Cosmogenic background suppression at the ICARUS using a concrete overburden

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for the ICARUS Collaboration

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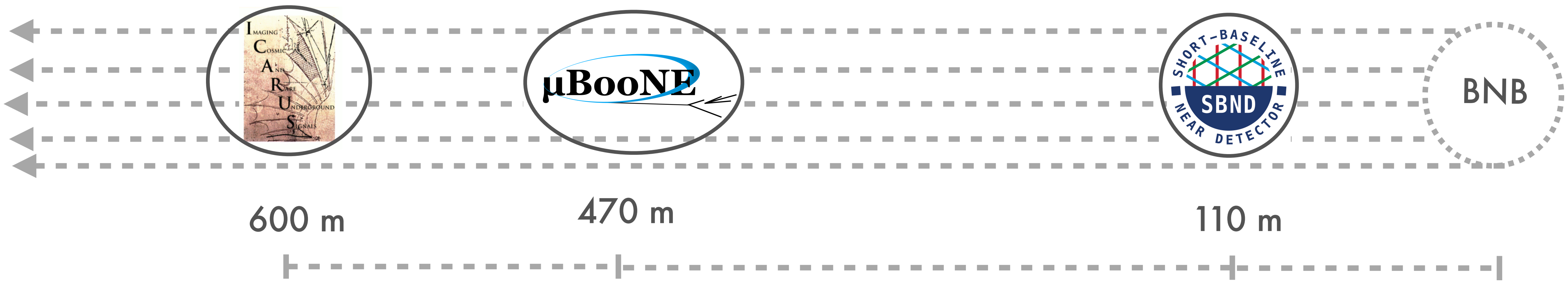
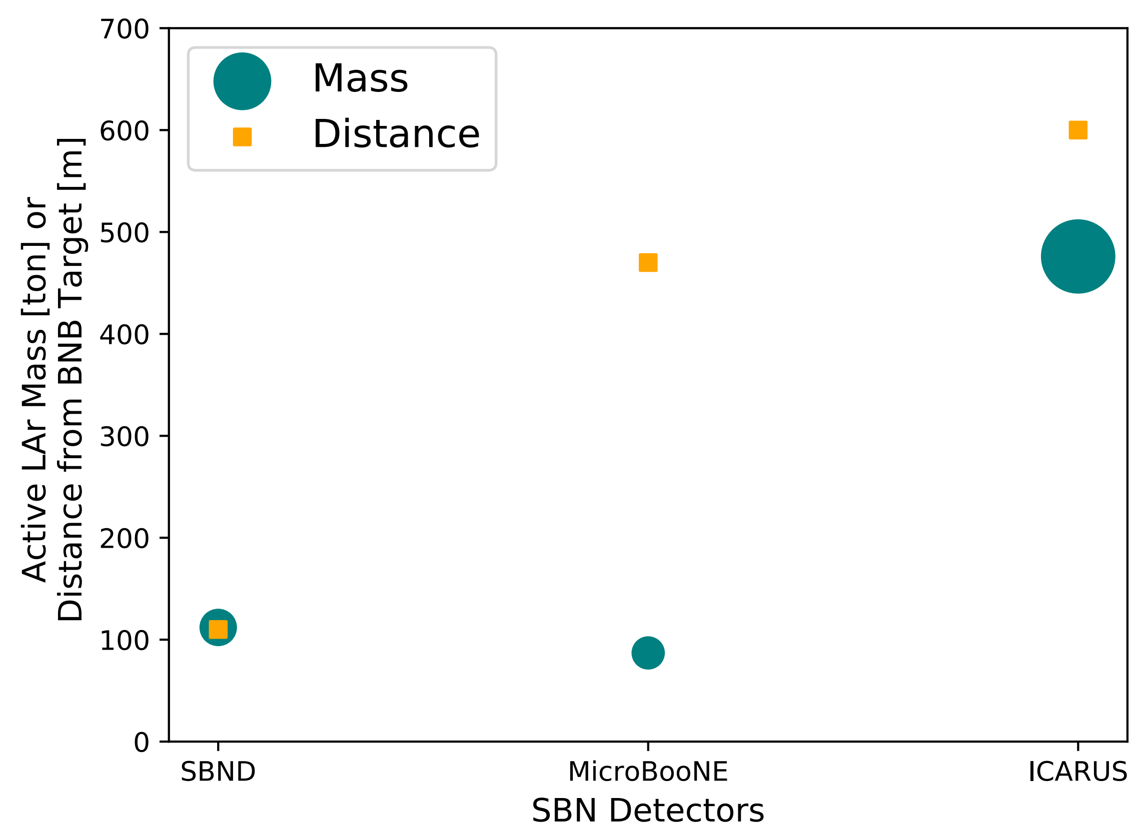
Short Baseline Neutrino Experiment at Fermilab



- The Short Baseline Neutrino (SBN) experiment will provide a clarification on the sterile neutrino puzzle, by looking at both appearance and disappearance channels with three LAr-TPCs (ICARUS acting as far detector).

- It is based on the liquid argon time projection chambers technology.

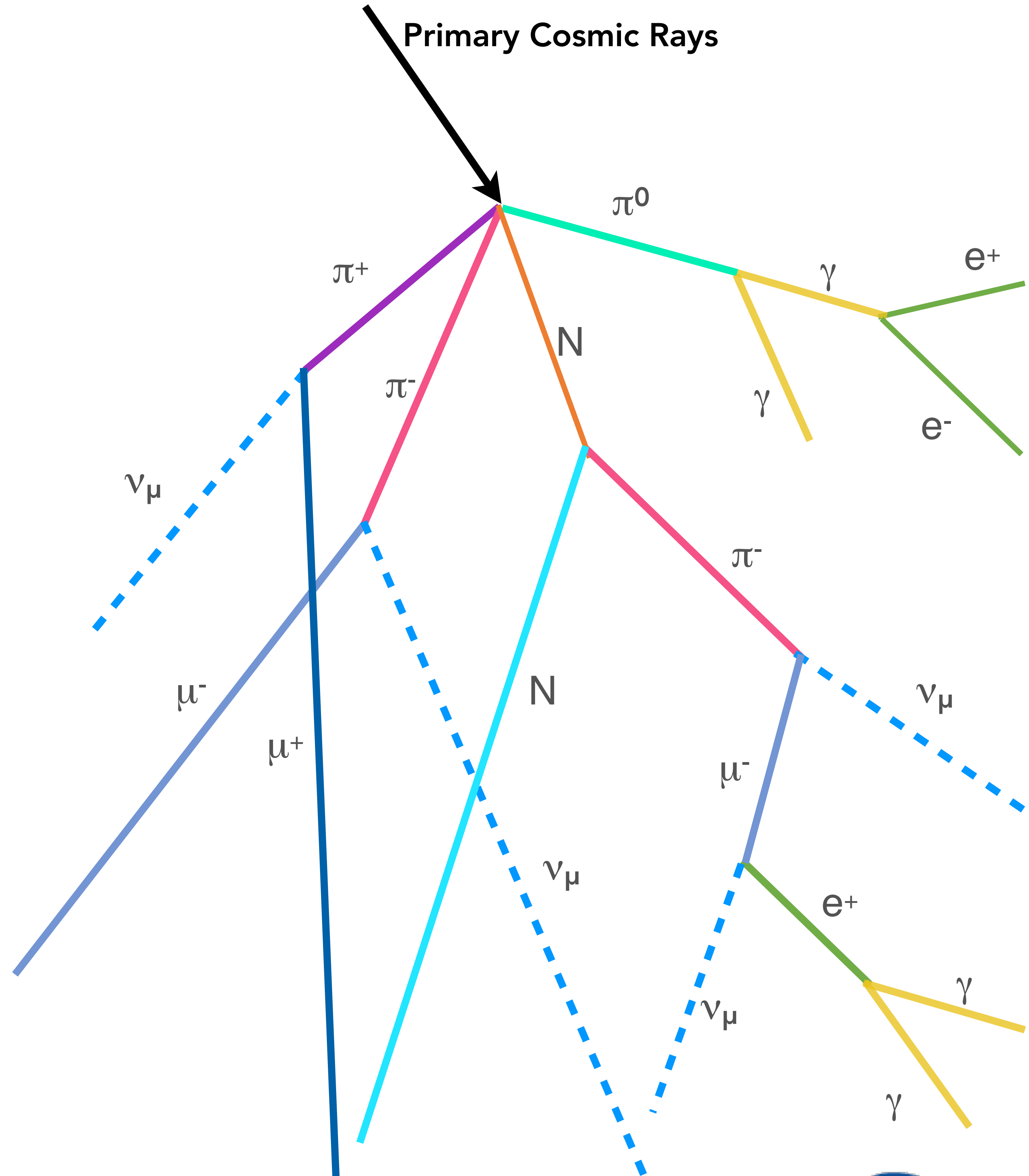


Motivation

- ICARUS is on the surface and exposed to huge cosmic activity, is the primary background for several physics analysis.

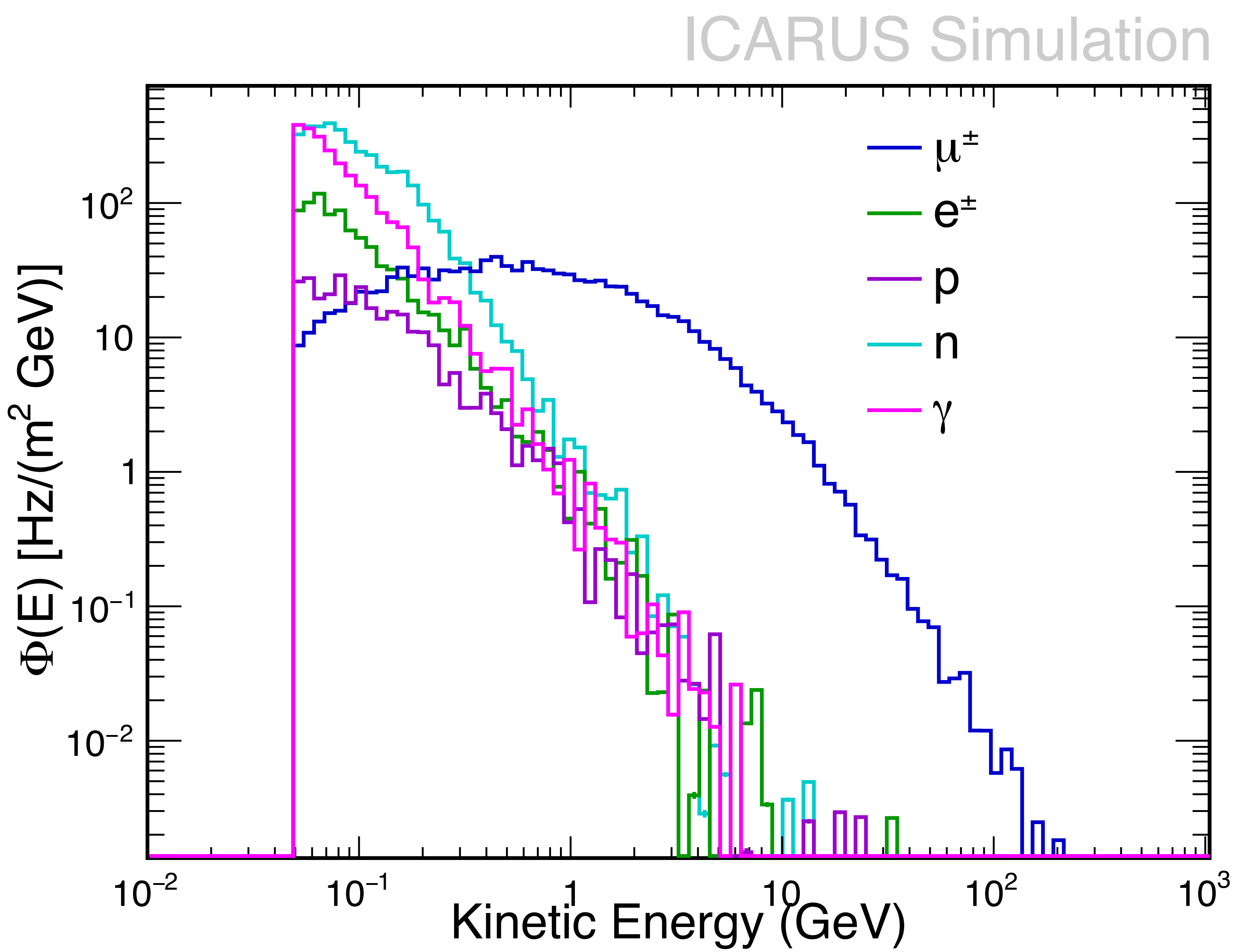
- The electro magnetic showers generated by cosmic particles crossing the detector in time with the beam spill have to be reduced as much as possible a priory since they could represent a background for the ν_e CC analysis.

- In the approved Fermilab SBN[1] experiment the impact of cosmic rays is mitigated by placing ~ 3 m concrete overburden placed on top of the ICARUS detector and ~4**π** coverage of Cosmic Ray Tagger (CRT) were introduced.



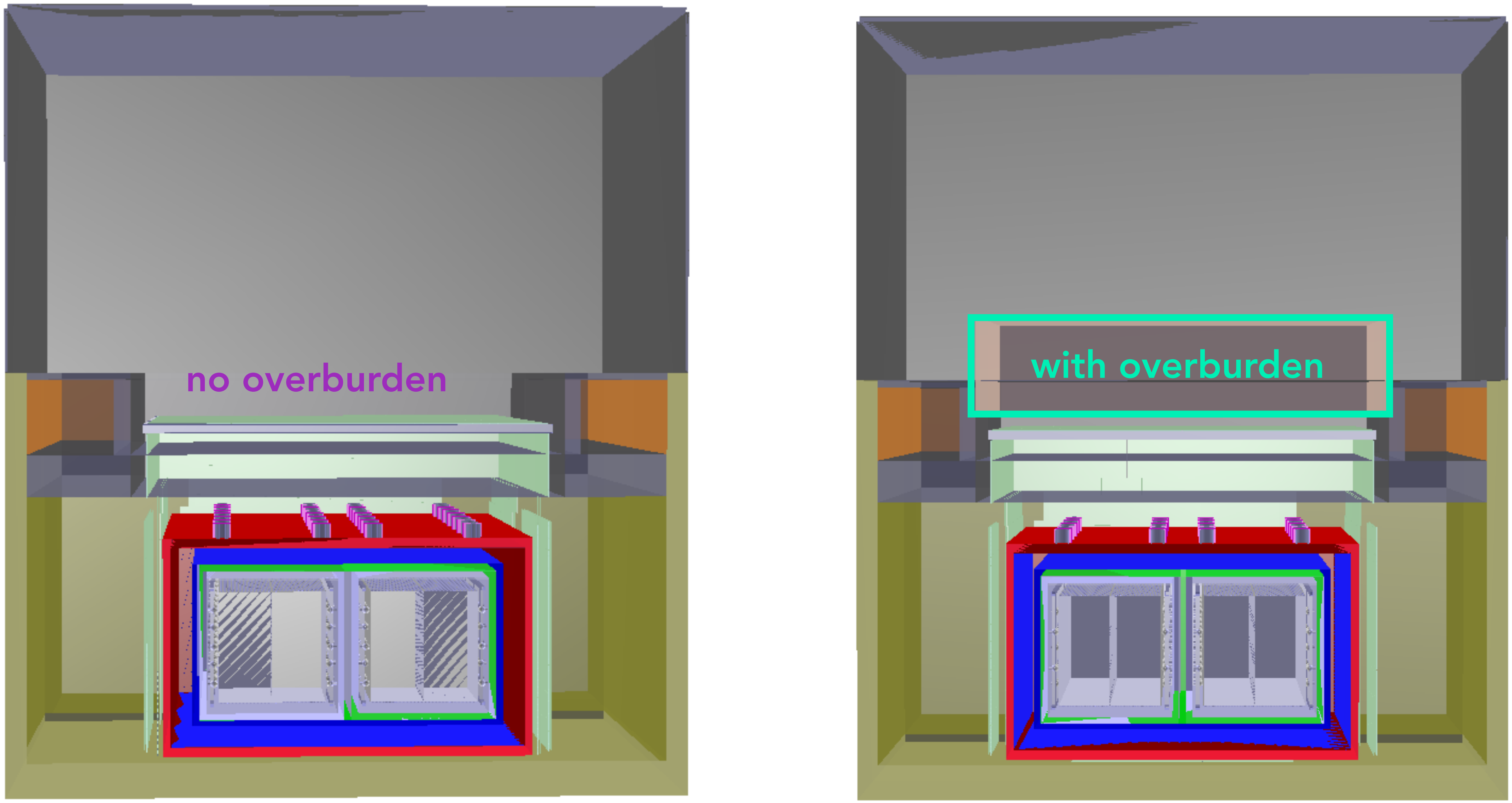
[1] arxiv: 1503.01520

Generation of Cosmogenic particle



- Primary cosmic rays are simulated using CORSIKA version 7.4003.
- Above 50 MeV kinetic energy are simulated.

Cosmic rays simulation in ICARUS setups

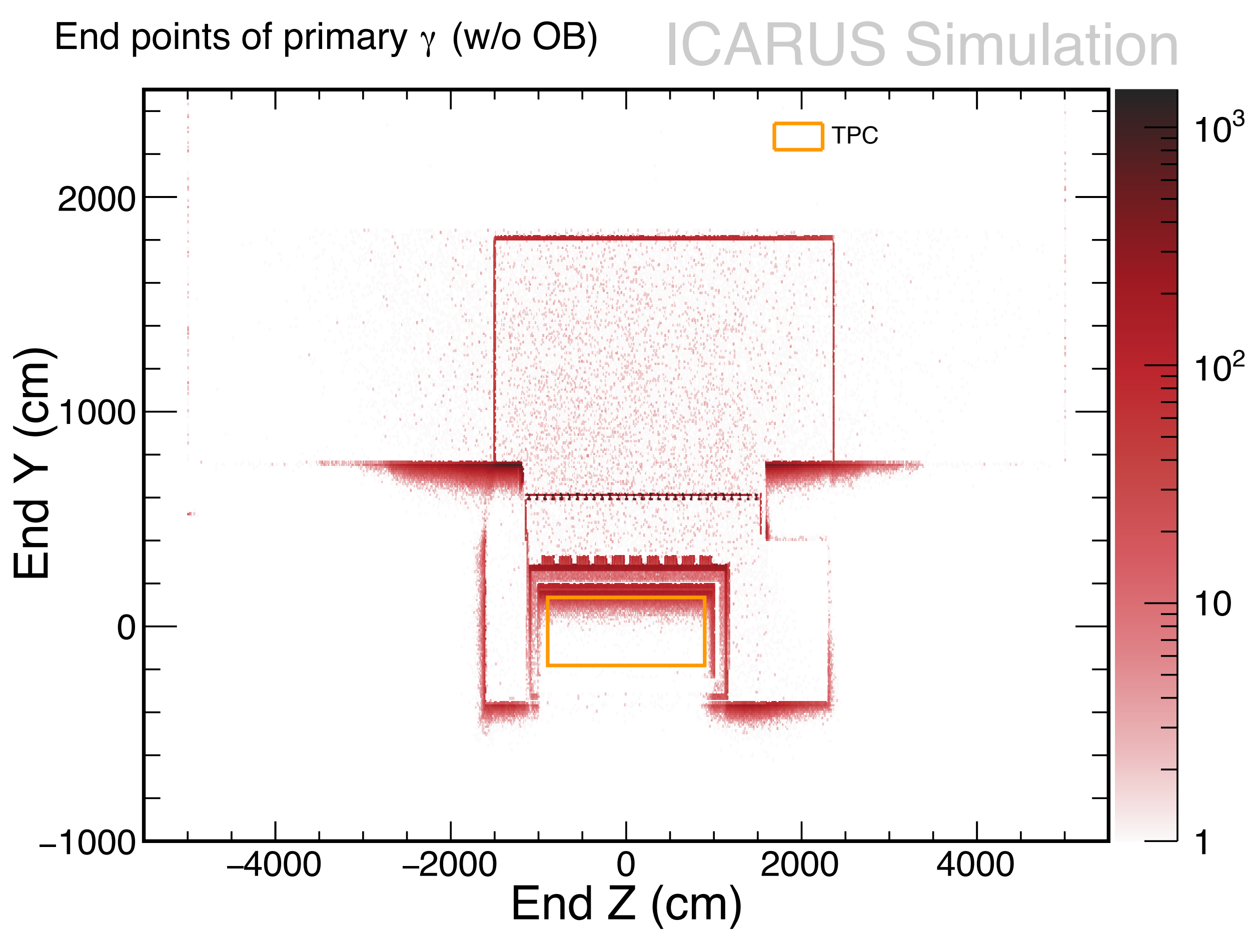


- Understanding the role of overburden in the reduction of the cosmics.
- For each configuration an event statistics for the 3 years data taking (6.6e20 POT).

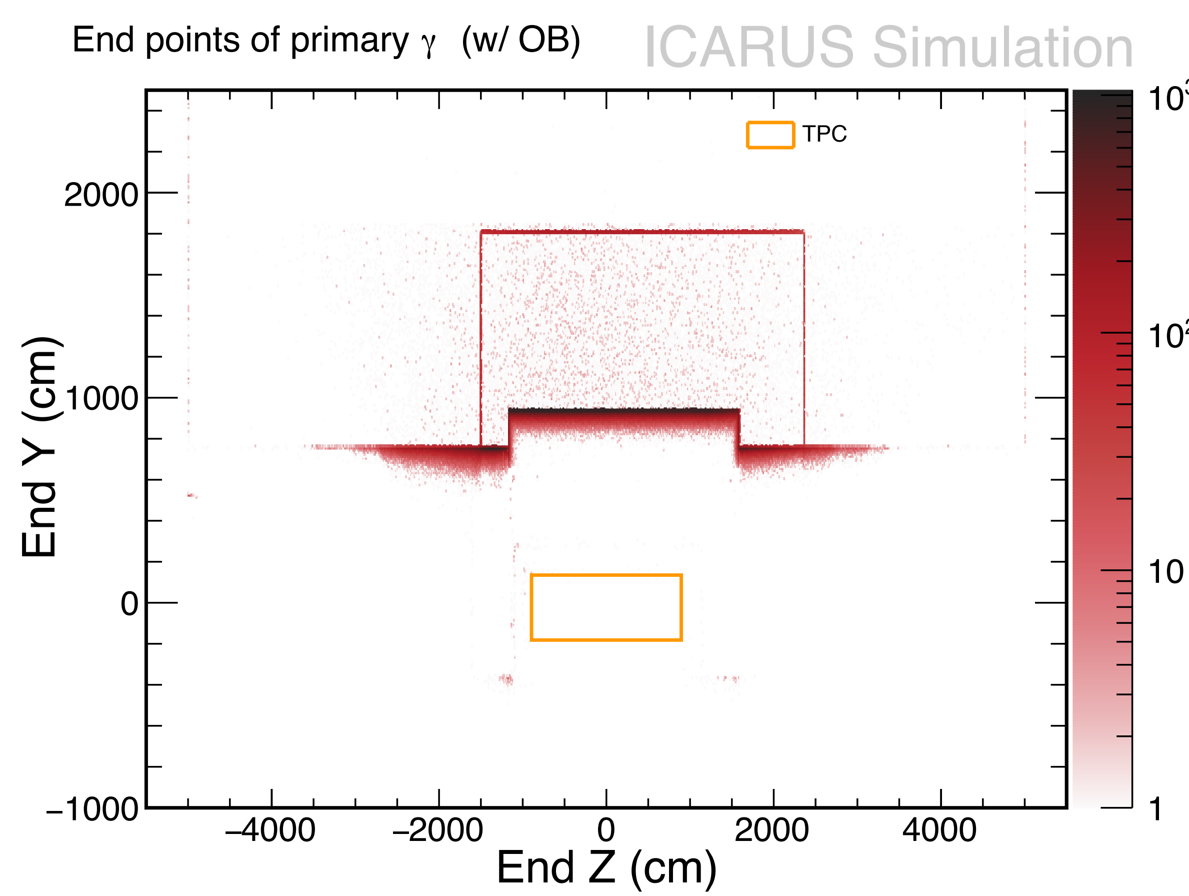
Primary Cosmic Particles Reaching to the Active Liquid Argon

End position of Primary Photons

no overburden



with overburden



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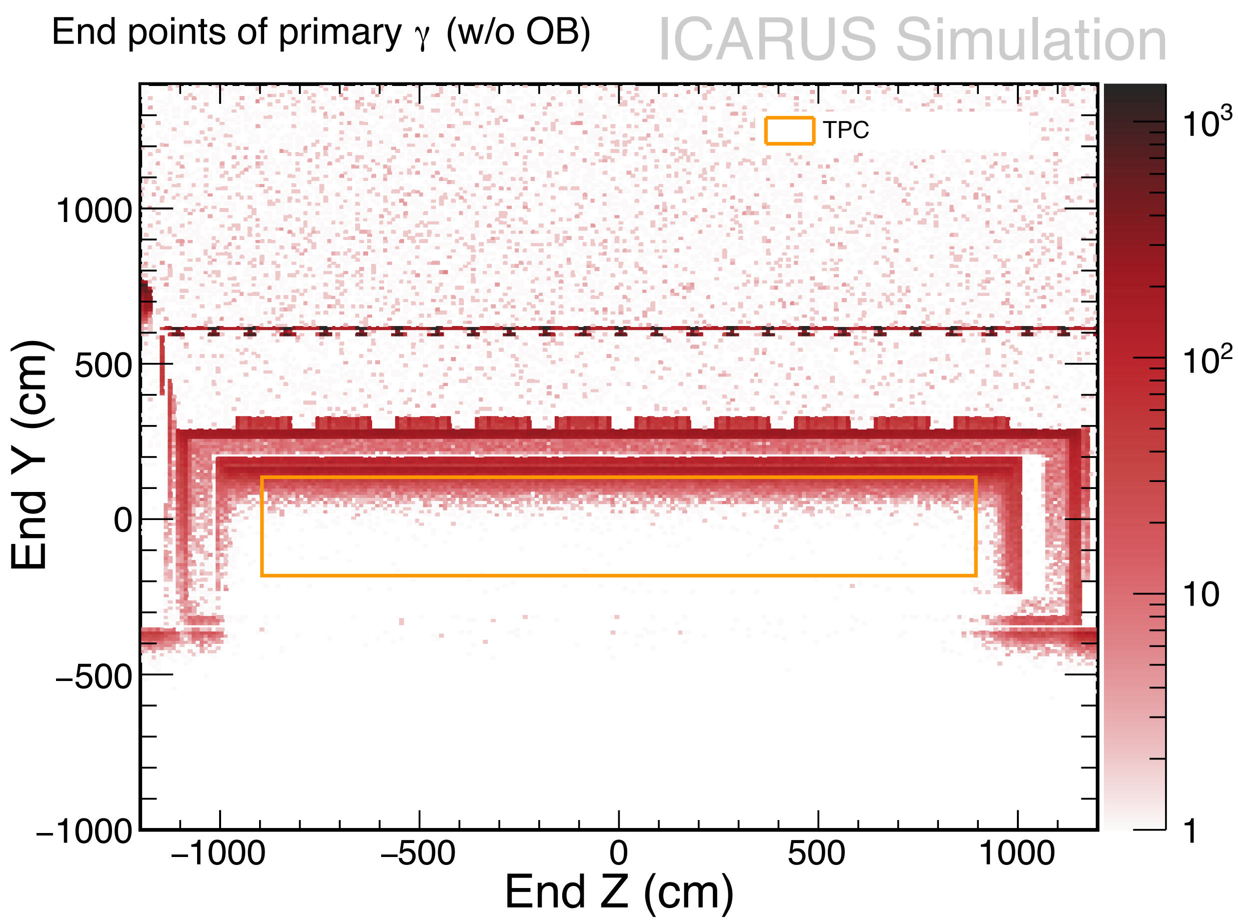
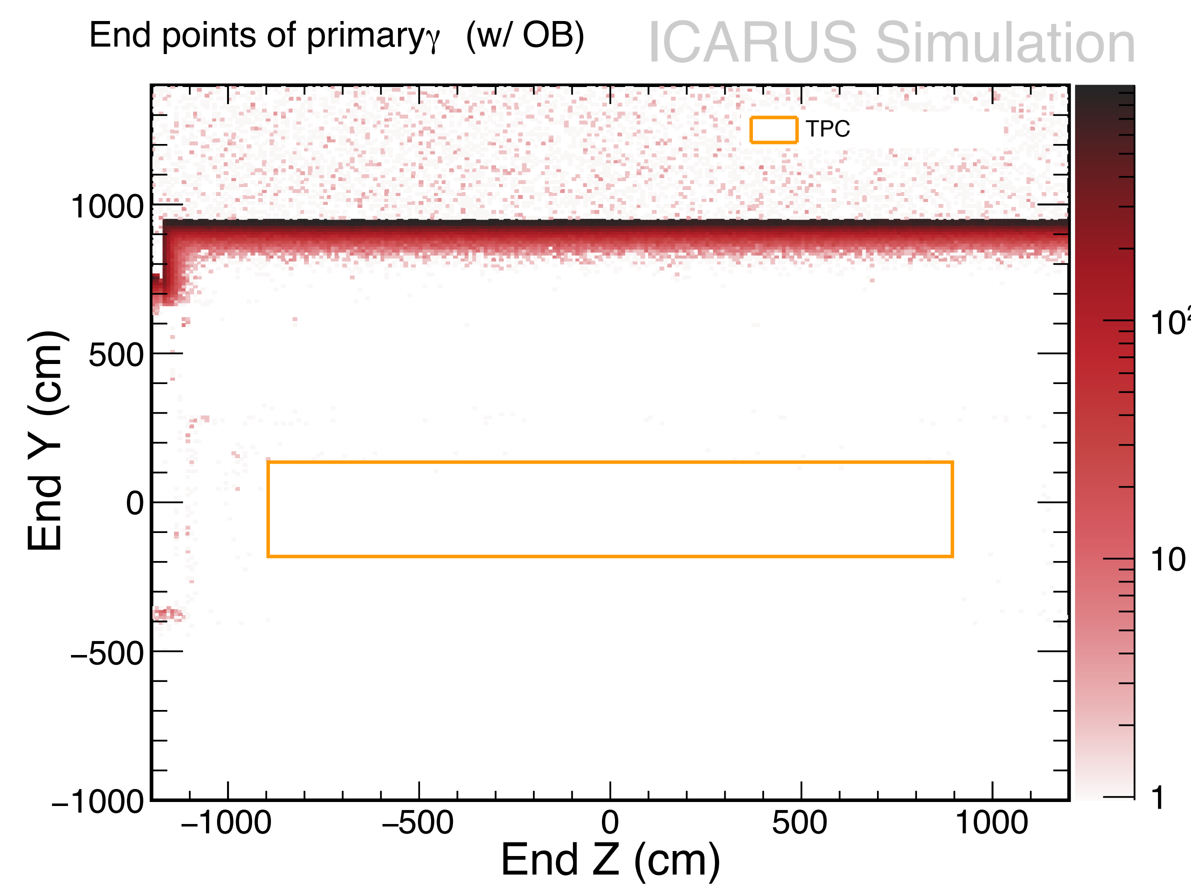


with overburden



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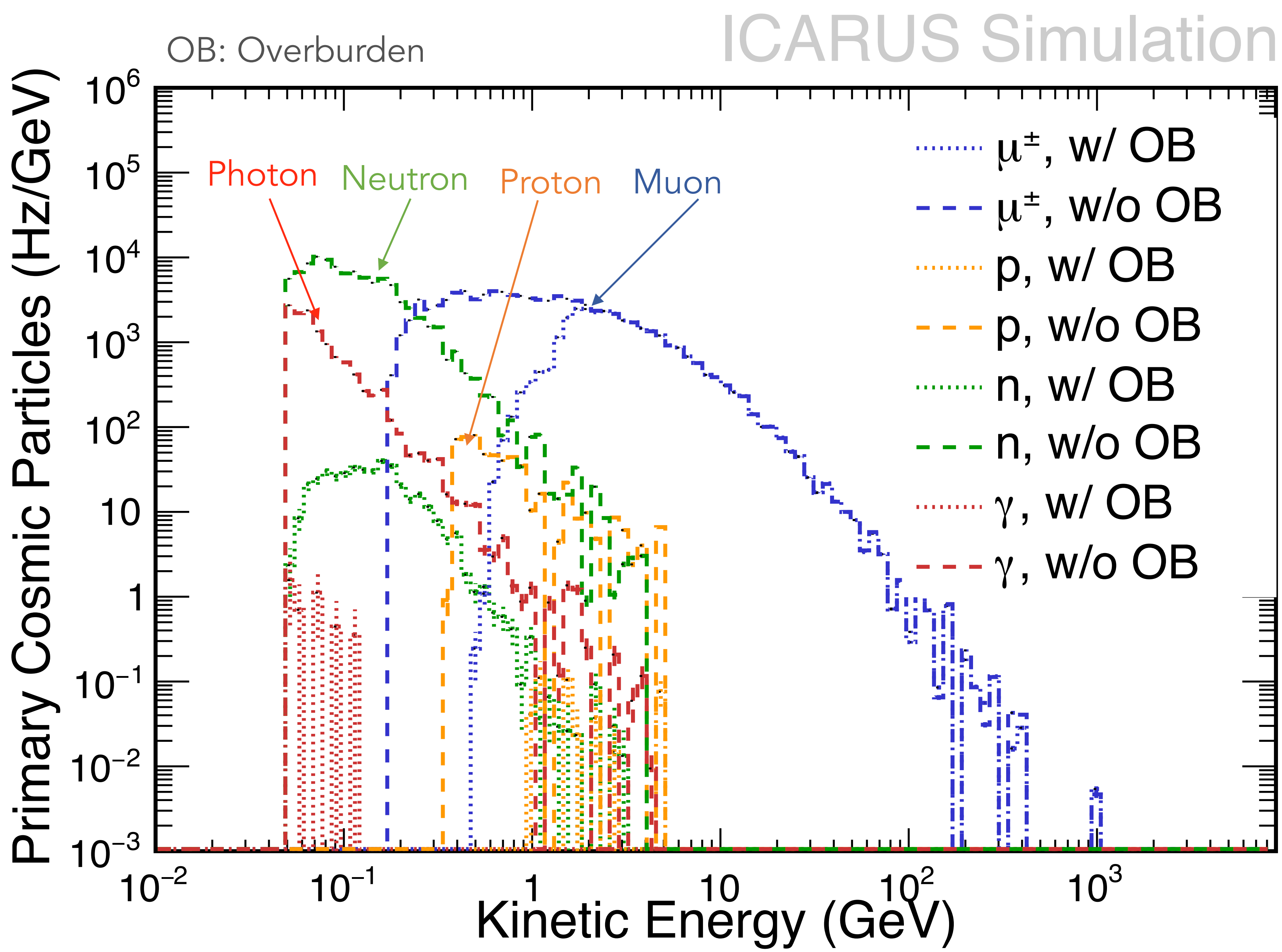
Cosmic Particles in Active Liquid Argon



- The overburden reduces the dominant muon flux by ~ 25%.
- More effective for the hadrons, by a factor ~150 of primary neutrons and a full suppression of primary photons.

Cosmogenic Electromagnetic Activity in the ICARUS

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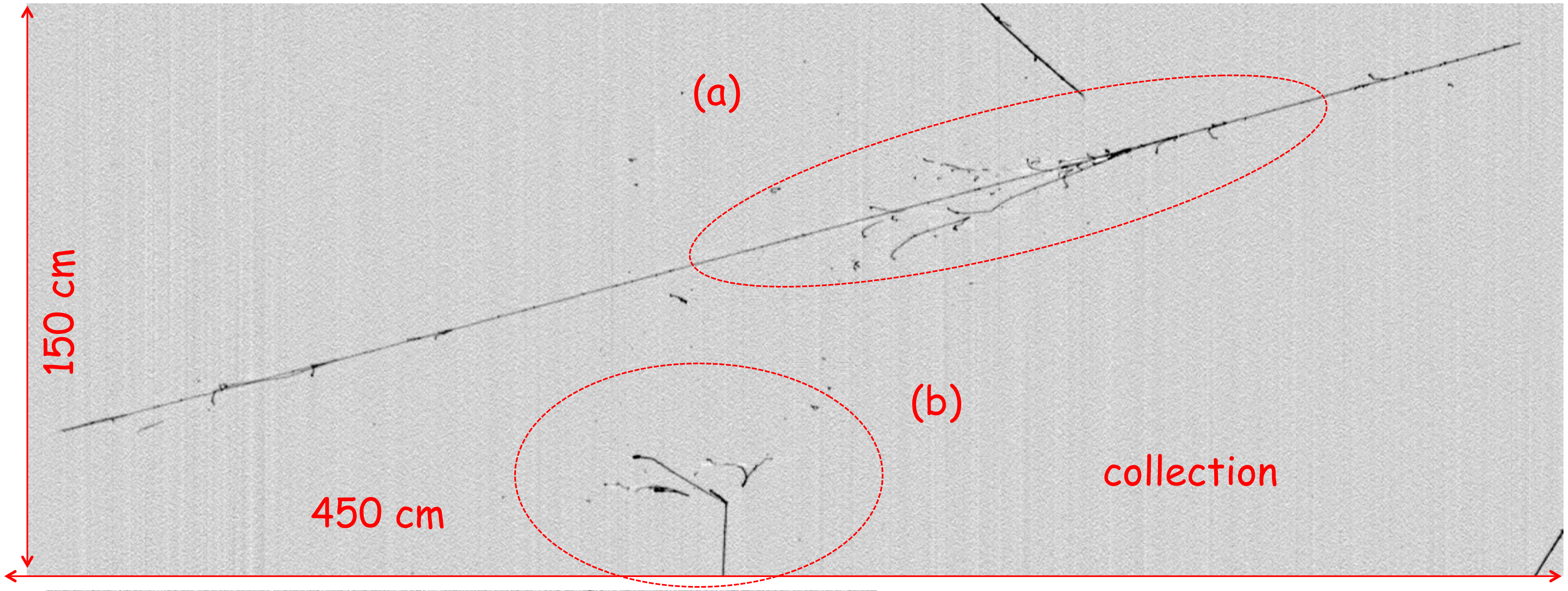
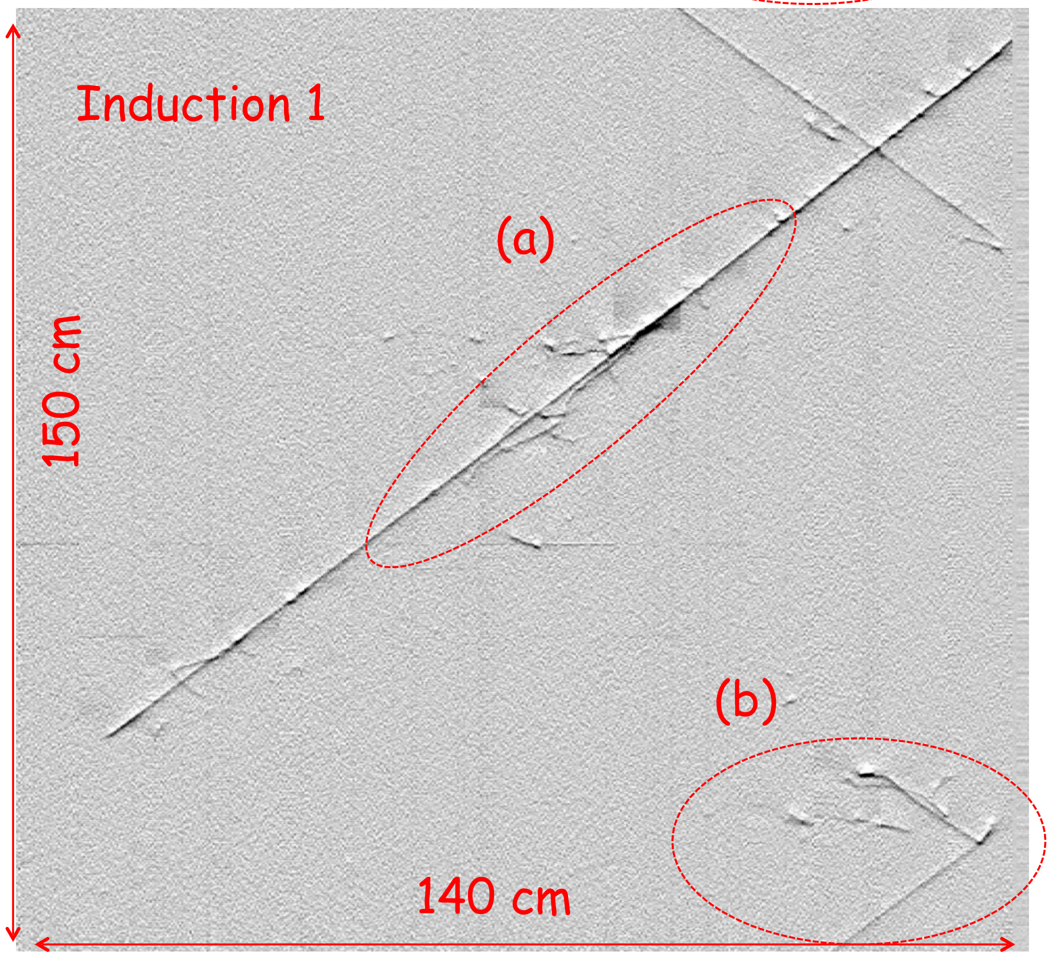


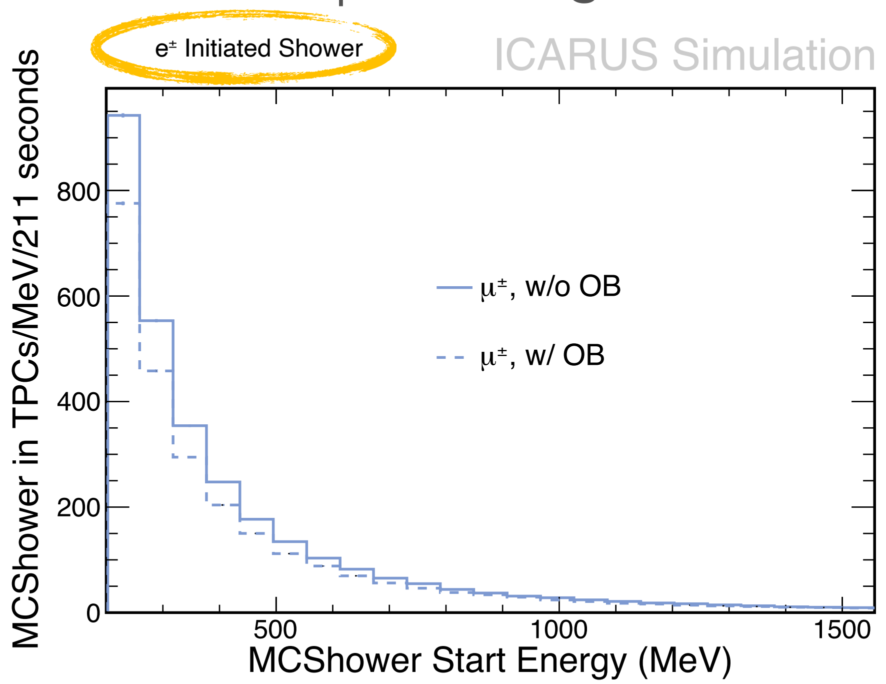


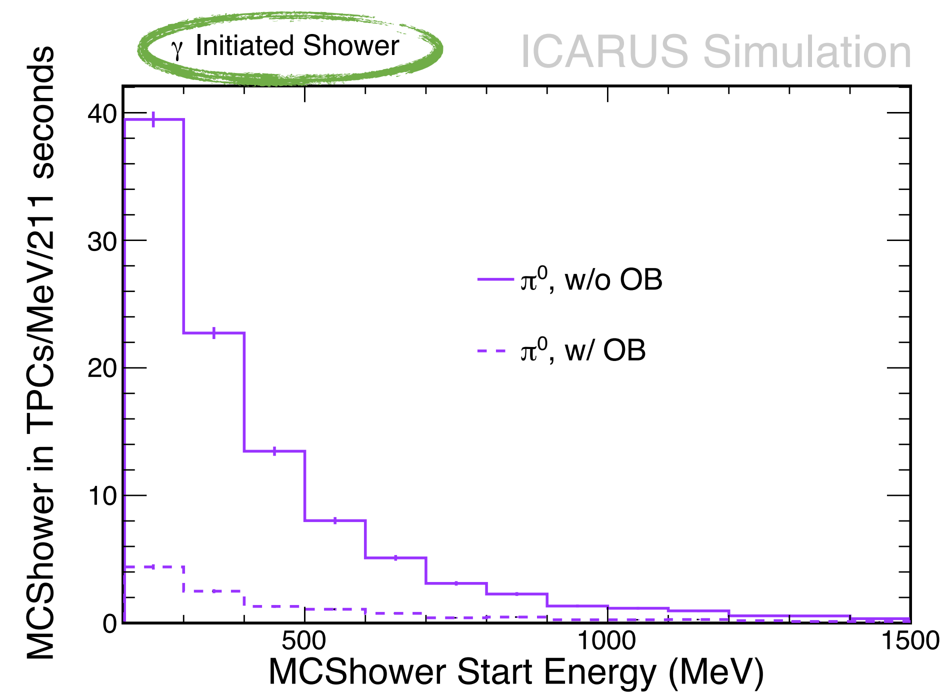
- (a) An example of a muon emitting an high energy delta ray developing a shower.

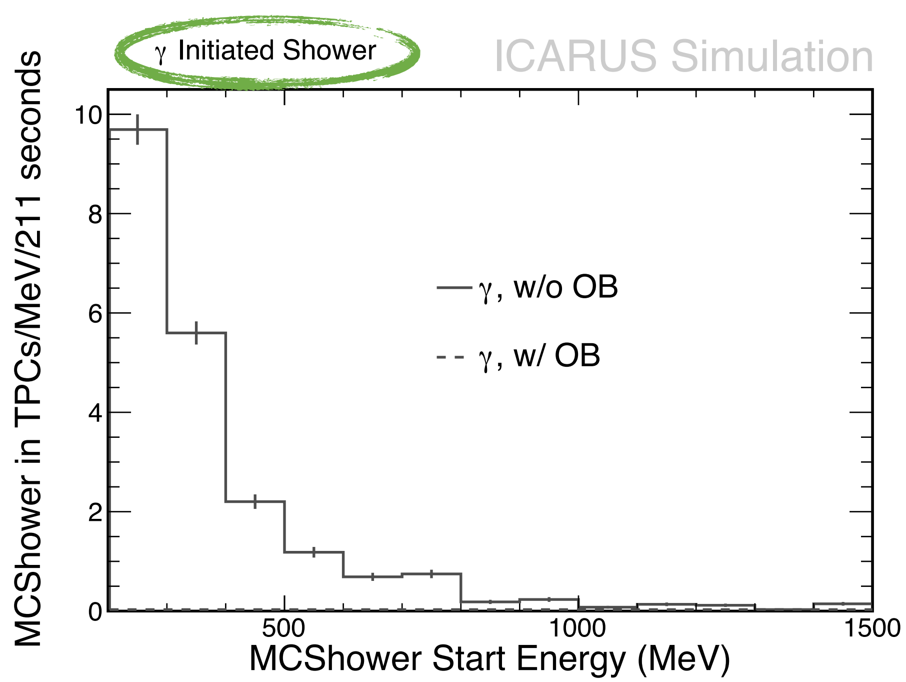
- (b) cosmic neutron interacting in the active argon producing a π^0 decaying into two photons.

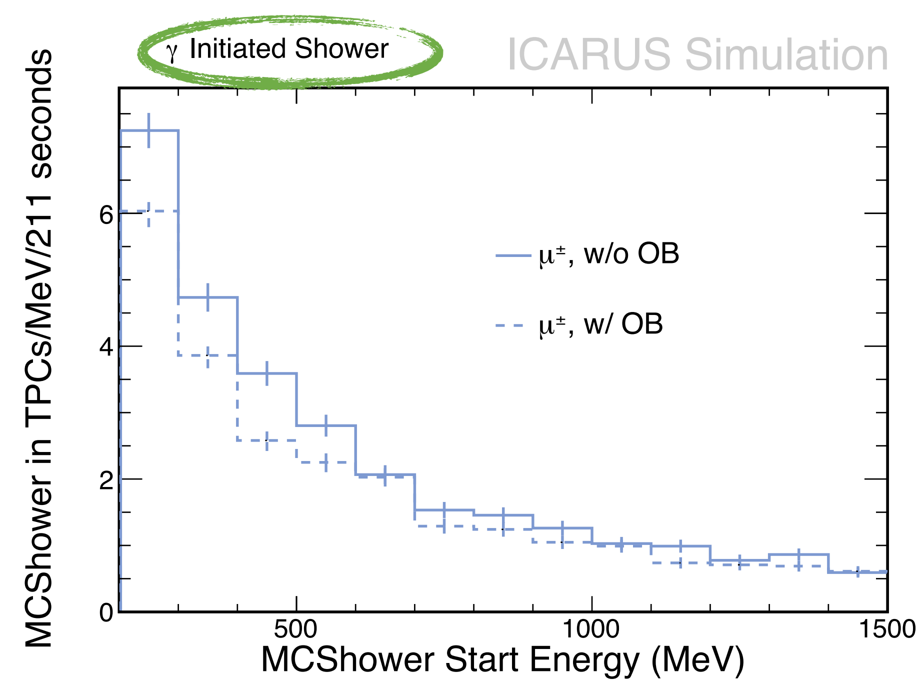
Electromagnetic Showers Energy

- > 200 MeV shower energy, cosmic muons are larger contributor and primary $e^{\pm}$ are tiny fraction on producing $e^{\pm}$ initiated showers.
- > 200 MeV they are mostly produced by π^0 with minor contributions from primary γ and brems by muons.







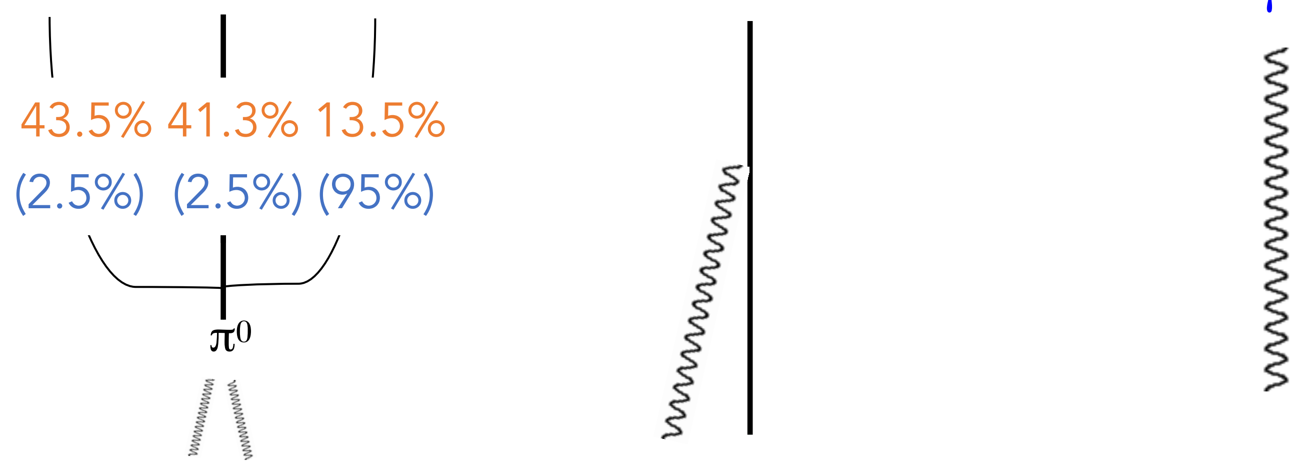


Short Baseline Neutrino

Showers from γ initial particle: without (with) overburden

- Three main categories of events are involved in the production of γ showers (E>200 MeV) inside the liquid argon.

	γ from π^0	γ from μ brems	Primary γ
Primary cosmic particle	n, p, μ	μ	γ
without OB	43.5% 41.3% 13.5%		
with OB	(2.5%) (2.5%) (95%)		
Total in 211 s active LAr	12290 γ (989 γ)	3630 brem γ (3270 brem γ)	2231 primary γ (negligible)

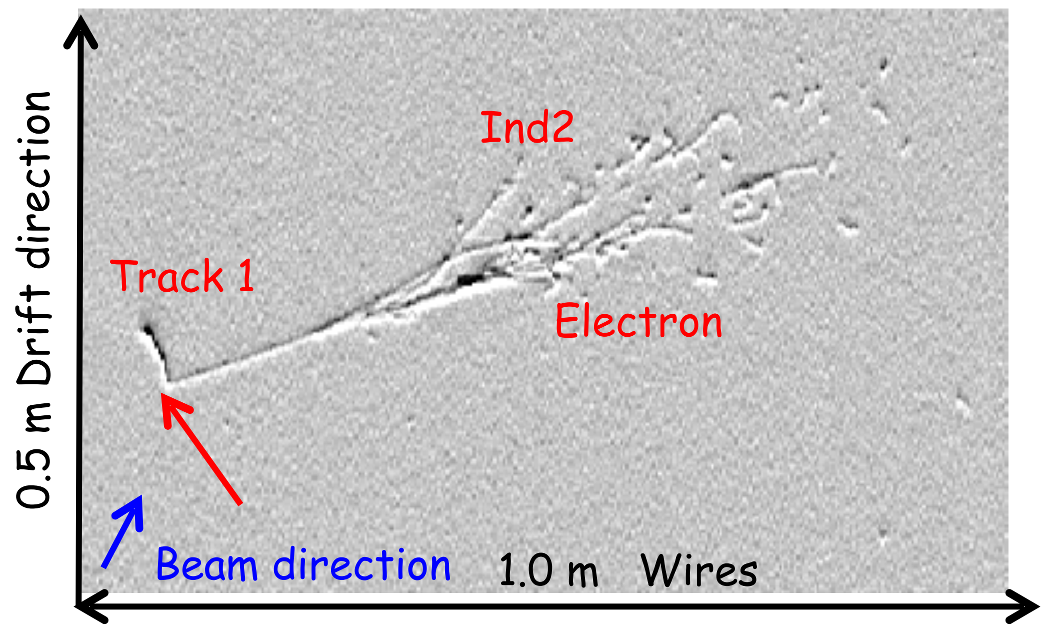


- In absence of overburden the dominant contribution is from the π^0, which is predominantly produced by incoming cosmic hadrons.

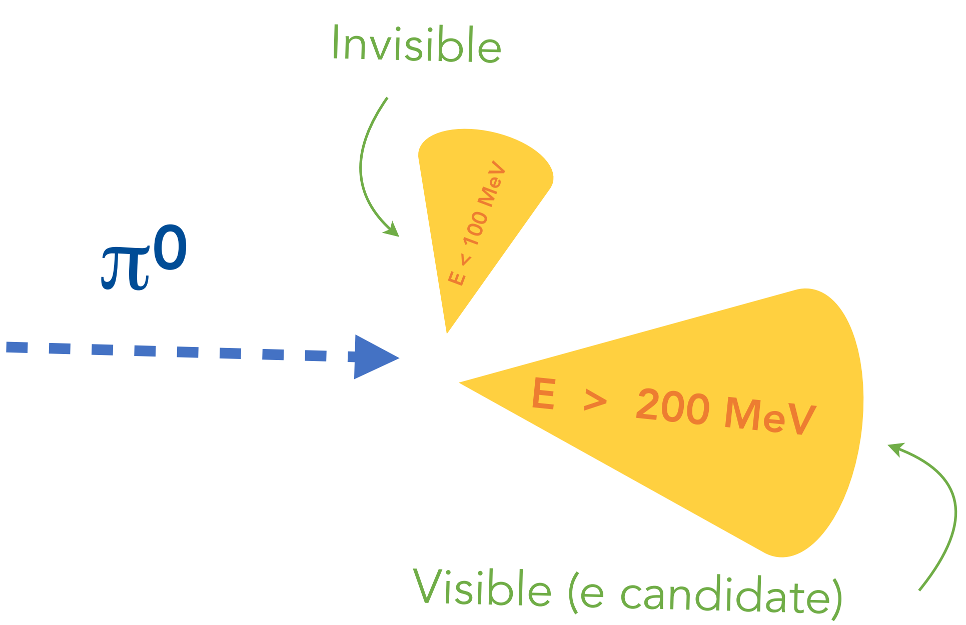
- Overburden strongly suppress hadrons and removes primary γ and associated showers.

π^0 Selected as Background ν_e Candidate

Showers from π^0 in the total 3 years



- If a cosmic event produces one π^0 which produces a leading showers E>200 MeV (electron candidate) and an another sub leading shower with E <100 MeV (undetected), this event is selected as background ν_e candidate.



Events	Without OB	With OB
Events with π^0	2059	174
Primary γ	501	0

Summary

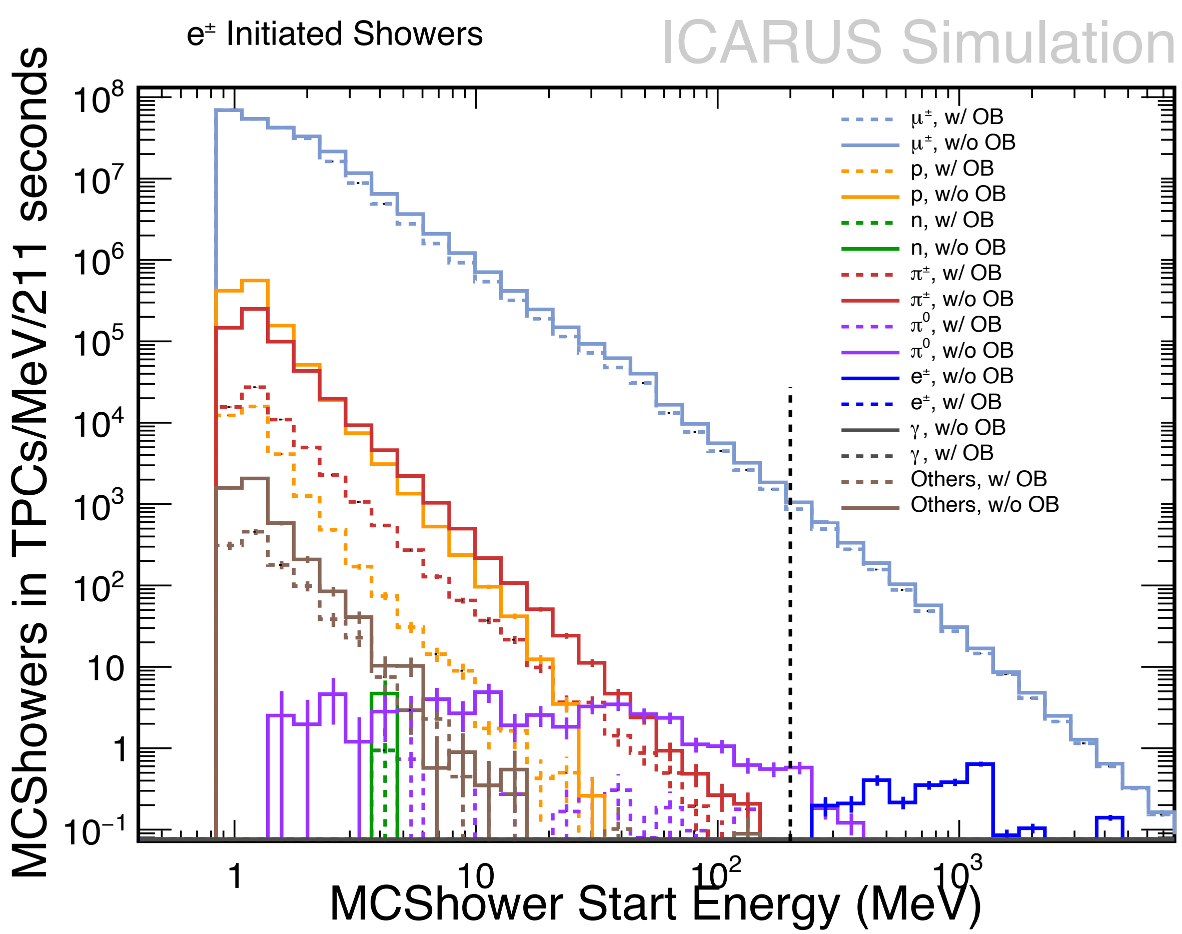
- For the SBN sterile neutrino search we must remove as many controllable backgrounds as possible in the experiment setup.
- We have quantified the reduction of cosmic backgrounds in particular using the overburden has been investigated with new detailed MC simulations exploiting the accurate description of the geometry and composition of the experimental setup.
- The overburden is very effective in reducing the hadrons while fully eliminating the electromagnetic cosmic ray components.

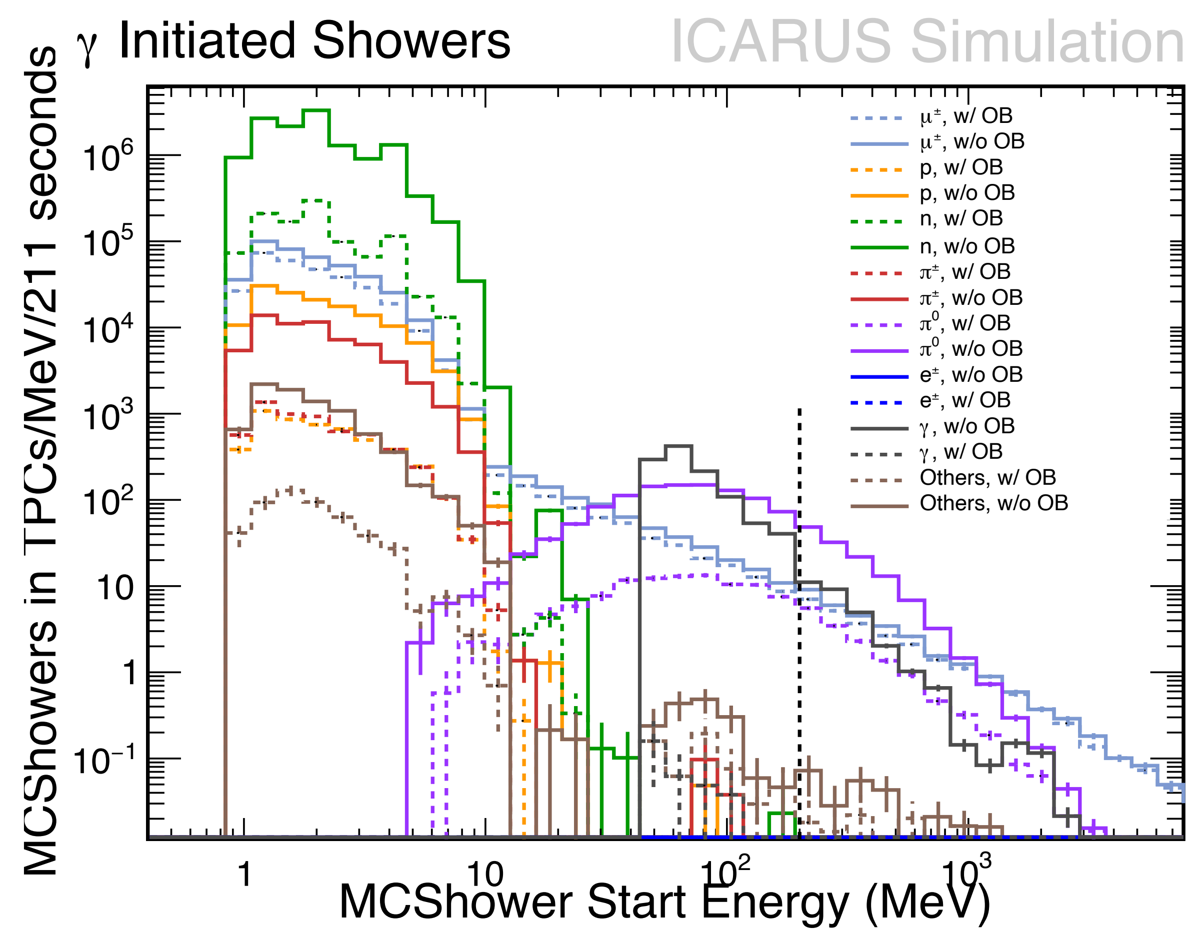
Thank you

Acknowledgement: **Department of Energy, USA**

Electromagnetic Showers Energy

- > 200 MeV shower energy, cosmic muons are larger contributor and primary $e^{\pm}$ are tiny fraction on producing $e^{\pm}$ initiated showers.
- > 200 MeV they are mostly produced by π^0 with minor contributions from primary γ and brems by muons.

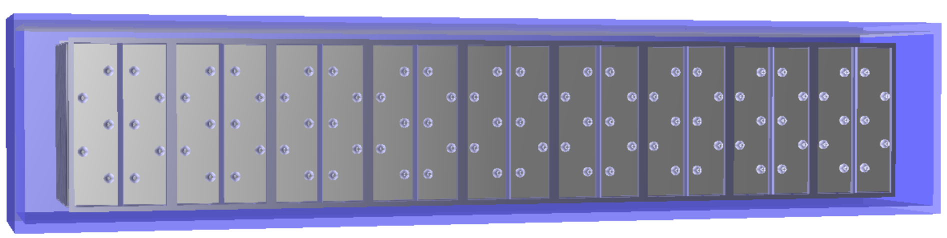




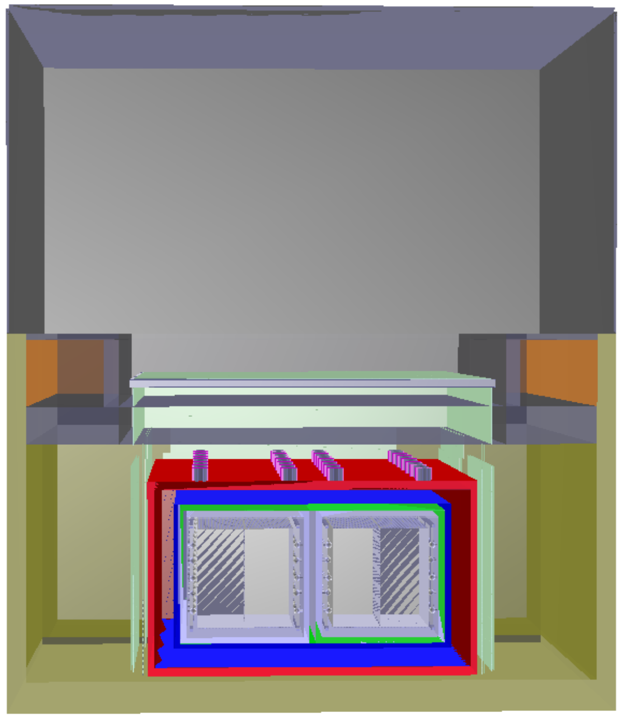
Number of electromagnetic showers in the ICARUS TPCs in 211 seconds (6.6×10^{20} POT), classified based on the shower mother particle. **Dotted black line** shows the position of 200 MeV.

Cosmic rays simulation in ICARUS setups

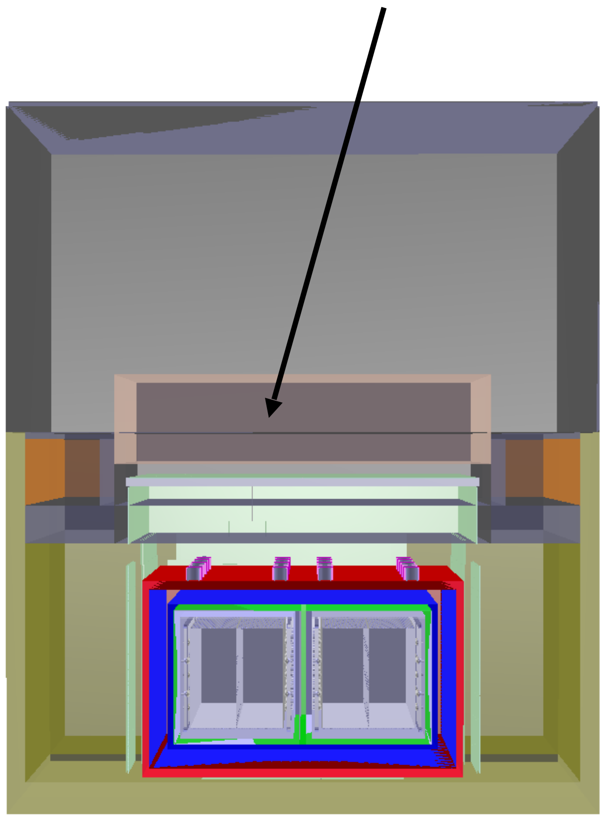
1. LAr only
no surroundings
no overburden



2.
with surroundings
no overburden



3.
with surroundings
with overburden



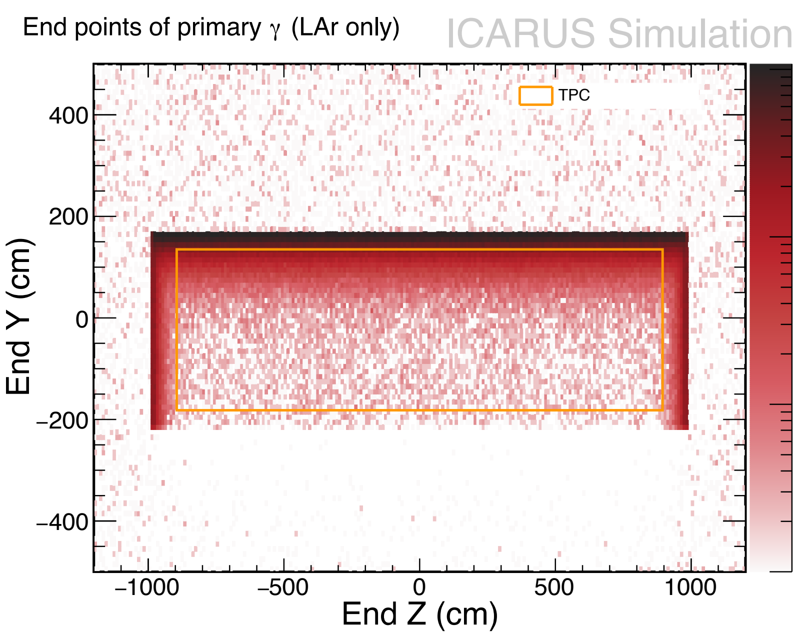
- To understand the role of the different elements in the reduction of the cosmics reaching the active detector.
- For each configuration an event statistics for the 3 years data taking (6.6e20 POT).

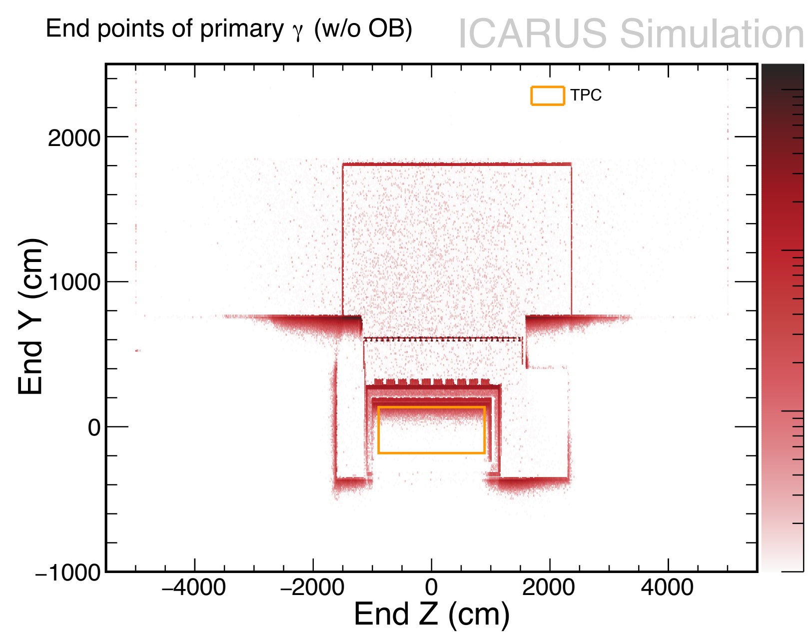
End position of Primary Photons

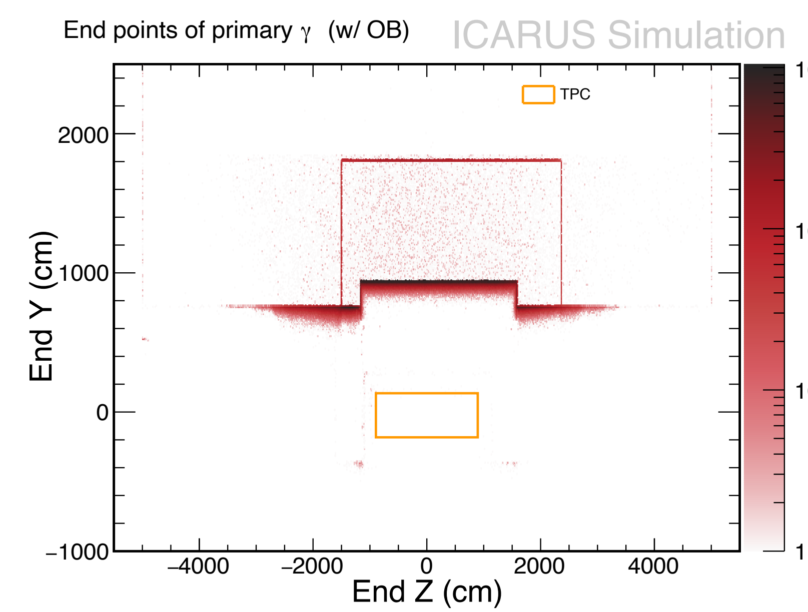
1. LAr only
no surroundings
no overburden

2.
with surroundings
no overburden

3.
with surroundings
with overburden







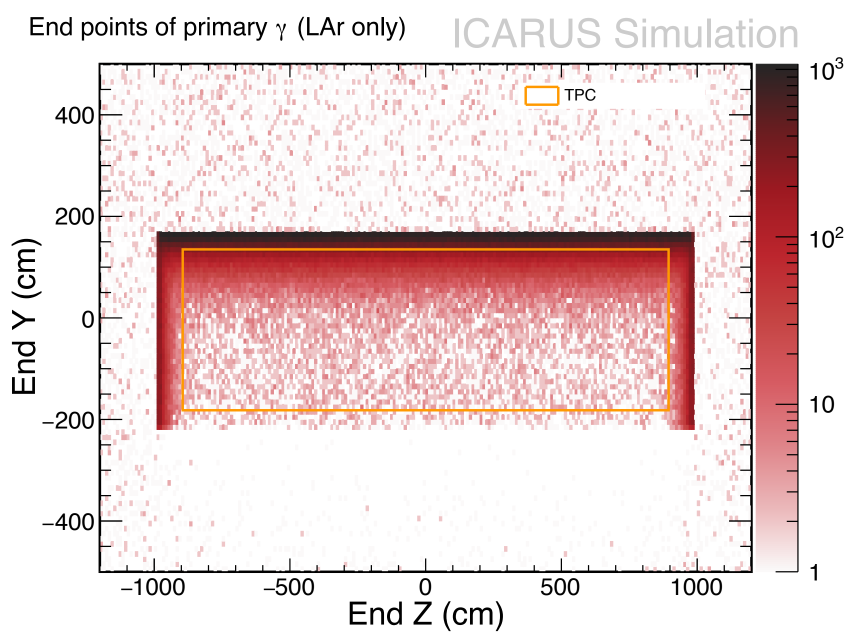
- To understand the role of the different elements in the reduction of the cosmics reaching the active detector.
- For each configuration an event statistics corresponding to an exposure of ~217s, slightly larger than the 211s expected for the 3 years data taking (6.6e20 POT).
- Recorded the cosmic particles reaching the active liquid argon.

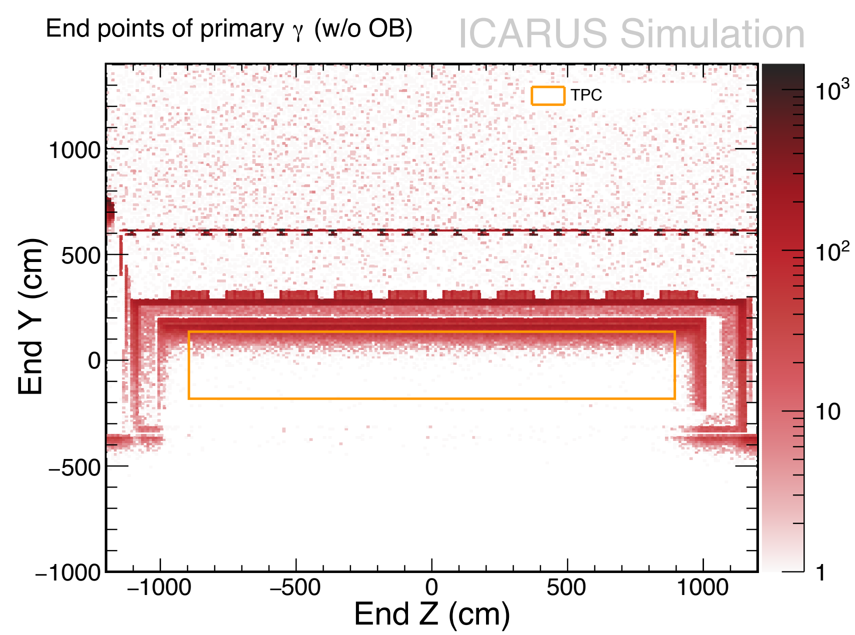
End position of Primary Photons (zoom)

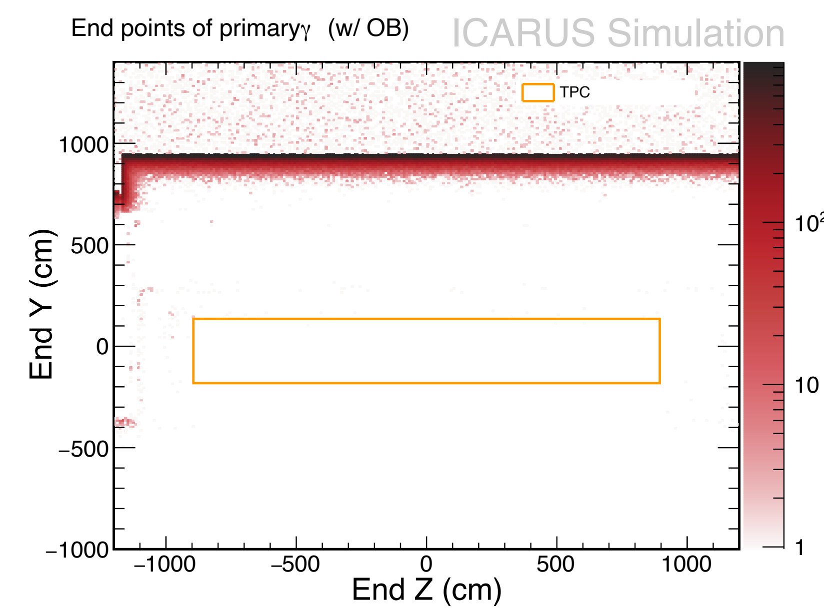
1. LAr only
no surroundings
no overburden

2.
with surroundings
no overburden

3.
with surroundings
with overburden







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Cosmic Particles in Active Liquid Argon

1. LAr only
no surroundings
no overburden

vs

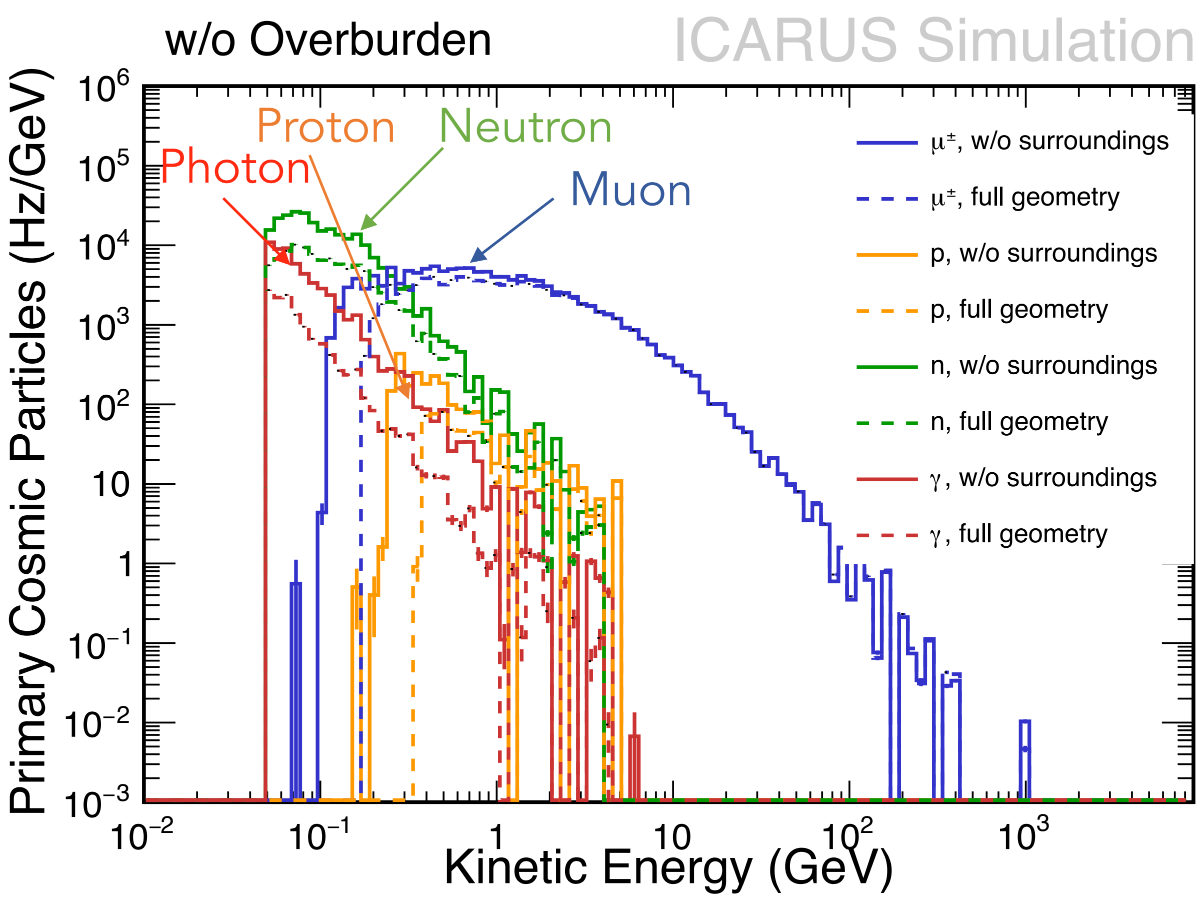
2.
with surroundings
no overburden

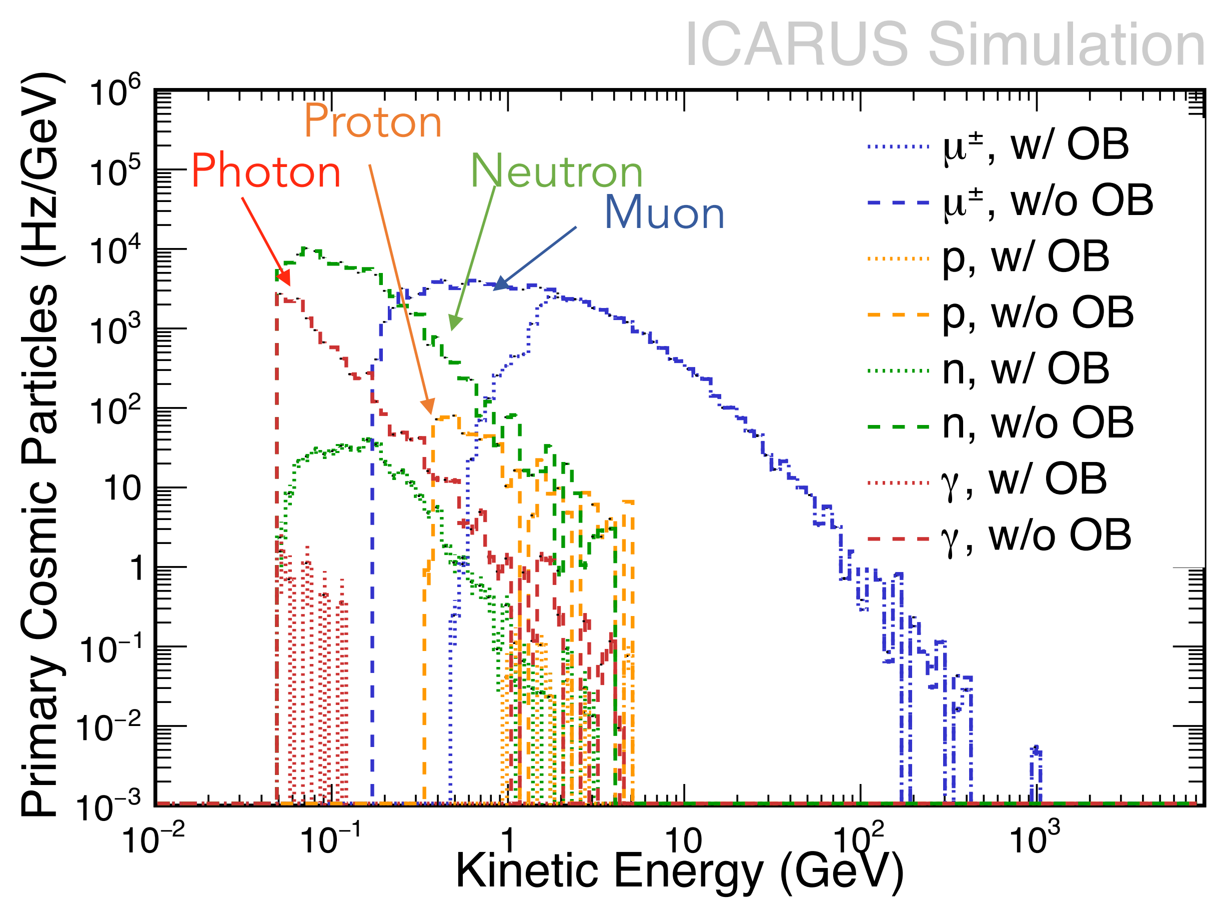
2.
with surroundings
no overburden

vs

3.
with surroundings
with overburden

OB: Overburden





Solid lines: number of primary cosmic particles that intersect the TPCs w/o surroundings.
Dashed lines: number of primary cosmic particles that intersect the TPCs w/o OB.
Dotted lines: number of primary cosmic particles that cross the TPCs if an OB is added.

ICARUS Geometry

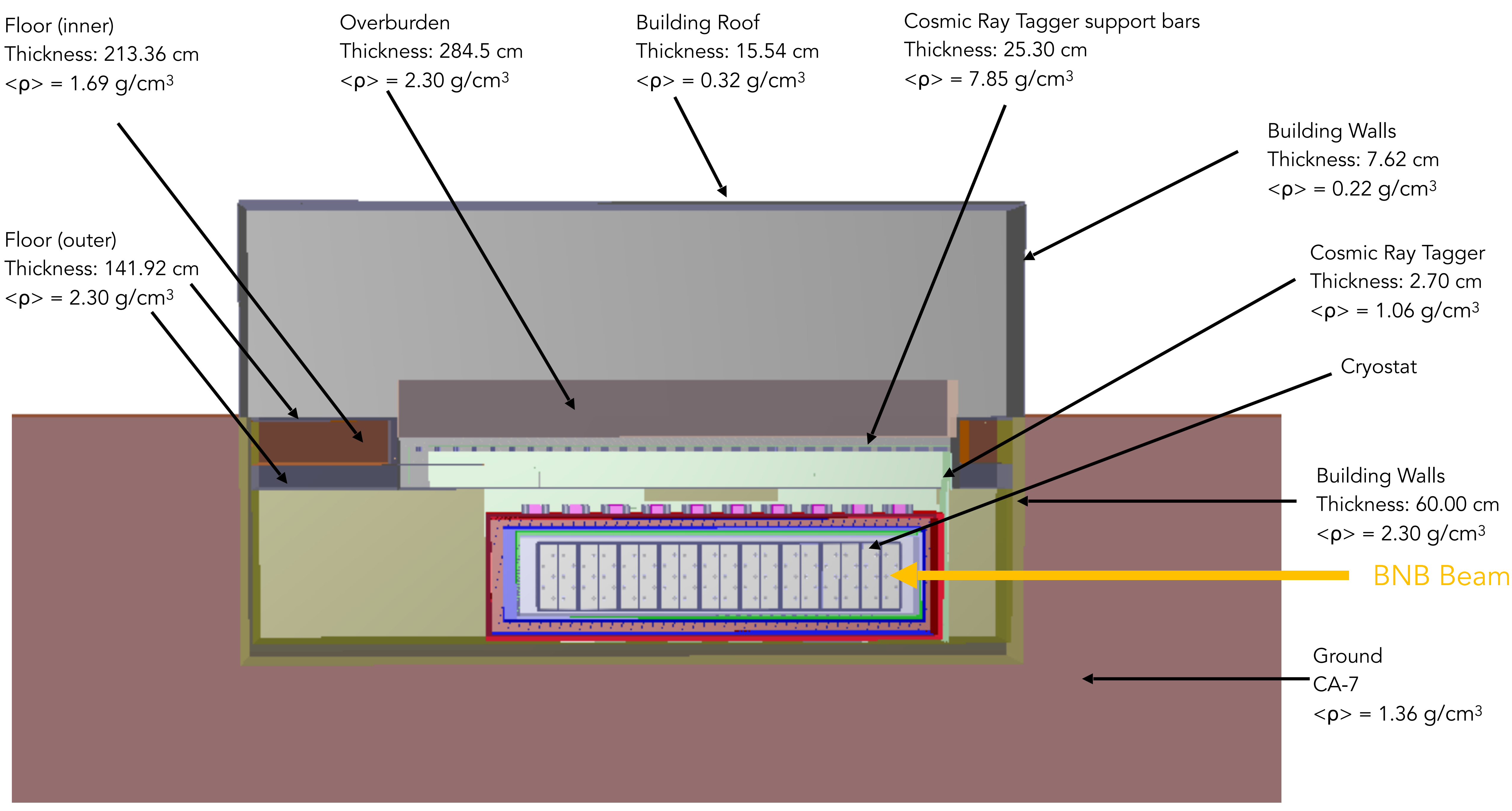


Image Credit : Marta Torti and Alessandro Menegolli