Tests of the neutron detector NEURAD of the EXPERT/SuperFRS experiment collaboration

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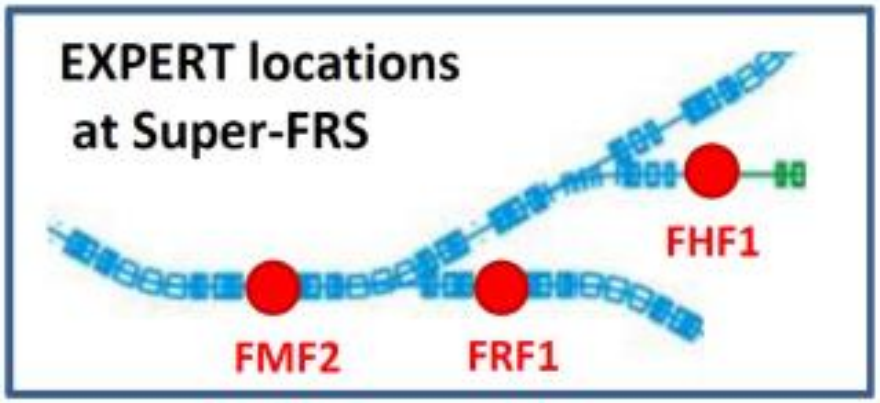
- **NeuRAD detector** in frame of EXPERT project @ SuperFRS FAIR
- **Timing of NeuRAD** – why do we need it?
- **Test of NeuRAD prototype** in FLNR JINR, Dec. 2016
- **Data analysis** of the test in Dubna
- **Lab test** in GSI
- **Summary and plans**

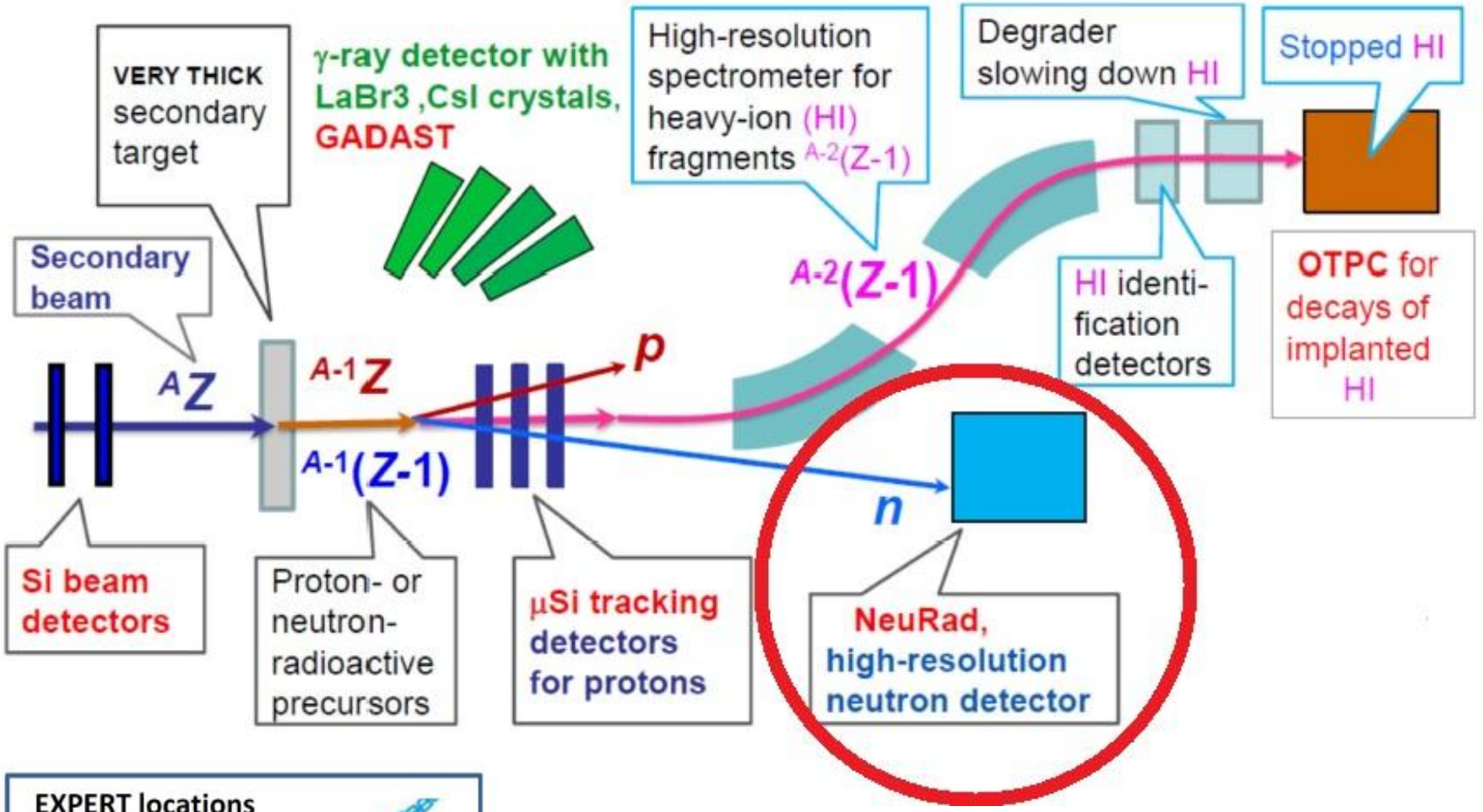
EXPERT project @ SuperFRS

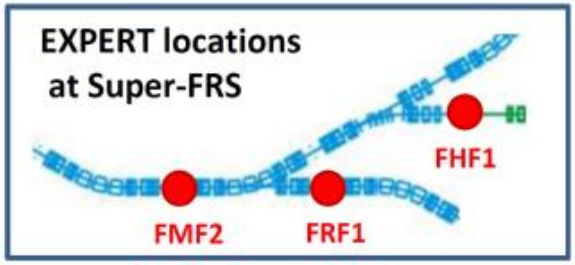
• EXPERT - part of the physics program of the Super-FRS Experiment Collaboration



• Studies of the unknown exotic nuclear systems in the furthermost parts of the nuclear landscape – beyond neutron and proton drip-lines

EXPERT project @ SuperFRS





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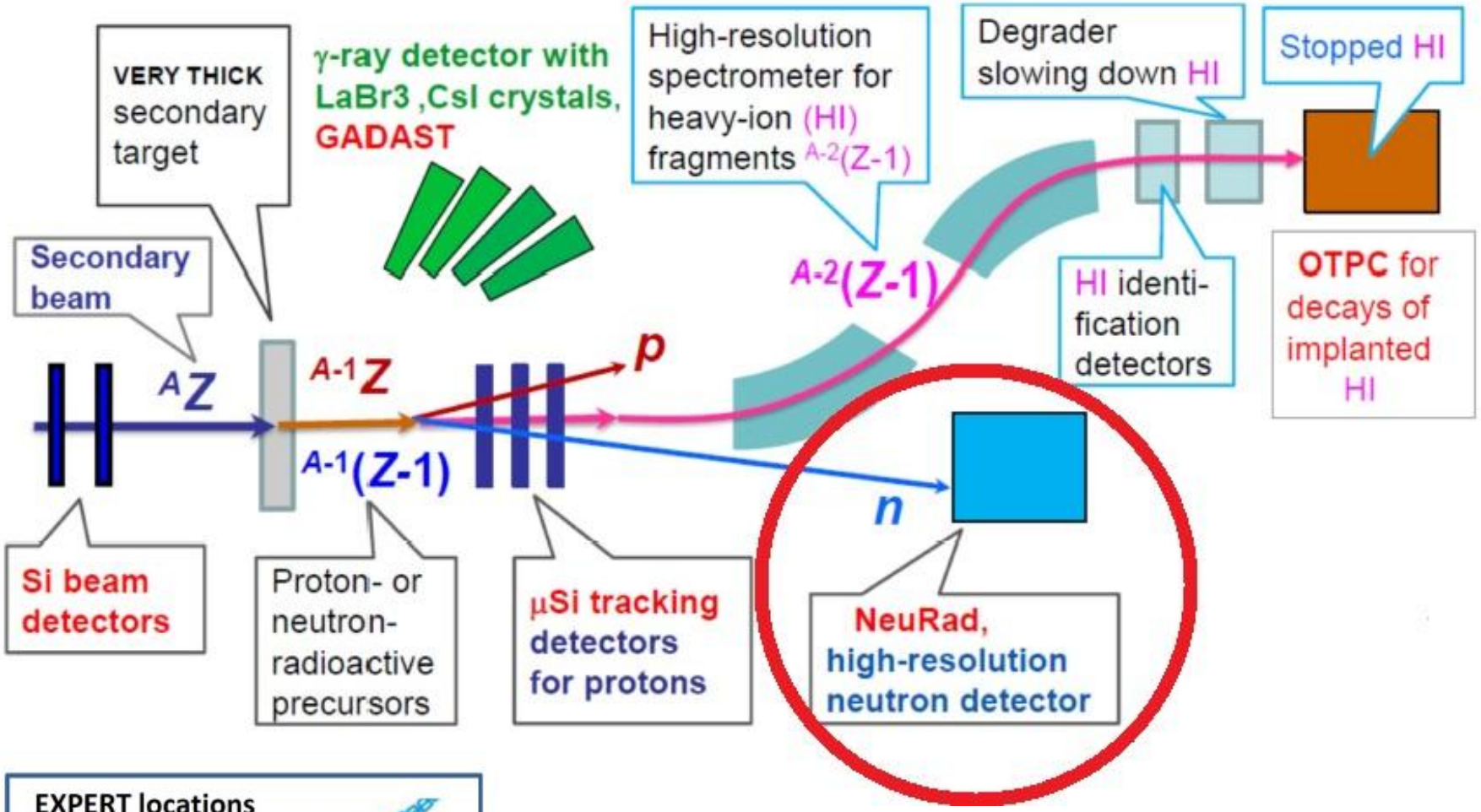
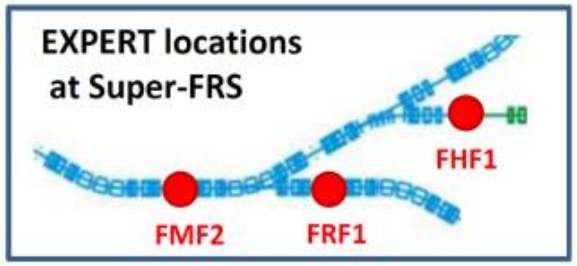
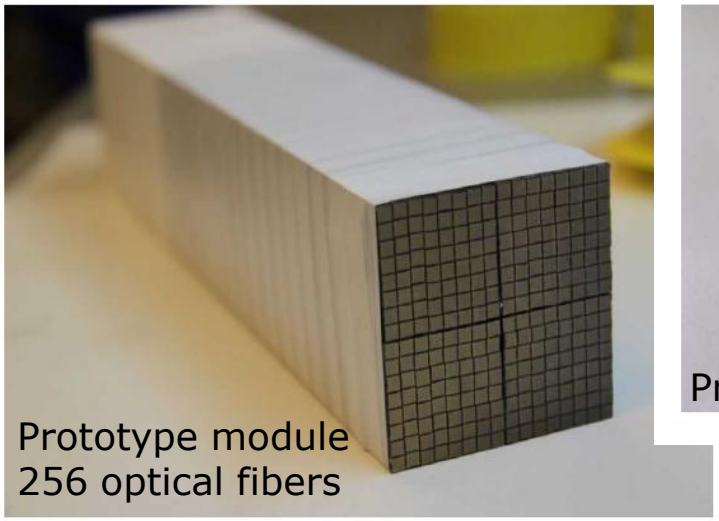
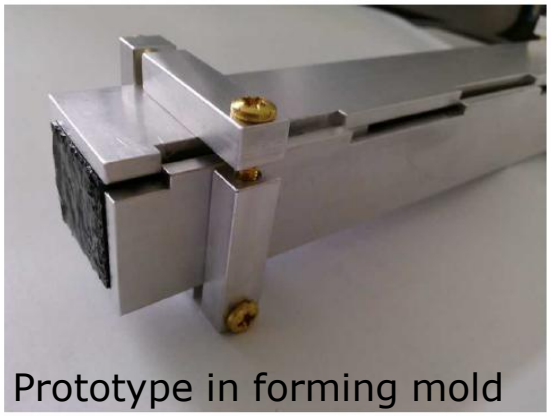




Total angular range **12 mrad** – low transfer momentum, corresponding to the decay energies expected in the range of **0.1 – 100 keV**.

NeuRAD neutron detector

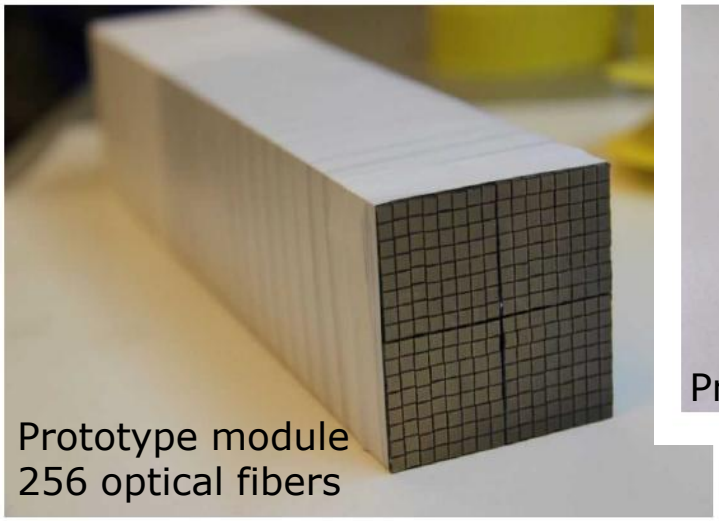

Prototype module
256 optical fibers


Prototype in forming mold

- 10000 fibers
- 1m long
- cross section of 3x3 mm^2
- 36 modules in total

Scintillating fibers are grouped into bundles with square cross section.
Each bundle is read out by two multi-anode PMT used as photo detectors.

NeuRAD neutron detector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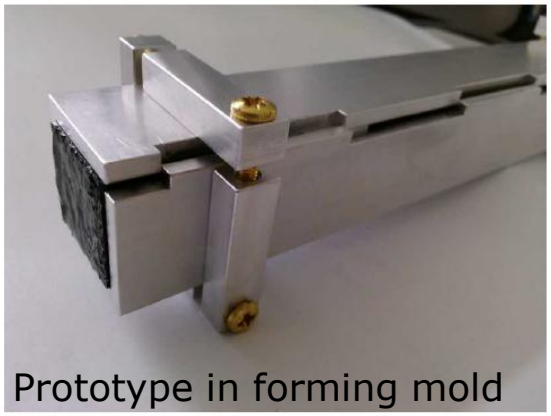
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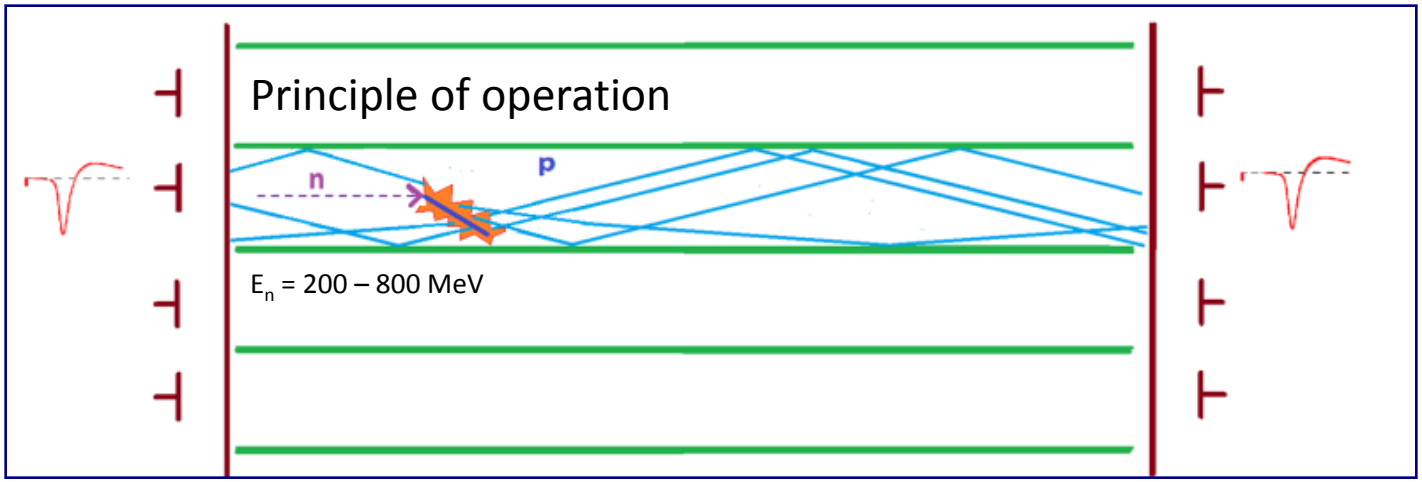
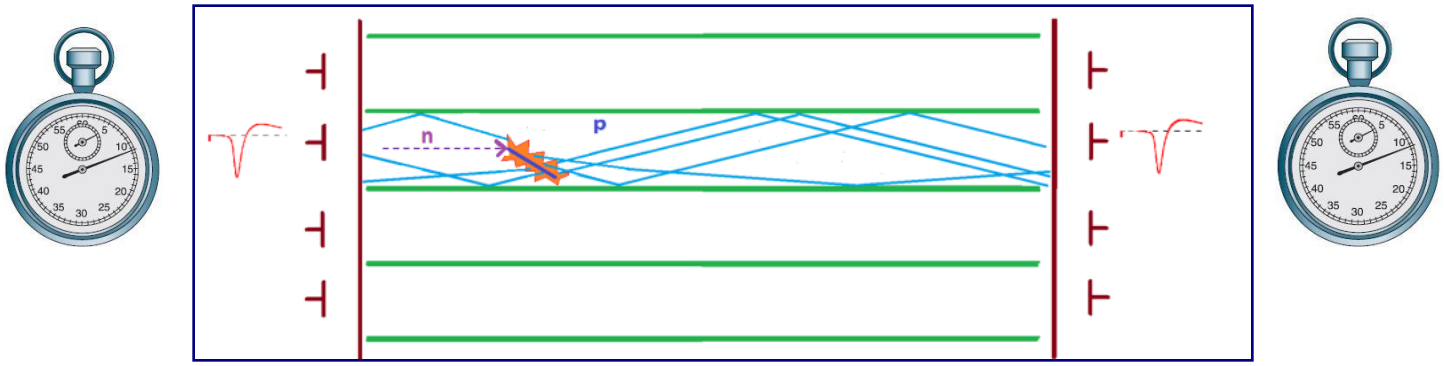


Timing characteristics

- **Longitudinal coordinate** of the neutron interaction along the fiber (~ 6 cm position resolution or down to 0.5 ns)
- **The very first hit** (neutron event) should be determined
- Avoid **neutron cross-talk**



Test in Dubna, December 2016

- **NeuRAD prototype** in black box with 2 PMTs
- Oscilloscope **Tektronix MS07354** (10 GS/s, 1000 sampling points)
- **DRS4 digitizer board** (5GS/s, 1024 sampling points)

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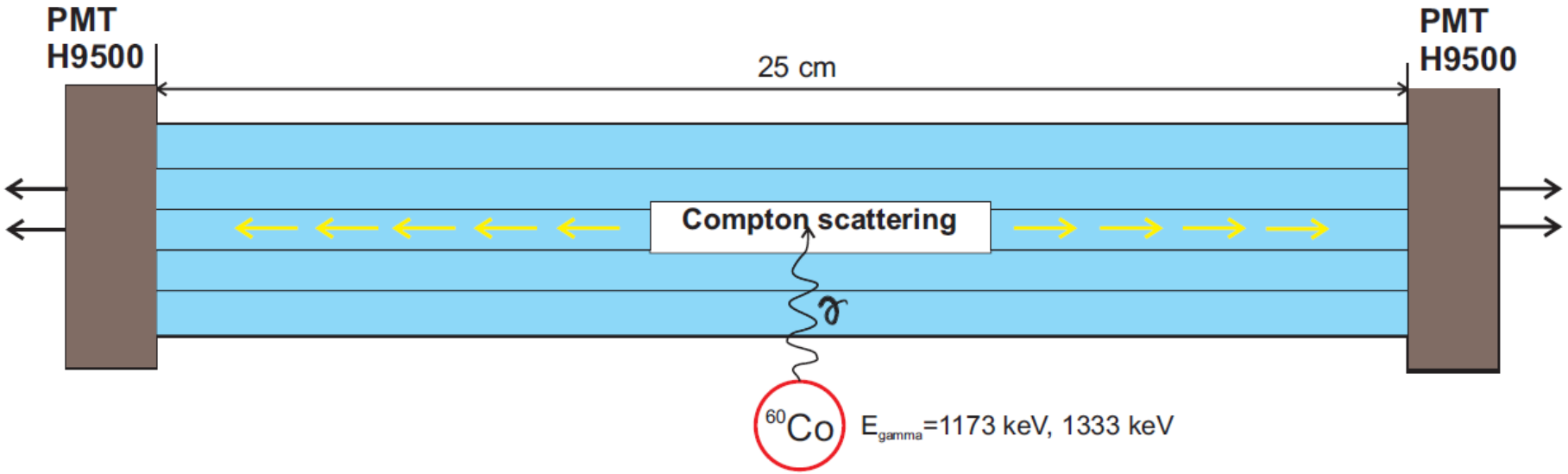
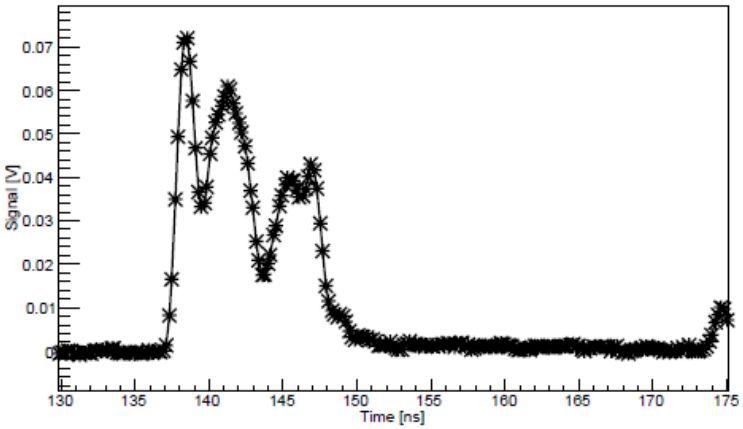
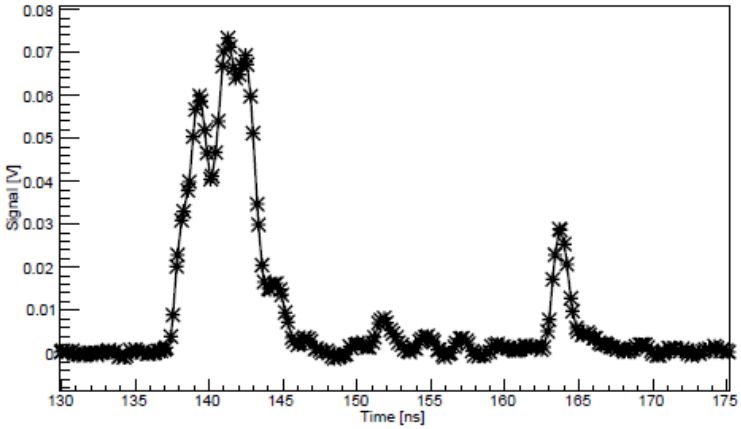


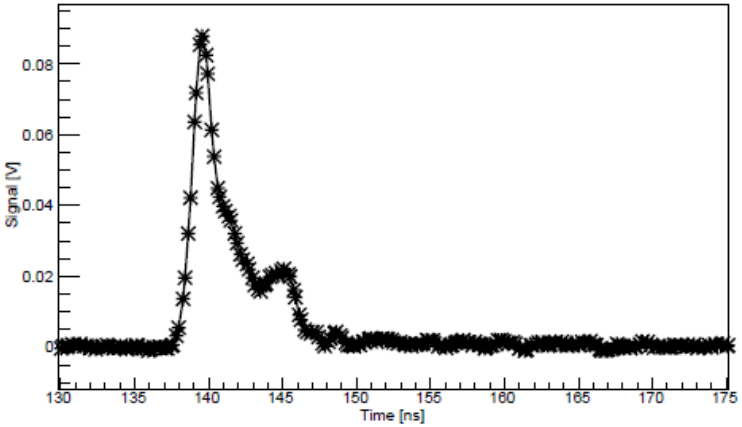
- Compare results from two acquisition systems

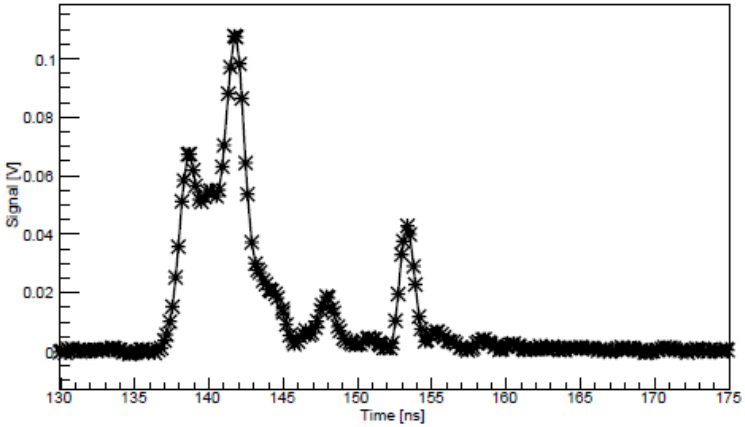
Test in Dubna, December 2016

- Signal shapes (rise times ~ 1.5 ns)
- Pulse shape is **varied very much**: reflection of light, low amount of collected light, gamma re-scattering

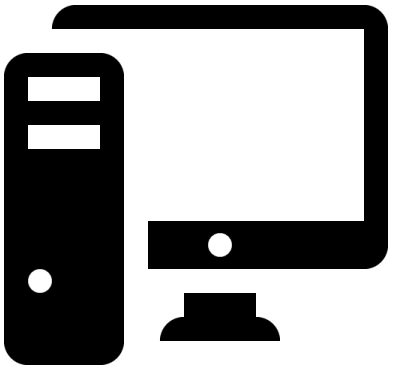








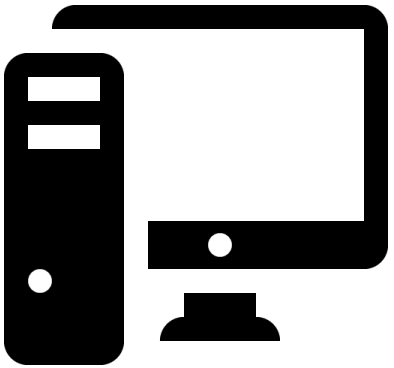
Data analysis



Techniques:

- **C**onstant **F**raction **D**iscrimination
- **L**eading **E**dge analysis
- Front edge fit
- Corrections on the Time-over-Threshold, rise time and slope coefficient.

Data analysis



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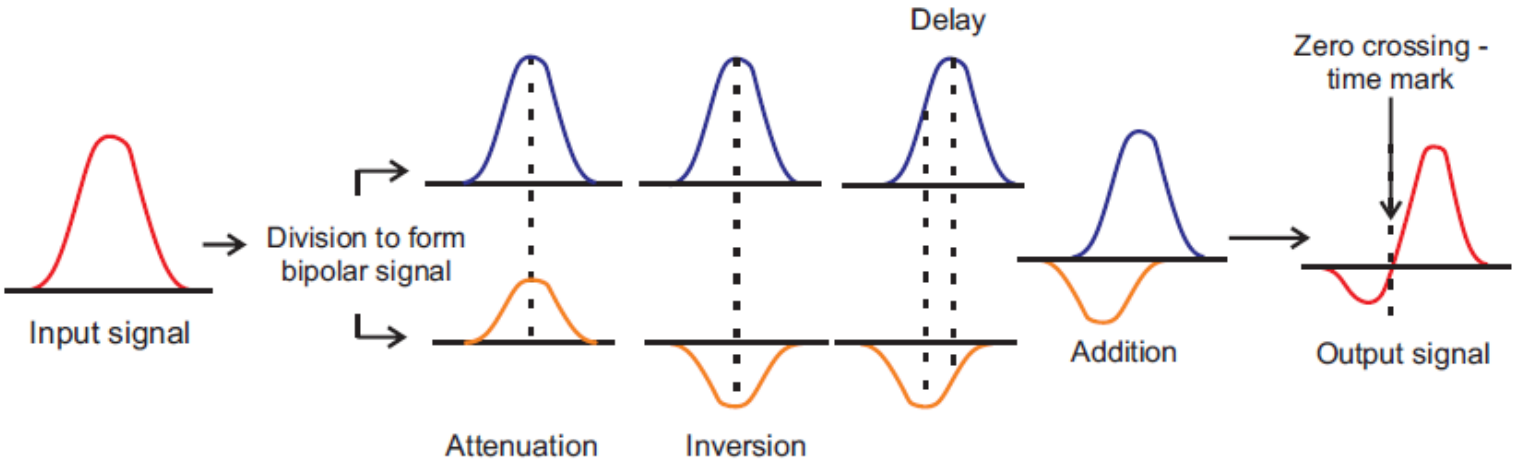
Tool:

- New **pulse shape analysis software** is being implemented using ROOT (still developing).

Constant Fraction Discrimination



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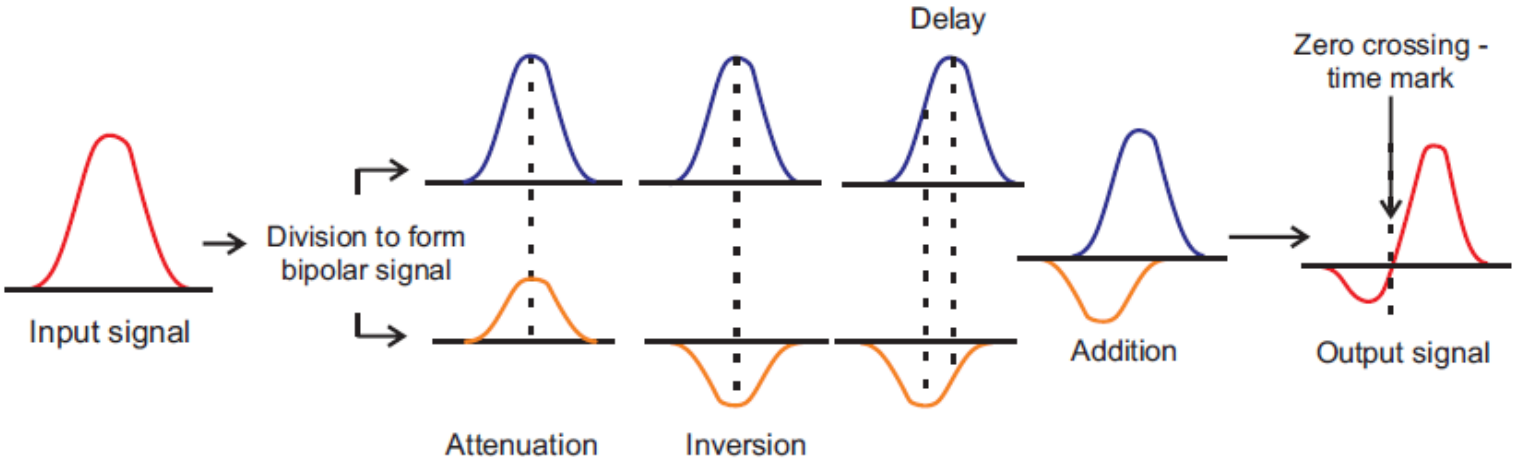
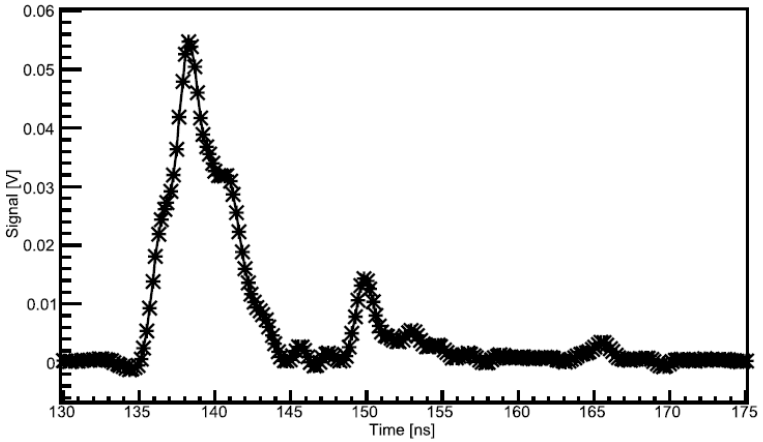
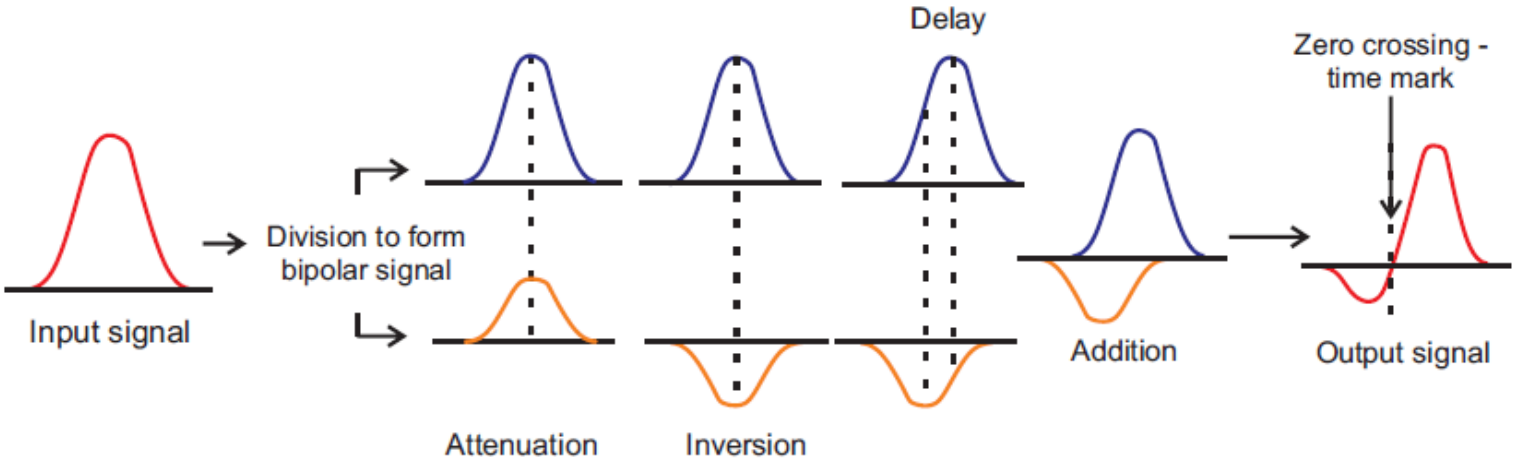
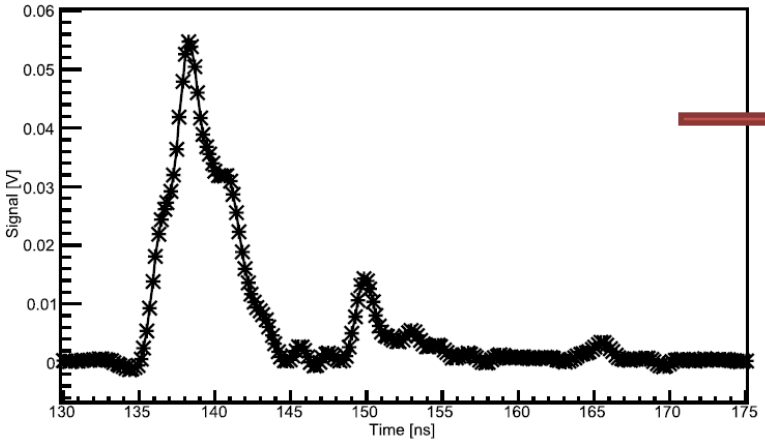


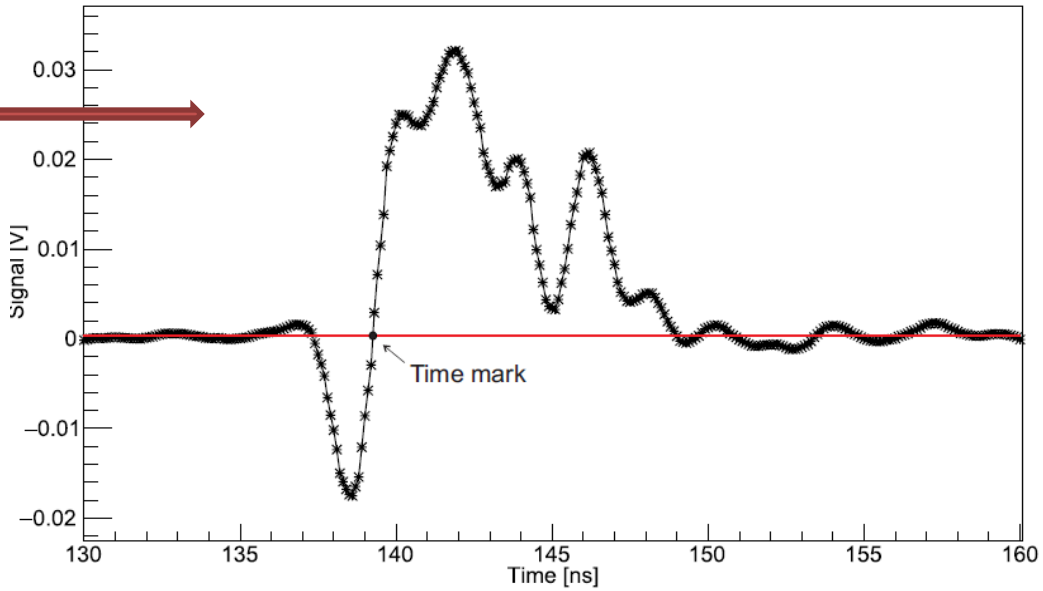


Attenuation value 0.3
Delay 1.5 ns

Constant Fraction Discrimination







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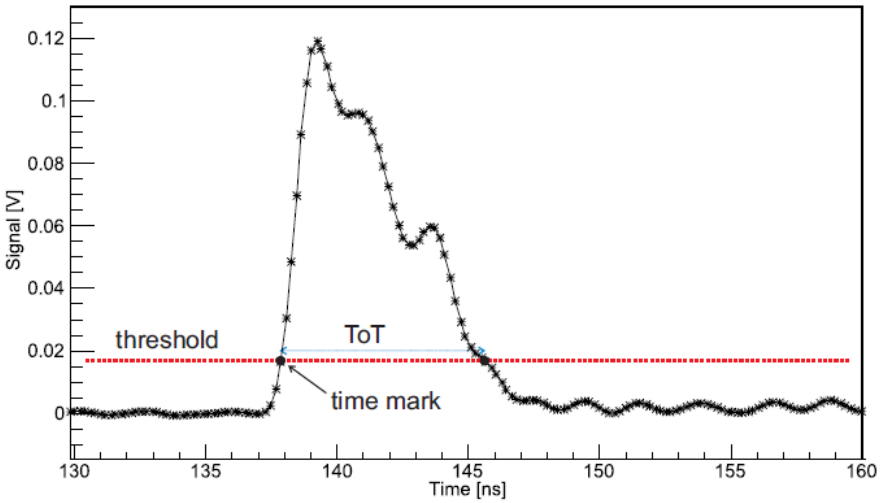
Leading edge analysis

- Leading Edge Analysis
- Time-over-Threshold

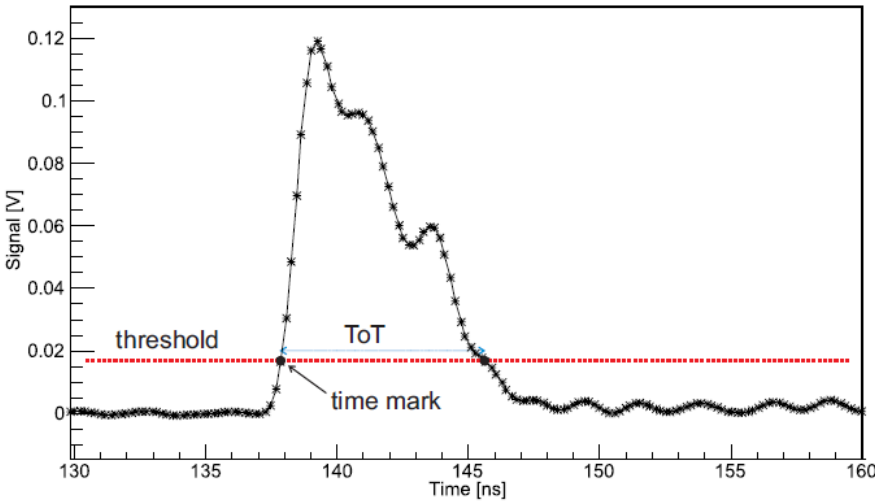


- Threshold value ~ 0.02 V to avoid one-electron events

- Front edge fit

Leading edge analysis

- Leading Edge Analysis
- Time-over-Threshold



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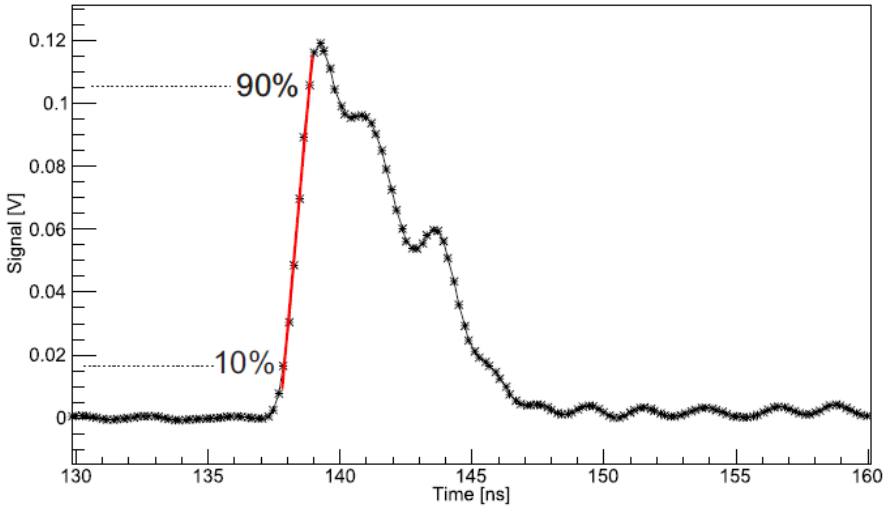
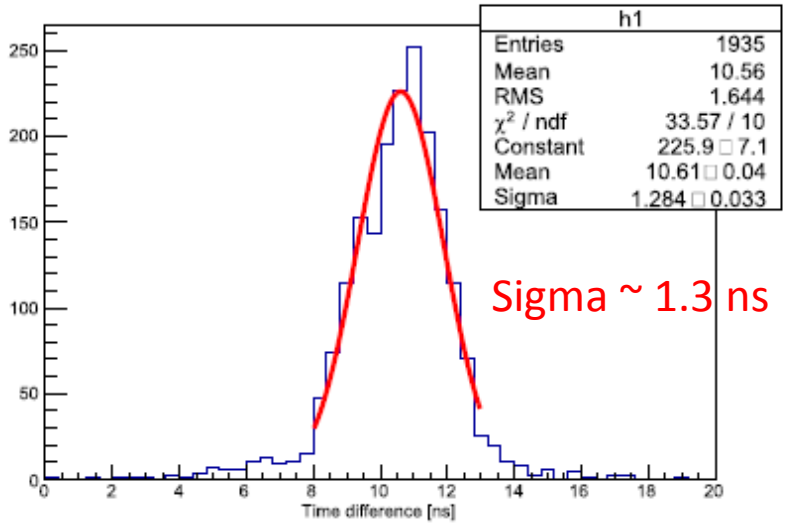


- Threshold value ~ 0.02 V to avoid one-electron events

Time difference histograms

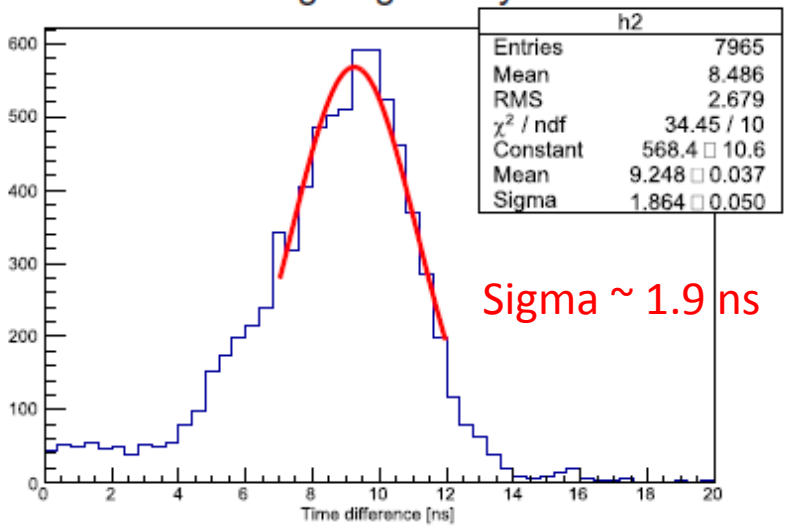
- **Time difference between signals from two sides of one fiber**

Constant Fraction Discrimination



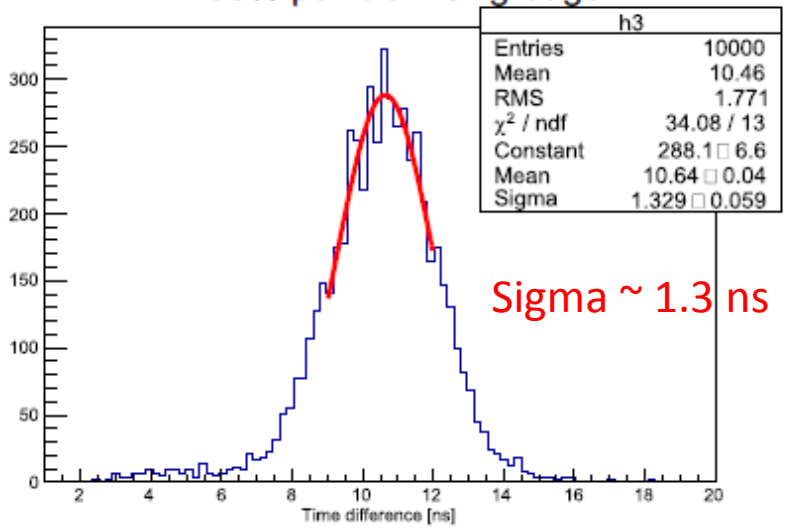
Sigma ~ 1.3 ns

Leading Edge Analysis



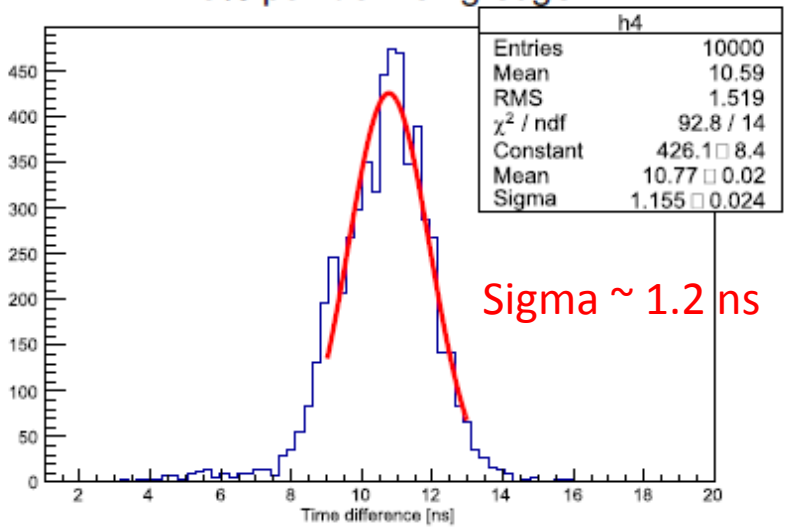
Sigma ~ 1.9 ns

50% point of rising edge



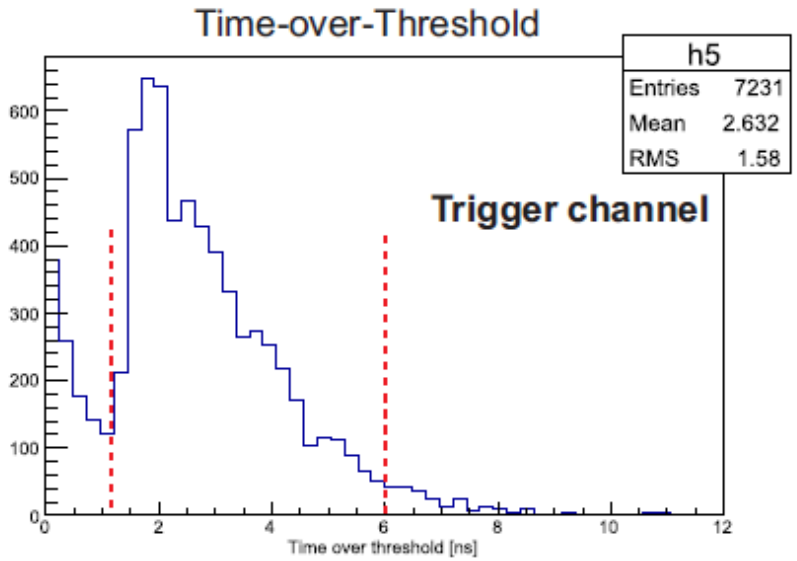
Sigma ~ 1.3 ns

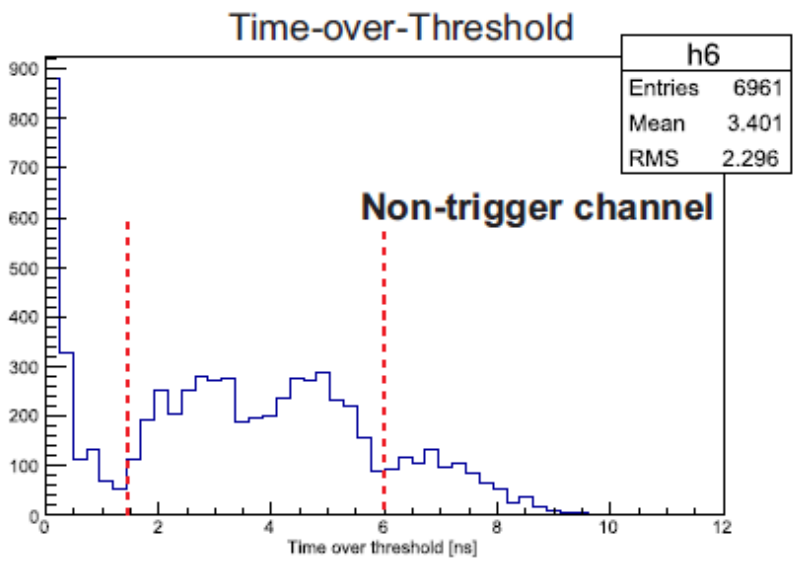
10% point of rising edge

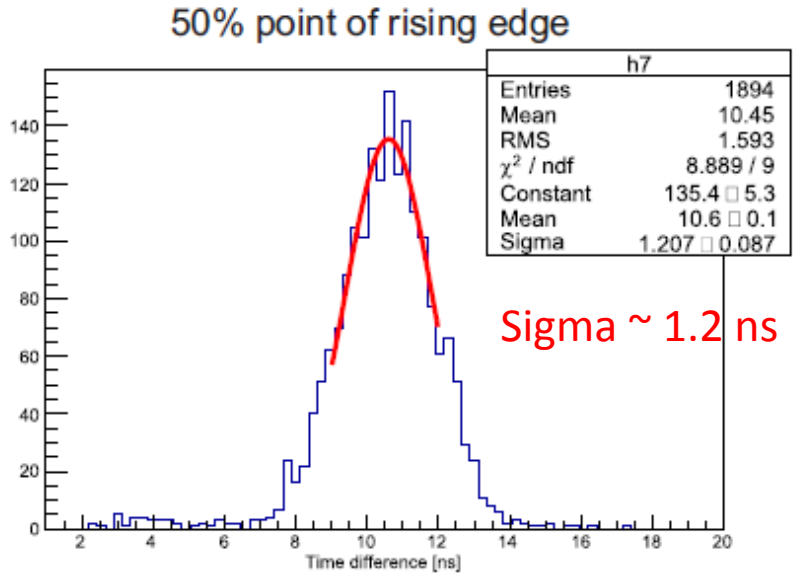


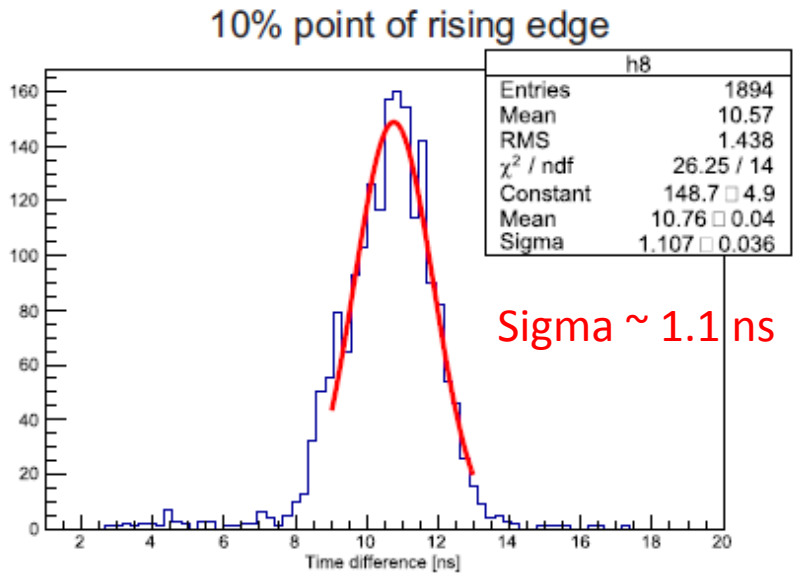
Sigma ~ 1.2 ns

Time difference histograms

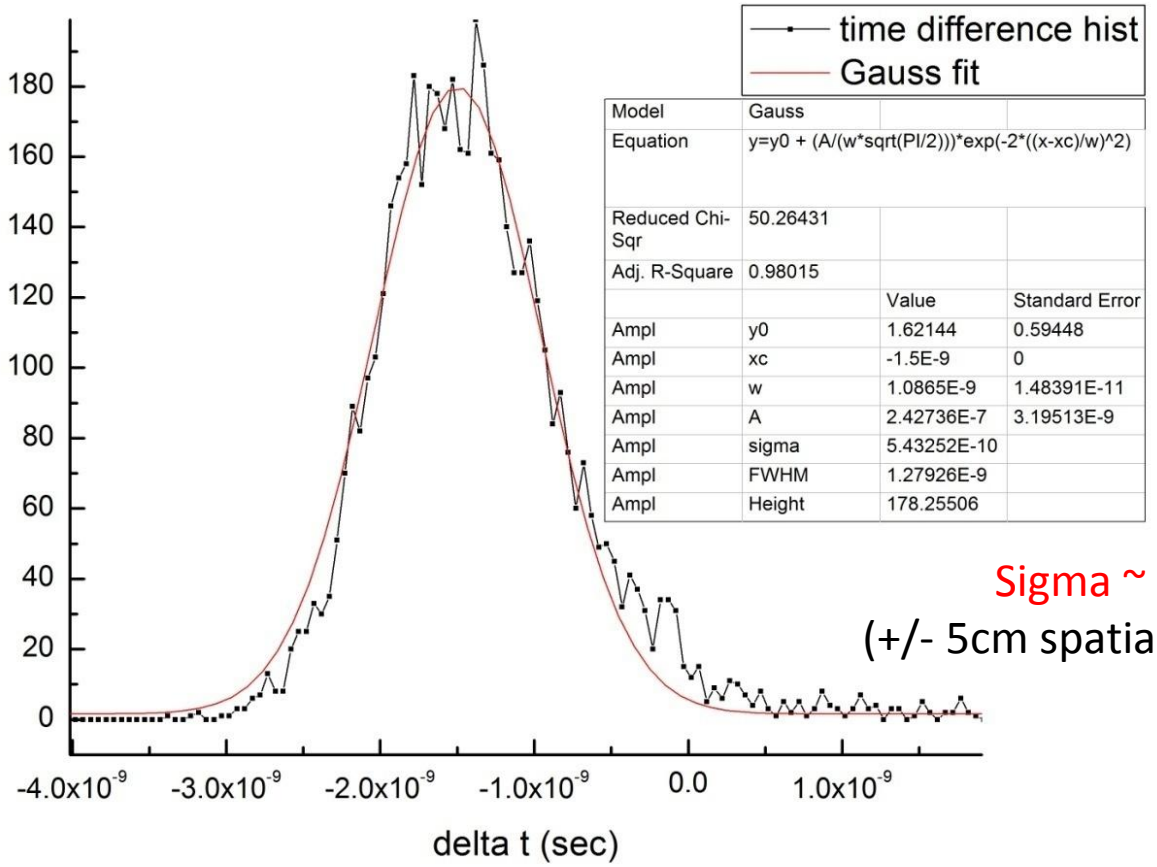








Lab test @ GSI, February 2017



Model	Gauss		
Equation	y=y0 + (A/(w*sqrt(PI/2)))*exp(-2*((x-xc)/w)^2)		
Reduced Chi-Sqr	50.26431		
Adj. R-Square	0.98015		
		Value	Standard Error
Ampl	y0	1.62144	0.59448
Ampl	xc	-1.5E-9	0
Ampl	w	1.0865E-9	1.48391E-11
Ampl	A	2.42736E-7	3.19513E-9
Ampl	sigma	5.43252E-10	
Ampl	FWHM	1.27926E-9	
Ampl	Height	178.25506	

Sigma ~ 0.5 ns

(+/- 5cm spatial uncertainty)

- **Thin scintillator** (4 mm), 2 PMTs in black box
- **^{137}Cs** with E_{gamma} = 672 keV
- **Oscilloscope** Le Croy WavePro 7300, 20 GS/s
- Time difference between **50% of signal rising edges** (analog of CFD)

Summary and plans

- With current data and analysis procedure the time resolution is about 1 ns
- Lab test showed that the time resolution can be improved down to 0.5 ns
- More tests will be done with multi-channel electronics (PETsys)

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