

# **SHiNESS: search for hidden neutrinos at the ESS**

**STEFANO ROBERTO SOLETI, DONOSTIA INTERNATIONAL PHYSICS CENTER LLP2024, 5 JULY 2024**

## Fundación "la Caixa"





## **S iNESS** *<sup>c</sup>2IJCLab, Universit´e Paris-Saclay, CNRS/IN2P3, 91405 Orsay, France E-mail:* roberto.soleti@dipc.org art 2021.<br>Externe 26 Feb 2022



#### **STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS** Figure 1: ESS pulses of the ESS pulse of the fact the structure in terms of the structure in the structure of the structure in the struct

beam delivery. The proton beam pulse has a rate of 14 Hz with 2.8 ms long spills, giving a ating target wheel made of 1 ungsten bricks:



# **The European Spallation Source** SMINESS

- The ESS will produce the most intense neutron beam in the world via nuclear spallation.
- A proton beam will impinge on a rotating target wheel made of Tungsten bricks:
	- **• 2 GeV energy**
	- 14 Hz rate
	- 2.8 ms long spills
	- $3.92 \times 10^{-2}$  duty factor
- Approximately **one order of magnitude more intense** than the Spallation Neutron Source at Oak Ridge.



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**SMINESS** 



- Spallation sources produce an intense flux of neutrinos as a *byproduct* through  $\pi^+$  decay at rest (DAR) and subsequent  $\mu^+$  decay
- The energy spectra of DAR neutrinos is well known (in *π*+ The energy spectra produced by these processes are well known [53, 56]. The ⌫*<sup>µ</sup>* flux is contrast with conventional neutrino beams), making spallation sources an excellent tool to probe for **new**  $\frac{2}{\alpha}$   $\frac{10}{\alpha}$   $\frac{1}{\beta}$   $\frac{backgrounds}{n}$   $\frac{2}{\beta}$   $\frac{8}{\beta}$   $\frac{20}{\beta}$   $\frac{1}{\beta}$   $\frac{1}{\beta}$   $\frac{1}{\beta}$   $\frac{20}{\beta}$   $\frac{1}{\beta}$   $\frac{20}{\beta}$   $\frac{1}{\beta}$   $\frac{20}{$ **physics.**





 $\pi^+ \rightarrow \mu^+ + \nu_\mu$ 

## **The ESS as a neutrino source** target. Negative pions are economic pions are economic absorbed by nuclei before they can decay, while  $\sim$ positive ones lose energy as they propagate and finally decay at rest through:



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# arxiv:2311.18509v3 [hep-ex] 26 Feb 2024

### **STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS**



- Searching for **new physics at spallation sources** is not a novel idea: LSND at LAMPF, KARMEN at ISIS, JSNS2 at J-PARC, etc.
- However, the exceptional intensity of the ESS beam allows to reach **unprecedented sensitivities** for several new physics scenarios:



# **New physics at the ESS**



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	- Light sterile neutrino (LSND/MiniBooNE anomaly, gallium anomaly)



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# **New physics at the ESS**





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- However, the exceptional intensity of the ESS beam allows to reach **unprecedented sensitivities** for several new physics scenarios:
	- Light sterile neutrino (LSND/MiniBooNE anomaly, gallium anomaly)
	- $10^{-8}$  $\sum_{\nu=1}^{\infty} 10^{-7}$  $10<sup>°</sup>$  $10^{-7}$ **• Heavy neutral leptons**  $\mathfrak{a}$ **SHINESS**  $(2 \text{ years})$ PIENU PIENU  $\overline{(B_R)}_{\mathcal{U}_{\mathcal{U}_{\mathcal{A}_{\mathcal{N}}}}}$  $E_{\widetilde{\mathcal{L}}}$  $4t$ *|UµN|*  $\boldsymbol{\mathcal{C}}$

 $10^{-9}$ 

**Dipc** 

# **New physics at the ESS**







0*.*02 0*.*04 0*.*06 0*.*08 0*.*10 0*.*12

(2017)

 $M_N$ <sup>[GeV]</sup>

### STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS 4 to the expected sensitivity of the  $\mathcal{A}$  experiment  $\mathcal{A}$ . The dashed lines correspond to dashed lines correspond to the dashed lines correspond to  $\mathcal{A}$



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	- **JETHE HEUUTHO (LOND/IVIII IIDOONE a**
	- **•** Heavy neutral leptons
	- 10<sup>5</sup> PIENU  $\mathbf{a}$ th **IO IIIIXIIIENIIEETIX UIIIIEIII**I **• Neutrino mixing matrix unitarity**

# **New physics at the ESS**



#### **STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS 4 4 4 5 AM.** to the expected sensitivity of the  $\mathcal{A}$  experiment  $\mathcal{A}$ . The dashed lines correspond to dashed lines correspond to the dashed lines correspond to  $\mathcal{A}$ Figure 14: <sup>2</sup> analysis with one degree of freedom for the ¯⌫*<sup>e</sup>* appearance channel as a



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## **Dipc**

*<sup>c</sup>2IJCLab, Universit´e Paris-Saclay, CNRS/IN2P3, 91405 Orsay, France* • Although the ESS is a facility focused on spallation neutrons, a **[comprehensive particle physics program](https://arxiv.org/abs/2211.10396)** 

multiple leptons in the final state, produced in the decay of heavy neutrinos. The baseline • In particular, our group at DIPC is focused on the **[detection of coherent elastic neutrino-nucleus scattering](https://indico.cern.ch/event/1342813/contributions/5913877/attachments/2877548/5039702/Magnificent.pdf)** located 25 m far from the ESS beam target. We show that SHiNESS will be able to hi<br>|
|
|
|







- has been proposed.
- (CEvNS) with three different technologies (cryogenic CsI, p-type
- Clear synergy with a  $\pi^+$  DAR experiment: having a complement  $\frac{1}{n}$  and  $\frac{1}{n}$  and measurement can reduce the flux uncertainty (which is  $\sim$ 10% at SNS).  $\pi^+$  DAR experiment: having a complete





# **Particle physics at the ESS**



**Cryogenic undoped CsI**

**p-type point contact Ge**



## STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS



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**high pressure gas TPC**

#### **STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS**  $\overline{r}$   $\overline{r}$   $\overline{r}$   $\overline{r}$  and  $\overline{r}$   $\overline{r}$  are proton beam direction is from the proton is from  $\overline{r}$ right to left. The red circle represents the proposed SHiNESS tank, drawn to scale. proved by reconstructing the Cherenkov cone using the first hundreds of picoseconds of the  $\blacksquare$



# **SHiNESS proposal**



resolution of approximately 20 cm (see figure 8b). This value can be significantly im-distribution of approximately im-

*JHEP* **03 (2024) 148 [arXiv:2311.18509 \[hep-ex\]](https://arxiv.org/abs/2311.18509)**



- volume) to detect neutrino interactions and HNL decays. • We propose a **liquid scintillator tank** (42 ton active
- Detector is placed **25 m far from the beam target** off-axis in the backward direction (to suppress backgrounds).
- Light is detected by **large-area PMTs** and **Incom LAPPDs**, which allow to distinguish between Cherenkov and scintillation, **enabling directionality**.

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- PPO cocktail, proving a good and a long attenuation length ( neutrino physics (SNO+, RENO, etc.)
- 



#### STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS **the contact of a set of a set of a set o** (b) Position resolution in the *x* axis for a 20 MeV





# **Scintillation/Cherenkov discrimination**



- **Scintillation photons** are abundant and allow to measure the **energy** of the event.
- Abstract: The upcoming European Spallation Source (ESS) will soon provide the most • However, they are produced ~isotropically and with a certain emission time constant, giving no it<br>e **information on the directionality**.
- $\mathbf{I}$ considerably improve current global limits for the three cases outlined above. Although in • Cherenkov photons, on the other hand, are emitted promptly and along the direction of the particle, producing the typical Cherenkov rings.



## STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS

**bipc** 

Charge [a. u.]  $\frac{a}{\alpha}$ Charge  $10^{2}$ 







- 
- 
- the interaction in the interaction in the interaction in the interaction interaction in the interaction in the Cherenkov towards the visible.



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#### STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS (b) Wavelength spectrum for Cherenkov and Cherenkov and Cherenkov and Cherenkov and Cherenkov and Cherenkov an<br>Cherenkov and Cherenkov an

colored segments (in red the particle tracks generated by the particle tracks generated by the positron, in gr<br>In green the ones the positron, in green the ones the on

#### ⌫¯*<sup>e</sup>* <sup>+</sup> *<sup>p</sup>* ! *<sup>e</sup>*<sup>+</sup> <sup>+</sup> *n.* (4.1) **e** +12 C = +2, (4.2) and (4.2)  $(1.48 \pm 0.15) \times 10^5$ ref. [117]. Both the KARMEN [82] and the LSND experiment [115] found this calculation  $s = \frac{1}{2\pi}$  and  $s = \frac{1}{2\pi}$   $\frac{1}{2\pi}$   $\frac{1}{2\pi$

4.1.1 Inverse beta decay

and on carbon atoms:

where the control of the control of

the dependence on the total width of the total width of the HNL e $\alpha$ ectively drops out. HNL e $\alpha$ 

carbon targets:<br>carbon targets:<br>carbon targets:

The total number of oscillated ¯⌫*<sup>e</sup>* events, assuming a 100% oscillation probability and a 10% systematic uncertainty, is given by the sum of the interactions on the proton and ि द्वारा स्वास्थ्य स<br>अन्वयः स्वास्थ्य स backgrounds, we apply a timing cut of 2 beam spills (7.6 ms), which has an ecoel of 2 beam spills (7.6 ms), which has a 30%. Figure 12 shows the time distribution of the <sup>12</sup>Ngs +-decay for two consecutive beam The yearly ⌫*<sup>e</sup>* flux from ⇡<sup>+</sup> DAR is the same as the ⌫¯*<sup>µ</sup>* one of eq. (4.3), given the the detector with an energy larger than 17.3 MeV, assuming a 10% systematic uncertainty, and the systematic unc<br>Assuming a 10% systematic uncertainty, and 17.3 MeV, assuming a 10% systematic uncertainty, and the systematic  $\sqrt{2.98}$  is  $\sqrt{2.28}$  and  $\sqrt{4.29}$ respectively. Both cross sections were measured by the KARMEN experiment and found in good agreement with the calculation for the calculation for the large beam spill of the ESS, in the ESS, in it is not possible to distinguish between  $\mathbf{h}_1$ , produced by produced by produced by produced by produced b<br>In the case of and and  $\bm{p}$ , produced by slower  $\bm{p}$ ,  $\bm{p}$  and  $\bm{p}$  and  $\bm{p}$  and  $\bm{p}$  and  $\bm{p}$  and  $\bm{p}$  and  $\bm{p}$ where  $\alpha$  are a 3<sup>.</sup>24  $\alpha$  = 3.24  $\alpha$  fluxes. The sum of the sum

4.1.1 Inverse beta decay

The interaction of ¯⌫*<sup>e</sup>* in the liquid scintillator can be detected through to observation of

the IBD process both on protons:

⌫¯*<sup>e</sup>* <sup>+</sup> *<sup>p</sup>* ! *<sup>e</sup>*<sup>+</sup> <sup>+</sup> *n.* (4.1)

#### **Process Events/year Detection** The interaction of ¯⌫*<sup>e</sup>* in the liquid scintillator can be detected through to observation of ⌫¯*µ* production process of eq. (2.1). The number of ⌫*<sup>e</sup>* yearly charged-current interactions in

**e** C C C C C C C C C C

#### Neutrino 11 4 Expected number of signal events 4.1 Neutrino detection • *<sup>N</sup>*<sup>C</sup> = 1*.*<sup>70</sup> ⇥ <sup>10</sup><sup>30</sup> is the number of carbon targets; production process of eq. (2.1). The number of ⌫*<sup>e</sup>* yearly charged-current interactions in the detector with an energy larger than 17.3 MeV, assuming a 10% systematic uncertainty,

⌫¯*µ*

12.<br>∪a

*<sup>e</sup>* <sup>C</sup>!*e*+*n*11B) *·* ⌫¯*<sup>µ</sup>*

## where:

NC interface: 
$$
^{12}C + \nu \rightarrow ^{12}C^* + \nu
$$
  
\n $^{12}C^* + \nu^{12}C^* + \nu$   
\n $^{12}C^* + \nu^{12}C + \gamma$  (7.33  $\pm$  0.73)  $\times$  10<sup>4</sup>

maximum kinetic energy of 16.3 MeV and the decay has a lifetime of 15.9 ms [116], which is a lifetime of 15.9 ms [

in good agreement with the data. The data is a second with the data in the data in the data in the data in the

4.1.3 Neutral-current interactions and the current interactions are all the current interactions are all the c<br>1.3 Neutral-current interactions and the current interactions are all the current interactions are all the curr

= 93*.*5⇥10<sup>42</sup> cm<sup>2</sup> is the ¯⌫*<sup>µ</sup>* flux-averaged cross section for the IBD process

on proton [26, 112];

#### **Inverse beta de dinverse heta inverse beta de la component with the data.**

process on carbon [26, 113];

• ✏det = 0*.*5 is the assumed SHiNESS detector eciency.

The ⌫*<sup>e</sup>* can interact on carbon via the charged-current channel:

significantly longer than the beam spill. Thus, in order to reduce the amount of steady-state

30%. Figure 12 shows the time distribution of the <sup>12</sup>Ngs +-decay for two consecutive beam

$$
\mathbf{p}(\mathbf{x})
$$

spills.

 $c_1$  as a ref.  $c_2$  as a ref.  $c_3$  as a ref.  $c_4$  as a ref.  $c_5$  as a ref.  $c_6$  as a ref.  $c_7$  as a ref.  $c_8$ 

**CC interactic**  $\frac{\nu_e + {}^{12}{\rm C} \rightarrow {}^{12}{\rm Ngs} + e^-}{ {}^{12}{\rm Ng}} \left[ \frac{1}{2} \right] \left[ (2.19 \pm 0.22) \times 10^3 \right]$  $\mu + 12 \left( \frac{1}{2} \right)$   $\mu + 12 \left( \frac{1}{2} \right)$ The experimental signature of this process is the emission of  $t_{\text{e}}$  is the emission of  $\sim 12$   $\text{N}_{\text{gs}} \rightarrow 12 \text{ C} + e^+ + \nu_e$  (4.19  $\pm$  0.44)  $\times$  10 The experimental signature of this process is the emission of  $\mathbb{R}^n$  of a positron followed by the emission of  $\mathbb{R}^n$  $\begin{bmatrix} \text{108} \ \text{106} \ \text{107} \ \text{118} \ \text{128} \ \text{138} \ \text{149} \ \text{159} \ \text{169} \ \text{179} \ \text{180} \ \text{180} \ \text{191} \ \text{192} \ \text{193} \ \text{101} \ \text{102} \ \text{119} \ \text{119} \ \text{120} \ \text{130} \ \text{160} \ \text{170} \ \text{180} \ \text{191} \ \text{192} \ \text{101$  $\frac{12}{\text{Ngs}} \rightarrow \frac{12}{\text{C}} + e^{1} + \nu_e$  $\nu_e + {}^{12}C \rightarrow {}^{12}N_{gs} + e^-$  (1.6) (9.10  $\pm$  0.99)  $\vee$  $^{12}$ Ngs  $\rightarrow$   $^{12}$  C +  $e^{+}$  +  $\nu_{e}$ 4.1.3 Neutral-current interactions and the second second second second second second second second second second<br>Although the second secon neutral current (NC) channel and the subsequent (NC) channel and the subsequent emission of 15.11 MeV : 11 MeV<br>In the subsequent emission of 15.11 MeV : 11 Me a 10% systematic uncertainty, in the systematic uncertainty of the systematic uncertainty of the systematic unc<br>The systematic uncertainty of the systematic uncertainty of the systematic uncertainty of the systematic uncer

significantly longer than the beam spill. Thus, in order to reduce the amount of steady-state

=*N*<sup>C</sup> *·* ⌫<sup>12</sup>

#### delay the capture and its capture  $\frac{1}{12}$  shows the time and charge distribution. Figure  $(2.19 \pm 0.22) \times 10^9$  $(2.19 \pm 0.22) \times 10^3$ All the the three neutrino tensions  $\frac{1}{12}$ ,  $\frac{1}{12}$  and  $\frac{1}{12}$  and  $\frac{1}{12}$  and  $\frac{1}{12}$  ( $2.19 \pm 0.22$ )  $\times 10^5$

## $(7.33 \pm 0.73) \times 10^4$

neutral current (NC) channel and the subsequent emission of 15.11 MeV :

The yearly ⌫*<sup>e</sup>* flux from ⇡<sup>+</sup> DAR is the same as the ⌫¯*<sup>µ</sup>* one of eq. (4.3), given the

events inside the signal time window is 30%. The signal time window is 30% window is 30% window is 30% window i

=*N*<sup>C</sup> *·* ⌫<sup>12</sup>

4 Expedition of the signal events of signa<br>A result of signal events of signal events

*<sup>e</sup>* <sup>C</sup>!*e*12Ngs *·* ⌫*<sup>e</sup>* (*E*⌫*<sup>e</sup> >* 17*.*3 MeV) *·* ✏det *·* ✏time (4.7)

=(2*.*<sup>19</sup> *<sup>±</sup>* <sup>0</sup>*.*22) ⇥ <sup>10</sup><sup>3</sup> events*/*year*,*

*<sup>e</sup>* C!*e*12Ngs

the IBD process both on protons: IBD protons: IBD protons: IBD protons: IBD protons: IBD protons: IBD protons:<br>IBD protons: IBD pr

= 8*.*<sup>9</sup> ⇥ <sup>10</sup><sup>42</sup> cm<sup>2</sup> is the flux-averaged cross section as calculated in

delayed neutron capture and its emission. Figure 11 shows the time and charge district and charge district an

The flux-averaged cross sections for ⌫*<sup>e</sup>* and ¯⌫*<sup>µ</sup>* and for the monoenergetic ⌫*<sup>µ</sup>* were cal-

= 2*.*8⇥10<sup>42</sup> cm<sup>2</sup>

=*N*<sup>C</sup> *·* <sup>12</sup>C⌫!12C⇤⌫

#### **STEFANO ROBERTS: STEFANO ROBERT - SHIP - SHIP** The size flux from same as the same of eq. (4.3), g<br>The same as the same as the same as the same of eq. (4.3), given the same of eq. (4.3), given the same of eq. All the three neutrino types  $\overline{a}$  and  $\overline{a}$ ,  $\overline{a}$  and  $\overline{a}$  and  $\overline{a}$  and the carbon atom through the carbon atom the carbon atom through the carbon atom the carbon atom the carbon atom the carbon atom the

*·* ⌫

4.2 Decays of Heavy Neutral Leptons

backgrounds, we apply a time a timing cut of 2 beam spills (7.6 ms), which has an ecoes which has a time  $\sim$ 

## **S iNESS** *<sup>c</sup>2IJCLab, Universit´e Paris-Saclay, CNRS/IN2P3, 91405 Orsay, France* • Neutrino oscillations generally assume a unitary  $3 \times 3$  lepton mixing matrix U (using e.g. the

- PMNS parametrization).
- The unitarity of the matrix, however, only holds in a limited amount of neutrino mass models.
- In general, in the presence of n additional neutrinos, the mass Lagrangian in the extended neutrino sector is diagonalized by a  $(n + 3) \times (n + 3)$  mixing matrix.
- SHiNESS is expected to be sensitive to the closure of the **unitarity triangle in the eμ sector**, by comparing the measured number of **IBD events** and the expected one.



 $\mathcal{L}_{\mathcal{A}}$  and  $\mathcal{L}_{\mathcal{A}}$  years (orange) of data taking. Existing limits at  $90$ 

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# **Neutrino mixing matrix**





•



 $N$ 

# **MiniBooNE/LSND anomaly**

- could be compatible with the existence of a light sterile neutrino  $(\sim 1 \text{ eV}^2)$ .
- SHiNESS can **definitely rule out** this scenario through the IBD channel.
- Main background is the  $\bar{\nu}_e$  intrinsic beam component (which comes with a large uncertainty).



#### **STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS** FUR MIUUEN NEUTRINUS AT THE ESS SERVICE OF A VIEW O Figure 15: *Left:* Reconstructed energy spectrum for IBD candidate events. The filled

## **SMINESS**

**ns**, which *<sup>b</sup>Instituto de F´ısica Te´orica (IFT-CFTMAT), CSIC-UAM, Calle de Nicol´as Cabrera 13–15, Cam-*• The MiniBooNE and LSND experiments observed an **excess of electron (anti)neutrino interactions**, which  $\mathbf{c}$ 







## design of the detector comprises an active volume filled with 42 ton of liquid scintillator, located 25 m far from the ESS beam target. We show that SHiNESS will be able to considerably improve current global limits for the three cases outlined above. Although in rk<br>18

#### *pus de Cantoblanco, E-28049 Madrid, Spain <sup>c</sup>2IJCLab, Universit´e Paris-Saclay, CNRS/IN2P3, 91405 Orsay, France* • GALLEX, SAGE and BEST experiments observed a **deficit of electron neutrino events** when exposed to

# **Gallium anomaly**



- radioactive sources.
- Also in this case, a possible explanation could be the **presence of a light sterile neutrino**.
- SHiNESS can also definitely exclude the parameter space for this anomaly using the **CC channel**.

## STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS Figure 15: *Left:* Reconstructed energy spectrum for IBD candidate events. The filled

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- *E-mail:* roberto.soleti@dipc.org • The detector can be used also to search for long-lived particles produced near the beam target.  $\sum_{n=1}^{\infty}$ baselines; non-unitarity mixing in the active neutrino sector; or an excess of events with multiple leptons in the final state, produced in the decay of heavy neutrinos. The baseline e<br>Ir • We explored the sensitivity for **heavy neutral leptons** (HNLs), but other scenarios are being explored the sensitivity for heavy neutral leptons (HNLs), but other scenarios are being
- investigated (e.g. axion-like particles, ALPs).
- For HNLs, two possible cases are possible:
- **Electron mixing**, with the HNL being produced from the decay of muons and pions:  $\cdot$  FI

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## **Heavy neutral leptons** 1eutral lepton <sup>768</sup>⇡<sup>3</sup> *<sup>|</sup>UµN <sup>|</sup>*

decay with the control of t

$$
\Gamma(N \to e^+ e^- \nu_e) = \frac{G_F^2 m_N^5}{768\pi^3} |U_{eN}|^2 (1 + 4\sin^2 \theta_W + 8\sin^4 \theta_W)
$$

It the mixing with the UNII hoing produced from the decay of muone and for  $m_{xx} < m - m$  from nions: • **Muon mixing**, with the HNL being produced from the decay of muons and, for  $m_N < m_{\pi} - m_{\mu}$ , from pions: **decay width:**<br>The contract with the contract of the contract

(3.10)

$$
\Gamma(N \to e^+e^-\nu_\mu) = \frac{G_F^2 m_N^5}{768\pi^3} |U_{\mu N}|^2 (1 - 4\sin^2\theta_W + 8\sin^4\theta_W)
$$

#### **STEFANO ROBERTO SOLETI - SHINESS: SEARCH FOR HIDDEN NEUTRINOS AT THE ESS** (b) Electron mixing. The contract mixing mixing mixing mixing. The contract mixing mixing mixing mixing mixing



- The  $e^+e^-$  can be detected in the liquid scintillator tank by looking for compatible energy **depositions** and **Cherenkov cones**.
- $\mathbf{I} \cap \mathcal{D}$ multiple leptons in the final state, produced in the decay of heavy neutrinos. The baseline • Analogous studies have been conducted for other  $\pi$ <sup>+</sup>DAR experiments (e.g. LSND, JSNS<sup>2</sup>), but located 25 m far from the ESS beam target. We show that SHiNESS will be able to considerably improve current global limits for the three cases outlined above. Although in the **directionality capabilities of SHiNESS**, enabled by the LAPPDs, allow to reach worldr<br>J<br>J **leading sensitivities** in the 10-100 MeV mass range.

# **HNL sensitivity**





**Dipc** 







**SMINESS** 

## **Summary**



- **SHiNESS** is a **relatively cheap** and small-scale experiment using proven technologies.
- It will exploit the intense flux of well-characterized  $\pi^+$ DAR neutrinos produced as a byproduct of the spallation beam at the ESS.
- It does not require any update to the current ESS beam (**no need for ESS Neutrino Super Beam**).
- It has the potential to set world-leading sensitivities for several new physics scenarios: **light sterile neutrinos**, **neutrino mixing unitarity**, **heavy neutral leptons** have been explored.
- Interested in collaborating? **[Contact me](mailto:roberto.soleti@dipc.org?subject=SHiNESS)**!