Please complete and submit this ATLAS Standard Form to ATLAS RHA Coordinator (ARC), at least 2 weeks after the date of the test.

1. General information:

1.1	Date of the test:	05/17/2003
1.2	Pre-selection, or Qualification ? (specify)	Qualification
1.3	Name of the ATLAS (or other) System:	MUON CSC
1.4	Name of the board in the System:	ASM 1
1.5	Person responsible for the test:	Anand Kandasmy
1.6	Institute:	Brookhaven National Laboratory
1.7	Email:	anand@bnl.gov
1.8	Person responsible for RHA of the Board:	Anand Kandasmy
1.9	Institute:	Brookhaven National Laboratory
1.10	Email:	anand@bnl.gov

2. Component:

2.1	Name:	**IC71 (ASM1 CSC Preamp/Shaper)**
2.2	Part Number:	**IC71**
2.3	Type (see section 13.1):	Linear Device
2.4	Function (see section 13.1):	Charge amplification and Shaping
2.5	Main specification of the component:	
2.6	Design (specify: COTS/ASIC):	CMOS ASIC
2.7	Design center (if known):	Brookhaven National Laboratory
Manufacturer:		
2.8	Name of the manufacturer:	Agilent (HP)
2.9	Address of the manufacturer (if known):	
2.10	Phone of the manufacturer (if known):	
2.11	Email of the manufacturer (if known):	
2.12	Web URL of the manufacturer (if known):	
Sampling:		
2.13	Number of tested components (irradiated):	4
2.14	Number of reference components (un-irradiated):	1
Batch origin:		
2.15	Batch origin (Homogeneous/Unknown):	Homegeneous
2.16	Manufacturing date code (for homogeneous batch):	T17E-AT(MOSIS)
2.17	Manufacturing line code (for homogeneous batch):	
Technology:		
2.18	Name of the technology (if known):	HP AMOS14TB
2.19	Technology (CMOS/BiCMOS/Bipolar/AsGa/Other):	CMOS
2.20	Minimum geometry (µm) :	0.5
Package:		
2.21	Type:	QFP
2.22	Part number:	IC71
2.23	Number of pin:	100
2.24	Ceramic ? Plastic ? hybrid ? (specify)	Plastic

3. Radiation:

3.1	Name of the radiation facility:	Northeast Proton Theraphy Center
3.2	Address of the radiation facility:	Massachusetts Gen. Hospital/Boston
3.3	Radiation source (see 13.2) :	Cyclotron
3.4	Radiation type (see 13.2) :	Proton Beam
3.5	Radiation energy (MeV) :	226
3.6	Minimum & maximum flux (particle per second) :	8E9 protons.cm^{-2}/sec
3.7	Total fluence after last step (1 MeV eq. n/cm^2) :	2.6E13
3.8	TID after last step (Gy) :	14000
3.9	Dosimetry / Calibration method:	Vacuumless faraday cup

4. Radiation test method (see 12.3):

4.1	ATLAS Standard NIEL Test Method?	Y
4.2	Other TID test method (specify)?	

5. Thermal and voltage stresses:

5.1	Temperature (ºC) :	25
5.2	Supply voltage (specify) :	3.3V
5.3	AC operation (Y/N) ?	N
5.4	If “yes” to 5.3, which AC operation?	
5.5	If “yes” to 5.3, which frequency?	

Please select and complete one or several sections among sections 6 to 9, according to the device and function(s) you are testing:

6. If your circuit is an analog circuit or contains analog functions:

6.1	Did you search for parasitic transient if any?	N
6.2	Did you record parasitic transient if any?	N
6.3	Did you search for permanent dysfunction if any?	N
6.4	Did you record permanent dysfunction if any?	N
6.5	Did you measure current consumption?	Y
6.6	Did you record current consumption?	Y
6.7	Did you perform an automatic power cycle if a permanent dysfunction or current increase occurs?	N

6.8 Description of operation and measurements of the analog (part of) circuit:

The device currents were monitored online during irradiation using a data acq. system. The test was interested in observing for any latchups that might occur.

7. If your circuit is a digital circuit or contains digital functions:

7.1	Did you check all functions in the circuit (Y/N) ?	
7.2	If “no” to 6.13, which function did you not exercise (specify) ?	
7.3	At what frequency did you exercise the circuit?	
7.4	Did you search for transient errors (Y/N) ?	
7.5	Did you automatically record transient errors if any (Y/N) ?	
7.6	Did you search for permanent errors (Y/N) ?	
7.7	Did you automatically record permanent errors if any (Y/N) ?	
7.8	Did you perform an automatic reset after a permanent error if any (Y/N) ?	
7.9	Did you perform an automatic power cycle after a permanent error if any (Y/N) ?	
7.10	Description of operation and measurements of the digital (part of) circuit:	

8. If your circuit is a memory or a register, or contains memory(ies) or registers:

8.1	Did you check all the memories and registers of the device under test (Y/N) ?	
8.2	If “no” to 8.1, which memories or registers will you not check (specify)?	
8.3	Did you search for 0 => 1 upsets (Y/N) ?	
8.4	Did you search for 1 => 0 upsets (Y/N) ?	
8.5	Time required to write in the memory or in the register under test?	
8.6	After a “write” sequence, do you read the memory or register once, or periodically (answer by “*once*” or “*each [time between 2 consecutive read]*”) ?	
8.7	After a “write” sequence, what is the time during which the memory or the register is (once or periodically) read ?	
8.8	Did you automatically record bit errors if any (Y/N) ?	
8.9	Did you check the “write” function of the memory or register after permanent upset if any (Y/N) ?	
8.10	Did you perform an automatic reset after permanent upset if any (Y/N) ?	
8.11	Did you perform an automatic power cycle after permanent upset if any (Y/N) ?	
8.12	Description of operation and measurements of the memories and/or of the registers:	

9. If your circuit is an elementary device:

Power transistors		
9.1	Did you search for burnout ignition?	
9.2	Did you record the rate of burnout ignition if any?	
Optocouplers		
9.3	Did you search for permanent dysfunction if any?	
9.4	Did you record permanent dysfunction if any?	
PIN diodes		
9.5	Did you measure the rate of parasitic transient pulses (Y/N) ?	
9.6	Did you record the rate of parasitic transient pulses?	
9.7	Description of operation and measurements of the device under test:	

10. Rejection criteria:

	Measured parameter	Rejection Criteria
10.1	Charge Gain and Shaping time	> 10%
10.2	Noise	> 20%
10.3		
10.4		
10.5		

11. Results:

	11.1	11.2	11.3	11.4	11.4	11.5	11.6	11.7
	Serial number of the device under test	number of SEU / total fluence	number of bits permanently stuck / total fluence	number of SEL / total fluence	number of destructive SEE / Total fluence	recovery after power cycle (Y/N)?	recovery after reset (Y/N)?	Failure mechanism (if any): for component “dead” or out of specification, give explanations and numbers
1	7							None
2	8							None
3	9							None
4	10							None
5								

11. Results, cont.

	11.1	11.2	11.3	11.4	11.4	11.5	11.6	11.7
	Serial number of the device under test	number of SEU / total fluence	number of bits permanently stuck / total fluence	number of SEL / total fluence	number of destructive SEE / Total fluence	recovery after power cycle (Y/N)?	recovery after reset (Y/N)?	Failure mechanism (if any): for component "dead" or out of specification, give explanations and numbers
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

12. Comments

Use the space below to comment test results, or to report them if the above-dedicated space is inappropriate for you.

The devices are tolerant to high energy hadrons (> 20 MeV) and did not exhibit latchups during irradiation. The circuit parameter changes due to irradiation are well within the rejection criteria set.
See attached document.

13. Guidelines

13.1 Type and Function

Type	Function
Analogue device	ADC; Analogue memory; Analogue multiplexor; DAC; LVDS driver; LVDS receiver; Modulator/Demodulator; Voltage/Frequency converter
Data transmission Component	Receiver; Transceiver; Transmitter
Front-end electronic device	Drift Time Measurement; Multiple functions; Readout memory
Linear device	Amplifier; Comparator; Operational amplifier; Voltage reference;
Memory	SRAM
Microprocessor or peripheral	Microcontroller; Microprocessor
Optoelectronic component	Laser; Light emitting diode – LED; PIN diode; VCSEL
Power device	DC-DC converter; Power transistor; Voltage regulator
Programmable device	EEPROM; FPGA; Lookup table; Programmable delay
Passive component	Capacitor
Interfaces/Communication	LVDS; Switch
Mixed A/D device	Multiple functions
Logic gates	NOR, NAND, etc.

13.2 Radiation source and type

Source of radiation	Type of radiation
Accelerator	Electron, proton, spallation neutron
Am-241	Ions (fission products)
Cf-252	Ions (fission products)
Co-60	Photon gamma 1.173 MeV and 1.332 MeV
Cs-137	Photon gamma 0.662 MeV
Cyclotron	Proton, ion (specify), spallation neutron
Reactor	Neutron
Tandem accelerator	Protons, ions
Van-de-Graaf	Electron
X-Ray generator	Photon X

13.3 Radiation test methods:

see ATLAS Policy on Radiation Tolerant Electronics rev. 2, pp. 20-26

http://atlas.web.cern.ch/Atlas/GROUPS/FRONTEND/WWW/RAD/RadWebPage/ATLASPolicy/APRTE_rev2_250800.pdf

BROOKHAVEN NATIONAL LABORATORY	**US ATLAS** **MUON SPECTROMETER** **CATHODE STRIP CHAMBER**	
Anand Kandasamy anand@bnl.gov	SEE/SEU Test Report For CSC Front-end Electronics	7/2/2003

1. Overview:

SEE/SEU tests using high energy particles (> 20 MeV) tests were conducted on preamplifier/shaper integrated circuits for the Cathode Strip Chamber front-end electronics. This test was targeted towards the analog circuitry that performs charge amplification. The analog charge amplification and shaping circuit identified as IC71 is a custom ASIC developed at Brookhaven National Laboratory and fabricated in 0.5 μm CMOS technology

2. Hadron fluence Levels in CSC.

Worst case Simulated Radiation Levels (SRL) and Radiation Tolerance Criteria (RTC) for the CSC is given below. This data is obtained from the ATLAS Radiation Tolerance Criteria documents and extraction tools.

Qualification/Pre-selection:

Zmin (cm)	Zmax (cm)	Rmin (cm)	Rmax (cm)	SRLsee/seu (>20 MeV $h.cm^{-2}$/10 years)	RTCsee/seu (>20 MeV $h.cm^{-2}$/10 years)
760	770	80	90	1.52×10^{12}	1.52×10^{13}

RTCsee/seu = SRLsee/seu * SFsim * SFldr * SFlot
SFsim = 5 (Simulation)
SFldr = 1 (Low Dose Rate)
SFlot = 2 (Lot Variation)

For production qualification the SFlot factor decreases to 1 and hence the RTC decreases to 7.6×10^{12} (>20 MeV $h.cm^{-2}$/10 years).

3. SEE/SEU Radiation Test Setup

A total of 4 test devices and 1 reference device was screened and used for the test. The test devices were obtained from a homogenous lot. The devices were biased under their normal operating condition. The four test devices were monitored for latchups due to see/seu effects during the irradiation period. The device parameters were measured prior to irradiation and upon receiving the devices back from the reactor.

The devices were irradiated using 226 MeV protons derived from the cyclotron at Northeast Proton Therapy center in Boston. Four of the devices were stacked and irradiated together with less than 1% degradation in fluence from top of the stack to the bottom.

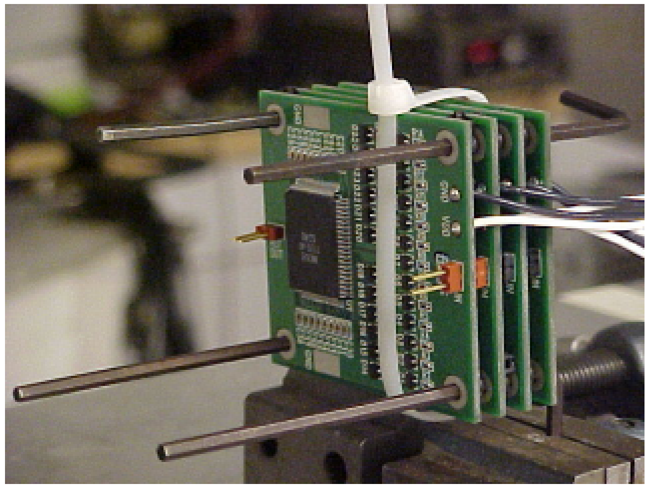


Figure 1. Preamp/Shapers Stack

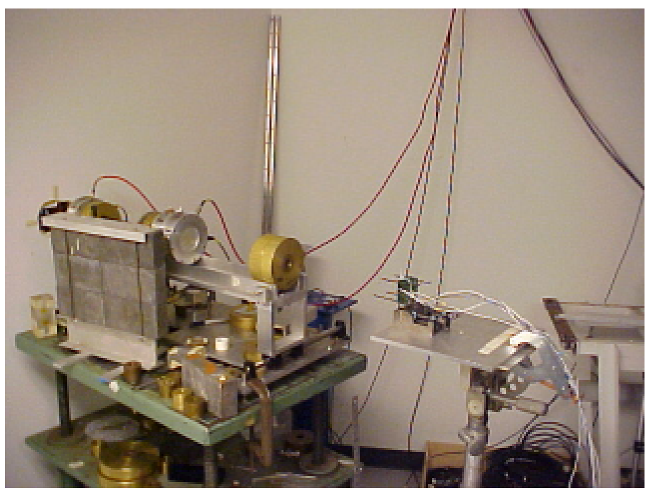


Figure 2. Preamp/Shaper Stack and the proton beam line

Electronics gain, shaping time, Equivalent Noise charge, input & output dc levels and current consumption of the devices were monitored and the rejection criteria for the devices were formulated as any failed channel or degradation of one or more parameters beyond the 10% level for charge gain, shaping time and 20% level for noise.

A total fluence of 2.6 $x10^{13}$ $protons.cm^{-2}$, which well above the RTC was delivered to the devices

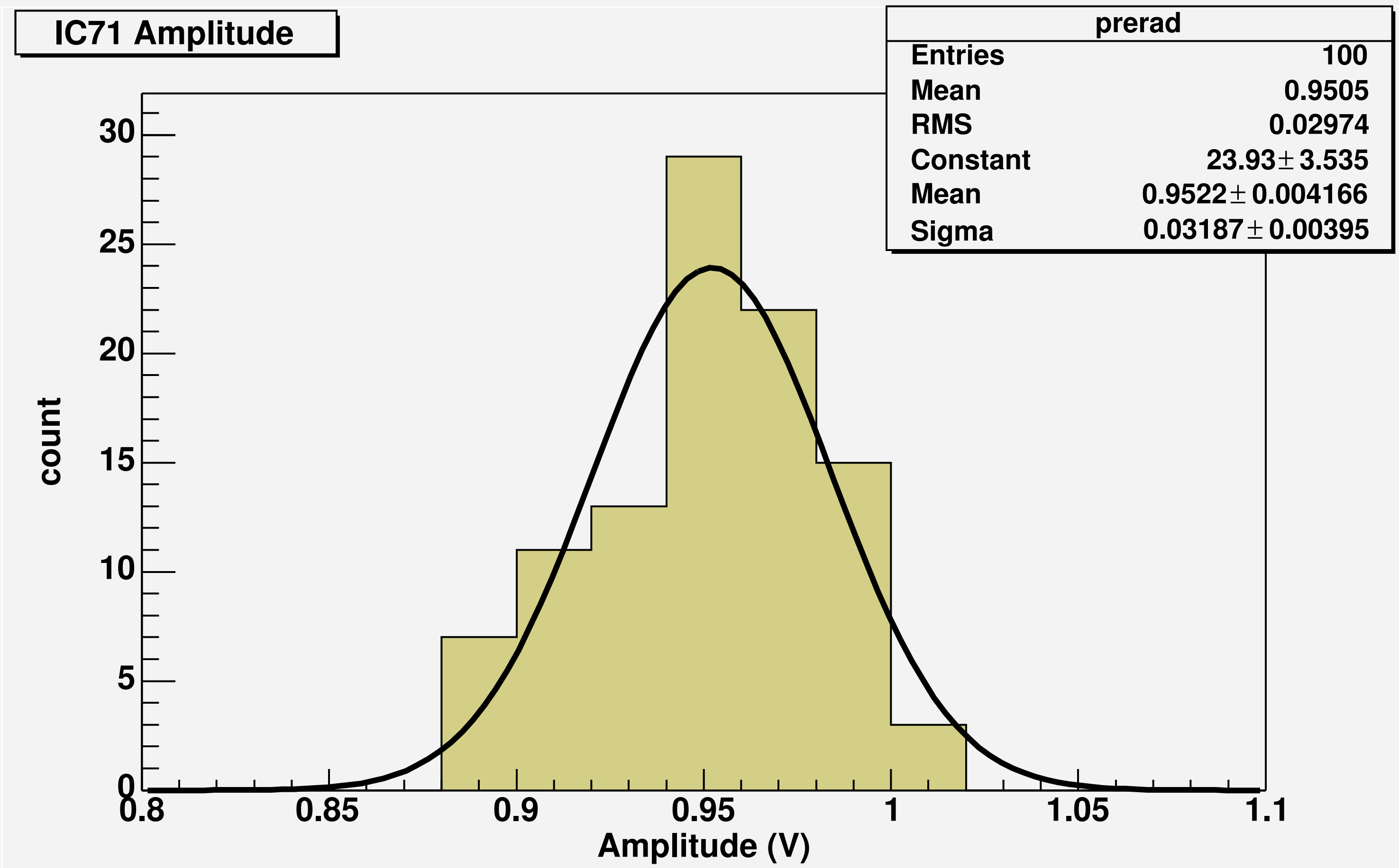
4. Test Results

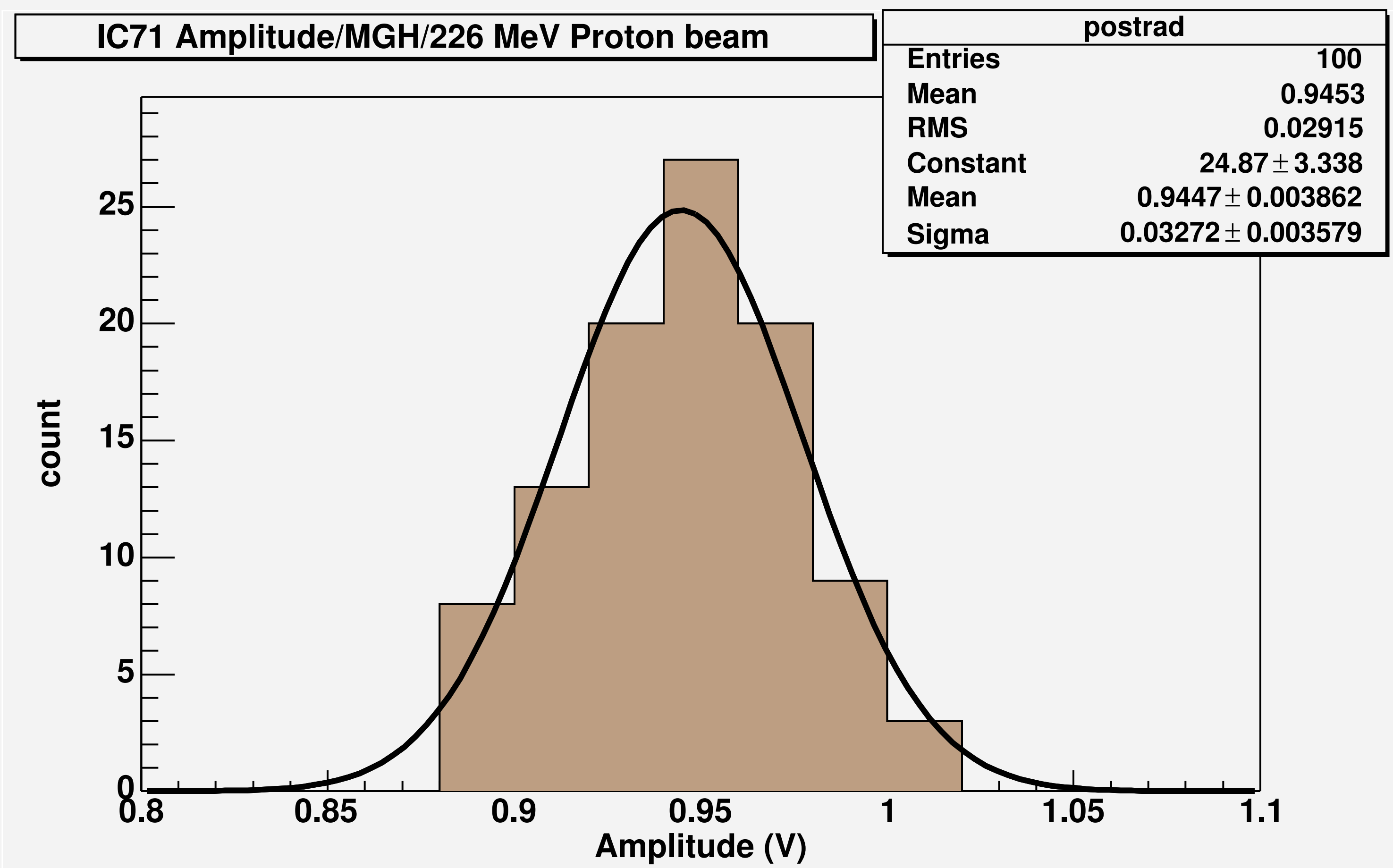
A total of 100 front-end channels were irradiated and none of them exhibited failures or exceeded the rejection criteria. The worst case degradation observed is outlined in the following table.

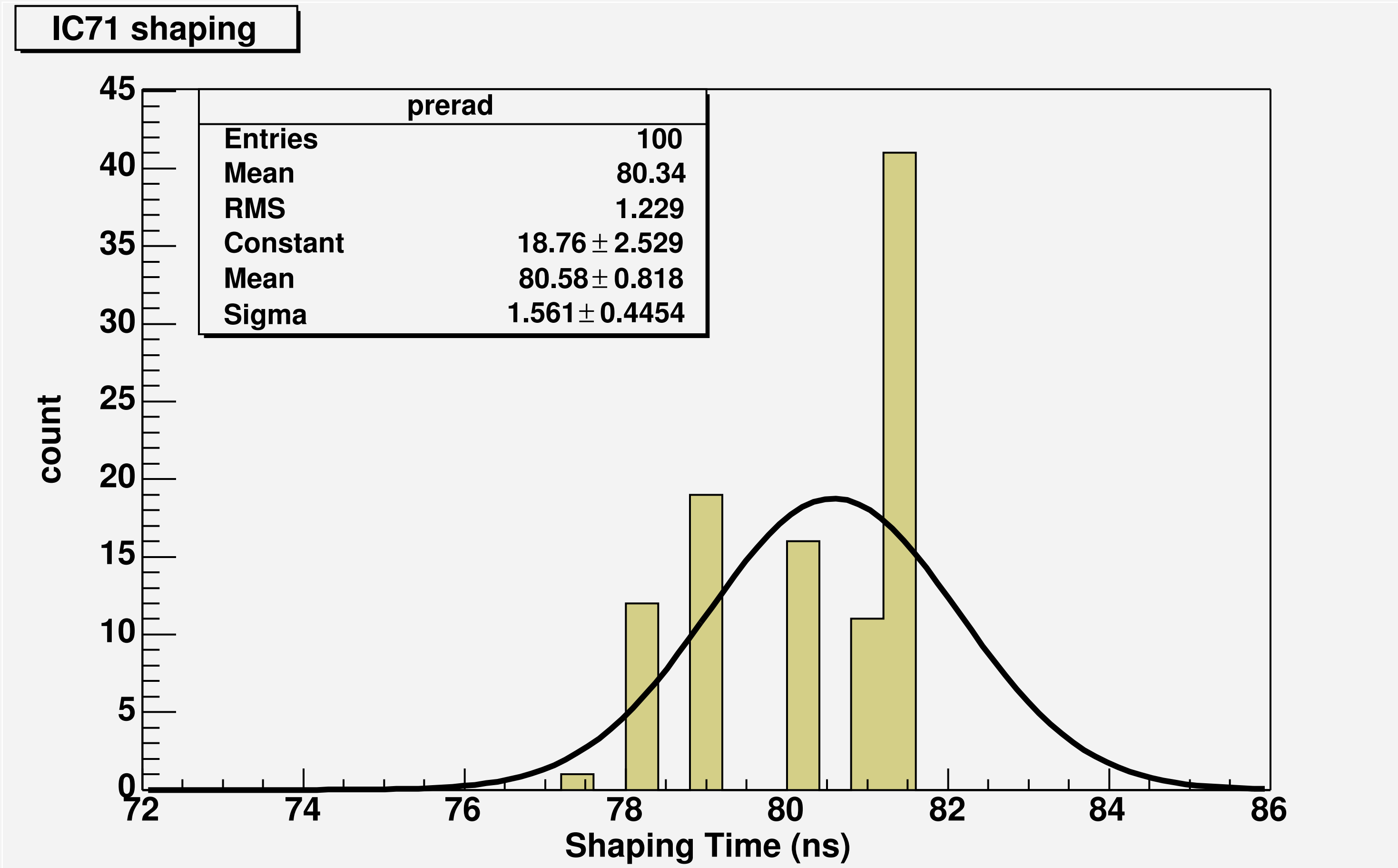
Parameter	% Change from Pre-Radiation Measurement
Charge Gain	0.5%
Shaping Time	0.8%
ENC	12.9%
Device Current	1.42%

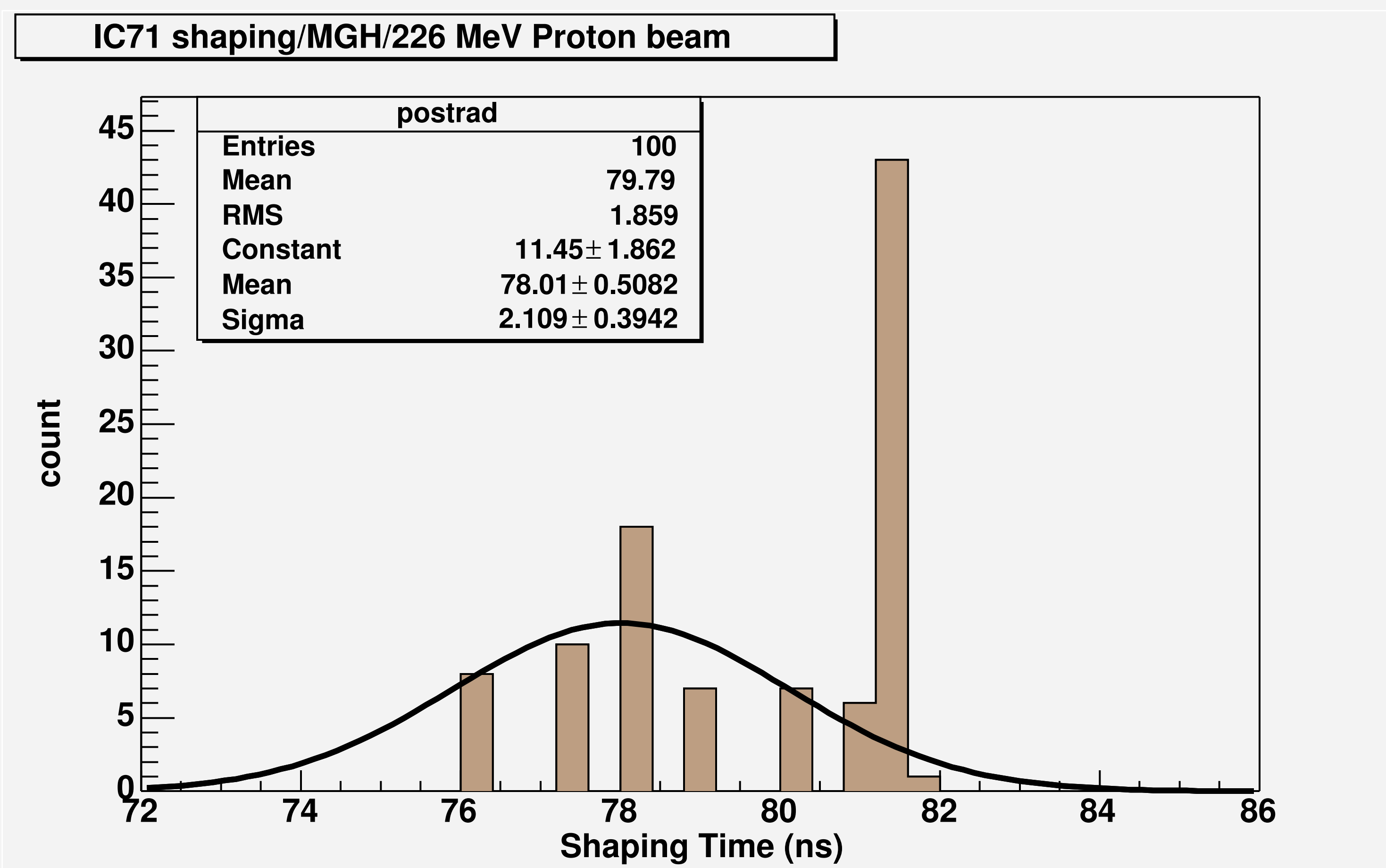
5. Conclusion:

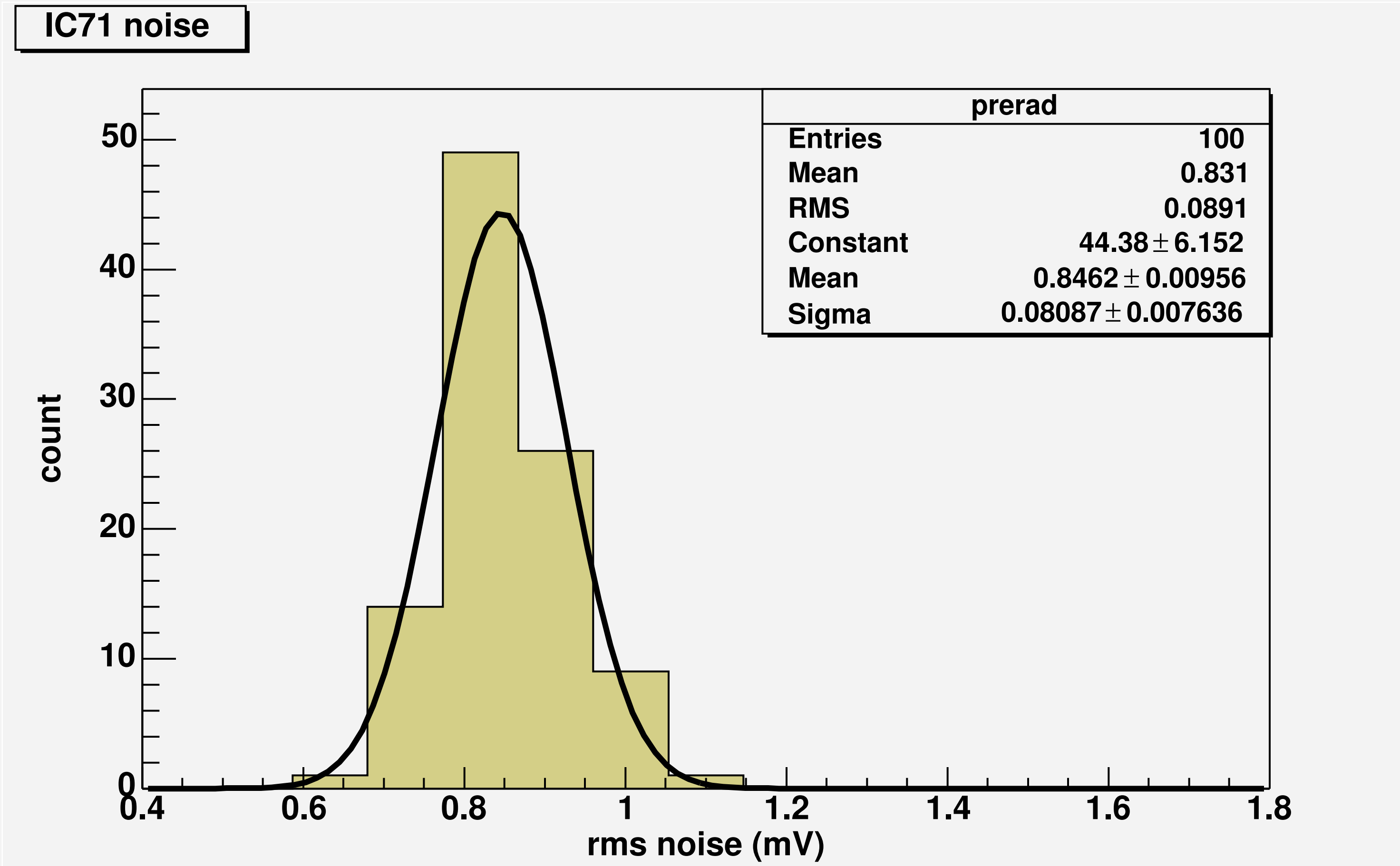
IC71 Preamp/Shaper was irradiated upto the Radiation tolerance criteria fluence for high energy hadrons. No single event effects or upsets were observed. The degradation of the front-end electronics module due to irradiation is well within the acceptable range for the CSC electronics requirement.

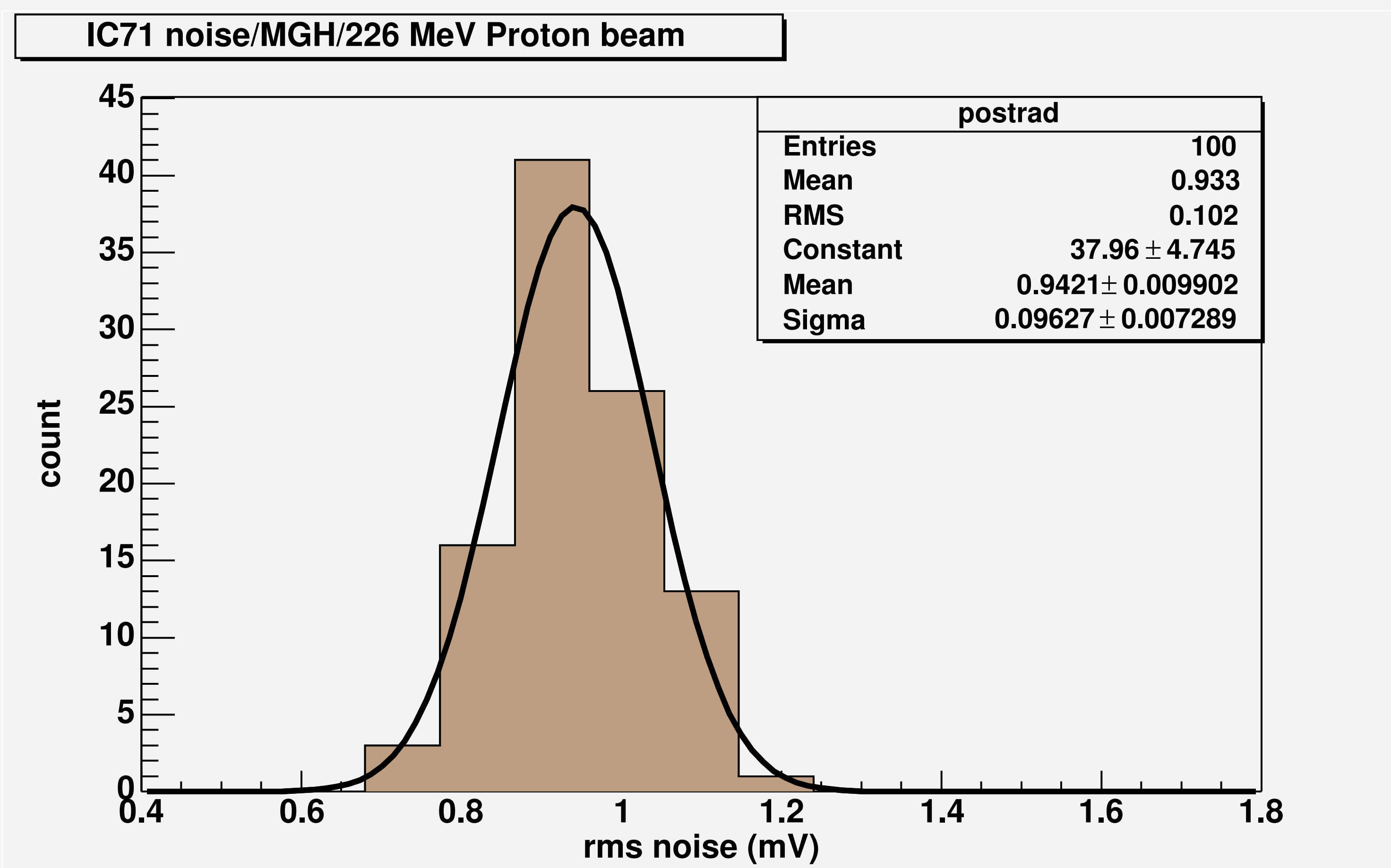

IC71 Amplitude
prerad
Entries 100
Mean 0.9505
RMS 0.02974
Constant 23.93 ± 3.535
Mean 0.9522 ± 0.004166
Sigma 0.03187 ± 0.00395
count
Amplitude (V)

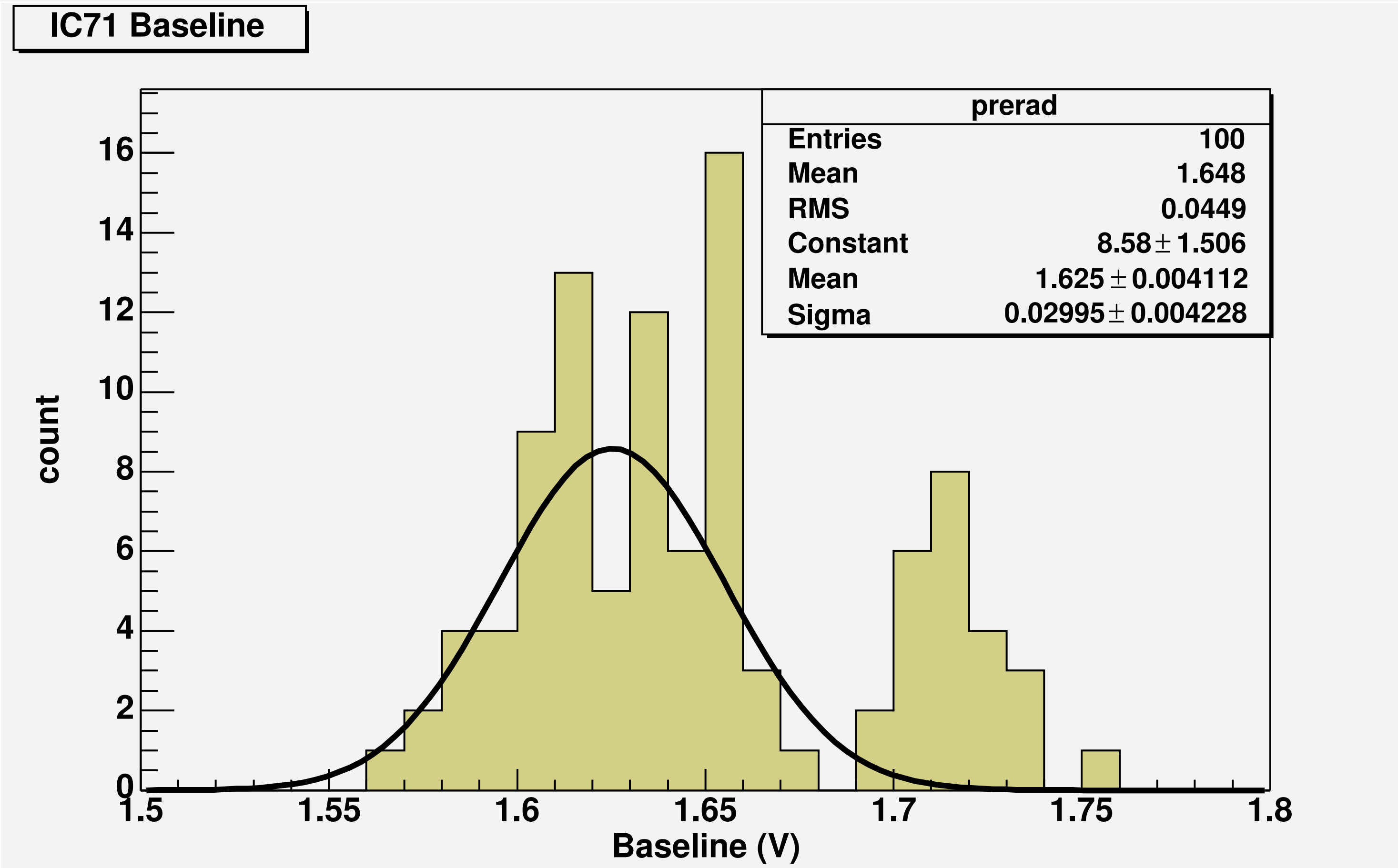

IC71 Amplitude/MGH/226 MeV Proton beam
postrad
Entries 100
Mean 0.9453
RMS 0.02915
Constant 24.87 ± 3.338
Mean 0.9447 ± 0.003862
Sigma 0.03272 ± 0.003579
count
Amplitude (V)

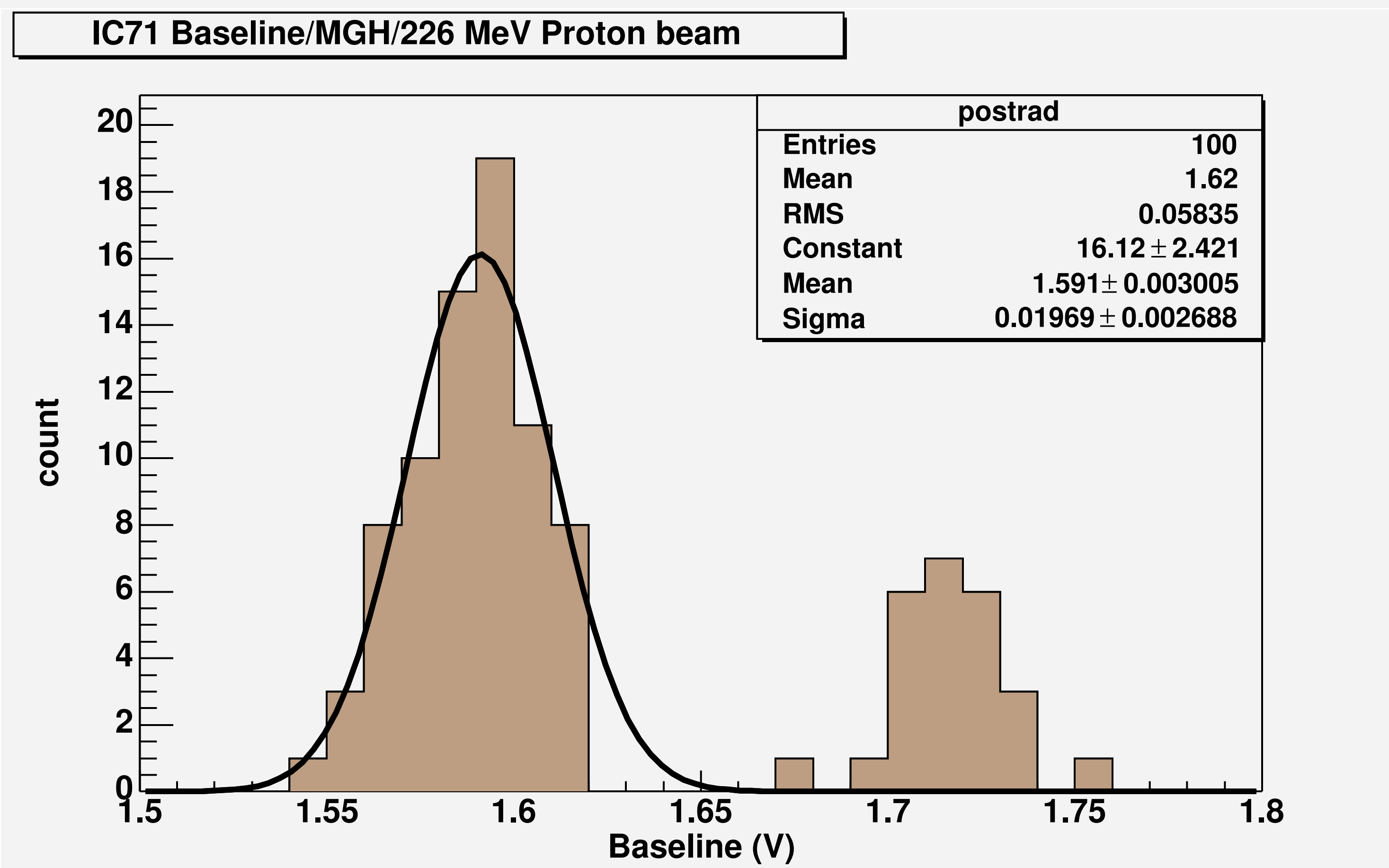

IC71 shaping
prerad
Entries 100
Mean 80.34
RMS 1.229
Constant 18.76 ± 2.529
Mean 80.58 ± 0.818
Sigma 1.561 ± 0.4454
count
0
5
10
15
20
25
30
35
40
45
72
74
76
78
80
82
84
86
Shaping Time (ns)

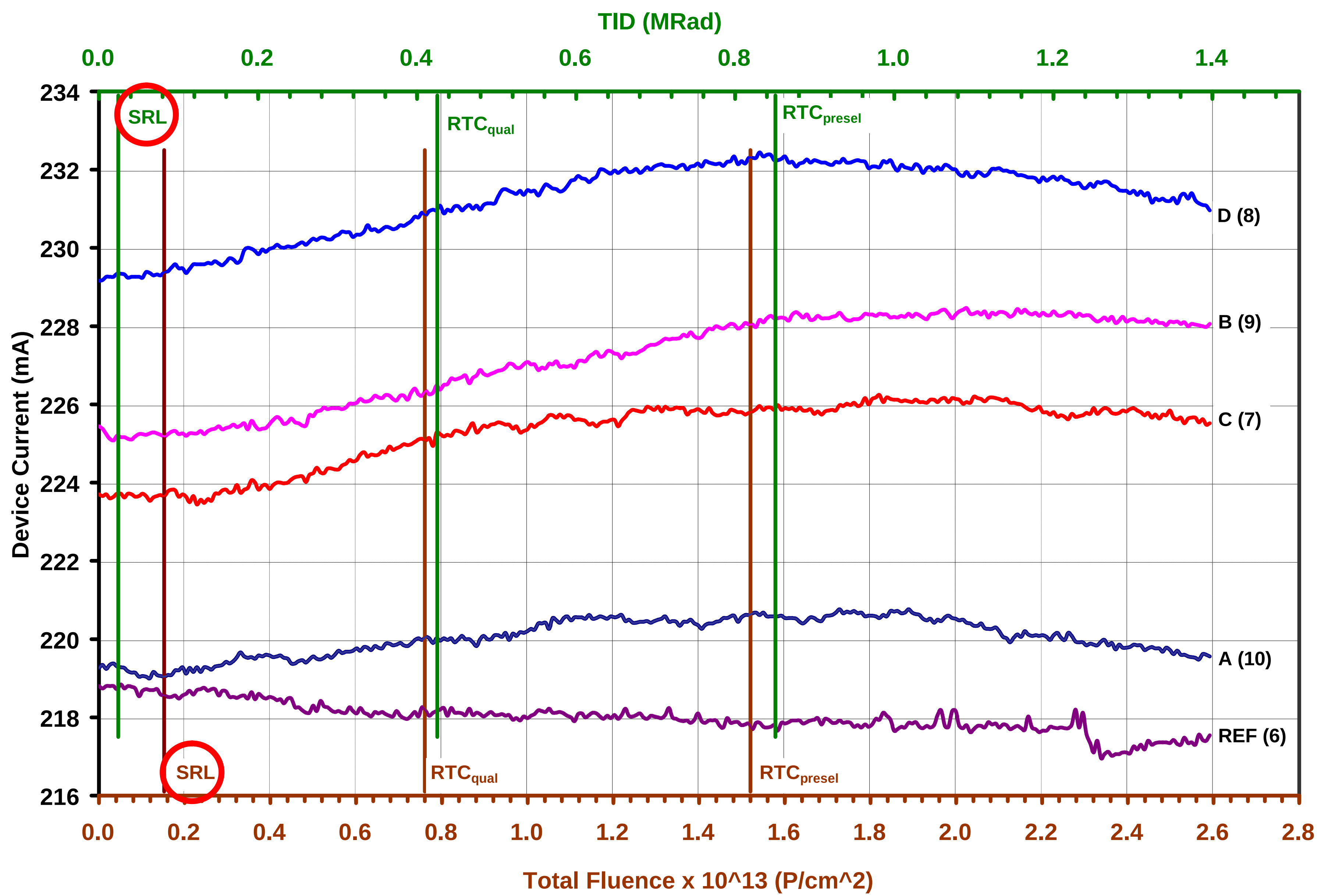

IC71 shaping/MGH/226 MeV Proton beam
postrad
Entries 100
Mean 79.79
RMS 1.859
Constant 11.45 ± 1.862
Mean 78.01 ± 0.5082
Sigma 2.109 ± 0.3942
count
0
5
10
15
20
25
30
35
40
45
72
74
76
78
80
82
84
86
Shaping Time (ns)


IC71 noise
prerad
Entries 100
Mean 0.831
RMS 0.0891
Constant 44.38 ± 6.152
Mean 0.8462 ± 0.00956
Sigma 0.08087 ± 0.007636
count
rms noise (mV)
0
10
20
30
40
50
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8


IC71 noise/MGH/226 MeV Proton beam
postrad
Entries 100
Mean 0.933
RMS 0.102
Constant 37.96 ± 4.745
Mean 0.9421 ± 0.009902
Sigma 0.09627 ± 0.007289
count
rms noise (mV)
0
5
10
15
20
25
30
35
40
45
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8


IC71 Baseline
prerad
Entries 100
Mean 1.648
RMS 0.0449
Constant 8.58 ± 1.506
Mean 1.625 ± 0.004112
Sigma 0.02995 ± 0.004228
count
Baseline (V)
1.5
1.55
1.6
1.65
1.7
1.75
1.8
0
2
4
6
8
10
12
14
16


IC71 Baseline/MGH/226 MeV Proton beam
postrad
Entries 100
Mean 1.62
RMS 0.05835
Constant 16.12 ± 2.421
Mean 1.591 ± 0.003005
Sigma 0.01969 ± 0.002688
count
Baseline (V)
1.5
1.55
1.6
1.65
1.7
1.75
1.8
0
2
4
6
8
10
12
14
16
18
20



TID (MRad)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Device Current (mA)
234
232
230
228
226
224
222
220
218
216
SRL
RTC$_{qual}$
RTC$_{presel}$
SRL
RTC$_{qual}$
RTC$_{presel}$
D (8)
B (9)
C (7)
A (10)
REF (6)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
Total Fluence x 10^13 (P/cm^2)