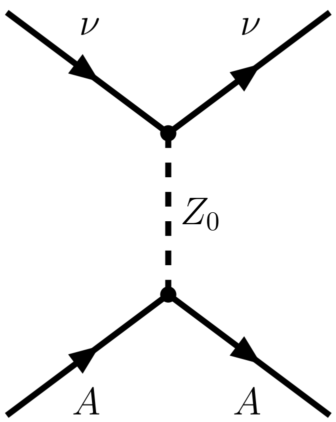
• Coherent-NCvAS first predicted by Freedman in 1974 at Fermilab



• Differential cross section for finite momentum transfer

$$\frac{d\sigma}{dE} = \frac{G_F^2}{4\pi}[(1-4\sin^2\theta_w)Z-(A-Z)]^2 M\left(1-\frac{ME}{2E_\nu^2}\right)F(Q^2)^2$$

• For most of the target nucleus, the coherence condition is fulfilled by neutrino energy of

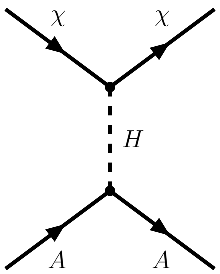
$$E_\nu < \frac{1}{R_N} \simeq 50\ \mathrm{MeV} \qquad E_{max} \simeq \frac{2E_\nu^2}{M} \simeq \mathcal{O}(100)\ \mathrm{keV}$$

• Requires a ton-scale detector with ~10 keV energy threshold

$$R \simeq \mathcal{O}(10^3)\left(\frac{\sigma}{10^{-39}cm^2}\right)\times\left(\frac{\Phi}{10^{13}\nu/year/cm^2}\right)\times\left(\frac{M}{ton}\right) events/year$$

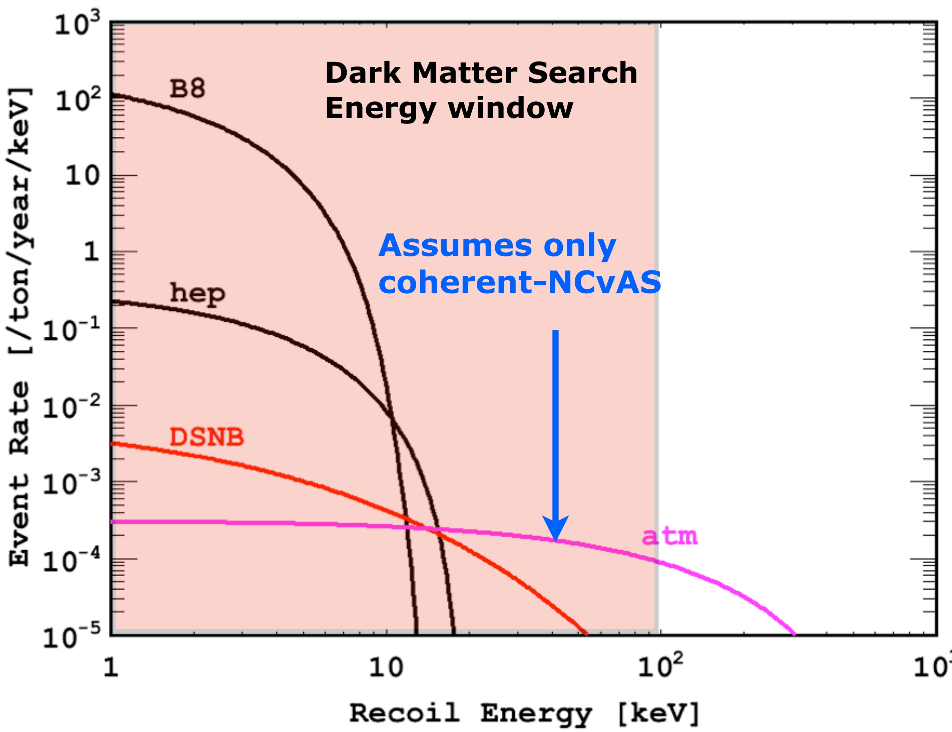
→ **Recent innovation of Dark Matter detector technology makes it possible to access coherent-NCvAS**

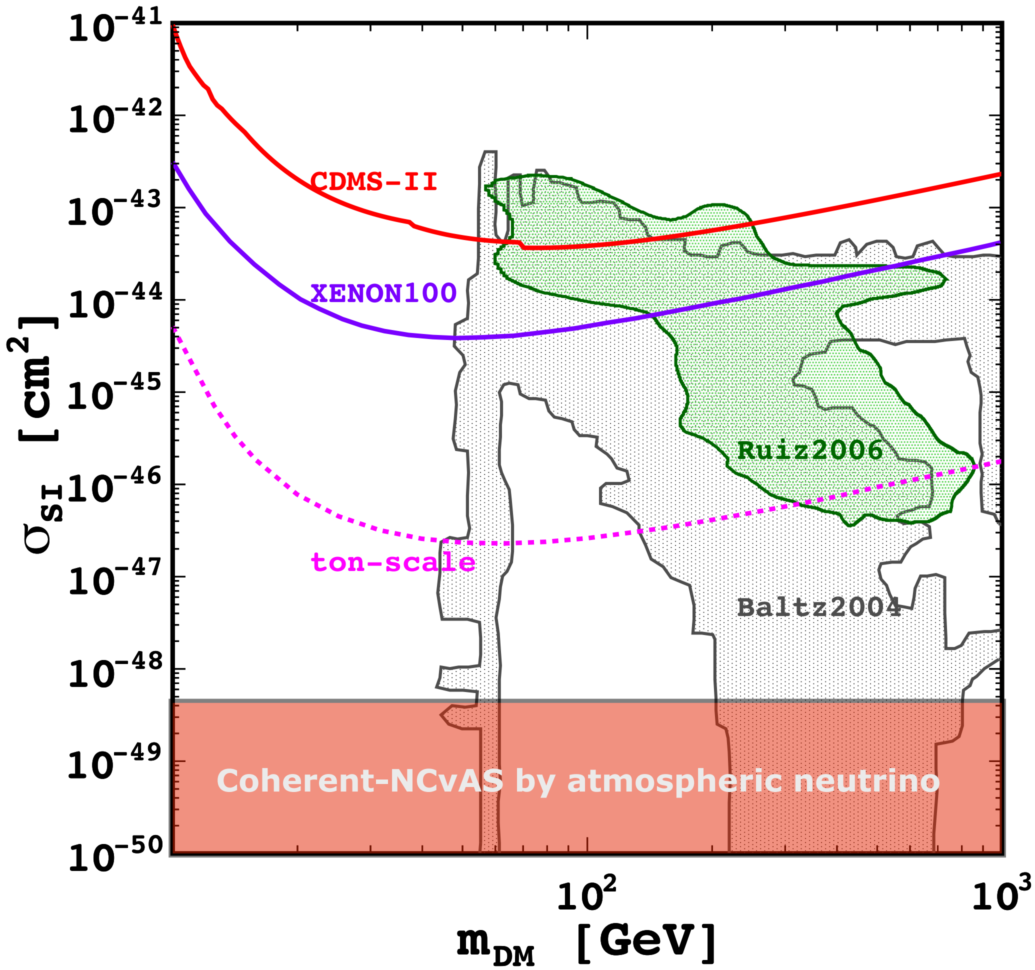
- Coherent scattering of atmospheric neutrino is an irreducible background in the future *O*(10 ton) scale Dark Matter experiments



$$\sigma_{\chi N} \simeq \frac{4}{\pi}\mu^2[Zf_p + (A-Z)f_n]^2$$

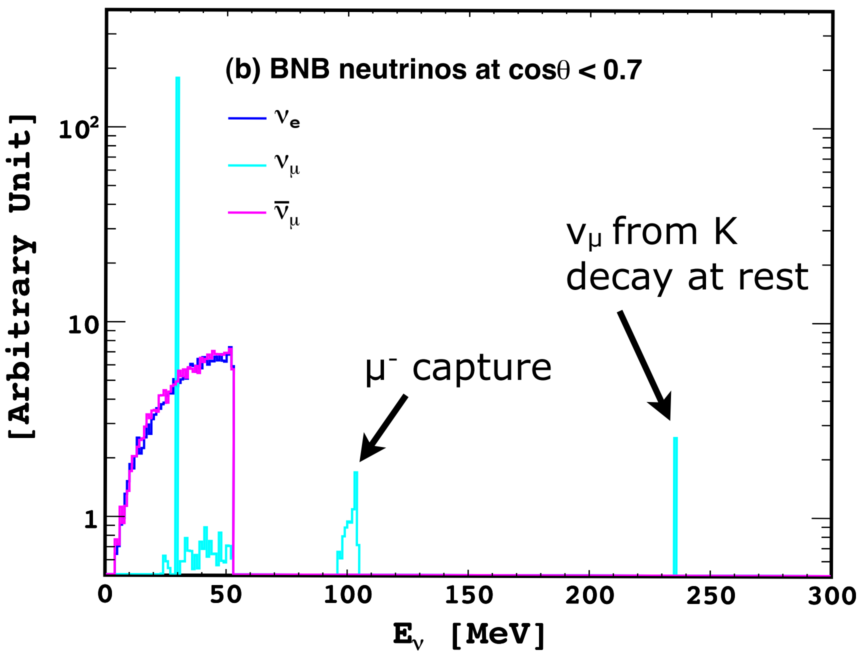
$$\frac{dR}{dE} = \frac{\sigma_0}{m_\chi}\frac{A^2}{2\mu_n^2}F_A^2(E) \times \rho_0 \int_{v_m} \frac{f(v)}{v}dv$$

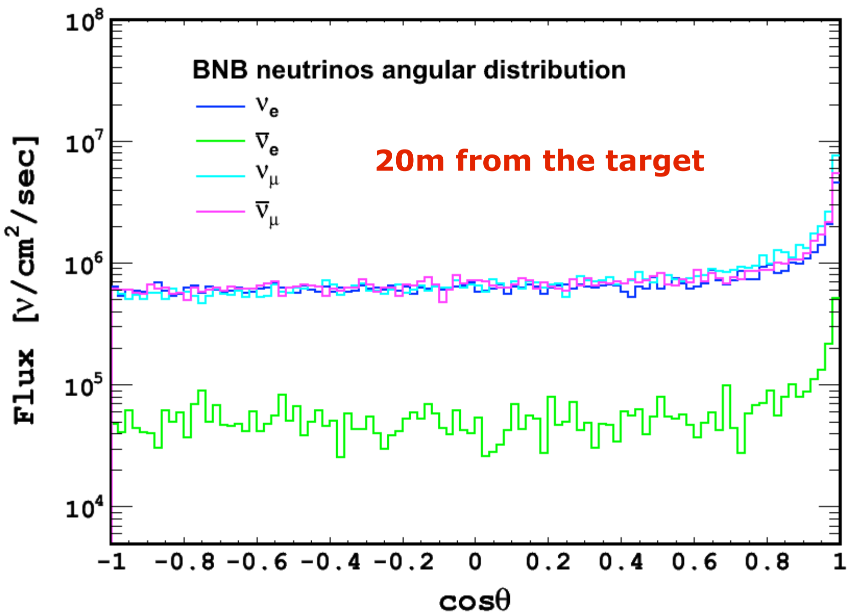




- Sensitivity of Dark Matter detectors will be saturated out by irreducible atmospheric neutrino backgrounds

From Booster Beam MC (S. Brice)





Beam MC Configuration

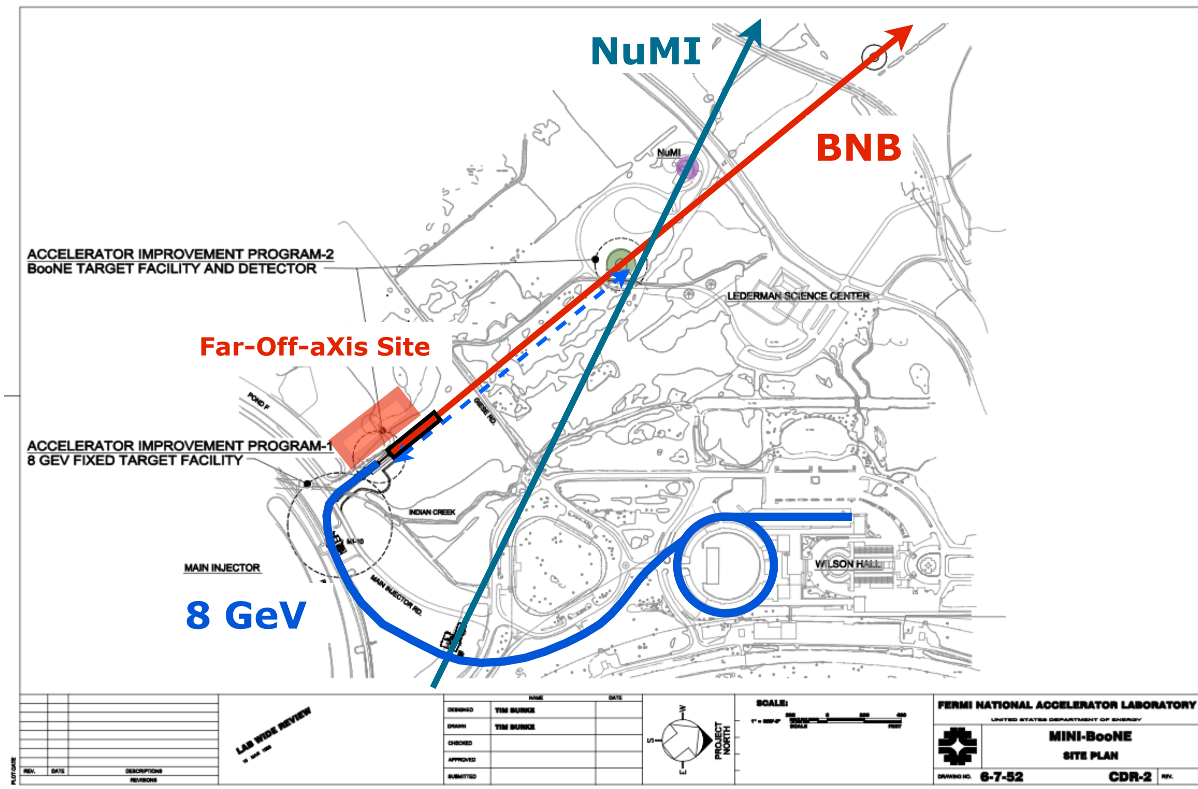
- Use standard Booster Beam MC
  - release stopping pion cuts in the original MC
- 8 GeV, 5Hz 5x10^{12} Protons on Be target
  - 32 kW max power (w/ NUMI beam ~ 8 kW)

Dominant neutrino production process at the Far-Off-aXis is pion decay at rest

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \qquad E(\nu_\mu) = 29.9 \text{ MeV}$$

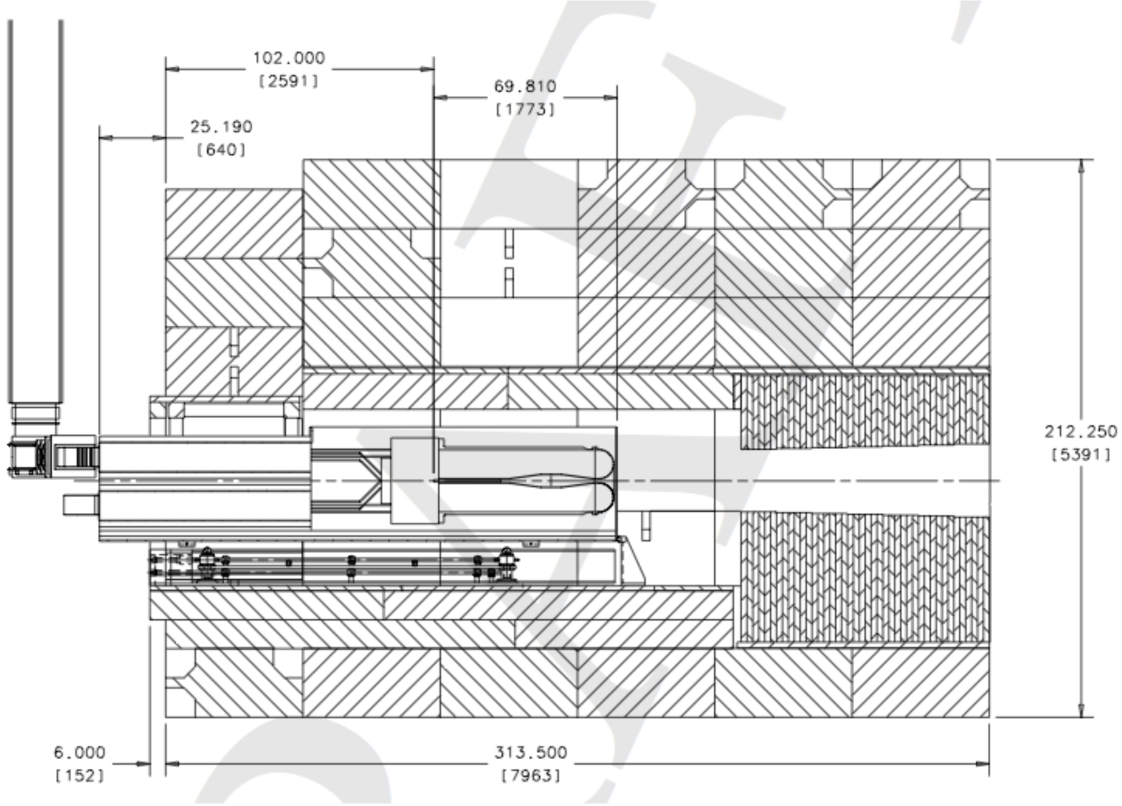
$$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e \qquad \text{delay} = 2.2\ \mu s$$

⇨ **$\phi \sim 5 \times 10^5\ \nu/cm^2/s$ (@20m, cosθ<0.5)**



Measuring Coherent Elastic Neutral Current Neutrino Nucleus Scattering at Fermilab

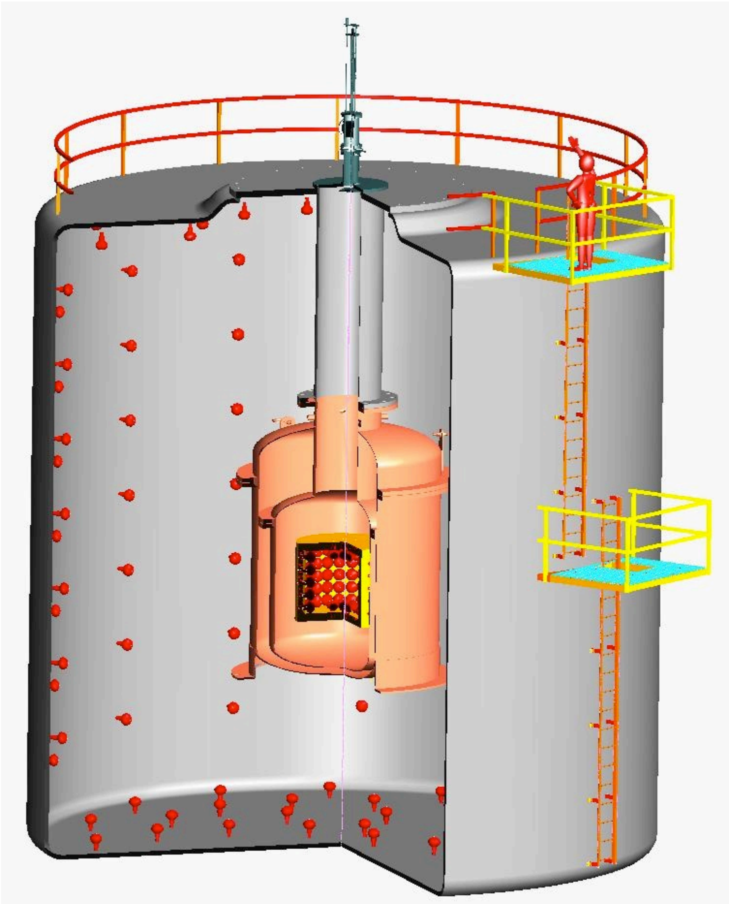
- **Neutrino Source at Oak Ridge SNS**
  - 1GeV proton on Hg, 24uC/pulse, 60Hz → 1.4MW
  - ϕ(@20m) = 10^7 ν/cm²/s
    - but practical location is 46m away from the target
  - **ϕ(@46m) = 2×10^6 ν/cm²/s**
- **Fermilab Far-Off-aXis BNB**
  - 8GeV proton on Be, 6.4uC/pulse, 5Hz → 32kW
  - ϕ(@20m) = 5×10^5 ν/cm²/s
  - **ϕ(@10m) = 2×10^6 ν/cm²/s**
  - → beam induced neutron BG is the key issue
  - → requires a detailed MC study

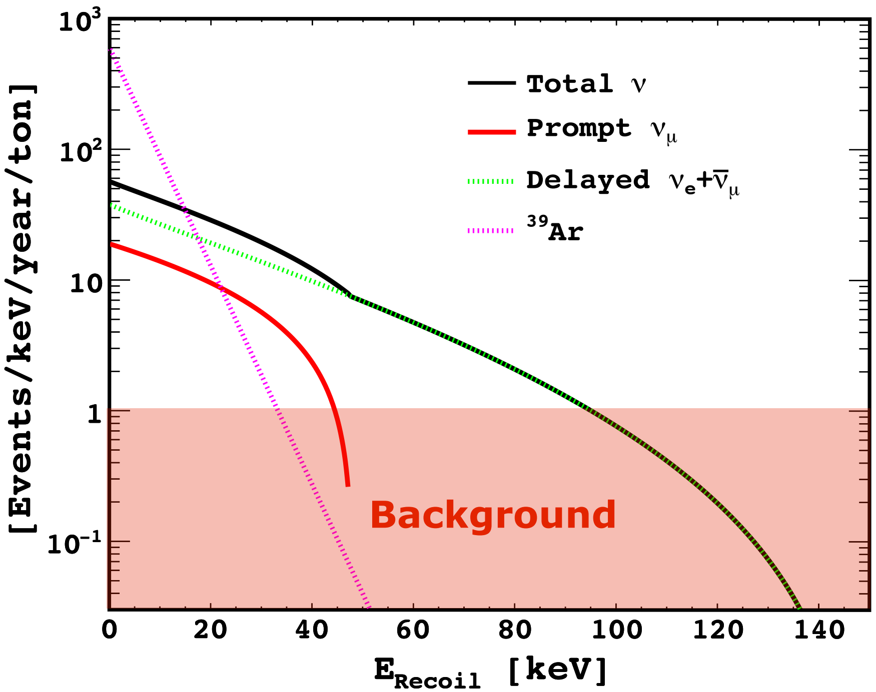


- Very impressive shielding at BNB target
  - total ~2.5m-thick steel
  - additional ~2.5m-thick concrete
- Ballpark estimation of beam induced neutron flux at 10m seem to be OK
  - → need detailed MC study
- Cosmogenics would then important issue

Measuring Coherent Elastic Neutral Current Neutrino Nucleus Scattering at Fermilab

A ton-scale LAr detector may perform the first ever observation of the coherent-NCνAS at Fermilab





- Steady state background rejection factor ~10^{-5}
- Use pulse shape discrimination of nuclear recoil (fast) and electron recoil (slow) signal in LAr
- Well known detector technology (DEAP/CLEAN)
- Expected Event Rate in a single-phase LAr detector: ~200evt/ton/yr (E_{th}>30 keV, @20m, 32kW and w/ NUMI: ~50 evt/ton/yr)
- Project-X 8GeV, 0.3MW pulsed beam will provide intensive high energy neutrinos. The same beam will provide very precious byproduct - low energy neutrinos with 4π coverage.

Current Collaboration

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Duke: Kate Scholberg
Indiana: Rex Tayloe

- **We can make the first ever observation of Coherent-NCνAS at Fermilab**