JINR grant #2

Photon and neutral meson reconstruction

Dmitry Blau,

Oleg Golosov,

Evgenia Nekrasova,

Dmitri Peresunko

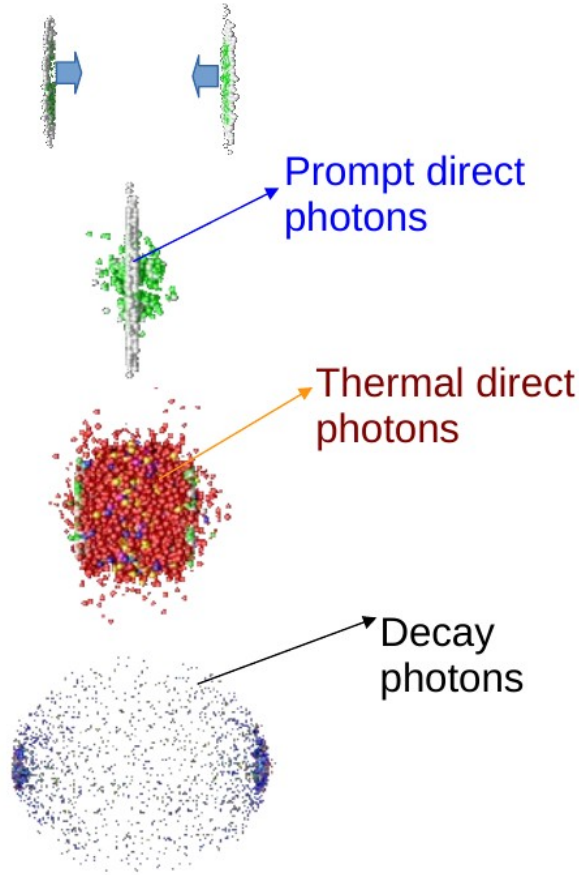
NRC “Kurchatov institute”

Grant 2: goals

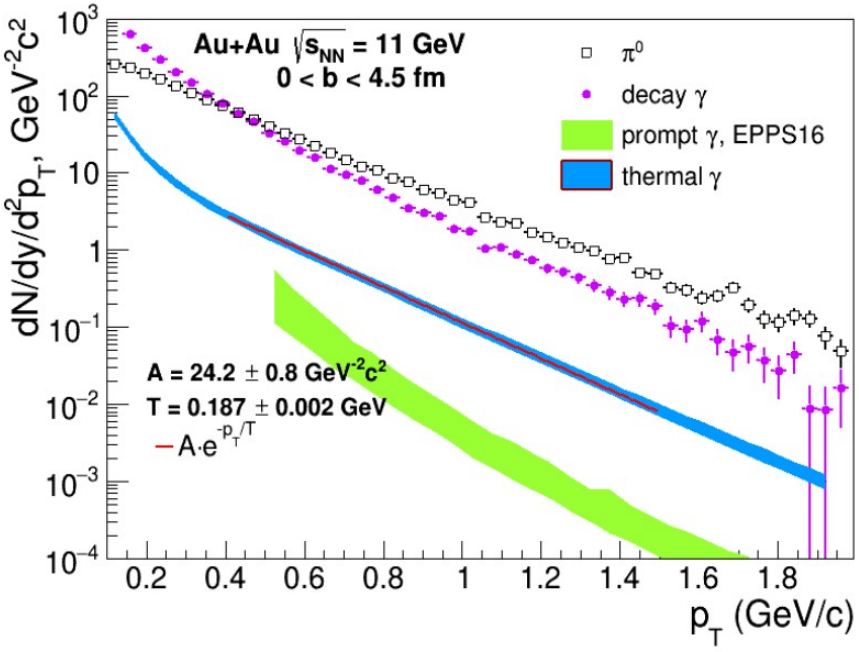
- Calculation of the yield and collective of direct photons in Bi-Bi collisions at $\sqrt{s_{NN}}$ = of 9.2 GeV within URQMD in hybrid mode
- Development, support and improvement of the data analysis framework.
- Analysis of data from a centralized Monte Carlo simulation of Bi-Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV to estimate systematic uncertainties in measuring the neutral pion yield
- Analysis of data from a centralized Monte Carlo simulation of Bi-Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV to estimate systematic uncertainties in measuring collective flow of neutral mesons
- First report: Cross-PWG meeting, Aug. 22

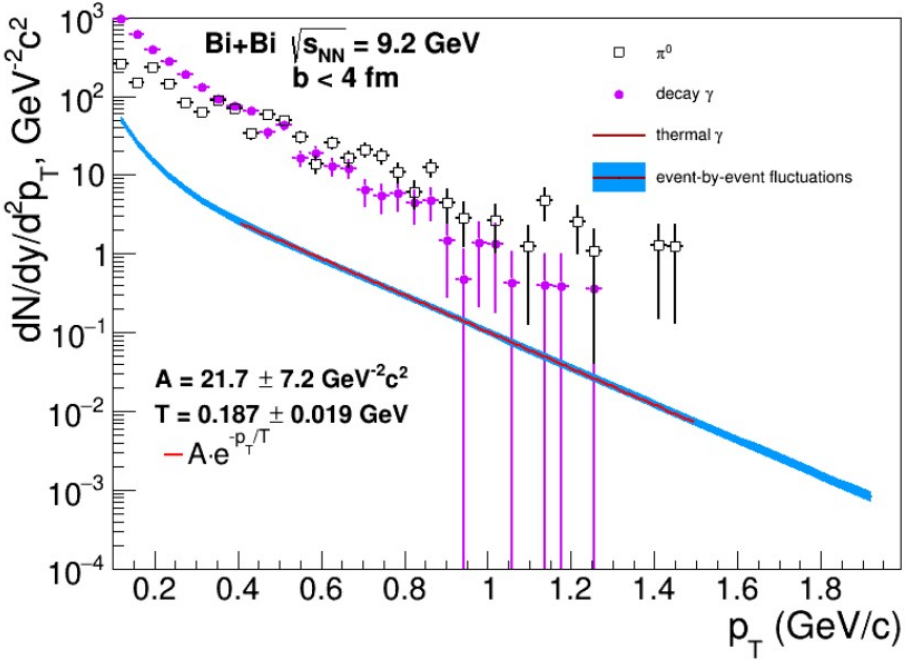
Updated theoretical predictions
(Dmitry Blau)

- UrQMD in hydro mode (bag EOS)
- prompt + thermal direct photons
- «Direct Photon Production in Heavy-Ion Collisions at NICA Energies»,D. Blau, D. Peresunko, Phys.Part.Nucl. 52 (2021) 4, 681-685



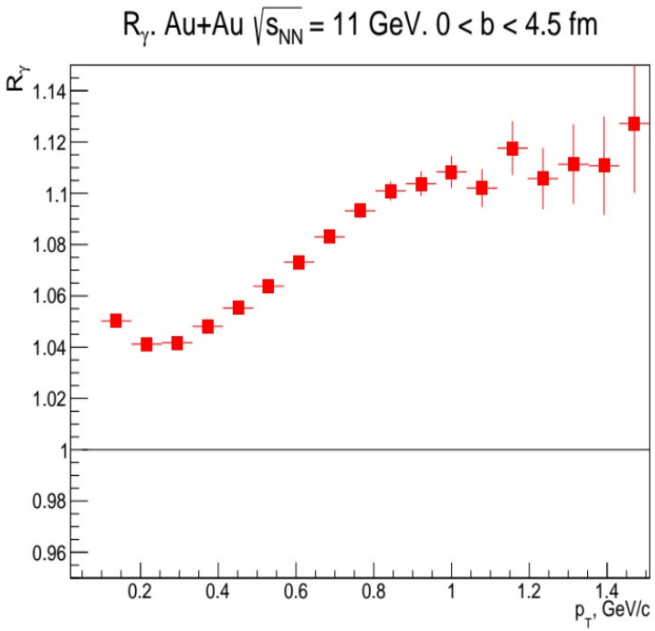
Comparision Au+Au vs Bi-Bi (Dmitry Blau)

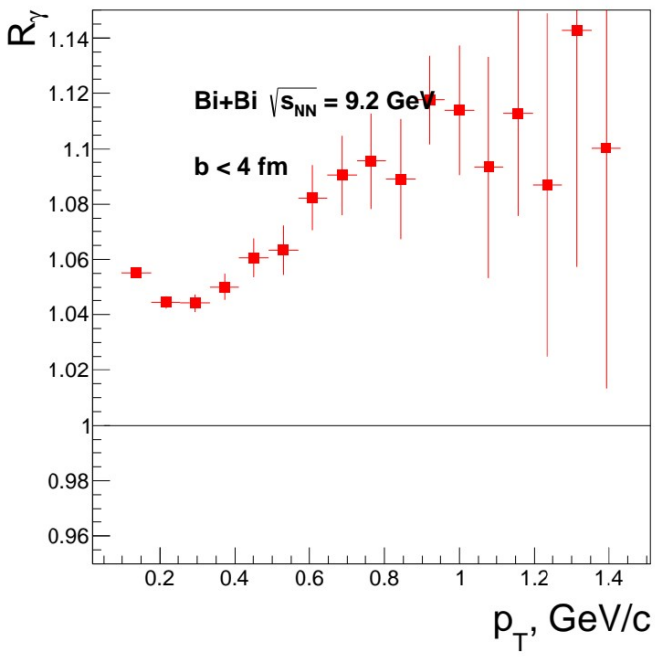




Absolute yield in Bi-Bi is smaller, but slope and relative yield is similar to Au+Au collisions

Photon double ratio

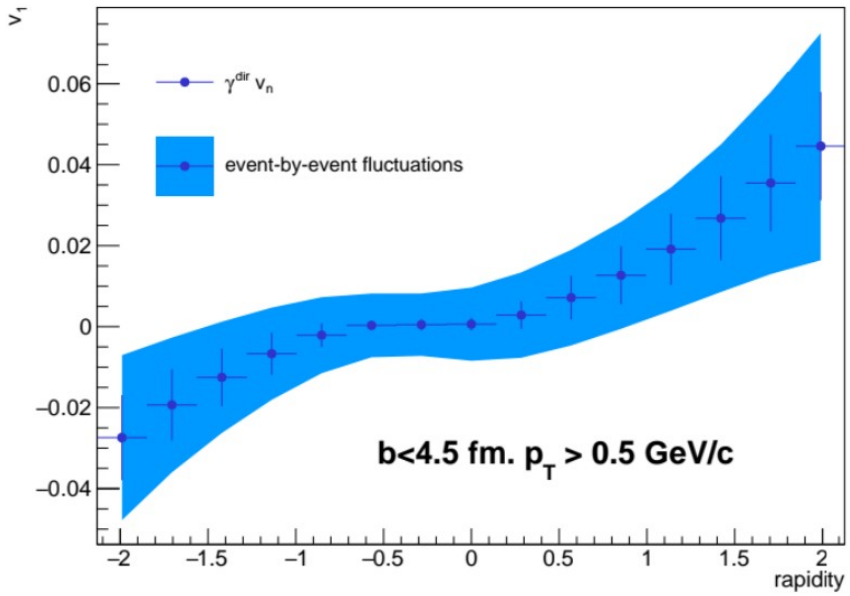


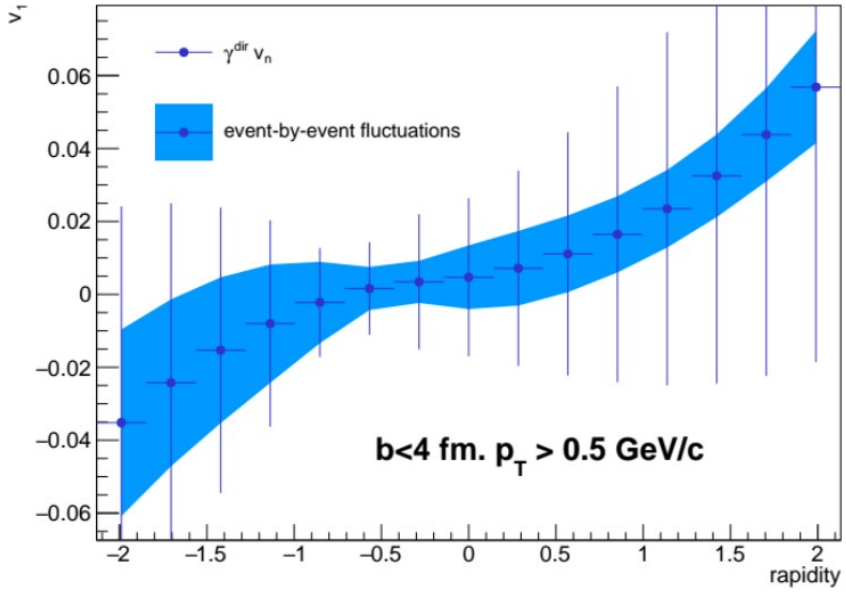


$$R_\gamma = \frac{\frac{N_\gamma^{incl}}{N_\pi^{data}}}{\frac{N_\gamma^{decay}}{N_\pi^{MC}}} \approx \frac{N_\gamma^{incl}}{N_\gamma^{decay}}$$

Double ratio is key quantity showing possibility to extract direct photon yield. Significant excess over unity means direct photon contribution.
In Bi-Bi it is close to one in Au-Au

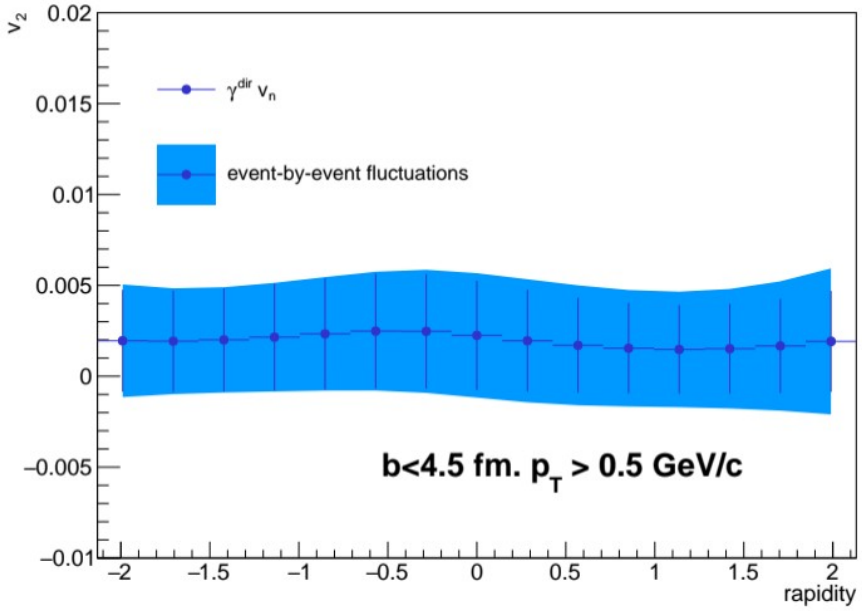
Directed flow of direct photons

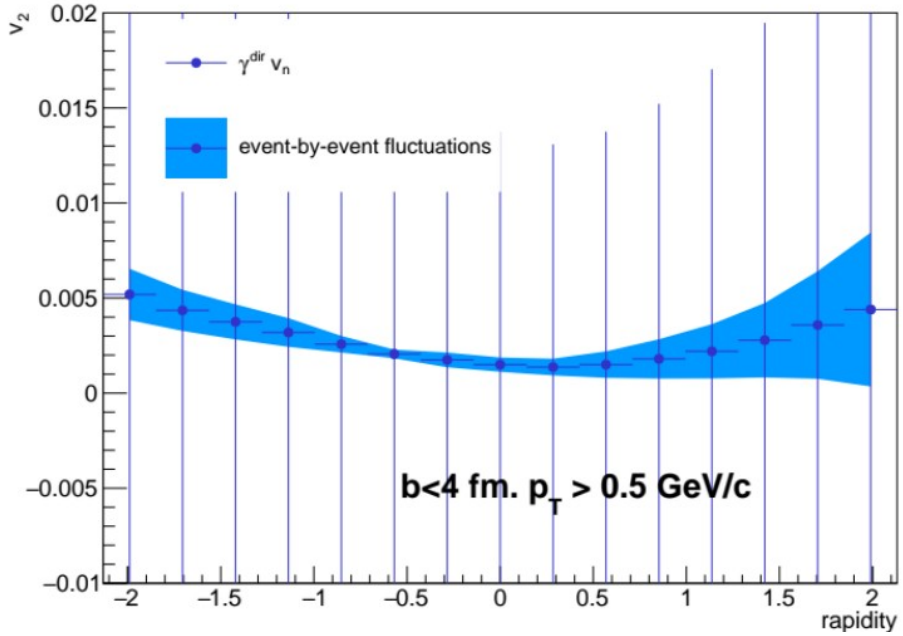




Directed flow slightly larger in Bi-Bi. Slightly more peripheral sample?

Elliptic flow of direct photons





Direct photon flow in Bi-Bi slightly larger than in Au-Au, while event-by-event fluctuations are smaller. Same effect as for directed flow?

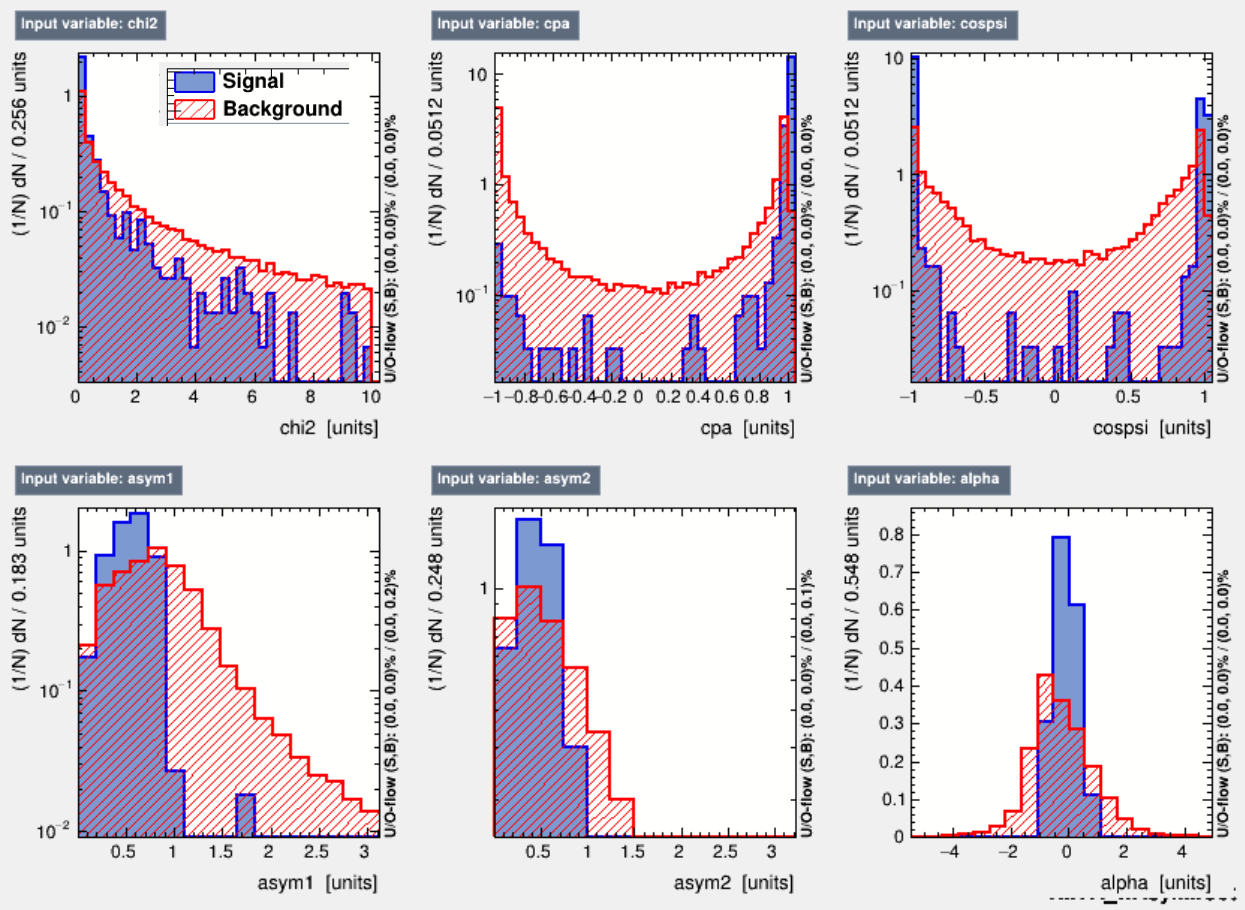
ToDo: increase statistics and cross-check reduction of EbE fluctuations

Software development

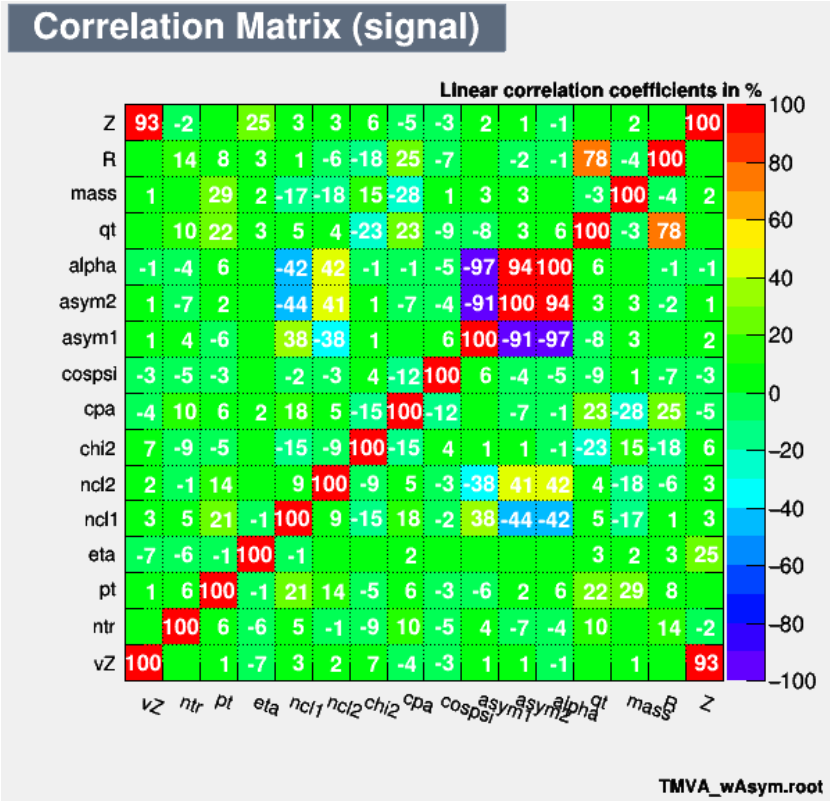
- Clustrizer ToDo
  - Purifying clusters from cells below thresholds
  - Optimizing cuts (E_{min}, E_{seed}, E_{locMax})
- V0 finder
  - Move V0 finder to standalone class
    - mpdroot/physics/evPID/MpdV0Maker.h
  - Fills branch with V0s per event
    - mpdroot/physics/evPID/MpdV0.h
  - Identify photon conversion V0s via cuts or via Multy Variable Analysis (Boosted Decision Tree algorithm)
  - Improve reconstructed momentum using MVA regression
  - ToDo: detailed comparison of cut and BDT approaches
- Neutral meson/photon analysis class mpdroot/physics/photons/MpdConvPi0.h
  - consumes prepared V0s, ECAL clusters and produce histograms for analysis
  - was used in Train 1 and Train 2 scans
  - ToDo: cut optimilzation, adding histograms for v_2 analysis, bug fixes

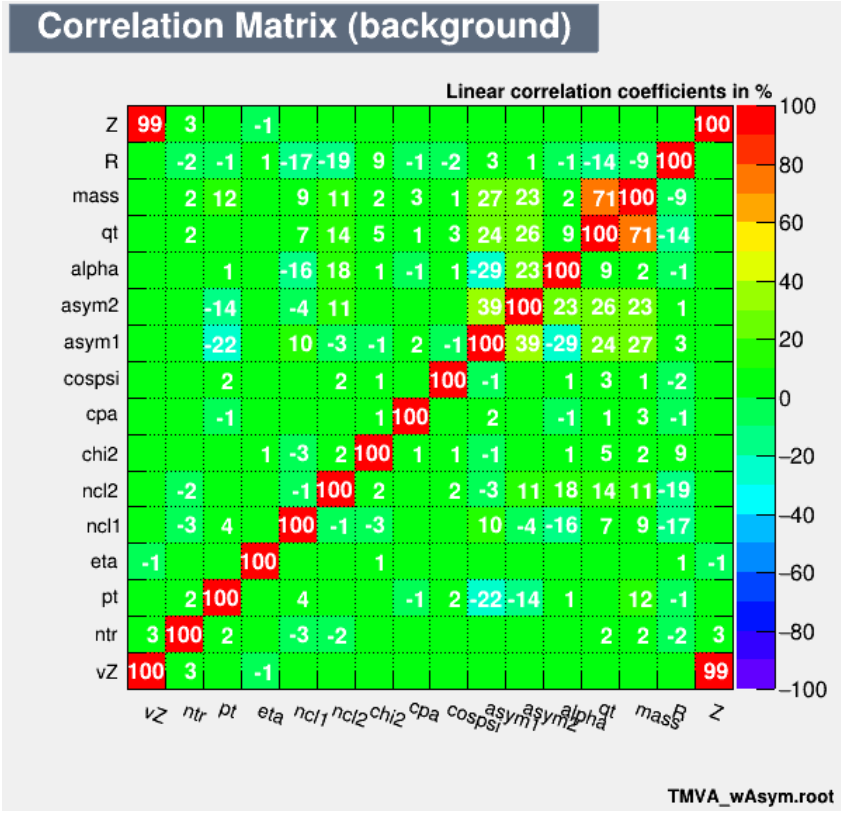
V0 finder: input variables

- vZ: event vertex z coordinate
- ntr: number of tracks
- pt: V0 pt
- eta: V0 eta
- ncl1, ncl2: number of TPC clusters
- chi2: chi2 of the Kalman fit
- cpa: cosine of angle between momentum and dirction from secndary vertex to primary vertex
- cospsi: cosive of agle of pair orientation w.r.t. magnetic field
- asym1, asym2: track momentum asymmetry
- alpha, qt: Armenteros-Podalansky variables
- mass: m_{ee} pair mass
- R, Z: conversion radius and z coordinate



Variables correlation

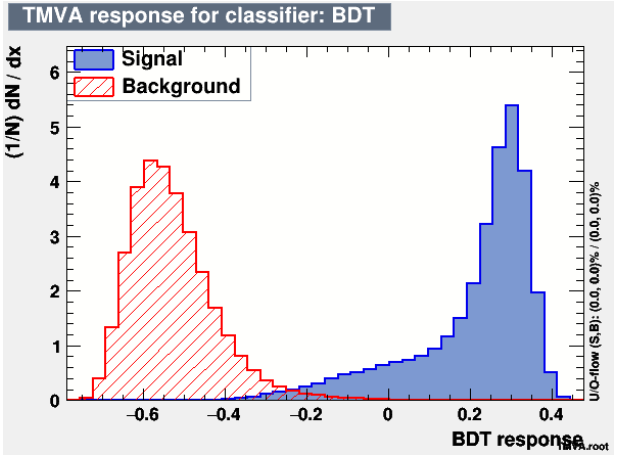


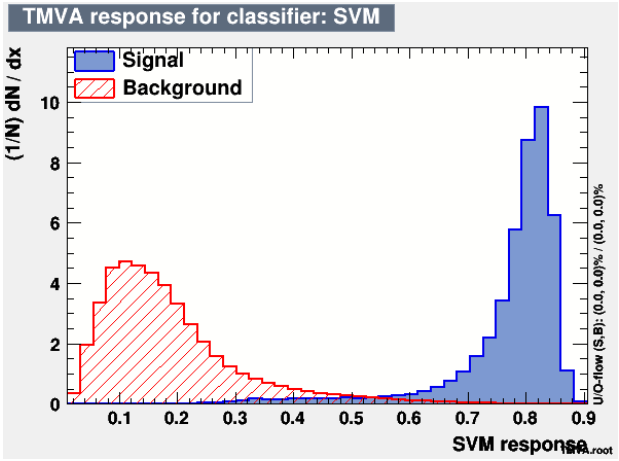


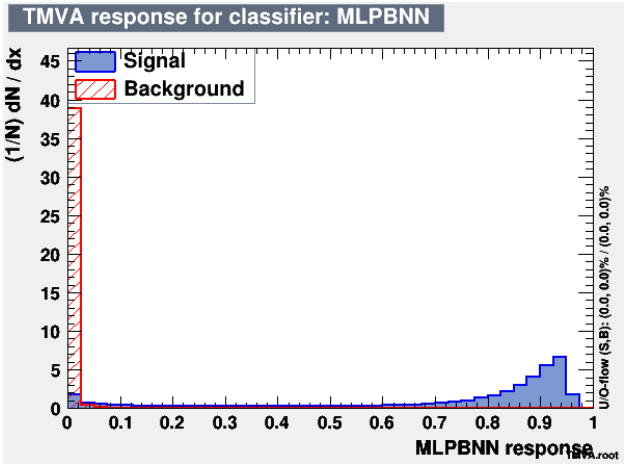
Most of variables are independent. Some correlated, e.g. event vZ and conversion Z, asymetry and alpha. Some correlations not obvious: ncl vs asym, qt and R. To be optimized

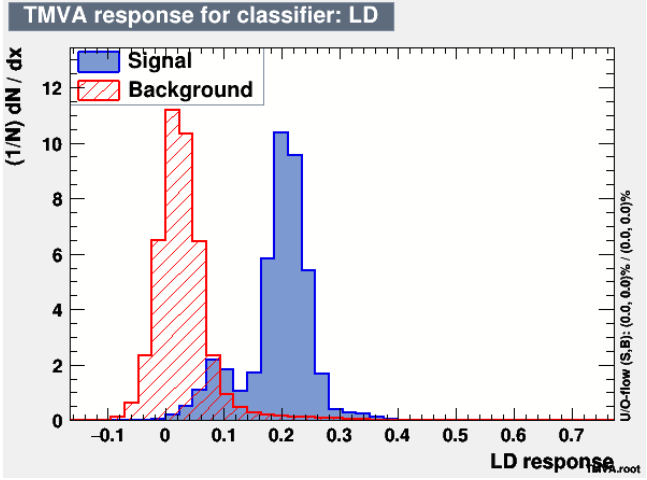
Classifiers outputs

Some classification algorithms provide clear separation of signal and background (random pairs)



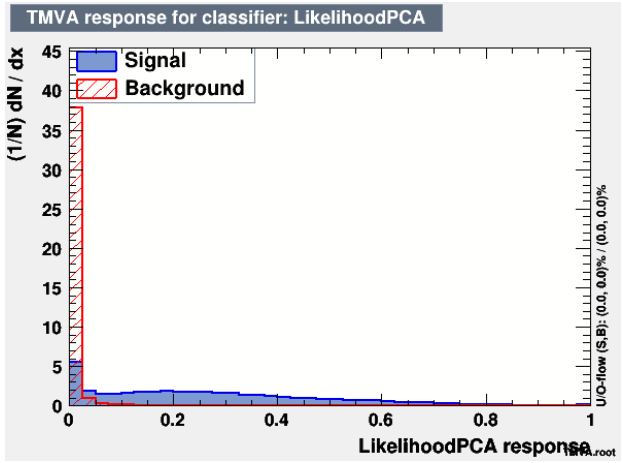


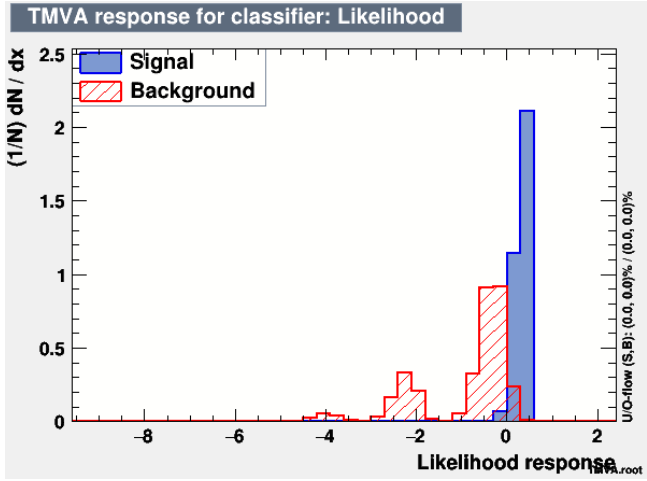


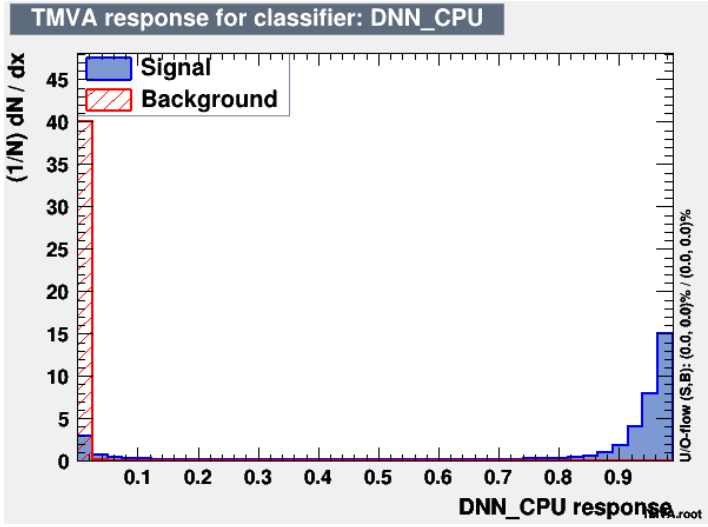


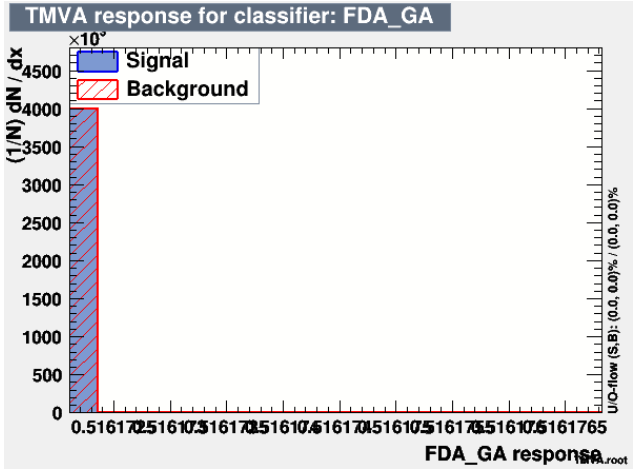
Classifiers outputs (2)

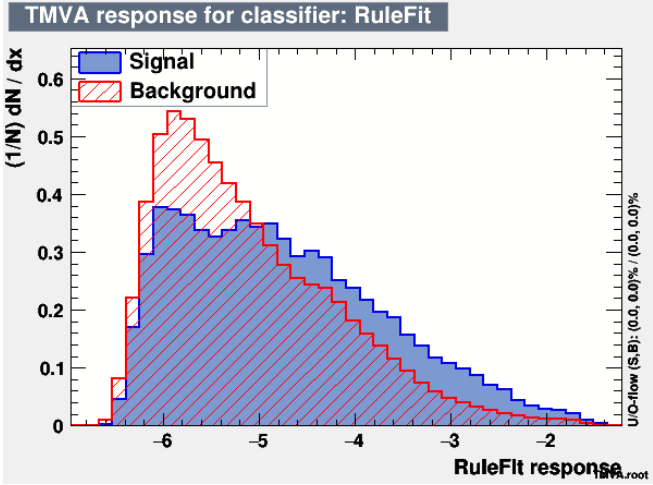
Some clussifiers do not separate signal/background (e.g. RuleFit)



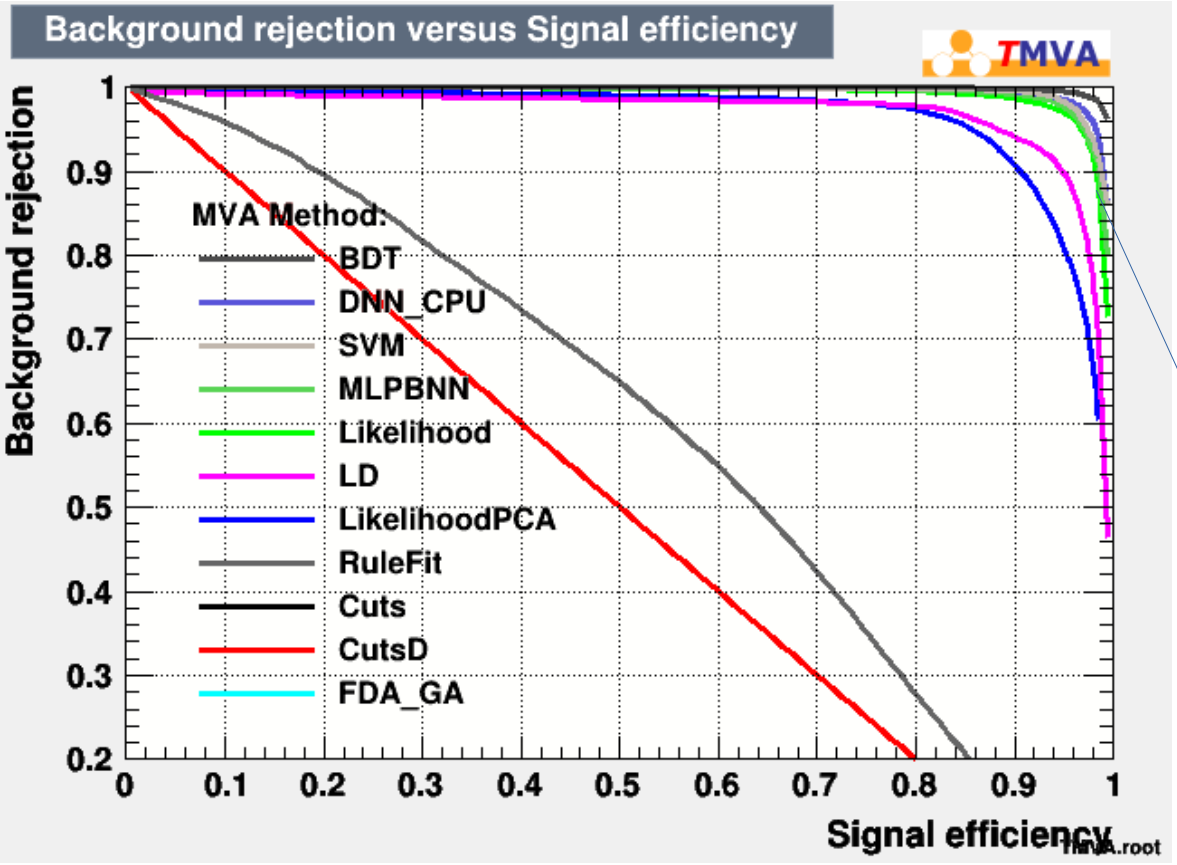


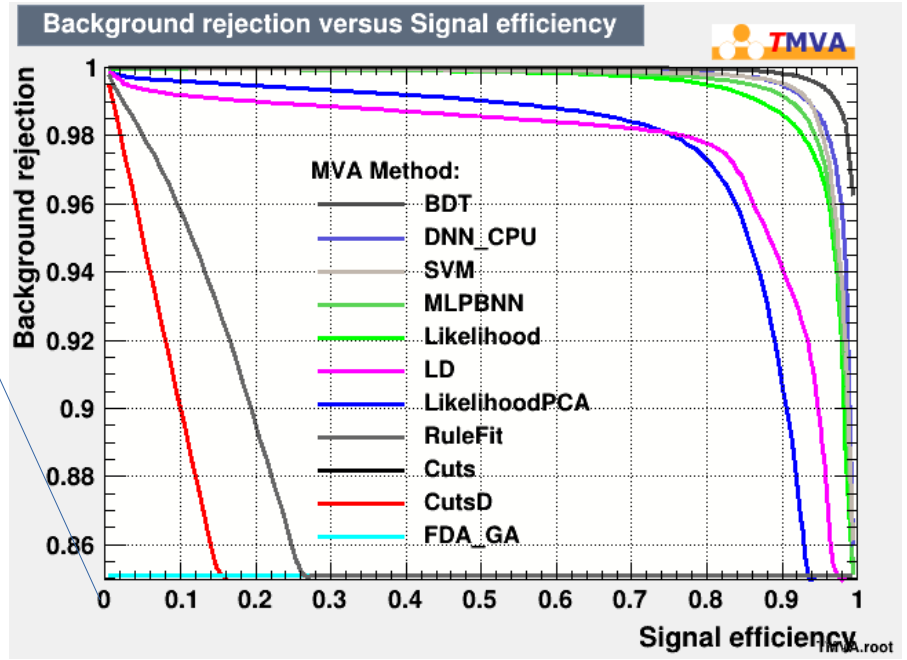






Operation response curves

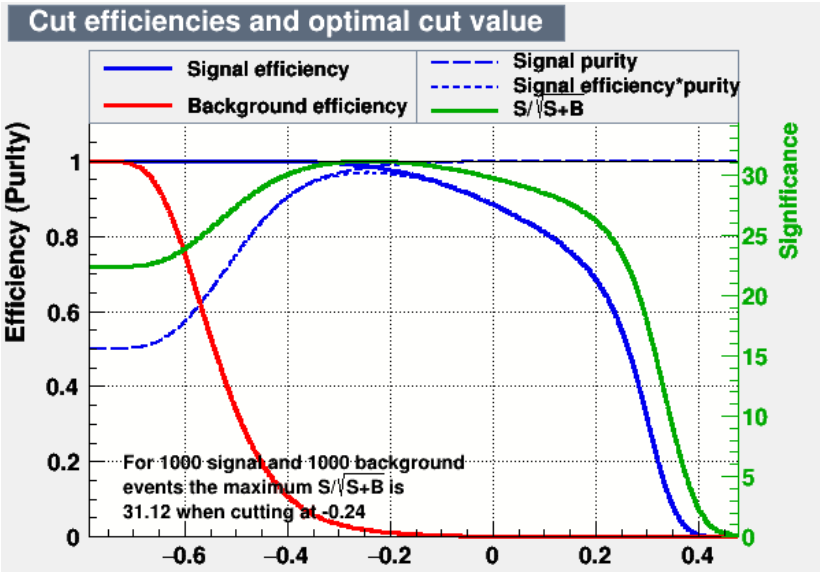


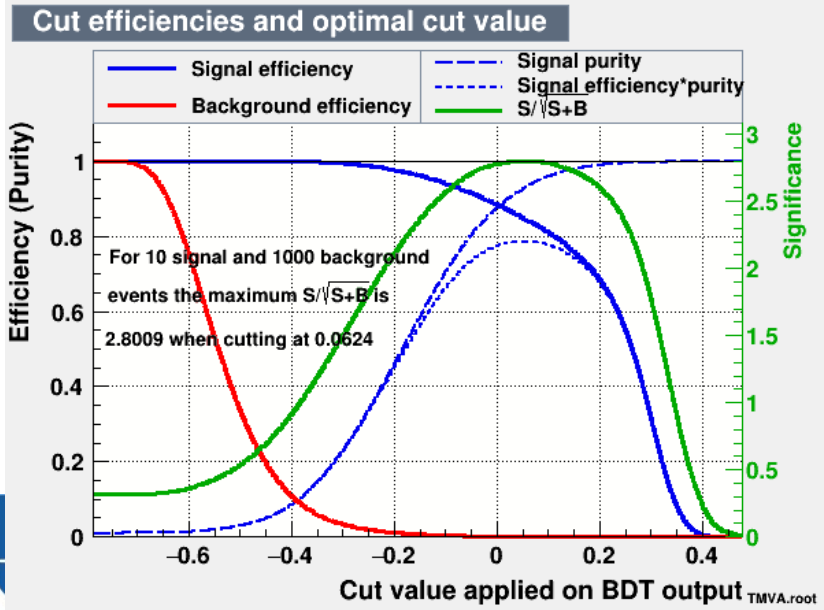


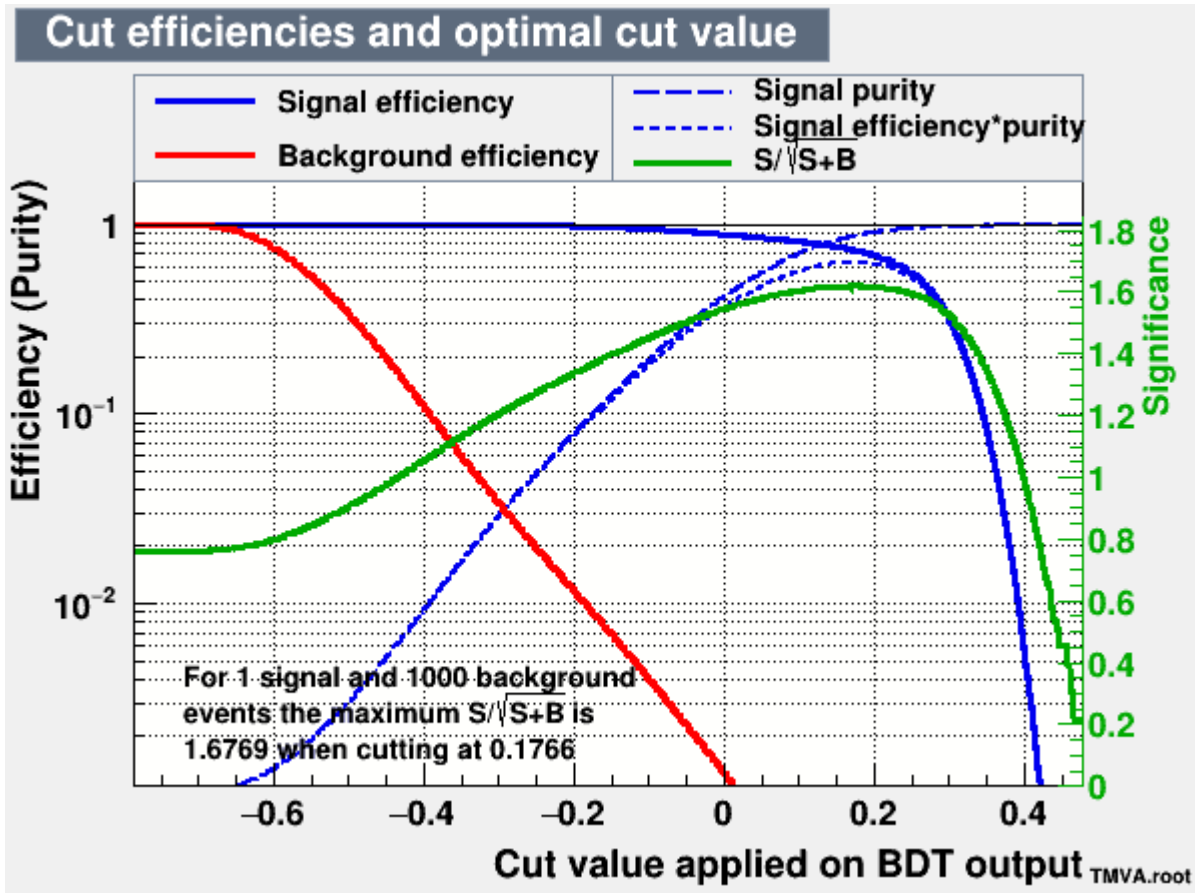
Best performance:
BDT, SVM, DNN_CPU

Bad performance: CutsD, RuleFit, LikelihiidPCA, LD

BDT optimal cut



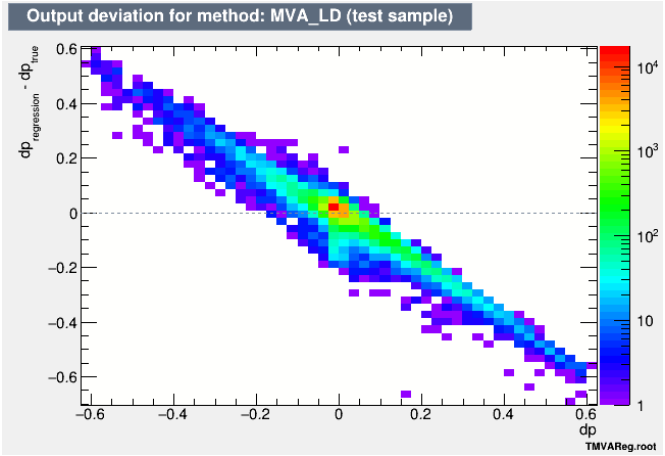


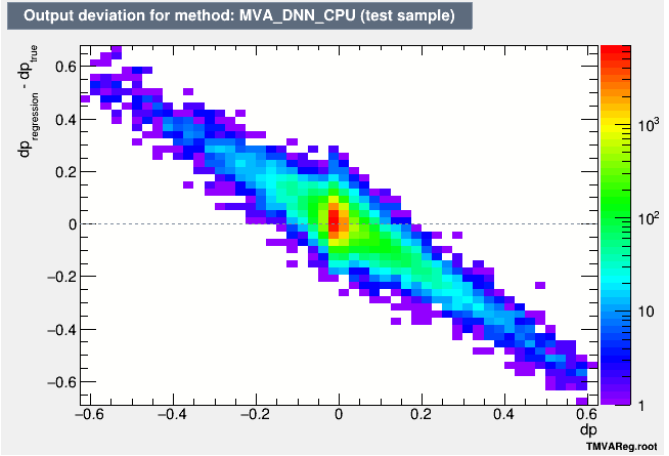


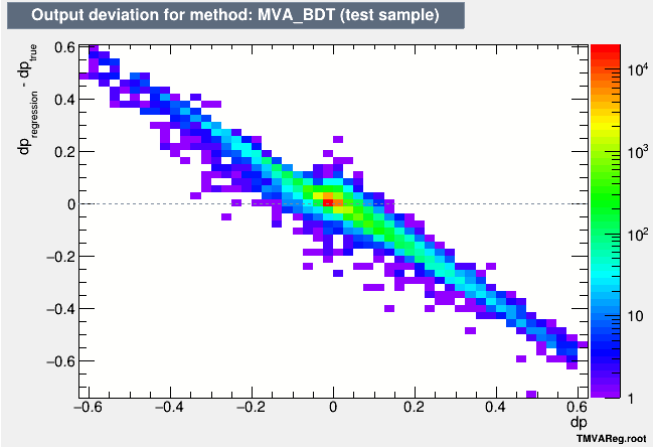
Use cut maximizing significance in the case 1/1000 S/Bg V0s

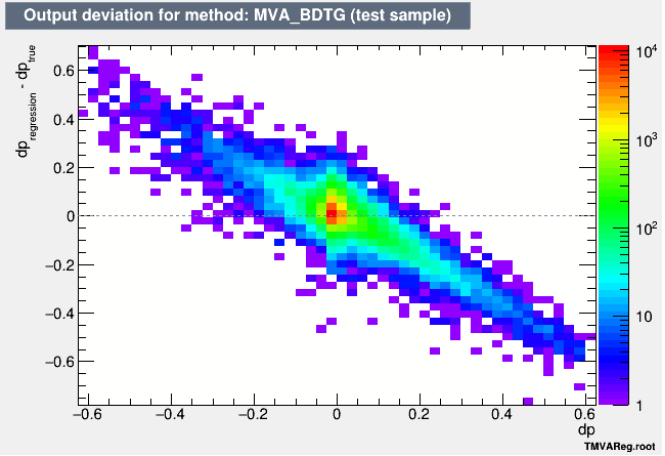
Regression

- Try to improve momentum resolution by accounting info from V0 parameters
  - dEdx
  - m_{ee}
  - q_t
  - ....
- Correction
  - $dp=p_t^{rec} - p_t^{true}$



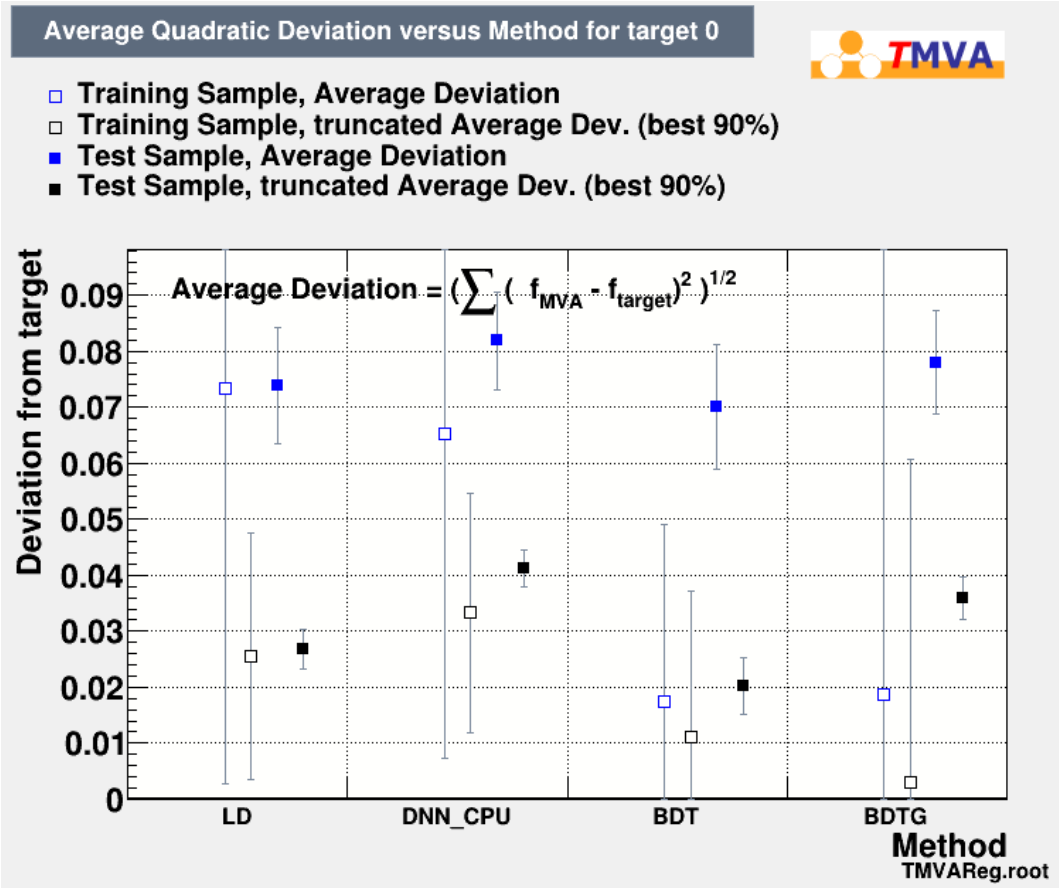






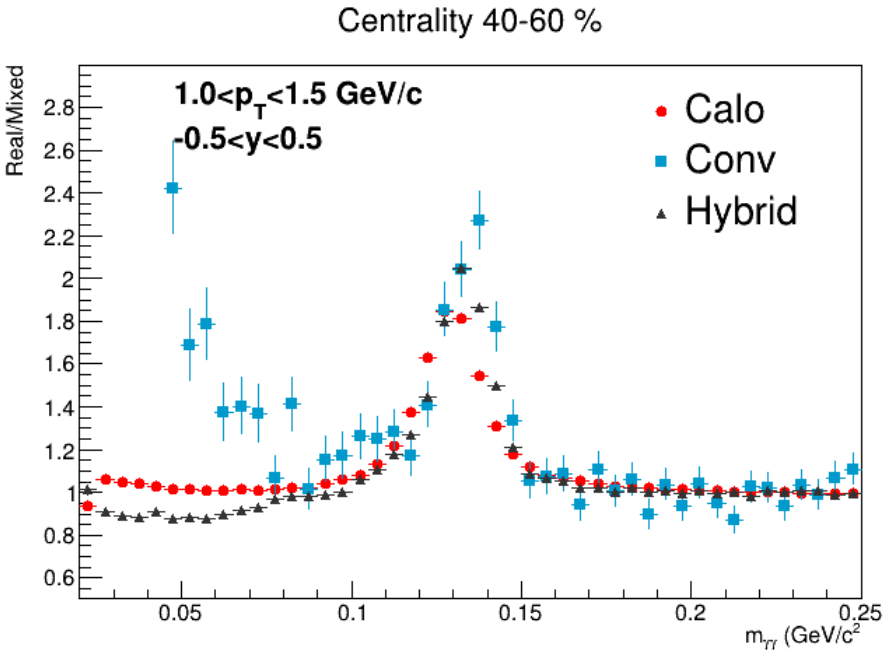
Regression

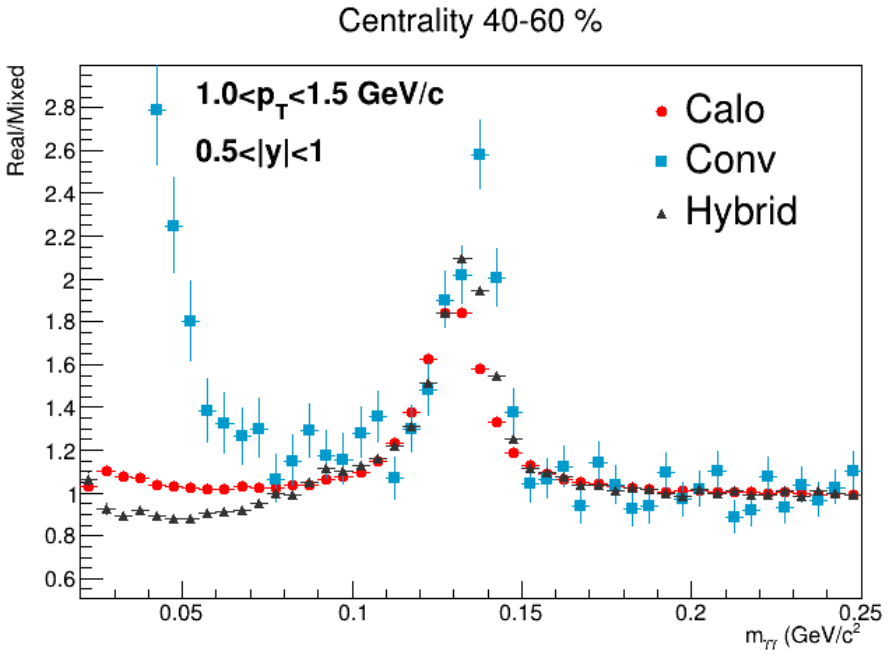
- All algorithms provide comparable RMS
- BDT RMS slightly smaller
- BDT used for V0 classification
- Try regression in π^0 analysis



Neutral pion analysis (E.Nekrasova)

π^0 spectra and rapidity distributions





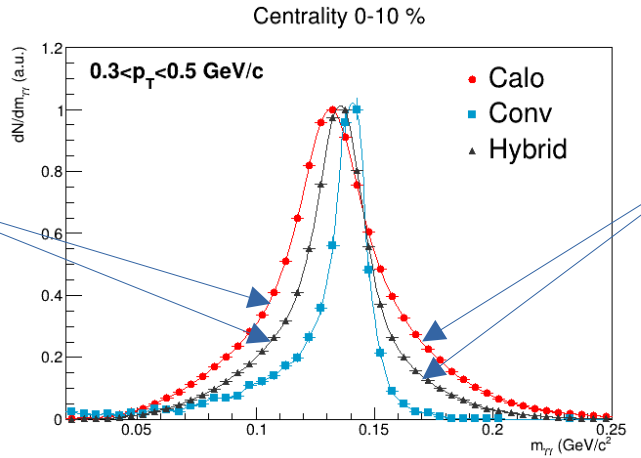
Conversion shows the largest Signal/Bg ratio, calorimeter — smallest
Minor dependence of Signal/Background on rapidity

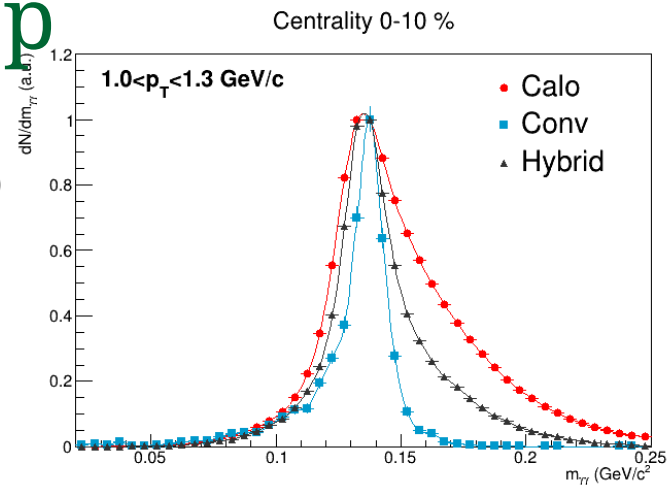
Conversion and cluster overlap

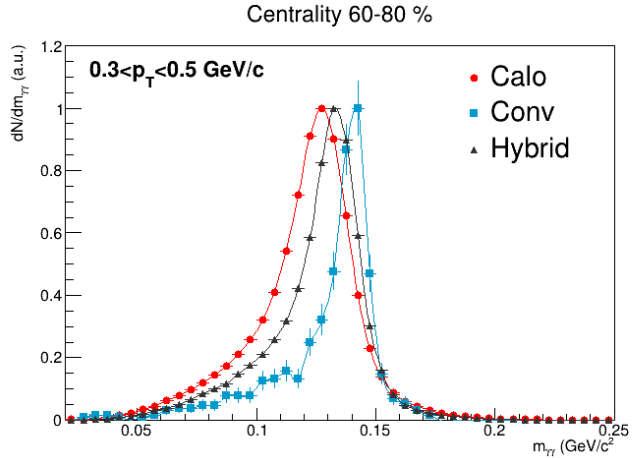
Photon conversion $e^{\pm}$ E loss

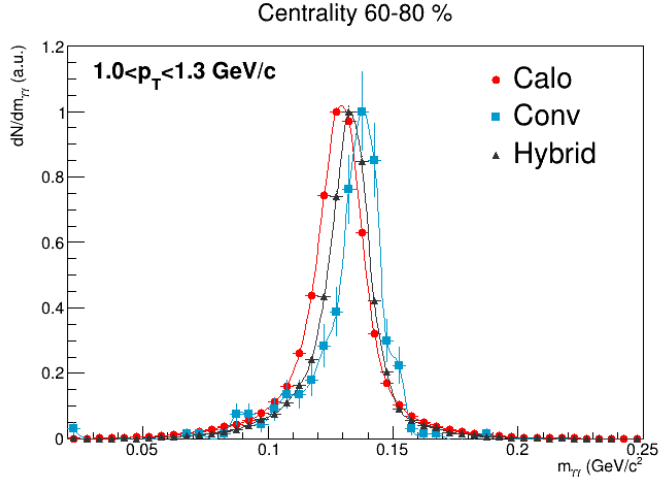
Cluster overlap

- High p_T, peripheral: ideal peak
- Low pT: increased relative contribution from conversion and Eloss
- Central: cluster overlap





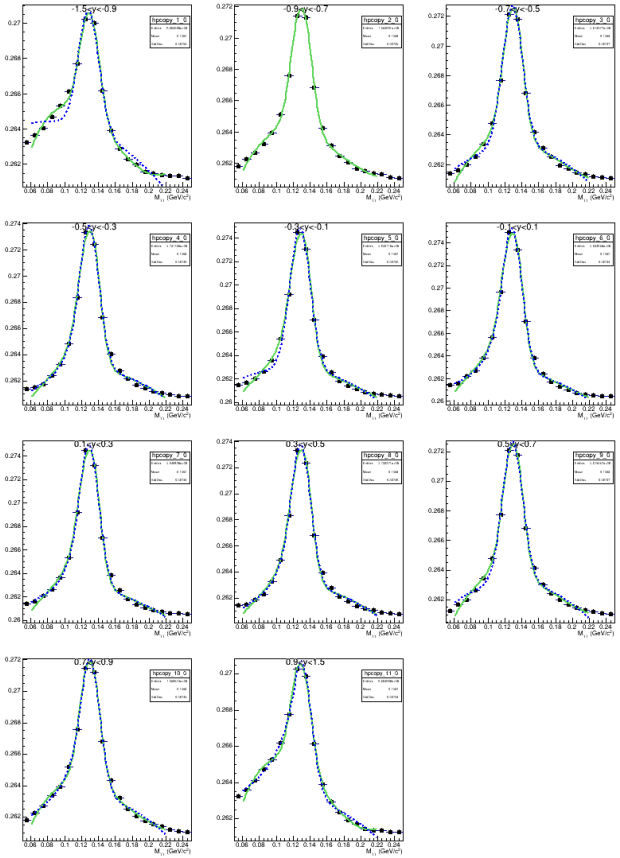




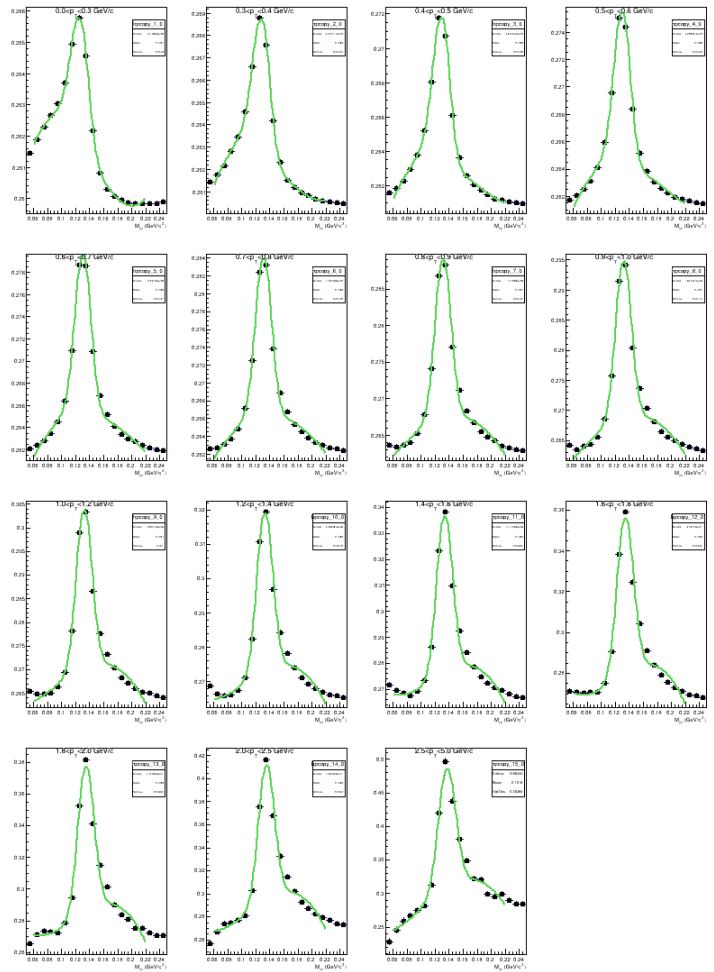
Neutral pion yield

- To calculate random and correlated background, first construct Real/Mixed ratio and fit background with polinomial

rapidity

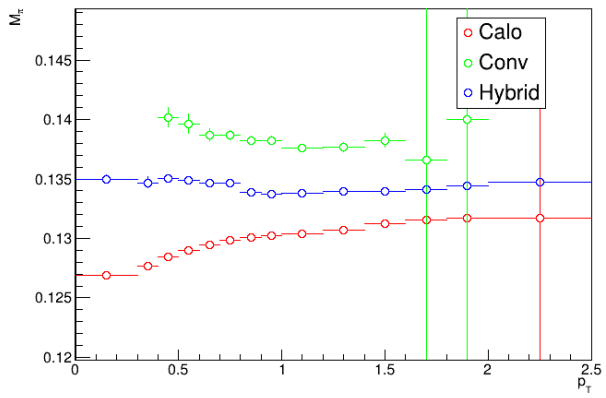


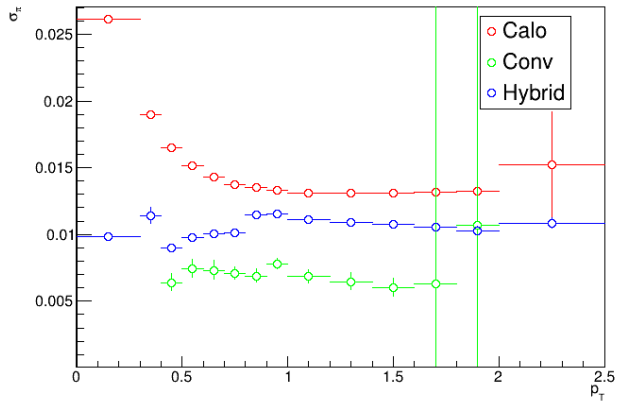
p_T

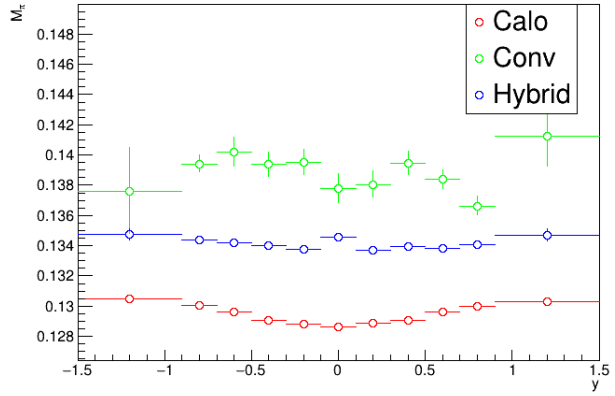


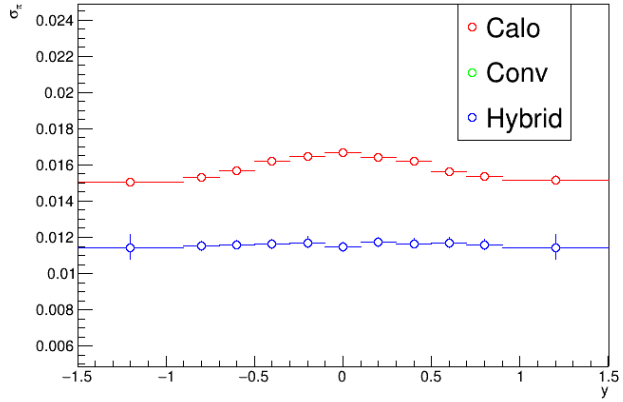
Peak position and width dependense

- Calorimeter
  - Some p_T dependence =>improve non-linearity
  - Minor y-dependence of resolution => small detoriaration of resolution at large z
- Conversion
  - Peak position shifted to higher m
  - No rapidity dependence
- Hybrid
  - Mass and width intermediate bewteen Calo and Conversion

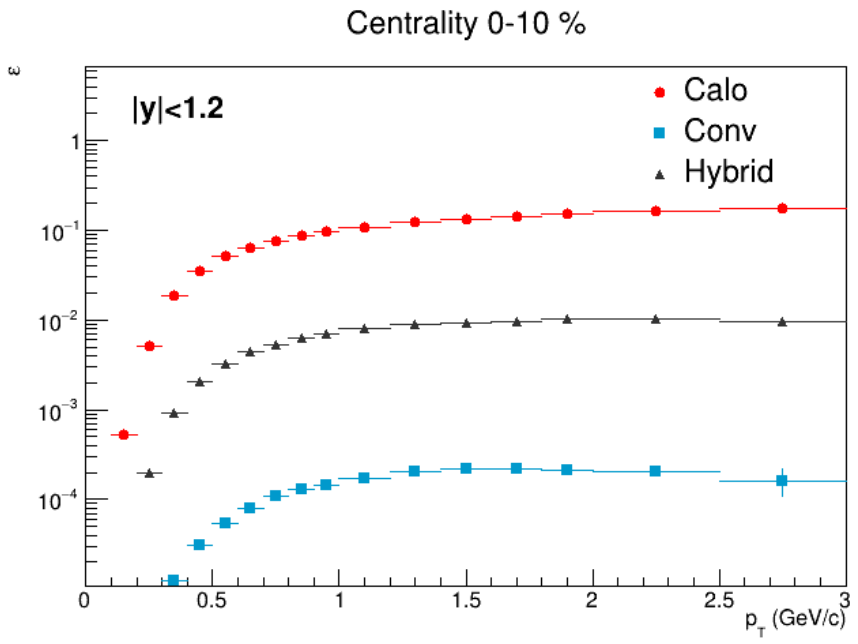


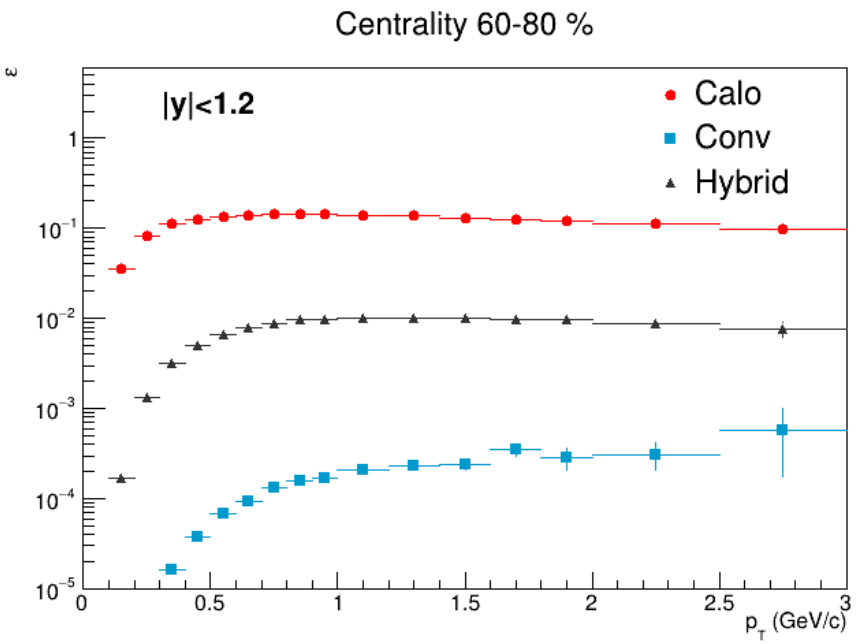






Effieincy


Centrality 0-10 %
|y|<1.2
Calo
Conv
Hybrid
ε
p_T (GeV/c)


Centrality 60-80 %
|y|<1.2
Calo
Conv
Hybrid
ε
p_T (GeV/c)

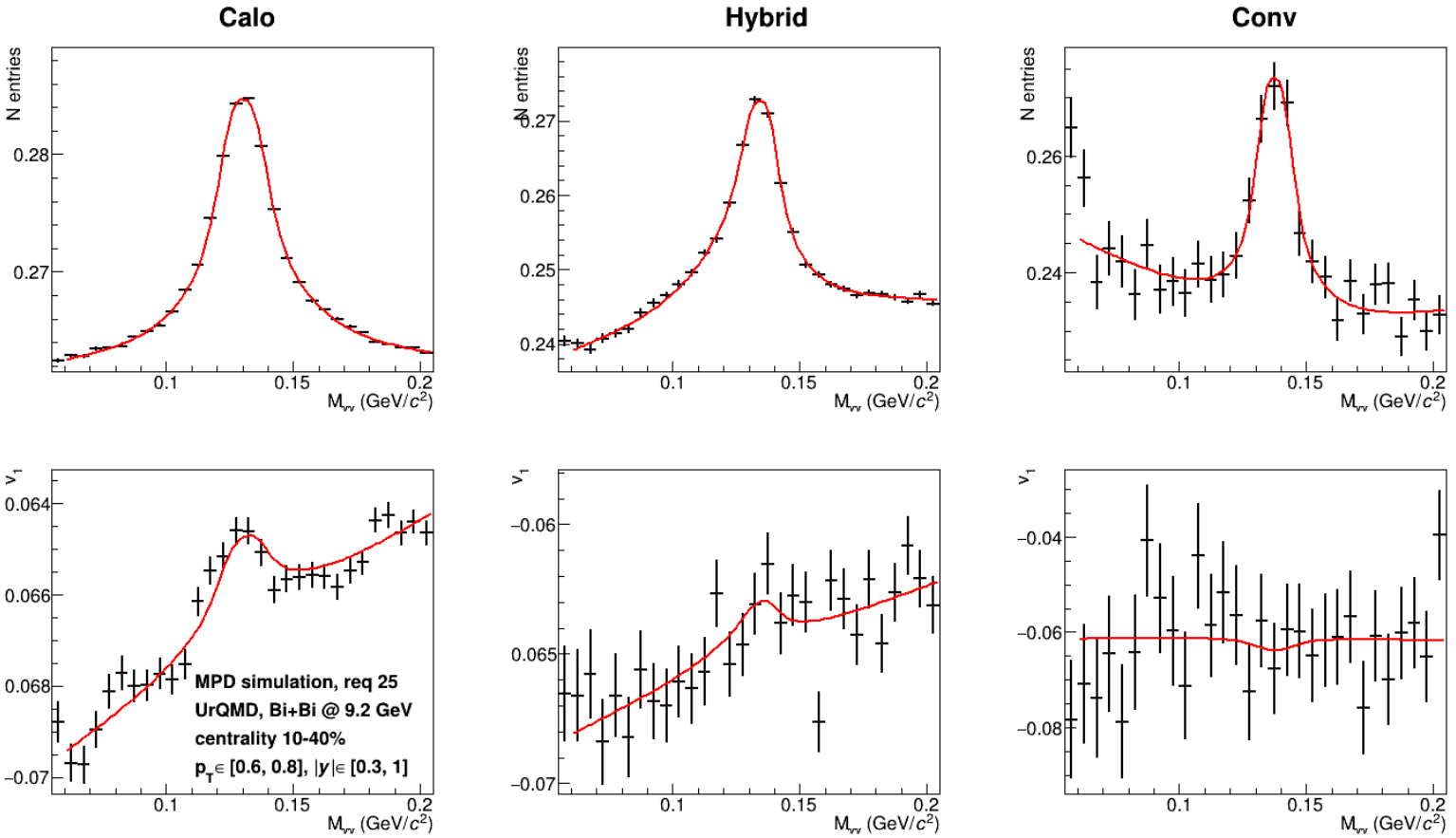
π^0 analysis summary

- Software produces reasonable results
  - Expected mass and width dependence on p_T and y for 3 methods
- Strong photon conversion electron E-loss contributions
  - ToDo: try to reduce with PID cuts (reduced efficiency)
- Strong cluster overlap contribution
  - ToDo:
    - Use core energy in next train
    - Test cluster purifying avfter unfolding
    - Reduce with dispersion PID
    - Optimize clusterization thresholds

π^0 flow (O. Golosov)

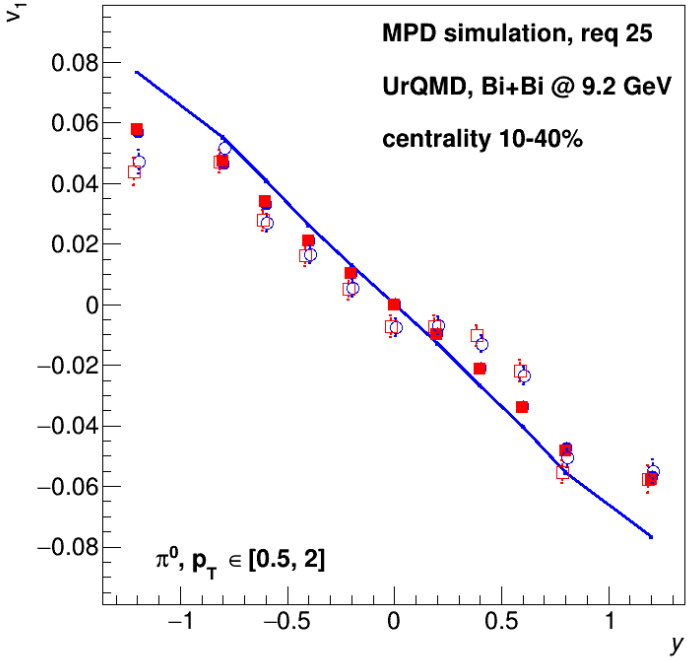
$$v_{all}(M_{inv}) = \frac{n_{sig}(M_{inv})v_{sig} + n_{bg}(M_{inv})(v_{bg}^{const} + v_{bg}^{lin} * M_{inv})}{n_{sig} + n_{bg}}$$

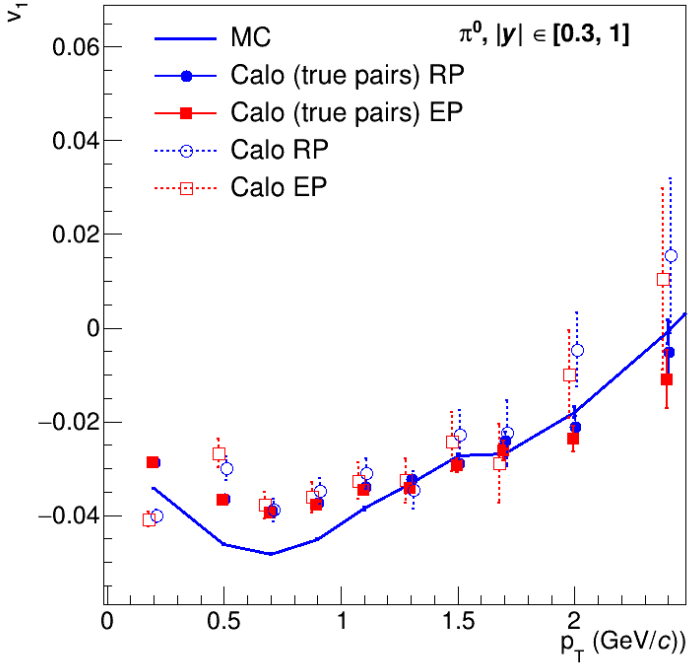
- Code implemented in the analysis class mpdroot/physics/photons/MpdConvPi0.h
- Output of train 2 is analyzed
- $v_n(m)$ is fit with function above with proportion of signal pairs estimated from Real/Mixed ratio



π^0 flow (ECAL)

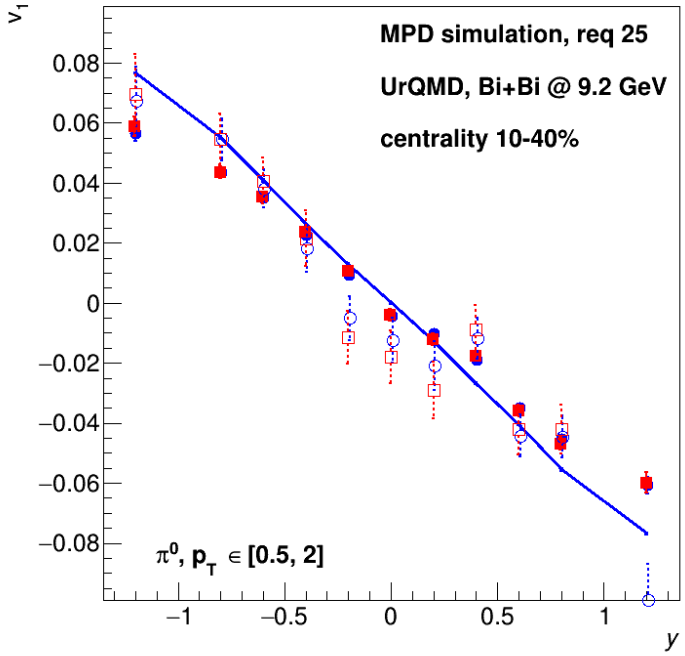
- Pion flow can be extracted for all 3 reconstruction techniq
- Flow estimeted w.r.t. t reaction plane
- MC (solid line) do not contain long-lived resonance decays and deviates from the measured flow (to be checked)
- Filled symbols: true pa

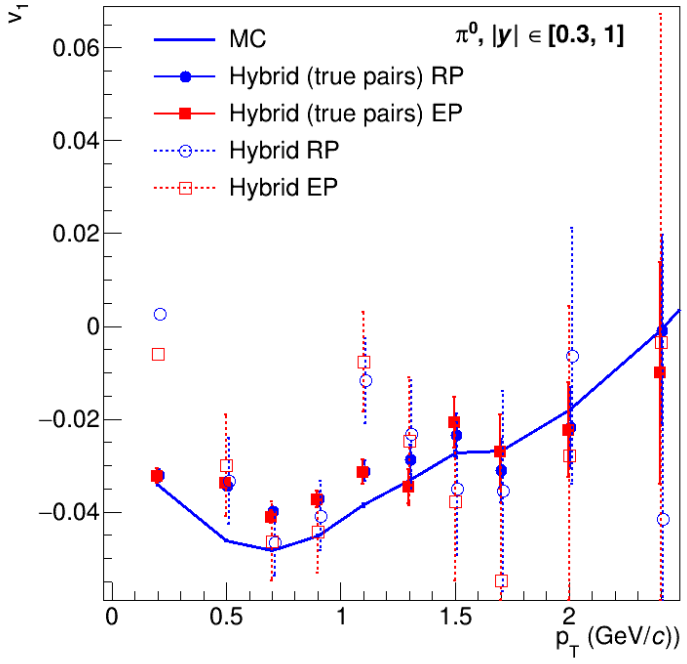




π^0 flow (Hybrid)

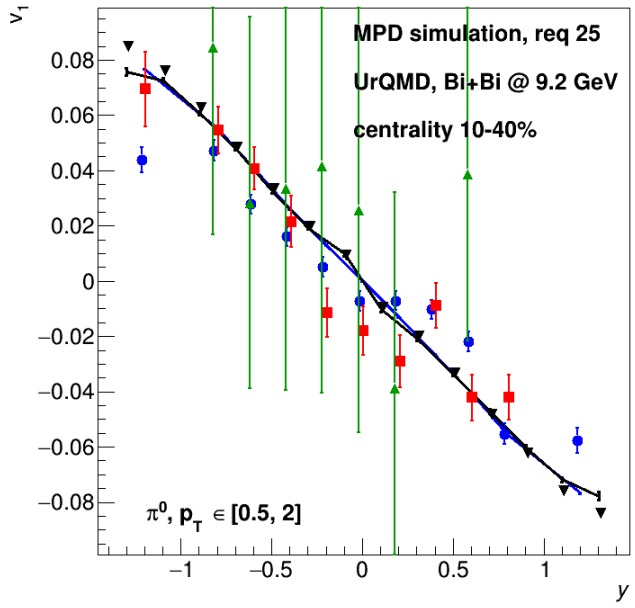
- Pion flow can be extracted for all 3 reconstruction techniques
- Flow estimeted w.r.t. true reaction plane
- MC (solid line) do not contain long-lived resonance decays and deviates from the measured flow (to be checked)
- Filled symbols: true pairs

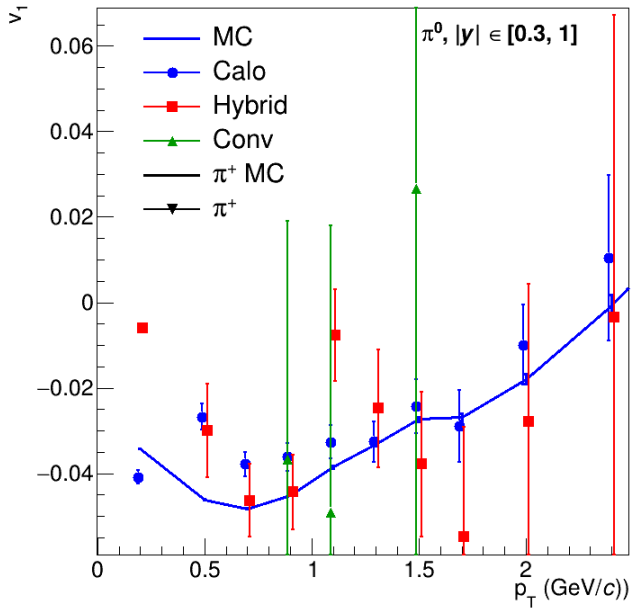




Comparison to charged pions

- On the generator level flow of neutral and charged pions coincides
- Neutral pion flow shows some deviations
  - Imperfections of the fitting procedure
  - Improve S/Bg with E_{core} and PID cuts





Conclusions

- Direct photon production in Bi-Bi collisions $\sqrt{s_{NN}}$ = of 9.2 GeV was estimated
- Analysis software is being developped, BDT identification of V0 implemented
- Basic analyses started
  - First results look reasonable
  - Few strange points were observed both in pion spectra and flow
  - Software updates are prepared to be tested in next analyses trains