CLAS12 Inclusive Electroproduction Cross Section Analysis

N. Markov, Jefferson Lab
for the CLAS collaboration

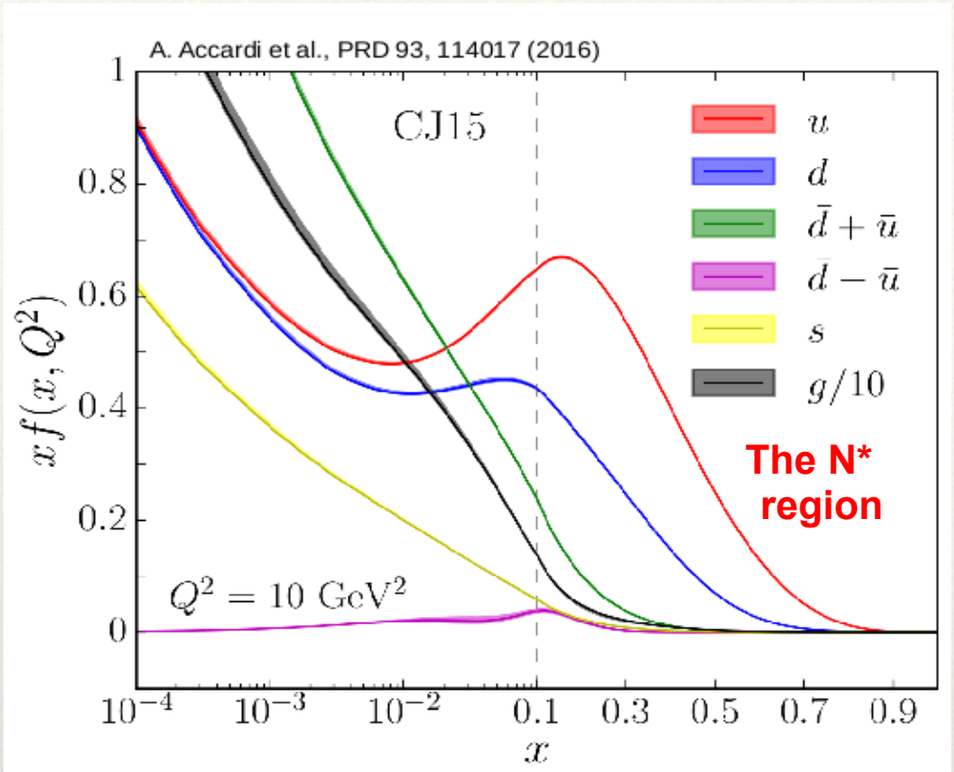
CEBAF Large Acceptance Spectrometer

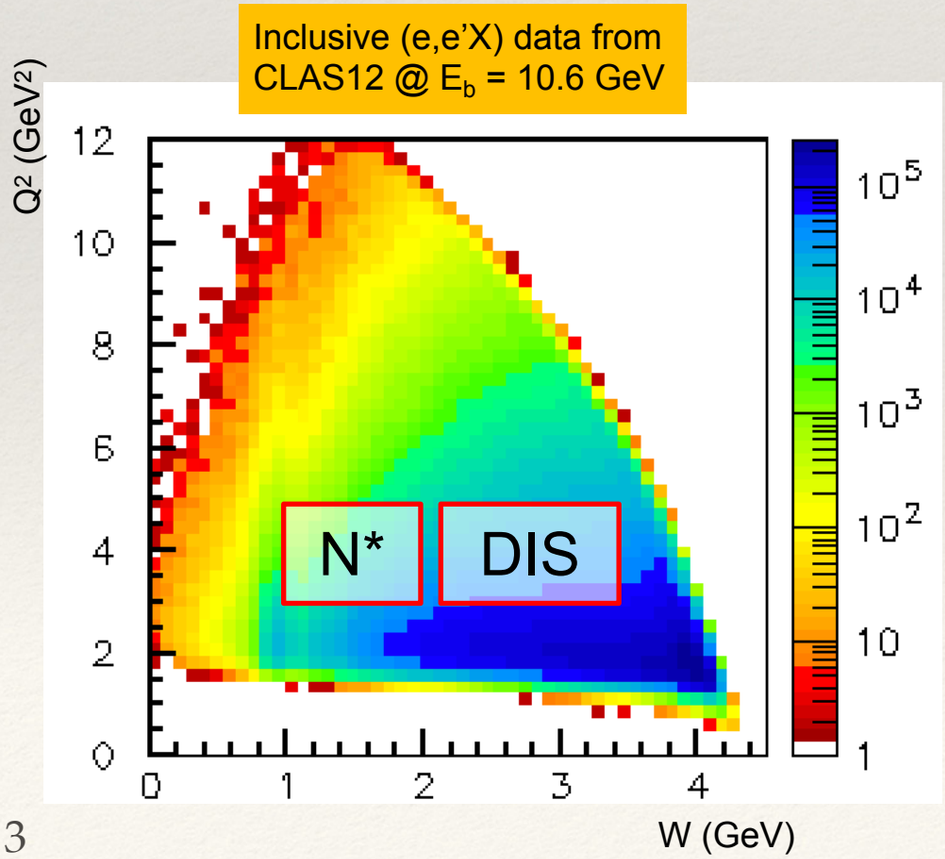
Jefferson Lab

Overview

- Introduction and motivation
- Electron Identification and data analysis
- Next steps and outlook
- Summary

Extending Knowledge of the Nucleon PDF in the Resonance Region

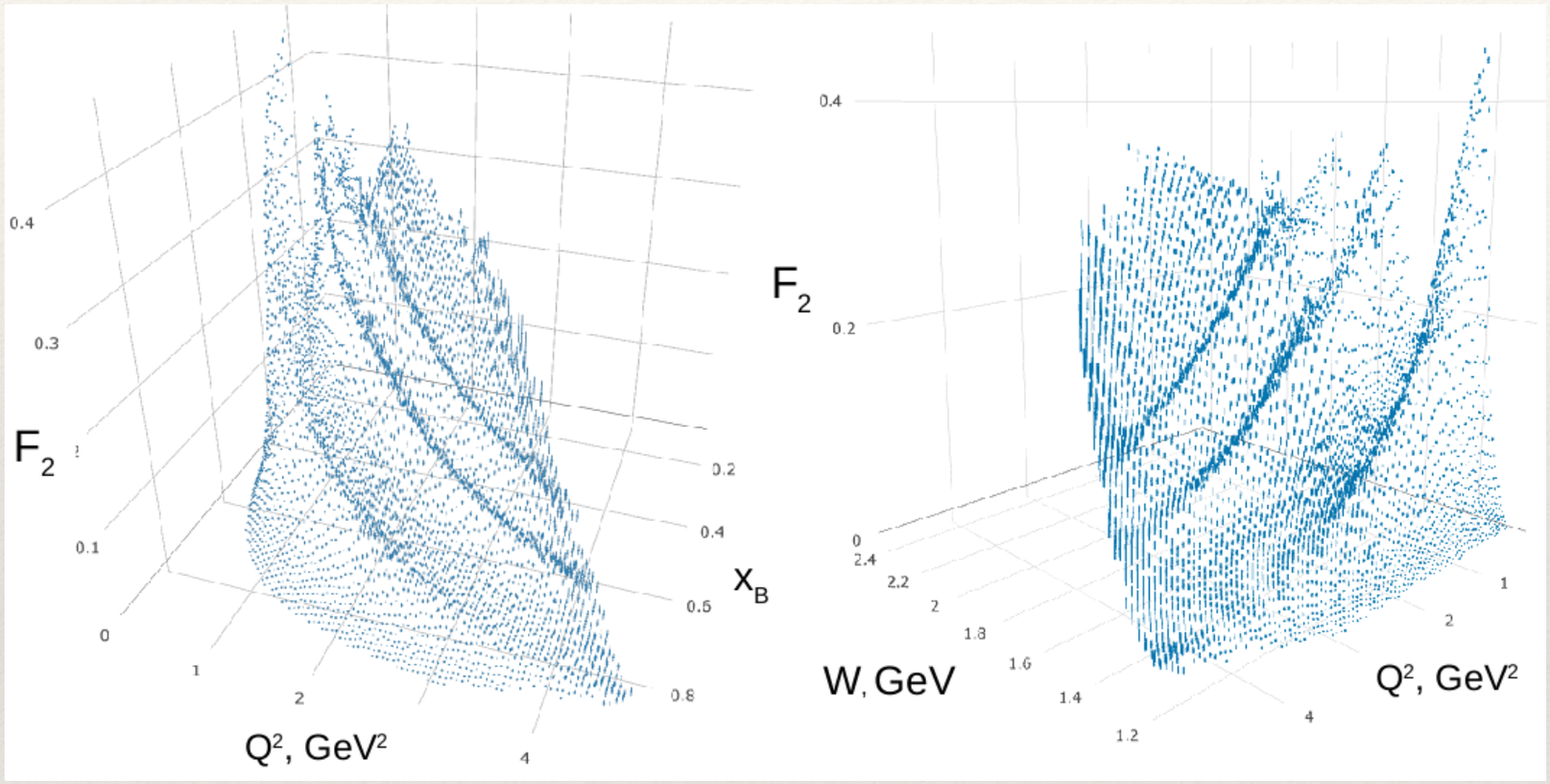




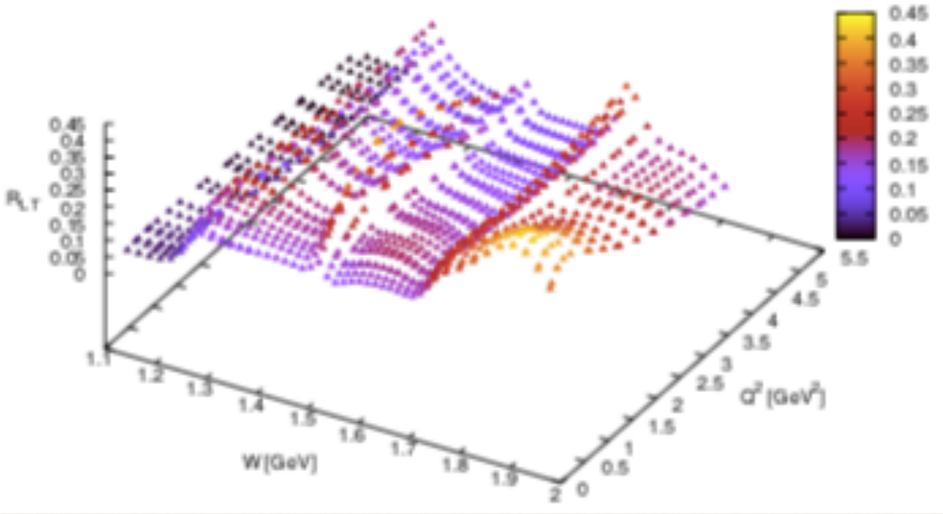
- Study of ground state nucleon PDF from inclusive electron scattering offers an effective tool for nucleon structure exploration
- The global QCD-driven analyses have provided detailed information on the quark and gluon PDFs in a wide range of x_B from 10^{-4} to above 0.9 and at Q^2 from 1 - 10^4 GeV^2
- PDF studies in the resonance region at W < 2.0 GeV require accounting for resonance contributions
- Hall A/C provided accurate (e,e'X) data in resonance region; due to limited acceptance, data are available on correlated (W,Q^2) grid and offer limited W-coverage at a given Q^2 – a few 100 MeV at Q^2>4.0 GeV^2
- (e,e'X) data from CLAS12 with almost 4π-acceptance cover the W-range from pion threshold to 4.0 GeV in all Q^2-bins
- Advances in the developments of the quasi-/pseudo-PDF concepts allow to evaluate the ground nucleon PDF starting from the QCD Lagrangian.

Inclusive Structure Function F_2 from CLAS Data

The F_2 structure function was measured with CLAS in the N* region with large coverage over x_B/W as a function of Q^2



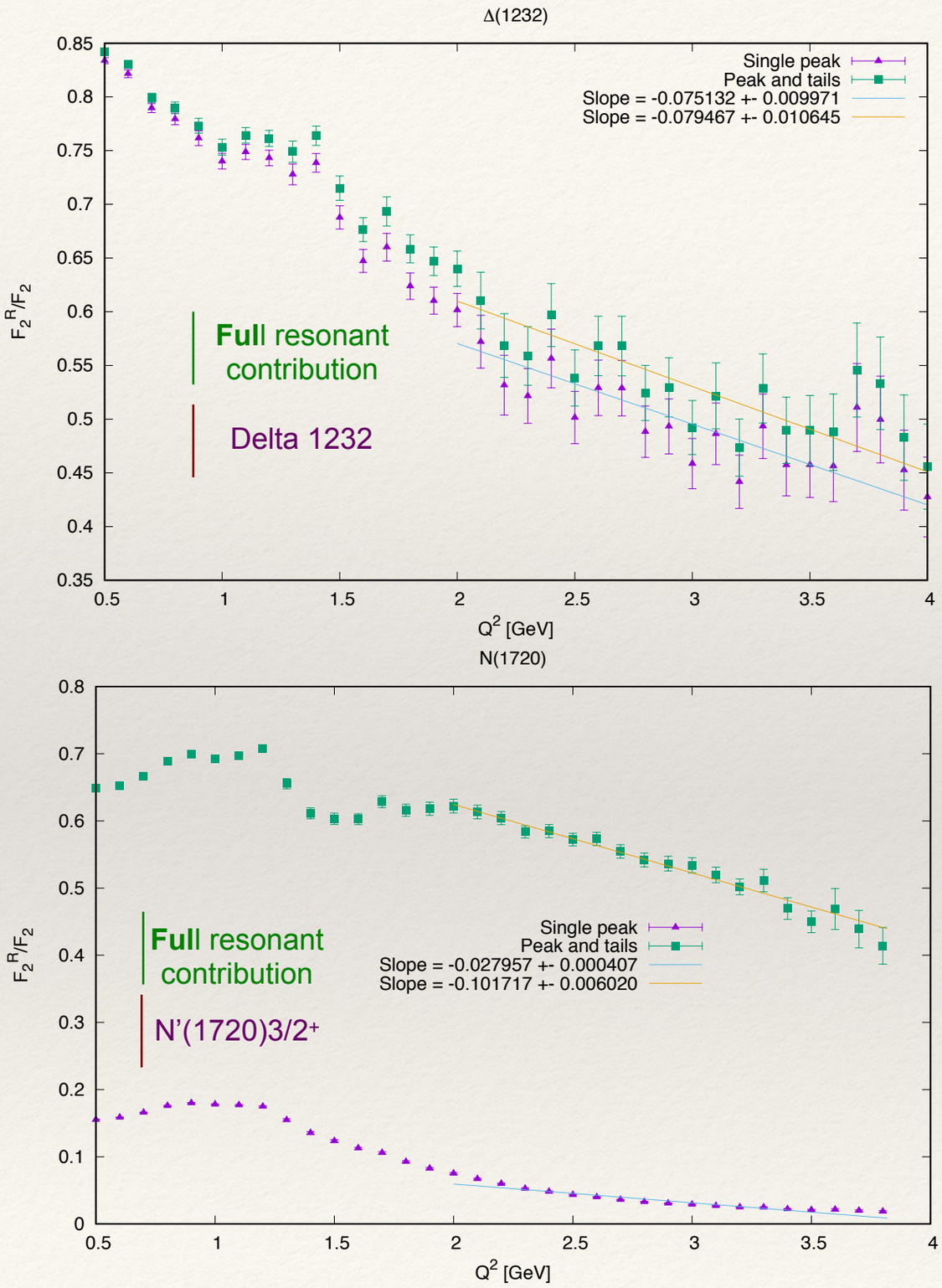
Ratio $R_{LT}=\sigma_L/\sigma_T$ from Hall A/C data



Y. Liang, PhD thesis, The American University (2003)

The preliminary results on longitudinal (σ_L) and transverse (σ_T) inclusive cross sections in the resonance region have become available from the Jlab experimental data for the first time (A.N. Hiller Blin et al., in preparation)

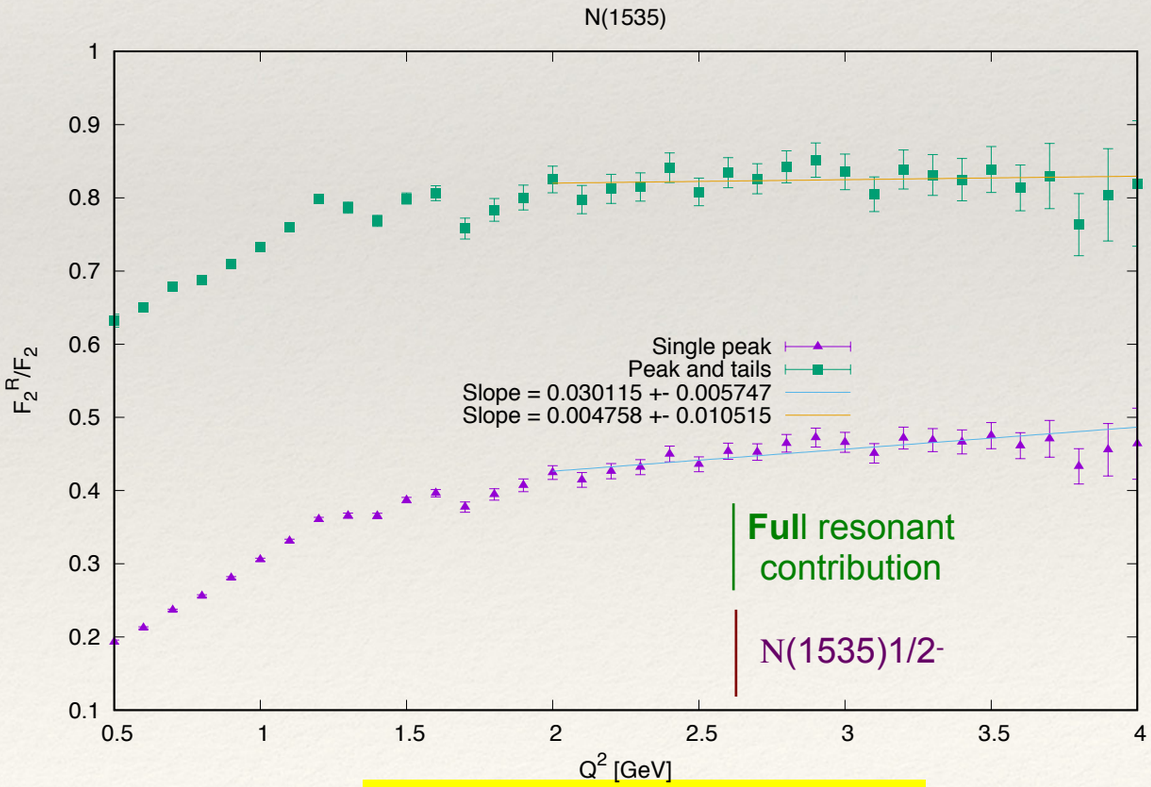
Resonant Contributions into Inclusive Electron Scattering from the Jlab Data



New N' (1720)3/2+ state has been recently observed:
V.I.Mokeev et al, Phys.Lett B 805,13457 (2020).

Resonance contribution into F2 structure function

- Significant (>40%) resonant contributions at $Q^2<4.0$ GeV^2 in the region of W<1.8 GeV.



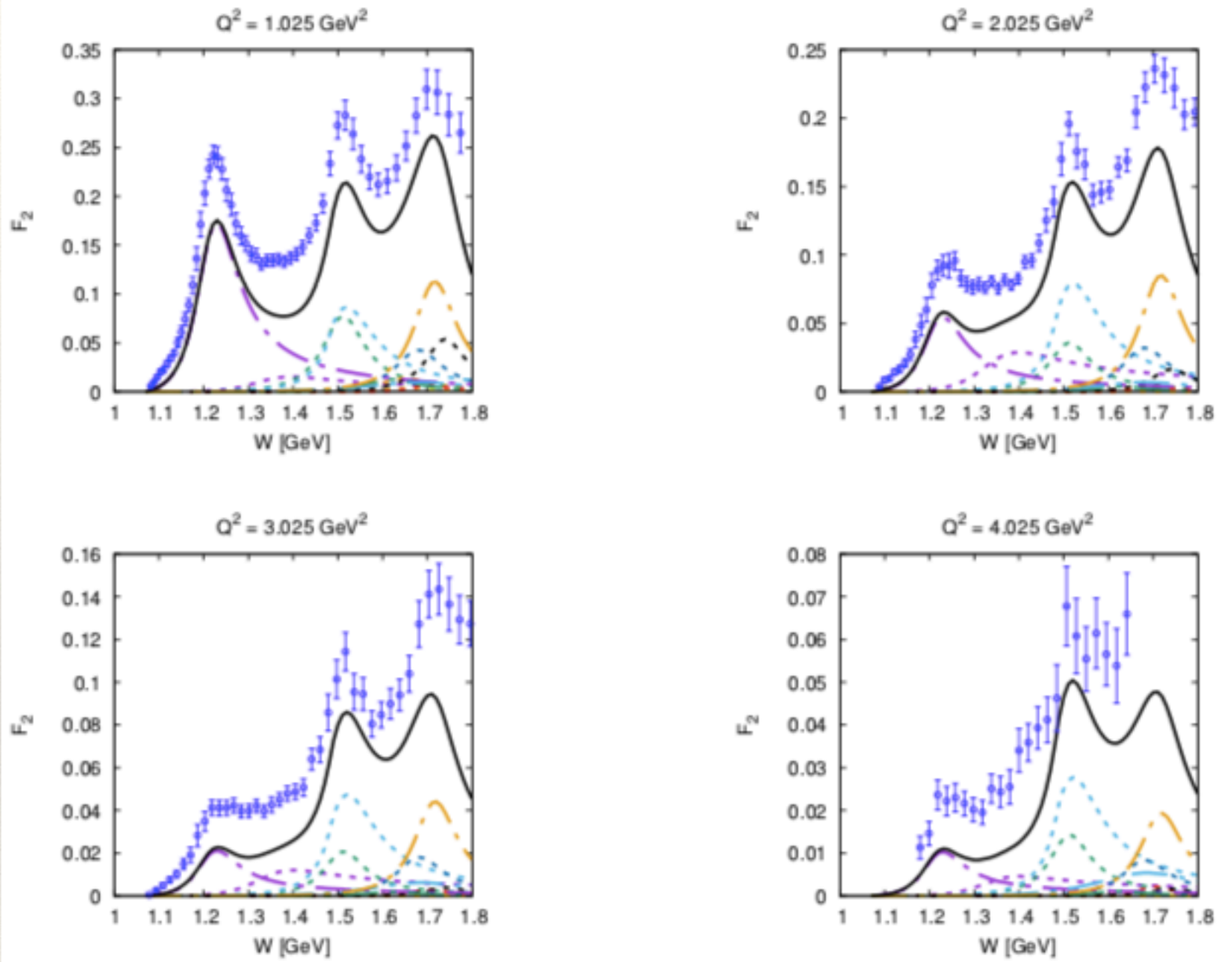
A.N. Hiller Blin, et al
JPAC,Theory and Physics Div.

Resonant Contributions into Inclusive Electron Scattering from the Jlab Data

- Resonant contributions at Q^2>2.0 GeV^2 either Q^2-independent or show smooth decrease with Q^2; indication for sizable leading or sub-leading twist contributions into the resonant parts. The data in a broader Q^2 range will allow for the twist-decomposition of the resonant part moments.

- Different Q^2-evolution of the F^R_2/F_2 ratio in the 1st, 2nd, and 3-rd resonance regions. Studies of the all prominent N* electroexcitation are critical for evaluation of the resonant contribution into inclusive electron scattering.

Insight into the Ground State of Nucleon PDF in the Resonance Region



The $F_2(W,Q^2)$ inclusive structure functions were evaluated from the CLAS experimental results by employing the Hall C data on σ_L/σ_T ratio.

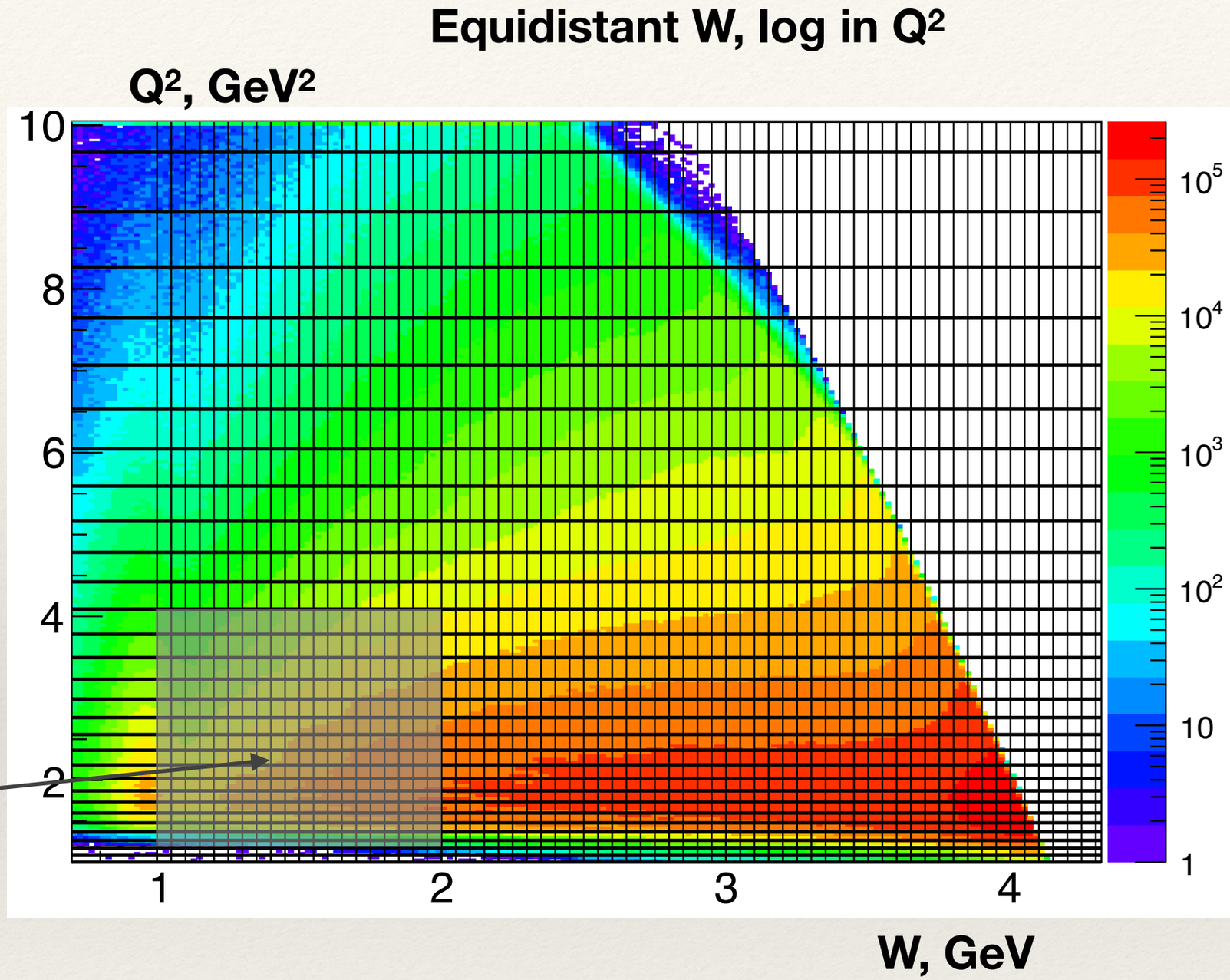
- Resonant contributions are computed by employing the CLAS results on $\gamma_v pN^*$ electrocouplings;
- Non-resonant contributions can be evaluated from the parameterized nucleon PDF, i.e. JAM-parameterisation;
- The PDF parameters determined from the fit of the resonant & non-resonant contributions to the data on $F_2(W,Q^2)$; inclusive structure functions will provide the insight into the ground state of the nucleon PDF in the resonance region;
- Extension of these studies with CLAS12 at $Q^2>4.0$ GeV^2 will allow us to explore the evolution of the nucleon PDF in the resonance region at the distances where the transition from quark-gluon confinement to pQCD regimes of strong interaction is expected.

Data analysis

Dataset

- RGA Fall 2018
- 10.6 GeV electron beam
- Torus -100%
- Solenoid -100%
- 5 cm liquid hydrogen target
- Pass1 dataset, runs 5032 - 5419

Kinematic Coverage and Binning



Reasonable and comparable statistics in all Q2 bins;
Good coverage and details over W;
Compatible with DIS studies.

Data analysis

RG-A Analysis Overview and Procedures

Data analysis

The CLAS Collaboration and RGA has put a lot of efforts into the crucial common parts of the data analysis:

- Electron ID;
- Fiducial cuts;
- Background merging and efficiency;
- Momentum correction;
- Simulation.

Hadron Structure Group is actively involved in these activities with the final goal to extract cross section of Inclusive electron scattering.

Inclusive Electron Scattering in the Resonance Region from a Hydrogen Target with CLAS12

D.S. Carman,[1] B. Clary,[2] K. Joo,[2] E. Golovach,[3] R. Gothe,[4] K. Hicks,[5]
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[2] *University of Connecticut, Storrs CT 06269*
[3] *Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, 119234 Moscow, Russia*
[4] *University of South Carolina, Columbia, South Carolina 29208 and*
[5] *Ohio University, Athens, Ohio 45701*

(Dated: March 19, 2020)

Inclusive electron scattering cross sections from a hydrogen target at a beam energy of 10.6 GeV have been measured with data collected from the CLAS12 spectrometer at Jefferson Laboratory. These high-precision data cover a wide kinematic area in invariant energy W up to 4 GeV and four-momentum transfer Q^2 from 1 to 10 GeV^2. Using a framework developed based on the resonant contributions determined with data from the CLAS spectrometer spanning W up to 2 GeV and Q^2 up to 4.5 GeV^2 that has been extrapolated into the kinematic regime of the CLAS12 measurements, estimates for the resonant contributions to inclusive electron scattering have been determined with small systematic uncertainties. Together these data from CLAS and CLAS12 provide important information regarding the nucleon parton distributions through the nucleon resonance region in the regime of large Bjorken scaling variable x_B, as well as detailed insight for studies of quark-hadron duality.

A complete draft of the paper intended for the publication in Phys. Rev. Lett. is prepared.

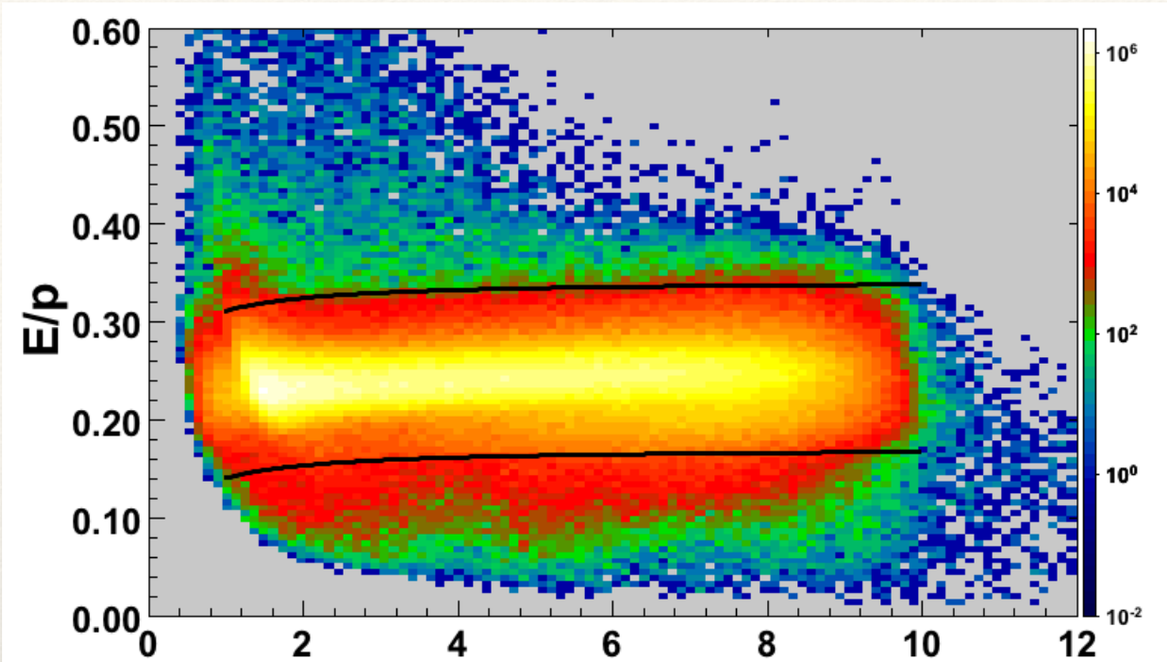
Data analysis

Electron ID

Event builder

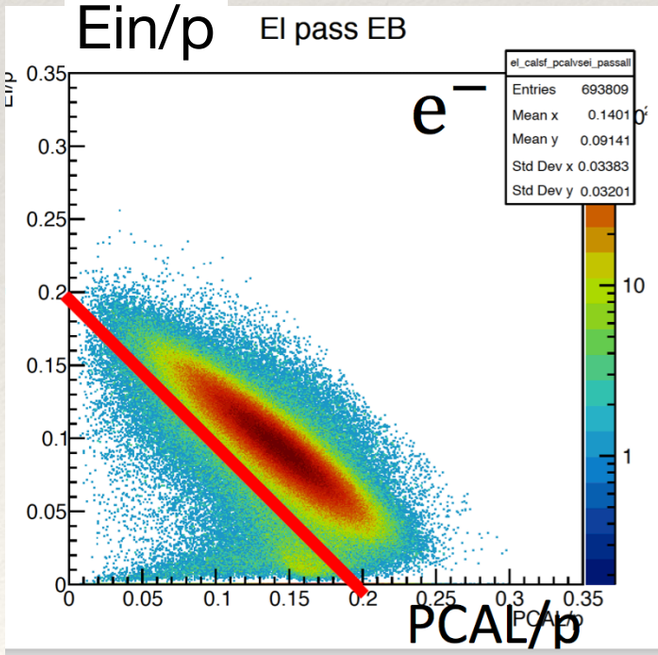
- Limited to Forward Detector (5 -35 degrees coverage in polar angle)
- Electrons are selected by the CLAS12 Event Builder
  - Negative track with a hit in TOF, ECAL and HTCC;
  - 2.0 photoelectrons in HTCC;
  - 60 MeV in PCAL;
  - 5-sigma cuts on a parameterized momentum-dependent sampling fraction.

Forward Calorimeter sampling fraction for electrons



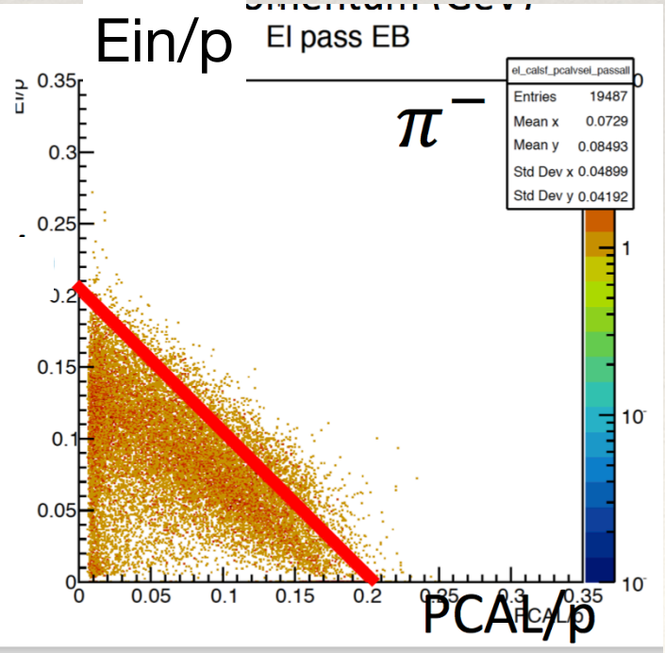
Improvements

- Electron ID selection;
- Updated sample fraction parameterization in the EB.



Simulation

Red line indicated where e^-/π^- can be separated to improve PID



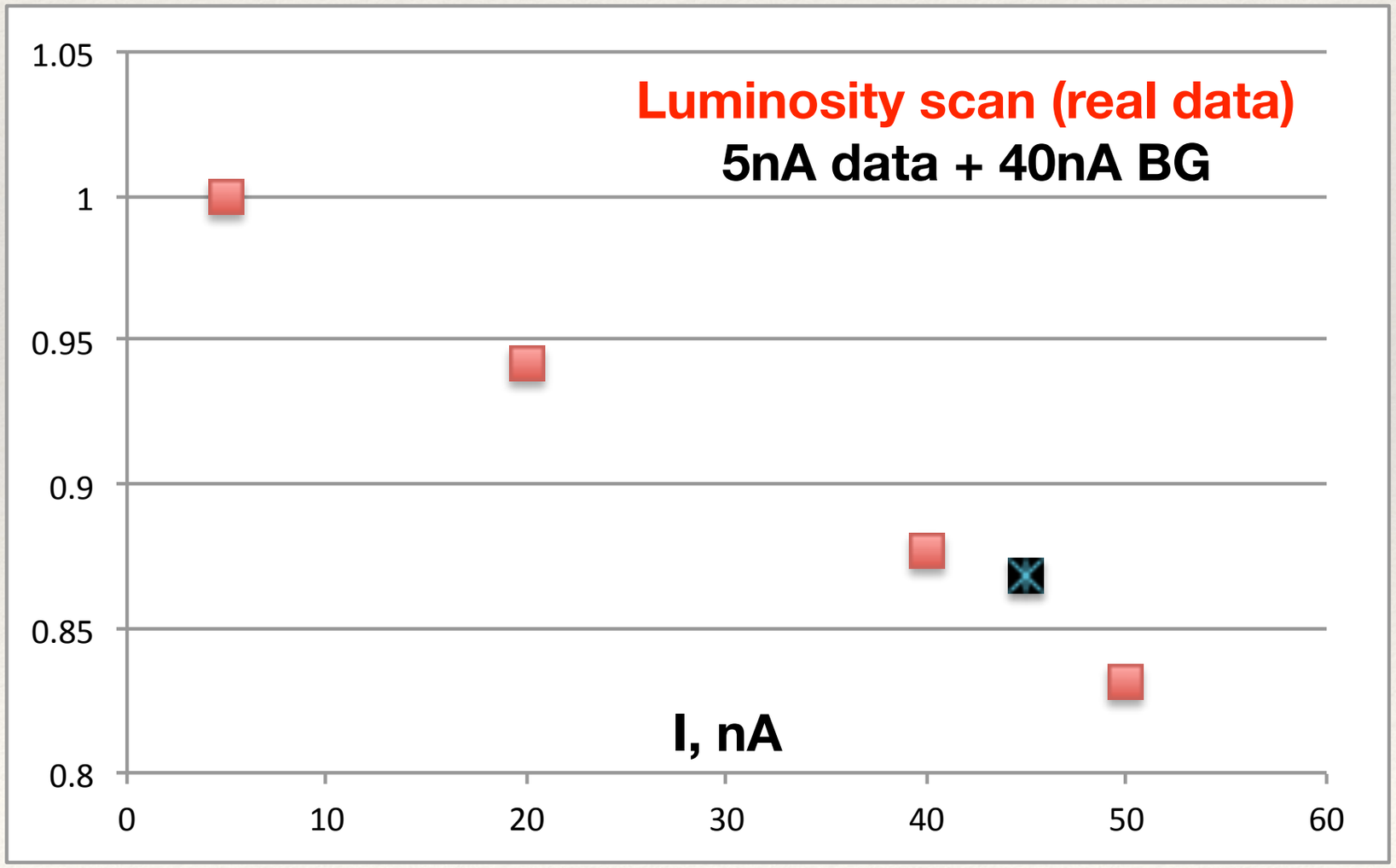
Data analysis

Efficiency and background merging

There is a difference in the normalized by Faraday cup event yield between runs with different beam current. We are dealing with electrons, so will concentrate on their behavior.

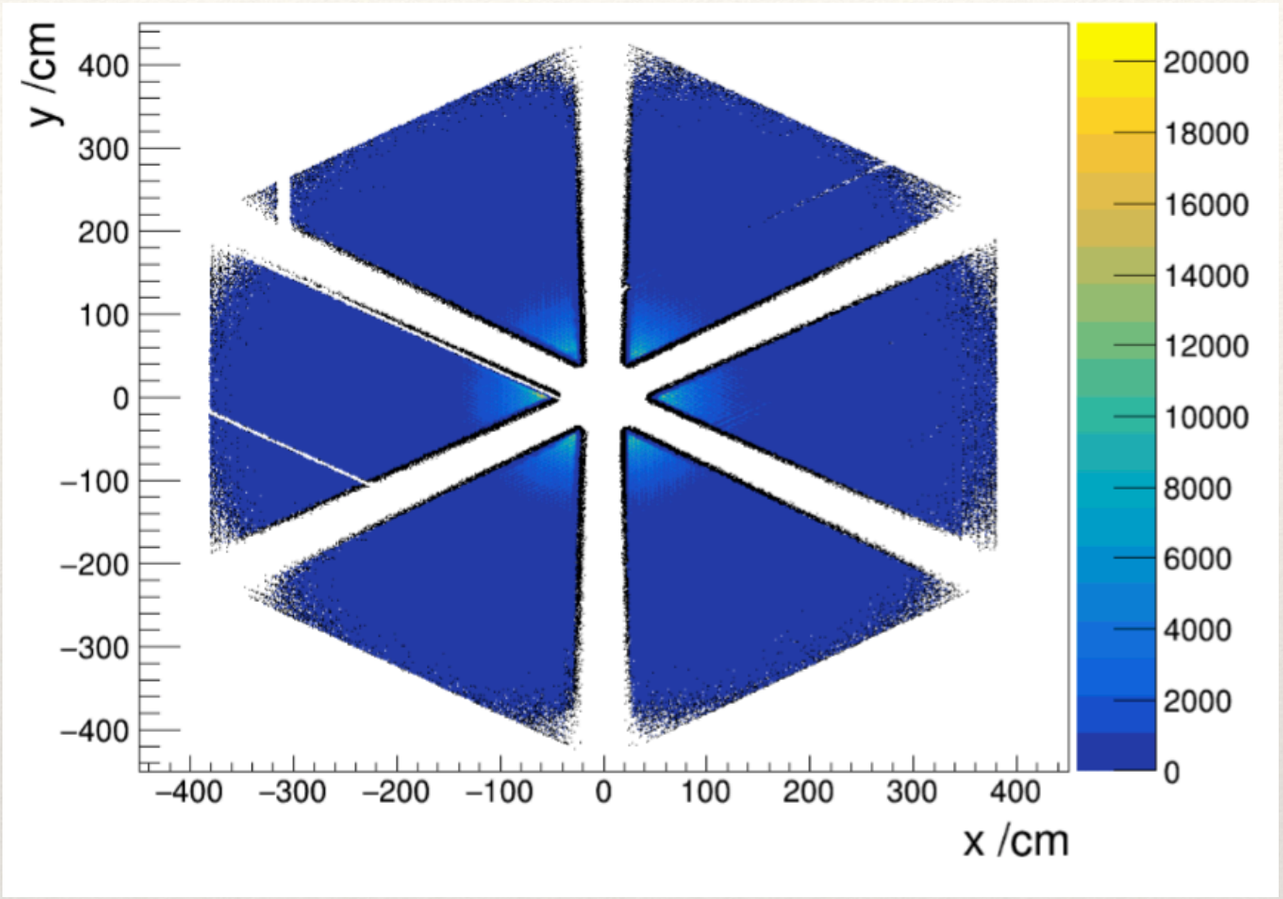
Procedure:
random trigger hits are extracted from the 45 nA data files;
timing of hits is aligned between data and simulation;
This hits are added to
- 5 nA (low current) data
- Inclusive electron simulation

Reconstruction is run on events with additional background hits (both data and low lumi simulation).

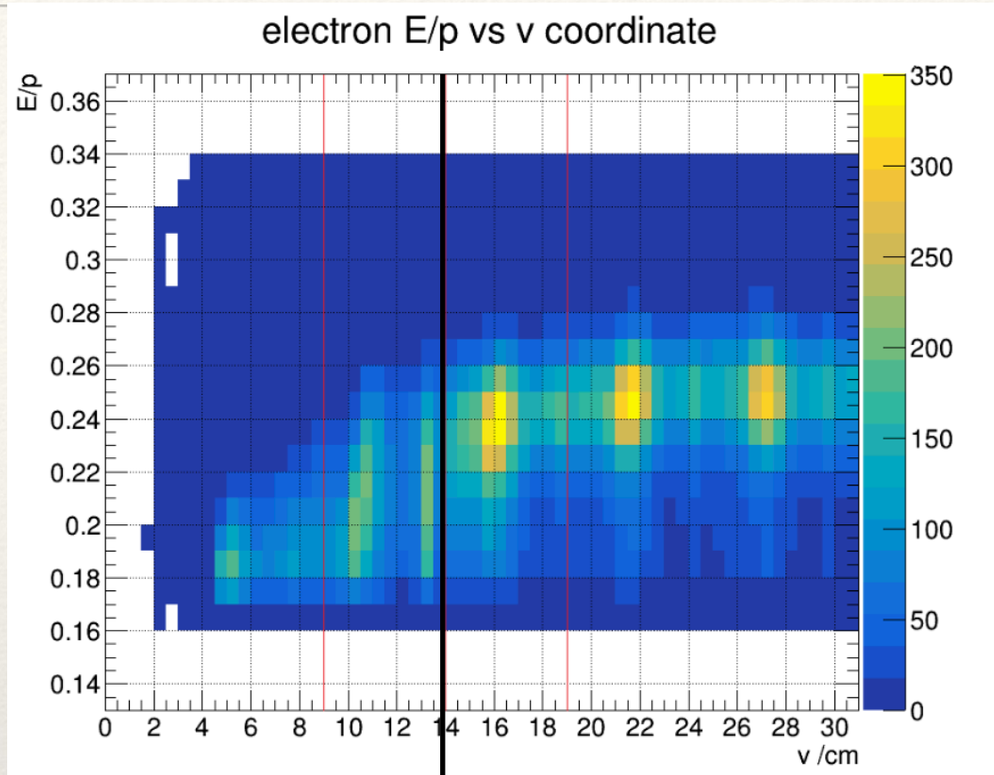


PCAL Fiducial cuts

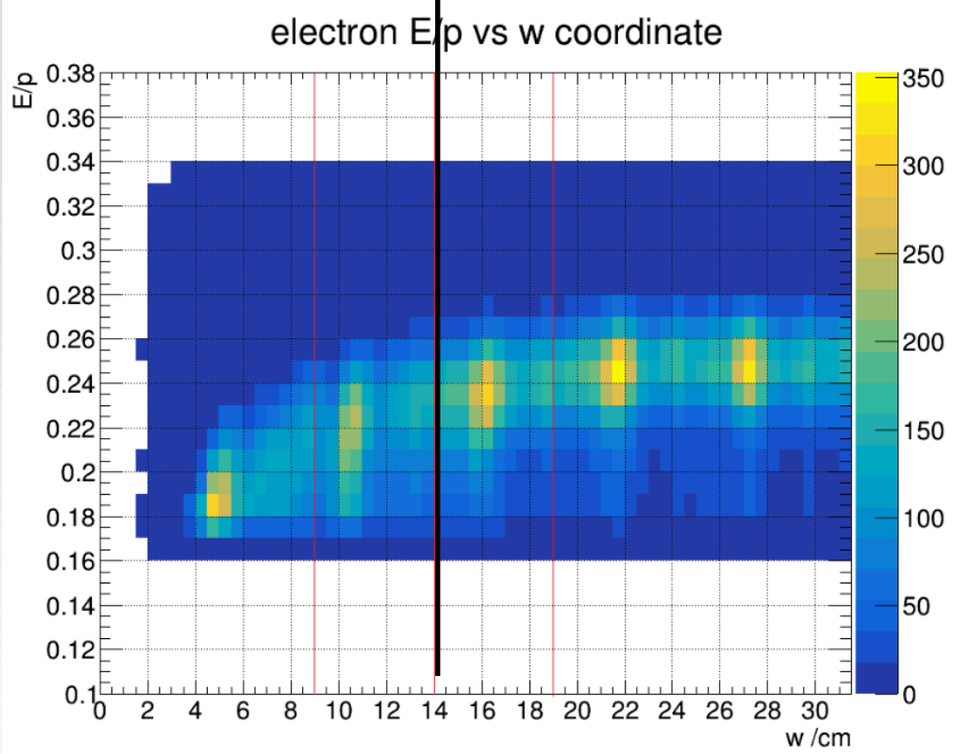
PCAL X vs Y



Plot from RGA Analysis Note (Stefan)



PCAL Medium fiducial cuts



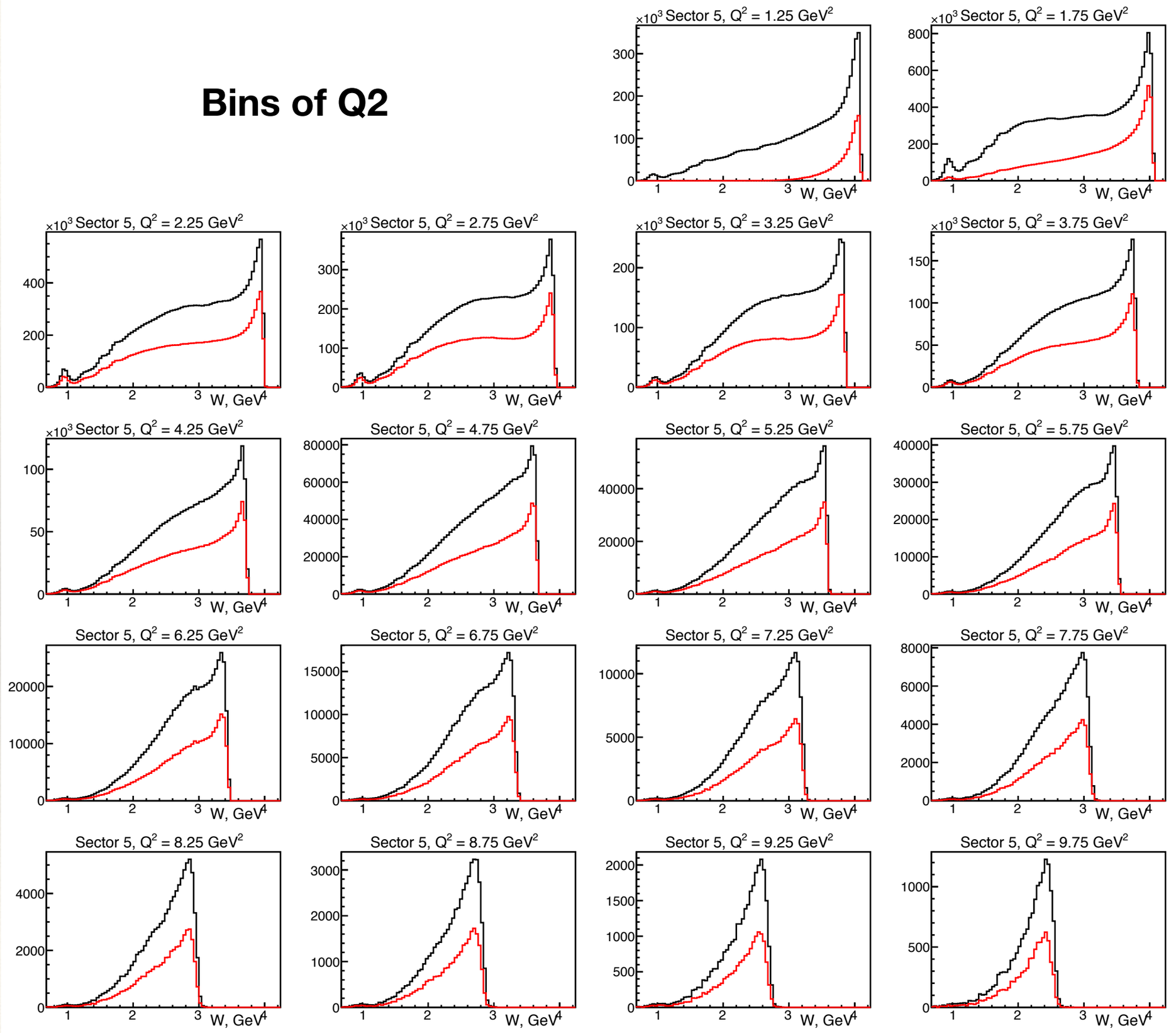
Fiducial Cuts and Electron Yield

No Cut

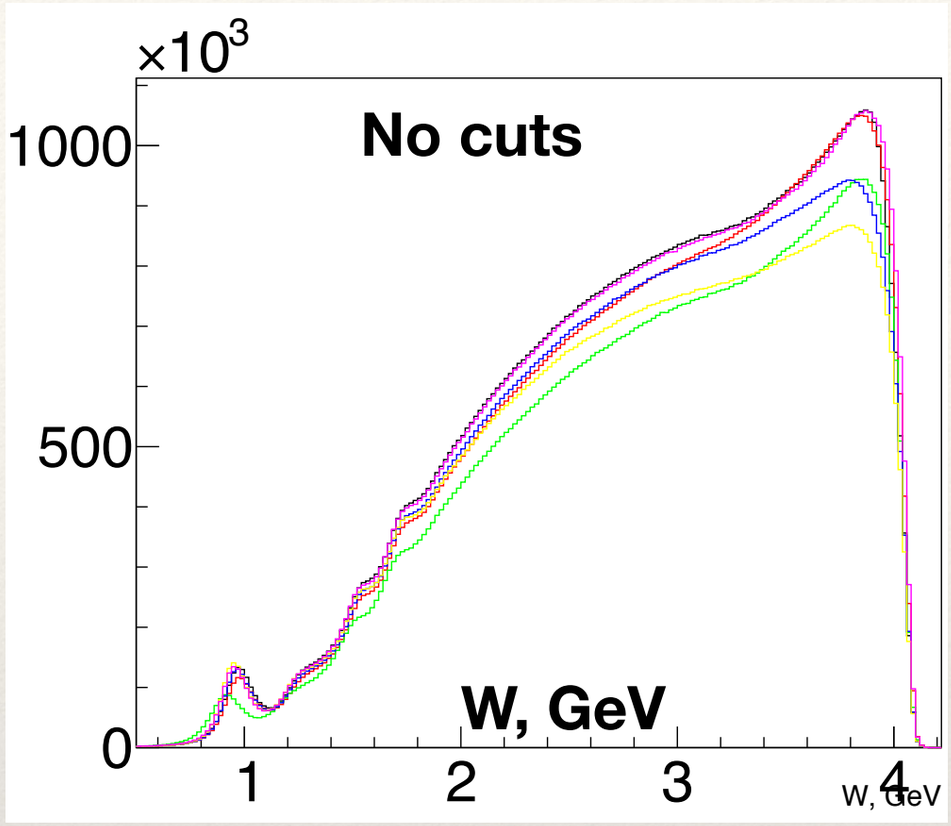
Cut

No advanced detector information is used (bad scintillators, wires, PMTs). Might improve picture even more.

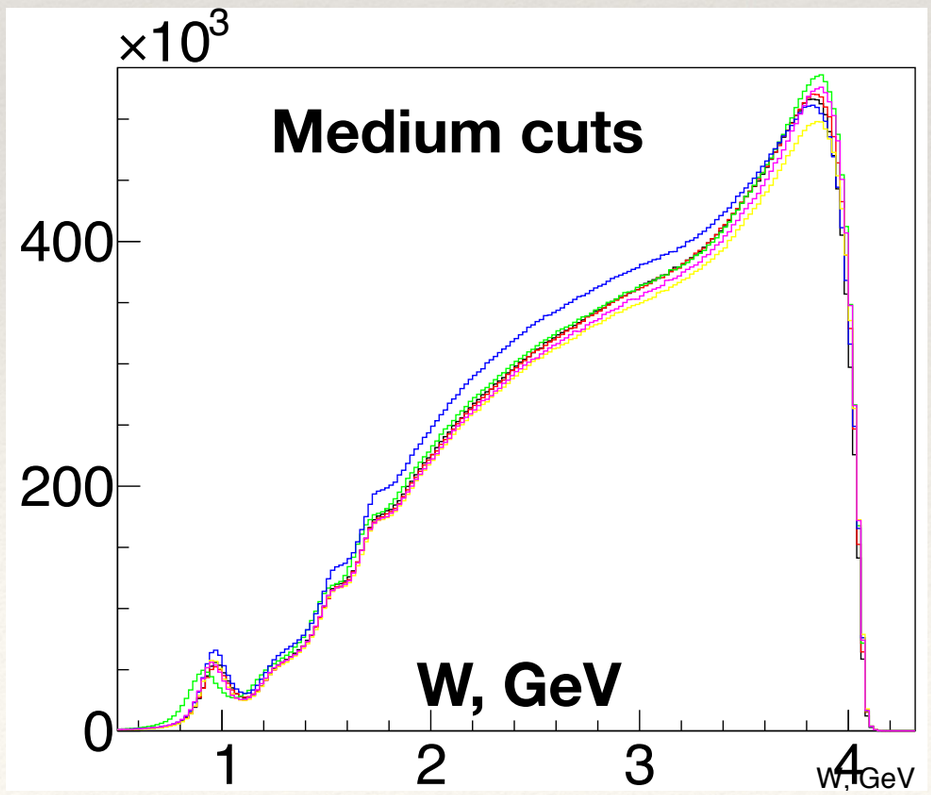
Bins of Q2

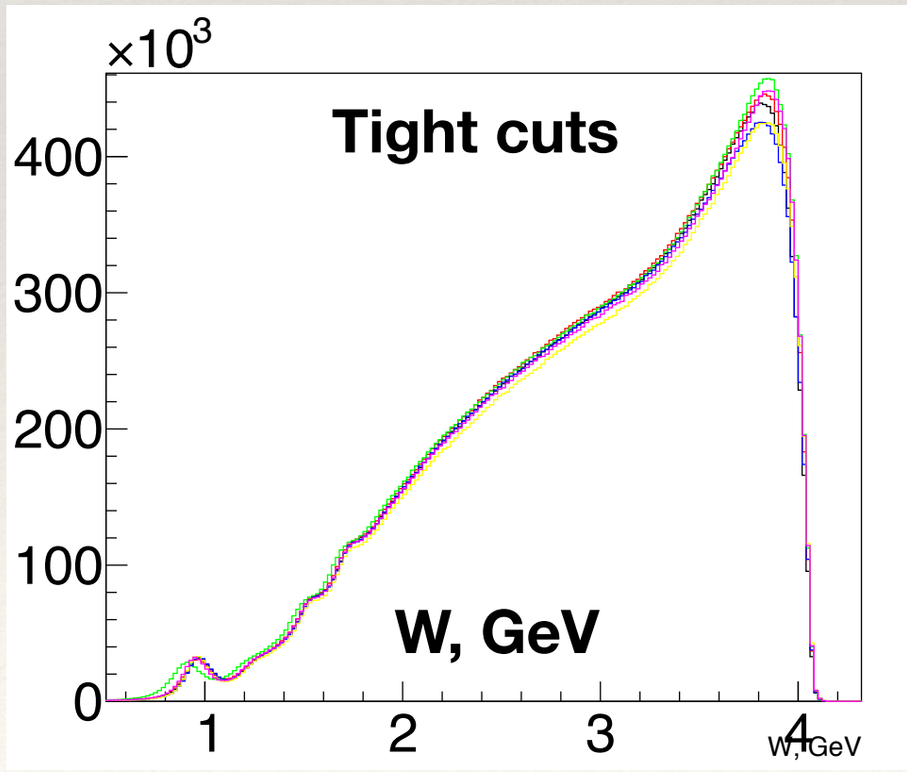


Fiducial Cuts and Electron Yield



Sector 1
Sector 2
Sector 3
Sector 4
Sector 5
Sector 6



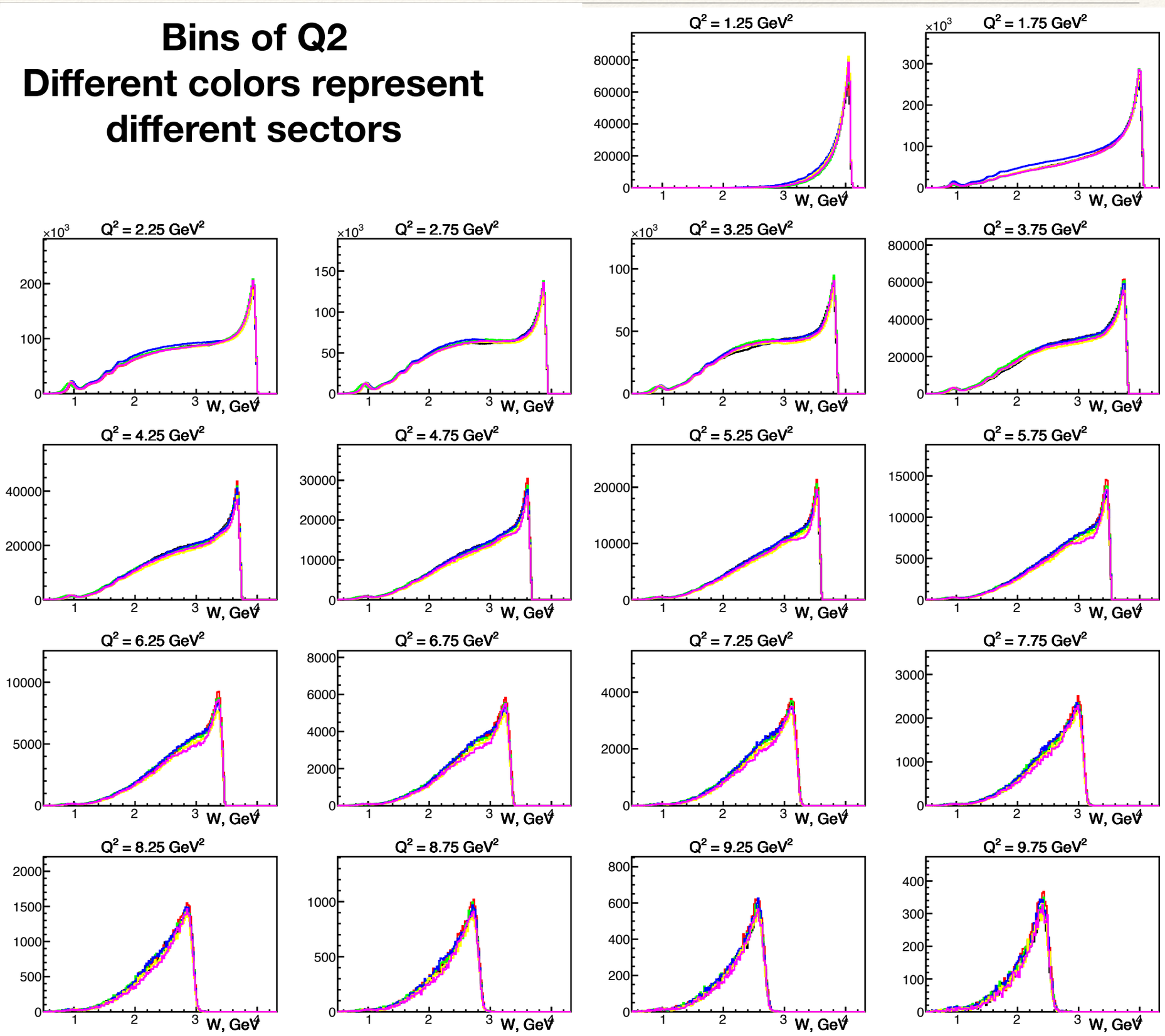


Fiducial Cuts and Electron yielD

Medium fiducial cuts

Sector 1
Sector 2
Sector 3
Sector 4
Sector 5
Sector 6

Bins of Q2
Different colors represent different sectors

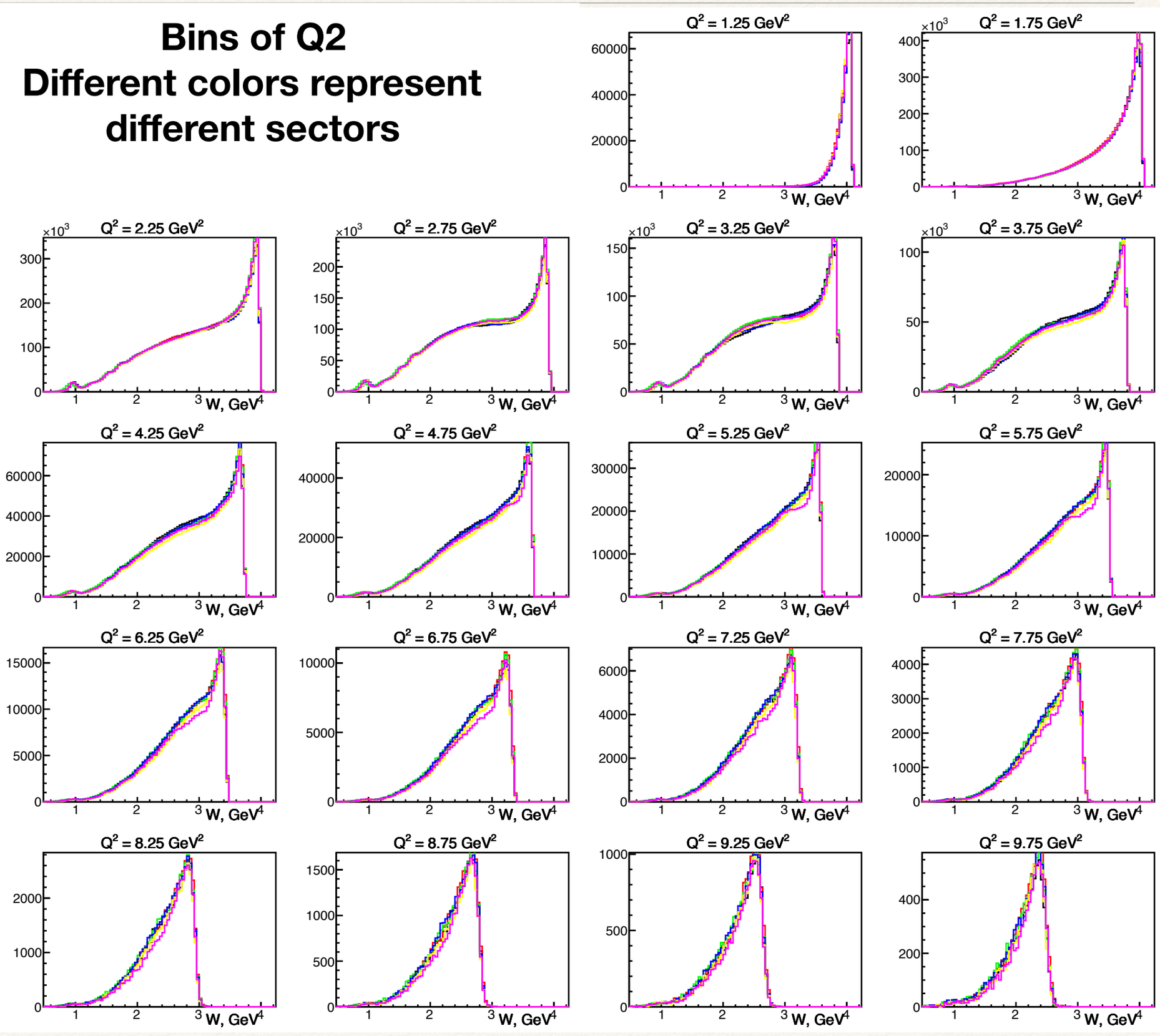


Fiducial Cuts and Electron Yield

Tight fiducial cuts

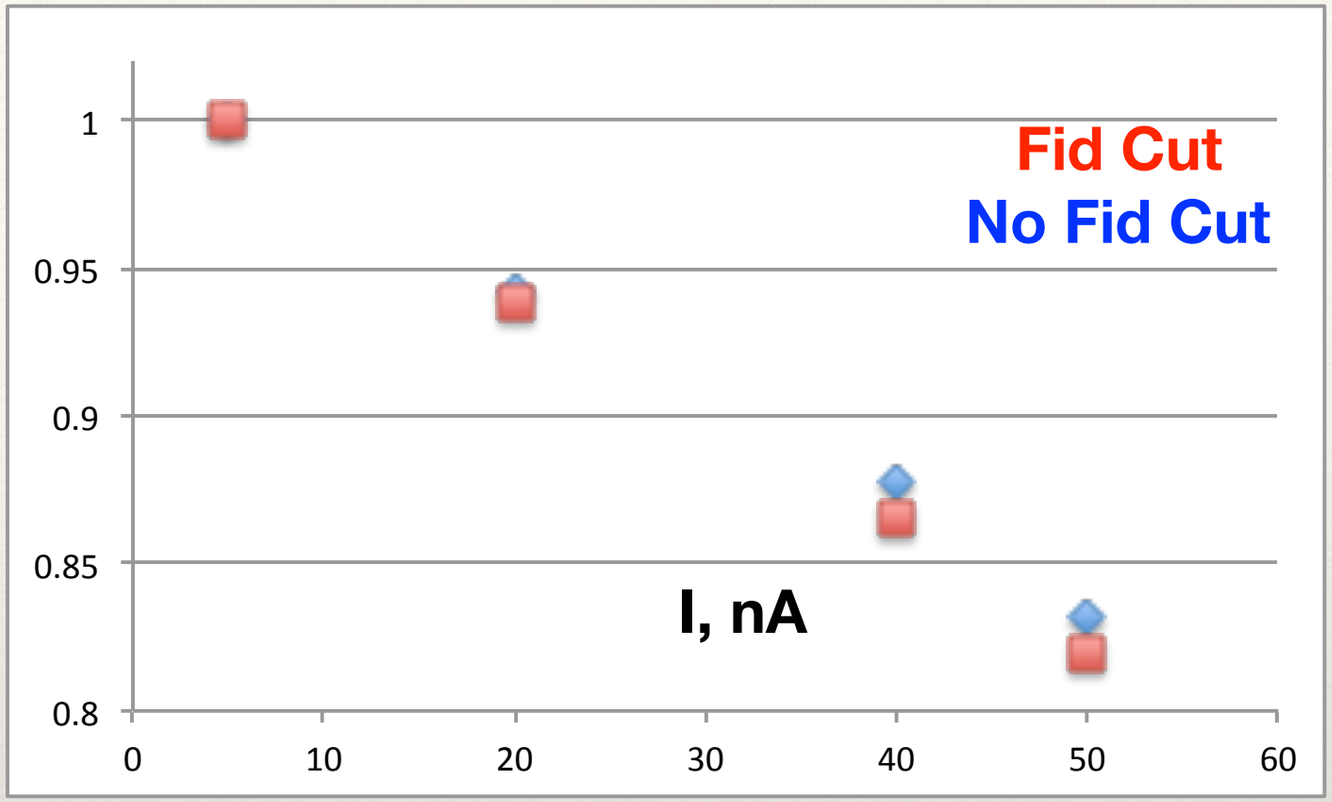
Sector 1
Sector 2
Sector 3
Sector 4
Sector 5
Sector 6

Bins of Q2
Different colors represent different sectors

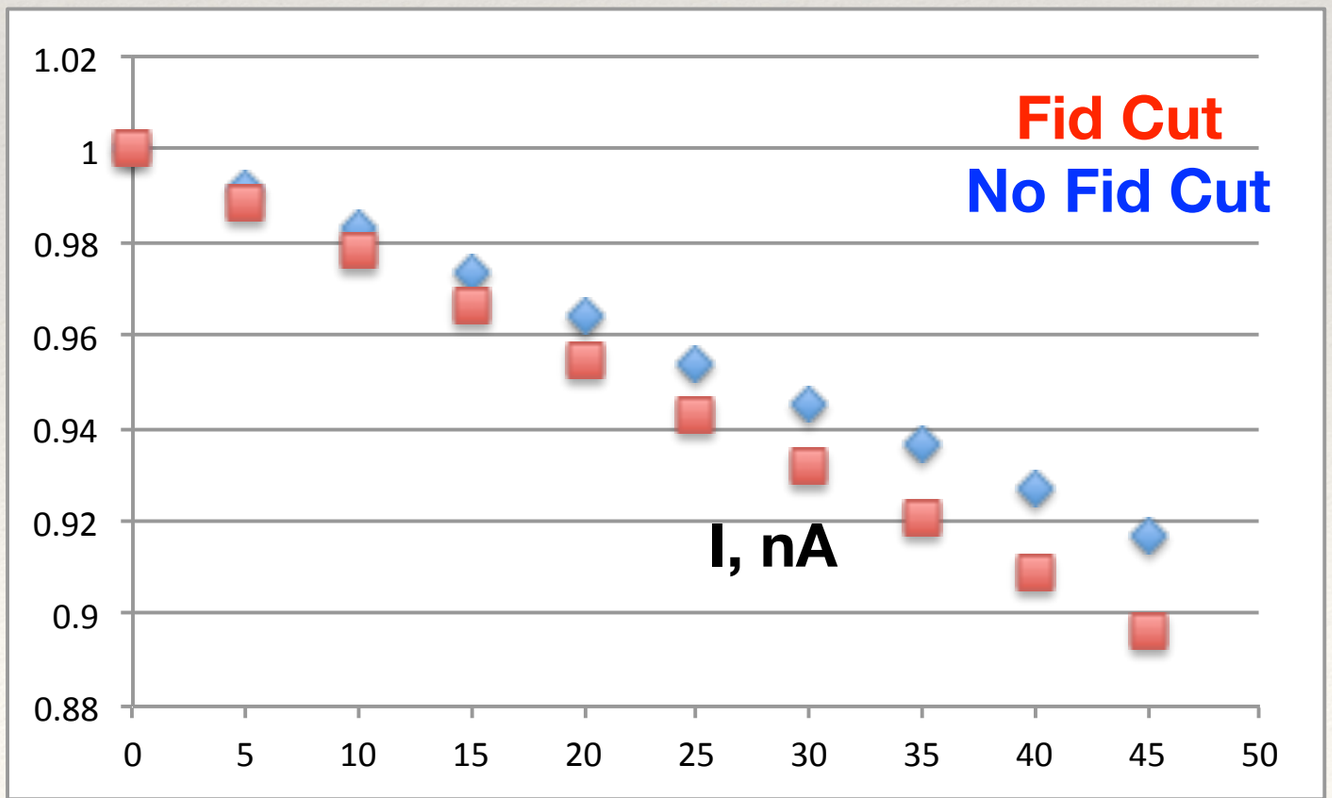


Fiducial cuts and tracking efficiency

Data



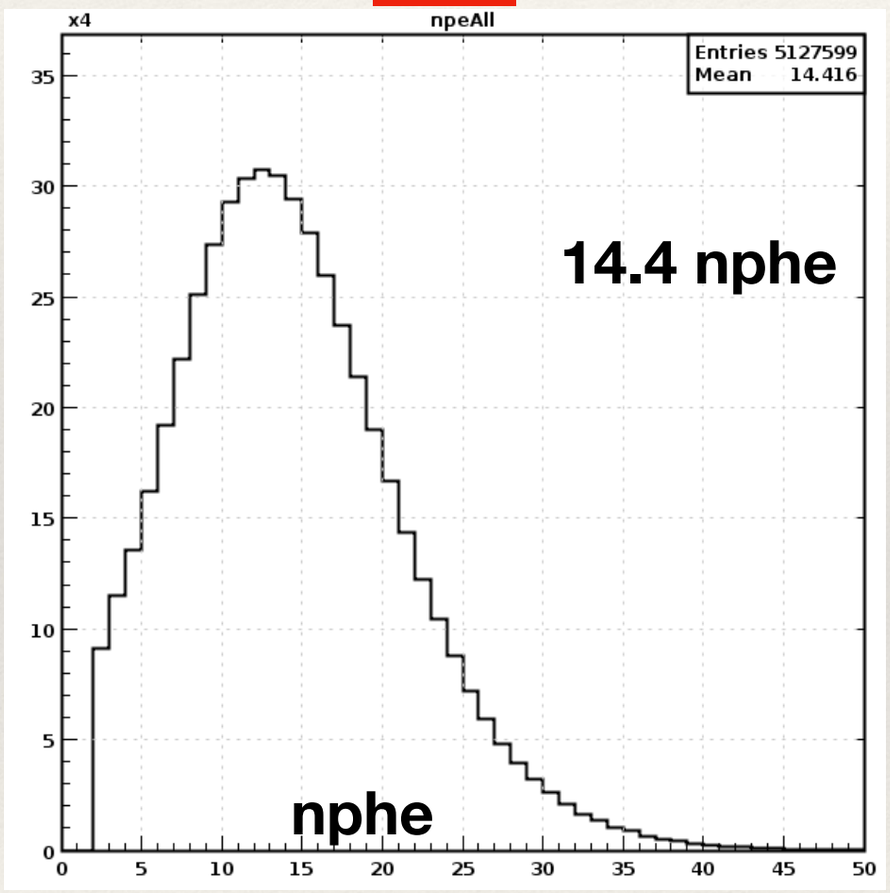
Simulation



HTCC in Simulation

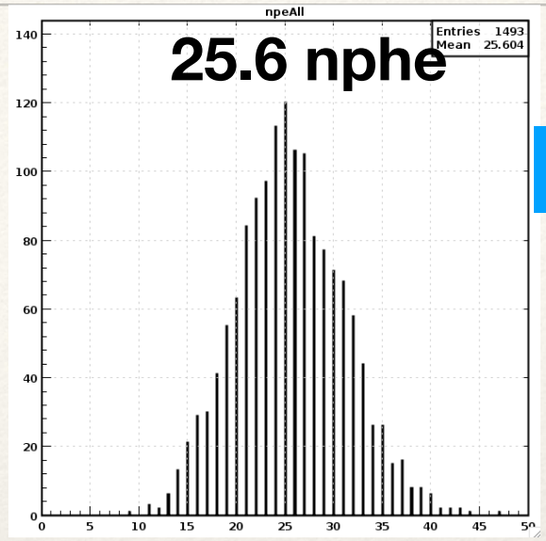
- HTCC response is different in data and simulation;
- HTCC is used in electron ID;
- Need to adjust simulation.

Data



Initial state:

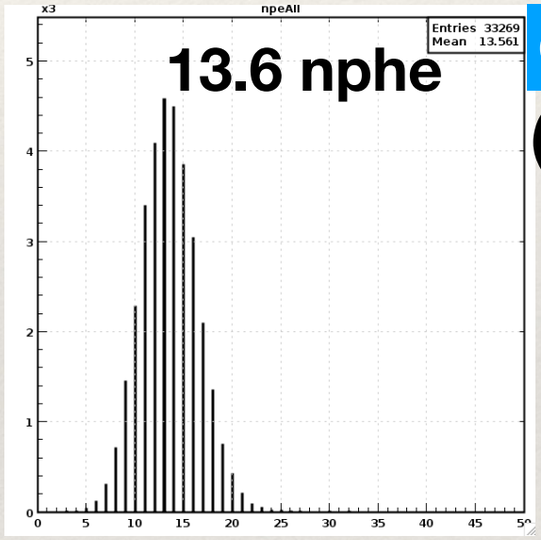
Simulation



GEMC4.3.2

nphe

After gain adjustment:

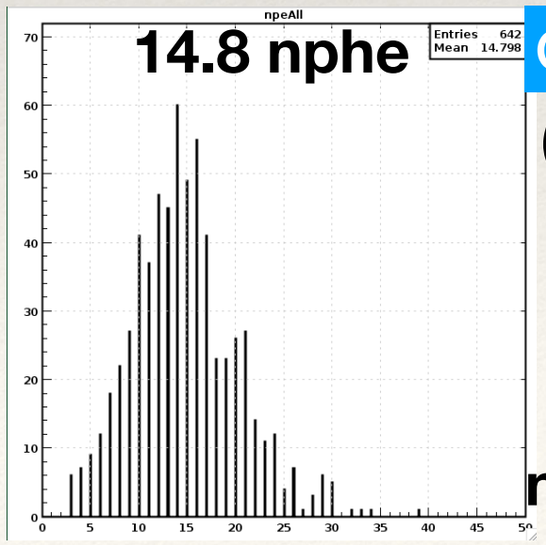


GEMC4.4

(on farm)

nphe

After smearing:



GEMC4.4'

(in testing)

nphe

Acceptance and Luminosity Corrections

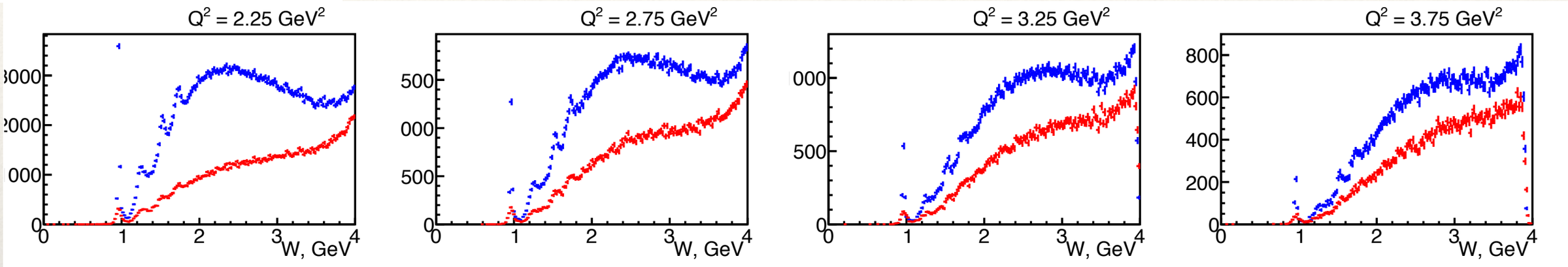
Generated events

Reconstructed simulation events

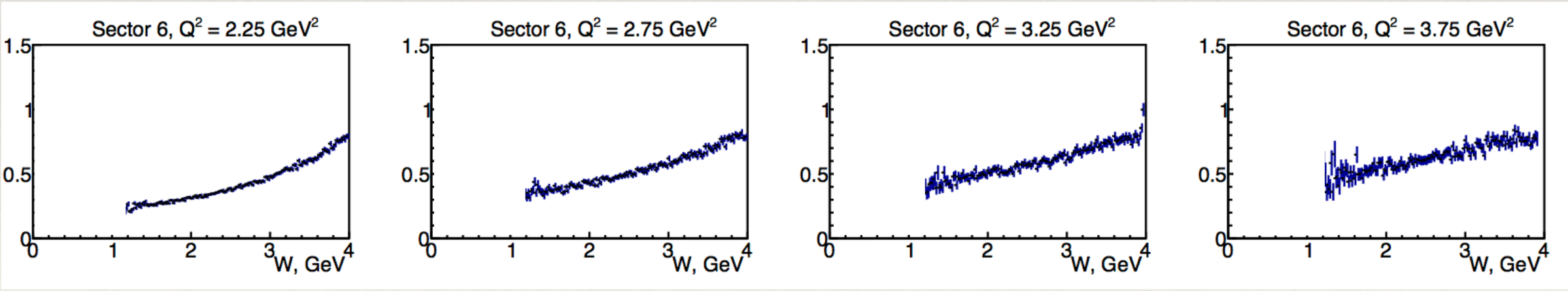
Inclusive event generator: M. Sargsyan, CLAS-NOTE 90-007 (1990).

Includes elastic and radiative effects

Same reconstruction algorithms are used between data and simulation.
Both generated and reconstructed events display main features of inclusive electron cross section, namely elastic peak, resonance region with “bumps” and smooth DIS region.



Acceptance Correction



Sample of the acceptance correction for a few Q^2 bins

Luminosity Correction

Luminosity correction is based on the geometry and properties of the target (5 cm long liquid hydrogen) and integrated beam charge on the Faraday Cup. Need a correction (available, will be implemented in the next iteration of trains)

Data analysis

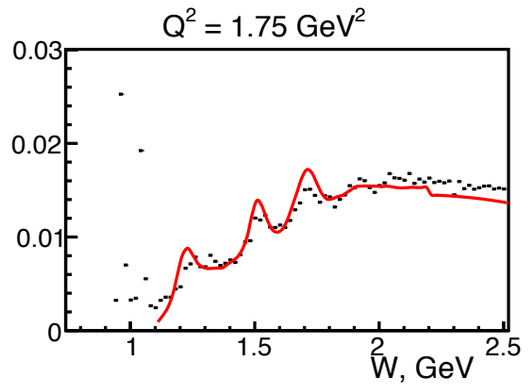
Results

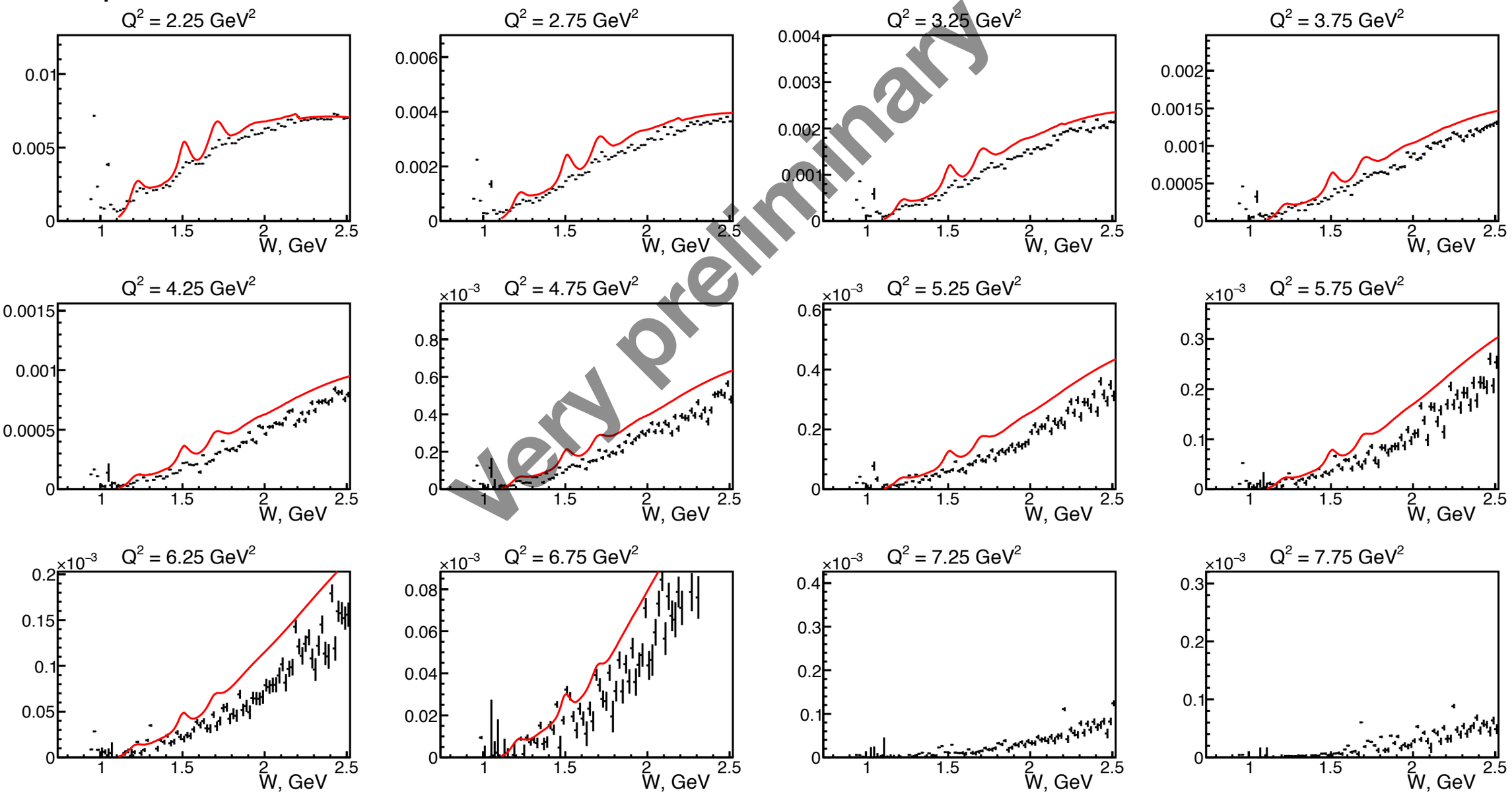
All sectors combined
Simplistic Electron ID
No momentum corrections
Simplistic tracking efficiency
Not corrected Faraday cup charge
Acceptance correction with old simulation

CLAS12 preliminary results
World data

Normalized yield

arb units





Future plans

- Improvement of electron ID procedure;
- Better understanding of detector/tracking efficiency, both from the low lumi data analysis and background merging procedure with simulation;
- Momentum corrections;
- Application of radiative corrections;
- Better understanding of the CLAS12 resolution;
- Study of the systematic uncertainties;
- Finalize simulation.

Summary

- Preliminary results on the inclusive electron scattering cross section are available from the CLAS12 in the kinematic area of W from 1.0 GeV to 2.0 GeV in any given Q^2 bin within Q^2 range from 2.0 GeV^2 to 10 GeV^2;

- Working closely with the fiducial cut task force, tracking efficiency task force and momentum correction task force to finalize electron ID and yield determination;

- Results with updated procedures are expected soon;

- Knowledge of the resonance contribution paves the way to study the parton distribution of the ground state nucleon in the resonance region;

- These experimental results (based only on electron detection in the Forward Detector) and the developed physics analysis tools make this work an excellent candidate for a first publication from CLAS12.

CEBAF Large Acceptance Spectrometer

Jefferson Lab