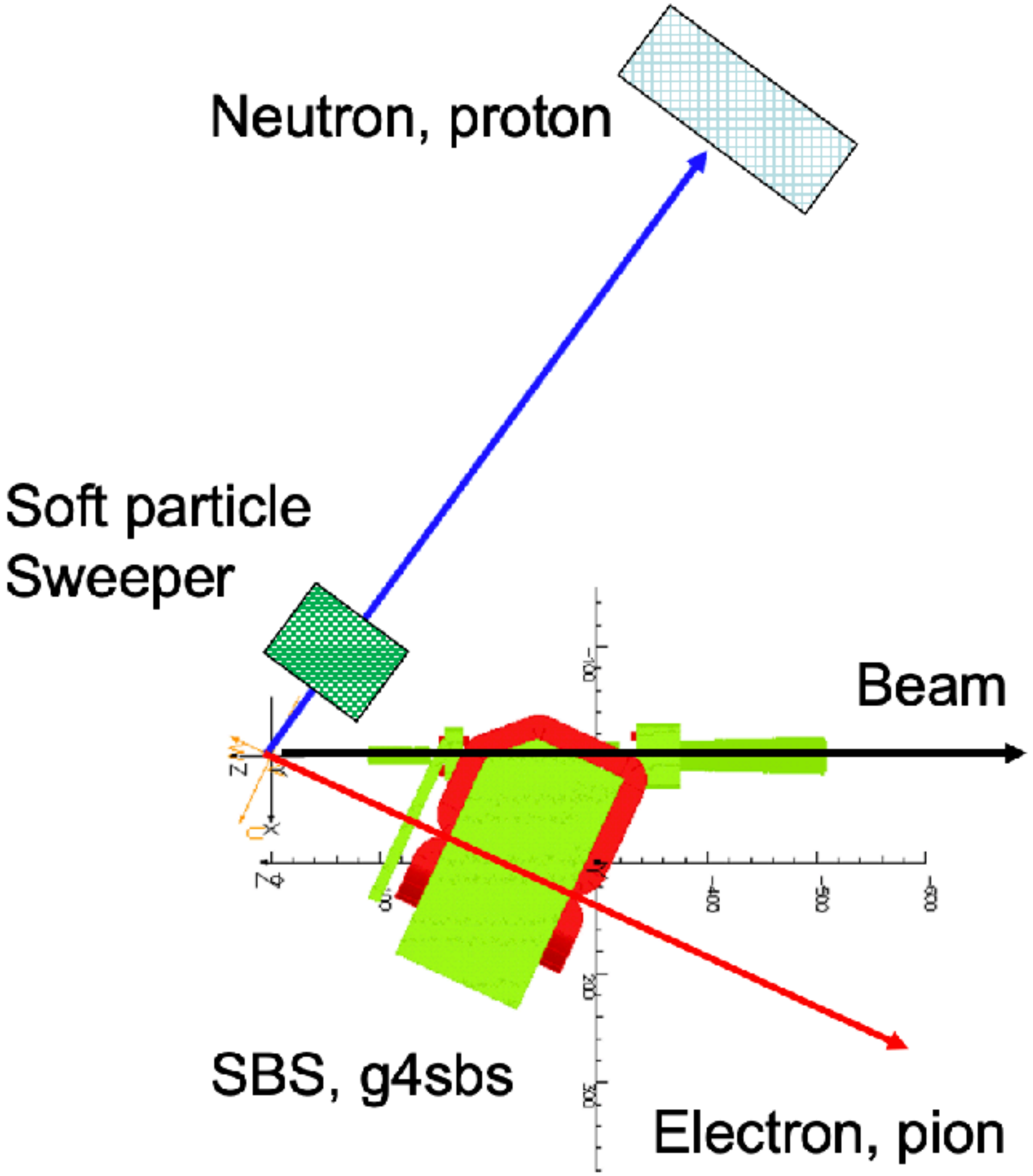
Summary of Letter of Intent

Numbers to set the scale of the challenges

$$\vec{e}^- + p \rightarrow \nu_e + n$$

Jim Napolitano, Inaugural Axial FF Collaboration Meeting, 14 September 2024

Letter of Intent to PAC 52 (Summer 2024)



Key Assumptions

- A 500-hour data taking run with a beam on a 10-cm-long LH2 target in Hall C.
- A 100 μA electron beam at 2.2 GeV energy with a high degree of circular polarization.
- SBS to veto events from the processes with the final state electron or pion.
- A large size high efficiency neutron detector with time resolution better than 100 ps at a distance of 15 m from the target (75 msr).
- A magnet covering the neutron arm acceptance to sweep out charged particles.

Challenging Numbers

i.e. Why I was told this was a stupid idea 38 years ago

The background-to-signal ratio is something like 10^7.

- Weak reaction rates are much smaller than electromagnetic reaction rates
- Neutrons from pion photo production on protons have close kinematics
- Protons (which might fake neutrons) from elastic scattering have the exact same kinematics
- Many other reactions lead to other backgrounds that we must contend with

Naive Hopefulness

- The reaction can only proceed with left-handed electrons.

  If we can get the backgrounds down to a reasonable level, then it can be subtracted precisely by reversing the incident electron spin.

- The neutron from this reaction is faster than neutrons from any electromagnetic reaction at the same kinematics.

  A good neutron detector with precision time-of-flight and energy measurement will be helpful for reducing backgrounds.

Why the idea has been resurrected

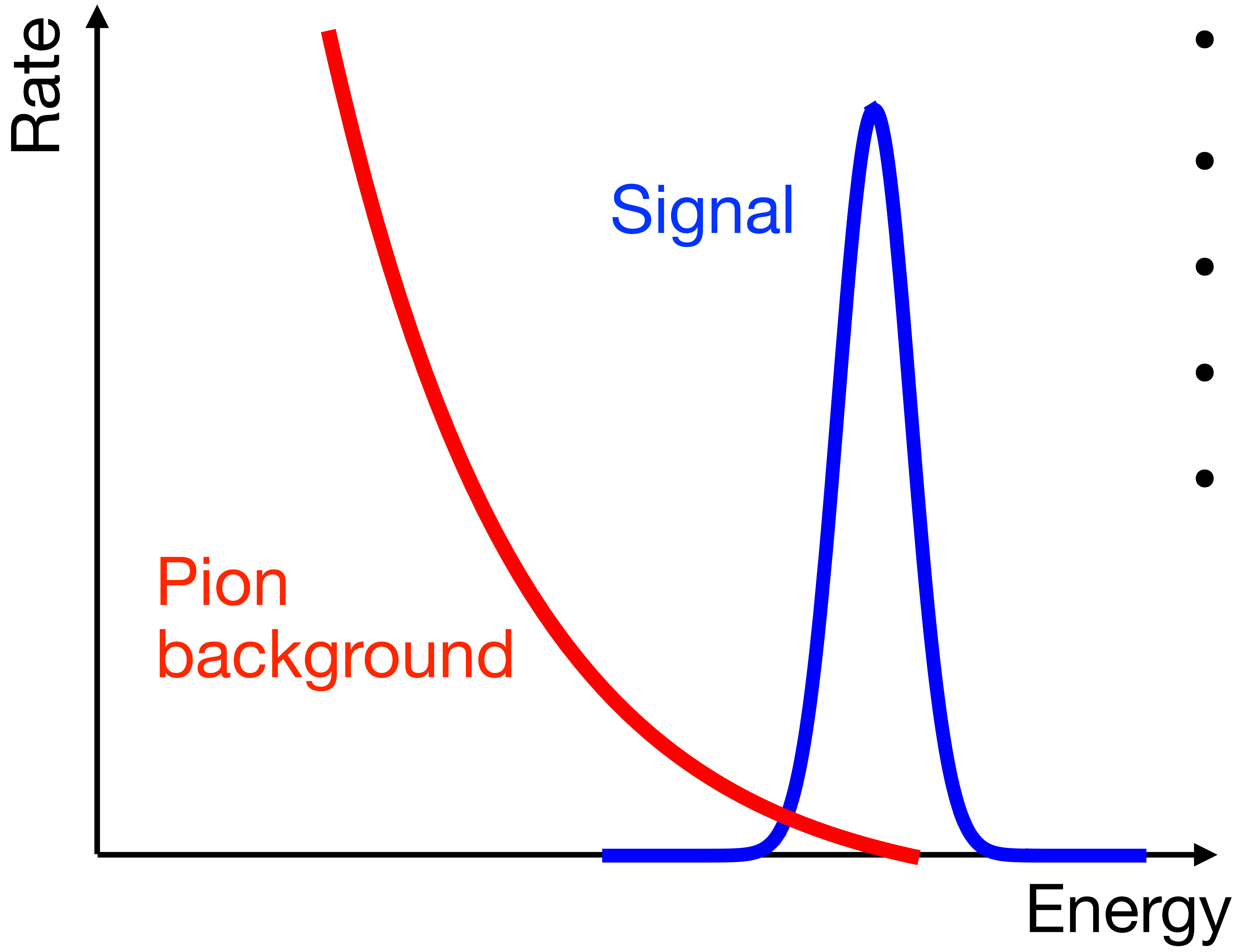
Short answer: The SBS facility

- We can now deal with the necessary high rate and high acceptances
- The SBS magnet can serve as an electron detector for removal of background from elastic ep scattering
- Perhaps some upgrades of HCAL will be enough for the neutron detector

"Quick and dirty" simulation suggests we can get the background-to-signal ratio down to around 10^3 from 10^7.

Then we rely on beam polarization for the final background subtraction.

Schematic of Signal and Background



- θ_n=30°, $\Delta\Omega_n$=75msr, 15m from target
- Assume 100ps neutron TOF resolution
- Rate (signal) ≈ 23 per hour
- Rate (Pion background) ≈ 40K per hour
- Rate (ep Elastic) ≈ 4K per hour (tricks!)

☞ Expected result on signal cross section is $(1.1\pm0.3)\times10^{-39}$ cm^2/sr

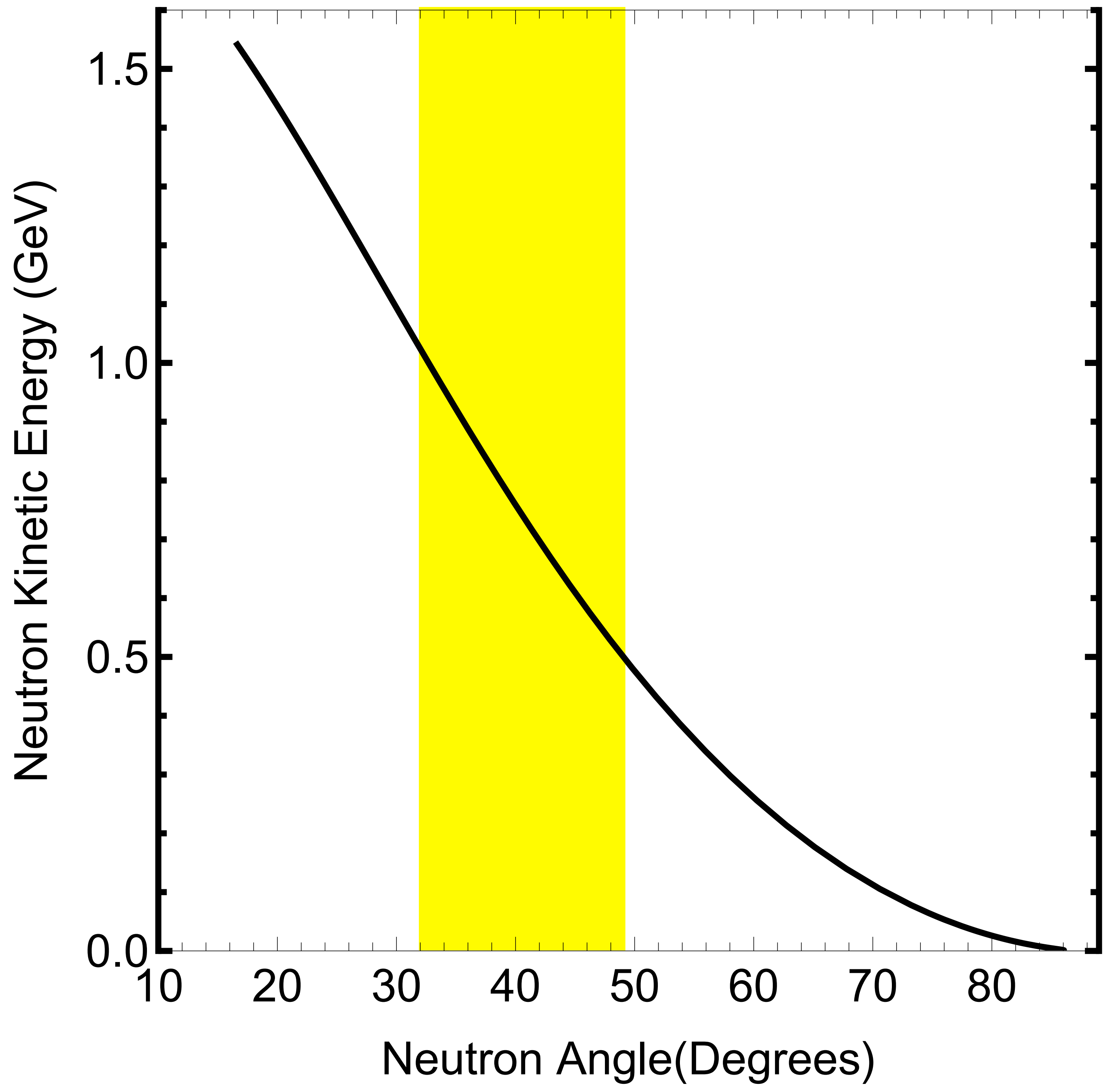
Comments from PAC52

Issues: Overall, the proposal needs a more detailed description of the measurement itself, the associated theory, and the detector setup that will be used. A full simulation and description detailing the strategy for background rejection will be critical content for a full proposal.

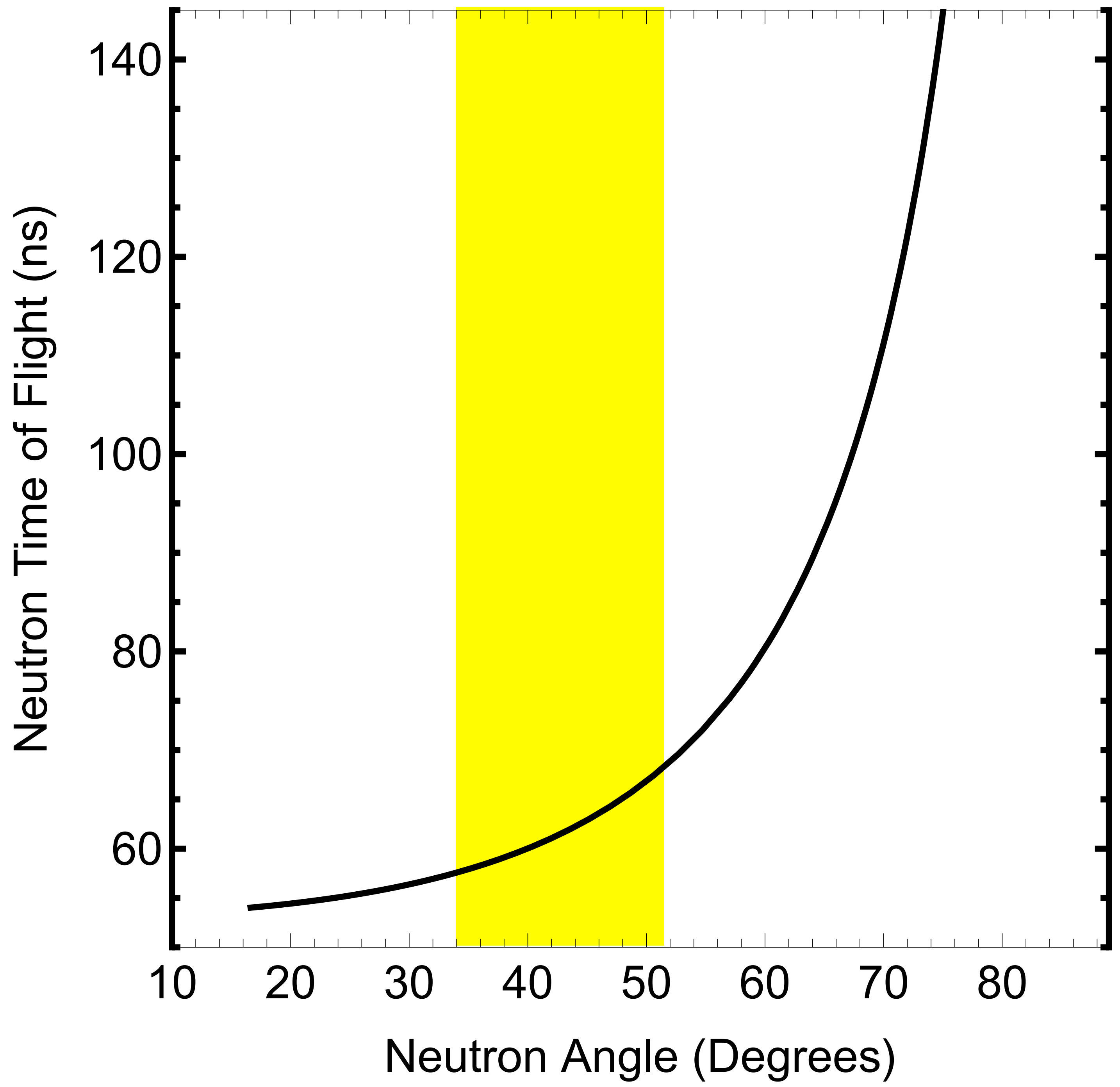
Summary: This LOI offers a unique opportunity to measure the axial-vector form factor (the least well-known nucleon form factor) in a very different manner than is commonly probed in neutrino scattering. Such a measurement is of considerable importance for accelerator-based neutrino oscillation experiments. The PAC encourages the proponents to proceed to a full proposal after the above issues are addressed. The PAC encourages the use of a full Monte Carlo simulation to assess detector performance, background levels, and systematic uncertainties. If this method of extracting the axial-vector form factor proves successful, the PAC notes that this could become part of a larger measurement campaign. In particular, a measurement of the Q^2 dependence of the axial-vector form factor would be of great interest to the neutrino scattering community.

Representative neutron kinematics

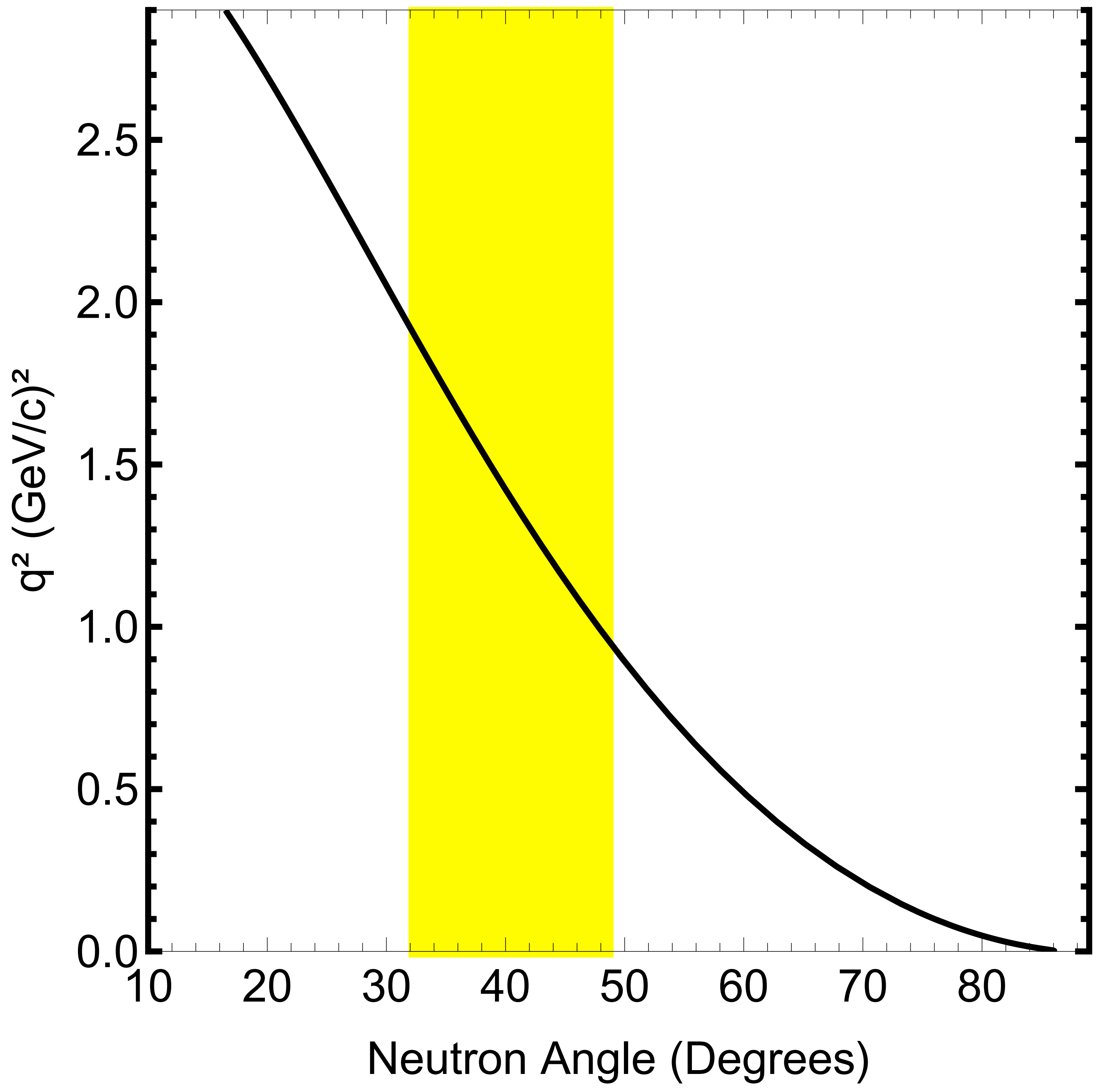
Kinetic Energy



Time of Flight



Momentum Transfer



I think it is fair to consider the first measurement a “proof of principle.”

The Work That Needs to be Done

- Get a clear understanding of the theory including the specific contribution to the cross section from the axial vector form factor.
- Design of the electron and neutron detectors
- Full simulation of all backgrounds
- Calculation of signal rates including detection efficiencies
- Preparation of the proposal

The physics is very sexy! Let’s have some fun.