Simulation of the Timing Electronics in C++

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Simulation of the Timing Electronics

- simulation of time resolution
- simulation in MATLAB (Jean-Francois)
  - ready
  - gives good results
- simulation in C++
  - almost ready
  - results are not yet 100% compatible with the MATLAB simulations
  - simulation in C++ is faster
    - simulations with larger statistics possible
  - code to be used in the detector simulations
    - as a block for Geant4

Simulation of the Timing Electronics

- compare different methods
  - single threshold
  - multiple threshold
  - constant fraction
  - pulse sampling
- understand the parameters to specify a fast sampling integrated electronics
- compare with the test-beam measurements
- part of larger simulations
  - Roman pots for ATLAS
  - medical applications

Input Parameters

- MCP parameters
  - rise time — 200 ps
  - fall time — 0 ps
  - gain — 1e5
  - number of photo-electrons — 50

→ electronics shaper
f(t) = t * exp(-t/tau)

- shot noise
  - shot noise current
- electronics parameters
  - gain — 1
  - number of adc bits (digitization) — 16
  - signal bandwidth — 1.5 GHz
  - temperature — 300 K
  - electronics noise

total noise in the simulation
shown on next slides:
50% MCP noise
50% electronics noise

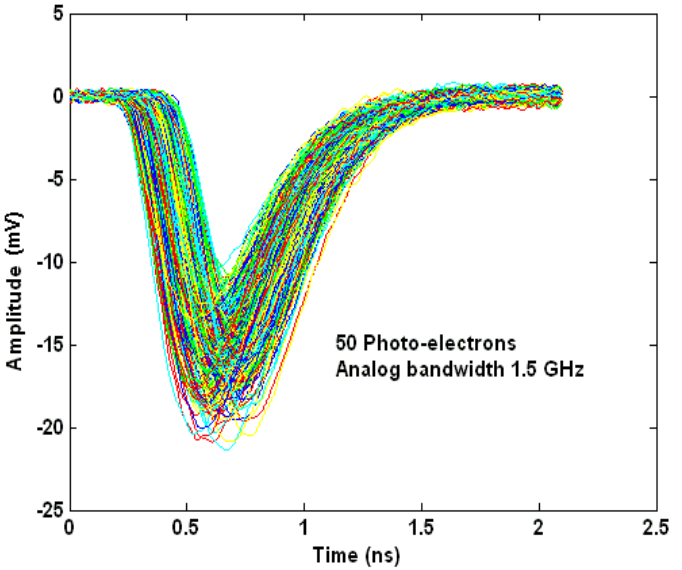
Input Parameters

- sampling parameters
  - sampling frequency 40 GHz
  - sampling jitter 0 ps (can be set to any value in the simulation)

- random delays of MCP pulses
  - in order to randomize the sampling process
    (as if using a clock asynchronous from the pulse)

- amplitude spectrum
  - normal distribution

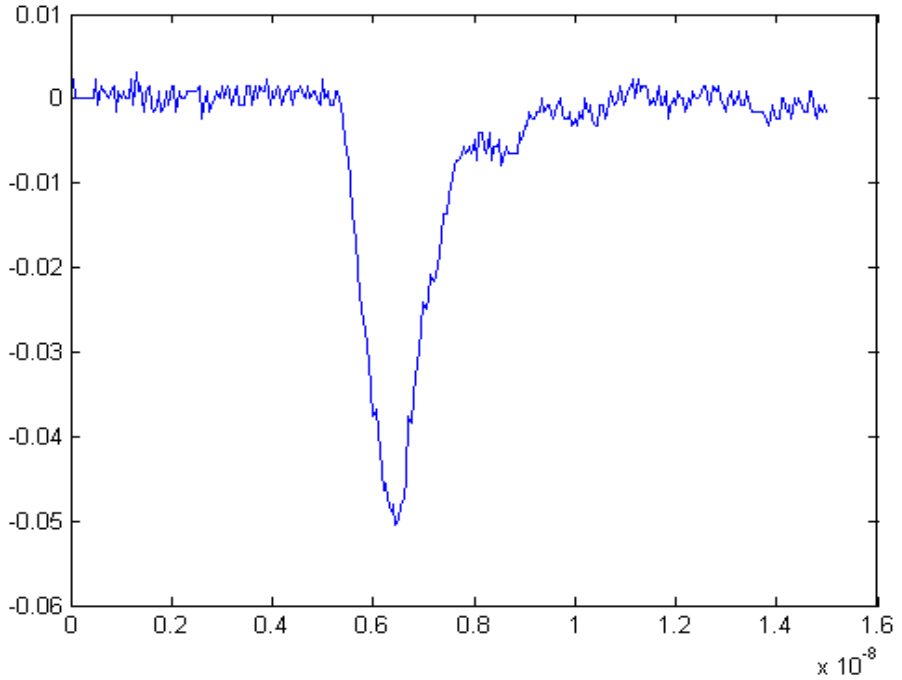
plot from the MATLAB simulation



parameters for other methods
(single threshold, multi threshold, constant fraction)

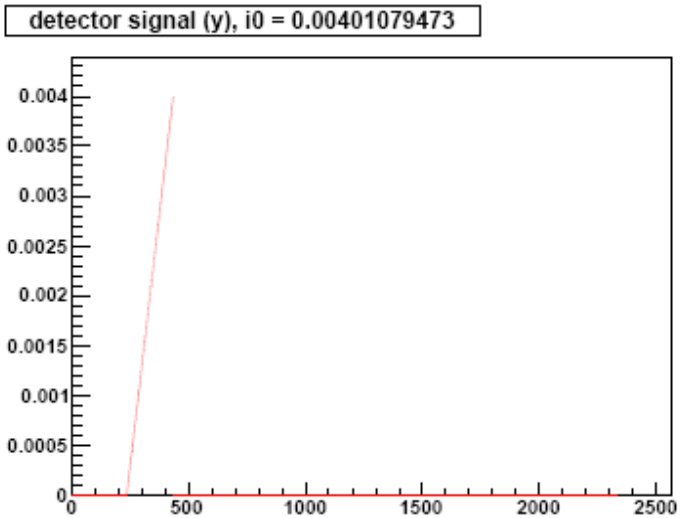
MCP Signals

- MCP pulse obtained at the beam-test at FNAL
- typical MCP signal pulse is 20 - 30 photo-electrons

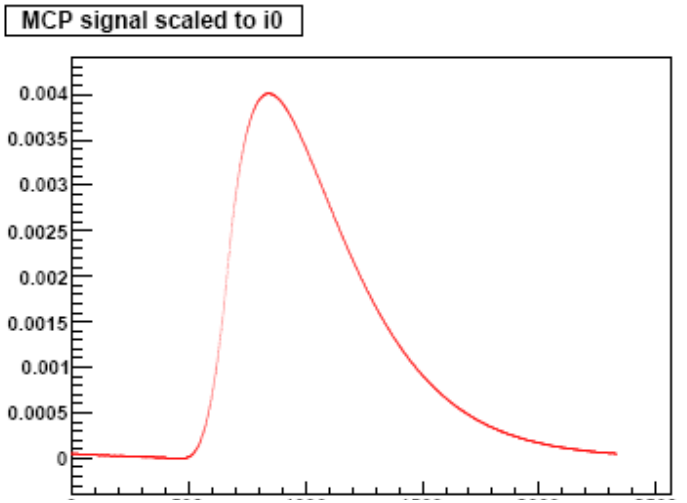


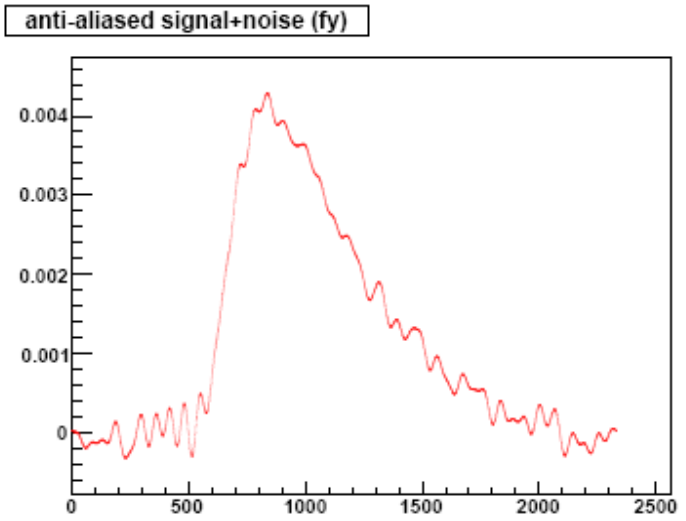
- MATLAB simulation give similar results as the beam-test

Waveform



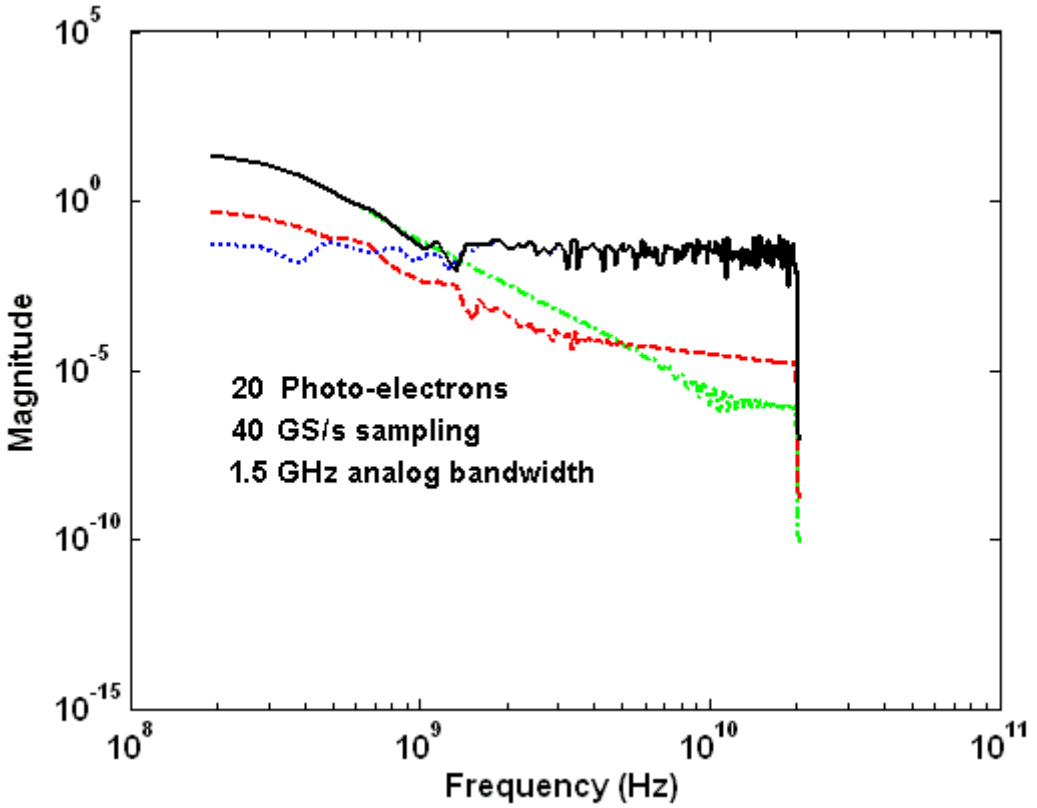
electronics shaper
f(t) = t * exp(-t/tau)





- waveform can be parametrised
  - can be used for PMT and SiPMT as well

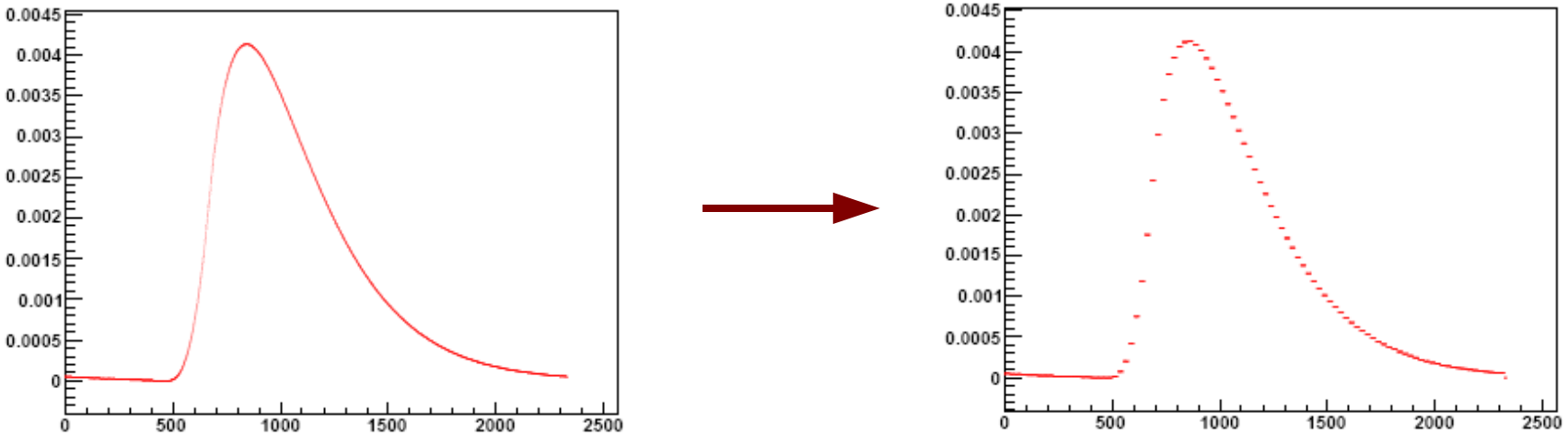
Fourier Spectrum



Green **MCP signal**
Red **MCP Shot noise**
Blue **Electronics noise**
Black **All**

50% shot noise
50% electronics noise

Sampling


0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
500
1000
1500
2000
2500

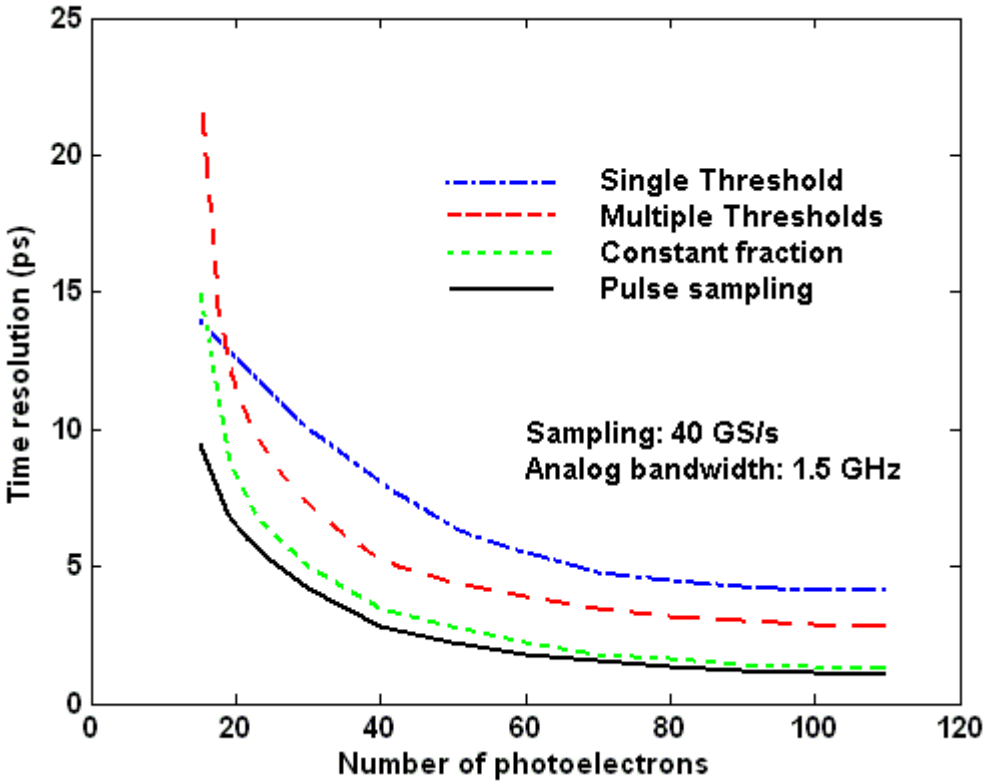
Output

- time resolution
- amplitude resolution

- depending on signal/noise ratio (and other parameters)
  - set by MCP noise and electronics noise

Time Resolution vs. Number of Photoelectrons

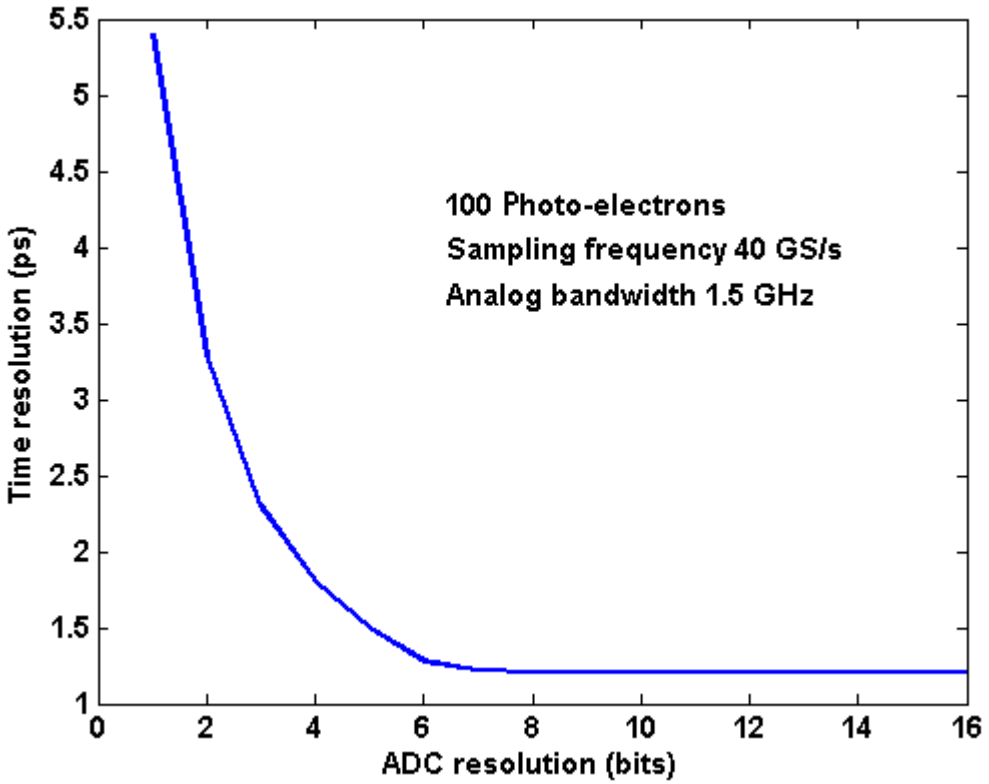
- different methods
  - single threshold
  - multiple threshold
  - constant fraction
  - pulse sampling



result from the MATLAB simulation

Time Resolution vs. ADC Bits

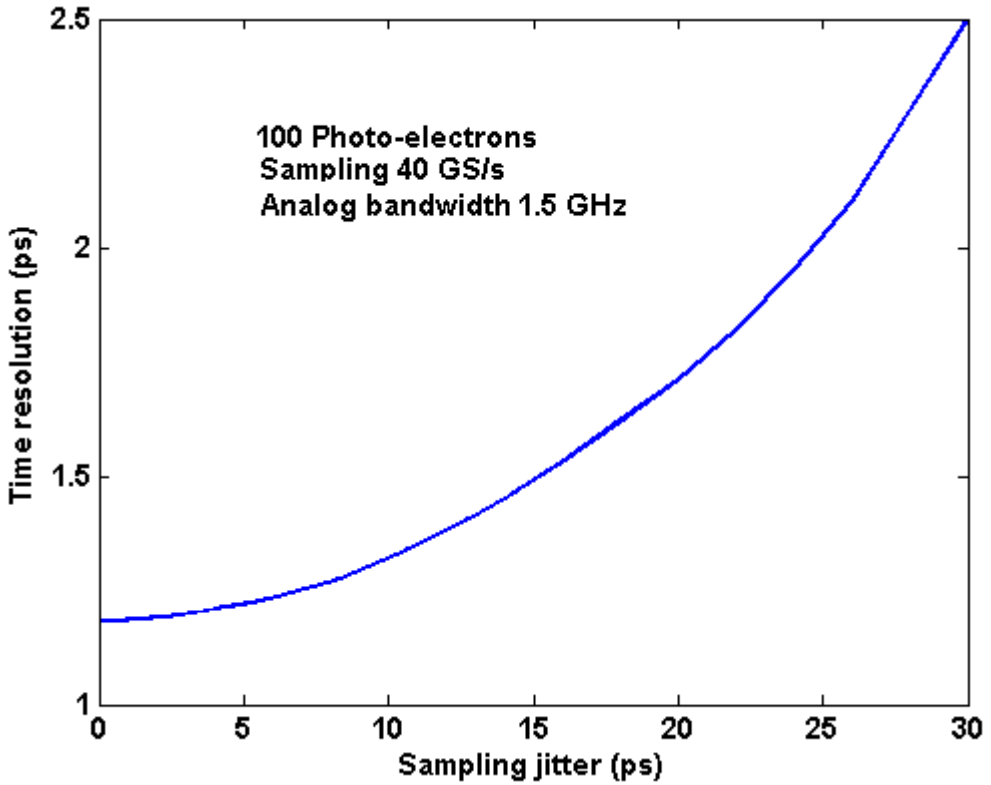
- 16 bits is ideal
- 8 bits is still good



result from the MATLAB simulation

Time Resolution vs. Sampling Jitter

- 0 ps jitter is ideal
- 10 ps is still good



result from the MATLAB simulation

Summary

- simulation of time resolution
  - depends on signal/noise ratio and other parameters
  - different methods

- C++ code
  - results not yet 100% compatible with the MATLAB code
  - faster
  - to be used in the detector simulation