The NA65/DsTau experiment: measuring the tau-neutrino production cross section

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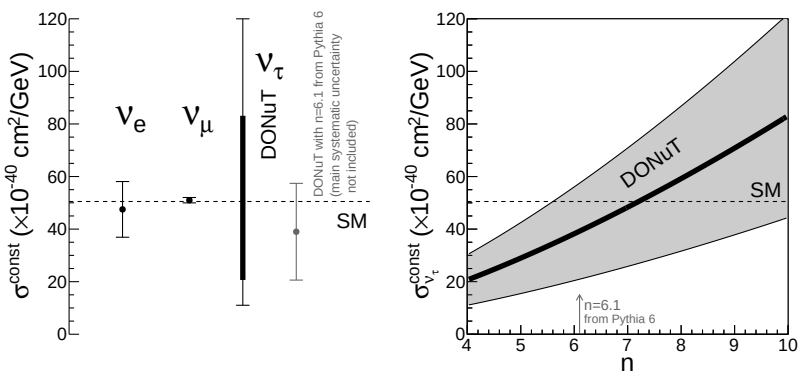
Outline

1. Physics Motivation
2. Experimental technique
3. Current status
4. Prospects

Physics Motivation

The ν_τ interaction cross-section is known with less accuracy than other neutrinos.

- the poor accuracy is due to low statistics (only 9 ν_τ detected by DONuT, first that detected ν_τ; 10 ν_τ detected by OPERA)
- the ν_τ flux in DONuT was roughly estimated by PYTHIA and the final result has 50% systematic error
- DsTau experiment aims to measure the tau neutrino production in proton-nuclei interaction and to decrease the systematic uncertainty in ν_τ produced flux to 10%
- the statistical error of the cross section is expected to be reduced to 2% in future experiments with large statistics of registered ν_τ (SHiP)



Study of charm production in proton-nucleus interactions

- expected 10^5 events having pair charms

Experimental technique

The DsTau experiment will highlight the ν_τ from D_s leptonic decay

$D_s \to \tau + \nu_\tau$ is the main source of ν_τ in the neutrinos beams

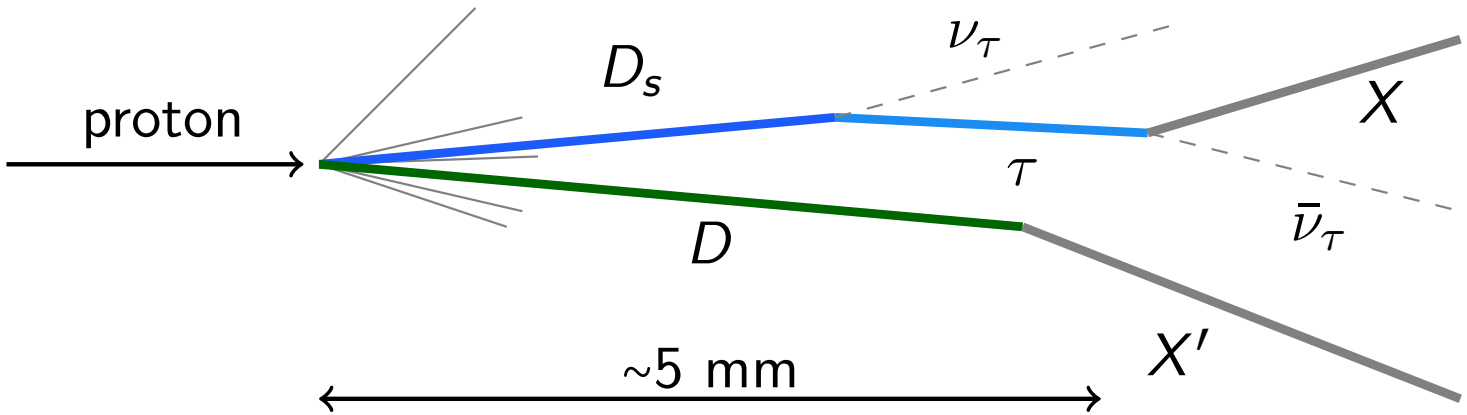
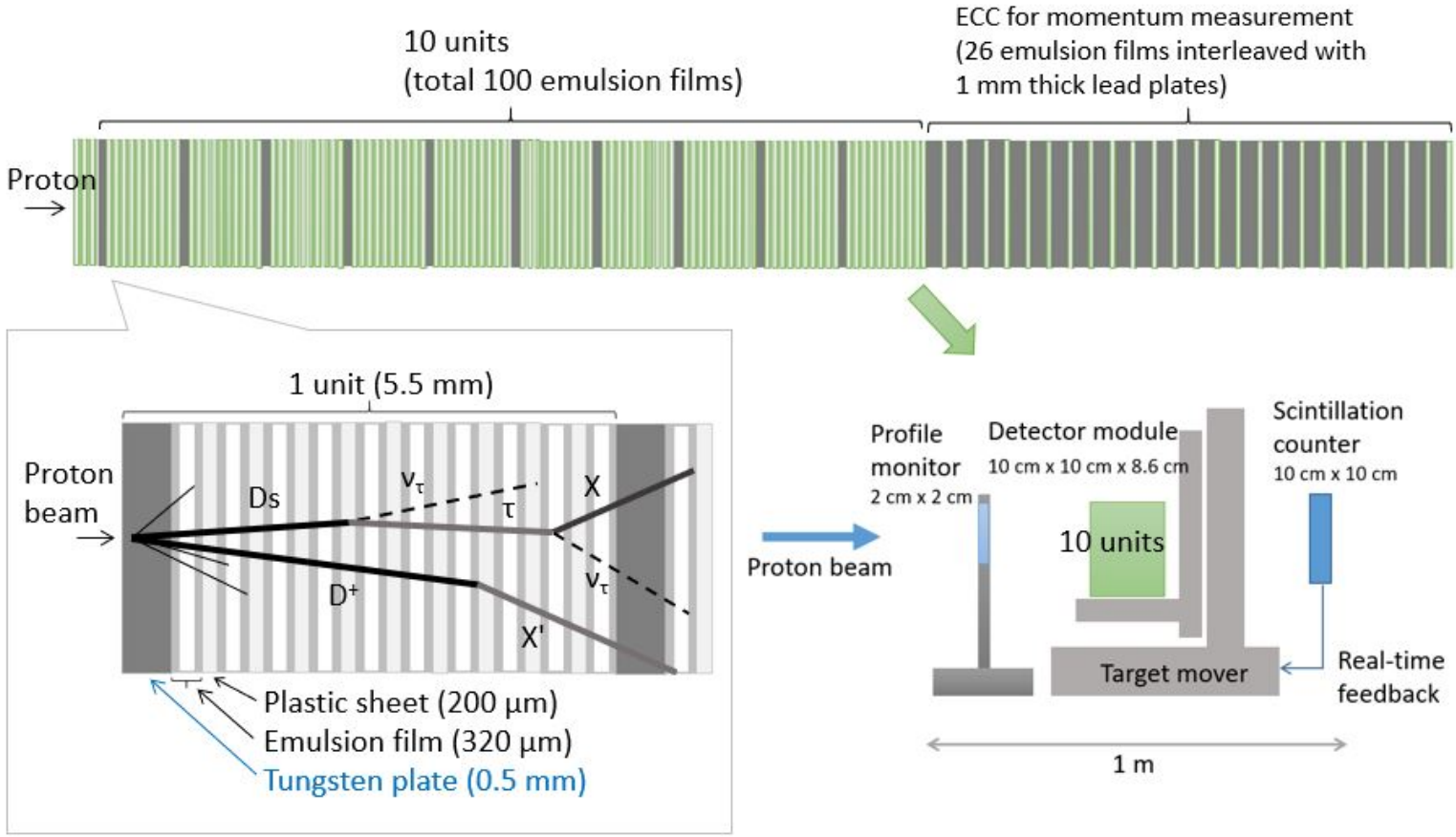


Figure: Double-kink topology of $D_s \to \tau \to X$ events.

Decay candidates are selected by the peculiar topology of the reaction
Average kink angle of $D_s - \tau$ is 6.2 mrad → **very challenging!**

D_s (lifetime $5 \times 10^{-13} s$) is produced by 400 GeV protons from CERN-SPS on Tungsten/Molybdenum targets



400 modules with high accuracy tracking detectors: nuclear emulsion

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

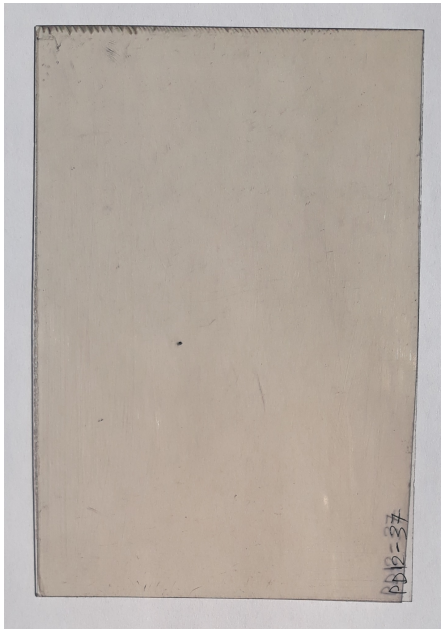


Figure: DsTau emulsion plate with 2 emulsion layers on a plastic base

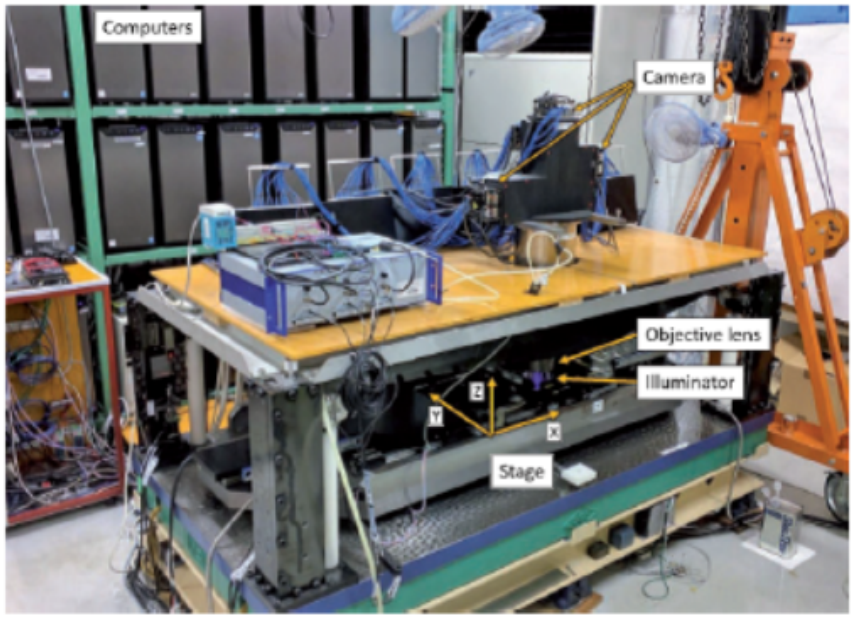


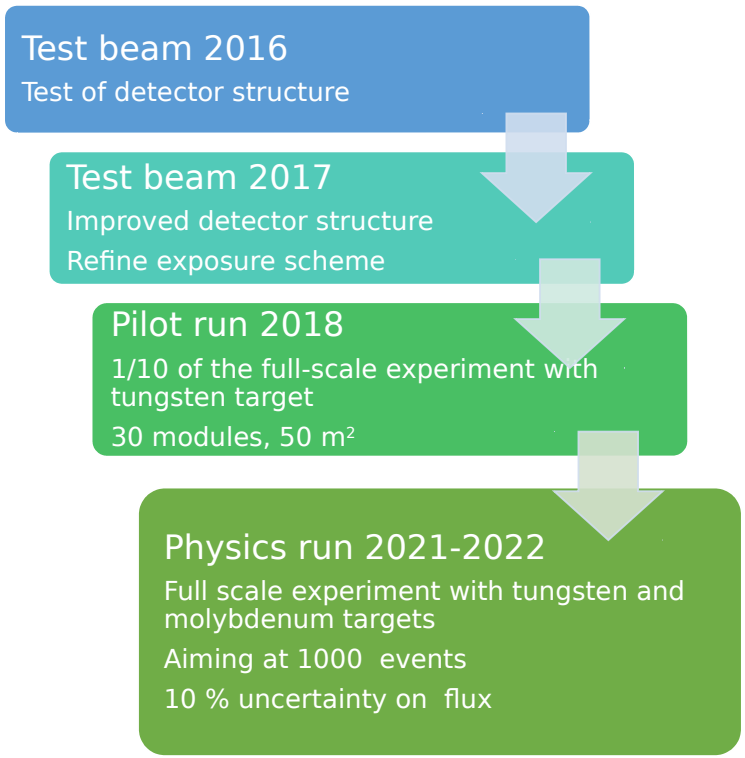
Figure: Hyper Track Selector-HTS

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

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

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

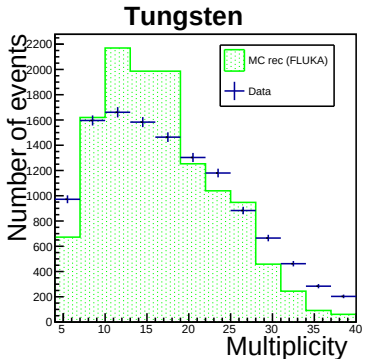
Current status of the Pilot run

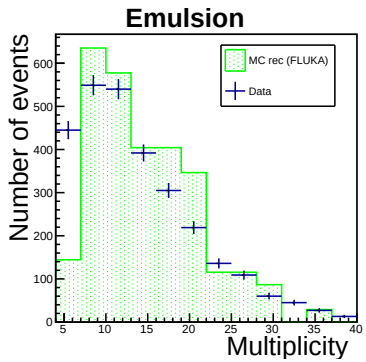


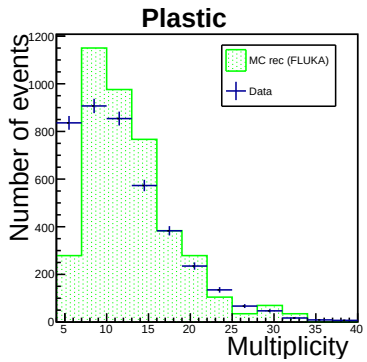
Pilot run 2018

- 30 modules were exposed
- performed to validate and justify the technique
- the emulsions have been scanned and are processed now
- development of the data processing algorithms

Preliminary results







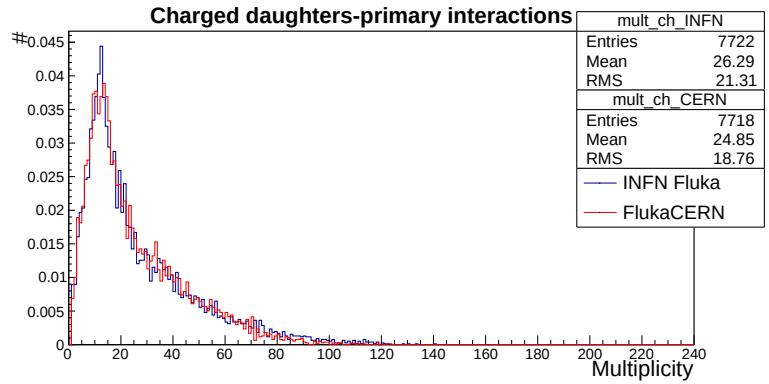


Figure: Mean multiplicity: W 17.1256, Emulsion 13.5006, Plastic 11.4961

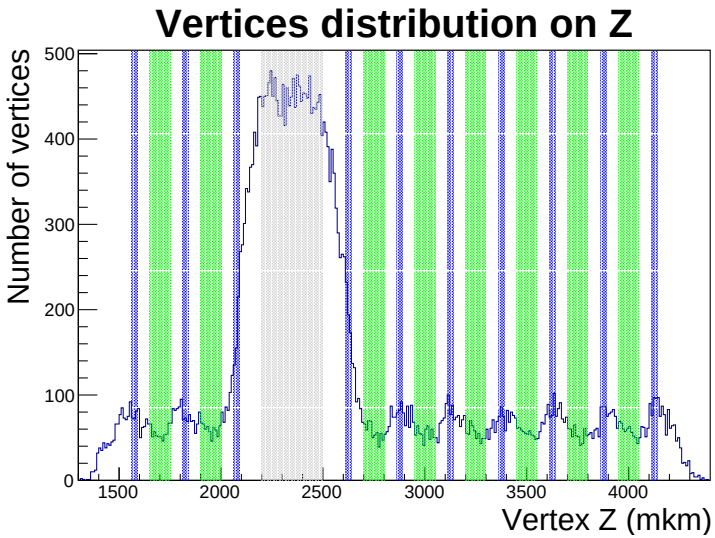


Figure: grey-W, blue-emulsion, green-plastic

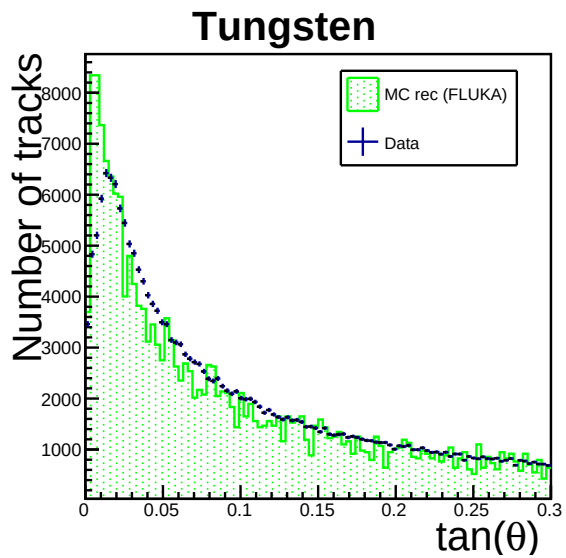
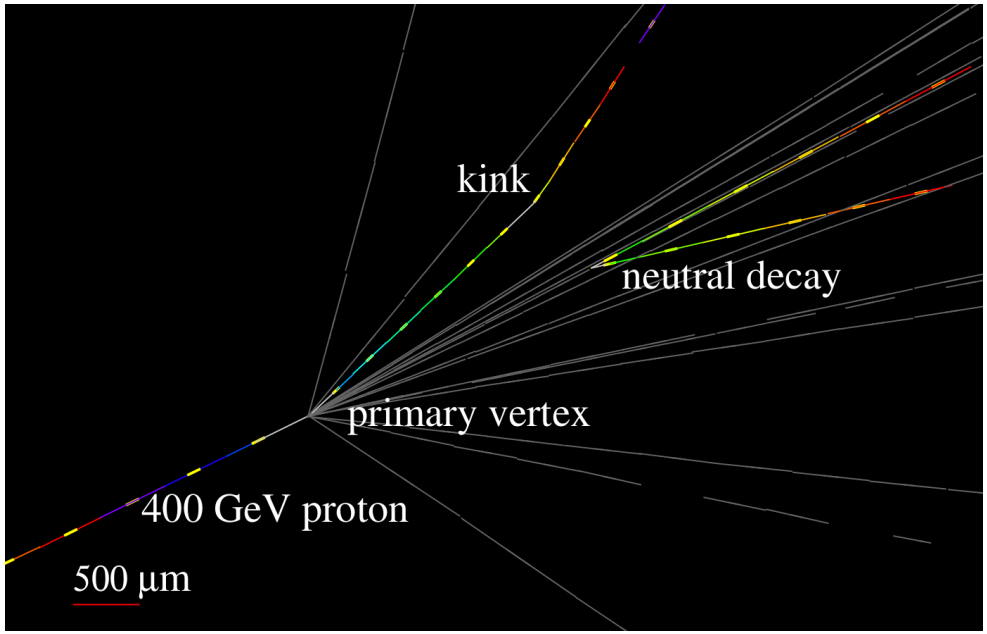


Figure: Normalization to the number of vertices in data; mean value data (MC) 0.0946 (0.0905)



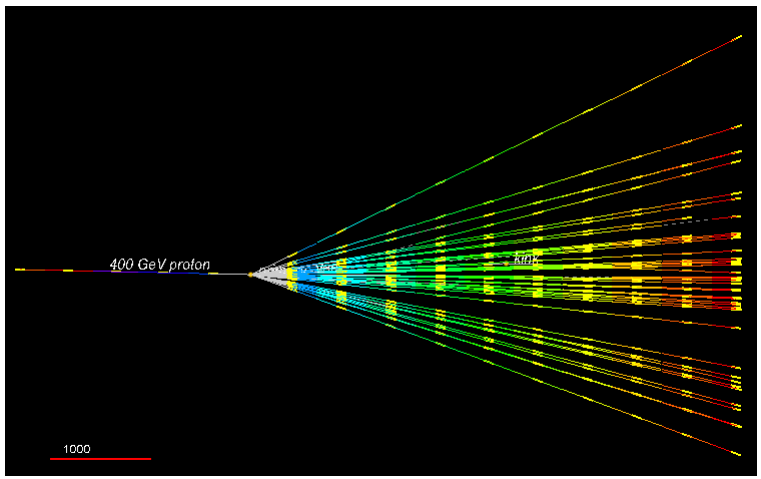


Figure: Example of DsTau reconstructed events

Our data:

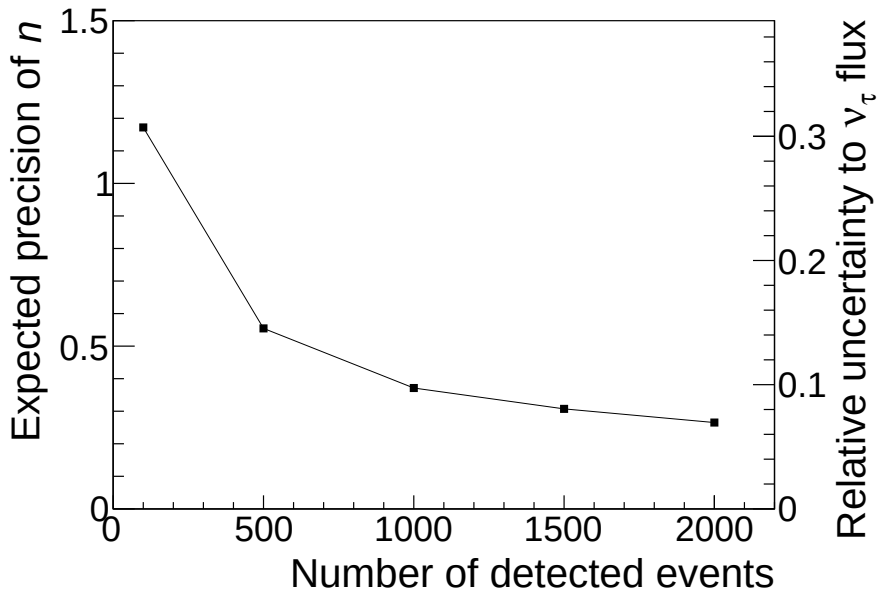
- very big track + vertices densities
- extremely high resolution of modern emulsions
- automatic scanning by HTS

Prospects

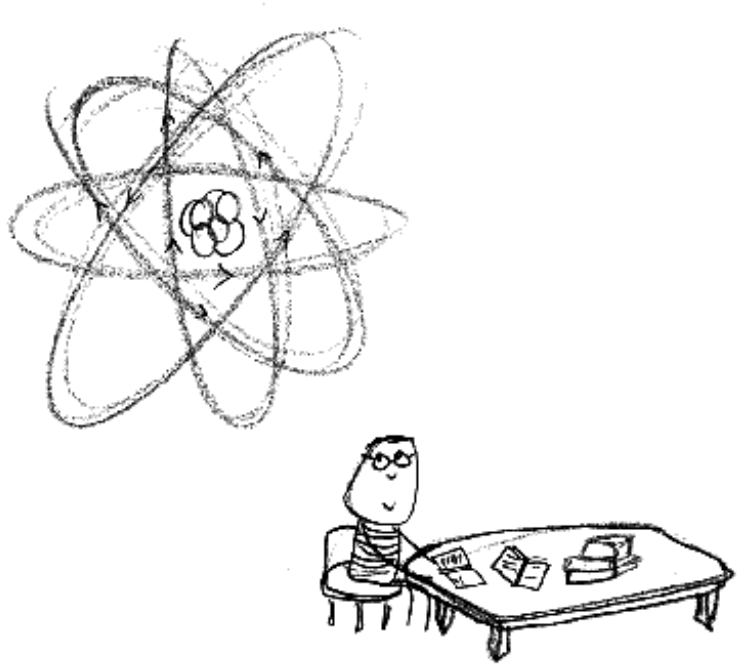
- Physics run starts in October 2021, with W and Mo targets
- 4.6×10^9 protons, 2.3×10^8 proton interactions, 10^5 charm pairs, 1000 $D_s - \tau$ decays
- Development of MC and data analysis tools

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

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

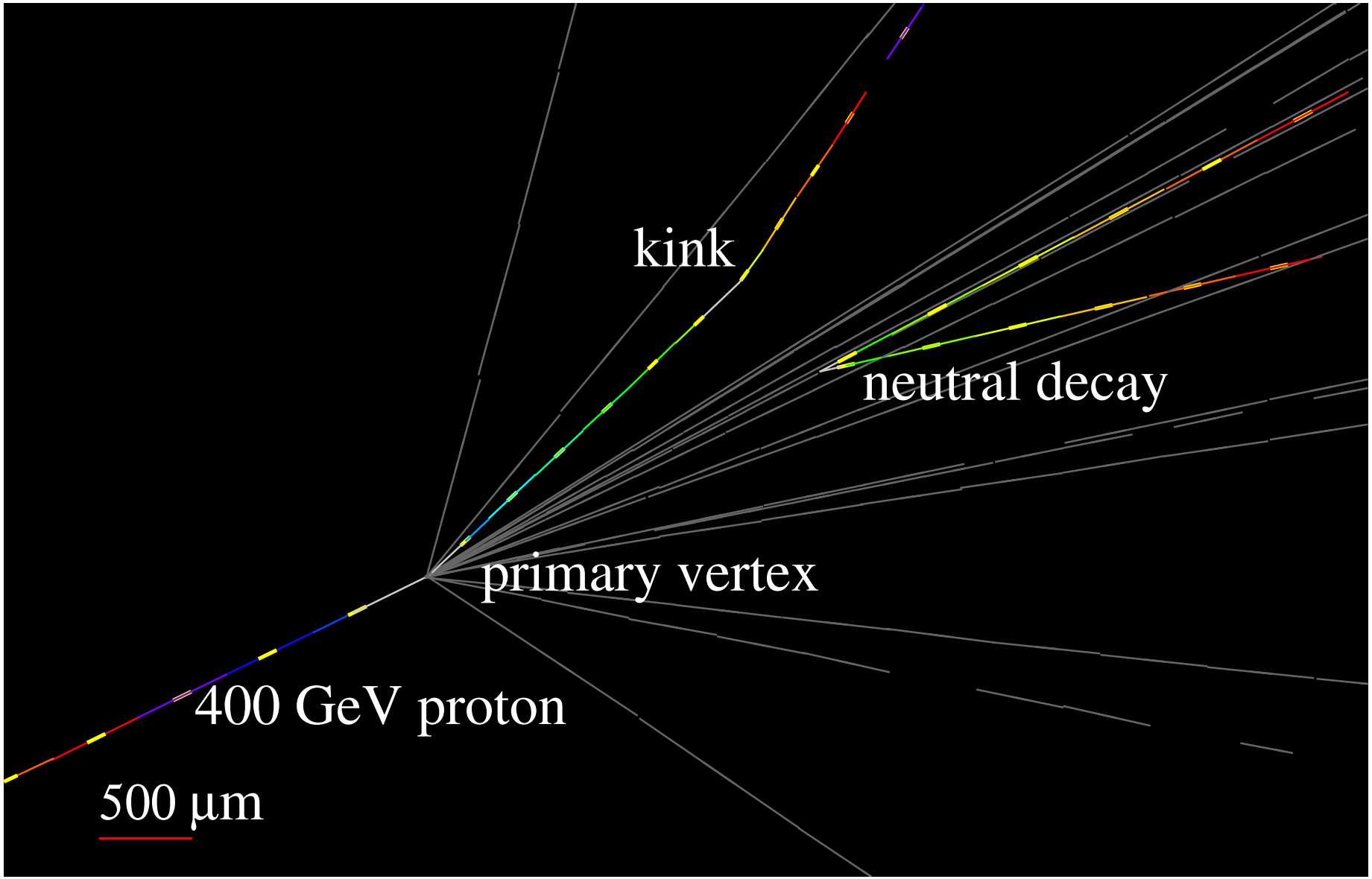


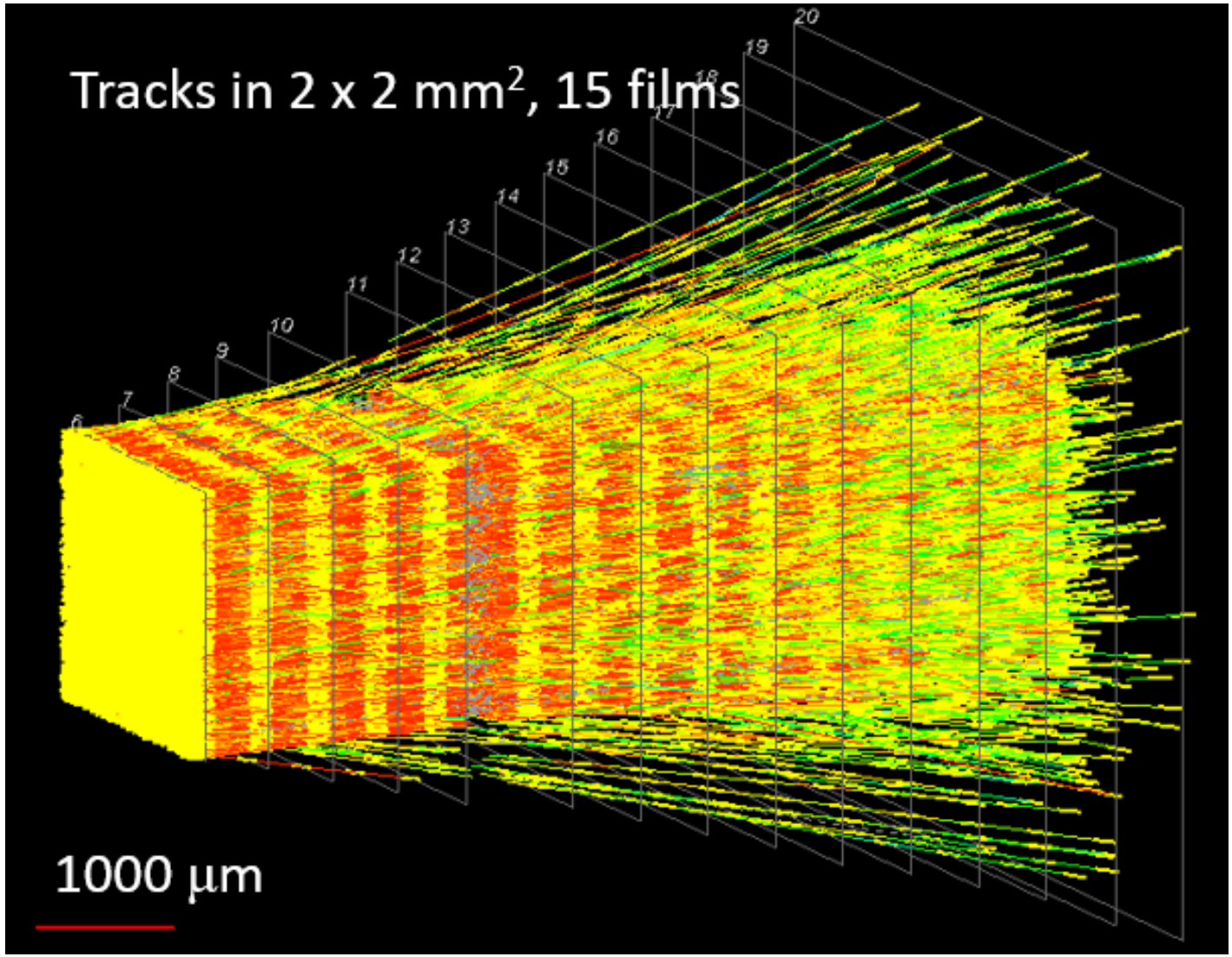
HAPPINESS IS



...studying physics.

Back-up slides


kink
neutral decay
primary vertex
400 GeV proton
500 µm


Tracks in 2 x 2 mm^2, 15 films
6
7
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20
1000 µm

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.

Table: Fluka codes for the particles found in both files.

Fluka code	Particle	Mass (MeV)
-6	α	3720
-5	3-He	2809
-4	triton	2809
-3	deuteron	1875.612762 $\pm$ 0.000075
1	proton	938.272081 $\pm$ 0.000006
2	antiproton	938.272081 $\pm$ 0.000006
3	electron	0.5109989461 $\pm$ 0.0000000031
4	positron	0.5109989461 $\pm$ 0.0000000031
10	muon+	105.6583745 $\pm$ 0.0000024
11	muon-	105.6583745 $\pm$ 0.0000024
13	pion+	139.57039 $\pm$ 0.00018
14	pion-	139.57039 $\pm$ 0.00018
15	kaon+	493.677 $\pm$ 0.016
16	kaon-	493.677 $\pm$ 0.016
20	sigma-	1197.449 $\pm$ 0.030
21	sigma+	1189.37 $\pm$ 0.07

Fluka code	Particle	Mass (MeV)
31	asigma-	1197.449 ± 0.030
33	asigma+	1189.37 ± 0.07
36	Xi-	1321.71 ± 0.07
37	Xi+	1321.71 ± 0.07
42	tau -	1776.86 ± 0.12
45	D+	1869.65 ± 0.05
46	D-	1869.65 ± 0.05
49	Ds+	1968.34 ± 0.07
50	Ds-	1968.34 ± 0.07
51	lambdaC+	2286.46 ± 0.14
57	antilambdaC-	2286.46 ± 0.14