Nab, a new precise study of neutron beta decay at SNS

Dinko Počanić

University of Virginia

Jefferson Lab
Newport News, VA,
4 May 2012

Outline

Goals and motivation

CKM matrix: V_{ud} (messy neutron results)

Non-$V - A$ interaction terms; Second class currents

Measurement principles

Electron-neutrino correlation a; detection function

Apparatus

Spectrometer and its optimization

Si Detectors; Electrode and vacuum systems

Overview of uncertainties

Event rates, statistical uncertainties

Systematic uncertainties

Polarized program: abBA/PANDA

Measurement principle

Rates and uncertainties

Summary

Neutron Decay Parameters (SM)

$$\frac{dw}{dE_e d\Omega_e d\Omega_\nu} \simeq p_e E_e (E_0 - E_e)^2$$

$$\times \left[1 + a \frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b \frac{m}{E_e} + \langle \vec{\sigma}_n \rangle \cdot \left(A \frac{\vec{p}_e}{E_e} + B \frac{\vec{p}_\nu}{E_\nu} \right) + \ldots \right]$$

where:

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

$$B = 2 \frac{|\lambda|^2 - \mathrm{Re}(\lambda)}{1 + 3|\lambda|^2} \qquad \lambda = \frac{G_A}{G_V} \ (\text{with } \tau_n \Rightarrow \text{CKM } V_{ud})$$

also:

$$C = \kappa (A + B) \quad \text{where} \quad \kappa \simeq 0.275 \, .$$

Goals of the Nab experiment

- Measure the electron-neutrino parameter **a** in neutron decay

  with accuracy of $\boxed{\frac{\Delta a}{a} \simeq 10^{-3}}$

current results:	-0.1054 ± 0.0055	Byrne et al '02
	-0.1017 ± 0.0051	Stratowa et al '78
	-0.091 ± 0.039	Grigorev et al '68

- Measure the Fierz interference term **b** in neutron decay

  with accuracy of $\boxed{\Delta b \simeq 3 \times 10^{-3}}$

  current results: **none** (in n decay)

Quark-lepton (Cabibbo) universality

Basic weak-interaction **V-A** form (e.g., μ decay):

$$\mathcal{M} \propto \langle \mathbf{e} | \mathbf{l}^{\alpha} | \nu_{\mathbf{e}} \rangle \rightarrow \bar{\mathbf{u}}_{\mathbf{e}} \gamma^{\alpha} (\mathbf{1} - \gamma_{\mathbf{5}}) \mathbf{u}_{\nu}$$

is replicated in hadronic weak decays:

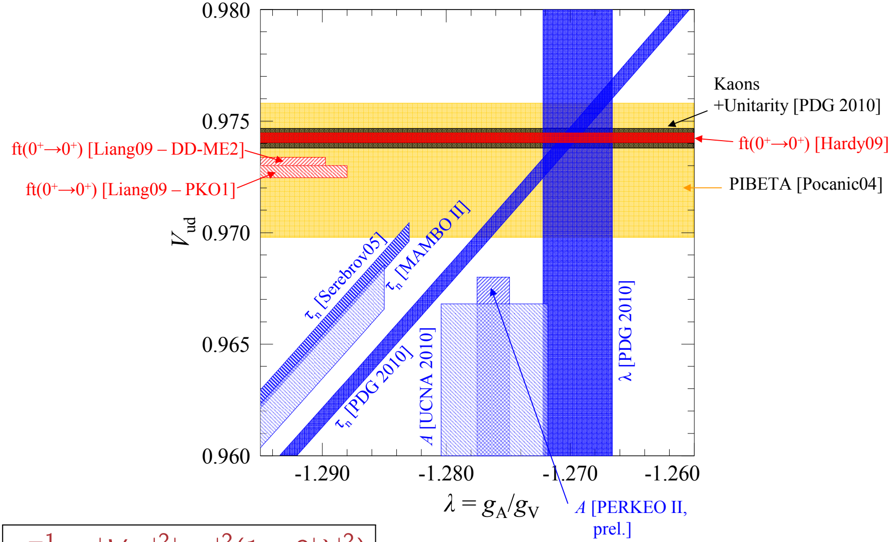
$$\mathcal{M} \propto \langle \mathbf{p} | \mathbf{h}^{\alpha} | \mathbf{n} \rangle \rightarrow \bar{\mathbf{u}}_{\mathbf{p}} \gamma^{\alpha} (\mathbf{G_V} - \mathbf{G_A} \gamma_{\mathbf{5}}) \mathbf{u}_{\mathbf{n}} \quad \text{with} \quad \mathbf{G_{V,A}} \simeq \mathbf{1} \, .$$

Departure from $\mathbf{G_V = 1}$ (**CVC**) comes from weak quark (Cabibbo) mixing:
$\mathbf{G_V = G_\mu \cos\theta_C (= G_\mu V_{ud})} \quad \mathbf{\cos\theta_C \simeq 0.97}$

3 **q** generations lead to the
Cabibbo-Kobayashi-Maskawa (CKM) matrix (1973): $\begin{pmatrix} \mathbf{V_{ud}} & \mathbf{V_{us}} & \mathbf{V_{ub}} \\ \mathbf{V_{cd}} & \mathbf{V_{cs}} & \mathbf{V_{cb}} \\ \mathbf{V_{td}} & \mathbf{V_{ts}} & \mathbf{V_{tb}} \end{pmatrix}$

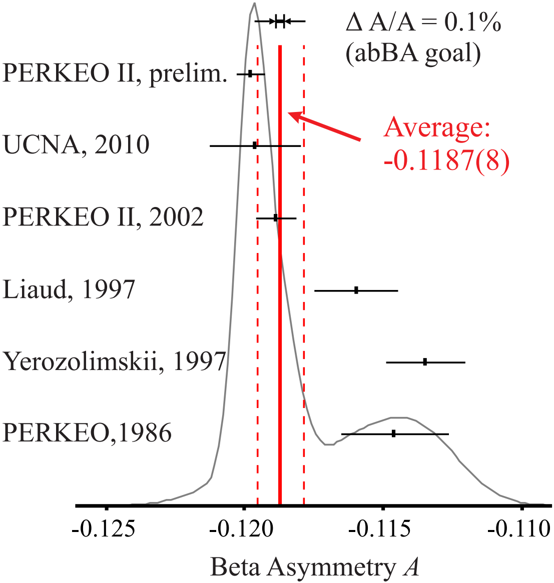
CKM unitarity cond.: $\mathbf{\Delta V^2 = 1 - (|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2) \overset{?}{=} 0}$,
stringently tests the SM.

SM parameters determining V_{ud}



$$\boxed{\tau_n^{-1} = |V_{ud}|^2 |g_V|^2 (1 + 3|\lambda|^2)}$$

Status of A and λ in n decay

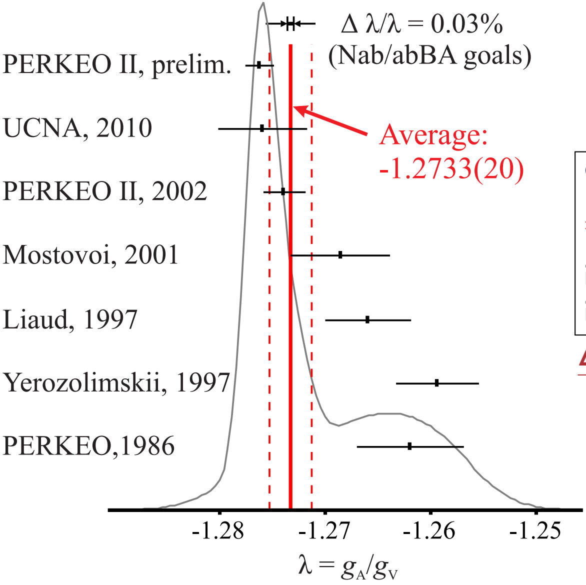


Uncertainty of the average scaled up by factor **2.3×**

Global fit $\chi^2/\text{dof} = 27/5$!

Statistical probability for this χ^2 is 6×10^{-5}.

Status of A and λ in n decay (cont'd)



Goals for Δa, ΔA:

$$\Rightarrow \boldsymbol{\Delta\lambda \simeq 3.5 \times 10^{-4}}$$

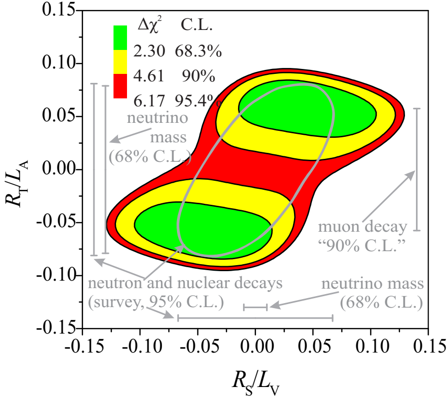
i.e., an order of magn. improvement.

$$\frac{\Delta\lambda}{\lambda} \simeq 0.27\frac{\Delta a}{a} \simeq 0.24\frac{\Delta A}{A}$$

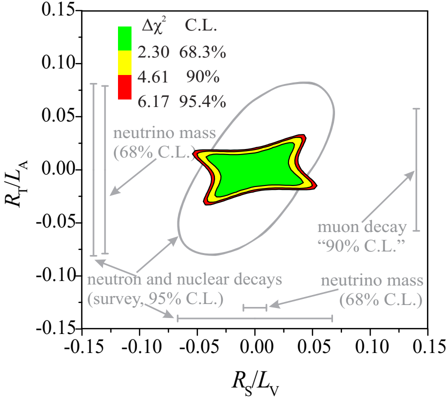
n-decay correlation parameters beyond $\mathbf{V_{ud}}$

- Beta decay parameters constrain L-R symmetric, SUSY extensions to the SM. [Reviews: Herczeg, Prog. Part. Nucl. Phys. **46**, 413 (2001), N. Severijns, M. Beck, O. Naviliat-Čunčić, Rev. Mod. Phys. **78**, 991 (2006), Ramsey-Musolf, Su, Phys. Rep. **456**, 1 (2008)]
- Fierz int. term, never measured for the n, along with B, offers a sensitive test of non-$(V-A)$ terms in the weak Lagrangian (S, T).
  [S. Profumo, M. J. Ramsey-Musolf, S. Tulin, PRD **75**, 075017 (2007)]
- Measurement of the electron-energy dependence of a and A can separately confirm CVC and absence of SCC.
  [Gardner, Zhang, PRL **86**, 5666 (2001), Gardner, hep-ph/0312124]
- A connection exists between non-SM (e.g., S, T) terms in $d \to ue\bar{\nu}$ and limits on ν masses. [Ito + Prézaeu, PRL **94** (2005)]

Updated limits for RH *S* and *T* currents *n* decay



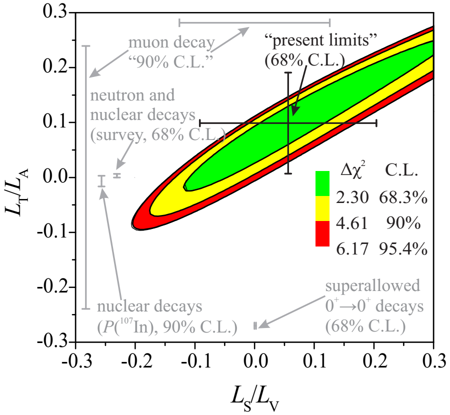
Present limits (*n* decay data)
(SM values at origin of plot.)
[$\tau_n = 881.8(13)\,\mathrm{s}$]



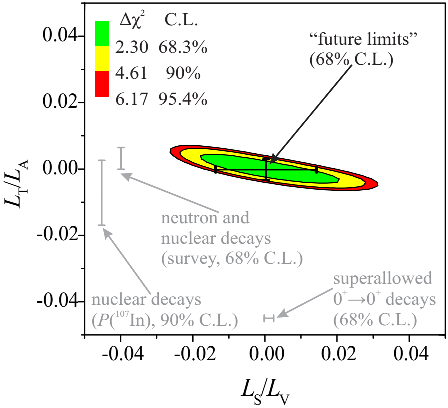
Projected limits with: τ_n, $a = -0.10588(10)$, $b \equiv 0$, $A = -0.1186(1)$, $B = 0.9807(30)$, $C = -0.23875(24)$.

[After: G. Konrad, W. Heil, S. Baeßler, D. Počanić, F. Glück, arXiv 1007.3027.]

Limits for LH *S* and *T* currents *n* decay



Present limits (*n* decay data)
(SM values at origin of plot.)
[$\tau_n = 881.8(13)\,\mathrm{s}$]



Projected limits with: τ_n, $a = -0.10588(10)$, $b = 0 \pm 0.003$, $A = -0.1186(1)$, $B = 0.9807(30)$, $C = -0.23875(24)$.

[After: G. Konrad, W. Heil, S. Baeßler, D. Počanić, F. Glück, arXiv 1007.3027.]

Correlation parameters with recoil correction

[Gardner, Zhang, PRL **86**, 5666 (2001), Gardner, hep-ph/0312124]

Most general form of hardonic weak current consistent with (V-A):

$$\langle \mathbf{p(p_p)}|\mathbf{J}^{\mu}|\mathbf{n(p_n,P)}\rangle =$$

$$\bar{\mathbf{u}}_{\mathbf{p}}(\mathbf{p_p})\Big(\mathbf{f_1(q^2)}\gamma^{\mu} - \mathbf{i}\frac{\mathbf{f_2(q^2)}}{\mathbf{M_n}}\mathbf{q}^{\mu} + \frac{\mathbf{f_3(q^2)}}{\mathbf{M_n}}\mathbf{q}^{\mu} + \mathbf{g_1(q^2)}\gamma^{\mu}\gamma_5$$
$$- \mathbf{i}\frac{\mathbf{g_2(q^2)}}{\mathbf{M_n}}\sigma^{\mu\nu}\gamma_5\mathbf{q}_{\nu} + \frac{\mathbf{g_3(q^2)}}{\mathbf{M_n}}\gamma_5\mathbf{q}^{\mu}\Big)\mathbf{u_n(p_n,P)}$$

$$\mathbf{a,A,B} \Rightarrow \lambda = \frac{\mathbf{g_1}}{\mathbf{f_1}} \qquad \text{while} \quad \tau_{\mathbf{n}} \propto (\mathbf{f_1})^2 + 3(\mathbf{g_1})^2$$

However, $\mathbf{f_2}$ (weak magnetism) and SCC's ($\mathbf{g_2}$,$\mathbf{g_3}$), remain unresolved in beta decays (best tested in A=12 system). With recoil corrections, Gardner and Zhang find:

$$\mathbf{a(E_e)} = \text{func}(\mathbf{f_2}) \qquad \text{while} \qquad \mathbf{A(E_e)} = \text{func}(\mathbf{f_2,g_2})$$

Current and planned experiments aiming to measure a

1. **Nab**: goal is to measure $\Delta a/a \simeq 10^{-3}$
   - Discussed in this talk.

2. **aCORN**: goal is to measure $\Delta a/a < 1\,\%$; (with $0.5\,\%_{\text{syst}}$)
   - Funded, under way at NIST,
   - Uses only part of neutron decay phase space.

3. **aSPECT**: aims to measure $\Delta a/a \simeq 3 \times 10^{-3}$ ($\sim 1\,\%$ short-term)
   - Funded and running;
   - Singles measurement!
   - will become part of the **PERC** program with improvements.

How to accomplish the goals of Nab?

Measure: $\frac{\Delta a}{a} \simeq 10^{-3}$ and $\Delta b \simeq 3 \times 10^{-3}$.

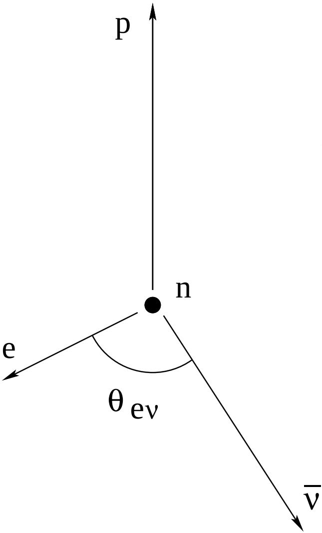
Basic approach: $(n \to p + e^- + \bar{\nu}_e)$

- Detect electrons directly, in Si detectors,
- Measure electron energy in Si detectors,
- Detect protons, after acceleration, in Si detectors,
- Determine proton momentum from TOF over a long flightpath (electron provides start pulse).

A complex magneto-electrostatic apparatus is required to guide particles (nearly) adiabatically to detectors.

Location: FnPB at SNS (backup NG-C at NIST).

Electron–neutrino angle from E_e and E_p



Conservation of momentum in **n** beta decay,

$$\vec{p}_\mathrm{p} + \vec{p}_\mathrm{e} + \vec{p}_\nu = 0\,,$$

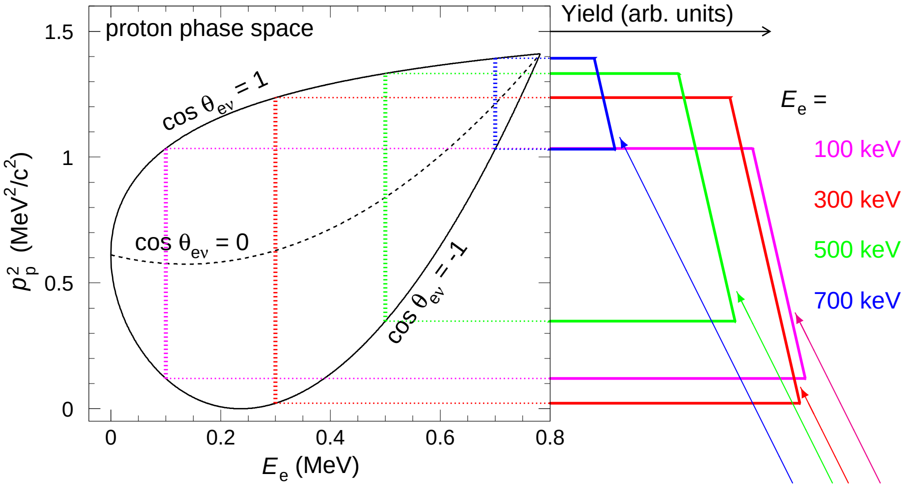
yields

$$p_\mathrm{p}^2 = p_\mathrm{e}^2 + 2p_\mathrm{e}p_\nu \cos\theta_{\mathrm{e}\nu} + p_\nu^2\,.$$

Neglecting proton recoil energy, $E_\mathrm{e} + E_\nu = E_0$, so that $p_\nu = E_0 - E_\mathrm{e}$. Therefore:

$\cos\theta_{\mathrm{e}\nu}$ is uniquely determined by measuring E_e and E_p (or $p_\mathrm{p} \Rightarrow \mathrm{TOF}_\mathrm{p}$).

Nab measurement principles: proton phase space



$\boxed{\text{Slope} \propto \mathbf{a}}$

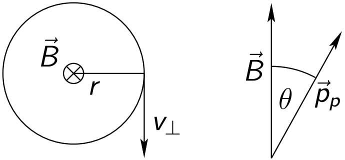
NB: For a given E_e, $\cos\theta_{e\nu}$ is a function of p_p^2 only.

Numerous consistency checks are built-in!

But wait: protons fly in all directions!

(not just straight to a small detector) How, then, do we relate TOF to p_p?

Answer: **adiabatic longitudinalization**!



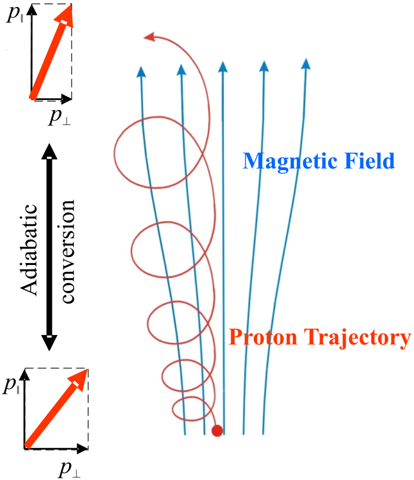
$$\frac{mv_\perp^2}{r} = ev_\perp B \quad \text{or} \quad r = \frac{mv_\perp}{eB} .$$

Conservation of $\vec{L}$ and E yields:

$$L = mv_\perp r = \frac{m^2 v^2 \sin^2\theta}{eB} = \text{const.},$$

or

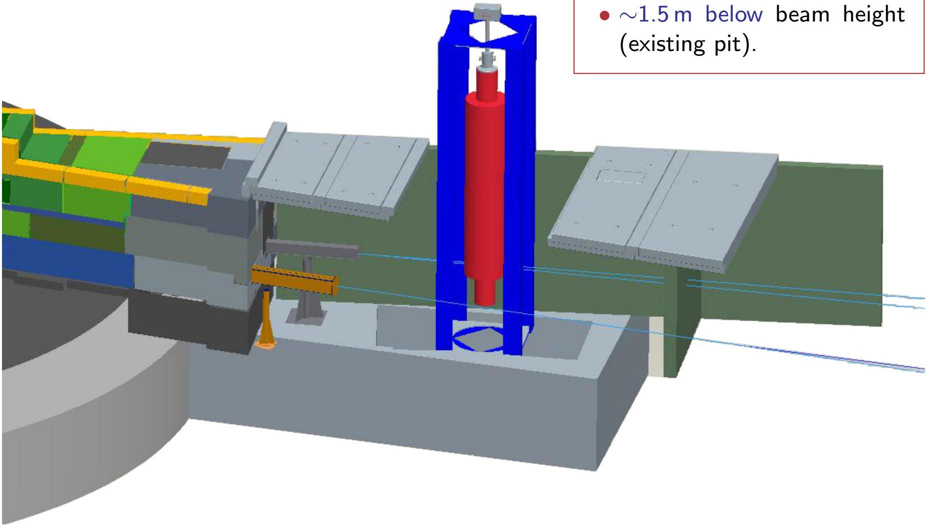
$$\boxed{\sin\theta_{pB} \propto \sqrt{B}} .$$



Nab apparatus in FnPB

Apparatus extends:

- ~6 m above beam height,
- ~1.5 m below beam height (existing pit).

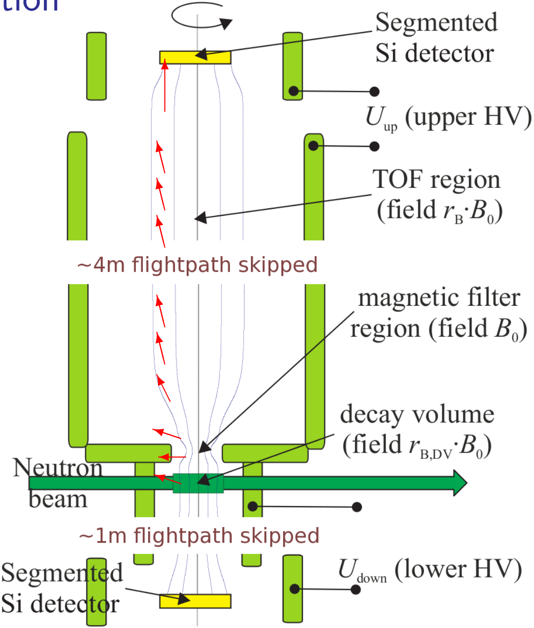


Nab principles of operation

- Collect and detect both electron and proton from neutron beta decay.
- Measure E_e and TOF_p and reconstruct decay kinematics

Key requirements:

- Magnetic field shape,
- Electrode system,
- Hermeticity,
- Ultra-high vacuum
- Silicon detectors,
- No particle trapping.



Measurement principles: detection function

Proton time of flight in B field:

$$t_{\rm p} = \frac{f(\cos\theta_{\rm p,0})}{p_{\rm p}} \qquad \text{where} \qquad \cos\theta_{\rm p,0} = \left.\frac{\vec{p}_{\rm p0}\cdot\vec{B}}{p_{\rm p0}B}\right|_{\text{decay pt.}} \quad .$$

For an adiabatically expanding field prior to acceleration,

$$f(\cos\theta_{\rm p,0}) = \int_{z_0}^{l} \frac{m_{\rm p}\,dz}{\cos\theta_{\rm p}(z)} = \int_{z_0}^{l} \frac{m_{\rm p}\,dz}{\sqrt{1-\frac{B(z)}{B_0}\sin^2\theta_{\rm p,0}}} \,.$$

To this we add effects of magnetic reflections and, also, of electric field acceleration.

Key requirements on the detection function

The proton momentum distribution for $E_\mathrm{e} = \mathrm{const.}$ within the phase space bounds is given by

$$P_p(p_\mathrm{p}^2) = \kappa_1 + \kappa_2 a p_\mathrm{p}^2 \,, \qquad [\text{recall: } \cos\theta_{e\nu} = f(p_\mathrm{p}^2)]$$

while

$$P_t\left(\frac{1}{t_\mathrm{p}^2}\right) = \int P_p(p_\mathrm{p}^2)\, \Phi\left(\frac{1}{t_\mathrm{p}^2}, p_\mathrm{p}^2\right) dp_\mathrm{p}^2 \,.$$

Detection function Φ relates the proton momentum and time-of-flight distributions!

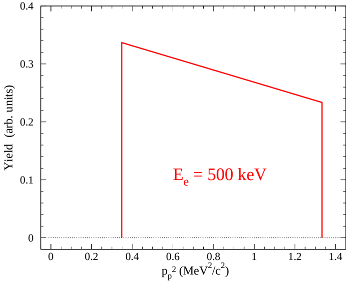
To extract **a** reliably:

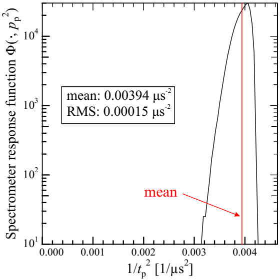
- Φ must be as narrow as possible,
- Φ must be understood precisely.

⇒ (near-)adiabaticity in spectrometer design.

Spectrometer optimization: detection function

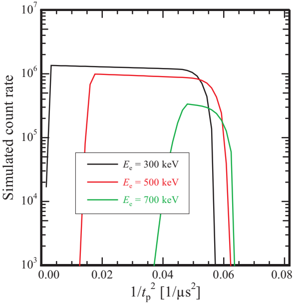
kine-
matic
input

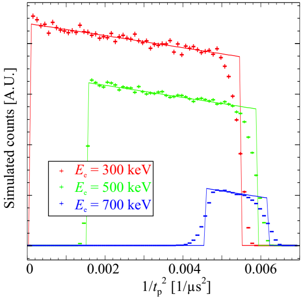




E_p = 500 eV

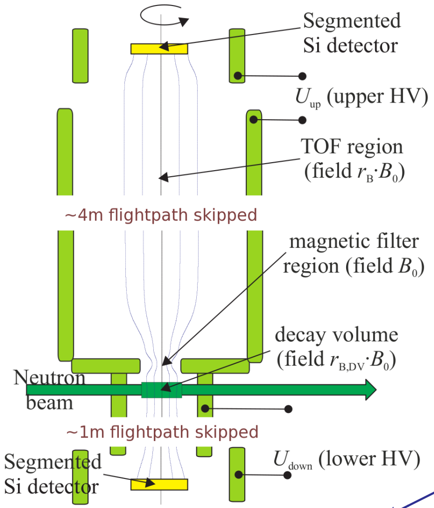
analyt.
calcul'n





MC
GEANT
simul'n

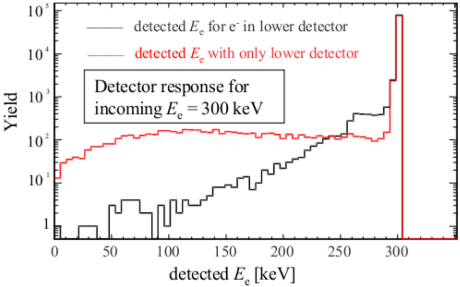
E_e measurement optimization (backscattering)

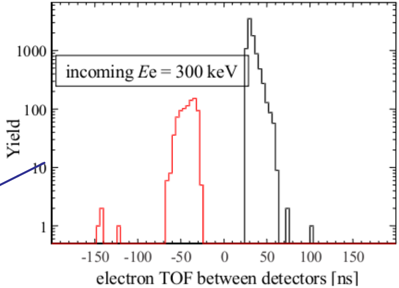


~4m flightpath skipped

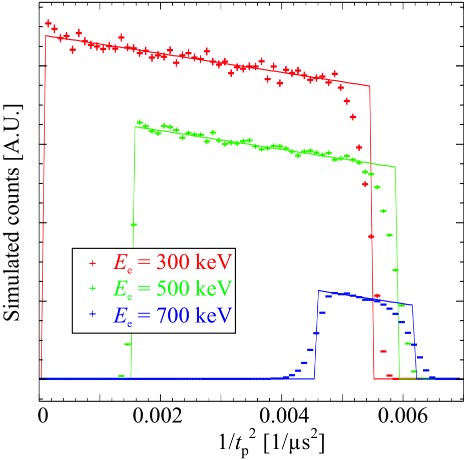
~1m flightpath skipped

$\Delta t \leq 20\,\text{ns}$ required



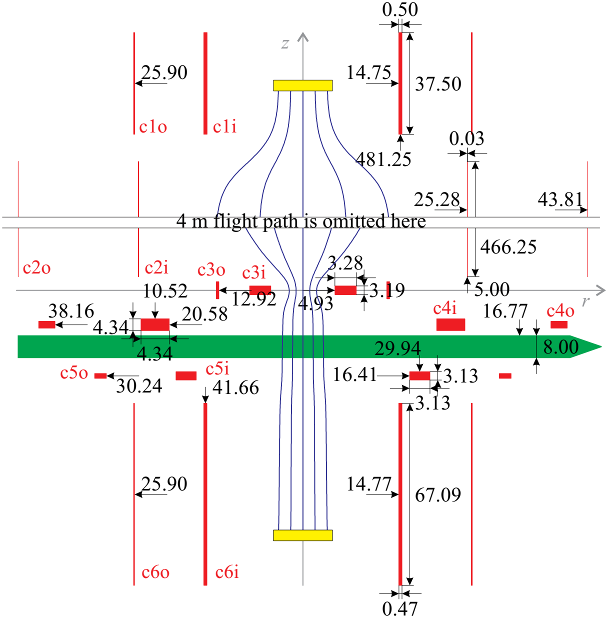


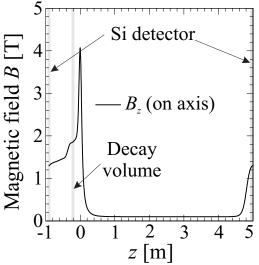
Analysis strategy

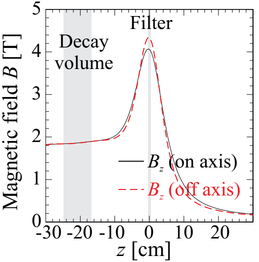


- Use edges to determine and verify shape of detection function $\Phi(p_p, 1/t_p)$;
- Use central part of $P_t(1/t_p^2)$ ($\sim 70\%$) to extract **a**.

Spectrometer Coil design and $\vec{B}$ field profile



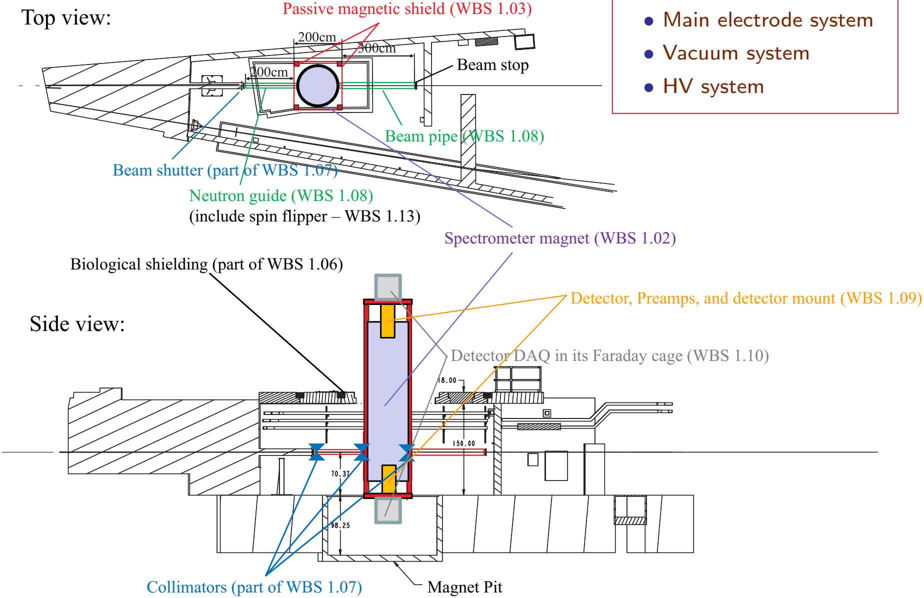




Key components of the Nab apparatus:

Not shown in figure:

- Main electrode system
- Vacuum system
- HV system



Top view:

Passive magnetic shield (WBS 1.03)

Beam stop

Beam pipe (WBS 1.08)

Beam shutter (part of WBS 1.07)

Neutron guide (WBS 1.08)
(include spin flipper – WBS 1.13)

Spectrometer magnet (WBS 1.02)

Biological shielding (part of WBS 1.06)

Side view:

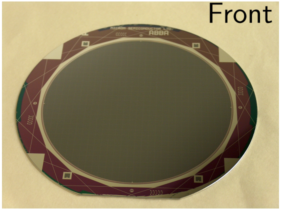
Detector, Preamps, and detector mount (WBS 1.09)

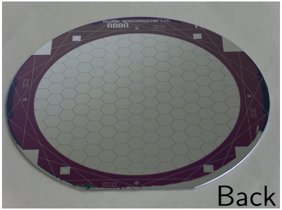
Detector DAQ in its Faraday cage (WBS 1.10)

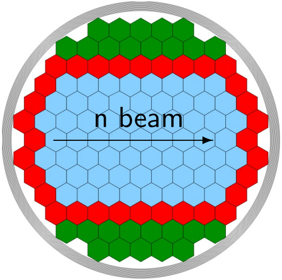
Collimators (part of WBS 1.07)

Magnet Pit

Si detector prototypes (15 cm diameter)







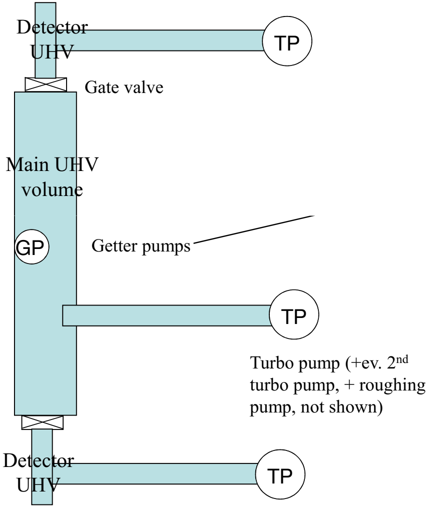
LANL group has full-size prototypes from Micron Corp.
Full thickness $\mathbf{t} = \mathbf{2}\,\mathrm{mm}$; dead layer thickness $\mathbf{t_d} \leq \mathbf{100}\,\mathrm{nm}$.

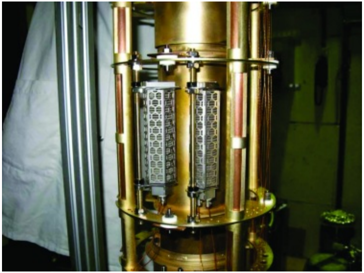
Key properties:

- hermeticity preserved with Si detectors,
- beam imaged (p–e correlated in ≤ 7 pixels),
- detect protons down to ∼15 keV.

Further detailed testing currently under way at LANL.

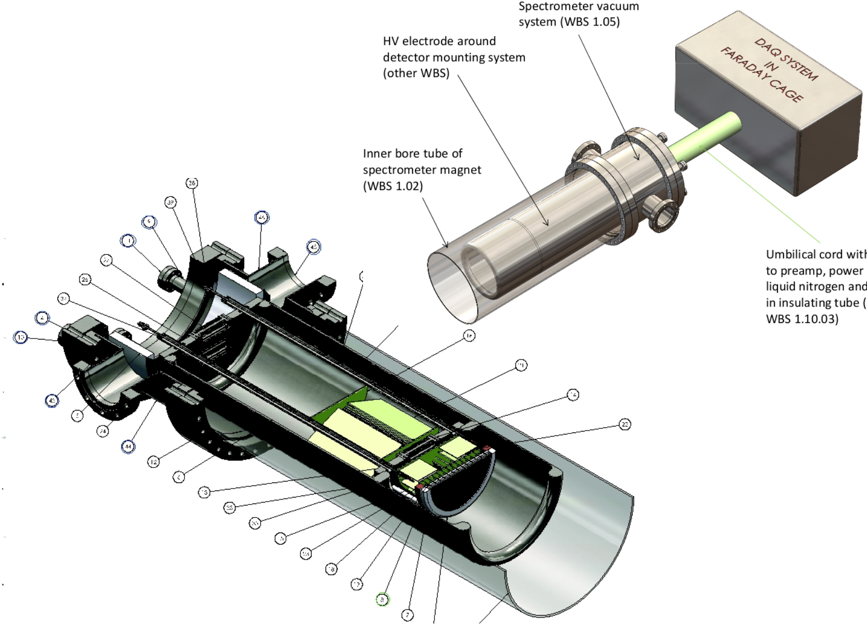
Nab electrode and vacuum system





- Must be well integrated with rest of spectrometer,
- $P_{\text{res.gas}} < 10^{-8}$ Torr, to avoid scattering, HV discharges,
- Three sets of pumps: external turbos, cold bore, internal getter,
- Electrode coatings — sensitive issue (more below)

Electrode, detector and readout package



Spectrometer vacuum system (WBS 1.05)

HV electrode around detector mounting system (other WBS)

Inner bore tube of spectrometer magnet (WBS 1.02)

Umbilical cord with cables to preamp, power cables, liquid nitrogen and gas lines in insulating tube (part of WBS 1.10.03)

Statistical uncertainties for **a** and **b**

Statistical uncertainties for **a**

$E_{\mathrm{e,min}}$	0	100 keV	100 keV	300 keV
$t_{\mathrm{p,max}}$	–	–	100 μs	40 μs
$\sigma_{\mathbf{a}}$	$2.4/\sqrt{N}$	$2.5/\sqrt{N}$	$2.5/\sqrt{N}$	$2.5/\sqrt{N}$
$\sigma_{\mathbf{a}}{}^{\dagger}$	$2.5/\sqrt{N}$	$2.6/\sqrt{N}$	$2.6/\sqrt{N}$	$2.7/\sqrt{N}$
$\sigma_{\mathbf{a}}{}^{\S}$	$4.1/\sqrt{N}$	$4.1/\sqrt{N}$	$4.1/\sqrt{N}$	$4.1/\sqrt{N}$

† with $\mathbf{E}_{\mathrm{calib}}$ and $\mathbf{L}_{\mathrm{TOF}}$ variable; § using inner 70% of $\mathbf{p}_{\mathbf{p}}^{\mathbf{2}}$ data.

Statistical uncertainties for **b**

$E_{\mathrm{e,min}}$	0	100 keV	200 keV	300 keV
$\sigma_{\mathbf{b}}$	$7.5/\sqrt{N}$	$10.1/\sqrt{N}$	$15.6/\sqrt{N}$	$26.3/\sqrt{N}$
$\sigma_{\mathbf{b}}{}^{\dagger\dagger}$	$7.7/\sqrt{N}$	$10.3/\sqrt{N}$	$16.3/\sqrt{N}$	$27.7/\sqrt{N}$

†† with $\mathbf{E}_{\mathrm{calib}}$ variable.

Nab event rates, statistics and running times

Nab expects data rates of about 600 evts./s.
In a typical ∼10-day run of 7×10^5 s of net beam time we would achieve

$$\frac{\boldsymbol{\sigma}_{\mathbf{a}}}{\mathbf{a}} \simeq \mathbf{2 \times 10^{-3}} \qquad \text{and} \qquad \boldsymbol{\sigma}_{\mathbf{b}} \simeq \mathbf{6 \times 10^{-4}}$$

We plan to collect samples of $1 - 2 \times 10^9$ events in several 6–8-week runs.

Overall accuracy will **not be statistics-limited**.

Analysis methods to be used:

A. parametrize edges and width of $\Phi(p_{\rm p}, 1/t_{\rm p})$ by fitting; use central part of Φ ($\sim$ 70%) to extract **a** in a multiparameter fit, and

B. specify all possible parameters of Φ by direct measurement; ⇒ treat **a**, $\boldsymbol{\mu} = \overline{\mathbf{1/t_p^2}}\mathbf{(p_p)}$, and $\mathbf{N_{decays}}$ as free parameters in a two-step fitting procedure,

- as well as a hybrid of the two methods.

Nab systematic uncertainties: Method B

Experimental parameter		$(\Delta a/a)_{\mathrm{SYST}}$
Magnetic field:	curvature at pinch	5×10^{-4}
	ratio $r_\mathrm{B} = B_\mathrm{TOF}/B_0$	2.5×10^{-4}
	ratio $r_\mathrm{B,DV} = B_\mathrm{DV}/B_0$	3×10^{-4}
L_TOF, length of TOF region		(*)
U inhomogeneity:	in decay / filter region	5×10^{-4}
	in TOF region	1×10^{-4}
Neutron Beam:	position	4×10^{-4}
	width	2.5×10^{-4}
	Doppler effect	small
	unwanted beam polarization	small
Adiabaticity of proton motion		1×10^{-4}
Detector effects:	E_e calibration	(*)
	E_e resolution	5×10^{-4}
	Proton trigger efficiency	2.5×10^{-4}
Accidental coincidences		small
Residual gas		small
Background		small
Sum		1×10^{-3}

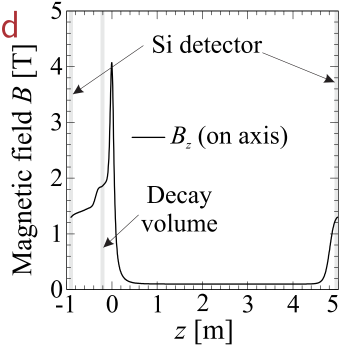
(*) Free fit parameter

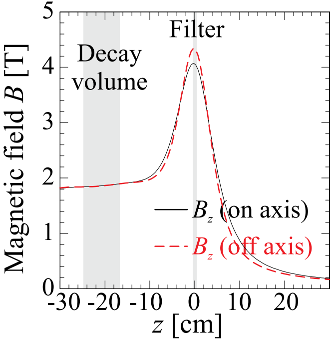
Systematic uncertainty budget: $\vec{B}$ field

Experimental parameter	$(\Delta a/a)_{\mathrm{SYST}}$
Magnetic field:	
…curvature at pinch	5×10^{-4}
…ratio $r_B = B_{\mathrm{TOF}}/B_0$	2.5×10^{-4}
…ratio $r_{B,\mathrm{DV}} = B_{\mathrm{DV}}/B_0$	3×10^{-4}
Sum	1×10^{-3}

Steps:

1. Measure field map (relative measurement).
2. Determine position of electron and proton flux tubes in field map.





Systematic uncertainty budget: Electrostatic potential

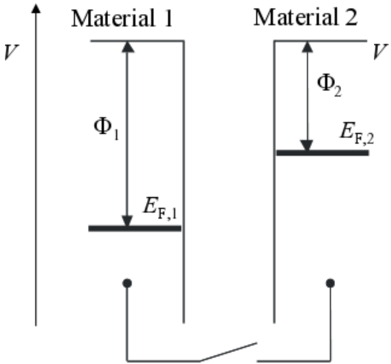
Experimental parameter	$(\Delta a/a)_{\mathrm{SYST}}$
El. pot. inhomogeneity:	
. . . in decay vol./filter reg.	5×10^{-4}
. . . in TOF region	1×10^{-4}
Sum	1×10^{-3}

Key specification:

Electrostatic potential fluctuations in decay volume and filter region

$$\boxed{\Delta U < 10\,\mathrm{mV}}\,.$$

Different metals: $\Delta U \sim 1\,\mathrm{V}$.
Different crystal orient.: $\Delta U \sim 300\,\mathrm{mV}$.



Systematic uncertainty budget: Adiabaticity

Experimental parameter	$(\Delta a/a)_{\mathrm{SYST}}$
Adiabaticity of proton motion	1×10^{-4}
Sum	1×10^{-3}

Adiabatic approximation fails for lower overall $\vec{B}$, with these consequences:

- proton TOF is changed,
- proton passage through filter field not according to expectations, i.e.,
- detection function Φ not as well described analytically.

Effects of B field scaling:

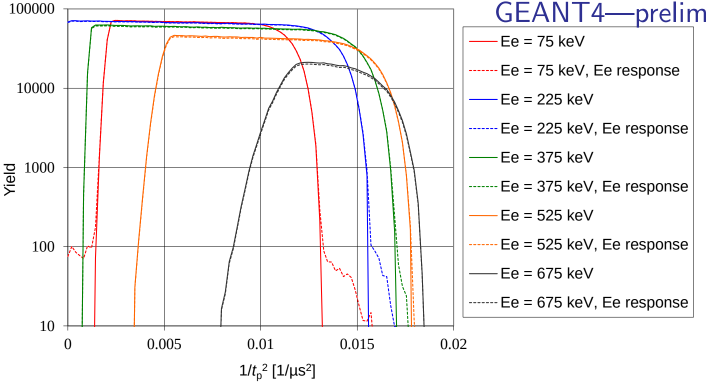
B scale factor	**0.2**	**0.3**	**0.5**	**0.7**	**2**
$\Delta(1/t_\mathrm{p}^2)$	-0.40%	-0.10%	$-1.6 \cdot 10^{-4}$	$-4 \cdot 10^{-5}$	$8 \cdot 10^{-5}$
Protons lost	0.70%	0.40%	0.15%	$6 \cdot 10^{-4}$	$-5 \cdot 10^{-4}$
$\Delta a/a$	-4.7%	-1.0%	-0.2%	$-5 \cdot 10^{-4}$	$4 \cdot 10^{-4}$
$\Delta\langle\cos\theta_0\rangle$	$5 \cdot 10^{-4}$	$2 \cdot 10^{-4}$	$6 \cdot 10^{-4}$	negligible	negligible

⇒ Considerable flexibility in scaling of B remains!

Systematic uncertainty budget: E_{e} resolution

Experimental parameter	$(\Delta a/a)_{\mathrm{SYST}}$
Electron energy resolution	1×10^{-4}
Sum	1×10^{-3}

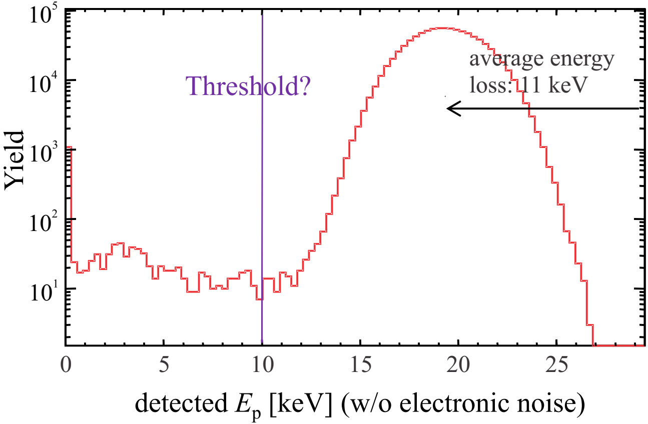
Uncertainty on a is based on a 1% determination of electron energy response.


GEANT4—preliminary!

Systematic uncertainty budget: Proton trigger efficiency

Experimental parameter	$(\Delta a/a)_{\mathrm{SYST}}$
Proton trigger efficiency	2.5×10^{-4}
Sum	1×10^{-3}

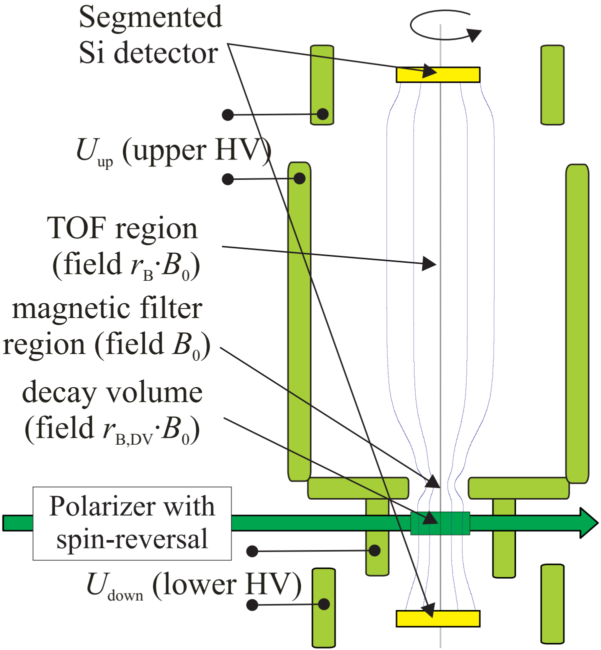
Uncertainty in a is based on a 10 keV threshold and measurement of efficiency slope of 50%.



Remarks on the Polarized Program

abBA/PANDA configuration:

- A: detect electrons in upper, protons in lower detector;
- B/C: detect protons in upper, electrons in lower detector;



abBA/PANDA rates and statistical uncertainties

Additions to Nab apparatus: (supermirror) polarizers

Event rates:

$$\text{decays in DV:} \quad \mathbf{n_d = \frac{dN_d}{dt} \simeq 250\,s^{-1}}\,, \quad \text{and}$$

$$\text{e's in UD:} \quad \mathbf{n_{eU} = \frac{dN_{eU}}{dt} \simeq 30\,s^{-1}}\,.$$

(He-3 polarizers may give higher rates.)

$\mathbf{E_e}$ lower cutoff (keV)	none	100	200	250
$\boldsymbol{\sigma_A}$ (symm., 2 det's)	$\mathbf{2.7/\sqrt{N_d}}$	$\mathbf{2.9/\sqrt{N_d}}$	$\mathbf{4.8/\sqrt{N_d}}$	$\mathbf{7.4/\sqrt{N_d}}$
$\boldsymbol{\sigma_A}$ (asymm., 1 det.)	$\mathbf{4.3/\sqrt{N_d}}$	$\mathbf{4.8/\sqrt{N_d}}$	$\mathbf{7.8/\sqrt{N_d}}$	$\mathbf{11.9/\sqrt{N_d}}$

To reach $\mathbf{\Delta A/A = 1 \times 10^{-3}}$ we need $\mathbf{N_d = 1.7 \times 10^9}$ or **75 live days**.

abBA/PANDA systematic uncertainties

Experimental parameter		$(\Delta A/A)_{\mathrm{SYST}}$
Neutron Beam:	position	not relevant
	profile & edge effect	small
	Doppler effect	small
	polarization	$\leq 1 \times 10^{-3}$
U inhomogeneity:		small
Detector effects:	E_e calibration	2×10^{-4}
	Trigger efficiency	small
Accidental coincidences		small
Residual gas		small
Background		small
Sum		under study

Key points about Nab

- Nab offers an alternative way to access $\boldsymbol{\lambda = g_A/g_V}$ with competitive precision,
- makes full use of phase space information available,
- coincident measurement technique provides high level of background suppression,
- not statistics–limited,
- polarized program (abBA/PANDA) is a natural and highly competitive continuation,
- can run at both FnPB/SNS and NG-C/NIST.
- funded!

The 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], T.E. Chupp[13], V. Cianciolo[3], C. Crawford[6], E. Frlež[2], M.T. Gericke[7], F. Glück[8], G.L. Greene[3,9], R.K. Grzywacz[9], V. Gudkov[10], F.W. Hersman[5], A. Klein[11], M. Lehman[2§], 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[14].

[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] Univ. of Michigan
[14] North Carolina State Univ.

[†] Co-spokesmen
[*] Experiment Manager
[‡] On-site Manager
[§] Graduate Students

Home page: http://nab.phys.virginia.edu/