A method for measuring coherent elastic neutrino-nucleus scattering at a far off-axis high-energy neutrino beam target

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SciBath Detector

- 80 L open volume of mineral oil based liquid scintillator
- Neutrons recoil off protons, create scintillation
- 768 wavelength shifting fibers readout
- IU built custom digitizer: 12 bit, 20 MS / s
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Sample Neutron Candidate Event

SciBath Detector for ANNIE -- R.L. Cooper
Sample Muon Candidate Event

Event Num: 109 (1206)
Multiplicity: 204
Total PEs: 412.6
PEs ← X: 126.0 Y: 158.1 Z: 128.5
PEs^2 ← X: 337.9 Y: 668.8 Z: 360.9
T0: 3.27227153 s
Time to last BIB: 0.0009486 s

X = 9.7 ± 5.4 cm -- skew = -1.64 -- kurt = 6.62
Y = -4.0 ± 11.6 cm -- skew = 0.47 -- kurt = 2.14
Z = -6.1 ± 6.1 cm -- skew = 0.90 -- kurt = 4.70

T = 24.7 ± 36.9 s -- skew = 6.92 -- kurt = 60.43
EigenVals: 196.01, 183.20, 34.72
EigenVct 1: 0.65X + -0.19Y + 0.74Z
EigenVct 2: -0.75X + 0.39Y + 0.59Z
EigenVct 3: 0.12X + -0.93Y + -0.34Z
Point χ^2: 1562.27 Track χ^2: 1496.78

μ = 6.9 ± 12.7 cm -- skew = -0.41 -- kurt = 2.00
Track length, ellipsoid: 58.69, rod: 47.70
Spherical radius: 18.57 Eigenvector length: 42.86
n / $\mu$ Particle Discrimination

![Graph showing n and $\mu$ particle discrimination](image)
Calibrating the SciBath Detector

- Low-light LED pulser ($Y \rightarrow Z$)
- Use cosmic rays with known energy deposit ($X \rightarrow Y$) requires previous calibration to count photons
- Detect 6 PEs / MeV → want to improve
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Fermilab Measurement Sites

MINOS Near

BNB Target

NuMI Target

2/12– 5/12

10/11 – 2/12

SciBath Detector for ANNIE -- R.L. Cooper
MI-12 Neutron Background Run

- Neutron flux ~20 m from target
- In-line behind beam target (ground)
- 29 Feb. – 23 Apr., 2012
- $4.9 \times 10^{19}$ total protons on target (POT) ($4.5 \times 10^{12}$ per pulse)
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MI-12 Beam Time Per PE “Group”

- **HIGH PE** group shows beam time structure

- **MEDIUM PE** group has few-μs excess – slower neutrons arriving later

- **LOWEST PE** group has significant excess – 200 μs lifetime from \( n(p, d)\gamma \) neutron capture reaction
BNB Neutron Energy Spectrum

• $E_n$ unfolded from PEs spectrum simulation of detector response

• $2.44 \pm 0.34$ pulse$^{-1}$ m$^{-2}$ ($E_n > 40$ MeV)

• Lose sensitivity > 200 MeV;

• Neutron spectrum 20 m from BNB

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NOTE: variable PE bin width
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Direction Spectrum

- High PE protons will be track-like; can be imaged

- Principle component analysis yields eigenvector

- Back-projecting direction spectrum tends to point upstream of target ?!

- Tracking validated with cosmic rays and NuMI beam
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Direction Spectrum

- Sensitive to $n(p,d)\gamma$ reaction and see copious beam-correlated rate

- Accidental rates too high for capture-gating $\rightarrow$ statistical sensitivity
Current Studies

• 2012 measurements at one position with no shielding

• We are improving SciBath, building concrete shielding

• Locate a viable location for CENNS & CAPTAIN

• Survey the area with portable detector
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Beam Off-Target Rates (> 0.5 MeV)

50 m Absorber
- 6 m from Fe beam stop
- 310 n / 10^{16} POT

Collimator
- 8 m from Be beam target
- 5608 n / 10^{16} POT

Stairwell
- 9 m from Be beam target
- 1384 n / 10^{16} POT

Target 90° FOX
- 20 m from Be beam target
- 390 n / 10^{16} POT

2012 SciBath Loc
- 20 m from Be beam target
- 211 n / 10^{16} POT

≈ 2.7×10^{16} / hr

Neutron spectrum unfolding underway
Summer 2015 Plans

• Plan to measure near BNB target building for CENNS, CAPTAIN, and general SBN program (May or June for 1 month)

• Measure in SciBooNE hall higher energy neutrino-induced neutrons: relevant for ANNIE, microBooNE, and SBN (May or June for 1 month)

• We want to help the neutron measurement efforts and are eager for additional support: siting, shifts, analysis, etc.