LAST DEVELOPMENTS OF PLASTIC SCINTILLATORS FOR HIGH ENERGY PHYSICS.

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OUTLINE

History of plastic scintillator (PS) in HEP

Problems

Motivation

The development of the PS sensitivity to

✓ ***thermal and fast neutrons***

The improvement of evolution parameters

PLASTIC SCINTILLATOR

Plastic scintillators are known from the early 60-th and are widely used in high energy physics since 1970.

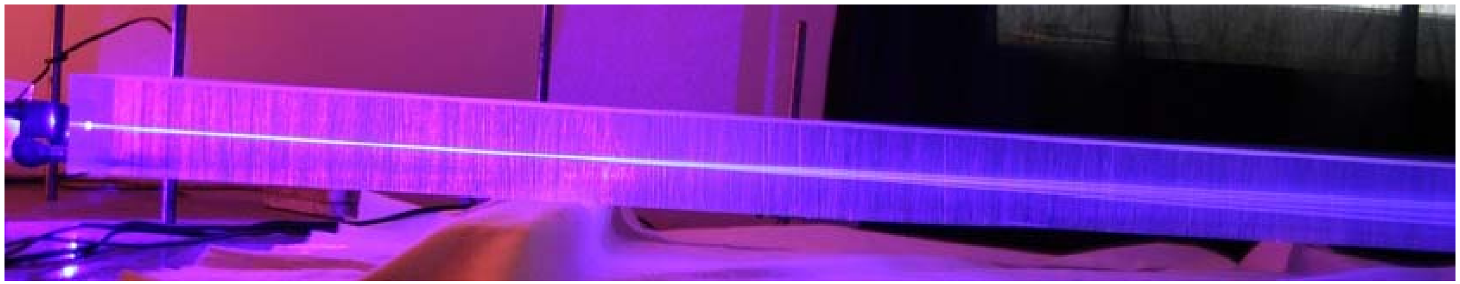
PS content was designed in the early 60-th of the last century

-polystyrene, polyvinyltoluene (polymer base)

-para-terphenyl (activator)

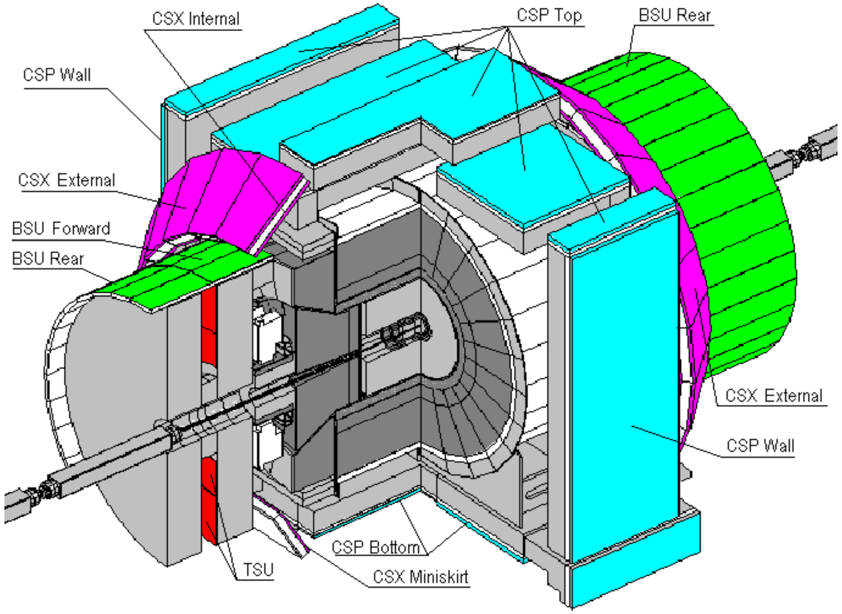
-POPOP (shifter)

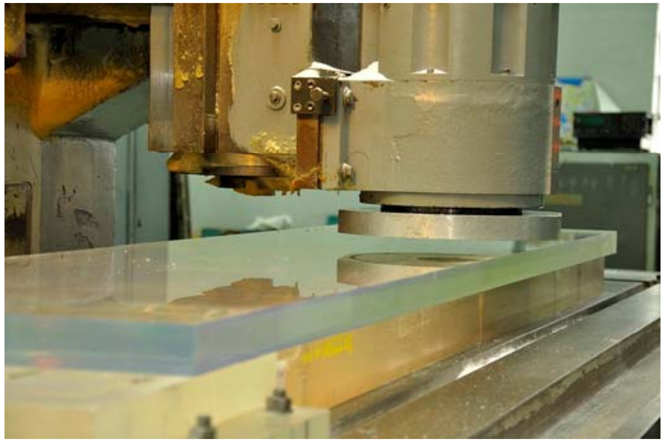
-Light yield – 10000 photons/MeV



AS A VETO SYSTEMS

For CDF experiment





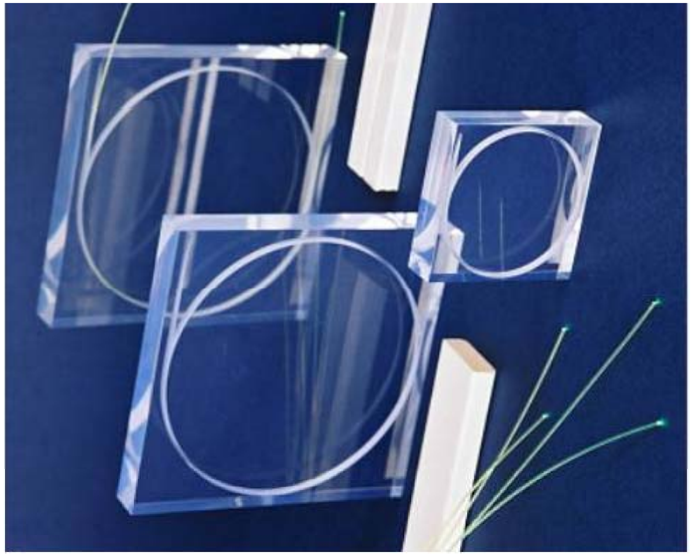
counter	length, cm	width, cm	thickness, cm
CSPL1	240	30,5	2
CSP L2	310	30,5	2
CSP L3	320	30,5	2
BSU	163	16,6	1,5

The area of muon detector is some hundreds of square meters – so, there are special requirements to PS transparency – not less than 2.8 m.

Operation life time must be not less than 10 years, so there are special requirements to radiation hardness.

AS ELEMENTS OF THE CALORIMETER SYSTEM

Tiles

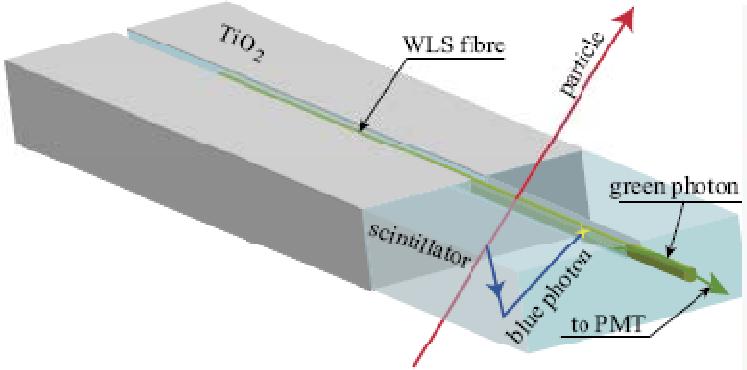


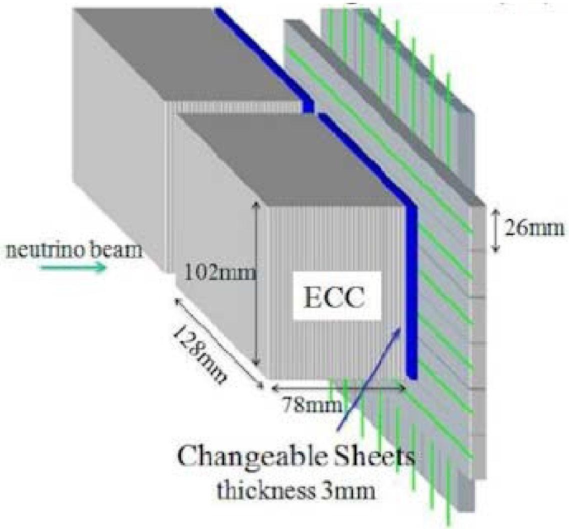
CMS hadron calorimeter

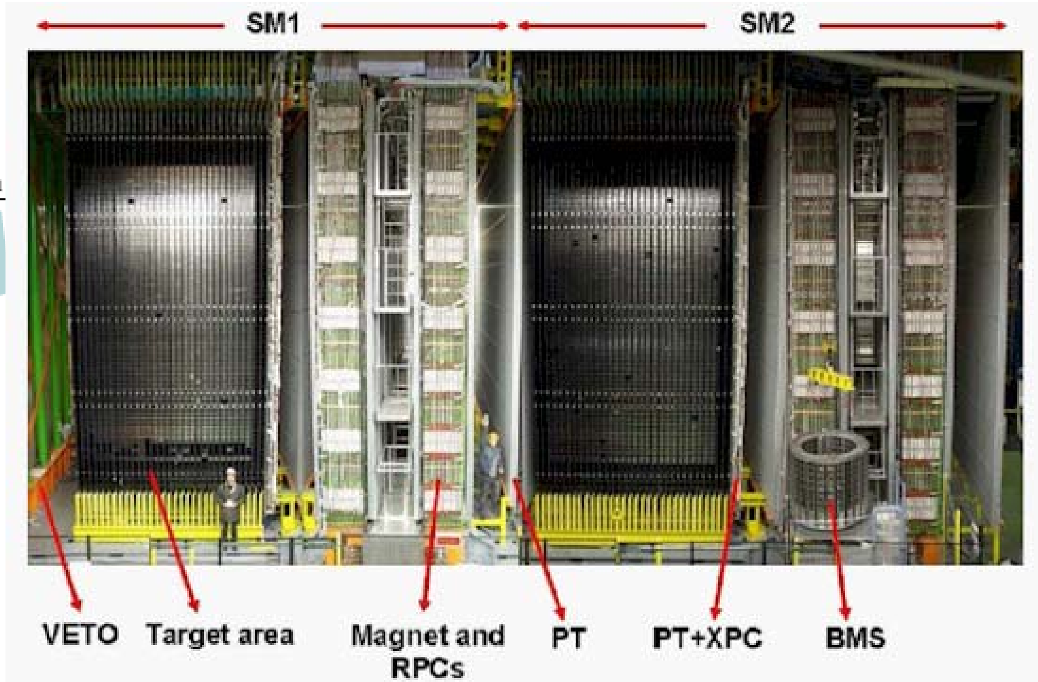
History of plastic scintillator (PS) in HEP

AS A POSITION SENSITIVE DETECTOR OPERA

Strips







PROBLEMS

In present time it is observed the evolution in HEP experimental techniques, but there are no progress in the development of PS properties.

The PS are the same as in the beginning of their history

MOTIVATION

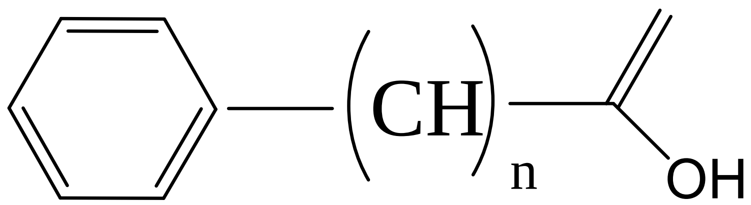
Evolution of a physical experiment – increasing the energy and luminosity - poses new demands to PS properties

- **It is necessary to develop PS sensitive to neutron radiation (slow and fast neutrons)**
- **To improve PS timing characteristics**

UPLOADED PS

To disperse neutron sensitive elements (such as Gd) in a polymer medium of PS

It is necessary to find suitable organic form for such elements

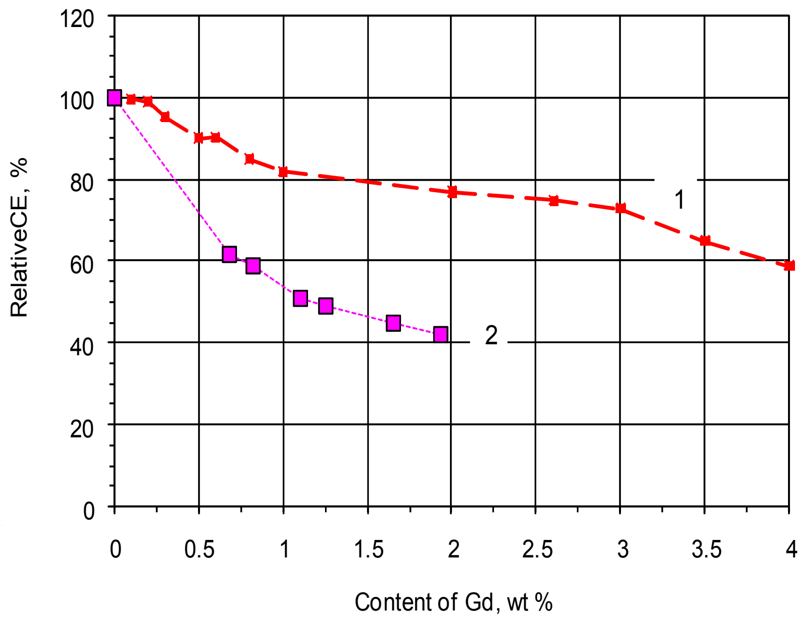


The most suitable organic form

thermal neutrons
Current state

UPLOADED PS

complex	Solubility by Gd ,%	Scint. eff., %
n=1 phenylacetic acid	0.02	80
n=2 hydrocinnamic acid	0.1	85
n=3 phenylbutyric acid	1	96
n=4 phenylvaleric acid	1	98



Most suitable compounds are complexes of gadolinium ion with phenyl carbon acids of different length of alkyl chain

Dependence of relative light yield $\eta(C)$ on Gd content in PS with Gd, that have the best light yield compared to literature data:
1 - $Gd(PhV)_3 \cdot 2TPPO$; 2 - $Gd(NO_3)_3(TBP)_3$

UPLOADED PS

We reach the level of 4 wt % Gd preserving 60 % light output.

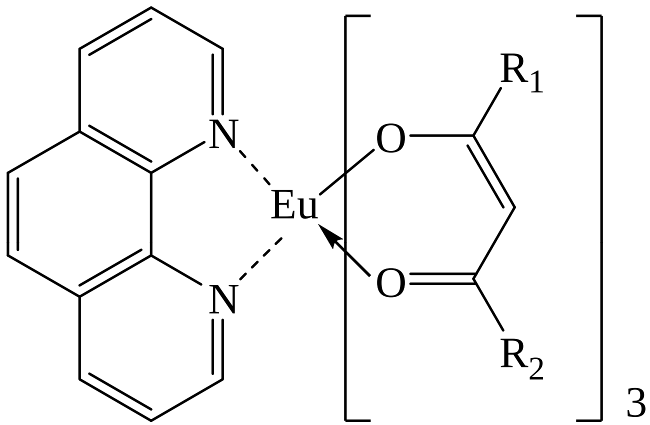
Evaluation of the bulk production

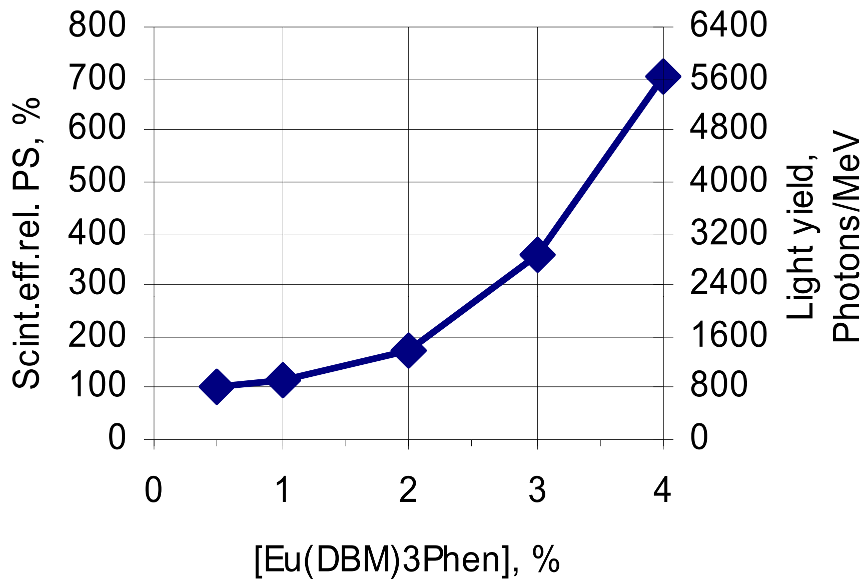
TRIPLET SENSITIVE CENTER

fast neutrons
Idea

It is well known that result of interaction high-energy particles with the polymer base of PS is the formation of excited singlet and triplet states.

The metal-organic complexes of Eu can be transfer excitation energy from triplet states of a polymer matrix

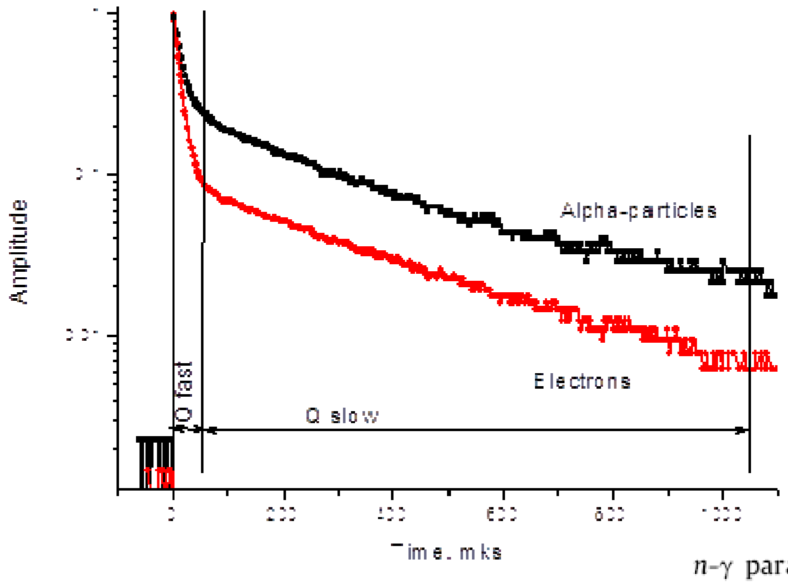


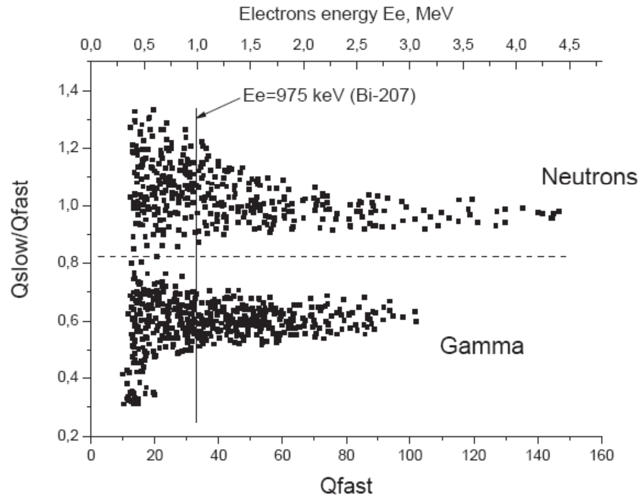


By creating two centers in PS volume sensitive to singlet and triplet excite energy respectively it can create fast neutron sensitive PS.

TRIPLET SENSITIVE CENTER

fast neutrons
Current state





Averaged and normalized oscillograms of pulses from Pu-239 source alpha particles (Eα = 5.4 MeV and Bi-207 source electrons (Ee = 0.975 MeV)

n-γ parameter FOMs for PSs with different additive contents for particles with $E > 350$ keVee energy.

Sample	Additives content %			FOM	Remarks
	Triplet activator Eu[DBM]$_3$Phen	Singlet activator DMDPA	Wavelength shifter L59		
1	2.5	0.7	0.03	1.2	
2	3.0	1.0	0.05	1.37	
3	3.5	1.5	0.04	1.30	Cloudy
4	2.5	1.0	0.03	1.19	
5	4.0	1.0	0.03	1.10	Cloudy
6	3.0	2.0	0.03	1.23	
7	3.0	0.5	0.03	1.21	

TRIPLET – TRIPLET ANNIGILATION

- The main condition of realizing – close proximity favoring the exchange interaction
- Polymer medium must contain many molecules long lived triplet states
- Typical content:

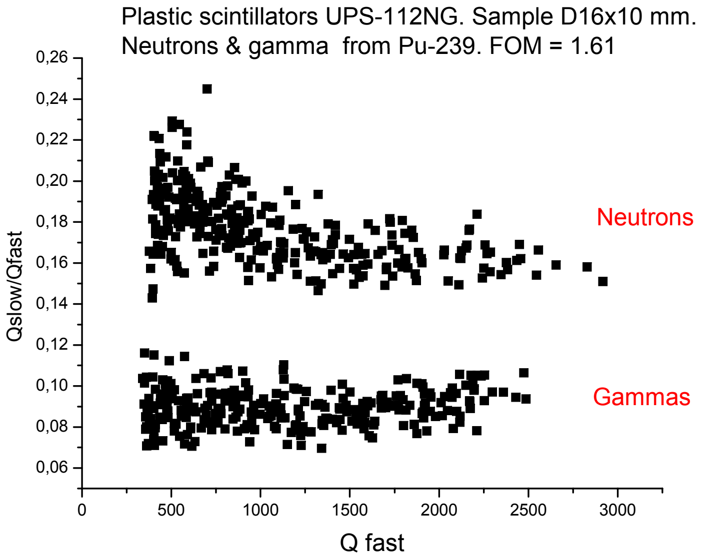
✓ Polystyrene base – 60 wt %

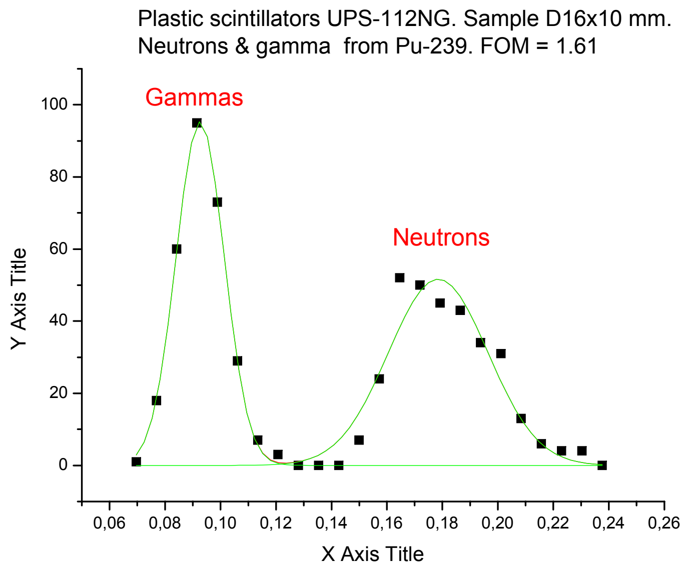
✓ Active additive PPO – 40 wt %

✓ Activator – molecules of biphenyl anthracene – 0.1 wt %

Triplet – triplet annihilation

fast neutrons
Current state





Plastic Scintillator	Light Yield, % (rel. anthracene)	n/γ –discrimination FOM	Microhardness by Vickers HV, MPa
UPS-110NG	52	2.41	24
UPS-111NG	54	1.61	178
UPS-112NG	51	1.61	120
UPS-923A	57	-	231
BC408	65	-	182

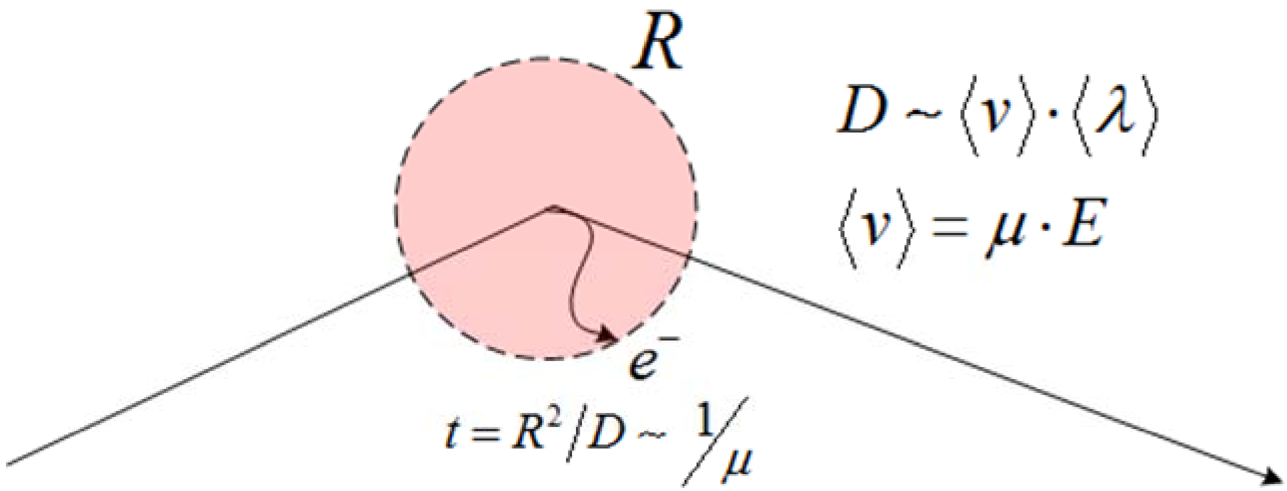
FAST NEUTRON REGISTRATION

It is necessary to continue researches of searching for new composition

Evaluation of the bulk production

fast plastic idea

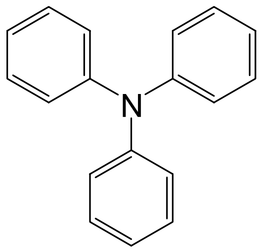
MOBILITY INCREASING - THE WAY TO IMPROVING PROPERTIES



The rise time of a scintillation flash is directly connected with electrons mobility in a medium. Changing the electrons mobility it is possible to change the scintillation characteristics of a medium, for instance, the rising time

CHANGING OF ELECTRONS MOBILITY IN A POLYMER MEDIUM

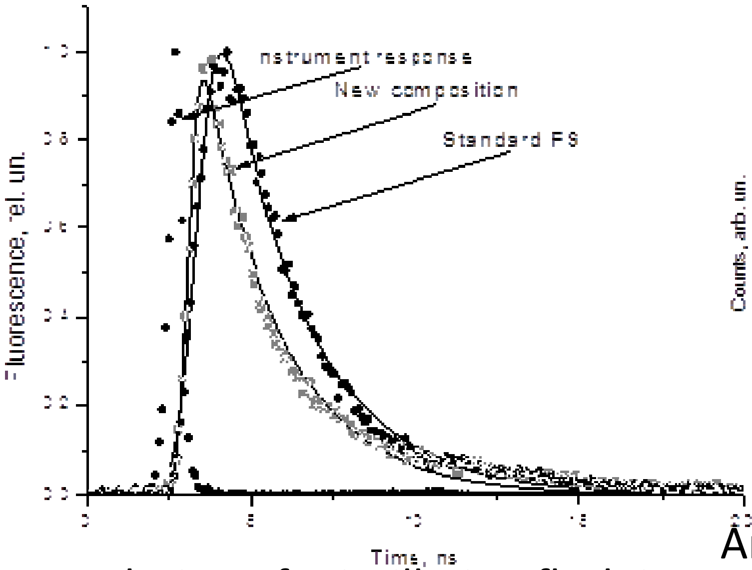
fast plastic
Current state



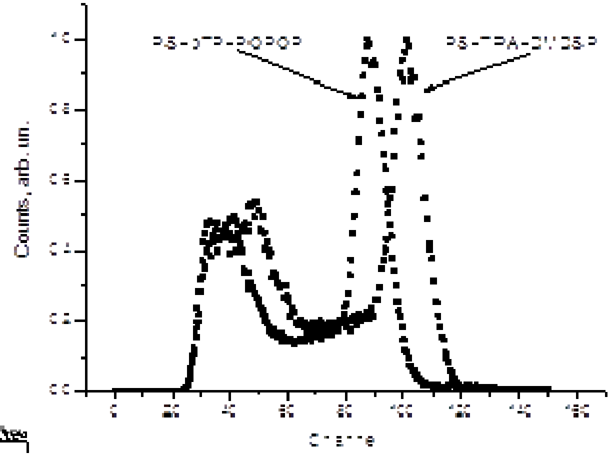
Triphenylamine moleculeTPhA

PS+20%TPhA

$\mu \sim 2 \cdot 10^{-6} sm \cdot V^{-1} s^{-1}$



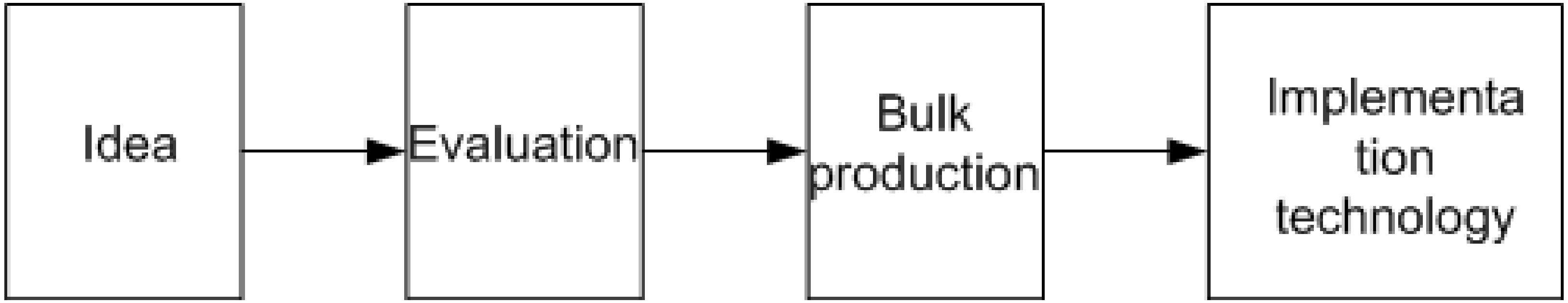
Evolution of scintillation flash in a polymer scintillator



Amplitude spectra of scintillation composition with 0.6PS+0.4NPA+0.02DMDSP.

The rise time of the scintillator based on polystyrene and TPA decreased to 0.49 ns compared to 0.85 ns of the standard scintillator with increased light yield

SEQUENCE OF IMPLEMENTATION



Now we are in the initial stages

CONCLUSIONS

- ***The ways are founded for wide-range changing properties of Gd loaded plastic scintillator***
- ***Find a way for the creation neutron sensitive PS and fast PS***

What we have to do?

- ***It is necessary to establish the limit of possibility of changing the PS timing characteristics***
- ***To make a step from laboratory routine to industrial implementation***