

Refined Simulations of Double Pion Electroproduction for CLAS22

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Columbia, SC

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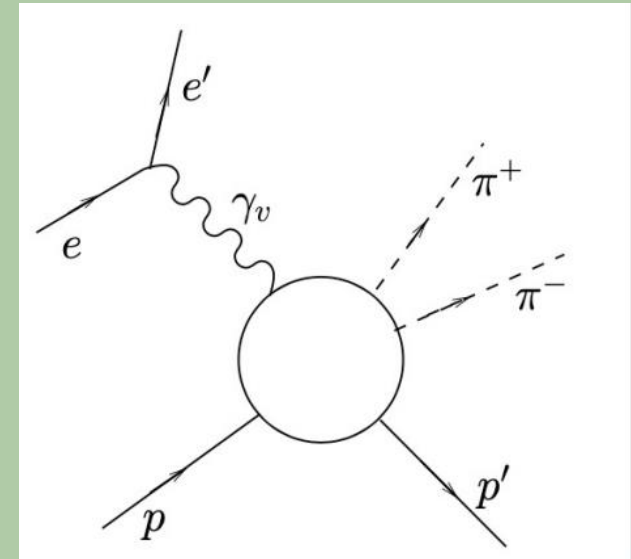
Outline

- Context
- Updated histograms
 - Acceptance
 - Momentum vs. Δt
 - Missing mass squared resolution
- Feasibility
 - Integrated hadronic cross section
 - Needed integrated luminosity, needed integrated charge, and needed beam time

Context

- Simulating final state used by the program to extract cross sections and resonance parameters (in the resonance region)
- Includes comparison with CLAS12 TwoPion channel
- Feasibility study to see if these measurements can be extended to CLAS22

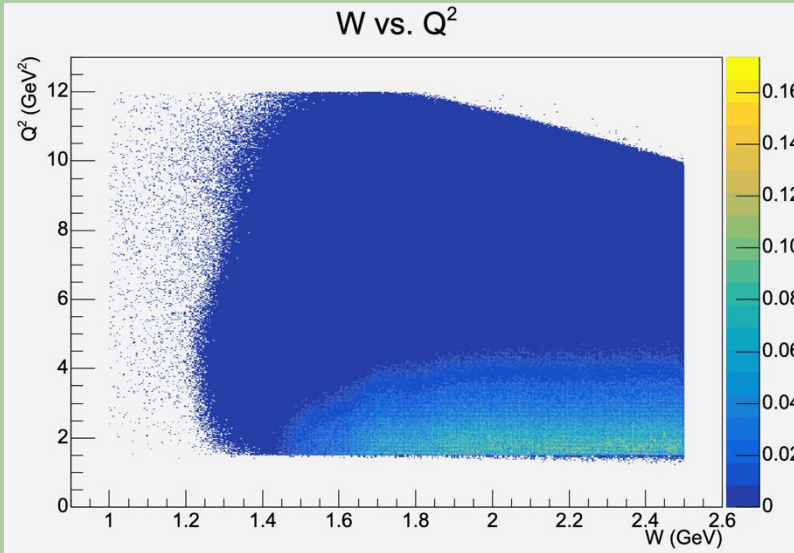
$$e + p \rightarrow e' + p' + \pi^+ + \pi^-$$



Invariant mass vs. four-momentum transfer squared (W vs. Q^2)

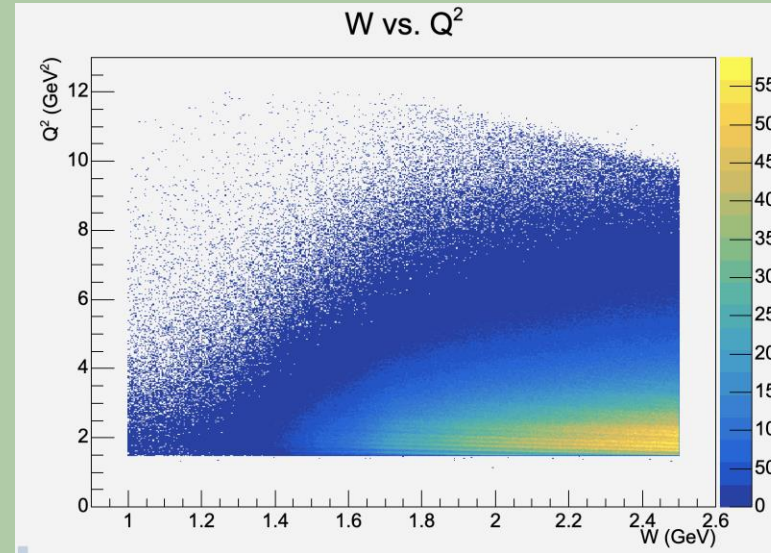
10.6 GeV simulation

TWOPEG event generator, pass 2



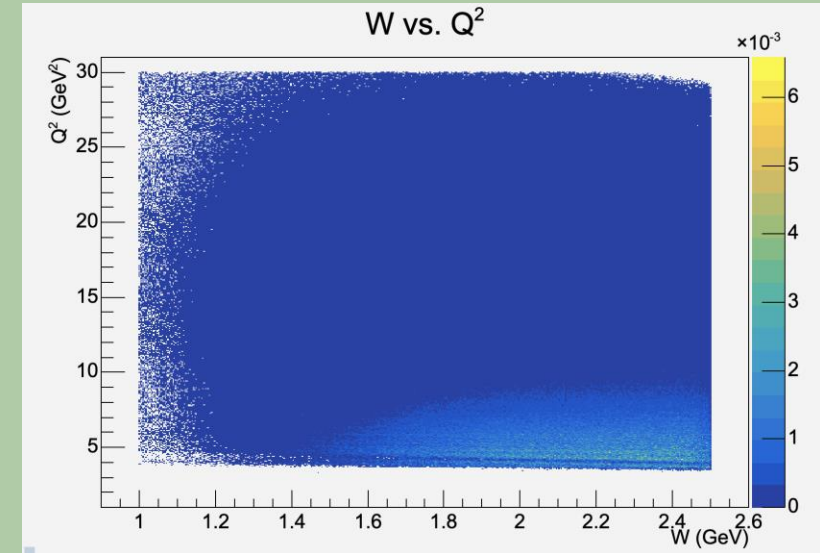
10.6 GeV experiment

Fall 2018, inbending, pass 2, golden runs



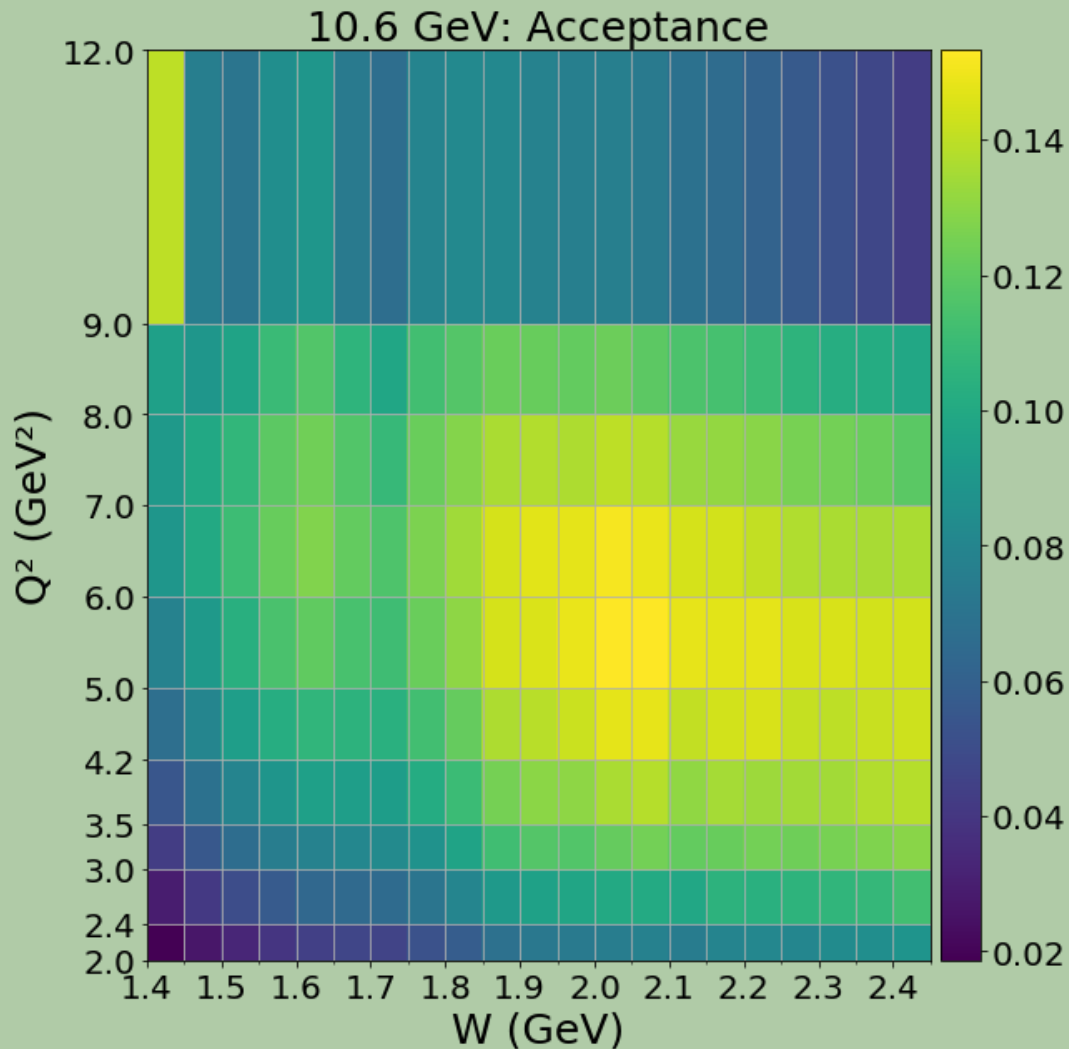
22.0 GeV simulation

TWOPEG event generator, pass 2



- Goal for 22 GeV: increase four momentum transfer (Q^2)

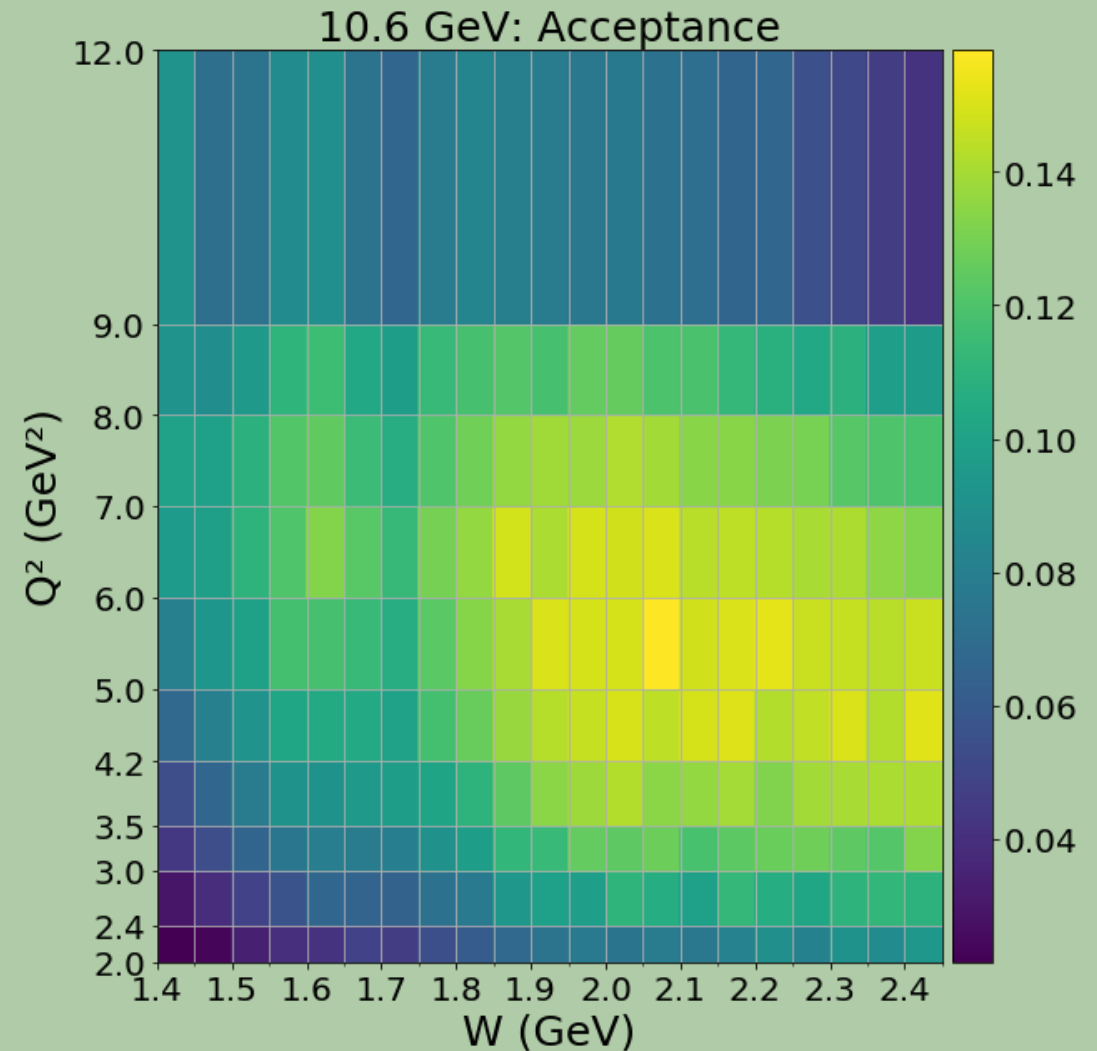
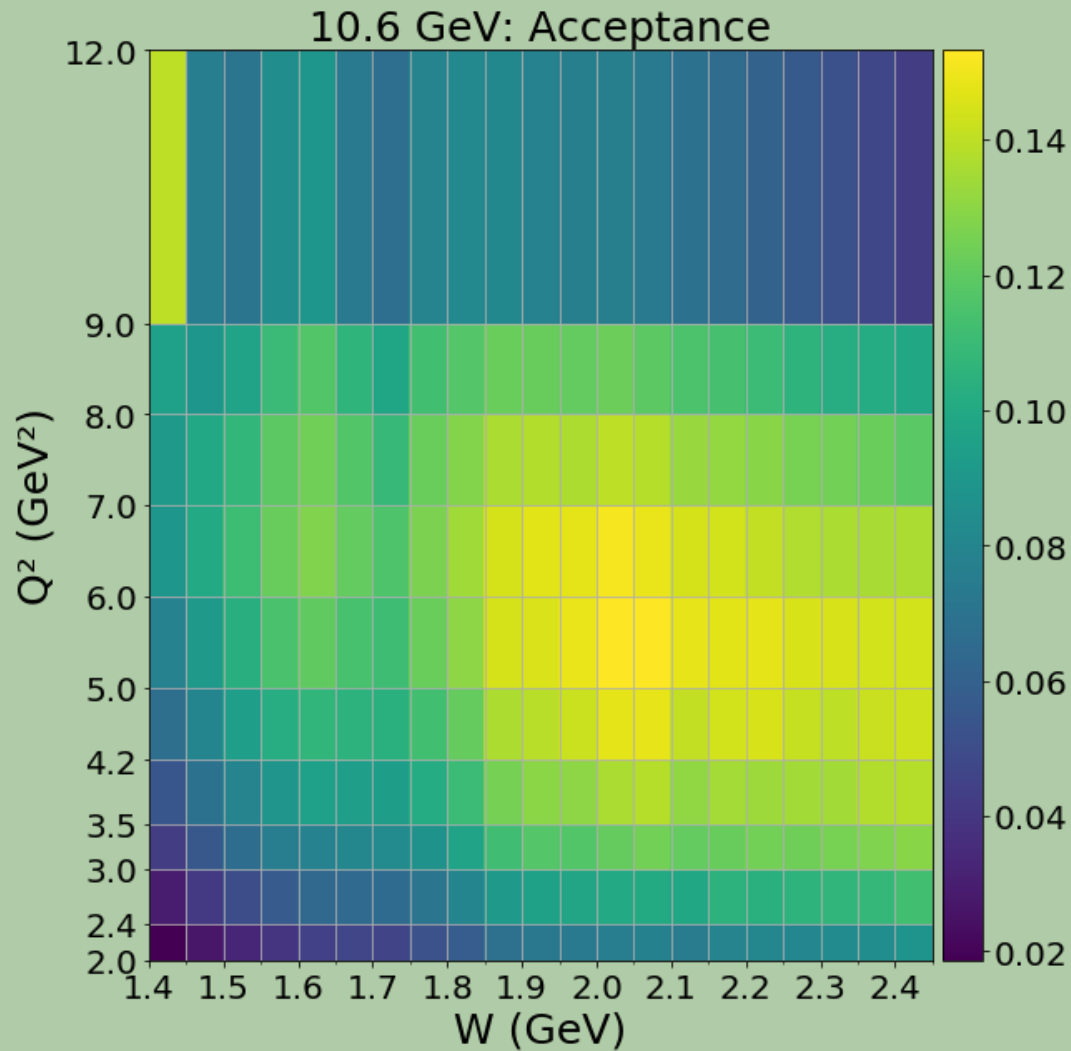
Acceptance



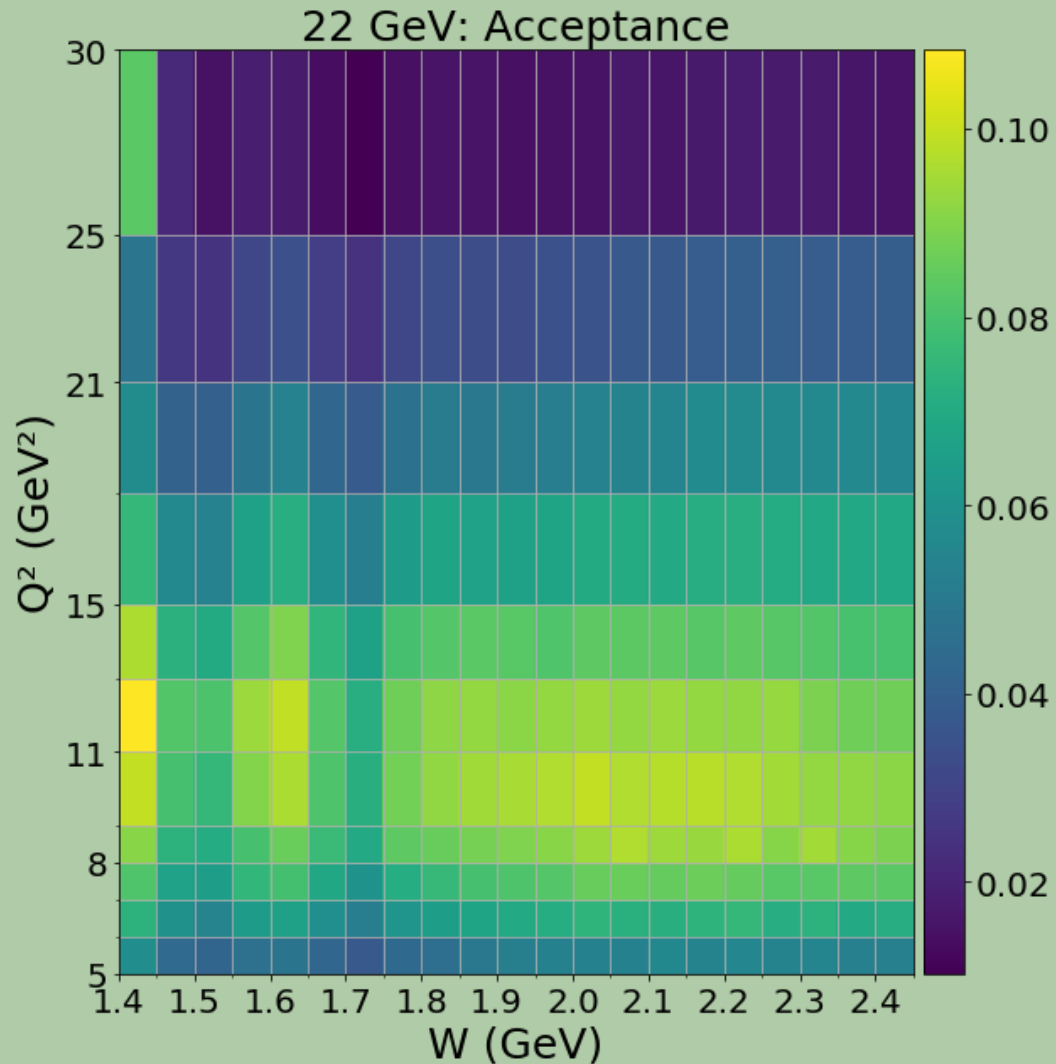
$$\text{Acceptance} = \frac{\sum \text{weights}_{\text{reconstructed}}}{\sum \text{weights}_{\text{generated}}}$$

- Weights are cross sections averaged in each bin
- Artificially large acceptance (yellow bin, low W , high Q^2)
- Limited number of significant figures
- Weights appear as zero due to lack of precision

Acceptance

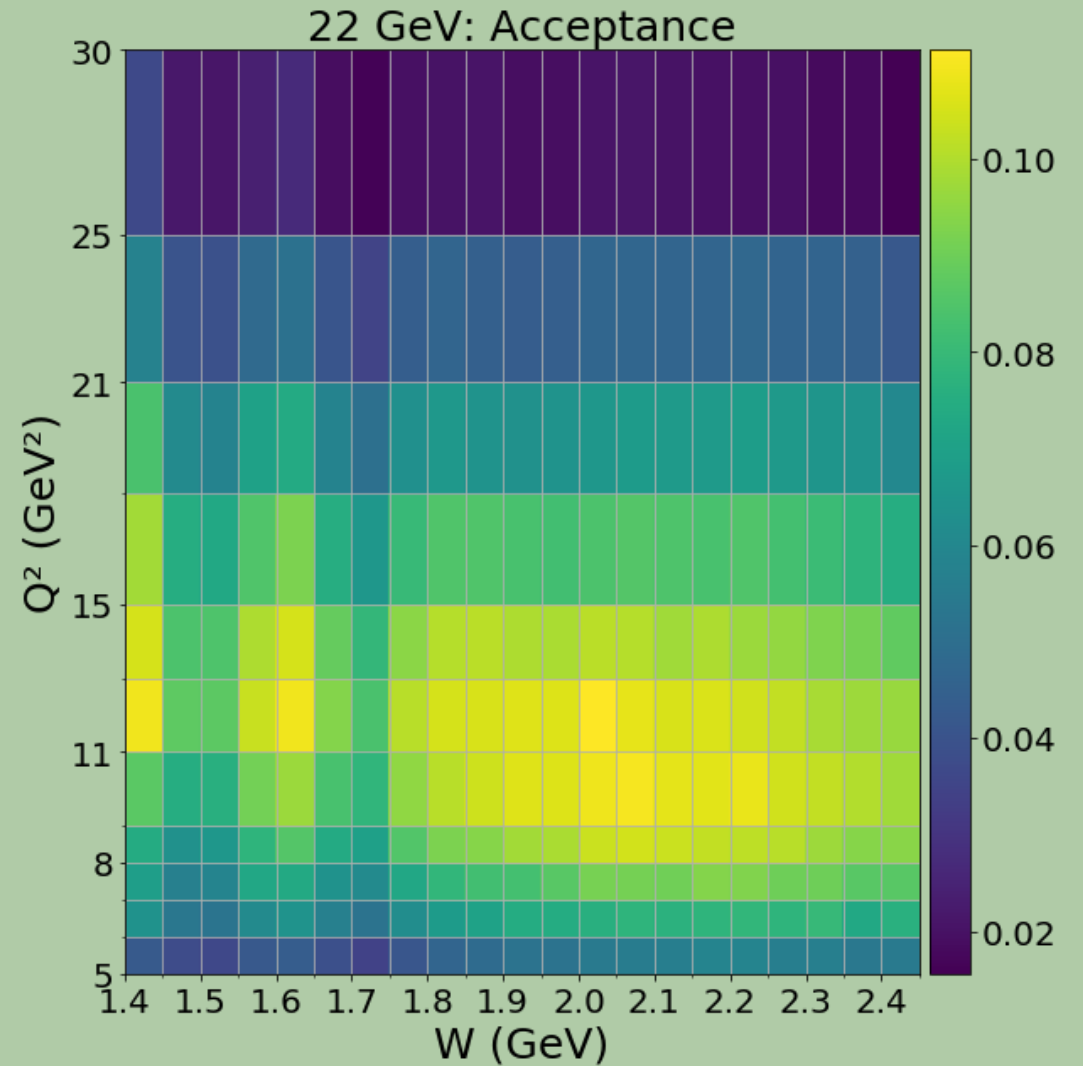
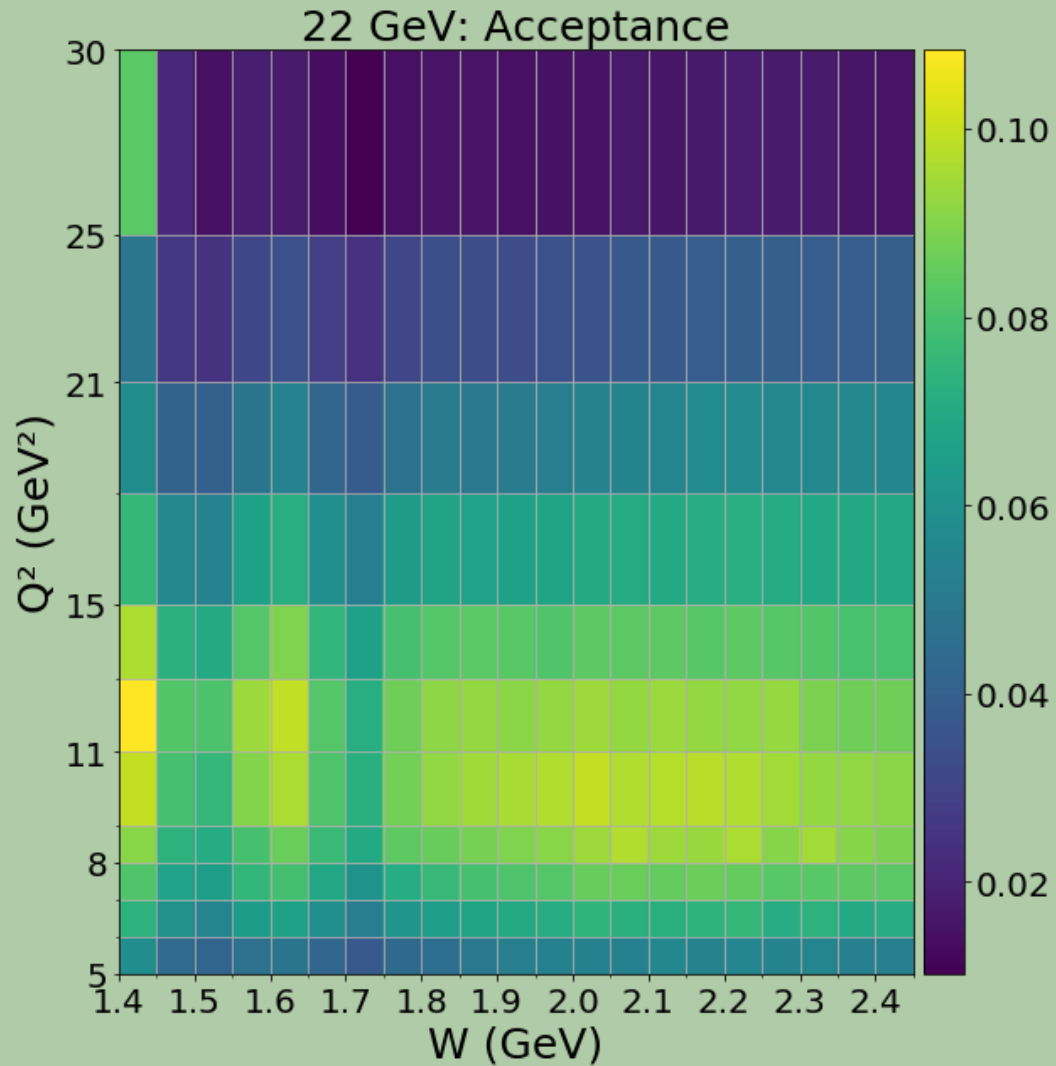


Acceptance



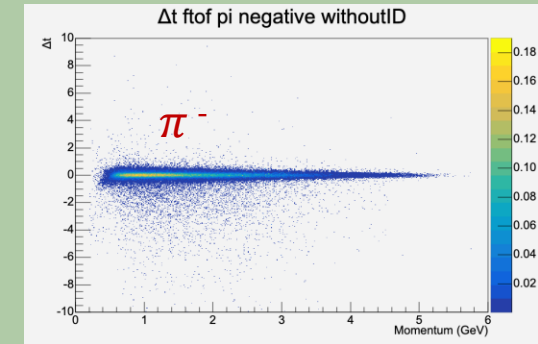
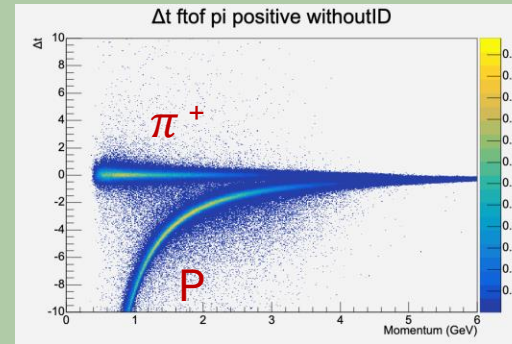
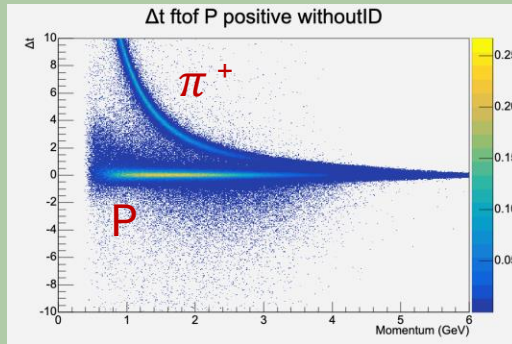
- Similar problem seen in 22 GeV simulation
- Low W , high Q^2 range known for weights equal to zero
- Zeros due to lack of precision
- Increase precision, decrease artificially high acceptance

Acceptance

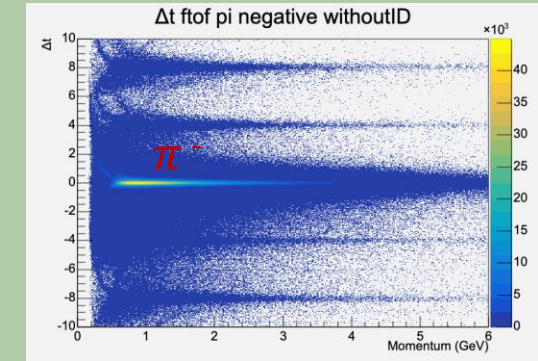
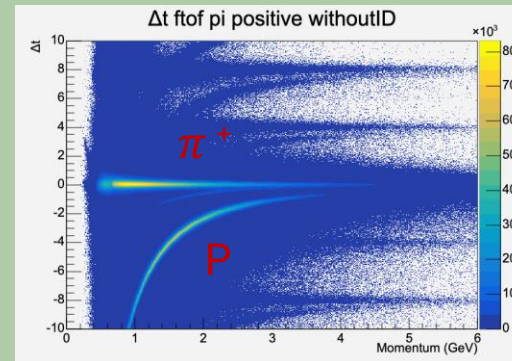
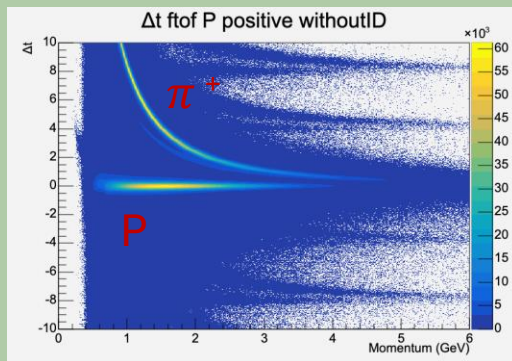


Momentum vs. Δt , forward detector, without ID

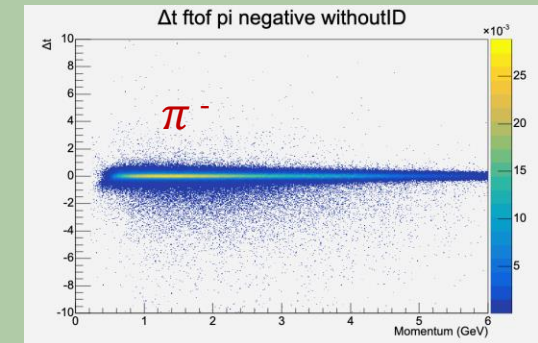
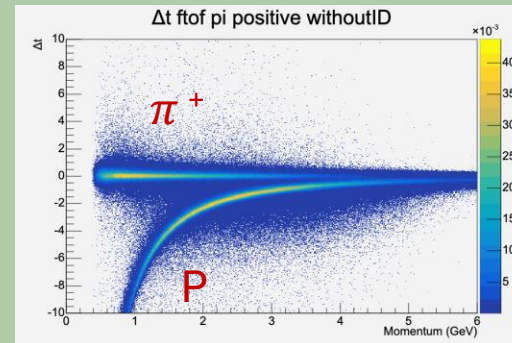
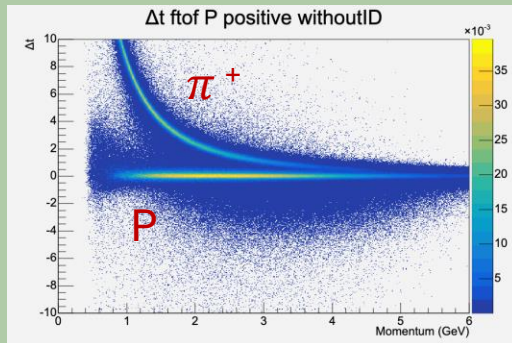
10.6 GeV
simulation



10.6 GeV
experiment

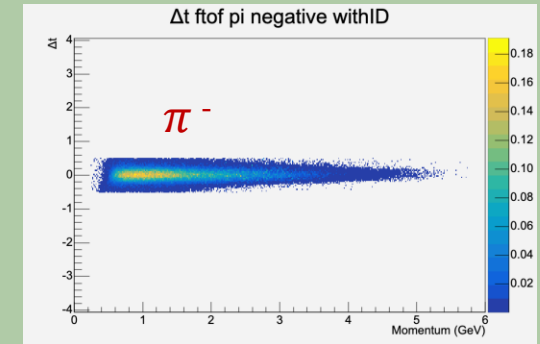
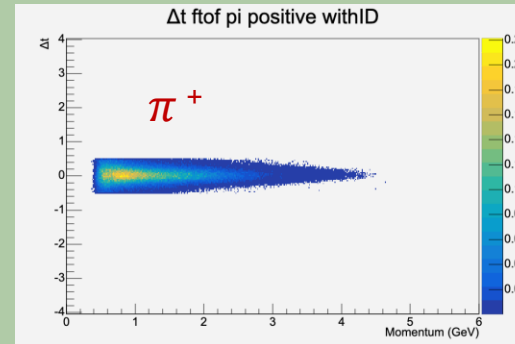
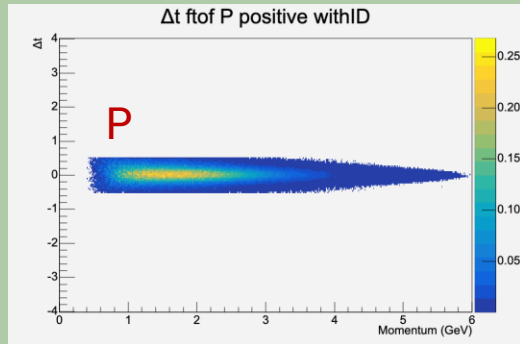


22.0 GeV
simulation

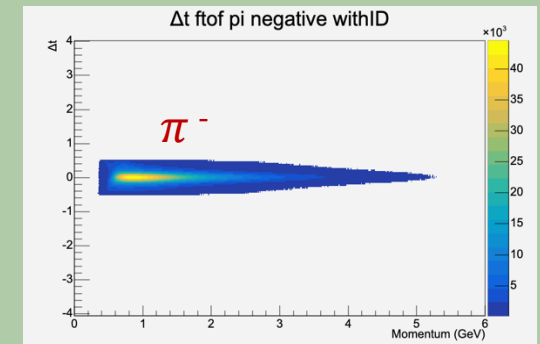
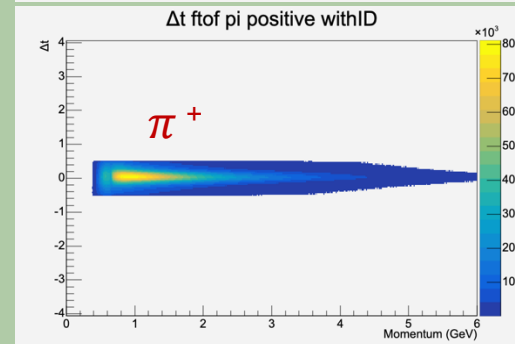
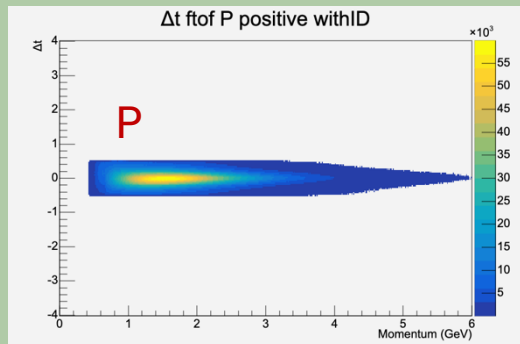


Momentum vs. Δt , forward detector, with ID

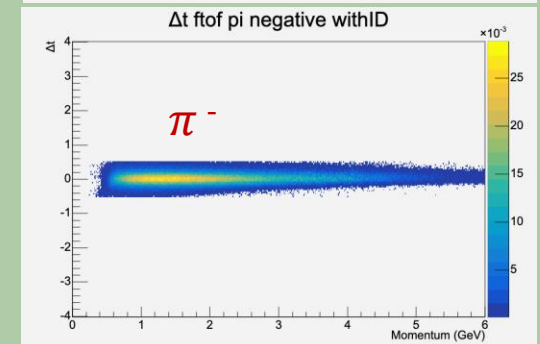
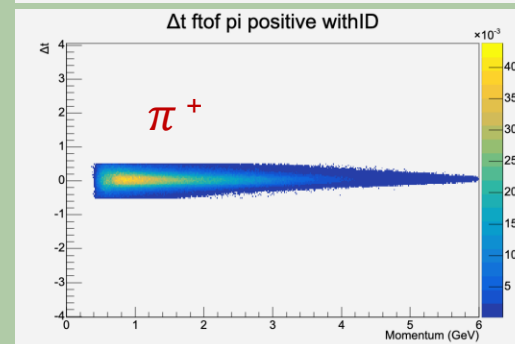
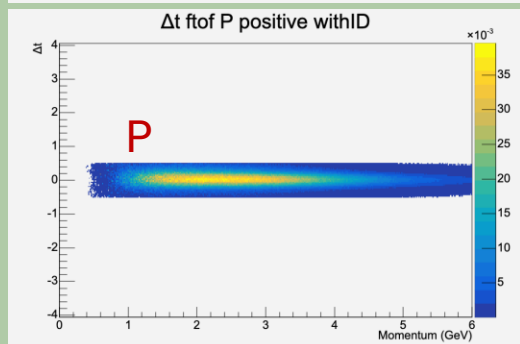
10.6 GeV
simulation



10.6 GeV
experiment



22.0 GeV
simulation



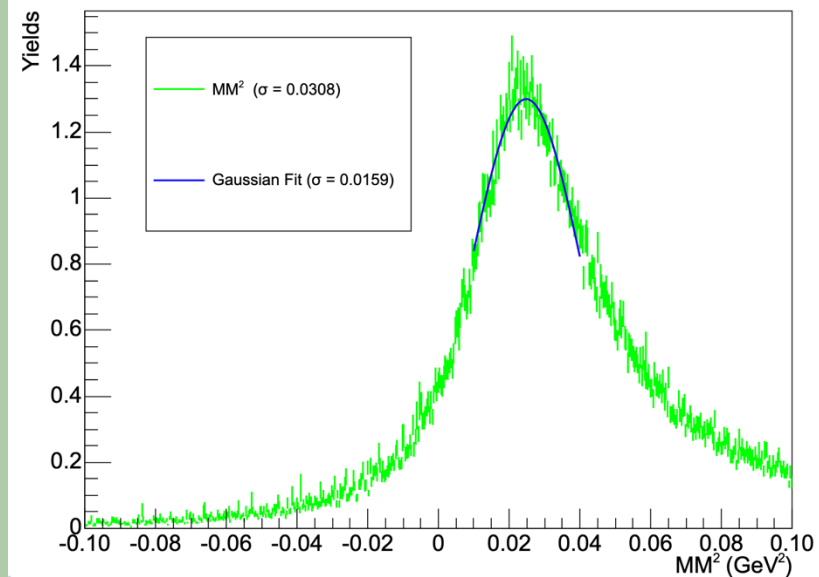
Missing Mass Squared Resolution, m_{Pim}

10.6 GeV simulation
TWOPEG event generator, pass 2

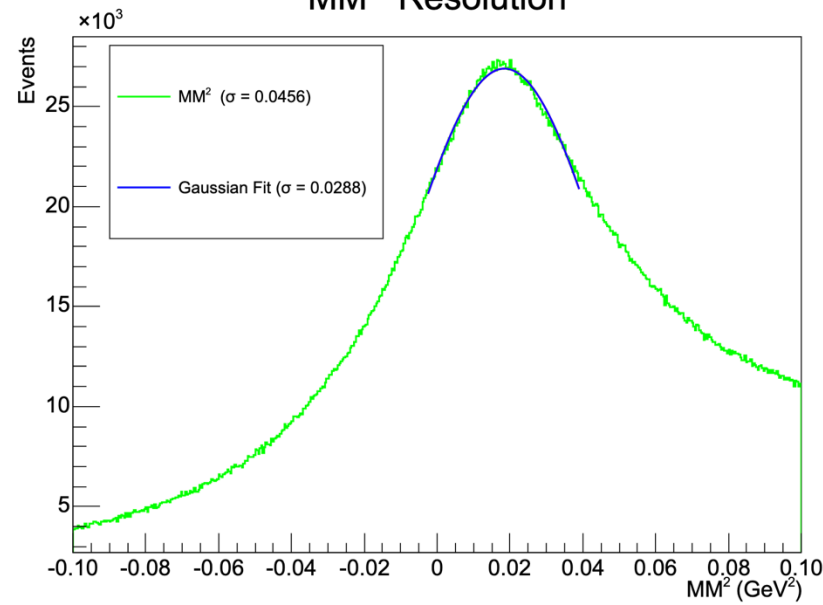
10.6 GeV experiment
Fall 2018, inbending, pass 2, golden runs

22.0 GeV simulation
TWOPEG event generator, pass 2

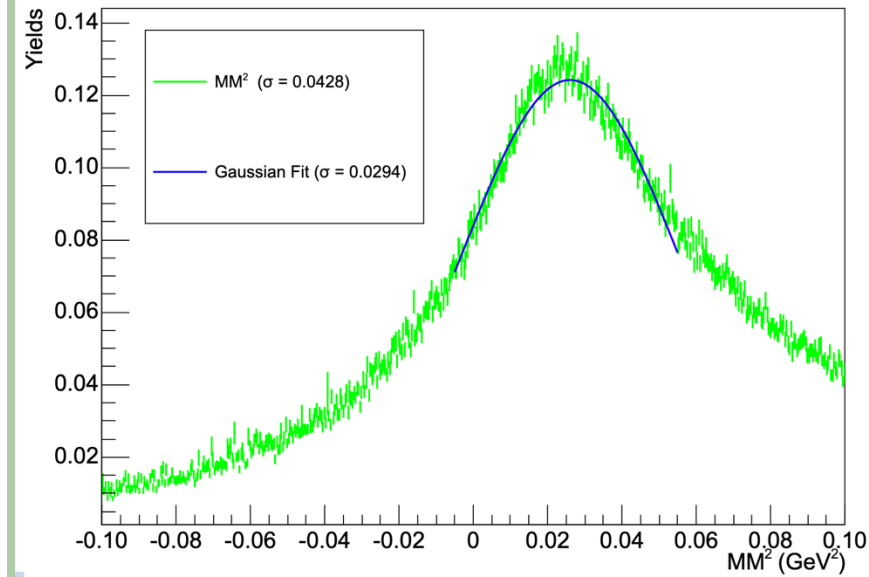
MM² Resolution



MM² Resolution



MM² Resolution

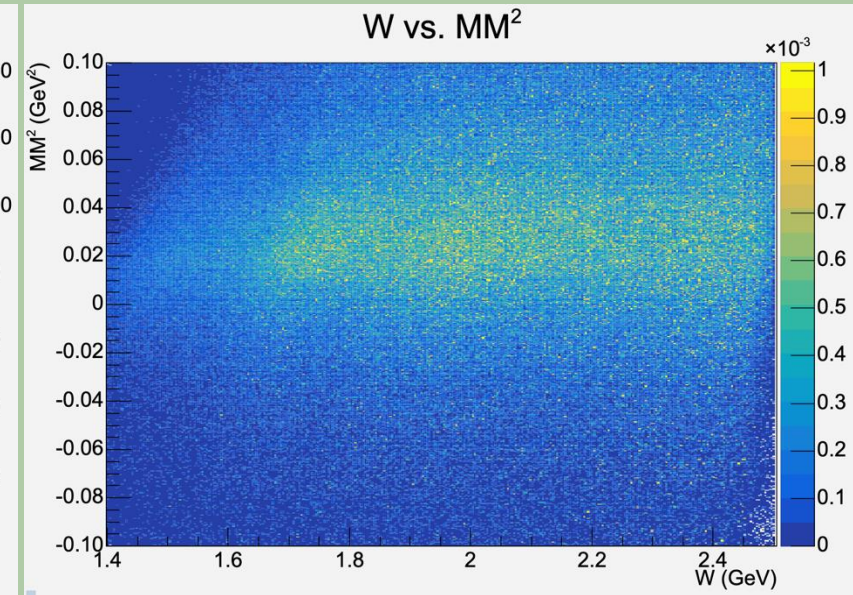
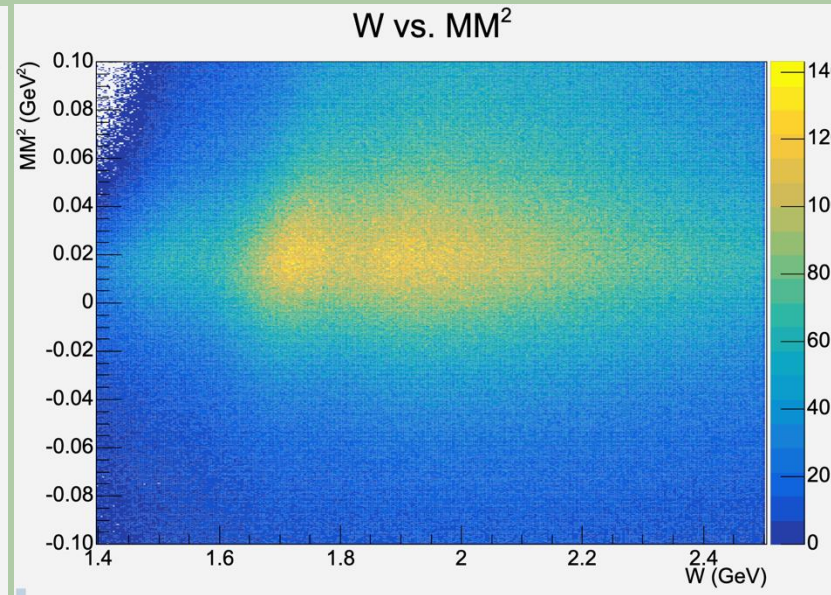
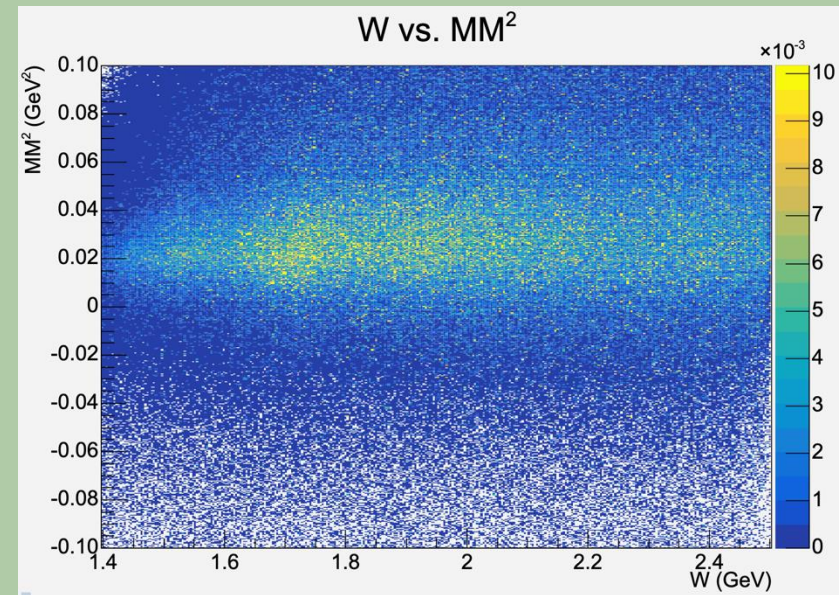


W vs. MM^2 for mPim

10.6 GeV simulation
TWOPEG event generator, pass 2

10.6 GeV experiment
Fall 2018, inbending, pass 2, golden runs

22.0 GeV simulation
TWOPEG event generator, pass 2

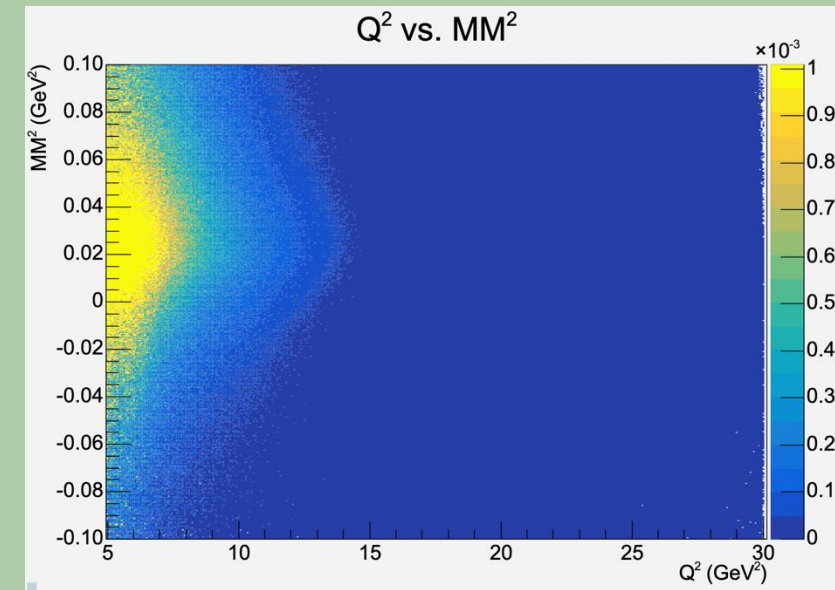
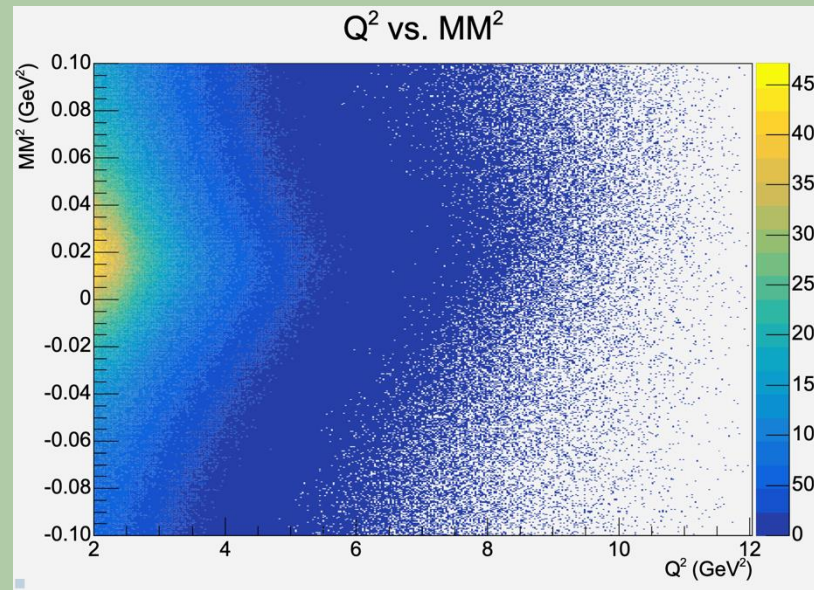
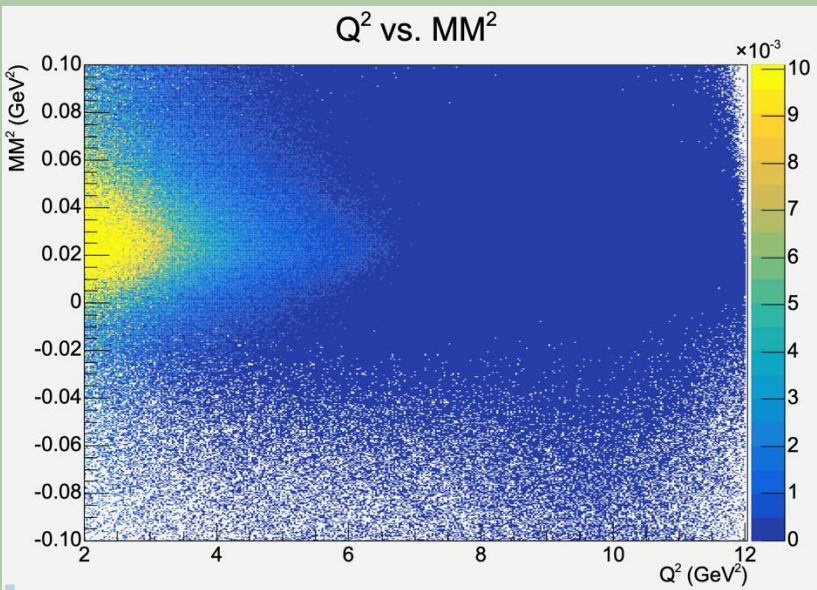


Q^2 vs. MM^2 for mPim

10.6 GeV simulation
TWOPEG event generator, pass 2

10.6 GeV experiment
Fall 2018, inbending, pass 2, golden runs

22.0 GeV simulation
TWOPEG event generator, pass 2

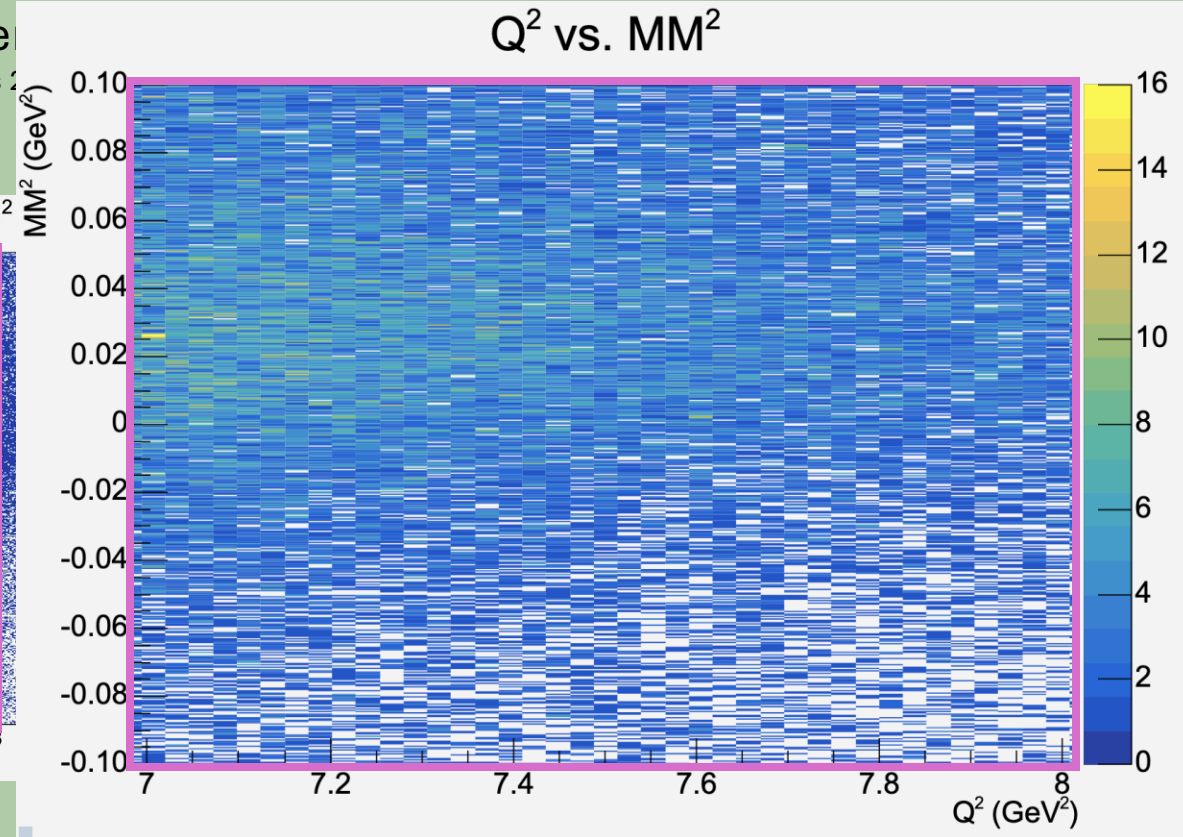
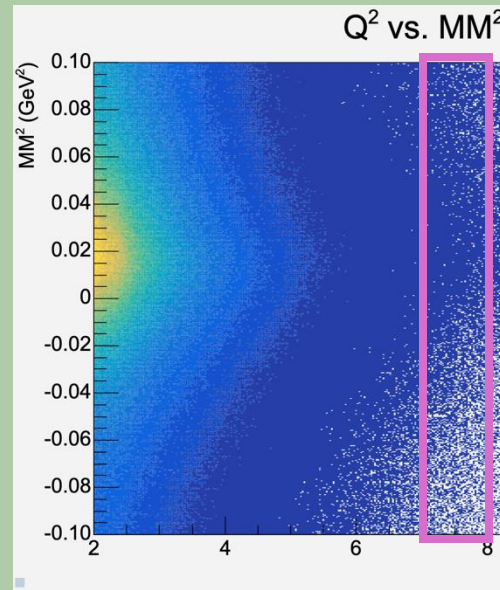
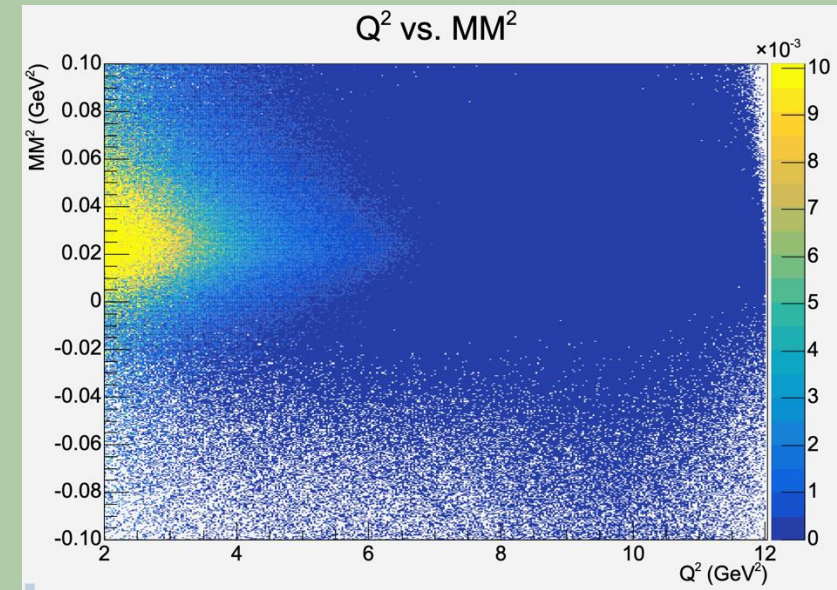


Q^2 vs. MM^2 for mPim

10.6 GeV simulation
TWOPEG event generator, pass 2

10.6 GeV exper
Fall 2018, inbending, pass 2

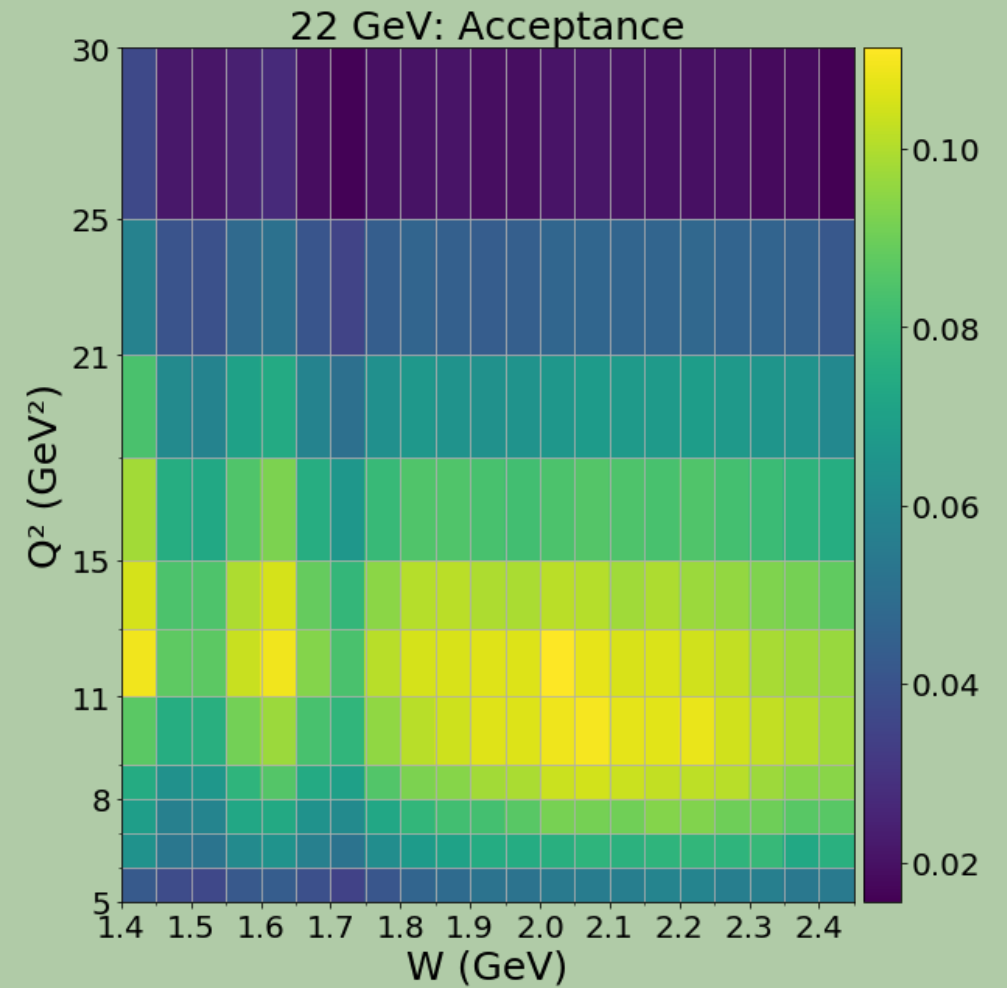
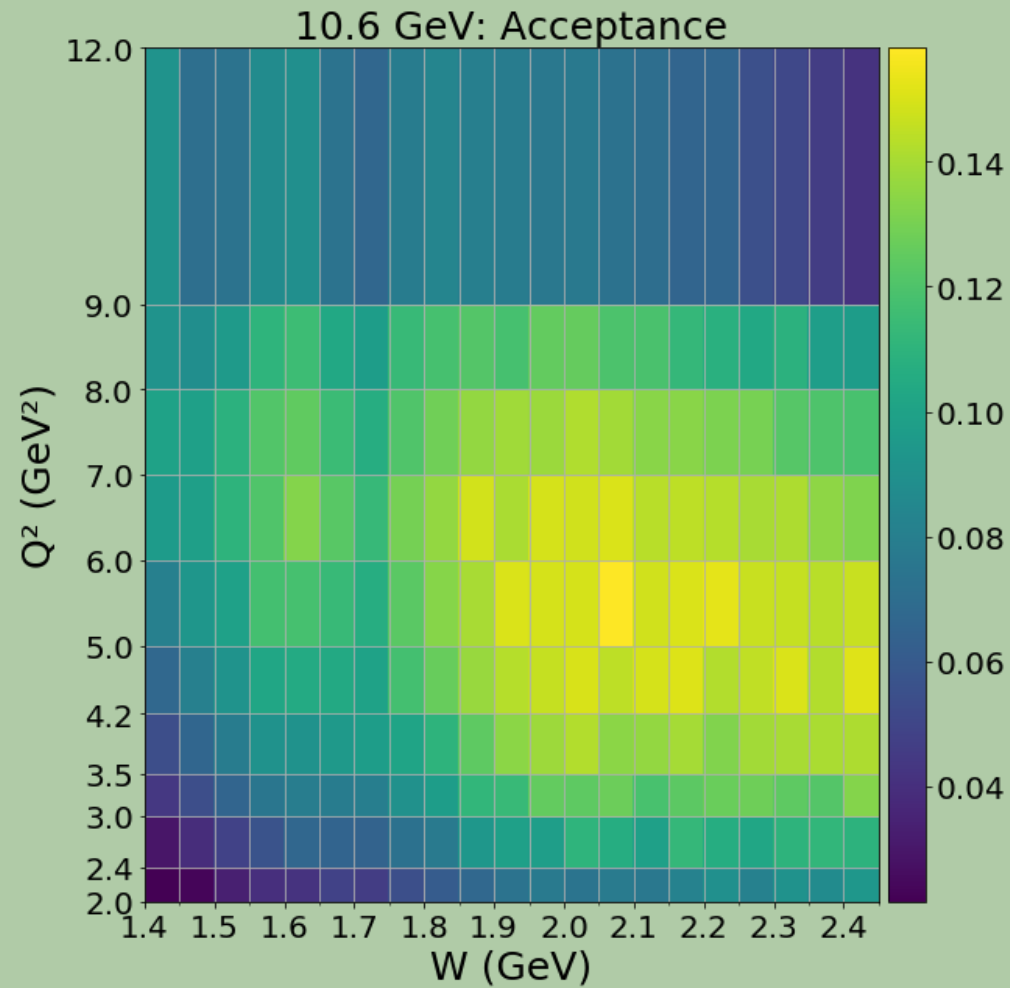
Q^2 vs. MM^2



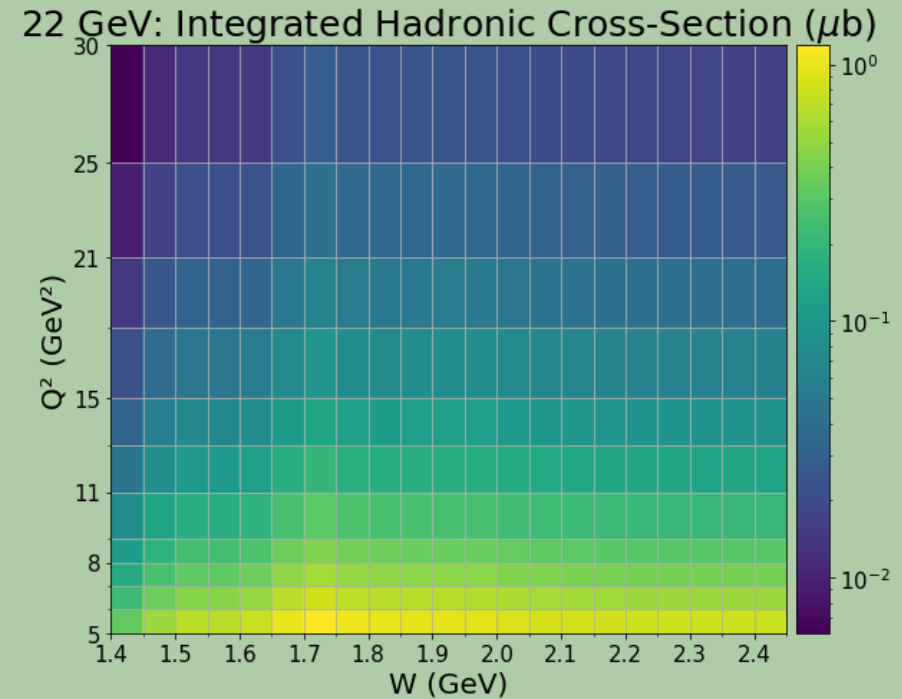
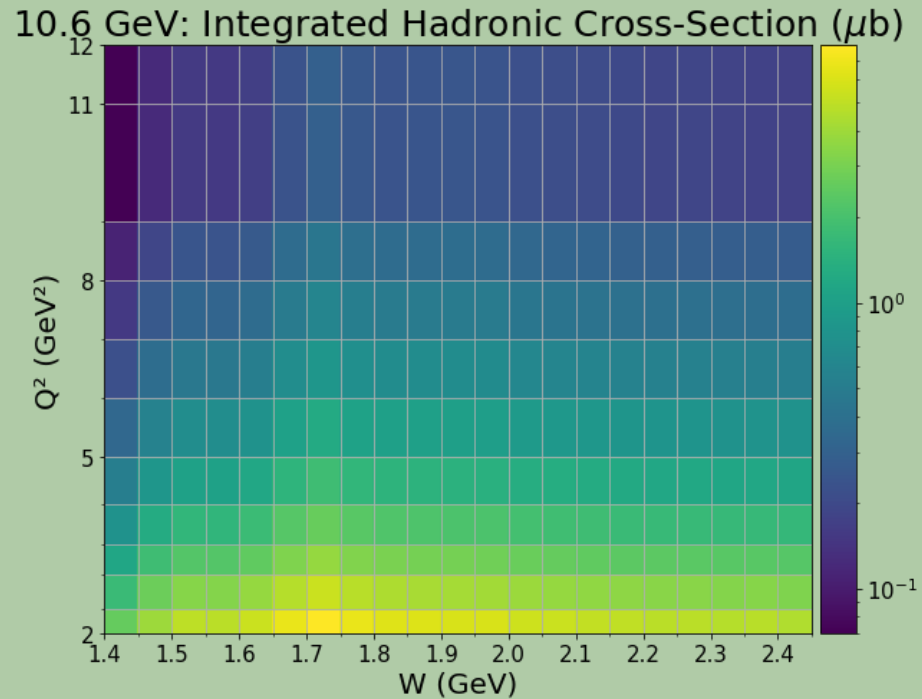
Feasibility

- Integrated hadronic cross section
- Needed integrated luminosity
- Needed integrated charge
- Needed beam time, in years

Acceptance

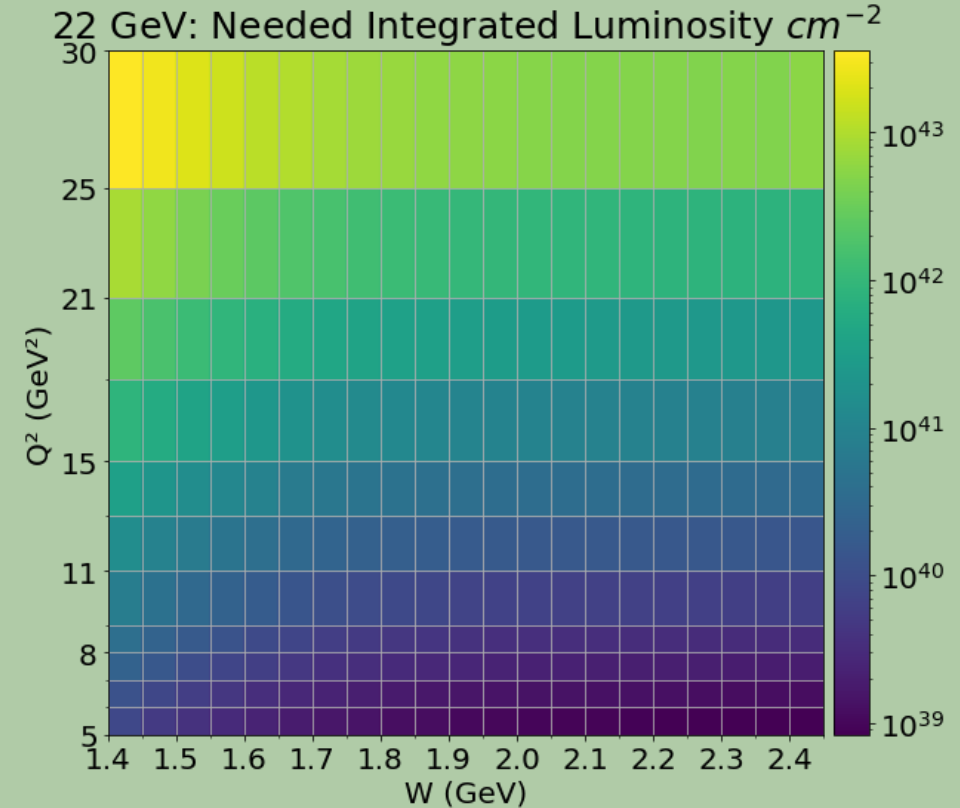
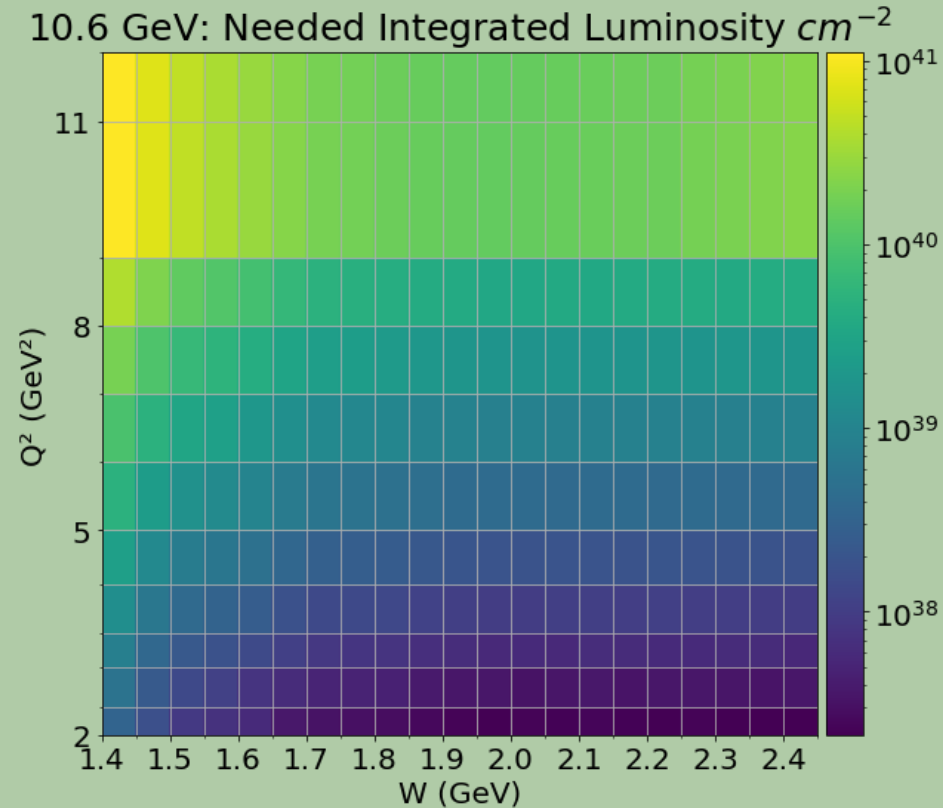


Integrated hadronic cross sections



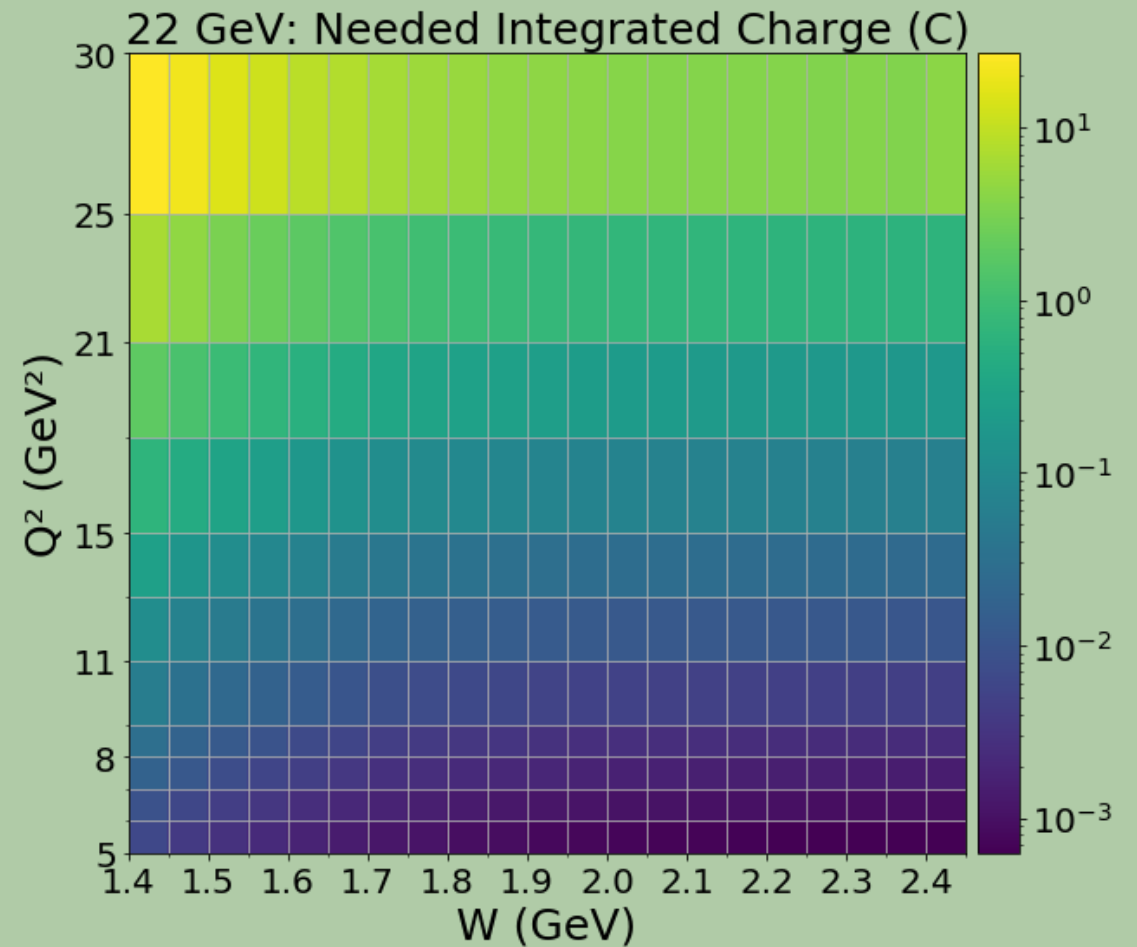
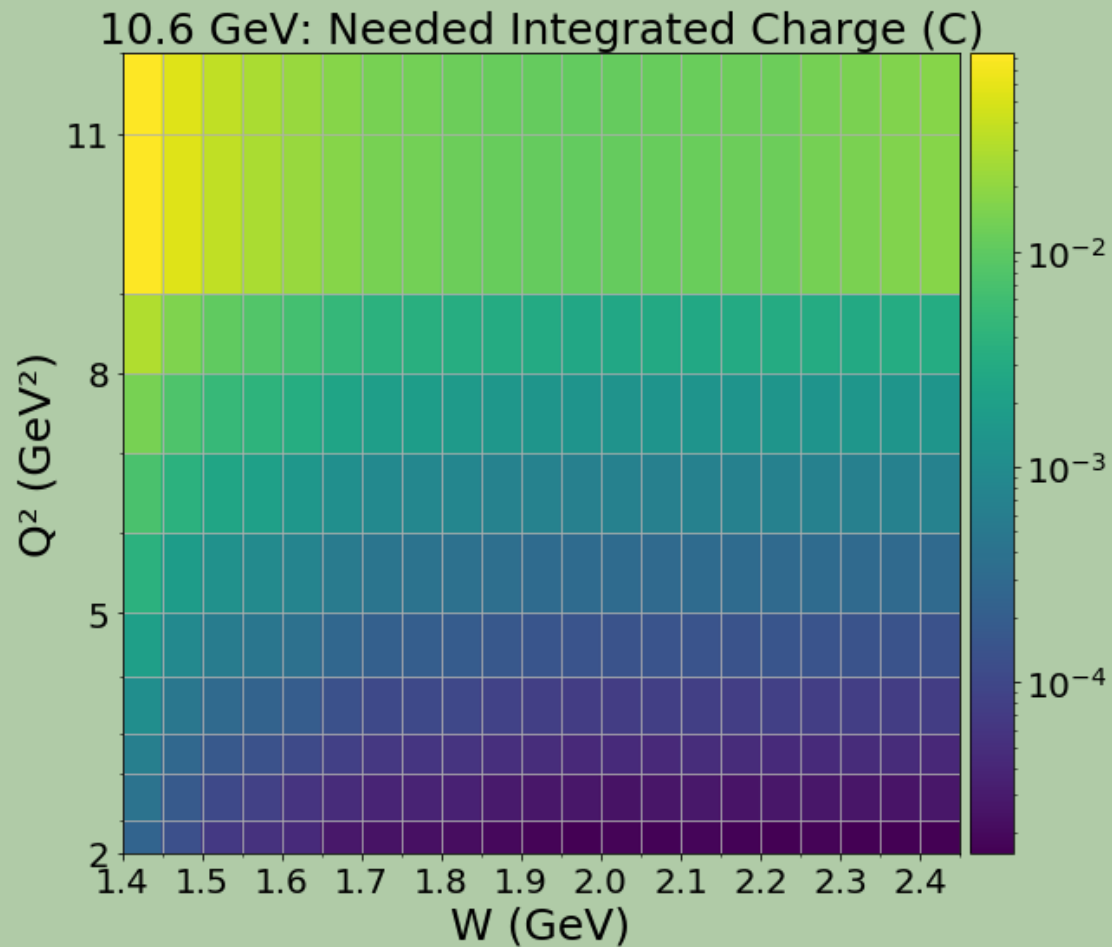
- Total probability for double pion electroproduction
- σ_{had} = sum of gen weights / number of gen events
- Cross section calculated to be represented in microbarns
 - $1 \mu\text{b} = 10^{-30} \text{ cm}^2$

Needed luminosity



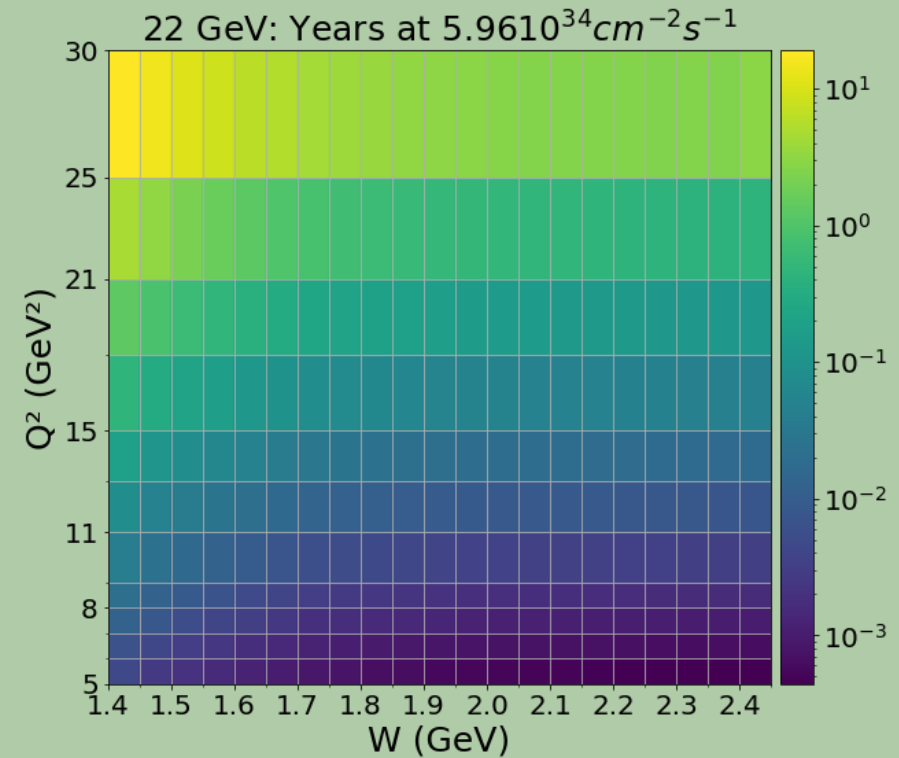
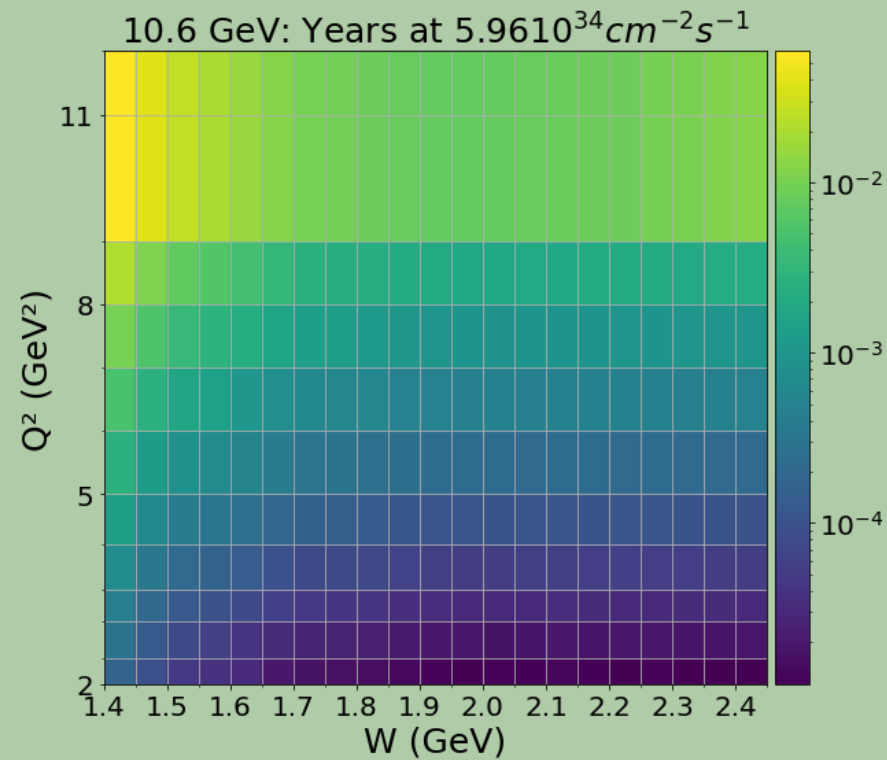
- σ_{elec} calculated similarly to σ_{had}
- Luminosity \mathcal{L} determined from acceptance and σ_{elec}

Needed integrated charge



- Charge calculated from luminosity by dividing out target density

Beam time needed, in years



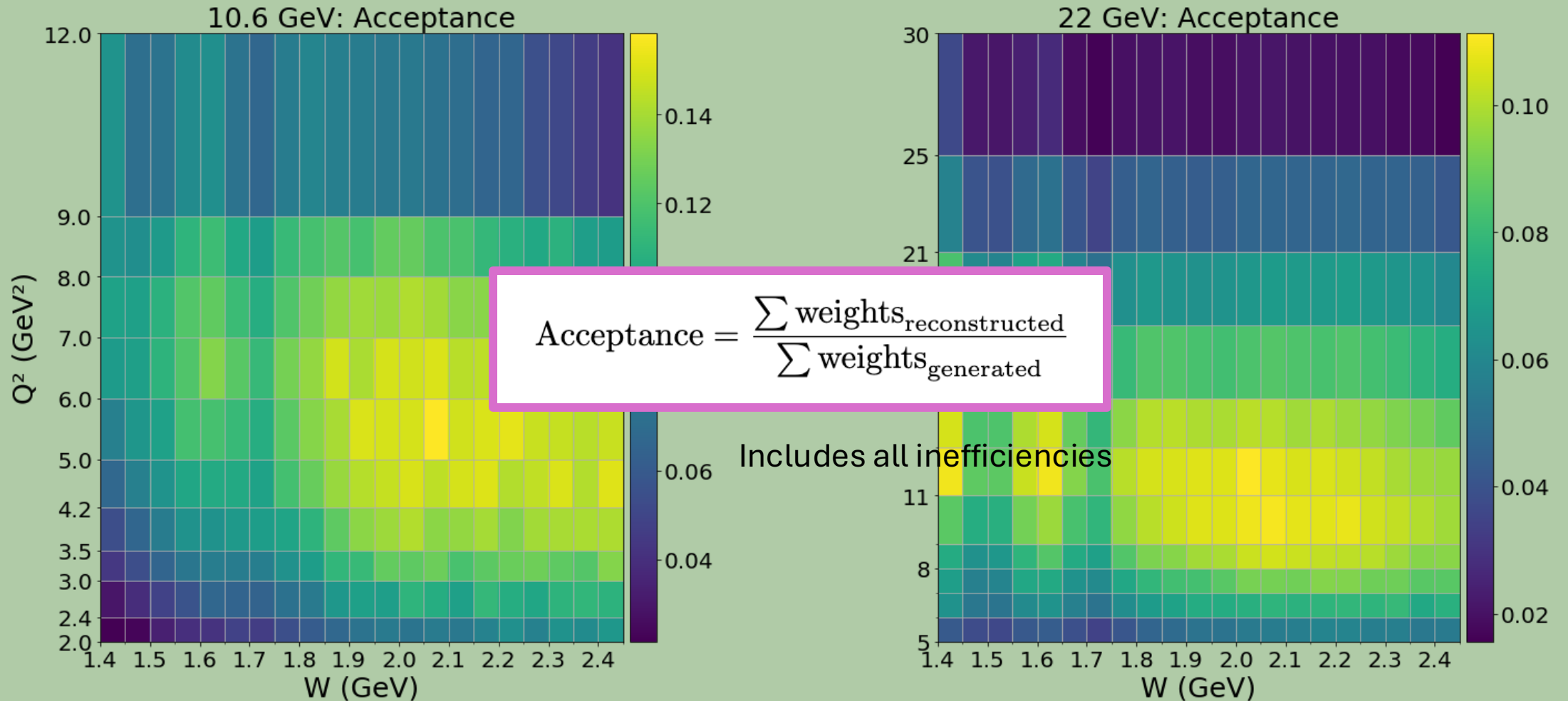
- Calculation for 10.6 GeV: implementing all analysis cuts [3/2], Golden Run Selection [3], PAC Days [2]
- For 22 GeV: 8 (16) years at $5.96 \cdot 10^{34} \text{cm}^{-2} \text{s}^{-1}$ **or** 11 (22) months at $5 \cdot 10^{35} \text{cm}^{-2} \text{s}^{-1}$
 - Days (PAC Days)

Conclusion

- Acceptance calculation improved with increased precision in the TWOPEG event generator
- Resolution for 10.6 GeV experiment (Fall 2018, inbending, golden runs) is comparable to resolution for 22 GeV simulation
- Needed beam time at designed luminosity is of the order of 11 months (22 PAC months)
 - Too early to say definitively how many PAC days (need more statistics)

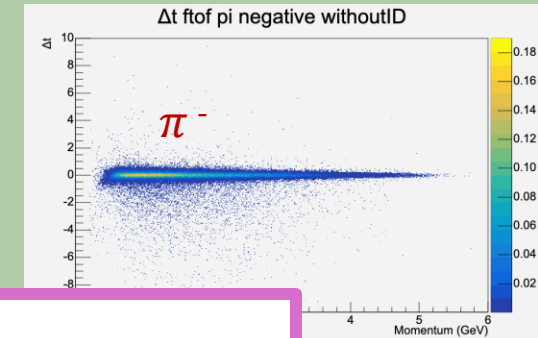
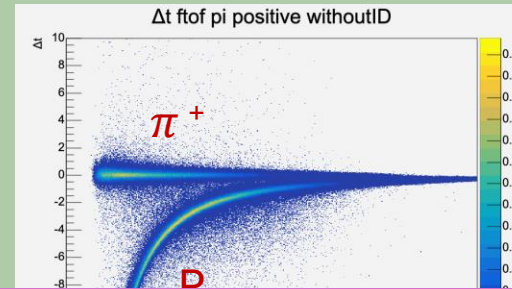
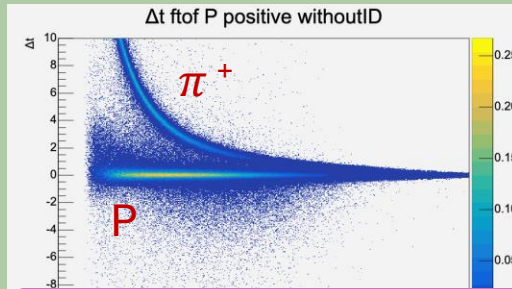
Back up slides

Acceptance

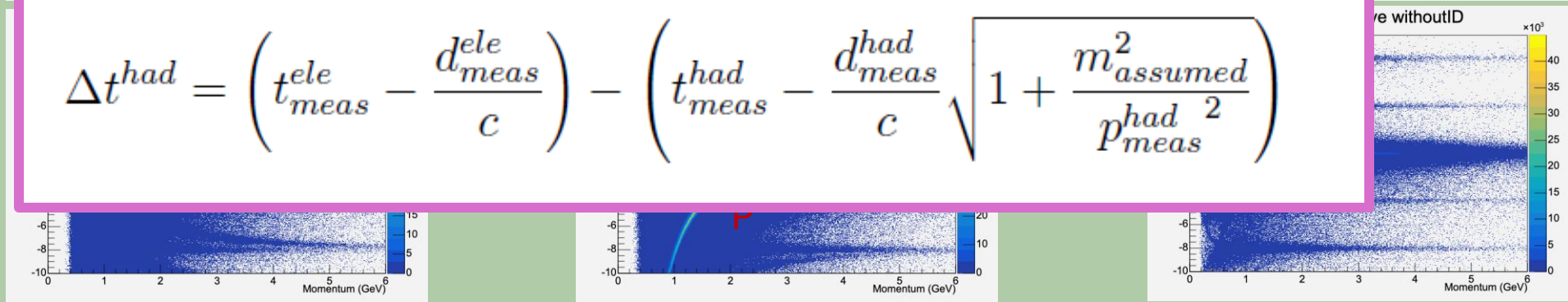


Momentum vs. Δt , forward detector, without ID

10.6 GeV
simulation

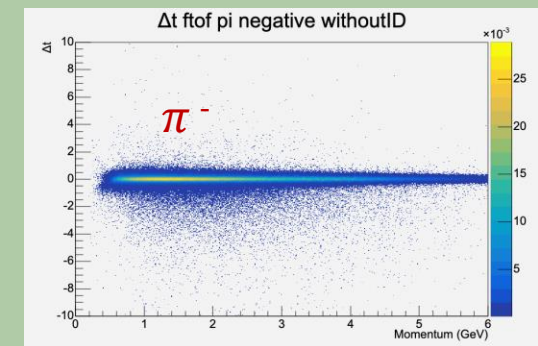
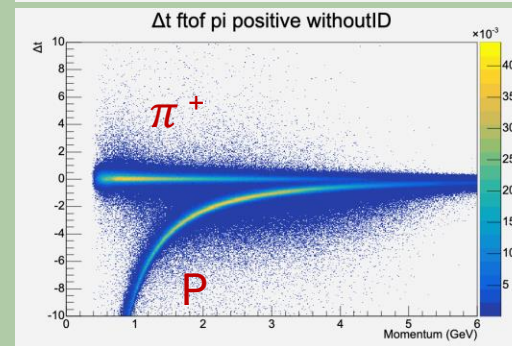
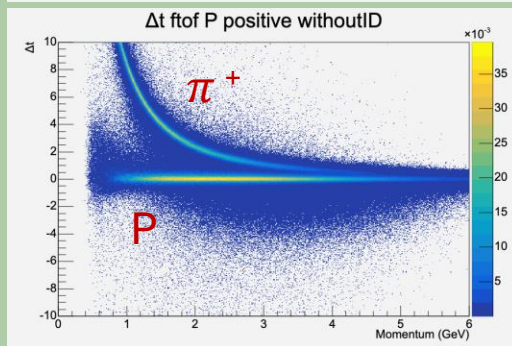


10.6 GeV
experiment



$$\Delta t^{had} = \left(t_{meas}^{ele} - \frac{d_{meas}^{ele}}{c} \right) - \left(t_{meas}^{had} - \frac{d_{meas}^{had}}{c} \sqrt{1 + \frac{m_{assumed}^2}{p_{meas}^{had\ 2}}} \right)$$

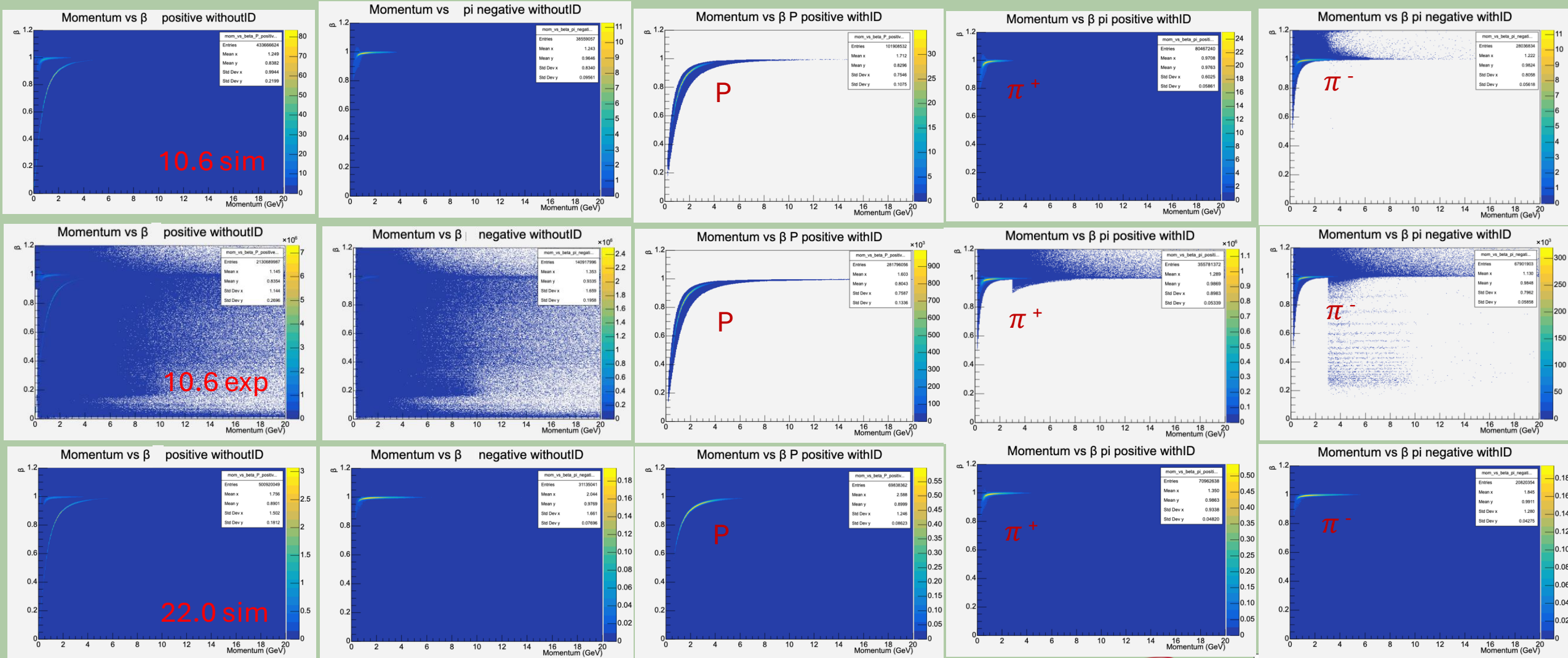
22.0 GeV
simulation



Momentum vs. β

Without ID

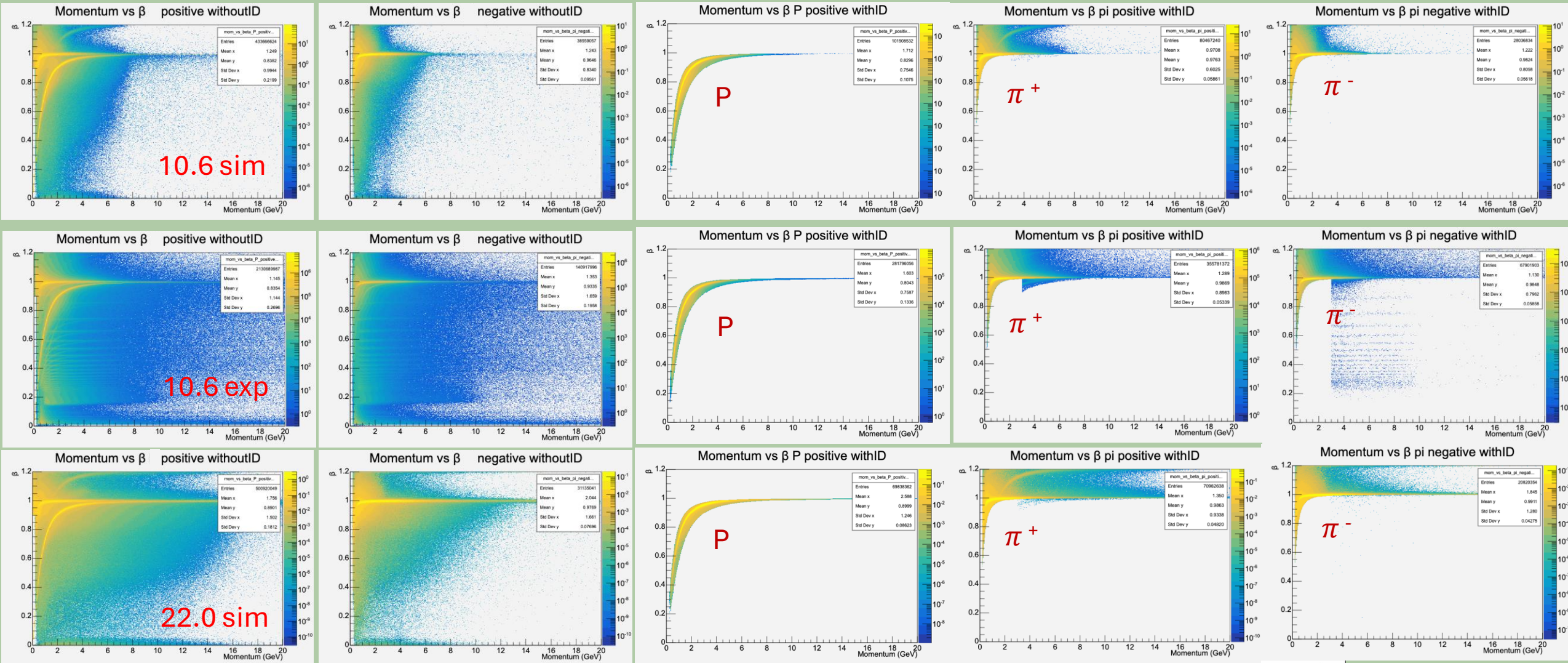
With ID



Momentum vs. β , log scale

Without ID

With ID

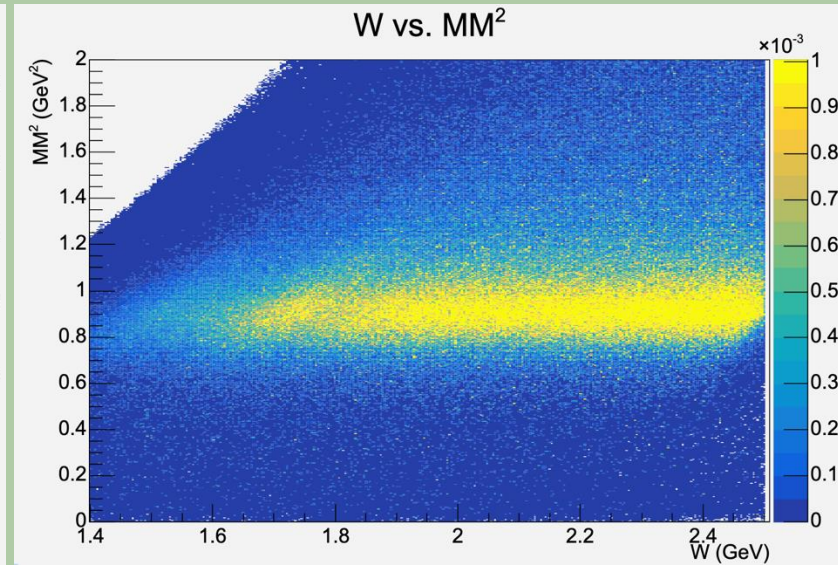
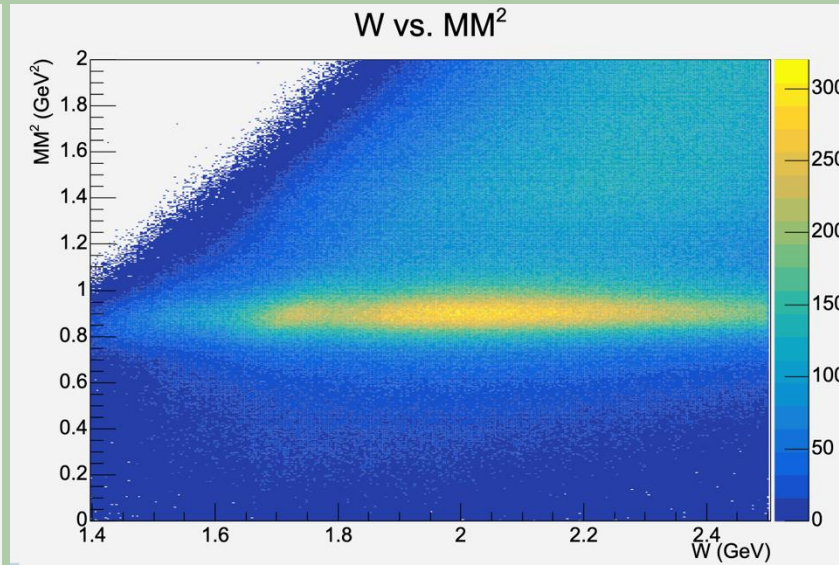
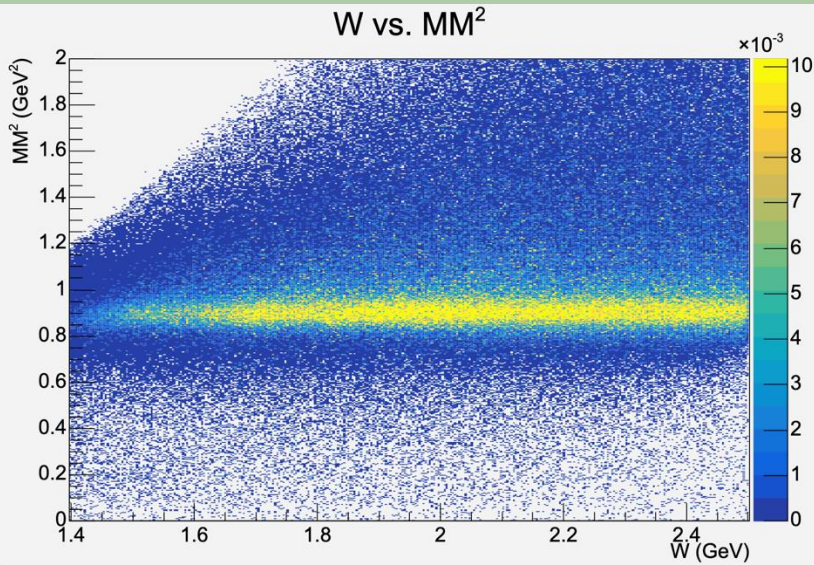


W vs. MM^2 for mProt

10.6 GeV simulation
TWOPEG event generator, pass 2

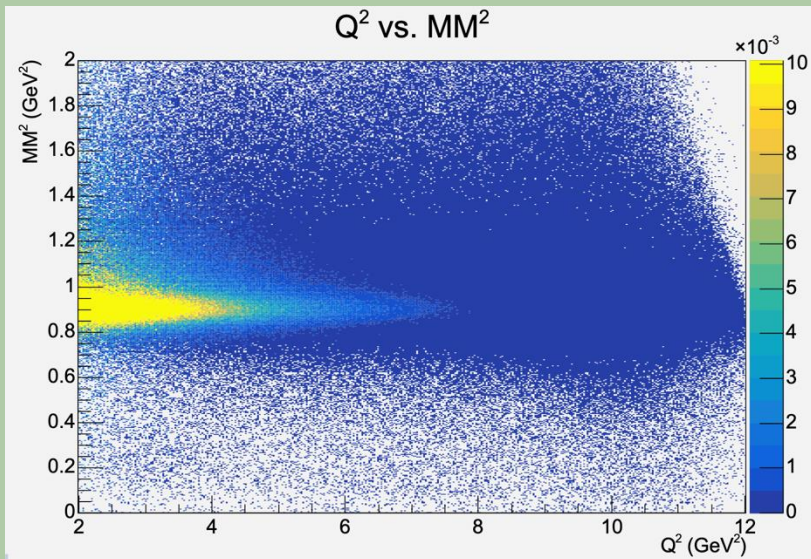
10.6 GeV experiment
Fall 2018, inbending, pass 2, golden runs

22.0 GeV simulation
TWOPEG event generator, pass 2

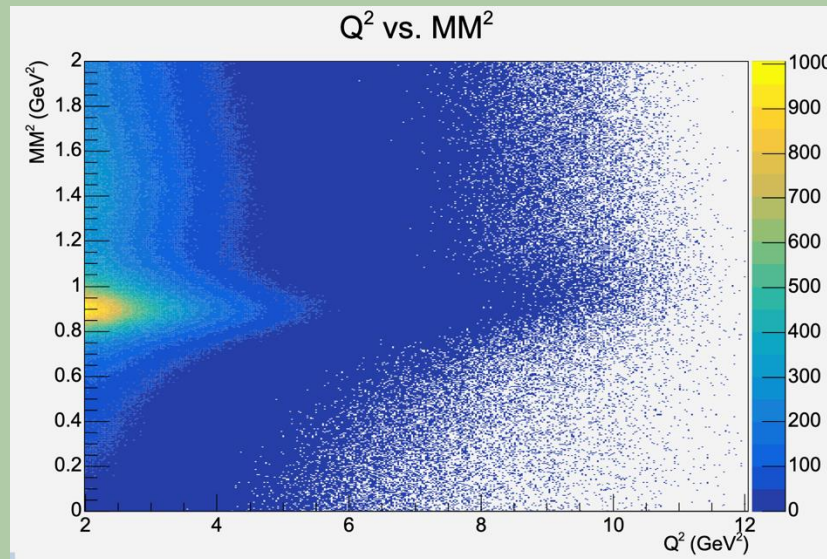


Q^2 vs. MM^2 for mProt

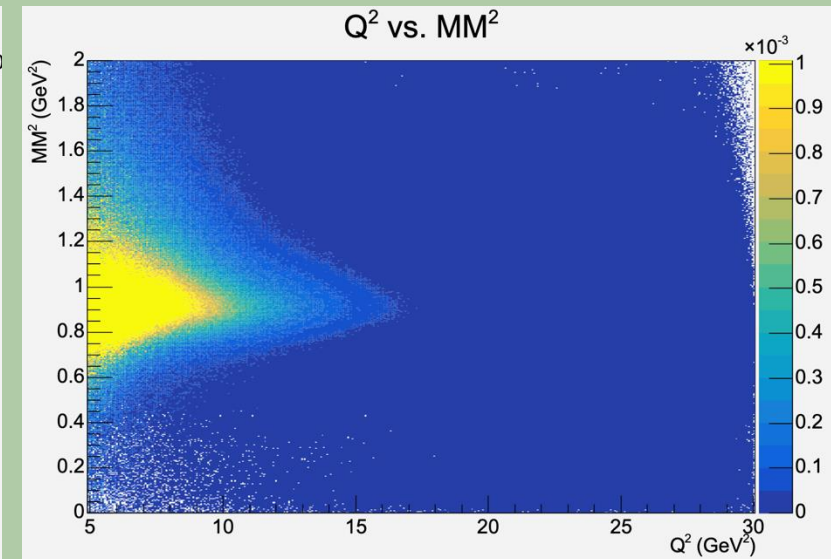
10.6 GeV simulation
TWOPEG event generator, pass 2



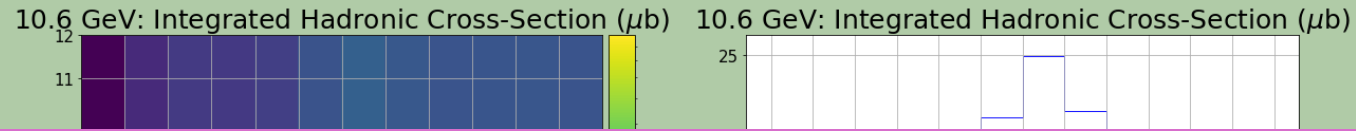
10.6 GeV experiment
Fall 2018, inbending, pass 2, golden runs



22.0 GeV simulation
TWOPEG event generator, pass 2



Integrated hadronic cross sections



$$\Phi = \frac{\left(\omega - \frac{Q^2}{2M_P}\right)}{137 \cdot 2\pi \cdot E_{\text{beam}} \cdot Q^2 \cdot (1 - \epsilon)} \cdot \frac{W}{E_{\text{beam}} \cdot M_P}$$

$$\sigma = \frac{\sum \text{weights}_{\text{generated}}}{\text{number of generated events} \cdot \Phi} \cdot \left[\frac{1}{\left(1 + \frac{Q^2}{0.7}\right)^{0.31660}} \right] \cdot \left[\left(\frac{1}{\left(1 + \frac{0.65}{0.7}\right)} \right)^{-1.18085} \right]$$

Φ = flux, 1/GeV³

ω = energy transfer (virtual photon energy), GeV

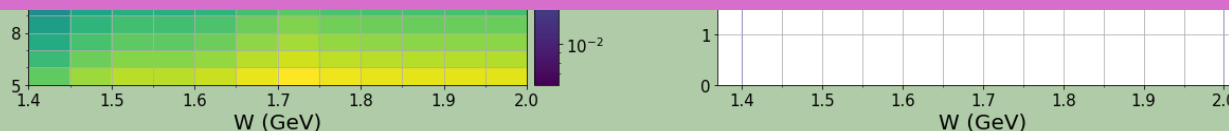
M_P = mass of proton, GeV

E_{beam} = energy of electron beam, GeV

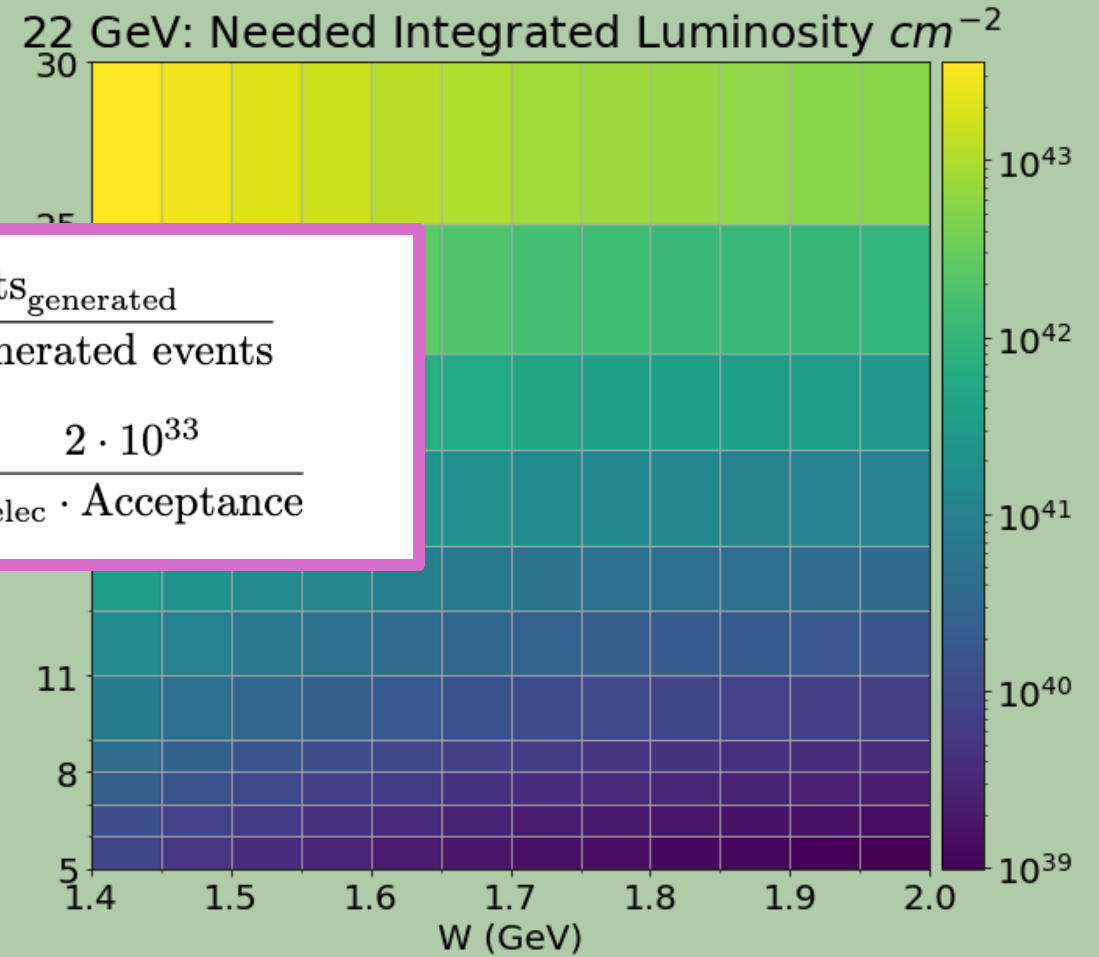
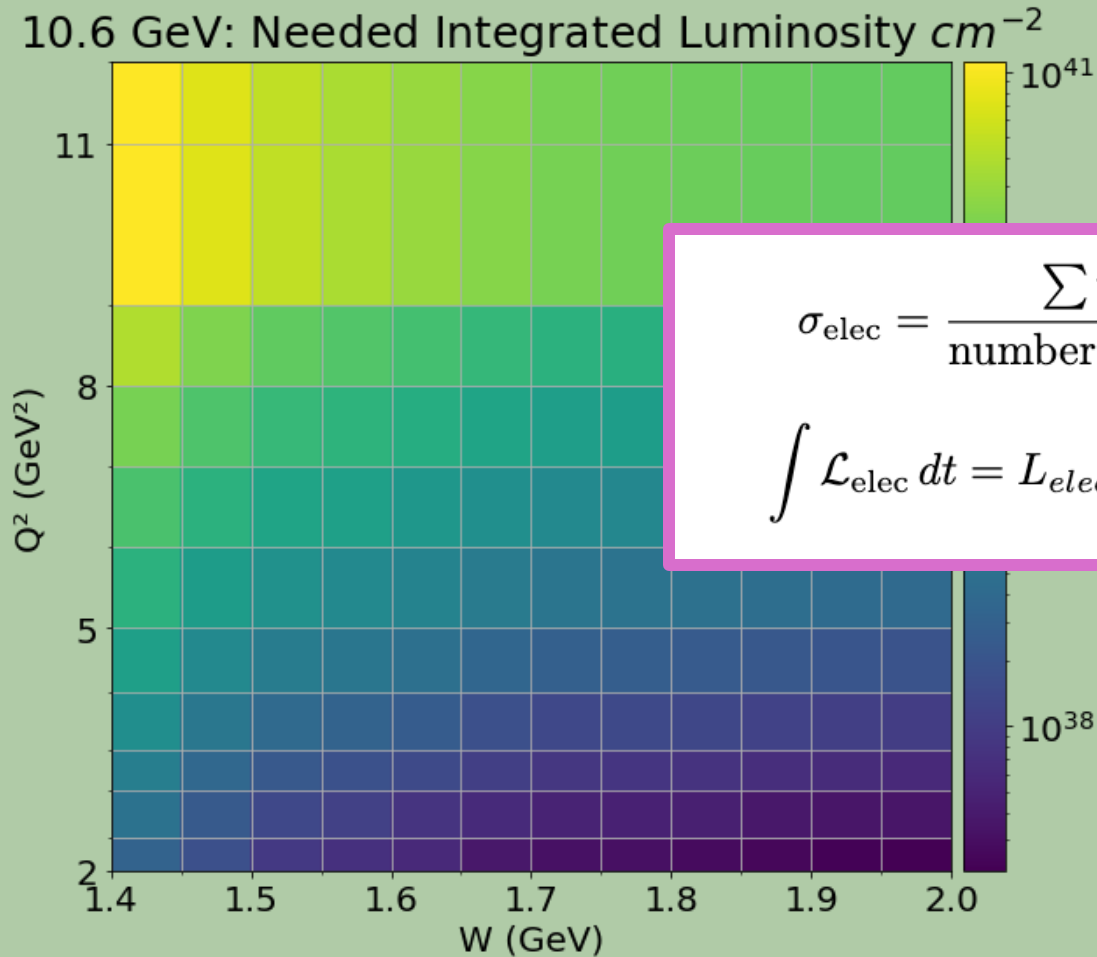
σ = cross section, 1 μb = 10⁻³⁰ cm²

$\sum \text{weights}_{\text{generated}}$ = sum of generated event weights, cm²

terms in brackets [] = correction factors, dimensionless



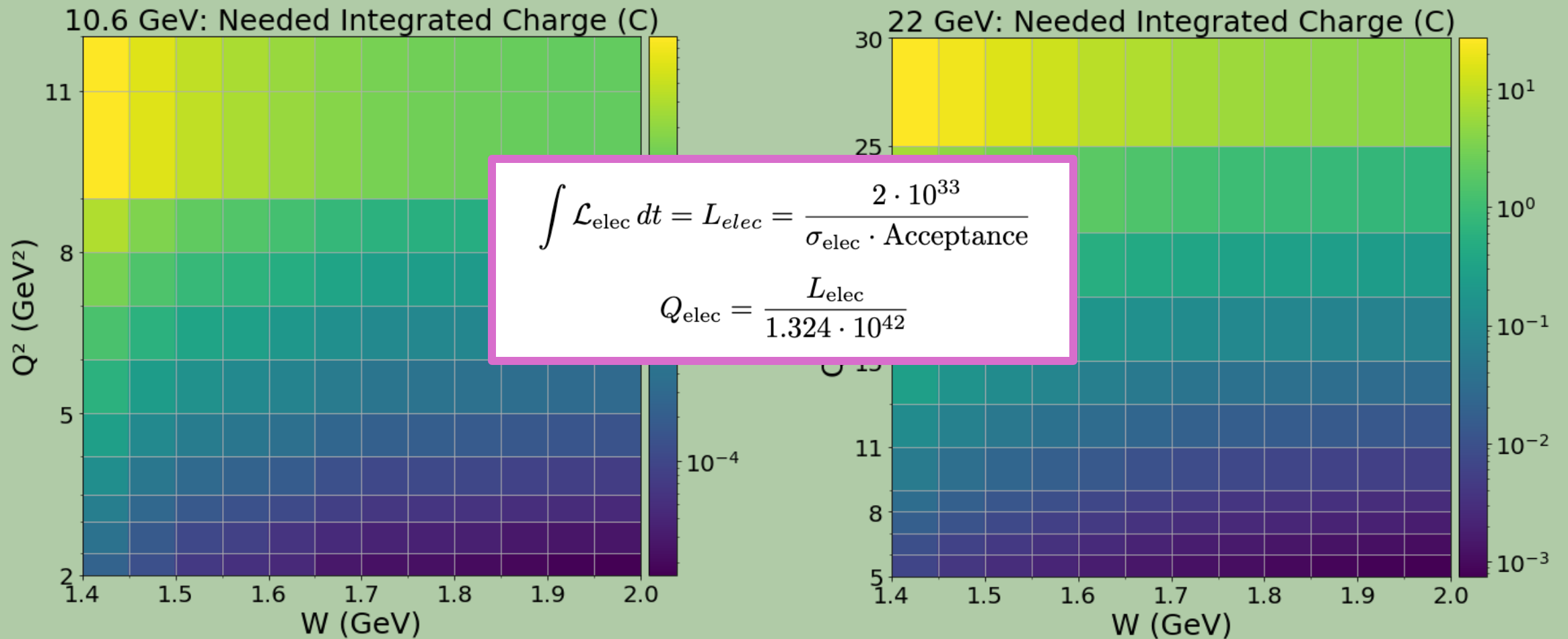
Needed luminosity



$$\sigma_{\text{elec}} = \frac{\sum \text{weights}_{\text{generated}}}{\text{number of generated events}}$$

$$\int \mathcal{L}_{\text{elec}} dt = L_{\text{elec}} = \frac{2 \cdot 10^{33}}{\sigma_{\text{elec}} \cdot \text{Acceptance}}$$

Needed integrated charge



Calculation of time needed

$$\text{Acceptance} = \frac{\sum \text{weights}_{\text{reconstructed}}}{\sum \text{weights}_{\text{generated}}}$$

$$\Phi = \frac{\left(\omega - \frac{Q^2}{2M_P}\right)}{137 \cdot 2\pi \cdot E_{\text{beam}} \cdot Q^2 \cdot (1 - \epsilon)} \cdot \frac{W}{E_{\text{beam}} \cdot M_P}$$

$$\sigma = \frac{\sum \text{weights}_{\text{generated}}}{\text{number of generated events} \cdot \Phi} \cdot \left[\frac{1}{\left(1 + \frac{Q^2}{0.7}\right)^{0.31660}} \right] \cdot \left[\left(\frac{1}{\left(1 + \frac{0.65}{0.7}\right)} \right)^{-1.18085} \right]$$

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M_P = mass of proton, GeV

E_{beam} = energy of electron beam, GeV

σ = cross section, 1 μb = 10⁻³⁰ cm²

$\sum \text{weights}_{\text{generated}}$ = sum of generated event weights, cm²

terms in brackets [] = correction factors, dimensionless

$$\sigma_{\text{elec}} = \frac{\sum \text{weights}_{\text{generated}}}{\text{number of generated events}}$$

$$\int \mathcal{L}_{\text{elec}} dt = L_{\text{elec}} = \frac{2 \cdot 10^{33}}{\sigma_{\text{elec}} \cdot \text{Acceptance}}$$

$$Q_{\text{elec}} = \frac{L_{\text{elec}}}{1.324 \cdot 10^{42}}$$

$$T_{\text{sec}} = \frac{Q_{\text{elec}}}{45 \cdot 10^{-9} \text{ C/s}}$$

$$T_{\text{years}} = \frac{\frac{Q_{\text{elec}}}{45 \cdot 10^{-9}}}{31,536,000 \text{ s/year}}$$

Time needed, in years

