The SHiP experiment at CERN and the role of the LIP group within the collaboration

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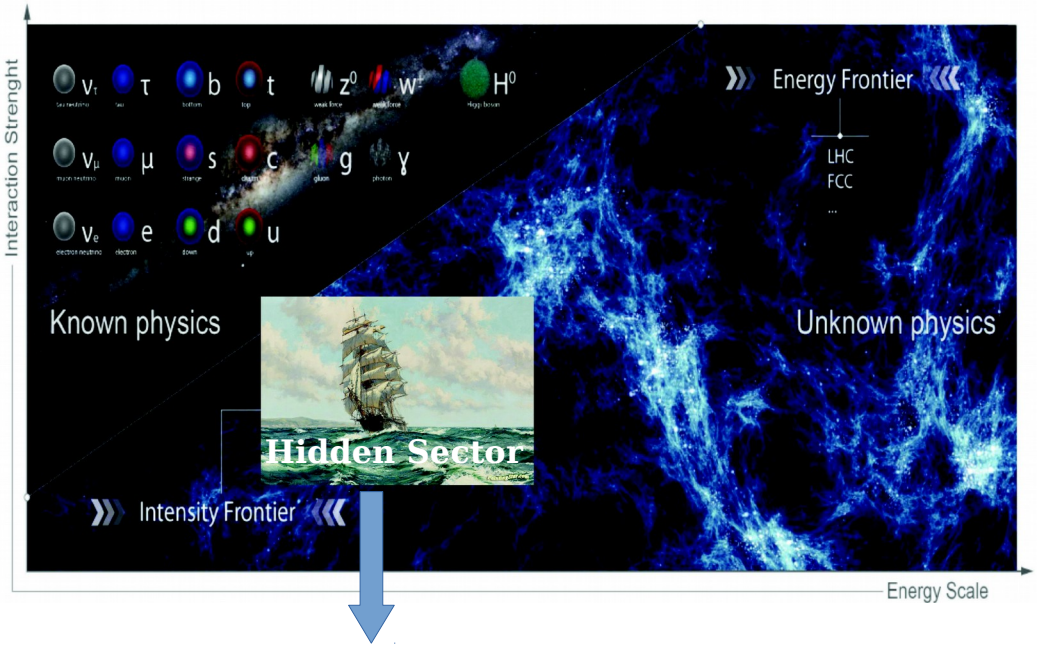
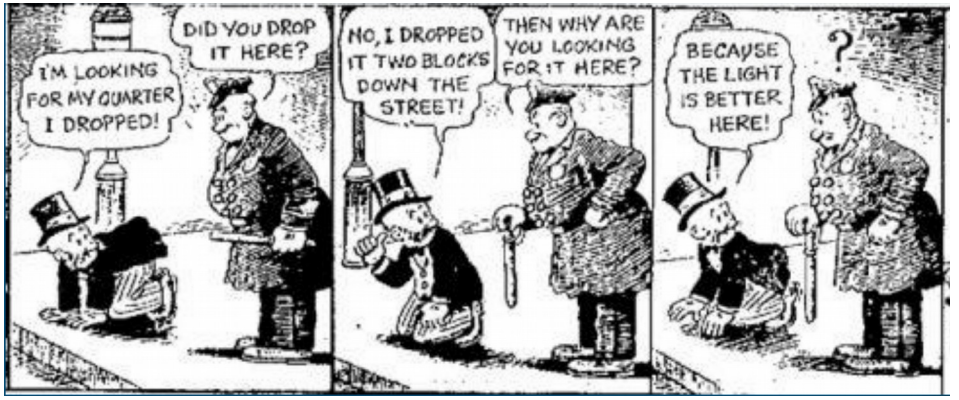
Main Physics goal

- SHiP will search for new particles that are capable of providing an explanation for the following well established observational phenomena: dark matter, baryonic asymmetry of the Universe, neutrino masses/oscillations and inflation

What if the solution to these phenomena is below the Fermi scale?





SHiP will search for a very weakly coupled Hidden Sector, via portals, at the intensity frontier!

The world view imposed by the Hidden Sector (HS)

- The idea behind the HS phenomenology is that the **SM + HS with light messengers is all there is up to the Planck scale** *(the dynamics of the HS may drive the dynamics and anomalies of the SM)*:

$$L_{world} = L_{SM} + L_{mediation} + L_{HS}$$

Visible Sector

$SU(3)_c \times SU(2)_L \times U(1)_Y$

Messenger interaction

"Portals"

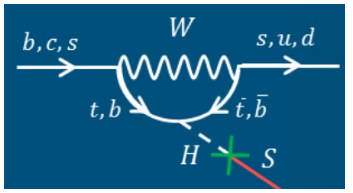
Hidden Sector

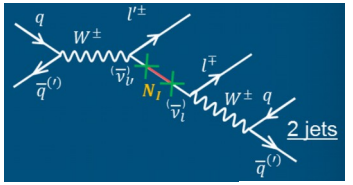
"Dark Standard Model"

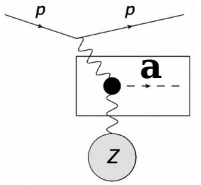
SHiP will search for long-lived hidden particles using the following portals:

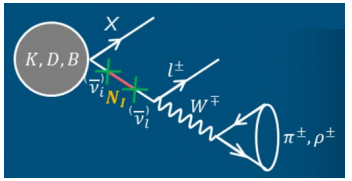
Portal	Coupling to SM
Dark Photon, A'	$\epsilon / (2\cos\theta_w) F'_{\mu\nu} B_{\mu\nu}$
Dark Higgs, S	$(\mu S + \lambda S^2) H^\dagger H$
Axion or ALP, a	$a / f_a (F_{\mu\nu} F^{\mu\nu})$
Sterile neutrino, N	$\Sigma F_{\alpha l} (\bar{L}_\alpha H) N_l$

Ex. of HP production (O(10^{-10})):

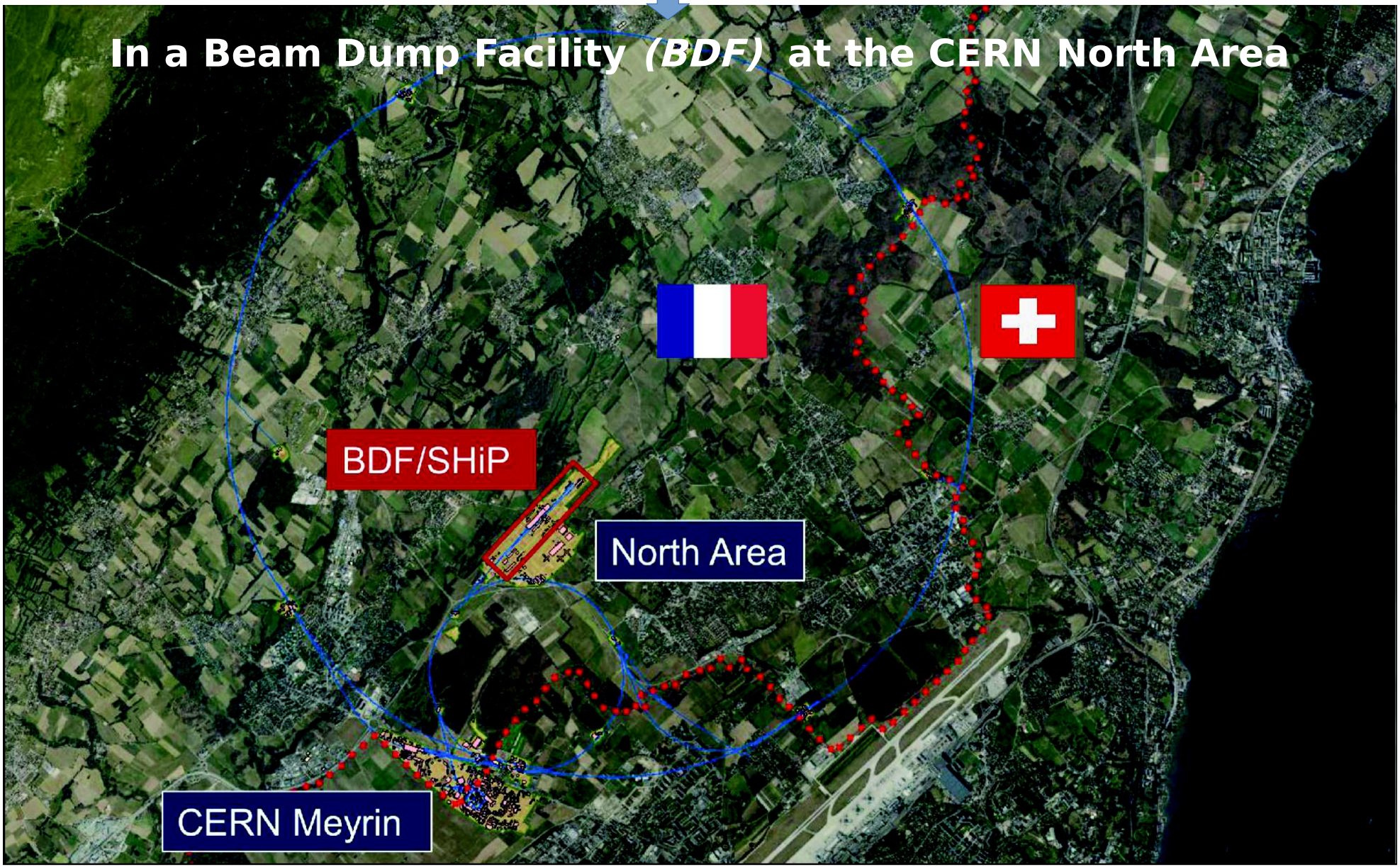




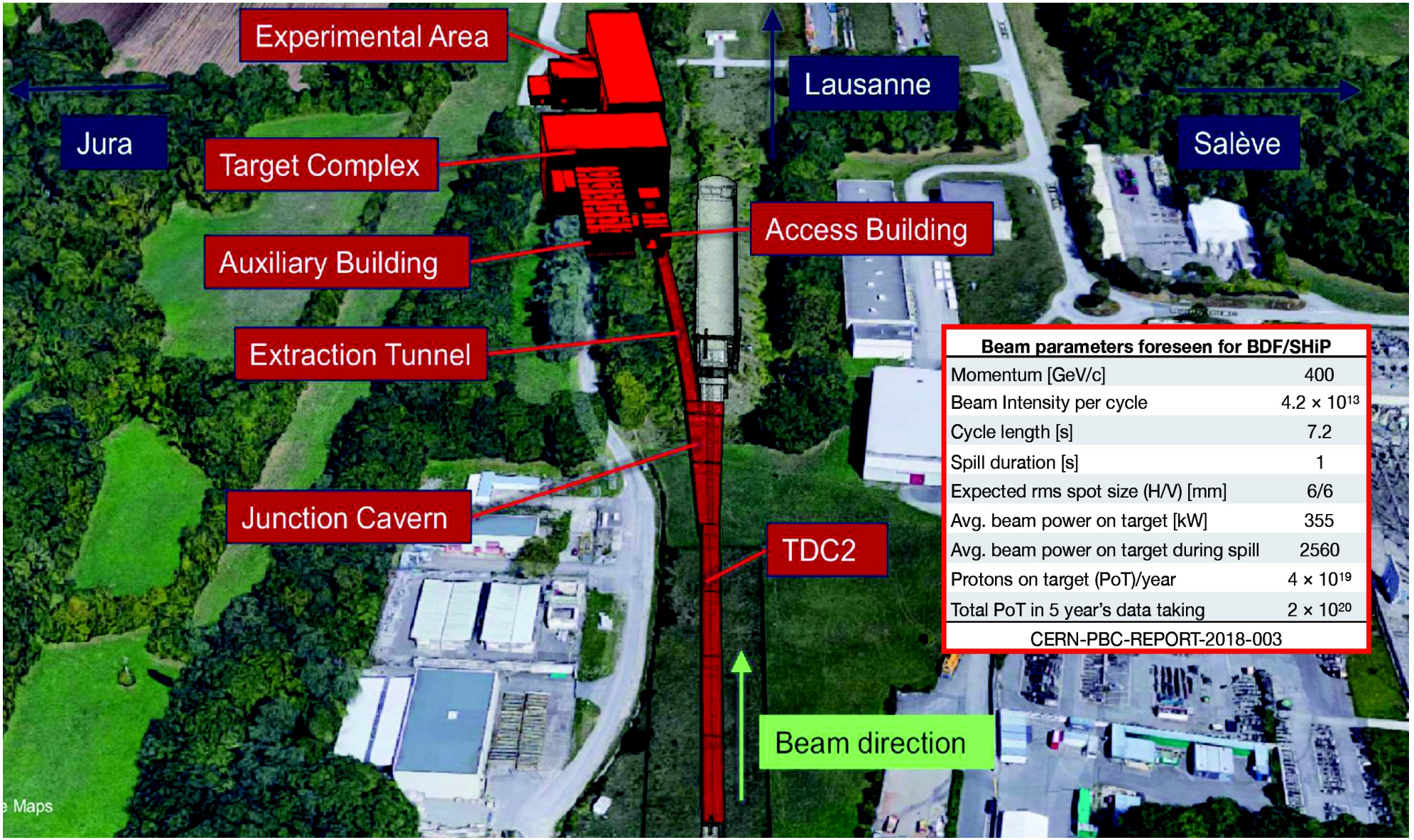




Where will the SHiP experiment be located?



SHiP will make use of a new beam line capable of delivering maximum proton beam intensity from the SPS accelerator

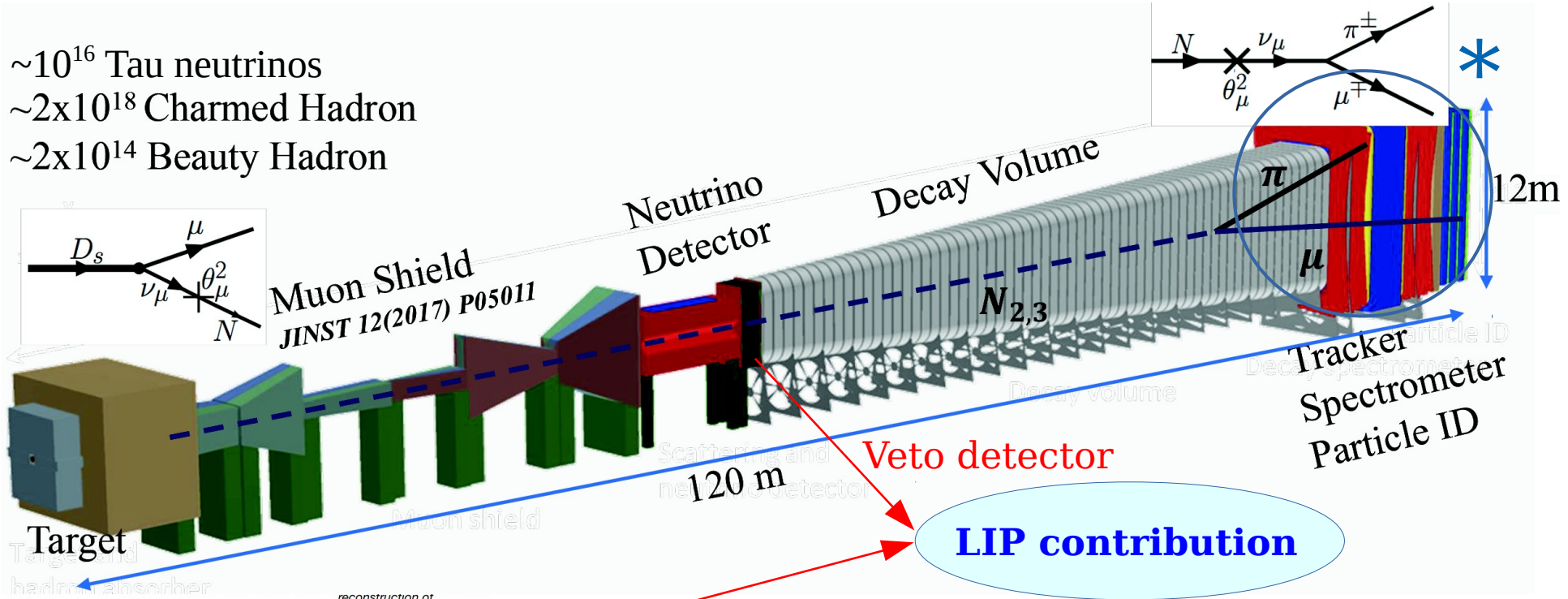


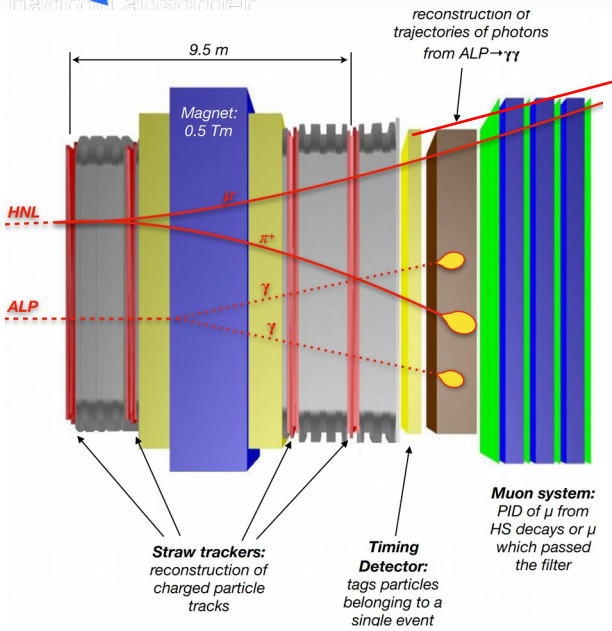
Beam parameters foreseen for BDF/SHiP	
Momentum [GeV/c]	400
Beam Intensity per cycle	4.2×10^{13}
Cycle length [s]	7.2
Spill duration [s]	1
Expected rms spot size (H/V) [mm]	6/6
Avg. beam power on target [kW]	355
Avg. beam power on target during spill	2560
Protons on target (PoT)/year	4×10^{19}
Total PoT in 5 year's data taking	2×10^{20}

CERN-PBC-REPORT-2018-003

Spectrometer for a discovery experiment with “zero background”

~10^{16} Tau neutrinos
~2x10^{18} Charmed Hadron
~2x10^{14} Beauty Hadron

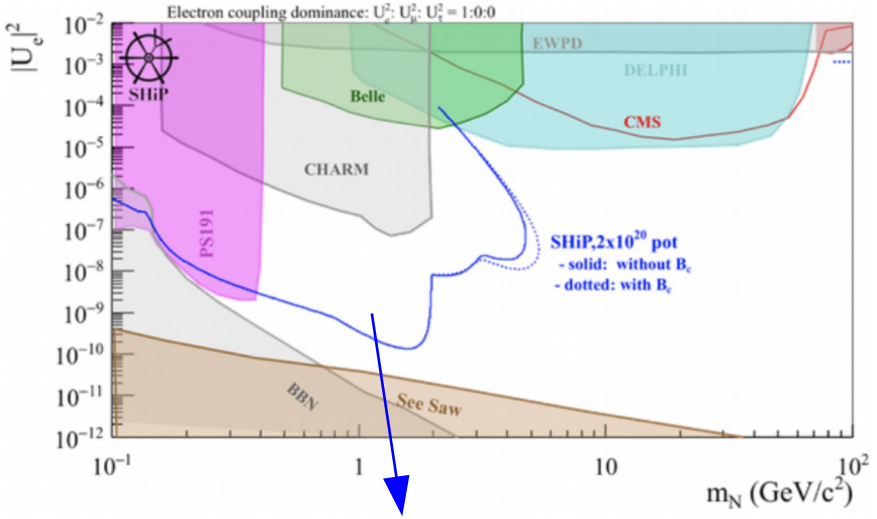




Main decay modes of hidden particles ***(l = e, μ)***	
Model [vector *(V)*, scalar *(S)*, axion *(A)* , neutrino *(N)*]	**Final State**
N portal, neutralino	$l^{\pm}\pi^{\mp}$, $l^{\pm}k^{\mp}$, $l^{\pm}\rho$, $\rho^{\pm}\rightarrow\pi^{\pm}\pi^0$
V, S, A portals, sgoldstino	l^+l^-, $\pi^+\pi^-$, k^+k^-
N portal, neutralino, axino	$l^+l^-\nu$
A portal, sgoldstino	gg
sgoldstino	$\pi^0\pi^0$

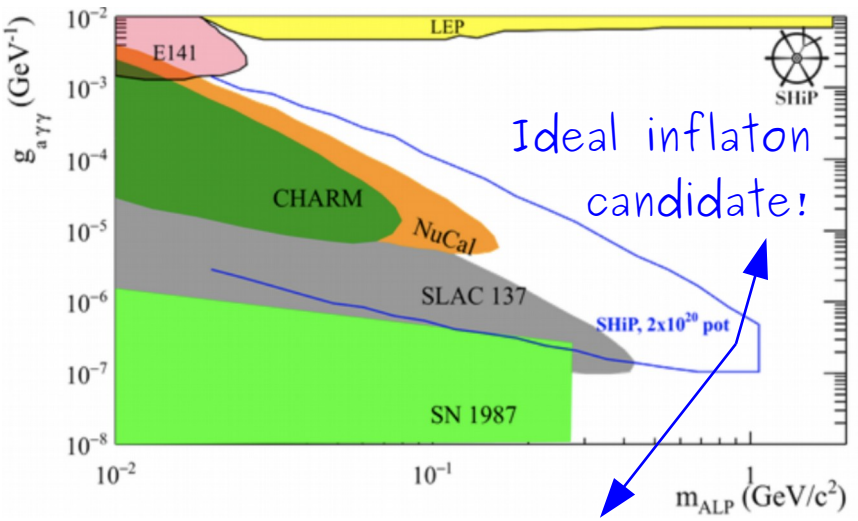
Hidden Sector sensitivities

Sterile Neutrinos *(HNLs)*



Explain baryonic asymmetry, neutrino masses and the origin of dark matter

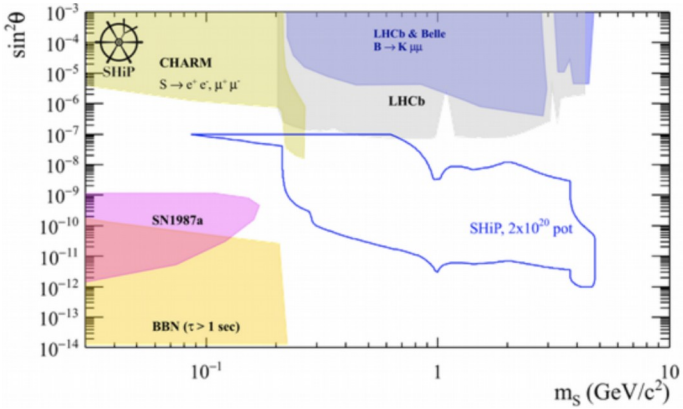
Axion-Like Particles



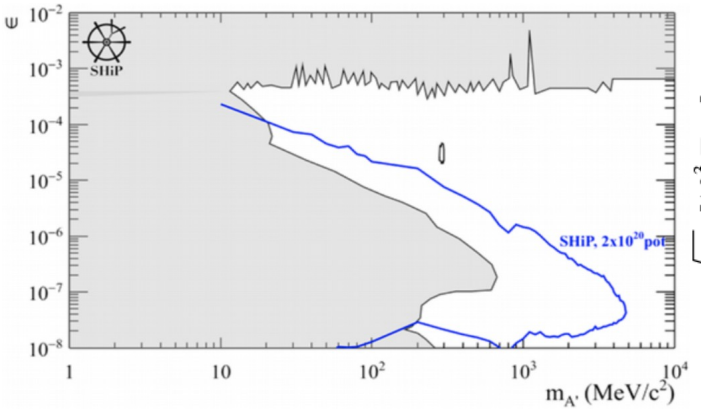
Ideal inflaton candidate!

Recreate reaheating phase of the early universe via ALP → γγ?

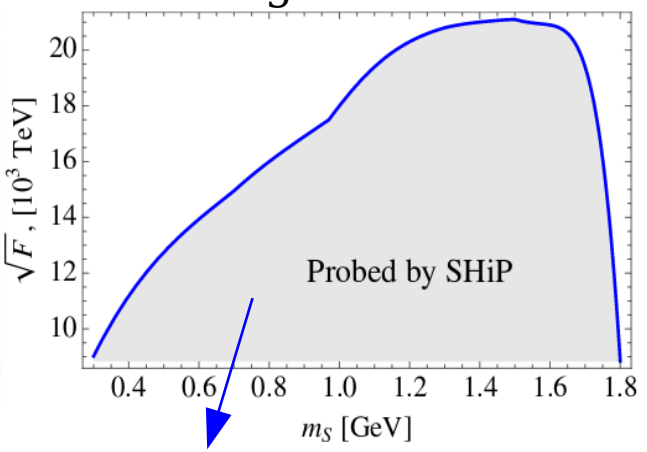
Dark Scalars



Dark Photons

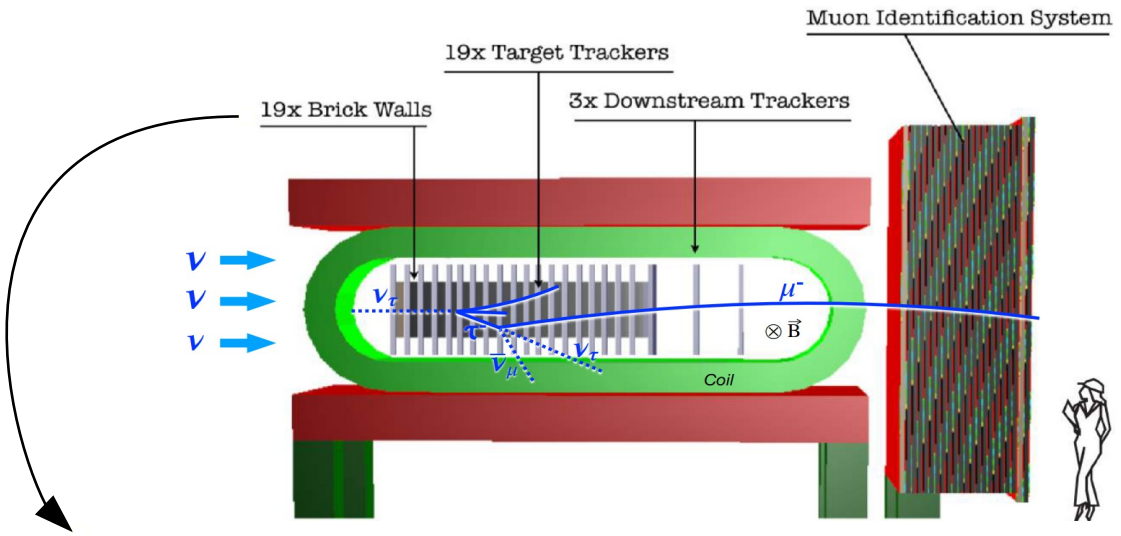


Sgoldstinos

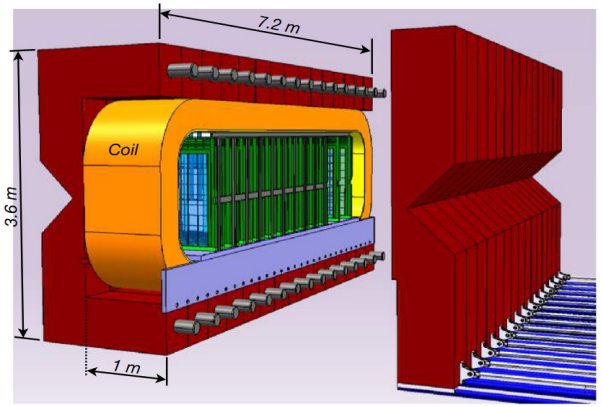


Test Supersymmetry breaking scale up to 10^3 TeV!

Neutrino and Light Dark Matter (LDM) Physics at SHiP



Neutrino detector



Passive material+emulsion films *(sub-micrometric position and milli-radian angular resolution)*

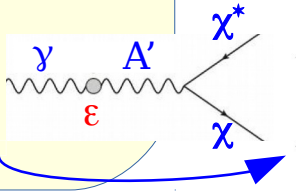
SM Physics:

- 3 flavours ν_e, ν_μ, ν_τ, and ditinguish ν and $\bar{\nu}$
- ν_τ & $\bar{\nu}_\tau$ physics *(~10 ^{4}events),* including $\mu_B(\nu_\tau)$
- Structure functions $F_4(x, Q^2)$ and $F_5(x, Q^2)$
- Neutrino-induced charm production
- Proton strangeness and nuclear effects via ν-DIS

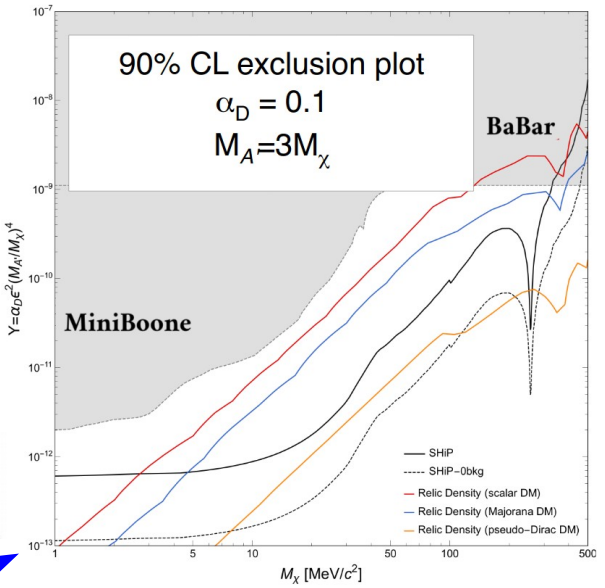
HS Physics:

- LDM detection via scattering off electrons

~$10^{20}\gamma$ @SHiP

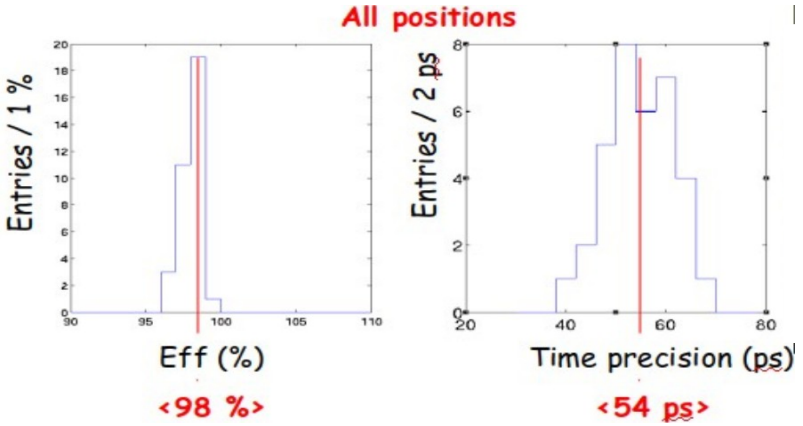


Light dark matter

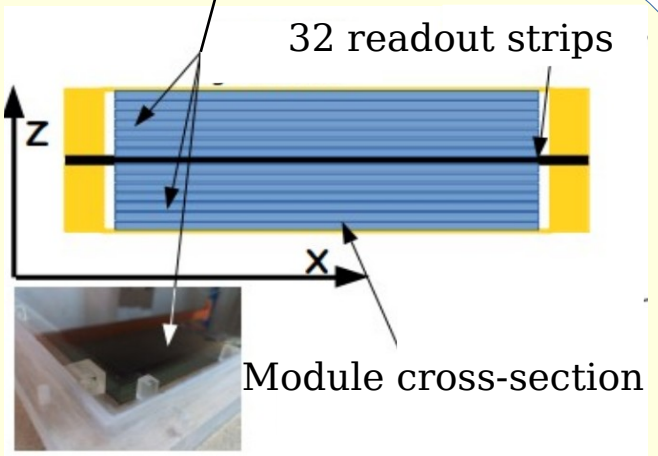


Main LIP contribution for SHiP: Timing and Veto Detectors

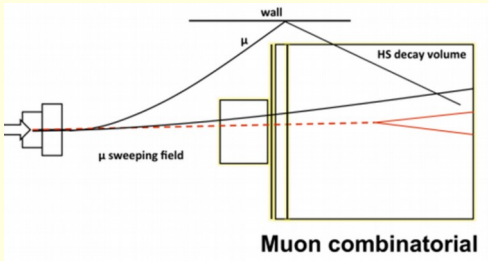
RPC Timing Detector prototype tested @CERN:
(Competition: plastic scintillators with σ_t = 85 ps)



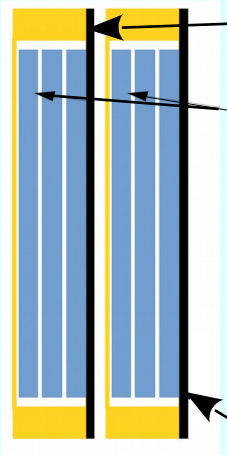
RPC module of 14 glasses (0.3 mm apart):
160 cm (y) × 120 cm (x) × 1 mm (z)



35 modules covering 50 m² to suppress:



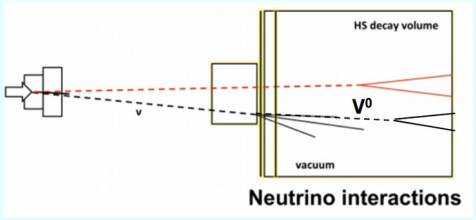
Veto Detector with σ_t= 300 ps:



32 horizontal strips to measure time

Base element formed by 2 RPC modules of 3 glasses: 105 cm (y) × 223 cm (x) × 2 mm (z)

5 double modules covering 10 m² to suppress



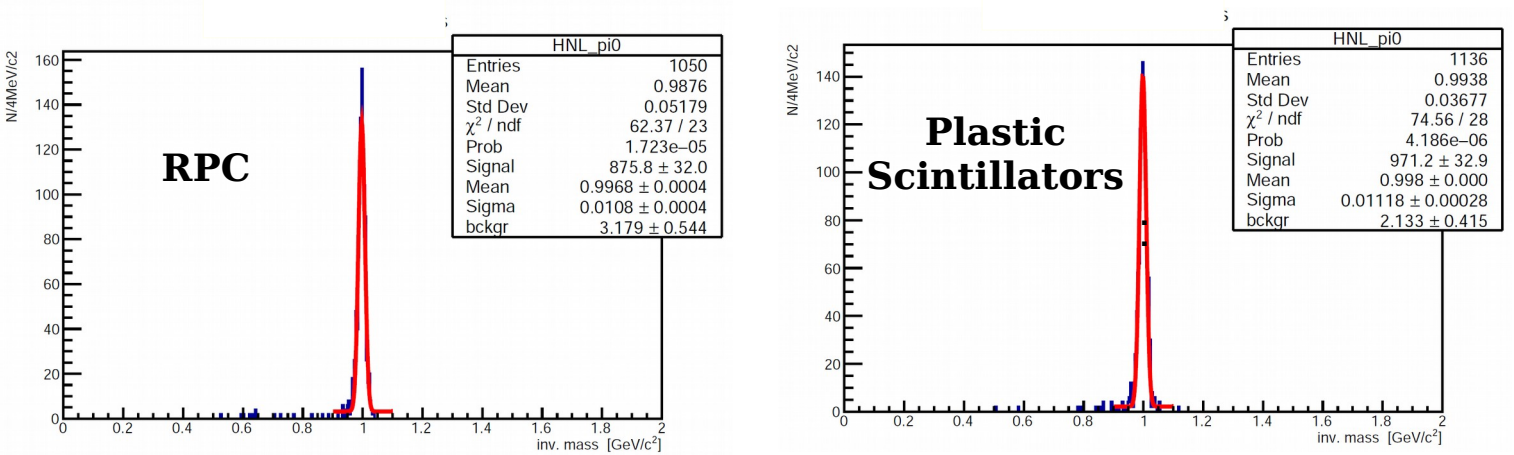
64 vertical strips to measure also position

Both detectors already implemented in FairShip (simulation software)

Ongoing work

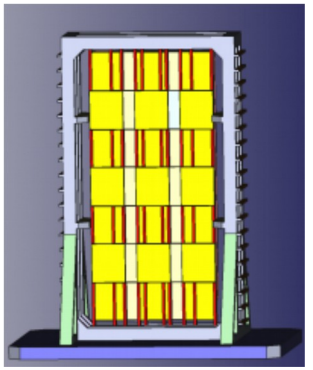
- Evaluation of the impact of the RPC material budget in the SplitCal *(calorimeter downstream of the timing detector)* performance:

HNL (1 GeV) → $\mu^-\rho^+$ (→ $\pi^+\pi^0$ (→ $\gamma\gamma$)):



The RPC does not hinder the reconstruction of hidden particles

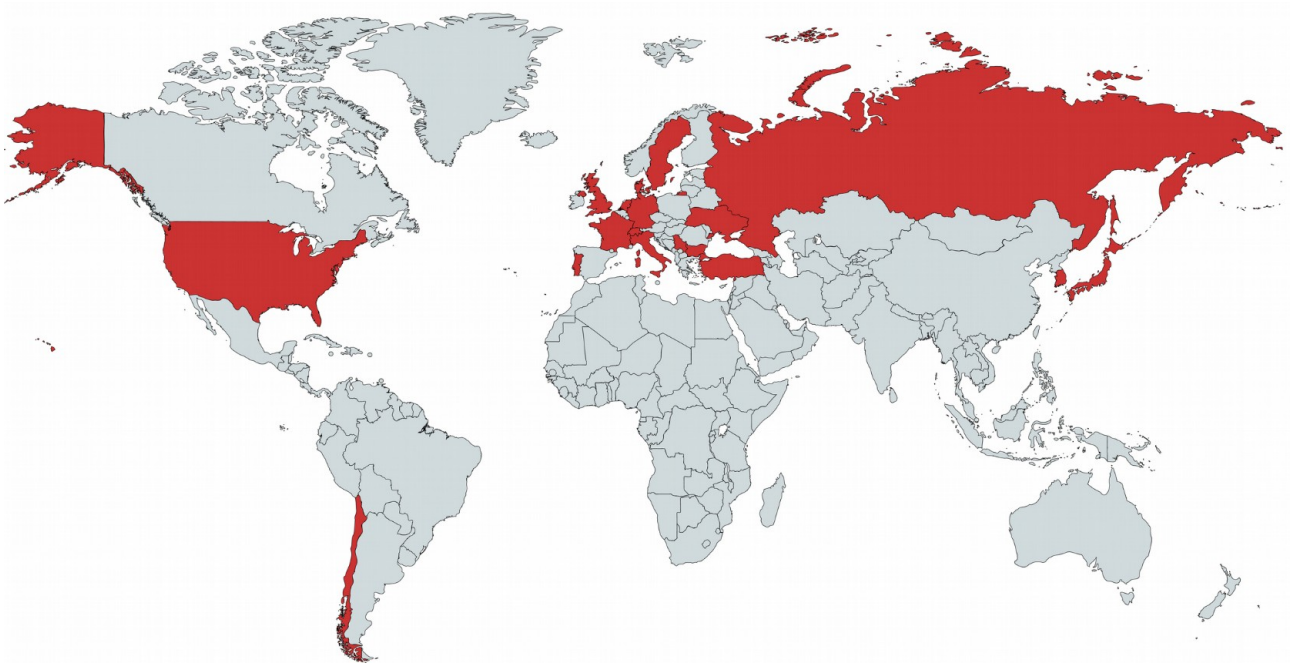
- Design of the mechanical structure for the timing detector



- Optimisation of muon & veto detectors using μ-flux simulations
- Test the performance of both veto & timing detectors, in a multi-hit environment, using a SAMPIC *(SAMpler for PICosecond)* readout chip

Status of the SHiP collaboration

- **SHiP is a CERN recognized collaboration**, since 2014, and is presently formed by 290 researchers from 53 institutes of 18 countries:



A three-year TDR phase (during which LIP will make important contributions) is expected to be approved in 2020 with the goal of starting to take data in 2027