

Calibration of Spectrometer Central Angles using Hall A HRS in $^1\text{H}(e,e'p)$

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for The Authors of JLAB-TN-00-024 and JLAB-TN-02-032

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Beam Energy

$$e = m_p \left(-\cot \frac{\theta_e}{2} \cot \theta_p - 1 \right) + E_s + E_r$$

θ_e : Electron scattering angle

θ_p : Proton scattering angle

m_p : Proton mass

E_s : Beam energy straggling

E_r : Internal bremsstrahlung for pre-radiation

Angular Derivatives

$$\frac{\partial e}{\partial \theta_e} = \frac{m_p}{2} \left(1 + \cot^2 \frac{\theta_e}{2} \right) \cot \theta_p$$

$$\frac{\partial e}{\partial \theta_p} = m_p \cot \frac{\theta_e}{2} \left(1 + \cot^2 \theta_p \right)$$

Where

$$\cos \theta_e = (\cos \theta_0^e - \tan(\phi_{tg}^e - \phi_{tg}^b) \sin \theta_0^e) / \eta_e$$

$$\cos \theta_p = (\cos \theta_0^p - \tan(\phi_{tg}^p - \phi_{tg}^b) \sin \theta_0^p) / \eta_p$$

$$\eta_e = \sqrt{1 + \tan^2(\theta_{tg}^e - \theta_{tg}^b) + \tan^2(\phi_{tg}^e - \phi_{tg}^b)}$$

$$\eta_p = \sqrt{1 + \tan^2(\theta_{tg}^p - \theta_{tg}^b) + \tan^2(\phi_{tg}^p - \phi_{tg}^b)}$$

Fitting Procedure

$$e = e_i + \left(\frac{\partial e}{\partial \theta_0^e} \right)_i \delta \theta_0^e + \left(\frac{\partial e}{\partial \theta_0^p} \right)_i \delta \theta_0^p$$

$$\frac{\partial e}{\partial \theta_0^e} = \left(\frac{\partial e}{\partial \theta_e} \right) \left(\frac{\partial \theta_e}{\partial \theta_0^e} \right)$$

$$\frac{\partial \theta_e}{\partial \theta_0^e} = \frac{\sin \theta_0^e + \tan \phi_{tg}^e \cos \theta_0^e}{\eta_e \sin \theta_e}$$

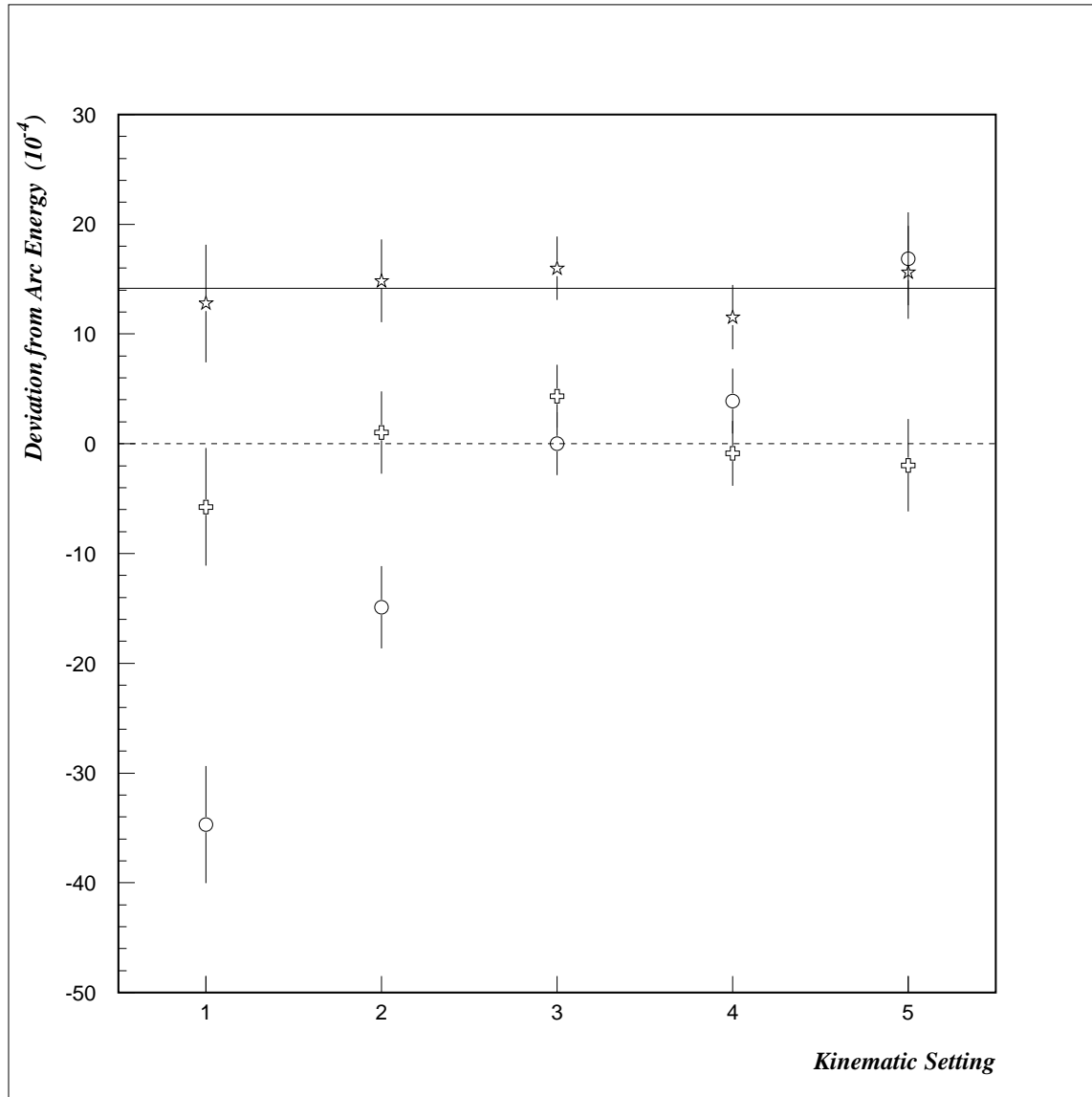
$$\chi^2 = \sum_i \left[e - e_i - \left(\frac{\partial e}{\partial \theta_0^e} \right)_i \delta \theta_0^e - \left(\frac{\partial e}{\partial \theta_0^p} \right)_i \delta \theta_0^p \right]^2 / \sigma_i^2$$

$$\sigma_i^2 = \left(\frac{\partial e}{\partial \theta_0^e} \right)_i^2 (\delta \theta_0^e)^2 + \left(\frac{\partial e}{\partial \theta_0^p} \right)_i^2 (\delta \theta_0^p)^2$$

Data Sets

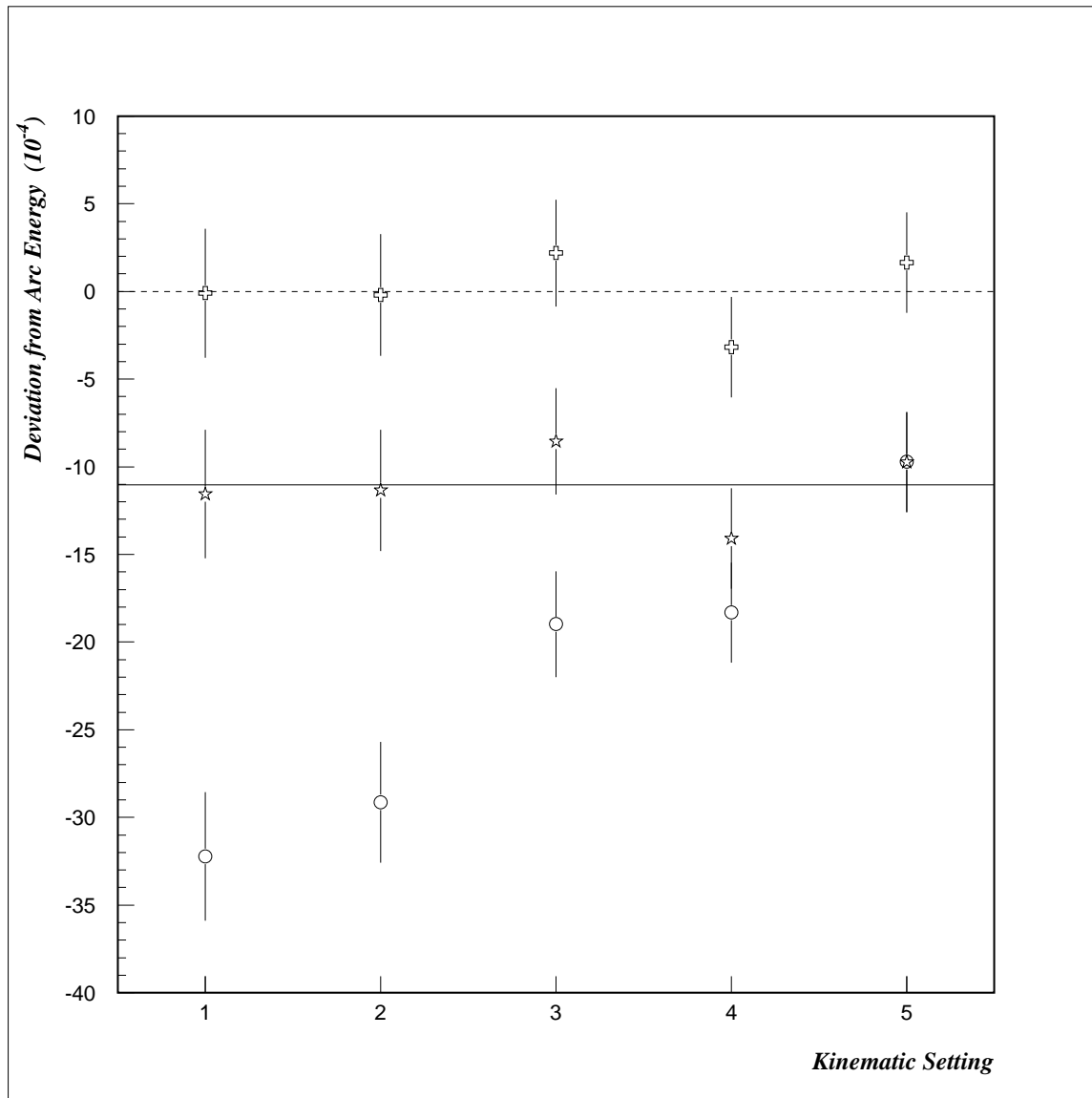
Data Set	Period	Arc Energy (MeV)	Left Arm	Right Arm
I	April 1-2 2000	3085.8 ± 0.6	Electron	Proton
II	May 20-21 2000	4530.6 ± 0.9	Electron	Proton
III	July 8-9 2000	3413.5 ± 3.4 (Extrapolated)	Proton	Electron

Set I Energy Deviations



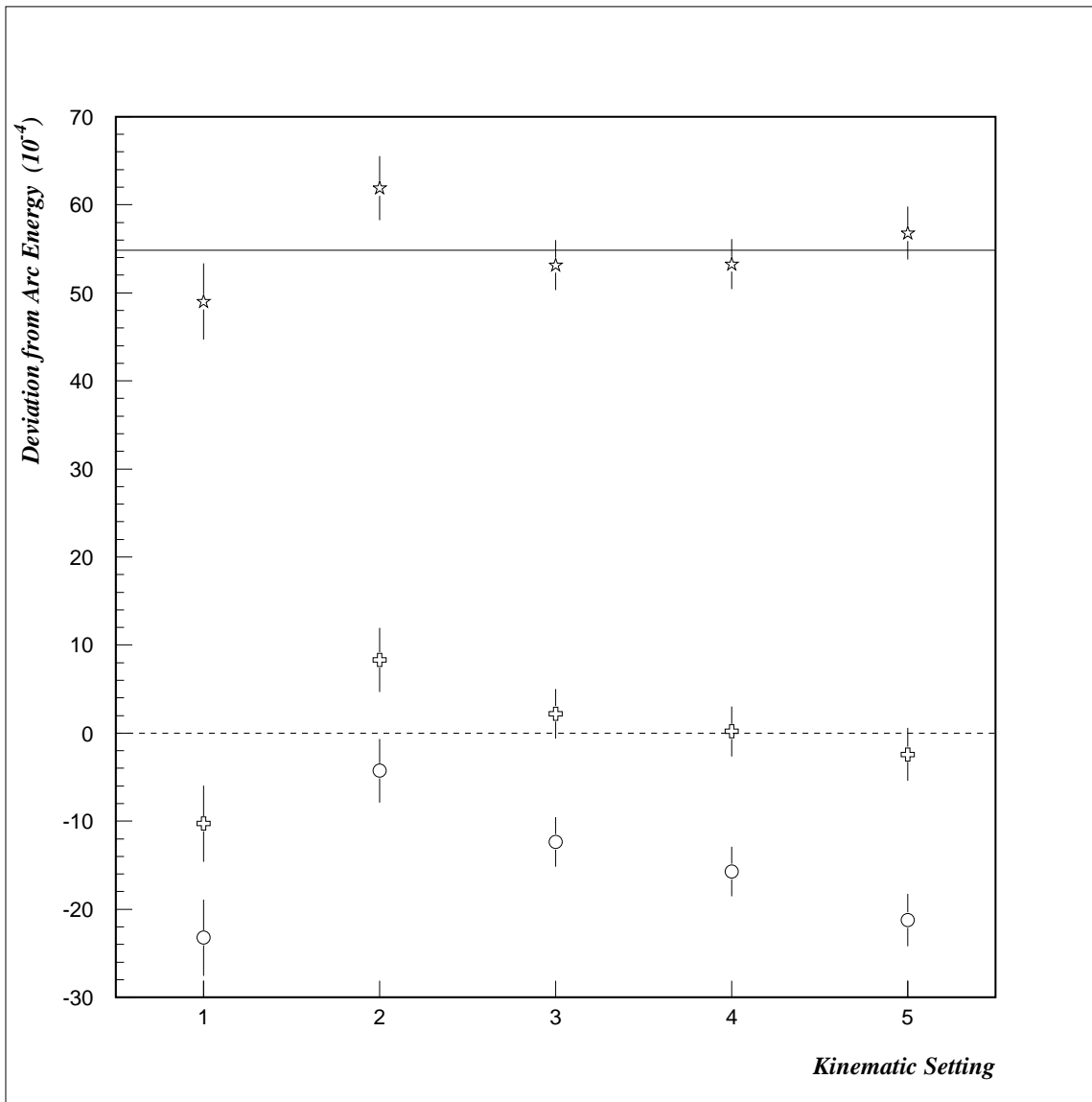
- Before fit**
- ☆ 3-parameter fit**
- + 2-parameter fit**
- 3-par. fit Wt. Ave.**
- - - 2-par. fit Wt. Ave.**

Set II Energy Deviations



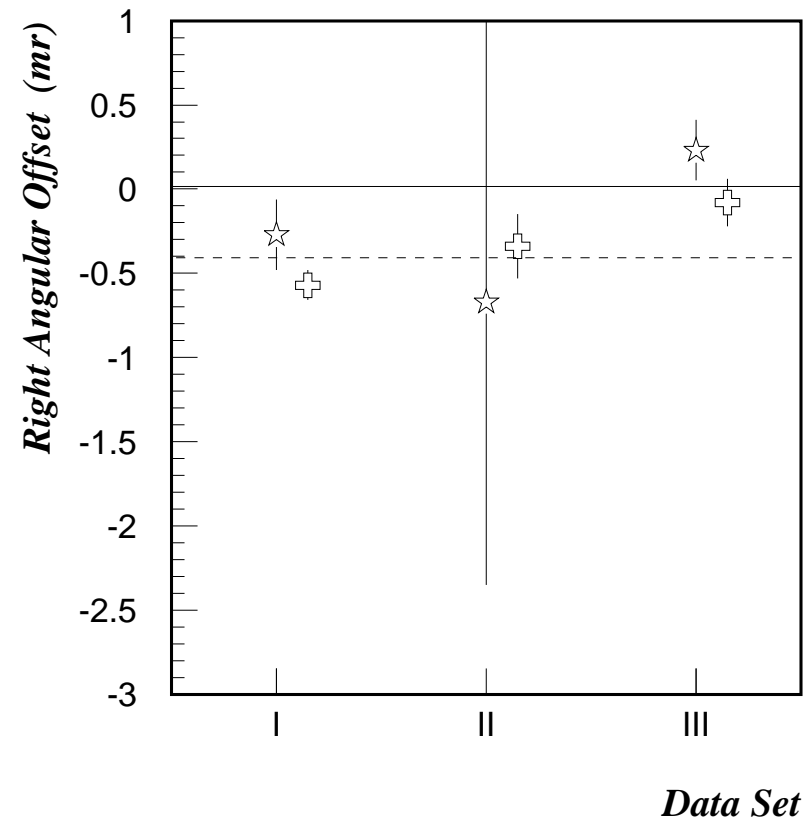
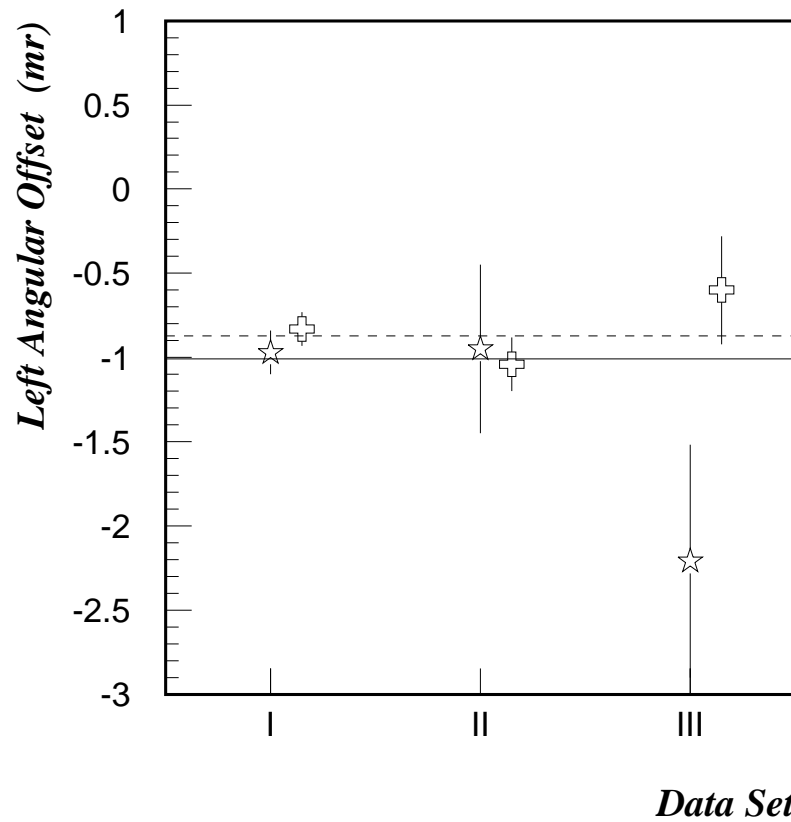
- o** Before fit
- ☆** 3-parameter fit
- +** 2-parameter fit
- 3-par. fit Wt. Ave.
- - -** 2-par. fit Wt. Ave.

Set III Energy Deviations



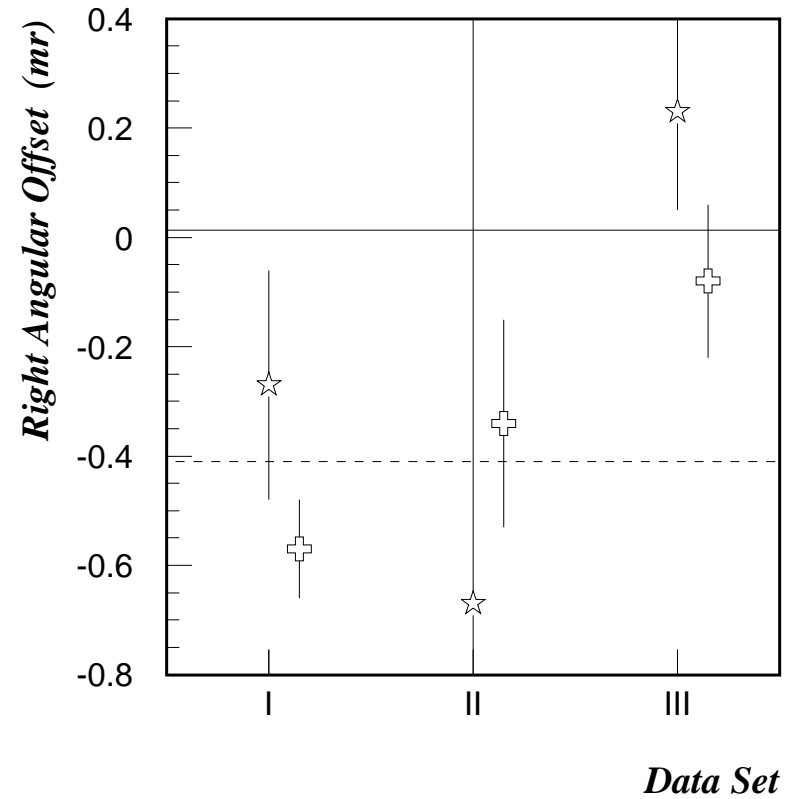
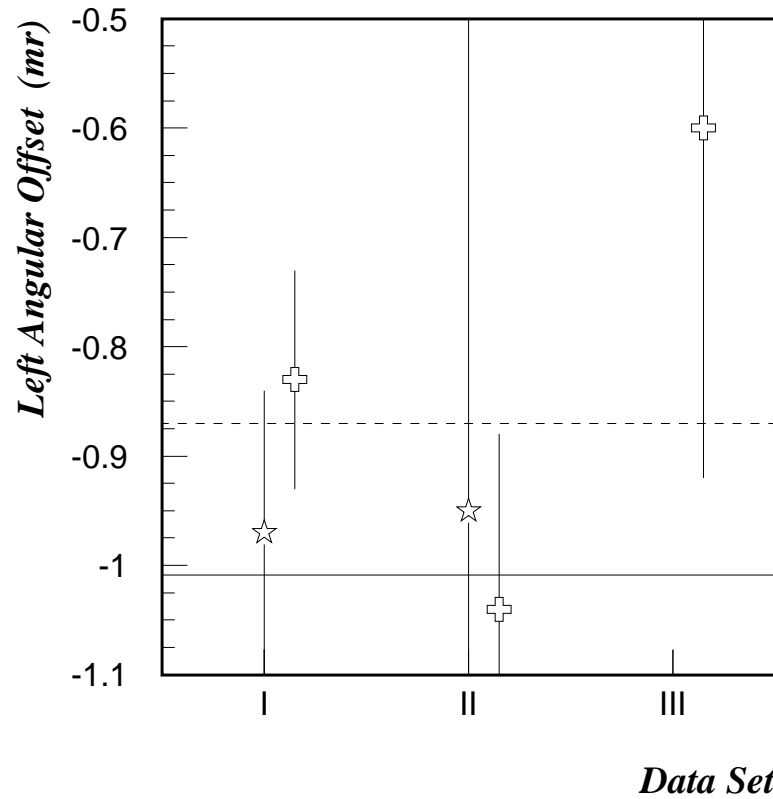
- Before fit**
- ☆ 3-parameter fit**
- + 2-parameter fit**
- 3-par. fit Wt. Ave.**
- - - 2-par. fit Wt. Ave.**

Angular Offsets (1)



- ☆ 3-parameter fit
- + 2-parameter fit
- 3-param. fit Wt. Ave.
- - - 2-param. fit Wt. Ave.

Angular Offsets (2)



- ★ 3-parameter fit
- + 2-parameter fit
- 3-param. fit Wt. Ave.
- - - 2-param. fit Wt. Ave.

3-parameter Fit Summary

Data Set	e (GeV)	$\frac{e}{e_{Arc}} - 1$ (10^{-4})	Left Angular Offset (mr)	Right Angular Offset (mr)
I	3090.2 ± 2.8	$+14.3 \pm 10.0$	-0.97 ± 0.13	-0.27 ± 0.21
II	4525.6 ± 25.8	-11.0 ± 56.9	-0.95 ± 0.50	-0.67 ± 1.68
III	3432.2 ± 7.9	$+54.8 \pm 23.1$ (e_{Arc} is extrap.)	-2.21 ± 0.69	$+0.23 \pm 0.18$
I & II Wt. Ave.	—	—	-0.97 ± 0.13	-0.28 ± 0.21
I, II & III Wt. Ave.	—	—	-1.01 ± 0.12	$+0.01 \pm 0.14$

2-parameter Fit Summary

Data Set	Arc Energy (MeV)	Left Angular Offset (mr)	Right Angular Offset (mr)
I	3085.8 ± 0.6	-0.83 ± 0.10	-0.57 ± 0.09
II	4530.6 ± 0.9	-1.04 ± 0.16	-0.34 ± 0.19
III	3413.5 ± 3.4 (Extrapolated)	-0.60 ± 0.32	-0.08 ± 0.14
I & II Wt. Ave.	—	-0.89 ± 0.08	-0.53 ± 0.08
I, II & III Wt. Ave.	—	-0.87 ± 0.08	-0.41 ± 0.07

Conclusions

- Lacking of an actual Arc energy measurement led to significant inaccuracy → large uncertainties in the spectrometer angular offsets.
- It is possible that the spectrometer absolute angular offsets change with time due to some other factors.
- More extensive *ep* scans were performed later to study these changes.

References

- P. E. Ulmer, Talk given in the Hall A Collaboration Meeting (2000)
- P. E. Ulmer, H. Ibrahim and N. Nilanga, JLAB-TN-00-024 (2000)
- H. Ibrahim, P. E. Ulmer and N. Nilanga, JLAB-TN-02-032 (2002)