Probing QGP with b-Jets

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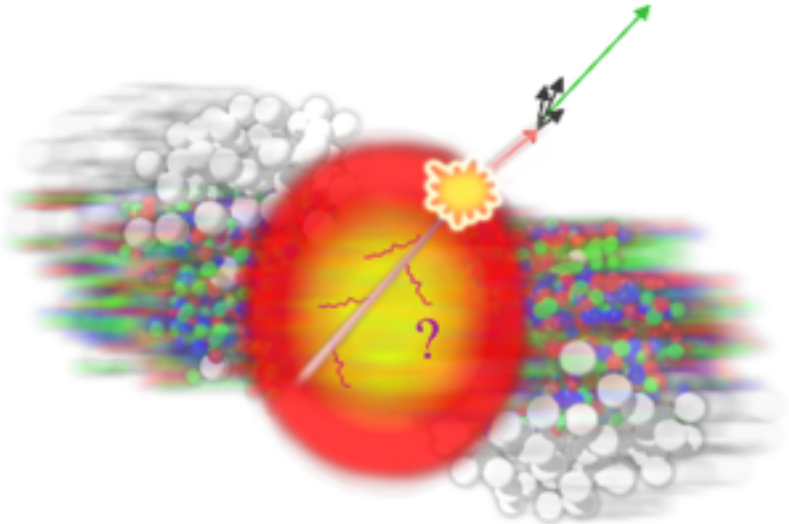
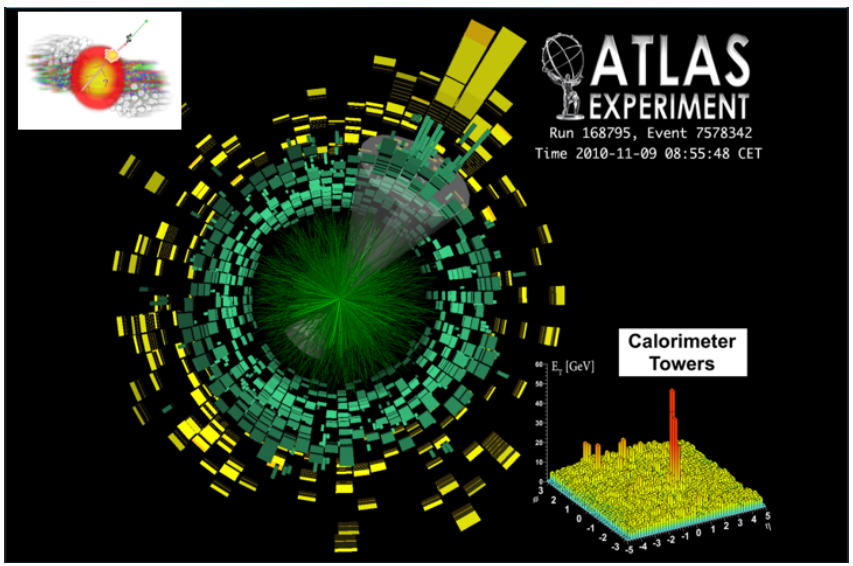
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Heavy Ion Physics

- Heavy Ion central collisions form a plasma of quarks and gluons (QGP)
- It's possible to study QGP through modifications in the characteristics of particles when they pass through it
- Bottom quarks are the least affected in QGP
- **Challenge:**

  Heavy Ion collisions have more underlying event than p+p collisions





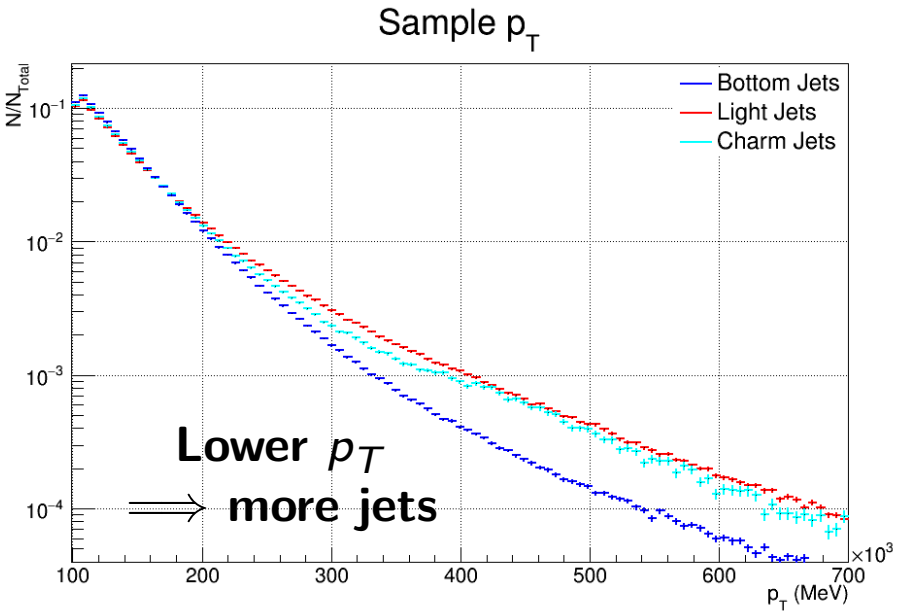
Goals

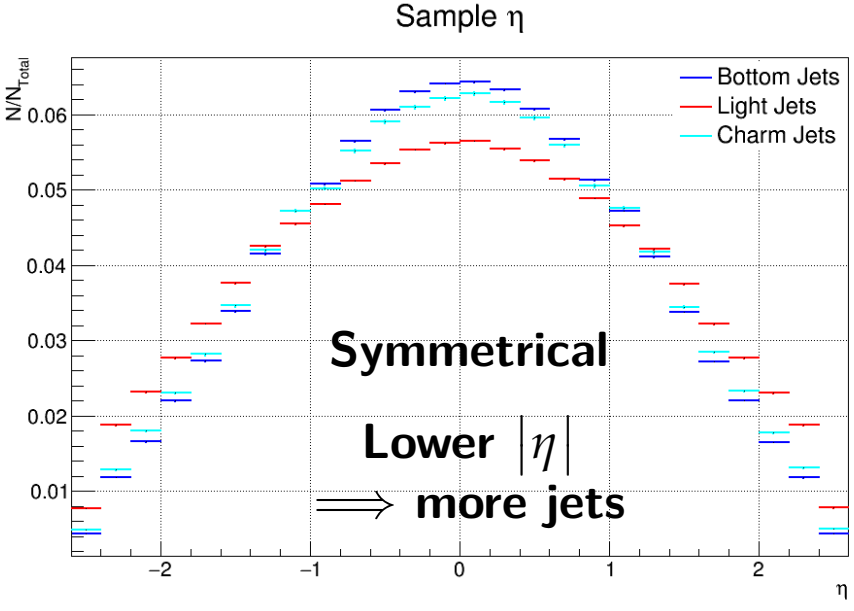
- Identification of bottom quark jets using multivariable method $\longrightarrow$ Boosted Decision Trees
- Study of the kinematic distributions of the b-jets: transverse momentum p_T, pseudorapidity $\left|\eta\right|$, azimuthal angle ϕ
- Comparison with the distributions of light quark jets
- Systematic study of performance

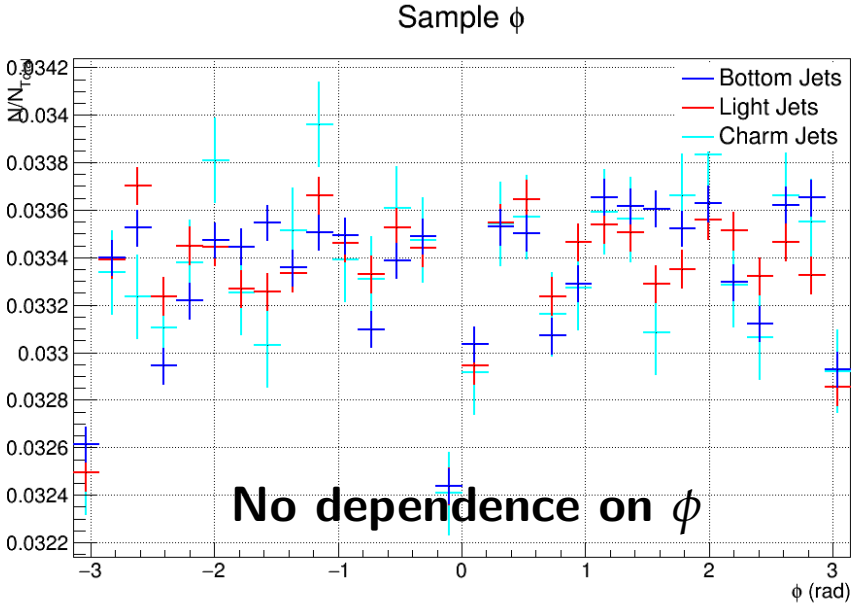
Kinematic Distributions

p+p Monte Carlo Sample

Clear distributions



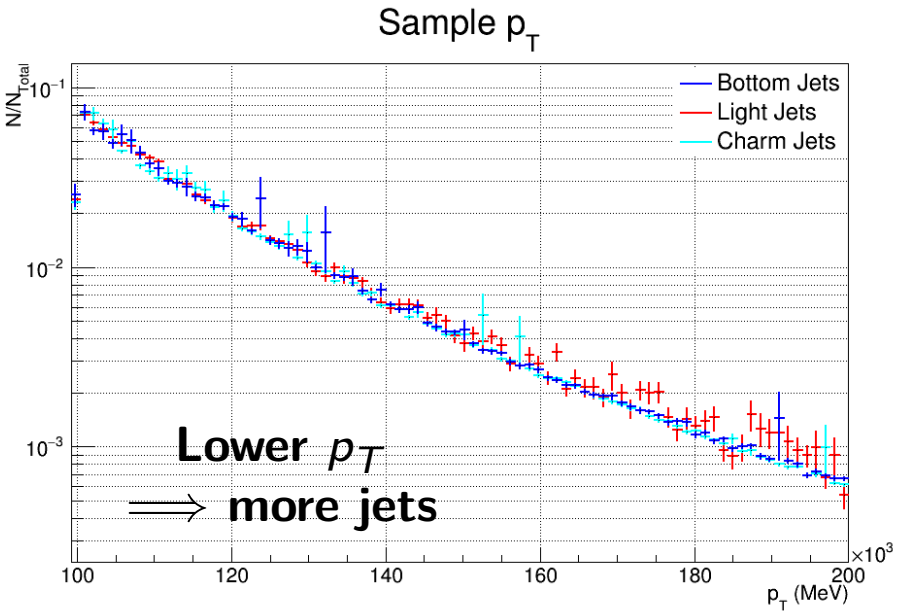


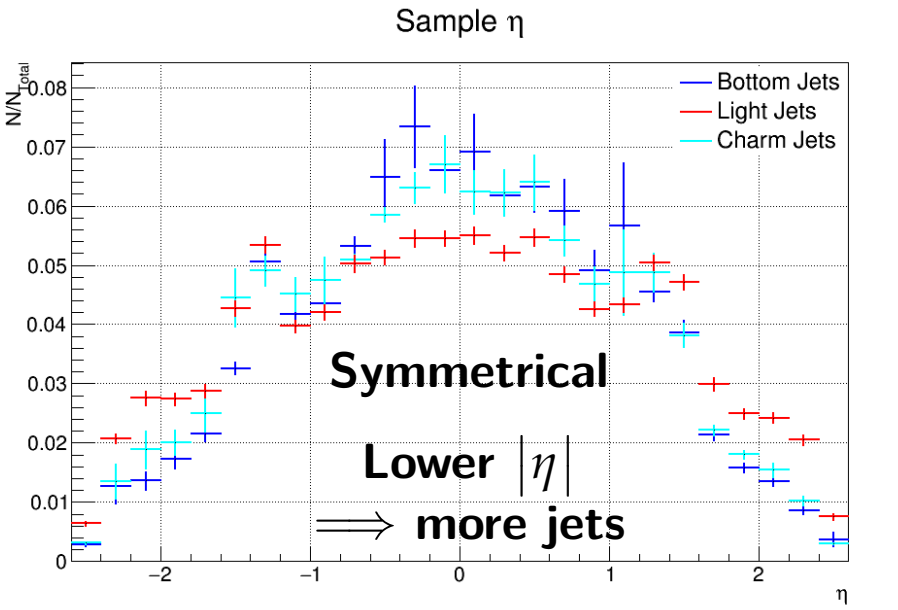


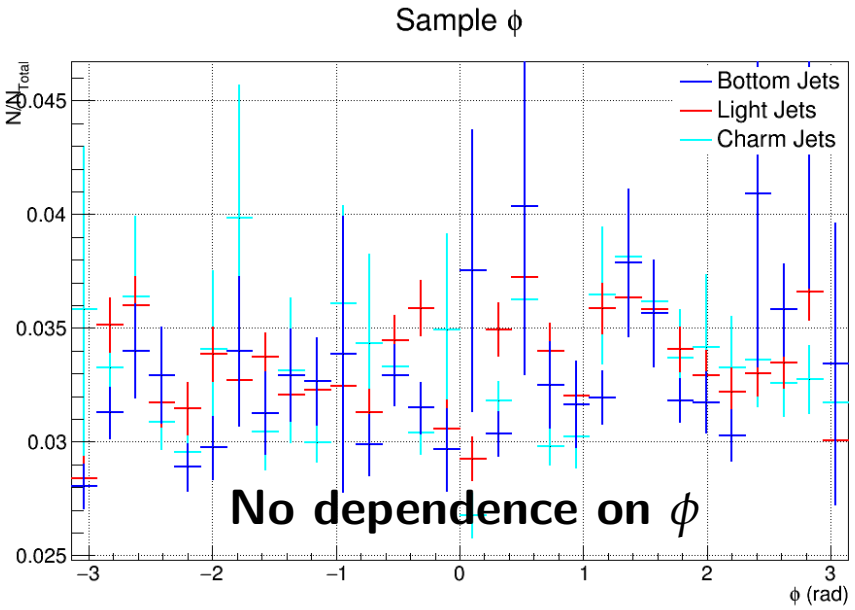
Kinematic Distributions

Pb+Pb Monte Carlo Sample

Lack of statistics







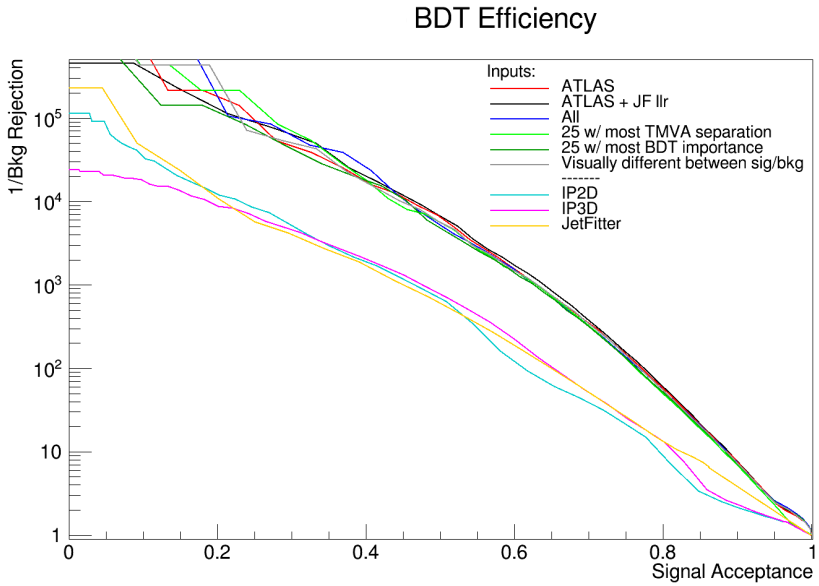
BDT Input Variables

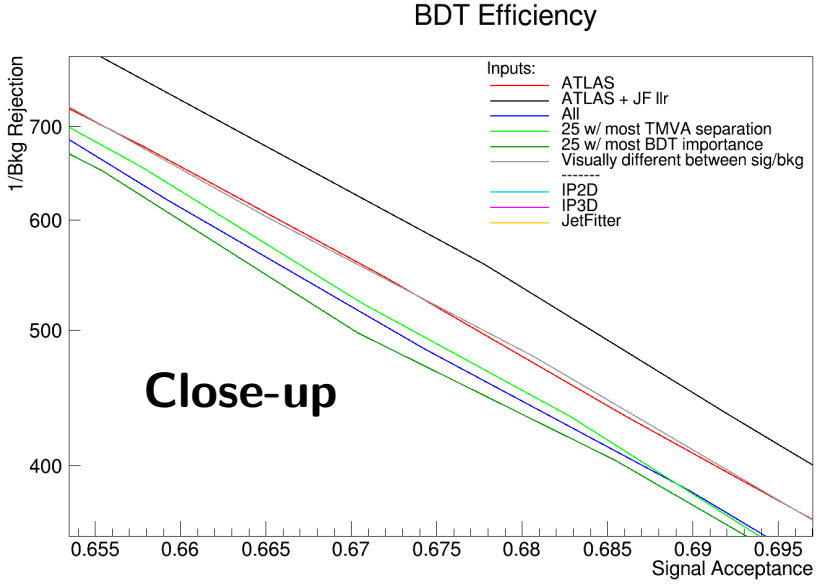
Input varibles by TMVA ranking

1	ip3d_cllr_pbpu	14	sv1_efc
2	ip3d_cllr_pcpu	15	jf_n2t
3	ip2d_cllr_pbpu	16	jf_llr
4	ip2d_cllr_pcpu	17	jf_sig3d
5	ip2d_cllr_pbpc	18	pT
6	sv1_m	19	jf_m
7	ip3d_cllr_pbpc	20	abseta
8	sv1_deltaR	21	jf_efc
9	sv1_n2t	22	jf_ntrkAtVx
10	sv1_sig3d	23	jf_nvtx
11	sv1_ntrkv	24	jf_nvtx1t
12	sv1_Lxy	25	jf_dRFlightDir
13	sv1_L3d		

Tunning of input variables optimized to p+p (Higgs$\rightarrow b\bar{b}$ analysis)

p+p MC Sample

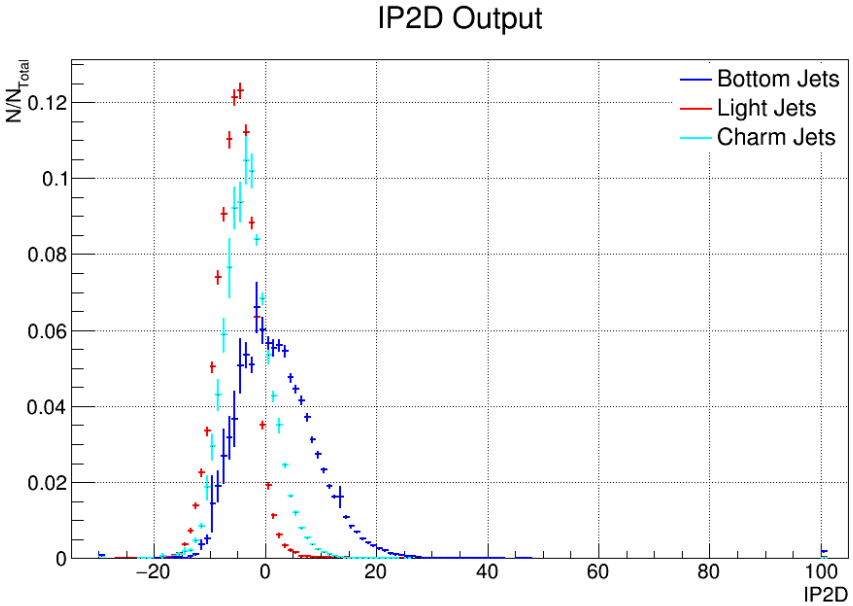


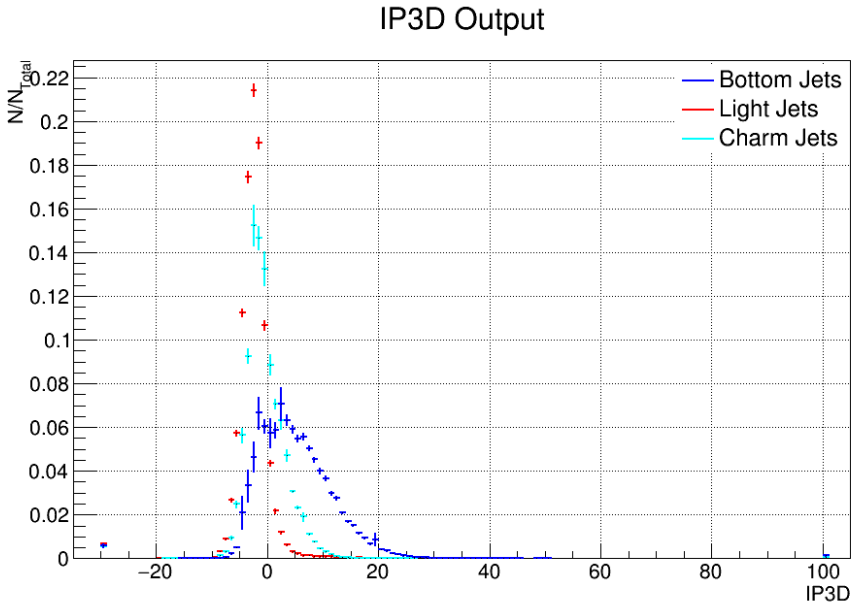


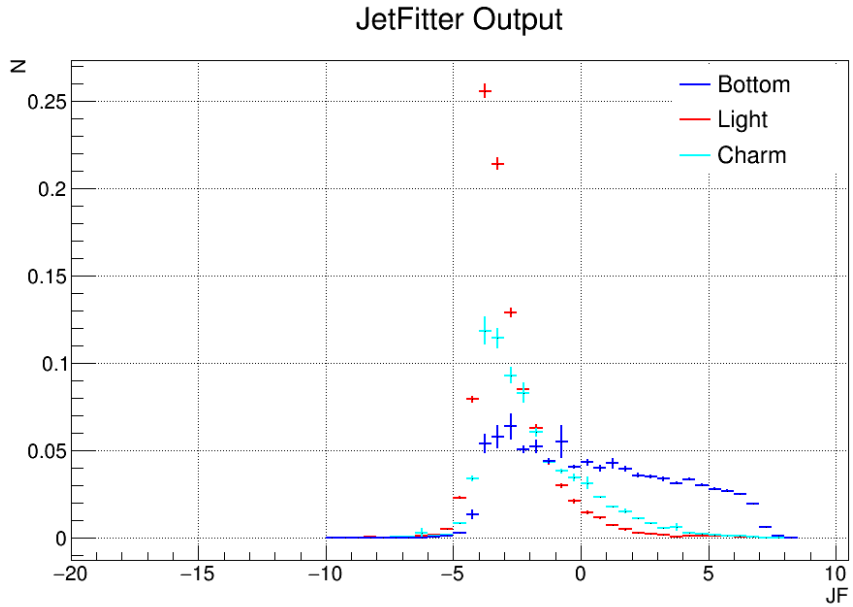
BDT Input Variables vs. BDT Results

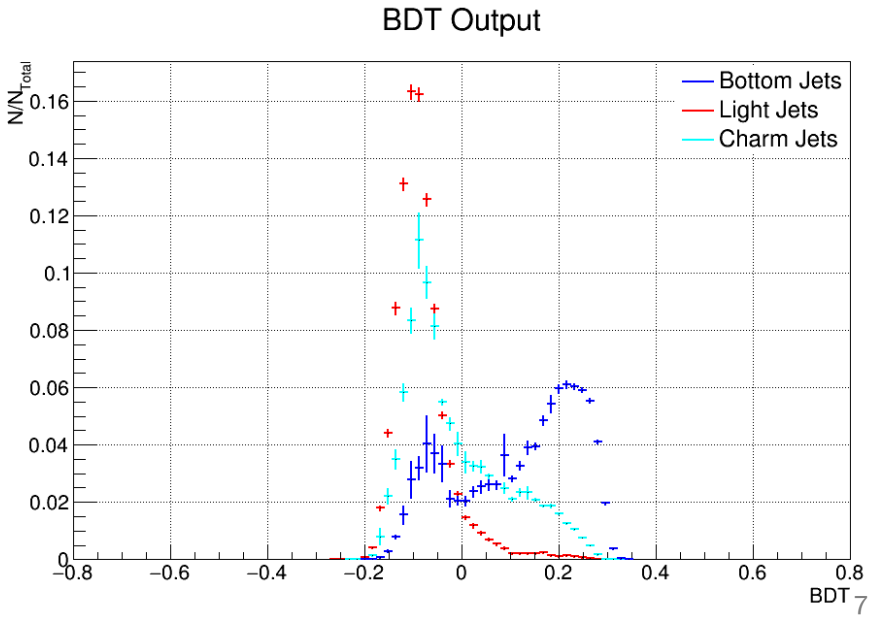
Pb+Pb MC Sample

BDT → better separation





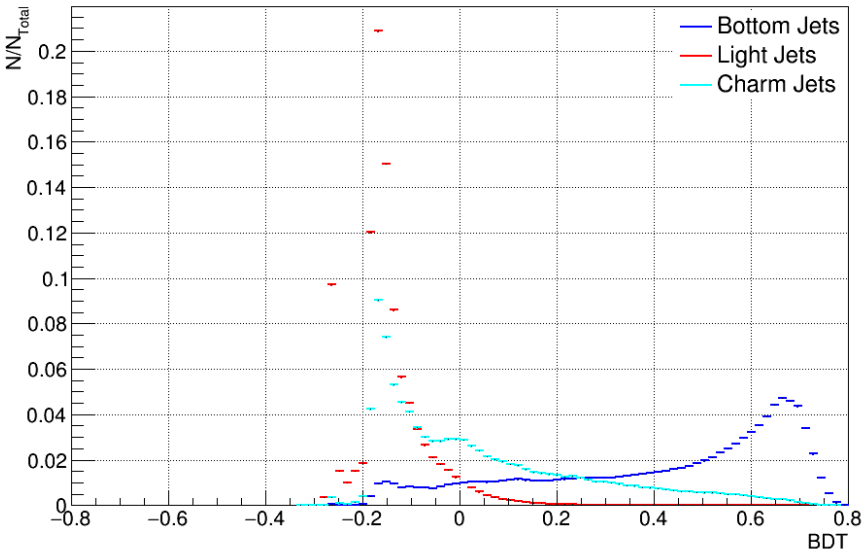




BDT Results - Sensitivity to p_T

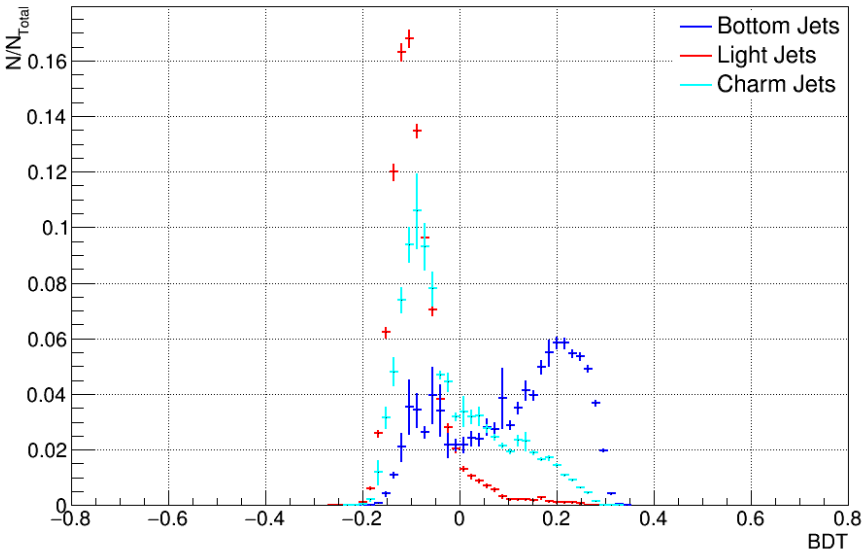
p+p MC Sample

BDT: $p_T \in [100, 120]$ GeV

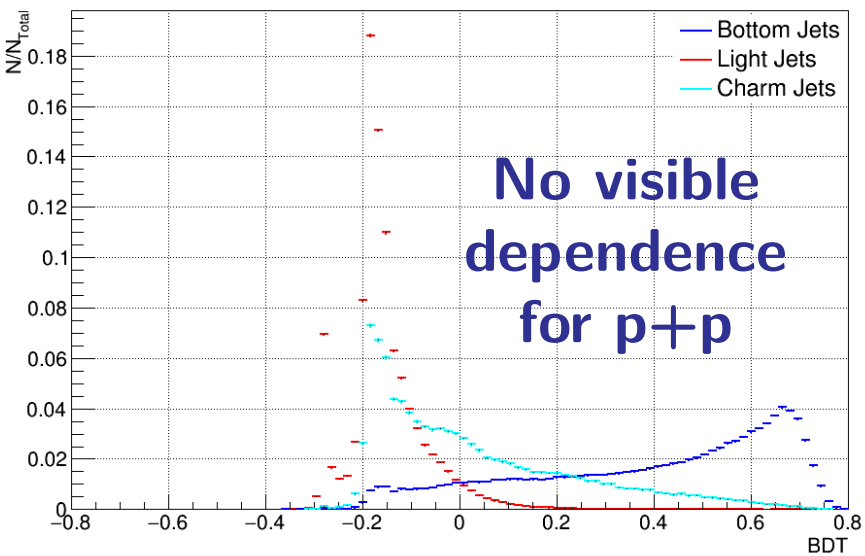


Pb+Pb MC Sample

BDT: $p_T \in [100, 120]$ GeV

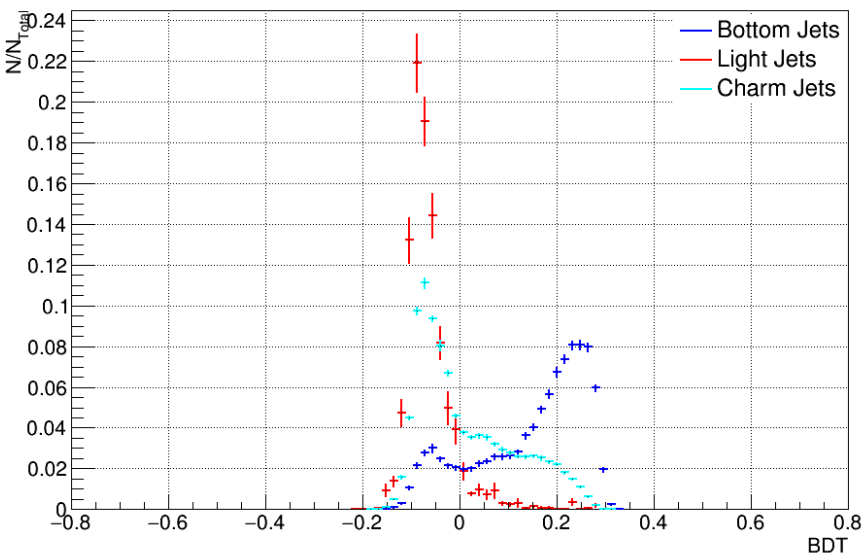


BDT: $p_T \in]160, 180]$ GeV



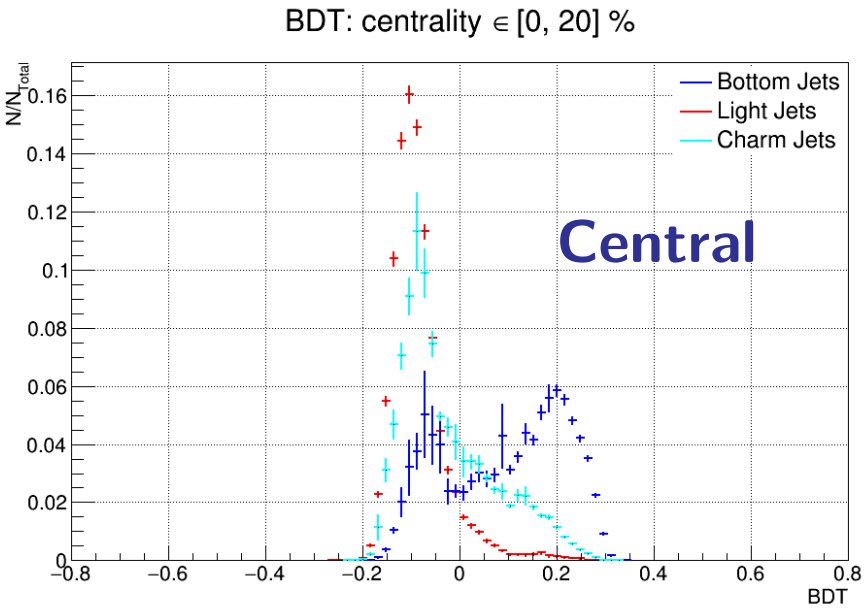
No visible dependence for p+p

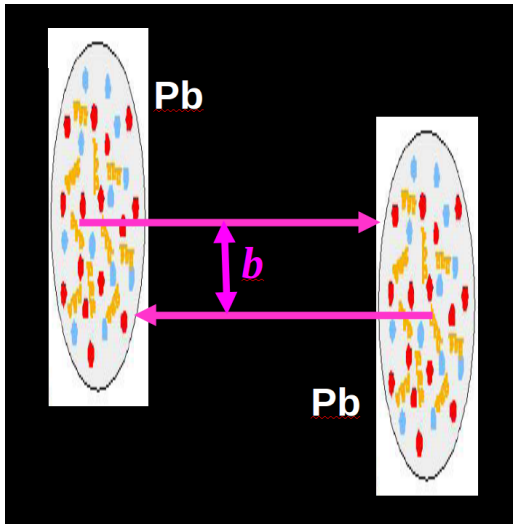
BDT: $p_T \in]160, 180]$ GeV

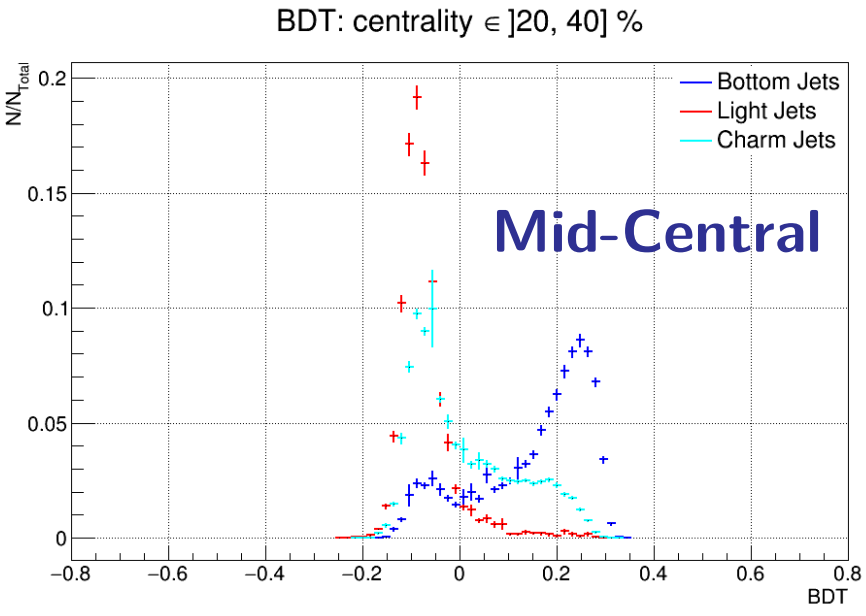


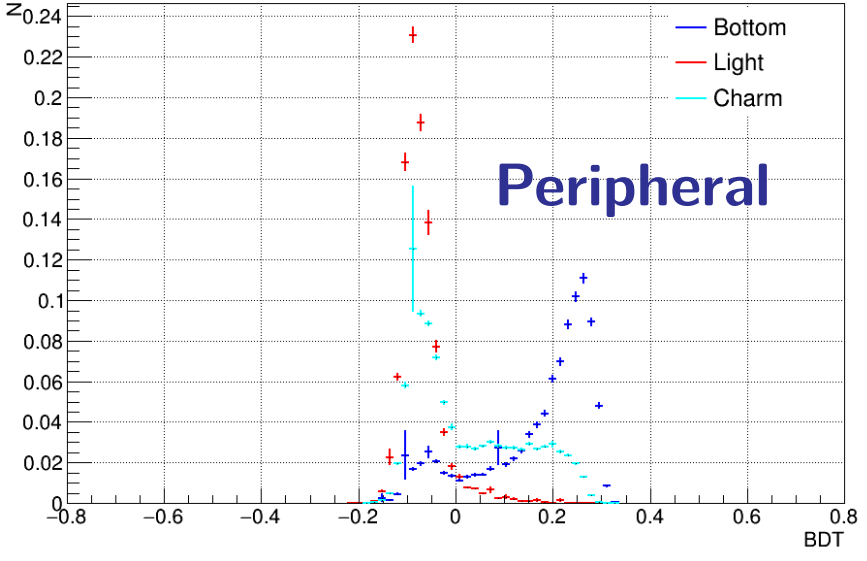
BDT Results - Sensitivity to collision centrality

Less central $\Longrightarrow$ better separation





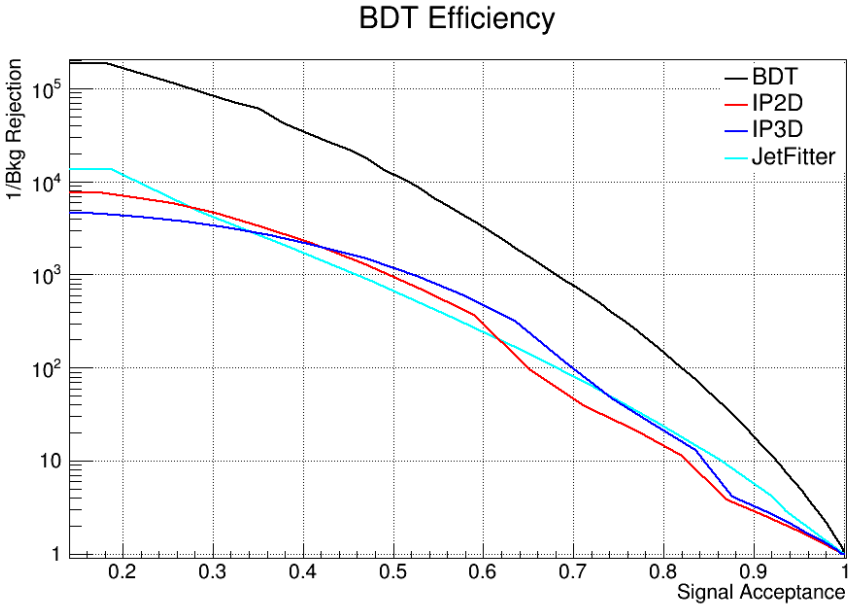




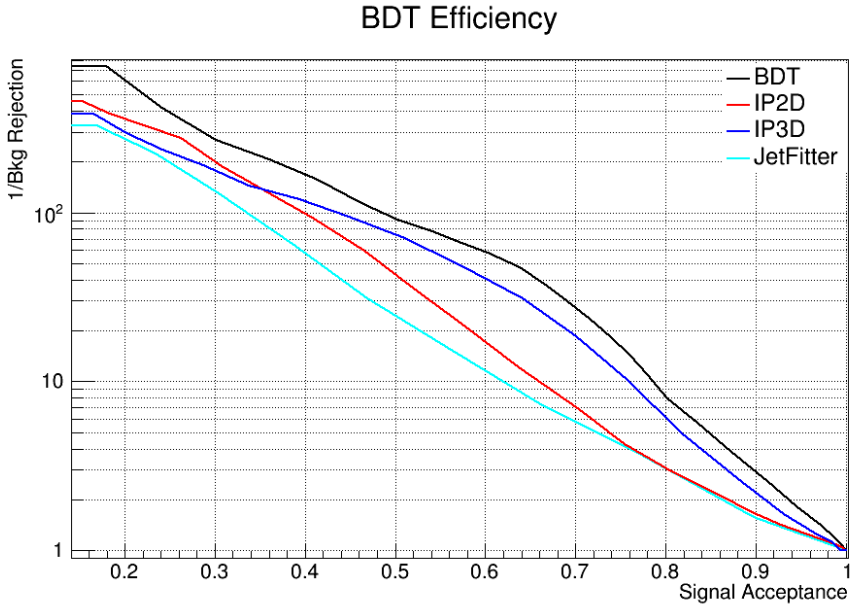
Efficiency vs Background Rejection

Performance: BDT vs earlier methods

p+p MC Sample



Pb+Pb MC Sample

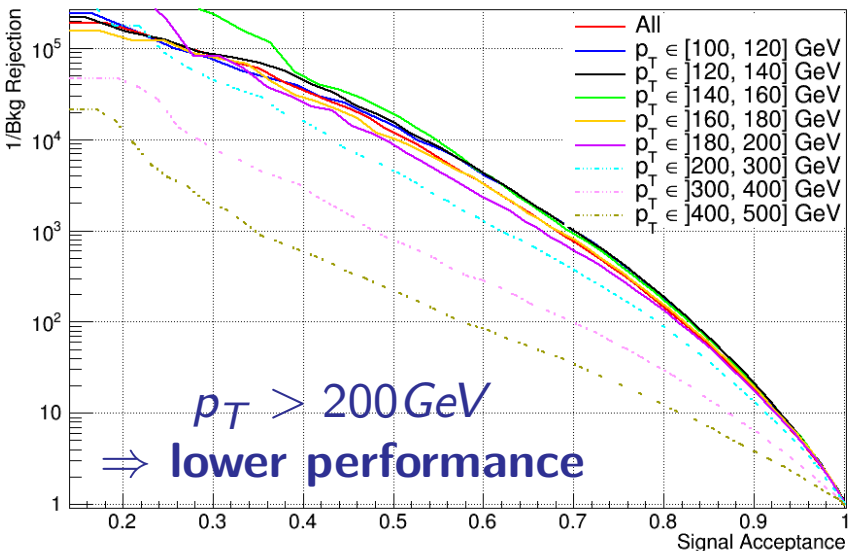


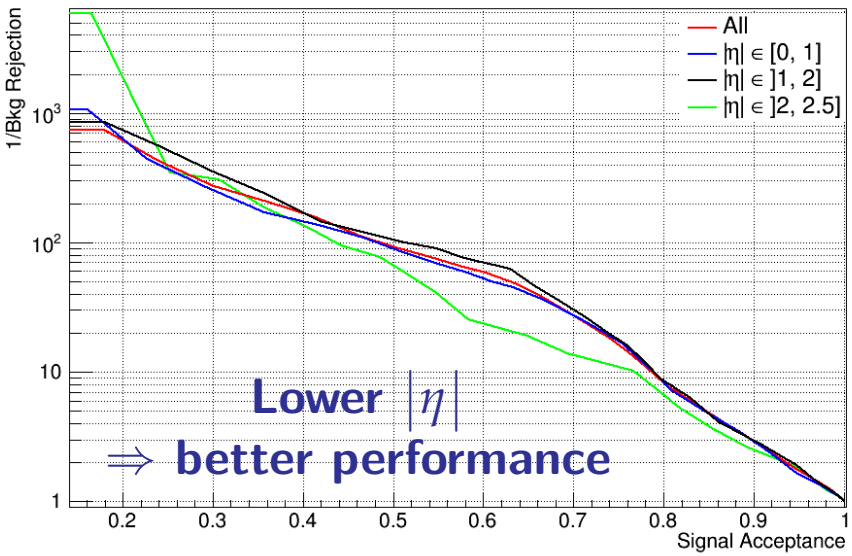
Consistently better performance than all previous methods!

BDT Performance

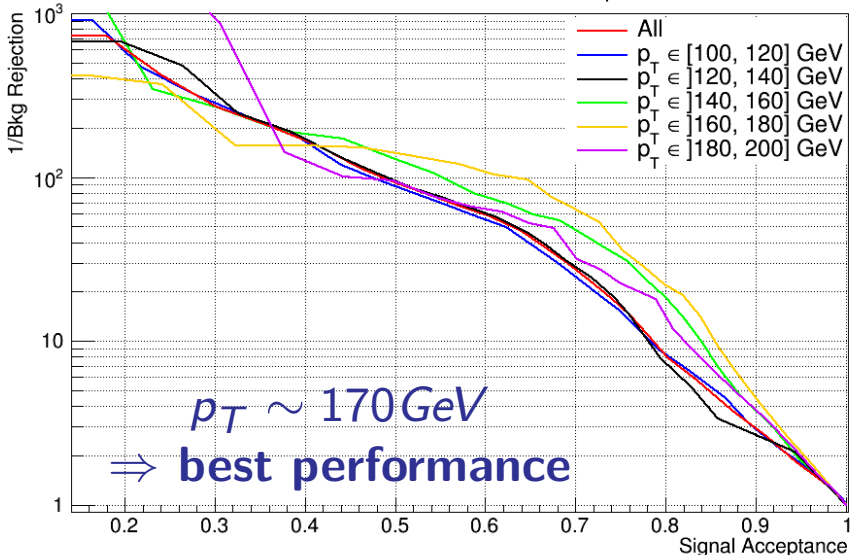
Sensitivity to p_T and η

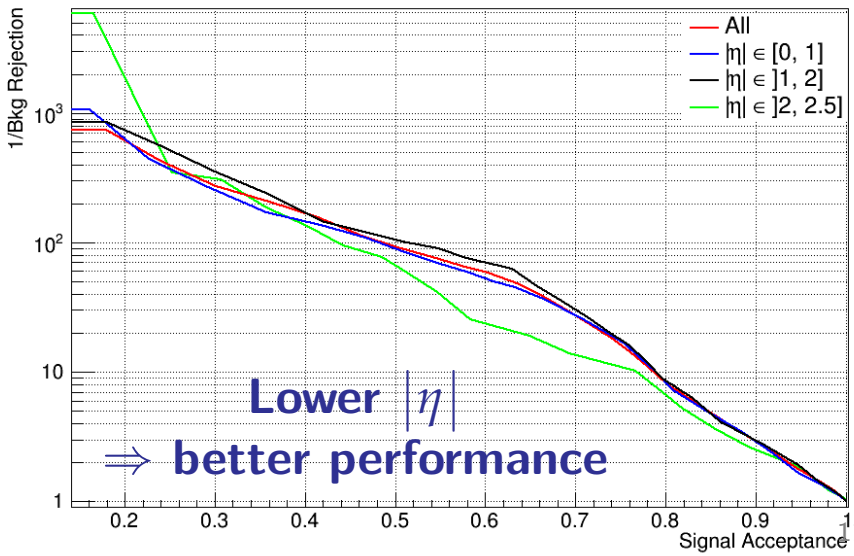
p+p MC Sample





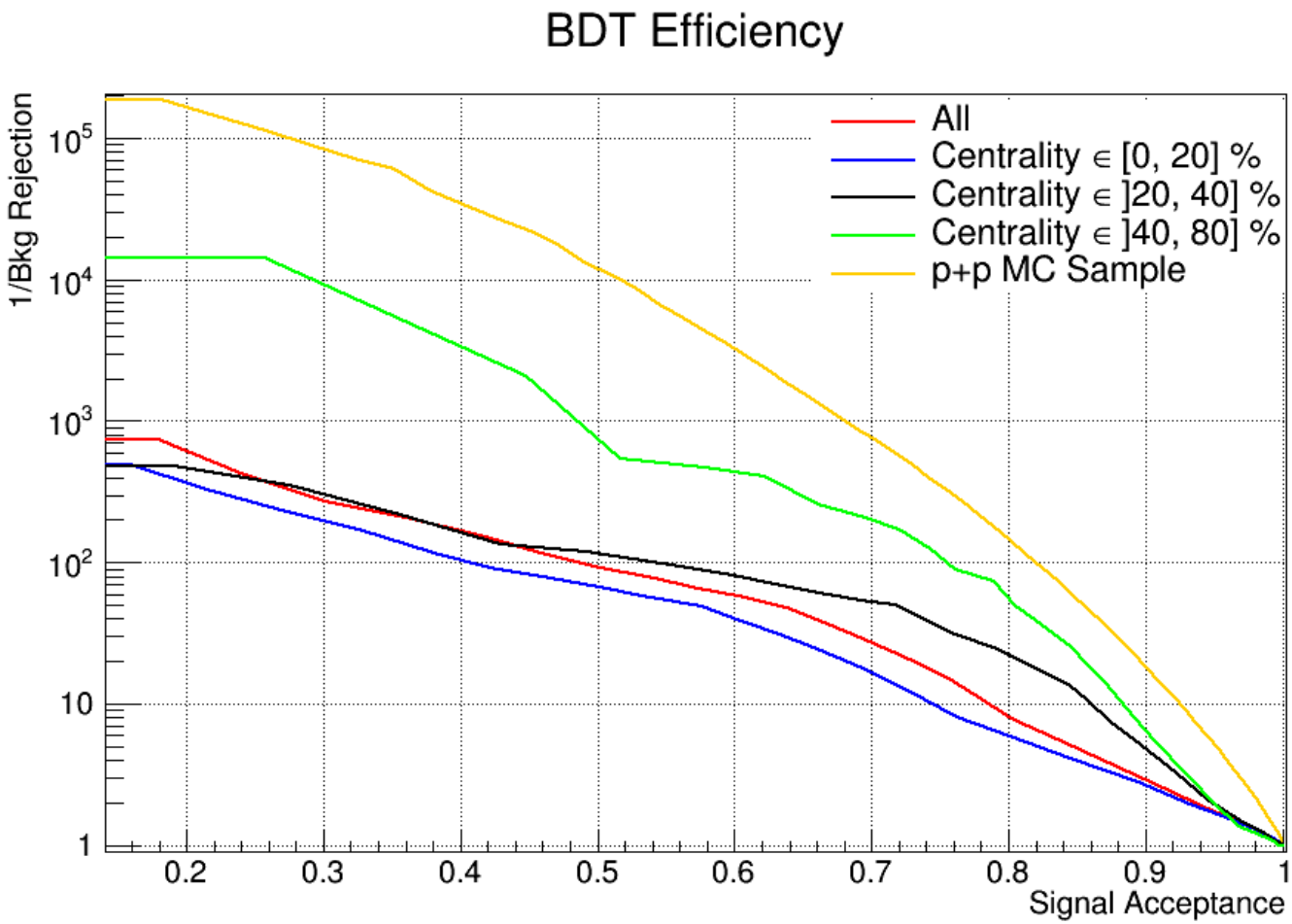
Pb+Pb MC Sample





BDT Performance

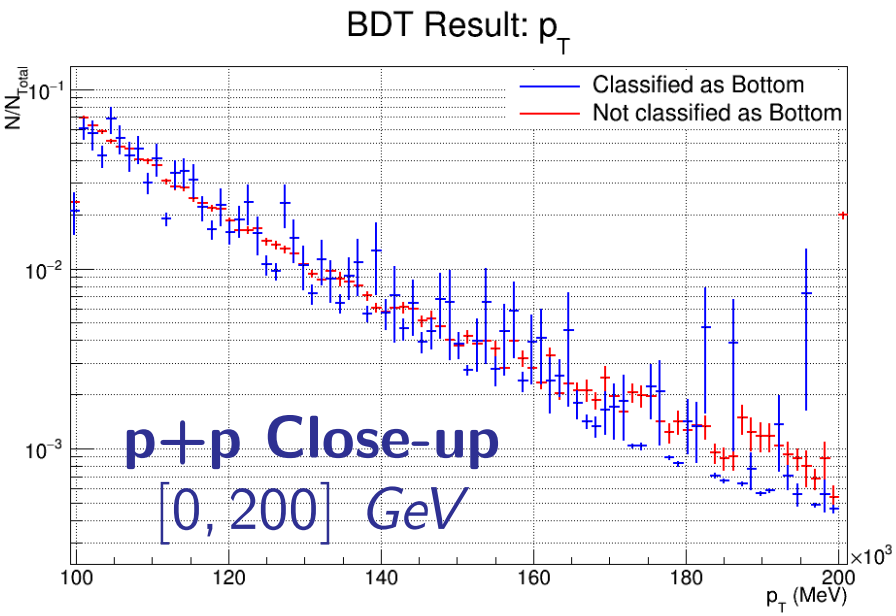
Sensitivity to Collision Centrality

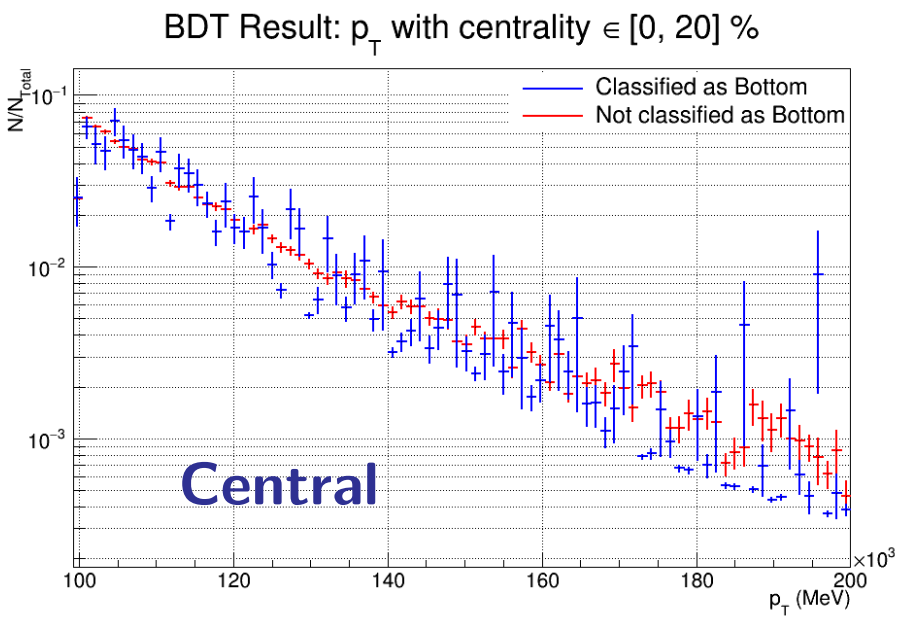


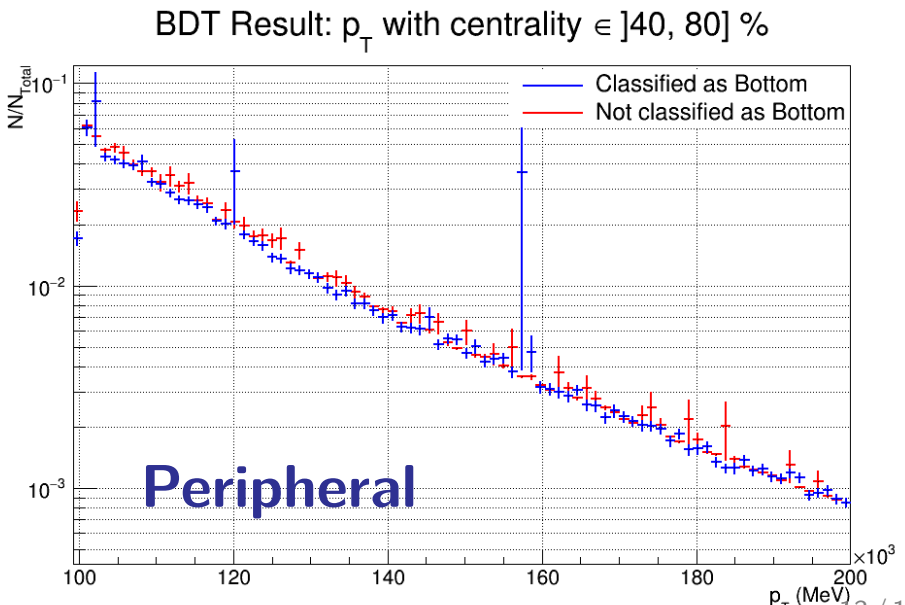
- Better performance on p+p MC Sample $\longrightarrow$ obviously!
- Lower collision centrality $\Longrightarrow$ better performance
- Pb+Pb MC Sample dominated by central collisions

Jet Classification in p+p and Pb+Pb

p_T Distribution







- BDT Working point: 50% signal efficiency
- Tunning of input variables optimized for p+p (Higgs$\rightarrow b\bar{b}$ analysis)
- Input variables and BDT itself should be optimized for Pb+Pb

Conclusions

- BDT method developed is better than previous b-tagging methods
- Bottom quarks harder (but still possible) to identify in central collisions
- Kinematic region with best performance: peripheral collisions with $\left|\eta\right| < 2$ and $p_T \in [140, 180]$ *GeV*
- Study limited by statistics in Pb+Pb Monte Carlo collisions
- Next step: application of BDT to real data

References


Angerami, A. (2012), *Jet quenching in relativistic heavy ion collisions at the LHC*, Columbia University

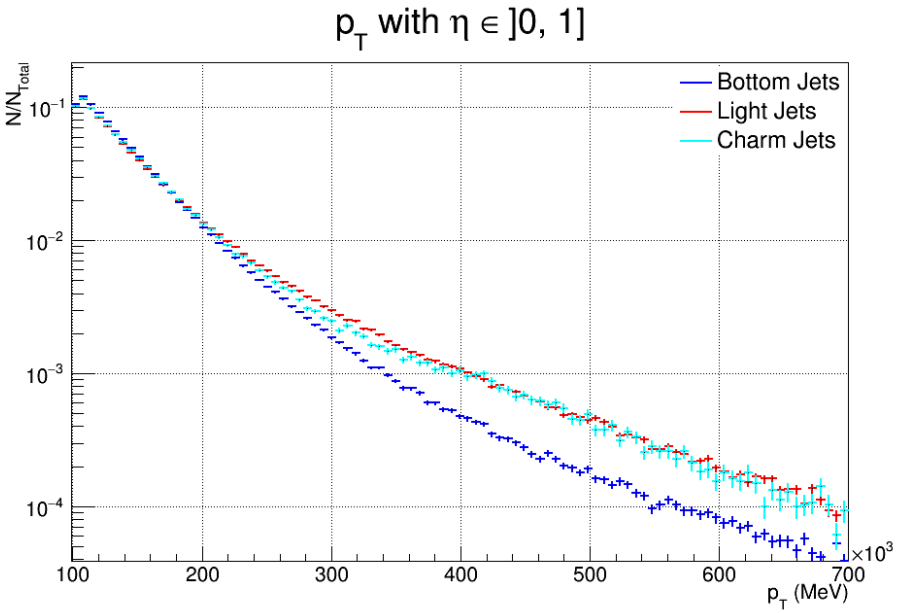

The ATLAS Collaboration (2016), *Performance of b-jet identification in the ATLAS experiment*, CERN

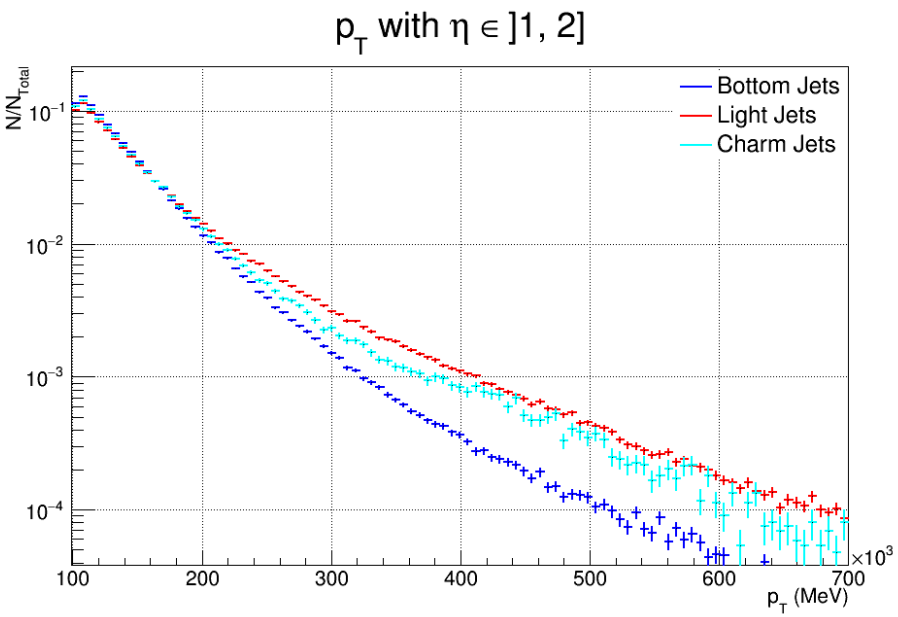

Toolkit for Multivariate Data Analysis with ROOT - Users Guide (2017),
`https://root.cern.ch/download/doc/tmva/TMVAUsersGuide.pdf`

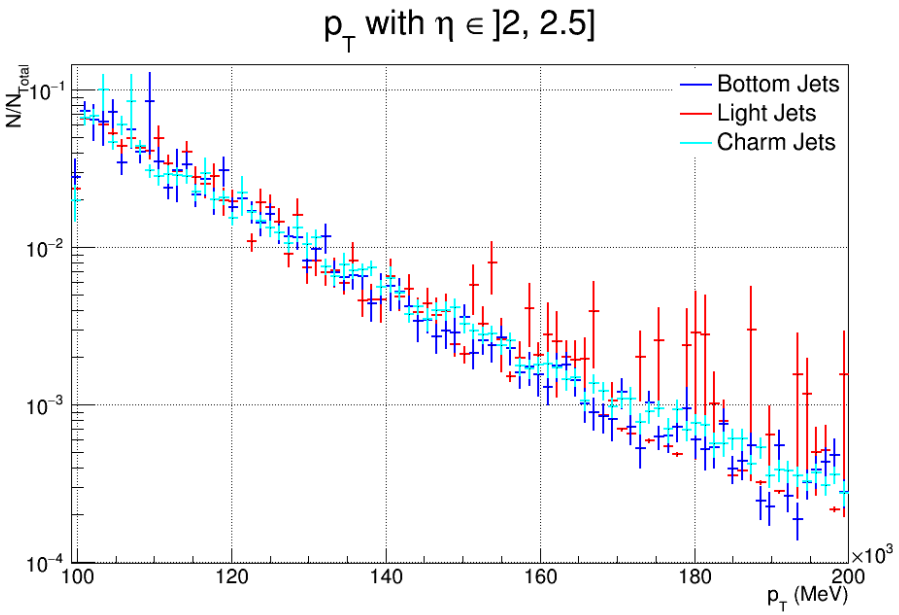
Backup

p_T Distribution with $|\eta|$

p+p MC Sample

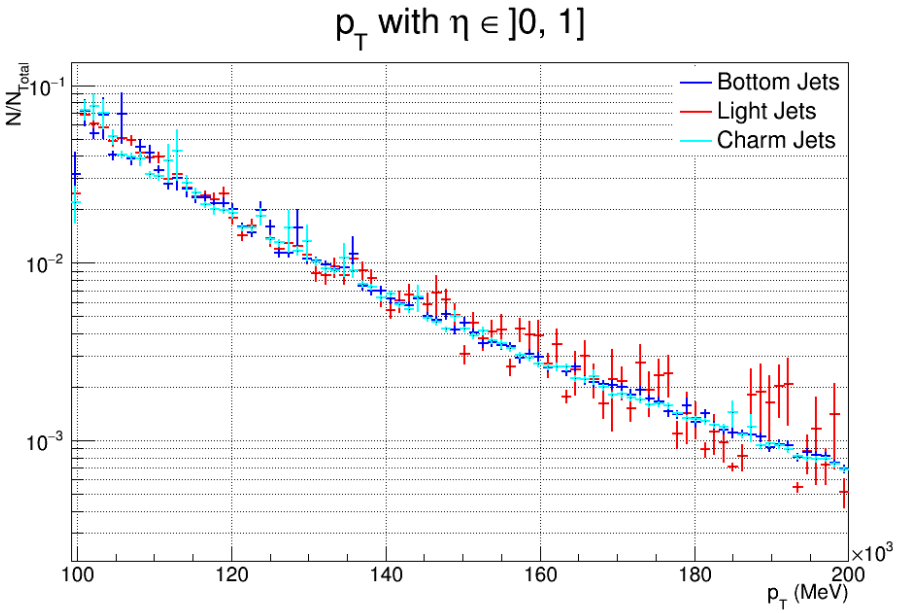


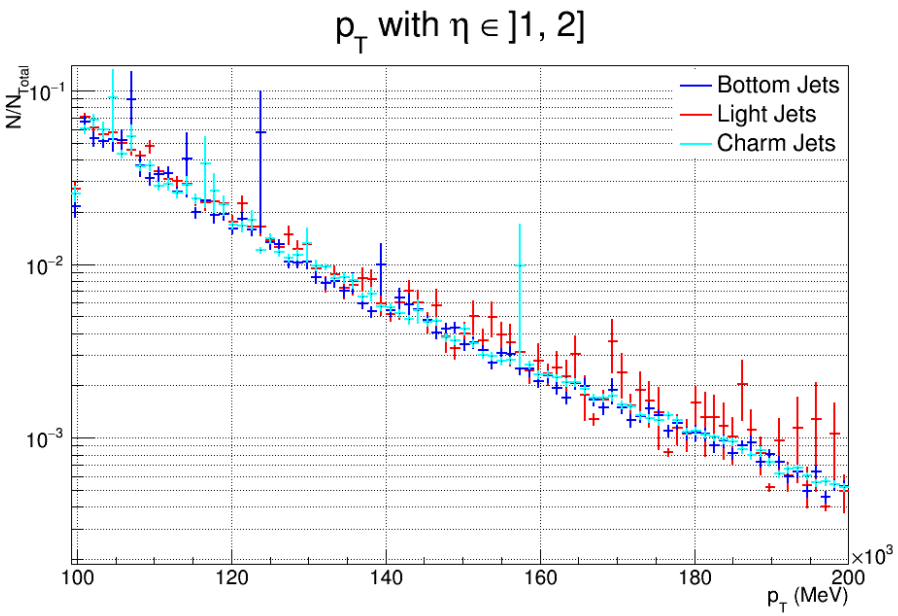


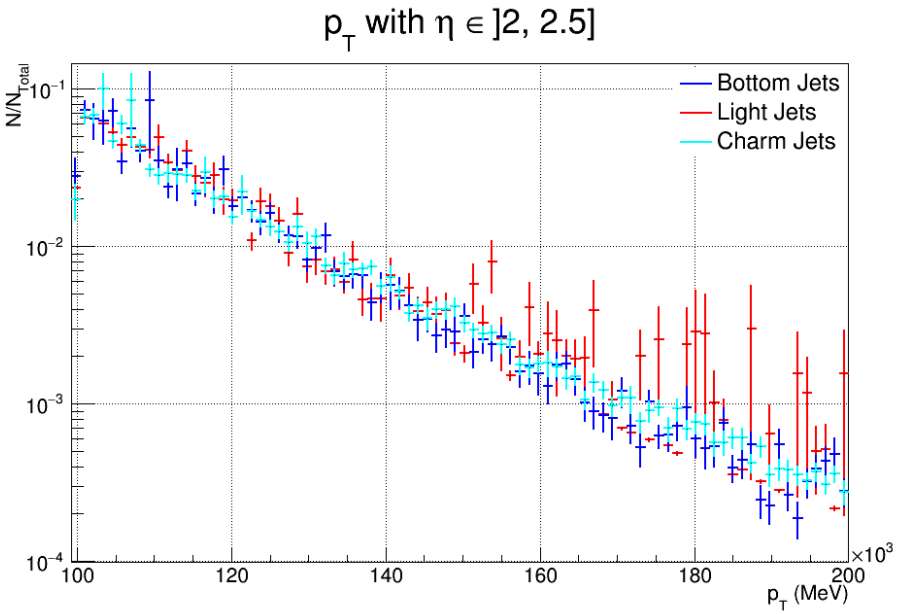


p_T Distribution with $|\eta|$

Pb+Pb MC Sample

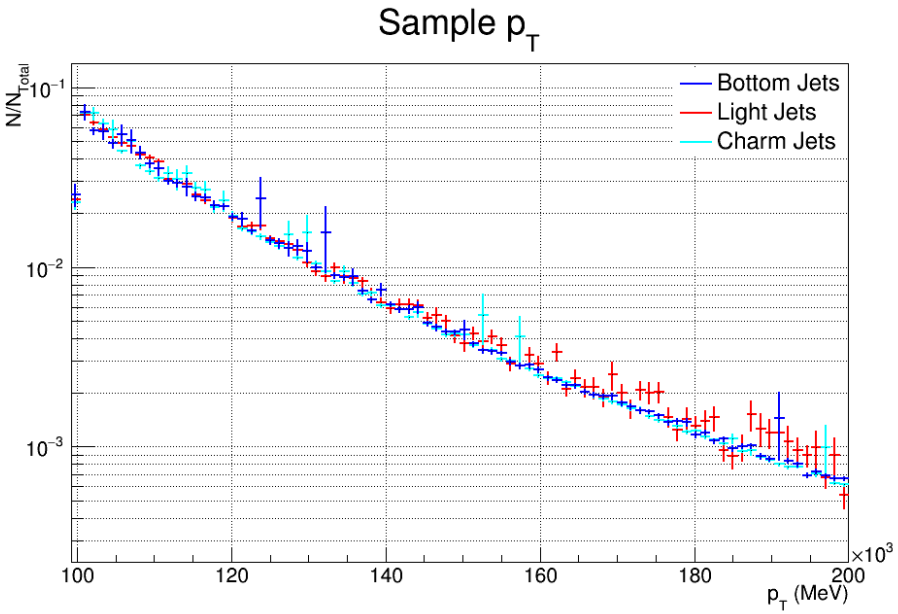


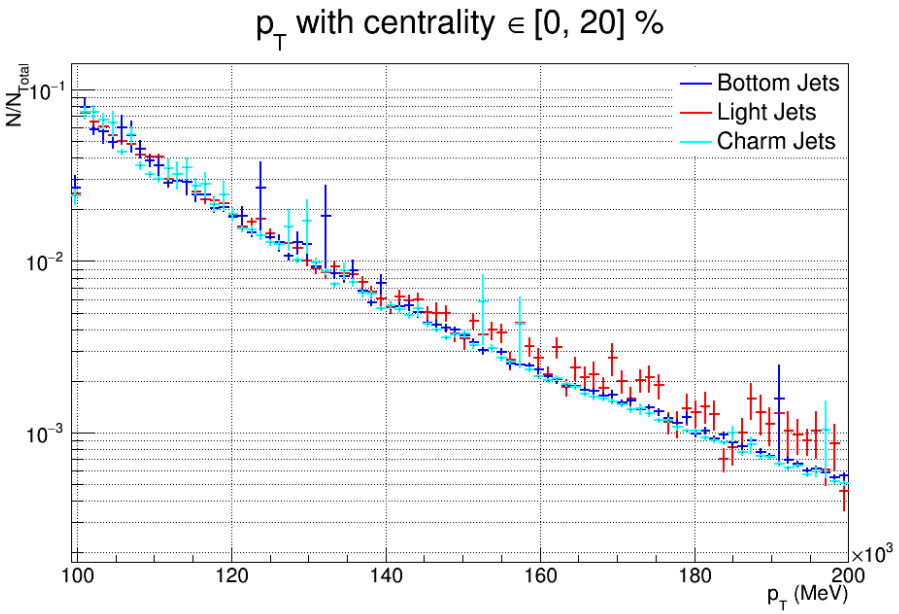


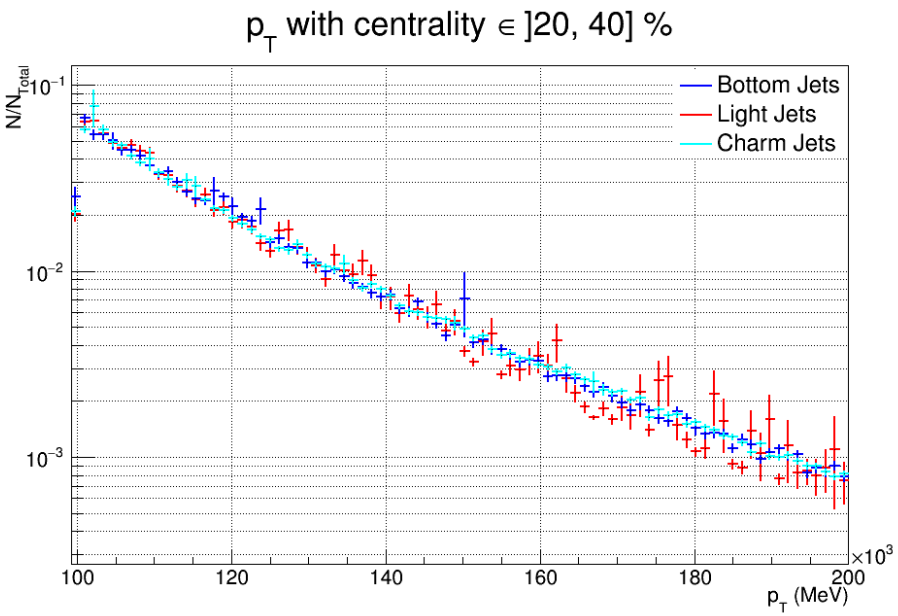


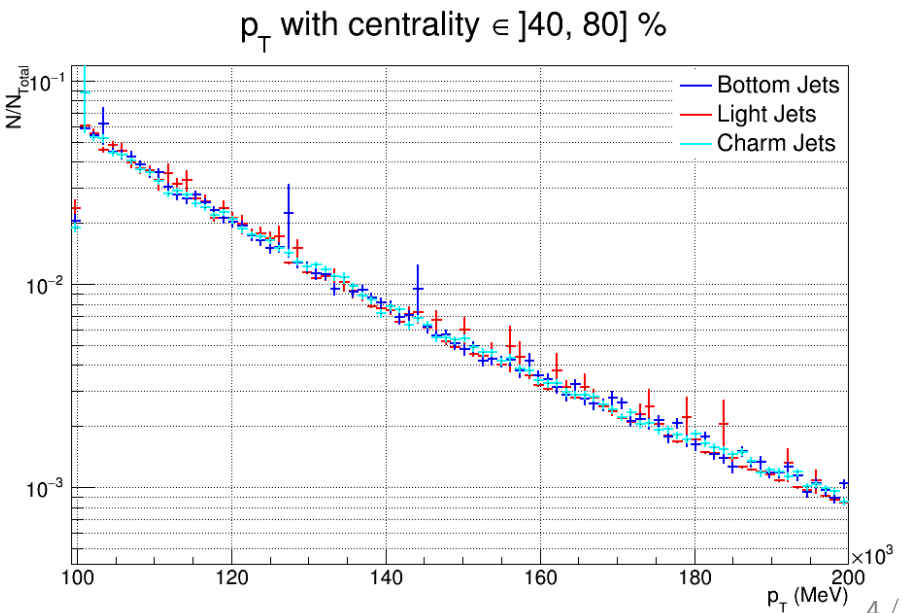
p_T Distribution with Collision Centrality

Pb+Pb MC Sample



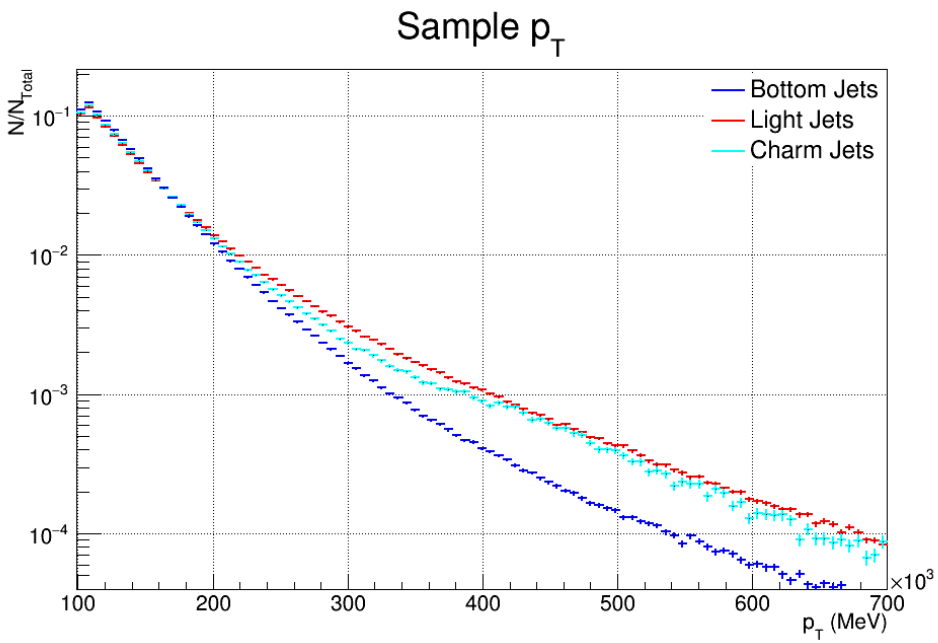


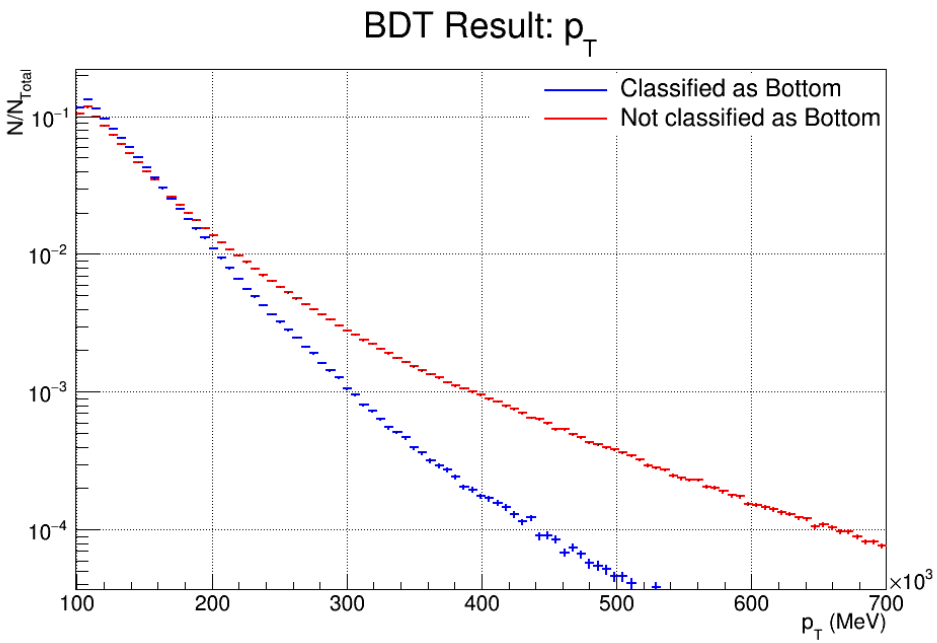




p_T Distribution

BDT Result on p+p MC Sample





BDT Efficiency

Various Training->Application Combinations