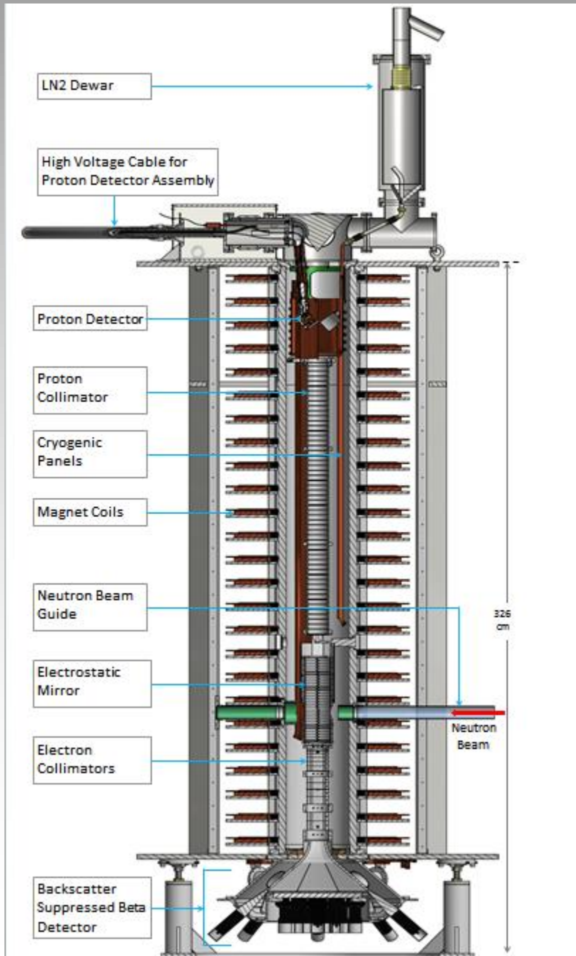
A Measurement of the Electron-Antineutrino Correlation in Free Neutron Beta Decay (aCORN)

Alexander Komives
DePauw University
for the
aCORN Collaboration



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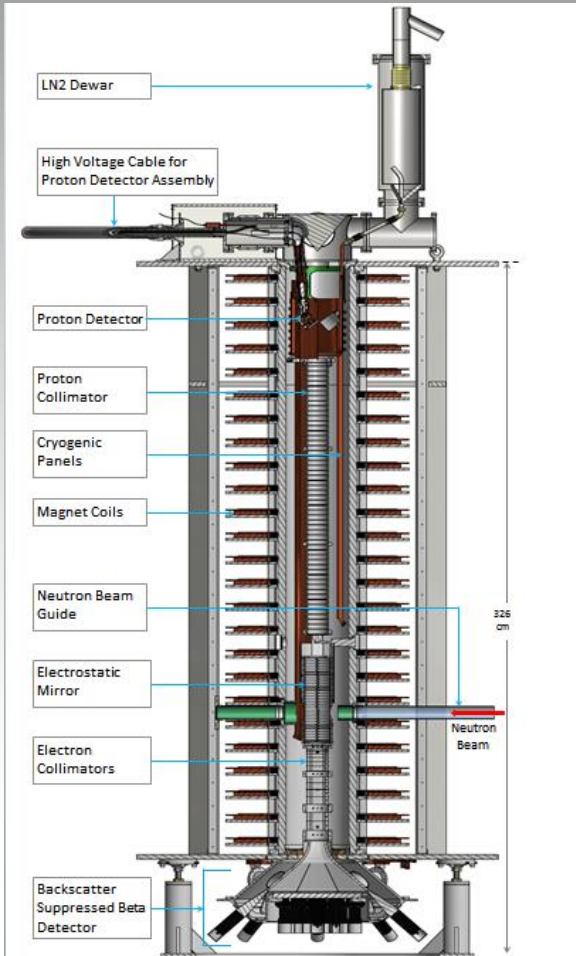
A Measurement of the Electron-Antineutrino Correlation in Free Neutron Beta Decay

- Motivations
- Method/Apparatus
- Analysis
- Systematics
- PRELIMINARY Result



Neutron Decay Correlation Coefficients

$$N \propto \frac{1}{\tau_n} E_e|\vec{p}_e|(Q-E_e)^2\left[1+a\frac{\vec{p}_e\cdot\vec{p}_\nu}{E_eE_\nu}+\vec{\sigma}\cdot\left(A\frac{\vec{p}_e}{E_e}+B\frac{\vec{p}_\nu}{E_\nu}+D\frac{(\vec{p}_e\times\vec{p}_\nu)}{E_eE_\nu}\right)\right]$$

From the Standard Electroweak Model ($\lambda = g_A/g_V$):

$$\tau_n = \left(\frac{2\pi^3\hbar^7}{m_e^{\,5}c^4 f}\right)\frac{1}{G_V^{\,2}+3G_A^{\,2}}$$

$$\tau_n = 880.3 \pm 1.1$$ seconds

$$A = -2\frac{\mathrm{Re}\{\lambda\}+\lambda^2}{1+3\lambda^2}$$

$$A = -0.1184 \pm 0.0010$$

$$B = -2\frac{\mathrm{Re}\{\lambda\}-\lambda^2}{1+3\lambda^2}$$

$$B = 0.9807 \pm 0.0030$$

$$a = \frac{1-\lambda^2}{1+3\lambda^2}$$

$$a = -0.103 \pm 0.004$$

values from K.A. Olive *et al.* (Particle Data Group) Chin. Phys. C, **38**, 090001 (2014) and 2015 update.

Test of the Standard Model

(within framework of V-A interaction
and neglecting terms of recoil order)

$$F_1 = 1 + A - B - a = 0$$

$$F_2 = aB - A - A^2 = 0$$

Using current values:

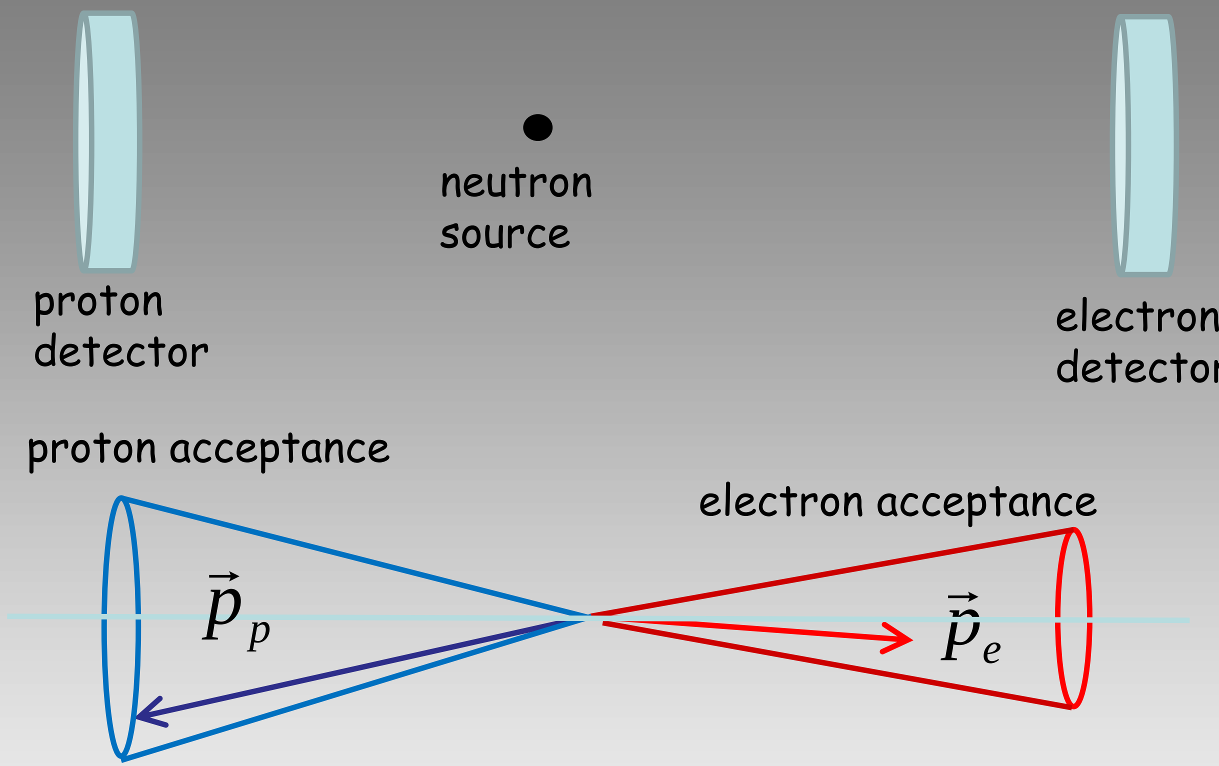
$F_1 = 0.0027 +/- 0.0058$
$F_2 = 0.0023 +/- 0.0041$

errors predominantly due to uncertainty in "a"

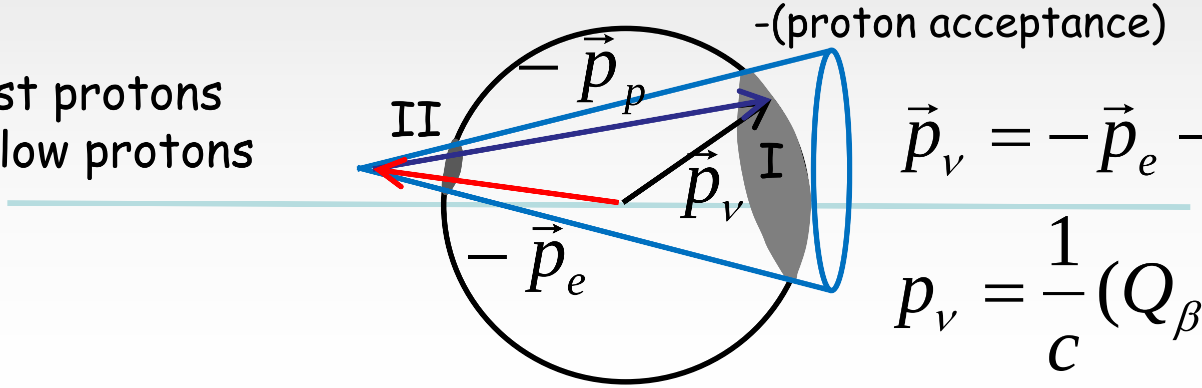
Other Reasons for a Precise (about 1%) Measurement of “a”

- Right-handed currents
- Scalar and Tensor interactions
- Limits on CVC violation and second-class currents
- Unitarity of CKM weak mixing matrix
- Independent measure of λ (g_A/g_V) without complications of polarimetry

aCORN Method



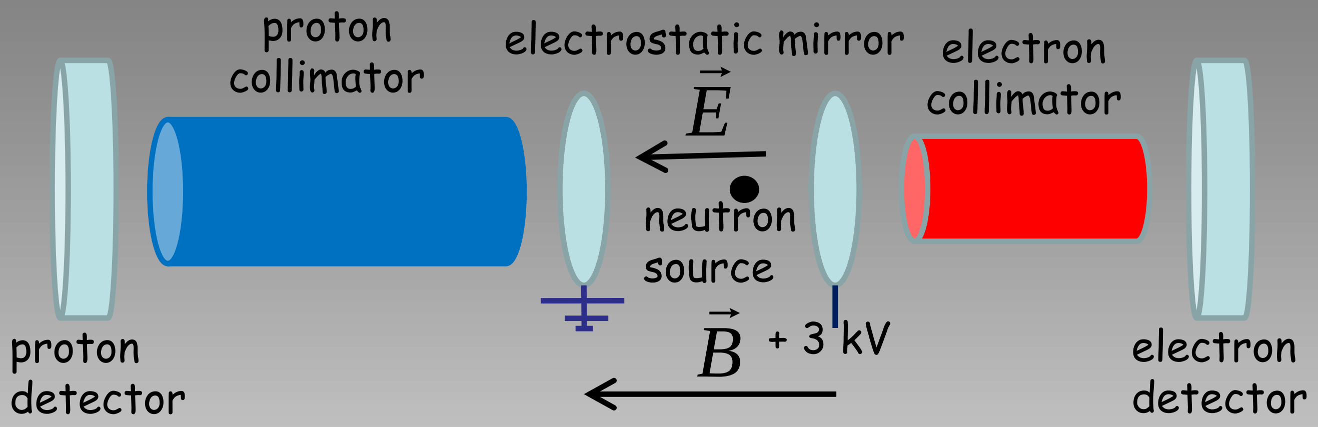
Region I: Fast protons
Region II: Slow protons

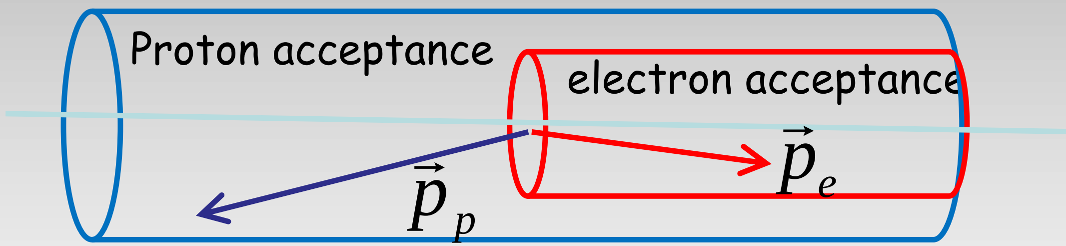


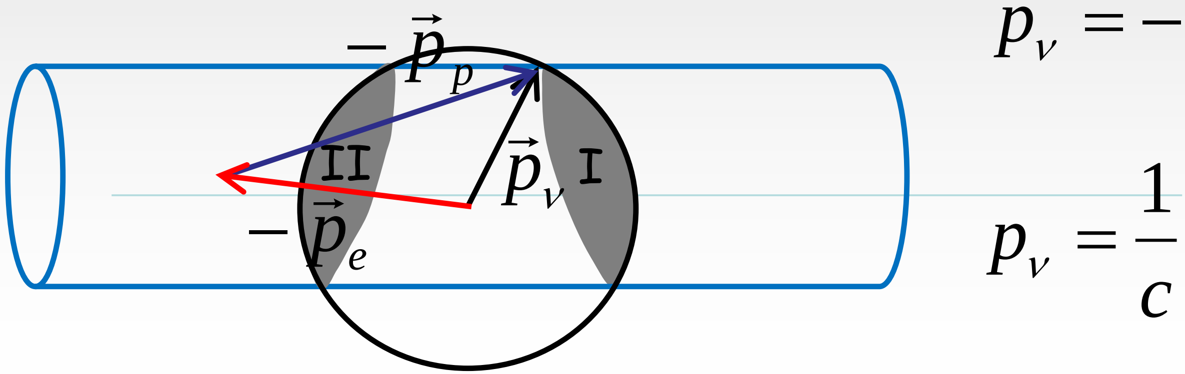
$$\vec{p}_\nu = -\vec{p}_e - \vec{p}_p$$

$$p_\nu = \frac{1}{c}(Q_\beta - E_e)$$

aCORN Method







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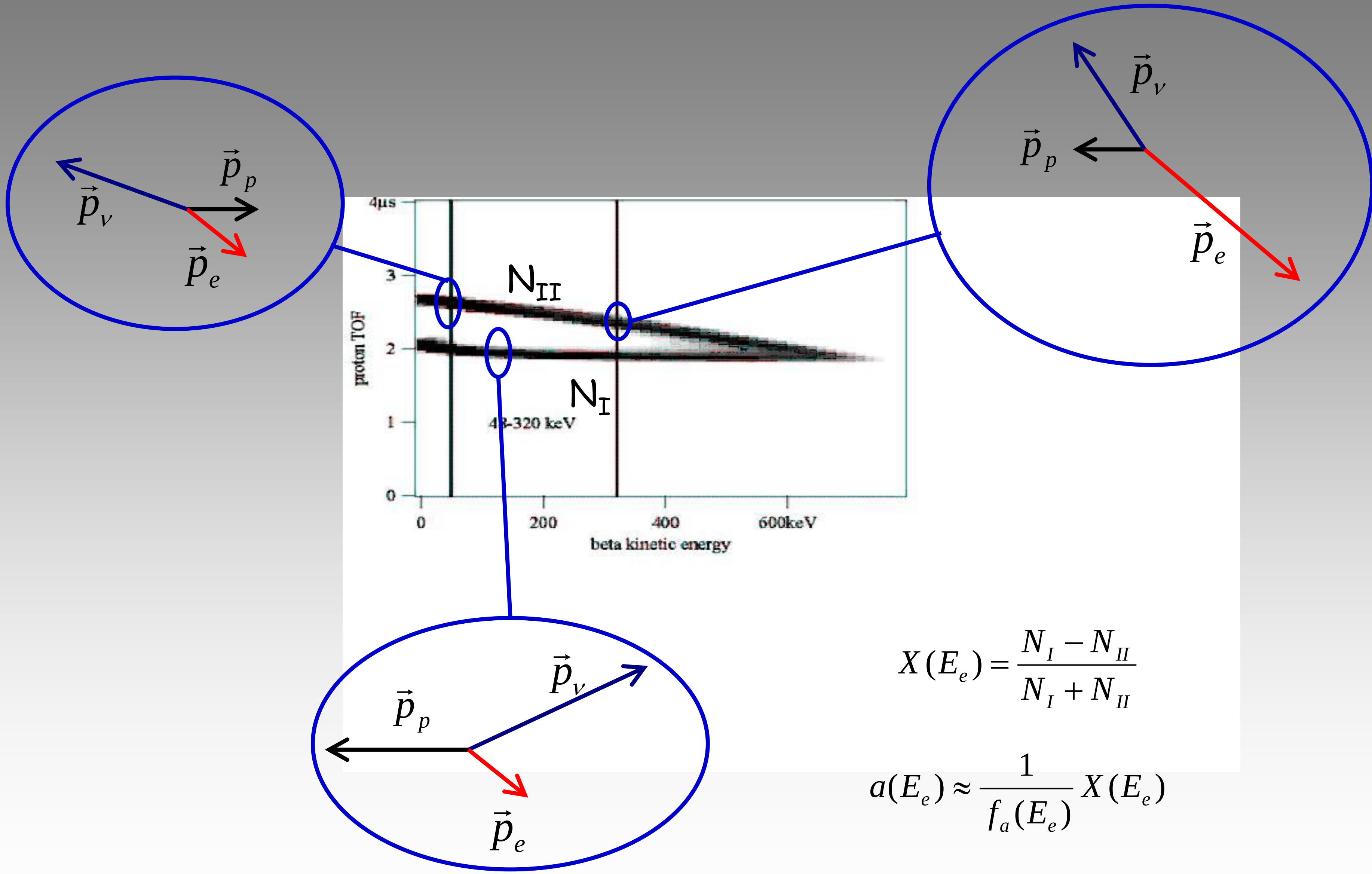
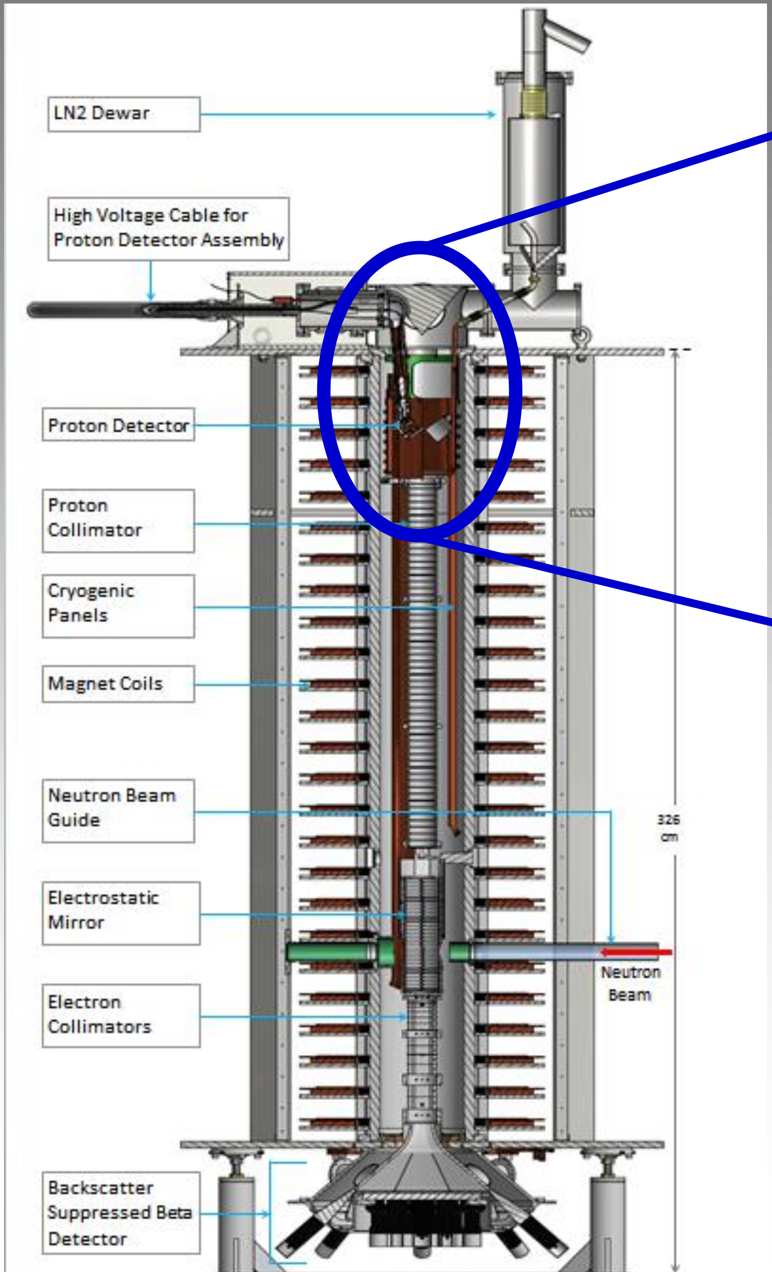
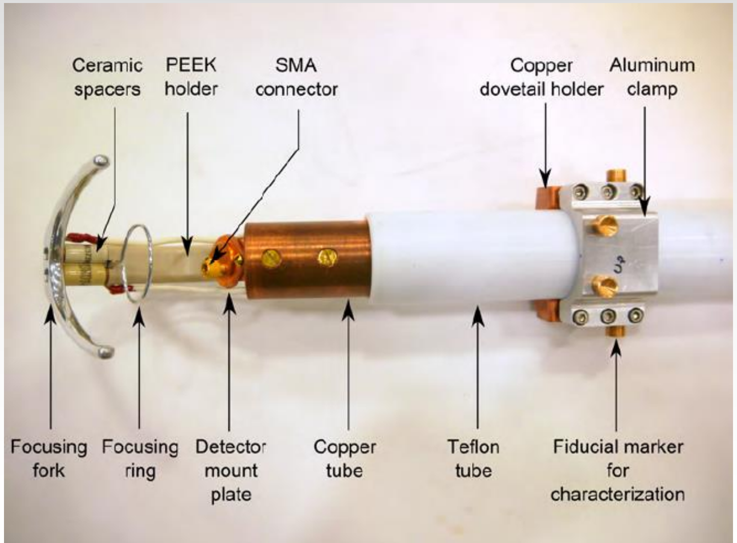


$$X(E_e) = \frac{N_I - N_{II}}{N_I + N_{II}}$$

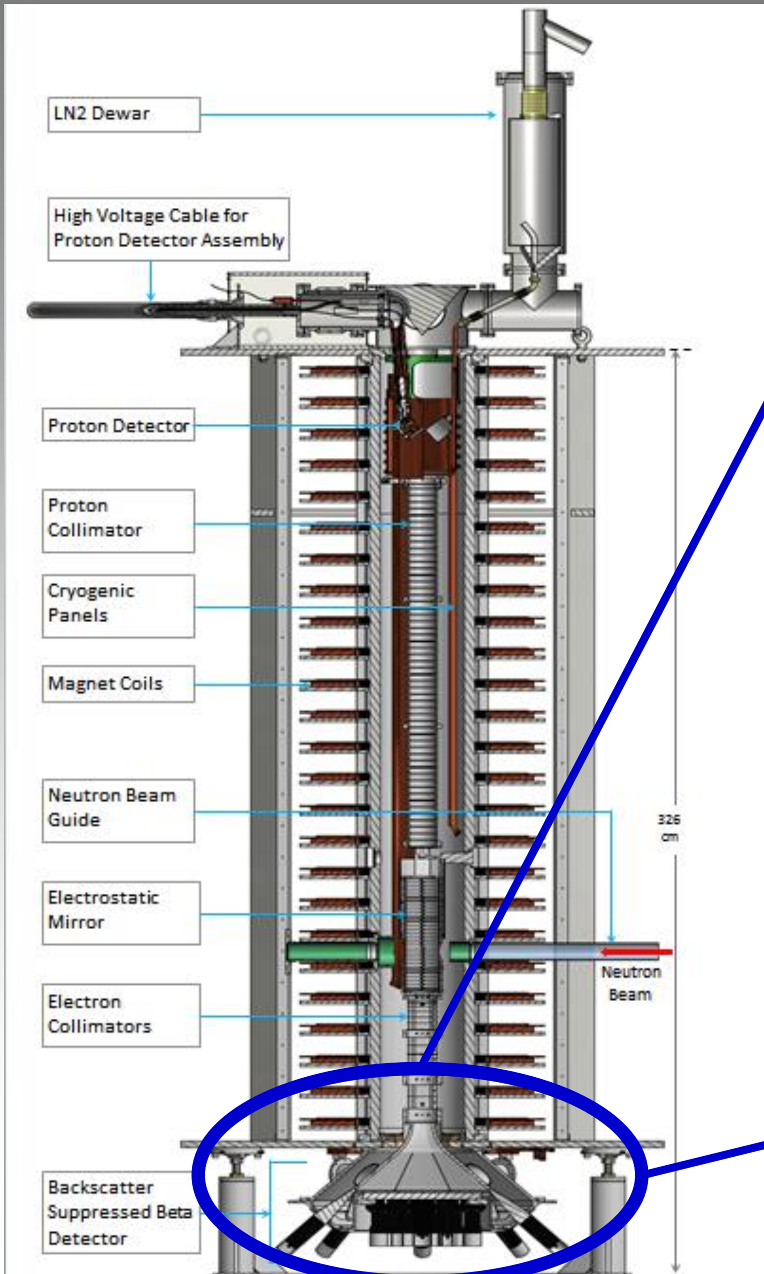
$$a(E_e) \approx \frac{1}{f_a(E_e)} X(E_e)$$

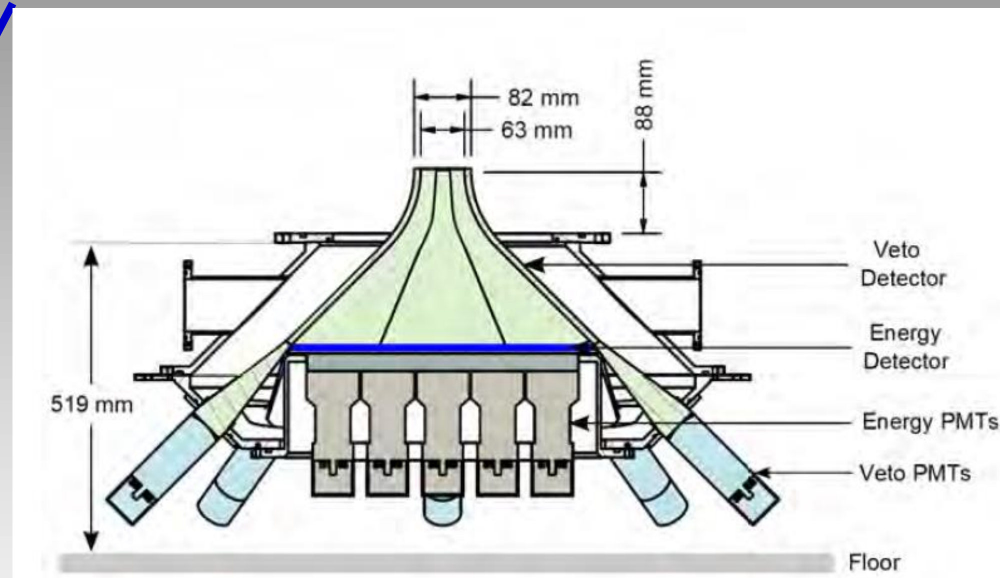
aCORN Apparatus





aCORN Apparatus





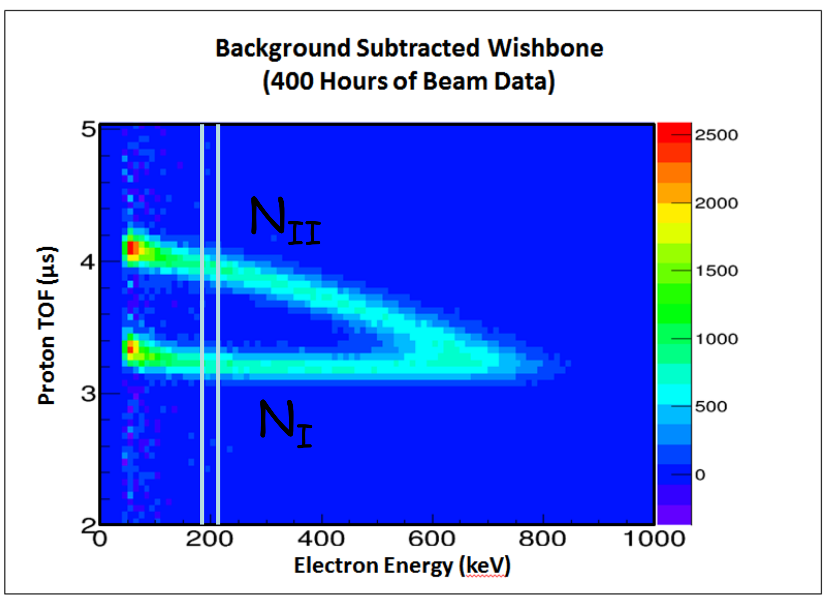
NG-6 Data Set

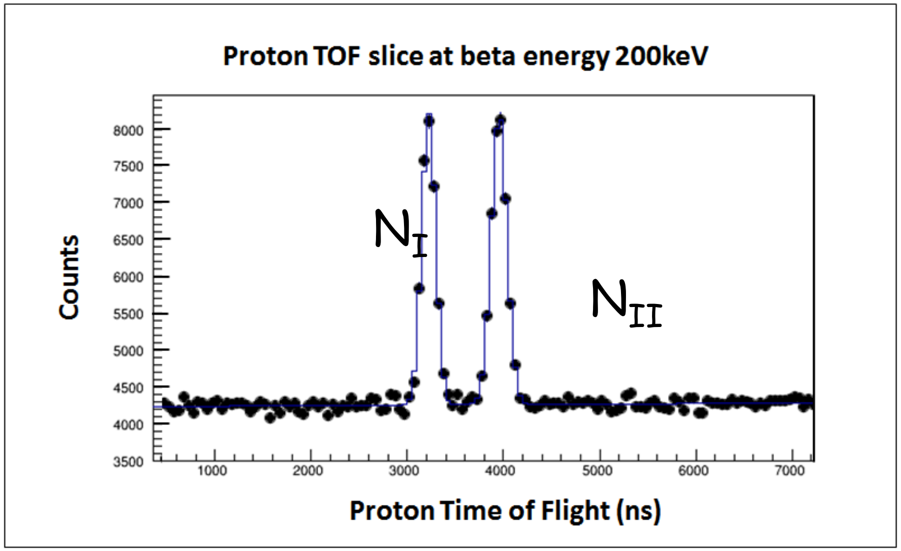
Group	B Field	Time (Hrs)
A	Down	479
B	Up	427
C	Up	420
D	Down	256
E	Down	324

$$N \propto \frac{1}{\tau_n} E_e \left|\vec{p}_e\right| (Q - E_e)^2 \left[1 + a \frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + \vec{\sigma} \cdot \left(A \frac{\vec{p}_e}{E_e} + B \frac{\vec{p}_\nu}{E_\nu} + D \frac{\left(\vec{p}_e \times \vec{p}_\nu\right)}{E_e E_\nu} \right) \right]$$

Data Analysis

- Energy calibrated
- Background subtracted
- Deadtime corrected
- Beta veto events removed
- Electrostatic Mirror correction
- Proton Soft Threshold correction





The Geometric Function $f_a(E_e)$

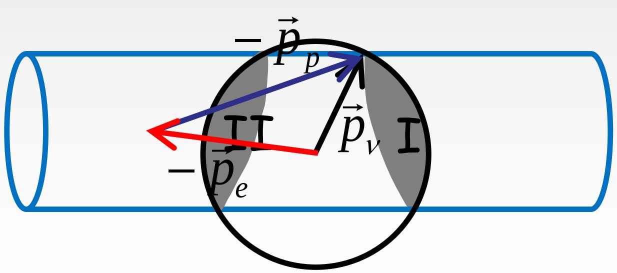
wishbone asymmetry: $X(E_e)=af_a(E_e)$

$$f_a(E_e)=\frac{1}{2}v\left(\phi^I(E_e)-\phi^{II}(E_e)\right)$$

$\phi^I(E_e)$, $\phi^{II}(E_e)$ are the average angle between electron and antineutrino momentum vectors for all momenta within the aCORN acceptance, independent of the beta decay distributions.

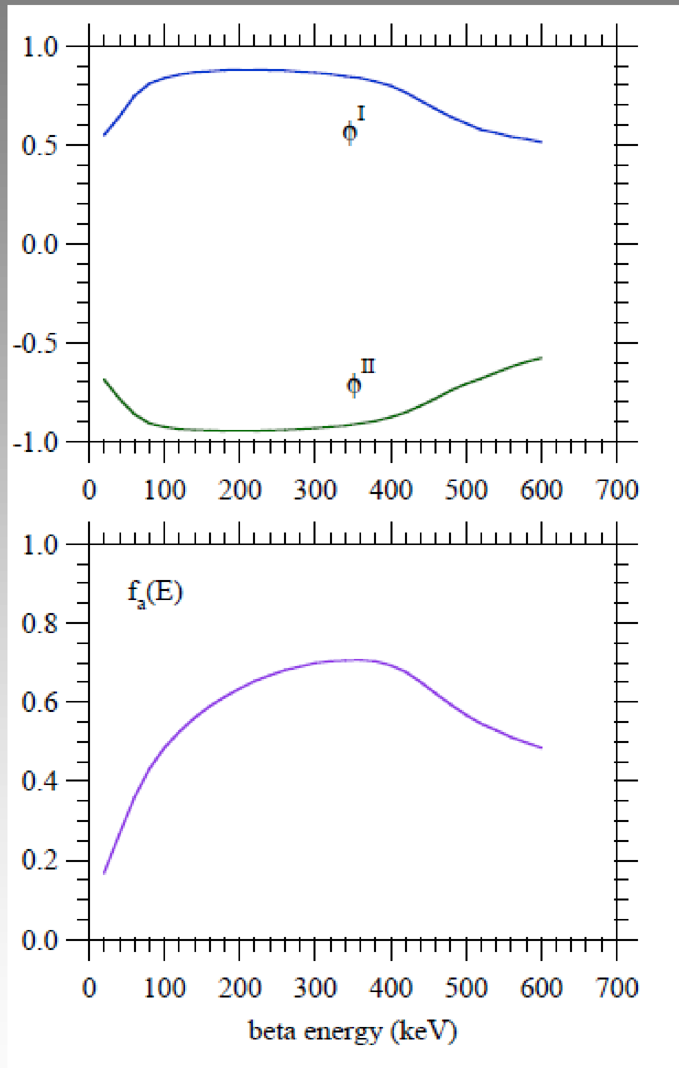
$fa(E_e)$ depends ONLY on:

- magnetic field strength
- collimator geometry
- neutron beam density distribution (weakly)

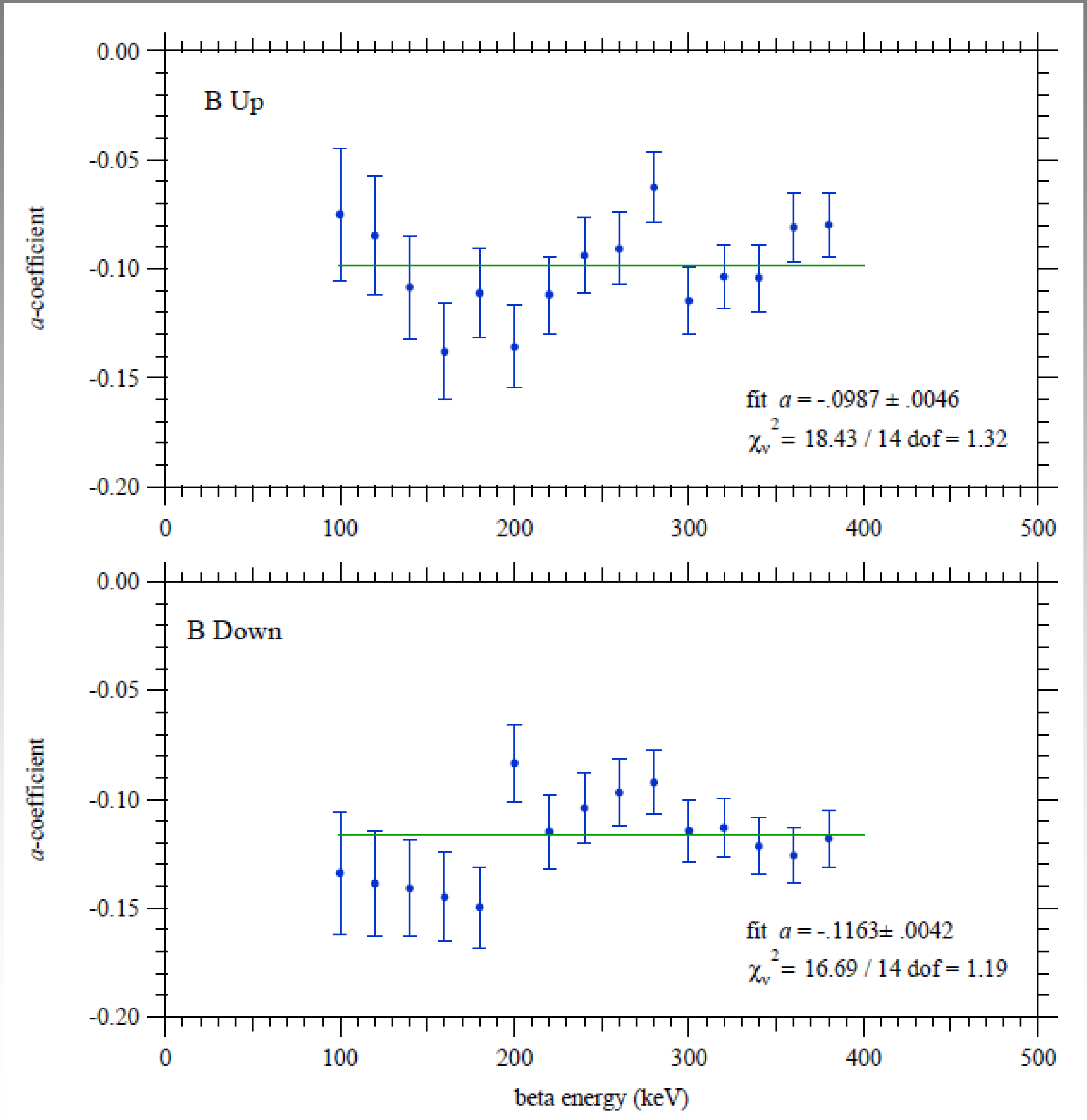


$$\varphi^I(E_e)=\frac{\int d\Omega_e\int_I d\Omega_\nu\cos\theta_{e\nu}}{\Omega_e\Omega_\nu^I}$$

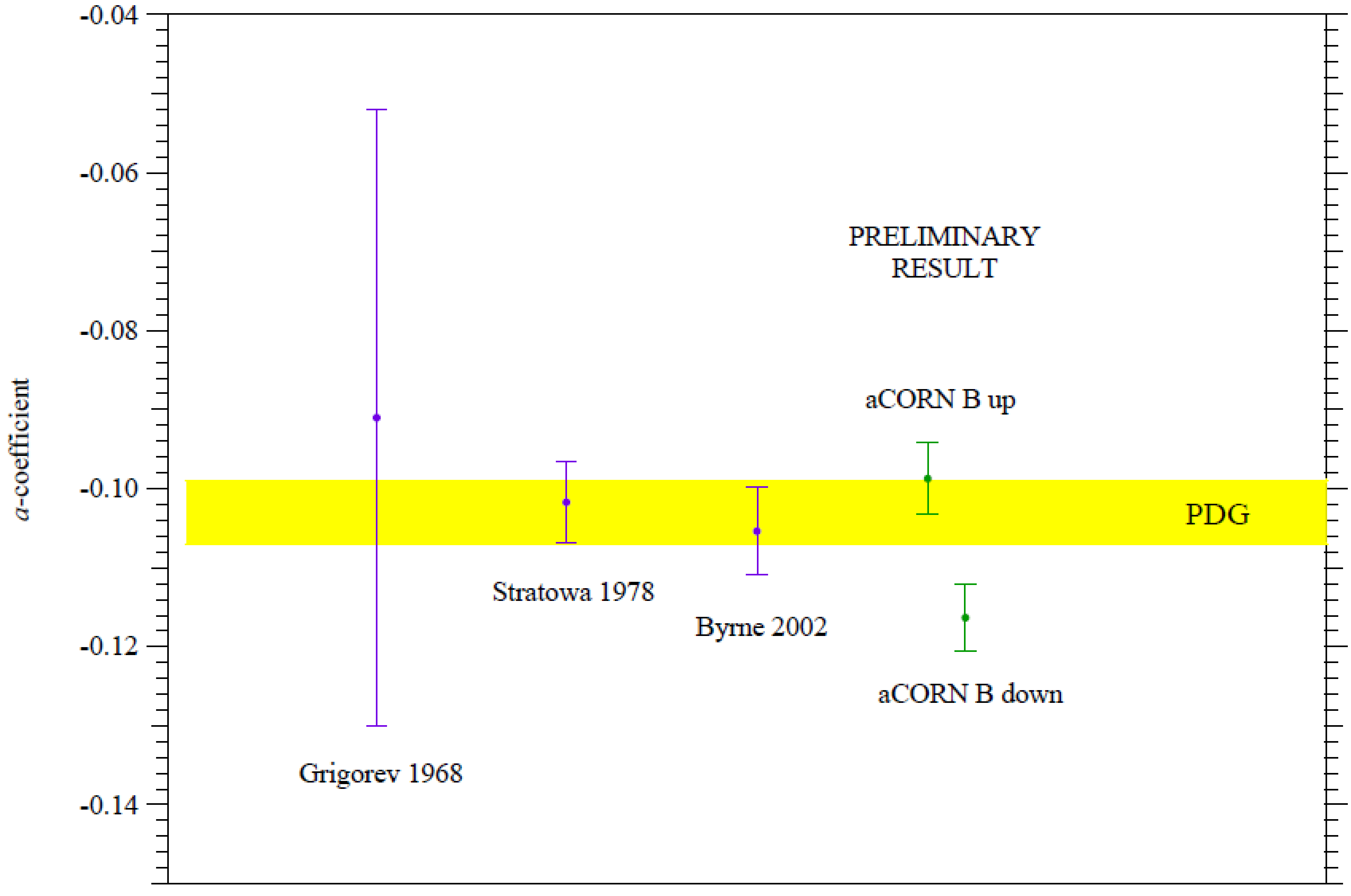
$$\varphi^{II}(E_e)=\frac{\int d\Omega_e\int_{II} d\Omega_\nu\cos\theta_{e\nu}}{\Omega_e\Omega_\nu^{II}}$$



Ratio of $X(E_e)/f_a(E_e)$



Preliminary NG-6 Result



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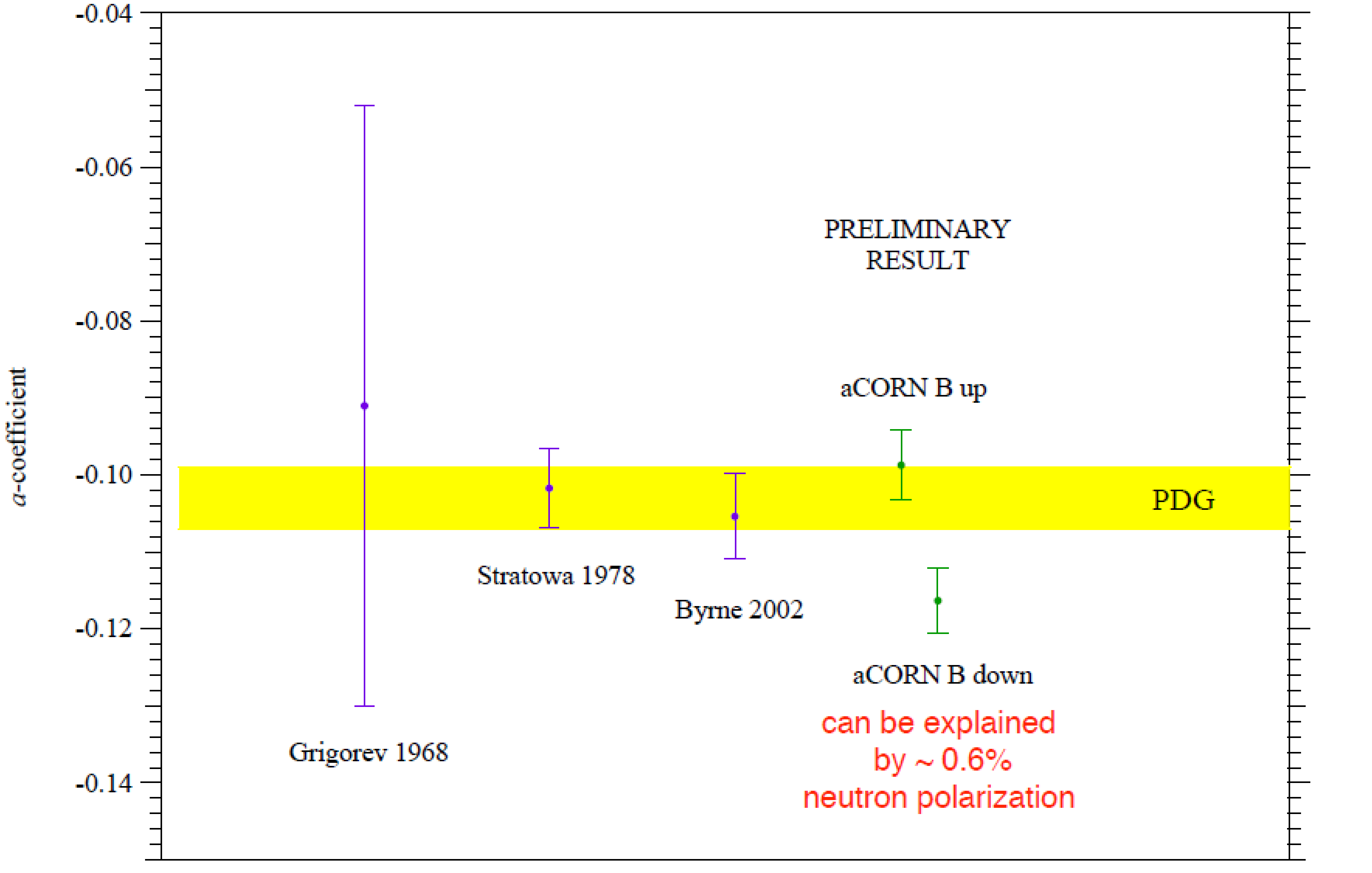
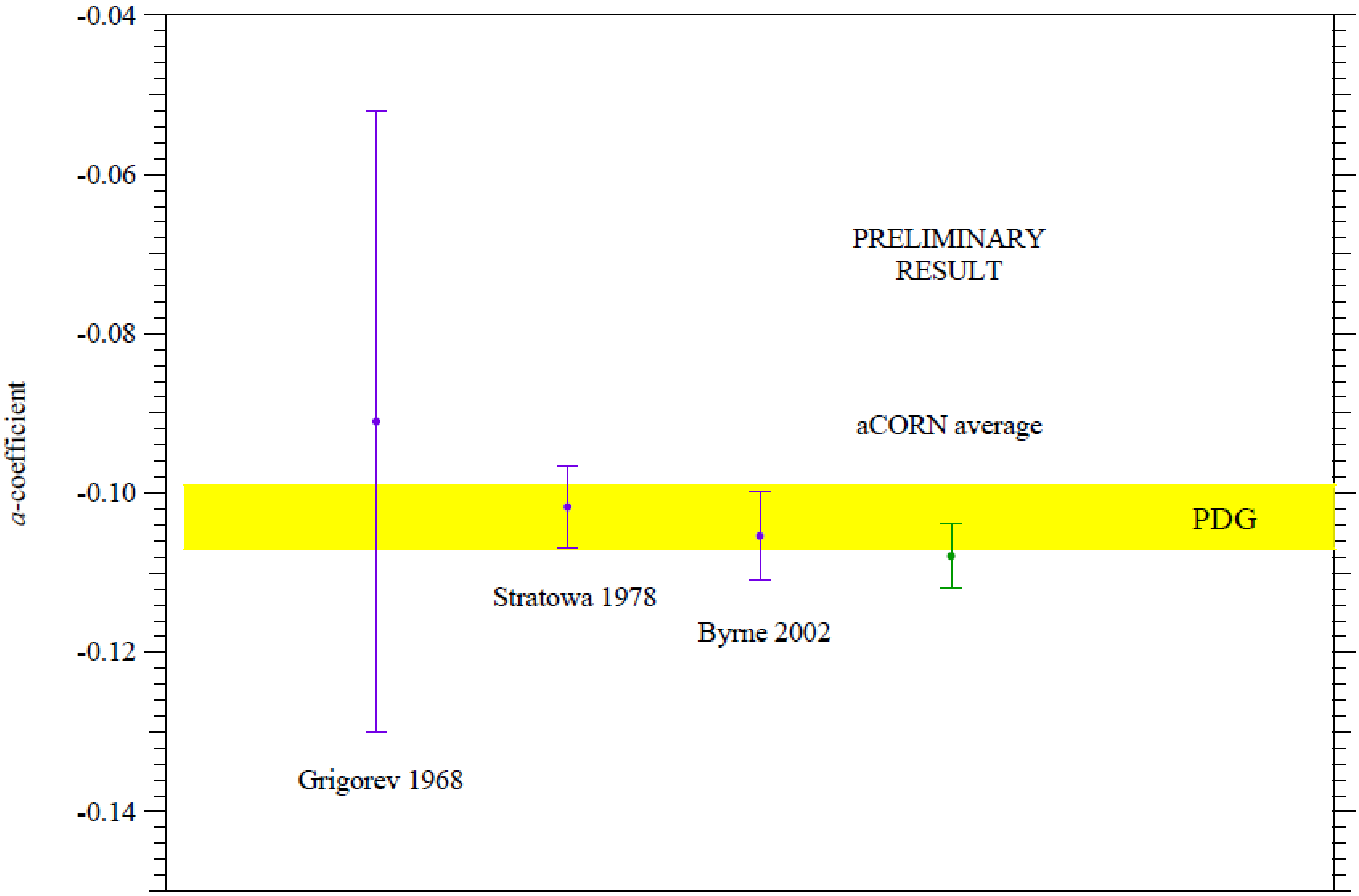


Preliminary NG-6 Result



Preliminary NG-6 Result Error Budget

	"a" correction	"a" σ	relative σ
electrostatic mirror	0.0058	0.0012	0.0113
proton soft threshold	-0.0031	0.0007	0.0066
absolute B field	-0.0001	0.0005	0.0047
B field shape	0.0003	0.0008	0.0076
residual gas	0.0005	0.0005	0.0043
e scattering	-0.0015	0.0015	0.0142
beta spect. energy cal.		0.0003	0.0028
proton collimator alignment		0.0005	0.0046
p scattering	0.0004	0.0005	0.0046
wishbone asymmetry calc.		0.0008	0.0076
total systematic	0.0023	0.0026	0.0241
statistical		0.0030	0.0280
total uncertainty		0.0040	0.0367

$$a = -0.1079 \pm 0.0040$$

aCORN on New NG-C Beamline

- aCORN moved to new NG-C end position at NIST in 2015
- Ran on NG-C from July 2015 to September 2016
- ~ 5x NG-6 wishbone event rate, signal/bkgd similar to NG-6
- Collected a good data set ~ 10 times NG-6
- Improved systematics
- We expect a new result with relative uncertainty < 2%

Conclusions

- 1906 hours of data taken on NG-6
- Initial analysis performed
- Several systematic effects considered
- **PRELIMINARY** result within 4%
- NG-C run just completed with an expected <2% result