

Inclusive Electron Scattering off Protons with CLAS12

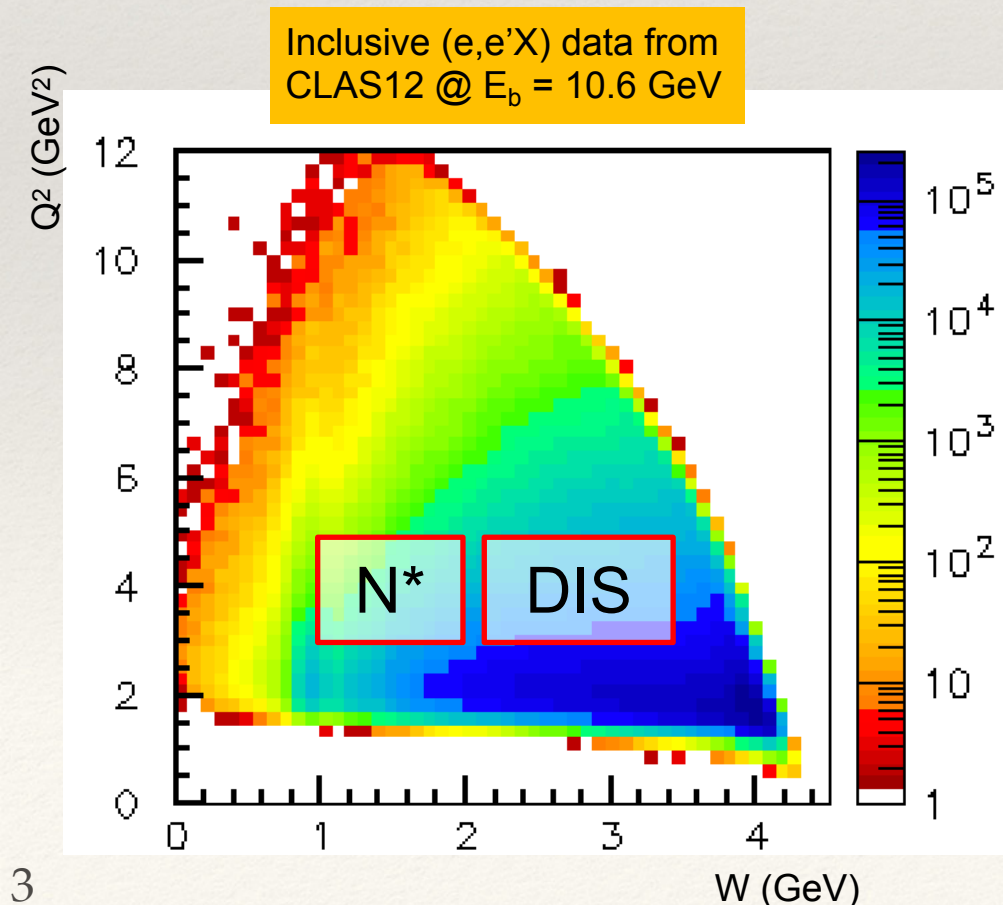
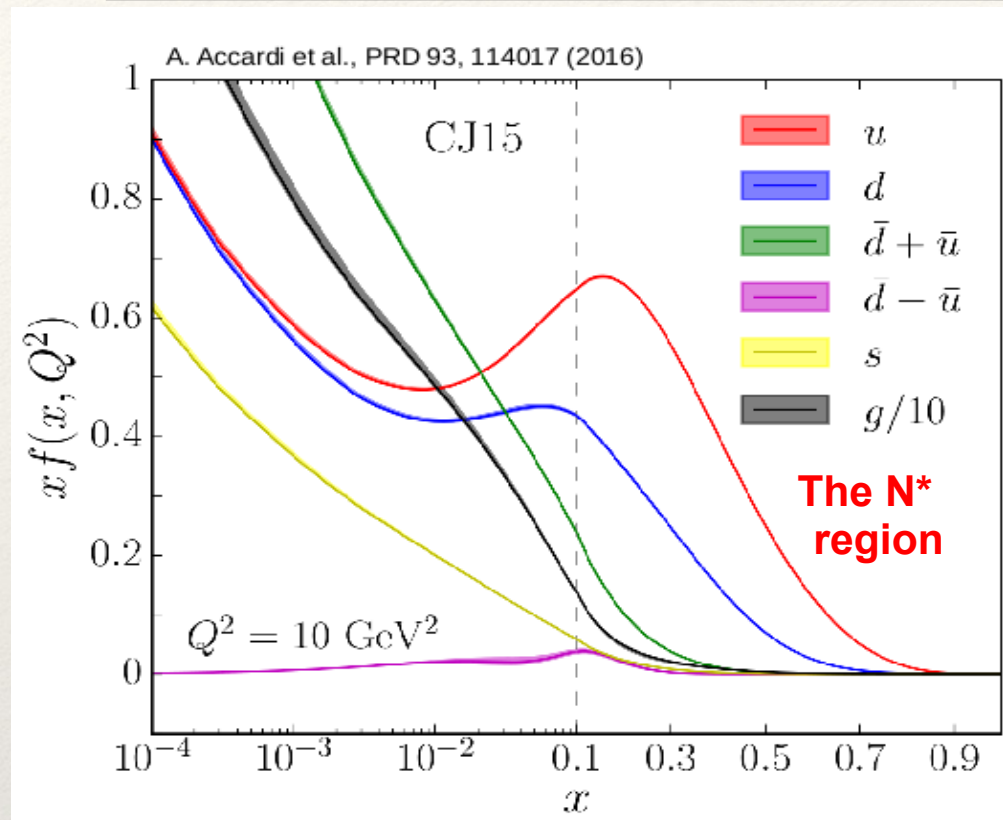
N. Markov, Jefferson Lab & University of Connecticut
for the CLAS collaboration



Introduction and motivation

- Measurement of the unpolarized inclusive electron scattering cross section in the resonance and deep inelastic regimes;
- Data allows for a wide kinematic coverage: $1.1 \text{ GeV} < W < 4.0 \text{ GeV}$ and Q^2 up to 12 GeV^2 combines interests of the CLAS12 N^* structure and DIS physics groups;
- First step is extension of the inclusive electron scattering data in the resonance region towards photon virtualities of $Q^2 > 4.0 \text{ GeV}^2$ and evaluation of the resonant contributions from the CLAS6 results on resonance electrocouplings;
- Gain insight into the parton distributions in the ground nucleons at large x_B in the resonance region;
- New opportunities in exploration of the transition between the resonance and DIS regions and in the studies of quark-hadron duality;
- First cross section measurement from CLAS12 detector. Requires very good understanding of the CLAS12 properties. Indispensable for the next absolute measurements.

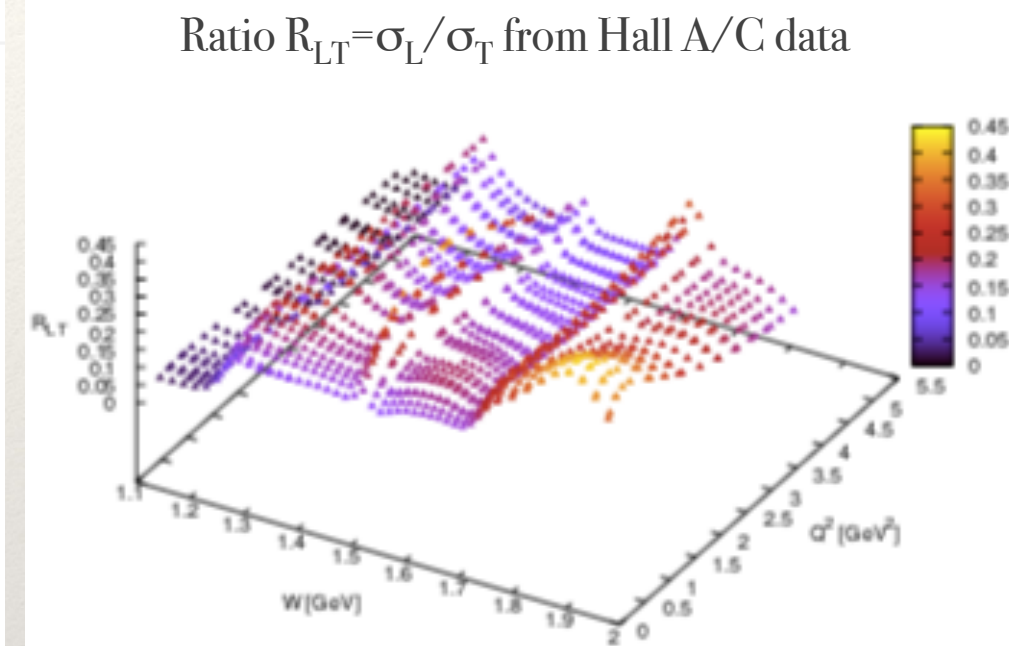
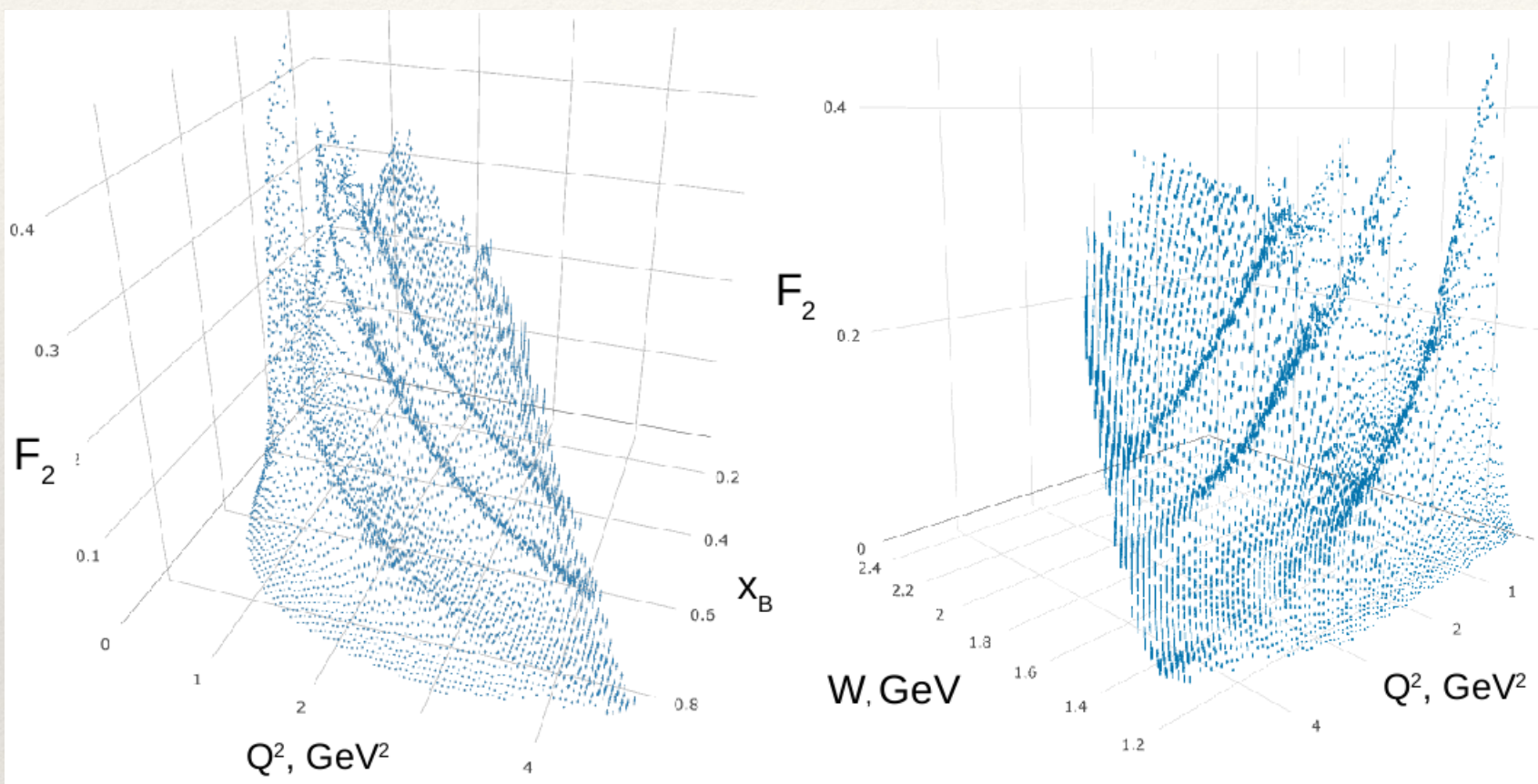
Extending Knowledge of the Nucleon PDF in the Resonance Region



- 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 $1 - 10^4 \text{ GeV}^2$
- PDF studies in the resonance region at $W < 2.0 \text{ GeV}$ 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 $Q^2 > 4.0 \text{ GeV}^2$
- (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

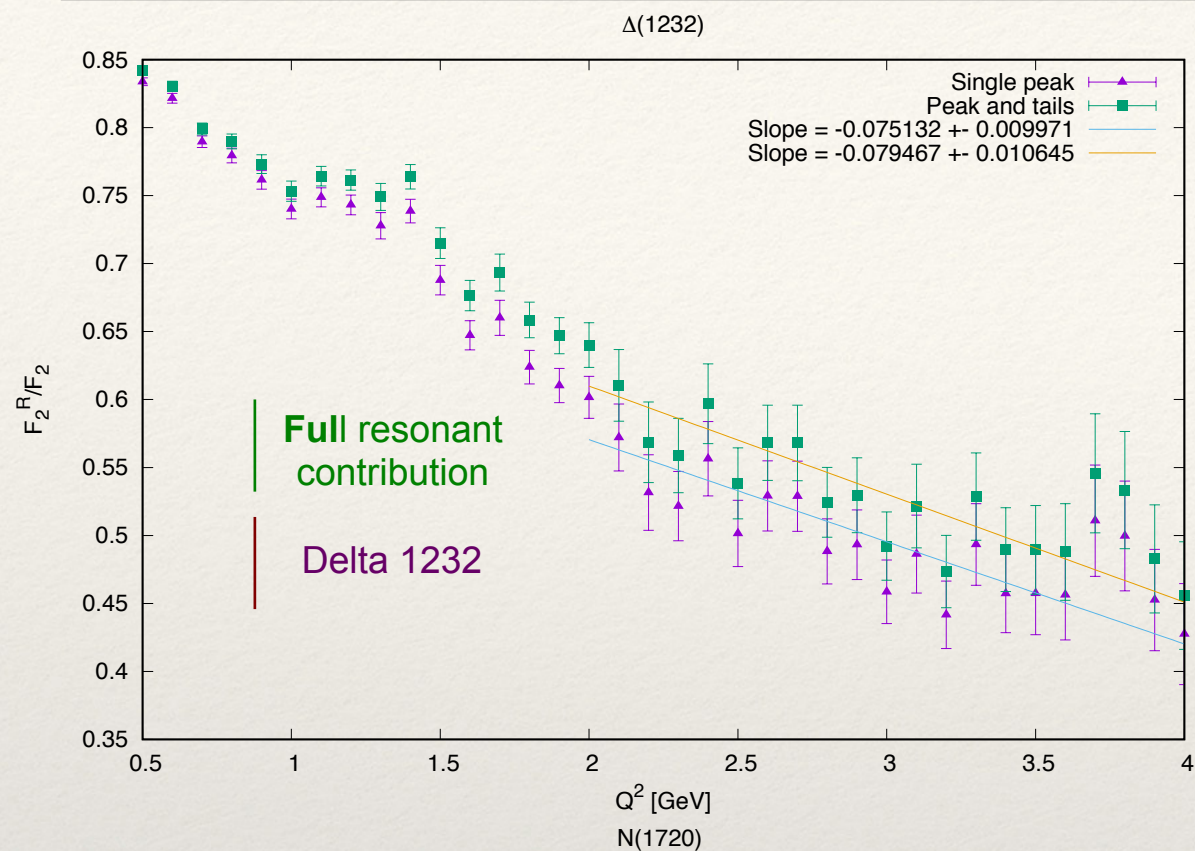
The F_2 structure function was measured with CLAS in the N^* region with large coverage over x_B/W as a function of Q^2



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

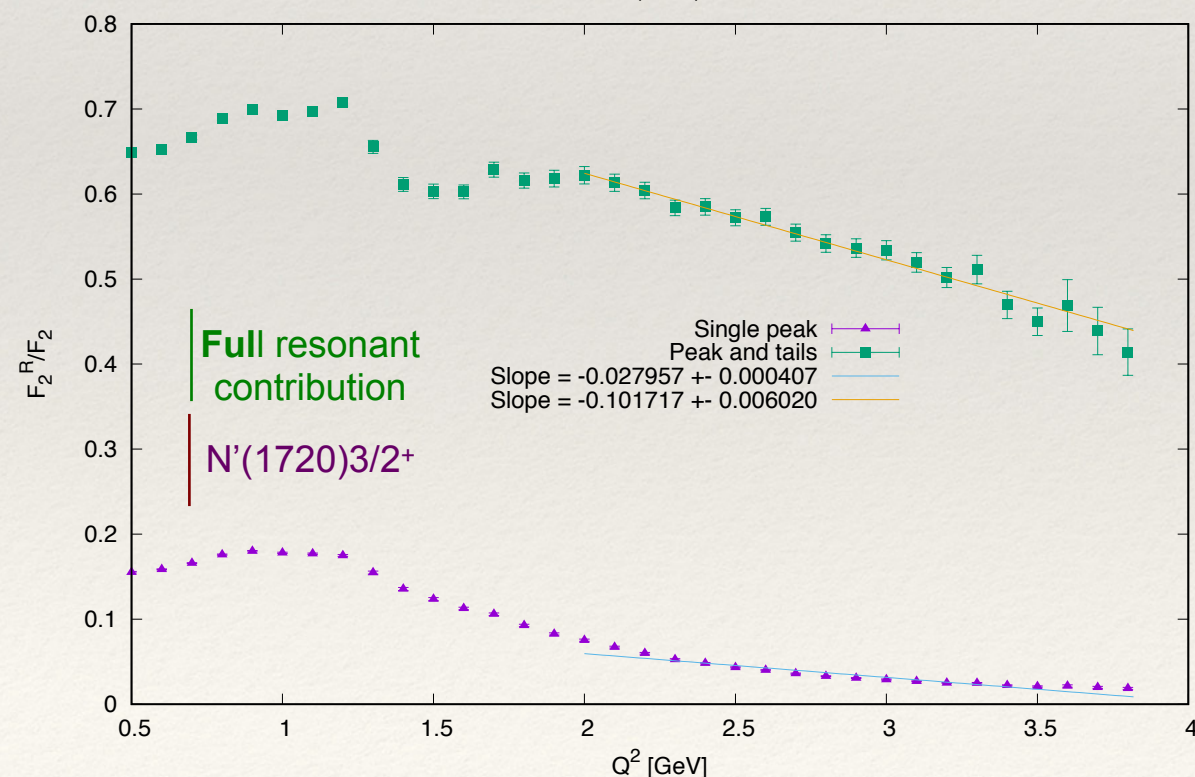
The preliminary results on longitudinal (σ_L) and transverse (σ_T) inclusive cross sections in the resonance region have become available from the JLab experimental data for the first time (A.N. Hiller Blin et al., paper in preparation)

Resonant Contributions into Inclusive Electron Scattering from the JLab Data

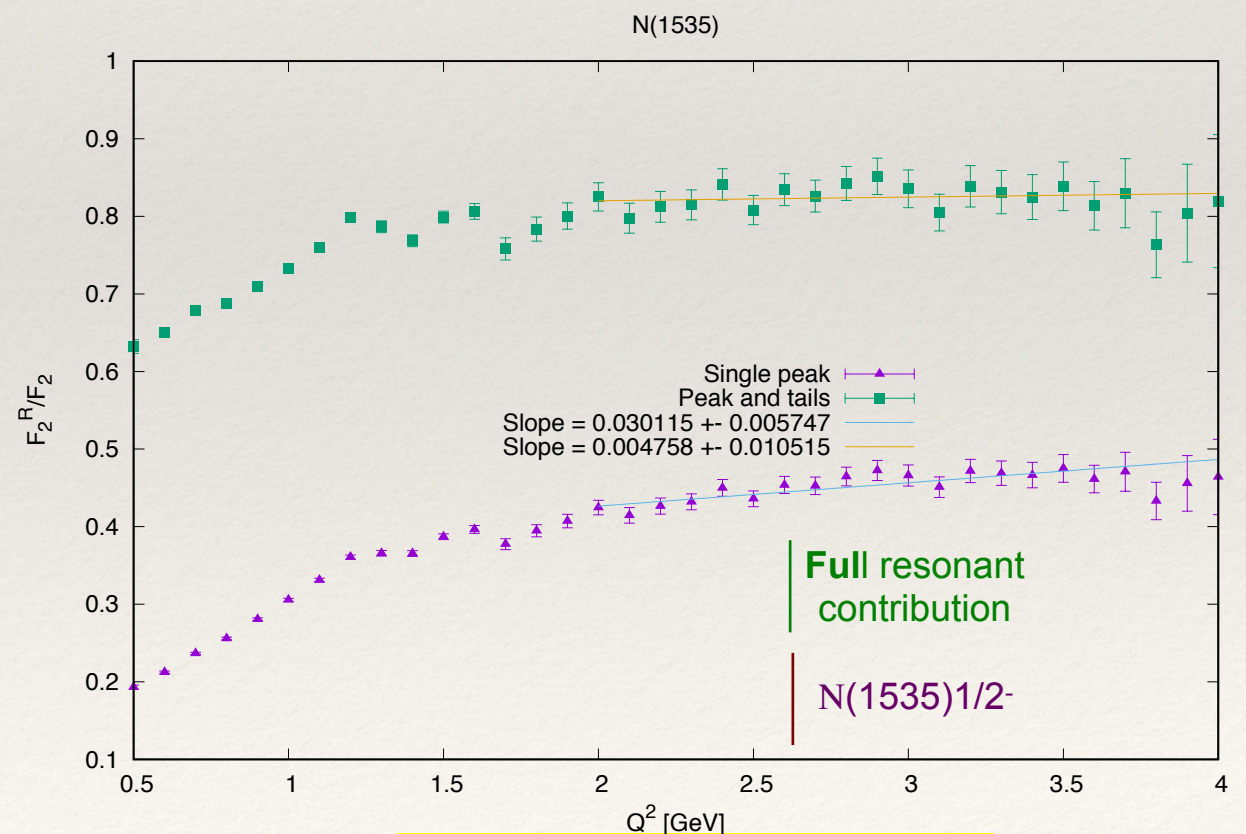


Resonance contribution into F_2 structure function

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



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



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

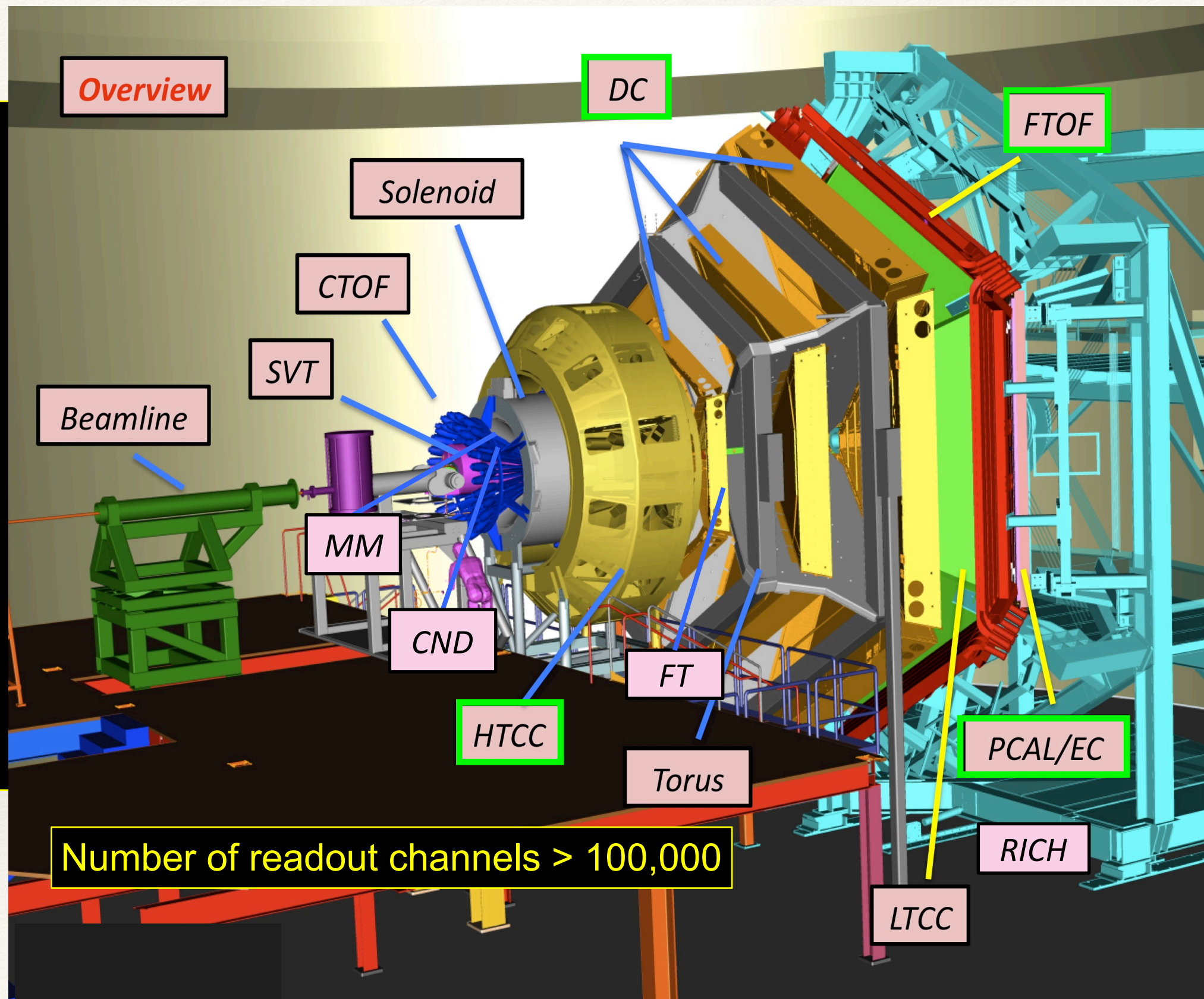
CLAS12 Detector

Forward Detector (FD)

- TORUS magnet
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter
- Forward ToF System
- Pre-shower calorimeter
- E.M. calorimeter
- Forward Tagger
- RICH detector

Central Detector (CD)

- Solenoid magnet
- Silicon Vertex Tracker
- Central Time-of-Flight
- Central Neutron Detector
- MicroMegas



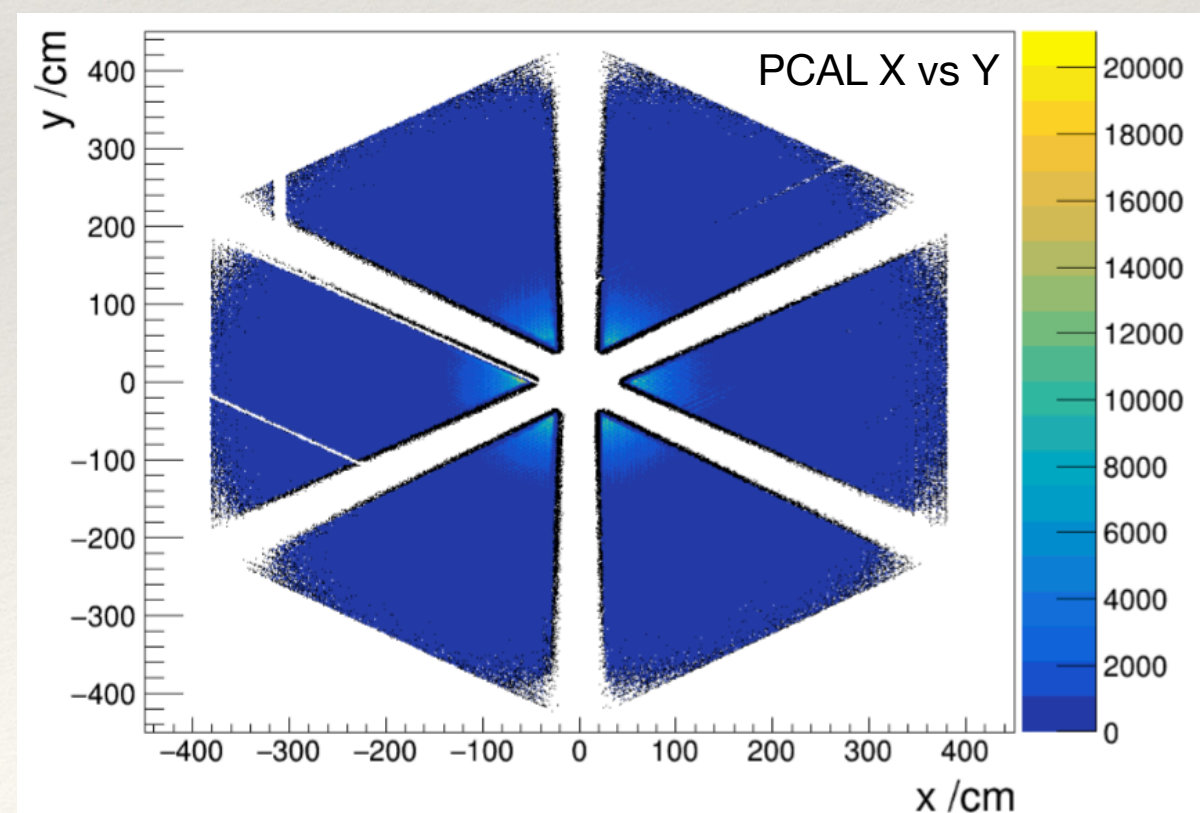
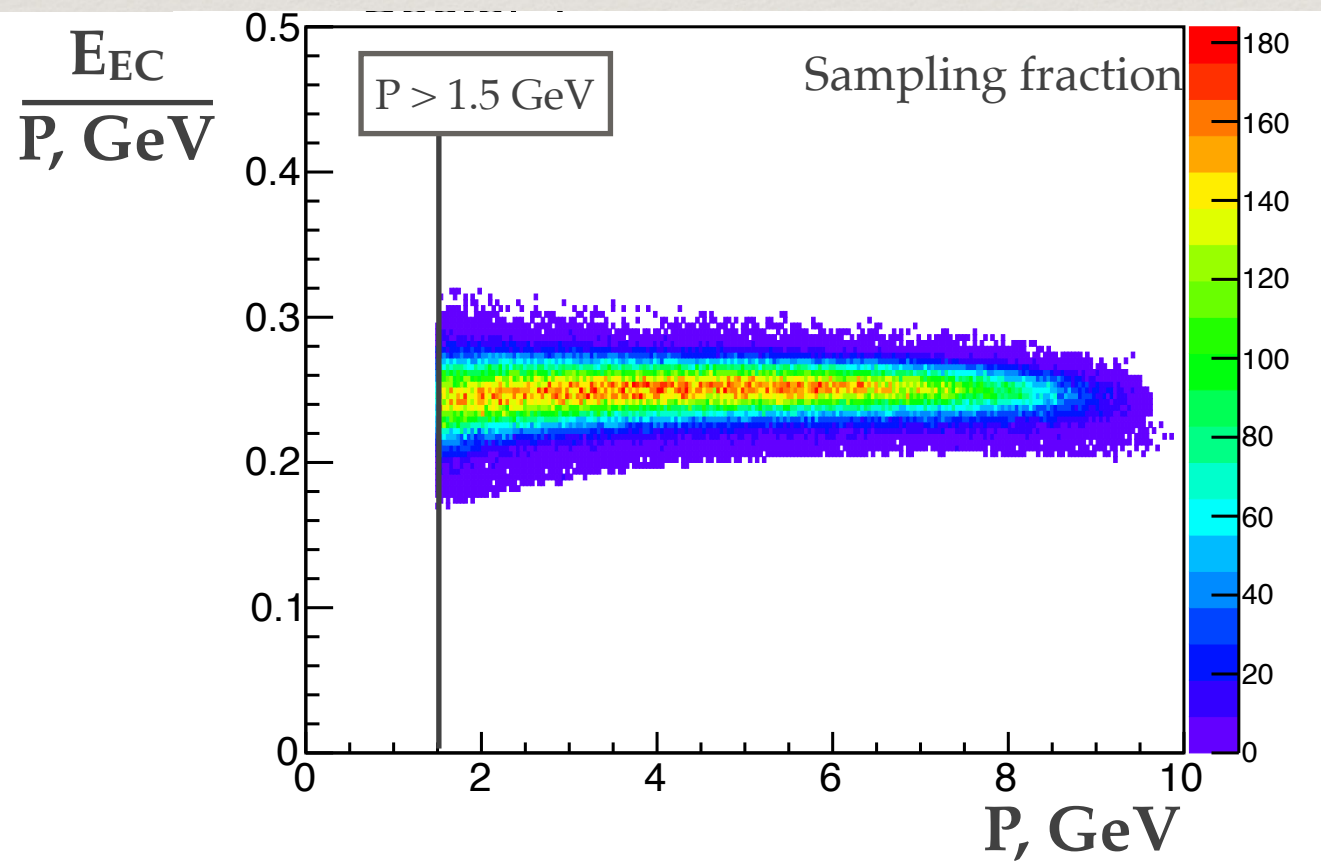
Analysis schematics

- ❖ Electron ID and event selection;
- ❖ Radiative, bin centering, and kinematical corrections;
- ❖ Simulation and acceptance corrections;
- ❖ Luminosity correction.

Electron ID

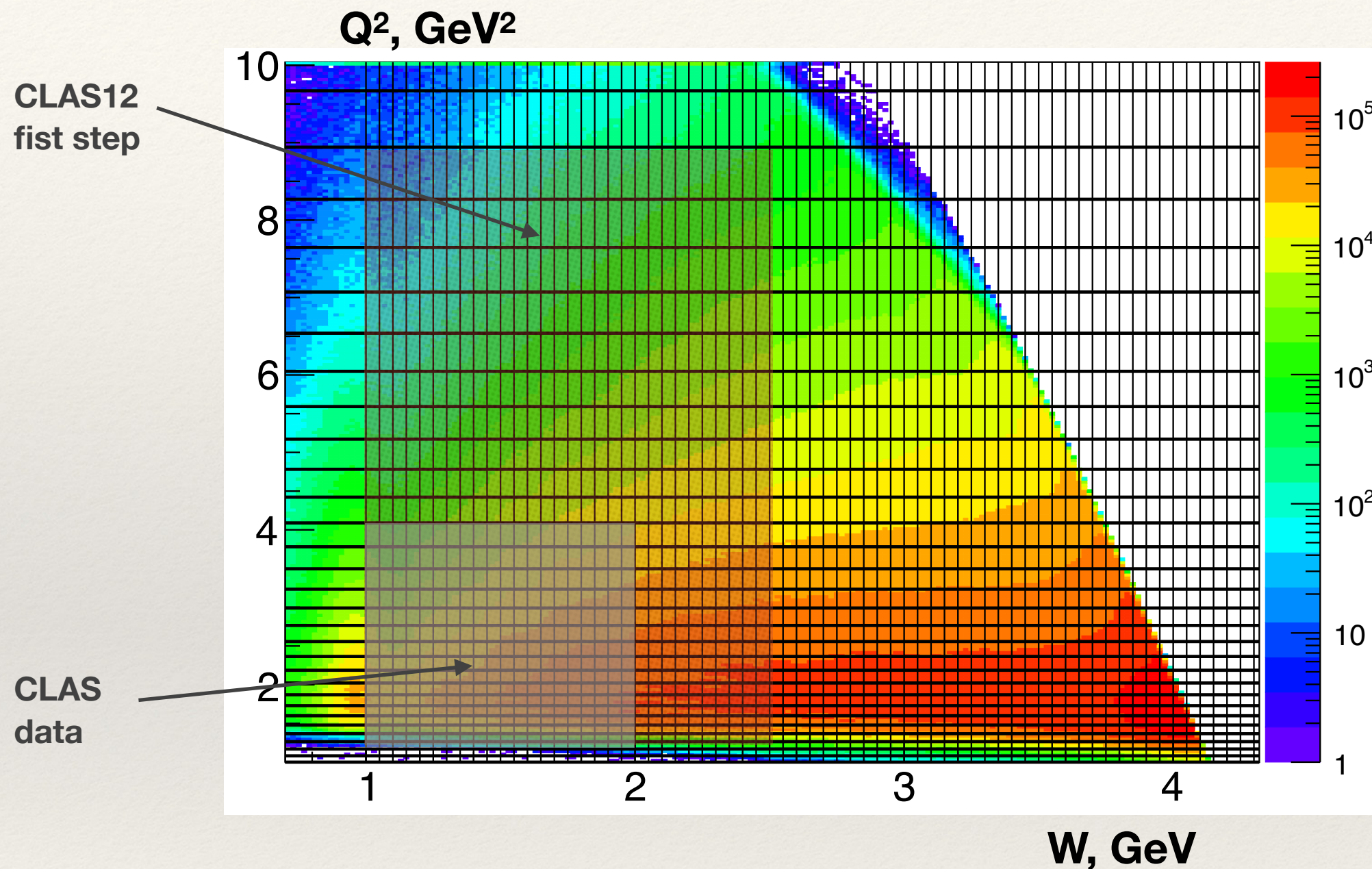
- ❖ Limited to Forward Detector (5 -35 degrees coverage in polar angle)
- ❖ Electrons are selected by the CLAS12 Event Builder
 - Negative track in **DC** with a hit in **TOF**, **ECAL** and **HTCC** and a highest momentum;
 - 2.0 photoelectrons in HTCC;
 - 60 MeV in PCAL;
- ❖ Additional cuts:
 - 3- σ cuts on a parameterized momentum-dependent sampling fraction;
 - Vertex cut;
 - $P > 1.5$ GeV
 - PCAL fiducial cut.

Standard Run Group A Cuts



Kinematic Coverage and Binning

Equidistant W, log in Q^2



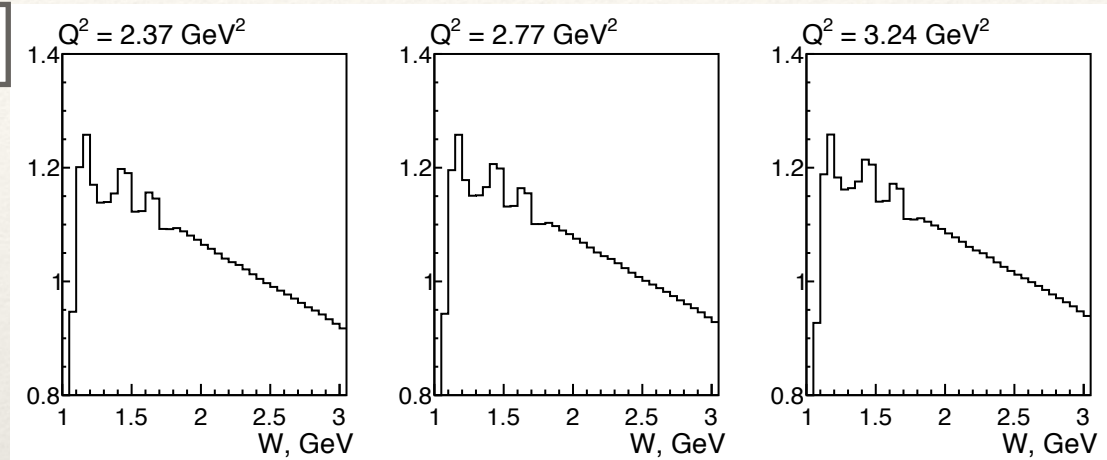
Reasonable and comparable statistics in all Q^2 bins;
Good coverage and details over W ;
Compatible with DIS studies.

Corrections

❖ Radiative corrections

- ❖ Based on the event generator capable to output cross section with and without Mo and Tsai radiate correction as well as elastic radiative tail;
- ❖ Calculated in each (W, Q^2) bin;

RC



❖ Bin Centering Correction

- ❖ Value of the cross section in the center of the bin can be different from the average value in the bin;
- ❖ By using the same event generator, we calculate cross section in many points within each bin over W and Q^2 and compare average between them to the center value. This ratio in our bin centering correction.

❖ Kinematical correction

- ❖ Momentum of the particle can be reconstructed slightly off due to detector misalignment, uncertainty in our knowledge of the magnetic field, etc;
- ❖ Based on the overdetermined kinematics (elastic scattering, elastic radiative scattering) we can reconstruct true electron momentum while trusting some the variables and develop appropriate correction.

Acceptance and Luminosity Corrections

Generated events

Reconstructed simulation events

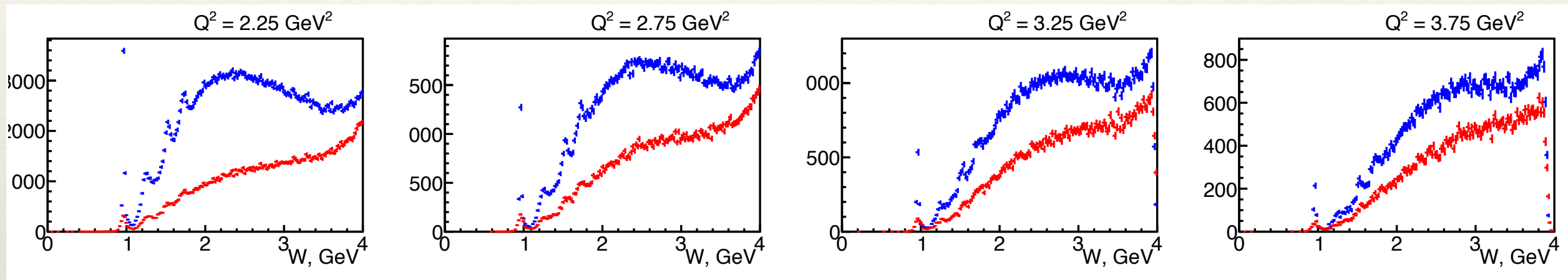
Inclusive event generator: M. Sargsyan, CLAS-NOTE 90-007 (1990).

Includes elastic and radiative effects

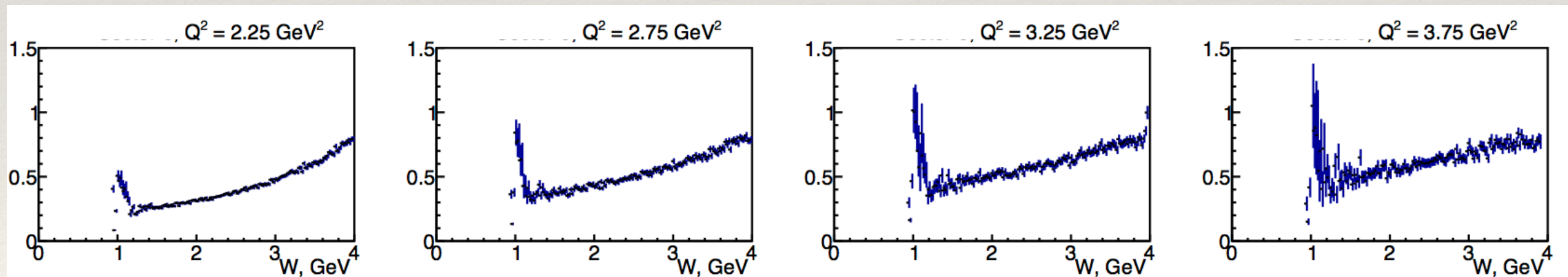
Same reconstruction algorithms are used between data and simulation.

Both generated and reconstructed event display main features of inclusive electron cross section, namely elastic peak, resonance region with “bumps” and smooth DIS region.

The scaling of the tracking efficiency with the beam current is implemented.



Acceptance Correction



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

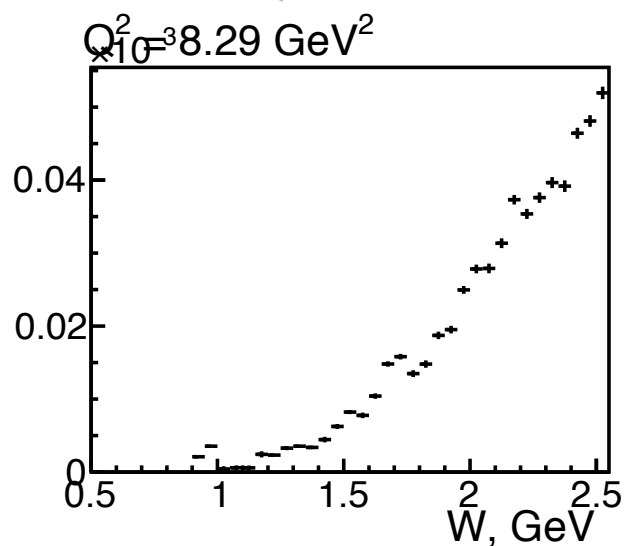
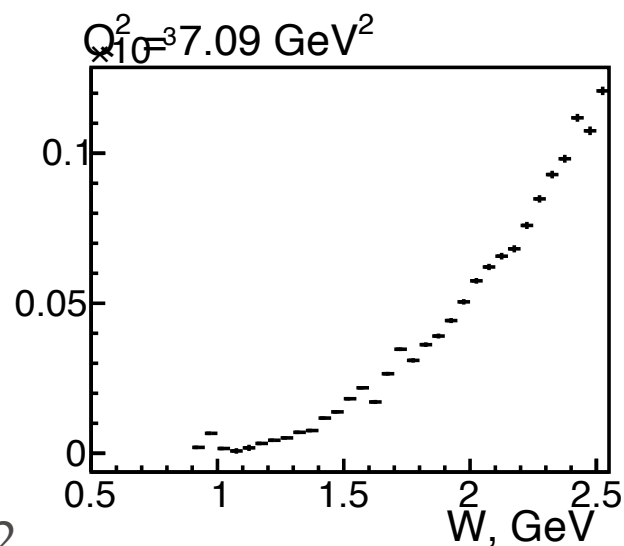
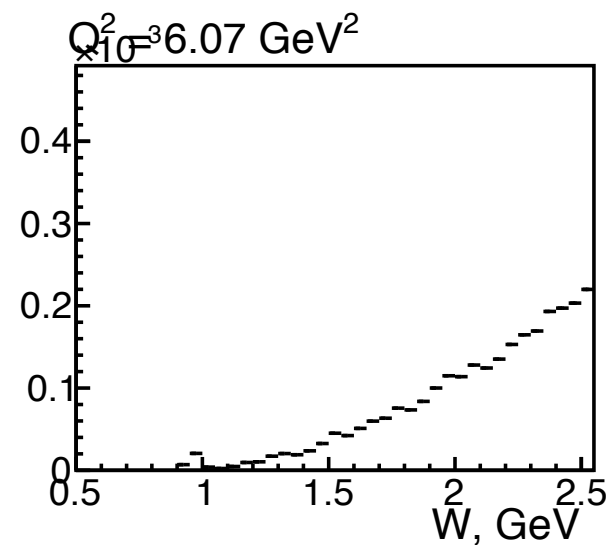
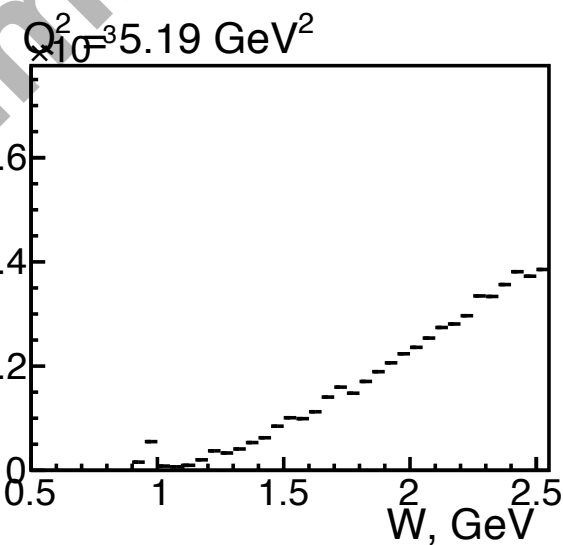
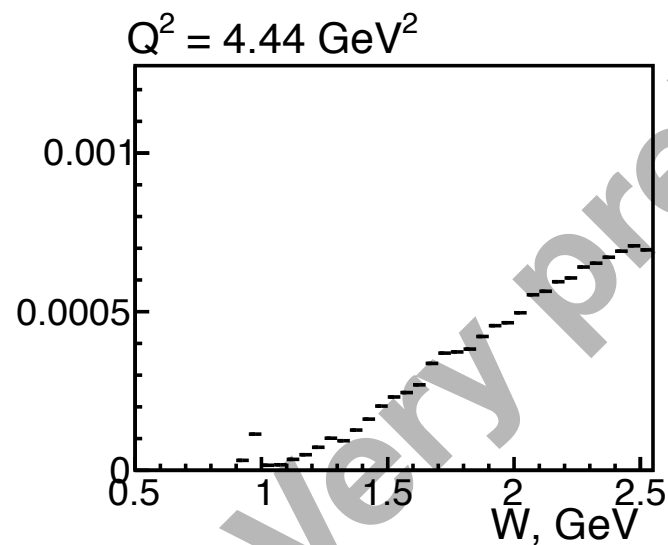
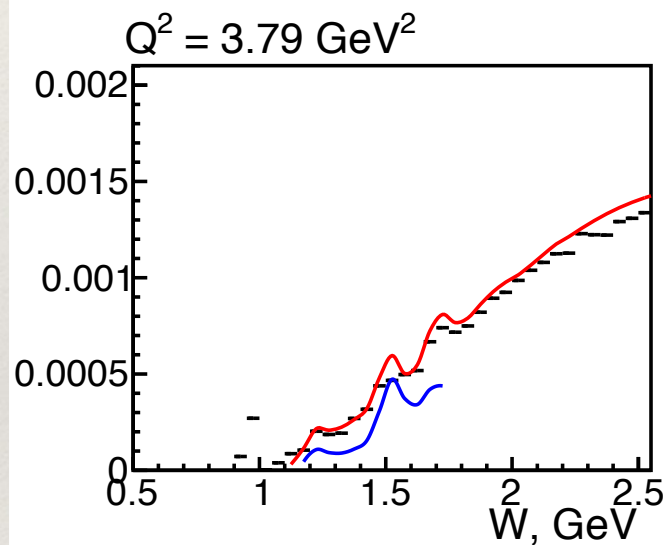
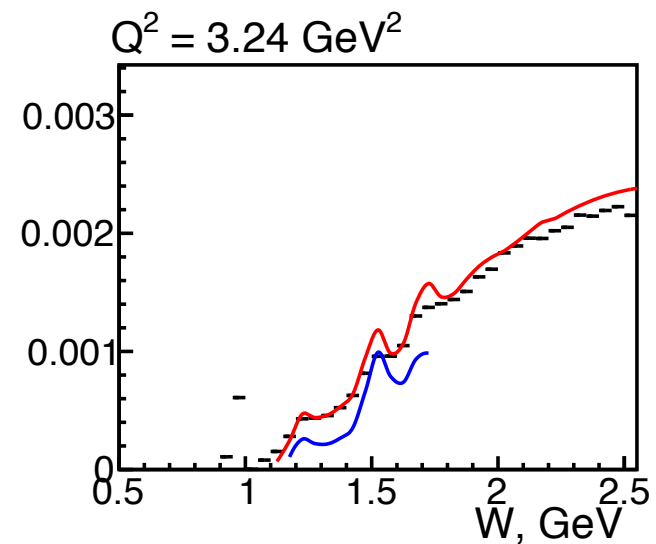
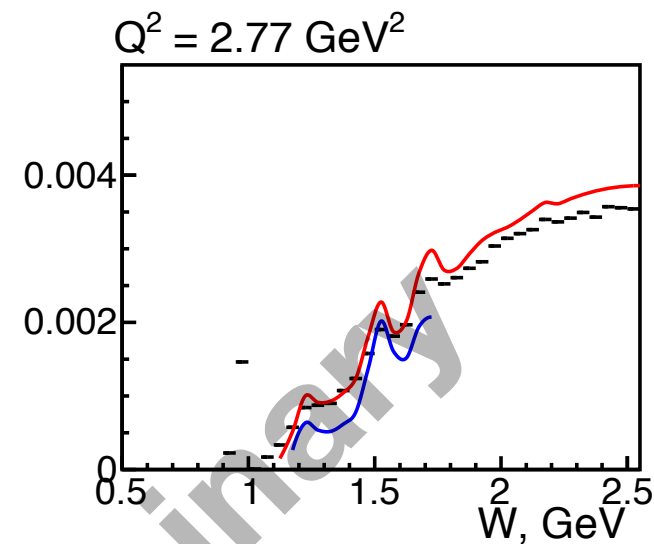
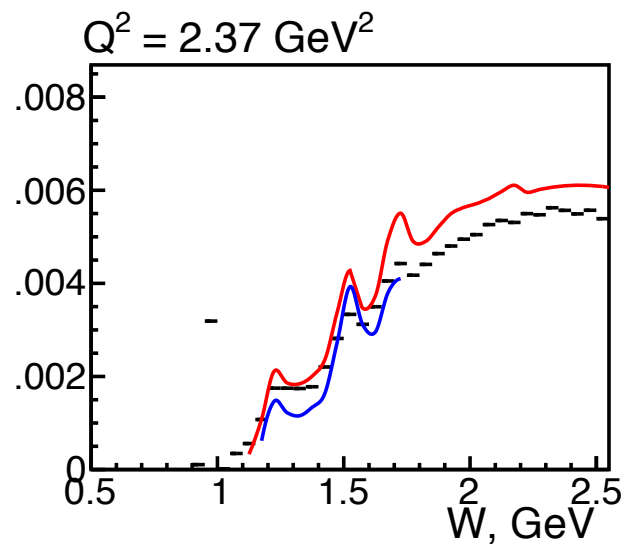
Luminosity Correction

Luminosity correction is based on the geometry and properties of the target (5 cm length liquid hydrogen) and integrated beam charge collected on the Faraday cup. It is accounted for the Live Time of the Data

Acquisition system.

Results

Luminosity and acceptance corrected yield with radiative corrections.



MSU parameterization of the world data
Resonance contribution from CLAS6 data

Future plans

- ❖ Improvements of electron ID procedure;
- ❖ Bin centering and momentum correction;
- ❖ Better understanding of the detector efficiency;
- ❖ Extensive systematic studies.

Summary

- Preliminary results on the acceptance corrected and luminosity normalized yields of inclusive electron scattering events have become available from the CLAS12 in the kinematic area of $1.1 \text{ GeV} < W < 2.5 \text{ GeV}$ and $2 \text{ GeV}^2 < Q^2 < 9 \text{ GeV}^2$;
- The shapes of the W -dependencies of the event yields are in a reasonable agreement with the obtained from the interpolation of the CLAS/world data on inclusive electron scattering;
- The combined resonance contribution to inclusive electron scattering based on the CLAS results on $\gamma_v p N^*$ electrocouplings has been evaluated and overlaid with the measured experimental data;
- The next step is the extraction of the inclusive electron scattering cross sections including careful analysis of systematics and detailed understanding of the CLAS12 efficiency;
- The approach for the evaluation of the individual resonance contributions to inclusive electron scattering based on the CLAS results on $\gamma_v p N^*$ electrocouplings has been developed and published. It is ready to use in the inclusive data analysis.

