Development of high-precision neutron detector NeuRad within the project EXPERT

Muzalevsky Ivan

FLNR JINR

Dubna State University

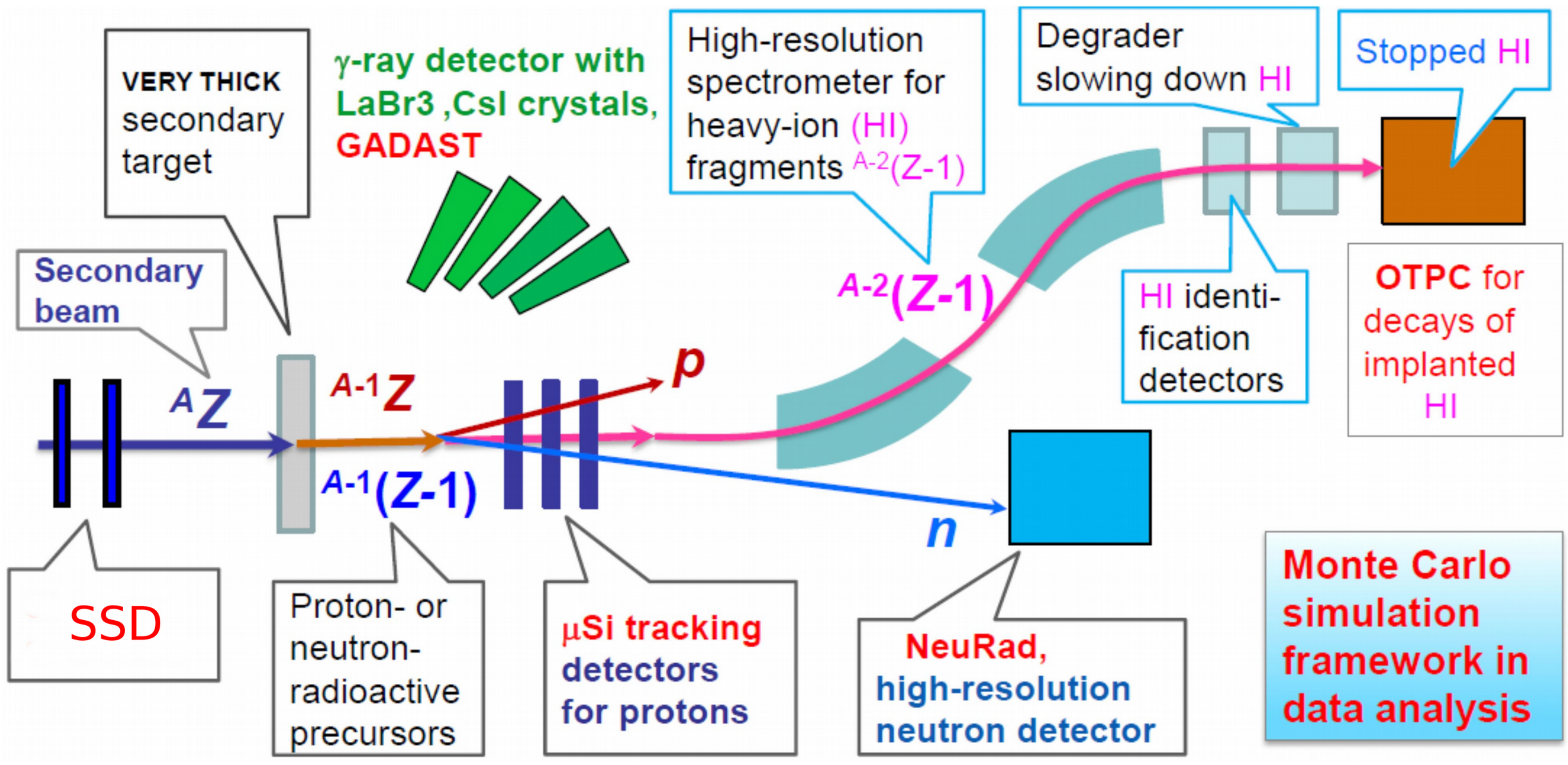
EXPERT

(EXotic Particle Emission and Radioactivity by Tracking)

- Studies of unknown exotic nuclear systems beyond proton and neutron drip-lines
- Study exotic nuclei? - radioactive beams!
- EXPERT – part of Super-FRS Experiment Collaboration at FAIR

Main GOALS: search and investigation of

- exotic radioactivity (2p,2n,4p,4n)
- resonance decays
- exotic excitation modes



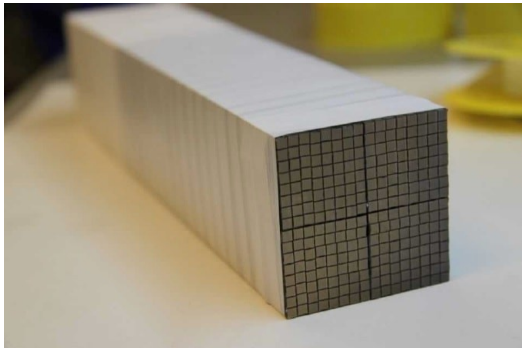
NeuRad

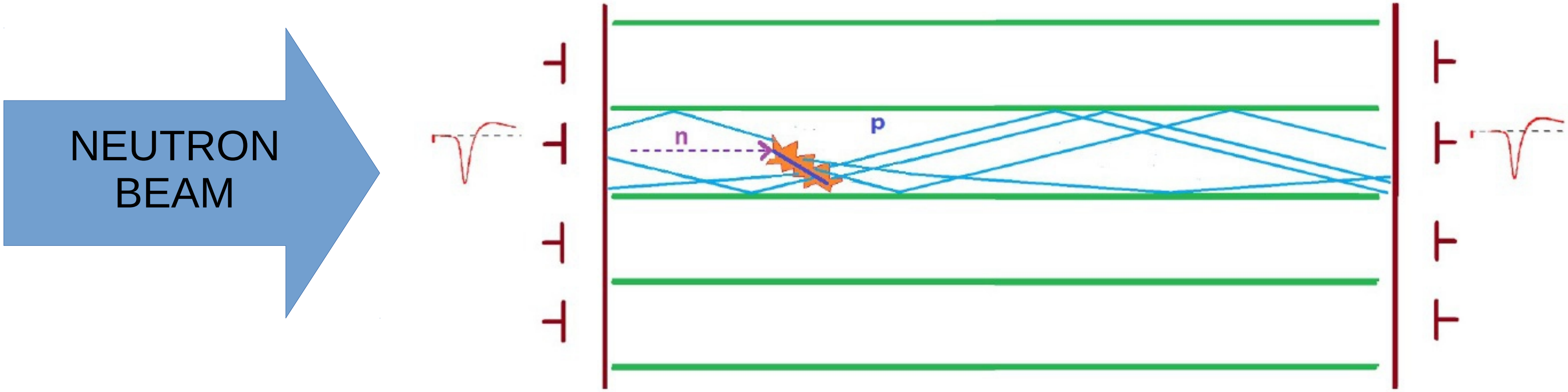
Neutron Radioactivity detector

More than **10000 fibers** in module structure.

Bundle:

- 256 fibers 3x3x1000 mm
- MAPMT from each side





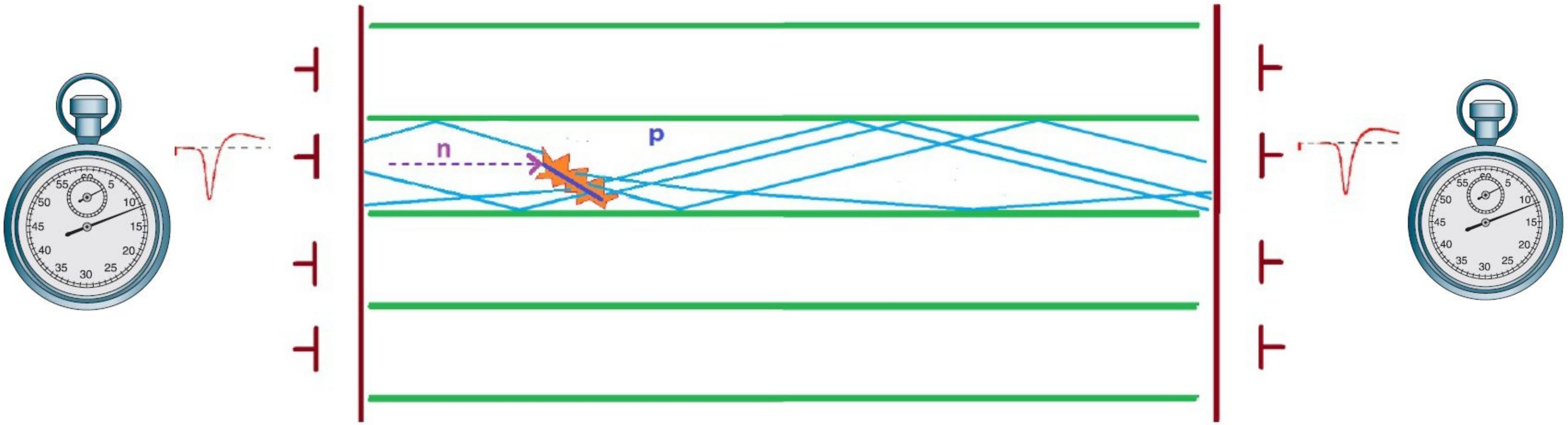
- **Longitudinal coordinate** of the interaction along the fiber
- **Determination the very first hit**
- Avoid **neutron cross-talk**

NeuRad time and coordinate resolution

$$\vec{Z} = \Delta\tau\frac{c}{n}$$

- relation of coordinate and time difference of signals

0,5 ns time resolution provides about 10 cm coordinate resolution



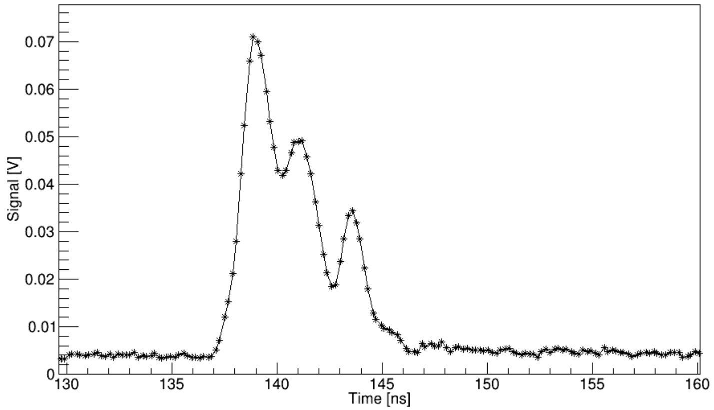
How can we achieve it?

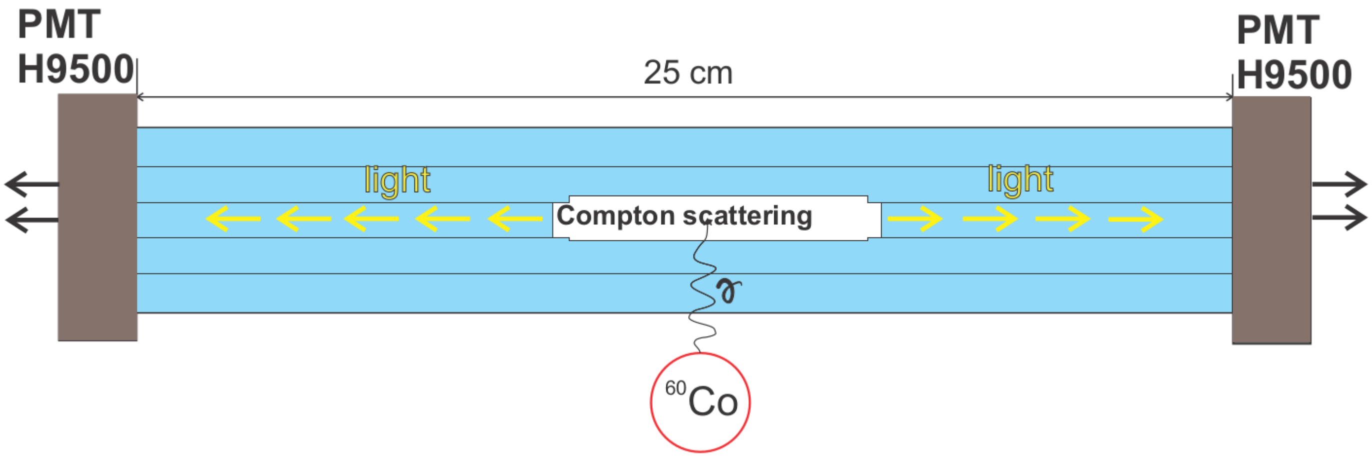
NeuRad prototype tests in Dubna:

- 256 scintillation fibers 3 x 3 x 250 mm
- MAPMT HAMAMATSU9500
- Source – **60Co**, collimated
- **DRS4 digitizer board** (5GS/s)
- Oscilloscope **Tektronix MSO7354** (10GS/s)

Reference measurements at GSI:

- Thin scintillator 50 x 50 x 4 mm
- Source – **137Cs**
- Oscilloscope **Le Croy** (20 GS/s)





E_{gamma}=1173 keV, 1333 keV

Data analysis

Tool: New pulse shape analysis software implemented in **ExpertRoot** (still under development)

http://er.jinr.ru/

Developted methods

Time properties

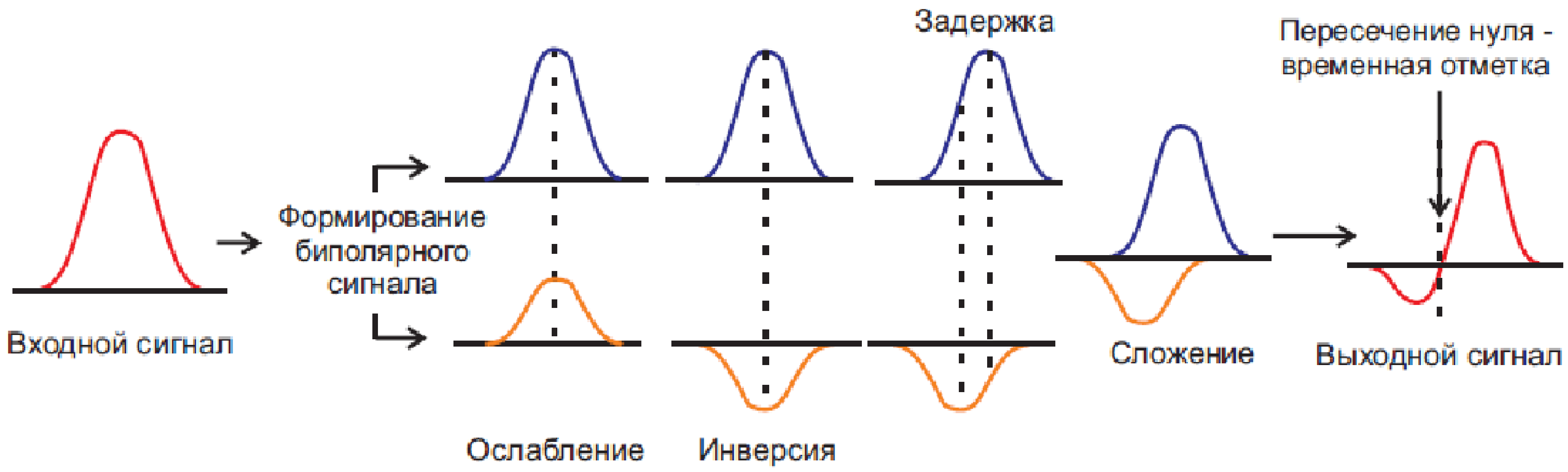
- Constant Fraction Discriminator
- Leading Edge Discriminator
- Front edge analysis

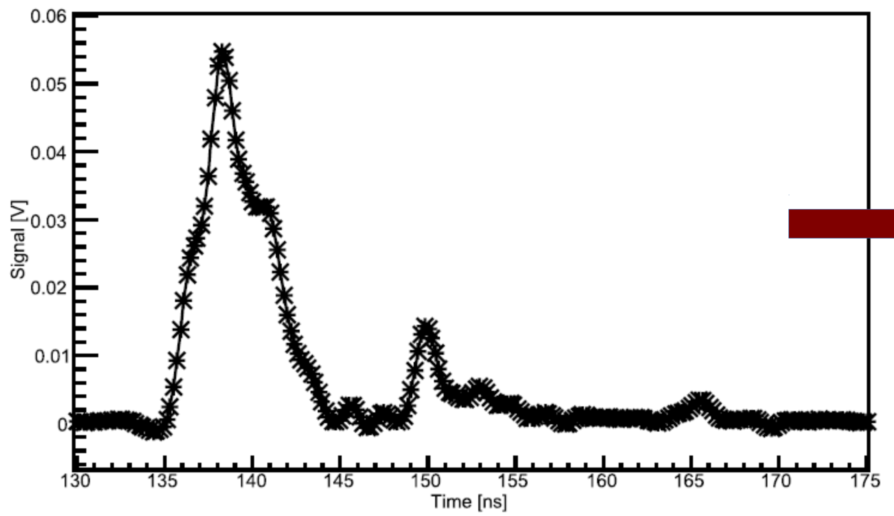
Determining selection values

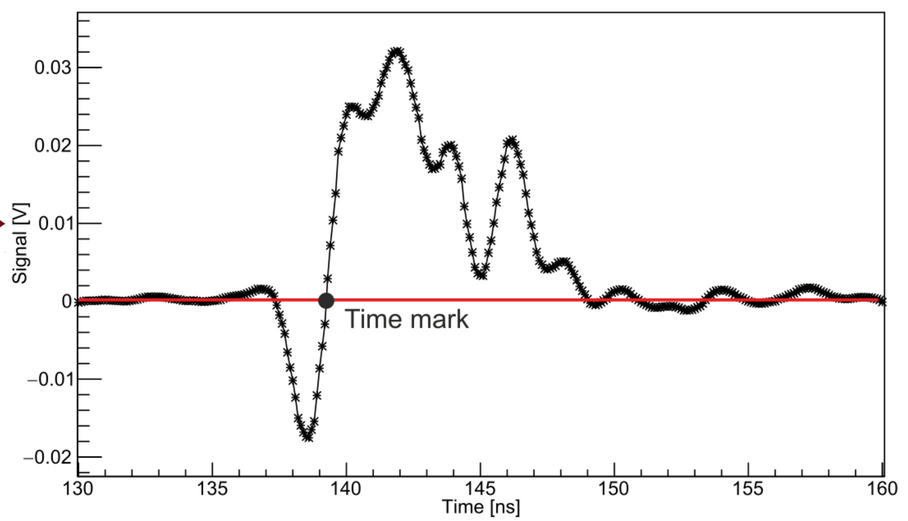
- Anode charge
- Time-over-Threshold
- Scintillator decay time
- Front edge slope and rising time

If we want to choose digitizing equipment for NeuRad we should find out which method is the most applicable to determine signal time

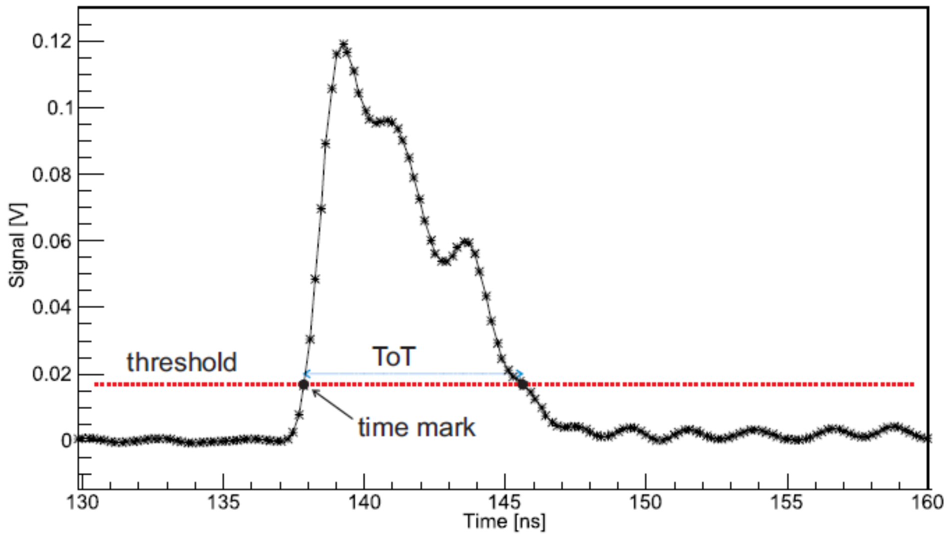
Constant Fraction Discriminator

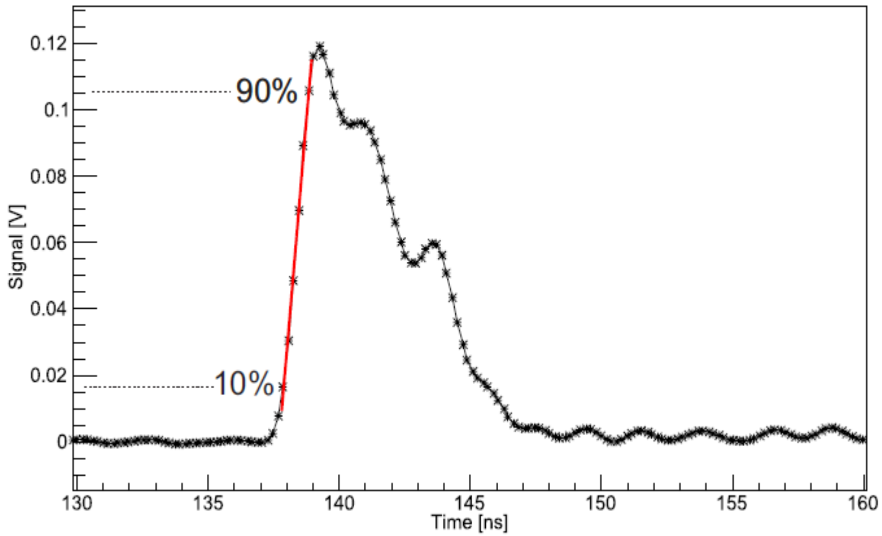




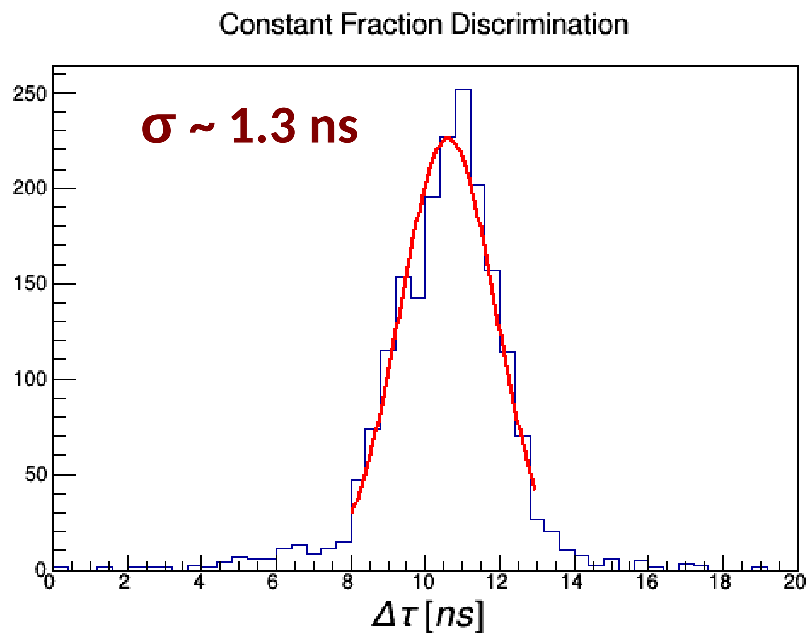


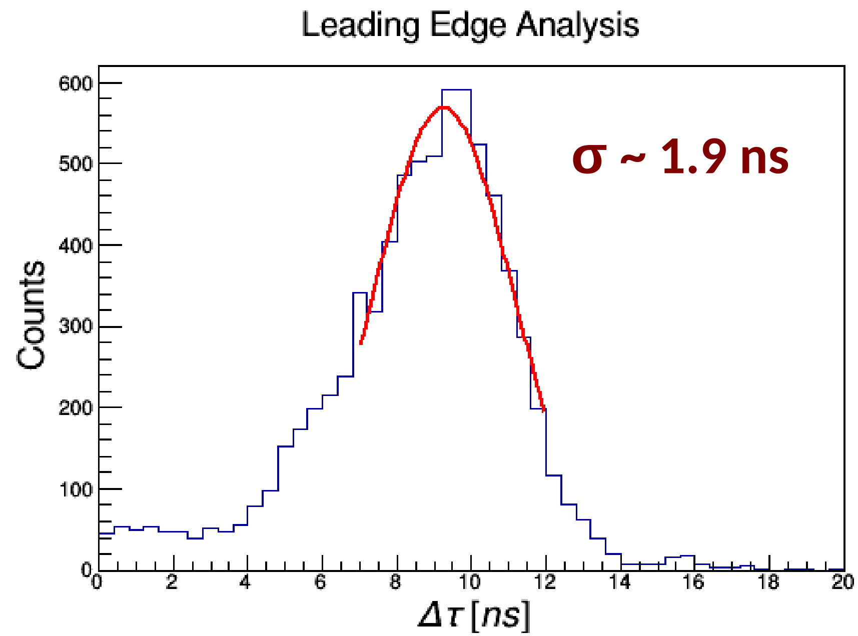
Leading **E**dge **D**iscriminator
Front edge fit
Time-**o**ver-**T**hreshold

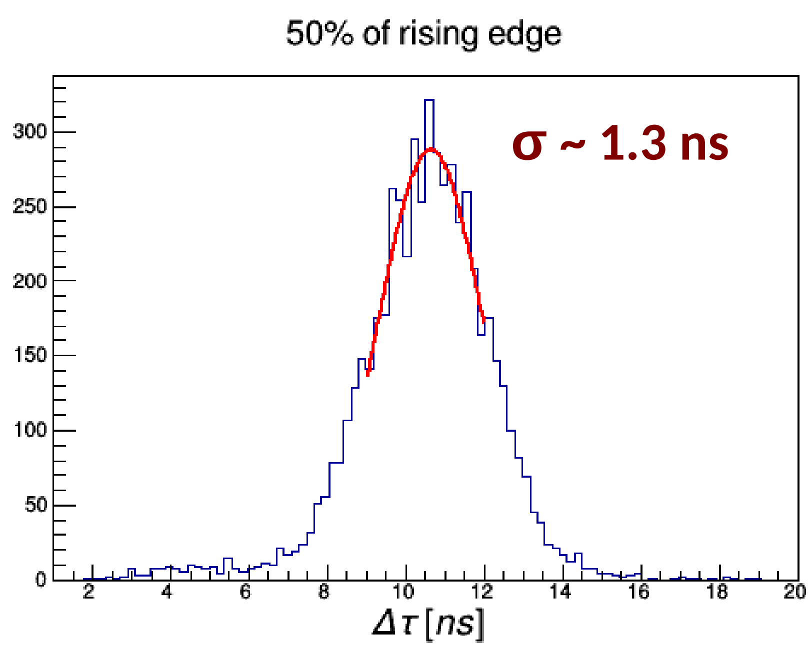


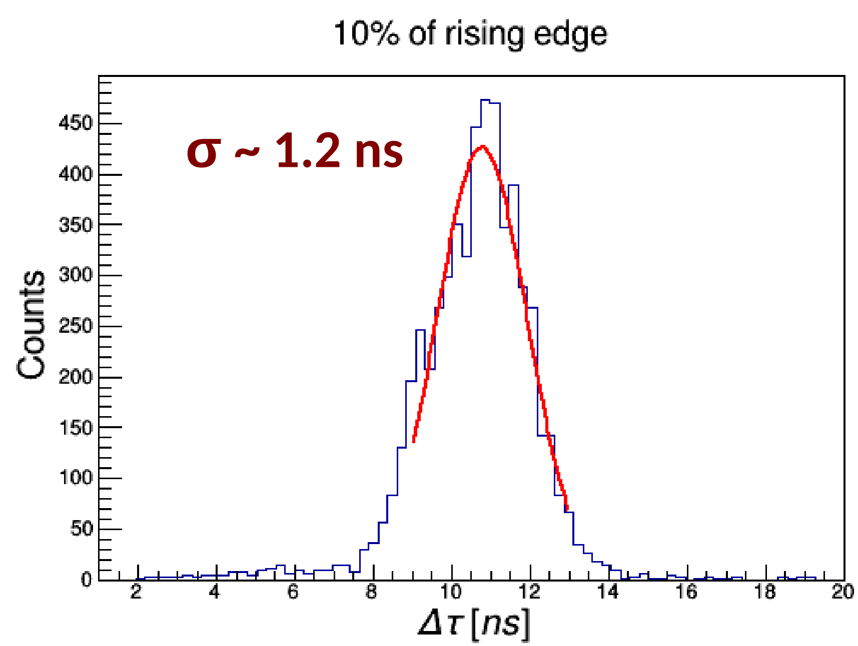


NeuRad: time precision









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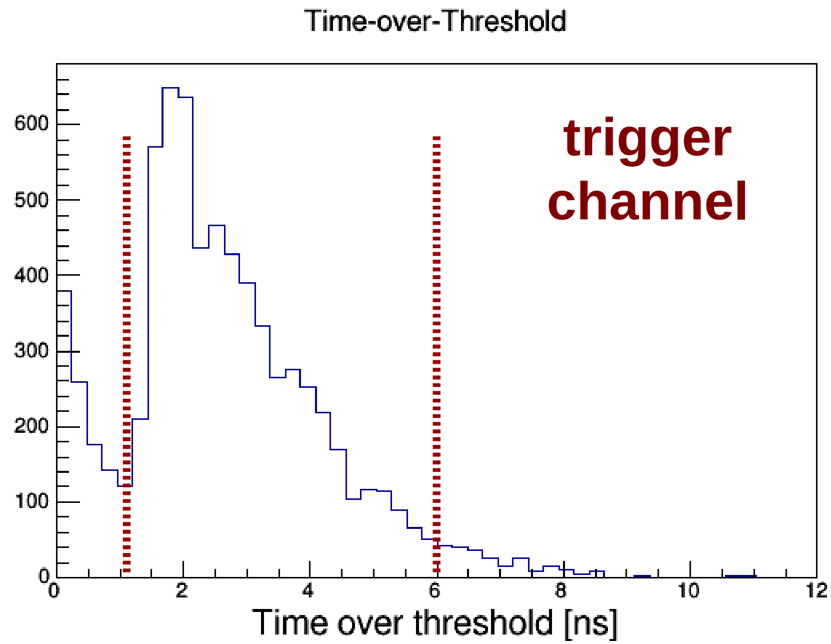
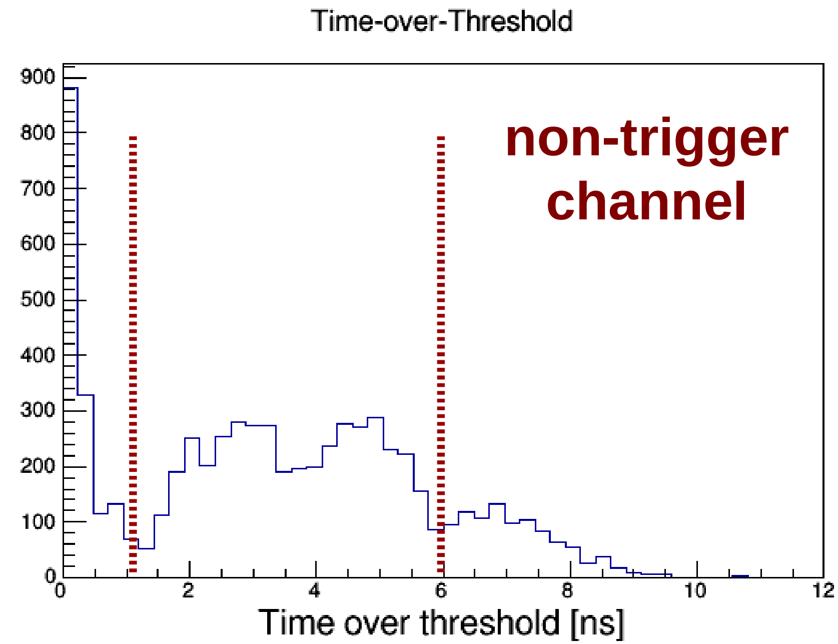
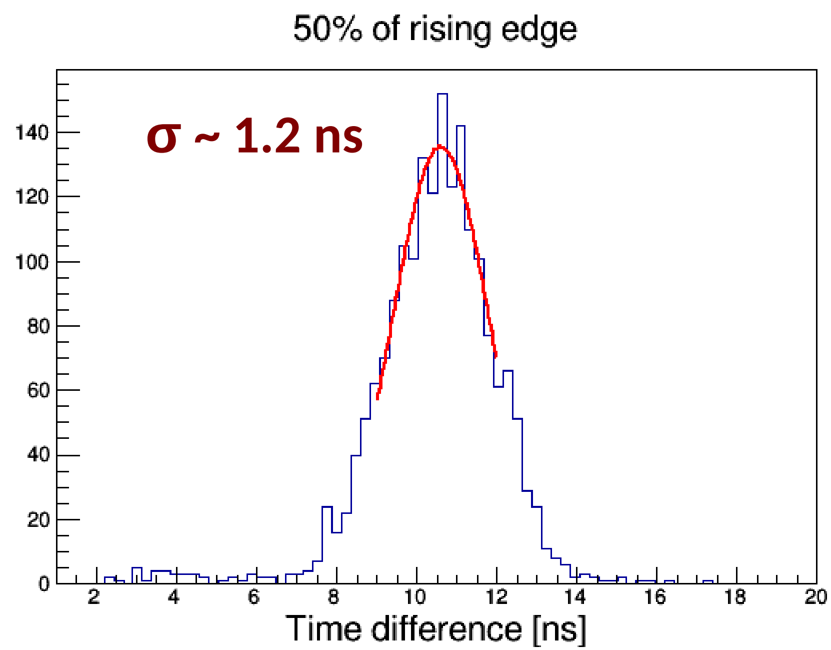
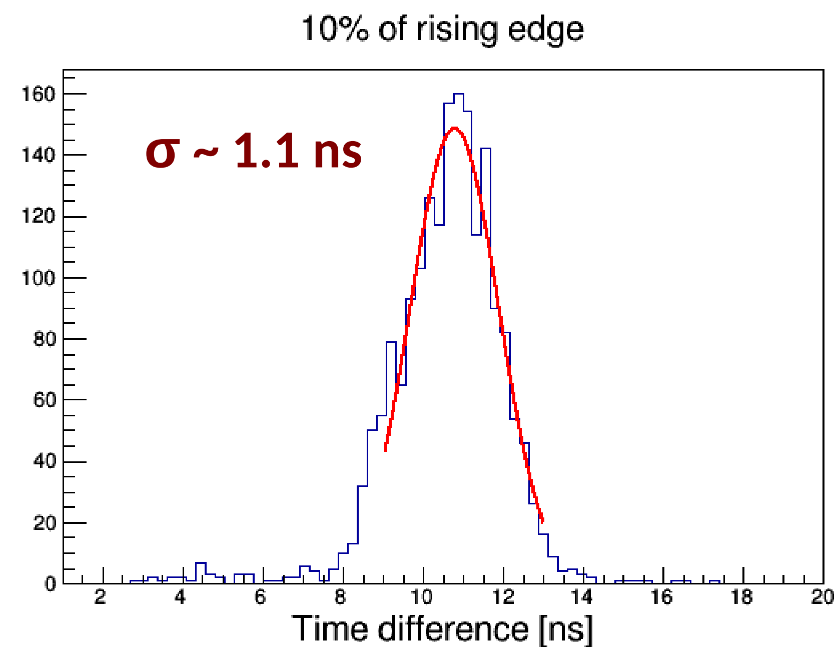
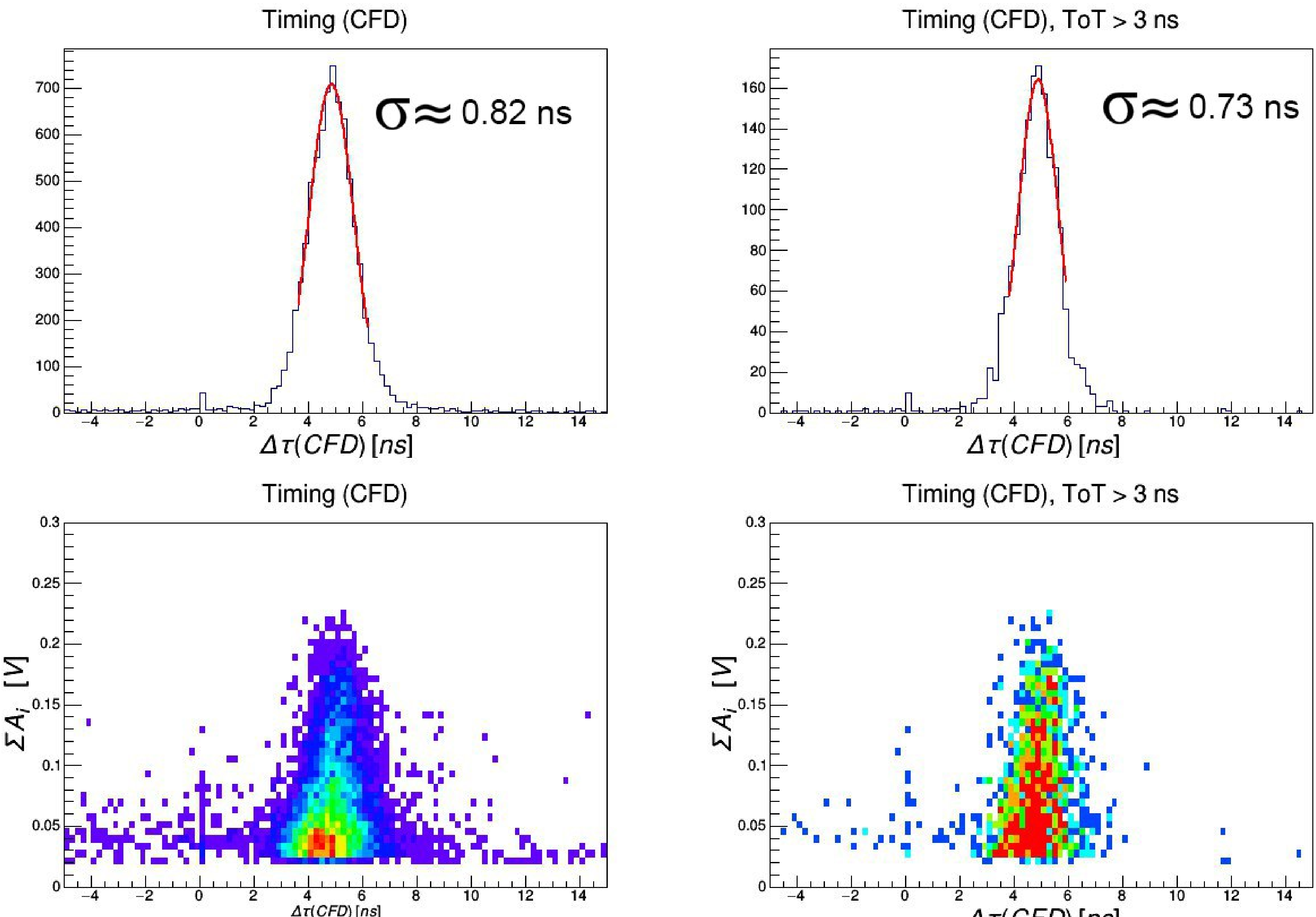








NeuRad: reference measurements



Modeling experiment in EXPERTroot

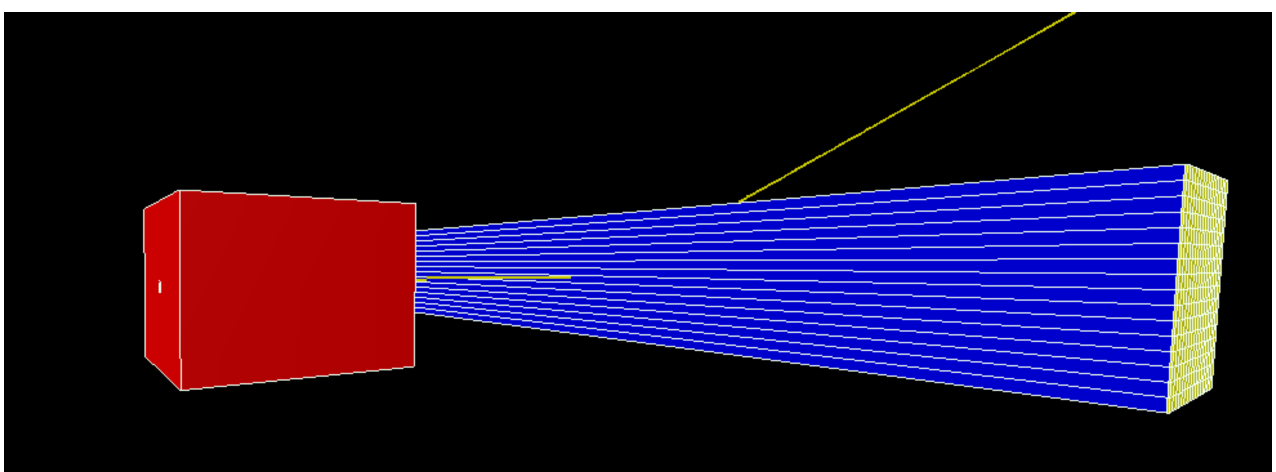
EXPERTroot is a framework for Monte-Carlo simulations detector responses signals, reconstruction of events and analysis data of the EXPERT experiment.

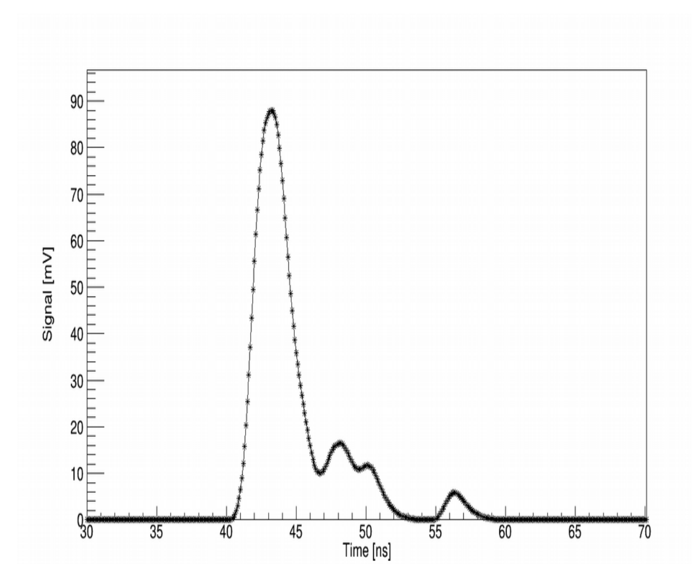
- GEANT4
- $dL_i = Q_i \cdot dE_i,$
- Birk's law $Q_i = \dfrac{A}{1 + B\frac{dE_i}{dx_i} + C\left(\frac{dE_i}{dx_i}\right)^2}$
- Amplitude and anode time of single electron signal

$$A_{pe} = |N(A, \sigma)|$$

$$T_{pe} = T_k + N(D_{\mathrm{PMT}}, J_{\mathrm{PMT}}).$$

- Single electron signal shape $U(t) = a\, A_{pe}\,(t - T_{pe})^2 \exp\left(-\dfrac{t - T_{pe}}{b}\right)$





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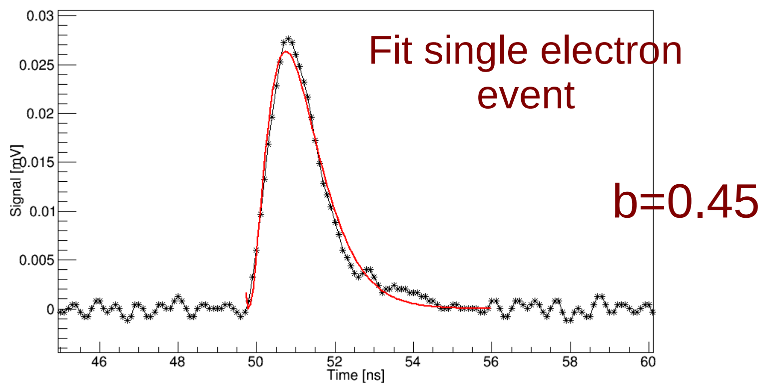

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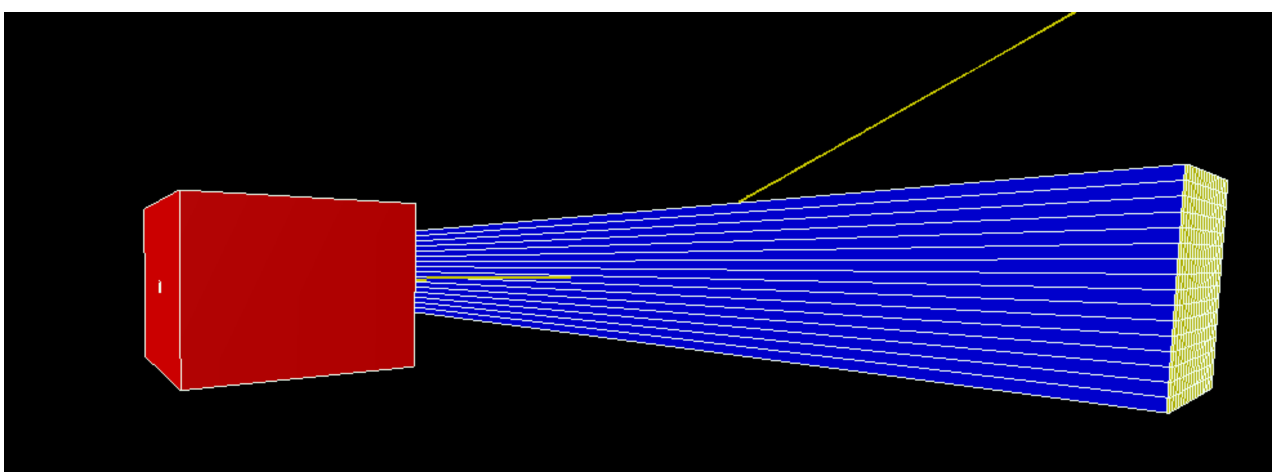
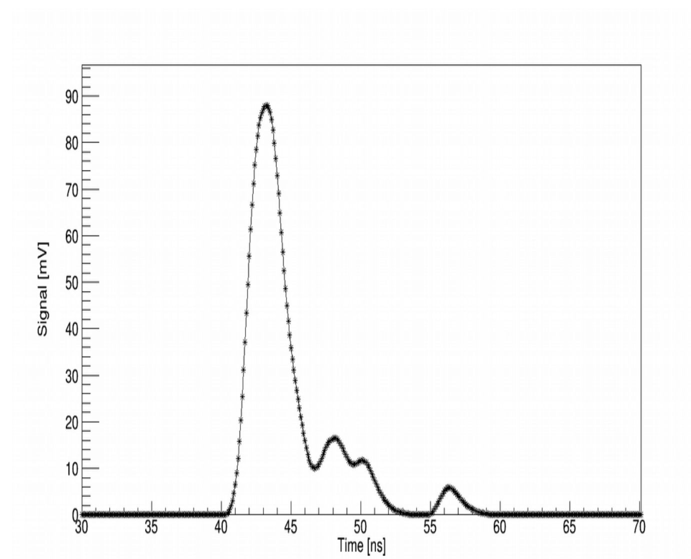
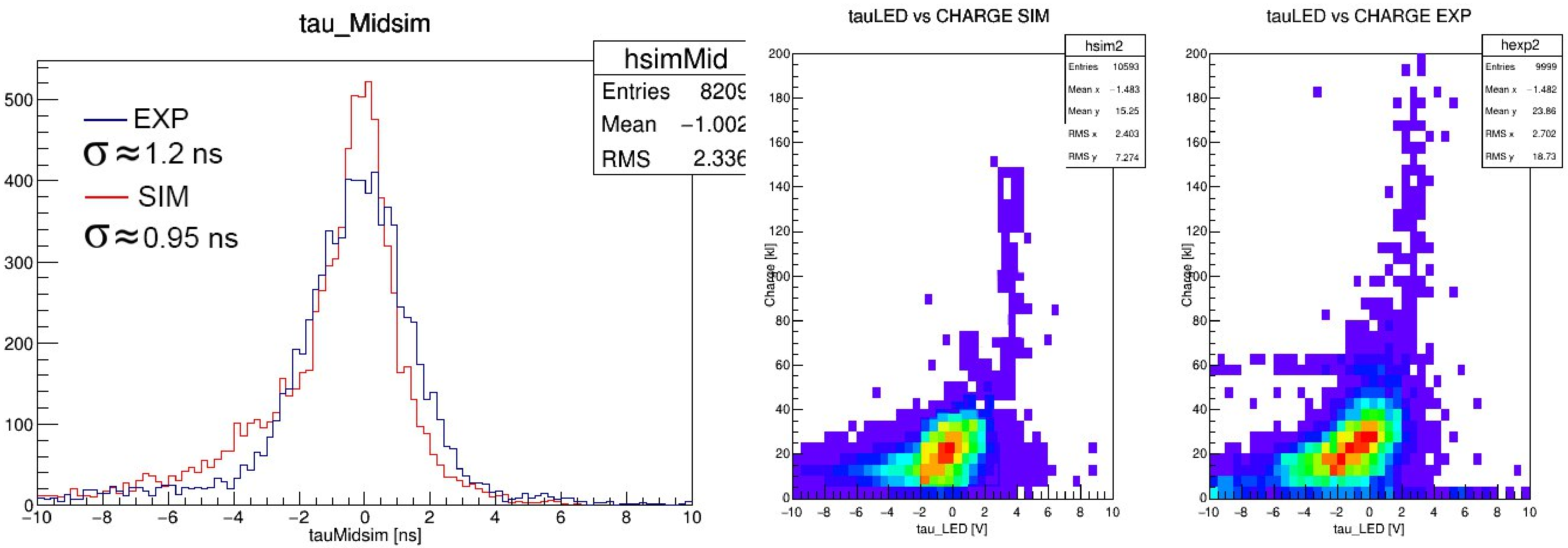




Compare



- Experimental time resolution = 2,83 ns
- Simulation time resolution = 2,24 ns

Thanks for attention

Virtual signal form