

# Optimization of the neutron detector prototype cell



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# Aim

- Optimal ratio of detector acceptance unit price and time resolution

Parameters affecting the time resolution of the detector:

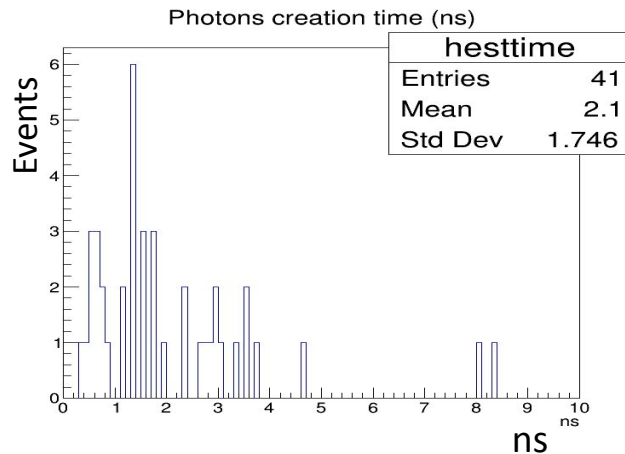
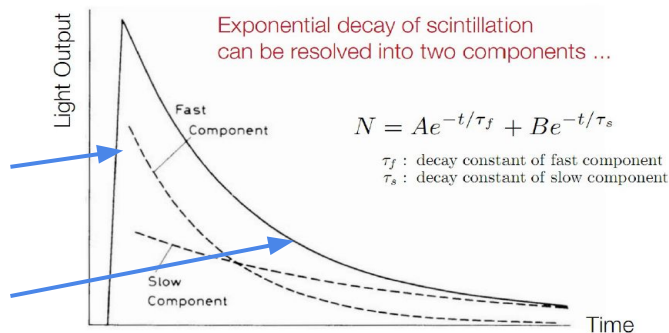
- Time properties of the scintillator
- Time properties of SiPM
- Reflective surface of the scintillator
- Method of light transmission to SiPM

# Factors determining time properties

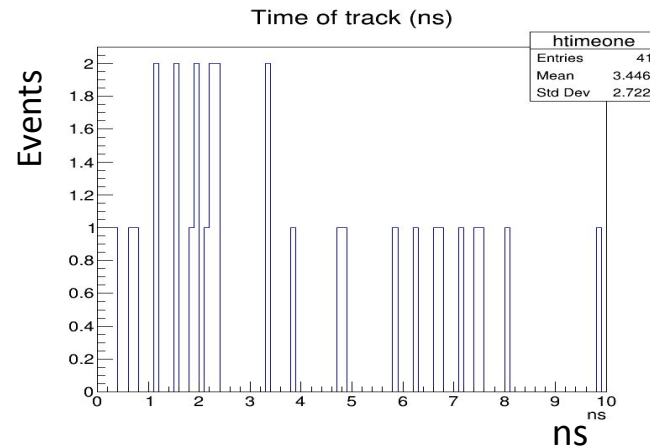
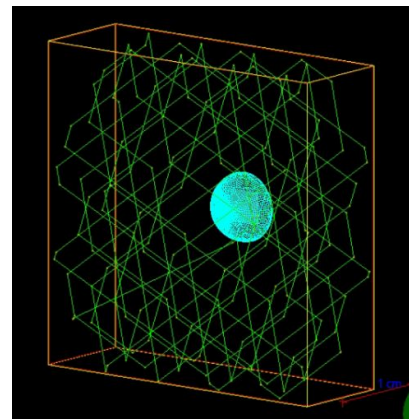
## Flashing time

Front  
time

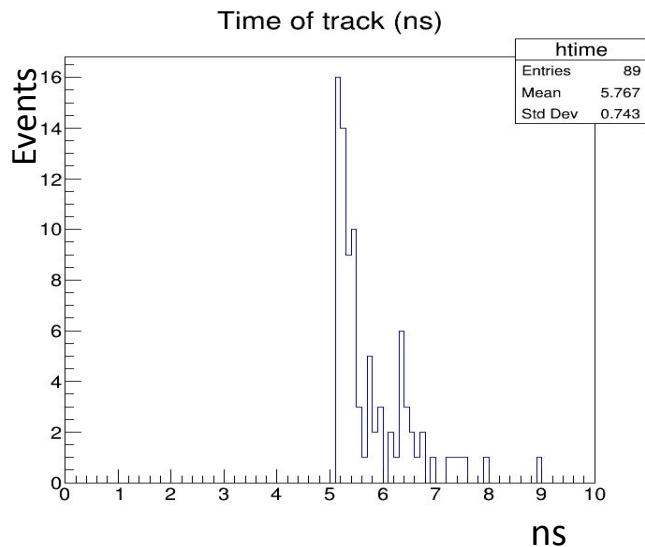
Decay  
time



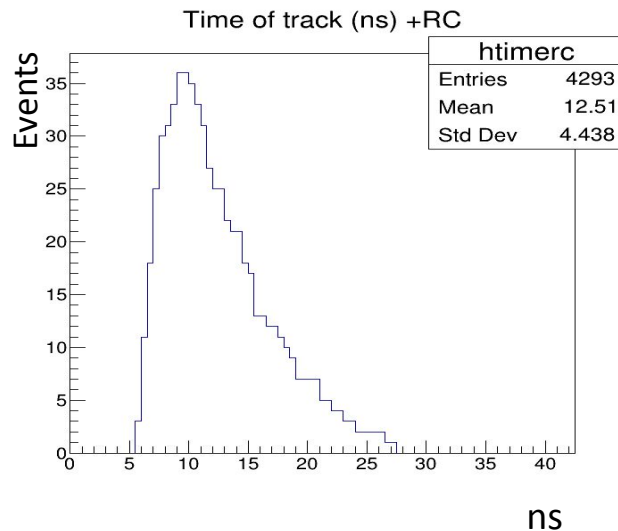
## Light transportation time



# Signal generation

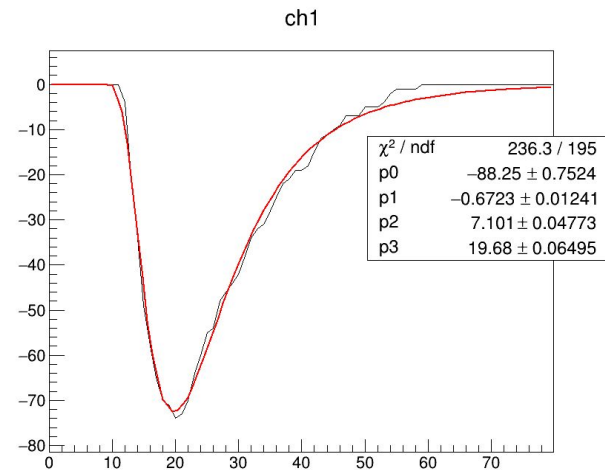


Photon transportation time



$$U_f = U_0 \left( 1 - e^{\frac{-(t-t_0)}{R_f C_f}} \right)$$

$$U_b = U_0 * e^{\frac{-(t-t_0)}{R_b C_b}}$$



Fitted signal by the Novosibirsk function

$$f(x) = e^{-\frac{\ln^2 q_y + \Lambda^2}{2\Lambda^2}}, \quad q_y = 1 + \frac{\Lambda(x-x_0)}{\sigma} \times \frac{\sinh(\Lambda\sqrt{\ln 4})}{\Lambda\sqrt{\ln 4}}$$

# Characteristics of the scintillator and SiPM

## Scintillators

Scintillators based on polyvinyltoluene **EJ-200** and **EJ-228** with the following characteristics

	EJ-200	EJ-228
Scintillator efficiency (photons/1 MeV e <sup>-</sup> )	10000	10200
Front Time (ns)	0.9	0.5
Decay Time (ns)	2.1	1.4
Light attenuation length (cm)	380	380

## SiPM

**Sensl MICROFJ-30035** 3x3 mm<sup>2</sup> and 60035 6x6 mm<sup>2</sup> **Hamamatsu S12572-015P** 3x3mm<sup>2</sup> and **S13360-6050PE** 6x6 mm<sup>2</sup>

	Hamamatsu		Sensl	
Size, mm <sup>2</sup>	3x3	6x6	3x3	6x6
Front Time (ns)	3.5	6.5	3	5
Decay Time (ns)	150	300	120	400
Quantum efficiency, %	25	40	30	50

## Type of scintillator and SIPM

The number of photons from the MIP was generated in proportion to the thickness of the scintillator

Thickness, mm  FIXED	Scintillator	MPV (p.e. )		Time resolution, ns	
				Hamamatsu FIXED	
		3x3	6x6	3x3	6x6
30	<b>EJ-200</b>	234	1350	0,535	0,2
30	<b>EJ-228</b>	236	1346	0,429	0,174

The EJ-228 better than EJ-200 by 21%

## Type of scintillator and SIPM

The number of photons from the MIP was generated in proportion to the thickness of the scintillator

Thickness, mm  FIXED	Scintillator  FIXED	MPV (p.e. )		Time resolution, ns			
				Hamamatsu		Sensl	
		3x3	6x6	3x3	6x6	3x3	6x6
30	EJ-228	236	1346	0,429	0,174	0,443	0,166

Sensl is better than Hamamatsu by 5%

6x6 mm is better than 3x3 mm by about **3 times**

## Type of scintillator and SIPM

The number of photons from the MIP was generated in proportion to the thickness of the scintillator

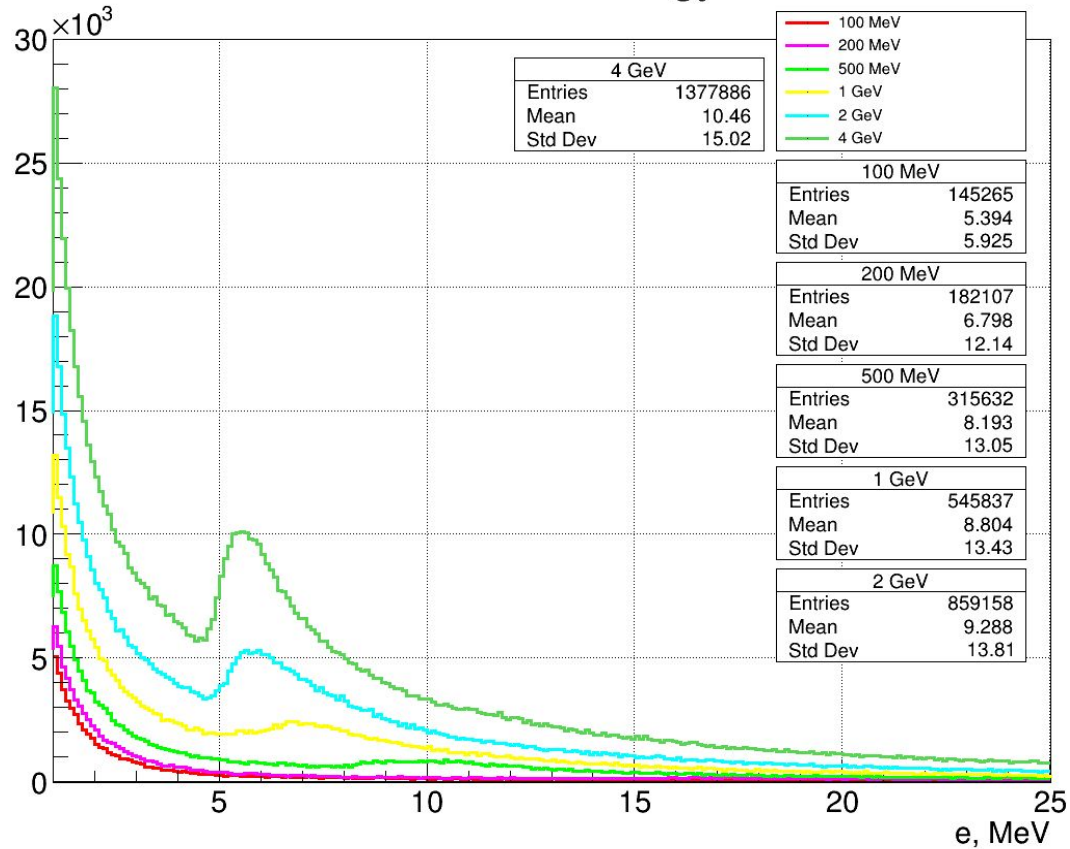
Thickness, mm	Scintillator	MPV (p.e. )		Time resolution, ns			
				Hamamatsu		Sensl	
		3x3	6x6	3x3	6x6	3x3	<b>6x6</b>
30	EJ-200	234	1350	0,535	0,2	0,521	0,21
20	EJ-200	157	1198	0,663	0,216	0,579	0,219
10	EJ-200	150	973	0,615	0,226	0,74	0,221
<b>30</b>	<b>EJ-228</b>	236	1346	0,429	0,174	0,443	<b>0,166</b>
20	EJ-228	213	1205	0,461	0,189	0,449	0,19
10	EJ-228	189	973	0,425	0,216	0,379	0,202

For EJ -228 scintillator and SiPM Sensl 6x6 mm<sup>2</sup> the time resolution is 0.166 ns

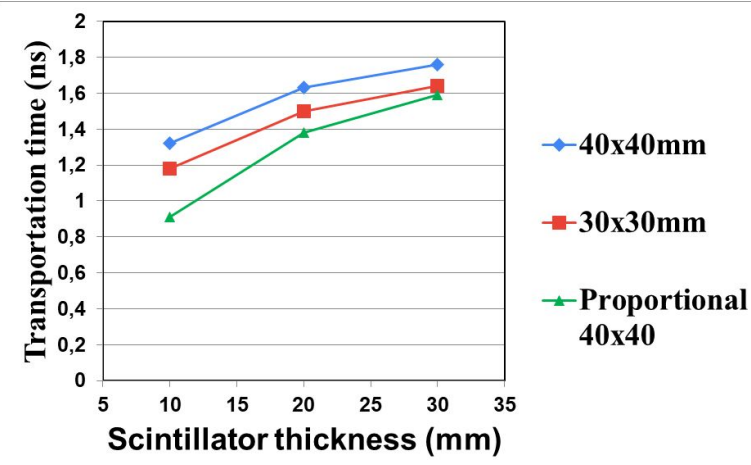
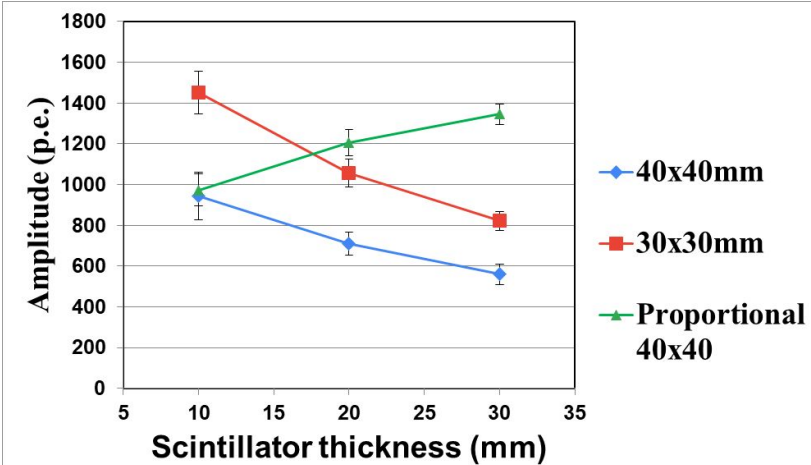


# Model of the response to passing neutron in the HGN design

## HGN cell energy



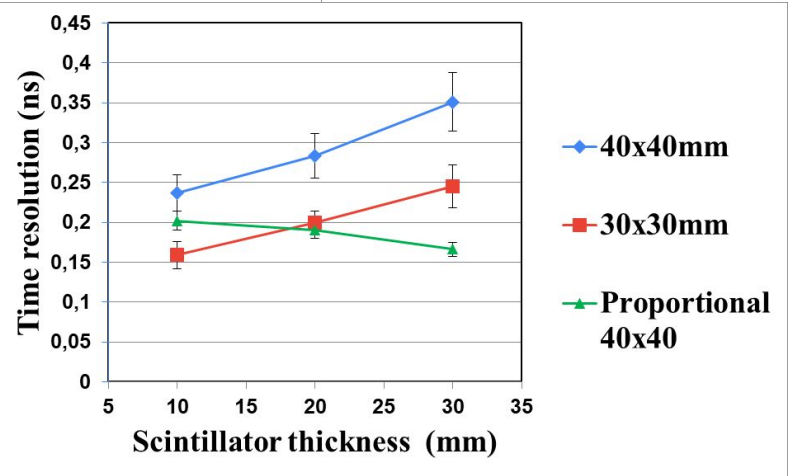
# Thickness of the scintillator



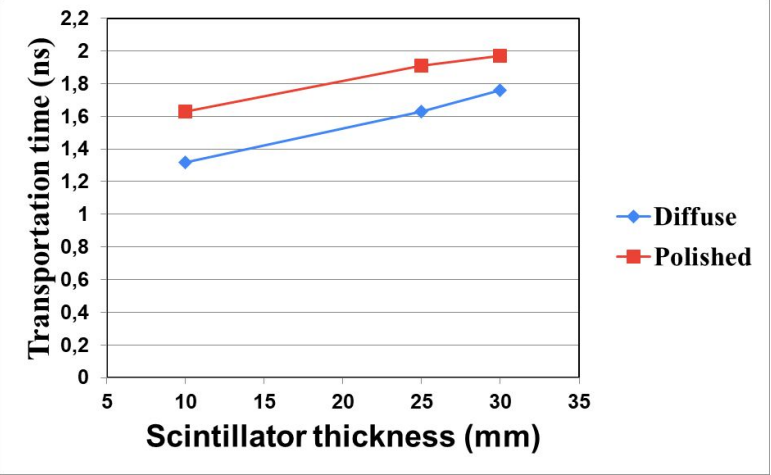
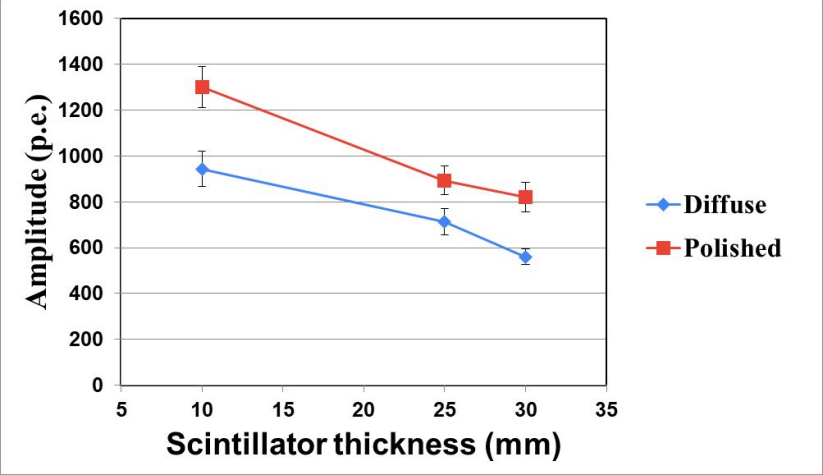
## Fixed number of photons in event

Diffuse wrapper  
SiPM Sensl 6x6 mm<sup>2</sup>  
Scintillator EJ-228

Transverse size 30x30 gives **41% better** time resolution than 40x40, but increases the number of cells



# Reflective surface of the scintillator



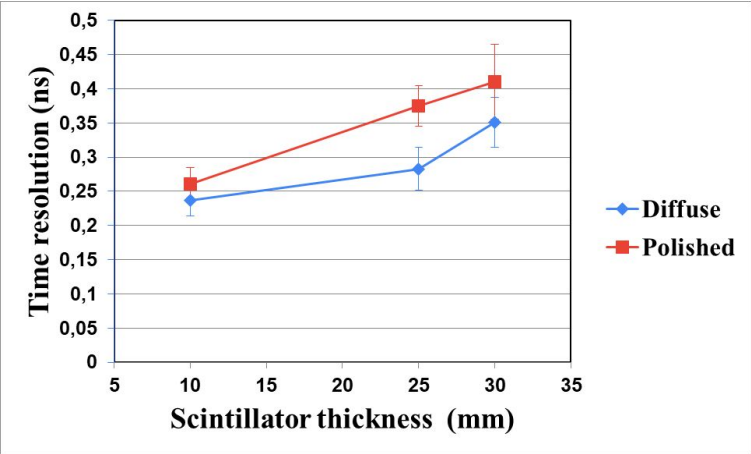
## Fixed number of photons in event

Diffuse and polished wrapper

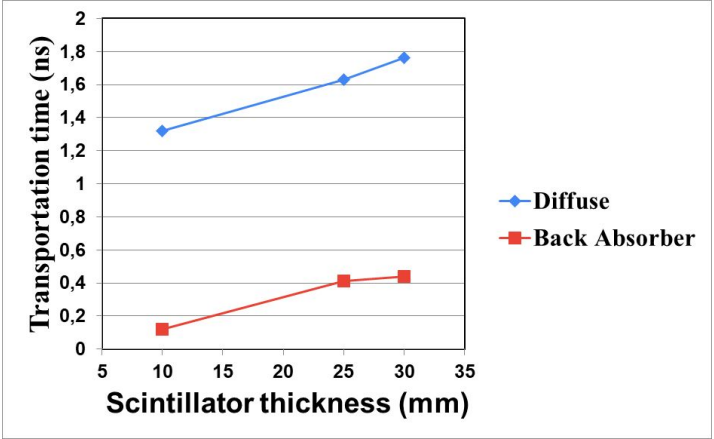
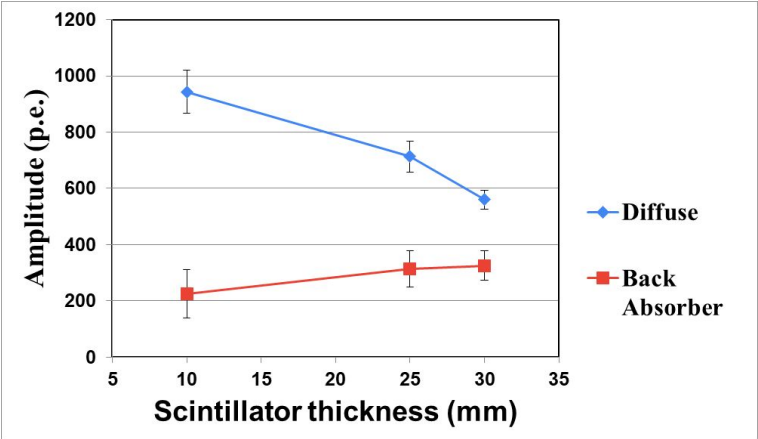
SiPM Sensl 6x6 mm<sup>2</sup>

Scintillator EJ-228

Diffuse reflector is better than specular one by **24%**

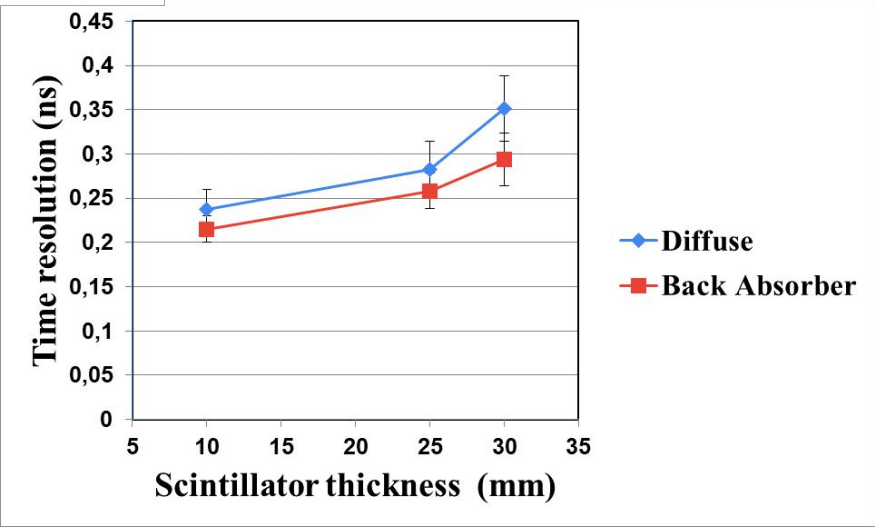


# Combinations of reflective surfaces of the scintillator



## Fixed number of photons in event

Diffuse wrapper and absorber  
5 faces - absorber and one front face - diffuse reflector  
SiPM Sensl 6x6 mm<sup>2</sup>  
Scintillator EJ-228



All diffuse faces are worse than 5 diffuse and one absorbing by **9%**  
The light transport time for 5 faces is 4 times less

# Conclusions

Use photodiode with larger area to increase the light collection from plastic and reduce time fluctuations

Use faster Sensl MICROFJ photomultiplier 6x6 mm<sup>2</sup>

Use fast scintillator EJ-228

Optimal is diffuse reflective wrapper for five faces and one absorbing face with SiPM

With other optimal conditions time resolution for **40x40x25** mm is **176** ps  
for **30x30x25** mm is **155** ps

