DsTau (NA65) – CERN experiment approved by CERN in June 2019

Study of tau-neutrino production at the CERN-SPS

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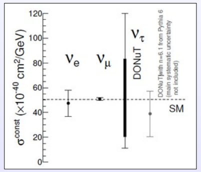
Tau-neutrinos

- Discovered by the DONuT collaboration (2000); cross-section measurement uncertainty >50%
- One of the least studied particles in the Standard Model
- Oscillated ν_τ: OPERA, Super-K, IceCube

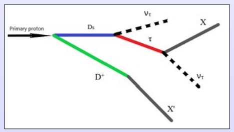
Physics motivation – reduce the uncertainty for:

- Testing Lepton Universality
- Neutrino oscillation experiments
- High energy astrophysical ν_τ



Differential production cross-section and D_s momentum

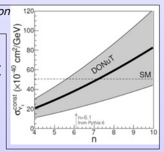
- ν_τ source: $D_S \rightarrow \tau \rightarrow X$ decays



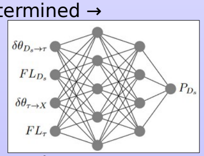
$$\frac{d^2\sigma}{dx_F \cdot dp_T^2} \propto \left(1-|x_F|\right)^n \cdot e^{-b \cdot p_T^2} \qquad x_F = \frac{2\, p_z^{CM}}{\sqrt{s}}$$

Longitudinal dependence — Transverse dependence

Cross-section parametrization used in DONuT

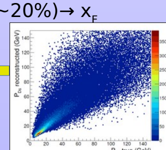


- Reduce the ν_τ cross-section measurement uncertainty, the D_S differential production cross section needs to be determined (DsTau Experiment)
- DS momentum cannot be directly determined → momentum reconstruction by topological variables:



- The variables were put in a neural network to determine momentum resolution (~20%)→ x_F reconstruction.

Δp/p = 20%

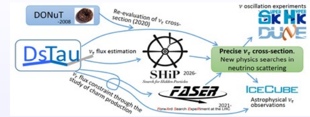


References

- https://na65.web.cern.ch
- DsTau Collaboration, DsTau: Study of tau neutrino production with 400 GeV protons from the CERN-SPS, JHEP01, (2020) 033 CERN-SPSC-2021-020 / SPSC-SR-295 1/06/2021
- Osamu Sato, for the DsTau Collaboration: Study of tau neutrino production with nuclear emulsion at CERN SPS (https://indico.cern.ch/event/982783/contributions/4362340/)

DsTau experiment physics goal

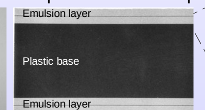
- Measurement of D_s double differential production cross section
- Reduce the systematic uncertainty from 50% to 10%
- Pave the way for future ν_τ experiments



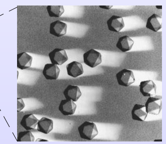
Nuclear emulsion detector

- 3D tracking device with good spatial resolution (50nm)
- Comprises silver halide crystals (200nm in diameter)
- The trajectory of a charged particle that passes through the emulsion is shown as a black track and can be observed under an optical microscope

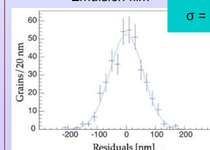
Emulsion film



Cross-sectional view

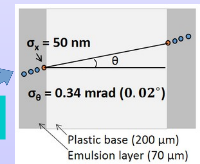


AgBr crystals

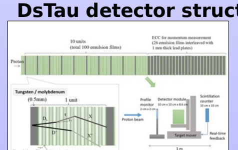


σ = 50nm

Angular resolution 0.35 mrad with 200 µm base



DsTau detector structure



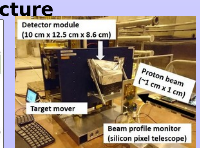
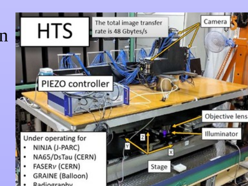


Photo of detector setup taken from the CERN SPS beamline

Uniform irradiation on detector surface

- The DsTau detector module is made up of 131 emulsion films, 10 tungsten plates and 25 lead plates
- Reading of emulsion films with the Hyper Track Selector at Nagoya University; scanning speed of ~0.5m²/h.
- A new scanning system (HTS-2) is under development



Test beams and pilot run

2016 test run	2017 test run	2018 pilot run
Test for detector structure	Improvement of detector structure	1/10th of the full experiment
	Improvement of beam exposure scheme	50%→30% uncertainty
		DONuT update ντ cross section

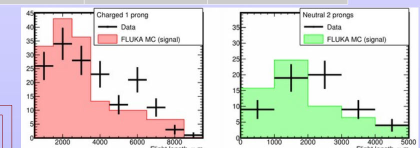
For the 2018 pilot run, all emulsions were made manually. An automated system for emulsion film production was implemented at Nagoya University, which was used to make the emulsion films for the 2021 physics run.

Data analysis

- 3.4253301×10^7 injected protons were analyzed
- 2.72120×10^5 proton interactions detected (1.47236×10^5 interactions in tungsten)
- 159 events with charm pair (115 events from tungsten interactions)

	Observed	Expected	
Vertices in tungsten	147236	155135	
		Signal	Background
Double decay topology	115	80.1±19.2	12.7±5.0

Flight length of charged charm candidates (red plot) and neutral charm candidates (green plot)



Prospects

- 2021 and 2022 physics runs – ν_τ production measurement by detecting 1000 $D_S \rightarrow \tau \rightarrow X$ events from 2.3×10^8 proton interactions on tungsten
- New detector configuration to be used