ATHENA-India Software Report and Future Plan

Neha Shah
For the ATHENA-India Group

- **<u>Fun4All-Status</u> (Convener: Dr. Chris Pinkenburg**
  Dr. Kolja Klauder)

  Panjab University (Simran)
  IIT Indore (Sagar and Siddhant)

Work Summary

- Energy, eta, and phi resolutions of Calorimeters in Fun4All framework
- Particles used : e-, π^-
- Details of Calorimeters:

Electromagnetic Calorimeters (EMCAL): Lead Tungstate (PWO) crystals

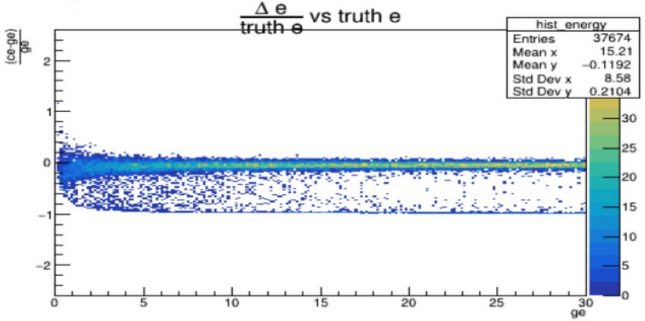
- Midrapidity (Barrel) (CEMC): $-1.5 < \eta < 1.2$
- Forward rapidity (Ion/forward direction) (FEMC): $1.3 < \eta < 3.3$
- Backward rapidity (Electron/backward direction) (EEMC): $-3.5 < \eta < -1.7$

Hadronic Calorimeters (HCAL): Steel absorber (inner), Al Absorber (outer) + plastic scintillator

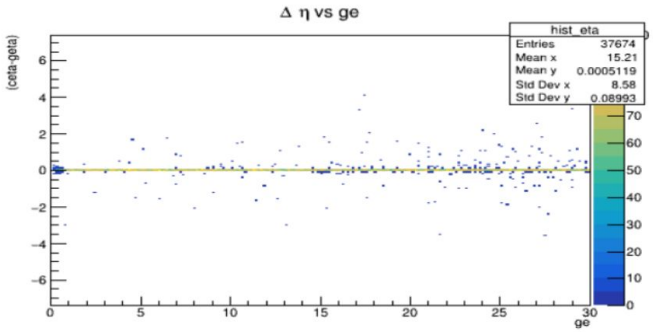
- Forward region (FHCAL): $1.2 < \eta < 3.5$
- Barrel (HCALIN, HCALOUT): $-1.1 < \eta < 1.1$

Resolution Study

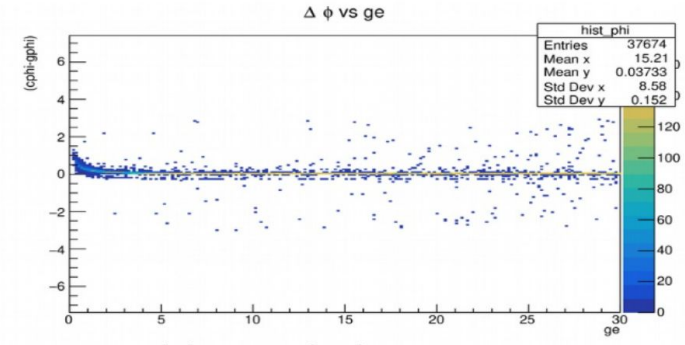
CEMC:



Energy Resolution



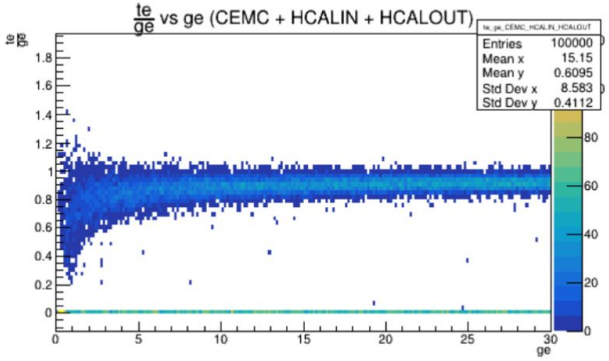
Eta resolution

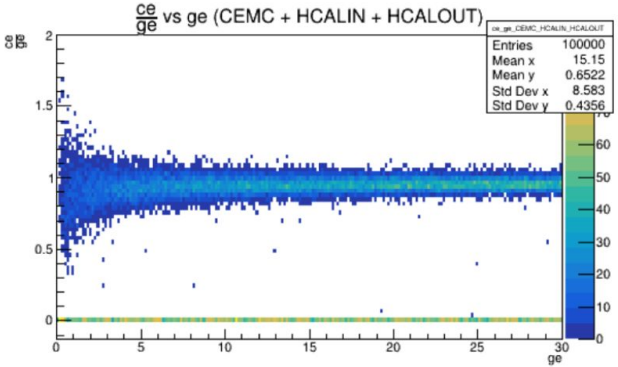


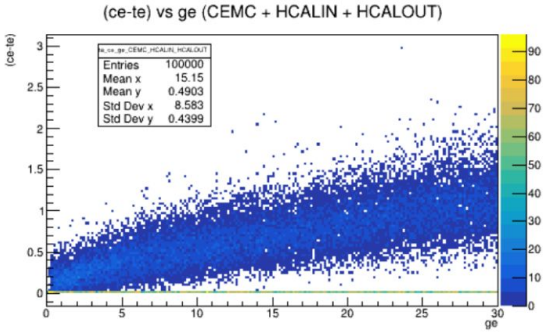
Phi Resolution

Energy Resolution for Towers and Clusters

- CEMC+HCALIN+HCALOUT
- Electron
- te – tower energy, ce – cluster energy, ge – generated energy



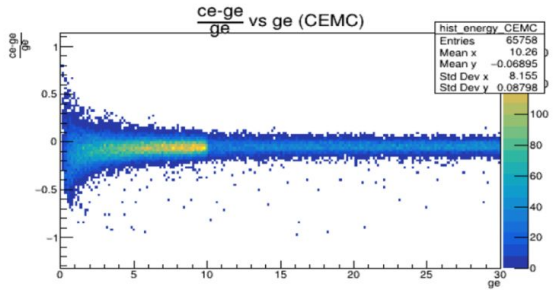


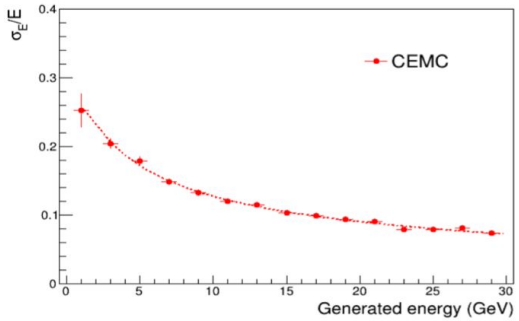


Work ongoing

- Streamline the current Fun4all framework
- Parameterize energy resolution for calorimeters

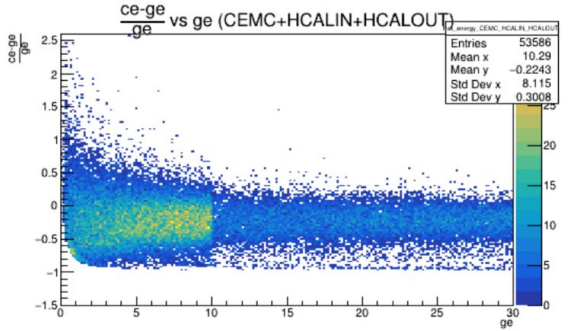
Cluster energy resolution: Electron

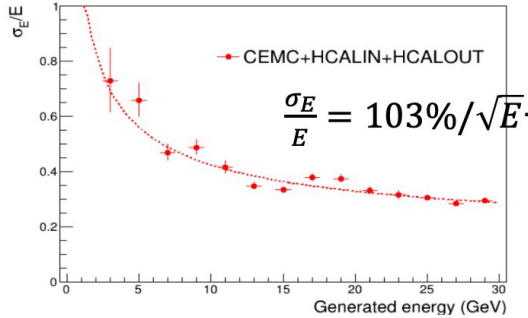




$\sigma_E/E = 28\%/E + 55\%/\sqrt{E} + 2\%$

Cluster energy resolution: Pion

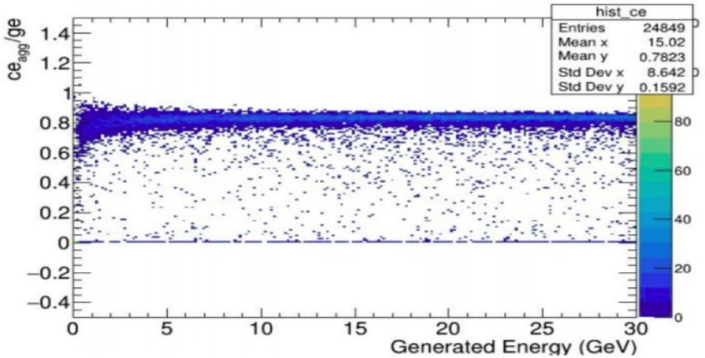


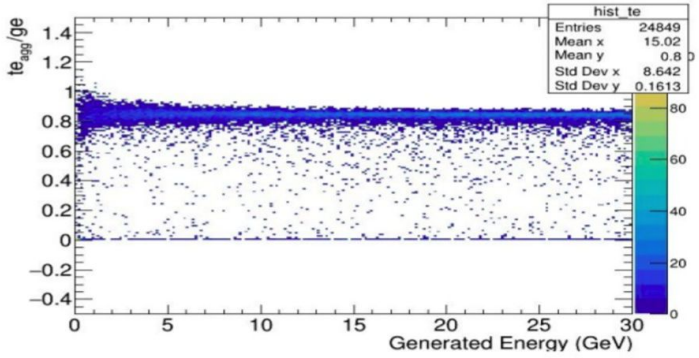


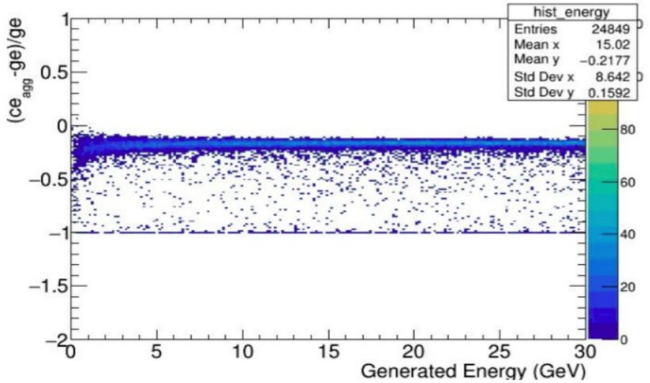
$\frac{\sigma_E}{E} = 103\%/\sqrt{E}+10\%$

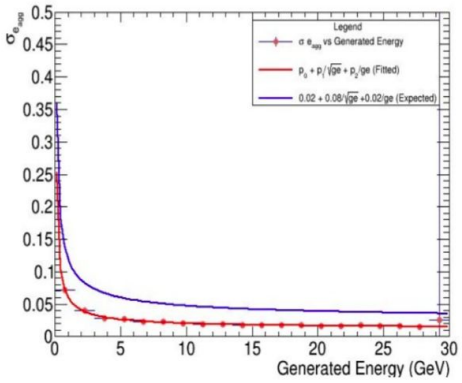
Work ongoing

FEMC (e-):









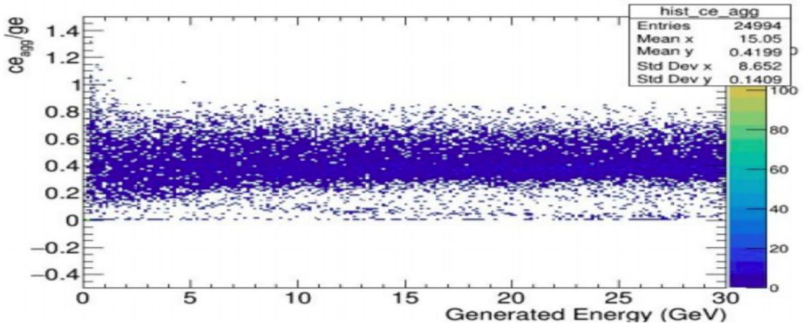
σe refers to the standard deviation of the Gaussian fitted to a slice of the `(ce-ge)/ge vs ge` plot. (shown on the previous slide)

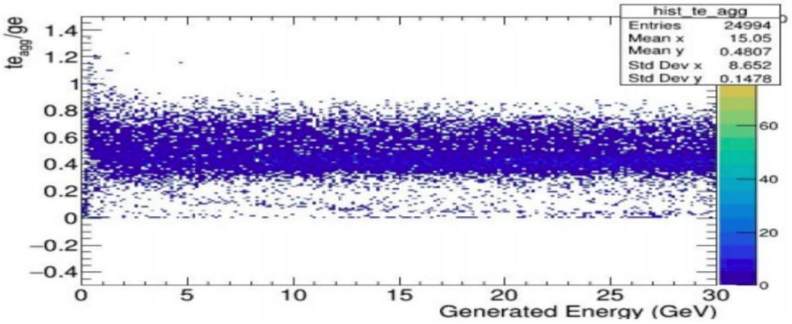
Number of bins = 20
Bin Width = 1.5 GeV

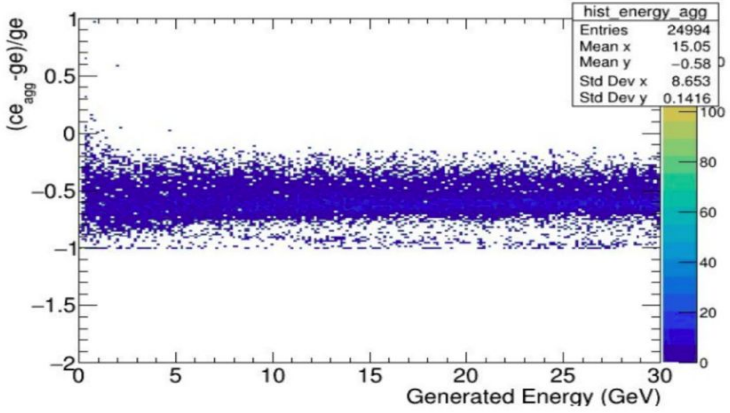
Fit Parameters:
p_0 = (0.00989952 +- 0.000836325)
p_1 = (0.0241553 +- 0.00462100) $GeV^{0.5}$
p_2 = (0.0268757 +- 0.00559569) GeV

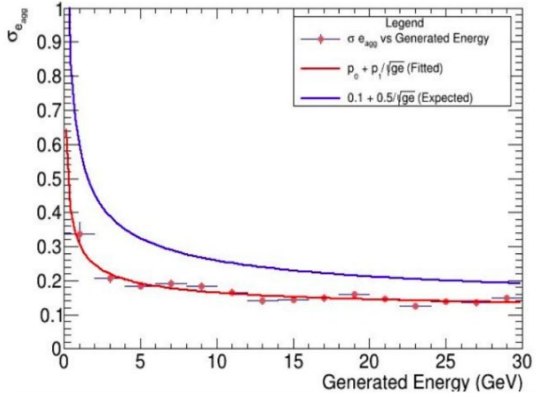
Work ongoing

FEMC+FHCAL (π^-):









σe refers to the standard deviation of the Gaussian fitted to a slice of the `(ce-ge)/ge vs ge` plot. (shown on the previous slide)

Number of bins = 15
Bin Width = 2 GeV

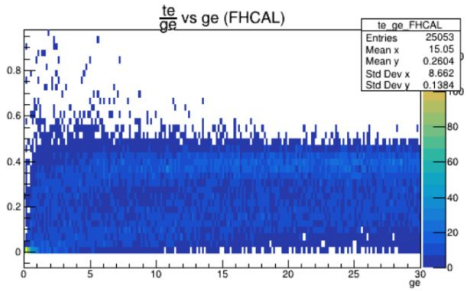
Fit Parameters:
p_0 = (0.0972296 +- 0.00668992)
p_1 = (0.211140 +- 0.0222952) $GeV^{0.5}$

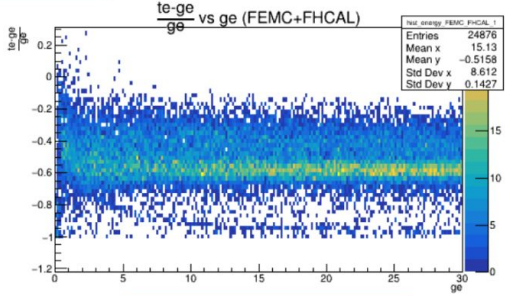
Current Status

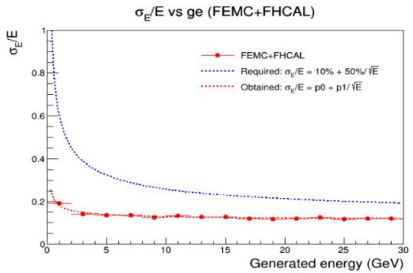
Energy calibration: FHCAL, Pion

- Manual clustering on towers using $\Delta\theta$, $\Delta\phi$
- Photon digitization turned off

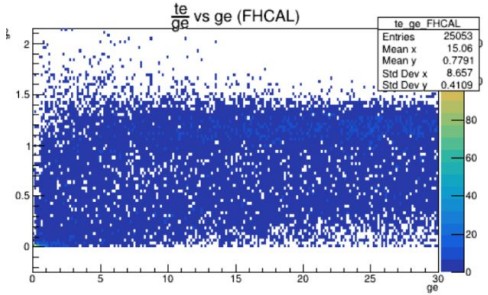
No calibration

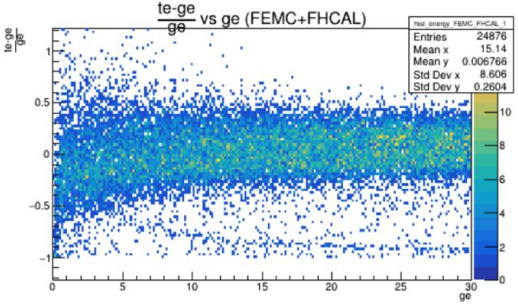


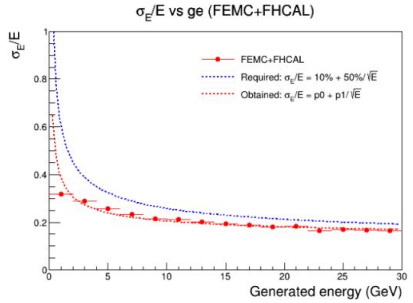




After calibration







Next Steps

- Sampling fraction for different calorimeters to be updated in the code - Chris
- Calibration to be improved
- Finalize the energy resolution

Future Directions:

- Switch between different calorimeters to characterize them.
- Tracking QA
- Study different input generators Pythia6, Pythia8, SARTE..

MC-Data Validation
(Convener: Dr. Markus Diefenthaler)

IIT Bombay, IIT Madras, IIT Delhi, IIT Patna, Punjab University, MNIT Jaipur, Goa University, Akal University

Primary Objectives : MC-Data Validation

- To study the global properties of hadronic final states in DIS events and other interesting observables at EIC energies by using different event generators.
- To study and compare the outcome of simulations with the existing HERA data and improvise the models to account for the differences/discrepancies, if any.
- To obtain the model expectations for different observables at EIC energies.

Immediate Work-Plan

- To study and compare the outcomes with different implementations of physics processes valid for DIS regime in different event generators (models) and to continue our ongoing efforts in this direction with HERA data
- To contribute towards required modifications in different software tools/event generators

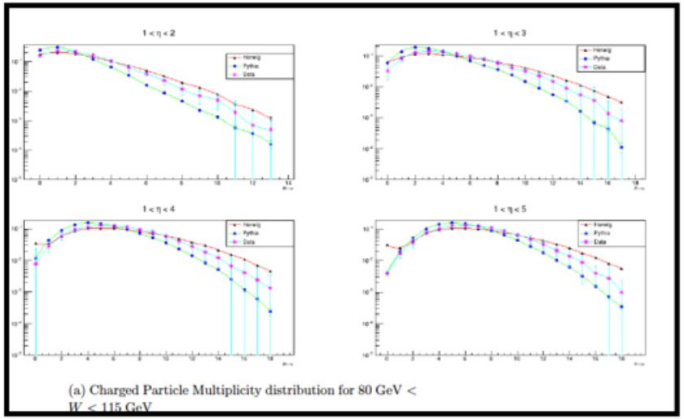
Ongoing work in this direction :

The HERA data is currently being compared with events generated using Pythia8, Herwig7 and Sherpa event generators.

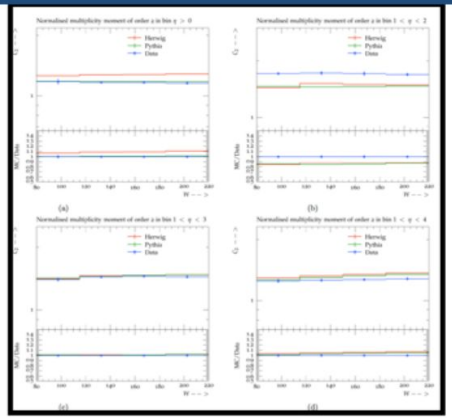
- Charged particle multiplicities in deep inelastic scattering at HERA (H1)
- Measurement of charged particle transverse momentum spectra in deep inelastic scattering (H1)
- Inclusive ϕ-meson production in neutral current deep inelastic scattering at HERA
- Measurement of inelastic $J\Psi$ production in deep inelastic scattering at HERA
- Diffractive Dijets in Photoproduction and inclusive jet production
- Transverse energy-energy correlations
- Observation of scaling violations in scaled momentum distributions at HERA .
- Energy flow and charged particle spectra.
- Single differential cross-section of D^* meson production.

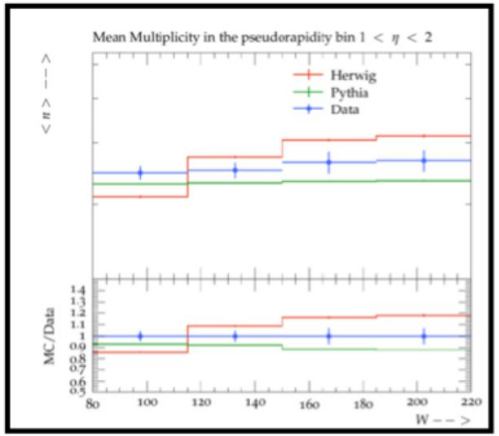
Multiplicity and transverse momentum distributions

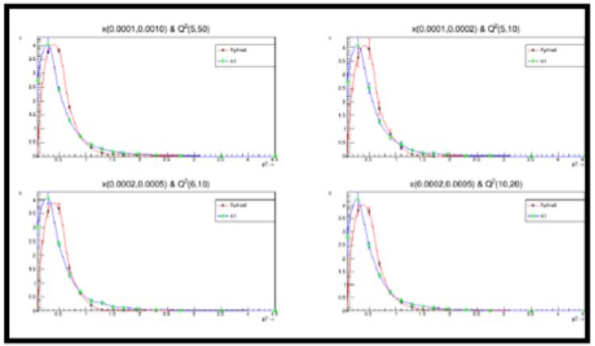
IITB



(a) Charged Particle Multiplicity distribution for 80 GeV < W < 115 GeV







D* and J/ψ cross-section

IITB

D*

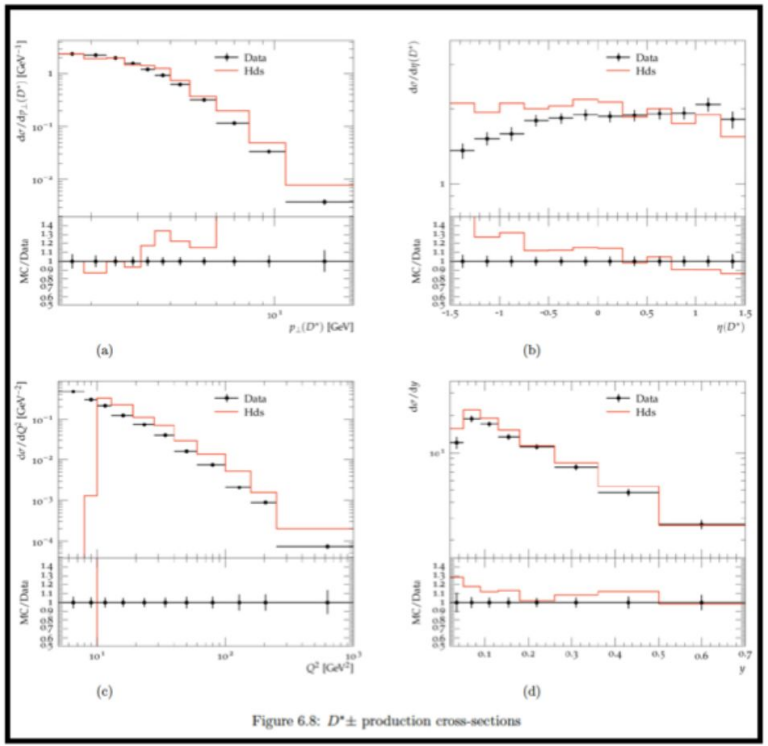
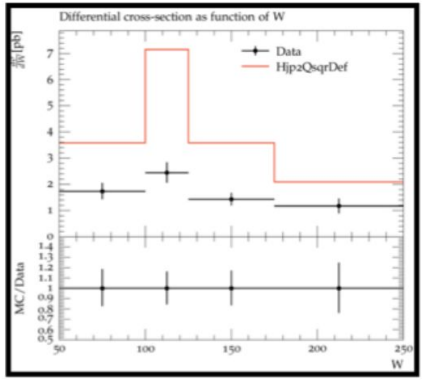
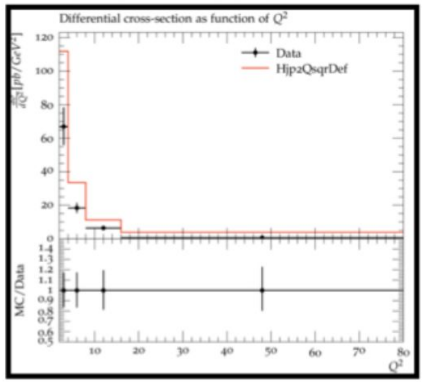


Figure 6.8: $D^{*}\pm$ production cross-sections

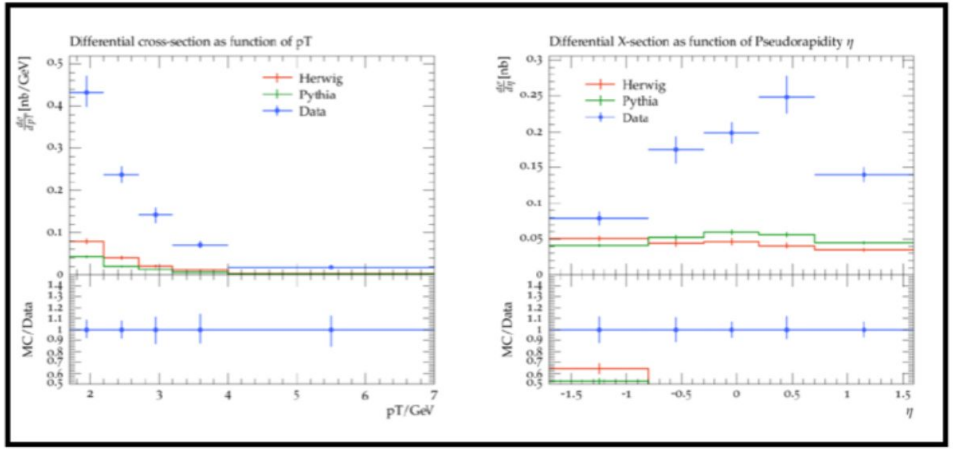
J/ψ

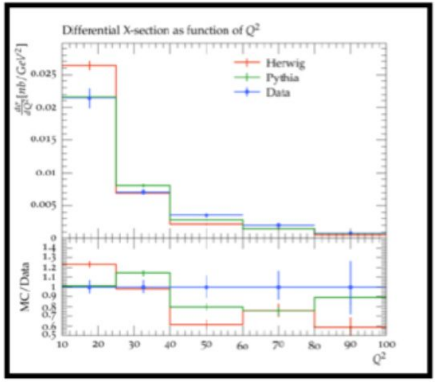




ϕ meson cross-section

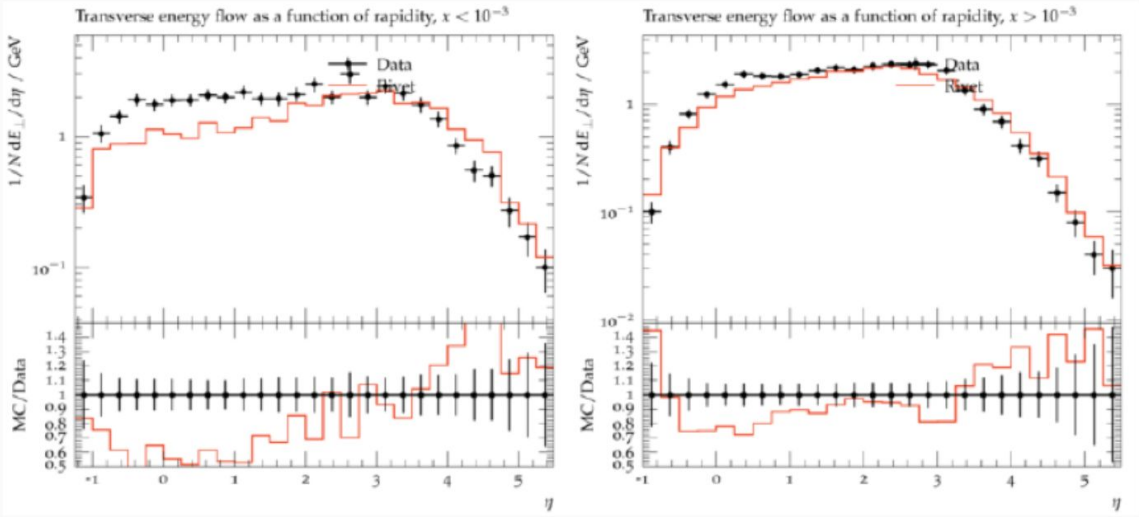
IITB





Energy flow as a function of rapidity(Pythia8)

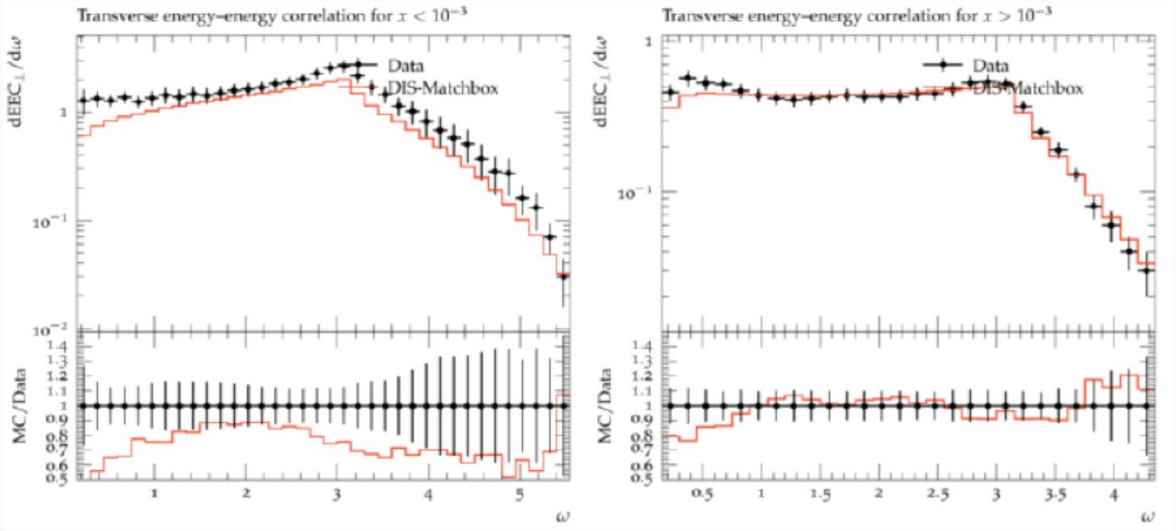
IITM



- In the $x < 10^{-3}$ plot, Pythia8 is mostly inaccurate except for mid rapidity region($2.5 < \eta < 3.5$).
- While, for the $x > 10^{-3}$ plot, Pythia8 results match data for most of the part except around the $\eta = 0$ region.
- In both the plots, the Pythia8 and data follow similar trends.

Transverse Energy-Energy Correlation(HERWIG7)

IITM

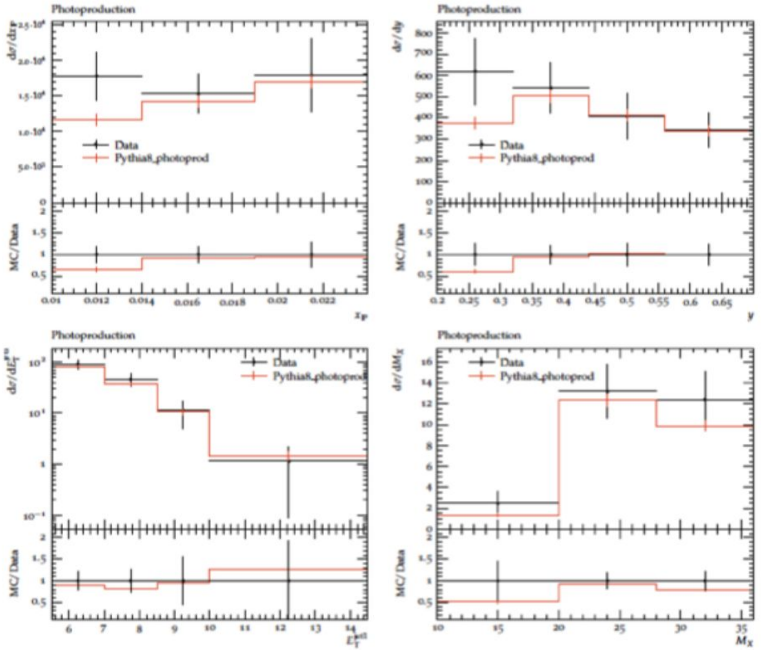


- In the $x < 10^{-3}$ plot, Herwig7 follows the trend of data, but it is seems to be shifted a little bit downwards.
- While, for the $x > 10^{-3}$ plot, Herwig7 results match data for almost the whole part.
- Hence, in this comparision too, we see Herwig7 performing much better than Pythia8.

Diffractive Dijets in Photoproduction - HERA Data

Goa University

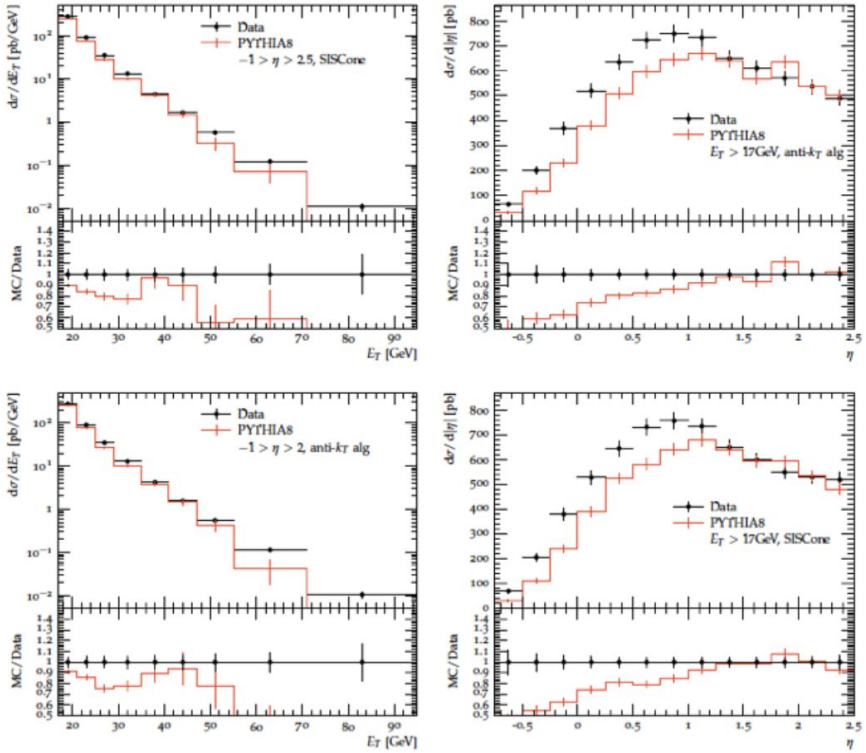
- Fraction of the proton momentum carried by Pomeron ($x_{\mathbb{P}}$) & Inelasticity
- Transverse energy of the leading jet and invariant mass of remanants



Inclusive-jet production - ZEUS Data

Goa University

- Jet Transverse Energy and η distributions (with SIS Cone & Anti-k_T)

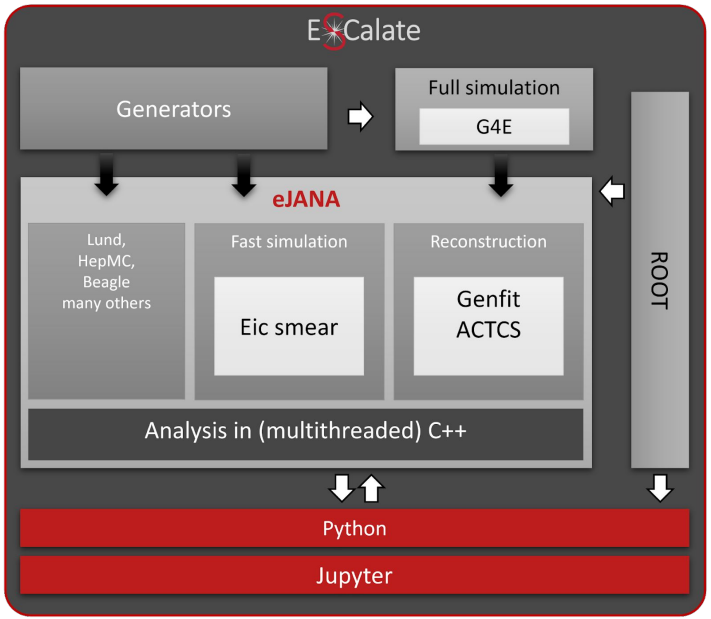


Escalate (Convener: Dr. Dmitry)

RKMRC, Narendrapur
IIT Indore

Escalate

Sayanta Neogi, RKMRC, Narendrapur



- **Escalate is a software that work full simulation of EIC.**
- **You can code python and c++ both.**
- **It is complete pkg of ROOT,g4e.etc all are inbuild.**
- **It is a JLeic base detector.**

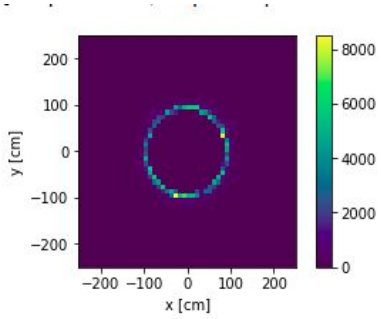
- Test some validation mc data (on going)
- Setup github CI (done)
- Make cmake compilation scripts (done)
- Add c++ lib to read MC file (on going)
- Generate PODio classes (done)
- Add python lib to read MC file (on going)
- Python documentation (on going)
- Ejpm setup (on going)

Escalate

(IIT Indore: Vineet Tripathy and Hassan Mustafa)

Validation Plots

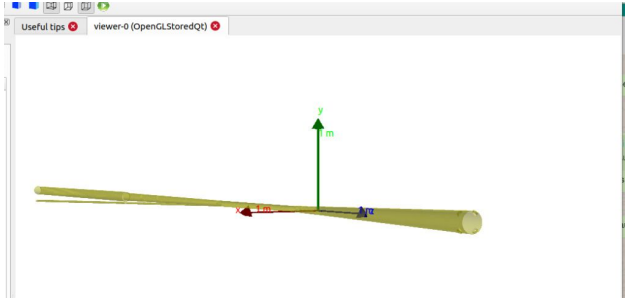
- Created Validation(reference) plots for different calorimeters and sensitive detectors.



cb_EMCAL occupancy Plot

Beamline Construction -

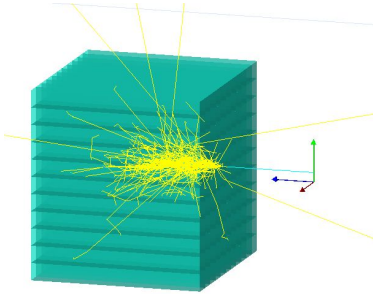
Detached Beamline construction from the detector construction.Constructed Beampipe from CAD files.



Beampipe Construction

Calorimeter ML

- Using Machine Learning to Separate pion and electron, based on energy deposited in 3x3 and 10x10 calorimeters, carry out analysis of mismatch.



Electron shower (10x10 calorimeter)

Code Refactoring - Lattice code can be used to generate magnetic field.Modified its structure to allow multi-threading and incorporated it in detector construction file

EIC-Smear (Convener: Dr. Kolja Klauder)

IIT Patna, IIT Madras, MNIT, Jaipur
Central University, Karnataka

EIC-Smear: IIT Patna

Student Contributor: Rajat Aggarwal

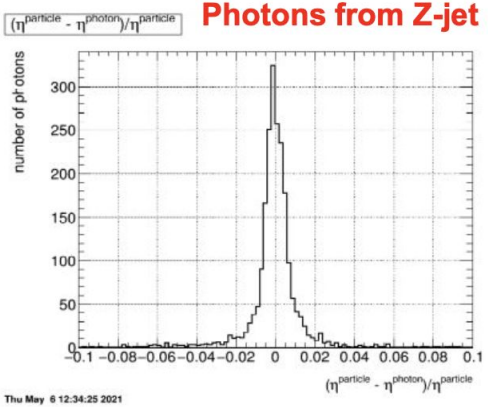
Comparison of EIC-Smear and Delphes

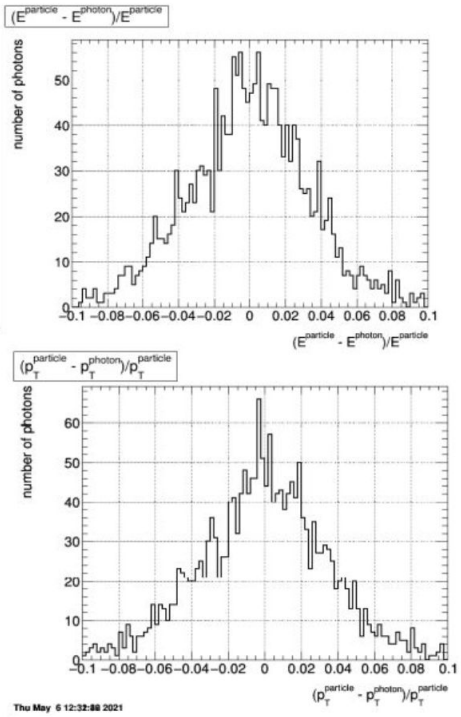
Successfully installed and able to compile examples in Delphes

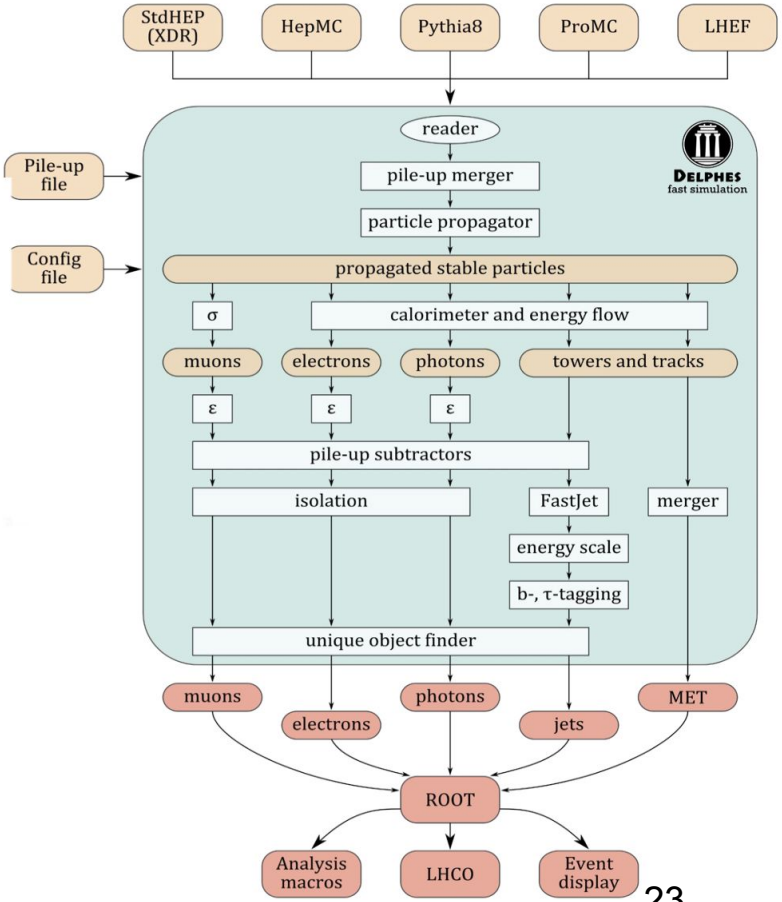
Future task:
write an example for both the methods

Make comparisons between two

Photons from Z-jet







EIC-Smear: IIT Madras

Student Contributor: Riya Thakkar

Unit Testing:

Used catch2, a unit testing framework and added unit tests to kinematics.cxx file.

Current task: Integrate catch2 and cmake for automated unit testing every time the eic-smear software is build and compiled.

Next task: Add unit-tests to other .cxx files in the eic-smear library.

Updating the kinematic parameters in qaplots.cxx:

Referred the yellow book chapter on Inclusive reactions to extract information on the ranges of various kinematic variables like eta, Q etcetera.

Updated the qaplots.cxx file in the detector/tests to match those specified ranges of kinematic variables.

Current task: Obtained a bnl remote account to compile and run qaplots.cxx file. Depending on the results, the parameters are to be further updated.

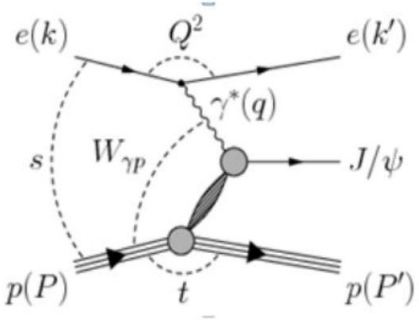
Future task: Update the kinematic parameters for other techniques of kinematic reconstruction and detector test files.

EIC-Smear: MNIT Jaipur

Student Contributor: Chitranshi Bakshi

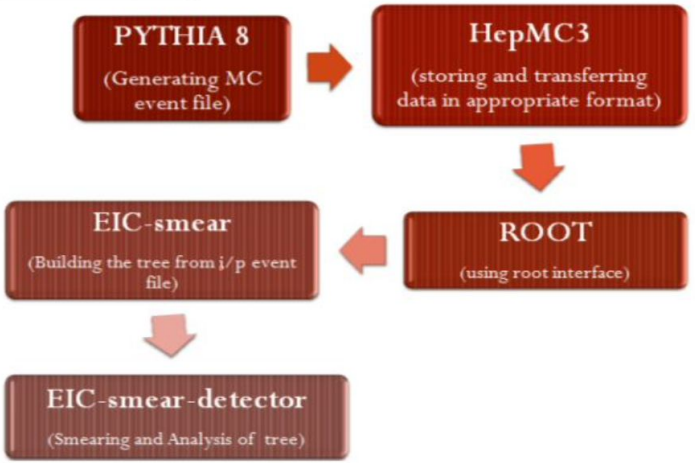
Study the smearing effect for Exclusive Physics with EIC

MNIT Jaipur Group: Chitranshi Bakshi (Master student) , Kavita Lalwani (Faculty)



- Input MC event file is generated using Pythia8 giving input parameters corresponding to exclusive reaction i.e J/ψ photo-production .
- Input event file is stored in form of Ttree in ROOT software to ease the reading and smearing process.
- Fast stimulations is performed effectively by using eic-smear software and eic-smear detector scripts.
- Smearing effect on different parameters of exclusive reactions are analyzed .
  - Reconstruction of mass of J/ψ (ongoing work).

Work flow chart

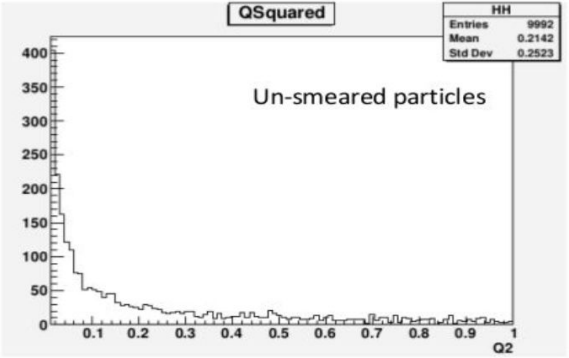


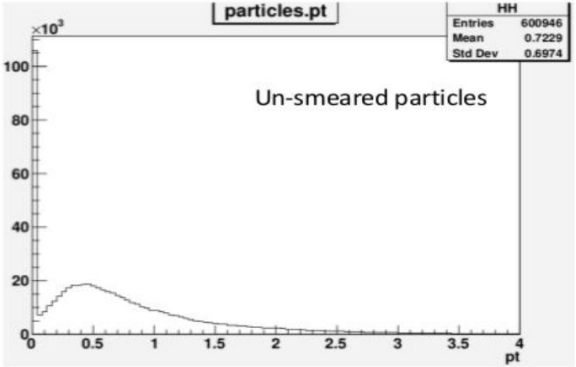
EIC-Smear: MNIT Jaipur

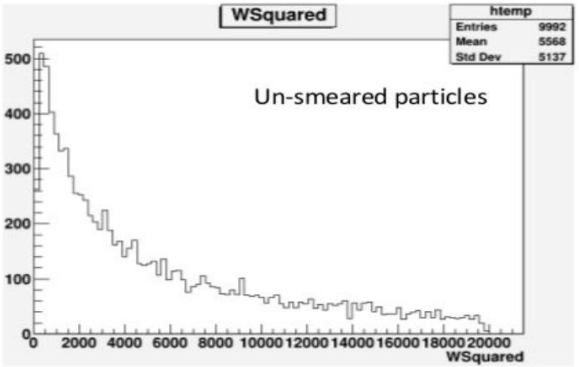
Student Contributor: Chitranshi Bakshi

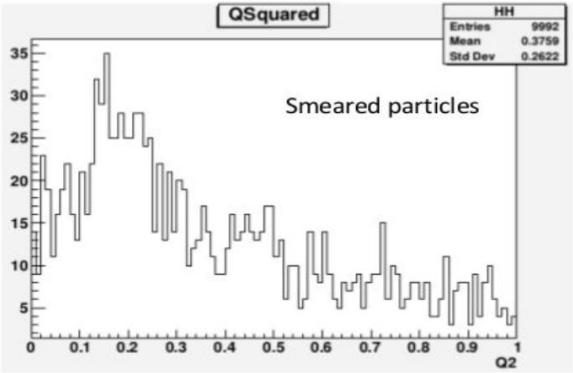
Results :-

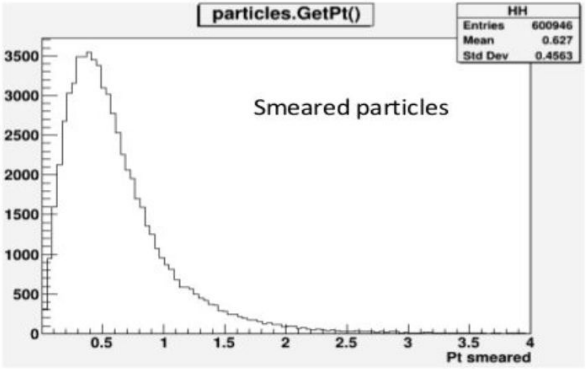
Smearing effect on Q^2, p_T and W^2 Distributions for proton, electron beam collision with energies 275 , 18 GeV respectively.

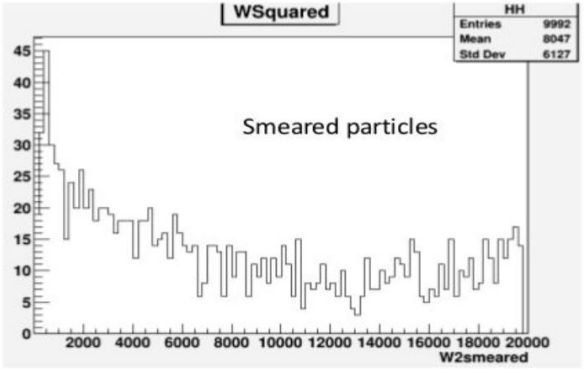






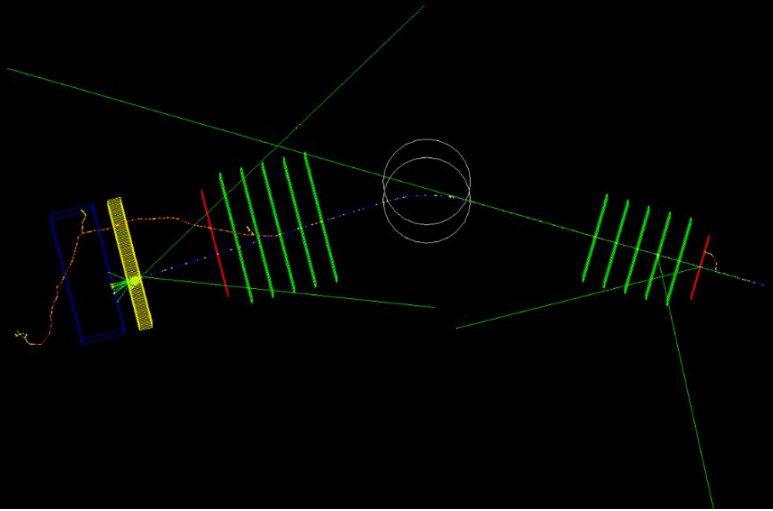






Project eAST

- Task to Indian group: develop a HepMC3 interface which will read event record and pass the information to the Geant4.
- Makoto Asai delivered Geant4 introductory lecture with some hands-on exercises to get familiar with Geant4, which will help in the development of eAST. Following picture is from one of the basic simulation example.



Athena-India software Group RoadMap

Hardware Plan:

Athena-India group is planning for hardware contribution in the following three detectors:

Silicon Vertex detector
MPGD based Tracking Detector
PID detector

Software Motivation:

- Hardware development requires a lot of inputs from the software. For a particular detector, if our students and postdocs get the exposure to both software and hardware, it will be a complete training for them.
- It will also be beneficial in our next funding proposal to Indian funding agencies.

Thank You!