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Calorimetry Precision Timing (CPT)

Caltech Group, CMS, CERN
Taylor Brunton Smith, 07-08-2014
[Supervisor: Adi Bornheim]

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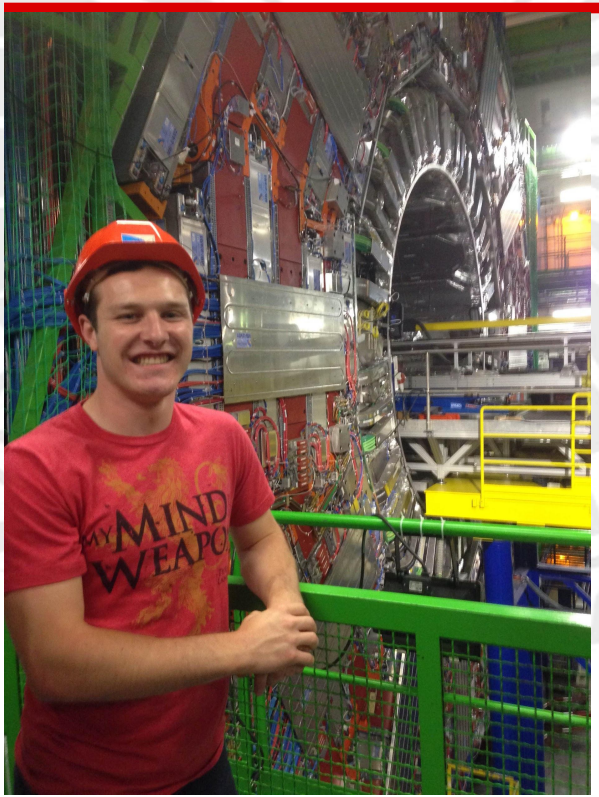
The Experiment: CMS



CMS
Compact Muon Solenoid

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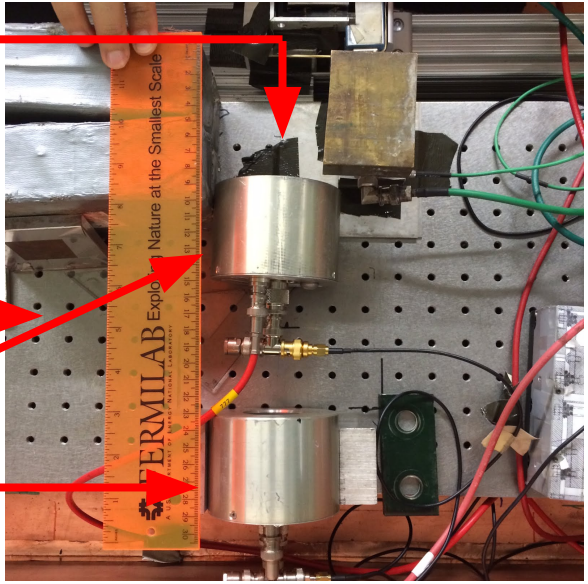
Analysing test beam data from Fermilab May

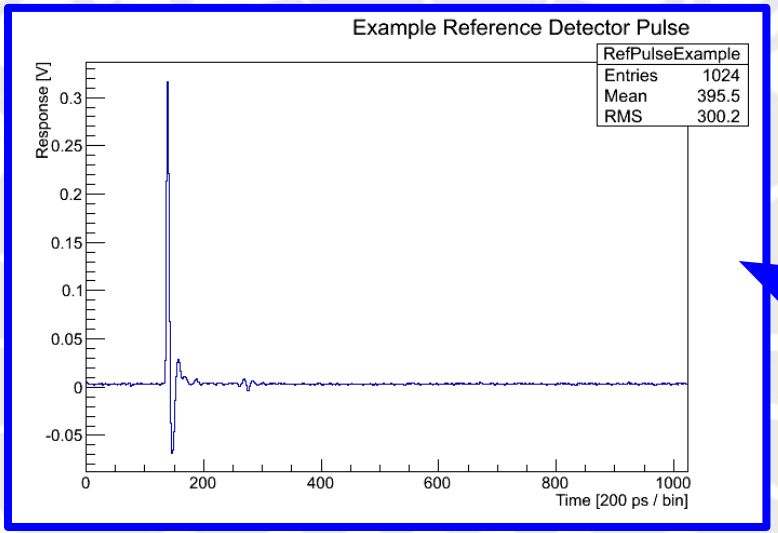
1.7 cm xtal runs at different energies (8, 16, 32 GeV)

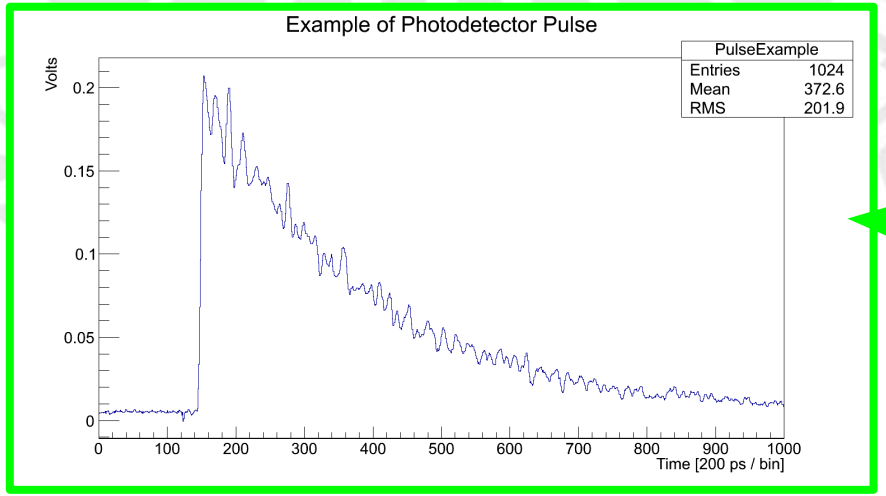
Electron beam from here

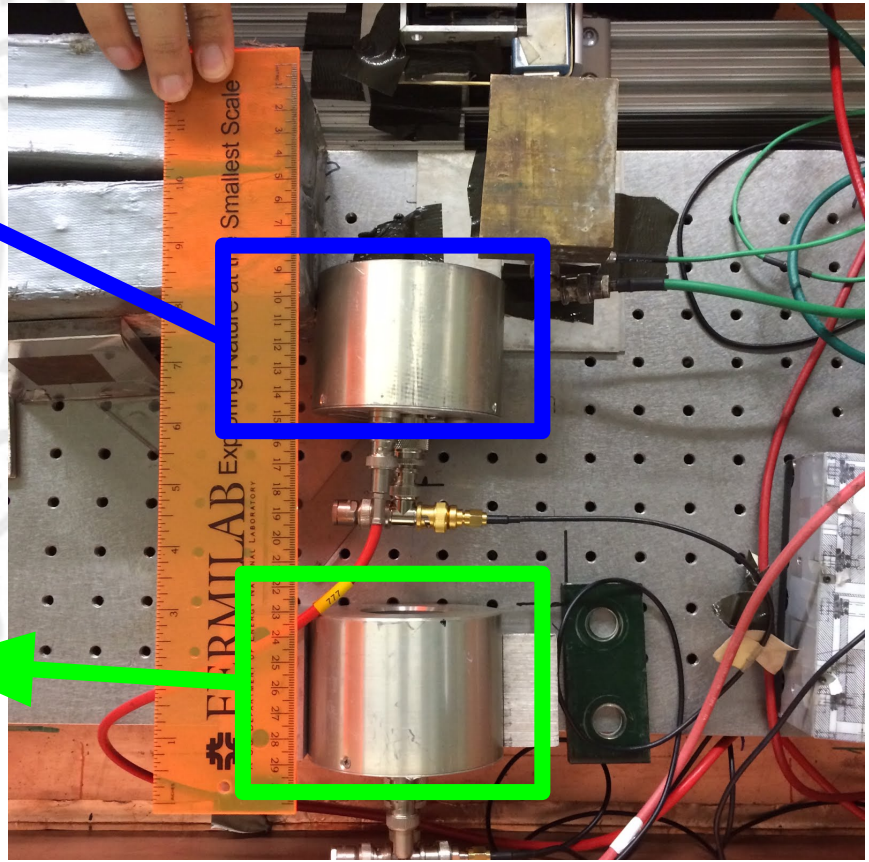
LYSO crystal here

Photek photodetectors here




Example Reference Detector Pulse
RefPulseExample
Entries 1024
Mean 395.5
RMS 300.2
Response [V]
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
200
400
600
800
1000
Time [200 ps / bin]


Example of Photodetector Pulse
PulseExample
Entries 1024
Mean 372.6
RMS 201.9
Volts
0.2
0.15
0.1
0.05
0
0
100
200
300
400
500
600
700
800
900
1000
Time [200 ps / bin]


Smallest Scale
FERMILAB

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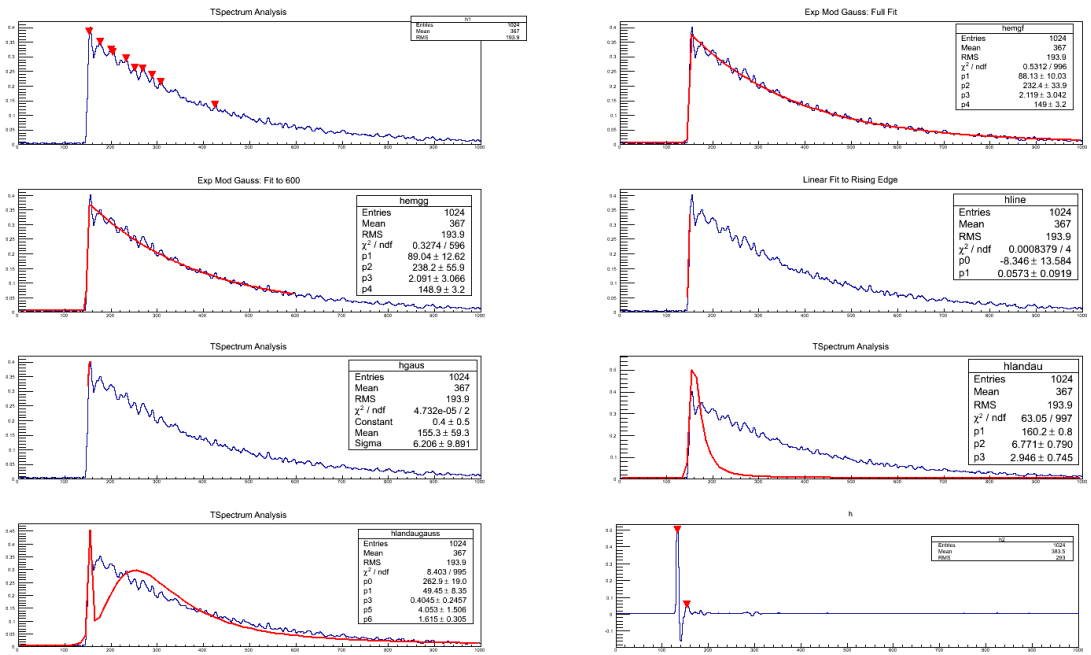

Ensemble of Fits

Interested in:

- ***Good time resolution***
- Good energy resolution
- Robustness (does fit work well for all energies, setups)
- Reliable (does not fail to converge, or fit poorly, often)
- Quality factors

SETTLED ON LINE TO RISING EDGE

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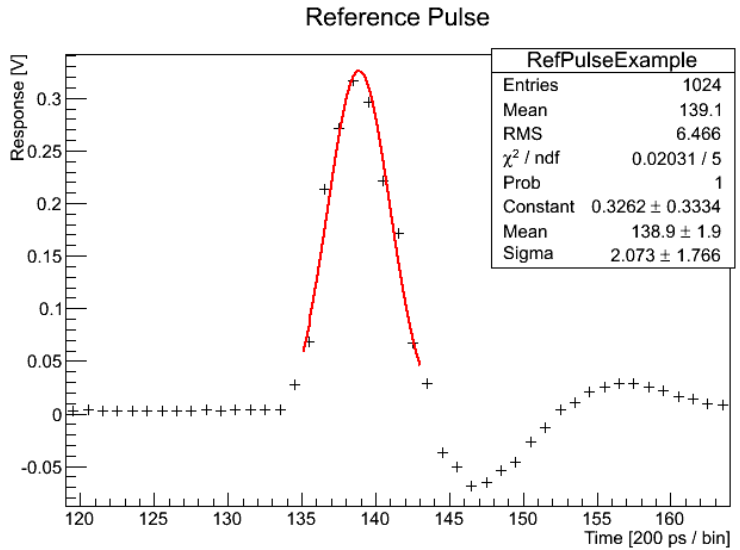
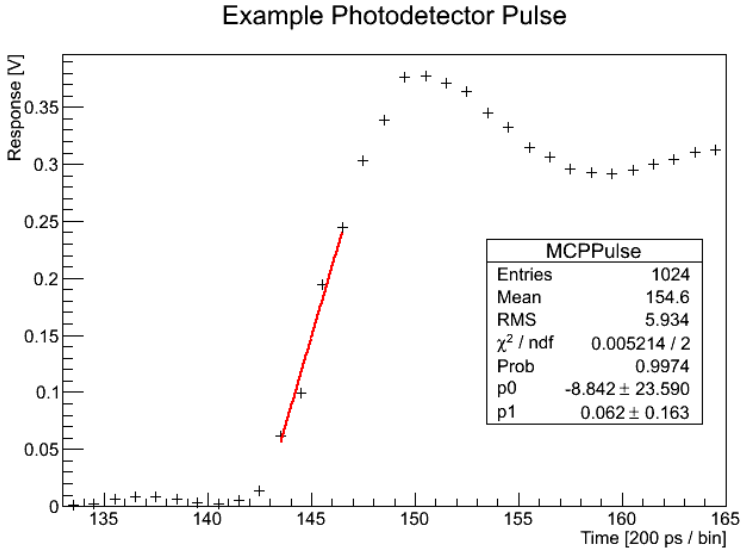
Linear Fit to Rising Edge: Best Time Resolution, Most Reliable





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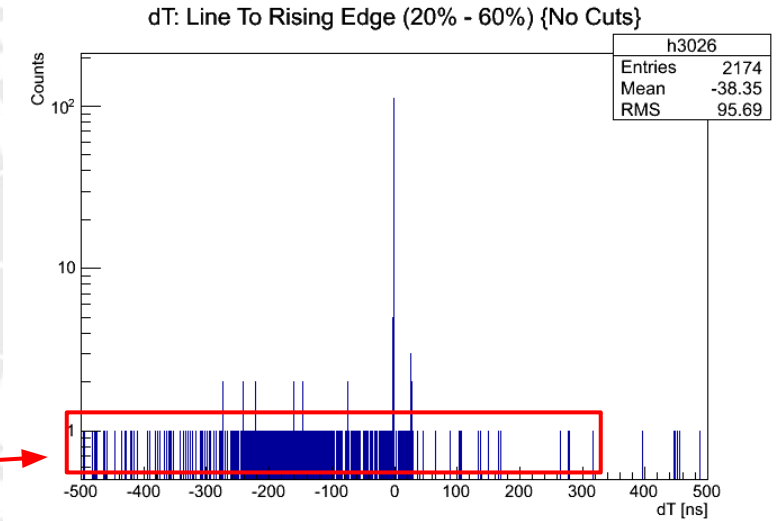
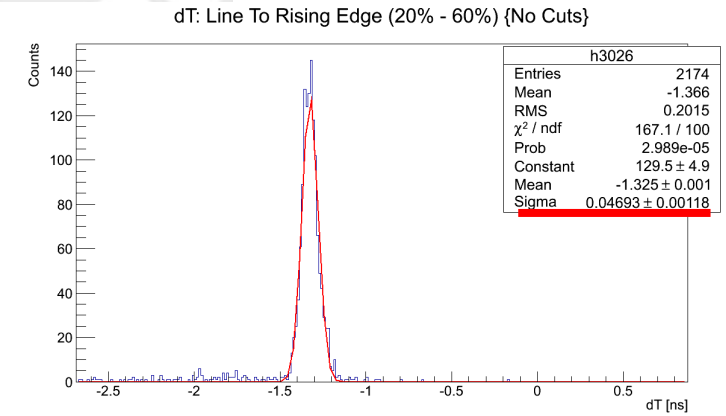
Pulse Selections

dT distribution for fitting a line to rising edge, no cuts applied



- Long-tailed background
- Can improve time resolution

Lets add cuts and see how they affect the dT distribution



~50 ps

We can do better!

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Pulse Selections

Need to make cuts on pulses to ensure that we are analysing “good pulses”

(to circumvent impurity of electron beam, showering effects, saturation, etc)

Current Selection Criteria on Events

0.02 V < Cerenkov Detector Amplitude - (Low end: ensure we’re measuring electrons)

0.02 < Photodetector Pulse Amplitude < 0.48 Volts - (Avoid readout saturation at 0.5 V and require large pulse in Photodetector)

Reference Pulse Amplitude > 0.02 - (Require direct hit in reference detector)

Auxiliary Detector Pulse Amplitude > 0.48 (Require saturation of aux detector, sign of showering started upstream by electron)

Quality Bits - (Require good “quality” of reference pulse shape, see later)

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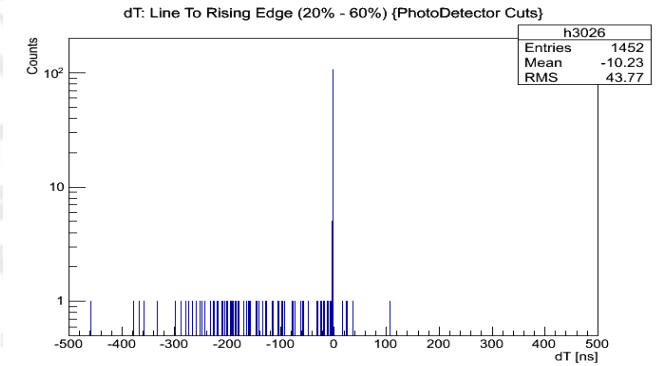
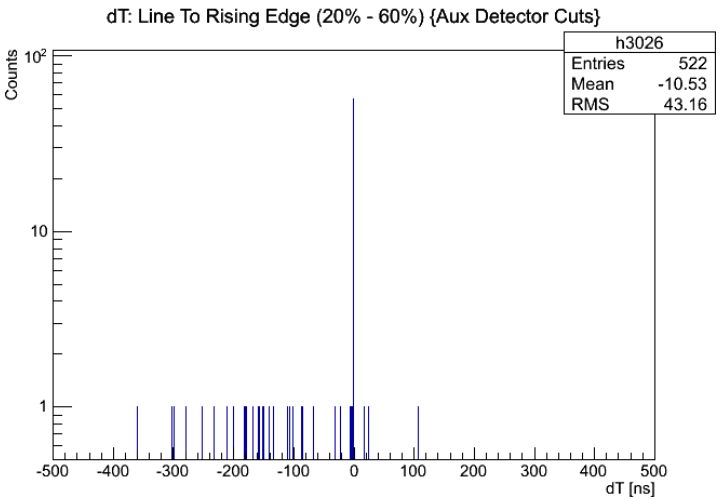
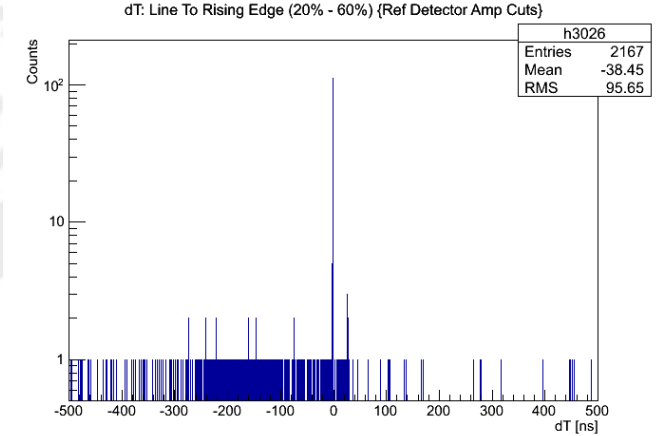
Pulse Selections Effects



Anti-saturation Cut on Photodetector Pulse Amplitude



Auxiliary detector pulse minimum



Reference Pulse Minimum

EACH IMPROVES TAIL WITHOUT DETRIMENTING PEAK

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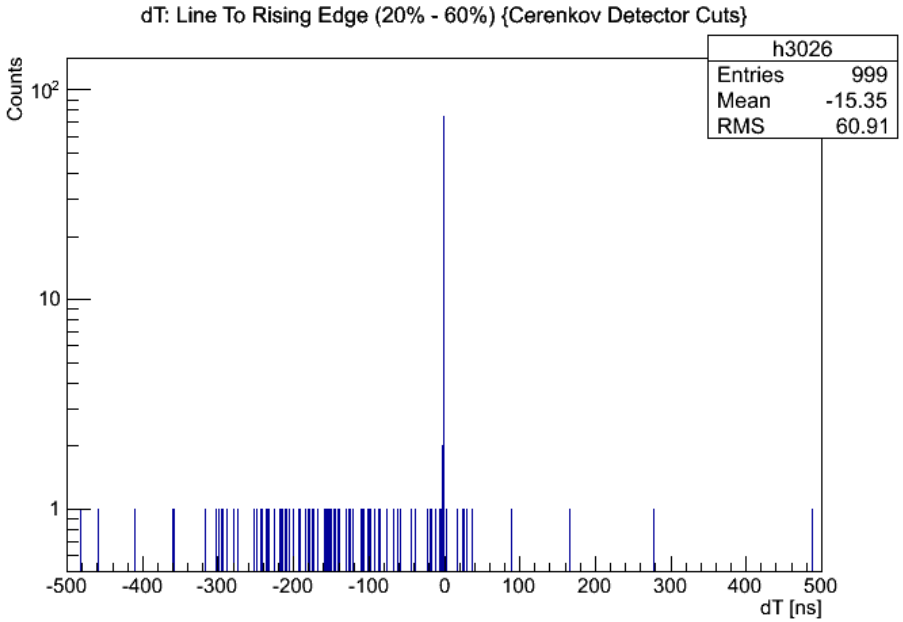
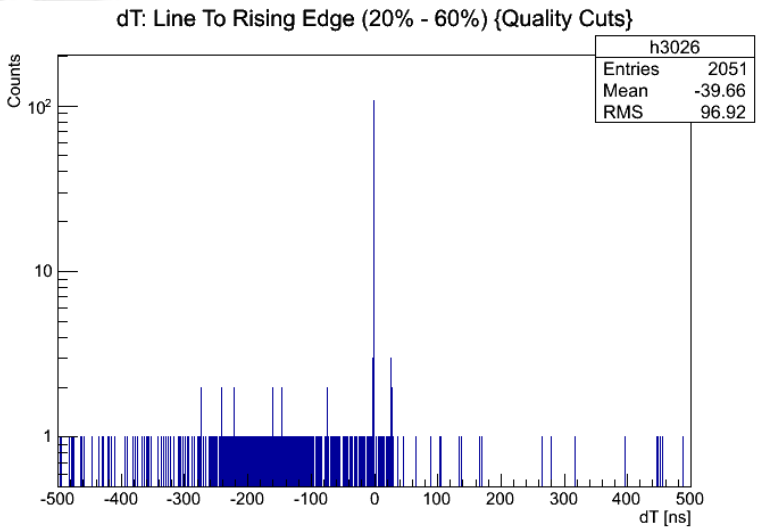
Pulse Selections Effects



Cerenkov Detector Response Cut



Quality Bits Cut

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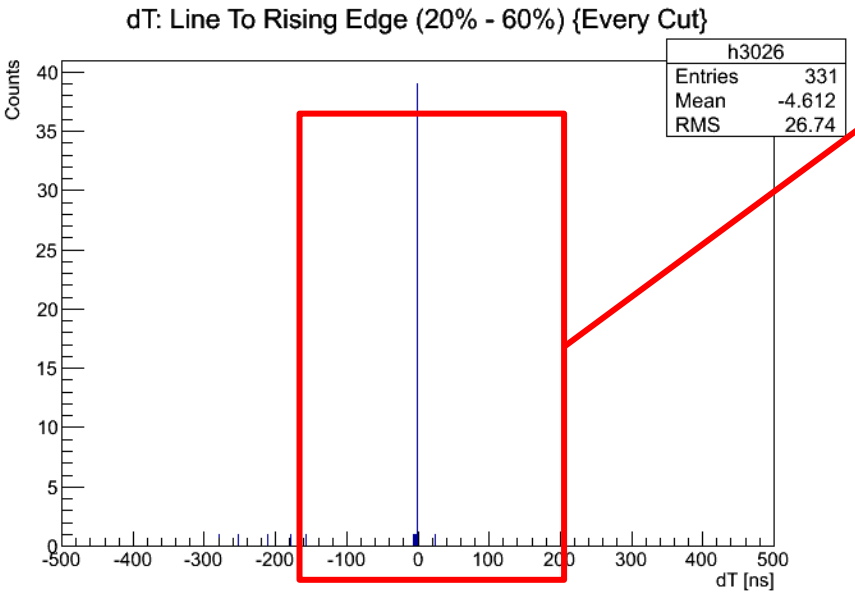
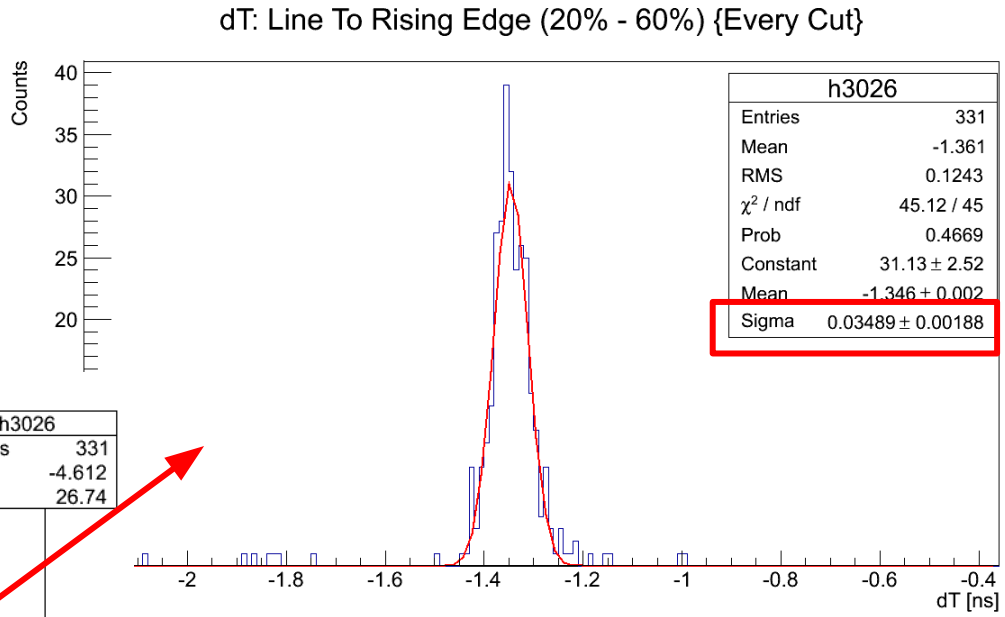
Pulse Selections

After full cut ensemble





Rough time resolution ~35 ps

8 GeV Electrons, 1.7 cm cube

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Conclusion:

~35 ps time resolution is achievable!

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For the Future:

New Testbeam in Progress at Fermilab!

- Collect more data with different sources, setups
- Increase data quality and uniformity
- Try different MCPs, DAQ, equipment
- Keep tuning for 20 ps target

THANK YOU!

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BACKUP SLIDES

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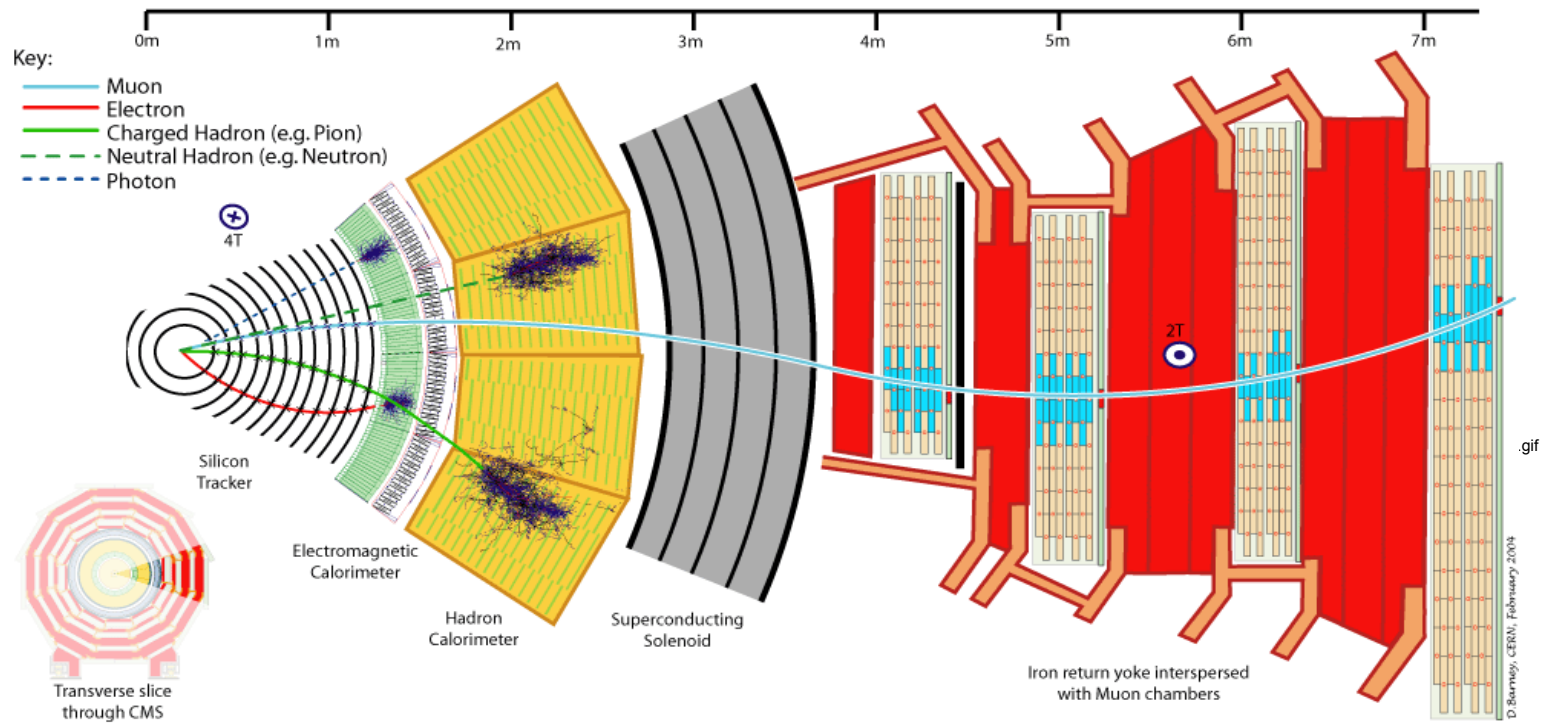
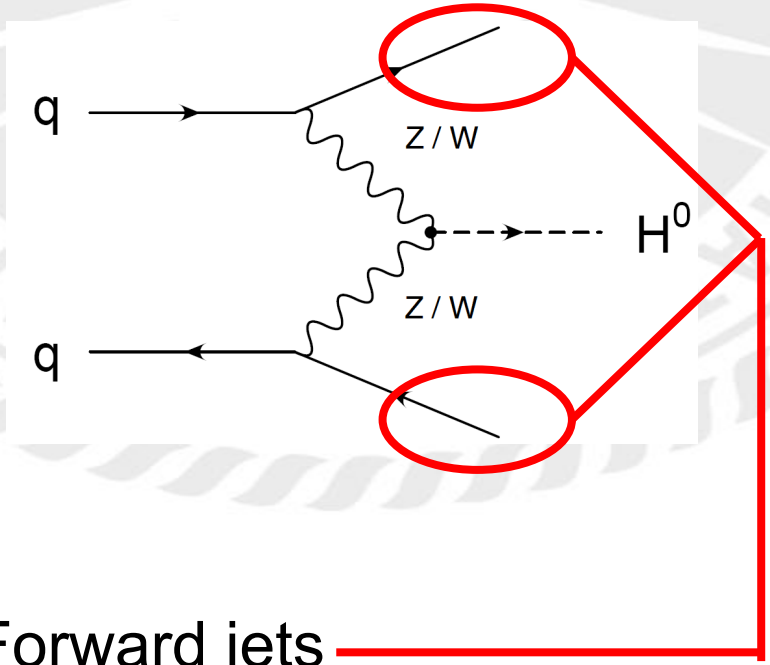
The Experiment: CMS

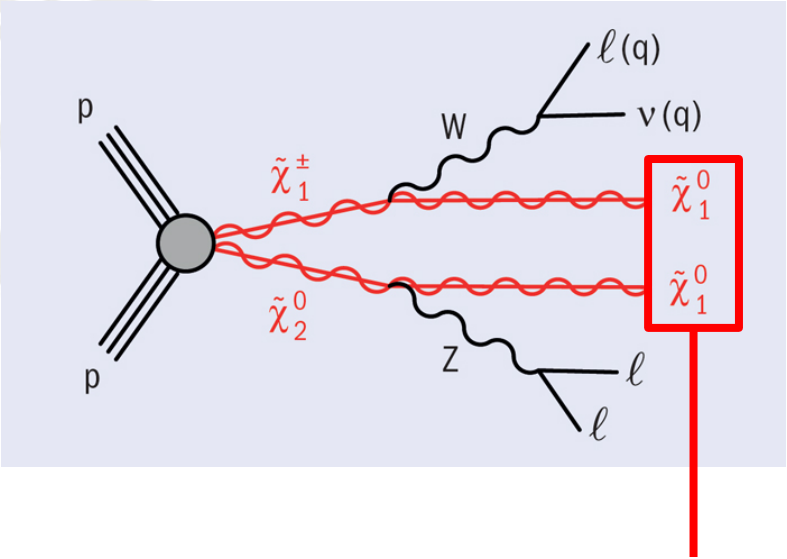


.gif

Physics Motivations: Key Signatures

Precision Higgs physics : SUSY LSP searches





Forward jets

Missing transverse energy

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Glossary

Pulse - The voltage vs time profile read out by the DRS boards, (See Fig 1.a)

Photodetector Pulse - Pulse profile of photodetector (either Hamamatsu or Photek) which reads out from the crystal

Reference Pulse - Pulse profile of photodetector which reads out from the reference (ie. nothing attached to it)

Cerenkov Pulse - Pulse profile of photodetector positioned at electron's Cerenkov angle in experimental setup (used to ensure that photodetector pulses are indeed due to electrons)

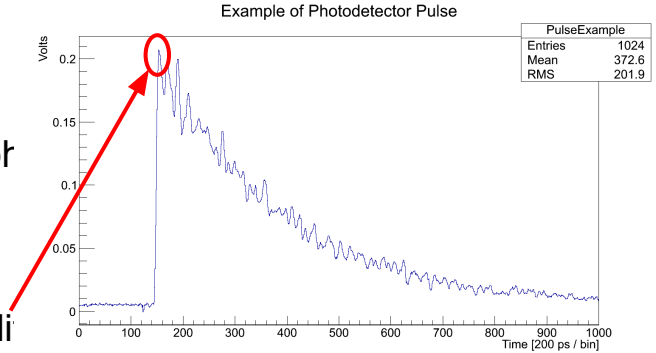
[Name of Pulse] Amplitude - Peak voltage attained by [Name of Pulse] in the measurement (Fig 1.a)

Fig 1.a:

An example of a pl

detector pulse

Photodetector pulse ampli



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Glossary (cont)

Rising Edge - The steep rise in voltage characteristic of when the pulse “arrives” (See Figure 1.b)

Peaks - The small crests in voltage fluctuation (See Figure 1.b)

[Name of Pulse] Histogram Integral - Value of sum of bins in [Name of Pulse]

[Name of Pulse] [Name of Fit] Integral - Value of integral of [Name of Fit] function which has been fit to the shape of [Name of Pulse]

Time Resolution - Standard deviation gaussian fit to the distribution of time differences between amplitude of reference detector and the extracted time of pulse (See Figure 2)

[Name of Fit] Energy Resolution - Determined by correlation of Histogram Integral and [Name of Fit] Integral

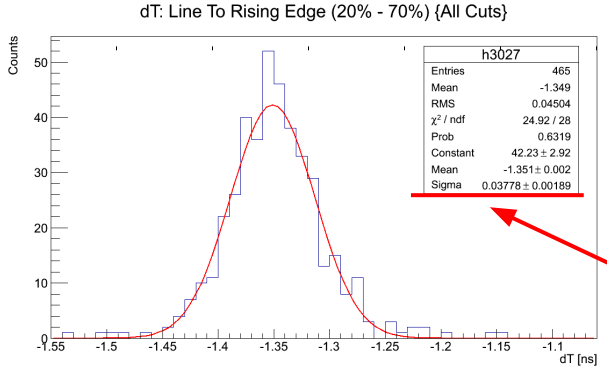


Fig 2:

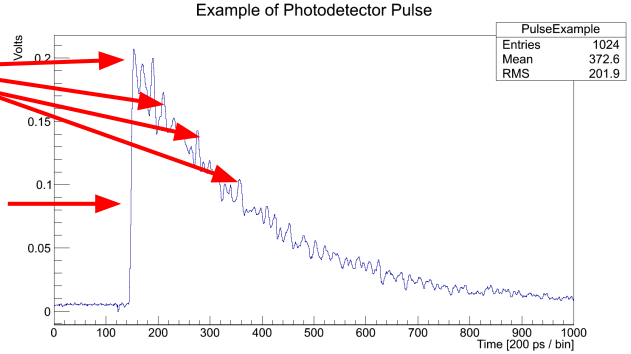
Distribution of dT for a specific time extraction

Time resolution ~37 picoseconds

Fig 1.b

Peaks

Rising Edge



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Ensemble of Fits

Line to Rising Edge - Find max amplitude. Fit from 20% amplitude to 60% amplitude

Landau - Fit Landau distribution to full pulse shape

Exp Mod Gauss (Full) - Fit Exponentially Modified Gaussian (http://en.wikipedia.org/wiki/Exponentially_modified_Gaussian_distribution) to the full pulse shape

Exp Mod Gauss (0 < t < 600) - Fit Exponentially Modified Gaussian from 0 to 120 ns (t in pulses is often measured in units of 0.2 ns)

Landau / Gauss - Fit superposition of Landau and normal distributions to full pulse shape

Gauss_3 - Fit Gaussian to largest peak (+/- 0.6 ns)

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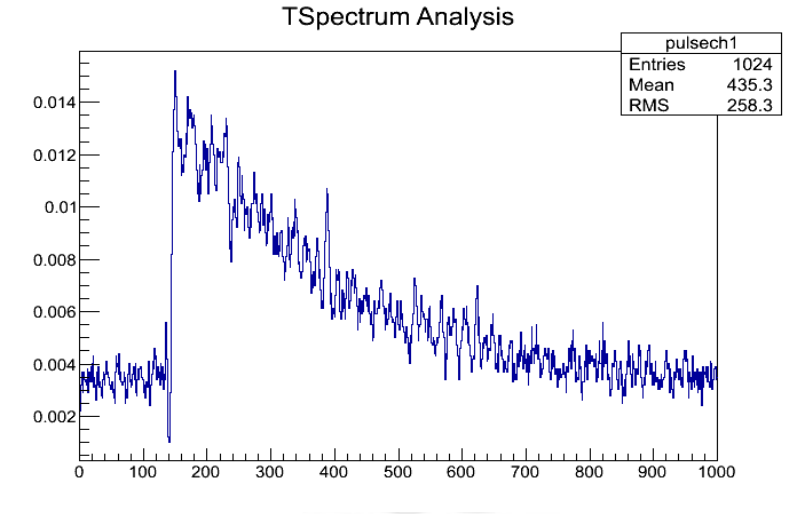
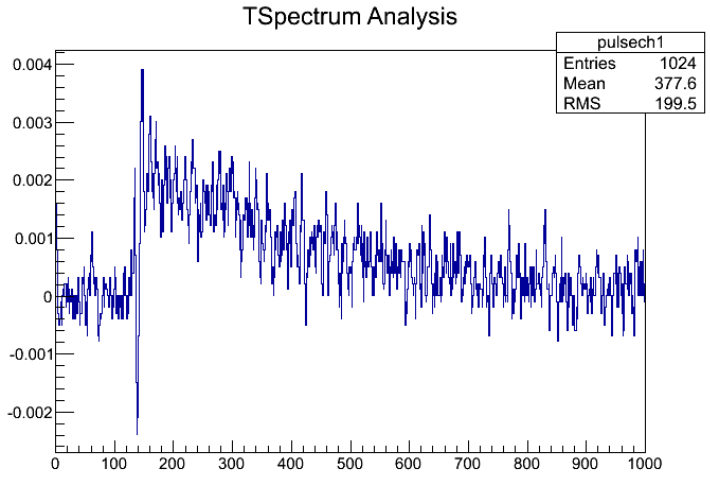
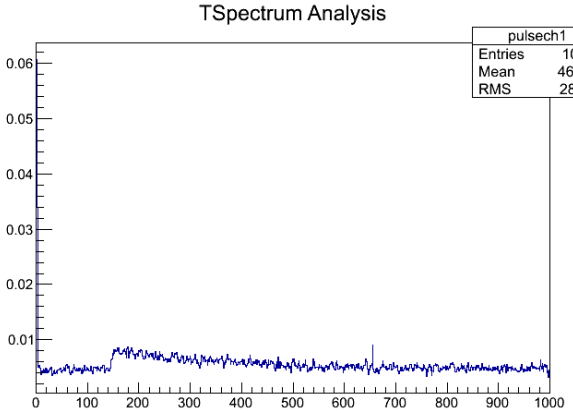
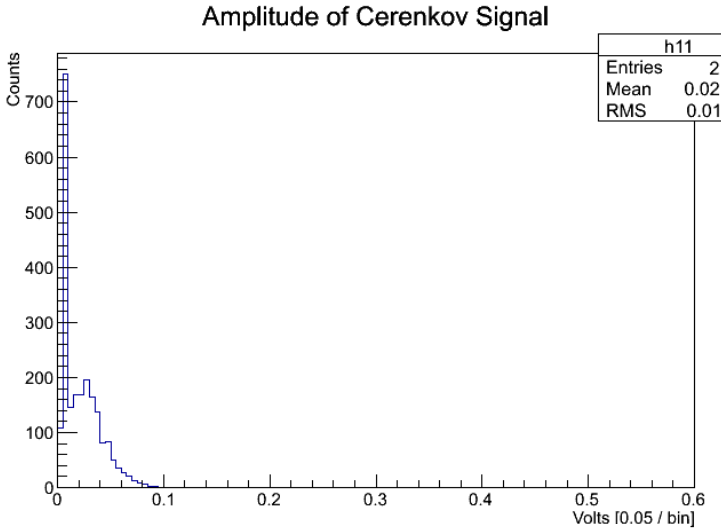
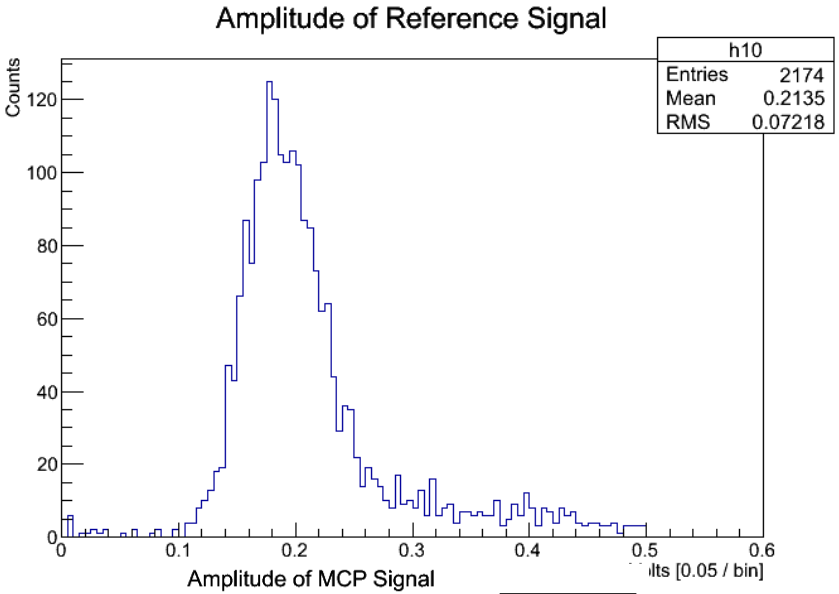
Some Bad Pulse Shape Examples:

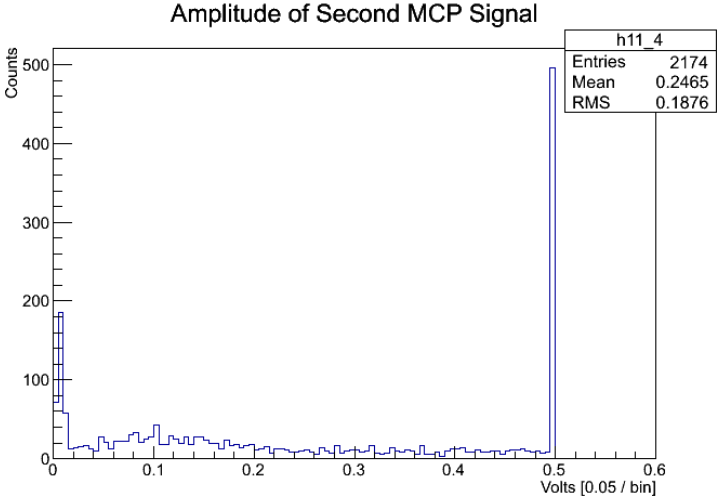


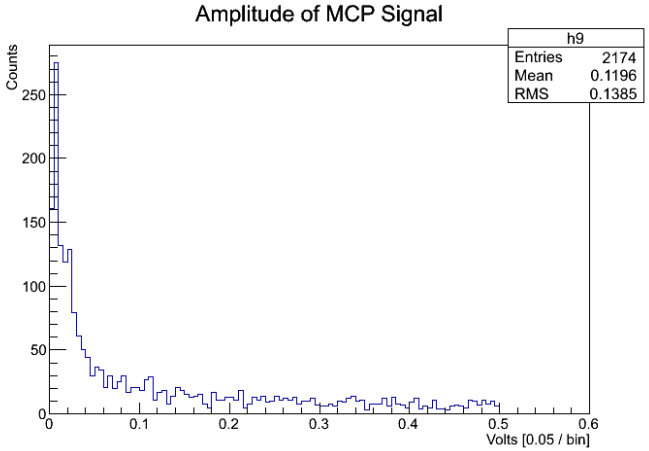





Amplitude of Cerenkov Signal
h11
Entries 2
Mean 0.02
RMS 0.01
Counts
Volts [0.05 / bin]


Amplitude of Reference Signal
h10
Entries 2174
Mean 0.2135
RMS 0.07218
Counts
Volts [0.05 / bin]


Amplitude of Second MCP Signal
h11_4
Entries 2174
Mean 0.2465
RMS 0.1876
Counts
Volts [0.05 / bin]


Amplitude of MCP Signal
h9
Entries 2174
Mean 0.1196
RMS 0.1385
Counts
Volts [0.05 / bin]

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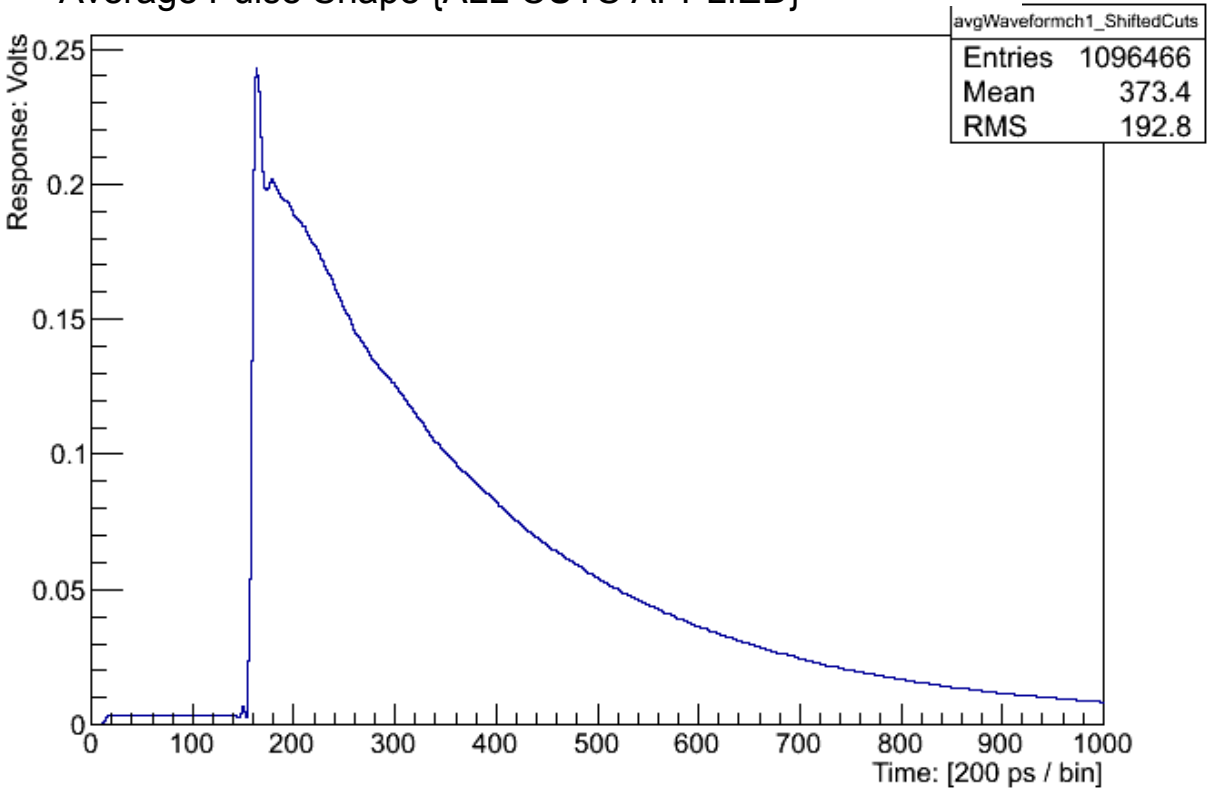
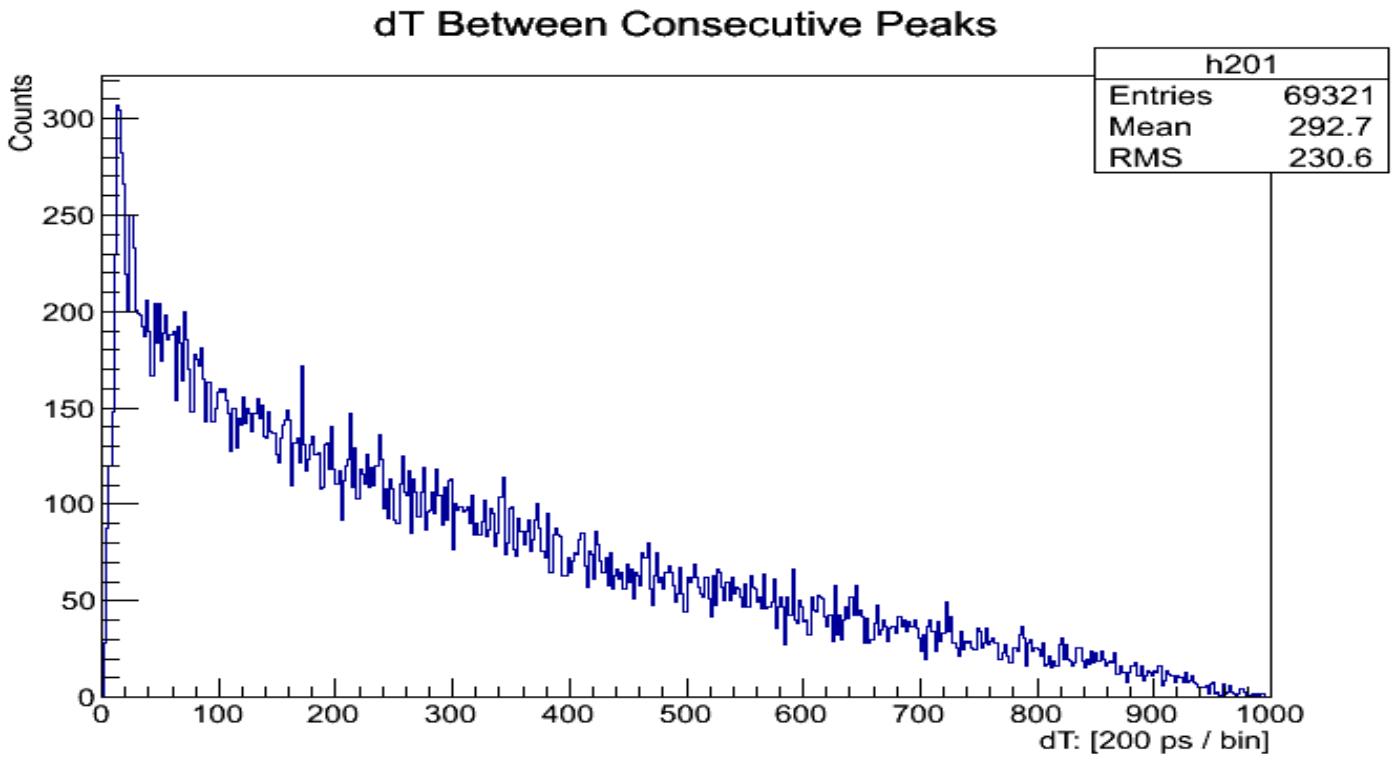
Average Pulse Shape {ALL CUTS APPLIED}





Nota Bene: EACH TICK IN TIME IS 200 ps

Corresponds to 40 ns spread at “peak”

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Quality Bits - Series of checks on the reference pulse shape

- Check for existence of pulse
- Require no large negative amplitude
- Require no saturation
- Require no sudden jumps by peak (indicative of double-hit)
- Require no flat top (indicative of saturation)
- Require exactly one pulse