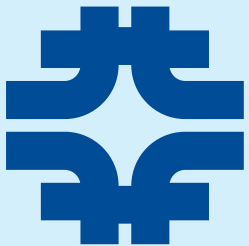


Cosmic Ray Studies for SBND

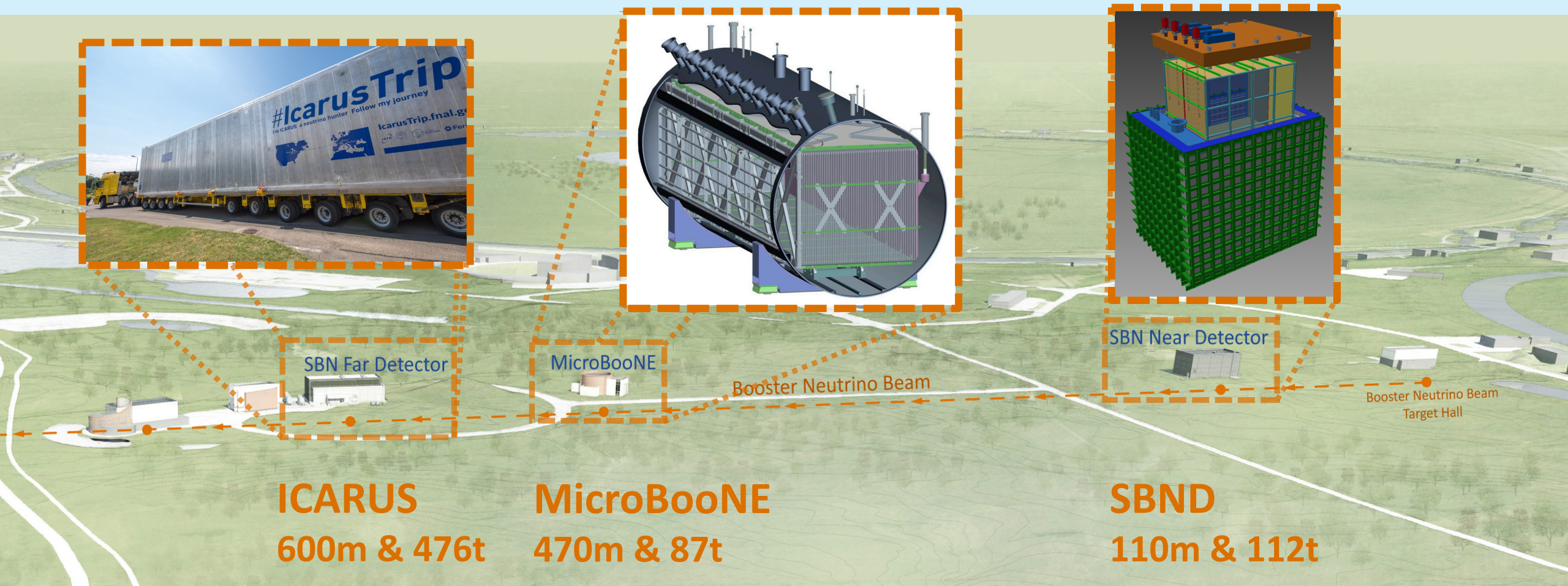
Michele Piero Blago

Supervised by

Roxanne Guenette and Corey Adams



The Short Baseline Neutrino Program



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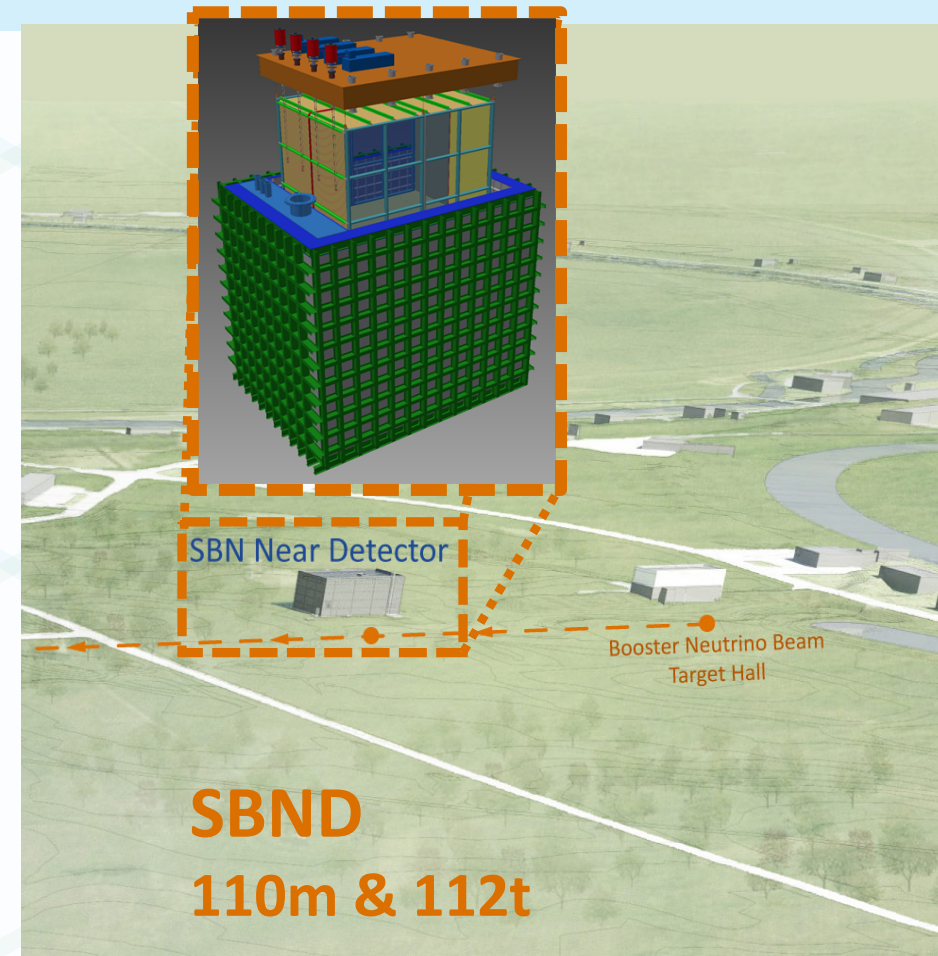
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Short Baseline Near Detector (SBND)

112 t active volume Liquid Argon Time Projection Chamber (LArTPC).

Provides unoscillated neutrino interaction data close to the BNB target (110 m).

Currently in construction phase, planned start of operation in 2019.



Short Baseline Near Detector (SBND)

Two Time Projection Chambers (TPCs):

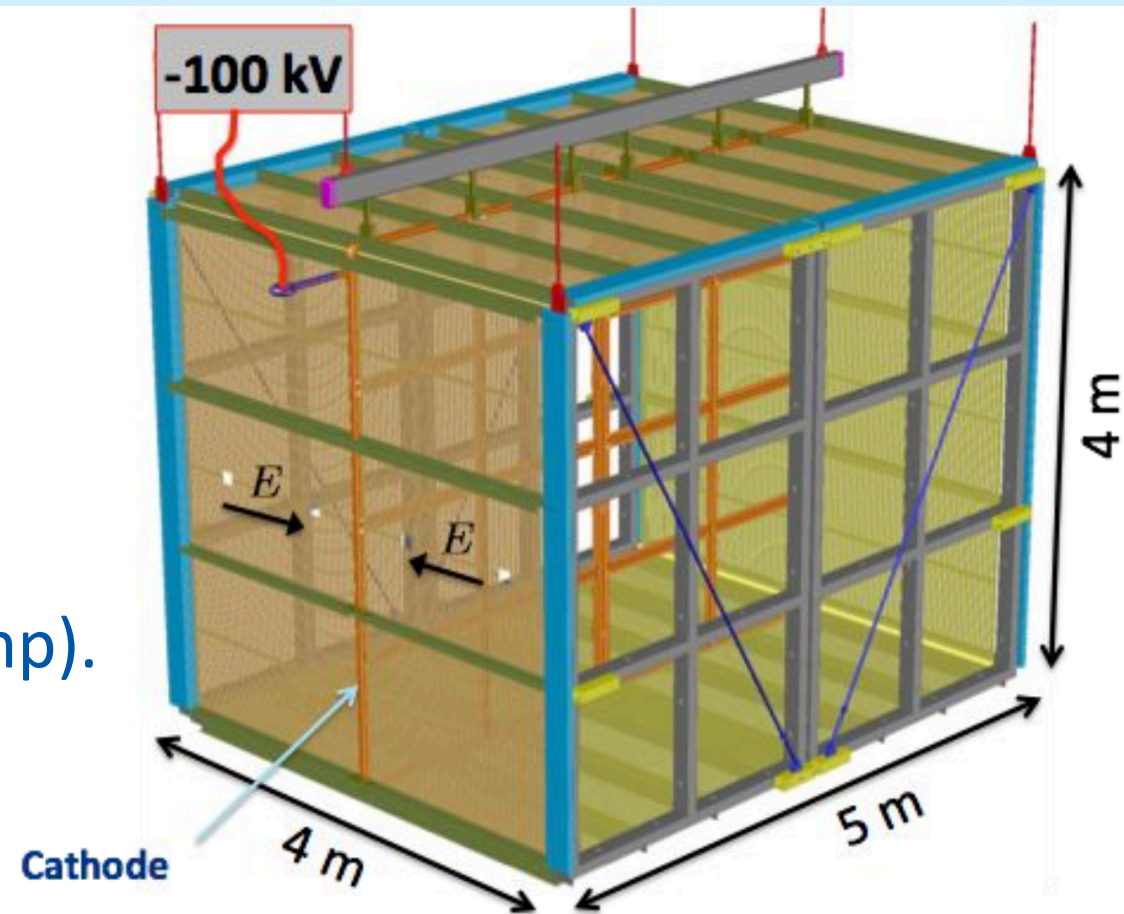
2 m drift distance (1.28 ms drift time at 500 V/cm).

3 wire planes ($0^\circ, \pm 60^\circ$).

3 mm pitch between wires.

120 8" PMTs: ~ immediate signal (time stamp).

Cosmic Ray Tagger: almost full coverage

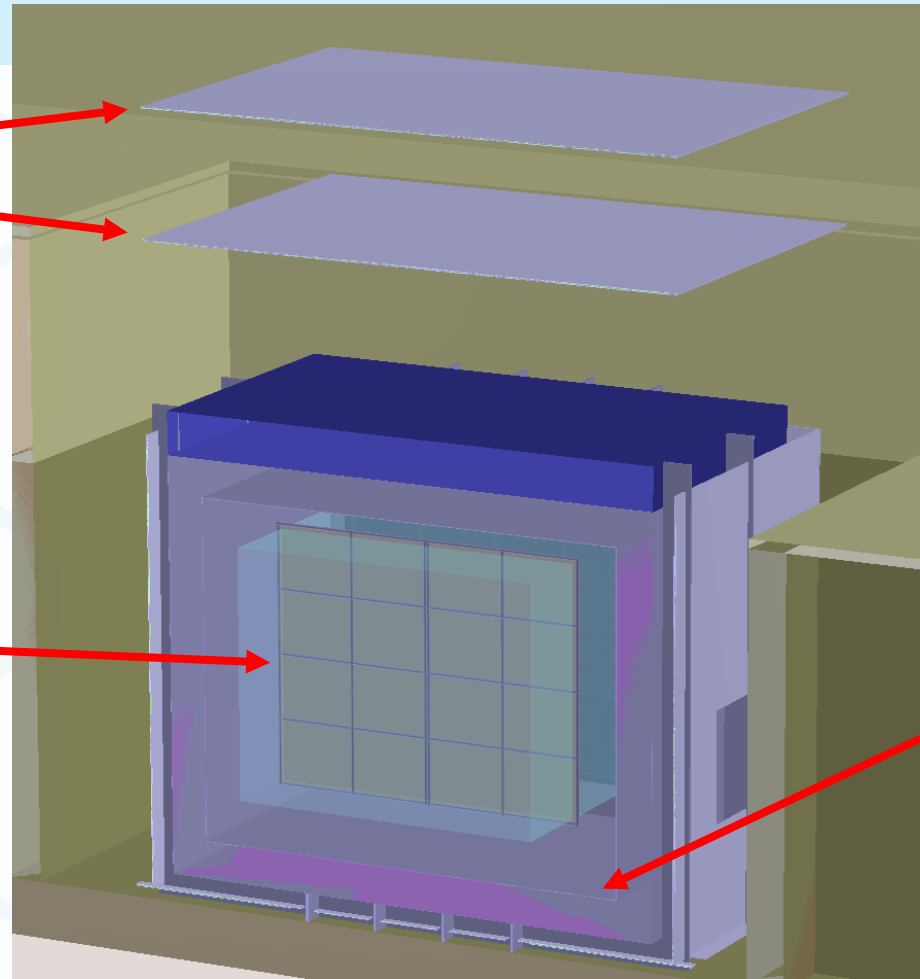


Overburden comparison

CRT

TPC

Cryostat



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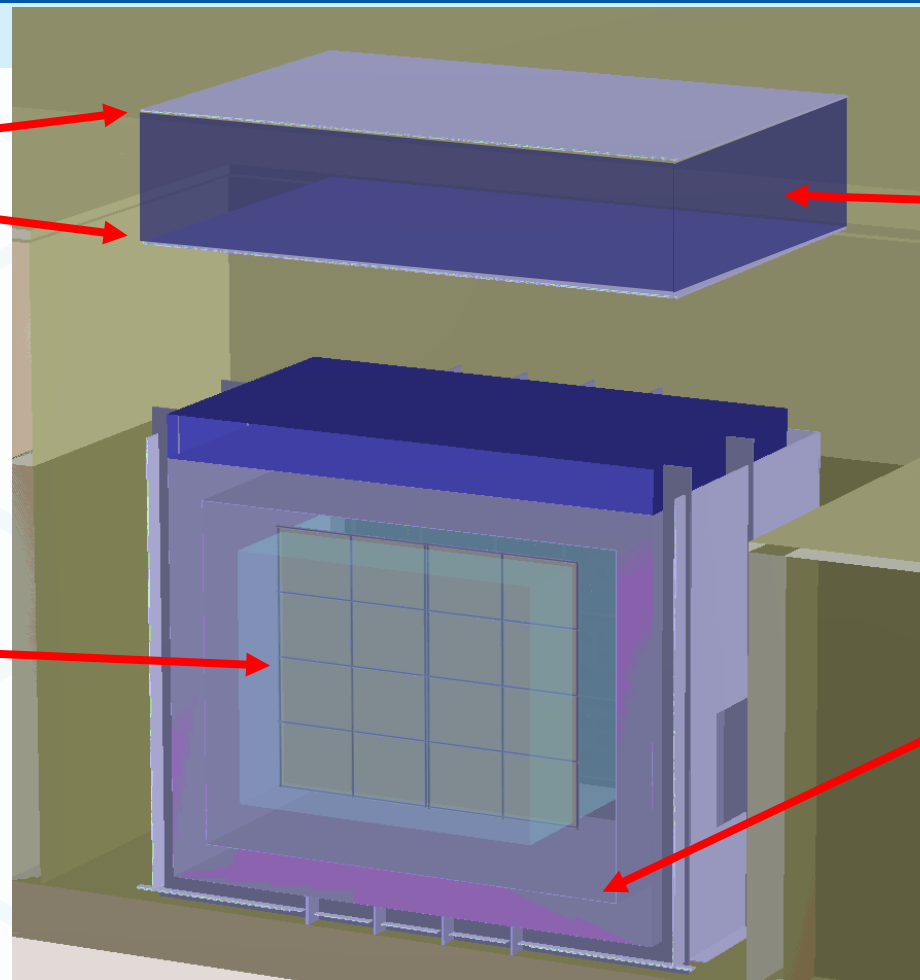
Overburden comparison

CRT

Overburden
(concrete)

TPC

Cryostat

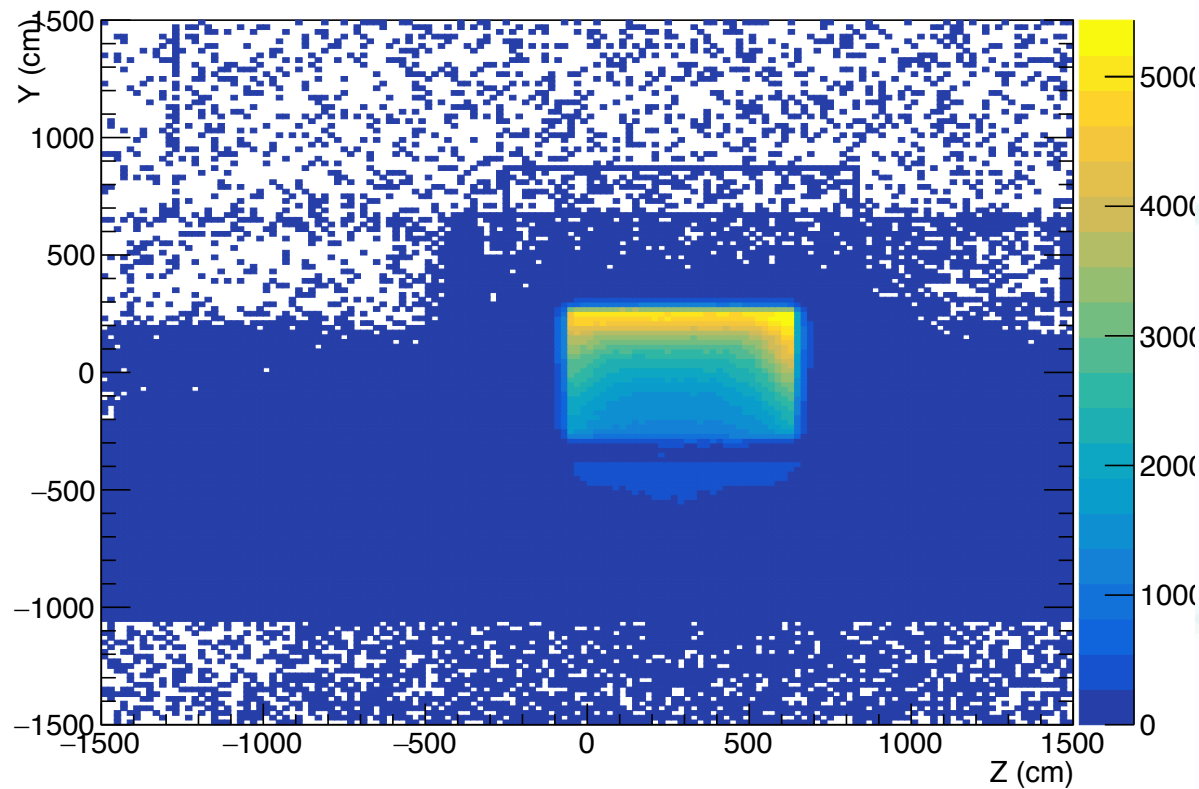


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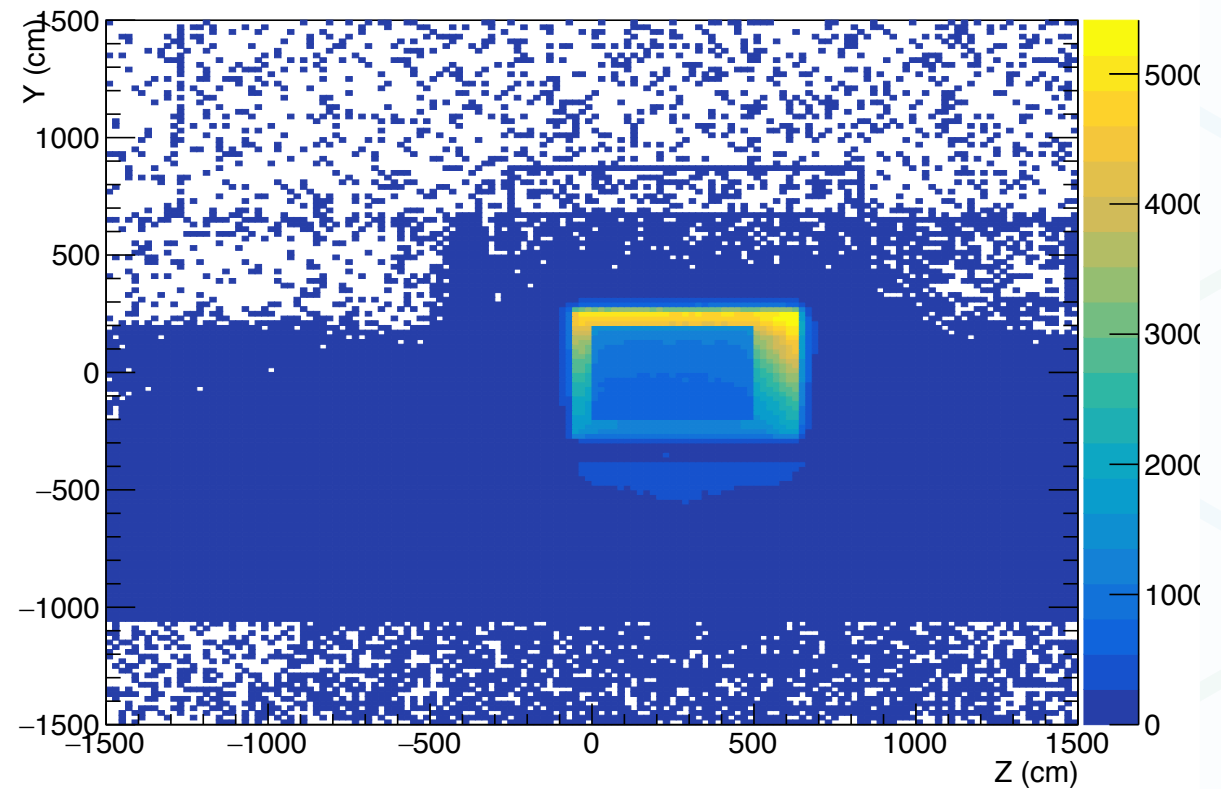
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Particle end position (side view)

YZ End positions



YZ End positions of particles stopping outside TPC

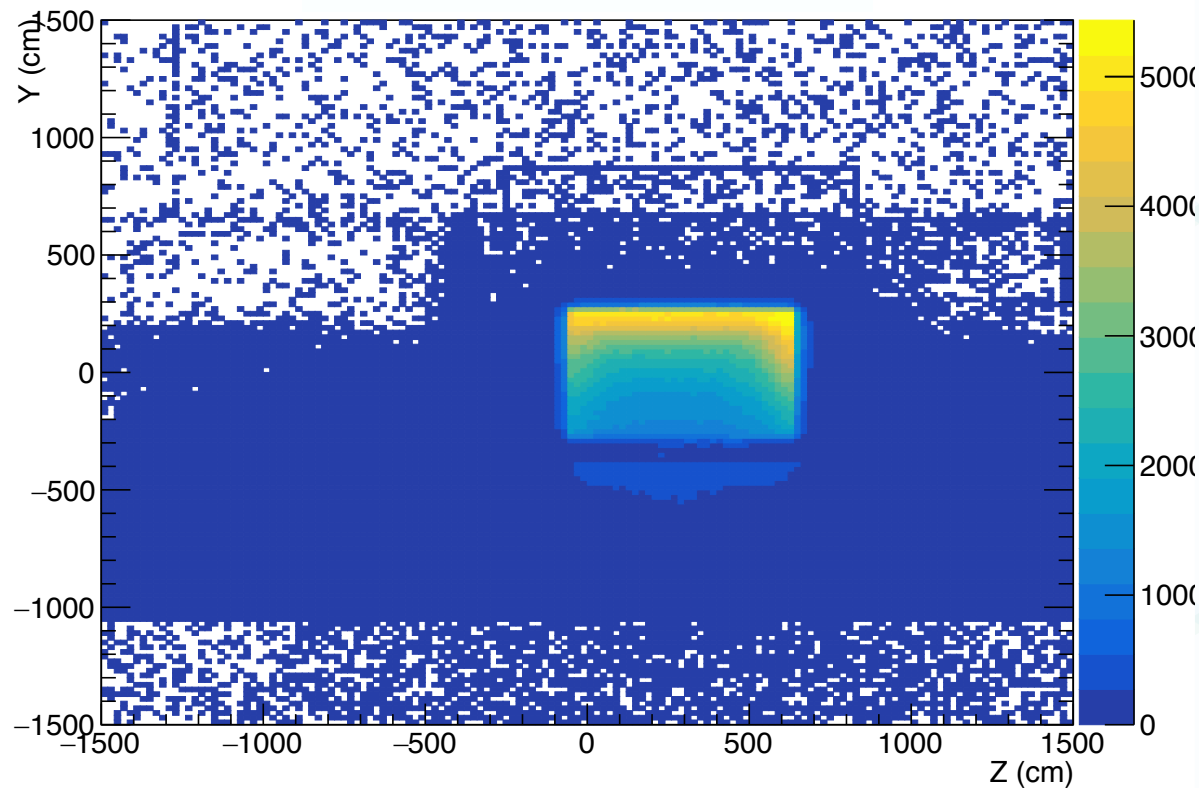


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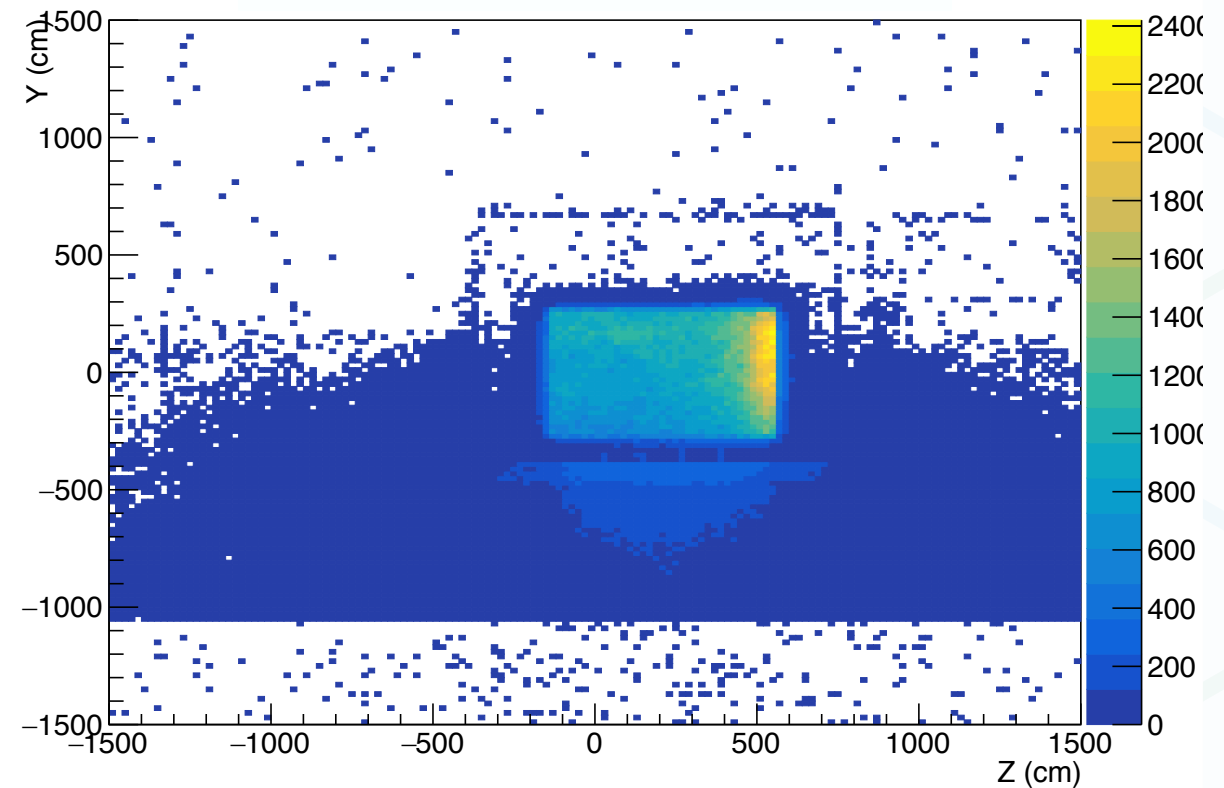
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Particle end position (side view)

No Overburden



Overburden installed

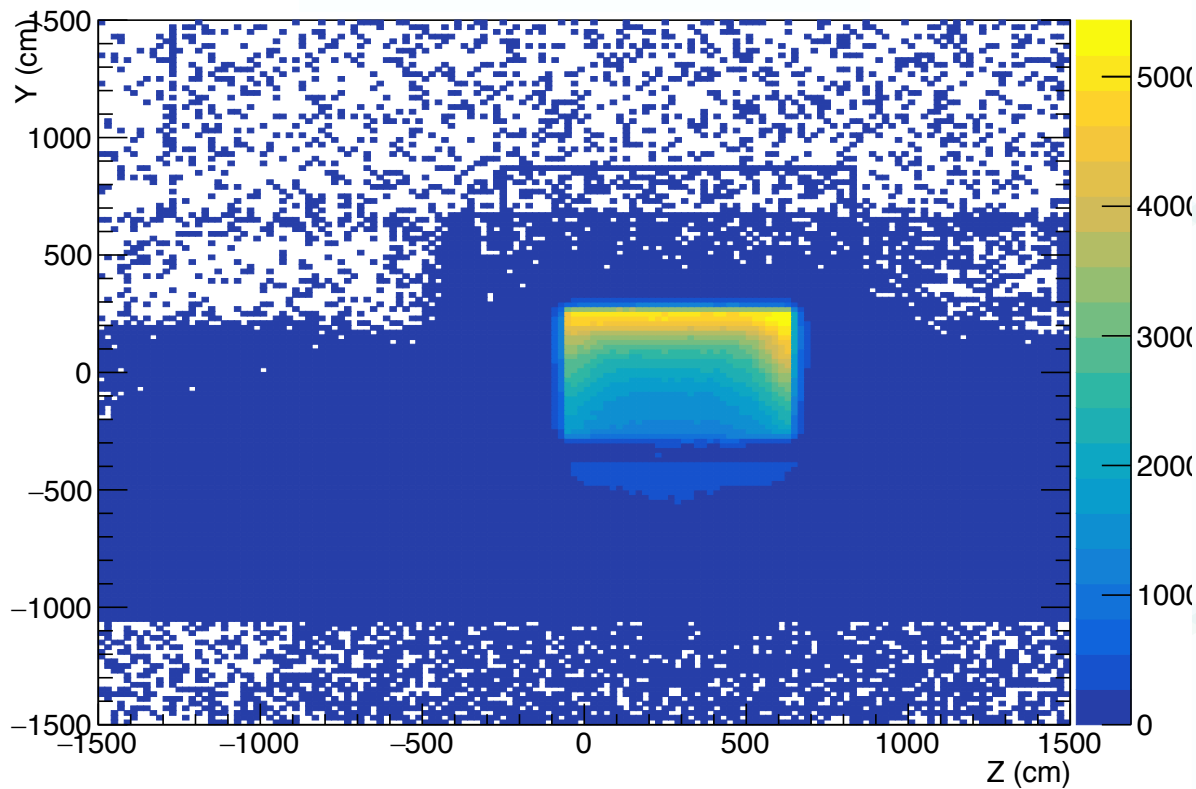


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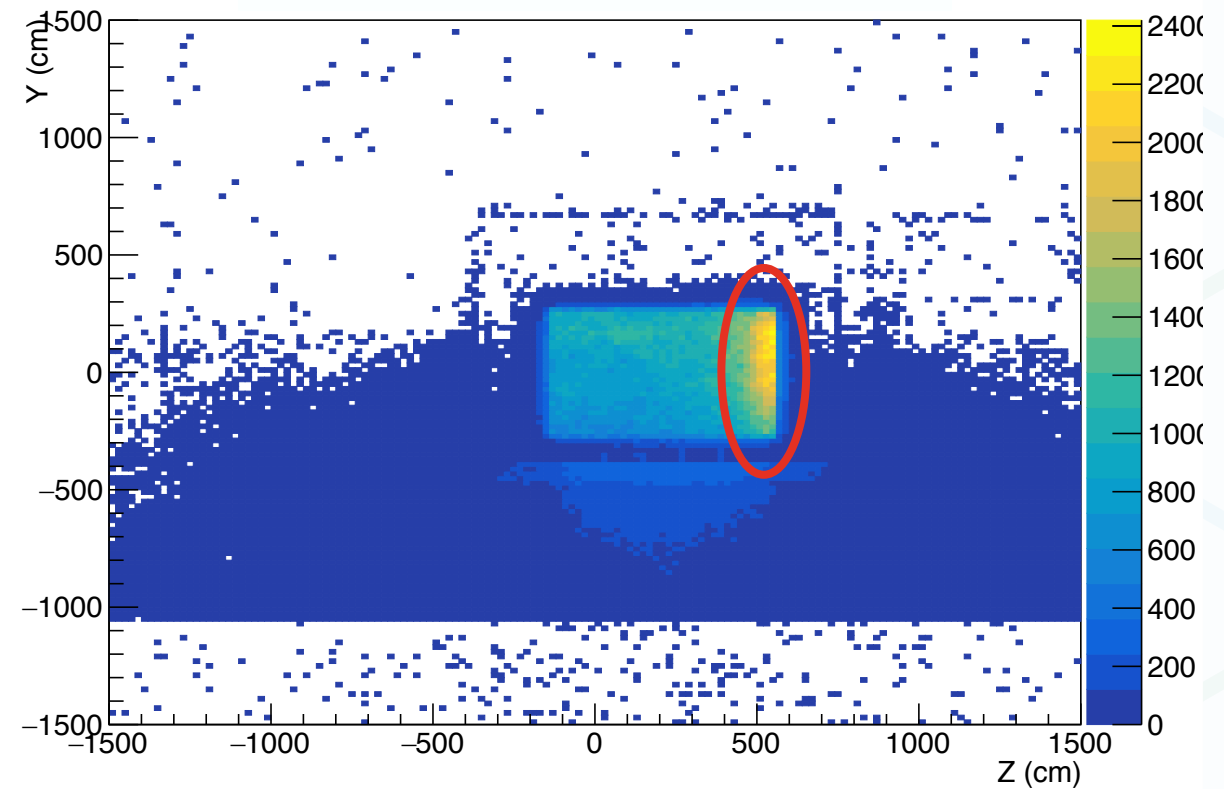
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Particle end position (side view)

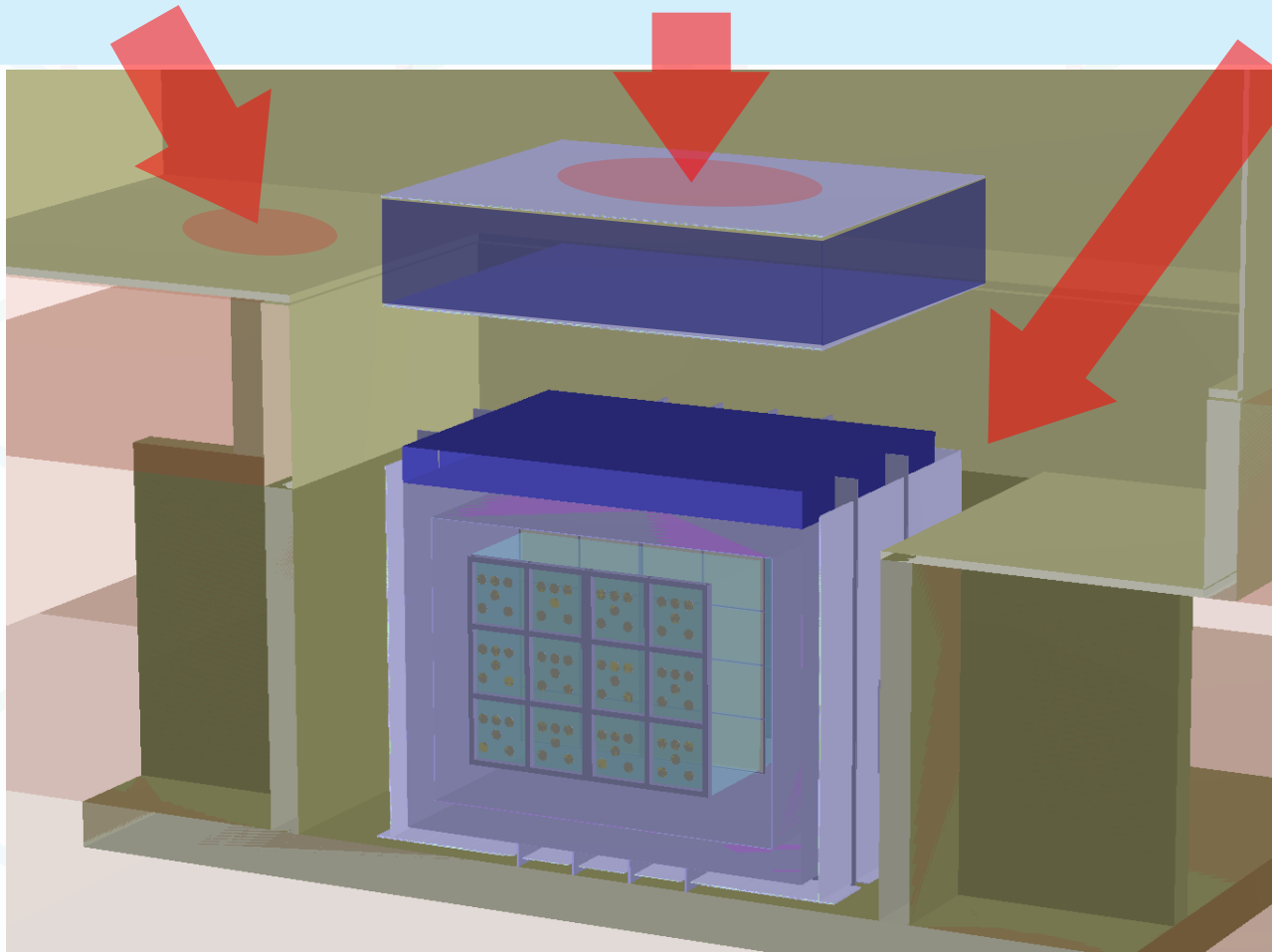
No Overburden



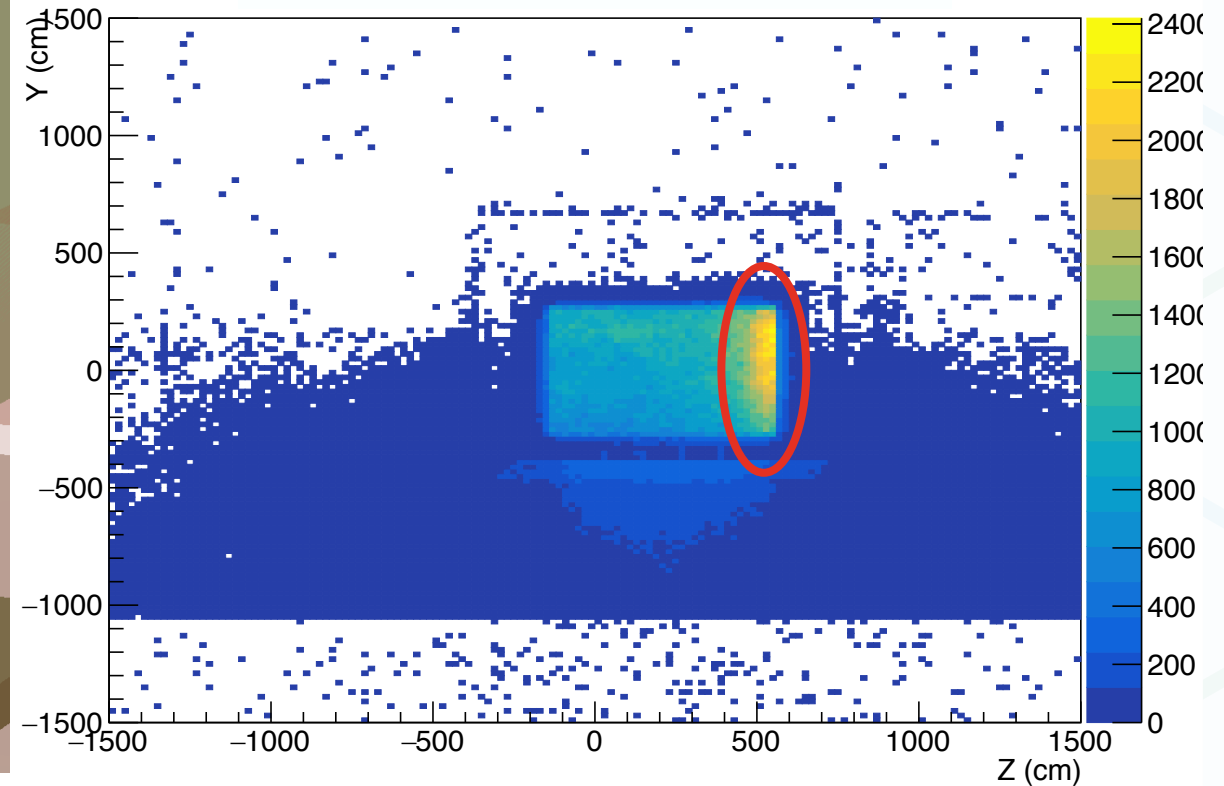
Overburden installed



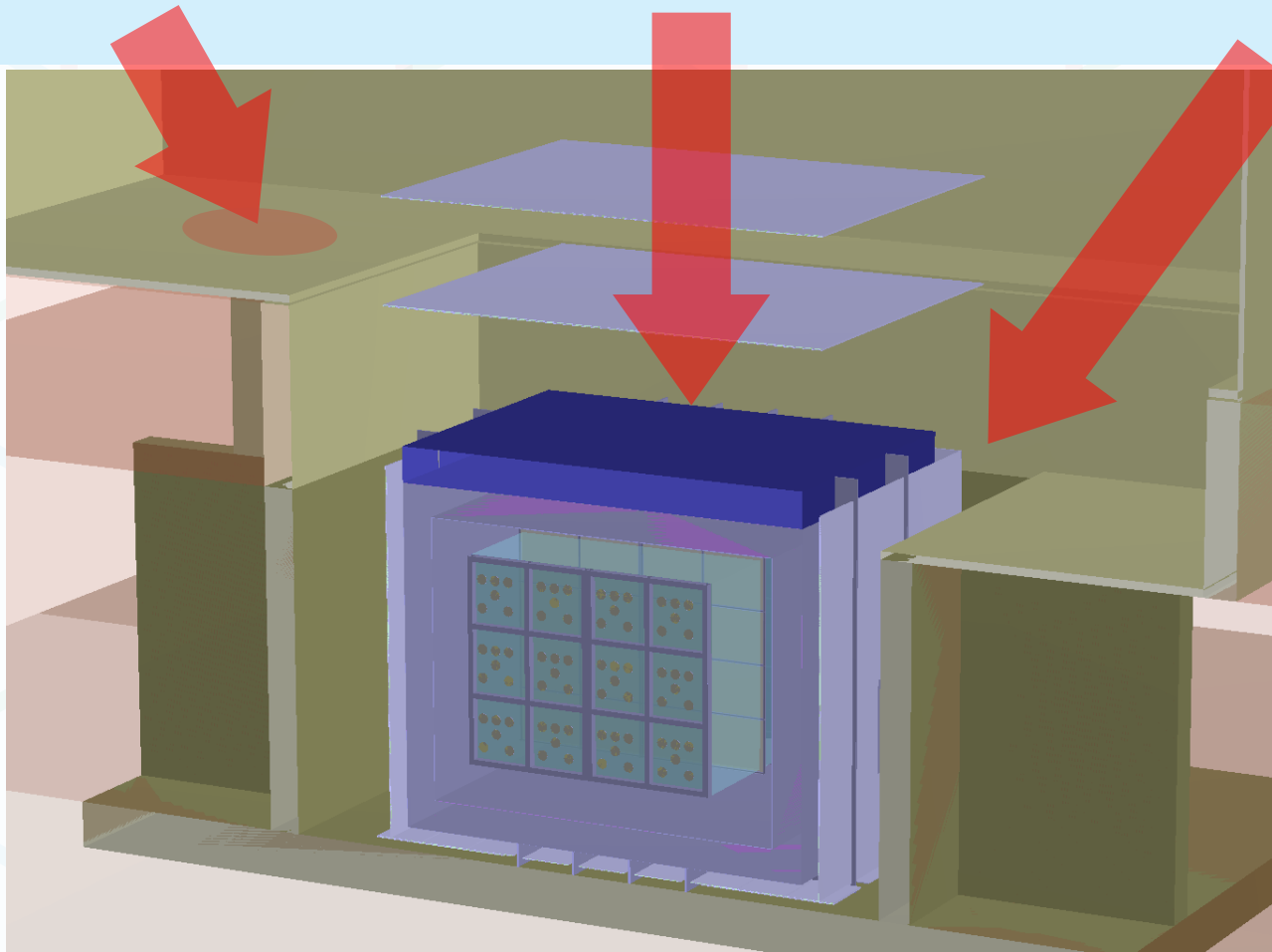
Particle end position (side view)



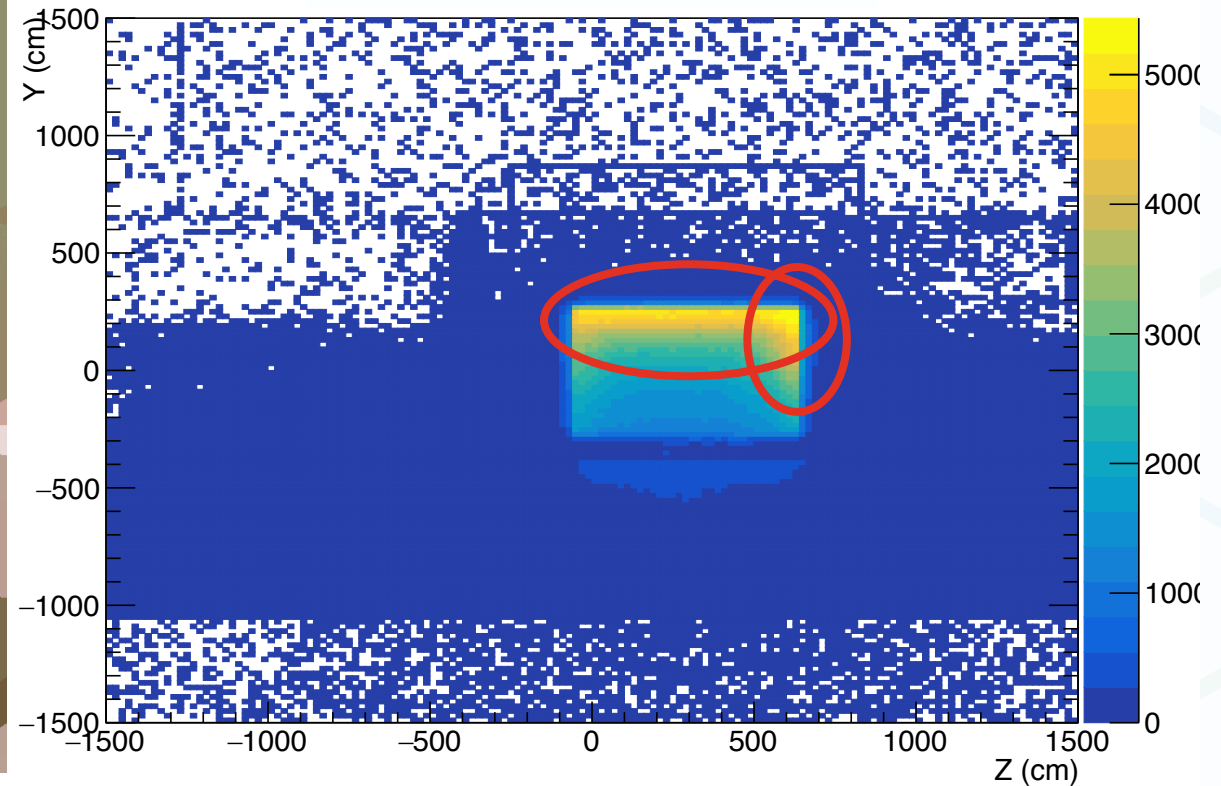
Overburden installed



Particle end position (side view)



No Overburden



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Overburden comparison (1.5 ms)

No Overburden

Particle Type	CORSIKA CMC FLUKA	
	Total	
μ^-	10.41 \pm 0.01	
μ^+	12.98 \pm 0.01	
neutron	0.736 \pm 0.002	
proton	0.374 \pm 0.001	
γ (>100 MeV)	0.0040 \pm 0.0001	
e^- (>100 MeV)	0.0020 \pm 0.0001	
e^+ (>100 MeV)	0.0024 \pm 0.0001	



17 %

17 %

35 %

52 %

18 %

0 %

20 %

Overburden installed

Particle Type	CORSIKA CMC FLUKA	
	Total	
μ^-	8.93 \pm 0.02	
μ^+	11.09 \pm 0.02	
neutron	0.544 \pm 0.006	
proton	0.246 \pm 0.004	
γ (>100 MeV)	0.0034 \pm 0.0005	
e^- (>100 MeV)	0.0020 \pm 0.0003	
e^+ (>100 MeV)	0.0020 \pm 0.0003	



Overburden comparison (relative)

No Overburden

Particle Type	CORSIKA CMC FLUKA	
	Total	
μ^-	100 %	
μ^+	100 %	
neutron	100 %	
proton	100 %	
γ (>100 MeV)	100 %	
e^- (>100 MeV)	100 %	
e^+ (>100 MeV)	100 %	



17 %
17 %
35 %
52 %
18 %
0 %
20 %

Overburden installed

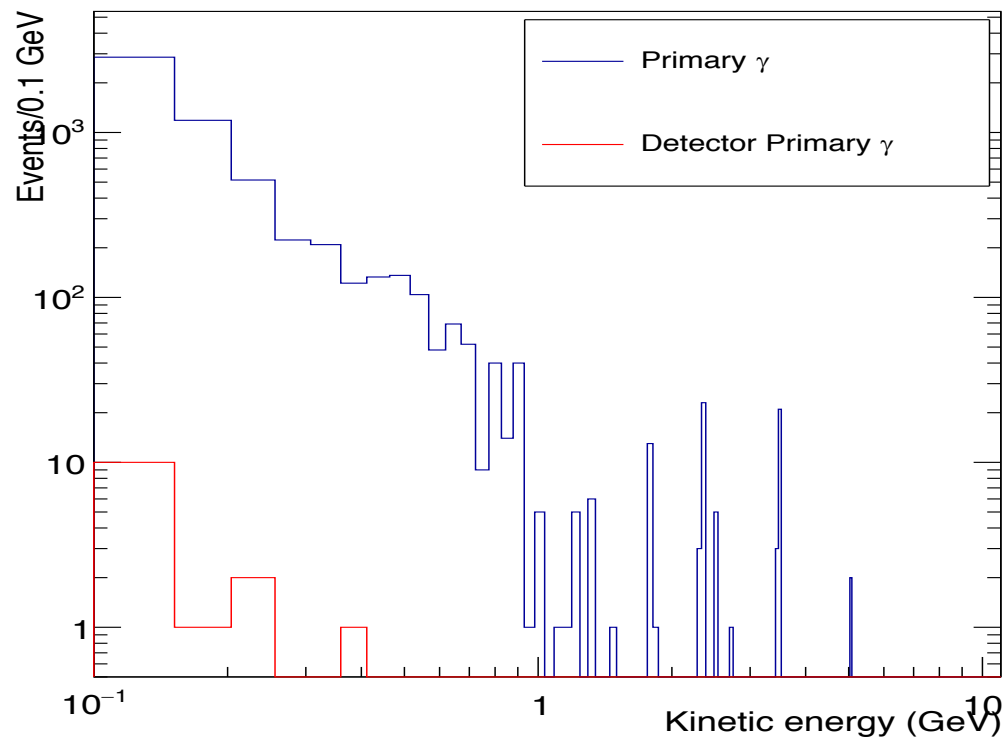
Particle Type	CORSIKA CMC FLUKA	
	Total	
μ^-	83 %	
μ^+	83 %	
neutron	65 %	
proton	48 %	
γ (>100 MeV)	18 %	
e^- (>100 MeV)	100 %	
e^+ (>100 MeV)	80 %	



Particle energy (Photons)

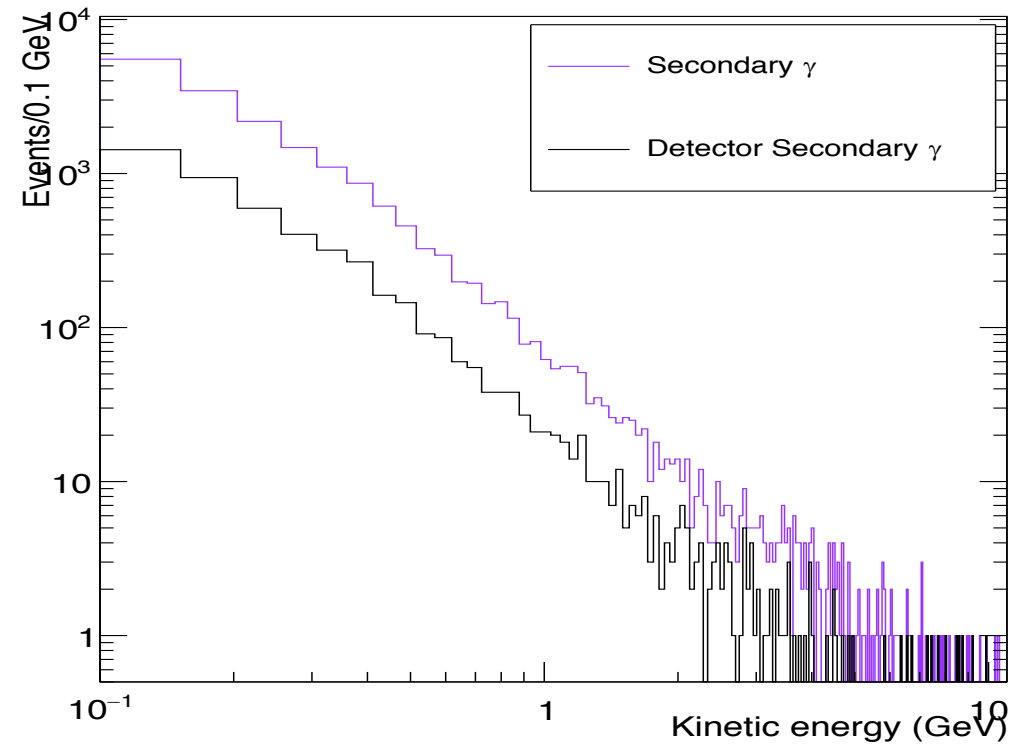
Primaries

Kinetic Energy of primary photons in TPC

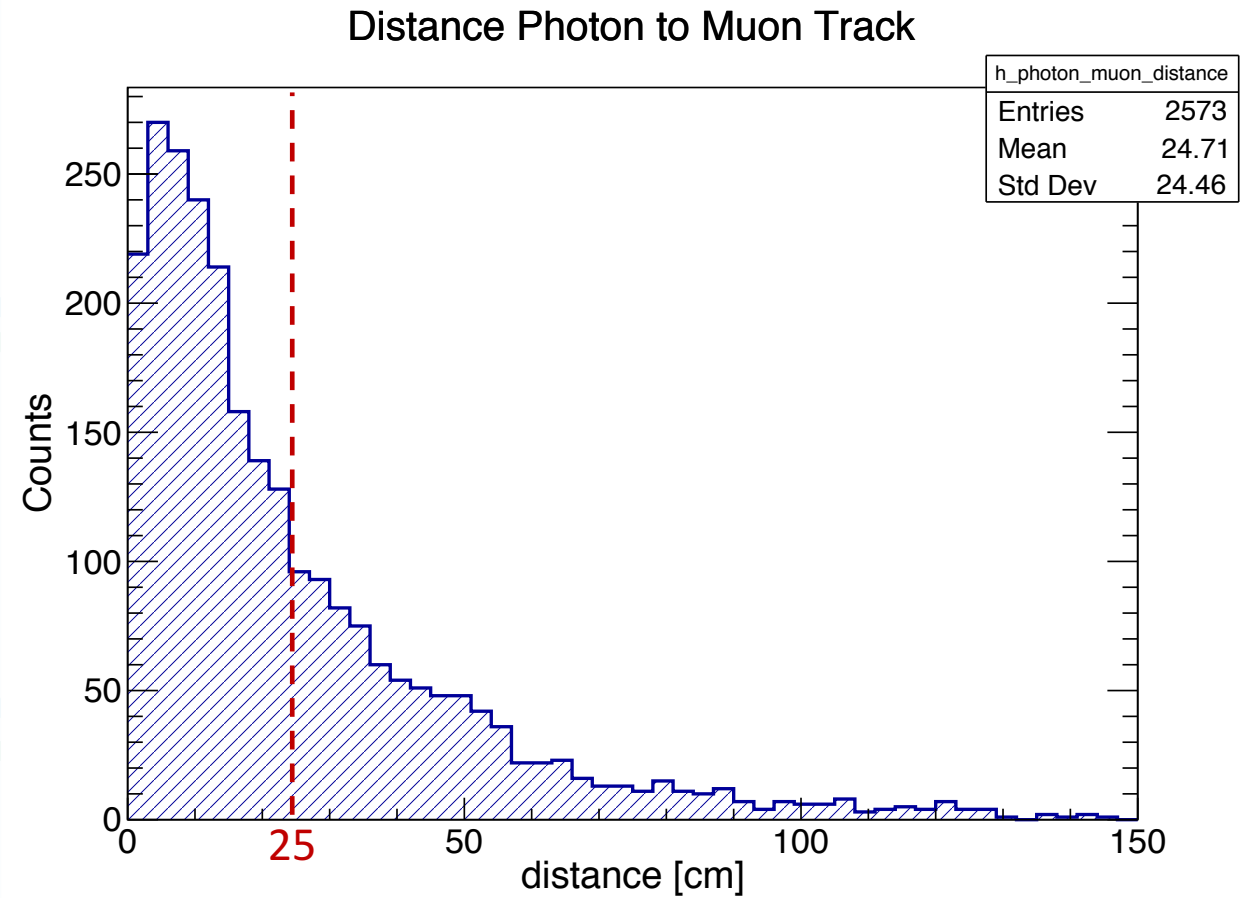
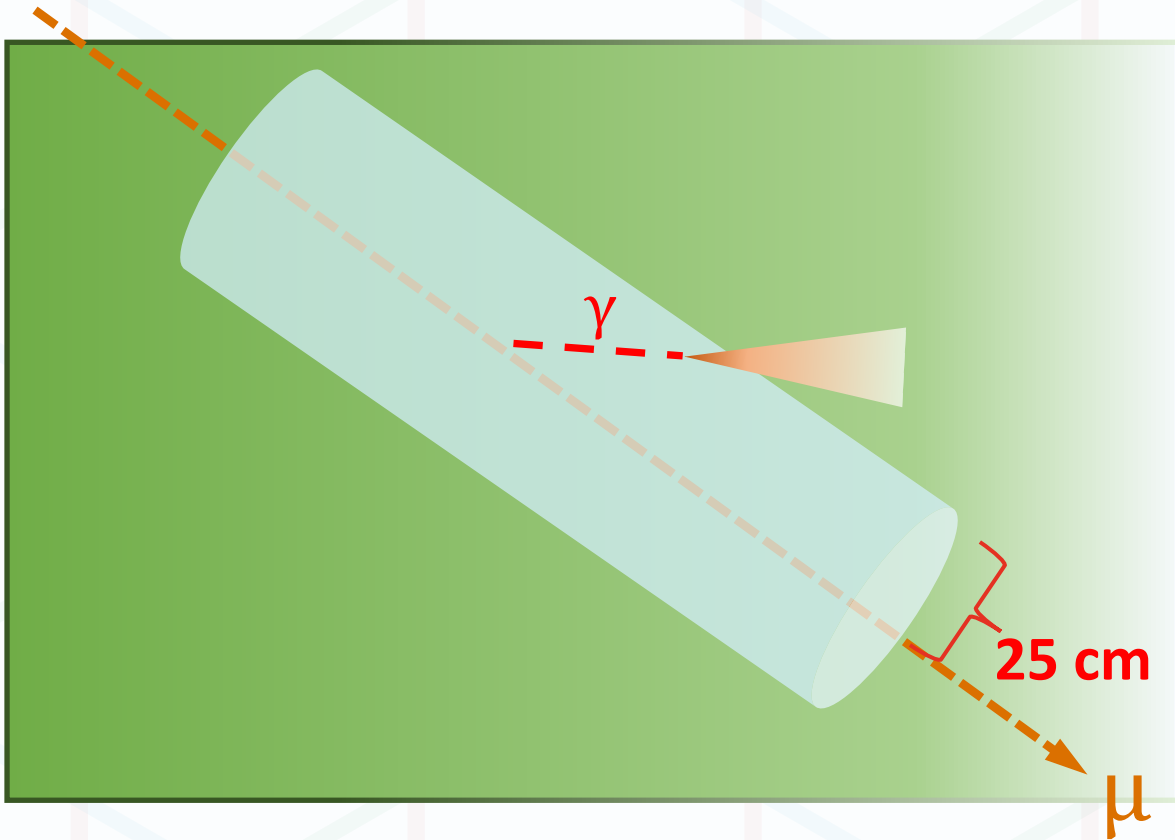


Secondaries

Kinetic Energy of secondary photons in TPC

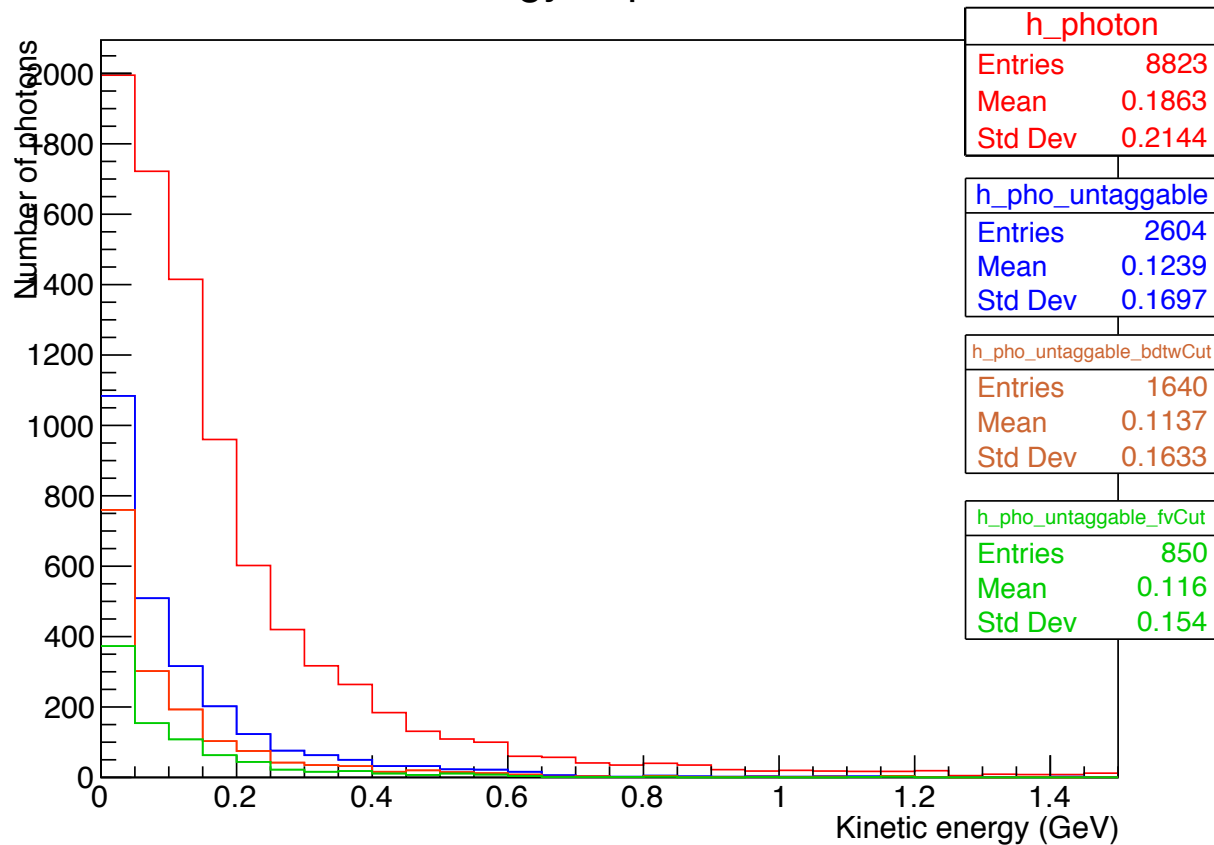


Photon bckg: muon cylinder cut



Photon background

Kinetic energy of photons in TPC



Total number of photons: **8823**

Untaggable*: **2604 (100 %)**

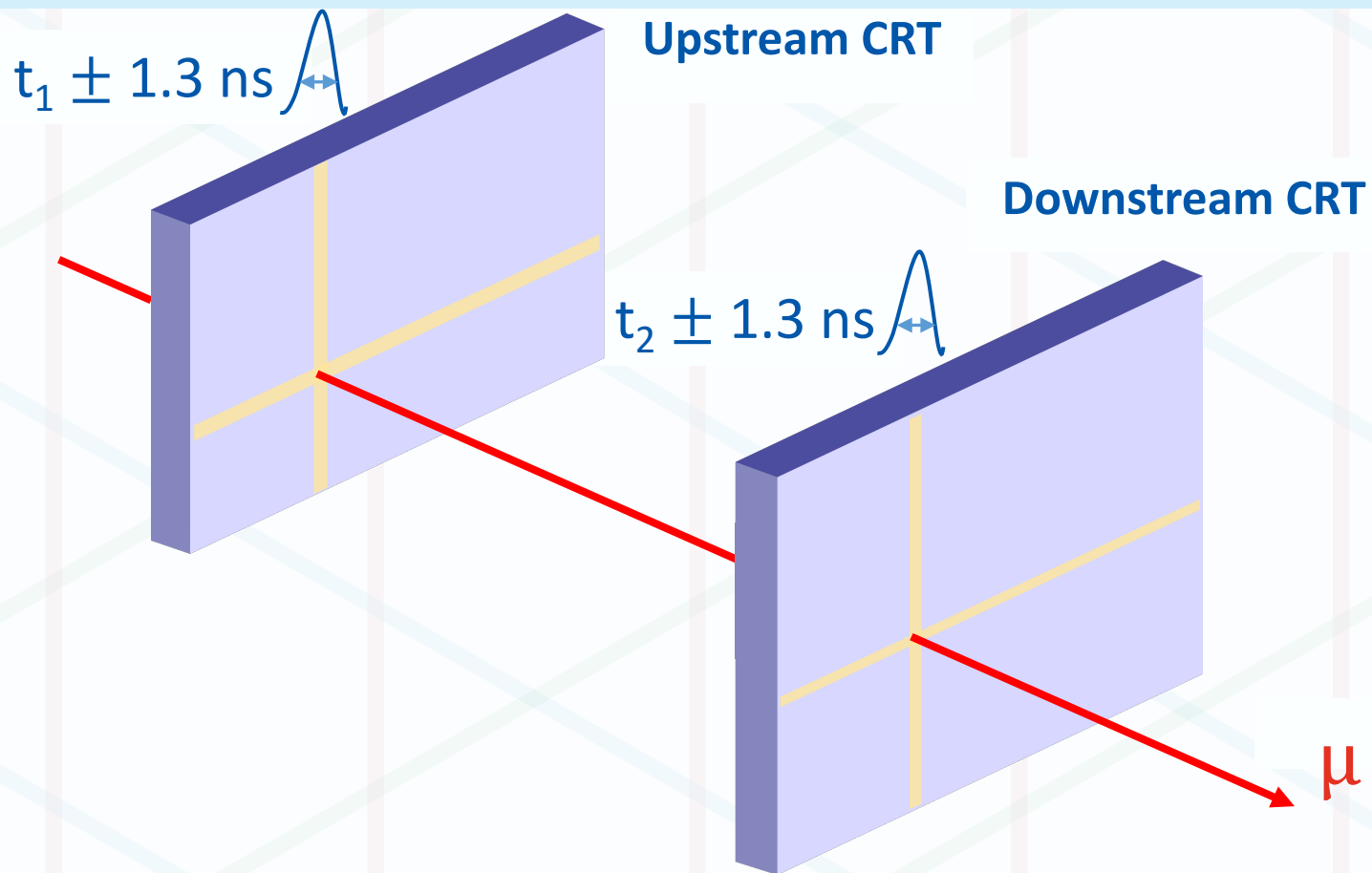
Untaggable BDtoW-cut : **1640 (63 %)**

Untaggable FV-cut: **850 (33 %)**

- * • photon that initiates the shower is **created outside** the TPC active volume
- or **ancestors** traced back to the particle that enters the TPC active volume are **all neutral**
- or photon is **outside primary muon cylinder**.



CRT timing study



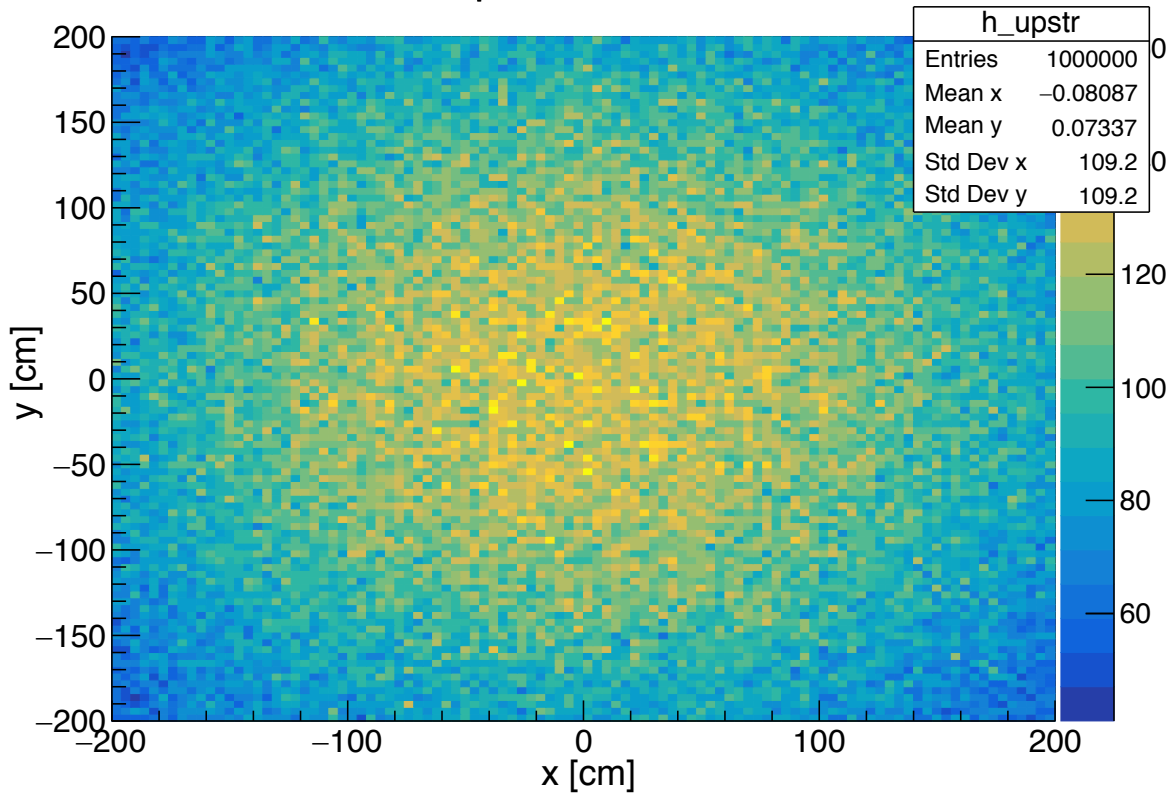
Muon upstream hit generated with gaussian spread according to CRT data.

Extrapolated to downstream CRT and TOF calculated

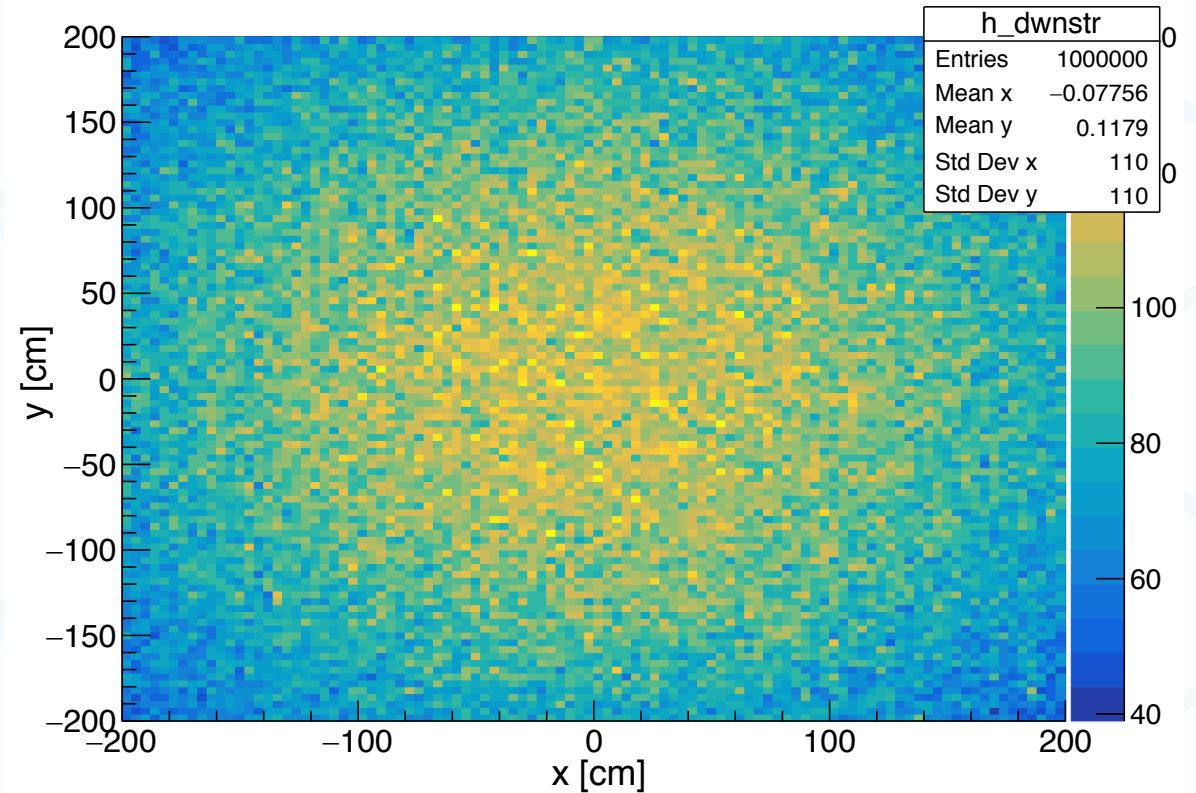
$$\mu \text{ Timing} = t_1 + \text{TOF} + t_2$$

Random generated hits for CRT study

Upstream CRT

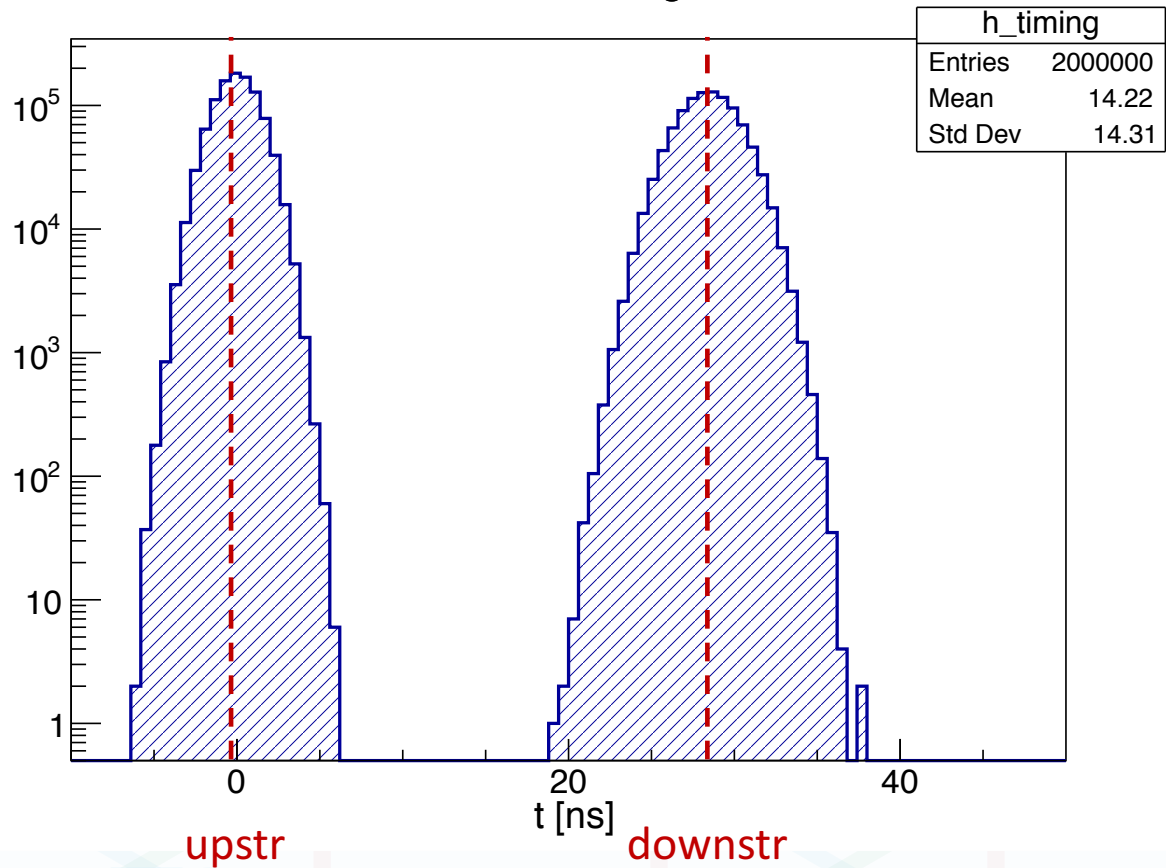


Downstream CRT



CRT timing study

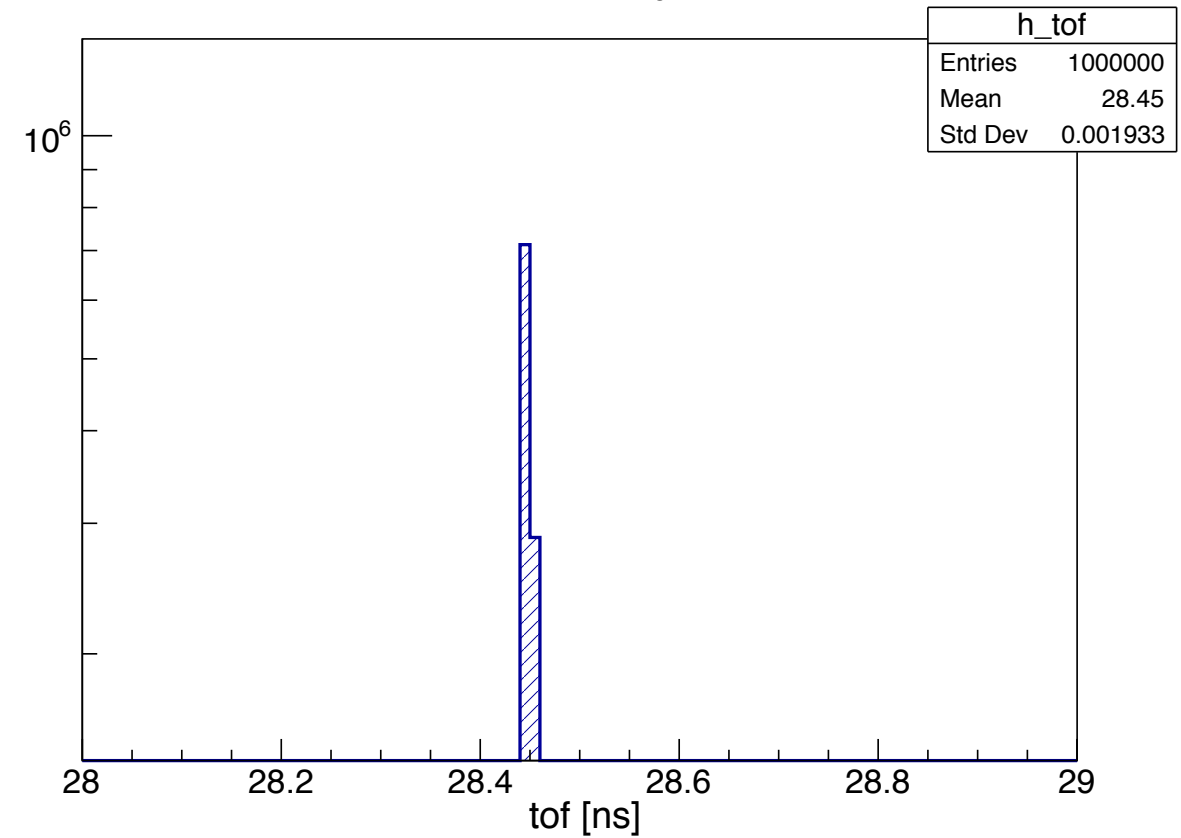
CRT Timing



upstr

downstr

Time of Flight



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Summary

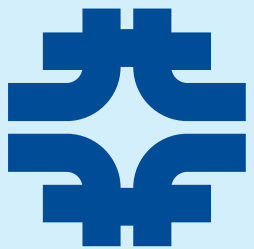
The SBND simulation geometry was adjusted according to the results of this study.

Particle rate comparison indicates the feasibility of an overburden.

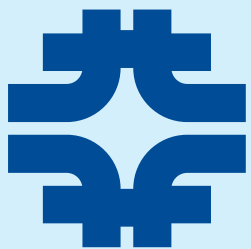
Photon background reduced by muon cylinder cut. Further cuts necessary.

Preliminary CRT timing study suggests a good separation between up- and downstream hit timing.





Backup



Short Baseline Near Detector (SBND)

Two Time Projection Chambers (TPCs):

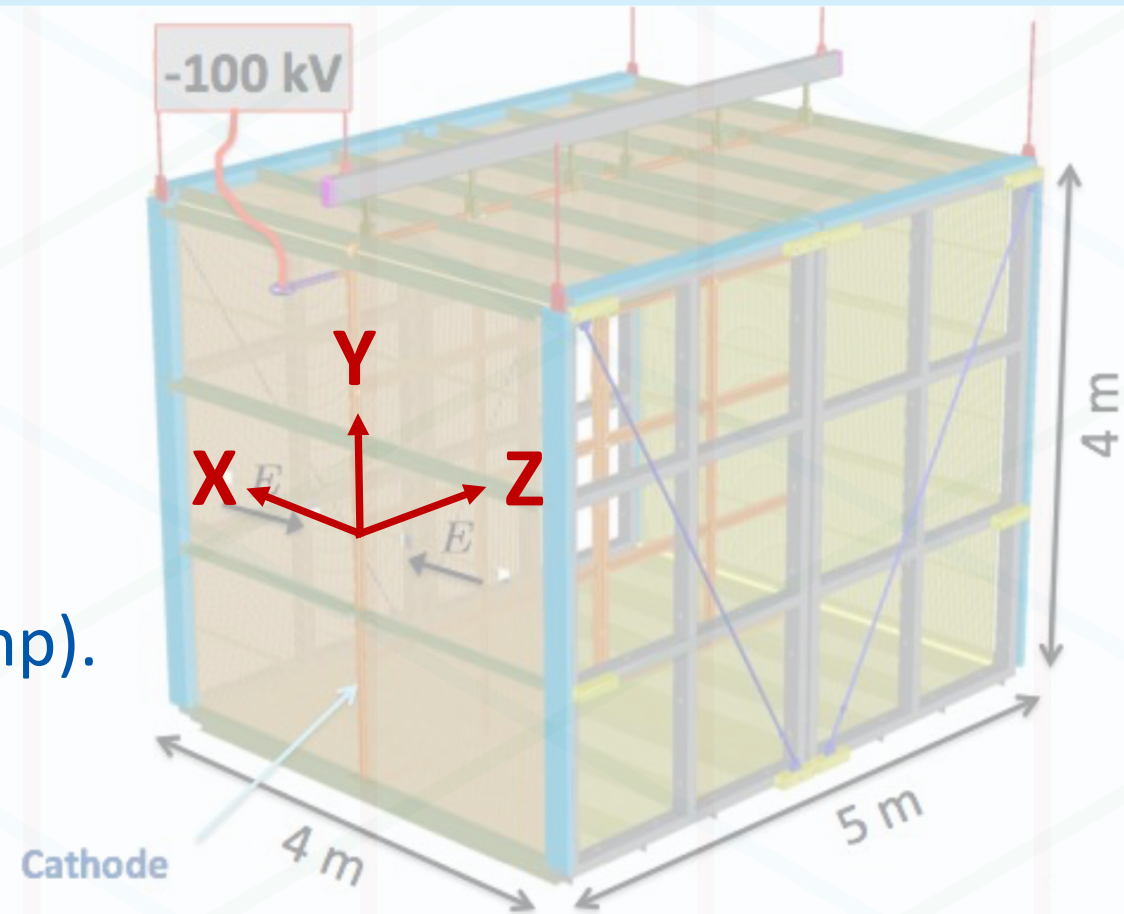
2 m drift distance (1.28 ms drift time at 500 V/cm).

3 wire planes ($0^\circ, \pm 60^\circ$).

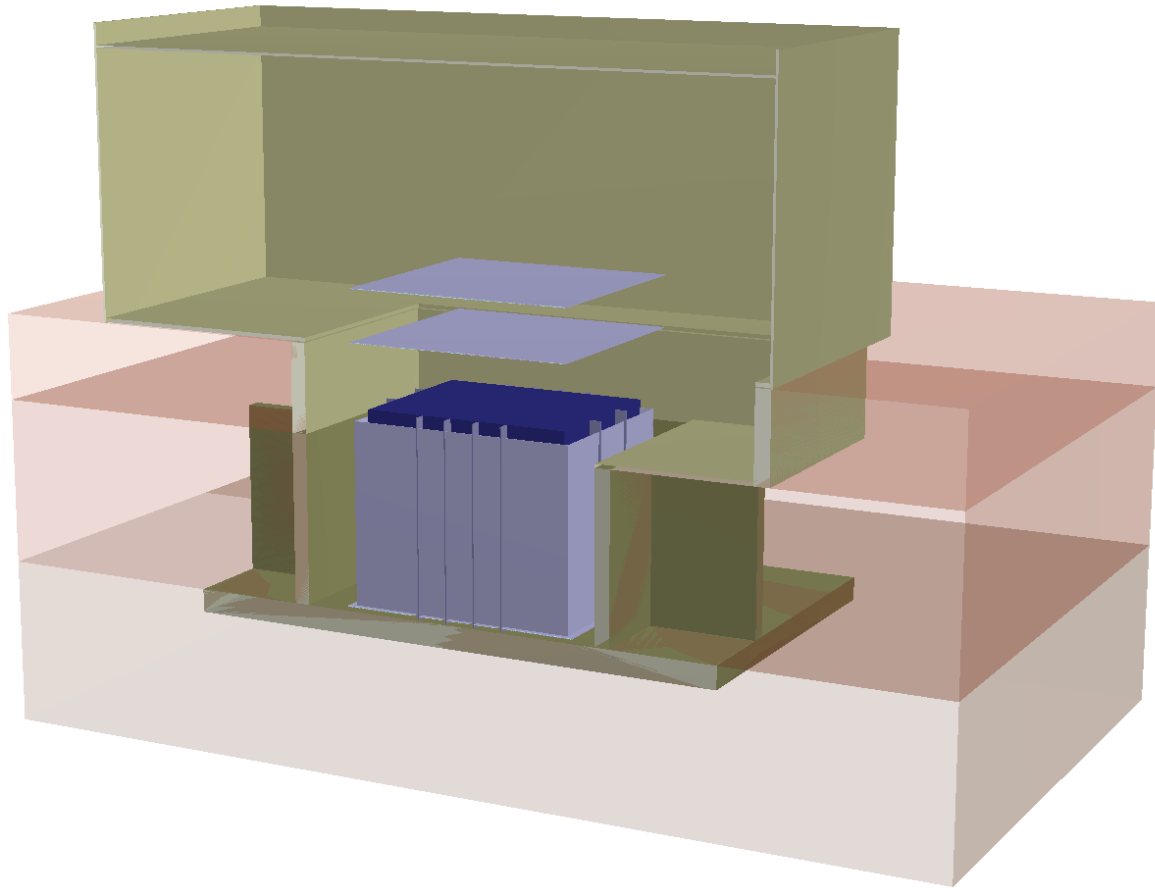
3 mm pitch between wires.

120 8" PMTs: ~ immediate signal (time stamp).

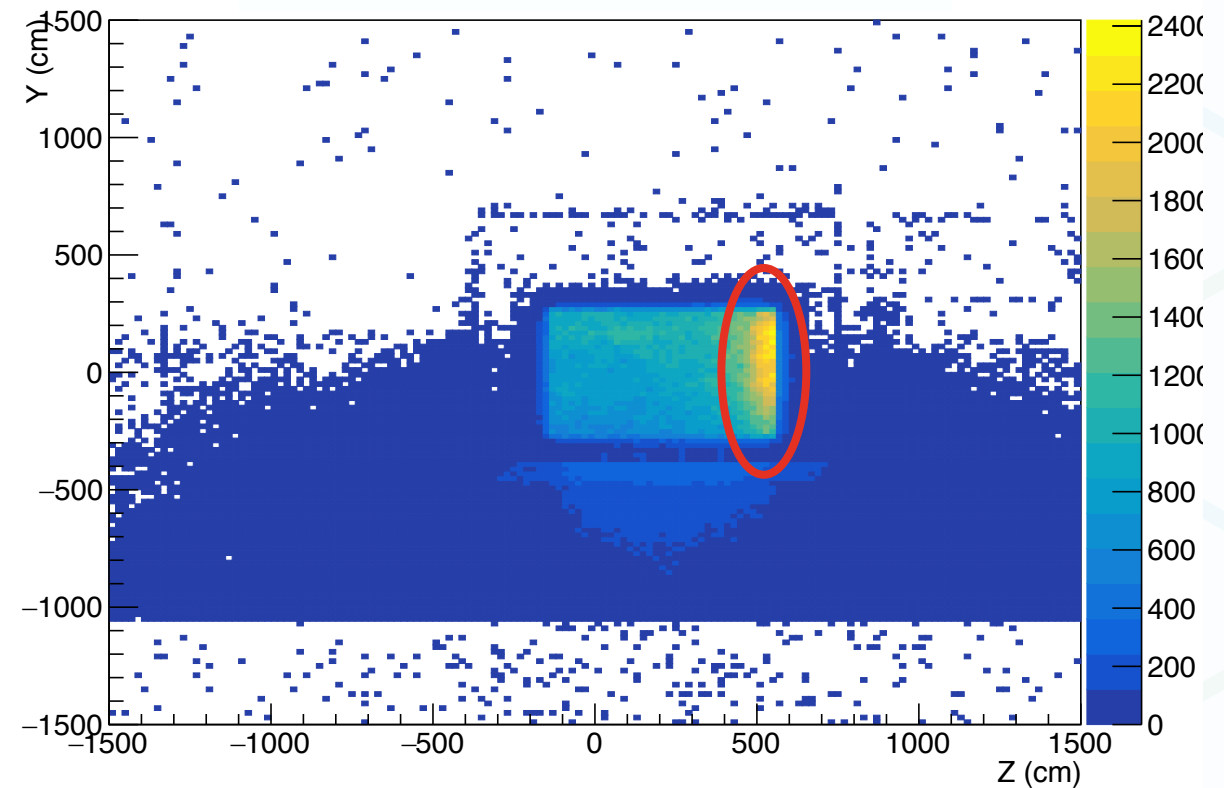
Cosmic Ray Tagger: almost full coverage



Particle end position (side view)

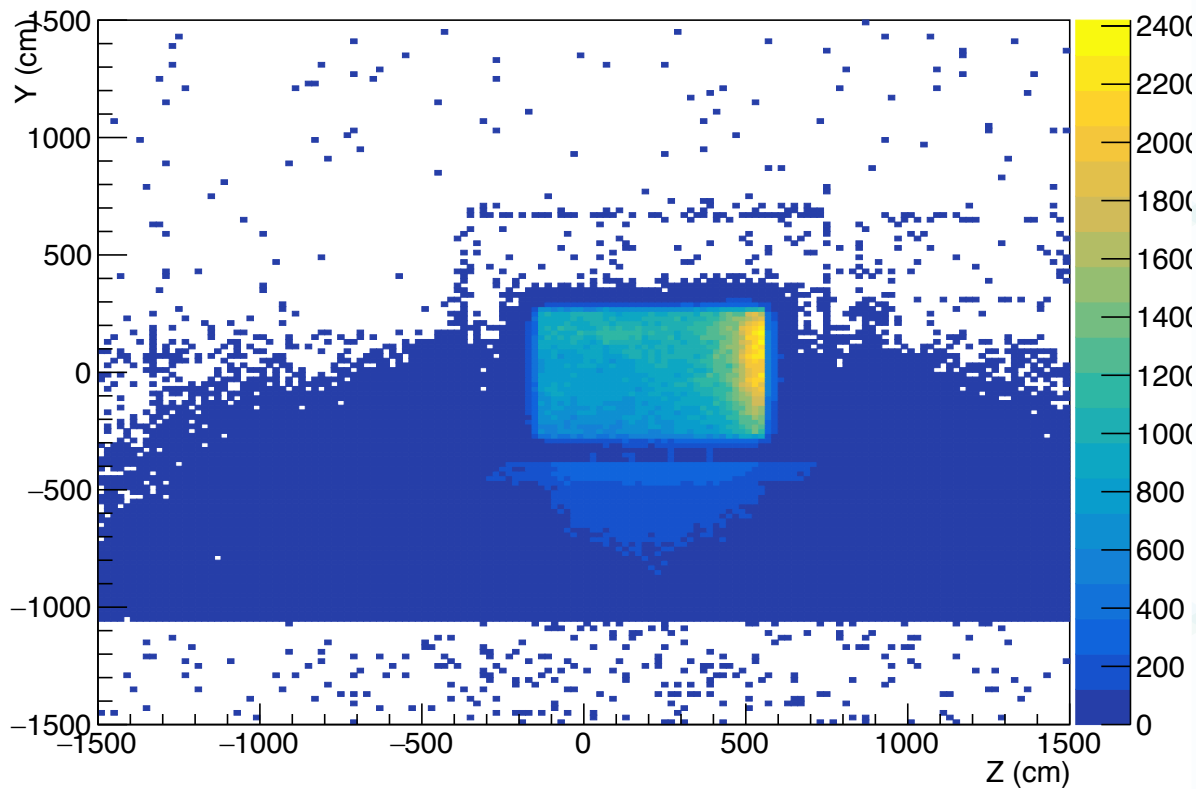


Overburden installed

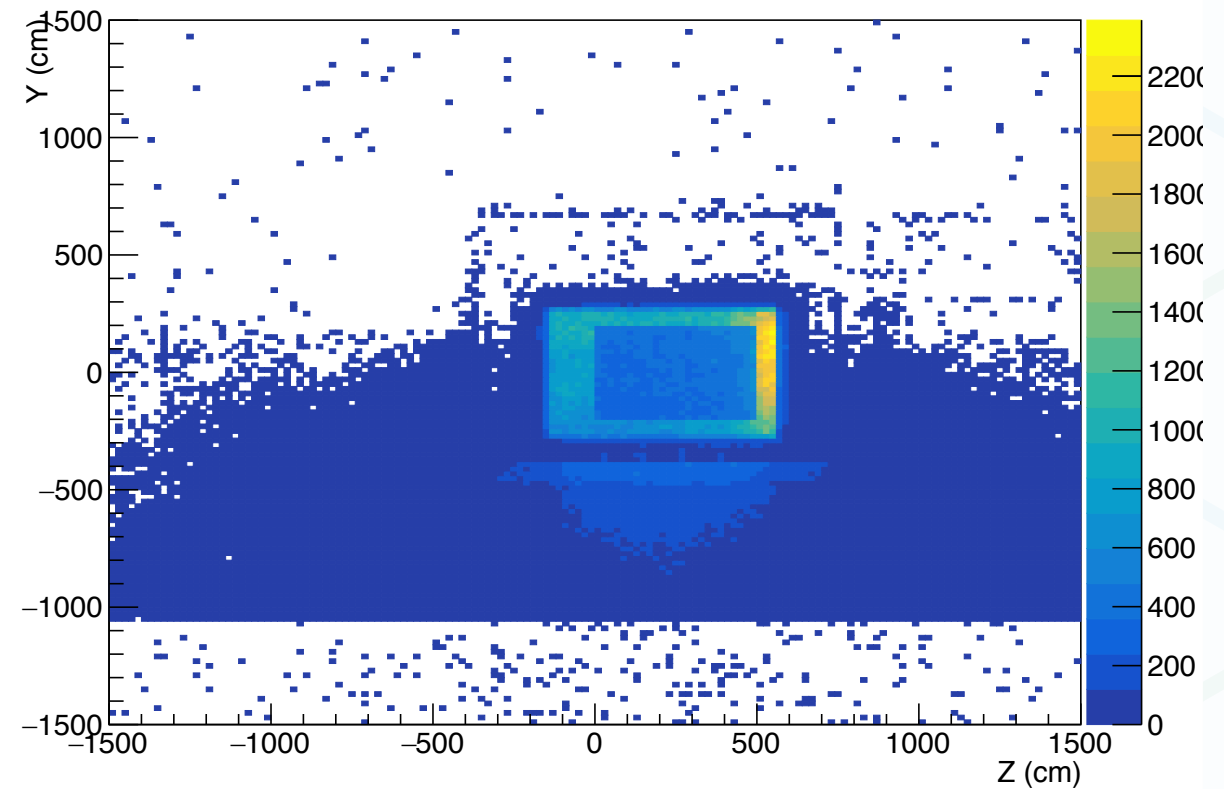


Overburden installed (side view)

YZ End positions



YZ End positions of particles stopping outside TPC



Overburden comparison

No Overburden

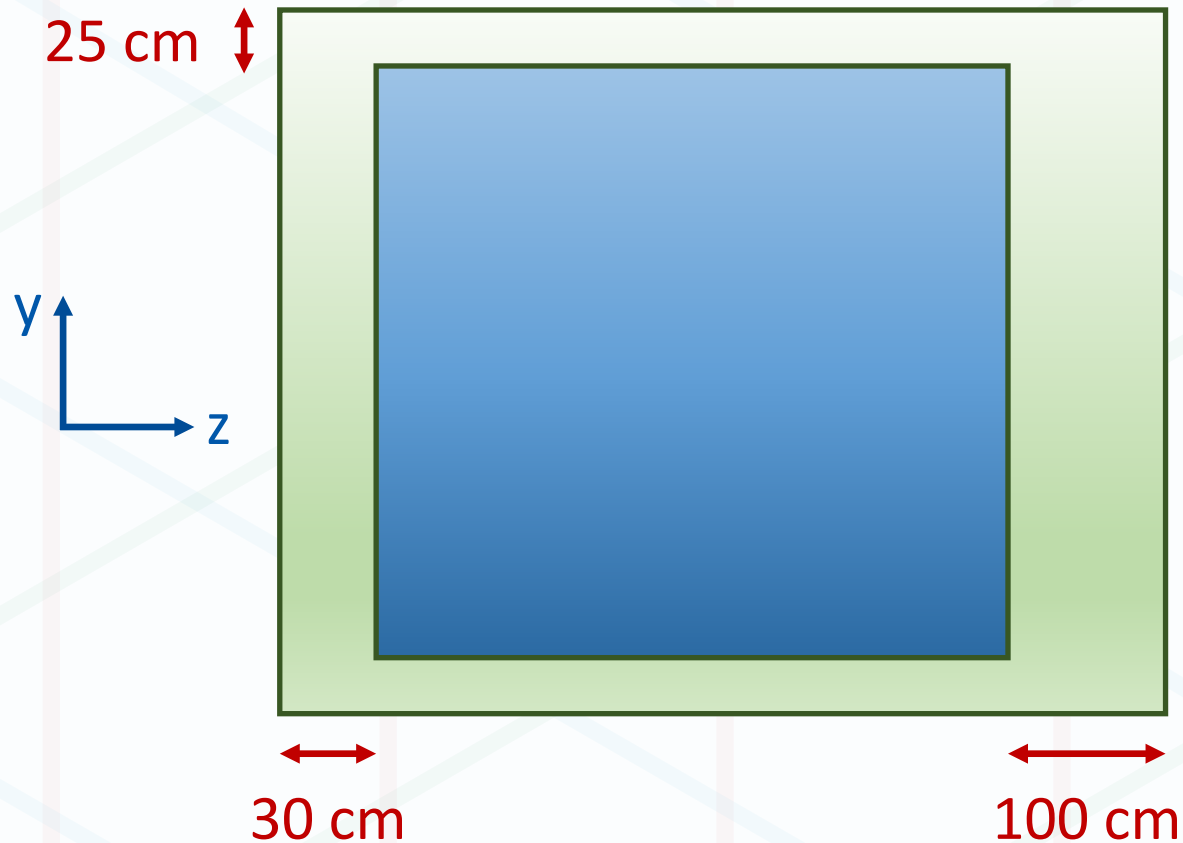
Overburden installed

Particle Type	CORSIKA CMC FLUKA		
	Primaries	Secondaries	Total
μ^-	10.406 ± 0.007	0.0003 ± 0.00001	10.4068 ± 0.007
μ^+	12.977 ± 0.007	0.0024 ± 0.0001	12.977 ± 0.007
neutron	0.0988 ± 0.0006	0.647 ± 0.002	0.736 ± 0.002
proton	0.0013 ± 0.0001	0.373 ± 0.001	0.374 ± 0.001
γ (>100 MeV)	0.0001 ± 0.00001	0.0039 ± 0.0001	0.0040 ± 0.0001
e^- (>100 MeV)	0.0 ± 0.0	0.0020 ± 0.0001	0.0020 ± 0.0001
e^+ (>100 MeV)	0.0 ± 0.0	0.0024 ± 0.0001	0.0024 ± 0.0001

Particle Type	CORSIKA CMC FLUKA		
	Primaries	Secondaries	Total
μ^-	8.926 ± 0.021	0.0020 ± 0.0001	8.928 ± 0.021
μ^+	11.079 ± 0.024	0.0014 ± 0.0003	11.093 ± 0.024
neutron	0.036 ± 0.001	0.508 ± 0.005	0.544 ± 0.006
proton	0.0006 ± 0.0002	0.2458 ± 0.0035	0.246 ± 0.004
γ (>100 MeV)	0.0002 ± 0.00001	0.0032 ± 0.0004	0.0034 ± 0.0005
e^- (>100 MeV)	0.0 ± 0.0	0.0020 ± 0.0003	0.0020 ± 0.0003
e^+ (>100 MeV)	0.0 ± 0.0	0.0020 ± 0.0003	0.0020 ± 0.0003



Photon Bckg: Fiducial Volume Cut



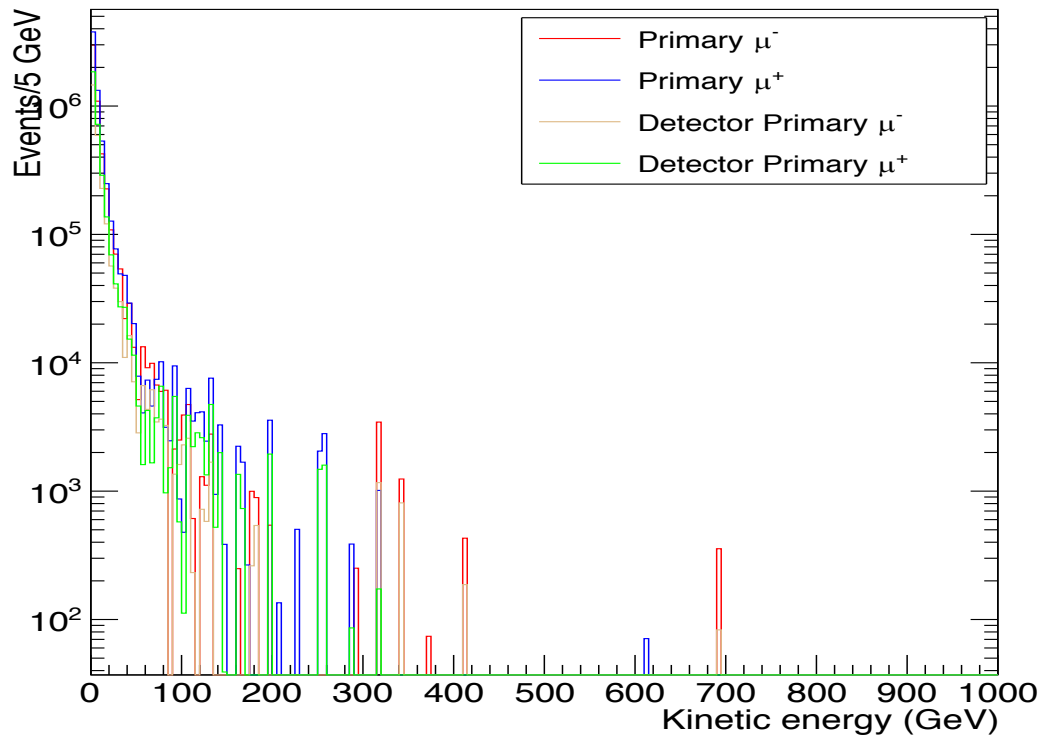
In z-direction: 30 cm distance upstream and 100 cm distance downstream to wall.

Distance to all other walls: 25 cm.

Particle energy (Muons)

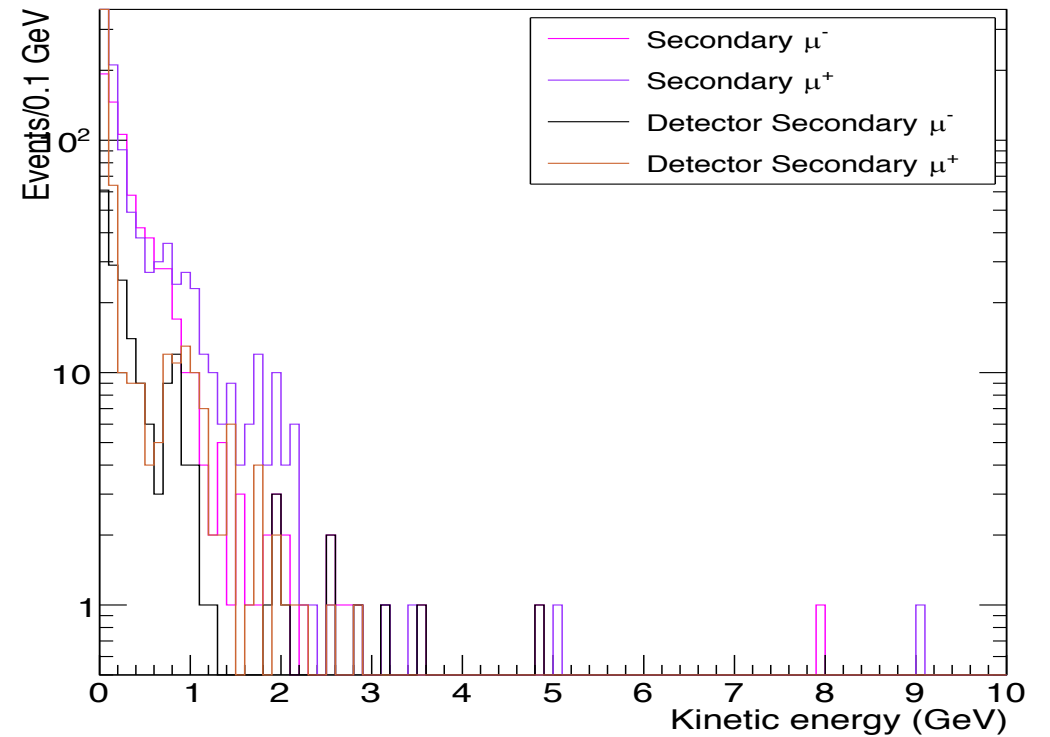
Primaries

Kinetic Energy of primary μ^-/μ^+ in TPC



Secondaries

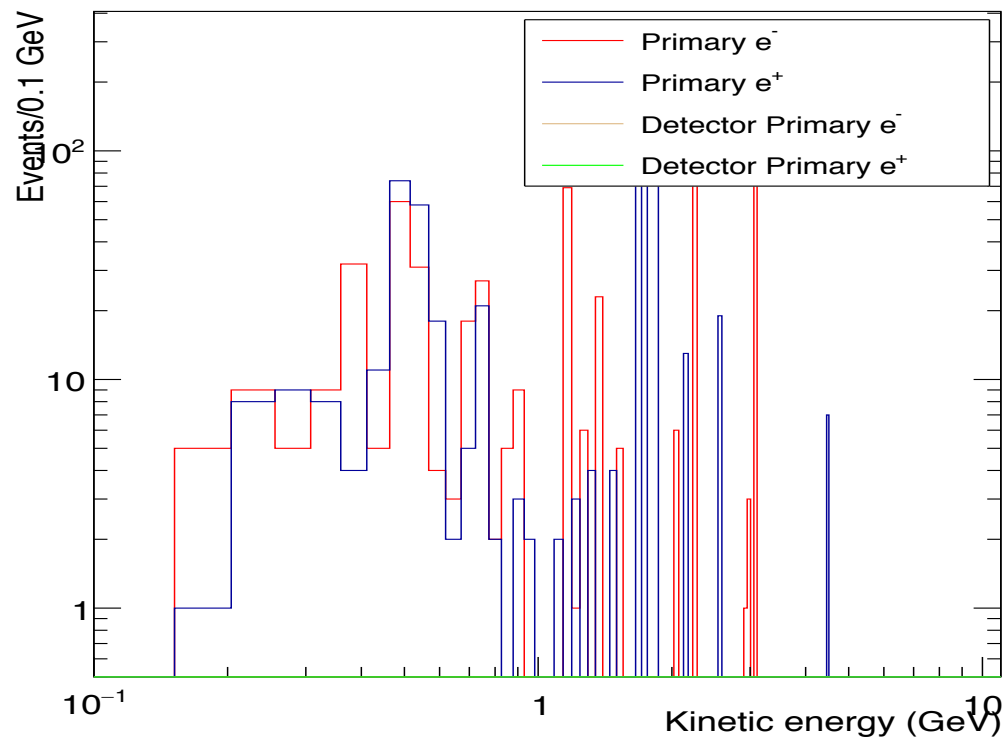
Kinetic Energy of secondary μ^-/μ^+ in TPC



Particle energy (Electrons)

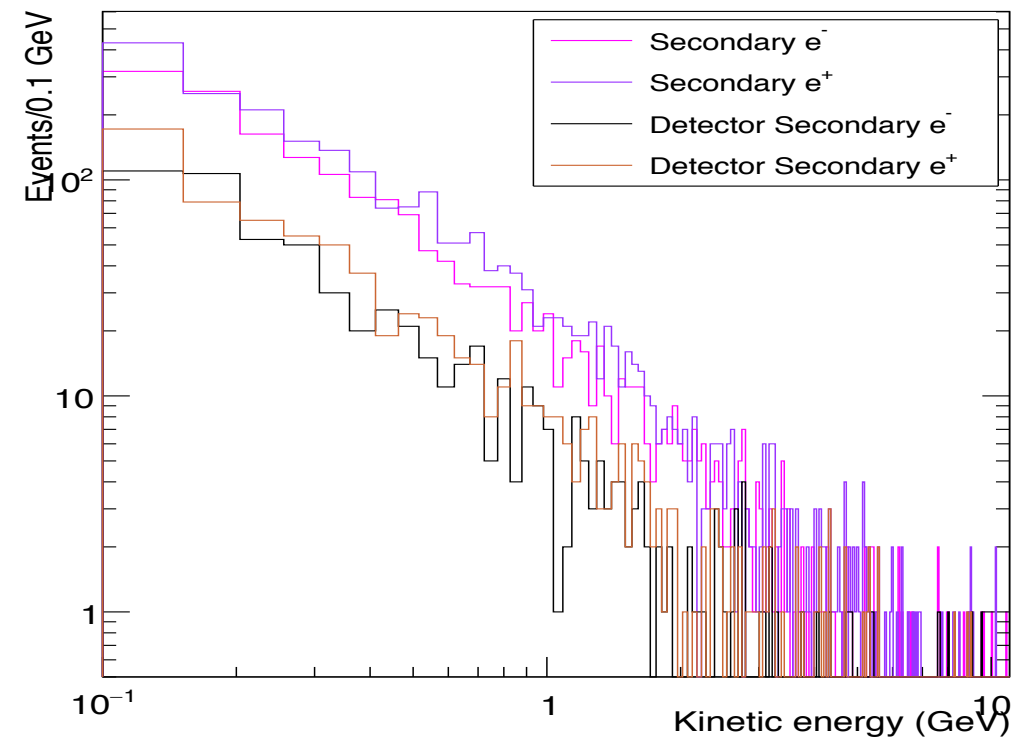
Primaries

Kinetic Energy of primary e^-/e^+ in TPC



Secondaries

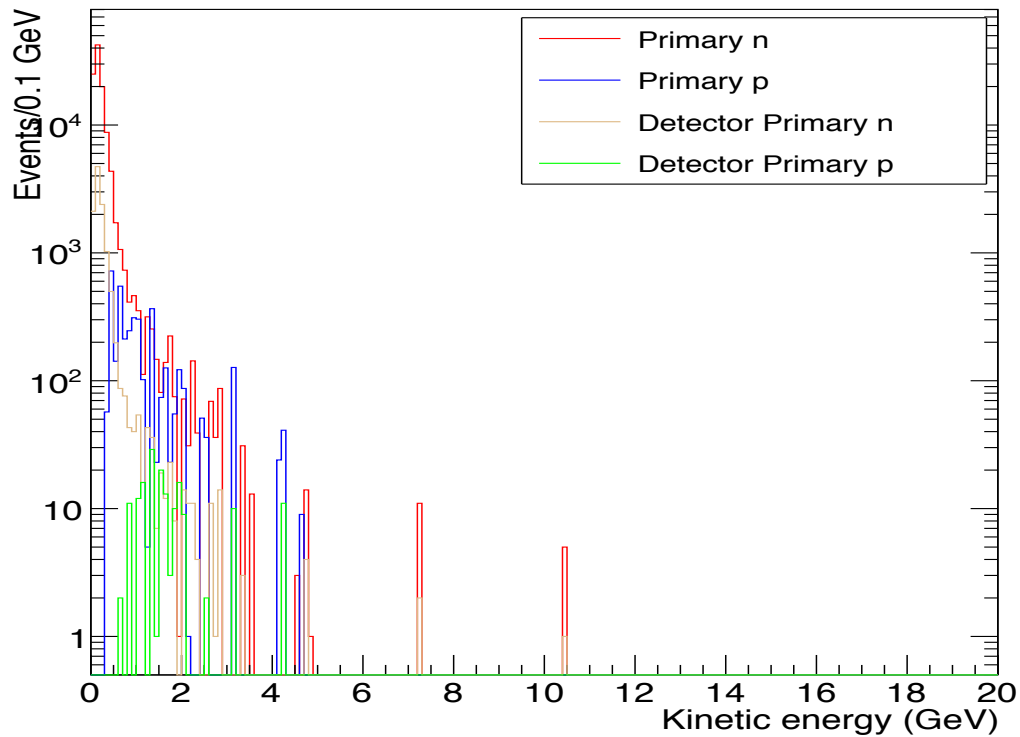
Kinetic Energy of secondary e^-/e^+ in TPC



Particle energy (Neutrons & Protons)

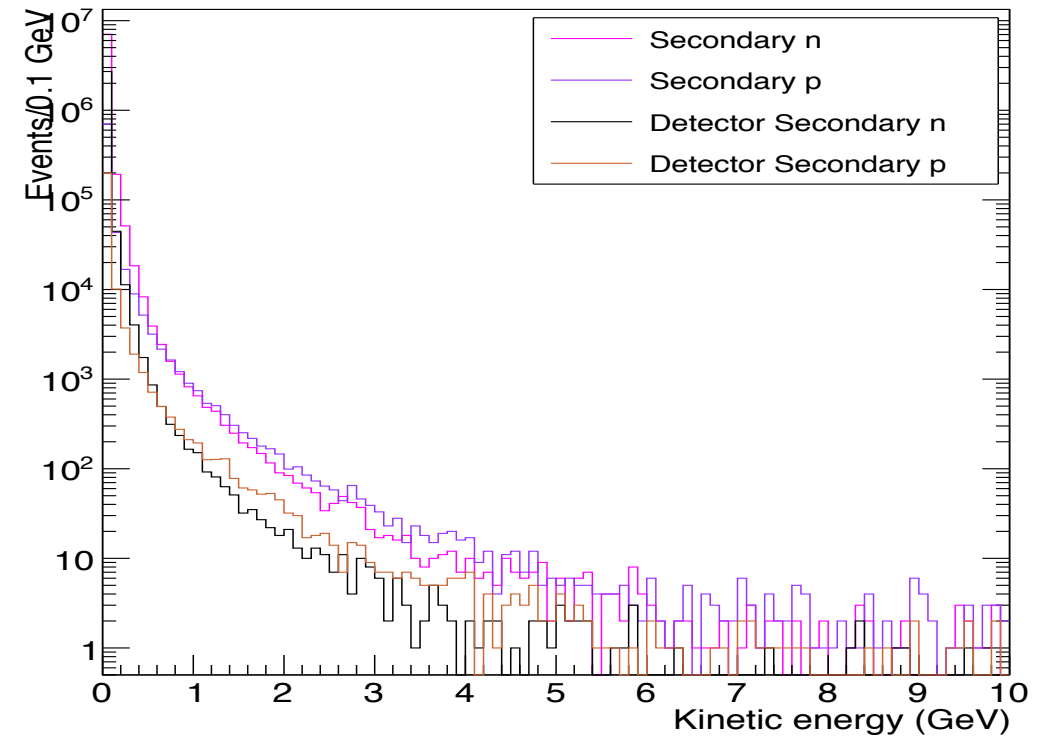
Primaries

Kinetic Energy of primary n/p in TPC

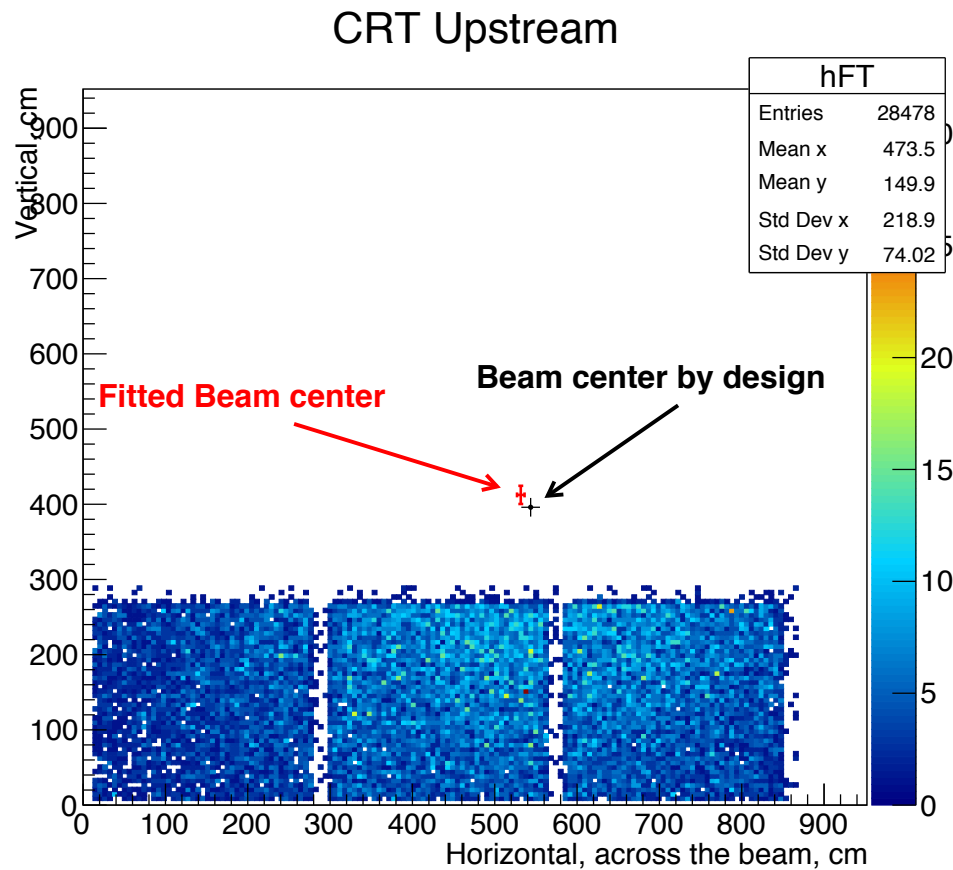


Secondaries

Kinetic Energy of secondary n/p in TPC



CRT upstream data



First data collected by SBND'S cosmic ray taggers.

Indicates beam position and spread.

(Created using Igor Kreslov's macros).



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