Performances of event reconstruction algorithms in the DsTau(NA65) experiment at CERN-SPS

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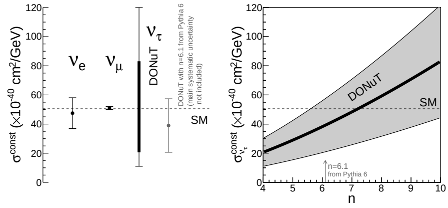
1. Physics Motivation
2. DsTau experimental technique
3. Performances
   - Reconstruction of primary proton interactions
   - Reconstruction efficiency and resolution

1. Evaluation of ν_τ flux produced in p-nucleus interactions

- The ν_τ interaction cross-section is known with worse accuracy than for other neutrinos, due to low statistics of registered tau neutrinos and large systematic errors in tau neutrino flux estimation for the beams
- $D_s \to \tau + \nu_\tau$ is the main source of ν_τ in the accelerator neutrino beams
- DsTau will measure the Ds double-differential production cross-section (inclusively decaying to τ and ν_τ) in proton-nuclei interaction with a purpose of improving the ν_τ flux prediction (down to 10%) in future experiment with large statistics of registered ν_τ (SHiP)

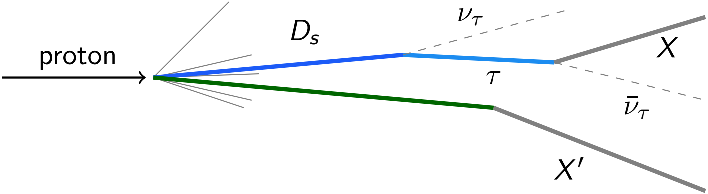


Left: $\nu, \bar{\nu}$ averaged energy independent cross section of all neutrino flavors. Right: ν_τ cross section in DONuT experiment, as a function of the parameter n.

2. Study of charm production in proton-nucleus interactions

- expected 10^5 events having pair charms

In the DsTau experiment, D_s is produced by 400 GeV protons from CERN-SPS on W/Mo targets



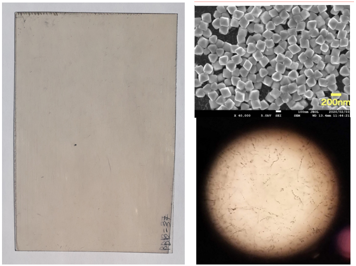
Double-kink topology of $D_s \to \tau \to X$ events

Decay candidates are selected by the peculiar double kink topology of the reaction

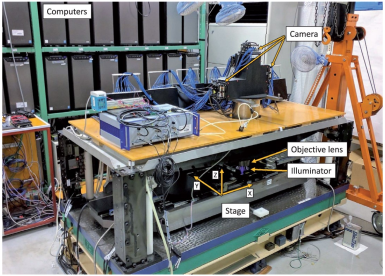
- Average kink angle of $D_s - \tau \sim 10$ mrad (G4 p-W)
- Average kink angle of τ decay 96 mrad
- Ds decay length (mean lifetime: $5 \times 10^{-13} s$) $\sim$ 2.4 mm (G4, Fluka, p-W)
- τ decay length (mean lifetime: $3 \times 10^{-13} s$) $\sim$ 1.4 mm (G4)

$\to$ **very challenging!** $\to$ high resolution tracking emulsion detectors

Nuclear emulsion detector in DsTau



left: $25 \times 20\ cm^2$ DsTau emulsion plate with 2 emulsion layers on a plastic base; right: electron microscope view and traces under the microscope



Hyper Track Selector-HTS

- intrinsic angular resolution 0.35 mrad, spatial resolution 0.4 μm
- **high density of tracks** $10^5 - 10^6 tracks/cm^2$

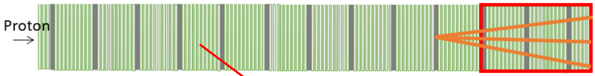
- automatic procedure
- scanning speed $0.5m^2/hour/layer$
- angular resolution $2mrad$

After scanning, the information about the tracks is in digital format

Films development

→ several chemical processes similar with photographic plate development

Structure of detector modules (not in scale)



600 m^2 high accuracy emulsion films on plastic bases (120 modules)

beam monitor + target mover → uniform exposure 3×10^5 protons/cm^2

The analysis chain

Emulsion read-out:

1. Films development
   - make the particles tracks visible for microscope
2. Automatic scanning with HTS
   - digital microtracks (the part of the track left in each emulsion layer)
   - microtracks are combined → basetracks

Offline dedicated software for the reconstruction of events:

3. Basetracks are combined in tracks (tracks reconstruction)
4. Alignment
5. Vertex reconstruction
   - 2 dedicated software (standard, fast-under development)

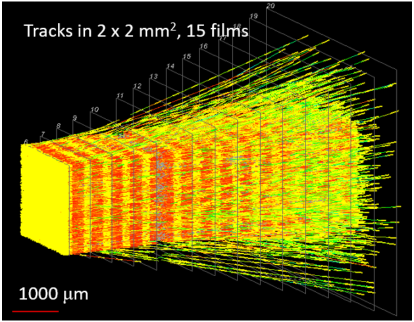
Dedicated software for the extraction of events of interest:

6. Searching events with secondary vertices corresponding to short lived particles
7. Searching for Ds decaying τ

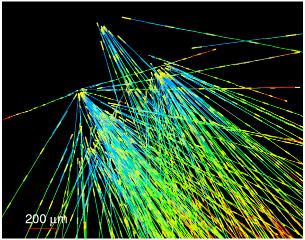
Under analysis

4.6×10^9 protons, 2.3×10^8 proton interactions, 10^5 charm pairs, 1000 $D_s - \tau$

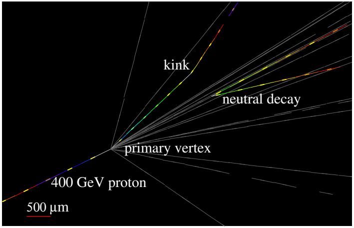
Tracks and primary proton interactions reconstruction



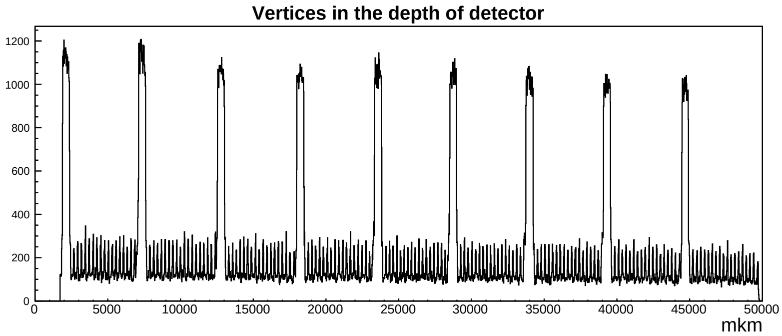
Proof of the technique capabilities: reconstruction and recognition of events is a high track density environment

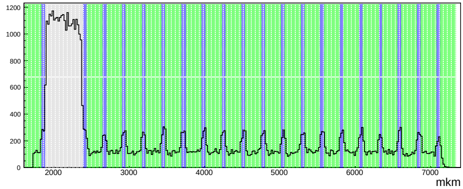


Examples of DsTau 3D reconstructed events



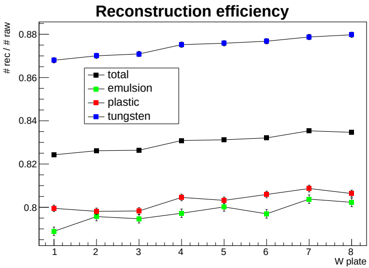
Example of DsTau reconstructed double charm event (neutral and 1 prong decaying particles visible)

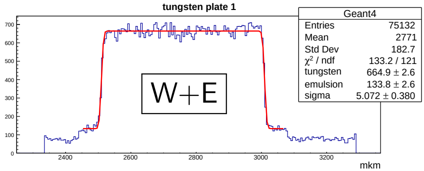


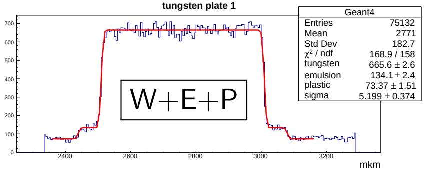


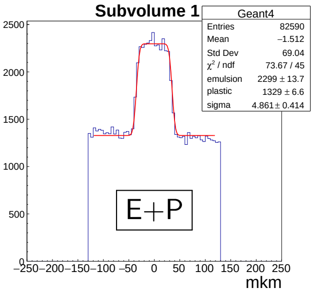
⟶ Subsample containing the interactions in the so-called 'first subvolume', with the first tungsten target

Reconstruction resolution and efficiency - G4 data



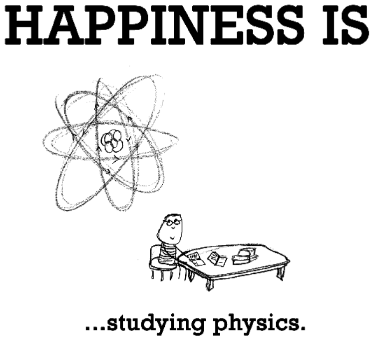






Resolution (μm)	
W+E	5.37 ± 0.14
W+E+P	5.57 ± 0.13
E+P	4.64 ± 0.15

- the algorithms are capable to reconstruct events in a track density of 10^5-10^6 tracks/cm^2
- the primary events are reconstructed with a resolution of $\sim 5\ \mu$m



2021 and 2022 data taking at CERN-SPS

Thank you for your attention!

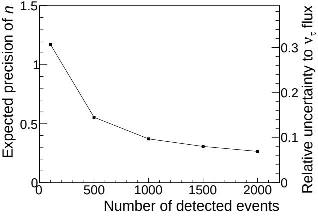
Back-up slides

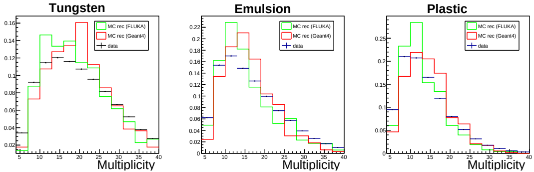
- 2018: 30 modules (with a surface of $12.5 \times 10\ cm^2$) were exposed, all plates scanned, all reconstructed
- 2021: 17 modules (with a surface of $25 \times 20\ cm^2$) exposed, scanning should start next year
- 2022: 17 modules exposed
- 2023: at least 25 modules will be exposed

DsTau web site:
`https://na65.web.cern.ch/`

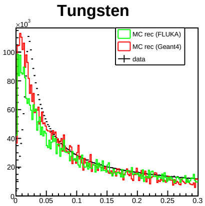
`https://link.springer.com/article/10.1007/JHEP01(2020)033`

Experiment proposal:
`https://arxiv.org/pdf/1708.08700.pdf`





Multiplicity comparison of data with Fluka and G4



Angular distribution of primary daughters, normalization to the number of vertices in data

	Tungsten	Emulsion	Plastic
G4	19.45±0.24	15.61±0.35	14±0.23
Fluka	18.9±0.25	15.08±0.38	12.78±0.23
data	19.33±0.02	16.03±0.03	13.59±0.02

mean values of multiplicities

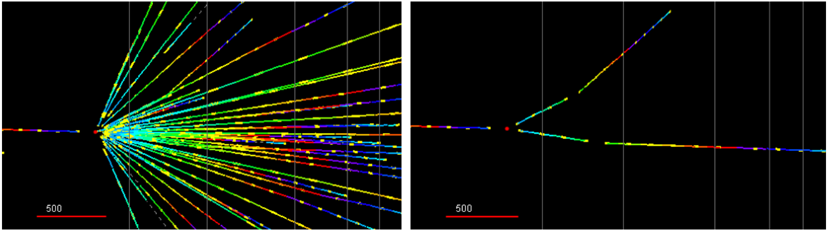
	Tungsten (rad)
Geant4	0.106±0.0007
Fluka	0.119±0.0007
data	0.123 ± 0.00004

mean values of angular distributions of primary daughters, created in tungsten

The final goal of the experiment is to measure the **Ds decaying via tau cross section**. For this, not only the number of the events have to be known, but also the efficiencies for recognising these events has to be calculated.

Codes for estimation of detection efficiency are under development: efficiency of Ds reconstructed track recognition (38.09 ± 0.13) % and for τ track 25.3 ± 0.1 % according to Geant4 data

Codes capable to recognise Ds decaying tau are under development.



Event with double (charged) charm candidates [1]

The DsTau experiment will highlight the ν_τ from D_s leptonic decay
$\rightarrow$ In DONuT experiment, 95% of ν_τ sources were from $D_s \rightarrow \tau + \nu_\tau$

Measurement of D_s differential production cross section:

$$\frac{d^2\sigma}{dx_F \cdot dp_T^2} \propto (1- \mid x_F \mid)^n \cdot e^{-b \cdot p_T^2}, \tag{1}$$

where x_F is the longitudinal momentum $p_L/p_L max$ and p_T is the transverse momentum. n and b are the parameters controlling the longitudinal and transverse dependence of the differential production cross section, respectively.