$B^0 \to K^* \mu^- \mu^+$ Selection Update

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with input from Eluned Anne Smith

$B^0 \to K^* \mu^- \mu^+$ meeting, CERN
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Topics on discussion

1. Trigger
2. Data/MC corrections
3. BDT training
4. PID re sampling
5. Exotic pollutions to $\mathrm{B} \to \mathrm{K}^{*}\mathrm{J}/\psi$.
6. VARIA

Trigger efficiencies L0Muon

⇒ We studied the trigger efficiency on Run2 MC.

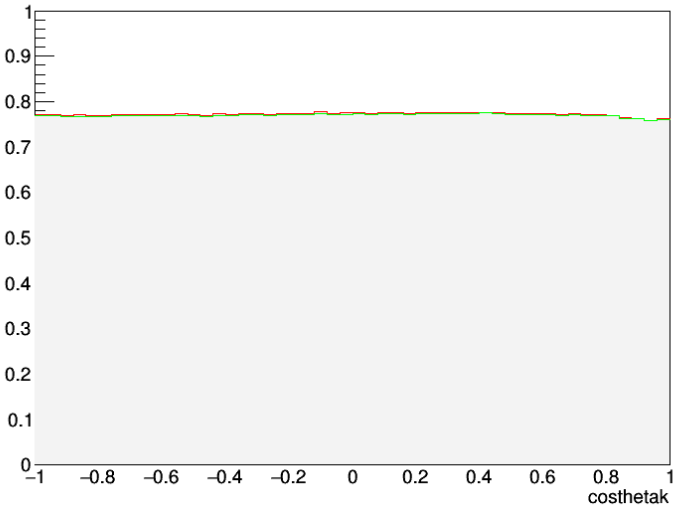
Name	Absolute ϵ	Relative ϵ
L0Muon	78.1065 %	——–
Hlt1TrackMVA	74.5579%	95.4568%
Hlt1TwoTrackMVA	76.7186%	98.2231%
Hlt1TrackMuon	77.2776%	98.9388%
Hlt1DiMuonLowMass	77.4331%	99.1379%
Hlt1SingleMuonHighPT	77.4436%	99.1513%
Hlt1DiMuonHighMass	77.4518%	99.1619%
Hlt1TrackMVALoose	77.4518%	99.1619%
Hlt1TwoTrackMVALoose	77.4518%	99.1619%

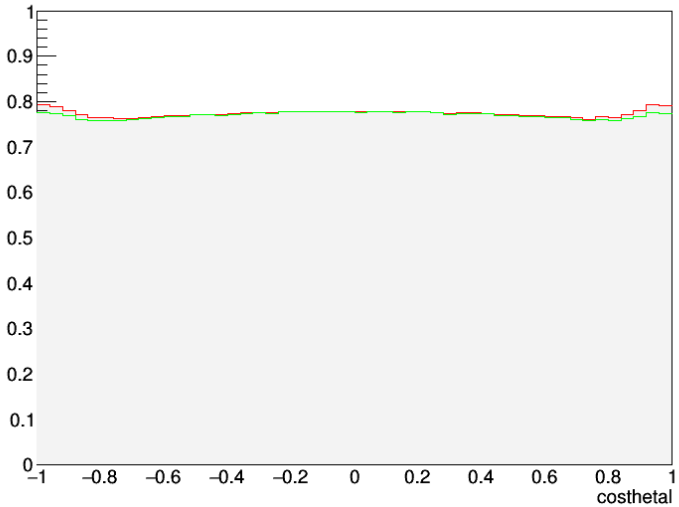
Trigger efficiencies L0Muon

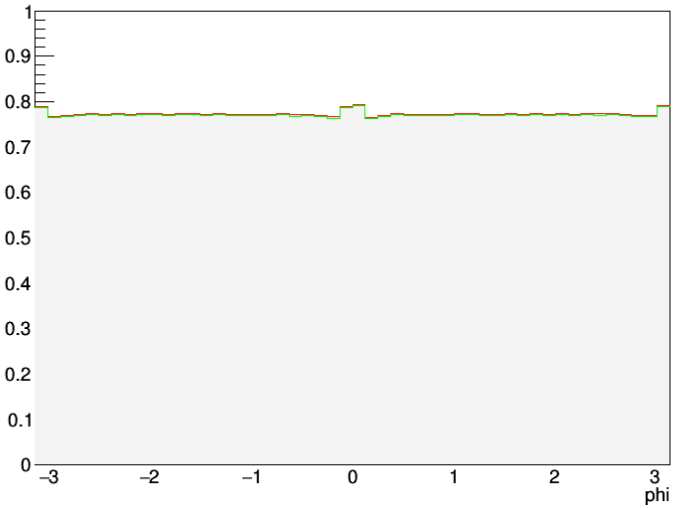
⇛ We studied the trigger efficiency on Run2 MC.

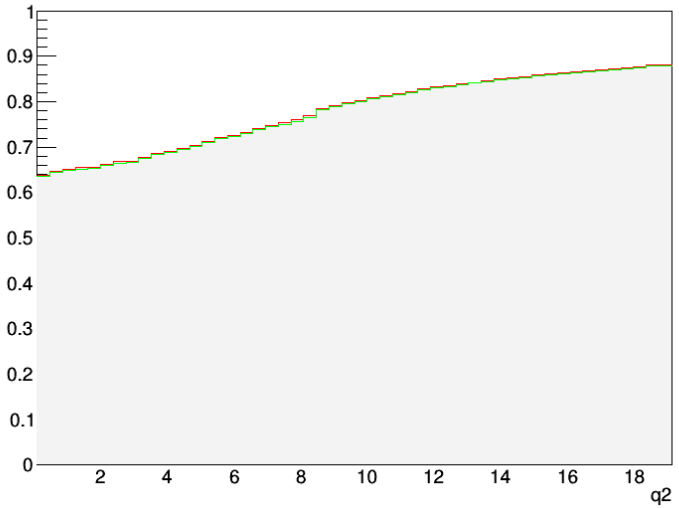
Name	Absolute ϵ	Relative ϵ
Hlt2TopoMu2BodyBBDT	70.296%	90.7609%
Hlt2DiMuonDetached	73.9044%	95.4198%
Hlt2Topo3BodyBBDT	75.2972%	97.2181%
Hlt2SingleMuon	75.9356%	98.0424%
Hlt2Topo2BodyBBDT	76.0233%	98.1556%
Hlt2TopoMuMu2BodyBBDT	76.0794%	98.228%
Hlt2TopoMu3BodyBBDT	76.0986%	98.2528%
Hlt2TopoMuMu4BodyBBDT	76.1101%	98.2677%
Hlt2TopoMuMu3BodyBBDT	76.1156%	98.2748%
Hlt2SingleMuonHighPT	76.125%	98.2869%
Hlt2SingleMuonRare	76.1288%	98.2918%
Hlt2Topo4BodyBBDT	76.1291%	98.2922%
Hlt2TopoMu4BodyBBDT	76.1291%	98.2922%
Hlt2SingleMuonLowPT	76.1291%	98.2922%

Trigger efficiencies L0Muon









Trigger efficiencies L0Muon||L0DiMuon

⇛ We studied the trigger efficiency on Run2 MC.

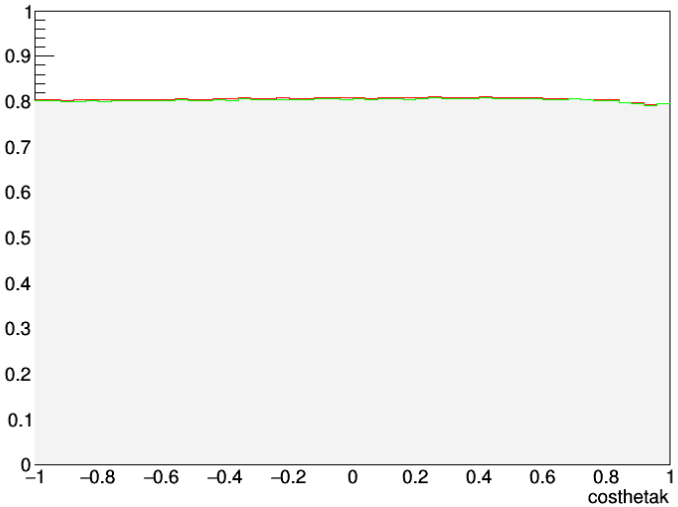
Name	Absolute ϵ	Relative ϵ
L0Muon||L0DiMuon	81.5517 %	——-
Hlt1TrackMVA	77.7613%	95.3522%
Hlt1TwoTrackMVA	80.0632%	98.1748%
Hlt1TrackMuon	80.6849%	98.9371%
Hlt1SingleMuonHighPT	80.7013%	98.9573%
Hlt1DiMuonLowMass	80.8558%	99.1467%
Hlt1DiMuonHighMass	80.864%	99.1568%
Hlt1TrackMVALoose	80.864%	99.1568%
Hlt1TwoTrackMVALoose	80.864%	99.1568%

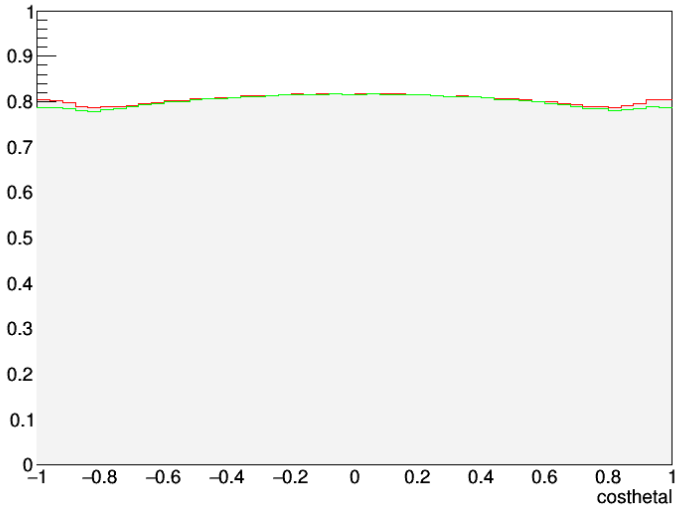
Trigger efficiencies L0Muon||L0DiMuon

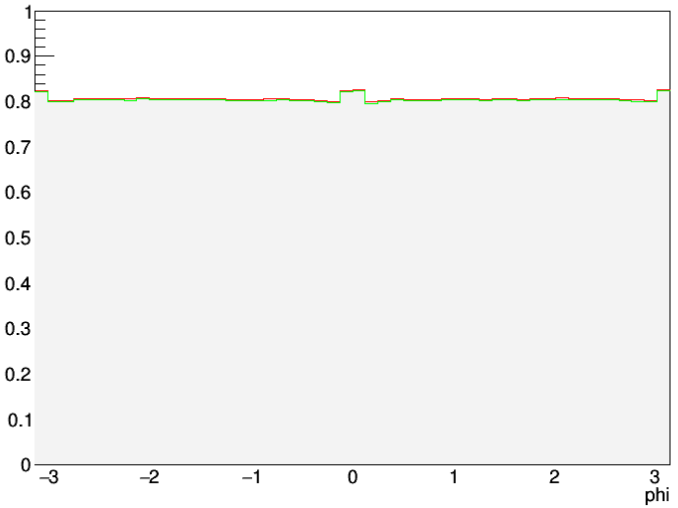
⇛ We studied the trigger efficiency on Run2 MC.

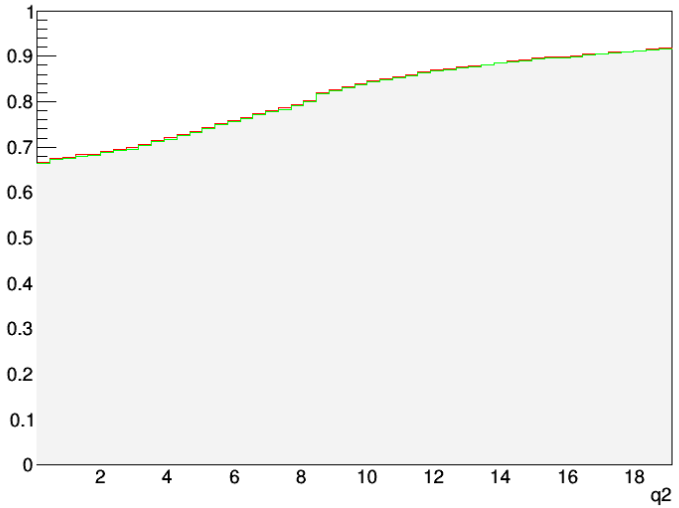
Name	Absolute ϵ	Relative ϵ
Hlt2TopoMu2BodyBBDT	73.269%	90.6077%
Hlt2DiMuonDetached	77.1023%	95.348%
Hlt2Topo3BodyBBDT	78.5627%	97.154%
Hlt2SingleMuon	79.2459%	97.9989%
Hlt2Topo2BodyBBDT	79.3382%	98.1131%
Hlt2TopoMuMu2BodyBBDT	79.3965%	98.1852%
Hlt2TopoMu3BodyBBDT	79.4168%	98.2103%
Hlt2TopoMuMu4BodyBBDT	79.43%	98.2266%
Hlt2SingleMuonHighPT	79.4394%	98.2382%
Hlt2TopoMuMu3BodyBBDT	79.4454%	98.2456%
Hlt2SingleMuonRare	79.4493%	98.2504%
Hlt2Topo4BodyBBDT	79.4495%	98.2507%
Hlt2TopoMu4BodyBBDT	79.4495%	98.2507%
Hlt2SingleMuonLowPT	79.4496%	98.2508%

Trigger efficiencies L0Muon||L0DiMuon









Trigger validation on the $B \rightarrow K^* J/\psi$

	eff. (%)	S	B	S/B	S/sqrt(B)
−− L0Muon −−	after selection				
Hlt2TopoMu2Body	70.296	322746	18191.9	17.74	2392.9
Hlt2DiMuonDetached	73.9044	360522	22940.8	15.72	2380.3
Hlt2Topo3Body	75.2972	360904	22952.8	15.72	2382.2
Hlt2SingleMuon	75.9356	360912	22955.9	15.72	2382.1
Hlt2Topo2Body	76.0233	360959	22958.6	15.72	2382.2
Hlt2TopoMuMu2Body	76.0794	360990	22968.2	15.72	2381.9
Hlt2TopoMu3Body	76.0986	361008	22969.1	15.72	2382.0
Hlt2TopoMuMu4Body	76.1101	361022	22970.6	15.72	2382.0
Hlt2TopoMuMu3Body	76.1156	361030	22971.6	15.72	2382.0
Hlt2SingleMuonHighPT	76.125	361048	22971.7	15.72	2382.1
Hlt2SingleMuonRare	76.1288	361048	22971.7	15.72	2382.1
Hlt2Topo4Body	76.1291	361049	22971.3	15.72	2382.2
Hlt2TopoMu4Body	76.1291	361050	22971.3	15.72	2382.2
Hlt2SingleMuonLowPT	76.1291	361050	22971.3	15.72	2382.2

Trigger validation on the $B \to K^* J/\psi$

−− L0Muon ll L0DiMuon −−	after selection					
Hlt2TopoMu2Body	73.269	379252	23109.3	16.41	2494.8	
Hlt2DiMuonDetached	77.1023	424681	29341.2	14.47	2479.3	
Hlt2Topo3Body	78.5627	425103	29367.5	14.48	2480.6	
Hlt2SingleMuon	79.2459	425123	29357.8	14.48	2481.1	
Hlt2Topo2Body	79.3382	425176	29366.8	14.48	2481.1	
Hlt2TopoMuMu2Body	79.3965	425213	29373.6	14.48	2481.0	
Hlt2TopoMu3Body	79.4168	425232	29379.5	14.47	2480.9	
Hlt2TopoMuMu4Body	79.43	425239	29391.4	14.47	2480.4	
Hlt2SingleMuonHighPT	79.4394	425271	29379.3	14.48	2481.1	
Hlt2TopoMuMu3Body	79.4454	425274	29389.1	14.47	2480.7	
Hlt2SingleMuonRare	79.4493	425275	29389.1	14.47	2480.7	
Hlt2Topo4Body	79.4495	425285	29375.3	14.48	2481.4	
Hlt2TopoMu4Body	79.4495	425286	29375.3	14.48	2481.4	
Hlt2SingleMuonLowPT	79.4496	425286	29375.3	14.48	2481.4	

Trigger validation on the $B \rightarrow K^*\psi(2S)$

	MC eff. (%)	S	B	S/B	S/sqrt(B)
−− L0Muon −−	after selection				
Hlt2TopoMu2Body	70.296	19914.9	1752.18	11.37	475.8
Hlt2DiMuonDetached	73.9044	21850.6	2340.36	9.34	451.7
Hlt2Topo3Body	75.2972	21849.3	2342.72	9.33	451.4
Hlt2SingleMuon	75.9356	21855.6	2339.78	9.34	451.8
Hlt2Topo2Body	76.0233	21855.6	2339.78	9.34	451.8
Hlt2TopoMuMu2Body	76.0794	21856.6	2339.82	9.34	451.8
Hlt2TopoMu3Body	76.0986	21857.2	2339.13	9.34	451.9
Hlt2TopoMuMu4Body	76.1101	21857.2	2339.13	9.34	451.9
Hlt2TopoMuMu3Body	76.1156	21857.6	2338.99	9.34	451.9
Hlt2SingleMuonHighPT	76.125	21858.5	2339.38	9.34	451.9
Hlt2SingleMuonRare	76.1288	21858.5	2339.38	9.34	451.9
Hlt2Topo4Body	76.1291	21858.5	2339.38	9.34	451.9
Hlt2TopoMu4Body	76.1291	21858.5	2339.38	9.34	451.9
Hlt2SingleMuonLowPT	76.1291	21859.8	2339.26	9.34	452.0

Trigger validation on the $B \rightarrow K^*\psi(2S)$

	MC eff. (%)	S	B	S/B	S/sqrt(B)
−− L0Muon −−	after selection				
Hlt2TopoMu2Body	70.296	19914.9	1752.18	11.37	475.8
Hlt2DiMuonDetached	73.9044	21850.6	2340.36	9.34	451.7
Hlt2Topo3Body	75.2972	21849.3	2342.72	9.33	451.4
Hlt2SingleMuon	75.9356	21855.6	2339.78	9.34	451.8
Hlt2Topo2Body	76.0233	21855.6	2339.78	9.34	451.8
Hlt2TopoMuMu2Body	76.0794	21856.6	2339.82	9.34	451.8
Hlt2TopoMu3Body	76.0986	21857.2	2339.13	9.34	451.9
Hlt2TopoMuMu4Body	76.1101	21857.2	2339.13	9.34	451.9
Hlt2TopoMuMu3Body	76.1156	21857.6	2338.99	9.34	451.9
Hlt2SingleMuonHighPT	76.125	21858.5	2339.38	9.34	451.9
Hlt2SingleMuonRare	76.1288	21858.5	2339.38	9.34	451.9
Hlt2Topo4Body	76.1291	21858.5	2339.38	9.34	451.9
Hlt2TopoMu4Body	76.1291	21858.5	2339.38	9.34	451.9
Hlt2SingleMuonLowPT	76.1291	21859.8	2339.26	9.34	452.0

Trigger Summary

⇛ We propose: `L0Muon` || `L0DiMuon`
`Hlt1TrackMVA`, `Hlt1TwoTrackMVA`, `Hlt1TrackMuon`
`Hlt2TopoMu2BodyBBDT`, `Hlt2DiMuonDetached`,
`Hlt2Topo3BodyBBDT`, `Hlt2SingleMuon`, `Hlt2Topo2BodyBBDT`

⇛ Simplifies life, unifies the selection for 2015 and 2016 and keeps the same efficiency.

⇛ Eluned found same results with her independent studies.

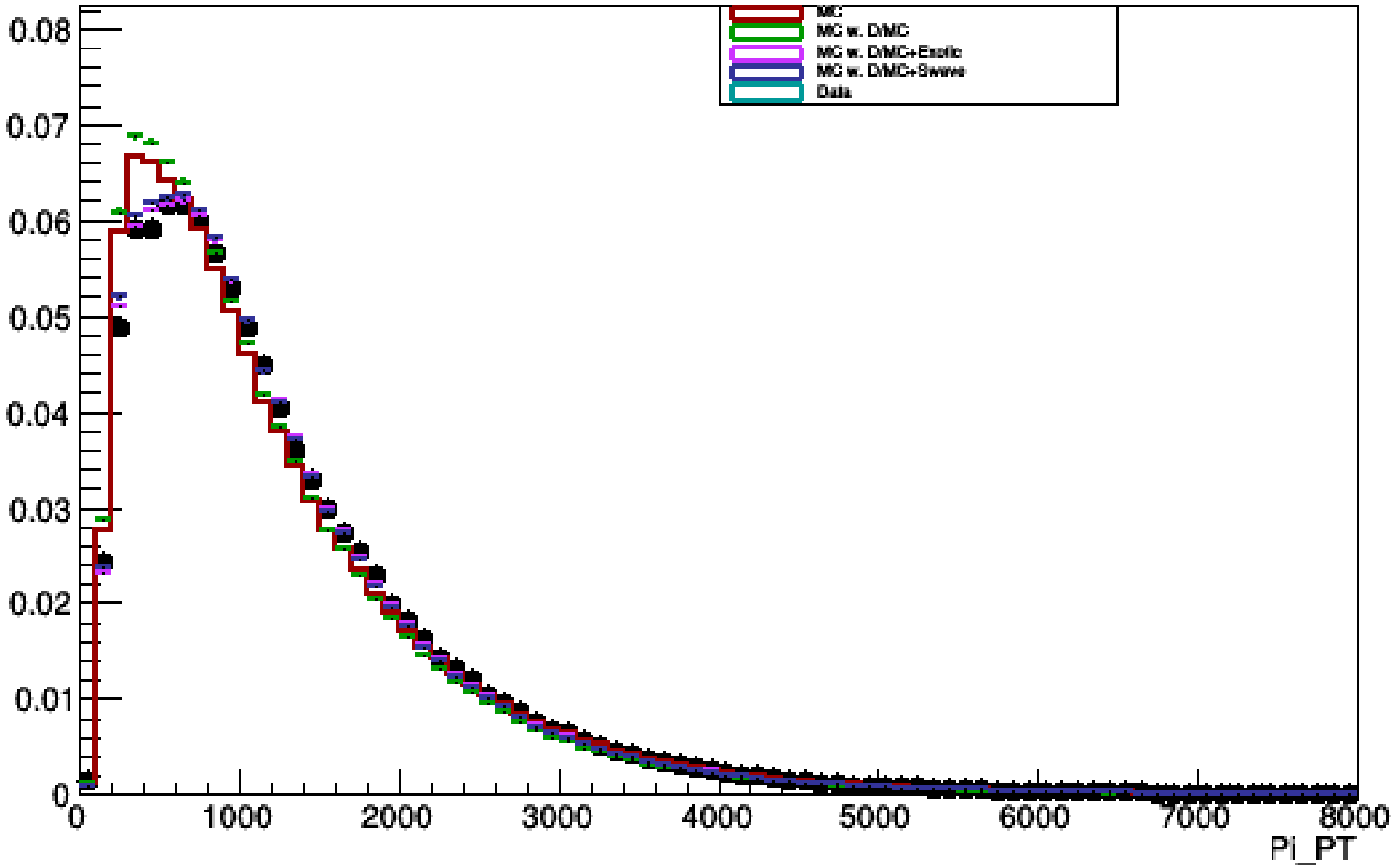
⇛ Total numbers:

L0	Simple HLT	Full HLT
`L0Muon`	76.41%	76.64%
`L0Muon`	79.77%	80.00%

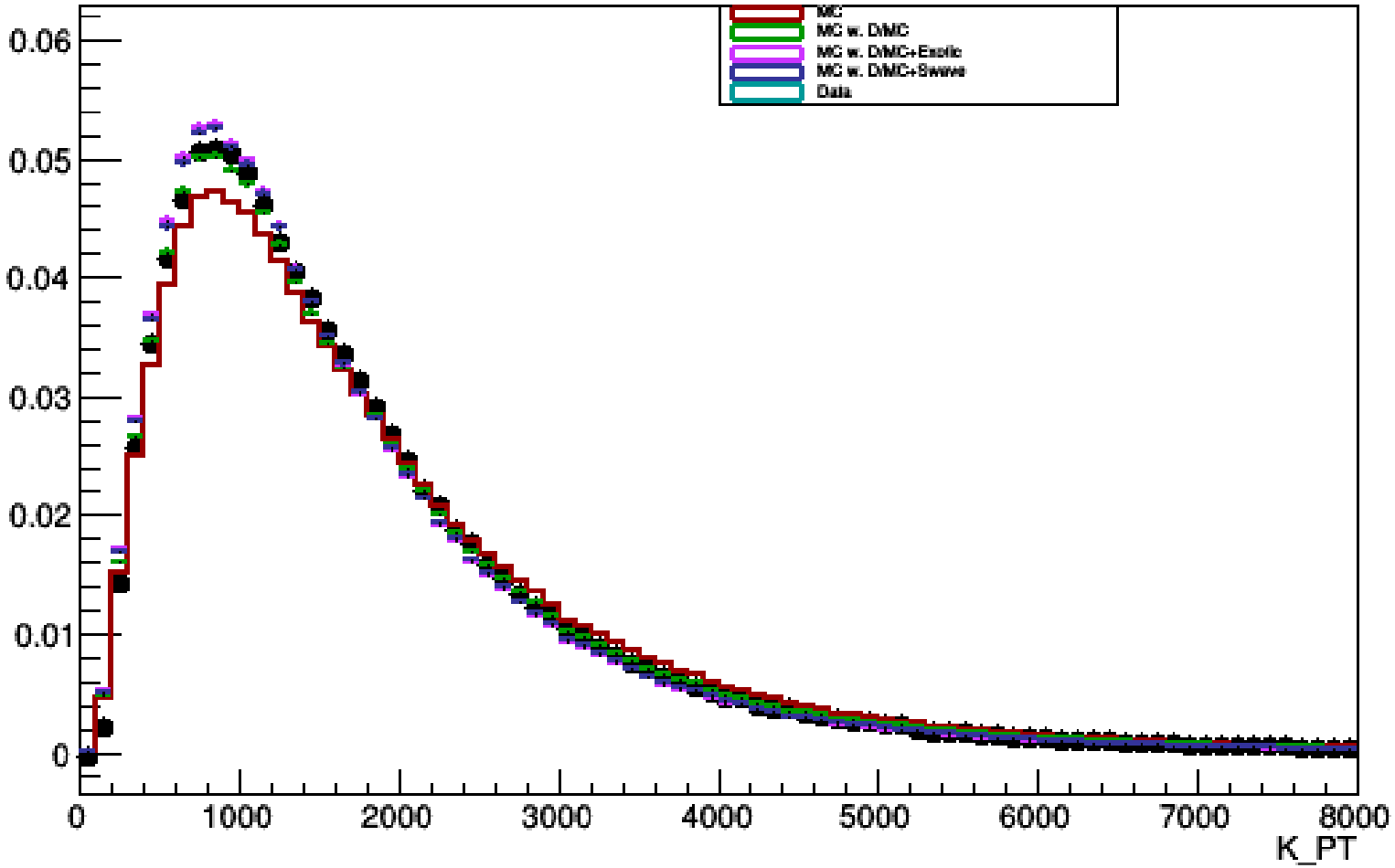
Data/MC corrections 2

⇛ Our biggest systematic came from the π p_T spectrum.
⇛ Lets get rid of this issue:)
⇛ The idea is the following: we compare our p-wave MC with what we have in data.
⇛ What I did is to compute the weight: real model / pwave model.
⇛ I then apply the weight to our MC and compare with data.

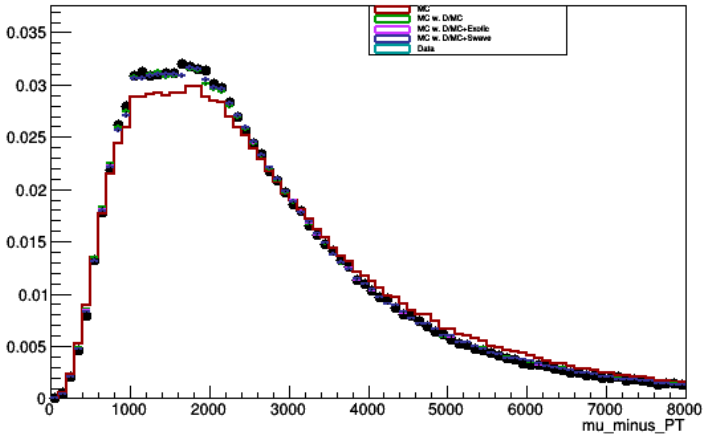
Data/MC corrections 2

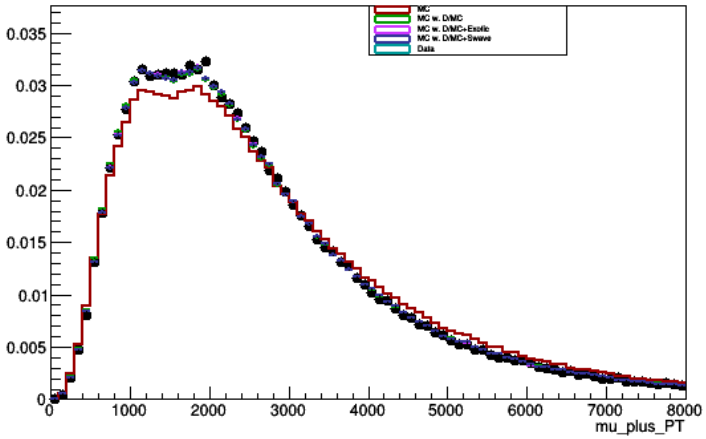


Data/MC corrections 2



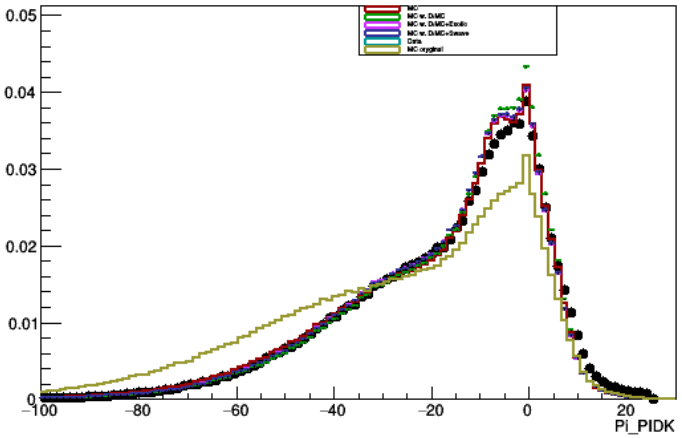
Data/MC corrections 2

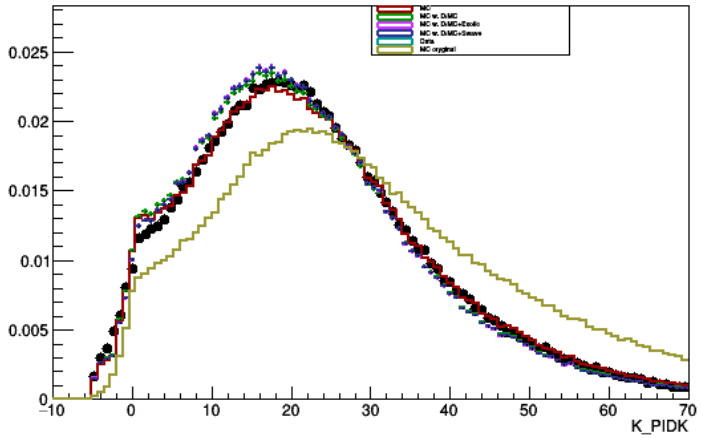


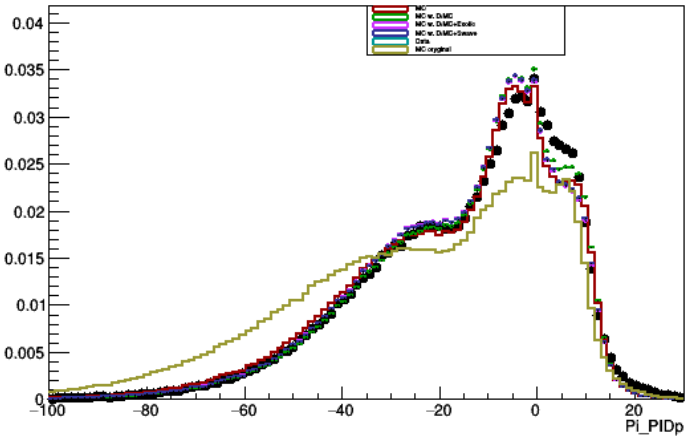


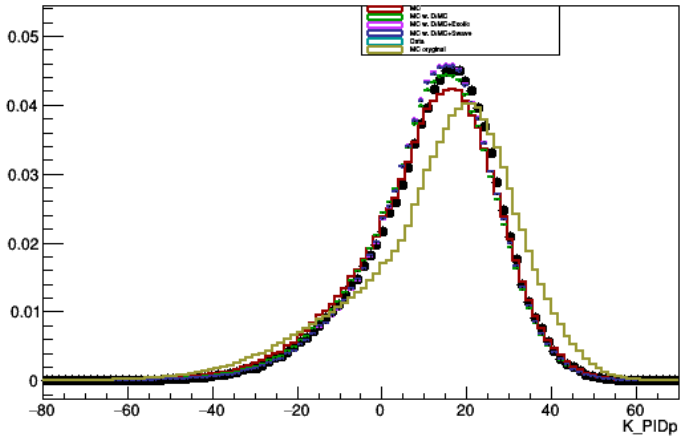
Meerkat- PID corrections

⇒ We have made first PID corrections using Meerkat:







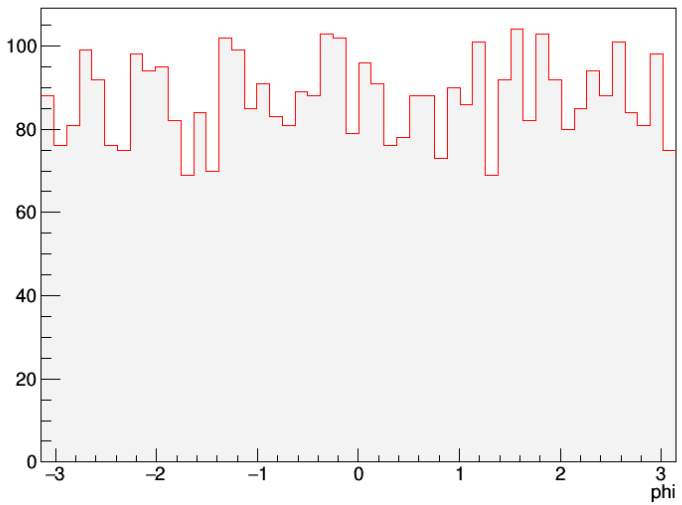


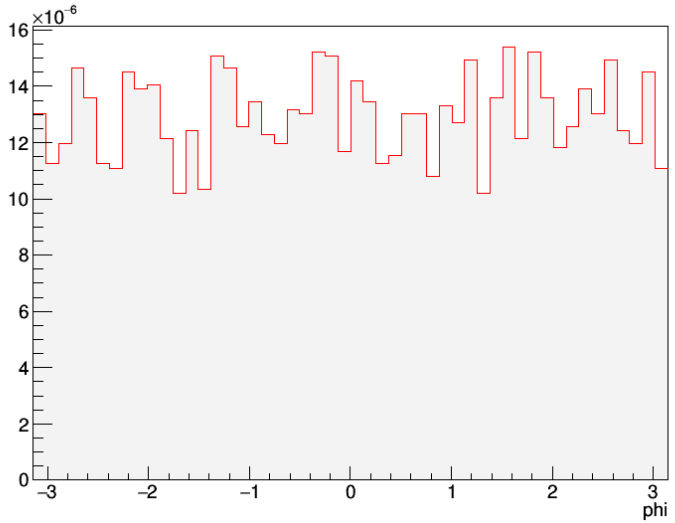
⇒ We are still missing the muon re sampling(ongoing).

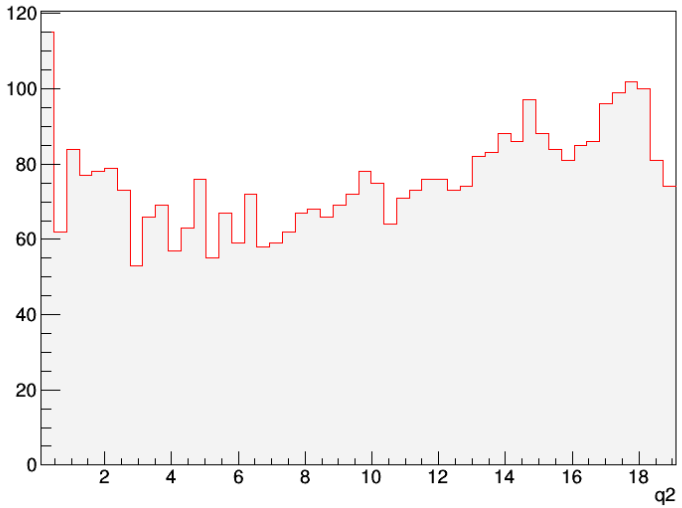
⇒ We will cross check with old re sampling.

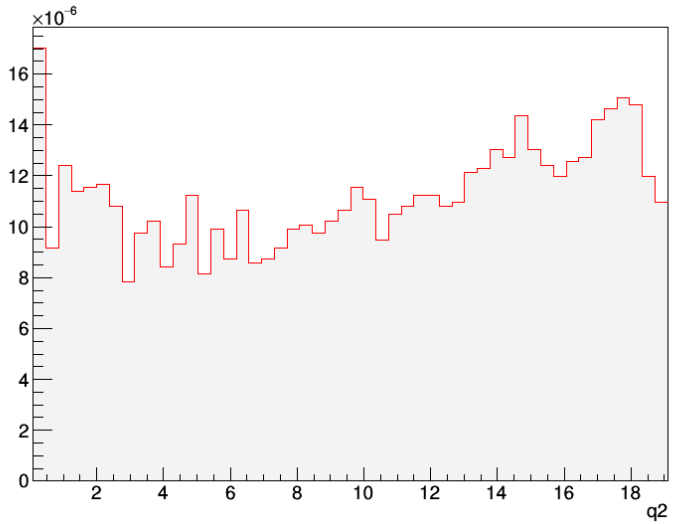
Angle separation

⇛ Let's see the angle separation between the two tracks:



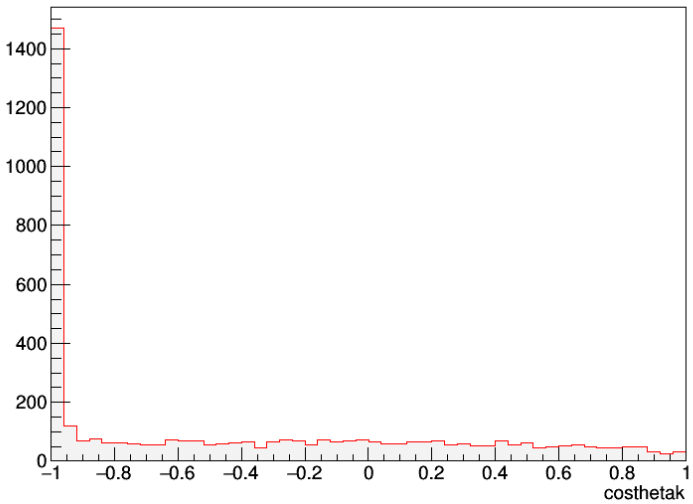


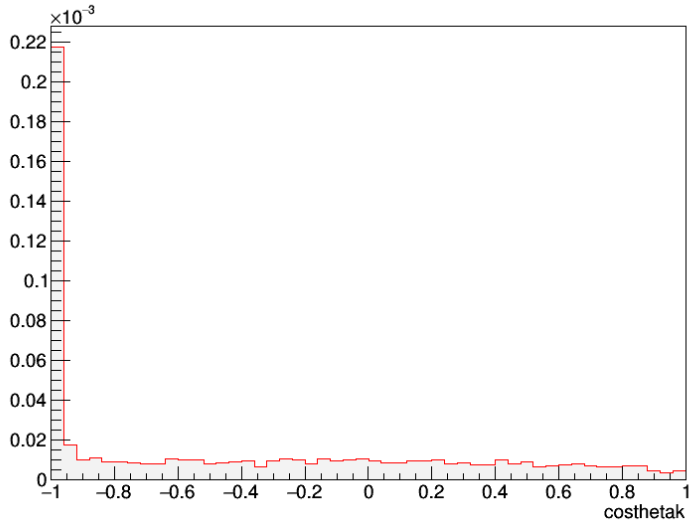


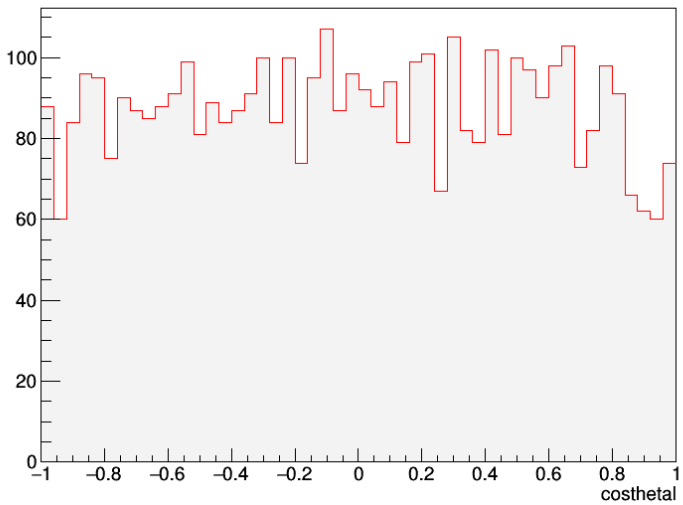


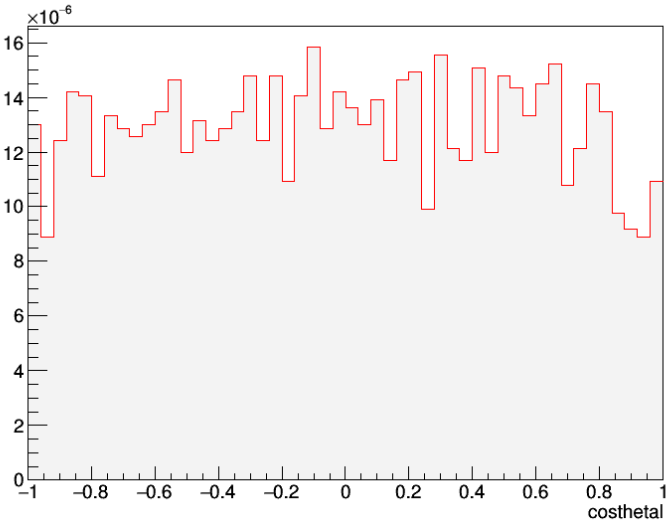
Angle separation

⇛ Let's see the angle separation between the two tracks:



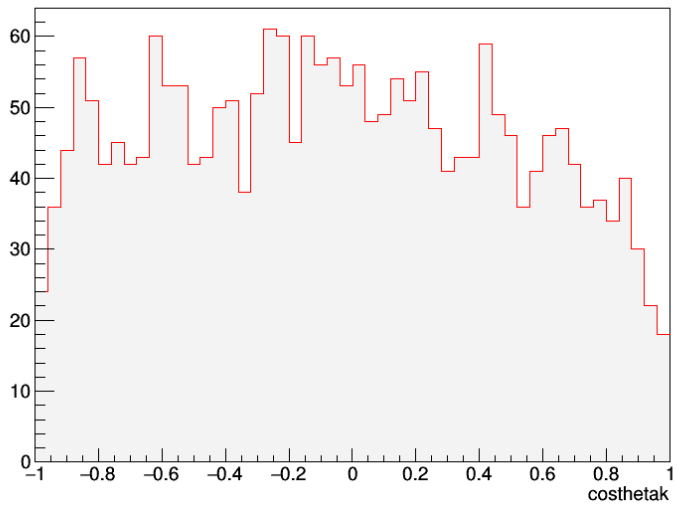


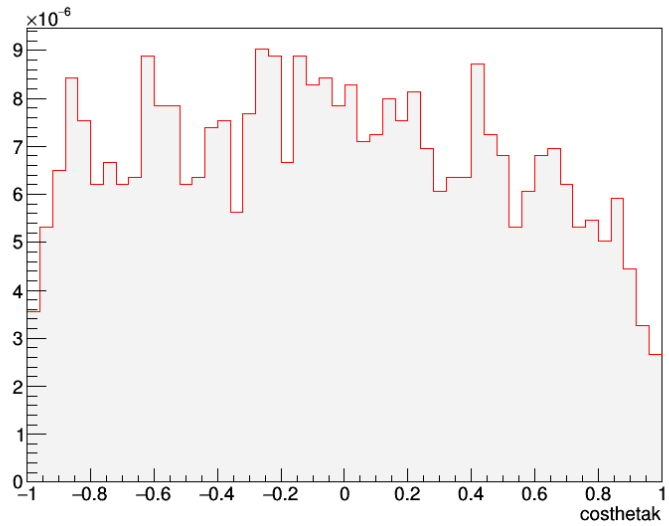


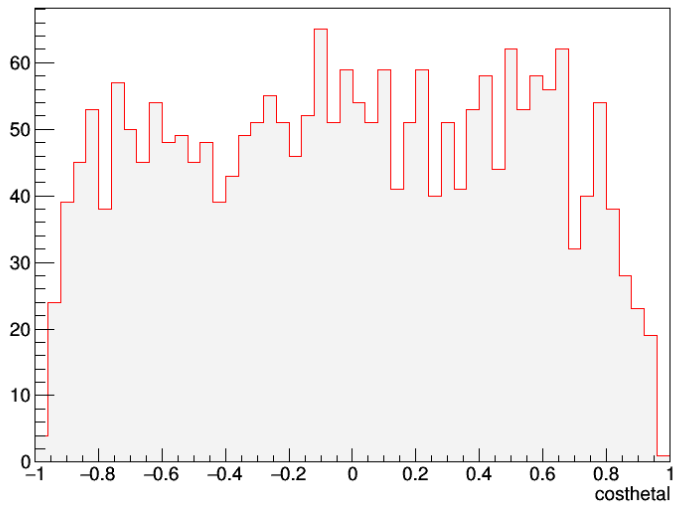


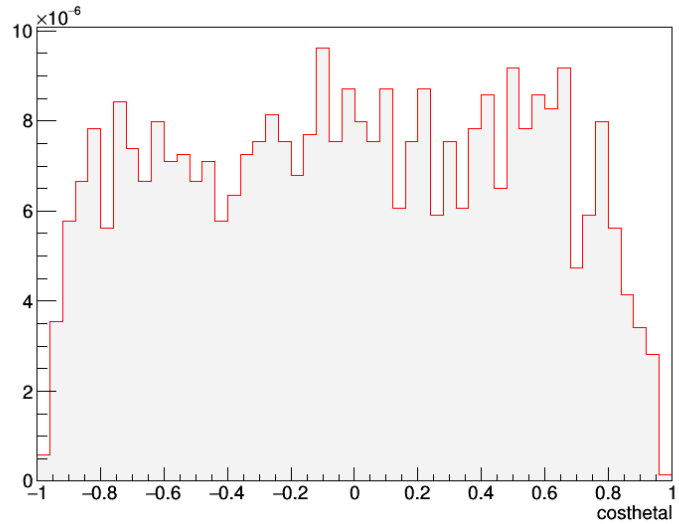
Angle separation

⇛ Release the $\mathrm{K}\ \pi$ angle:



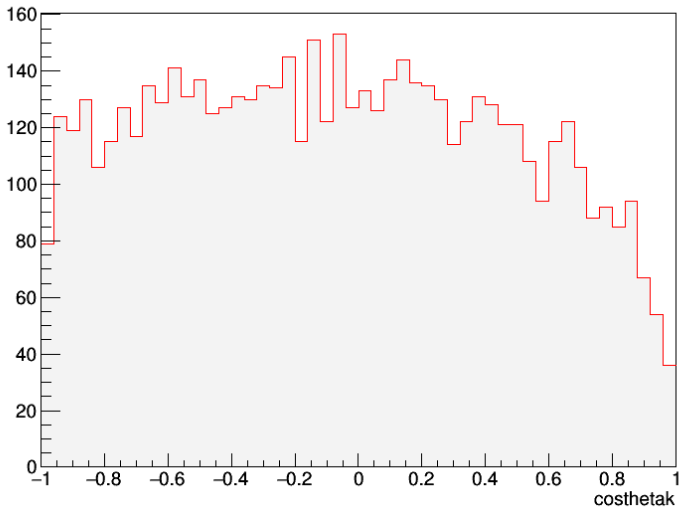


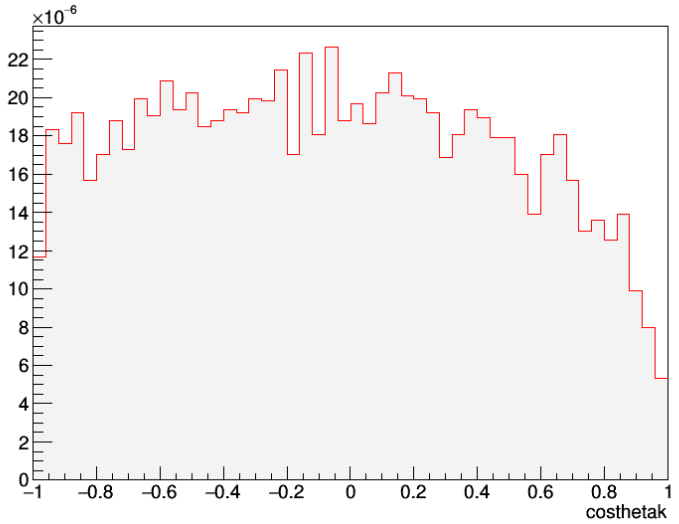


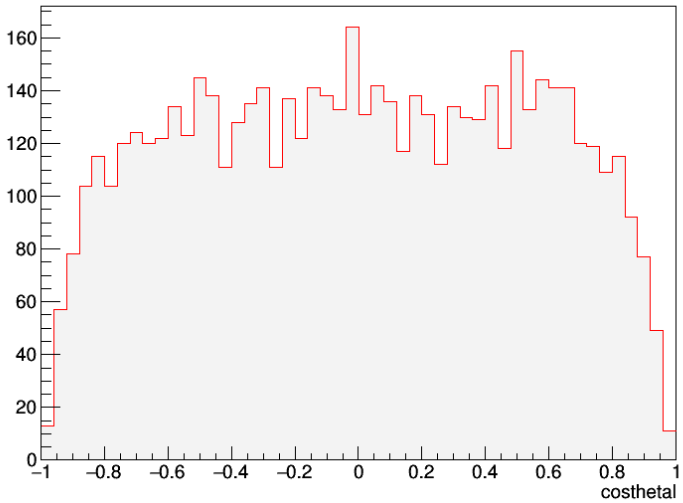


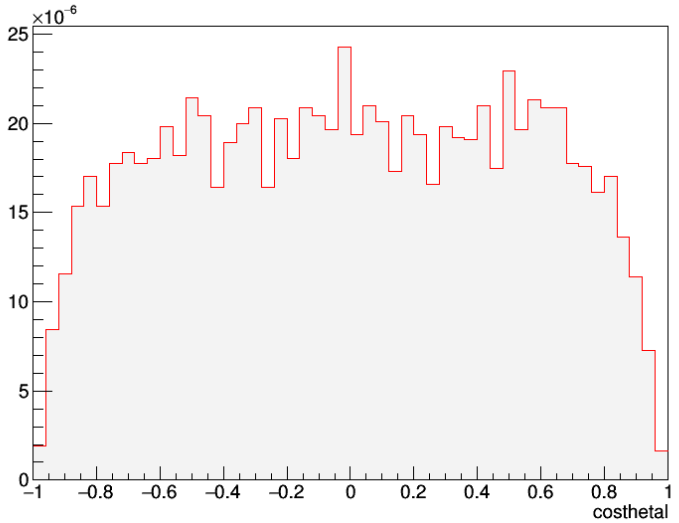
Angle separation

⇛ Release the K π angle and tighter the other angles:



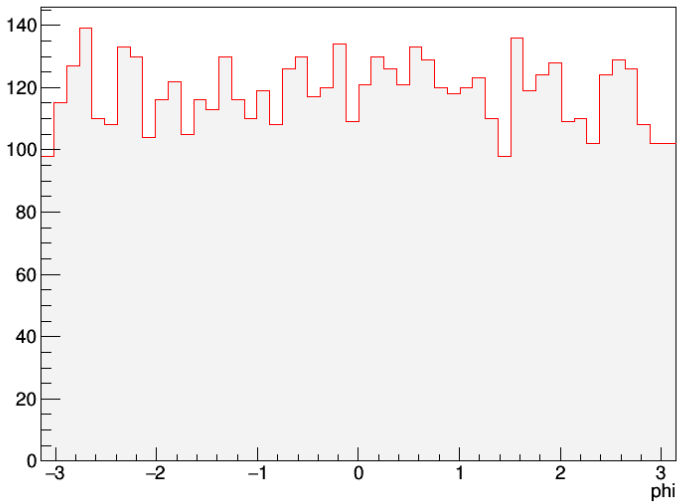


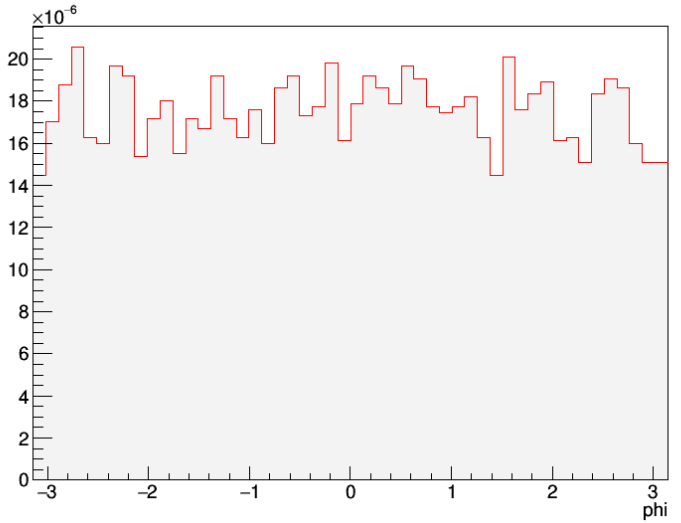


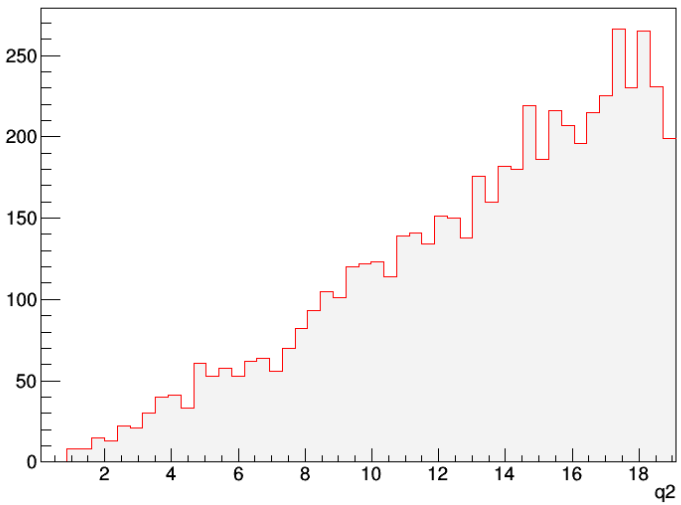


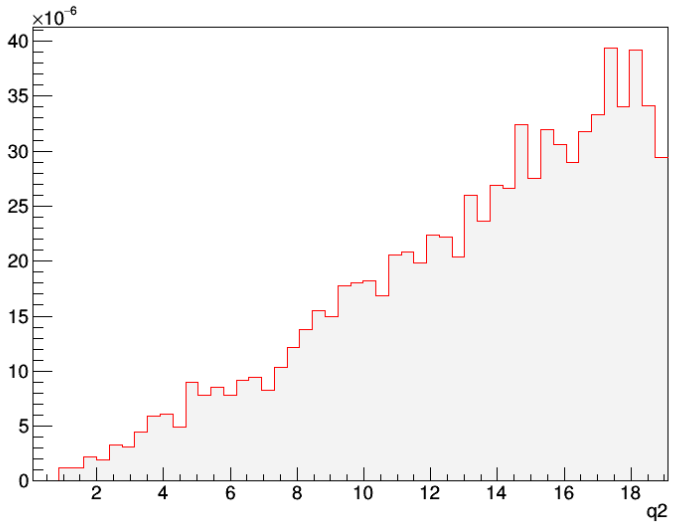
Angle separation

⇛ Release the K π angle and tighting the other angles:



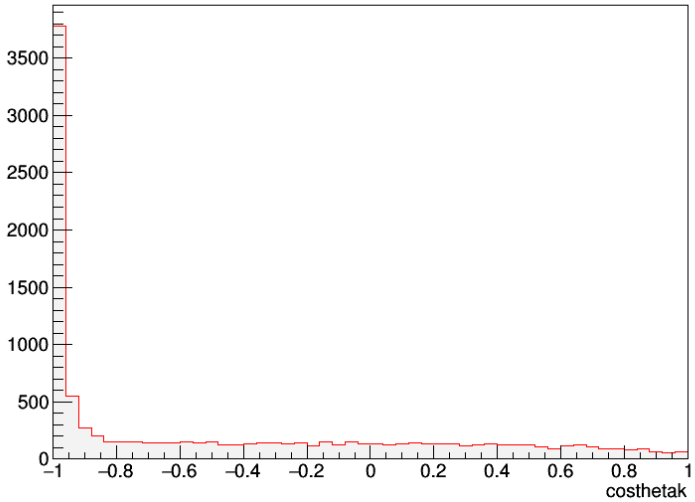


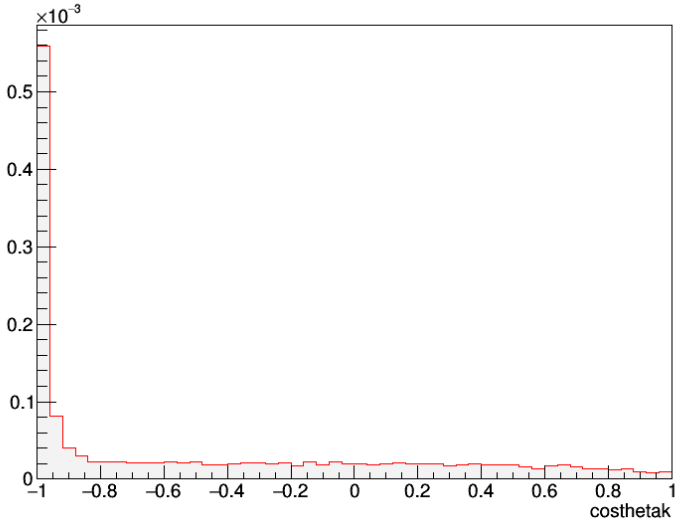


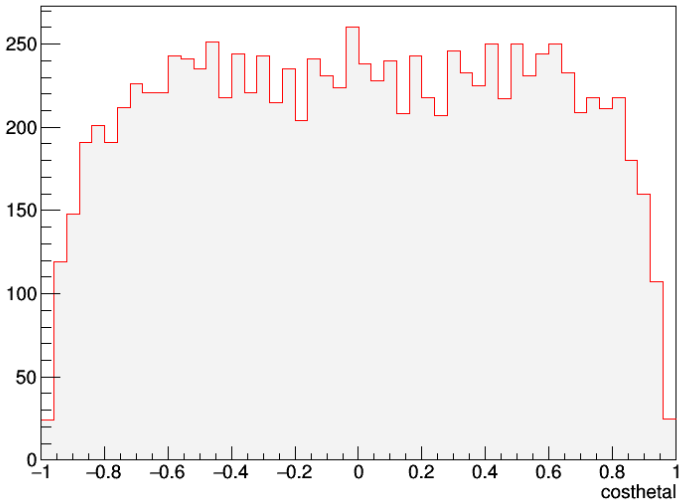


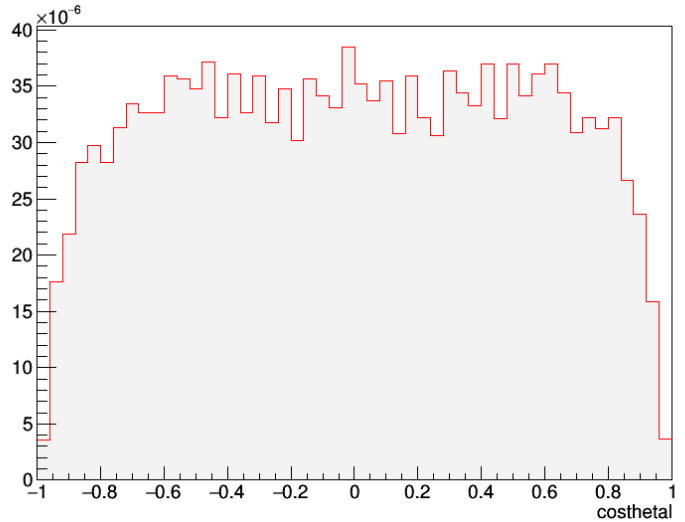
Angle separation

⇛ Everything tighting:



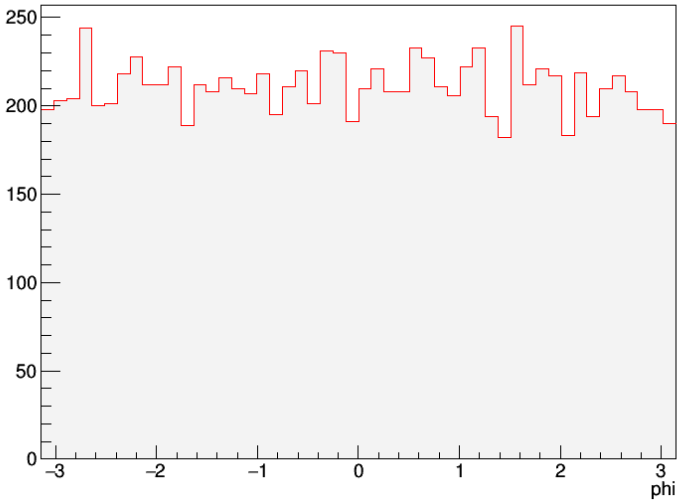


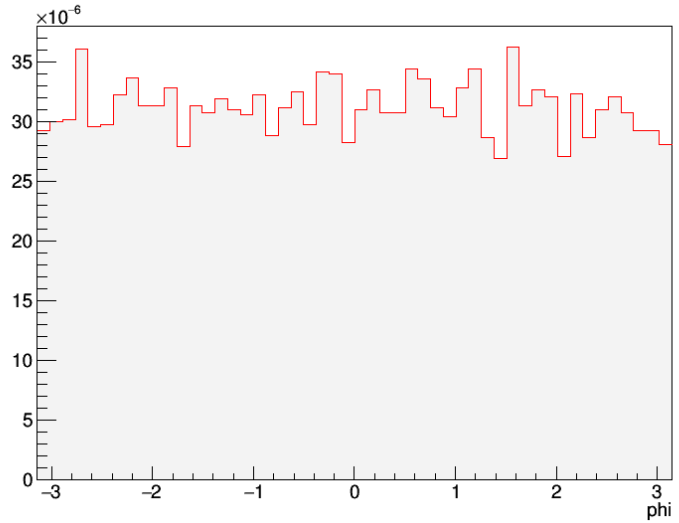


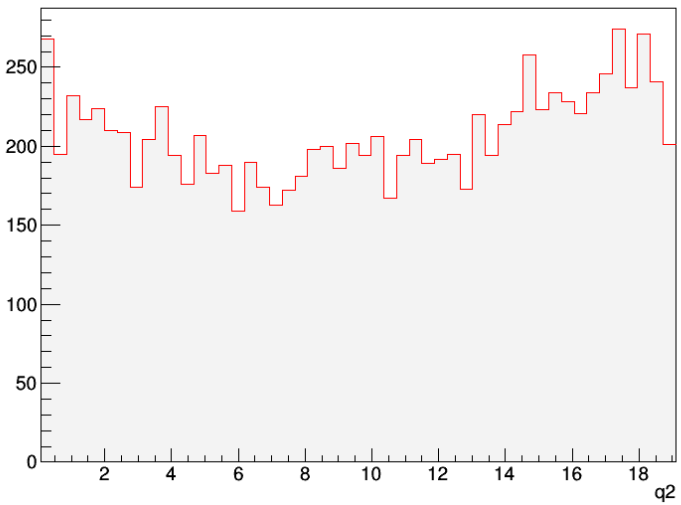


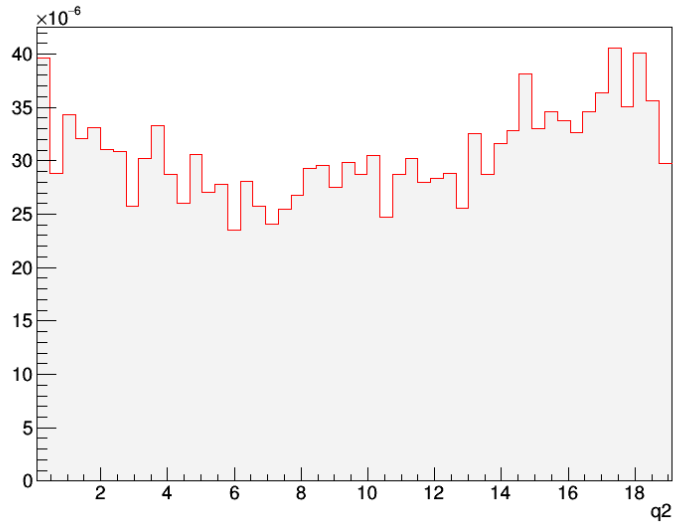
Angle separation

⇛ Everything tighting:







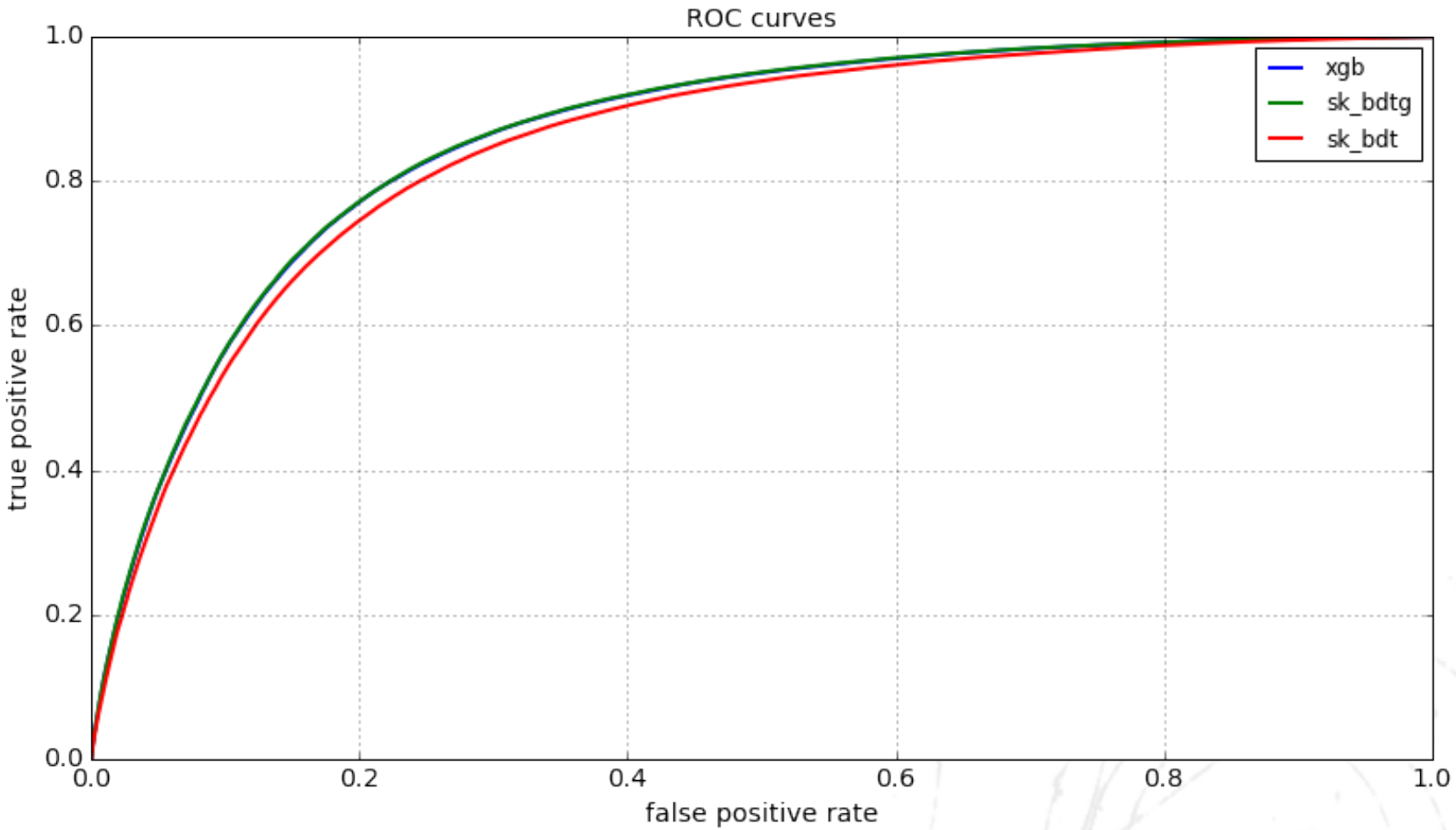


BDT

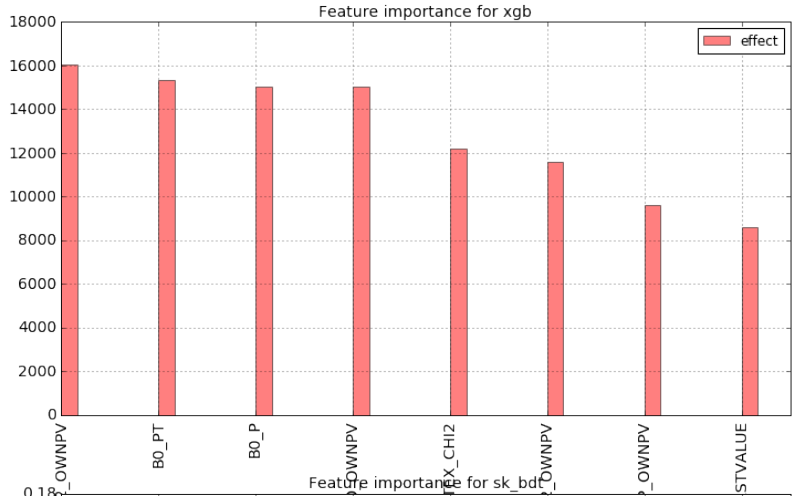
⇛ We have started to train the BDT.
⇛ For now we used MC PHSP as signal and side-bands.
⇛ Variables:

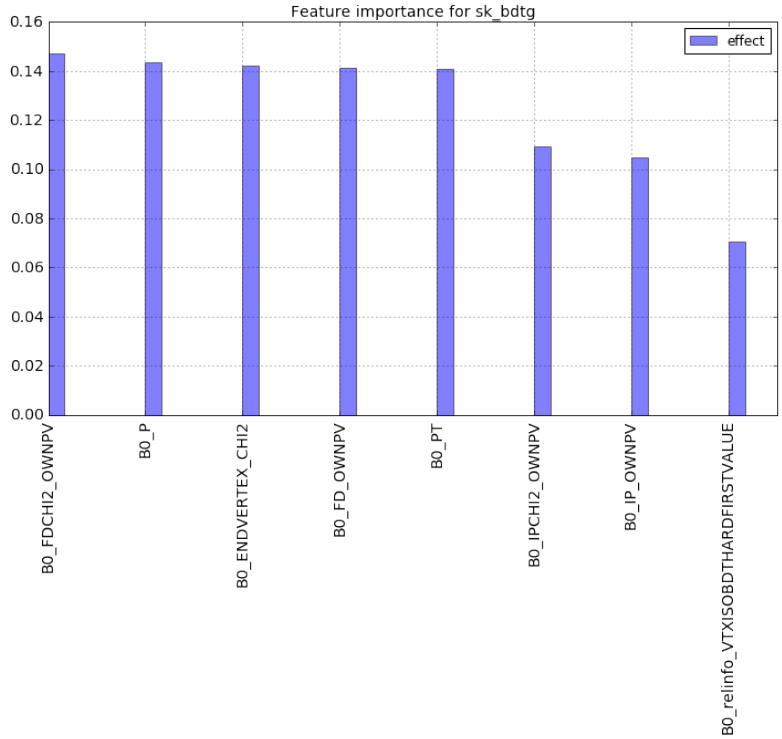
- `B0_ENDVERTEX_CHI2`
- `B0_IP_OWNPV`
- `B0_IPCHI2_OWNPV`
- `B0_FD_OWNPV`
- `B0_FDCHI2_OWNPV`
- `B0_P`
- `B0_PT`
- `B0_relinfo_VTXISOBDTHARDFIRSTVALUE`

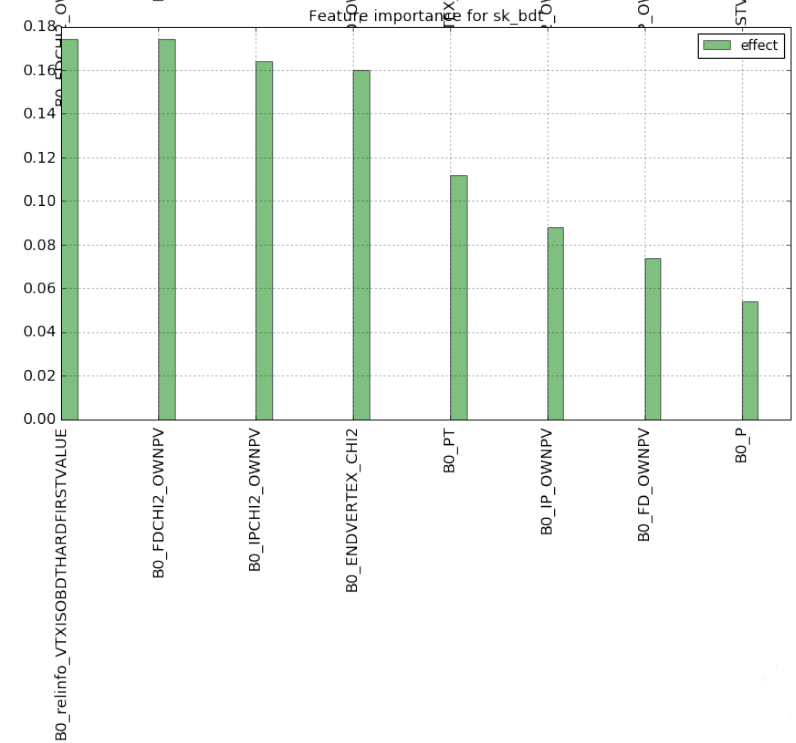
BDT ROC


ROC curves
xgb
sk_bdtg
sk_bdt
true positive rate
false positive rate
0.0
0.2
0.4
0.6
0.8
1.0

BDT ranking


Feature importance for xgb
effect
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
B0_PT
B0_P


Feature importance for sk_bdtg
effect
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
B0_FDCHI2_OWNPV
B0_P
B0_ENDVERTEX_CHI2
B0_FD_OWNPV
B0_PT
B0_IPCHI2_OWNPV
B0_IP_OWNPV
B0_relinfo_VTXISOBDTHARDFIRSTVALUE


Feature importance for sk_bdt
effect
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
B0_relinfo_VTXISOBDTHARDFIRSTVALUE
B0_FDCHI2_OWNPV
B0_IPCHI2_OWNPV
B0_ENDVERTEX_CHI2
B0_PT
B0_IP_OWNPV
B0_FD_OWNPV
B0_P

Conclusions

- PID works reasonably well, but still needs a bit of work.
- To fully test the BDT we need the re sampled MC.
- I think we can fix the preselection today.
- Trigger study performed.
- Discrepancy on the `Pi_PT` fixed and others are under control.

Backup