# A New Proposal to Measure the Nucleon Axial Vector Form Factor

## What? Why? How? When?


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# What is the Axial Vector Form Factor?

## Charged Weak Current Analog of the Electromagnetic FF's

Vector Interaction

$$\langle p+q\,|\,J_V^\mu\,|\,p\rangle = \bar{u}(p+q)\left[F_1(q^2)\gamma^\mu + \frac{\kappa}{2m}F_2(q^2)i\sigma^{\mu\nu}q_\nu\right]u(p)$$

You are very familiar with these form factors.

Axial-Vector Interaction

$$\langle p+q\,|\,J_A^\mu\,|\,p\rangle = \bar{u}(p+q)\left[F_A(q^2)\gamma^\mu\gamma^5 + F_{PS}(q^2)q^\mu\gamma^5\right]u(p)$$

Well measured at zero momentum transfer (beta decay).

Our goal is to measure $F_A(q^2)$ at finite momentum transfer.

*The only existing measurements use pion production with PCAC or neutrino reactions, but each have issues with precision of interpretation!*

# Why Do We Want to Measure It?

## (Besides being another fundamental QCD observable!)

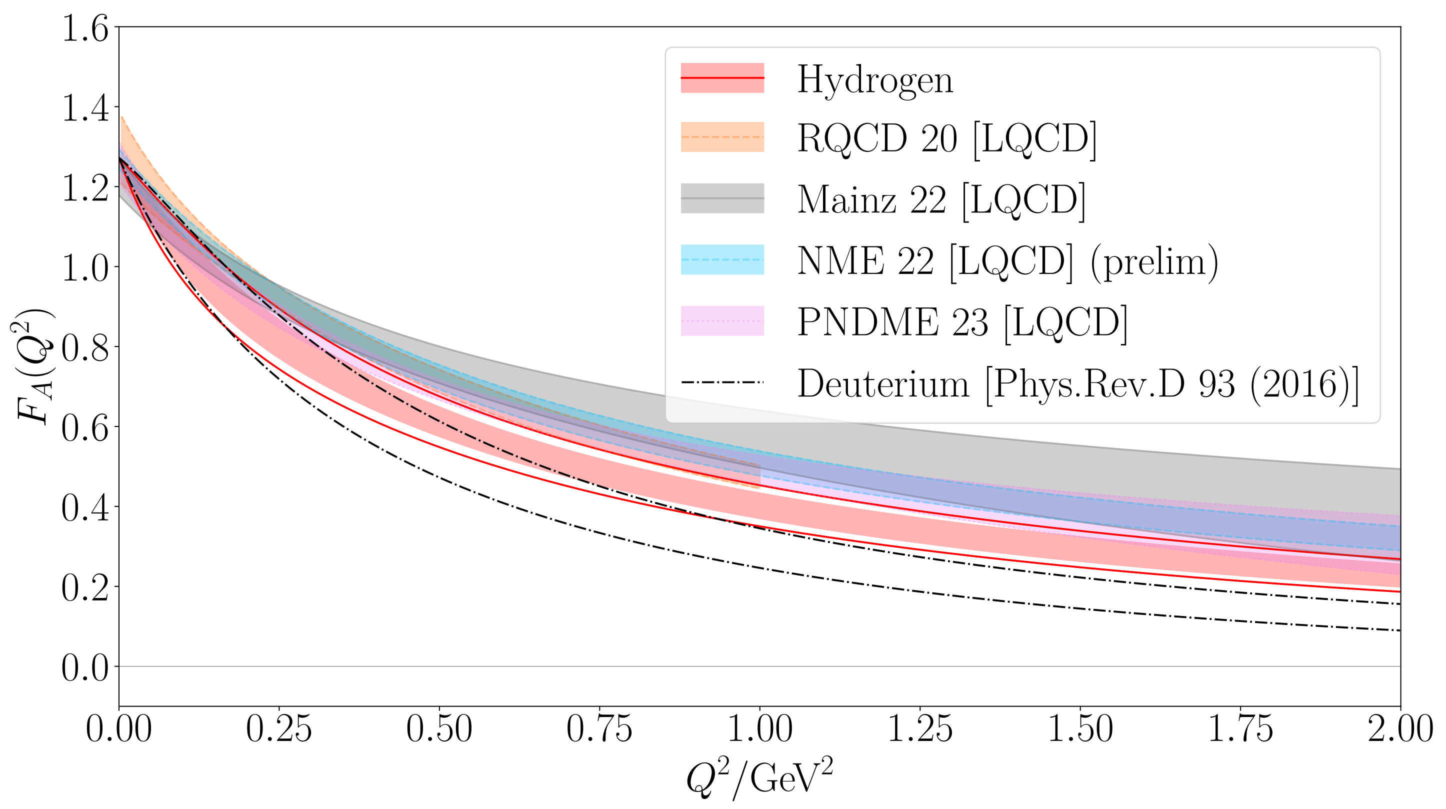
- New constraints on Generalized Parton Distributions

(Peter Kroll)

$$
\begin{aligned}
F_A^{(3)}(t) &= \int_0^1 \left[\widetilde{H}_v^u(x,\xi,t) - \widetilde{H}_v^d(x,\xi,t)\right] dx \quad \text{Valence quarks} \\
&+ 2\int_0^1 \left[\widetilde{H}^{\bar{u}}(x,\xi,t) - \widetilde{H}^{\bar{d}}(x,\xi,t)\right] dx \quad \text{Sea quarks (small)}
\end{aligned}
$$

- Important input for DUNE and other high energy neutrino experiments

(Aaron Meyer)

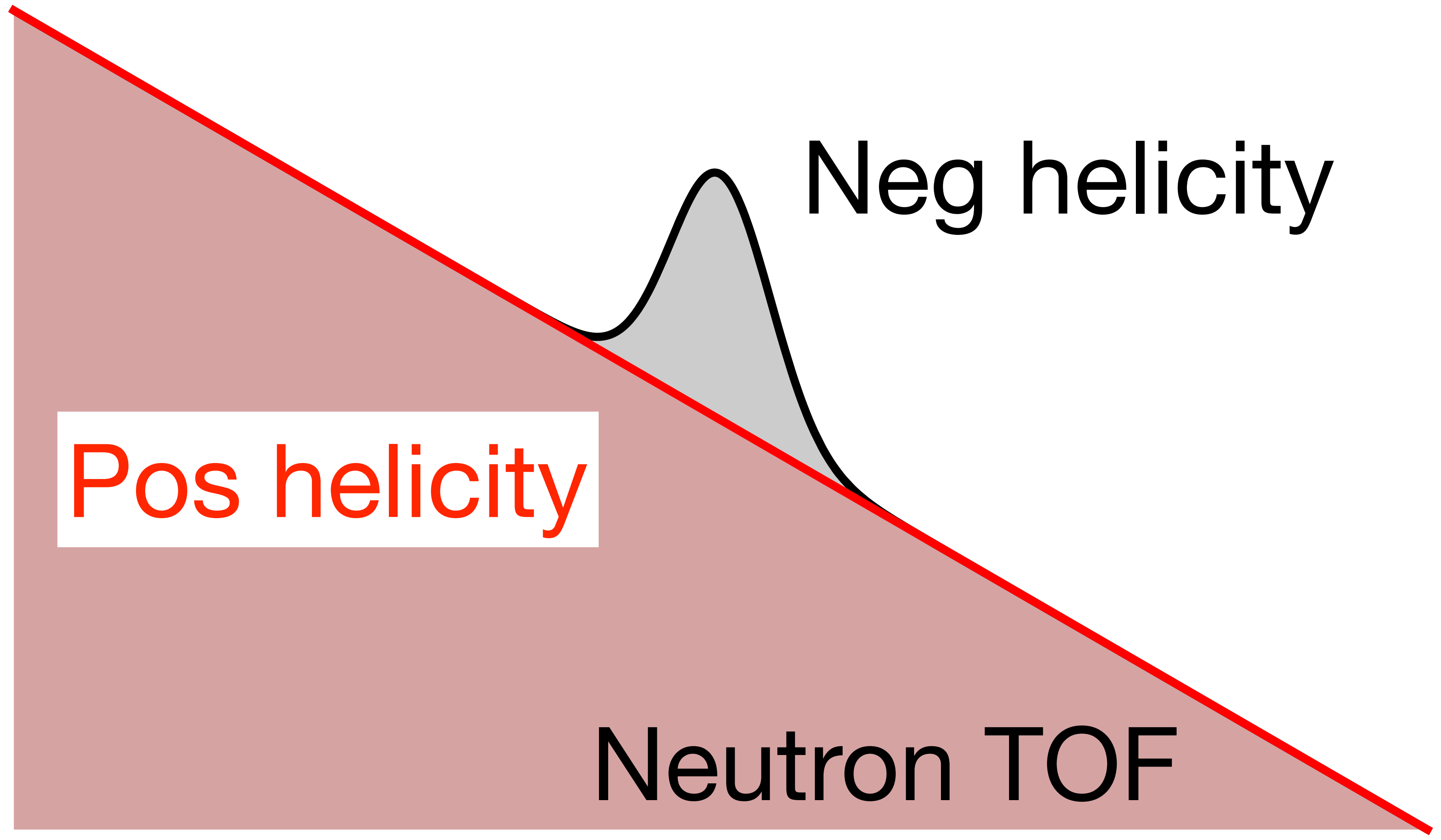



Important constraints on LQCD calculations needed to untangle neutrino oscillations in DUNE.

(Even a 25% measurement helps a lot.)

# How Are We Going To Do It?

- Detect the neutron from $\vec{e}^- p \to \nu_e n$
- Identify neutron using time-of-flight
- Minimize backgrounds from pion production, elastic $ep$, and other sources
- Subtract remaining background using data from right handed electrons

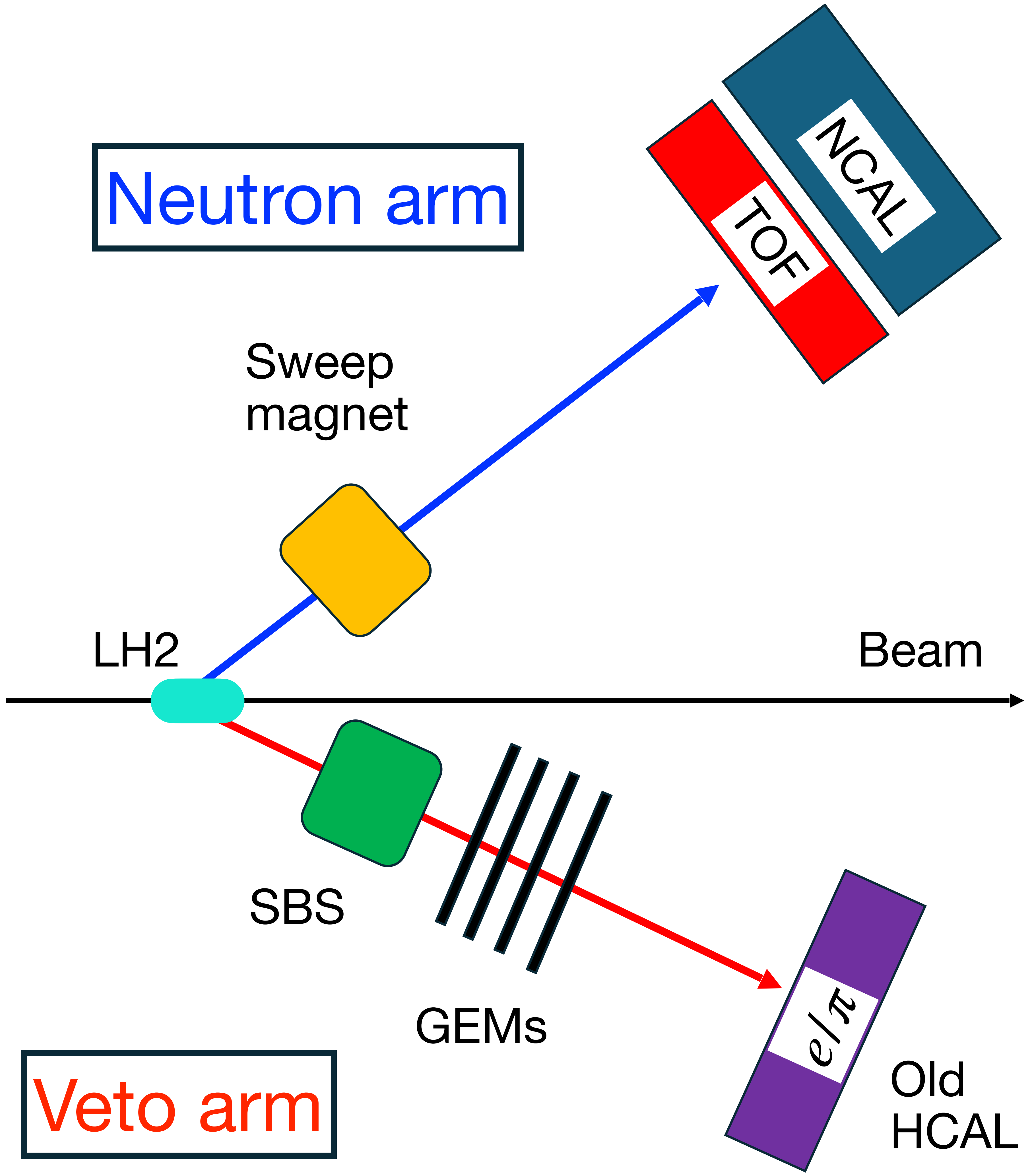



The primary challenge is to reduce the backgrounds from electromagnetic processes ($10^7$ larger than our signal) so that background subtraction yields a statistically useful signal.

The idea has been around a while!

- LOI to PAC 1 (JN) *Not a typo!*
- LOI to PAC 25 (A Deur)
- LOI to PAC 52 (JN and BBW)

# Experimental Setup and Parameters



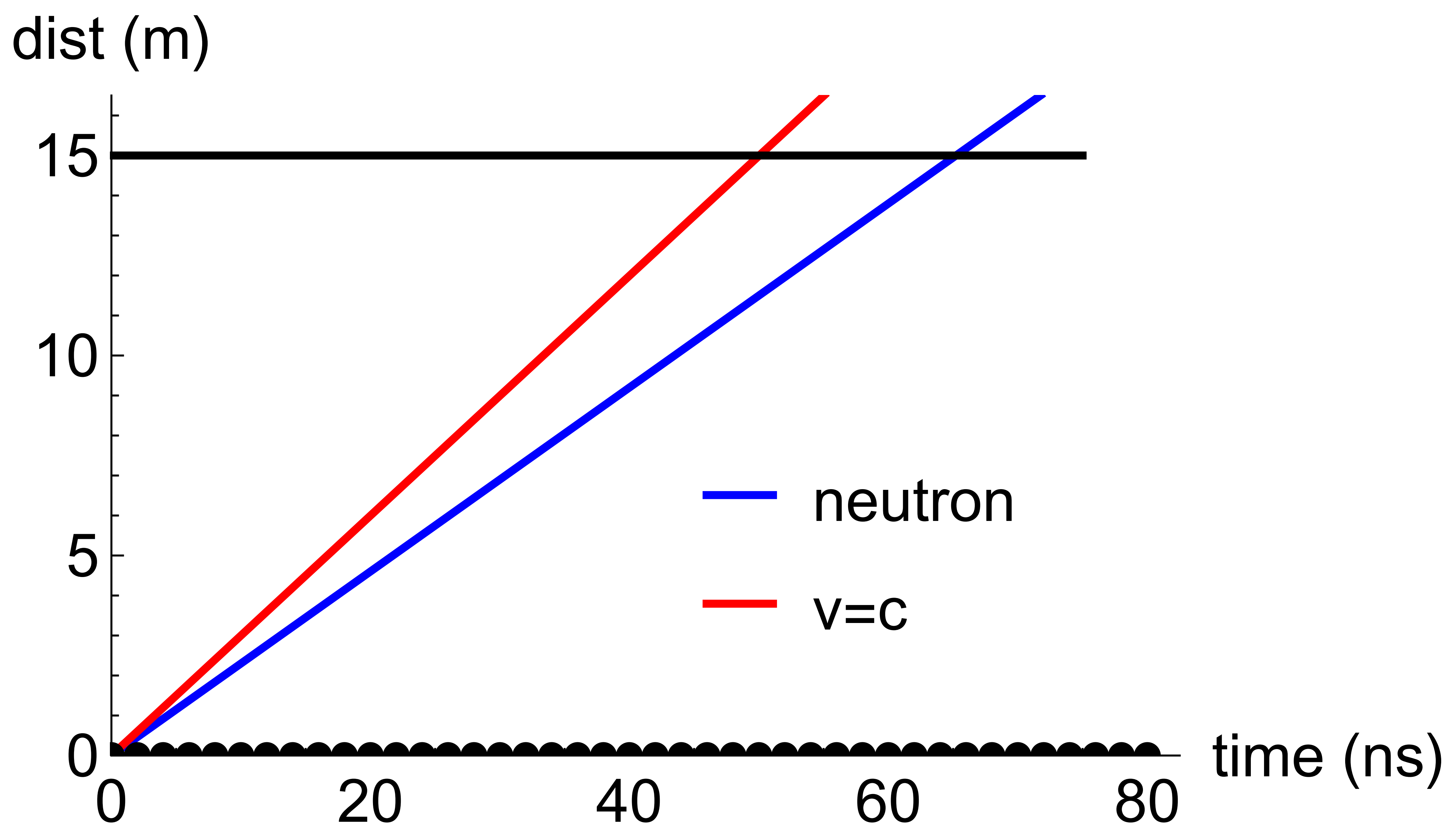

First run will be "proof of principle"

- E=2.2 GeV, 100$\mu$A, P=85%
- 10cm LH2 target, 500 hours
- $\theta_n$=48°, $Q^2 = 1\text{GeV}^2$, $T_n$ = 525 MeV
- 15m to TOF detectors, $\Delta\Omega$=75 msr
- Expect to get $\sigma_{TOF}$=100 ps
- Detection efficiency ≈ 30%
- SBS (50 msr) used to calibrate and for pion channel detection
- Ultimate background rate ≈ 2 Hz
- Calculated signal rate ≈ 0.01 Hz

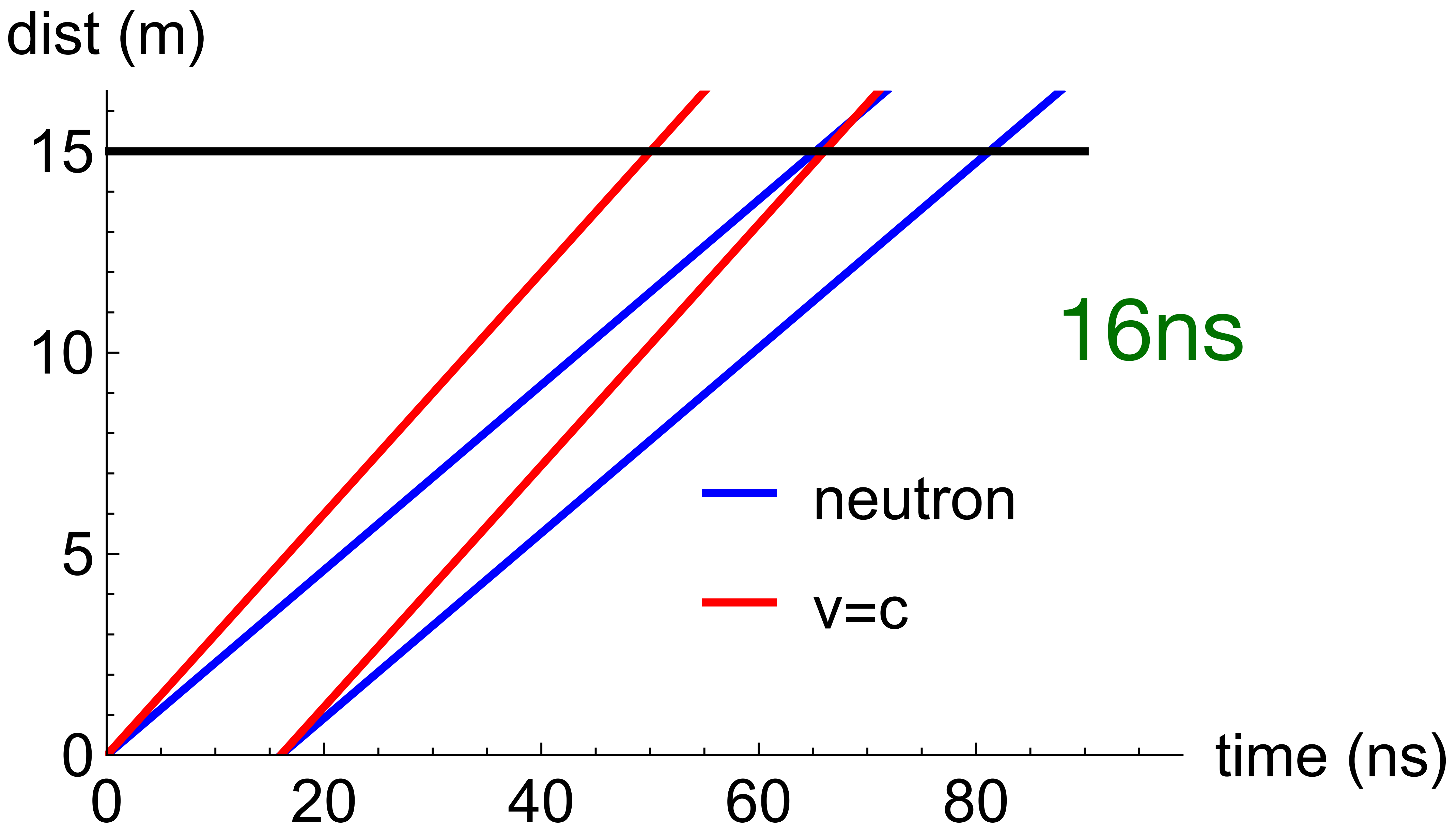
➠ Statistical precision on $F_A \approx 25\%$

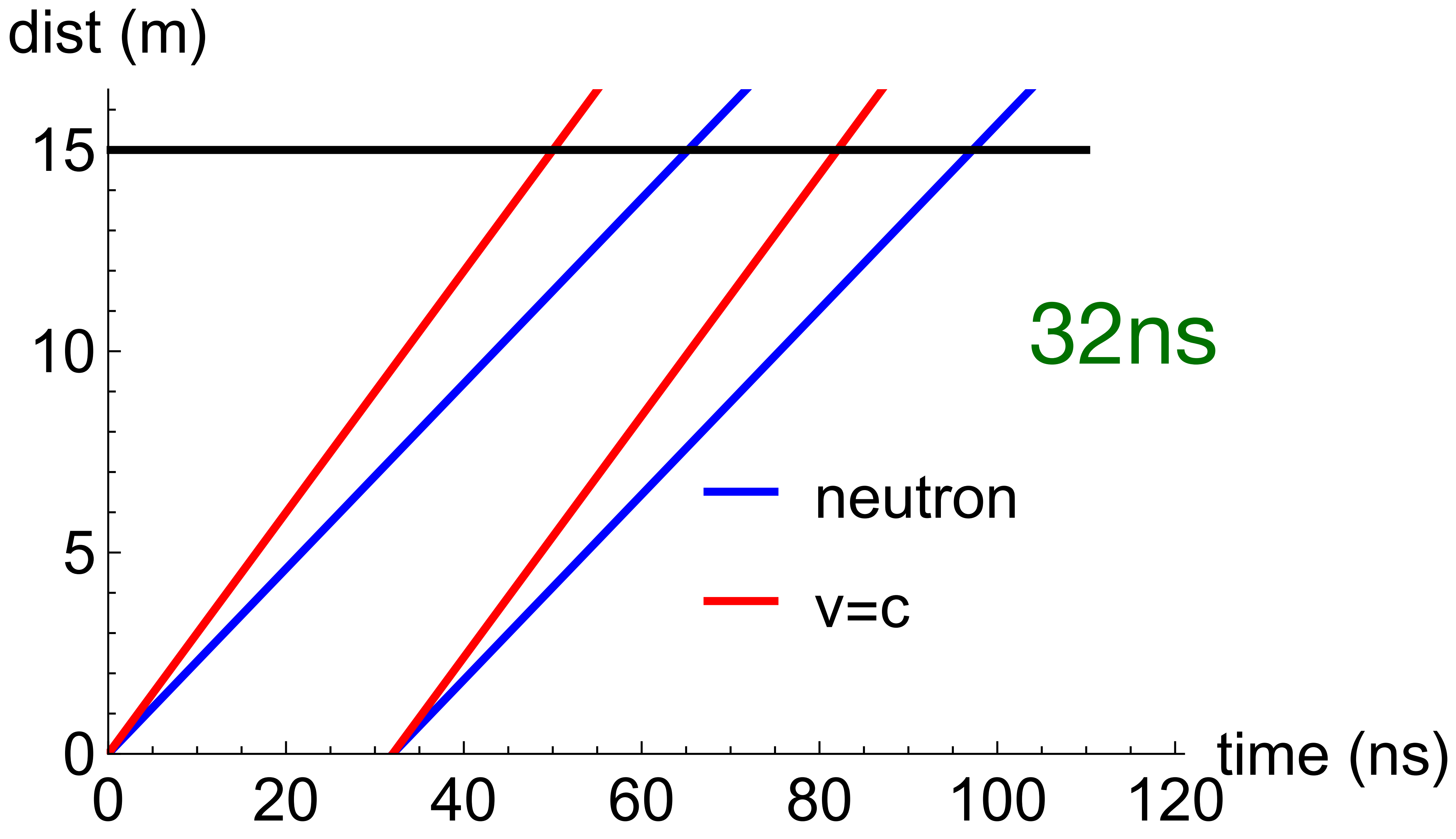
# Beam Structure

Pulses separated by 2ns will lead to background from overlaps




Discussions ongoing to achieve high current with large bunch spacing.

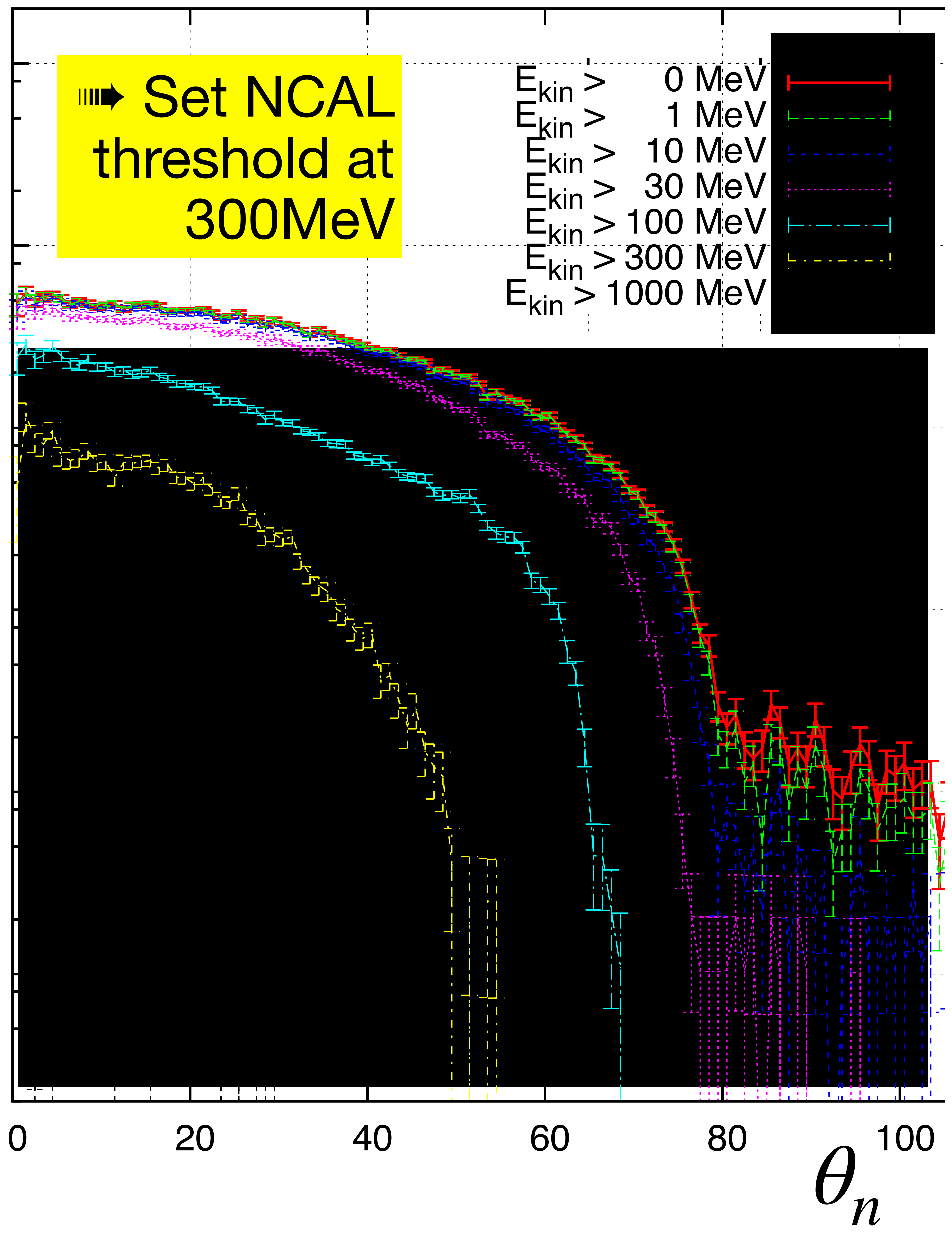


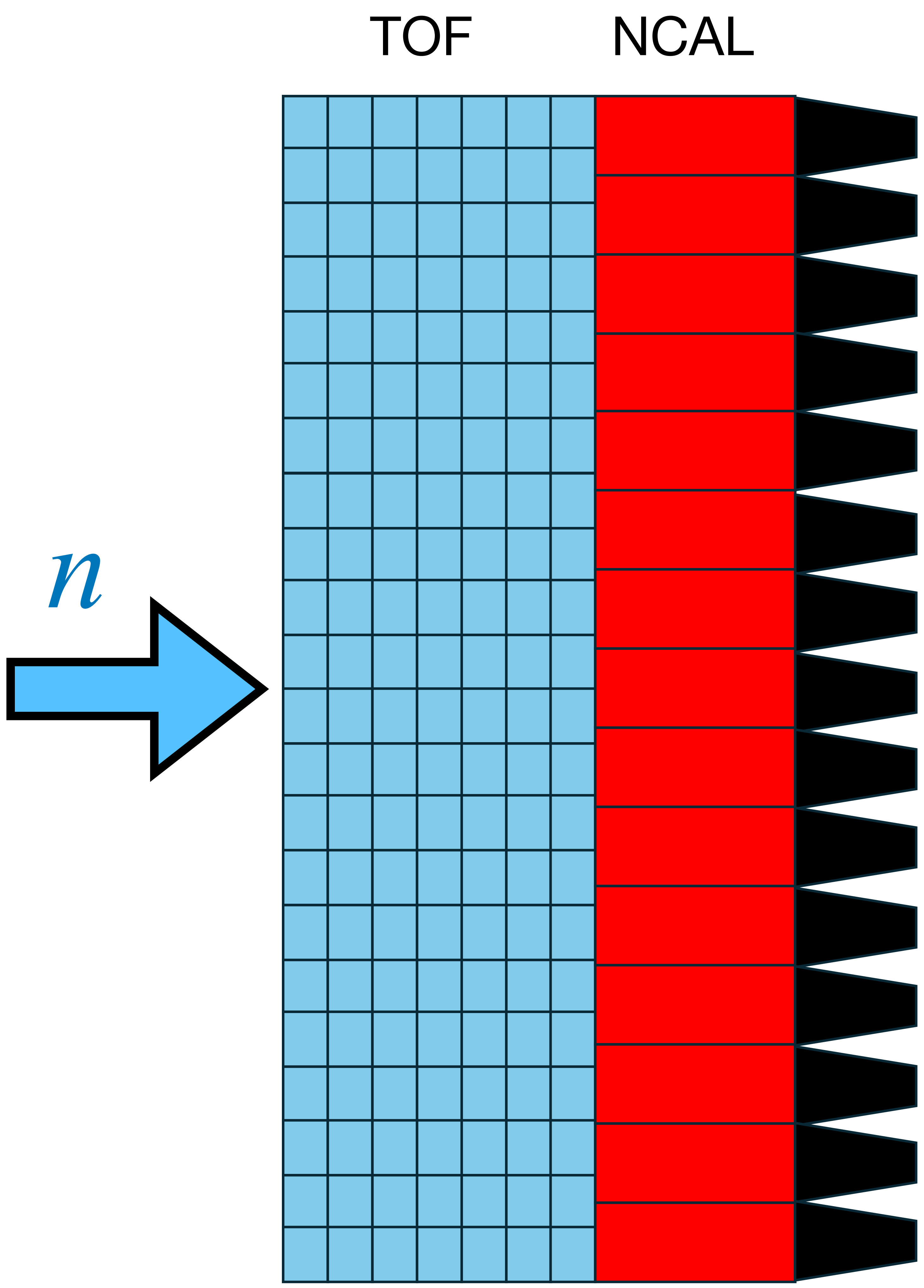



# Many Simulations Underway

$e + LH_2 \rightarrow n + X$

(Pavel Degtiarenko)



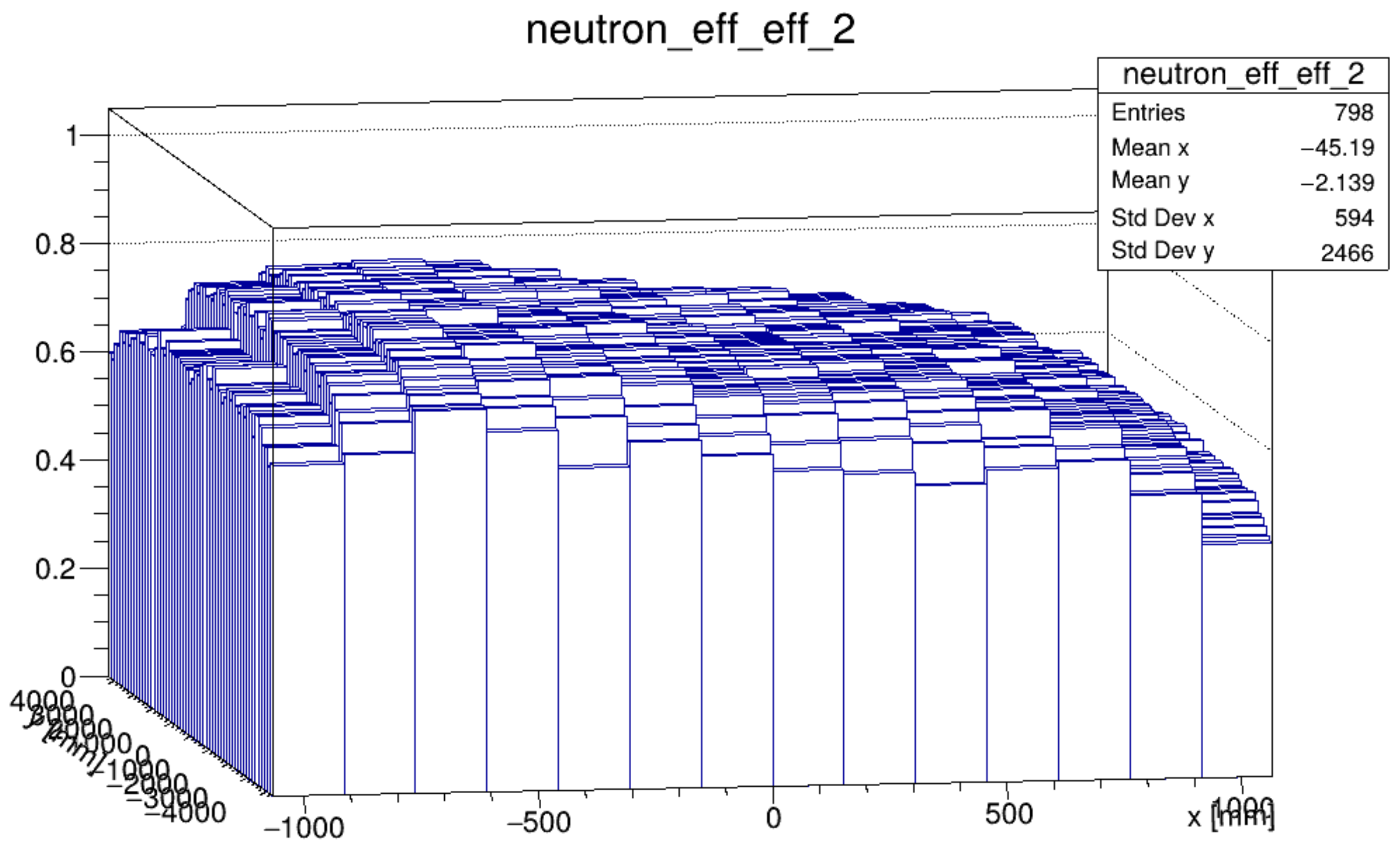




## Neutron reconstruction and detection efficiency

(Weizhi Xiong)

Reconstruction using 5×5 cluster in NCAL with energy deposition > 300 MeV

➠ Find ≈60% efficiency



# When: Proposal and Realistic Schedule

- Our immediate goal is a complete proposal to PAC 53 (Summer 2025)

  Lots of work to do on the physics justification, settle on parameters for experimental equipment, and <u>especially simulation</u> to justify online and offline background minimization.

- Need to eventually design and build TOF detector and couple it with NCAL

  Good input from Hall B on high resolution TOF. We have already started working on building a prototype for testing.

- Work with SBS to install other components in Hall C

  Probably smart to integrate this into the SBS program for Hall C.