



Physics Studies for ND280 Upgrade

Post-fit Correlation matrix, pn_Evis input

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Pn_Evis input for fitter

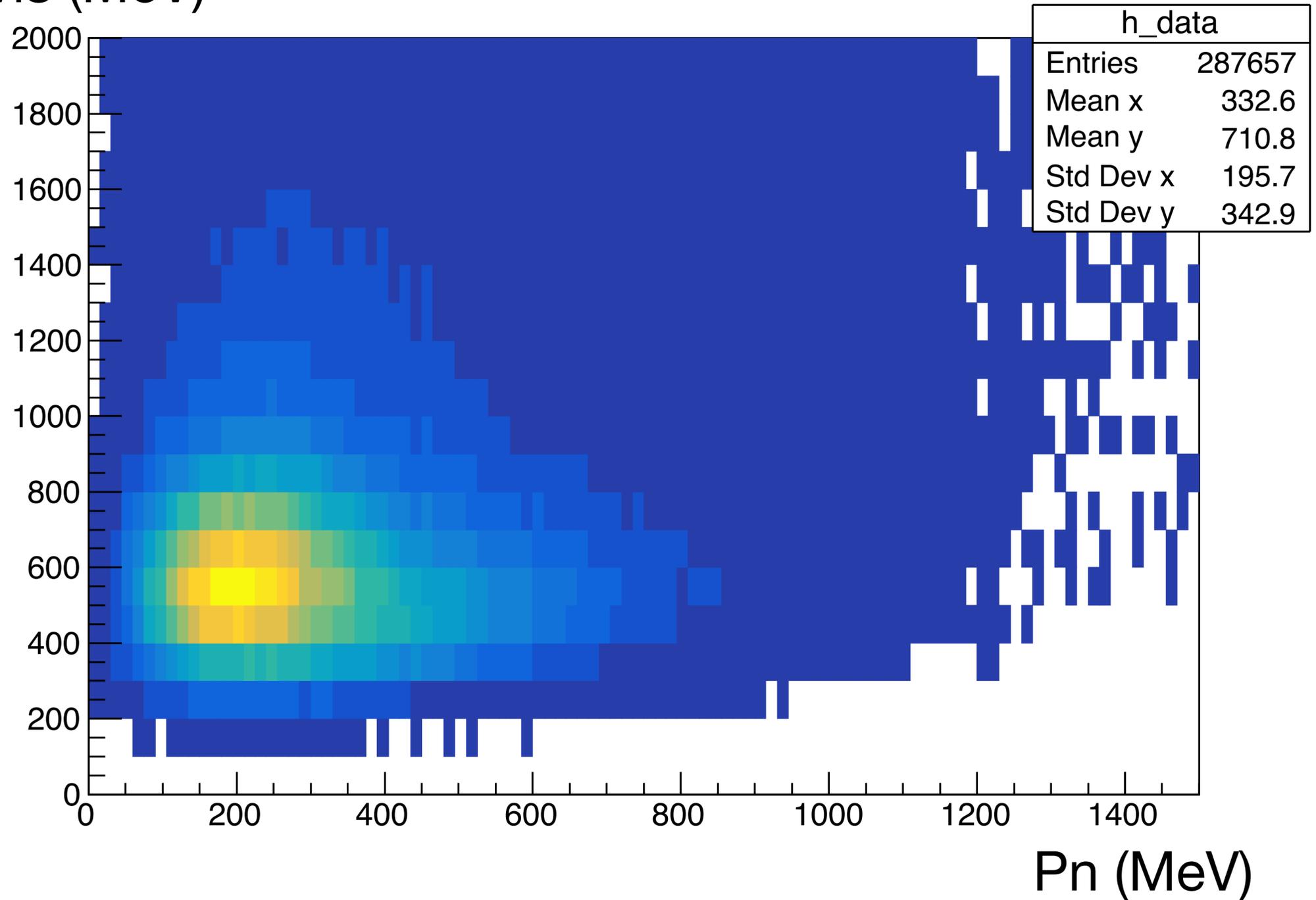
Evis = E visible (visible outgoing particle)
= E_muon + kinetic E of proton

- CCQE_c1 200-400MeV
- CCQE_c2 400-600MeV
- CCQE_c3 600-800MeV
- CCQE_c4 800-1000MeV
- CCQE_c5 1000-1200MeV
- CCQE_c6 1200-1400MeV

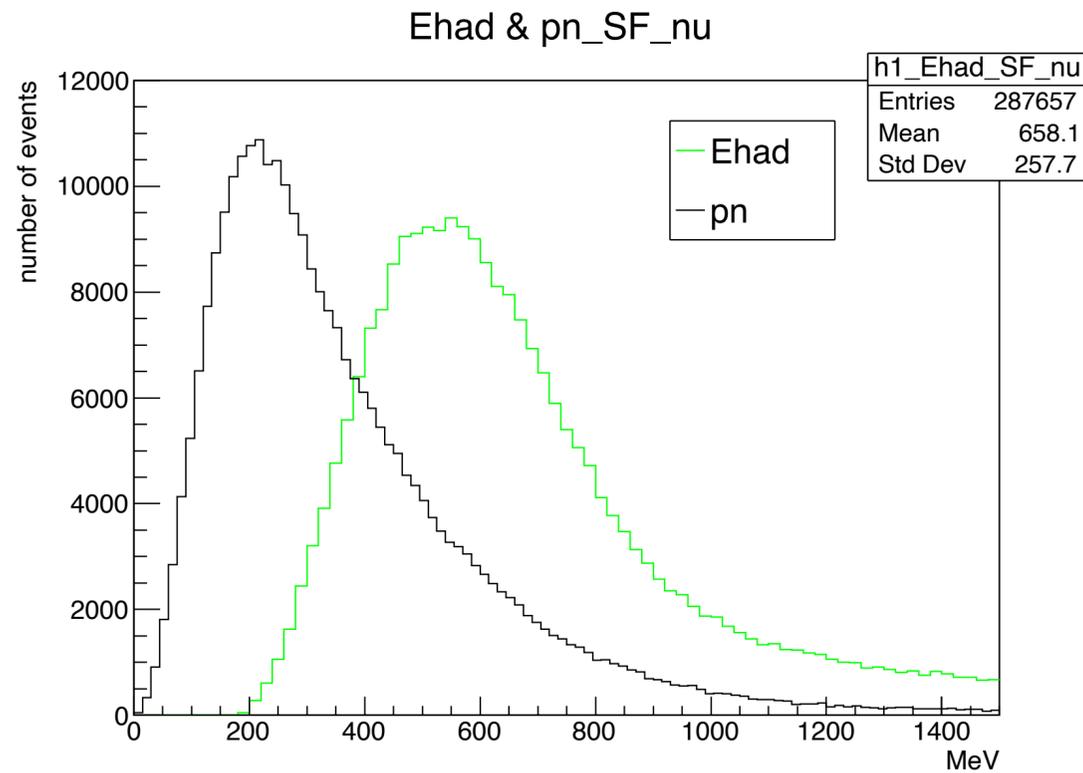
- 2p2h_c1: <800MeV
- 2p2h_c2: >800MeV

Evis (MeV)

data

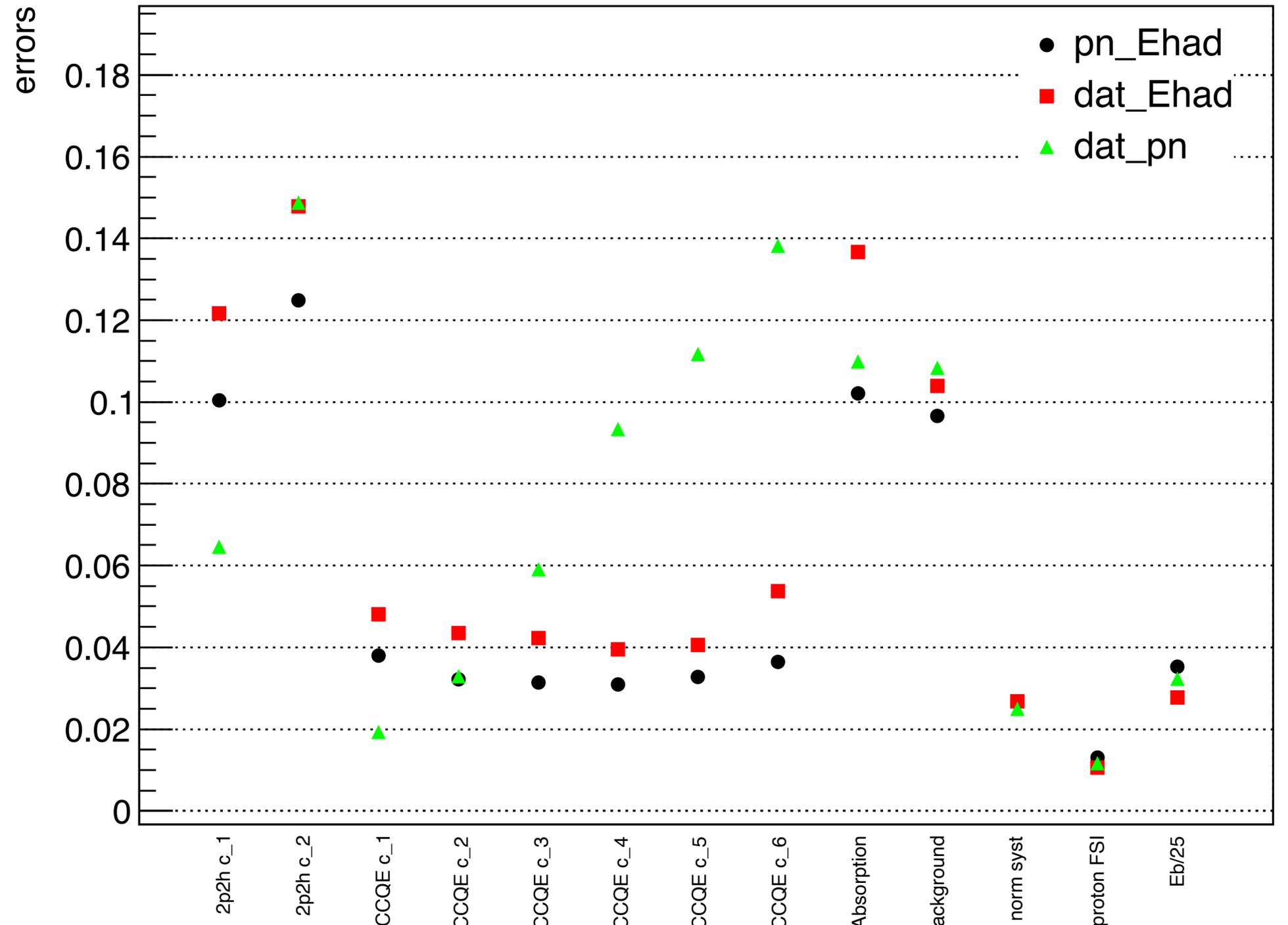


Result for pn_Evis as input



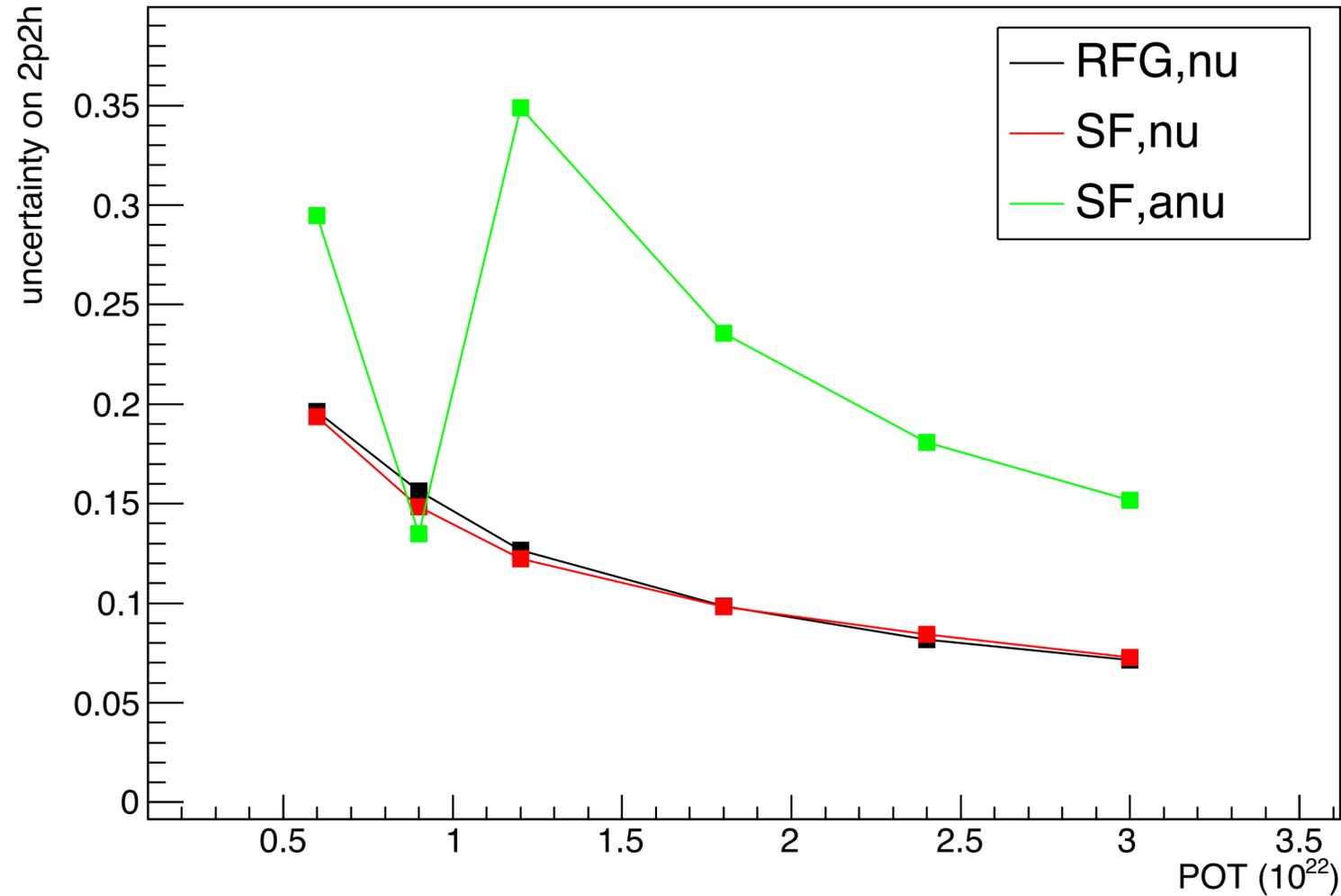
pn_Evis have better result than dat_Evis

Parameters' errors with different obser



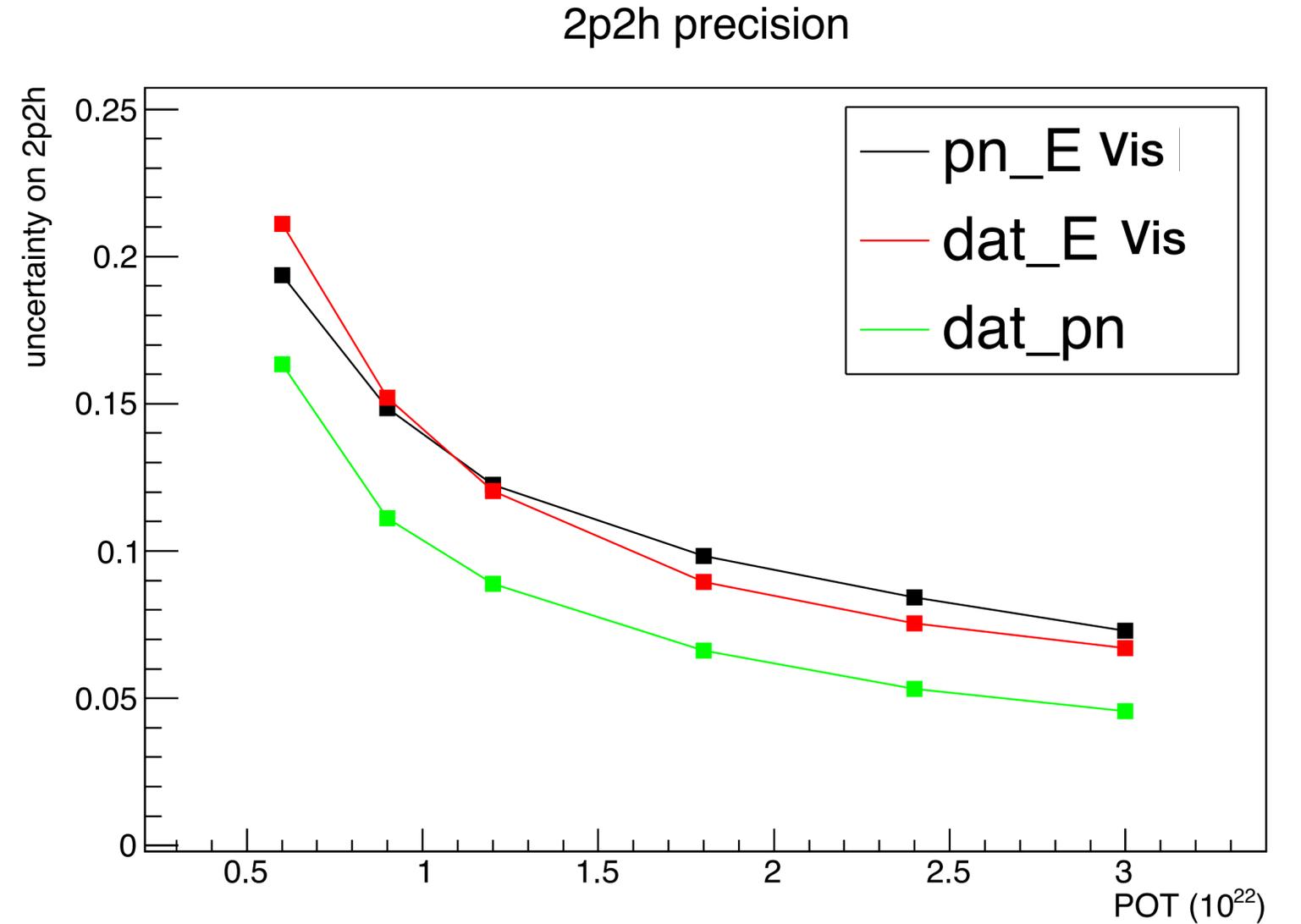
Comparing the models: in back up

2p2h precision (%)



Model comparison, pn_Evis

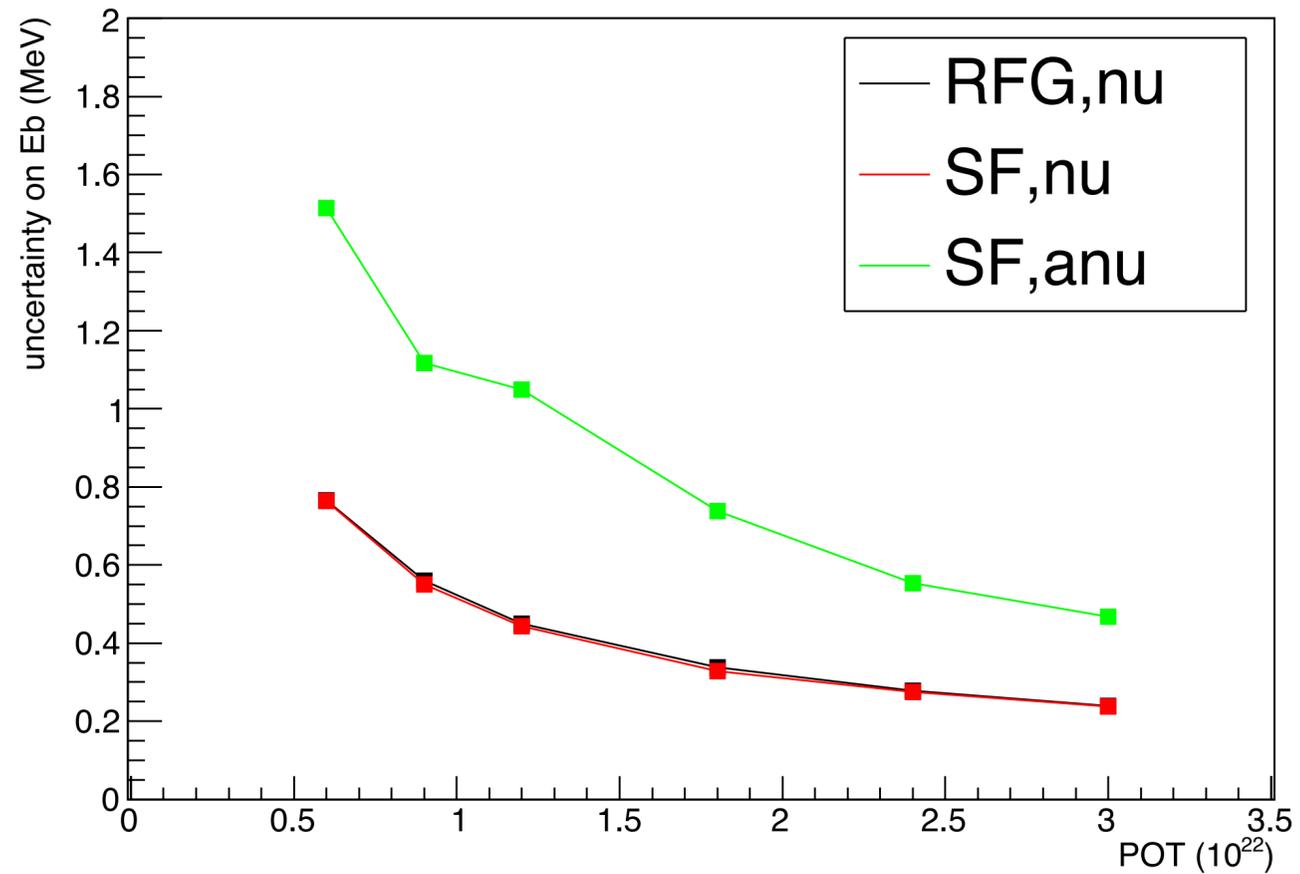
Anti-neutrino does not have enough statistic at low POT for a good fit.



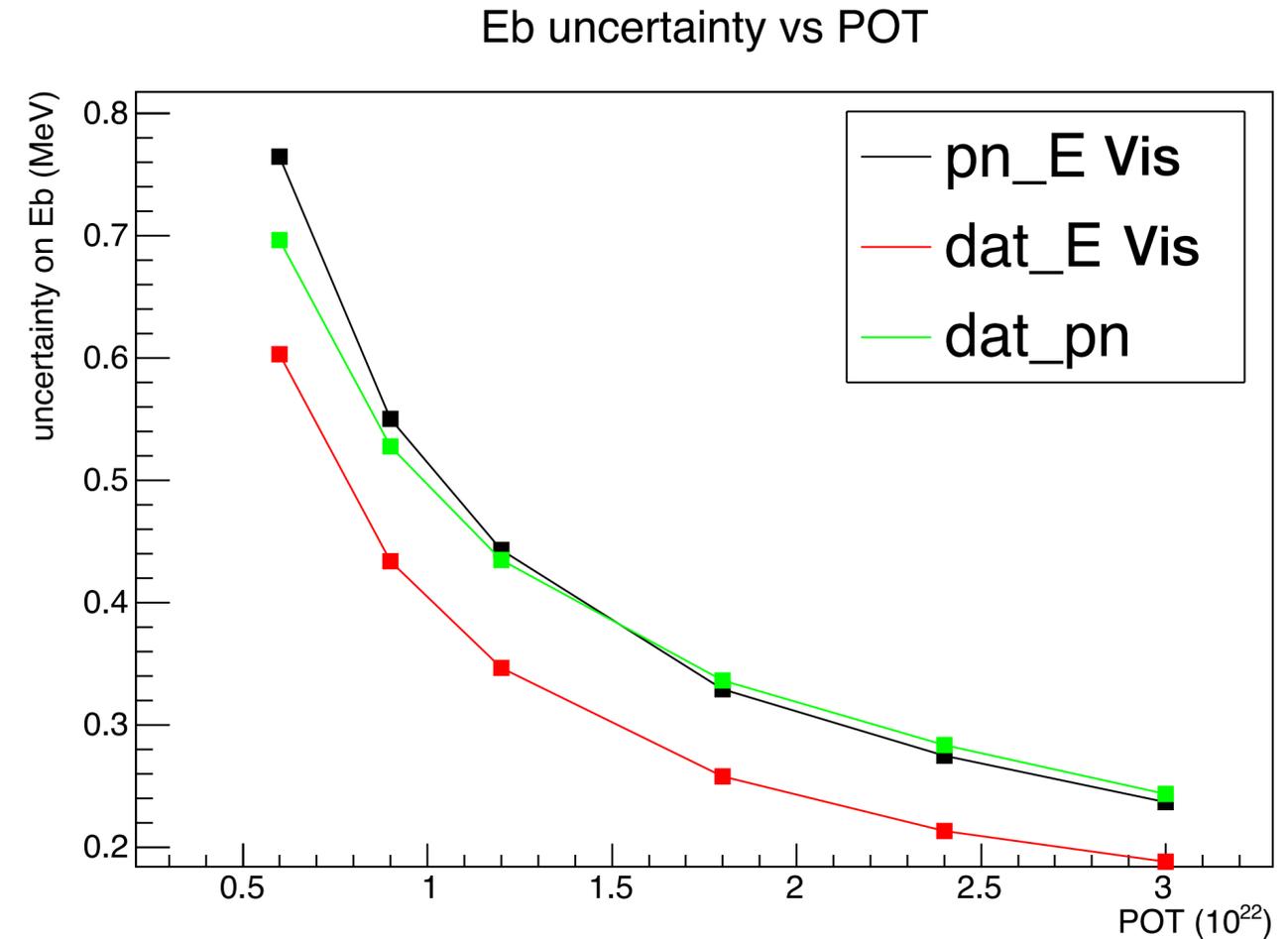
Input comparison, SF nu

dat_pn is the best input for 2p2h

Eb uncertainty (MeV)



Model comparison, pn_Evis

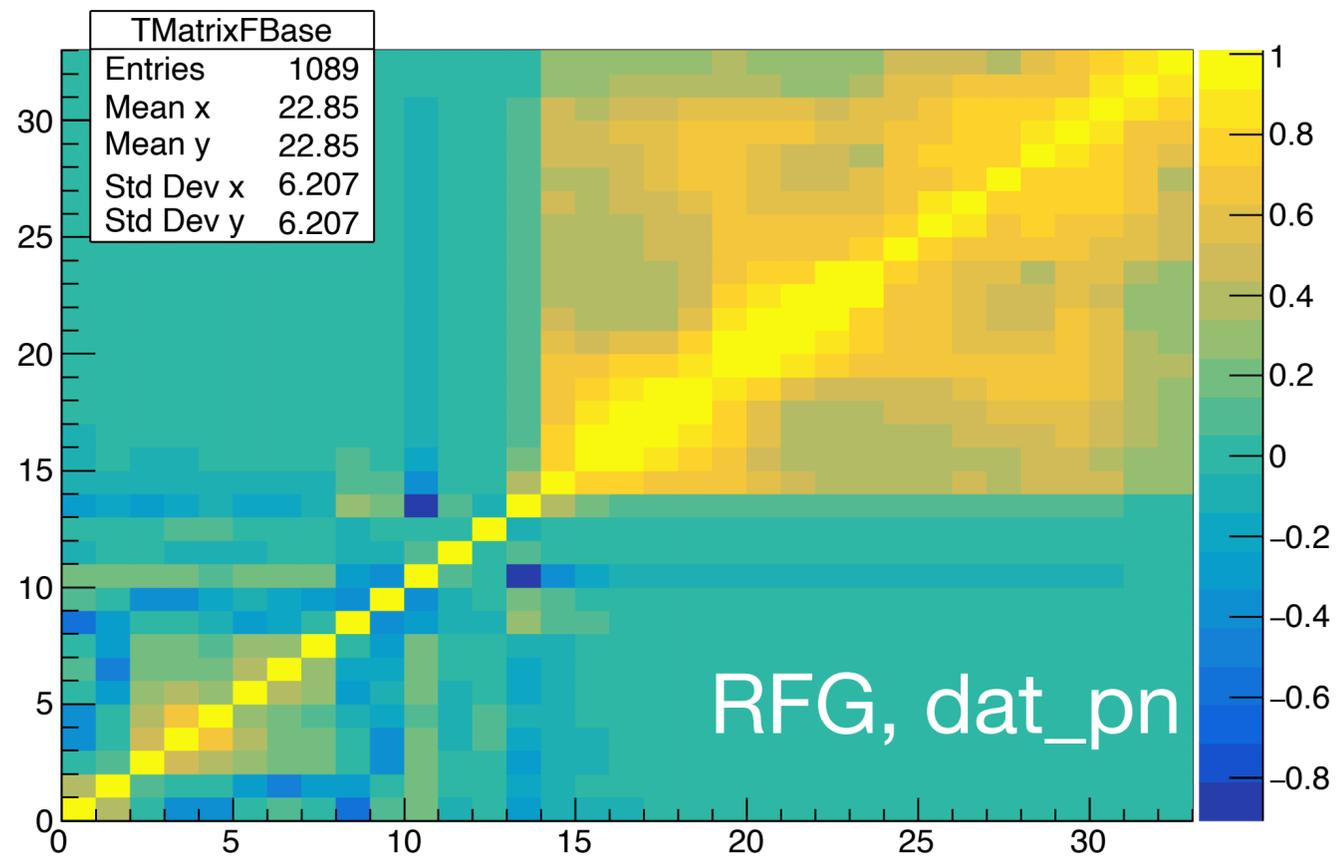
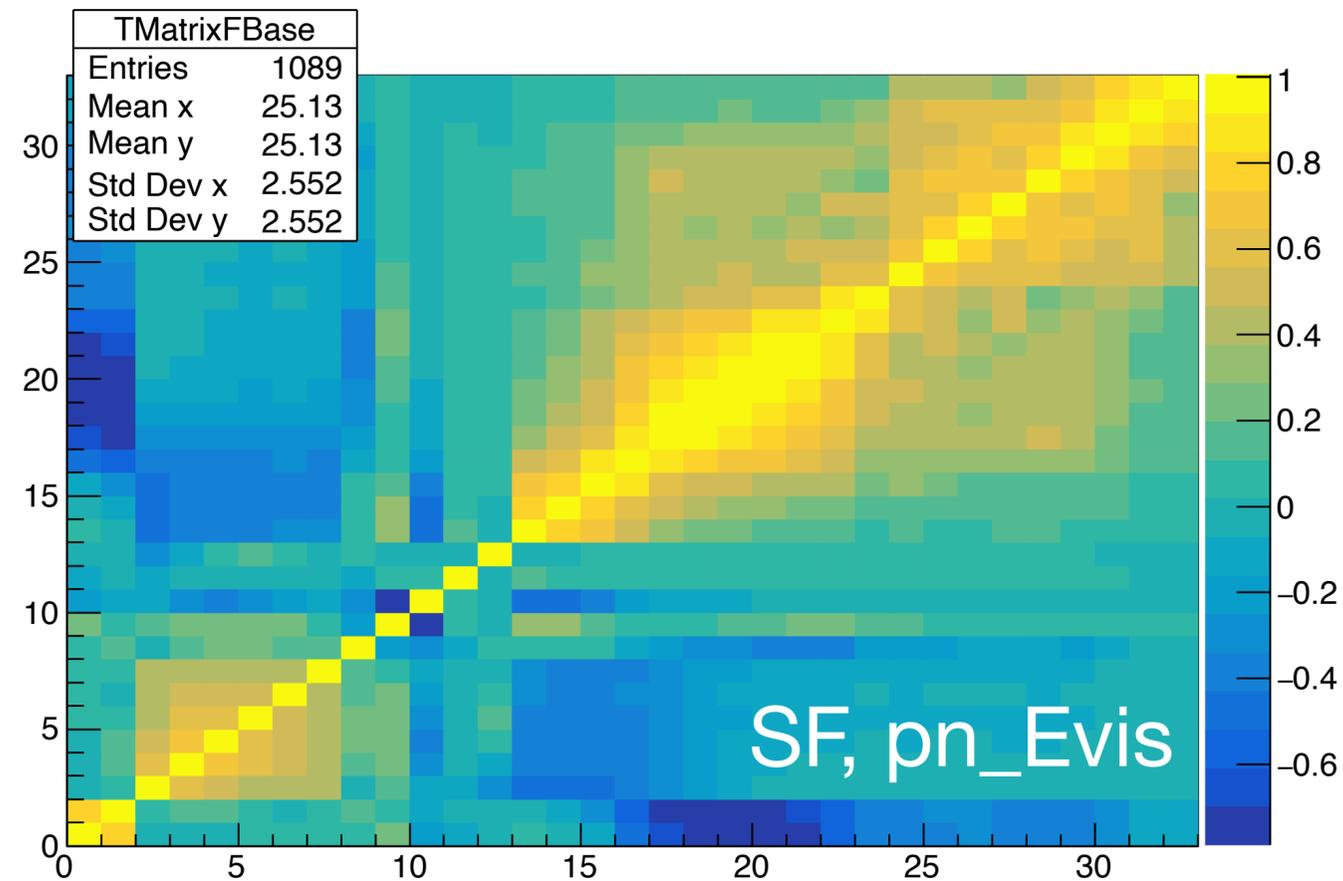


Input comparison, SF nu

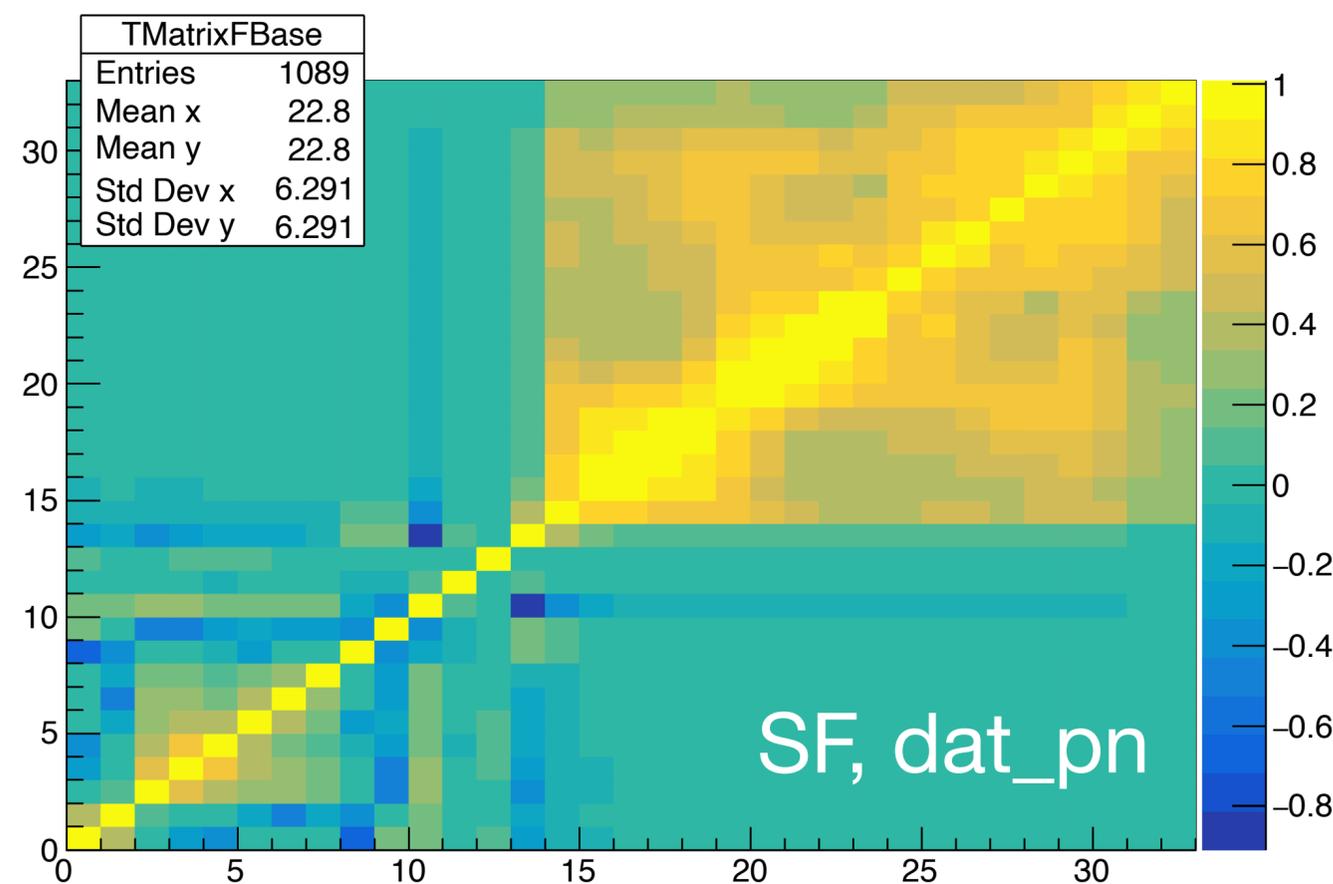
Don't like 2p2h, Eb have the best uncertainties with dat_Evis input

Post-fit correlation matrix

0->1: 2p2h
2->7: CCQE
8->9: pion FSI
10: norm cyst
11: proton FSI
12: Eb
>12: flux



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Summary

- Depending on the parameter that we want to constrain, we can choose the appropriate input, the range of parameter on the input distribution.
- From the post-fit correlation matrixes, flux and cross section parameters are almost uncorrelated with each other.
- After discussion with Stephen,
CCQE, 2p2h parameters should be applied to pn only
Flux parameters should be applied to E_vis only
- At the moment: fit Evis with only one bin of dpT which is $dpT < 40$ MeV. This is especially interesting for antineutrino (<https://arxiv.org/pdf/1912.01511.pdf>).

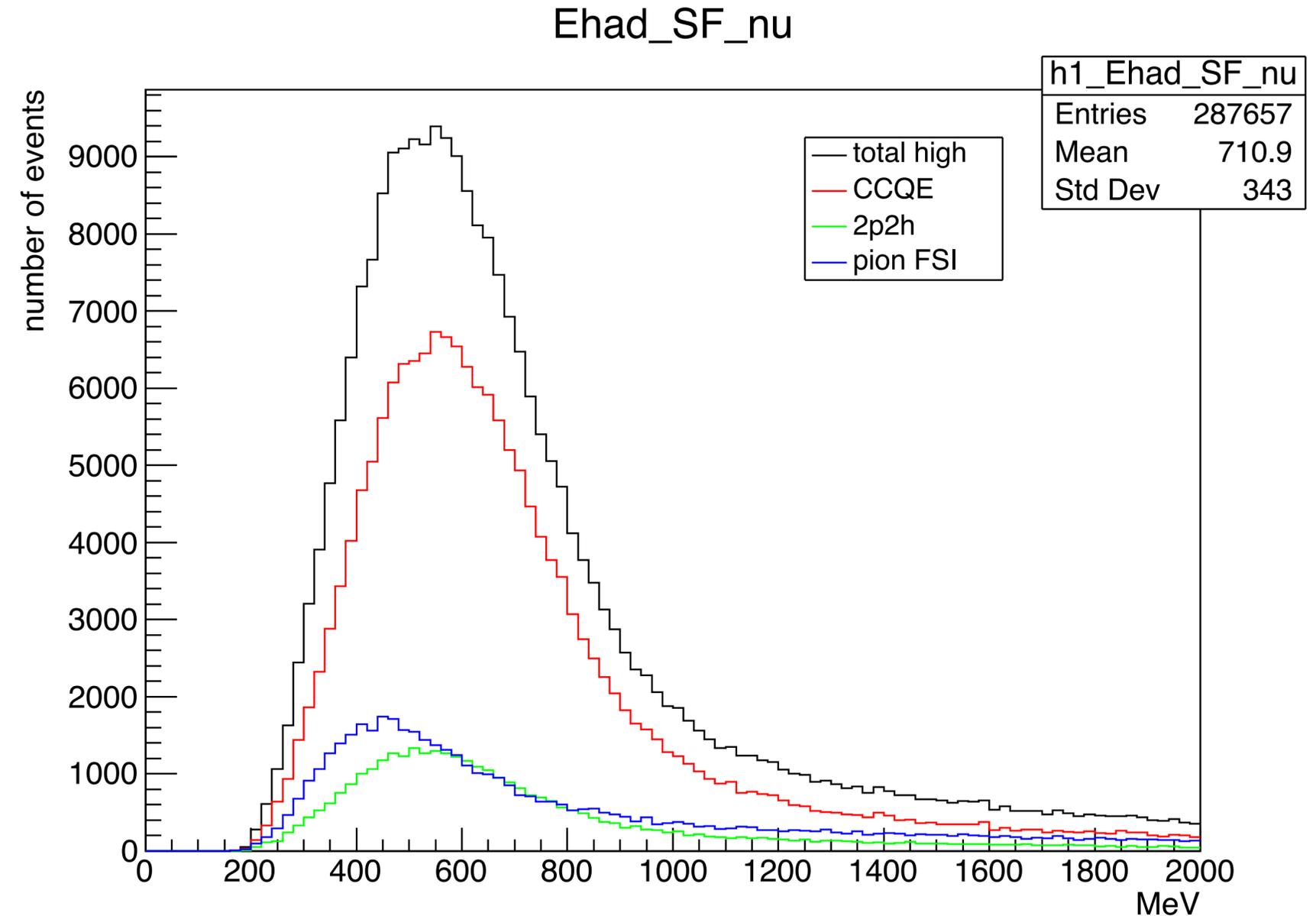
Back up

Ehad distribution for nu

Another kind of variable that we can use for the fitter is Ehad

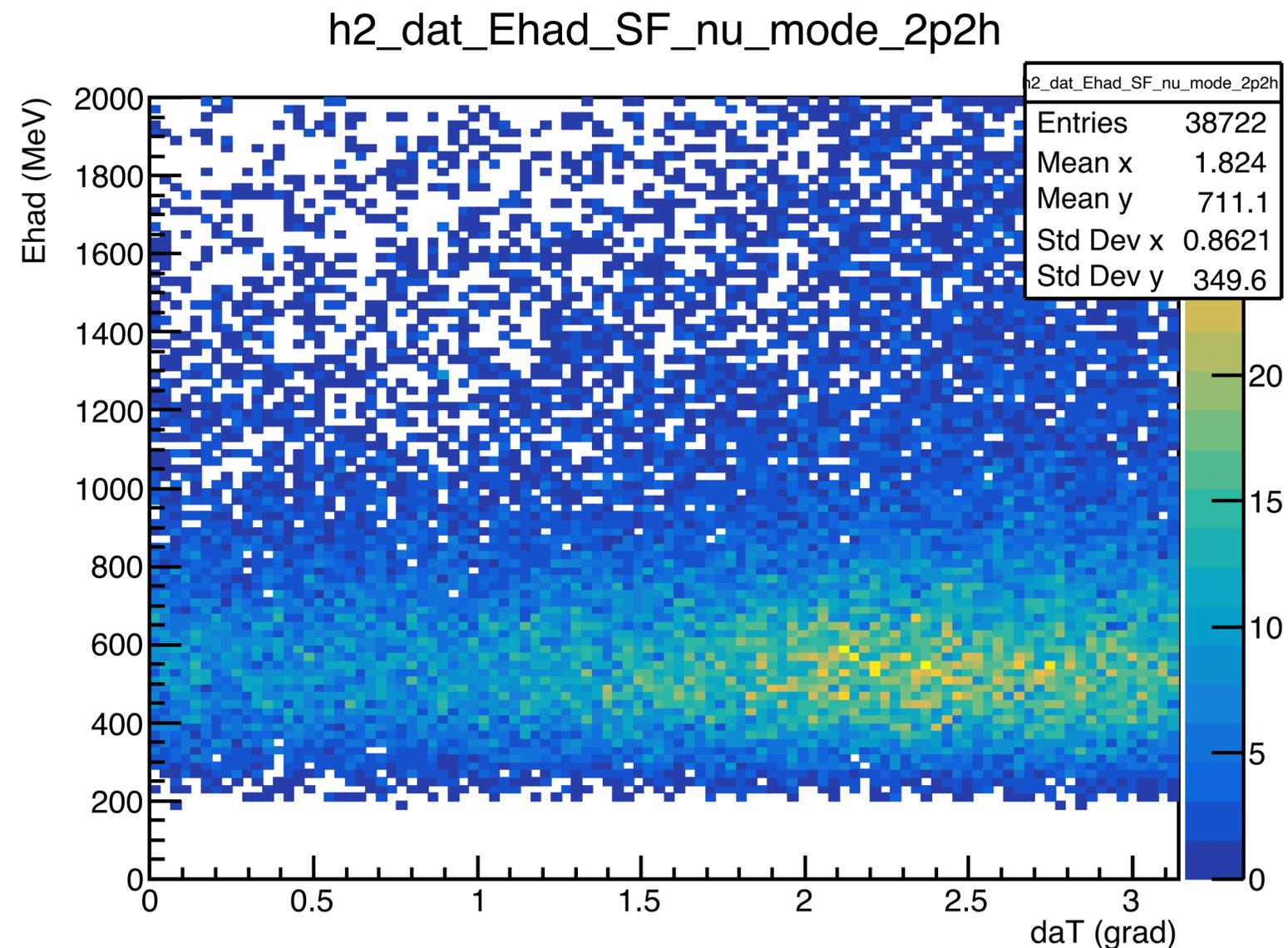
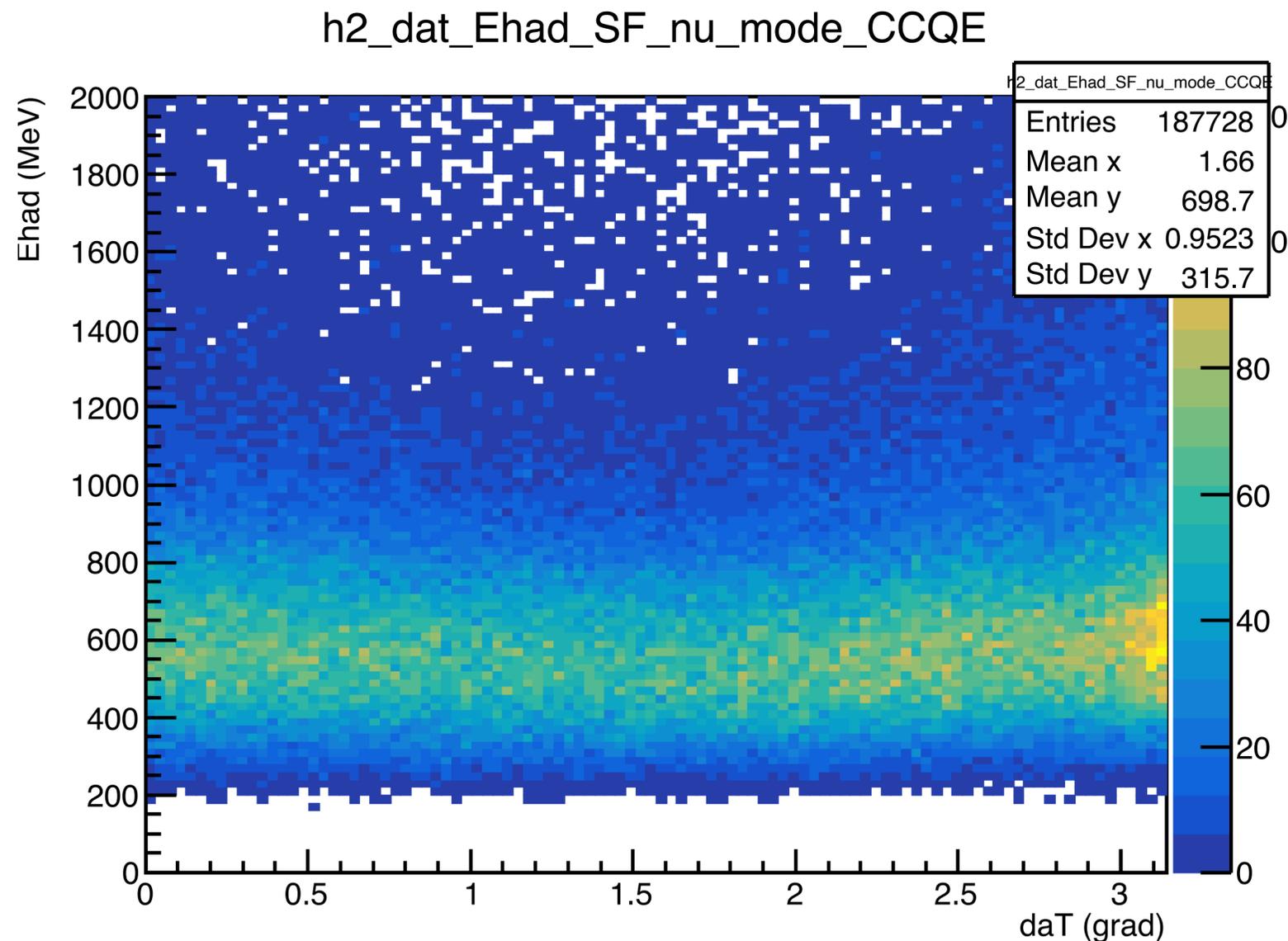
$E_{had} = E_{muon} + \text{kinetic } E \text{ of proton}$
 $\text{kinetic } E \text{ of neutron for anti-}\nu$

Peaks around 600MeV
which is neutrino energy



Anti-nu case in back up

$\delta_{\alpha T}$ and Ehad 2D distribution

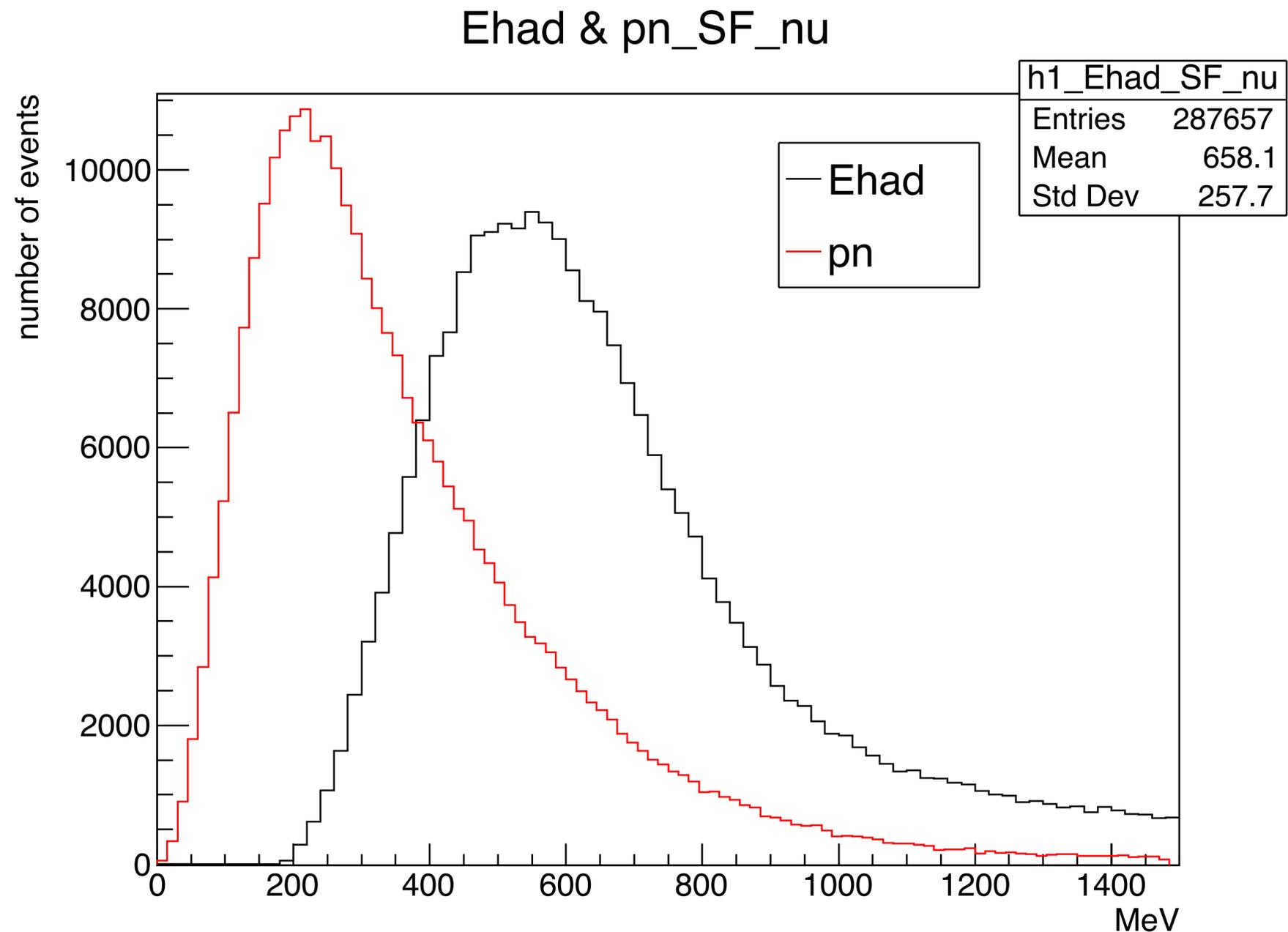


No point under 200MeV, the CCQE focus on 600 MeV while the 2p2h spreads in the area which is below 600MeV (agree with our expectation).

Ehad vs pn distribution for nu

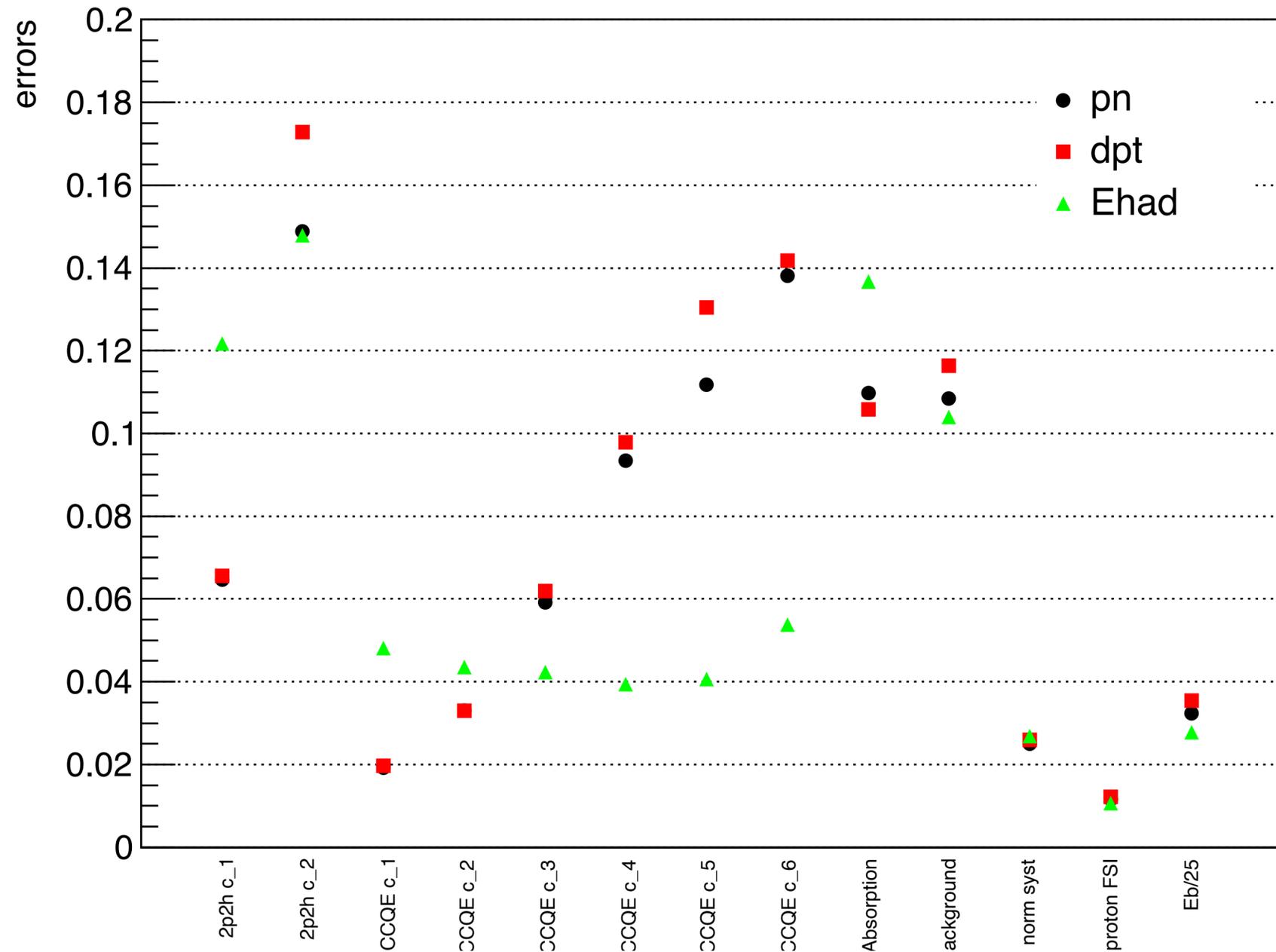
Due to the differences in Ehad and nucleon momentum (pn) distribution, we need to change the range of CCQE parameters.

Old		New	
CCQE_c1	0-100MeV	CCQE_c1	200-400MeV
CCQE_c2	100-200MeV	CCQE_c2	400-600MeV
CCQE_c3	200-300MeV	CCQE_c3	600-800MeV
CCQE_c4	300-500MeV	CCQE_c4	800-1000MeV
CCQE_c5	500-700MeV	CCQE_c5	1000-1200MeV
CCQE_c6	700-1000MeV	CCQE_c6	1200-1400MeV

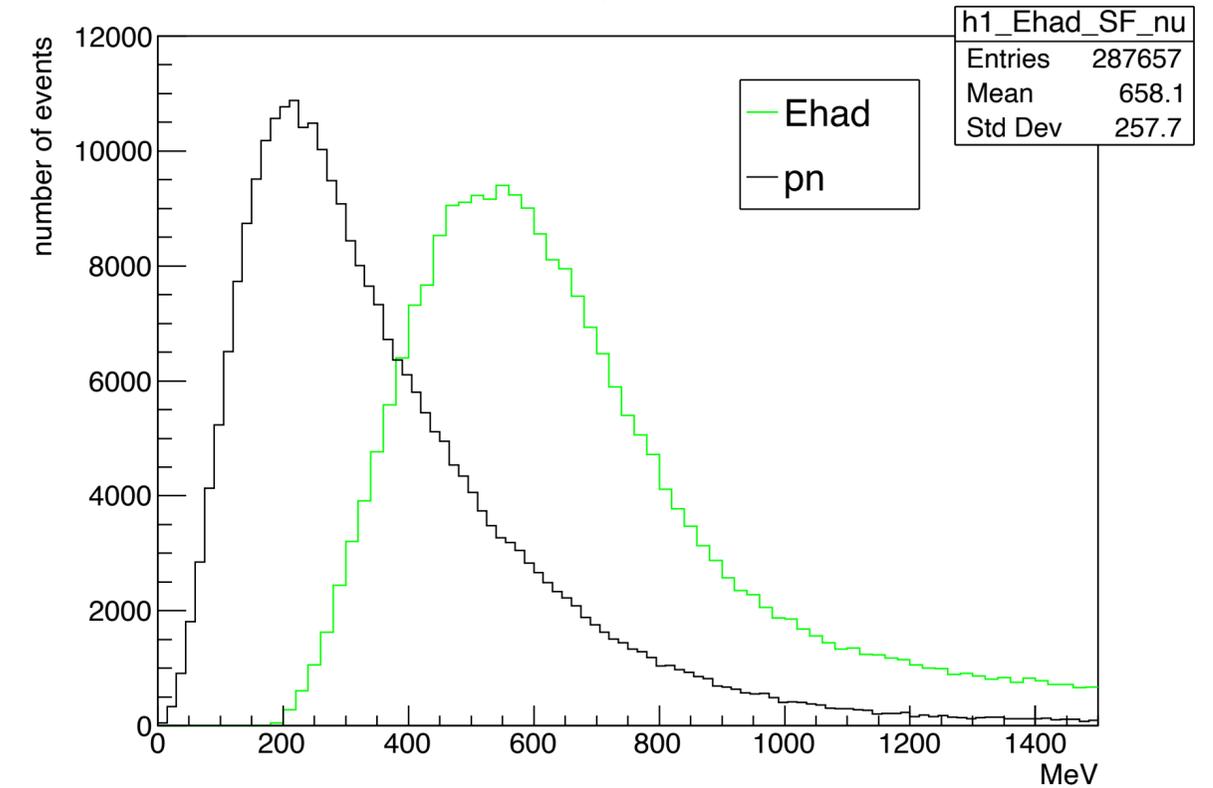


Different observables

Parameters' errors with different obser



Ehad & pn_SF_nu



The CCQE parameters range:
200-1400MeV

CCQE errors with Ehad are stably good while it increases in pn and dpt case since we are moving to its tail

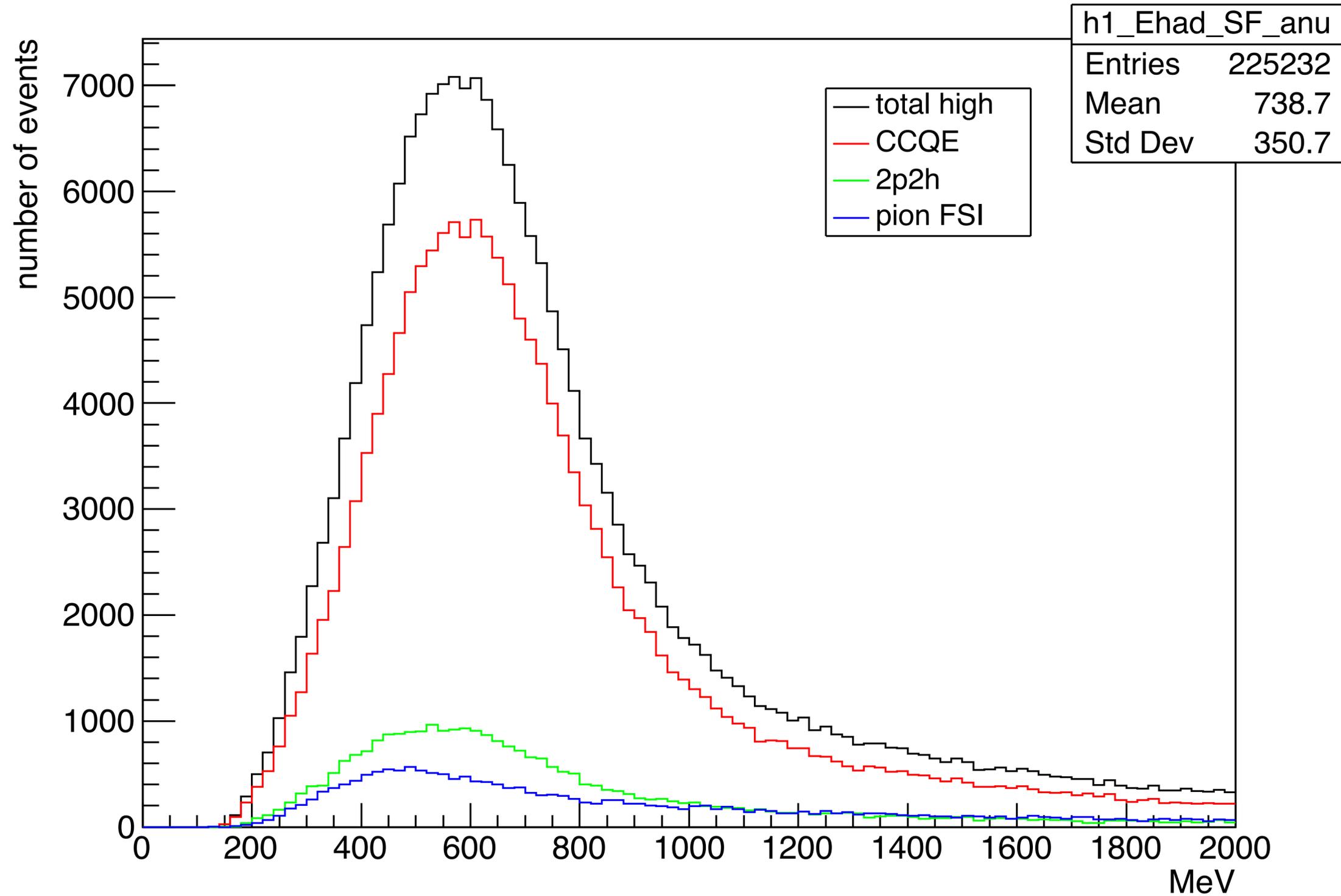
First 2p2h <800MeV

second 2p2h >800MeV

=> The first one is better since 2p2h bias our reconstructed E_{nu} at low energy.

Ehad distribution for anti-nu

Ehad_SF_anu



Results after fit for Ehad as input

Parameters' errors with different model

