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RECENT RESULTS FROM THE DSTAU(NA65) EXPERIMENT

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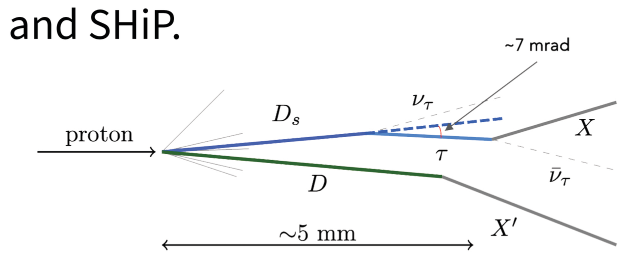
Abstract: The DsTau (NA65) experiment at CERN is designed to measure the inclusive differential cross section for D_s meson production in proton–nucleus (p–A) interactions, where the D_s meson decays into a tau lepton and a tau neutrino. The DsTau detector is based on the nuclear emulsion technique, which provides exceptional spatial resolution and enables precise detection of short-lived particles such as charmed hadrons. In this presentation, we report the first results from the analysis of pilot-run data, with particular emphasis on the performance of proton interaction vertex reconstruction in high track-density environments. The collected data are compared with predictions from several Monte Carlo event generators. The current status of the D_s search is also presented.

1 INTRODUCTION & MOTIVATION

• **The Tau Neutrino (ν_τ) Constraint:** The ν_τ is the least accurately measured lepton in the Standard Model. Prior to the DsTau (NA65) experiment, fewer than 30 direct ν_τ detection vertices had been observed globally.

• **Lepton Universality (LU):** Precise measurement of the ν_τ interaction cross-section (σ) allows us to test LU in neutrino scattering.

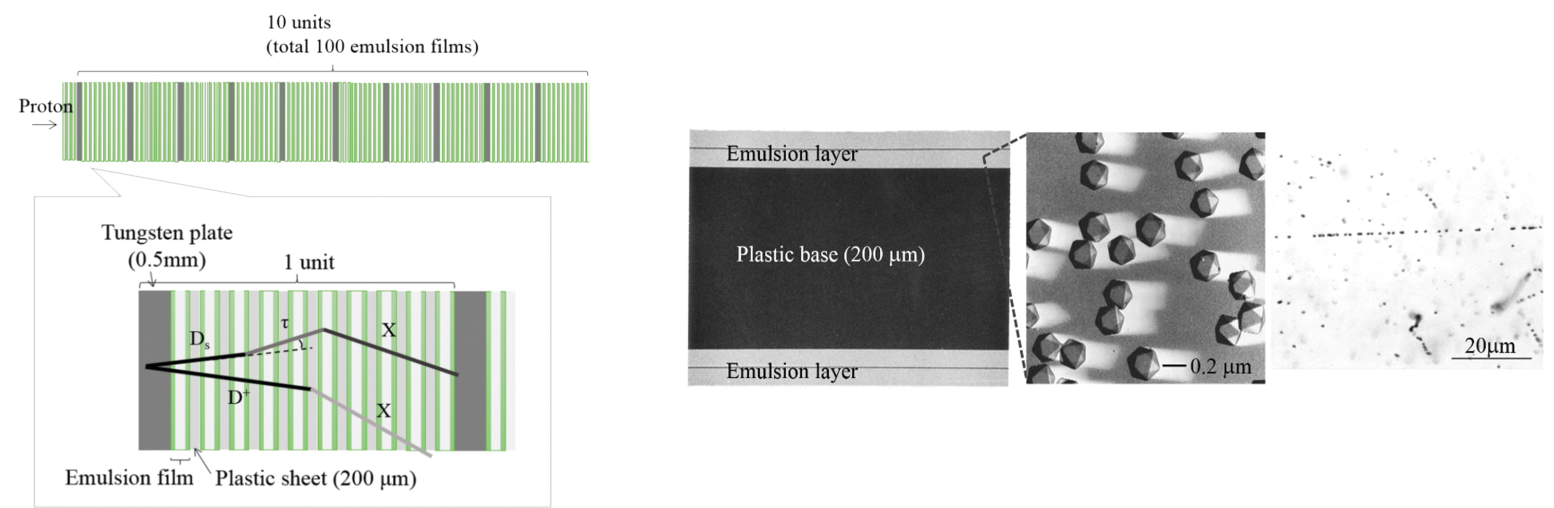
• **Experimental Objective:** Measure the differential production cross-section of D_s mesons at the CERN SPS to reduce the systematic uncertainty on the ν_τ flux from > 50% down to under 10%. This provides critical input for future experiments like FASER, SND@LHC, and SHiP.



2 EXPERIMENTAL SETUP & EMULSION TECHNIQUE

• **The Scale Challenge:** Because of the short lifetime of the D_s meson, its typical flight length before decay is only a few millimeters. Its decay topology appears as a double-kink signature plus a pair charm partner decay.

• **Nanometric Resolution:** The tracking resolution must handle a tiny $D_s \to \tau$ decay kink angle of ~ **7 mrad**. This reqtuires nuclear emulsion films, which offer a sub-micron spatial resolution of **50 nm**.

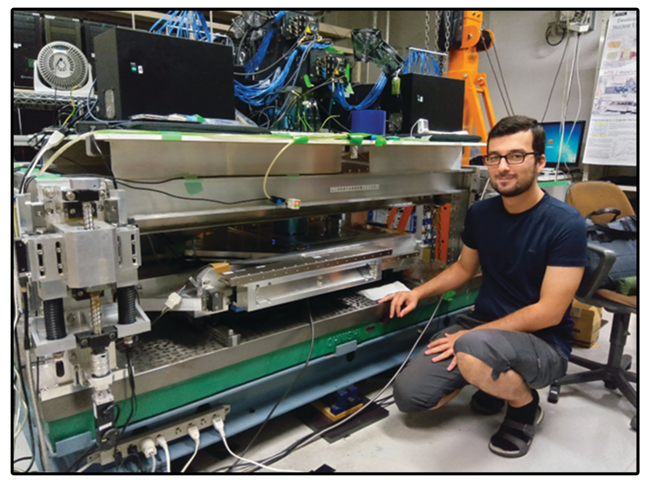


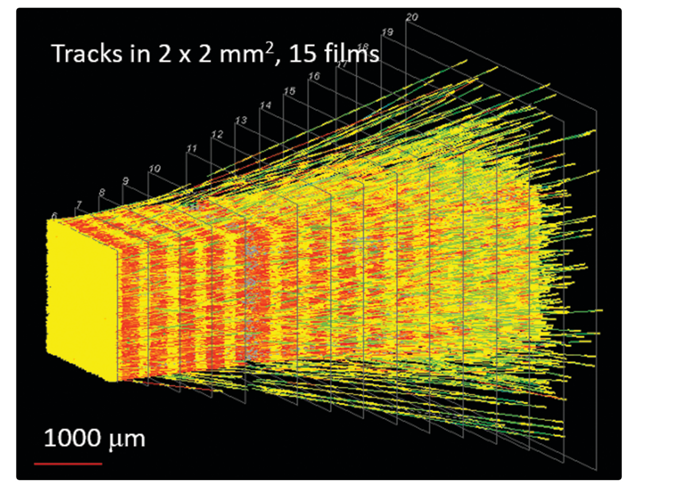
3 DATA ACQUISITION & FAST SCANNING SYSTEMS

• **High-Density Tracking:** Exposing the target modules to the 400 GeV proton beam yields extremely high track densities (~ **10^5 protons/cm²**), translating into massive datasets.

• **Hyper Track Selector 2 (HTS2):** HTS2 automated scanning system developed at Nagoya University. HTS2 achieves an ultra-fast scanning speed of **15000 cm²/hour**, reading out track segments (microtracks) across the full surface area of the film.

• **Signal Reconstruction:** Readout data is fed into high-throughput GPU processing clusters. Microtracks from individual emulsion layers are aligned using specialized software algorithms to reconstruct full,continuous 3D particle trajectories across the entire detector.

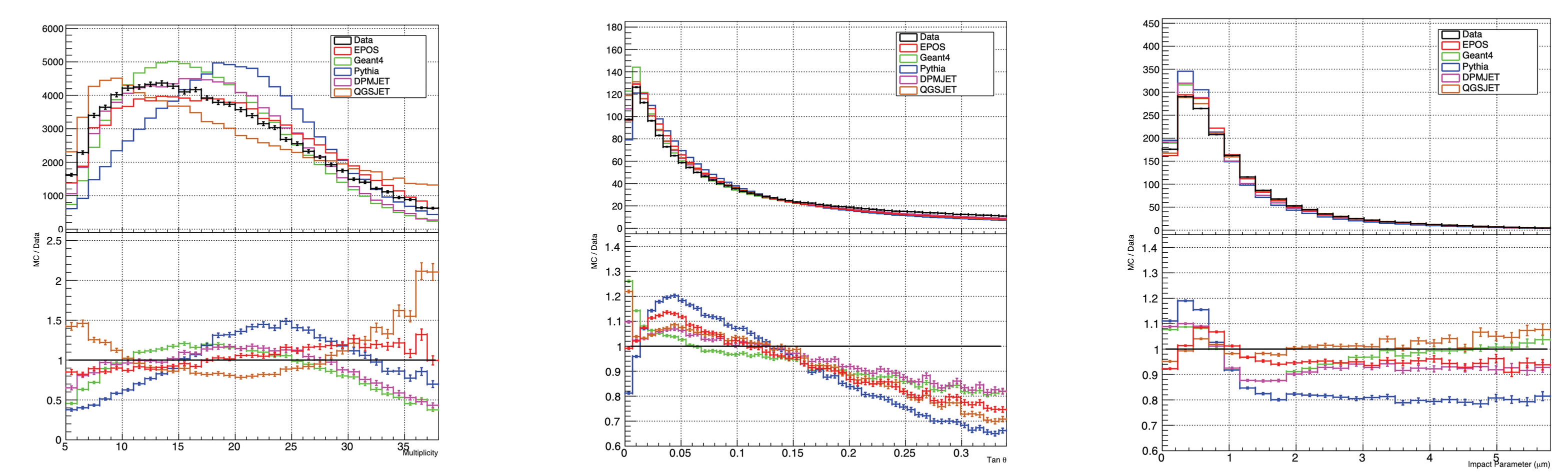




4 MC SIMULATIONS & INTERACTION LENGTH

• **Simulation Infrastructure:** Proton-Tungsten interactions are simulated using a series of hadronic event generators: **Geant4, Pythia, EPOS, QGSJET,** and **DPMJET**. Generated trajectories undergo data-driven resolution smearing to precisely model real detector tracking conditions.

• **MC/Data Comparison:** Global baseline parameters including Track Multiplicity, Angular Distribution (*tan ϑ*), and Impact Parameter (IP) are directly compared against experimental results, showing strong agreement with EPOS and data across the baseline distributions.

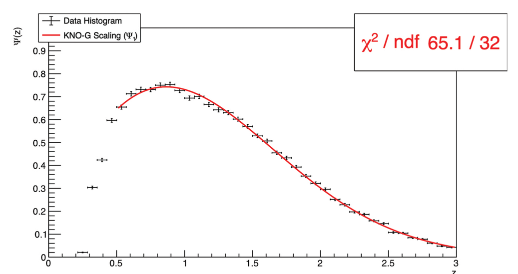


• **Interaction Length:** A sub-sample of the 2018 pilot data was analyzed to measure the proton interaction length (λ_p) in the Tungsten (W) target by evaluating the beam survival rate across 8 successive sub-volumes. The experimental measurement aligns exceptionally well with both the hadronic simulation predictions and the latest data analyses, confirming excellent tracking efficiency:

- Data Measurement: **93.7 ± 2.6 mm**
- EPOS Simulation Prediction: **95.8 ± 2.8 mm**

5 KNO-G SCALING & MULTIPLICITY EFFECTS

• **KNO-G Scale Invariance:** The charged multiplicity was tested against the Koba-Nielsen-Olesen-Gotsman (KNO-G) scaling function $\psi(z)$. The resulting scaling distribution confirms underlying scale-invariance behaviors in high-multiplicity regimes.

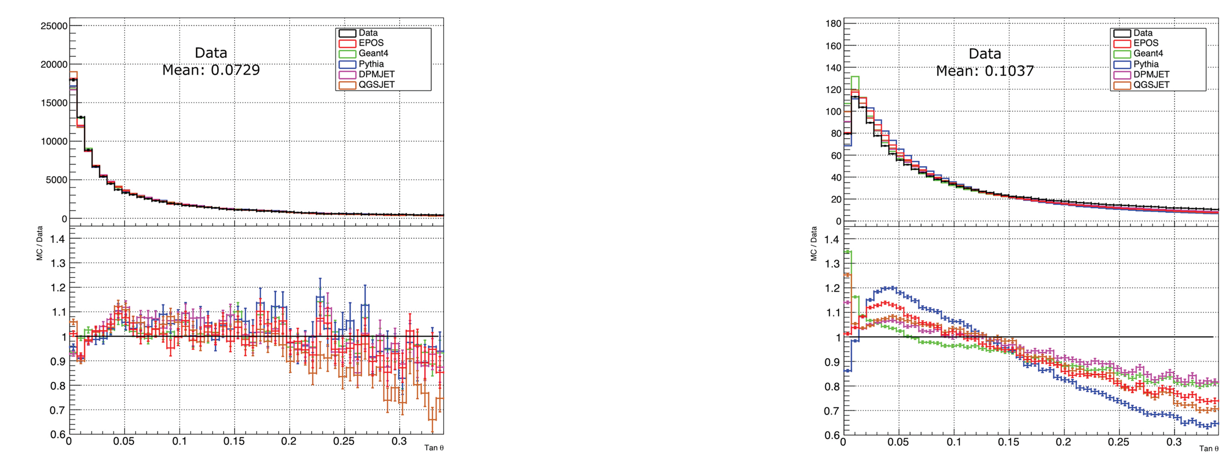


• **The Track Slope Dilemma:** Detailed MC/Data comparisons of baseline tracking variables revealed a structural discrepancy: at high track multiplicities, the EPOS generator systematically overestimates the average track slope (*tan ϑ*).

• **Multiplicity Phase Space Breakdown:**

Low Multiplicity (< 10 tracks): Strong agreement across all models and data, driven by the constant transverse momentum.

High Multiplicity (≥ 10 tracks): The data points begin to visibly diverge.EPOS systematically under-estimates the angular spread at higher track angles.



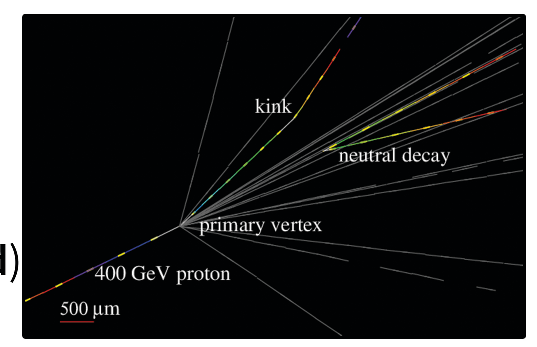
6 CANDIDATE ANALYSIS & BDT MOMENTUM

• **Decay Search Selection:** From proton interactions, secondary tracks were filtered using selection criteria.

Variable	Selection	Description
$p_{D_s}^{\text{true}}$	> 2 GeV	Valid momentum range
FL_{D_s}	$0.9 < FL_{D_s} < 5$ mm	D_s flight length
FL_τ	$0.9 < FL_\tau < 5$ mm	τ flight length
$\theta_{D_s\to\tau}$	$3 < \theta_{D_s\to\tau} < 10$ mrad	$D_s - \tau$ kink angle
$\theta_{\tau\to X}$	$\theta_{\tau\to X} > 15$ mrad	τ decay kink angle
FL_{comp}	$0.1 < FL_{comp} < 5$ mm	*Companion* flight length

• **The Golden Candidate:** A clean double-decay topology was isolated and verified with the following kinematics:

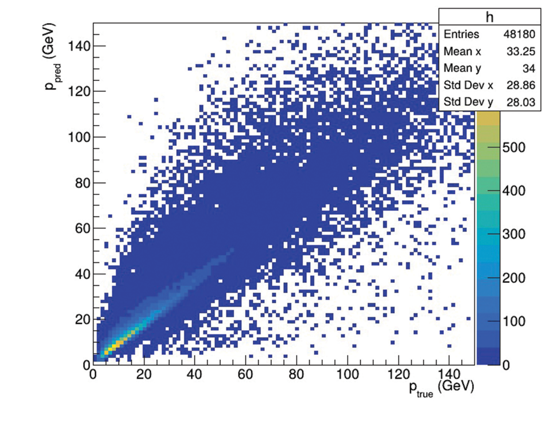
- $D_s \to \tau$: Flight length of **2.35 mm** (kink = **8.3 mrad**)
- $\tau \to X$: Flight length of **4.59 mm** (kink = **28.9 mrad**)
- Charm Partner: Flight length of **5.44 mm** (kink = **40.9 mrad**)



• **BDT Momentum Estimation:** Using a Gradient Boosted Decision Tree (GBDT) trained on Geant4 kinematics:

- Flight Length of D_s
- Flight Length of τ
- Kink angle between $D_s \to \tau$
- Kink angle at τ decay

the Golden Candidate's true D_s momentum was successfully reconstructed at **23.08 GeV/c**.



SUMMARY:

- λ_p Measurement: Measured at **93.7 ± 2.6 mm**, aligning with simulations.
- KNO-G Scaling: Verified multiplicity scale-invariance.
- BDT Momentum: Reconstructed D_s momentum at **23.08 GeV/c**.

REFERENCES:

1. S. Aoki et al. (DsTau Collaboration), JHEP 2020, 33 (2020).
2. S. Aoki et al., JINST 18, P10008 (2023).
3. S. Aoki et al., Eur. Phys. J. C 85, 230 (2025).

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