Tracking performance of EIC Geant4 simulation based on sPHENIX

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OUTLINE

★ Introduction
★ Brief discussion on work assigned
★ Updates in simulation framework
★ Results obtained for pion in the detector
★ Results obtained for electron in the detector
★ Conclusions

Tracking geometry used with sPHENIX GEANT4 simulation framework

- **The vertex tracker:** The framework uses 3 layers of silicon vertex trackers. There are two layers in the most inner vertex layers and one additional layer is added in between to produce a tight-packed three-layer vertex track immediate outside the beam pipe for robust pattern recognition.
- **The Time Projection Chamber (TPC):** A Ne-based gas is used inside the chamber volume which extends from 20 cm to 80 cm in radius.
- **The forward and backward momentum trackers:** Methane-GEM based tracking stations are used for both forward (hadron-going side - FGEM) and backwards (electron-going side - EGEM) *for low eta region* having uniform resolution of 70um whereas a silicon tracker is used for *higher eta region* added later to the framework.

About GEANT4 simulation framework

This project required a set of macros which can be run either by using Singularity container (offline mode) or racf account(online mode).

- Macros – downloaded from the git repository https://github.com/sPHENIX-Collaboration/macros
- For the offline mode, the singularity container can be downloaded either by mounting sPHENIX CVMFS or downloading sPHENIX build via HTTPS archive.

  https://github.com/sPHENIX-Collaboration/Singularity

  After mounting the singularity container, the environment must be set using the following command.

  source /opt/sphenix/core/bin/sphenix_setup.sh -n
- In the online mode using rcf/racf account, only environment needs to be set in order to run the macros.
- The primary macro used for tracking analysis in this work is

  Fun4All_G4_EICDetector.C

Work already done:

For ease of quantifying tracking performance, muons were used in GEANT 4 simulations to study the tracking system which was analyzed by a Kalman-filter-based full detector track fit algorithm. Figure 1 shows the momentum resolution of the system when muons are fired at different pseudorapidities.

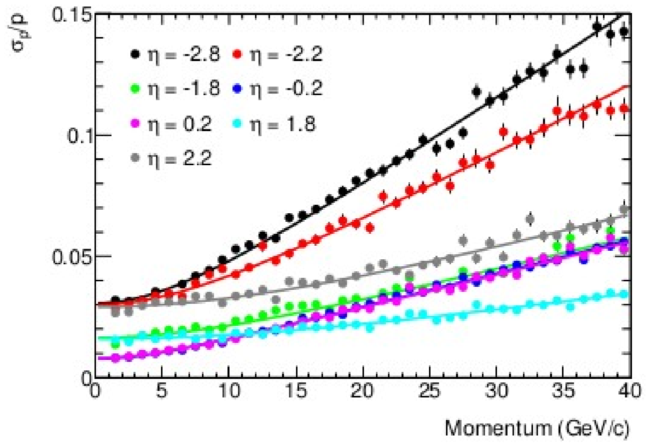


Fig. 1: Reference: sPHENIX-note sPH-cQCD-2018-001

OUR TASK:

★ Update this figure with pion in the detector
- with constraint of using the smeared truth vertex for tracking
- Without this constraint on tracking

★ Put electron in the detector to obtain the corresponding trend in momentum resolution.

We have generated <u>50000 events</u> for all etas to get a clear trend in momentum resolution

Brief discussion on the work and new updates related to EIC simulation framework

Vertex tracking:

- ❑ Vertex of a reaction is the point where the reaction takes place and its knowledge is important for reconstruction of track of produced particles. But it’s not possible to directly obtain the position of real vertex and its needs to be reconstructed with vertex fitting.
- ❑ The smeared truth vertex is the vertex obtained by reconstruction of path of produced particles whose path gets smeared or changed due to the detector geometry.
- ❑ Constraint used on vertex tracking: using smeared truth vertex for vertex tracking

Addition of new beam pipe and detector adjustments

- During March 2020, there has been an update in the simulation framework with addition of a new beam pipe and forward silicon trackers for high pseudorapidities (>2.0).
- Earlier GEM trackers were being used for forward and backward tracking, but forward momentum measurement can be improved with silicon tracker for high pseodorapidities ***which has been verified by us in this work.***

Results obtained for PION in the detector:

❖ **With constraint on vertex tracking:** The following figures show comparison between results for muon and pion in the detector

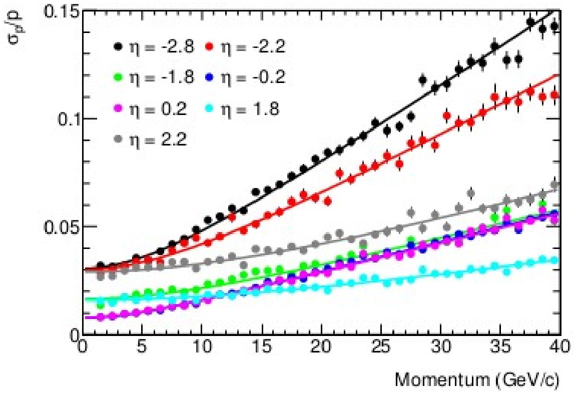


Fig 1. Results for muon in detector
Reference: sPHENIX-note sPH-cQCD-2018-001

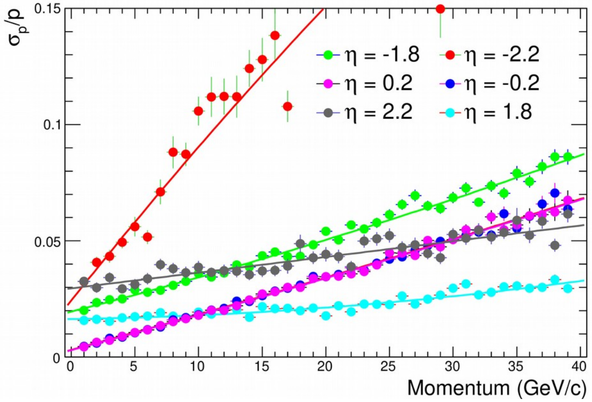


Fig 2. Pion at different pseudorapidities using old macro with GEM trackers

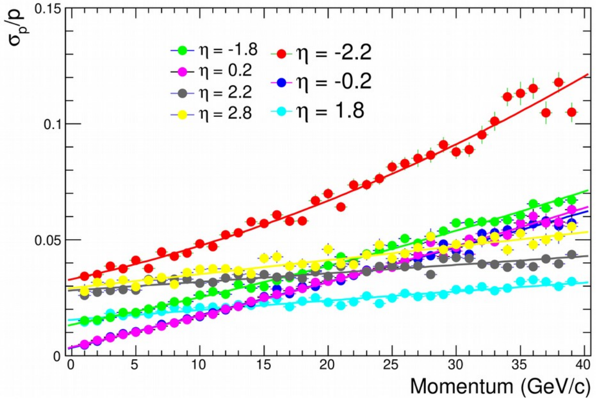
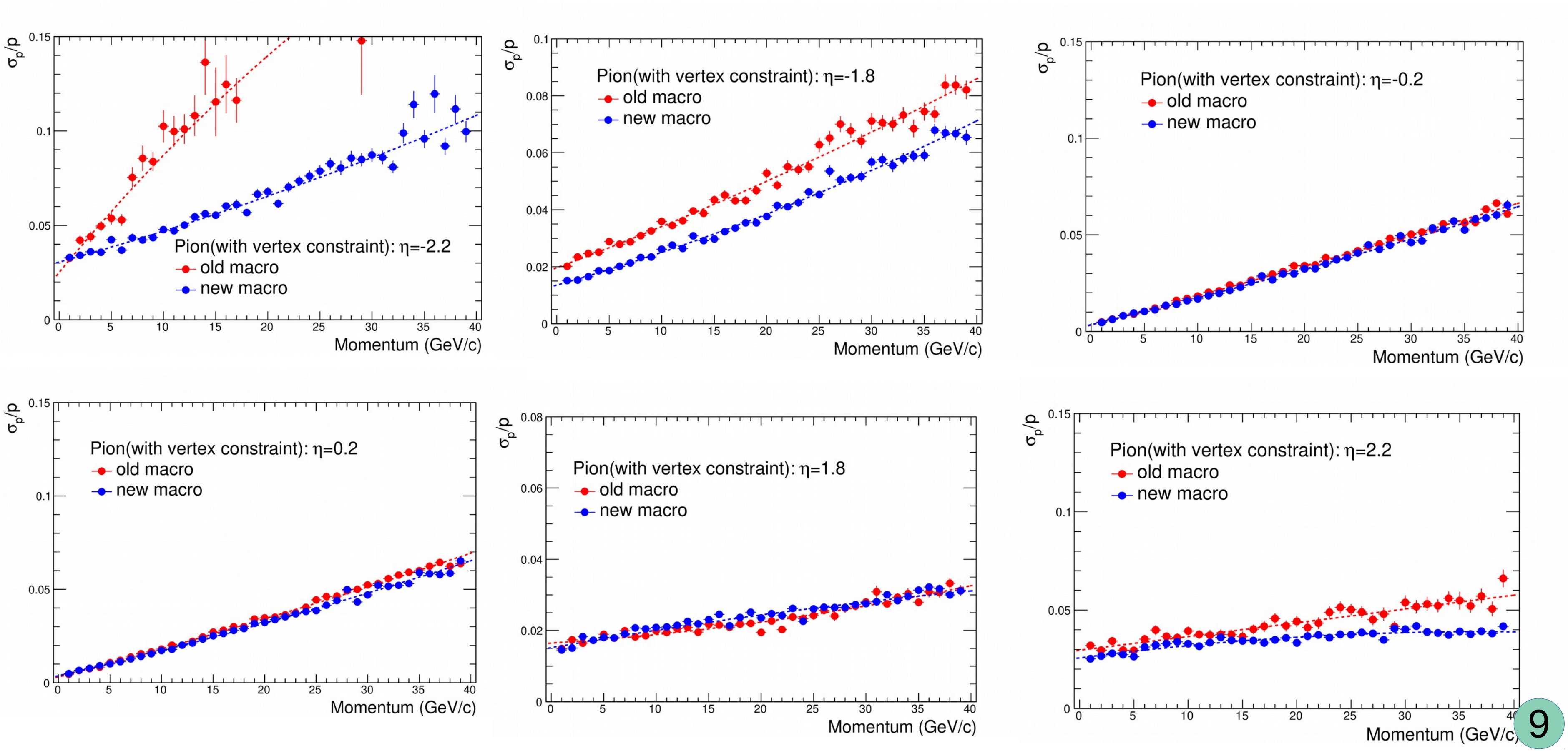


Fig 3. Pion at different pseudorapidities using new macro with silicon trackers

Comparing the results from old and new macro



❖ With relaxed constraint on vertex tracking:

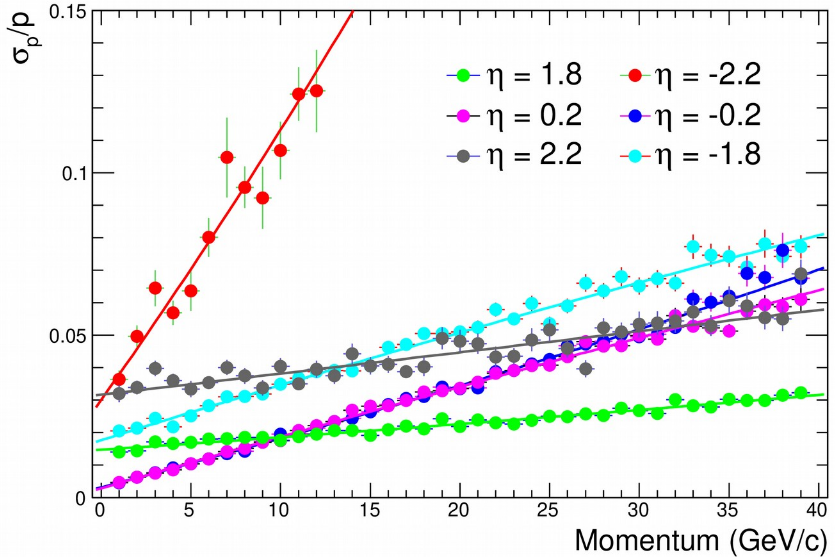


Fig 4. Pion with relaxed vertex constraint at different pseudorapidities **using old macro which used GEM trackers**

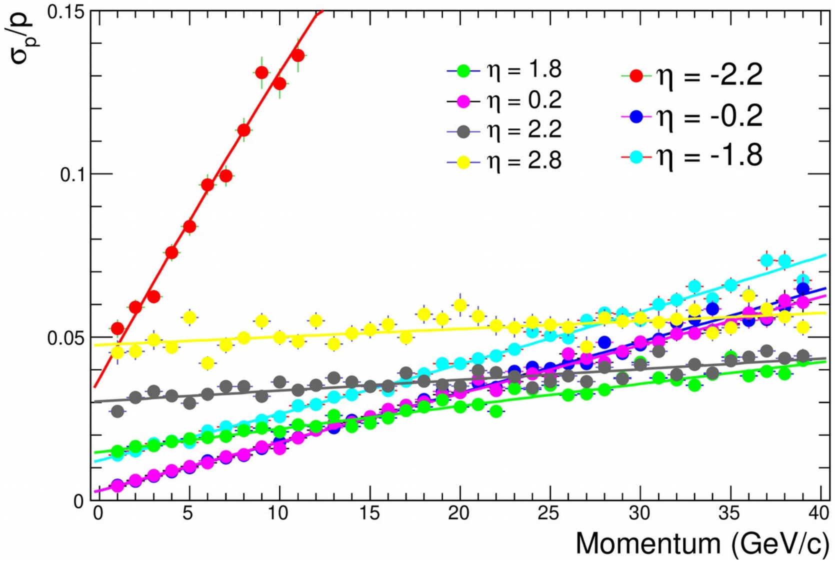
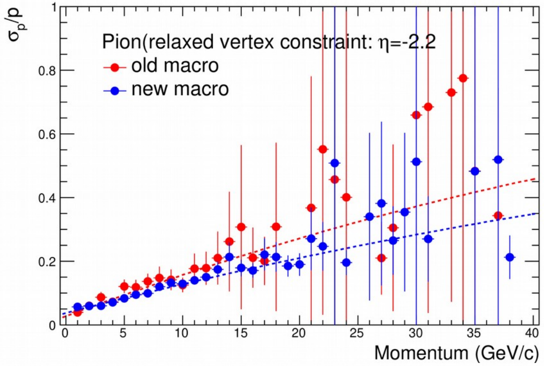
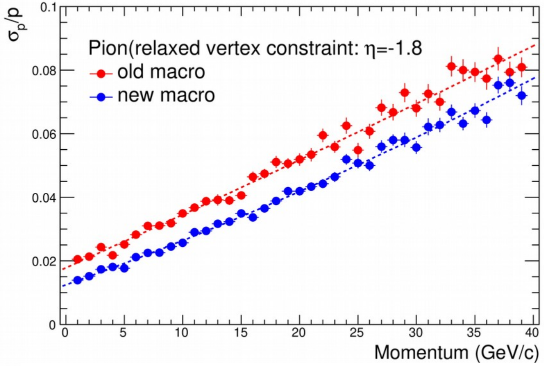
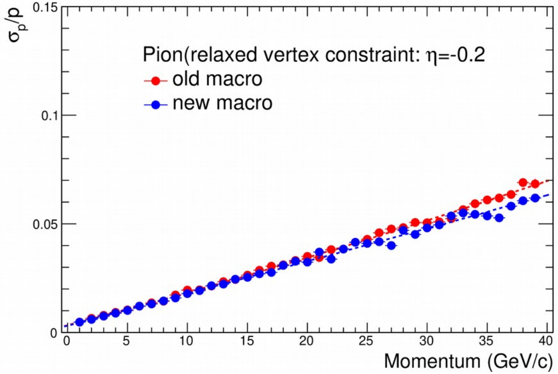


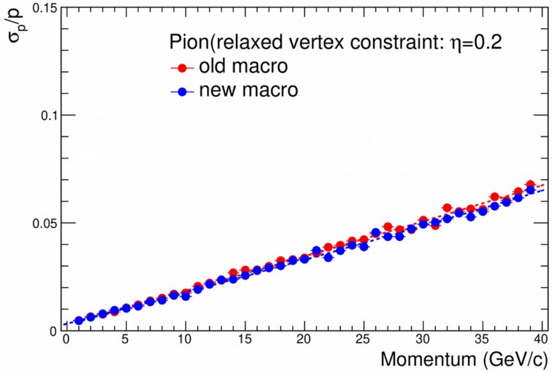
Fig 5. Pion with relaxed vertex constraint at different pseudorapidities **using new macro which used silicon trackers**

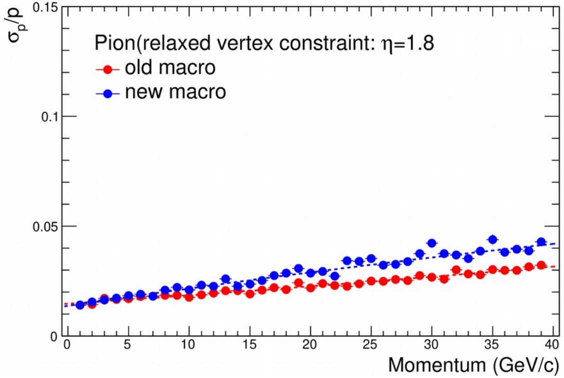
Comparing the results from old and new macro

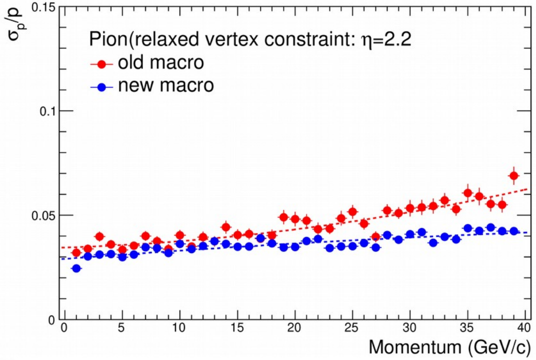












Comparing the results with and without vertex constraint

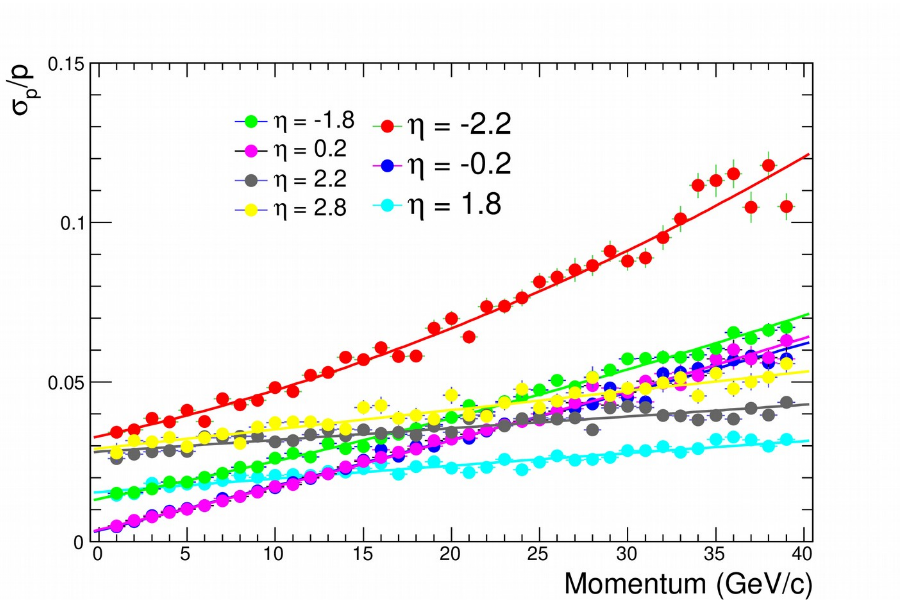


Fig 3. Pion at different pseudorapidities **with constraint on smeared truth vertex tracking** using new macro with silicon trackers

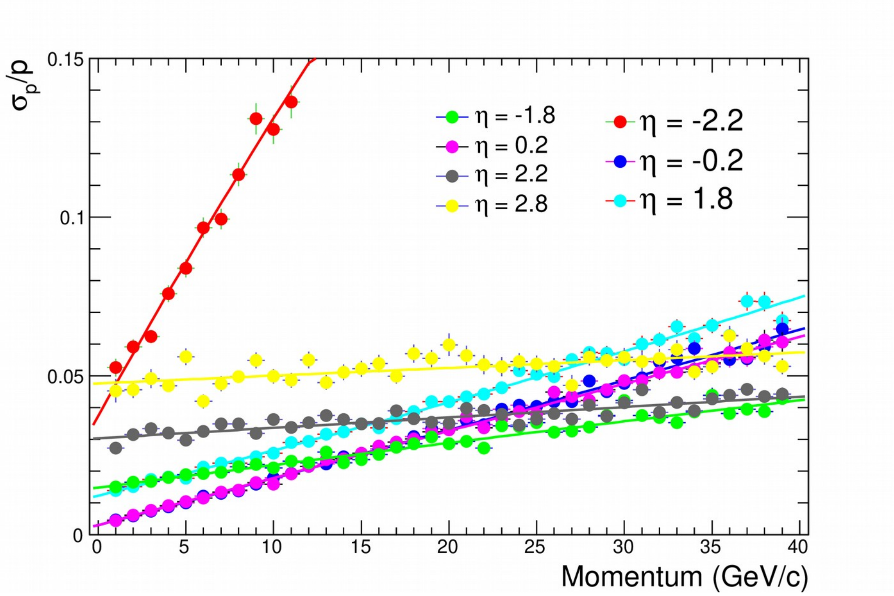


Fig 5. Pion at different pseudorapidities **with relaxed vertex constraint** using new macro which used silicon trackers

The momentum resolution worsens as we remove the constraint on vertex tracking.

Results for Electron in the detector

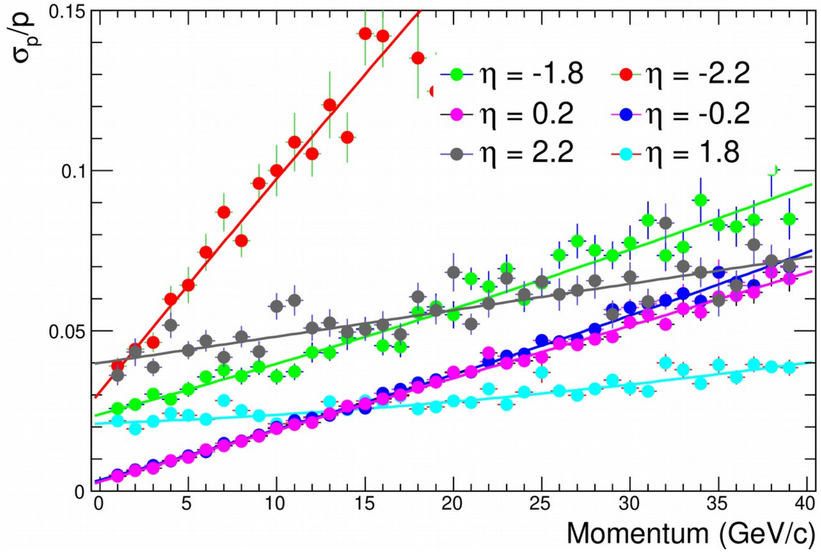


Fig 6. Electron at different pseudorapidities using **old macro with GEM trackers with constraint on vertex tracking**

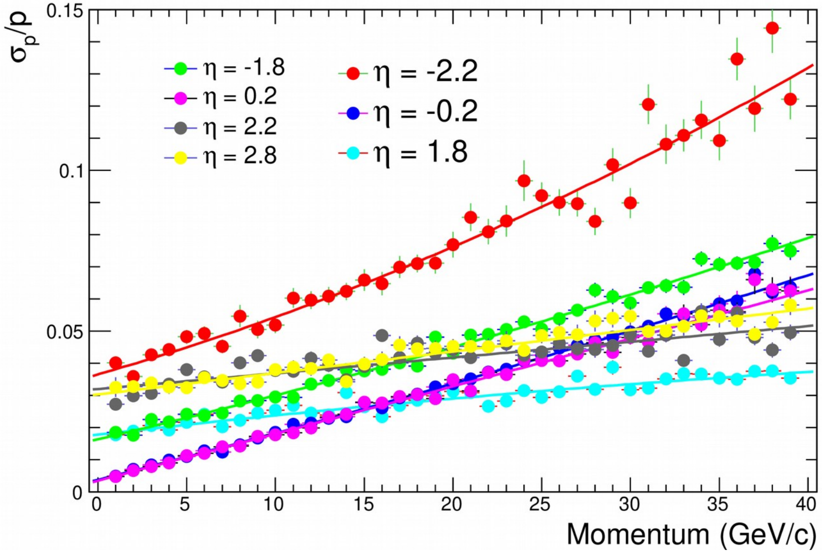
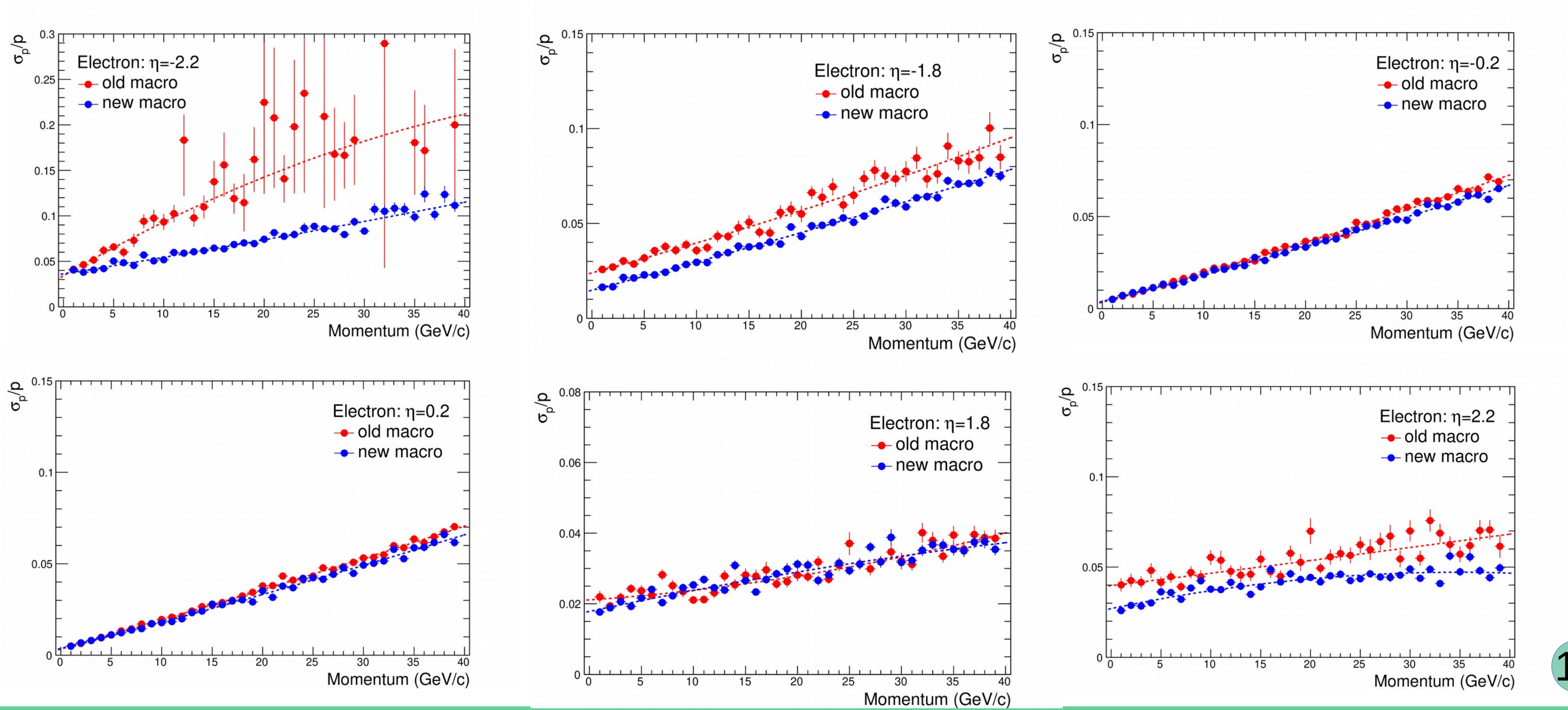


Fig 7. Electron at different pseudorapidties using **new macro with silicon trackers with constraint on vertex tracking**

Comparing the results obtained from old and new macro



Comparing pion and electron

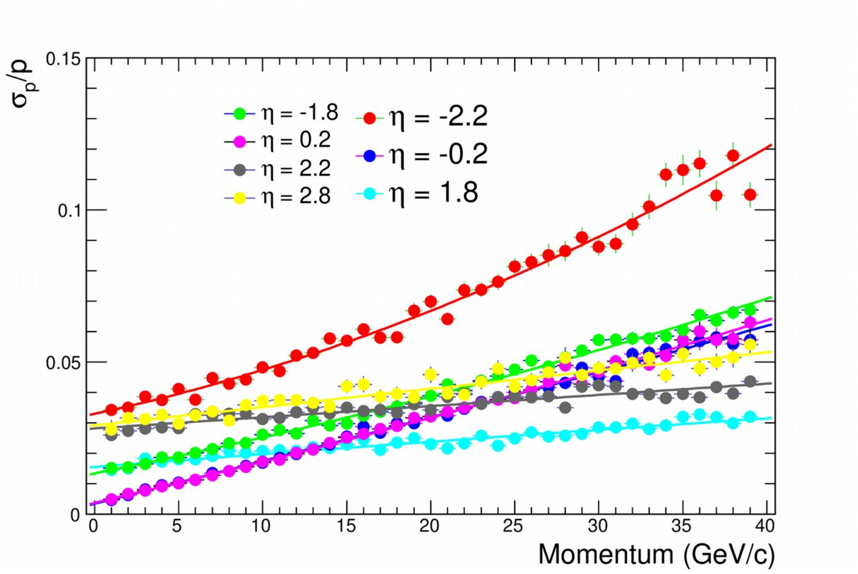


Fig 3. Pion at different pseudorapidities using new macro with silicon trackers

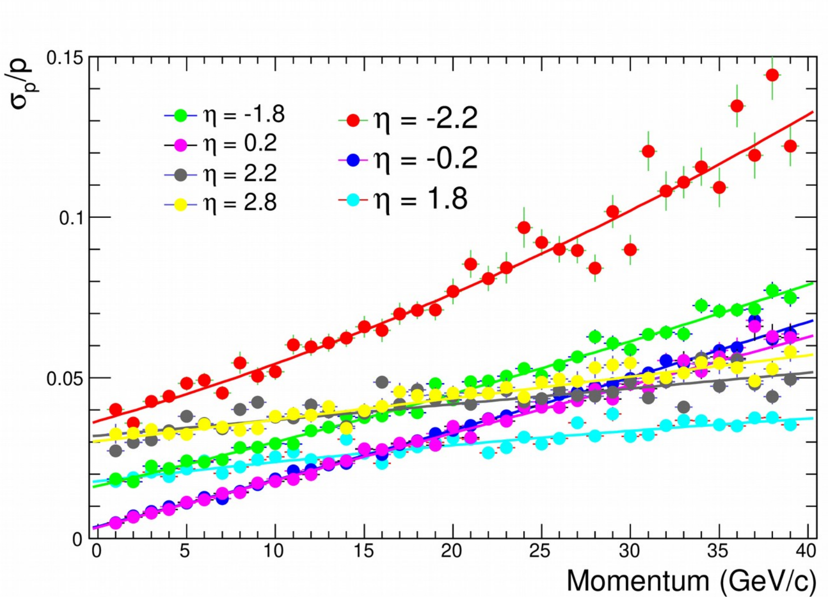
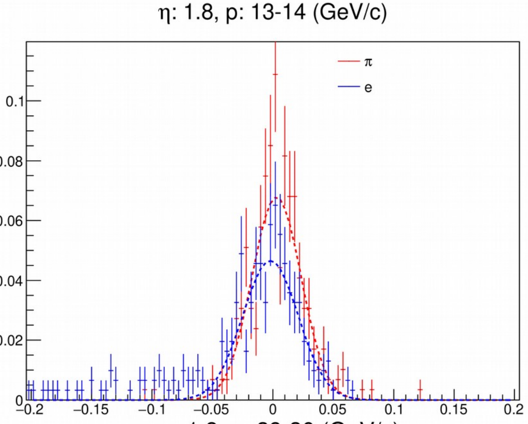
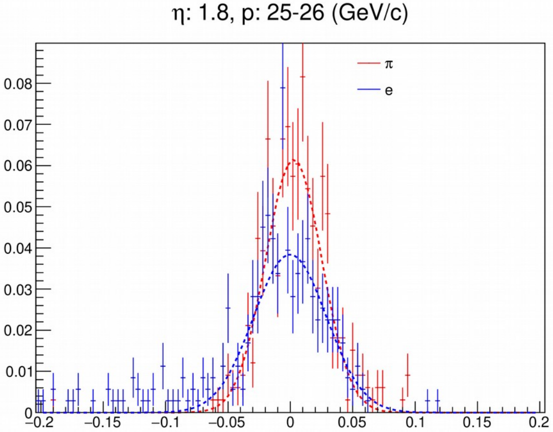


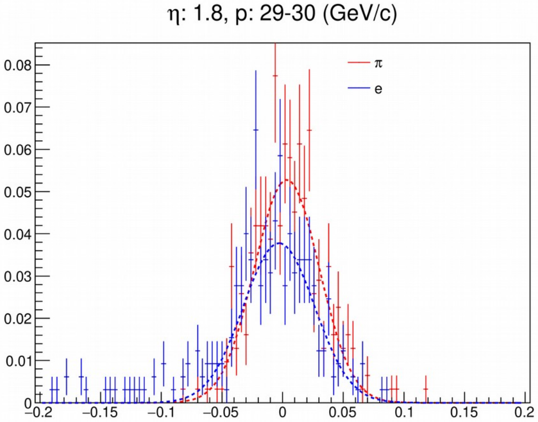
Fig 7. Electron at different pseudorapidties using new macro with silicon trackers with constraint on vertex tracking

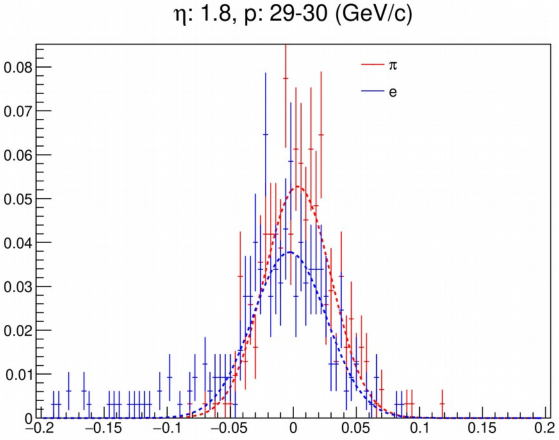
Due to additional bremsstrahlung radiation in case of electron, the momentum resolution degrades as we go from pion to electron.

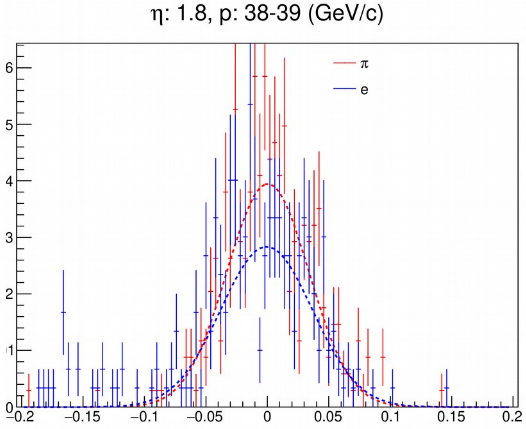
Evidence of bremsstrahlung radiation – tail in the momentum distribution of electron

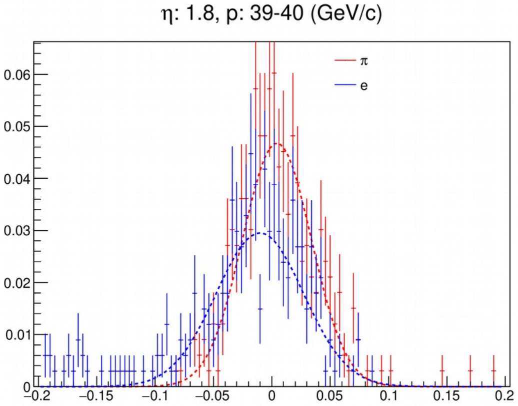












Conclusions:

- Putting the constraint of truth vertex tracking leads to better momentum resolution
- Momentum resolution degrades when we switch from pion to electron due to added bremsstrahlung radiation in case of electron.
- Addition of silicon trackers has improved momentum for higher pseudorapidities whereas trend for intermediate pseudorapidities is same as before.

Outlook:

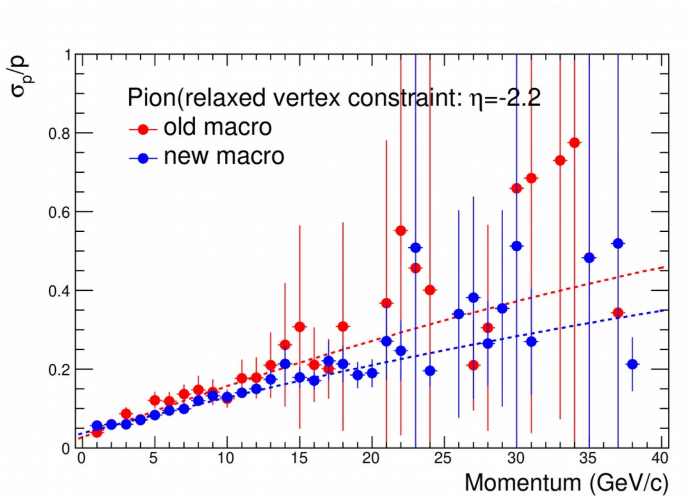
We have volunteered for the call for help in benchmarking softwares for simulations of physics and detector responses. Looking forward for this opportunity!

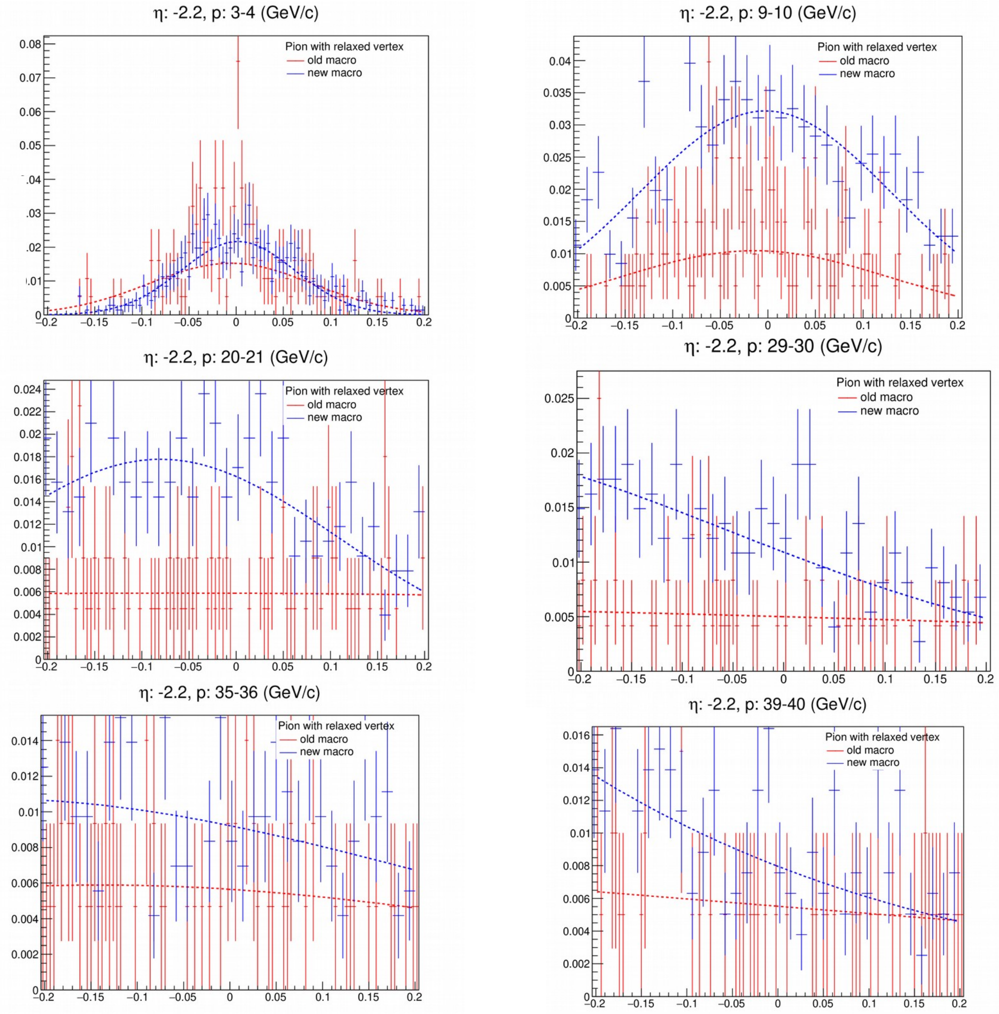
ACKNOWLEDGEMENTS:

I would like to express my gratitude towards Jin Huang and Christine Aidala for giving us the opportunity to work on this project.

I thank Jin Huang for his feedback and helping clearing doubts regarding various aspects of this project.

Thank You!





Amt. Of statistics = 100000

But still not much improvement in momentum resolution...