



Physics Studies for ND280 Upgrade

**New Spectral Function dials results; Hydrogen normalisation
studies; Cross-section comparison: NEUT & Martini model**

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Introduction to fitter code

In order to reduce the systematic uncertainty for the neutrino oscillation parameters, we need to know better the neutrino-nucleus interaction model, and obtain better precision for interaction modes (CCQE, 2p2h, other)

- We have developed a fitter and a model of systematics uncertainties in order to quantify the impact of the use of Single Transverse Variables in the ND280 upgrade in order to reduce systematics uncertainties
- The fitter input will be 2D histograms of STVs (dat_pn).
- I just finish implementing new dials of Spectral Function model. After debugging, the fitter is much stable and I am finalising the results.

Fitter goals

Before

Value and precision of

- 2p2h_c1 0-600MeV
- 2p2h_c2 (>600MeV)
- CCQE_c1 0-150MeV
- CCQE_c2 150-300MeV
- CCQE_c3 300-450MeV
- CCQE_c4 450-600MeV
- CCQE_c5 600-750MeV
- CCQE_c6 750-900MeV
- pion Absorption FSI norm
- pion Background FSI norm
- norm syst
- proton FSI
- Hydrogen interaction norm
- Eb/25 (for easy plot since other parameter values are 1)

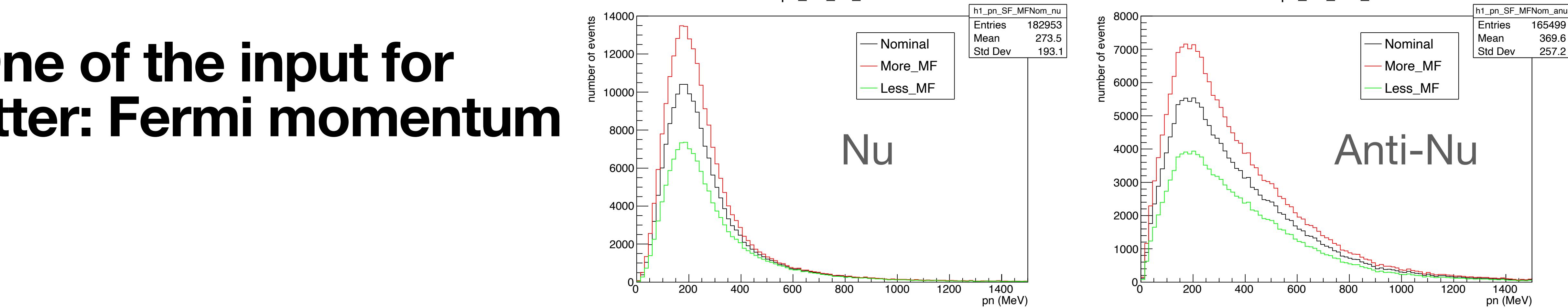
After

Value and precision of

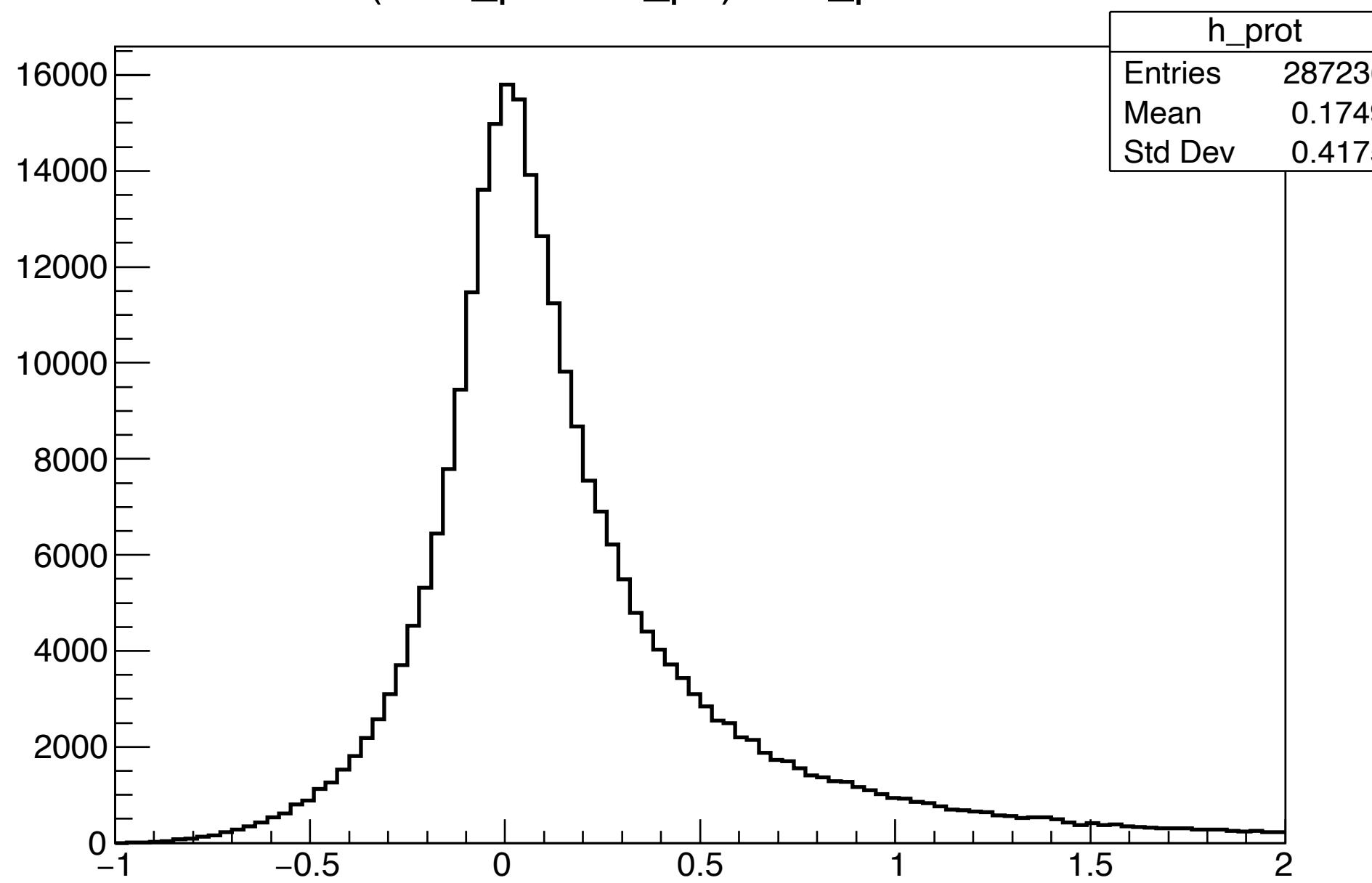
All are the same except for the replacement of CCQE parameters by new Spectral Function dials

- P Shell and S Shell interaction
- Mean Field (MF) and Short Range Correlation (SRC)

One of the input for fitter: Fermi momentum



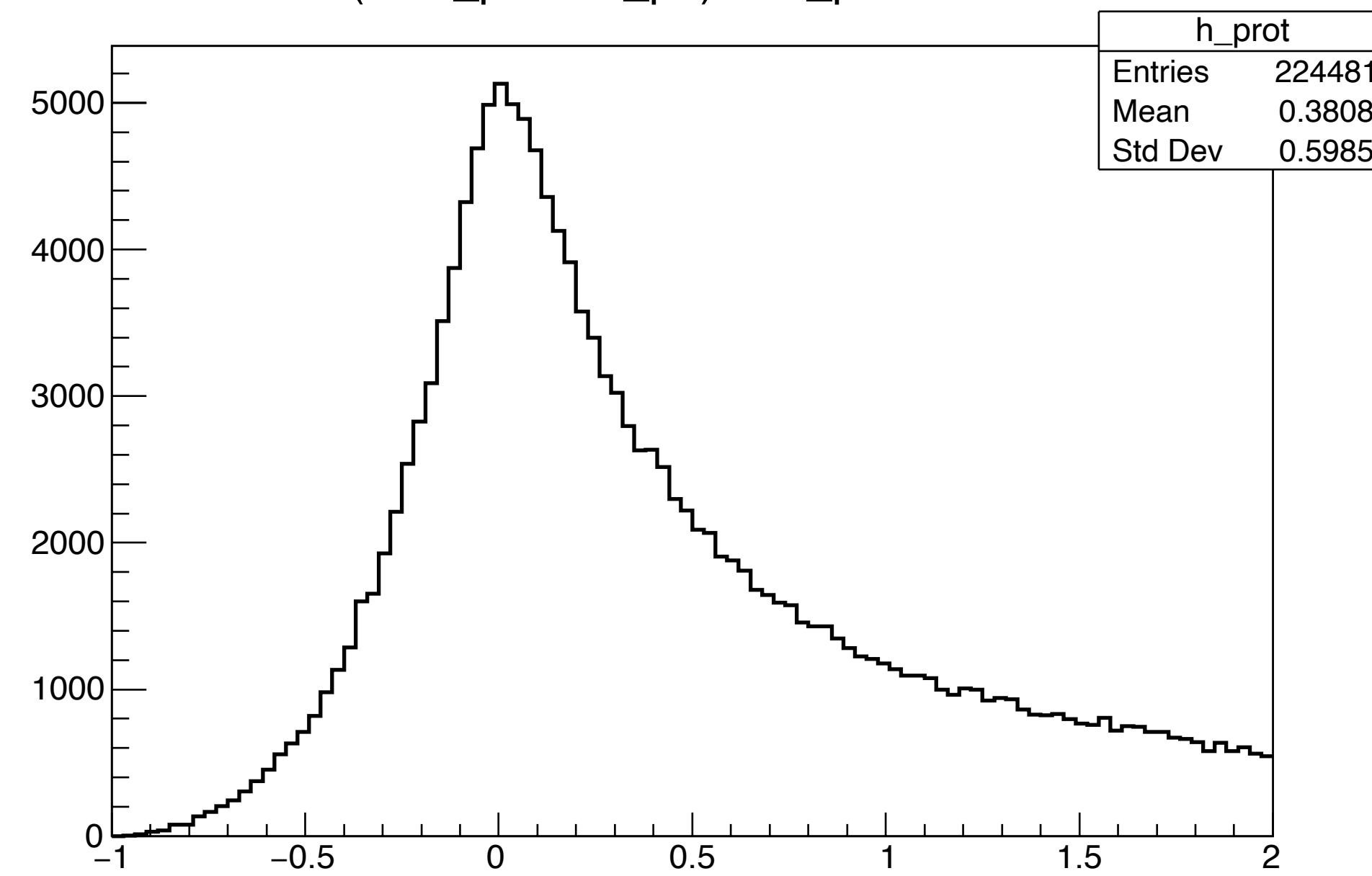
(reco_pn-true_pn)/true_pn for nu



Neutrino

(reco_pn-true_pn)/true_pn

(reco_pn-true_pn)/true_pn for anu



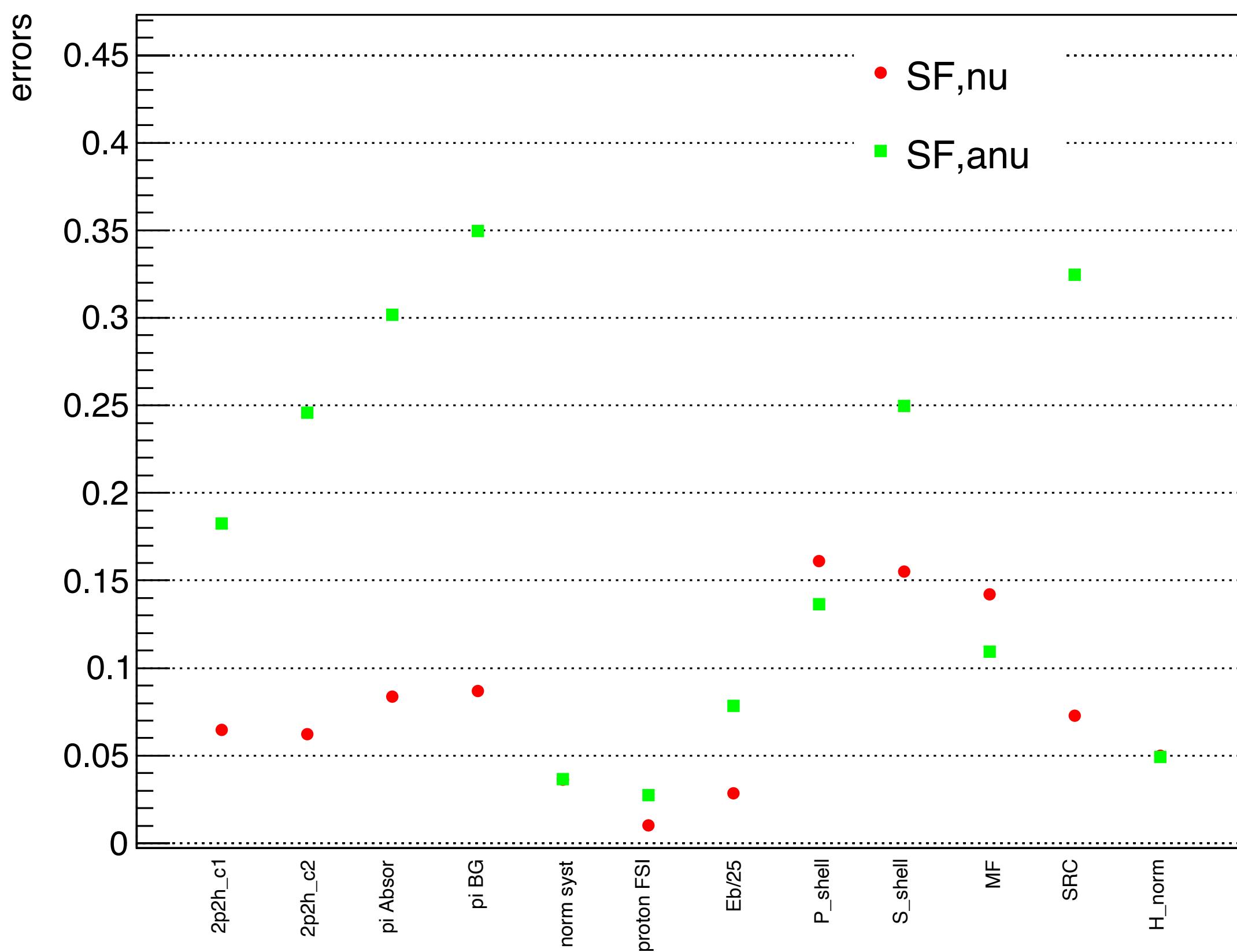
Anti-Neutrino

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The effect of the tail on fit results

Fit with (reco dat, reco pn)

Parameters' errors with different model

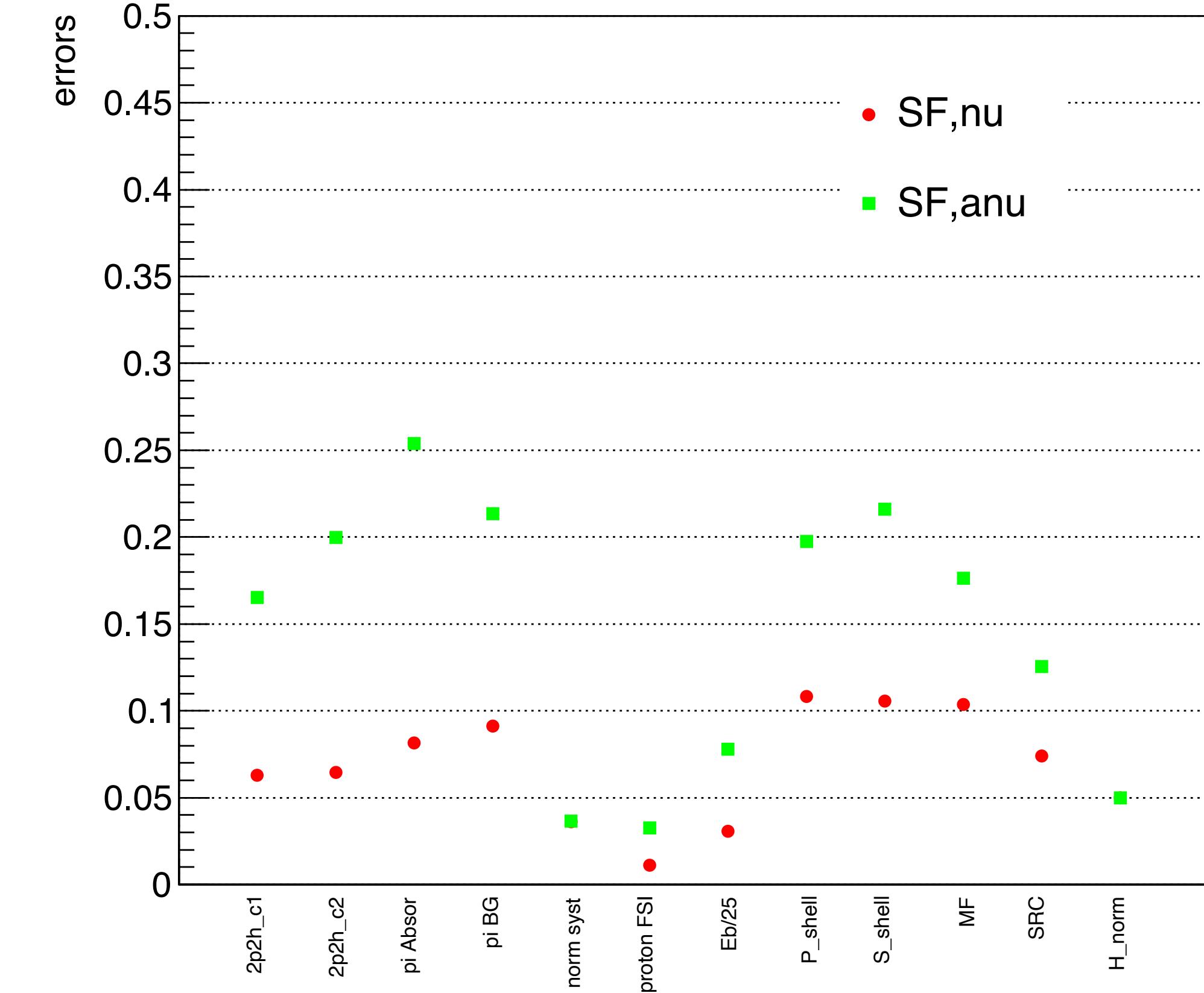


Scale = 1.5

POT = 0.9×10^{22} POT

Fit with (true dat, true pn)

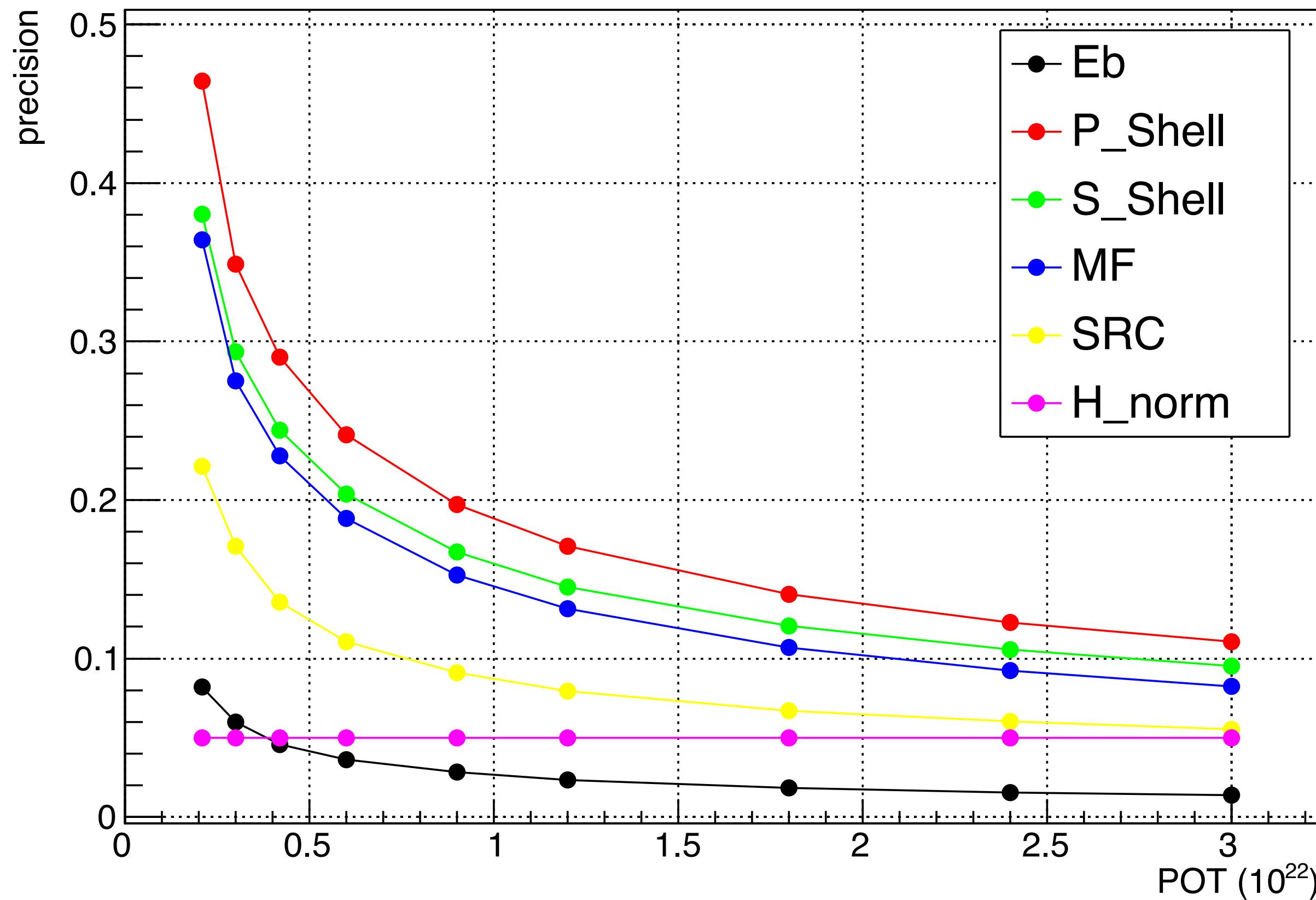
Parameters' errors with different model



Parameter precision vs POT

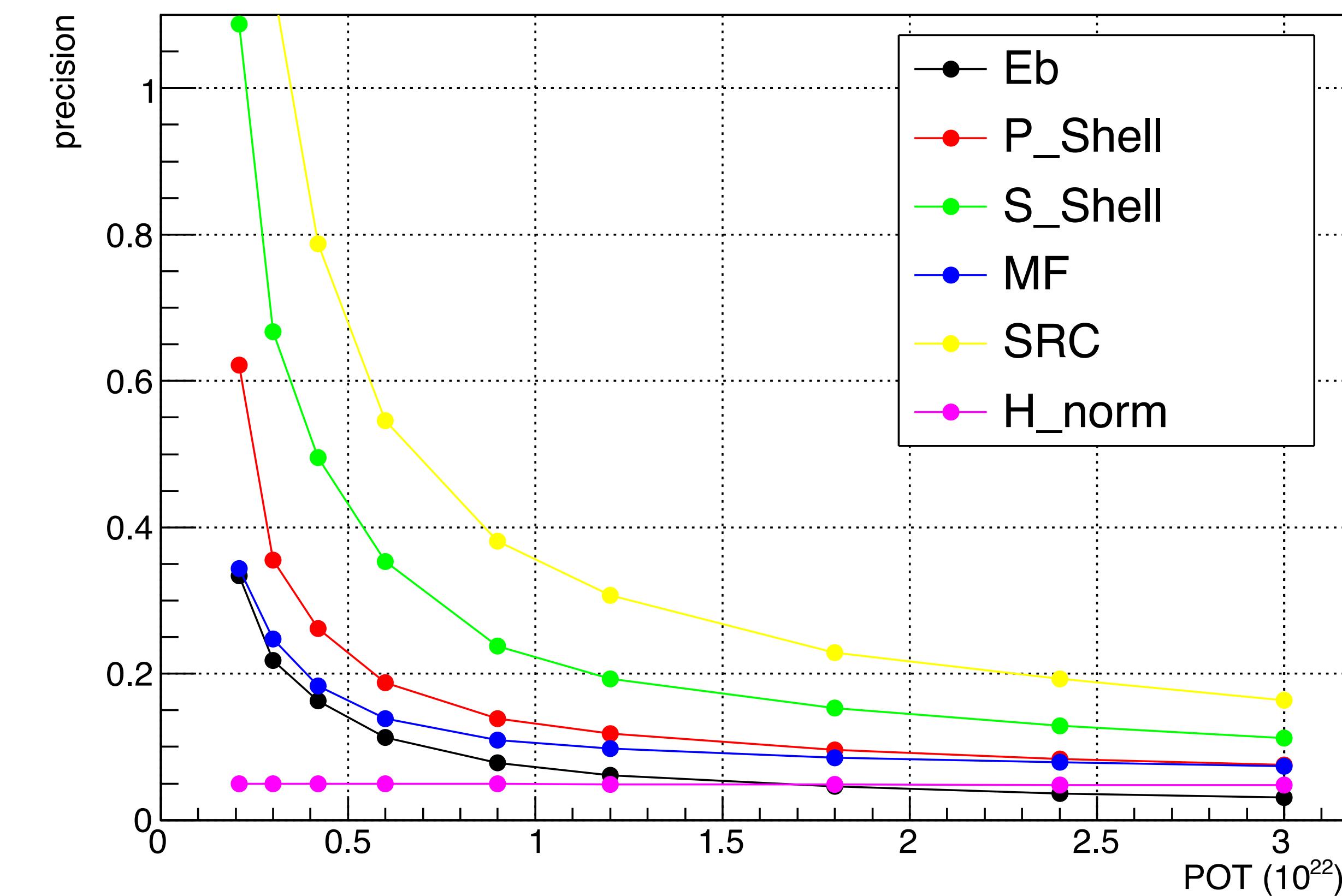
POT: Protons on target

dat_pn_nu



Neutrino

dat_pn_anu

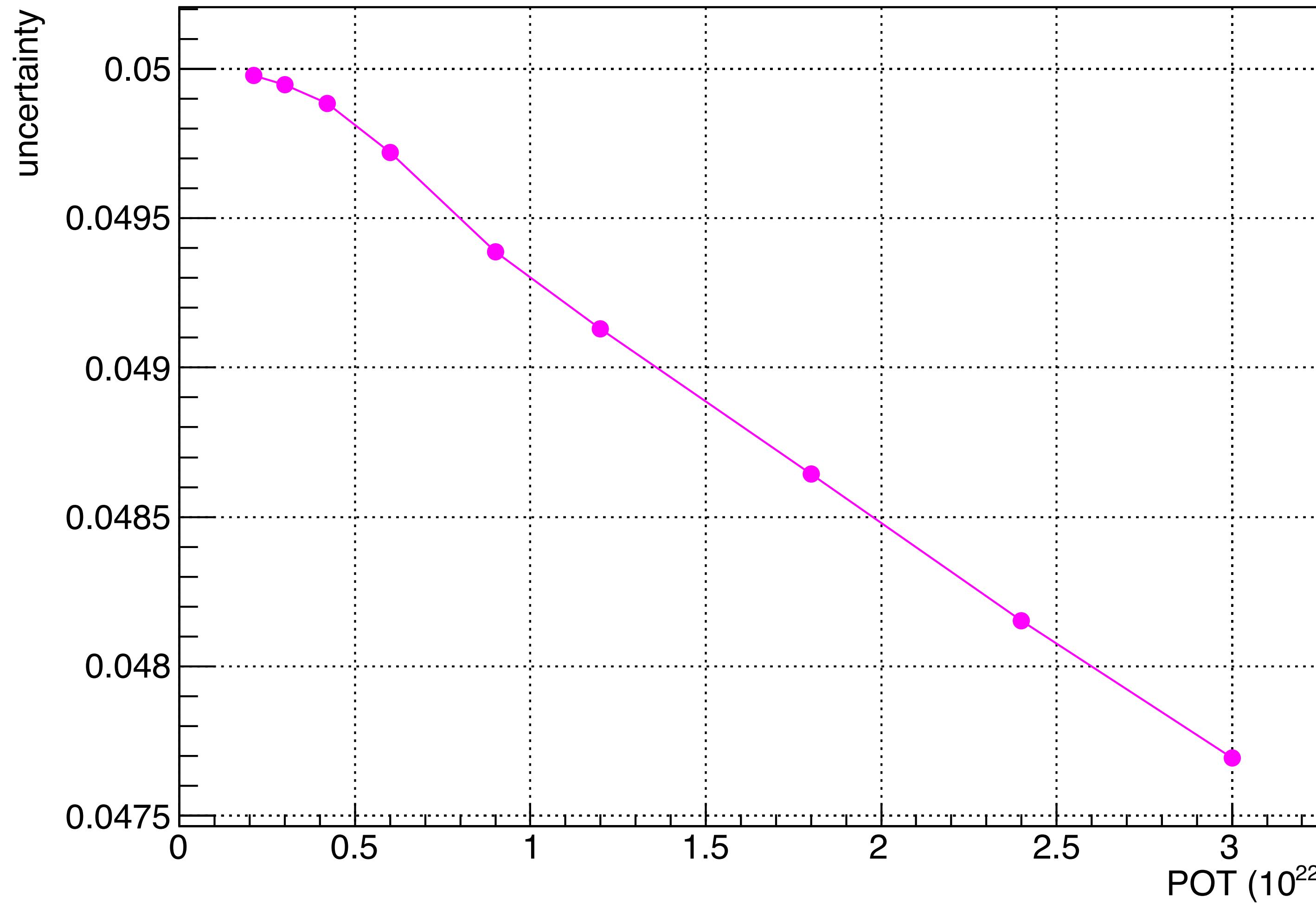


All parameters precision is below 20% for POT = $2 \cdot 10^{22}$

Anti-Neutrino

Results after removing the flux

H_norm dat_pn



H_norm is expected to have anti-correlations with the flux. But I didn't see that.

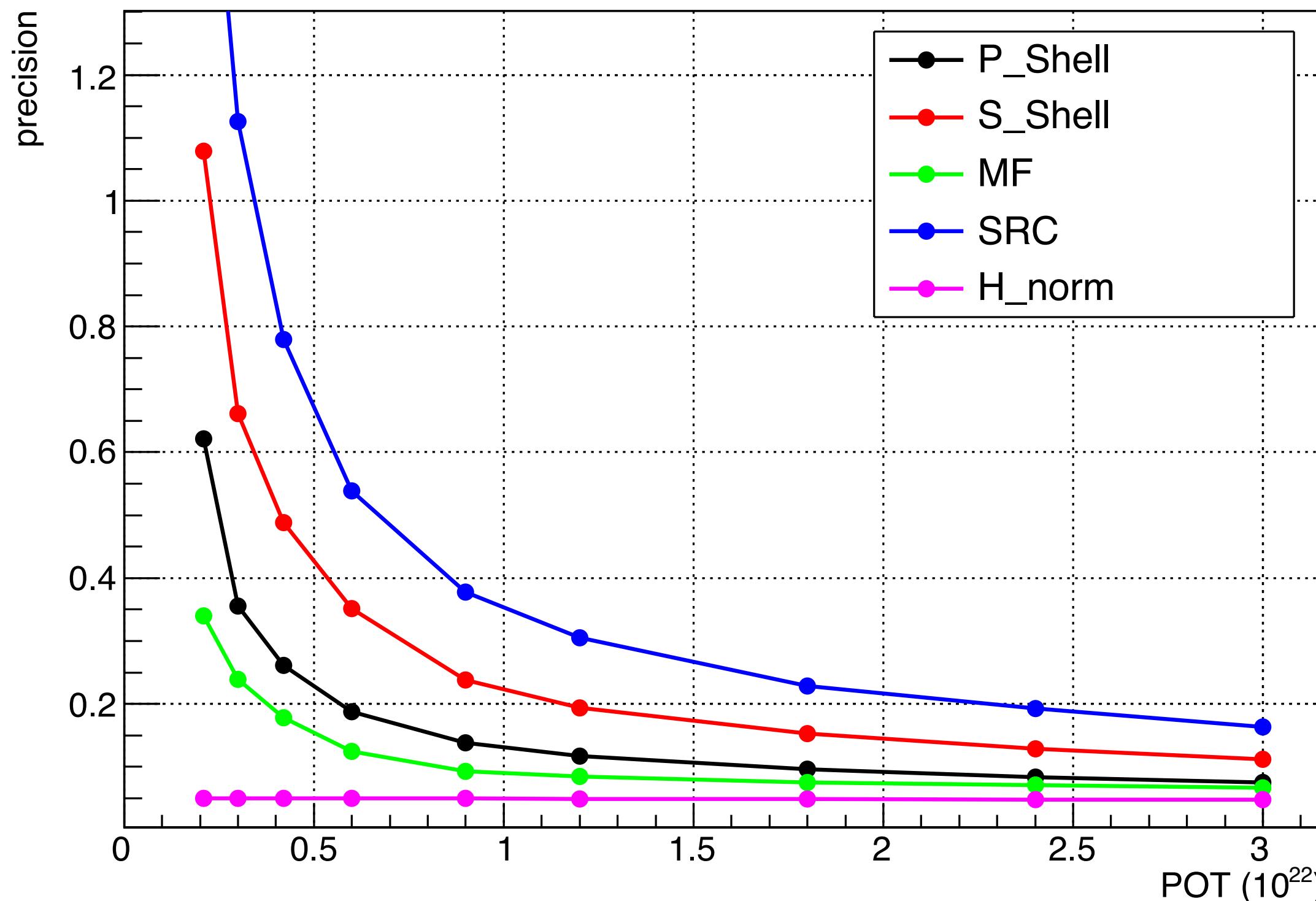
"The real flux uncertainty is usually parametrised by a set of dials that weight events according to which true neutrino energy bin they are in" said Stephen.

In this fitter we use binned fitter, and for most of the input we used, we don't know the true neutrino energy of each event (for example dat_pn), so we can't use this.
=>Remove the flux parameters from fitter

Results after removing the flux

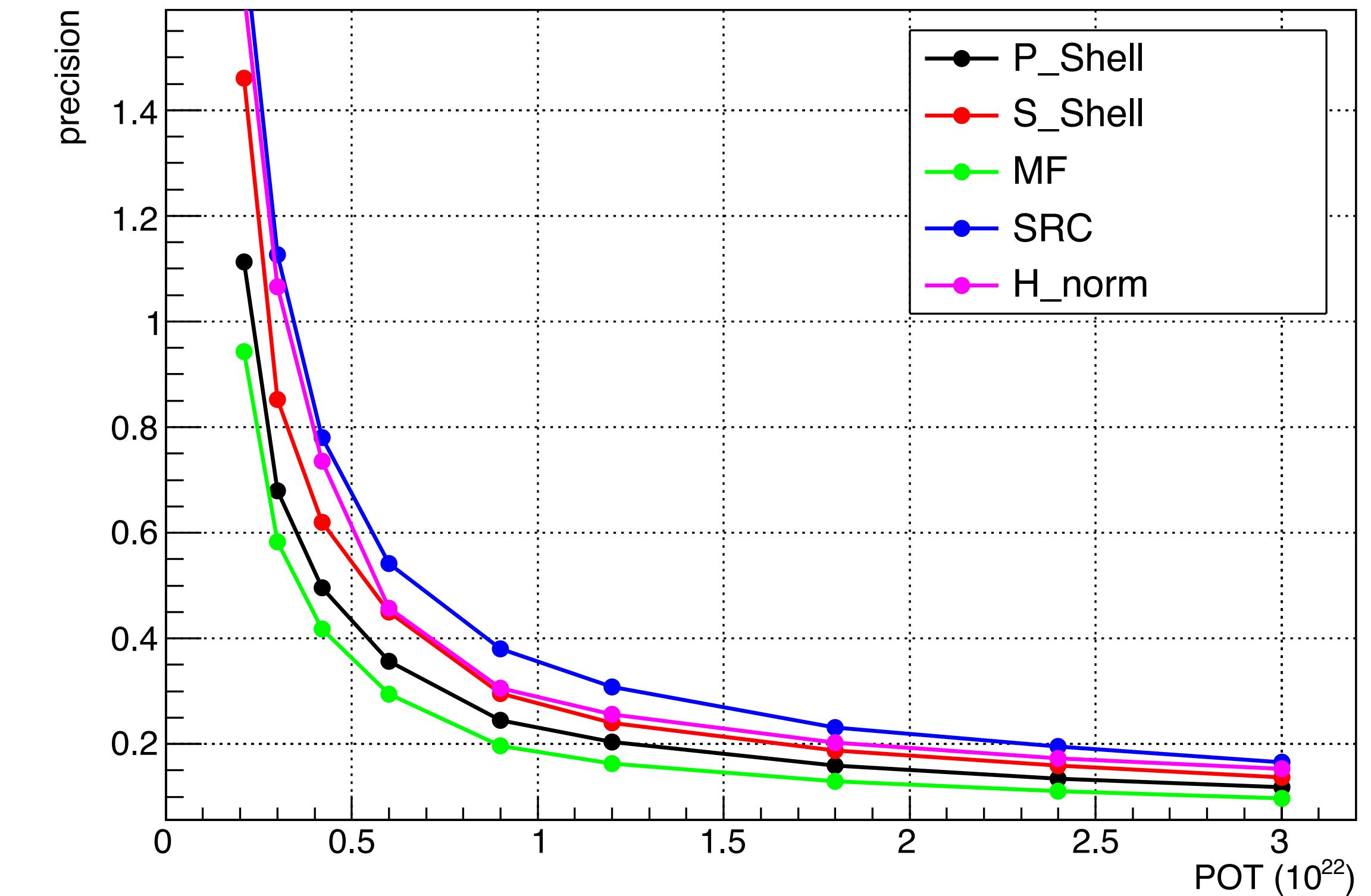
Now I add some switches which help to add or remove parameters easier

dat_pn_anu



With prior value of Hydrogen normalisation

dat_pn_anu



Without prior value of Hydrogen normalisation

H_norm is much more sensitive to POT, for other parameters, the appearance of prior H_norm can affect the their precision at low value of POT (we don't see big effect at 3×10^{22} POT)

Cross section comparison between NEUT and Martini mode

- Extract cross-section from NEUT MC file:

From p_μ histograms, I reweight it by $1E39 * fScaleFactor$ to get the integrated xsec for each nucleon in p_μ bin and $\cos \theta_\mu$ bin. Then I divide it by the bin width of p_μ

$$\text{and } \cos \theta_\mu \text{ to get } \frac{d^2\sigma}{d(p_\mu)d(\cos \theta_\mu)}.$$

Only Charged Current interactions were taken into account.

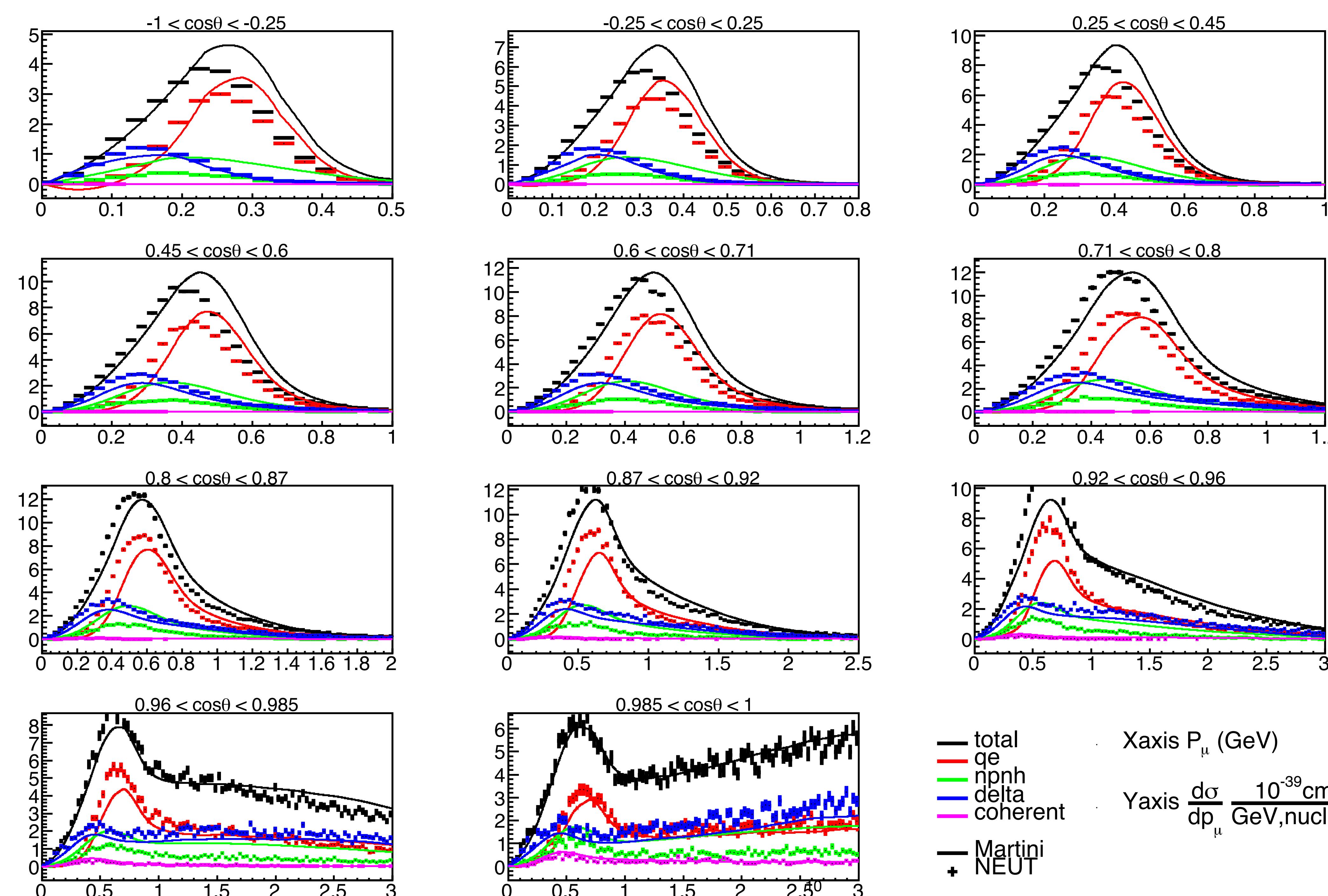
CCQE=>mode =1 (NEUT code)

NPNH=>mode =2

Delta => mode =11,12,13

Coherent =>mode =16

- Then this differential cross section will be compared with Martini's one.



The NEUT file is updated
by Stephen
Now we have data for LFG
and for Carbon interaction
only

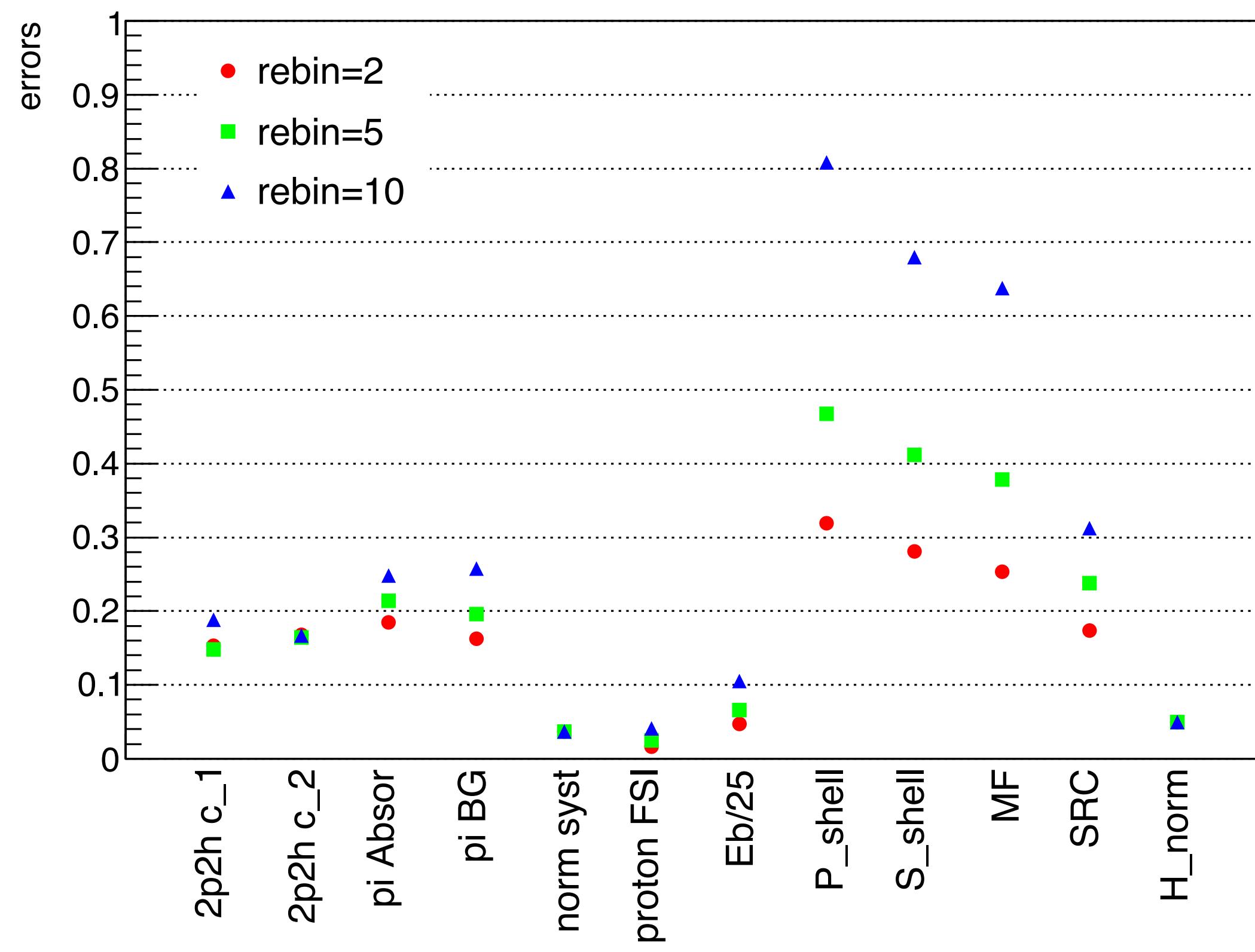
Summary

- I have better understanding about the fitter behaviour. I also re-plot some old studies with new SF dials for finalising.
- I just started working on the new cross section project and hope to have more interesting results soon

Thank you

BU

Parameters' errors with different rebinY(dat_pn),SF,nu



Parameters' errors dat_pn_SF_nu

