University of Glasgow

NINO Cards and BigBite Timing Hodoscope Update

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SBS Collaboration Meeting,

Jefferson Lab, 22/07/16

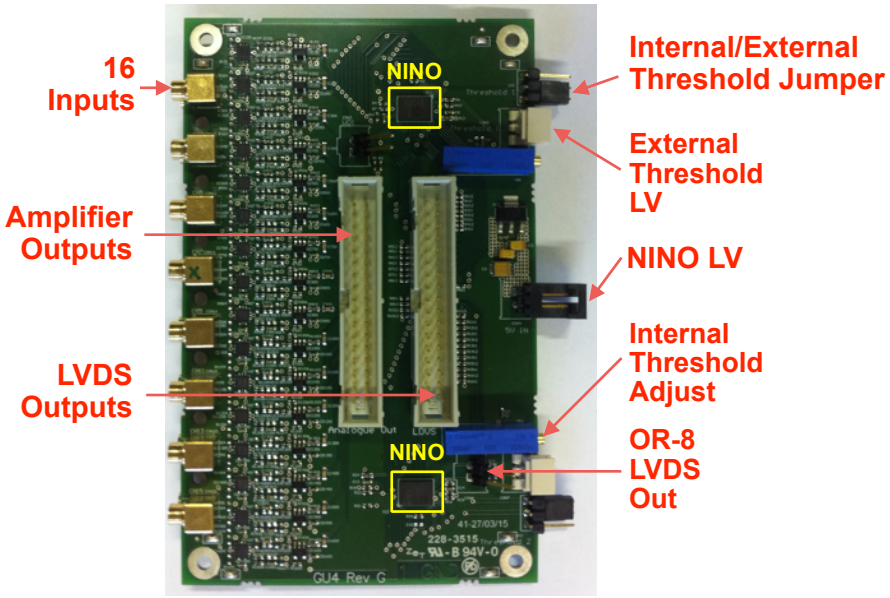
NINO ASIC Amplifier/Discriminator Cards

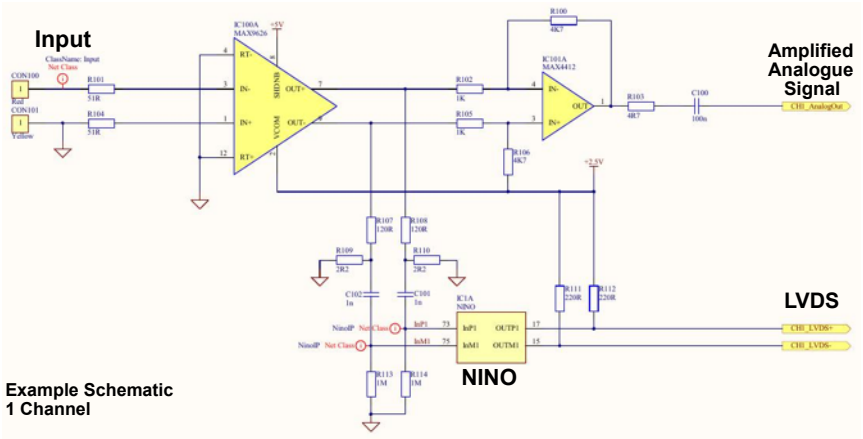
Parameter	Value
Voltage Supply	2.5V
Power	27mW/channel
Peaking Time	1ns
FE Time Jitter	<10ps
Signal Range	30fC - 2pC ($1.8e^5$ - $1.2e^7$ e-)
Discriminator	10fC - 100fC (0.62 - $1.2e^5$ e-)
Noise	< 2500 e-
Output	LVDS
Rate capability	>> 10MHz
Input Impedence	~50Ω

- NINO: ultra-fast, low-power, front-end differential amplifier/ discriminator ASIC (doi:10.1016/j.nima.2004.07024)
- Single photon sensitive, scintillator signals may require attenuation

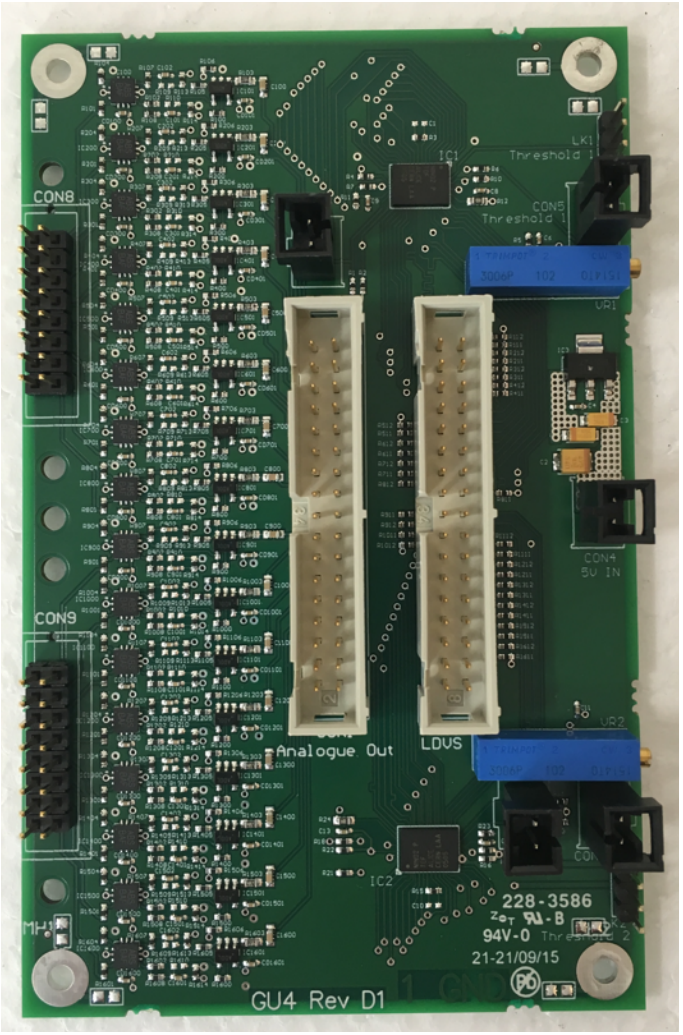
- Several BB/SBS detectors planning to use NINO based FE cards
- BB: GRINCH; timing hodoscope; SBS: CDet; (RICH; HCal)

- 16-channel amplifier/discriminator cards developed (2 NINOs)
- Outputs: amplified; LVDS (time-over-threshold charge); OR (1/NINO)
- Internal potentiometer or external LV for threshold circuit control



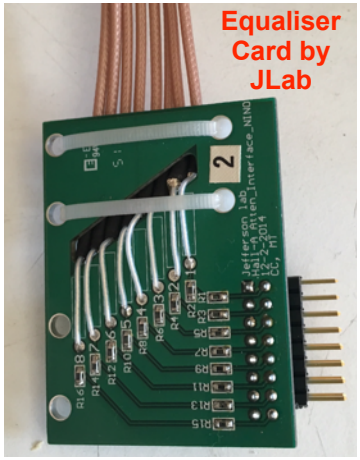


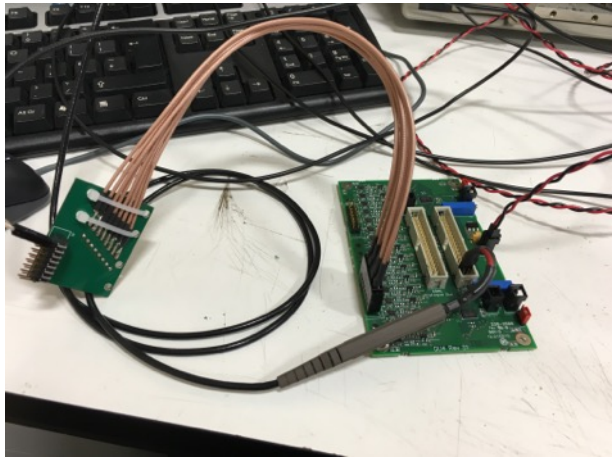
NINO ASIC Amplifier/Discriminator Cards - Rev D1 Status



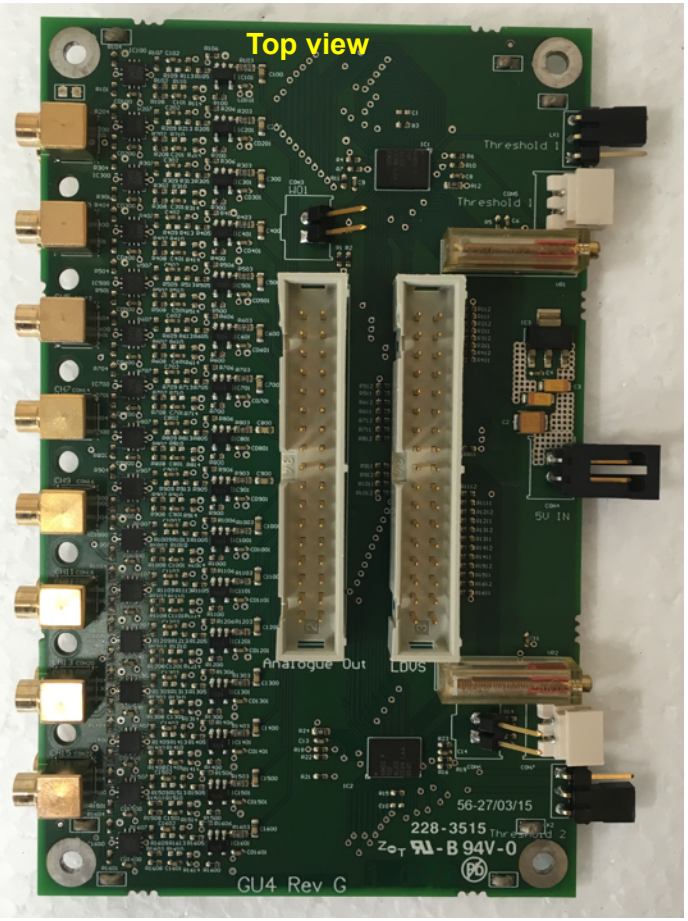
- **SBS Coordinate Detector**
- 6 modules totalling 2352 channels = 147 FE cards (min)
- 2 x 8-pair IDC connectors
- Gain equaliser card will be connected to input

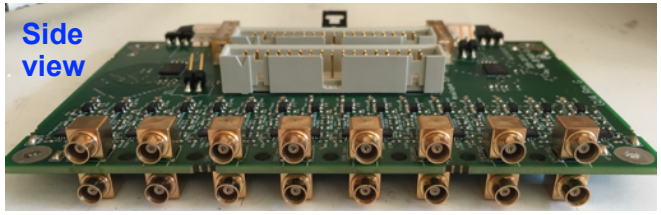
- Configuration finalised Aug 2015
- Production of 28 cards outsourced to Zot company
- Cards received and tested in Glasgow (Nov 2015)
- **28 cards delivered to JLab to instrument 1st module (June 2016) - currently under test**
- Await results on 28 cards' performance then start production of remaining 157 cards (185 cards requested)





NINO ASIC Amplifier/Discriminator Cards - Rev G Status

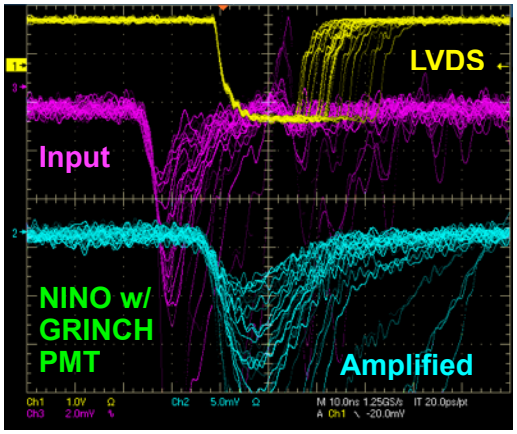




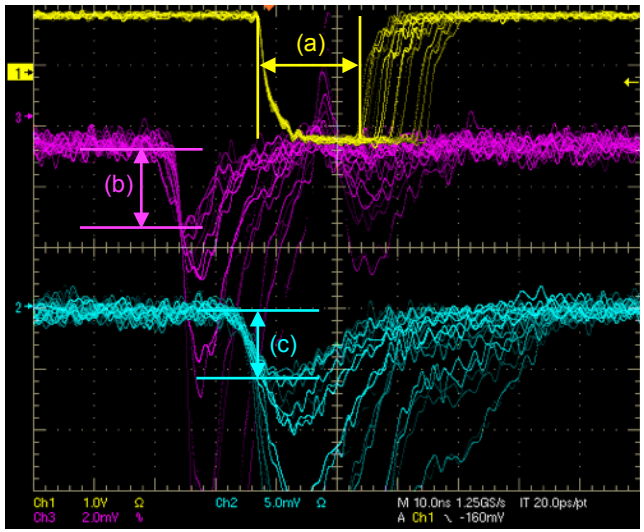
- **BB GRINCH (35 cards)** and **Timing Hodoscope (12 cards)**
- MCX co-axial connector types

- Configuration finalised early 2015 - order of 50 cards outsourced
- Original production with Zot delayed - PCB fault
- 50 corrected cards received June 2015
- Input connector problem - sent back for re-seating
- End of Aug 2015 re-seated cards received
- Cards tested - 39 fine, 11 still with issues

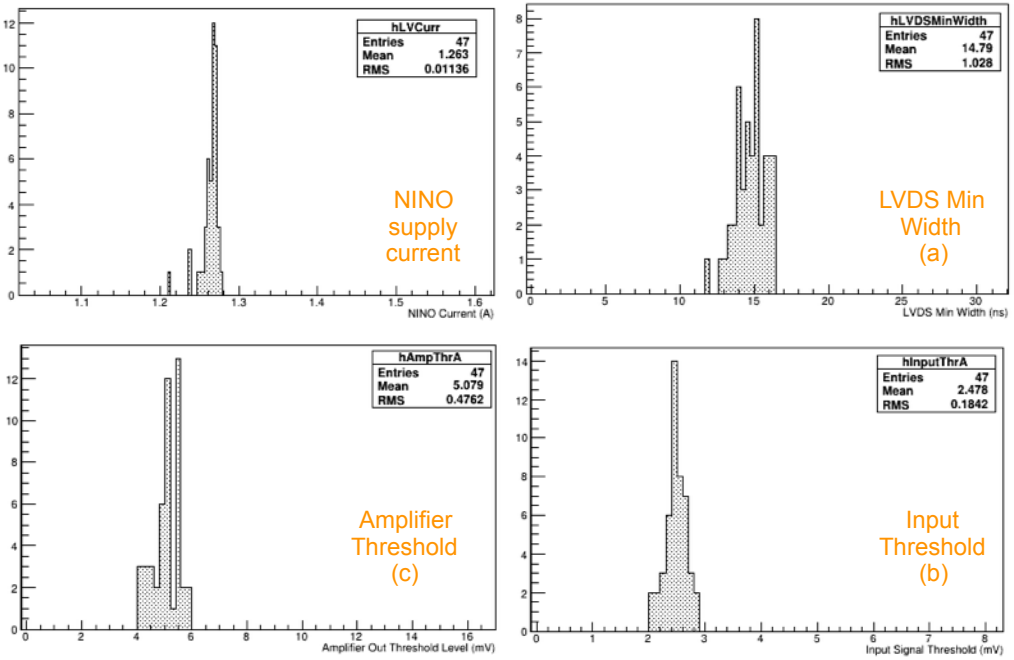
- Sufficient cards to instrument GRINCH
- Oct 2015, 8 boards + cables sent to JLab for GRINCH prototype
- Remaining 27 GRINCH cards and cables currently in transit/delivery
- Sufficient remaining cards for TH instrumentation + spares, although repairs on most needed
- 1.5m MCX co-ax cables for TH in Glasgow



NINO Cards - Tests of Production Cards

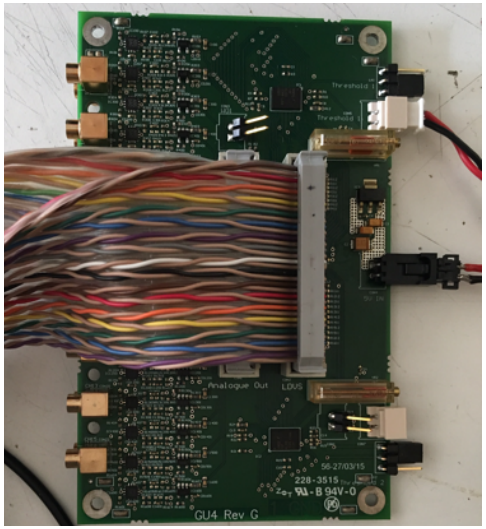


Examples: 47 RevG cards



- Cards received from company tested in Glasgow before shipping to JLab
- Input: 3 x 3 x 1 cm plastic scintillator coupled to single channel PMT, with cosmic muons
- Measured with oscilloscope: input; analogue amplified out; LVDS out (via 1GHz probe)
- Test procedure established/repeated for every card with parameters to be noted:
  - current drawn; noise levels; LVDS height/width; threshold level of input and amplified output; low/high thresholds; internal/external threshold control
- All channels of each card checked to be functioning

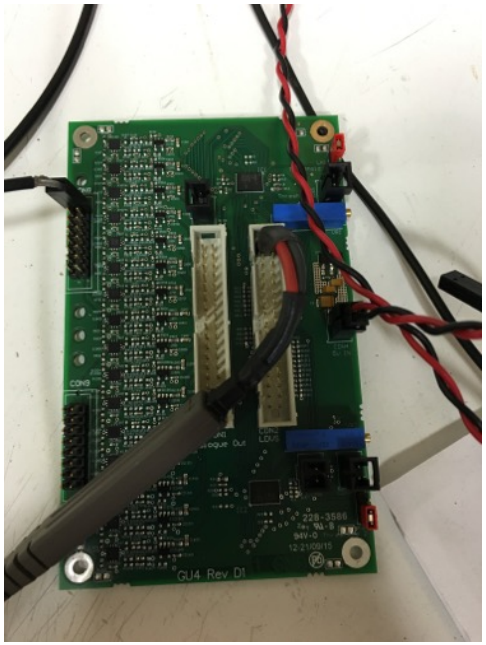
NINO Cards - Set-Up for Further Studies

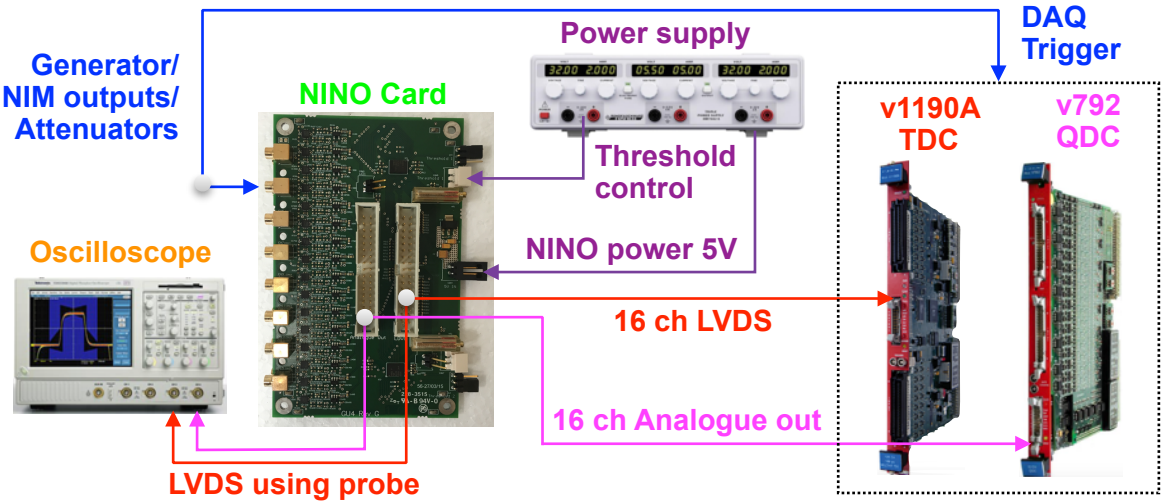


Several studies of NINO cards performed using generated pulses

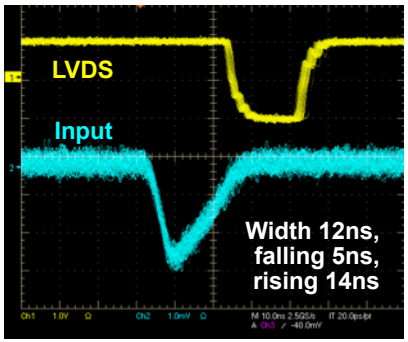
Set-Up/Equipment:

- Tektronix AFG3102 waveform generator
- NIM units (gate generator/coincidence unit etc) alternative input
- Attenuation diodes (some cases)
- NINO Cards
- CAEN v1190A 100ps multi-hit TDC (LVDS outputs)
- CAEN v792 100fC QDC (analogue outputs)
- Signals connected to TDC/QDC by ~6-10m flat ribbon cables
- Tektronix TDS5054B digital oscilloscope
- HAMEG HM7042-5 power supply





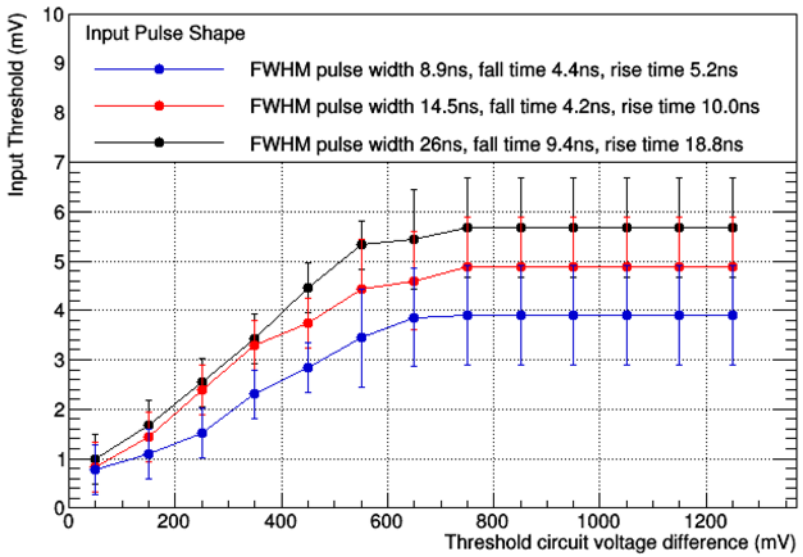
NINO Cards - Threshold Scans

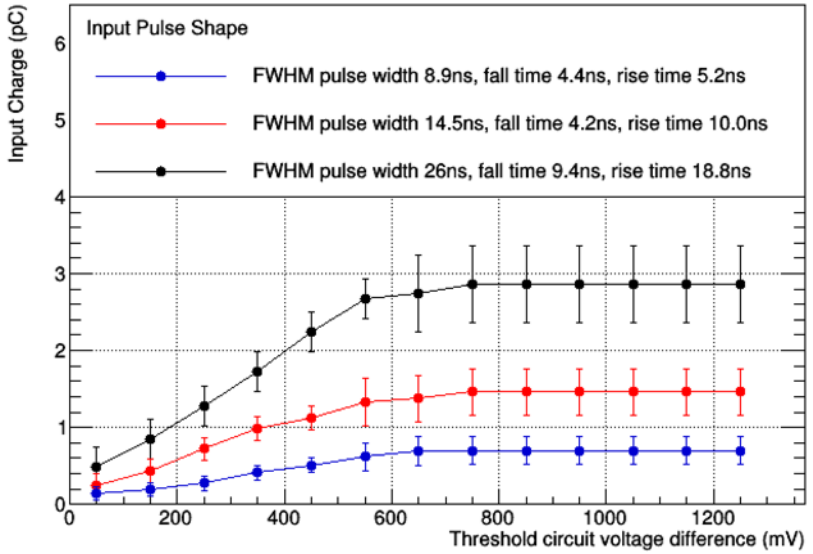


Study of NINO threshold as a function of input pulse height and shape

Method:

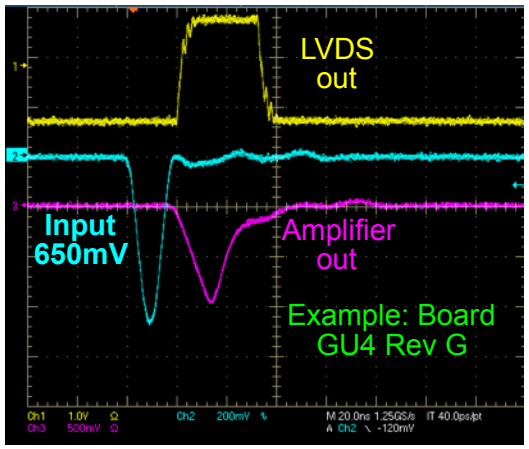
- External threshold circuit control
- Signal generator as input; oscilloscope to measure signals
- Increase input amplitude until NINO LVDS triggers cleanly on input
- Repeat for several thresholds
- 3 input pulse shapes; signal height spanned 10s p.e. before attenuation
- (n.b. Threshold circuit voltage difference = LV supplied - 1.25V)





- Dependence upon pulse shape
- Saturation behaviour expected
- NINO integration time is shorter than duration of input pulses used

NINO Cards - Crosstalk Studies

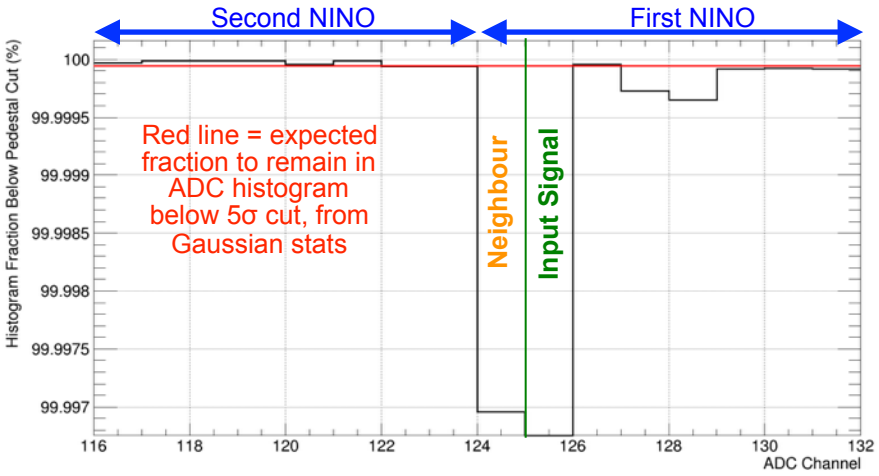


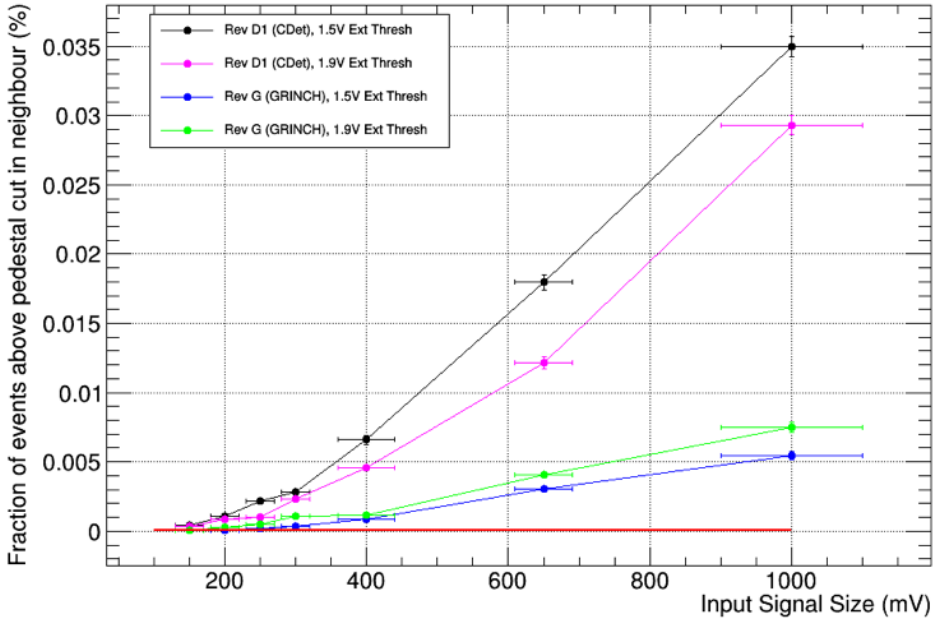
Study for “analogue”/spurious crosstalk hits:

- Input signal from generator on one channel only varied from 150mV to 1V (unreasonably high on purpose)
- External threshold (both 1.5V (lower) and 1.9V (higher))

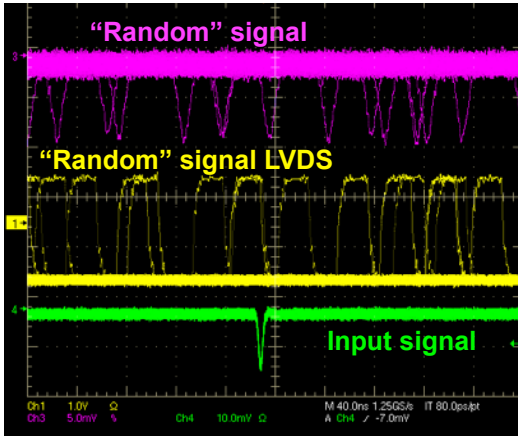
- TDC spectra checked for digital hits above threshold in neighbours
- No TDC hits observed (apart from 6/~6e6 events for worst case 1.5V thresh, 1V in for CDet board)

- ADC spectra checked for charge sharing/induced hits in neighbours
- Next neighbour always affected the strongest but overall values negligible
- Slightly larger values in Rev D1 compared to Rev G



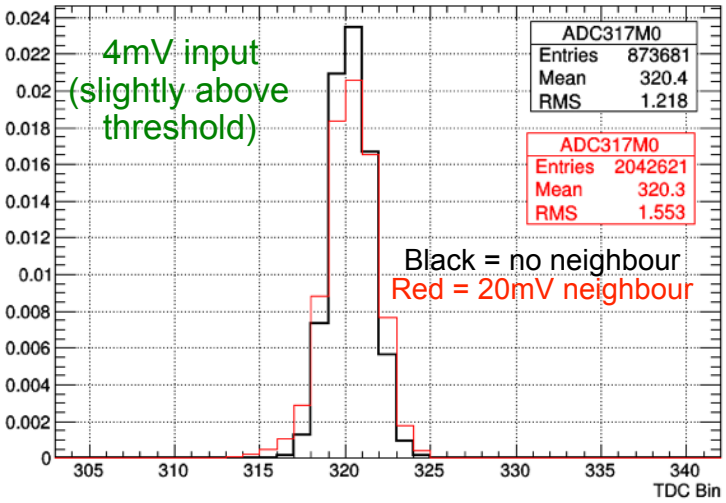


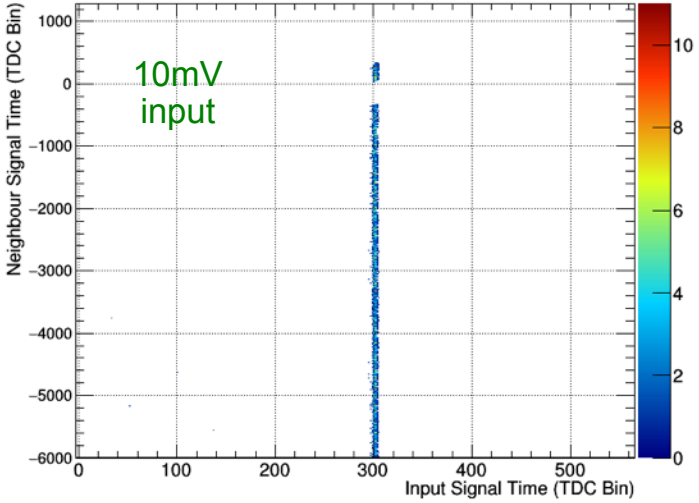
NINO Cards - Crosstalk Studies



Study for crosstalk influence on digital hits (method1):

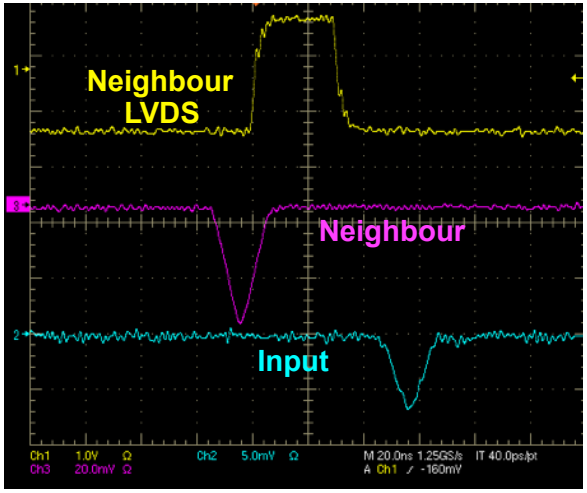
- Stable signal in 1 NINO input using NIM units
- Signal varied from just below threshold to ~10mV
- External threshold 1.5V (lower setting)
- Pulse generator for "random" signal in neighbouring channel
- "Random" pulse not correlated by any trigger from stable pulse
- "Random" frequency > stable pulse frequency
- Different frequencies/input sizes (20mV, 100mV, 600mV) tested, but no noticeable difference in effect





- Neighbour pulse had no significant effect on input signal timing
- With input signal just below threshold (3mV), no digital hits were found with tested "random" neighbour pulses present

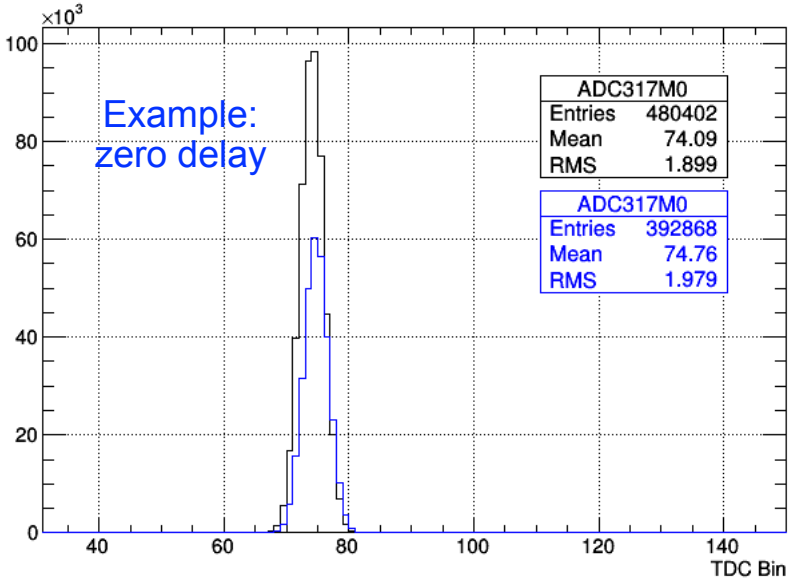
NINO Cards - Crosstalk Studies

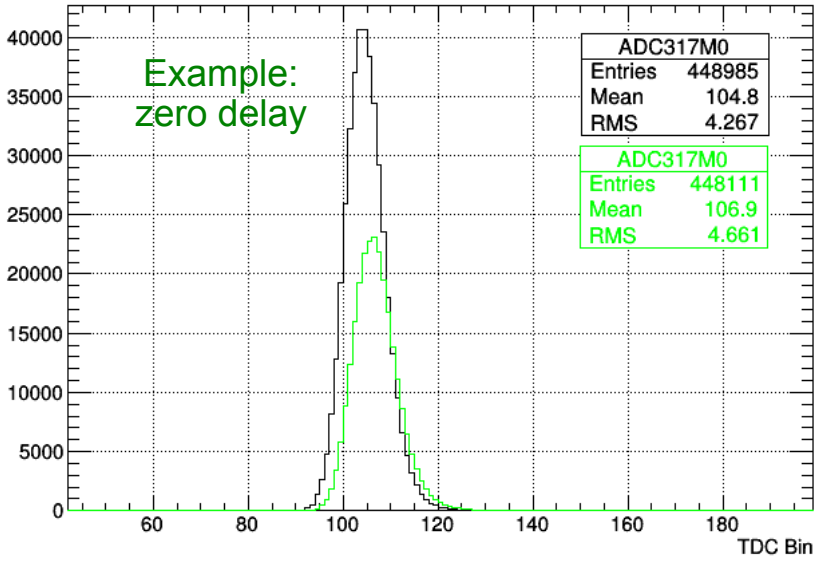


Study for crosstalk influence on digital hits (method2):

- Pulse generator used for NINO input
- Signals: 4mV just on/above threshold and 7mV slightly above
- Different pulse generator channel for neighbour signal (~40mV)
- Delay between input and neighbouring channel signals varied (neighbour scanned from 60ns before and after true input)

- Input TDC spectrum fitted with Gaussian, parameters studied as a function of neighbour delay
- Control data sets taken with no neighbour signal present to asses normal fluctuation levels

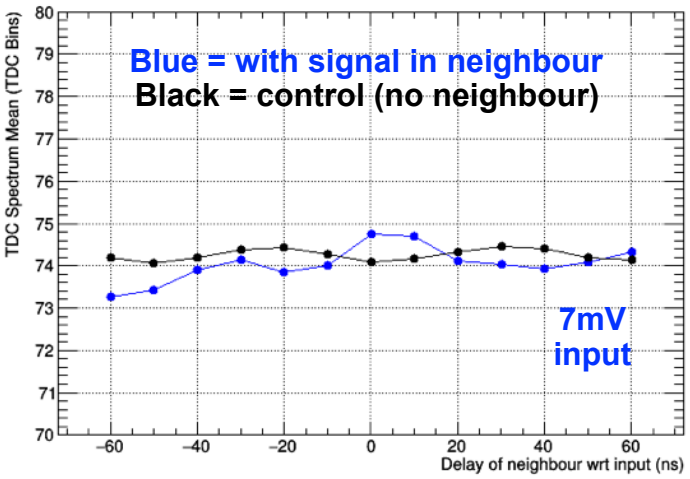


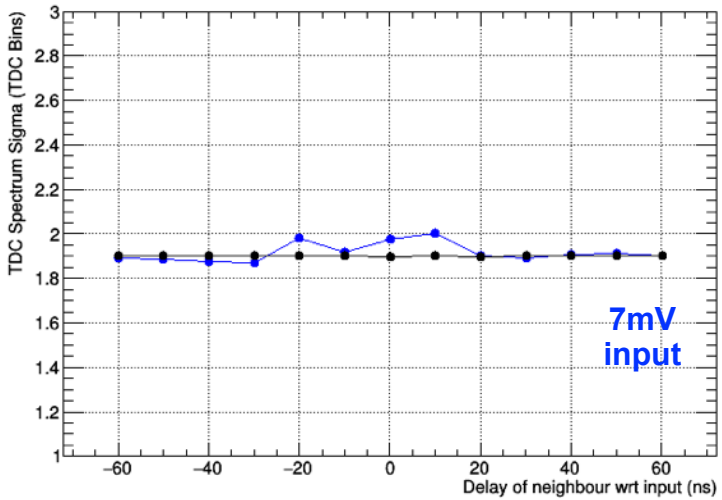


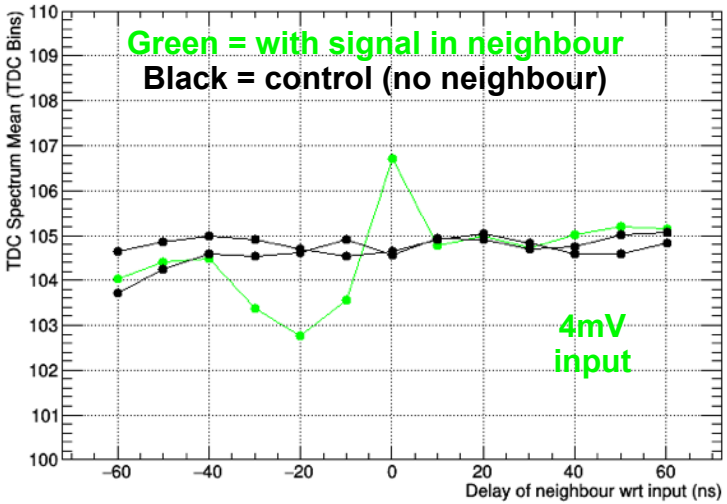
- No drastic effect on timing spectra, although decrease in efficiency observed

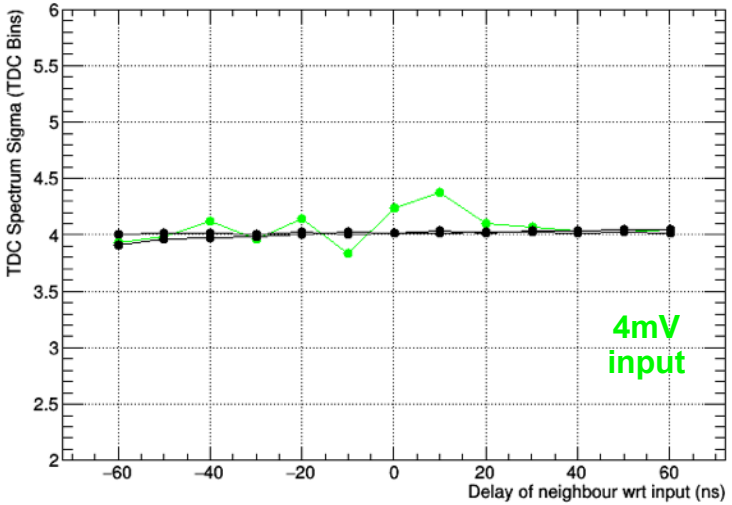
NINO Cards - Crosstalk Studies

Study for crosstalk influence on digital hits (method2):



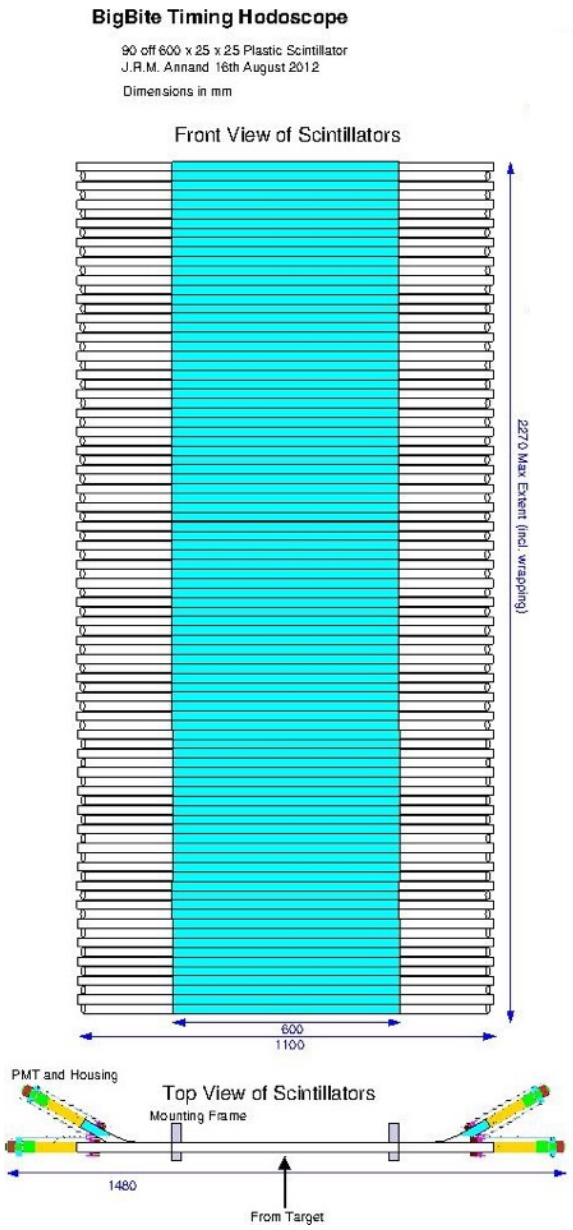






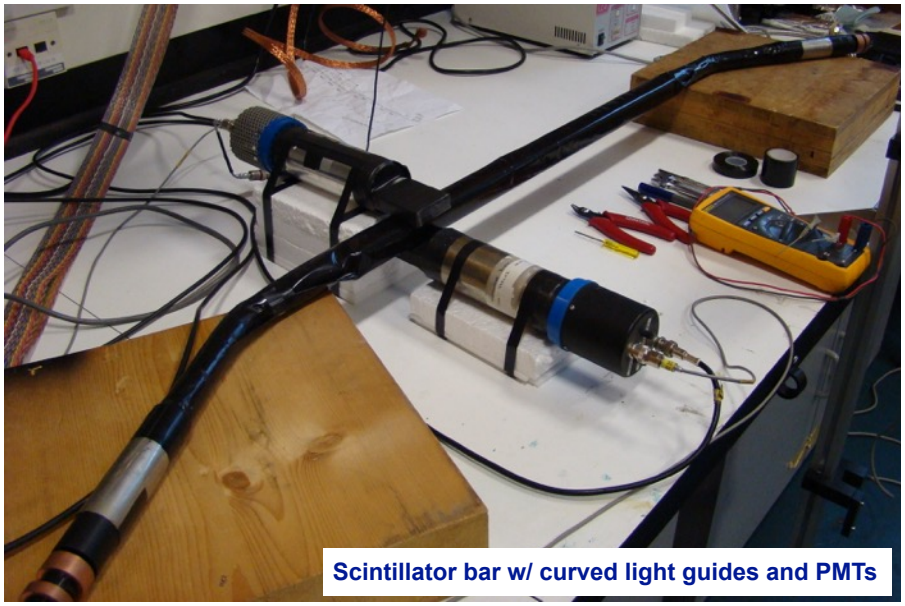
- Also repeated delay scan of 40mV neighbouring channel with true input signal just below threshold at 3mV, but recorded no digital LVDS hits in below threshold channel

BigBite Timing Hodoscope



- **Provide high precision trigger timing information**
  - Important for 2-arm (e,e'N) measurements
  - Hodoscope e' hit reference time for nucleon time of flight measurements in SBS
- Additionally: pulse height information and high efficiency for MIP over BB momenta range; hit position information may assist tracking
- Positioned between pre-shower and shower calorimeters
- Vertically stacked scintillator bars with readout at each end by single channel PMTs
- Set-up:
  - 90 EJ200 plastic scintillator bars (600 x 25 x 25 mm)
  - Light guide at each end - alternate straight and curved light guides to accommodate PMTs + housings in space
  - 180 ET 9142 PMTs (ET Enterprises) and custom bases
  - NINO Rev G FE cards
  - Frame (await final configuration)

BigBite Timing Hodoscope - Scintillators, Light Guides

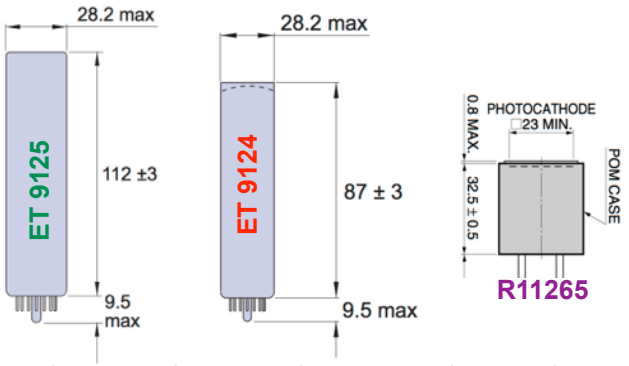

Scintillator bar w/ curved light guides and PMTs

- 90 (+6 extra) EJ200 plastic scintillator bars procured from Eljen technologies
- Light guides glued using UV curable cement
- Plan to wrap bars in tedlar (opaque, thin, doesn't reflect)
- Optical grease will be used for PMT joint
- Assembly of bars/light guide gluing completed in Glasgow and shipped to JLab (before end 2015)

Light guides


Light guide coupled to PMT

BigBite Timing Hodoscope - PMTs, Bases



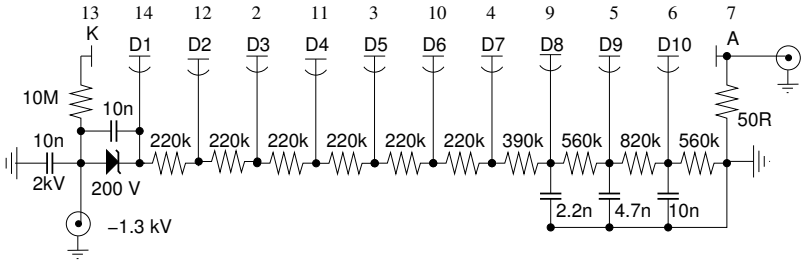
PMT	Rise Time (ns)	Transit Time (ns)	Transit Time Jitter (ns)	QE @ 400nm	Max Gain ($x10^7$)
ET 9125	4.5	33	4.0	28%	2.0
ET 9124	1.5	19	1.5	28%	1.0
R11265	1.3	5.8	0.27	35/43%	0.13

- Cosmic ray tests (J. Annand, 2015): 1 scintillator bar; dual-ended readout; curved light guides; NINO card
- ET 9125 (BaBar DIRC); **ET 9124**; Hamamatsu R11265
- Time resolutions (from mean time TDC distributions) 0.31ns; **0.15ns**; 0.10ns
- ET 9124 optimal trade-off between performance/cost
- **200 ET 9124 PMTs procured, currently in Glasgow**

Voltage divider for ET9142SB 28mm PMT, Hall–A JLab.

J.R.M.Annand 28/05/2014, modified PS Lumsden 30/03/2016

Modified plastic scintillator, –ve HV for higher current operation.

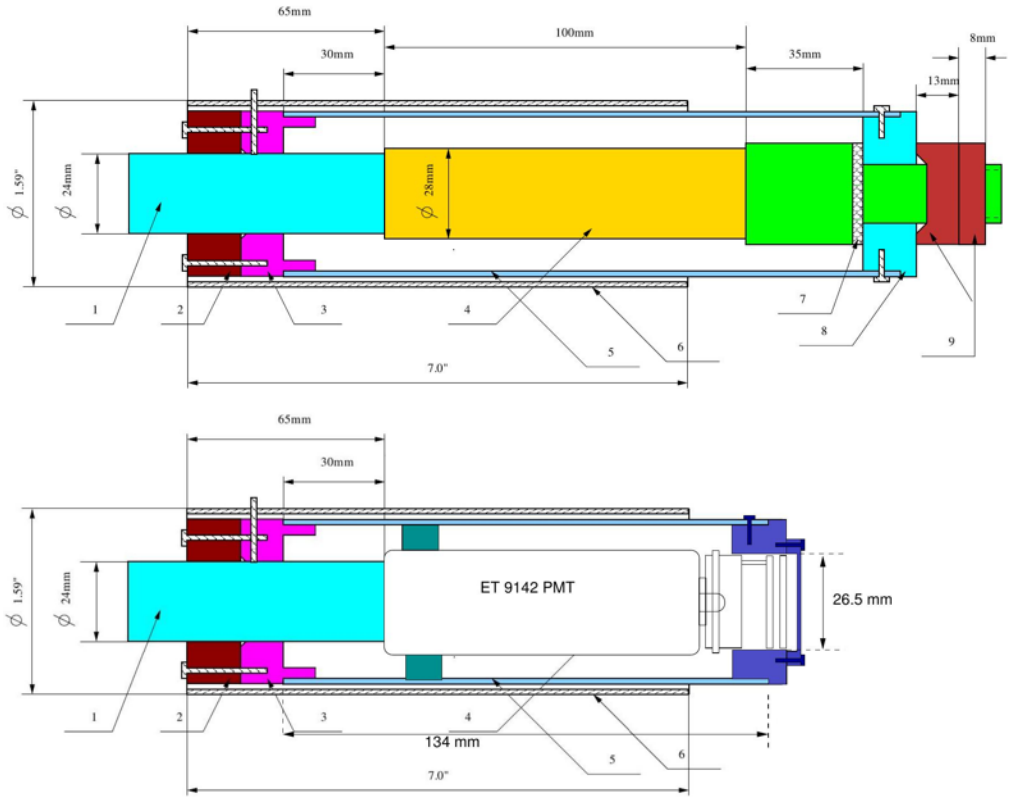


Resistors 0.330W, 150V 200ppm/C

Vmax 1.5kV Imax 0.35 mA

- **Custom bases designed:**
- Faster signal return to baseline/cheaper than ET option
- Single MCX connector
- BaBar PMT pattern HV connector
- PCB compliant with dimensions BaBar container
- Set for -ve HV
- Low gain (benefit from NINO high sensitivity)
- High linearity over wide dynamic range
- Production out-sourced to Zot company (Scotland)
- **200 bases currently under construction**, completion before end summer 2016

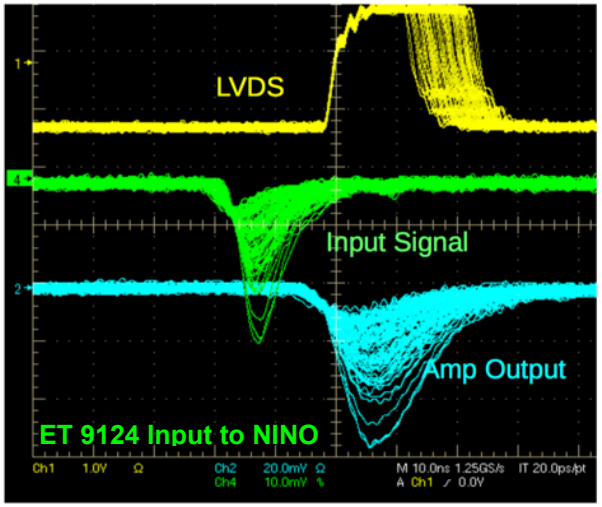
BigBite Timing Hodoscope - PMT Mounts



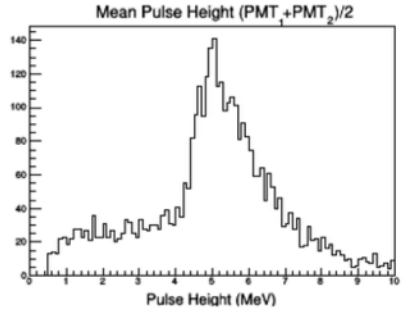
Original Drawing/design:
Albert Shahinyan,
ET 9125 PMTs

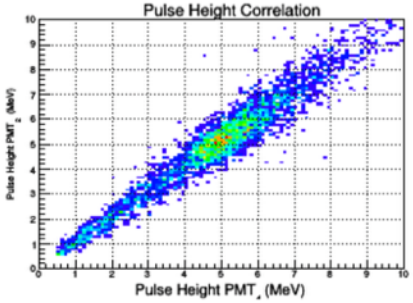
- **Mount for PMTs will require small modification**
- Original drawing for ET9125 PMTs (length 112mm)
- ET9124 and ET9125 same diameters, but **ET9124 is shorter** (length 87mm)
- If already constructed, housing could be machined/shortened
- Light guide, PMT and base diameters constant, no modification in this direction required

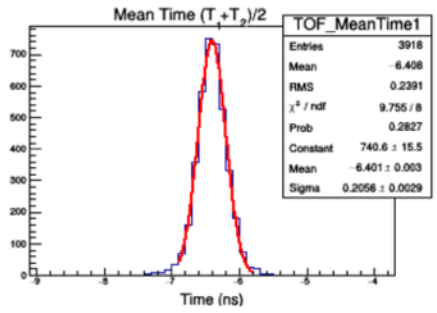
BigBite Timing Hodoscope - NINO Cards and Example Data

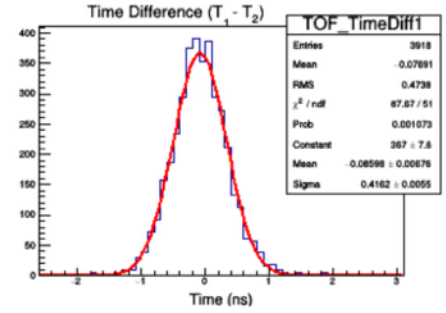


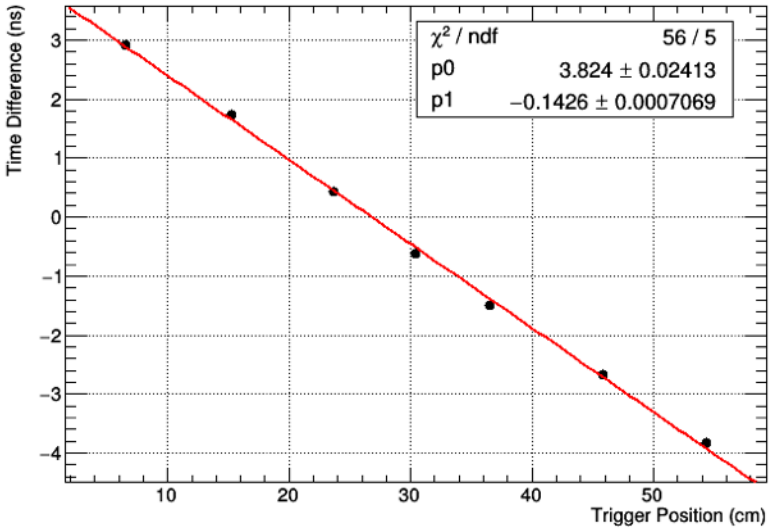
- NINO Card Rev G
- 12 cards (180 PMTs)
- 15 manufactured and available
- 11/15 currently require study/minor repairs
- Sufficient 1.5m co-axial MCX cables procured and in Glasgow, ready to ship
- Cosmic tests performed with prototype bar and ET 9124 confirm use of NINO card for typical signal sizes and required timing











Summary

NINO Front End Cards:

- Currently 2 production-version FE cards based on NINO ASIC
- MCX co-axial inputs (Rev G) or 2 x 8-pair IDC connectors (Rev D1)

- 28 cards produced for CDet and currently under test with 1st module
- If performance satisfactory will manufacture a further 157 cards

- 35 cards have been produced for GRINCH (and sufficient cables procured)
- 8 cards + cables currently at JLab and tests on-going for prototype module
- Remaining cards + cables to instrument entire GRINCH in delivery to JLab

- Characterisation tests show high sensitivity of NINO threshold and minimal crosstalk

BB Timing Hodoscope:

- 96 scintillator/light-guide bars procured, constructed, delivered to JLab
- 200 PMTs procured, currently in Glasgow; bases under construction, expected completion imminent
- 15 Rev G NINO cards produced, enough to instrument TH. 11 currently need repair after issues with input connectors
- Outstanding issues for TH:
    - Final design and construction of frame and time-line/deadline for this
    - PMT mounts require modification
    - 11 NINO cards require repair