GUNDAM for OA 2024

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GUNDAM group

LLR meeting group discussion
Wednesday, 22nd November 2023

ND280 fit for OA 2024

- New reparameterisation (a.k.a splinification) of Near Detector Systematics using splines

- New **4π selection** (Fwd + Bwd + High Angle muons)
  - observed improved constraints of the cross-section systematics
  - 4π samples acceptance matches SK much better !

- Updated cross-section model

- Move from production 6 MC to **production 7 MC**

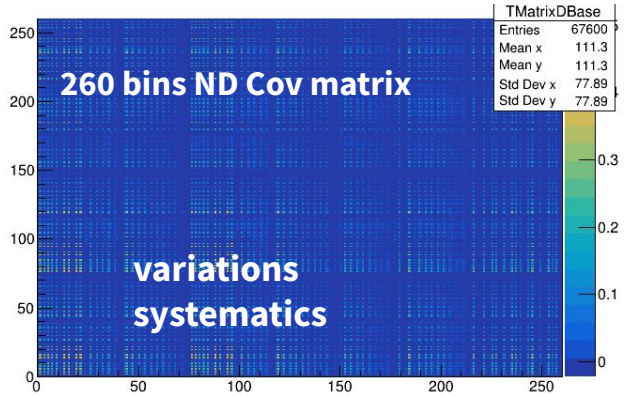
ND Systematic Reparameterisation

- We can treat some of the ND280 systematics parameters with the same approach we use for most of cross-section systematics (i.e. via response functions)

- We have two kind of detector systematics in ND280 :
  - Weight systematics: each event associates weight (e.g SI pion and proton)
  - Variation systematics : affect observable quantities (p_μ and event topologies), e.g momentum resolution

- Easy to reparameterize weight systematics, while for variation systematics we kept the covariance matrix approach

- In this way the number has reduced from hundreds of parameters to 260 normalisations + 80 (prod 6 MC) to 107 (prod 7 MC) weights systematics parameters !



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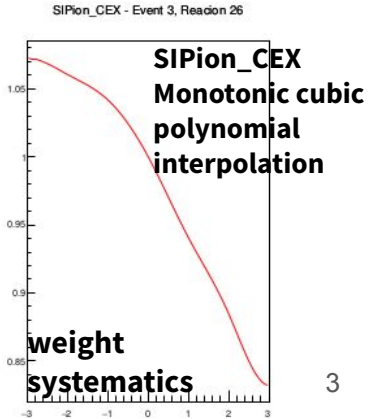


Move to production 7 MC and new 4π selection

- Implementation of a new set of cross-section parameters, see here ✓
- Implementation of a new set of ND weight systematics, see here ✓
- Implementation of a new set of samples (HA, Bwd) ✓
- Only using a subset of inputs (not the full statistics- run 4a,8w, 6,7 MC)
- Flux, cross-section (without Eb) and weight systematics **enabled**
- Eb cross-section and ND variation systematics **disabled**
    - cross-section Eb parameters need new templates and a new binning usually generated by MaCh3 but will be produced by GUNDAM
- Preliminary tests to check the agreement between GUNDAM and MaCh3
    - Nominal event rate
    - Likelihood scans

→ Perfect agreement for cross-section parameters

→ Disagreements for some ND weight systematics

Nominal Event rate production 7MC and 4π selection

New samples HA and Bwd

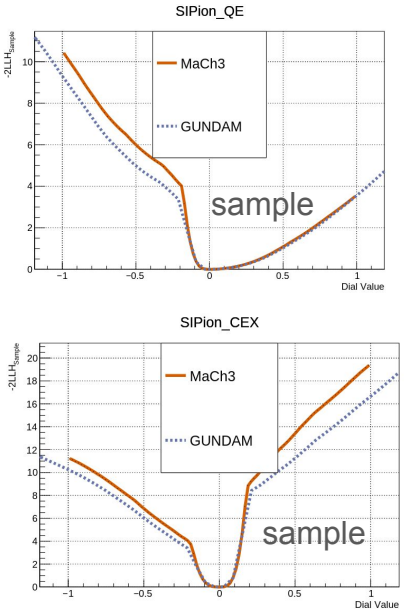
	MC Only (No Weight) Binned			POT weights			FluxNomWeight (**without** the weight of 2 for NC1g			All weights (Flux+Xsec(wo Eb)+ND weight system		
Sample	GUNDAM	MaCh3	(M-G) / M	GUNDAM	MaCh3	(M-G) / M	GUNDAM	MaCh3	(M-G) / M	GUNDAM	MaCh3	(M-G) / M
FGD1 numuCC 0pi Fwd 0 protons no photon:	117540	117540	0.00%	6277.351	6277.35	0.00%	6721.765557	6721.77	0.00%	6182.69	6182.69	0.00%
FGD1 numuCC 0pi Fwd N protons no photon:	56893	56893	0.00%	3036.973	3036.97	0.00%	3350.869283	3350.87	0.00%	2979.17	2979.17	0.00%
FGD1 numuCC 0pi Bwd NoPhoton No Protons	4256	4256	0.00%	227.423	227.423	0.00%	233.826348	233.826	0.00%	240.564	240.564	0.00%
FGD1 numuCC 0pi Bwd NoPhoton N Protons	3292	3292	0.00%	175.673	175.673	0.00%	178.217599	178.218	0.00%	160.982	160.982	0.00%
FGD1 numuCC 0pi HA NoPhoton No Protons	16968	16968	0.00%	906.137	906.137	0.00%	934.643	934.643	0.00%	866.618	866.618	0.00%
FGD1 numuCC 0pi HA NoPhoton N Protons	13599	13599	0.00%	725.404	725.403	0.00%	739.551	739.551	0.00%	615.935	615.935	0.00%
FGD1 numuCC 1Pi HAFwd NoPhoton	3183	3183	0.00%	170.133	170.133	0.00%	183.629607	183.63	0.00%	171.785	171.785	0.00%
FGD1 numuCC 1pi Fwd no photon:	40580	40580	0.00%	2169.691	2169.69	0.00%	2526.91	2526.91	0.00%	2443.12	2443.12	0.00%
FGD1 numuCC other Fwd no photon:	12826	12826	0.00%	686.751	686.751	0.00%	854.901521	854.901	0.00%	864.745	864.745	0.00%
FGD1 numuCC photon Fwd:	23266	23266	0.00%	1244.737	1244.74	0.00%	1520.19	1520.19	0.00%	1495.98	1495.98	0.00%
FGD2 numuCC 0pi Fwd 0 protons no photon:	126455	126455	0.00%	6736.174	6736.17	0.00%	7218.41	7218.41	0.00%	6606.16	6606.16	0.00%
FGD2 numuCC 0pi Fwd N protons no photon:	45956	45956	0.00%	2450.610	2450.61	0.00%	2739.36	2739.36	0.00%	2527.03	2527.03	0.00%
FGD2 numuCC 0pi Bwd NoPhoton No Protons	2957	2957	0.00%	157.447	157.447	0.00%	161.80065	161.801	0.00%	145.695	145.695	0.00%
FGD2 numuCC 0pi Bwd NoPhoton N Protons	1784	1784	0.00%	95.370	95.3698	0.00%	96.8058	96.8058	0.00%	83.3873	83.3873	0.00%
FGD2 numuCC 0pi HA NoPhoton No Protons	16142	16142	0.00%	859.368	859.368	0.00%	881.702	881.702	0.00%	812.611	812.61	0.00%
FGD2 numuCC 0pi HA NoPhoton N Protons	8197	8197	0.00%	436.922	436.922	0.00%	447.507	447.507	0.00%	381.849	381.849	0.00%
FGD2 numuCC 1Pi HAFwd NoPhoton	2009	2009	0.00%	106.939	106.939	0.00%	116.269087	116.269	0.00%	111.644	111.644	0.00%
FGD2 numuCC 1pi Fwd no photon:	32569	32569	0.00%	1735.928	1735.93	0.00%	2033.906039	2033.91	0.00%	2032.01	2032.01	0.00%
FGD2 numuCC other Fwd no photon:	11393	11393	0.00%	607.824	607.824	0.00%	756.408	756.408	0.00%	803.064	803.063	0.00%
FGD2 numuCC photon Fwd:	22038	22038	0.00%	1174.644	1174.64	0.00%	1436.146367	1436.15	0.00%	1409.89	1409.89	0.00%
FGD1 anti-numuCC 0pi:	71865	71865	0.00%	6337.783	6337.78	0.00%	6441.56	6441.56	0.00%	5875.21	5875.21	0.00%
FGD1 anti-numuCC 1pi:	5696	5696	0.00%	503.213	503.213	0.00%	542.993417	542.993	0.00%	520.96	520.96	0.00%
FGD1 anti-numuCC other:	10098	10098	0.00%	889.631	889.631	0.00%	977.816	977.816	0.00%	946.963	946.963	0.00%
FGD2 anti-numuCC 0pi:	69409	69409	0.00%	6168.096	6168.1	0.00%	6281.36	6281.36	0.00%	5686.22	5686.22	0.00%
FGD2 anti-numuCC 1pi:	5221	5221	0.00%	464.214	464.214	0.00%	502.219691	502.22	0.00%	479.127	479.127	0.00%
FGD2 anti-numuCC other:	9456	9456	0.00%	838.972	838.972	0.00%	925.481	925.481	0.00%	895.232	895.232	0.00%
FGD1 NuMuBkg CC0pi in AntiNu Mode:	25910	25910	0.00%	2284.597	2284.6	0.00%	2656.51	2656.51	0.00%	2439.72	2439.72	0.00%
FGD1 NuMuBkg CC1pi in AntiNu Mode:	8592	8592	0.00%	757.236	757.236	0.00%	901.565	901.565	0.00%	871.134	871.134	0.00%
FGD1 NuMuBkg CCother in AntiNu Mode:	7482	7482	0.00%	660.788	660.788	0.00%	819.72	819.72	0.00%	818.553	818.553	0.00%
FGD2 NuMuBkg CC0pi in AntiNu Mode:	25503	25503	0.00%	2263.711	2263.71	0.00%	2623.704299	2623.7	0.00%	2395.98	2395.98	0.00%
FGD2 NuMuBkg CC1pi in AntiNu Mode:	7044	7044	0.00%	622.923	622.923	0.00%	745.044	745.044	0.00%	717.934	717.934	0.00%
FGD2 NuMuBkg CCother in AntiNu Mode:	7175	7175	0.00%	636.675	636.674	0.00%	789.127405	789.127	0.00%	778.941	778.941	0.00%
Totals:	815354	815354	0.00%	52409.339	52409.3308	0.00%	57339.91967	57339.9278	0.00%	53360.9033	53360.9013	0.00%

Perfect agreement between GUNDAM and MaCh3 for MC only, POTWeight, Flux Nom.Weight and when All weights are applied (Flux+Xsec (without Eb) + weight systematics)

Nominal Event rate production 7MC and 4π selection

Sample	Weight systematics only- POTWeight			Xsec Nom. weights (Without binned xsec, **without**		
	GUNDAM	MaCh3	(M-G) / M	GUNDAM	MaCh3	(M-G) / M
FGD1 numuCC 0pi Fwd 0 protons no photon:	6277.351	6277.35	0.00%	5845.949	5845.95	0.00%
FGD1 numuCC 0pi Fwd N protons no photon:	3036.973	3036.97	0.00%	2855.043	2855.04	0.00%
FGD1 numuCC 0pi Bwd NoPhoton No Protons	227.423	227.423	0.00%	189.206	189.206	0.00%
FGD1 numuCC 0pi Bwd NoPhoton N Protons	175.673	175.673	0.00%	142.820	142.82	0.00%
FGD1 numuCC 0pi HA NoPhoton No Protons	906.189	906.137	-0.01%	809.673	809.721	0.01%
FGD1 numuCC 0pi HA NoPhoton N Protons	725.404	725.403	0.00%	622.903	622.903	0.00%
FGD1 numuCC 1Pi HAFwd NoPhoton	170.116	170.133	0.01%	154.729	154.712	-0.01%
FGD1 numuCC 1pi Fwd no photon:	2169.691	2169.69	0.00%	2148.673	2148.67	0.00%
FGD1 numuCC other Fwd no photon:	686.751	686.751	0.00%	685.114	685.114	0.00%
FGD1 numuCC photon Fwd:	1244.737	1244.74	0.00%	1227.299	1227.3	0.00%
FGD2 numuCC 0pi Fwd 0 protons no photon:	6736.174	6736.17	0.00%	6254.407	6254.41	0.00%
FGD2 numuCC 0pi Fwd N protons no photon:	2450.610	2450.61	0.00%	2334.668	2334.67	0.00%
FGD2 numuCC 0pi Bwd NoPhoton No Protons	157.447	157.447	0.00%	131.623	131.623	0.00%
FGD2 numuCC 0pi Bwd NoPhoton N Protons	95.370	95.3698	0.00%	77.773	77.7726	0.00%
FGD2 numuCC 0pi HA NoPhoton No Protons	859.368	859.368	0.00%	758.565	758.565	0.00%
FGD2 numuCC 0pi HA NoPhoton N Protons	436.999	436.922	-0.02%	374.860	374.936	0.02%
FGD2 numuCC 1Pi HAFwd NoPhoton	106.939	106.939	0.00%	96.656	96.6564	0.00%
FGD2 numuCC 1pi Fwd no photon:	1735.928	1735.93	0.00%	1725.578	1725.58	0.00%
FGD2 numuCC other Fwd no photon:	607.824	607.824	0.00%	606.384	606.384	0.00%
FGD2 numuCC photon Fwd:	1174.644	1174.64	0.00%	1165.183	1165.18	0.00%
FGD1 anti-numuCC 0pi:	6337.783	6337.78	0.00%	5836.992	5836.99	0.00%
FGD1 anti-numuCC 1pi:	503.213	503.213	0.00%	488.082	488.082	0.00%
FGD1 anti-numuCC other:	889.631	889.631	0.00%	864.865	864.865	0.00%
FGD2 anti-numuCC 0pi:	6168.096	6168.1	0.00%	5665.920	5665.92	0.00%
FGD2 anti-numuCC 1pi:	464.214	464.214	0.00%	452.414	452.414	0.00%
FGD2 anti-numuCC other:	838.972	838.972	0.00%	821.672	821.672	0.00%
FGD1 NuMuBkg CC0pi in AntiNu Mode:	2284.597	2284.6	0.00%	2122.731	2122.73	0.00%
FGD1 NuMuBkg CC1pi in AntiNu Mode:	757.236	757.236	0.00%	737.583	737.583	0.00%
FGD1 NuMuBkg CCother in AntiNu Mode:	660.788	660.788	0.00%	654.563	654.563	0.00%
FGD2 NuMuBkg CC0pi in AntiNu Mode:	2263.711	2263.71	0.00%	2105.248	2105.25	0.00%
FGD2 NuMuBkg CC1pi in AntiNu Mode:	622.923	622.923	0.00%	611.512	611.512	0.00%
FGD2 NuMuBkg CCother in AntiNu Mode:	636.675	636.674	0.00%	631.877	631.877	0.00%
Totals:	52409.450	52409.3308	0.00%	49200.563	49200.671	0.00%

Discrepancies between both fitters looking SI parameters sample LLH scans



HA samples disagreements

Conclusion

Production 7 MC and 4π sample selection:

- cross-section parameters (**without Eb**) from the new cross-section model agree between GUNDAM and MaCh3

  ○ New cross-section Eb splines and binning must be generated by GUNDAM (should start soon)

- ND weight systematics disagree between GUNDAM and MaCh3

  →Change the weight capped to 10

  →Find weights different from 1

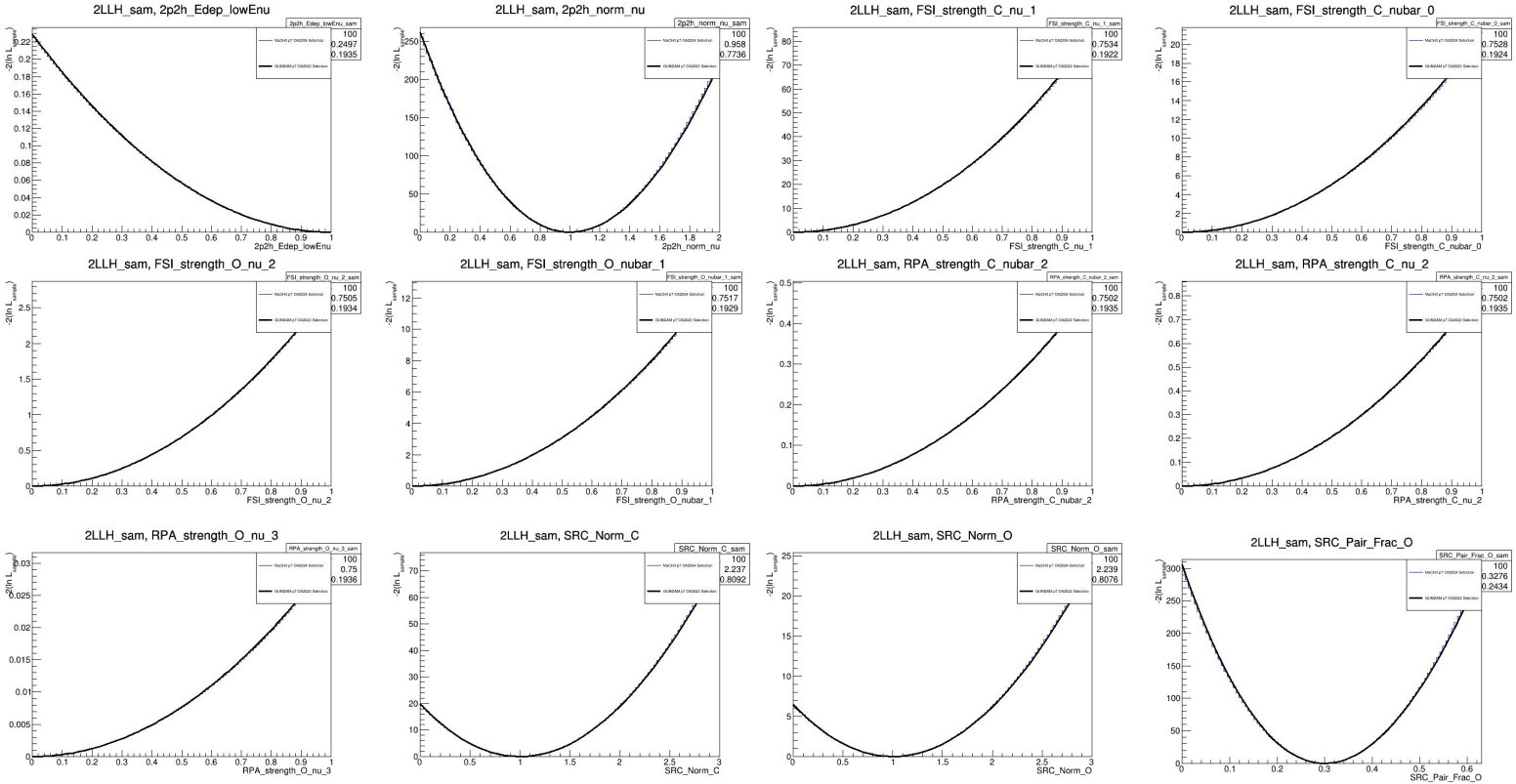
  →Check nominal event rate of ND weight systematics one by one

- Goal :
  → Fix SIPion (mostly) ND weight systematics issue (sample part of llh scans) + Nominal event rate differences (correlated ?)
  → Use all the statistics and run an Asimov fit

Back-up

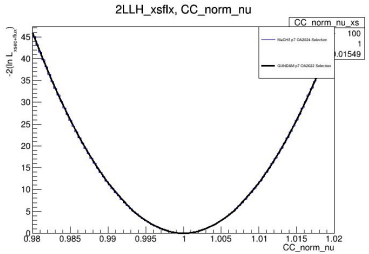
More cross-section sample llh scans with production 7 and 4π selection

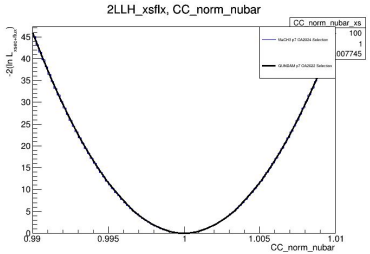
– GUNDAM p7
– MaCh3 p7

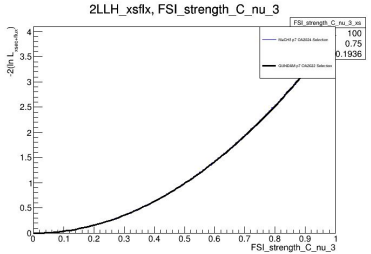


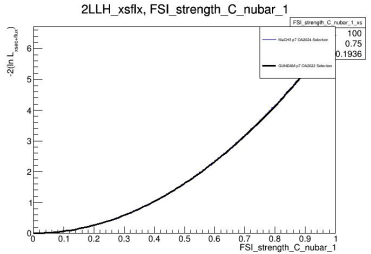
More cross-section penalty llh scans with production 7 and 4π selection

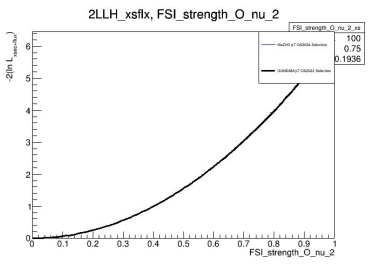
– GUNDAM p7
– MaCh3 p7

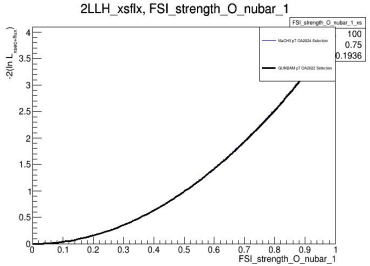


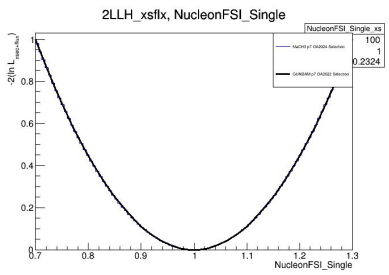


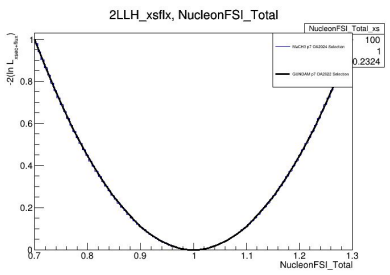


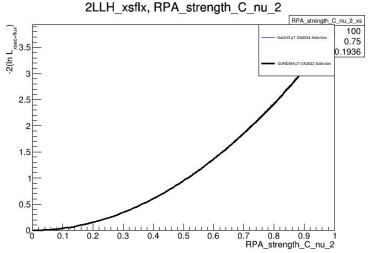


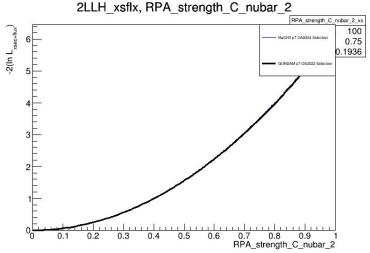


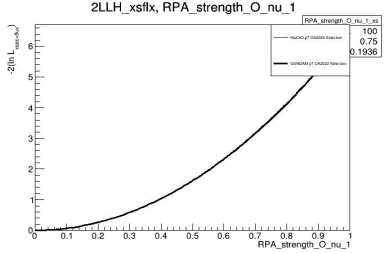


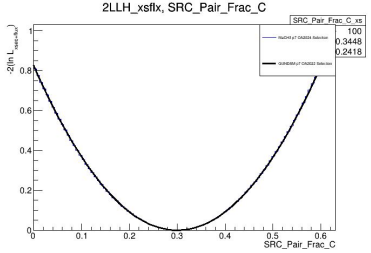






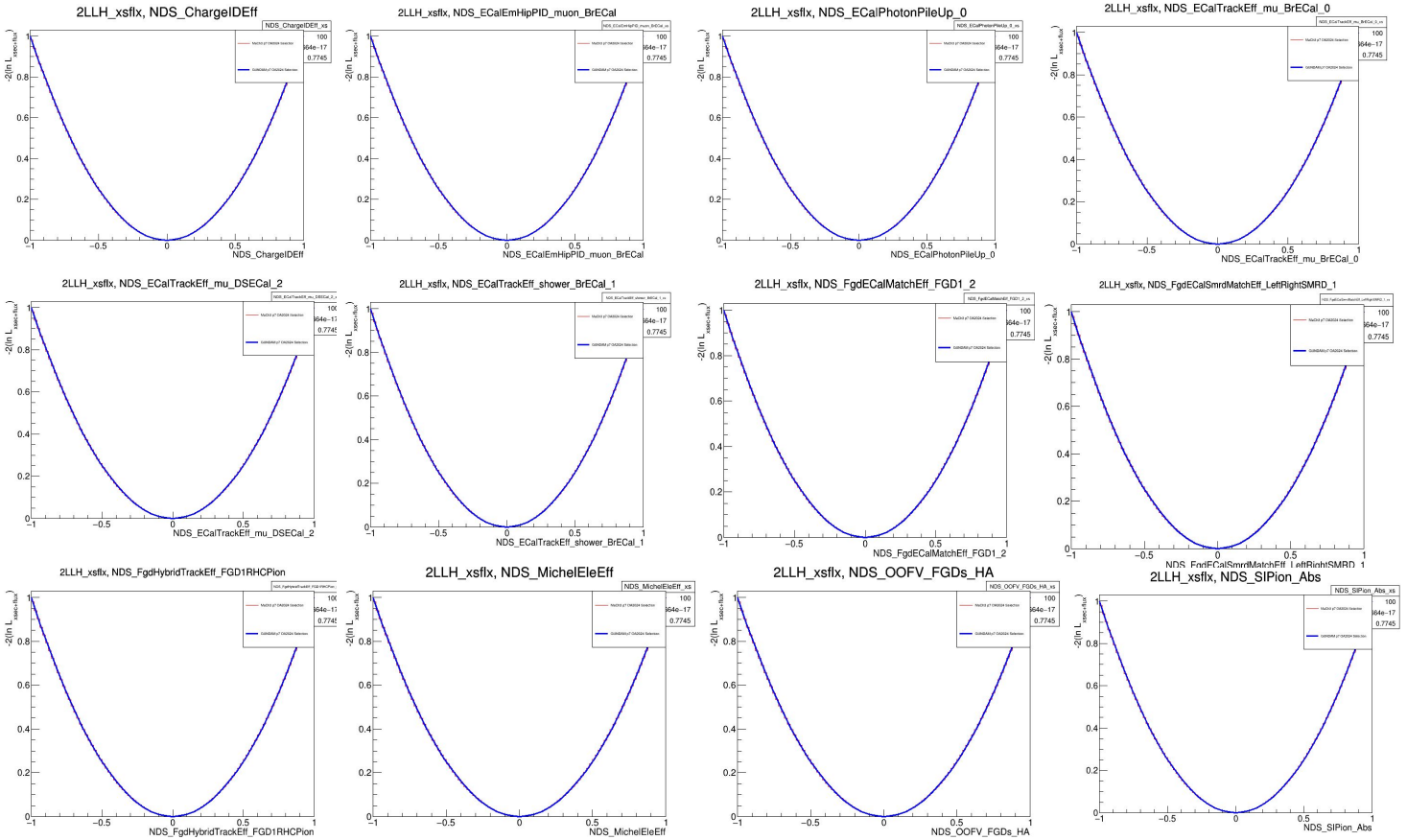






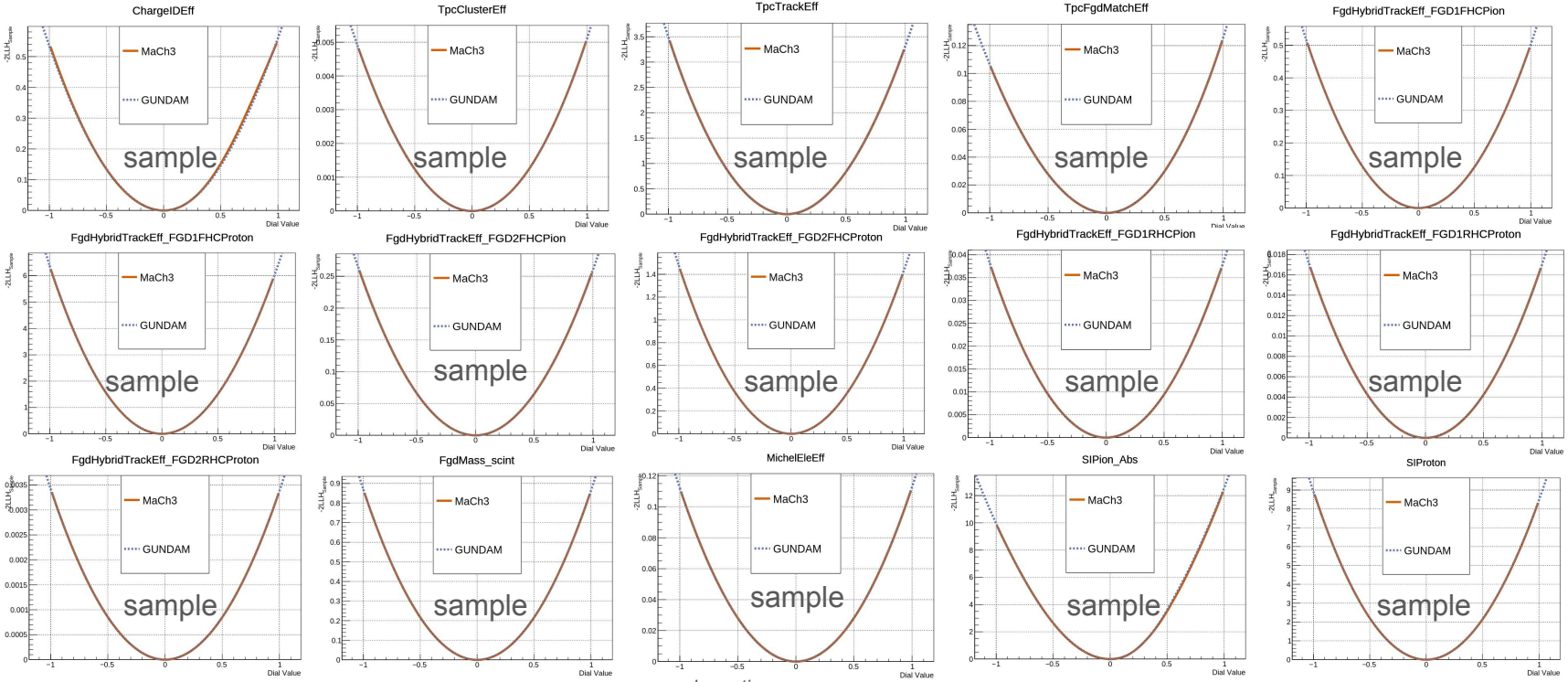
ND weight systematics penalty llh scans with production 7 and 4π selection

— MaCh3 p7
— GUNDAM p7

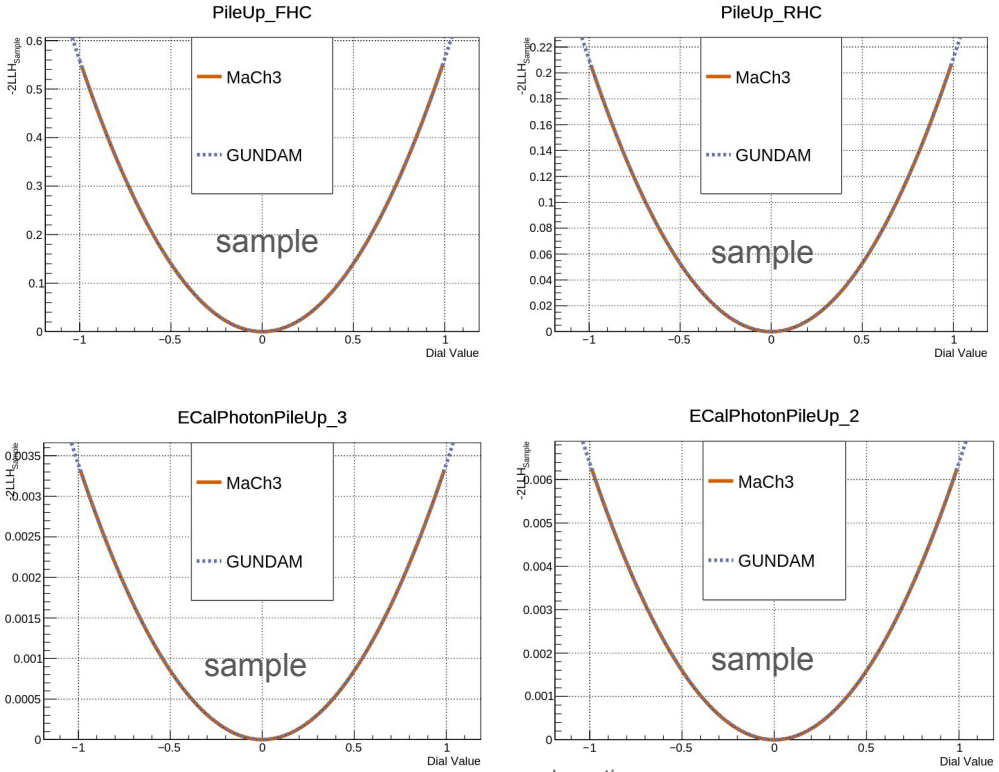


Good news from MaCh3 side !

- turning off the psyche dependence in MaCh3 seems to correct large majority of the differences (need to look into further)
- May be caused by Pmu = 0 events being removed from the inputs (won't be the case for the next set of inputs which are currently in the works)



Good news from MaCh3 side !



ND Weight systematics issue and steps to fix it

OA 2021

2021 Sample Selection and production 6

- Nominal Event rate ✓
- Xsec LLH scans ✓
- ND LLH Scans ✓
- complete set of inputs
- All systematics enabled
- = perfect agreement between GUNDAM/MaCh3

OA 2024

- New sets of Xsec, Nd weights systematics and sample with the new 4pi Selection

2024 4pi Sample Selection and production 7

- Nominal Event Rate ✗
- Xsec LLH scans ✓
- ND LLH scans ✗
- just a part of the inputs (4a,6,7,8w)
- Eb Xsec and ND Variation systematics disabled
- = disagreement between GUNDAM/MaCh3

Steps to fix it

1. **Verification of settings and inputs**
   - Same inputs
   - Same new sets of parameters
   - Same weights capped in config file, binning, ND spline interpolation type (monotonic)
2. **Focus on sample ND weight LLH scans**
   - Less event from GUNDAM side
   - Causes could be : the binning, the treatment of 1 knot splines by GUNDAM, the weight at the nominal value moving
3. **Check of splines outside GUNDAM**
   - Try to find a strange behavior and its source
   - Compare splines from p6 to p7
4. **TO DO : Check of splines inside GUNDAM compared to MaCh3**
   - Treatment of some splines different from MaCh3 to GUNDAM ?
   - Some weight application different in MaCh3 ?

ND fit goals and framework used

- ND fit used to **constrain the flux and cross-section models** and provide a tuned model for oscillation analysis
  - **Ingredients of ND fit** : samples (FGD1+2 - 22 samples of OA 2022), uncertainty models (detector, cross-section and flux)
- BANFF (***Beam And ND280 Flux measurement task Force***)
  - Framework based on a “Gradient descent method” via Minuit2 → Migrad/HESSE
  - Used so far for several previous OA
- GUNDAM (***Generic fitter for Upgraded Near Detector Analysis Methods***): synthesis of two experiences Super-xsLLhFitter + BANFF
  - Validation against BANFF and Super-xsLLhFitter of the framework described in TN-458 and currently in internal review. Remaining investigations ongoing on the reproduction on BANFF postfit Chi2
    - See talk of Margherita Buizza-Avanzini, Ciro Riccio and Adrien Blanchet
- MaCh3: Framework using Markov Chain Monte Carlo (MCMC), is a simultaneous near and far detector fit whereas BANFF and GUNDAM provide a covariance matrix with best-fit parameters to the OA fitters

New inputs made with

Changes:

- Made with 4Pi coverage selections
- Improved the names of ND detector spline parameters to be more interpretable
- Add new systematics specific to 4Pi selections
- only keep an event if the charged lepton momentum is strictly greater than 0 (before was greater than or equal to zero) (altered ND280GenWeights slightly from develop to do this)
- Added updated OA2024 NIWG parameters
- Updated to the latest develop branches of relevant software (currently no OA2024 Freezes)
- Also include data spline files
- calculate POT using P7 data files instead of p6
- only 4a,8w,6 & 7 MC inputs

flattrees: highland2Master_2_90_1 https://nextcloud.nms.kcl.ac.uk/f/1762220 ROOT: 5.34/36

gcc: 5.4.0

highland: 3.4

psyche: 4.3

neut: develop - 059eec151f80a87e6fedcc254d49568cdc068c0e (tag **5.6.4**_RC1)

NIWGReWeight: develop - 7655af277c6640fa04789e5d3ebbad06c9def463 + merged branch feature_SRCpmissDial (should be equivalent to commit 6aa8bbe)

T2KReWeight: develop - c1cc4d805c6d3b8c27c9fcd081bcdf850f49c293

OAGenWeightsApps: develop - 9bc01d67bfa9075b950b3cbf2e77a5ee016ff730

config for ND280GenWeights: 2024/ND280_OA2024_Config_NoMirroring.toml

config for makeND280SystSplines: 2024/NDSyst_OA2024Selections.toml

New Cross-section model (xsec covariance matrix)

- New FSI/RPA parameters → Final states interaction and collective nuclear effect

p_reg = 1
O/C corr 0.8
nu/anu corr 0.8

	Strength, C, nu					Strength, C, nubar					Strength, O, nu					Strength, O, nubar				
Strength, C, nu	1.0000	0.4372	0.1715	0.0673	0.0294	0.8000	0.3498	0.1372	0.0538	0.0235	0.6400	0.2798	0.1098	0.0431	0.0188	0.5120	0.2238	0.0878	0.0344	0.0151
	0.4372	1.0000	0.3922	0.1538	0.0673	0.3498	0.8000	0.3138	0.1230	0.0538	0.2798	0.6400	0.2510	0.0984	0.0431	0.2238	0.5120	0.2008	0.0787	0.0344
	0.1715	0.3922	1.0000	0.3922	0.1715	0.1372	0.3138	0.8000	0.3138	0.1372	0.1098	0.2510	0.6400	0.2510	0.1098	0.0878	0.2008	0.5120	0.2008	0.0878
	0.0673	0.1538	0.3922	1.0000	0.4372	0.0538	0.1230	0.3138	0.8000	0.3498	0.0431	0.0984	0.2510	0.6400	0.2798	0.0344	0.0787	0.2008	0.5120	0.2238
	0.0294	0.0673	0.1715	0.4372	1.0000	0.0235	0.0538	0.1372	0.3498	0.8000	0.0188	0.0431	0.1098	0.2798	0.6400	0.0151	0.0344	0.0878	0.2238	0.5120
Strength, C, nub	0.8000	0.3498	0.1372	0.0538	0.0235	1.0000	0.4372	0.1715	0.0673	0.0294	0.8000	0.3498	0.1372	0.0538	0.0235	0.6400	0.2798	0.1098	0.0431	0.0188
	0.3498	0.8000	0.3138	0.1230	0.0538	0.4372	1.0000	0.3922	0.1538	0.0673	0.3498	0.8000	0.3138	0.1230	0.0538	0.2798	0.6400	0.2510	0.0984	0.0431
	0.1372	0.3138	0.8000	0.3138	0.1372	0.1715	0.3922	1.0000	0.3922	0.1715	0.1372	0.3138	0.8000	0.3138	0.1372	0.1098	0.2510	0.6400	0.2510	0.1098
	0.0538	0.1230	0.3138	0.8000	0.3498	0.0673	0.1538	0.3922	1.0000	0.4372	0.0538	0.1230	0.3138	0.8000	0.3498	0.0431	0.0984	0.2510	0.6400	0.2798
	0.0235	0.0538	0.1372	0.3498	0.8000	0.0294	0.0673	0.1715	0.4372	1.0000	0.0235	0.0538	0.1372	0.3498	0.8000	0.0188	0.0431	0.1098	0.2798	0.6400
Strength, O, nu	0.6400	0.2798	0.1098	0.0431	0.0188	0.8000	0.3498	0.1372	0.0538	0.0235	1.0000	0.4372	0.1715	0.0673	0.0294	0.8000	0.3498	0.1372	0.0538	0.0235
	0.2798	0.6400	0.2510	0.0984	0.0431	0.3498	0.8000	0.3138	0.1230	0.0538	0.4372	1.0000	0.3922	0.1538	0.0673	0.3498	0.8000	0.3138	0.1230	0.0538
	0.1098	0.2510	0.6400	0.2510	0.1098	0.1372	0.3138	0.8000	0.3138	0.1372	0.1715	0.3922	1.0000	0.3922	0.1715	0.1372	0.3138	0.8000	0.3138	0.1372
	0.0431	0.0984	0.2510	0.6400	0.2798	0.0538	0.1230	0.3138	0.8000	0.3498	0.0673	0.1538	0.3922	1.0000	0.4372	0.0538	0.1230	0.3138	0.8000	0.3498
	0.0188	0.0431	0.1098	0.2798	0.6400	0.0235	0.0538	0.1372	0.3498	0.8000	0.0294	0.0673	0.1715	0.4372	1.0000	0.0235	0.0538	0.1372	0.3498	0.8000
Strength, O, nub	0.5120	0.2238	0.0878	0.0344	0.0151	0.6400	0.2798	0.1098	0.0431	0.0188	0.8000	0.3498	0.1372	0.0538	0.0235	1.0000	0.4372	0.1715	0.0673	0.0294
	0.2238	0.5120	0.2008	0.0787	0.0344	0.2798	0.6400	0.2510	0.0984	0.0431	0.3498	0.8000	0.3138	0.1230	0.0538	0.4372	1.0000	0.3922	0.1538	0.0673
	0.0878	0.2008	0.5120	0.2008	0.0878	0.1098	0.2510	0.6400	0.2510	0.1098	0.1372	0.3138	0.8000	0.3138	0.1372	0.1715	0.3922	1.0000	0.3922	0.1715
	0.0344	0.0787	0.2008	0.5120	0.2238	0.0431	0.0984	0.2510	0.6400	0.2798	0.0538	0.1230	0.3138	0.8000	0.3498	0.0673	0.1538	0.3922	1.0000	0.4372
	0.0151	0.0344	0.0878	0.2238	0.5120	0.0188	0.0431	0.1098	0.2798	0.6400	0.0235	0.0538	0.1372	0.3498	0.8000	0.0294	0.0673	0.1715	0.4372	1.0000

- RPA/FSI Will pass from 5 bins for each parameters to 3 bins in the next generation of inputs
- swap of prior uncertainty for P1_2Shell_MF_Norm_O and P3_2Shell_MF_Norm_O
- new Nucleon FSI parameters (Total - which controls total nucleon FSI probability - and Single - which controls nucleon FSI pion production probability)
- SRC parameters (Pair Frac C/O - change the ratio of pn and nn pairs for SRC and Shape C/O - modify the missing momentum for SRC)

IDs and samples

```
Sample: 123.  FGD1 numuCC 0pi Fwd NoPhoton No Protons
Sample: 124.   FGD1 numuCC 0pi Fwd NoPhoton N Protons
Sample: 125.  FGD1 numuCC 0pi Bwd NoPhoton No Protons
Sample: 126.   FGD1 numuCC 0pi Bwd NoPhoton N Protons
Sample: 131.   FGD1 numuCC 0pi HA NoPhoton No Protons
Sample: 132.    FGD1 numuCC 0pi HA NoPhoton N Protons
Sample: 114.           FGD1 numuCC 1Pi HAFwd NoPhoton
Sample: 108.             FGD1 numuCC 1Pi Fwd NoPhoton
Sample: 109.           FGD1 numuCC Other Fwd NoPhoton
Sample: 119.                    FGD1 numuCC Photon Fwd
Sample: 149.  FGD2 numuCC 0pi Fwd NoPhoton No Protons
Sample: 150.   FGD2 numuCC 0pi Fwd NoPhoton N Protons
Sample: 151.  FGD2 numuCC 0pi Bwd NoPhoton No Protons
Sample: 152.   FGD2 numuCC 0pi Bwd NoPhoton N Protons
Sample: 157.   FGD2 numuCC 0pi HA NoPhoton No Protons
Sample: 158.    FGD2 numuCC 0pi HA NoPhoton N Protons
Sample: 140.           FGD2 numuCC 1Pi HAFwd NoPhoton
Sample: 134.             FGD2 numuCC 1Pi Fwd NoPhoton
Sample: 135.           FGD2 numuCC Other Fwd NoPhoton
Sample: 145.                    FGD2 numuCC Photon Fwd
Sample: 59.                      FGD1 anti-numuCC 0pi
Sample: 60.                      FGD1 anti-numuCC 1pi
Sample: 61.                    FGD1 anti-numuCC other
Sample: 65.                      FGD2 anti-numuCC 0pi
Sample: 66.                      FGD2 anti-numuCC 1pi
Sample: 67.                    FGD2 anti-numuCC other
Sample: 71.        FGD1 NuMuBkg CC0pi in AntiNu Mode
Sample: 72.        FGD1 NuMuBkg CC1pi in AntiNu Mode
Sample: 73.      FGD1 NuMuBkg CCother in AntiNu Mode
Sample: 77.        FGD2 NuMuBkg CC0pi in AntiNu Mode
Sample: 78.        FGD2 NuMuBkg CC1pi in AntiNu Mode
Sample: 79.      FGD2 NuMuBkg CCother in AntiNu Mode
```

NEW !

NEW !

New ND weights parameters

FgdECalMatchEff_FGD1_0
FgdECalMatchEff_FGD1_1
FgdECalMatchEff_FGD1_2
FgdECalMatchEff_FGD1_3
FgdECalMatchEff_FGD2_0
FgdECalMatchEff_FGD2_1
FgdECalMatchEff_FGD2_2
FgdECalMatchEff_FGD2_3
FgdECalSmrdMatchEff_TopBottomSMRD_0
FgdECalSmrdMatchEff_TopBottomSMRD_1
FgdECalSmrdMatchEff_TopBottomSMRD_2
FgdECalSmrdMatchEff_TopBottomSMRD_3
FgdECalSmrdMatchEff_LeftRightSMRD_0
FgdECalSmrdMatchEff_LeftRightSMRD_1
FgdECalSmrdMatchEff_LeftRightSMRD_2
FgdECalSmrdMatchEff_LeftRightSMRD_3

TPCP0DMatchEff_0
TPCP0DMatchEff_1
TPCP0DMatchEff_2
TPCP0DMatchEff_3
TPCP0DMatchEff_4
TPCP0DMatchEff_5
TPCP0DMatchEff_6
TPCP0DMatchEff_7
TPCP0DMatchEff_8
TPCP0DMatchEff_9

- GUNDAM uses cubic monotonic interpolation for weight systematics
- No correlation and all with a prior uncertainty of 1
- Nominal value at zero