Kinematics corrections for CLAS12
(intermediate report)

Volker Burkert

CLAS Collaboration Meeting

July 22, 2020

Working Group Members

https://clasweb.jlab.org/wiki/index.php/Run_Group_A
Kinematical Corrections

Weekly meetings since April 13, 2020.

The Team:

- Joshua Artem Tan (KNU)
- Brandon Clary (UConn)
- Stefan Diehl (Giessen/UConn)
- **Andrey Kim** (UConn) todays presentation
- Kyungseon Joo (UConn)
- Francois X. Girod (UConn)
- Latifa Elouadrhiri (JLab)
- Daniel Carman (JLab)
- Wooyoung Kim (KNU)
- Volker Burkert (JLab)

Outline

- Reminder of the situation with CLAS
- What is different with CLAS12 ?
- Plan for CLAS12 kinematic corrections
- What has been done so far
- Conclusions and future plans

Kinematic corrections for CLAS

- Many different approaches have been used, some dedicated to specific reactions, others very sophisticated with hundreds of fit parameters involving changing orientation of the drift chambers.

- For one specific approach corrections were based on elastic scattering events for electrons (negative charge) and on exclusive process ep => e'π^+n for positive charges, and cross checks with ep => ep$\pi^0/\eta/\omega$.

- Corrections largely dominated by charged particle momentum due to poorly known magnetic field. The Torus magnet coils in CLAS had tolerances in positioning of $\pm$3mm, and coils could shrink and move in not well constrained fashion when cooled and when energized.

- Effect of fixed current in Mini-Torus versus different Torus currents

- Tracking detectors were surveyed and aligned leading to small polar angle corrections.

Documentation

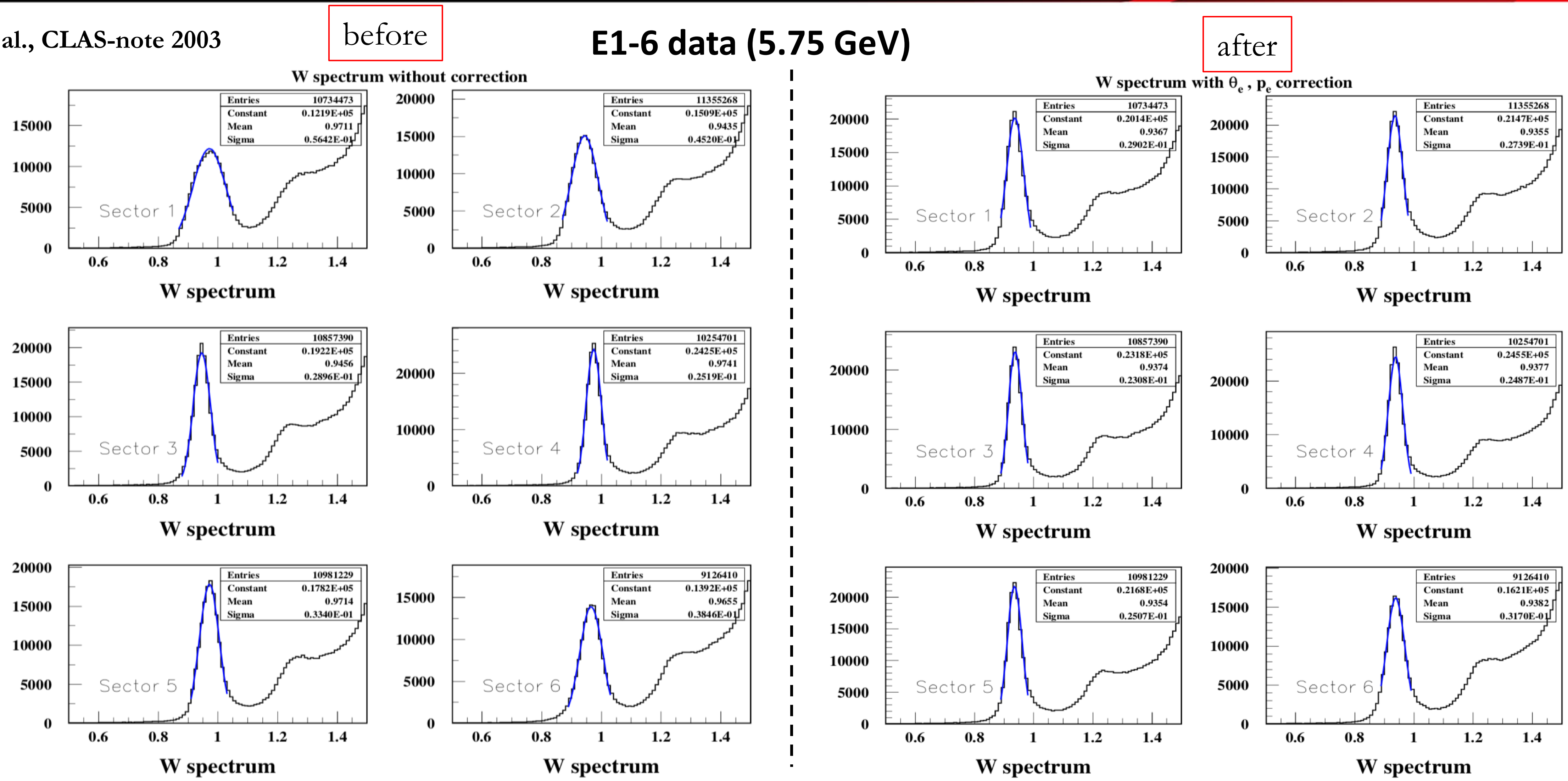
Old (CLAS6) Docs

- El. Corr. 4.4 GeV
- General momentum correction form for CLAS
- Beam Energy Measurements with ep -> ep (CLAS)
- Momentum Correction for E6
- Momentum corrections for E1-6 using kinematical fits
- Kinematics Corrections for CLAS
- Kinematic Fitting in CLAS
- Determining Momentum and Energy Corrections for g1c Using Kinematic Fitting
- Techniques in Kinematic Fitting
- CLAS Momentum Corrections for e1c, e1-6, e1f

Elastic ep scattering corrections

K. Park et al., CLAS-note 2003

E1-6 data (5.75 GeV)



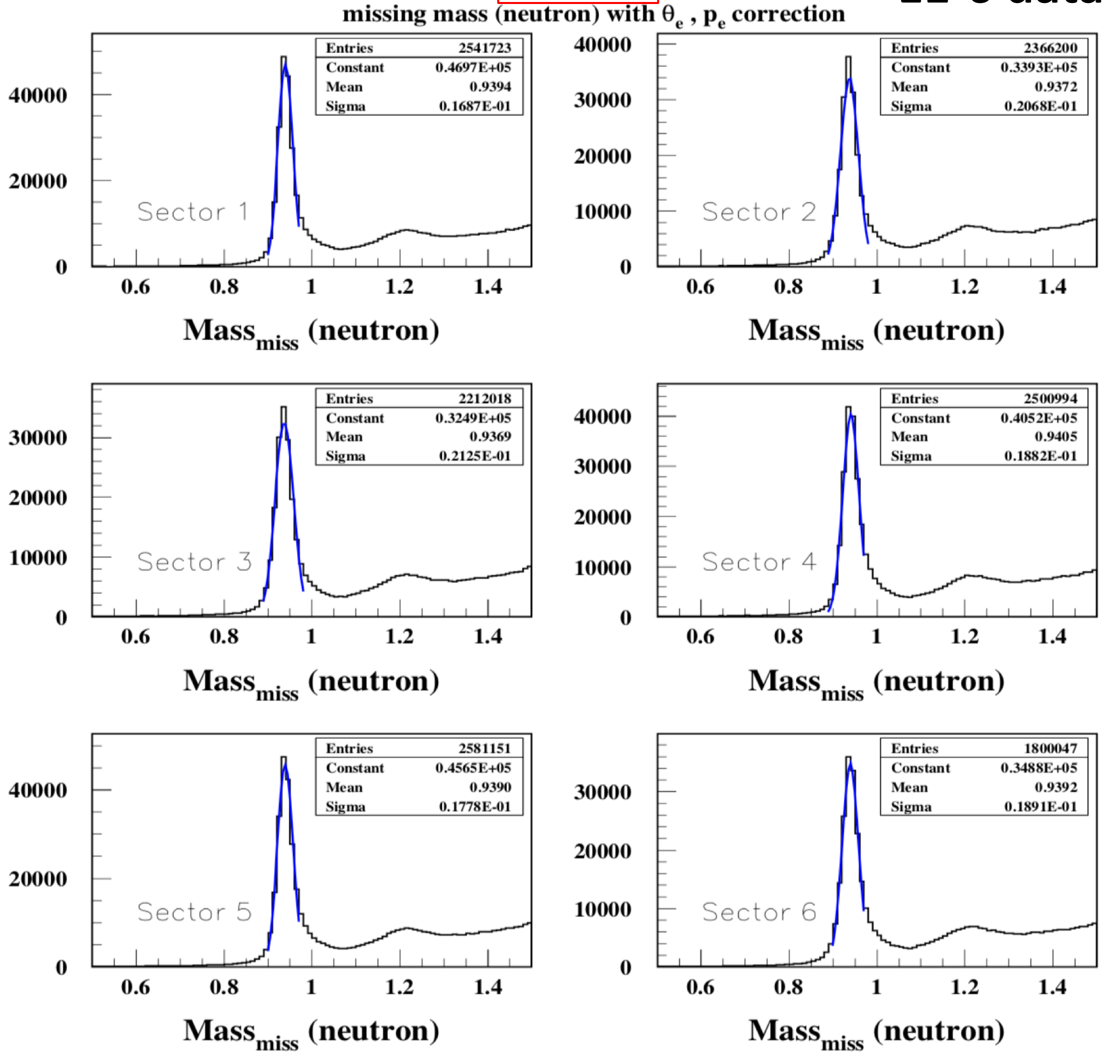
Corrections studied in 10 CLAS notes from different groups

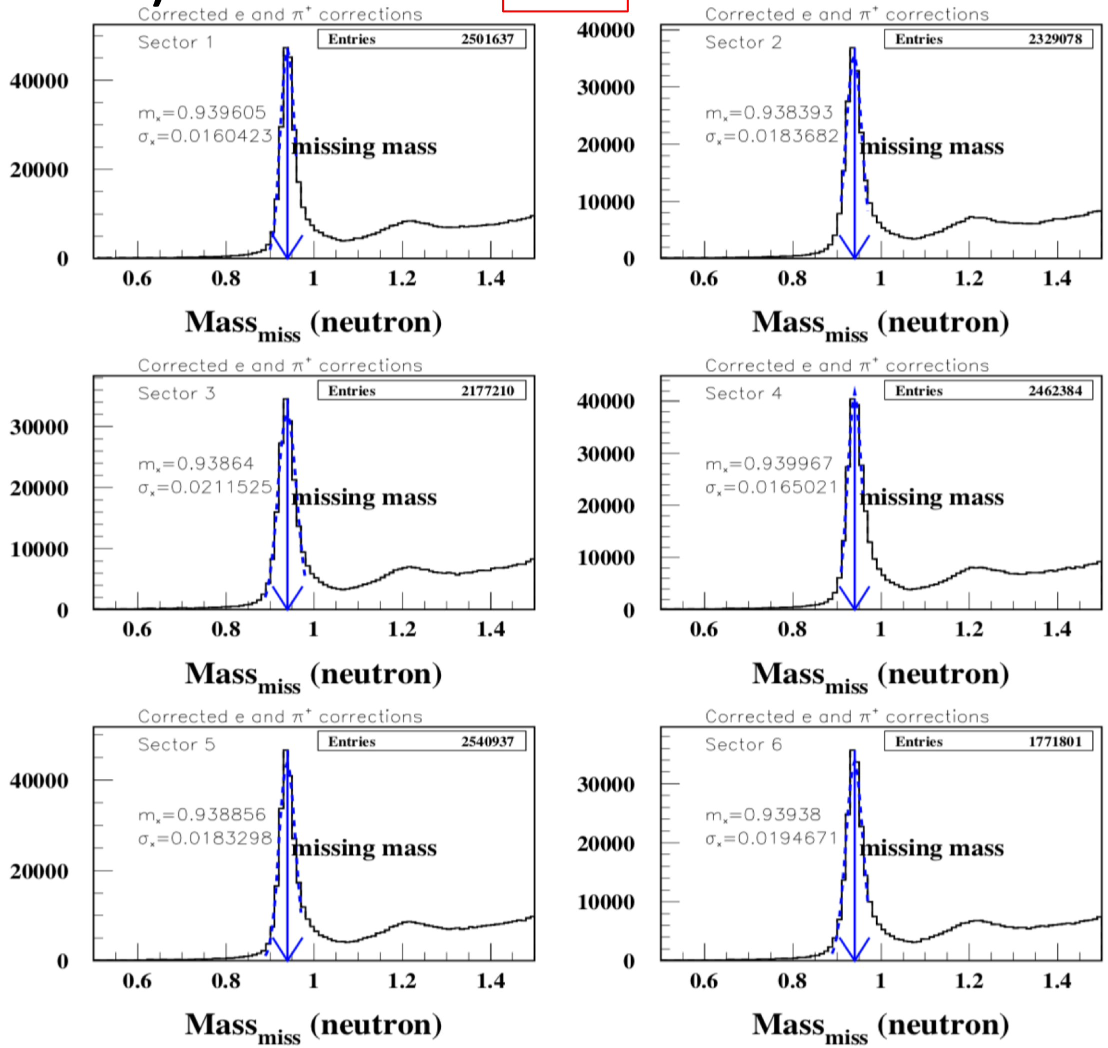
$e\pi^+n$ corrections after electron corrections

before

E1-6 data (5.75 GeV)

after





CLAS Missing masses of π^0, η, ω

e1-6 Data

Before corrections

DATA:

π^0: 155 MeV

η: **560.1 MeV**

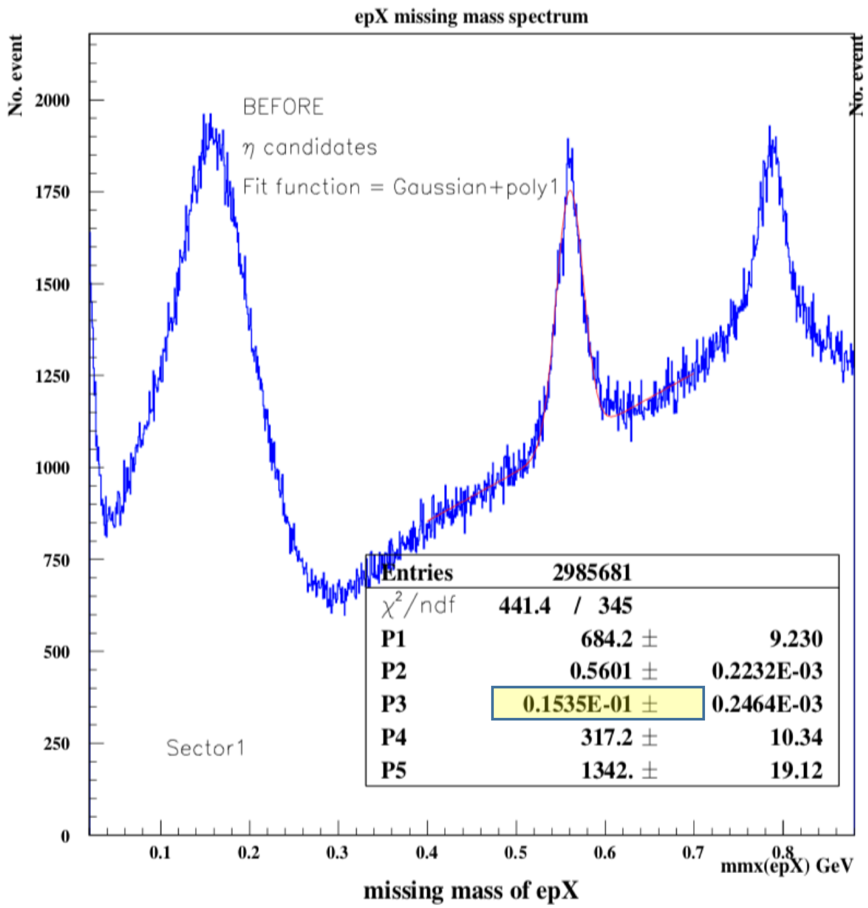
ω: 788 MeV

PDG:

π^0: 135.0 MeV

η: **547.8 MeV**

ω: 782.6 MeV



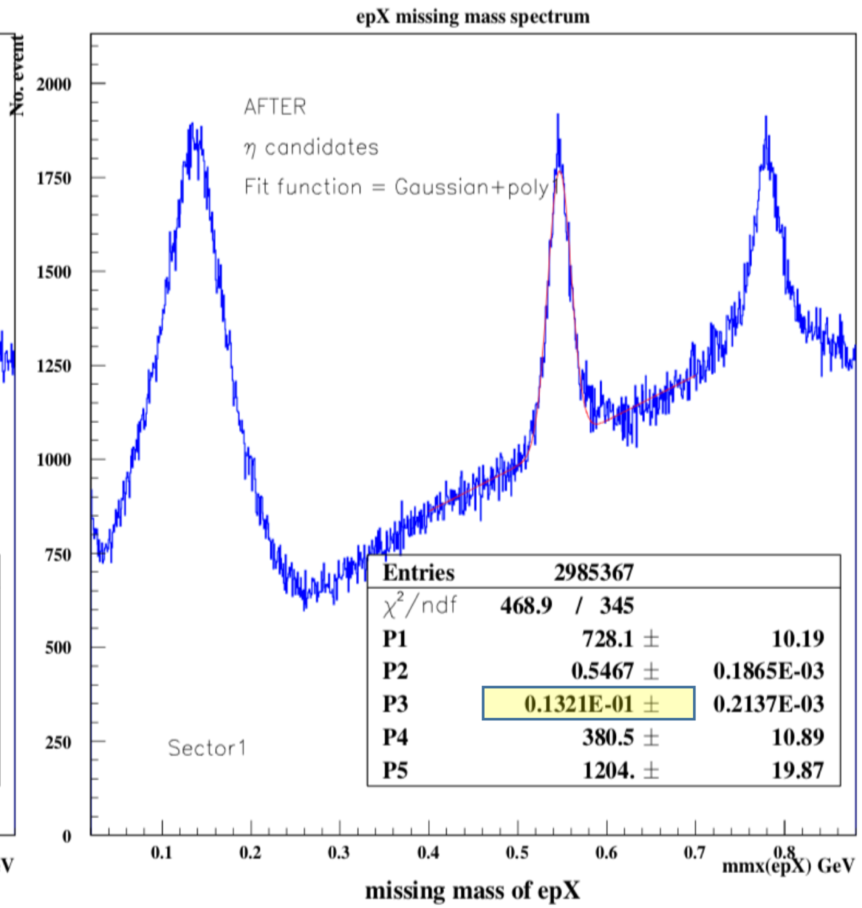


Figure 27: Missing mass spectrum of $e'pX$ (η) in sector 1

After corrections

DATA:

π^0: 135 MeV

η: **546.7 MeV**

ω: 781 MeV

PDG:

π^0: 135.0 MeV

η: **547.8 MeV**

ω: 782.6 MeV

On to CLAS12 @ 11 GeV

Expected to have a better situation in CLAS12 FD

- Magnetic field distribution better known as CLAS12 Torus was assembled under our own control
- S.C. coil movements are much more constrained by their attachments to the precisely machined cold hub
- The magnetic field was accurately mapped (in critical parts).

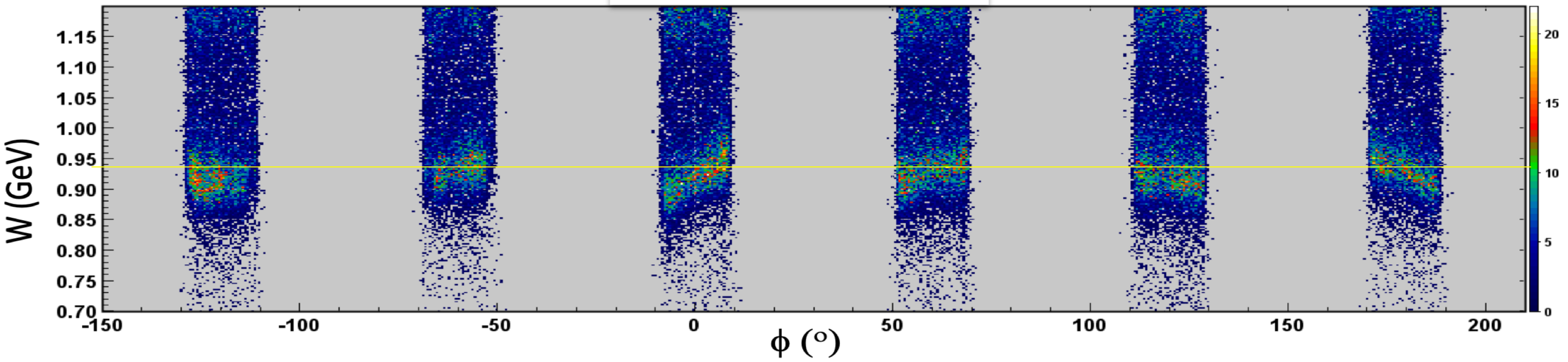
Complications in CLAS12

- Elastic ep scattering at 11 GeV does not cover significant part of available phase space – need to include other reactions
- Central Detector and the Forward Detector are mechanically decoupled and independently assembled
- The strong solenoid field bends charged particles in azimuthal angle.

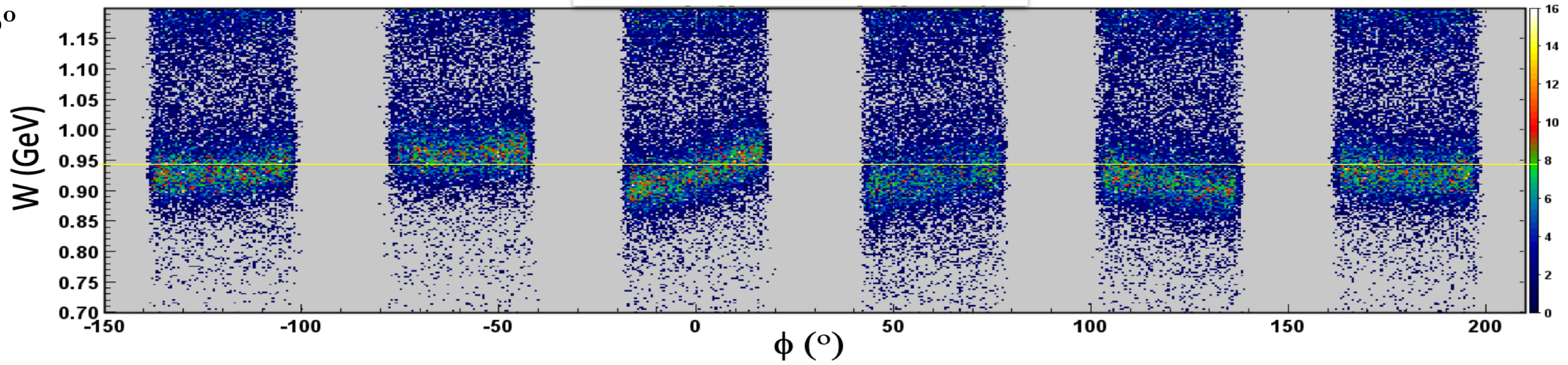
The case for kinematic corrections in CLAS12

Elastic band shows ϕ dependence – different by sector

$\theta_e = 8^o$

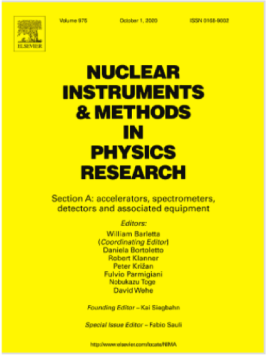


$\theta_e = 15^o$



Correction status October 2019

With 2018/19 corrections from
J. A. Tan, S. Diehl, F.X. Girod



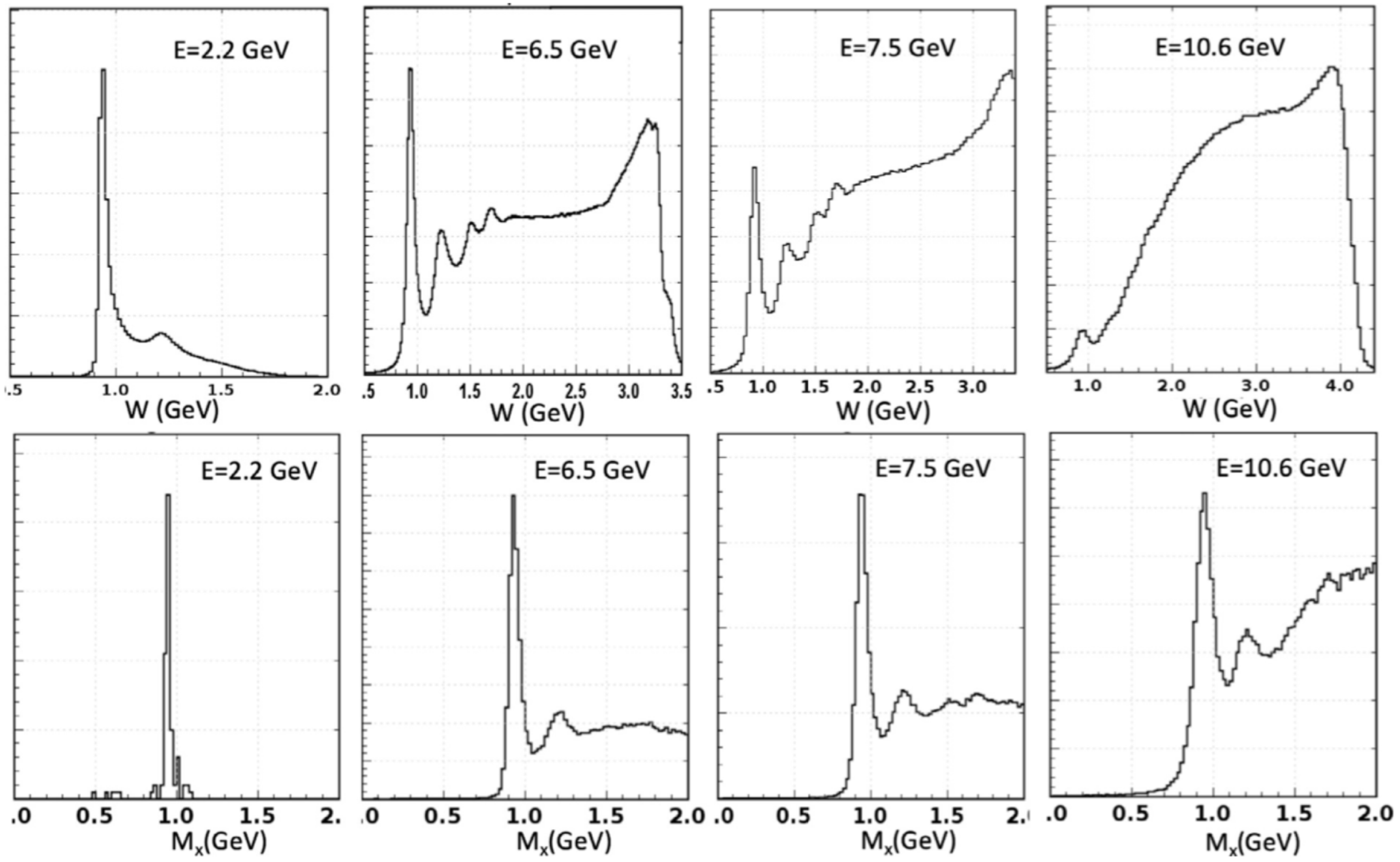
Nuclear Inst. and Methods in Physics Research, A 959 (2020) 163419

2.2 GeV: P/V = 8.6 (out)
6.5 GeV: P/V = 4.7 (out)
7.5 GeV: P/V = 3.6 (out)
10.6GeV: P/V = 1.5 (in)

ep -> e'X

6.5 GeV: P/V = 7.0
7.5 GeV: P/V = 5.2
10.6 GeV: P/V = 2.6

ep -> e'π^+X

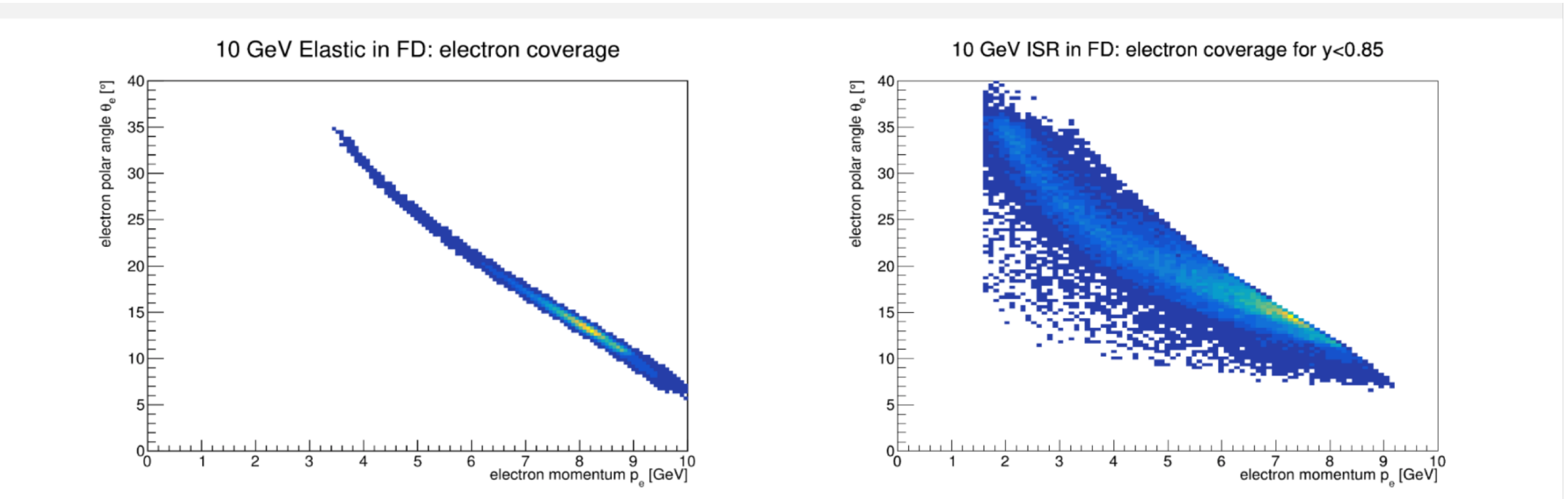


Near term plan for CLAS12 kinematic corrections

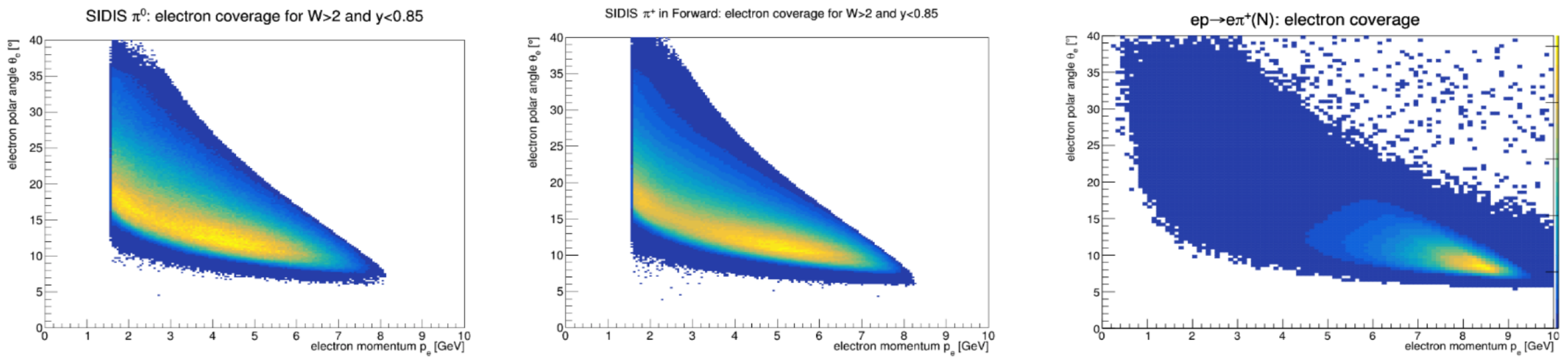
- Based on exclusive processes develop leading order corrections based on RGA & RGK data for use in the analysis of first publications
- Use elastic ep events to start, with all available energies and in/out-bending electrons
- Extend to elastic radiative events to cover more of the momentum-polar angle space
- Use other exclusive processes, e.g. ep => $e\pi^+(n)$, $ep\pi^+\pi^-$, ..
- Cross check results on missing masses of $ep\pi^0$, $ep\eta$, $ep\omega$, $ep\eta'$, $ep\phi$ ..
- **Focus today** on ep, $ep\gamma$ –> ep, $e\pi^+X$

Electron coverage for elastic and ISR kinematics

- Over-constrained kinematics of elastic ep scattering and knowledge of beam energy enable correcting electron momentum from its scattering angle.
- Using ISR elastic scattering corrections can be extended to lower momentum.
- Additional kinematic fitting of exclusive processes can be used to further extend the coverage.

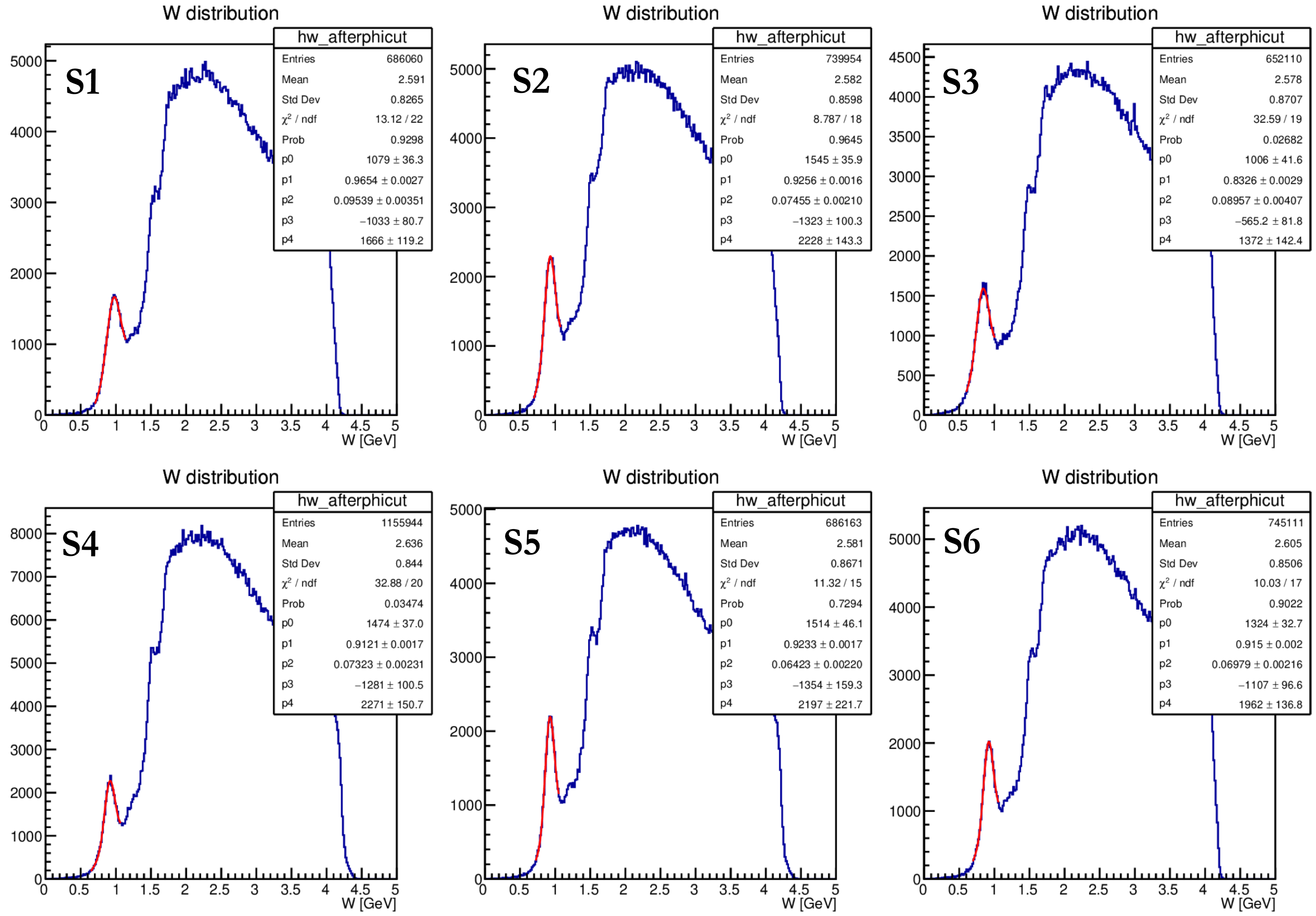


- Electron angular and momentum coverage from elastic events is **very limited**
- ISR events provide much wider range of electron coverage, **more suitable for electrons from other reactions**
- For application to other reactions we need to extrapolate the momentum corrections
- The electron coverage for some of the major reactions is shown below: SIDIS π^+, SIDIS π^0, exclusive $e\pi^+(N)$



Elastic scattering at 10.6 GeV (in-bending)

W-spectrum with proton in the FD



W_{el} = 833 MeV (S3)
912 – 965 MeV

ΔW_{el} = 64 -95MeV

Corrections from elastic scattering

Kinematics corrections from elastic scattering

if we trust beam energy E_0 and electron angle θ_e we can calculate electron momentum:

$$p_e^{calc} = \frac{E_0}{1 + 2E_0 \sin^2\left(\frac{\theta_e}{2}\right) / M_p}$$

$$\Delta p_e = p_e^{measured} - p_e^{calc}$$

CLAS-Note 2003-012

Kinematics Corrections for CLAS

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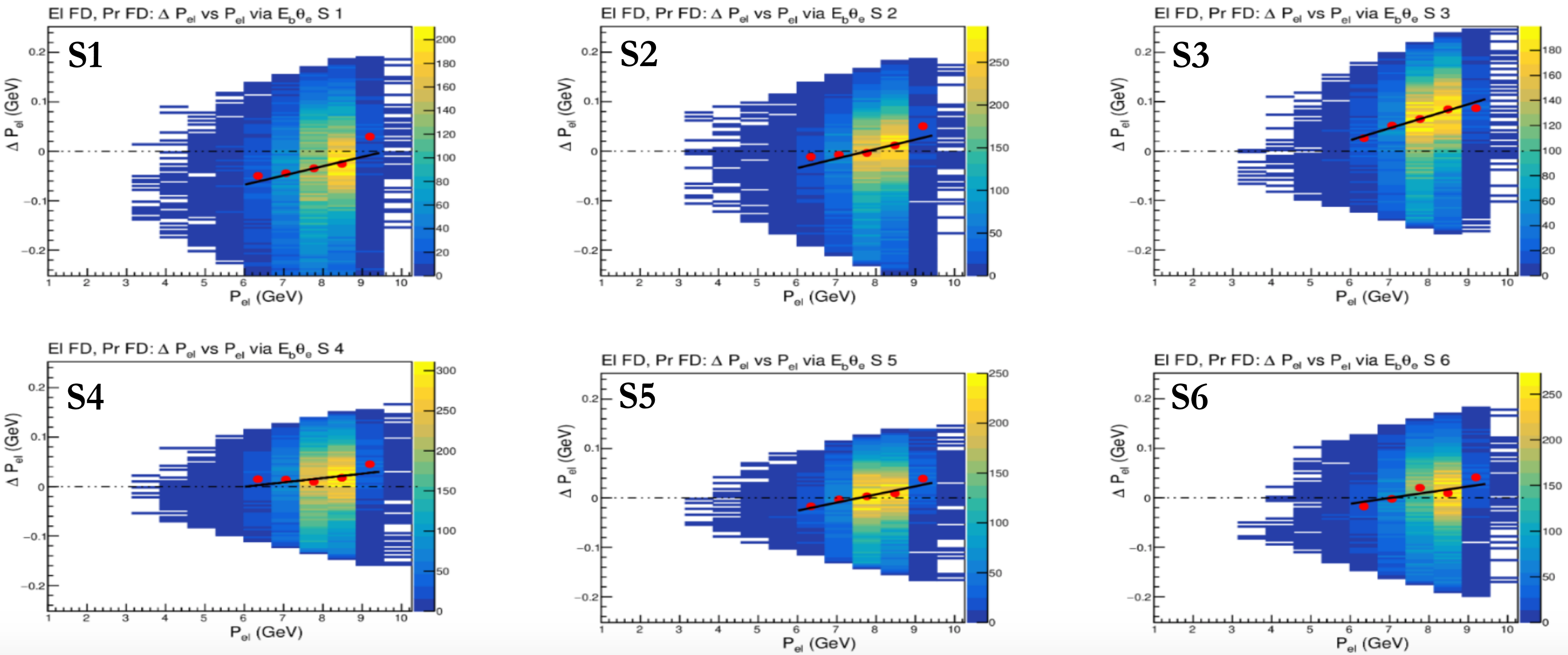
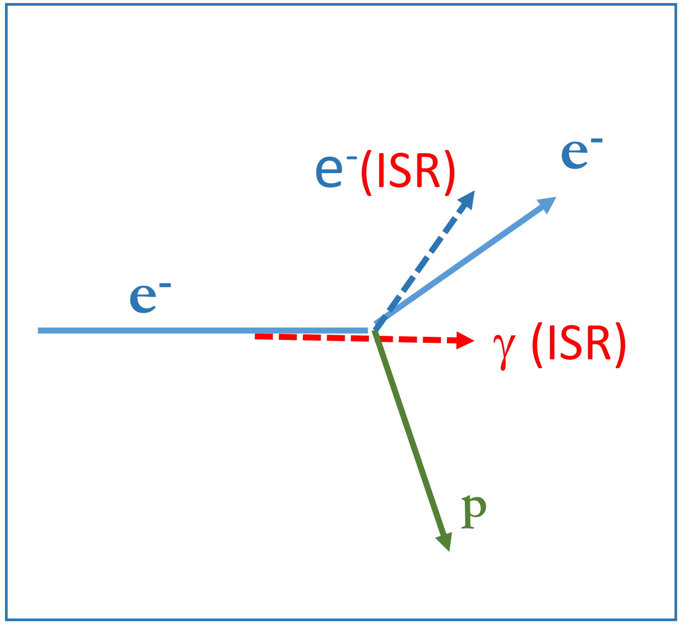
Kyungpook National University, Daegu, Korea 702-701
Jefferson Lab, 12000 Jefferson Avenue, Newport News, VA 23606

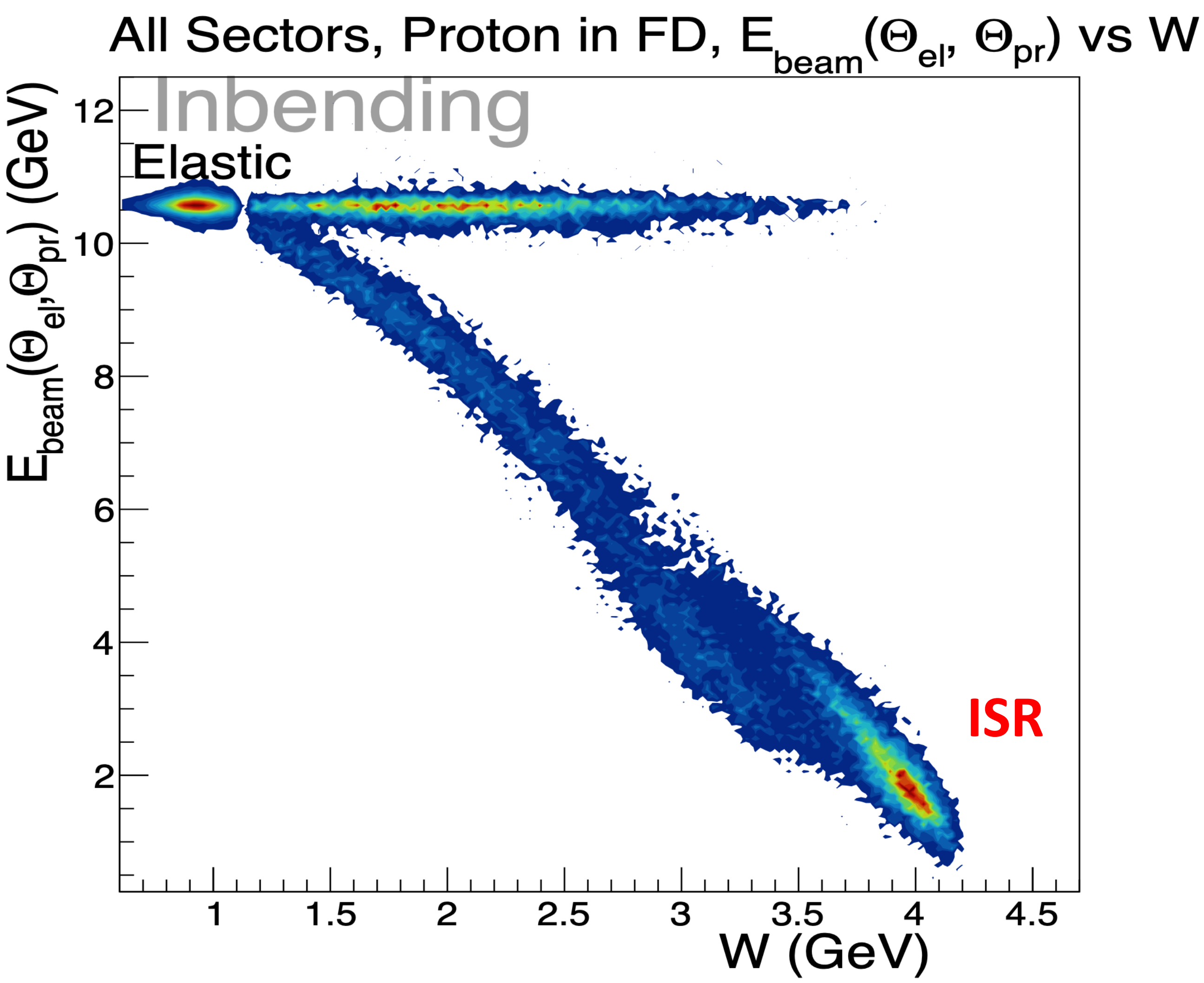
August 11, 2003

E_0 - correct
θ_e - correct

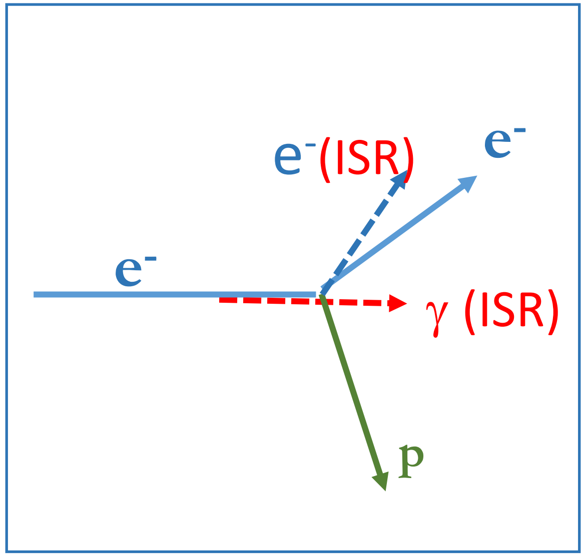


ISR in Elastic Scattering at 10.6 GeV



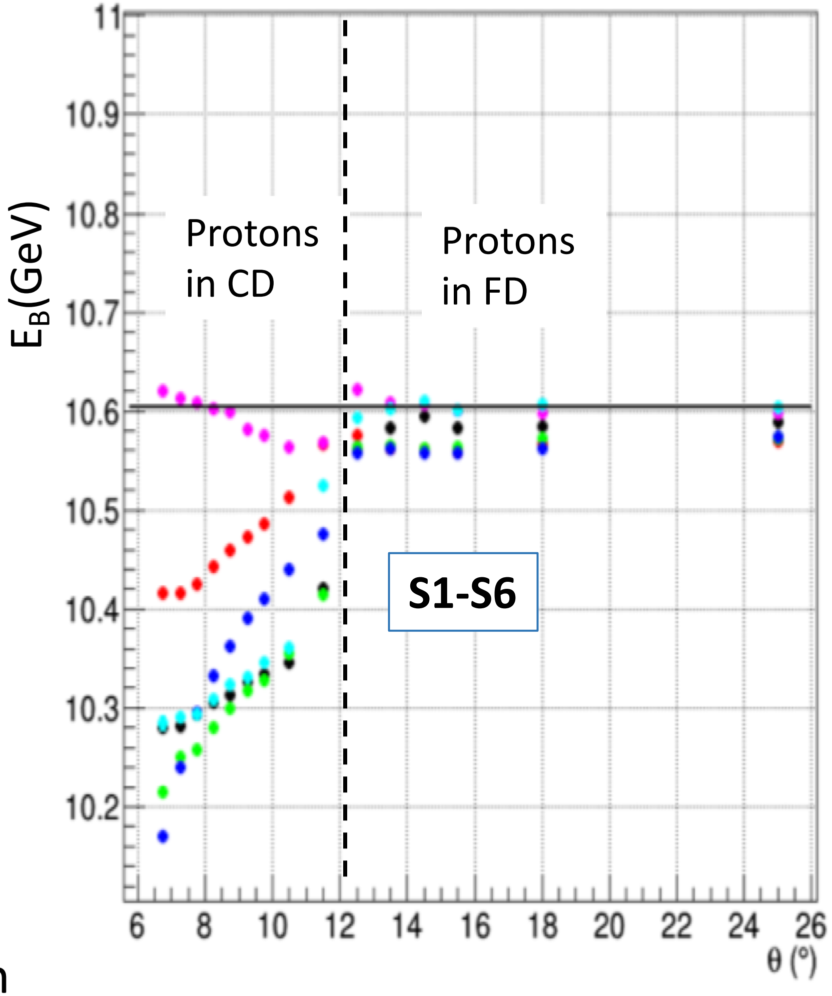


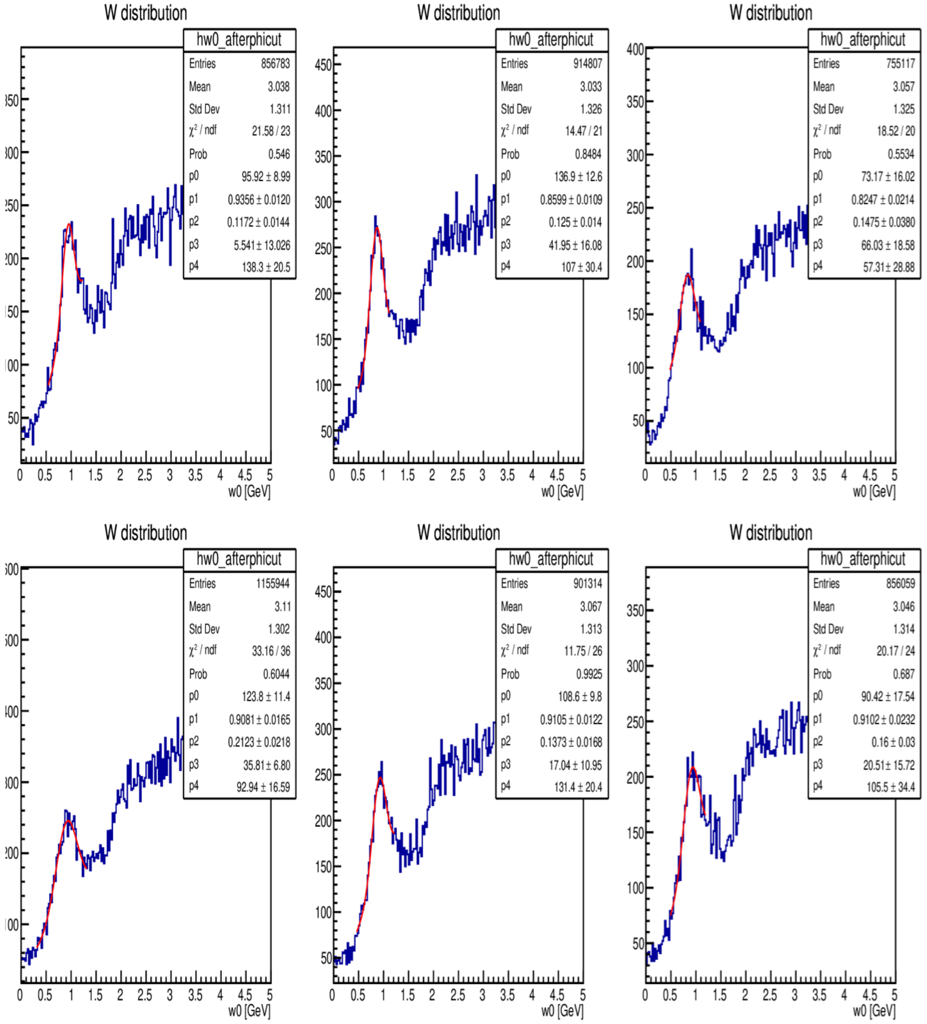
ISR - Elastic Events (proton in FD)



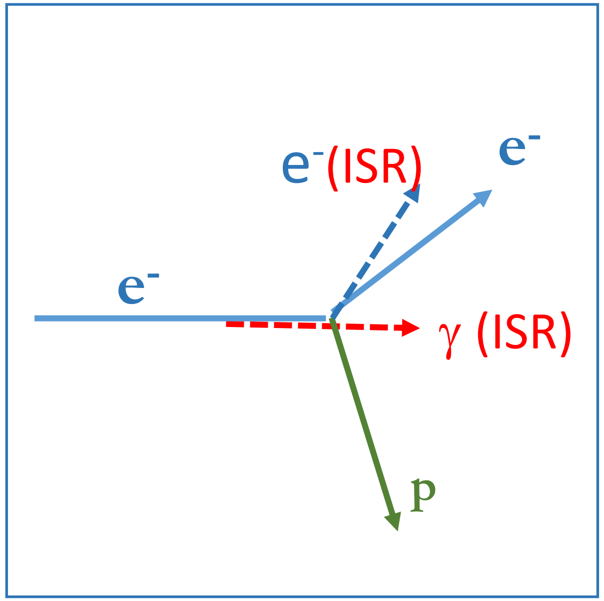
- Energy of scattered electron after ISR is unknown. Assuming electron and proton angles are known, the effective "beam" energy can be computed.

- Significant widening of ΔW in elastic peak up to factor 2.



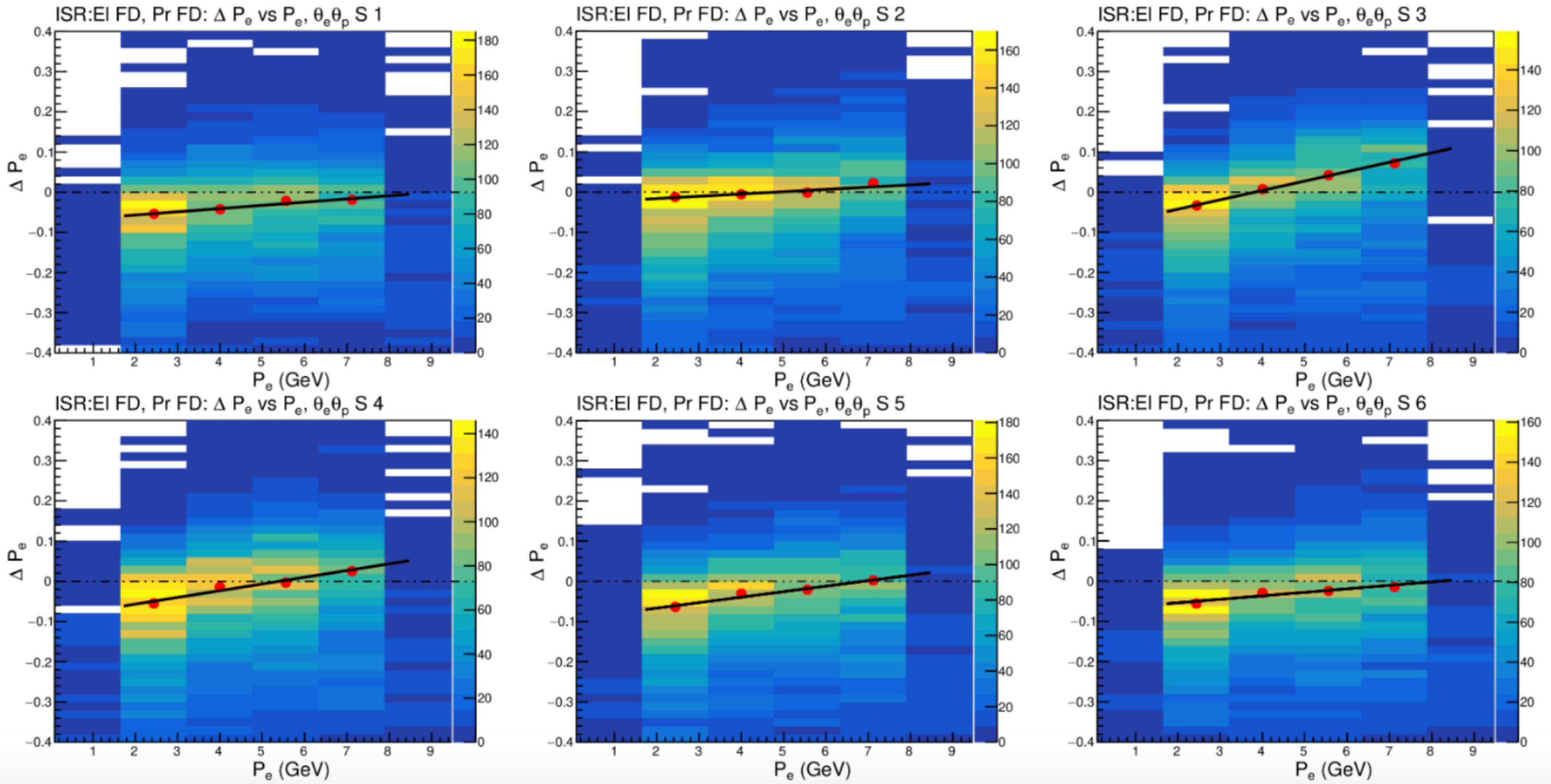


Kinematic corrections from ISR events



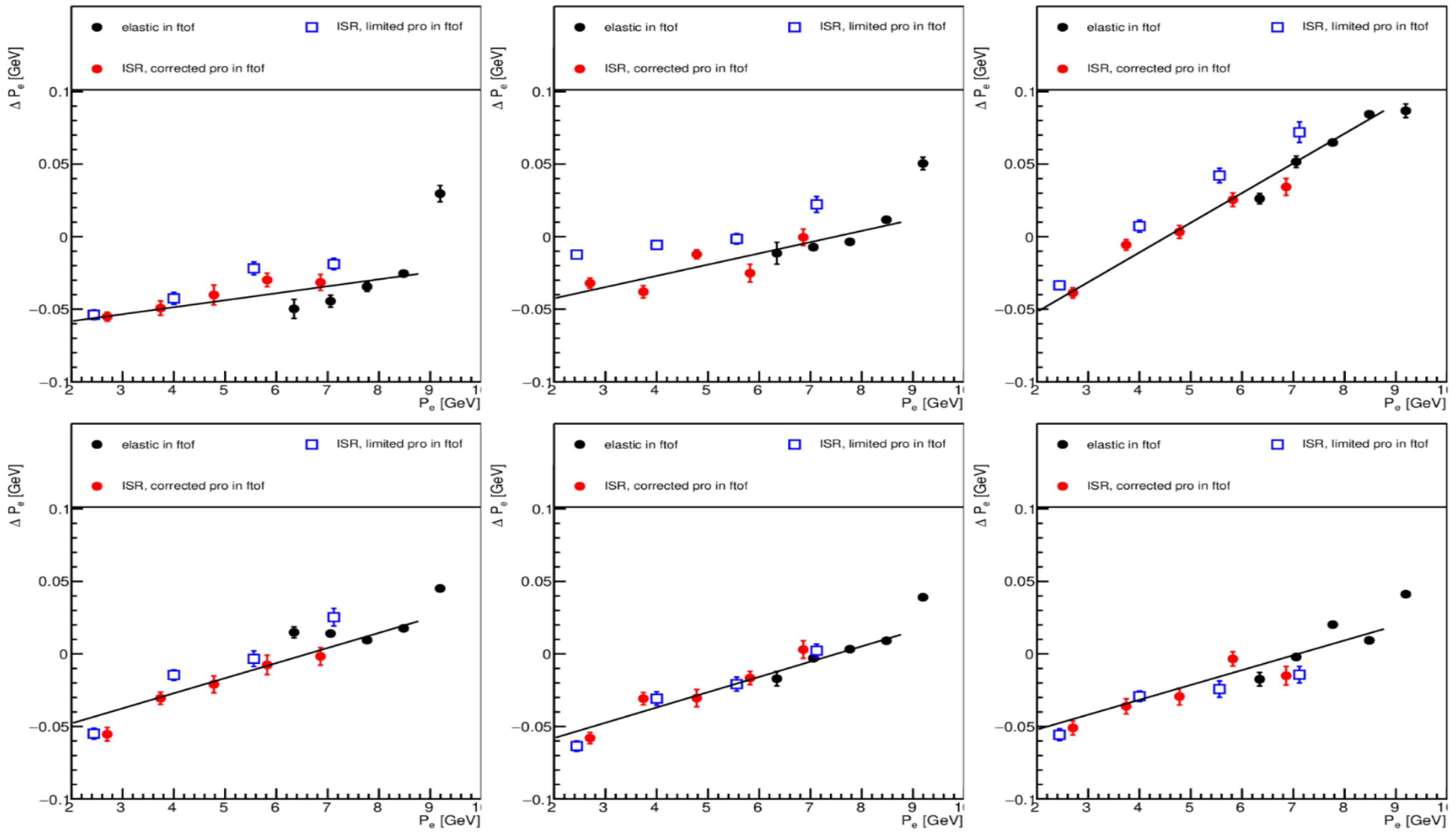
Compute electron momentum from "beam" energy e_0 using θ_e and θ_p

$$p_e = \frac{e_0}{1 + 2e_0 \sin^2\left(\frac{\theta_e}{2}\right)/M_p}, \text{ where } e_0 = f(\theta_e, \theta_p)$$

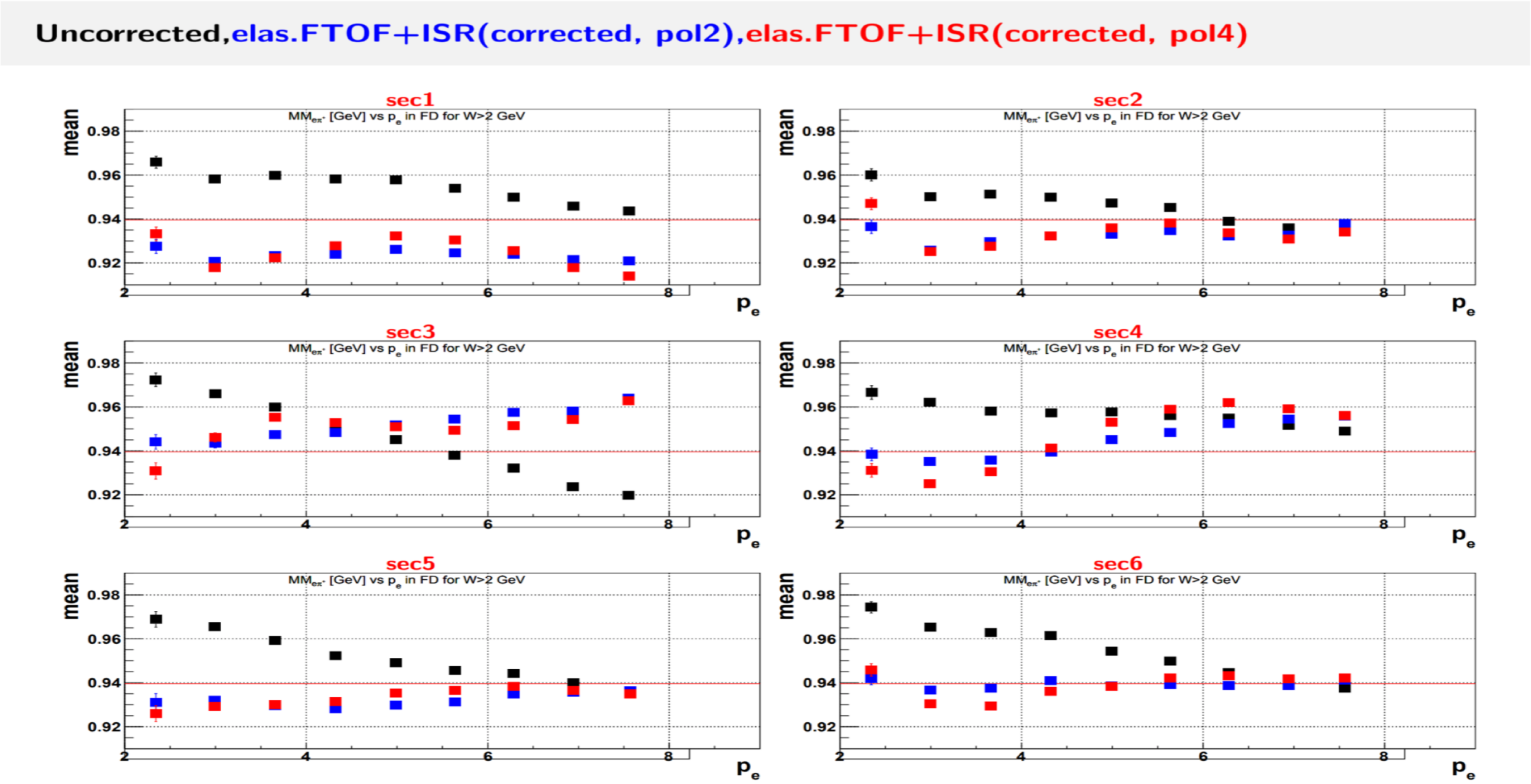


Combining elastic and ISR corrections

- Elastic protons in FD
- ISR events with elastic Protons in FD
- ISR events with corrected elastic Protons in FD



Combine corrections from elastic and ISR



$e\pi^+X$

➔ **Some improvements from elastic and ISR, but not consistent in all sectors**

Explore - Use $e\pi^+X$ events for electron corrections

Define χ^2 for minimization:

$$\chi^2 = \sum_{i<bins} \left(\frac{MM_i - M_n}{\Delta M_i} \right)^2 \quad (1)$$

- MM_i and ΔM_i - mean values and errors extracted from the fit described before
- M_n - neutron mass
- the smaller the χ^2 the better the effect of the correction

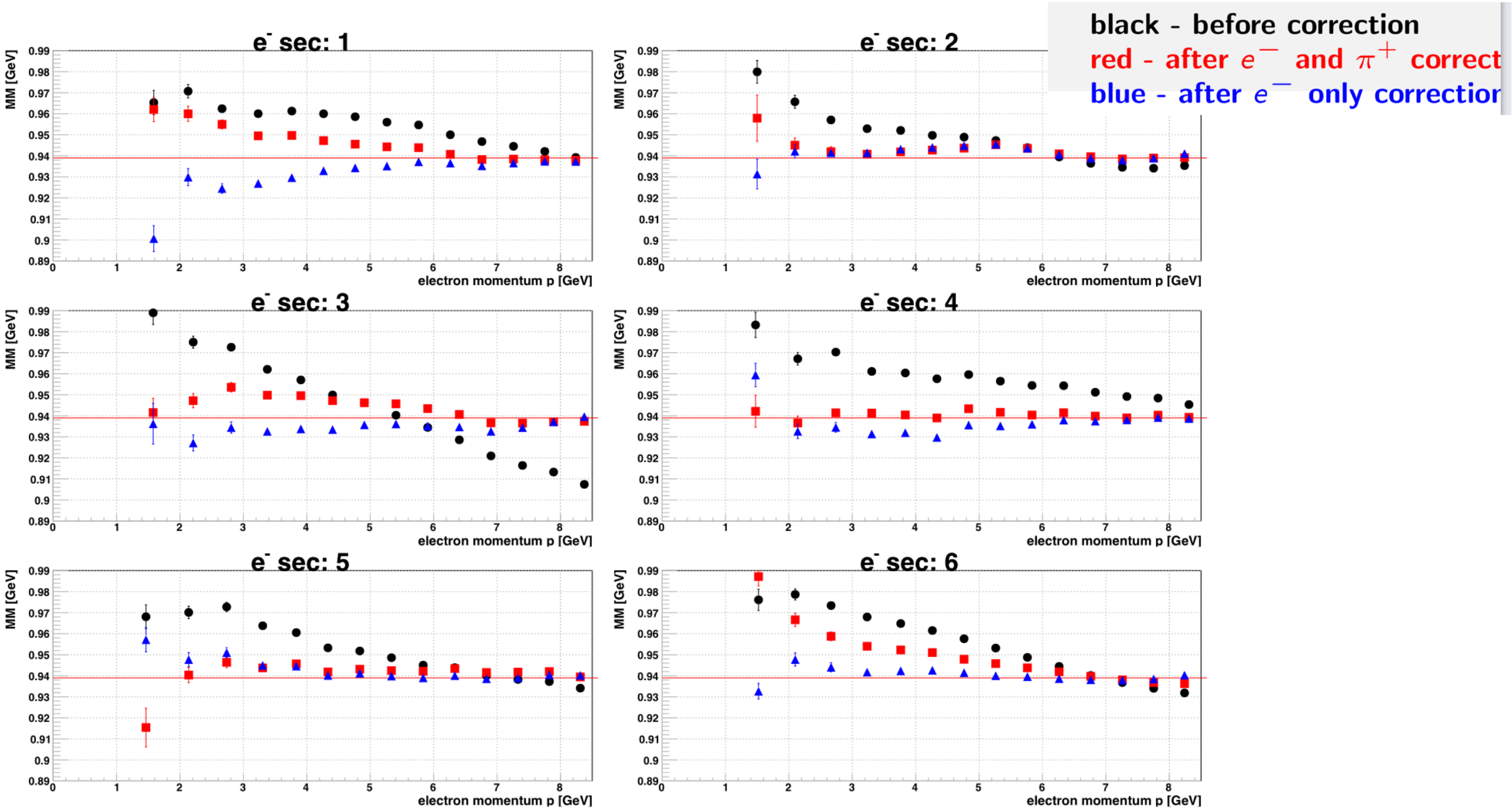
Current status: finding the best parameters for electron and pion simultaneously

- introduce ϕ dependence into correction function:

$$p^{new} = (a_0 + b_0\phi + c_0\phi^2) + (a_1 + b_1\phi + c_1\phi^2)p$$

- we have 6 parameters for each sector: **36 total**
- ϕ is a vertex azimuthal angle, local to sector, i.e. has a distribution -30° and 30°

$e\pi^+X$ versus electron momentum

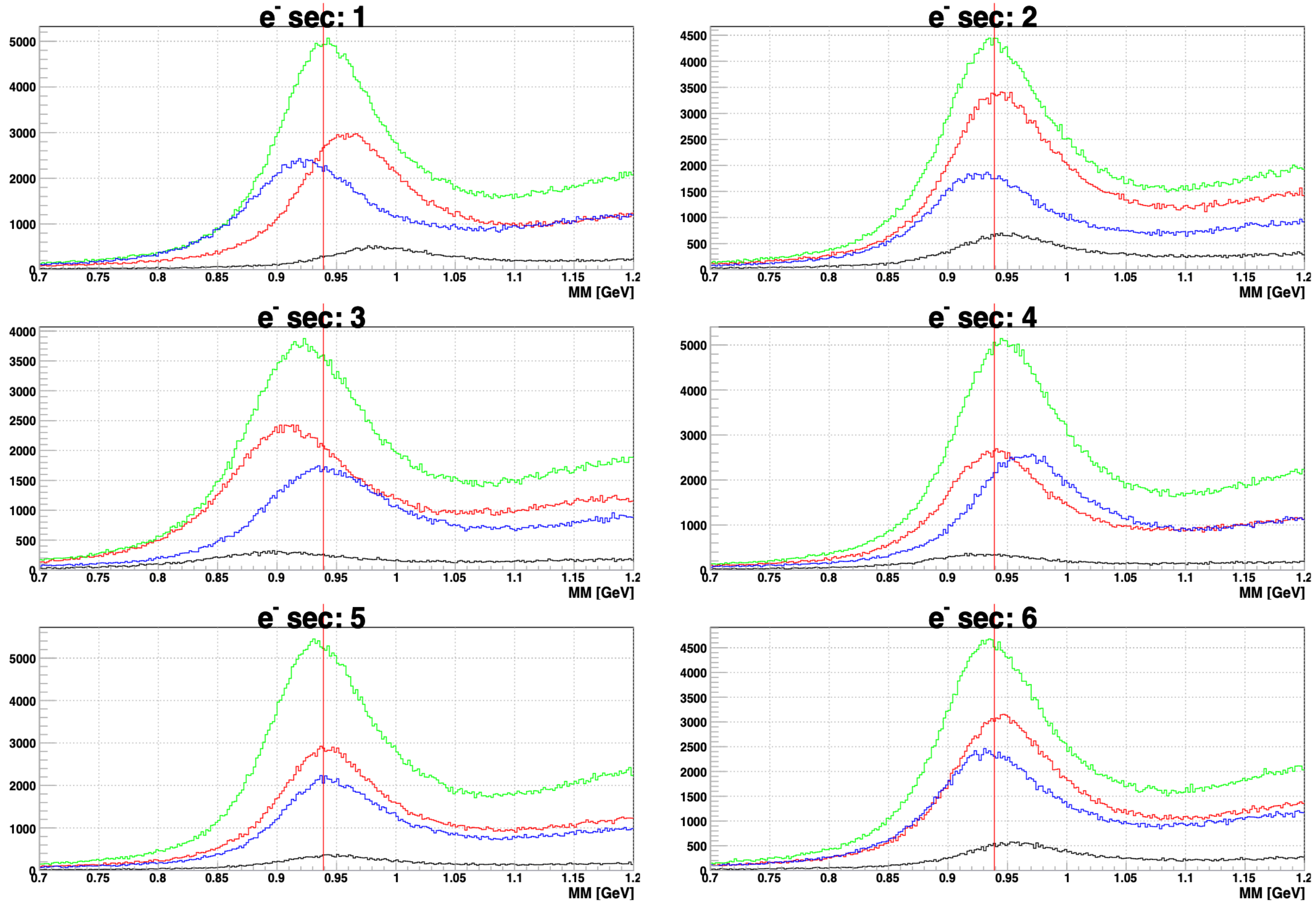


Azimuthal dependence in $e\pi^+X$

Before corrections

MM for $e\pi^+X$ for **4** ϕ **bins**, before correction

black: $\phi_e < -10^\circ$
red: $-10 < \phi_e < 0^\circ$
green: $0 < \phi_e < 10^\circ$
blue: $\phi_e > 10^\circ$



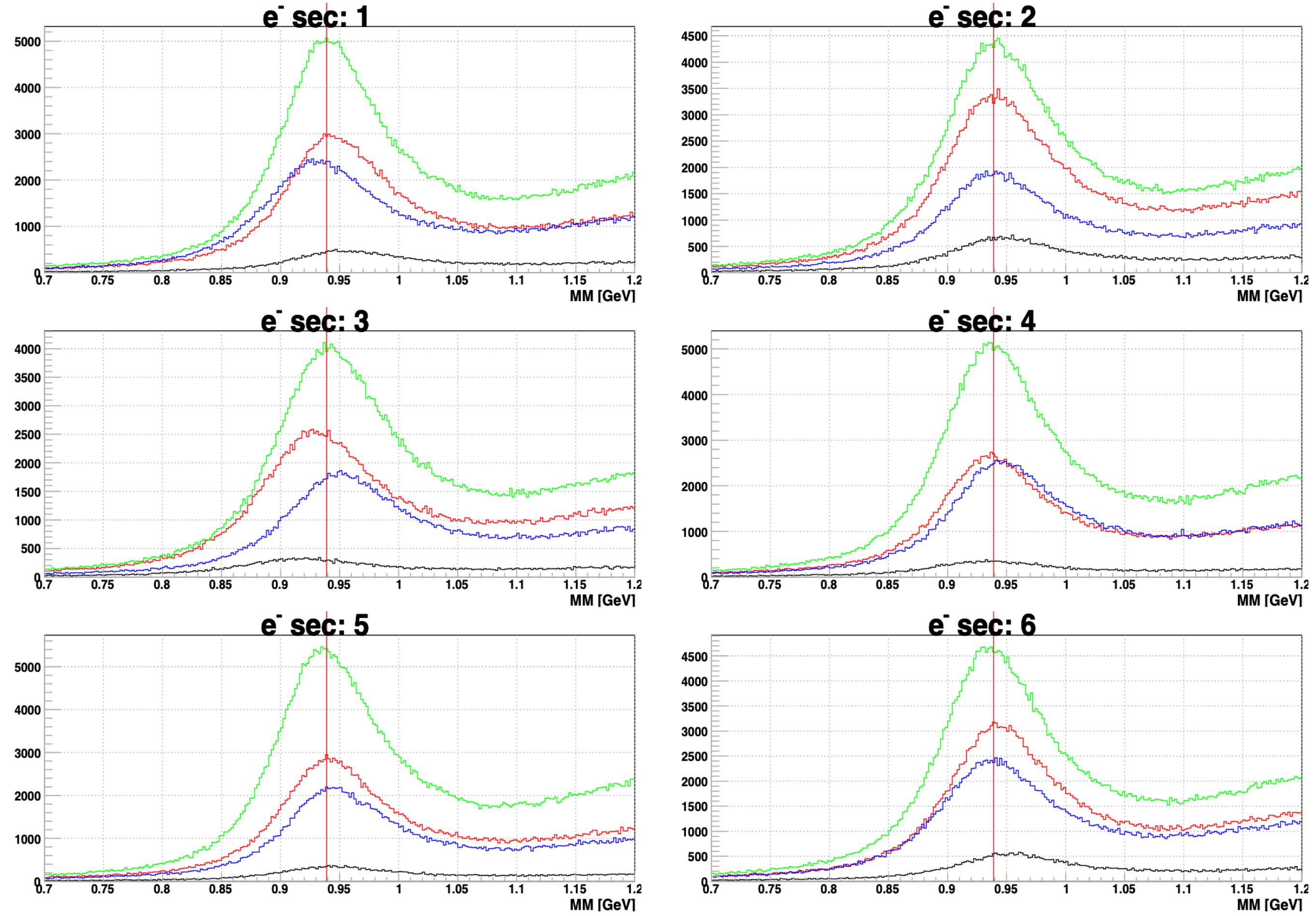
Significant ϕ – dependencies in most sectors

Include azimuthal dependence in $e\pi^+X$

After e^- and π^+ corrections

MM for $e\pi^+X$ for **4 ϕ bins**, after e^- and π^+ correction

black: $\phi_e < -10^\circ$
red: $-10 < \phi_e < 0^\circ$
green: $0 < \phi_e < 10^\circ$
blue: $\phi_e > 10^\circ$



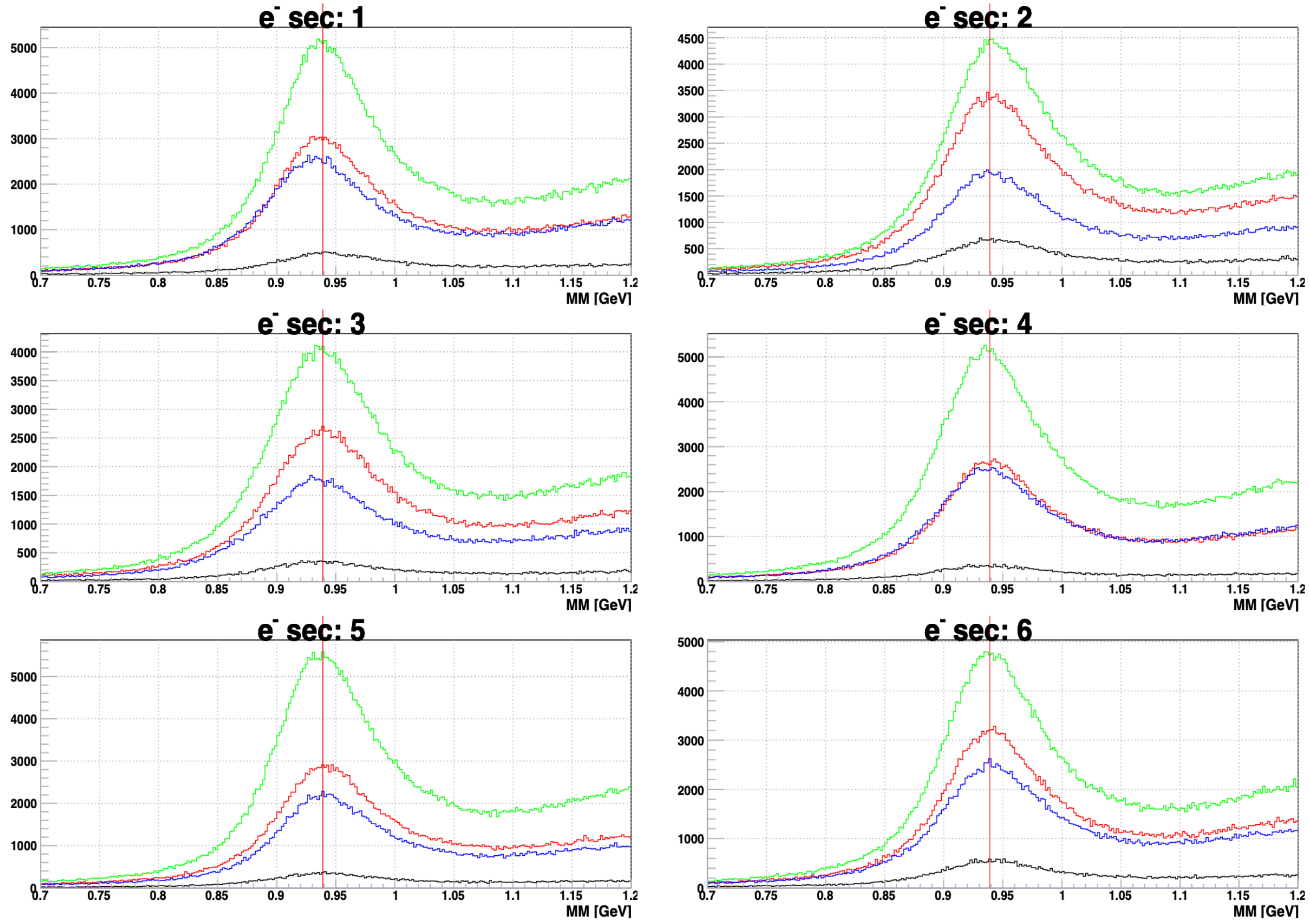
Significant ϕ – dependencies remaining **in several** sectors

Include azimuthal dependence in $e\pi^{+}X$

After e^- corrections only

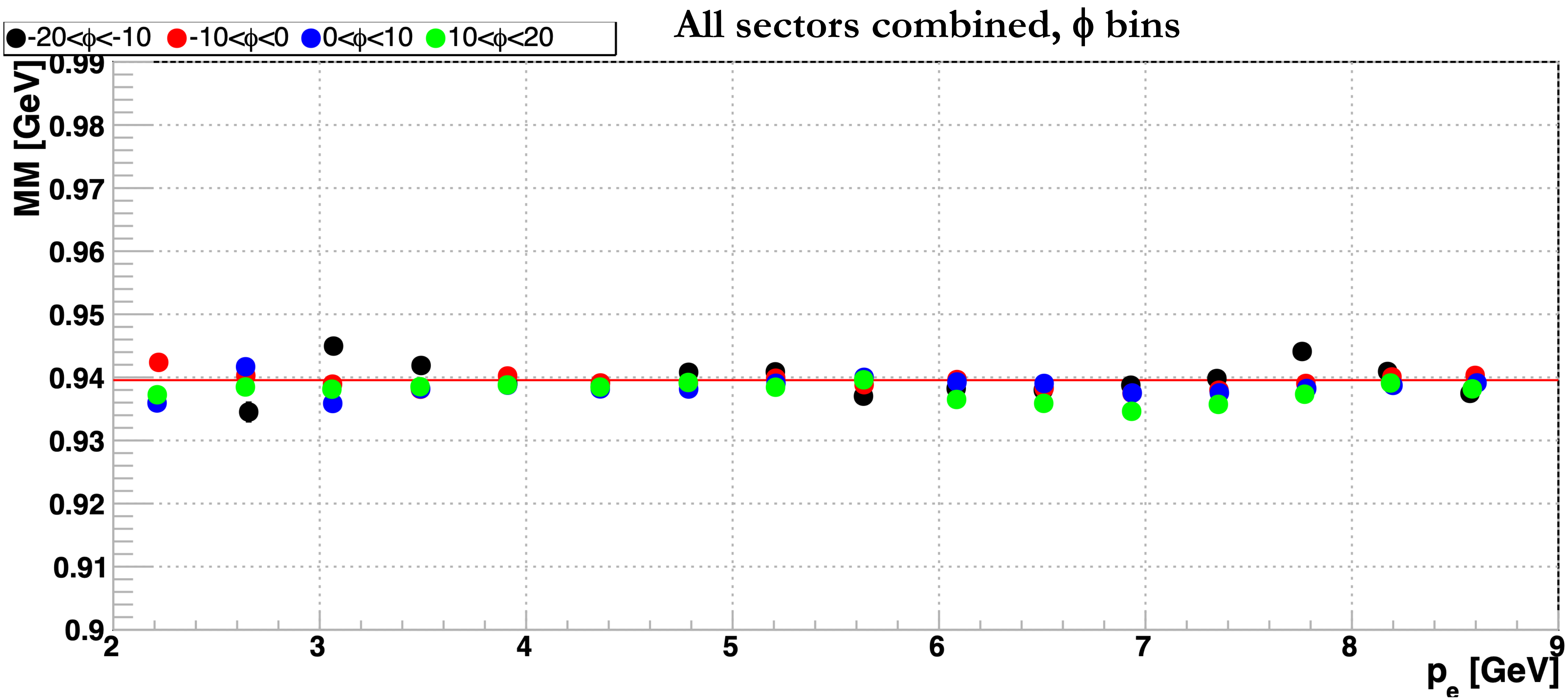
MM for $e\pi^+X$ for **4** ϕ **bins**, after e^- only correction

black: $\phi_e < -10^\circ$
red: $-10 < \phi_e < 0^\circ$
green: $0 < \phi_e < 10^\circ$
blue: $\phi_e > 10^\circ$

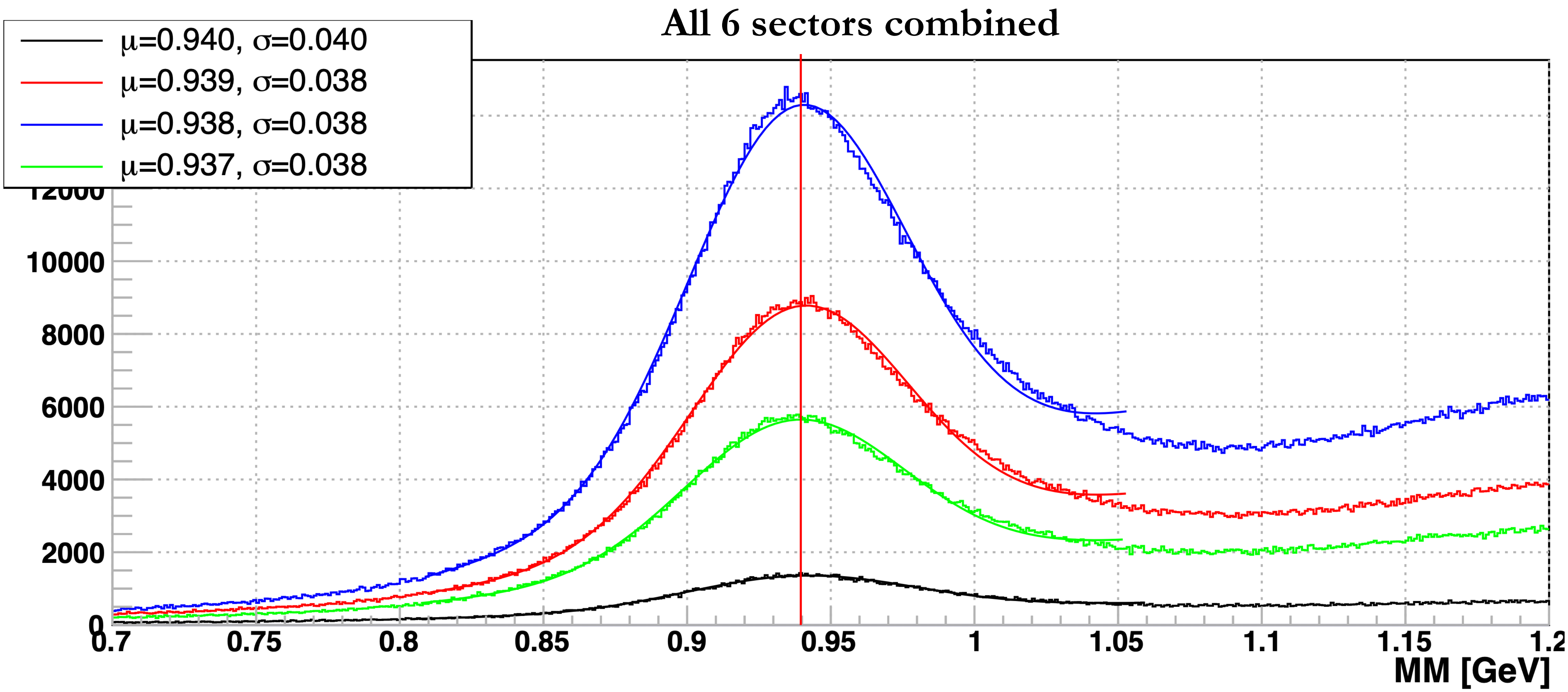


Nearly all azimuthal dependencies in all sectors removed.

Missing mass $e\pi^+(n)$ centroid



Missing mass $e\pi^{+}(n)$ for 4 ϕ ranges



Summary and Outlook

Intermediate conclusions (from FD study)

- Correction functions significantly improve missing mass peak position in $e\pi^+X$
- Resolutions also improved
- Variation of electron kinematics alone yields better results than varying both electron and π^+ simultaneously (needs further understanding)

Next steps

- Include other channels from RGA in fit function, e.g. MM epX (π^0), $ep\pi^+\pi^-$
- Include RGA electron out-bending data, all suitable channels
- Include RGK data (once cooked)
    - Lower energies 6.5 and 7.5 GeV to cover other areas of the phase space
    - Out-bending electrons (i.e. in-bending π^+)

Future plans

- Corrections for the Central Tracker, both SVT and BMT.
- Automate correction procedure
- Coordinate with Software Group the implementation
- Produce technical note
- Write section on RGA Common Analysis note