DsTau (NA-65): study of tau neutrino production at CERN-SPS

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Abstract

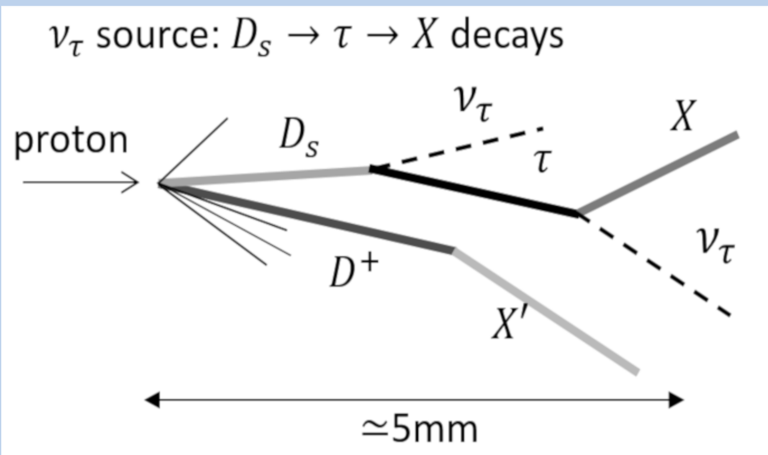
The lack of data for the process of tau neutrino production in high energy proton interactions causes the largest uncertainty in current and future measurement of tau neutrino interaction cross section, preventing a precise test of Lepton Flavour Universality in neutrino scattering. DsTau (NA65) at CERN-SPS is a recently approved experiment, which aims to study this process. The main source for tau neutrinos is the decay of D_s mesons, namely $D_s \to \tau$ and then $\tau \to X$. The peculiar D_s cascade decay topology ("double kink") in a few millimeters range is detected by the nuclear emulsion tracker due to its excellent spatial resolution. A large amount of charmed particles decay events ($\sim \mathbf{10^5}$) is expected to be detected as well, providing a possibility for interesting by-product studies, in particular a search for intrinsic charm in a proton. A pilot data sample was collected in 2018. Main data sample (ten times more events) will be collected in 2021-2022.

Goals and principles of the experiment

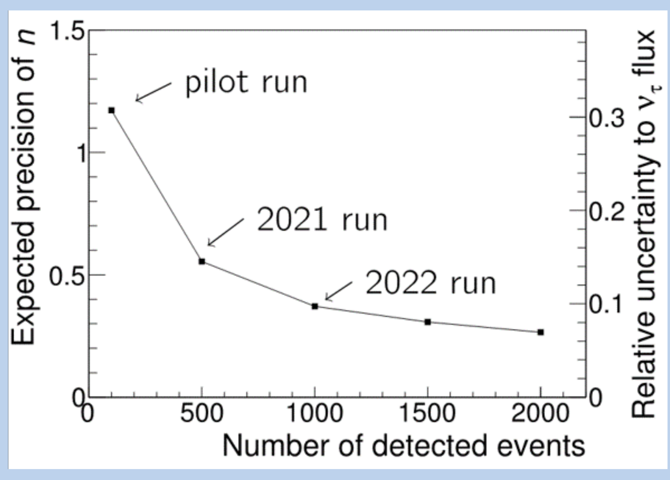
Goals:

- Studying ν_τ production
- Reducing the systematic uncertainty of ν_τ flux prediction
- Testing Lepton Universality in neutrino interactions
- Measuring D_s double differential production cross section
- Providing fundamental input for future experiments

The main source of tau neutrinos is the decay of D_s mesons, which has a distinct topology. After collecting 100% of the data it is expected to identify $\sim$ **1000** $D_s \to \tau$ decays.



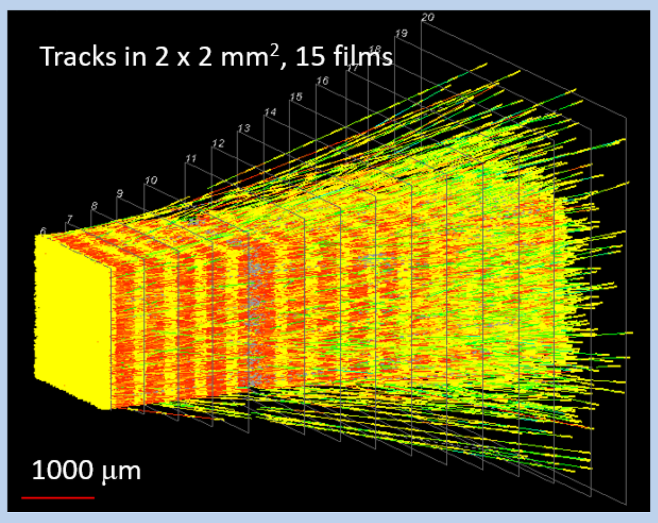
The signal topology



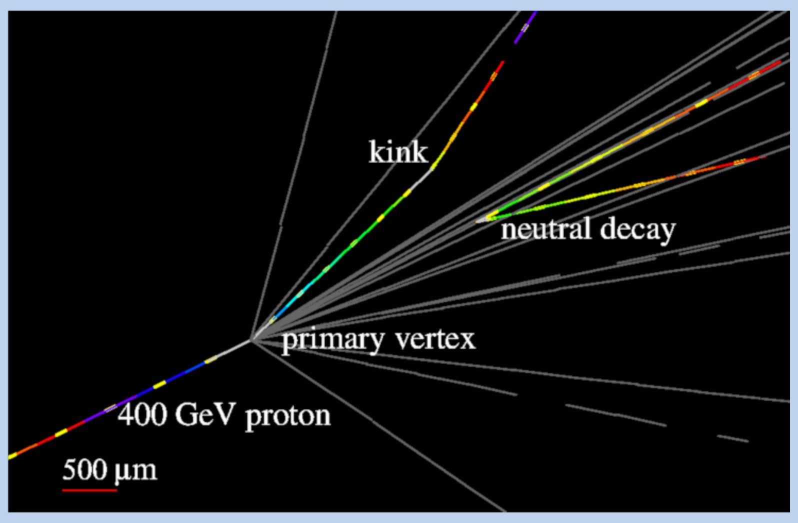
Expected precision of the DsTau experiment

Scanning and reconstruction

- The track density is very high – $\sim \mathbf{10^5}$ tracks/cm^2
- In modern emulsion experiments, the information is extracted with help of fully automatic scanning stations with a speed of about 5000 cm^2 per hour
- The scanning is done in two stages: first all emulsions are scanned by a fast HTS scanning system with a relatively coarse spacial and angular resolution, after which interesting events are scanned at slower but more precise scanning systems



Reconstructed tracks in 2×2 mm^2 area of 15 emulsion films



A reconstructed event with topology similar to the signal one

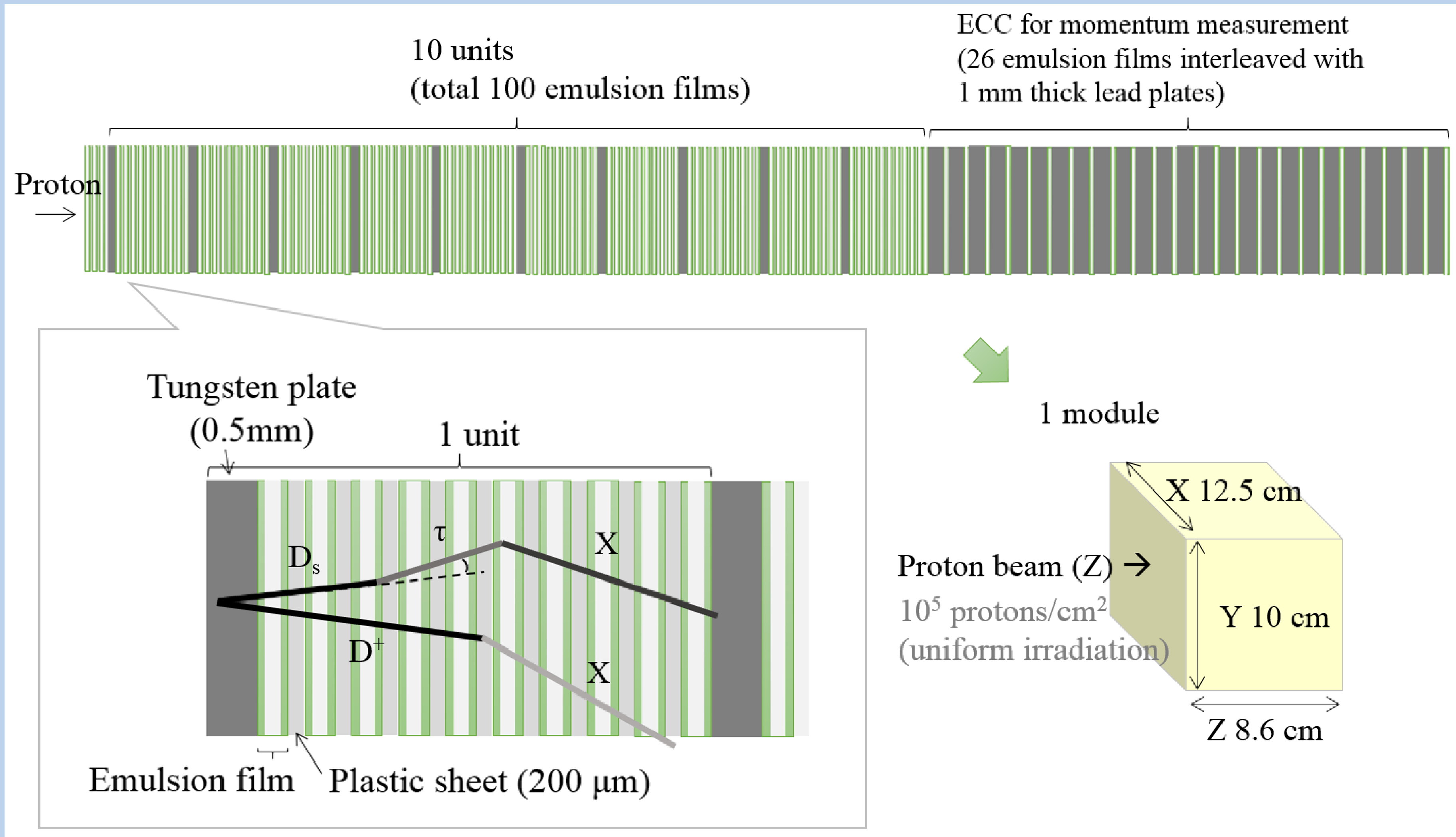
Schedule

Run	Emulsion exposure	Goal
Test beam 2016	10 modules	Test the setup Prove principle
Test beam 2017	2 modules	Refine exposure scheme
Pilot run 2018	30 modules (48 m^2)	Test large data taking Estimate background Collect $\sim$ **10%** of all data Revise DONUT results
Physics run 2021-2022	338 modules (545 m^2)	Collect all data Obtain final results

Project schedule. Green – finished steps, yellow – in progress, orange – future stages

Experimental setup

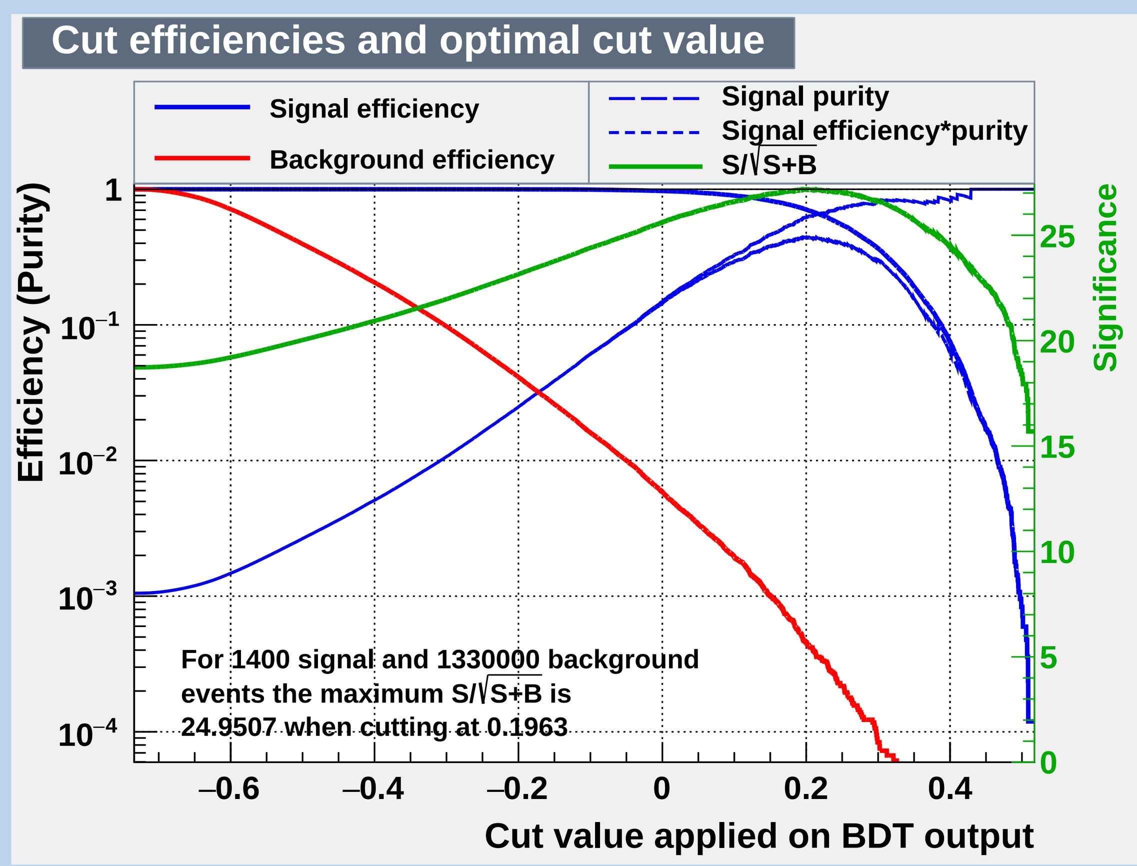
Event registration is a challenge: all the decays take place at a scale of millimetres, moreover, the kink angle of $D_s \to \tau$ is anticipated to be very small, about 7 mred on average. Therefore an emulsion detector with nanometric spatial resolution is used to efficiently recognize the events.



Schematic view of the module structure. Each tungsten target plate followed by 10 emulsion films alternated by 9 plastic sheets acting as a tracker and decay volume of 4.8 mm. The sensitive layers of emulsion detectors are indicated by green color. This basic structure is repeated 10 times, and then followed by a lead-emulsion ECC structure for measurement of the momentum of the daughter particles

Evaluating charged hadronic background

- The main background consists of hadronic interaction events with the topology similar to the signal one
- Background has to be evaluated separately for two signal channels – one with a charged charmed particle, which was born together with the D_s meson, and another with a neutral partner
- Approximately **575** (out of $\sim$ **2500**) charged channel signal events and **27650** background events are expected to pass selection with rectangular cuts on the first stage of scanning
- Boosted Decision Tree method was used to improve signal-background separation. The following variables were chosen for separation:
  - Path of $D_s + \tau$
  - Kink angle of $\tau \to X$ decay
  - Longitudinal coordinate of τ decay
  - Impact parameter of X to primary vertex
  - Path of charmed partner
  - Kink angle of partner $\to X'$ decay
  - Longitudinal coordinate of partner's decay
  - Impact parameter of X' to primary vertex



BDT plots for signal-background separation

- Using BDT method expected number of charged channel signal events was increased to **1398** events with the same level of background ($\sim$ **28000** events)

References

DsTau: study of tau neutrino production with 400 GeV protons from the CERN-SPS *The DsTau collaboration, Aoki, S., Ariga, A. et al. J. High Energ. Phys. (2020) 2020: 33.*