CEE ZDC event centrality determination

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- Event centrality determination strategy
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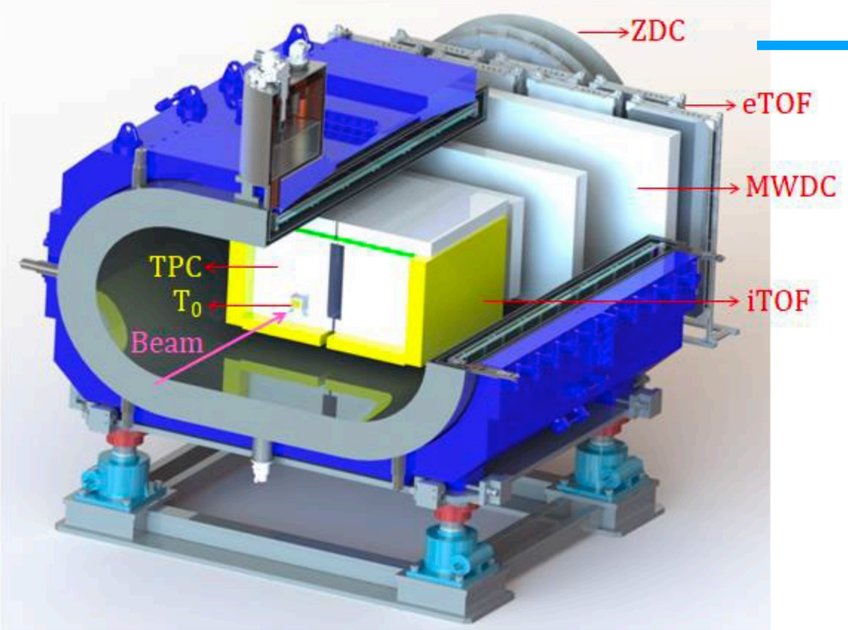
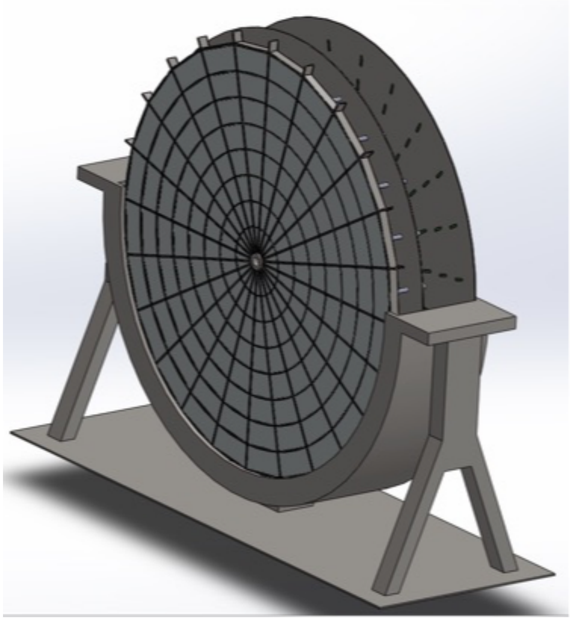
Introduction





Main goal of the ZDC:

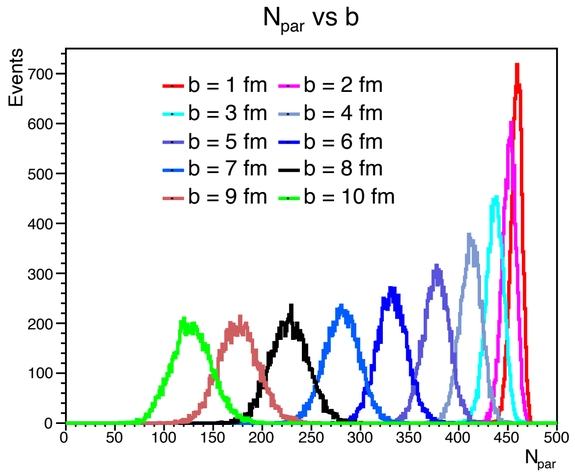
- Event plane reconstruction
- Event centrality determination

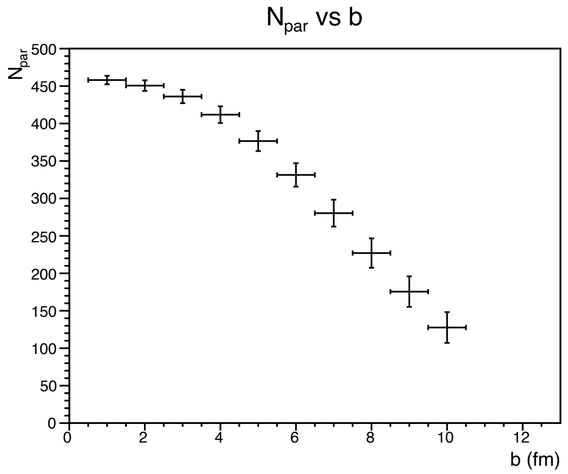
Structure:

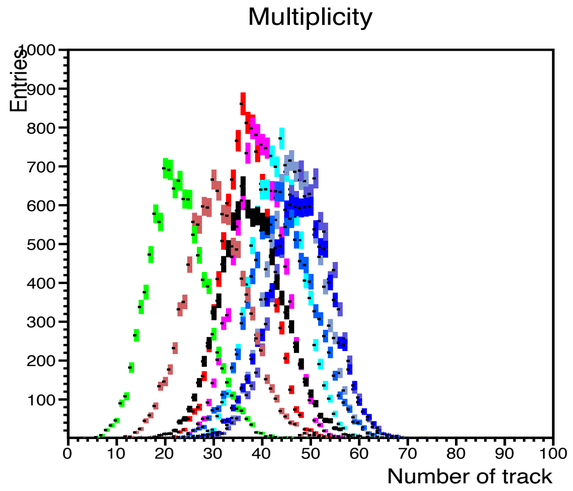
- Plastic scintillator (4 cm) + PMT
- 8 rings, 24 sectors, 192 modules

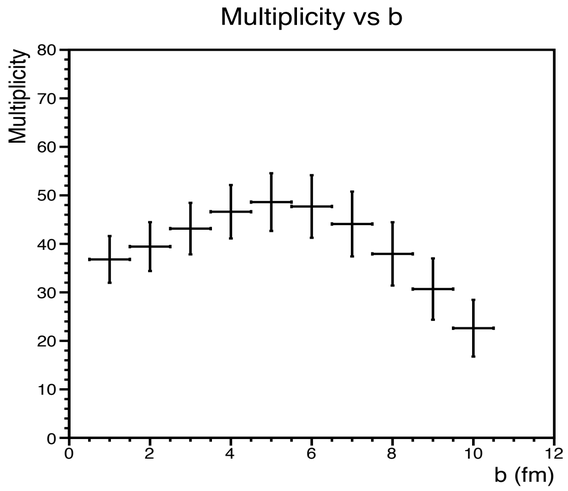
The collision centrality can only be deduced from the measured charged particles in experiments and the determination of the collision centrality in low-energy collisions has always been a major challenge!

IQMD QA









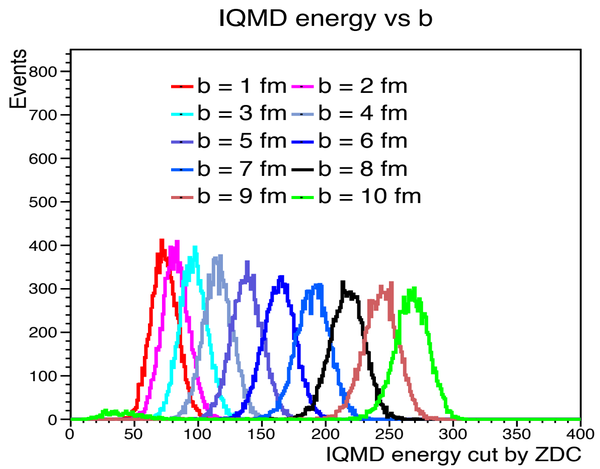
Generated level(IQMD):

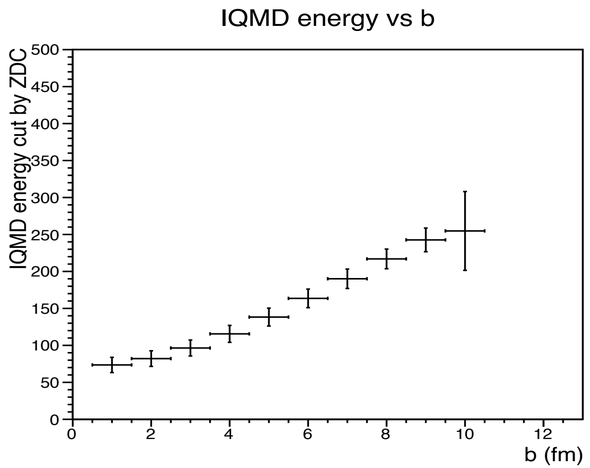
- Strong centrality dependence for **Npar**

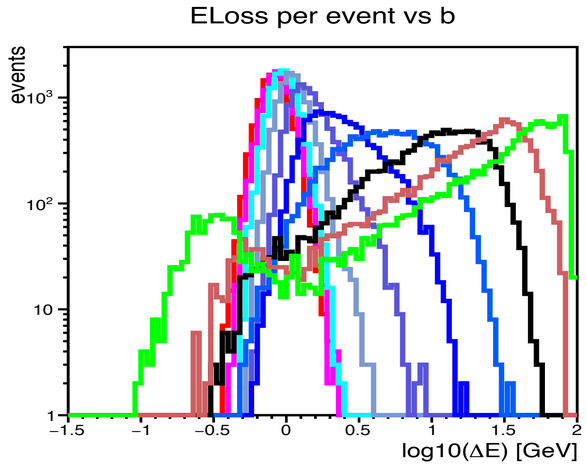
Reconstruction level(IQMD + GEANT):

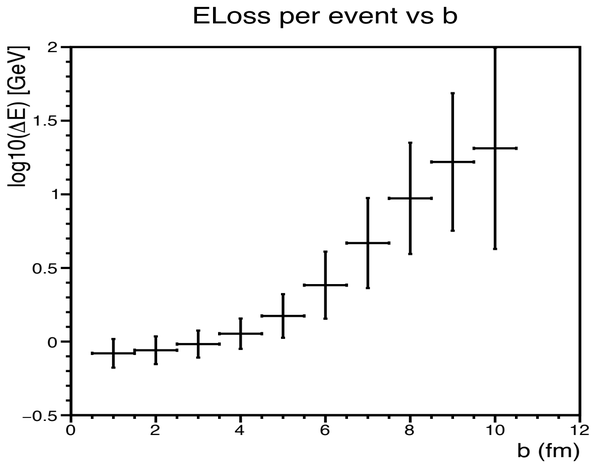
- Weak centrality dependence for **multiplicity** (acceptance limitation for ZDC)

IQMD QA









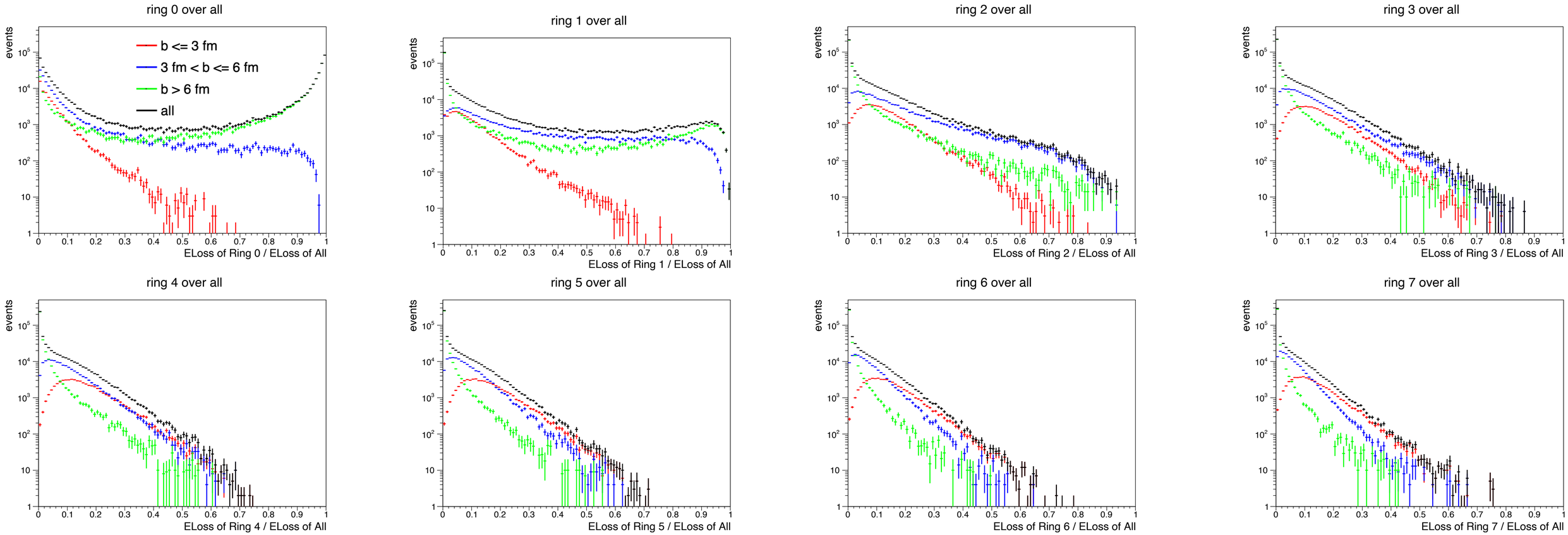
Generated level (IQMD):

- Strong centrality dependence for **total energy per event**

Reconstruction level (IQMD + GEANT):

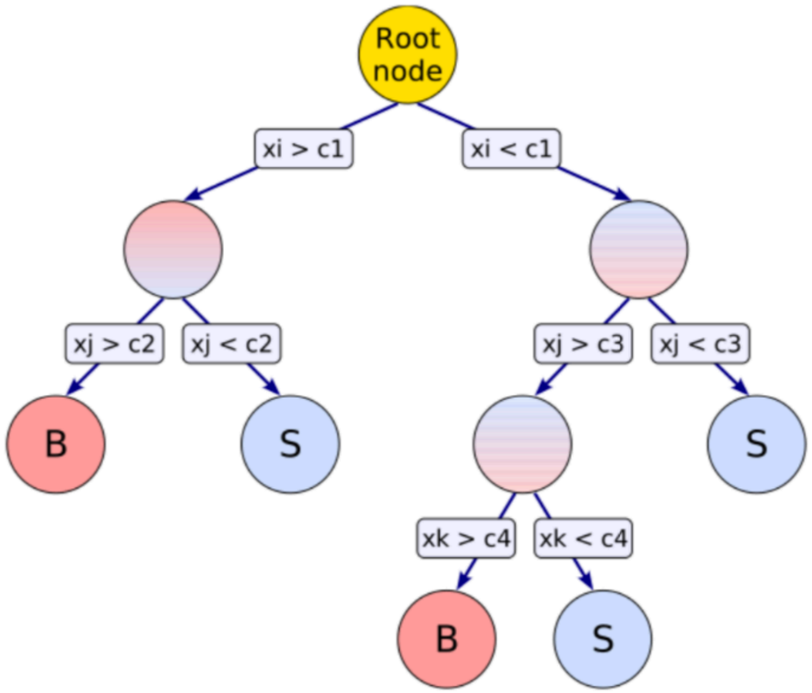
- Strong centrality dependence for **energy loss**, however the statistic uncertainty is large

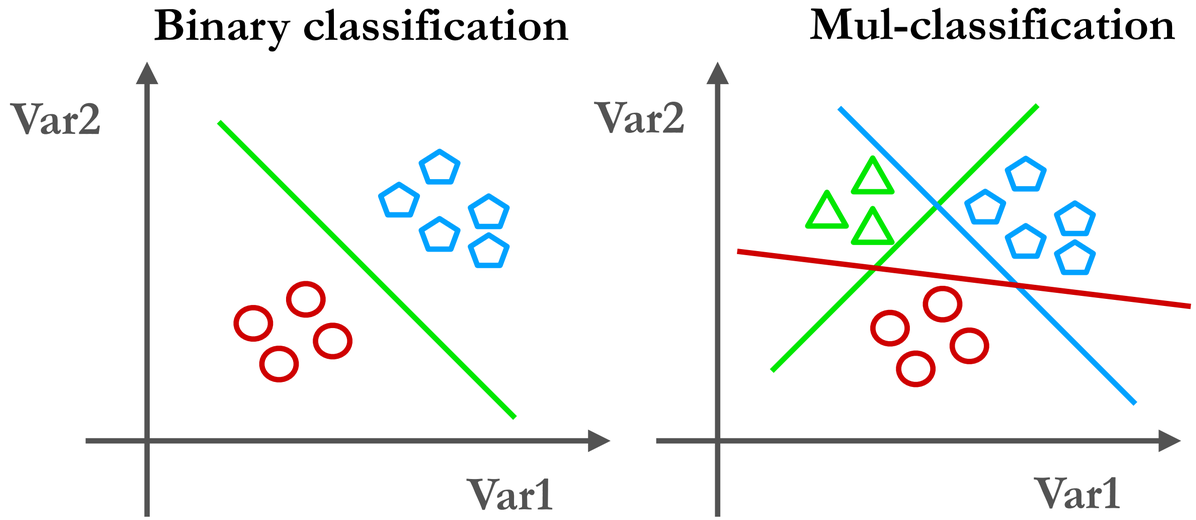
IQMD QA



- **additional variables**: $R_{ring} = \Delta E_{ring}/\Delta E_{ZDC}$ (the energy loss ratio between each ring with total energy loss)
- **Three centrality class:** central: b <= 3 fm , mid-central: 3 < b < 7 fm, peripheral: b >= 7 fm

Boost Decision Tree





- **Ntrees**: number of decision trees;
- **MinNodeSize**: minimum event numbers for one node ;
- **MaxDepth**: Maximal layer number;
- **nCuts**: number of grid points in variable range used in finding optimal cut in node splitting.

dmlc XGBoost

hipe4ML

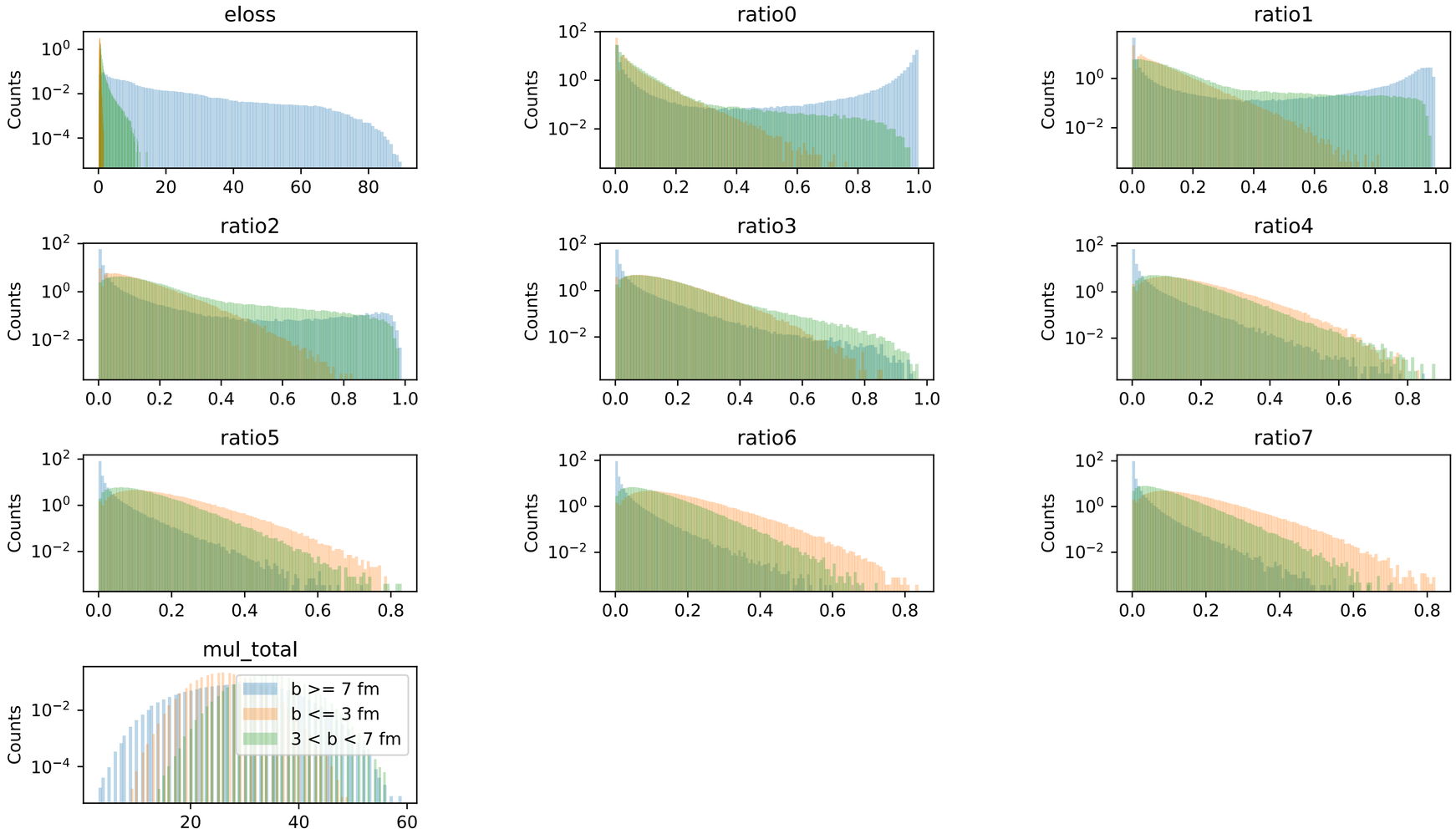
https://github.com/hipe4ml/hipe4ml

https://github.com/dmlc/xgboost

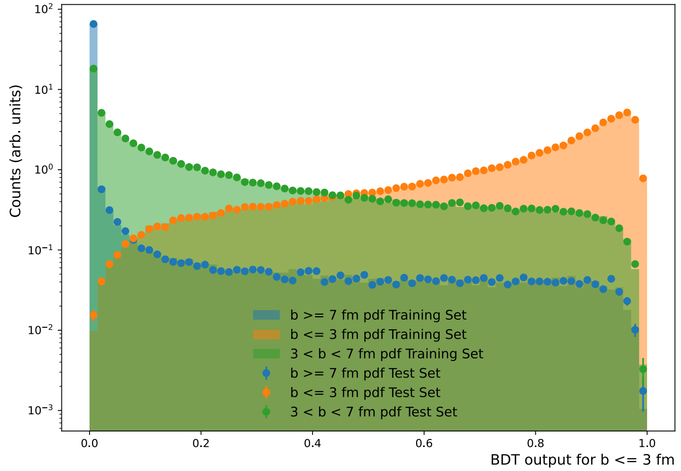
BDT training input

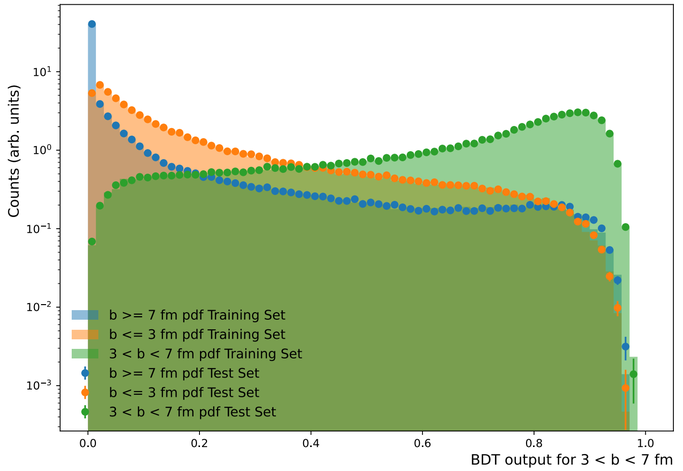
- **Variable used for training**: ΔE_{ZDC}, $R_{ring} = \Delta E_{ring}/\Delta E_{ZDC}$, fired channel (multiplicity)

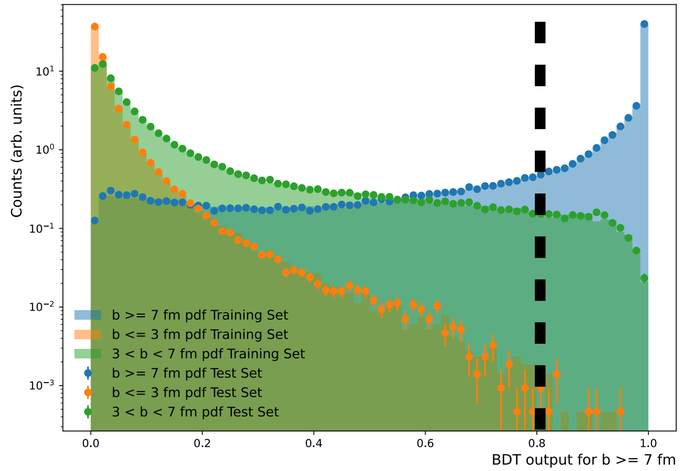
- **Three centrality class:**
  - central: b <= 3 fm
  - mid-central: 3 < b < 7 fm
  - peripheral: b >= 7 fm



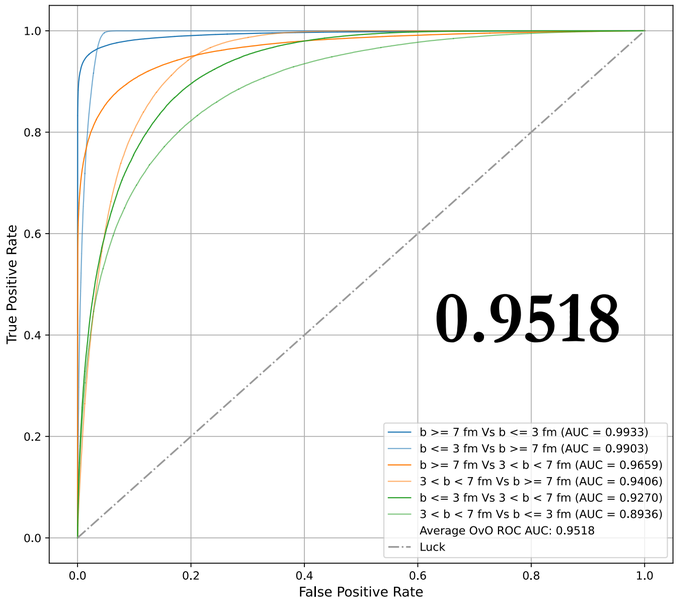
BDT training output







Cut



0.9518

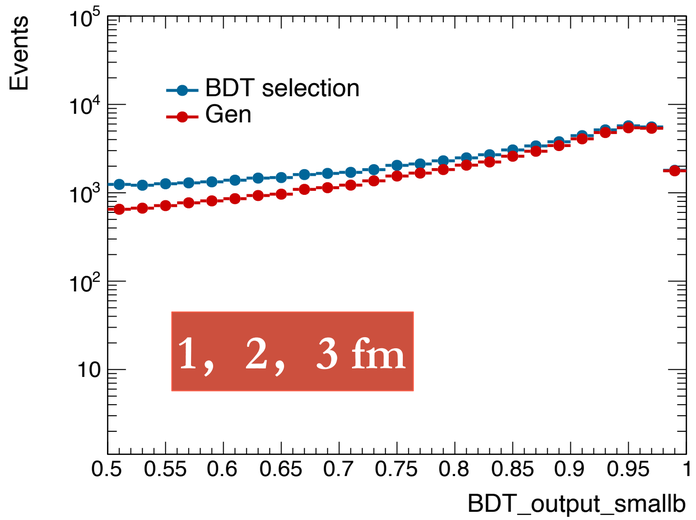
- Feedback the scores of each class:

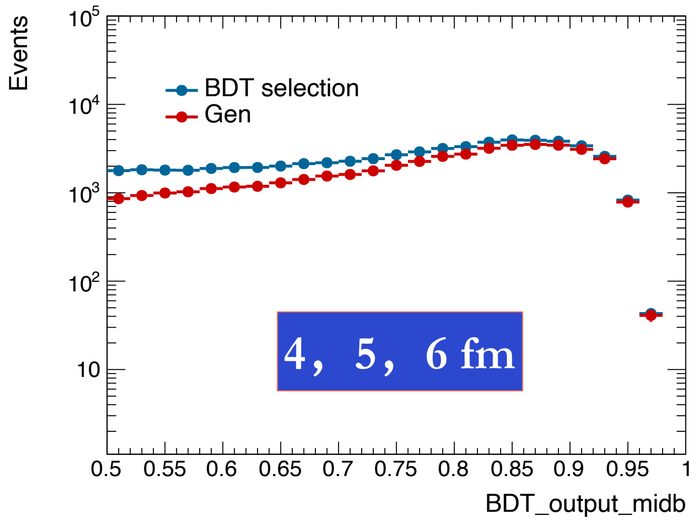
  prob(central) + prob(mid-central) + prob(peripheral) = 1

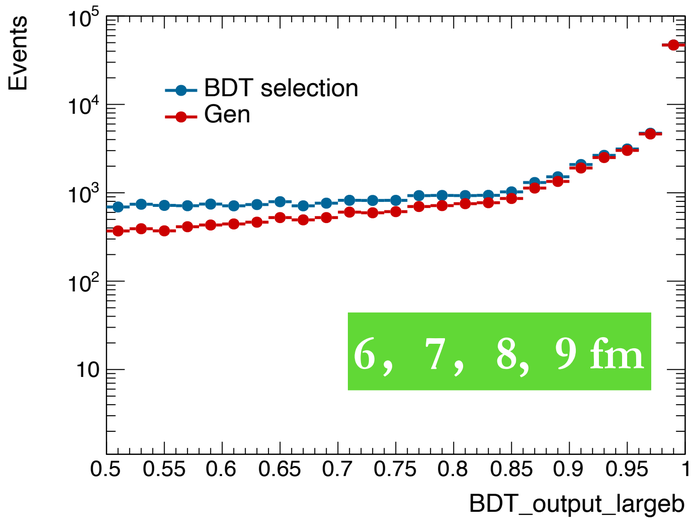
- Scores are used to select the centrality class
- Mode performance with ROC curve : AUC > 0.95

Model application

- **Apply models on 200000 mix-event**
  - **BDT selection: BDT cut**
  - **Gen: truth**







- Purity and efficiency for the BDT selection

Score > 0.85	central	mid-central	peripheral
Purity	93%	91%	98%
Efficiency	49%	25%	78%

- High purity with the good efficiency
- For mid-central: affected by the volume fluctuation of the initial state of the collision system

Summary

1. **Simulation QA**
   - Rec. Level is not perfect to distinguish the centrality class
2. **Study the centrality determination with BDT**
   - performance of the BDT model is good
   - High purity for the event centrality classification(> 90%), efficiency is good enough (> 25%)
3. **The simulation results show good performance of using ZDC to determine event centrality classes**

Backup

Importance of vars :