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RESEARCH & DEVELOPMENT OF DIFFERENT ADVANCED SPECTROSCOPY PORTAL MONITORS ON THE BASE OF SINGLE TECHNOLOGICAL PLATFORM

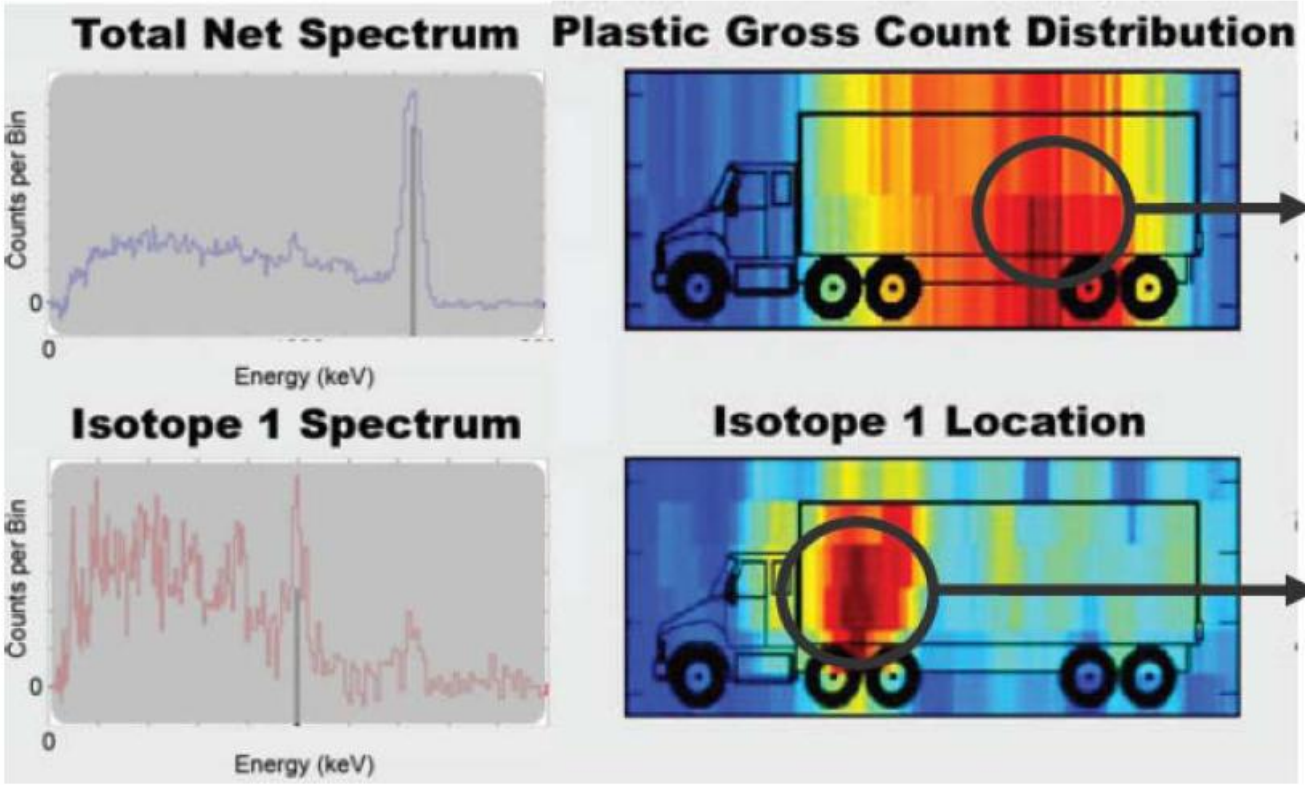
Disadvantages of non-spectroscopic portal monitors

- Disability to identify isotopes and as a consequence a lot of false alarms
- Possibility of masking prohibited radioactive substance by the material with natural radioactivity

Example of alarm data

Material	%
Kitty liter	34
Medical (Tc, I, Tl)	16
Abrasives	8
Refractory material	8
Scouring pads	6
Mica	5
Potassium/Potash	5
Granite slabs	4
Toilet bowels & tile	4
Trucks/cars	2

Masking of one radioactive material by another one



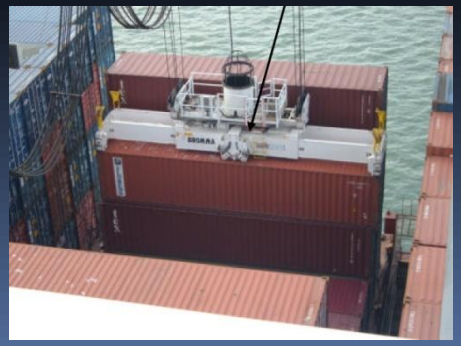
Radiation portal monitors

ypes of RPM (standard)

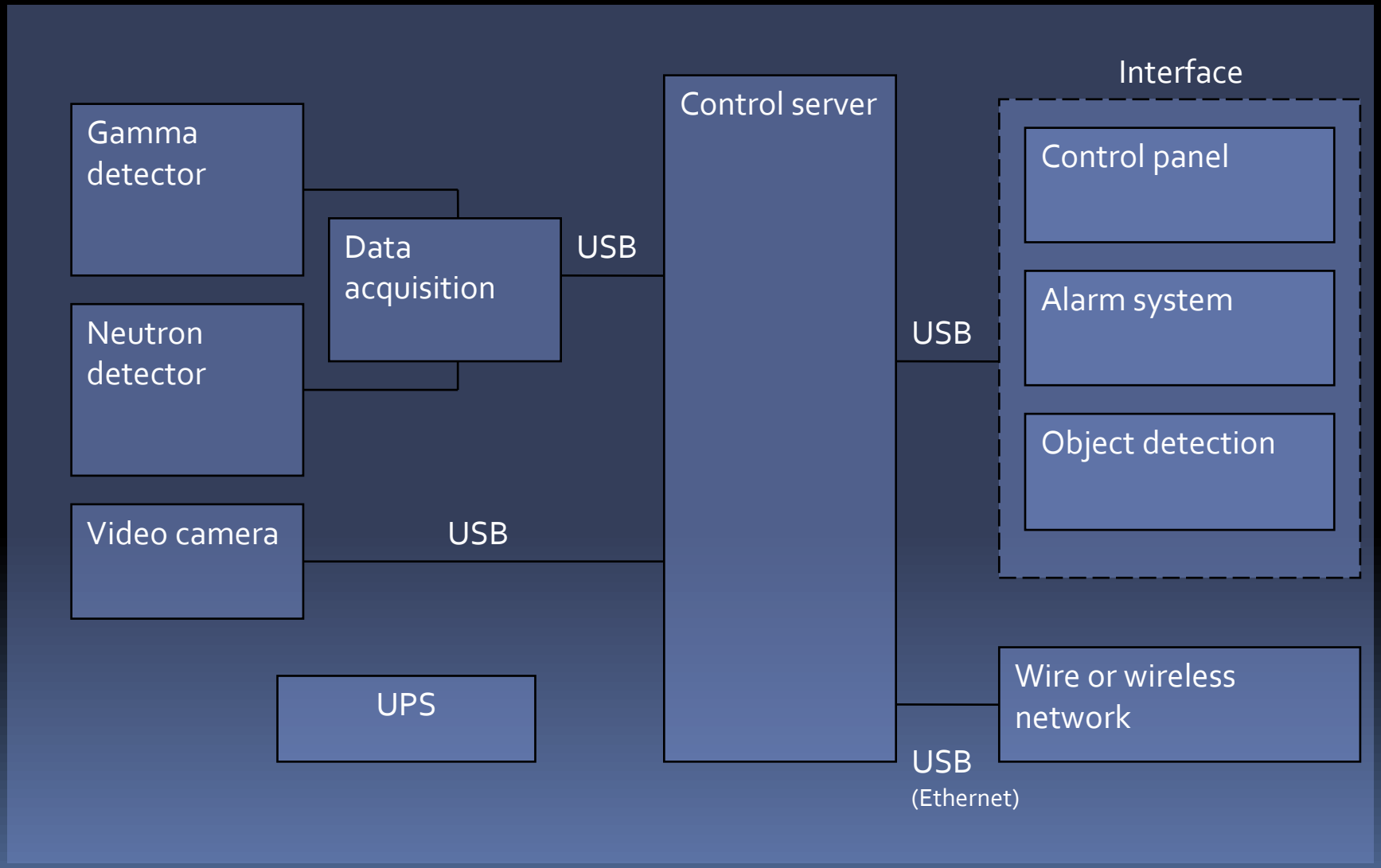
- Conveyer
- Pedestrian
- Vehicle
- Rail vehicle

ypes of RPM (non-standard)

- Portable
- Embedded into crane
- Mobile



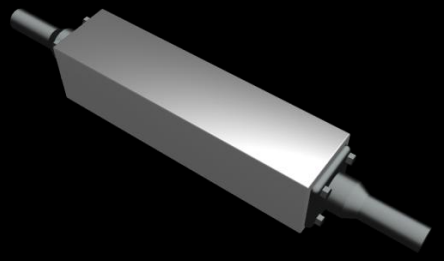
ASP block diagram



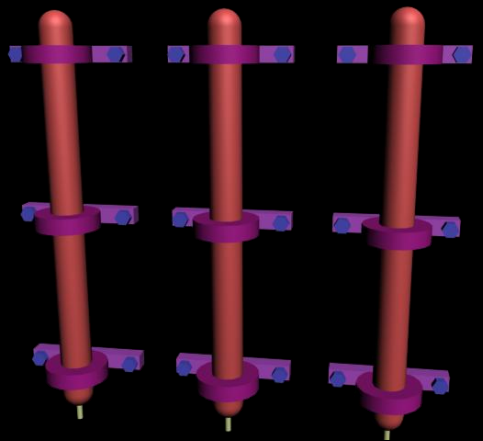
Single technological platform

Detection panel

Gamma channel



Neutron channel



Electronics

Variants of ASP on the base of detection panels

Vehicle portal monitor

Rail vehicle portal monitor

Two levels of unification (internal units and detection panels) can minimize cost of ASP and time of development

Requirements to ASP

- IEC 62484 "Radiation protection instrumentation – Spectroscopy-Based Portal Monitors used for the Detection and Identification of Illicit Trafficking of Radioactive Material"
- ANSI N42.38 – 1 WD-F1 American National Standard Performance Criteria for Spectroscopy-Based Portal Monitors used for Homeland Security

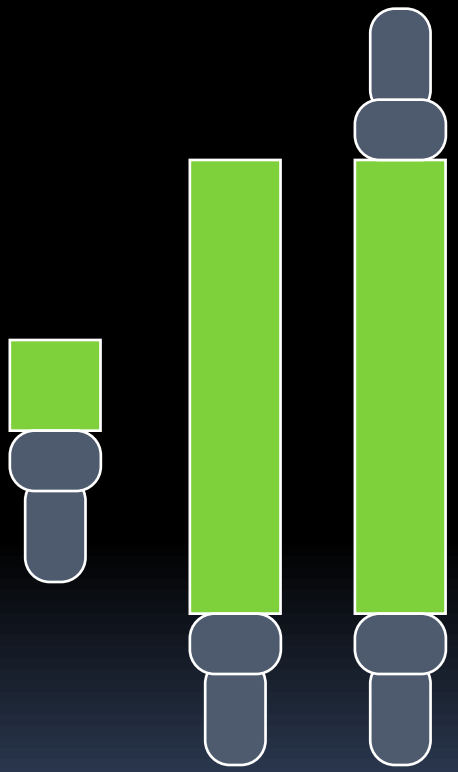
Sensitivity

Objects speed

Resolution

Ability to distinguish radioactive materials

Detectors for gamma channel



Sensitivity

Big volume

Resolution

High energy resolution

Standard detectors

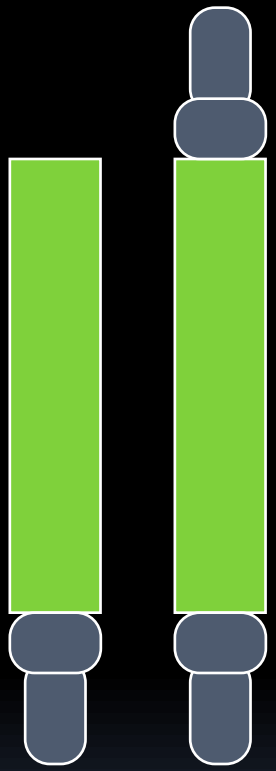
16 detectors in 2 frames

Totem Plus, Rotemi

Temperature instability + spectra summation

Although each detector has 6.5% energy resolution, the resolution of the whole system is ~ 7.5%

Long detectors



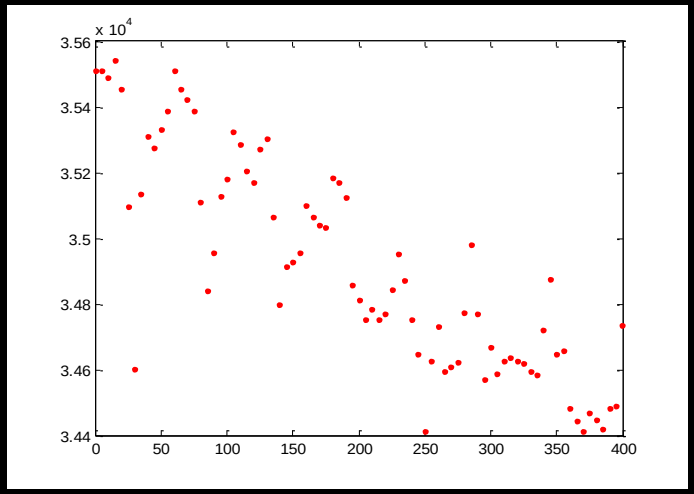
The amount of light emitted after each gamma quant interaction
Is proportional to deposited energy

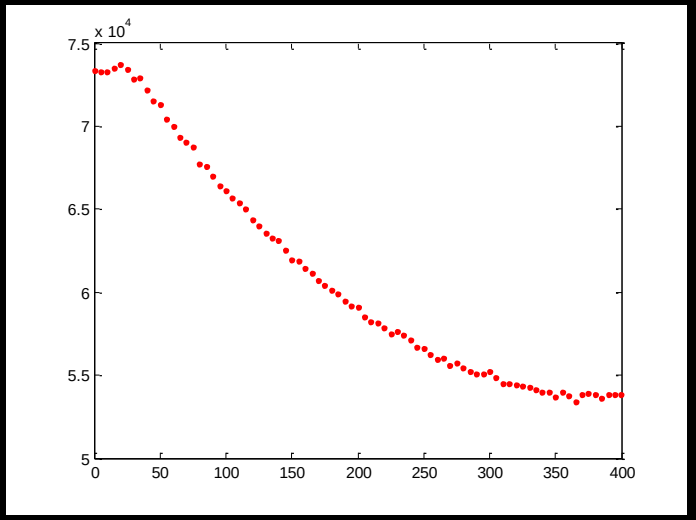
PMT signal is determined by light pulse intensity and light collection efficiency

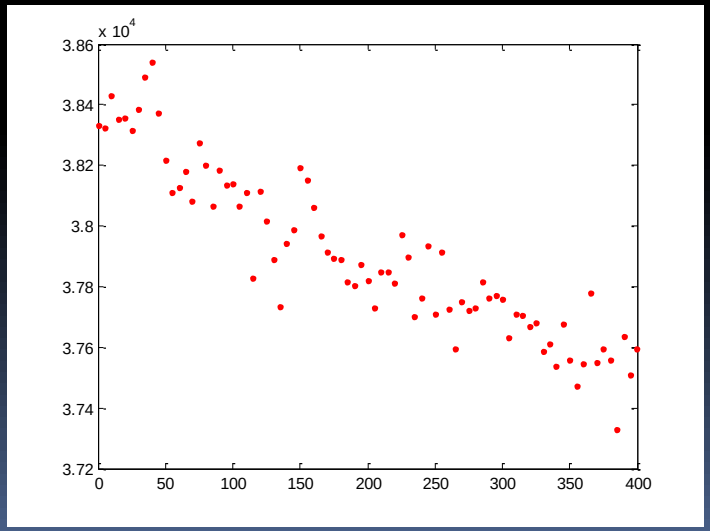
Energy resolution of the detector is determined by scintillation material an detector design

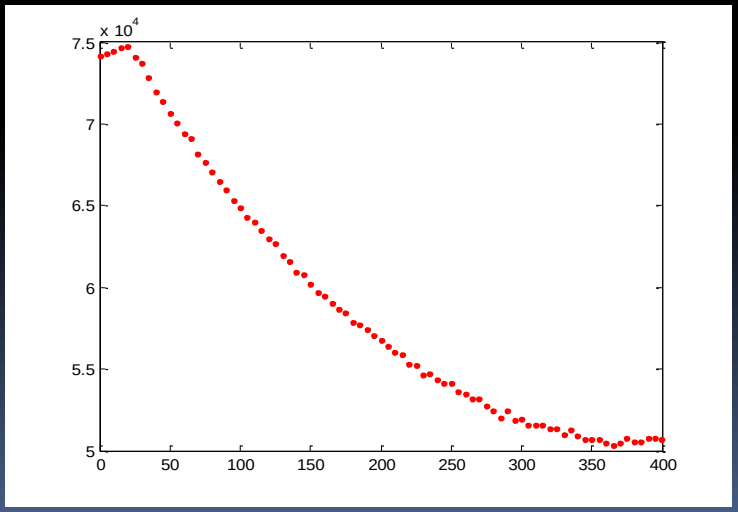
Non uniform light collection leads to degradation of energy resolution

Long detector with 1 PMT







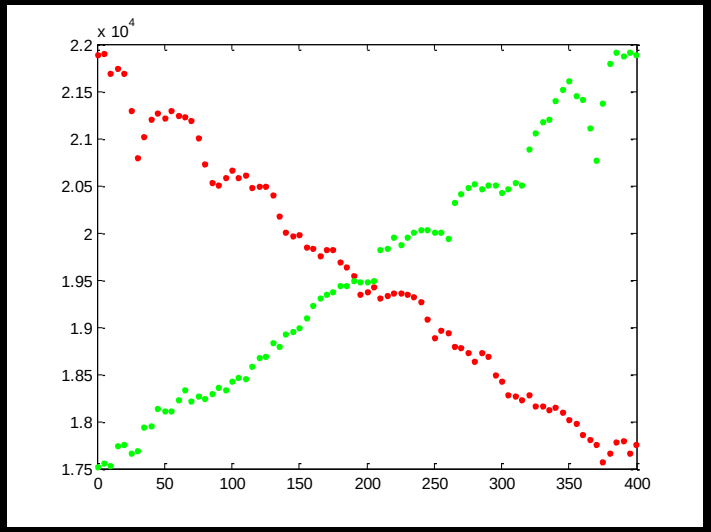


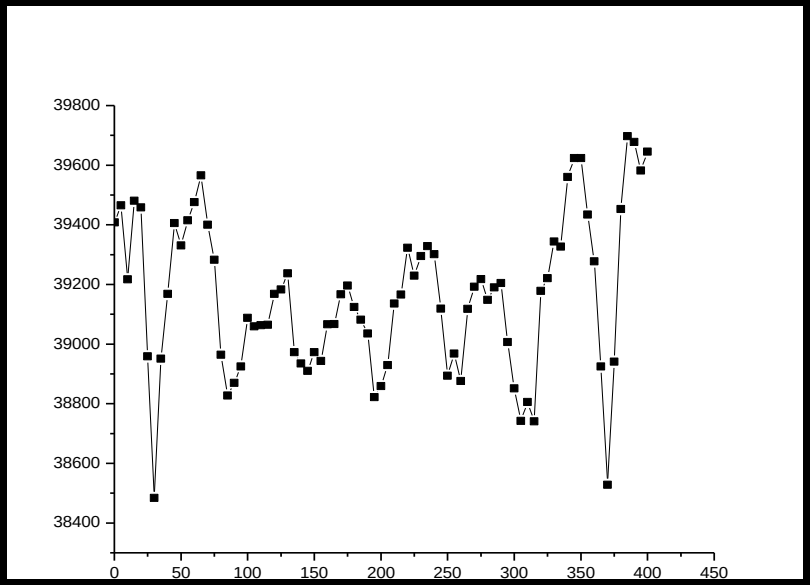
Mirror reflector

Diffusive reflector

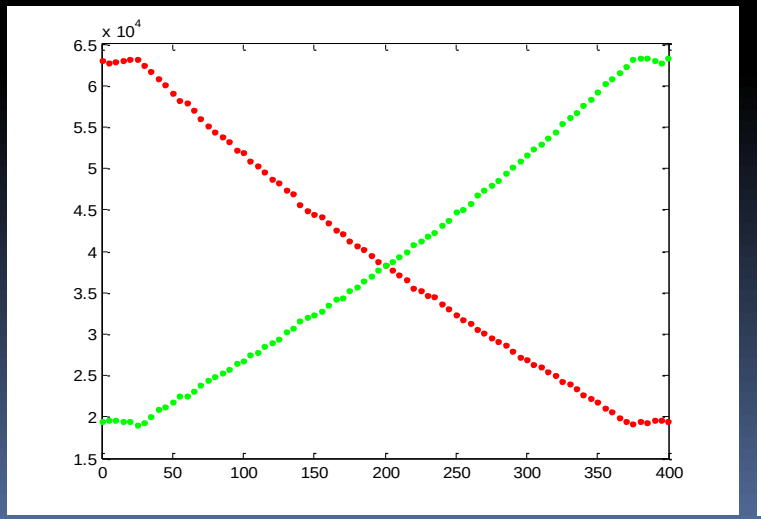
Long detector with 2 PMT

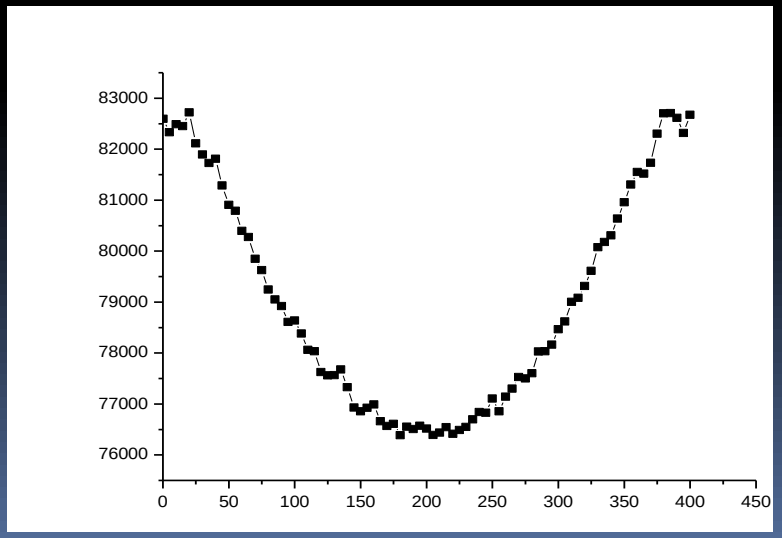
Mirror





Diff



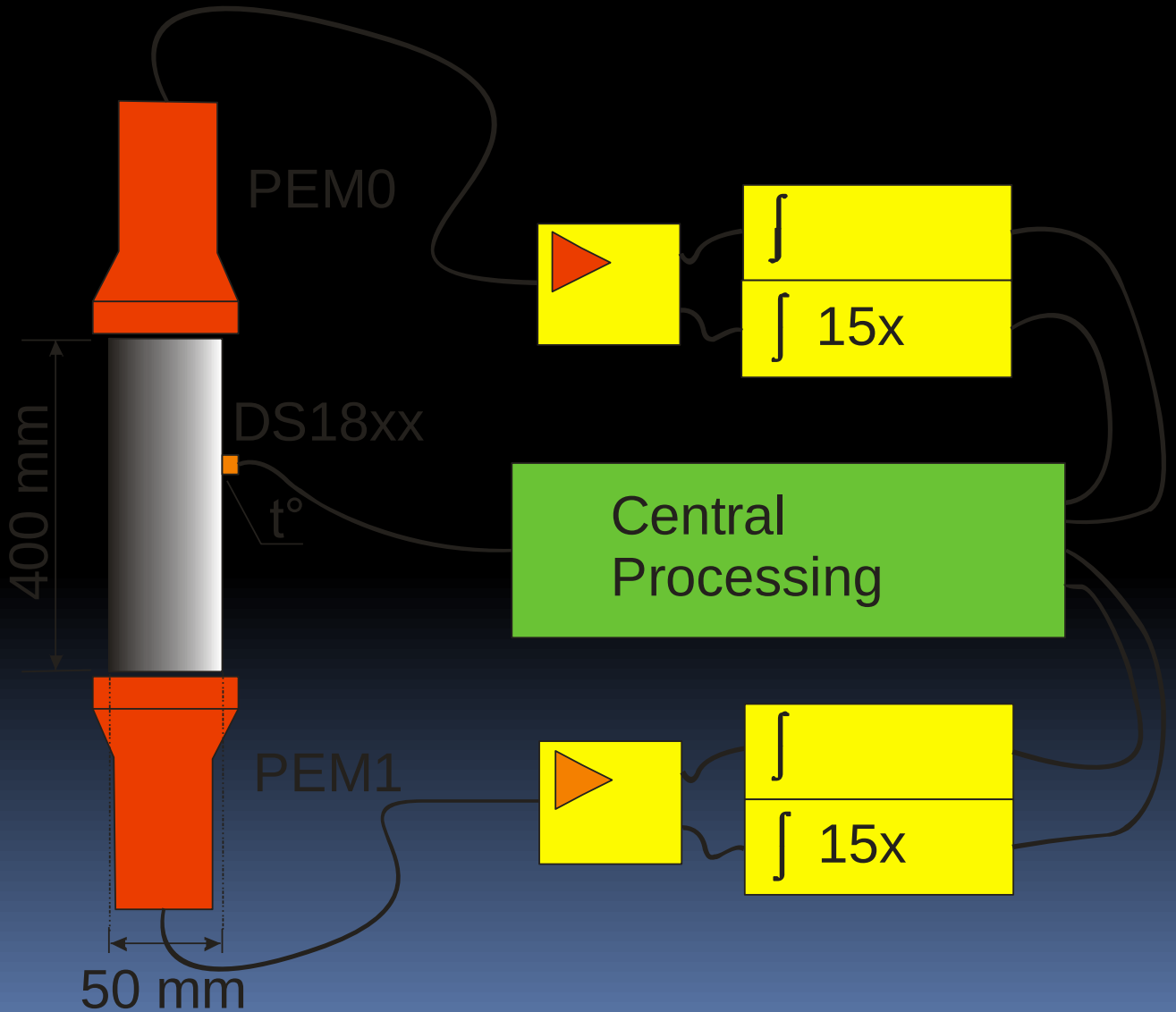


Uniformity of light collection

Round				Rectangular			
Mirror		Diffusive		Mirror		Diffusive	
Position	Section	Position	Section	Position	Section	Position	Section
2,22%	14,58%	27,91%	0,53%	1,48%	0,52%	33,73%	0,62%

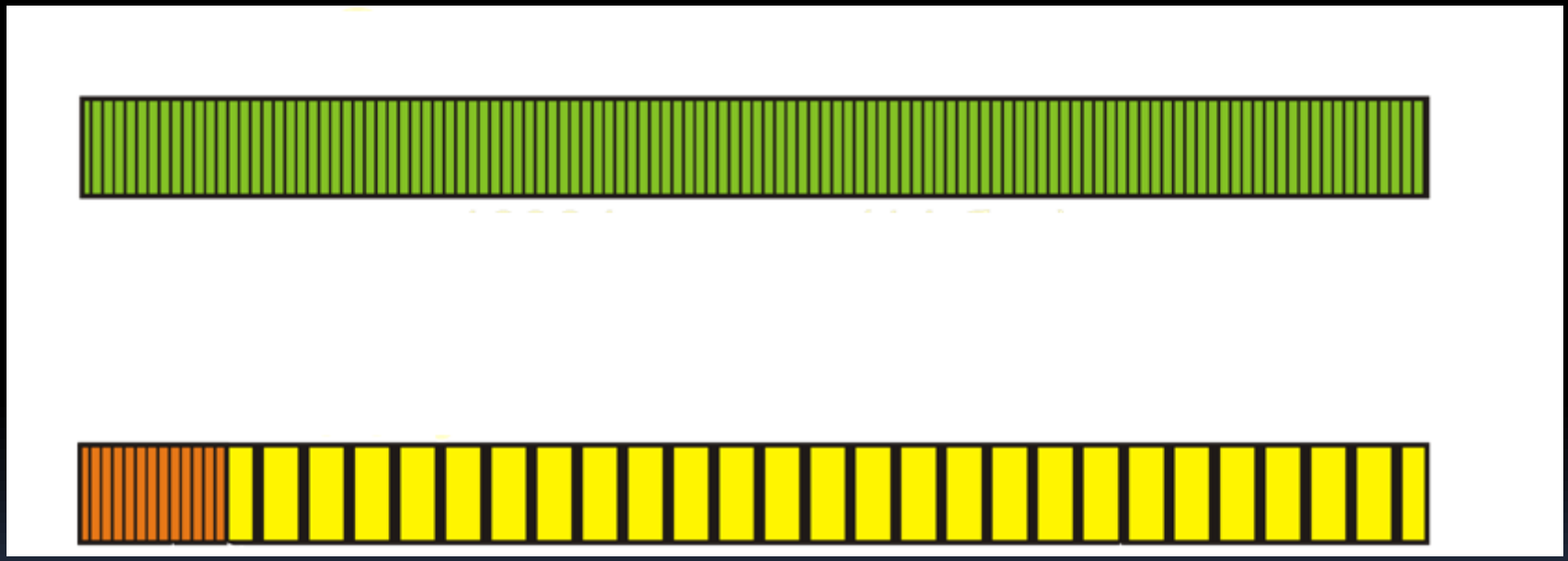
	Round				Rectangular			
	Mirror		Diffusive		Mirror		Diffusive	
	Position	Section	Position	Section	Position	Section	Position	Section
1 ФЭУ	15,17%	14,65%	94,27%	0,90%	13,21%	1,23%	103%	1,08%
Сумм. сигнал	0,94%	14,17%	5,62%	0,45%	1,00%	0,84%	7,03%	0,23%

Data acquisition block diagram



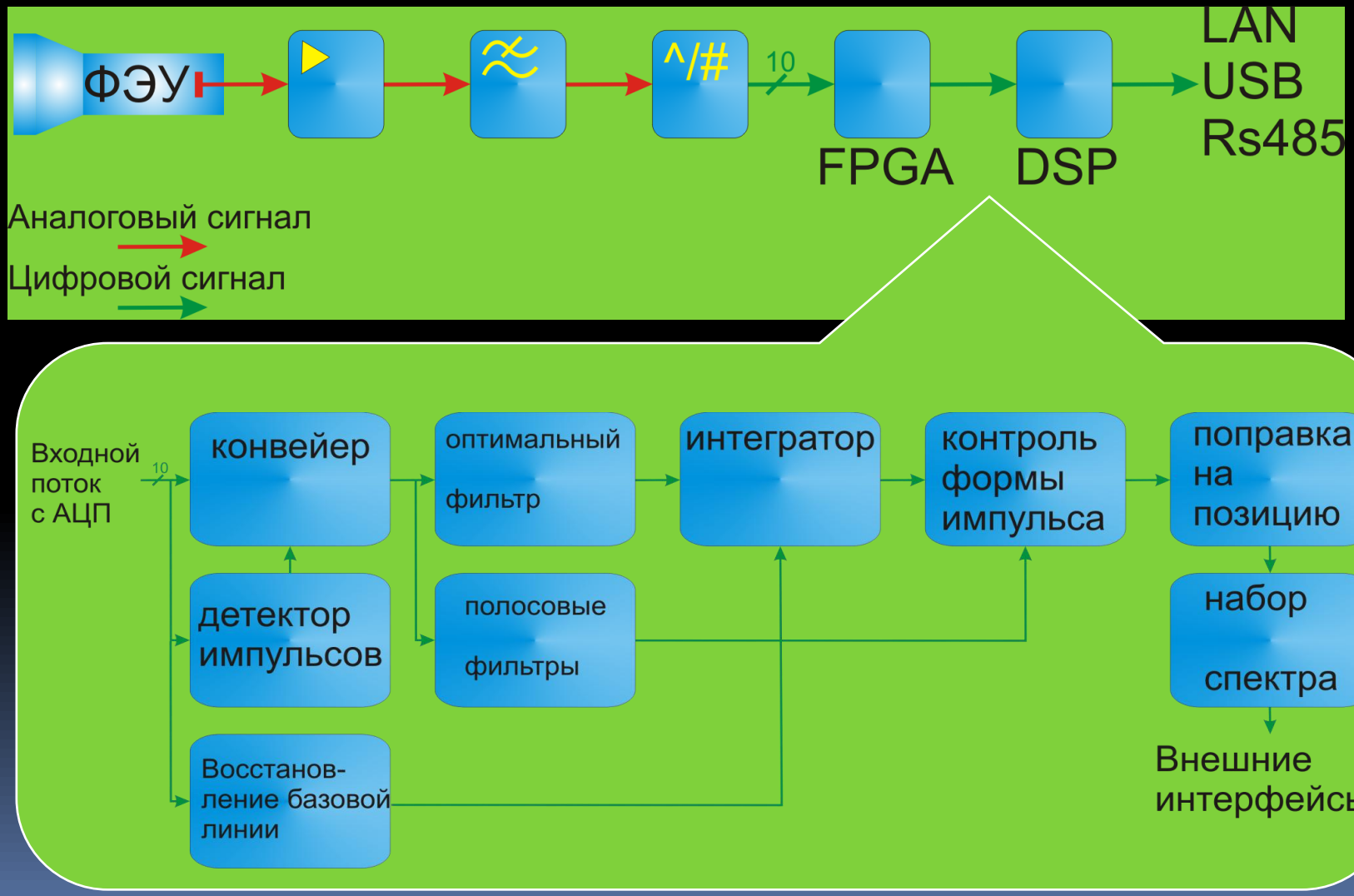
Dinamic range

Single channel system 16K

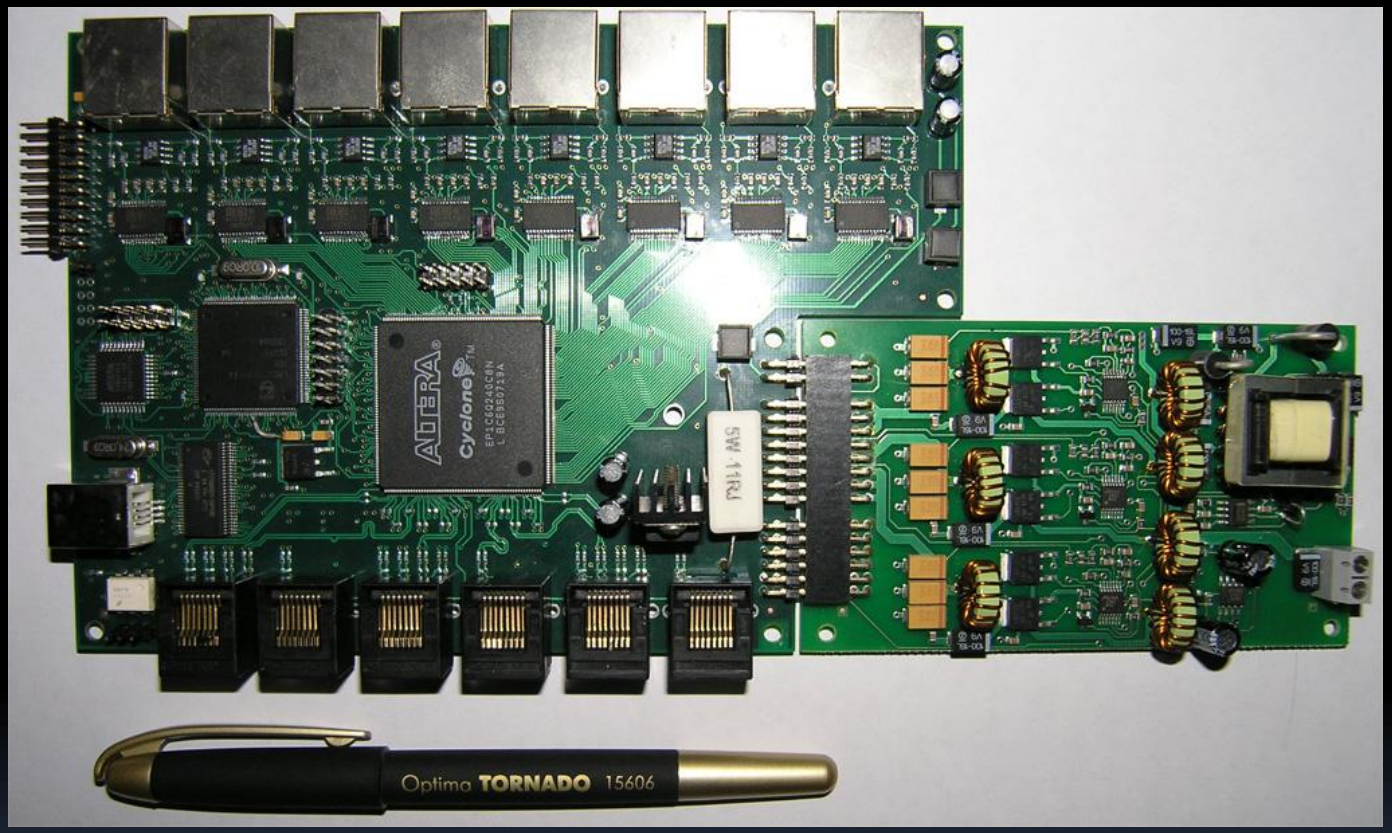


Dual channel system 1K + 1K

PMT digital signal processing

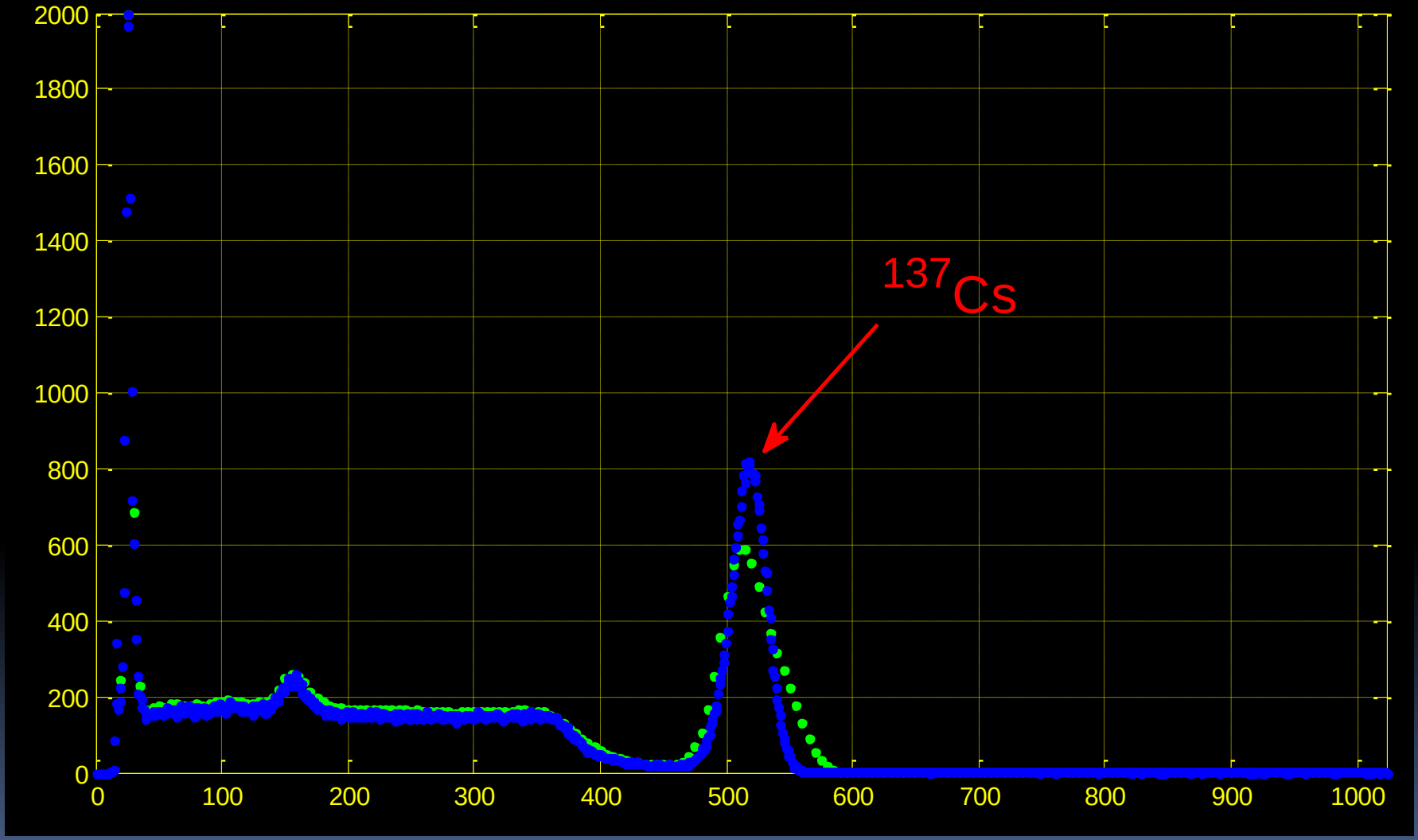


Acquisition system

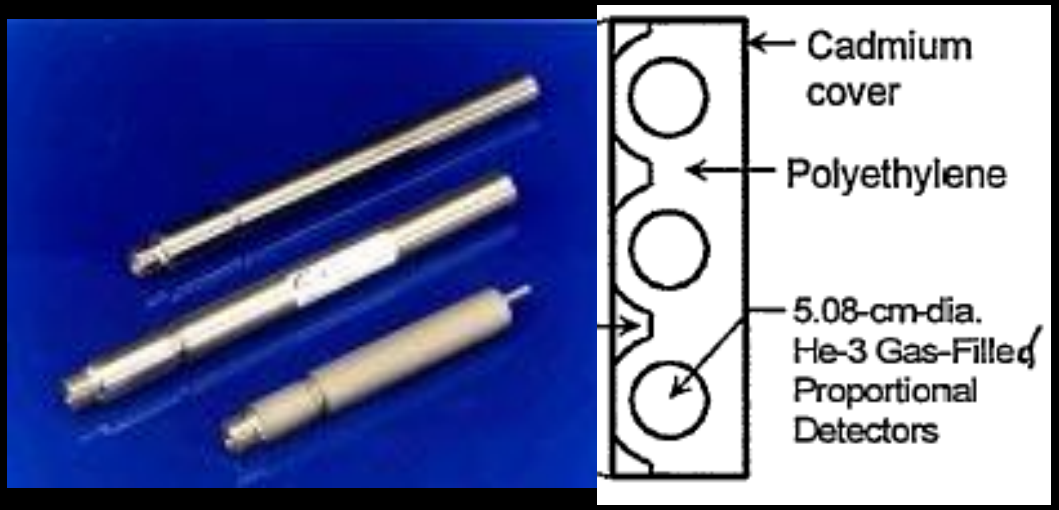


8 channels can process signals from 2 dual PMT detectors
Free run 40 MHz 10 bit ADC
Fully digital signal processing
USB interface

Position sensitivity



He neutron detector



\+

Insensitive to gamma
Good sensitivity

\-

Periodical replacement is required

What else can be used for neutron detection?

Neutron detection

$n + {}^{6}Li \rightarrow {}^{4}He + {}^{3}H + 4.79\ MeV$ $\sigma = 950$ barn

$n + {}^{10}B \rightarrow {}^{7}Li^{*} + {}^{4}He \rightarrow {}^{7}Li + {}^{4}He + 0.48\ MeV\ \gamma + 2.3\ MeV(93\%)$ $\sigma = 3600$ barn

$\rightarrow {}^{7}Li + {}^{4}He + 2.8\ MeV\ (7\%)$

$n + {}^{113}Cd \rightarrow {}^{114}Cd^{*} \rightarrow$ $\sigma = 20000$ barn

$n + {}^{155}Gd \rightarrow {}^{156}Gd^{*} \rightarrow \gamma$ $\sigma = 60000$ barn

$n + {}^{157}Gd \rightarrow {}^{158}Gd^{*} \rightarrow \gamma$ $\sigma = 230000$ barn

Reaction: $n + {}^{10}B \rightarrow$

$^{7}Li + {}^{4}He + 2.8\ MeV$

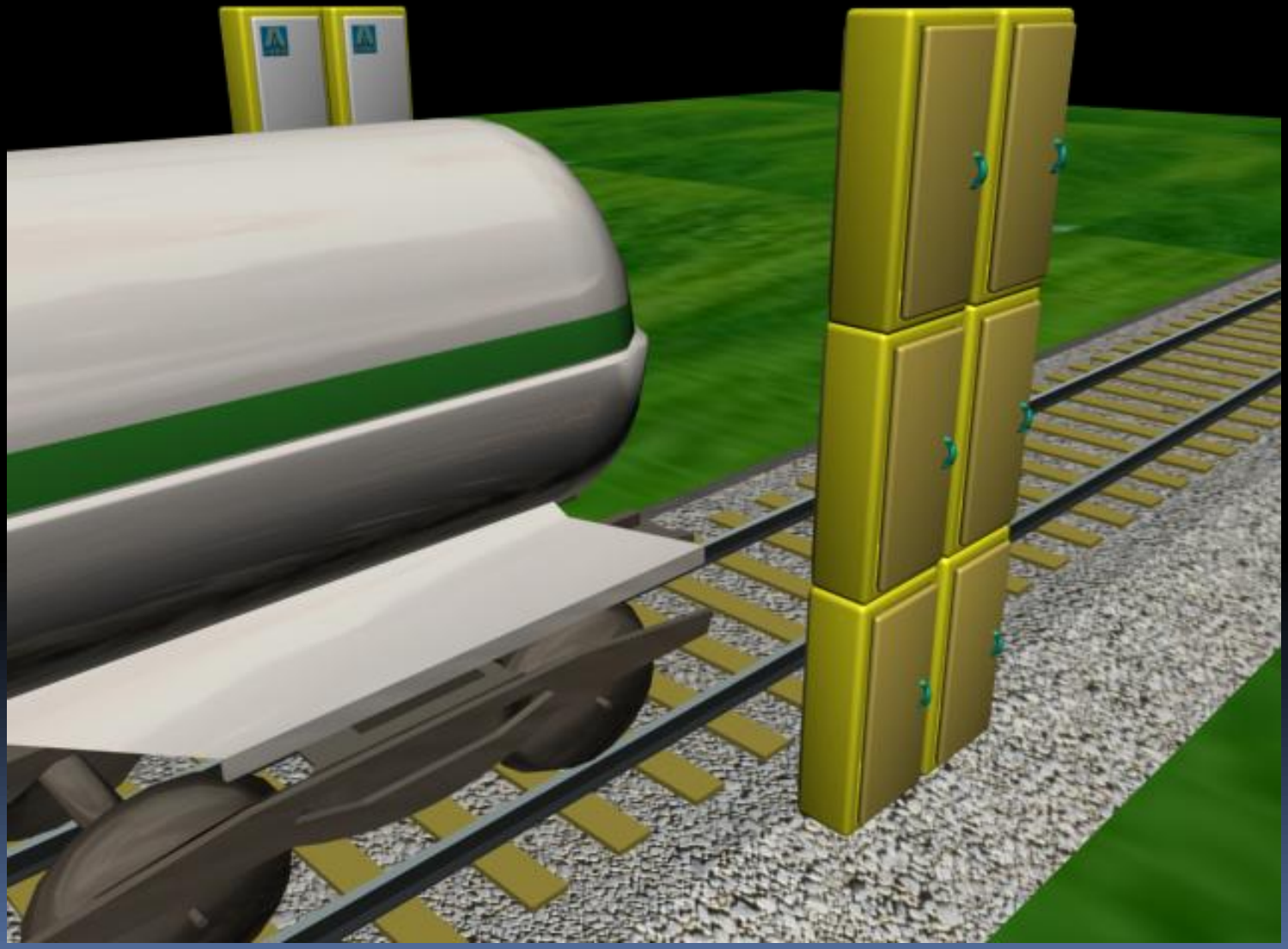
ZnS(Ag) scintillator with B^{10}

Scintillator is deposited on the plexiglass light guide, that works as a light guide and as a neutron moderator

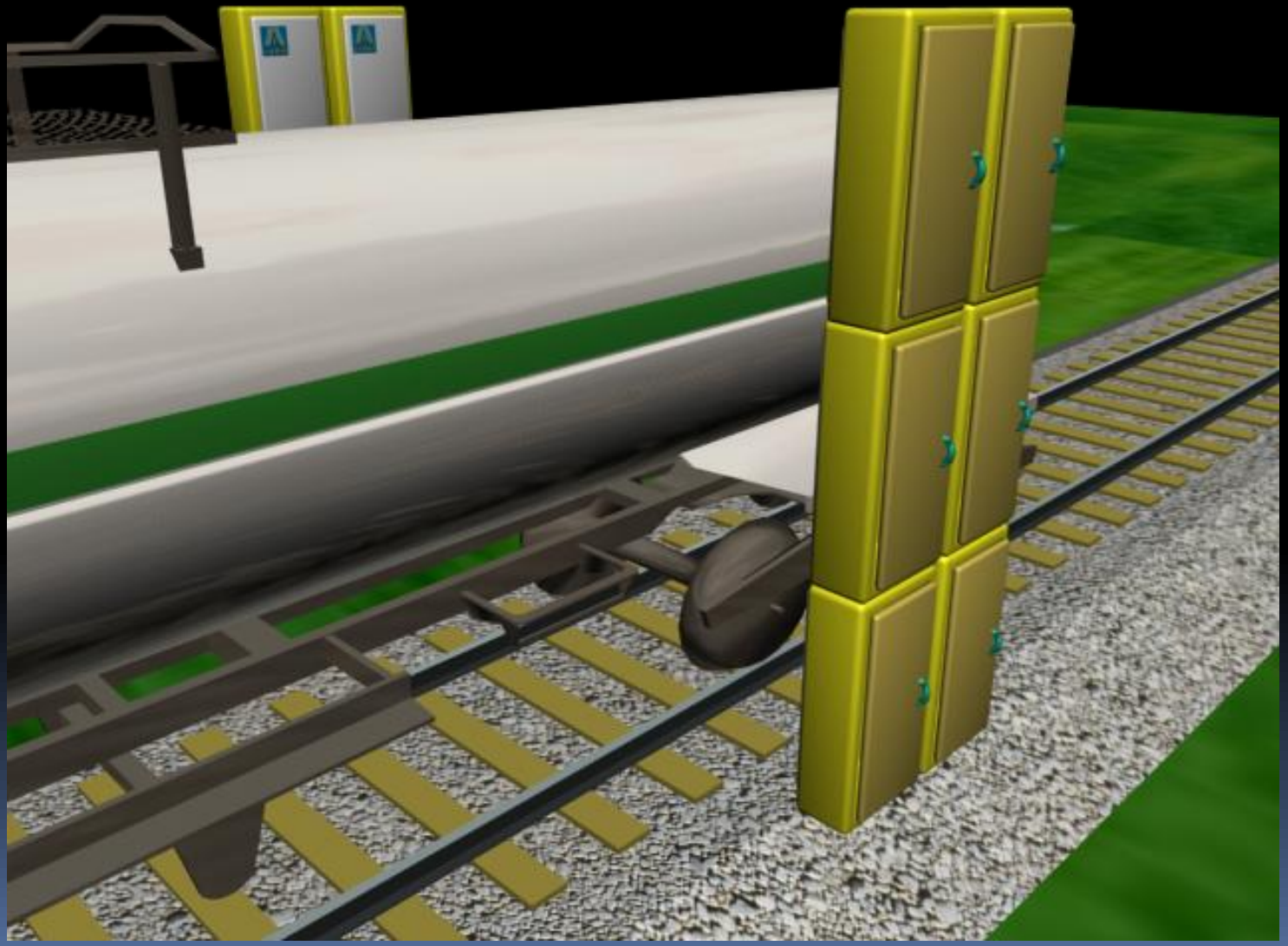
Insensitive to gamma

Detector with big working surface could be made

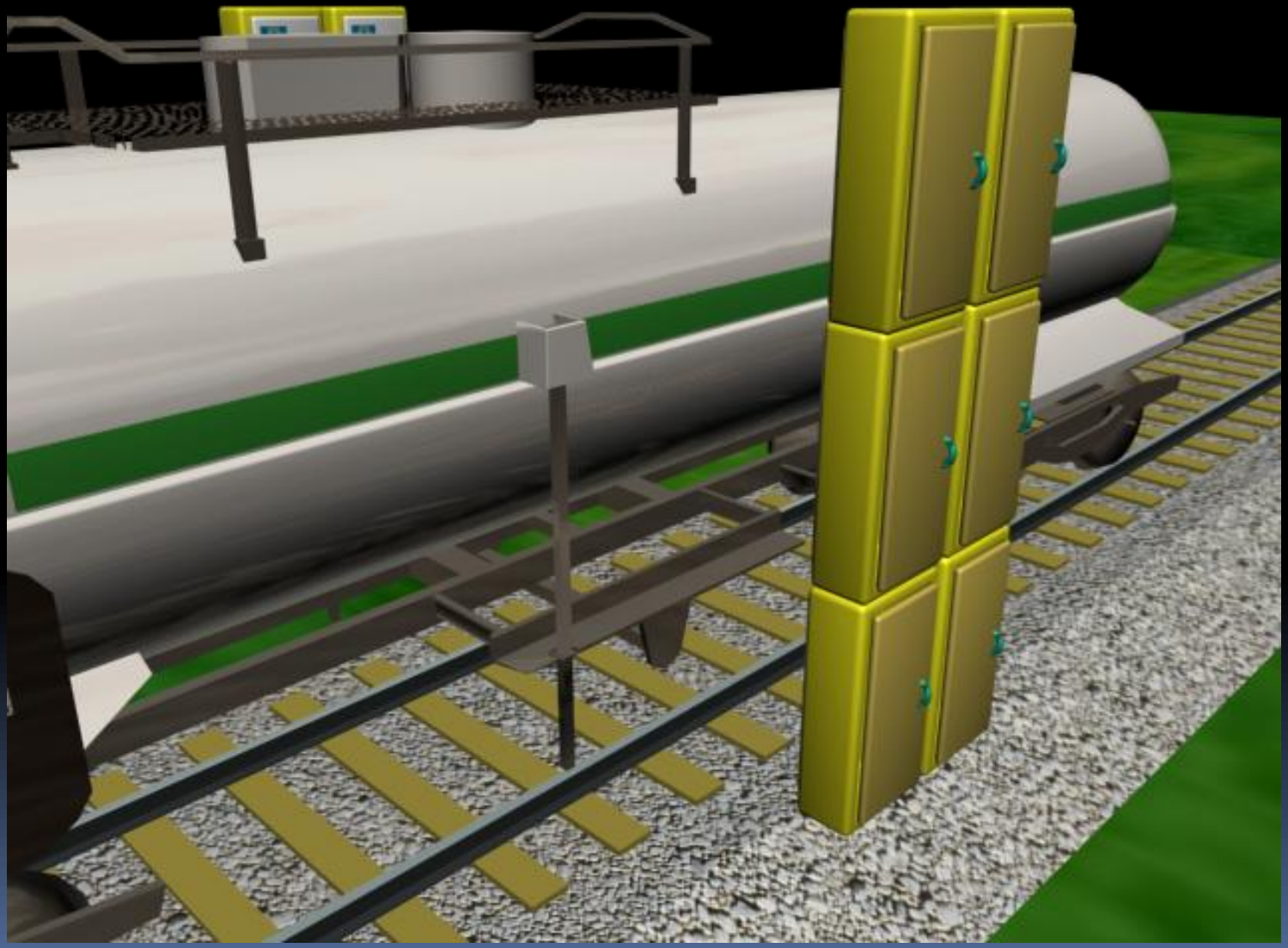
Signal processing in a time domain



Signal processing in a time domain

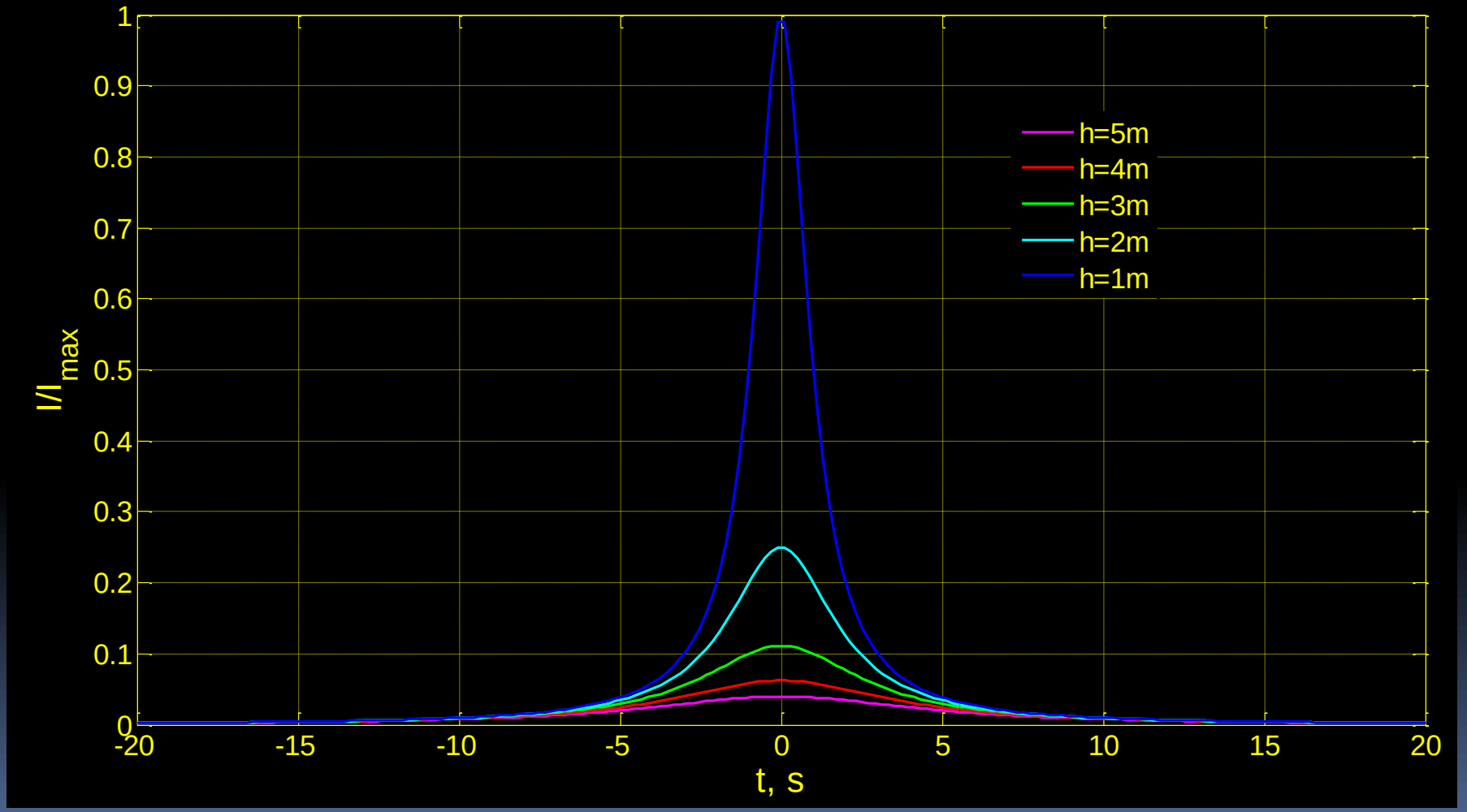


Signal processing in a time domain



Signal processing in a time domain

Signal processing in a time domain



Optimal filter

$$I(t) \equiv I_k; \quad k = 1..N.$$

$$Y(t) \equiv Y_k = \sum_n h_n I_{k-n}$$

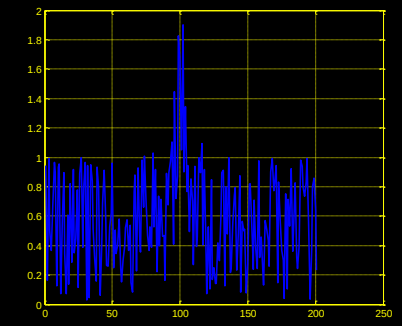
Wiener filter:

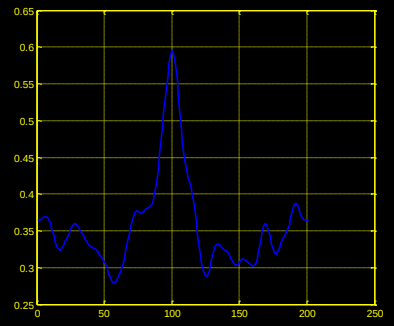
$$\min \varepsilon^2 = \sum_k \left(Y_k - I_k^{ref} \right)^2$$

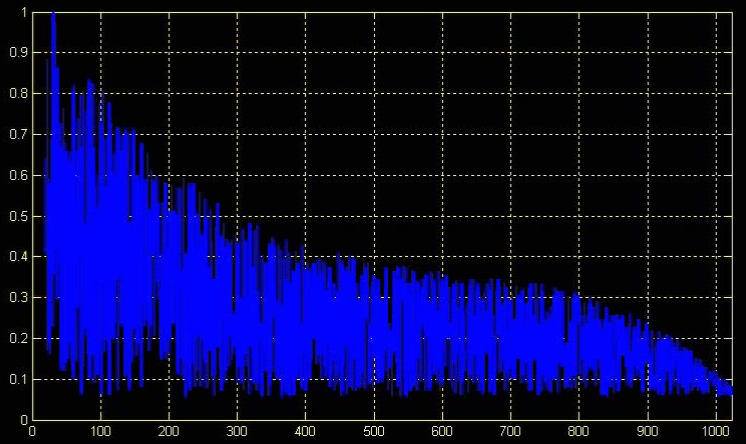
Detection filter:

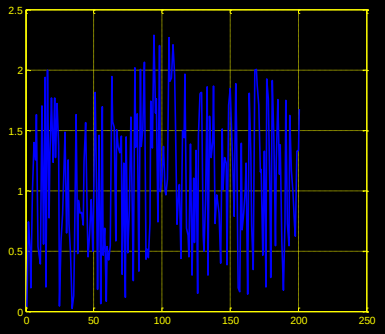
$$\max \rho = \left(Y_k \right)^2 / \delta^2;$$

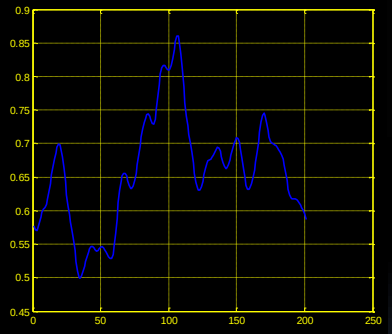
Signal filtration

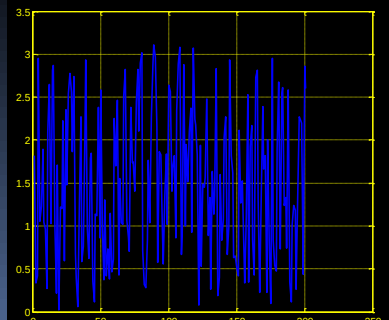


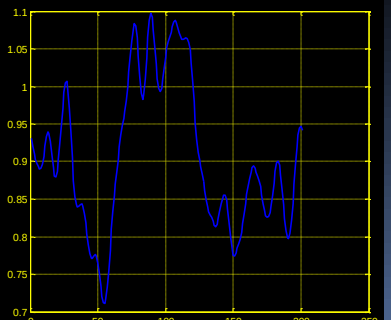


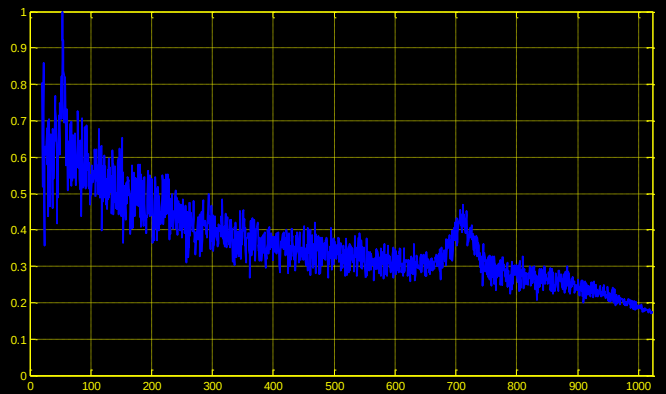












THANK YOU FOR YOUR ATTENTION