CLAS Collaboration meeting, JLAB

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Kinematic Corrections for CLAS 12

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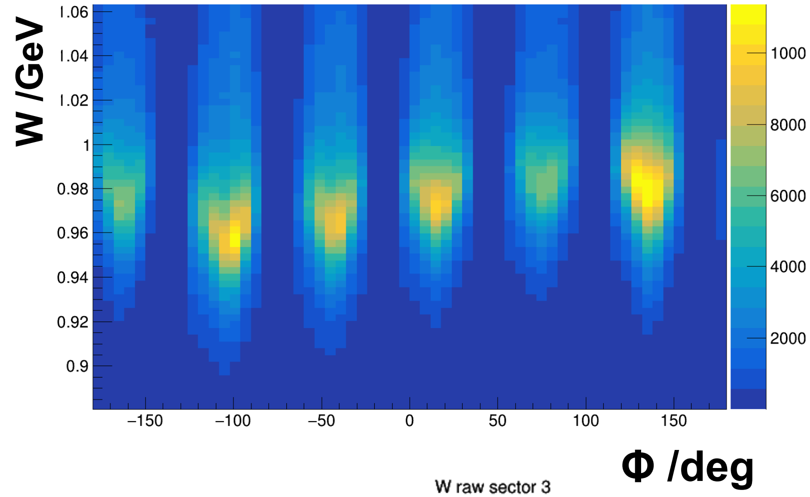
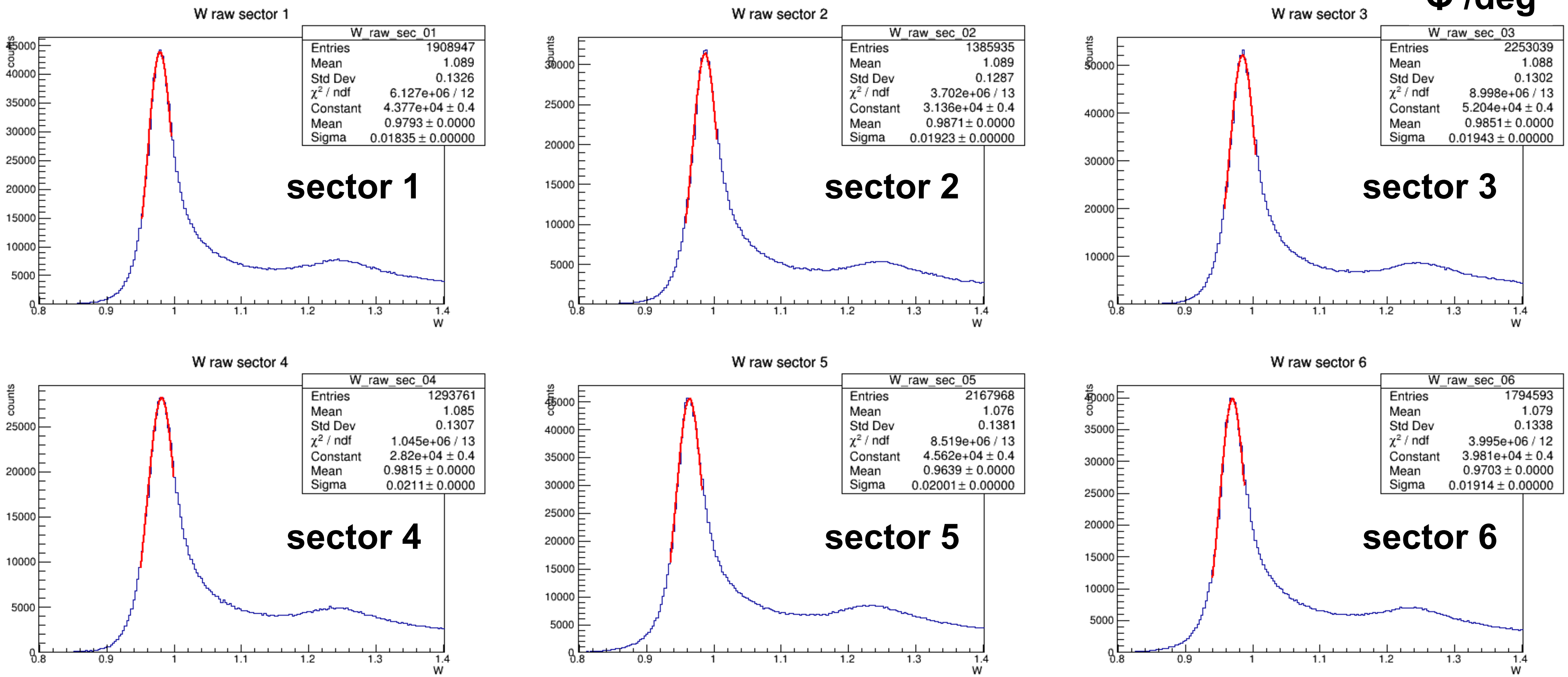
Motivation:
W spectra before correction
(CLAS12 run 2383 – 2.2 GeV - outbending field)



mean ~ 963 MeV - 987 MeV

σ ~ 19 – 21 MeV



Motivation

Observation: Elastic peak in the W spectrum of electrons
+ missing hadron masses appear at to high energies
and are wider than expected

→ Effect is small at 2.2 GeV but increases
with increasing momentum

→ Peaks are not visible any more at 10.6 GeV

Possible reason: - small errors in the magnetic field map
- misalignment of detectors, especially in DC
- calibration errors / uncertainties
- shift of the beam and or target position, ….

Solution: Minimize the error / uncertainty in the reconstruction inputs

But: Some effects can not be excluded completely

→ **Kinematic corrections are needed!**

Introduction

- CLAS 12 has two idenpendent magnetic fields and two spectrometer parts with different resolutions

→ Momentum corrections for electrons (detected in the FD) can not be based on protons, mainly detected in the CD

Correction approach: Use well known correlation between the θ scattering angle of elastically scattered electrons and their momentum

$$ep \rightarrow e'p'$$

→ At 2.2 GeV most electrons are scattered elastically

→ Corrections based on a single run with relatively low statistics

Implementation based on: Run 2383 (100 % outbending torus field, 2.22 GeV, 5 nA)

→ New torus field map (as of 01/25/2018)

Basic concept of the momentum correction

For eleastic scattering:
(W < 1.05 GeV for the 2.2 GeV data)

$$P_e^{corr} = \frac{E_{beam}}{1 + \frac{2 \cdot E_{beam} \cdot \sin^2(\theta_e / 2)}{M_p}}$$

Define: $x = \frac{P_{corr}}{P_{meas}}$ ⟹ $P_{corr} = x \cdot P_{meas}$

Interpreatation of the x value under ideal conditions:

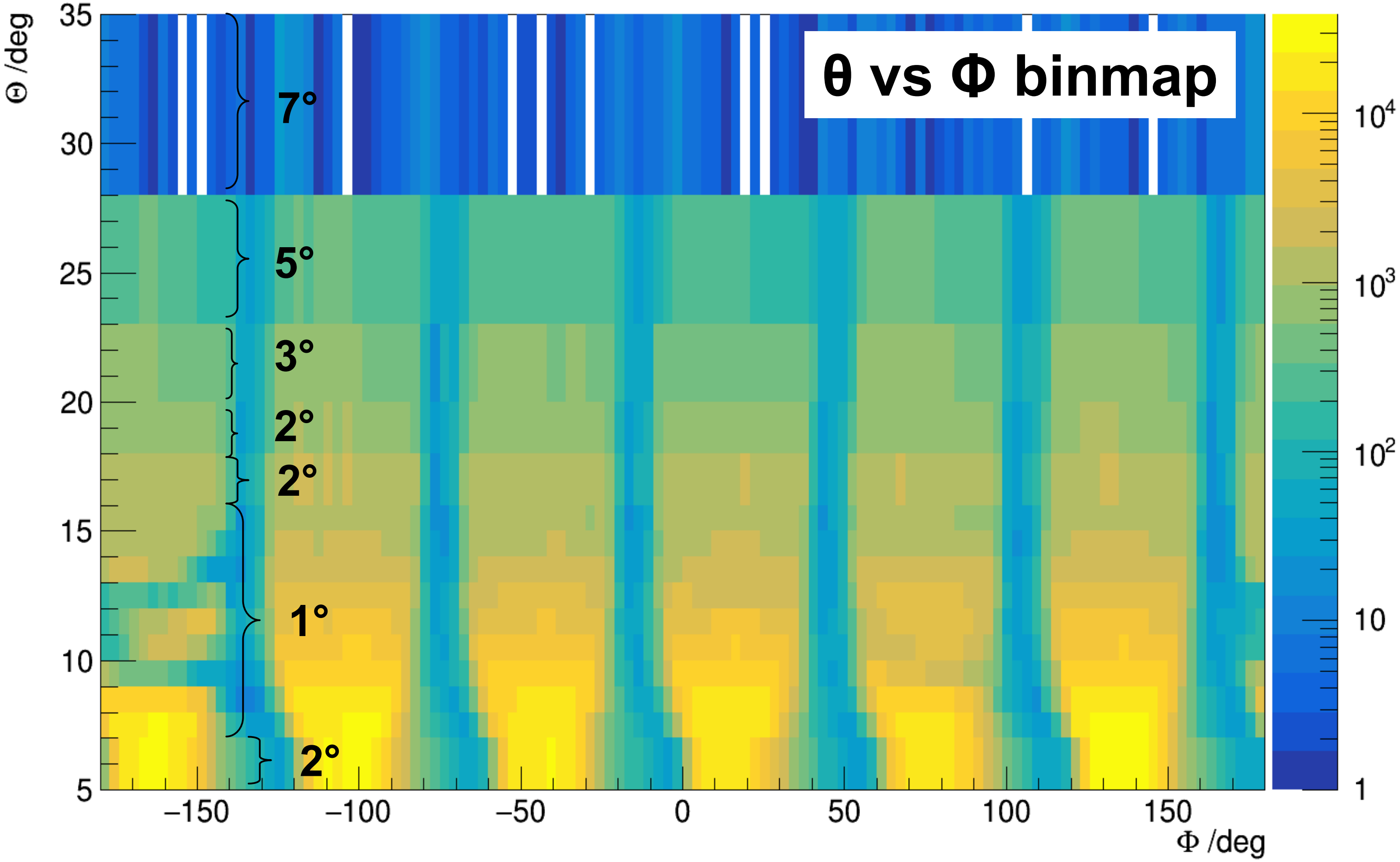
Momentum calculation from track radius: $p \approx 0.3 \cdot B \cdot R$

$$x = \frac{P_{corr}}{P_{meas}} = \frac{0.3 \cdot B_{corr} \cdot R}{0.3 \cdot B_{map} \cdot R} = \frac{B_{corr}}{B_{map}}$$ ⟹ $B_{corr} = x \cdot B_{map}$

In reality x also contains:

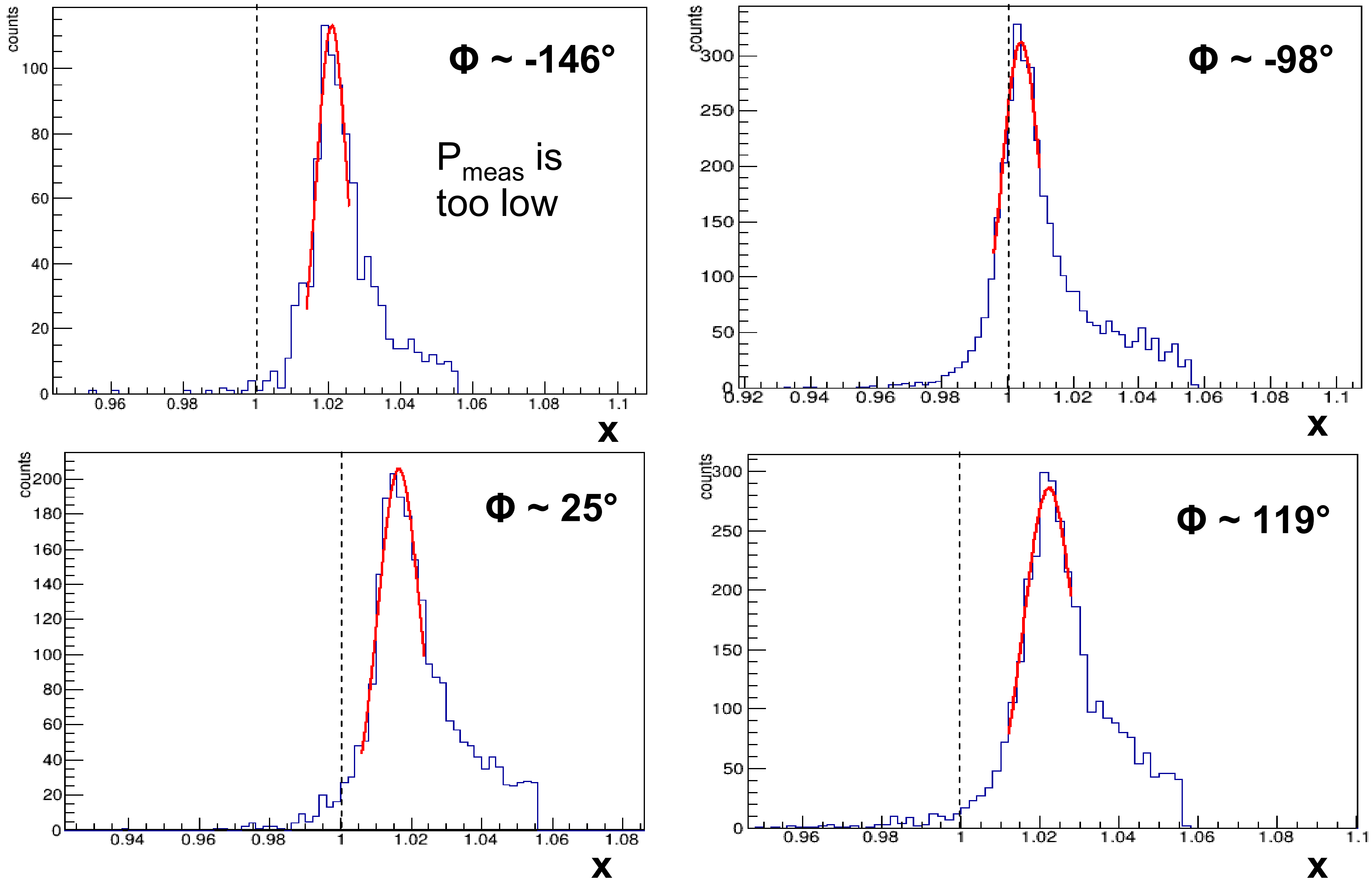
- Misalignment of Driftchambers, beam position and position of torus coils
- Calibration errors, …

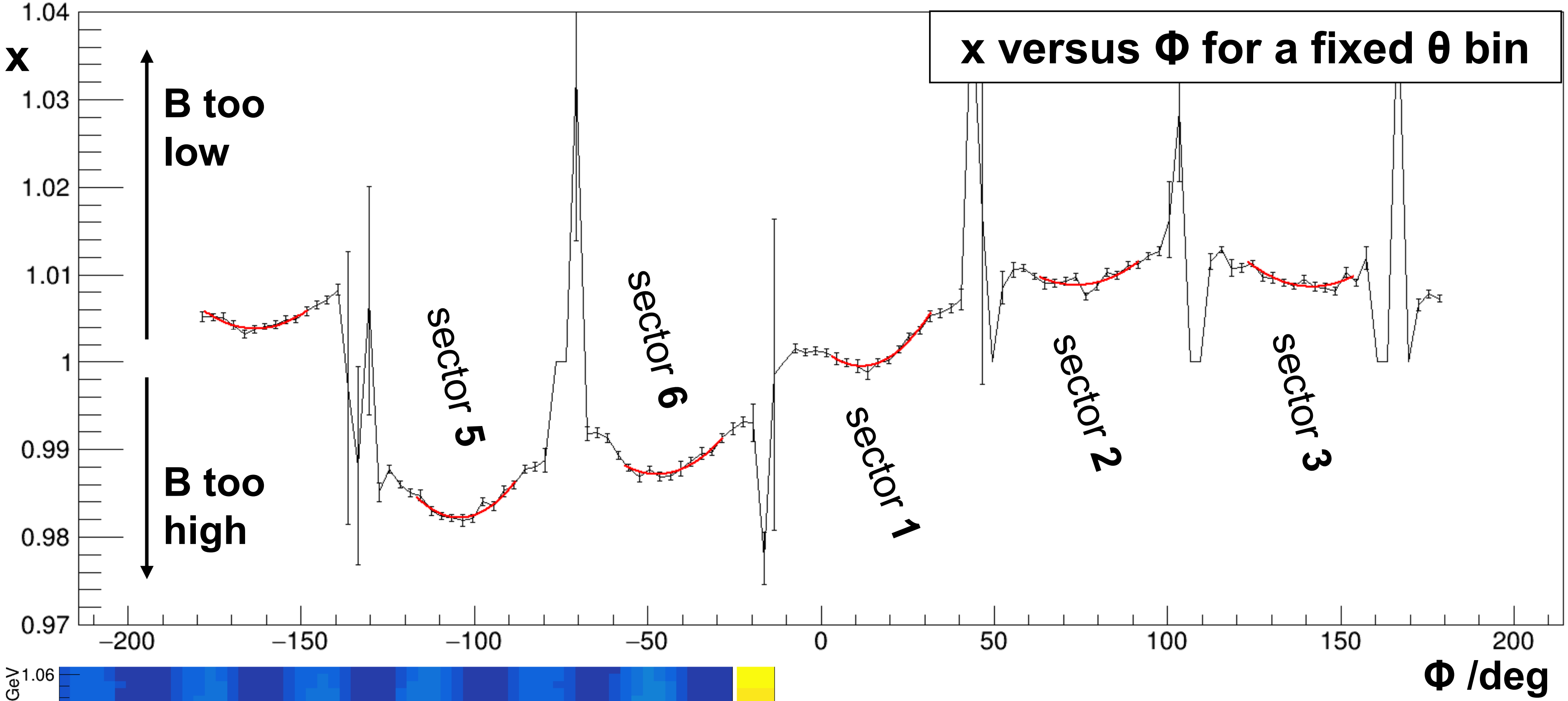
Method 1:
θ and Φ binned correction based on the reconstructed particles from the Eventbuilder

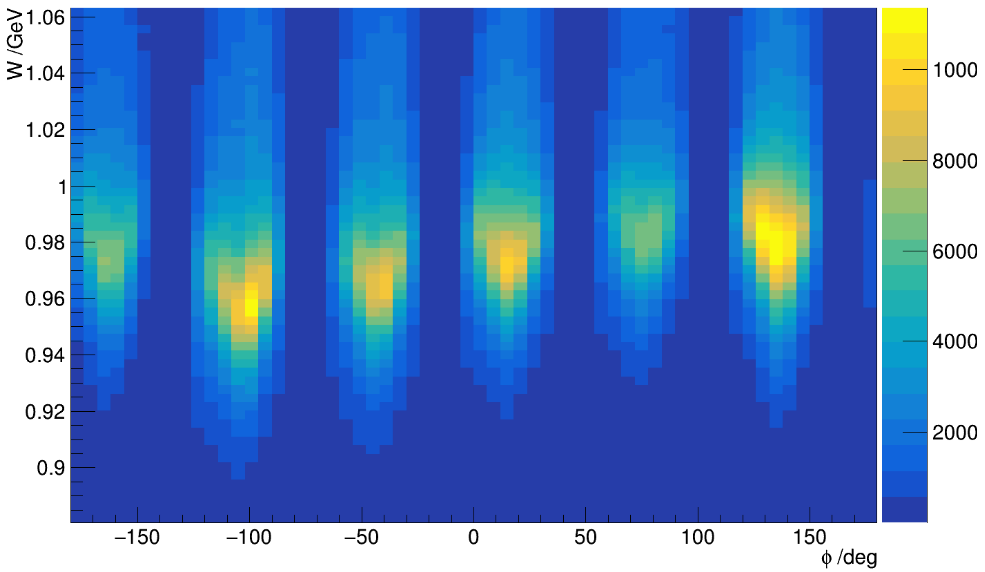


→ **in phi direction: 3° bins equally distributed**

$x = P_{corr} / P_{meas}$ for different Φ bins of θ = 11° - 12°







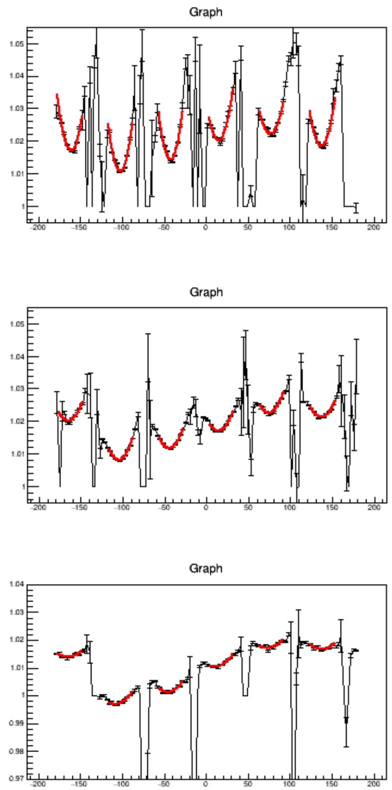
$$x = A + B \cdot \varphi + C \cdot \varphi^2$$

→ 1 fit for each sector

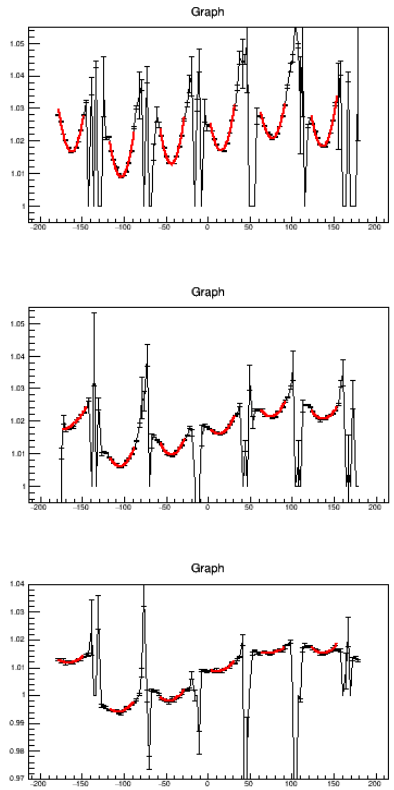
Under investigation:

$$x = A + B \cdot \sin(C \cdot \varphi + D) + E \cdot \varphi$$

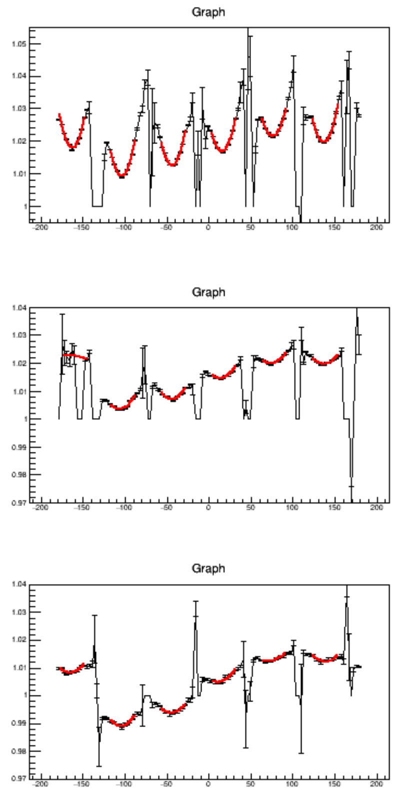
θ = 5° - 7°



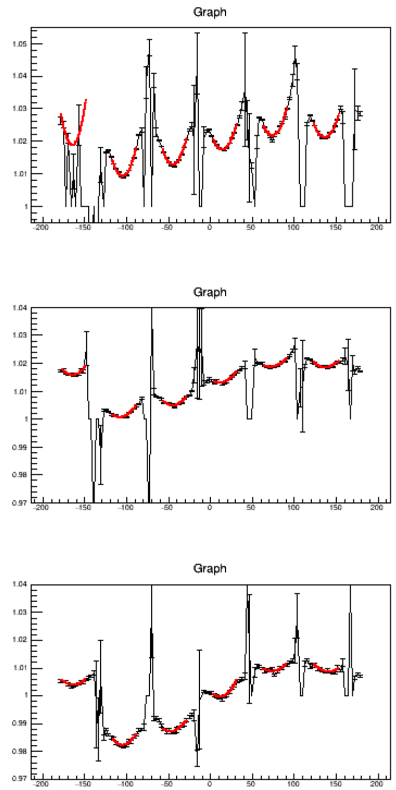
θ = 7° - 8 °



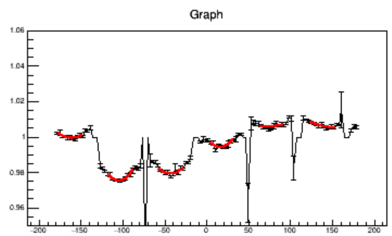
θ = 8° – 9°



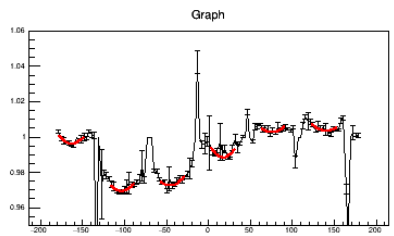
θ = 9° - 10°



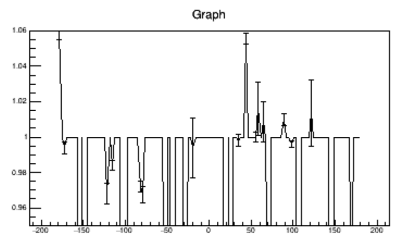
θ = 20° - 23°



θ = 23° - 28°

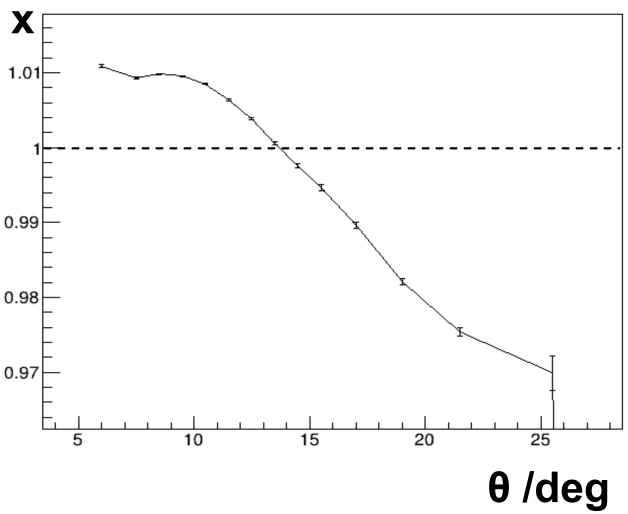


θ = 28° - 35°

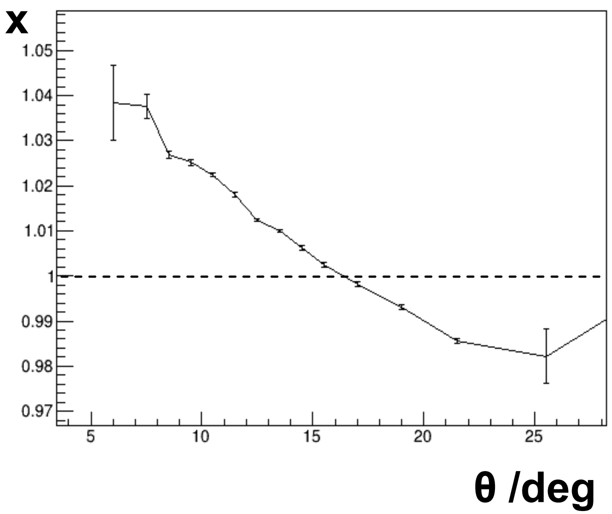


x versus θ for selected Φ bins

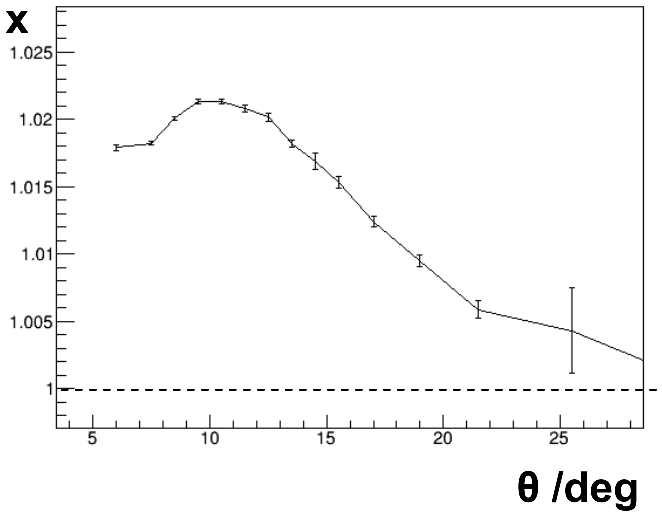
Φ ~ -170°



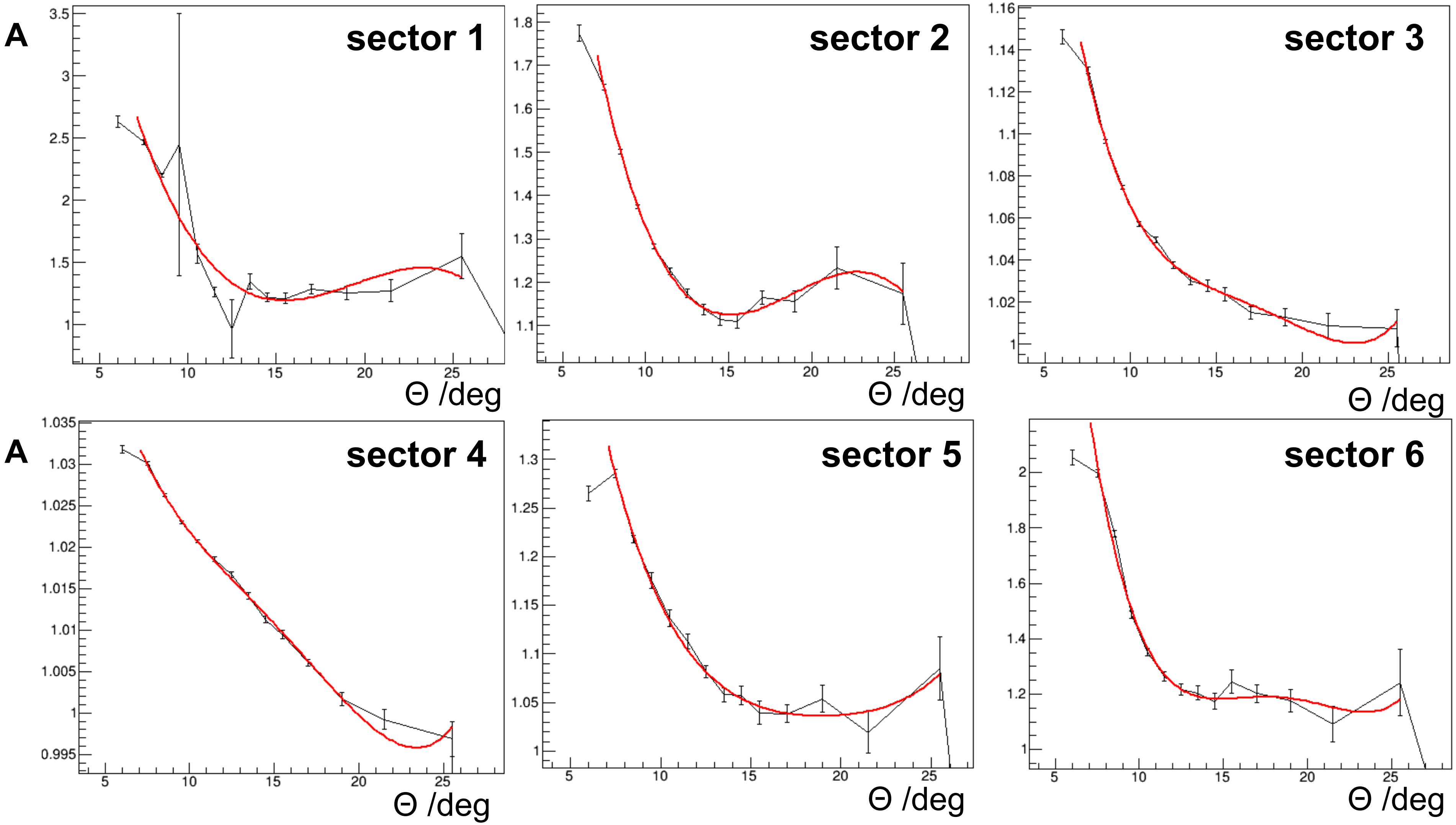
Φ ~ +10°



Φ ~ +140°

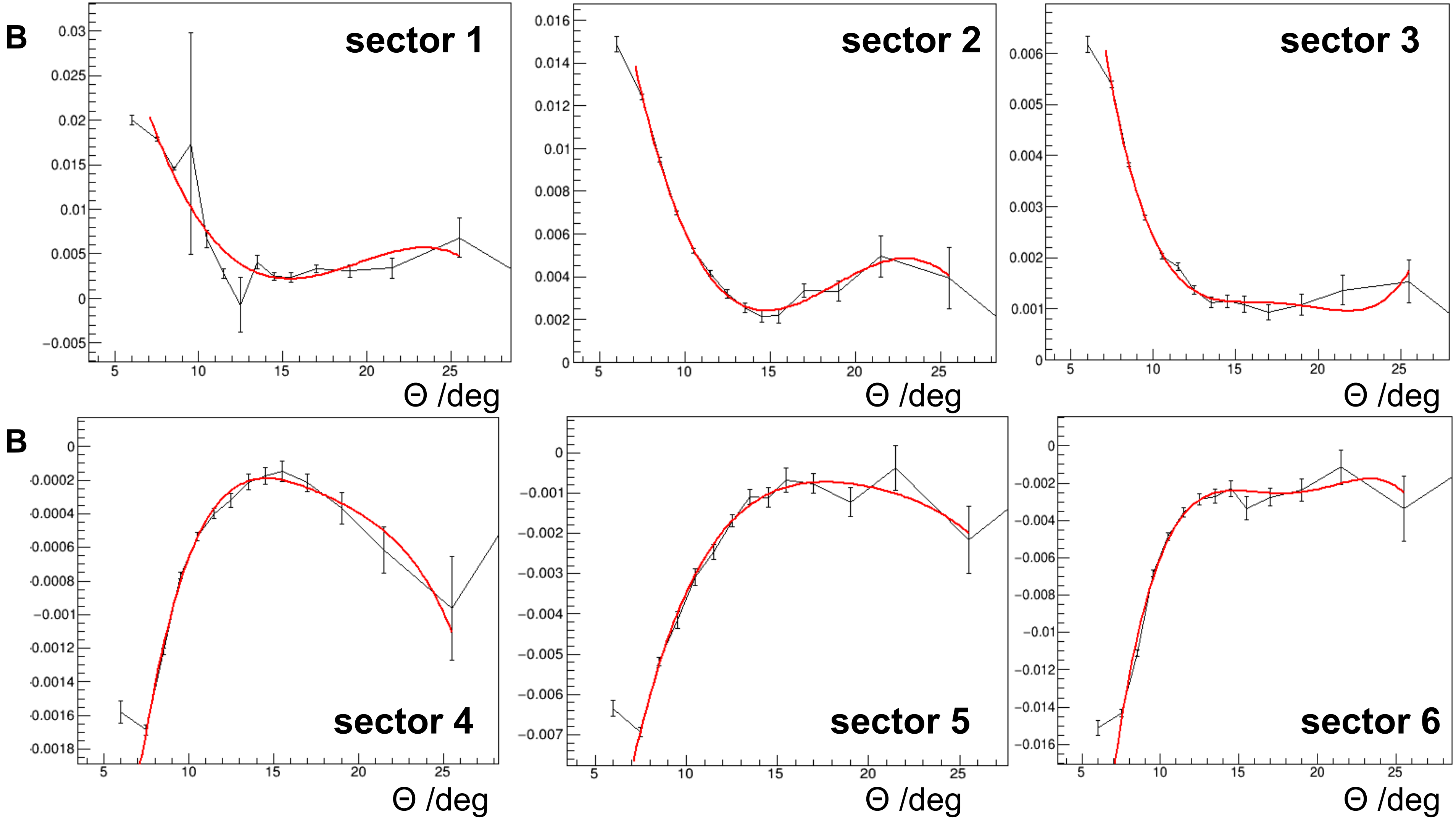


θ dependence of A from $x = A + B \cdot \varphi + C \cdot \varphi^2$



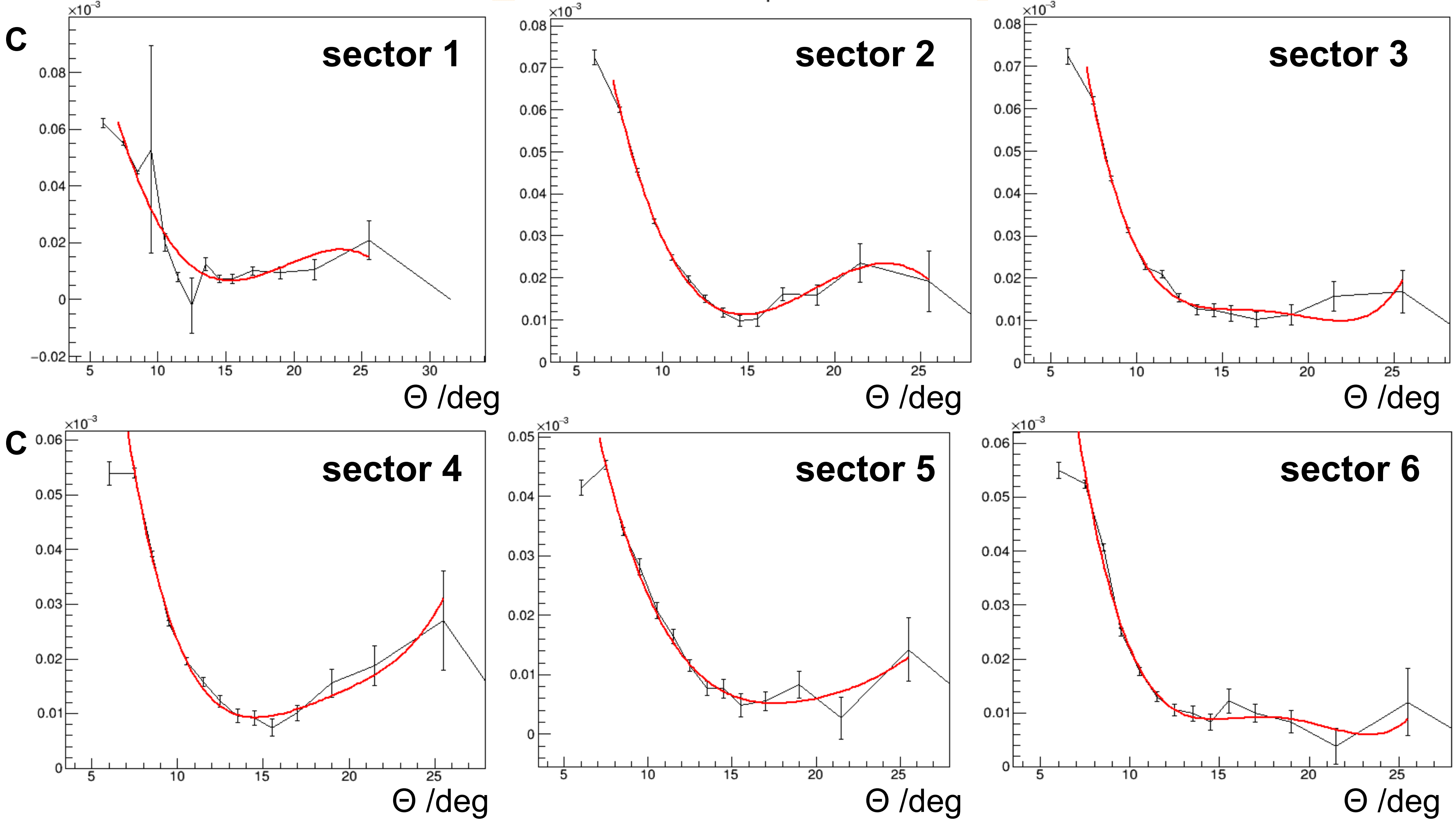
$$A = A_1 + A_2 \cdot \theta + A_3 \cdot \theta^2 + A_4 \cdot \theta^3 + A_5 \cdot \theta^4$$

θ dependence of B from $x = A + B \cdot \varphi + C \cdot \varphi^2$



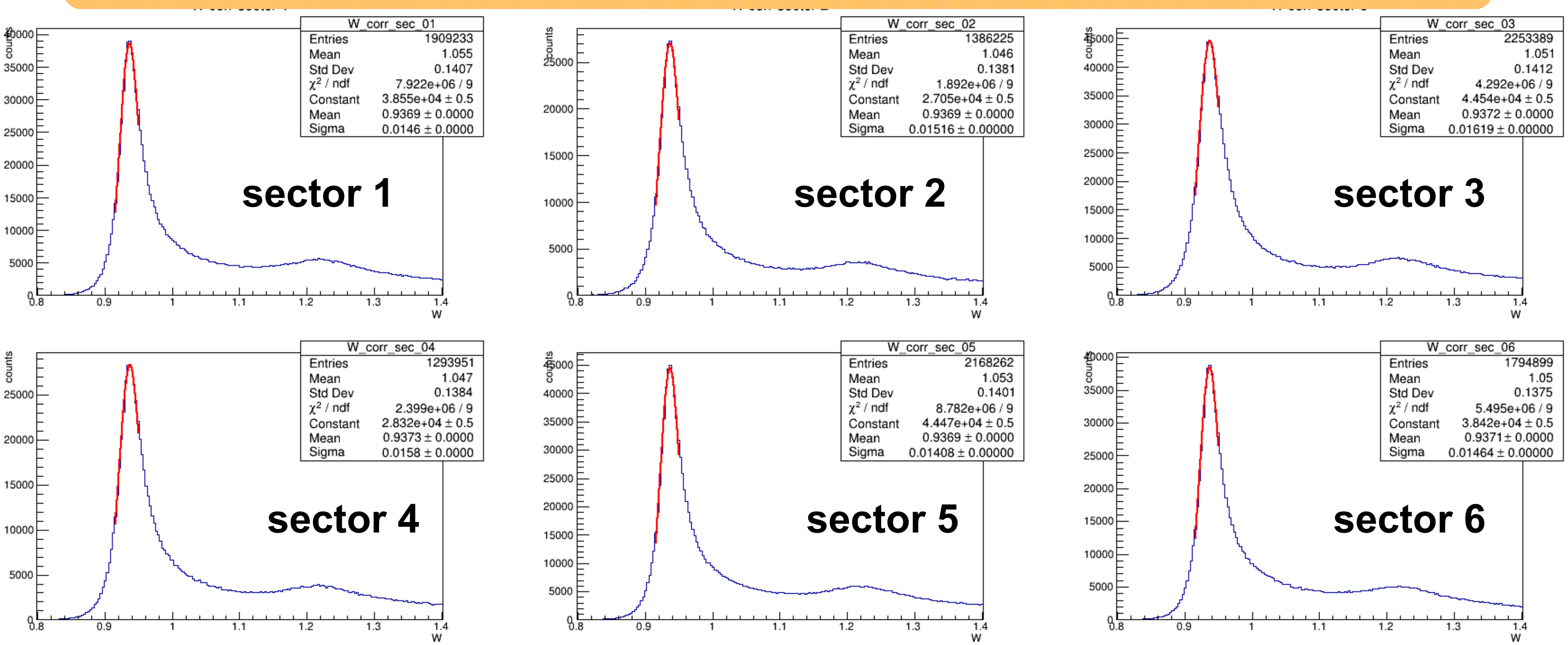
$$B = B_1 + B_2 \cdot \theta + B_3 \cdot \theta^2 + B_4 \cdot \theta^3 + B_5 \cdot \theta^4$$

θ dependence of C from $x = A + B \cdot \varphi + C \cdot \varphi^2$



$$C = C_1 + C_2 \cdot \theta + C_3 \cdot \theta^2 + C_4 \cdot \theta^3 + C_5 \cdot \theta^4$$

Elastic peak for the different sectors after the correction



mean value = 936.9 – 937.3 MeV

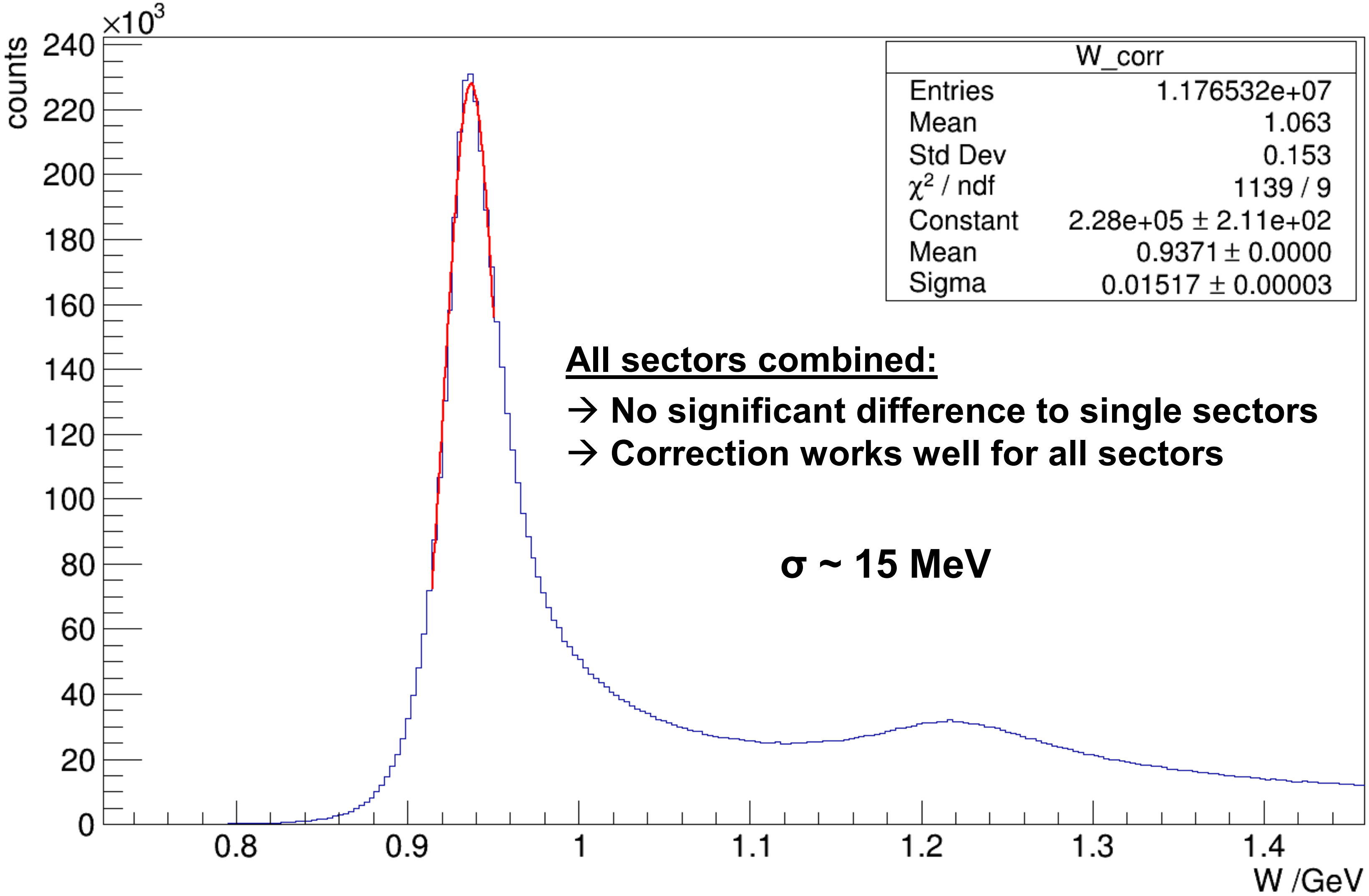
σ = 14.1 – 16.2 MeV

Before the correction:

mean value = 963 MeV and 987 MeV

σ ~ 19 – 21 MeV

Elastic peak in W for all sectors combined



All sectors combined:

→ **No significant difference to single sectors**

→ **Correction works well for all sectors**

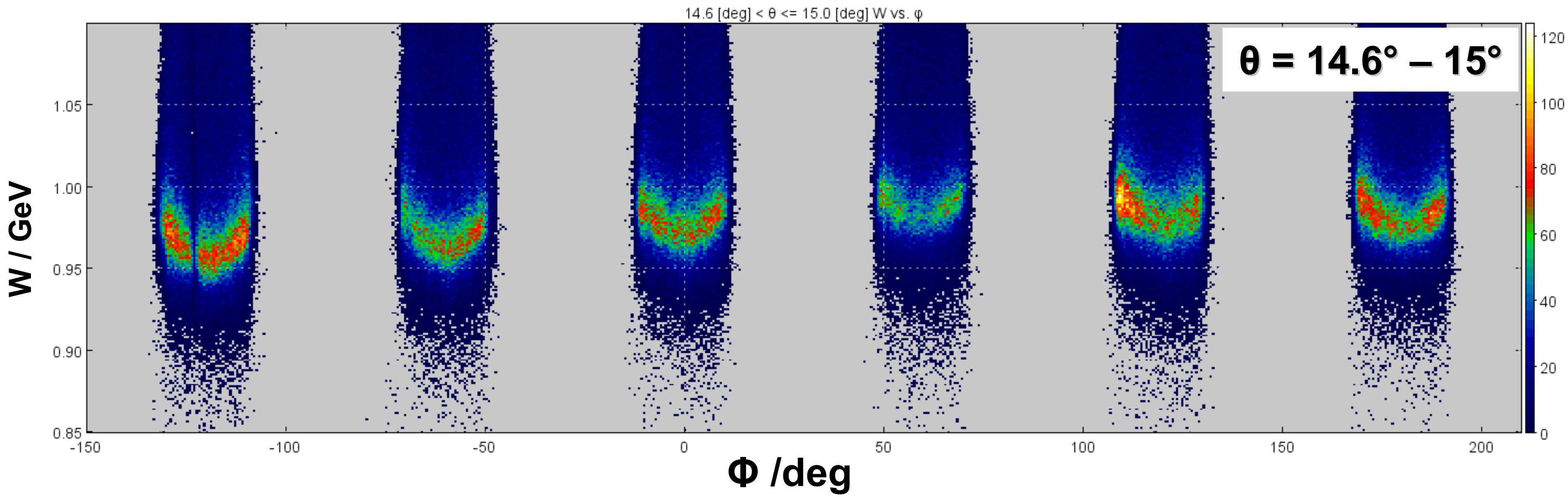
σ ~ 15 MeV

Method 2:

Binning based correction, based on the theta and phi angle from the hit position in region 1 of the Driftchambers

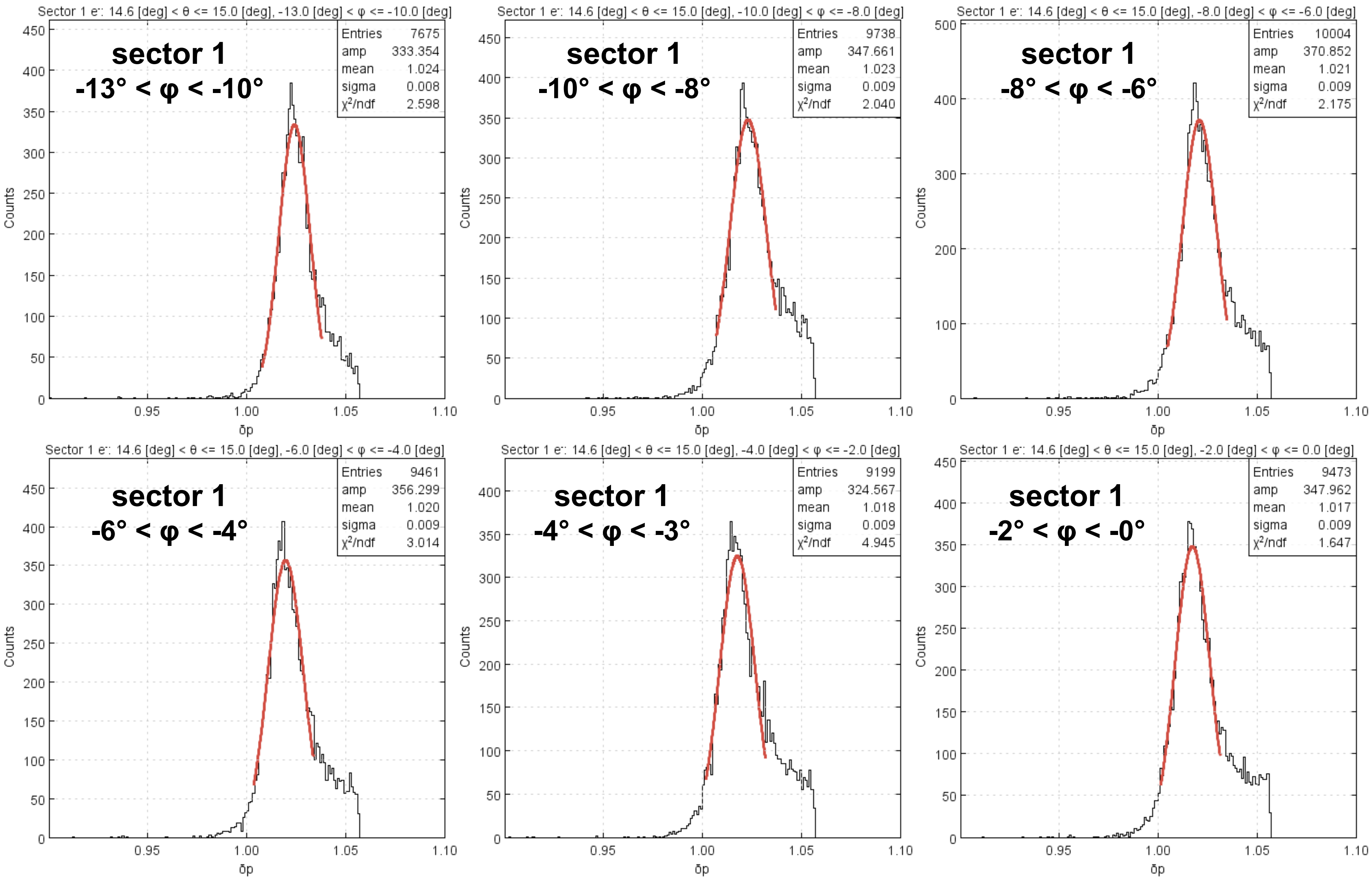
implemented by Joshua Artem Tan

➡ θ and Φ angle of the electron taken from region 1 of the DC (before the torus)

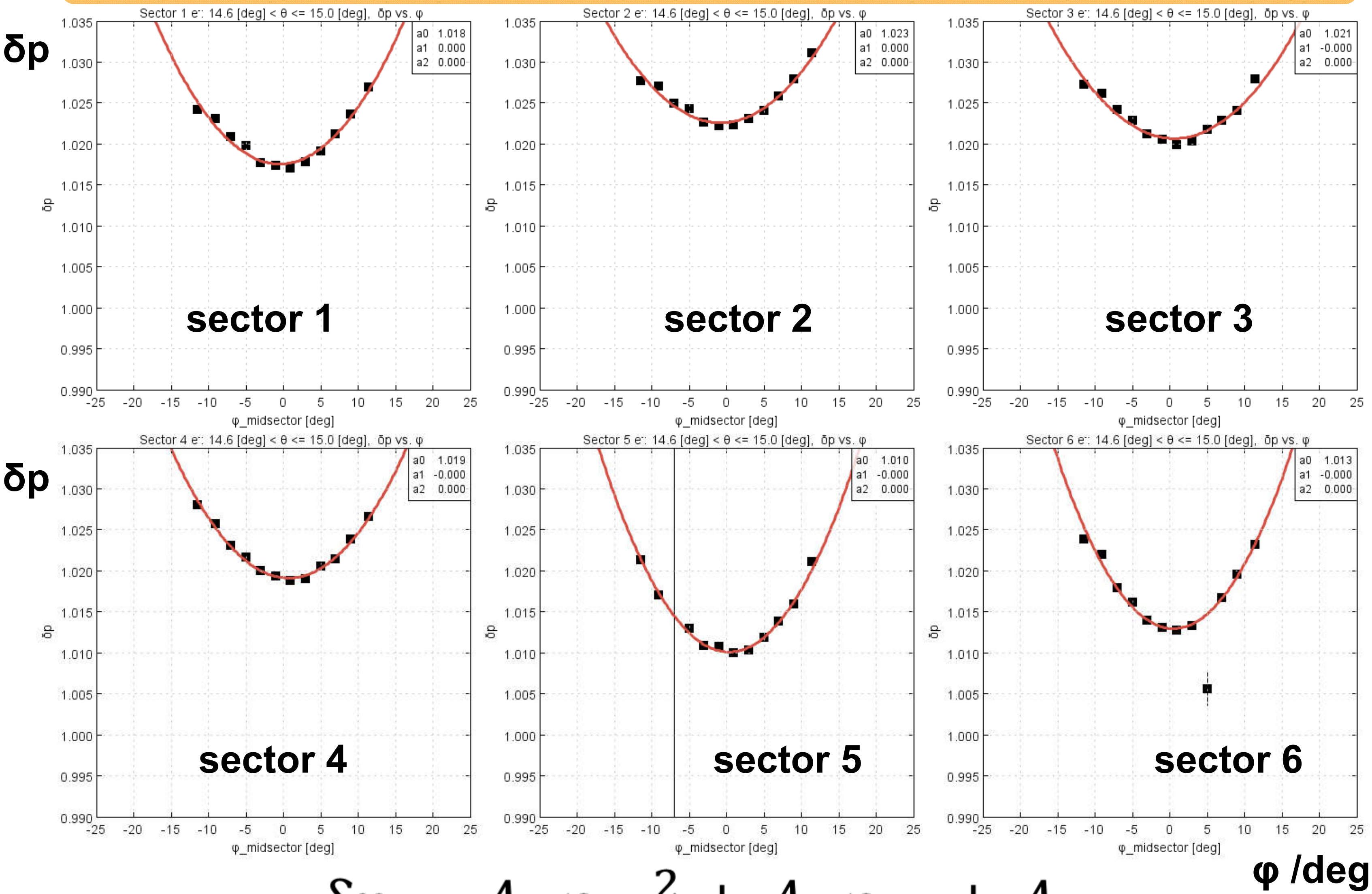


$$p_{correct} \equiv p_0 \delta p \;\Rightarrow\; \delta p = \frac{p_0}{p_{correct}} = x \;\Rightarrow\; \delta p = \frac{E}{p_0\left(1+\frac{2E}{M}\sin^2\frac{\theta_0}{2}\right)}$$

δp distributions for different φ bins at θ = 14.6° – 15°

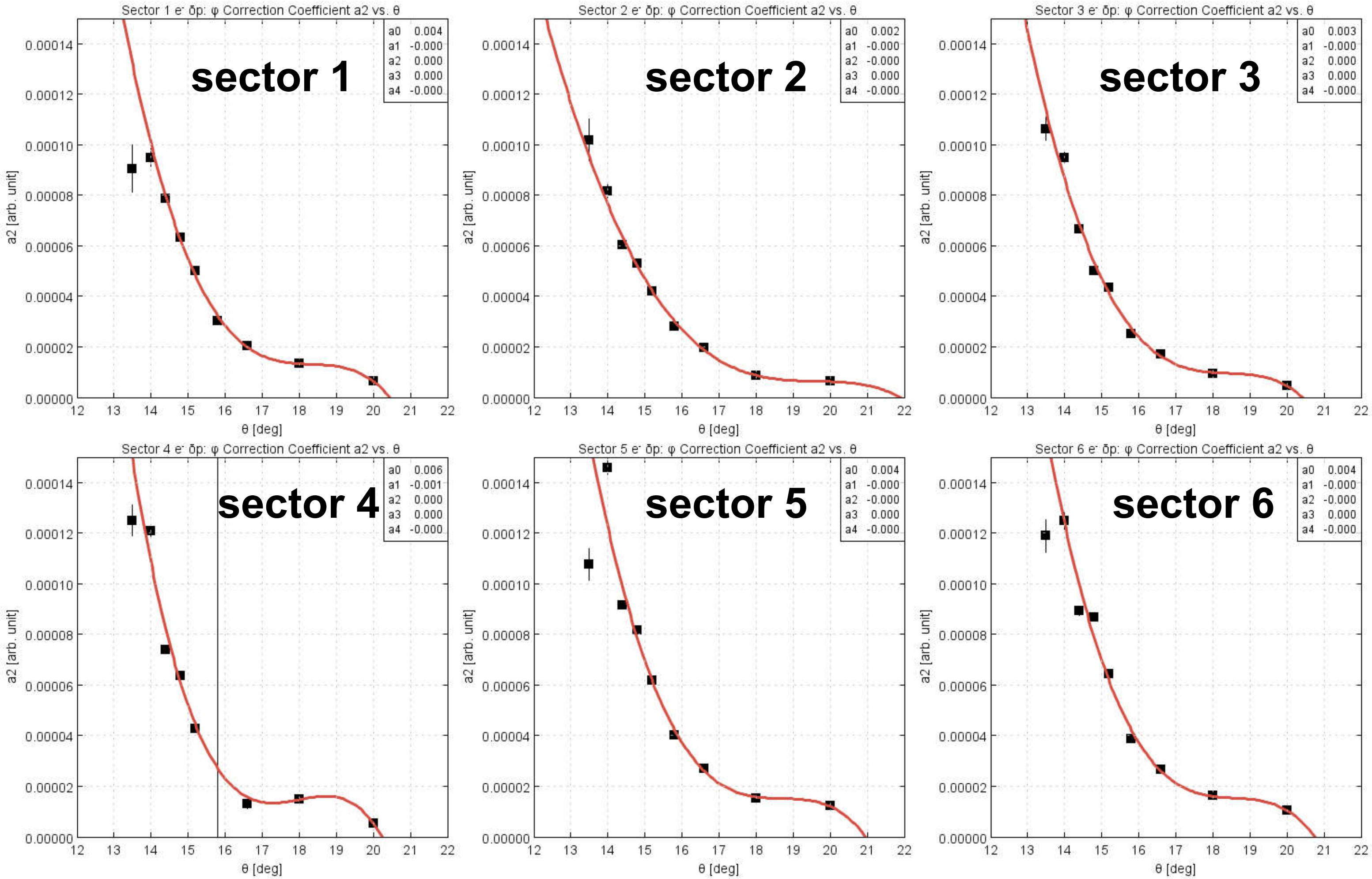


δp versus φ for the different sectors



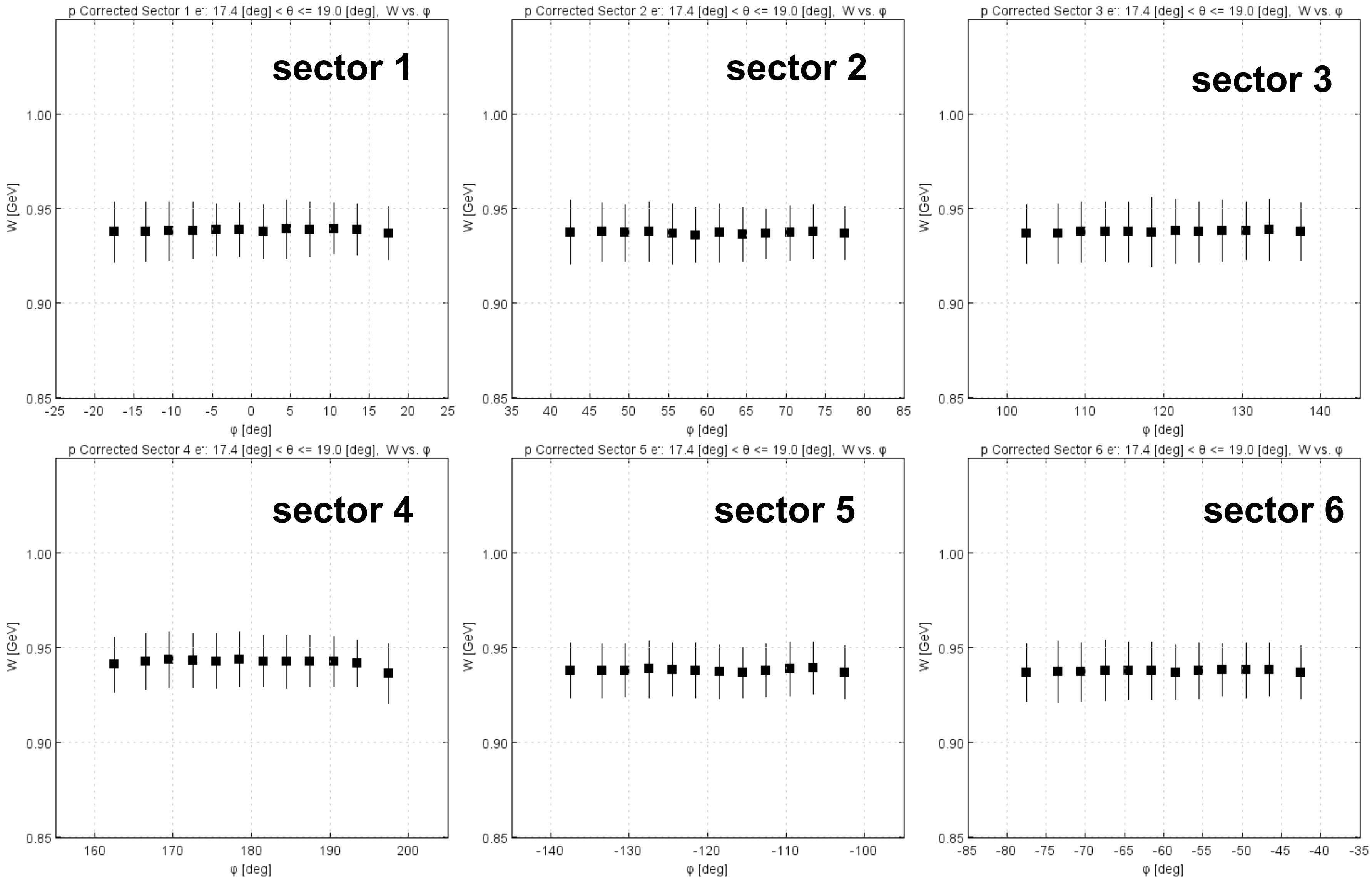
$$\delta p = A_2 {\varphi_{c1}}^2 + A_1 \varphi_{c1} + A_0$$

A_2 versus theta for the different sectors

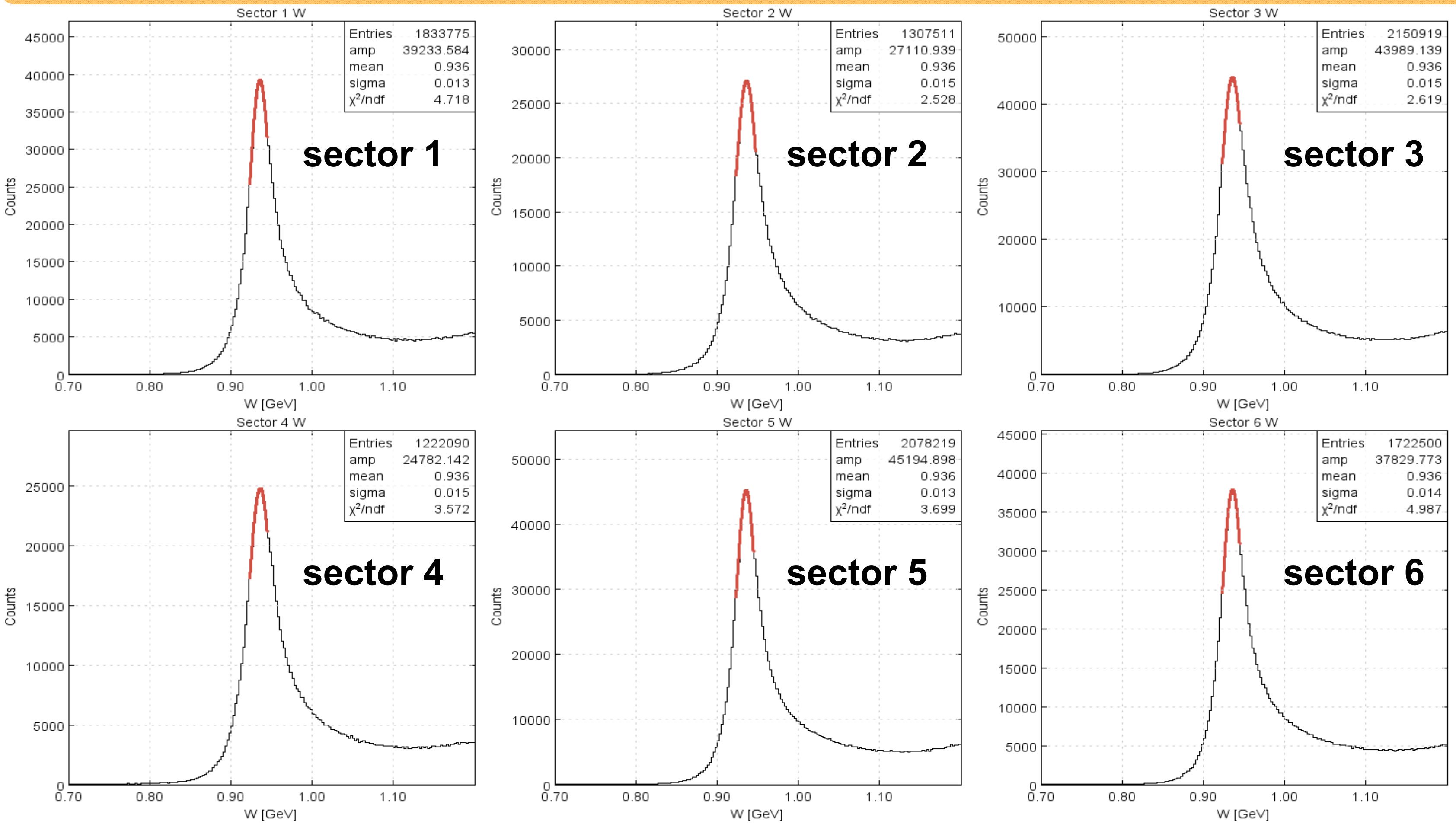


$$A_i = B_{i,4}{\theta_{c1}}^4 + B_{i,3}{\theta_{c1}}^3 + B_{i,2}{\theta_{c1}}^2 + B_{i,1}\theta_{c1} + B_{i,0}$$

φ dependence of the elastic peak in W after the correction



Elastic Peak in W for the 6 sectors after the correction



mean = 936 MeV

σ ~ 13 – 15 MeV

Considering the fit range,
results are comparabe to method 1

Possible θ angle correction

➡ Correct the θ angle based on the corrected momentum $p_0 \cdot \delta p$

$$\theta_{correct} \equiv \theta_0 \delta\theta$$

The formular for eleastic electron scattering provides:

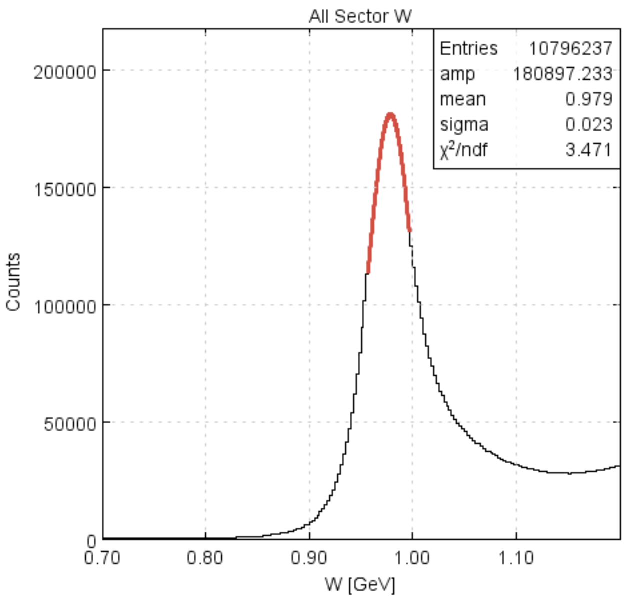
$$\delta\theta = \frac{1}{\theta_0} \cos^{-1}\left(1 + \frac{M}{E} - \frac{M}{p_0 \delta p}\right)$$

➡ Same procedure with a similar parametrisation as for the momentum correction can be applied

Problem: θ and p have different resolutions, which have to be studied

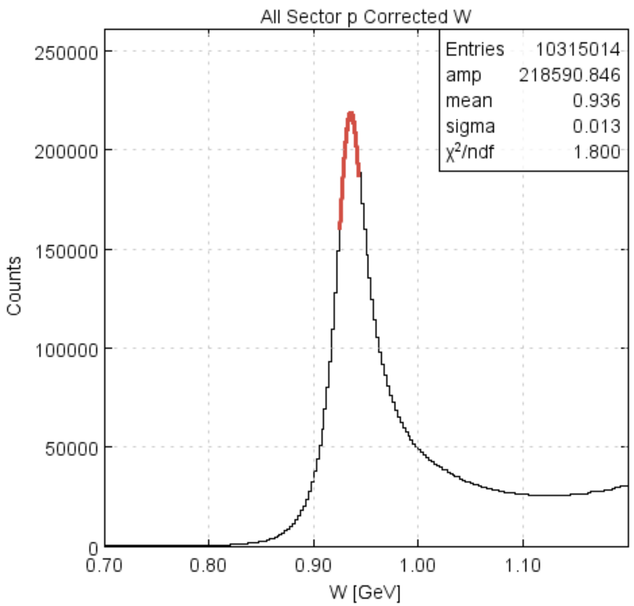
Alternative approach: θ correction based on the proton in the CD

results for the elastic peak combined over all sectors



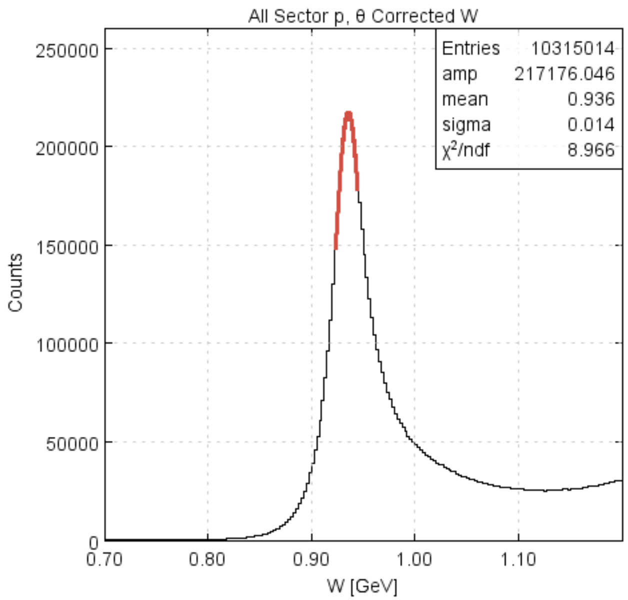
before correction

σ = 23 MeV



after p correction

σ = 13 MeV



after p and θ correction

σ = 14 MeV

Considering the fit range,
results are comparabe to method 1

Method 3:
Unbinned and simultaneous kinematic correction

implemented by David Riser

- **W is calculated by the following formula:**

$$W^2 = M_p^2 - 4Ep' \sin(\theta/2)^2 + 2M_p(E - p')$$

→ W equals the proton mass, if the electron is scattered eleastically

- **Define:** $$L = \frac{1}{N}\sum_{i=1}^{N}(M_p - W_i(\theta_i^{(corr)}, p_i^{(corr)}))^2$$

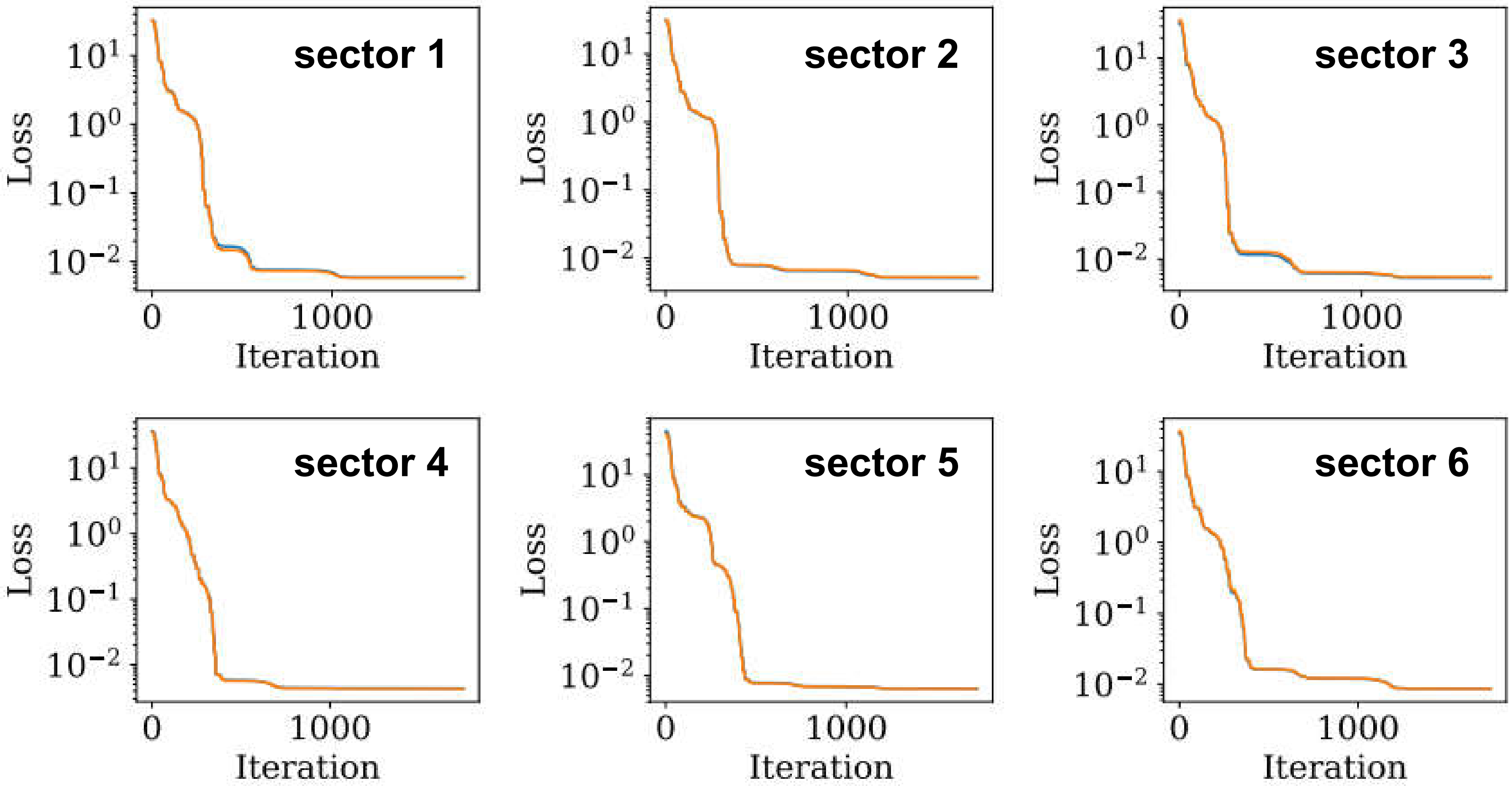
- **Minimize this expression for i.e. the following parametrization:**

$$\theta_i^{(corr)} = \theta_i(a_0 + a_1\phi + a_2\phi^2)$$

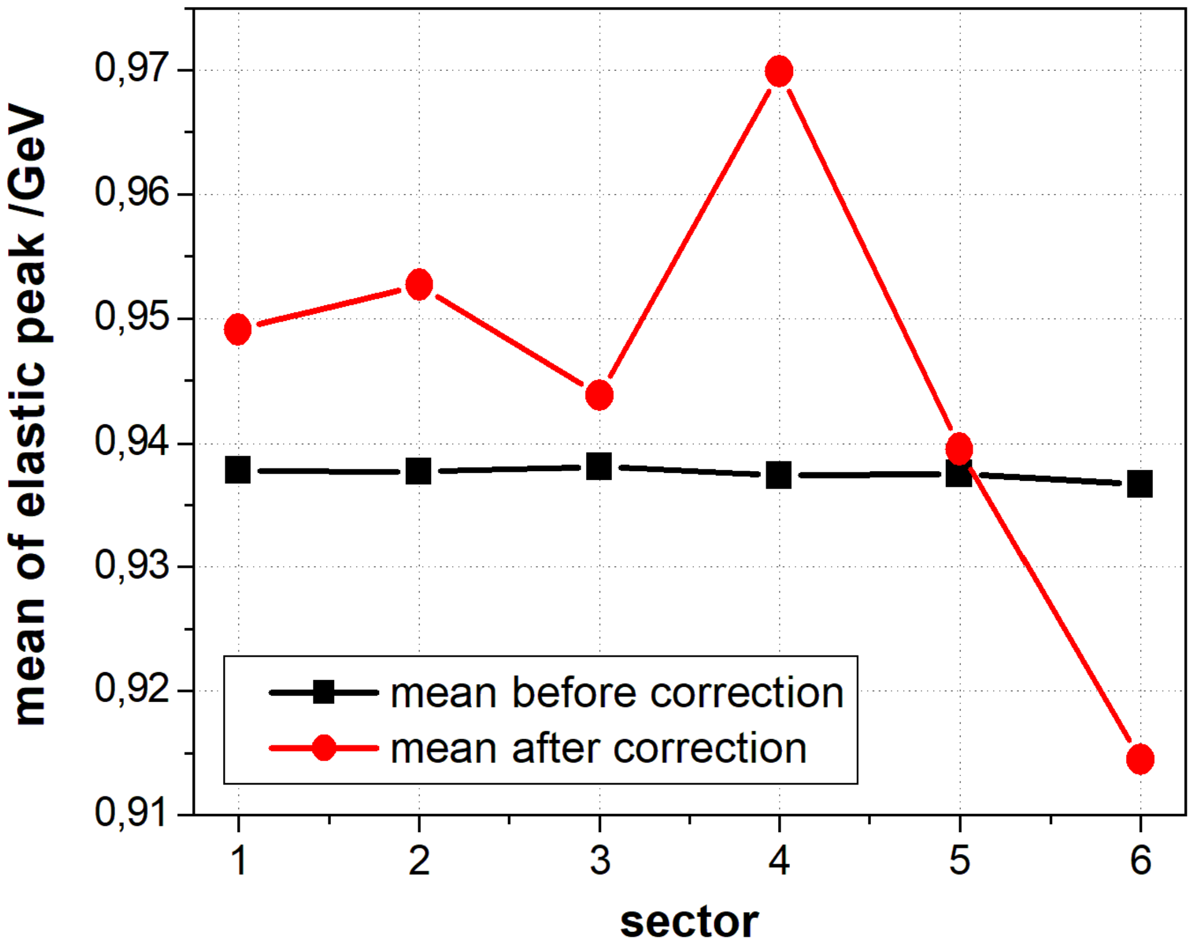
$$p_i^{(corr)} = p_i(b_{00} + b_{01}\phi + b_{02}\phi^2 + \theta(b_{10} + b_{11}\phi + b_{12}\phi^2) + \theta^2(b_{20} + b_{21}\phi + b_{22}\phi^2))$$

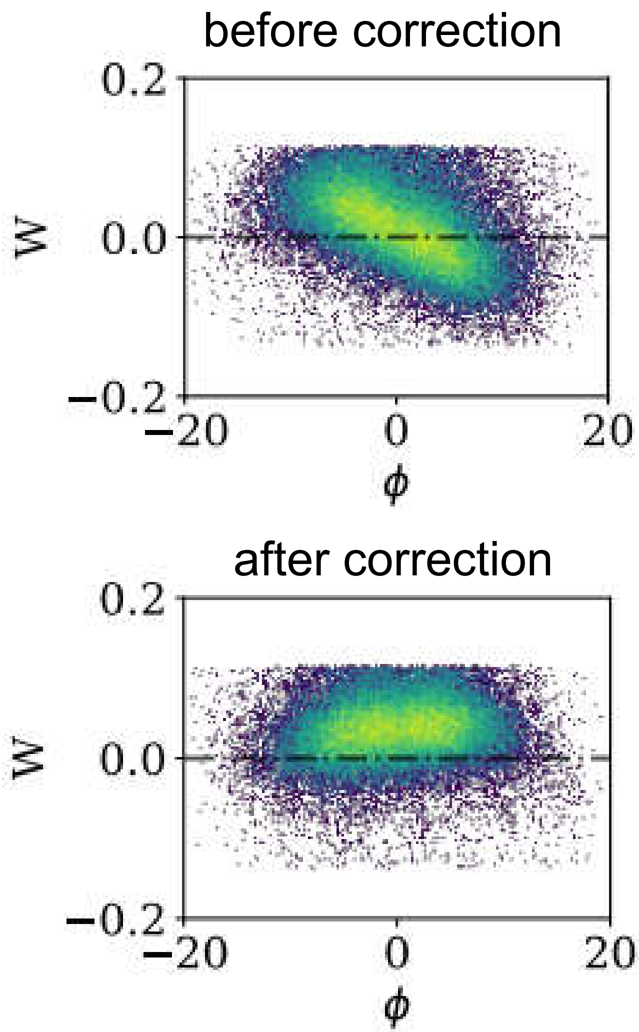
Minimization of the Parameters

- Parameters are randomly initialized and minimized in ~ 500 - 1000 iterations



Method tested based on CLAS6 e1f dataset





→ Method will be tested with CLAS12 data

Conclusion and Outlook

- 3 different methods for CLAS12 electron momentum correction have been presented
- Up to now 2 methods have been succesfully tested with 2.2 GeV CLAS12 data
- The elastic peak in W can be moved to the correct position and σ becomes significantly narrower
- Applicabilty of correction parameters extracted for 2.2 GeV to higher energies will be investigated
- Effect of the magnetic field on the correction parameters will be studied
- A kinematic correction will be the last step, first all other uncertainties leading to the observed effects should be minimized.
  - The introduced correction parameter x (δp) can be used to monitor the progress of the improvements.