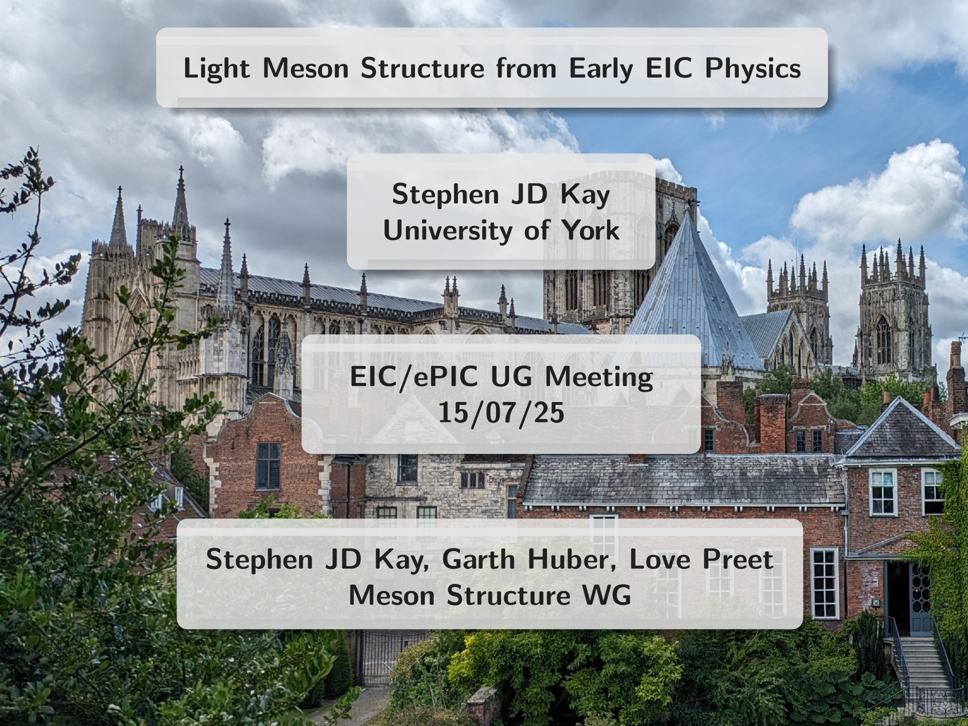


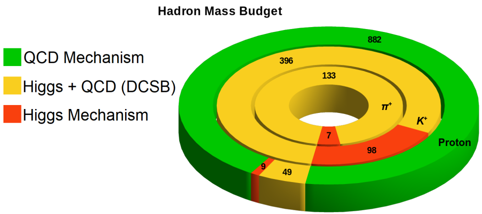
Light Meson Structure from Early EIC Physics

Stephen JD Kay
University of York

EIC/ePIC UG Meeting
15/07/25

Stephen JD Kay, Garth Huber, Love Preet
Meson Structure WG

Why Meson Structure - Hadron Mass Budgets

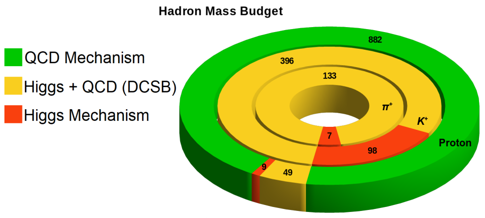


Revealing the structure of light pseudoscalar mesons at the electron–ion collider

J Arrington[1], C Ayerbe Gayoso[2], P C Barry[3,4], V Berdnikov[5], D Binosi[6], L Chang[7], M Diefenthaler[3], M Ding[6], R Ent[3], T Frederico[8], Y Furletova[3], T J Hobbs[3,9,10], T Horn[3,5,*], G M Huber[11], S J D Kay[11], C Keppel[3], H-W Lin[12], C Mezrag[13], R Montgomery[14], I L Pegg[5], K Raya[7,15], P Reimer[16], D G Richards[3], C D Roberts[17,18], J Rodríguez-Quintero[19], D Romanov[3], G Salmè[20], N Sato[3], J Segovia[21], P Stepanov[5], A S Tadepalli[3] and R L Trotta[5]

Image - G. Huber, modified figure from paper listed.

Why Meson Structure - Hadron Mass Budgets

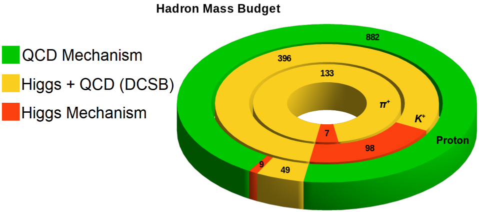


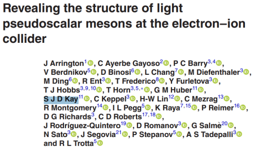
Revealing the structure of light pseudoscalar mesons at the electron–ion collider

J Arrington[1], C Ayerbe Gayoso[2], P C Barry[3,4], V Berdnikov[5], D Binosi[6], L Chang[7], M Diefenthaler[3], M Ding[6], R Ent[3], T Frederico[8], Y Furletova[3], T J Hobbs[3,9,10], T Horn[3,5,*], G M Huber[11], S J D Kay[11], C Keppel[3], H-W Lin[12], C Mezrag[13], R Montgomery[14], I L Pegg[5], K Raya[7,15], P Reimer[16], D G Richards[3], C D Roberts[17,18], J Rodríguez-Quintero[19], D Romanov[3], G Salmè[20], N Sato[3], J Segovia[21], P Stepanov[5], A S Tadepalli[3] and R L Trotta[5]

- Only the portion in red is directly from the Higgs current
- Multiple mechanisms at play to give hadrons their mass

Image - G. Huber, modified figure from paper listed.

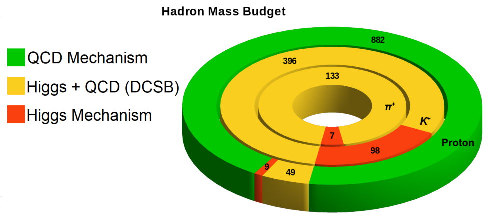


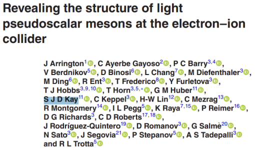

Revealing the structure of light pseudoscalar mesons at the electron–ion collider

J Arrington[1], C Ayerbe Gayoso[2], P C Barry[3,4], V Berdnikov[5], D Binosi[6], L Chang[7], M Diefenthaler[3], M Ding[6], R Ent[3], T Frederico[8], Y Furletova[3], T J Hobbs[3,9,10], T Horn[3,5,*], G M Huber[11], S J D Kay[11], C Keppel[3], H-W Lin[12], C Mezrag[13], R Montgomery[14], I L Pegg[5], K Raya[7,15], P Reimer[16], D G Richards[3], C D Roberts[17,18], J Rodríguez-Quintero[19], D Romanov[3], G Salmè[20], N Sato[3], J Segovia[21], P Stepanov[5], A S Tadepalli[3] and R L Trotta[5]

- Only the portion in red is directly from the Higgs current
- Multiple mechanisms at play to give hadrons their mass
  - Mass generation mechanisms intricately connected to structure

Why Meson Structure - Hadron Mass Budgets



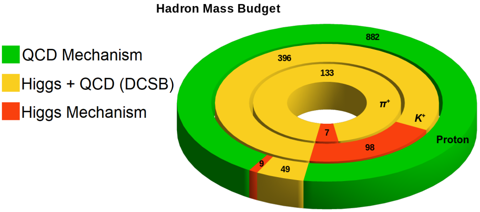


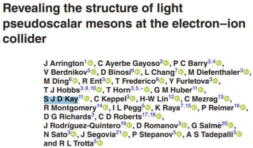
Revealing the structure of light pseudoscalar mesons at the electron–ion collider

J Arrington[1], C Ayerbe Gayoso[2], P C Barry[3,4], V Berdnikov[5], D Binosi[6], L Chang[7], M Diefenthaler[3], M Ding[6], R Ent[3], T Frederico[8], Y Furletova[3], T J Hobbs[3,9,10], T Horn[3,5,*], G M Huber[11], S J D Kay[11], C Keppel[3], H-W Lin[12], C Mezrag[13], R Montgomery[14], I L Pegg[5], K Raya[7,15], P Reimer[16], D G Richards[3], C D Roberts[17,18], J Rodríguez-Quintero[19], D Romanov[3], G Salmè[20], N Sato[3], J Segovia[21], P Stepanov[5], A S Tadepalli[3] and R L Trotta[5]

- Only the portion in red is directly from the Higgs current
- Multiple mechanisms at play to give hadrons their mass
  - Mass generation mechanisms intricately connected to structure
- **The simple $q\bar{q}$ valence structure of mesons makes them an excellent testing ground**

Why Meson Structure - Hadron Mass Budgets





Revealing the structure of light pseudoscalar mesons at the electron–ion collider

J Arrington[1], C Ayerbe Gayoso[2], P C Barry[3,4], V Berdnikov[5], D Binosi[6], L Chang[7], M Diefenthaler[3], M Ding[6], R Ent[3], T Frederico[8], Y Furletova[3], T J Hobbs[3,9,10], T Horn[3,5,*], G M Huber[11], S J D Kay[11], C Keppel[3], H-W Lin[12], C Mezrag[13], R Montgomery[14], I L Pegg[5], K Raya[7,15], P Reimer[16], D G Richards[3], C D Roberts[17,18], J Rodríguez-Quintero[19], D Romanov[3], G Salmè[20], N Sato[3], J Segovia[21], P Stepanov[5], A S Tadepalli[3] and R L Trotta[5]

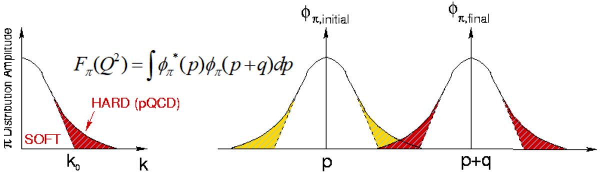
- Only the portion in red is directly from the Higgs current
- Multiple mechanisms at play to give hadrons their mass
  - Mass generation mechanisms intricately connected to structure
- **The simple $q\bar{q}$ valence structure of mesons makes them an excellent testing ground**
- What can we examine to look at their structure?

Quantifying Meson Structure - Meson Form Factors

- Charged pion ($\pi^{\pm}$) and kaon ($K^{\pm}$) form factors (F_{π}, F_{K}) are key QCD observables
  - Momentum space distributions of partons within hadrons

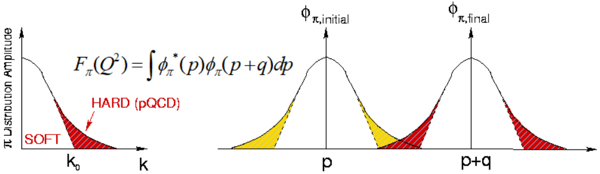
Quantifying Meson Structure - Meson Form Factors

- Charged pion ($\pi^{\pm}$) and kaon ($K^{\pm}$) form factors (F_{π}, F_{K}) are key QCD observables
  - Momentum space distributions of partons within hadrons



Quantifying Meson Structure - Meson Form Factors

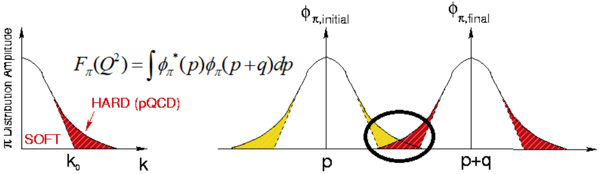
- Charged pion ($\pi^{\pm}$) and kaon ($K^{\pm}$) form factors (F_{π}, F_{K}) are key QCD observables
  - Momentum space distributions of partons within hadrons



- Meson wave function can be split into ϕ_π^{soft} ($k < k_0$) and ϕ_π^{hard}, the hard tail

Quantifying Meson Structure - Meson Form Factors

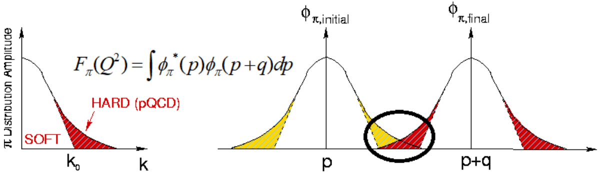
- Charged pion ($\pi^{\pm}$) and kaon ($K^{\pm}$) form factors (F_{π}, F_{K}) are key QCD observables
  - Momentum space distributions of partons within hadrons



- Meson wave function can be split into ϕ_{π}^{soft} ($k < k_0$) and ϕ_{π}^{hard}, the hard tail
  - Can treat ϕ_{π}^{hard} in pQCD, cannot with ϕ_{π}^{soft}
  - Form factor is the overlap between the two tails (right figure)

Quantifying Meson Structure - Meson Form Factors

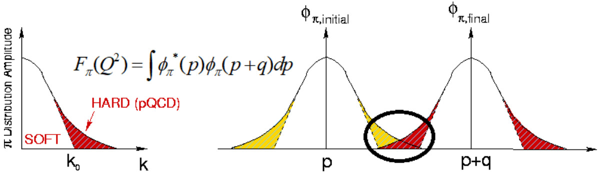
- Charged pion ($\pi^{\pm}$) and kaon ($K^{\pm}$) form factors (F_{π}, F_{K}) are key QCD observables
  - Momentum space distributions of partons within hadrons



- Meson wave function can be split into ϕ_{π}^{soft} $(k < k_0)$ and ϕ_{π}^{hard}, the hard tail
  - Can treat ϕ_{π}^{hard} in pQCD, cannot with ϕ_{π}^{soft}
  - Form factor is the overlap between the two tails (right figure)
- **F_{π} and F_{K} of special interest in hadron structure studies**

Quantifying Meson Structure - Meson Form Factors

- Charged pion ($\pi^{\pm}$) and kaon ($K^{\pm}$) form factors (F_{π}, F_{K}) are key QCD observables
  - Momentum space distributions of partons within hadrons



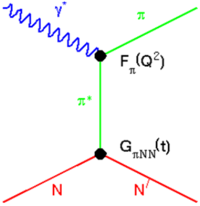
- Meson wave function can be split into ϕ_{π}^{soft} ($k < k_0$) and ϕ_{π}^{hard}, the hard tail
  - Can treat ϕ_{π}^{hard} in pQCD, cannot with ϕ_{π}^{soft}
  - Form factor is the overlap between the two tails (right figure)
- **F_{π} and F_{K} of special interest in hadron structure studies**
  - π - Lightest QCD quark system, simple
  - K - Another simple system, contains strange quark

Measurement of F_π at High Q^2

- To access F_π at high Q^2, must measure F_π indirectly
  - Use the "pion cloud" of the proton via $p(e, e'\pi^+ n)$

Measurement of F_π at High Q^2

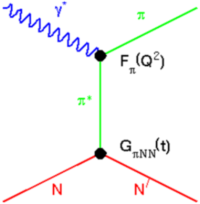
- To access F_π at high Q^2, must measure F_π indirectly
  - Use the "pion cloud" of the proton via $p(e, e'\pi^+ n)$
- At small $-t$, the pion pole process dominates σ_L



Measurement of F_π at High Q^2

- To access F_π at high Q^2, must measure F_π indirectly
  - Use the "pion cloud" of the proton via $p(e, e'\pi^+ n)$
- At small $-t$, the pion pole process dominates σ_L
- In the Born term model, F_π^2 appears as -

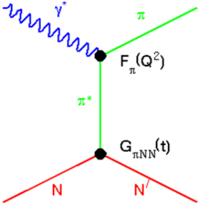
$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t-m_\pi^2)} g_{\pi NN}^2(t) F_\pi^2(Q^2, t)$$



Measurement of F_π at High Q^2

- To access F_π at high Q^2, must measure F_π indirectly
  - Use the "pion cloud" of the proton via $p(e, e'\pi^+ n)$
- At small $-t$, the pion pole process dominates σ_L
- In the Born term model, F_π^2 appears as -

$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t - m_\pi^2)} g_{\pi NN}^2(t) F_\pi^2(Q^2, t)$$

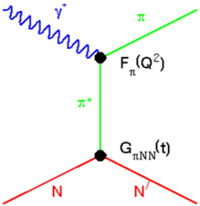


- We do not use the Born term model

Measurement of F_π at High Q^2

- To access F_π at high Q^2, must measure F_π indirectly
  - Use the "pion cloud" of the proton via $p(e, e'\pi^+ n)$
- At small $-t$, the pion pole process dominates σ_L
- In the Born term model, F_π^2 appears as -

$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t - m_\pi^2)} g_{\pi NN}^2(t) F_\pi^2(Q^2, t)$$

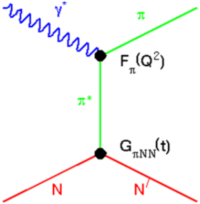


- We do not use the Born term model
- Drawbacks of this technique -
  - Isolating σ_L experimentally challenging
  - Theoretical uncertainty in F_π extraction
    - Model dependent
      (smaller dependency at low -t)

Measurement of F_π at High Q^2

- To access F_π at high Q^2, must measure F_π indirectly
  - Use the "pion cloud" of the proton via $p(e, e'\pi^+ n)$
- At small $-t$, the pion pole process dominates σ_L
- In the Born term model, F_π^2 appears as -

$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t - m_\pi^2)} g_{\pi NN}^2(t) F_\pi^2(Q^2, t)$$



- We do not use the Born term model
- Drawbacks of this technique -
  - Isolating σ_L experimentally challenging
  - Theoretical uncertainty in F_π extraction
    - Model dependent (smaller dependency at low -t)
- At a collider, must isolate $d\sigma_L/dt$ from measured $d\sigma_{uns}/dt$, using a model
- Measure **D**eep **E**xclusive **M**eson **P**roduction (**DEMP**)

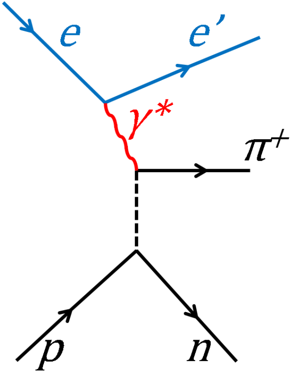
Ingredients for DEMP

- DEMP as a process is fairly self descriptive!
- Consider the $p(e, e'\pi^+ n)$ reaction

Ingredients for DEMP

- DEMP as a process is fairly self descriptive!
- Consider the $p(e, e'\pi^+n)$ reaction

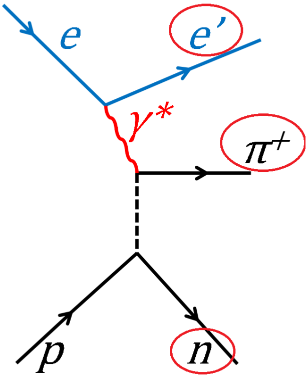
- e scatters from p, exchanging γ^*



Ingredients for DEMP

- DEMP as a process is fairly self descriptive!
- Consider the $p(e, e'\pi^+ n)$ reaction

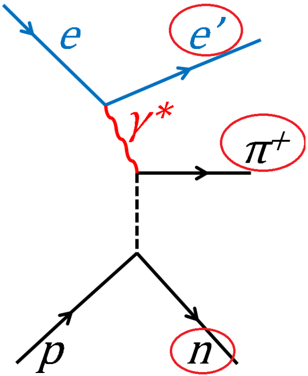
- e scatters from p, exchanging γ^*
- e', π^+ and n final state



Ingredients for DEMP

- DEMP as a process is fairly self descriptive!
- Consider the $p(e, e'\pi^+ n)$ reaction

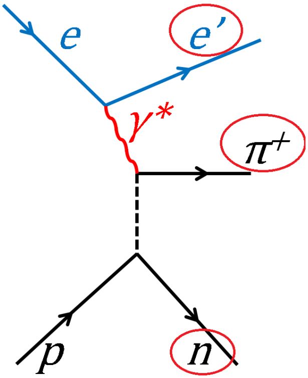
- e scatters from p, exchanging γ^*
- e', π^+ and n final state
- $e' \rightarrow$ Central detecter/electron endcap
- $\pi^+ \rightarrow$ Central detector/hadron endcap
- $n \rightarrow$ Far-Forward Detectors (ZDC)



Ingredients for DEMP

- DEMP as a process is fairly self descriptive!
- Consider the $p(e, e'\pi^{+}n)$ reaction

- e scatters from p, exchanging γ^{*}
- e', π^{+} and n final state
- $e' \rightarrow$ Central detecter/electron endcap
- $\pi^{+} \rightarrow$ Central detector/hadron endcap
- $n \rightarrow$ Far-Forward Detectors (ZDC)
- Can also measure $n(e, e'\pi^{-}p)$ in $e + D$ collisions
- Kaon DEMP, $\pi^{+} \rightarrow K^{+}$ and $n \rightarrow \Lambda^{0}$
  - (or Σ^{0})



- **So just need $e + p$ or $e + D$ collisions**

Early Science - Opportunities for DEMP

- Given our requirements, $e + p$ or $e + D$ collisions, what do the early science prospects look like?

Early Science - Opportunities for DEMP

- Given our requirements, $e + p$ or $e + D$ collisions, what do the early science prospects look like?

	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
YEAR 1	e+Ru or e+Cu	10 x 115	0.9	NO (Commissioning)	N/A
YEAR 2	e+D e+p	10 x 130	11.4 4.95 - 5.33	LONG	NO TRANS
YEAR 3	e+p	10 x 130	4.95 - 5.33	LONG	TRANS and/or LONG
YEAR 4	e+Au e+p	10 x 100 10 x 250	0.84 6.19 - 9.18	LONG	N/A TRANS and/or LONG
YEAR 5	e+Au e+3He	10 x 100 10 x 166	0.84 8.65	LONG	N/A TRANS and/or LONG

Note: the eA luminosity is per nucleon

Early Science - Opportunities for DEMP

- Given our requirements, $e + p$ or $e + D$ collisions, what do the early science prospects look like?

	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
YEAR 1	e+Ru or e+Cu	10 x 115	0.9	NO (Commissioning)	N/A
YEAR 2	e+D e+p	10 x 130	11.4 4.95 - 5.33	LONG	NO TRANS
YEAR 3	e+p	10 x 130	4.95 - 5.33	LONG	TRANS and/or LONG
YEAR 4	e+Au e+p	10 x 100 10 x 250	0.84 6.19 - 9.18	LONG	N/A TRANS and/or LONG
YEAR 5	e+Au e+3He	10 x 100 10 x 166	0.84 8.65	LONG	N/A TRANS and/or LONG

Note: the eA luminosity is per nucleon

- Opportunities with 10x130 and 10x250 e+p as early as year 2

Early Science - Opportunities for DEMP

- Given our requirements, $e + p$ or $e + D$ collisions, what do the early science prospects look like?

	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
YEAR 1	e+Ru or e+Cu	10 x 115	0.9	NO (Commissioning)	N/A
YEAR 2	e+D e+p	10 x 130	11.4 4.95 - 5.33	LONG	NO TRANS
YEAR 3	e+p	10 x 130	4.95 - 5.33	LONG	TRANS and/or LONG
YEAR 4	e+Au e+p	10 x 100 10 x 250	0.84 6.19 - 9.18	LONG	N/A TRANS and/or LONG
YEAR 5	e+Au e+3He	10 x 100 10 x 166	0.84 8.65	LONG	N/A TRANS and/or LONG

Note: the eA luminosity is per nucleon

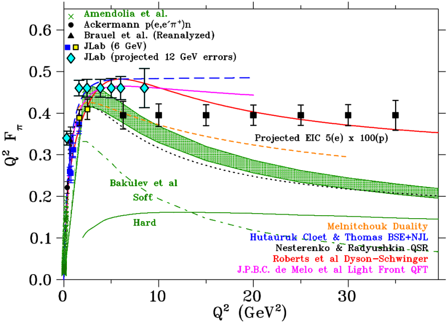
- Opportunities with 10x130 and 10x250 e+p as early as year 2
- Assume $\int \mathcal{L} = 5\ fb^{-1}$ in projections

Where we were...

- Early simulations and projections for F_π looked promising

Where we were...

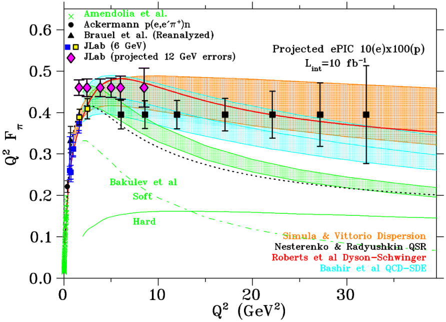
- Early simulations and projections for F_π looked promising
- Initially focused on 5x100



Where we were...

- Early simulations and projections for F_π looked promising

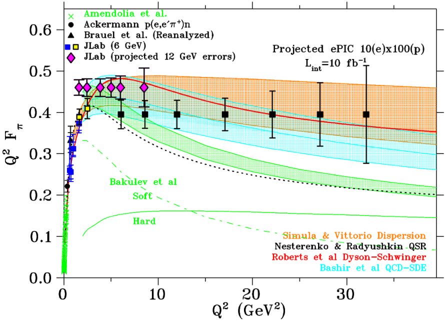
- Initially focused on 5x100
- 10x100 also looked good



Where we were...

- Early simulations and projections for F_π looked promising

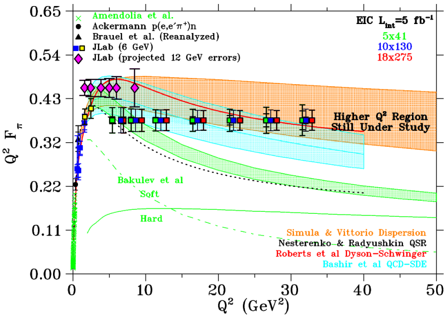
- Initially focused on 5x100
- 10x100 also looked good
- Higher Q^2 seemed to be statistics constrained



Where we were...

- Early simulations and projections for F_π looked promising

- Initially focused on 5x100
- 10x100 also looked good
- Higher Q^2 seemed to be statistics constrained
- Improvements to generator efficiency + bug fix

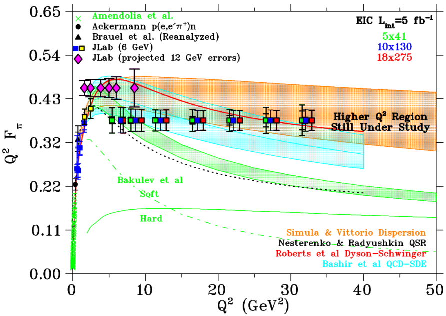


- Signs that $Q^2 > 35 GeV^2$ looked possible
  - Across multiple beam energy combinations
  - May need higher $\int \mathcal{L}$ than early science

Where we were...

- Early simulations and projections for F_π looked promising

- Initially focused on 5x100
- 10x100 also looked good
- Higher Q^2 seemed to be statistics constrained
- Improvements to generator efficiency + bug fix
- Only one "early science" config here though!



- Signs that $Q^2 > 35 GeV^2$ looked possible
  - Across multiple beam energy combinations
  - May need higher $\int \mathcal{L}$ than early science

Where we are now

- Focus has shifted to the early science programme and what we can achieve in the first few years
- 10x130 is the main measurement of interest here
  - Processed and refined simulations here

Where we are now

- Focus has shifted to the early science programme and what we can achieve in the first few years
- 10x130 is the main measurement of interest here
  - Processed and refined simulations here
- 10x250 is a "new configuration"
- Updated DEMPgen (more on that soon) to incorporate this

Where we are now

- Focus has shifted to the early science programme and what we can achieve in the first few years
- 10x130 is the main measurement of interest here
  - Processed and refined simulations here
- 10x250 is a "new configuration"
- Updated DEMPgen (more on that soon) to incorporate this
- Processed 10x250 events with personal simulation run
- Re-wrote earlier analysis code from Love Preet
  - More flexible, not one code per beam energy

Where we are now

- Focus has shifted to the early science programme and what we can achieve in the first few years
- 10*x*130 is the main measurement of interest here
  - Processed and refined simulations here
- 10*x*250 is a "new configuration"
- Updated DEMPgen (more on that soon) to incorporate this
- Processed 10*x*250 events with personal simulation run
- Re-wrote earlier analysis code from Love Preet
  - More flexible, not one code per beam energy
- Simulated statistics limiting → refined generator
  - Process in distinct Q^2 ranges → More events generated at high Q^2
  - Narrowed $-t$ generation range
  - For F_π studies, only want low $-t$

Where we are now

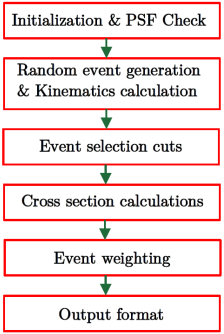
- Focus has shifted to the early science programme and what we can achieve in the first few years
- 10x130 is the main measurement of interest here
  - Processed and refined simulations here
- 10x250 is a "new configuration"
- Updated DEMPgen (more on that soon) to incorporate this
- Processed 10x250 events with personal simulation run
- Re-wrote earlier analysis code from Love Preet
  - More flexible, not one code per beam energy
- Simulated statistics limiting $\rightarrow$ refined generator
  - Process in distinct Q^2 ranges $\rightarrow$ More events generated at high Q^2
  - Narrowed $-t$ generation range
  - For F_π studies, only want low $-t$
- Need to provide a new release for DEMPgen and submit latest files as a sim campaign request

How we got there - DEMPgen

- DEMPgen - **D**eep **E**xclusive **M**eson **P**roduction event generator
- Fixed target (JLab) and colliding beams (EIC) modes

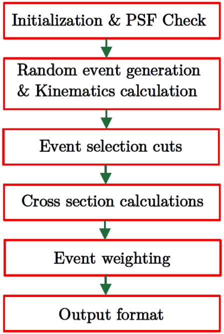
How we got there - DEMPgen

- DEMPgen - **D**eep **E**xclusive **M**eson **P**roduction event generator
- Fixed target (JLab) and colliding beams (EIC) modes
- Feed in an input .json file
  - Specify conditions
  - Beam energies, number of events etc



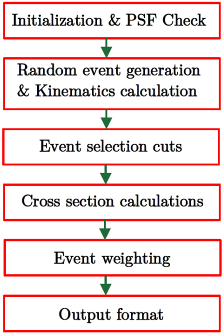
How we got there - DEMPgen

- DEMPgen - **D**eep **E**xclusive **M**eson **P**roduction event generator
- Fixed target (JLab) and colliding beams (EIC) modes
- Feed in an input .json file
  - Specify conditions
  - Beam energies, number of events etc
- Several reactions available
  - $p(e, e'\pi^+ n)$
  - $p(e, e' K^+ \Lambda)$
  - ...



How we got there - DEMPgen

- DEMPgen - **D**eep **E**xclusive **M**eson **P**roduction event generator
- Fixed target (JLab) and colliding beams (EIC) modes
- Feed in an input .json file
  - Specify conditions
  - Beam energies, number of events etc
- Several reactions available
  - $p(e, e'\pi^+ n)$
  - $p(e, e'K^+\Lambda)$
  - ...
- Further details in recent paper



https://doi.org/10.1016/j.cpc.2024.109444

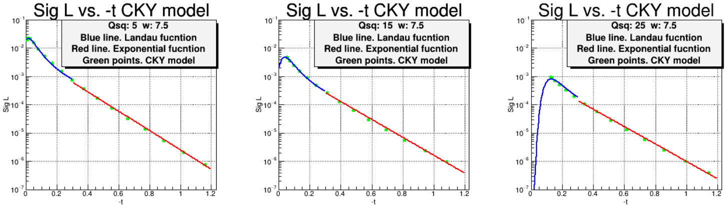
DEMPgen - Parametrisation

- DEMPgen uses parameterised Regge-based models
  - Uses the CKY model for $p(e, e'\pi^{+}n)$

Authors of model are - T.K. **C**hoi, K.J. **K**ong and B.G. **Y**u - **CKY**

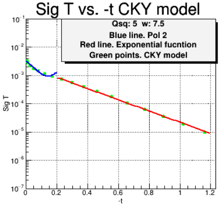
DEMPgen - Parametrisation

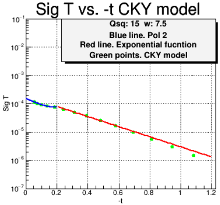
- DEMPgen uses parameterised Regge-based models
  - Uses the CKY model for $p(e, e'\pi^+ n)$
- Parameterise σ_L and σ_T across broad kinematic range applicable to EIC
  - $5 < Q^2 < 35$, $2 < W < 10$, $0 < -t < 1.3$

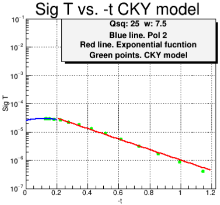


DEMPgen - Parametrisation

- DEMPgen uses parameterised Regge-based models
  - Uses the CKY model for $p(e, e'\pi^+ n)$
- Parameterise σ_L and σ_T across broad kinematic range applicable to EIC
  - $5 < Q^2 < 35$, $2 < W < 10$, $0 < -t < 1.3$

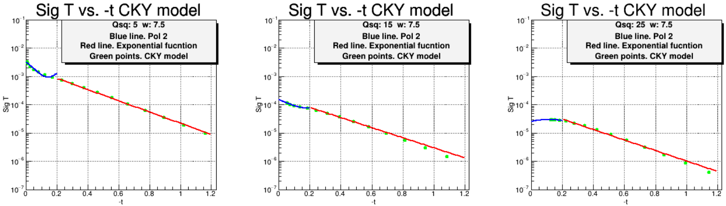






DEMPgen - Parametrisation

- DEMPgen uses parameterised Regge-based models
  - Uses the CKY model for $p(e, e'\pi^+ n)$
- Parameterise σ_L and σ_T across broad kinematic range applicable to EIC
  - $5 < Q^2 < 35$, $2 < W < 10$, $0 < -t < 1.3$

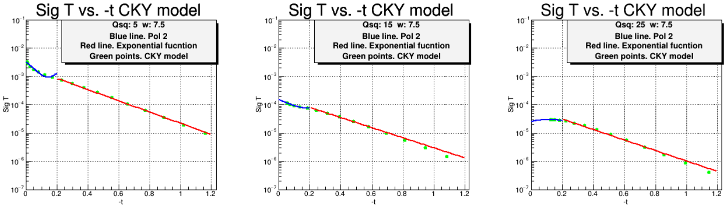


- Kaon reactions → Use VGL model

Authors of model are - M.**V**anderhaeghen, M. **G**uidal and J.-M.**L**aget - **VGL**

DEMPgen - Parametrisation

- DEMPgen uses parameterised Regge-based models
  - Uses the CKY model for $p(e, e'\pi^+ n)$
- Parameterise σ_L and σ_T across broad kinematic range applicable to EIC
  - $5 < Q^2 < 35$, $2 < W < 10$, $0 < -t < 1.3$



- Kaon reactions $\rightarrow$ Use VGL model
- To access $Q^2 > 35$ GeV^2, need to parameterise model in this range and add to generator

Simulation Overview

- Generated new 10x130 and 10x250 files from DEMPgen

Simulation Overview

- Generated new 10x130 and 10x250 files from DEMPgen
- Used DEMPgen v1.2.3* to generate new files
  - Assume $\int \mathcal{L} = 5\ fb^{-1}$ in projections

Used $\mathcal{L} \approx 0.2629 \times 10^{33} cm^{-2} s^{-1}$, based upon assumptions on per fill $\int \mathcal{L}$ in Elke's slides. * - A modified version, will provide a v1.2.4 release soon.

Simulation Overview

- Generated new 10x130 and 10x250 files from DEMPgen
- Used DEMPgen v1.2.3* to generate new files
  - Assume $\int \mathcal{L} = 5\ fb^{-1}$ in projections
- Ran $p(e, e'\pi^{+}n)$ split into three Q^2 ranges
  - $3 < Q^2 < 10$, $10 < Q^2 < 20$ and $20 < Q^2 < 35$
  - Roughly ∼400k generated per Q^2 range
- Constrained $-t$ to $< 0.4\ GeV^2$

Technically, actually a cut on the range of $\theta_{e'}$ values, directly feeds into Q^2

Simulation Overview

- Generated new 10x130 and 10x250 files from DEMPgen
- Used DEMPgen v1.2.3* to generate new files
  - Assume $\int \mathcal{L} = 5\ fb^{-1}$ in projections
- Ran $p(e, e'\pi^{+}n)$ split into three Q^2 ranges
  - $3 < Q^2 < 10$, $10 < Q^2 < 20$ and $20 < Q^2 < 35$
  - Roughly $\sim$400k generated per Q^2 range
- Constrained $-t$ to $< 0.4\ GeV^2$
- Ran independently for now
  - Used 10x130 and 10x250 epic-craterlake detector config
  - ip6_ep_130x10 and ip6_ep_250x10 afterburner configs applied
  - Plots shown are from own simulation

Simulation Overview

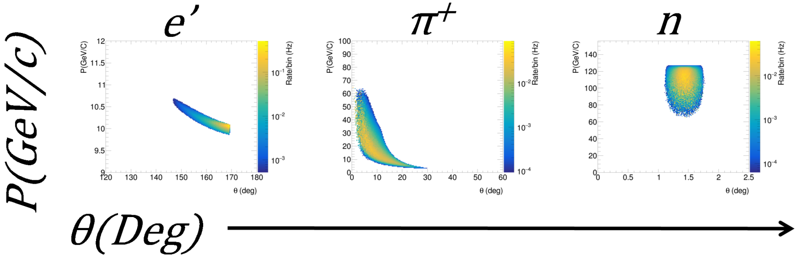
- Generated new 10x130 and 10x250 files from DEMPgen
- Used DEMPgen v1.2.3* to generate new files
  - Assume $\int \mathcal{L} = 5 \ fb^{-1}$ in projections
- Ran $p(e, e'\pi^{+}n)$ split into three Q^2 ranges
  - $3 < Q^2 < 10$, $10 < Q^2 < 20$ and $20 < Q^2 < 35$
  - Roughly $\sim$400k generated per Q^2 range
- Constrained $-t$ to $< 0.4 \ GeV^2$
- Ran independently for now
  - Used 10x130 and 10x250 epic-craterlake detector config
  - ip6_ep_130x10 and ip6_ep_250x10 afterburner configs applied
  - Plots shown are from own simulation
- Need to produce new release of DEMPgen, then will update campaign files and request

DEMP Kinematics - Truth Distributions

- A quick reminder of DEMP kinematics with 10x130 events

DEMP Kinematics - Truth Distributions

- A quick reminder of DEMP kinematics with 10x130 events
- e' and π^+ hit the central detector, neutron in FF detectors
    - ZDC in particular critical for low $-t$ neutrons
- Note that the Z scale is a rate in Hz



Beam effects *not* removed here.
Note, in η the ranges are $-1.15 < \eta_{e'} < -2.45$, $0 < \eta_{\pi^+} < 0.9$ and $4 < \eta_n < 5.1$.

DEMP Analysis Overview - Event Selection Cuts

- Need to select out e', π^+, n triple coincidence events
- To begin, require that simultaneously we have -

DEMP Analysis Overview - Event Selection Cuts

- Need to select out e', π^+, n triple coincidence events
- To begin, require that simultaneously we have -
  - One negatively charged track in the $-z$ direction (the e')
  - One positively charged track in the $+z$ direction (π^+)
  - A high energy reconstructed neutron in the ZDC
    - $E_n > 40\ GeV$ ($> 120\ GeV$ for 10x250)
    - $\theta^*_n < 4\ mrad$

θ^* is after a rotation of 25 mRad around the proton axis to remove the crossing angle

DEMP Analysis Overview - Event Selection Cuts

- Need to select out e', π^+, n triple coincidence events
- To begin, require that simultaneously we have -
  - One negatively charged track in the $-z$ direction (the e')
  - One positively charged track in the $+z$ direction (π^+)
  - A high energy reconstructed neutron in the ZDC
    - $E_n > 40\ GeV$ ($> 120\ GeV$ for 10x250)
    - $\theta^*_n < 4\ mrad$
- Cut on difference between ZDC hit and p_{Miss} track angles
  - $-0.09^\circ < \Delta\theta^* < 0.14^\circ$ ($-0.07^\circ < \Delta\theta^* < 0.17^\circ$ for 10x250)
  - $|\Delta\phi^*| < 55^\circ$ ($|\Delta\phi^*| < 80^\circ$ for 10x250)
  - $1.8 * E_{eBeam} < \sum (E - P_z) < 2.2 * E_{eBeam}$

$\vec{P}_{Miss} = (\vec{e} + \vec{p}) - (\vec{e'}_{Rec} + \vec{\pi}_{Rec})$ - More on this in a moment

DEMP Analysis Overview - Event Selection Cuts

- Need to select out e', π^+, n triple coincidence events
- To begin, require that simultaneously we have -
  - One negatively charged track in the $-z$ direction (the e')
  - One positively charged track in the $+z$ direction (π^+)
  - A high energy reconstructed neutron in the ZDC
    - $E_n > 40\ GeV$ ($> 120\ GeV$ for 10x250)
    - $\theta_n^* < 4\ mrad$
- Cut on difference between ZDC hit and p_{Miss} track angles
  - $-0.09^\circ < \Delta\theta^* < 0.14^\circ$ ($-0.07^\circ < \Delta\theta^* < 0.17^\circ$ for 10x250)
  - $|\Delta\phi^*| < 55^\circ$ ($|\Delta\phi^*| < 80^\circ$ for 10x250)
  - $1.8 * E_{eBeam} < \sum(E - P_z) < 2.2 * E_{eBeam}$
- Also cut on $-t_{eXBABE} < 1.4$ and $W_{rec} > 0$
  - Using the TRECO convention for -t reconstruction methods

DEMP Analysis Overview - Event Selection Cuts

- Need to select out e', π^+, n triple coincidence events
- To begin, require that simultaneously we have -
  - One negatively charged track in the $-z$ direction (the e')
  - One positively charged track in the $+z$ direction (π^+)
  - A high energy reconstructed neutron in the ZDC
    - $E_n > 40\ GeV$ ($> 120\ GeV$ for 10x250)
    - $\theta^*_n < 4\ mrad$
- Cut on difference between ZDC hit and p_{Miss} track angles
  - $-0.09° < \Delta\theta^* < 0.14°$ ($-0.07° < \Delta\theta^* < 0.17°$ for 10x250)
  - $|\Delta\phi^*| < 55°$ ($|\Delta\phi^*| < 80°$ for 10x250)
  - $1.8 * E_{eBeam} < \sum(E - P_z) < 2.2 * E_{eBeam}$
- Also cut on $-t_{eXBABE} < 1.4$ and $W_{rec} > 0$
  - Using the TRECO convention for -t reconstruction methods
- PID using PDG code assignment not used currently

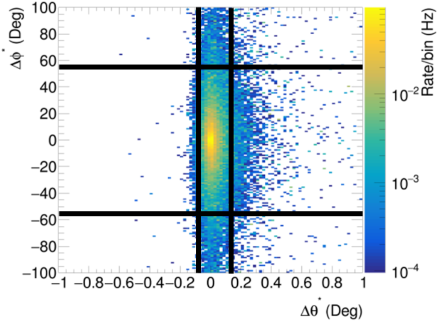
DEMP Analysis Overview - $\Delta\theta^*$ and $\Delta\phi^*$ Cuts

- P_{Miss} vector should correspond with hit location on the ZDC
- For a non-exclusive event, P_{Miss} vector should not correspond to a real ZDC hit/cluster
  - Effectively an additional "exclusivity" constraint

DEMP Analysis Overview - $\Delta\theta^*$ and $\Delta\phi^*$ Cuts

- P_{Miss} vector should correspond with hit location on the ZDC
- For a non-exclusive event, P_{Miss} vector should not correspond to a real ZDC hit/cluster
  - Effectively an additional "exclusivity" constraint
- Select $-0.09^{\circ} < \Delta\theta^* < 0.14^{\circ}$ and $-55^{\circ} < \Delta\phi^* < 55^{\circ}$

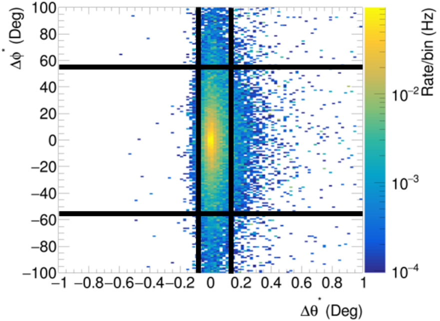
- $\Delta\theta^* = \theta^*_{pMiss} - \theta^*_{ZDC}$
- $\Delta\phi^* = \phi^*_{PMiss} - \phi^*_{ZDC}$



DEMP Analysis Overview - $\Delta\theta^*$ and $\Delta\phi^*$ Cuts

- P_{Miss} vector should correspond with hit location on the ZDC
- For a non-exclusive event, P_{Miss} vector should not correspond to a real ZDC hit/cluster
  - Effectively an additional "exclusivity" constraint
- Select $-0.09^\circ < \Delta\theta^* < 0.14^\circ$ and $-55^\circ < \Delta\phi^* < 55^\circ$

- $\Delta\theta^* = \theta^*_{pMiss} - \theta^*_{ZDC}$
- $\Delta\phi^* = \phi^*_{PMiss} - \phi^*_{ZDC}$
- Simulation is **exclusive only**, inclusive events spread over broader range



DEMP Analysis Overview - $-t$ Reconstruction

- Can reconstruct $-t$ in multiple ways (see t_{RECO} document)
- "Best" way for DEMP is $\rightarrow$ -t$_{eXBABE} = (\vec{p} - \vec{n}_{Corr})^2$

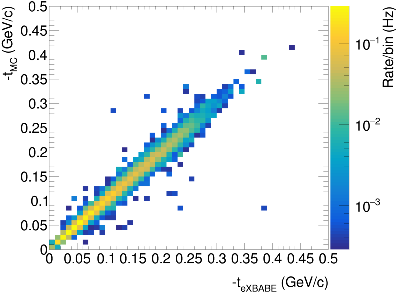
DEMP Analysis Overview - $-t$ Reconstruction

- Can reconstruct $-t$ in multiple ways (see t_{RECO} document)
- “Best” way for DEMP is $\rightarrow$ -t$_{eXBABE} = (\vec{p} - \vec{n}_{Corr})^2$
- Exploit exclusive nature of the reaction, generic implementation available in code here

DEMP Analysis Overview - $-t$ Reconstruction

- Can reconstruct $-t$ in multiple ways (see t_{RECO} document)
- "Best" way for DEMP is $\rightarrow$ -$t_{eXBABE} = (\vec{p} - \vec{n}_{Corr})^2$
- Exploit exclusive nature of the reaction, generic implementation available in code here

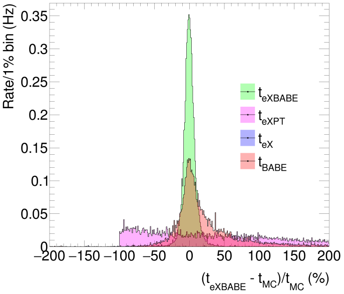
- $-t_{eXBABE}$ correlates well with truth



DEMP Analysis Overview - $-t$ Reconstruction

- Can reconstruct $-t$ in multiple ways (see t_{RECO} document)
- "Best" way for DEMP is $\rightarrow$ $-t_{eXBABE} = (\vec{p} - \vec{n}_{Corr})^2$
- Exploit exclusive nature of the reaction, generic implementation available in code here

- $-t_{eXBABE}$ correlates well with truth
- Far better than methods using uncorrected neutron track (t_{BABE}) and methods utilising electron information (t_{eX}) and electron P_T (t_{eXPT}) info



$\sigma(eXBABE) = 10.95$, $\sigma(eXPT) = 83.05$, $\sigma(eX) = 110.2$, $\sigma(BABE) = 42.82$. **All $e'\pi^+n$ triple coincidence events**

Kinematic Reconstruction - Q^2

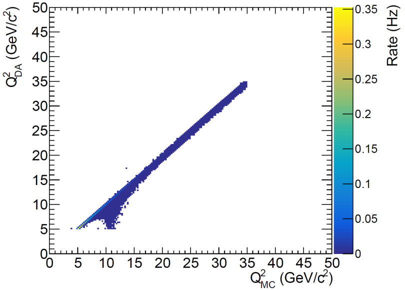
- Various ways to calculate Q^2 (and $\therefore x, y$)
- Evaluated the electron, JB, DA and sigma methods

See details of each calculation in this tutorial

Kinematic Reconstruction - Q^2

- Various ways to calculate Q^2 (and $\therefore x, y$)
- Evaluated the electron, JB, DA and sigma methods
- DA method appears to perform best for DEMP across broad kinematic range

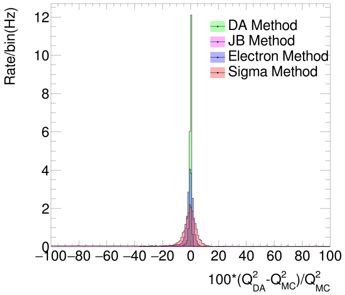
- Q^2_{DA} correlates well with truth



Kinematic Reconstruction - Q^2

- Various ways to calculate Q^2 (and $\therefore x, y$)
- Evaluated the electron, JB, DA and sigma methods
- DA method appears to perform best for DEMP across broad kinematic range

- Q^2_{DA} correlates well with truth
- Electron and sigma methods perform OK, but not as well.
- JB method clearly not valid for these kinematics



$\sigma(DA) = 1.359$, $\sigma(JB) = N/a$, $\sigma(Electrom) = 3.623$, $\sigma(Sigma) = 6.877$.

Analysis Status - QA Plot Overview

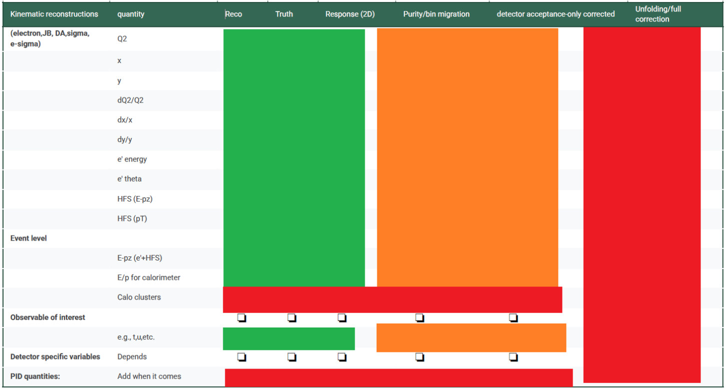
Kinematic reconstructions	quantity	Reco	Truth	Response (2D)	Purity/bin migration	detector acceptance-only corrected	Unfolding/full correction
(electron,JB, DA,sigma, e-sigma)	Q2						
	x						
	y						
	dQ2/Q2						
	dx/x						
	dy/y						
	e' energy						
	e' theta						
	HFS (E-pz)						
	HFS (pT)						
Event level							
	E-pz (e'+HFS)						
	E/p for calorimeter						
	Calo clusters						
Observable of interest		❑	❑	❑	❑	❑	
	e.g., t,u,etc.						
Detector specific variables	Depends	❑	❑	❑	❑	❑	
PID quantities:	Add when it comes						

Analysis Status - QA Plot Overview

Kinematic reconstructions	quantity	Reco	Truth	Response (2D)	Purity/bin migration	detector acceptance-only corrected	Unfolding/full correction
(electron,JB, DA,sigma, e-sigma)	Q2						
	x						
	y						
	dQ2/Q2						
	dx/x						
	dy/y						
	e' energy						
	e' theta						
	HFS (E-pz)						
	HFS (pT)						
Event level							
	E-pz (e'+HFS)						
	E/p for calorimeter						
	Calo clusters						
Observable of interest		❑	❑	❑	❑	❑	
	e.g., t,u,etc.						
Detector specific variables	Depends	❑	❑	❑	❑	❑	
PID quantities:	Add when it comes						

- Applies to both beam energies under study

Analysis Status - QA Plot Overview



Kinematic reconstructions	quantity	Reco	Truth	Response (2D)	Purity/bin migration	detector acceptance-only corrected	Unfolding/full correction
(electron,JB, DA,sigma, e-sigma)	Q2						
	x						
	y						
	dQ2/Q2						
	dx/x						
	dy/y						
	e' energy						
	e' theta						
	HFS (E-pz)						
	HFS (pT)						
Event level							
	E-pz (e'+HFS)						
	E/p for calorimeter						
	Calo clusters						
Observable of interest		☐	☐	☐	☐	☐	
	e.g., t,u,etc.						
Detector specific variables	Depends	☐	☐	☐	☐	☐	
PID quantities:	Add when it comes						

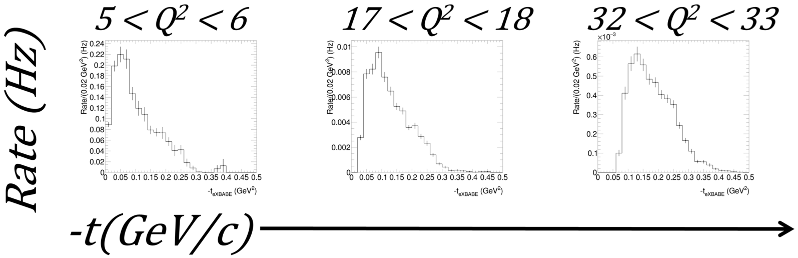
- Applies to both beam energies under study
- Code produces a pdf of main (green) QA plots, will tidy up and add to note (more on the note soon!)

DEMP Analysis Results - $Q^2, -t$ Binning

- After applying cuts, bin in Q^2 and $-t$

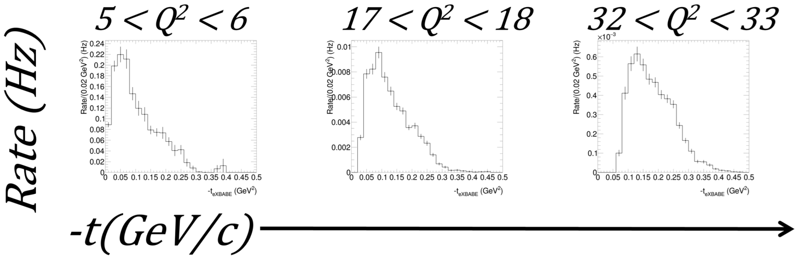
DEMP Analysis Results - $Q^2, -t$ Binning

- After applying cuts, bin in Q^2 and $-t$
  - $-t$ bins 0.02 GeV/c wide



DEMP Analysis Results - $Q^2, -t$ Binning

- After applying cuts, bin in Q^2 and $-t$
  - $-t$ bins 0.02 GeV/c wide
  - Q^2 bins 1 GeV^2 wide
  - Rebin if stats low
- From rate per bin, extrapolate to number of events with $\int \mathcal{L} = 5\ fb^{-1}$, project to F_π

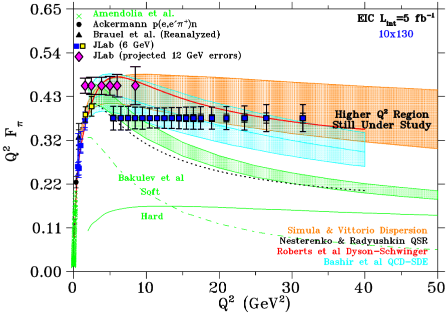


DEMP Analysis Results - F_π Projections

- ePIC opens up high Q^2 F_π regime

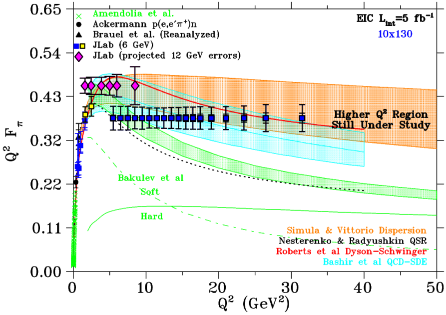
DEMP Analysis Results - F_π Projections

- ePIC opens up high Q^2 F_π regime
- **Error bars represent real projected error bars**
  - Inner bar - statistical
  - Outer bar - systematic
  - $\delta R = R$, $R = \sigma_L/\sigma_T$
  - $R = 0.013 - 014$ at lowest $-t$ from VR model



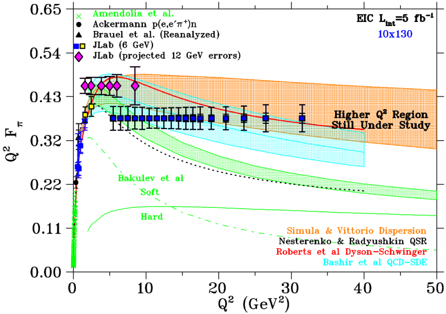
DEMP Analysis Results - F_π Projections

- ePIC opens up high Q^2 F_π regime
- **Error bars represent real projected error bars**
  - Inner bar - statistical
  - Outer bar - systematic
  - $\delta R = R$, $R = \sigma_L/\sigma_T$
  - $R = 0.013 - 014$ at lowest $-t$ from VR model
- Much finer Q^2 binning now!
- 10x250 projections very soon, likely to be comparable



DEMP Analysis Results - F_π Projections

- ePIC opens up high Q^2 F_π regime
- **Error bars represent real projected error bars**
  - Inner bar - statistical
  - Outer bar - systematic
  - $\delta R = R$, $R = \sigma_L/\sigma_T$
  - $R = 0.013 - 014$ at lowest $-t$ from VR model
- Much finer Q^2 binning now!
- 10x250 projections very soon, likely to be comparable



- Even from modest $\int \mathcal{L}$ in early science programme, looks promising!
- How high in Q^2 will be possible with full $\mathcal{L}$?

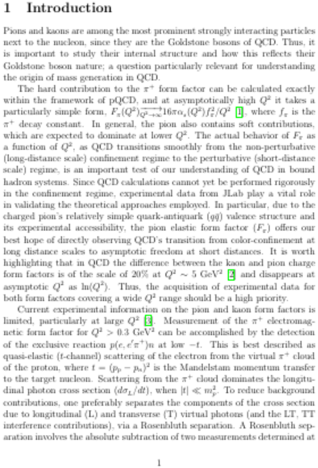
Analysis Note Status

- Analysis note writing in progress

Analysis Note Status

- Analysis note writing in progress

- Background/motivation text incorporated
- Need to write simulation overview and event selection sections still



1 Introduction

Pions and kaons are among the most prominent strongly interacting particles next to the nucleon, since they are the Goldstone bosons of QCD. Thus, it is important to study their internal structure and how this reflects their Goldstone boson nature; a question particularly relevant for understanding the origin of mass generation in QCD.

The hard contribution to the π^+ form factor can be calculated exactly within the framework of pQCD, and at asymptotically high Q^2 it takes a particularly simple form, $F_\pi(Q^2)\xrightarrow[Q^2\to\infty]{}16\pi\alpha_s(Q^2)f_\pi^2/Q^2$ [1], where f_π is the π^+ decay constant. In general, the pion also contains soft contributions, which are expected to dominate at lower Q^2. The actual behavior of F_π as a function of Q^2, as QCD transitions smoothly from the non-perturbative (long-distance scale) confinement regime to the perturbative (short-distance scale) regime, is an important test of our understanding of QCD in bound hadron systems. Since QCD calculations cannot yet be performed rigorously in the confinement regime, experimental data from JLab play a vital role in validating the theoretical approaches employed. In particular, due to the charged pion's relatively simple quark-antiquark ($q\bar{q}$) valence structure and its experimental accessibility, the pion elastic form factor (F_π) offers our best hope of directly observing QCD's transition from color-confinement at long distance scales to asymptotic freedom at short distances. It is worth highlighting that in QCD the difference between the kaon and pion charge form factors is of the scale of 20% at $Q^2 \sim 5$ GeV^2 [2] and disappears at asymptotic Q^2 as $\ln(Q^2)$. Thus, the acquisition of experimental data for both form factors covering a wide Q^2 range should be a high priority.

Current experimental information on the pion and kaon form factors is limited, particularly at large Q^2 [3]. Measurement of the π^+ electromagnetic form factor for $Q^2 > 0.3$ GeV^2 can be accomplished by the detection of the exclusive reaction $p(e, e'\pi^+)n$ at low $-t$. This is best described as quasi-elastic (t-channel) scattering of the electron from the virtual π^+ cloud of the proton, where $t = (p_p - p_n)^2$ is the Mandelstam momentum transfer to the target nucleon. Scattering from the π^+ cloud dominates the longitudinal photon cross section ($d\sigma_L/dt$), when $|t| \ll m_p^2$. To reduce background contributions, one preferably separates the components of the cross section due to longitudinal (L) and transverse (T) virtual photons (and the LT, TT interference contributions), via a Rosenbluth separation. A Rosenbluth separation involves the absolute subtraction of two measurements determined at

1

Analysis Note Status

- Analysis note writing in progress

- Background/motivation text incorporated
- Need to write simulation overview and event selection sections still
- QA plots all produced and ready to place in
- Need to finalise 10x250 projection plot

1 Introduction

Pions and kaons are among the most prominent strongly interacting particles next to the nucleon, since they are the Goldstone bosons of QCD. Thus, it is important to study their internal structure and how this reflects their Goldstone boson nature; a question particularly relevant for understanding the origin of mass generation in QCD.

The hard contribution to the π^+ form factor can be calculated exactly within the framework of pQCD, and at asymptotically high Q^2 it takes a particularly simple form, $F_\pi(Q^2) \xrightarrow[Q^2\to\infty]{} 16\pi\alpha_s(Q^2)f_\pi^2/Q^2$ [1], where f_π is the π^+ decay constant. In general, the pion also contains soft contributions, which are expected to dominate at lower Q^2. The actual behavior of F_π as a function of Q^2, as QCD transitions smoothly from the non-perturbative (long-distance scale) confinement regime to the perturbative (short-distance scale) regime, is an important test of our understanding of QCD in bound hadron systems. Since QCD calculations cannot yet be performed rigorously in the confinement regime, experimental data from JLab play a vital role in validating the theoretical approaches employed. In particular, due to the charged pion's relatively simple quark-antiquark ($q\bar{q}$) valence structure and its experimental accessibility, the pion elastic form factor (F_π) offers our best hope of directly observing QCD's transition from color-confinement at long distance scales to asymptotic freedom at short distances. It is worth highlighting that in QCD the difference between the kaon and pion charge form factors is of the scale of 20% at $Q^2 \sim 5$ GeV^2 [2] and disappears at asymptotic Q^2 as $\ln(Q^2)$. Thus, the acquisition of experimental data for both form factors covering a wide Q^2 range should be a high priority.

Current experimental information on the pion and kaon form factors is limited, particularly at large Q^2 [3]. Measurement of the π^+ electromagnetic form factor for $Q^2 > 0.3$ GeV^2 can be accomplished by the detection of the exclusive reaction $p(e, e'\pi^+)n$ at low $-t$. This is best described as quasi-elastic (t-channel) scattering of the electron from the virtual π^+ cloud of the proton, where $t = (p_p - p_n)^2$ is the Mandelstam momentum transfer to the target nucleon. Scattering from the π^+ cloud dominates the longitudinal photon cross section ($d\sigma_L/dt$), when $|t| \ll m_p^2$. To reduce background contributions, one preferably separates the components of the cross section due to longitudinal (L) and transverse (T) virtual photons (and the LT, TT interference contributions), via a Rosenbluth separation. A Rosenbluth separation involves the absolute subtraction of two measurements determined at

1

Future Analysis Improvements

- Analysis is not static, always room to improve and refine!
- Several planned updates/tests

Future Analysis Improvements

- Analysis is not static, always room to improve and refine!
- Several planned updates/tests
  - Electron finder, implement something like the inclusive group?
  - More robust electron ID

Future Analysis Improvements

- Analysis is not static, always room to improve and refine!
- Several planned updates/tests
  - Electron finder, implement something like the inclusive group?
  - More robust electron ID
  - Incorporate cluster info more broadly
  - Refine PID in central region more broadly, more confidence in e' and π assignment

Future Analysis Improvements

- Analysis is not static, always room to improve and refine!
- Several planned updates/tests
  - Electron finder, implement something like the inclusive group?
  - More robust electron ID
  - Incorporate cluster info more broadly
  - Refine PID in central region more broadly, more confidence in e' and π assignment
  - As full PID assignment in EICrecon matures, transition to utilising this

Future Analysis Improvements

- Analysis is not static, always room to improve and refine!
- Several planned updates/tests
  - Electron finder, implement something like the inclusive group?
  - More robust electron ID
  - Incorporate cluster info more broadly
  - Refine PID in central region more broadly, more confidence in e' and π assignment
  - As full PID assignment in EICrecon matures, transition to utilising this
- Generator updates also planned

Future Analysis Improvements

- Analysis is not static, always room to improve and refine!
- Several planned updates/tests
  - Electron finder, implement something like the inclusive group?
  - More robust electron ID
  - Incorporate cluster info more broadly
  - Refine PID in central region more broadly, more confidence in e' and π assignment
  - As full PID assignment in EICrecon matures, transition to utilising this
- Generator updates also planned
  - Parameterise broader Q^2 range
  - Incorporate improvements from kaon module to pion module
  - New student at University of Regina will look at this when they start (Autumn)

What next?

- As well as improving the existing analysis, There's lots more to do for DEMP!

What next?

- As well as improving the existing analysis, There's lots more to do for DEMP!
- Need to look at eD reactions
  - Start with early science config
  - Rapid simulation or a generator modification?

What next?

- As well as improving the existing analysis, There's lots more to do for DEMP!
- Need to look at eD reactions
  - Start with early science config
  - Rapid simulation or a generator modification?
- $p(e, e'K^{+}\Lambda)$ channel to look at for 10x130 too
  - Λ^0 reconstruction in the ZDC expected soon
  - Initial signs look promising
  - Can hopefully check performance quickly
  - Analysis code should not need too much modification

https://doi.org/10.48550/arXiv.2412.12346 S.J. Paul et. al.

What next?

- As well as improving the existing analysis, There's lots more to do for DEMP!
- Need to look at eD reactions
  - Start with early science config
  - Rapid simulation or a generator modification?
- $p(e, e'K^+\Lambda)$ channel to look at for 10x130 too
  - Λ^0 reconstruction in the ZDC expected soon
  - Initial signs look promising
  - Can hopefully check performance quickly
  - Analysis code should not need too much modification
- Of course, when generator refinements are made, will also need to re-process

Deuterium Studies

- Model used to isolate σ_L from measured $d\sigma_{uns}/dt$
- Examine π^+/π^- ratios as a test of the model

Deuterium Studies

- Model used to isolate σ_L from measured $d\sigma_{uns}/dt$
- Examine π^+/π^- ratios as a test of the model
- Examine $^2H(e, e'\pi^+ n)n$ and $^2H(e, e'\pi^- p)p$ in same kinematics as $p(e, e'\pi^+ n)$, look at ratio

$$R = \frac{\sigma\left[n(e, e'\pi^- p)\right]}{\sigma\left[p(e, e'\pi^+ n)\right]} = \frac{|A_V - A_S|^2}{|A_V + A_S|^2}$$

Deuterium Studies

- Model used to isolate σ_L from measured $d\sigma_{uns}/dt$
- Examine π^+/π^- ratios as a test of the model
- Examine $^2H(e, e'\pi^+ n)n$ and $^2H(e, e'\pi^- p)p$ in same kinematics as $p(e, e'\pi^+ n)$, look at ratio

$$R = \frac{\sigma\left[n(e, e'\pi^- p)\right]}{\sigma\left[p(e, e'\pi^+ n)\right]} = \frac{|A_V - A_S|^2}{|A_V + A_S|^2}$$

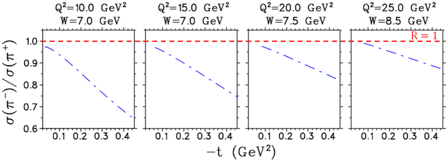
- R will be diluted if σ_T *not* small *or* if there are significant non-pole contributions to σ_L

Deuterium Studies

- Model used to isolate σ_L from measured $d\sigma_{uns}/dt$
- Examine π^+/π^- ratios as a test of the model
- Examine $^2H(e, e'\pi^+ n)n$ and $^2H(e, e'\pi^- p)p$ in same kinematics as $p(e, e'\pi^+ n)$, look at ratio

$$R = \frac{\sigma\left[n(e, e'\pi^- p)\right]}{\sigma\left[p(e, e'\pi^+ n)\right]} = \frac{|A_V - A_S|^2}{|A_V + A_S|^2}$$

- R will be diluted if σ_T *not* small *or* if there are significant non-pole contributions to σ_L
- Compare R to model expectations



T.Vrancx, J. Ryckebusch, PRC 89(2014)025203

Summary

- 10on130 pion results look good, even with low $\int \mathcal{L}$ expected from early physics
  - Need further generator updates to determine how high in Q^2 is actually viable. 50 GeV^2? 100 GeV^2?
  - New student at URegina will focus on this when they start ($\sim$Autumn), but will need onboarding time

Summary

- 10on130 pion results look good, even with low $\int \mathcal{L}$ expected from early physics
  - Need further generator updates to determine how high in Q^2 is actually viable. 50 GeV^2? 100 GeV^2?
  - New student at URegina will focus on this when they start ($\sim$Autumn), but will need onboarding time
- 10x250 events processed and look good, just need to finalise the projection plot
- Still need deuteron studies

Summary

- 10on130 pion results look good, even with low $\int \mathcal{L}$ expected from early physics
  - Need further generator updates to determine how high in Q^2 is actually viable. 50 GeV^2? 100 GeV^2?
  - New student at URegina will focus on this when they start ($\sim$Autumn), but will need onboarding time
- 10x250 events processed and look good, just need to finalise the projection plot
- Still need deuteron studies
- Also need to revisit $K^+\Lambda^0$
  - New ZDC Λ^0 reconstruction algorithm expected in main ePIC simulation soon
  - Λ^0 reconstruction in ZDC looks very promising
  - Expect rapid results when it is available

Summary

- 10on130 pion results look good, even with low $\int \mathcal{L}$ expected from early physics
  - Need further generator updates to determine how high in Q^2 is actually viable. 50 GeV^2? 100 GeV^2?
  - New student at URegina will focus on this when they start (∼Autumn), but will need onboarding time
- 10x250 events processed and look good, just need to finalise the projection plot
- Still need deuteron studies
- Also need to revisit $K^+\Lambda^0$
  - New ZDC Λ^0 reconstruction algorithm expected in main ePIC simulation soon
  - Λ^0 reconstruction in ZDC looks very promising
  - Expect rapid results when it is available
- Last but not least, need to get text into analysis note!
  - Plots all ready, just need placing in

Thanks for listening, any questions?

With thanks to the Meson Structure Working Group

stephen.kay@york.ac.uk

This research was supported by UK Research and Innovation: Science and Technology Facilities council (UKRI:STFC) grant ST/W004852/1 and the Natural Sciences and Engineering Research Council of Canada (NSERC) grant SAPPJ-2023-00041