

# $\nu_\tau$ -physics with the SHiP experiment

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DER FORSCHUNG | DER LEHRE | DER BILDUNG

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- 1 The SHiP Experiment
- 2 The SHiP- $\nu_\tau$  Detector
- 3 Drift-Tubes for the SHiP- $\nu_\tau$  Detector
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## Scientific Motivation

- explore the domain of very weakly interacting particles

## Experimental realization

- new beam-dump facility at the SPS
- 50 m long 10 m wide vacuum decay volume instrumented with magnetic spectrometer

## Perfect environment for $\tau$ -neutrino production

- neutrino detector in front of hidden particle detector
  - measurement of  $\nu_\tau$  and  $\bar{\nu}_\tau$  cross-sections and more
- 
- positive review from SPSC
- recommendation to prepare a Comprehensive Design Report
- will provide input into the next update of the European Strategy for Particle Physics in 2018/2019

## Technical Proposal

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)



CERN-SPSC-2015-036  
SPSC-P-350  
8 April 2015

### Technical Proposal

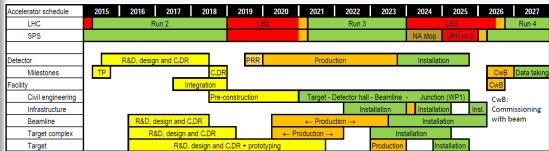
#### A Facility to Search for Hidden Particles (SHiP) at the CERN SPS

The SHiP Collaboration<sup>1</sup>

##### Abstract

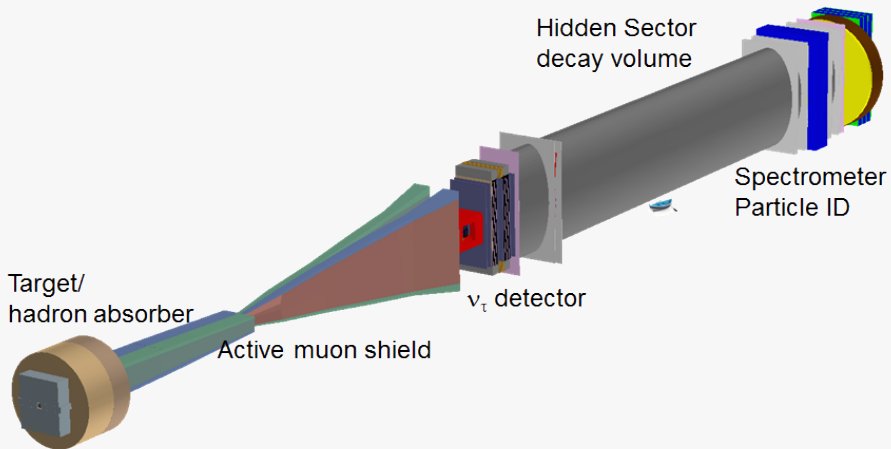
A new general purpose fixed target facility is proposed at the CERN SPS accelerator which is aimed at exploring the domain of hidden particles and subtle nonresonance with rare oscillations. Hidden particles are predicted by a large number of models beyond the Standard Model. The high intensity of the SPS 400 GeV beam allows probing a wide variety of models containing light long-lived exotic particles with masses below  $\mathcal{O}(10)$  GeV/c<sup>2</sup>, including very weakly interacting low-energy SUSY states. The experimental programme of the proposed facility is capable of being extended in the future, e.g. to include direct searches for Dark Matter and Lepton Flavour Violation.

<sup>1</sup> Authors are listed on the following page.

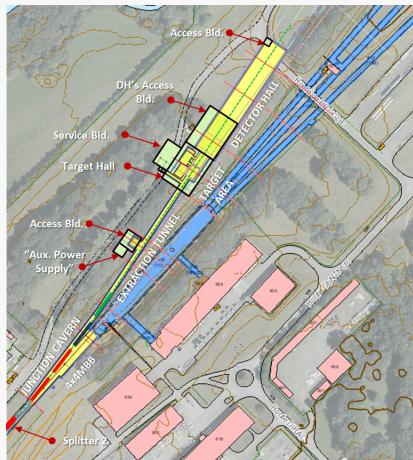
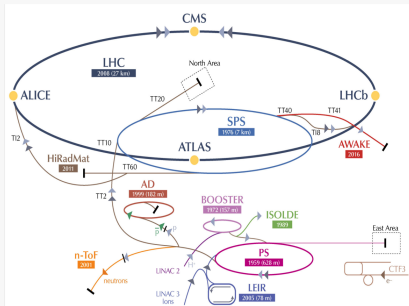


- project started 2014 with CERN taskforce
- Technical Proposal and Physics Proposal published last spring
- Comprehensive Design Report in 2018
- construction and installation 2021-2026
- data taking and analysis starting 2026

~ 250 physicists from 47 institutions / 15 countries

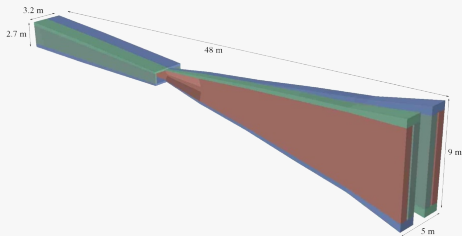


# Fixed Target Facility @ SPS (North Area)



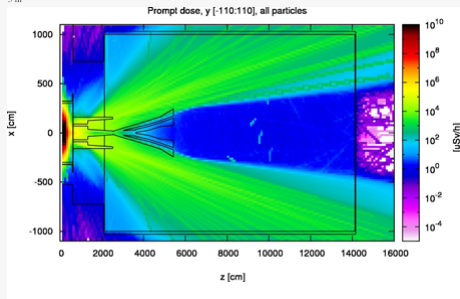
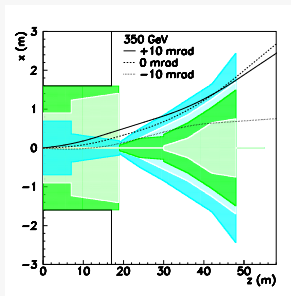
- 400 GeV protons
- Target: 58 cm Mo (4  $\lambda$ ), 58 cm W (6  $\lambda$ )
- $4 \cdot 10^{13}$  pot/spill
- 1 s spill every 7 s
- $2 \cdot 10^{20}$  pot in 5 years

# Magnetic Sweeper



Deal with  $10^{10}$  muons/spill

- active muon shield and passive absorber
- less than 100k  $\mu$ /spill remaining



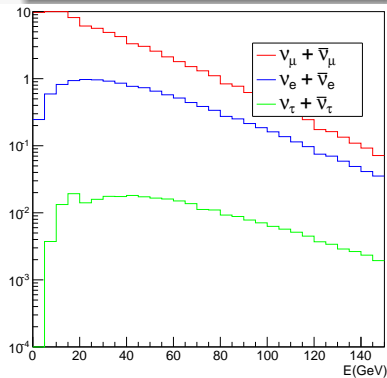
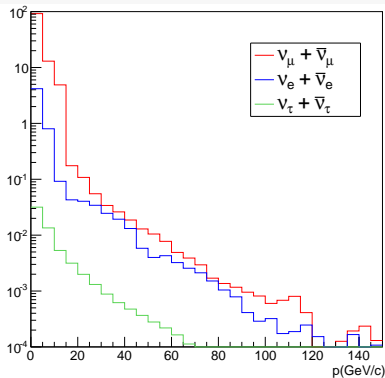
# Neutrino Production

## $\nu$ -production @ $p$ -target

- $5.7 \cdot 10^{15}$   $\nu_\tau$  and  $\bar{\nu}_\tau$
- $5.7 \cdot 10^{18}$   $\nu_\mu$  and  $\bar{\nu}_\mu$
- $3.7 \cdot 10^{17}$   $\nu_e$  and  $\bar{\nu}_e$

## Interactions @ $\nu$ -target

	$\langle E \rangle$ (GeV)	Number of $\nu$
$\nu_\mu$	30	$2.3 \cdot 10^6$
$\nu_e$	46	$3.4 \cdot 10^5$
$\nu_\tau$	58	$7.1 \cdot 10^3$
$\bar{\nu}_\mu$	27	$9.5 \cdot 10^5$
$\bar{\nu}_e$	46	$1.4 \cdot 10^5$
$\bar{\nu}_\tau$	58	$3.6 \cdot 10^3$



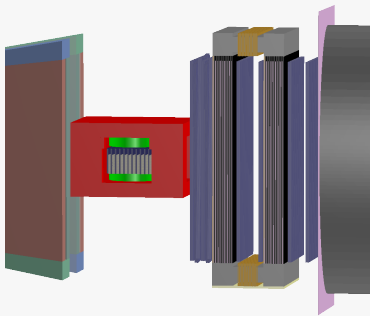


Direct measurements of tau neutrino CC-interaction fairly recent

- DONUT:  $9 \pm 1.5$  events
  - no distinction between  $\nu_\tau$  and  $\bar{\nu}_\tau$
- OPERA: 5 events
  - only  $\nu_\tau$

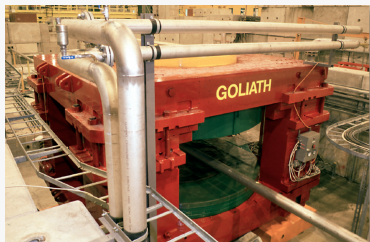
SM Physics opportunity for SHiP

- $\mathcal{O}(10000)$   $\nu_\tau/\bar{\nu}_\tau$  interactions
- study the properties and cross-section
- first observation of  $\bar{\nu}_\tau$
- extraction of  $F_4$  and  $F_6$  structure functions



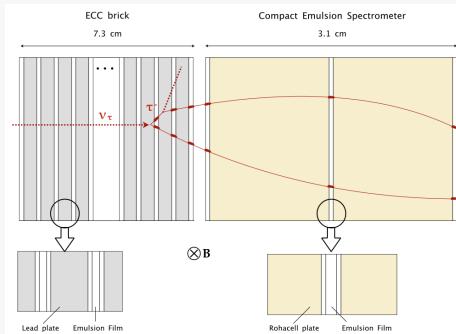
## Neutrino Target

- magnetized, modular target based on Emulsion Cloud Chamber technique
- 9.6 tons emulsion target
- planes of real-time detectors for timing and event identification



## Magnetic Spectrometer

- identification of muons
  - discrimination of background from charm events
- mainly reuse of OPERA spectrometer



## ECC Brick

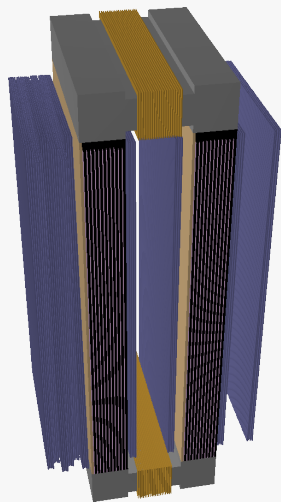
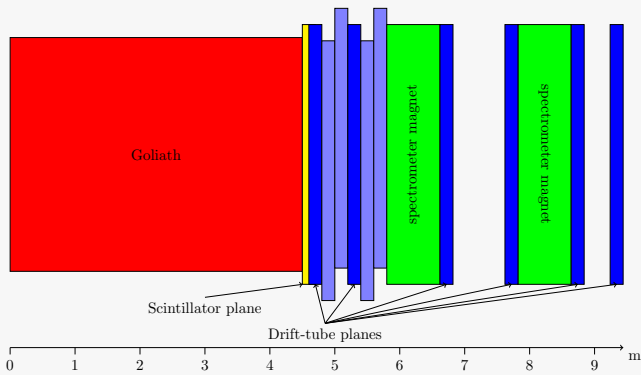
- 57 emulsion films (AgBr) with sub-micron resolution
- interleaved with 56 lead plates
- $128 \times 102 \times 79 \text{ mm}^3$ , 8.3 kg

## Compact Emulsion Spectrometer

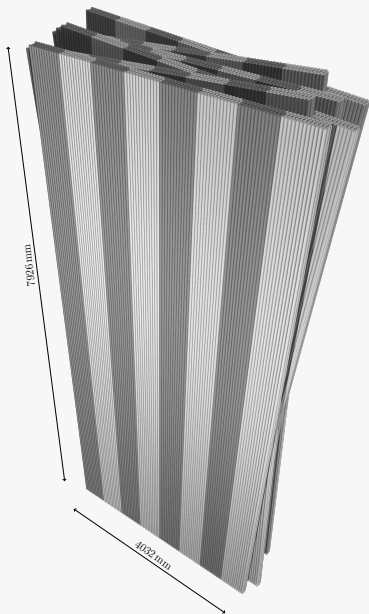
- behind each brick
- light material to minimize multiple scattering

- 11 walls of  $15 \times 7$  bricks  $\rightarrow$  1155 bricks
  - bricks will be exchanged every 6 months (10 replacements total)
  - $8700 \text{ m}^2$  total area of emulsion film
  - $\sim 300 \nu$ -interactions/brick  $- \sim 10^3$  particles/ $\text{mm}^2$
- $\rightarrow$  automated scanning of all emulsions

# Muon Magnetic Spectrometer



- (partial) re-use of the OPERA spectrometer
- drift-tubes for precision tracking
- new: 3D reconstruction of muons
  - deal with occupancy
  - connect muon tracks to target
  - use of Goliath as part of the spectrometer

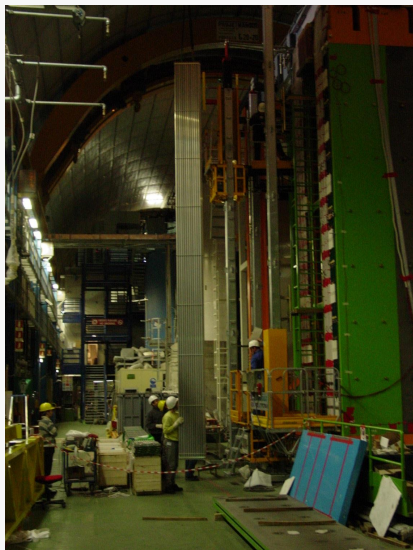


- aluminum tubes of 3.8 cm diameter
- 45  $\mu\text{m}$  gold-plated tungsten sense wire
- modules of  $4 \times 12$  staggered drift-tubes
- ten planes containing 8 modules each  
→ 3840 drift-tubes
- total width: 4 m @ center, 4.5 m @ ends

### Modifications needed

- stereo planes at angles of  $\pm 3.6^\circ$
- test of faster and more linear drift gas by adding  $\text{N}_2$
- new read-out electronics
  - read-out of all signals w/o a trigger
  - faster read-out times

⇒ R&D ongoing in Hamburg



- dismantling of OPERA has begun
- drift-tubes are stored in containers

Waiting for SHiP!

- SHiP experiment now proposed at CERN / SPS
- BSM-physics
  - can test a variety of models
- $\tau$ -neutrino physics (sturdy SM physics)
  - improvement of sensitivity by  $\mathcal{O}(200)$
- Technical Proposal submitted last spring
- Positive feedback from SPSC
- Next step: CDR
- Begin of data taking end of 2026