Introduction of B02

B02 group

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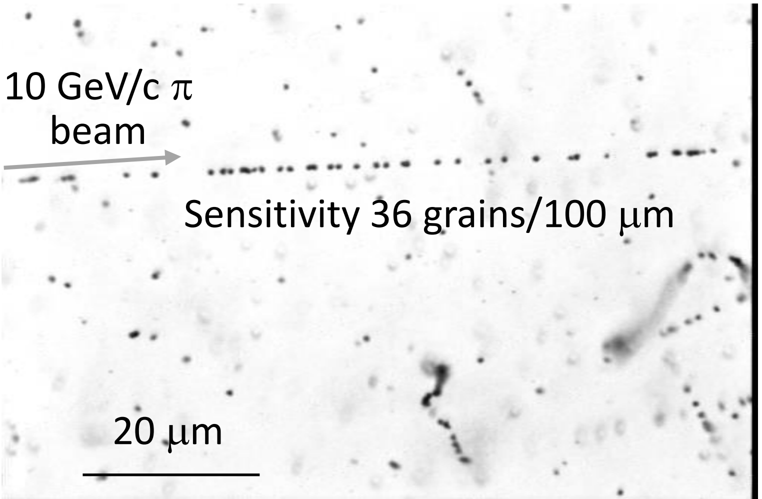
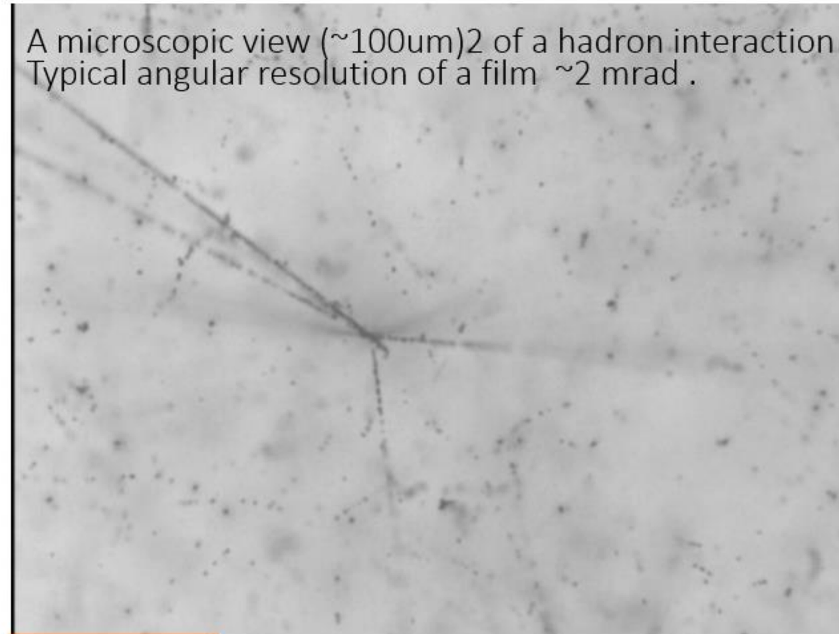
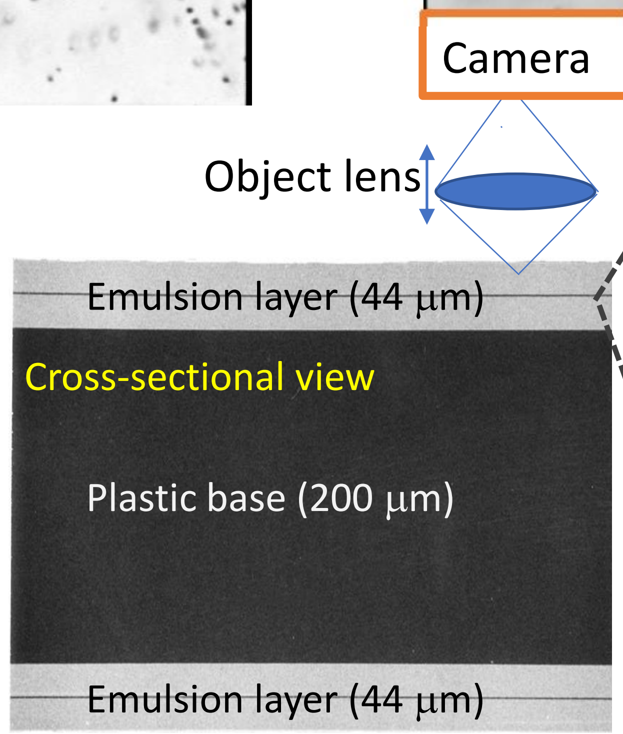
T.Ariga (Kyushu U.), S.Aoki (Kobe U.),S.Mikado (Nihon U.) et al.

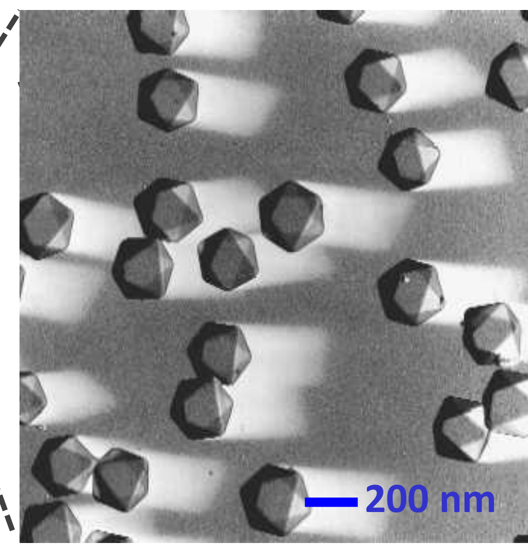
Nuclear Emulsion detector:

3D tracking device with 50 nm precision









AgBr crystal 10^{14} crystals in a film

Emulsion film

B02 subject and projects with B02 produced emulsion films .

B02 group subject :

Developing / constructing Nuclear Emulsion Production Facility to promote projects, scale of a total **nuclear emulsion area of several 100 m2 or 1000 m2**. (Status report by Next Speaker)

Running / Coming projects use Nuclear Emulsion produced by the new production machine.

There are 4 on-going **neutrino studies related experiments.**

- NINJA (J-PARC), Study of sub-GeV GeV neutrino interactions (dedicated talk by A. Kasumi , A02 tomorrow).
- DsTau (NA65 CERN SPS), Study for tau neutrino flux
- FASERν (LHC), Study of High Energy neutrino from the LHC
- SND (LHC) , Study of High Energy neutrino from the LHC

A brief introduction follows

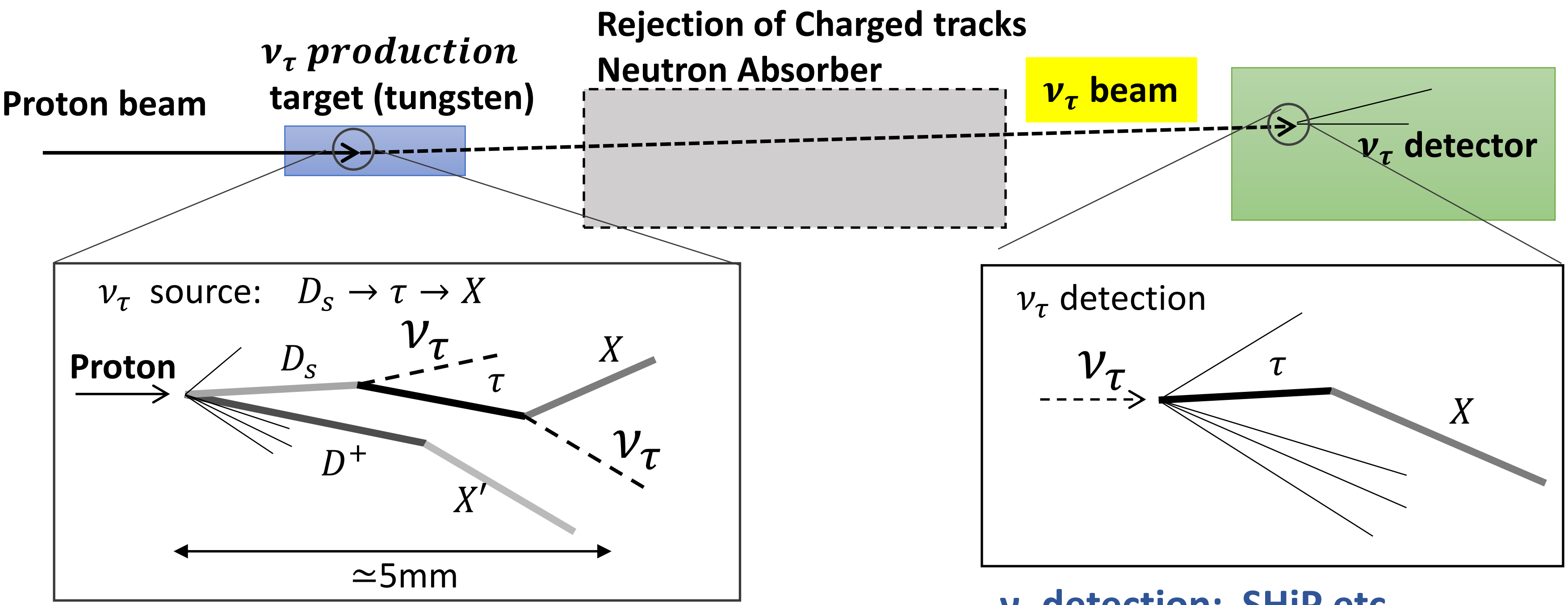
And **other projects.**

- GRAINE Precise measurement of cosmic gamma rays (Second Next talk)
  Balloon flights in 2023 -
- Scan Pyramids Muon radiography for Pyramid
  Observation from multiple observation site for targets

* There are **Presentations in this 領域研究会 meeting** about **Green parts** .

Tau neutrino cross section measurement

- concept -



ν_τ production study: DsTau

- **No data of Ds differential production cross-section**
- **Larger ~50% uncertainty of ν_τ flux**

ν_τ detection: SHiP etc.

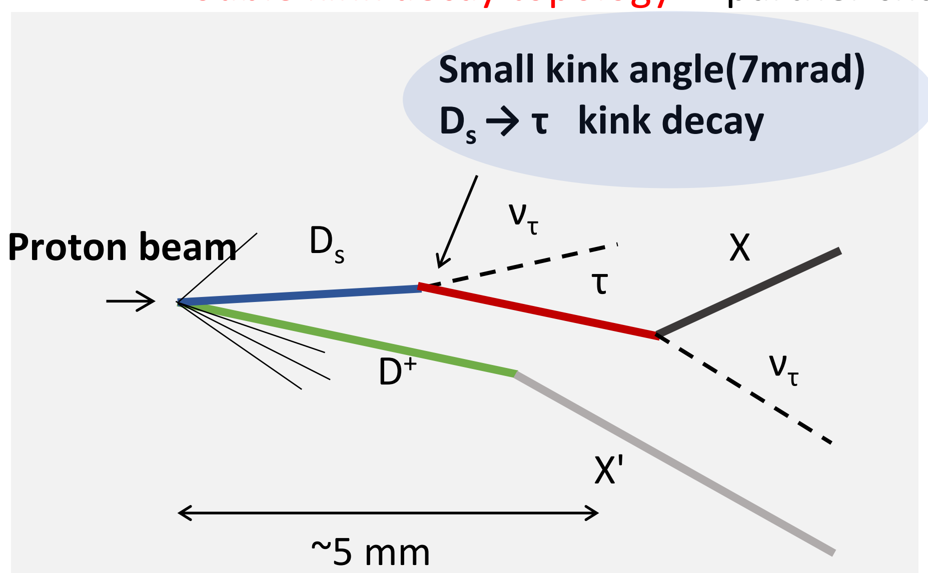
- 9 ν_τ detected by DONuT (bam ν_τ). 33% statistical error
- 10 ν_τ detected by OPERA (Oscillated ν_τ)
- SHiP ~ 10000 events a few % statistical error

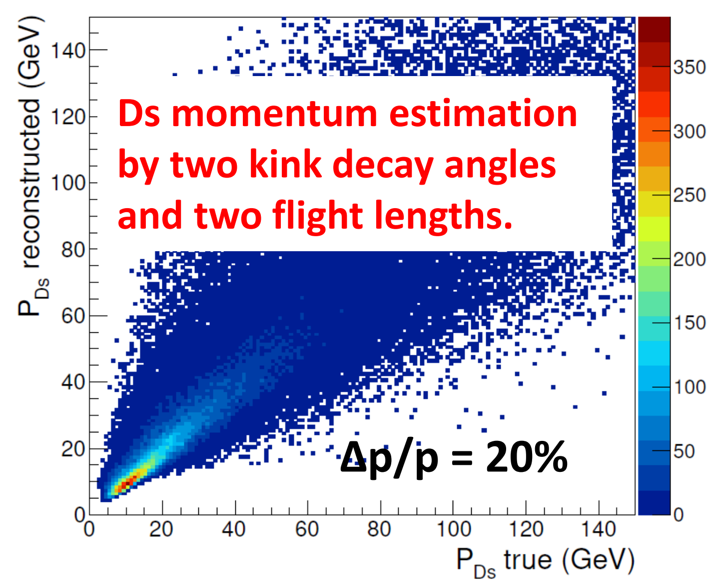
DsTau(CERN NA65)

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

- **Physics Target**
  - **Precise understanding of ντ production flux**
    - Measurement of differential (X_F, Pt) production cross section of Ds
  - Reduction of tau neutrino nucleon cross section uncertainty 50% → 10%
    - Update of tau neutrino cross section given by DONUT by new knowledge on tau neutrino flux.
    - Inputs for future tau neutrino projects : SHiP ν_τ
  - Byproduct study
    - **Charm production: forward production, 、intrinsic charm ?**
    - Charm hadron's interaction cross section measurement.

- **Tau neutrino production study principle**
  - Double kink decay topology + partner cham validation.





The detector structure (~400 modules)

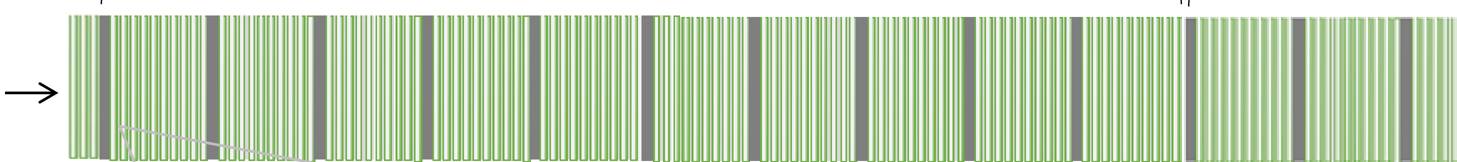
DsTau paper: 10.1007/JHEP01(2020)033

2.3x10[8] Proton-tungsten interactions （4.6x10[9] POT）

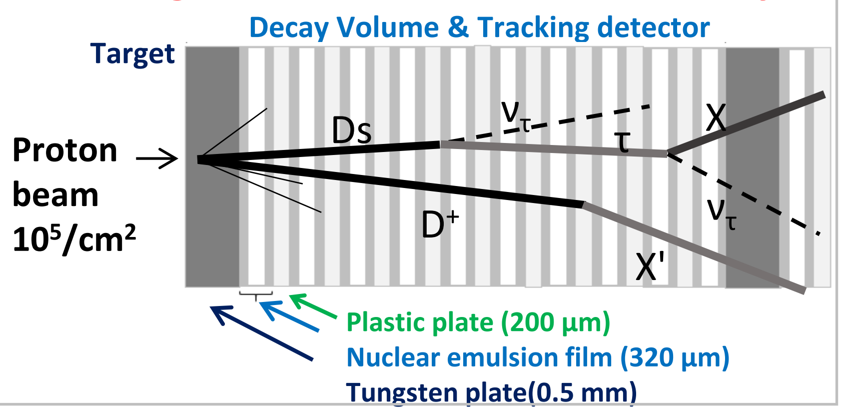
400GeV/c Proton beam

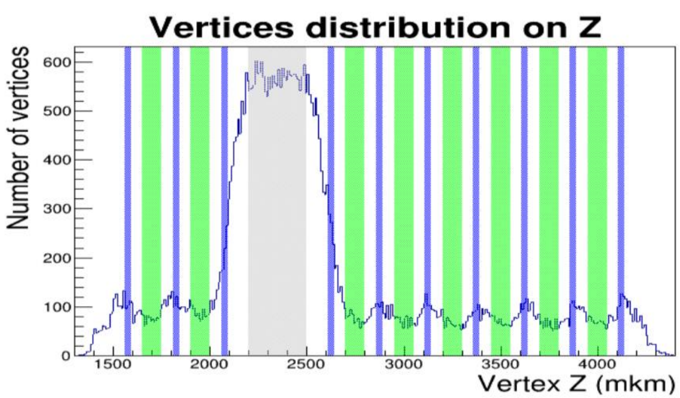
10 Units
(A total of 100 nuclear emulsion films)

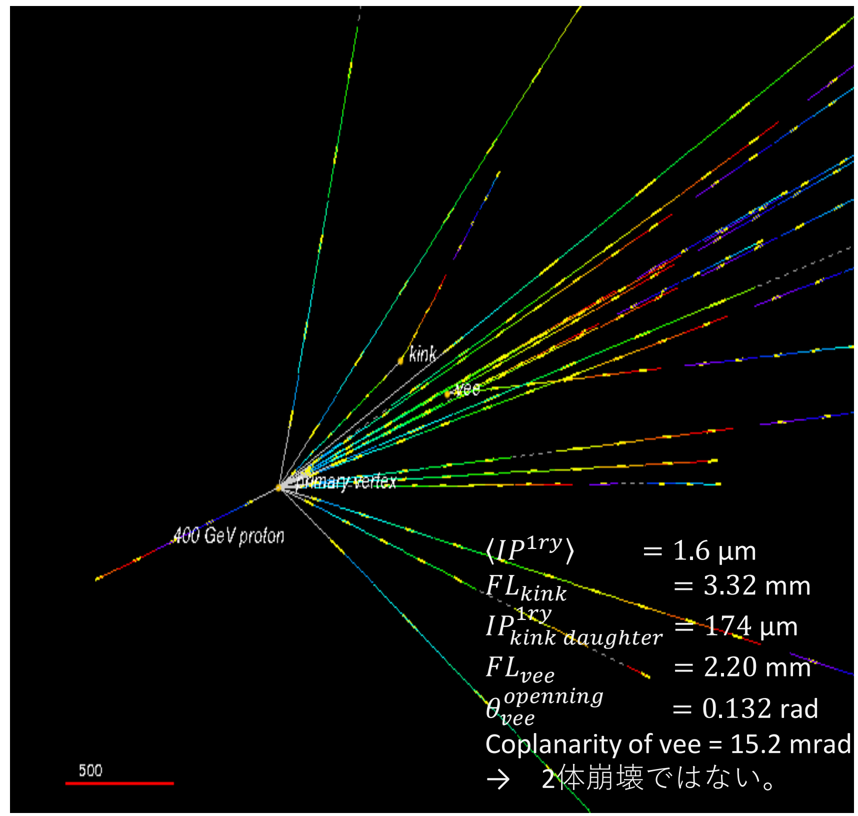
Another 2 units for momentum evaluation (25 films）



Detecting about 1000 Ds → τ →X decays



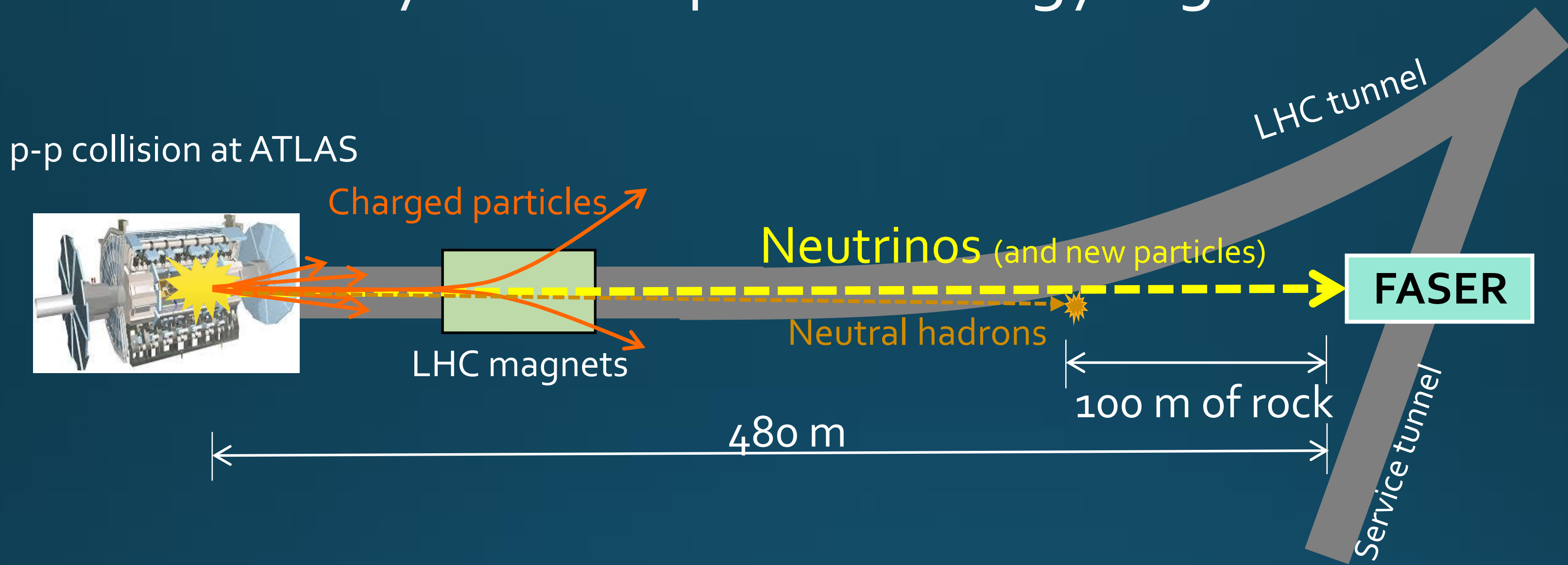


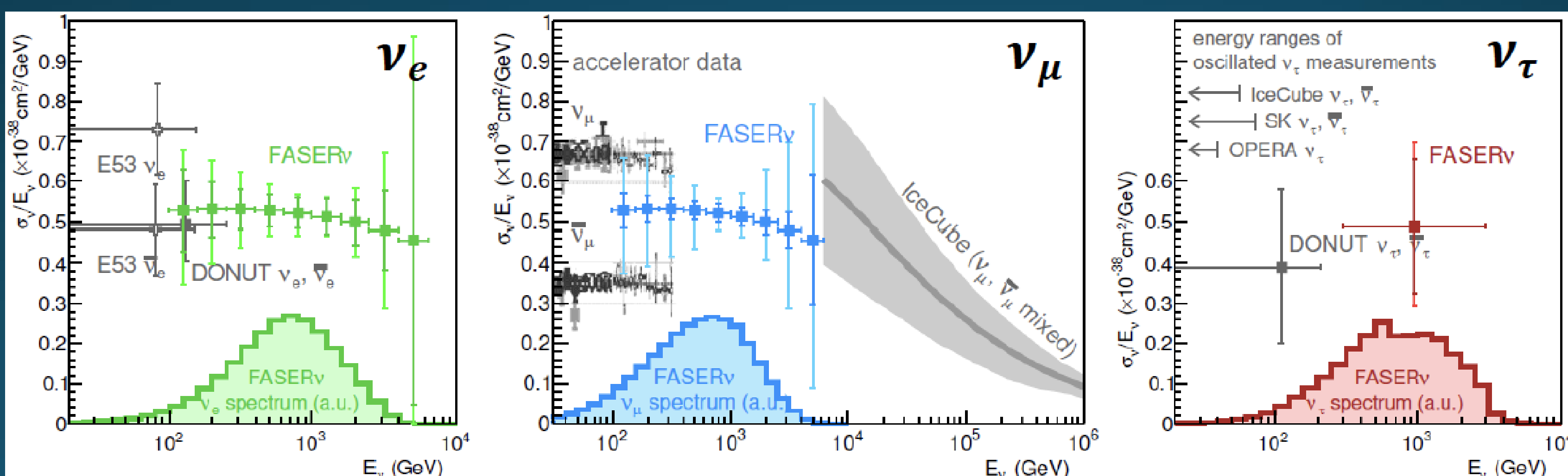


Schedule

Beam exposure	Detector modules	Total sum of emulsion films surface (m2)	Supplier	Comment /Status
Pilot run 2018	30	49	FUJI gel pouring at Nagoya, BERN	
Physics run 2021	**70**	**115**	**B02 product films**	**Exposure done** **Films are ready to scan**
Physics run 2022	**70**	**115**	**B02 product films**	**Films are under production by B02.**
Physics run 2023	**200**	**330**	**B02 product films**	

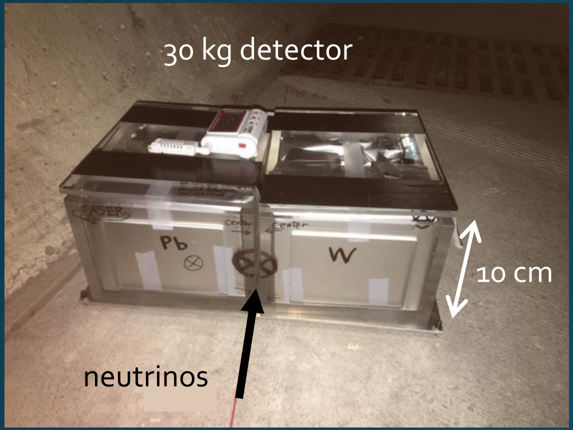
FASERν (ForwArd Search ExpeRiment): neutrinos study at un-explored energy region

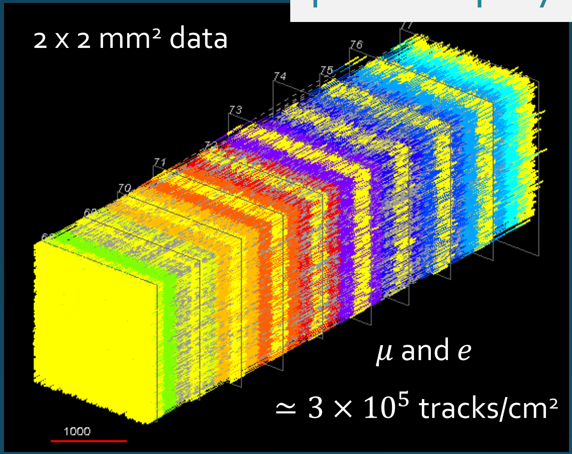


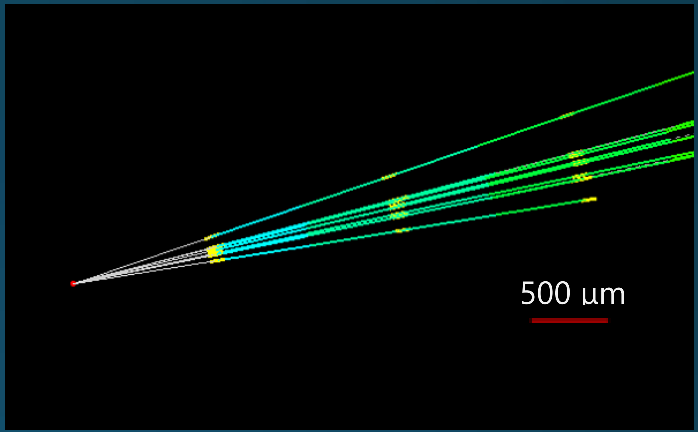


First observation of neutrino candidates from the LHC

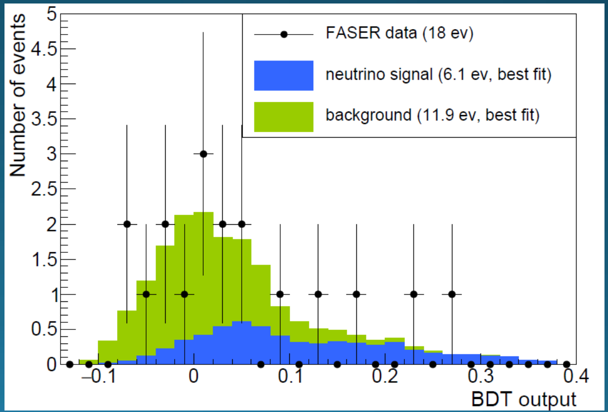
FASER Collaboration,
[**Phys. Rev. D 104, L091101 (2021),**]
press releases in Nov. 2021,
picked up by 43 news outlets [Altmetric]



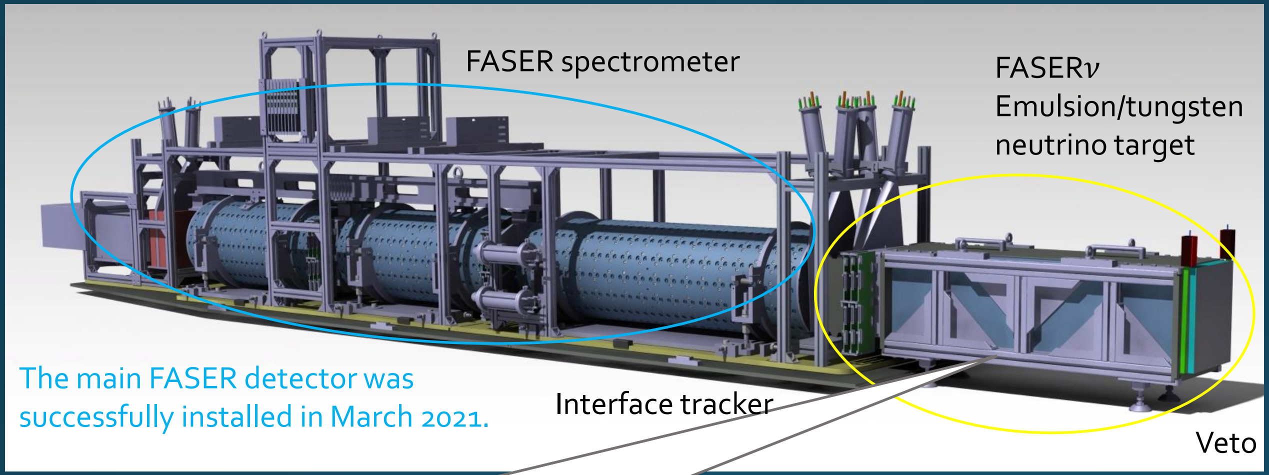


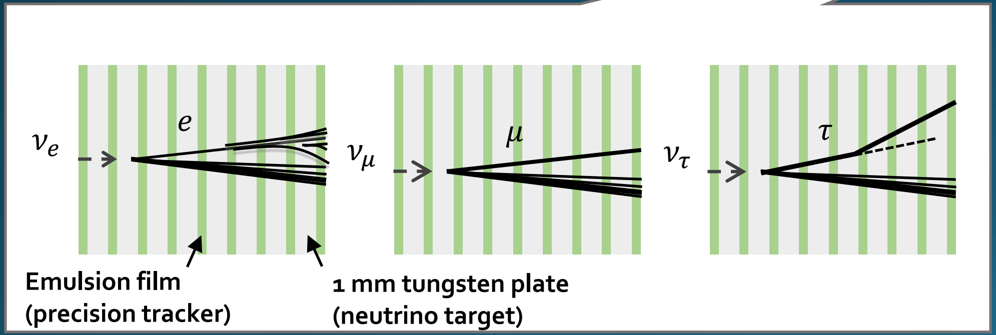


- A total of 30 kg emulsion cloud chamber exposed to LHC forward "beam" in 2018.
  - 12.2 fb^{-1} of data in Sep-Oct 2018
- The experimental concept was validated: neutrino study with the LHC is possible.
- Physics run in 2022 – 2024 (extended to 2025)



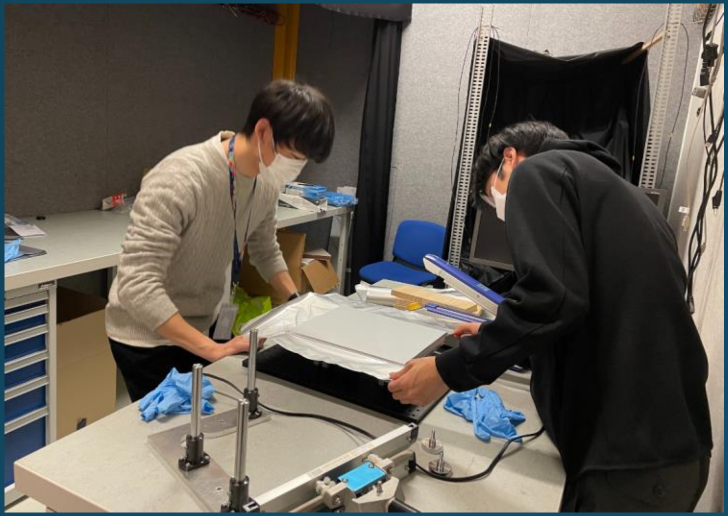
FASER/FASERν detector in LHC Run 3 (2022-2025)





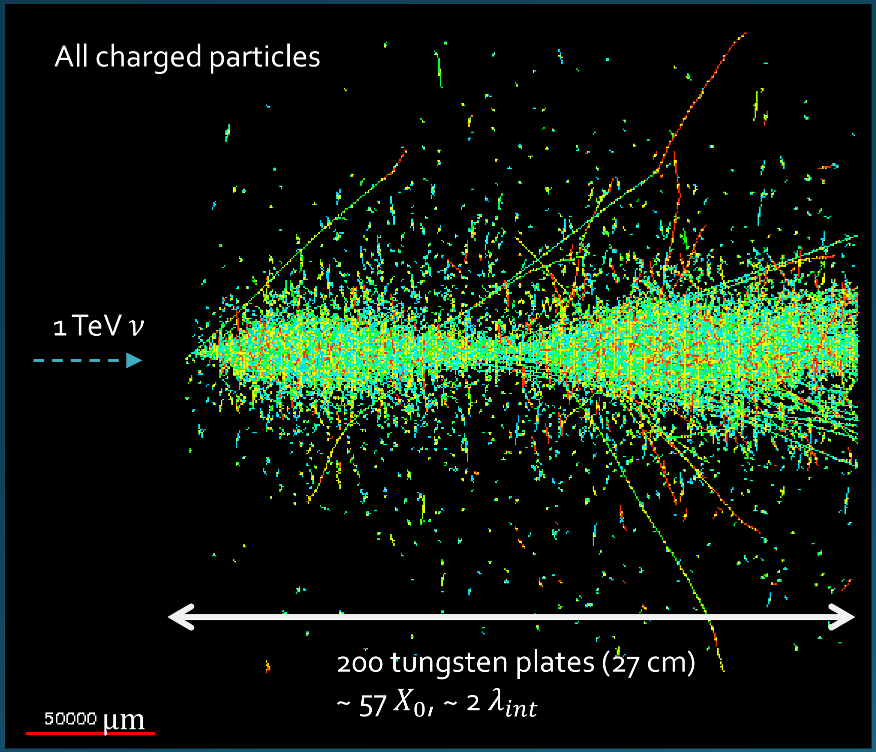
- A total weight of **1.1 ton** neutrino detector: tungsten and emulsion could chamber
- **3 neutrino flavors** will be detected and studied.
- **Emulsion films (~60 m²)** will be replaced 3 times per year.
- $\nu_\mu, \bar{\nu}_\mu$ will be identified using the FASER magnetic spectrometer.

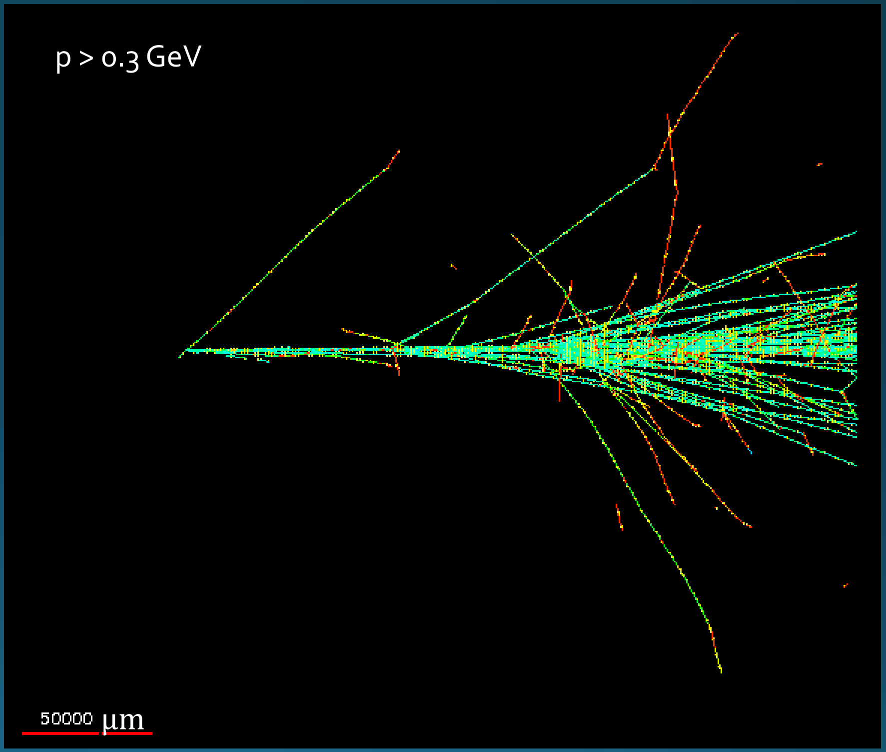
Preparation in progress for the first FASERν installation in Mar. 2022



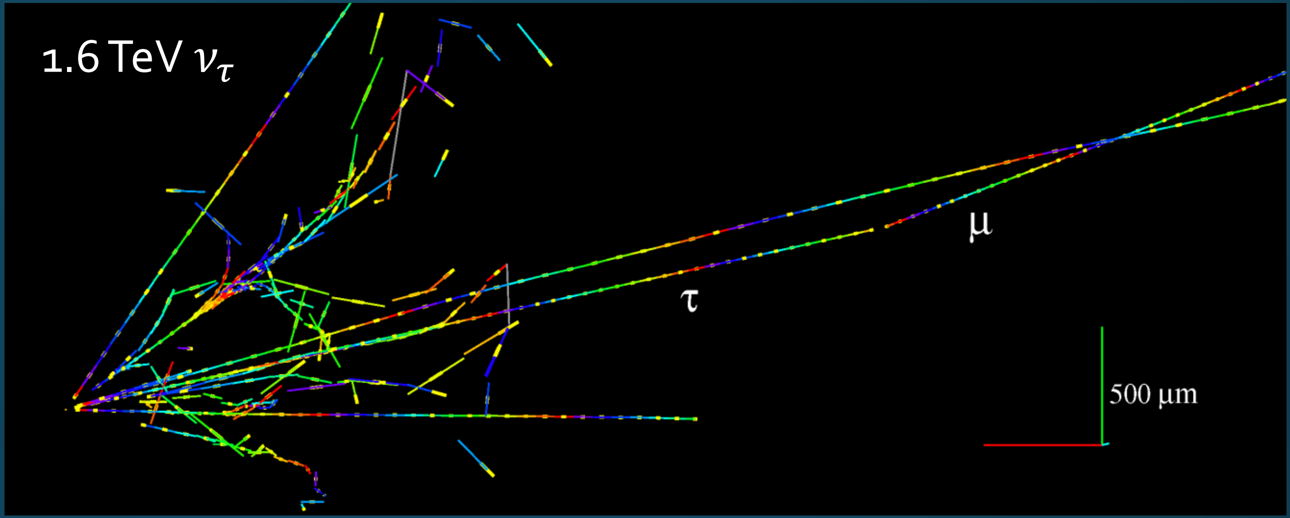
First batch of B02 emulsion delivered in time !

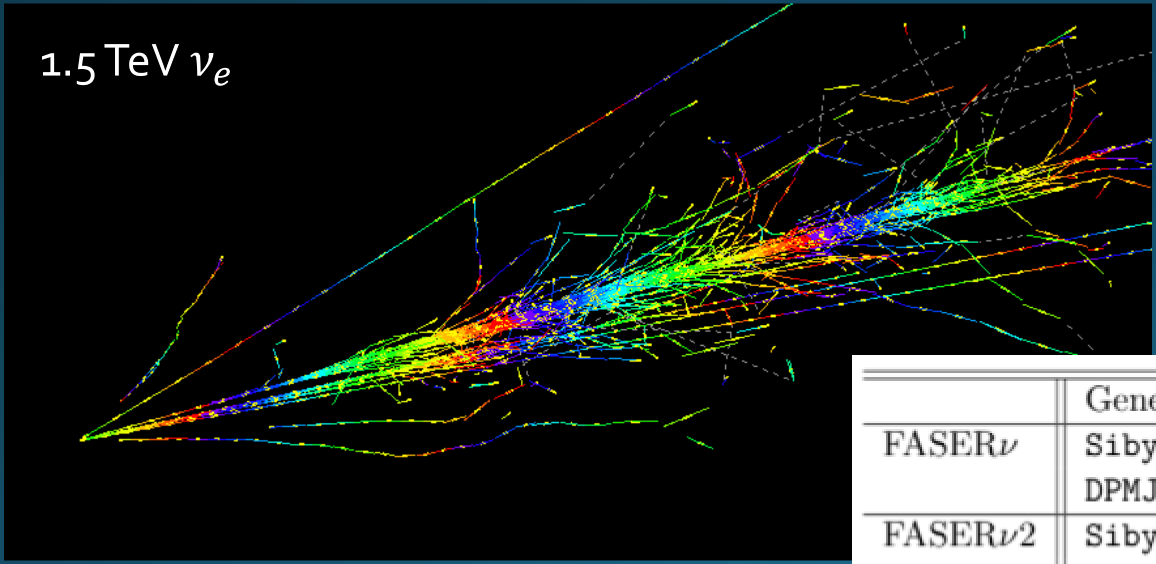
Simulated 1 TeV ν_μ CC interaction





Simulated ν_e and ν_τ events



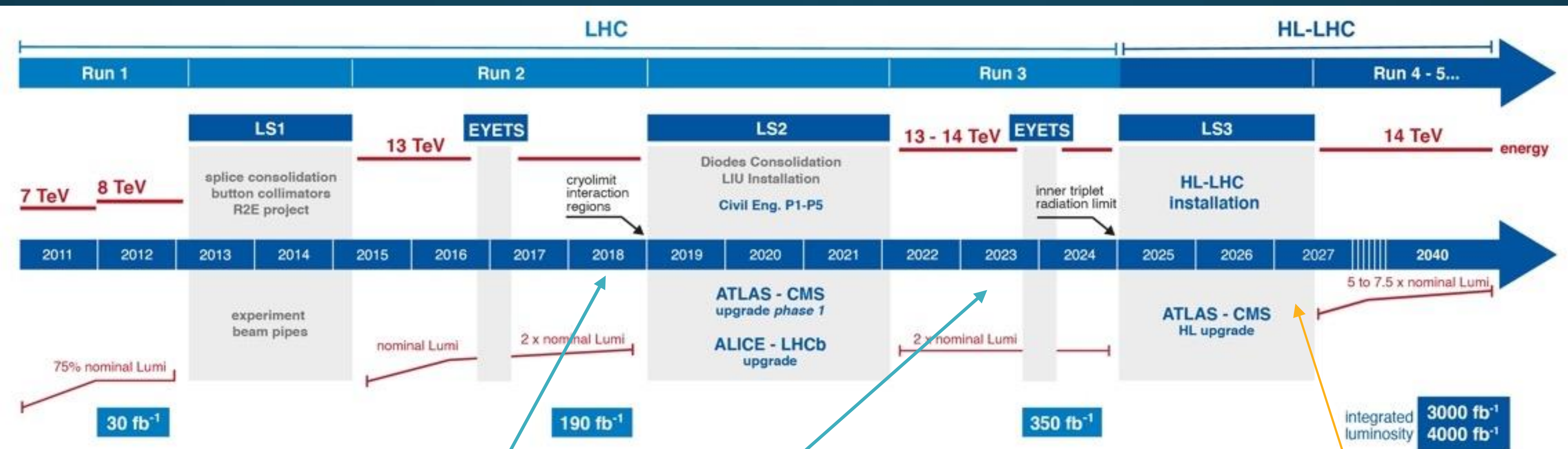


Expected neutrino event rates

	Generator	$\nu_e+\bar{\nu}_e$ CC	$\nu_\mu+\bar{\nu}_\mu$ CC	$\nu_\tau+\bar{\nu}_\tau$ CC
FASERν	Sibyll	0.9k	4.8k	15
	DPMJet	3.5k	7.1k	97
FASERν2	Sibyll	178k	943k	2.3k
	DPMJet	668k	1400k	20k

FASERν/FASERν2 schedule

- LHC Run-3 will start in 2022, aiming to double the integrated luminosity.
- HL-LHC, starting in 2027 (or later), will deliver 10 times more integrated luminosity.



Pilot run & background measurements in 2018

FASER's physics run ($\sim$150 fb^{-1} or more)

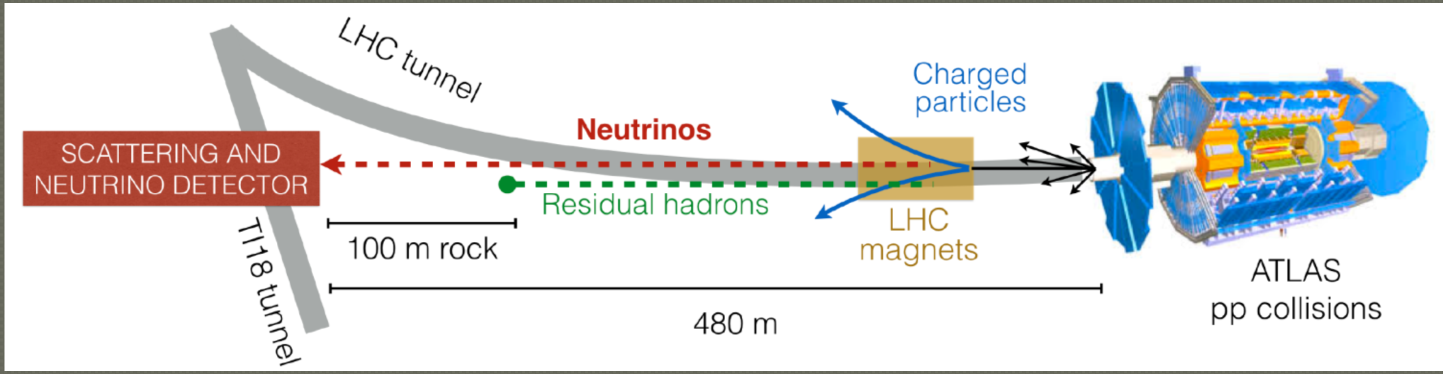
Forward experiment in HL-LHC

2022-25 physics run in LHC RUN3, 1.1 tons, a total area of film 540 m^2 (+180 m^2 for 2025)

2027- FASERν2@FPF in HL-LHC, 10-20 tons

First batch of B02 emulsion delivered for 2022 run

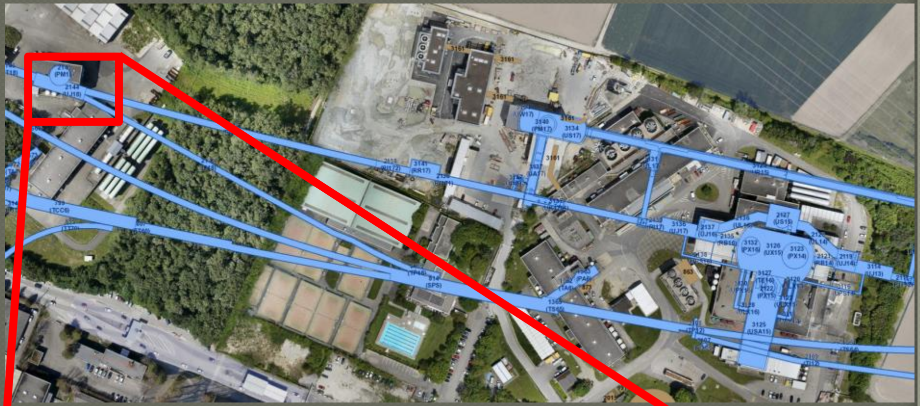
SND@LHC

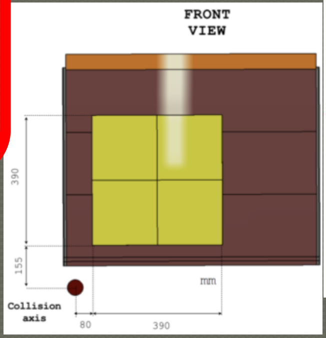


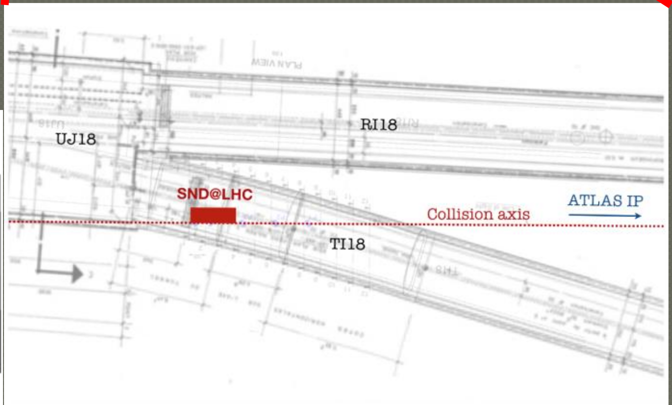
- Physics and SHiP SND(Scattering and Neutrino Detector) prototyping
  - LHC RUN3 ('22-'24) 150 fb^{-1}.
  - Neutrino as a probe of forward heavy flavor production can not be reached by LHCb
    - Complementary to FASERν (On and Off axis)
  - Lepton universality test on high energy neutrino

Location

- TI18 tunnel
  - Former service tunnel connecting SPS to LEP
  - Symmetric to TI12, where FASER is located
- ~480 m from ATLAS interaction point
  - Shielded with ~100 m of rock
- Angular acceptance :
  - Off-axis : $7.2 < \eta < 8.6$
  - Complementary to FASER
    - On-axis : $\eta > 8.8$

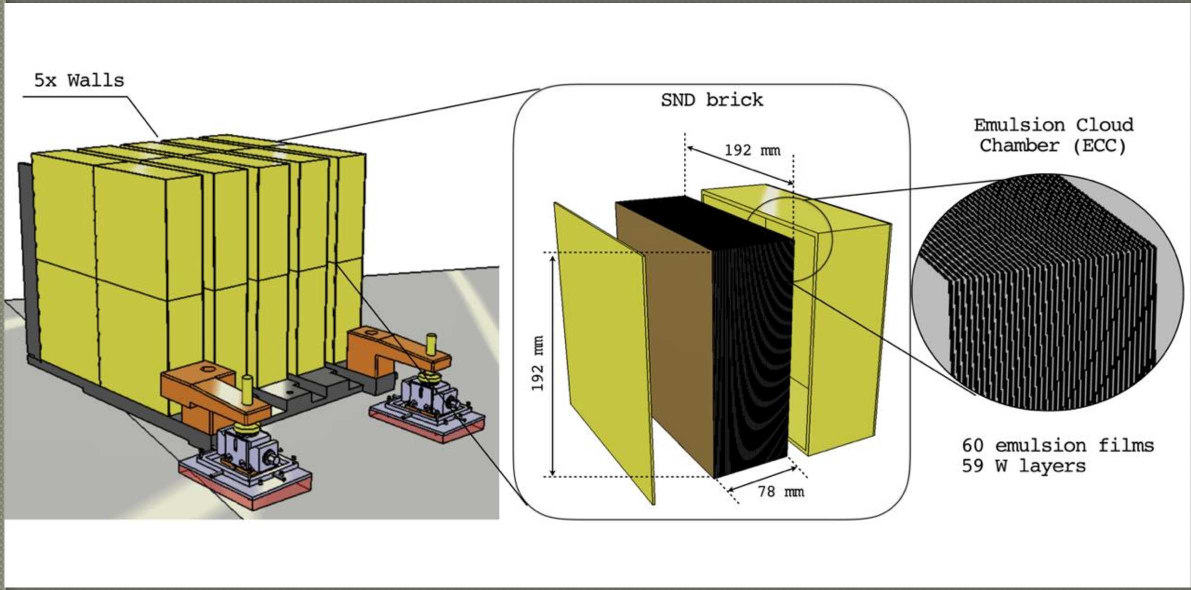






~480 m away

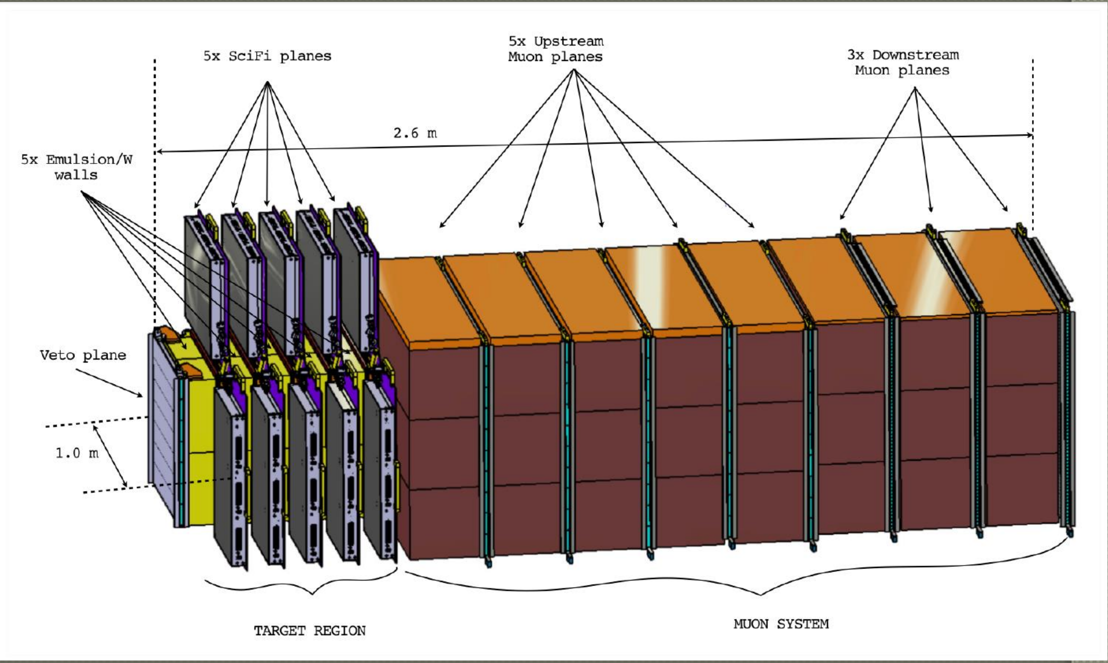
ECC target



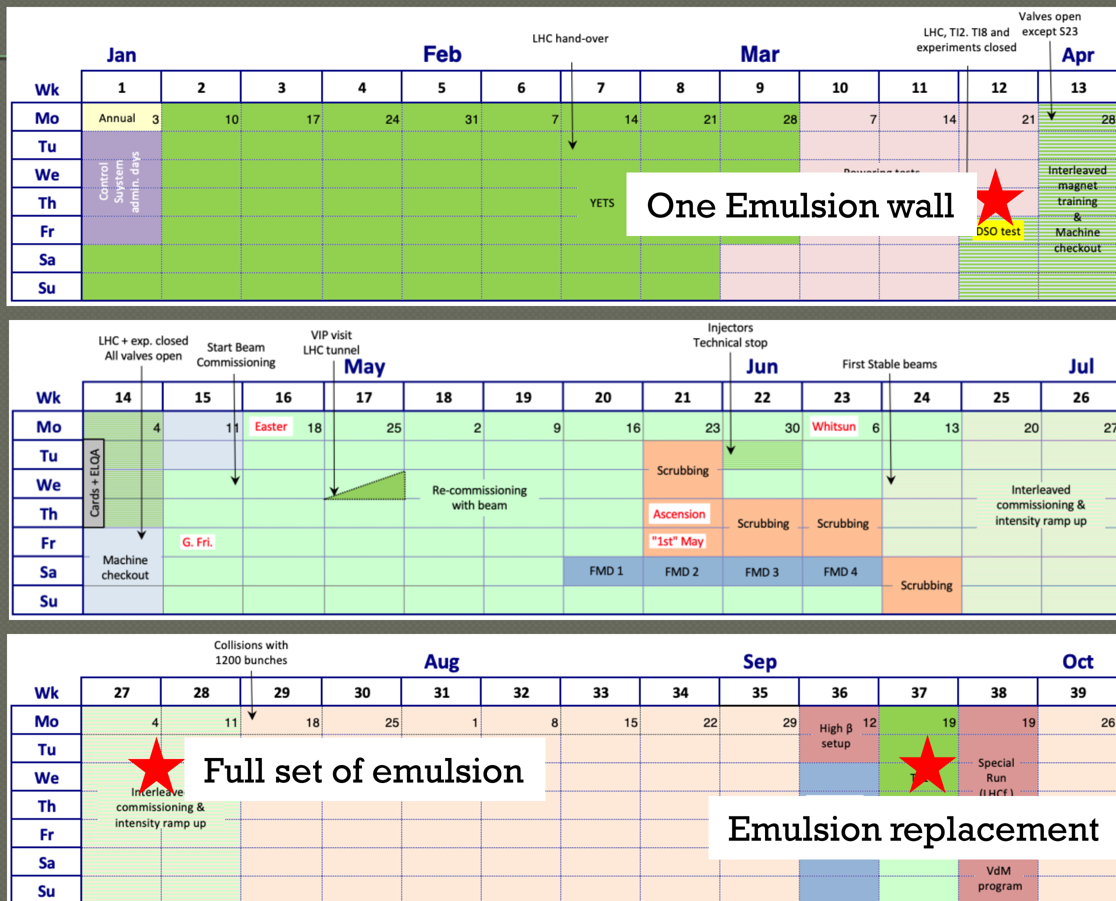
- Number of bricks : 20
  - walls: 5
  - Bricks per wall : 4
- Brick surface: 192x192 mm^2
  - Brick thickness: 78 mm
  - 60 films + 59 W plate
- Passive material : Tungsten
  - Total mass : 830 kg
  - Total emulsion surface : 44 m^2

Detector

- Veto
  - Scintillators : tag incoming muon
- Target region
  - ECC Target mass : **830kg**
    - 1/10 of SHiP SND (8tons)
    - 390mm x 390 mm x 5 walls
    - **44 m^2 emulsion x 6 exchange**
  - Scintillating fiber tracker/ECAL
    - Timestamp, position and EM calorimetry
- Muon system
  - Iron walls and scintillators
  - Muon ID and Energy measurement
  - Major difference wrt FASER



2022



First batch of B02 emulsion delivered for 2022 run

Summary of B02 Emulsion amount for

NINJA DsTau FASER SND@LHC

Installation / Beam exposure Year	NINJA Total Emulsion surface(m2)	DsTau Total Emulsion surface (m2)	FASERnu Total Emulsion surface (m2)	SND Total Emulsion surface (m2)
2018	10	49	30	0
2019	120	0	0	0
2020	25	0	0	0
2021	**0**	**115**	**0**	**0**
2022	**120**	**115**	**180**	**88**
2023	**380**	**330**	**180**	**88**
2024	**100**		**180**	**88**
2025	**600**		**180**	

B02 Emulsion

- B02 constructed a new emulsion production facility at Nagoya university.
- Started supplying emulsions to REAL projects and physics results will come soon !
- Together with production, polishing emulsion quality and production process improvement is continued in order to increase the production power and reduce man power ..

Thesis from B02 in 2021 academic year

Doctor thesis (2)

- Development of fine accuracy nuclear emulsion by focusing base material, Y. Manabe (Nagoya Univ)

- Precise Imaging of cosmic gamma-ray objects by emulsion telescope, Y. Nakamura (Nagoya Univ) → Digest version will come with second next talk.

Master thesis (3)

- Development of a detection method of nu-e interactions for the NINJA experiment, A. Kasumi (Nagoya Univ)

- Experimental demonstration of the most likely path method in proton radiography, L. Suzui (Nagoya Univ)

- Performance evaluation of Emulsion Spectrometer using Cosmic Rays, M. Yokogawa (Toho Univ)