MovingKnowledge17 International Neutrino Summer Student Program:

Study of electromagnetic showers and cosmic-ray induced electromagnetic background in the MicroBooNE

Monika Venckauskaite monika.venckauskaite@gmail.com
Supervisors: Roxanne Guenette, Roberto Soleti and Corey Adams

Study of the efficiency in the MicroBooNE experiment.

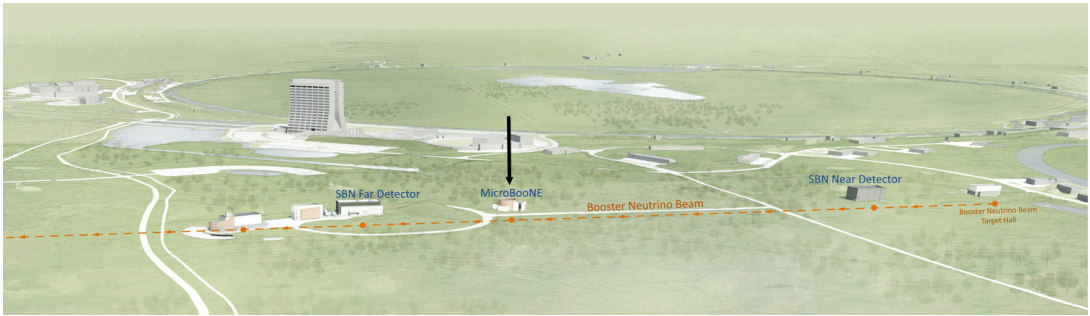
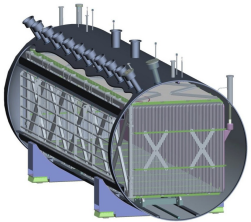


Figure: The location of the MicroBooNE experiment.

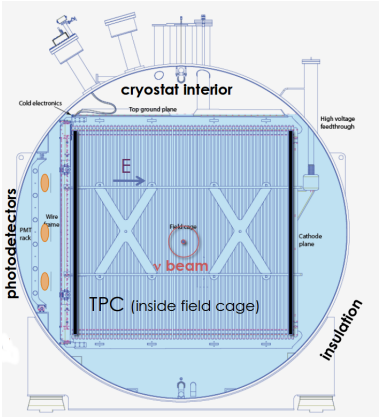
Contents
Study of efficiency in the MicroBooNE

The MicroBooNE detector

- 170 t LArTPC located in the Fermilab Booster Neutrino Beamline
- 2.5 m x2.3 m x10.2 m TPC
- 3 wire planes: 0, $\pm 60^{o}$ from vertical



(a) The MicroBooNE detector.



(b) Cross-sectional view of the MicroBooNE detector.

Goals of the MicroBooNE experiment:

Investigate **anomalous low energy excess** previously observed by MiniBooNE (predecessor experiment in the BNB, downstream from MicroBooNE)

Demonstrate background rejection capabilities and study **cosmic background** for future searches for new physics

- Perform high-statistics inclusive and exclusive **neutrino cross-section measurements on argon**
- Search for **supernova collapse neutrinos**, should a nearby supernova core collapse occur during MicroBooNE's lifespan
- Perform a definitive search for light **sterile neutrino oscillations** as a part of the Fermilab SBN program

Measurement of events in the LArTPC

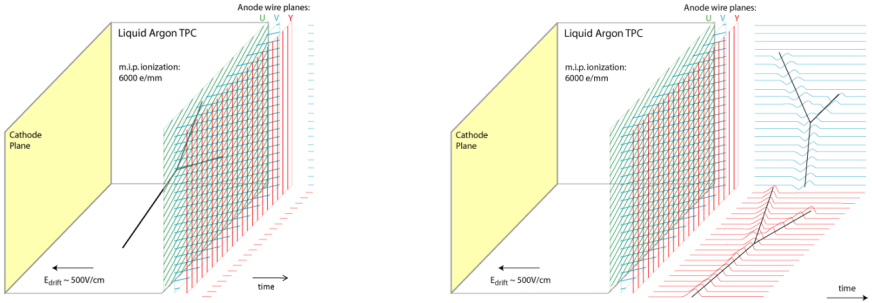
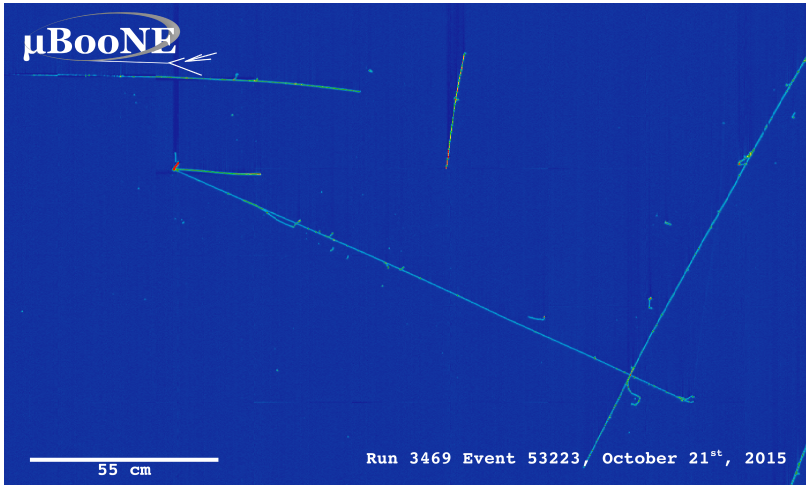
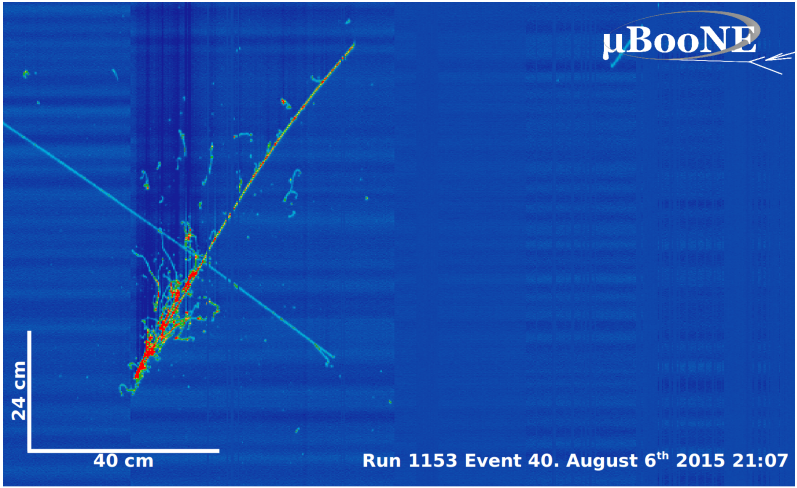


Figure: Ionization electrons are produced and move along the external electric field towards the anode planes, pass through the induction wire planes and are collected by the final collection wire plane.

Event display in the MicroBooNE detector: neutrino event



Event display in the MicroBooNE detector: cosmic event



Coordinate system in the LArTPC

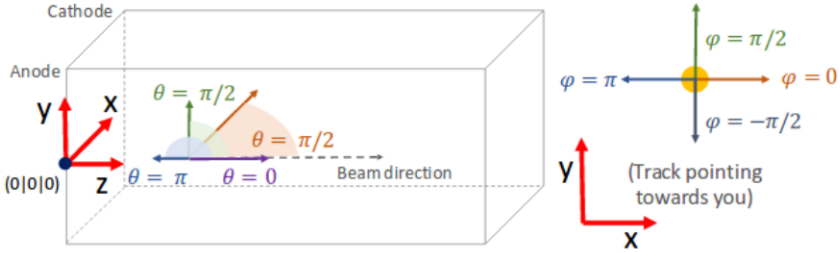
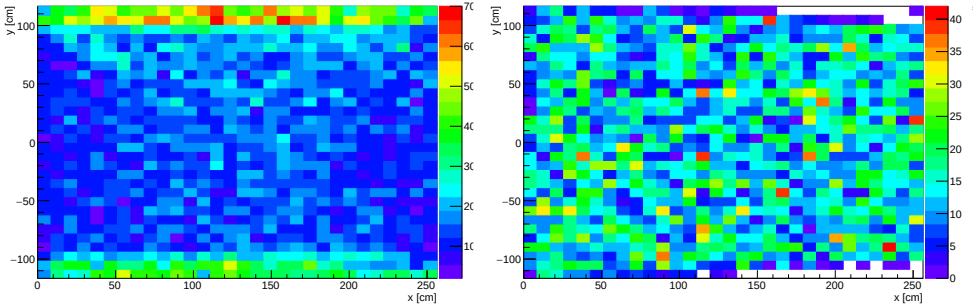


Figure: Coordinate system in the MicroBooNE detector.

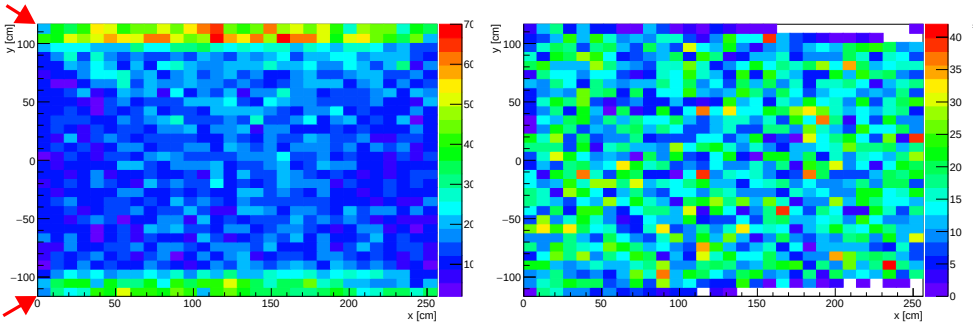
Event distribution in the MicroBooNE detector, XY plane, MC



(a) Cosmic event track start distribution in the fiducial volume of the MicroBooNE detector, XY plane.

(b) ν_e event vertex distribution in the fiducial volume of the MicroBooNE detector, XY plane.

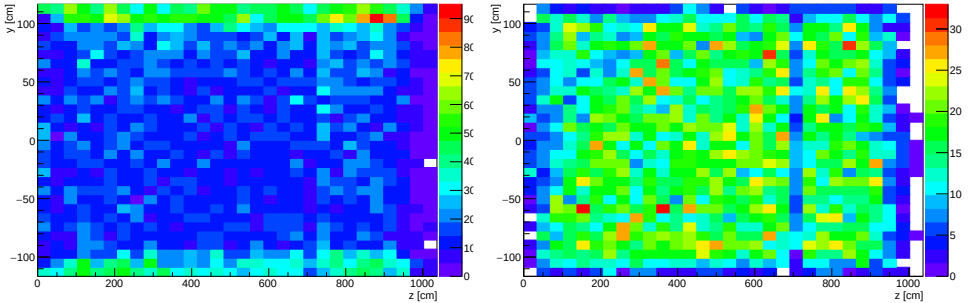
Event distribution in the MicroBooNE detector, XY plane, MC



(a) Cosmic event track start distribution in the fiducial volume of the MicroBooNE detector, XY plane.

(b) ν_e event vertex distribution in the fiducial volume of the MicroBooNE detector, XY plane.

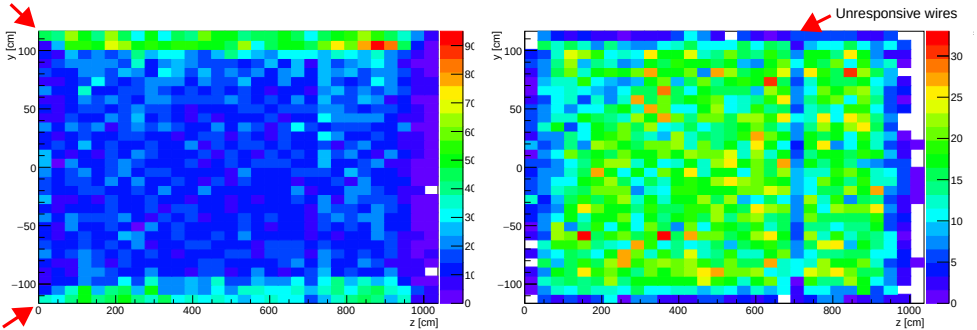
Event distribution in the MicroBooNE detector, ZY plane, MC



(a) Cosmic event track start distribution in the fiducial volume of the MicroBooNE detector, ZY plane.

(b) ν_e event vertex distribution in the fiducial volume of the MicroBooNE detector, ZY plane.

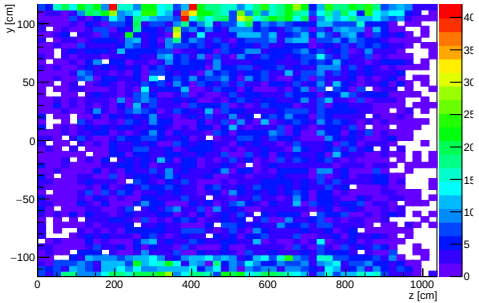
Event distribution in the MicroBooNE detector, ZY plane, MC



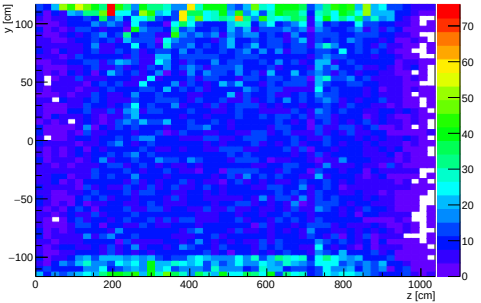
(a) Cosmic event track start distribution in the fiducial volume of the MicroBooNE detector, ZY plane.

(b) ν_e event vertex distribution in the fiducial volume of the MicroBooNE detector, ZY plane.

Event distribution in the MicroBooNE detector, ZY plane, Data



(a) Event track start distribution in the fiducial volume of the MicroBooNE detector with the beam turned off, ZY plane.



(b) Event vertex distribution in the fiducial volume of the MicroBooNE detector with a beam turned on, ZY plane.

Some definitions

Fiducial volume, in particle physics experiments, a volume for the subset of a process in which the distinctive process signatures are visible within the sensitive regions of the detector volume.

Efficiency:

$$\epsilon = \frac{N'_{events} \text{ in the active volume}}{N_{events} \text{ in the TPC}}$$

Voxelized TPC volume - divided into segments named as 'boxes'.

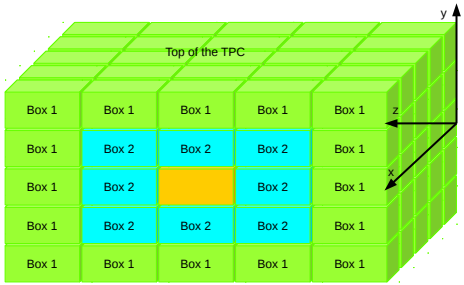


Figure: Cutting on the fiducial volume, green boxes indicate a symmetric cut. The TPC is divided into 50x50x50 equal volume segments (boxes).

Efficiency dependance on the cut on the fiducial volume

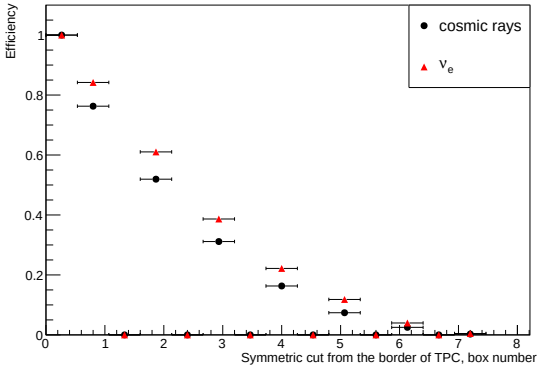
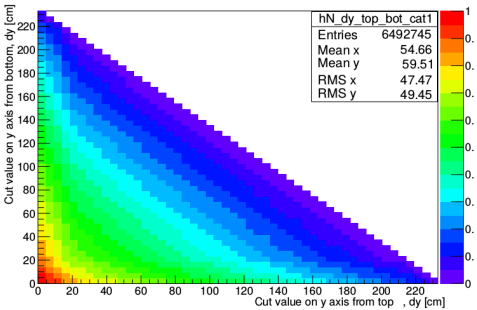
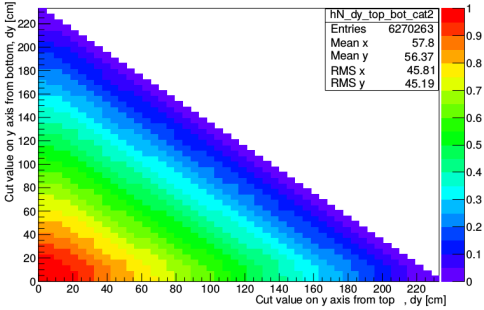


Figure: Efficiency dependance on the active volume of the detector applying symmetrical cuts, box number in x axis.

Efficiency dependance on the fiducial volume, top and bottom cuts for MC, y axis

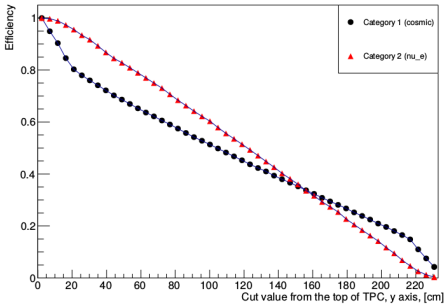


(a) Efficiency dependance on the cut on the fiducial volume for the cosmic events, y axis.

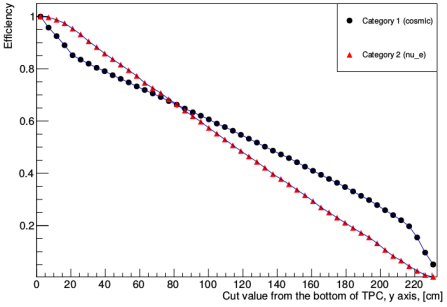


(b) Efficiency dependance on the cut on the fiducial volume for the ν_e events, y axis.

Efficiency dependance on the cut on y axis



(a) Efficiency dependance on the cut on the y axis, from the top of the TPC



(b) Efficiency dependance on the cut on the y axis, from the bottom of the TPC

Efficiency dependance on the active volume

Cut value [cm]	Active vol.	N_{cosmic}	ε_{cosmic}	N_{ve}	ε_{ve}
0	1.0000	15250	1.00000	11954	1.00000
23.3	0.9029	12242	0.89275	11424	0.95566
46.6	0.8058	10711	0.70236	10101	0.84498
69.9	0.7088	9479	0.62157	8964	0.74987
93.2	0.6117	8263	0.54183	7673	0.64187
139.8	0.4175	6003	0.39363	5096	0.42630
186.4	0.2233	3846	0.25219	2456	0.20545
233.0	0.0292	647	0.04242	37	0.00309

Figure: Number of events and efficiency dependance on the fiducial volume cut d.

Making cuts on y axis

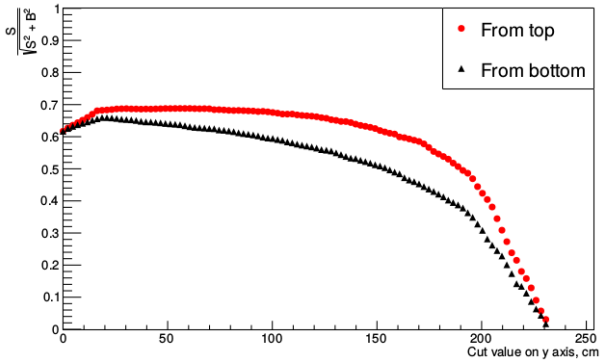
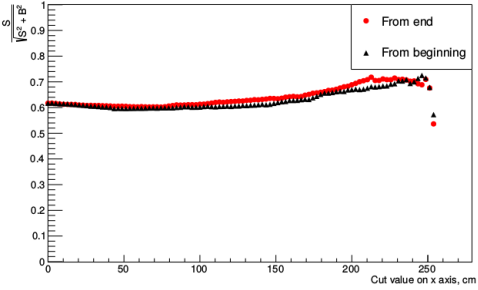


Figure: $\frac{S}{\sqrt{S^2+B^2}}$ dependance on the cut value on the y axis, from each the top and the bottom.

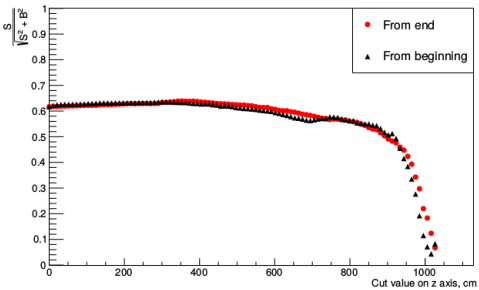
Cut value from top, [cm]	Signal, ν_e	Backgr., cosmic	$\frac{S}{\sqrt{S^2+B^2}}$	Cut value from bottom, [cm]	Signal, ν_e	Backgr., cosmic	$\frac{S}{\sqrt{S^2+B^2}}$
0.0	11954	15250	0.61692	0.0	11947	15250	0.61692
4.66	11920	14842	0.63577	4.66	11920	14472	0.63225
9.32	11826	13776	0.65136	9.32	11826	13776	0.64181
13.98	11636	12895	0.66993	13.98	11636	12895	0.65118
18.64	11424	12242	0.68226	18.64	11424	12242	0.65963
23.3	11165	11888	0.68459	23.3	11165	11888	0.65836
27.96	10960	11591	0.68705	27.96	10960	11591	0.65453
32.62	10675	10675	0.68662	32.62	10675	11303	0.65250
37.28	10374	11005	0.68593	37.28	10374	11005	0.64797
41.94	10101	10711	0.68609	41.94	10101	10711	0.64587

Figure: Number of events for both signal and background after applying different cut values on the y axis from the top and bottom.

Making cuts on x or z axis



(a) $\frac{S}{\sqrt{S^2+B^2}}$ dependance on the cut value on the x axis, from each the top and the bottom.



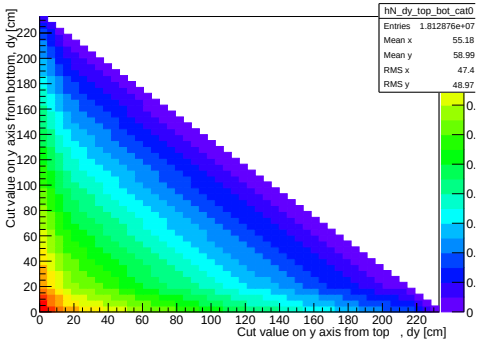
(b) $\frac{S}{\sqrt{S^2+B^2}}$ dependance on the cut value on the z axis, from each the top and the bottom.

Conclusions

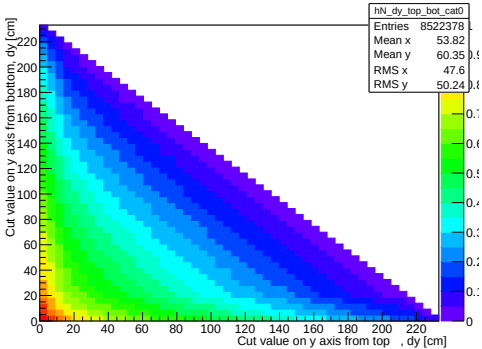
1. It is crucial to study the **cosmic background** in order to achieve the good background rejection rates and look for new physics.
2. Voxelized cuts on the fiducial volume are not ideal for distinguishing ν_e and cosmic events, cuts on each axis separately perform better.
3. Best selected cut value from the both top and bottom of y axis: **18.6 cm**.
4. Making cuts on either x or z axis does not result in better signal and background separation.
5. Additional variables are needed in order to remove the cosmic background.

Backup

Efficiency dependance on the fiducial volume, top and bottom cuts for data, y axis



(a) Efficiency dependance on the cut on the fiducial volume for the BNB data, y axis.



(b) Efficiency dependance on the cut on the fiducial volume for the external data, y axis.

Efficiency dependance on the kinetic energy of the proton

- Algorithm requires to have at least one track and one shower.

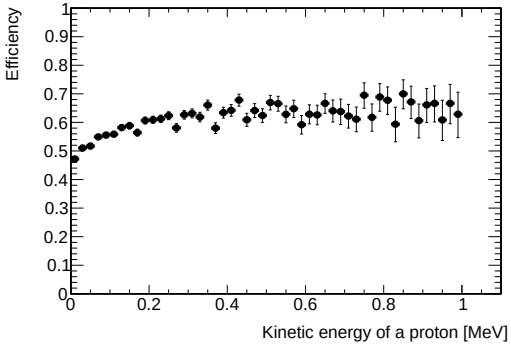


Figure: The dependance of the efficiency of the selection algorithm on the kinetic energy of a proton.

Efficiency dependance on the active volume

Cut value (Box)	Active vol.	N_{cosmic}	N_{ν_e}	ϵ_{cosmic}	ϵ_{ν_e}
0	1.0000	15250	11954	1.00000	1.00000
23.3 cm (5)	0.9029	12242	11424	0.80275	0.95566
46.6 cm (10)	0.8058	10711	10101	0.70236	0.84498
69.9 cm (15)	0.7088	9479	8964	0.62157	0.74987
93.2 cm (20)	0.6117	8263	7673	0.54183	0.64187
139.8 cm (30)	0.4175	6003	5096	0.39363	0.42630
186.4 cm (40)	0.2233	3846	2456	0.25219	0.20545
233 cm (50)	0.0292	647	37	0.04242	0.00309

Table: Number of events and efficiency dependance on the fiducial volume cut d.