Analysis and interactive visualization of neutrino event topologies registered in the OPERA experiment

Sergey Dmitrievsky

Dzhelepov Laboratory of Nuclear Problems

JINR, Dubna, Russia

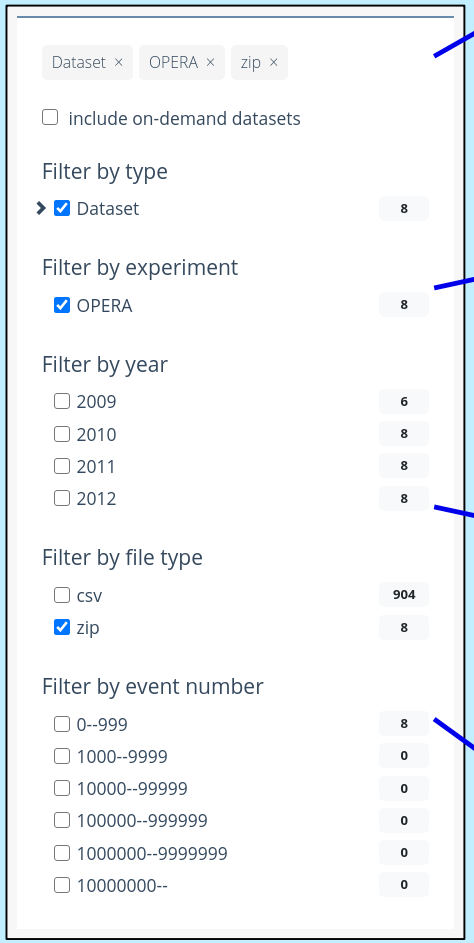
Task 1 (Introduction)

INTEREST @JINR, Wave 9, Project #253

Task 1

1) Download OPERA emulsion dataset for the neutrino-induced charmed hadron production studies from the Open Data Portal. Develop a C++ program for analysis of the dataset. Read the positions of the primary and the secondary interaction vertices as well as the parameters of the charm decay daughter particle tracks. Calculate and save to histograms **a)** flight lengths of charmed hadrons and **b)** impact parameters of the daughter particle tracks with respect to the primary neutrino interaction vertices. Save the histograms to a ROOT or to an image file. Compare the results with the ones published in the corresponding OPERA paper.

Downloading the OPERA datasets



Emulsion data for neutrino-induced charmed hadron production studies

The dataset was extracted from the official OPERA data repository. It contains 50 muon neutrino interactions with the lead target where a charmed hadron is reconstructed in the final state. Neutrin...

Dataset Derived OPERA

for the Task 1)

Emulsion data for track multiplicity

The dataset was extracted from the official OPERA data repository. It contains 817 muon neutrino interactions with the lead target where a muon was reconstructed in the final state. This happens in th...

Dataset Derived OPERA

for the Task 2)

Emulsion data for neutrino tau appearance studies

This dataset was extracted from the official OPERA data repository and it contains all the emulsion data information for the ten tau neutrino candidates, identified after an extensive analysis that...

Dataset Derived OPERA

for the Task 3)

Electronic detector data for tau neutrino appearance studies

This dataset was extracted from the official OPERA data repository and it contains all the data of the electronic detectors for the ten tau neutrino candidates, identified after an extensive analys...

Dataset Derived OPERA

for the Task 4)

How were these data validated?

During the data taking, all the runs recorded by OPERA are certified as good for physics analysis if the trigger and all sub-detectors show the expected performance. Moreover, the time stamp of the event should lie within the gate open by the CNGS beam signal. The data certification is based first on the offline shifters evaluation and later on the feedback provided by all sub-detector experts. Based on the above information, stored in a specific database, the Data Quality Monitoring group verifies the consistency of the certification and prepares an ascii file of certified runs to be used for physics analysis. For this specific data record, dedicated calibration procedures are performed to align the emulsion films each other and with the electronic detectors. These procedures with the corresponding results are saved in a dedicated database where data quality experts certify the results and prepare files to be used for the track and vertex reconstruction, thus being available for physics analysis.

Files

Filename	Size	
emulsion-data-for-charm-studies.zip	48.5 kB	Download

Disclaimer

The open data are released under the Creative Commons CC0 waiver. Neither OPERA nor CERN endorse any works, scientific or otherwise, produced using these data. All releases will have a unique DOI that you are requested to cite in any applications or publications.

PUBLIC DOMAIN

From the OPERA paper

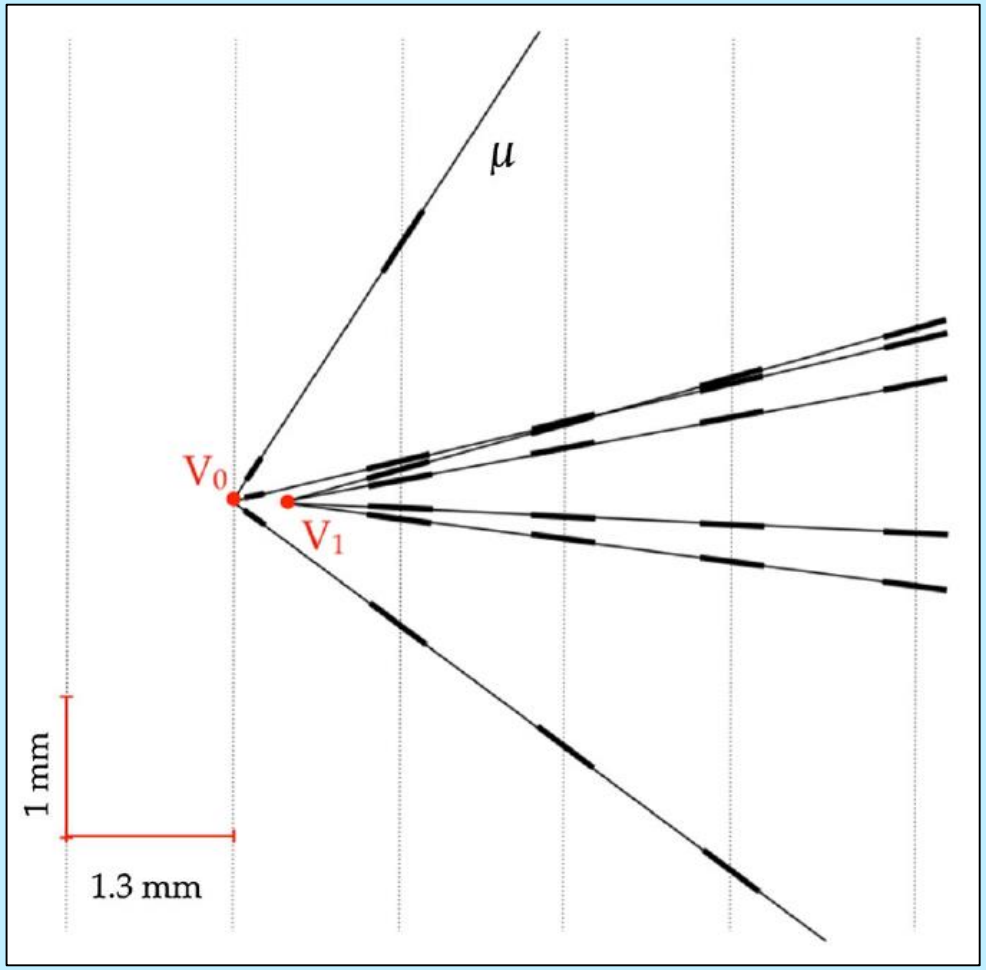
[Eur. Phys. J. C (2014) 74:2986]

Total number of fully analyzed ν events: 2925

Table 2 Summary of expected charm and background events compared to observed events. Statistical and systematic errors are summed in quadrature

Decay topology	Events			
	Expected charm	Expected background	Expected total	Observed
1-prong	21 ± 2	9 ± 3	30 ± 4	19
2-prong	14 ± 1	4 ± 1	18 ± 1	22
3-prong	4 ± 1	1.0 ± 0.3	5 ± 1	5
4-prong	0.9 ± 0.2	–	0.9 ± 0.2	4
Total	40 ± 3	14 ± 3	54 ± 4	50

50 ν_μ interactions with the lead target where a charmed hadron was reconstructed in the final state



Sketch of a reconstructed ν_μ charged-current interaction with a candidate charmed hadron observed in the final state.

Description of the variables from the *.csv files

These variables can be used just for crosschecks/comparison (optionally)

We will read these variables and use them for our calculations

*_Vertices.csv

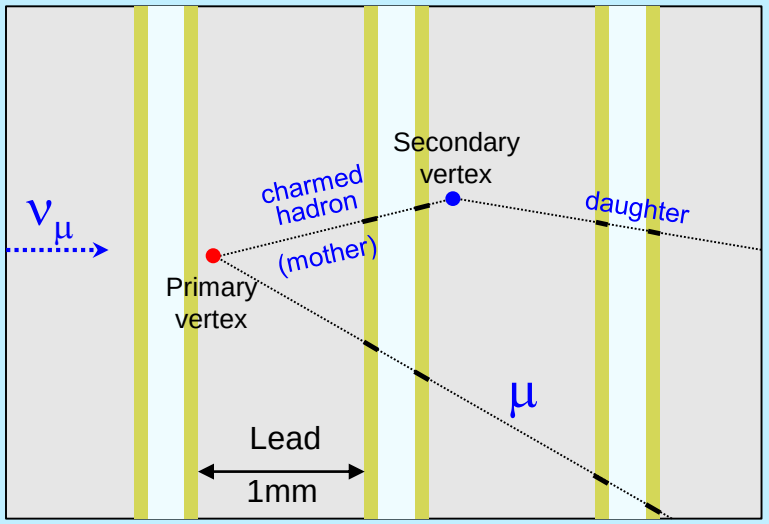
*_TrackLines.csv

Dataset semantics

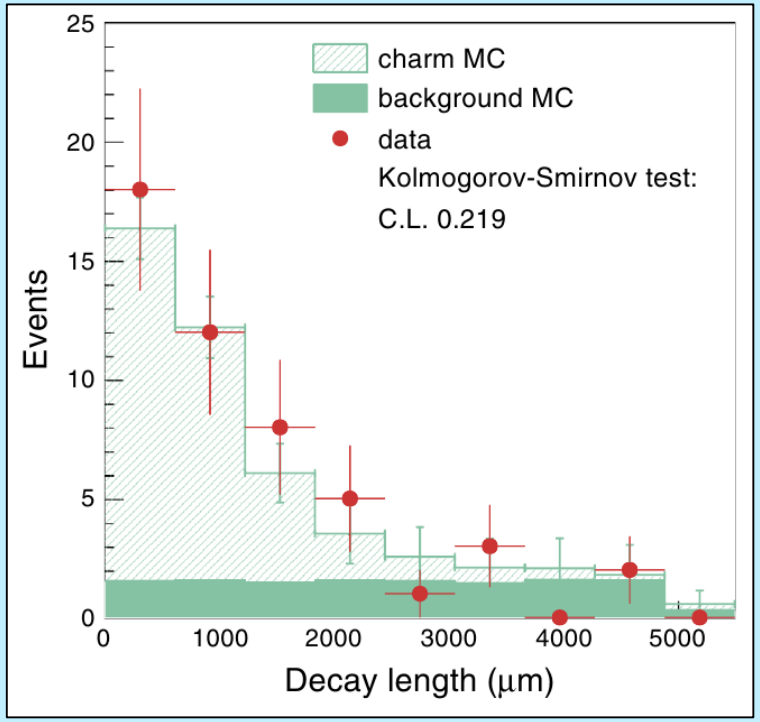
Variable	Description
categ	category of a decay topology: 1 - short; 2 - long
decL	decay length (in micrometers)
globPosX	X position of a vertex in the OPERA detector system of reference (in cm)
globPosY	Y position of a vertex in the OPERA detector system of reference (in cm)
globPosZ	Z position of a vertex in the OPERA detector system of reference (in cm)
ip1	impact parameters of the 1st daughter tracks with respect to the primary neutrino interaction vertex (in micrometers)
ip2	impact parameters of the 2nd daughter tracks with respect to the primary neutrino interaction vertex (in micrometers)
ip3	impact parameters of the 3rd daughter tracks with respect to the primary neutrino interaction vertex (in micrometers)
ip4	impact parameters of the 4th daughter tracks with respect to the primary neutrino interaction vertex (in micrometers)
posX	For Electronic Detector events, X position of a drift tube, RPC, Target Tracker hit in the OPERA detector system of reference (in cm). For Emulsion Detector events, X position of a track/vertex in the OPERA brick system of reference (in micrometers).
posX1	X position of the beginning of a line in the OPERA brick system of reference (in micrometers)
posX2	X position of the end of a line in the OPERA brick system of reference (in micrometers)
posY	For Electronic Detector events, Y position of an RPC hit in the OPERA detector system of reference (in cm). For Emulsion Detector events, Y position of a track/vertex in the OPERA brick system of reference (in micrometers).
posY1	Y position of the beginning of a line in the OPERA brick system of reference (in micrometers)
posY2	Y position of the end of a line in the OPERA brick system of reference (in micrometers)
posZ	For Electronic Detector events, Z position of a drift tube, RPC, Target Tracker hit in the OPERA detector system of reference (in cm). For Emulsion Detector events, Z position of a track/vertex in the OPERA brick system of reference (in micrometers).
posZ1	Z position of the beginning of a line in the OPERA brick system of reference (in micrometers)
posZ2	Z position of the end of a line in the OPERA brick system of reference (in micrometers)
prong	decay topology: 1 - 1-prong, 2 - 2-prong, 3 - 3-prong, 4 - 4-prong
trType	type of a track: 9 - charmed hadron, 1 - muon; 10 - daughter particle; 2 - hadron at primary vertex
vertType	type of a vertex: 1 - primary vertex; 2 - secondary vertex

Calculation of the flight lengths of charmed hadrons

Flight length (or decay length) of a charmed hadron is just a distance between the primary and the secondary vertices of the neutrino interaction event, i.e., the distance between two points in 3D space.

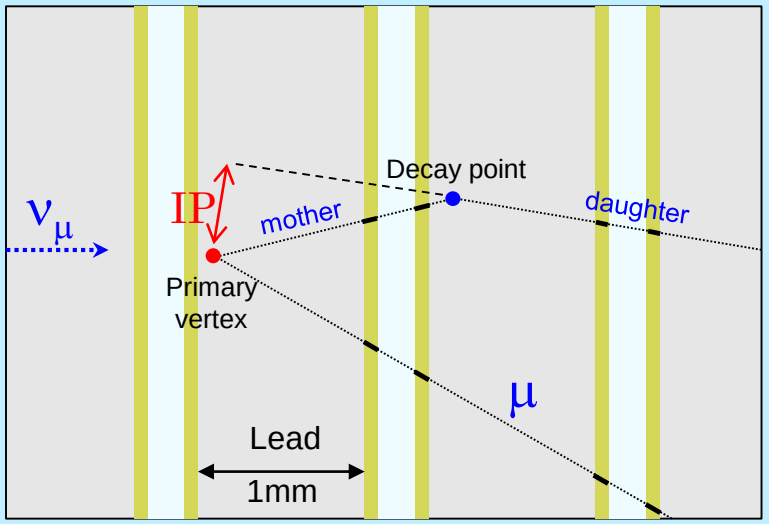


Result from the article

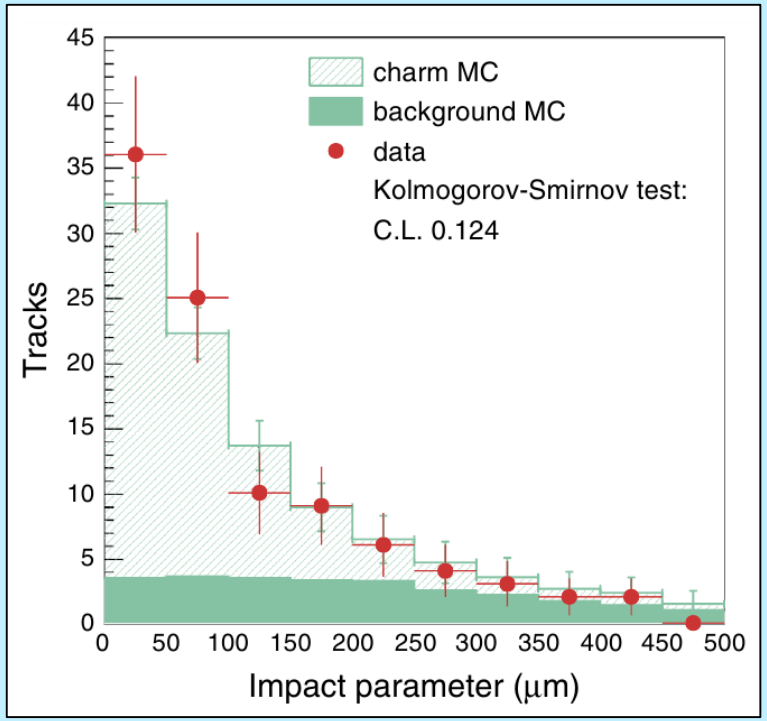


Calculation of the impact parameters of the daughter particle tracks with respect to the primary neutrino interaction vertex.

Impact parameter (IP) is a distance between the daughter particle track and the primary neutrino interaction vertex, i.e., the distance between a line and a point in 3D space.



Result from the article



Backup slides

Histograms in ROOT

A very comprehensive description:
https://root.cern/doc/master/classTH1.html

A ROOT Guide For Beginners (Chapter 5 is about the histograms):
https://root.cern.ch/root/htmldoc/guides/primer/ROOTPrimer.pdf

ROOT Histogram tutorials:
https://root.cern/doc/master/group__tutorial__hist.html