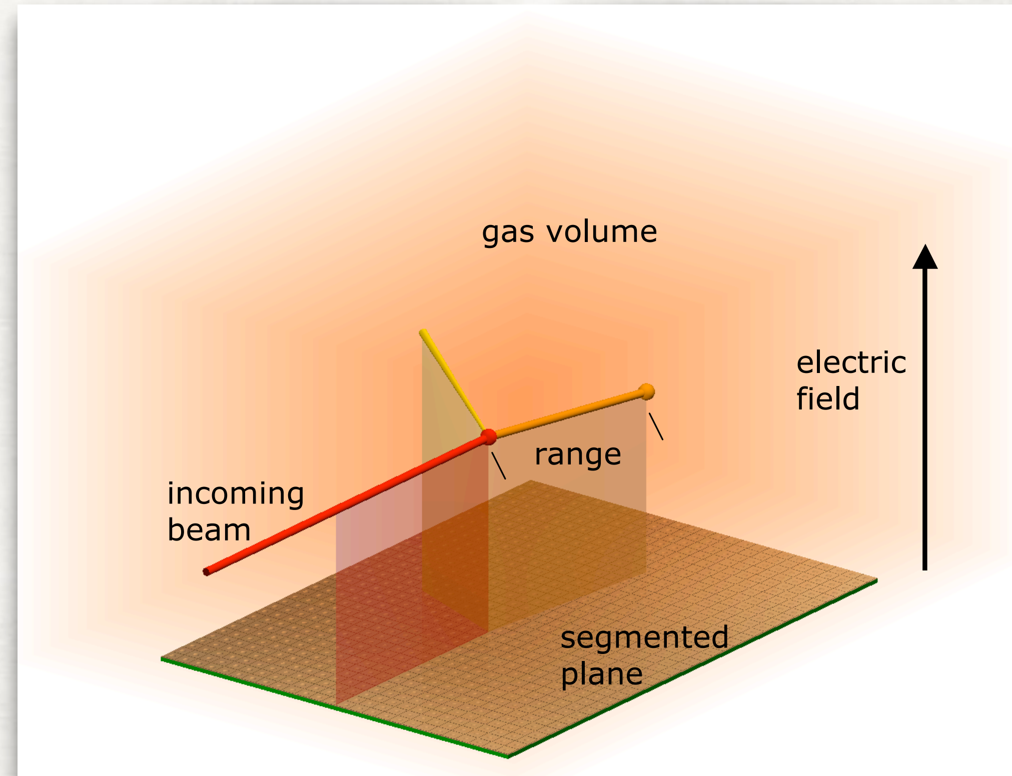
CHARACTERISATION OF THE GET ELECTRONICS FOR SI DETECTOR APPLICATIONS

A.T. LAFFOLEY
ON BEHALF OF THE ACTAR TPC COLLABORATION

OUTLINE

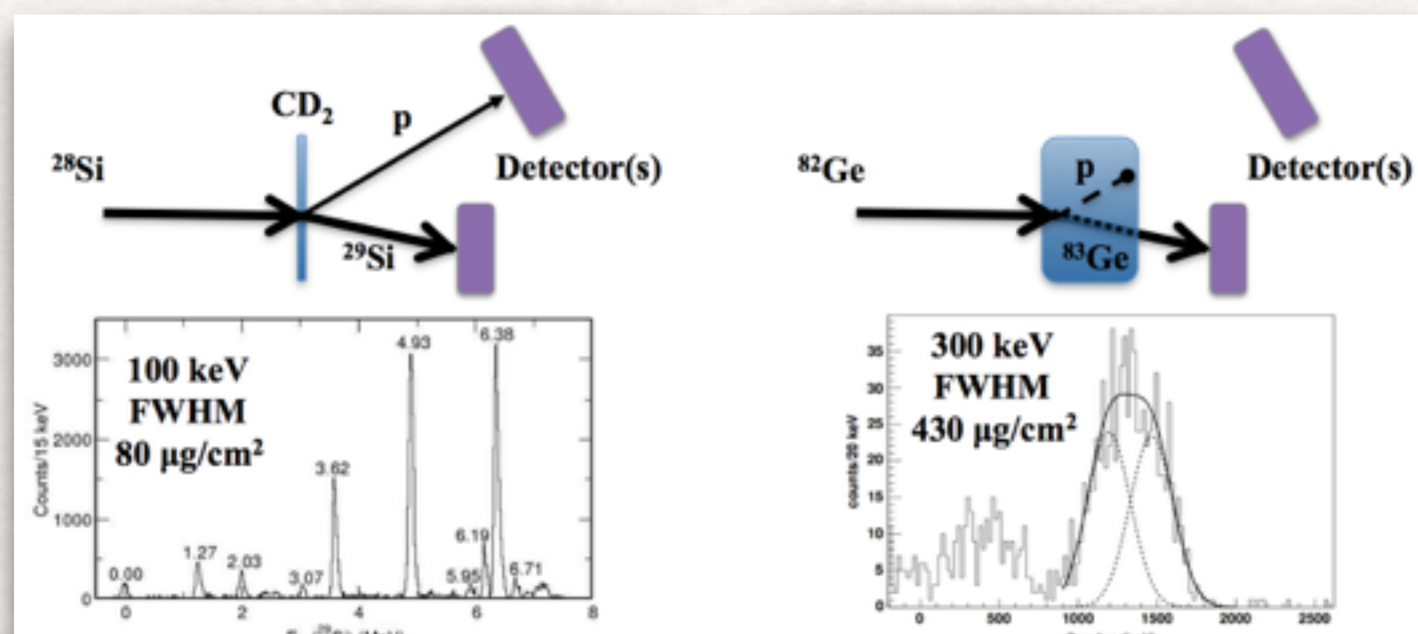
- Overview of ACTAR TPC project
- Description of General Electronics for TPCs (GET)
- Overview of Si performance (baseline noise, resolution, etc.)
- Investigation of system dead time

WHAT IS AN ACTIVE TARGET?



- Based on time projection chamber (TPC) concept from particle physics
  - Gas is both detector **and** target
  - Event-by-event reconstruction in 3D
  - High efficiency (+ low energy threshold)

- Advantages over conventional approaches



J.C.Lighthall et al., NIM A 622 97 (2010)

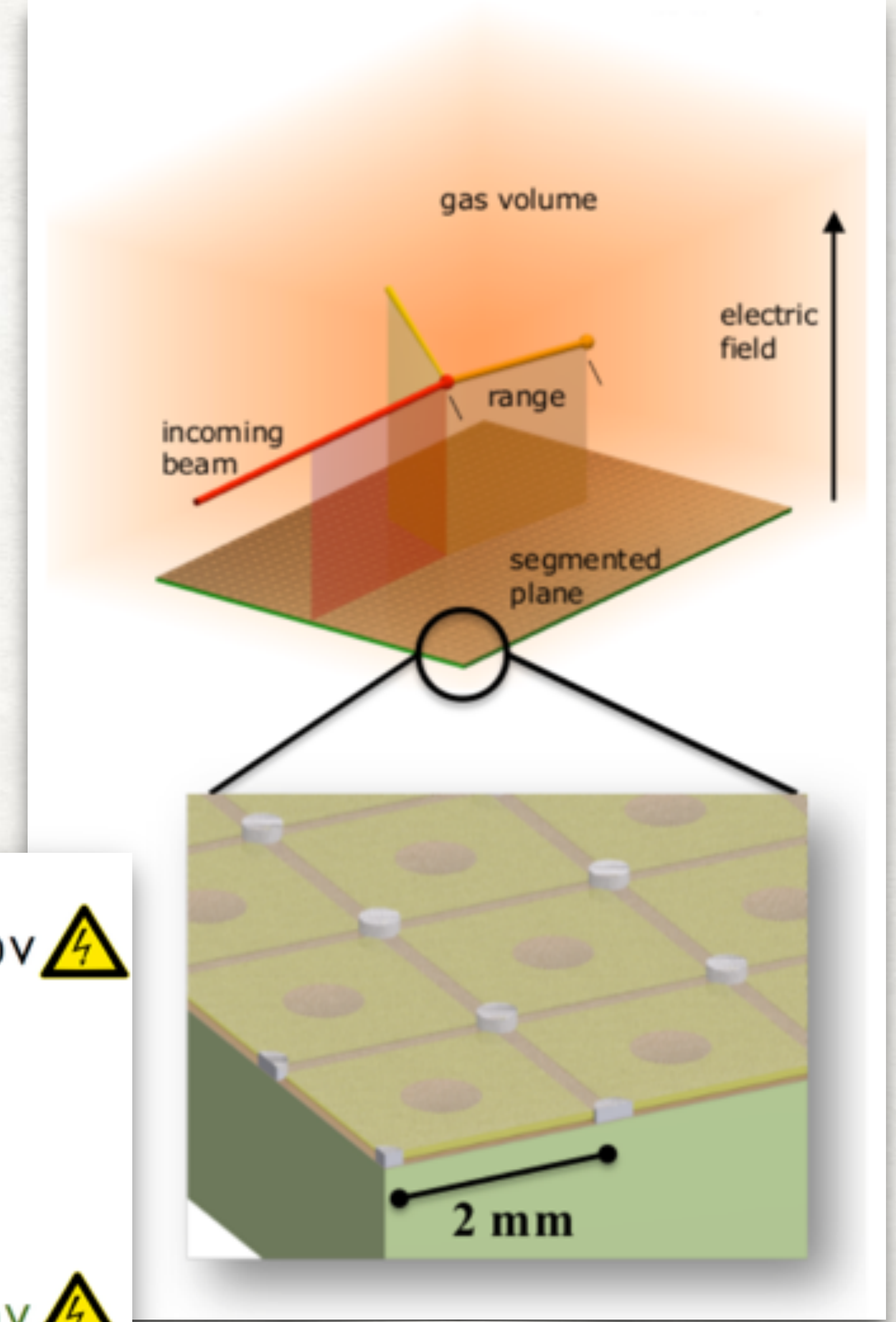
J.S. Thomas et al., PRC 71, 012302 (2005)

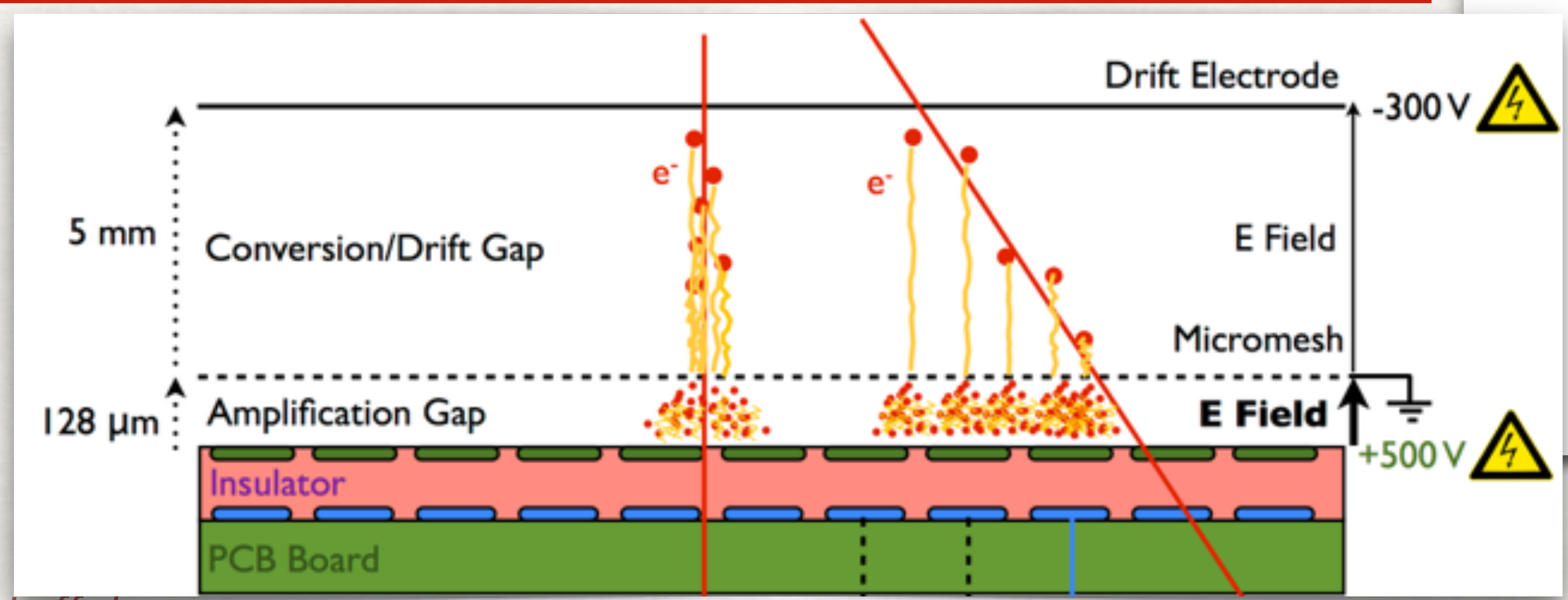
- Thin target experiments:
  - Need very high rates
  - Not feasible with exotic nuclei

- Thick target experiments:
  - Significant losses in target
  - Degraded resolution

BASIC DESIGN ASPECTS

- **Drift Region**
  - Particles ionise gas along their trajectories
- **Amplification Region**
  - Micromegas – J. Pancin *et al.*, NIMA 735, 532 (2014)
- **Pixelated Pad Plane**
  - Very high density: 2x2 mm^2 (= 25 channels/cm^2)
  - Total 16384 fully digitised electronics channels (GET)
- **Auxiliary Detectors**
  - Telescopes for escaping particles (Si and/or CsI walls)
  - $LaBr_3$ or $CeBr_3$ for γ rays (SpecMAT, O. Poleshchuk)

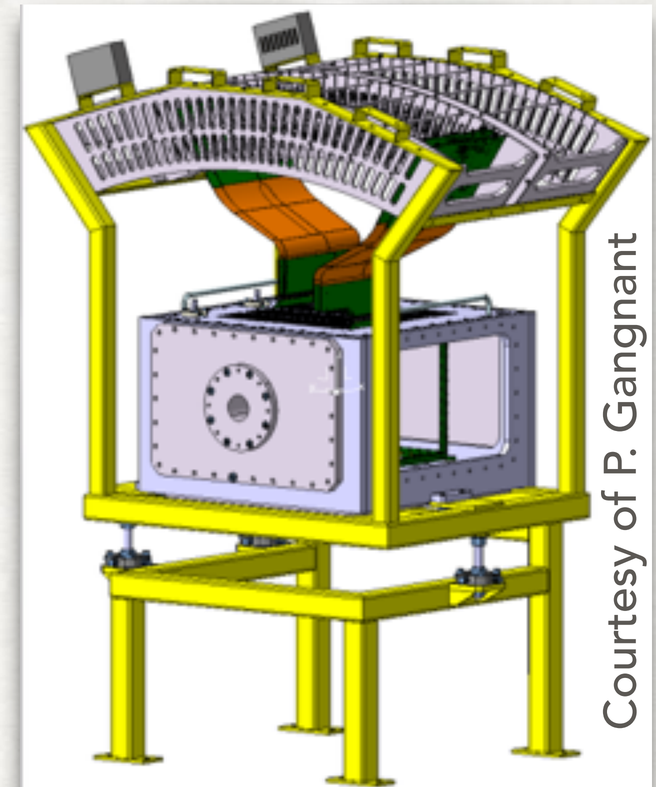




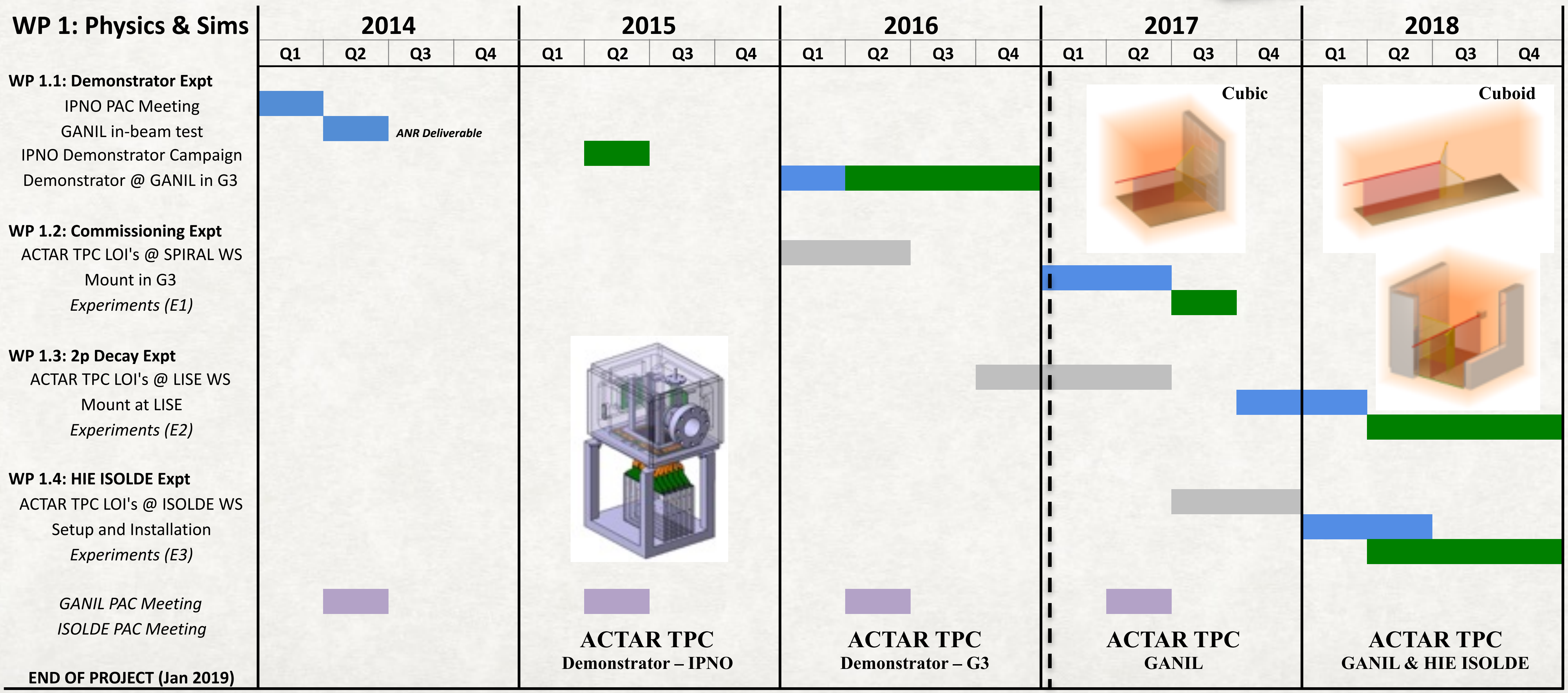
ACTAR TPC: TIMELINE

- ERC Grant awarded to G.F. Grinyer for ACTAR TPC (Jan. 2014–Jan. 2019)

- 2012–2016: Research and Development
  - Building of prototype and tests
  - GET electronics development



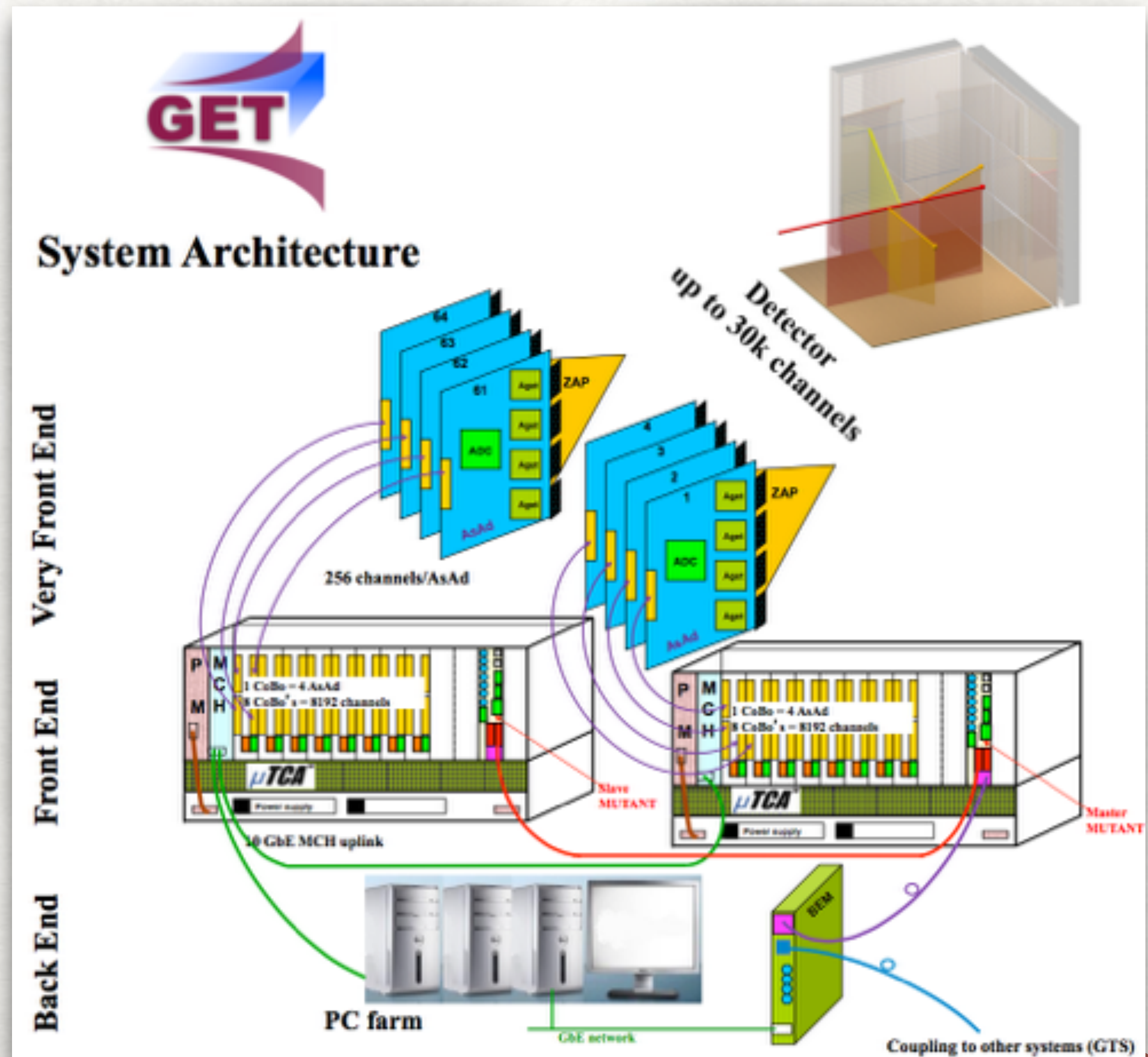
Courtesy of P. Gangnant



ACTAR TPC ELECTRONICS

- Using GET (General Electronics for TPCs)
  - Wave digitiser using 512 analogue memory cells @ 100 MHz (max)
  - L0/L1/L2 trigger capabilities (external, multiplicity & higher order)
  - Zero suppression, full & partial readout for reducing data traffic
  - ANR funded project (Nov. 2009–Oct. 2013; IRFU/CEA, CENBG, GANIL, MSU)

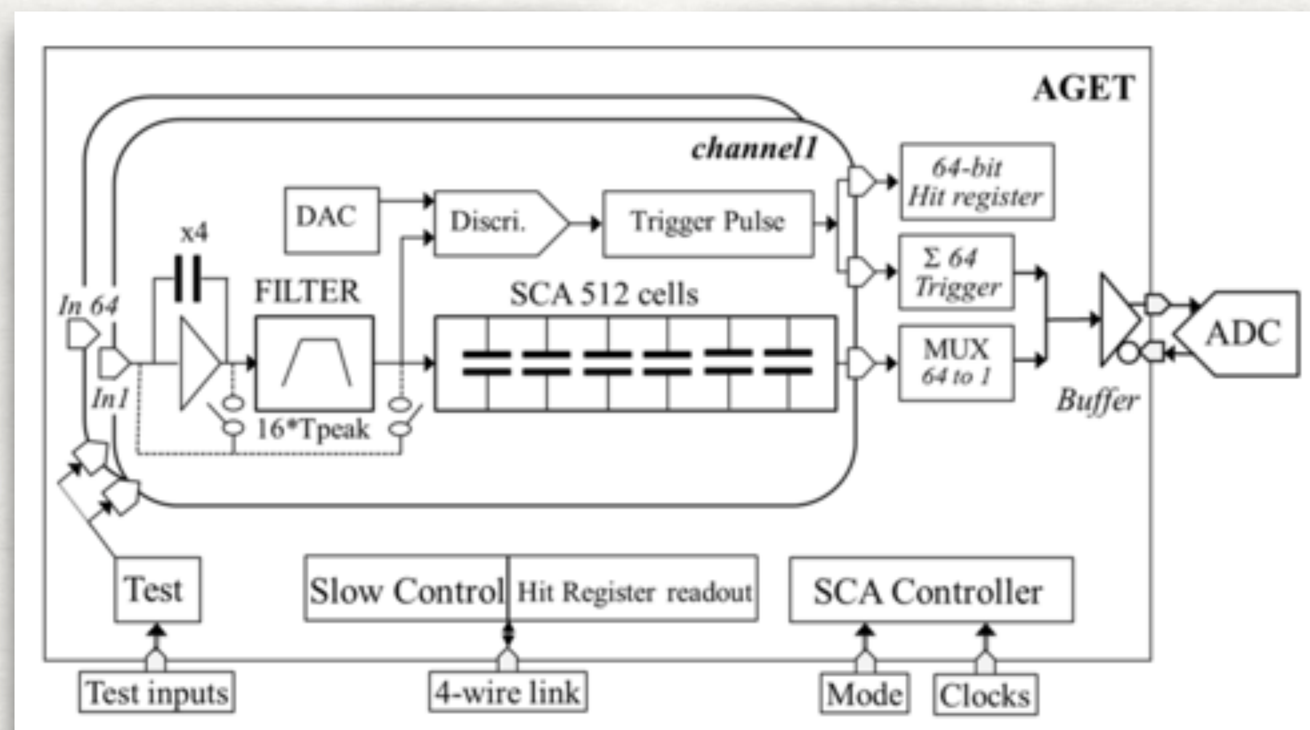
Electronics exist and hardware is ready to use!



Courtesy of GET Collaboration

GET ARCHITECTURE

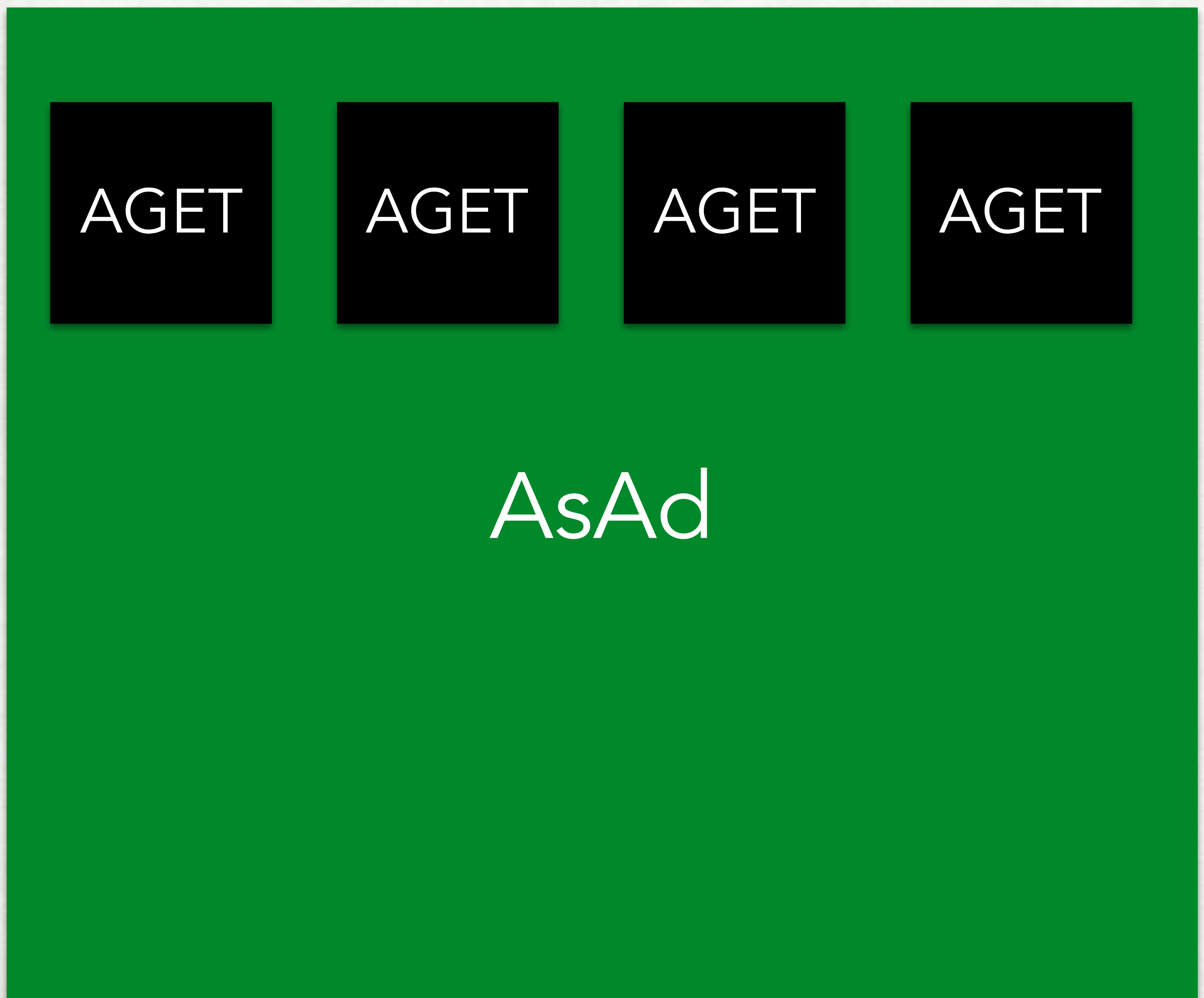
AGET



AGET:

- 64 input channels
- 4 fixed-pattern noise (FPN) channels
- 512 circular memory cells
- Four built-in preamplifiers with fixed gain
  (120 fC, 240 fC, 1 pC, 10 pC)
- Generates multiplicity signal

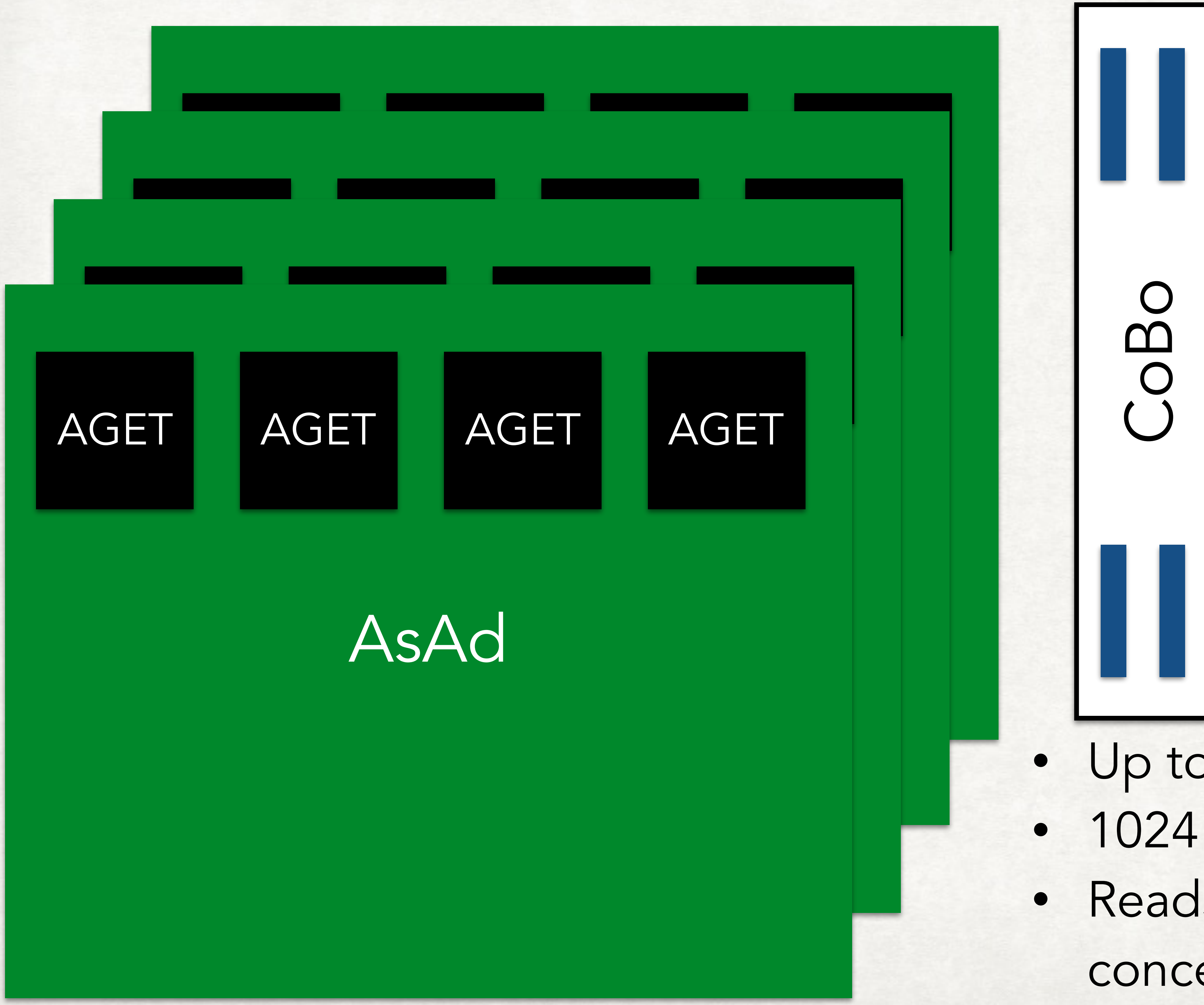
GET ARCHITECTURE



AsAd:

- 4 AGET/AsAd card
- 256 channels
- 12-bit ADC

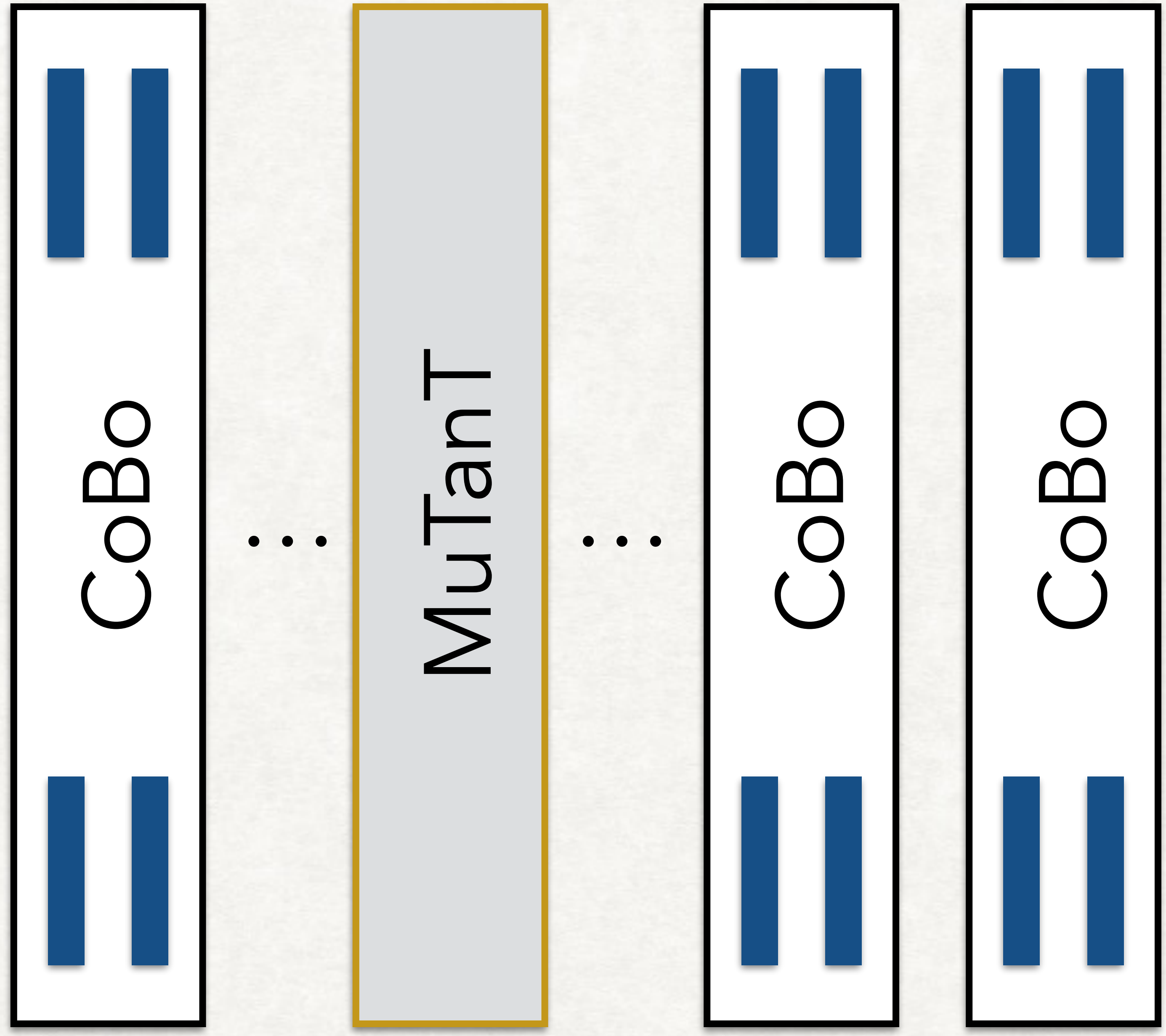
GET ARCHITECTURE



CoBo:

- Up to 4 AsAd/CoBo
- 1024 channels
- Reads, reduces, and concentrates data

GET ARCHITECTURE



MuTanT:

- Distributes master clock
- Provides 3-level trigger system

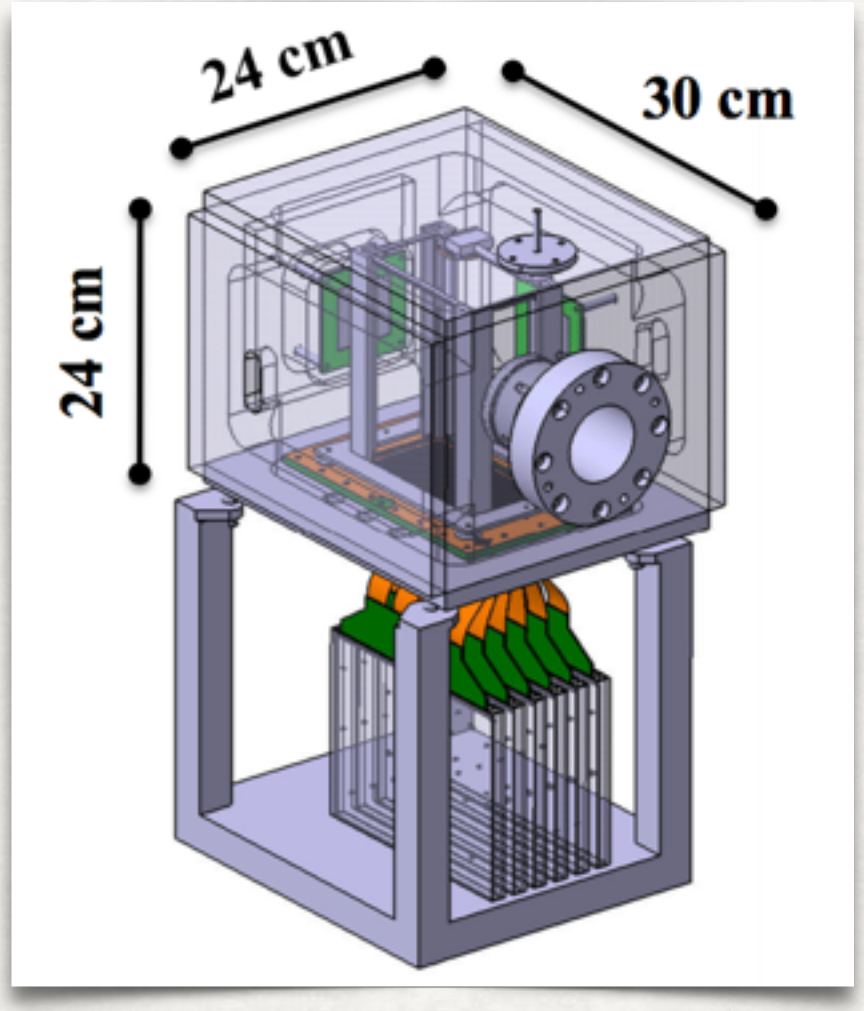
(L0 = external, L1 = multiplicity, L2 = software level trigger)

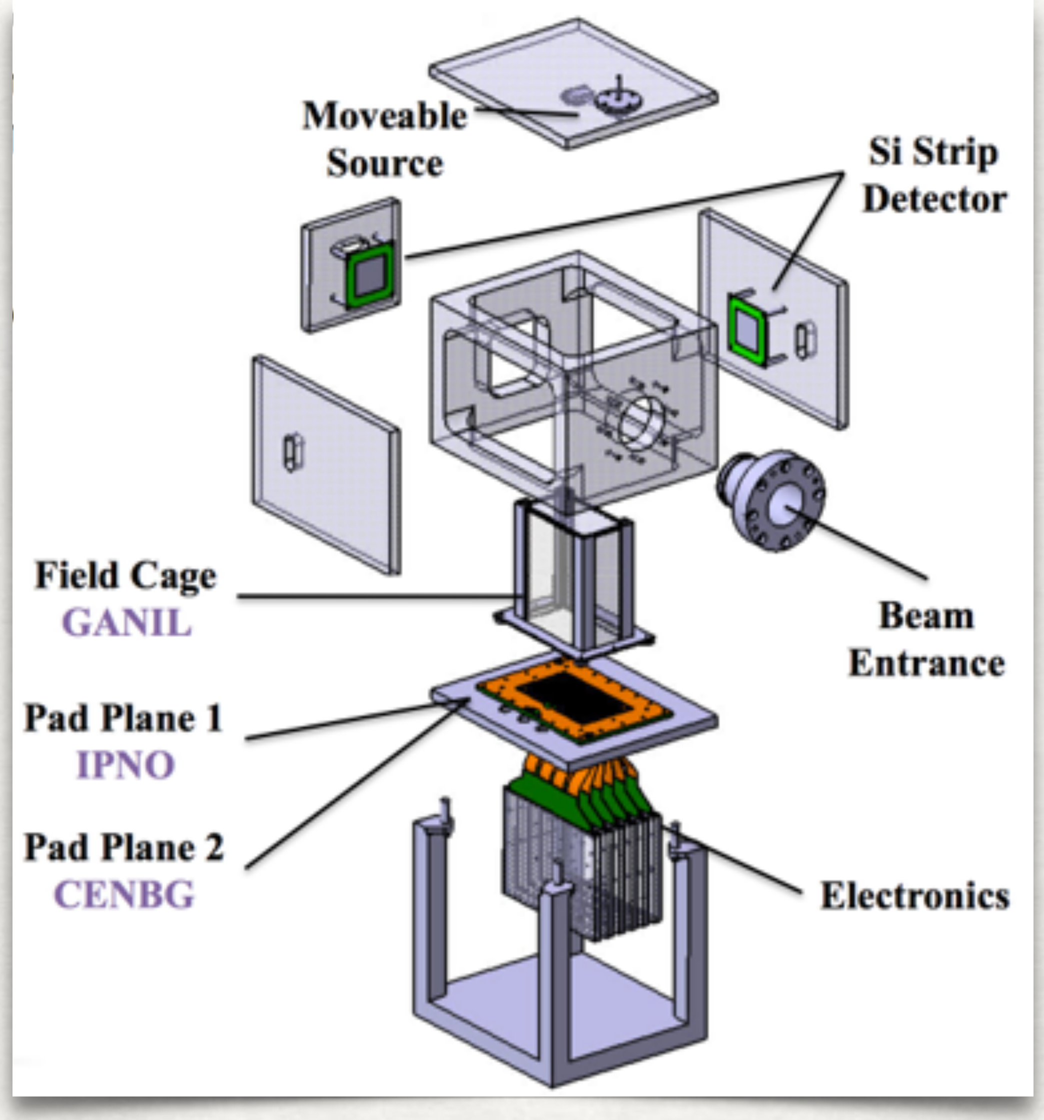
µTCA Crate:

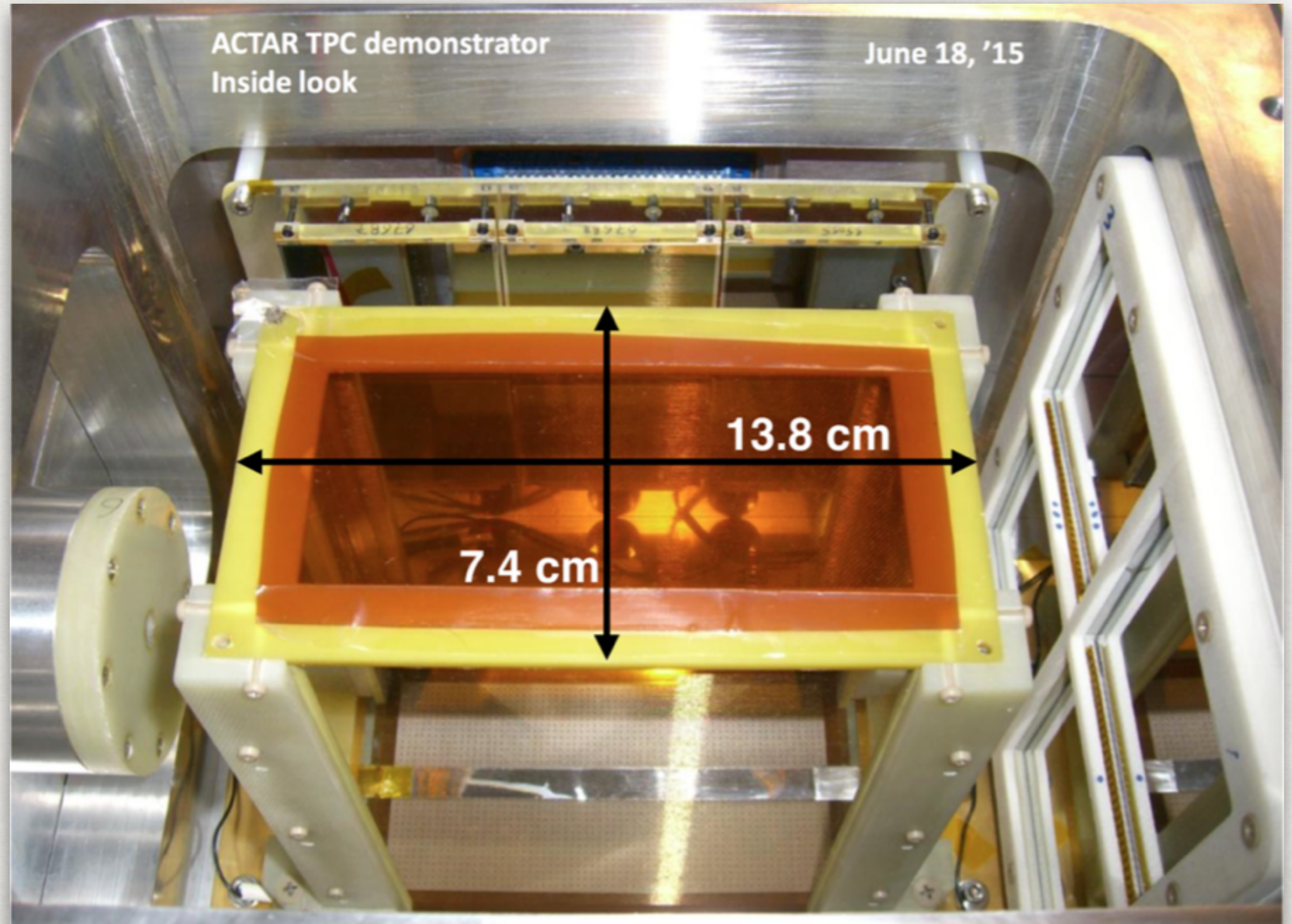
- Up to 11 CoBos (11264 channels)
- Adjustable writing clock frequency (1–100 MHz)
- Controlled by MuTanT

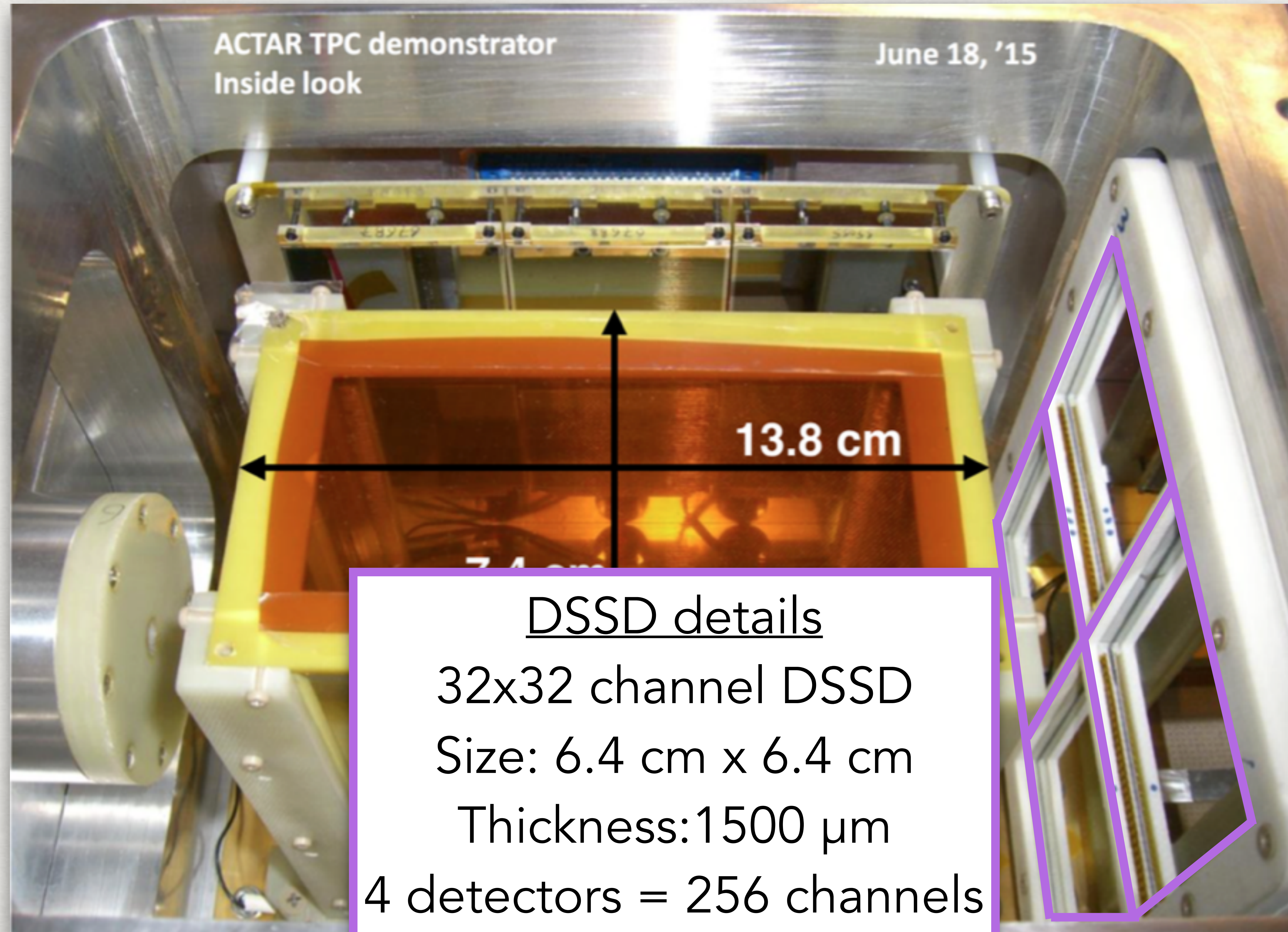
ACTAR TPC DEMONSTRATOR

- 2048-channel electronics test bench
  - Two detectors with identical chamber design (GANIL and CENBG)
  - Mechanics scalable to final design (1/8 scale)
  - 12 Si detectors perpendicular to beam axis
  - 4 DSSD downstream






ACTAR TPC demonstrator
Inside look
June 18, '15
13.8 cm
7.4 cm



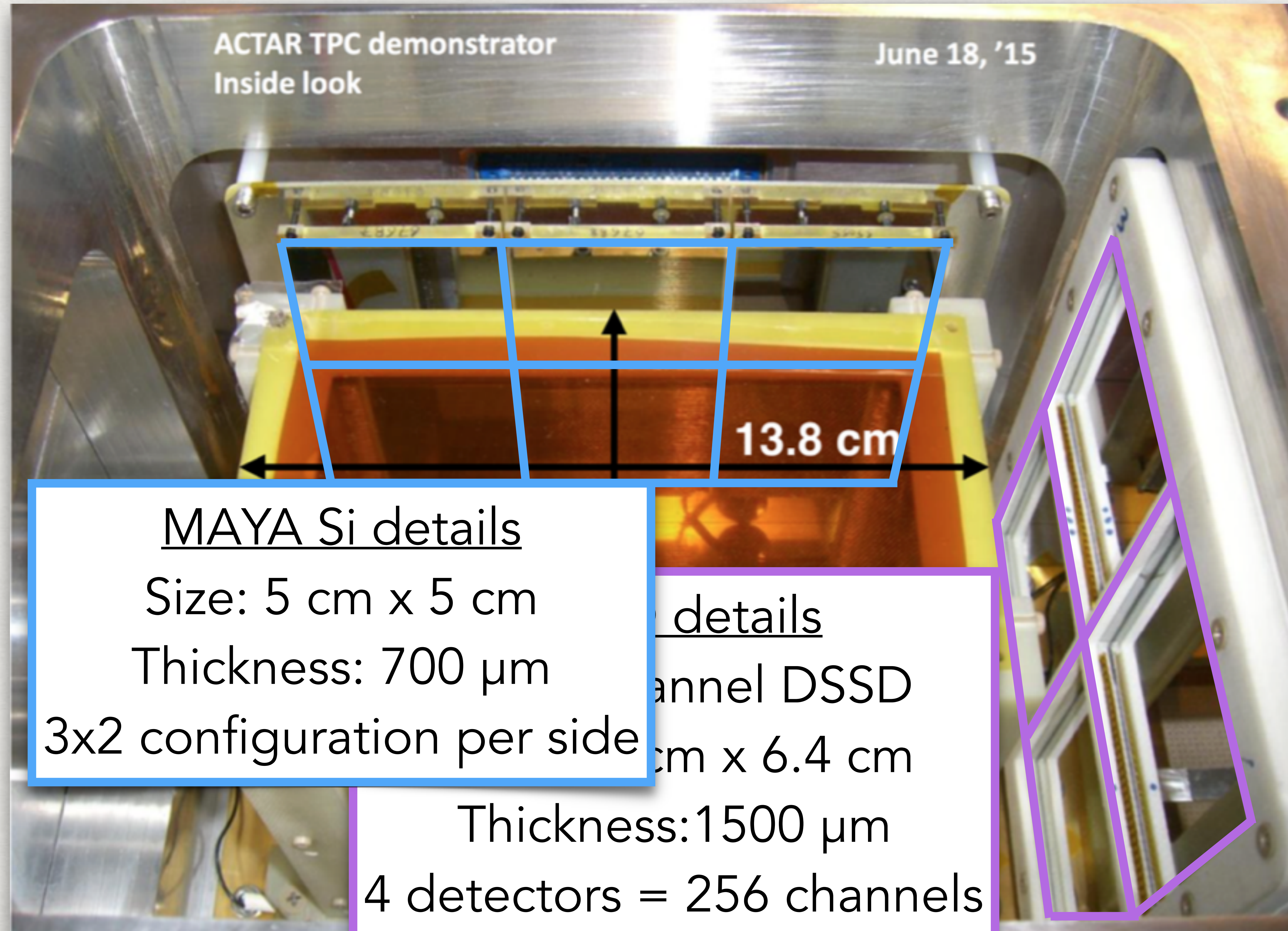
<u>DSSD details</u>

32x32 channel DSSD

Size: 6.4 cm x 6.4 cm

Thickness:1500 µm

4 detectors = 256 channels



<u>MAYA Si details</u>

Size: 5 cm x 5 cm

Thickness: 700 μm

3x2 configuration per side

<u>details</u>

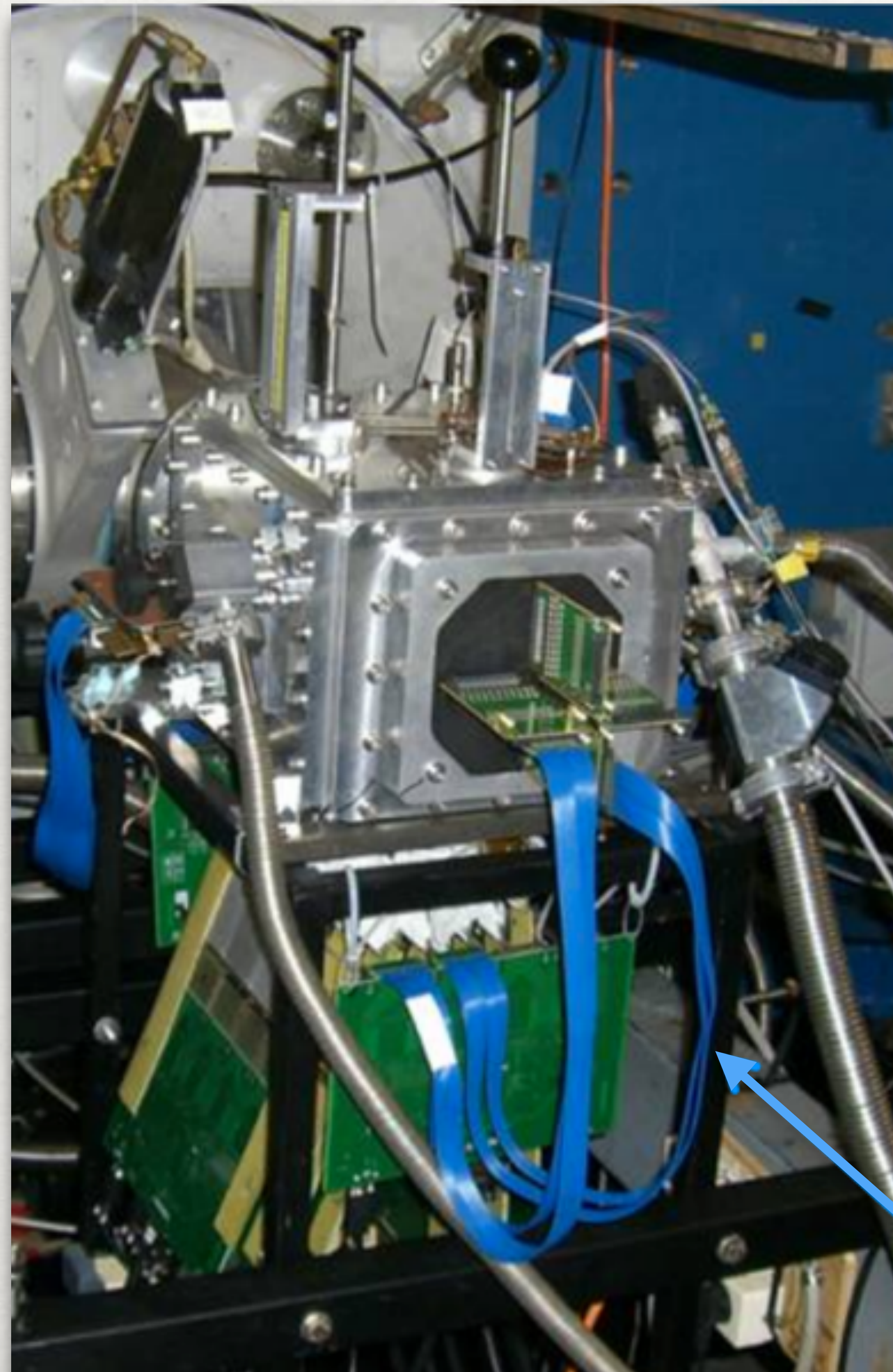
annel DSSD

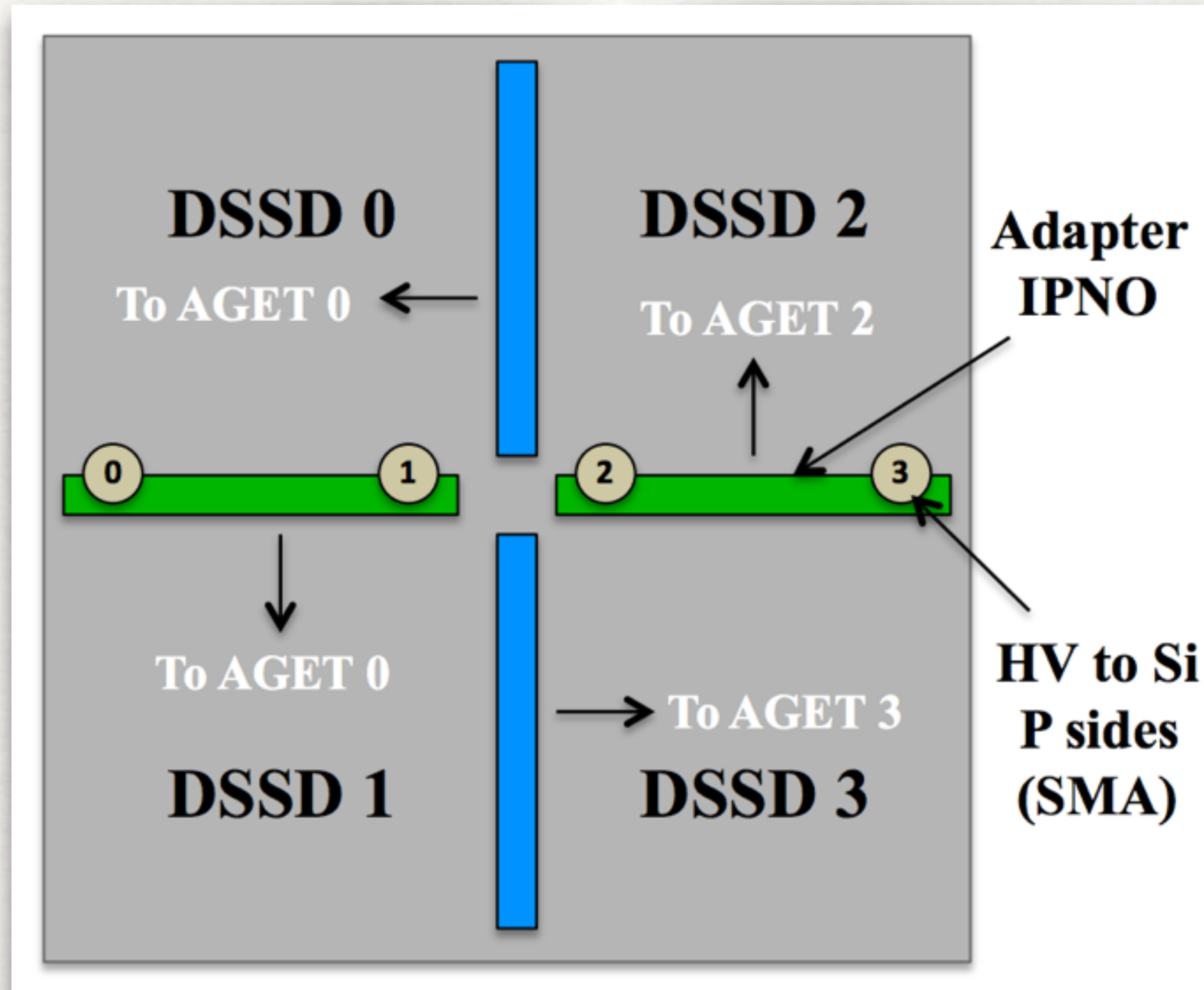
cm x 6.4 cm

Thickness:1500 μm

4 detectors = 256 channels

DSSD CONNECTORS





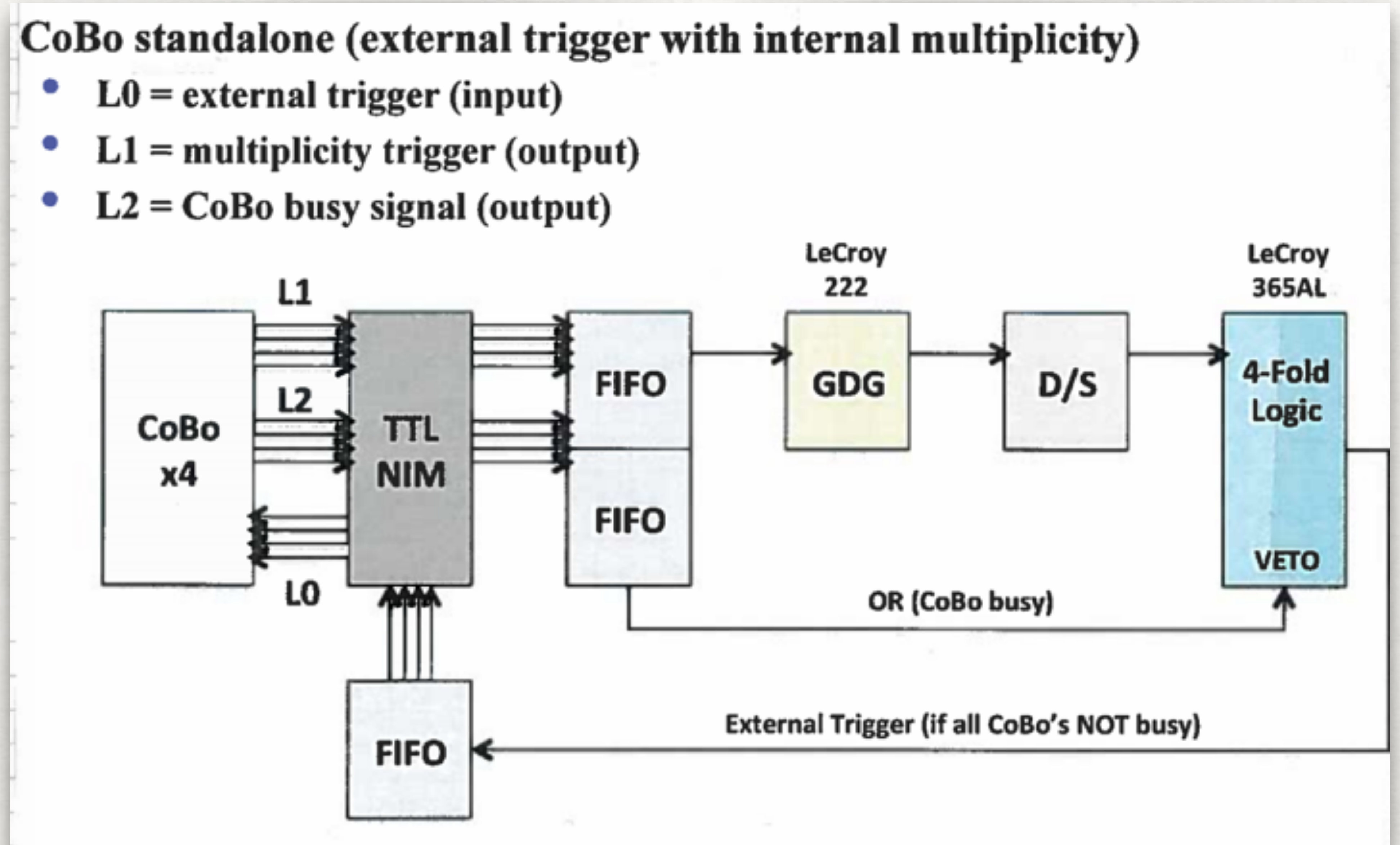
N card = back strips

P card = front strips

Cable to AsAd

SAMTEC ERM8 ⟷ ERM8

TRIGGER LOGIC

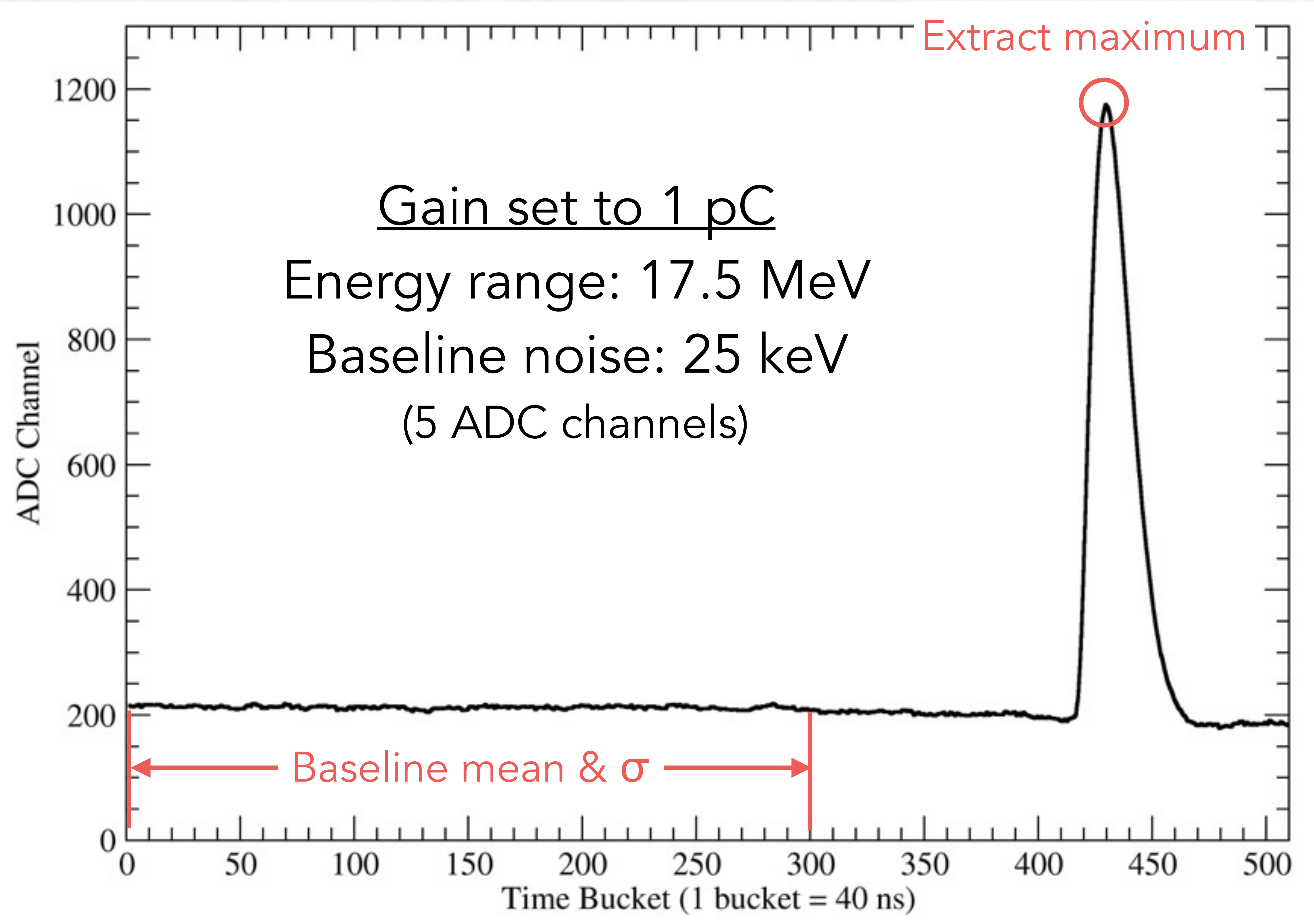


L1 Trigger: M = 1 DSSD multiplicity

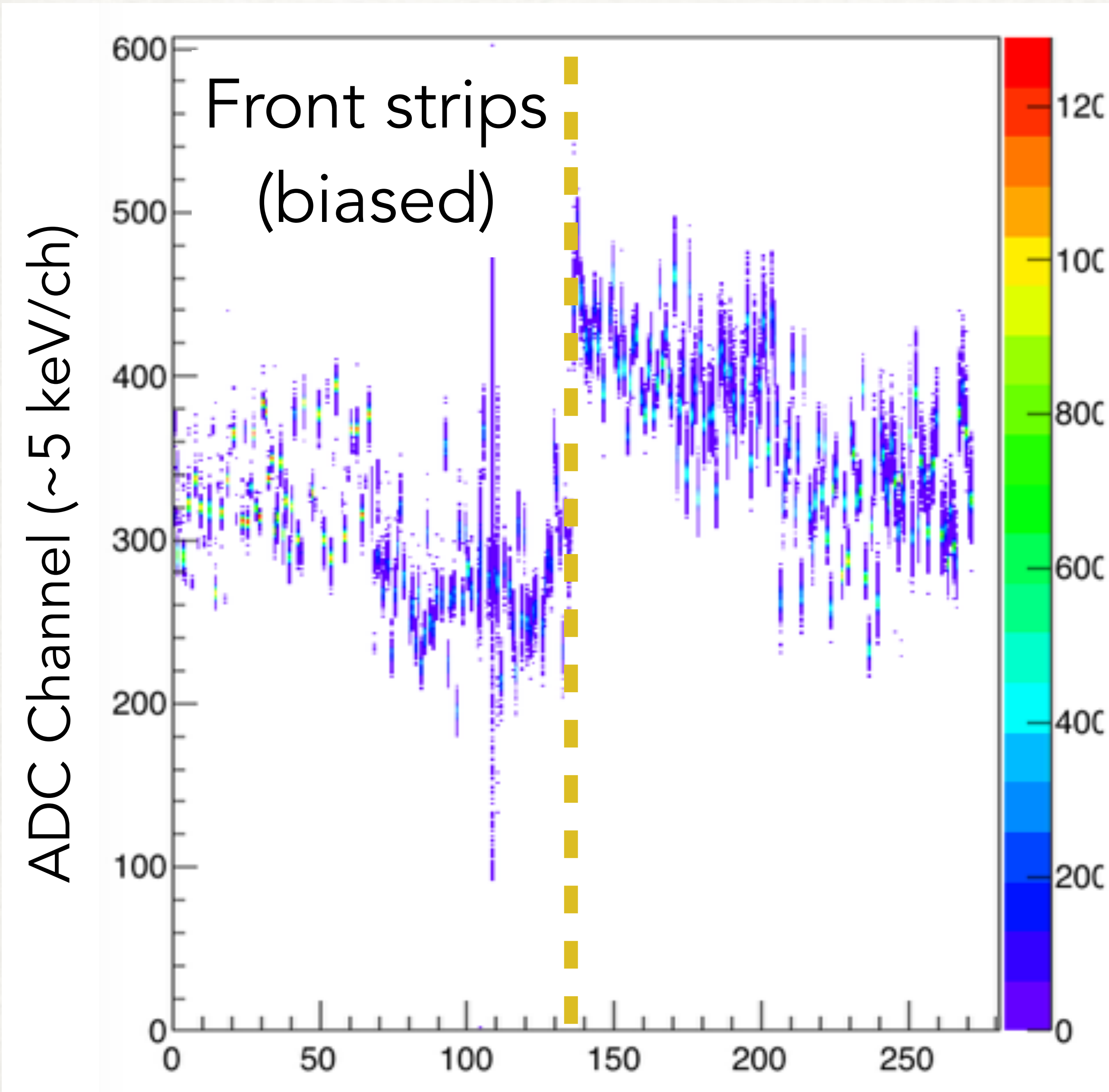
Triple α source for DSSD calibration

^{239}Pu (5.15 MeV); ^{241}Am (5.48 MeV); ^{244}Cm (5.8 MeV)

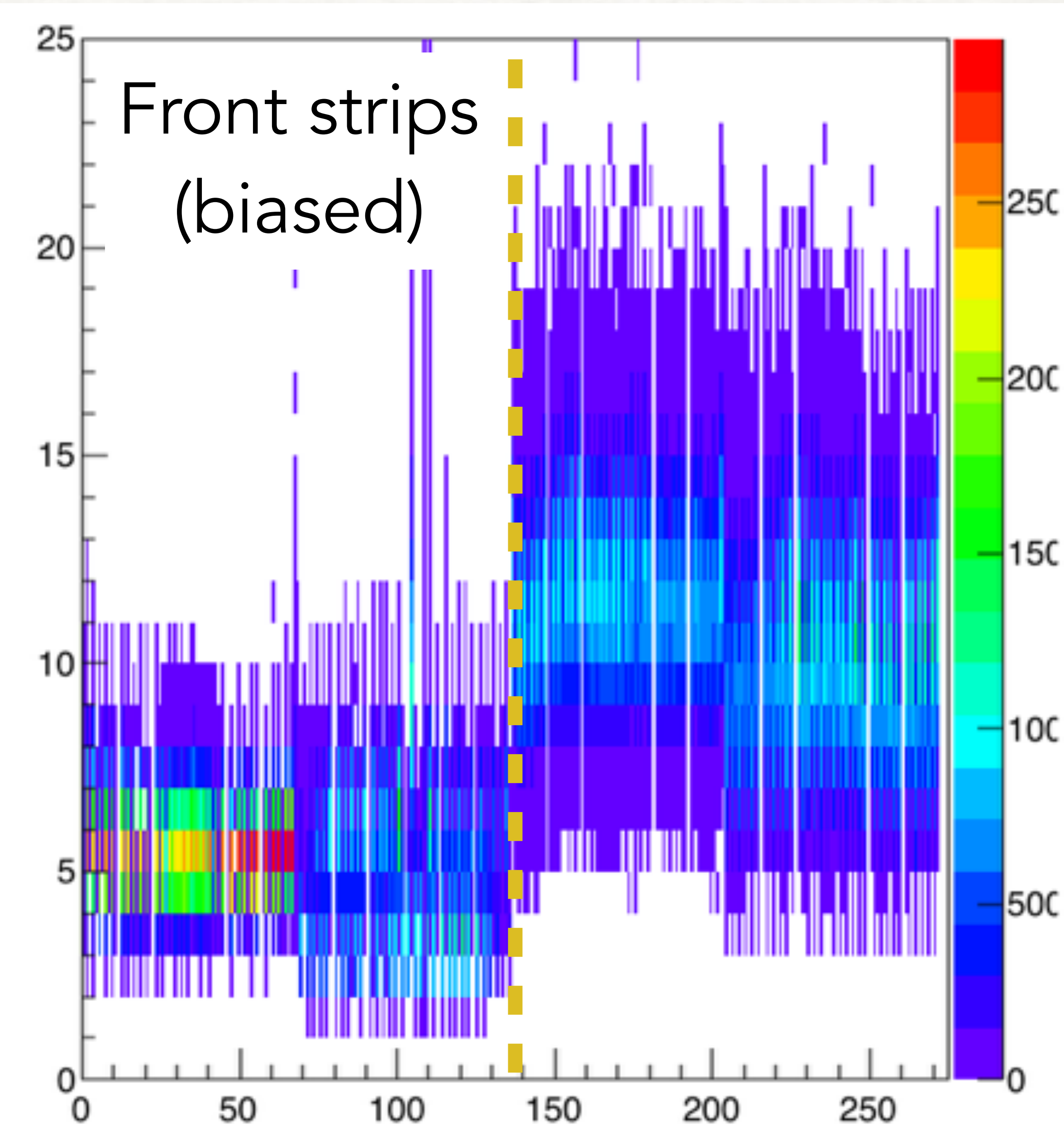
SAMPLE DSSD SIGNALS



DSSD Baseline Mean



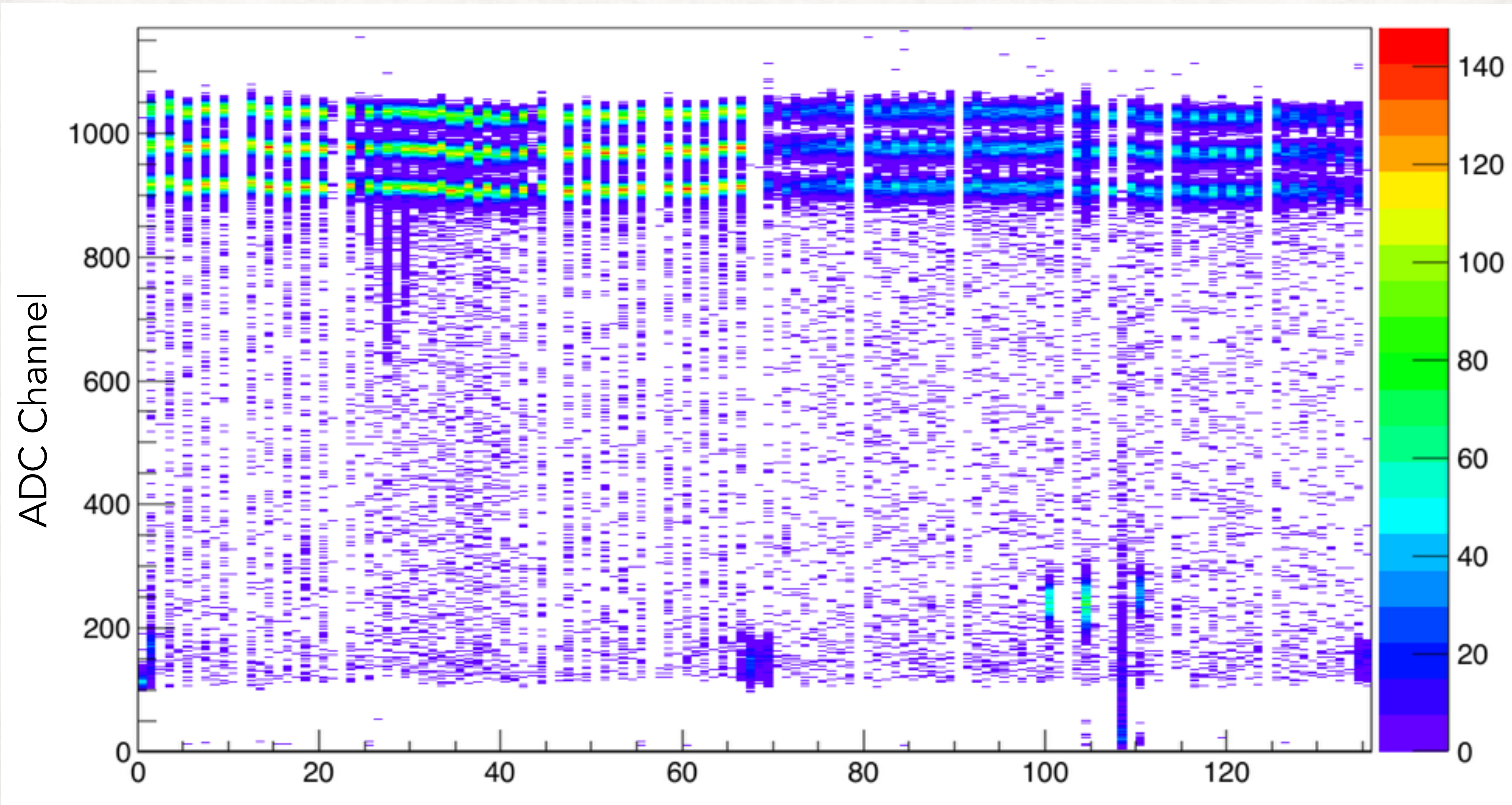
DSSD Baseline σ



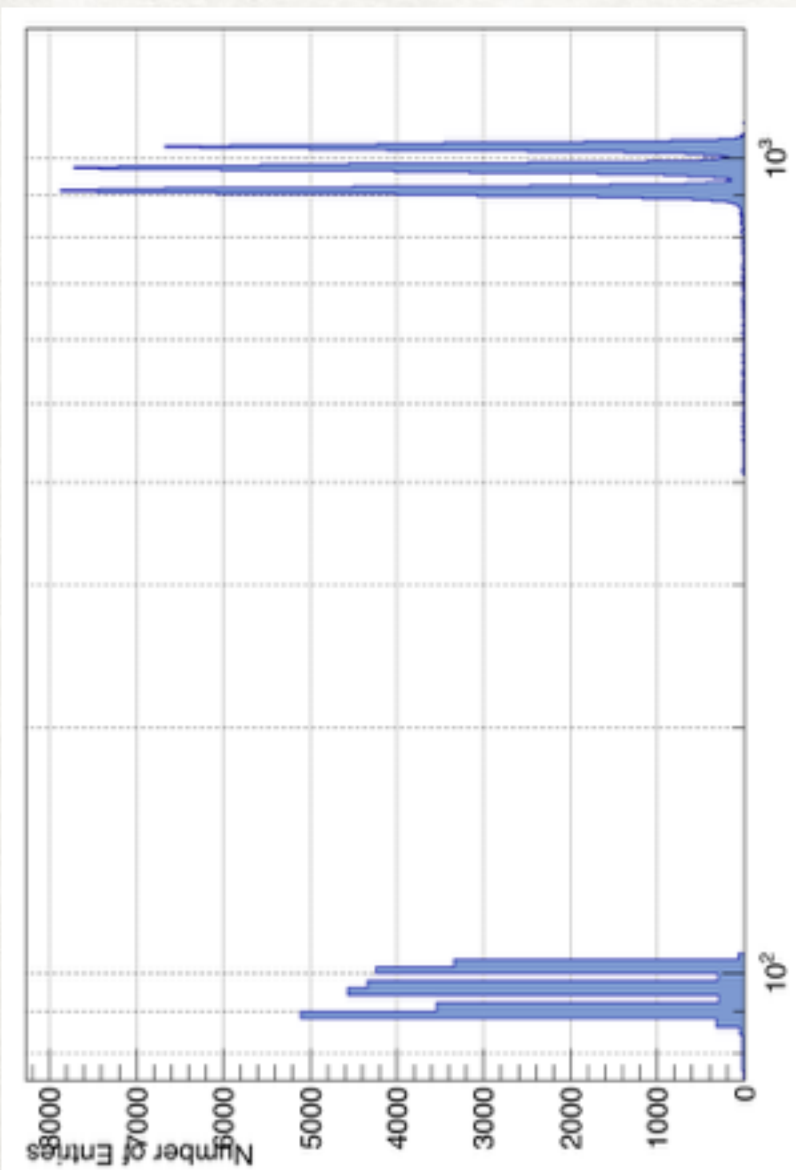
Detector biased to 150 V
(300 V full depletion)

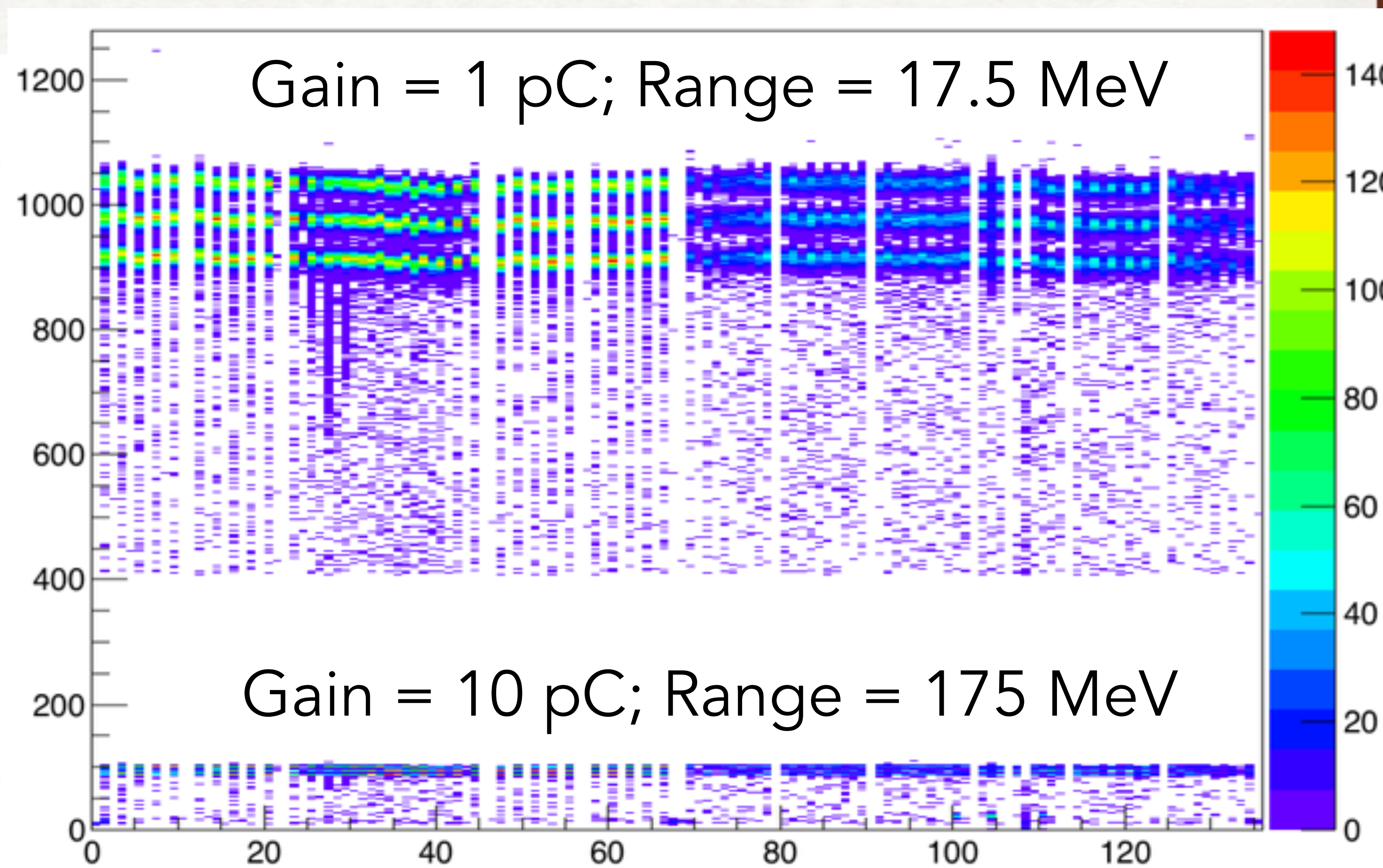
Alpha Energies

Gain = 1 pC; Range = 17.5 MeV

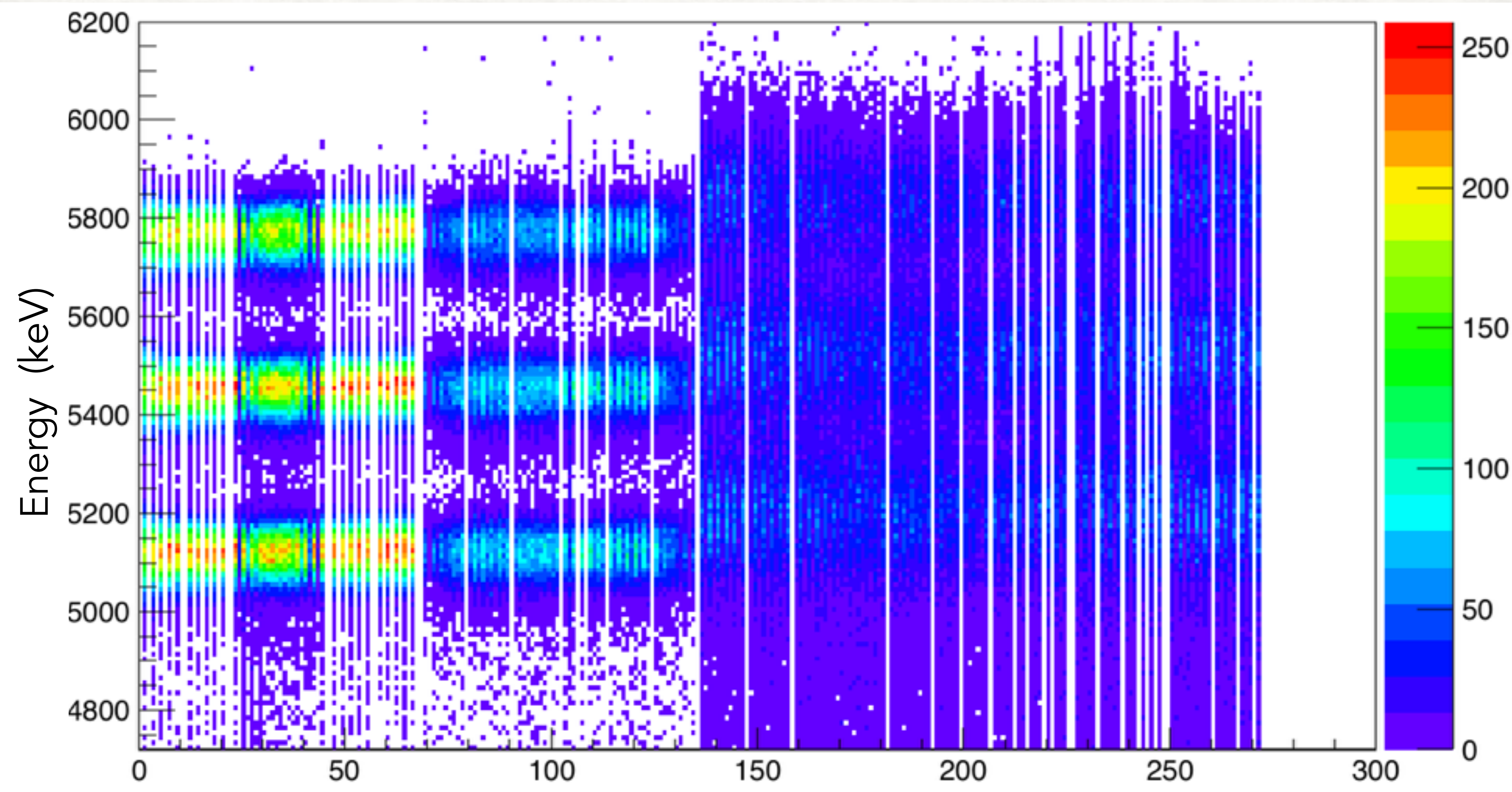


Comparison between GET gain settings

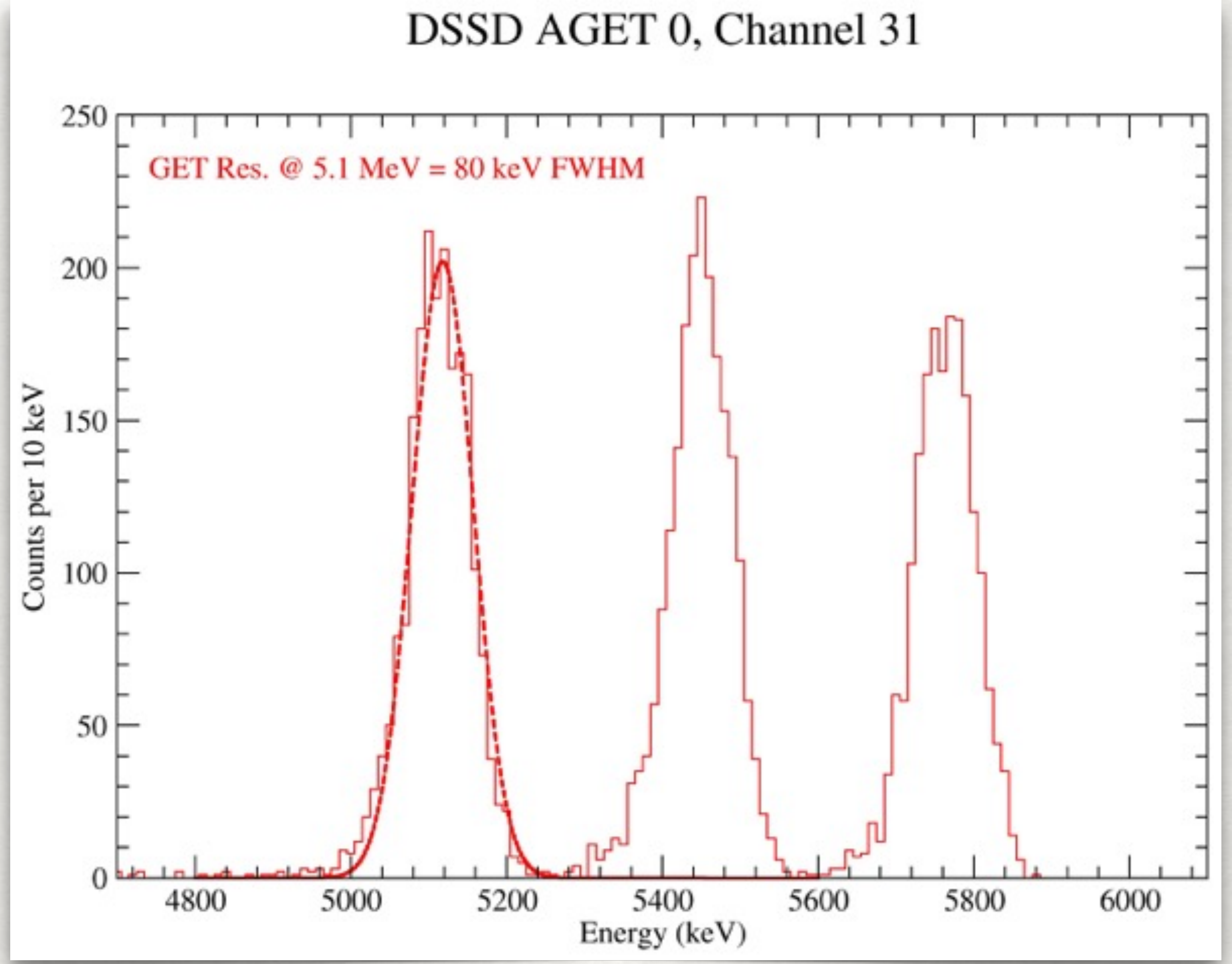




Alpha Energies



DSSD SI RESOLUTION



<u>Resolution @ 5.1 MeV</u>

GET: 80 keV FWHM

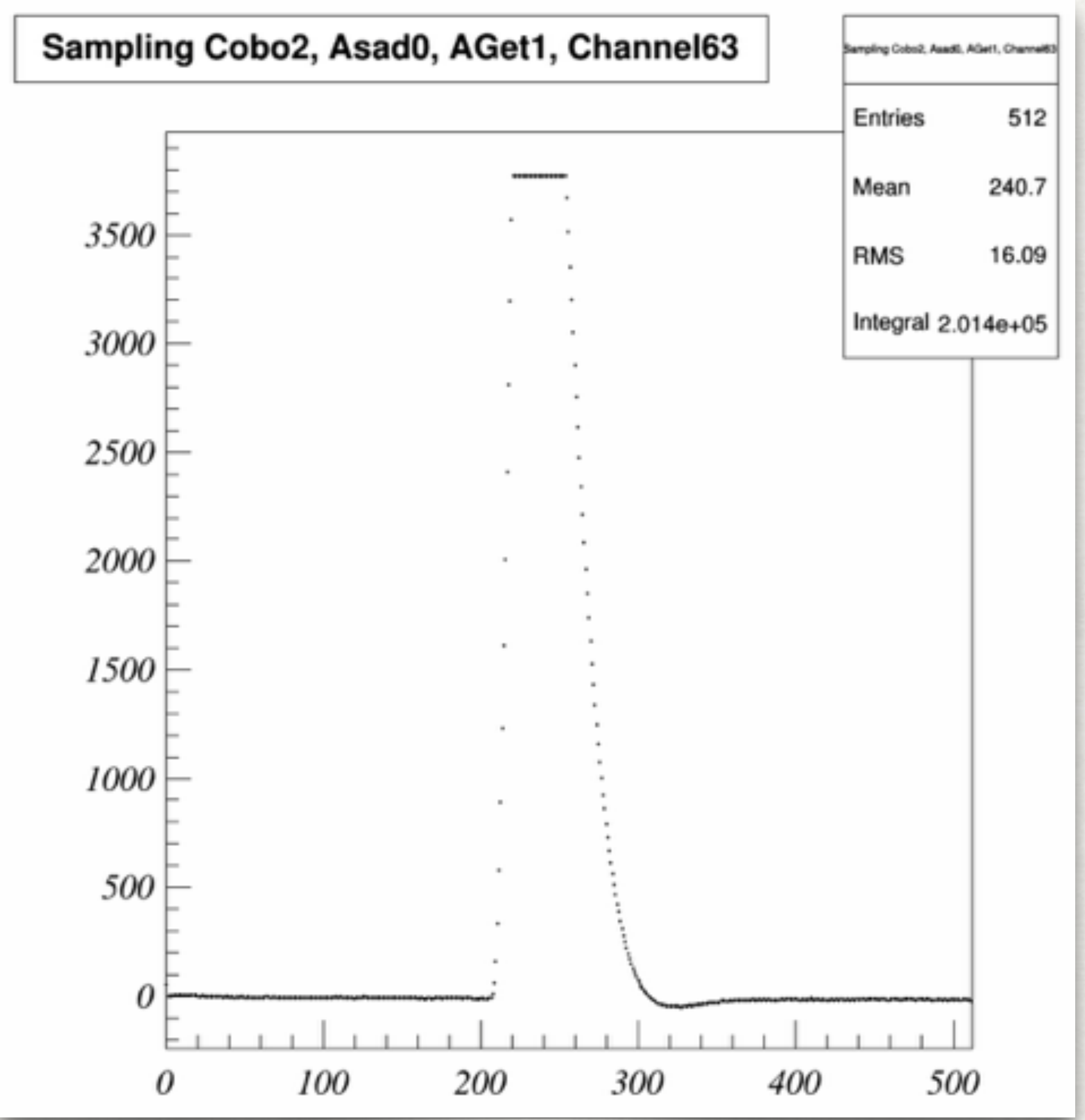
<u>Gain set to 1 pC</u>

Energy range: 17.5 MeV

Baseline noise: 25–80 keV

(5–15 ADC channels)

RECOVERY OF SATURATED SIGNALS



<u>Experiment @ IPNO:</u>

^{12}C @ 6.6 MeV/u

He:iC_4H_{10} (90%:10%) @ 1 atm

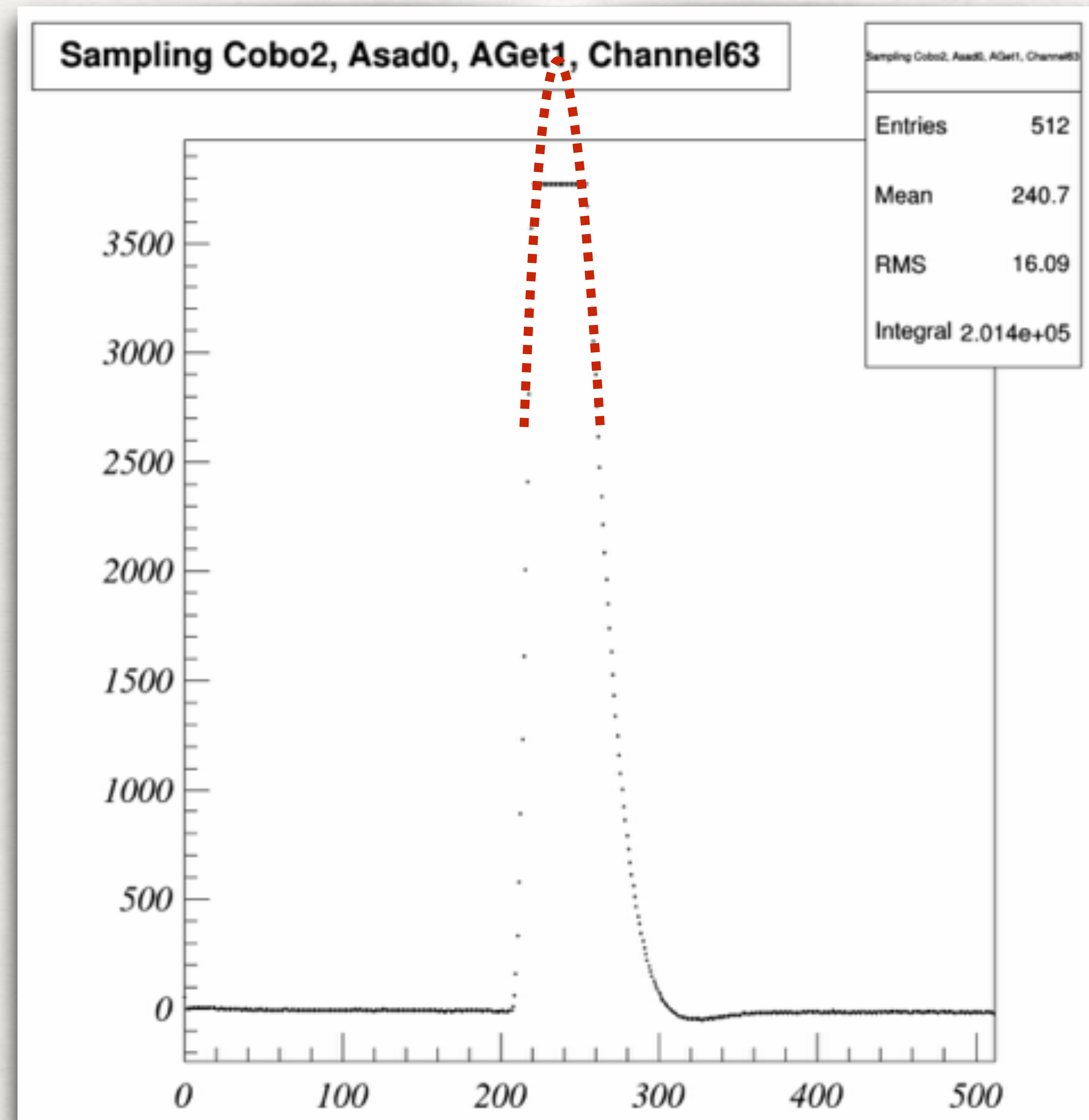
1 pC Gain = 17.5 MeV E_{range}

10 pC Gain = 175 MeV E_{range}

How to detect 20–30 MeV particles?

Saturated signal prevalence: 33% in DSSD, 7% in MAYA, 2% in Pads

RECOVERY OF SATURATED SIGNALS



<u>Experiment @ IPNO:</u>

^{12}C @ 6.6 MeV/u

He:iC_4H_{10} (90%:10%) @ 1 atm

1 pC Gain = 17.5 MeV E_{range}

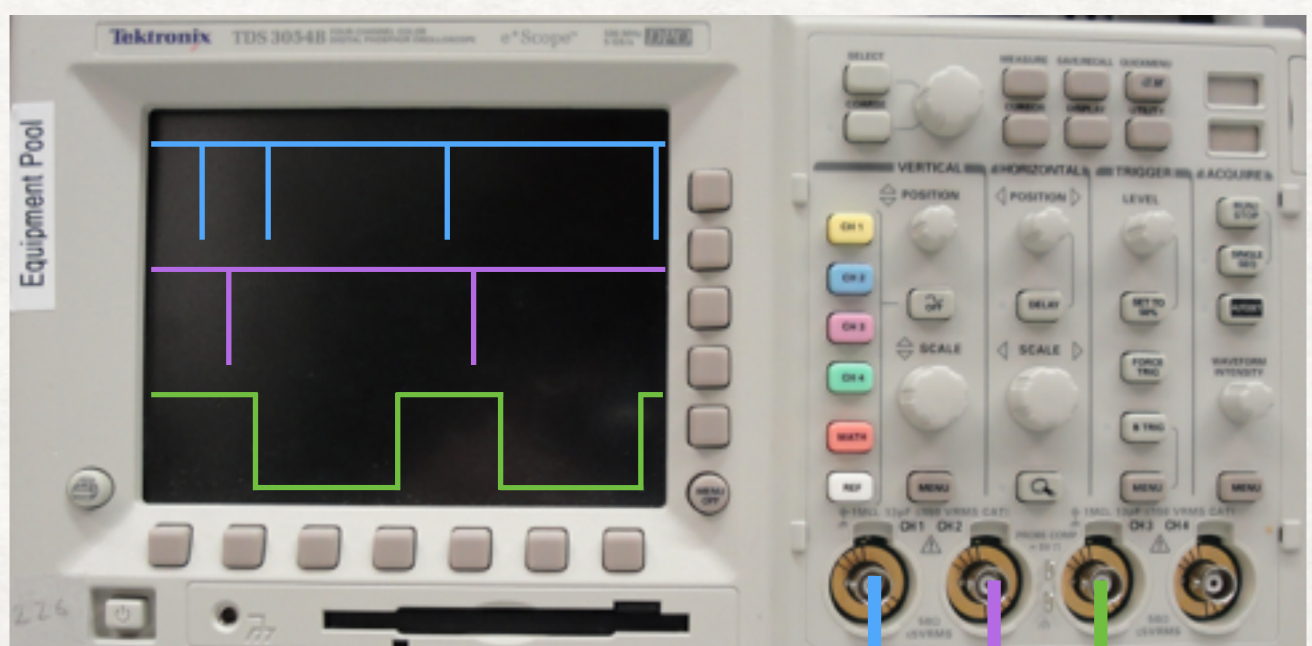
10 pC Gain = 175 MeV E_{range}

How to detect 20–30 MeV particles?

Saturated signal prevalence: 33% in DSSD, 7% in MAYA, 2% in Pads

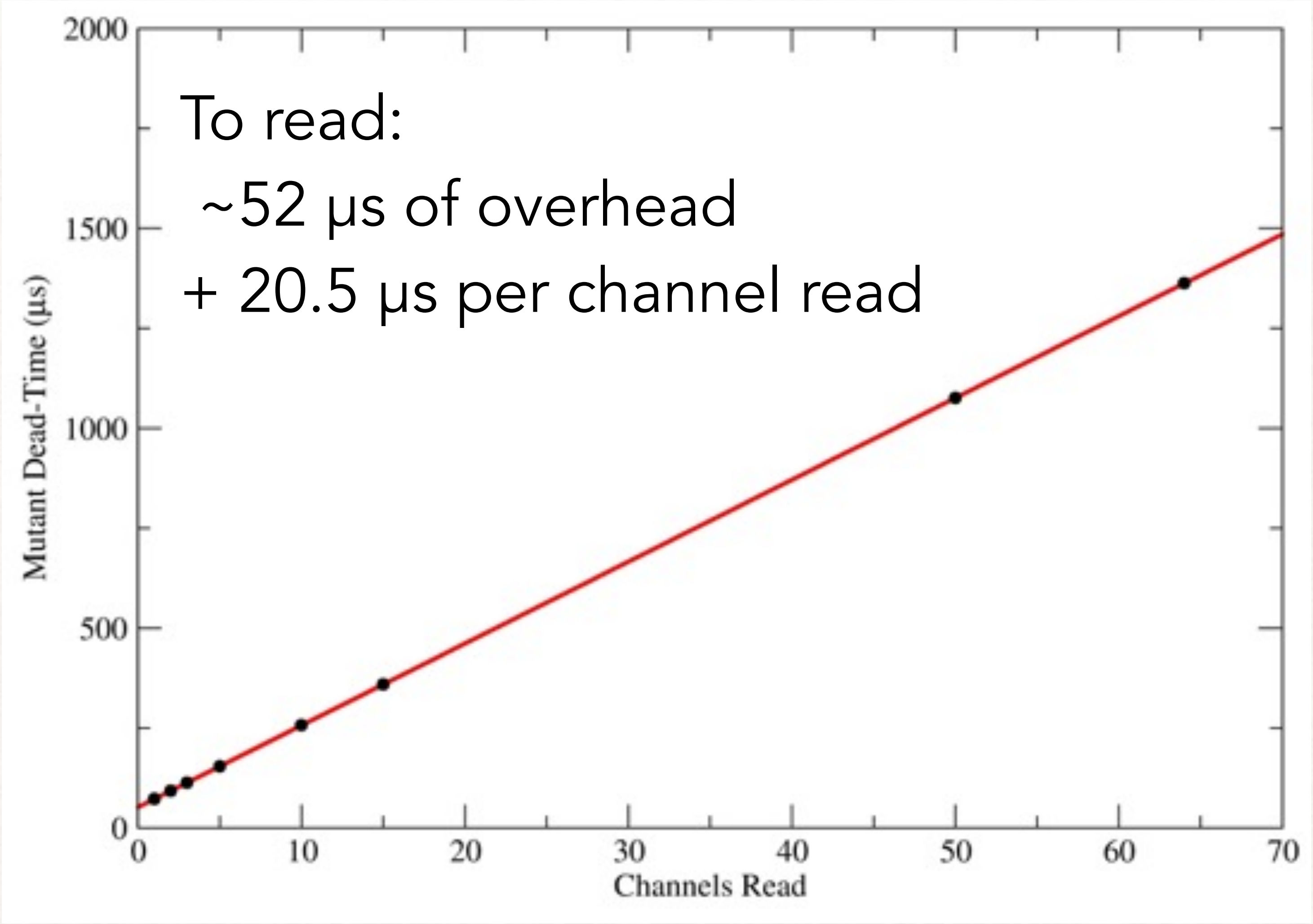
TESTING MUTANT DEAD TIME

- **Trigger:** Poisson distributed random pulser
- **Dead time:** Measured per event from MuTanT LEMO output
- **Live time:** Measured accepted trigger requests as TVal LEMO output. Ratio of trigger requests to accepted triggers gives live time



MUTANT DEAD TIME

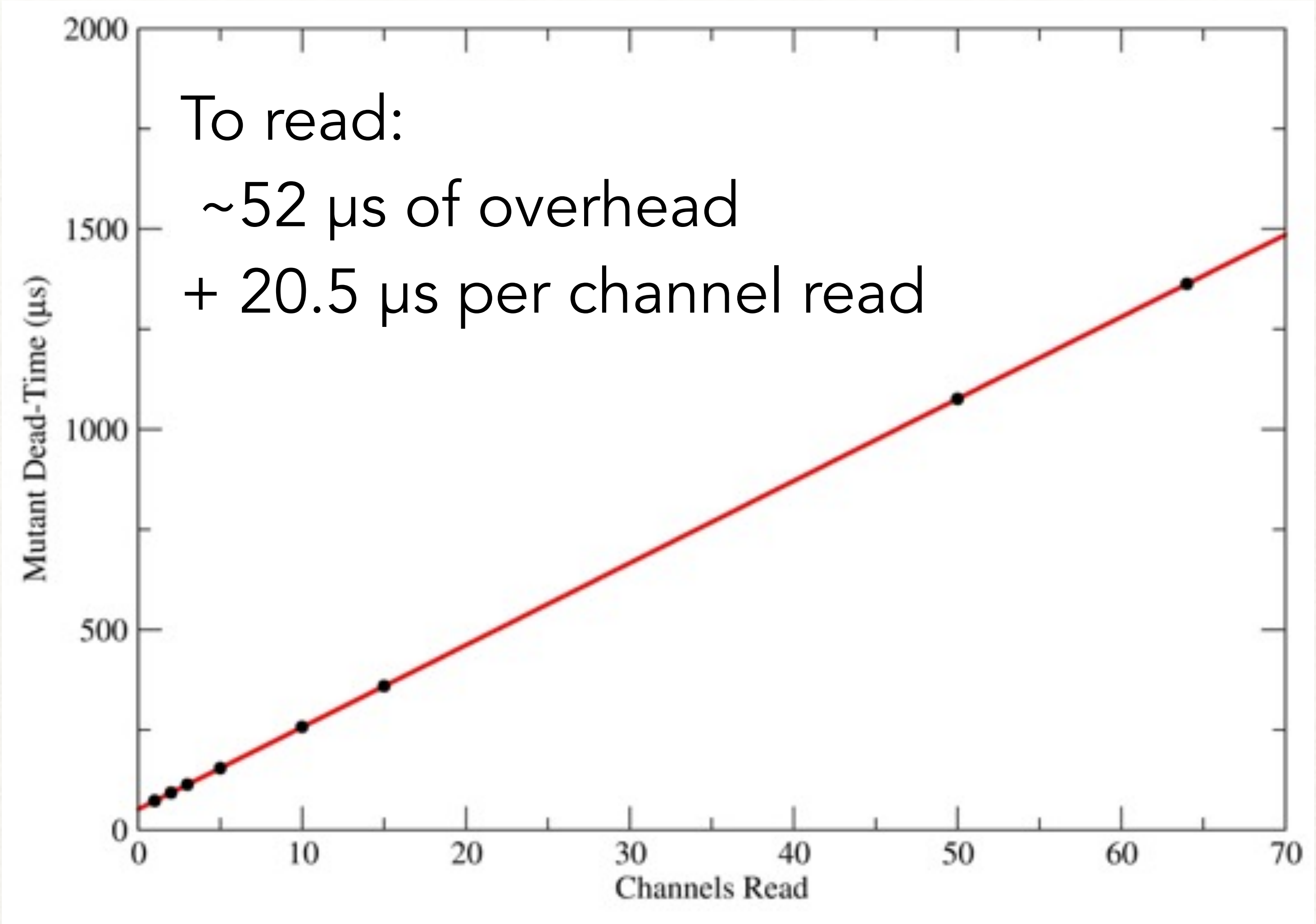
- MUTANT dead time signal width measured with oscilloscope



- Dead time set only by AGET chip with most channels being read (parallelisation at AGET level)

MUTANT DEAD TIME

- MUTANT dead time signal width measured with oscilloscope

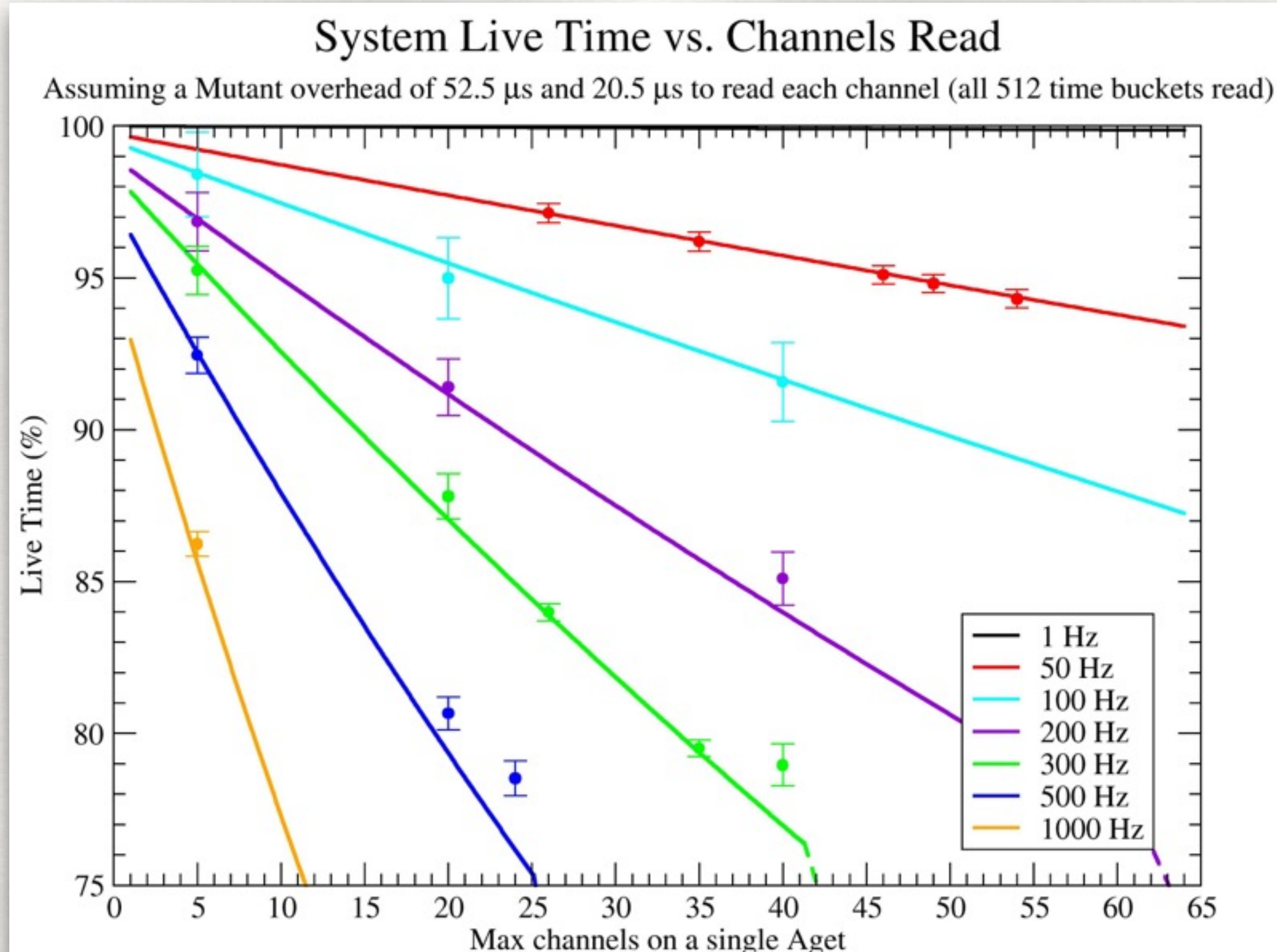


- Dead time set only by AGET chip with most channels being read (parallelisation at AGET level)

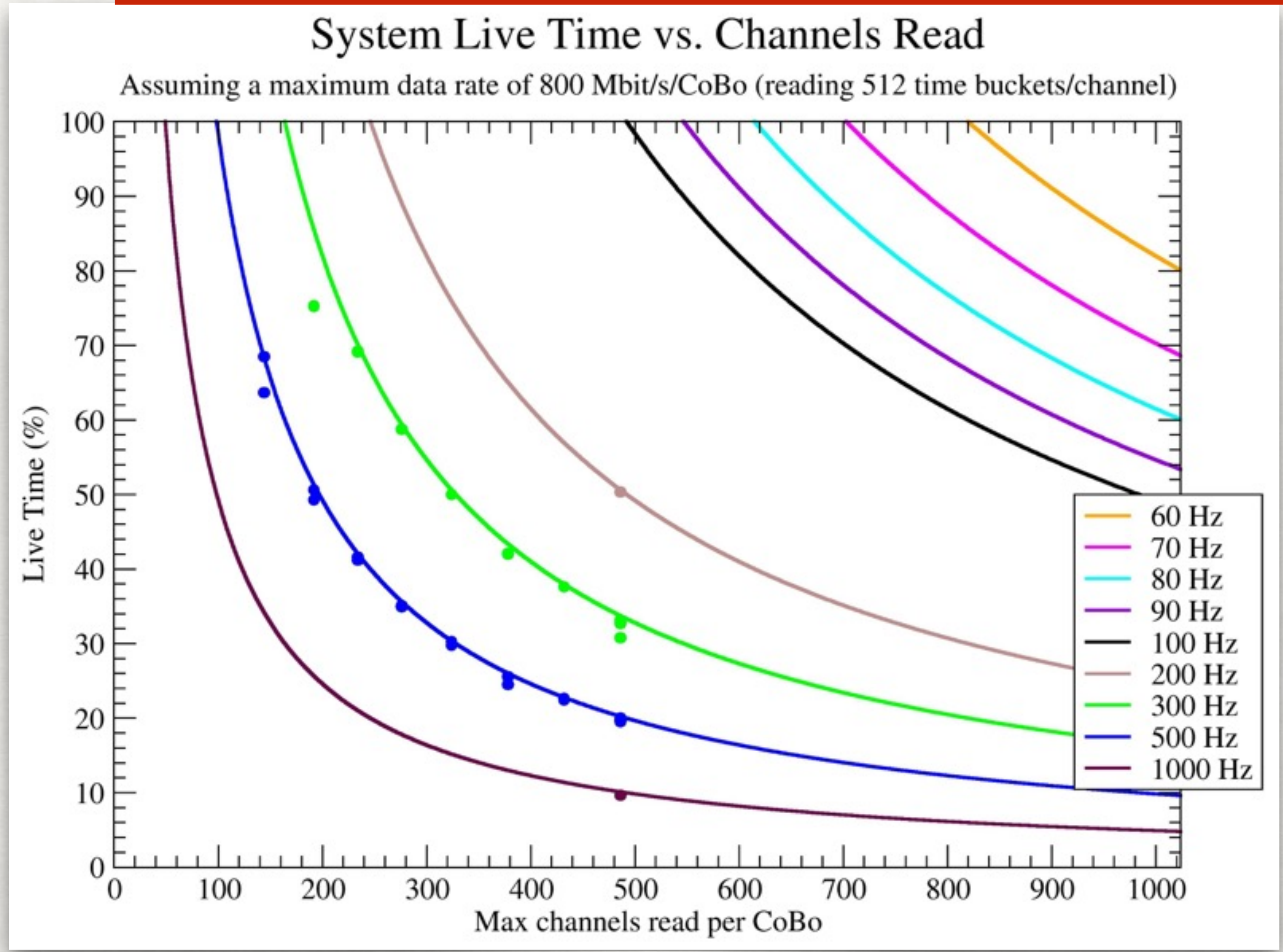
$$P(R\tau) = 1 - e^{-R\tau}$$

where R is trigger request rate and τ is dead time per event

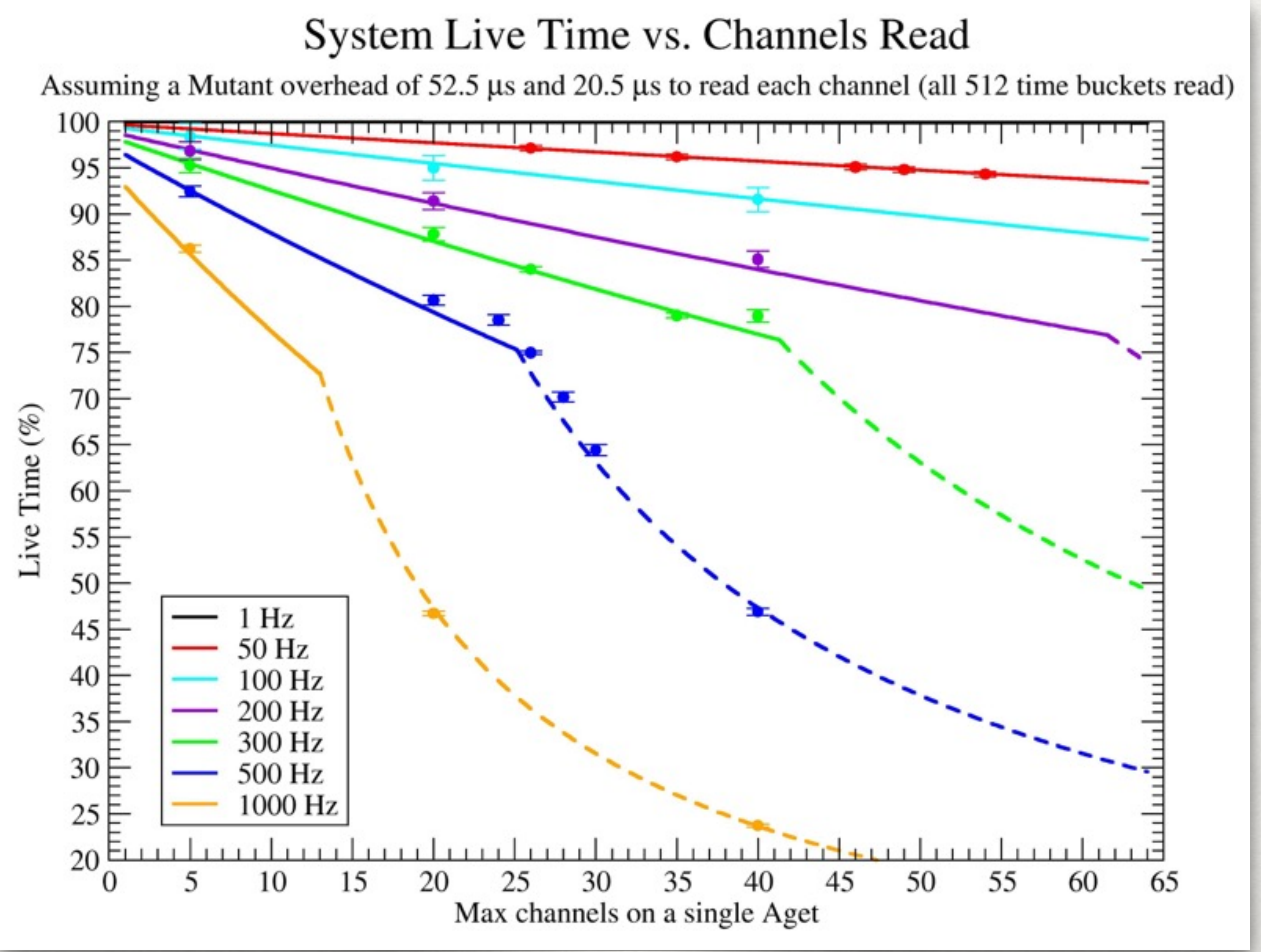
$$LT(R\tau) = 100e^{-R\tau}$$



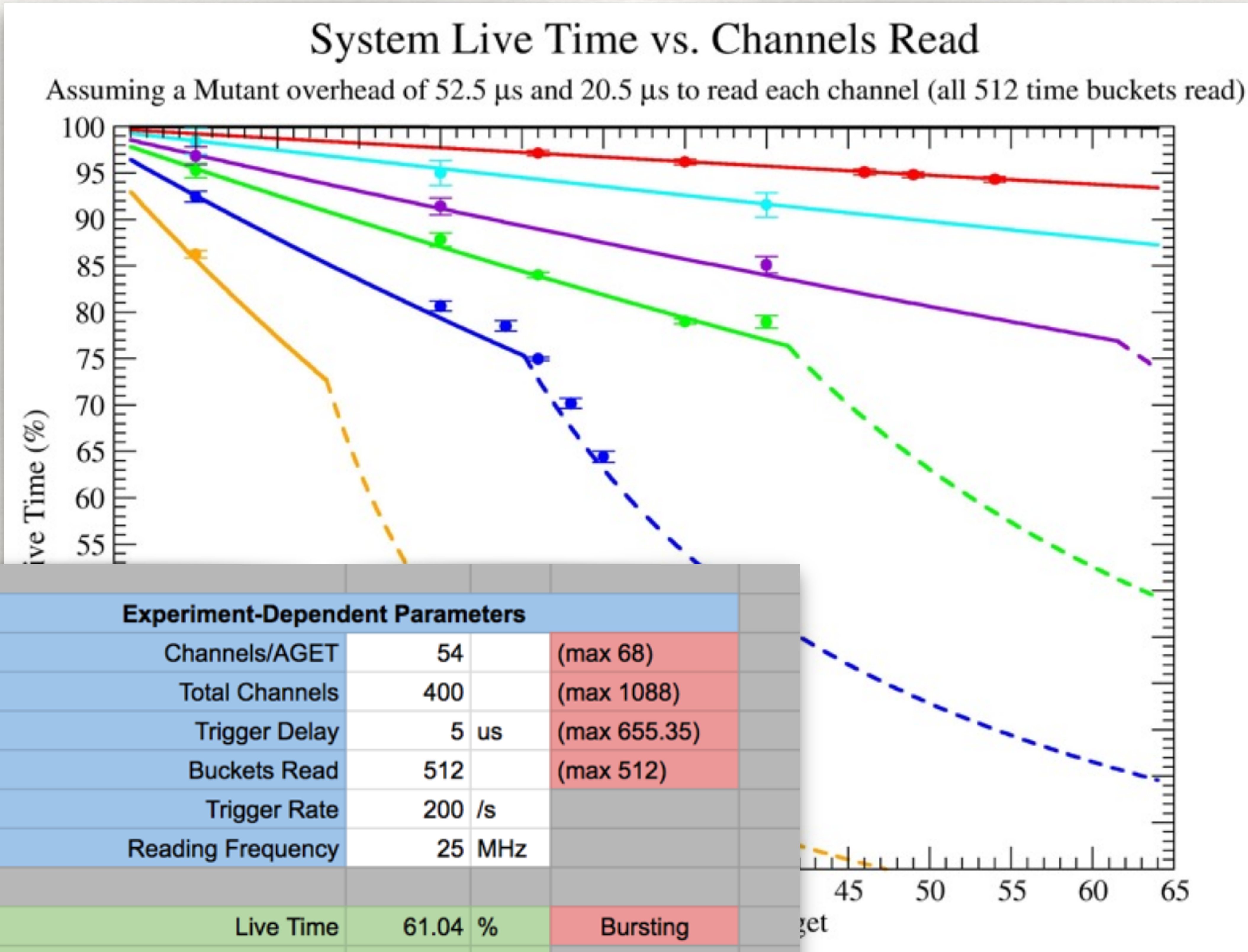
Dead time dominated by bursting associated with 800 Mbit/s data transfer rate limit



SYSTEM LIVE TIME



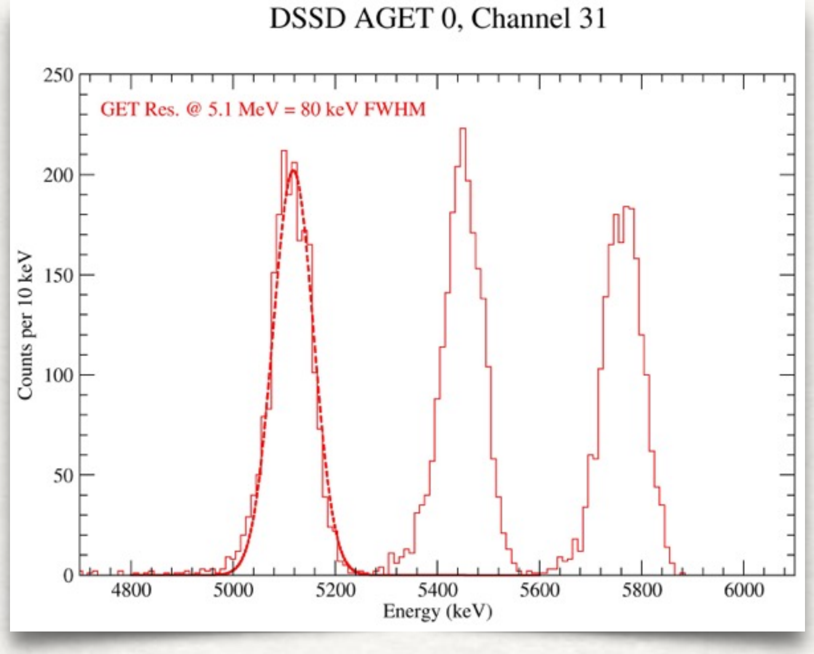
SYSTEM LIVE TIME



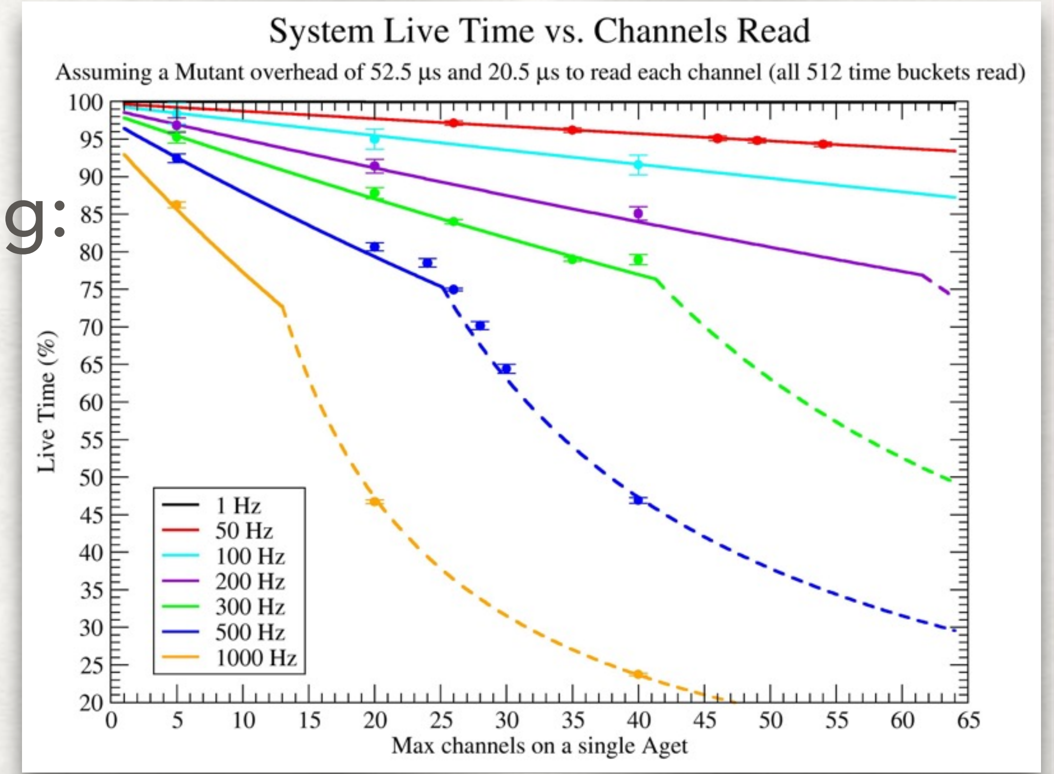
Experiment-Dependent Parameters			
Channels/AGET	54		(max 68)
Total Channels	400		(max 1088)
Trigger Delay	5	us	(max 655.35)
Buckets Read	512		(max 512)
Trigger Rate	200	/s	
Reading Frequency	25	MHz	
Live Time	61.04	%	Bursting
CoBo Data Transfer Rate	100.00	MB/s	

CONCLUSION AND SUMMARY

- DSSD Si resolution **~80 keV** FWHM (@ 5.1 MeV) with GET



- Energy range:
  - 120 fC – 2.5 MeV
  - 240 fC – 5 MeV
  - **1 pC – 20 MeV**
  - 10 pC – 200 MeV
- Baseline noise: **25 keV** (~5 ADC channels)
- System live time can be estimated knowing:
  - Max channels read on a single AGET
  - Max channels read on a single CoBo
  - Trigger delay
  - Time buckets read per channel
  - Trigger request rate



COLLABORATION

GANIL

M. Blaizot
P. Bourgault
S. Damoy
B. Duclos
G. Fremont
P. Gangnant
J. Goupil
G.F. Grinyer
A.T. Laffoley
S. Lecerf
L. Legeard
C. Maugeais
B. Mauss
M. Michel
J. Pancin
T. Roger

GANIL

P. Senecal
C. Spitaels
K. Turzo
G. Voltolini
V. Vandevoorde
G. Wittwer
F. Saillant

CEA/IRFU

E.C. Pollacco
P. Sizun

K.U. Leuven

M. Babo
S. Ceruti
J. Daemen*
T. Marchi
O. Poleshchuk
R. Raabe
F. Renzi
J.A. Swartz*
C. Wouters*
J.C. Yang

CENBG

B. Blank
J. Giovinazzo
T. Goigoux
J.L. Pedroza
J. Pibernat

USC

H. Alvarez-Pol
M. Camaaño
B. Fernández
P. Konczykowski*

IPNO

F. Flavigny
G. Minier*
P. Rosier*

RIKEN

D. Suzuki

+ GET Team

Students

Postdocs + CDD

Alumni *

ACKNOWLEDGMENTS

- The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013)/ERC Grant agreement n° 335593 (ACTAR TPC)

- For more information: http://pro.ganil-spiral2.eu/laboratory/detectors/actartpc