# Precision Measurement of *a* and *b* in Neutron $\beta$ Decay

## The Nab/abBA Experimental Program

L. Peter Alonzi III, for the Nab Collaboration

University of Virginia

April APS Meeting,
Denver, 03 May 2009

# Outline

# World Neutron Experimental Results and Nab goal

Electron-neutrino parameter **a**:

$$\text{Experimental results} \begin{cases} -0.1054\,(55) & \text{Byrne et al, [2002]} \\ -0.1017\,(51) & \text{Stratowa et al, [1978]} \\ -0.091\,(39) & \text{Grigorev et al, [1968]} \\ -0.103\,(4) & \text{PDG, [2008]} \end{cases}$$

Nab goal: $$\frac{\Delta a}{a} \simeq 1 \times 10^{-3}$$

Fierz interference term **b**:

$$\text{Experimental results} \begin{cases} \textit{none} \end{cases}$$

Nab goal: $$\Delta b \simeq 3 \times 10^{-3}$$

# World Neutron Experimental Results and Nab goal

Electron-neutrino parameter **a**:

Experimental results $\begin{cases} -0.1054\,(55) & \text{Byrne et al, [2002]} \\ -0.1017\,(51) & \text{Stratowa et al, [1978]} \\ -0.091\,(39) & \text{Grigorev et al, [1968]} \\ -0.103\,(4) & \text{PDG, [2008]} \end{cases}$

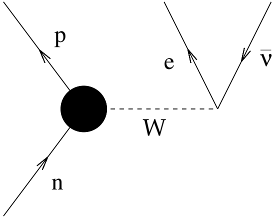
Nab goal: $$\frac{\Delta a}{a} \simeq 1 \times 10^{-3}$$

Fierz interference term **b**:

Experimental results { *none*

Nab goal: $$\Delta b \simeq 3 \times 10^{-3}$$

# Neutron Decay Rate




$$\frac{dw}{dE_e d\Omega_e d\Omega_\nu} \simeq k_e E_e (E_0 - E_e)^2$$
$$\times \left[ 1 + a \frac{\vec{k}_e \cdot \vec{k}_\nu}{E_e E_\nu} + b \frac{m_e}{E_e} + \langle \vec{\sigma}_n \rangle \cdot \left( B \frac{\vec{k}_\nu}{E_\nu} + A \frac{\vec{k}_e}{E_e} \right) \right]$$

$$a = \frac{1 - |\lambda|^2}{1 + 3|\lambda|^2} \qquad A = -2 \frac{|\lambda|^2 + \mathrm{Re}(\lambda)}{1 + 3|\lambda|^2} \qquad B = 2 \frac{|\lambda|^2 - \mathrm{Re}(\lambda)}{1 + 3|\lambda|^2}$$

$$\lambda = \frac{G_A(0)}{G_V(0)} \qquad (\text{with } \tau_n \Rightarrow \text{CKM } V_{ud})$$

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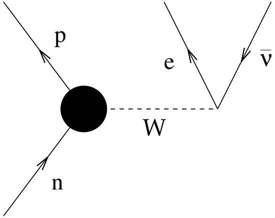


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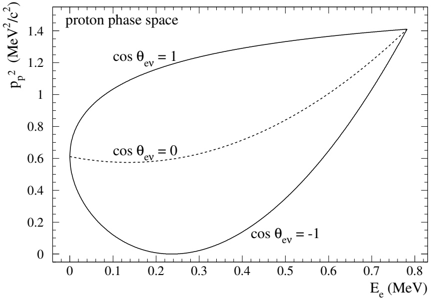
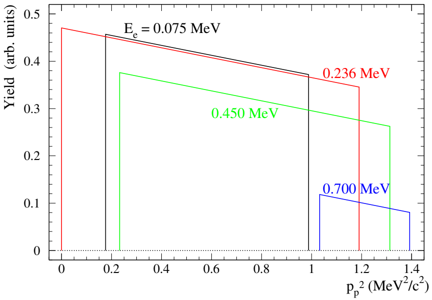
$\lambda = \frac{G_A(0)}{G_V(0)}$ (with $\tau_n \Rightarrow$ CKM $V_{ud}$)

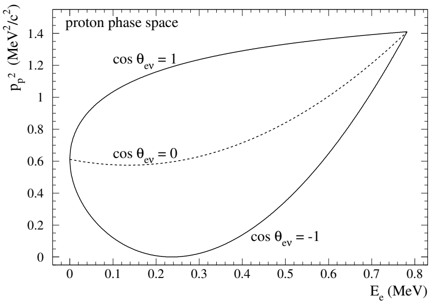
# Decay Kinematics

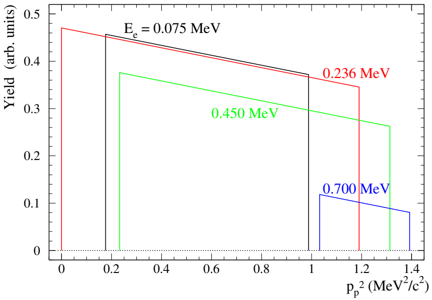



- $E_p \sim$ eV and $E_e \sim$ 0-800 keV
- For a given $\mathbf{E_e}$
  - $\cos\theta_{e\nu}$ is a function of $p_p^2$ only $\quad (p_p^2 = p_e^2 + p_\nu^2 + 2p_e p_\nu \cos\theta_{e\nu})$
  - $\dfrac{dw}{dE_e d\Omega_e d\Omega_\nu} \simeq Constant + a\, p_p^2$

# Decay Kinematics

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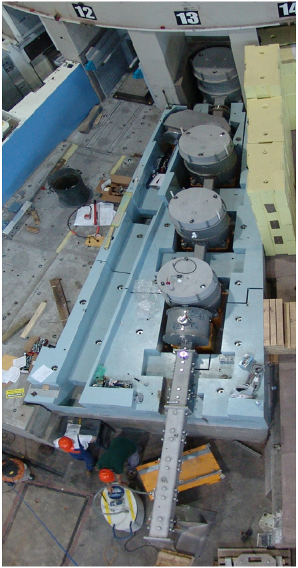
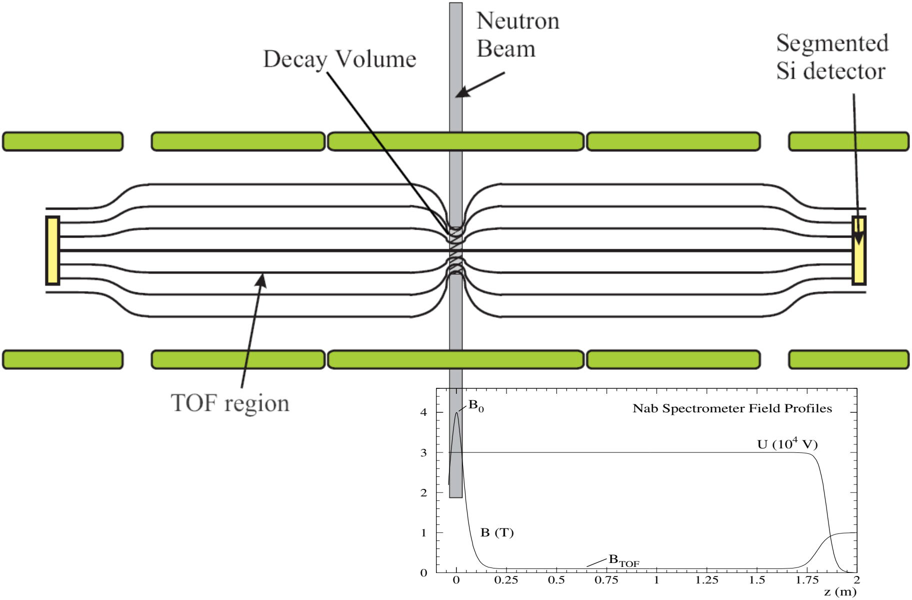
# Beamline 13: Spallation Neutron Source, Oak Ridge, TN

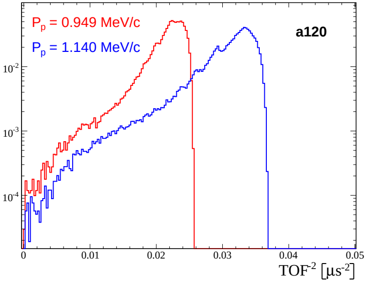


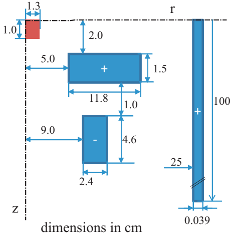

# The Nab Symmetric Configuration



# Geant4 Simulation

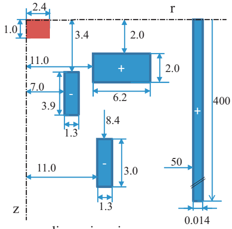
a120 ⟶



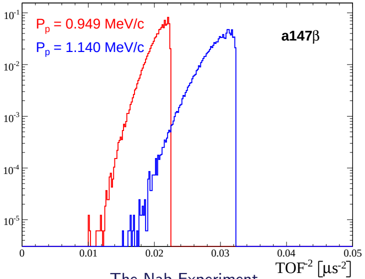

dimensions in cm

Current density: 3500 A/cm$^2$




dimensions in cm

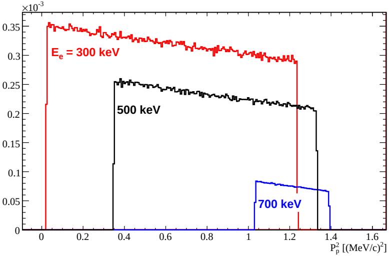
Current density: 3500 A/cm$^2$



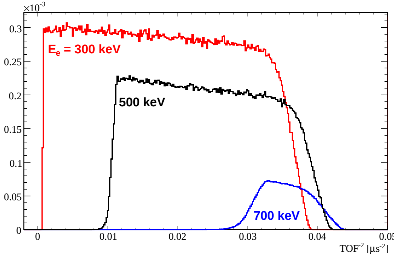

⟵ a147$\beta$

# Geant4 Simulation

## Ideal Spectrometer

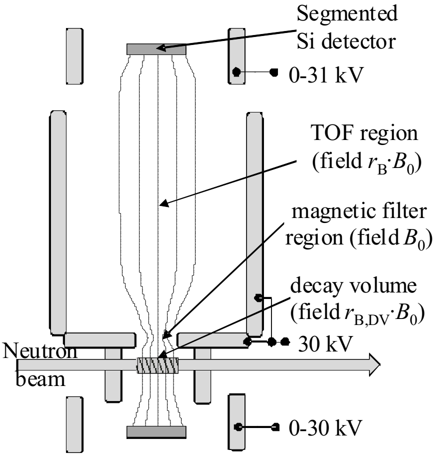



## Practicable Spectrometer




| $E_e$ | Measured $a$ |
|---|---|
| Seed | -0.10500 |
| 300 keV | -0.10526(10) |
| 500 keV | -0.10509(10) |
| 700 keV | -0.10529(10) |

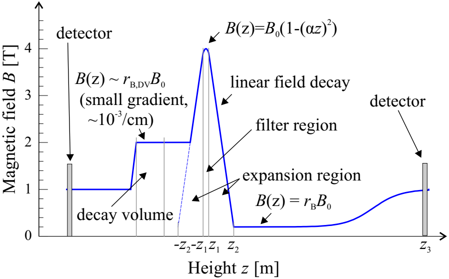
# Basic design and features of asymmetric Nab




Stefan Baeßler, March 2009

Features:

- **U** tolerance $\sim \mu V \rightarrow \sim mV$
- magnetic $\cos\theta$ filter
- no count rate penalty vs. symmetric Nab



# The Nab collaboration

R. Alarcon[1], L.P. Alonzi[2], S. Baeßler[2*], S. Balascuta[1], J.D. Bowman[3†], M.A. Bychkov[2], J. Byrne[4], J.R. Calarco[5], V. Cianciolo[3], C. Crawford[6], E. Frlež[2], M.T. Gericke[7], F. Glück[8], G.L. Greene[9], R.K. Grzywacz[9], V. Gudkov[10], F.W. Hersman[5], A. Klein[11], J. Martin[12], S.A. Page[6], A. Palladino[2], S.I. Penttilä[3], D. Počanić[2†], K.P. Rykaczewski[3], W.S. Wilburn[11], A.R. Young[13], G.R. Young[3].

[1]Arizona State University
[2]University of Virginia
[3]Oak Ridge National Lab
[4]University of Sussex
[5]Univ. of New Hampshire
[6]University of Kentucky
[7]University of Manitoba
[8]Uni. Karlsruhe/RMKI Budapest
[9]University of Tennessee
[10]University of South Carolina
[11]Los Alamos National Lab
[12]University of Winnipeg
[13]North Carlolina State Univ.

[*]Experiment Manager
[†]Co-spokesmen

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