Resonance PV Asymmetry Measurement with SoLID

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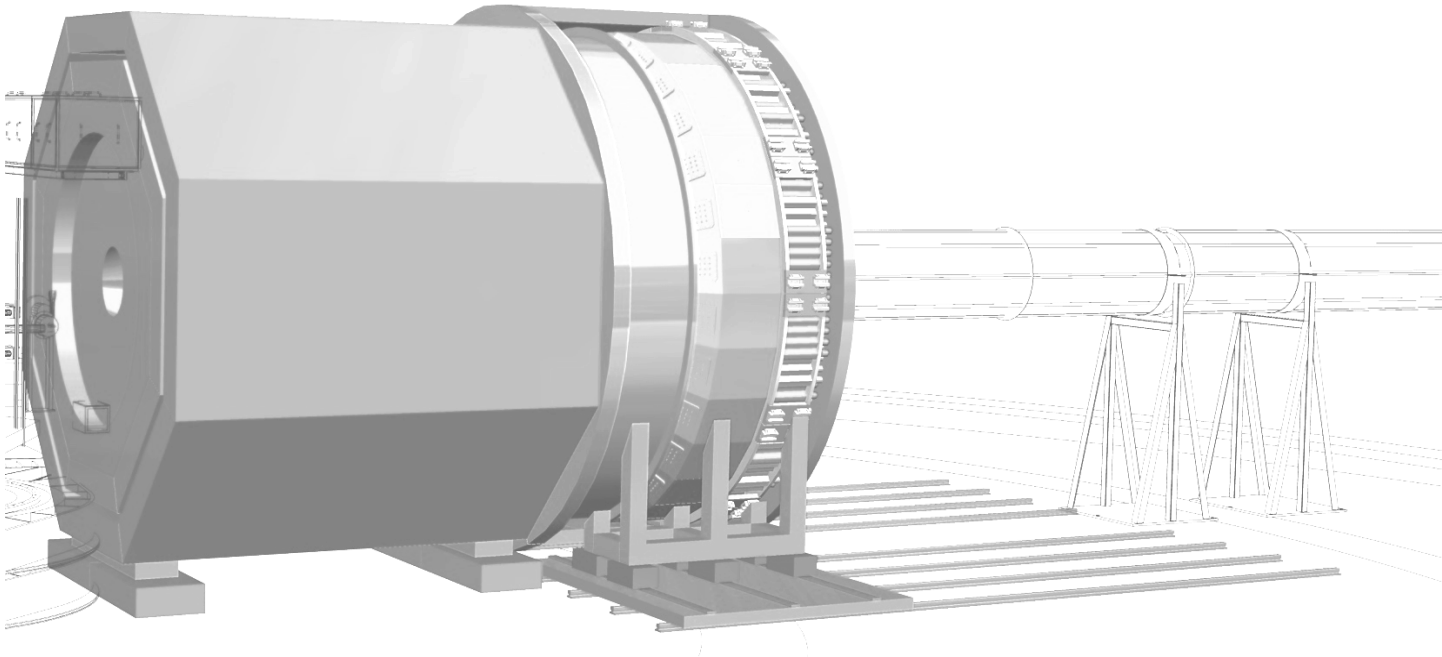
INT 22-81W Virtual Workshop
June 28th 2022

Outline

- General info and physics motivation
- Experimental apparatus
- Projected results
- Summary



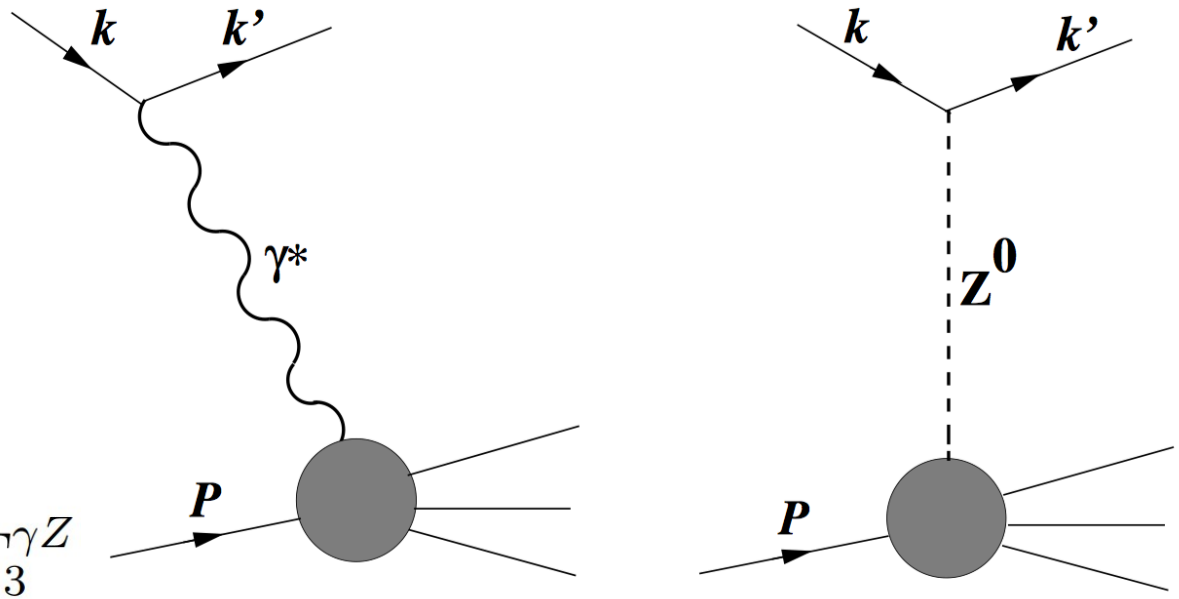
General info – PVES Asymmetry

- The parity-violating electron scattering (PVES) asymmetry

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

- The asymmetry dominated by electroweak γZ interference structure function:

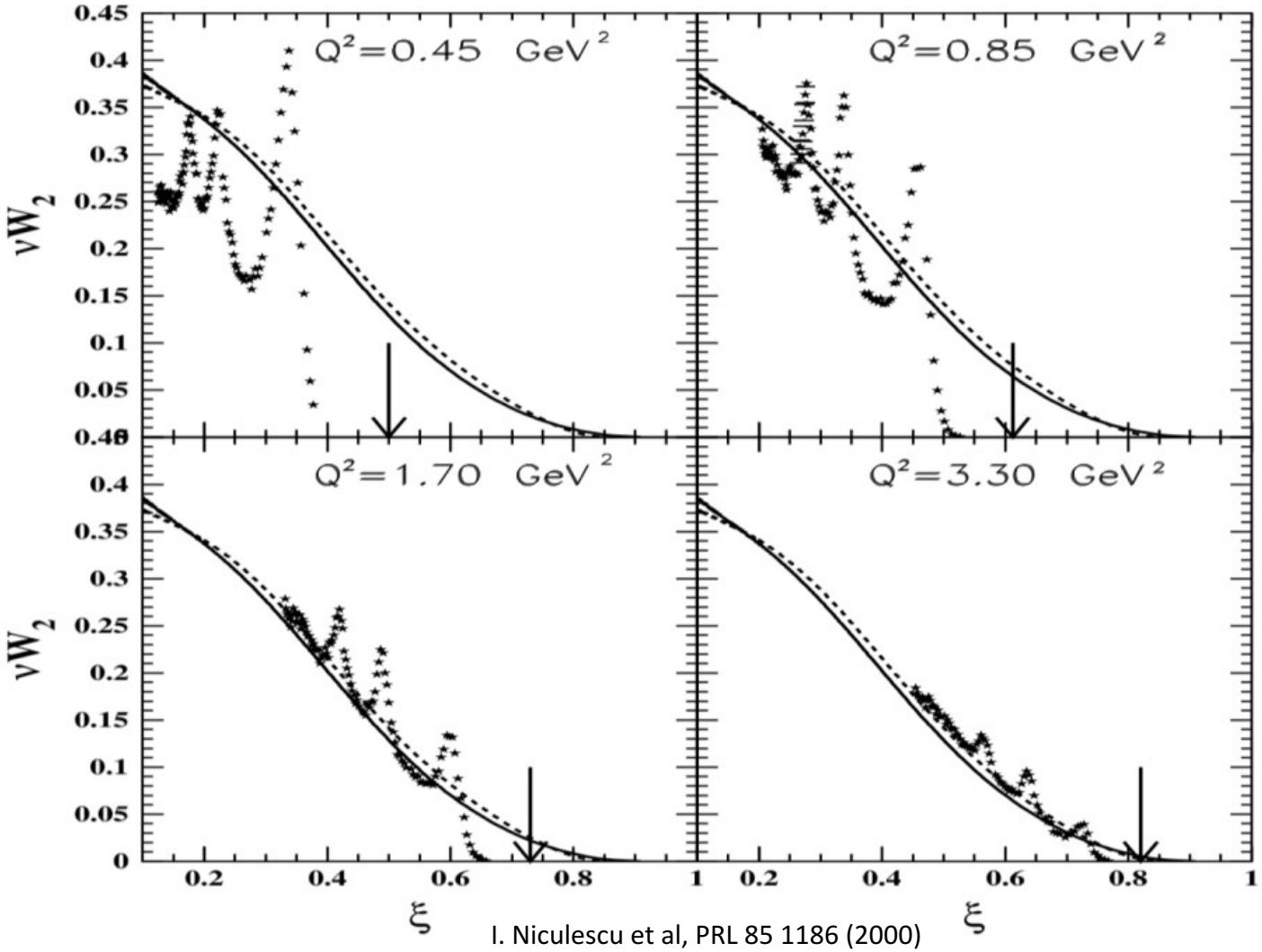
$$A_{PV} = g_A^e \left(\frac{G_F Q^2}{2\sqrt{2}\pi\alpha}\right) \frac{Y_1 F_1^{\gamma Z} + Y_2 F_2^{\gamma Z} + \frac{g_V^e}{g_A^e} Y_3 x F_3^{\gamma Z}}{Y_1 F_1^{\gamma\gamma} + Y_2 F_2^{\gamma\gamma}}$$



- Powerful and popular tool for testing the Standard model, but measurement in the nucleon resonance region are still scarce
- Propose to measure the Apv in the resonance region in parallel to the SoLID-PVDIS experiment

Physics Motivation – Quark-Hadron Duality

- First proposed by Bloom and Gilman in 1970
- Low energy cross sections averaged over the resonance structures resemble those at asymptotically high energies
- Verified in F2, FL, g1, A_1^P… and also Apv at the level of 10% to 15%



I. Niculescu et al, PRL 85 1186 (2000)

$$\xi = \frac{2x}{\sqrt{1+\sqrt{1+\frac{4x^2M_N^2}{Q^2}}}}$$

Physics Motivation – Quark-Hadron Duality

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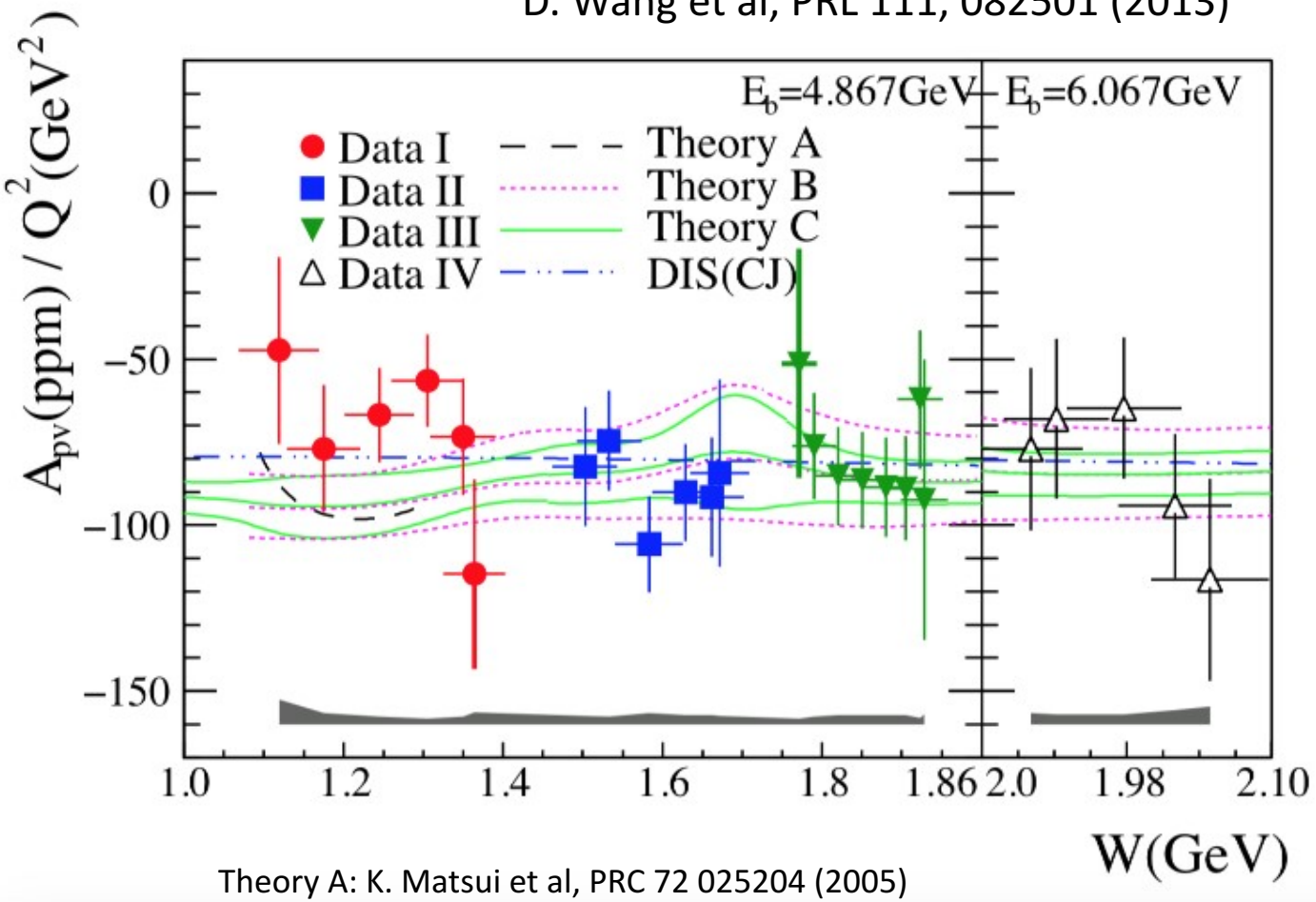
D. Wang et al, PRL 111, 082501 (2013)



Theory A: K. Matsui et al, PRC 72 025204 (2005)
Theory B: M. Gorchtein et al, PRC 84 015502 (2011)
Theory C: N. L. Hall et al, PRD 88 013011 (2013)
DIS (CJ): J. F. Owens et al, PRD 87, 094012 (2013)

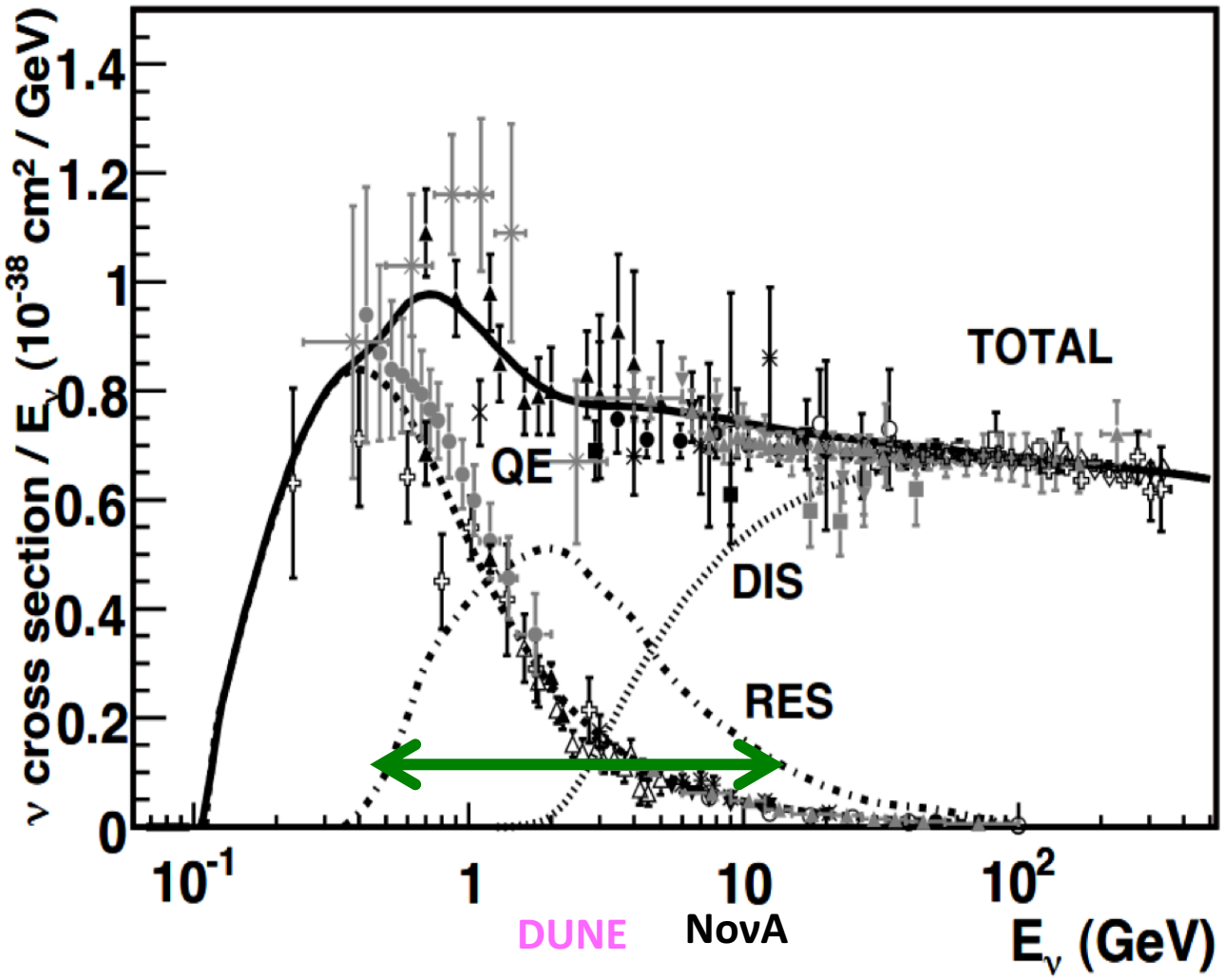
Physics Motivation – Impact on Neutrino Experiments

- Need accurate predictions for the cross section integrated over the neutrino energy spectrum (relies on the MC simulation)

- Electromagnetic structure functions, form factors: assume CVC, PCAC, an Chiral Symmetry.

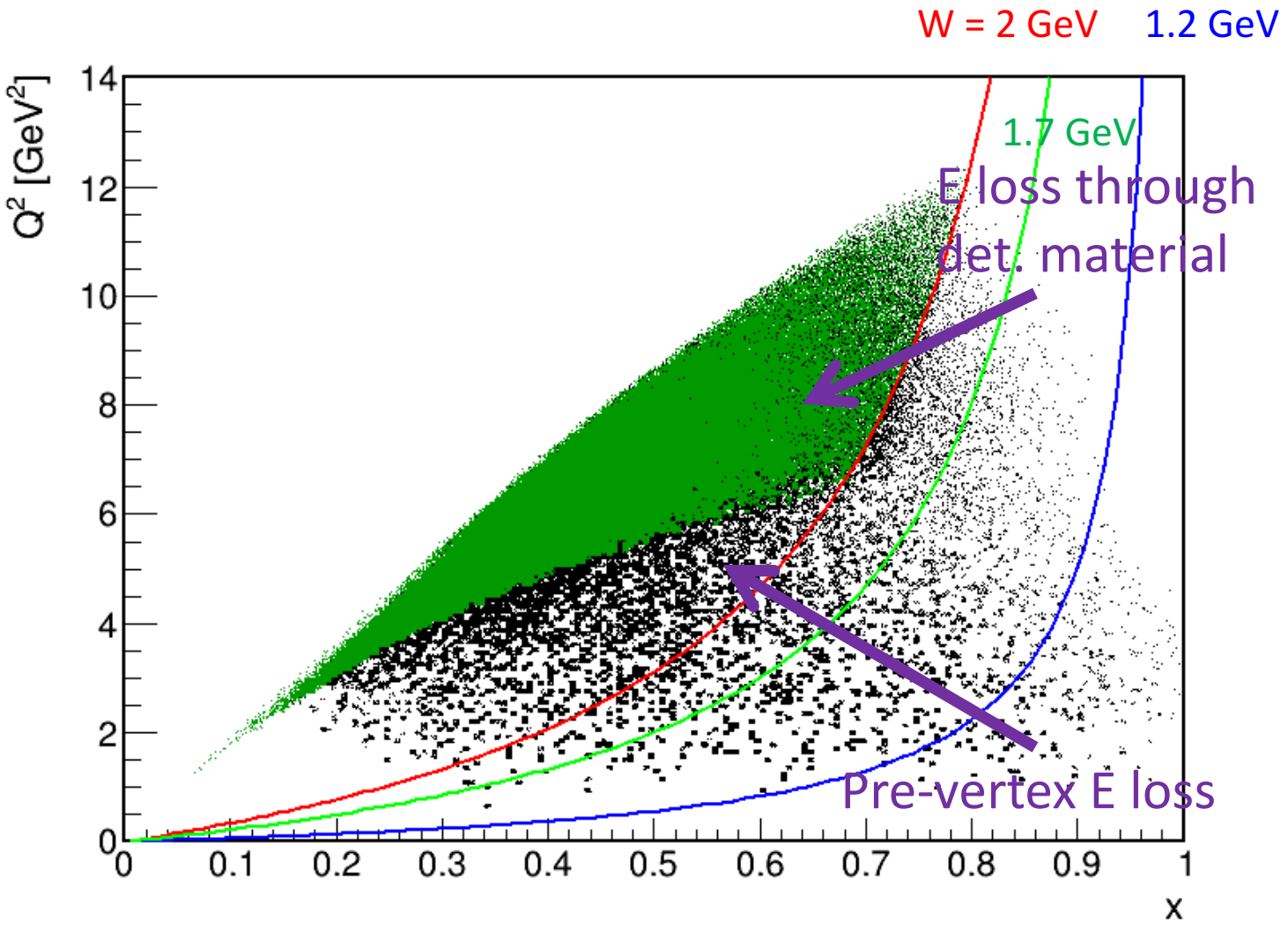
PVES provides constraints on the structure function for the models used to predict the neutrino cross sections.

J. A. Formaggio and G. P. Zeller. Rev. Mod. Phys., 84:1307–1341, Sep 2012

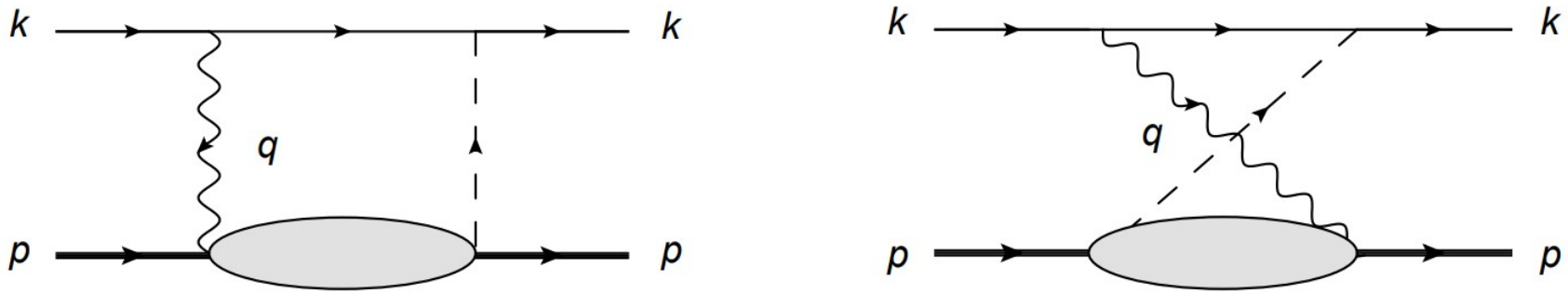


Physics Motivation – External RC for SoLID-PVDIS

- Events from the resonance region can "move" into the DIS region through radiative effects
- Green distribution obtained with nominal beam energy (11GeV) and measured momentum
- Black distribution shows "true" values including pre-vertex E loss
- About 10% of the events coming from the resonance region, but current existing data do not have enough precision and coverage

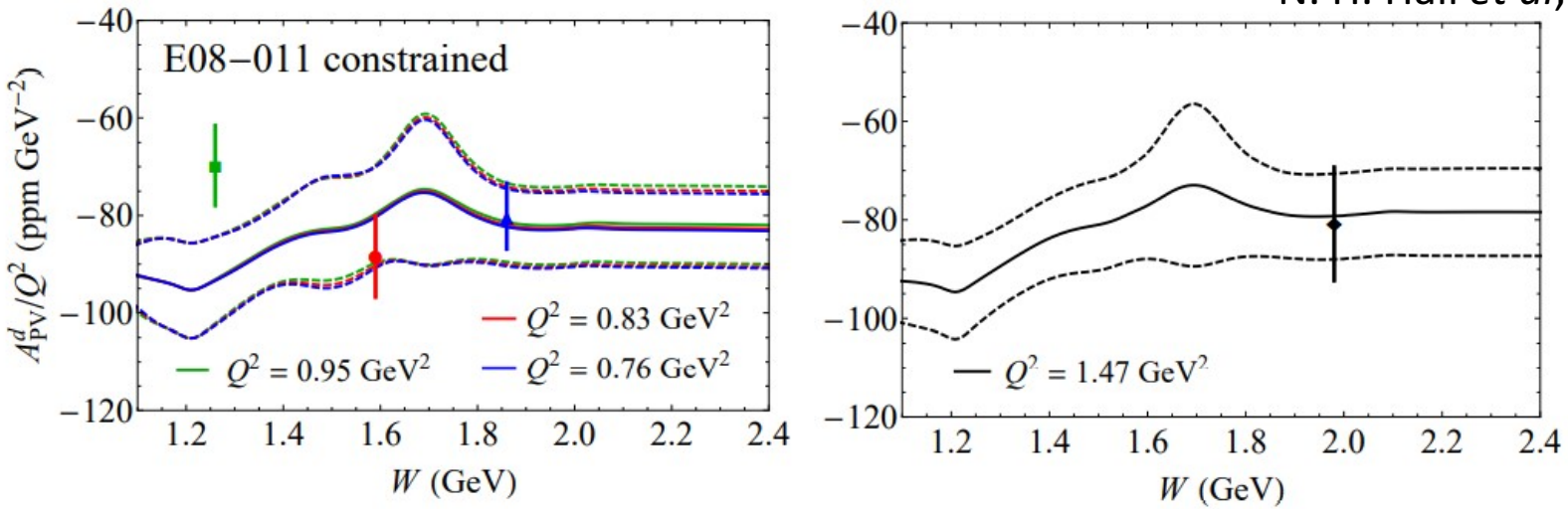


Physics Motivation – $F^{\gamma Z}$ Structure Functions and the γZ Box Diagram



- Can be used for constrain the AJM model and calculate the γZ Box Diagram, important to have low Q^2 and high x resonance data
- SoLID 6.6 and 4.4 GeV data, provide slightly higher Q^2 coverage compared to the 6GeV PV-Res data (E08-11), 1.5 to 6 GeV^2, W from 1.1 to 2.0 GeV

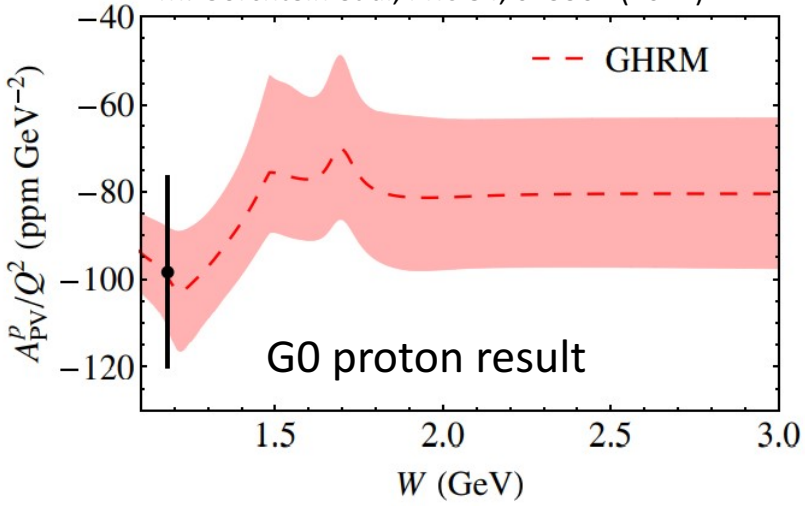
N. H. Hall *et al*, PRD 88. 013011



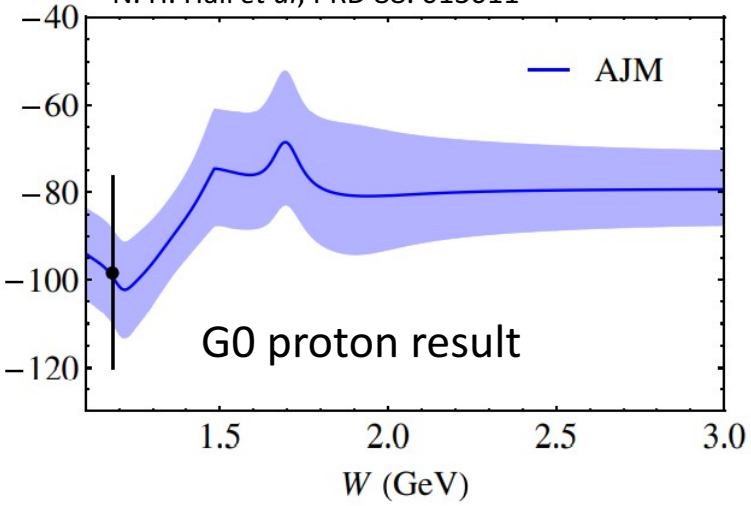
Current Resonance Apv Data

- Uncertainties at the level of 10% or larger, verify quark-hadron duality at (10~15)% level
- Cover much lower Q^2 region (< $2GeV^2$), not enough for the external RC for SoLID-PVDIS
- The proposed measurement can provide much more precise data and larger kinematic coverage

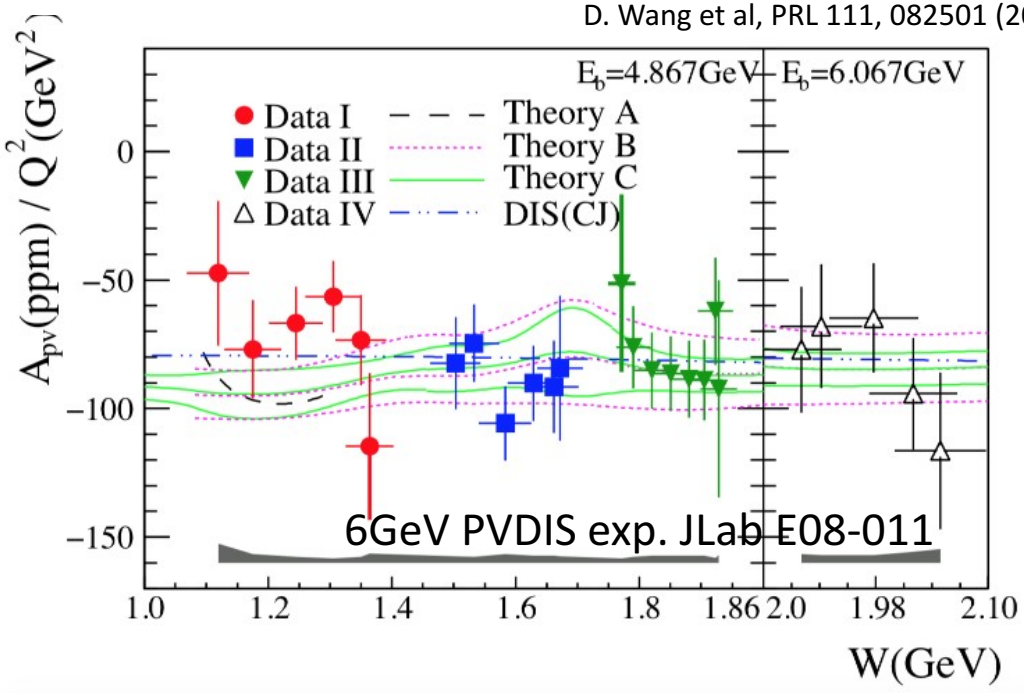
M. Gorchtein et al, PRC 84, 015502 (2011)



N. H. Hall *et al*, PRD 88. 013011

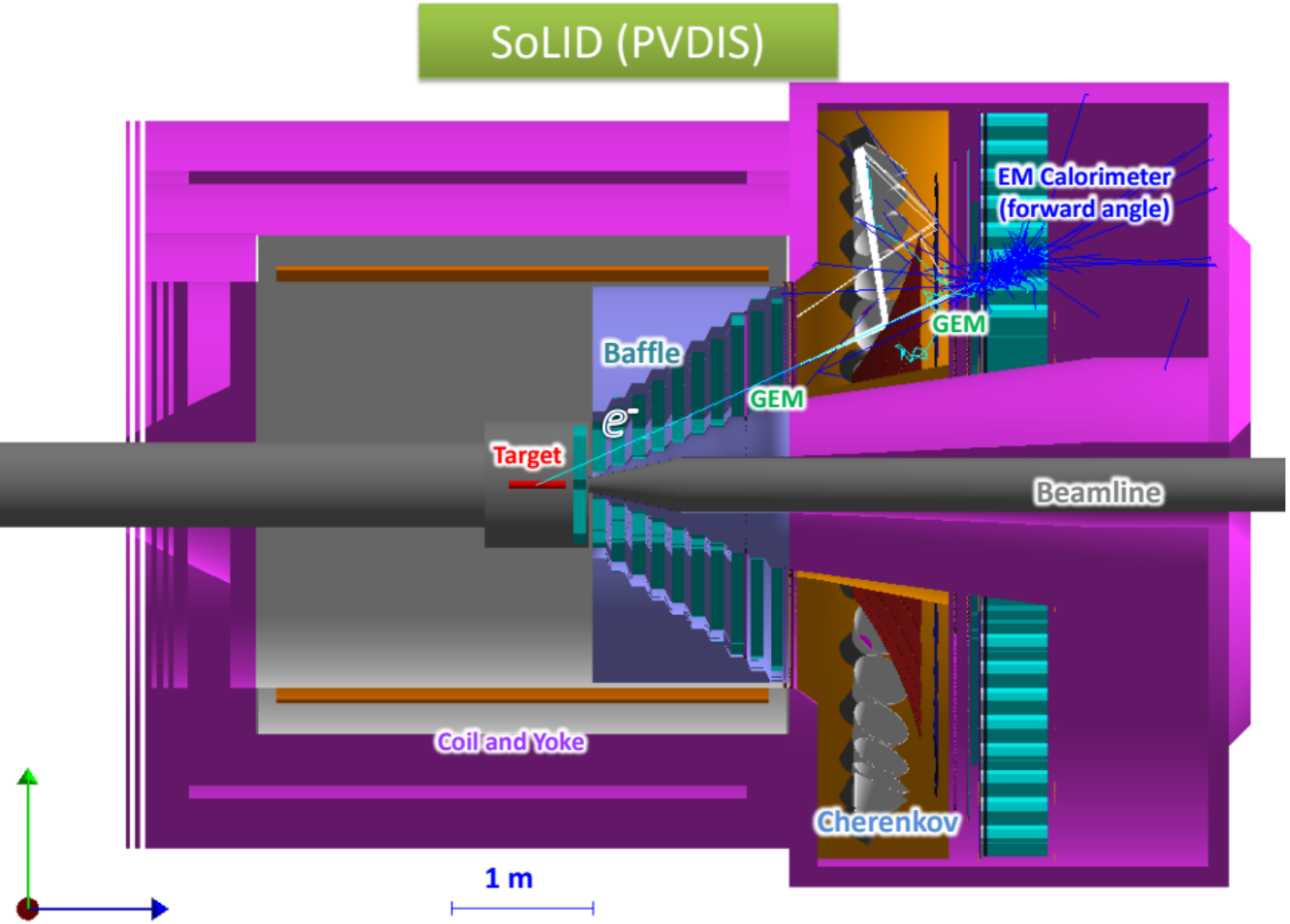


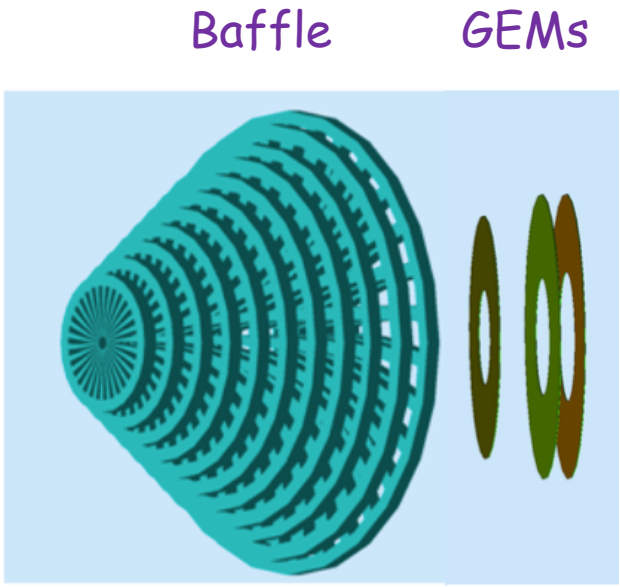
D. Wang et al, PRL 111, 082501 (2013)

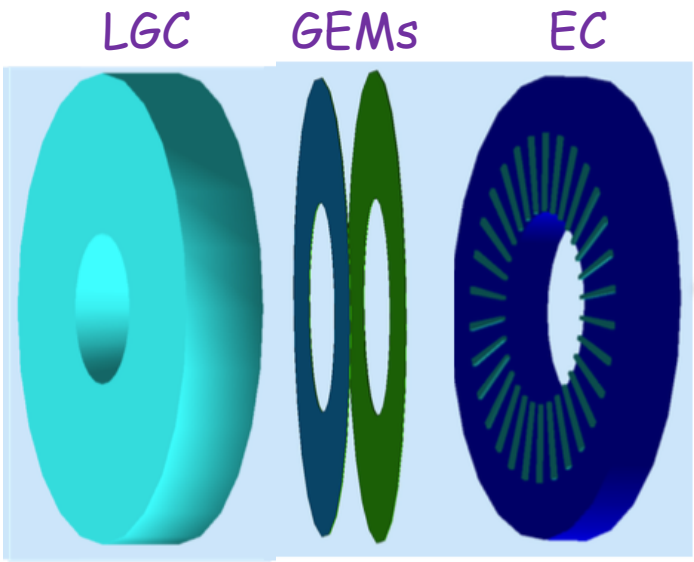


SoLID Experimental Apparatus

- SoLID spectrometer: large acceptance and can handle very high luminosity (10^{37} to 10^{39} $cm^{-2}s^{-1}$)

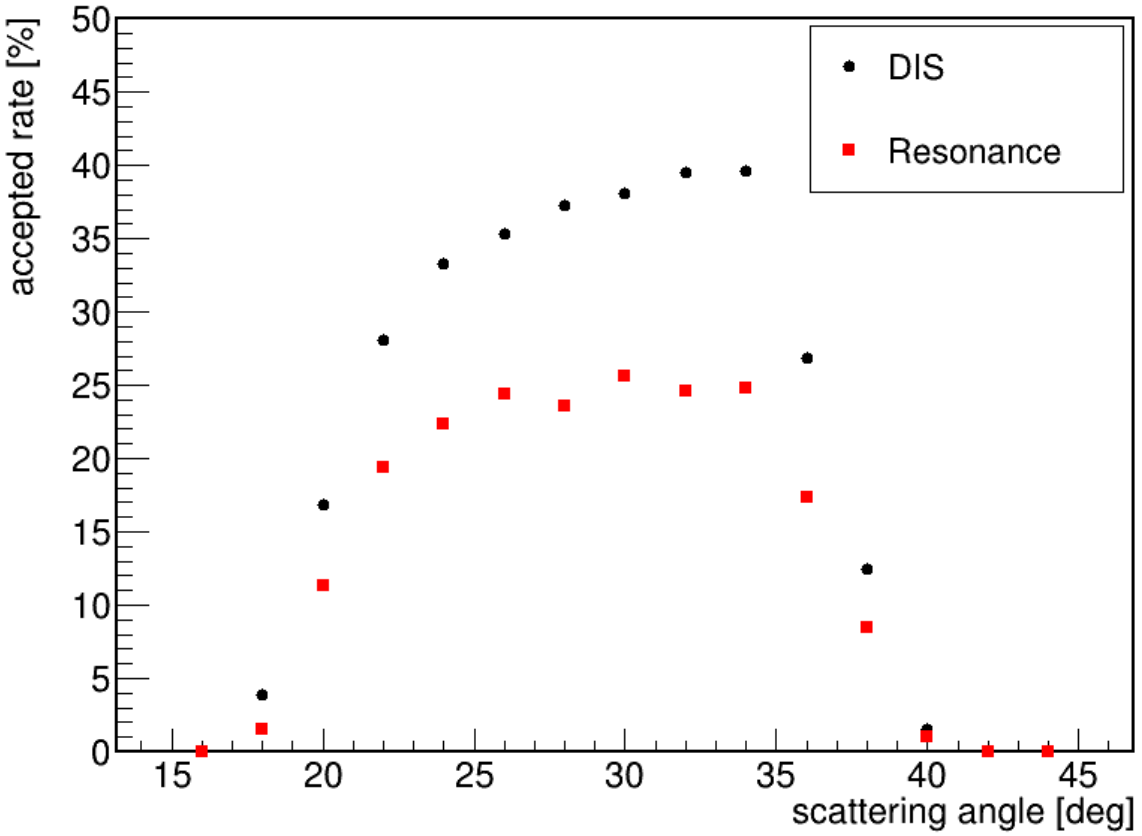






SoLID Experimental Apparatus

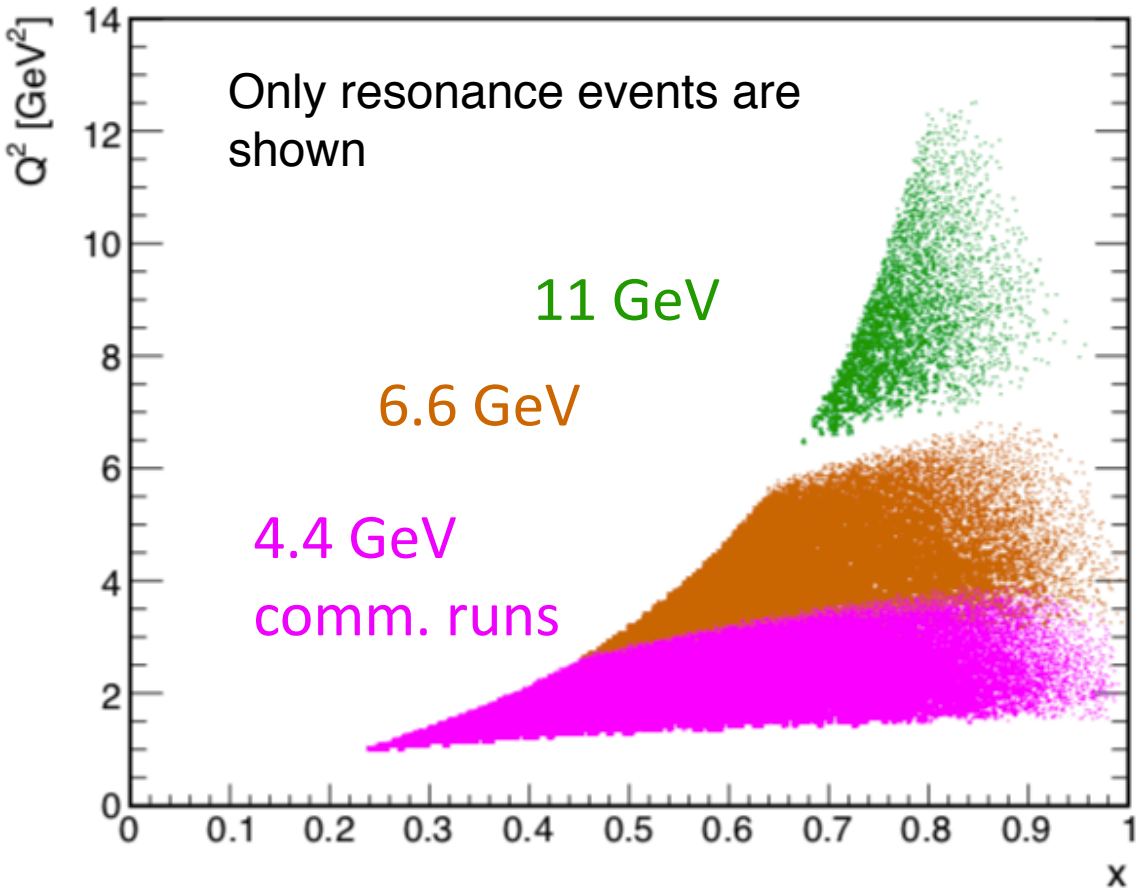
- SoLID-PVDIS detector configuration
  - $1\ GeV^2 < Q^2 < 12\ GeV^2$
  - $x_{Bjorken} > 0.3$
  - Scattering angle ~22° to ~35°
  - Luminosity ~ $10^{39}\ cm^{-2}s^{-1}$
  - Momentum resolution ~ 2%
  - Polar angle resolution ~ 1mrad
  - Baffle optimized for DIS events with x > 0.55, $Q^2 > 6\ GeV^2$ and W > 2 GeV, for the resonance events (W < 2 GeV) the acceptance is still acceptable



Beam Current and Run Plan

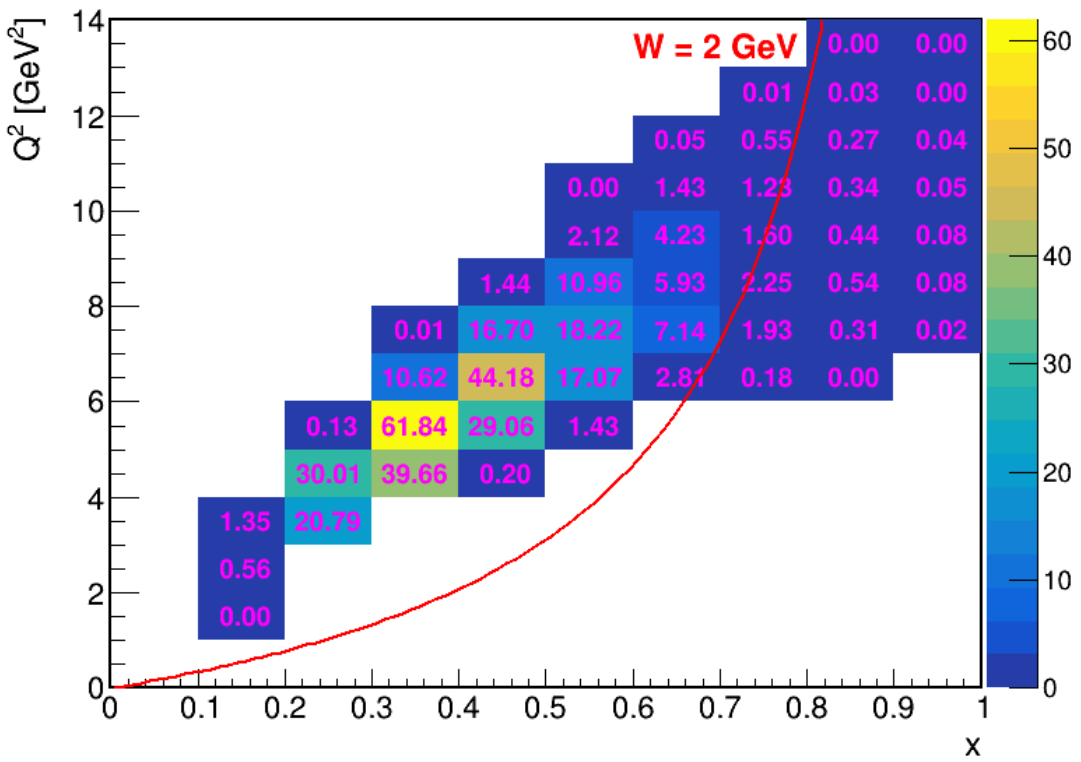
- This run-group experiment plan to take data simultaneously with the SoLID-PVDIS experiment
- Focus on LD2 target at the moment, but will take LH2 data too if PVDIS switches the target
- Assume 50uA for all beam currents

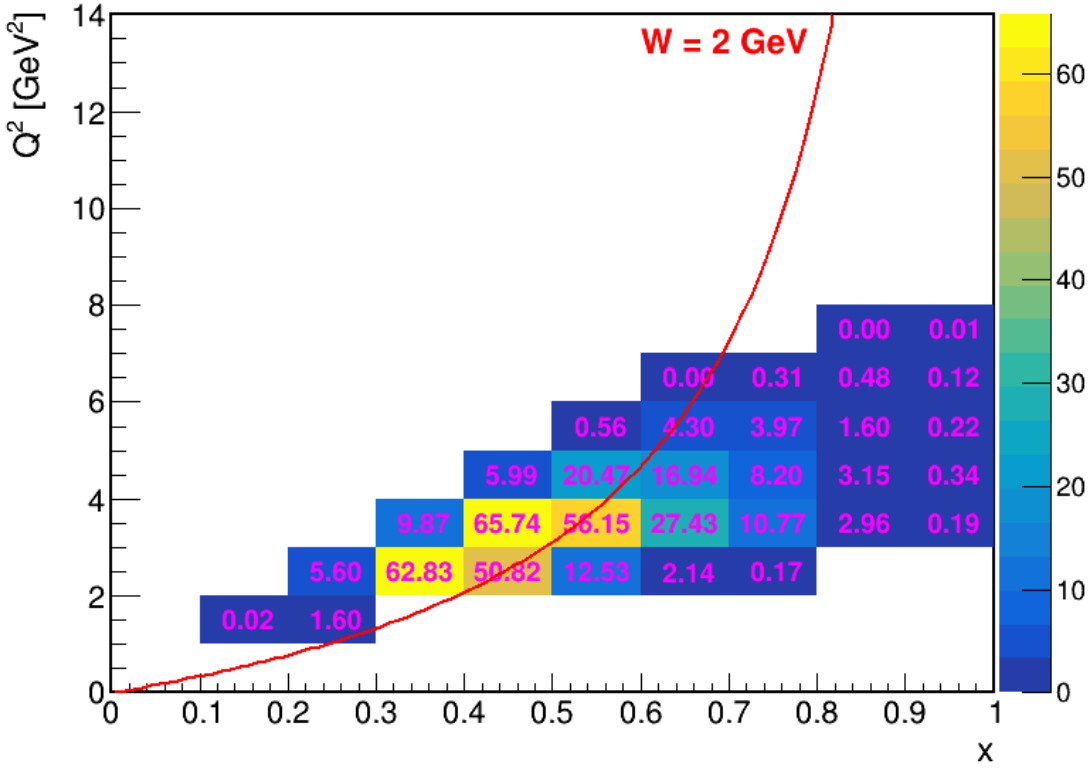
Beam Energy [GeV]	Run Time [Day]	Q^2 range [GeV^2]	x range
11	120	6.0 ~ 12.0	> 0.7
6.6	30	2.0 ~ 6.0	> 0.45
4.4 (commissioning)	9	1.0 ~ 4.0	> 0.25



Kinematic Coverage and Expected Event Rates

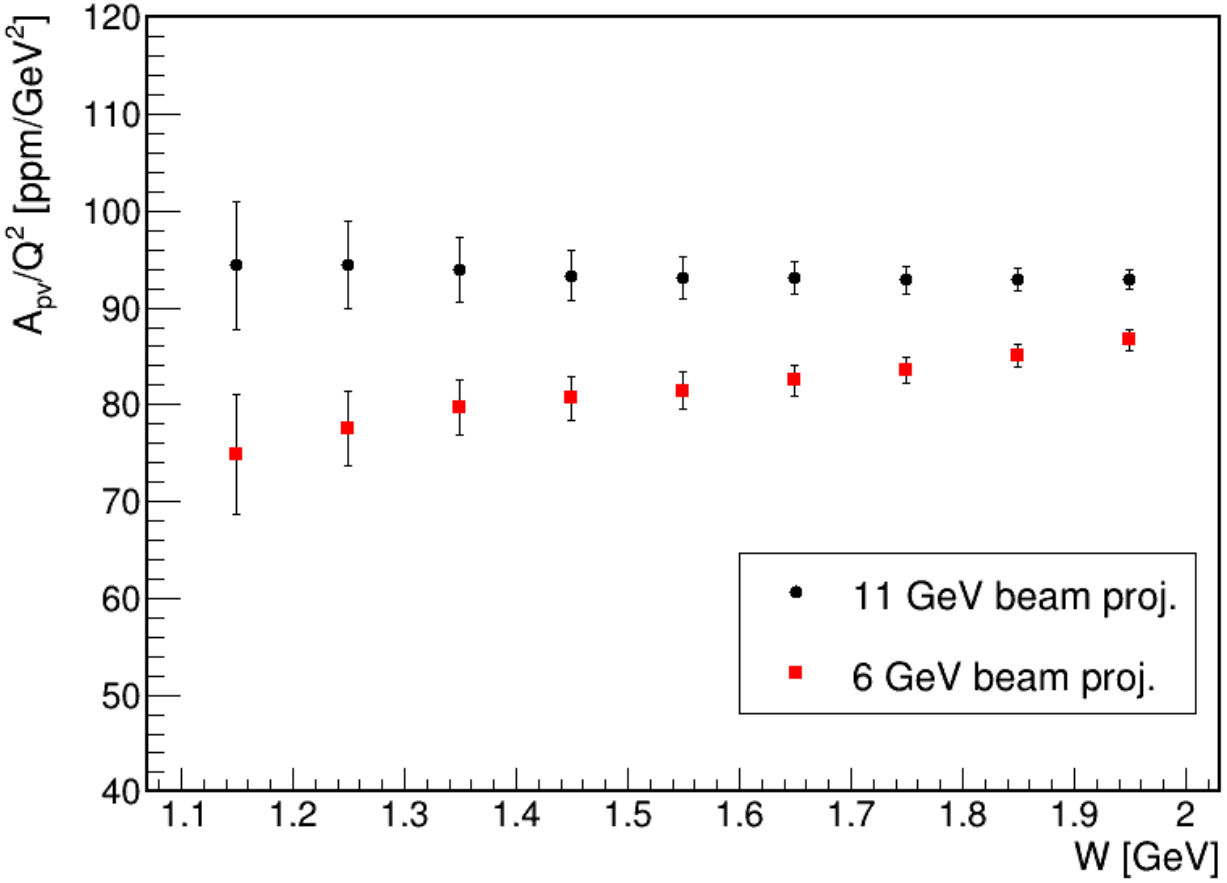
- Kinematic coverage:
  - 6 GeV^2 to 12 GeV^2 for Q^2, 0.7< x < 1 for 11 GeV
  - 2 GeV^2 to 8 GeV^2 for Q^2, 0.5 < x < 1 for 6.6 GeV
- Event rate in the resonance region: ~7kHz for the 11 GeV and ~150kHz for the 6.6 GeV
- 120 days with 11 GeV, 30 days with 6.6 GeV
- With 40cm LD2 target

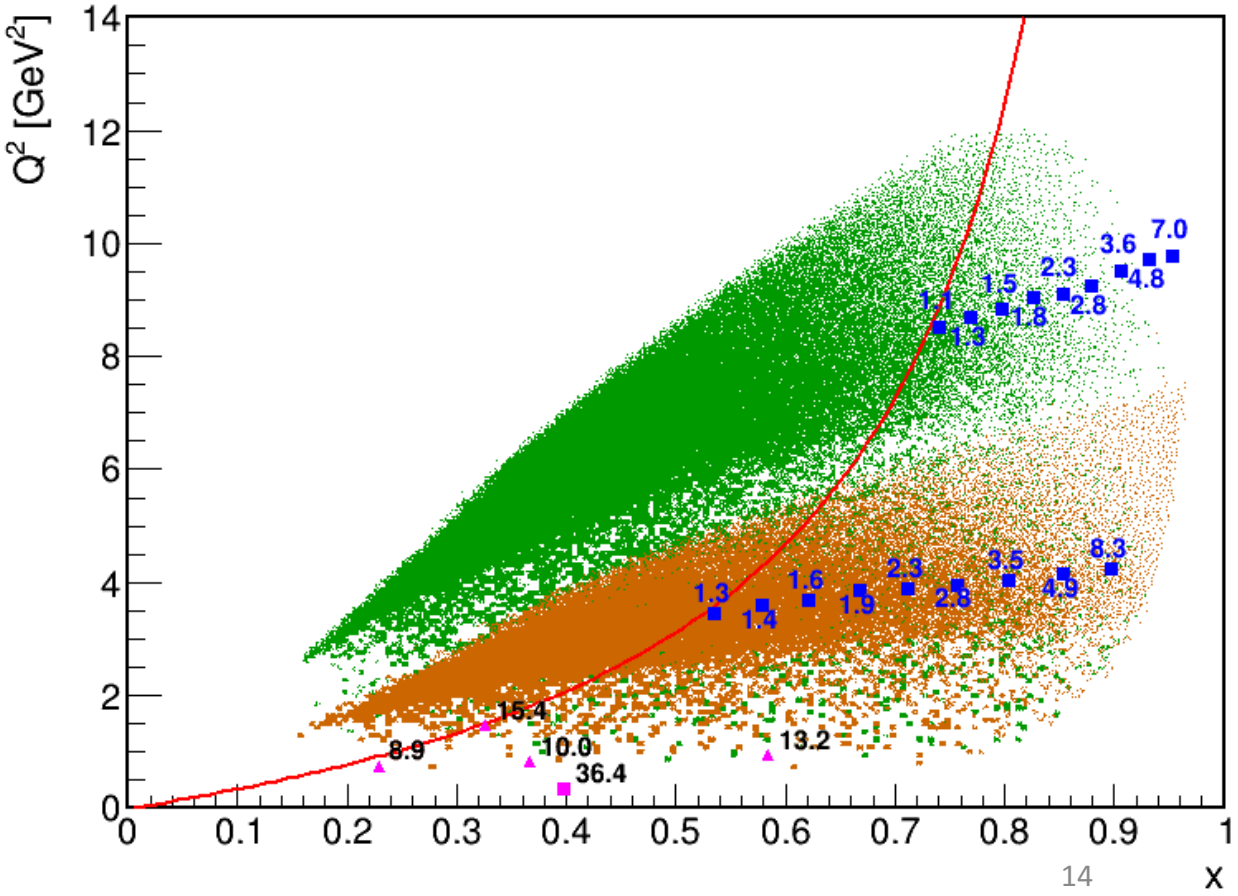




Projected Results on Apv

- Assuming 120 days with the 11GeV at 50uA current, and 30 days with 6.6 GeV beam
- 9 bins in W, with 0.1 GeV bin width
- Stat. uncertainties 1.1% to 7.0% for 11 GeV and 1.3% to 8.3% for 6.6 GeV

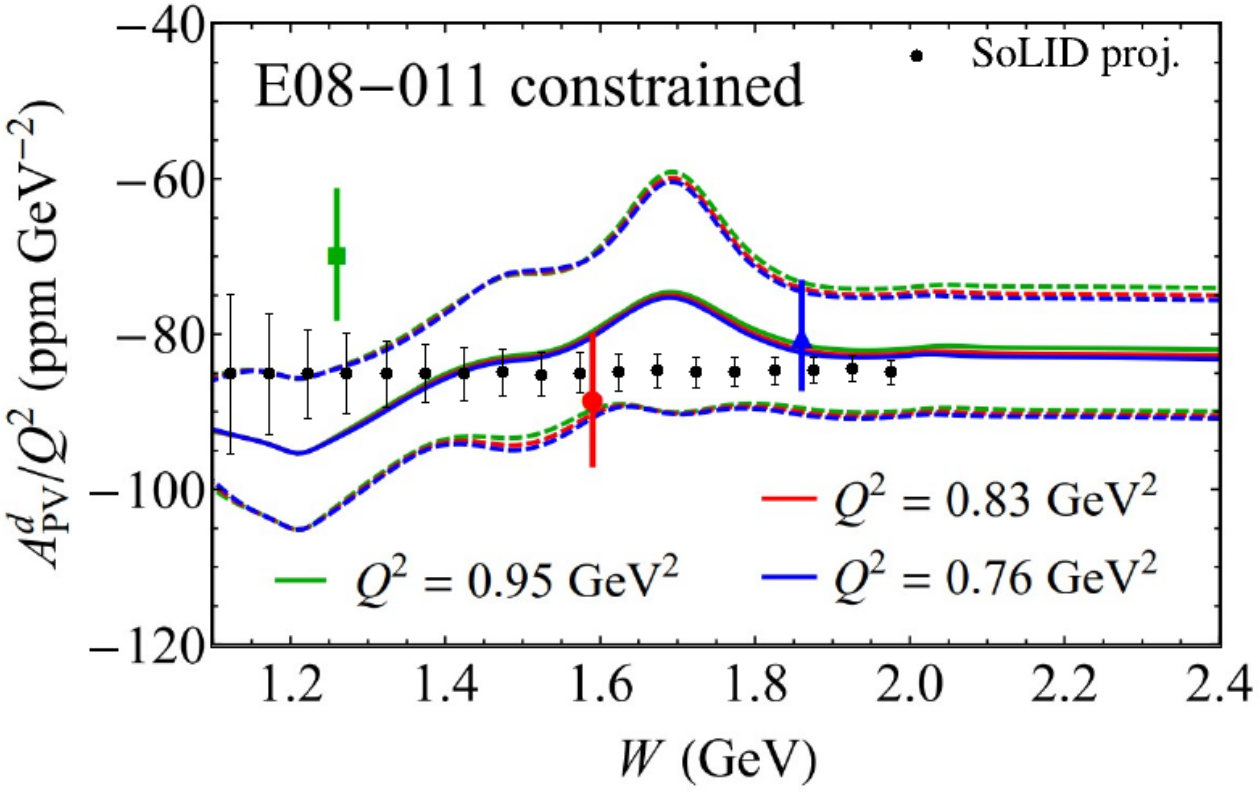




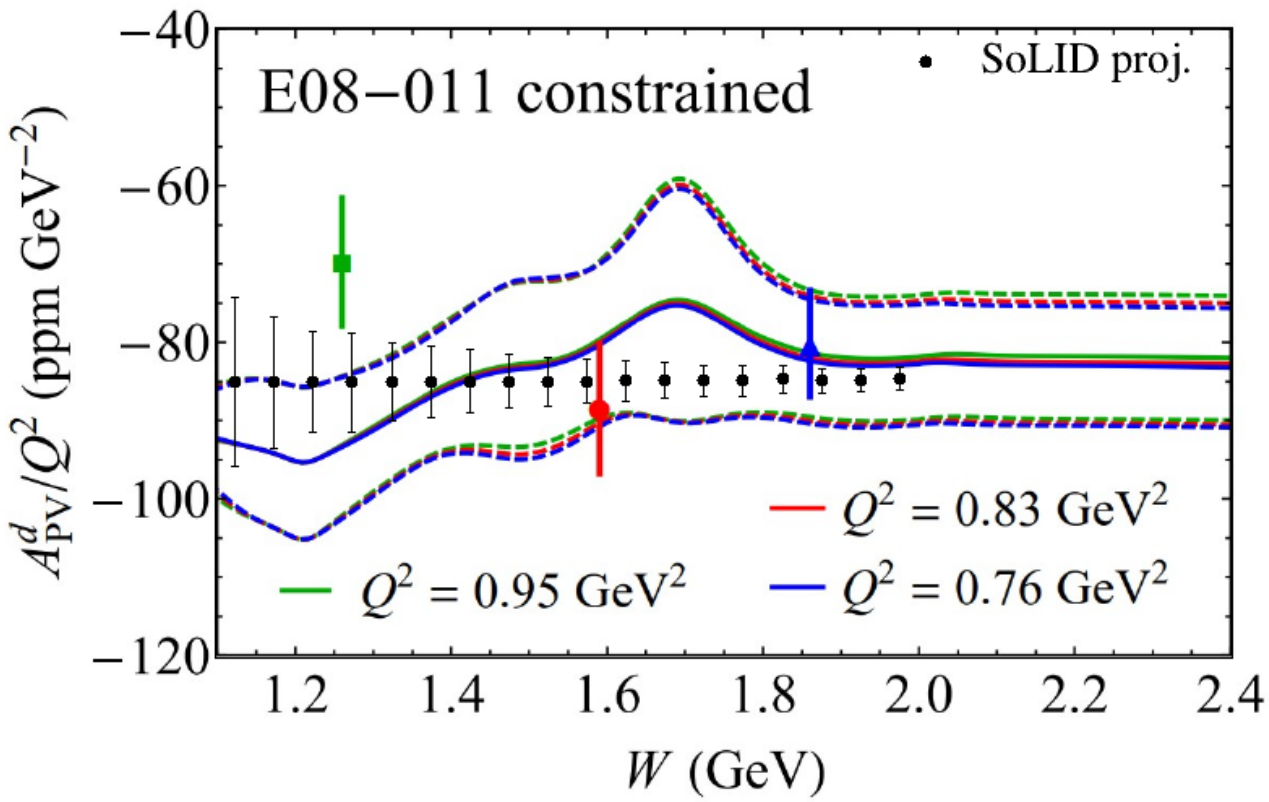
Projected Results on Apv

- Black points: projected Apv results from the proposed experiment, with 0.05 GeV bin in W
- Colored curve: AJM model calculation with input from the E08-011 constrains, at lower Q^2
- Would be nice to have AJM model calculation for SoLID resonance Q^2

N. H. Hall *et al*, PRD 88. 013011



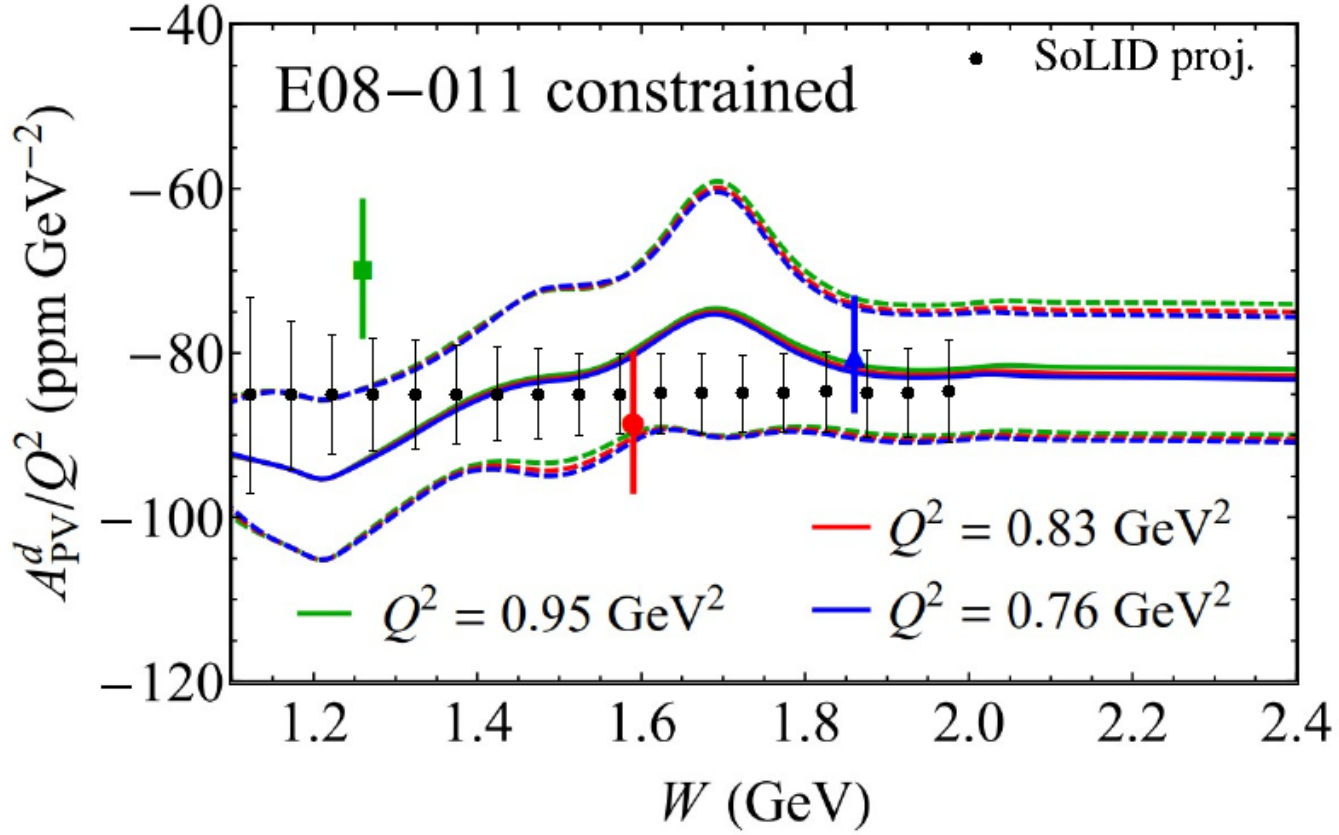
SoLID 6.6 GeV, 30 days, $Q^2 \sim 3.5$ GeV^2



SoLID 11 GeV, 120 days, $Q^2 \sim 9$ GeV^2

Projected Results on Apv

- Black points: projected Apv results from the proposed experiment, with 0.05 GeV bin in W
- Colored curve: AJM model calculation with input from the E08-011 constrains, at lower Q^2
- Would be nice to have AJM model calculation for SoLID resonance Q^2

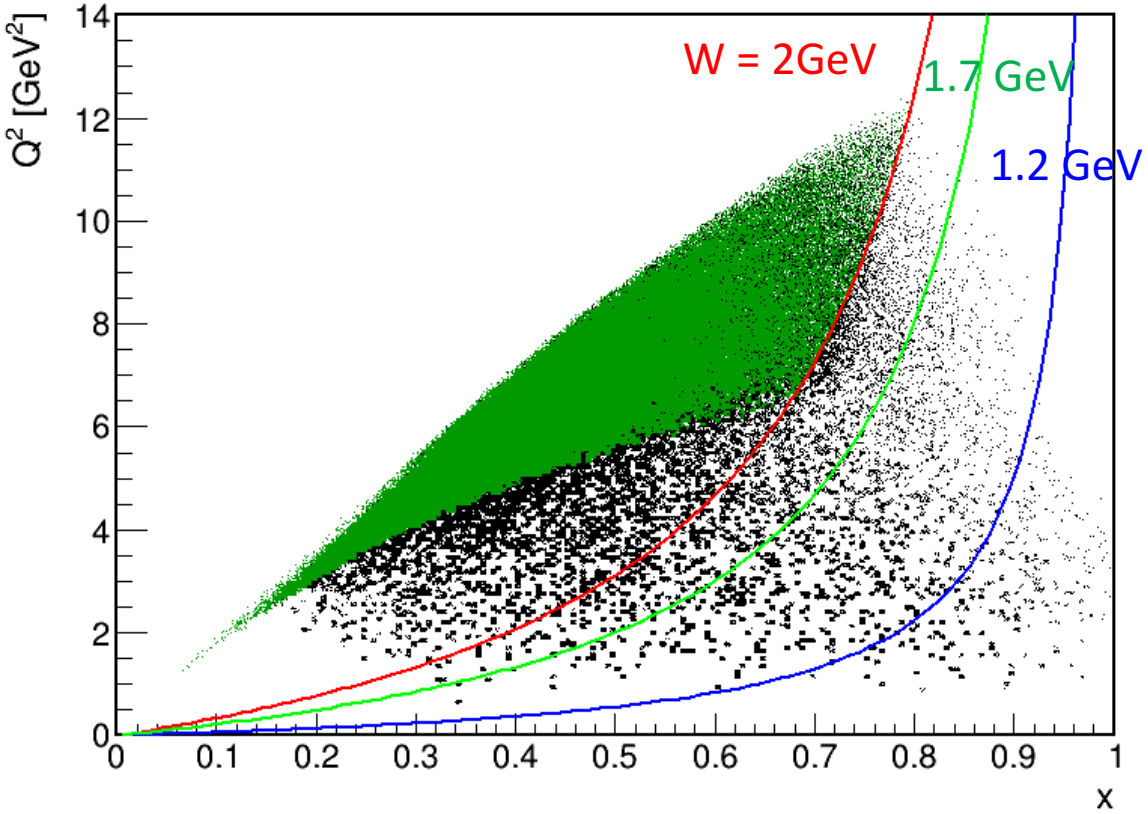


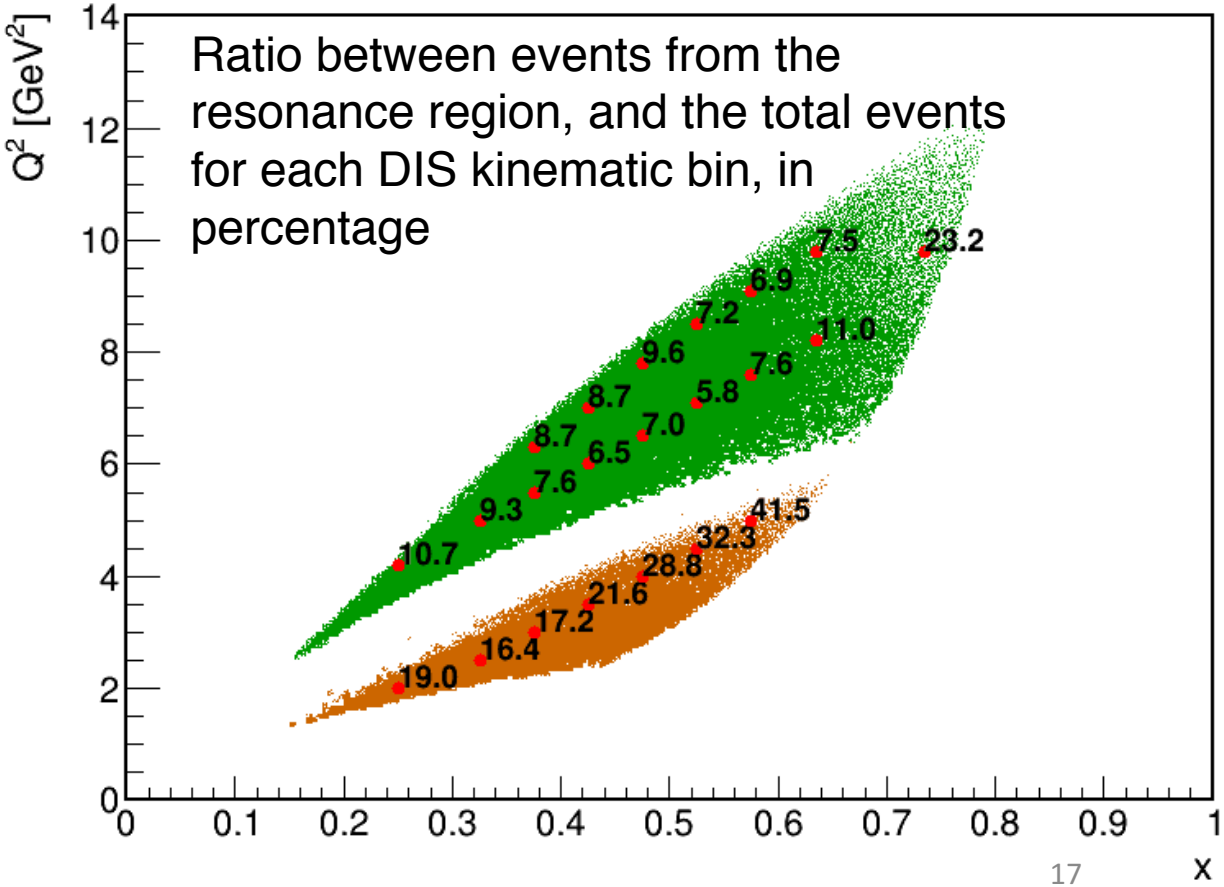
N. H. Hall *et al*, PRD 88. 013011

SoLID 4.4 GeV, 9 days, $Q^2 \sim 2.0$ GeV^2

Projected Results for PVDIS External RC Uncertainty

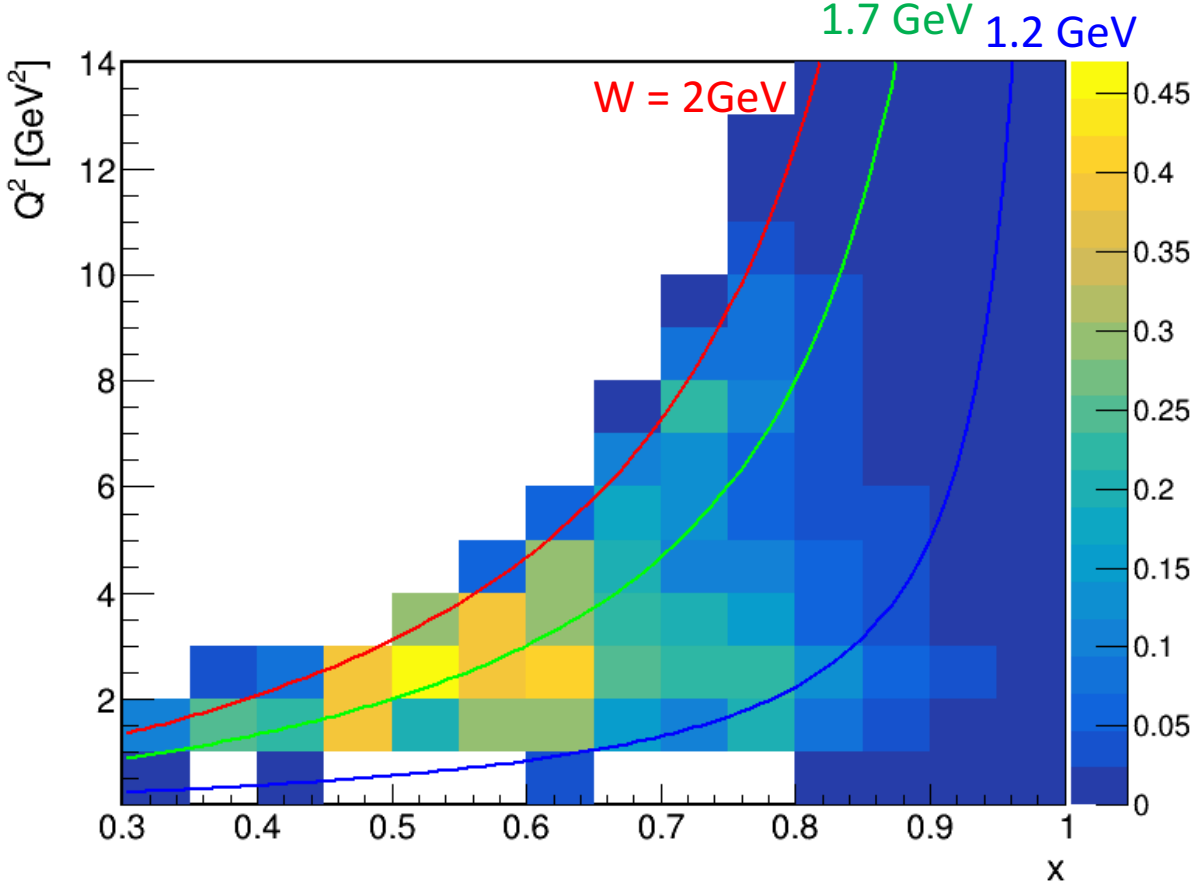
- For the 11 GeV data set, about 9% of the “DIS” events are coming from the resonance region, due to external radiative effects
- Resonance asymmetry measurement at the level of 2% will be needed to help suppressing the uncertainty from RC to below 0.2%

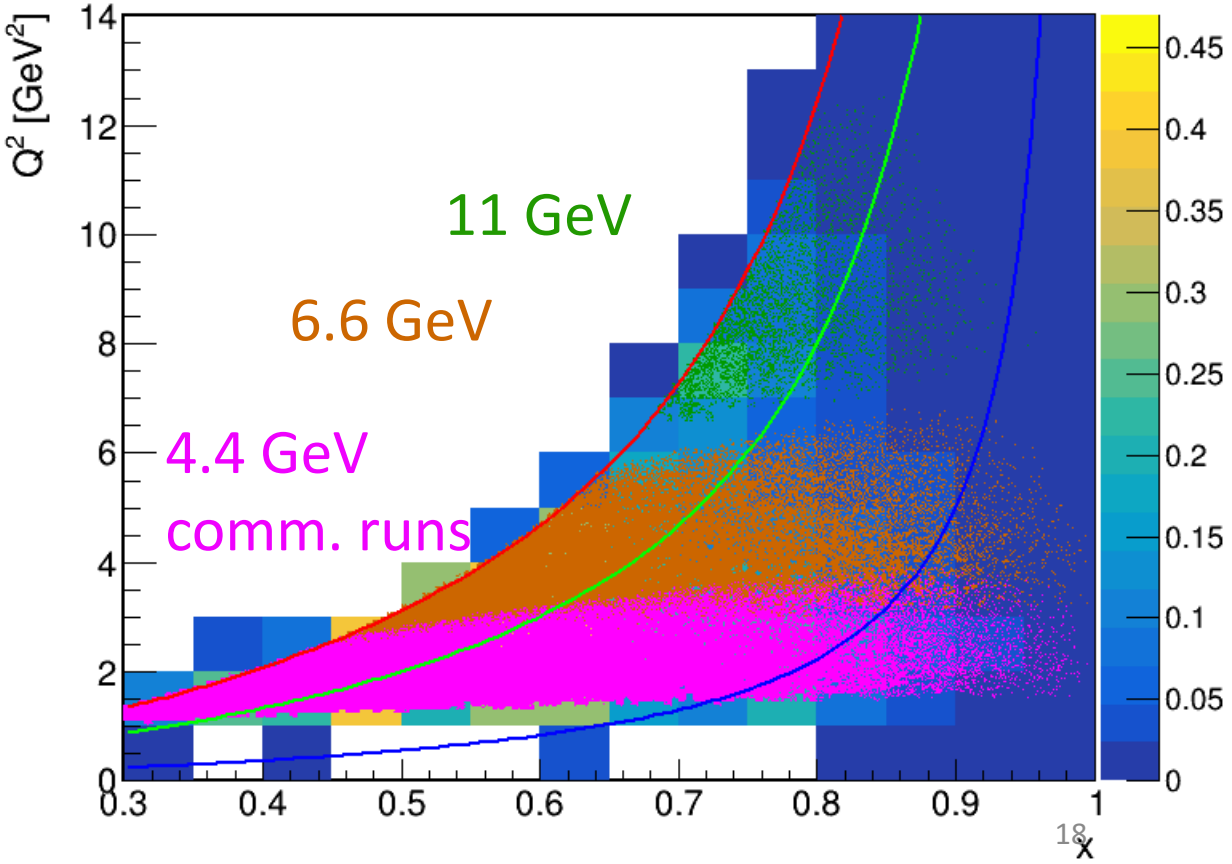




Projected Results for PVDIS External RC Uncertainty

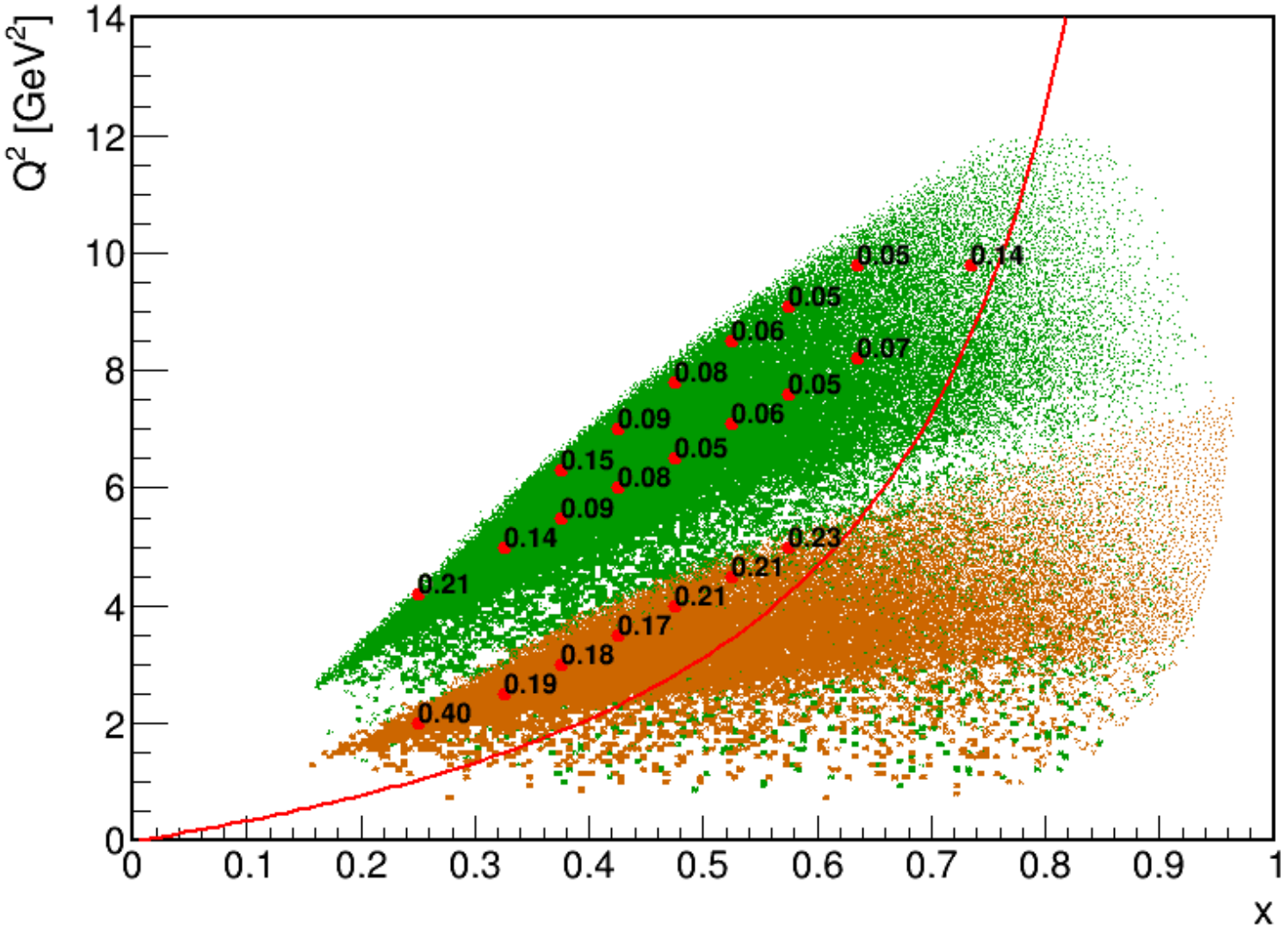
- Most of the resonance events coming from low Q^2 and mid-x region
- The relevant resonance region covered very well by the 11 GeV, 6.6 GeV and 4.4 GeV data





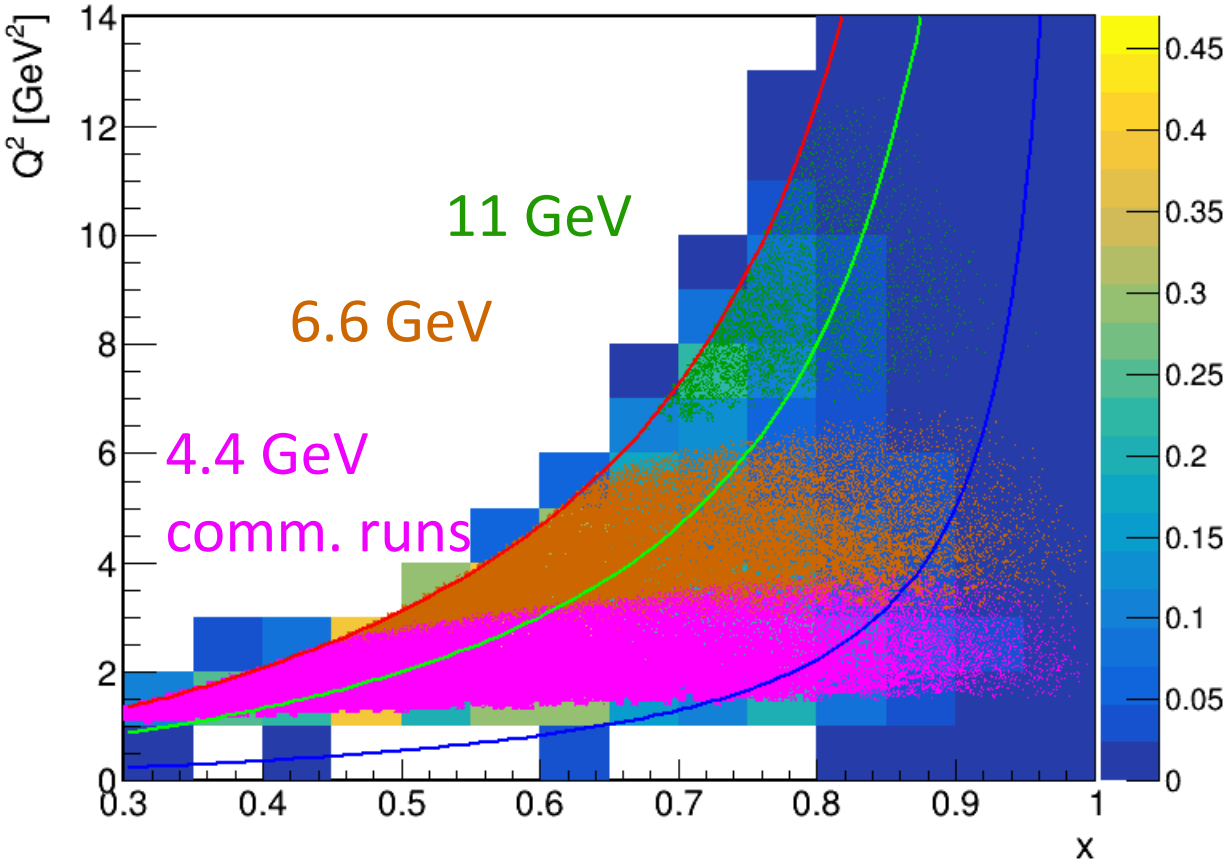
Projected Results for PVDIS External RC Uncertainty

- Estimated systematic uncertainty from external RC for the PVDIS kinematic bins
- All numbers in percentage
- Expect the uncertainties to be much less than 0.2% for the 11 GeV data set
- Uncertainties at the level of 0.2% for the 6.6 GeV data set



Systematic Uncertainties

- Many systematic uncertainties are shared with the PVDIS experiment
- Slightly larger uncertainty from RC compared to the PVDIS:
  - Expect smaller uncertainties as we go to the DIS region
  - On average, expect the uncertainty to be 1% per W = 0.1 GeV bin, much smaller compared to the stat. uncertainty
- Current systematic uncertainty estimation about 1.1%
- We are still working on a number of systematic studies:
  1. Elastic contribution
  2. Cherenkov efficiency
  3. …



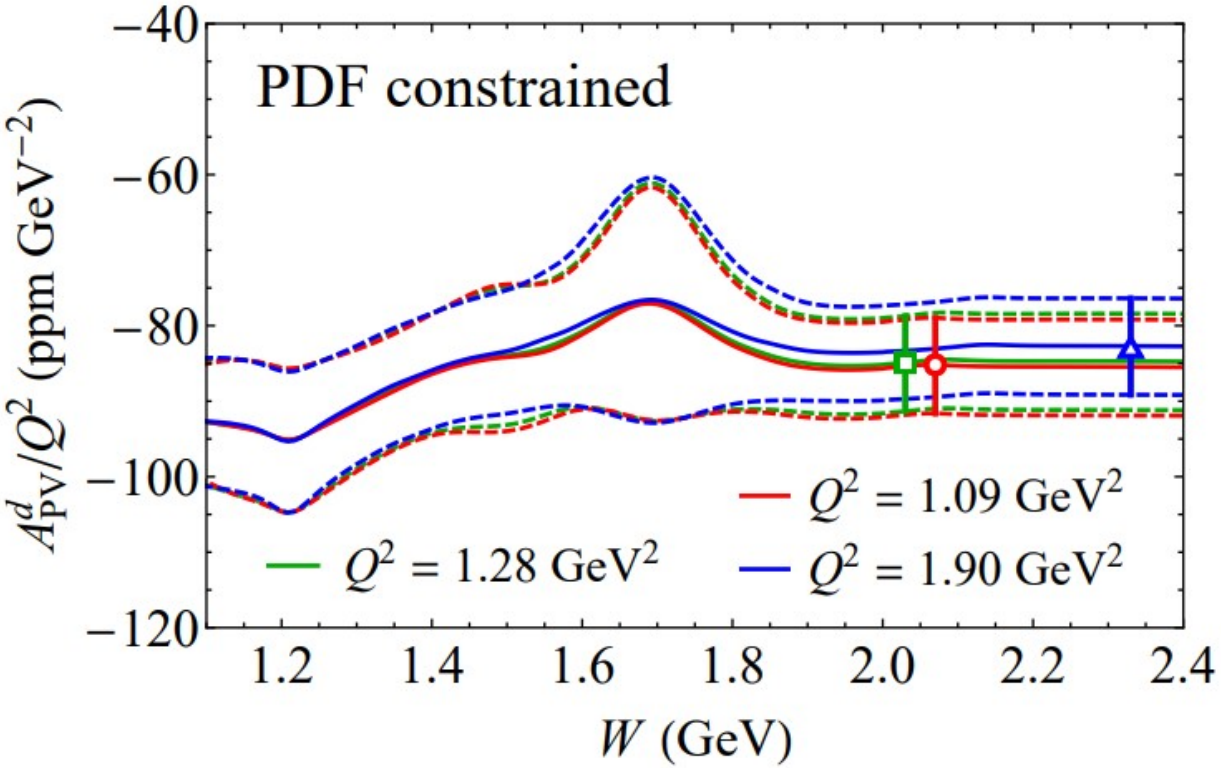
Polarimetry	0.4
Q^2	0.2
Radiative corrections	~1.0
Reconstruction errors	0.2
	1.1

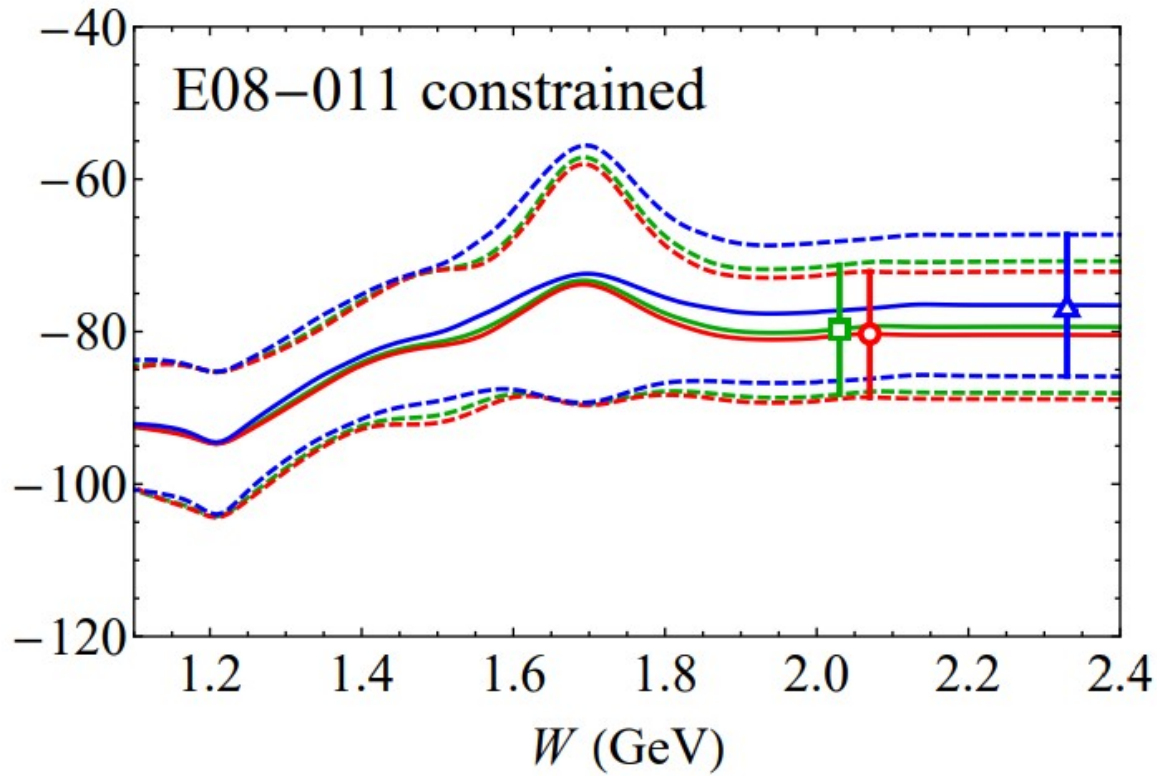
Summary

- We are preparing a run-group proposal that plan to take data simultaneously with the SoLID-PVDIS experiment
- Plan to submit in summer 2023
- Precision measurement for Apv in the resonance region (1.1 GeV < W < 2 GeV)
- Verification for the quark-hadron duality in the electroweak sector
- Important input for the neutrino interaction in the few GeV region
- Crucial for external RC for the PVDIS measurement
- Can be used to study the $F^{\gamma Z}$ Structure Functions, constrain AJM model and possibly γZ Box Diagram

- Currently we are working on a number of systematics and hope to strengthen the physics motivation, any input will be much appreciated!

Back Up


PDF constrained
A^d_{PV}/Q^2 (ppm GeV^{-2})
−40
−60
−80
−100
−120
1.2
1.4
1.6
1.8
2.0
2.2
2.4
W (GeV)
Q^2 = 1.09 GeV^2
Q^2 = 1.28 GeV^2
Q^2 = 1.90 GeV^2


E08−011 constrained
−40
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2.2
2.4
W (GeV)