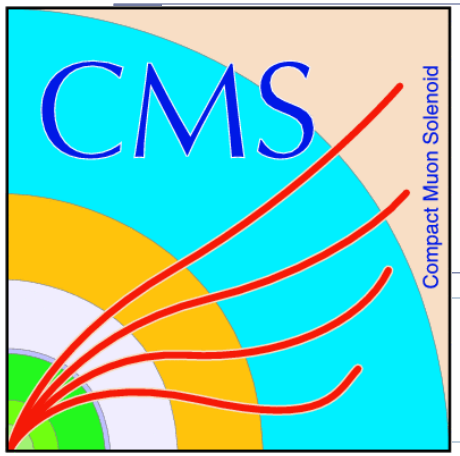
Improving Time Resolution of BCM1F



Pueh Leng Tan
Supervisors: Wolfgang Lohmann,
Elena Castro, Olga Novgorodova

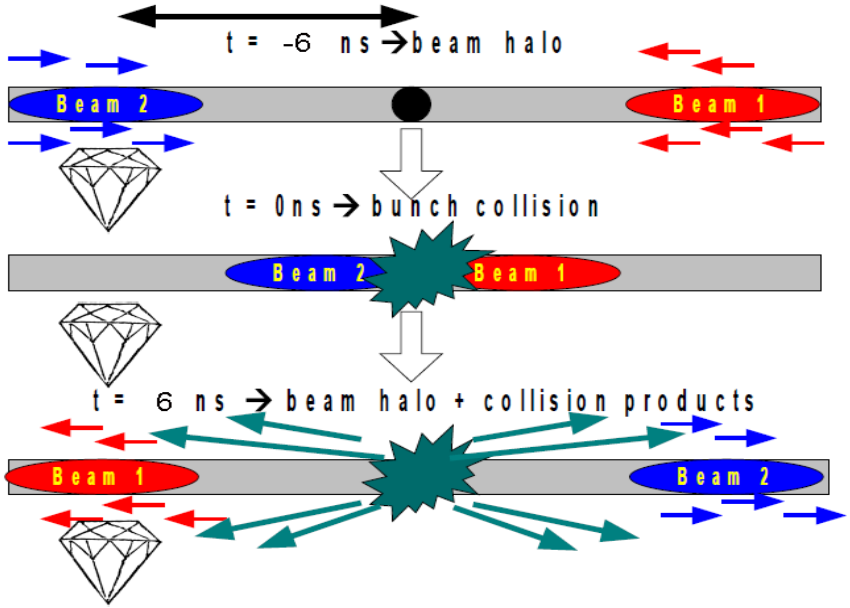
Special Thanks: Hans Henschel, Wolfgang Lange

Overview

- Introduction: CMS, Discriminators (recap)
- Experiments
  - Objective and Methodology
  - Results: Time resolution, Double-peak resolution
- Simulations
  - Methodology
  - Results: Time resolution
- Conclusions
- Questions

CMS

- Monitor beam condition around CMS interaction point
  - Need to improve resolution to see halo peaks within main peak caused by collision products
  - Beam halo arrives 12 ns before collision products



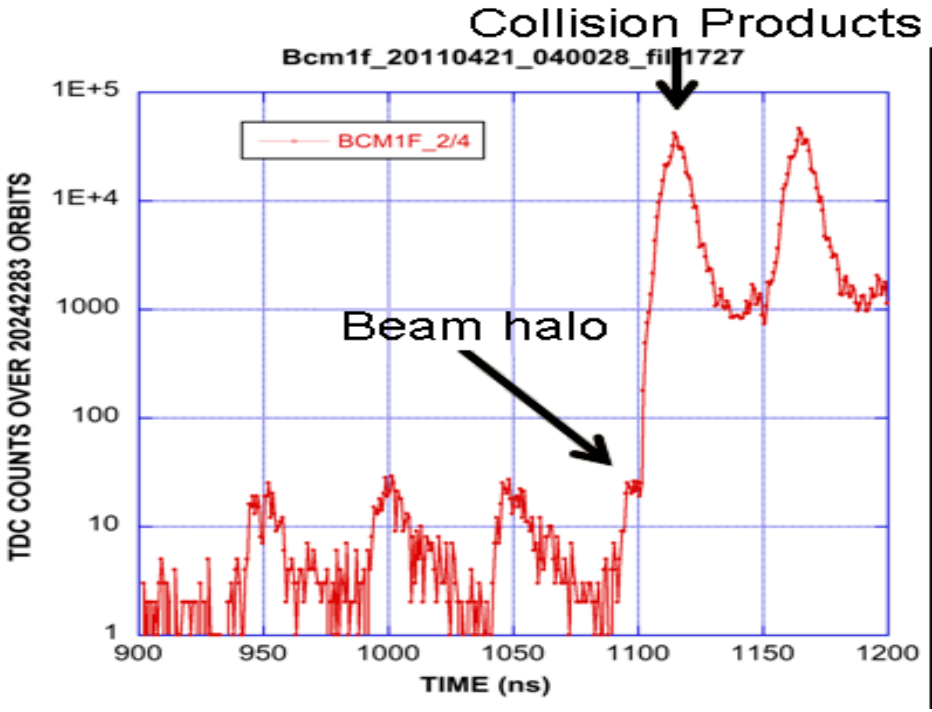
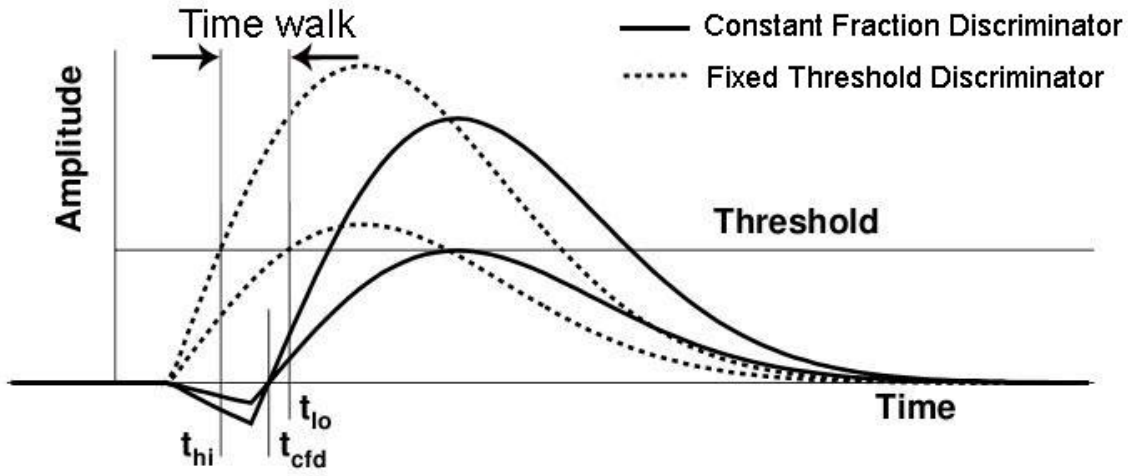


Figure (left) from Hempel, M., Data analysis for BCM1F4LHC
Figure (right) from Lohmann, W., BCM1F Workshop Report

Discriminators

- Current: Fixed Threshold Discriminator
- Possible replacement: Constant Fraction Discriminator

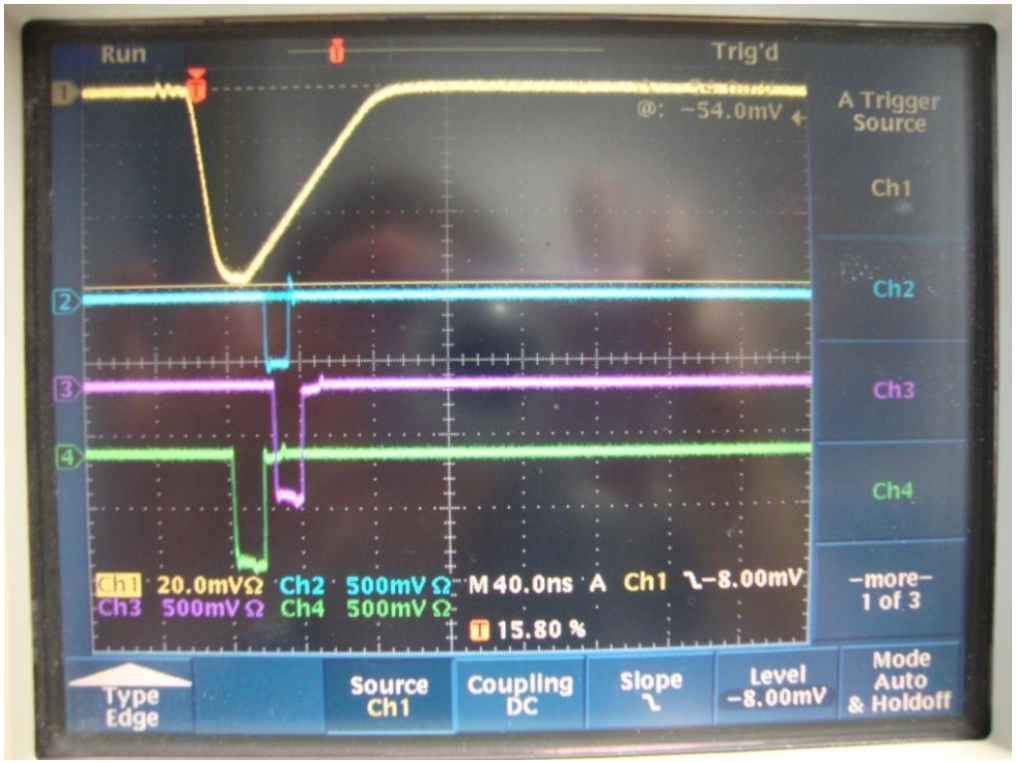


- Discriminators
  - CAEN v258B (Fixed Threshold Discriminator)
  - CAEN v812, PSI CFD950 (Constant Fraction Discriminator)

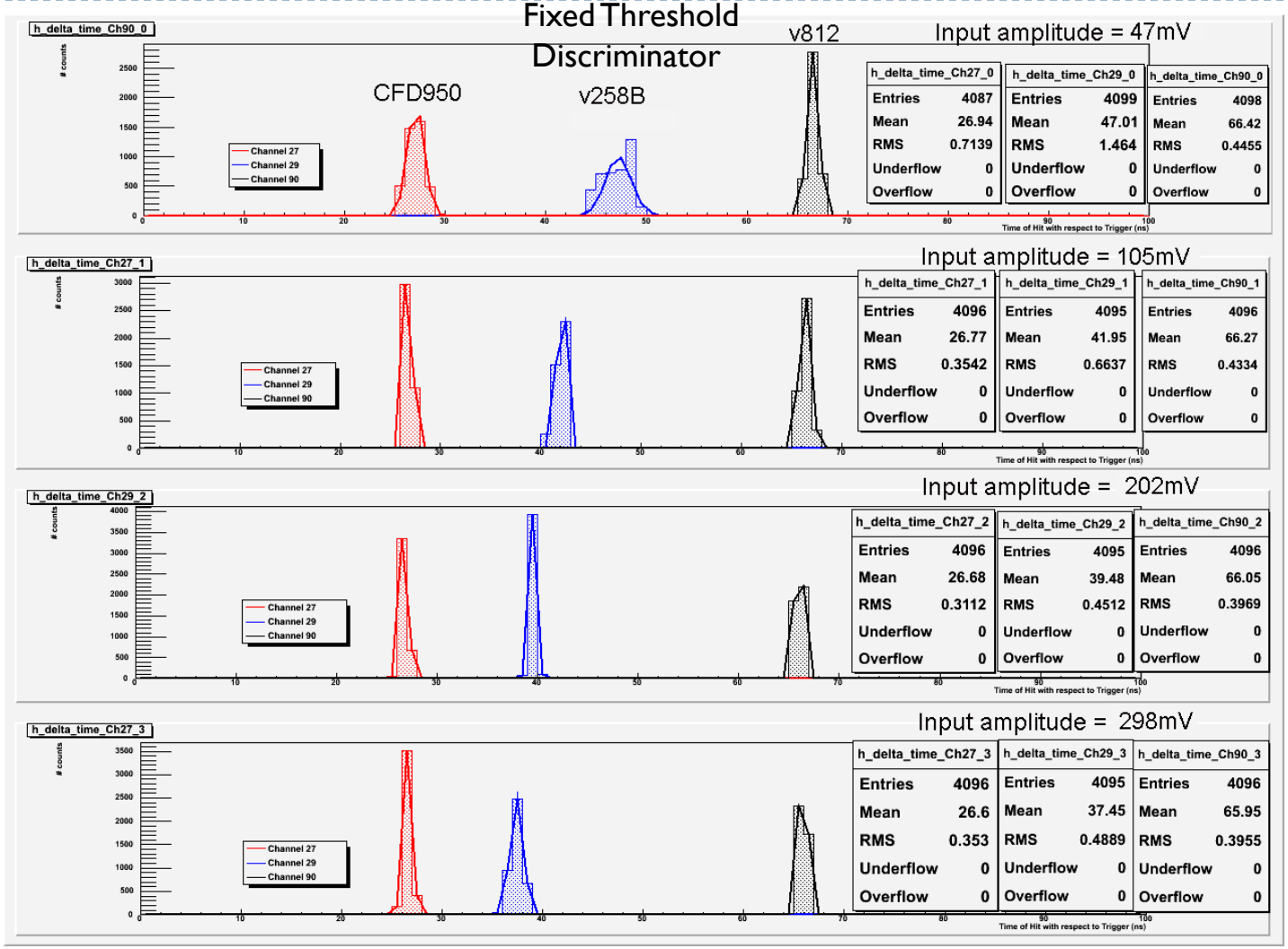
Figure from online resource

Experiments: Objective and Methodology

- Compare performance of discriminators
  - Measure time resolution using TDC (time-to-digital converter)



Results


Fixed Threshold Discriminator
CFD950
v258B
v812
Input amplitude = 47mV
h_delta_time_Ch90_0
h_delta_time_Ch27_0
Entries 4087
Mean 26.94
RMS 0.7139
Underflow 0
Overflow 0
h_delta_time_Ch29_0
Entries 4099
Mean 47.01
RMS 1.464
Underflow 0
Overflow 0
h_delta_time_Ch90_0
Entries 4098
Mean 66.42
RMS 0.4455
Underflow 0
Overflow 0
Channel 27
Channel 29
Channel 90
counts
Time of Hit with respect to Trigger (ns)
Input amplitude = 105mV
h_delta_time_Ch27_1
Entries 4096
Mean 26.77
RMS 0.3542
Underflow 0
Overflow 0
h_delta_time_Ch29_1
Entries 4095
Mean 41.95
RMS 0.6637
Underflow 0
Overflow 0
h_delta_time_Ch90_1
Entries 4096
Mean 66.27
RMS 0.4334
Underflow 0
Overflow 0
Input amplitude = 202mV
h_delta_time_Ch29_2
h_delta_time_Ch27_2
Entries 4096
Mean 26.68
RMS 0.3112
Underflow 0
Overflow 0
h_delta_time_Ch29_2
Entries 4095
Mean 39.48
RMS 0.4512
Underflow 0
Overflow 0
h_delta_time_Ch90_2
Entries 4096
Mean 66.05
RMS 0.3969
Underflow 0
Overflow 0
Input amplitude = 298mV
h_delta_time_Ch27_3
h_delta_time_Ch27_3
Entries 4096
Mean 26.6
RMS 0.353
Underflow 0
Overflow 0
h_delta_time_Ch29_3
Entries 4095
Mean 37.45
RMS 0.4889
Underflow 0
Overflow 0
h_delta_time_Ch90_3
Entries 4096
Mean 65.95
RMS 0.3955
Underflow 0
Overflow 0

Results

- RMS of histogram as time resolution
- Compare time resolution by taking ratio
  - $RMS_{\text{Fixed Threshold Discriminator}}$ / $RMS_{\text{Constant Fraction Discriminator}}$

Input amplitude /mV	v812	CFD950
47	3.286	2.051
105	1.531	1.874
202	1.137	1.450
298	1.236	1.385

- Both CFD are comparable
- v812 has better time resolution for small input signals

Double-peak resolution

- Input signals
  - Rise time = 25 ns
  - Trailing edge = 80 ns
  - Amplitude = 24 mV
- Discriminators
  - Threshold = -10 mV

Discriminator	Type	Double-peak resolution /ns
v258B	Fixed threshold	90±20
v812	Constant fraction	145±2
CFD950	Constant fraction	No stable output for input signals < 50 mV

Double-peak resolution

- Input signals
  - Rise time = 25 ns
  - Trailing edge = 80 ns
  - Amplitude = 24 mV
- Discriminators
  - Threshold = -10 mV

Input signal

CFD950

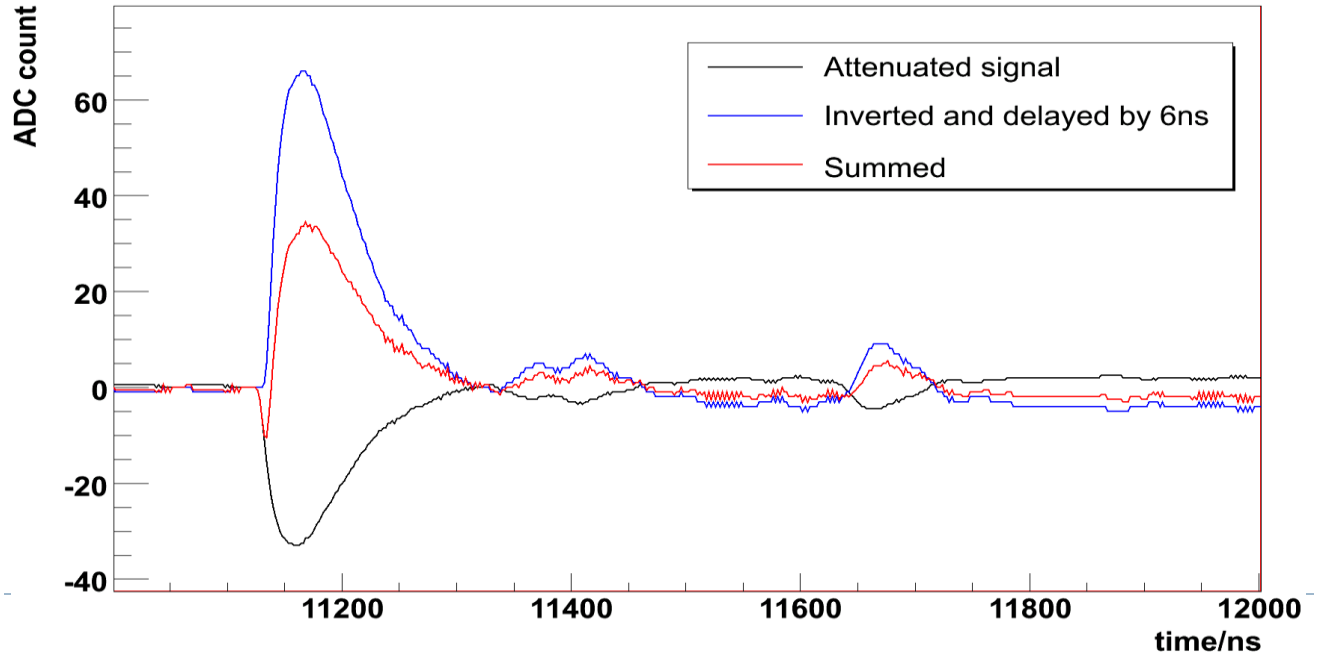
v258B

v812

Discriminator	Type	Double-peak resolution /ns
v258B	Fixed threshold	90±20
v812	Constant fraction	145±2
CFD950	Constant fraction	No stable output for input signals < 50 mV

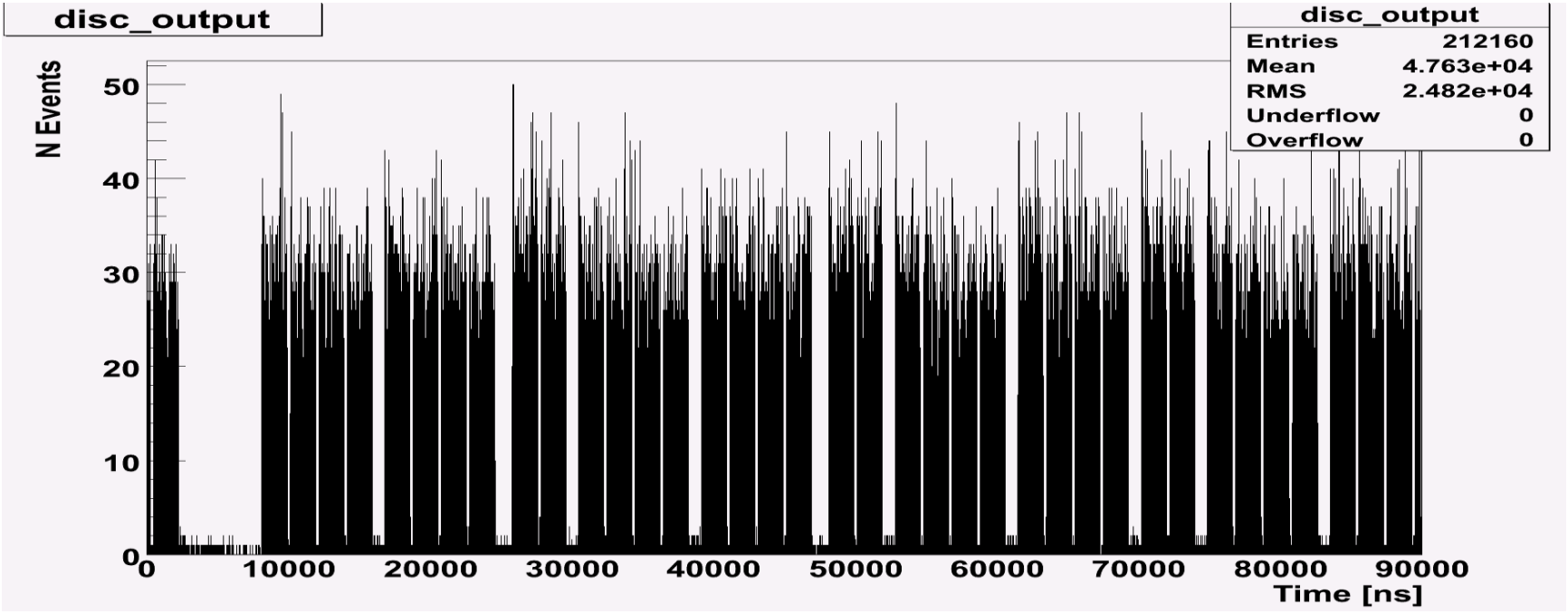
Simulations

- C++, ROOT
- Summing original with inverted delayed signal
- Triggering at zero-crossing
- Using signals sampled by analog-to-digital converter(ADC)

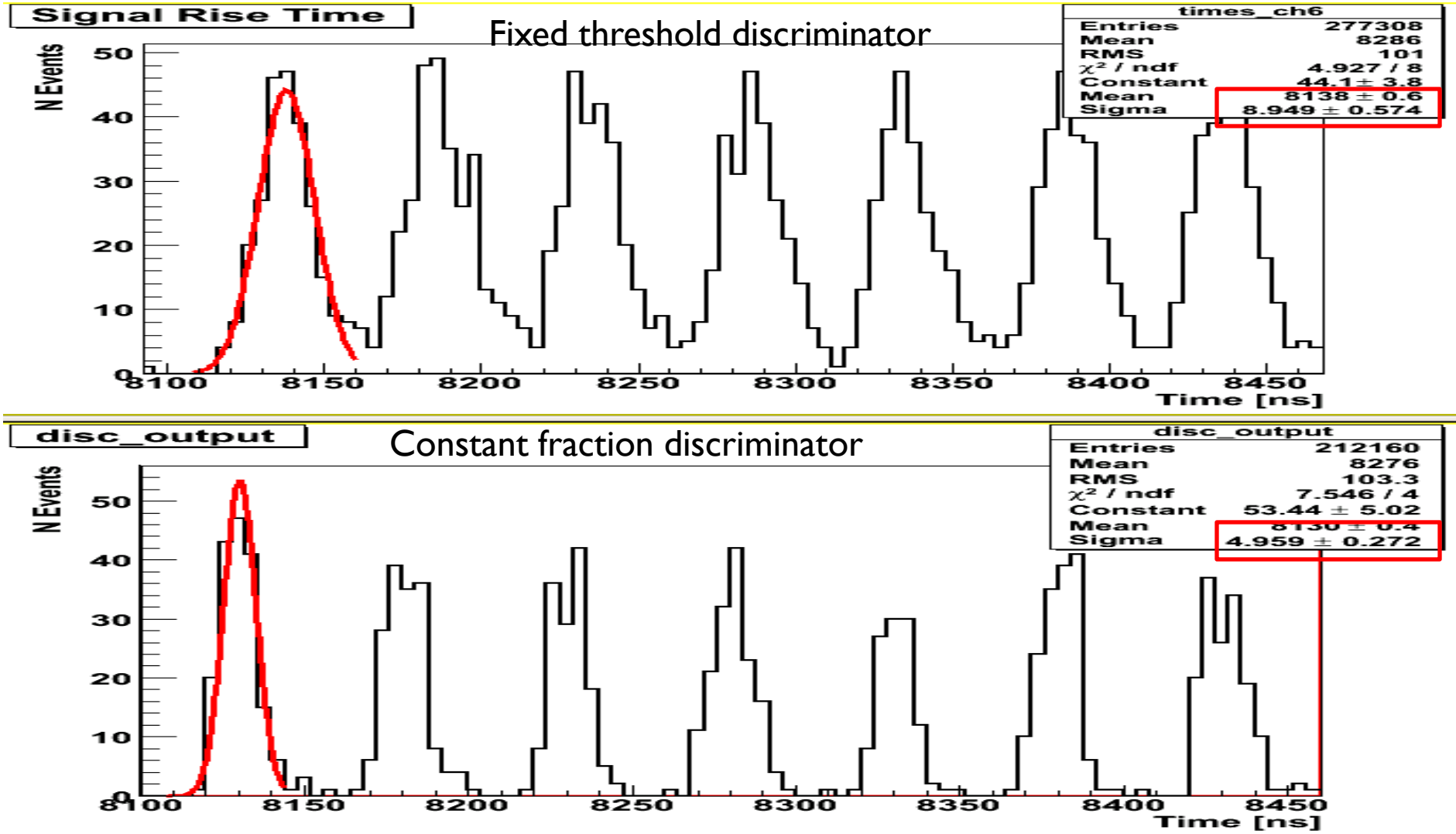


Simulation Parameters

- Constant fraction = 0.2
- Internal delay = 4 ns
- Threshold = 2 ADC counts (9.2 mV)
- Baseline calculation between 4000ns and 6000ns



Simulation Results



Top figure: Simulation of fixed threshold discriminator by Olga Novgorodova

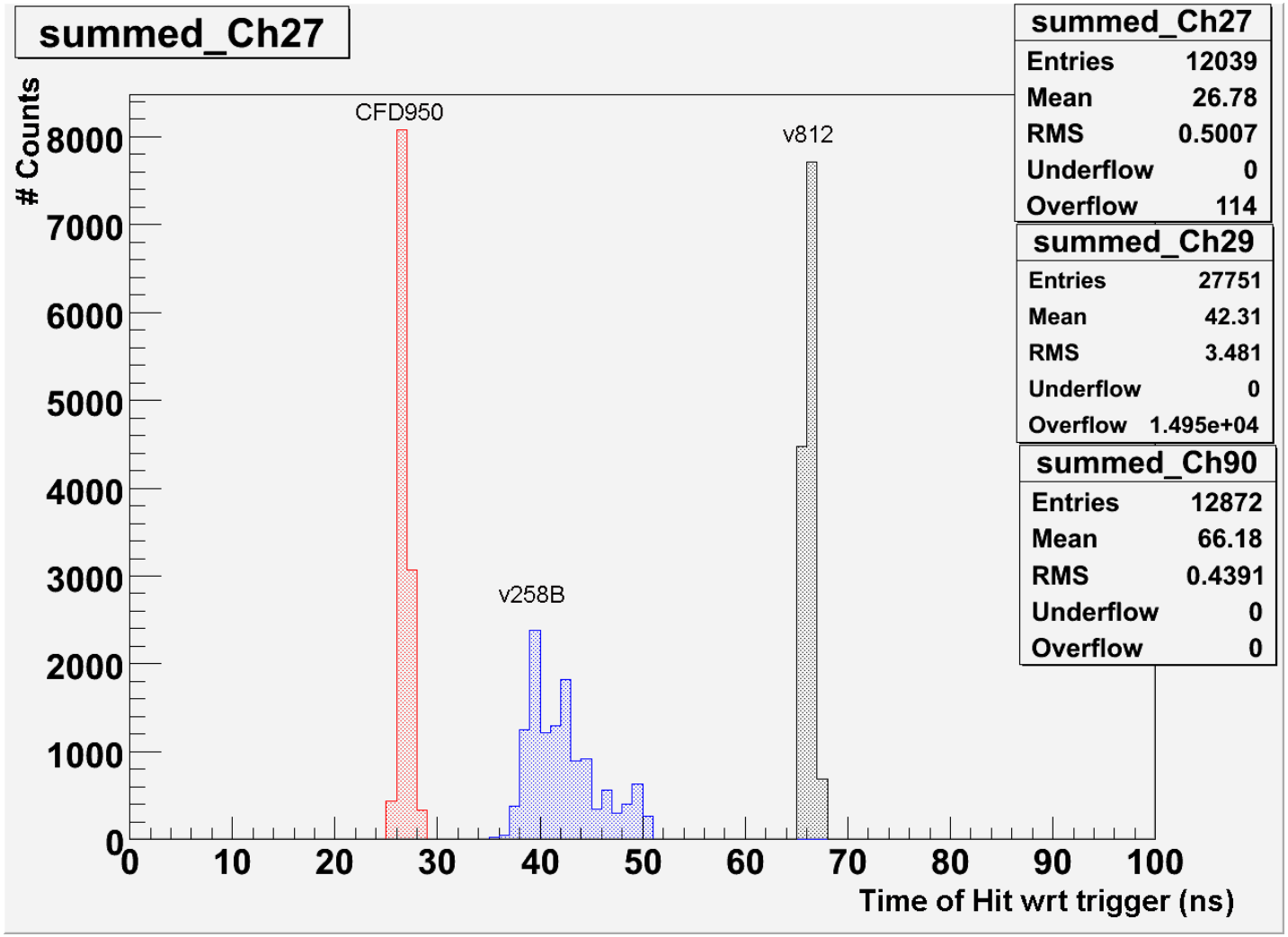
Conclusions

- CFD does improve time resolution
  - Experiment : v812 improves time resolution by factor of 3, CFD950 improves time resolution by factor of 2.
  - Simulation: CFD improves time resolution by factor of 2.
- Double-peak resolution
  - v812 (CFD) double-peak resolution factor of 1.5 poorer.
  - No signals from CFD950 for input signals smaller than 50mV.

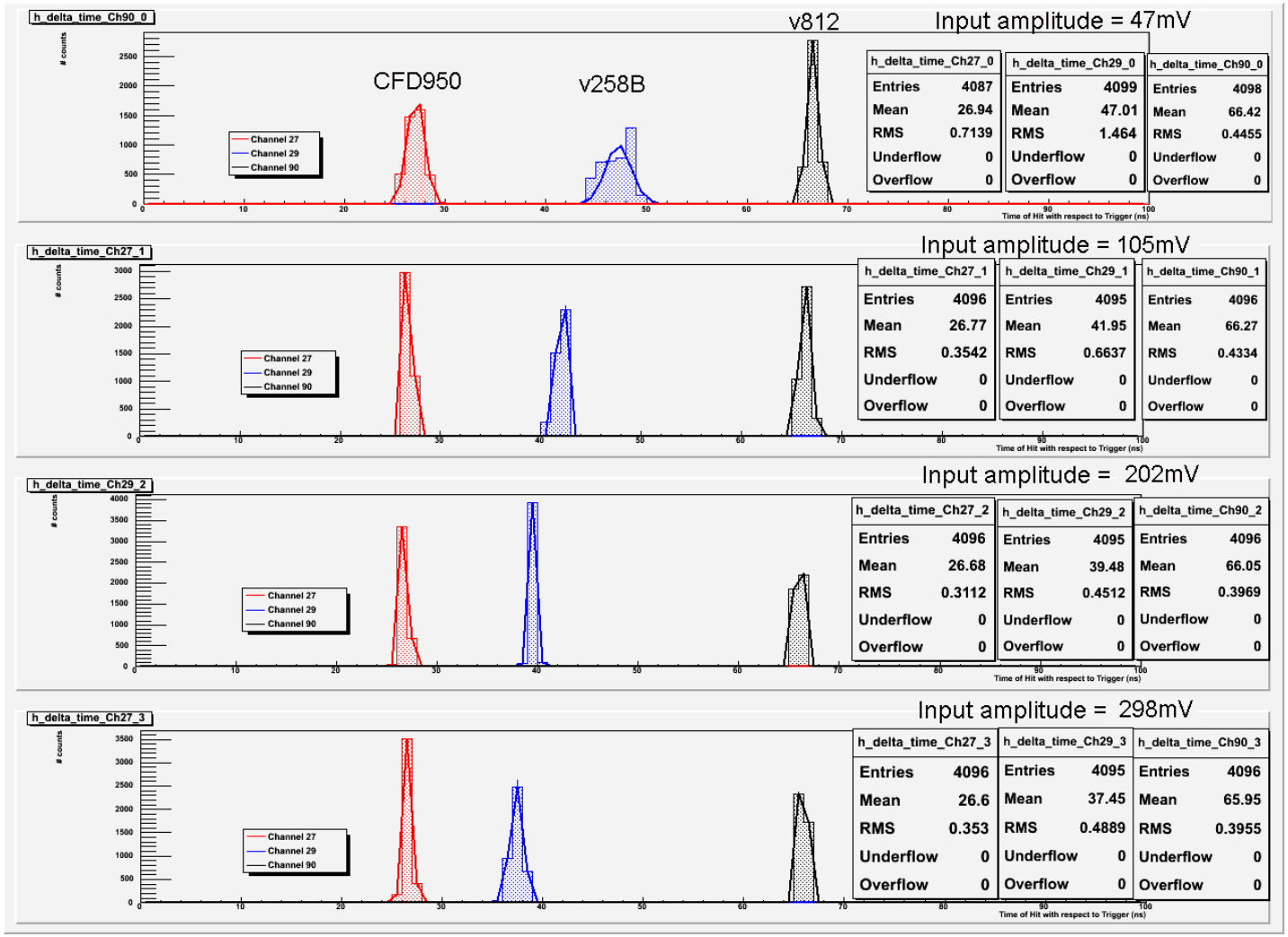
Questions

Thank you

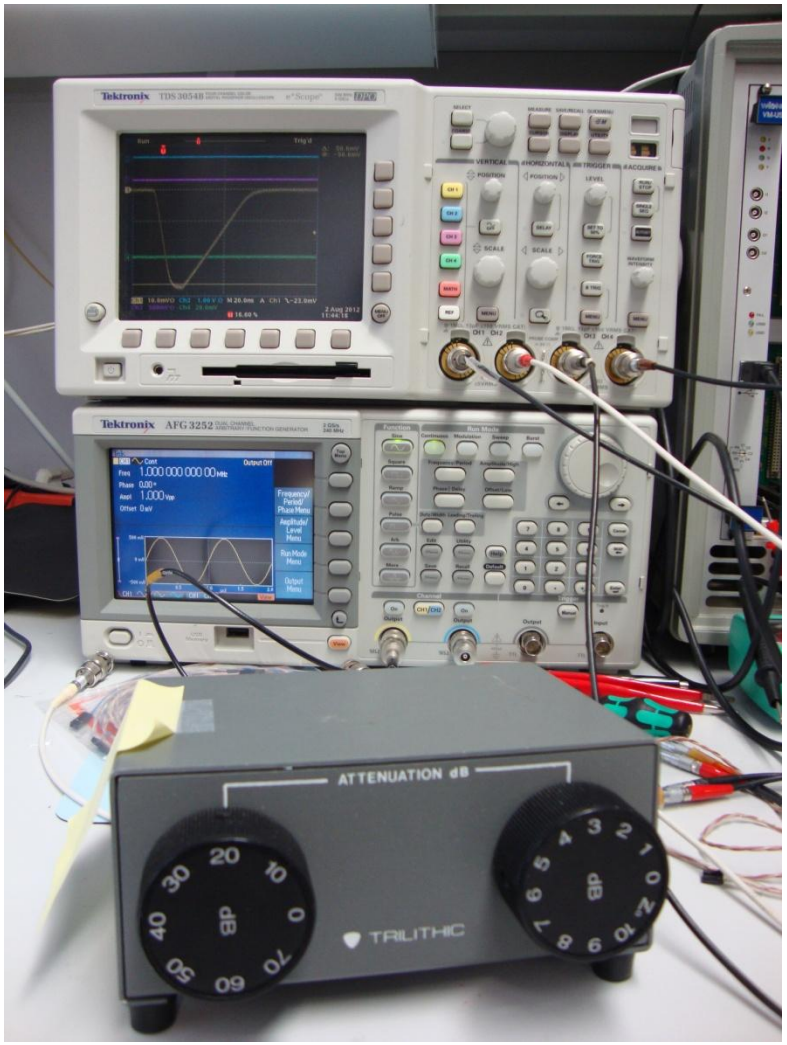
Summing over various input amplitudes



20mV amplitude modulation

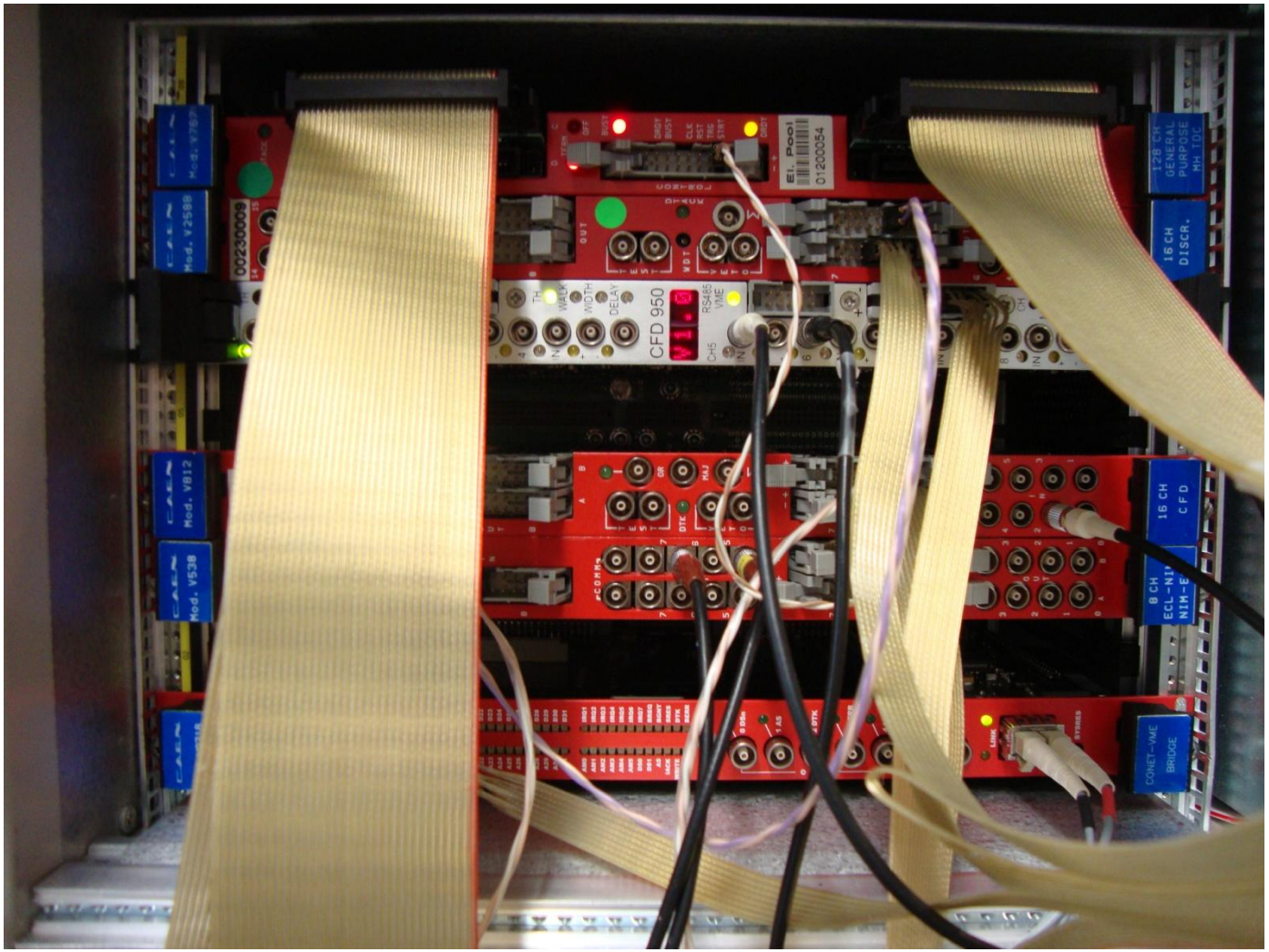


In the lab


Tektronix TDS 3054B
Tektronix AFG 3252
ATTENUATION dB
TRILITHIC

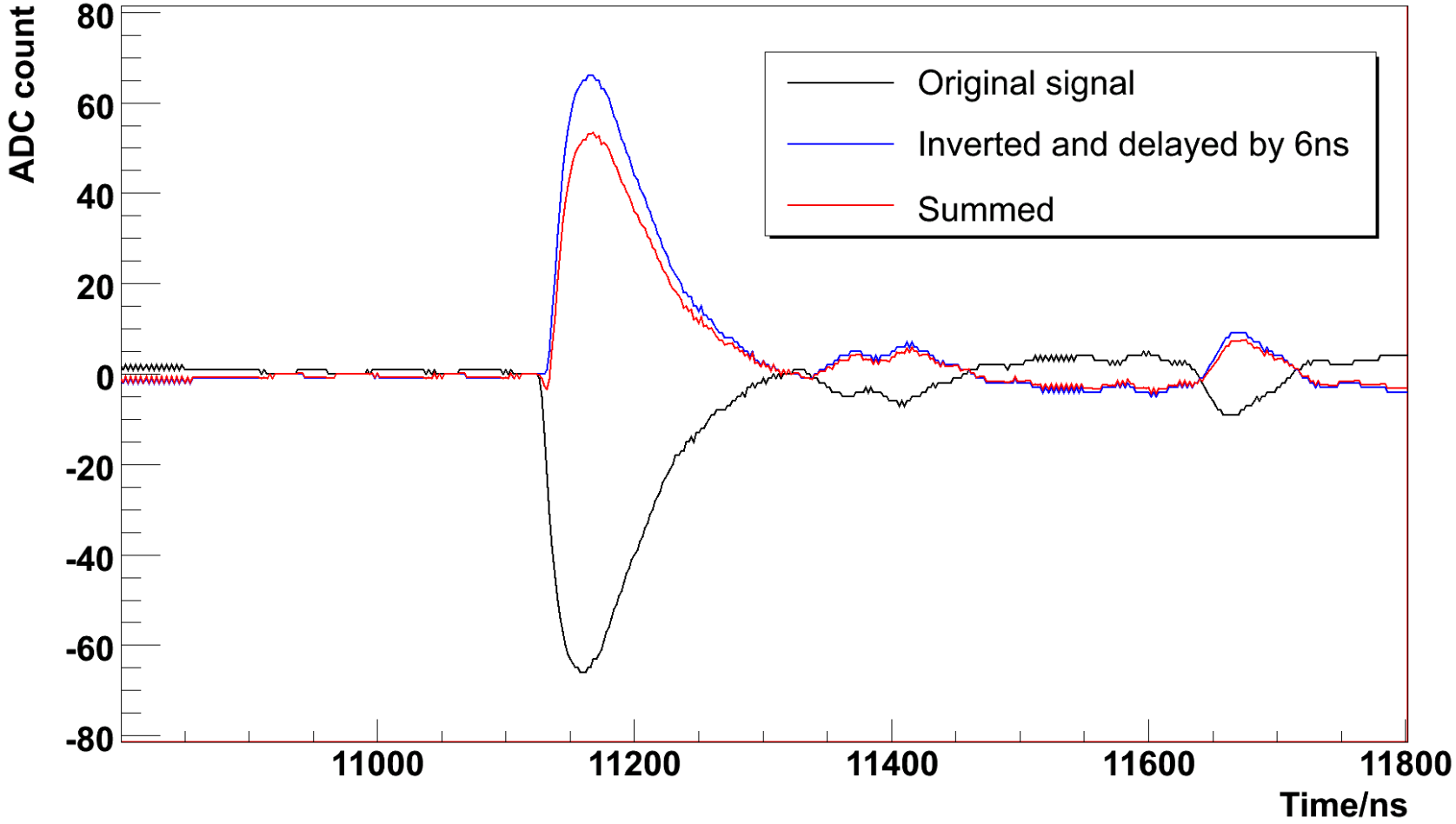
Function generator, attenuator

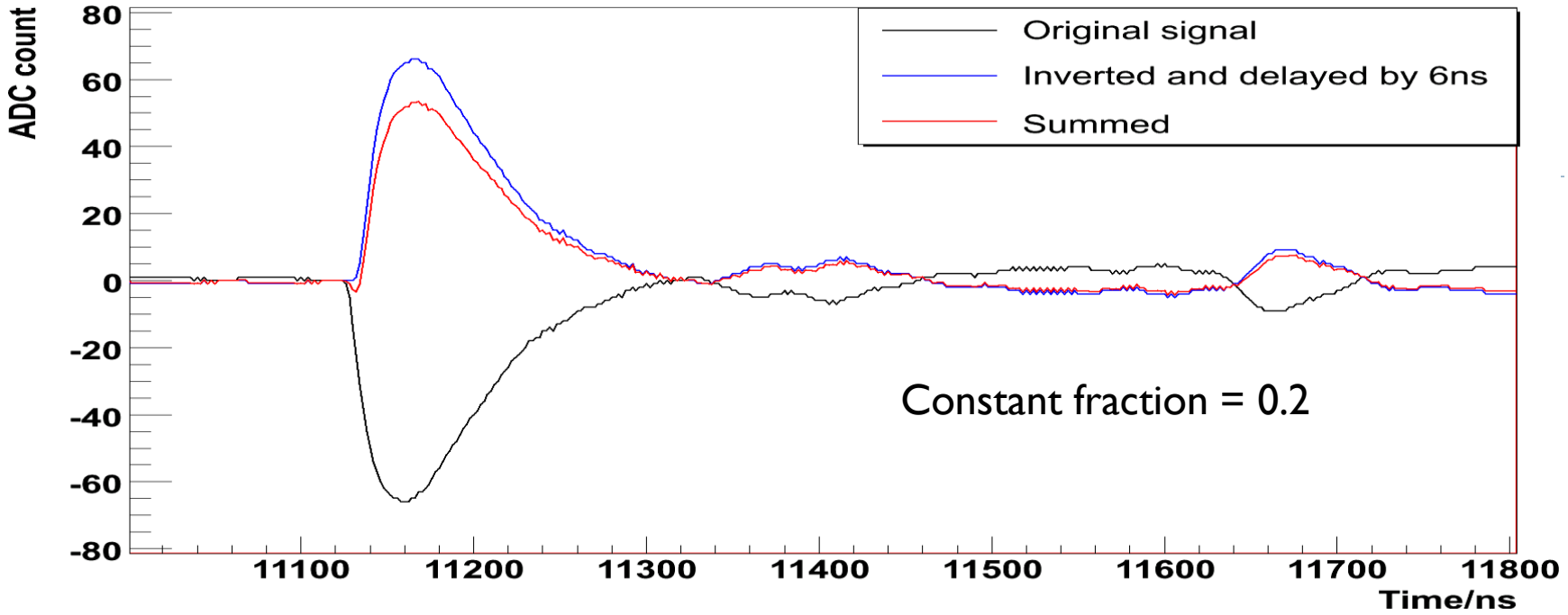
NIM crate

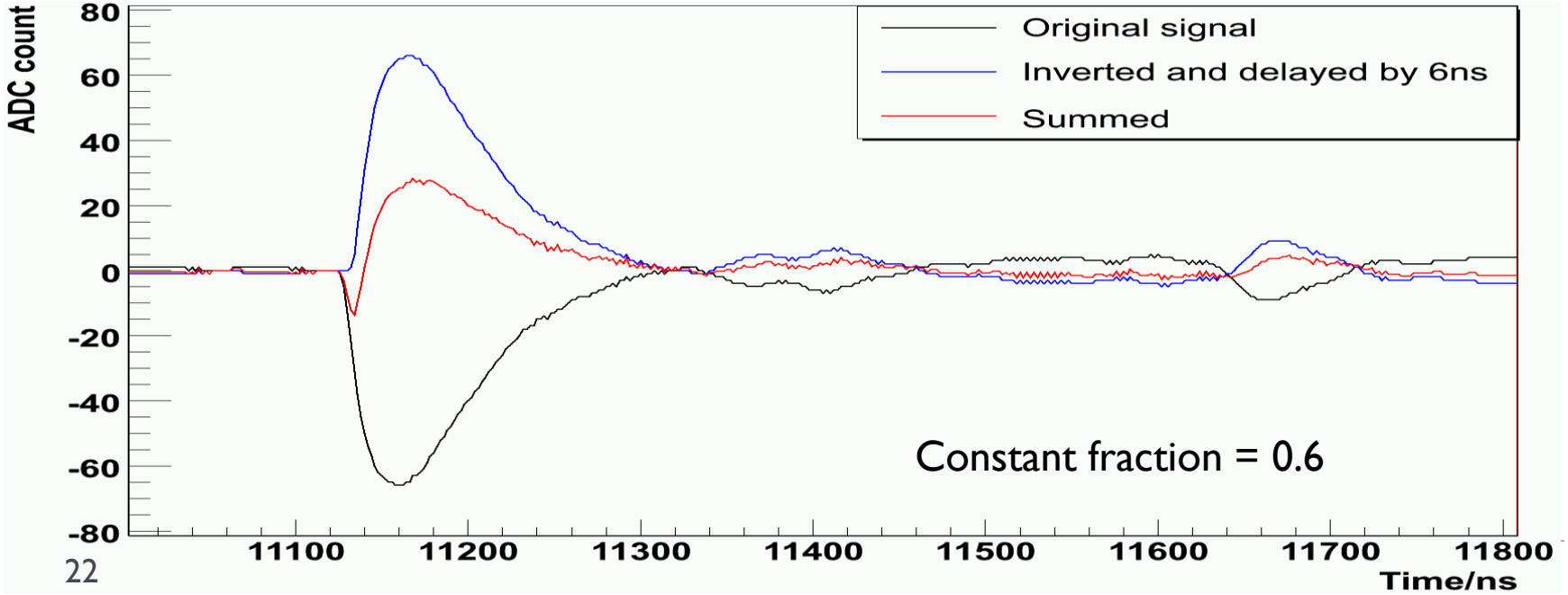

CFD 950
16 CH CFD
16 CH DISCR.
128 CH GENERAL PURPOSE MH TDC
CONET-VME BRIDGE

Constant fraction 0.2

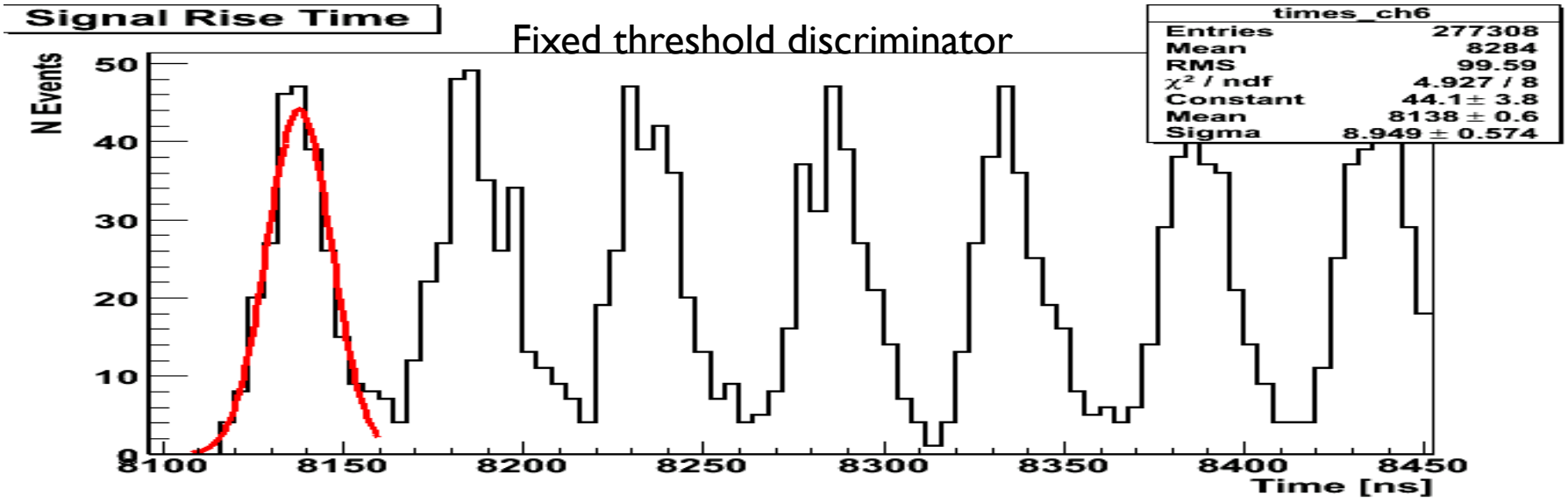
- Shifts triggering point

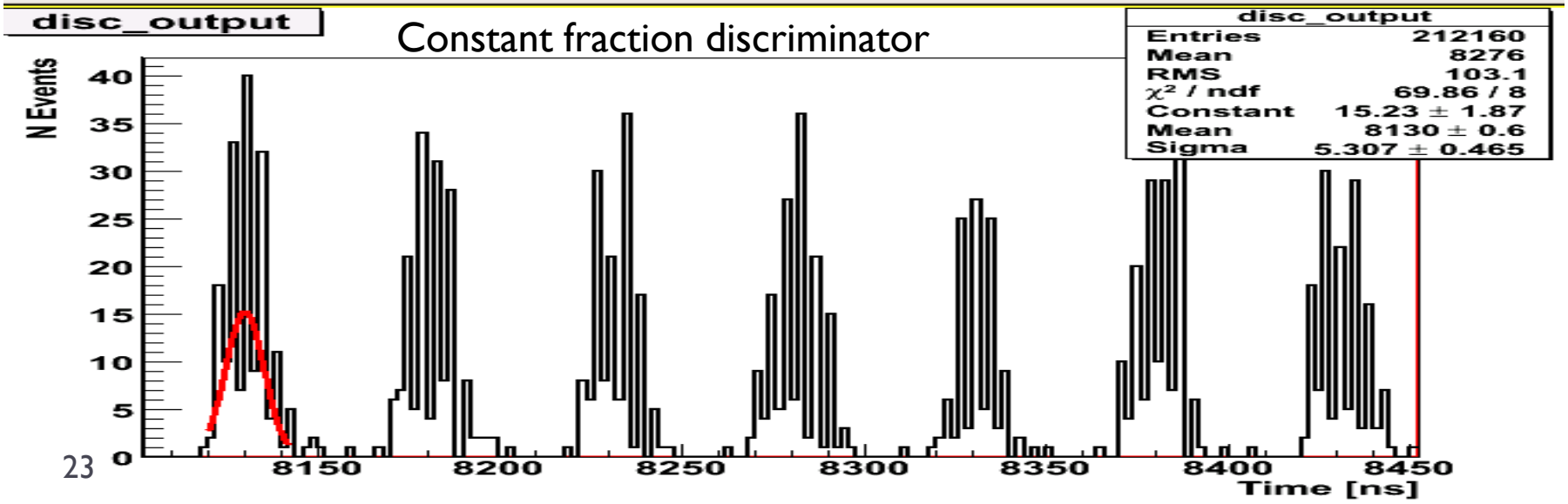



ADC count
80
60
40
20
0
-20
-40
-60
-80
11100
11200
11300
11400
11500
11600
11700
11800
Time/ns
Original signal
Inverted and delayed by 6ns
Summed
Constant fraction = 0.2

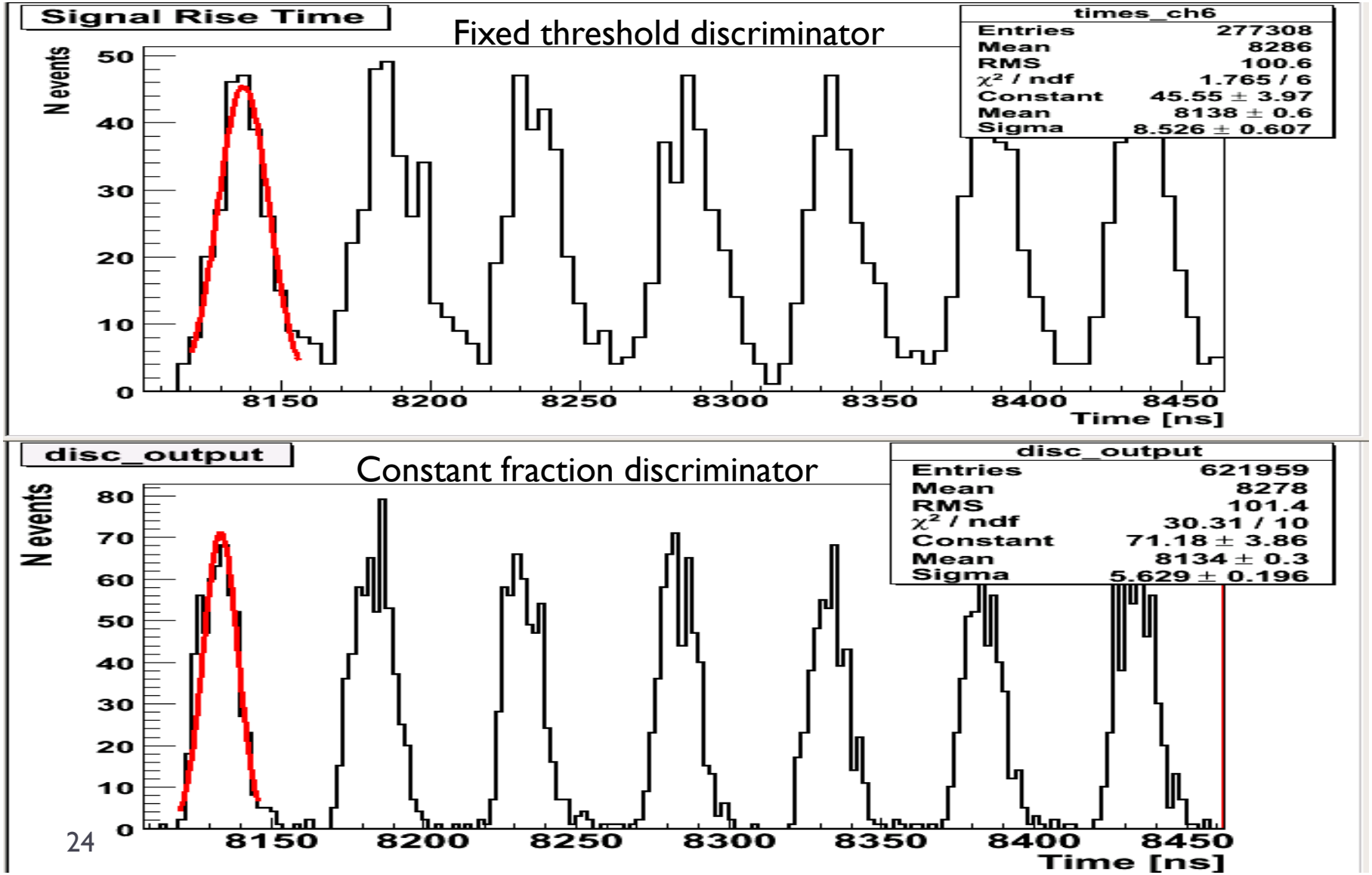

ADC count
80
60
40
20
0
-20
-40
-60
-80
11100
11200
11300
11400
11500
11600
11700
11800
Time/ns
Original signal
Inverted and delayed by 6ns
Summed
Constant fraction = 0.6

No rebinning





Constant fraction 0.4



Possible beam halo. Constant fraction 0.4