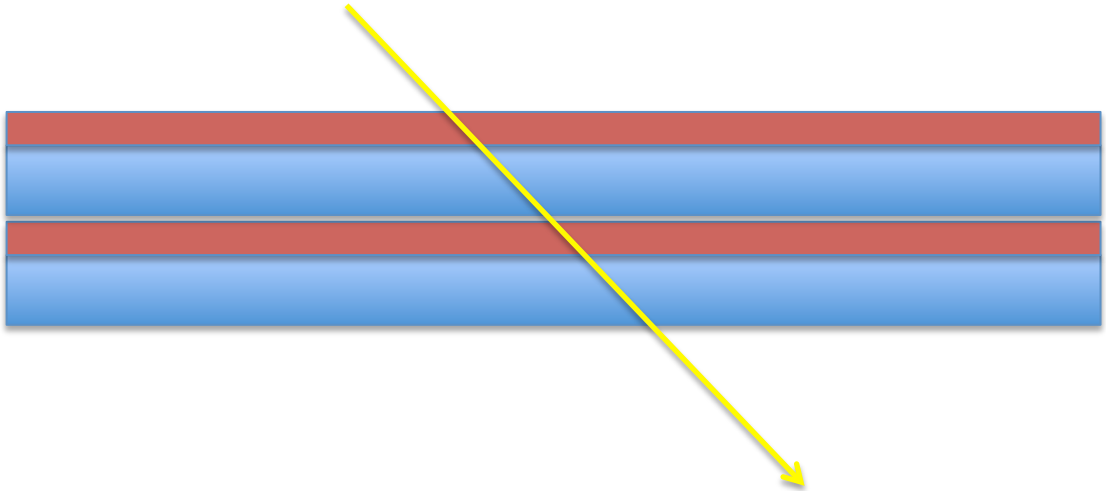
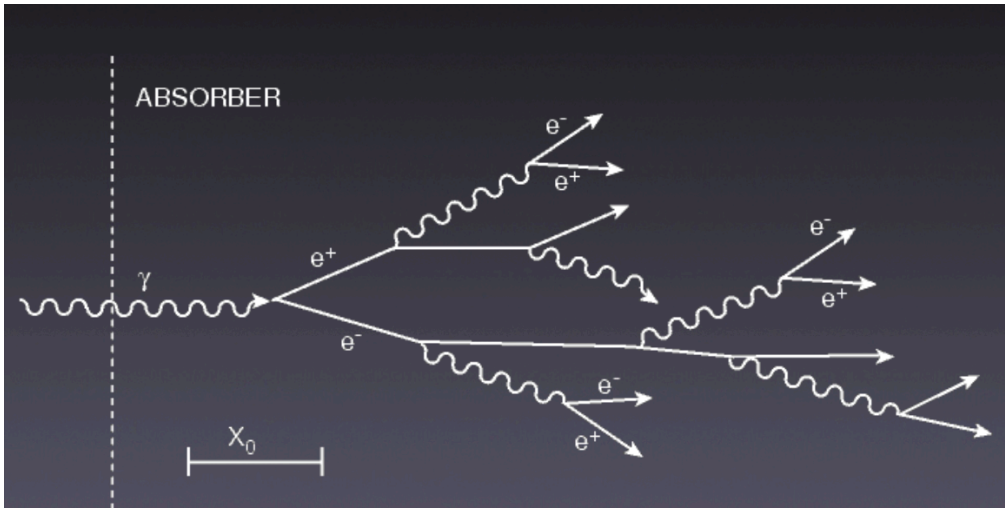
Timing resolution study

Detection mechanism (1)

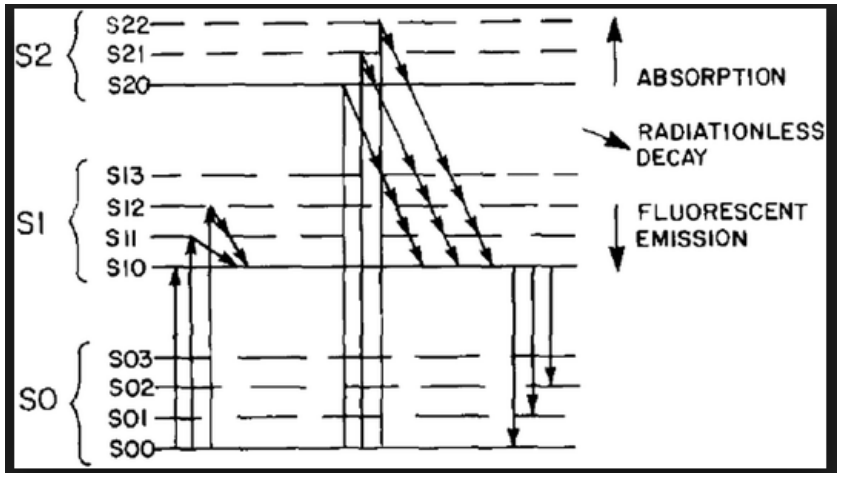
- Pb-scintillator sandwich structure
  - Pb : Absorber
  - Scint : readout
- Particles interact with Pb and Scint.
  - In case of KOTO, we mainly want to detect gamma.
    - ~1GeV
- Gamma make signal via
  - Photoelectric effect
  - Compton scat.
  - **Pair creation**
    - **With bremsstrahlung**
    - **~Z^2 dependence**

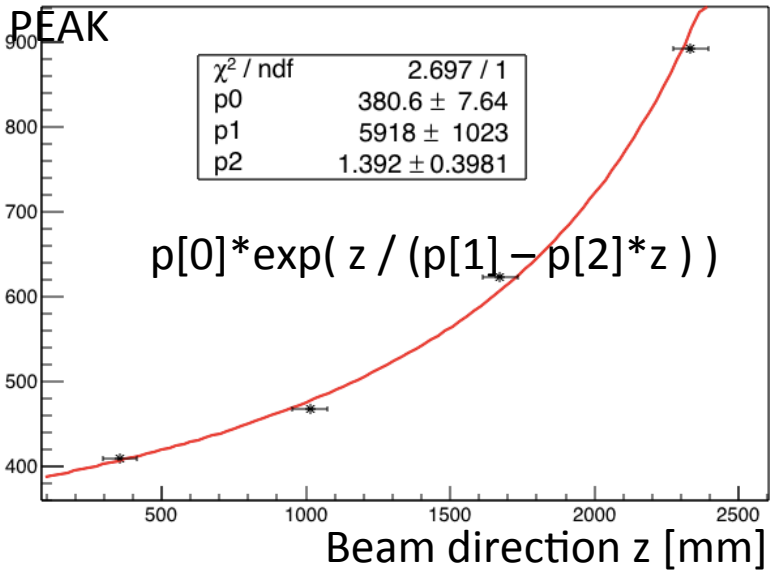




Detection mechanism (2)

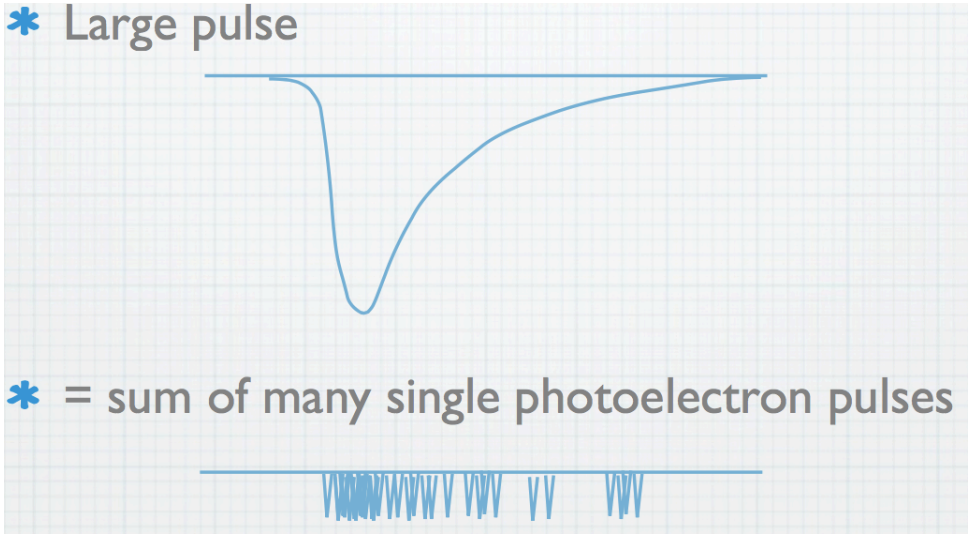
- Scintillating light
  - Exited atomic electron
  - Ionized electron
    - Makes many light again
    - Landau distribution
  - Exponential PDF
- Attenuation effect
  - Absorption
  - Scat.
- Readout





Timing resolution study

- Scintillating light
  - Exponential PDF
  - gaussian dispersion for each photoelectron
    - Exp * gaus
  - Other explanation
    - Rising time & falling time
    - $\mathrm{Exp}(-t/\mathrm{tau}_f) - \mathrm{Exp}(-t/\mathrm{tau}_r)$



Simulating pulse

- Generate each photoelectron pulse
  - Gaussian, use pulse width
- With exponential PDF (decay time)

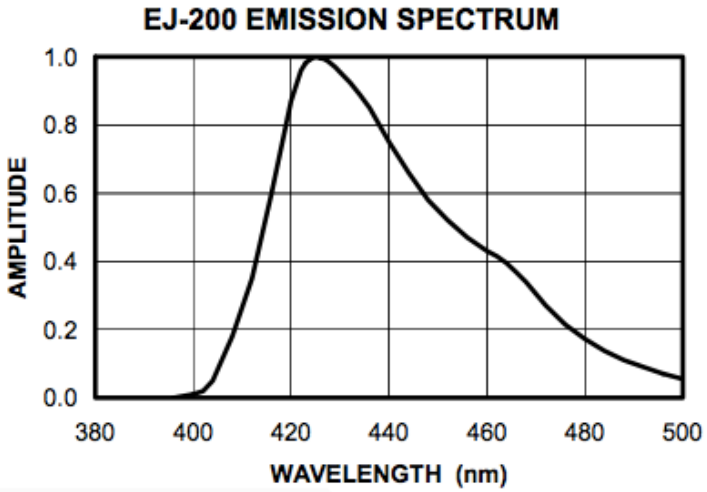
Physical and Scintillation Constants:

Light Output, % Anthracene	64
Scintillation Efficiency, photons/1 MeV e^-	10,000
Wavelength of Max. Emission, nm	425
Rise Time, ns	0.9
Decay Time, ns	2.1
Pulse Width, FWHM, ns	~2.5
No. of H Atoms per cm^3, x 10^{22}	5.17
No. of C Atoms per cm^3, x 10^{22}	4.69
No. of Electrons per cm^3, x 10^{23}	3.33
Density, g/cc:	1.023

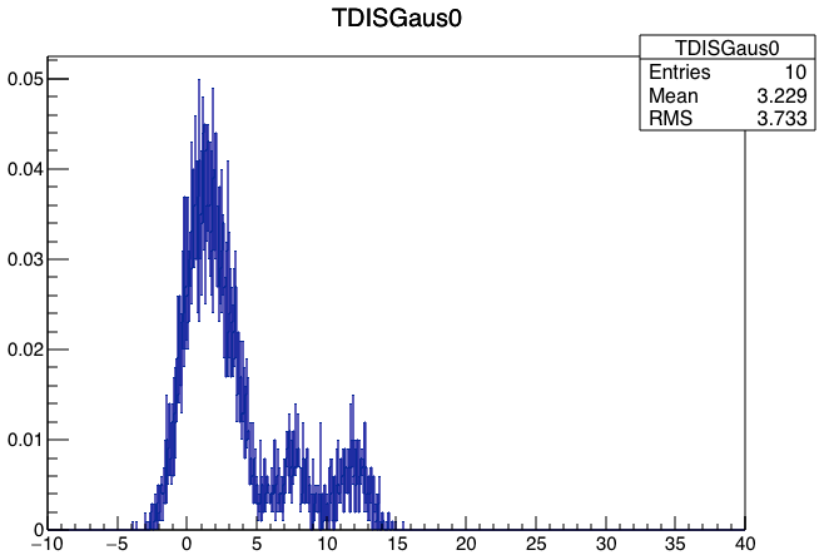
Polymer Base: ..... Polyvinyltoluene
Refractive Index: 1.58
Vapor Pressure: ..... Is vacuum-compatible
Coefficient of Linear Expansion: ..... 7.8 x 10^{-5} below +67°C

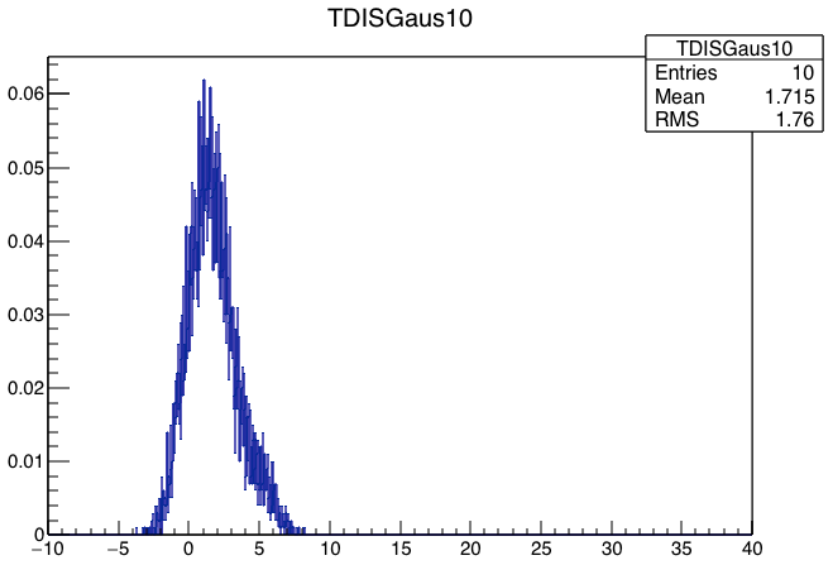
Light Output vs. Temperature:
At +60°C, L.O. = 95% of that at +20°C
No change from +20°C to -60°C

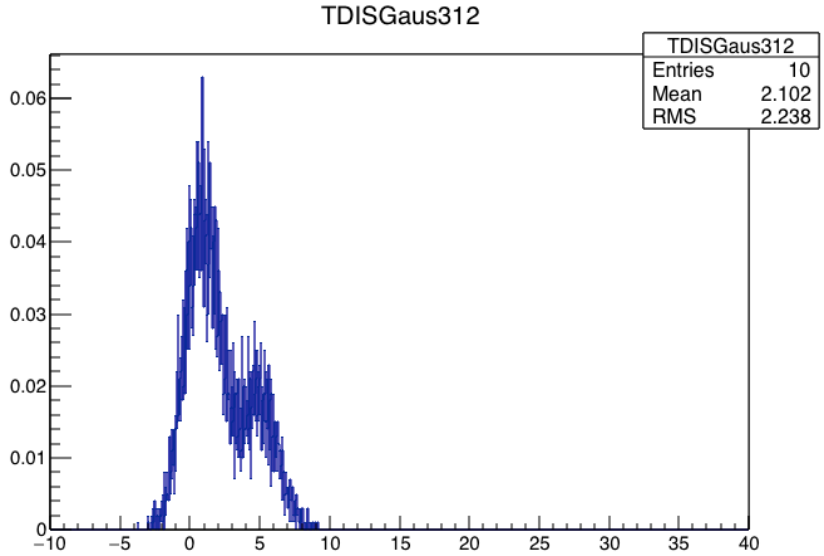
Chemical Compatibility: Is attacked by aromatic solvents, chlorinated solvents, ketones, solvent bonding cements, etc. It is stable in water, dilute acids and alkalis, lower alcohols and silicone greases. It is safe to use most epoxies and "super glues" with EJ-200.

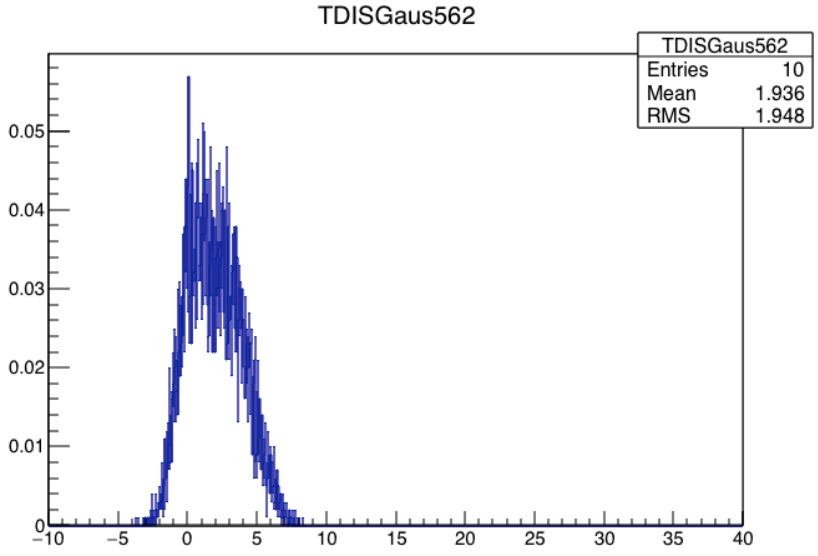


N.P.E.=10



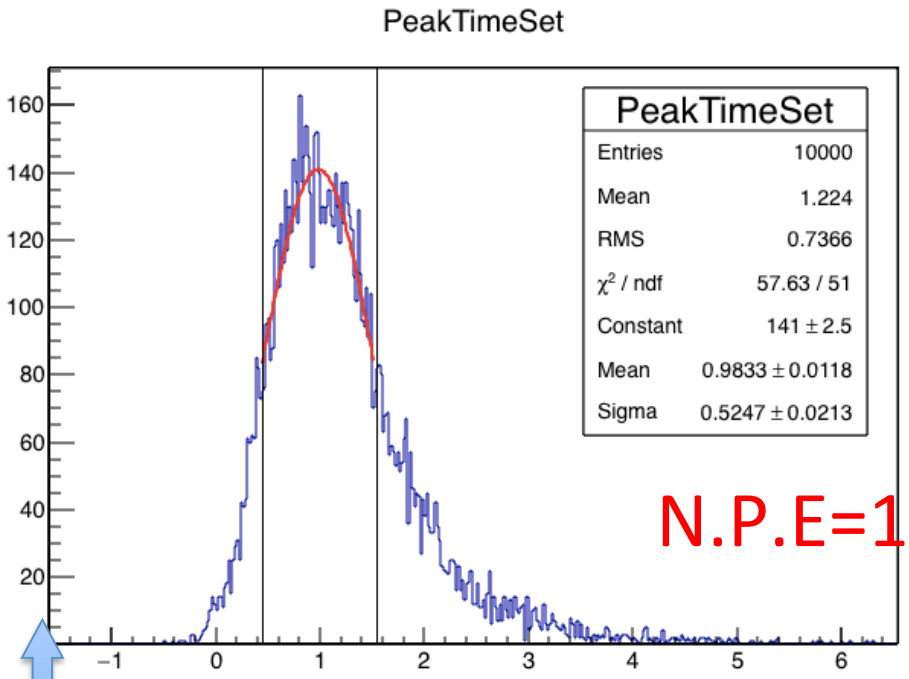


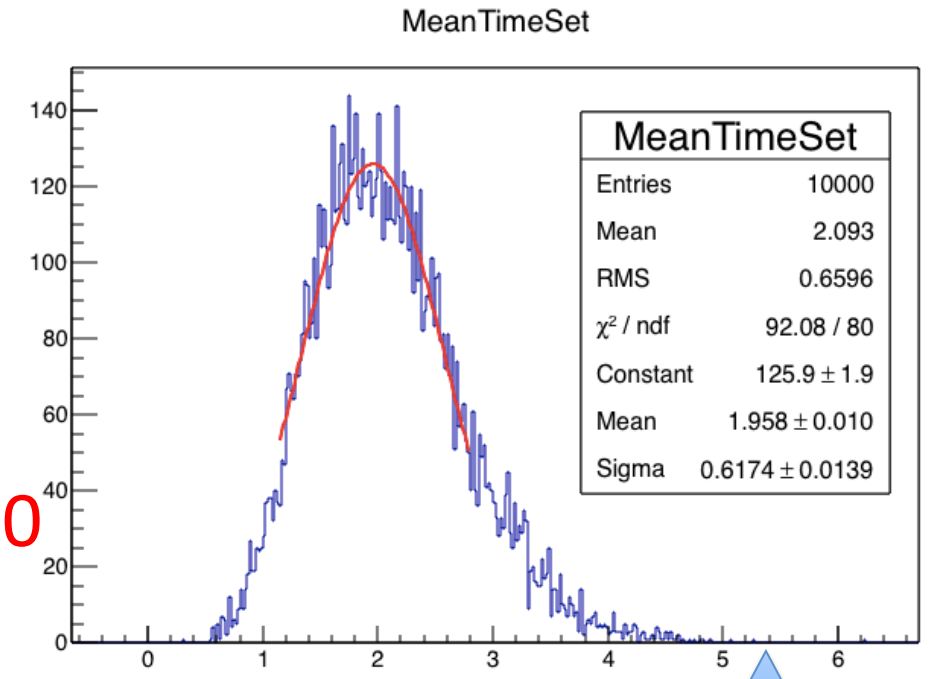




- Simulated pulses shape in case of N.P.E=10

Pulse timing

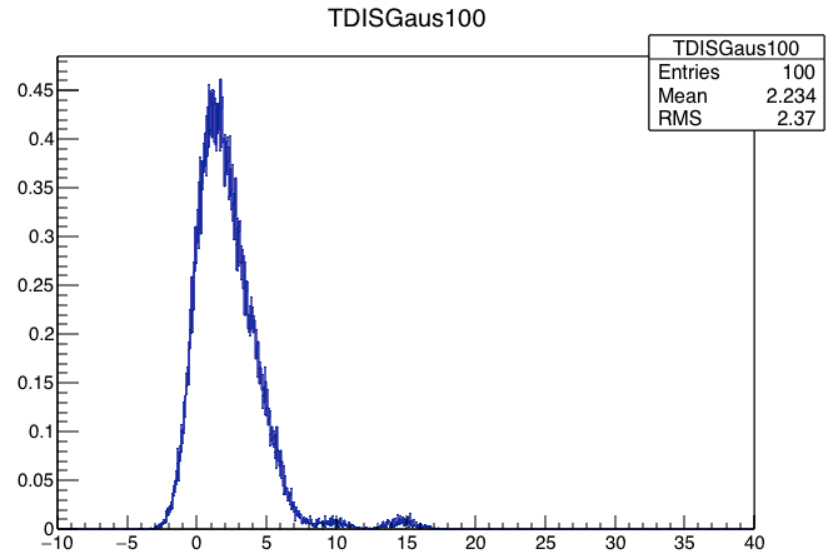


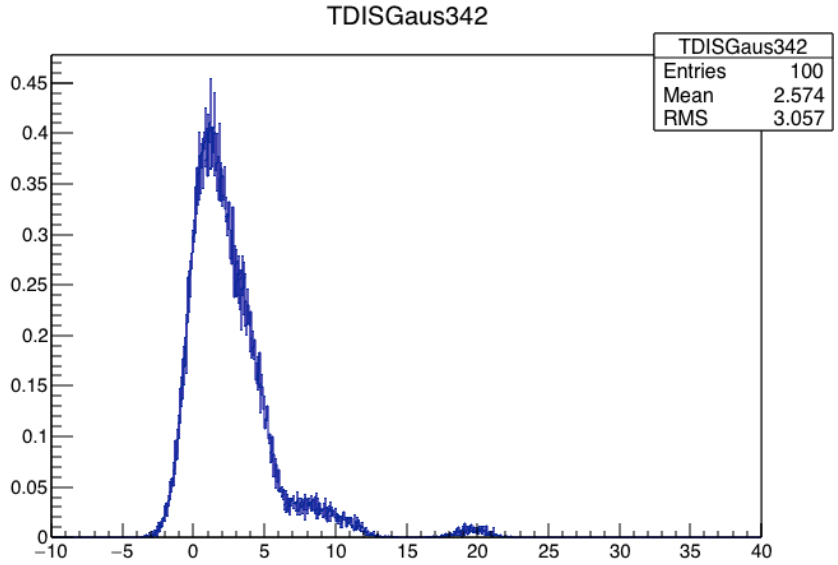


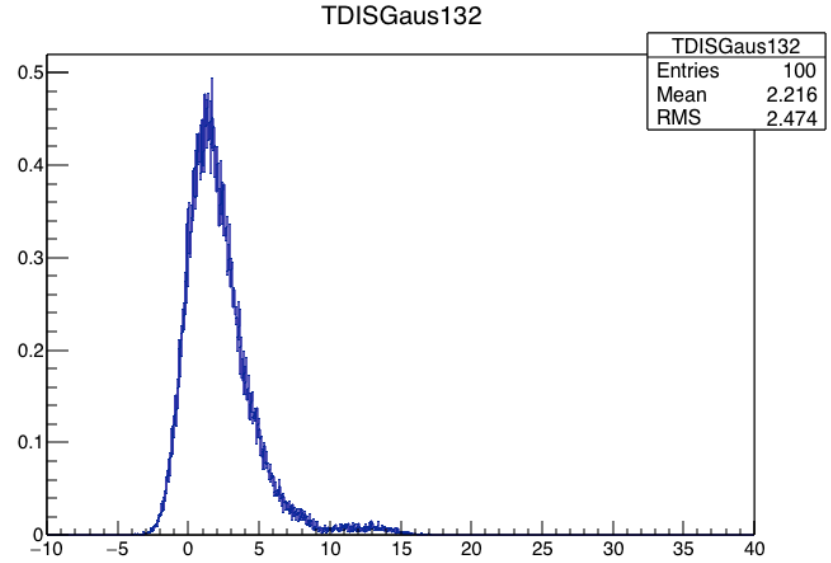
N.P.E=10

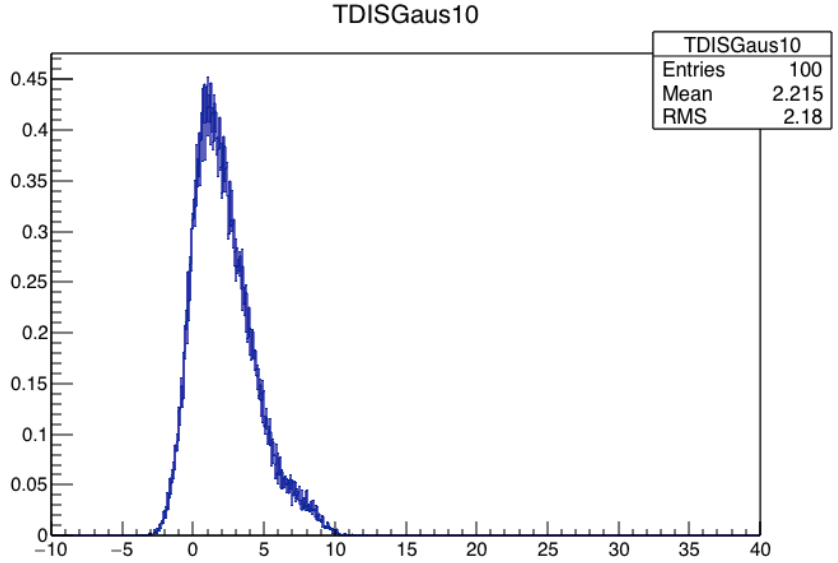
- Pulses have many timing reference
  - **Mean timing of pulse (ADC weight)**
  - **Peak timing of pulse**
  - 0.5 P.E. threshold

N.P.E=100



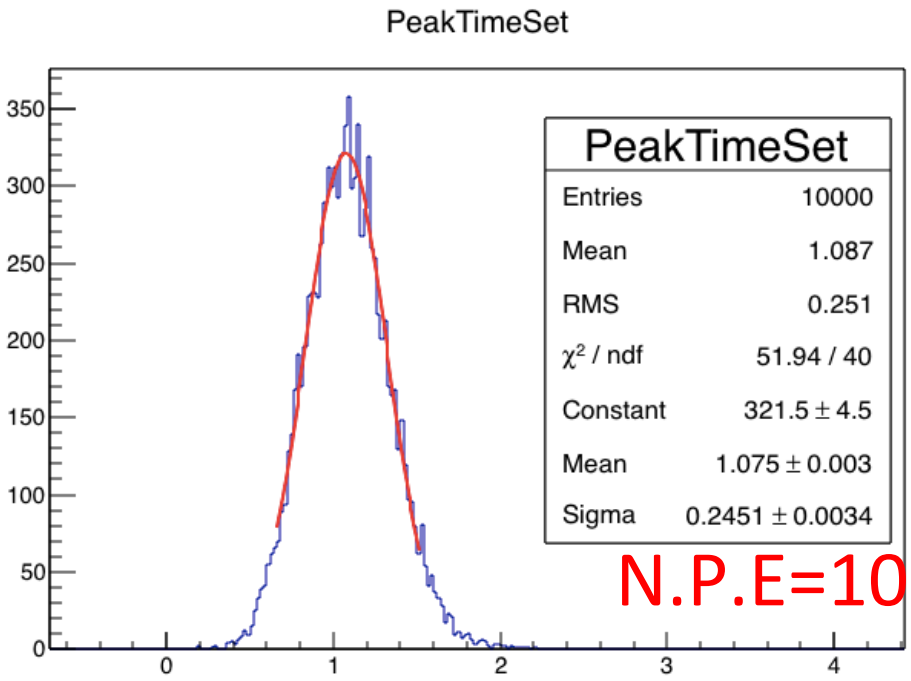




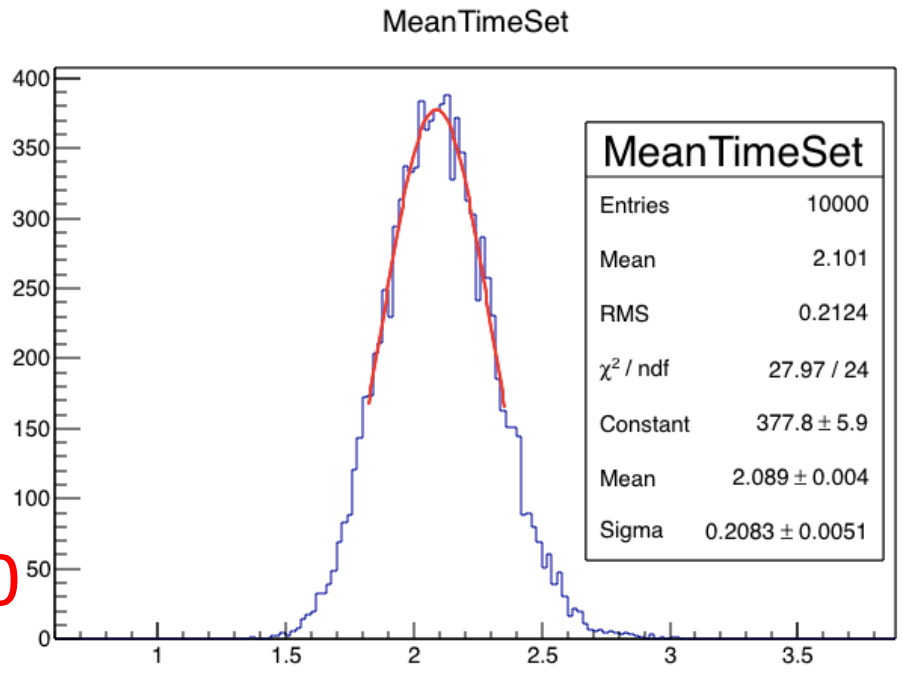


- Simulated pulses shape in case of N.P.E=100

Pulse timing



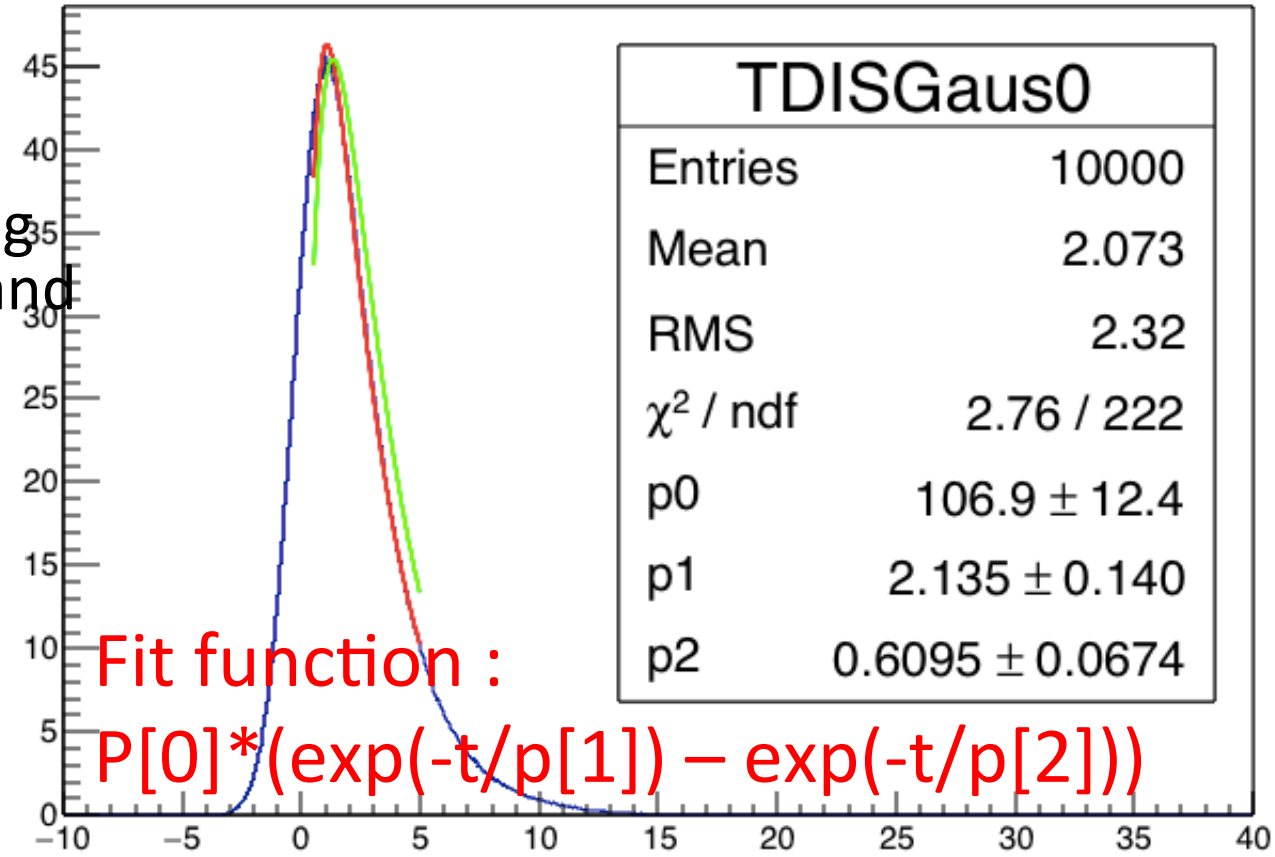
N.P.E=100



- Simulate pulses for other N.P.E.s

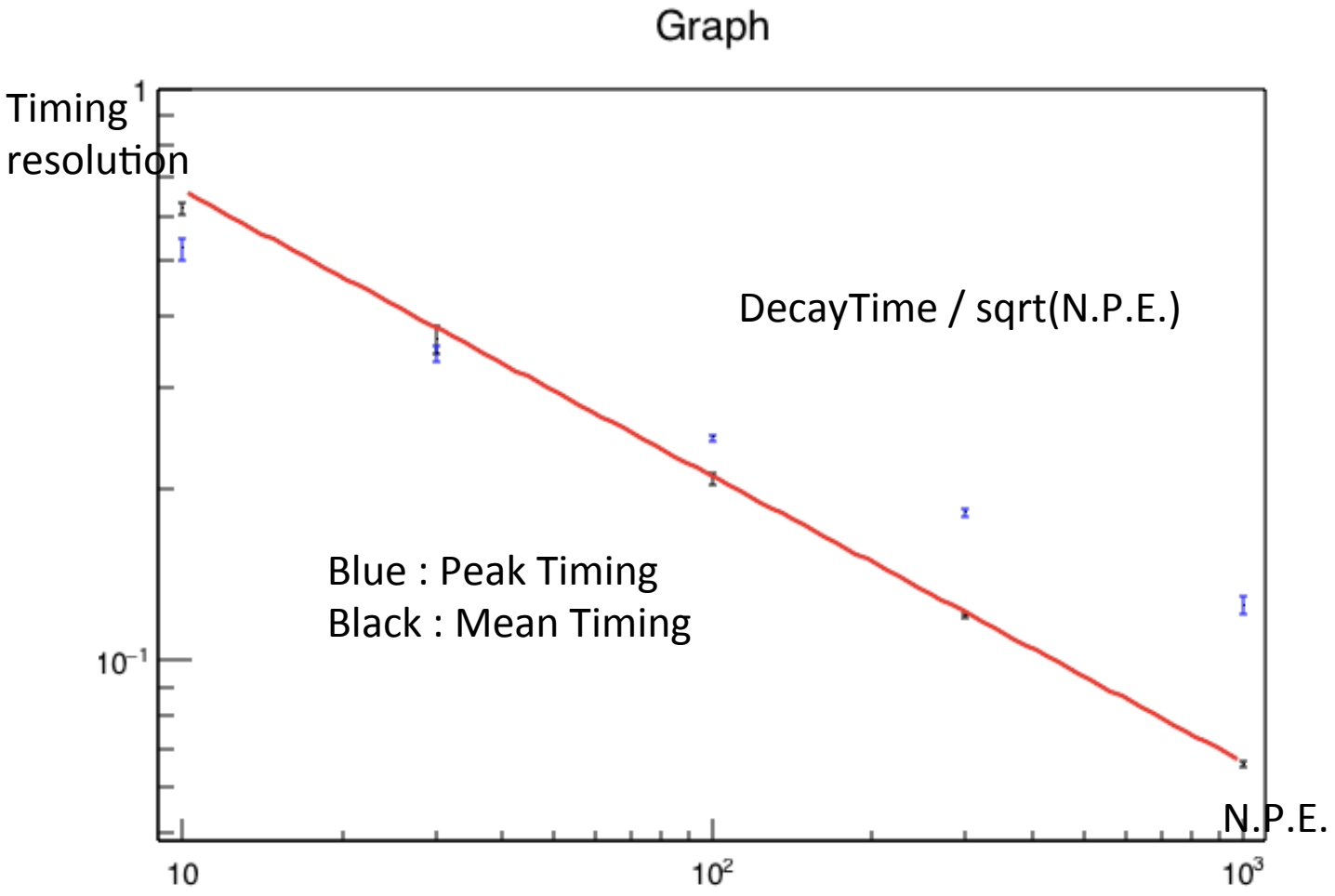
N.P.E = 10000

- pulse shape fitting with rising time and falling time
  - P1 : falling time
    - ~2.1ns
  - P2 : rising time
    - ~0.6ns
  - For EJ-200



- Blue line : histogram from exp*gaus
- Red line : fitted function
- Green line : expected distribution by Scint. Rising time and falling time

Timing resolution vs N.P.E.



- estimate mean timing using N.P.E.
- Peak timing estimation?