

Rb measurement at CEPC MC Level

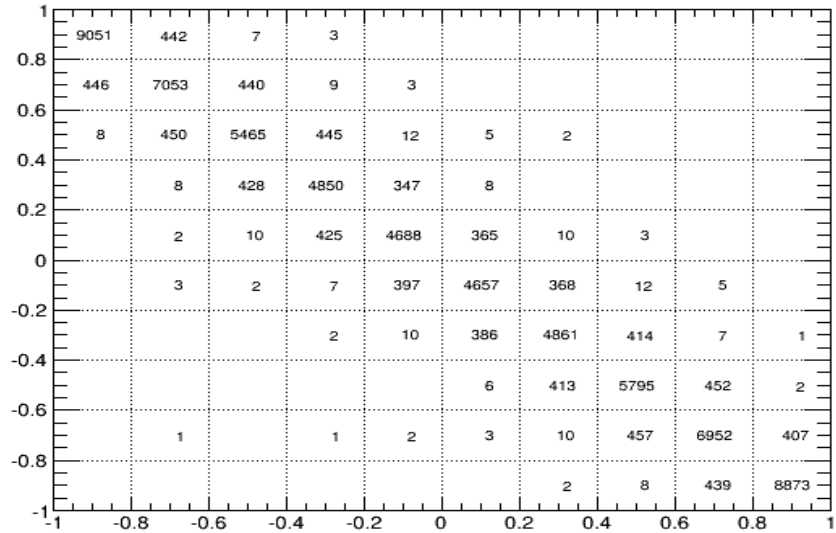
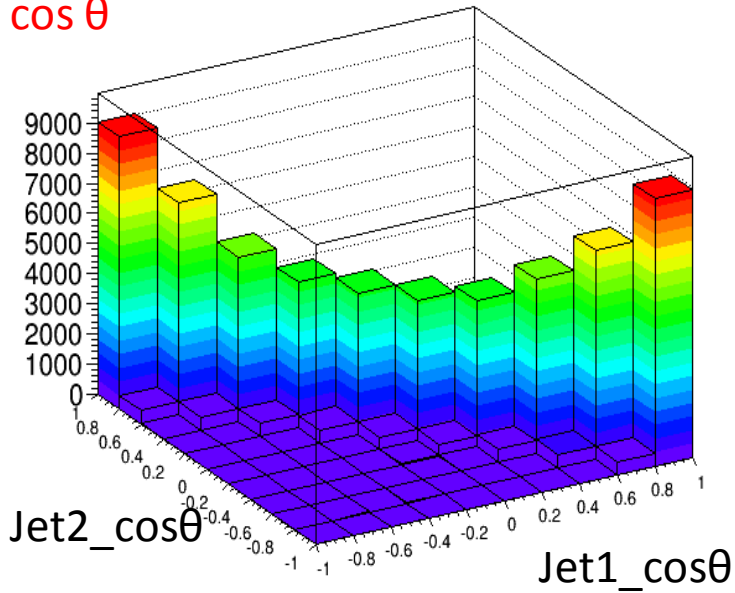
Bo Li



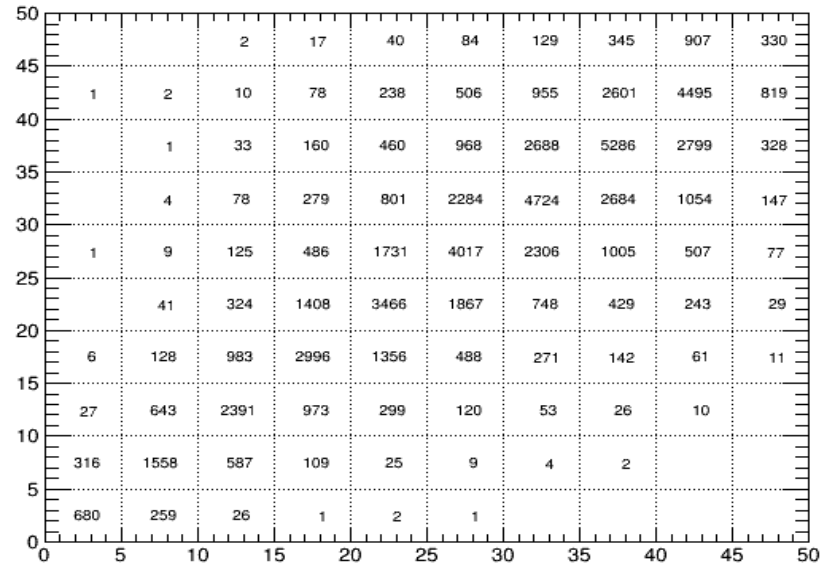
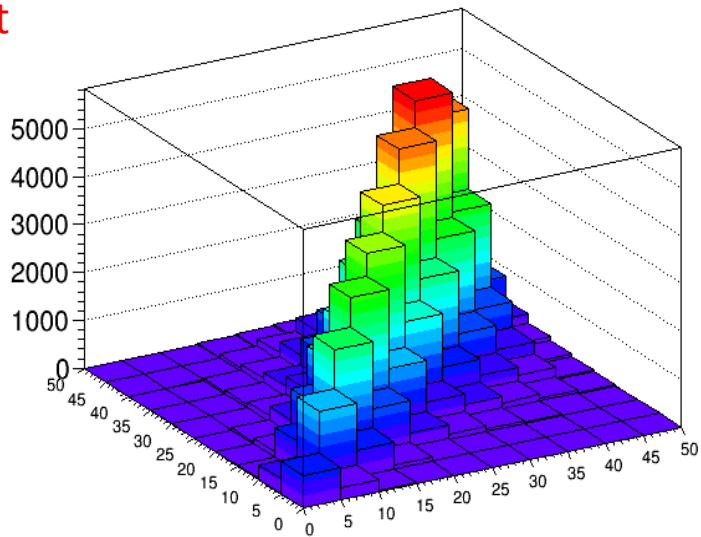
2D Correlation Factor

zbb

cos θ

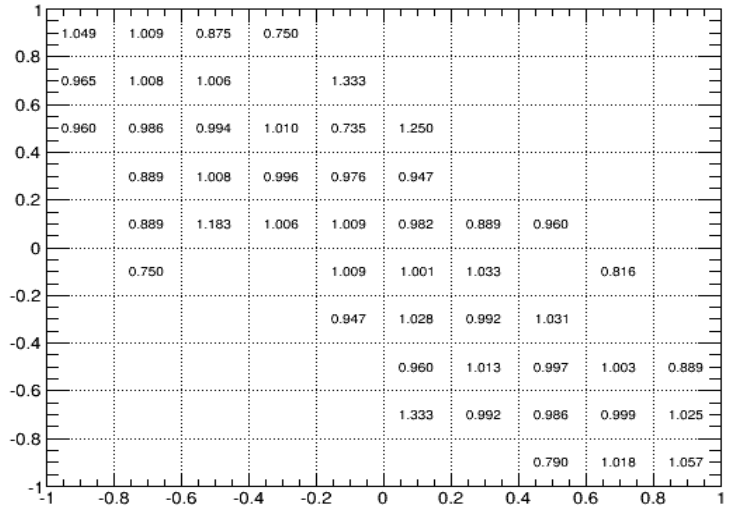
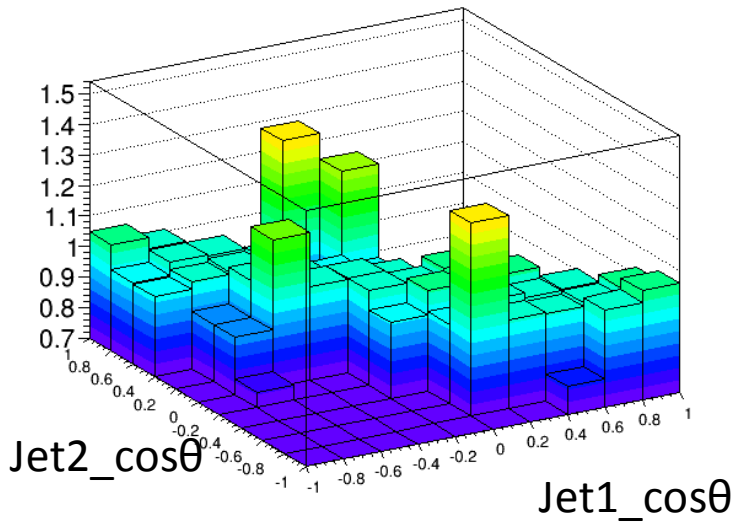


Pt

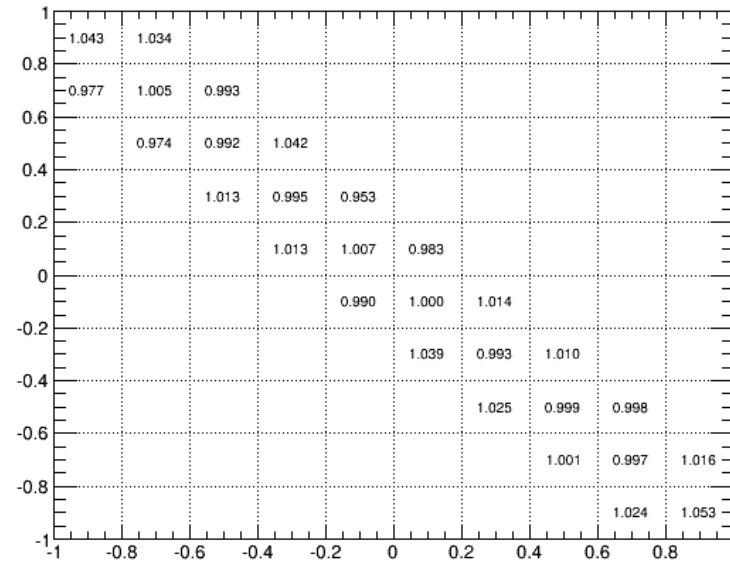
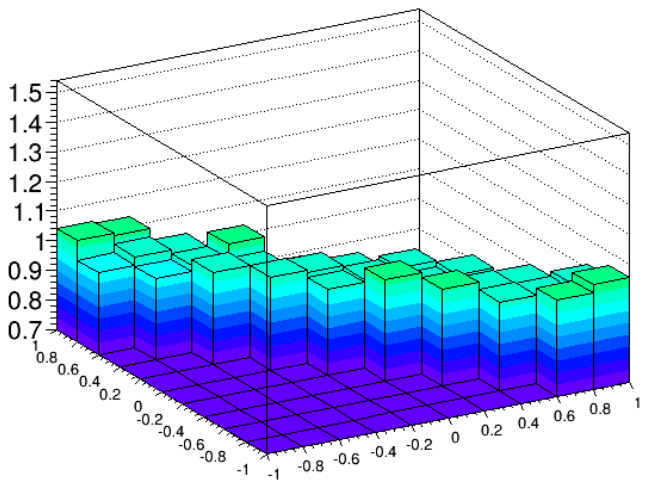


2D Correlation Factor

Zbb Prob>0.7

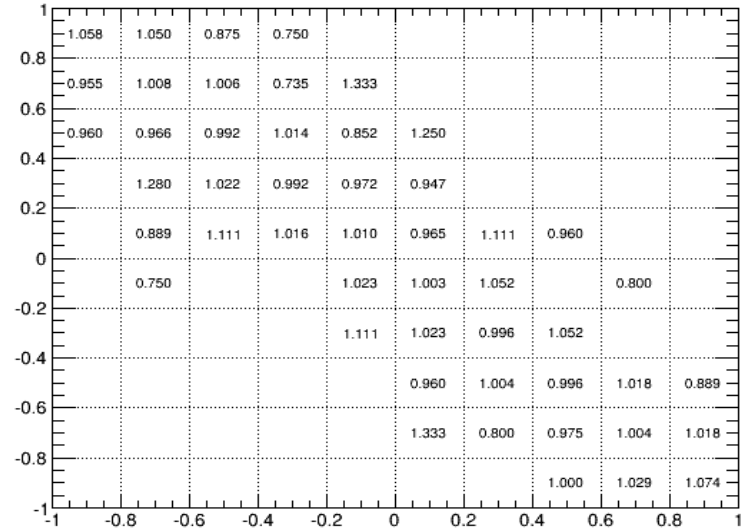
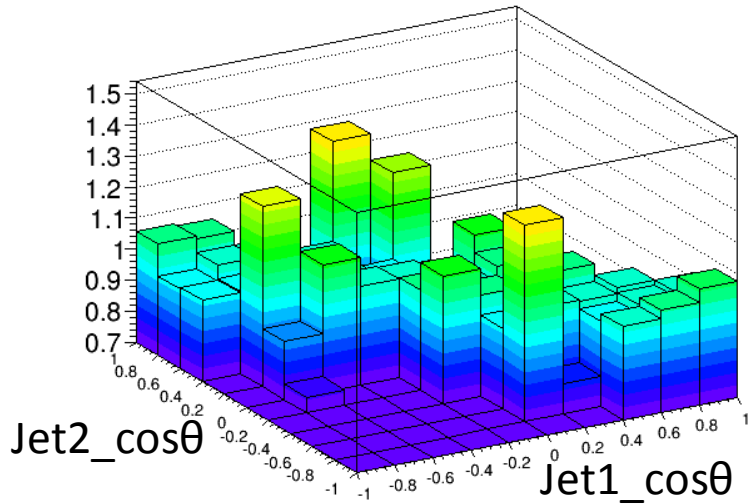


Cut: $180^\circ - \Delta\theta(\text{jet1}, \text{jet2}) < 5^\circ$

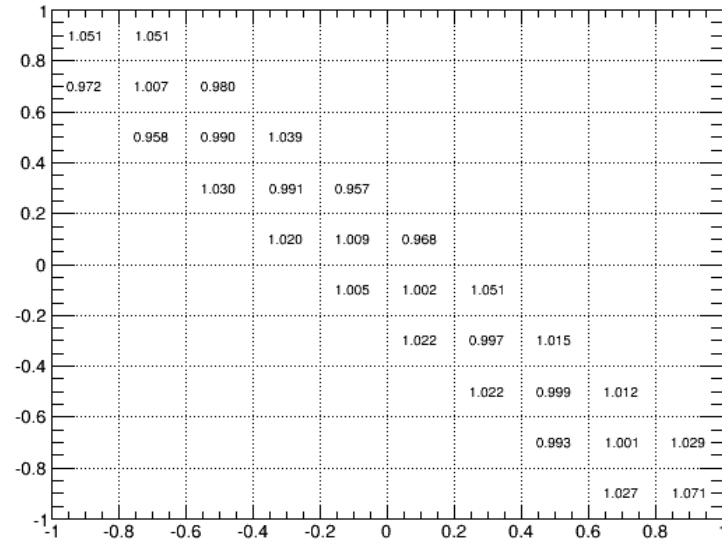
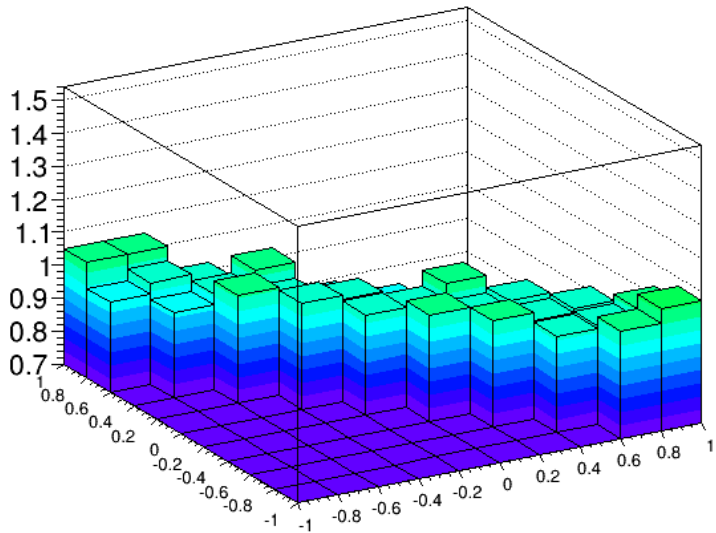


2D Correlation Factor

Zbb Prob>0.8

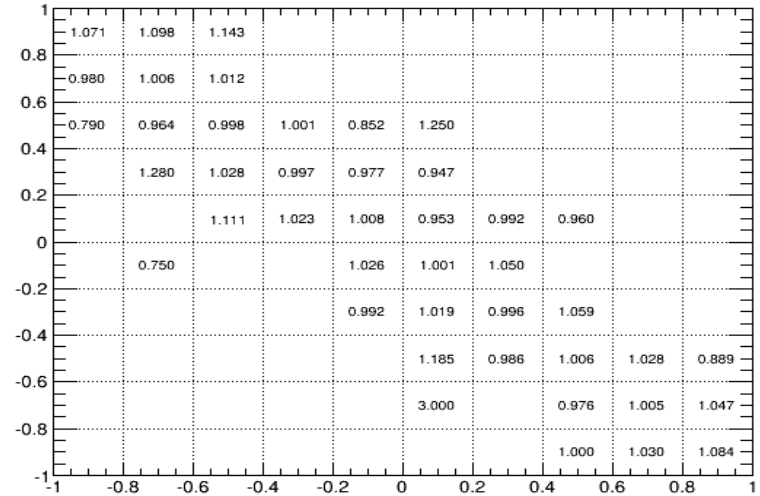
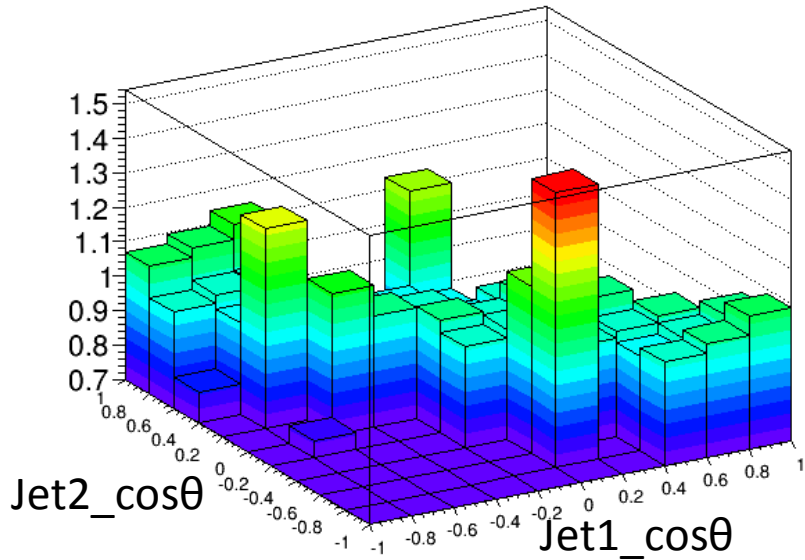


Cut: $180^\circ - \Delta\theta(\text{jet1}, \text{jet2}) < 5^\circ$

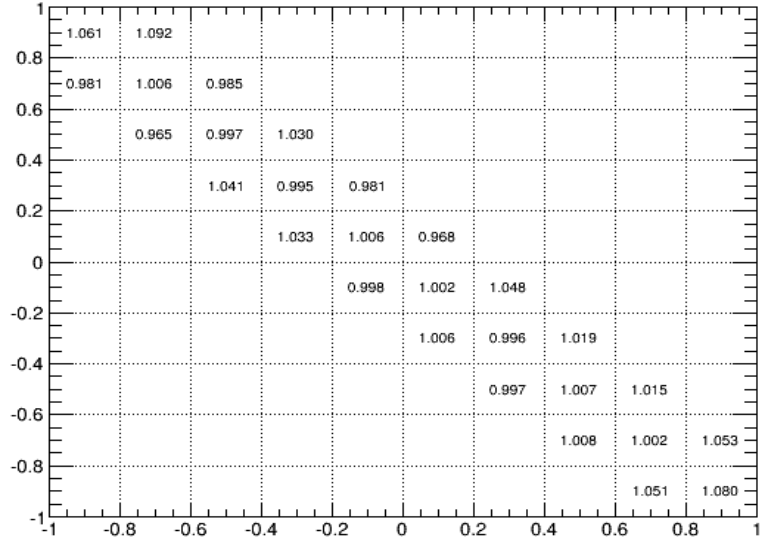
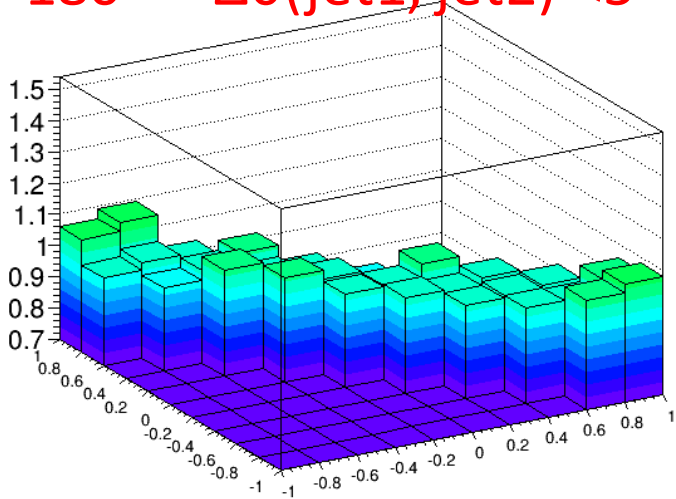


2D Correlation Factor

Zbb Prob>0.9

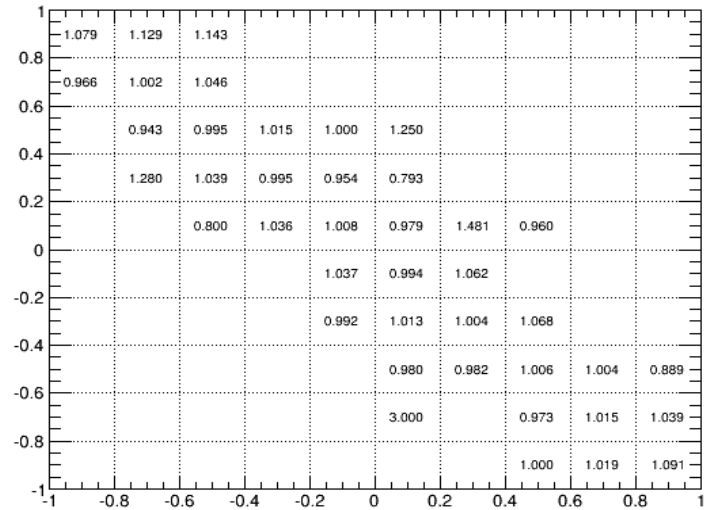
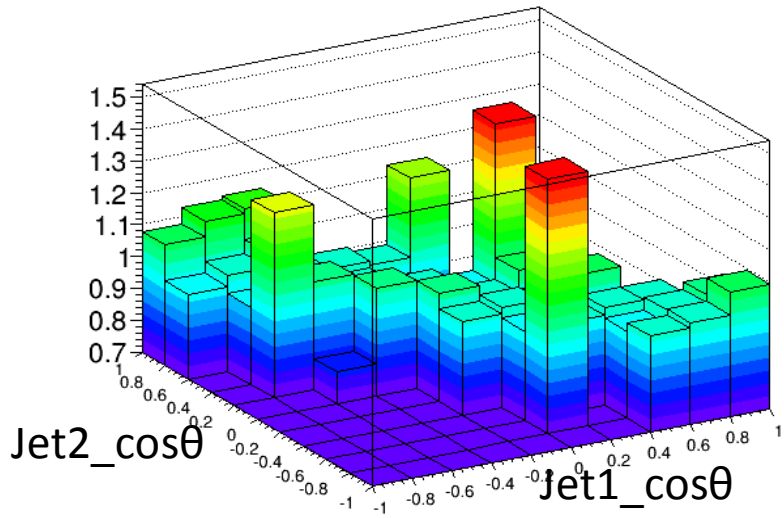


Cut: $180^\circ - \Delta\theta(\text{jet1}, \text{jet2}) < 5^\circ$

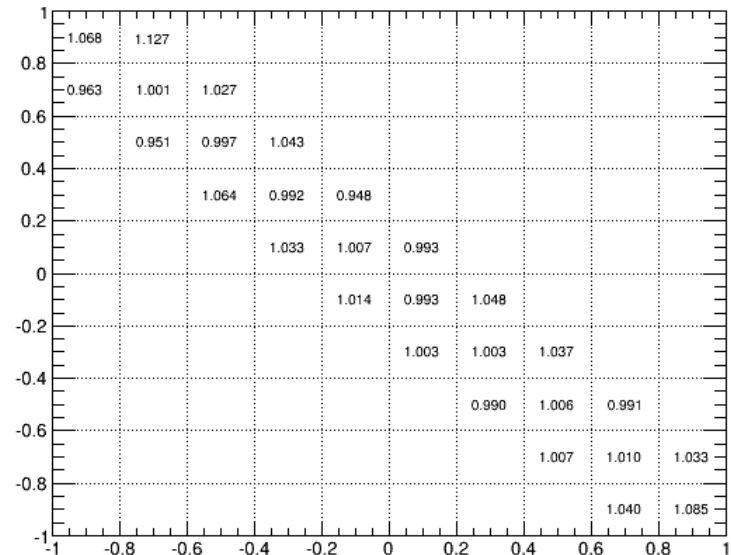
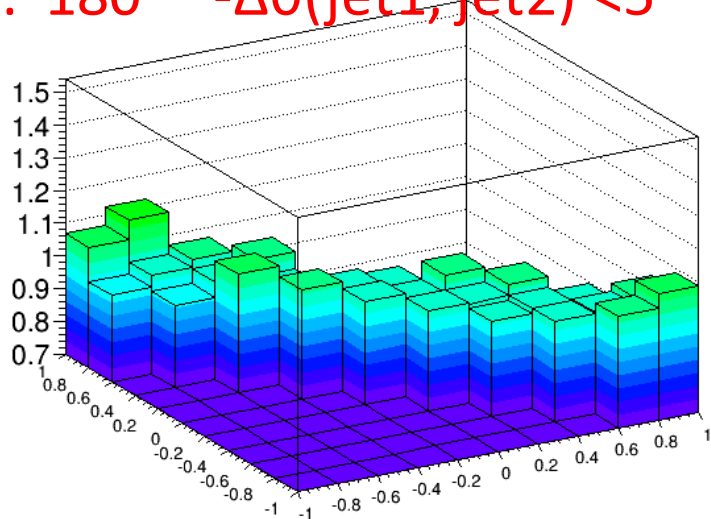


2D Correlation Factor

Zbb Prob>0.95

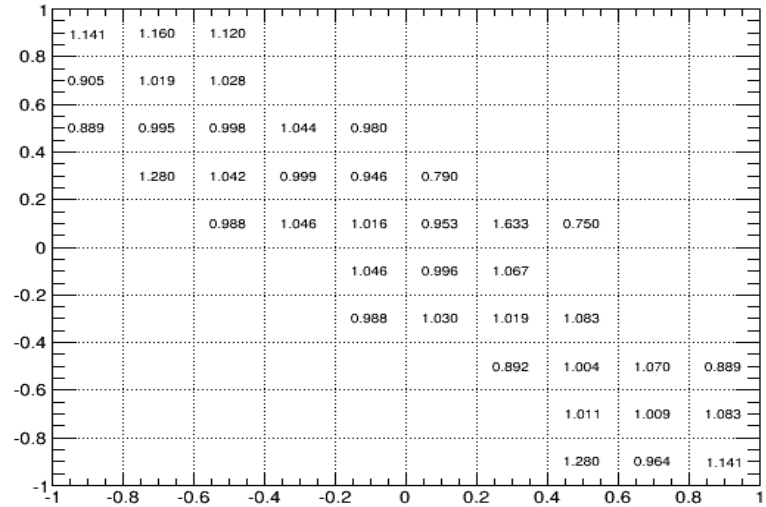
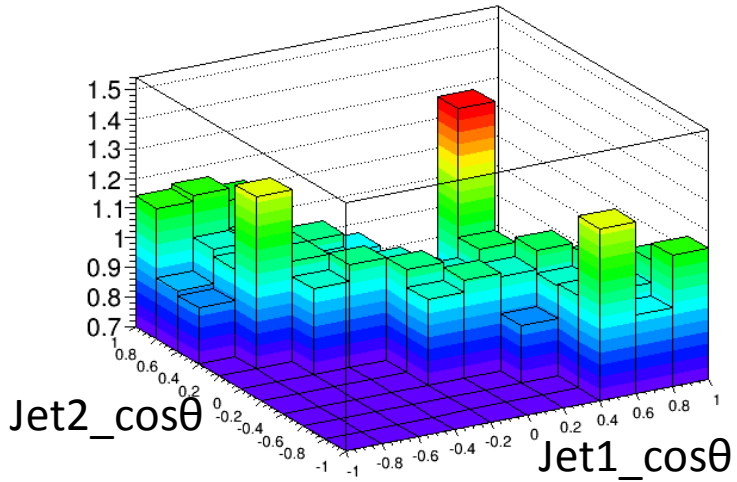


Cut: $180^\circ - \Delta\theta(\text{jet1}, \text{jet2}) < 5^\circ$

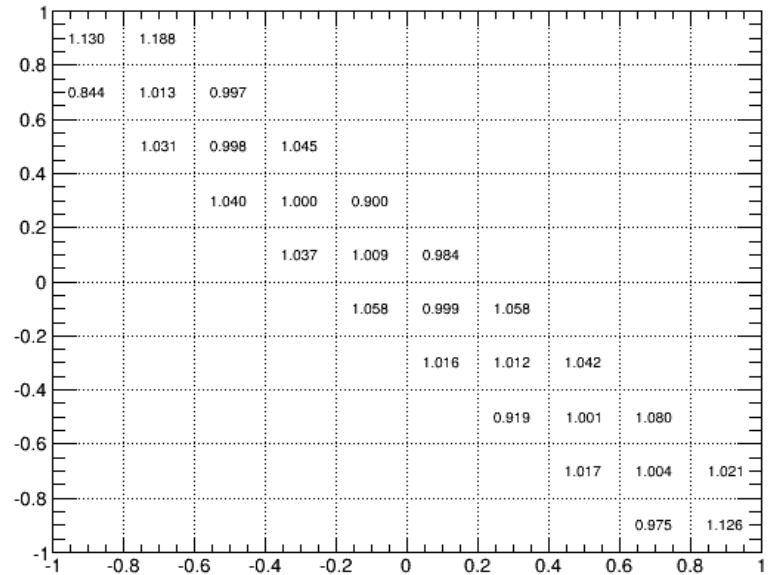
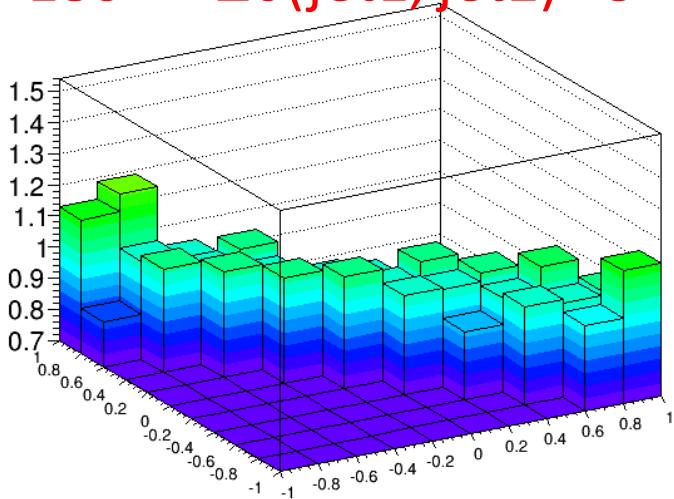


2D Correlation Factor

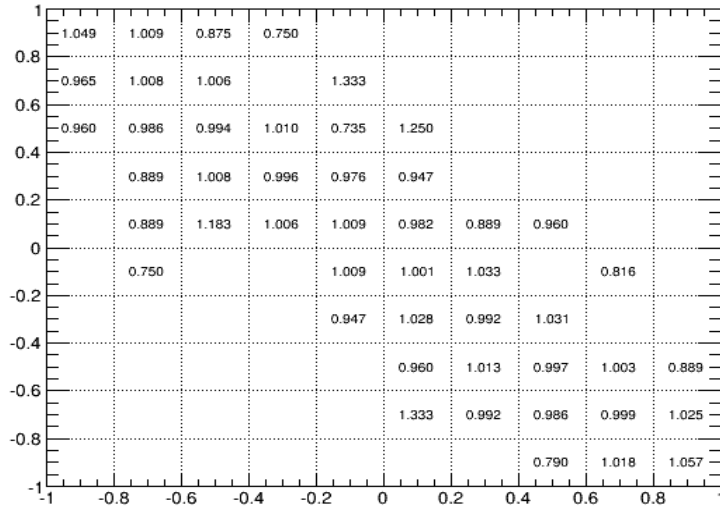
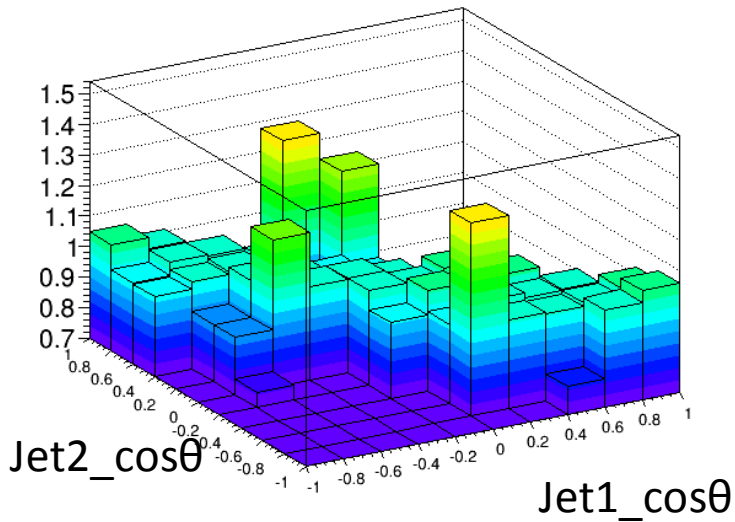
Zbb Prob>0.99



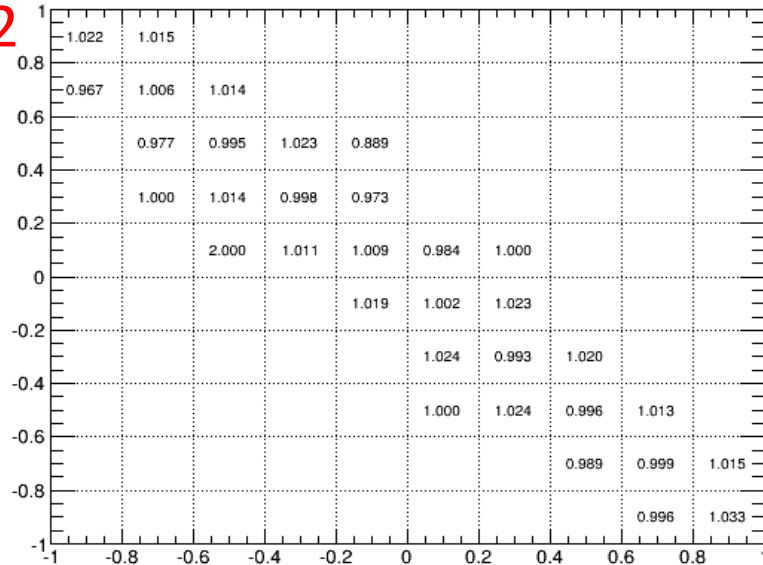
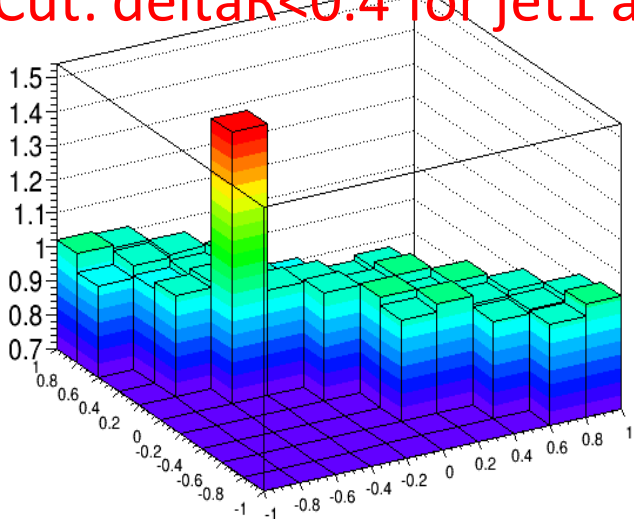
Cut: $180^\circ - \Delta\theta(\text{jet1}, \text{jet2}) < 5^\circ$



backup

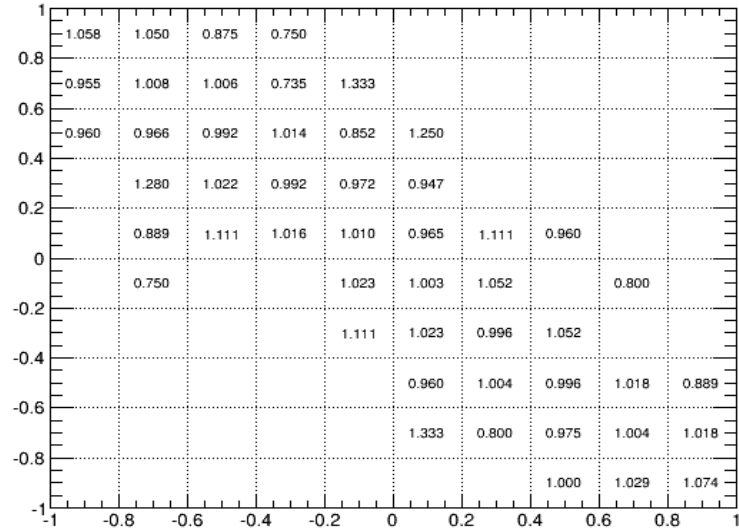
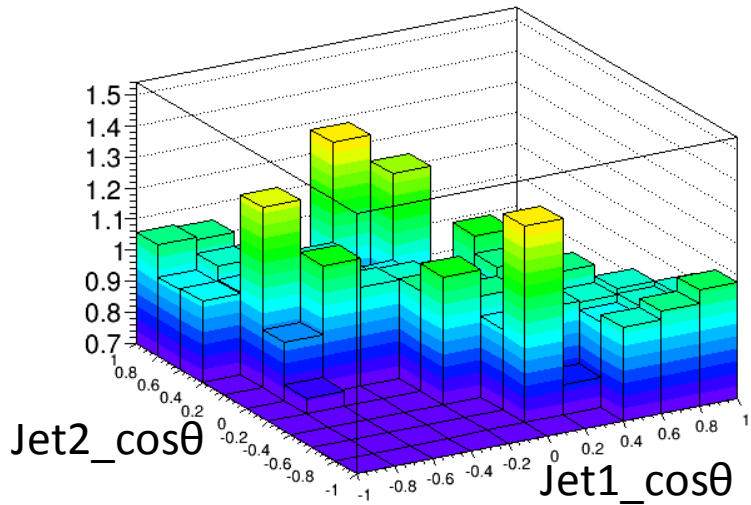


Cut: $\Delta R < 0.4$ for jet1 and jet2

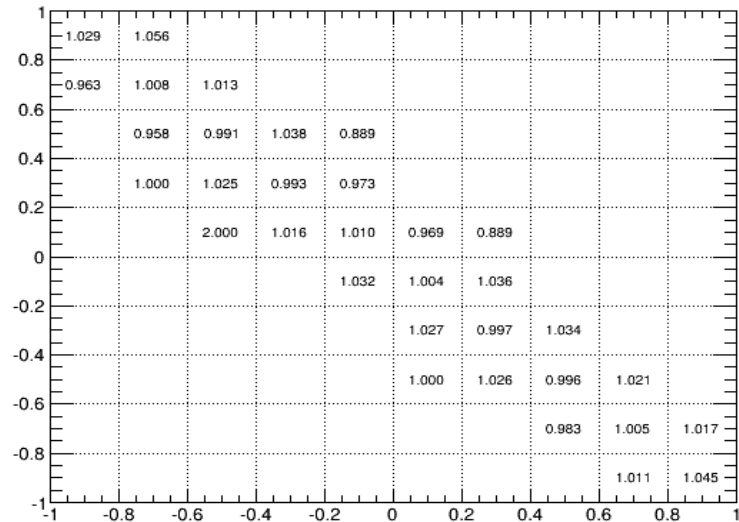
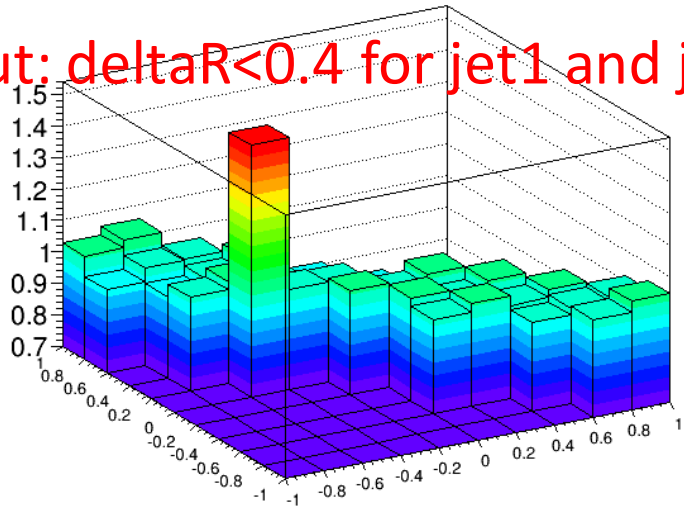


2D Correlation Factor

Zbb Prob>0.8

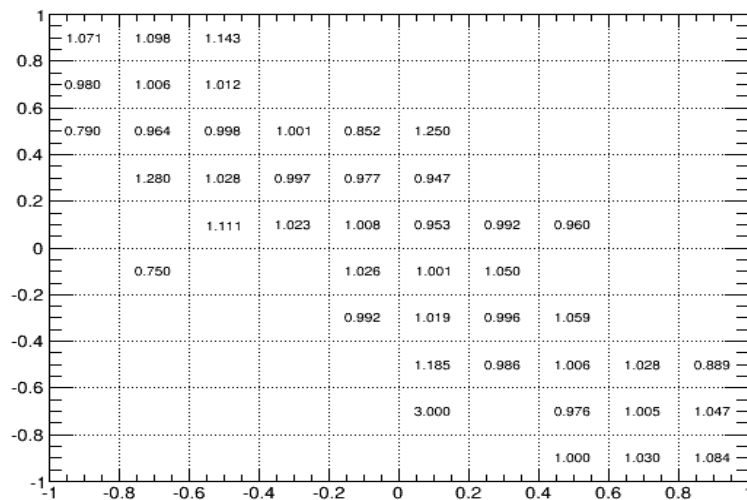
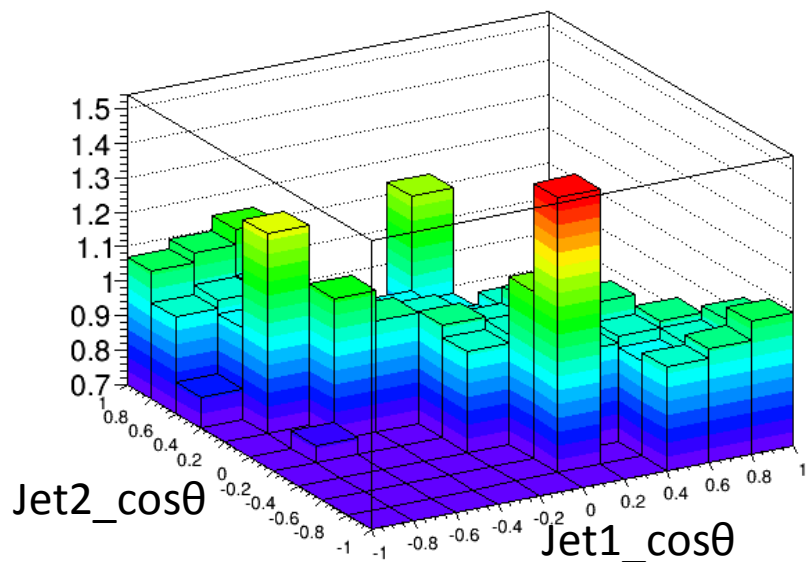


Cut: $\Delta R < 0.4$ for jet1 and jet2

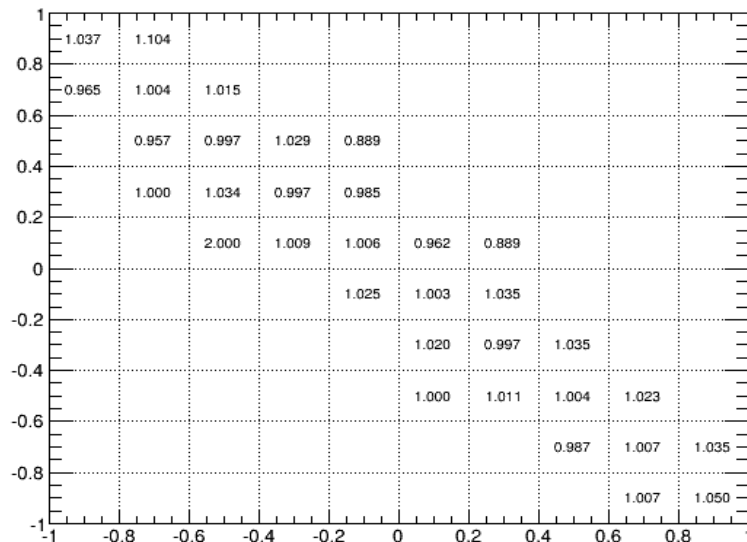
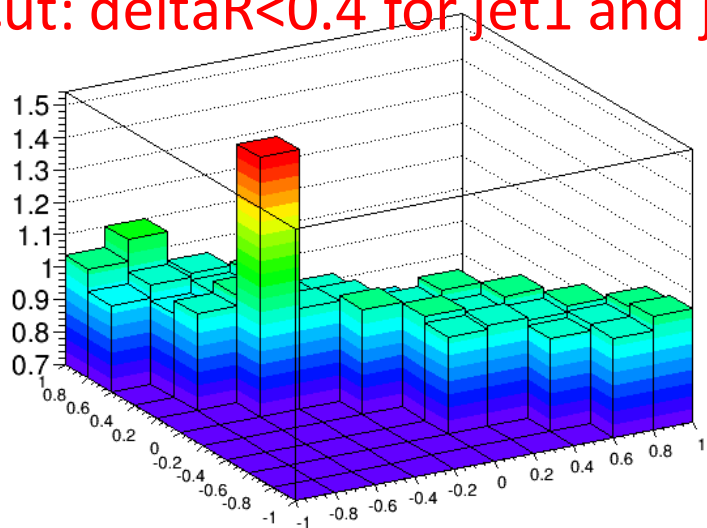


2D Correlation Factor

Zbb Prob>0.9

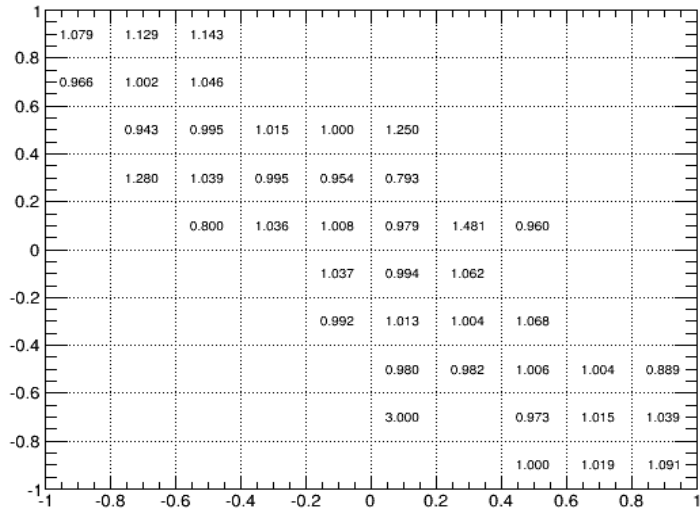
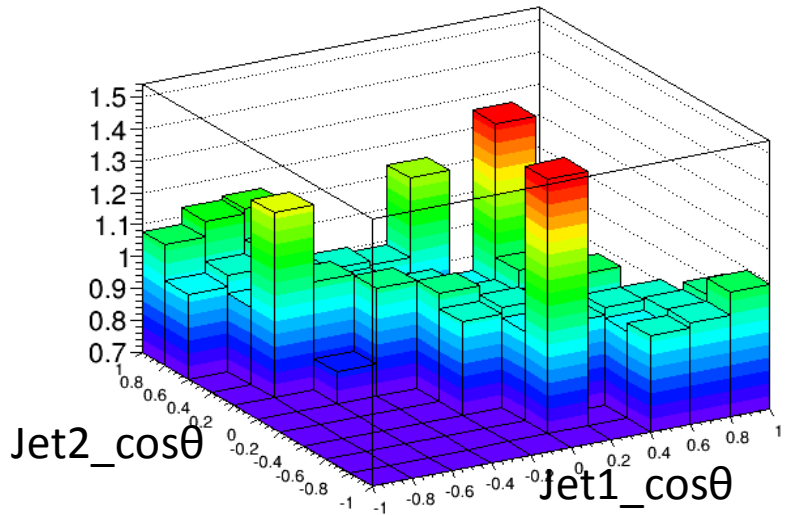


Cut: $\Delta R < 0.4$ for jet1 and jet2

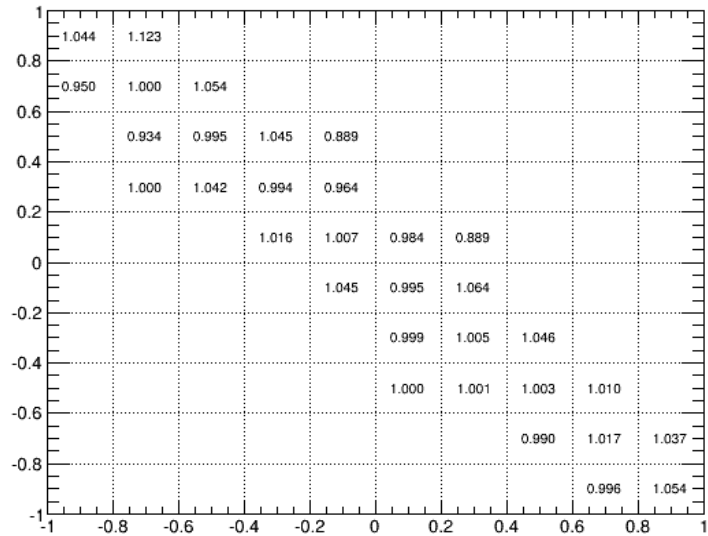
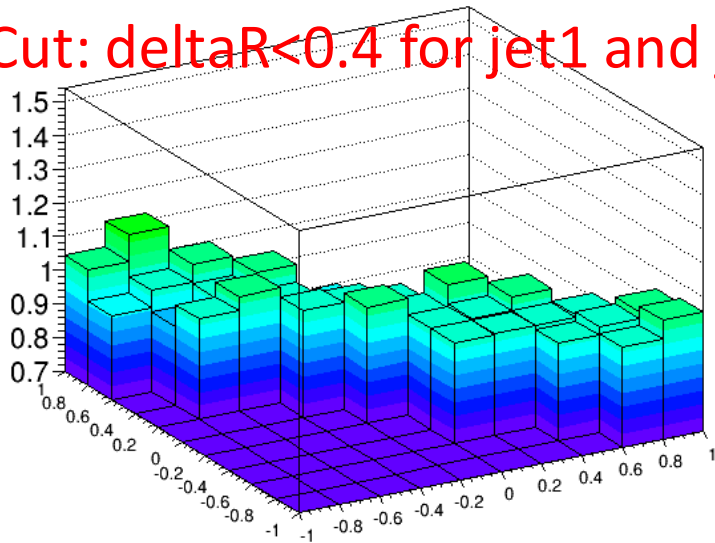


2D Correlation Factor

Zbb Prob>0.95

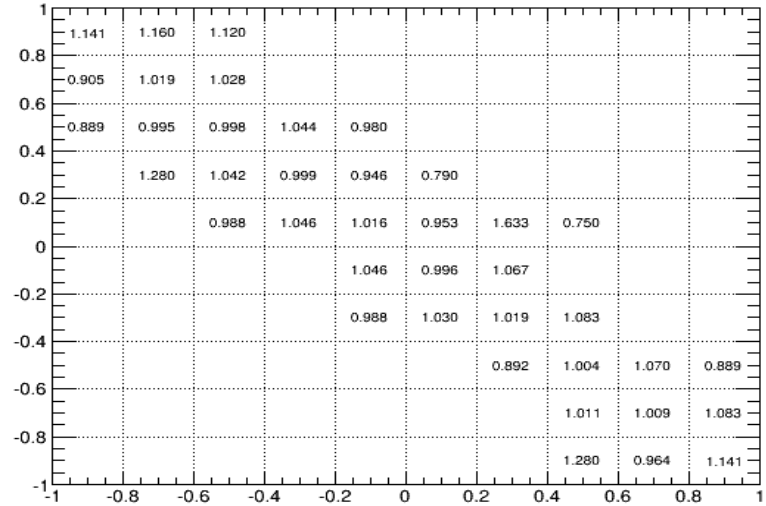
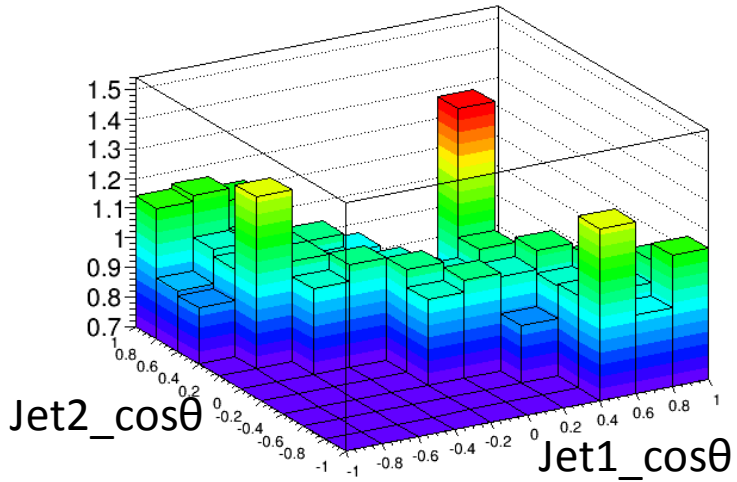


Cut: $\Delta R < 0.4$ for jet1 and jet2

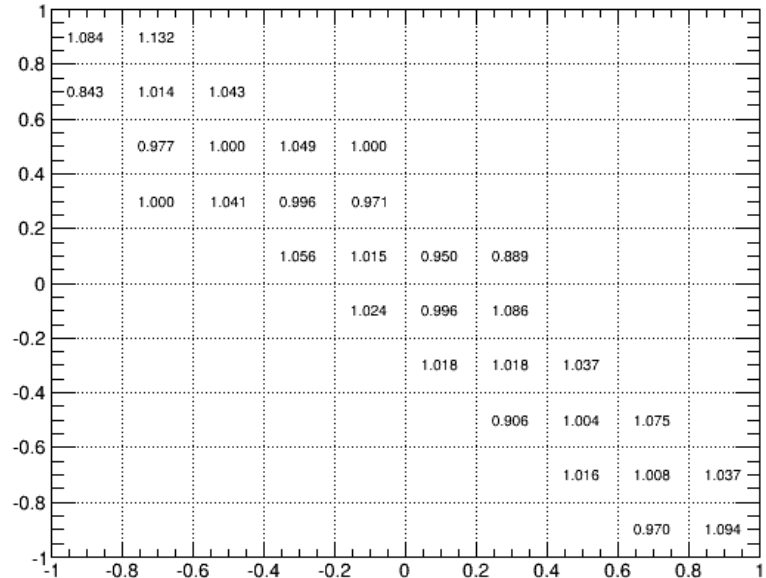
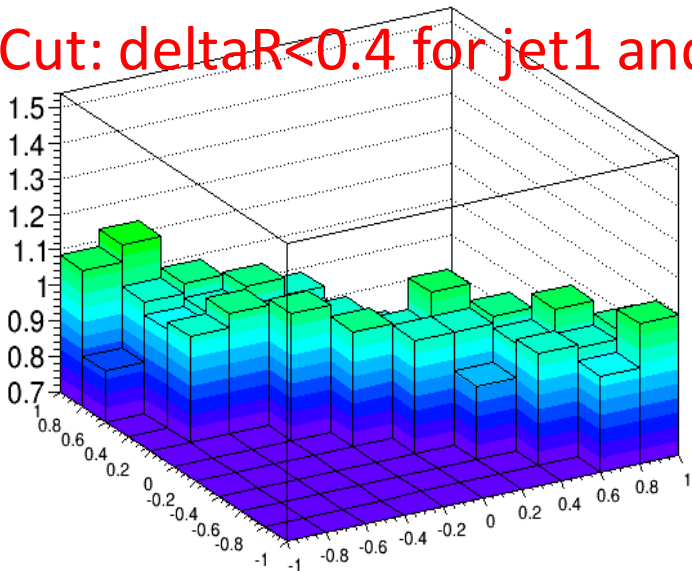


2D Correlation Factor

Zbb Prob>0.99

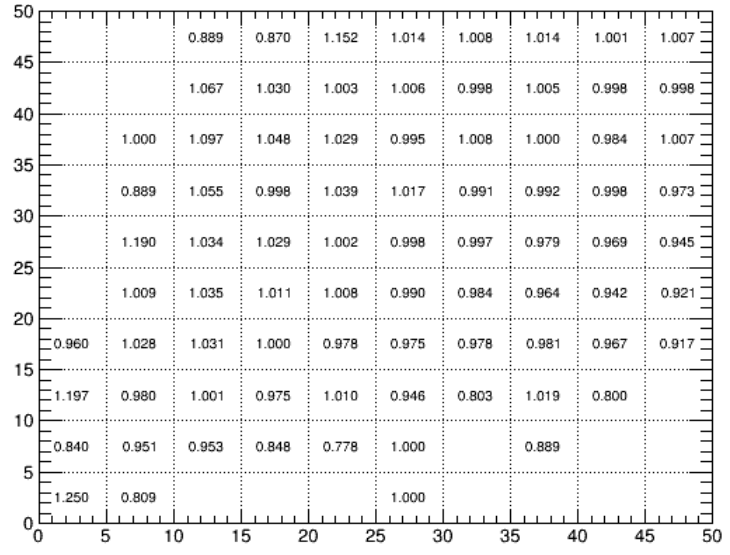
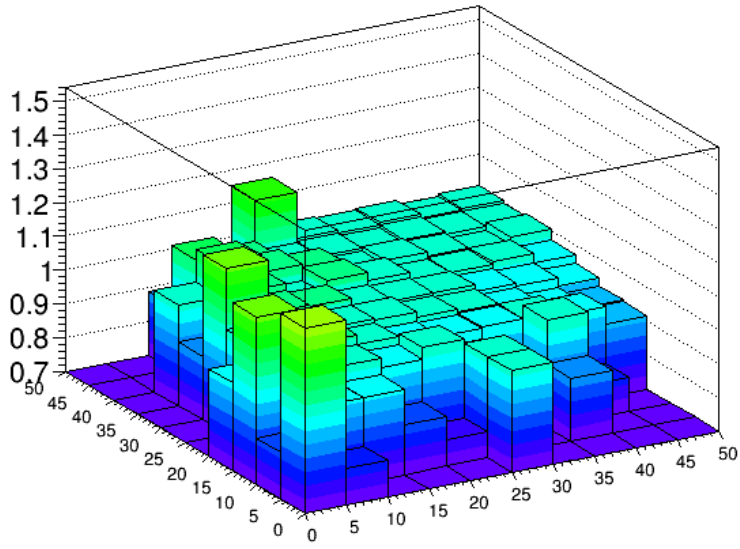
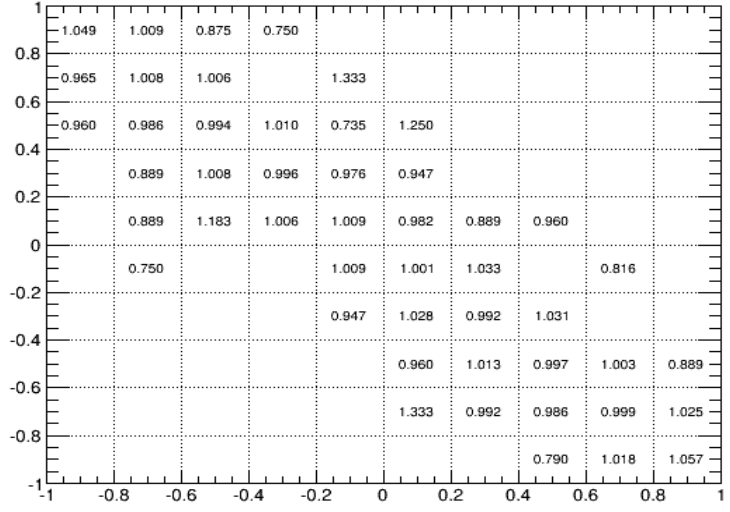
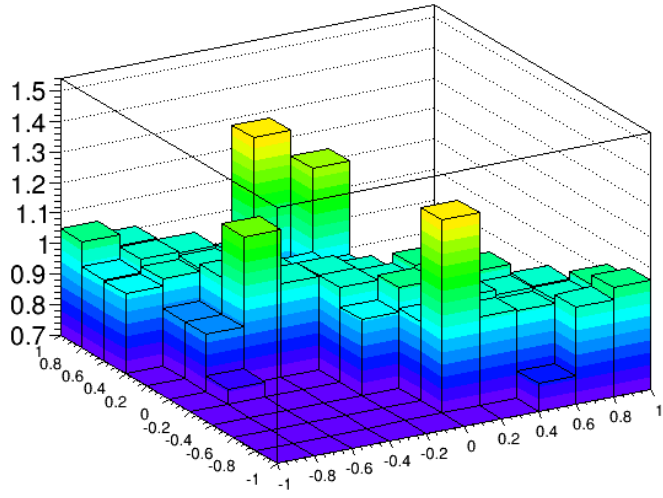


Cut: $\Delta R < 0.4$ for jet1 and jet2



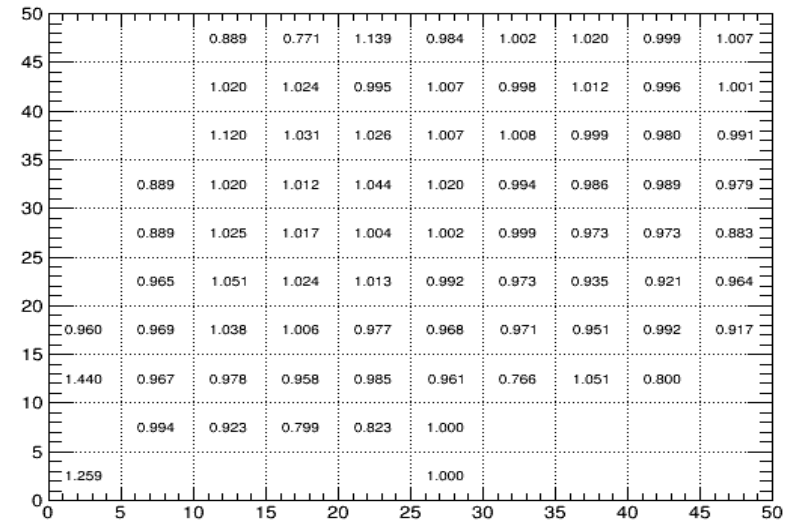
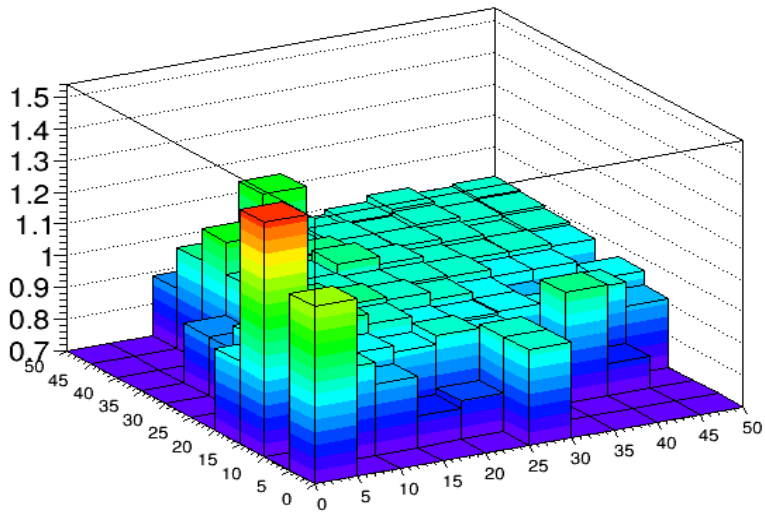
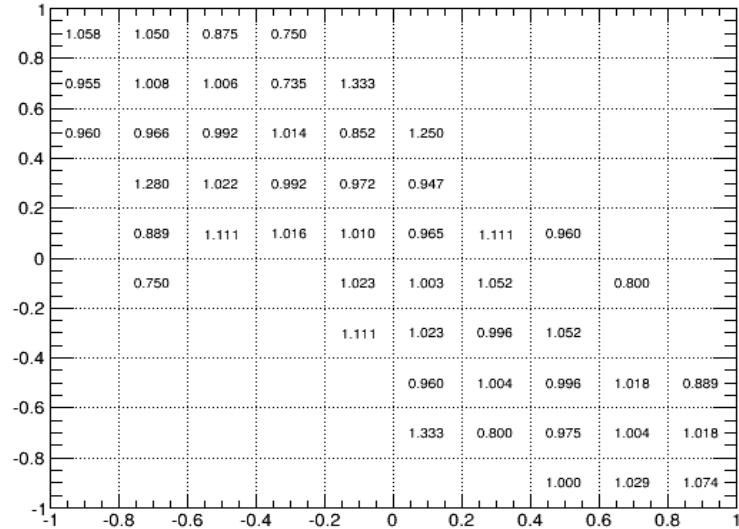
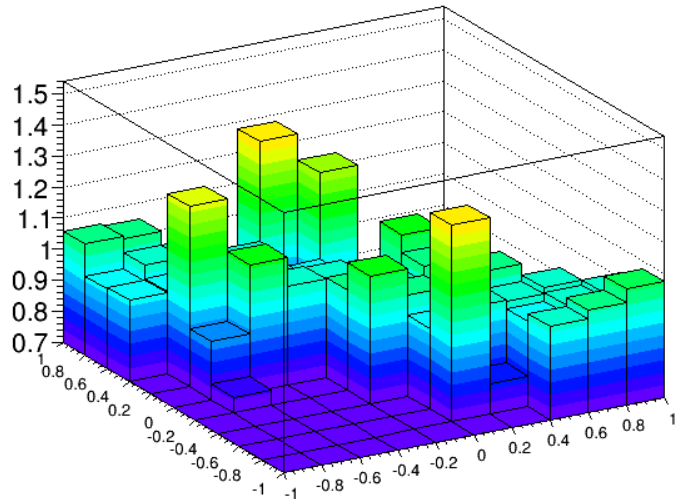
2D Correlation Factor

Zbb Prob>0.7



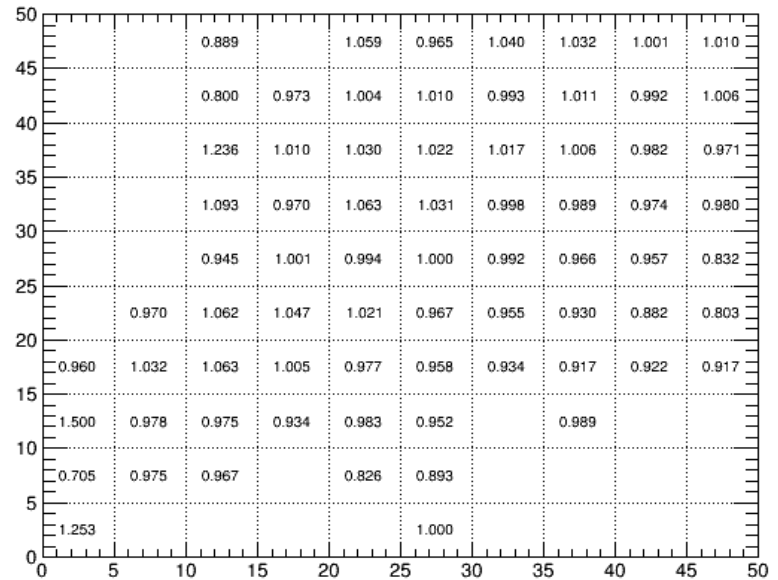
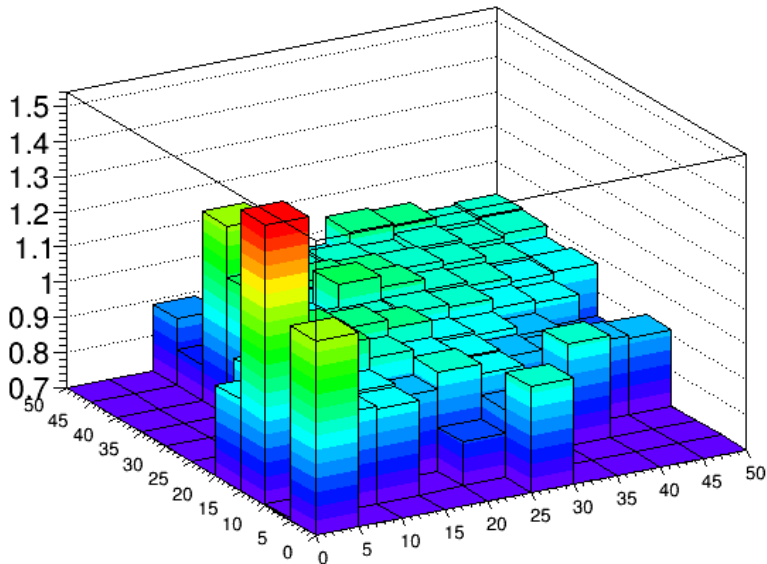
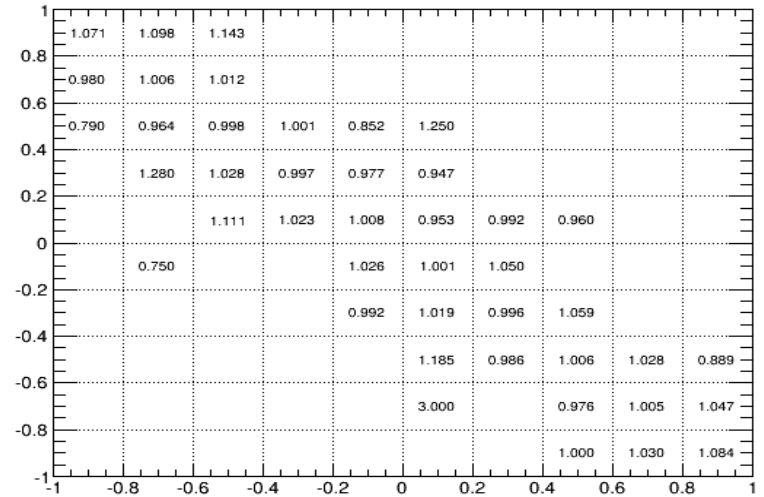
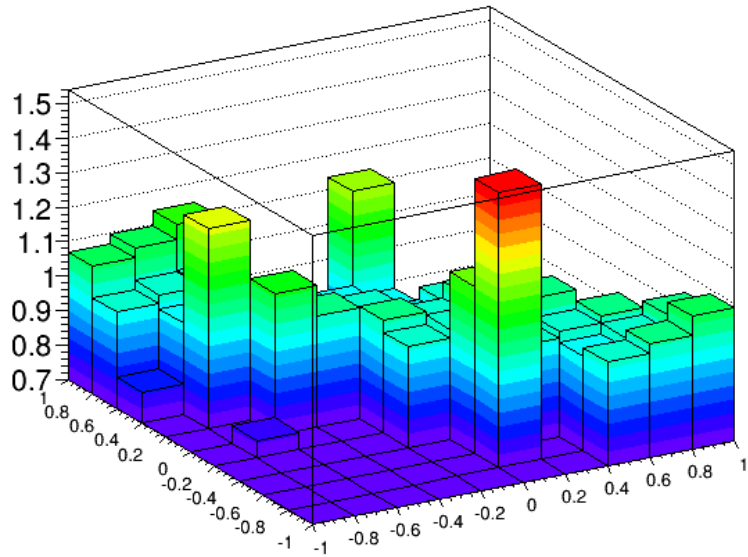
2D Correlation Factor

Zbb Prob>0.8



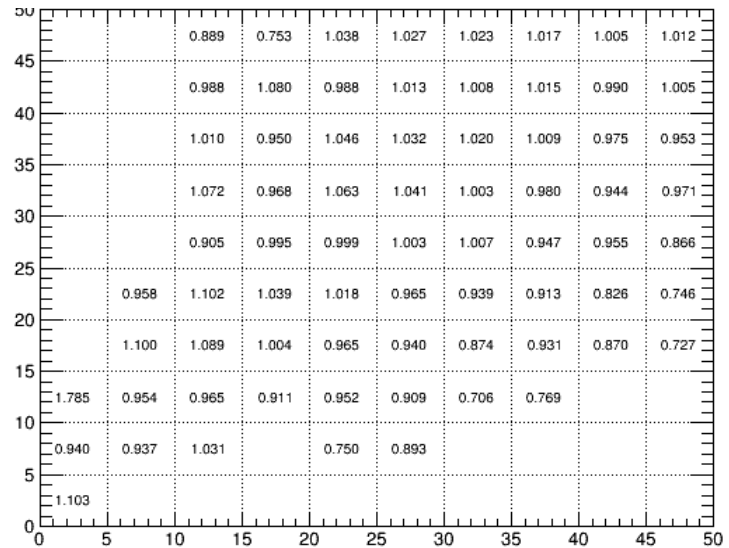
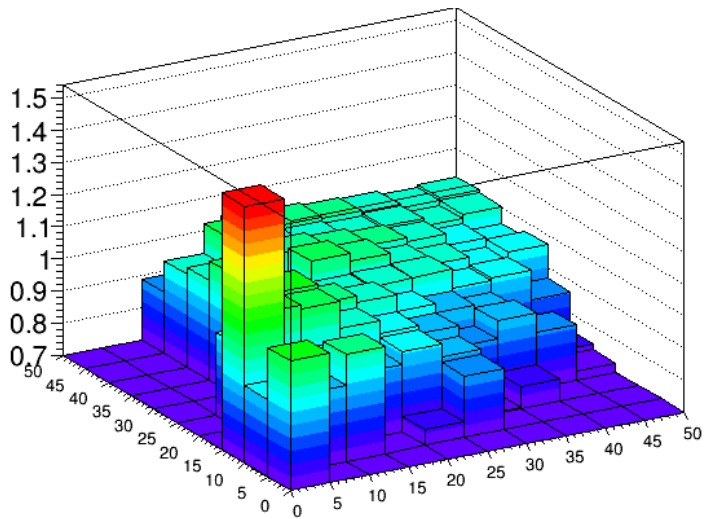
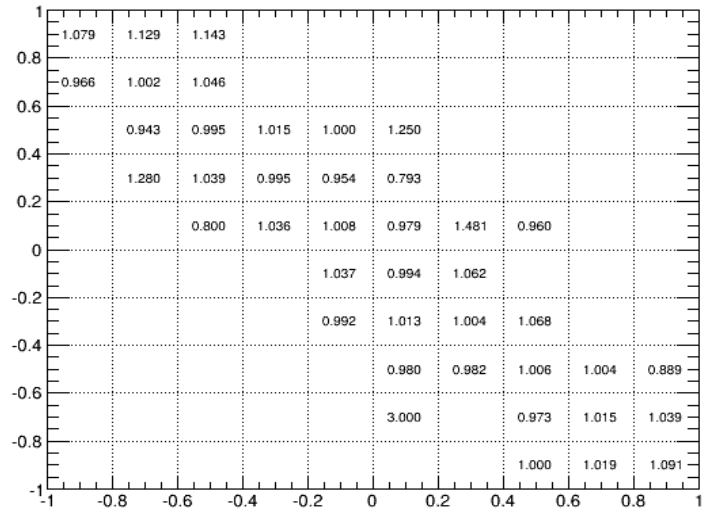
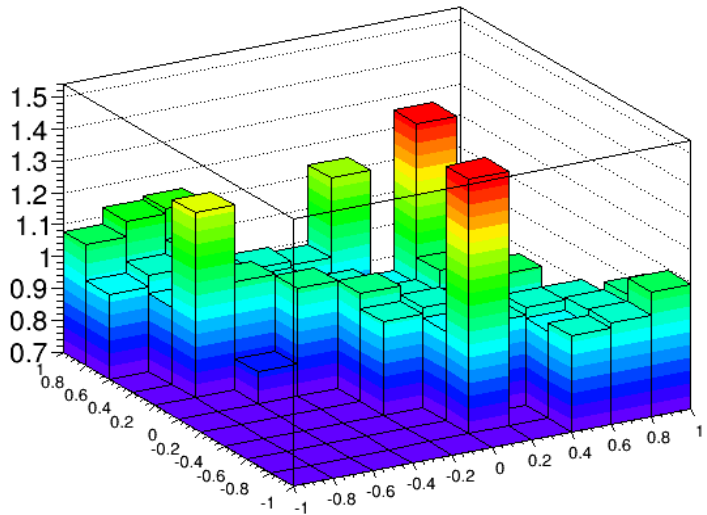
2D Correlation Factor

Zbb Prob>0.9



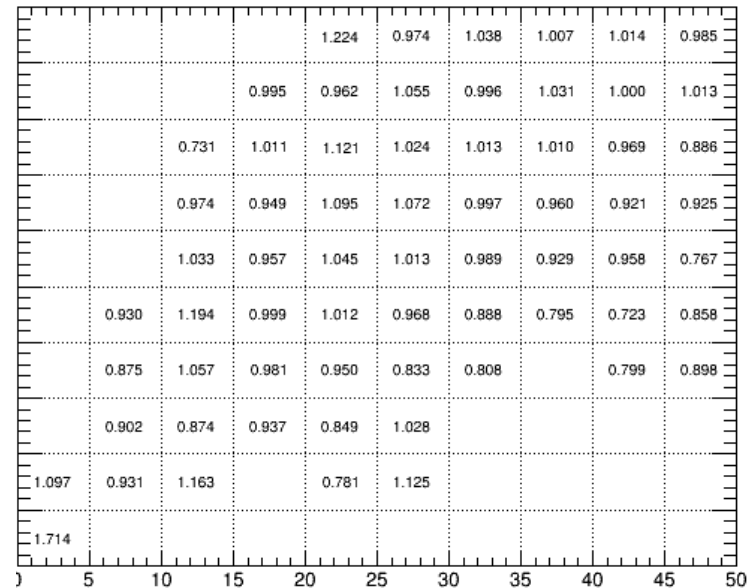
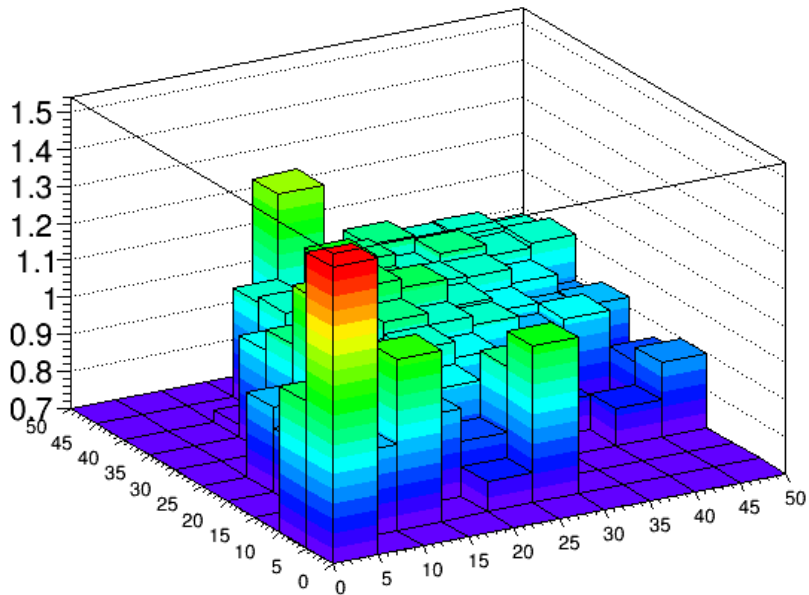
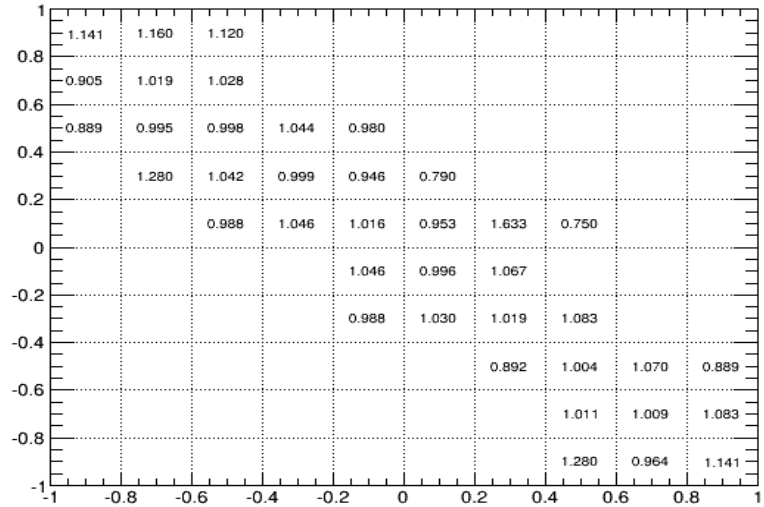
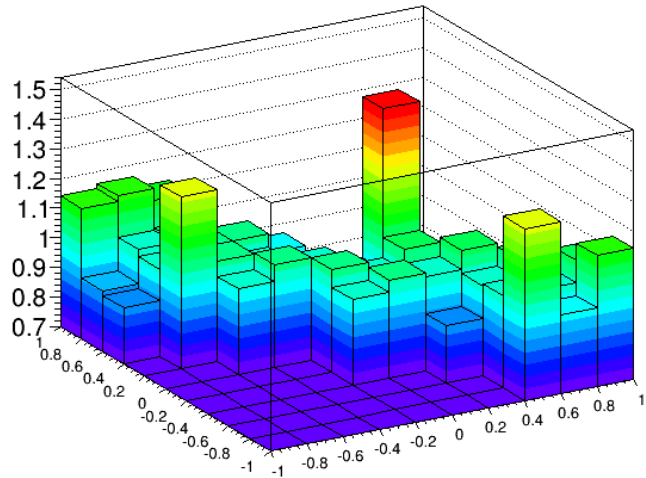
2D Correlation Factor

Zbb Prob>0.95

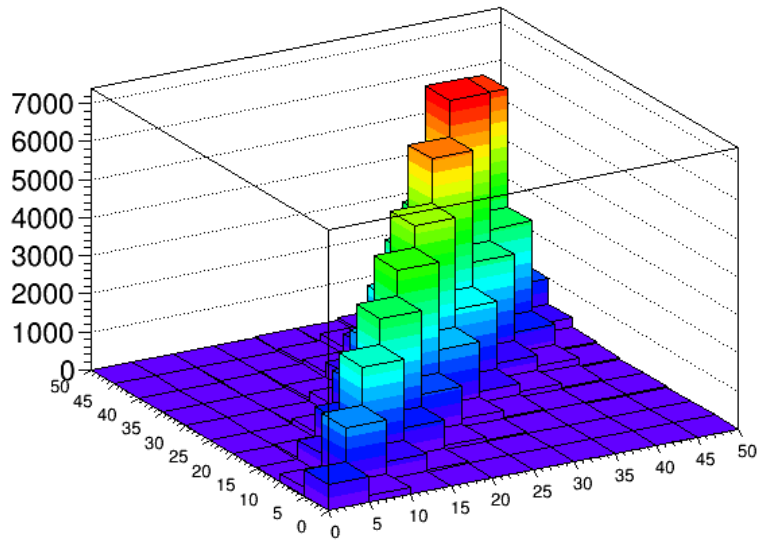
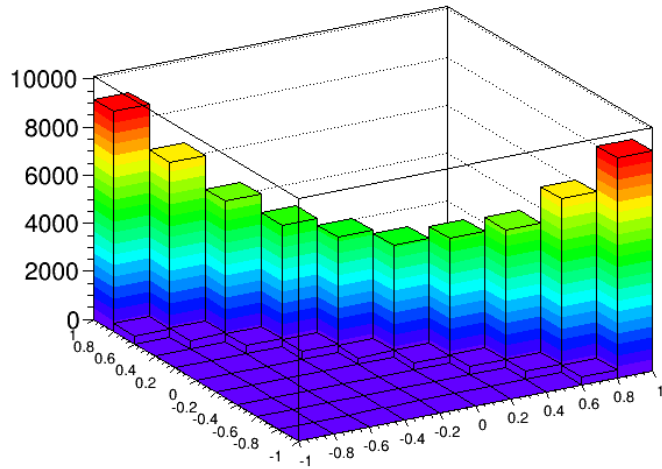


2D Correlation Factor

Zbb Prob>0.99



2D Correlation Factor

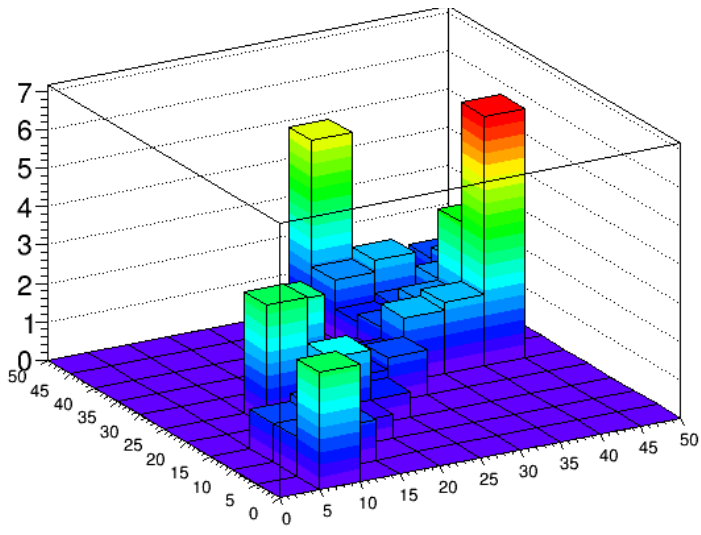
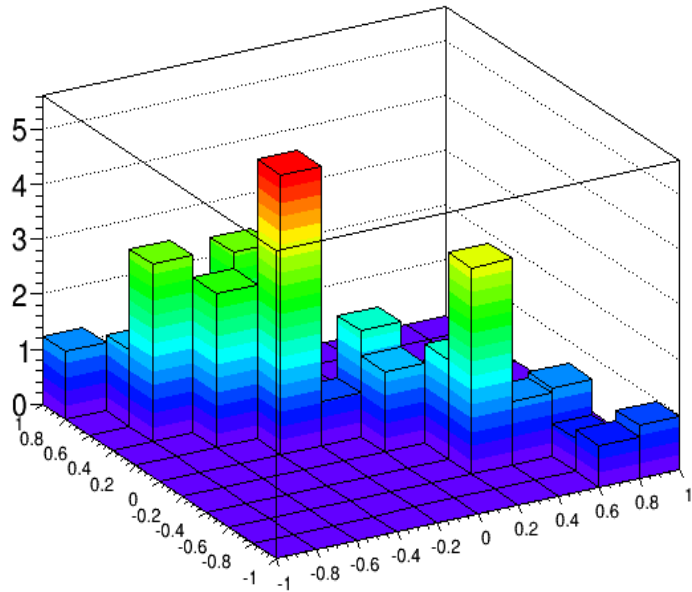


ZCC

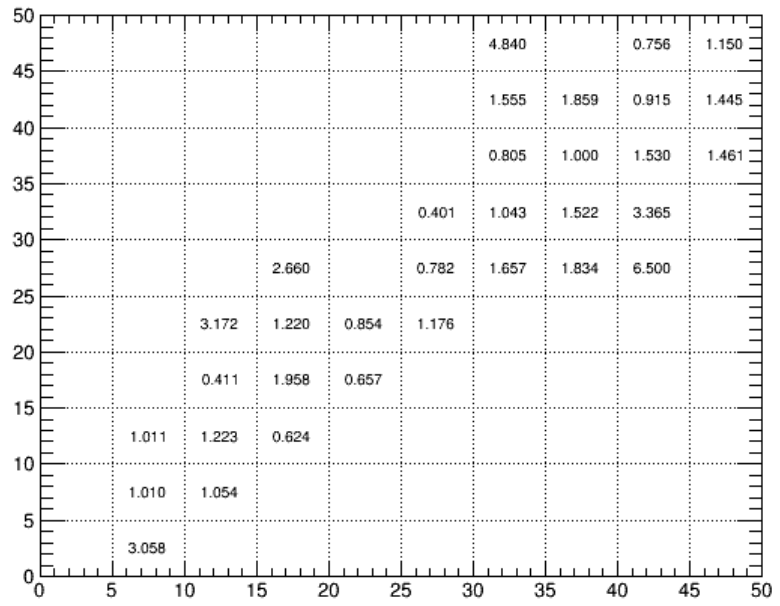
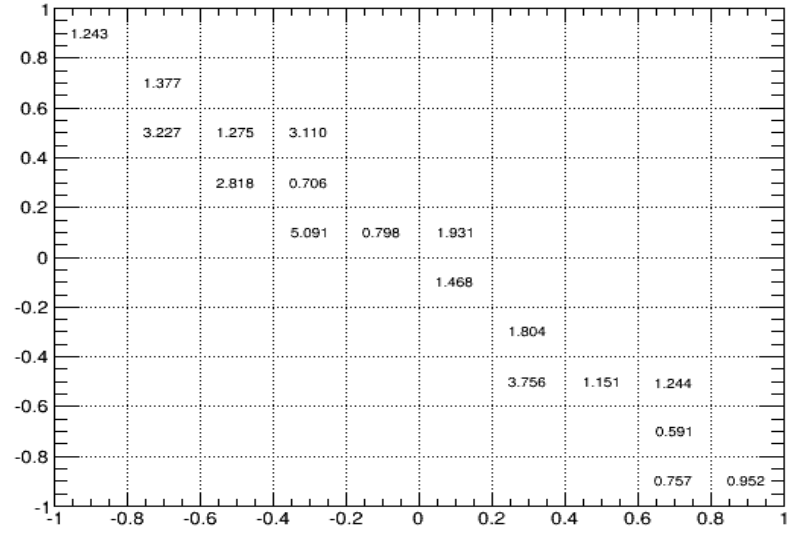
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0.8											
0.6	335	7260	374	3	2						
0.4	1	363	5866	311	2						
0.2		4	341	5073	270	2					
0	1		4	308	4774	278	4				
-0.2	2		2	3	277	4640	301	4	3	1	
-0.4				1	1	294	5146	311	3		
-0.6		1				1	2	339	5727	381	2
-0.8						1	1	2	349	7238	309
-1			1		1	1		7	334	9128	

50				3	9	30	98	335	1035	415	
45											
40		1	7	14	75	267	787	3287	6212	1016	
35		1	7	38	172	627	2903	6701	3096	351	
30			11	83	459	2255	5751	2806	742	89	
25		1	28	266	1692	4574	2157	530	234	30	
20		11	134	1208	3992	1676	375	145	54	6	
15	3	46	813	3292	1078	224	62	22	9	2	
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5	225	1584	481	44	7	3		1			
0	678	172	10								

2D Correlation Factor

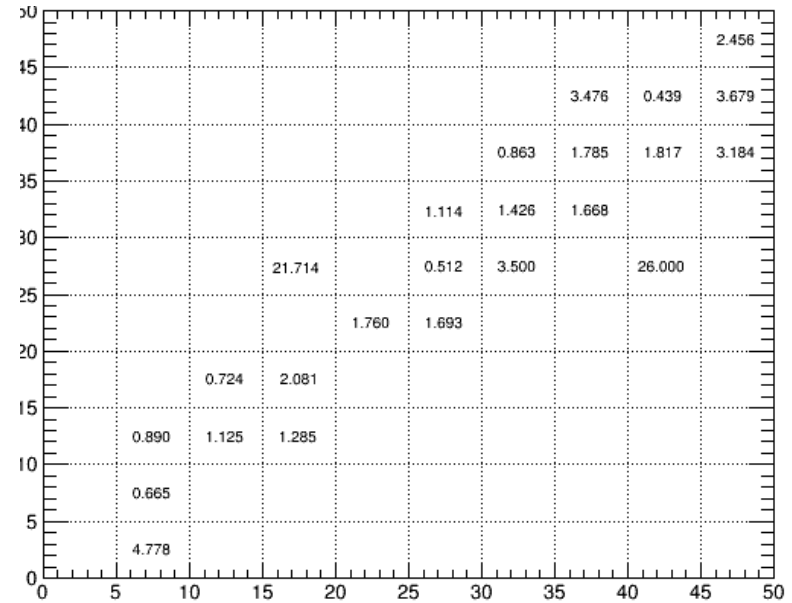
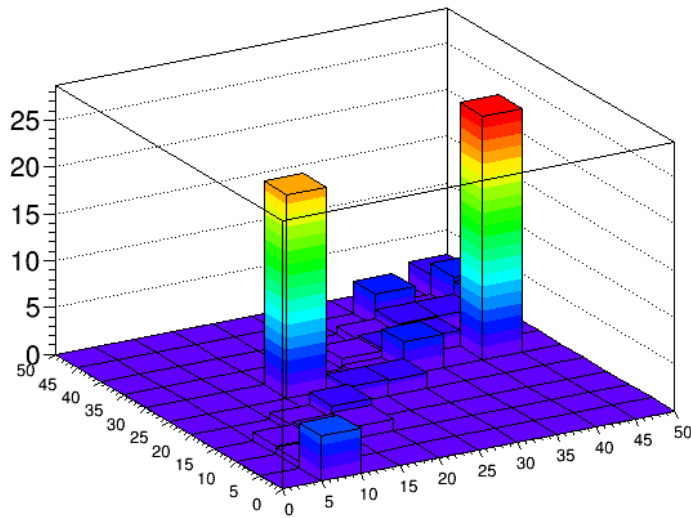
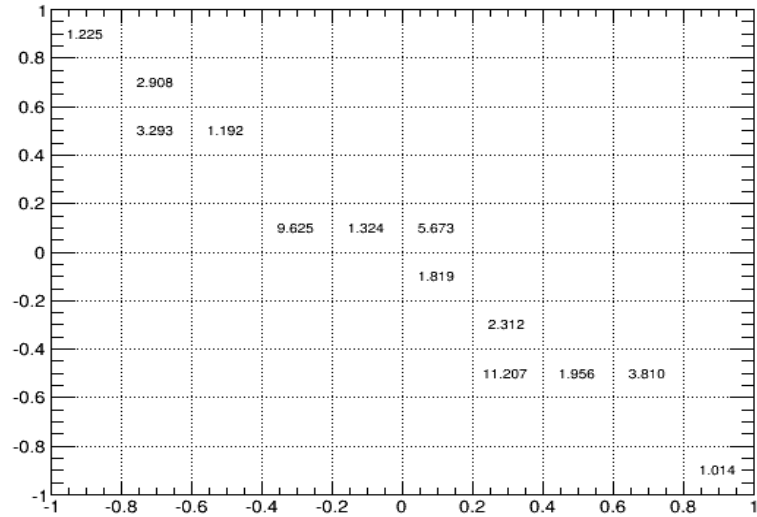
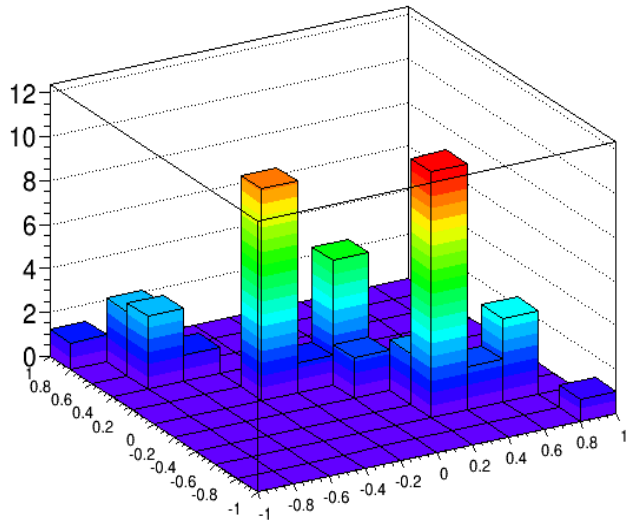


Zcc Prob>0.7



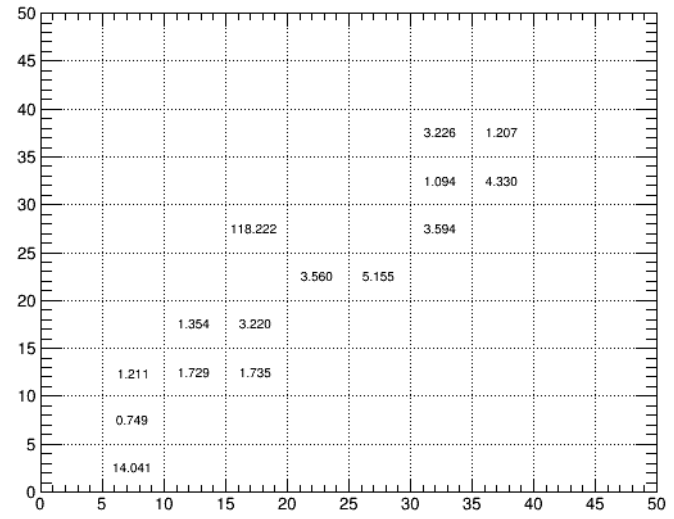
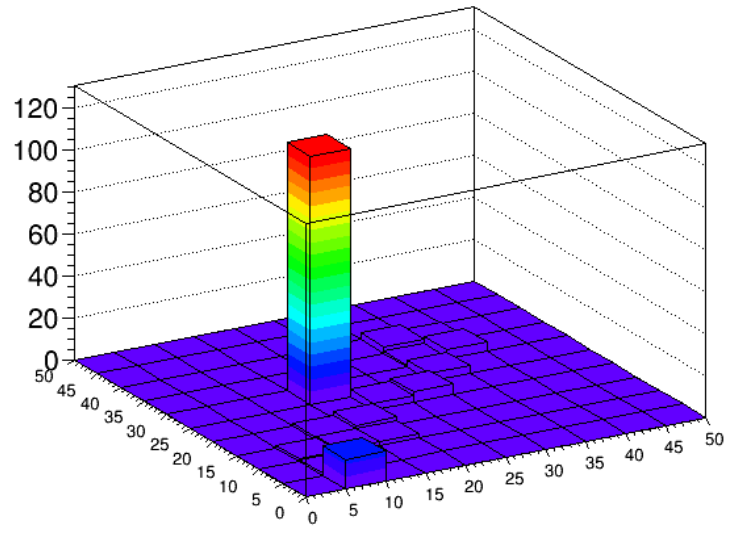
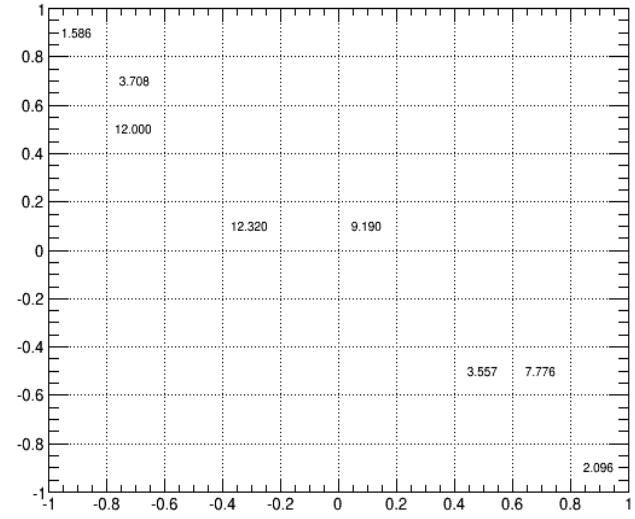
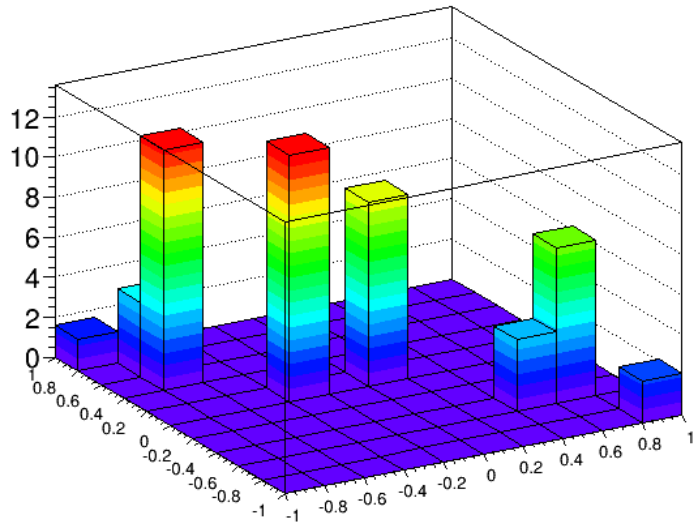
2D Correlation Factor

Zcc Prob>0.8

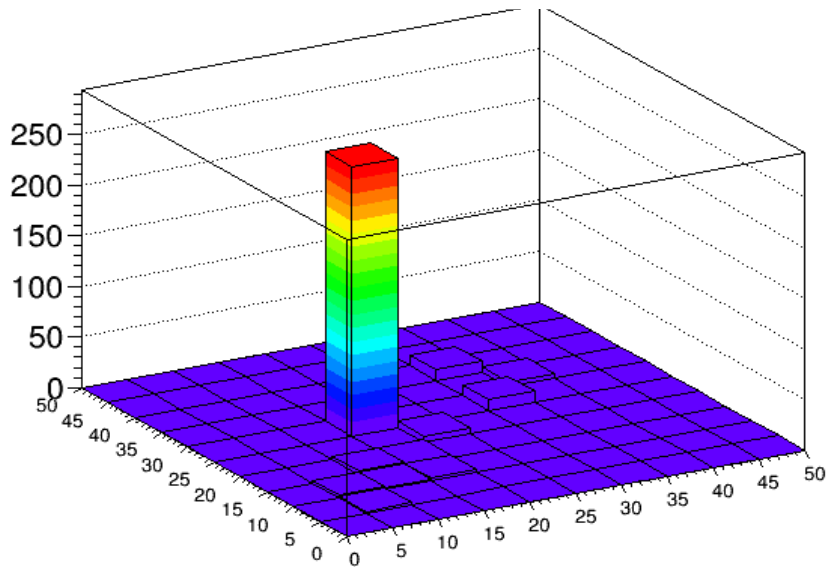
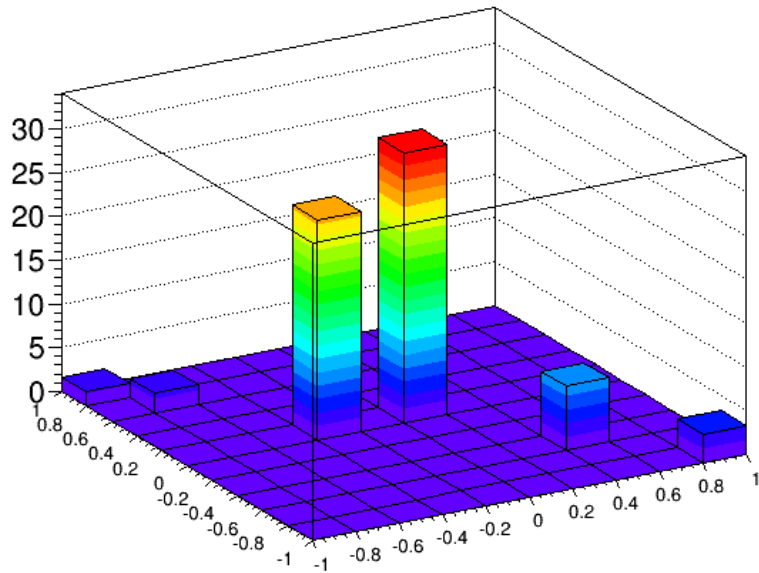


2D Correlation Factor

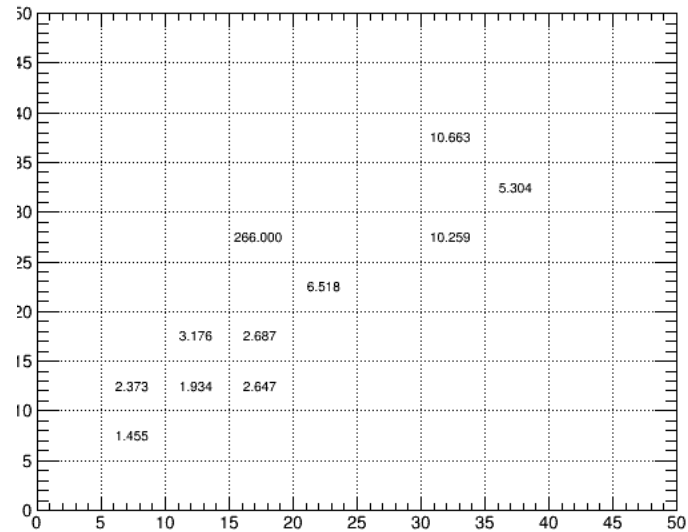
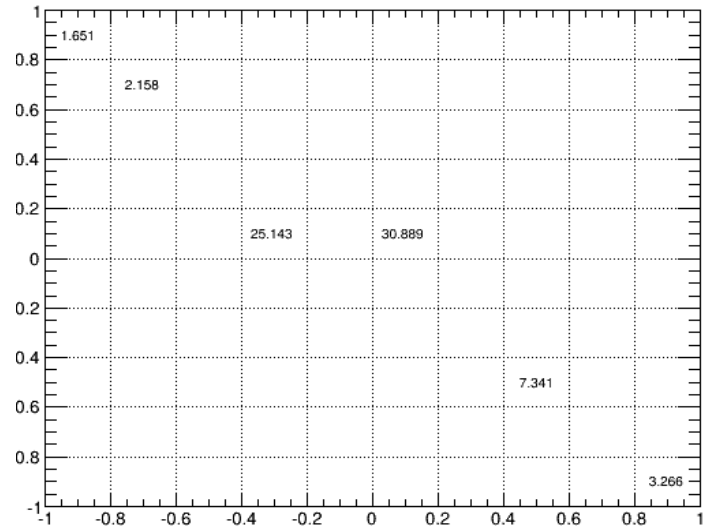
Zcc Prob>0.9



2D Correlation Factor

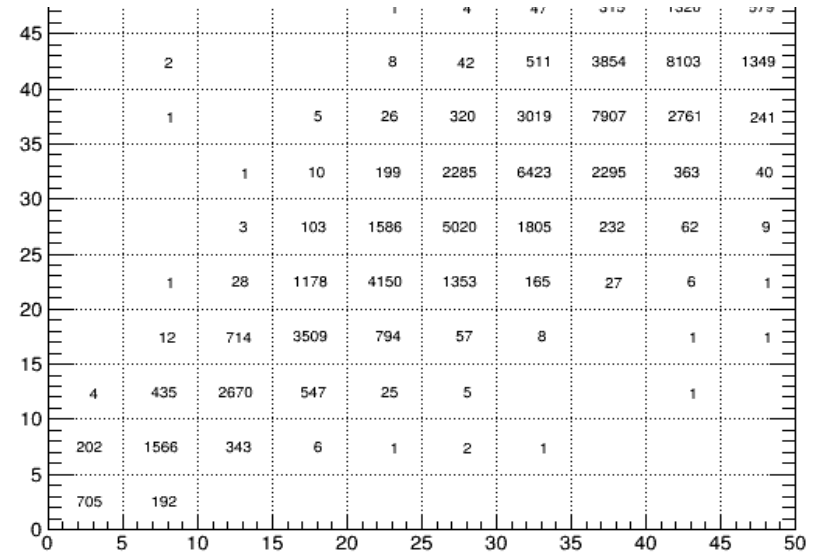
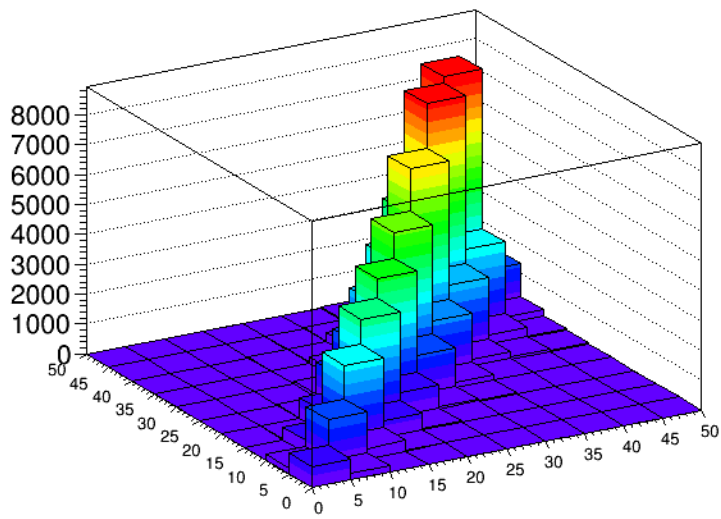
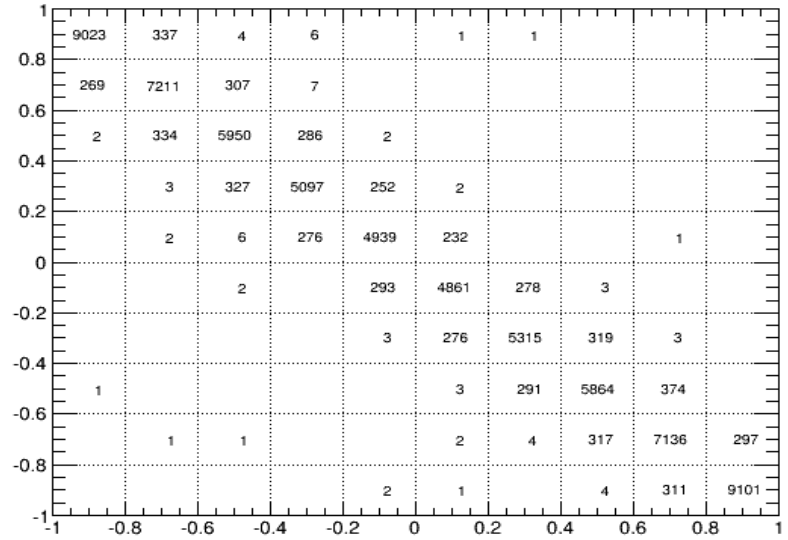
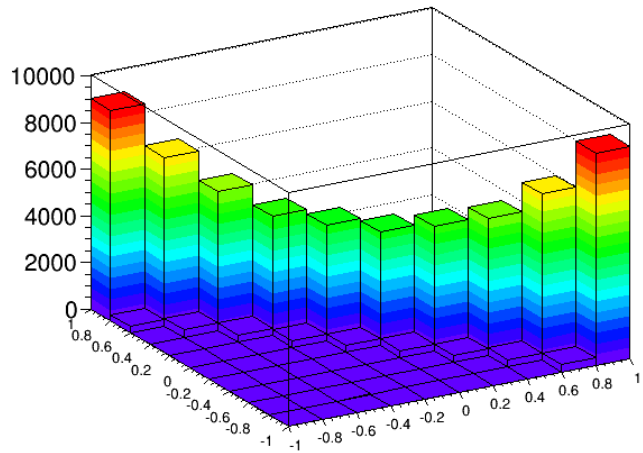


Zcc Prob>0.95

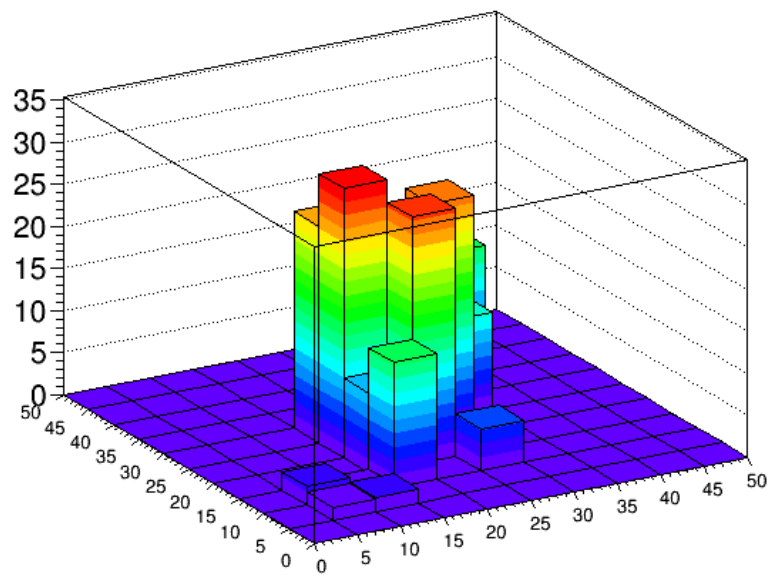
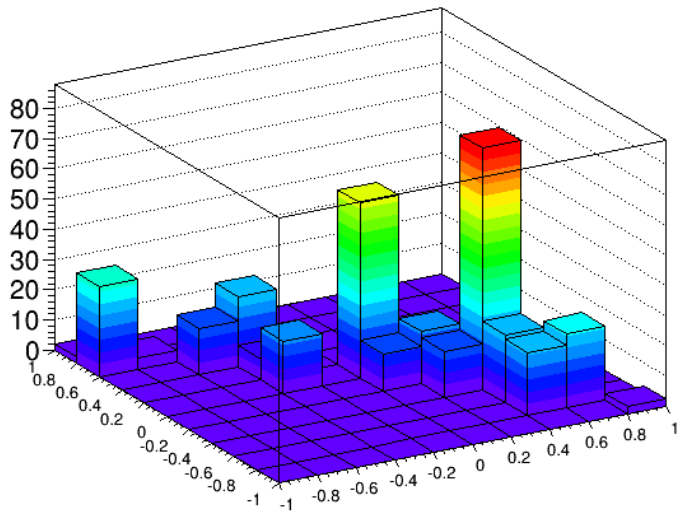


2D Correlation Factor

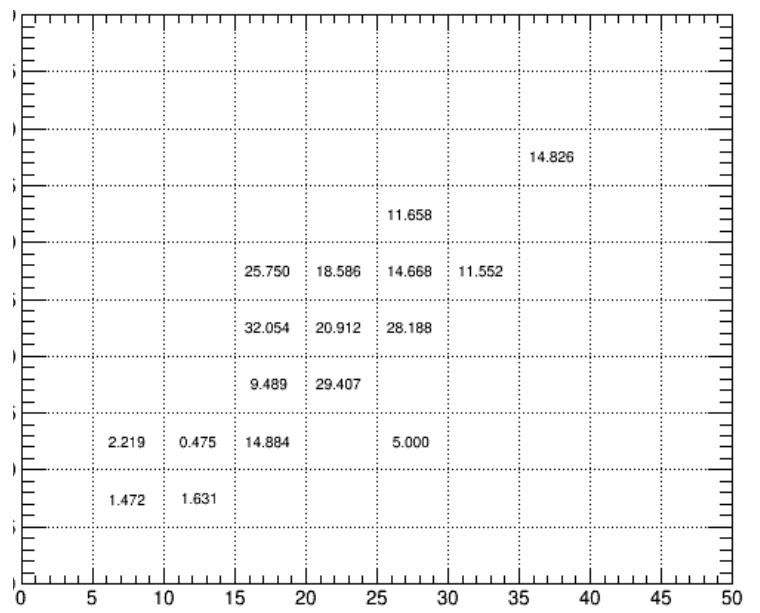
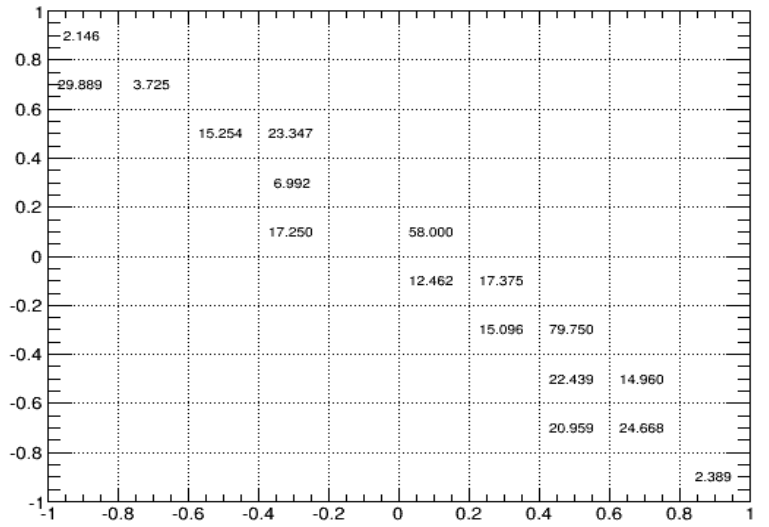
Zuds



2D Correlation Factor

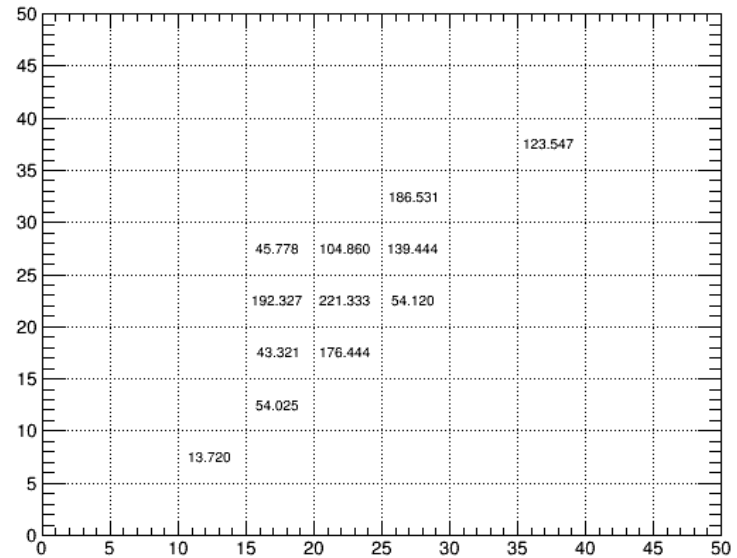
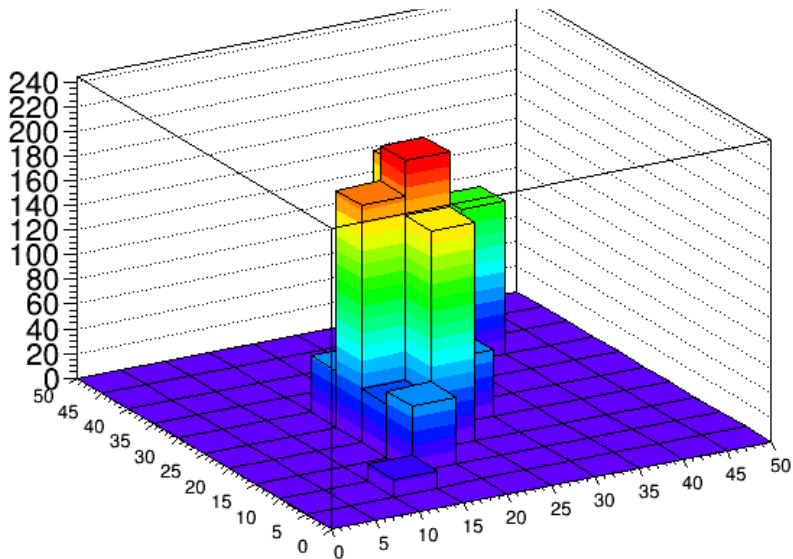
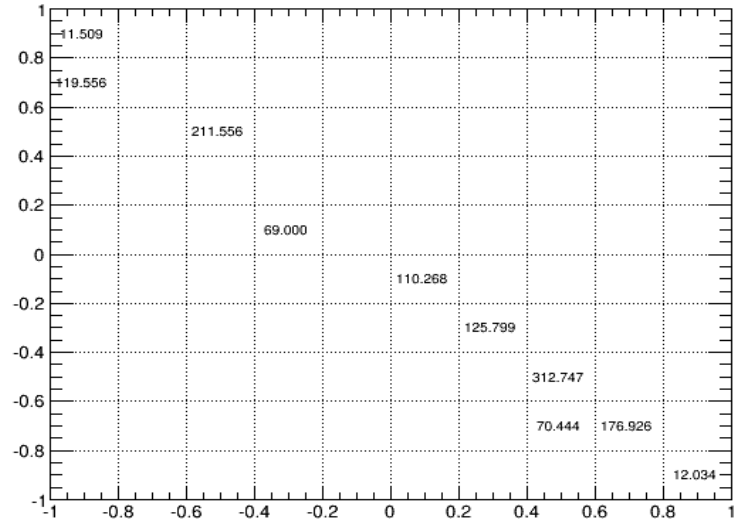
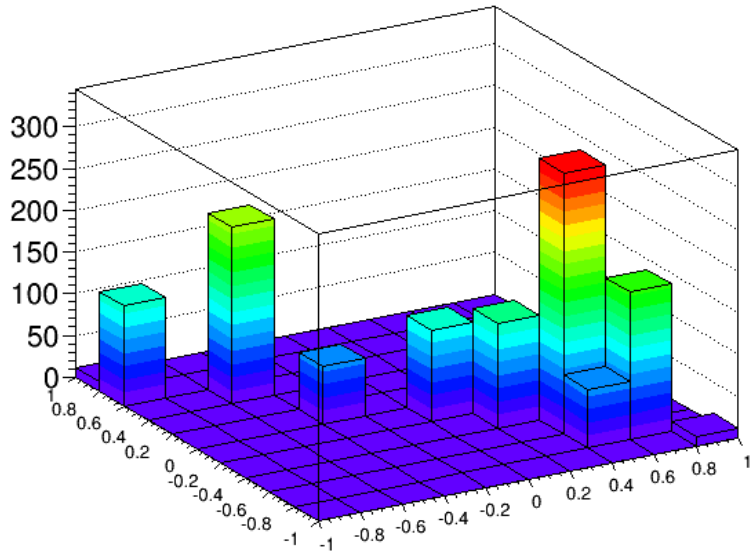


Zuds Prob>0.6



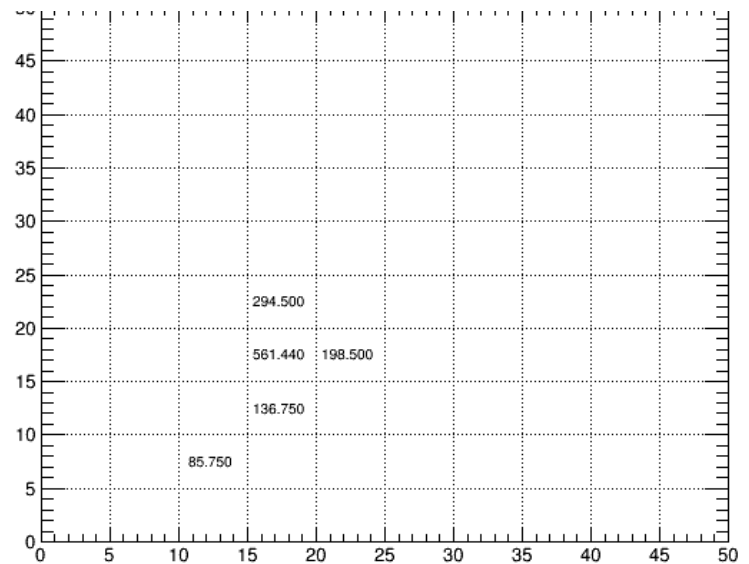
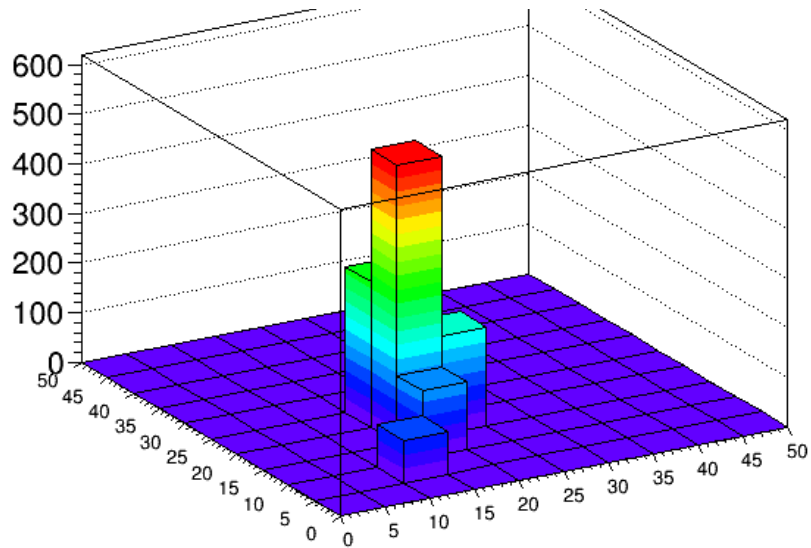
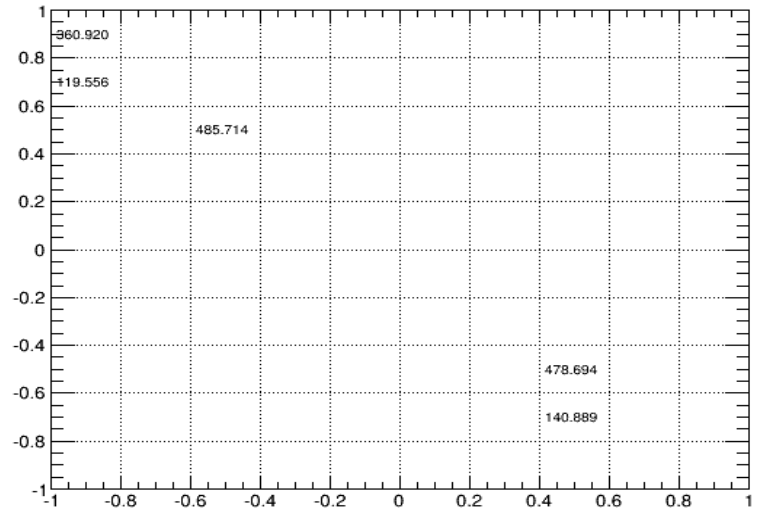
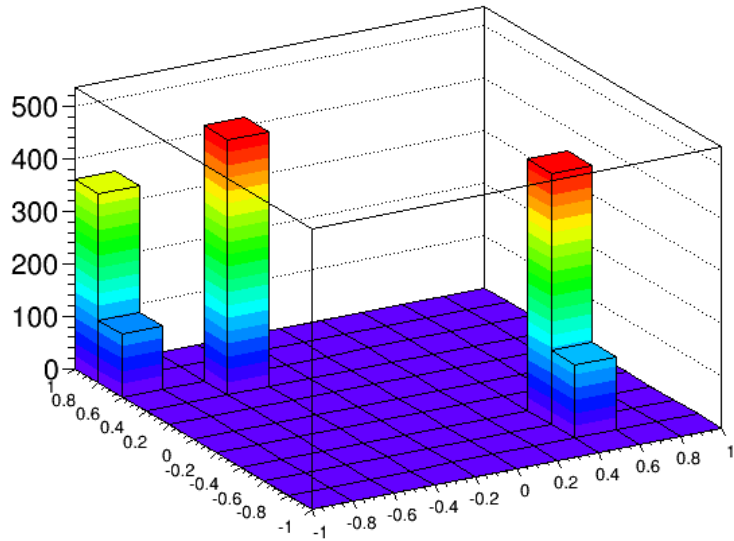
2D Correlation Factor

Zuds Prob>0.95



2D Correlation Factor

Zuds Prob>0.99



Btagging correlation factor

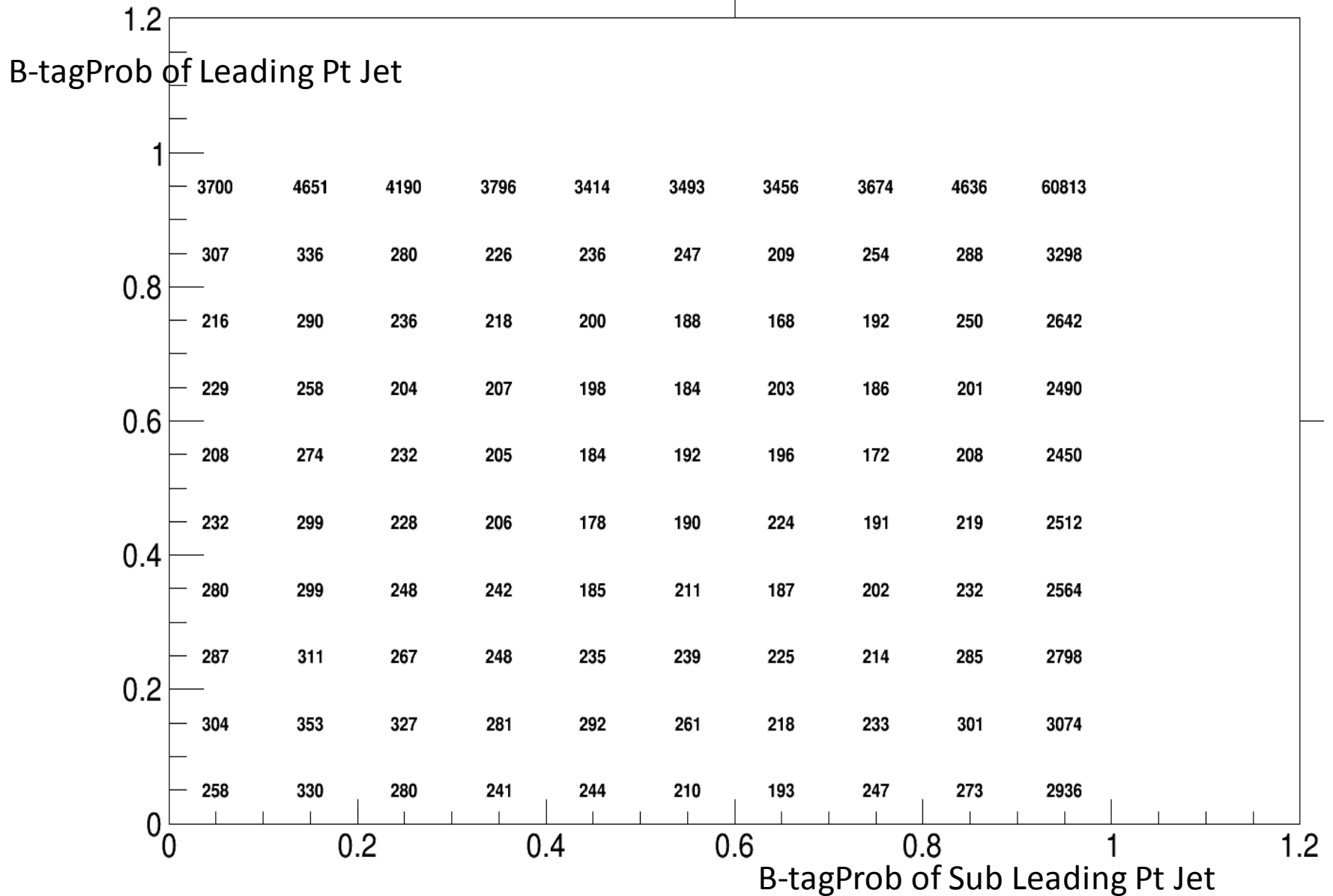
$$C_b = \frac{\varepsilon_{2jet-tagged}}{(\varepsilon_{1jet-tagged})^2}$$

Cut: $\Delta R < 0.4$ for jet1 and jet2

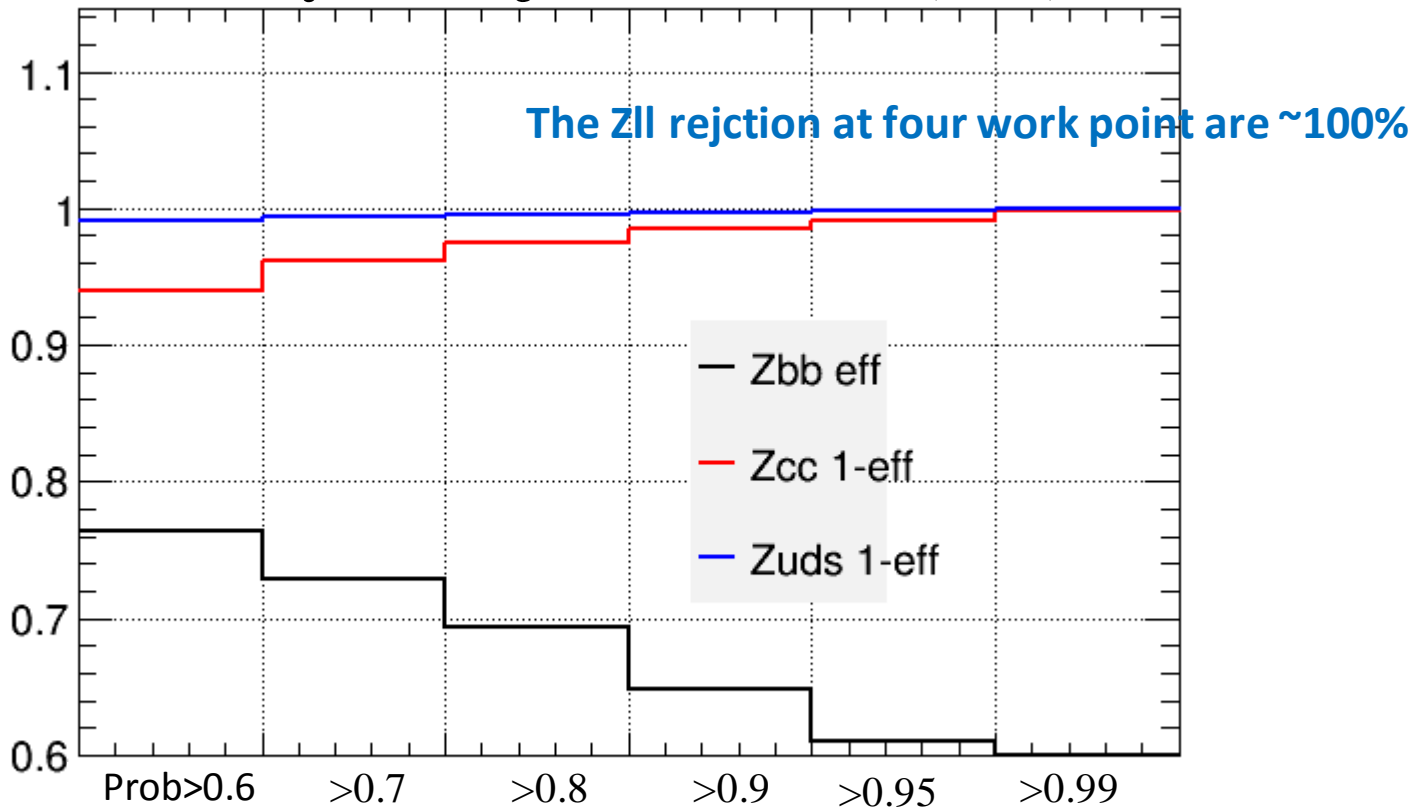
	Prob >0.6	>0.7	>0.8	>0.9	>0.95	>0.99
Zbb	1.015+0.014	1.021+0.014	1.026+0.015	1.033+0.016	1.036+0.016	1.062+0.019
	1.008+0.014	1.012+0.015	1.017+0.015	1.021+0.016	1.024+0.017	1.044+0.019
ZCC	1.159+0.085	1.173+0.123	1.452+0.212	1.980+0.416	2.686+0.760	0.000
	1.109+0.090	1.176+0.134	1.379+0.222	1.743+0.417	2.155+0.733	0.000
zuds	7.568+1.477	14.35+3.210	23.86+6.182	45.76+13.97	73.92+26.31	203.0+132.2
	4.467+1.278	6.078+2.285	11.43+4.698	15.09+8.571	34.21+20.49	0.000

backup

2D B_likelihood



Effency and rejection for Zbb,Zcc,Zll



	Prob>0.6	Prob>0.7	Prob>0.8	Prob>0.9	0.95	0.99
Zbb_eff	0.7640	0.7294	0.6931	0.6488	0.6097	0.4749
Zcc_Rej:	0.9402	0.9610	0.9755	0.9858	0.9911	0.9978
Zll_Rej	0.9911	0.9941	0.9959	0.9973	0.9981	0.9994

Btagging correlation factor

$$C_b = \frac{\varepsilon_{2jet-tagged}}{(\varepsilon_{1jet-tagged})^2}$$

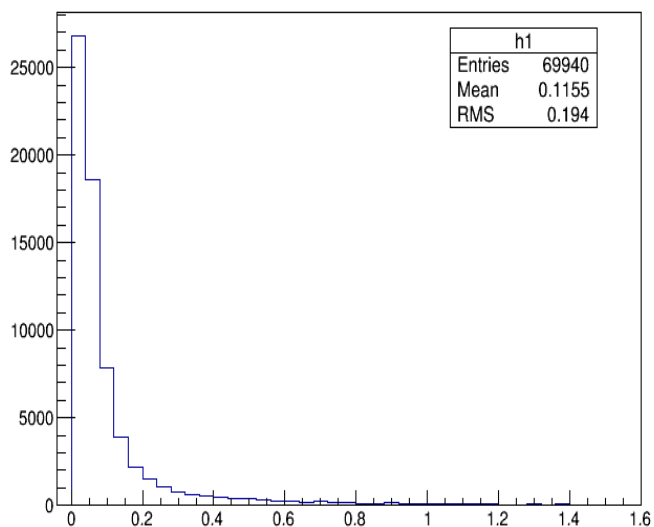
	Prob >0.6	>0.7	>0.8	>0.9	>0.95	>0.99
C_{Zbb}	1.015±0.014	1.021±0.014	1.026±0.015	1.033±0.016	1.036±0.016	1.062±0.019
C_{Zcc}	1.159±0.085	1.173±0.123	1.452±0.212	1.980±0.416	2.686±0.760	0.000
C_{Zuds}	7.568±1.477	14.35±3.210	23.86±6.182	45.76±13.97	73.92±26.31	203.0±132.2

2jet-tagged eff in Zcc and Zuds

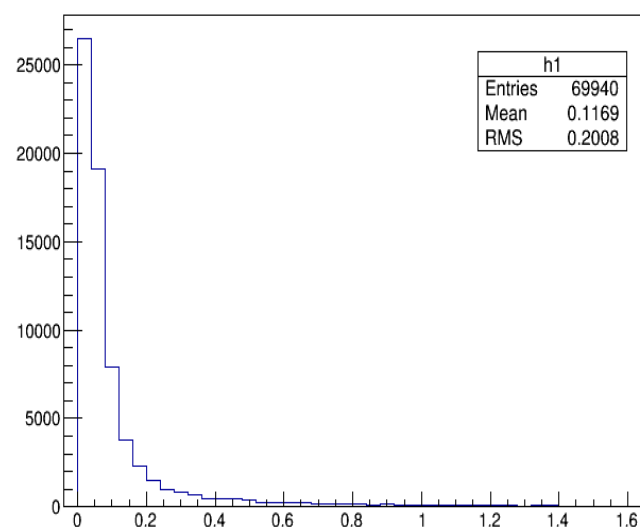
	Prob >0.6	>0.7	>0.8	>0.9	>0.95	>0.99
Zcc_2beff:	0.004146	0.001787	0.0008722	0.0004003	0.0002145	0.000
Zll_2beff:	0.0006005	0.0005004	0.0004003	0.0003289	0.0002574	7.149e-05

Btagging correlation factor

- Check the deltaR of jet vs truejet
 - TLorentzVector::DeltaR



jet1



jet2

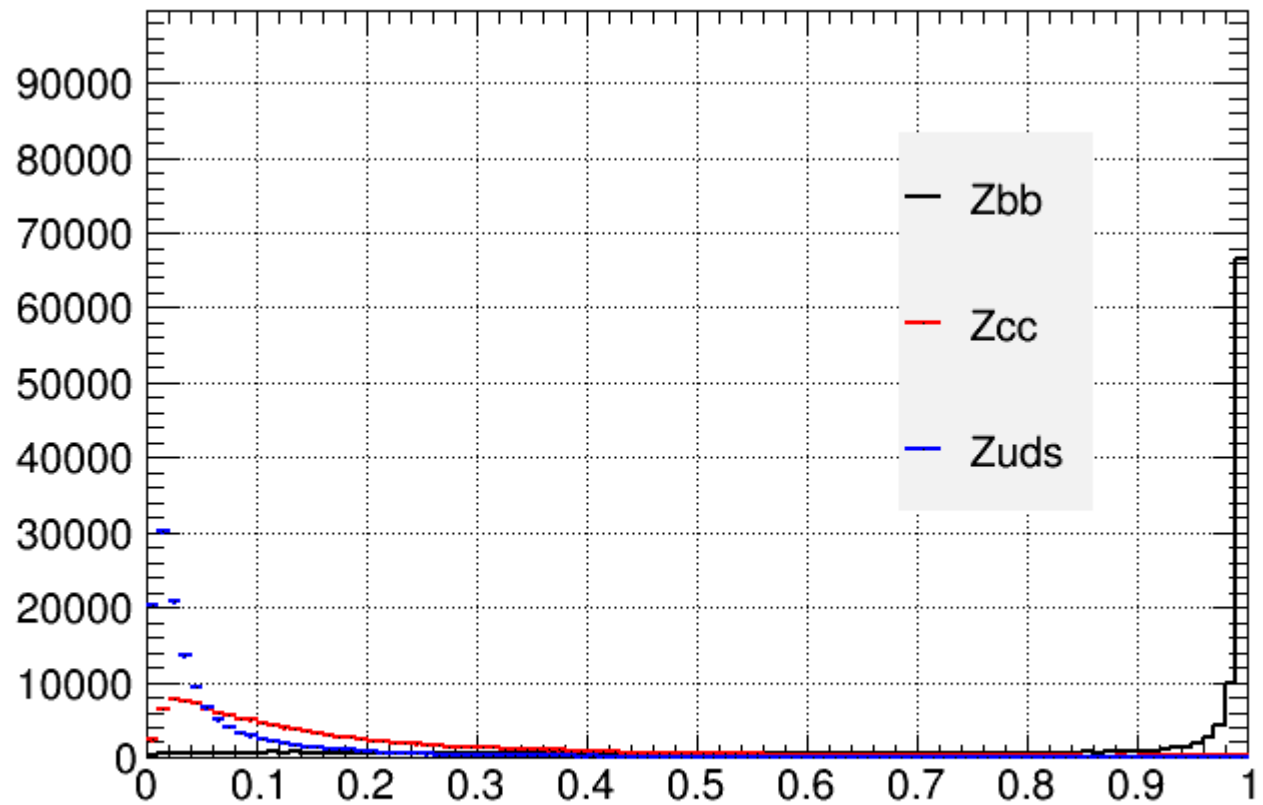
Btagging correlation factor

$$C_b = \frac{\varepsilon_{2jet-tagged}}{(\varepsilon_{1jet-tagged})^2}$$

Cut: $\Delta R < 0.4$ for jet1 and jet2

	Prob >0.6	>0.7	>0.8	>0.9	>0.95	>0.99
Zbb	1.015+0.014	1.021+0.014	1.026+0.015	1.033+0.016	1.036+0.016	1.062+0.019
	1.008+0.014	1.012+0.015	1.017+0.015	1.021+0.016	1.024+0.017	1.044+0.019
ZCC	1.159+0.085	1.173+0.123	1.452+0.212	1.980+0.416	2.686+0.760	0.000
	1.109+0.090	1.176+0.134	1.379+0.222	1.743+0.417	2.155+0.733	0.000
zuds	7.568+1.477	14.35+3.210	23.86+6.182	45.76+13.97	73.92+26.31	203.0+132.2
	4.467+1.278	6.078+2.285	11.43+4.698	15.09+8.571	34.21+20.49	0.000

Btagging correlation factor



Btagging correlation factor

$$C_b = \frac{\varepsilon_{2jet-tagged}}{(\varepsilon_{1jet-tagged})^2}$$

	Prob >0.01	>0.02	>0.03	>0.04	>0.05	>0.06
C_{zcc}	0.9999+-0.008	0.9995+--0.008	0.9994+-0.008	0.9998+-0.008	1.001+-0.009	0.9997+-0.009
C_{zuds}	1.006+-0.008	1.034+-0.010	1.067+-0.012	1.097+-0.014	1.132+-0.017	1.162+-0.019

	Prob >0.01	>0.02	>0.03	>0.04	>0.05	>0.06
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Eff_Zcc_1tag:	0.9835	0.9380	0.8827	0.8289	0.7777	0.7313
Eff_Zcc_2tag:	0.9671	0.8794	0.7786	0.6870	0.6051	0.5346
Eff_Zuds_1tag:	0.8544	0.6394	0.4911	0.3940	0.3270	0.2801
Eff_Zuds_2tag:	0.7342	0.4225	0.2574	0.1704	0.1210	0.09116

Get From Mixed MC Sample

$$\frac{N_t}{2N_{had}} = R_b \varepsilon_b + R_c \varepsilon_c + (1 - R_b - R_c) \varepsilon_{uds}$$

$$\frac{N_{tt}}{N_{had}} = C_b R_b \varepsilon_b^2 + C_c R_c \varepsilon_c^2 + C_{uds} (1 - R_b - R_c) \varepsilon_{uds}^2$$

$R_c, \varepsilon_c, \varepsilon_{uds}$
 C_b, C_c, C_{uds}
 Get from MC

$$C_b = \frac{\varepsilon_{2jet-tagged}}{(\varepsilon_{1jet-tagged})^2}$$

1.015 1.021 1.026 1.033

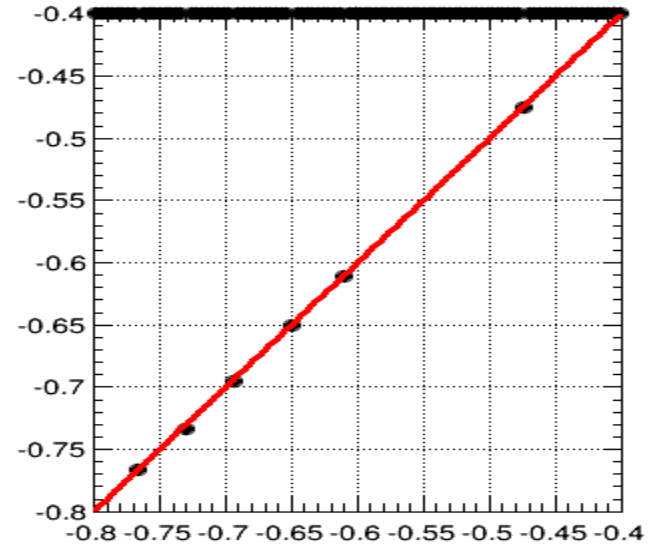
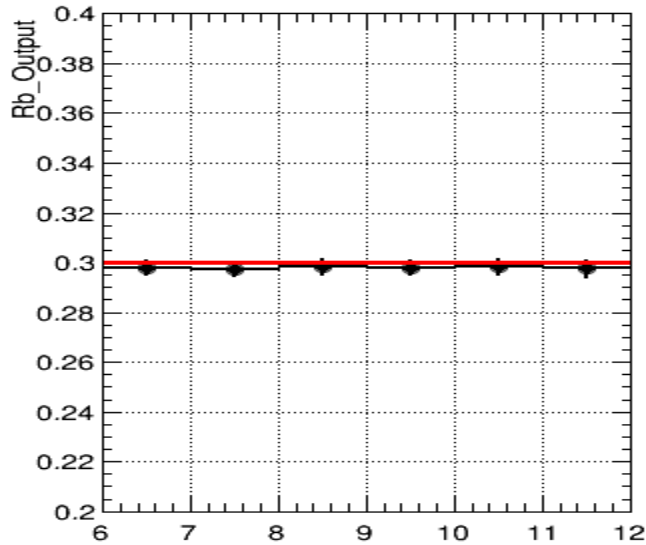
Following this procedure, we can measured the R_b, ε_b

The Z hadronic 'DATA' is mixed by MC samples: Zbb **sample1**, Zcc **sample1**, Zll **sample1**
 We set $R_b=0.3, R_b=0.5, R_b=0.7$ as the Input R_b to mix the 'DATA'

The $R_c, \varepsilon_c, C_b, C_c, C_{uds}$ is gotten by MC samples: Zbb **sample2**, Zcc **sample2**, Zll **sample2**

So if **sample1** ≠ **sample2**, which means the MC $R_c, \varepsilon_c, C_b, C_c, C_{uds}$ are different from the Truth in 'DATA'

Input Rb=0.3, Four BtagProb work point: Prob>0.6, >0.7, >0.8, >0.9



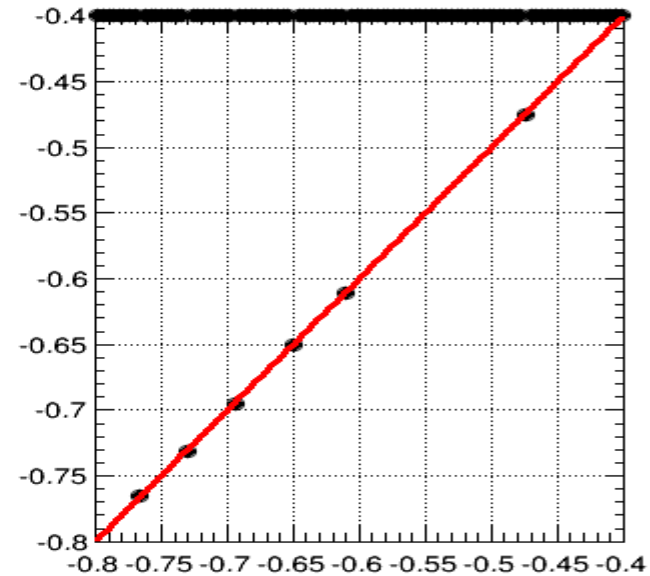
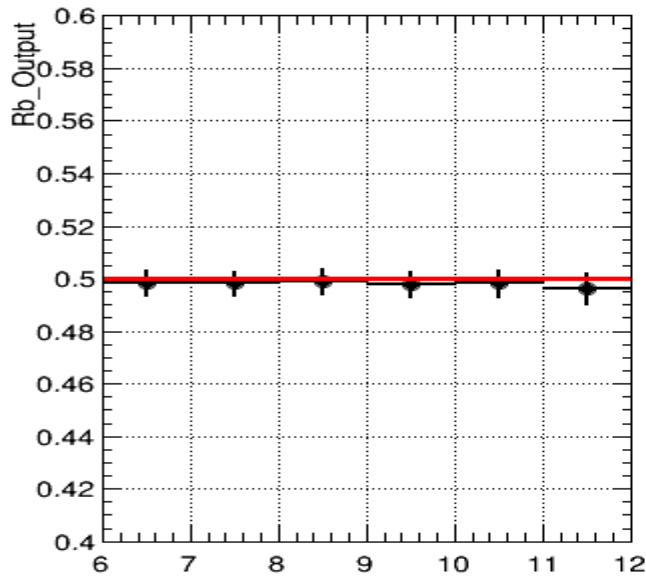
Input Rb: 0.3000

Output Rb: 0.2981 0.2975 0.2984 0.2980 0.2985 0.2977

Input eff: 0.7643 0.7300 0.6936 0.6480 0.6087 0.4721

Output eff: 0.7668 0.7333 0.6956 0.6508 0.6109 0.4756

Input Rb=0.5, Four BtagProb work point: Prob>0.6, >0.7, >0.8, >0.9



Input Rb: 0.5000

Output Rb: 0.4985 0.4981 0.4988 0.4980 0.4982 0.4962

Input eff: 0.7643 0.7300 0.6936 0.6480 0.6087 0.4721

Output eff: 0.7657 0.7316 0.6946 0.6501 0.6105 0.4756

Summary

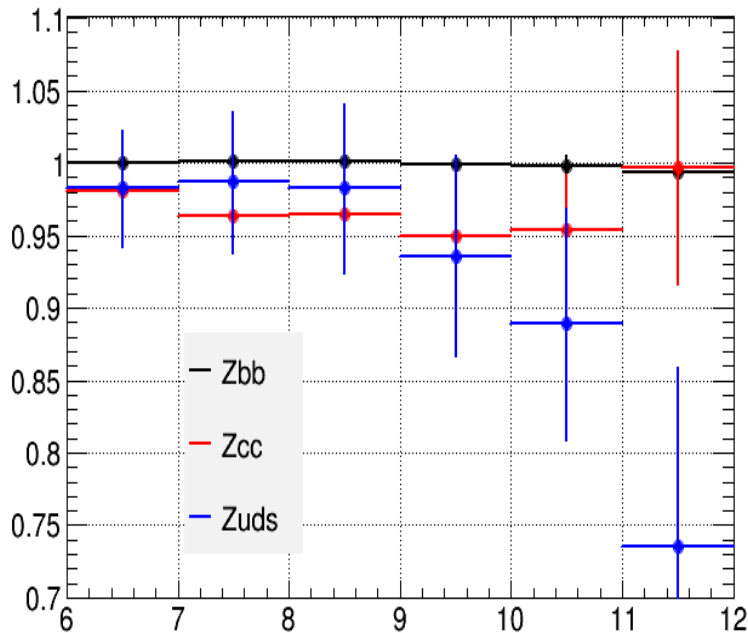
- The IO test shows Analysis code worked as expected.
- Increase the statistics of 'DATA' and MC.
- Study the FSClasser: know well about the procedure at event reconstruction level.

Result

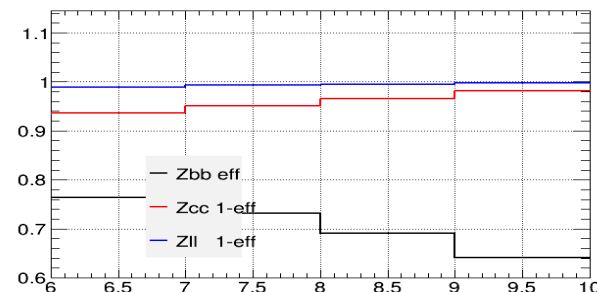
the measured **Rb** and **effb** in DATA are different from the Input Truth Rb and effb **at Prob>0.9**

The R_c , ϵ_c , C_b , C_c , C_{uds} is got by MC samples: Zbb **sample2**, Zcc **sample2**, Zll**sample2**
So if DATA **sample1** \neq sample2, which means the MC R_c , ϵ_c , C_b , C_c , C_{uds} is different from the 'DATA'

The difference as a Ratio: Eff in 'DATA' / Eff in MC



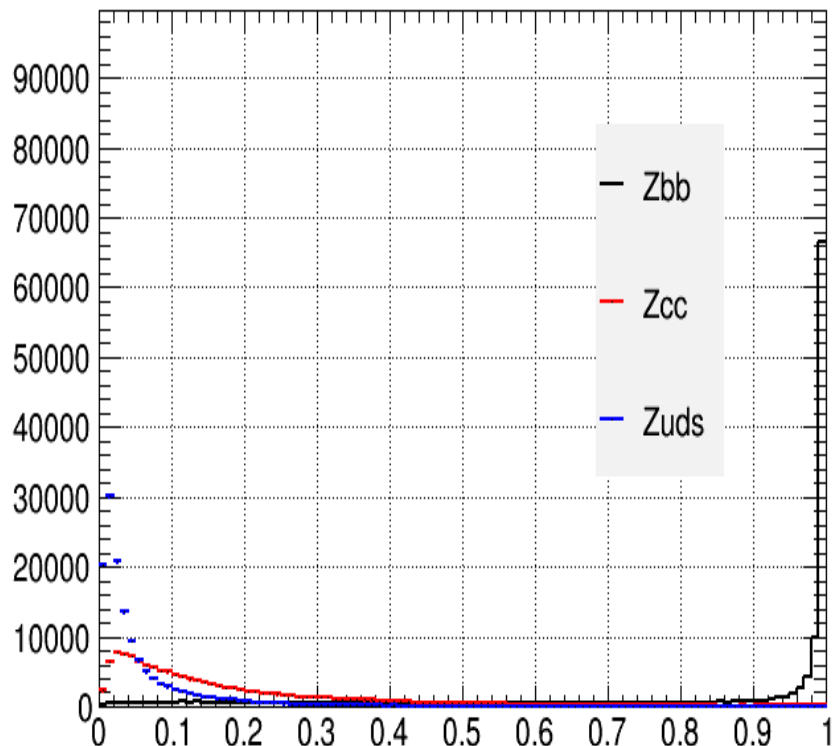
1. ϵ_b difference between DATA and MC are very small
2. ϵ_c and ϵ_{uds} differences are big **at Prob>0.9** :
 - which may come from the very low statistics after Btagging
 - which will lead to the difference in the IO test
3. ϵ_{uds} effect is very small, as **The Zll rejection at four work point are ~100%**



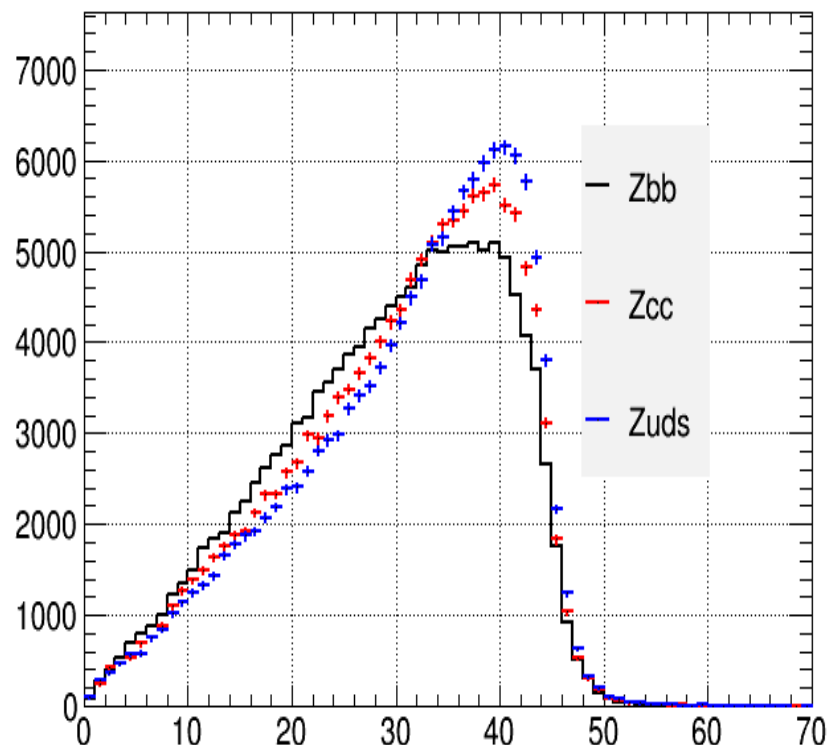
- Basic information
- Btag performance
- Method

JetBtag Prob

all the 2jets

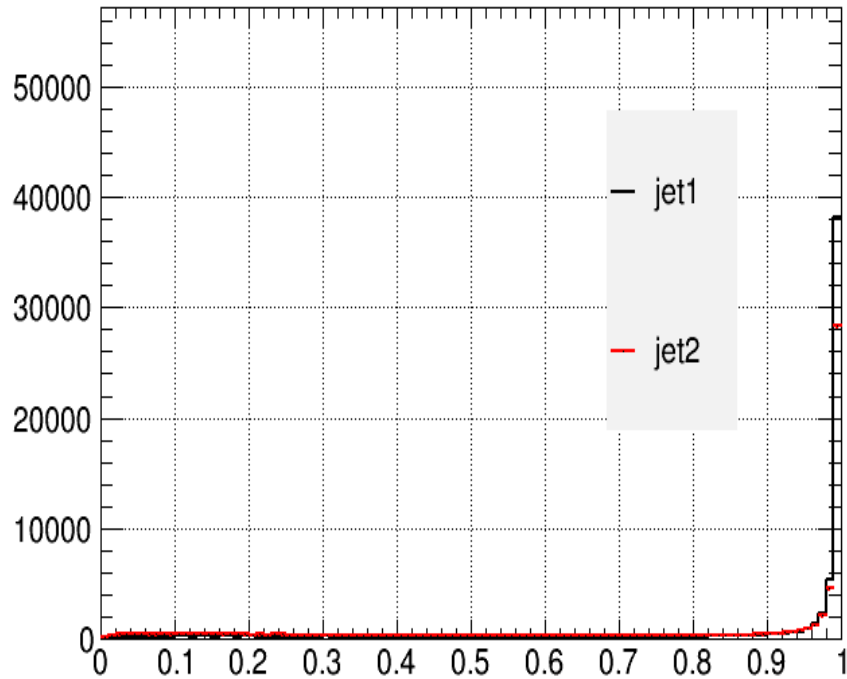


JetPt

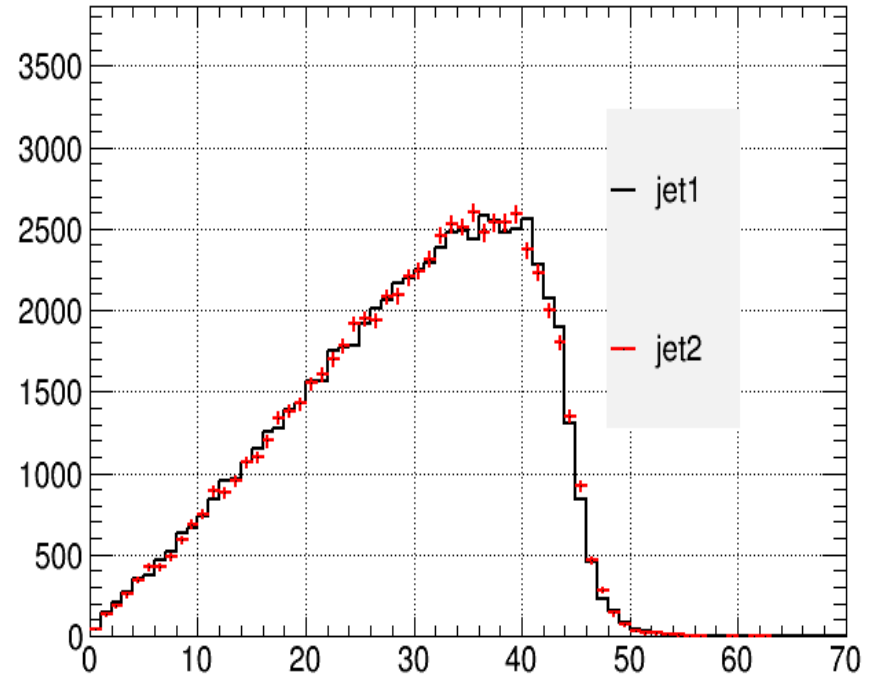


- The BtagProb are different for Zbb, Zcc and Zll
- Four BtagProb Work Point are used :
 - The $BtagProb > 0.6$, $BtagProb > 0.7$, $BtagProb > 0.8$, $BtagProb > 0.9$

JetBtag Prob

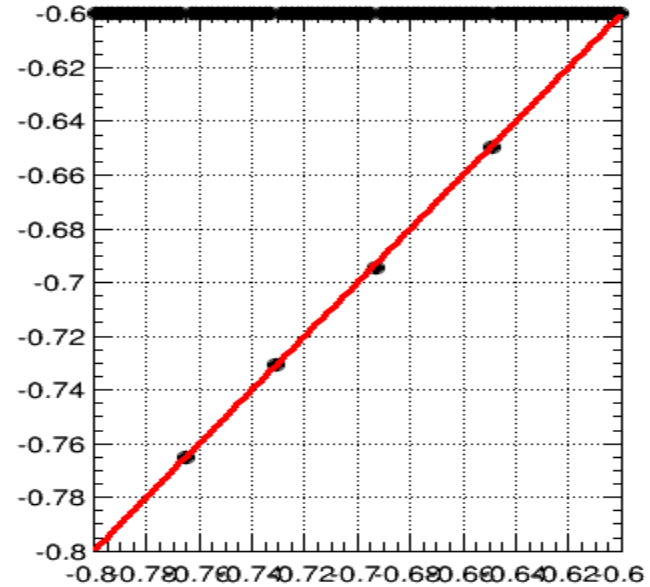
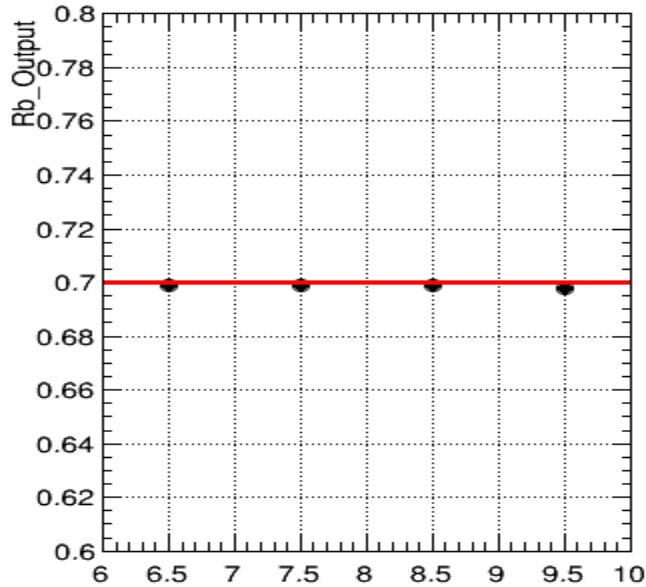


JetPt



Jet1 vs jet2

Input Rb=0.7, Four BtagProb work point: Prob>0.6, >0.7, >0.8, >0.9



Input Rb: 0.7000

Output Rb: 0.6988 0.6988 0.6991 0.6979

Input eff: 0.7643 0.7300 0.6936 0.6480

Output eff: 0.7652 0.7308 0.6942 0.6498

Result

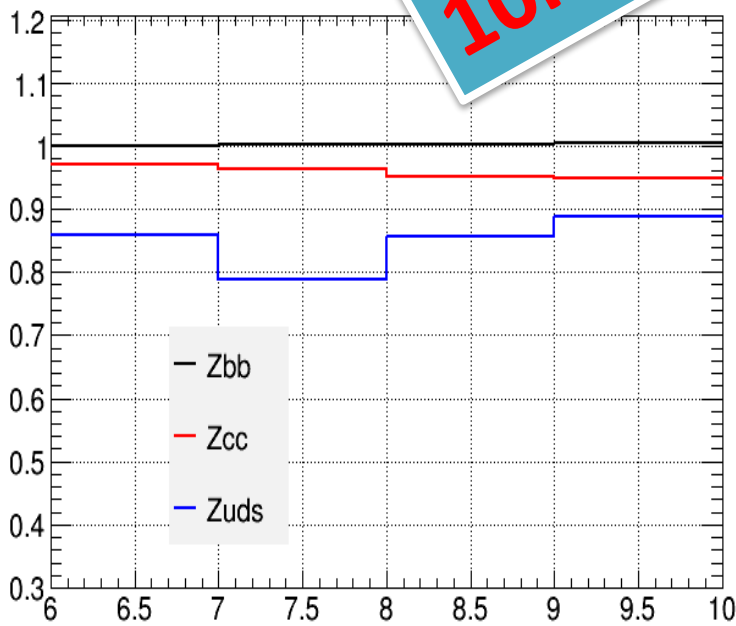
We can see the measured R_b and eff_b in DATA are different from Truth R_b and eff_b

The R_c , ϵ_c , C_b , C_c , C_{uds} is got by MC sample $sample1$, Zc $sample2$, Zc $sample2$, Zll $sample2$
 So if $sample1 \neq sample2$, which means the MC R_c , ϵ_c , C_b , C_c , C_{uds} is different from the 'DATA'

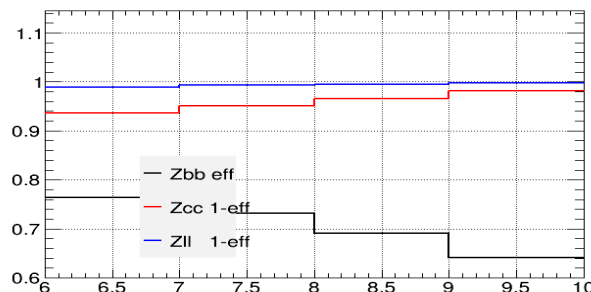
10k events in the past

The difference as a Ratio: Eff in 'DATA' vs MC

ϵ_b difference between DATA and MC are very small



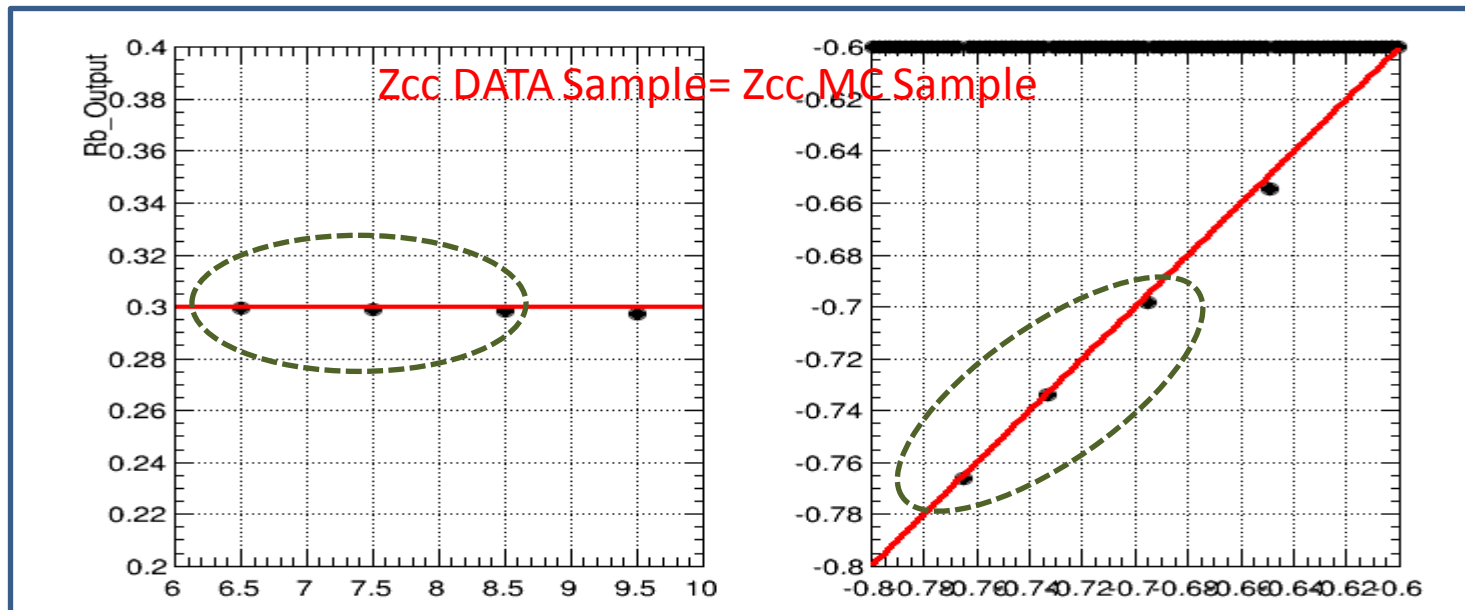
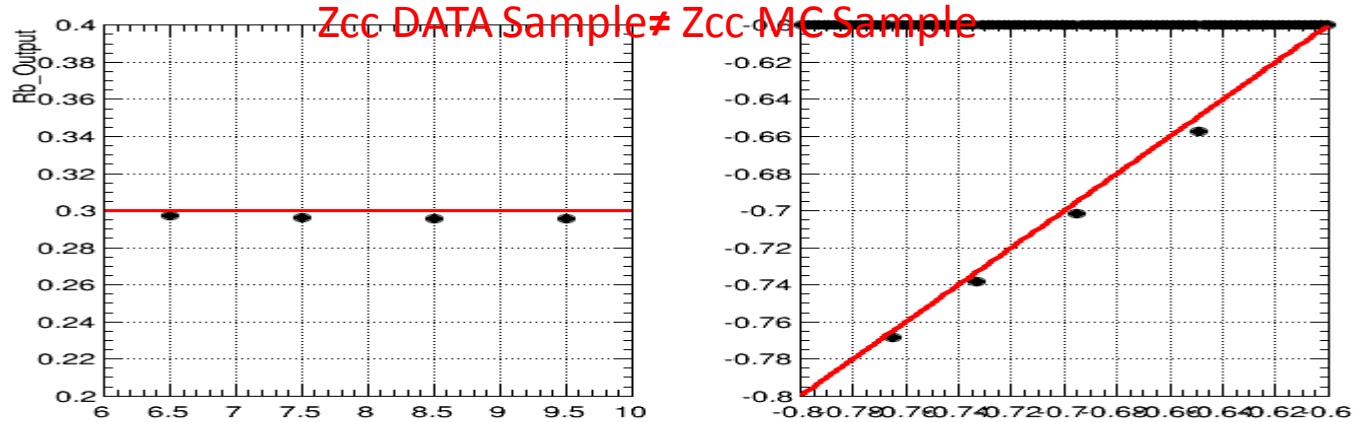
- ϵ_c and ϵ_{uds} difference are very big:
 - which may come from the very low statistics after Btagging
 - which will lead to the difference in the IO test
- ϵ_{uds} effect is very small, as **The Zll rejection at four work point are ~100%**



Check

Input Rb=0.3

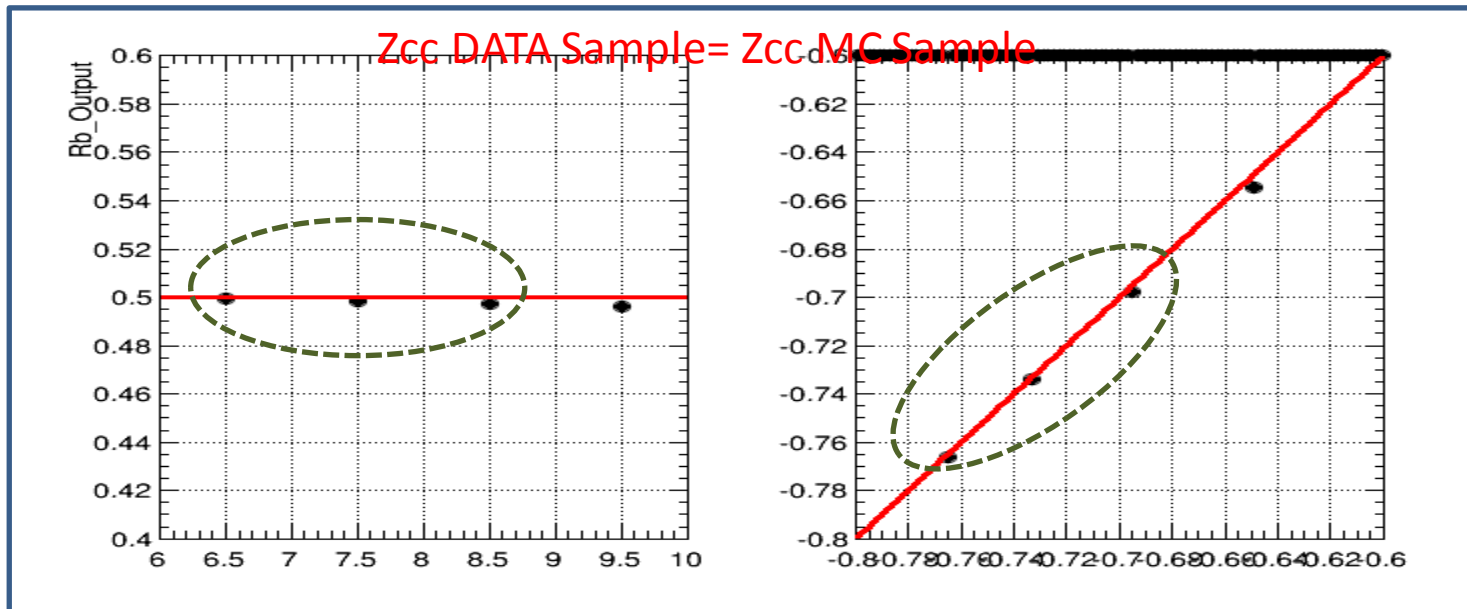
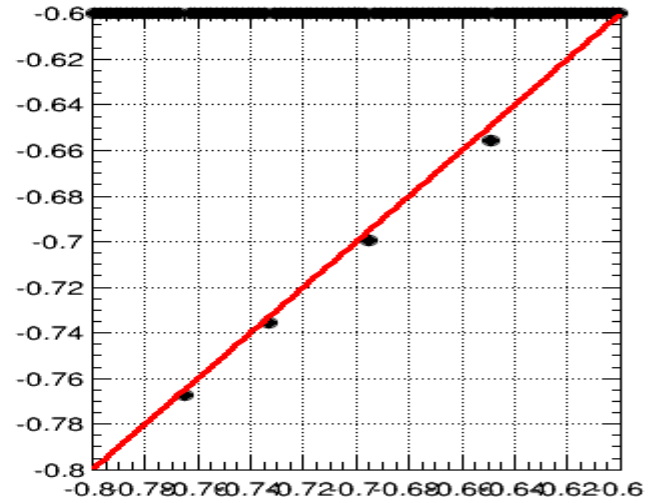
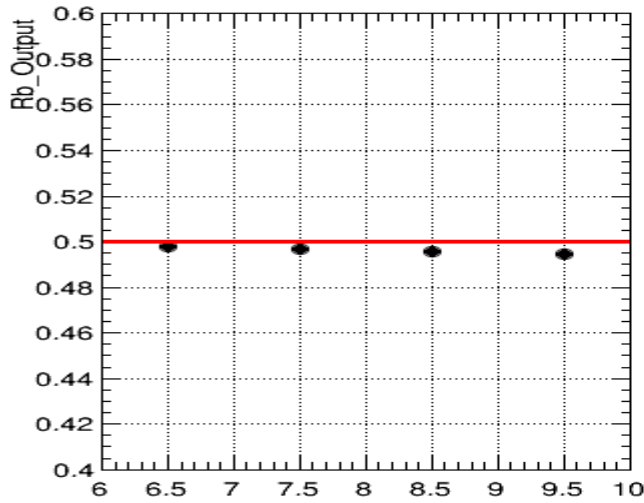
We redo the IO test by 'DATA' and MC with **same Zcc** sample



We can see the differences of measured **Rb** and **effb** between DATA and MC are smaller

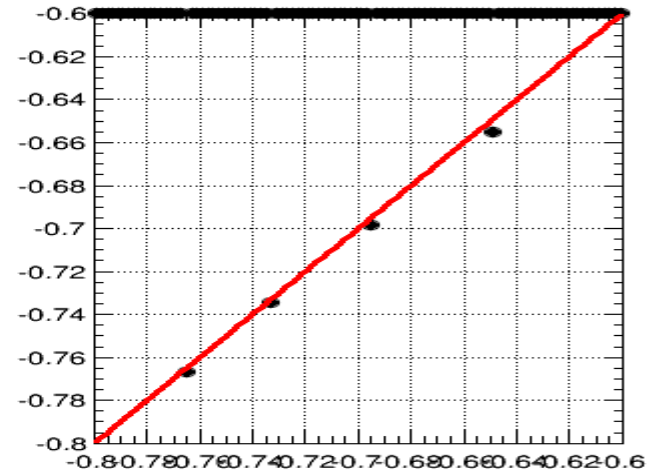
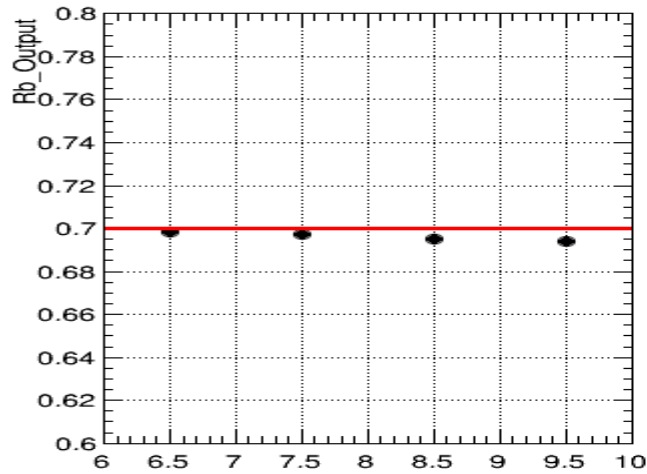
Check

Input Rb=0.5

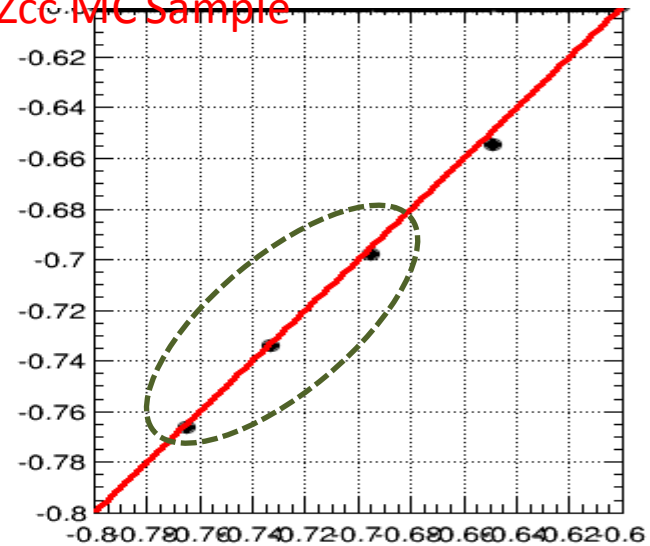
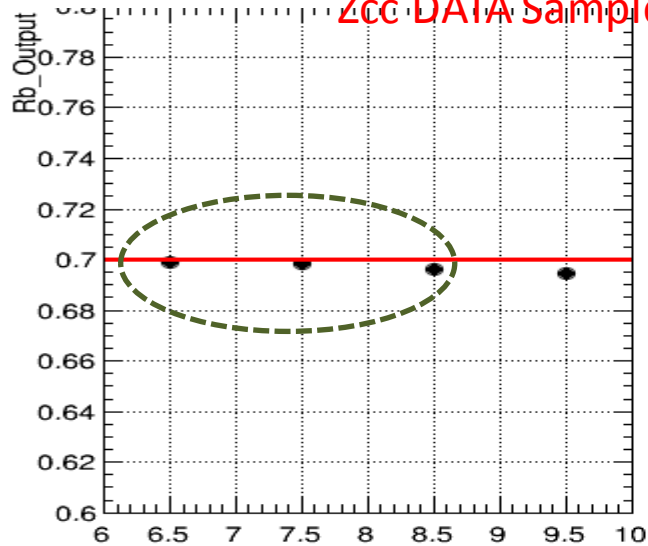


Check

Input Rb=0.7



Zcc DATA Sample = Zcc MC Sample



backup

'DATA' and MC all are used the same sample

