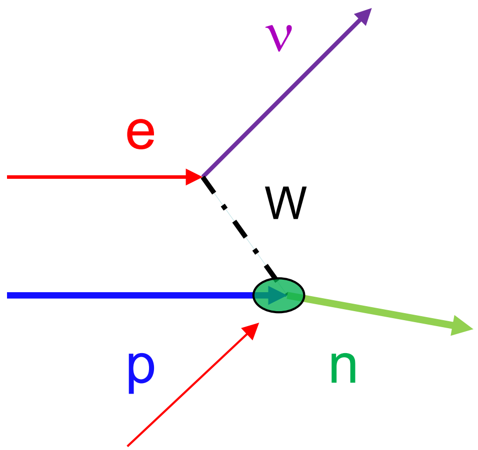
The Nucleon Axial-Vector Form Factor from the $p(\vec{e},n)\nu_e$ reaction



W exchange,
inverse β-decay

Axial Vector Form Factor

PR12-25-009 to PAC 53

T. Averett, J. Napolitano, B. Wojtsekhowski, W. Xiong

The collaboration

X.Bai, A.Camsonne, S.Covrig, P.Degtiarenko, A.Deur, C.Ghosh, O.Hansen, W.Henry, D.Higinbotham, D.Jones, M.Jones, C.Keppel, D.Mack, D.Meekins, B.Raydo, R.Suleiman, A.Tadepalli, M.Ungaro, B.Wojtsekhowski (spokesperson-contact), A.Arcuri, D.E.King, J.Napolitano (spokesperson), D.Armstrong, T.Averett (spokesperson), E.Fuchey, M.Kordosky, R.Latosky, P.Vahle, M.Li, W.Xiong (spokesperson), Yi Yu, J.Golak, P.Kroll, D.Hamilton, R.Montgomery, G.Penman, R.Perrino, L.Girlanda, G.Co′, O.Benhar, E.Cisbani, F.Garibaldi, G.M.Urciuoli, A.Filippi, M.Mirazita, S.Tomassini, A.Bianconi, L.Venturelli, V.Mascagna, M.Bondi, G.Foti, A.Fulci, A.Pilloni, M.Filippini, G.Ciullo, M.Contalbrigo, P.Lenisa, L.L.Pappalardo, G.Cates, R.Lindgren, N.Liyanage, H.Nguyen, V.Nelyubin, K.Paschke, W.A.Tobias, A.Kakoyan, S.Mayilyan, A.Shahinyan, D.Dutta, H.Bhett, A.Nadeeshani, E.Wrightson, B.Tamang, M.Kohl, R.Richards, D.Jayakodige, A.C.Ndukwe, A.Flannery, S.Dhital, T.Patel, E.Pierce, K.Scott, M.Suresh, M.Bukhari, A.J.R.Puckett, A.Rathnayake, D.Adhikari, P.Markowitz, H.Szumila-Vance, E.C.Schulte, G.Niculescu, W.Brooks, C.Ayerbe Gayoso, C.E.Hyde, S.Bhattarai, R.S.Beminiwattha, M.Elaasar, D.Androic, P.Datta, R.Gilman, A.Ahmidouch, R.Marinaro, C.Mariani, A.Ankowski, V.Bellini

currently 100+ members from US, Italy, UK, China, Poland, Germany, …

Outline of the talk

- ❑ Proposal highlights
- ❑ Physics of Axial-Vector Form Factor
- ❑ Physics and data on AVFF, Minerva
- ❑ Experimental method. Layout in Hall C
- ❑ Cross section and rate of neutrino events
- ❑ Geant4 based MC results
- ❑ Trigger logic and DAQ
- ❑ Projected results
- ❑ Beam time request

Backup:

- o Plan of the prototype test run
- o PAC52, Theory, TAC, and ITAC reviews
- o Detailed MC results

Proposal highlights

- Axial-Vector Current in V-A since 1958, PCAC
- Neutrino scattering cross section, WACS observables
- 100% helicity effect in neutrino electro-production needs a highly polarized electron beam
- Missing mass method needs a neutron arm with 100 pico-second time resolution
- Background calculations done with three approaches
- Experiment has perspective in a wide range of Q^2
- Contribution to neutrino physics investigations, GPDs
- Test run for check MC and development of the detector
- Strong support from 100+ collaborators

Physics of the Axial-Vector Form Factor

$$M = \frac{G_F}{\sqrt{2}} \left(\bar{u}_p \gamma^\mu (c_V - c_A \gamma^5) u_n\right) \cdot \left(\bar{u}_e \gamma^\mu (1-\gamma^5) v_\nu\right)$$

V − A (nucleon) · V−A (lepton / fund. fermion)

$$< (p + q)|J_A^\mu|p > = \bar{u}(p+q) \left[F_A(q^2)\gamma^\mu\gamma^5 + \frac{q^\mu}{2m} F_P(q^2)\gamma^5\right] u(p)$$

Well developed theory

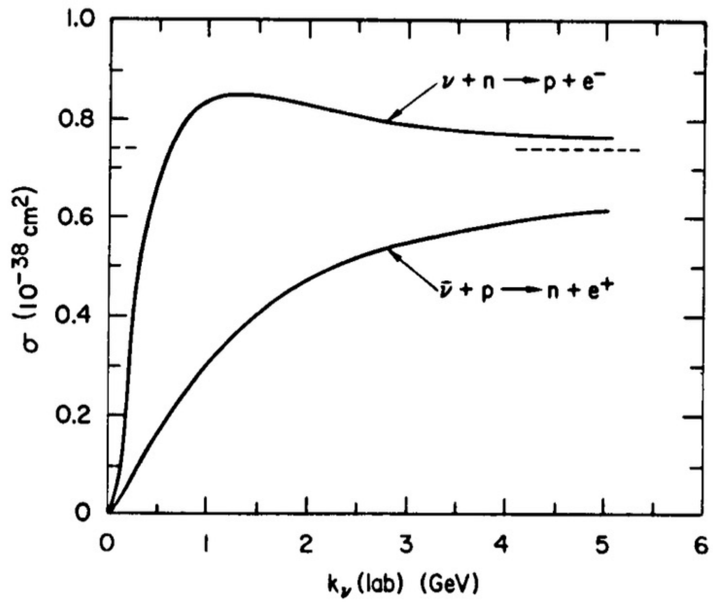
C.H. LLEWELLYN SMITH, PHYSICS REPORTS, 3, No. 5(1972) 261-379

$$\frac{d\sigma}{dQ^2}\begin{pmatrix}\nu n \to l^- p \\ \bar{\nu} p \to l^+ n\end{pmatrix} = \frac{M^2 G_F^2 \cos^2\theta_c}{8\pi E_\nu^2}\left[A(Q^2) \mp B(Q^2)\frac{(s-u)}{M^2} + C(Q^2)\frac{(s-u)^2}{M^4}\right],$$

$$A(Q^2) = \frac{m^2+Q^2}{4M^2}\left[\left(4+\frac{Q^2}{M^2}\right)|F_A|^2 - \left(4-\frac{Q^2}{M^2}\right)|F_V^1|^2 + \frac{Q^2}{M^2}\left(1-\frac{Q^2}{4M^2}\right)|\xi F_V^2|^2 + \frac{4Q^2}{M^2}\mathrm{Re}F_V^{1*}\xi F_V^2 + \mathcal{O}\left(\frac{m^2}{M^2}\right)\right],$$

$$B(Q^2) = \frac{Q^2}{M^2}\mathrm{Re}F_A^*(F_V^1 + \xi F_V^2),$$

$$C(Q^2) = \frac{1}{4}\left(|F_A|^2 + |F_V^1|^2 + \frac{Q^2}{4M^2}|\xi F_V^2|^2\right)$$



Physics of the Axial-Vector Form Factor

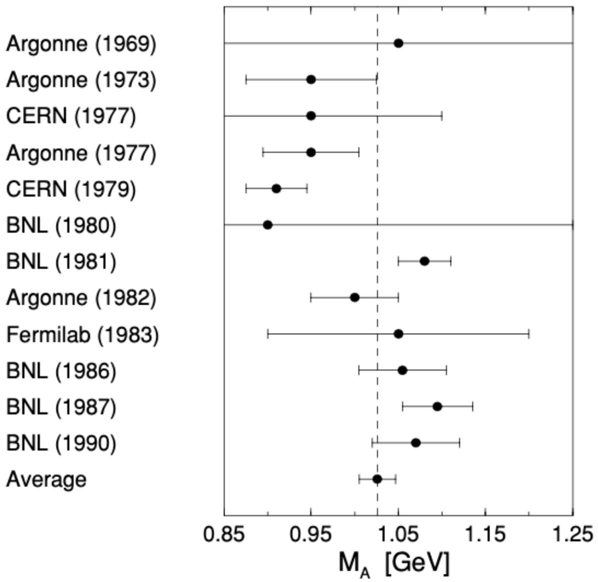
$$< (p + q)|J_A^{\mu}|p >= \bar{u}(p+q) \left[F_A(q^2)\gamma^{\mu}\gamma^5 + \frac{q^{\mu}}{2m} F_P(q^2)\gamma^5 \right] u(p)$$

$$F_A(t) = \frac{g_A}{(1-t/M_A^2)^2}$$

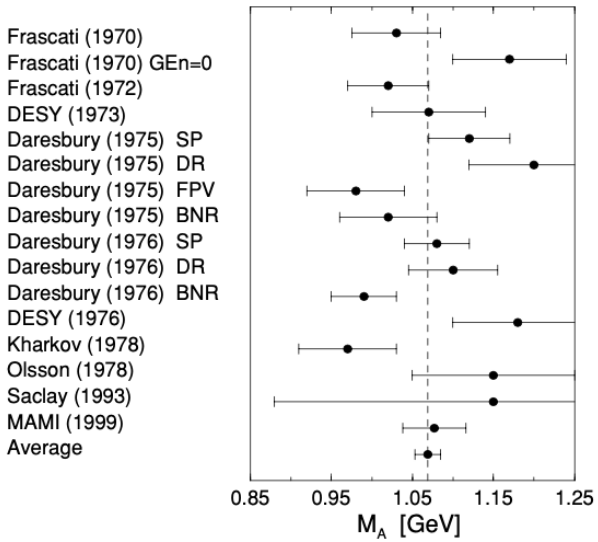
V. Bernard et al, J. Phys. G: Nucl. Part. Phys. **28** (2002) R1–R35

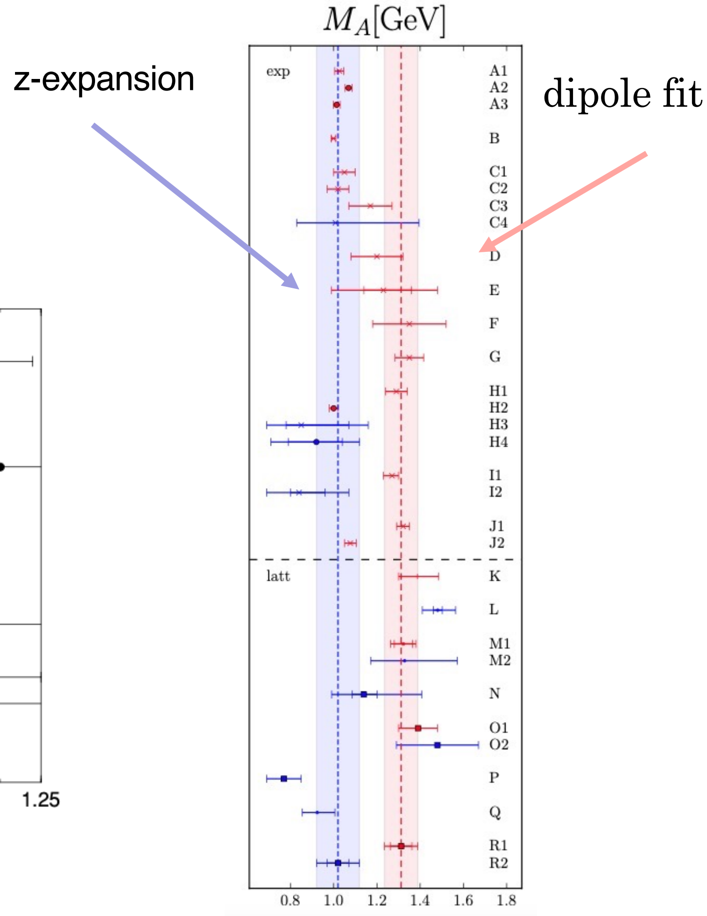
G. Bali et al., Journal of High Energy Physics 2020, 126 (2020).

Neutrino scattering



Pion electro-production





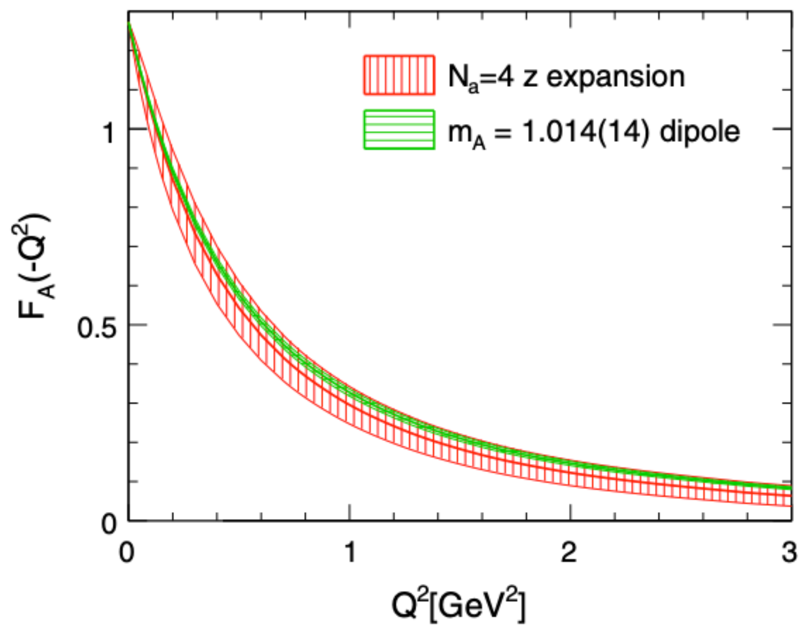
Precision for neutrino interaction

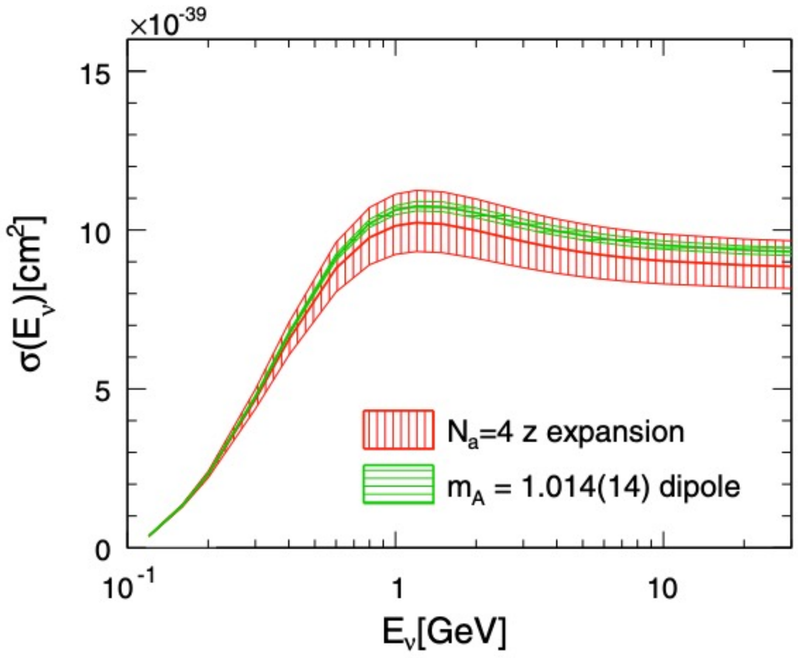
The GENIE Event Generator

Incoming true flux — Model ing Input — Measurement

$$\int P_{\nu_\mu \to \nu_e}(E_\nu, L)\ \Phi(E_\nu, 0)\ \sigma(E_\nu)\,\epsilon(E_\nu)\,S(E_\nu, E_\nu^{reco})\,dE_\nu \propto N(E_\nu^{rec}, L)$$

A. Meyer et al, PRD 93, 113015 (2016)



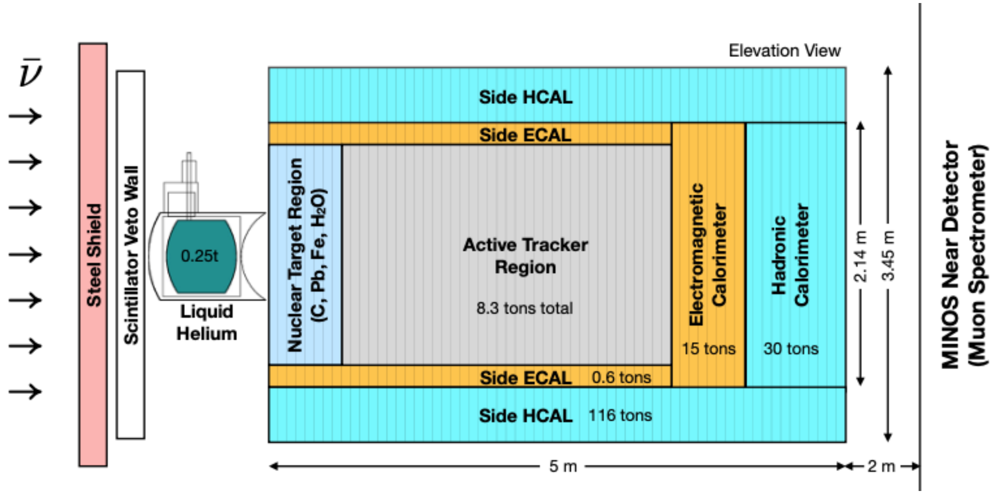


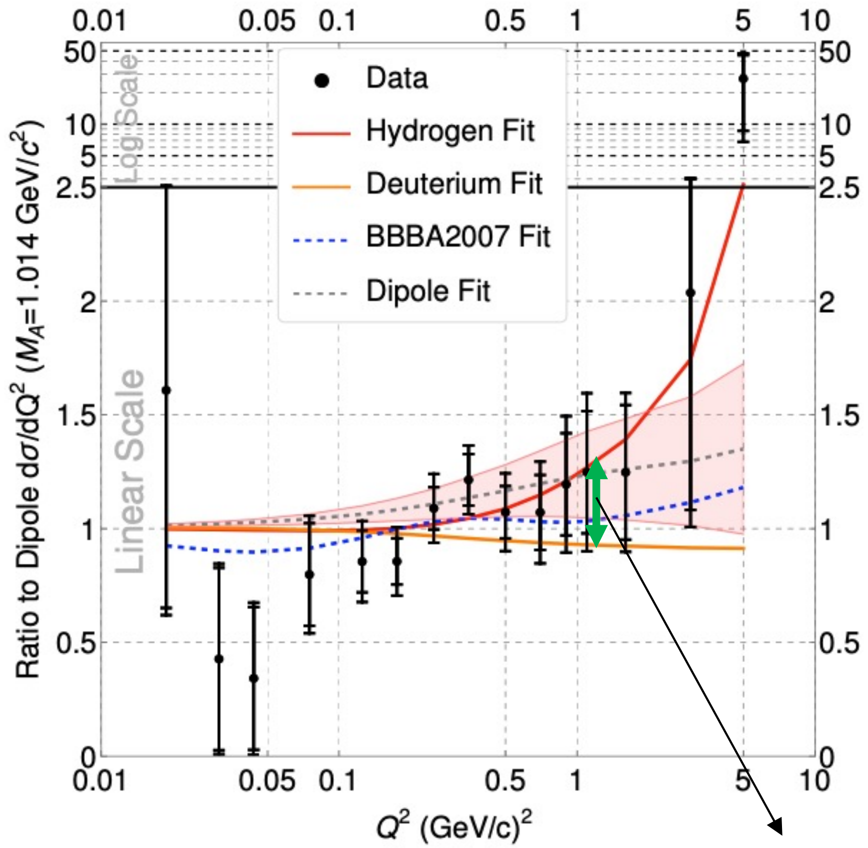
Minerva, data and results for F_A

Directly measure H from a CH target

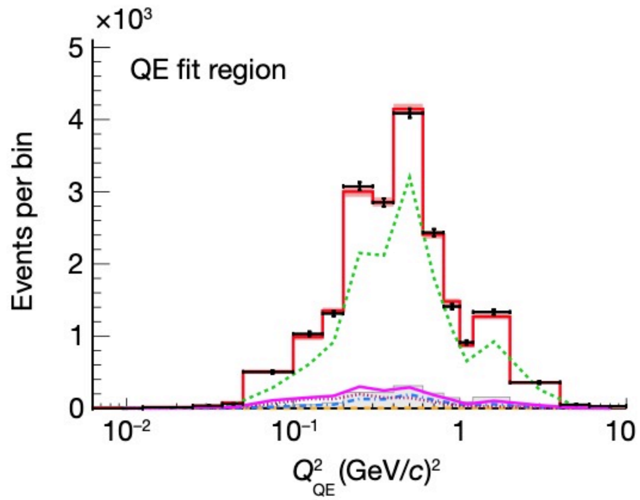
T. Cai et al., Nature 614, 48–53 (2023)

$$\bar{\nu}_\mu + p \to \mu^+ + n,$$





impact



The process of studying
Experimental challenges

$$\vec{e}^{\,-} + p \to n + \nu$$

Detection of only a neutron in two-body final state

Kinematics: E_{beam} = 2.2 GeV, θ_n = 48 deg, $Q^2 = 1\ (GeV/c)^2$

1. Neutrino event cross section is 1.35 x 10^{-39} cm^2/sr
2. Electron-proton cross section is 1.4 x 10^{-32} cm^2/sr
3. Pion-neutron production - 3.5 x 10^{-31} x $\Delta E_\gamma/E_\gamma$ cm^2/sr
   ~ 0.01
4. Background from the Al walls and secondary scattering

Proposed detector system in Hall C

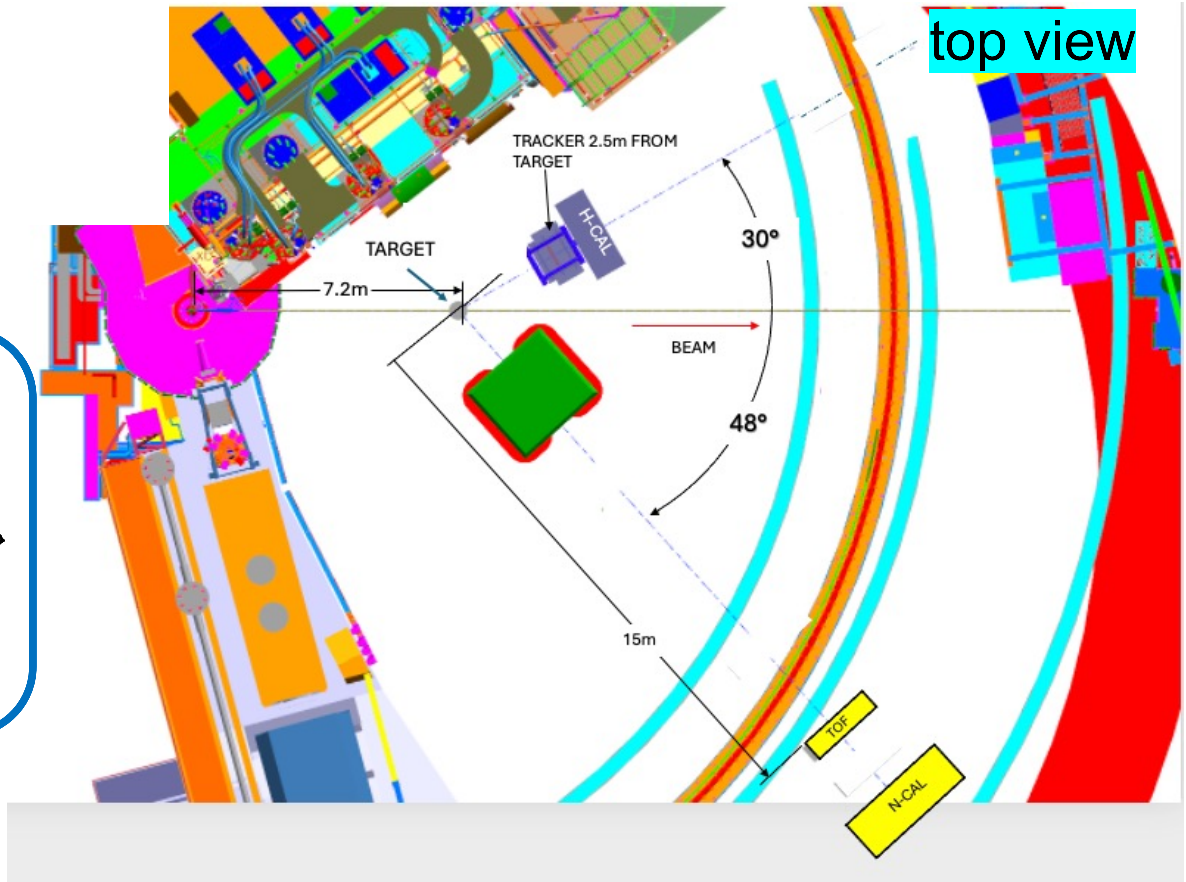
1. Neutron arm – Sweeper magnet, Time-of-Flight + Calorimeter
2. Veto arm – Calorimeter + GEM tracker (for calibration)
3. 15 meters from target to detector => 65 ns with 100 ps resolution
4. TOF to NCal 2.5 m distance for the beam bunch identification

signal

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

background

$$\vec{\gamma} + p \rightarrow \vec{n} + \pi^+$$
$$\vec{e}^- + p \rightarrow e^- + \vec{p}$$
$$\vec{\gamma} + p \rightarrow \vec{\Lambda} + K^+$$



Cross section of the $p(\vec{e}, n)\nu_e$ process

The axial form factor of the nucleon, P. Kroll, note 9/30/2024

M. Diehl and P. Kroll, Eur. Phys. J. C **73**

The hadronic weak current, $J^\mu = V^\mu(0) - A^\mu(0)$, reads

$$\langle n(p_f) \mid J^{\mu\dagger}(0) \mid p(p_i)\rangle = \bar{u}(p_f)\Big[F_1^{(3)}(t)\gamma^\mu + F_2^{(3)}(t)\frac{i\sigma^{\mu\nu}\Delta_\nu}{2m} - F_A^{(3)}(t)\gamma^\mu\gamma_5 - F_P^{(3)}(t)\frac{\gamma_5\Delta^\mu}{2m}\Big]u(p_i)$$

$$\frac{d\sigma}{dt} = \frac{1}{2\pi}\frac{1}{(s-m^2)^2}\left(\frac{G\cos\theta_c}{\sqrt{2}}\right)^2 \times \{\ \},$$

$$\{\ \} = \Big\{(s-m^2)^2\left(F_1^{(3)2} + F_A^{(3)2}\right) + t\Big[sF_1^{(3)2} - \frac{(s-m^2)^2}{4m^2}F_2^{(3)2} + (s-2m^2)F_A^{(3)2} - 2(s-m^2)\left(F_1^{(3)} + F_2^{(3)}\right)F_A^{(3)}\Big] + \frac{1}{2}t^2\Big[\left|F_1^{(3)} + F_2^{(3)} - F_A^{(3)}\right|^2 - \frac{s}{2m^2}F_2^{(3)2}\Big]\Big\}$$

$GPDs\ \tilde{H}(x,\xi,t)\ for\ \xi = 0$

$$F_A(t) = \int_0^1 dx\,\left[\widetilde{H}_v^u(x,t) - \widetilde{H}_v^d(x,t)\right] + 2\int_0^1 dx\,\left[\widetilde{H}^{\bar{u}}(x,t) - \widetilde{H}^{\bar{d}}(x,t)\right]$$

$for\ Q^2 = 1\,(GeV/c)^2$

$$\frac{d\sigma}{d\Omega_\nu} = 1.35 \times 10^{-39}\ cm^2/sr$$

$$\frac{\delta\sigma}{\sigma} \approx \frac{\delta F_A}{F_A}$$

Rate is 0.0044 Hz
after 25% efficiency

Concept of the experiment

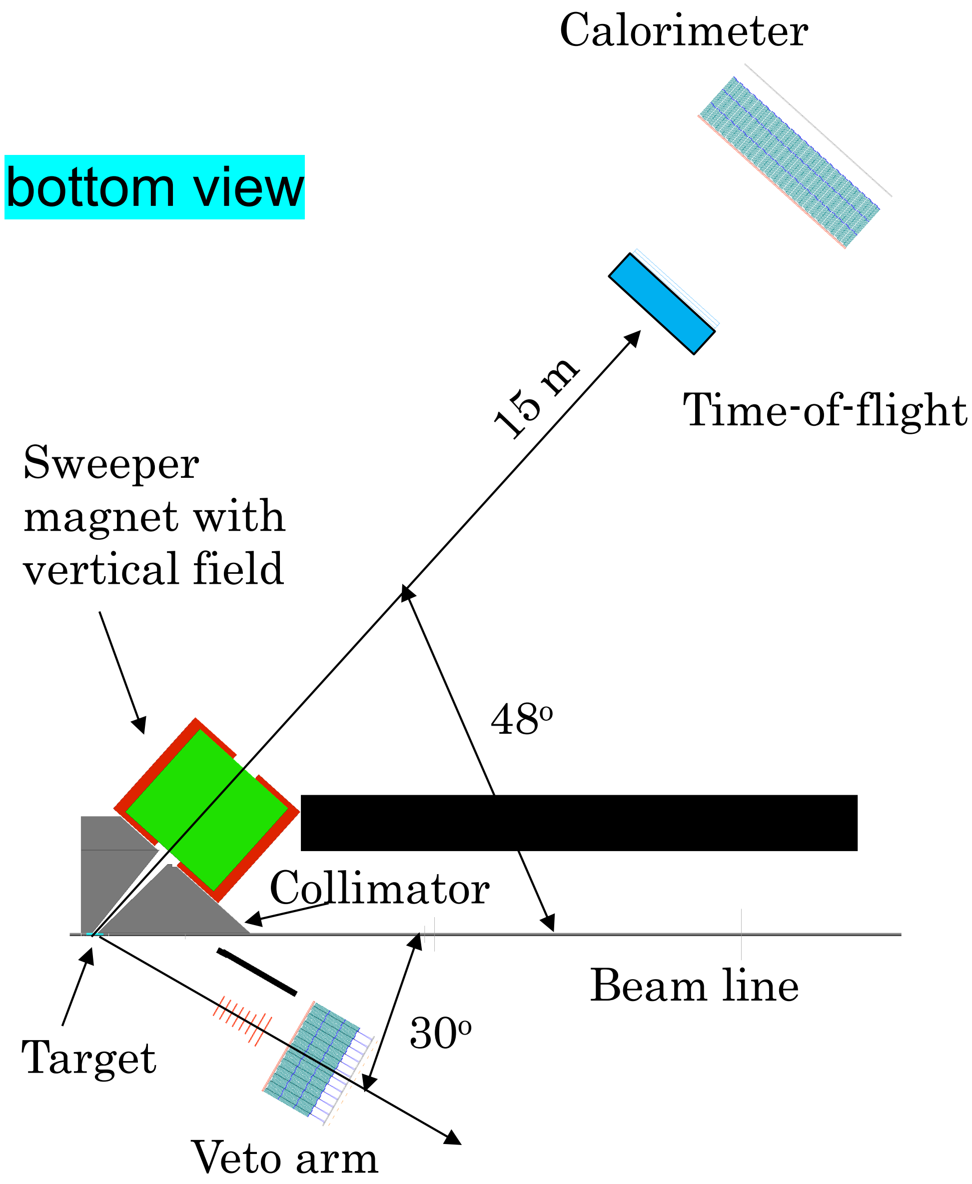
50 days of data taking, 10 cm LH2, 120 μA

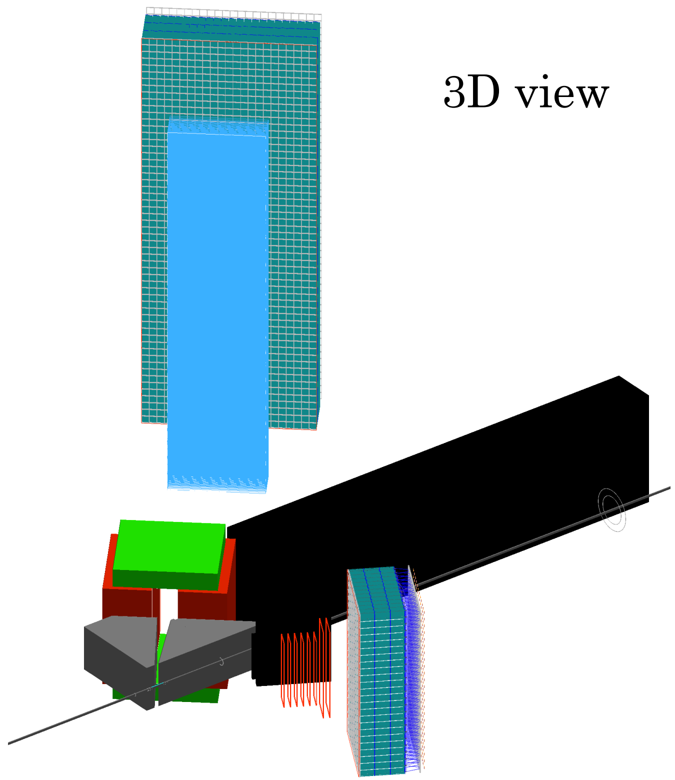
1. Polarized electron beam: n + ν events have 100% helicity asymmetry
2. Neutron spectrometer: 0.1% energy resolution from time-of-flight
   Incident electron/photon energy reconstruction rms 25 MeV
3. Trigger based on the calorimeter with high energy threshold
4. Rejection of most of the background events in the veto arm calorimeter
5. Magnet for sweeping charged particles from the neutron arm acceptance
6. Beam bunch identification in two-part neutron detector

Geant4 model of the detector system

2.2 GeV polarized electron beam
10-cm-long liquid hydrogen target
70 msr neutron detector at 48^o (+/- 4^o)
400 msr veto arm at -30^o

bottom view





Trigger logic and analysis steps

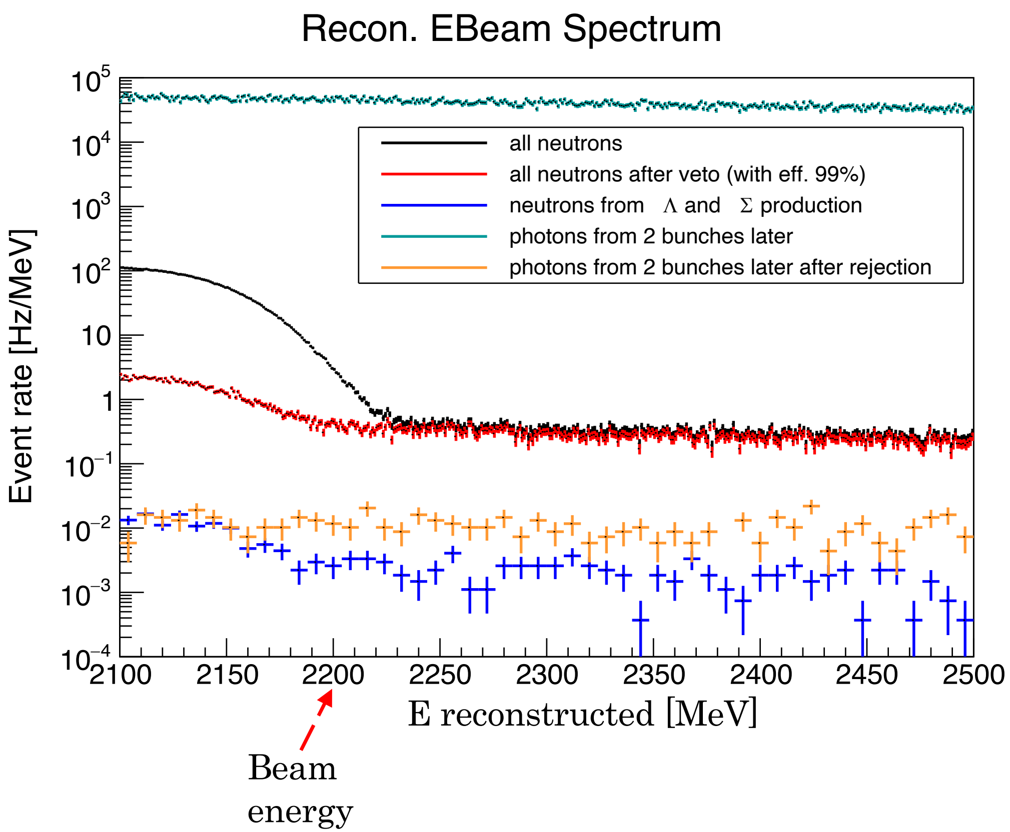
50 days of data taking, 10 cm LH2, 120 μA

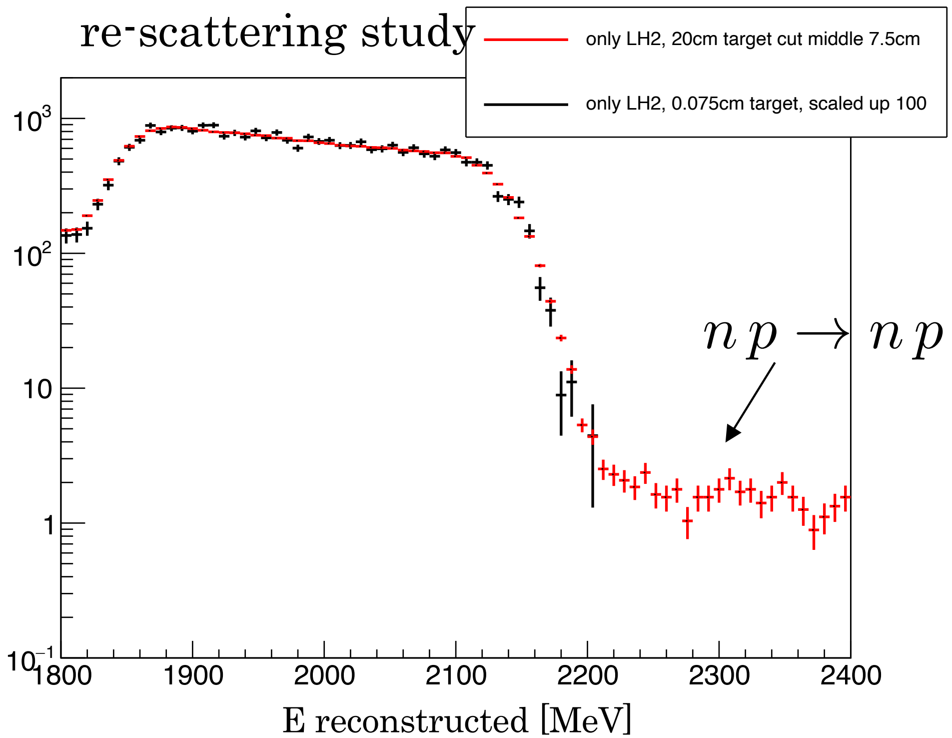
	Rates:
1. Large amplitude signal in the calorimeter (NCAL) (100 MeV) • Removed low energy neutrons and most prompt photons	25 MHz
2. Veto if the signal in veto arm (HCAL) above 650 MeV	0.25 MHz
3. Time-of-flight system hit correlated in time/position with NCAL • Record the event if TOF/NCAL within 10 ns and 0.25 m^2	25 kHz
4. TOF vs. NCAL time for the beam bunch identification • Remove event if incorrect beam bunch	
5. Beam energy reconstruction	
6. Helicity correlated signal at 2200 MeV	

Pion rates and MC predictions

Photo-production reactions

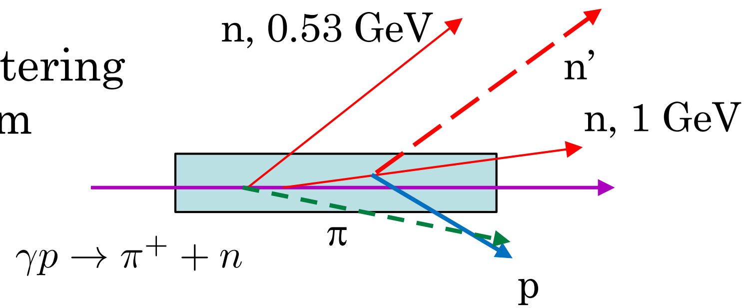
50 days of data taking, 10 cm LH2, 120 µA





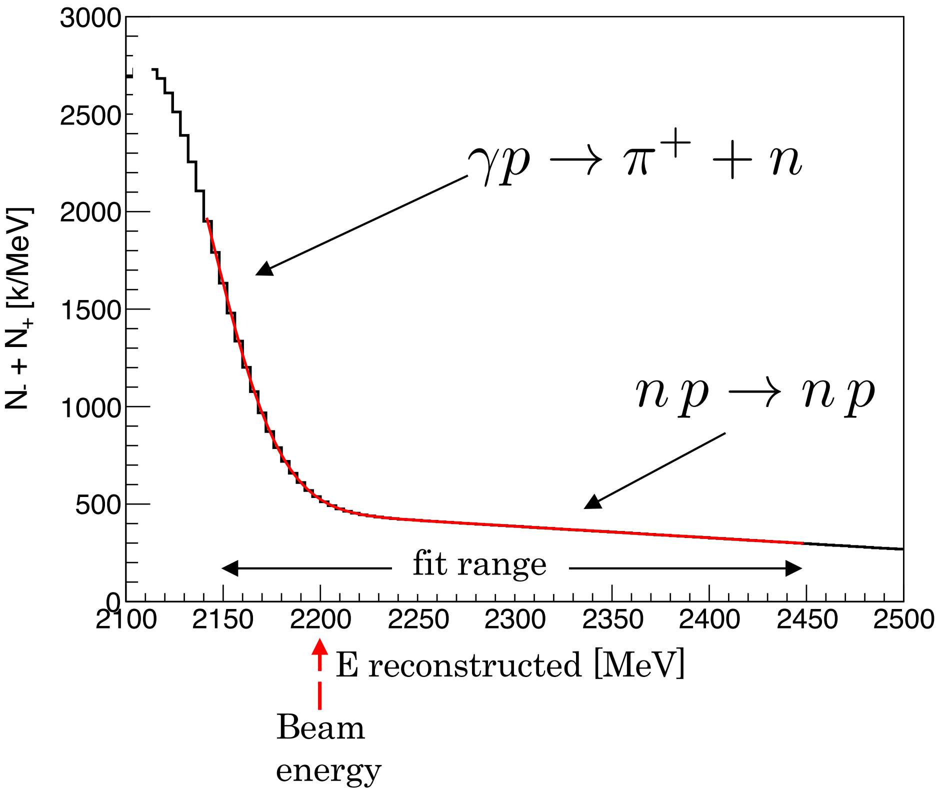
$$E_{reconst} = \frac{E_n - (M_p^2 + M_n^2)/2M_p}{1 + (P_n \cos\theta_n - E_n)/M_m}$$

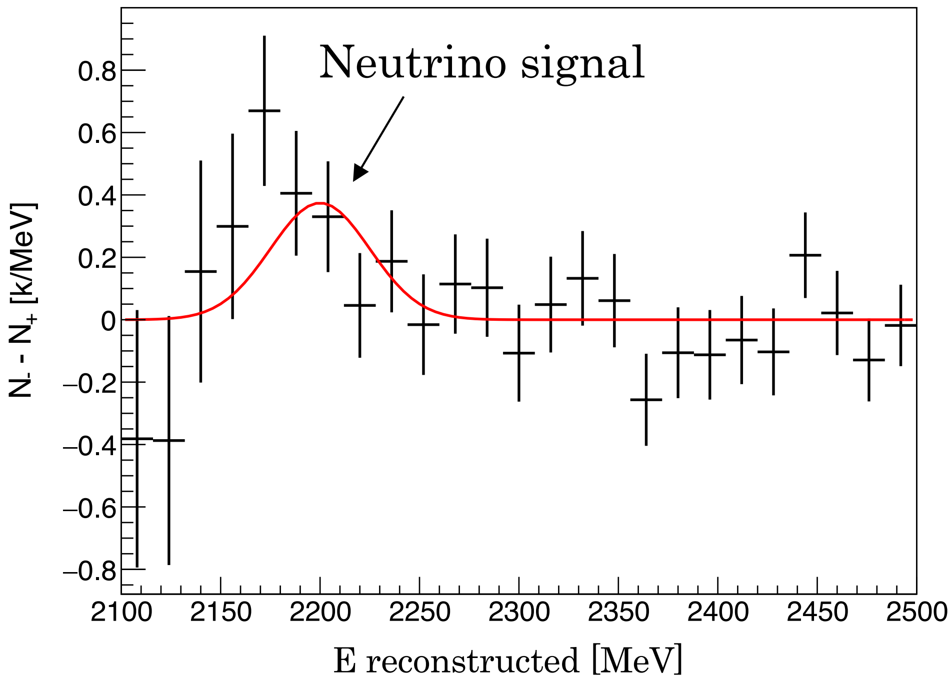
re-scattering diagram



Geant4-based MC results

Analysis of the reconstructed incident energy spectrum





Fit function has three components:
1. Signal (gaussian shape)
2. Background (gaussian tail)
3. Background (linear)

50 days of data taking, 120 μA

$(N^- - N^+)$ bin-by-bin analysis

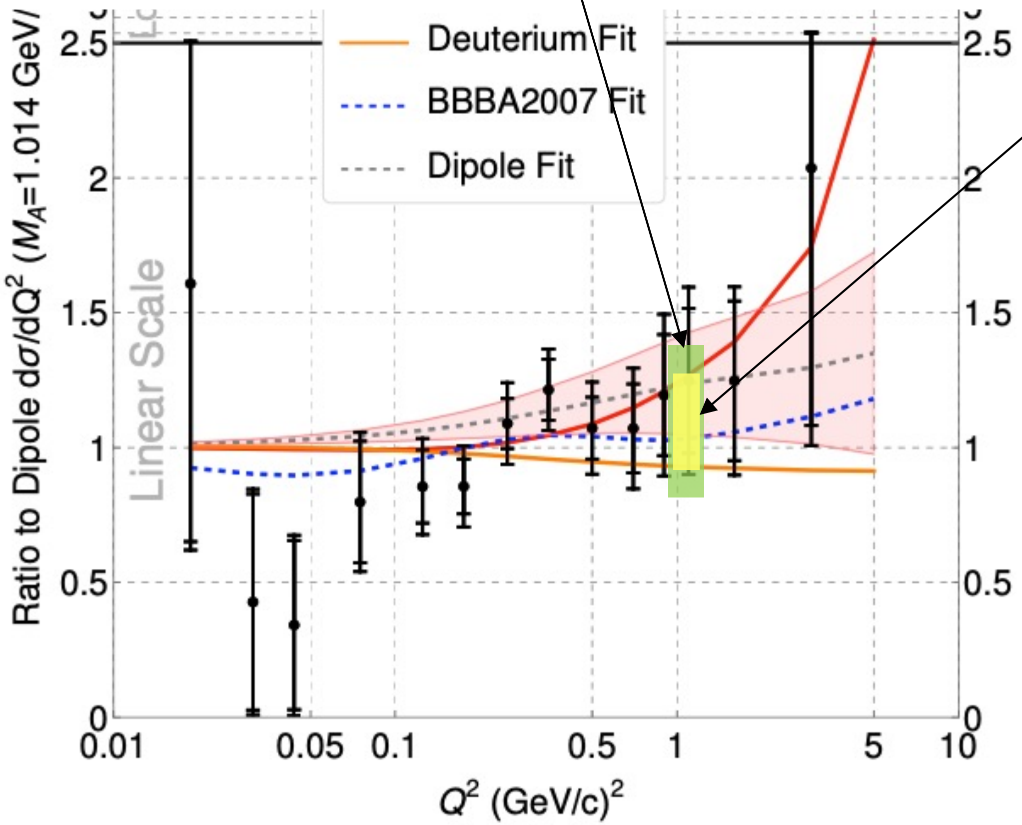
Signal = 19k +/- 6.5k events

On accuracy of the result

Projected conservative result and potential improvements

1. Presented projection is based on 100 ps time resolution and also conservative simulation which has 2x larger background than FLUKA provided.
If FLUKA prediction is correct the result will have 1.4 times better statistical accuracy

2. Time resolution < 50 ps (ATLAS, …, development at INFN, BNL, JLab for EIC)
with such resolution the result will have ~25% accuracy



at $Q^2 = 1\ \mathrm{GeV/c)}^2$

if $\sigma \to \sigma_c \times \binom{1.39}{0.61}$

$F \to F_{A,c} \times \binom{1.36}{0.66}$

we used M_A=1.08 GeV

Cross section determination

1. Fit the event distribution in reconstructed beam energy

$$\mathrm{E}_{reconst} = \frac{E_n - (M_p^2 + M_n^2)/2M_p}{1 + (P_n \cos\theta_n - E_n)/M_m}$$

2. Use helicity asymmetry and statistics

$$\frac{d\sigma}{d\Omega} = \frac{(\tilde{N}_- - \tilde{N}_+)/\eta_n}{P_b \times IL \times \Delta\Omega}$$

$\tilde{N}$ - corrected for $A_{background}$

IL – integrated luminosity

3. Relative statistical accuracy

$$\frac{\Delta\sigma}{\sigma} = \frac{1}{\sqrt{\tilde{N}_- + \tilde{N}_+} \times R} = \frac{\sqrt{\tilde{N}_- - \tilde{N}_+}}{\tilde{N}_- + \tilde{N}_+}$$

$R = S/(\tilde{N}_+ + \tilde{N}_-)$

S – number of signal events

Projected result

50 days of data taking, 10 cm LH2, 120 μA

Event type	Rate Hz, all cuts 310 MeV range	Total events	Asymmetry events	Accuracy, contr. frac
p(e,n)υ	0.0044	19k	1.0	
$\Lambda + \Sigma$	0.23	1M	~0.03	0.06
$\pi^+ + n$	34.5	150M	$< 10^{-6}$	< 0.01
Detector syst.	efficiency, ΔΩ, …			0.05
Statistics				0.34
Stat. + syst.				0.35

$$F_A / F_{A,Dipole} = 1 \pm 0.34(stat) \pm 0.08(syst) \text{ at } Q^2 = 1\,(\mathrm{GeV/c})^2$$

Summary and Beam time request

1. We propose a measurement of the Axial-Vector Form Factor using the inverse beta decay process at Q^2 of 1 $(GeV/c)^2$.

2. The calculated rate of the neutrino events allows us to collect about 19k events over two-month run. Calculated background projected to be acceptable and will be checked in the test run.

3. This experiment will be the first of this type with an electron beam and very likely will open the prospect of AVFF study in a wider range of Q^2.

4. The experiment will based on a 2.2 GeV polarized electron beam and a high resolution time-of-flight detector with a neutron calorimeter and an electron/pion veto arm made from the available detectors.

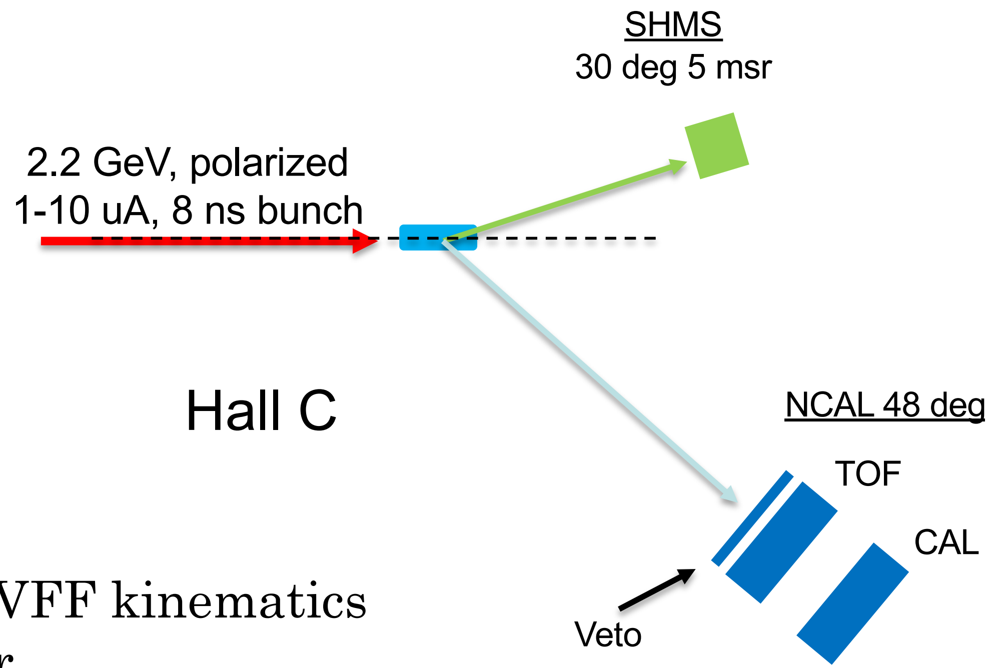
5. We are requesting 55 days of beam time with a current of 120 μA.

6. Prototype run will be very useful for progress of the experiment.

Prototype run goals and concepts

understand background

$$\vec{\gamma} + p \rightarrow \vec{n} + \pi^+$$
$$\vec{e}^- + p \rightarrow e^- + \vec{p}$$
$$\vec{\gamma} + p \rightarrow \vec{\Lambda} + K^+$$



- Measure the background rates for AVFF kinematics
- Verify time resolution of the detector
- Check operation of the collimator with the Al target
- Estimate the helicity asymmetry of the background

- Use SHMS spectrometer as a calibration/veto arm (5 msr)
- Built 10% solid angle neutron arm with 1/5 of thickness

Results of this run will provide foundation for experiment

PAC52 review

LOI12-24-009

Title: Measurement of the Nucleon Axial Vector Form Factor at $Q^2 = 1\ (GeV/c)^2$

Spokespersons: B. Wojtsekhowski (contact)

Motivation: This LOI proposes to measure the axial-vector form factor of the nucleon using the reaction $H(e^-, n)\nu_e$. Most of the existing experimental measurements of this form factor come from neutrino scattering experiments with wide-band beams and often with nuclear targets. In contrast, the uniqueness of the proposed measurement is that it will use a mono-chromatic (known) beam and a nucleon target. Knowledge of the axial-vector form factor is becoming increasingly important for

Issues: The LOI is short on detail and lacking in physics plots. 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. A plot of the planned accuracy of the axial-form factor measurement compared to existing measurements should be produced. It will also be important to tabulate to what extent existing vs. new experimental equipment will be required to carry out the planned measurement.

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.

Theory review

PR12-25-009: ***The Nucleon Axial-Vector Form Factor from the*** $p(\vec{e}, n)\nu_e$ ***Reaction***

D. Richards and T. Rogers

This proposal was submitted as an LOI last year, though with little theory background. The motivation remains strong, namely that the axial-vector form factors play an absolutely essential role in the interpretation of neutrino experiments such as those at DUNE where their knowledge must then be combined with the even greater challenge of the nuclear binding effects. However, a determination of them through an experimental process like that of the electromagnetic form factor is precluded primarily by the lack of a neutrino beam of well-specified energy. Here the proposal is to employ a different process whereby an electron or photon is scattered on a target and the outgoing neutron is detected. The motivation goes beyond that of the original LOI by connecting to the (axial-vector) GPD program. The challenge is the resolution of the signal from the substantial background, such as pion photoproduction, Much of the proposal is devoted to an understanding of the substantial background, such as pion photo-production, and elastic scattering, etc.. These are addressed through accurate time-of-flight of the neutron, vetoing on an outgoing electron, and careful calculation of the remaining backgrounds; the overall aim is 39% accuracy.

The proposal now includes an extensive description of the theoretical underpinning of the proposed experiment. There are a couple of comments about the theoretical framework that we would like to note. First, whilst a dipole form does provide a description of the form factors at small Q^2, the use of the z expansion, described in ref. [28], provides a more rigorous framework. Second, we were unclear about the correctness of the assumptions that go into equation (16). For example, in `arXiv:2501.00665`, Anderson and collaborators relax the requirement of a symmetric strange sea. Finally, characterizing such experiments as "benchmarking" lattice calculations is better expressed as a mutual confrontation of experiment with first-principles calculation. However, these comments do not detract from the strength of the proposal.

Replies to TAC review comment 6

6. There is a brief mention of beam from other halls "bleeding" into Hall C. This effect is said to be about 100 ppm of the beam from the other halls. While this is often the case, this is not a well-controlled phenomenon and it varies depending upon the accelerator setup. In fact, during a recent Moller measurement in Hall A in May 2025 we saw an order of magnitude higher bleed-through with 0.4 nA leakage into Hall A from Hall B which was running at 330 nA. With such a critical dependence on timing relative to the 2 picosecond RF beam pulses in order to reconstruct energy and with background processes often orders of magnitude higher than the physics process of interest, one worries that even this highly attenuated current between the pulses of the beam will lead to off-time spurious backgrounds that are impossible to differentiate from the main signal.

The value of "bleeding" will be monitored during production. The HAPPEX, G0, and Qweak experiments had a successful experience with the bleed-through current. They studied PV physics and much smaller asymmetry ($< 10^{-6}$) compared with that projected in AVFF ($\sim 10^{-4}$). We will measure bleed-through currents and keep them below 10 nA ($\sim 10^{-4}$ of the full 120 μA). The measurement of the bleed-through current will require a very short beam time with the laser for the Hall C beam switched off and measurement of the event rate in the neutron arm and veto arm when the sweeper magnet is switched off. For 10 nA bleed-through, the projected event rate is 20 Hz of high energy electron-proton events observed in both TOF+NCAL and HCAL.

Replies to all comments are provided to PAC

Replies to ITAC review comment 8

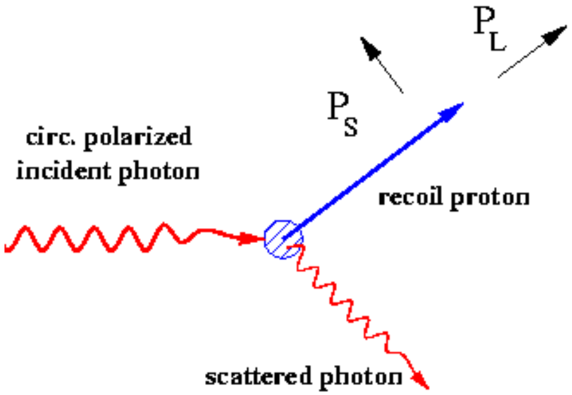
8. Given the very large backgrounds, even small helicity-dependent cross sections could have an impact on the measurement. For example, pion electroproduction could carry some small residual asymmetry due to the ϕ-dependent single spin asymmetry coupled with incomplete azimuthal coverage, or possible residual transverse electron beam polarization, leading to beam-normal single spin asymmetries. More discussion is merited.

The projected beam helicity asymmetry from the neutrino signal over background is on the scale of 0.001, which is much larger than the estimated asymmetry from the induced transverse spin of the neutron for the photo-production channel. A similar effect was analyzed in the approved strange FF experiment (analysis is published in NIM-A, 1031 (2022) 166565). The event rate from pion electro-production with significant momentum transfer is about 30 times less than the one from photo-production. The phi-dependent term in the pion electro-production is also reduced due to the small value of the average "sin(\phi)". Thanks to the large acceptance of the pion veto arm (400 msr vs. 50 msr required for the pure photo-production) the pions for all \phi angles will be detected (for events with the neutron detected). The non-zero "sin(\phi)" can come from the variation of the veto arm detector efficiency across the acceptance. The photo-production events with the reconstructed beam energy 2100-2200 MeV will be used to measure the remaining size of the phi-dependent helicity correlated effect and tune the veto arm rejection procedure if needed. The test run will be used to confirm the above considerations.

Replies to all ITAC comments are provided to PAC

F_A and Wide-Angle Compton Scattering

M. Diehl and P. Kroll, Eur. Phys. J. C **73**



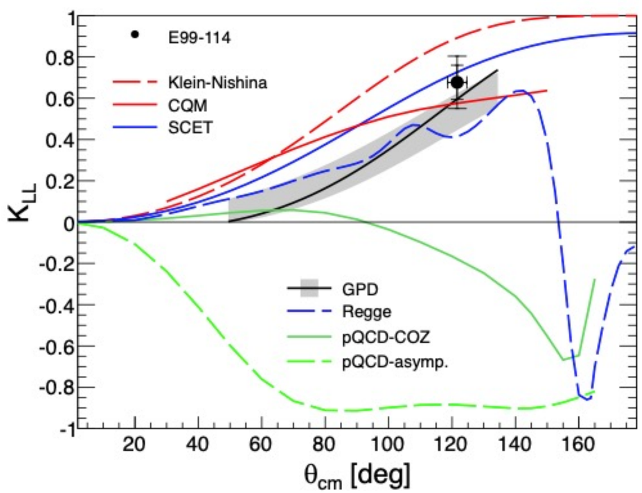
$$\frac{d\sigma_{RCS}}{d\sigma_{KN}} = \frac{(\hat{s}-\hat{u})^2}{\hat{s}^2+\hat{u}^2} R_V^2(t) + \frac{2\hat{s}\hat{u}}{\hat{s}^2+\hat{u}^2} R_A^2(t)$$

$$R_V(t) = \sum_a e_a^2 \int_{-1}^{+1} \frac{dx}{x} H^a(x;0,t) \quad , R_A(t) = \sum_a e_a^2 \int_{-1}^{+1} \frac{dx}{x} \widetilde{H}^a(x;0,t)$$

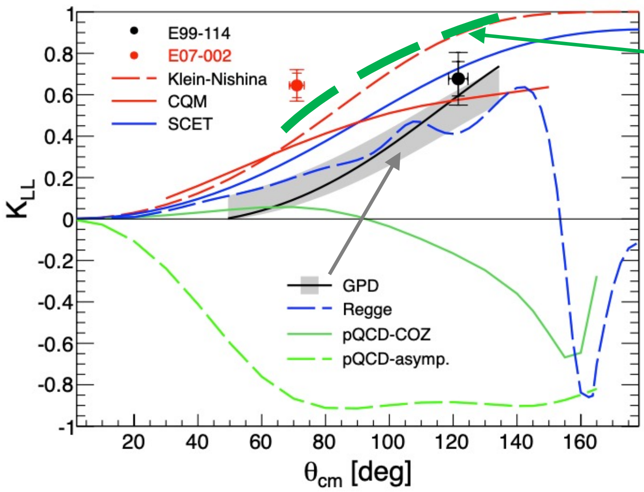
Polarization transfer asymmetry

$$K_{LL} \simeq 2 \frac{-t}{s-u} \frac{R_A(t)}{R_V(t)}$$

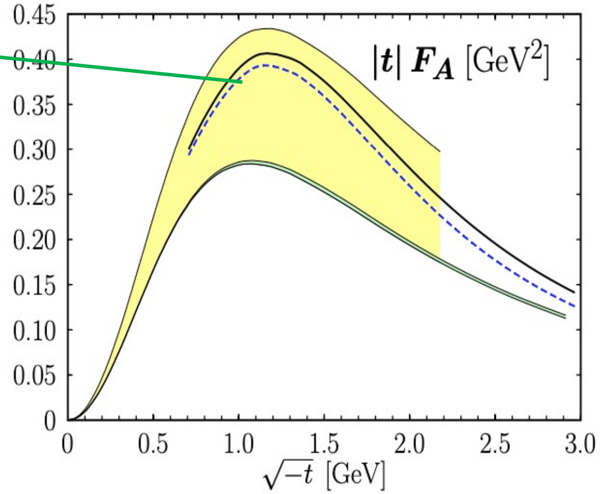
Hamilton et al. PRL94 (2005)



Fanelli et al. PRL115 (2015)

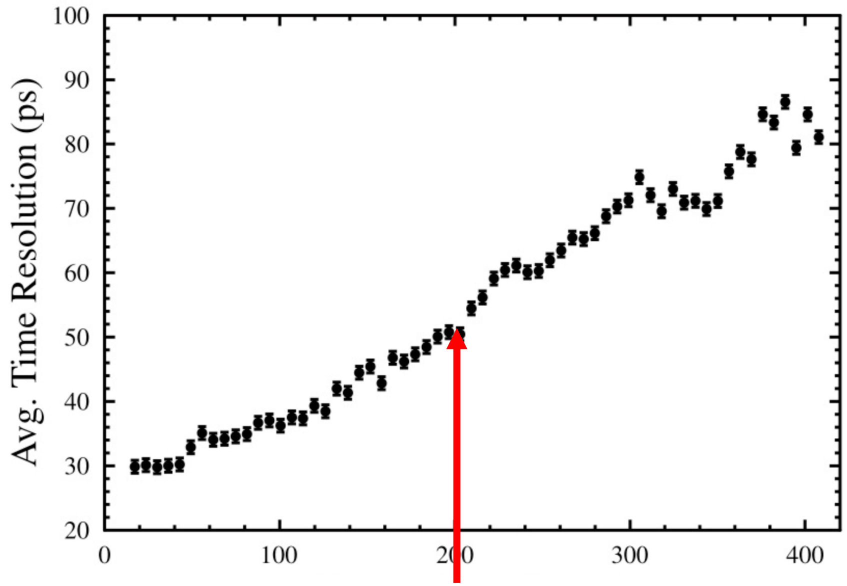


P. Kroll Eur.Phys.J. A 53 (2017) 6, 130



The time-of-flight detector

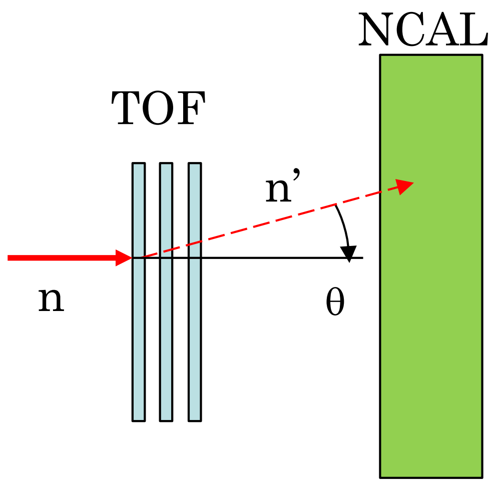
Hall B constructed a time-of-flight system (D. Carman) with 30-80 ps time resolution for charged particle, NIM-A, 960, 163629, 2020.

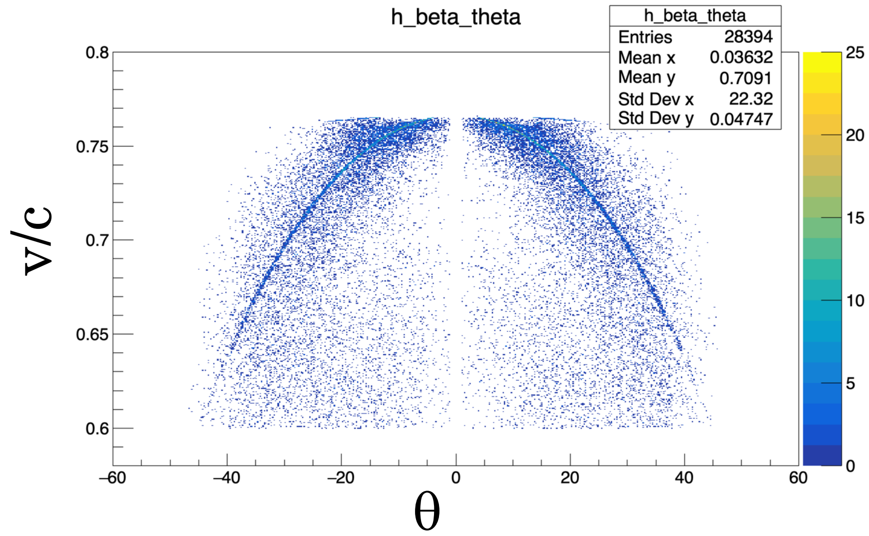


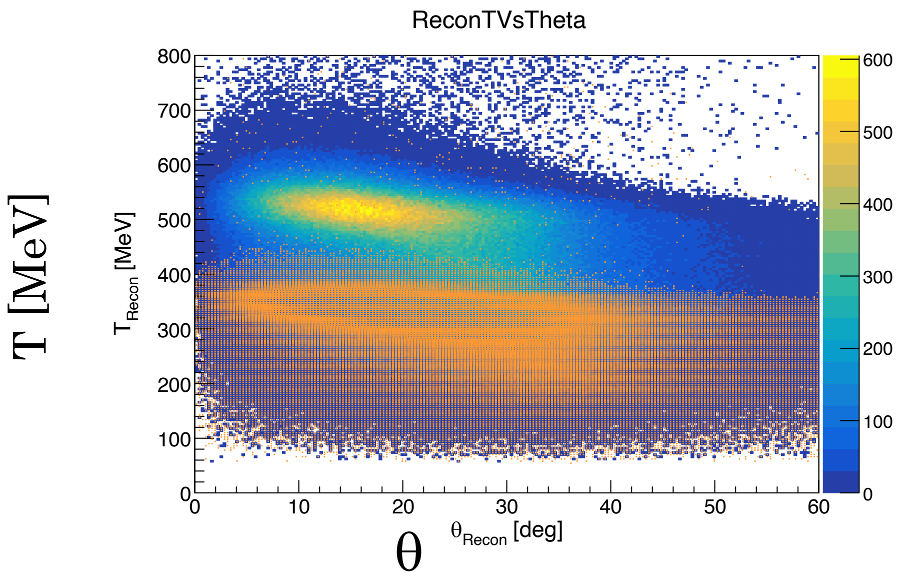
With a 200-cm-long detector and 3 MeV threshold (~5% neutron efficiency), projected time resolution is 100 ps.

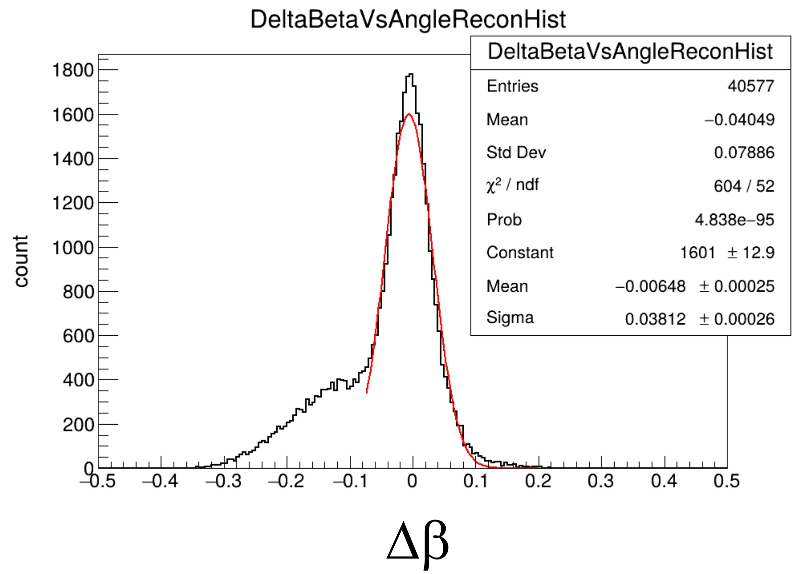
Recently proposed a modern photon detector allows time resolution for neutrons below 50 pico-seconds (also relevant to EIC).

Beam bunch determination



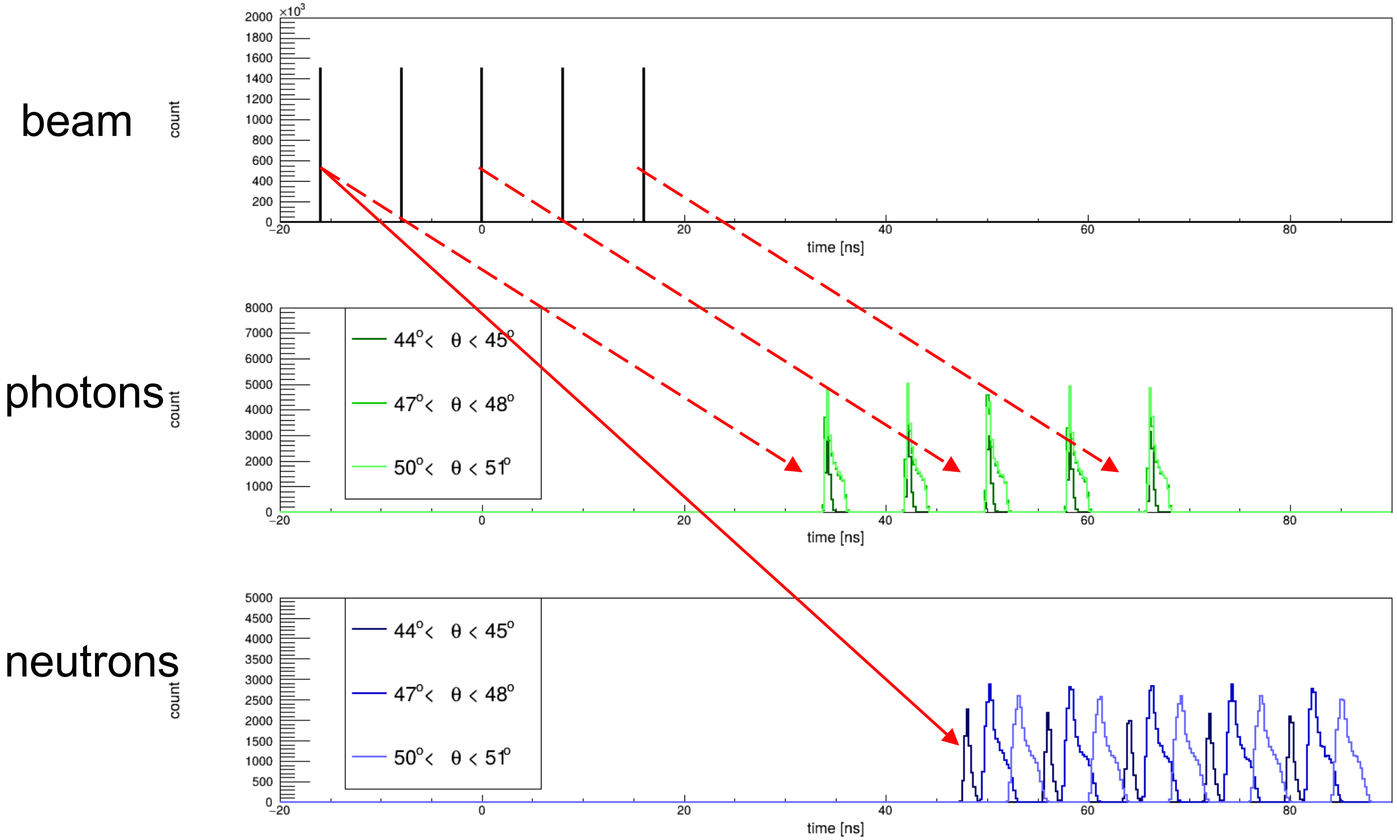






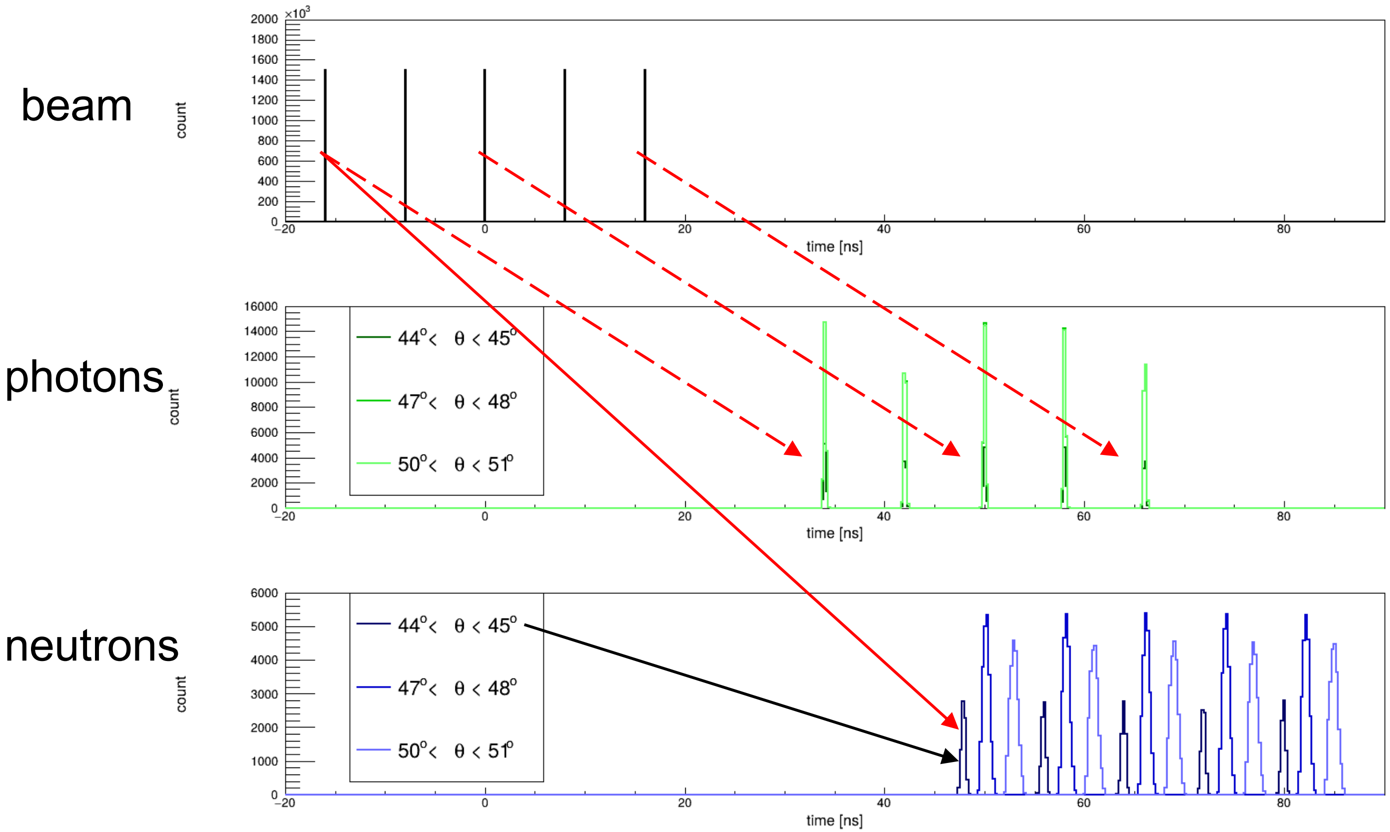
Beam bunch diagram

Arrival time (uncorrected on hit position in TOF)



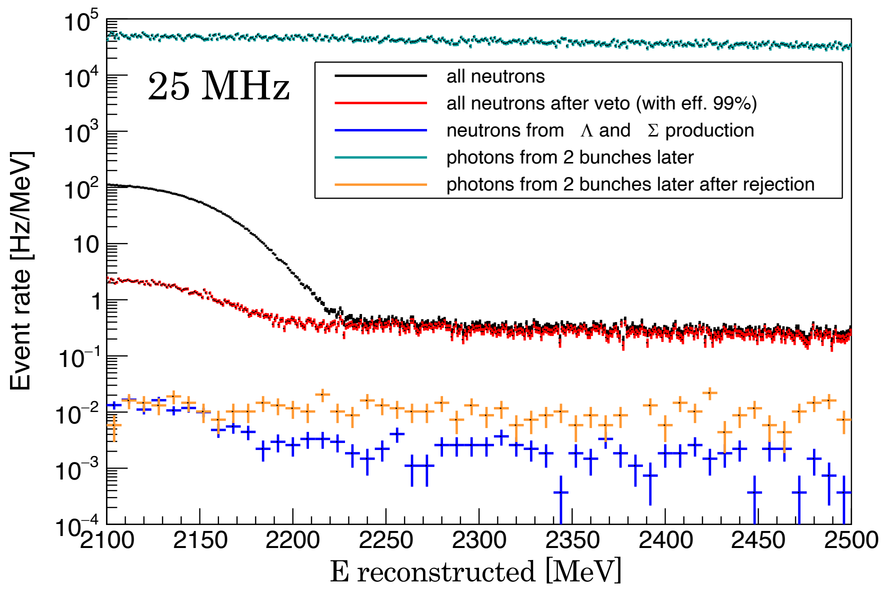
Beam bunch diagram

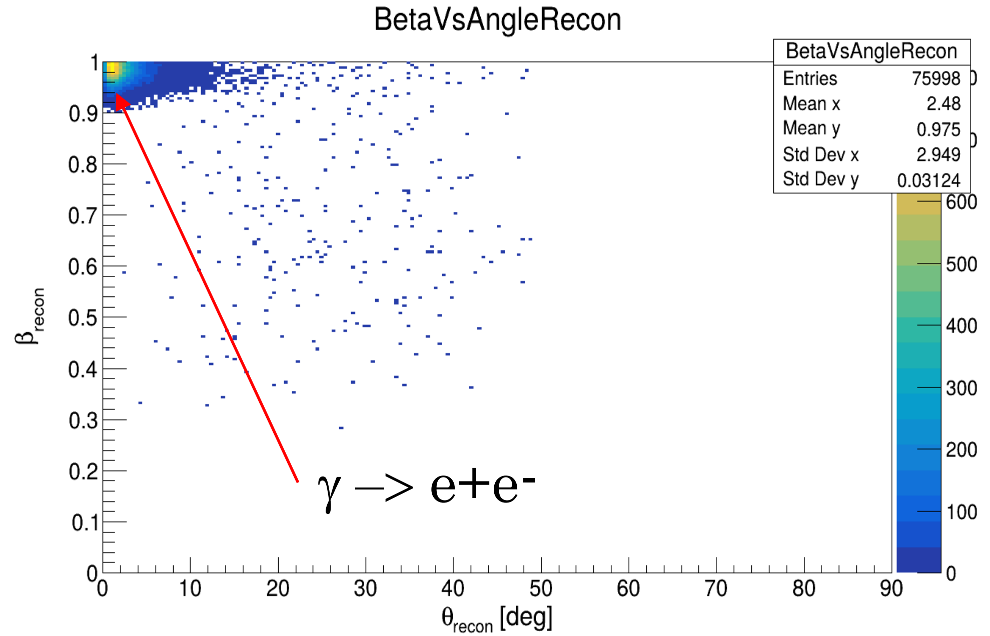
Arrival time (corrected for photon hit position in TOF)

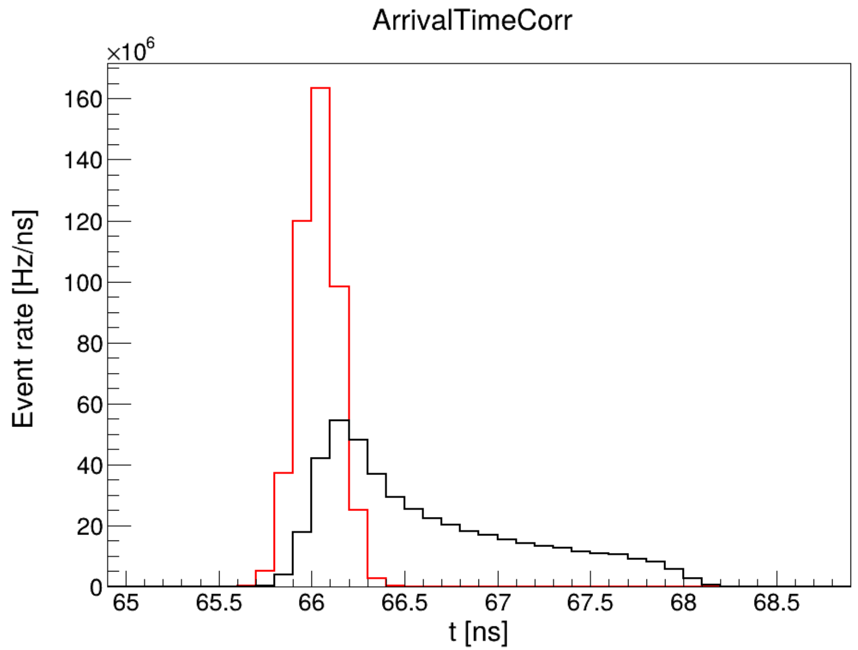


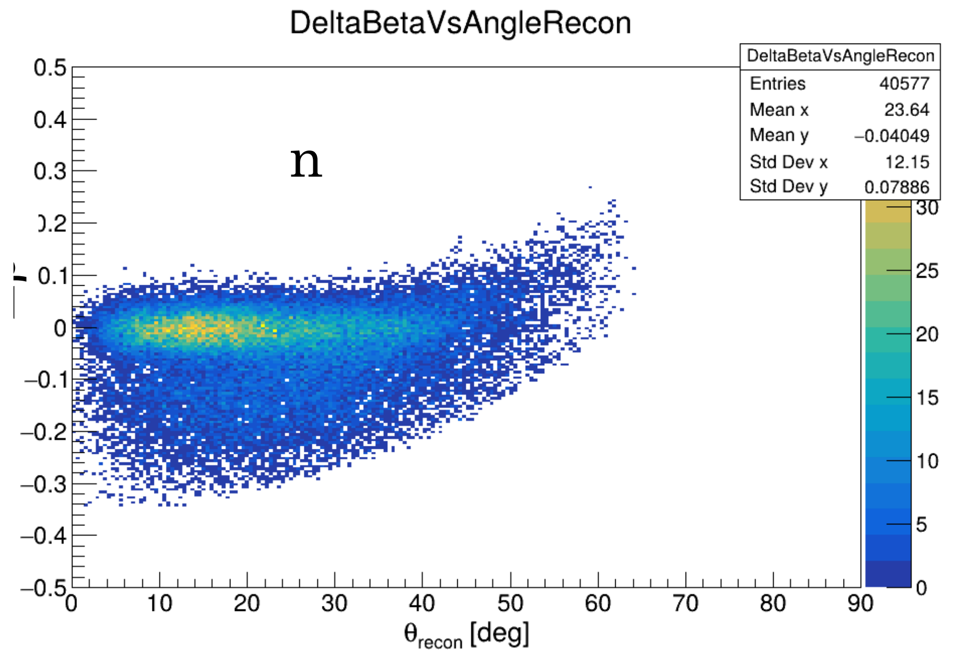
+/-0.25 ns cut to reduce photons could be applied

Prompt photon rejection









Helicity asymmetry of background, Lambda and Sigma photo-production

$$d\sigma/d\Omega_K \propto 1 + \alpha_-[P \cdot \cos\theta_y +$$

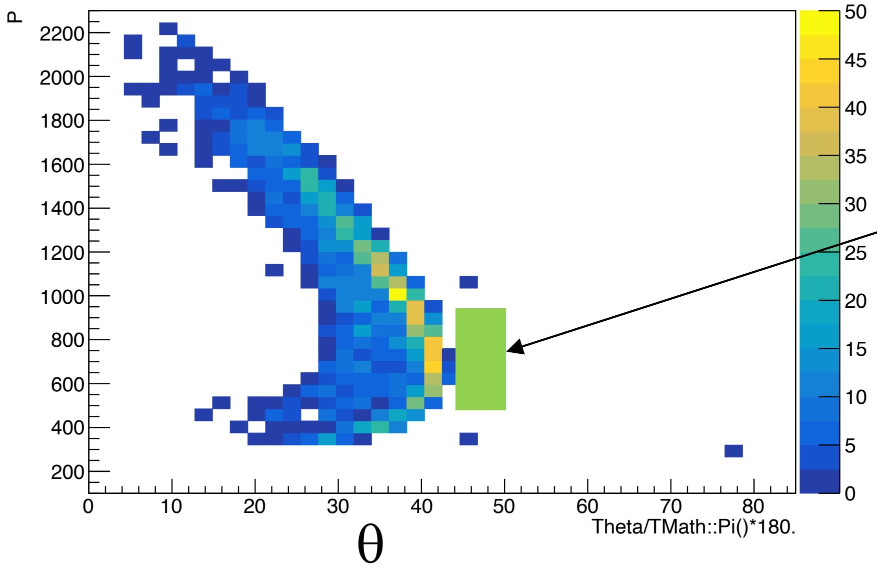
$$+ P_C^\gamma \cdot (\cos\theta_x C_x + \cos\theta_z C_z)]$$

$$\alpha_- = 0.64, \quad \cos\theta_z \approx 70^o$$

From Geant4-based MC the neutron rate of the $\Lambda+\Sigma$ processes is 0.23 +/- 0.04 Hz (in 310 MeV wide E_{rec} range).

Polarization of Λ (P) leads to a small background asymmetry :
In the $\Lambda 0$ events beam helicity P_C^γ leads to C_z related asymmetry of 0.03 +/- 0.008.
Taking into account the fraction of these events the background asymmetry is 0.0002.

Lambda momentum vs. its angle in lab



Neutrons from Λ decay are mostly missing the neutron arm acceptance (located at $\theta = 44^o - 52^o$).