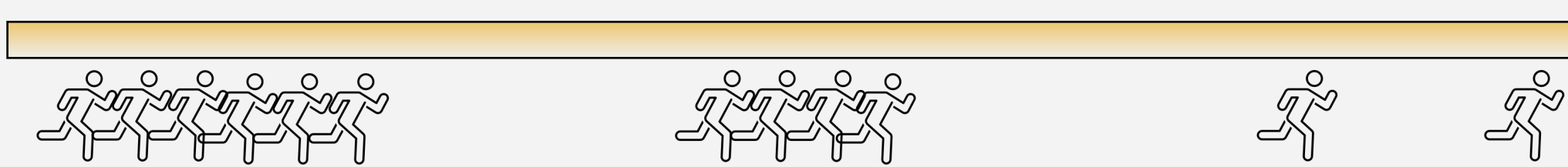
Exclusive/diffractive/tagging physics analyses in ePIC

Phase 1:
Physics process identified.
Generator available.

Phase 2:
Physics events passed thru ePIC software simulation.

Phase 3:
Physics benchmark made.
Codes/scripts submitted.



- Kong Tu, BNL

A diverse group with diverse physics programs

Rich physics programs:

- EIC White Paper (WP) and Yellow Report (YR) physics topics.
- Physics beyond EIC WP and YR are being developed
- Both ep and eA physics.
- DIS community at high/medium/low energy to high energy heavy-ion physics community.

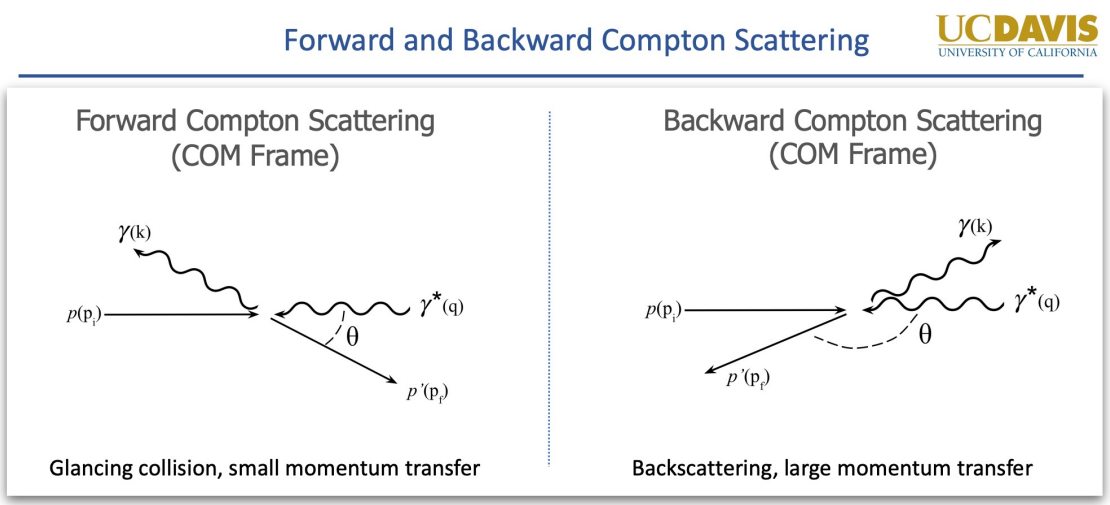
MC generators:

- BeAGLE, DEMP, EIC_mesonMC, EpIC, eSTARLight, IAger, Sartre, TOPEG, and more.

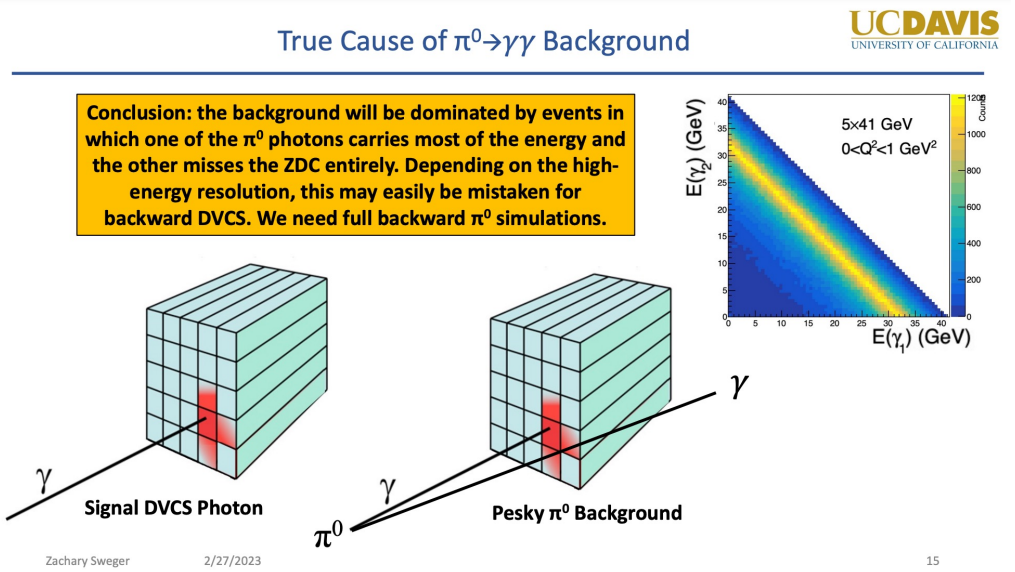
Detectors:

- Tracking, Calorimetry, PID, and most uniquely the **Far-Forward detector system**.

Phase 1 analyses – example 1



Sensitive to baryon stopping, Transition Distribution Amplitudes, Reggeon exchange, etc. [*D. Cebra et al 2022*]



Background dominated by pi0 productions.

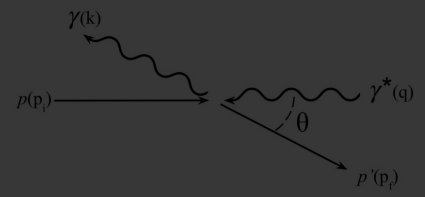
Led by Zach Sweger, Spencer Klein, et al.

Updated a few weeks ago with standalone simulation.

Phase 1 ana

Forward and Backwar

Forward Compton Scattering
(COM Frame)



Glancing collision, small momentum transfer

Sensitive to baryon stoppi
Distribution Amplitudes, R
[*D. Cebra et al 2022*]

Backward π^0 Simulation Results

UC DAVIS UNIVERSITY OF CALIFORNIA

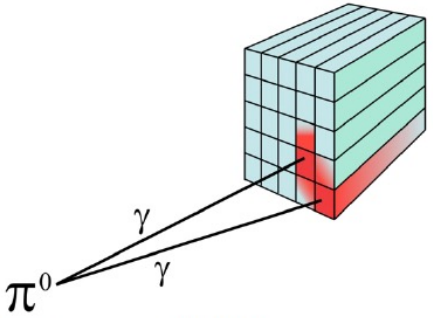
- Remember backward π^0 cross section is larger than backward VCS cross section

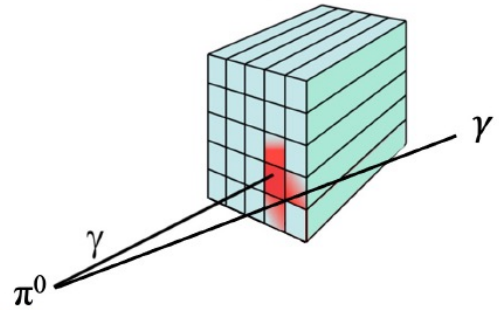
π^0 Both Photons in ZDC Acceptance

	5×41	10×100	18×275
$0<Q^2<1$ GeV^2	13%	72%	99%
$1<Q^2<10$ GeV^2	11%	69%	98%
$10<Q^2<20$ GeV^2	15%	79%	99%

π^0 Single-Photon in ZDC Rates

	5×41	10×100	18×275
$0<Q^2<1$ GeV^2	34%	21%	1%
$1<Q^2<10$ GeV^2	35%	24%	2%
$10<Q^2<20$ GeV^2	38%	18%	1%

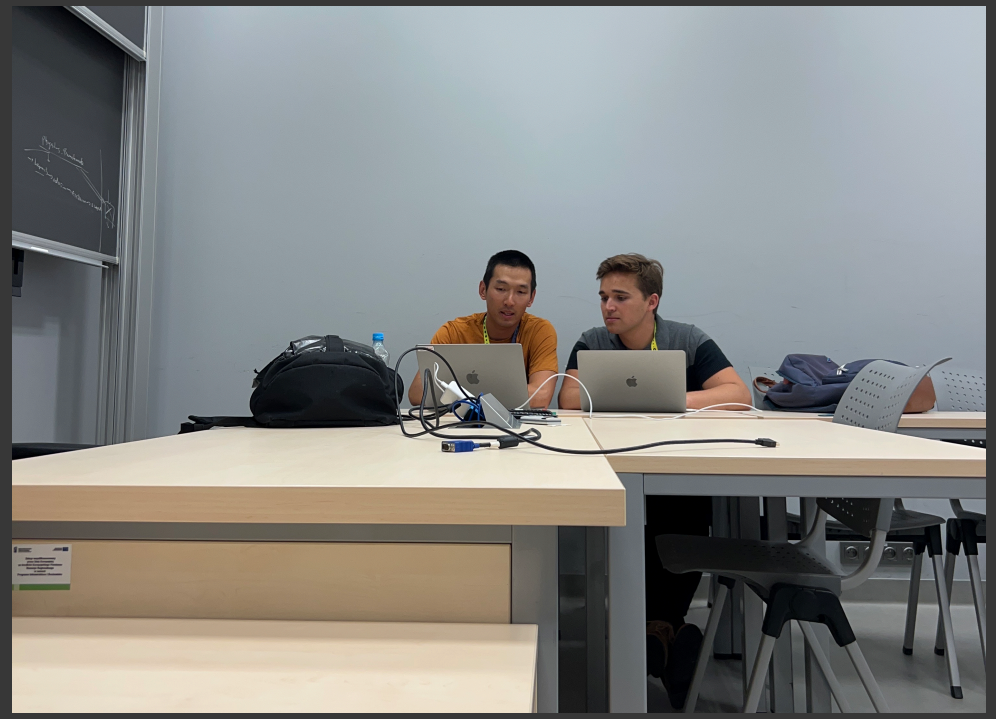




Zachary Sweger 6/26/2023 Exclusive/Diffractive/Tagging Meeting 9

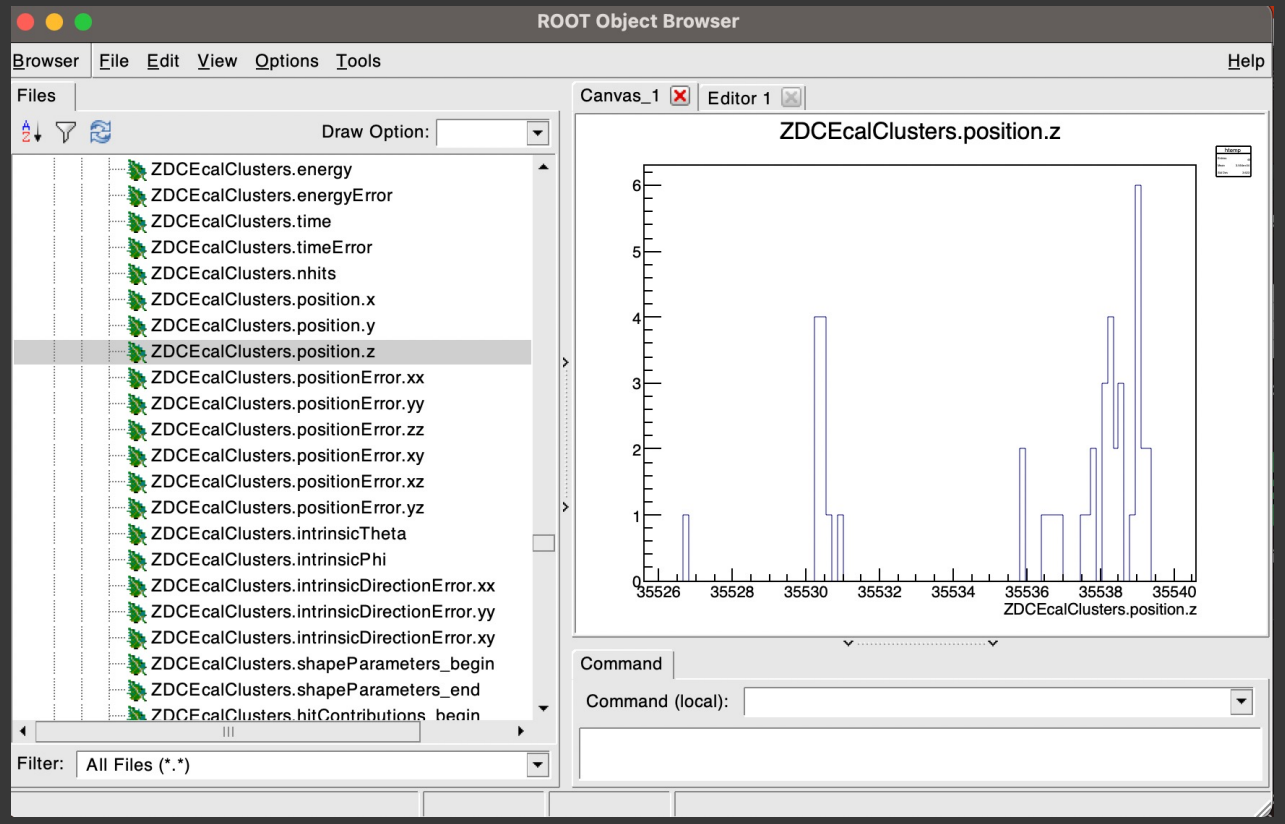
Will need Phase 2 (simulation in ePIC) and Phase 3 (benchmark)

Until yesterday... a mini-workfest



Thanks Barbara for finding us a room...

One hour later, full simulation results made.

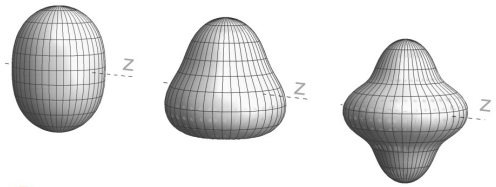


Phase 1 analyses – example 2

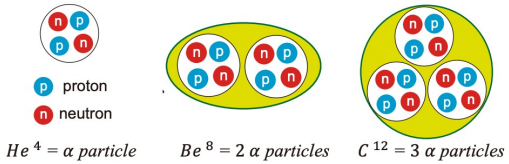
❖ Motivation

➢ EIC can be a unique tool for understanding the nuclear structure

✓ Understanding the nuclear deformation



✓ Understanding the α clustering



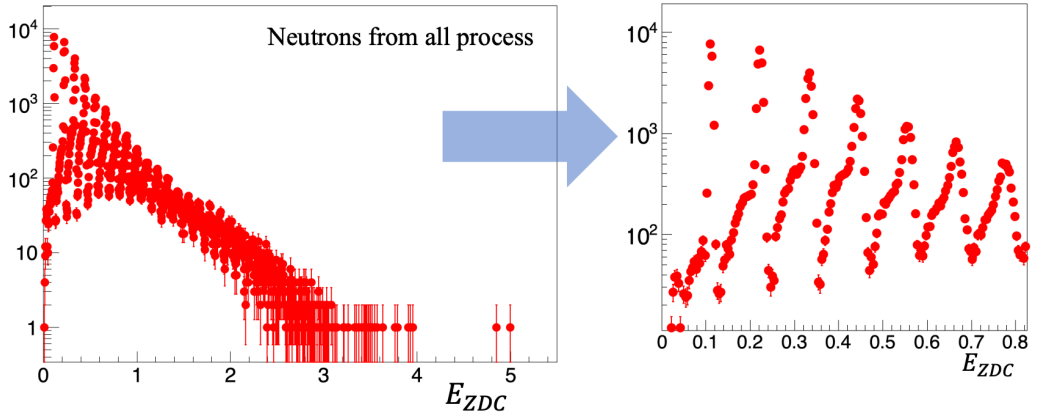
Can EIC provide additional constraints on nuclear deformation and the α clustering?

➢ Using the BeAGLE model

✓ Modifying the nucleus information in the model

❖ Neutrons in ZDC in central collisions

$$E_{ZDC} = \sum_{hit=0}^{N} E_{hit}$$



➢ Many peaks from evaporation processes.

➢ Can evaporation neutrons be used to study centrality?

EIC as a tool for nuclear structure.

ZDC can be used for centrality determination

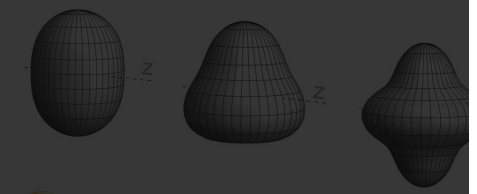
Led by Niseem Magdy, Bill Lee et al.

Phase 1 ar

❖ Motivation

➢ EIC can be a unique tool for un

✓ Understanding the nuclear deformati



Can EIC provide additional
the

➢ Using the BeAGLE m

✓ Modifying the nucleus

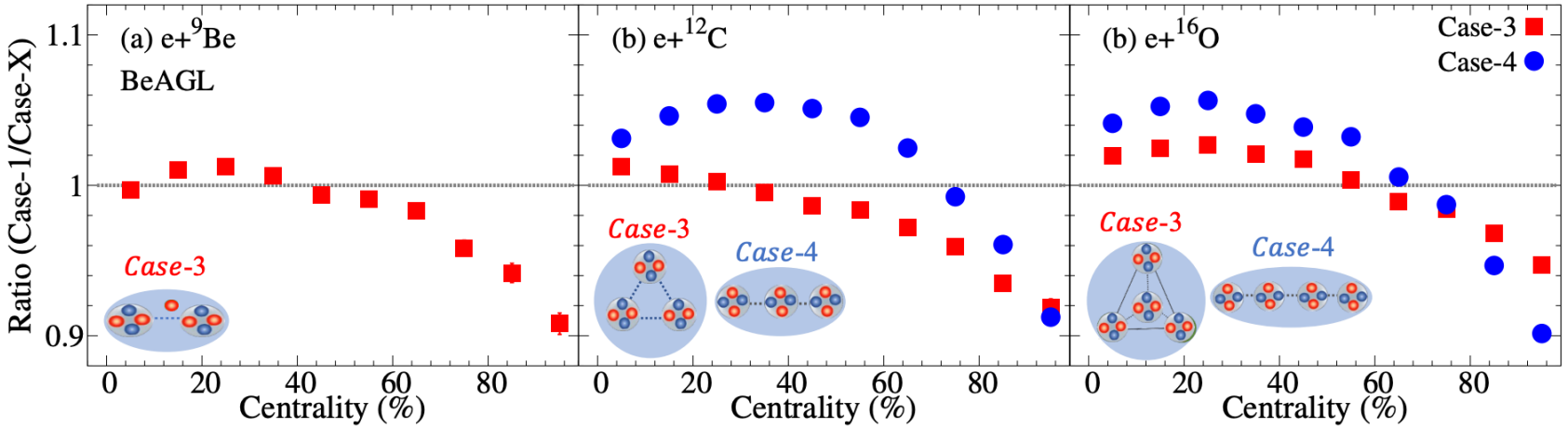
EIC as a tool for nuclea

❖ The α clustering

Case-1: Woods–Saxon
Case-3,4: Clustering random orientation

➢ The system energy/momentum

✓ The $\langle E \rangle$ and/or $\langle p \rangle$ measured in the forward detector is related to the impact parameter and the number of collisions



The $\langle E \rangle$ in B_0 is sensitive to α clustering in Be^9, C^{12}, and O^{16}

Still in an early state of the initial study
Will need Phase 2 (simulation in ePIC) and Phase 3 (benchmark)

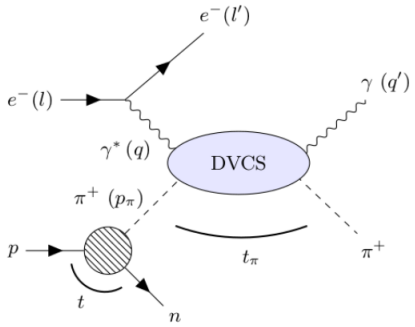
Other phase 1 analyses

DVCS eHe (G. Penman)
Deuteron incoherent breakup & vetos (M. Kim, A. Jentsch, K. Tu)
DEMP and Lambda polarization (J. Vanek, K. Tu)
XYZ spectroscopy (D. Glazier…)
DVMP in ep (N. Santiesteban and others)
…

Phase 2 analyses – example 1

Sullivan DVCS

- Instead of a pion beam, protons can provide a source of pions via the virtual meson cloud around the proton.
- Such pions are off-shell, but results can be extrapolated to on-shell pions for low momentum transfers.
- Golden channel for GPDs: Deeply Virtual Compton Scattering
- DVCS on the pion, with e, γ, π^+ and n in the final state



My simulation setup

- Event generation code provided by Maxime Defurne, based on calculation by Belitsky and Muller.
- GPD model computed with DSE equations by Chavez et al.
- Conversion of ROOT output to a hepmc file.
- Applying the afterburner to rotate proton beam by 25 mrad + smearing.
- Simulation in 23.01.0 with Arches setup
- Reconstruction with Jana2/EICrecon
- 100k Sullivan DVCS events with 275x18 GeV beam configuration.

Privately produced

Led by Olga Bessidskaia Bylund, Francesco Bossu, Maxime Defurne

Phase 2 analyse

Sullivan DVCS

- Instead of a pion beam, protons can provide a s
virtual meson cloud around the proton.
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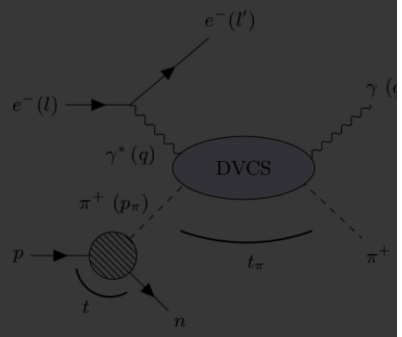
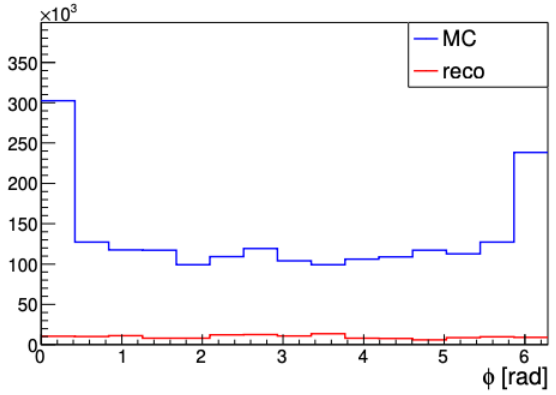
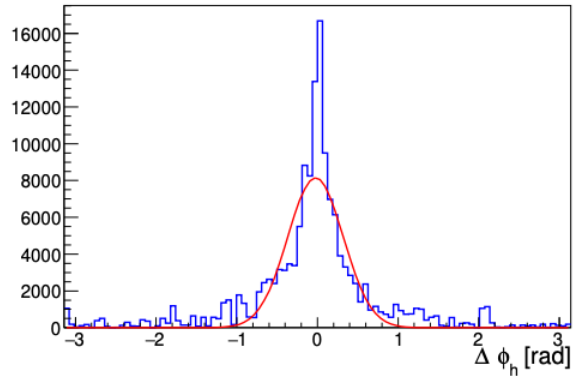


ϕ





ϕ: angle between leptonic and hadronic plane in the virtual photon-pion cloud CoM. Reconstruction efficiency $\epsilon = 0.07$. Resolution from Gaussian fit: 0.34 rad. 15 bins should be ok ($2\pi/15$=0.42). ϵ cutflow:

Exclusivity	0.37
$1 <= Q^2 < 100\text{GeV}^2$	0.32
ϕ! =nan	0.29
$M(N,\pi) > 2$ GeV	0.14
$10^{-3} < x_B^\pi < 10^{-2}$	0.07

Follow-up studies are needed with more up-to-date detector configurations

Phase 2 analyses – example 2

Vetoing Incoherent Events in ePIC

Objectives:

Short term: Rejection of **Incoherent** proccesses using ePIC simulation.

Long Term : Extending event selection to low Q2 region ($-3 < \log(Q2) < -2$)

Data:

We used BeAGLE generated events (Produced by Mark), where we started with events where $J/\psi \to \gamma \to \mu^+\mu^-$.

Note: This was done so we don't have to worry (for now) about the electron originating from the electron beam.

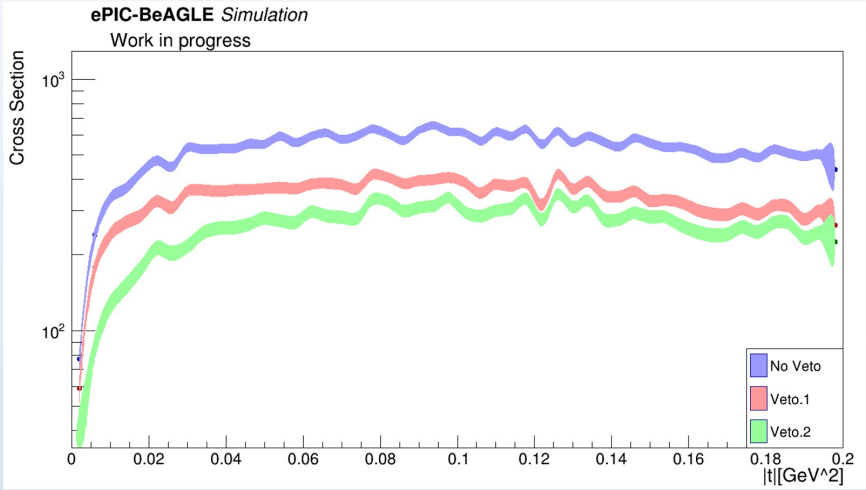
Current Vetoing Steps:

- Veto.1: No activity other than e^- and J/ψ ($\mu^+\mu^-$) in the main detector ($|\eta| < 4$) ;
- Veto.2: Veto.1 and no signal in the ZDC ($\Sigma E_{ZDC_{threshold}} > 100\ MeV$);
- Veto.3: Veto.2 and no signal in RP;
- Veto.4: Veto.3 and no signal in OMDs;
- Veto.5: Veto.4 and no signal in B0 tracker;
- Veto.6: Veto.5 and no signal in B0 ECAL.

Initial Results

Vetoing Steps:

- Veto.1: No activity other than e^- and J/ψ ($\mu^+\mu^-$) in the main detector ($|\eta| < 4$) ;
- Veto.2: Veto.1 and no signal in the ZDC ($\Sigma E_{ZDC_{threshold}} > 100\ MeV$);
- Veto.3: Veto.2 and no Proton in RP;
- Veto.4: Veto.3 and no signal in OMDs;
- Veto.5: Veto.4 and no signal in B0 tracker;
- Veto.6: Veto.5 and no signal in B0 ECAL.



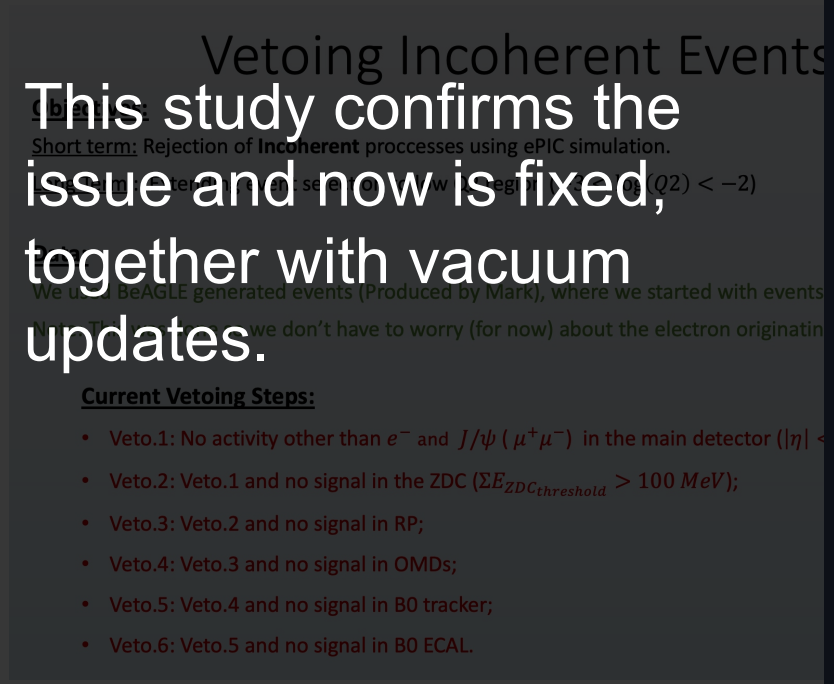
- **Unexpected**: Proton signal in RP appear in 100% of the events.

Privately produced

Led by Eden Mautner, Michael Pitt, Zvi Citron

Phase 2 analyses – example 2

This study confirms the issue and now is fixed, together with vacuum updates.

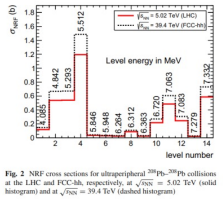


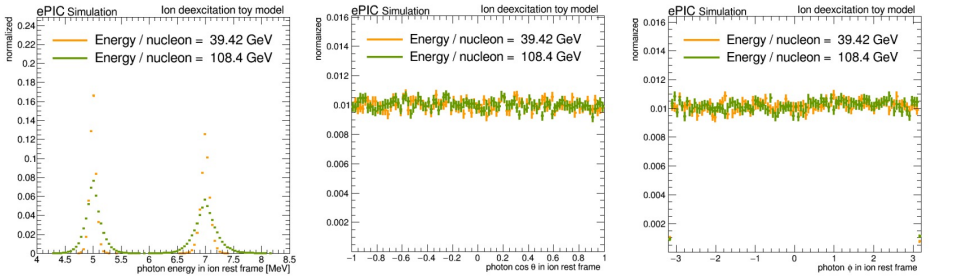
Led by Eden Mautner, Michael Pitt, Zvi Citron

Phase 2 analyses – example 3

Photon spectra

- Photons with two energies were generated: 5 MeV and 7 MeV, with $P(5MeV) = P(7MeV) = 0.5$. Motivated by the energy range of excited ions in PbPb collisions at the LHC, Eur. Phys. J. A (2021)
- Two hadron beam energies were considered[1]: 108 and 39.4 GeV/n

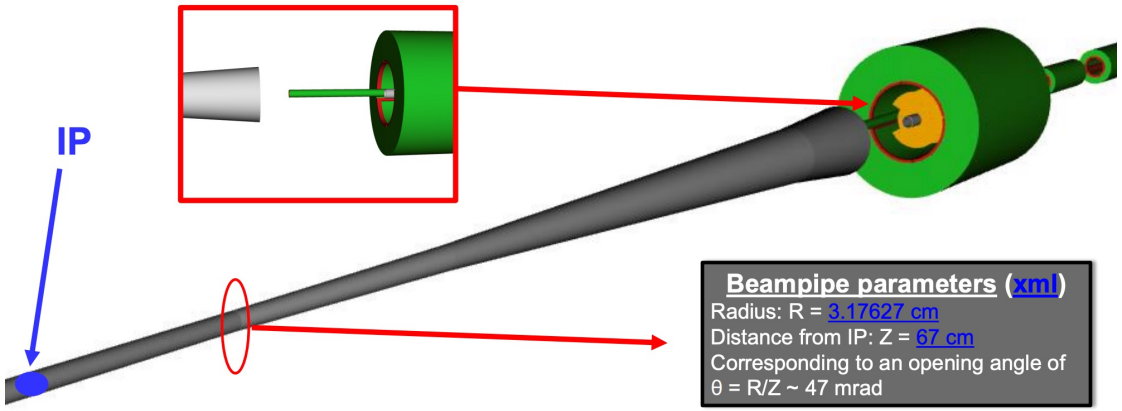




[1] Limited range constrained by the Afterburner, discussed here: https://github.com/eic/afterburner/issues/5

ePIC detector geometry

- Photons up to ~ 15 mrad don't cross the beampipe resulting in high acceptance in B0 detector.



Beampipe parameters (xml)
Radius: R = 3.17627 cm
Distance from IP: Z = 67 cm
Corresponding to an opening angle of
θ = R/Z ~ 47 mrad

Study of low energy photons detected by B0 and ZDC with simulation **privately produced**

Led by Michael Pitt, Eden Mautner, Zvi Citron

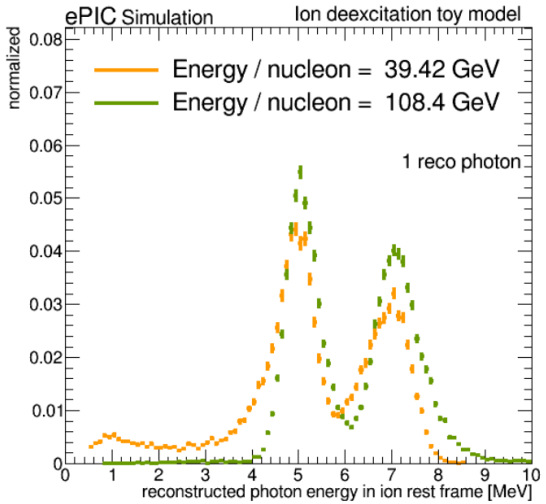
Brookhaven National Laboratory

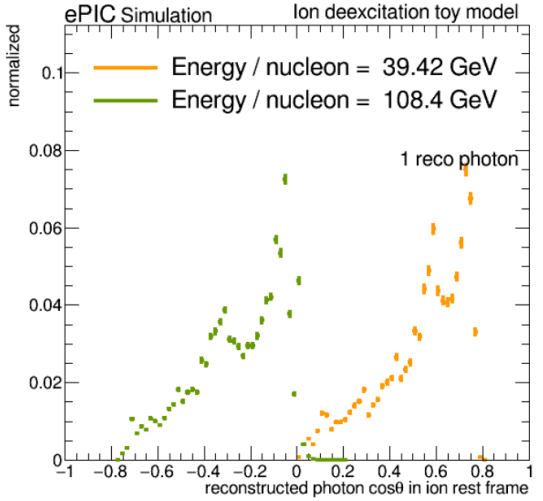
Phase 2 analyse

A good detector benchmark candidate

Simulation results

- Photons are reconstructed from the calibrated B0ECAL clusters.
  - Energy reconstruction – good separation for the toy model (ΔE = 2 MeV)
  - Angular reconstruction – large bias due to geometrical acceptance and resolution





27 June 2023

13

γ energy in A rest frame	Within B0 acceptance	B0 acceptance + At least one cluster in B0 with E > 50 MeV
5 MeV	40%	33%
7 MeV	40%	33%

privately produced

γ energy in A rest frame	Within ZDC acceptance	ZDC acceptance + Signal in ZDC above 0
5 MeV	60%	<1%
7 MeV	60%	<1%

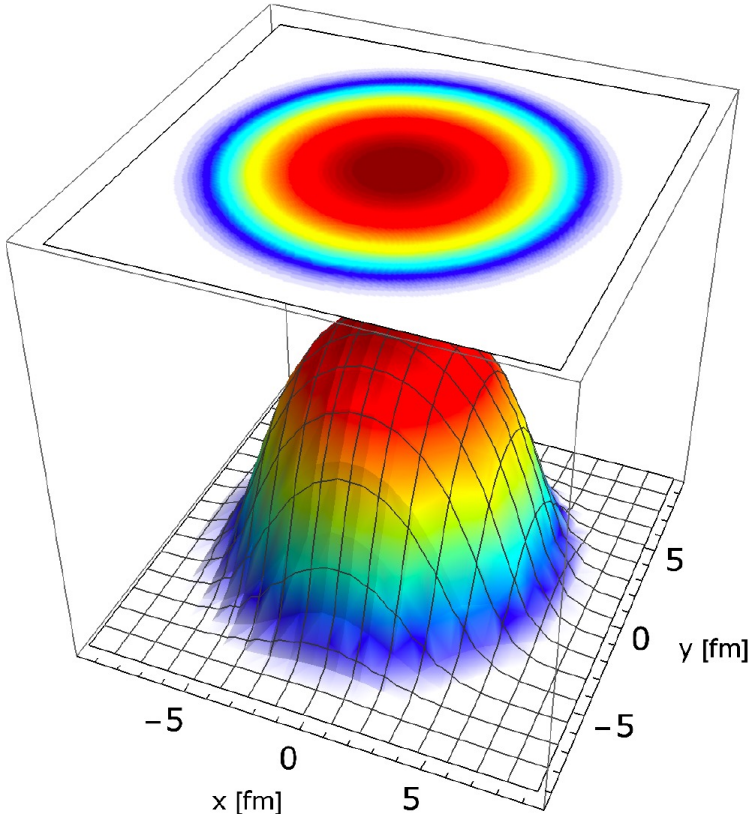
Phase 2 analyses

ePIC **simulation production samples** exist, but no analysis updates reported yet.

Upsilon 3 states separation (M. Kim, S. Klein)
TCS (D. Sokhan, K. Gates)
DVCS (S. Fazio, I. Korover, G. Penman)
DEMP on pion/kaon structure (S. Kay, G. Huber)

Will be followed up.

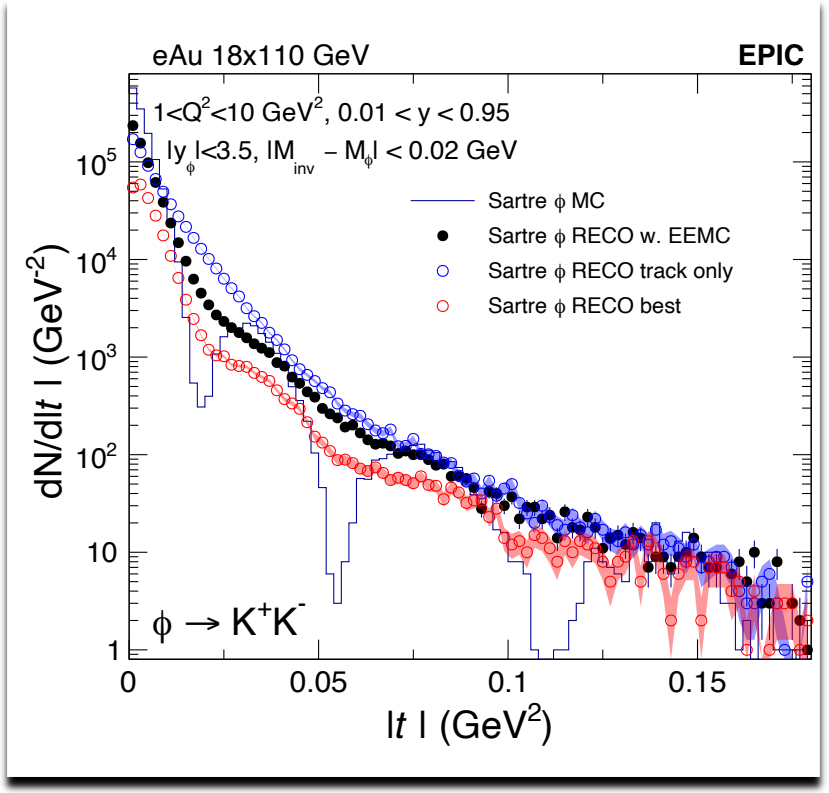
Phase 3 analyses – only 1 so far



Made by A. Kumar (IIT, Delhi)

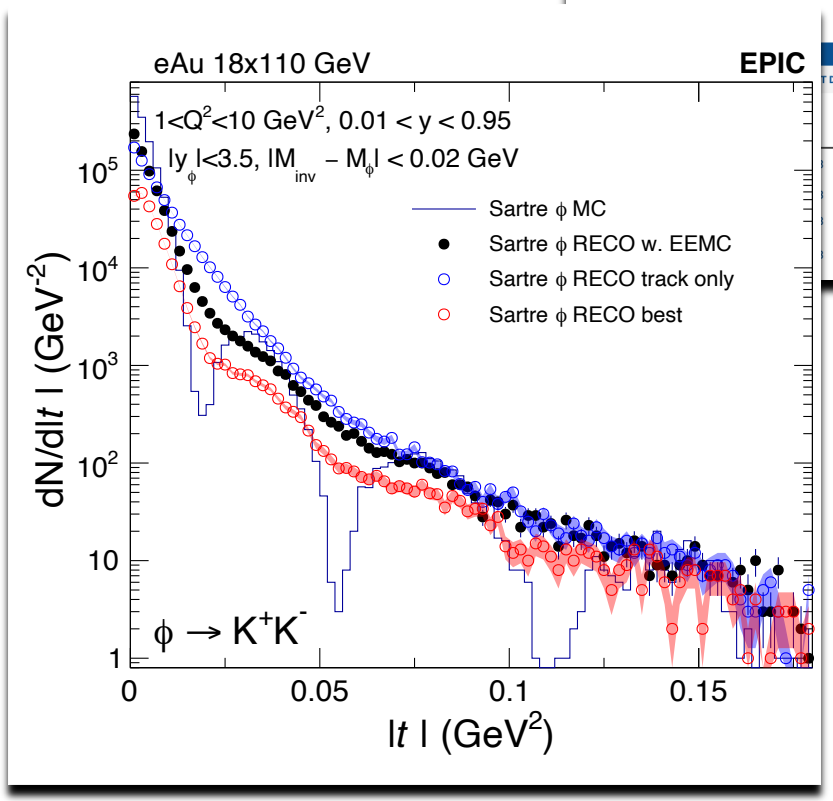
Momentum to Position:
(Fourier Transform)

$\vec{b}_{T,\text{gluon}} \leftrightarrow \vec{p}_{\text{gluon}}$



Resolution and FF detector acceptances to veto incoherent are the keys to this measurement

Phase 3 analyses – only 1 so far



Vector-Meson in eA @ ePIC

Smartsheet Tip → This is a google sheet to keep track the optimization process

PROJECT TITLE	Optimizing the *t* resolution of exclusive VM production in eA @ ePIC	COLLABORATION NAME	ePIC Collaboration
PROJECT CONTACT	Z. Tu (zhoudunming@bnl.gov)	DATE	1/25/23

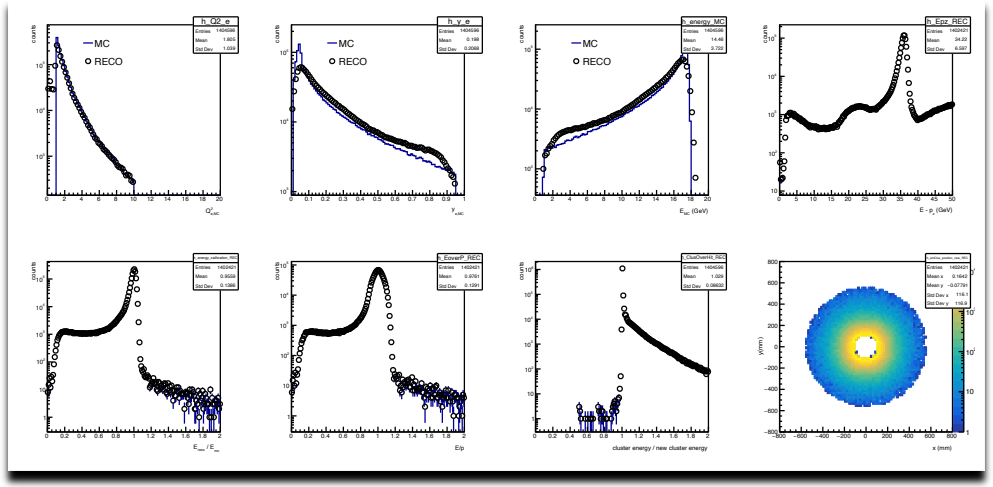
Default event and track selections to be baseline: Phase space selections: 2< Q2 < 10 GeV2, 0.01<y<0.085; leading clus. within 70mm of leading hit, energy calibration 4.5%; 150mm<cluster radius < 550mm, 0.8 < E/p (e') < 1.18; default source code here

DIS event elections and VM: 27 < E-pz < 40 GeV, 0.8 < E/p (e') < 1.18; |y_VM|<3.5, |eta_daug| < 3.0

Reconstructed results on -t: "best" = average of track only and EMCal+tracker result

Vector-Meson	Break-up mode
Phi	Coherent
Jpsi	Incoherent
Rho	

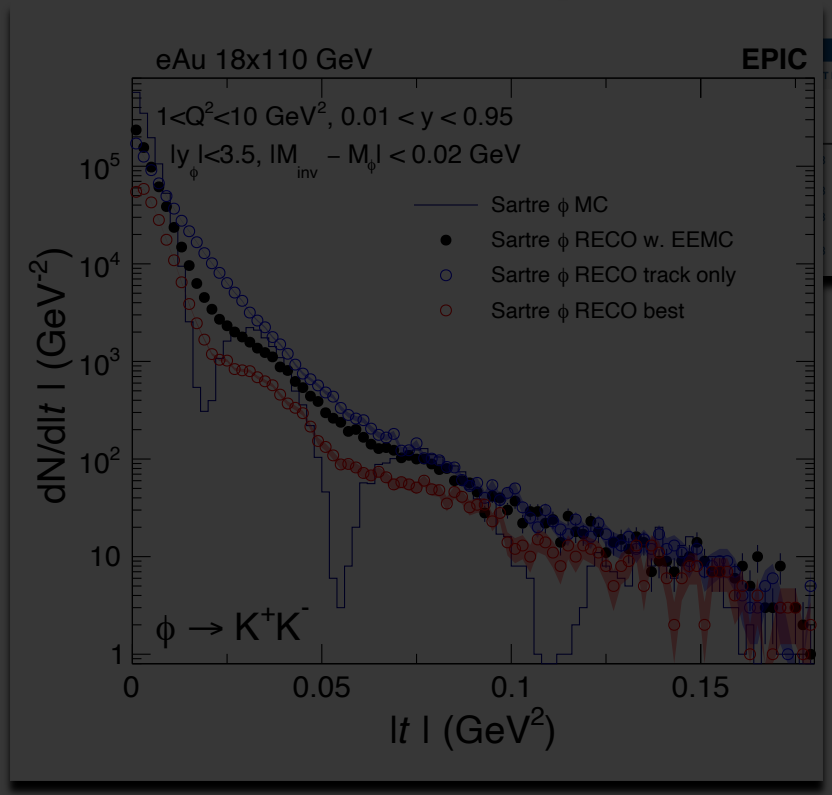
PROJECT DETAILS						Output file versions		-t RESOLUTION (dt/t,%)		
T DATE	END DATE	DURATION	ePIC Software version	Analyzers	DESCRIPTION	Default version v0	version number	1st minimum (0.015-0.025 in t)	2nd minimum (0.05-0.06 in t)	3rd minimum & beyound
						Results are linked		Method. L		
			arches.11.3	Kong Tu	Default version	link and link2. kinematics plots	v0	57.11%	12.73%	2.77%
			arches.11.3	Kong Tu	Default version	link and link2. kinematics plots	v0	37.33%	10.79%	4.28%
	1/26/23	1	arches.11.3	Kong Tu	Impact of the VM mass constraint	no changes	v1	37.33%	10.79%	4.28%
			arches.11.3	Kong Tu	Removed cluster radius lower cut off at 150mm & change the 1<Q2<10, 0.01<y<0.95	link and link2. kinematics plots	v2	45.05%	15.19%	3.54%

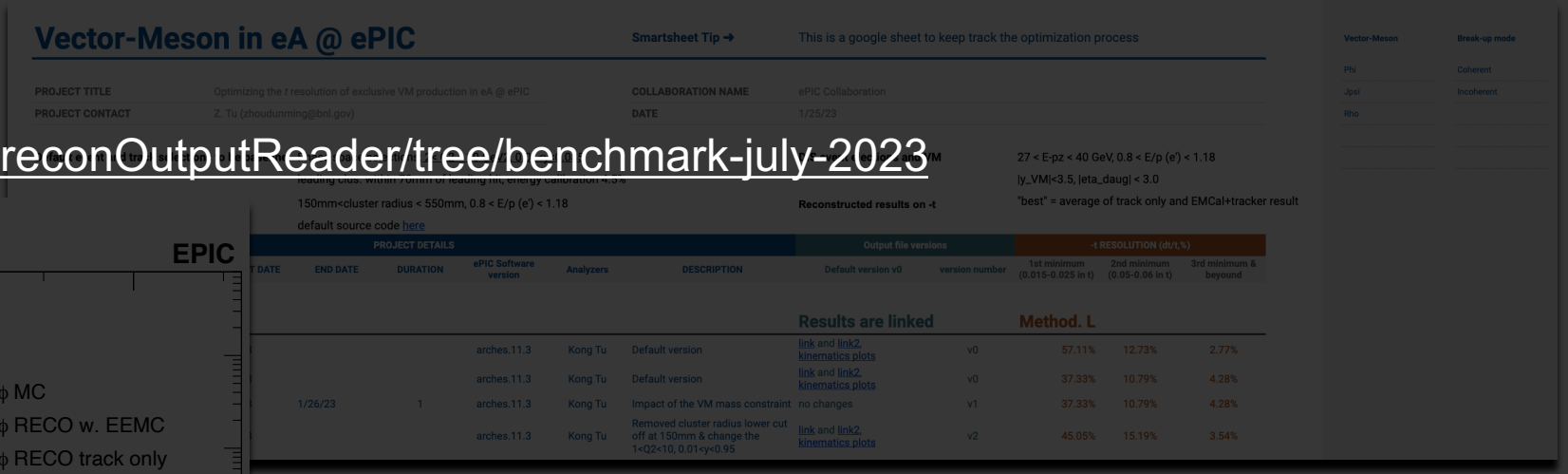


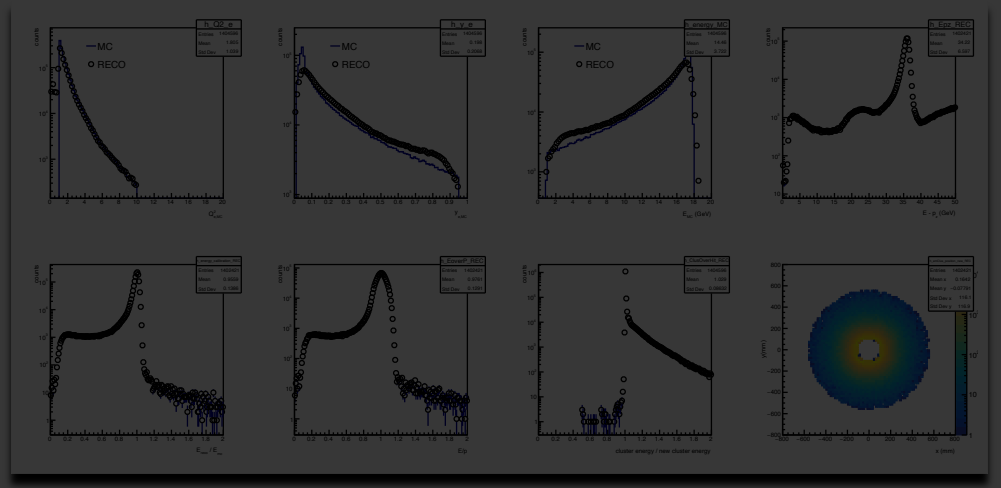
Phase 3 analyses – only 1 exists

Benchmark scripts submitted to Production WG for the July Campaign and future campaigns.

https://github.com/KongTu/EICreconOutputReader/tree/benchmark-july-2023







Summary and outlook

Phase 1:
Physics process identified.
Generator available.

Phase 2:
Physics events passed thru ePIC software simulation.

Phase 3:
Physics benchmark made.
Codes/scripts submitted.

- Many analyses are in Phase 1 & 2.
- The primary goal is to **move analyses to a later phase and the `benchmark` results can be easily/quickly checked to facilitate the detector developments and towards TDR.**
- New physics analyses are also encouraged, but highly suggested to go thru Phase 1-3.

- Exclusive/Diffractive/Tagging meeting biweekly (Monday Noon EST)
- eA study group meet up weekly (Tuesday 1pm EST)
- Workfest soon(?) for exclusive physics.