

High-angle matching systematics

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General

- In the present study (prod 6 T) we estimate high-angle matching systematics including new data;
- Last estimation was made in 2015 (prod 6 B).
- <https://www.t2k.org/nd280/physics/Obsolete/nu-mu/meetings/2015/06preCM/Merged/view>

2015

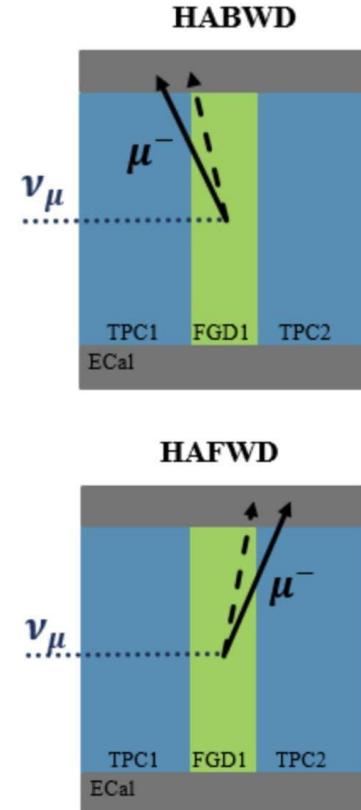
- Data samples: ND280 runs starting from Run~2 and up to Run~4 .

2021

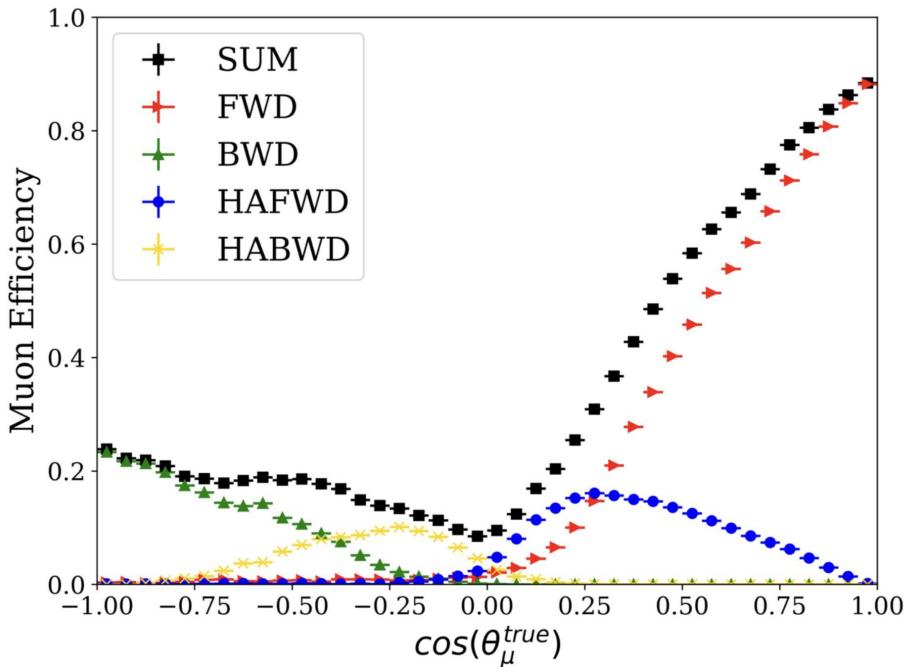
- Data samples: ND280 runs starting from Run~2 and up to Run~9 .

General

- In order to increase tracker phase space coverage need to deal with high-angle (w.r.t. to beam axis) FGD-non-TPC tracks 4pi analyses
- These high-angle samples include FGD(1/2)-(Barrel)ECal(-SMRD) topologies → are often composite objects built out of segments from 2-3 sub-detectors
- Need to estimate the corresponding matching systematics: FGD-ECal(-SMRD)



General

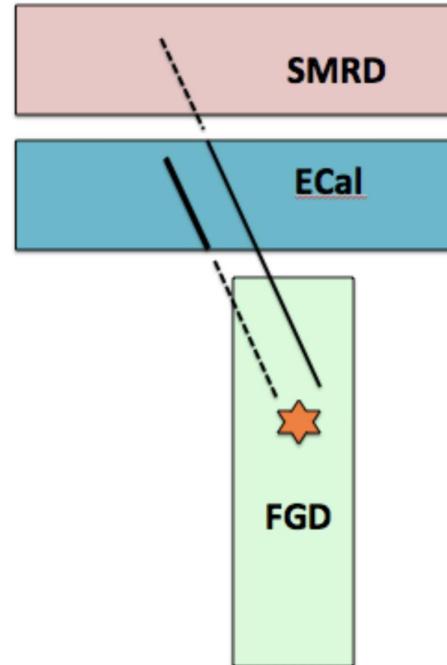


- Acceptance in the near detector increases if we include these areas (blue and yellow)
- These are the areas where systematics is needed

https://www.t2k.org/meet/collab/Collaboration_Meeting_dec2021/Talks/fri10dec2021/4pianalysesstatus

High-angle matching efficiency check

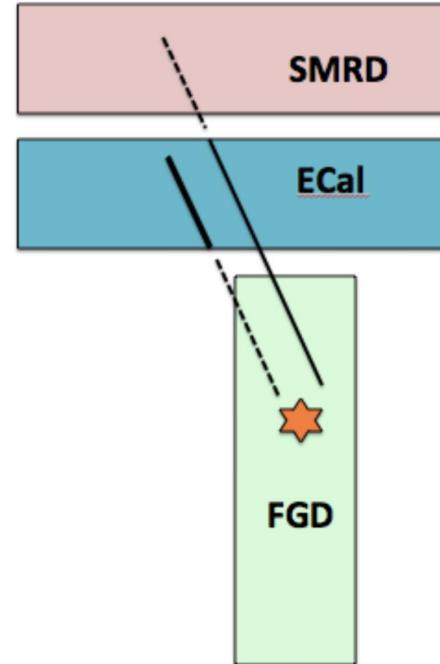
- FGD1/FGD2: ECal (non-TPC) track that points to FGD (crosses the FV when approximated with a straight line) and “leaks” inwards
- At least two hits in the FGD of interest in time bunch
- No TPC tracks in the neighbourhood (TPC1/TPC2 or TPC2/TPC3)
- Michel electron presence in the FGD of interest



Selection topologies

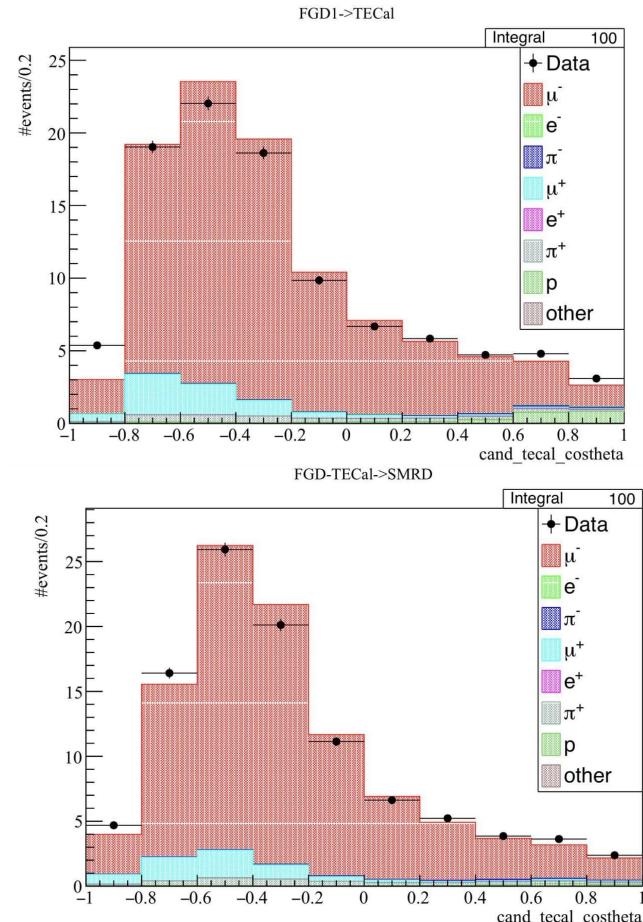
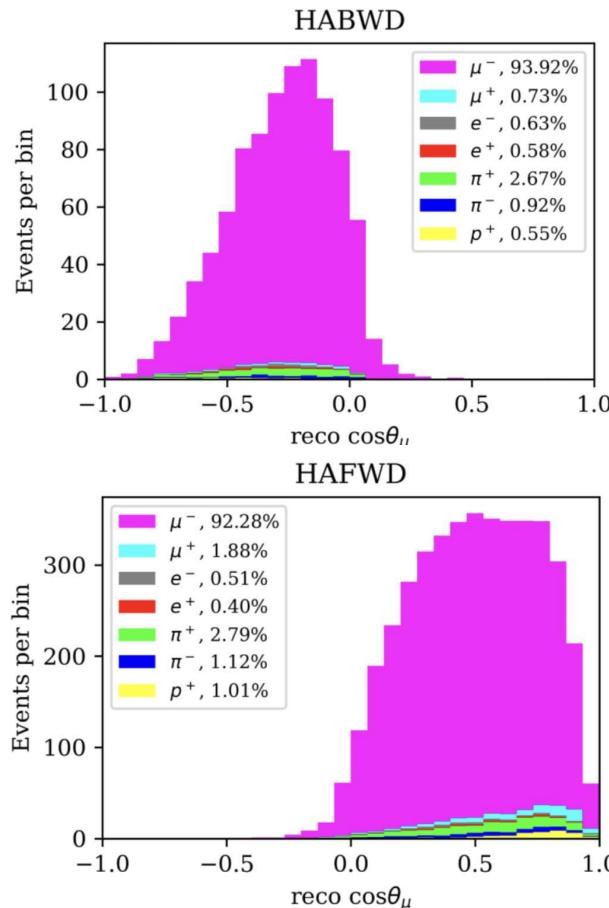
High-angle matching efficiency check

- FGD1/FGD2-ECal (non-TPC) track that points to SMRD (crosses the inner plane when approximated with a straight line) and “leaks” outwards from ECal
- Michel electron presence in the FGD of interest



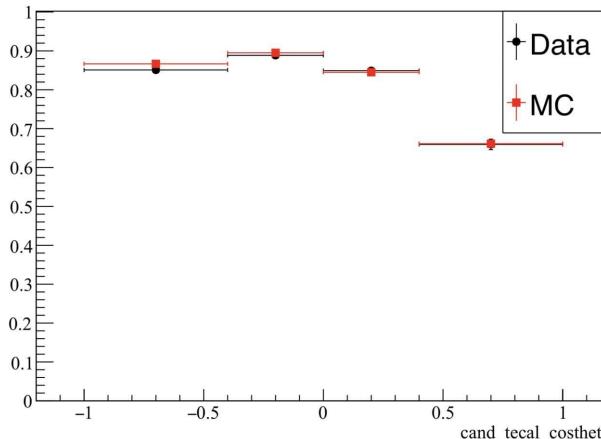
Selection topologies

Systematics control samples. Phase space checks



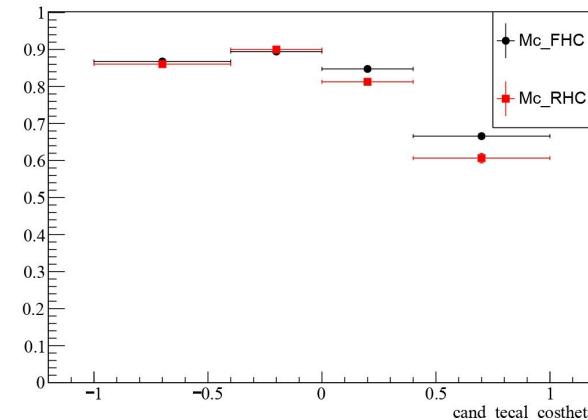
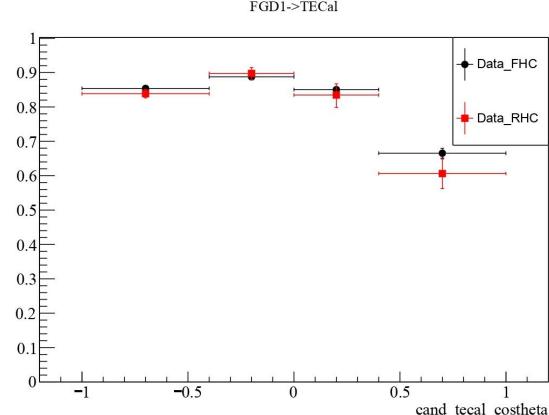
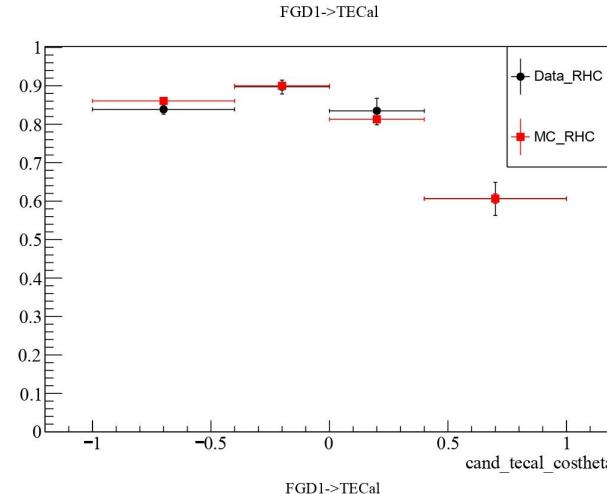
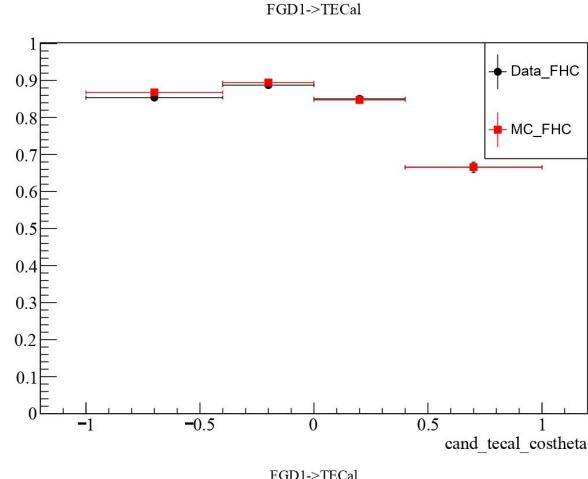
FGD1→TECal matching

FGD1->TECal

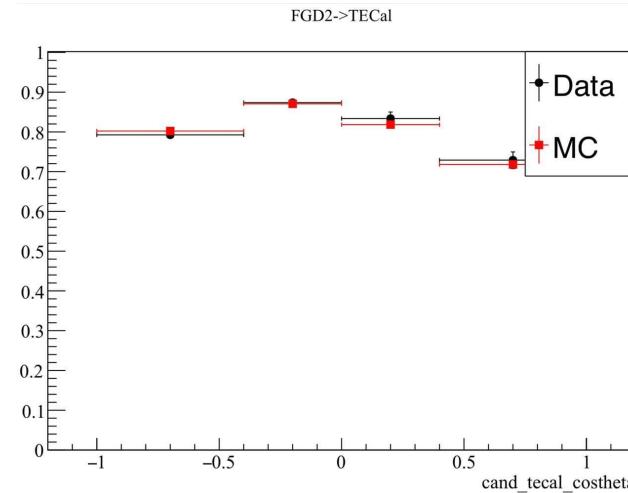


costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.85099	0.866637	0.00530578	0.00520386	0.00127346	0.00126663
-0,4	0	0.888573	0.895059	0.00602263	0.00583859	0.00141993	0.00140871
0	0,4	0.849072	0.845117	0.0103597	0.00998393	0.00257413	0.00255104
0,4	1	0.659455	0.661204	0.013498	0.0133277	0.00352984	0.00351793

FGD1→TECal matching (FHC/RHC)



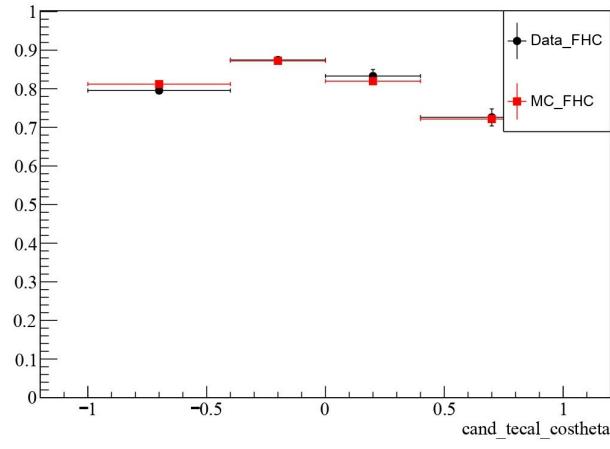
FGD2→TECal matching



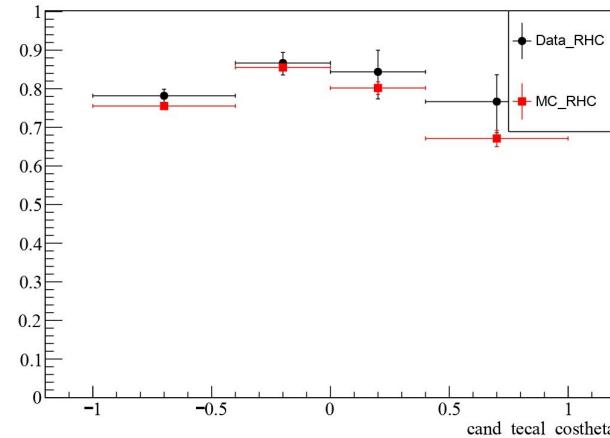
costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.792619	0.802246	0.00767253	0.00753529	0.00186726	0.00185845
-0,4	0	0.873717	0.87073	0.00953138	0.00913791	0.0023095	0.00228631
0	0,4	0.833671	0.818271	0.0172105	0.0163093	0.0043074	0.00425509
0,4	1	0.728929	0.717889	0.0215333	0.0208397	0.00545784	0.00541543

FGD2→TECal matching (FHC/RHC)

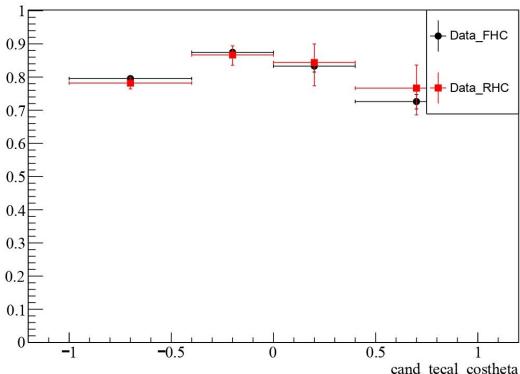
FGD2->TECal



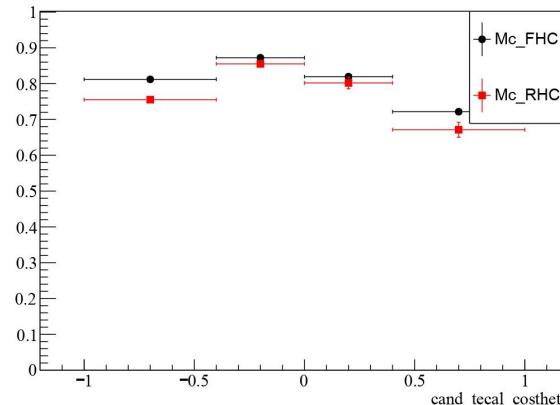
FGD2->TECal



FGD2->TECal



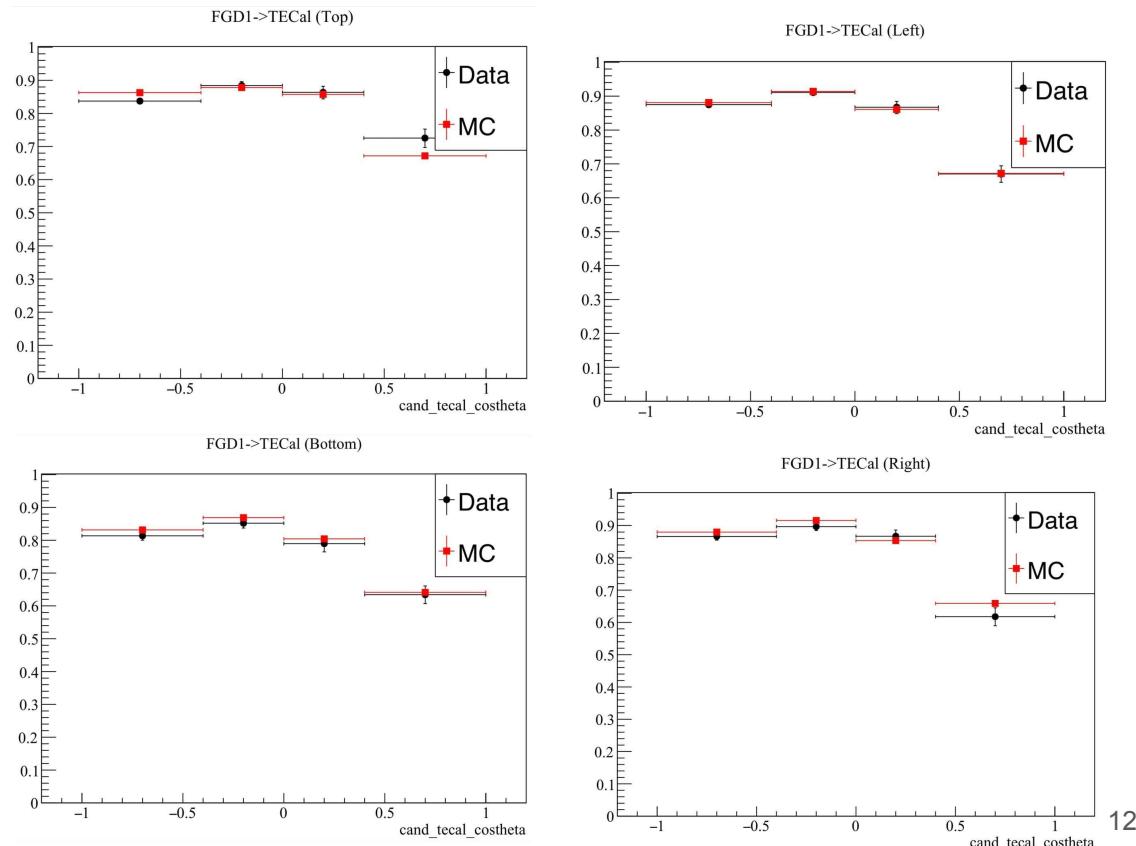
FGD2->TECal



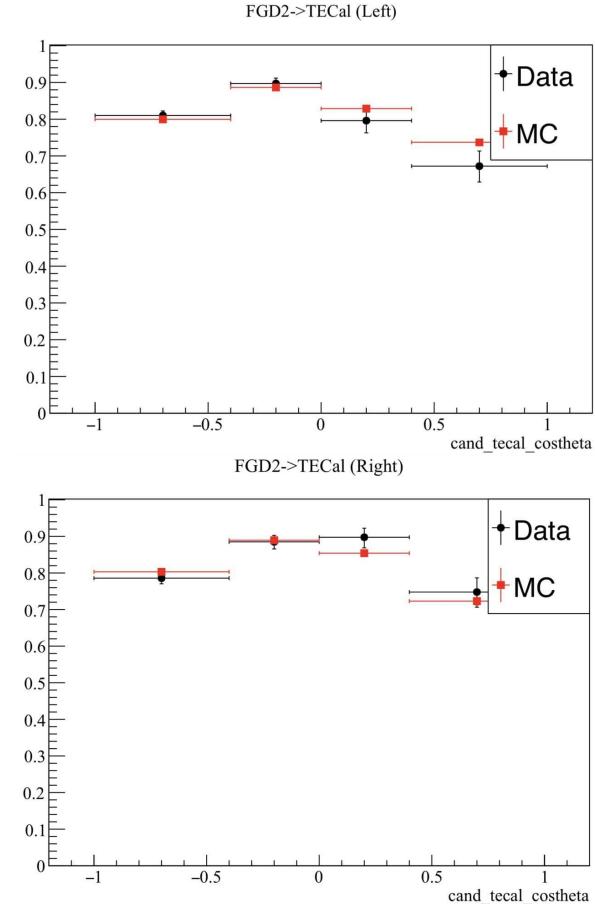
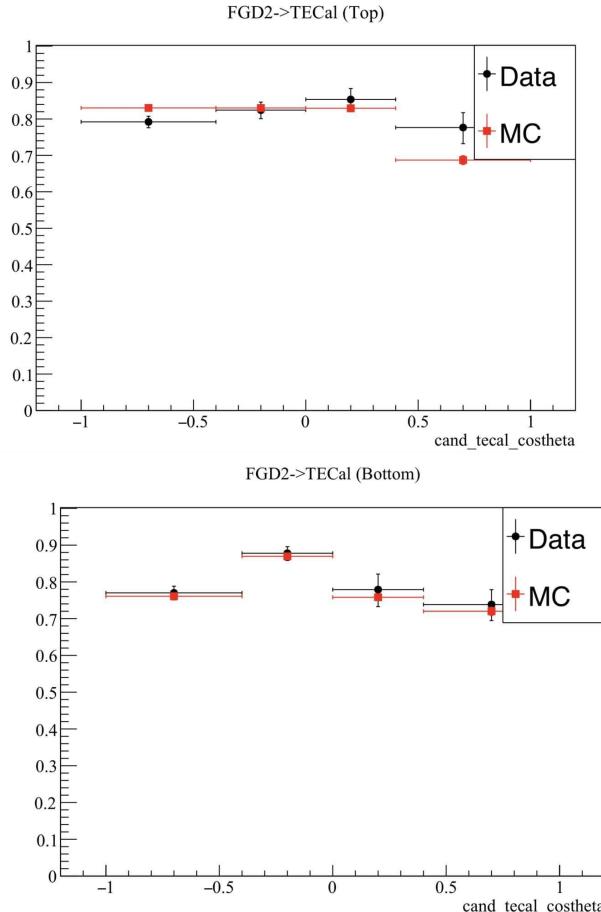
FGD1->TECal Split by TECal Module

The values for FGD1→TECal Top, Bottom, Right and Left are very close.

Results separately for each topology are in the backup slides

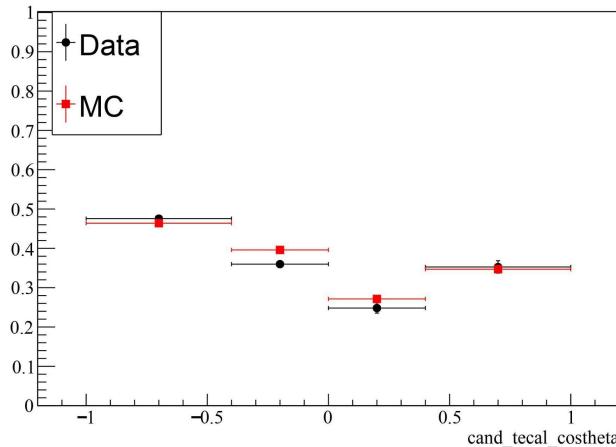


FGD2->TECal Split by TECal Module



FGD→TECal→SMRD

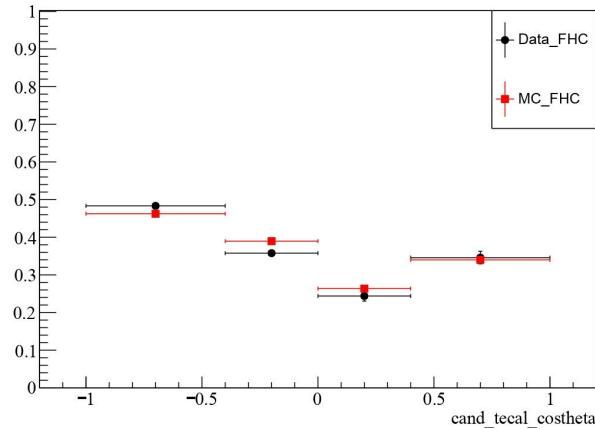
FGD-TECal->SMRD



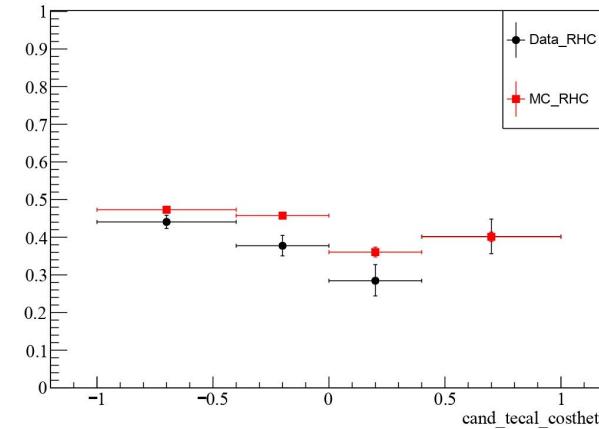
costheta low	costheta up	DATA	MC	ERROR DATA	ERROR MC	Yhigh DATA	Ylow DATA	Yhigh MC	Ylow MC
-1	-0,4	0.475601	0.464035	0.00756205	0.00195845	0.00756578	0.00755832	0.00195883	0.00195808
-0,4	0	0.359876	0.395999	0.00891399	0.00224926	0.00894615	0.00888171	0.00225073	0.0022478
0	0,4	0.248182	0.271378	0.0130232	0.00343469	0.0131749	0.0128697	0.00344377	0.00342558
0,4	1	0.35262	0.346991	0.0157805	0.00420766	0.0158873	0.0156729	0.00421562	0.00419968

FGD→TECal→SMRD

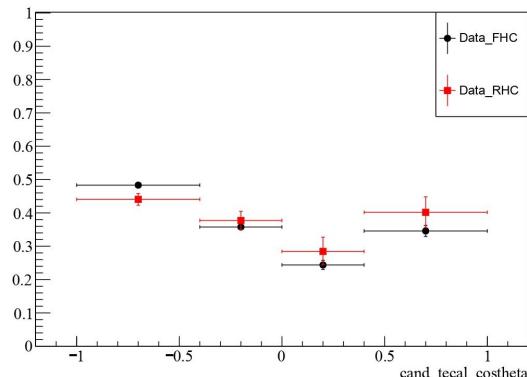
FGD-TECal->SMRD



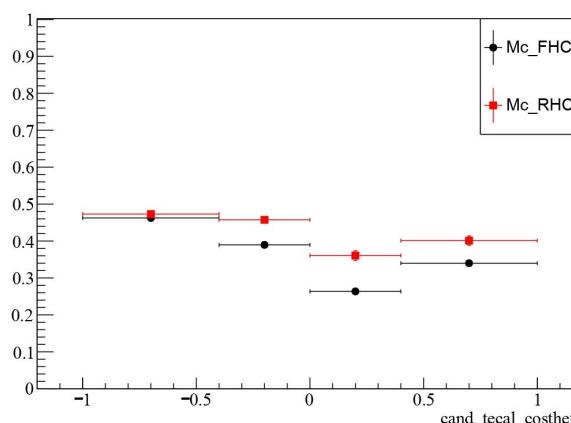
FGD-TECal->SMRD



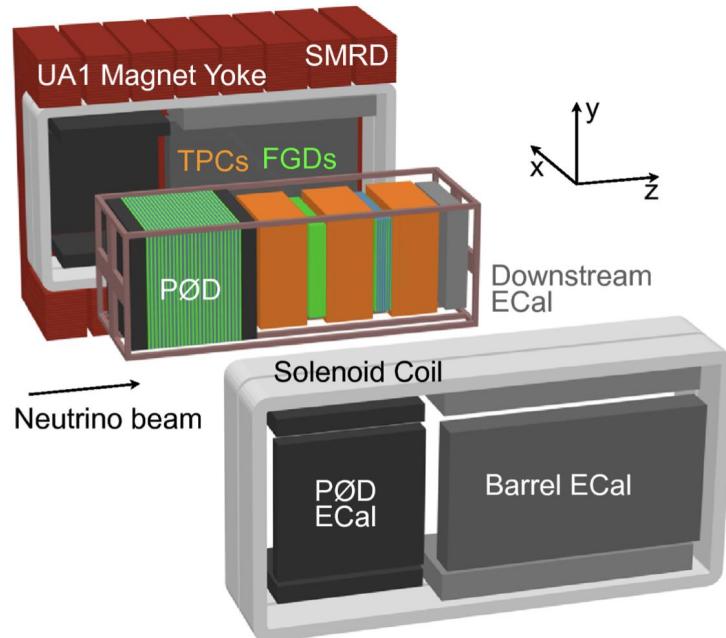
FGD-TECal->SMRD



FGD-TECal->SMRD



FGD→TECal SMRD

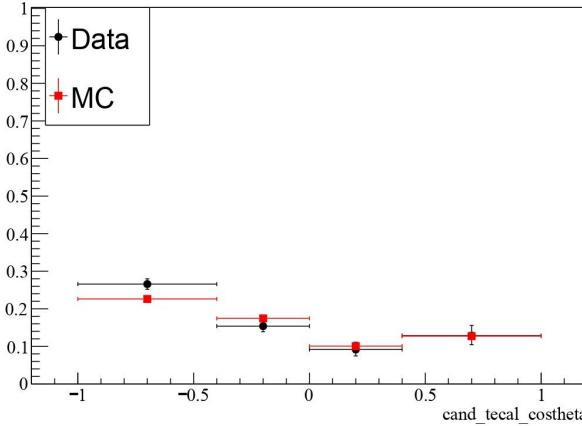


Due to the structure of the detector, the results for the FGD→TECal SMRD top-bottom, right-left topology will naturally be different, because of the solenoid coil

<https://arxiv.org/pdf/2002.09323.pdf>

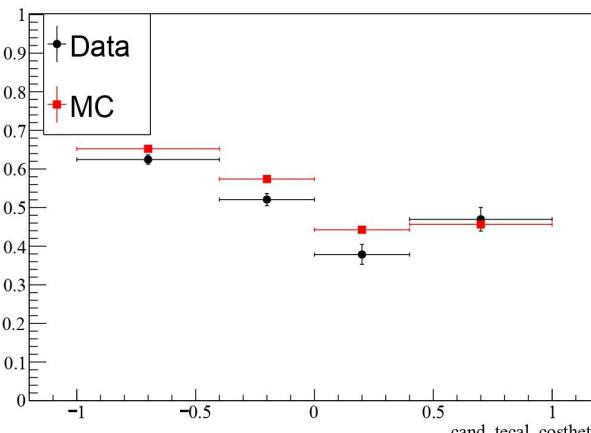
FGD→TECal SMRD(Top+Bottom, Left+Right)

FGD-TECal->SMRD(Top+Bottom)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.265734	0.22619	0.0138023	0.0141143	0.00313132	0.0031519
-0,4	0	0.153846	0.174478	0.0148415	0.0156664	0.00389604	0.00394233
0	0,4	0.0916335	0.100651	0.0171307	0.019298	0.00469675	0.00483021
0,4	1	0.128655	0.127218	0.0241124	0.0269943	0.00682698	0.00704224

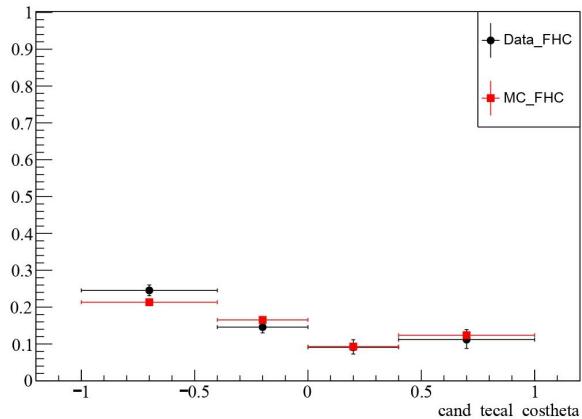
FGD-TECal->SMRD(Left+Right)



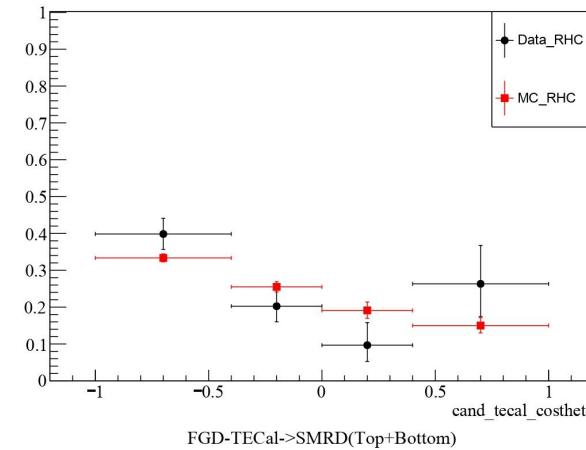
costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.624524	0.652296	0.0122588	0.0121533	0.00327033	0.00326079
-0,4	0	0.520812	0.573964	0.0159257	0.0158975	0.0040295	0.00402296
0	0,4	0.378531	0.442596	0.0254966	0.0259524	0.00715834	0.00717427
0,4	1	0.469697	0.456399	0.0305442	0.0306965	0.00815417	0.00816978

FGD→TECal SMRD(Top+Bottom) (FHC/RHC)

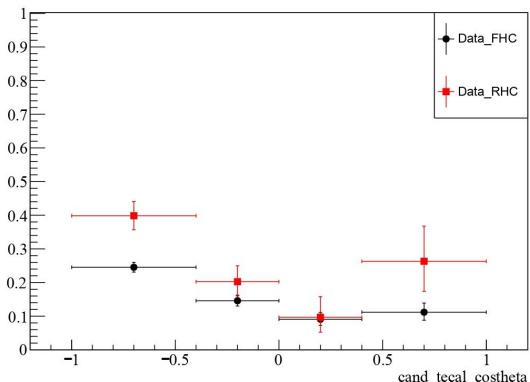
FGD-TECal->SMRD(Top+Bottom)



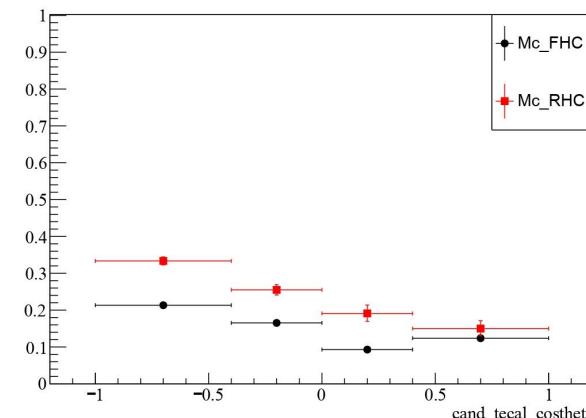
FGD-TECal->SMRD(Top+Bottom)



FGD-TECal->SMRD(Top+Bottom)

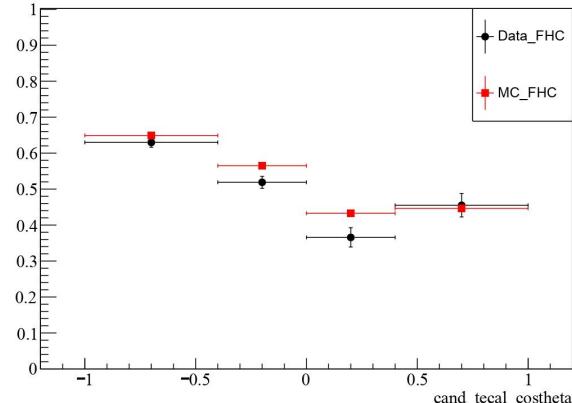


FGD-TECal->SMRD(Top+Bottom)

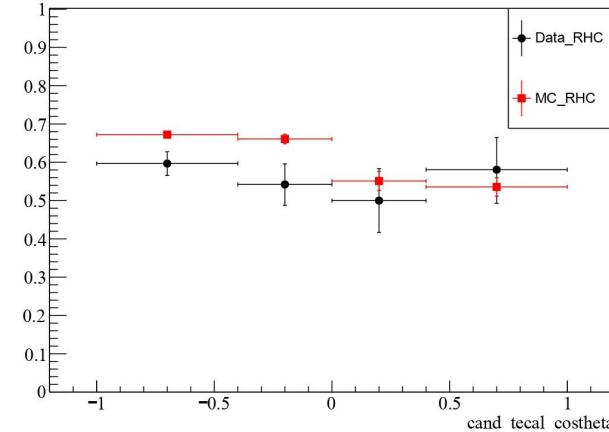


FGD→TECal SMRD(Left+Right) (FHC/RHC)

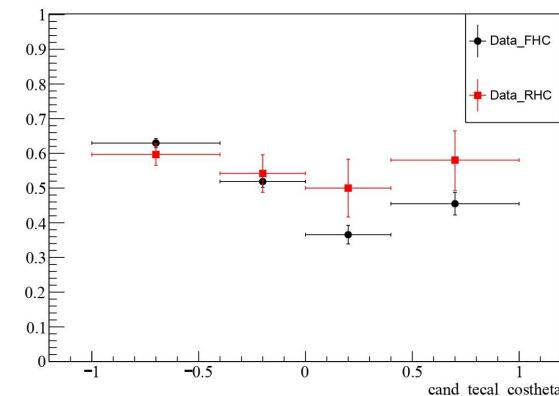
FGD-TECal->SMRD(Left+Right)



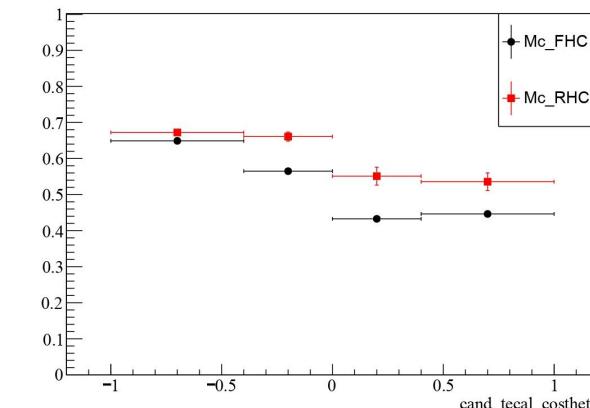
FGD-TECal->SMRD(Left+Right)



FGD-TECal->SMRD(Left+Right)



FGD-TECal->SMRD(Left+Right)



Summary

- We have revised the high-angle matching systematics relevant for 4pi analyses using 6T production and all available data from Run~2 and up to Run~9
- Estimated matching efficiencies and the corresponding uncertainties that can be used for systematic propagation

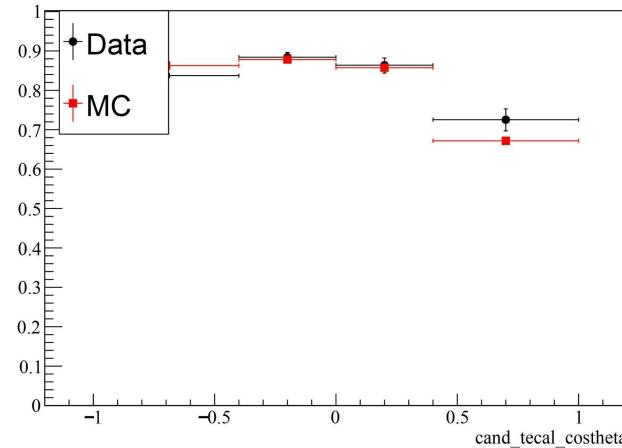
Next steps

- To check separately FHC and RHC
- To look at matching with low quality TPC tracks
- To check systematics for Production 7

Backup Slides

FGD1→TECal (Top)

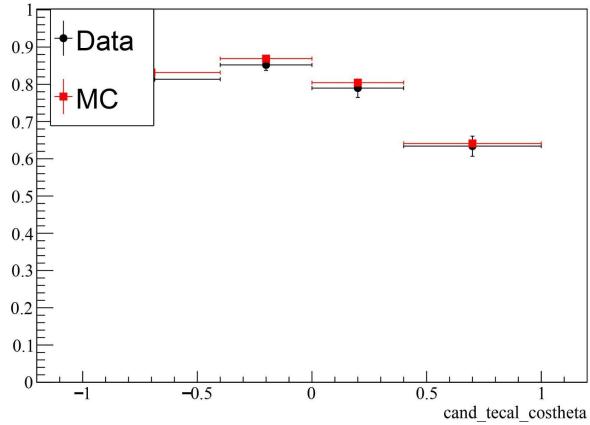
FGD1->TECal (Top)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.837442	0.862879	0.010416	0.0100693	0.00233999	0.0023178
-0,4	0	0.88408	0.878209	0.0129823	0.0121909	0.00310106	0.00305637
0	0,4	0.863777	0.857446	0.0198185	0.01832	0.00490109	0.00480919
0,4	1	0.72549	0.671804	0.028454	0.027281	0.00768803	0.0076271

FGD1→TECal (Bottom)

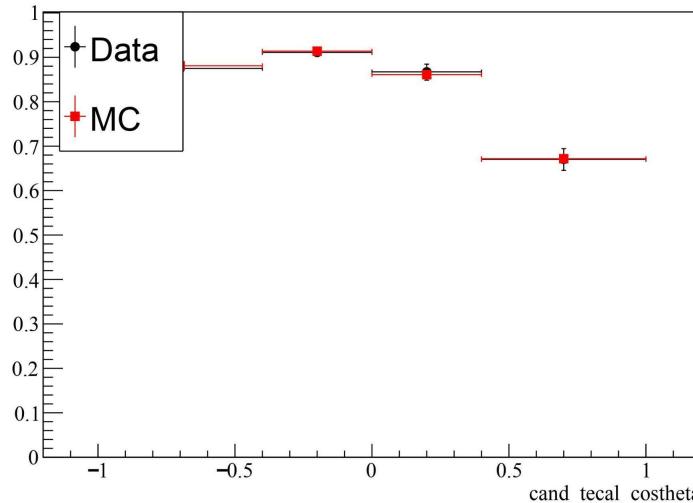
FGD1->TECal (Bottom)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0.4	0.813636	0.831625	0.013362	0.012887	0.00336797	0.00333253
-0.4	0	0.852033	0.868886	0.0146952	0.0139325	0.00321263	0.00316867
0	0.4	0.789855	0.804376	0.0251677	0.0237732	0.00585609	0.00576895
0.4	1	0.634069	0.641128	0.0272704	0.0267089	0.00737866	0.00733439

FGD1→TECal (Left)

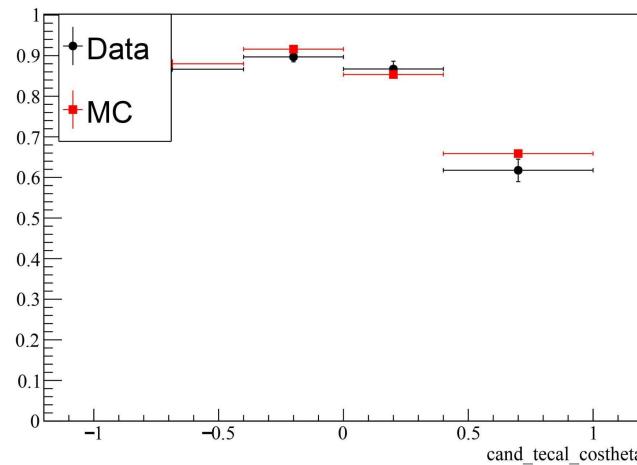
FGD1->TECal (Left)



cosec(theta) low	cosec(theta) up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.874918	0.880941	0.00863251	0.00830494	0.00221961	0.00219601
-0,4	0	0.910936	0.913877	0.00987829	0.00926013	0.00239402	0.0023545
0	0,4	0.867232	0.860946	0.0187125	0.0173317	0.00468656	0.00459989
0,4	1	0.67027	0.671846	0.0246995	0.024088	0.0064487	0.00640576

FGD1→TECal (Right)

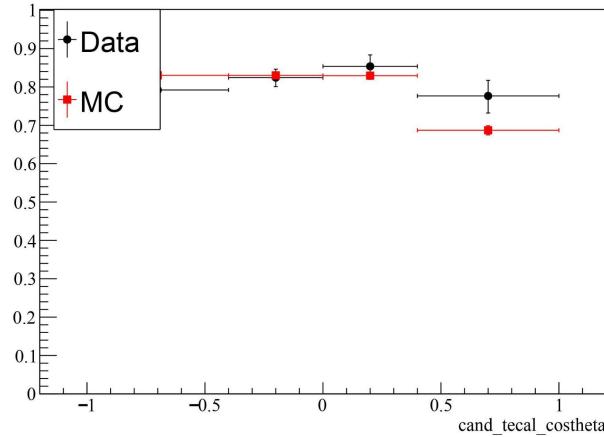
FGD1->TECal (Right)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.866592	0.879947	0.0116597	0.0111117	0.00259778	0.00256581
-0,4	0	0.896861	0.915994	0.0121576	0.0113665	0.0027307	0.00267799
0	0,4	0.867133	0.853465	0.020904	0.0191967	0.00530024	0.00519643
0,4	1	0.617647	0.658796	0.0279655	0.0274552	0.0069405	0.00689542

FGD2→TECal (Top)

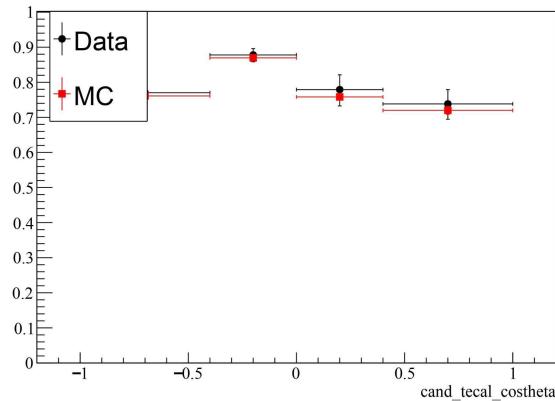
FGD2->TECal (Top)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0.4	0.792109	0.830316	0.0160946	0.0155041	0.00344114	0.00340451
-0,4	0	0.824373	0.830213	0.023512	0.0219673	0.00552607	0.0054323
0	0,4	0.853659	0.829425	0.0336489	0.0298465	0.008169	0.00796691
0,4	1	0.776596	0.687038	0.0445596	0.0406938	0.0121008	0.0119333

FGD2→TECal (Bottom)

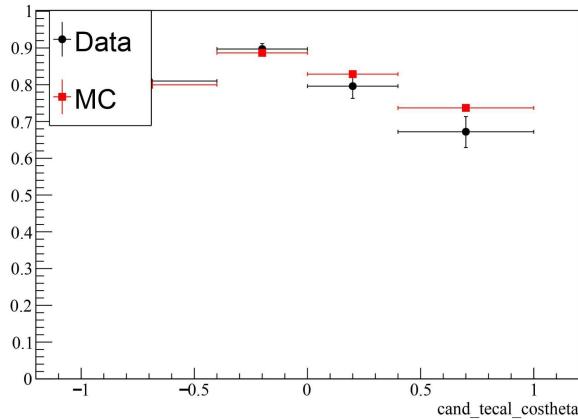
FGD2->TECal (Bottom)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.770138	0.761005	0.0189845	0.0182781	0.004944	0.00489766
-0,4	0	0.877888	0.869565	0.0196263	0.0179666	0.00472124	0.00462634
0	0,4	0.77907	0.758218	0.046485	0.0422278	0.00995238	0.00976974
0,4	1	0.738318	0.72	0.0436437	0.0407144	0.0112296	0.011049

FGD2→TECal (Left)

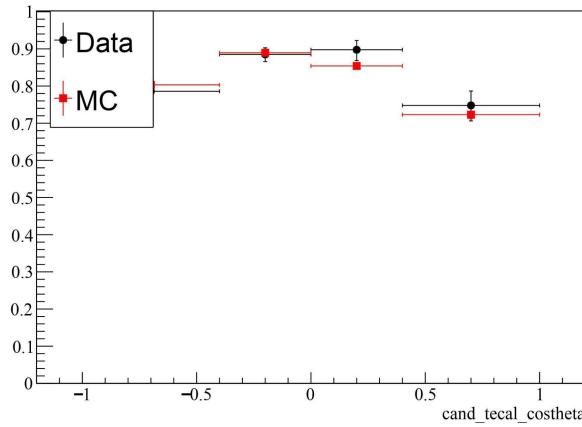
FGD2->TECal (Left)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.810073	0.799778	0.0129214	0.0124877	0.00324929	0.00322316
-0,4	0	0.897172	0.8866	0.0160806	0.0147201	0.0039889	0.00390895
0	0,4	0.796178	0.828877	0.0332639	0.0307686	0.00805091	0.00785536
0,4	1	0.672131	0.737056	0.0431326	0.0412751	0.0100008	0.00984028

FGD2→TECal (Right)

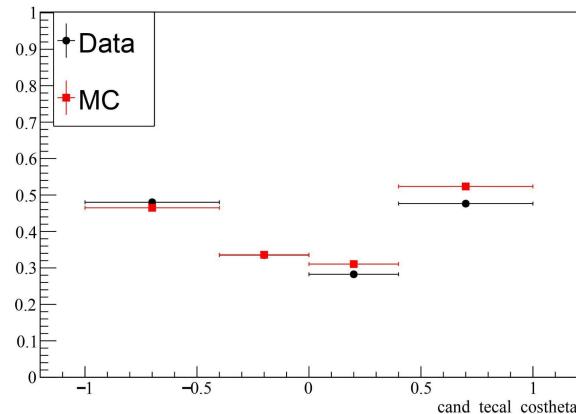
FGD2->TECal (Right)



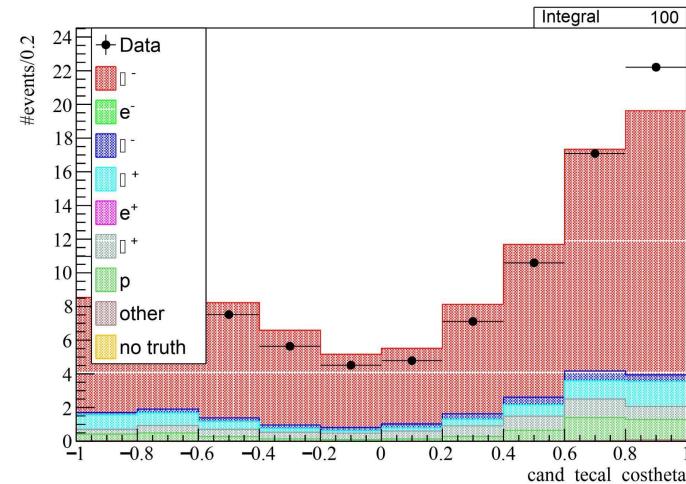
costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.785912	0.803154	0.0155009	0.0149748	0.00382797	0.00379087
-0,4	0	0.885135	0.889579	0.0193892	0.0176574	0.00449145	0.00438724
0	0,4	0.897638	0.854155	0.0289447	0.0247883	0.00841294	0.00815289
0,4	1	0.747826	0.723007	0.041642	0.0388043	0.0107255	0.0105574

TECal \rightarrow SMRD

TECal \rightarrow SMRD

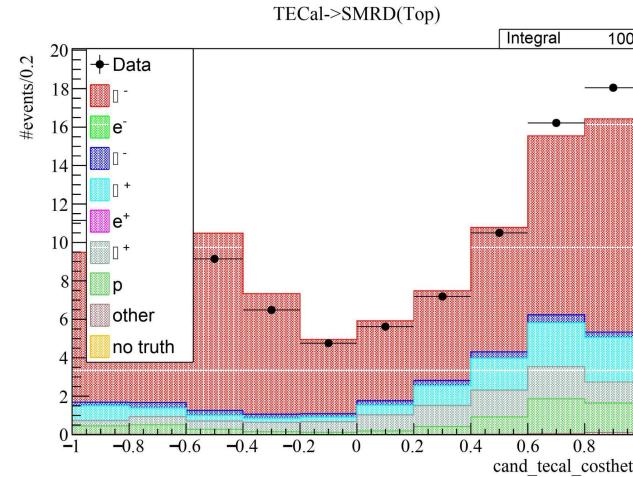
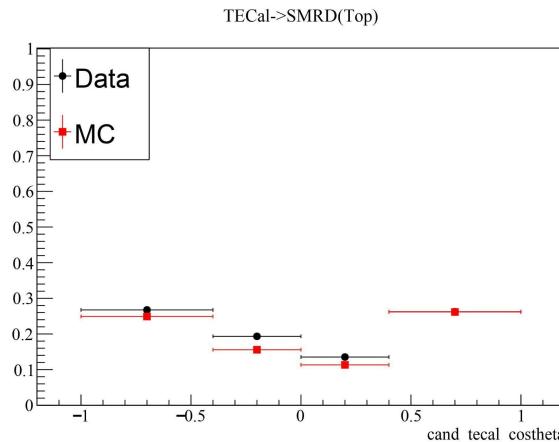


TECal \rightarrow SMRD



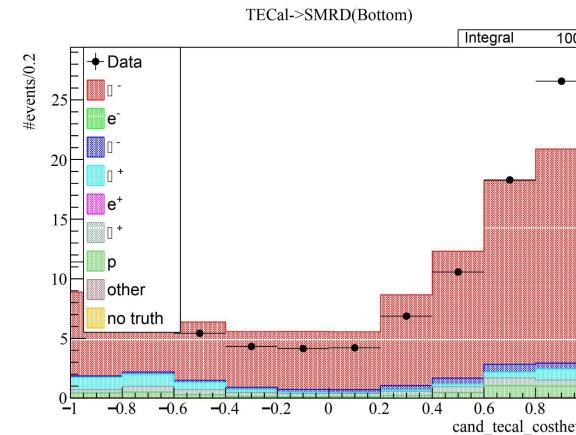
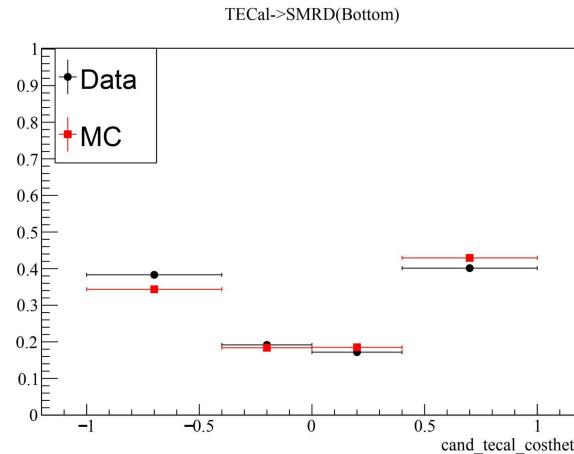
$costheta$ low	$costheta$ up	DATA	MC	Y_{low} DATA	Y_{high} DATA	Y_{low} MC	Y_{high} MC
-1	-0,4	0.480159	0.464984	0.00194722	0.00194762	0.000602033	0.000602098
-0,4	0	0.335193	0.336015	0.00305494	0.00306417	0.000846593	0.000847298
0	0,4	0.282533	0.310588	0.00269032	0.00270071	0.000769697	0.000770385
0,4	1	0.476444	0.523551	0.00146016	0.00146042	0.000440255	0.000440243

TECal \rightarrow SMRD(Top)



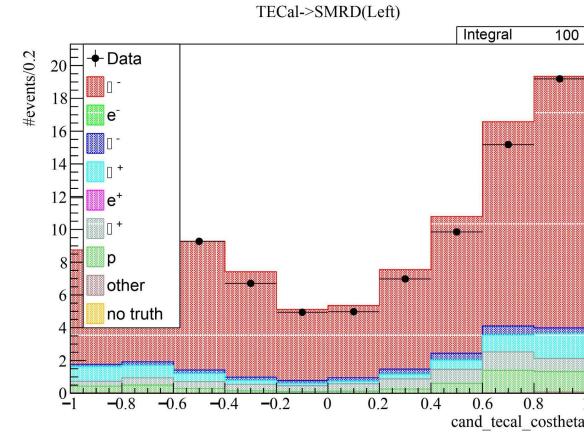
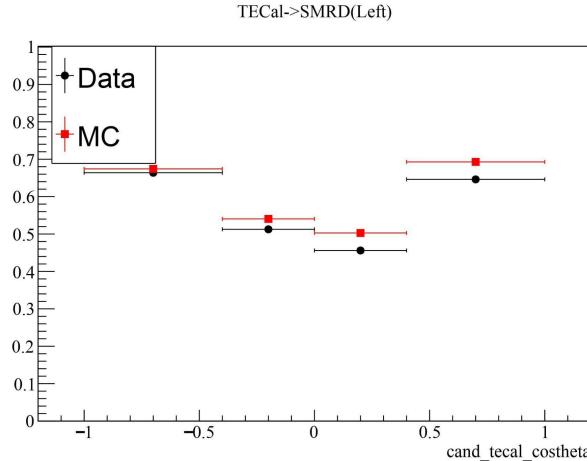
costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0.4	0.267504	0.24905	0.00385203	0.00387566	0.00108726	0.00108938
-0.4	0	0.193331	0.155723	0.00569681	0.00578319	0.00145877	0.00146624
0	0.4	0.13526	0.113232	0.0046128	0.00470301	0.00121957	0.00122725
0.4	1	0.26234	0.261752	0.00319665	0.00321348	0.00094968	0.000951155

TECal \rightarrow SMRD(Bottom)



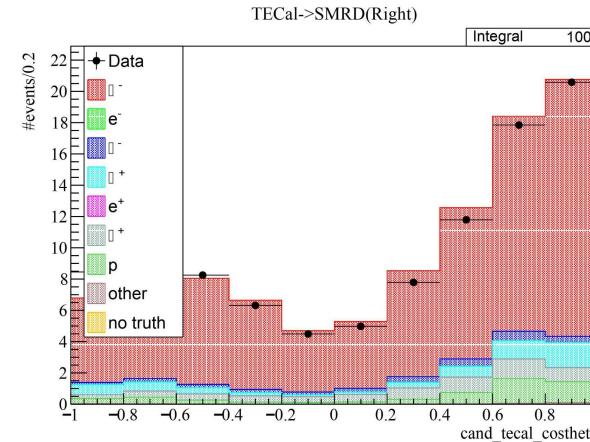
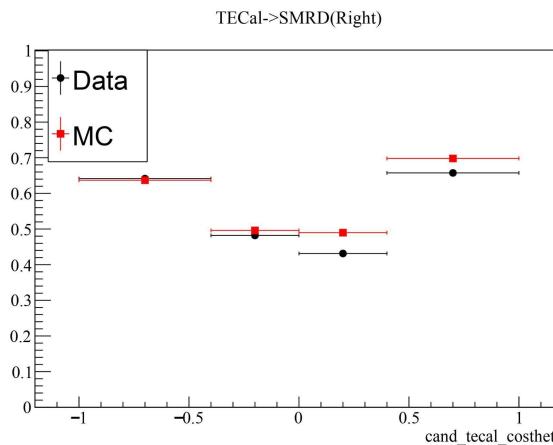
$costheta_{low}$	$costheta_{up}$	DATA	MC	Y_{high} DATA	Y_{low} DATA	Y_{high} MC	Y_{low} MC
-1	-0,4	0.383117	0.343666	0.00316198	0.00315541	0.00101891	0.00101796
-0,4	0	0.191696	0.183833	0.00441692	0.00436576	0.00120041	0.00119637
0	0,4	0.171882	0.185153	0.00370254	0.00366088	0.00106573	0.00106258
0,4	1	0.40137	0.429281	0.00214046	0.00213796	0.00071293 7	0.00071274 6

TECal →SMRD(Left)



costheta low	costheta up	DATA	MC	Ylow DATA	Yhigh DATA	Ylow MC	Yhigh MC
-1	-0,4	0.663853	0.674214	0.00349393	0.00348201	0.00108189	0.00108065
-0,4	0	0.512628	0.540437	0.00613279	0.00613027	0.00171328	0.00171265
0	0,4	0.45605	0.502802	0.0060271	0.00603569	0.00169377	0.00169371
0,4	1	0.64612	0.692845	0.00301532	0.00300759	0.00082199	0.000821171

TECal →SMRD(Right)



costheta low	costheta up	DATA	MC	$Y_{\text{low}} \text{ DATA}$	$Y_{\text{high}} \text{ DATA}$	$Y_{\text{low}} \text{ MC}$	$Y_{\text{high}} \text{ MC}$
-1	-0,4	0.641446	0.637003	0.00465219	0.00463451	0.00137145	0.00136996
-0,4	0	0.482045	0.496109	0.00753332	0.00753877	0.00203347	0.00203355
0	0,4	0.431403	0.48983	0.00686446	0.00688207	0.00184188	0.00184207
0,4	1	0.657457	0.69798	0.00332563	0.00331537	0.00087496	0.000874017