Backward Hadronic Calorimeter update

Update on physics motivation

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ePIC Calorimetry meeting 11.9.2024

THE OHIO STATE UNIVERSITY

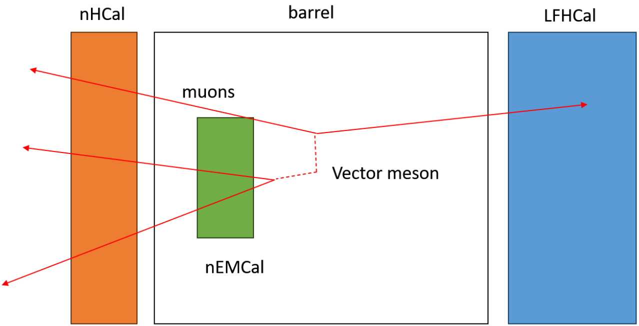
Outline

Motivation for nHCal

- At the July 2024 EPIC collaboration meeting there was concern raised about the need for the nHCAL. In this presentation, I will start going through several physics topics crucial to the EPIC program that justify the nHCAL.
- Members of H1 recognize that the lack of a backward HCAL hurt several important physics measurements, especially low-x related studies.
  - [NIM A386 (1997) 397-408]
  - [DESY 08-053]

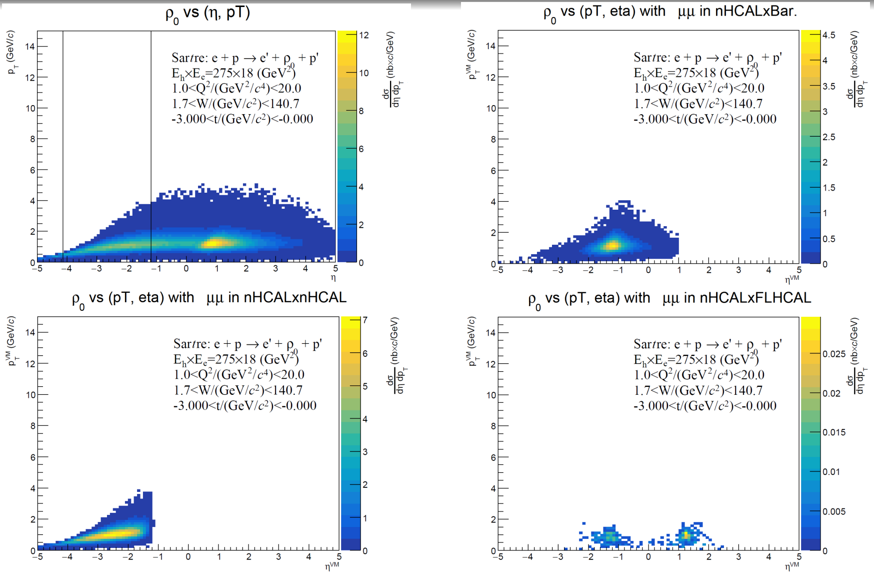
1. Measure vector mesons meson production in dimuon channel
   1. Crucial physics topic according to Yellow Report and EIC White Paper
      - Promised to be delivered by ePIC
      - [Nuclear Physics A 1026 (2022) 122447]
      - [BNL-98815-2012-JA; JLAB-PHY-12-1652]
   2. Access to low-pT VM's
   3. Increase acceptance
   4. Double statistics
   5. Muons not affected by bremsstrahlung
   6. Measure all VMs via dimuon final states (eg. $\phi \to KK \to \mu\mu$)
2. Measure diffractive dijets
3. Distinguish charged jets from those including neutrals
4. (next time) Improve scattered electron ID
5. (next time) Veto for dRICH

Vector meson reconstruction in dimuon channel



- Important for high y or low-p_T vector mesons - depends on type
- Increases acceptance
- Need projected MIP tracks and MIP signals in backward HCal and EMCal
  - μ/π distinction important, position resolution...
- Performance estimate required for TDR
- Simulations done by UIUC with event generators:
  - Simulated exclusive, diffractive $\rho_0, \phi, J/\psi, \rightarrow \mu\mu$ production in DIS regime with Sartre
  - Skipped PYTHIA8 for now, because of limitations of hard diffraction implementation
  - For ρ_0 and ϕ KK or even $\pi\pi$ decays may be more relevant than $\mu\mu$ due to low branching ratio

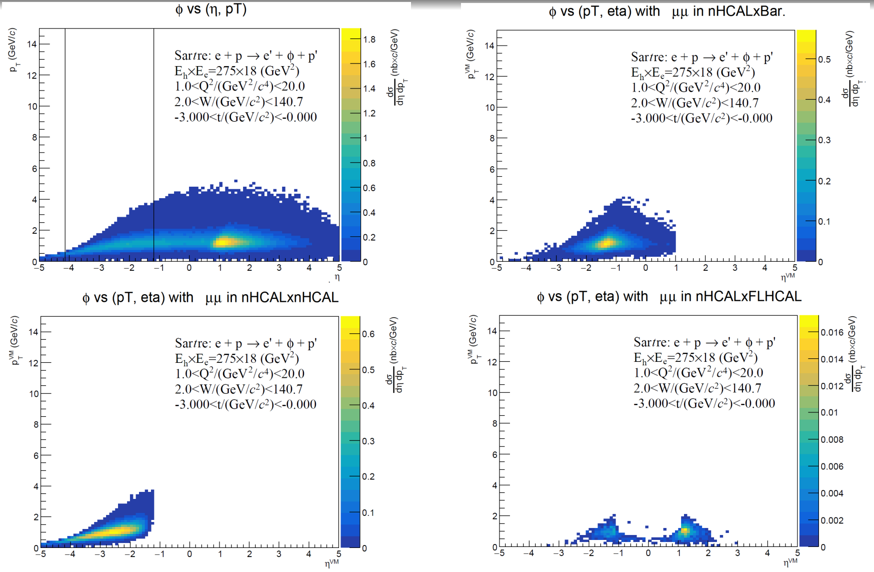
ρ_0 distributions with Sartre



Vincent Andrieux, UIUC

- Branching ratio $\rho_0 \to \mu\mu$ not included
- nHCal can extend the rapidity range, better access to low-x physics

ϕ distributions with Sartre



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- Branching ratio $\phi \to \mu\mu$ not included
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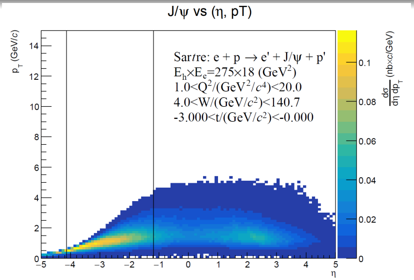
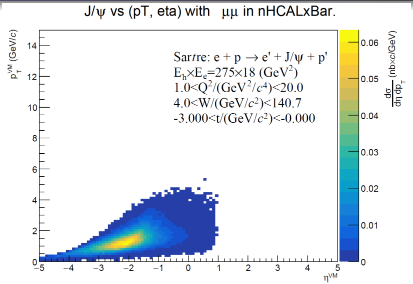
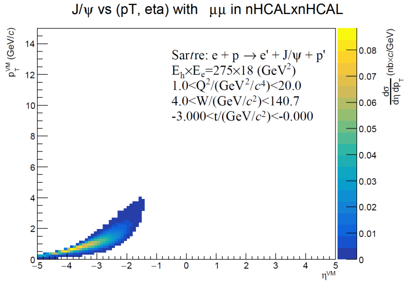
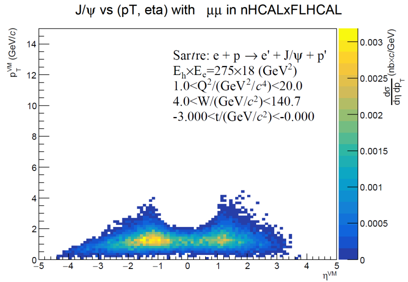
J/ψ distributions with Sartre









Vincent Andrieux, UIUC

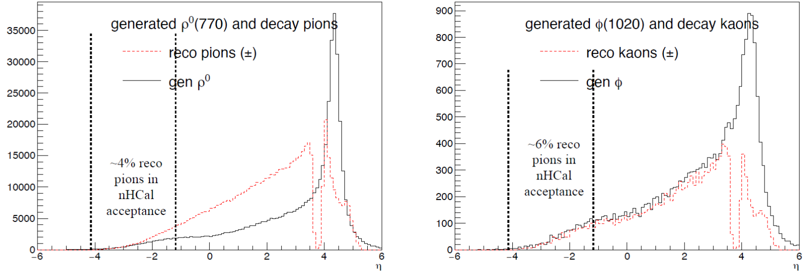
- Branching ratio $J/\psi \rightarrow \mu\mu$ not included
- nHCal is important for J/ψ study, what about Υ?

pythia8NCDIS_18x275_minQ2=1 large sample

ePIC

reconstructed mesons from the decay of vector mesons

Eta of thrown ρ^0 | $\rho \to \pi^+\pi^-$ $\phi \to K^+K^-$ | Eta of thrown $\phi(1020)$

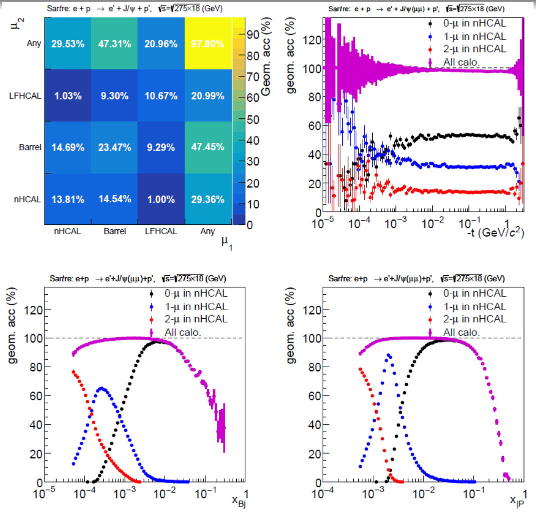


all available files of flavor "pythia8NCDIS_18x275_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_1"

Caroline Riedl, UIUC

- $\sim 4-6\%$ of mesons from VM decay in nHCal acceptance
- centrally generated PYTHIA8 with full simulation of the ePIC detector and tracks reconstructed
- studied decays: $\rho_0(770) \to \pi^+\pi^-$, $\phi(1020) \to K^+K^-$

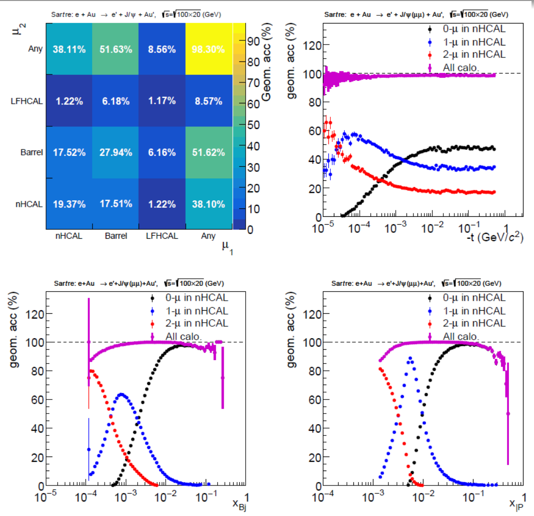
$J/\psi \to \mu\mu$, $e + p$, $18 \times 275\text{GeV}$



Vincent Andrieux, UIUC

- nHCal crucial to measurements below $x = 10^{-3}$
- Other detectors limited to $x = 10^{-3}$
- Necessary for one of the physics topics in EIC YR and promised by ePIC

$J/\psi \rightarrow \mu\mu$, $e + A$, 20×100GeV



Vincent Andrieux, UIUC

- nHCal crucial to measurements below $x = 10^{-2}$ in $e + A$
- Other detectors limited to $x = 10^{-2}$ in $e + A$
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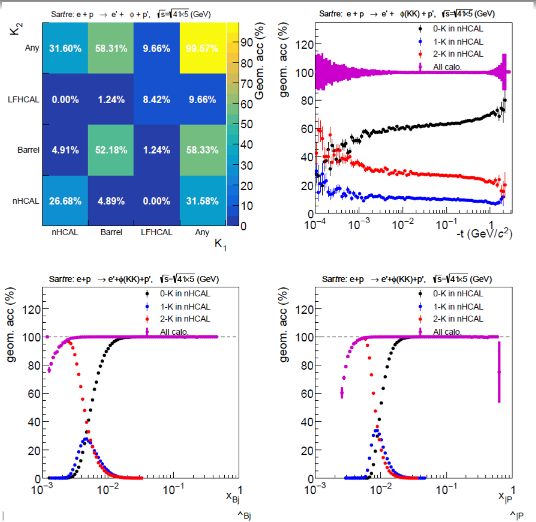
$\phi \to \mu\mu$, $e + p$, $5 \times 41\mathrm{GeV}$



Vincent Andrieux, UIUC

- nHCal crucial to measurements below $x = 10^{-2}$
- Other detectors limited to $x = 10^{-2}$
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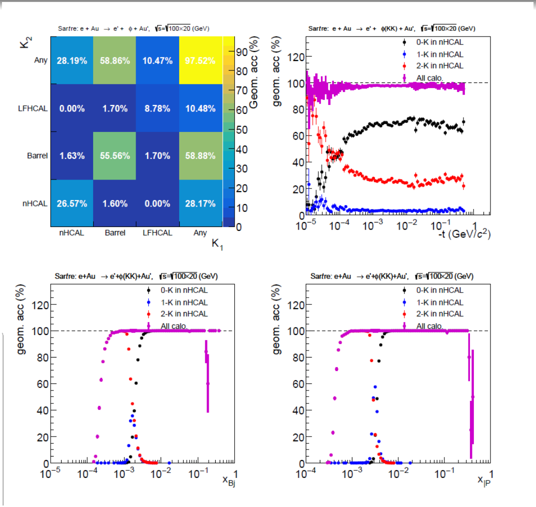
$\phi \to KK$, $e + A$, $20 \times 100\text{GeV}$



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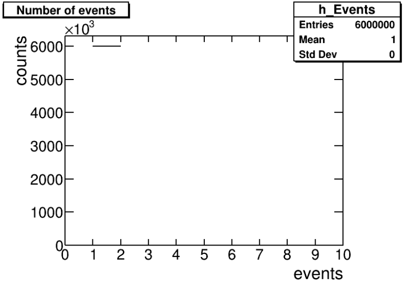
Diffractive dijets with nHCal

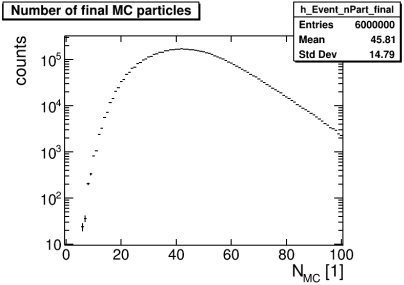
Diffractive dijet - simulation setup

- Simulation setup for diffractive dijets
- PYTHIA version 8.311 simulation from EIC container:
  - $18 \times 275\,\mathrm{GeV}$ $e + p$ collisions, $0 < Q^2 < 1\,\mathrm{GeV}^2$
  - $6M$ events
- Run at Ohio Supercomputing Center (OSC) to use local computing resources

Listing: Simulation settings

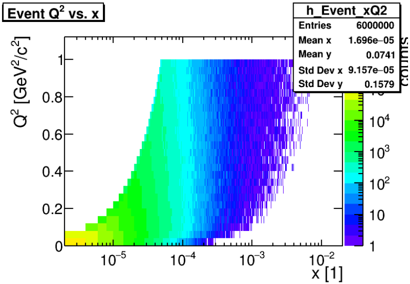
```
pythia8->ReadString("Beams:frameType=2");
pythia8->ReadString("Beams:idA=2212");
pythia8->ReadString("Beams:idB=11");
pythia8->ReadString("275.");
pythia8->ReadString("18.");
  //according to main342 for H1 dijets
pythia8->ReadString("PDF:lepton2gamma = on"); // Allow for photon-from lepton
pythia8->ReadString("Photon:ProcessType = 0"); // Allow all photon processes
pythia8->ReadString("Photon:Q2max = 1."); // Maximal Q2
pythia8->ReadString("HardQCD:all = on"); // All dijet MEs
pythia8->ReadString("PhotonParton:all = on"); // All dijet MEs with photons
pythia8->ReadString("PhaseSpace:pThatMin = 4."); // Minimal pT cut
pythia8->ReadString("MultipartonInteractions:pT0Ref = 3."); // Tuned ep value

// Setup of diffractive framework.
pythia8->ReadString("Diffraction:doHard = on");
pythia8->ReadString("Diffraction:sampleType = 1"); // 'PDF' sample
pythia8->ReadString("Diffraction:hardDiffSide = 2"); // Diff. on photon side
pythia8->ReadString("SigmaDiffractive:PomFlux = 7"); // H1 Fit B LO
pythia8->ReadString("PDF:PomSet = 6"); // H1 Fit B LO
```



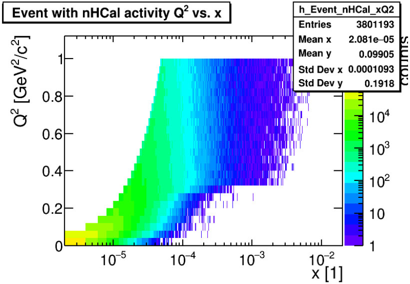


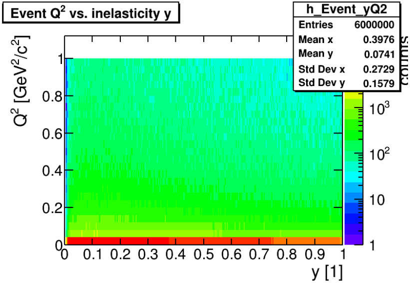
- First look at diffractive dijet events
- 45 final state particles on average
- Small amount of energy contained in diffractive dijets, rest mostly going forward

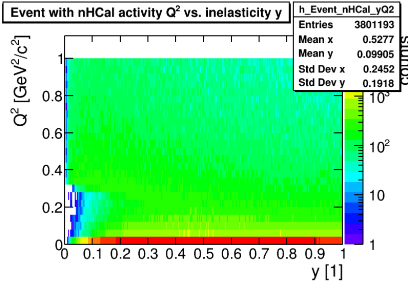
All events



With activity in nHCal

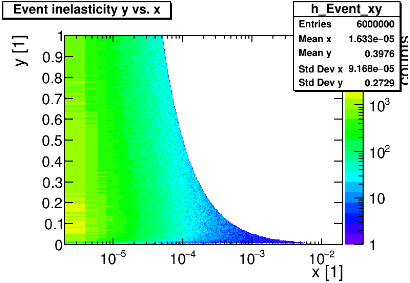




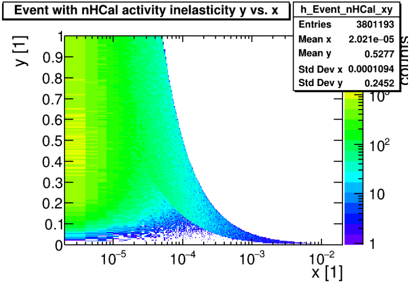


- 3.8*M* out of 6*M* (63%) events with activity in nHCal
- First look at diffractive dijet events
- nHCal crucial for low-x measurements coverage

All events

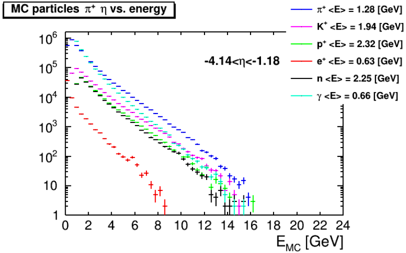


With activity in nHCal

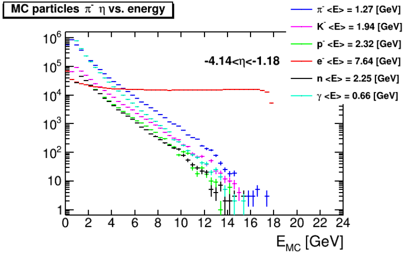


- 3.8M out of 6M (63%) events with activity in nHCal
- Includes scattered electron
- First look at diffractive dijet events
- nHCal crucial for low-x measurements coverage
- Looking for advice on the dijet clustering for next steps

positive charge



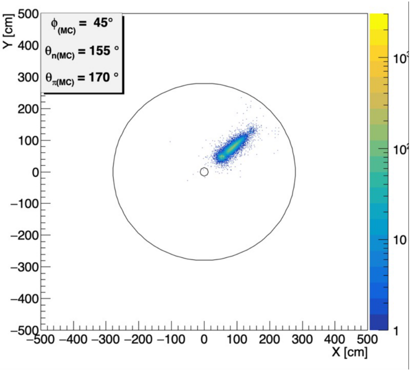
negative charge



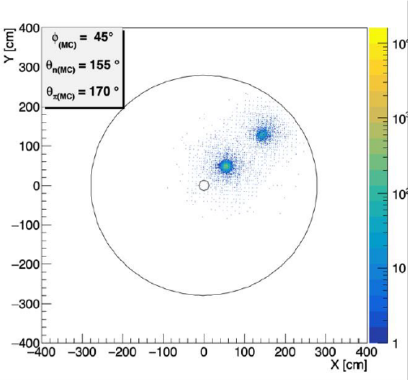
- Total energy distributions vs. η
  - Average neutron energy similar to inclusive events
- Kinetic energy is measured in nHCal

Jets with neutrals: 2-position resolution

bug



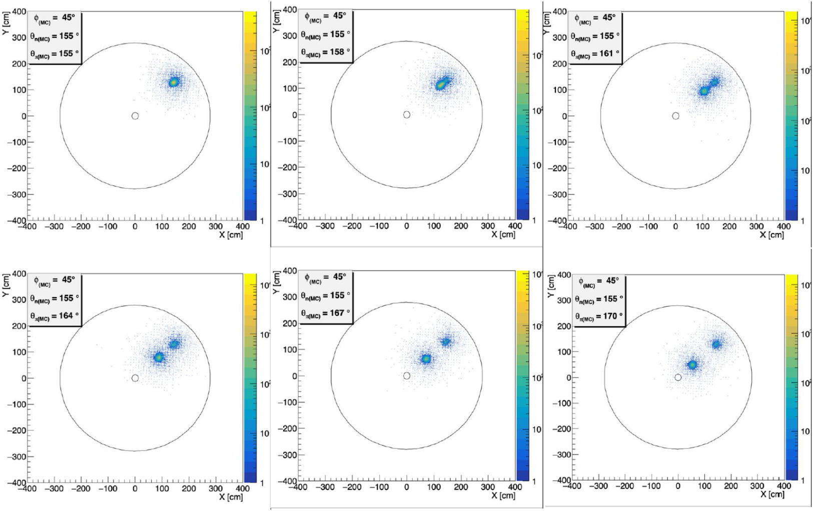
fixed



- Used 10× larger reco hit positions
- Caused clusters to be merged over 10× larger distance
- Fixed with help of Wouter `https://github.com/eic/EICrecon/pull/1598`
- Prevented us from getting reasonable results for 2-particle studies
- Affects also LFHCAL
- Possibly affected neutral jet study - results can improve!

2-particle resolution study

Increasing separation →

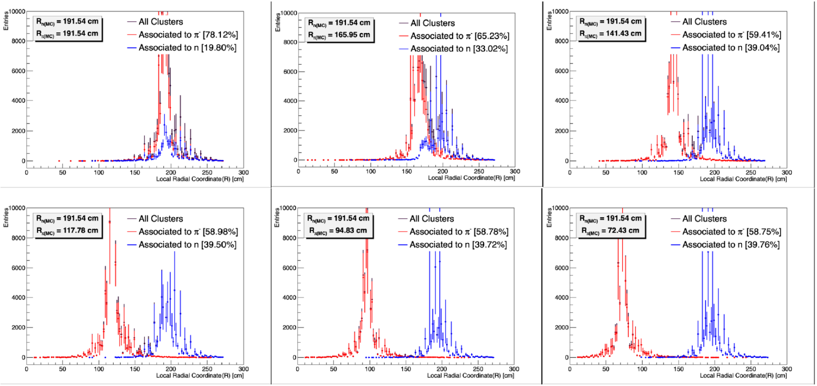


Subhadip Pal, CTU, Prague

- n and π clusters are well separated down to $30 - 40\text{cm} \approx 2\lambda_0$
- Detailed checks at closer distance in progress

2-particle distance

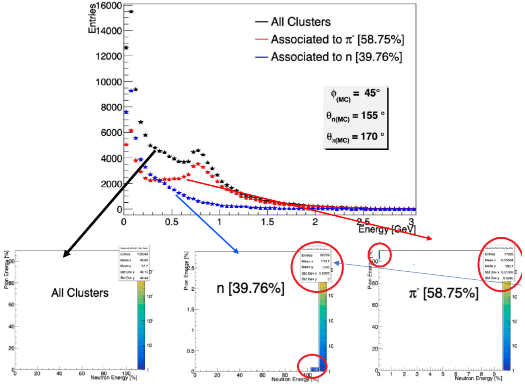
Increasing separation →



Subhadip Pal, CTU, Prague

- n and π clusters are well separated down to $30 - 40\ \mathrm{cm} \approx 2\lambda_0$
- Detailed checks at closer distance in progress
- Fraction of clusters MC-matched to n and π constant until they start to overlap

2-particle - cluster energy

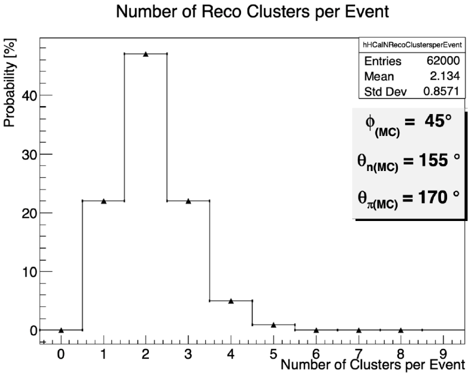


$$Pion(Neutron)Energy\% = \frac{\sum Pion(Neutron)RecohitEnergy}{ClusterEnergy} \times 100$$

Subhadip Pal, CTU, Prague

- Cluster energy for the case where n and π are separated by 120 cm
- Traced the energy to MC particle and summed reco hits
  - Sometimes exceeds 100% of cluster energy due to hit weight in clustering
- Further checks for the overlap case underway

2-particle - number of clusters

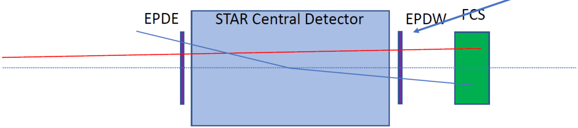


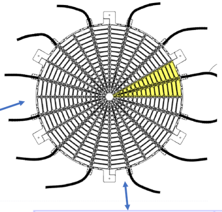
Subhadip Pal, CTU, Prague

- More than 2 clusters due to splitting
- Even for 120 cm, well separated case

Veto for dRICH

- RHIC is a living beast, you never know what it will throw at you !
- Run24 beam background is quite high due to multiple reasons
- Machine attempts to reduce background yielded modest improvements
- And at the end it is up to experiments to find efficient solutions to clean it up!





fcsJP2*EPDveto	
fcsJPA1*EPDveto	
fcsJPA0*EPDveto	
fcsJPBC1*EPDveto	
fcsJPBC0*EPDveto	
fcsJPDE1*EPDveto	
fcsJPDE0*EPDveto	
fcsDiJP*EPDveto	
fcsDiJPAsy*EPDveto	

- Upstream background polluted some FCS trigger by ~ 30% in Run24.
- EPD has enough resolution to apply timing veto cut to clean it up

- In ePIC. nHCal will help to shield dRICH from such events.
- + Timing information from both nHCla and forward HCal similar to EPDE/EPDW

Questions is will it be good to have something similar to EPD/BBC in ePIC? It is much simpler detectors than calorimeters. May be re-used (EPD) from STAR and sPHENIX? Space?

See Oleg's presentation:
https://indico.bnl.gov/event/20727/contributions/94377/

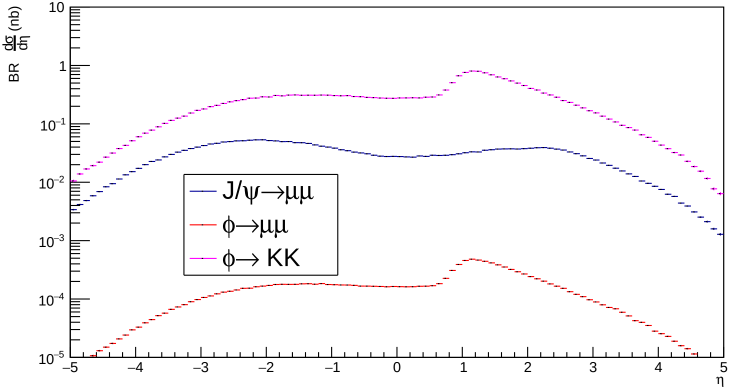
- We are working on realistic studies, but they require:
  - realistic background, full material budget, multiple detector reconstruction, timing info, etc.
- Potential to reject 30% or more background is worthwhile to investigate

Conclusions

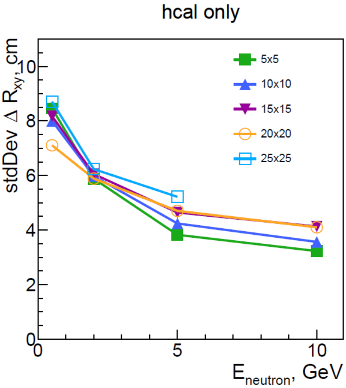
- Backward HCAL is crucial for delivering promised Physics
- Many low-x physics topics through diffractive events (VMs, dijets, etc.) require nHCAL and/or greatly benefit over other channels
- Other benefits are being actively studied (scattered electron ID, dRICH veto, etc.)
- H1 collaboration recognizes that lack of a backward HCAL limited physics output on key topics
- Physics requirements are being used to determine the baseline design requirements for the nHCAL - design presentation coming soon.

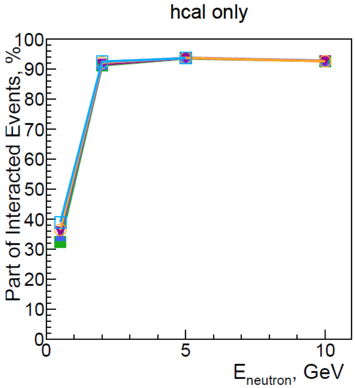
BACKUP

Vector meson channels comparison



Alexandr Prozorov, CTU

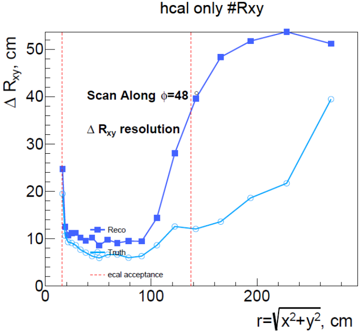




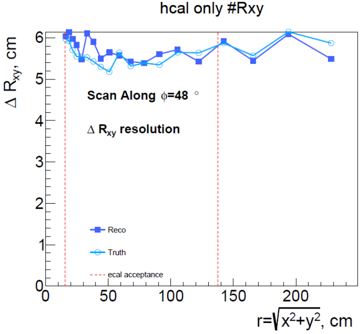
- Shoot single neutrons and compare ideal projections to RECO clusters
- Vary energy and tile size to obtain scaling
- Even large tiles up to 25 cm seem to be OK
- Need track projections and cluster matching in realistic DIS events - next steps

Alexandr Prozorov, CTU

Exploiting ϕ symmetry (see details), make a scan along single ϕ angle



full epic

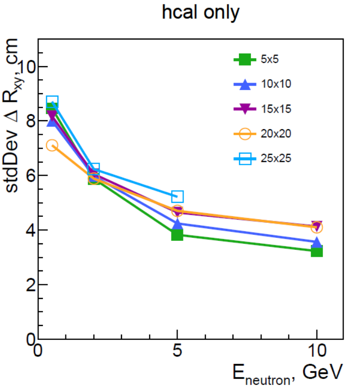


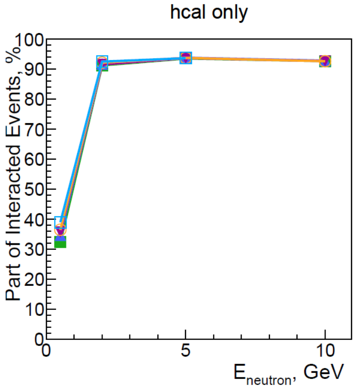
hcal only

- Barrel materials in front deteriorate the position resolution due to scattering

Single particle position resolution study

Alexandr Prozorov, CTU





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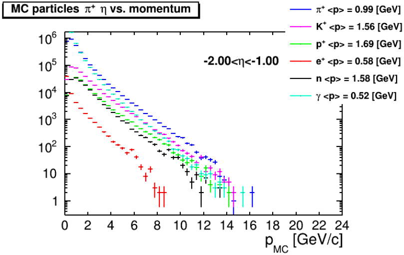
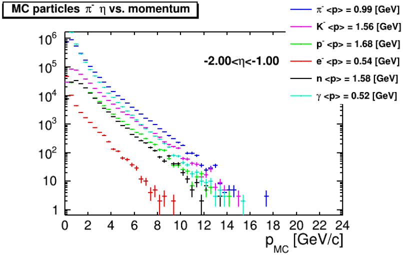
Particle distributions in nHCal

positive charge

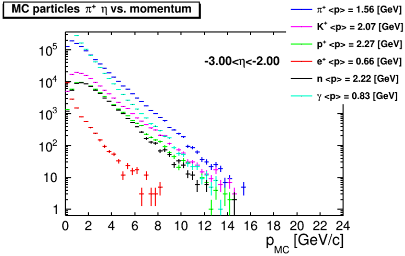


negative charge

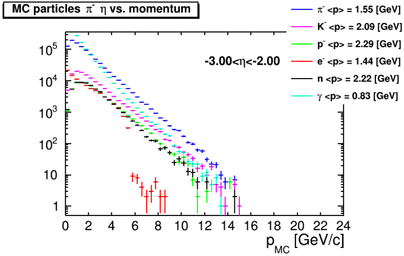


- Total energy distributions vs. η

positive charge



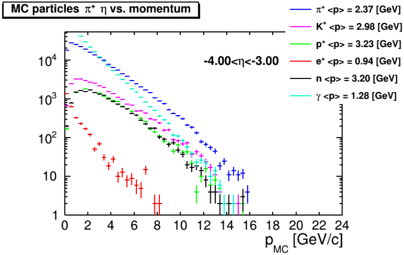
negative charge



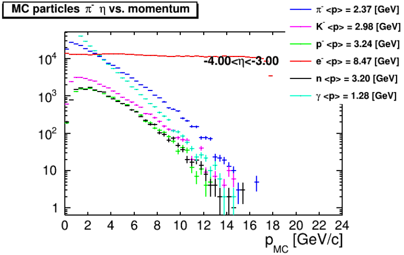
- Total energy distributions vs. η

Particle distributions in nHCal

positive charge



negative charge



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