# E12-10-002:
# $F_2$ Structure Functions at Large x

Abel Sun

# Outline

- ➢ Physics motivation
- ➢ Run plan
  - Running conditions
  - SHMS kinematics
  - HMS kinematics
  - Run time estimation
  - Backgrounds

# E12-10-002 Schedule

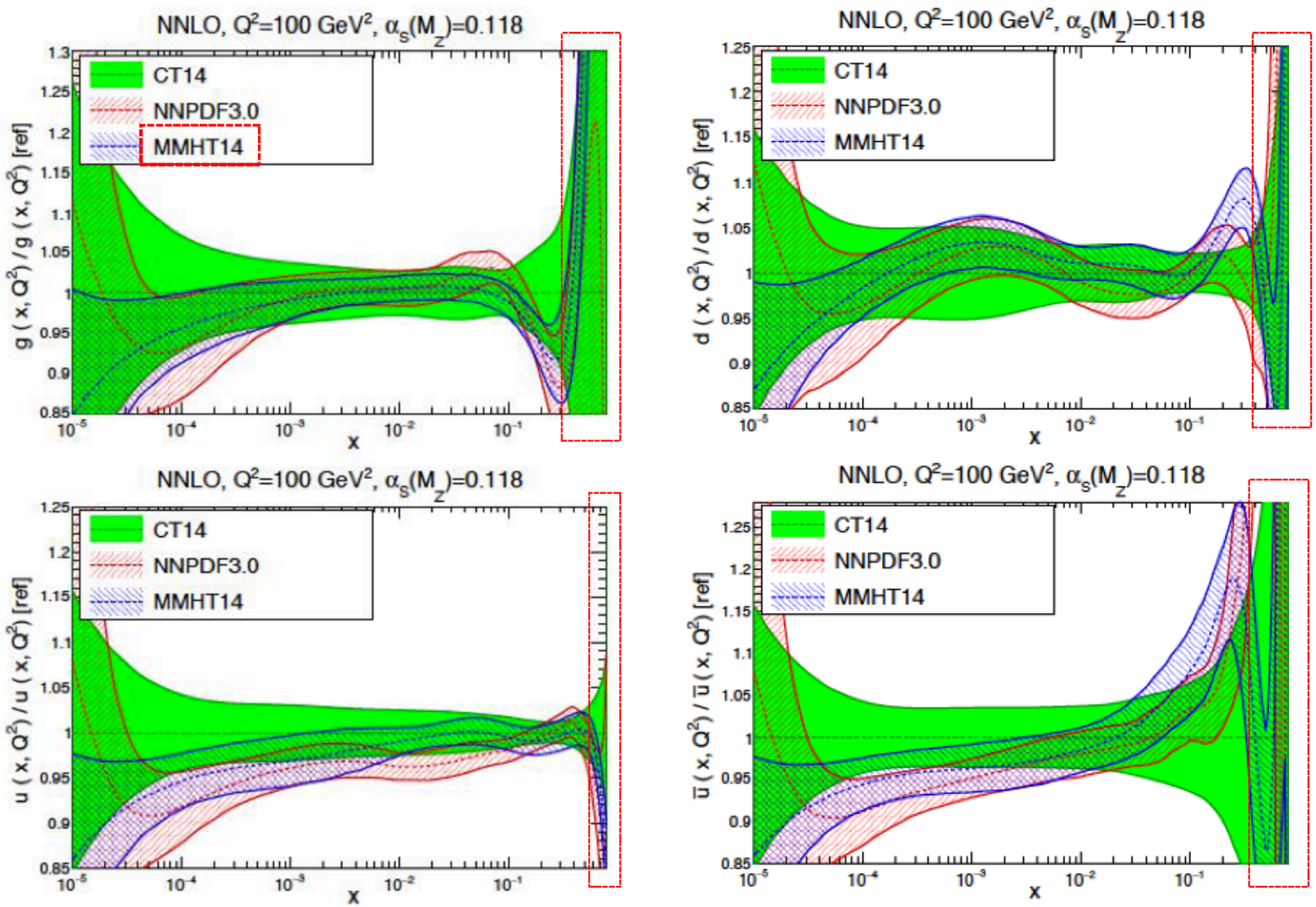
| | | | | |
|---|---|---|---|---|
| 75 | 12/12/17 | Tuesday | SHMS Comm./E12-10-002 | |
| 76 | 12/13/17 | Wednesday | SHMS Comm./E12-10-002 | |
| 124 | 01/30/18 | Tuesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 125 | 01/31/18 | Wednesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 126 | 02/01/18 | Thursday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 127 | 02/02/18 | Friday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 128 | 02/03/18 | Saturday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 129 | 02/04/18 | Sunday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 130 | 02/05/18 | Monday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 131 | 02/06/18 | Tuesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 132 | 02/07/18 | Wednesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 133 | 02/08/18 | Thursday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 134 | 02/09/18 | Friday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 135 | 02/10/18 | Saturday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 136 | 02/11/18 | Sunday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 137 | 02/12/18 | Monday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 138 | 02/13/18 | Tuesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 139 | 02/14/18 | Wednesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 140 | 02/15/18 | Thursday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 141 | 02/16/18 | Friday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 142 | 02/17/18 | Saturday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 143 | 02/18/18 | Sunday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 144 | 02/19/18 | Monday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 145 | 02/20/18 | Tuesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 146 | 02/21/18 | Wednesday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 147 | 02/22/18 | Thursday | E12-10-002/E12-10-008 | 10.6/65/-/250 |
| 148 | 02/23/18 | Friday | E12-10-002/E12-10-008 | 10.6/65/-/250 |

E12-10-002 2-day run on Dec.12, 13 at 6.4 GeV for R measurement

E12-10-002/008 starts on Jan.30,2017 and runs for 25 days

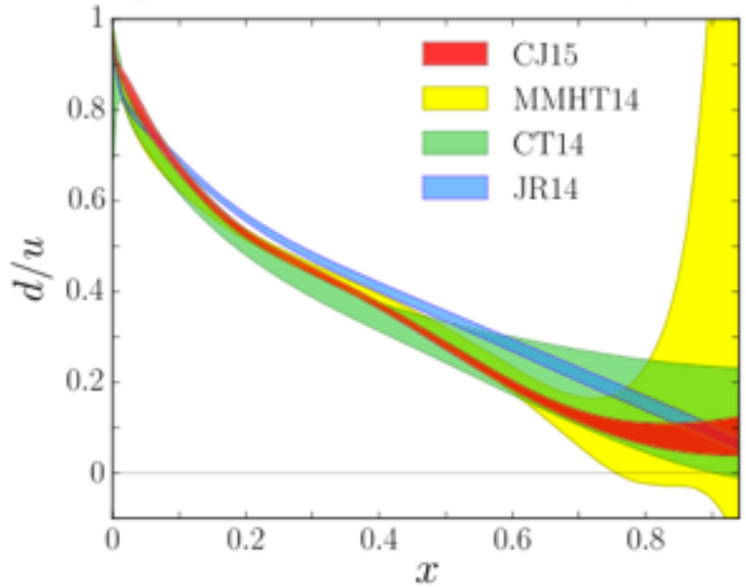
# Constrain PDFs at Large x

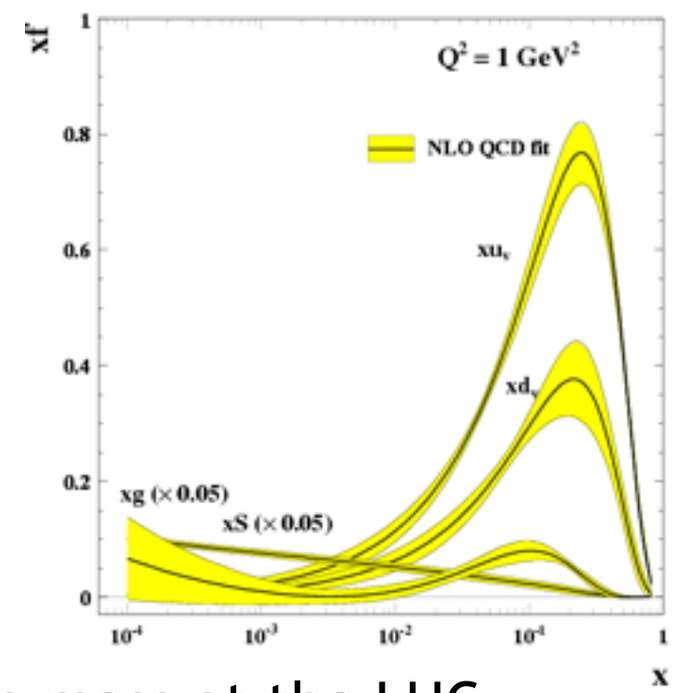
➢ Typical PDFs extraction still lacking in the required precision at low x and large x



# Why It's Important to Know PDFs at Large x?

➢ Relevant for studies of the non-perturbative dynamics of nucleons: d/u ratio at x=1 can give hints of how quarks are confined




➢ Poor knowledge of PDFs at large x propagates to low x

- Perturbative QCD evolution moves strength from large x, low $Q^2$ to low x, high $Q^2$
- The x-dependence of PDFs is parametrized at low $Q^2$ where most of their strength is at large x

➢ Partons need large energy to create a particle with large mass at the LHC

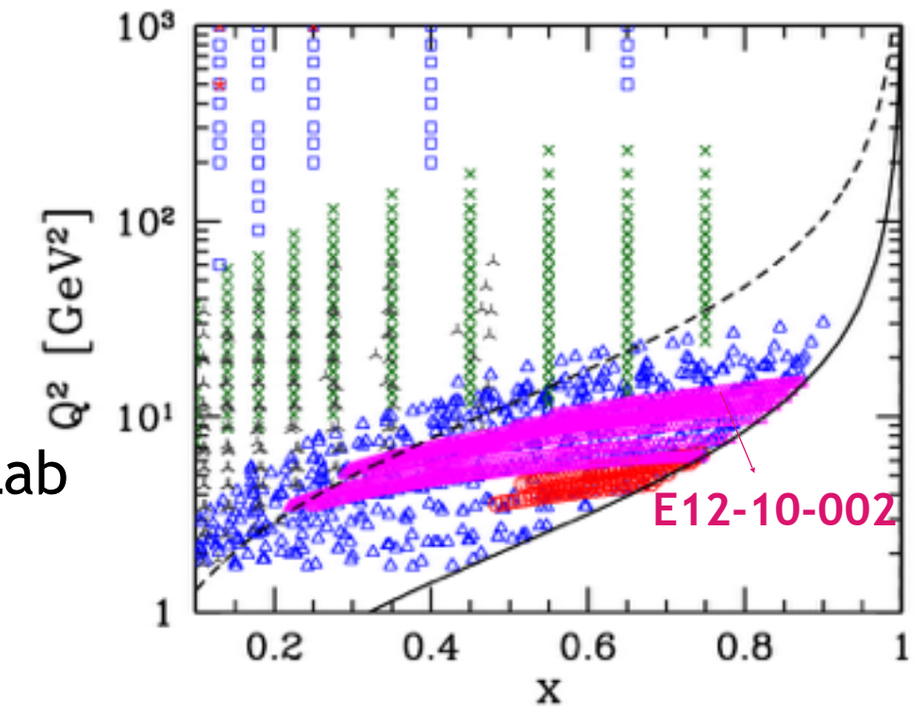
$$x = \frac{M}{\sqrt{s}} e^{y}$$

# $F_2$ Structure Functions at Large x

Experiments:

-> Hall C **E12-10-002 (2017)**: accesses $F_2^p$ and $F_2^d$ via **IS off proton and deuteron**

- DIS: constrain nucleon's PDFs within CTEQ-JLab framework



# $F_2$ Structure Functions at Large x

Experiments:

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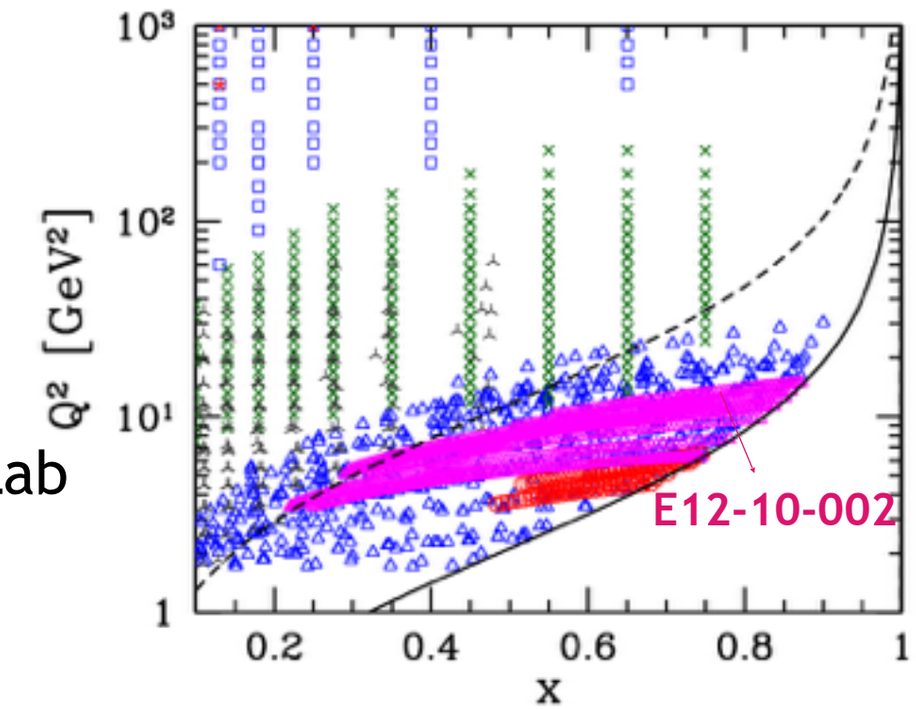
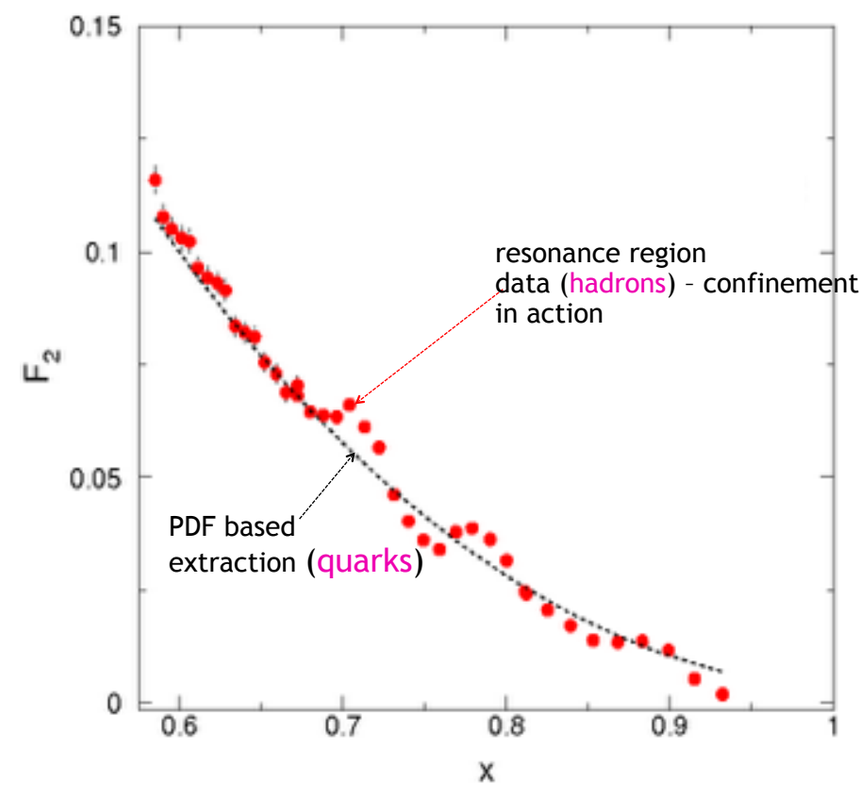



- DIS: constrain nucleon's PDFs within CTEQ-JLab framework

- Resonance region: study confinement and transition from confinement to asymptotic freedom, quark-hadron duality
- Resonance region: possibly include averaged resonance region data in the CJ fits



# How do we practically run E12-10-002?

# Inclusive Cross Section Measurements

➢ $F_2$ structure function obtained from cross section measurements

$$\frac{d^2\sigma}{d\Omega dE'} = (N_{measured} - BG)\frac{1}{N_e N_t}\frac{1}{d\Omega dE'}\frac{1}{A}\frac{1}{\varepsilon}$$

absolute cross section
with radiative effects

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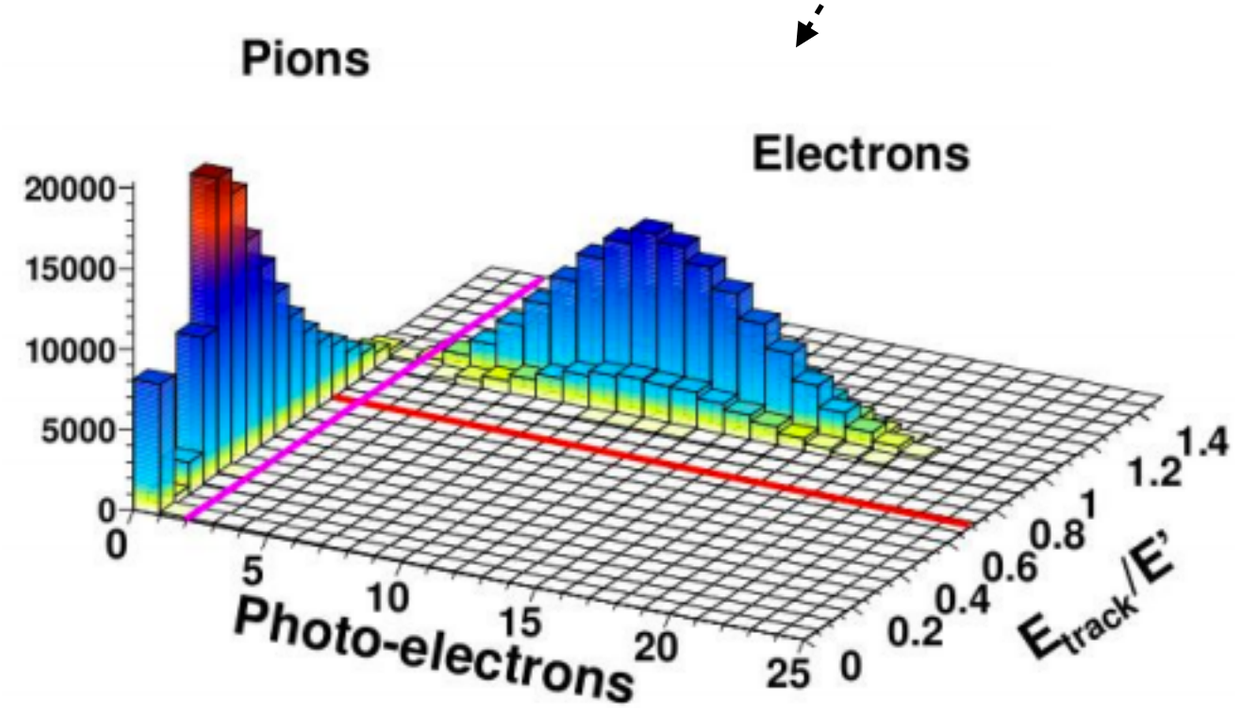
absolute cross section
with radiative effects



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absolute cross section
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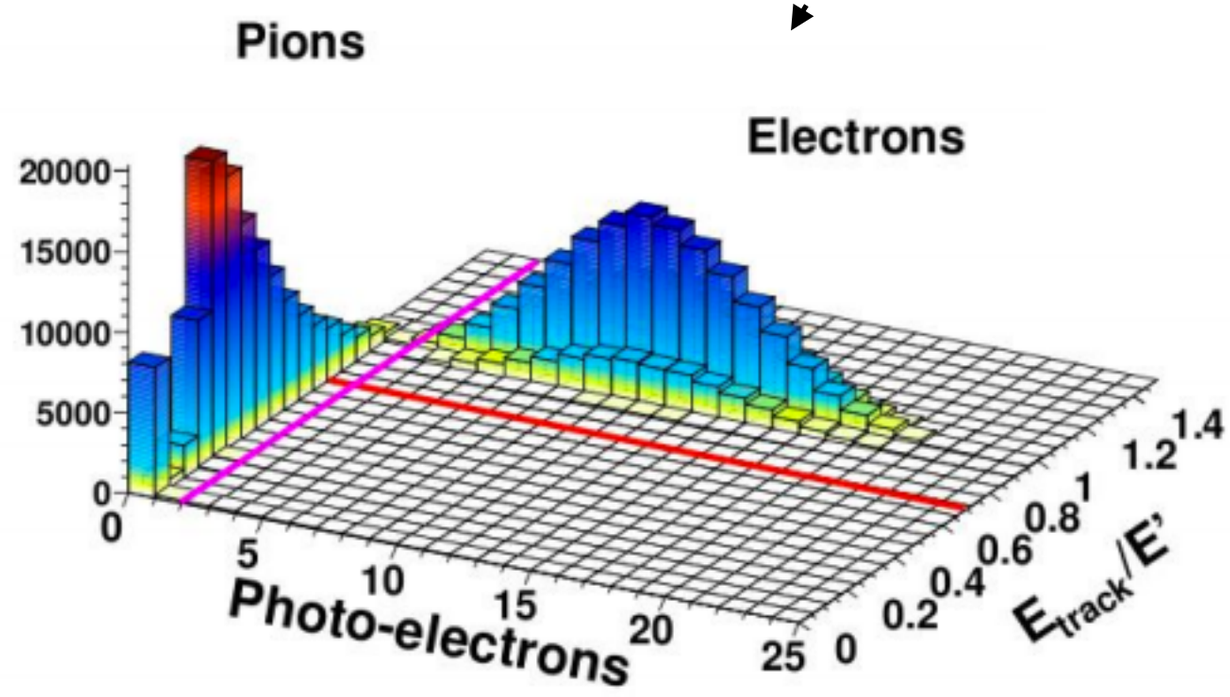



**Background**

- cryogenic target endcaps
- e- from decay of $\pi^0$ produced in the target
- contamination from pion response in PID

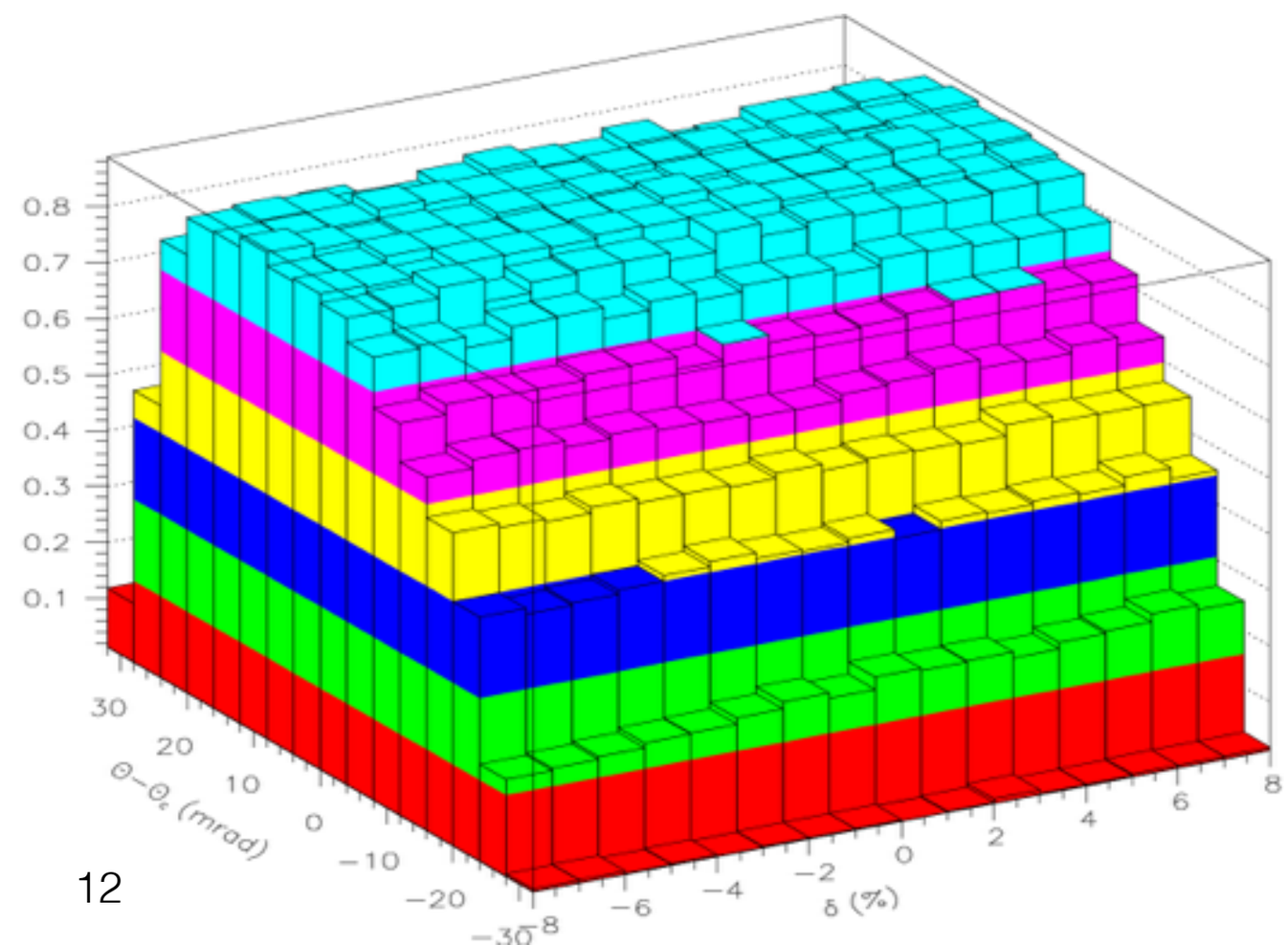
# Inclusive Cross Section Measurements

➢ F2 structure function obtained from cross section measurements

$$\frac{d^2\sigma}{d\Omega dE'} = (N_{measured} - BG)\frac{1}{N_e N_t}\frac{1}{d\Omega dE'}\frac{1}{A}\frac{1}{\varepsilon}$$

absolute cross section
with radiative effects

**acceptance**



# Inclusive Cross Section Measurements

➢ F2 structure function obtained from cross section measurements

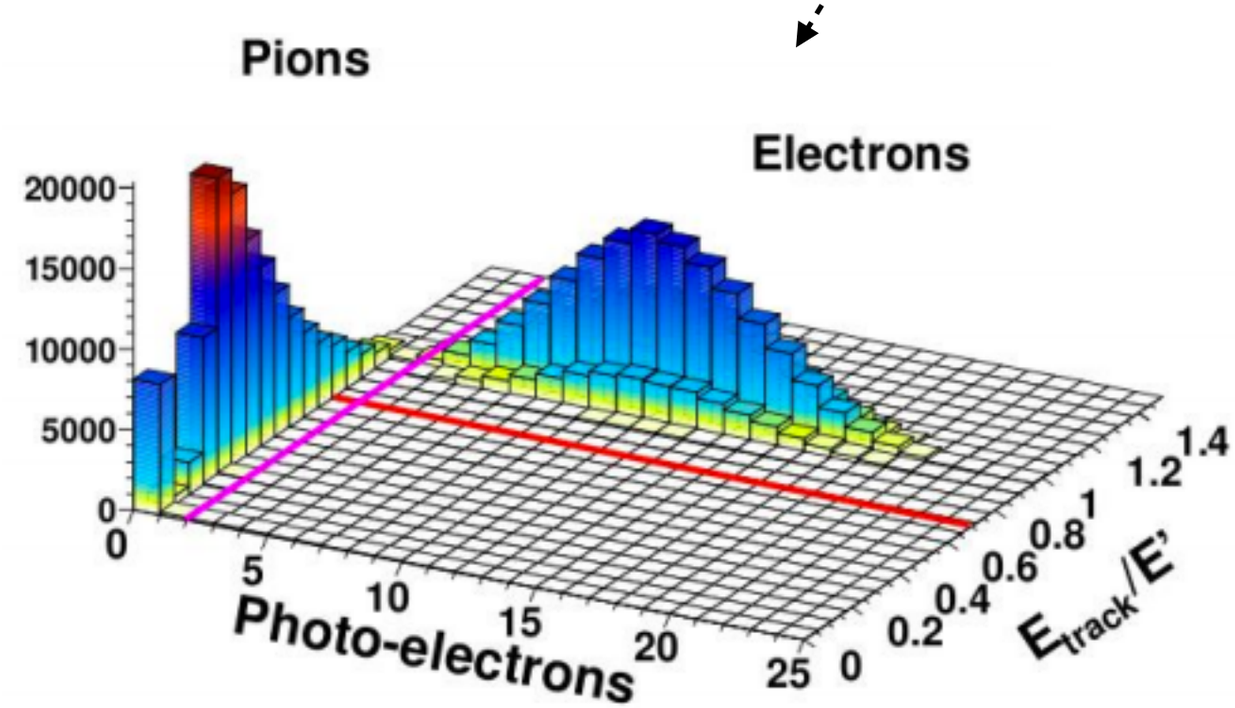
$$\frac{d^2\sigma}{d\Omega dE'} = (N_{measured} - BG)\frac{1}{N_e N_t}\frac{1}{d\Omega dE'}\frac{1}{A}\frac{1}{\varepsilon}$$

<u>experimental efficiencies</u>

detectors
front-end electronics
DAQ

absolute cross section
with radiative effects

acceptance




**<u>Background</u>**

- cryogenic target endcaps
- e- from decay of $\pi^0$ produced in the target
- contamination from pion response in PID

# E12-10-002 Running Conditions

- Unpolarized Beam

  energy: 10.6 and 6.4 for R measurement

  current: 30 μA or larger

- Targets

  10 cm hydrogen - production

  10 cm Deuterium - production

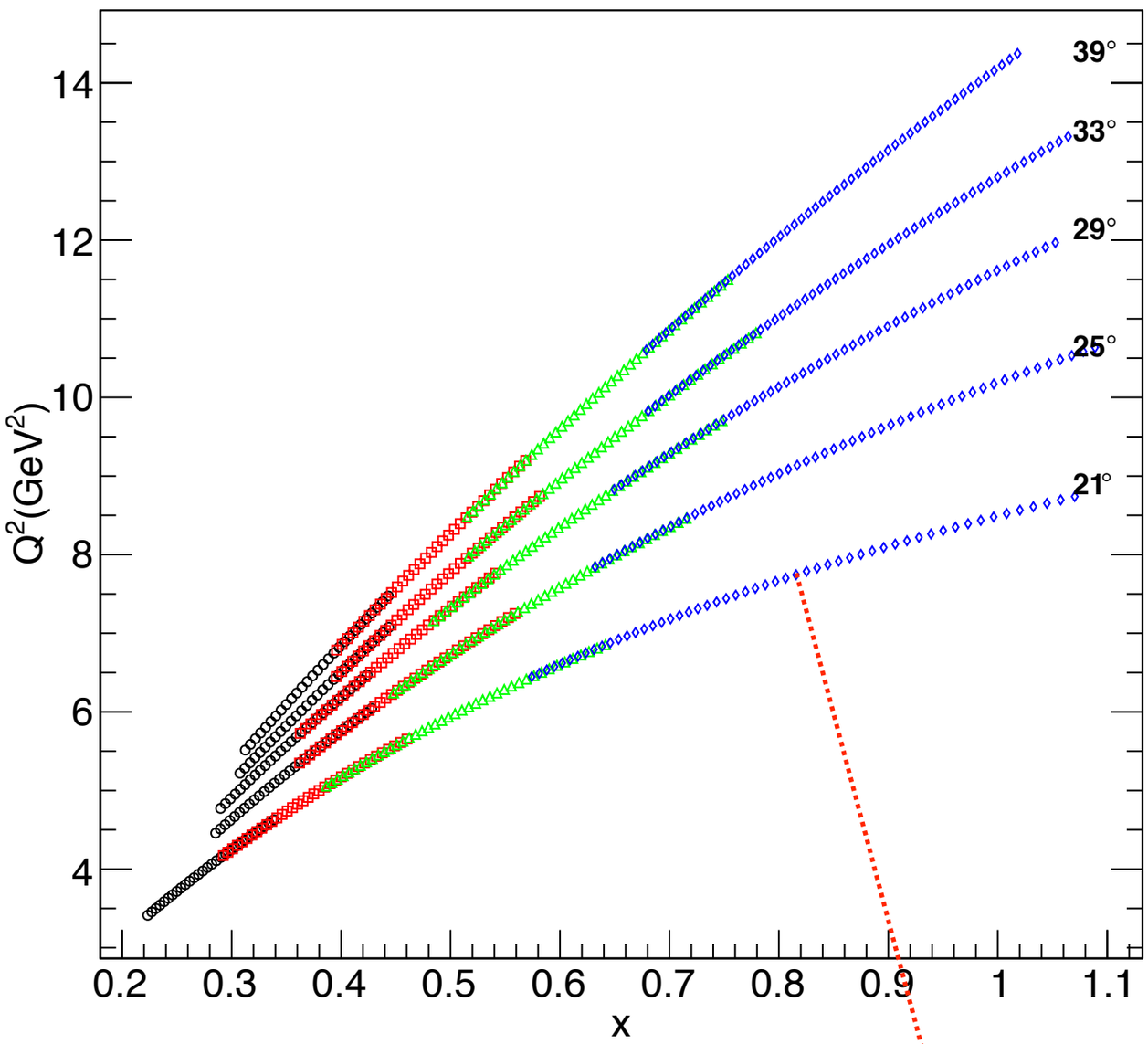
  Al foils - background measurement

- SHMS is used to take most of the production data

- HMS is used to measure highest $Q^2$ point and for cross-calibration with SHMS

# E12-10-002 Run Plan

➢ SHMS is used to take most of the production data




SHMS kinematic settings with 10.5732 GeV beam

| Angle | Momentum(GeV/c) |
|---|---|
| 21 | 2.7, 3.3, 4.0, 5.1 |
| 25 | 2.5, 3.0, 3.5, 4.4 |
| 29 | 2.0, 2.4, 3.0, 3.7 |
| 33 | 1.7, 2.1, 2.6, 3.2 |
| 39 | 1.3, 1.6, 2.0, 2.5 |

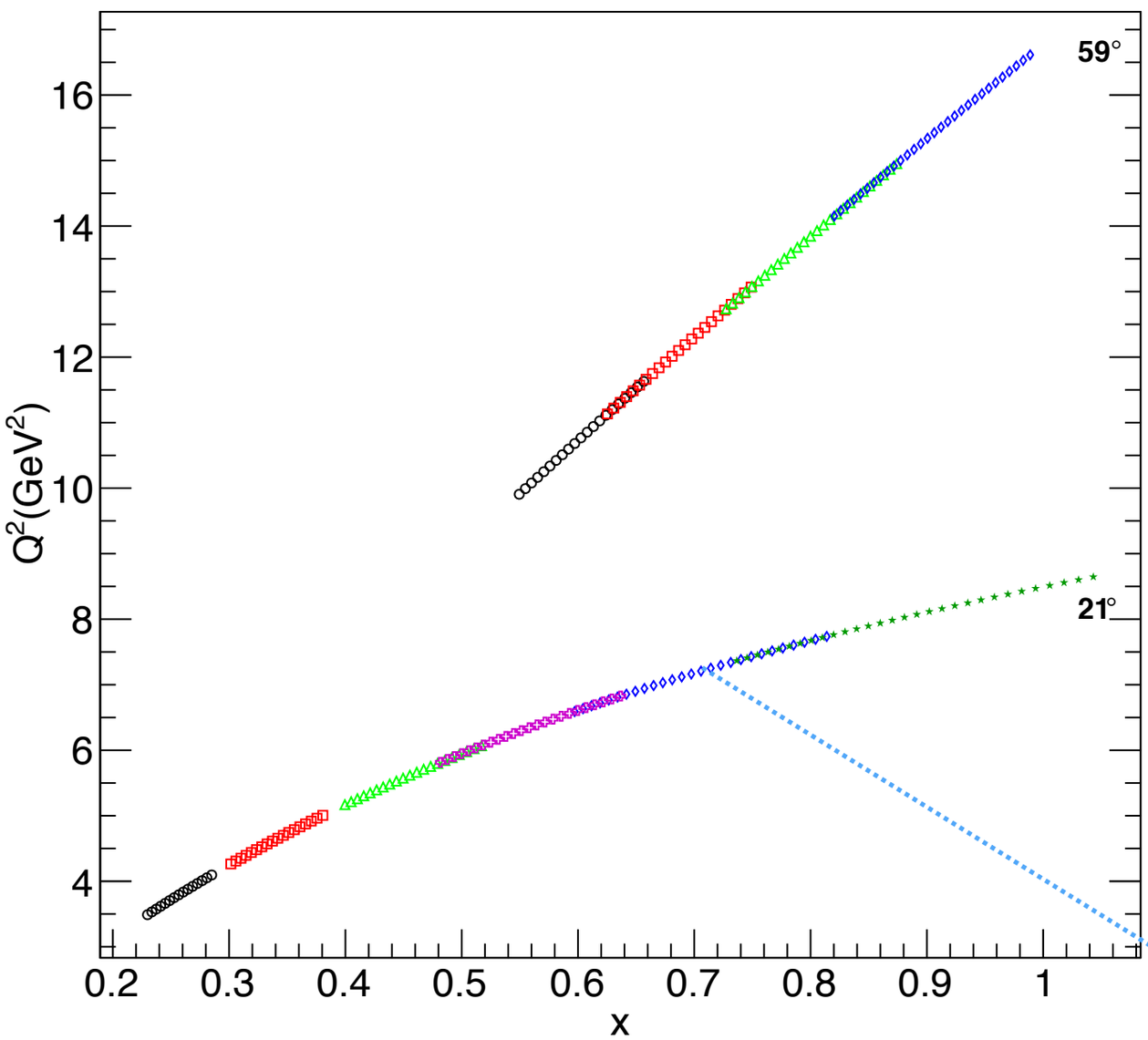
➢ 5 angle changes

➢ 20 momentum changes

different colors for different central momentum settings
cover a wide kinematic range because of large momentum acceptance

# E12-10-002 Run Plan

➢ HMS is used to measure highest $Q^2$ point and for cross-calibration with SHMS




HMS kinematic settings with 10.5732 GeV beam

| Angle | Momentum(GeV/c) |
|---|---|
| 21 | 2.7, 3.3, 4.0, 4.5, 5.1, 5.7 |
| 59 | 1.05, 1.18, 1.35, 1.50 |

59 deg: Production to push to highest x, $Q^2$

21 deg: commissioning data to cross-calibrate HMS and SHMS

➢ 2 angle changes

➢ 10 momentum changes

covered range is smaller than SHMS because of smaller momentum acceptance

During the SHMS production running at 25, 29, 33, 39 deg the HMS will take production data at 59 deg

# Production Rate, SHMS

$$N_{measured} = cross\,section * N_{beam} * N_{target}$$

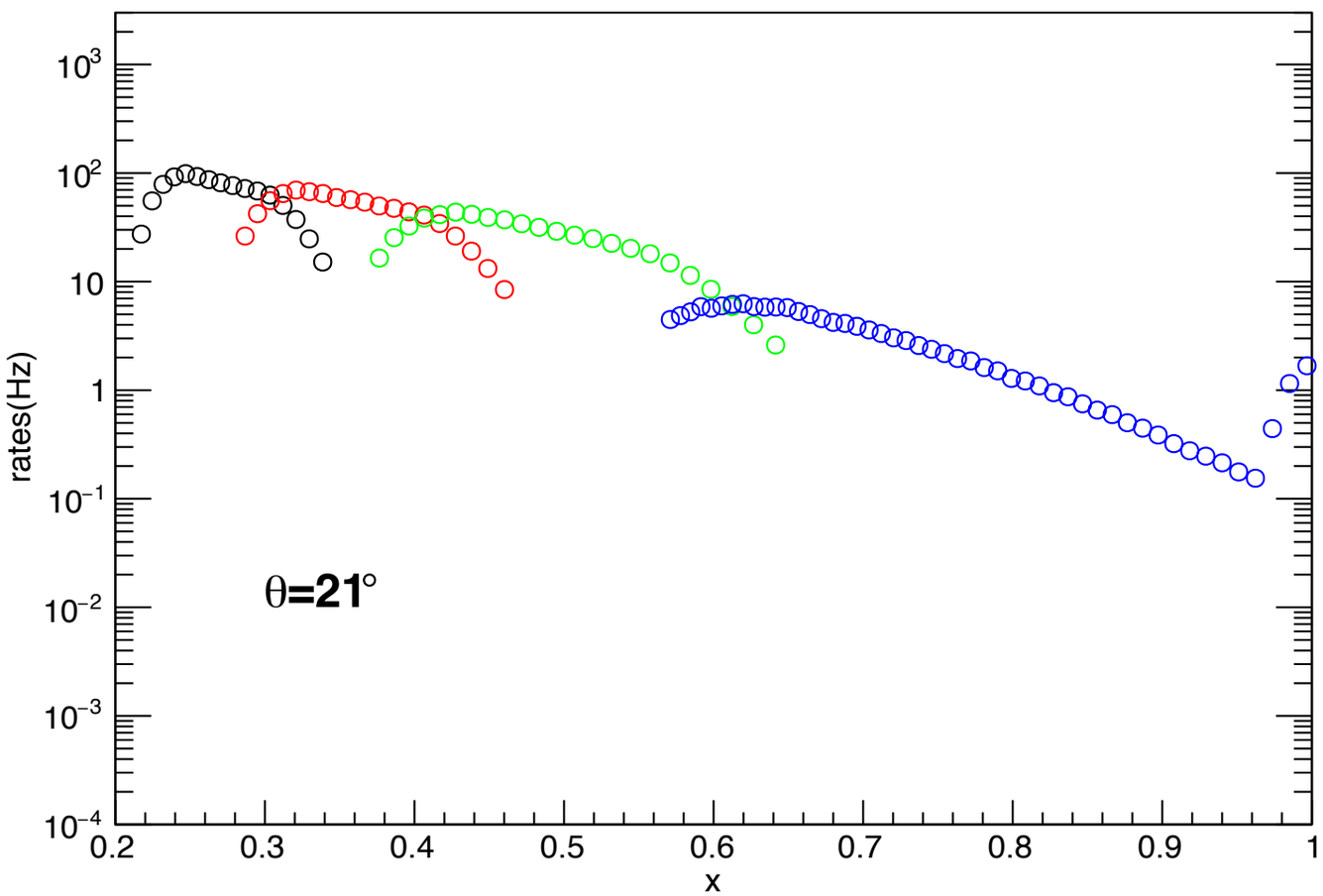
$$rate = \frac{d\sigma}{d\Omega dE'} * d\Omega * dE' * \frac{I}{Q_e} * \frac{N_A * \rho * t}{A}$$

beam current

target length

bin size of scattered electron energy

elementary charge

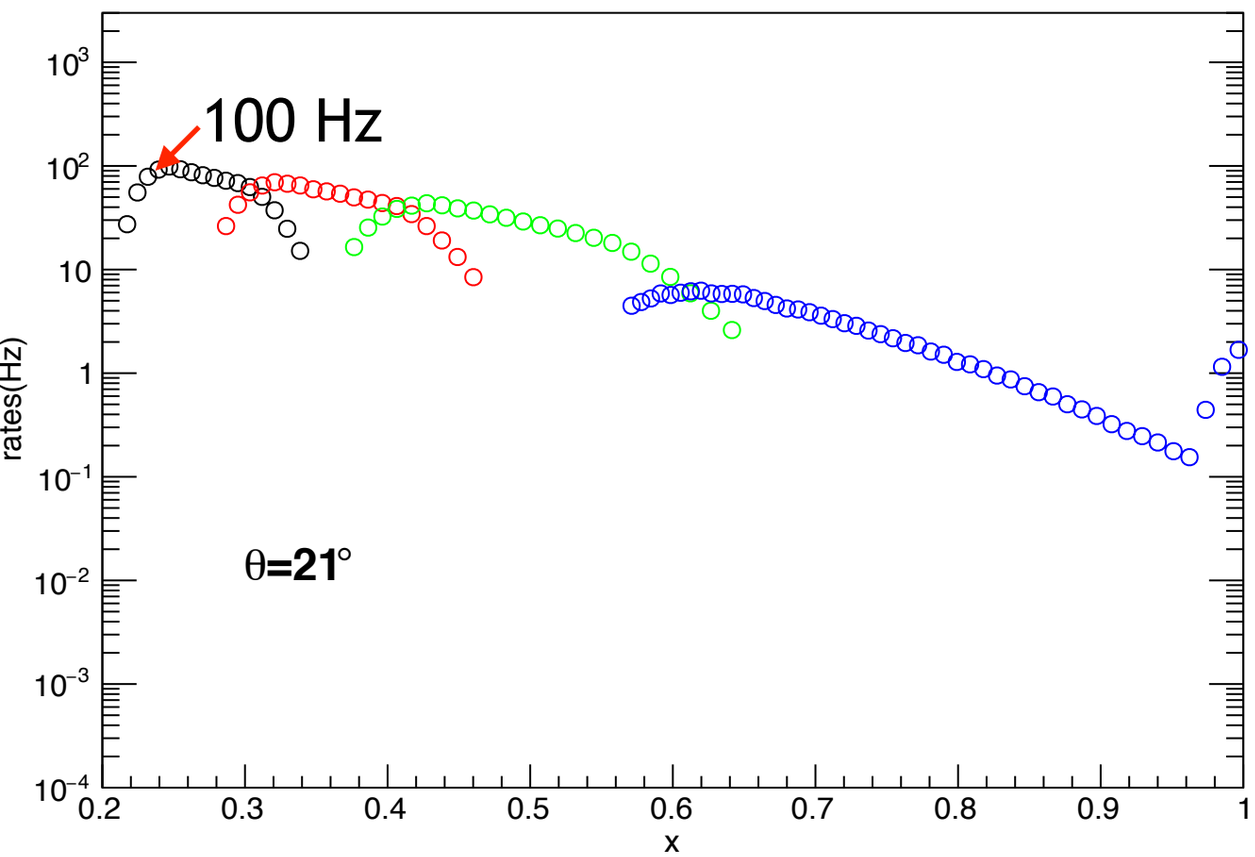



- Input parameters:
  - target length: 10 cm
  - beam current: 30 μA
  - $W^2$ bin size:
    - 0.1 $GeV^2$ in resonance region
    - 0.2 $GeV^2$ in DIS
- Shape due to detector acceptance effect

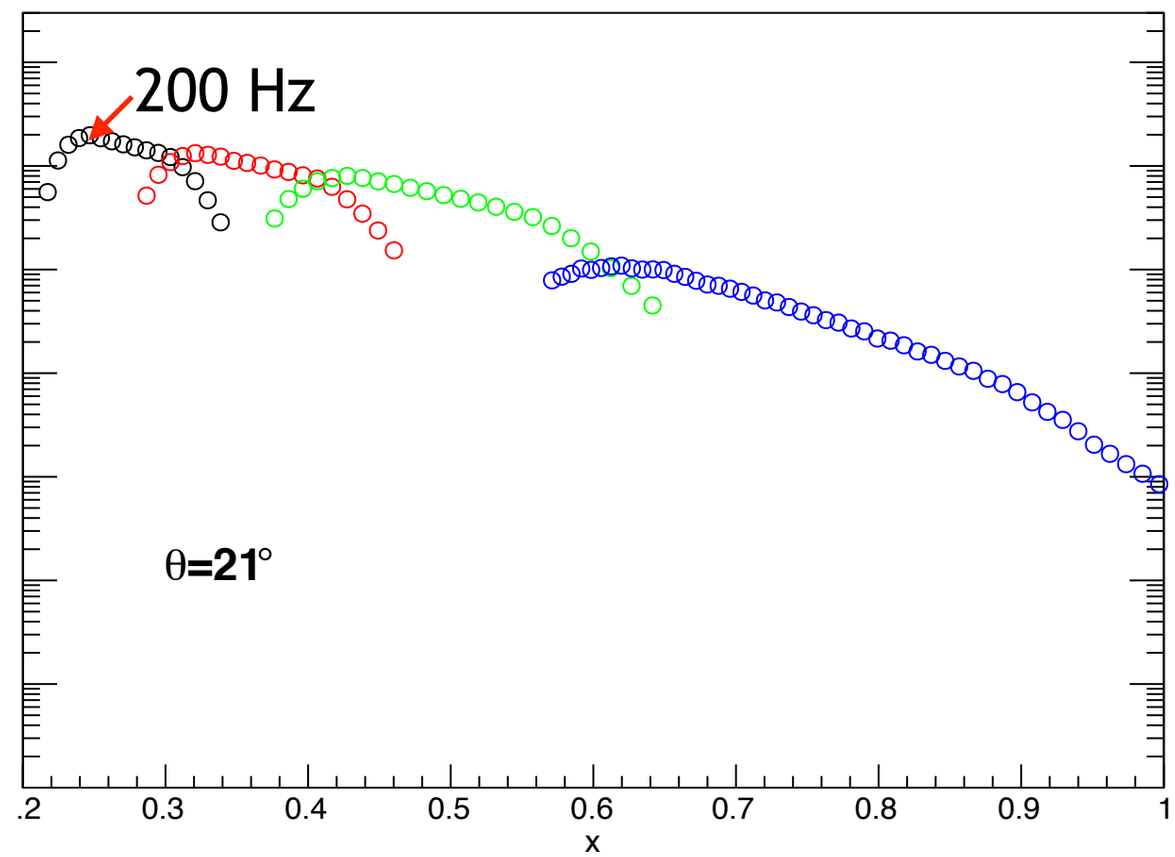
# Production Rates on H/D target, SHMS

➢ Rate plots

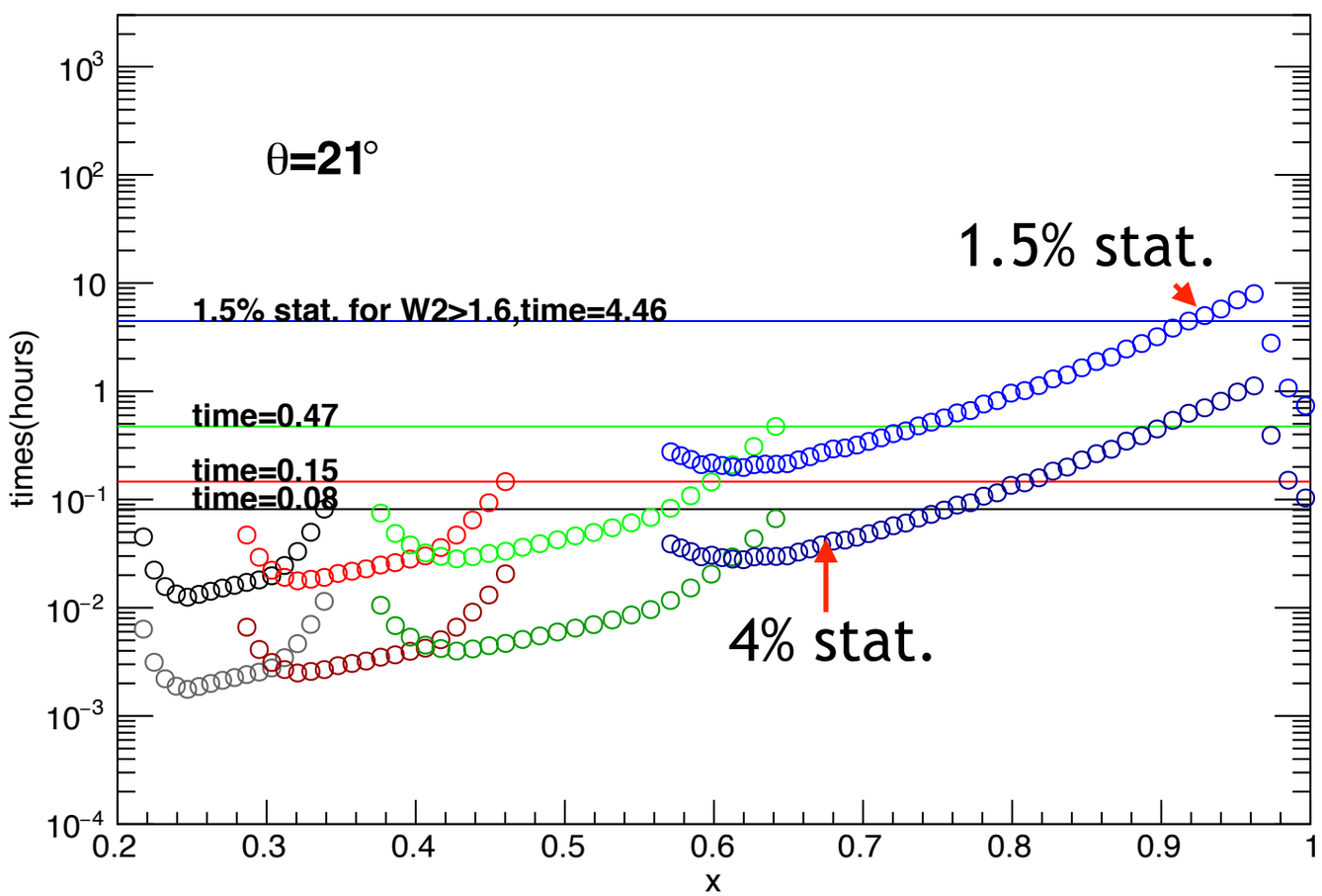
H target




D target



# Production Time Estimation, SHMS




- Input parameters:

  Target length: 10 cm

  Beam current: 30 μA

  $W^2$ bin size:

  0.1 $GeV^2$ in resonance region

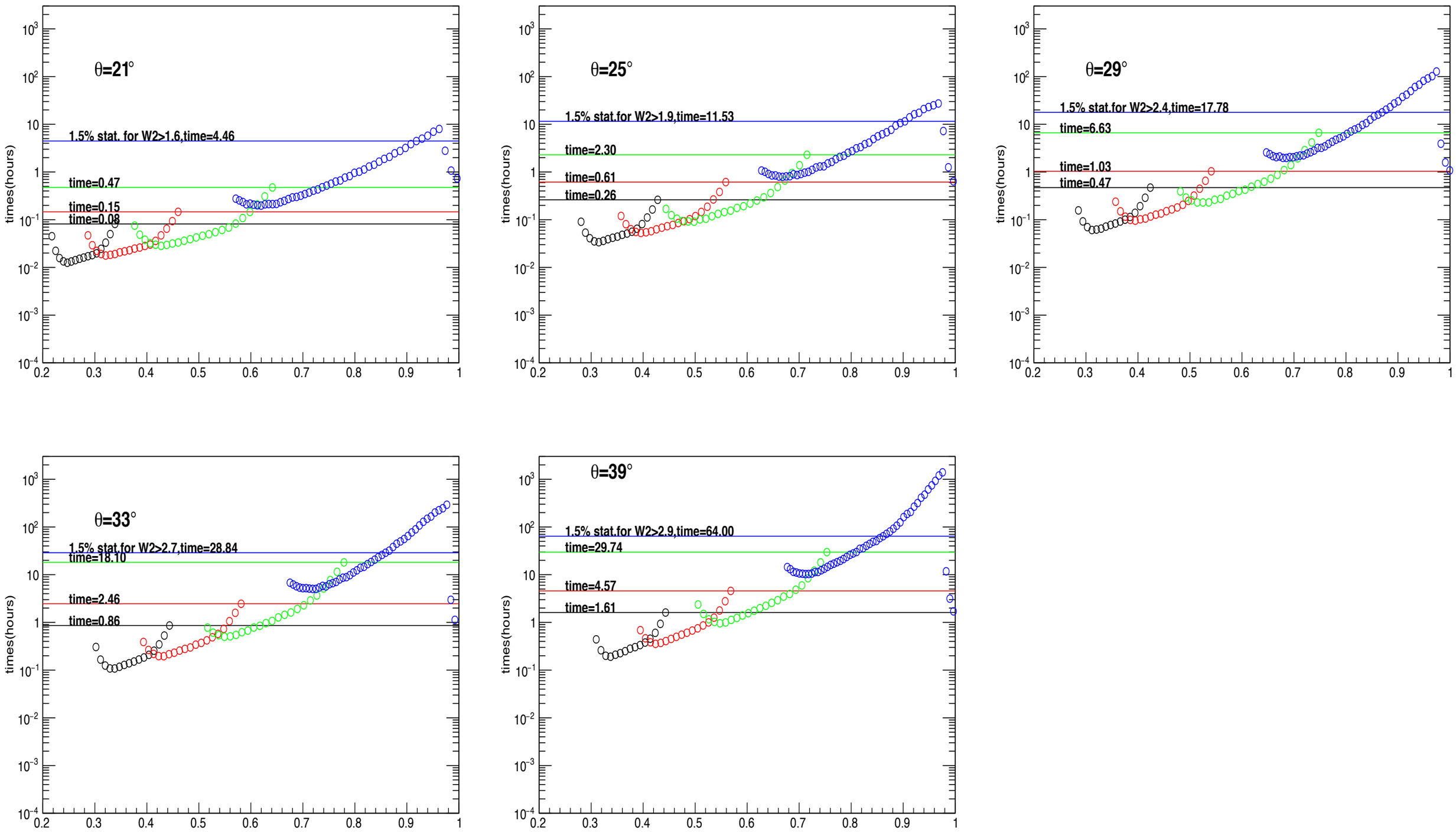
  0.2 $GeV^2$ in DIS

- Shape due to detector acceptance effect

- Shown are times corresponding to different statistical precisions

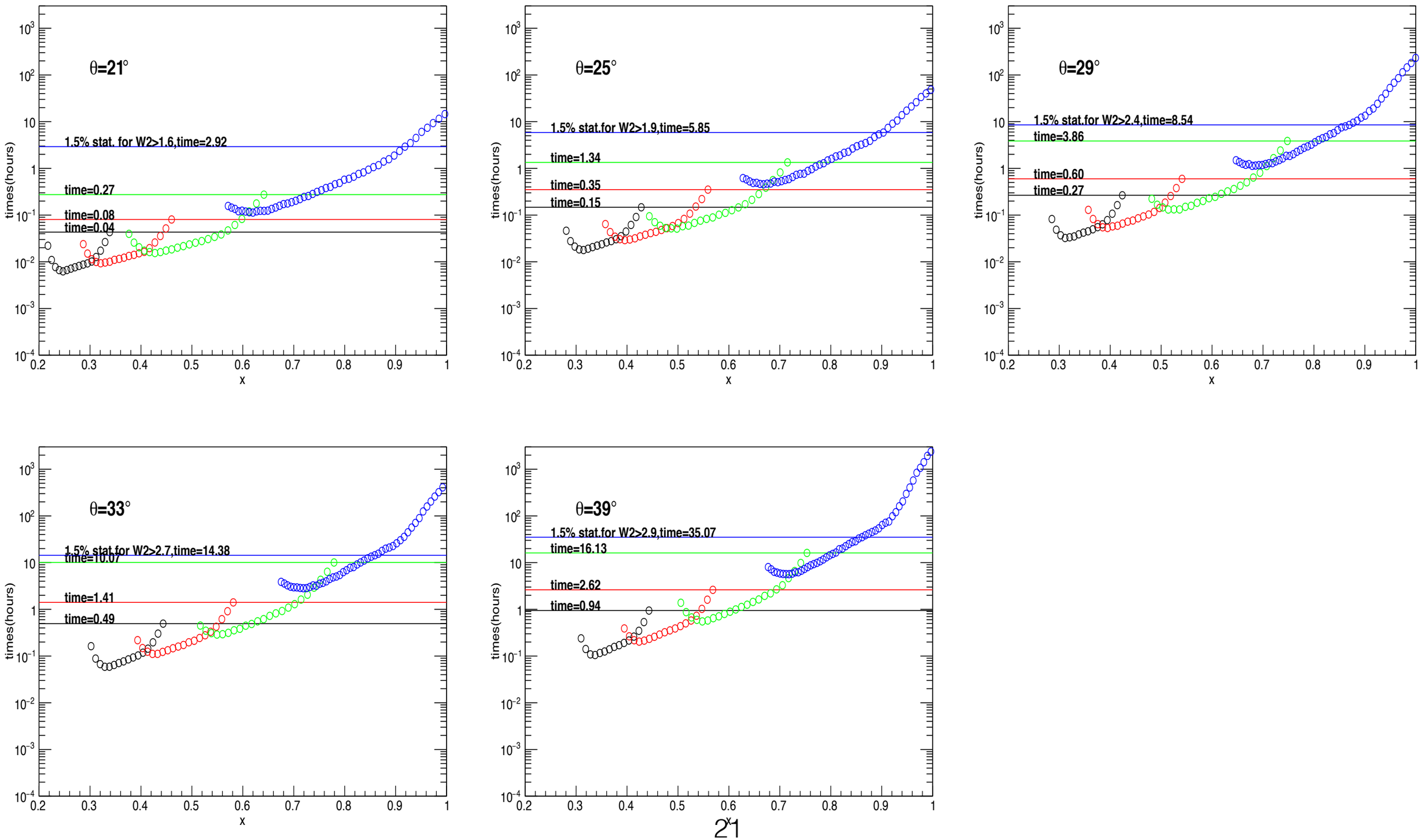
# H Production Time Estimation, SHMS

➢ Time estimations for all kinematics



# D Production Time Estimation, SHMS

➢ Time estimations for all kinematics



# Production Time Estimation

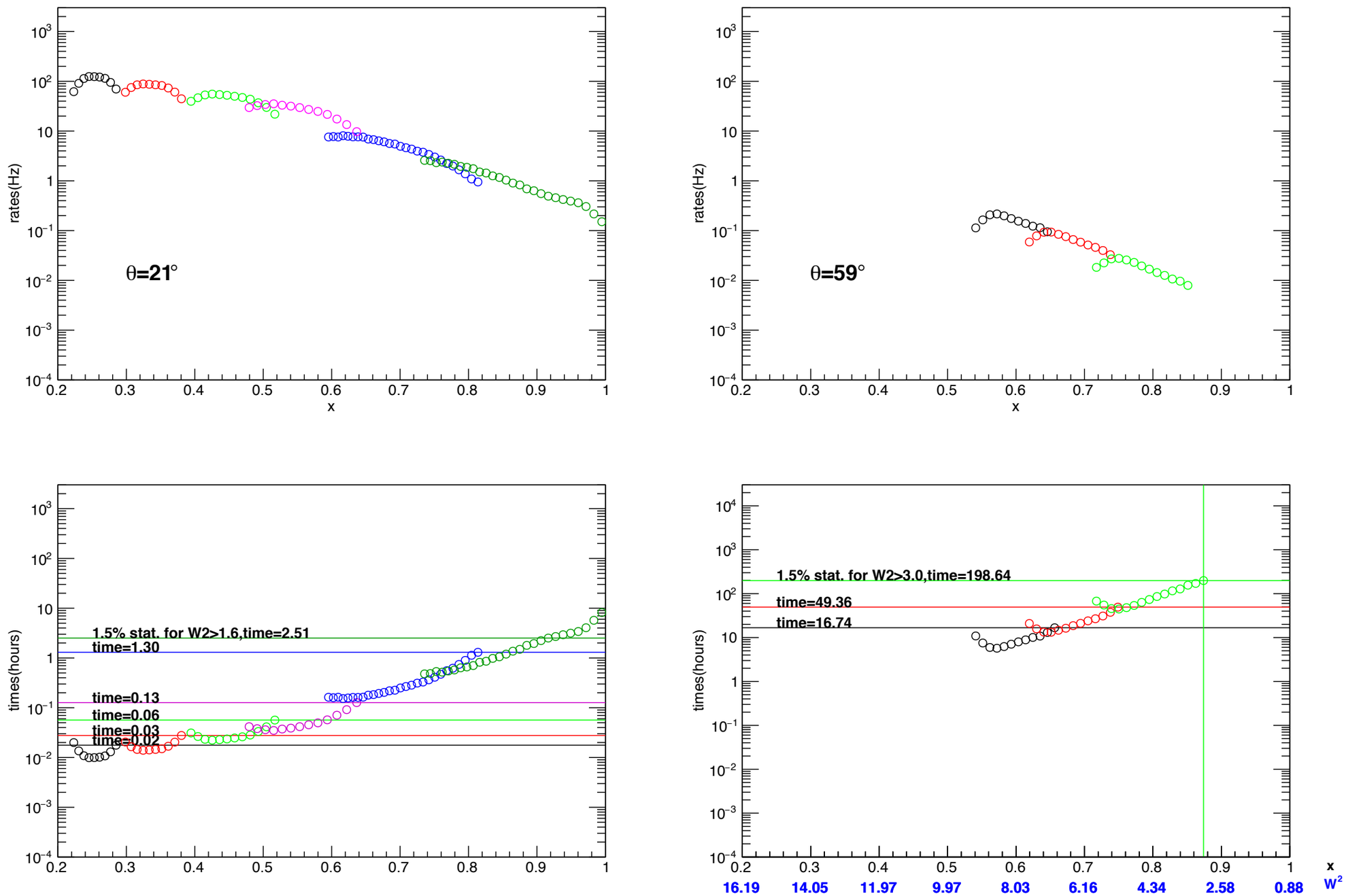
- 1.5% statistics

| Angle(deg) | Time(h) H target | Time(h) D target | 1.5% stat. for $W^2$>? |
|---|---|---|---|
| 21 | 5 | 3 | 1.6 |
| 25 | 15 | 8 | 1.9 |
| 29 | 26 | 14 | 2.4 |
| 33 | 50 | 27 | 2.7 |
| 39 | 100 | 54 | 2.9 |

statistical precision will be less than 1.5 % below the $W^2$ cuts

- Total time for H running: 196 h
- Total time for D running: 106 h
- Dummy run time: 15% of D target

# Production Rates on H target, HMS




- ➢ Rate at large angle is low
- ➢ HMS will stay at 59 deg after taking data at 21 deg

# Pion Contamination

➢ Maximum π/e ratio estimation: SHMS: π/e<250
HMS: π/e<150

➢ SHMS simulation

- For momenta between 1.4 and 4 GeV, π/e < 250
  Cherenkov rejection: HGC - 25:1 & LGC (Ar) - 25:1
  Calorimeter rejection: 150-200 (99.5 efficient)
  } π contamination 0.3%
- For momenta > 4 GeV, π/e < 2.5
  Cherenkov rejection: LGC (Ar) - 25:1
  Calorimeter rejection: 200 (99.5 efficient)
  } π contamination 0.1%

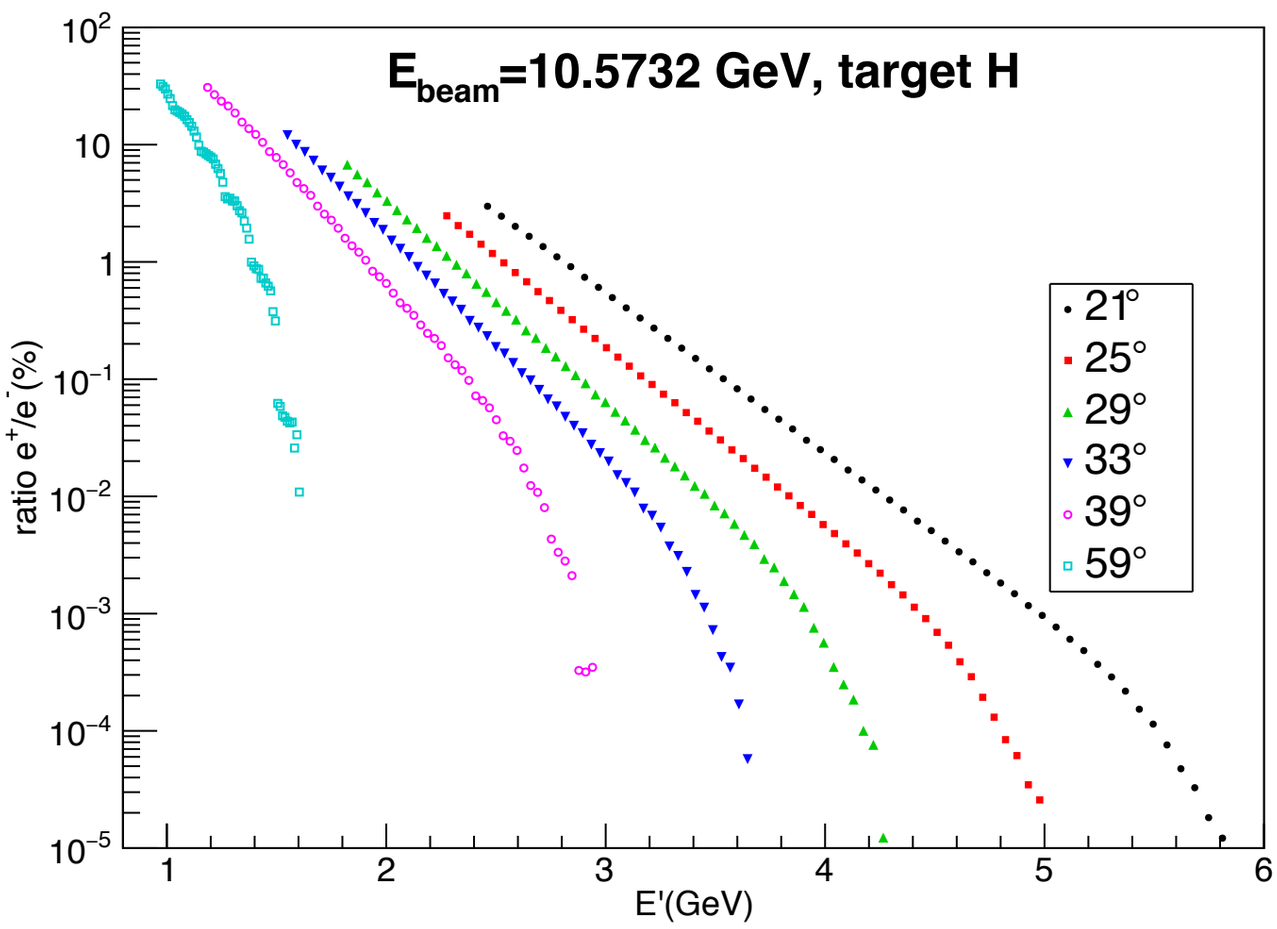
# Charge Symmetric Background

- Secondary electrons from $\pi^0 \to \gamma + e^- + e^+$ will pass PID cuts and be detected $e^-_{total} = e^-_{DIS} + e^-_{bg}$

- e+/e- ratio

  Target length: 10 cm

  $e^+$ cross section: P. Bosted's code based on Wiser's fit to π+ and π- production on H




We will measure charge symmetric background with the same spectrometer that detects the scattered electrons.

# SHMS Priority list

| Polarity | Angle | Momentum(GeV/c) |
|---|---|---|
| neg | 21 | 5.1, 4.0, 3.3, 2.7 |
| neg | 39 | 2.5, 2.0, 1.6, 1.3 |
| neg | 33 | 3.2, 2.6, 2.1, 1.7 |
| pos | 21 | 3.3, 2.7 |
| pos | 39 | 2.5, 2.0, 1.6, 1.3 |
| pos | 33 | 3.2, 2.6, 2.1, 1.7 |
| neg | 29 | 3.7, 3.0, 2.4, 2.0 |
| neg | 25 | 4.4, 3.5, 3.0, 2.5 |

➢ eliminate some momentum settings for positron running

# Going from Cross sections to $F_2$: Determination of R

- Cannot claim a precise extraction of $F_2$ from cross section without a precise knowledge of R

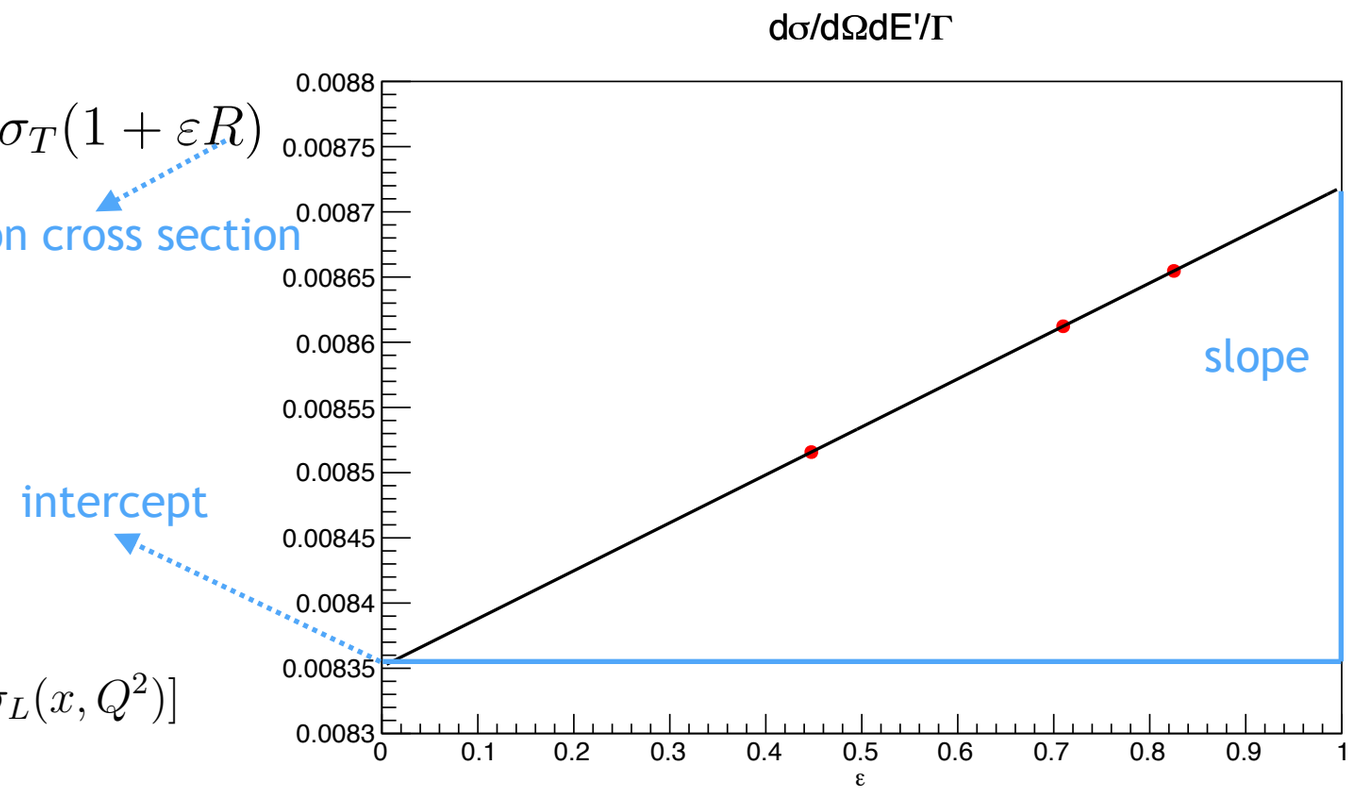
$$\frac{d\sigma}{d\Omega dE'} = \Gamma(\sigma_T(x,Q^2) + \varepsilon\sigma_L(x,Q^2)) = \Gamma\sigma_T(1+\varepsilon R)$$

ratio of longitudinal and transverse photo-absorption cross section

$$\varepsilon = \frac{1}{1 + 2\frac{\nu^2+Q^2}{Q^2}tan^2\frac{\theta}{2}}$$

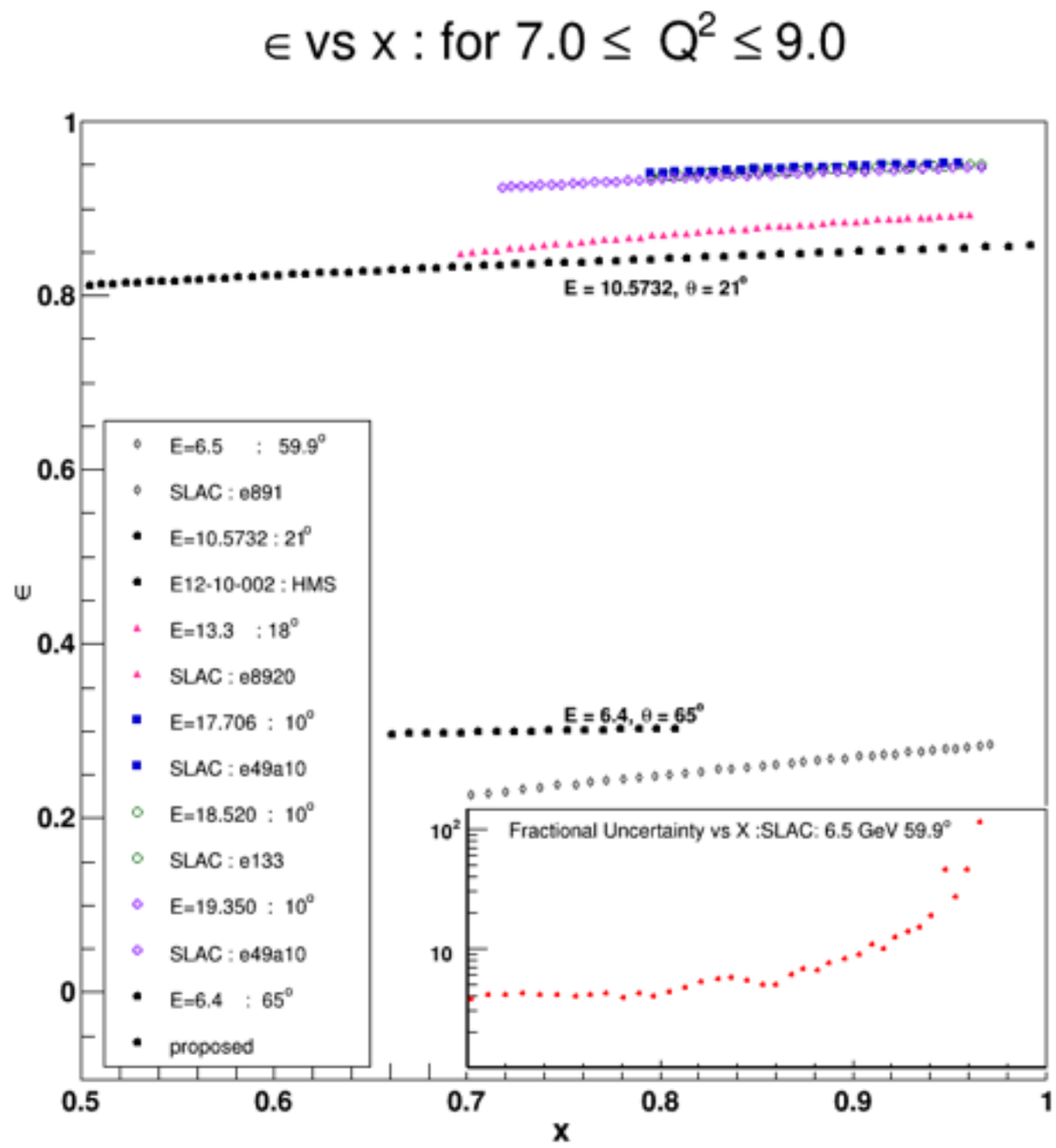
$$F_1(x,Q^2) = \frac{\kappa M}{4\pi^2\alpha}\sigma_T(x,Q^2)$$

$$F_2(x,Q^2) = \frac{\kappa}{4\pi^2\alpha}\frac{\nu}{1+\nu^2/Q^2}[\sigma_T(x,Q^2) + \sigma_L(x,Q^2)]$$

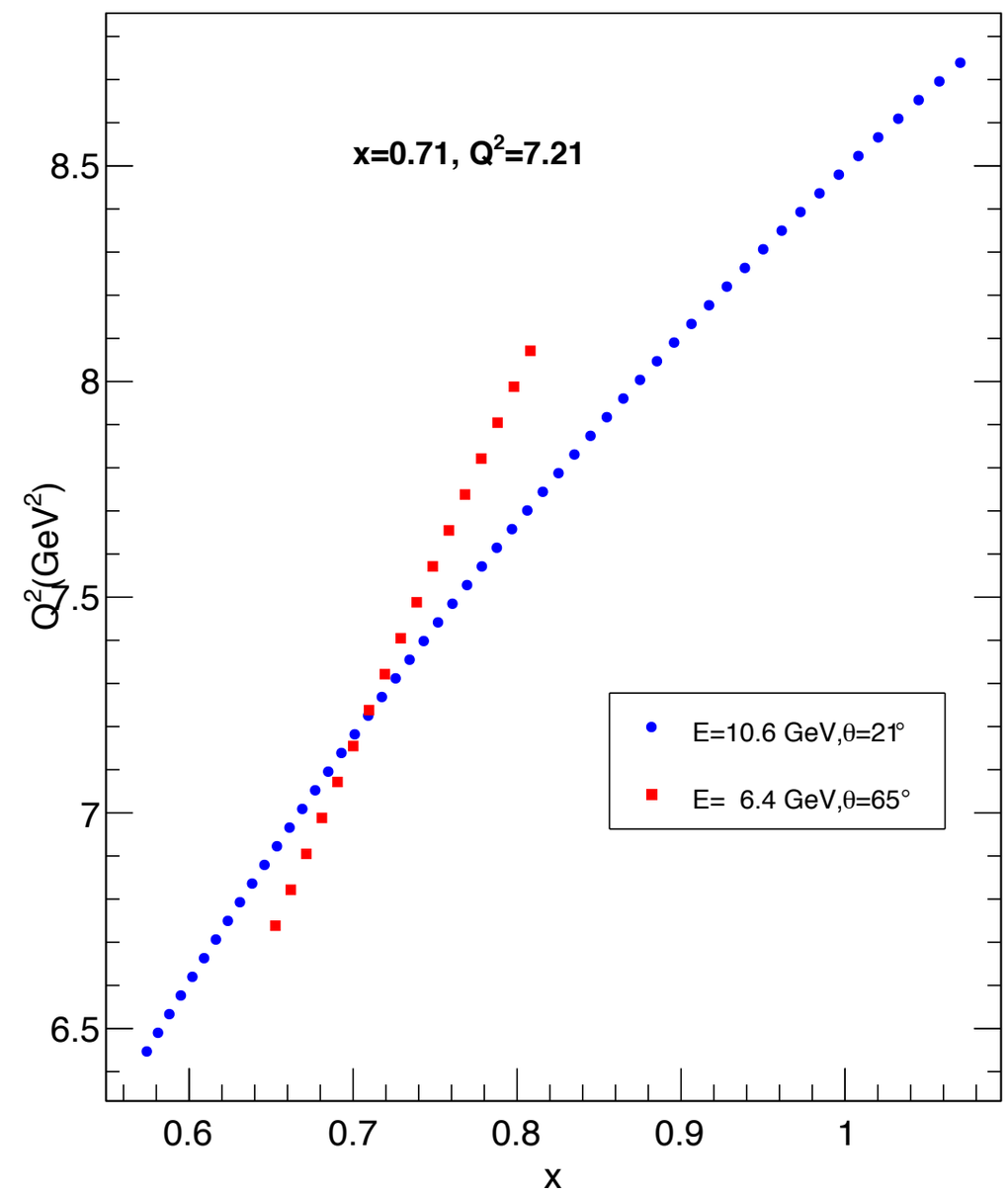



- Measurements at different beam energies than 10.6 GeV to extract R, especially in the region of large x and large $Q^2$

# Determination of R




cr. Deb Biswas



# Thank you.

Groups involved in preparation for running:

- E12-10-002
  Students: Abel Sun (CMU), Deb Biswas (HU)
  Spokespeople: Eric Christy, Thia Keppel, Simona Malace (contact), Ioana Niculescu
- E12-10-008
  Students: Kayla Craycraft (UT), Abishek Karki (MSU)
  Spokespeople: John Arrington, Aji Daniel, Dave Gaskell (contact), Nadia Fomin