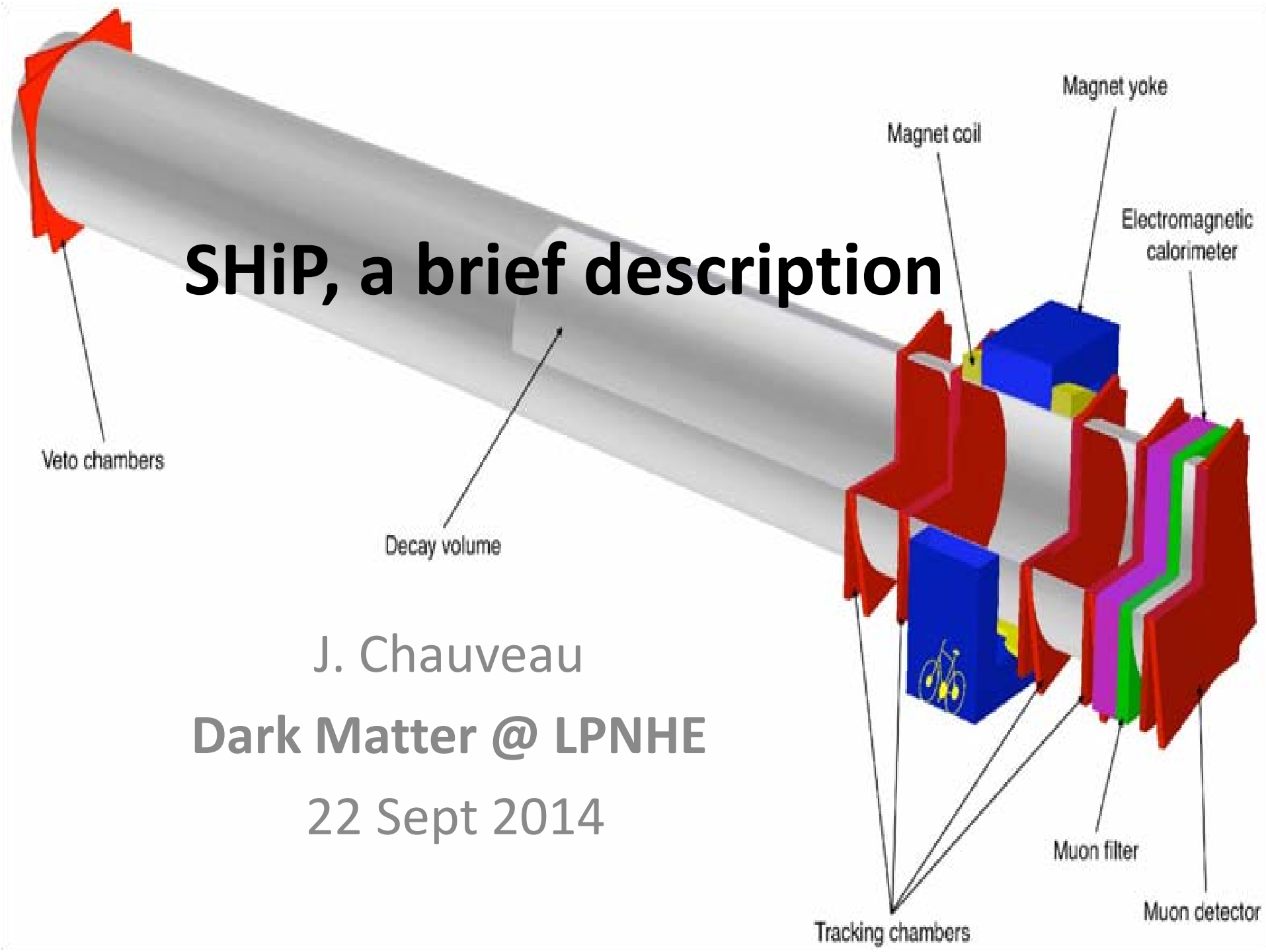


SHiP, a brief description

J. Chauveau

Dark Matter @ LPNHE

22 Sept 2014



SHiP abstract on their website

<http://ship.web.cern.ch/ship/>

The SHiP Experiment is a new **general-purpose fixed target facility at the SPS** to **search for hidden particles** as predicted by a very large number of recently elaborated models of Hidden Sectors which are capable of accommodating **dark matter, neutrino oscillations, and the origin of the full baryon asymmetry in the Universe**. Specifically, the experiment is aimed at **searching for very weakly interacting long lived particles** including **Heavy Neutral Leptons** - right-handed partners of the active neutrinos; **light supersymmetric particles** - sgoldstinos, etc; **scalar, axion and vector portals to the hidden sector**. The high intensity of the SPS and in particular the large production of charm mesons with the 400 GeV beam allow accessing a wide variety of light long-lived exotic particles of such models and of SUSY. Moreover, the facility is ideally suited to study the interactions of **tau neutrinos**.

Outline

- Physics motivation
- Experimental method
- Experimental setup
- Expected physics reach
- Timeline
- Pros and Cons for LPNHE

seminars by A. Golutvin (22 May), M. Shaposhnikov (02 June)

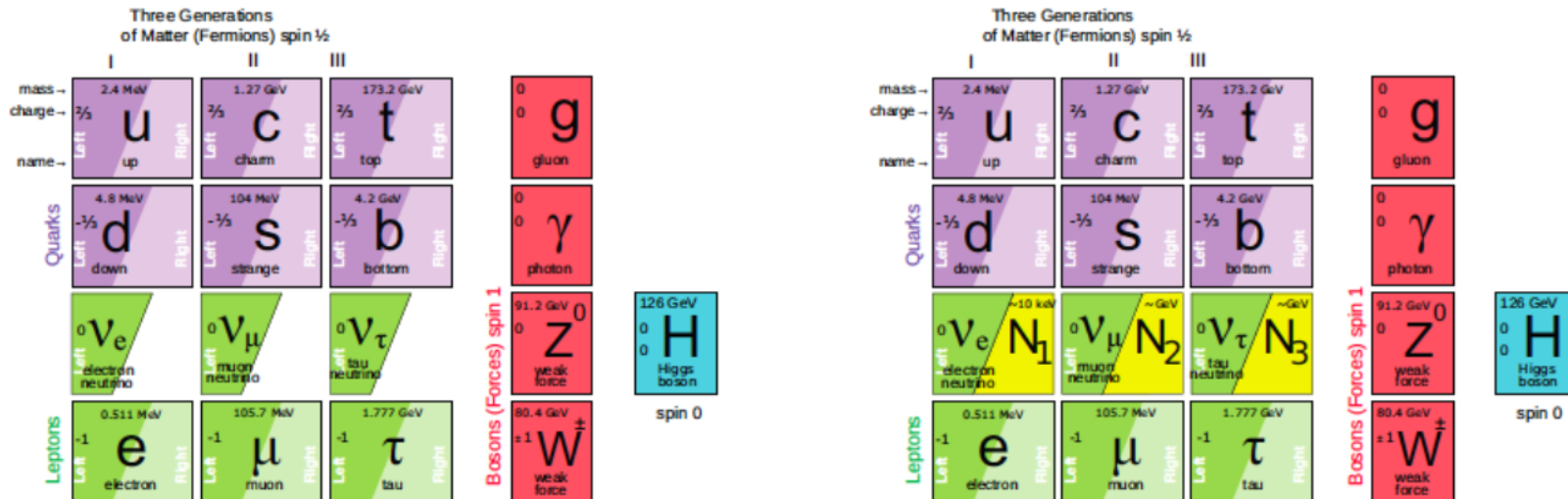
A hidden sector?

- Rather than being heavy, could new particles be light but very weakly interacting?
- e.g. new, light “hidden sector” of particles which are singlets wrt gauge group of the SM
- Several possibilities for renormalisable singlet operators which each involve some hidden sector particle **mixing** with some SM “portal particle” :

- **
 - **Vector portal** – new $U(1)$ $B_{\mu\nu}$ – massive vector photon (paraphoton, secluded photon...) mixing with regular photon $\rightarrow \epsilon B_{\mu\nu} F^{\mu\nu}$
 - **Higgs portal** – new scalar field $\chi \rightarrow (\mu\chi + \lambda\chi^2)H'H$
 - **Axial portal** – new axial-vector field a – Axion Like Particles (to distinguish from Peccei–Quinn axion) $\rightarrow (a/F)G_{\mu\nu}G^{\mu\nu}, (\partial_\mu a/F)\psi' \gamma_\mu \gamma_5 \psi$
- ***
 - **Neutrino portal** – new heavy neutral leptons (HNL) $\rightarrow YH^T N' L$

Neutrino portal observables: (Heavy Neutral Leptons)

ν MSM (T.Asaka, M.Shaposhnikov PL **B620** (2005) 17) **explains all short comings of the SM at once by adding 3 HNL: N_1 , N_2 and N_3**



N = Heavy Neutral Lepton - HNL

Role of N_1 with mass in keV region: dark matter

Role of N_2 , N_3 with mass in 100 MeV – GeV region: “give” masses to neutrinos and produce baryon asymmetry of the Universe

Role of the Higgs: give masses to quarks, leptons, Z and W and inflate the Universe.

New line in photon galaxy spectrum ???

Two recent publications in arXiv:

- arXiv 1402.2301

Detection of an unidentified emission line in the stacked X-ray spectrum of Galaxy Clusters, $E_\gamma \sim 3.56$ keV

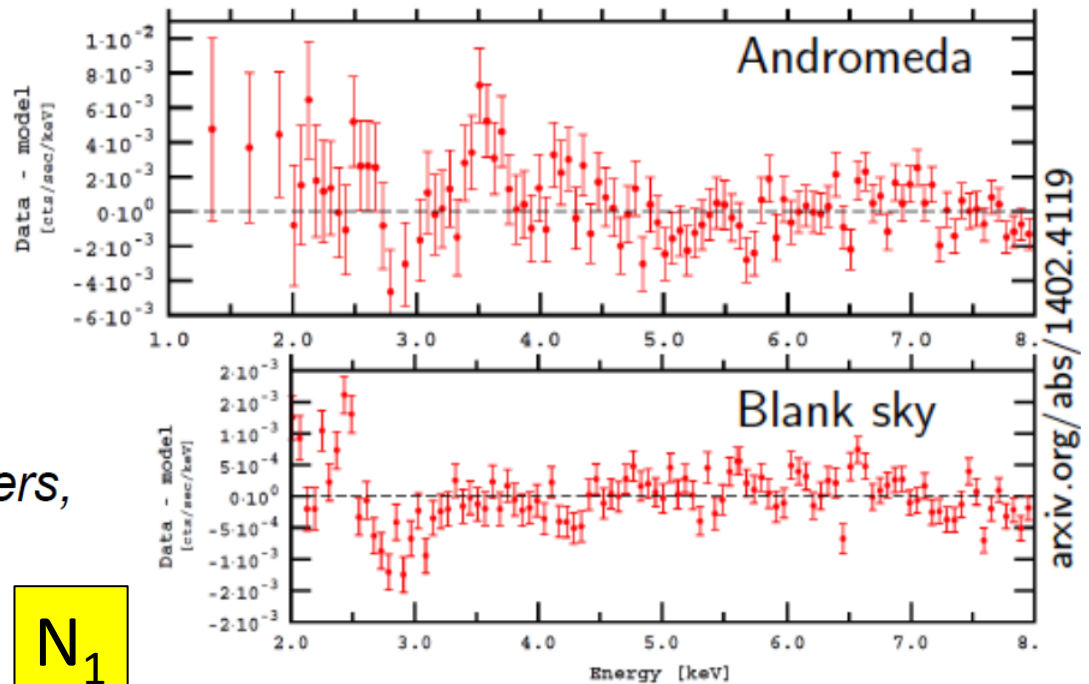
- arXiv 1402.4119

An unidentified line in X-ray spectra of the Andromeda galaxy and Perseus galaxy cluster, $E_\gamma \sim 3.5$ keV

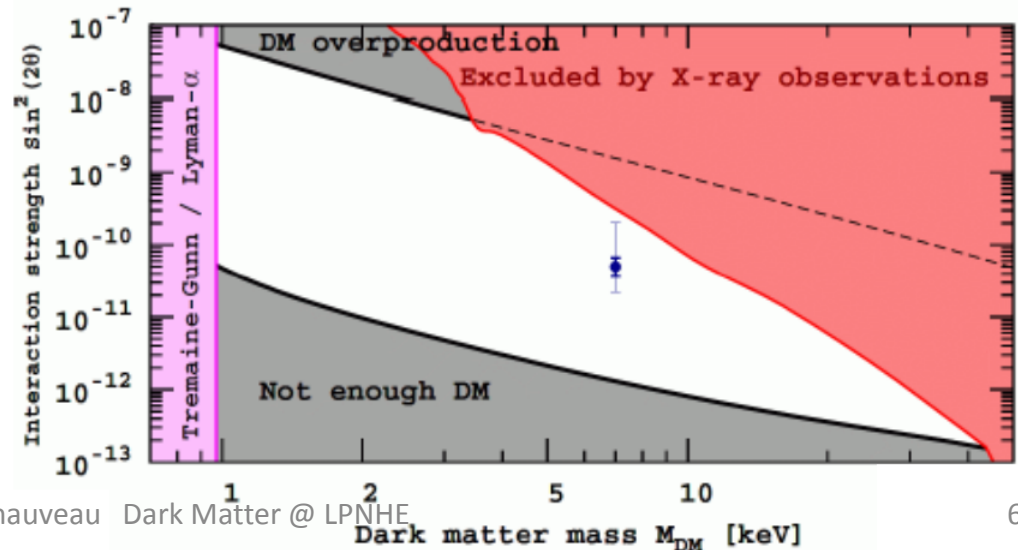
Will soon be checked by Astro-H with better energy resolution

22/09/2014

Golutvin seminar J. Chauveau Dark Matter @ LPNHE



arxiv.org/abs/1402.4119



N_2 N_3

Masses and couplings of HNLs

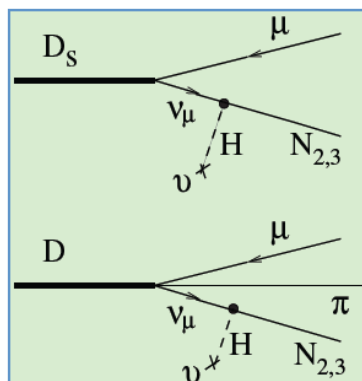
Mitesh Patel

- $M(N_2) \approx M(N_3) \sim \text{a few GeV} \rightarrow$ CPV can be increased dramatically to explain **Baryon Asymmetry of the Universe (BAU)**

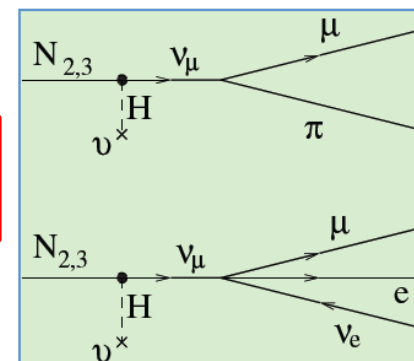
Very weak $N_{2,3}$ -to- ν mixing ($\sim U^2$) $\rightarrow N_{2,3}$ are much longer-lived than the SM particles

Example:

$N_{2,3}$ production in charm

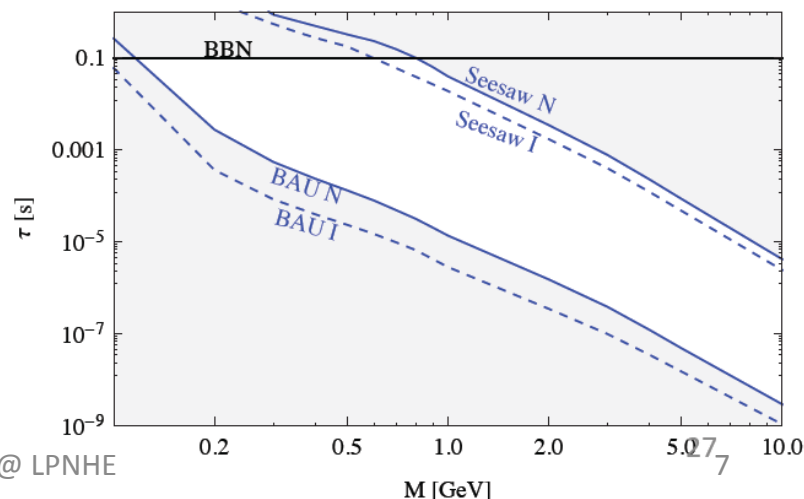


and subsequent decays



- Typical lifetimes $> 10 \mu\text{s}$ for $M(N_{2,3}) \sim 1 \text{ GeV}$
Decay distance $\mathcal{O}(\text{km})$
- Typical BRs (depending on the flavour mixing):

$$\begin{aligned} \text{Br}(N \rightarrow \mu/e \pi) &\sim 0.1 - 50\% \\ \text{Br}(N \rightarrow \mu^-/e^- \rho^+) &\sim 0.5 - 20\% \\ \text{Br}(N \rightarrow \nu \mu e) &\sim 1 - 10\% \end{aligned}$$



Expression of Interest

CERN-SPSC-2013-024 / SPSC-EOI-010

October 8, 2013

Proposal to Search for Heavy Neutral Leptons at the SPS

W. Bonivento^{1,2}, A. Boyarsky³, H. Dijkstra², U. Egede⁴, M. Ferro-Luzzi², B. Goddard², A. Golutvin⁴,
D. Gorbunov⁵, R. Jacobsson², J. Panman², M. Patel⁴, O. Ruchayskiy⁶, T. Ruf², N. Serra⁷, M. Shaposhnikov⁶,
D. Treille² (†)

¹*Sezione INFN di Cagliari, Cagliari, Italy*

²*European Organization for Nuclear Research (CERN), Geneva, Switzerland*

³*Instituut-Lorentz for Theoretical Physics, Universiteit Leiden, Niels Bohrweg 2, Leiden, The Netherlands*

⁴*Imperial College London, London, United Kingdom*

⁵*Institute for Nuclear Research of the Russian Academy of Sciences (INR RAN), Moscow, Russia*

⁶*Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland*

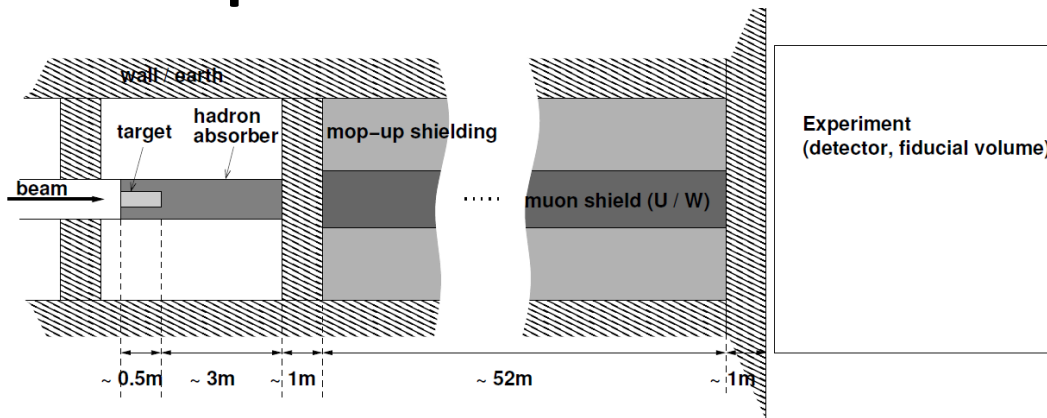
⁷*Physik-Institut, Universität Zürich, Zürich, Switzerland*

(†) *retired*

Experimental Design

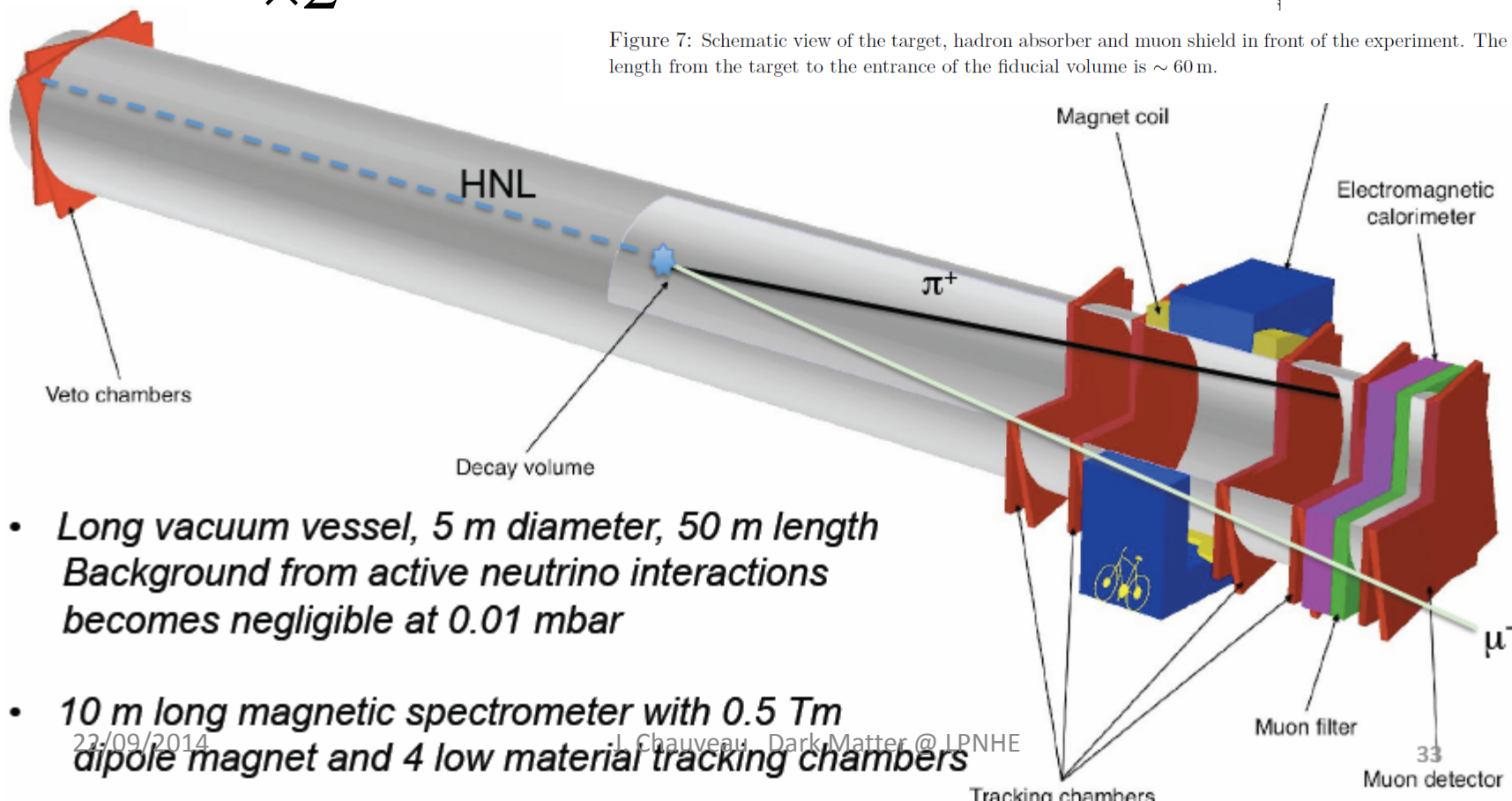
- $p+W \rightarrow D \text{ or } D_s + X$
- $D_{(s)} \rightarrow N \mu (+h)$ [also e]
- $N \rightarrow \mu\pi, \mu\rho, \nu e\mu, \dots$
- Target
- Dump
- Muon shield
- [decay vol. + detector]*2
- 2×10^{20} pot. 400 GeV. Slow.
- $BF \approx 10^{-8} - 10^{-12}$
- $BF \approx 0.1 - 50 \%$
- 50 cm (W) – 750 kW
- 3 m heavy stuff (W + ?? + concrete)
- 52 or 54 m (U or W or ??)
- 10 m each
- signal: $\theta_N \approx 50$ mrad, $\theta_{l,p} \approx 100$ mrad
 - short decay distance,
 - wide detector
- dominant background from ν in the last λ of shield

Experimental setup



×2

Figure 7: Schematic view of the target, hadron absorber and muon shield in front of the experiment. The total length from the target to the entrance of the fiducial volume is ~ 60 m.



- Long vacuum vessel, 5 m diameter, 50 m length
Background from active neutrino interactions becomes negligible at 0.01 mbar

- 10 m long magnetic spectrometer with 0.5 Tm dipole magnet and 4 low material tracking chambers

Experimental setup

- Straw chambers a la NA62
- Warm magnets LHCb inspired
- Shashlik EM-calorimeter
- Muon filter = iron wall + tracking station
- DAQ 24 ns slices

Expected Physics reach

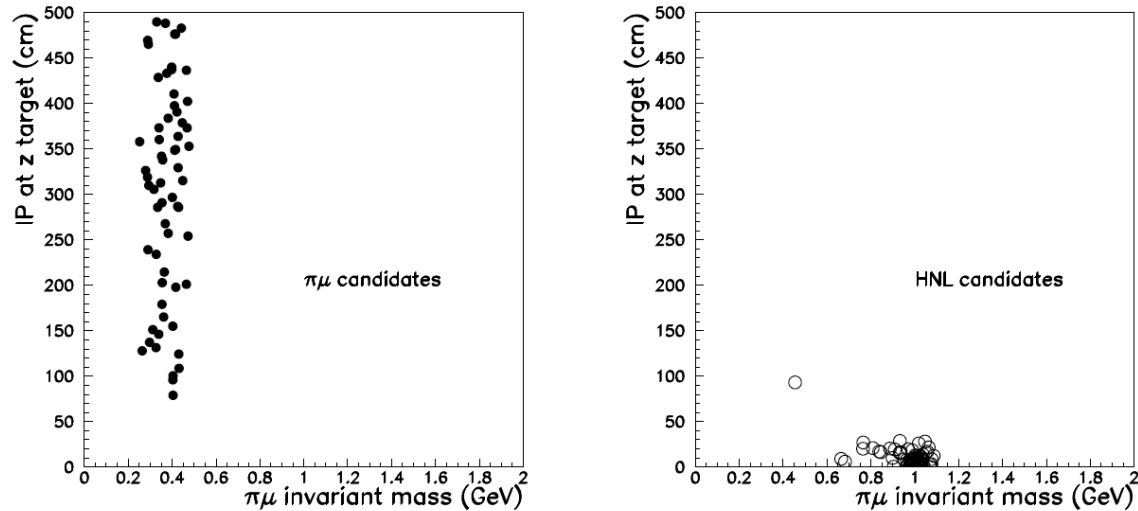


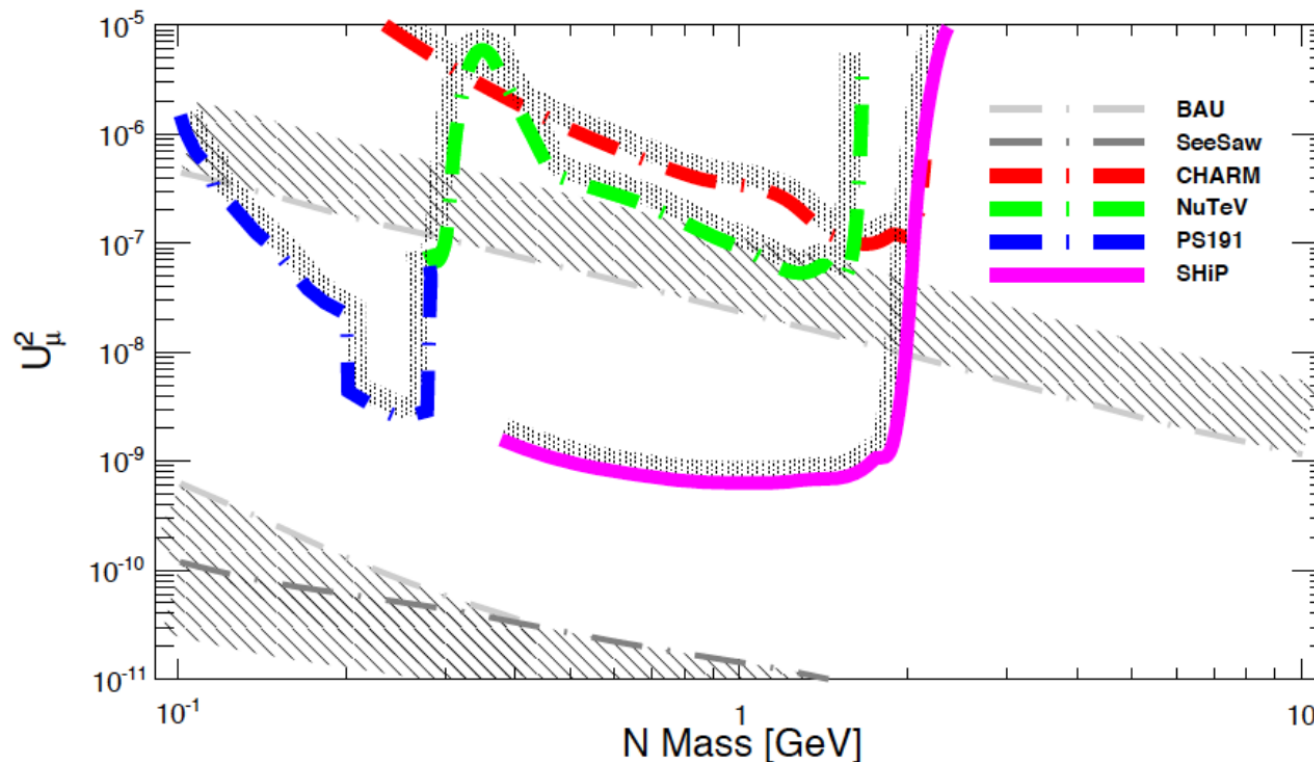
Figure 14: Invariant mass of two-prong candidates and their distance of closest approach (IP) to the W target (left) for background events generated with GEANT and GENIE, and (right) for $N \rightarrow \mu^- \pi^+$ with a 1 GeV invariant mass for the signal.

- $N_{sig} = N_{pot} \times 2 f_{cc} \times B(U^2) \times \varepsilon(U^2)$
- *Background tbd*

Expected Physics reach

Expected event yield (cont.)

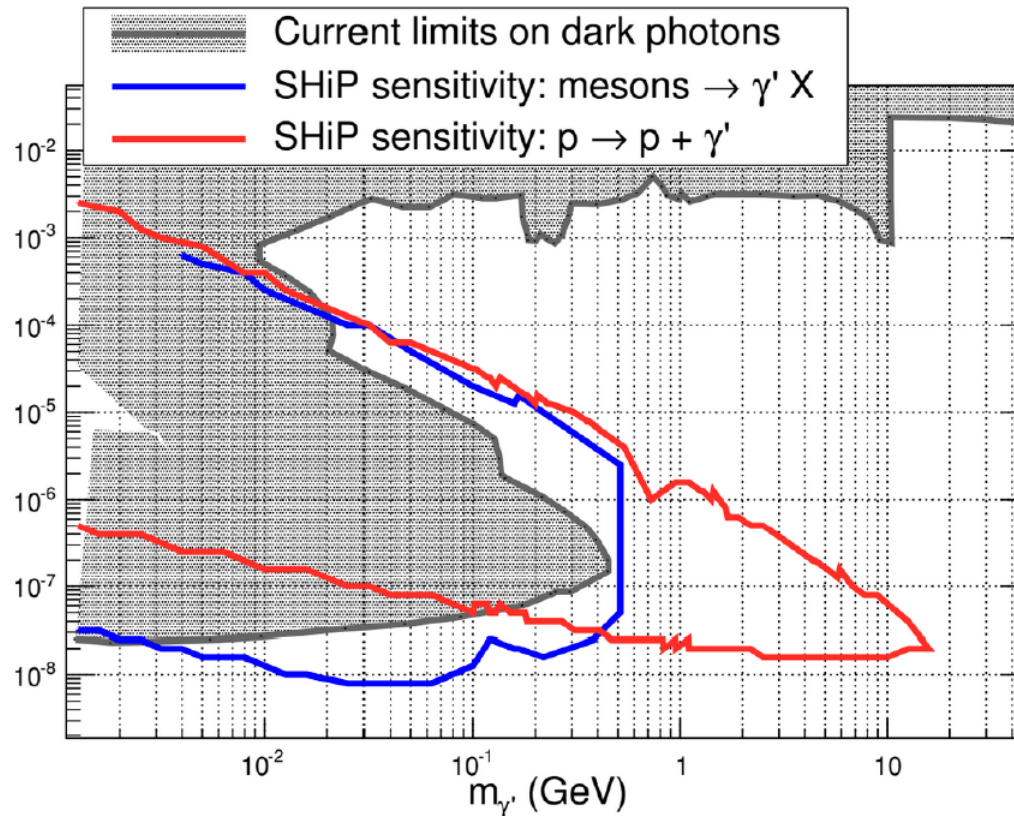
Assuming $U_\mu^2 = 10^{-7}$ (corresponding to the strongest experimental limit currently for $M_N \sim 1$ GeV) and $\tau_N = 1.8 \times 10^{-5}$ s
 $\sim 12k$ fully reconstructed $N \rightarrow \mu^- \pi^+$ events are expected for $M_N = 1$ GeV



120 events for cosmologically favoured region: $U_\mu^2 = 10^{-8}$ & $\tau_N = 1.8 \times 10^{-4}$ s

Expected Physics reach

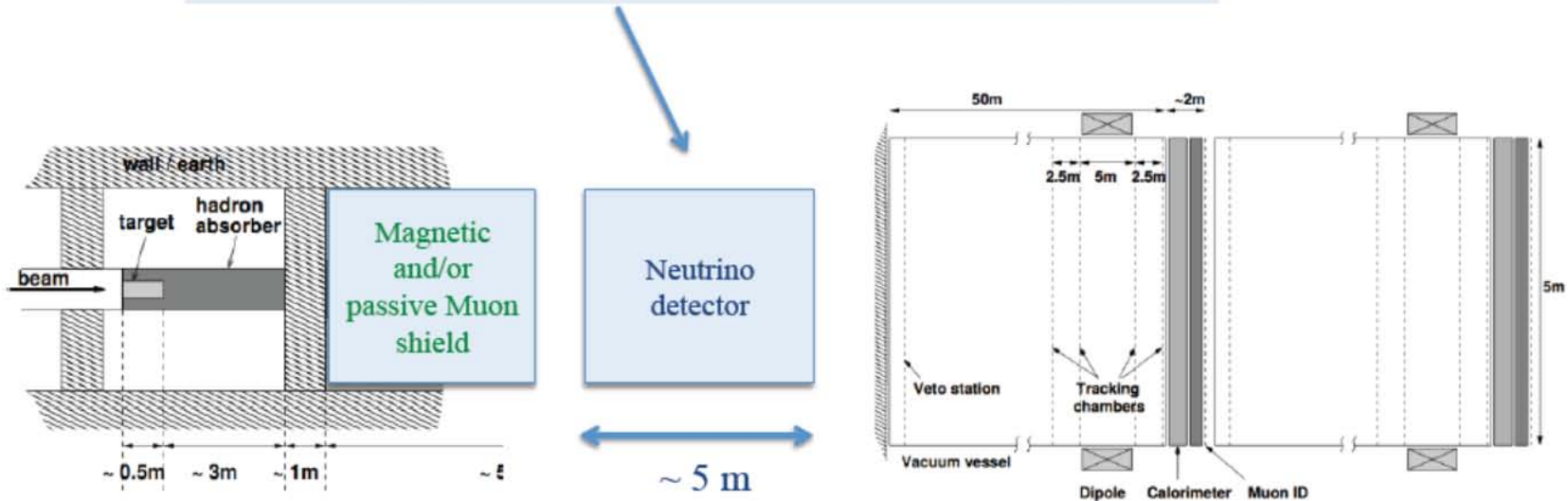
Sensitivity – vector portal



- Comparable studies for axion, higgs portals, R-parity violating neutralinos, light-goldstinos... in progress

Add a ν_τ detector

SM: ν_τ physics with 2×10^{20} pot



- Good physics program with a compact neutrino detector *Expect ~ 3400 ν_τ interactions in 6 tons emulsion target (5% of OPERA)*
- Tau neutrino and anti-neutrino physics
- Charm physics with neutrinos and anti-neutrinos
- Electron neutrino studies (high energy cross-section, only low energy studies for oscillations) and ν_e induced charm (~ 1000 events)



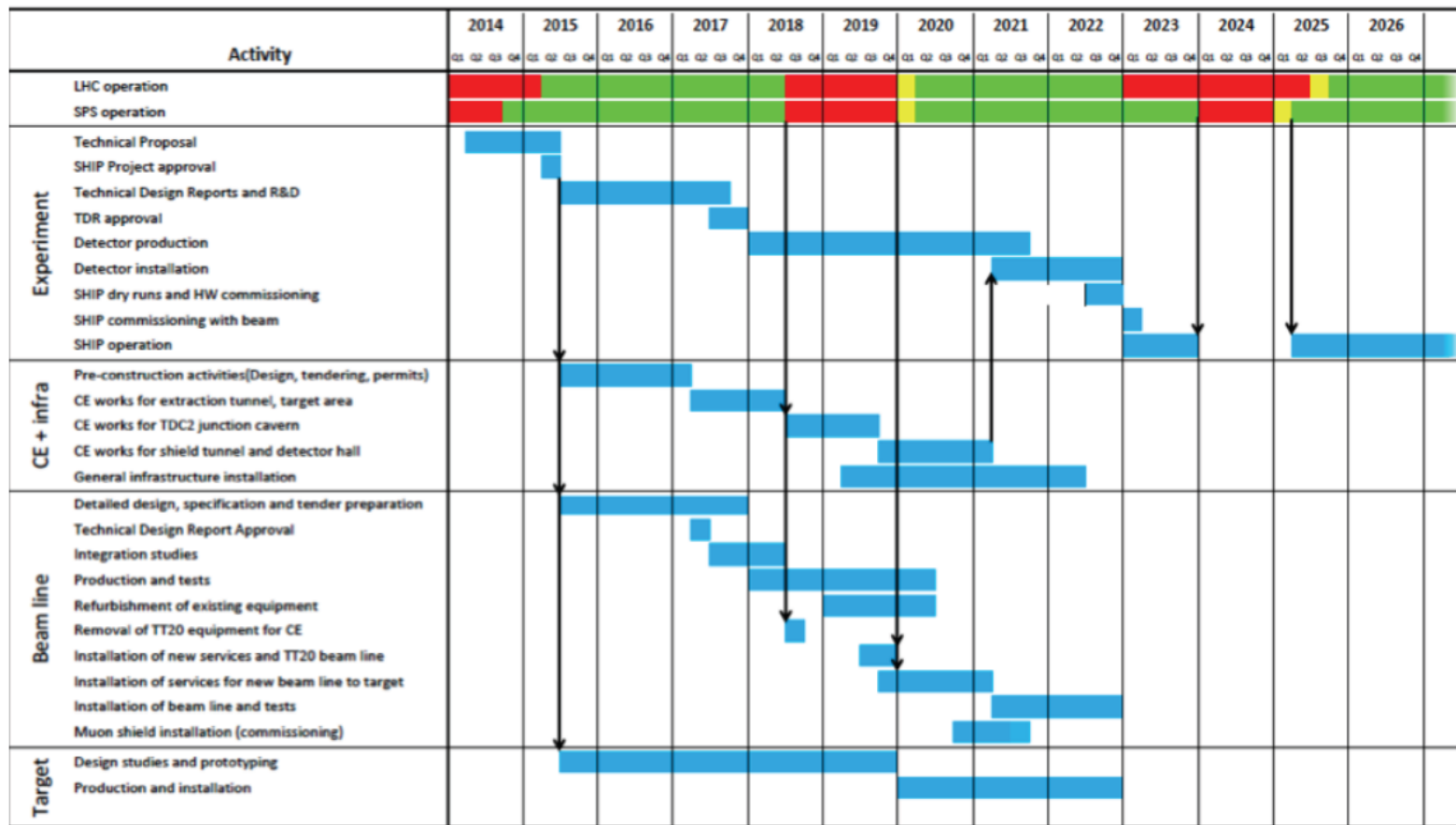
Prevezin North Area site



From task force report:



Schedule



- Technical proposal (2015)
- Technical Design Report (2018)
- Construction and installation (2018-2022)
- Commissioning (2022-2023)
- Data taking and analysis of 2×10^{20} pot (2023-2027)

Three stages in the preparation of the experiment: first the work for the TP which should be completed early 2015, then the TDRs to be finished by 2018, and finally the construction to start data taking in 2022.

✓ ***Contribution to the Technical Proposal to be completed by March 2015***

This document requires mainly an intellectual contribution. The current detector choices are based on existing technologies, so no essential R&D is required for the TP. Expect a tangible contribution to the detector conceptual design, evaluation of the physics reach, or software, simulation and computing activities. If considered necessary by the group, this phase may also include eventual R&D and test beam activity

✓ ***Assuming that the TP is approved by the CERN committees, the time scale for the preparation of the TDRs is 2016-2018. In particular the groups are expected***

- formulate an interest in a hardware and software contribution for the construction;*
- give an estimate of the strength of their group during the work for the technical proposal and for the preparation of the TDR*

✓ ***Assuming that the TDRs are approved by 2018, it would be valuable to understand the groups' prospects for contributing to the construction of the SHIP detector in 2018-2022***

Technical Proposal mid-2015

Scope of the Technical Proposal

- ✓ ***Widen physics case both for the BSM and SM physics***
- ✓ *Provide Conceptual Design Report (few options per sub-detector is ok at this stage)*
- ✓ *Detailed analysis of the sub-detector technologies complemented, if really needed, with some RD studies of prototypes.
No large scale detector modules is expected at this stage. It is however important to identify critical RD milestones for the TDR*
- ✓ *Full simulation based sensitivity reach and background evaluation for representative channels*
- ✓ *Provide cost evaluation of the detector*
- ✓ *Reach internal understanding who will do what for the TDR*

Experimental setup optimization

- Muon shield optimization
 - Passive/ active, magnetized ??
- Vacuum vessel geometry, construction
 - Determines magnet aperture
- Tracking in spectrometer technology
- Calorimeter photodetection
- Muon detector technology of sensors (SciFi?)
- ν_τ detector integration and specification!
- Upstream tagger/Veto/Timing
- Trigger and DAQ

Pros and Cons for LPNHE

- + vMSM attractive
- + Early in the project
- + CERN
- + Run in 2023
- + Serious proponents
- + LHCb commonalities
- + A few in IRFU/IN2P3
- + Technical opportunities
 - Tracking
 - Electronics + DAQ
 - UT, Timing D.

- Physics breadth
- Not (yet) leaders
- TP to be written mid 2015

± No technological challenge

LPNHE part of Technical Proposal ?

2nd SHiP Workshop and Collaboration Meeting (24-26 September 2014) - SeaMonkey

Fichier Édition Affichage Aller à Marque-pages Outils Fenêtre ?

Précédent Suivant Actualiser Arrêter <https://indico.cern.ch/event/336469/overview> Rechercher Imprimer

Accueil Marque-pages Les plus visités SeaMonkey et Mozilla Google init BABAR PPS Talks Bibles DM LPNHE UPMC SGWF biblio Prospective gd public phone SFP Etabliss UE javascript:DockBar.slid...

Dark Matter @ LPNHE - brainstorm... 42nd SLAC Summer Institute (04-1... Snowmass Working Group Reports First SHiP Workshop (10-12 June 2... SHiP Collaboration Hoist Sails | PH... 2nd SHiP Workshop and Collabora... SHiP Collaboration

Restricted Europe/Zurich J. Chauveau

2nd SHiP Workshop and Collaboration Meeting

24-26 September 2014
CERN
Europe/Zurich timezone

Overview
Scientific Programme
Timetable
Contribution List
Author List
My Conference
Participant List
Registration
Registration Form
Video Services

Contact
Richard.Jacobsson@c...

The SHiP Experiment is a new general-purpose fixed target facility at the SPS to search for hidden particles as predicted by a very large number of recently elaborated models of Hidden Sectors which are capable of accommodating dark matter, neutrino oscillations, and the origin of the full baryon asymmetry in the Universe. Specifically, the experiment is aimed at searching for very weakly interacting long lived particles including Heavy Neutral Leptons - right-handed partners of the active neutrinos; light supersymmetric particles - sgoldstinos, etc; scalar, axion and vector portals to the hidden sector. The high intensity of the SPS and in particular the large production of charm mesons with the 400 GeV beam allow accessing a wide variety of light long-lived exotic particles of such models and of SUSY. Moreover, the facility is ideally suited to study the interactions of tau neutrinos.

The objective of this second workshop and collaboration meeting is to review the progress in the different Working Groups towards the preparation of the Technical Proposal. The workshop will also be followed by a special Collaboration Meeting and a SHiP software tutorial.

Starts 24 Sep 2014 13:00
Ends 26 Sep 2014 18:00
Europe/Zurich

CERN

Powered by Indico

Extra

Technical Proposal mid-2015



Challenges



- ◉ A list of interesting key challenges to address
 - Number of protons-on-target: SPS configuration, extraction, beam delivery, radioprotection
 - Production target and radioprotection aspects
 - Muon filter optimization
 - Civil engineering and radioprotection aspects
 - Detector optimization for all final states
- hand-in-hand with
- background studies: extreme suppression of background requires high detection efficiencies and simulations
 - Detector alignment, calibration, and signal normalization

➔ A lot of work ahead!

Working groups

Appendix 2: List of working groups and contact persons

1. Theoretical support

Misha Shaposhnikov (mikhail.shaposhnikov@ep)
Dima Gorbunov (Dmitry.Gorbunov@cern.ch)

2. Experimental facility

Richard Jacobsson (Richard.Jacobsson@cern.ch)

- interface with beam lines, target and infrastructure
- muon shield
- vacuum vessel
- spectrometer magnet
- ...

3. Tracking

- tracking in the decay volume
Massimiliano Ferro-luzzi (massi@mail.cern.ch)
- tracking in the emulsion based spectrometer
Giovanni De Lellis (Giovanni.de.Lellis@cern.ch)

4. PID

Walter Bonivento (Walter.Bonivento@cern.ch)

- muon detector
- calorimetry
- ...

5. Computing and Software

Fons Rademakers (Fons.Rademakers@cern.ch)
Thomas Ruf (Thomas.Ruf@cern.ch)

- Computing model
- ...

6. Online & Trigger

Hans Dijkstra (dyk@mail.cern.ch)

7. Physics performance

Nico Serra (nicola.serra@cern.ch)

8. Miscellaneous

Andrey Golutvin (andrey.golutvin@cern.ch)

Contains detectors for which nobody has expressed clear interest so far:

- Timing Detector to provide time measurement
- Upstream tagger

We have already started a process of identifying contact persons for the various sub-tasks. Thus, your prompt input would be very timely and well appreciated!

The following persons have already expressed interest

Mitesh Patel (Imperial College) for the muon shield optimization,
Gaia Lanfranchi (LNF) for the MUON detector,
Mauro Villa (Bologna) and Victor Egorychev (ITEP) for calorimeter electronics and modules,
Andrey Ustyuzhanin (Yandex Data Analysis School) for computing model.