SBND and ICARUS Overburden Studies

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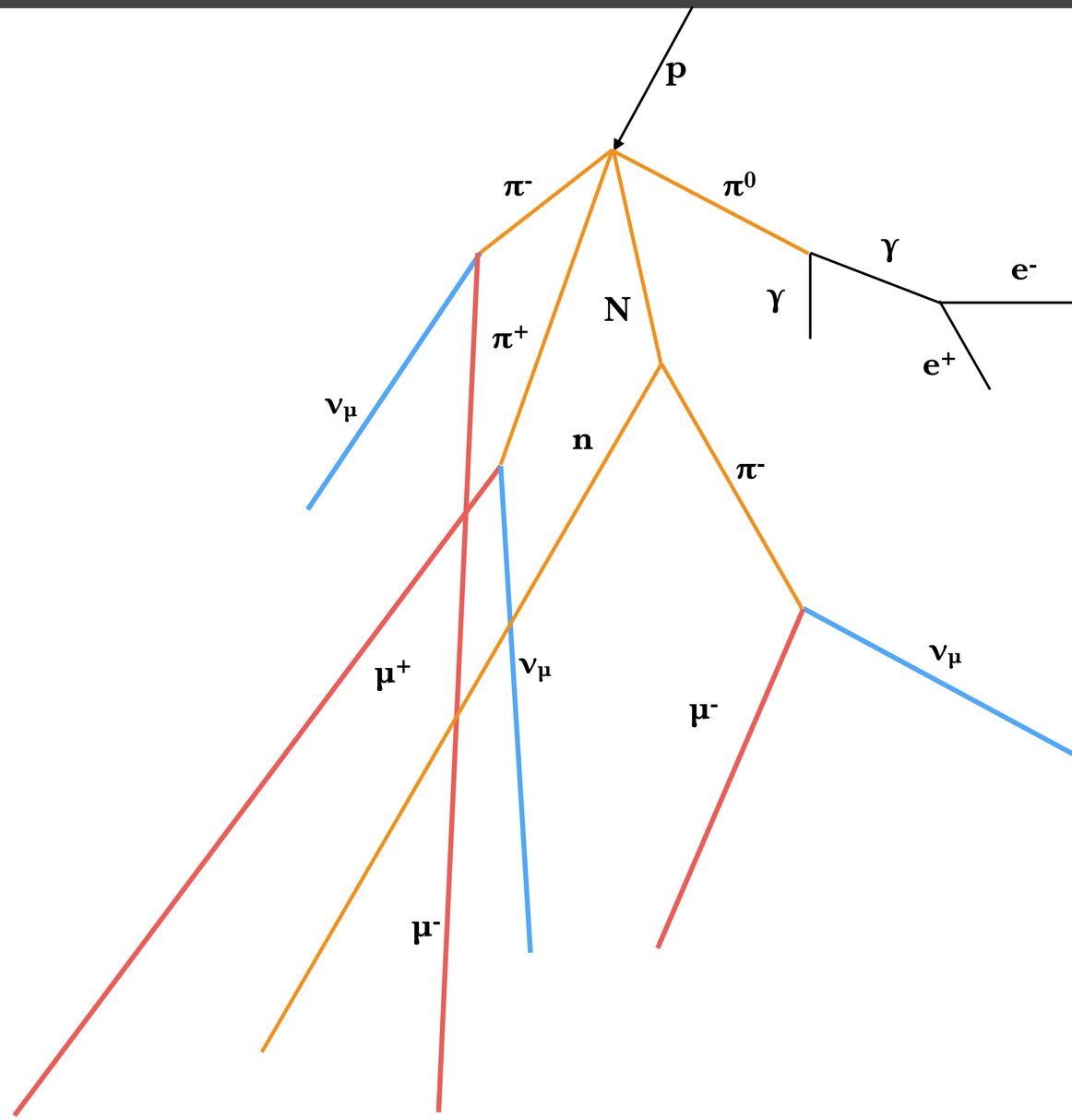
Introduction

Being on the surface, cosmic activity in the SBN detectors is the primary background for many physics analyses, and the purpose of a concrete overburden would be to reduce this activity in the detector.

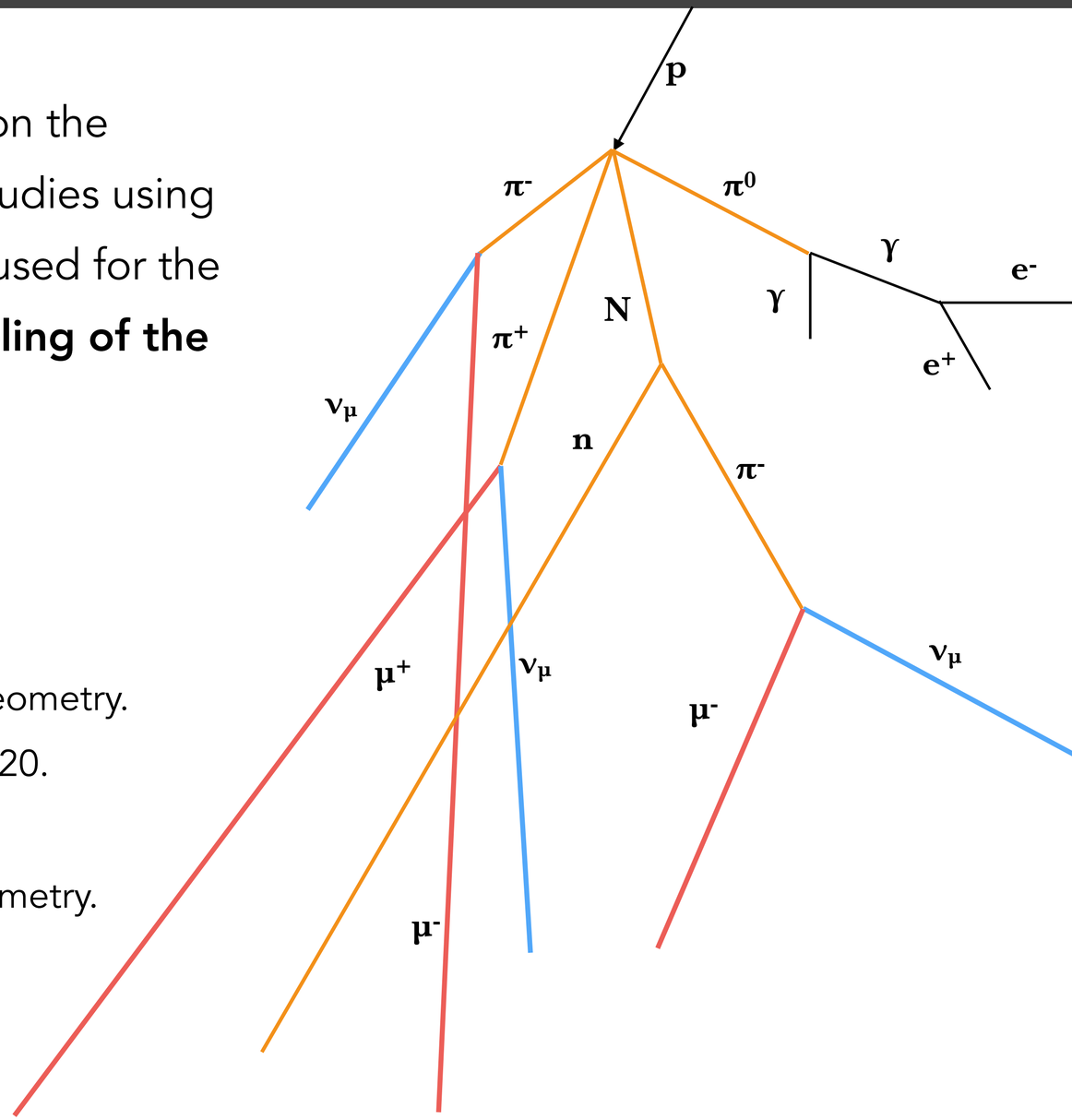
Overburden: a 3-meter-thick layer of concrete planned to be installed above the SBND and ICARUS detectors for cosmic-ray shielding.

(to be updated to 2.83 m of thickness)



Introduction

The effect of the overburden on the primary cosmics and on the electromagnetic activity generated by them is shown in these studies using the **latest available simulations**, which improve upon the ones used for the SBN proposal and in previous studies as they include **full modeling of the detectors and building geometries**.



Overburden studies timeline:

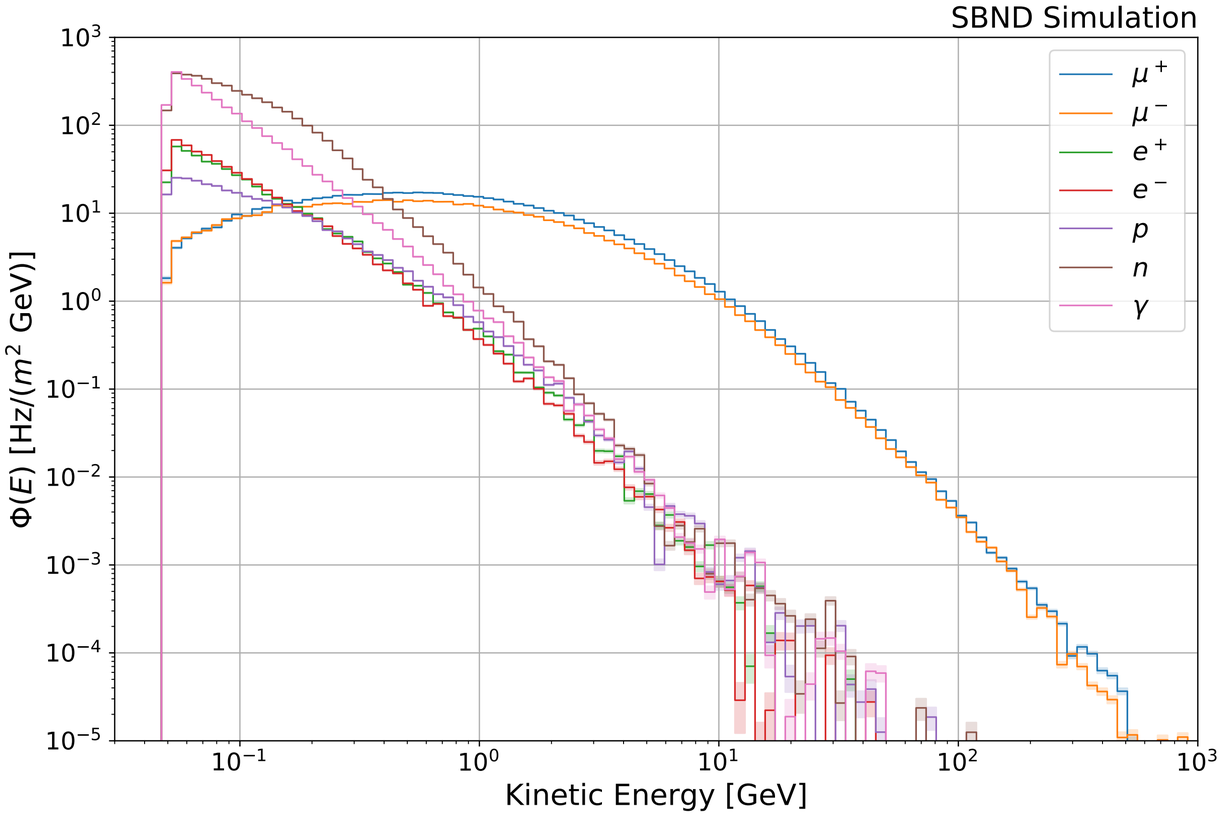
- SBND studies started in January 2020.
- SBND studies updated in Fall 2020 to include updates in the detector geometry.
- ICARUS studies, based on the same analysis code, started in October 2020.
- First pass of comparisons done before the Dec. 2020 PAC meeting.
- ICARUS studies recently updated to include updates in the detector geometry.
- Detailed comparisons started 10 days ago and are in progress.

Introduction

Outline:

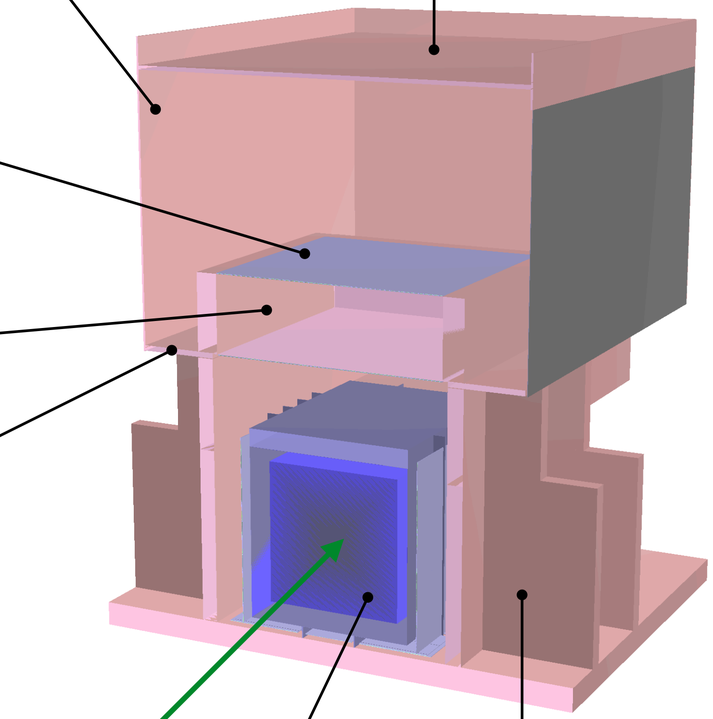
- SBND and ICARUS geometries
- Geometry configurations used in this study
- Effect of the geometry and overburden to the primary cosmic particles
- Importance of the geometry implementation in our simulations
- Neutrinos in the overburden

Cosmogenic fluxes from the CORSIKA simulation at 228 m above sea level

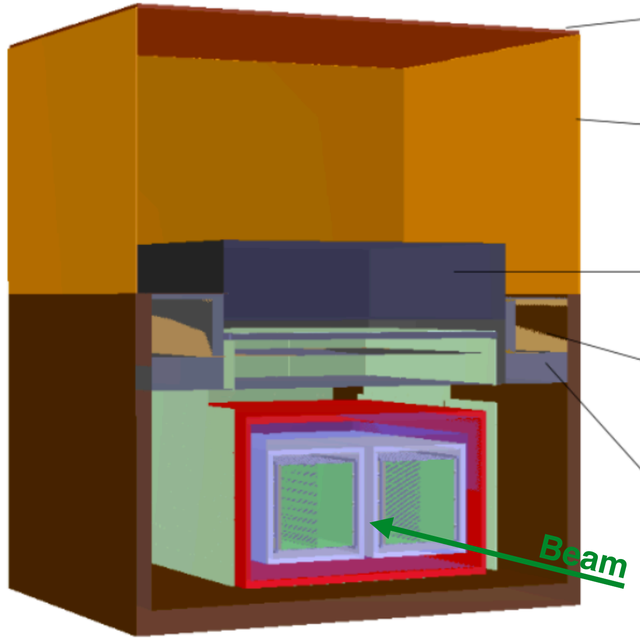


Detector Geometries

SBND



ICARUS



Geometry Configurations

We studied 3 configurations using the current geometry description in the simulation:

1 **w/o Surroundings**
w/o Overburden

TPC and Liquid Argon Volume

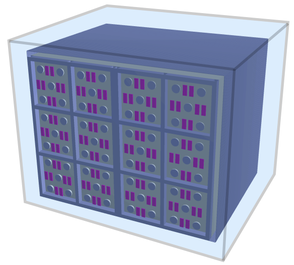
2 **w/ Surroundings**
w/o Overburden

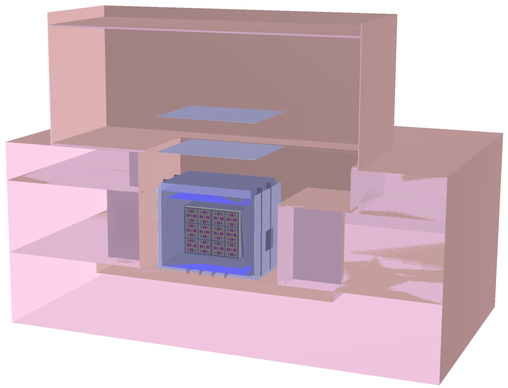
Full geometry, but without the overburden

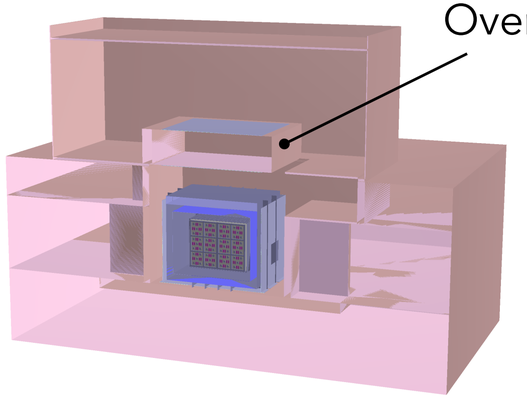
3 **w/ Surroundings**
w/ Overburden

Full geometry, with the overburden

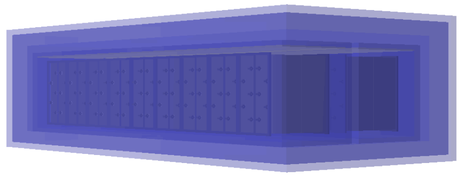
SBND

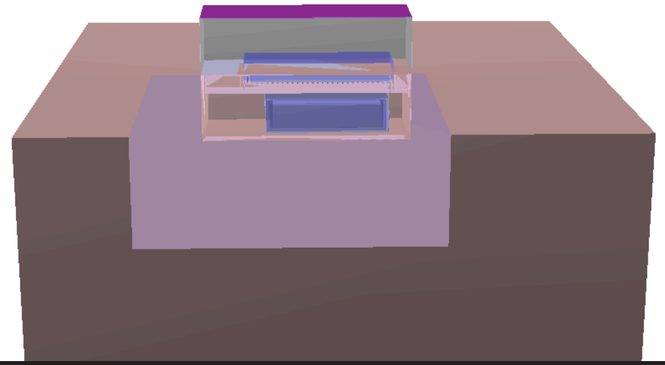


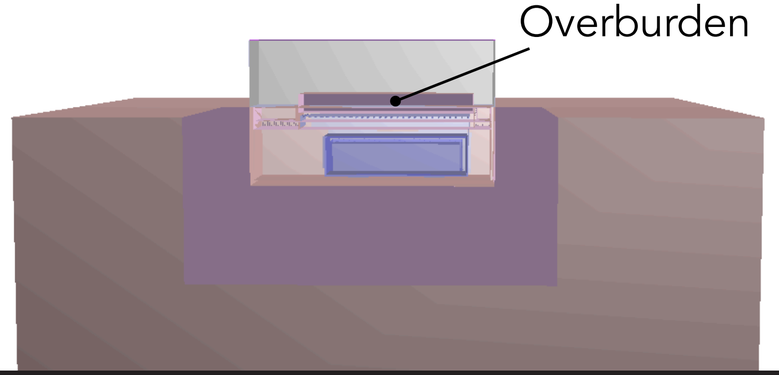




ICARUS







Geometry Configurations

For each configuration, we studied:

- The cosmic primaries entering the detectors
- The electromagnetic activity produced inside the detectors by:
  - muons
  - neutrons
  - protons
  - gammas
  - pions → π^0s being the most dangerous ones for a ν_e analysis

Detailed comparison of numbers for all configurations between SBND and ICARUS is in progress but not yet completed.

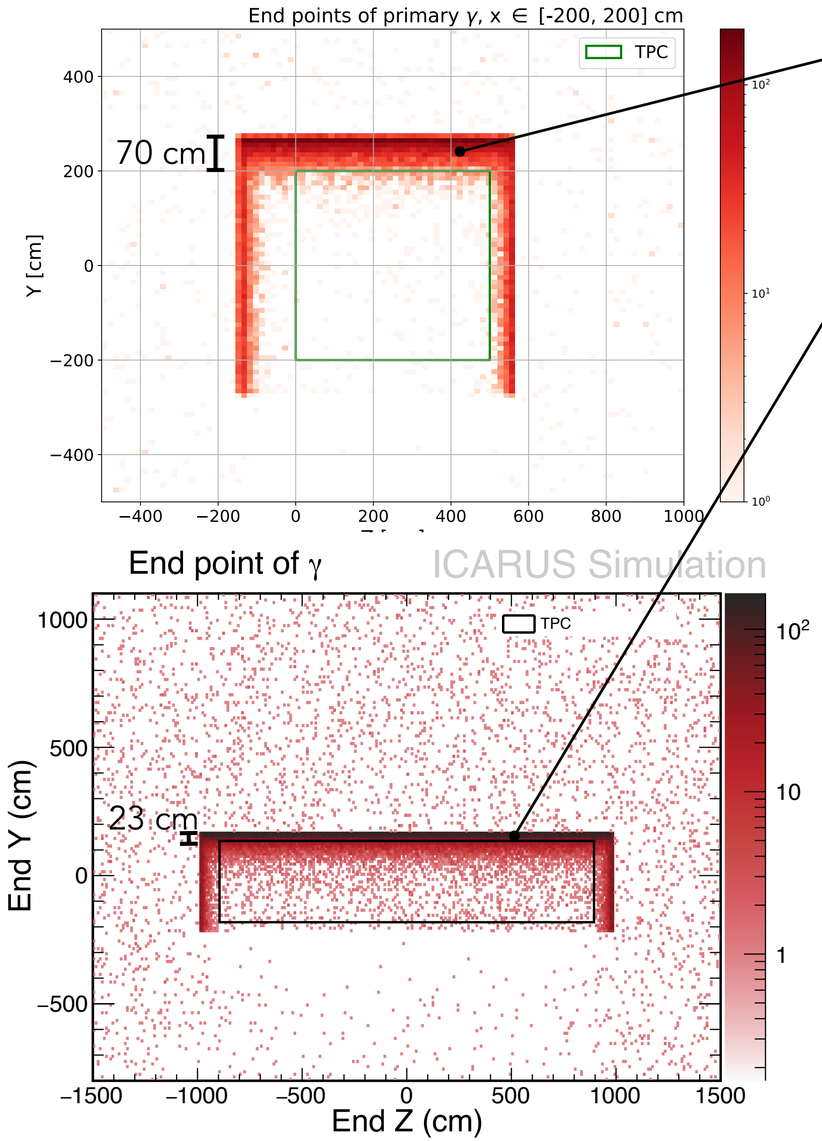
Details of the geometry have an important impact on the results.

Configuration 1: w/o Surroundings, w/o Overburden

SBND

ICARUS

Photons End Points



Inactive liquid argon

If we remove all the surroundings:

We see more primaries entering the active volume in ICARUS than in SBND.

Part of this can be explained by the layer of inactive LAr above the TPC.

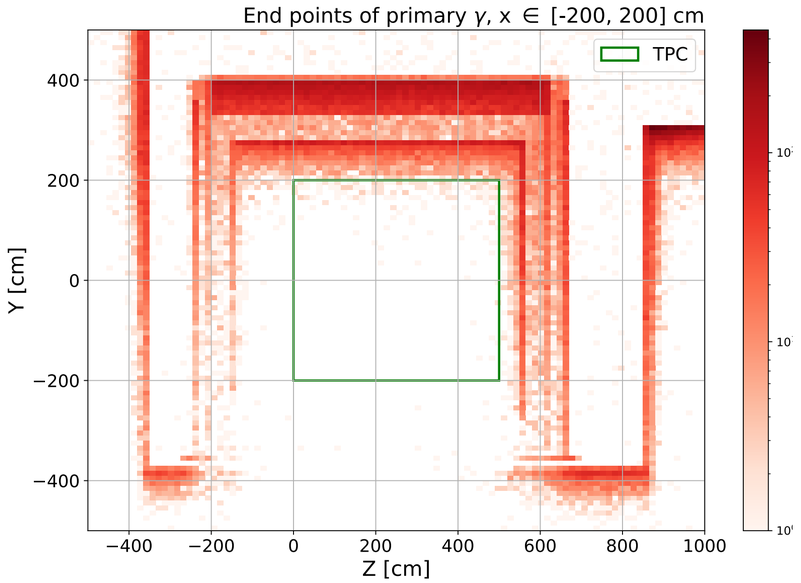
Inactive LAr thickness above TPC:

- SBND: 70 cm
- ICARUS: 23 cm

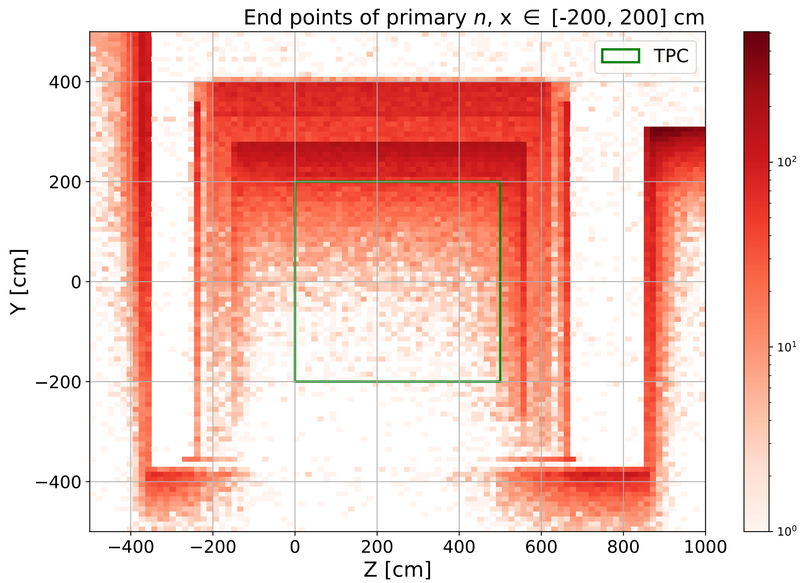
Configuration 2: w/ Surroundings, w/o Overburden

SBND

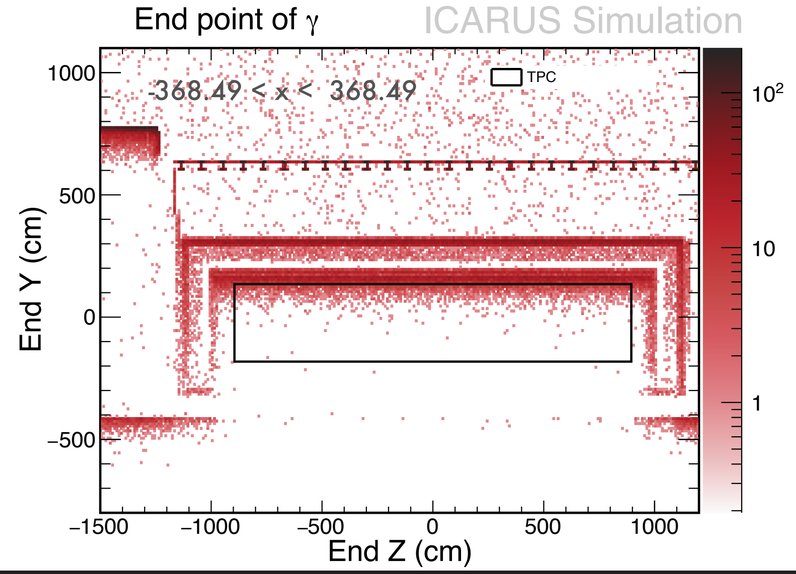
Photons End Points

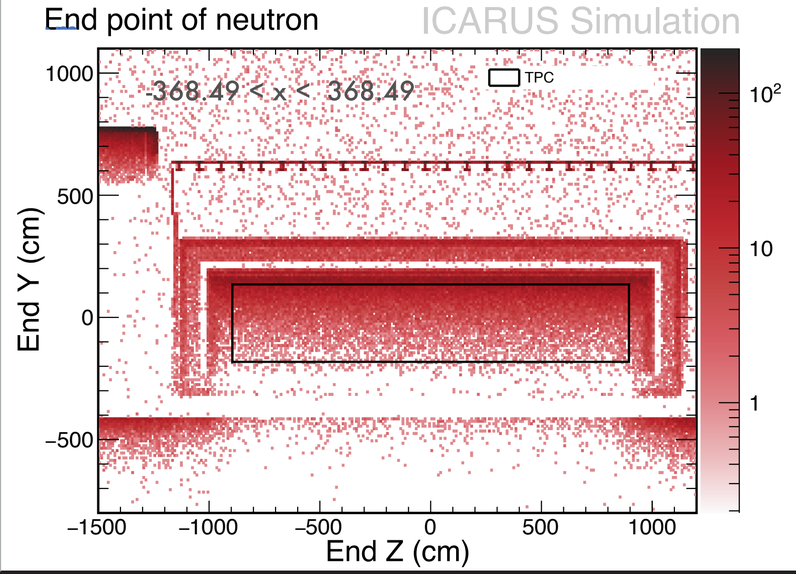


Neutrons End Points



ICARUS

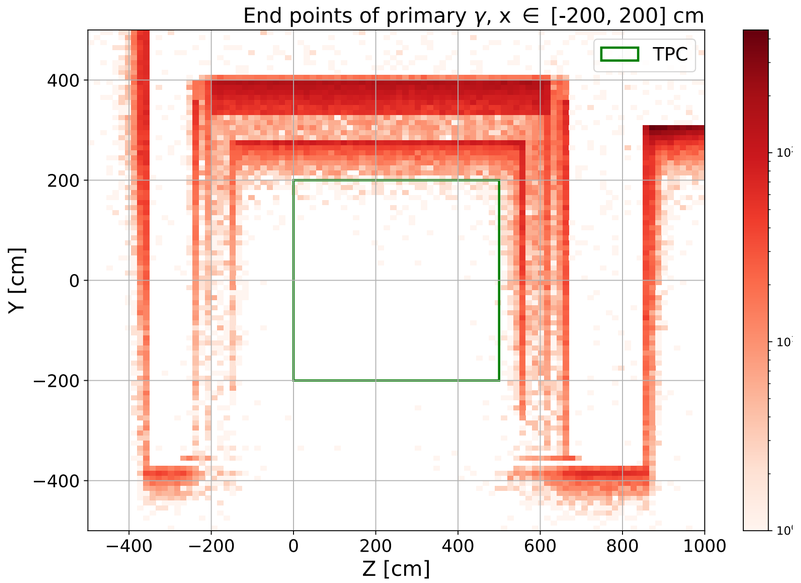




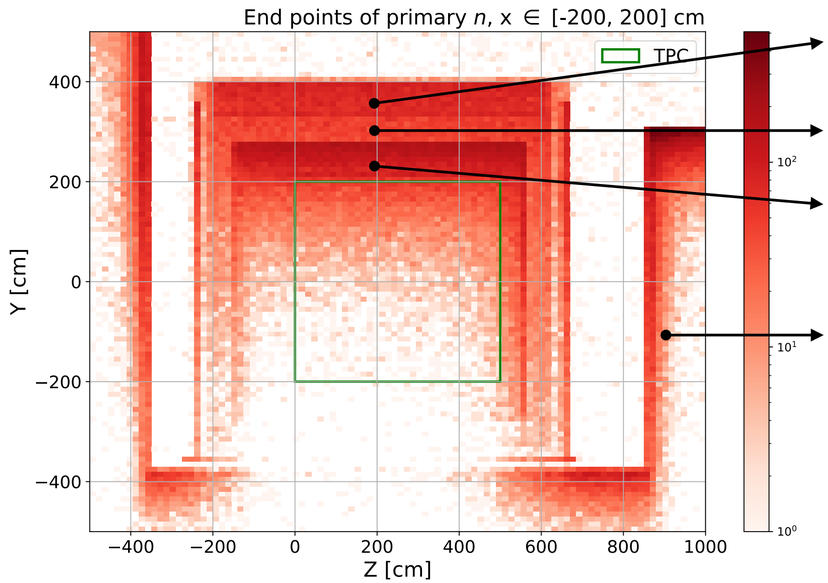
Configuration 2: w/ Surroundings, w/o Overburden

SBND

Photons End Points



Neutrons End Points



Top Cap

Insulation

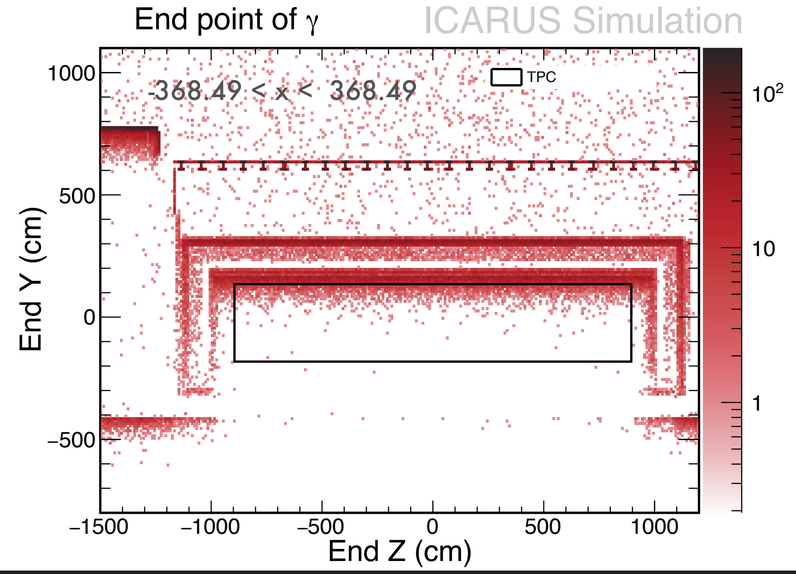
Inactive LAr

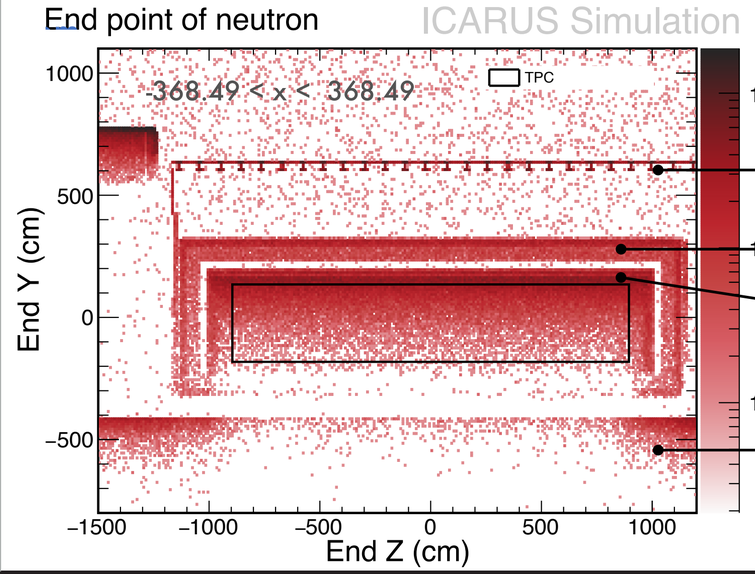
Pit Walls

Example:

The top cap in SBND stops many photons.

ICARUS





Cosmic Ray Tagger

Insulation

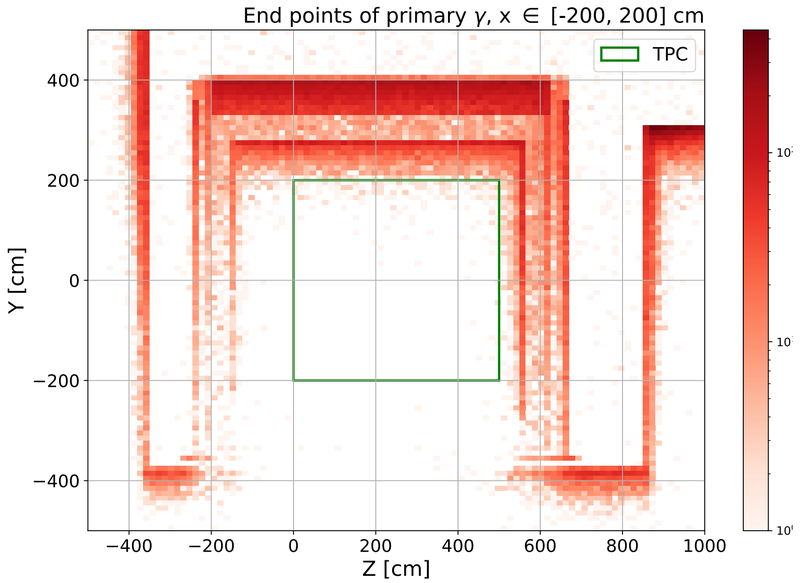
Inactive LAr

Pit Floor

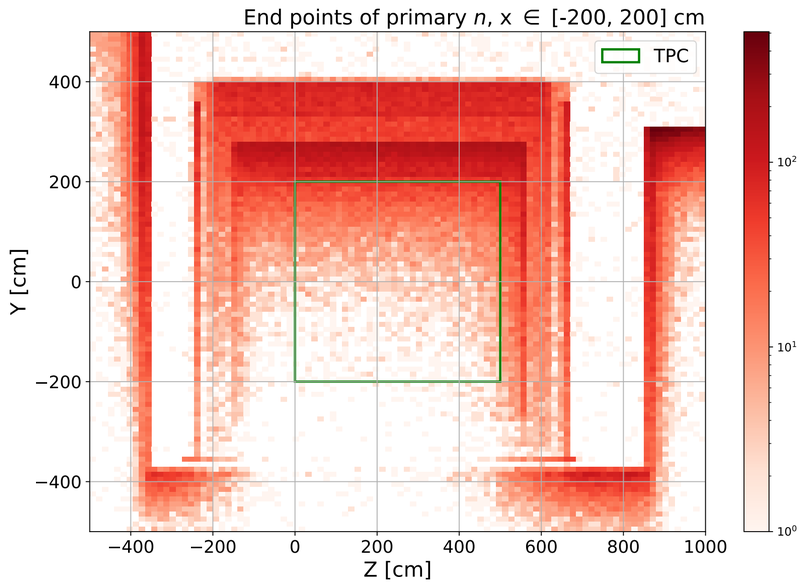
Configuration 2: w/ Surroundings, w/o Overburden

SBND

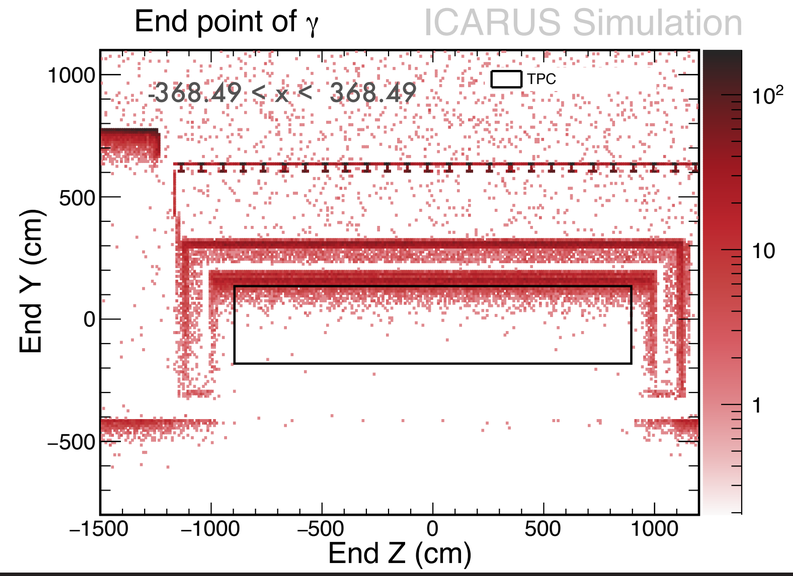
Photons End Points

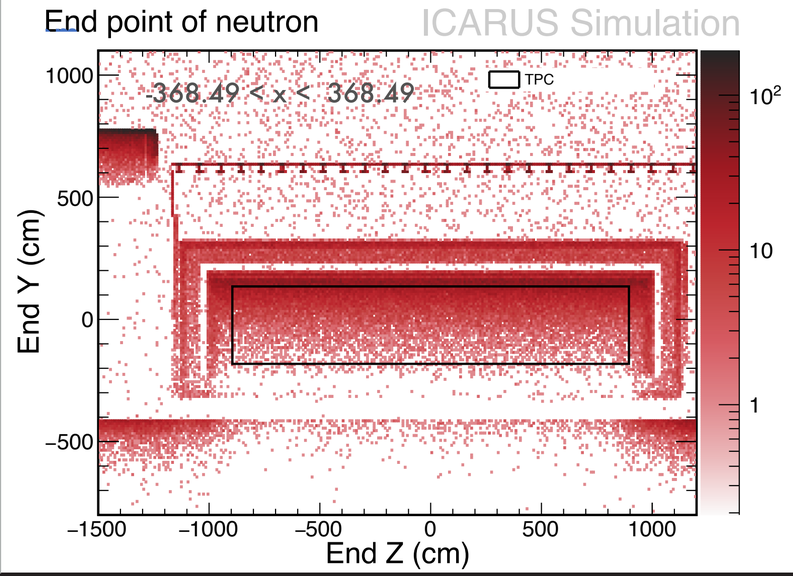


Neutrons End Points



ICARUS





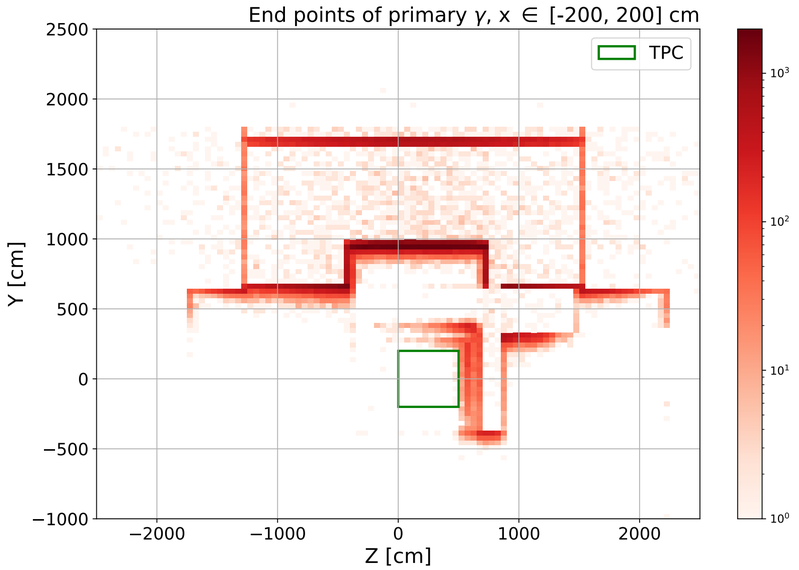
The surroundings in SBND reduce the number of primaries that enter the TPC more than they do in ICARUS.

The details of the geometry matter.

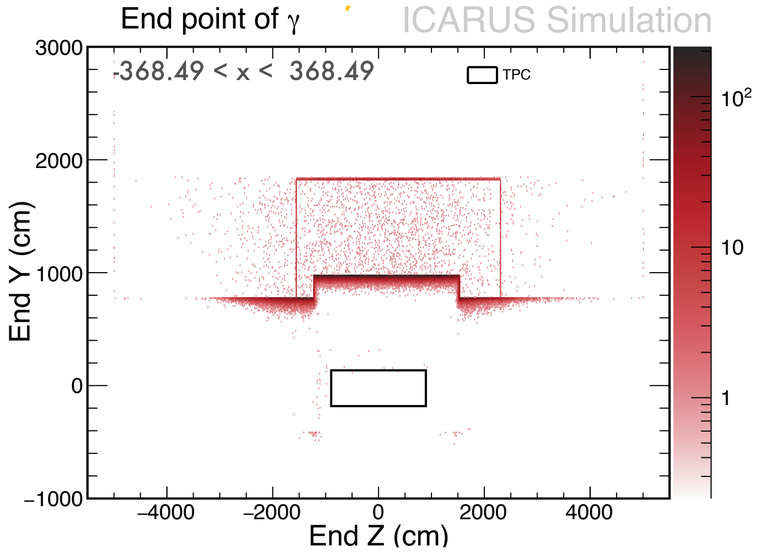
Configuration 3: w/ Surroundings, w/ Overburden

Photons End Points

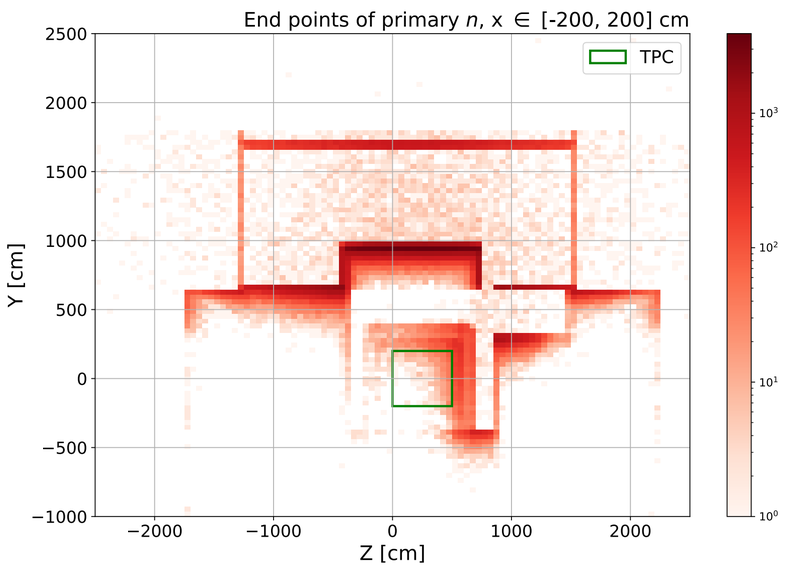
SBND

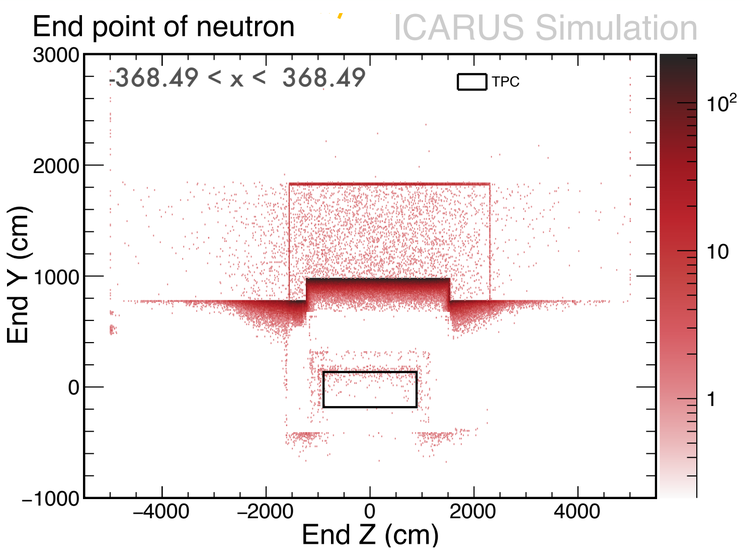


ICARUS



Neutrons End Points

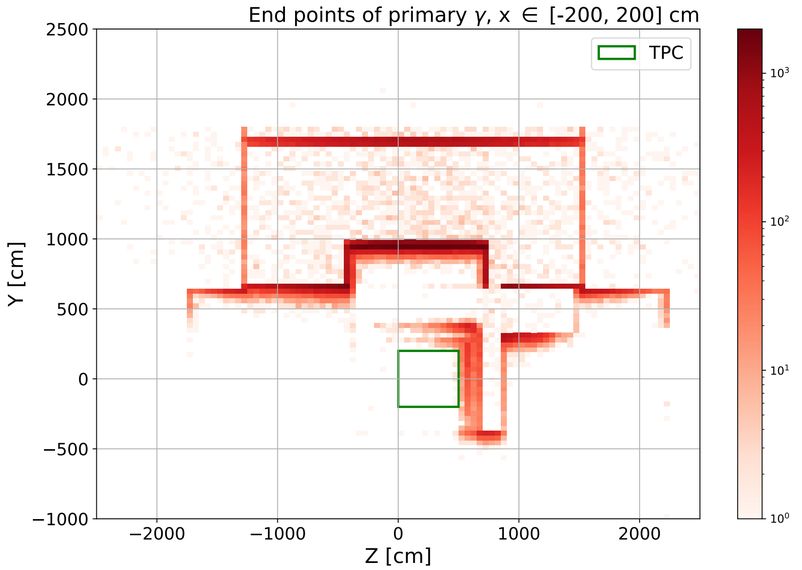




Configuration 3: w/ Surroundings, w/ Overburden

SBND

Photons End Points



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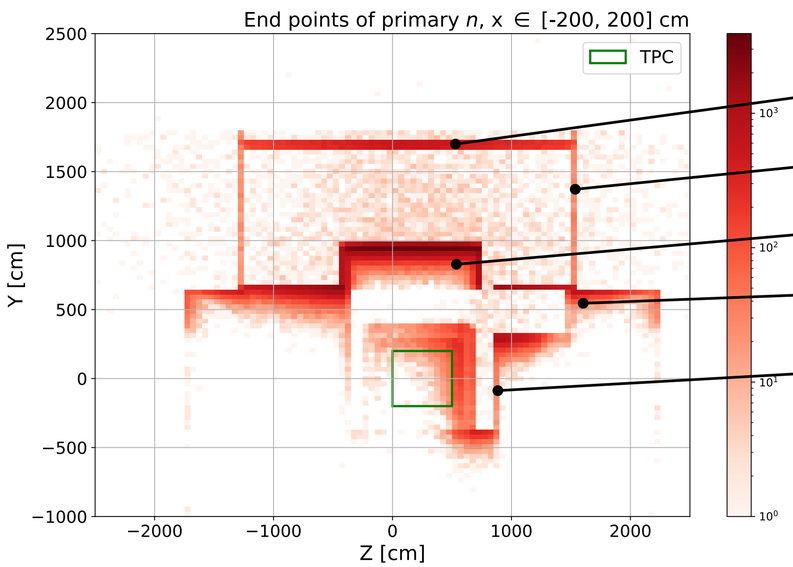
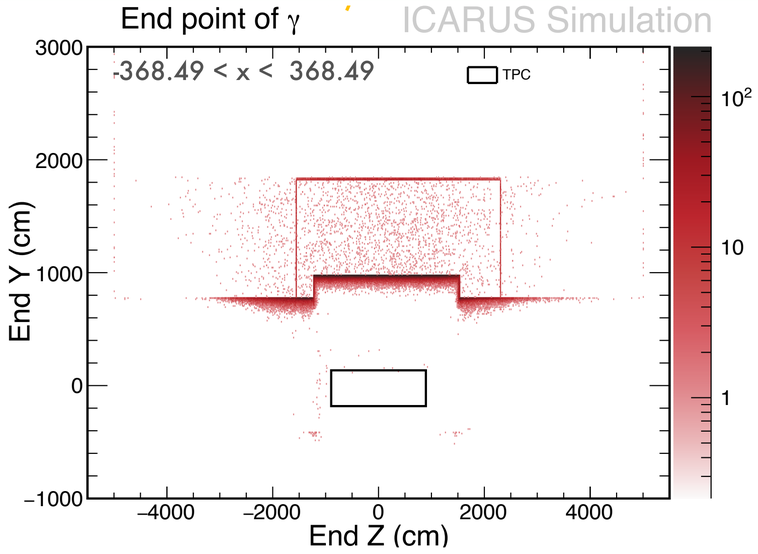
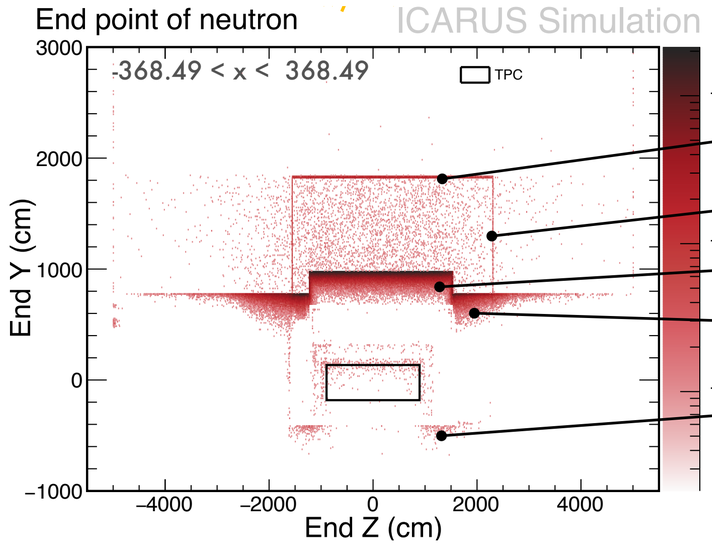


- Building Roof
- Building Walls
- Overburden
- Surrounding Ground
- Pit Walls

ICARUS



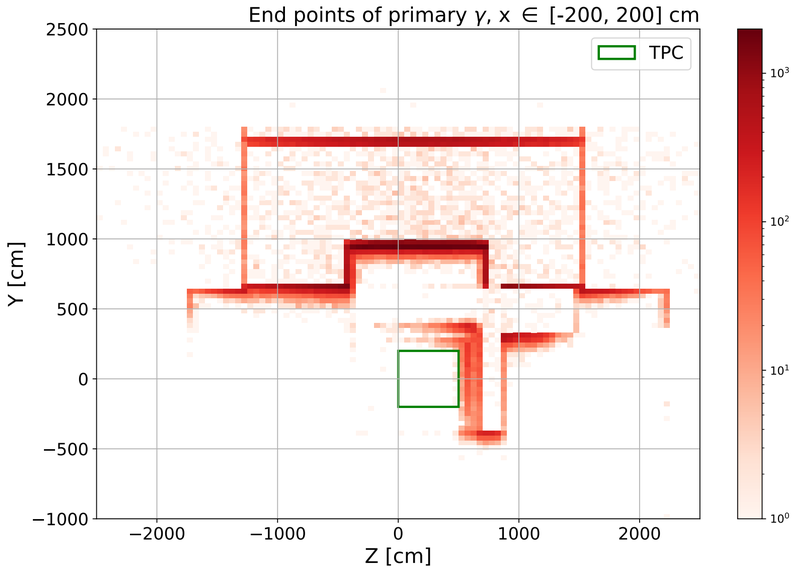


- Building Roof
- Building Walls
- Overburden
- Surrounding Ground
- Pit Floor

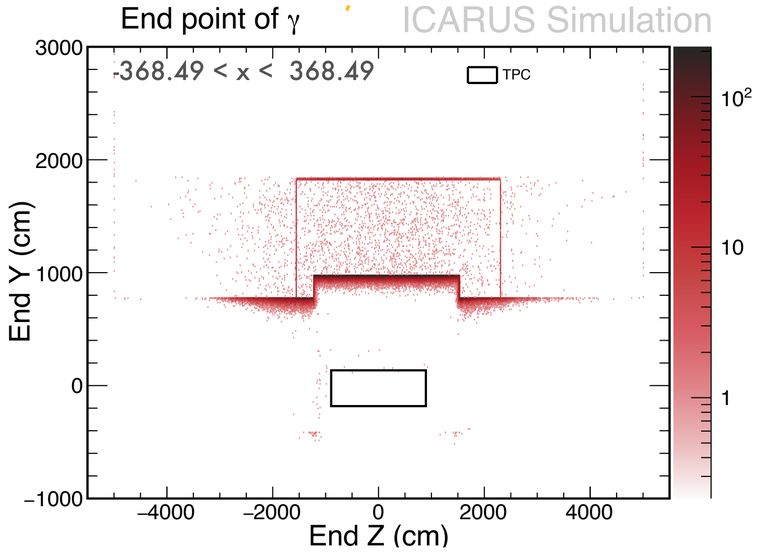
Configuration 3: w/ Surroundings, w/ Overburden

Photons End Points

SBND

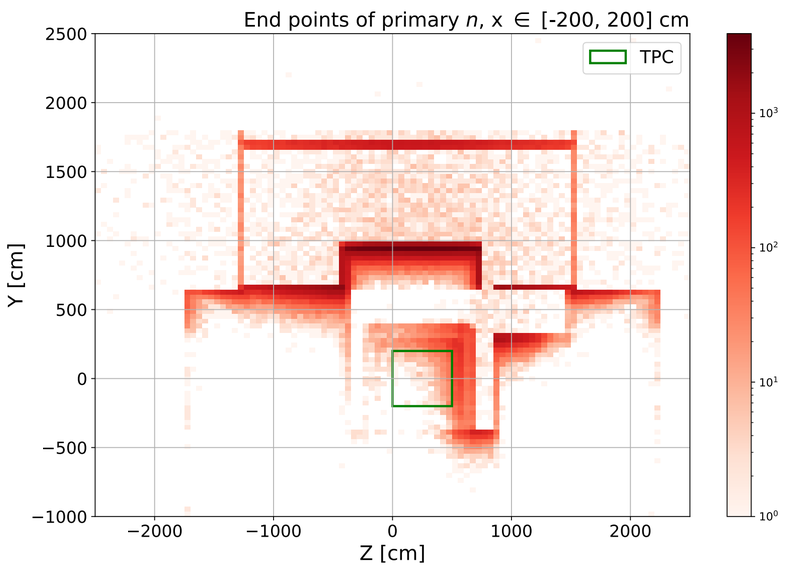


ICARUS

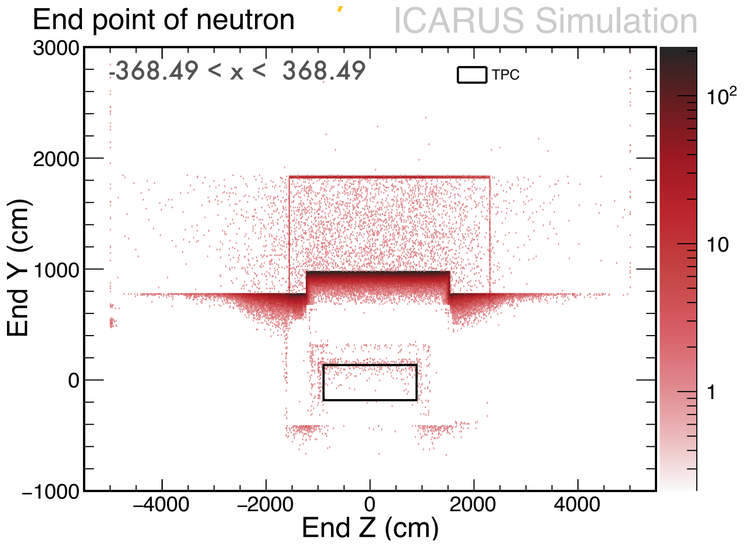


Neutrons End Points

SBND



ICARUS



When we add the overburden, the situation flips: we see more primaries entering in SBND, then they do in ICARUS.

Main reason: in SBND there still is a non-shielded region, where the mezzanine is.

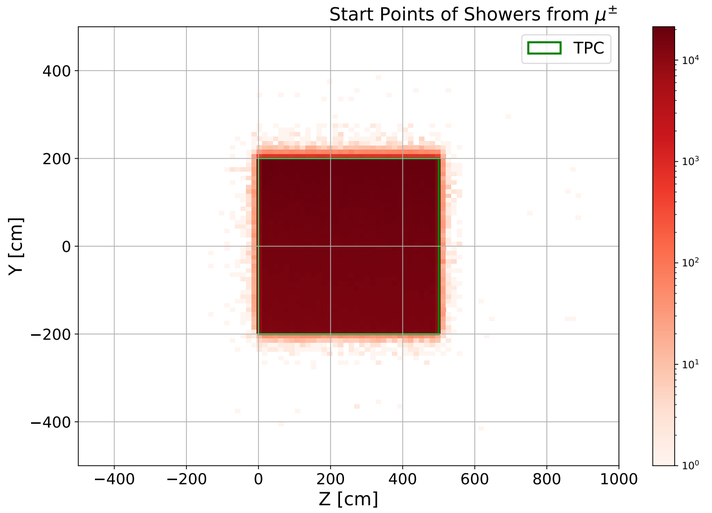
Start Points of Electromagnetic Showers From: (configuration 2)

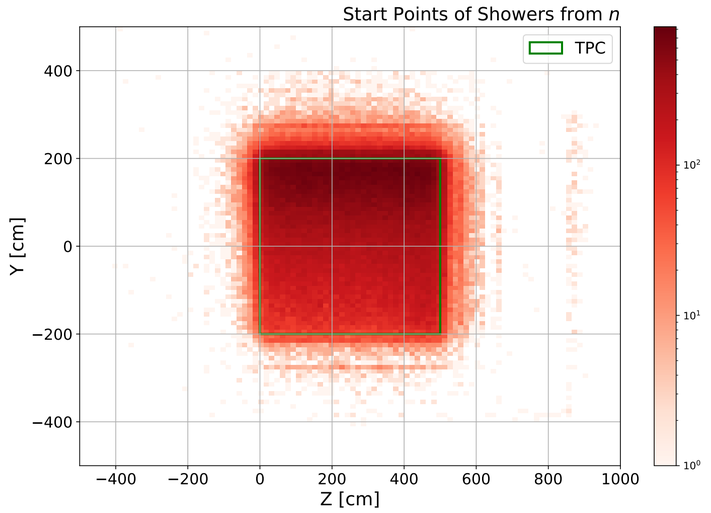
Muons

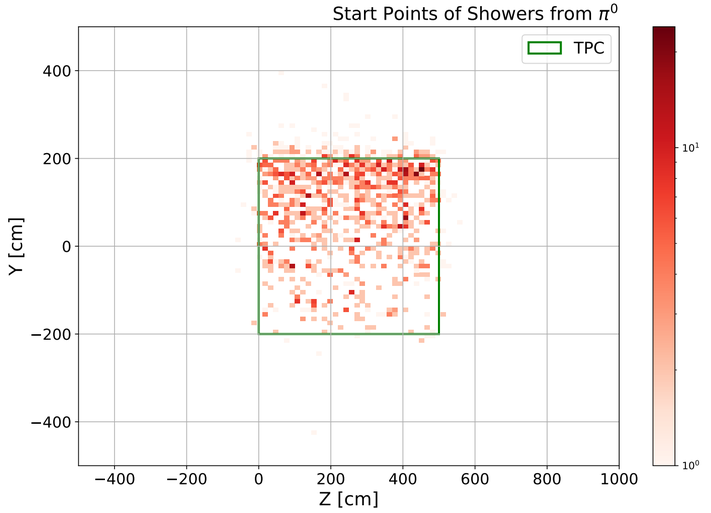
Neutrons

Neutral Pions

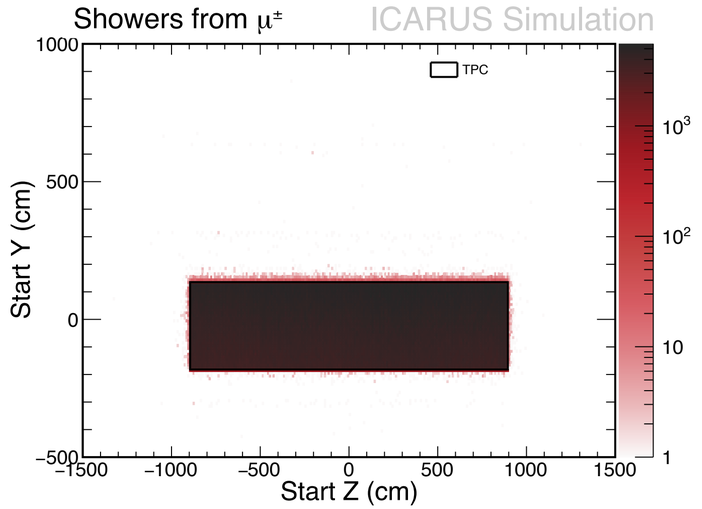
SBND

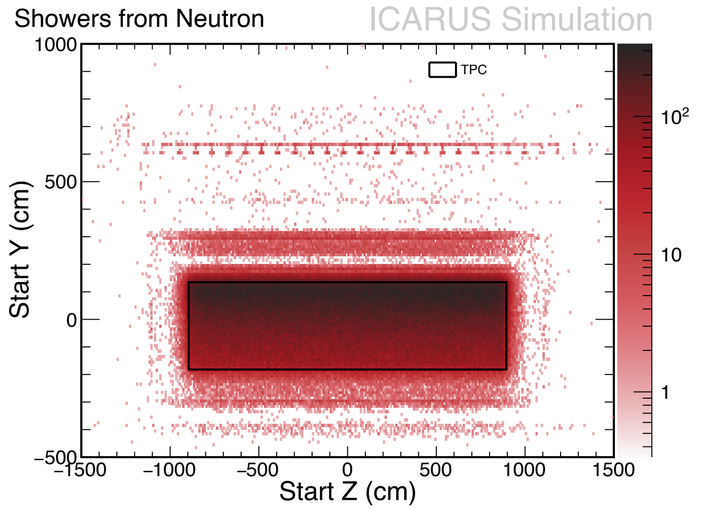


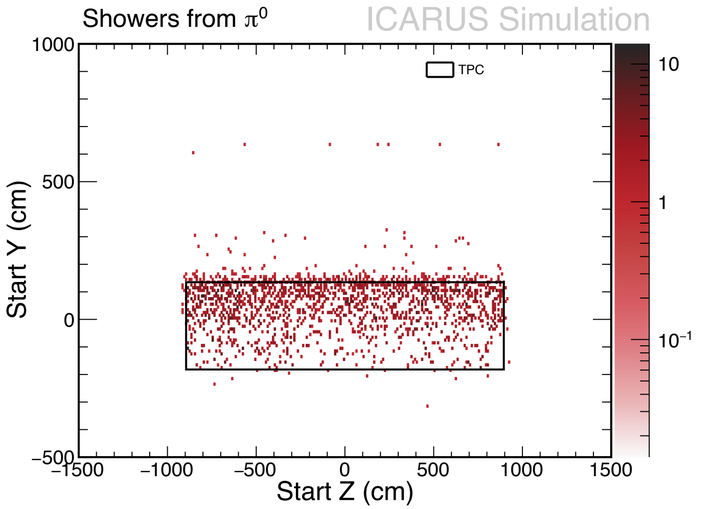




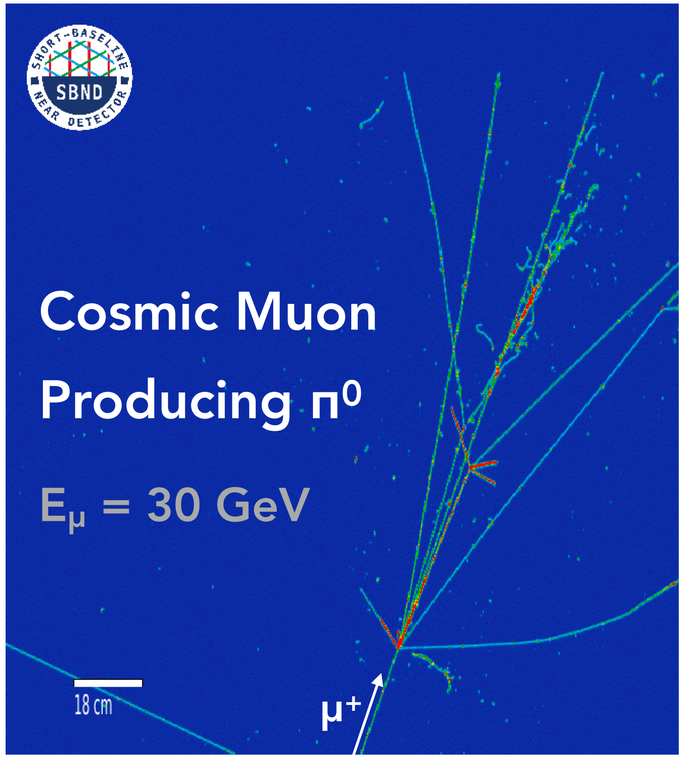
ICARUS

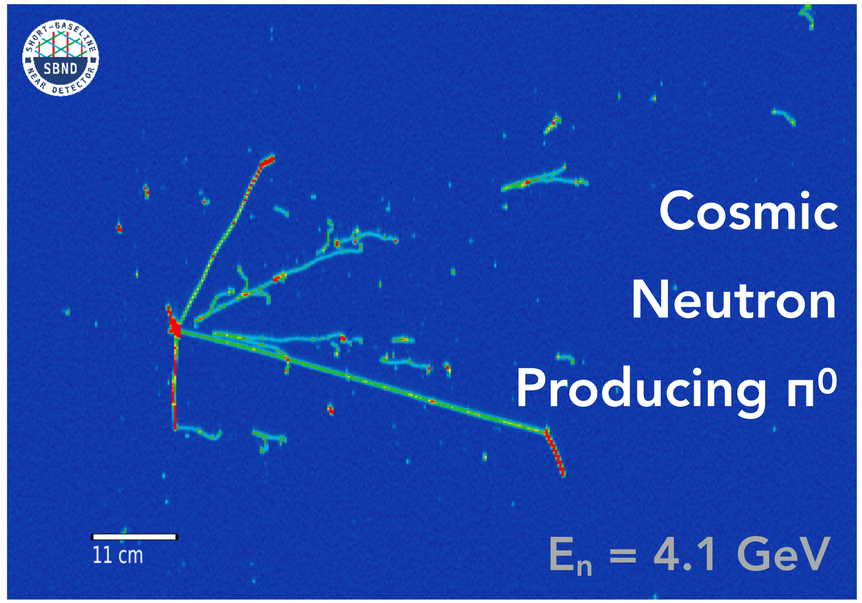


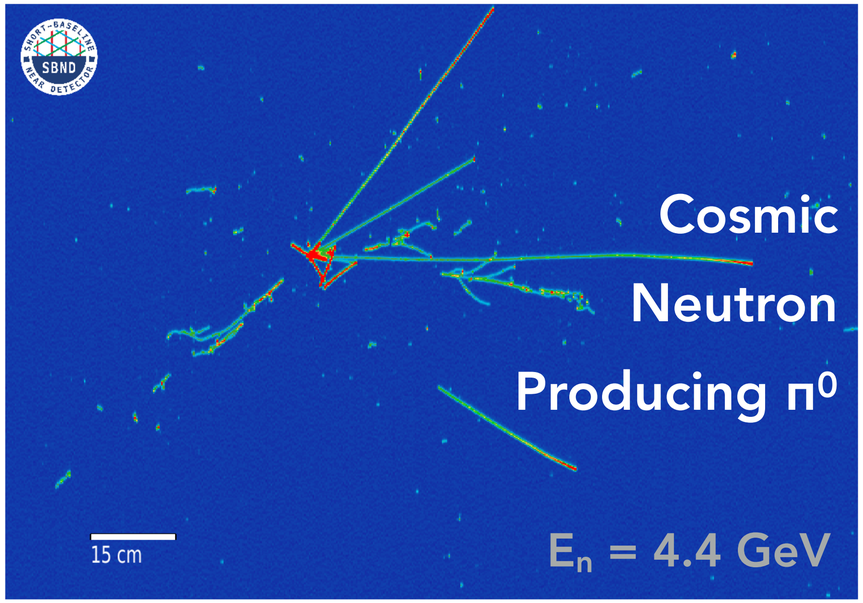




Electromagnetic Showers

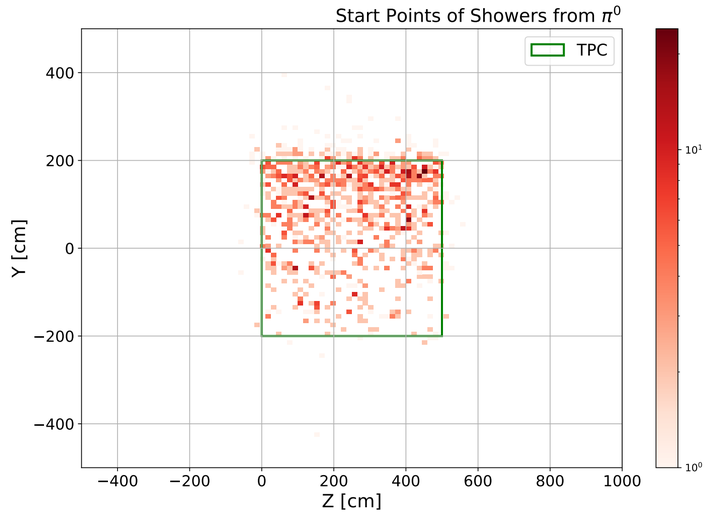


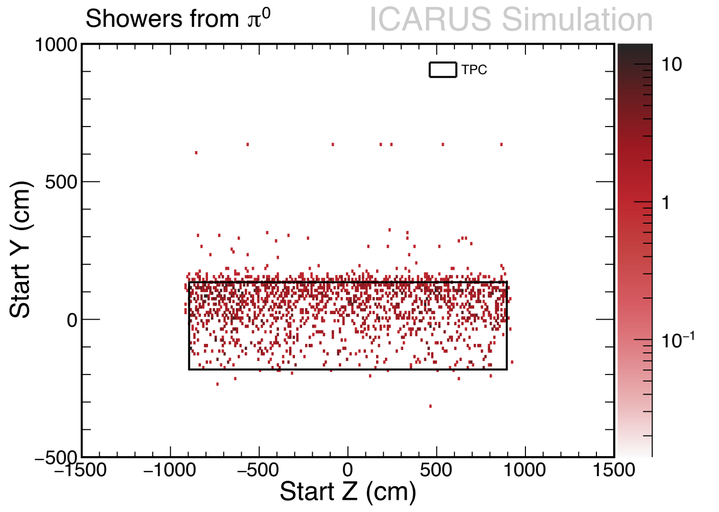




Examples of inelastic scatterings producing π^0

Neutral Pions





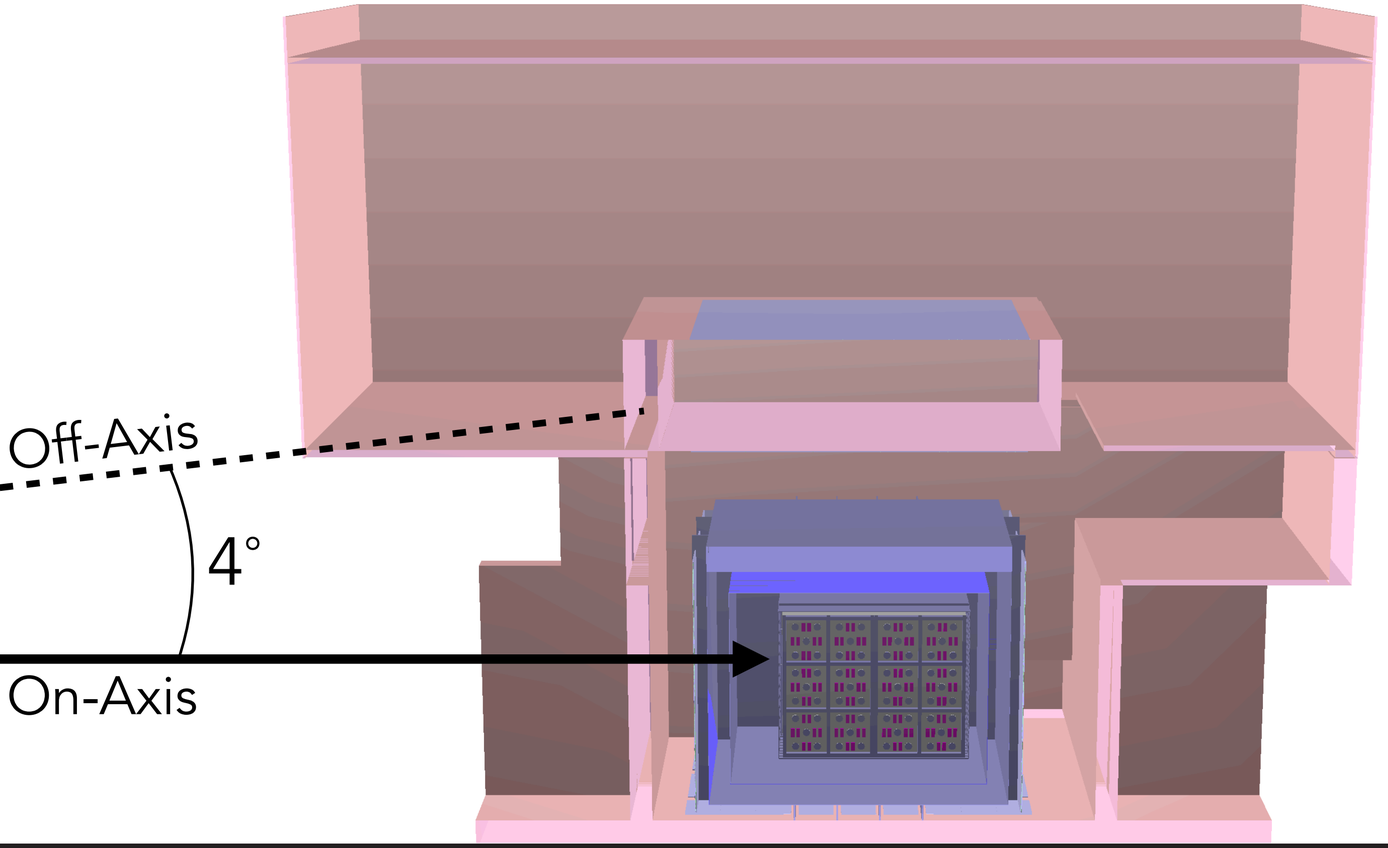
Current Status

- We have cross checked and verified the analysis code we are using.
- The studies show how important it is to have a proper description of the SBND and ICARUS geometries in our simulations.
- We found some issues with the geometry implementation in both SBND and ICARUS, for example:
  - we should use an overburden thickness of 2.8m instead of 3m,
  - we have different values for the density of the insulation foam in SBND and ICARUS,
  - TPC position in SBND is shifted in the wrong direction,
  - …
- More work is needed to improve the geometry description in both detectors with help from experts.
- Before comparing the final numbers and drawing conclusions, we will have to review the implementation of the geometries, together with experts who know the details of the detectors' designs.

Neutrinos in Overburden (SBND Case)

We studied neutrinos that interact with the overburden material

The overburden is ~4° degrees off-axis.



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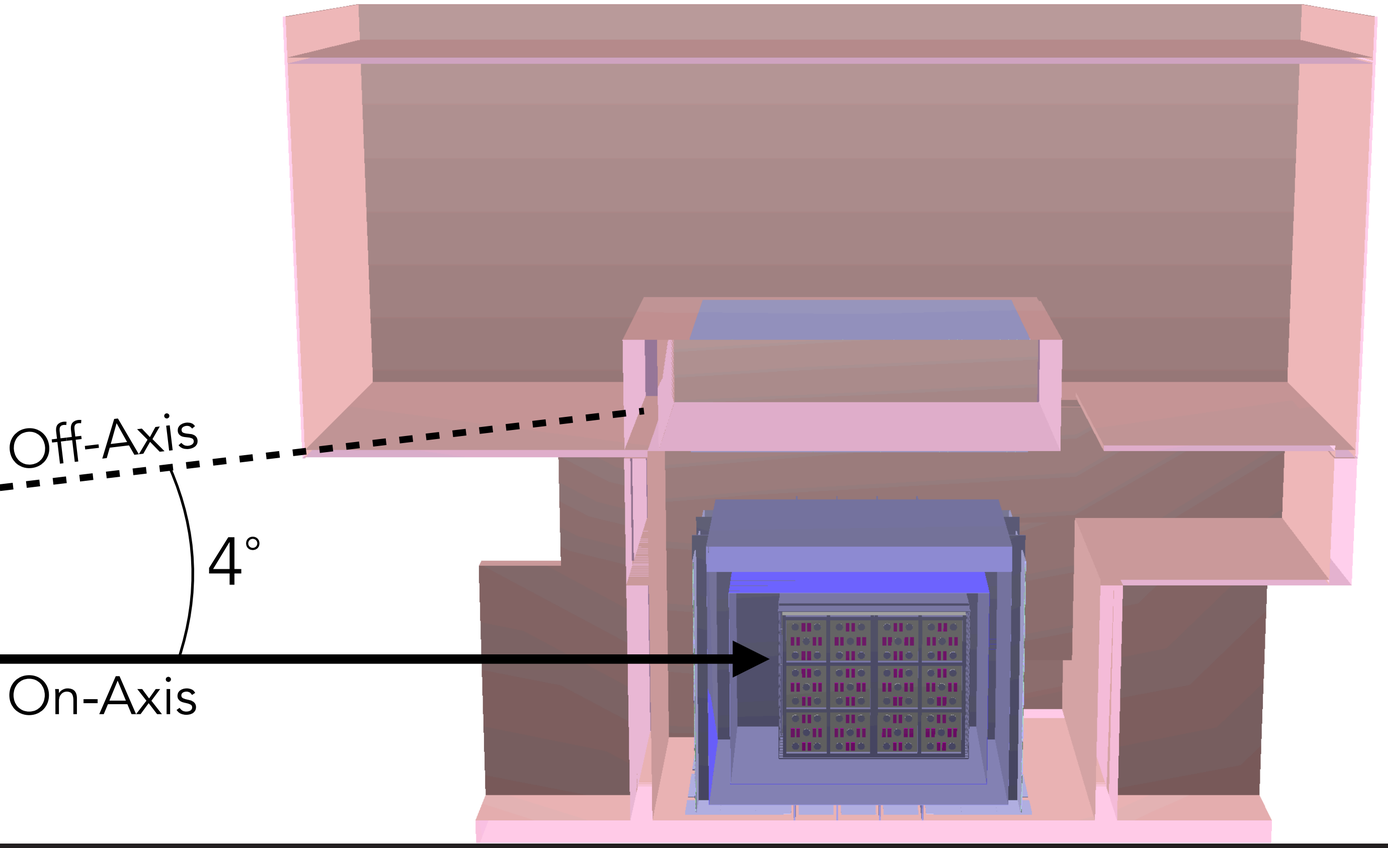
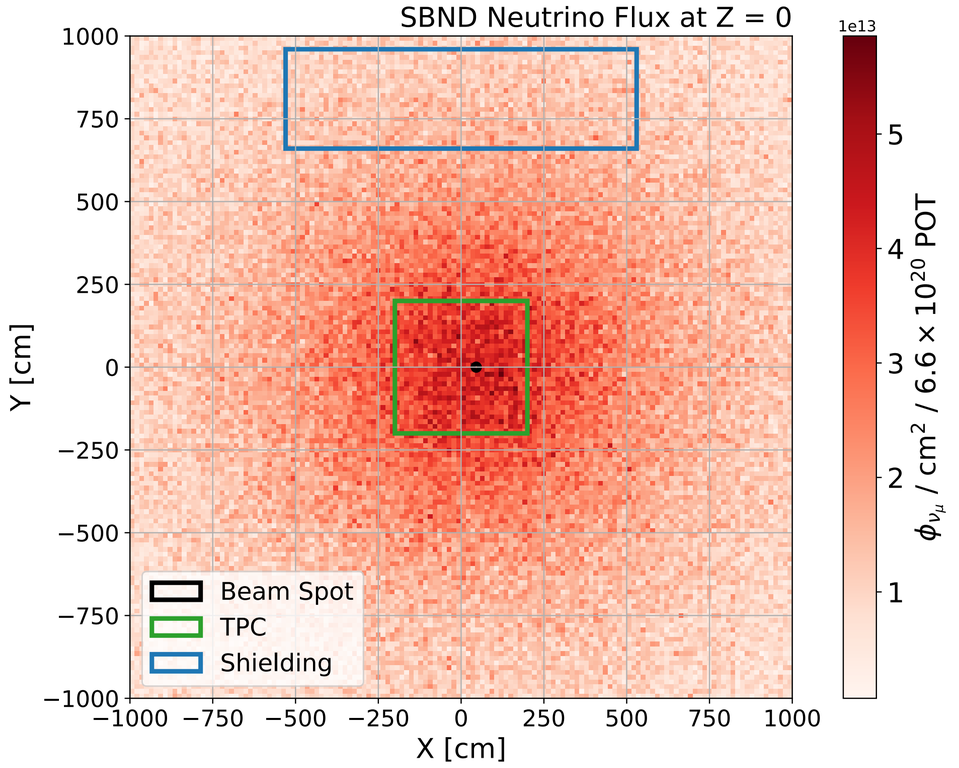


At the SBND location (110 m from the target), the flux falls rapidly from the center of the beamline to the overburden location, but it is not negligible.

Neutrino Flux @ SBND Location



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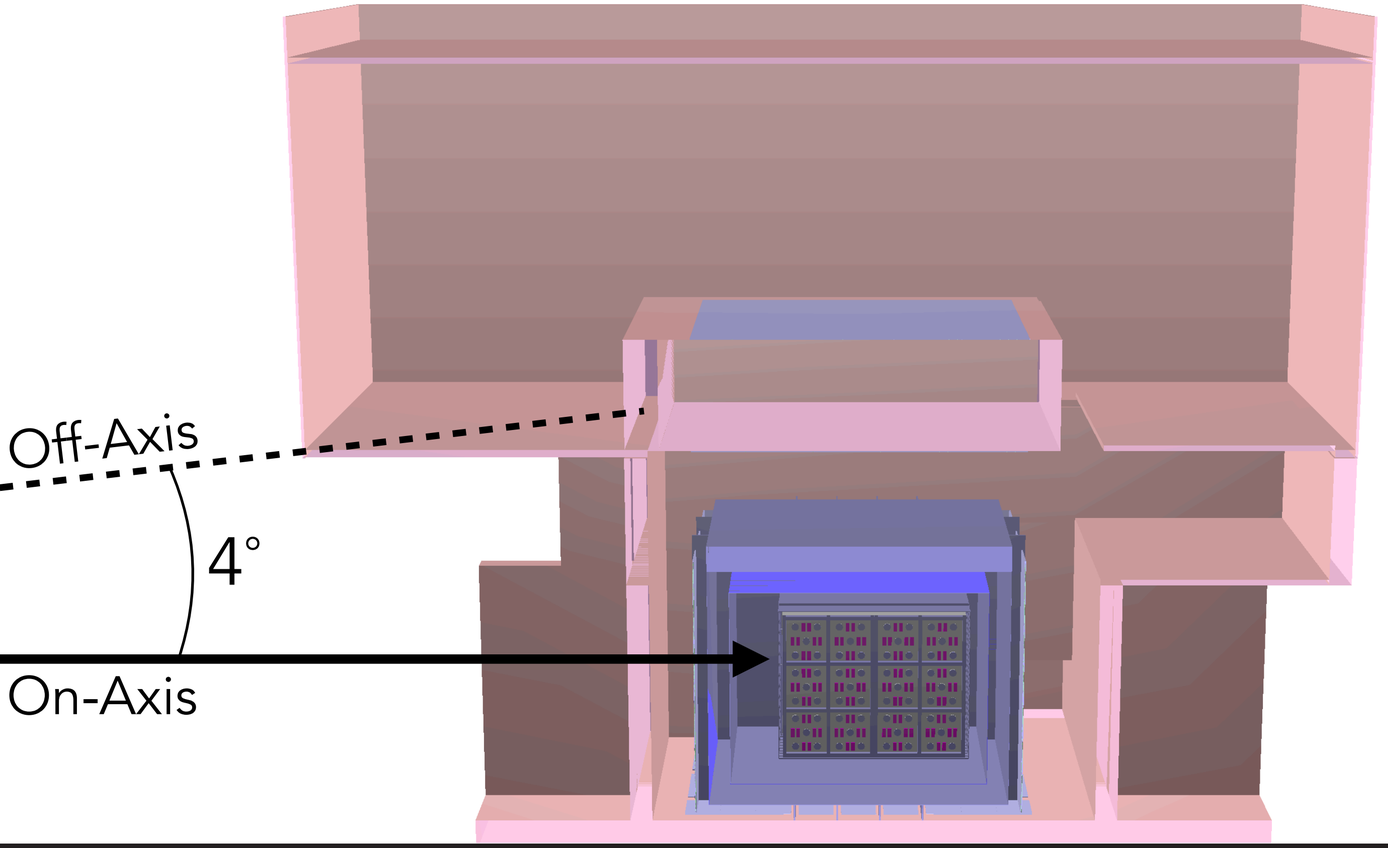
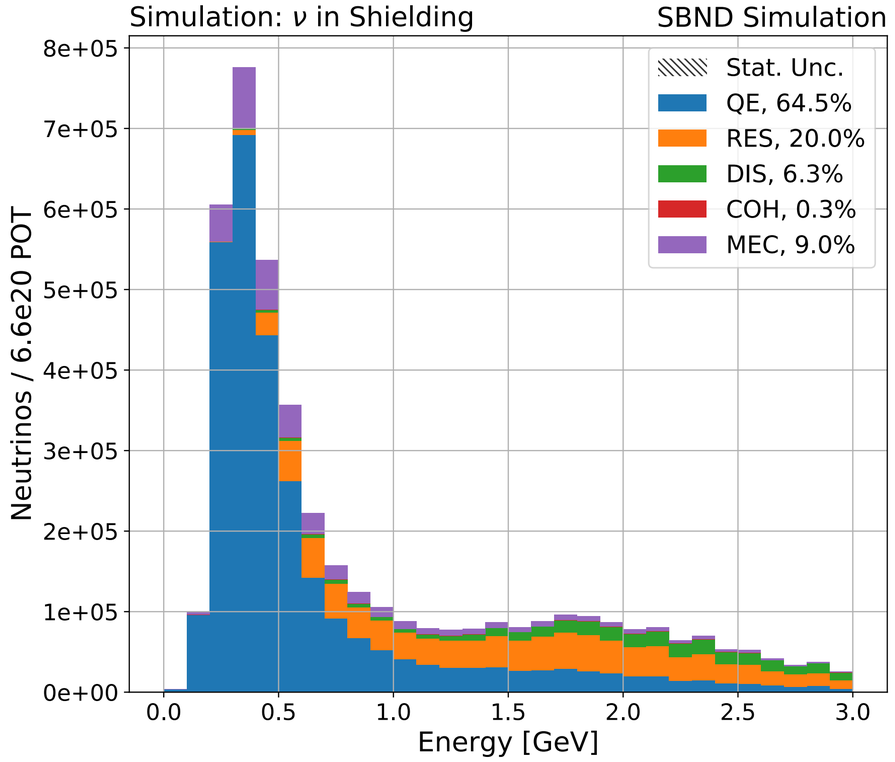
We studied neutrinos that interact with the overburden material

The overburden is ~4° degrees off-axis.



	Volume [m³]	Mass [t]	Interactions in 6.6e20 POT
Active Volume	80	112	**7.7 M**
Overburden	372	855	**4.7 M**

Energy Spectrum of Neutrinos Interacting in the OB



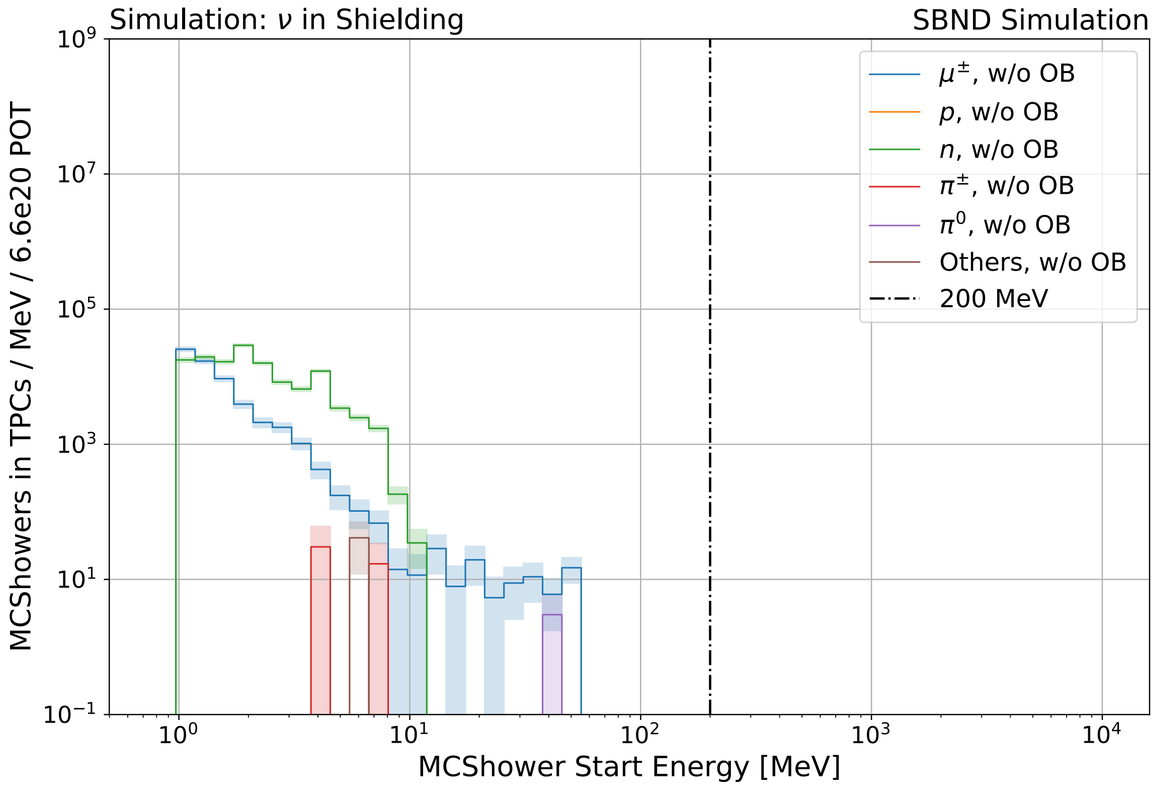
Neutrinos in Overburden (SBND Case)

Number of primary particles entering the detector in 6.6e20 POT:

Particle	Number
Muon	1681
Neutron	1561
Gamma	96

To be compared to ~2200 neutrons from cosmics

All showers in the detector originated by neutrino interactions in the overburden



Conclusions

- A detailed study is ongoing to understand the impact of the overburden in both SBND and ICARUS.
- Geometry implementation to be updated before final results.
- Neutrinos in the overburden to be studied for the ICARUS case.