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Neutrons

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Neutron TOF spectroscopy in a single-shot nanosecond neutron pulsed technique for a disclosure of hidden explosives and fissile materials

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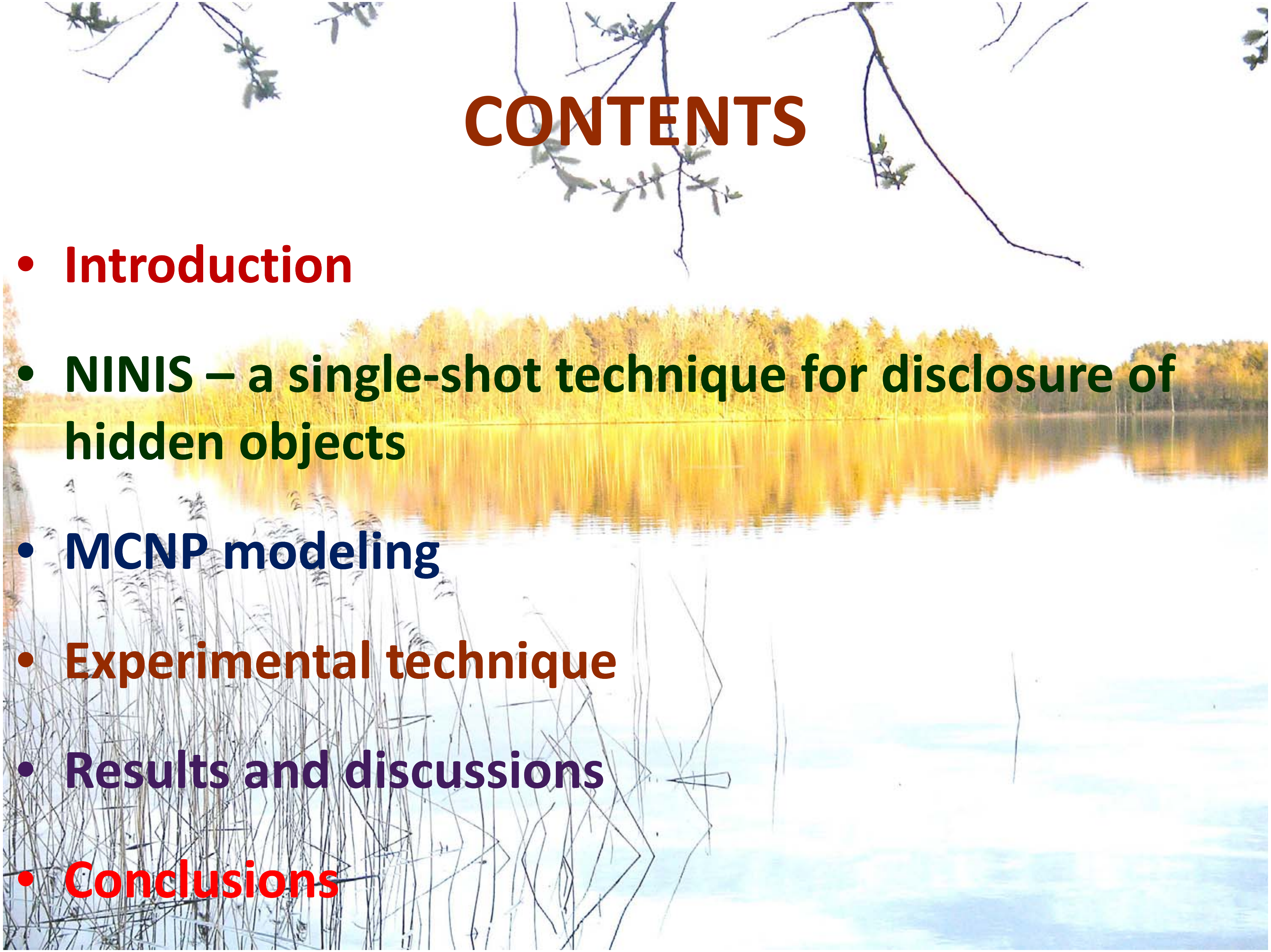

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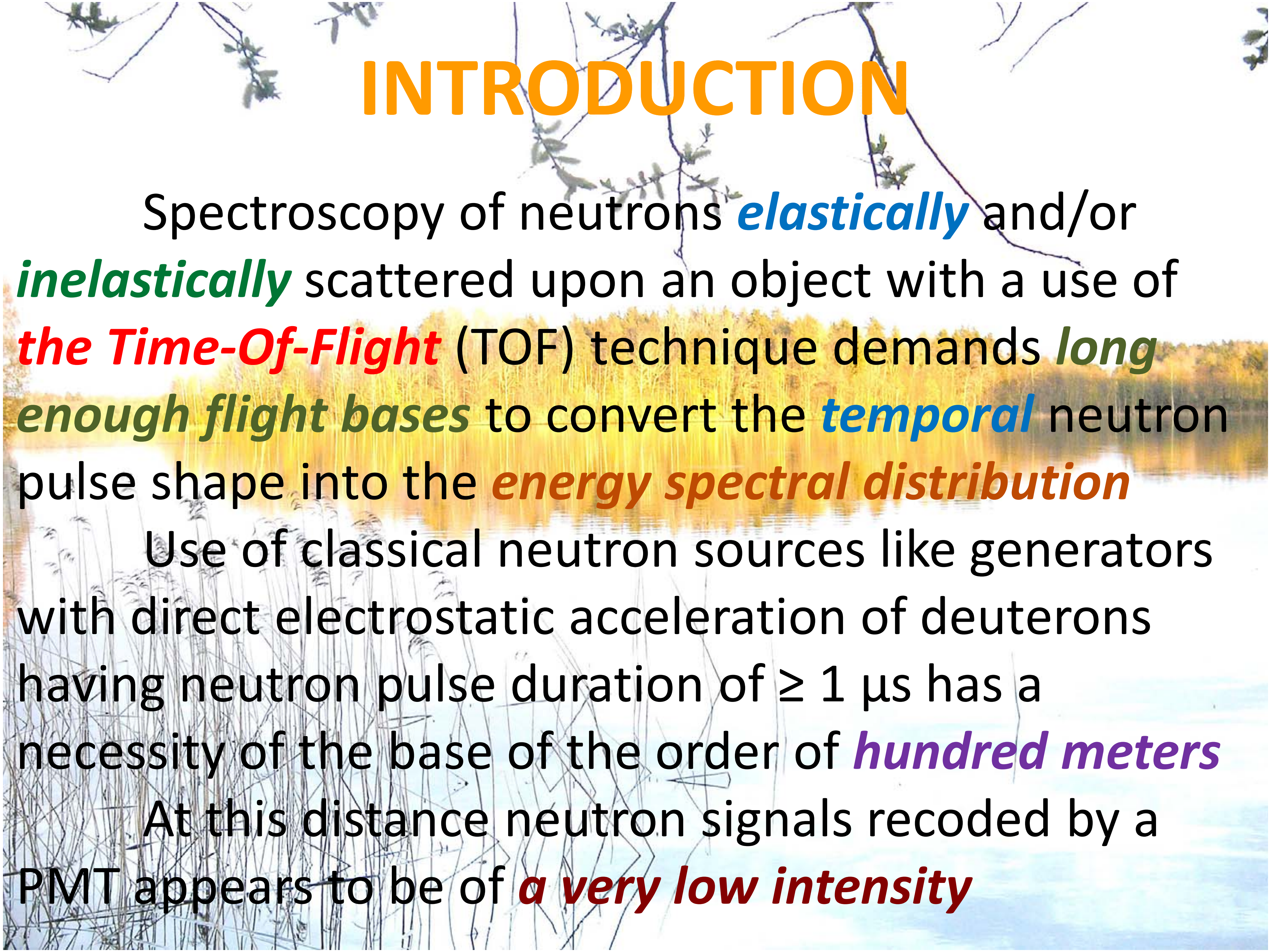
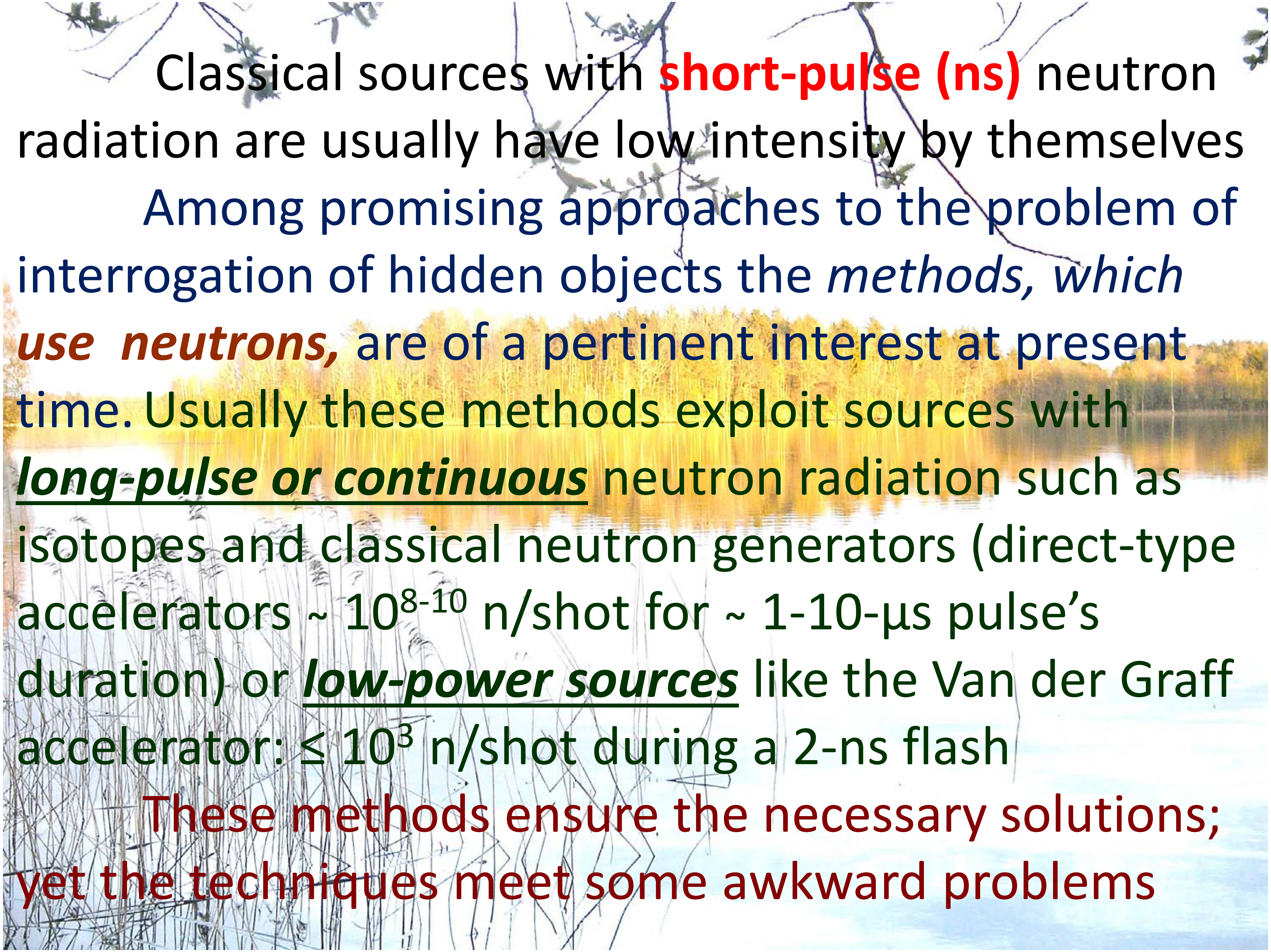


INTRODUCTION

Spectroscopy of neutrons ***elastically*** and/or ***inelastically*** scattered upon an object with a use of ***the Time-Of-Flight*** (TOF) technique demands ***long enough flight bases*** to convert the ***temporal*** neutron pulse shape into the ***energy spectral distribution***

Use of classical neutron sources like generators with direct electrostatic acceleration of deuterons having neutron pulse duration of ≥ 1 μs has a necessity of the base of the order of ***hundred meters***

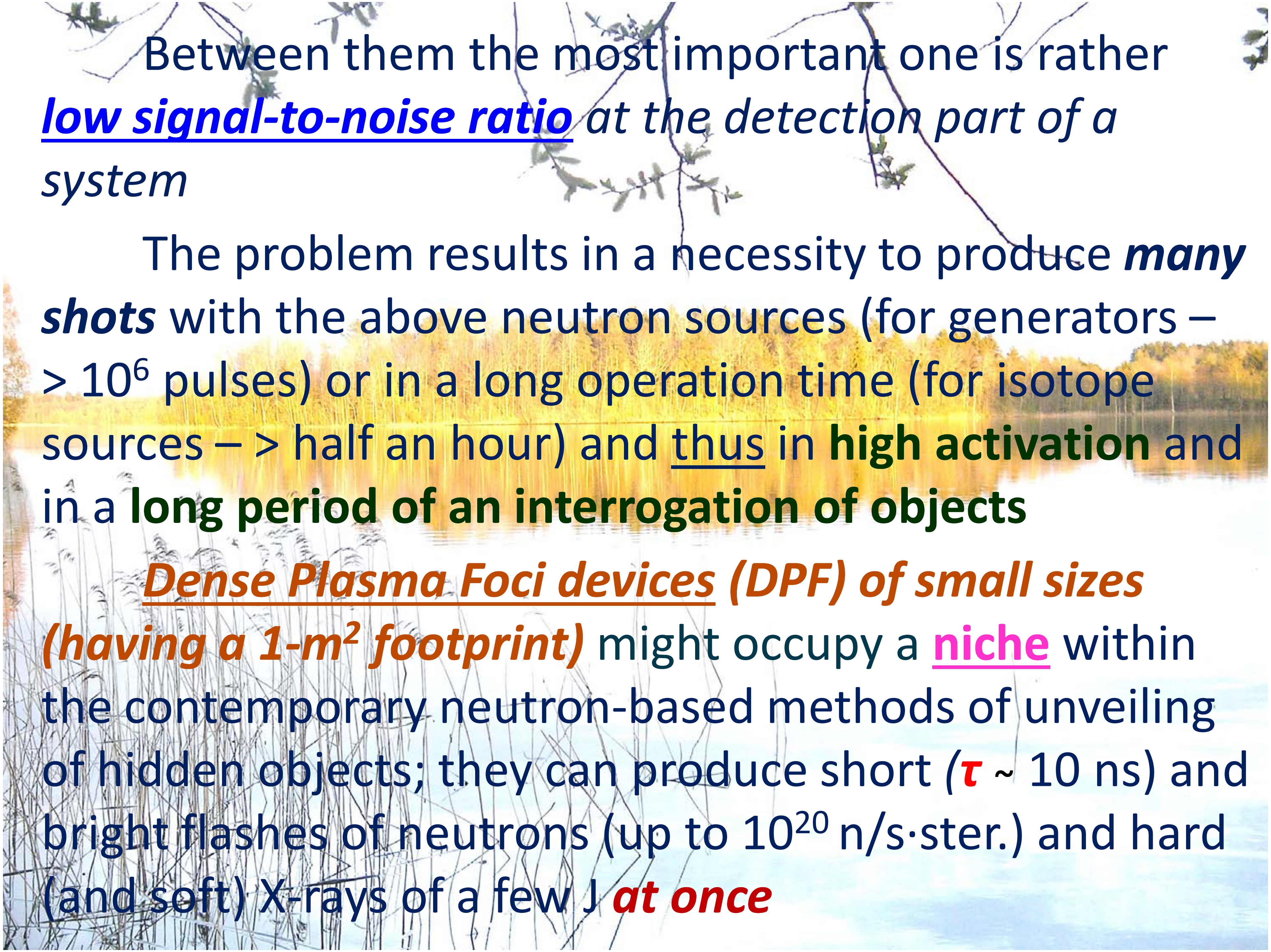
At this distance neutron signals recoded by a PMT appears to be of ***a very low intensity***



Classical sources with **short-pulse (ns)** neutron radiation are usually have low intensity by themselves

Among promising approaches to the problem of interrogation of hidden objects the *methods, which* ***use neutrons,*** are of a pertinent interest at present time. Usually these methods exploit sources with ***long-pulse or continuous*** neutron radiation such as isotopes and classical neutron generators (direct-type accelerators ~ 10^{8-10} n/shot for ~ 1-10-µs pulse's duration) or ***low-power sources*** like the Van der Graff accelerator: ≤ 10^{3} n/shot during a 2-ns flash

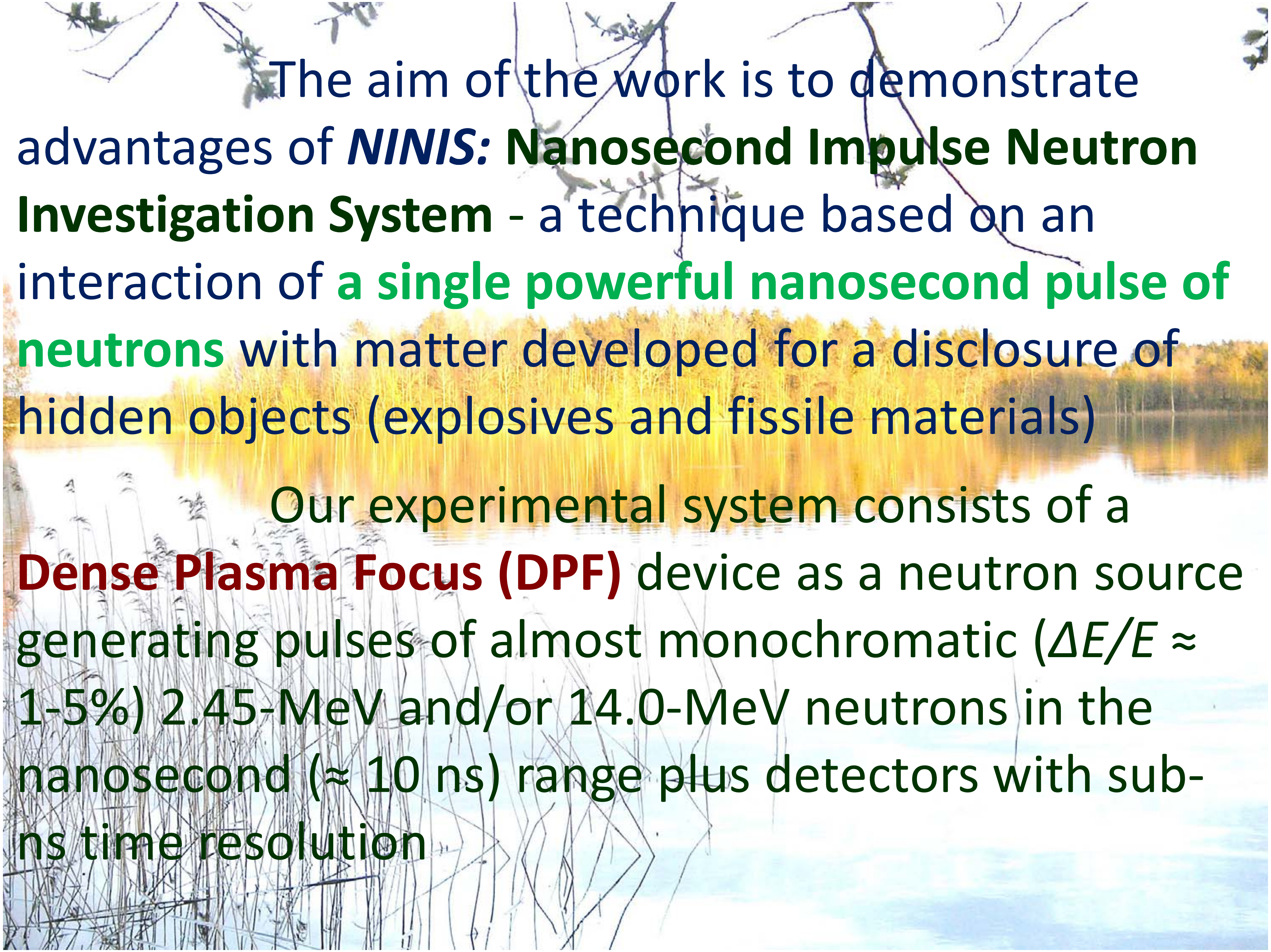
These methods ensure the necessary solutions; yet the techniques meet some awkward problems



Between them the most important one is rather ***low signal-to-noise ratio*** *at the detection part of a system*

The problem results in a necessity to produce ***many shots*** with the above neutron sources (for generators – > 10^6 pulses) or in a long operation time (for isotope sources – > half an hour) and thus in **high activation** and in a **long period of an interrogation of objects**

Dense Plasma Foci devices* (DPF) of small sizes (having a 1-m^2 footprint)** might occupy a **niche** within the contemporary neutron-based methods of unveiling of hidden objects; they can produce short ($\tau \sim 10$ ns) and bright flashes of neutrons (up to 10^{20} n/s·ster.) and hard (and soft) X-rays of a few J ***at once

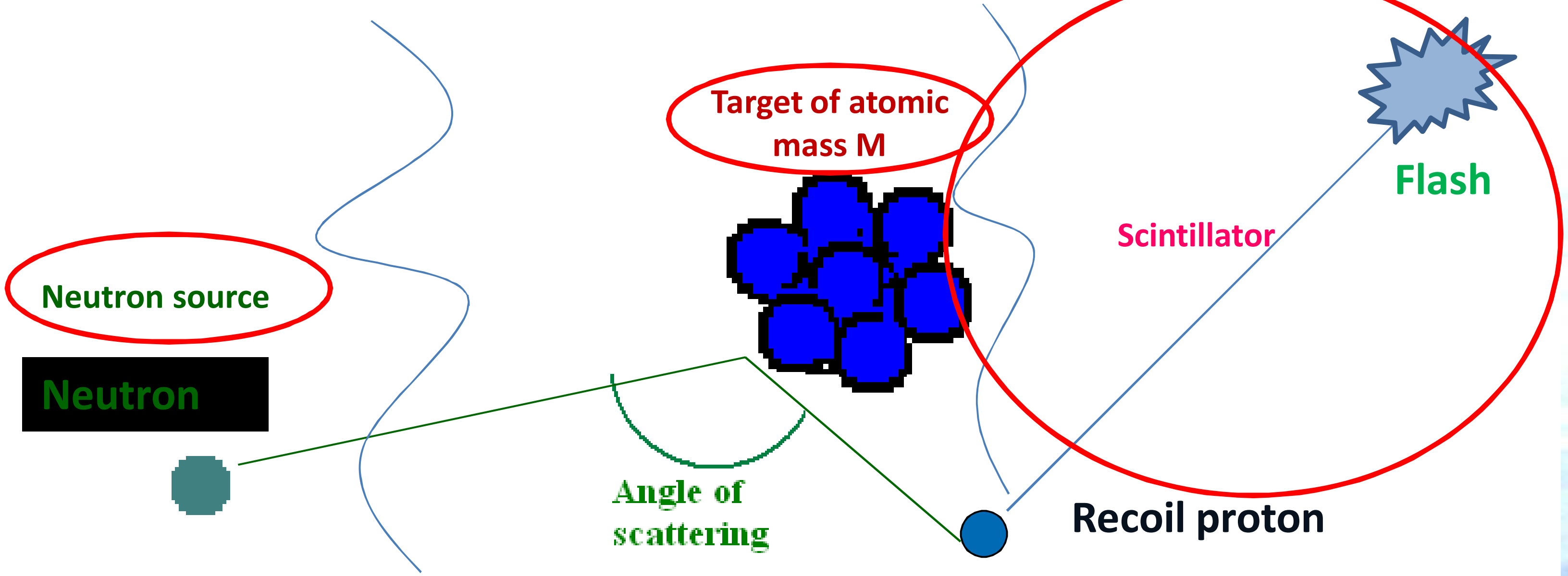


The aim of the work is to demonstrate advantages of ***NINIS:*** **Nanosecond Impulse Neutron Investigation System** - a technique based on an interaction of **a single powerful nanosecond pulse of neutrons** with matter developed for a disclosure of hidden objects (explosives and fissile materials)

Our experimental system consists of a **Dense Plasma Focus (DPF)** device as a neutron source generating pulses of almost monochromatic ($\Delta E/E \approx$ 1-5%) 2.45-MeV and/or 14.0-MeV neutrons in the nanosecond (≈ 10 ns) range plus detectors with sub-ns time resolution

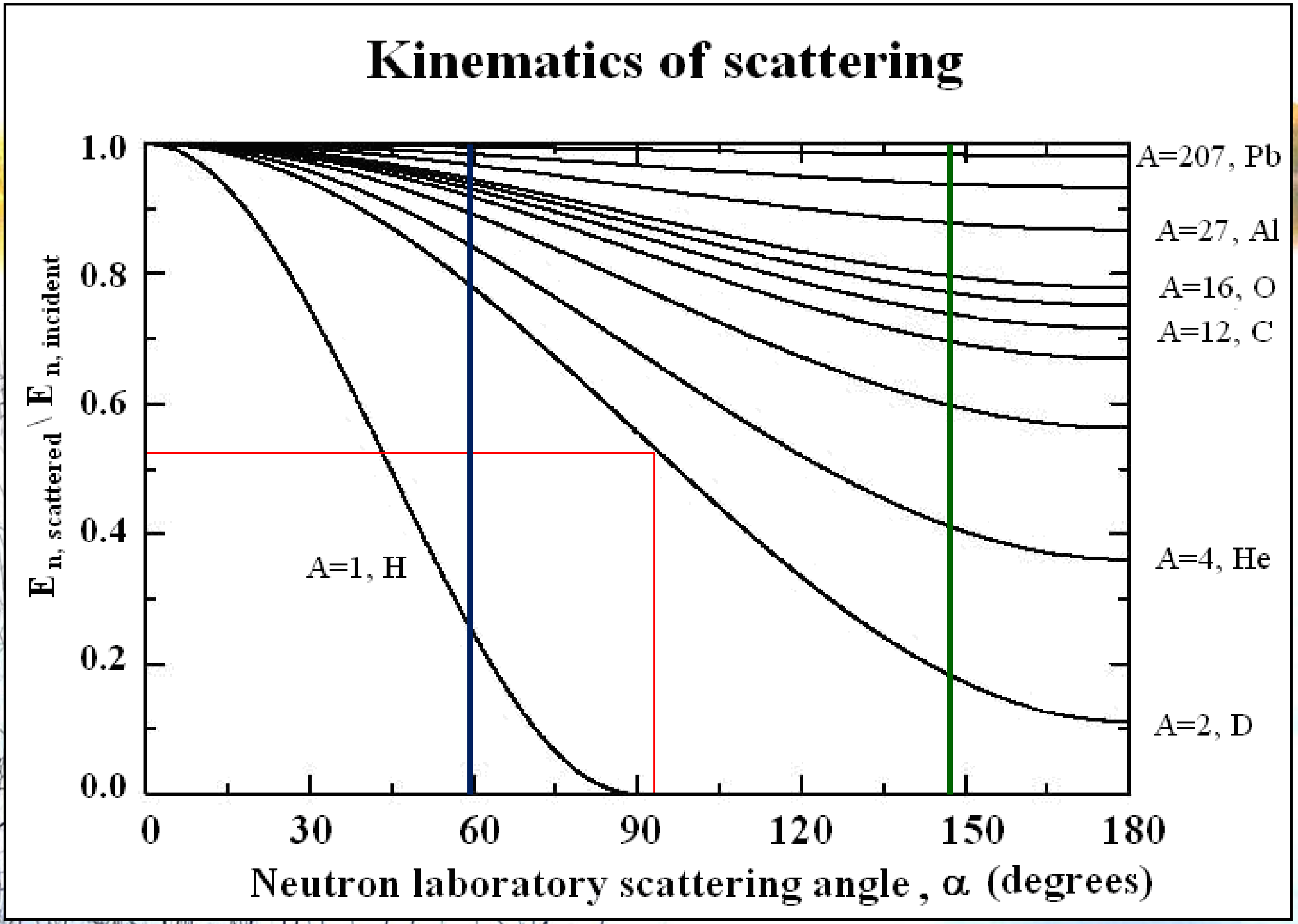
NINIS – a single-shot technique for disclosure of hidden objects

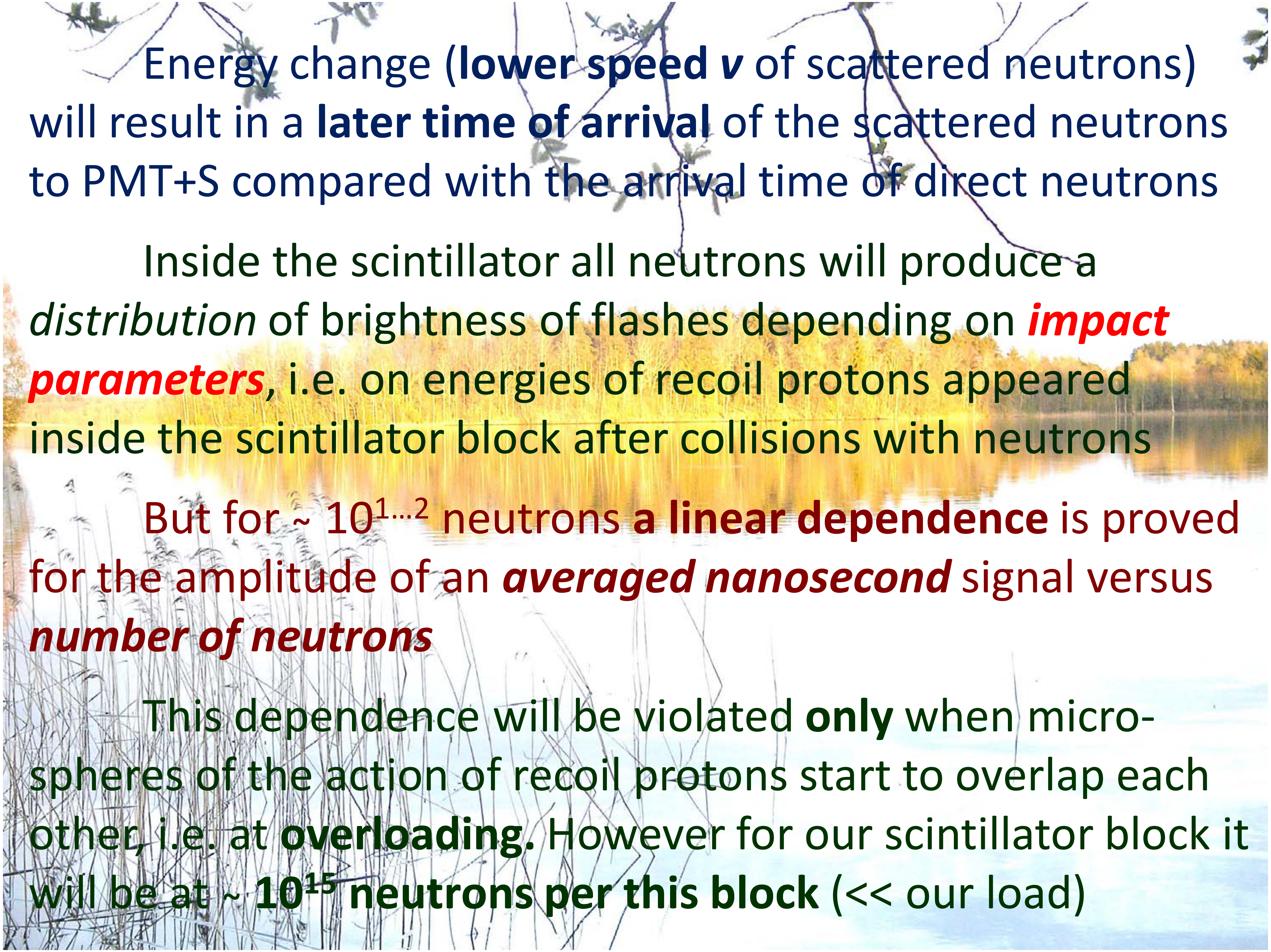
We use **elastic** – for explosives – and **inelastic** – for fissile materials - scattering of our almost mono-energetic neutrons ($\Delta E_n/E_0 \approx$ 3-5%) produced in D-D or D-T nuclear fusion reaction upon nuclei of unknown elements



After this collision the elastically scattered neutron will change its energy (and speed *v*) depending:

1) On **mass** of the nucleus-scatterer
2) On **angle** of scattering



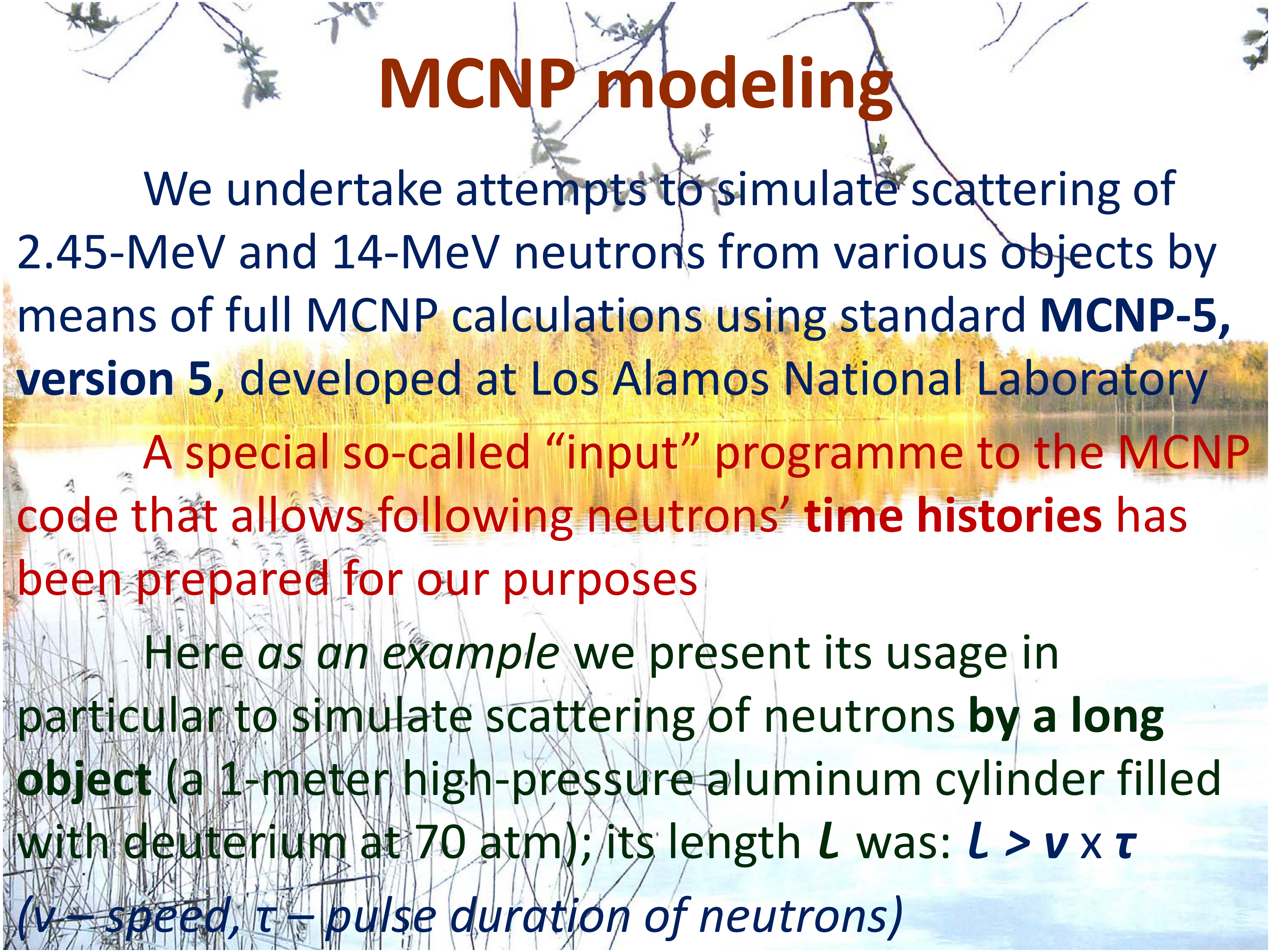


Energy change (**lower speed *v*** of scattered neutrons) will result in a **later time of arrival** of the scattered neutrons to PMT+S compared with the arrival time of direct neutrons

Inside the scintillator all neutrons will produce a *distribution* of brightness of flashes depending on ***impact parameters***, i.e. on energies of recoil protons appeared inside the scintillator block after collisions with neutrons

But for ~ $10^{1\ldots2}$ neutrons **a linear dependence** is proved for the amplitude of an ***averaged nanosecond*** signal versus ***number of neutrons***

This dependence will be violated **only** when micro-spheres of the action of recoil protons start to overlap each other, i.e. at **overloading.** However for our scintillator block it will be at ~ **10^{15} neutrons per this block** (<< our load)



MCNP modeling

We undertake attempts to simulate scattering of 2.45-MeV and 14-MeV neutrons from various objects by means of full MCNP calculations using standard **MCNP-5, version 5**, developed at Los Alamos National Laboratory

A special so-called “input” programme to the MCNP code that allows following neutrons’ **time histories** has been prepared for our purposes

Here *as an example* we present its usage in particular to simulate scattering of neutrons **by a long object** (a 1-meter high-pressure aluminum cylinder filled with deuterium at 70 atm); its length L was: $L > v \times \tau$

(v – speed, τ – pulse duration of neutrons)