

K. Long, 26 October, 2017



The nuSTORM experiment



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WHAT IS nuSTORM?

Neutrinos from stored muons



- Scientific objectives:
 - 1. %-level (v_eN)cross sections
 - Double differential
 - 2. Sterile neutrino search
 - Beyond Fermilab SBN

- Precise neutrino flux:
 - Normalisation: < 1%</p>
 - Energy/flavour precise

•
$$\pi \rightarrow \pi$$
 injection pass:
- "Flash" of y

nuSTORM oveview



- Fast extraction at >~ 100 GeV
- Conventional pion production and capture (horn)
 Quadrupole pion-transport channel to decay ring

Neutrino flux



- v_{μ} flash:
 - Pion: 6.3 × 10¹⁶ m⁻² at 50m
 - Kaon: 3.8 × 10¹⁴ m⁻² at 50m
 - Well separated from pion neutrinos

- v_e and v_μ from muon decay:
 - ~10 times as many v_e as, e.g.
 J-PARC beam
 - Flavour composition, energy spectrum
 - Use for energy calibration

WHY STUDY NEUTRINO INTERACTIONS?

To understand the nucleon and the nucleus

• Neutrino unique probe: weak and chiral:

Sensitive to flavour/isospin and 100% polarised

- How could neutrino scattering help?
 - Nucleon (e.g.):
 - Spin puzzle
 - Nucleus (e.g.):
 - Multi-nucleon correlations
 - Precise determination of:
 - Model parameters or, better,
 - Theoretical (ab initio) description
- Can the neutrino's unique properties compete with the rate in, e.g. electron scattering?
 - To be studied!
- Benefit of nuSTORM:
 - Precise flux and energy distribution





Systematic uncertainty and/or bias



Search for CPiV in Ibl oscillations

• Seek to measure asymmetry: $-P(v_{\mu} \succ v_{e}) - P(\overline{v}_{\mu} \succ \overline{v}_{e})$

- Event rates convolution of:
 - -Flux, cross sections, detector mass, efficiency, E-scale
 - Measurements at %-level required

- Lack of knowledge of cross-sections leads to:
 - -Systematic uncertainties; and
 - –Biases; pernicious if ν and $\overline{\nu}$ differ

THE BENEFIT OF nuSTORM

$v_e N$ cross section measurements

Gargamelle: 244 events at ~90% purity T2K: 315 events at ~65% purity





*Warning: not exactly σ. Actually dσ/dE^{, QE} integrated over bins in E_v

tically consistent.

Systematic uncertainties



CCQE measurement at nuSTORM

- CCQE at nuSTORM:
 - Six-fold improvement in systematic uncertainty compared with "state of the art"
 - Electron-neutrino cross section measurement unique
- Require to demonstrate:
 ~<1% precision on flux



10.1103/PhysRevD.89.071301; arXiv:1305.1419



Individual v_e measurements from T2K and MINERvA [10.1103/PhysRevLett.113.241803, 10.1103/PhysRevLett.116.081802]₁₃

nuSTORM & THE CERN PHYSICS BEYOND COLLIDERS STUDY GROUP

Physics Beyond Colliders study group



Elements of study

Physics case:

- Neutrino-scattering for:
 - Oscillation
 - Nuclear
- Specification:
 - Energy range:
 - Long- and short-baseline neutrino
 - Nuclear and particle physics
 - Acceptance:
 - Rate
 - Neutrino-energy calibration

- Accelerator:
 - Full simulation that demonstrates <~1% flux precision
 - Energy range (i.e. sweep down from max)
- Implementation:
 - Feasibility at CERN (see next slide)
- Detector:
 - Others are "on this", so:
 - Adopt performance of typical, or assumed, detector

Implementation @ CERN Exploratory study

- An initial proposal for siting at CERN, including:
 - SPS requirements
 - Fast extraction, beam-line
 - Target and target complex
 - Horn
 - Siting
 - Civil engineering
 - Radio-protection implications

Conclusions

Conclusions

- nuSTORM can deliver:
 - nN scattering measurements with precision required to:
 - Serve the long- and short-baseline neutrino programmes
 - Provide a valuable probe for nuclear physics
- CERN PBC study: innovative programme:
 - nuSTORM:
 - Delivers critical measurement: $v_e/v_\mu N$ scattering;
 - Has discovery potential: sterile neutrinos;
 - Potential for 6D ionization-cooling programme to follow MICE
- Muon accelerators have the potential to:
 - Revolutionise neutrino physics
 - Provide multi-TeV lepton-anti-lepton collisions

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