Cherenkov and scintillation light signals

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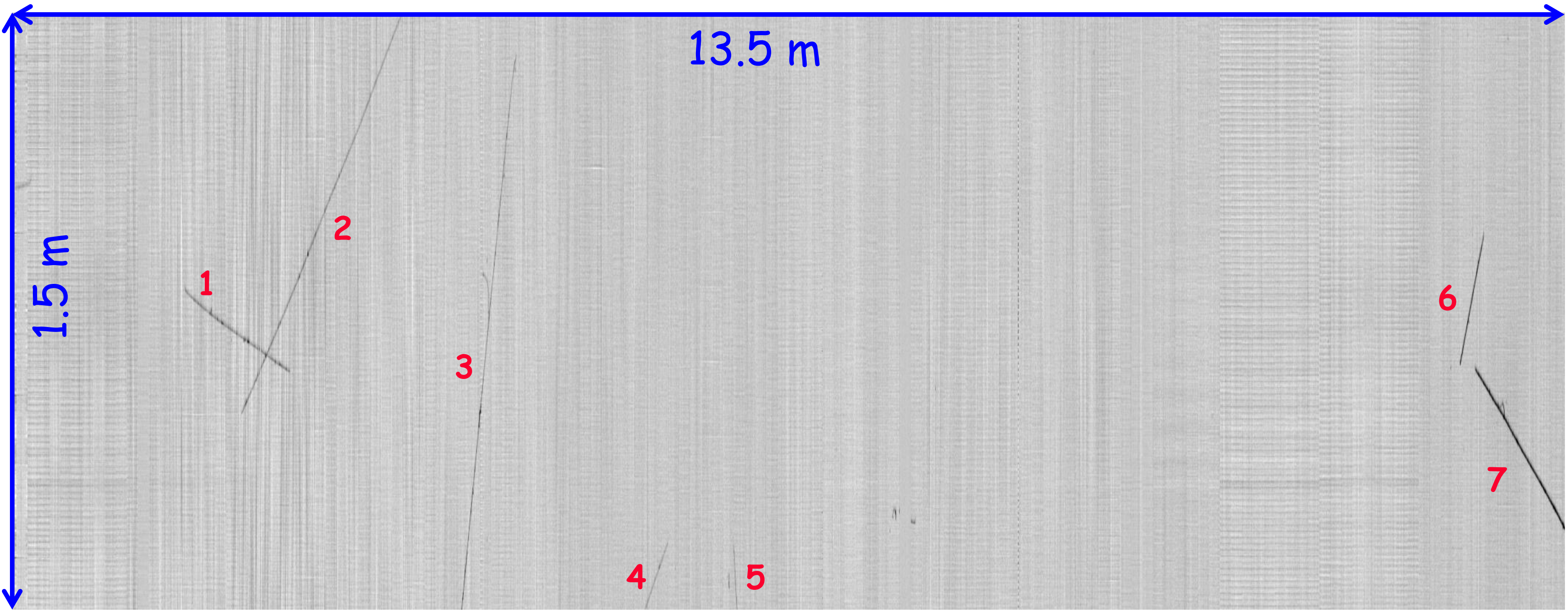
Motivation for a photo-detection system for ICARUS @ FNAL

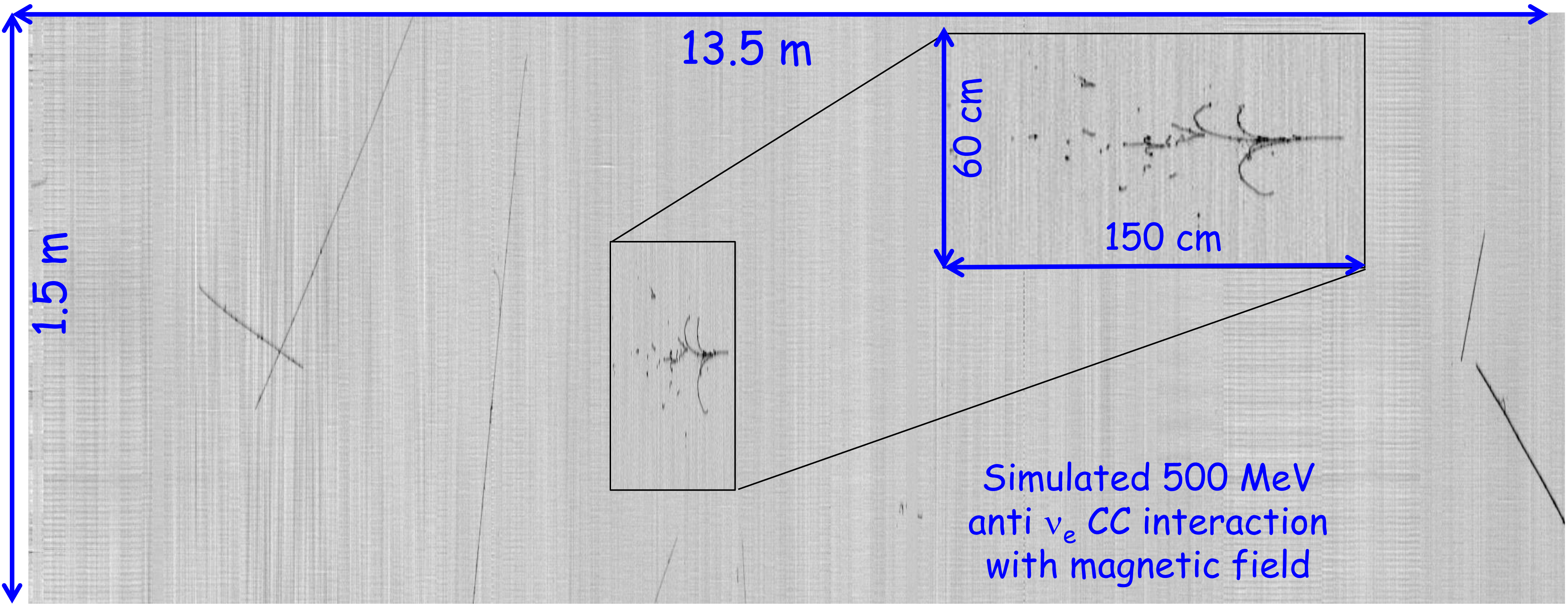
This is a 2001 Pavia surface (rather clean) event triggered by PMTs:



- Several cosmic muons tracks are seen, plus some residual e.m. activity.
- Each muon arrives inside a ~ 1 ms acquisition window.
- Each muon has its zero time (t0) signal provided by a suitable photo-detection system.

A “simulation” of a neutrino event at FNAL

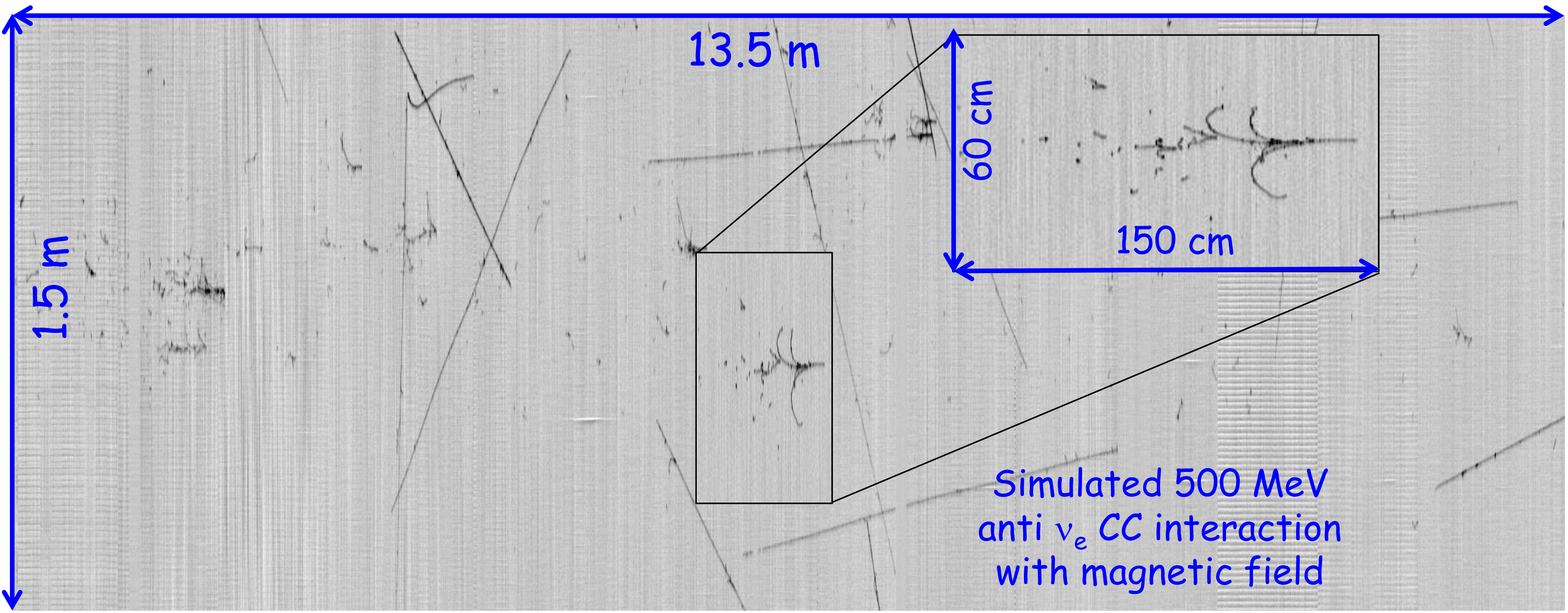
If we now suppose to go to FNAL with the same Pavia background:



- We want to associate all recorded t0’s with each track in the view.
- The idea is to build a photo-detection system which is also able to localize tracks inside the TPC volume so to uniquely associate each track with its t0.

The same neutrino in a crowded environment

Notice that at surface things can go even worse!



- In this case one should probably find other solutions beyond the photo-detection system to cope with a diffuse background.

Available light sources in liquid Argon

Two light sources, associated with each track crossing the liquid Argon (LAr) volume inside the ~ 1 ms acquisition window, are available:

- Scintillation light (isotropic emission)
- Cherenkov light (directional emission)

- Scintillation light was already used in ICARUS T600 at LNGS to trigger CNGS events and to provide the t0 information.
- 8" window PMTs, deposited with wave-length shifter and working at cryogenic temperature, were the successfully adopted solution to detect LAr VUV (128 nm) scintillation light.
- The use of magnetised LAr prevents us to use again PMTs as photo-detectors.
- Cherenkov light detection information in LAr dates back to the 10 m^3 prototype at LNGS (year 2000) and more studies have to be carried out on this item.

Scintillation light in liquid Argon

- Scintillation light emission in LAr is due to the radiative decay of excited molecules (Ar_2^*) produced by ionizing particles, releasing monochromatic VUV photons ($\lambda \sim 128$ nm) in transitions from the lowest excited molecular state to the dissociative ground state.

- A fast ($\tau \sim 6$ ns) and a slow ($\tau \sim 1.6$ μs) components are emitted.

- Their relative intensity depends on dE/dx, ranging from 1:3 in case of minimum ionizing particles (m.i.p.), up to 3:1 in case of alpha particles.

- This isotropic light signal propagates with negligible attenuation throughout each TPC volume.

- At the nominal drift field applied in ICARUS T600, approximately <u>40000 photons/cm</u> are produced for m.i.p. particles.

Cherenkov light in liquid Argon

- Experience from ICARUS 10 m^3 detector: M. Antonello et al., Nucl. Inst. Meth., A516 (2004) 348-363.

- Cherenkov light emission depends on the speed and electric charge of the through-going particle and on the refractive index of the medium: $n_{Ar} \sim 1.22$.

- For cosmic muons with $\beta \sim 1$: $\cos\theta_c \sim 34°$.

- The number of photons produced per unit frequency interval and per unit path length by an ultra-relativistic muon is:

$$\frac{d^2N}{d\lambda dx} = \frac{2\pi\alpha}{c} sin^2\theta_c$$

which means about <u>700 photons/cm</u> integrating in the sensitivity range of the 10 m^3 PMTs (160 nm < λ < 600 nm)

Cherenkov light in liquid Argon

- Despite the lower specific photon yield with respect to the scintillation VUV light, the Cherenkov light has the advantage to be directional, opening the field to the possibility to use it to localize cosmic background tracks inside the ICARUS T600 active volume.

- Moreover, in the considered hypothesis to dope the LAr with Tetra-Methyl Germanium (TMG) to recover the charge lost by electron-ion recombination, using the Cherenkov light for event timing and localization could be crucial for the proper operation of the detector.

- More studies and R&D are therefore mandatory to clarify if Cherenkov light detection in LAr is a real option to be implemented.