

# Master Thesis on JUNO

Status Report 01

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# Outline

## Introduction

- My background

- Purpose of the Master Thesis

## Atmospheric muon background

- Previous work

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- Type of interactions

- Charge Spectrum

- First Hit Time

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# Introduction : My background

- ▶ Bachelor and Master in Physics at ULB
- ▶ Mostly particle and mathematical physics courses
- ▶ Research internships at IIHE about JUNO (2023 and 2025)



# Introduction : Purpose of the Master Thesis

**Title :** Atmospheric neutrino signal - Analysis of the first data from the JUNO experiment (provisional)

## 1. First Part

- ▶ **Overview** of the JUNO experiment
- ▶ **Simulation data** analysis for **atmospheric neutrinos**

## 2. Second Part

- ▶ JUNO first data analysis in its **final configuration**  
(scintillator)
- ▶ **Identifying and characterizing** atmospheric neutrino events
- ▶ **Selection cuts** and **reconstruction algorithms** optimized and validated with simulations

# Atmospheric muon background : Previous work

For **water** in the detector :

## 1. Offline Data Simulations

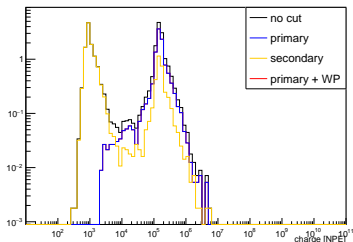
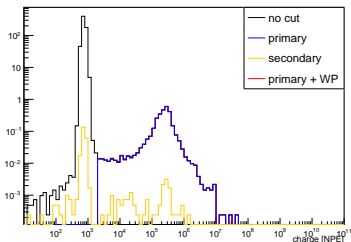
- ▶ Monte Carlo simulation for cosmic ray muons

## 2. Real Data with water

- ▶ Data taken in early 2025
- ▶ **TQ level** (COTI reconstruction at software level)

# Atmospheric muon background : Previous work

Atmospheric muon background :



- Atmospheric muon **charge spectrum** for water data in JUNO
- Comparison between **MC simulations** and **TQ data**

# Atmospherical Neutrinos : Simulations

## ► Data set

- GENIE neutrino MC simulations for atmospheric neutrinos (TQ level)
- Energy distribution up to 20 GeV
- $5 \times 10^5$  events simulated ( $\nu_e + \nu_\mu$ )
- Propagation of secondary particles in liquid scintillator with GEANT4

## ► Event selection

- Based on atmospheric muon background study (parameters to be optimized)

# Atmospherical Neutrinos : Type of interactions

Different types of neutrino detected :

- ▶ **Charged Current (CC) :**  $\nu_e$  and  $\nu_\mu$

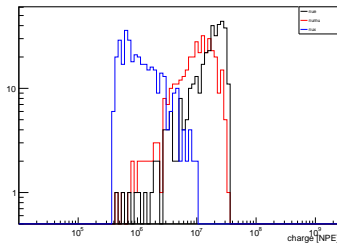
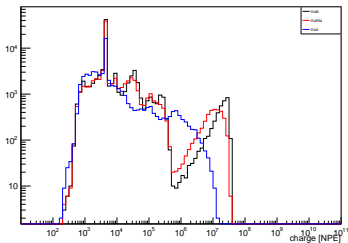
- ▶  $W^\pm$  exchanges with matter
- ▶ Produces a charged lepton :  $\nu_\ell + N \rightarrow \ell^- + X$
- ▶ Lepton flavour is preserved

- ▶ **Neutral Current (NC) :**  $\nu_x$

- ▶  $Z^0$  exchanges with matter
- ▶ Neutrino remains in final state:  $\nu_\ell + N \rightarrow \nu_\ell + X$
- ▶ No charged lepton produced, harder to detect



# Atmospherical Neutrinos : Charge Spectrum



- ▶ Charge spectrum for atmospheric neutrino events before (left) and after (right) selection cuts (secondary particles and background noise removed)
- ▶ NC events lower in charge :  $\nu_e + \text{atom} \rightarrow \nu_e + \text{atom}^*$  (energy *stays* in the  $\nu_e$ )

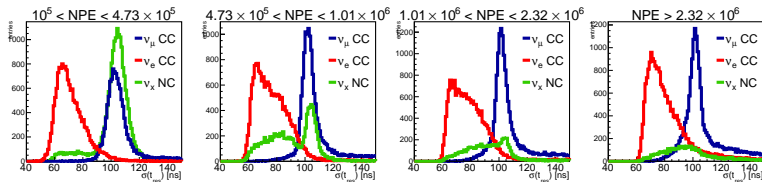
# Atmospherical Neutrinos : First Hit Time

- ▶ High precision measurement of the **photon arrival time** on the PMTs
- ▶ Gaussian smearing applied on the true MC hit time (3" PMTs)
- ▶ **Residual time**,  $t_{\text{res}}$ , to be aligned with a realistic DAQ window :

$$t_{\text{res}}^i = t_{\text{hit}}^i - \left( \frac{n \cdot R_V^i}{c} \right)$$

- ▶ **FHT**  $\equiv \sigma(t_{\text{res}})$  defined by the RMS of  $t_{\text{res}}$
- ▶ Discrimination variable for  $\nu_e$ ,  $\nu_\mu$  and  $\nu_x$  interactions

# Atmospherical Neutrinos : First Hit Time



Graph taken from *Atmospheric neutrino spectrum reconstruction with JUNO*, Oct. 2019 (ROOT stopped running on my computer...)

- ▶ **FHT distribution** for CC and NC interactions
- ▶ Separated by deposited charge (NPE)
- ▶ Variable used for **event selection** in order to **discriminate neutrino types**

## Next steps

- ▶ Optimization of **selection cuts** (including FHT)
- ▶ **Neuronal Network** implementation ??
- ▶ **State of the art** (JUNO experiment and atmospheric neutrino analyses/parameters)