Effective volume estimation of a standard Baikal-GVD cluster

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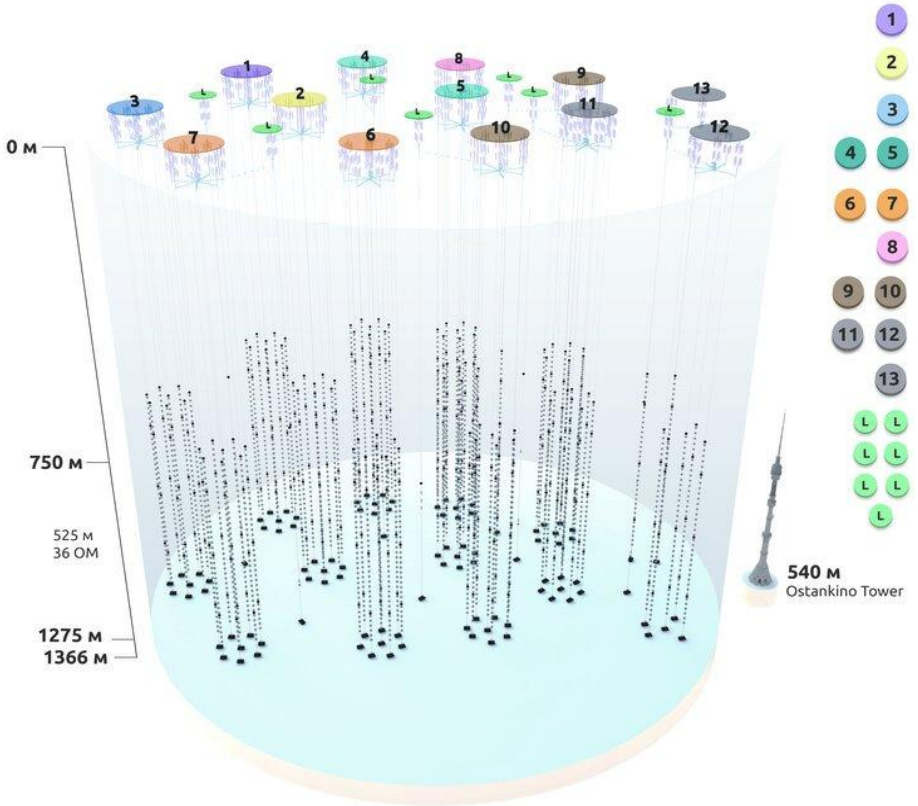
Baikal-GVD

Detection Principle of such experiments is based on the detection of Cherenkov light, which appears when particle is moving through medium with phase velocity up to the speed of light

Basic unit - cluster, containing 8 strings with 36 optical modules each

Until 2024 expedition, there was 13 working clusters



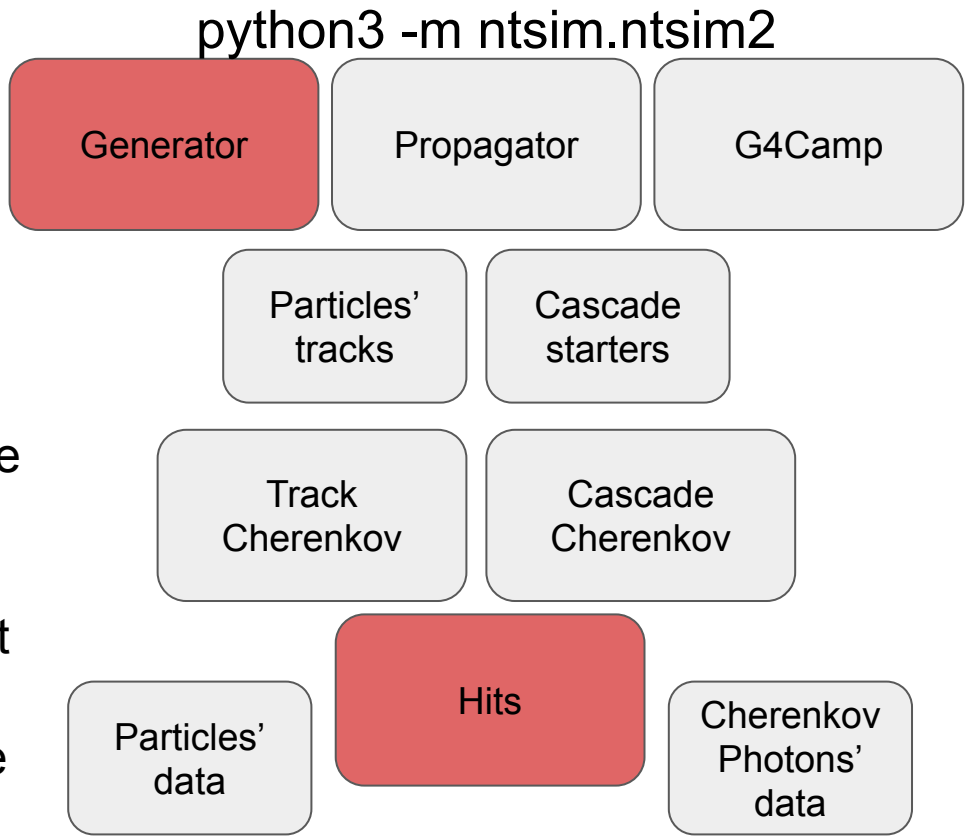
V. M. Aynutdinov, et al., 2023. Time Calibration of the Baikal-GVD Neutrino Telescope with Atmospheric Muons

NTSim Simulation Framework

<u>The NTsim is a framework</u>, which aims to simulate data for neutrino experiments, such as IceCube, KM3NET/Arca, Baikal-GVD, P-ONE and others planned in future, with the initial focus on the Baikal-GVD

<u>Development motivation:</u>

- User-friendly interface (graphic-interface launch/command-line launch)
- Different detector designs simulation(included in framework or set manually by users)
- To enhance the accuracy using diverse optimization methods



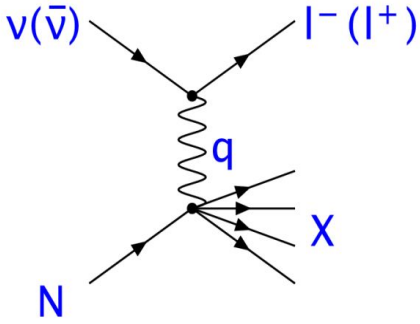
Neutrino generator - NuGen

NuGen is an NTSim module, developed to compute cross-sections for processes with HE neutrino. To count cross-sections it uses pre-evaluated x and y values, which can be integrated with Vegas package or set manually.

$$\frac{d^2\sigma}{d\Omega dE} \rightarrow \frac{d^2\sigma}{dxdy}$$

- in neutrino astronomy, the energy region which is to be observed is >100GeV, where the process of deep inelastic scattering is prevalent

- Deep inelastic scattering (DIS)

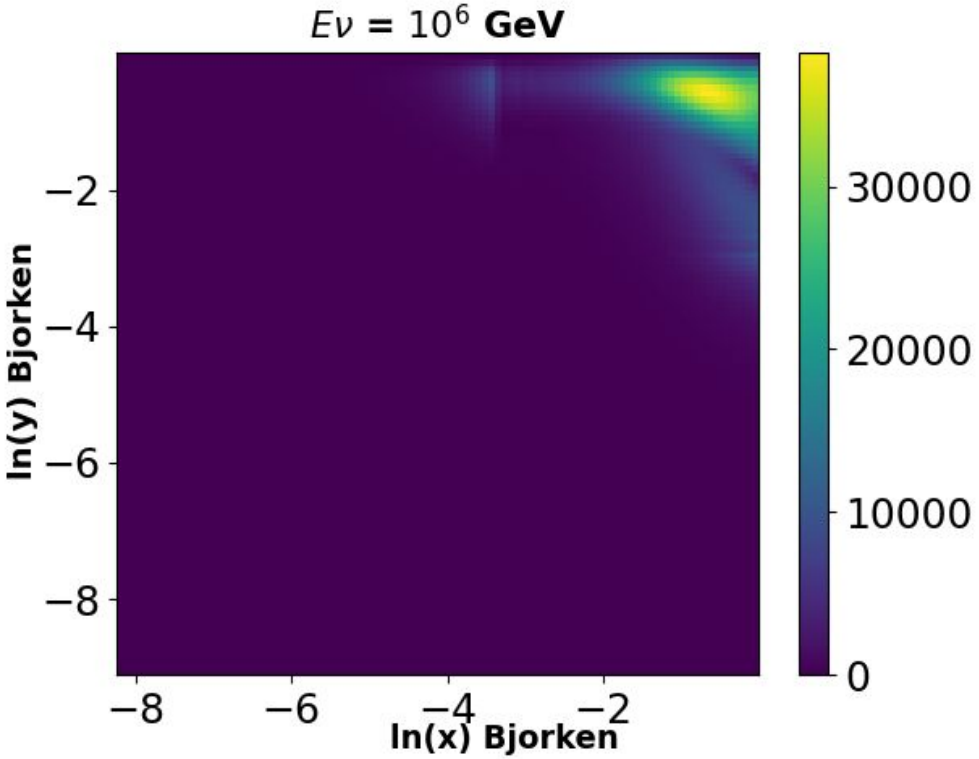


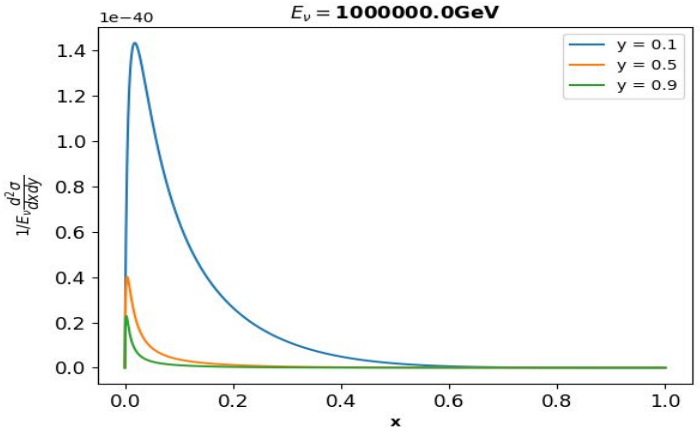
$$x_{bjorken} = -\frac{q^2}{2(P_N \cdot q)} \qquad y_{bjorken} = \frac{E - E'}{E}$$

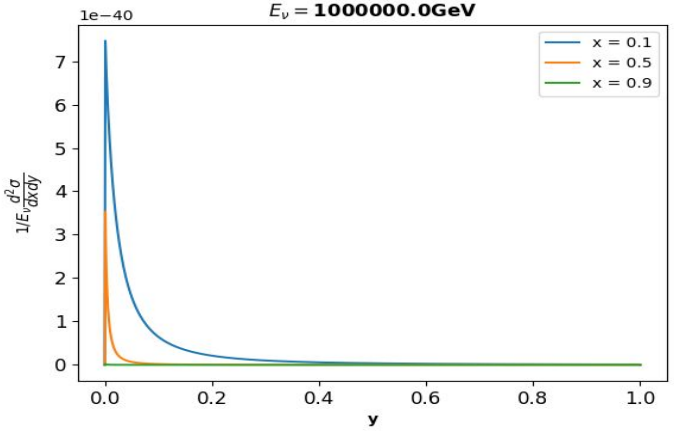
$$\frac{d^2\sigma^{\mathrm{DIS}}}{dxdy} = \frac{G_F^2 M_N E}{\pi(1+Q^2/M_W^2)^2} \sum_{i=1}^{5} A_i(x,y,E)\, F_i\left(x,Q^2\right)$$

$$K = (E, \vec{k})$$
$$K' = (E, \vec{k'})$$
$$q = K - K'$$

Cross-sections, $x_{bjorken}$ and $y_{bjorken}$ distributions







Effective volume estimation. Methods

For the procedure of an effective volume estimation some extra methods were added to the NuGen

NuGen

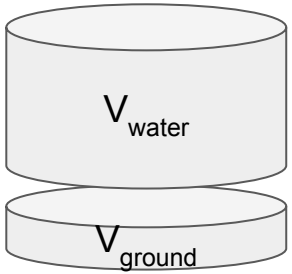
Probability choice of interaction medium

Probability choice of the interaction coordinates in the pre-counted volume

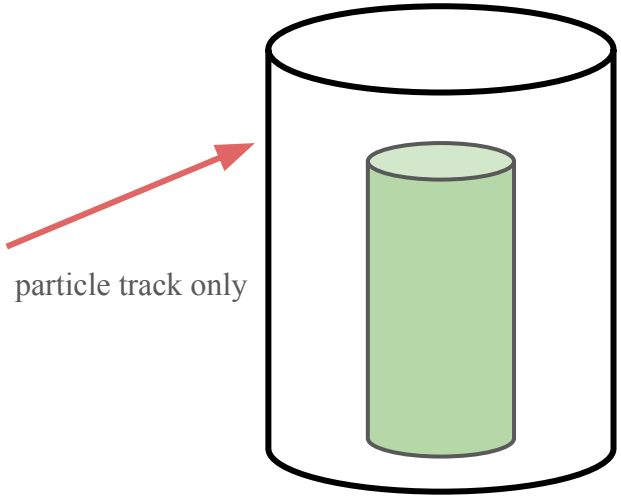
Photon generation volume restriction

$L = L_{muon}(E) + R_{detector}$

$R_{detector} = 60m$



Muon energy (GeV)	$\frac{1}{\rho}\left\|\frac{dE}{dx}\right\|$ (MeV cm^2/g)	CSDA range (g/cm^2)
1	2.109	4.706×10^2
10	2.507	4.260×10^3
100	3.020	3.629×10^4
1000	6.014	2.426×10^5
10^4	36.462	7.787×10^5
10^5	353.358	1.428×10^6



- instrumented volume

- cherenkov light generation volume

D.E. Groom, N.V. Mochov, S. Striganov, 2001. MUON STOPPING POWER AND RANGE TABLES 10 MeV—100 TeV

Effective volume estimation. Methods

Simulation process

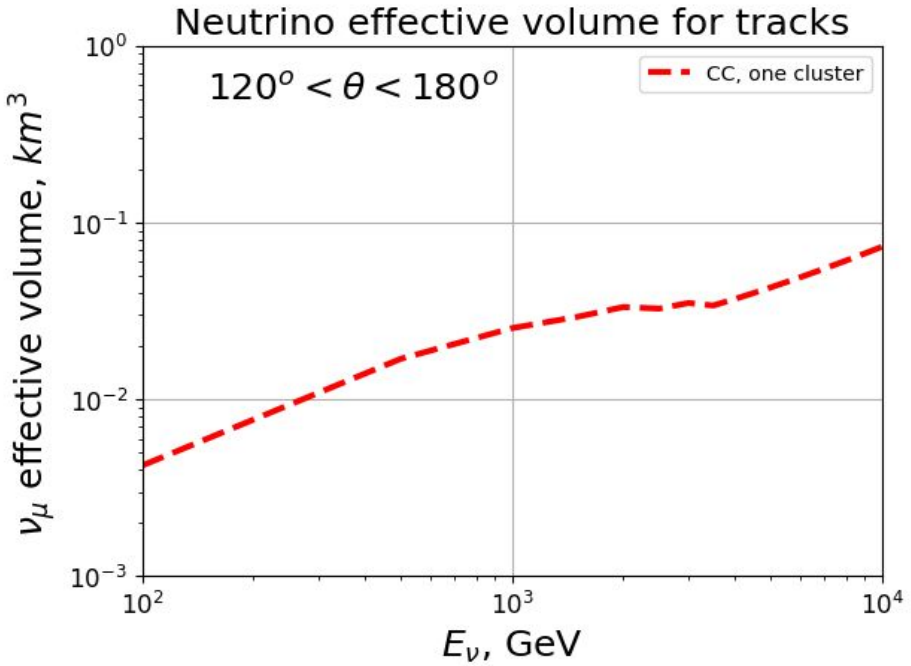
Hits – data on all the detected signal

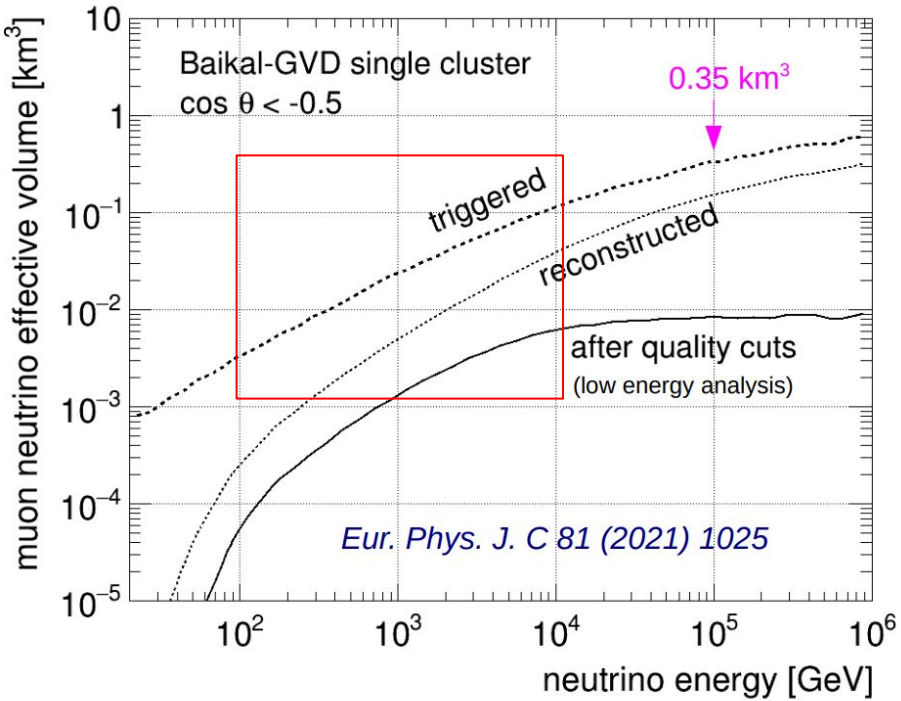
Trigger application to the detected signal

Triggered data = $N_{trigger}$ – triggered signal data

$$V_{eff} = \frac{N_{trigger}}{N_{events}} V$$

Comparison analysis





V. A. Allakhverdyan, et al., 2021. Measuring muon tracks in Baikal-GVD using a fast reconstruction algorithm

THANK YOU FOR YOUR ATTENTION!

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