Inclusive Systematics

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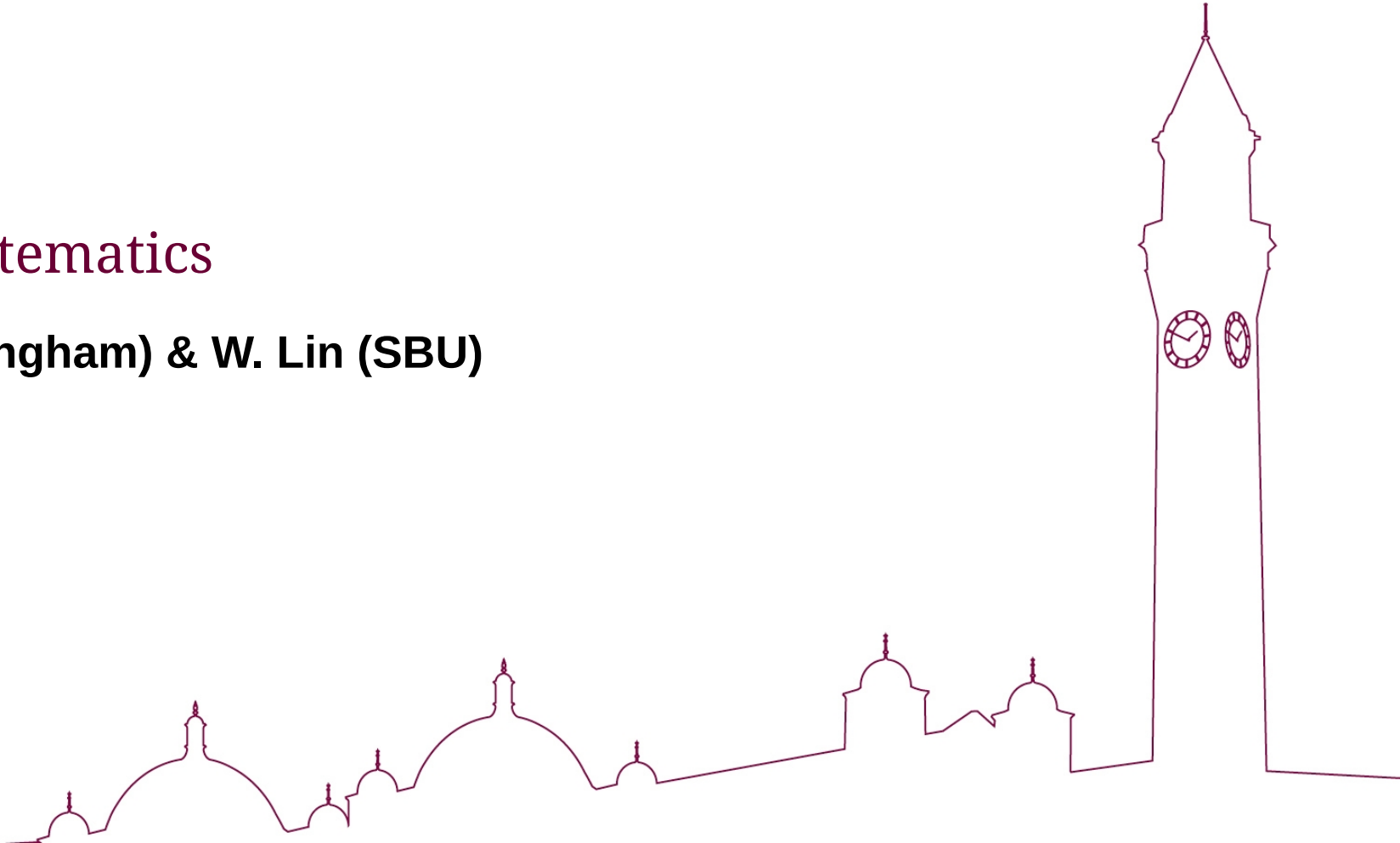
What systematics are we concerned with?

- There are many possible sources of systematic uncertainties
- Some contribute more than others

- Some impactful ones are:
  - Electron Finding Efficiency
  - Electron Energy scale
  - Electron Polar Angle
  - Hadronic Energy scale
  - Background modelling
  - QED Radiative Corrections

- ...and of course, luminosity/polarisation

Source	Region	Uncertainty
Electron energy scale	$z_{\mathrm{imp}} \leq -150\,\mathrm{cm}$	0.5% unc. $\oplus$ 0.3% corr.
	$-150 < z_{\mathrm{imp}} \leq -60\,\mathrm{cm}$	0.3% unc. $\oplus$ 0.3% corr.
	$-60 < z_{\mathrm{imp}} \leq +20\,\mathrm{cm}$	0.5% unc. $\oplus$ 0.3% corr.
	$+20 < z_{\mathrm{imp}} \leq +110\,\mathrm{cm}$	0.5% unc. $\oplus$ 0.3% corr.
	$z_{\mathrm{imp}} > +110\,\mathrm{cm}$	1.0% unc. $\oplus$ 0.3% corr.
Electron scale linearity	$E'_e < 11\,\mathrm{GeV}$	0.5%
Hadronic energy scale	LAr & Tracks	1.0% unc. $\oplus$ 0.3% corr.
	SpaCal	5.0% unc. $\oplus$ 0.3% corr.
Polar angle	θ_e	1 mrad corr.
Noise	$y < 0.19$	5% energy not in jets , corr.
	$y > 0.19$	20% corr.
Trigger efficiency	high y	0.3 − 2%
	nominal	0.3%
Electron track and vertex efficiency	high y	1%
	nominal	0.2 − 1%
Electron charge ID efficiency	high y	0.5%
Electron ID efficiency	high y $z_{\mathrm{imp}} < 20\ (> 20)$ cm	0.5% (1%)
	nominal $z_{\mathrm{imp}} < 20\ (> 20)$ cm	0.2% (1%)
Extra background suppression	$E'_e < 10\,\mathrm{GeV}$	$D_{ele} > 0.80 \pm 0.04$ corr.
High y background subtraction	high y	1.03 ± 0.08 corr.
QED radiative corrections	$x < 0.1,\, 0.1 \leq x < 0.3,\, x \geq 0.3$	0.3% , 1.0%, 2.0%
	high y: $y < 0.8\ (y > 0.8)$	1% (1.5%)
Acceptance corrections	high y	0.5%
	nominal	0.2%
Luminosity		4% corr.

https://arxiv.org/abs/1312.4821

Systematic uncertainty	Achieved at H1/ZEUS*	Expected at EIC[†]	Possible studies
Electron finder efficiency	0.2-5% (increase w y)	???	Tighten and relax cuts used in e-finding → study variation in efficiency
Electron energy scale	0.5-1.9% (increase w y) (1-5% on σ)	???	Take a guess – using 0.5% for now?
Electron polar angle	1mrad	???	Take a guess – using 1mrad for now?
Hadronic energy scale	2% (0.5-4% on σ)	???	Take a guess – using 1% for now?
Photoproduction background	10% (0.5-3% on σ)	2% on σ	Compare number of events produced by different generators that are reconstructed as DIS
QED radiative corrections	0.3-2% (increase w x,y)	1%	Compare size of radiative correction in bins with different event generators/generator settings
Luminosity	1.5%	1%	Use ~~1%~~ 1.5%?
Polarisation	N/A	<1% ?	Use ~~1%~~ 1.5%?

* choosing the better of the values in previous publications from H1, ZEUS   † numbers from YR
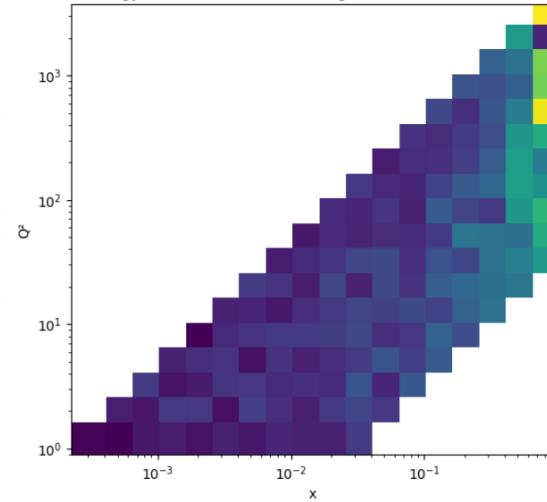
Impact of each Electron Energy Scale Systematic

Electron Energy Scale (+0.5%) Percentage Difference from Nominal (ele)

Electron Energy Scale (+0.5%) Percentage Difference from Nominal (esig)

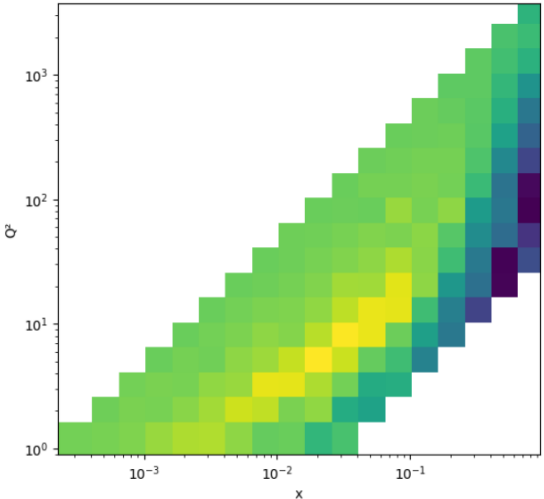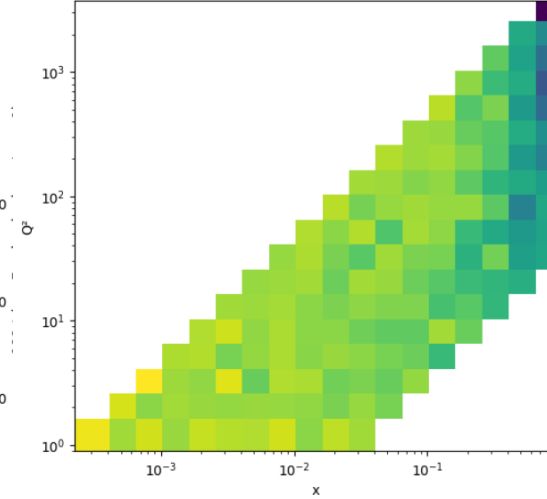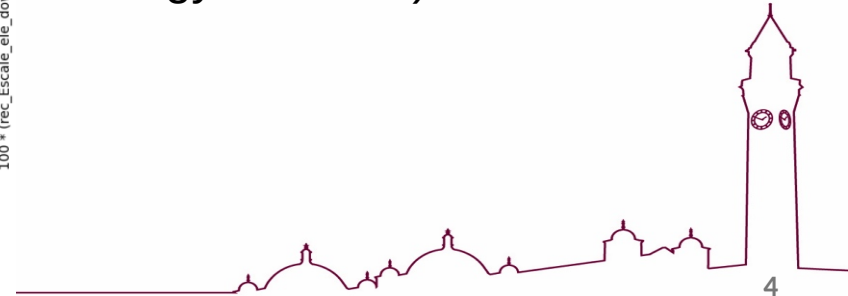Electron Energy Scale (-0.5%) Percentage Difference from Nominal (ele)
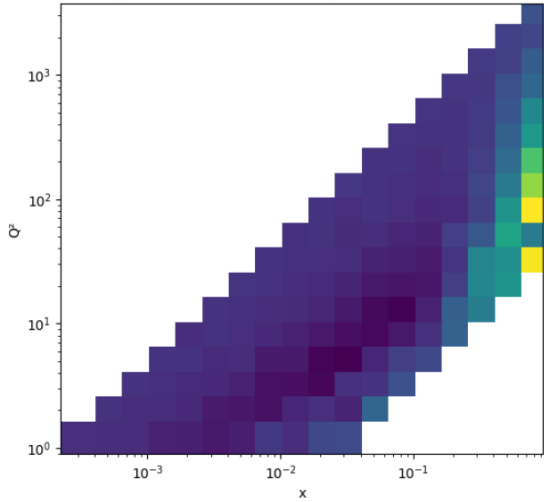
Electron Energy Scale (-0.5%) Percentage Difference from Nominal (esig)

- Electron method strongly impacted at low y (30-50% in most impacted bins), but typically small at moderate and high y

- E-Σ method more consistent across x-Q^2 plane, usually below a couple of percent

- No difference in DA (electron energy not used)

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Impact of each Hadron Energy Scale Systematic

Hadron Energy Scale (+1%) Percentage Difference from Nominal (esig)

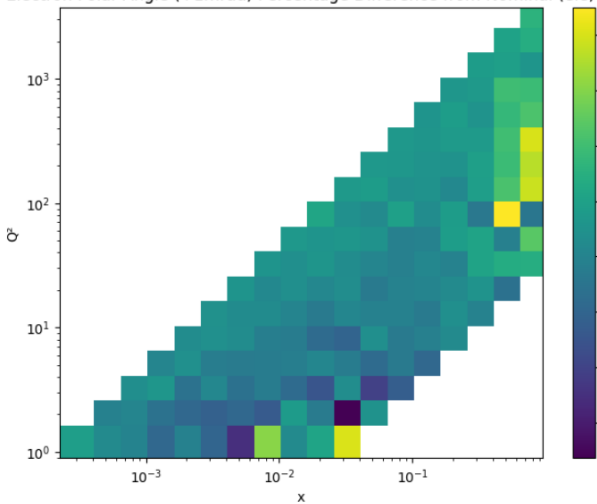Hadron Energy Scale (-1%) Percentage Difference from Nominal (esig)
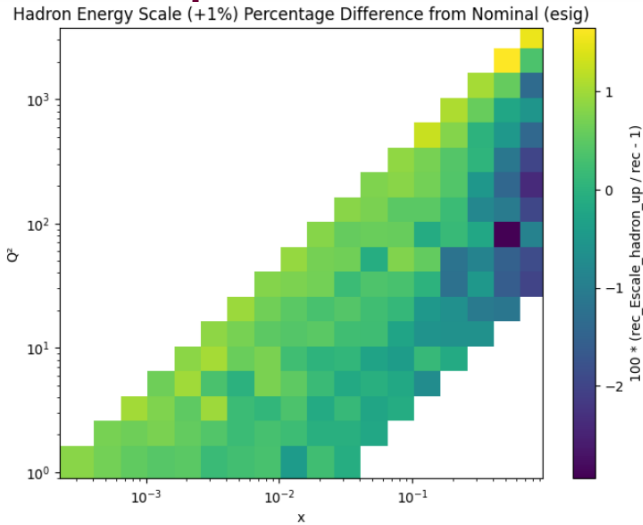
- HFS not used in electron method → no impact

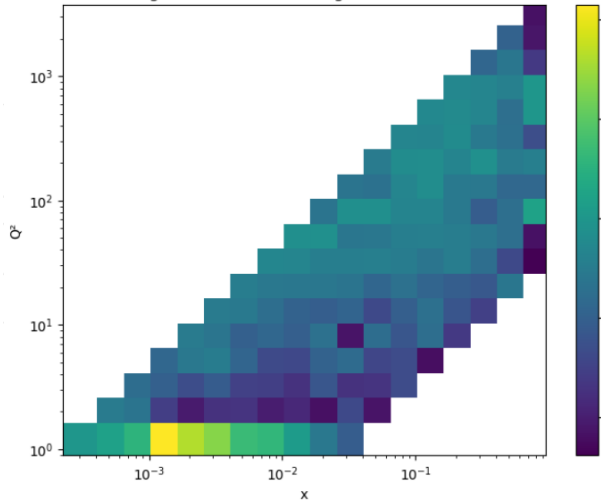- HFS angle calculated as $\delta_h / p_{t,h}$ → HFS energy cancels out → no impact on DA
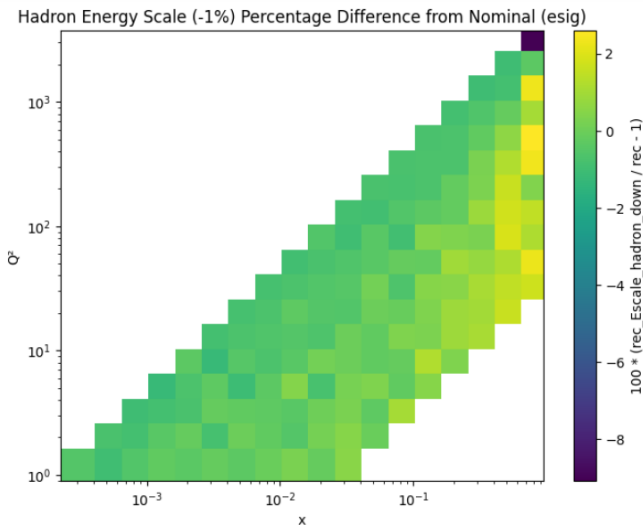
- E-Σ method impacted mostly at large x-Q^2, at most a couple of percent
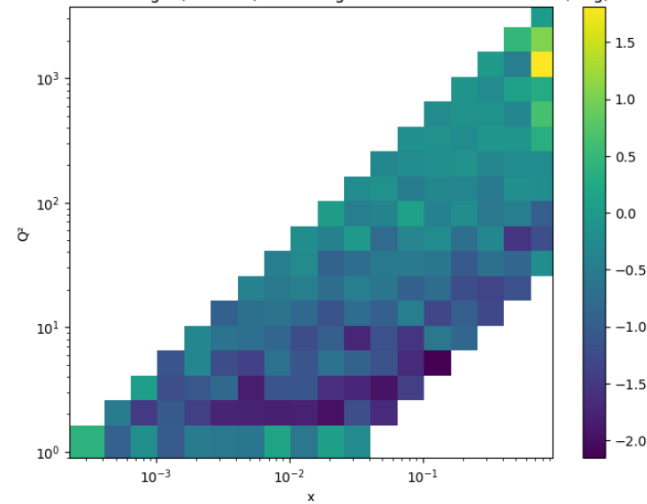
Impact of each Electron Polar Angle Systematic
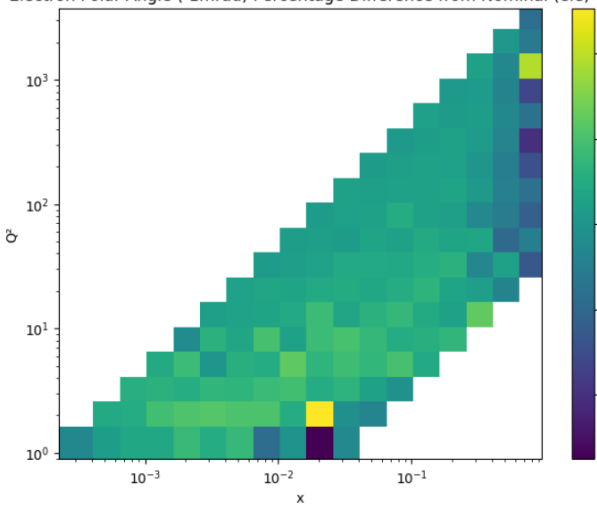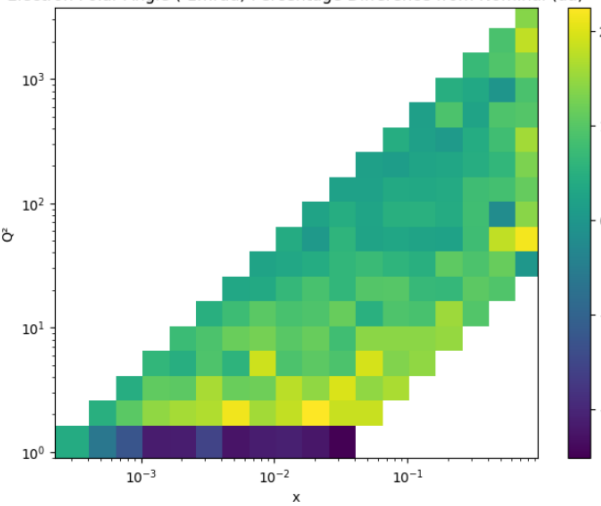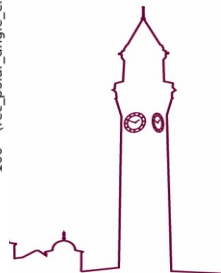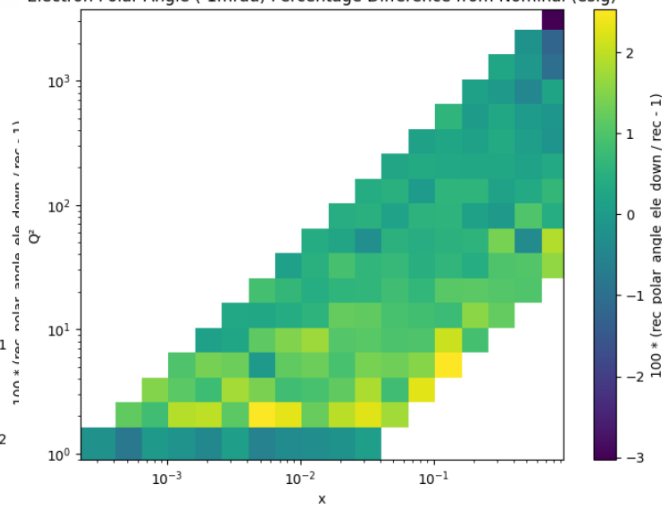
Total Uncertainty (%) from these 3 sources
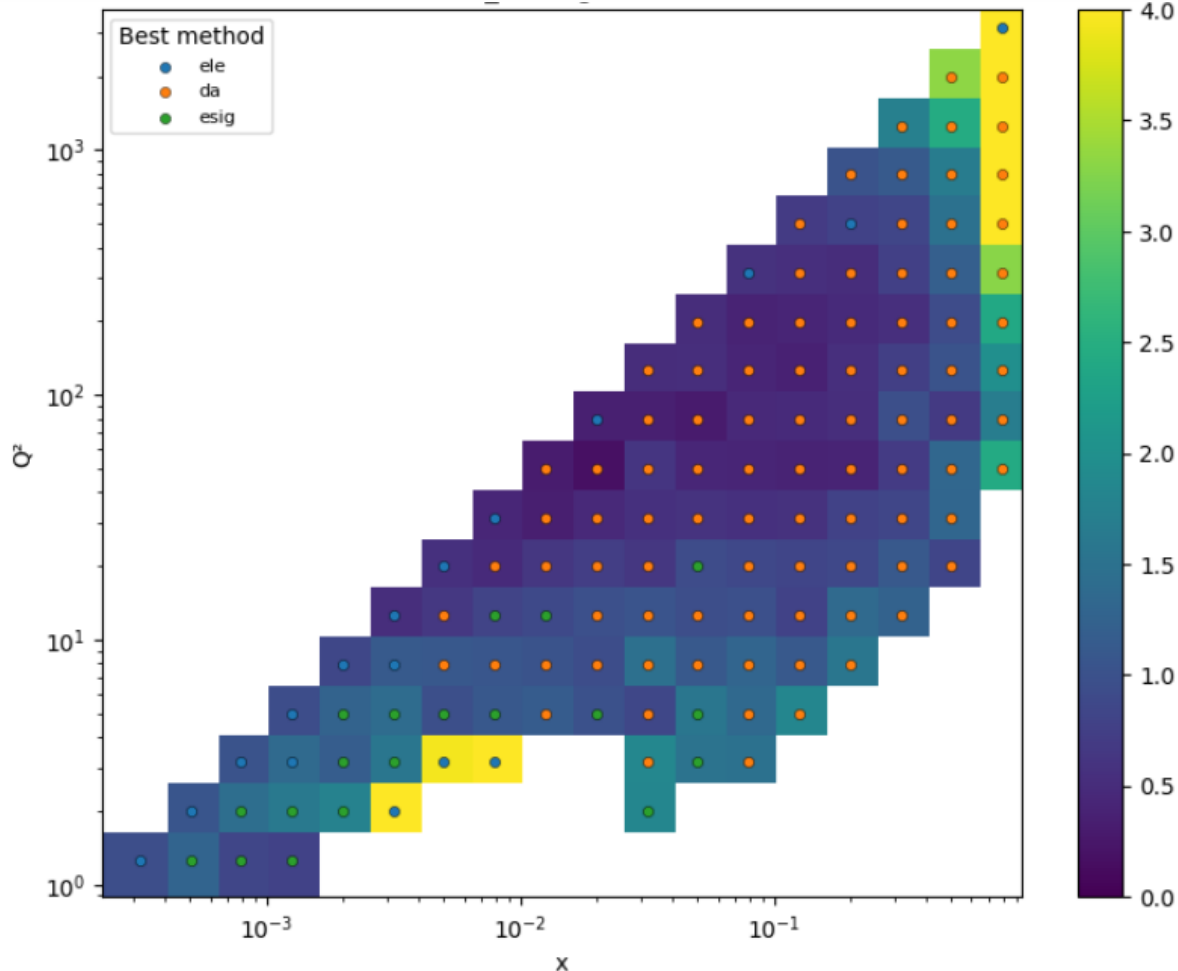
- Total uncertainty taken from sum in quadrature of statistical uncertainty (1fb^{-1}) and the average uncertainty from each systematic (0.5*(|+ve| + |-ve|))

- Plot the total uncertainty from the method that gives the best value
  - Require purity & stability > 30%

- Important: only considering 3 sources here, of which only 1 impacts the DA method → this spread will change with inclusion of more systematics

A_1^p systematics

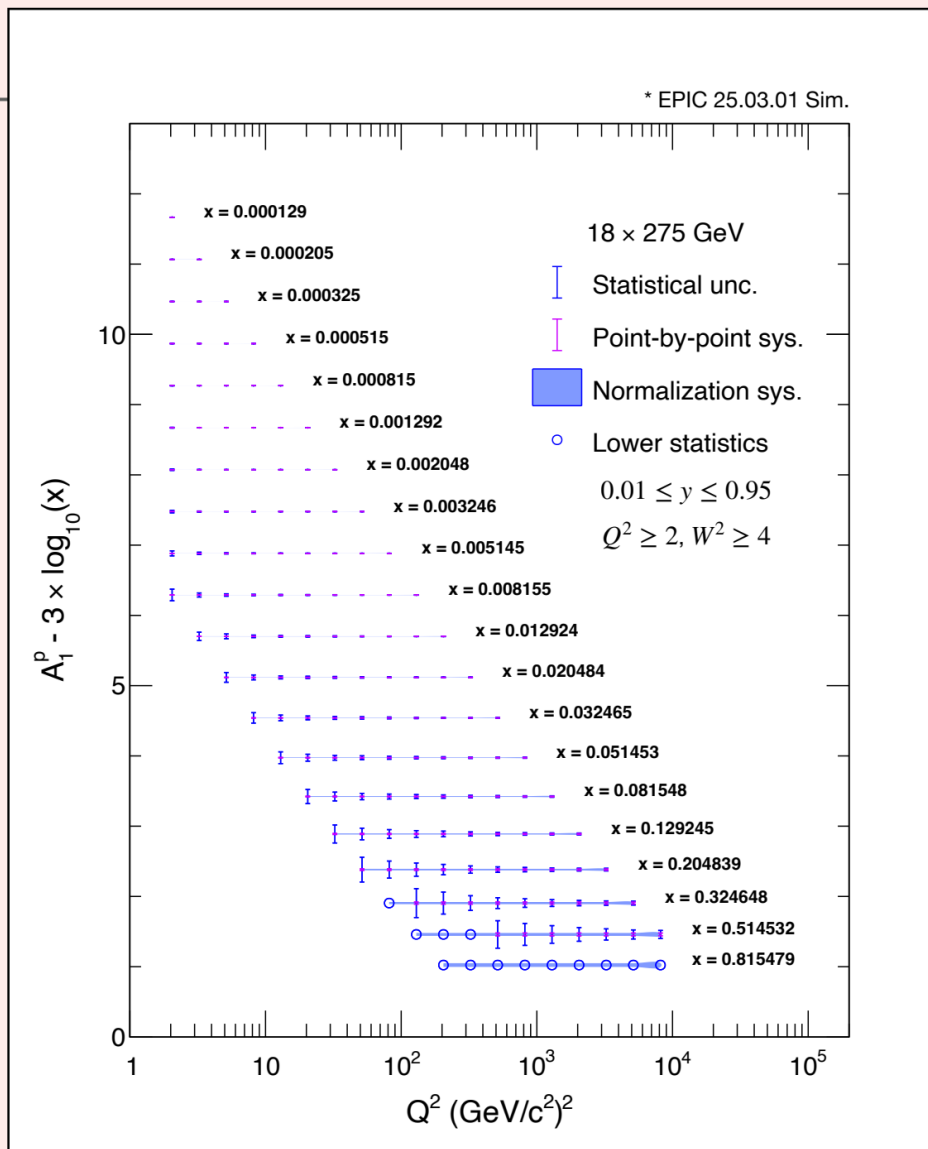- Statistical: $\delta A_{\parallel,\perp} \approx \dfrac{1}{\sqrt{N} P_e P_N}$

- Systematics is using <u>Barak's estimate</u> <u>for ATHENA</u> for $A_\parallel$

  - 1.5% point-by-point uncorrelated
  - 3% pion contamination
  - 3.5% normalization
    - 2% δP_e , 2% δP_N
    - 1-2% detector effects

- Estimated using $A_1 \approx \dfrac{A_\parallel}{D}$
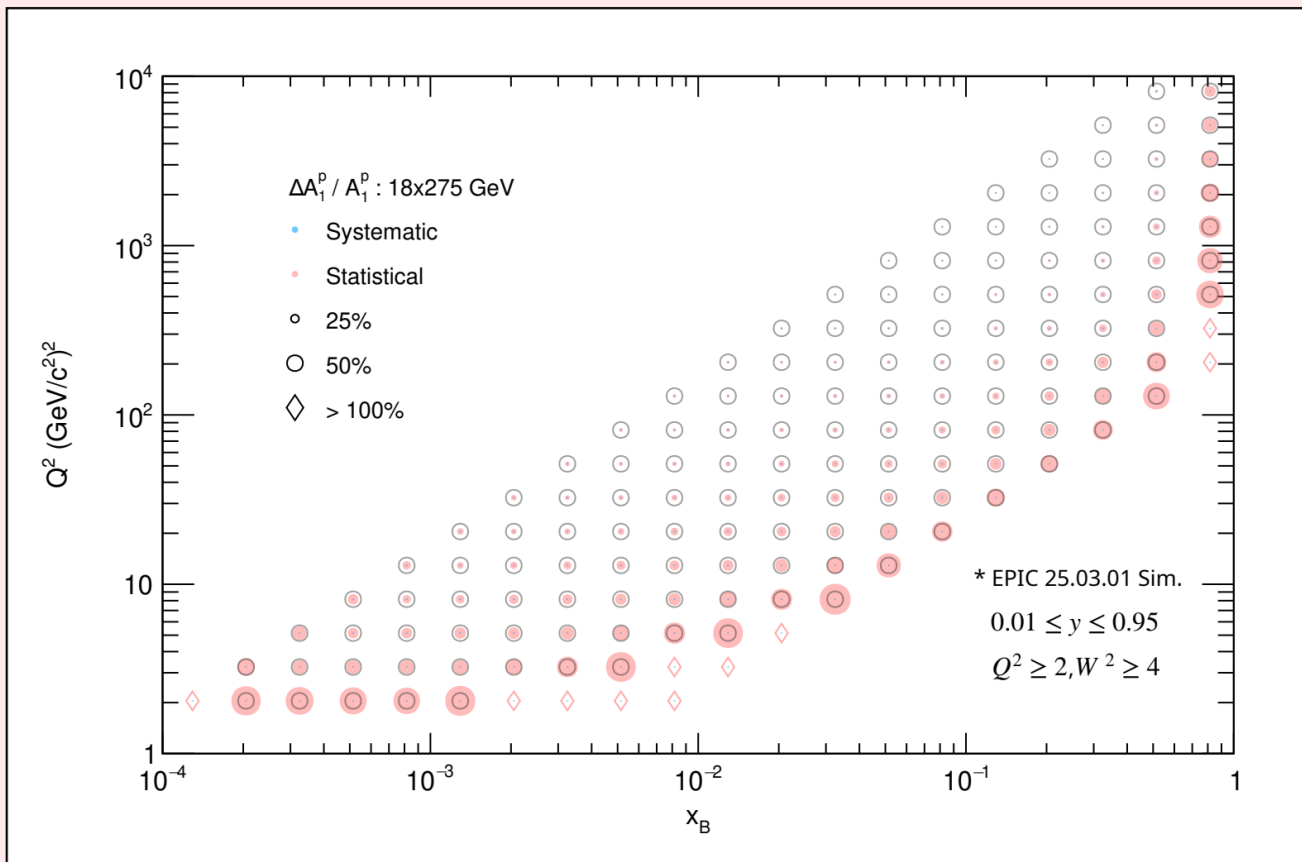

* EPIC 25.03.01 Sim.

A_1^p systematics

- Statistical: $\delta A_{\parallel,\perp} \approx \dfrac{1}{\sqrt{N} P_e P_N}$

- Systematics is using <u>Barak's estimate</u> <u>for ATHENA</u> for $A_\parallel$

  - 1.5% point-by-point uncorrelated

  - 3% pion contamination

  - 3.5% normalization

    - 2% δP_e, 2% δP_N

    - 1-2% detector effects

- Estimated using $A_1 \approx \dfrac{A_\parallel}{D}$

$\Delta A_1^p / A_1^p$: 18x275 GeV

- Systematic (blue)
- Statistical (pink)
- ◦ 25%
- ○ 50%
- ◇ > 100%

* EPIC 25.03.01 Sim.
$0.01 \leq y \leq 0.95$
$Q^2 \geq 2, W^2 \geq 4$

Q² axis: Q^2 (GeV/c²)²
x axis: x_B

- Statistical: $\delta A_{\parallel,\perp} \approx \dfrac{1}{\sqrt{N}P_e P_N}$

- Systematics is using <u>Barak's estimate</u> <u>for ATHENA</u> for $A_{\parallel}$

  - 1.5% point-by-point uncorrelated

  - 3% pion contamination

  - 3.5% normalization

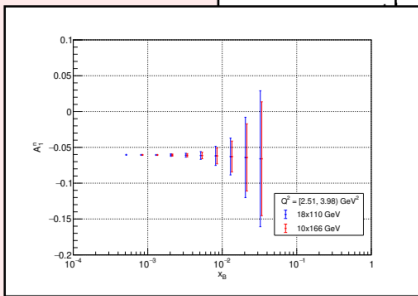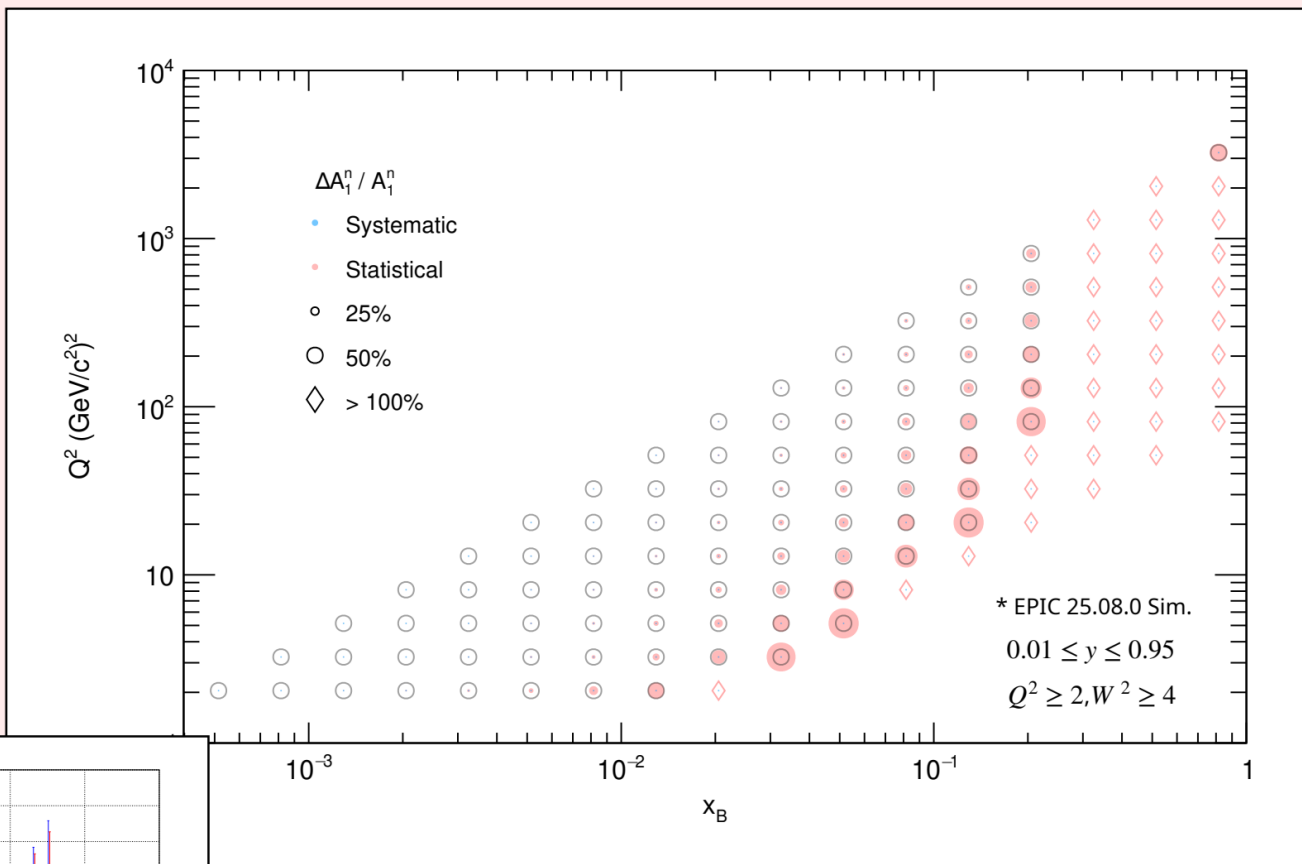   - 2% δP_e , 2% δP_N

    - 1-2% detector effects

- Estimated using $A_1 \approx \dfrac{A_{\parallel}}{D}$

$\Delta A_1^n / A_1^n$

- Systematic
- Statistical
- 25%
- 50%
- $\diamond$ > 100%

* EPIC 25.08.0 Sim.
$0.01 \leq y \leq 0.95$
$Q^2 \geq 2, W^2 \geq 4$

Summary

- Plans in place to study important systematics
  - So far estimations for three possible systematic uncertainties on NC σ_r measurement
  - More studies upcoming
- From the three uncertainties, vast majority of bins have <3% total uncertainty
  - Will see how this changes as other systematics are included
- YR/Athena inspire estimates for $A_1^{(n,p)}$ systematics – measurement dominated by statistical uncertainty

Next Steps

- Need to understand impact of beam and physics backgrounds + radiative corrections
  - Djangoh, photoproduction, merged background samples need to be generated and passed through sim/recon/analysis
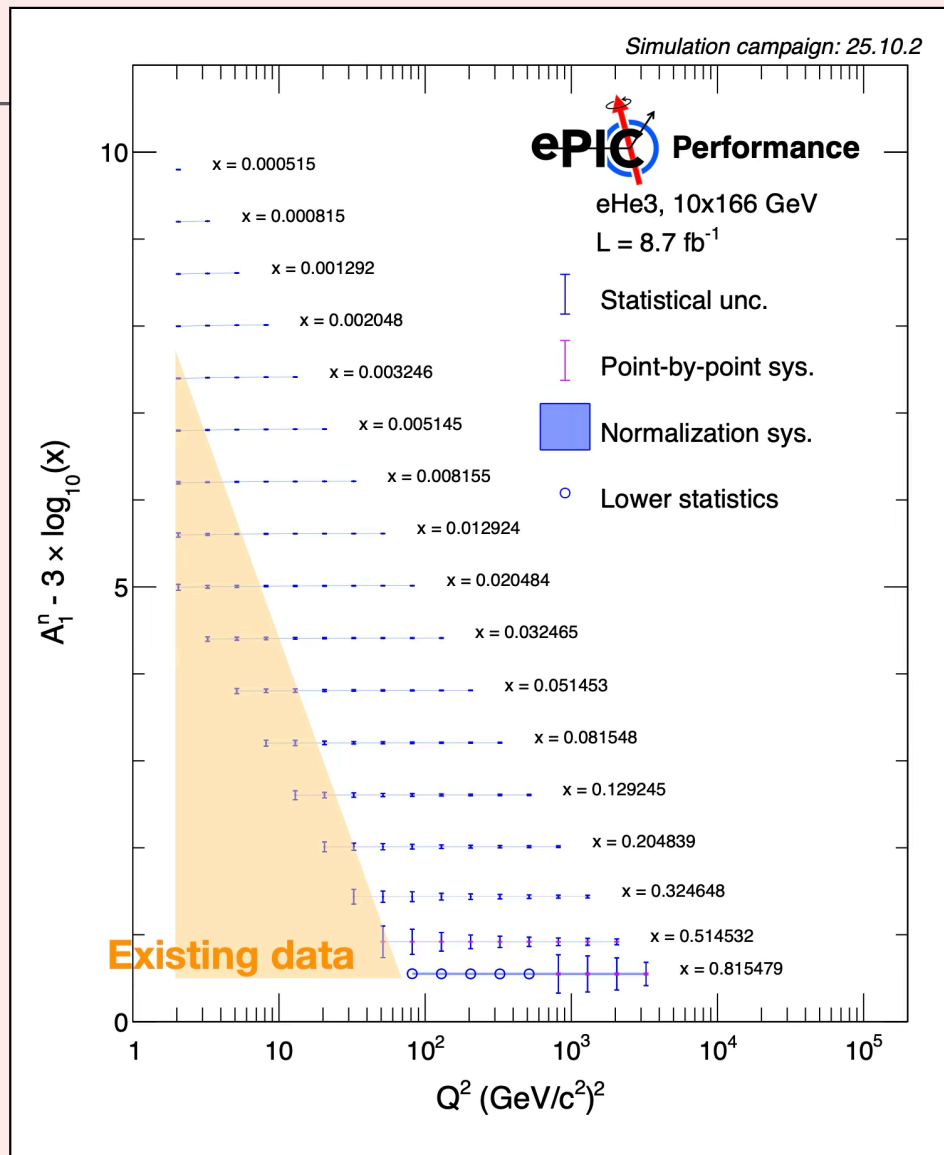 - Evaluate using realistic electron finder
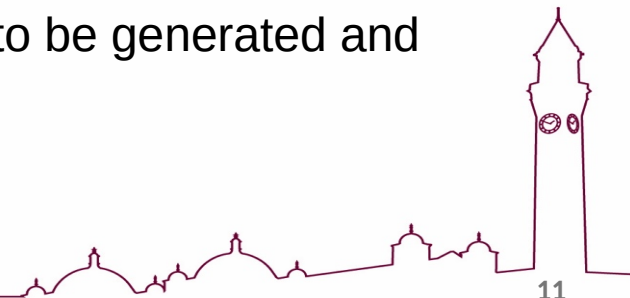
Backup

Projected A_1^n from $e\,{}^3$He DIS:

- Statistical: $\delta A_{\parallel,\perp} \approx \dfrac{1}{\sqrt{N}P_e P_N}$

- Systematics using <u>estimate for ATHENA</u> for $A_{\parallel}$

  - 1.5% point-by-point uncorrelated

  - 3% pion contamination

  - 4.7% normalization

    - 3% δP_e, 3% δP_N

    - 1-2% detector effects

- Estimated using $A_1 \approx \dfrac{A_{\parallel}}{D}$

- Systematics to be studied in more details

Projected g_1^n from e^3He DIS:

- $A_1 \sim g_1/F_1$ with F_1 calculated from <u>JAM22</u>

- $\Gamma = 8.65$ fb $^{-1}$, $P_e = P_n = 70\%$

- $0.01 < y < 0.95$, $Q^2 \, \mathcal{O} \, 2$, $W^2 > 4$

- Top plot: Includes statistical uncertainty,

  systematic estimate

- Bottom plot: Includes statistical uncertainty,

  systematic estimate, and F_1 uncertainty