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Hear It? – New Physics Calls For a Healthy Target!

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The progress brings new problems

Current and future Fermilab particle physics programs (e.g., Mu2e) require high-intensity secondary particle beams which can only be produced with a target.

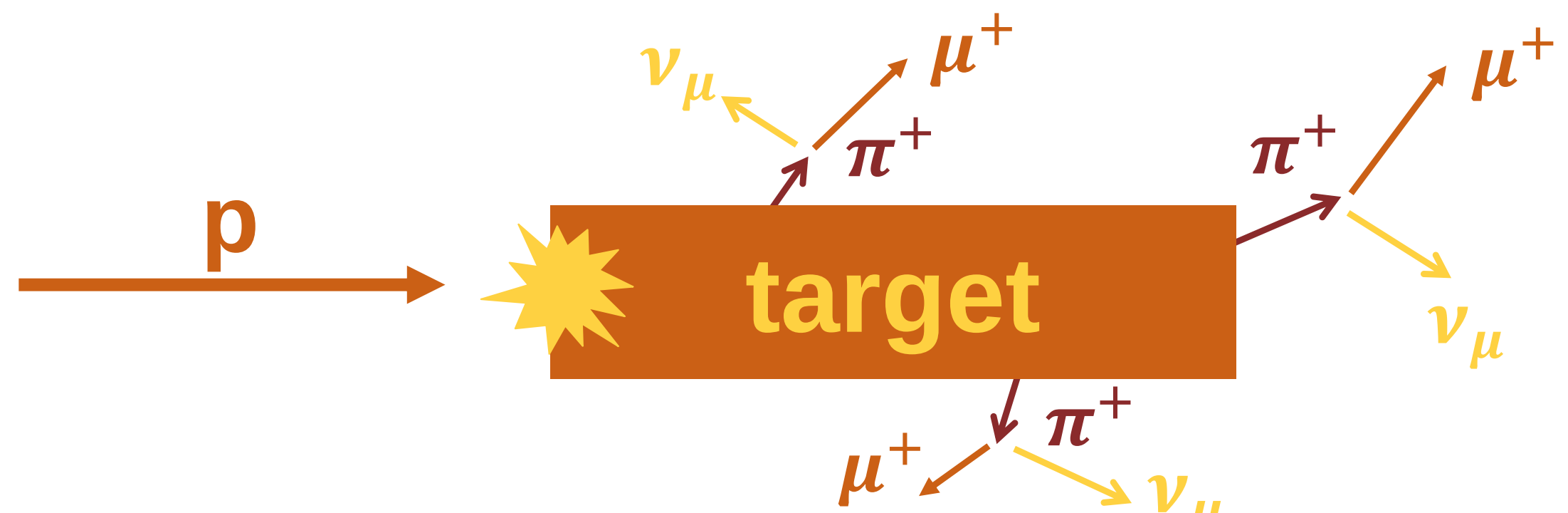


Fig. 1

A simplified muon production scheme.

Here, p, ν_μ , μ^+, and π^+ are protons, muon neutrinos, muons, and pions, respectively.

Most of the targets operate under extreme conditions. Subject to a 4T magnetic field and limited to a size of a pencil, some of them experience temperatures up to half their melting point. Severe radiation damage caused by a primary beam beating against the target every second changes its composition and decreases its lifetime.

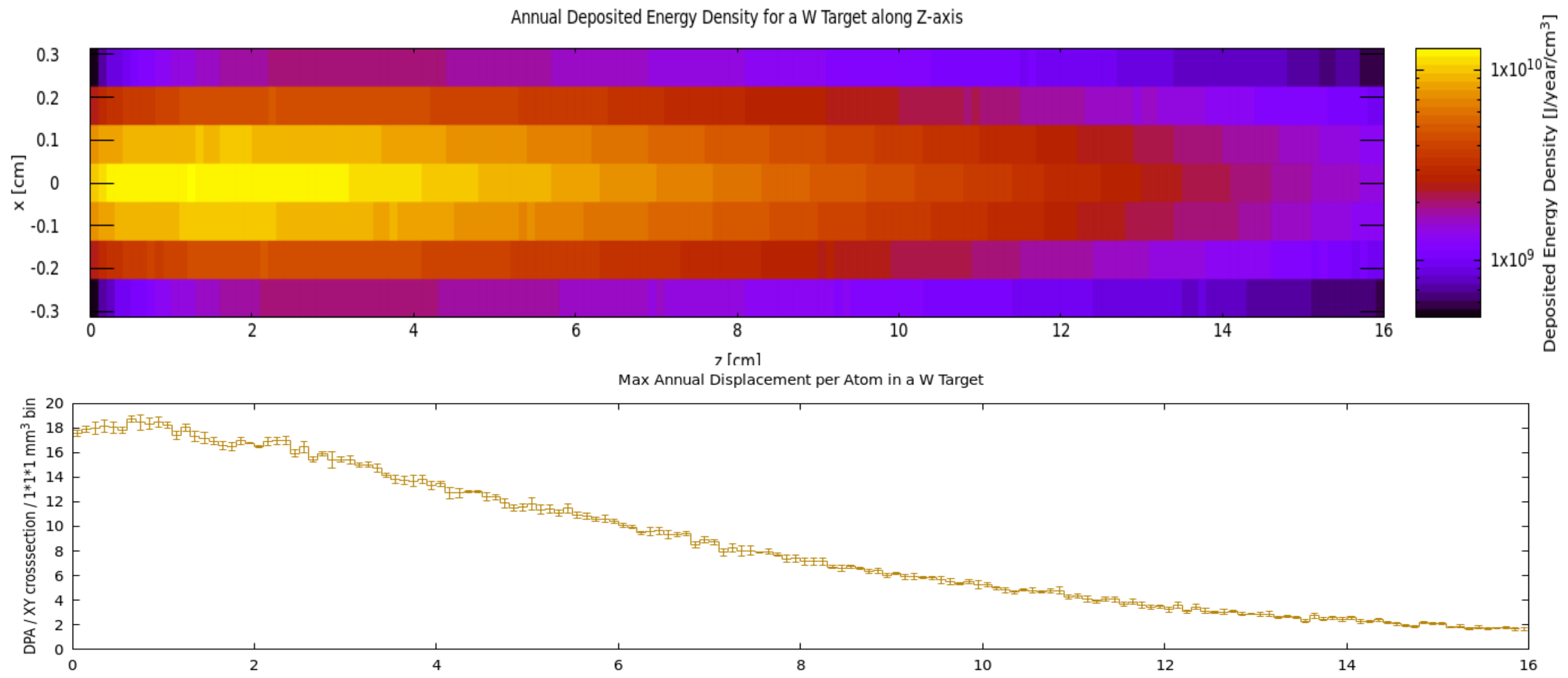
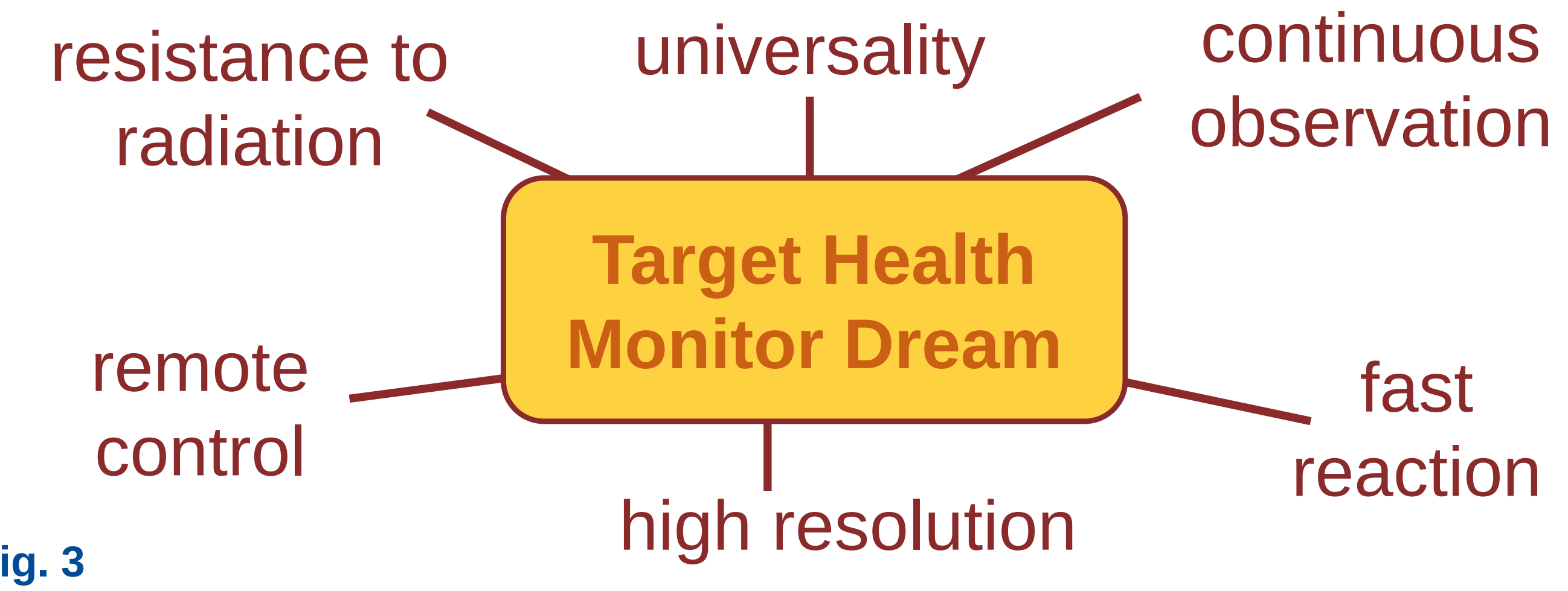


Fig. 2

FLUKA-generated energy deposition map (top) and maximum DPA vs z-axis (bottom) in cylindrical Tungsten target irradiated with the 8GeV proton beam for a year.

To protect target-based projects from failure, a system for continuously monitoring the state of the target throughout the experiment must be developed and implemented.



Target Health Monitor Dream

resistance to radiation

universality

continuous observation

remote control

fast reaction

high resolution

Fig. 3

The desired features of the Target Health Monitor system.

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We have a great plan!

Our Target Health Monitor (THM) concept is based on the reflectivity of polarized light at Brewster's angle θ_B.

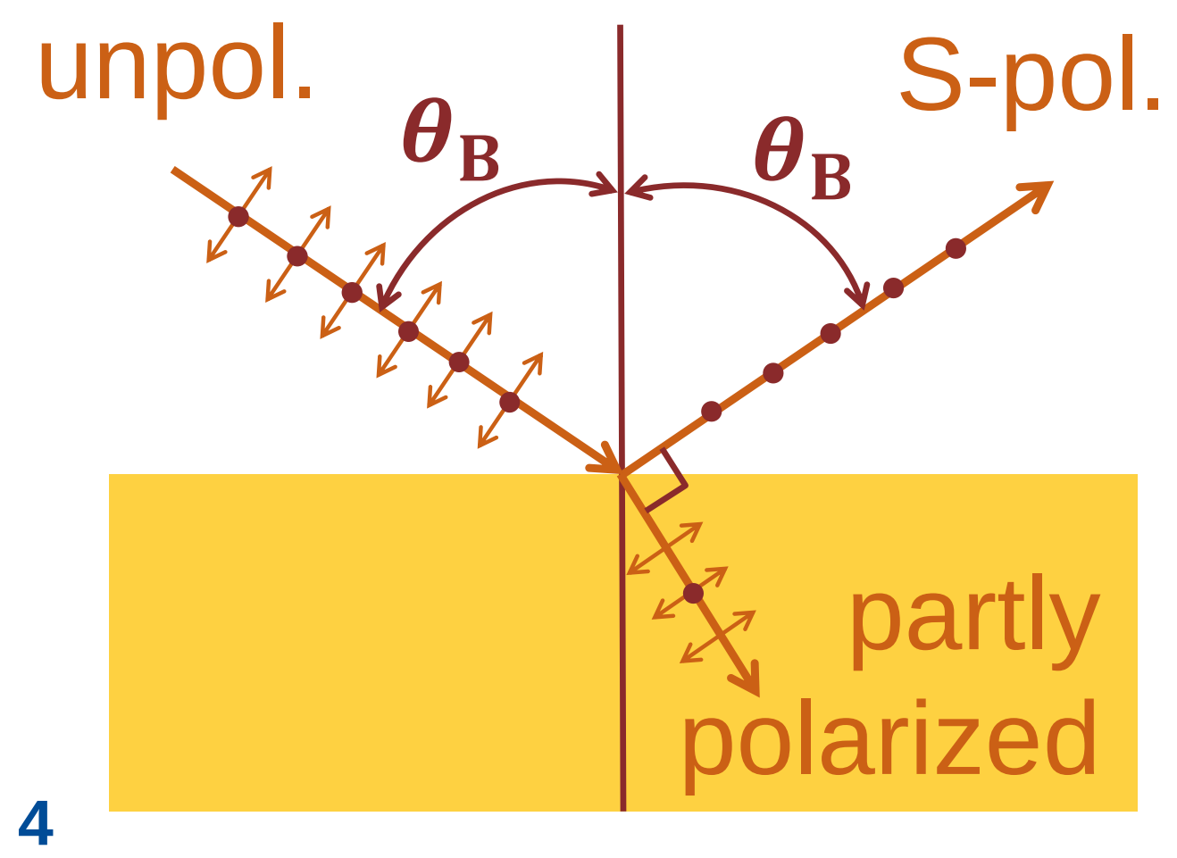

Fig. 4

Brewster's angle for a dielectric surface.

For a *dielectric* surface, θ_B is the incident angle at which all reflected light is horizontally (S) polarized, so the reflectance of the vertically (P) polarized light component is zero.

However, when the light hits the *conducting* surface at θ_B, the P-reflectance is minimized but nonzero.

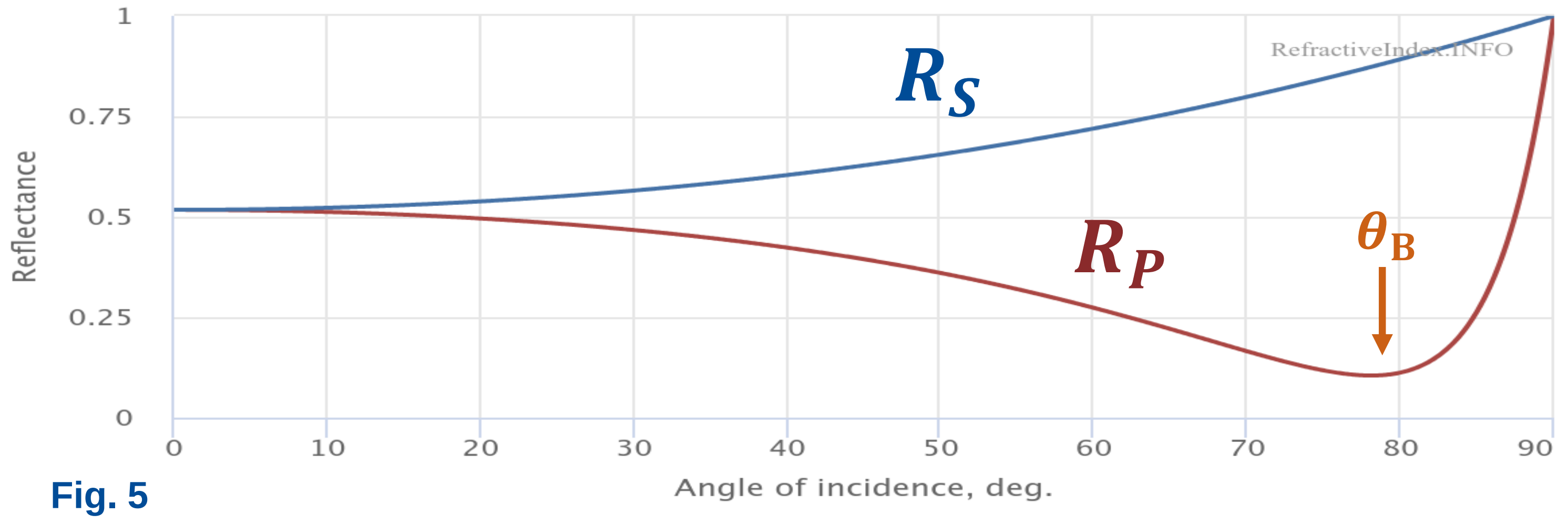

Fig. 5

Reflectance (R) of 670 nm S- and P-polarized light vs incident angle for Tungsten.

Our THM will employ the fact that radiation damage alters θ_B and R_P by changing the material composition.

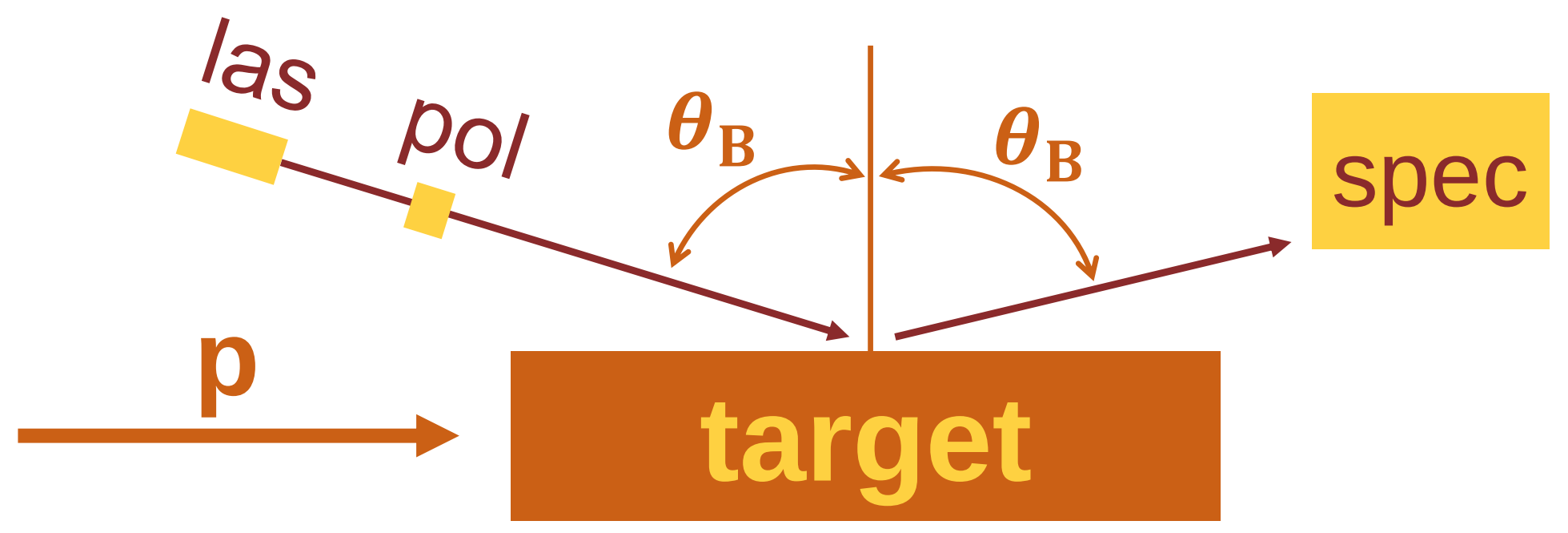

Fig. 6

The scheme of the THM functioning. Reflected from the target surface at θ_B, the P-polarized light is collected by a spectrometer. The discrepancies in the reflected spectrum are then detected, and the radiation-caused transmutations are analyzed.

How can we know it works?

To validate the THM concept, we must:

- measure R_P of prospective target materials at ~θ_B,
- repeat measurements for the irradiated samples,
- verify that minute compositional changes (e.g., 2% Re production in a W target) can be detected.

Conveniently, Brewster's angle for commonly used target materials ranges from 70º to 80º. Therefore, we chose θ=75º as the incident angle for our measurements.

The progress in solving the problems

We designed the experiment to validate our idea for the THM. The holders for the primary measurements were modeled and 3D printed with PLA.

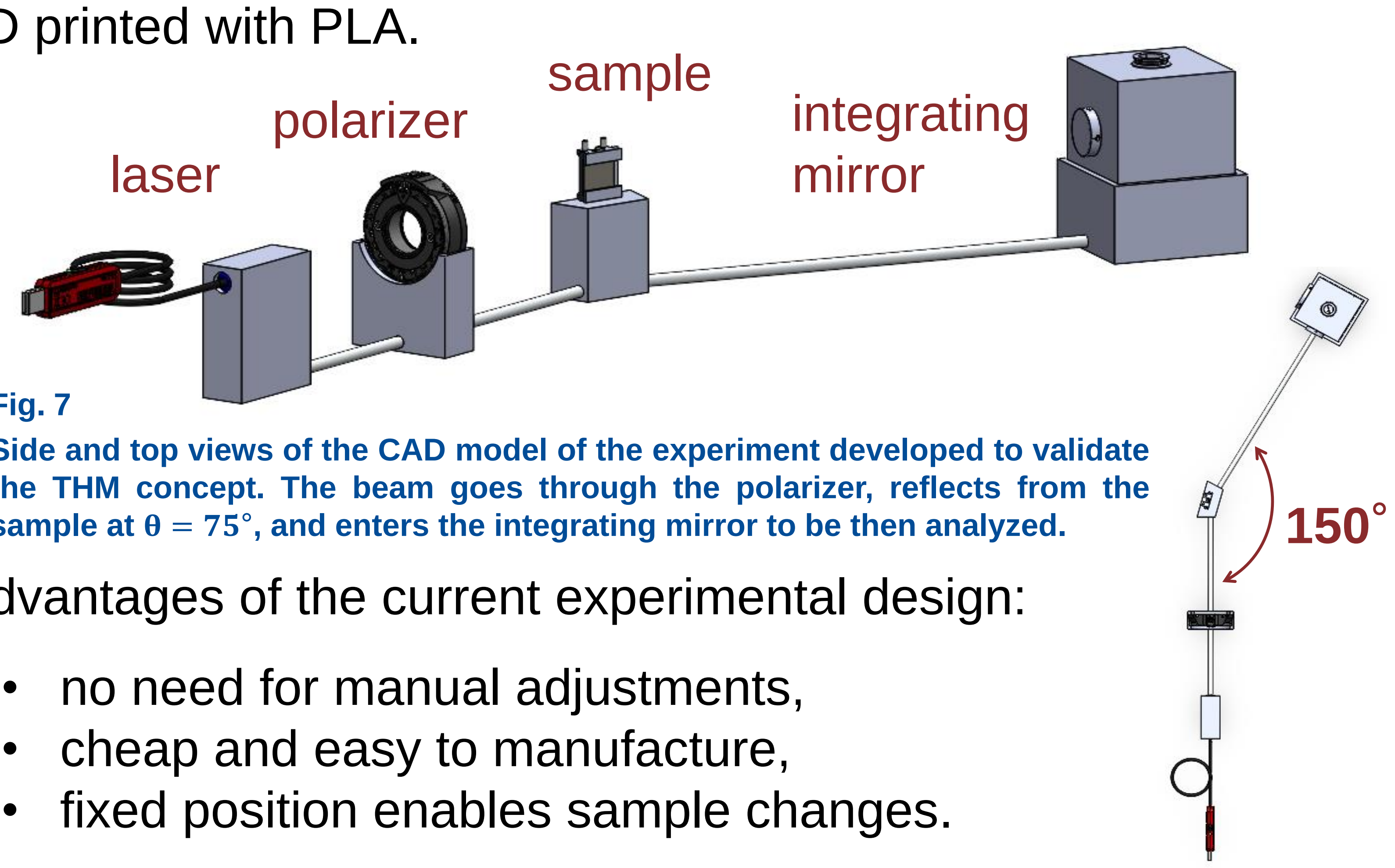

Fig. 7

Side and top views of the CAD model of the experiment developed to validate the THM concept. The beam goes through the polarizer, reflects from the sample at $\theta = 75°$, and enters the integrating mirror to be then analyzed.

Advantages of the current experimental design:

- no need for manual adjustments,
- cheap and easy to manufacture,
- fixed position enables sample changes.

The experiment is already running. Having tested the integrating mirror and polarizer, we prepare to collect the first data with pristine and irradiated Tungsten samples.

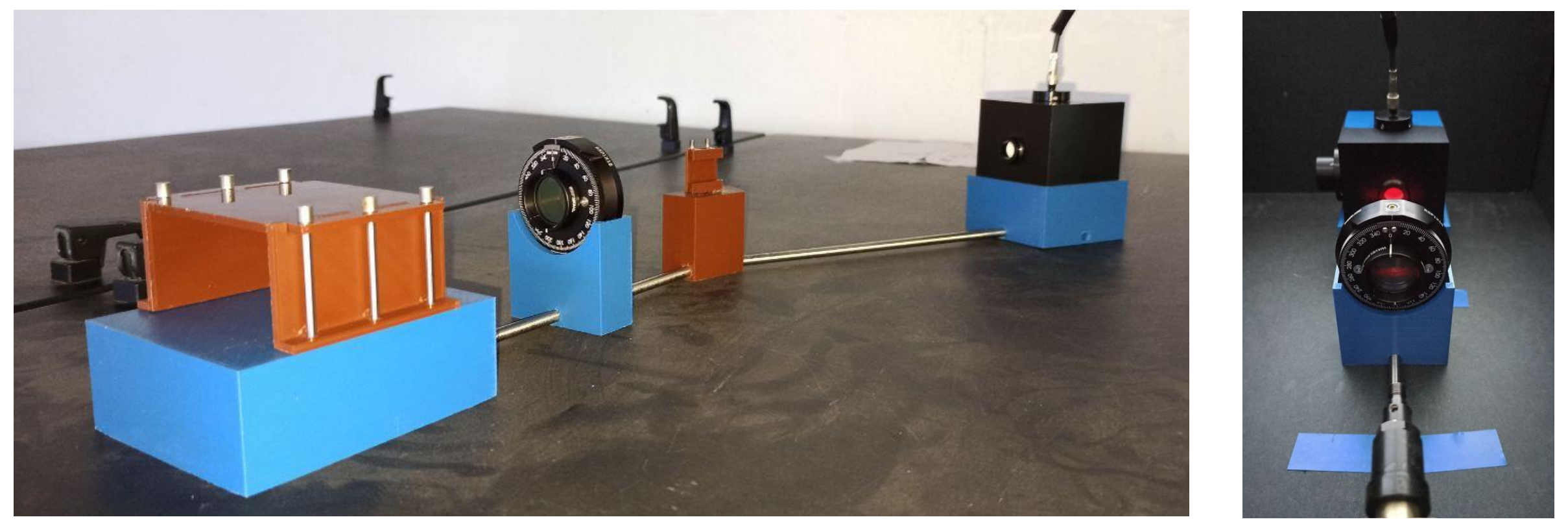

Fig. 8

The printed setup with a polarizer and integrating mirror (left).

The setup for testing the polarizer (right).

The more data, the better!

Particle physics software FLUKA has demonstrated the ability to simulate reflectance measurements based on the media refractive indices. Thus, FLUKA may (must!) be adapted as the secondary data source for future THM tests.

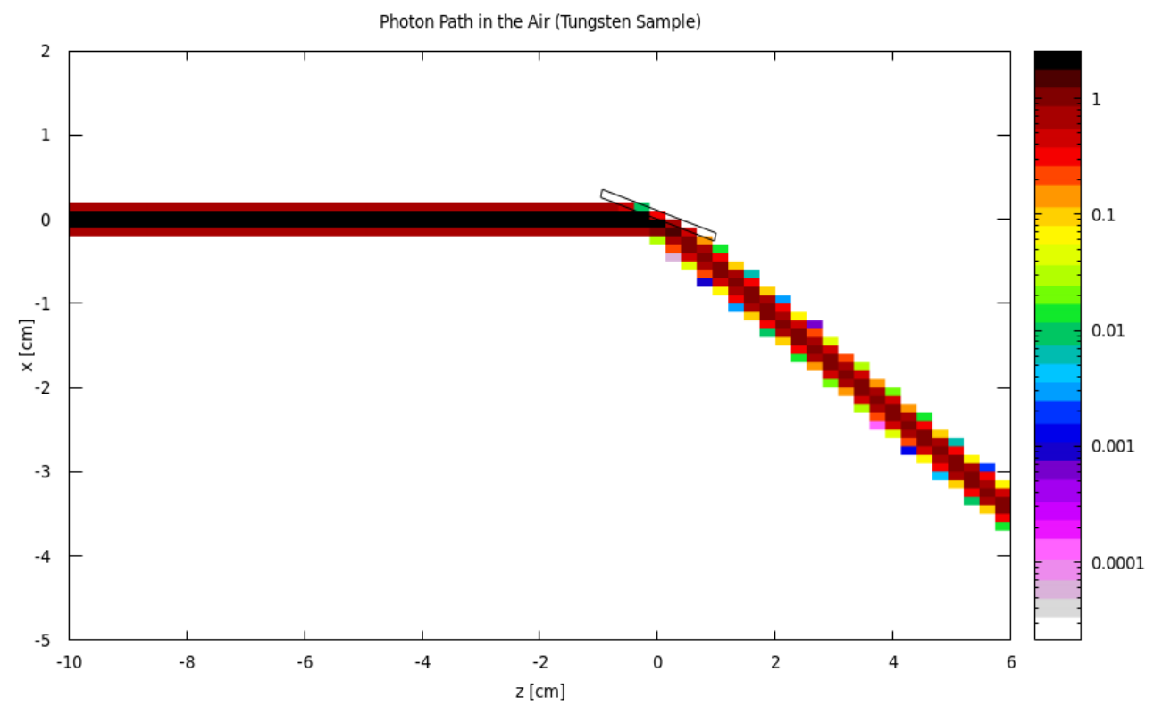

Fig. 9

FLUKA-simulated path of photons reflected from a W sample at $\theta = 75°$.

Acknowledgment

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