Preliminary results of the Pilot Run of NA65 (DsTau) experiment at CERN-SPS

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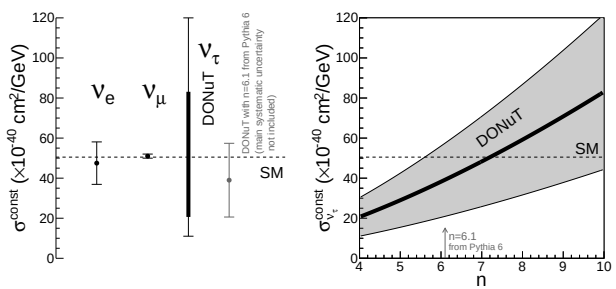
Outline

1. Physics Motivation
2. The experimental technique
3. Status of the experiment
   Reconstruction of primary proton interactions

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
- Measuring the double-differential cross-section of Ds production in proton-nuclei interaction inclusively decaying to τ and ν_τ
- DsTau will measure the Ds production cross-section 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)

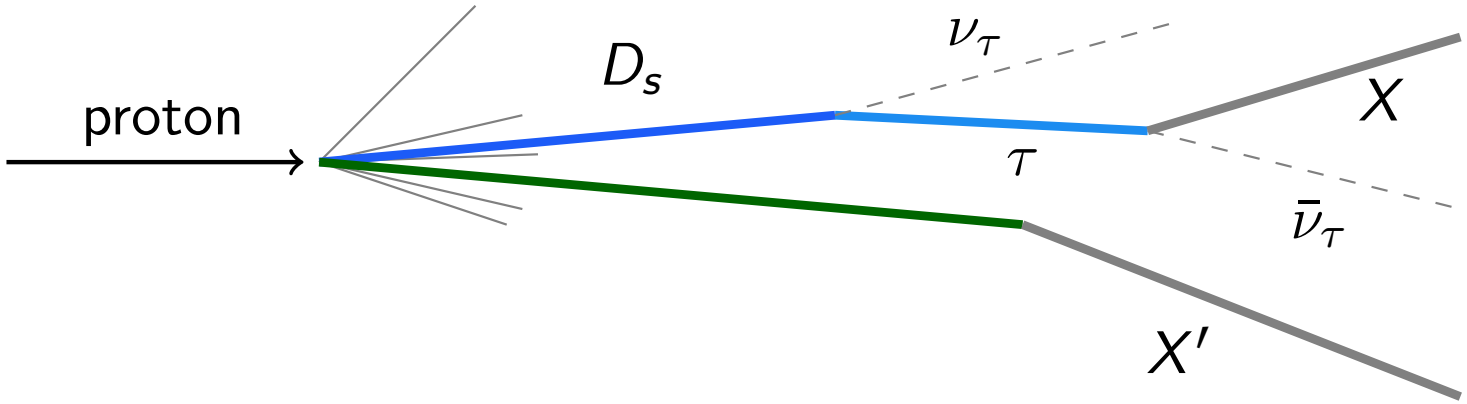


Left: $\nu, \bar{\nu}$ averaged energy independent cross section of all neutrino flavors. Right: ν_τ cross section in DONuT experiment, as a function of the parameter n.*S. Aoki et al, DsTau: study of tau neutrino production with 400 GeV protons from the CERN-SPS*

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



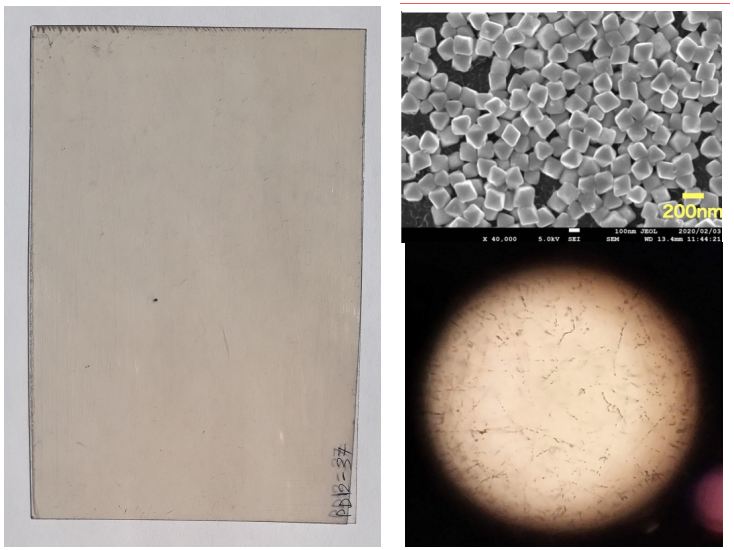
Double-kink topology of $D_s \to \tau \to X$ events

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

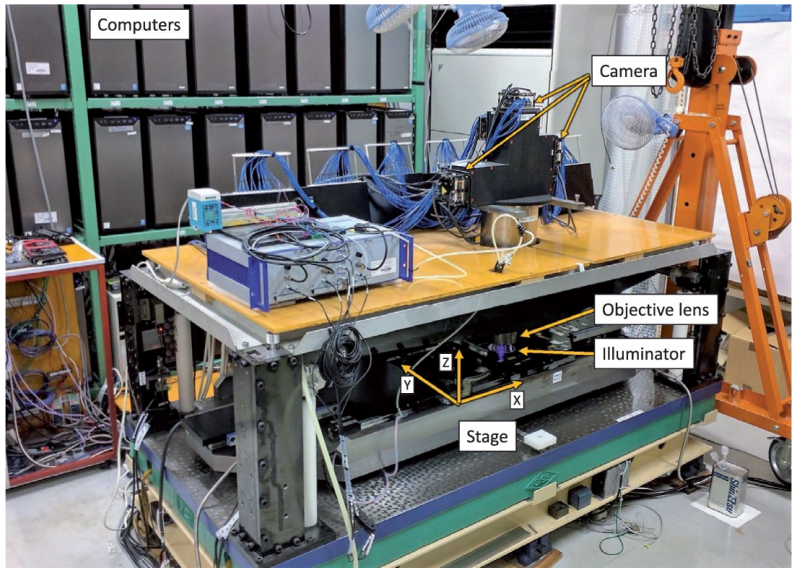
- Average kink angle of $D_s - \tau \sim 10$ mrad (G4)
- Average kink angle of τ decay 96 mrad
- Ds decay length (mean lifetime: $5 \times 10^{-13} s$) ~ 2.4 mm (G4, Fluka)
- τ decay length (mean lifetime: $3 \times 10^{-13} s$) ~ 1.4 mm (G4)

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

Nuclear emulsion detector in DsTau



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



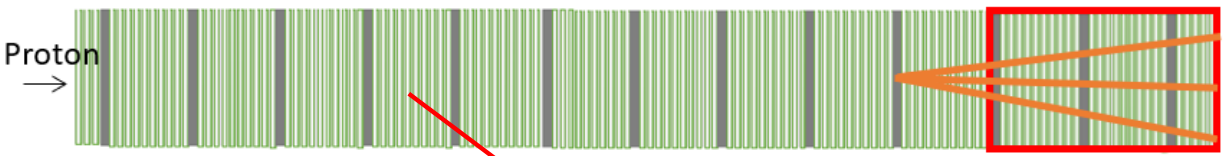
Hyper Track Selector-HTS

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

Experimental set-up

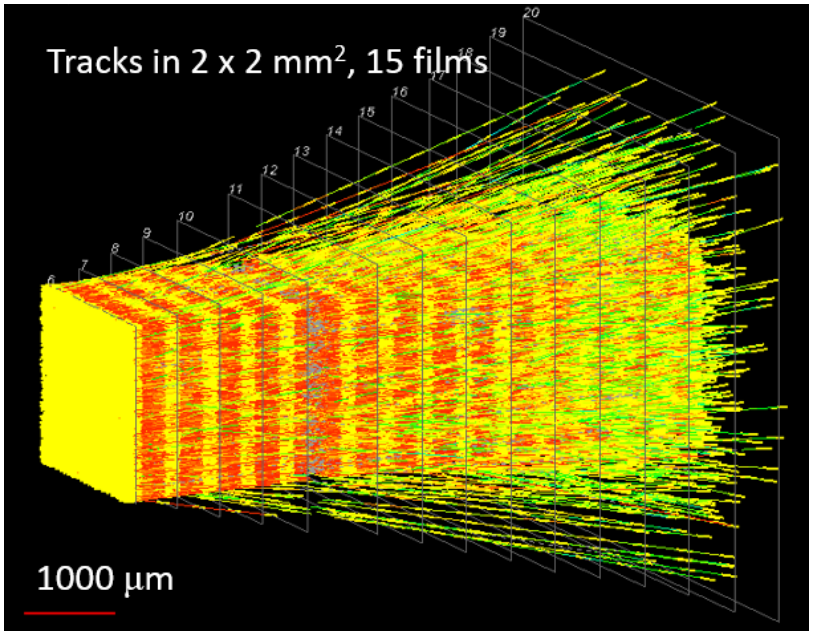
Structure of detector modules (not in scale)



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

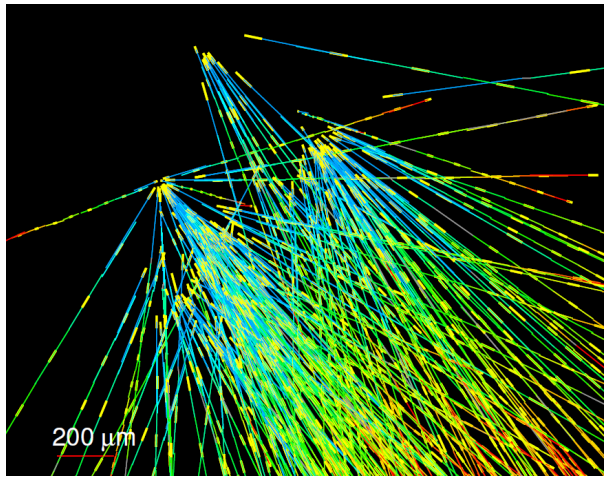
beam monitor + target mover → uniform exposure $3 \times 10^5 protons/cm^2$

Study of primary proton interactions

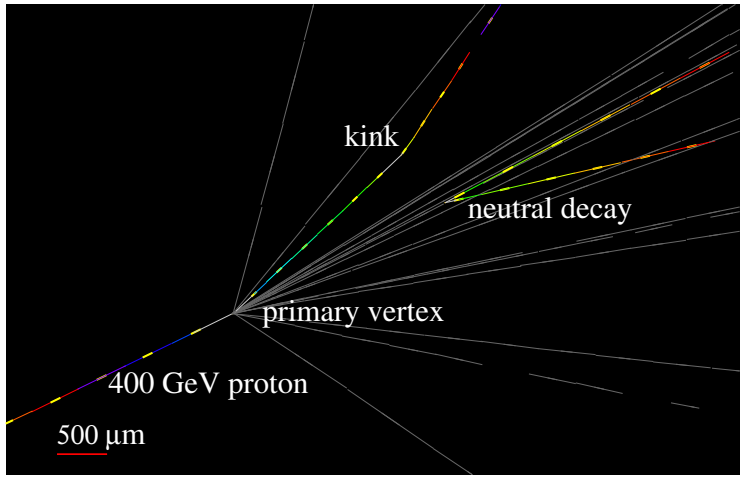


From primary proton interactions:

- proof of the technique capabilities
- measuring reconstruction resolution
- the capability to reconstruct tracks and recognise events in a high track density environment

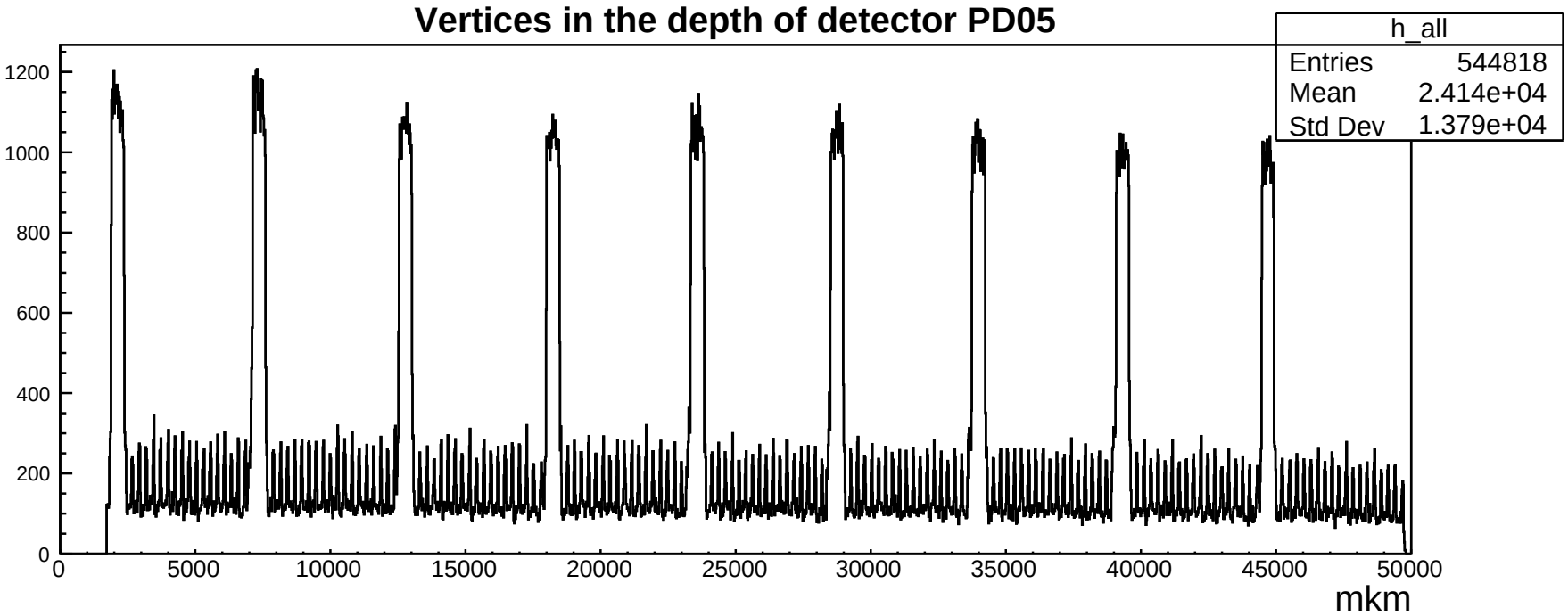


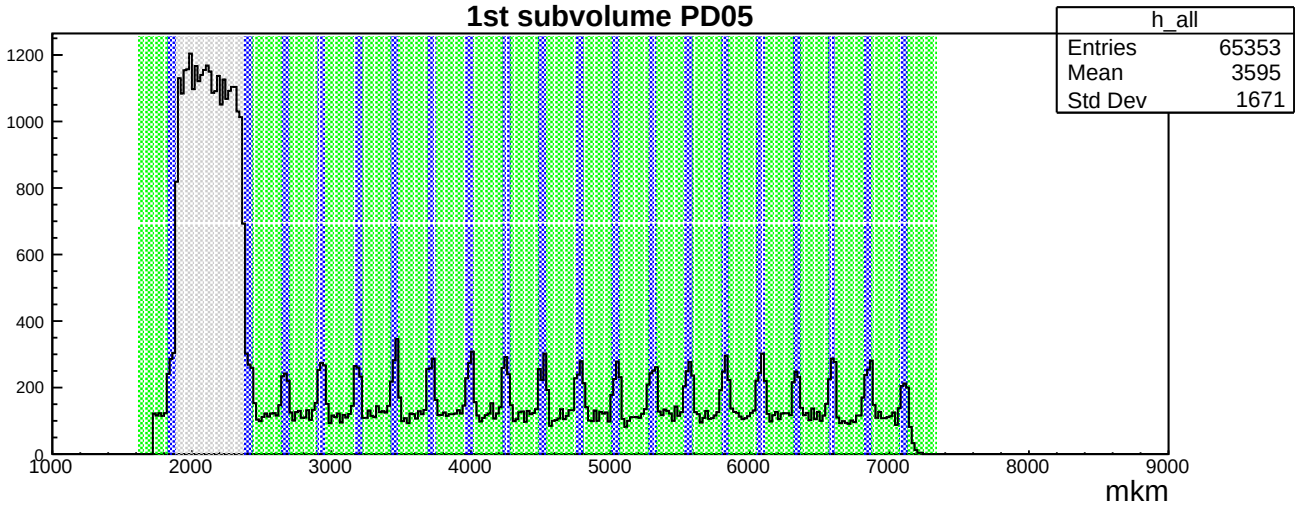
Examples of DsTau 3D reconstructed events



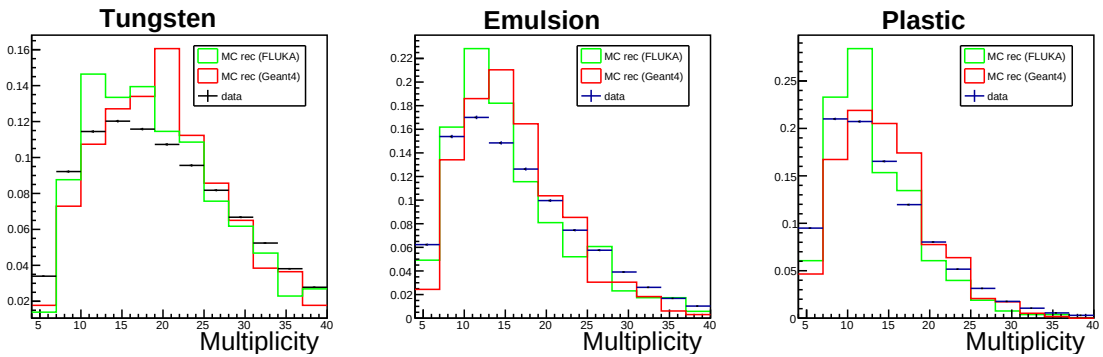
Example of DsTau reconstructed double charm event (neutral and 1 prong decaying particles visible)

Primary proton vertices reconstruction

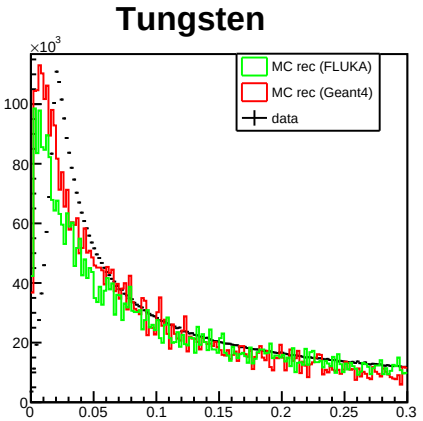




Data comparison with simulations



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

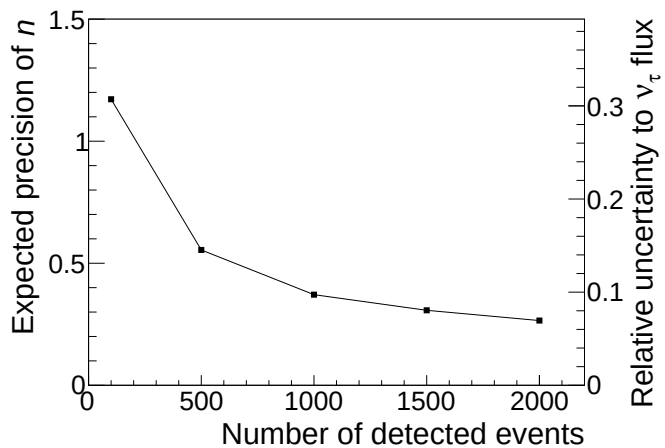
Status of the experiment

- 2018: 30 modules (with a surface of 12.5 × 10 cm^2) were exposed, all plates scanned, all reconstructed
- 2021: 17 modules (with a surface of 25 × 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`

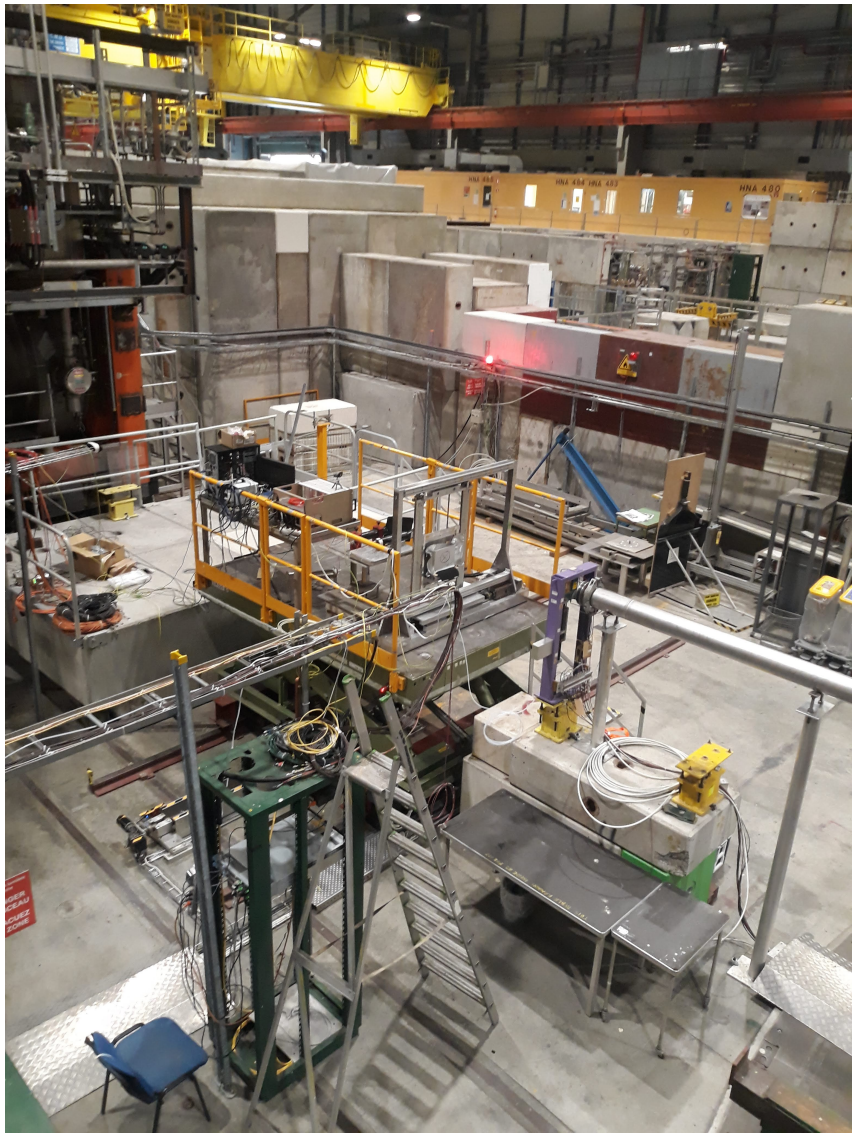
Experiment proposal:
`https://arxiv.org/pdf/1708.08700.pdf`



Prospects

- 4.6×10^9 protons, 2.3×10^8 proton interactions, 10^5 charm pairs, 1000 $D_s - \tau$ decays, according to previous estimations, will be analysed
- Algorithms for charm events recognition are under development
- Data analysis ongoing

Thank you for your attention!



2021 and 2022 data taking at CERN SPS

Back-up slides

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)

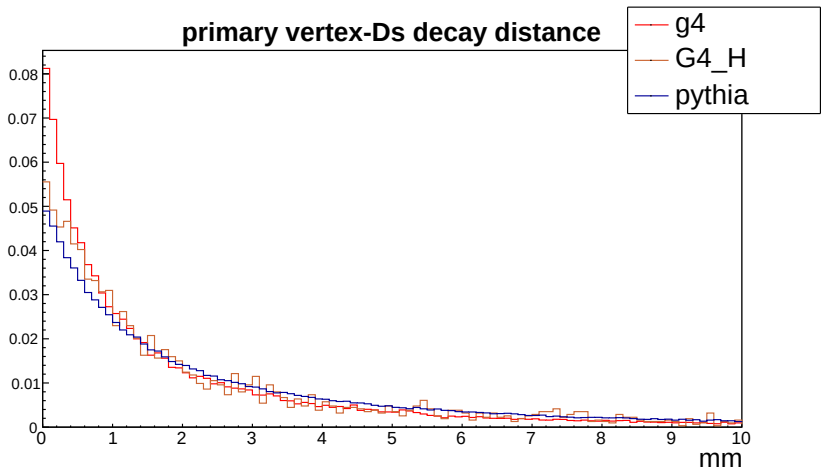
Dedicated software for the extraction of events of interest:

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

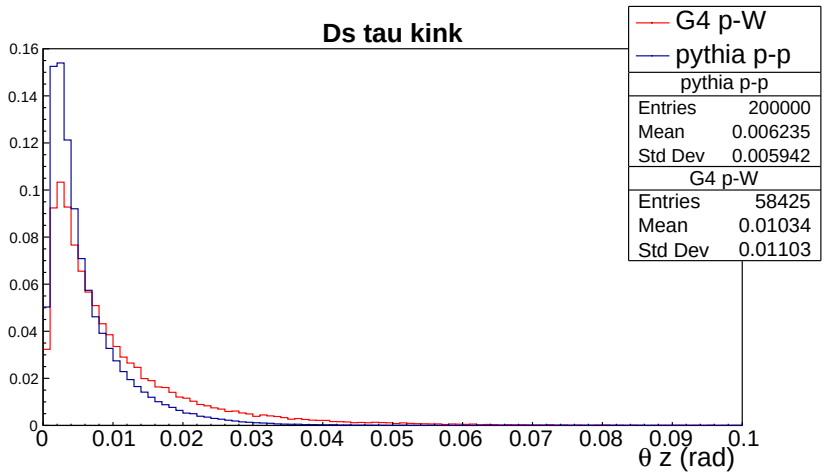
Films development

→ several chemical processes similar with photographic plate development

Predictions for Ds and τ detection



Ds decay length



Ds - τ kink

generator	mean (mm)	median	entries
pythia p-p	3.58 ± 0.01	1.72186	219649
G4 p-W	2.38 ± 0.02	1.08666	58425
G4 p-H	3.15 ± 0.09	1.40686	3133
fluka p-W	2.7 ± 0.57	1.95	23

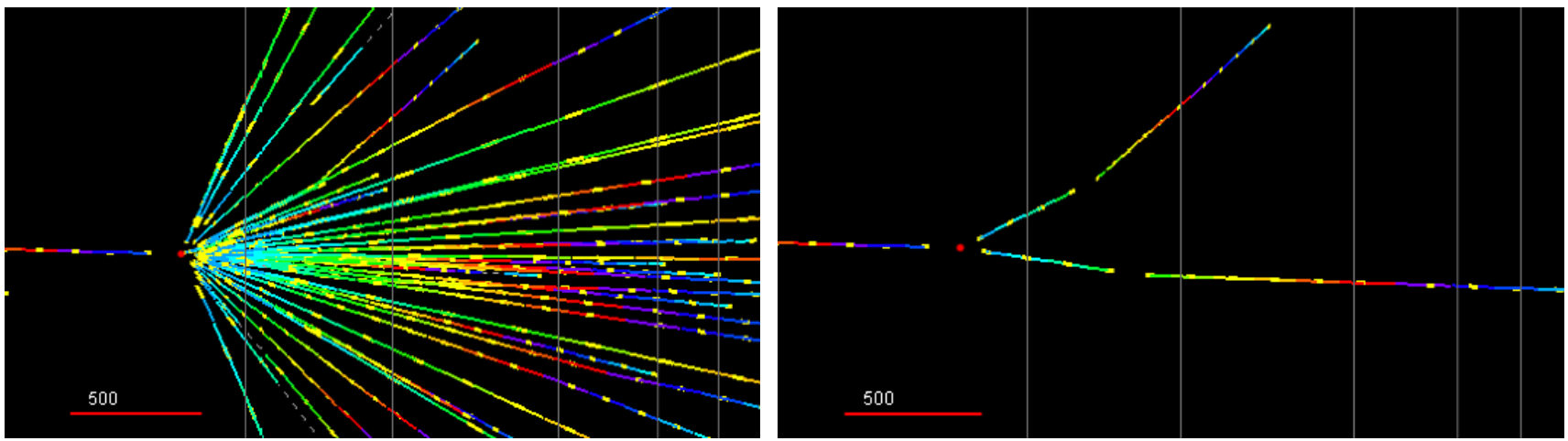
target	mean (rad)	median	entries
pythia p-p	$0.0062 \pm 1.3e-05$	0.0042	200000
G4 p-W	$0.0103 \pm 4.5e-05$	0.0066	58425

Solution for detecting Ds decaying $\tau \rightarrow$ high resolution tracking emulsion detectors

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 [2]

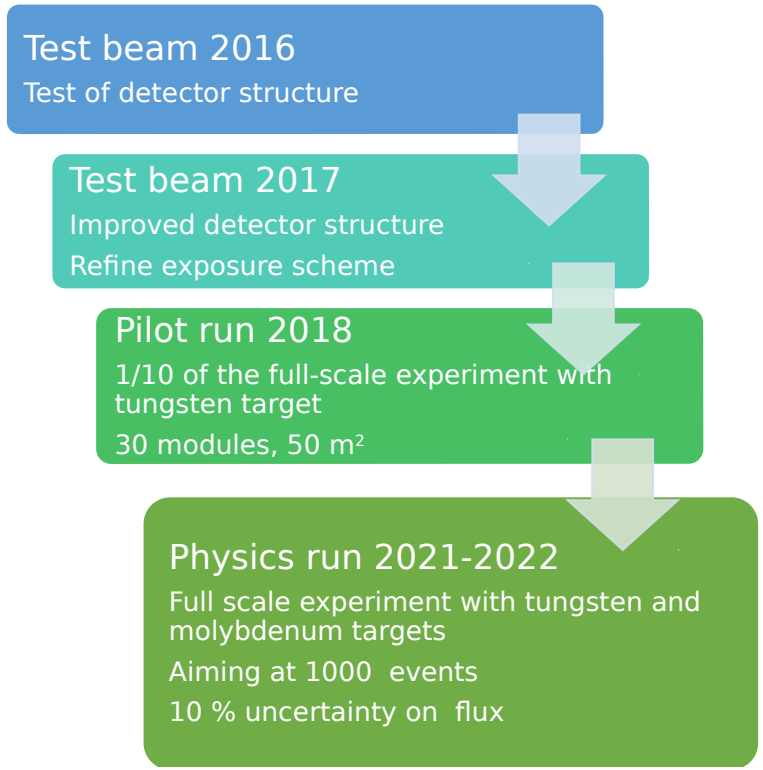
Current status of the experiment

Pilot run 2018

- 30 modules of 12.5cm × 10 cm were exposed
- performed to validate and justify the technique
- the emulsions have been scanned and are processed now
- **development of the data processing algorithms**

Physics Run 2021 and 2022

- 34 modules of 20 cm × 25 cm were exposed



Plan presented in [1]

Data analysis is ongoing. Algorithms for charm events recognition are under development.

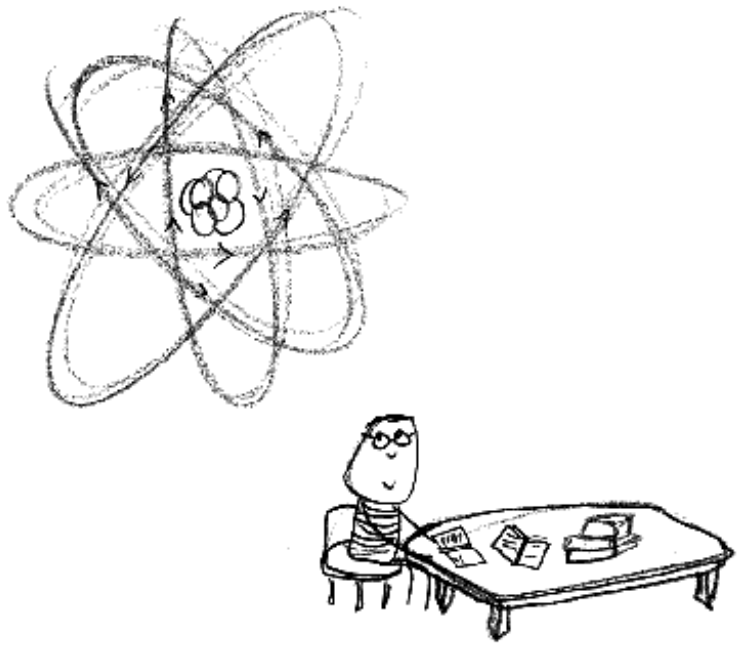
The DsTau experiment will highlight the ν_τ from D_s leptonic decay
$\rightarrow$ In DONuT experiment, 95% of ν_τ sources were from $D_s \rightarrow \tau + \nu_\tau$

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.

HAPPINESS IS



...studying physics.