Liquid Scintillator Neutron Detection System for Fast-ignition

Advances in Liquid Scintillation Spectrometry (LSC 2 0 1 7)

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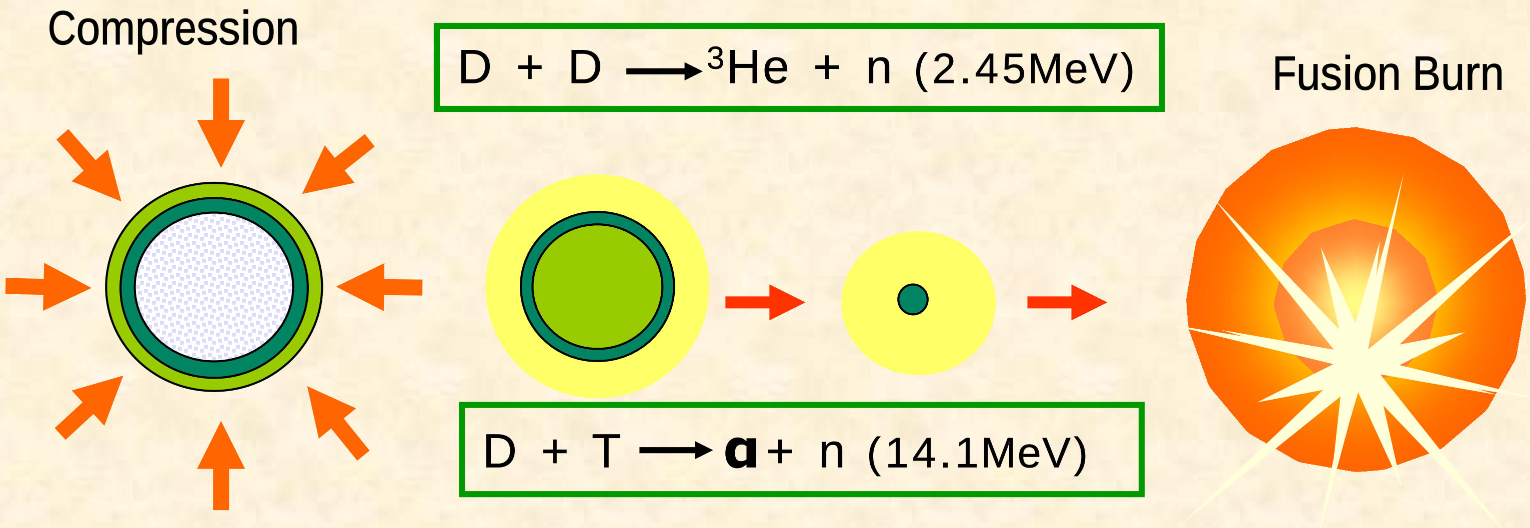
Neutron diagnosis in ICF



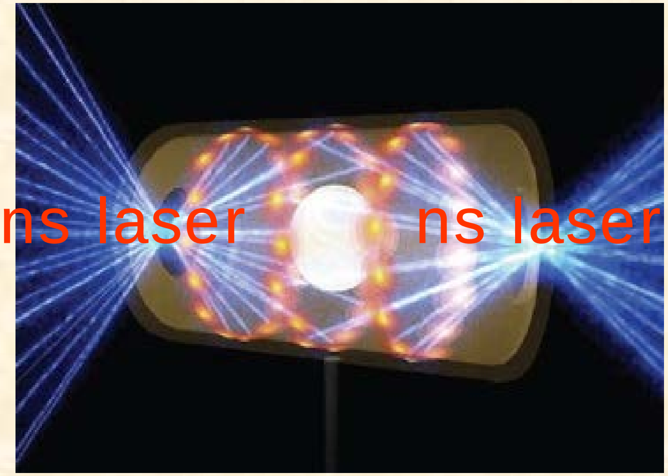
Neutron detectors in inertial confinement fusion experiments are predominantly used to measure the neutron yield and ion temperature of the primary fusion reactions. These experiments produce nearly monoenergetic neutron spectra with energies of 2.45 MeV for deuterium DD and14.1 MeV for deuterium-tritium DT-filled targets.

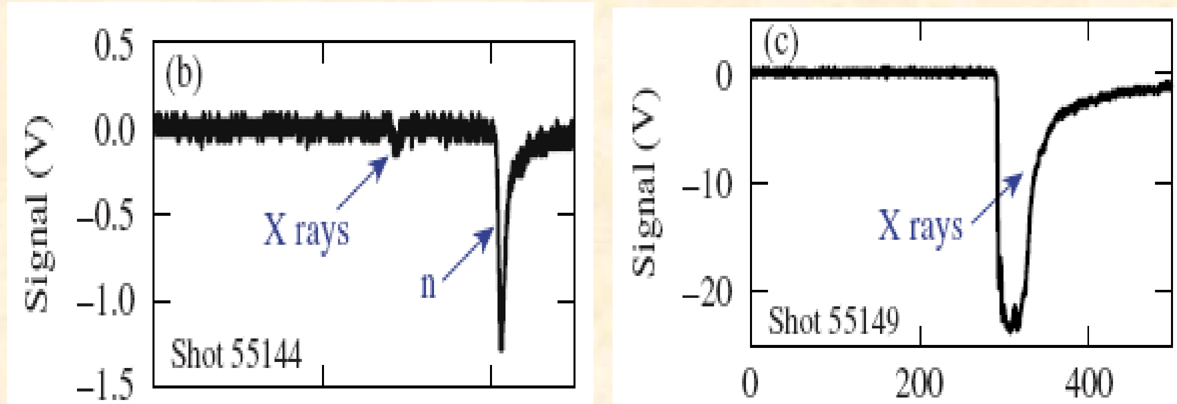
BF_3 Array

Cu Activation

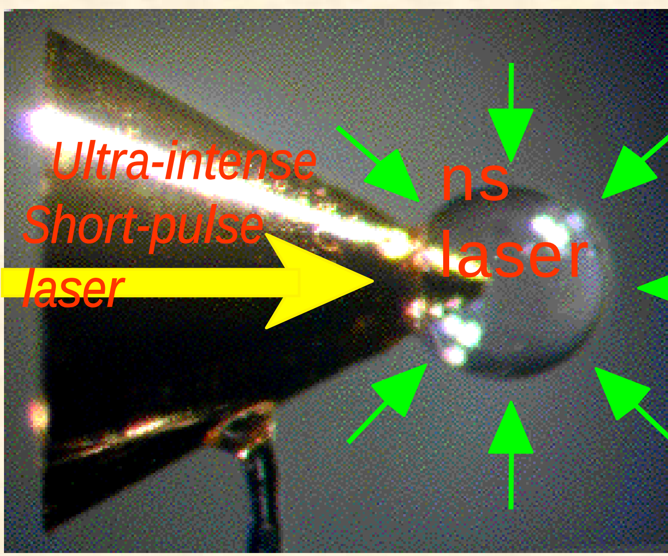
Scintillator

Challenge for neutron diagnosis in FI





Rev. Sci. Instrum. **81**, 10D302 (2010)



R.Kodama et al., Nature 412 (2001) 798

The detection of neutrons in fast-ignition experiments is very challenging since it requires the neutron detection system to recover within 10–100 ns from a high background orders of magnitude stronger than the signal of interest. The background the hard x-ray emission from short-pulse laser target interactions for the fast-ignition experiments.

How the liquid scintillator works?

Liquid scintillator:

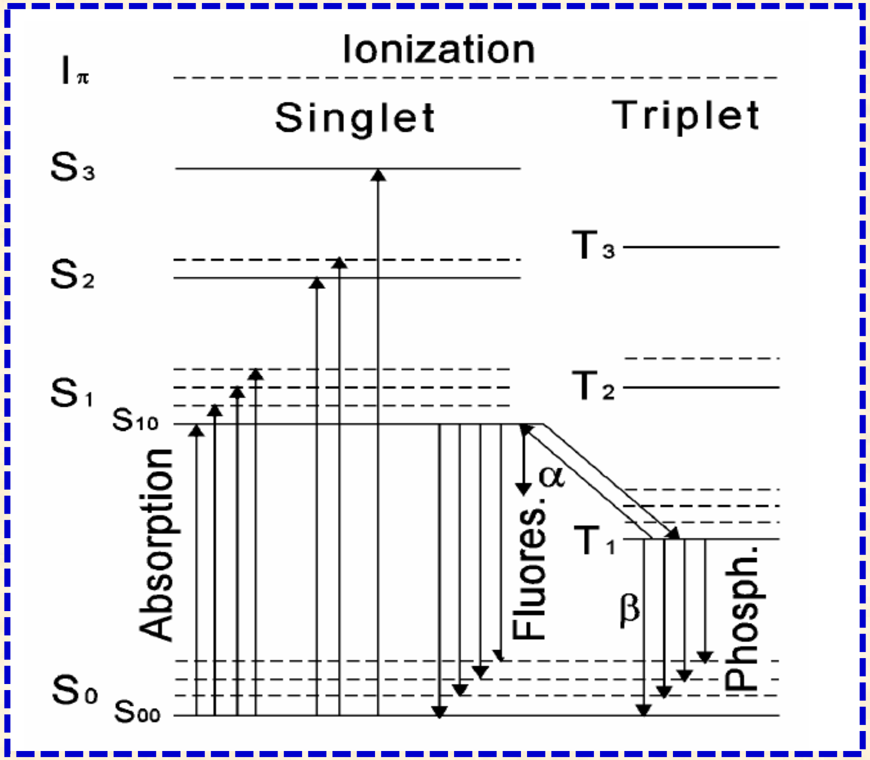
PX+PPO+bis-MSB

PXE+PPO+bis-MSB

DIN+PPO+bis-MSB

The basic components of an liquid scintillator are a solvent and one or more fluorescent solutes. Both solvent and solutes in the liquid scintillators are aromatic hydrocarbons featured in benzenoid and heterocyclic ring structures

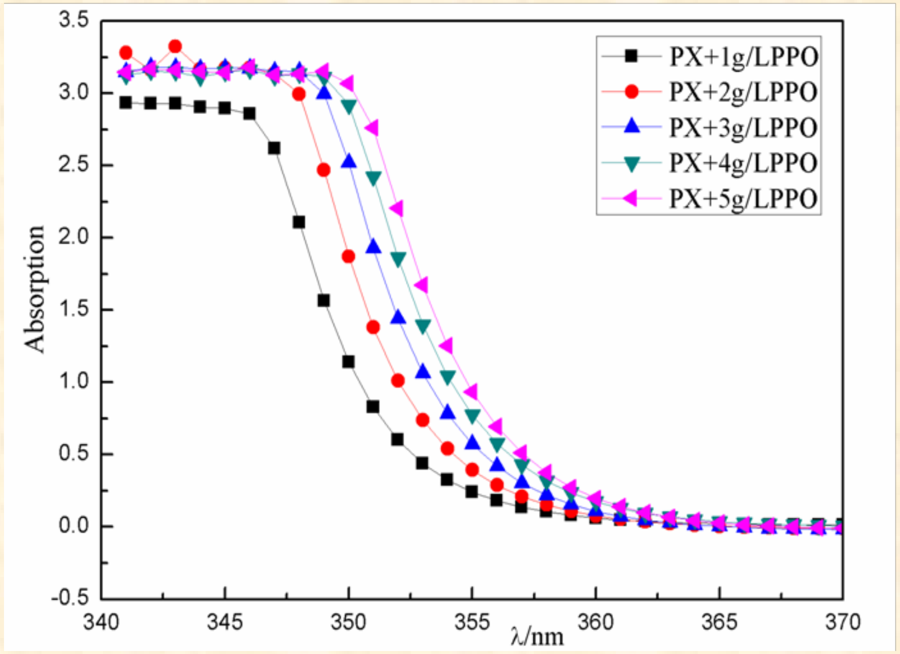
Wiki picture

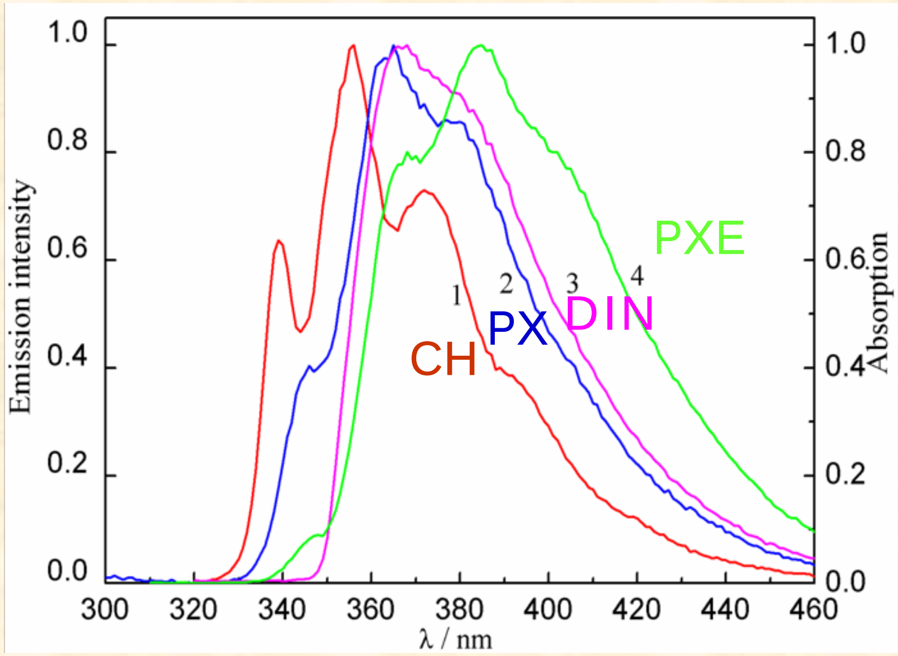


Most of the excitation energy is originally deposited in the solvent, in which rather long-lived states are excited. The energy is first transferred to a primary and thence to a secondary fluorescence, that progressively shift the wavelength of the emitted light to the visible.

Character of the Liquid Scintillator

Liquid scintillator sample: PX & DIN (solvent) +PPO(solute)

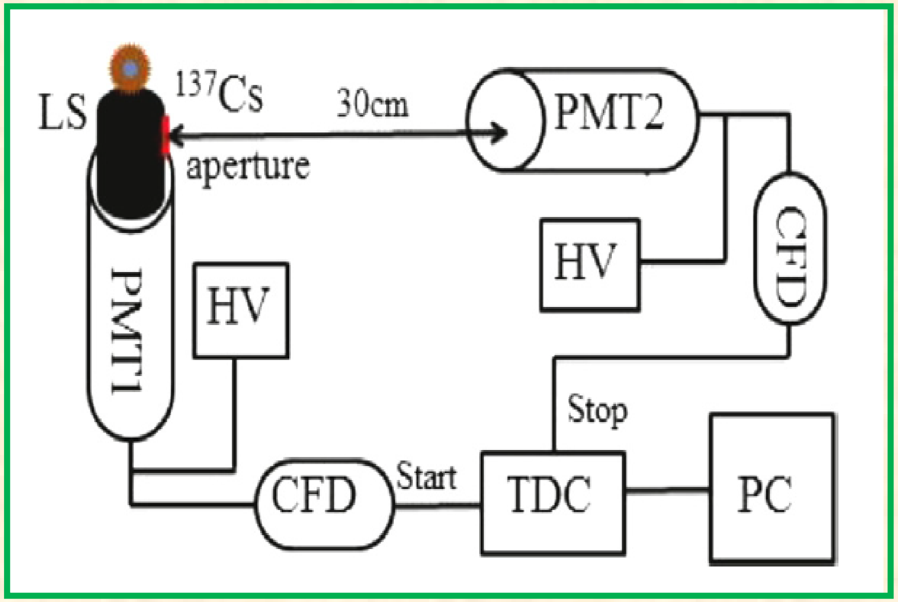


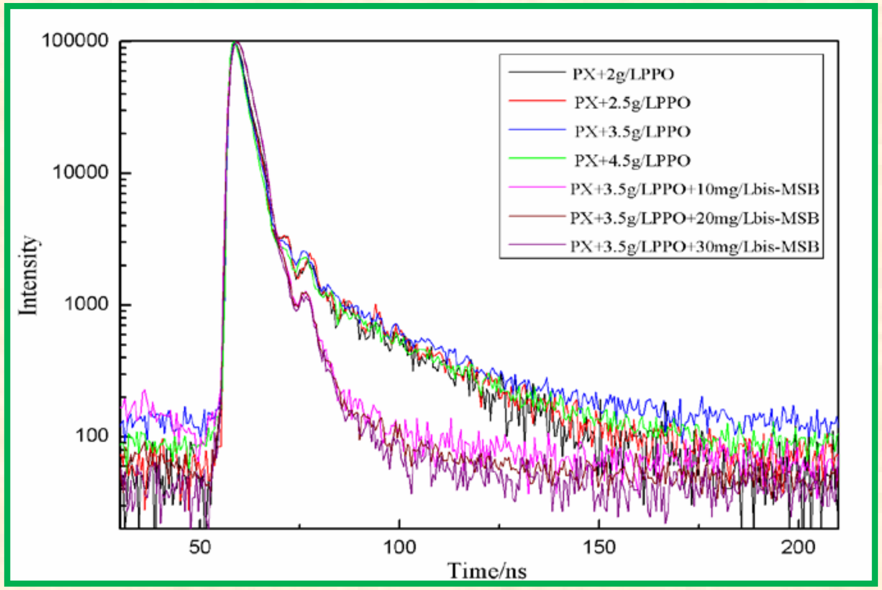


Absorption spectra of the liquid scintillator is tested at different PPO concentration.

Fluorescence spectra of the liquid scintillator with different solvent at the same PPO concentration, 3g/L .

Character of the Liquid Scintillator

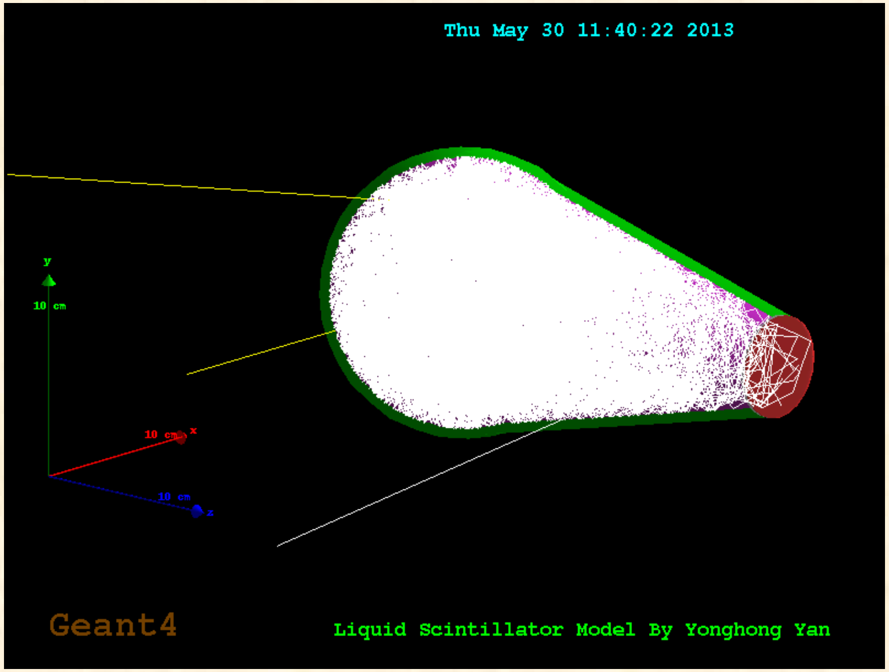


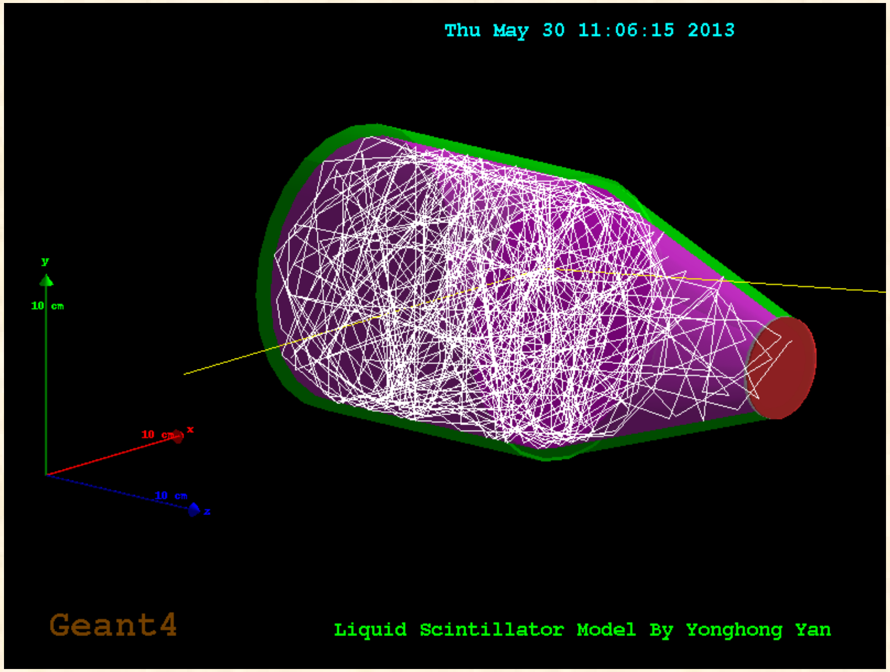


Schematic diagram of time-correlated single-photon counting technique for measuring the decay time of luminescence intensity. CFD: constant fraction discriminator and TDC: time-digital converter

The high-dynamic-range decay profiles of PPO and PPO+bis-MSB liquid scintillators. The PPO+bis-MSB scintillators have a less intense afterglow compared with the PPO scintillators.

Calculation model of the liquid detector

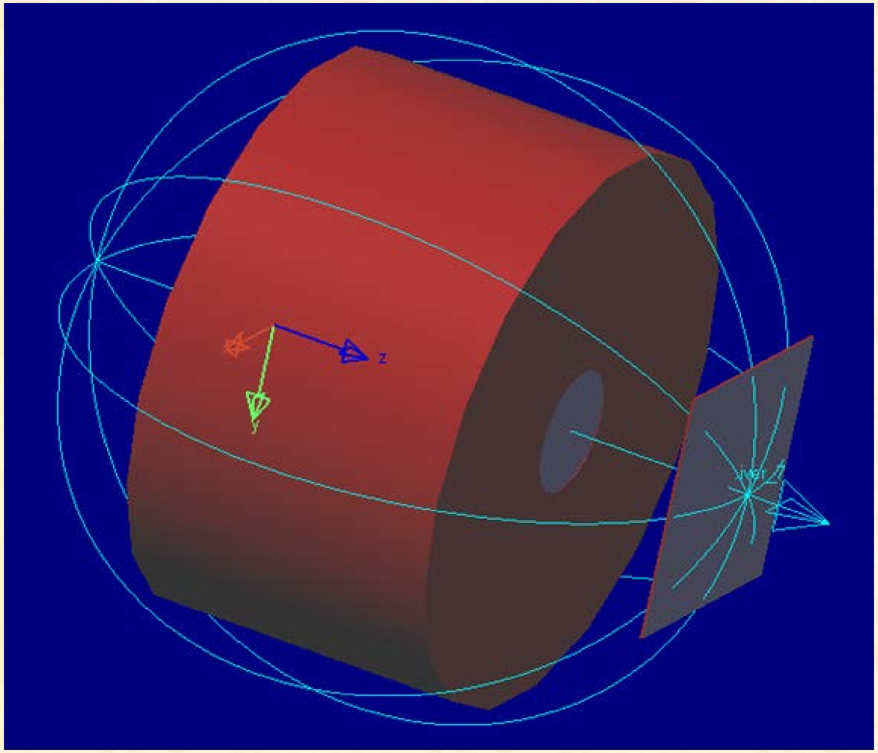


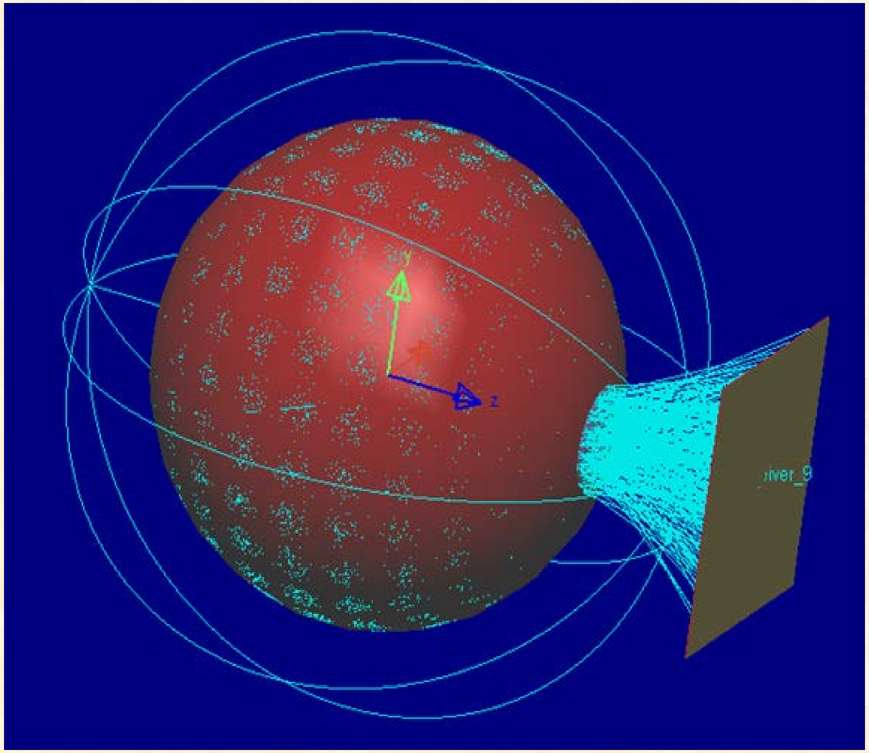


The calculation model was set up using Geant4. Including the incidence of the DD or DT neutron, elastomeric scattering and non-elastomeric scattering of the neutron are both considered in our calculation. The recoil protons lose their energy in the scintillator by ionization, excitation and radiation.

Calculation model of the liquid detector

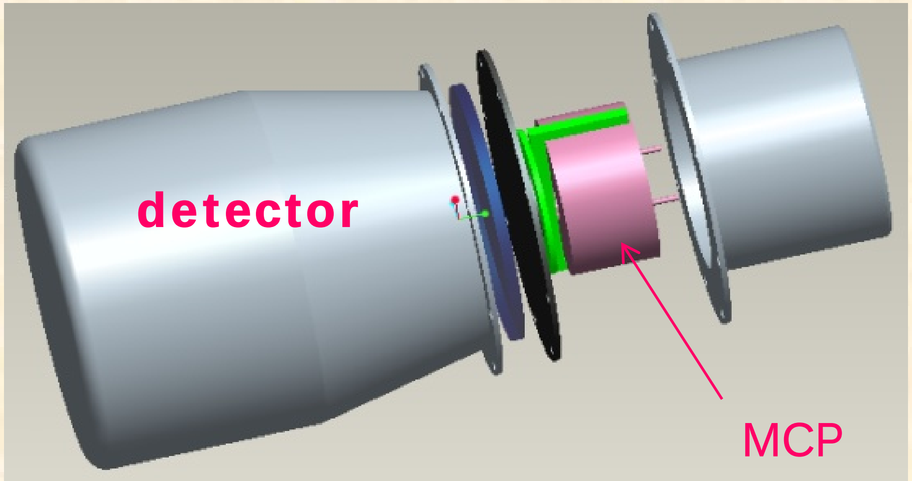
Light tracer code X-LAB is used to optimize the shape of the detector.

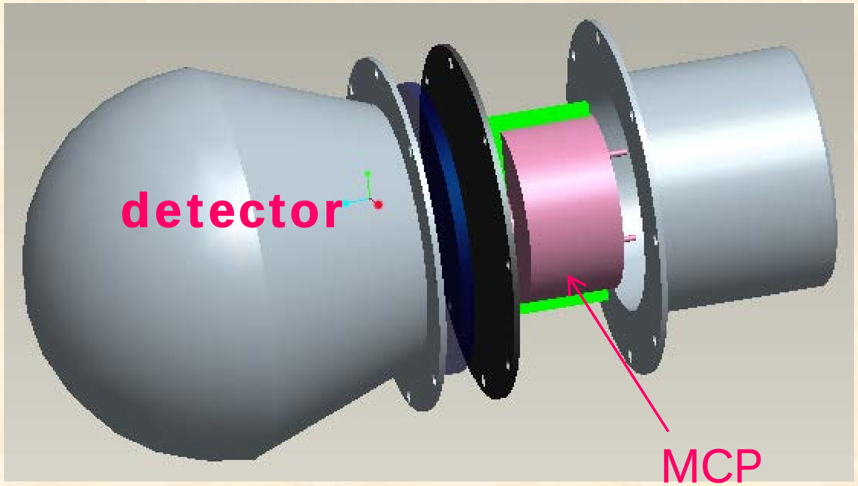




Cylindrical? Cube? Sphere? Icecream-like?

Integrated design of the liquid detector





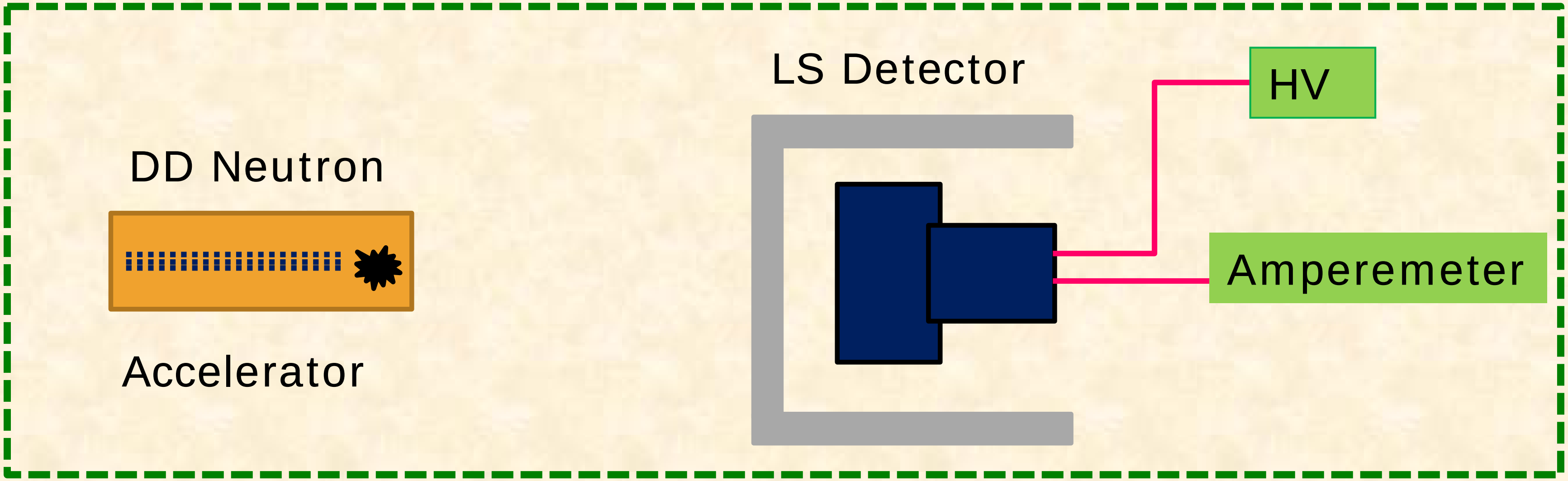
Sphere-cone

R(cm)	V(mL)	η	η(Edep>0.5MeV)	η(Edep>2MeV)
5	922.6	83.3%	73.1%	41%
6	1342.2	87.6%	78.6%	48.5%
7	1874.2	90.1%	83.1%	54.6%
8	2531.9	92.3%	86%	59.7%
9	3325.7	93.7%	88.5%	64.4%

column-cone

R(cm)	V(mL)	η	η(Edep>0.5MeV)	η(Edep>2MeV)
5	1062.21	83.3%	73.7%	43.2%
6	1618.7	87.9%	79.7 %	51.4%
7	2365.9	90.8%	84.2%	57.9%
8	3338.3	92.7%	87.3%	63.6%

Calibration of the liquid scintillator



The calibration experiment was performed on the K-400 accelerator.

The sensitivity of the detector：

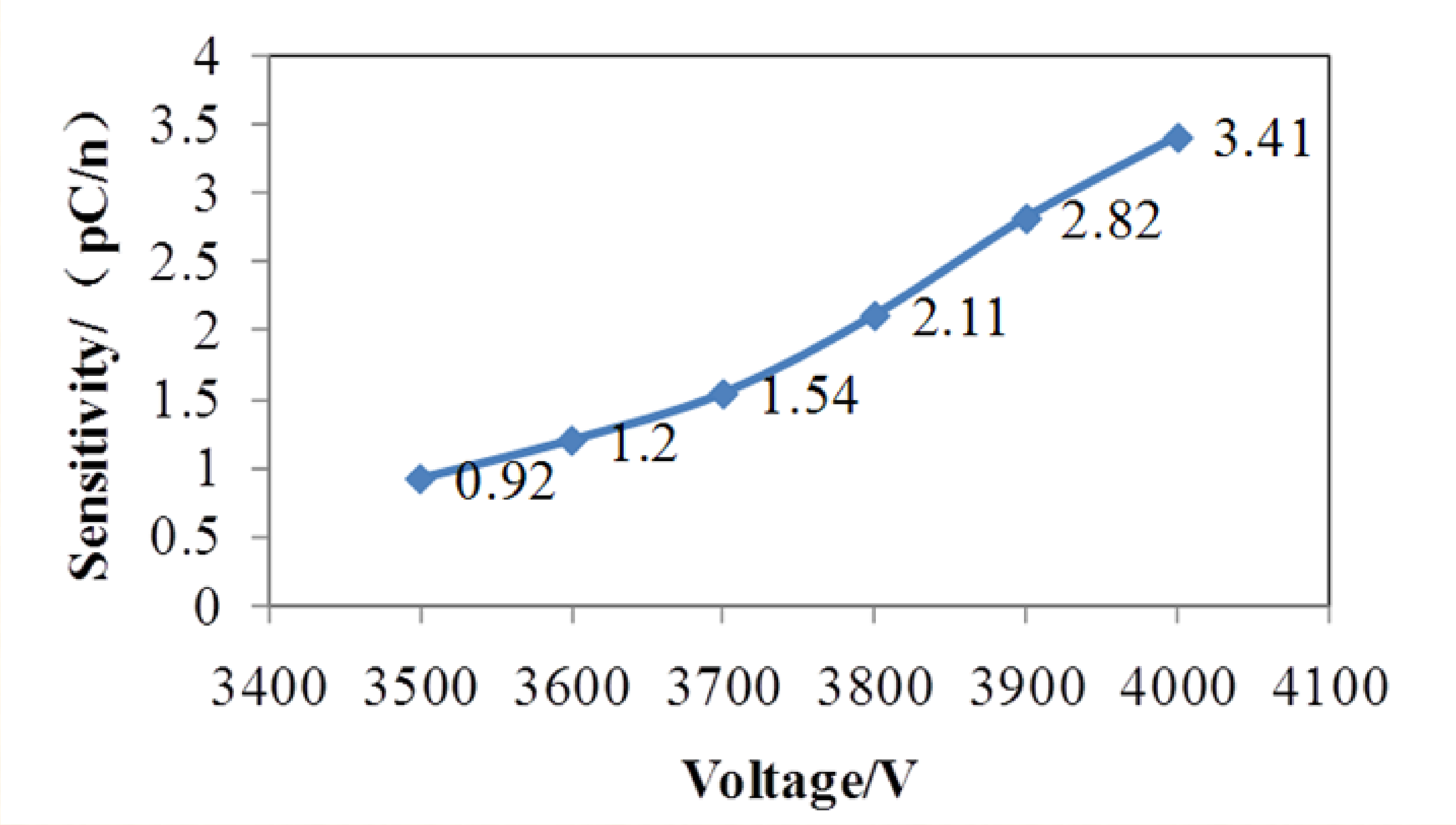
$$S(E) = Q(E) / \Phi(E)$$

S(E)——the sensitivity，(C.cm^2)

Φ(E)——the incent neutron flux，(1/cm^2)

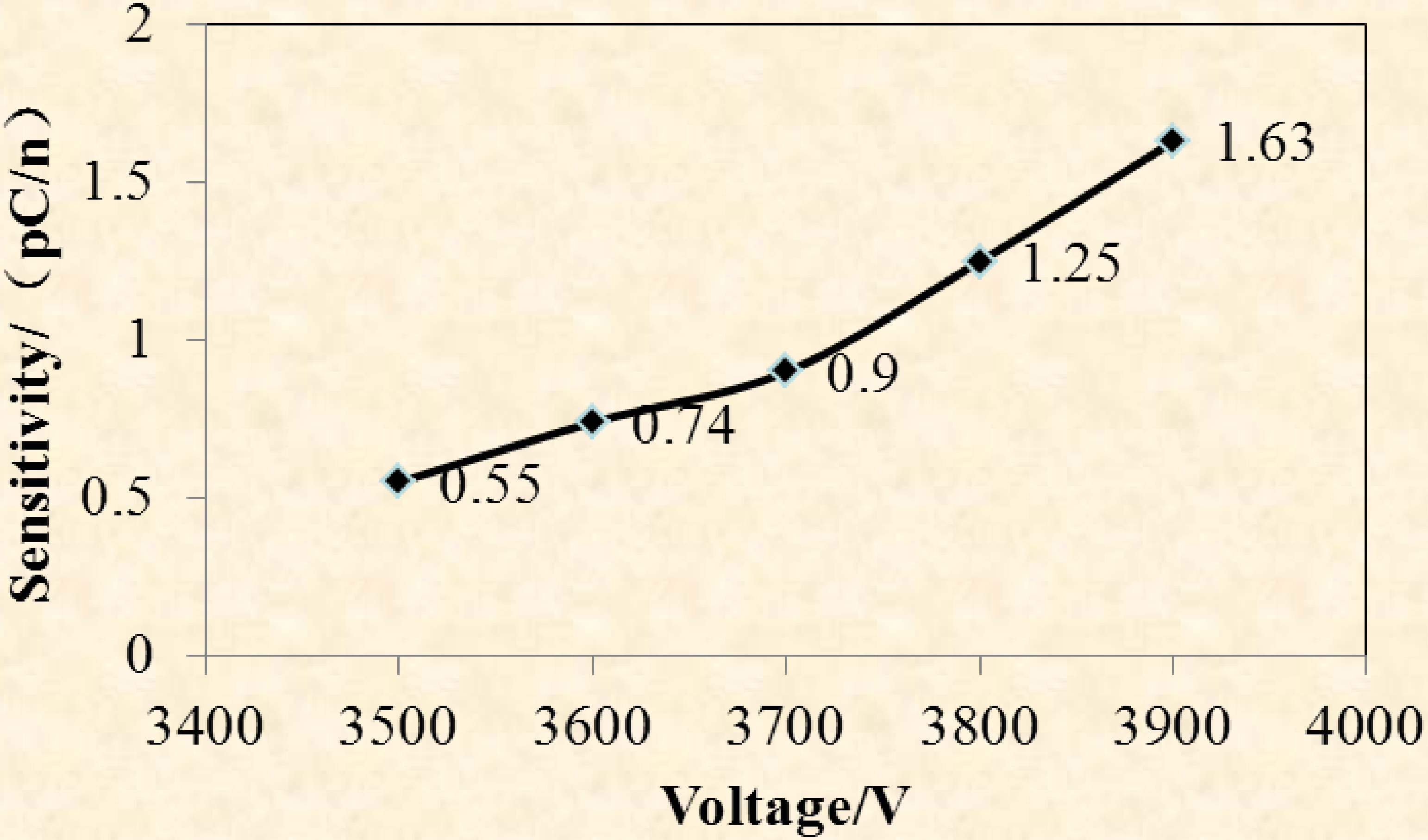
Q(E)——the out-put charge of the detector，(C)

Sensitivity of the liquid scintillator



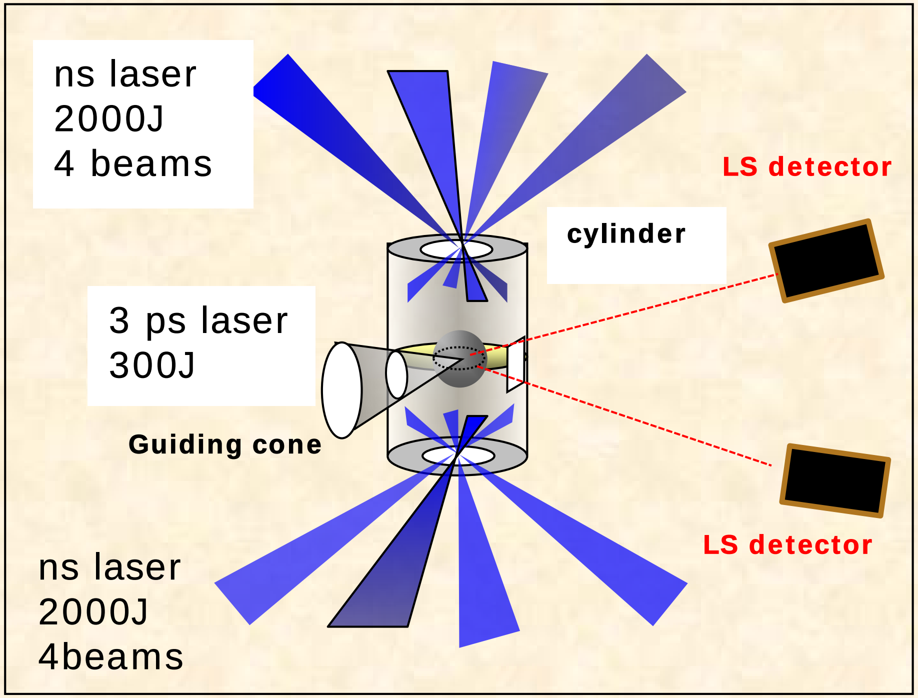
DD sensitivity of the 2 # Detector

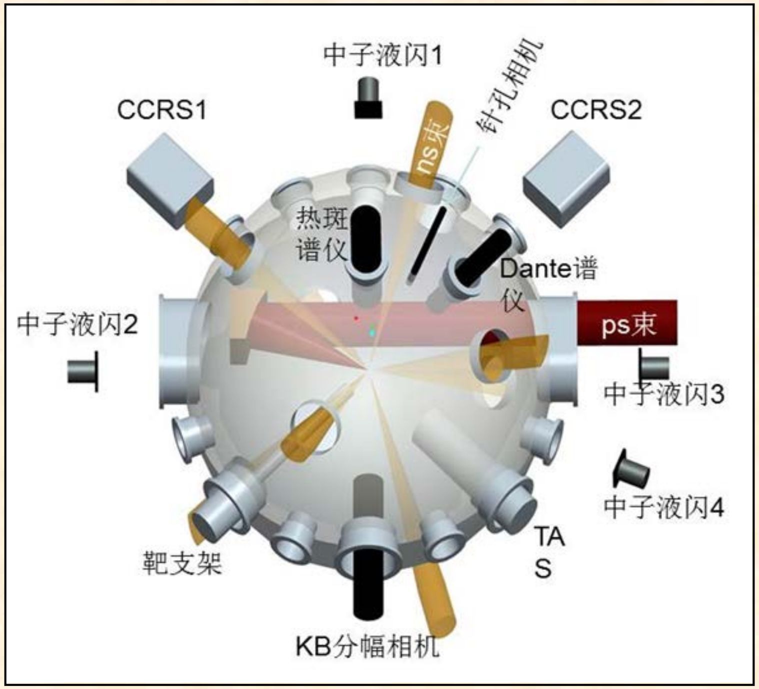
Sensitivity of the liquid scintillator



DD sensitivity of the 3# Detector

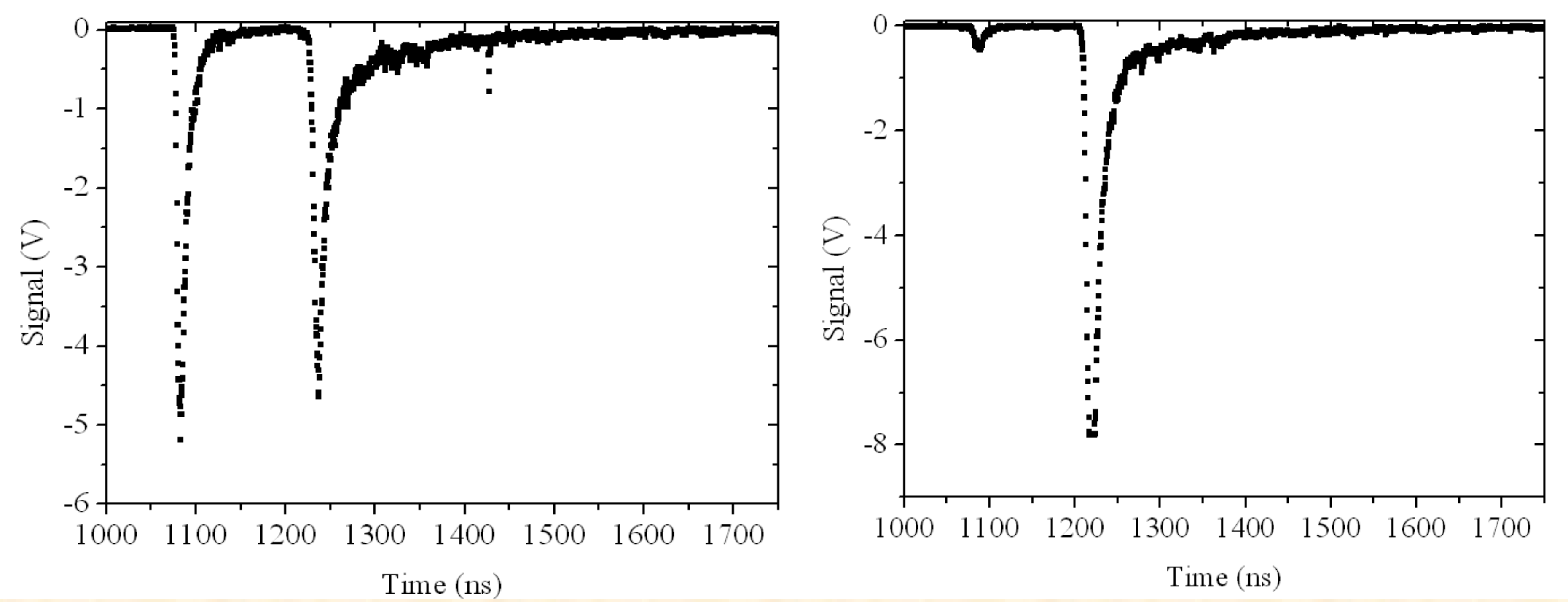
Application on ShenguangII-U facility





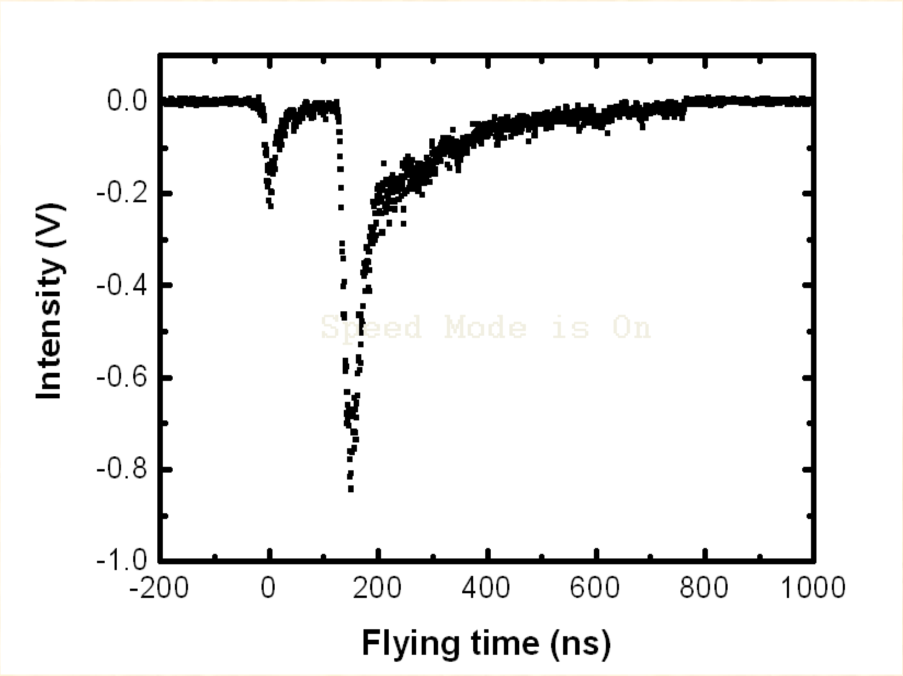
The indirect-drive fast ignition experiments were performed on the ShenguangII-U facility. Eight laser beams, 2.5 ns, 2000J,shaped-pulse, were injected in a cylindrical hohlraum targets, compressing the sphere shell. The ninth beam, 3ps, 300J, was used to produced electrons to ignite the compressed fuel. Our liquid scintillator detector was placed around the target chamber, 2.7~3.3m to the target.

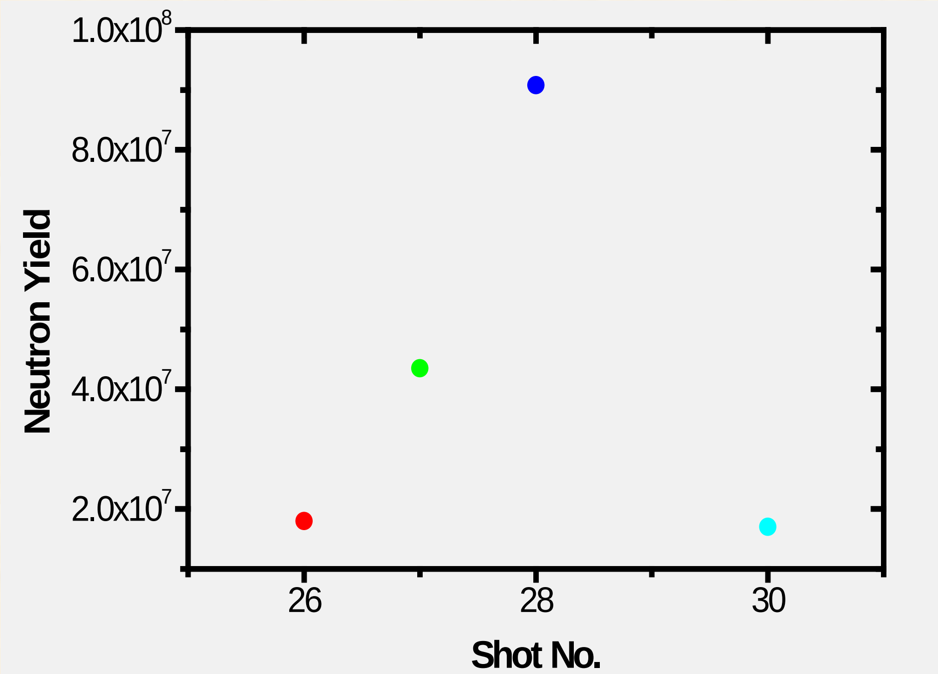
Typical Neutron Signal From FI Experiment



In the experiment, the MCP is gated by applying a negative pulse of the order of 200 V to the photocathode, which extracts the photoelectrons from the photocathode and prevents them from reaching the MCP.

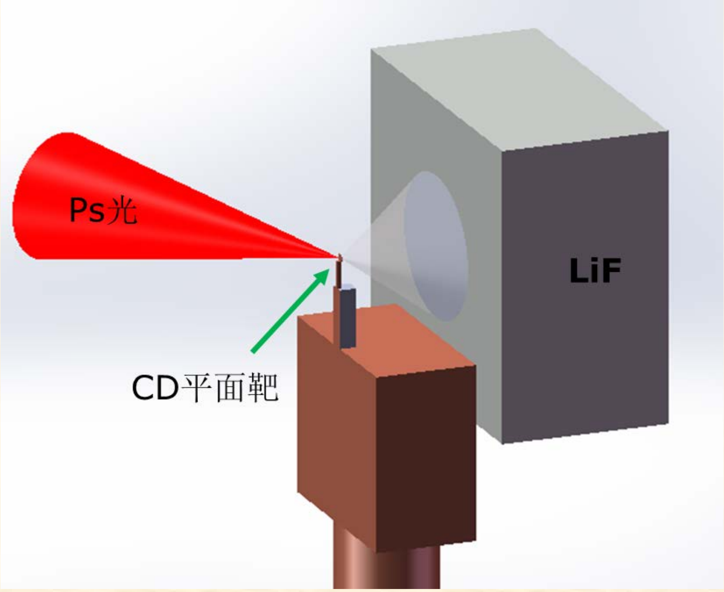
Neutron yield of the fast ignition





Our liquid scintillator detection system can clearly discriminate between the DD neutron signal and the hard X-rays. DD neutron yield in the shot with the PW heating laser was increased by a factor of 30-100 compared to without the PW heating laser.

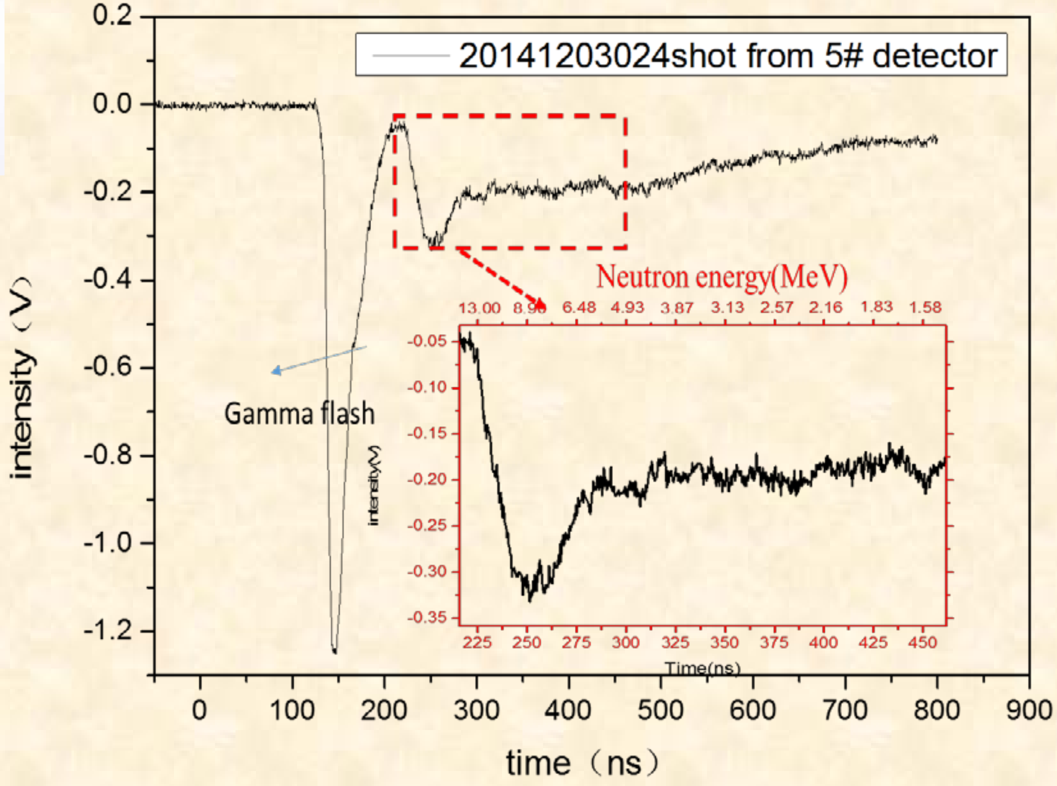
Application on (p,n)\(d,n) neutron detection



Target: 10um CD + 5mm LiF

Laser : 100±20J, 1ps

Reaction:（p，n）（d，n）



SUMMARY

- **We present several designs of liquid scintillator using Geant4 calculation from the injection of the neutrons to the light getting into the MCP. Our liquid scintillator is based on PPO, dissolved in xylene and enriched with molecular O_2.**

- **The liquid scintillator system was calibrated and then applied in fast ignition experiments. It could dramatically improve neutron diagnostics in fast ignition experiments where neutrons have to be detected in the presence of an intense γ-ray burst.**

- **The ability for liquid scintillator development, calculation model, integrate design, precise calibration, is established based on the research in the last few years.**

COLLABORATORS

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THANKS FOR YOUR ATTENTION