CEvNS @ JLab

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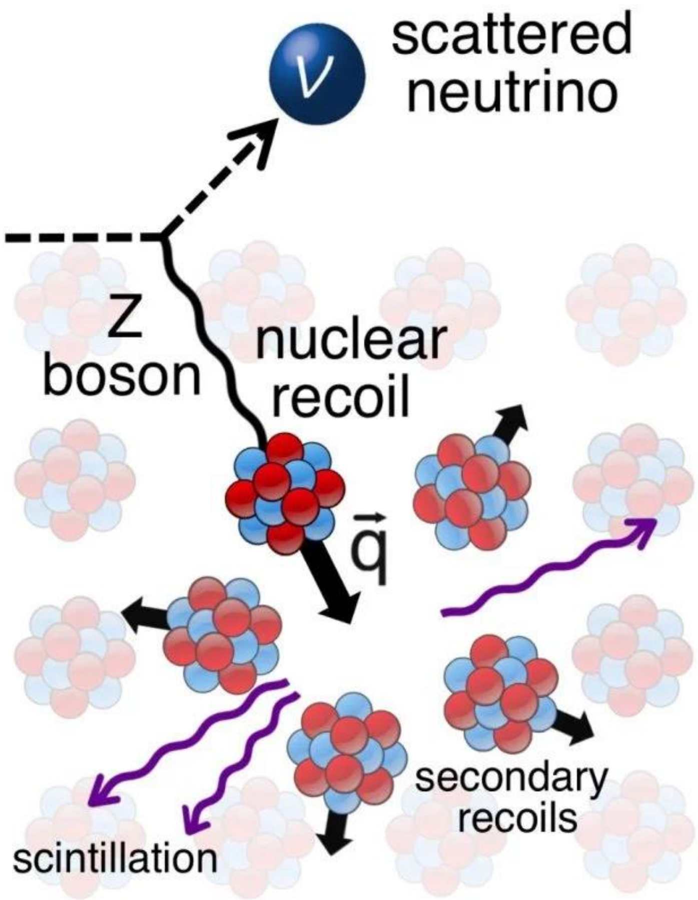
CEvNS

- Coherent elastic neutrino-nucleus scattering, or **CEvNS** is the process of a low energy neutrino scattering on a nucleus. In the process is exchange a Z_0 boson

- Is **coherent** because the neutrino interacts with the **nucleus as a whole**, not with individual nucleons

- **Recoil** nucleus have small energy, **few keV**.
- <u>->That's not easy to detect</u>



CEvNS Cross-Section

- CEvNS cross-section is quite large

  -> around 10^{-39}cm^2.

$$\frac{d\sigma}{dE_r} = \frac{m_N G_F^2}{2\pi}\left(2 - \frac{E_r m_N}{E_\nu^2}\right) Q_W^2$$

- It is proportional to coherent weak nuclear charge Q_w that quantifies the Z-nucleus vector coupling

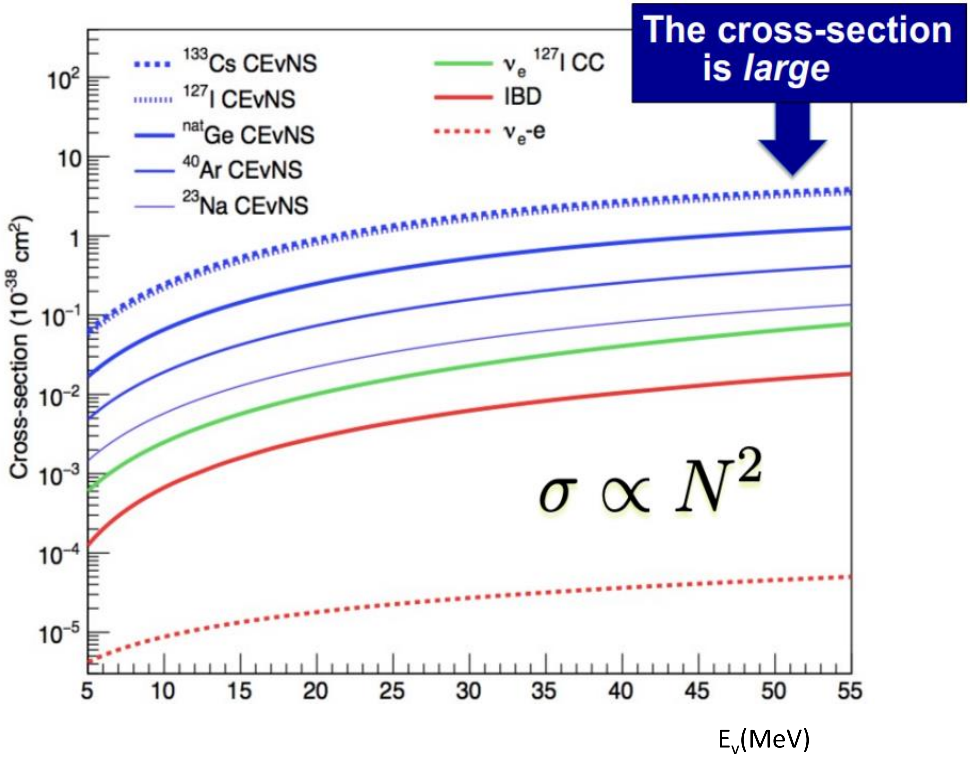
$$Q_W^2 = \left[N g_V^n F_N(q) + Z g_V^p F_Z(q)\right]^2$$

- Proton and neutron charges are define as

g^p_v=1/2 – 2 $\sin^2\theta_W$(Weinberg and angle), g^n_v=-1/2

- g^p_v~0 so

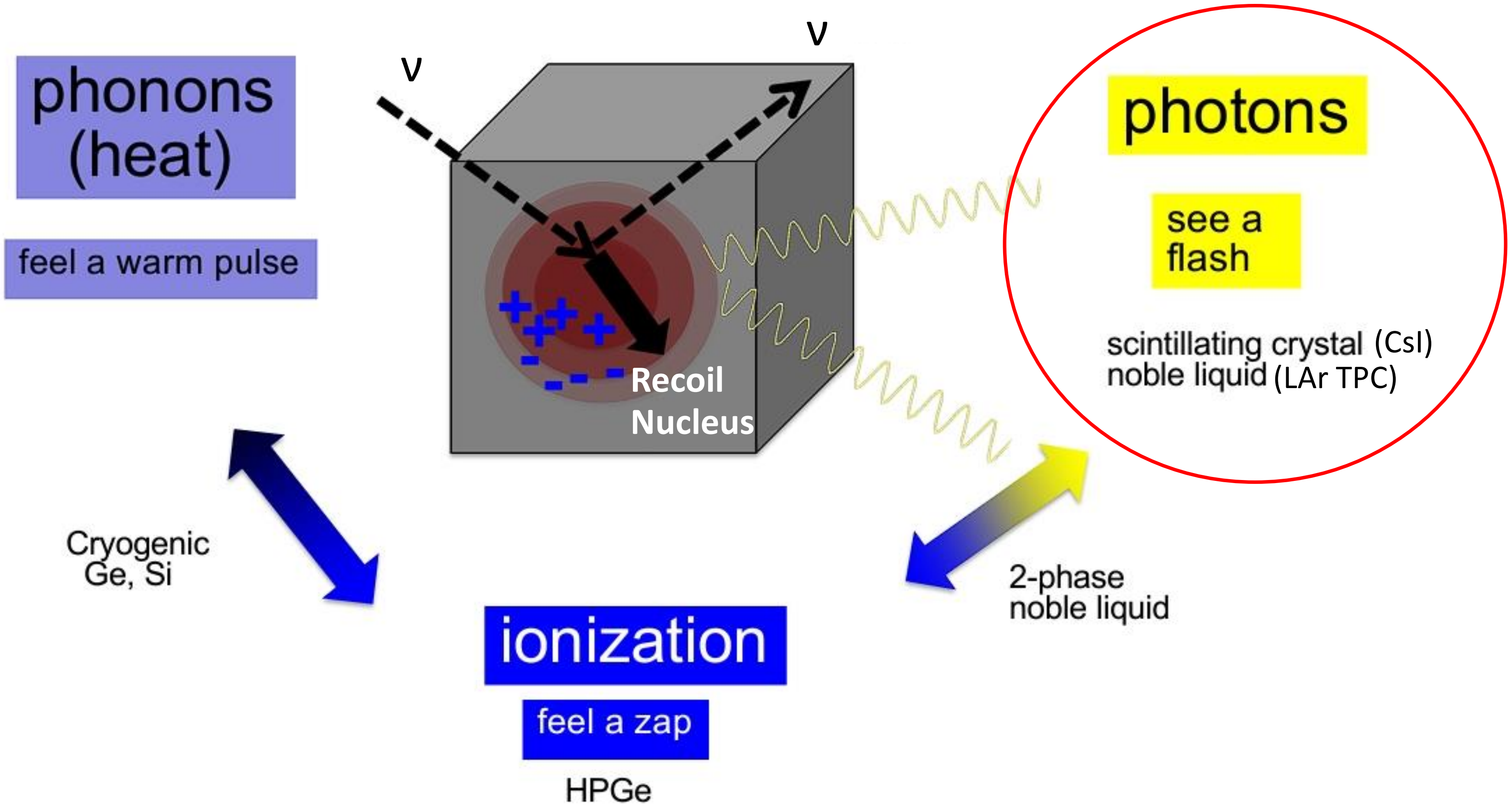
  -> cross-section proportional to N^2



Physics Interest

- CEvNS is a process sensitive to the **weak mixing angle**
  - **<u>θ_w appear in cross-section at tree-level</u>**
- RMS radius of the neutron distribution.
  - neutron skin thickness of a nucleus, Δr_{np}(nucleus) = $r^n_{rms} - r^p_{rms}$.
- Neutrino NSI
- Dark Matter
  - CEvNS background for DM search

Detection Methods



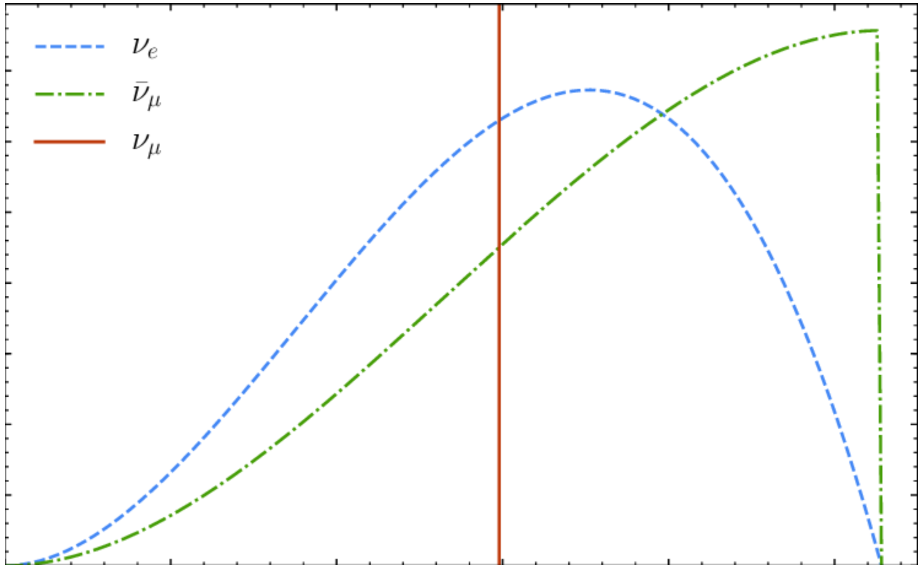
Neutrino at Jlab

- Neutrino production at Jefferson Lab
  - e-beam on Hall A Beam Dump can produces an intense ν-beam
  - Electron interact with dump generating π

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \qquad E_\nu \approx 30 \text{ MeV}$$
$$\mu^+ \rightarrow e^+ + \bar{\nu}_e + \nu_\mu \qquad 0 < E_\nu < 50 \text{ MeV}$$

  - π mainly decay (isotropically) at rest (DAR) in μ and ν
  - μ decay in 2 ν

  - π decay on flight produce a
  - small tail of higher energy neutrino



- e-Beam of about 10^{22} EOT/y can produce 10^{18} ν/year/m^2 (mainly DAR)

Signal Yield at JLab

- Yield calculation need to rewrite CEvNS cross-section introducing the nucleus kinetic energy T_A and three-momentum transfer |q|

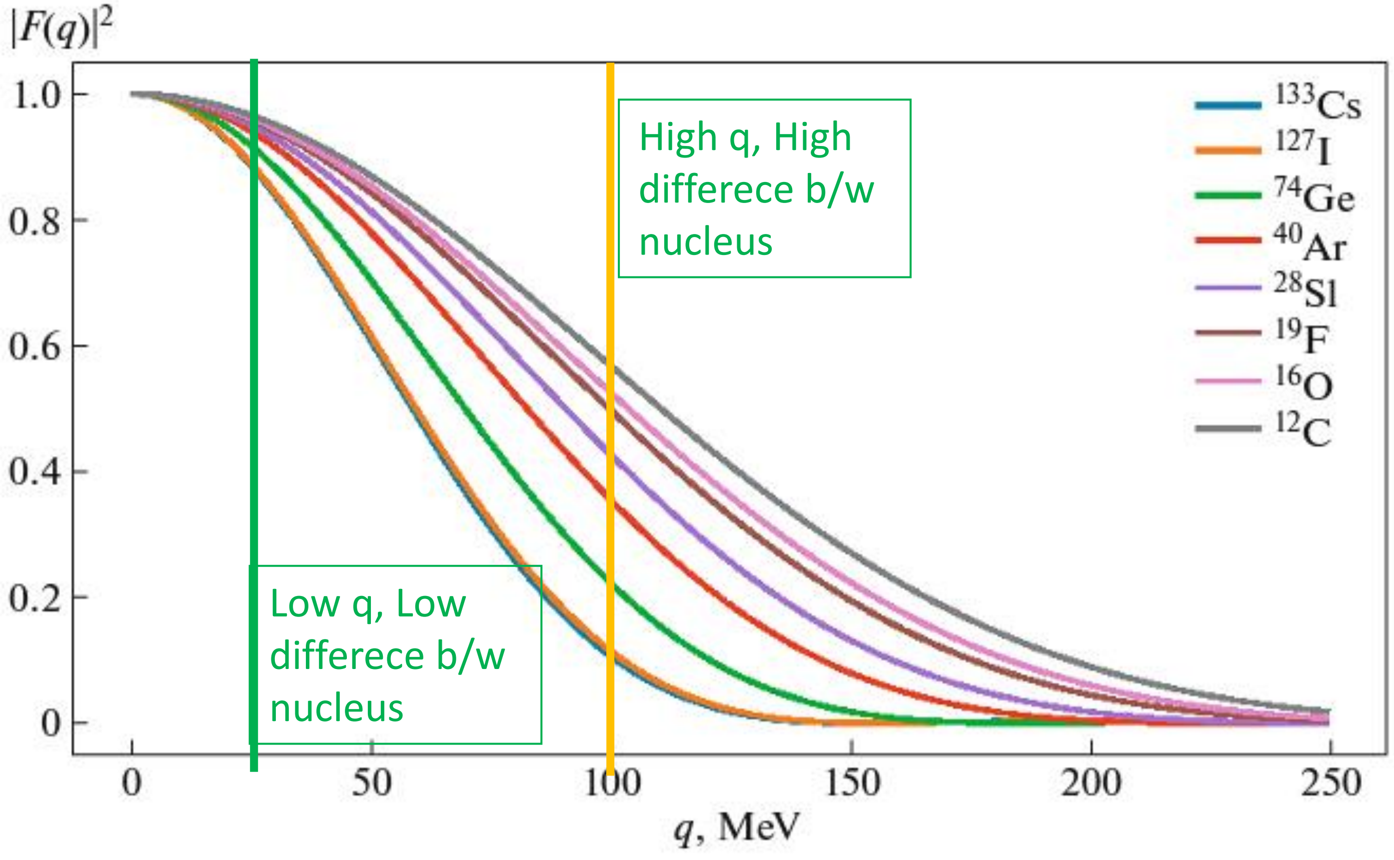
$$\frac{d\sigma_{\rm coh}}{dT_A} \approx \frac{G_F^2 m_A}{\pi}\left(1 - \frac{T_A}{T_A^{\rm max}}\right)|F(q)|^2 \left(g_V^n\right)^2 N^2,$$

$$|\boldsymbol{q}| = \left(E_\nu^2 + E_\nu'^2 - 2E_\nu E_\nu' \cos\theta\right)^{1/2} \simeq (2m_A T_A)^{1/2} \qquad T_A^{\rm max} = \lim_{\cos\theta\to -1} T_A \approx \frac{(2E_\nu - \Delta\varepsilon_{mn})^2}{2m_A},$$

- Last important term is the nucleus form factor |F(q)|

Signal Yield at JLab

- $|F(q)|^2$ depends on q and change with nucleus

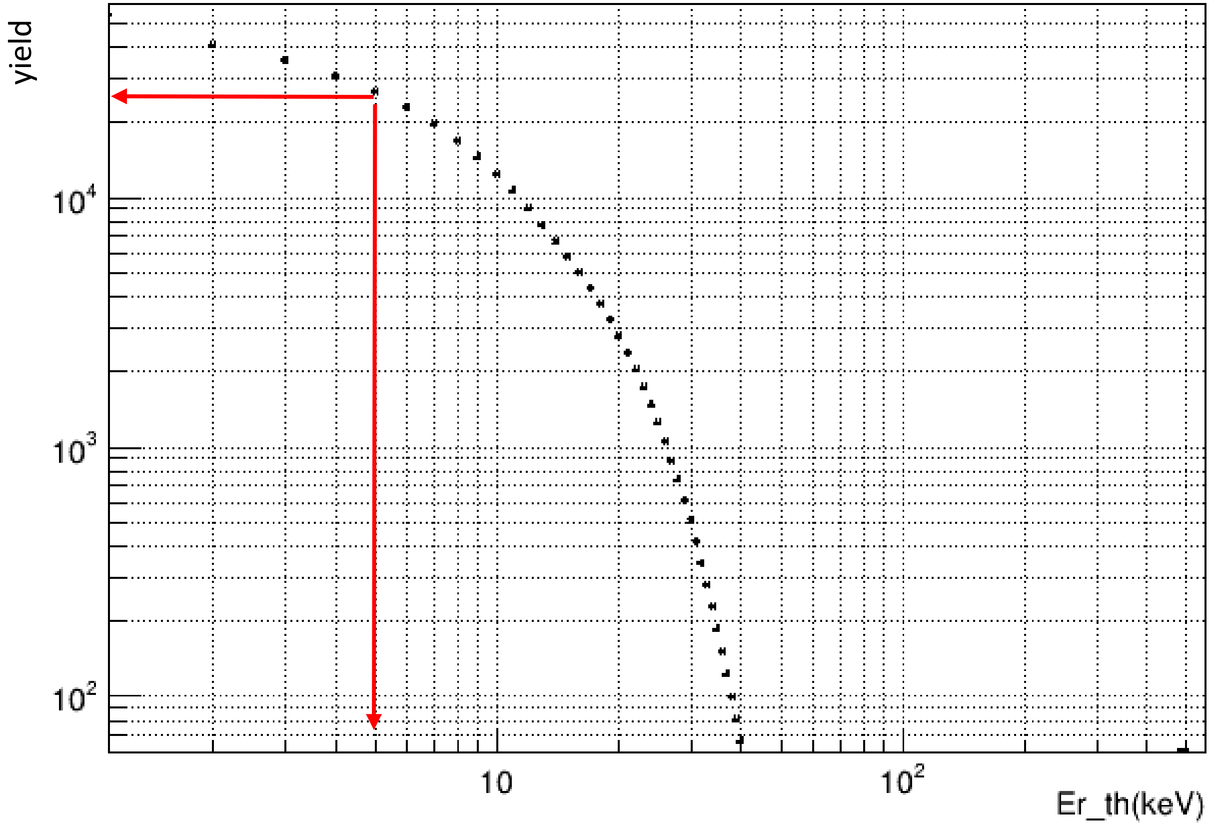


Heavy nuclei form factor drops rapidily but N^2 dependence still dominates

Signal Yield at JLab

- Deploying a 1 m^3 CsI crystal detector (nuBDX experiment)
- The yield depends on the mininum detectable recoil energy E_r
- With 5 KeV treshold about 10^4 CEvNS interactions/y

$$\frac{dR}{dE_r} = V_{\rm det}\,\rho(P)\,\frac{N_A}{m_{\rm molar}}\int_{E_\nu^{\rm min}}^{E_\nu^{\rm max}} \frac{d\sigma}{dT_A}\,\frac{d\Phi}{dE_\nu}\,dE_\nu$$



Summary

- The intense neutrino beam generated by JLab electron beam and Hall-A beam-dump can be used to study CEvNS

- High N scintillator crystal chosen to improve the interaction probability

- Great number on CEvNS events expected permit to measured Weak Mixing angle with good precision