Cryotarget needs for E91-004

Parity Violation in ^{4}He at Q^2=0.6 (GeV/c)^2

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This experiment is designed around the determination of the ^{4}He weak form factor (and the resulting strange quark contributions to it) at a specific momentum transfer of Q^2=0.6 (GeV/c)^2. The choice of momentum transfer is the location of the first maximum in the ^{4}He (electromagnetic) charge form factor. It is thus a local maximum in the cross section, leading to both relatively high count rates and a small gradient in the cross section with energy. At this momentum transfer, the parity-violating asymmetry is about 50 ppm. The experiment is entirely statistics limited, so the maximum possible luminosity is critical.

The parity violating asymmetry can be expressed very simply in terms of the helium form factors.

$$A_{PV} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}}\left[4\sin^2\theta_W + \frac{F^s}{F_C}\right]$$

In this expression, F^s is the strange quark contribution to the helium nucleus. At Q^2=0.6 (GeV/c)^2, this is A_{PV} = 49.7 ppm [1 + 100 F^s]. If one assumes a "one-body" approximation for the nuclear structure of ^{4}He (i.e., no contribution to the asymmetry from meson exchange currents), then the asymmetry can be expressed in terms of nucleon form factors as

$$A_{PV} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}}\left[4\sin^2\theta_W + \frac{2G_E^s}{(G_E^p + G_E^n)}\right]$$

The experiment was approved for 85 days of beam by PAC7 (25 days test, 60 days production). The following conditions were assumed at that time.

BEAM	energy	3.6 GeV
	current	100 μA
	polarization	50 %
HRS	angles	12.5°
	central momentum	3.5 GeV/c
	solid angle	7.5 x 2 msr
Target	density (10K, 70 atm)	0.17 g/cm^3
	length	20 cm
	beam power deposition	700 Watts

With these conditions, the elastic scattering rate into the detectors would be about 1 kHz per arm and in 60 days of production beam the error on the physics asymmetry would be ΔA = 20 ppm. This corresponds to an error in F^s of $\delta F^s = 4 \times 10^{-3}$, and a corresponding error on G_E^s of δG_E^s = 0.06.

It is clear that the assumed running conditions need to be updated.

1. One of the two spectrometers cannot go above 3.2 GeV/c, so the kinematics need to be adjusted.
2. The HRS solid angles are smaller than the design values. I assume spectrometer collimators will not be required, since we do not need to make an absolute cross section measurement.
3. It is possible that the experiment could run with a high polarization crystal. This could improve things if there is adequate current available (and the target can handle the power density).
4. The "High Power target" as was under construction by the Cal State LA group at the time of the proposal, does not exist.

In the table below I list the new assumed conditions, and the resulting fractional loss compared with the original conditions.

New assumed conditions for E91-004, and net resulting loss in efficiency.

	New conditions		fractional change
BEAM	energy	3.3 GeV	
	current	50 μA	
	polarization	70 %	1.0
HRS	angles	14°	
	central momentum	3.2 GeV/c	(0.8 from kinematics)
	solid angle	6.8 x 2 msr	0.9 (assumes no collimators)
Target	density (5K, 15 atm)	0.15 g/cm^3	0.88
	length	20 cm (15 cm viewable)	
	beam power deposition	350 Watts	
		net loss	**0.63**

With the above conditions, the production run time would need to go from 60 days to 95 days. Using a target with a viewable length of 10 cm would require increasing the run time for the experiment, from 60 days to 142 days. This is probably unacceptable to Hall A and to the PAC. So, the longer target cell is critical to the experiment. If 100 μA of beam high beam polarization is achievable, then a 10 cm viewable target would be acceptable. For a 10 cm (viewable) target and 100 μA of 70% polarized beam (500 Watt target), the error on the physics asymmetry in 60 days would be about ΔA= 17 ppm, resulting in about the same (slightly improved) error as before on either F^s or G_E^s.

One final comment is that two recent calculations [1,2] each predict an absolute magnitude for G_E^s (Q^2=0.6) of about 0.15 , but with opposite signs. In reference 1, the HAPPEX result is used to constrain the calculation. So even this relatively crude measurement would still provide meaningful constraints on theory.

[1] Hemmert, Kubis and Meissner, Phys Rev. **C60** 045501 (1999).
[2] Dong, Lui and Williams, Phys. Rev. **D58** 074504 (1998).