Ongoing Work of the ePIC Muon Identification Task Force

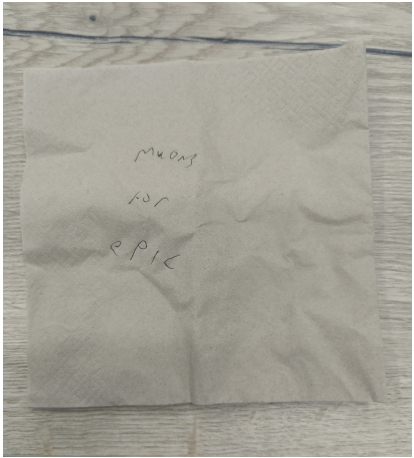
UK EIC Gathering, York

Stuart Fegan

University of York

December 8th, 2025

Muons for ePIC



Robust identification of muons in the ePIC detector has emerged as a desirable capability

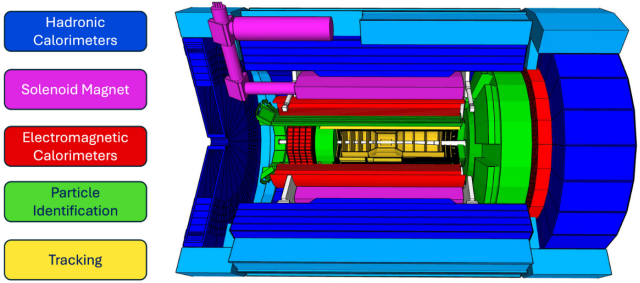
Several efforts beginning to coalesce as a *Muon Identification Task Force*

This presentation will give an overview of these efforts, with an emphasis on UK contributions

ePIC

ePIC - EIC Detector 1

- Central Detector; barrel and endcaps
- Comprises various detector systems around a solenoid magnet
- No dedicated muon detectors



Finding Muons - Challenges

Muons are charged, and have similar mass to pions

μ

$J = \frac{1}{2}$

Mass $m = 0.1134289259 \pm 0.0000000025$ u
Mass $m = 105.6583755 \pm 0.0000023$ MeV
Mean life $\tau = (2.1969811 \pm 0.0000022) \times 10^{-6}$ s
$\tau_{\mu^+}/\tau_{\mu^-} = 1.00002 \pm 0.00008$
$c\tau = 658.6384$ m
Magnetic moment anomaly $(g-2)/2 = (11659205.9 \pm 2.2) \times 10^{-10}$
$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}} = (-0.11 \pm 0.12) \times 10^{-8}$
Electric dipole moment $|\text{d}| < 1.8 \times 10^{-19}$ e cm, CL = 95%

$\pi^\pm$

$I^G(J^P) = 1^-(0^-)$

Mass $m = 139.57039 \pm 0.00018$ MeV (S = 1.8)
Mean life $\tau = (2.6033 \pm 0.0005) \times 10^{-8}$ s (S = 1.2)
$c\tau = 7.8045$ m

$\pi^\pm \to \ell^\pm \nu\gamma$ form factors [a]

$F_V = 0.0254 \pm 0.0017$
$F_A = 0.0119 \pm 0.0001$
F_V slope parameter $a = 0.10 \pm 0.06$
$R = 0.059^{+0.009}_{-0.008}$

In many ways, muons and pions are going manifest similarly to each other in ePIC

Finding Muons - Solutions

In many ways, muons and pions are going manifest similarly to each other in ePIC

What can we do?

Two approaches;

- Use properties of existing detectors to realise muon ID
- Use properties of physics analyses to make effective use of muon ID capability

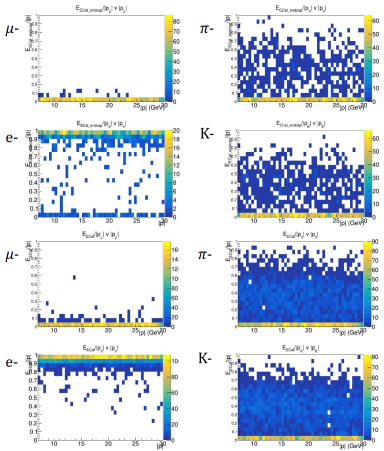
Muon Identification

Muon identification from calorimeter information

- E/p cuts
- Shower shape
- Veto from other detectors

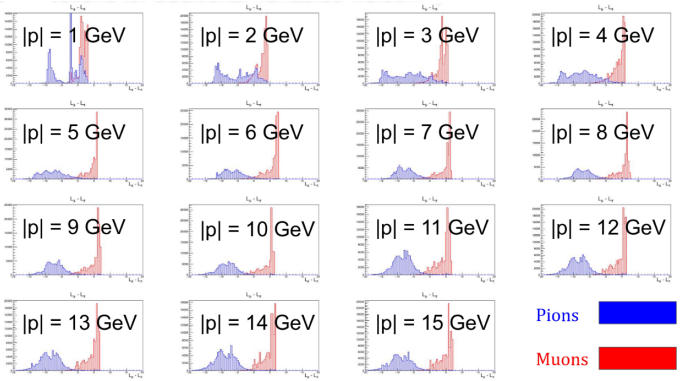
Plots on right show HCal E/p for the endcap (top) and barrel (bottom)

(A. Hurley, University of Massachusets from an $e \rightarrow \tau$ study in the EW/BSM group)



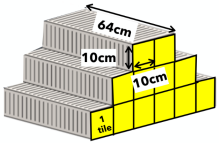
Muon Identification

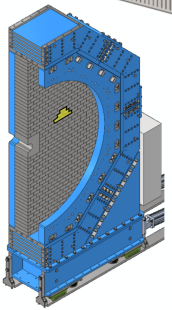
Andrew's study then summarises this into a log-likelihood for each species, allowing a cut for separation



Muon Identification

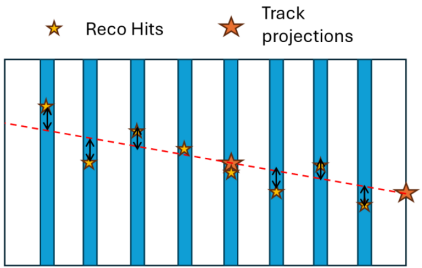
nHCal design:
10 layers of each
4 cm steel +
2.4 cm scintillator





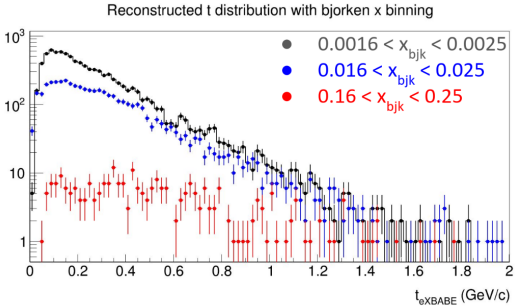
Utilise lower-level calorimeter information

- Treat each tile as an independent hit
- Check for consistency with a minimum ionising particle



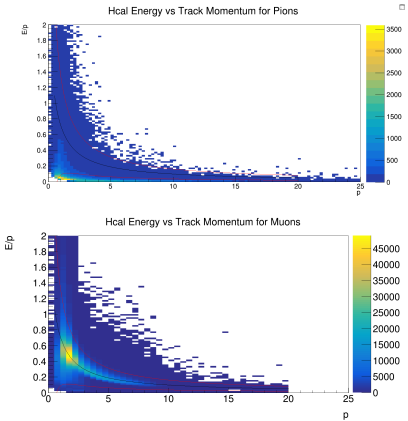
$J/\Psi \to \mu^+\mu^-$ DVMP

- Analysis by A. Smith (York)
- Complimentary to $J/\Psi \to e^+e^-$ analysis at New Hampshire



- Can probe gluon GPDs by measuring change in spatial gluon distribution from low to high x_B
- Initial evaluation of feasibility of reconstructing J/Ψ for DVMP evolving into optimising analysis and contributing to muon ID

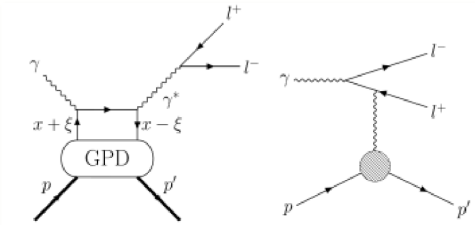
$J/\Psi \to \mu^+\mu^-$ DVMP



- Reproducing Andrew Hurley's technique on $J/\Psi \to \mu^+\mu^-$ DVMP
- Characterising difference between muons and pions in E/p distributions
- Simple cuts applied to select species of interest

$\mu^+\mu^-$ TCS

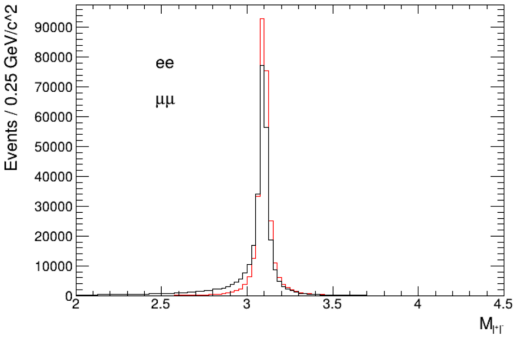
- Analysis by G. Penman (Glasgow)



- Hard exclusive electroproduction of a lepton pair; time-reversal symmetric process of DVCS
- Described by handbag diagram and Bethe-Heitler contribution, and interference between them $d\sigma = d(\sigma_{TCS} + \sigma_{BH} + \sigma_{INT})$

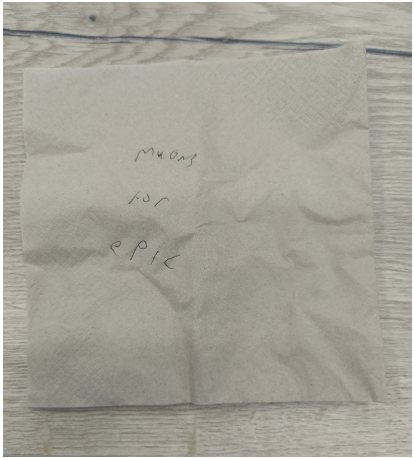
$\mu^+\mu^-$ TCS

- Analysis by G. Penman (Glasgow)



- TCS also possible with muons
- Work underway to understand and charcaterise backgrounds in $\mu\mu$ TCS
- Feedback to muon ID

The Muon Task Force



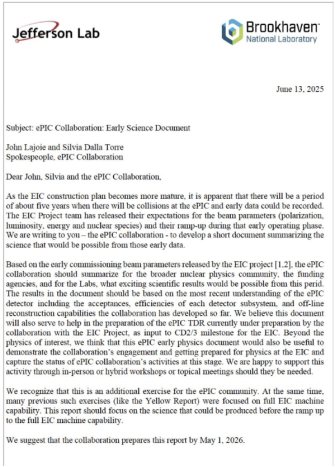
- Interested analysers in York and Glasgow have loosly formed a *Muon Task Force*
- Weekly meetings to compare notes on muon ID studies
- Attempting to formalise these efforts and fit into ePIC working group structures
- Expressions of interest from other groups

Possible Tasks

- Planning a series of joint summer students between Glasgow and York in 2026 to work on muon ID tasks
- DVMP on other vector mesons (e.g. Υ)
- Comparison of event generators
- Individual calorimeter element analysis

Towards a *Muon Finder*?

Early Science Report



Jefferson Lab

Brookhaven National Laboratory

June 13, 2025

Subject: ePIC Collaboration: Early Science Document

John Lajoie and Silvia Dalla Torre
Spokespeople, ePIC Collaboration

Dear John, Silvia and the ePIC Collaboration,

As the EIC construction plan becomes more mature, it is apparent that there will be a period of about five years when there will be collisions at the ePIC and early data could be recorded. The EIC Project team has released their expectations for the beam parameters (polarization, luminosity, energy and nuclear species) and their ramp-up during that early operating phase. We are writing to you – the ePIC collaboration - to develop a short document summarizing the science that would be possible from those early data.

Based on the early commissioning beam parameters released by the EIC project [1,2], the ePIC collaboration should summarize for the broader nuclear physics community, the funding agencies, and for the Labs, what exciting scientific results would be possible from this period. The results in the document should be based on the most recent understanding of the ePIC detector including the acceptances, efficiencies of each detector subsystem, and off-line reconstruction capabilities the collaboration has developed so far. We believe this document will also serve to help in the preparation of the ePIC TDR currently under preparation by the collaboration with the EIC Project, as input to CD2/3 milestone for the EIC. Beyond the physics of interest, we think that this ePIC early physics document would also be useful to demonstrate the collaboration's engagement and getting prepared for physics at the EIC and capture the status of ePIC collaboration's activities at this stage. We are happy to support this activity through in-person or hybrid workshops or topical meetings should they be needed.

We recognize that this is an additional exercise for the ePIC community. At the same time, many previous such exercises (like the Yellow Report) were focused on full EIC machine capability. This report should focus on the science that could be produced before the ramp up to the full EIC machine capability.

We suggest that the collaboration prepares this report by May 1, 2026.

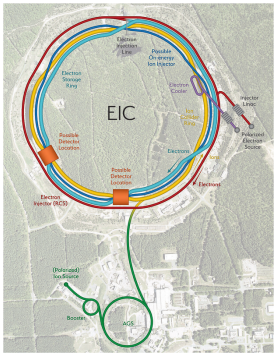
- Early Science Report due in May 2026
  - Robust muon ID will aid several aspects of the physics program
  - May not have a full muon finder by May, but we should have an idea of how one might be realised
  - Also an understanding of the physics impact of muon ID improvements on various studies
- In muon terms, a lot of this work is planned anyway

Towards the TDR

- Yes, the pre-TDR is just in, but the TDR proper will be on us before we know it
- Again, muon ID will feature
  - Existing muon ID section in preTDR
  - Jump off from here to continue the effort
- Should be due late 2026
- i.e. the next year will be critical to realising the potential of using muons in ePIC physics

Summary and Outlook

Muons are coming to ePIC...



- Muon ID studies in ePIC gathering pace
- This is a high-profile effort, with several groups contributing
- Attempting to formalise these efforts as an official task force in ePIC
- Major UK contributions from existing analyses, major benefits for all of ePIC