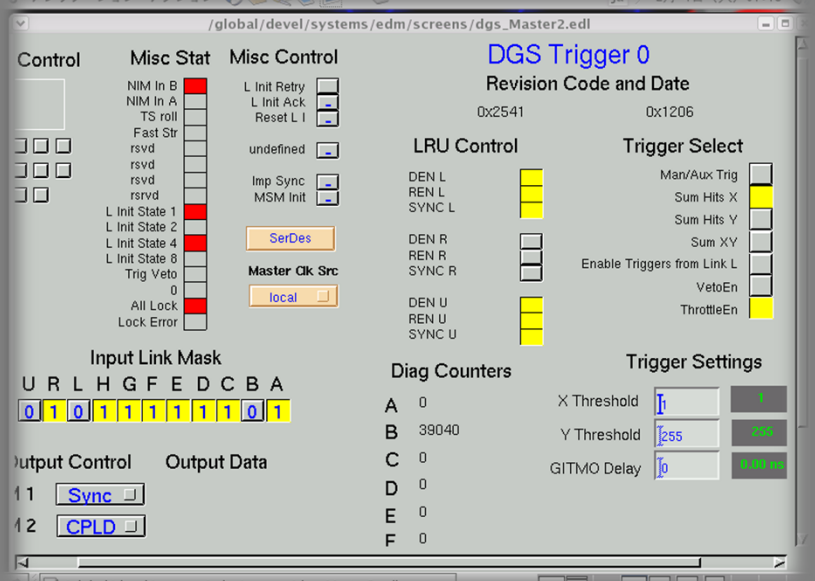


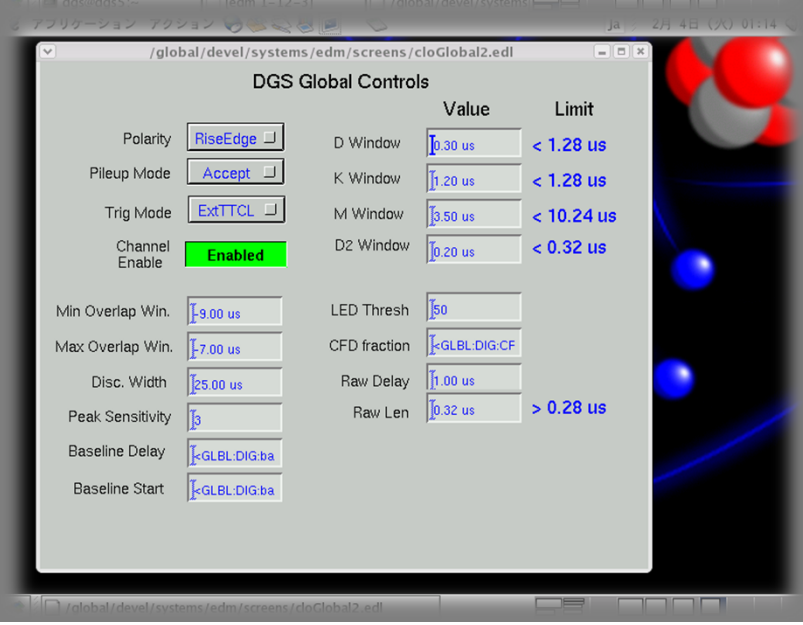


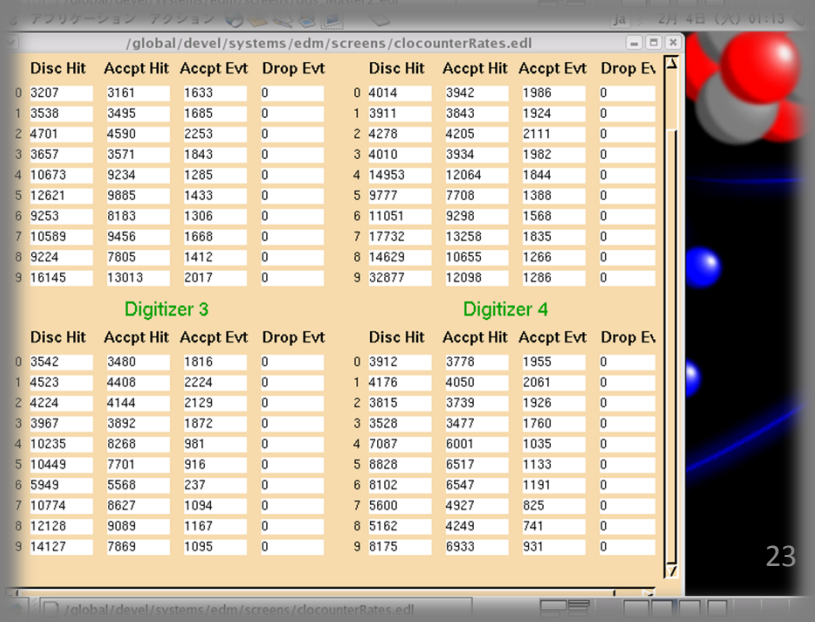
DAQ: EPICS based

Experimental Physics and Industrial Control System





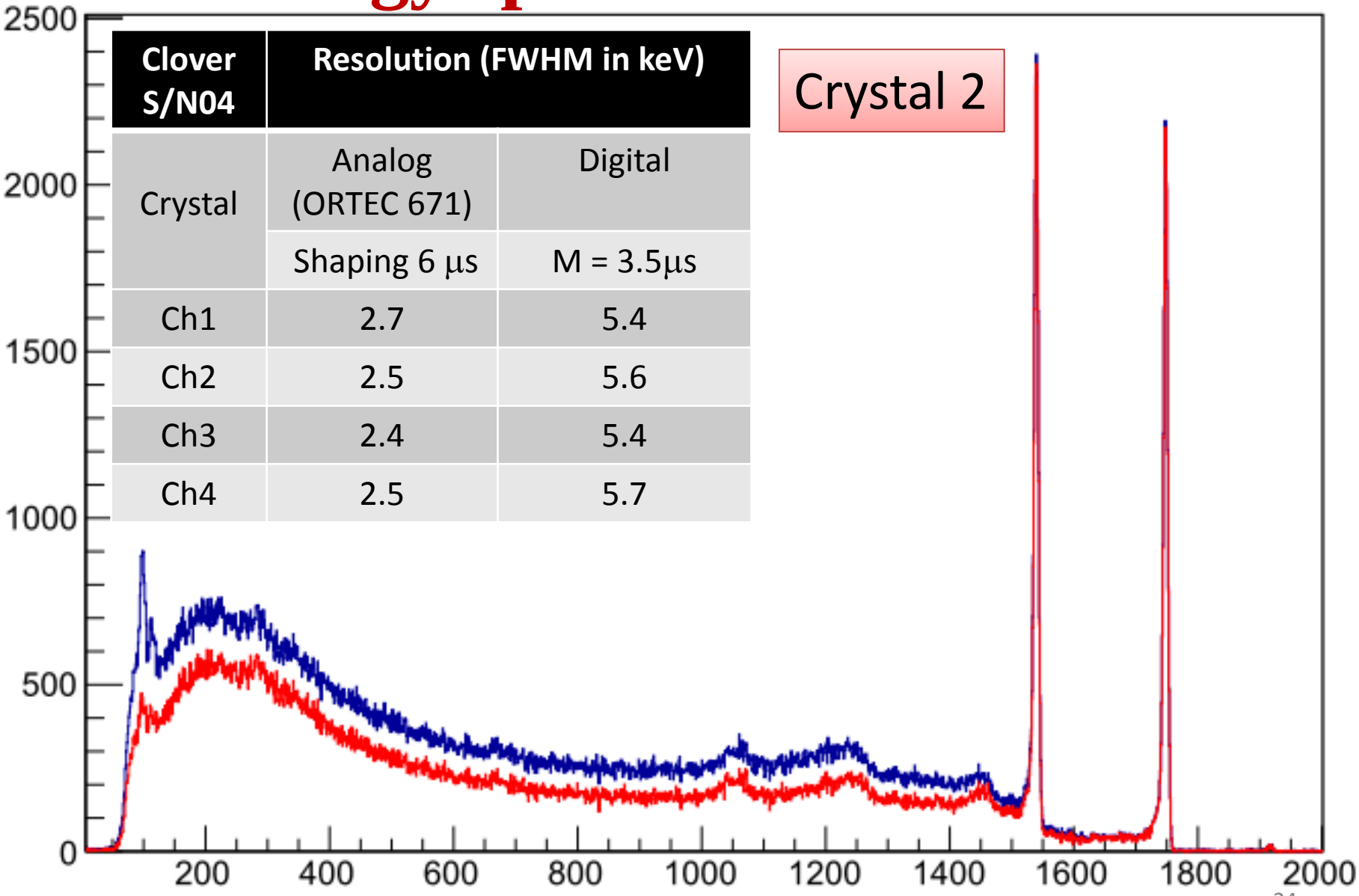




Energy spectrum with ^{60}Co

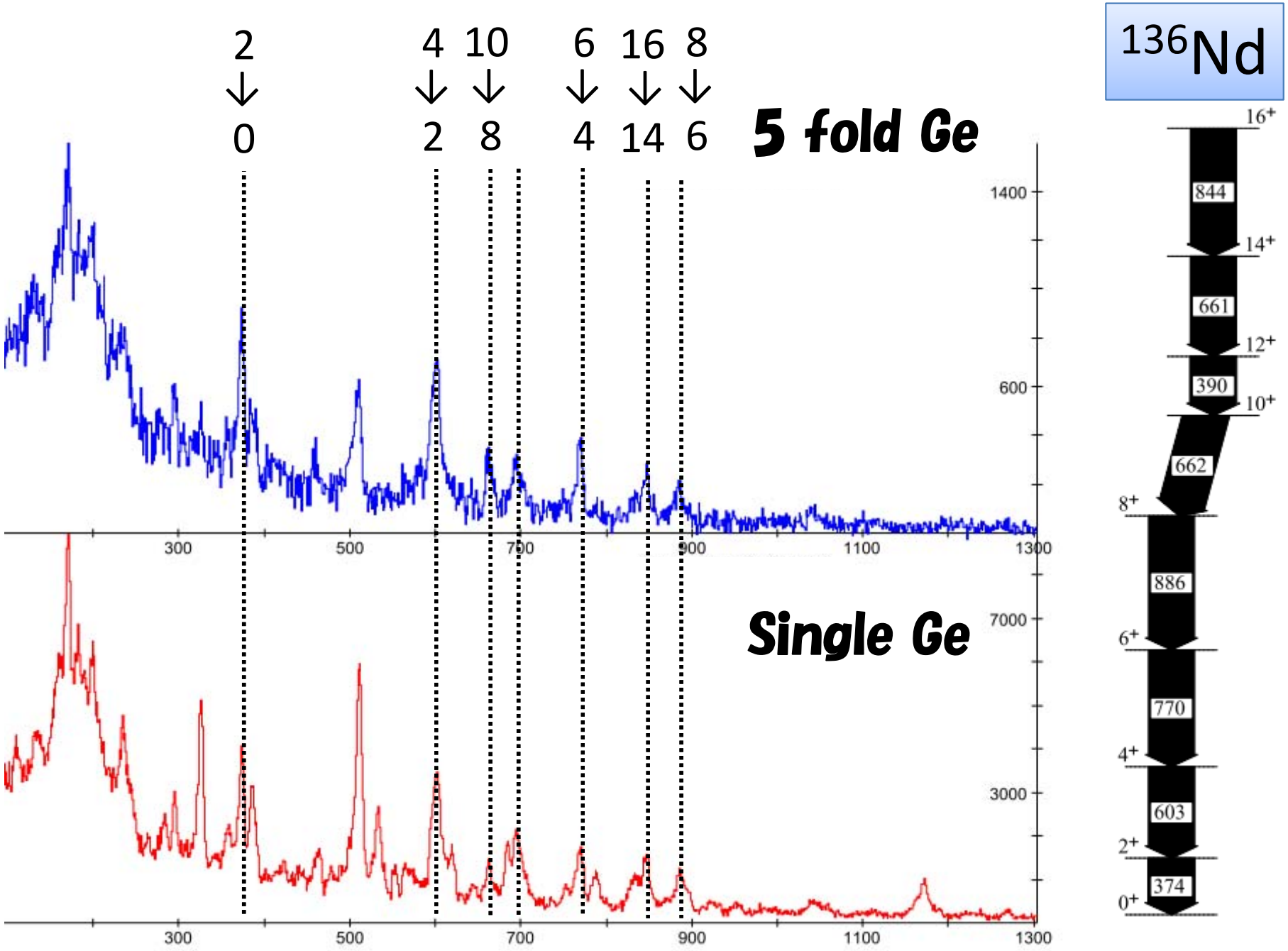
Clover S/N04	Resolution (FWHM in keV)	
Crystal	Analog (ORTEC 671)	Digital
	Shaping 6 μs	M = 3.5μs
Ch1	2.7	5.4
Ch2	2.5	5.6
Ch3	2.4	5.4
Ch4	2.5	5.7

Crystal 2



By Y. Yamamoto and N. Ichige

Not calibrated



E. Mergel et al., EPJ A15 417-420 (2002)

Summary

- Through put ratio measured at J-PARC T44
  - TPR= ～80% at ～500k/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 ssytem
  - Implementation to the E07 experiment