$\frac{\sigma^{H_2O}}{\sigma^{CH}}$ in bins of $E_{QE}(p_\mu, \cos\theta_\mu)$ with ν_μCC inlcusive selections in FGD1 and in FDG2

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Group Meeting
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UNIVERSITÉ DE GENÈVE

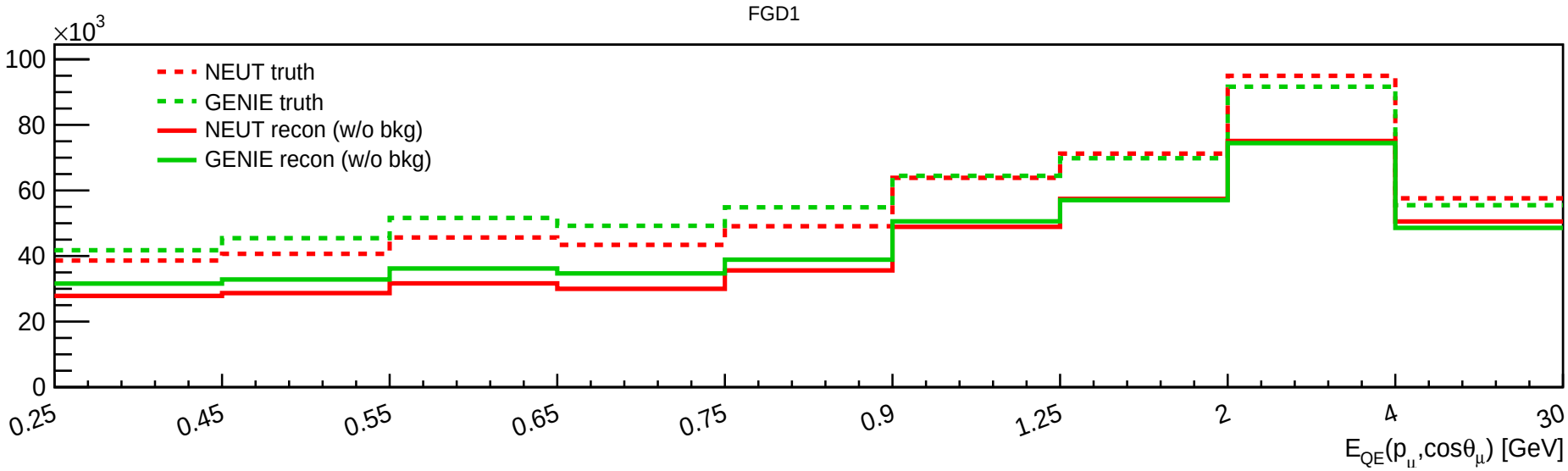
T2K

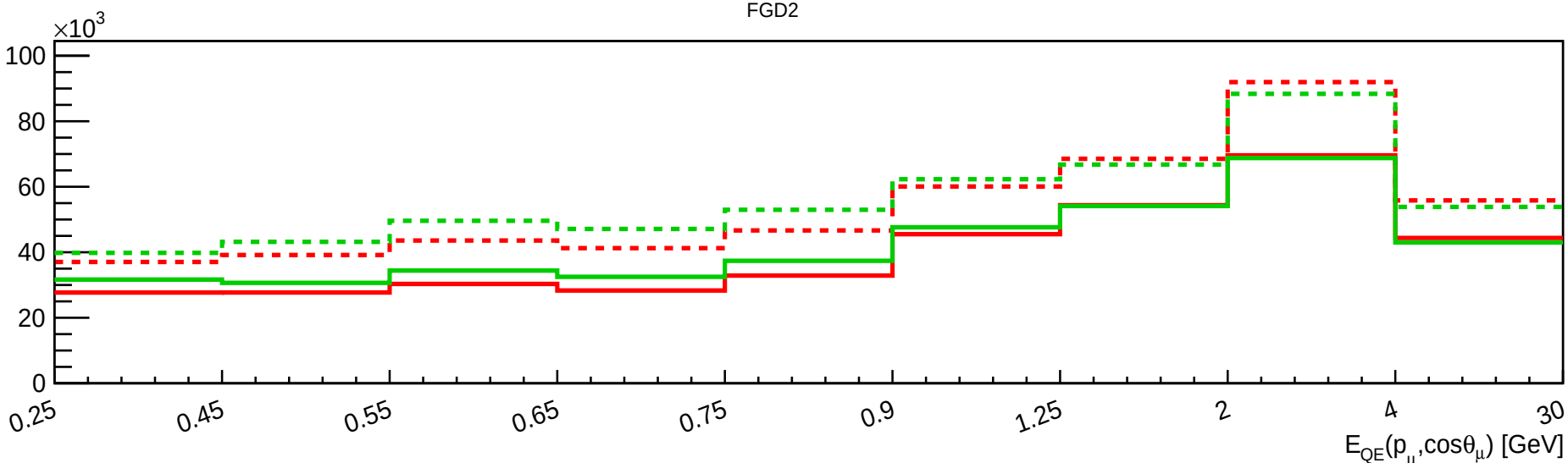
Genie as fake-data

bin	N_{fgd2}	N_{fgd1}	$N_{fgd2} - N_{fgd1} \cdot 52.7\%$
$[0.25, 0.45]$	1738.69	1734.46	824.896
$[0.45, 0.55]$	1659.84	1732.23	747.213
$[0.55, 0.65]$	1757.02	1853.25	780.632
$[0.65, 0.75]$	1568.53	1675.21	685.945
$[0.75, 0.90]$	1757.34	1909.58	751.284
$[0.90, 1.25]$	2353.05	2540.72	1014.48
$[1.25, 2.00]$	2737.73	2901.22	1209.23
$[2.00, 4.00]$	3459.34	3734.82	1491.65
$[4.00, 30.0]$	2202.50	2507.73	881.307

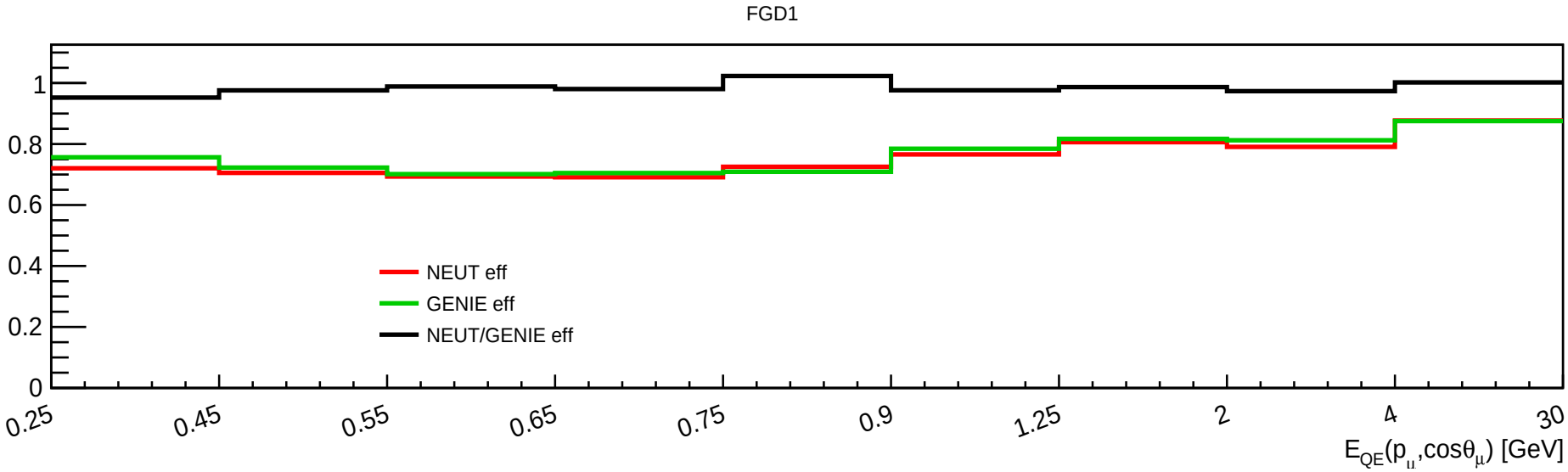
After bin by bin	and efficiency	corrections	
$[0.25, 0.45]$	2324.51	2407.48	1056.13
$[0.45, 0.55]$	2345.44	2455.99	1051.50
$[0.55, 0.65]$	2525.18	2672.89	1116.97
$[0.65, 0.75]$	2285.34	2424.32	1008.09
$[0.75, 0.90]$	2494.05	2632.54	1107.10
$[0.90, 1.25]$	3105.66	3317.43	1357.87
$[1.25, 2.00]$	3451.78	3599.21	1555.54
$[2.00, 4.00]$	4571.18	4723.71	2082.50
$[4.00, 30.0]$	2771.86	2858.83	1265.68

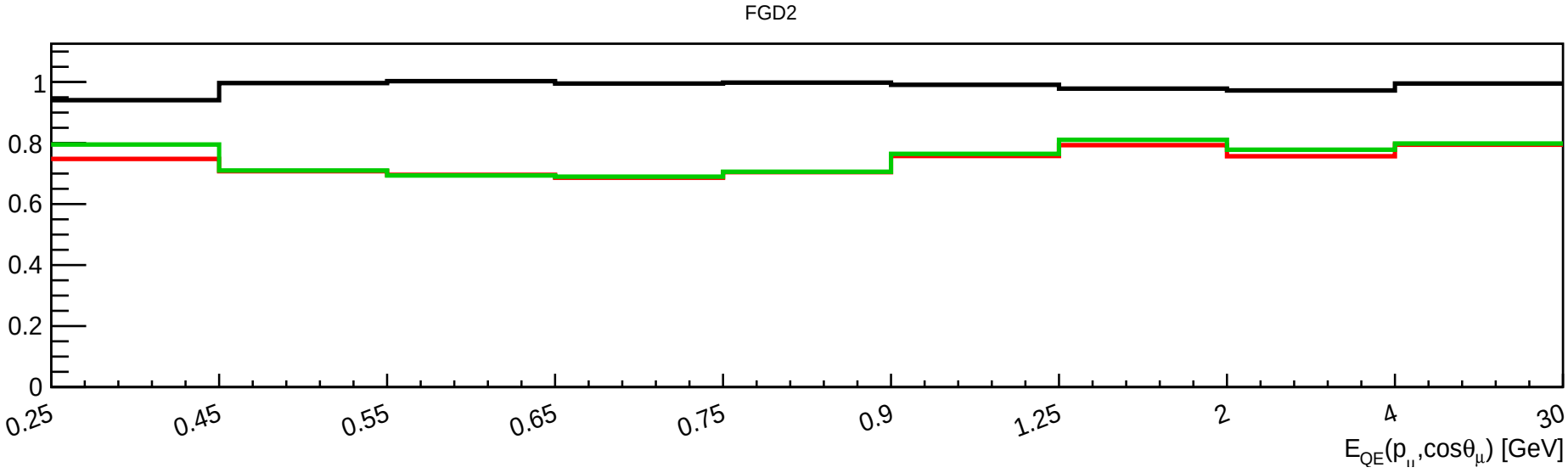
Distributions



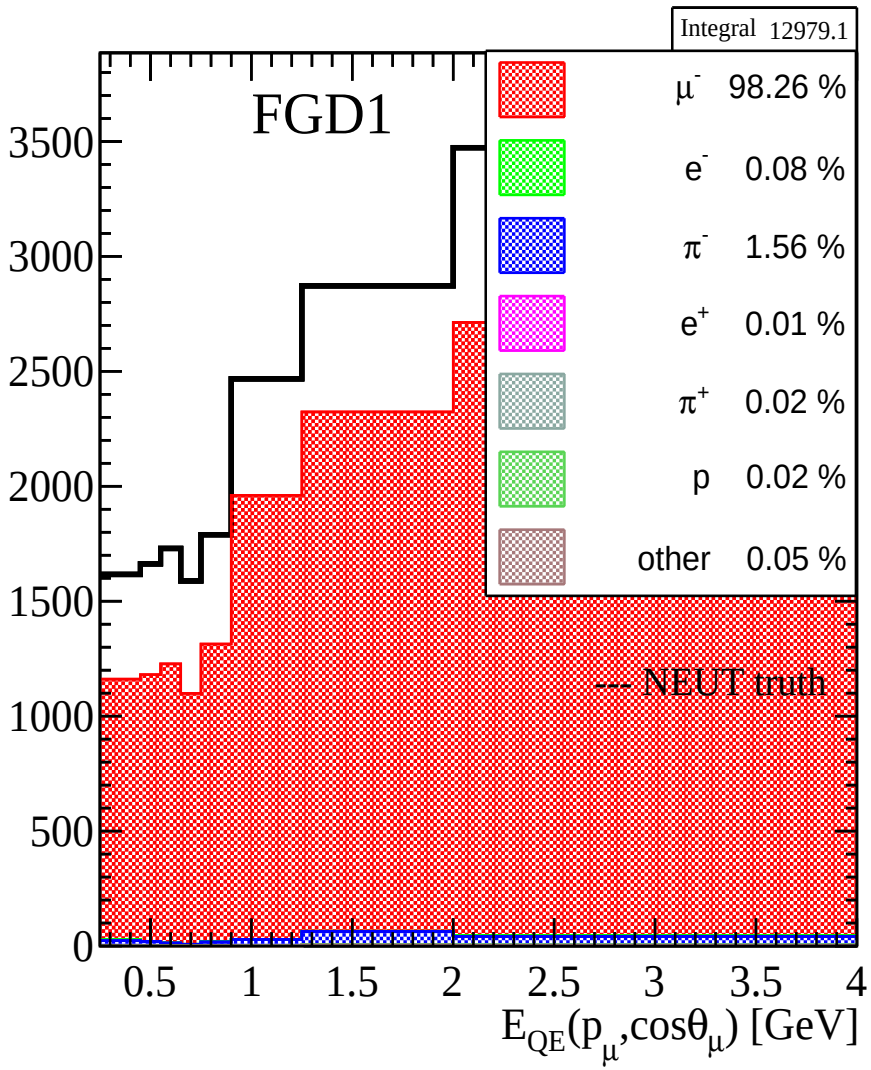


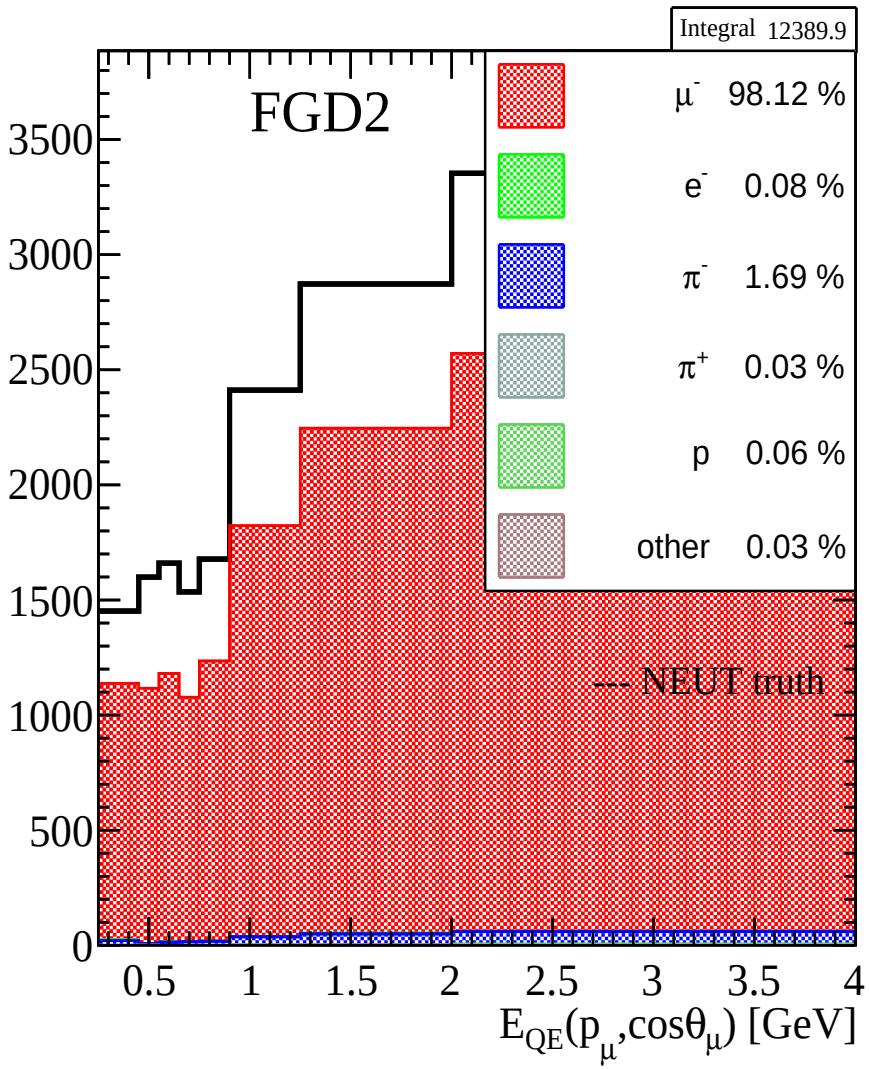
Distribution efficiencies



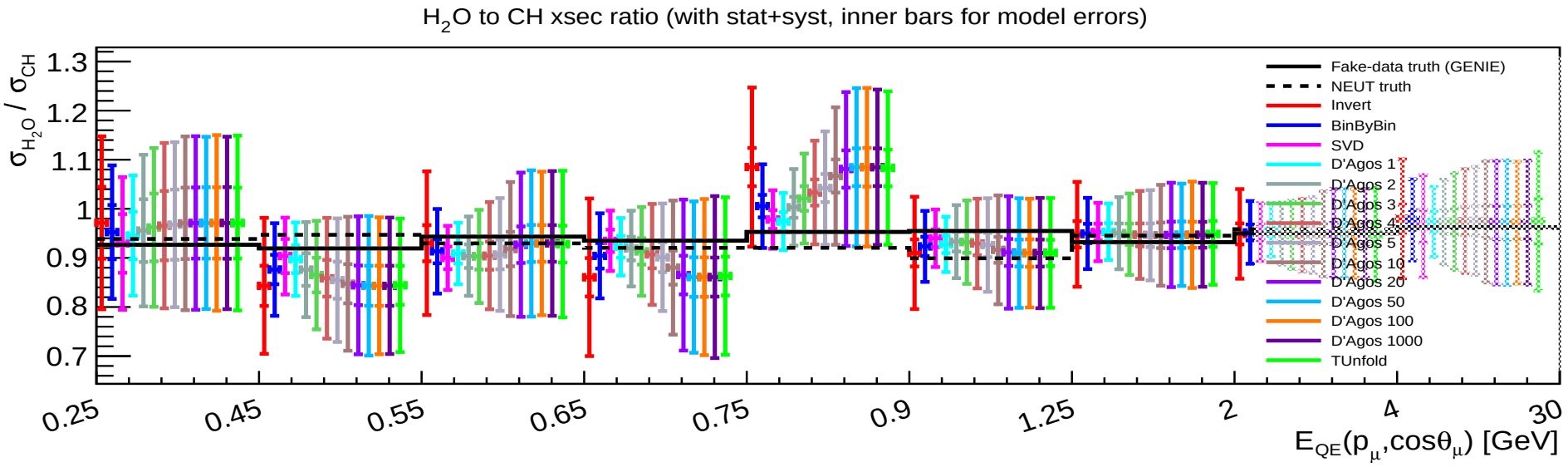


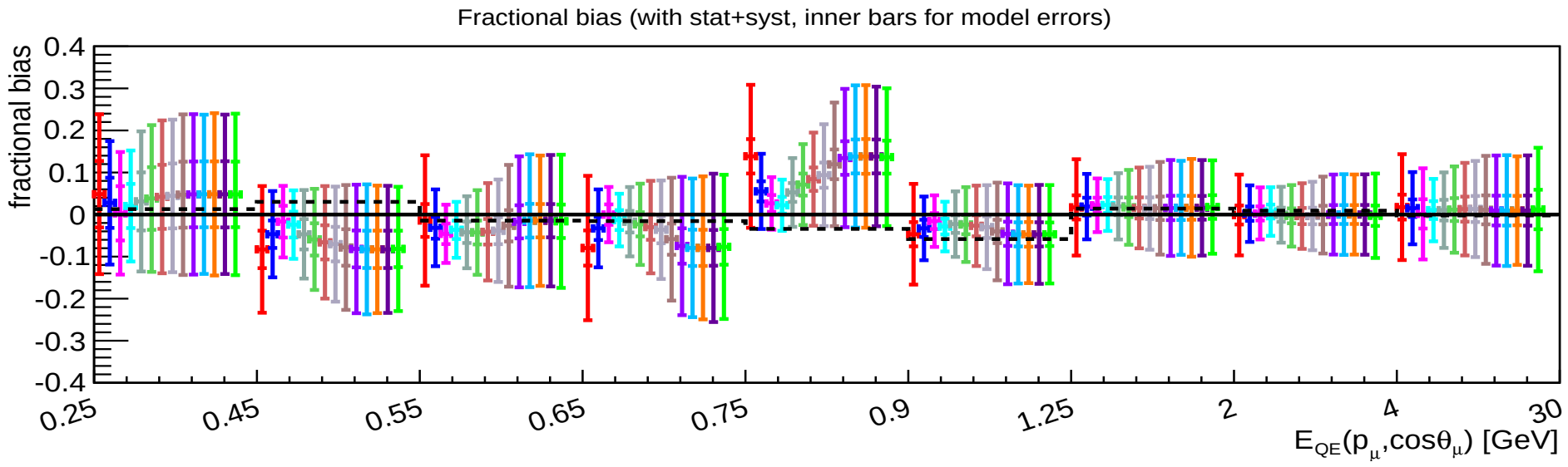
Distribution after bkg subtraction



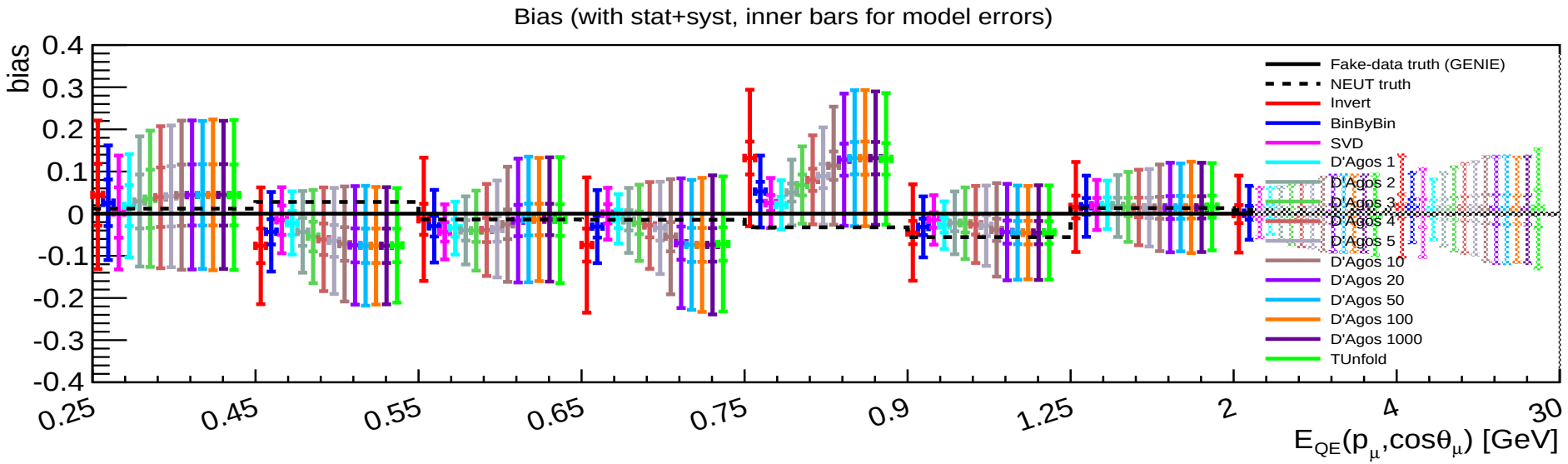


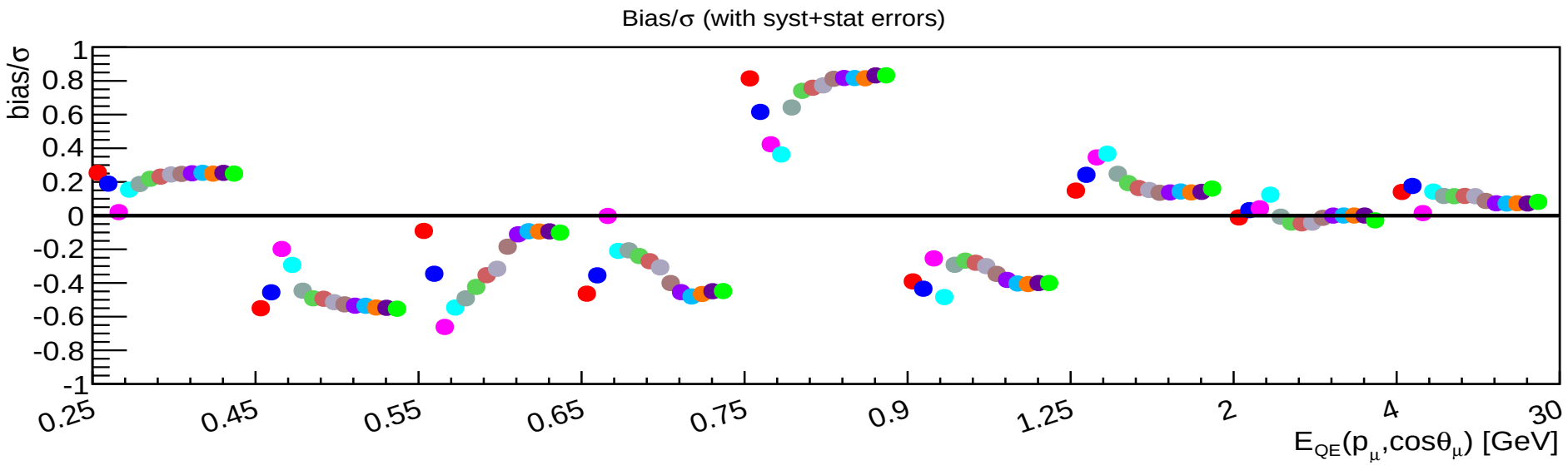
$\sigma_{H_2O}/\sigma_{CH}$



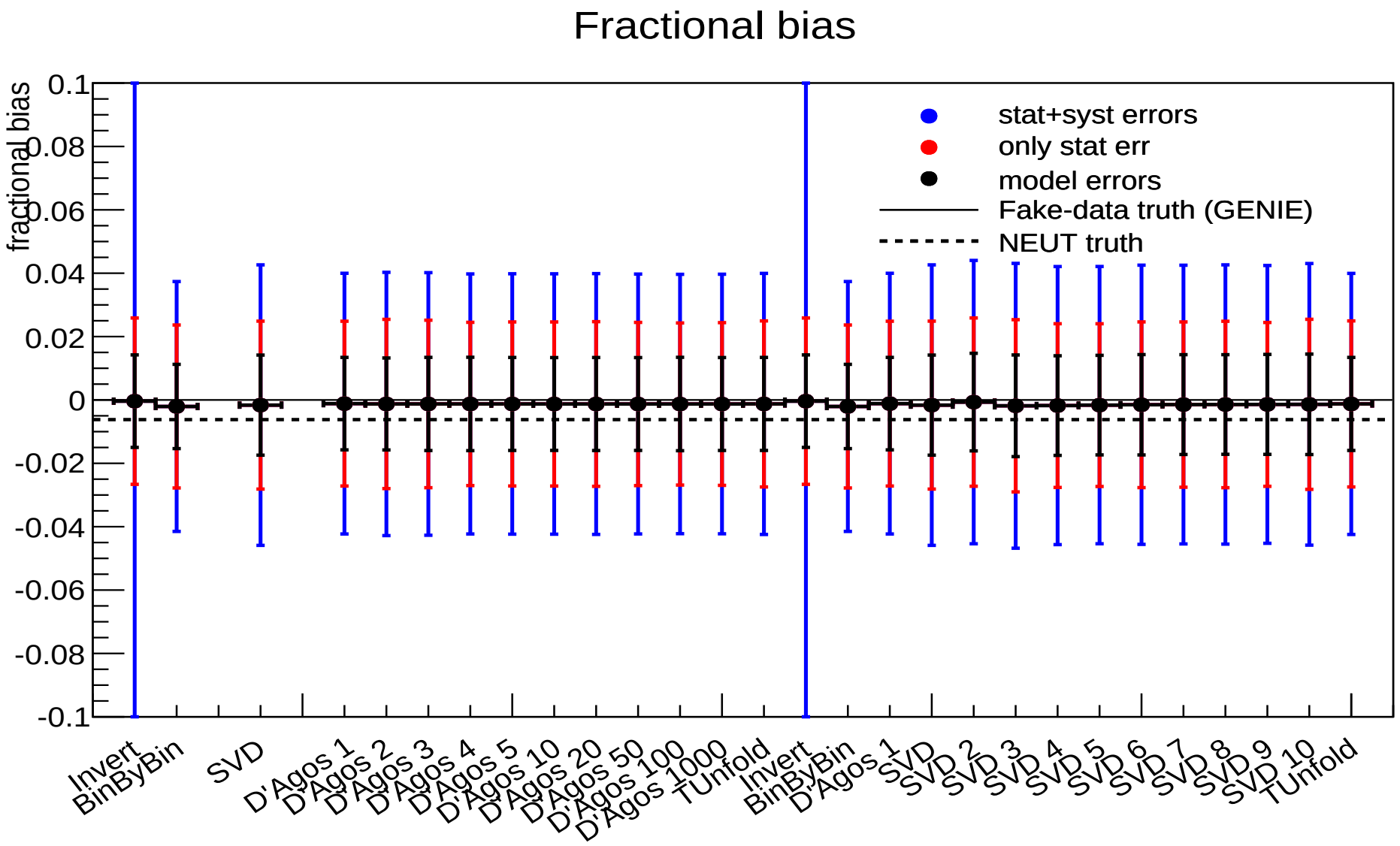


$\sigma_{H_2O}/\sigma_{CH}$

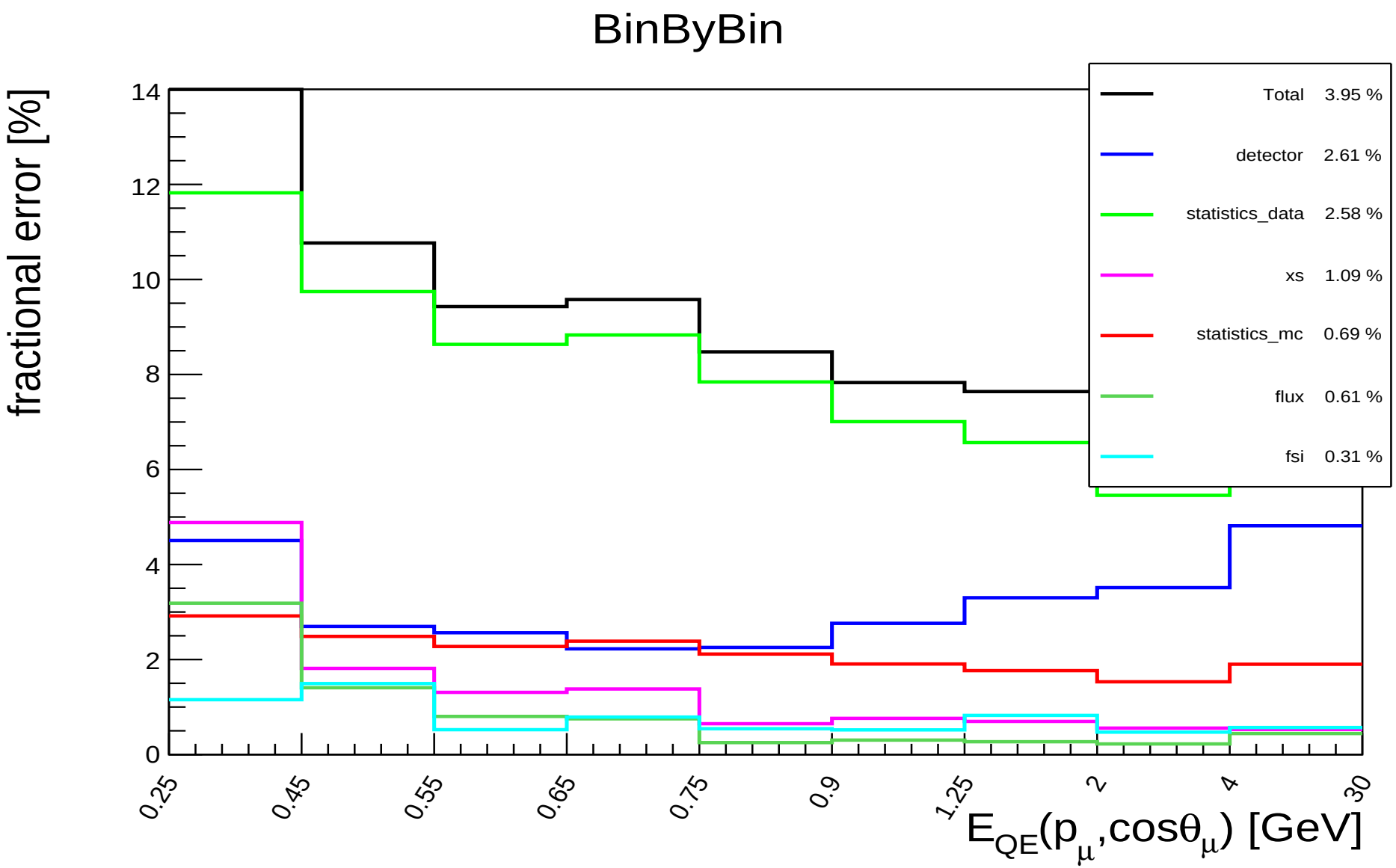




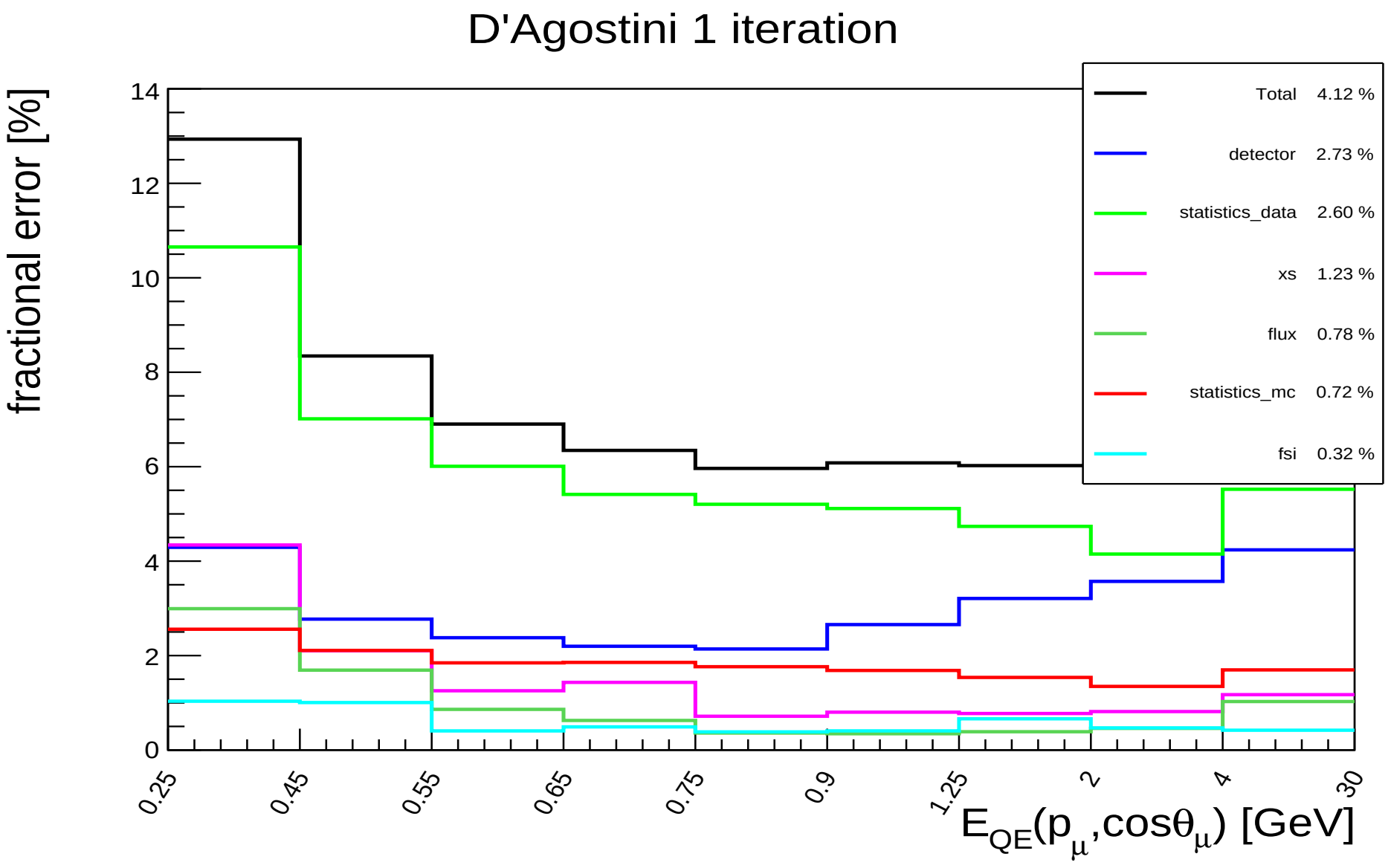
$\sigma_{H_2O}/\sigma_{CH}$



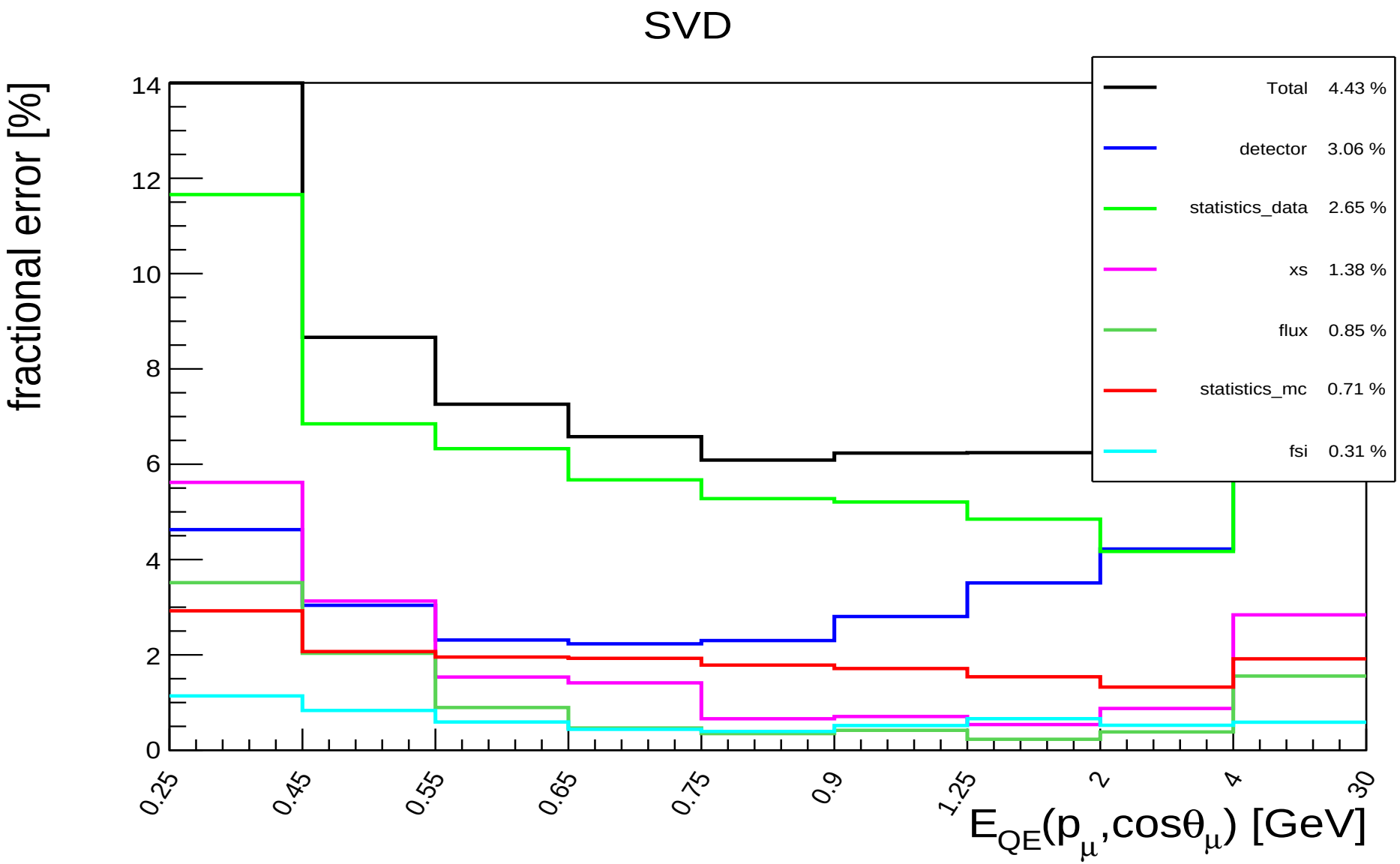
errors on $\sigma_{H_2O}/\sigma_{CH}$



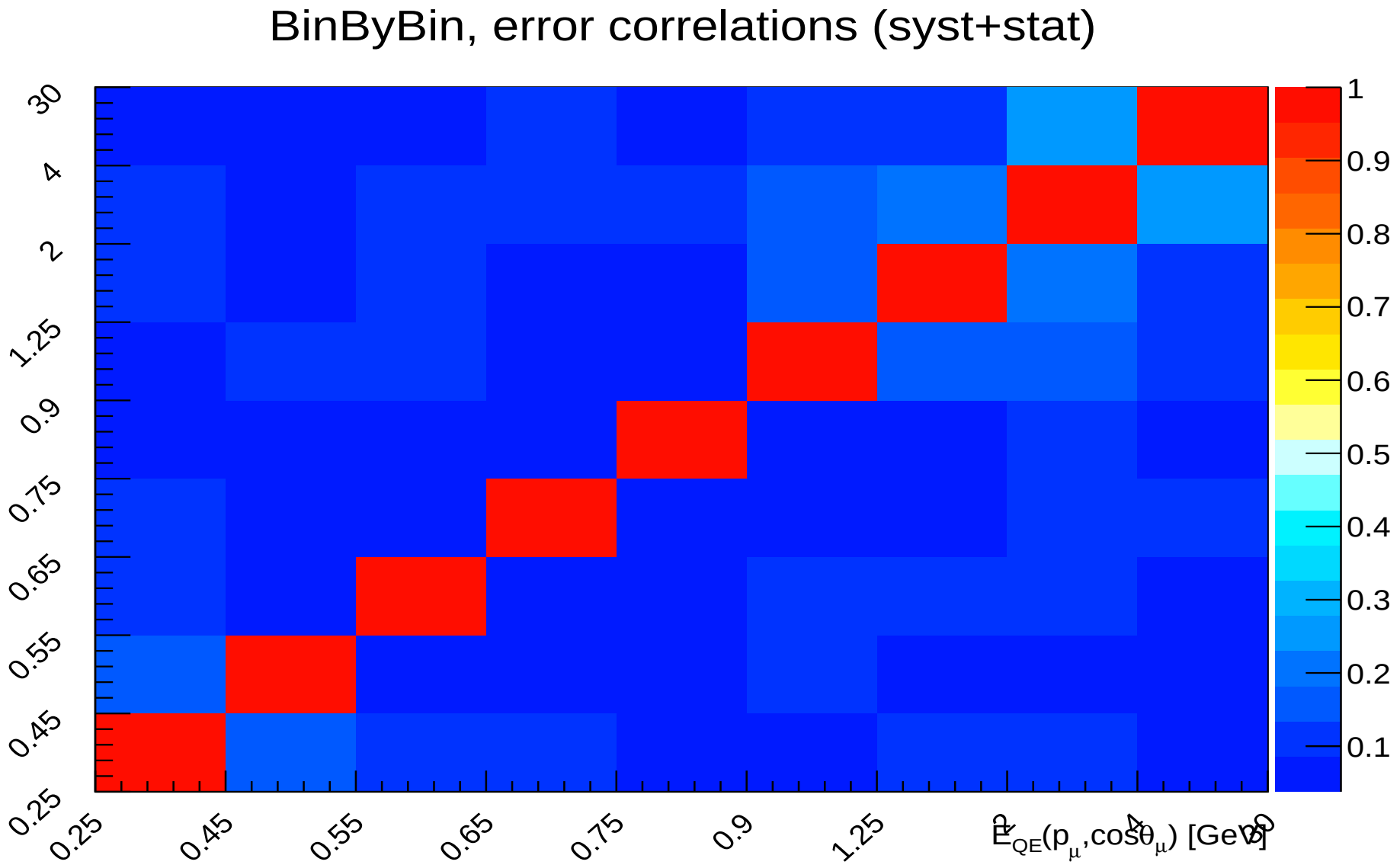
errors on $\sigma_{H_2O}/\sigma_{CH}$



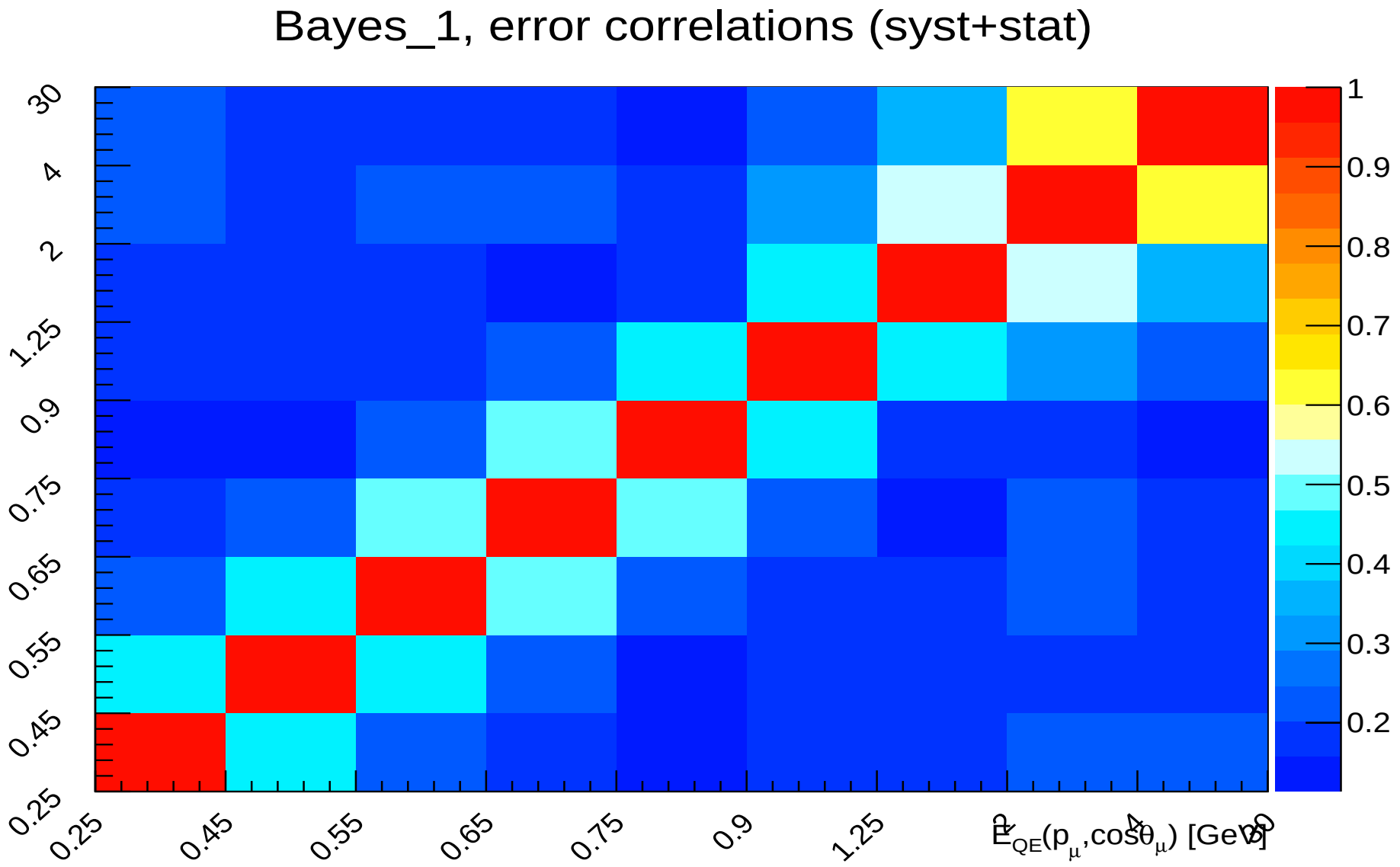
errors on $\sigma_{H_2O}/\sigma_{CH}$



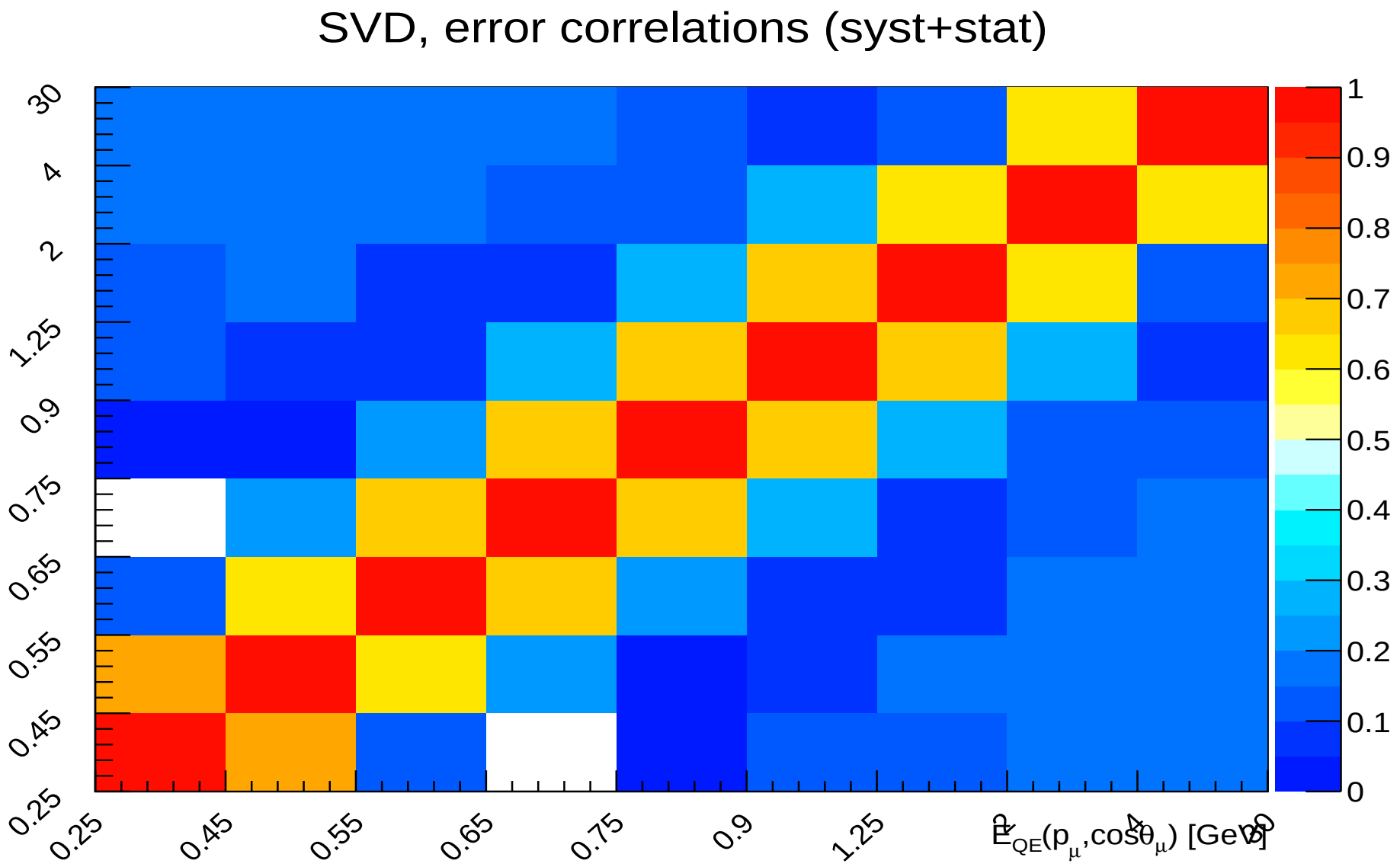
error correlations on $\sigma_{H_2O}/\sigma_{CH}$



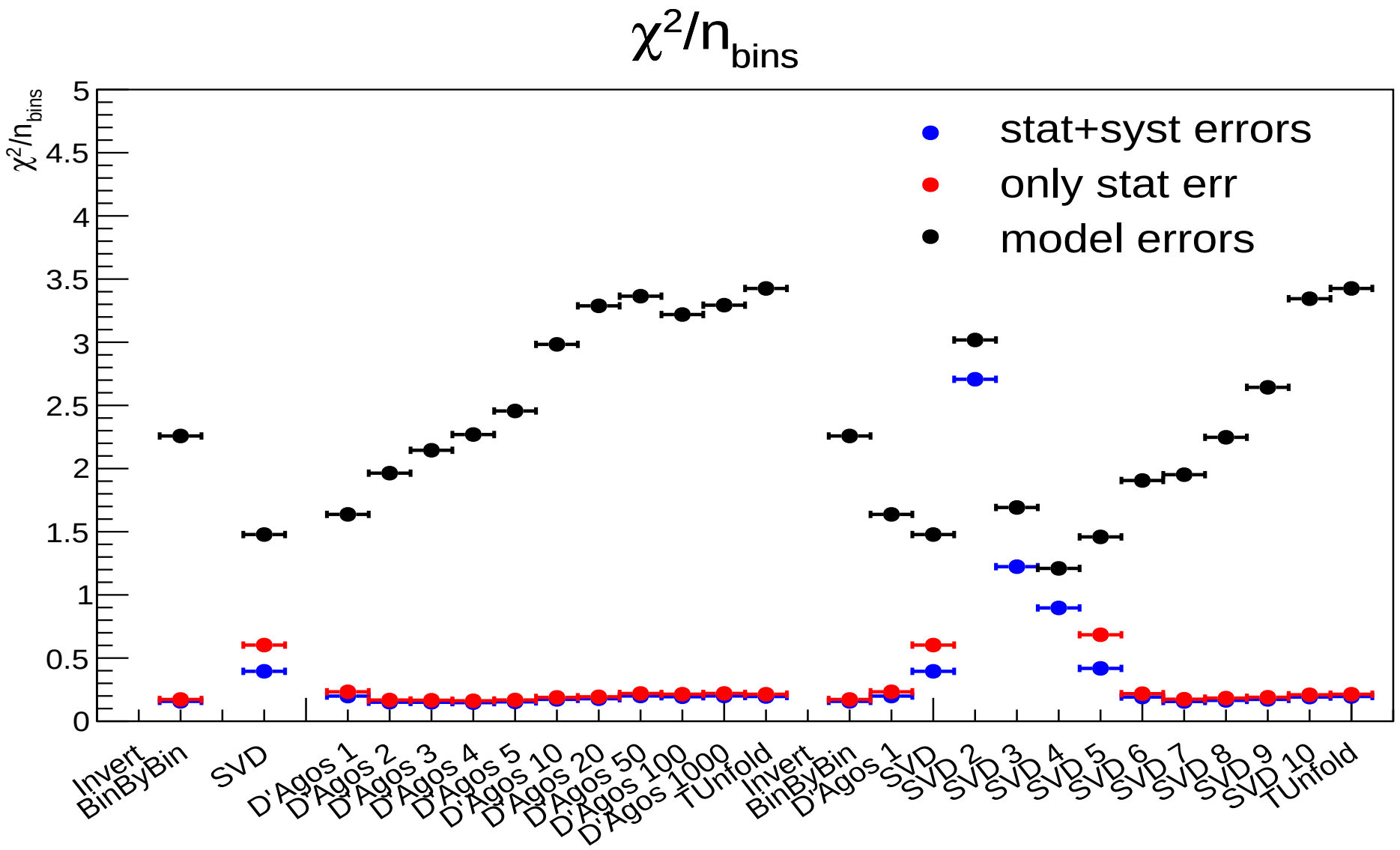
error correlations on $\sigma_{H_2O}/\sigma_{CH}$



error correlations on $\sigma_{H_2O}/\sigma_{CH}$



χ^2 for $\sigma_{H_2O}/\sigma_{CH}$



BACKUP

reconstructed ν energy for ν_μCC inclusive (CCQE formula)

- $< E >$ is well reproduced by MC for both FGDs at the level of 1.7 ± 3.1 / 650 MeV
- There's a shift of 9 ± 3 MeV between FG1 and FGD2, reproduced by MC (7.3 ± 0.9)

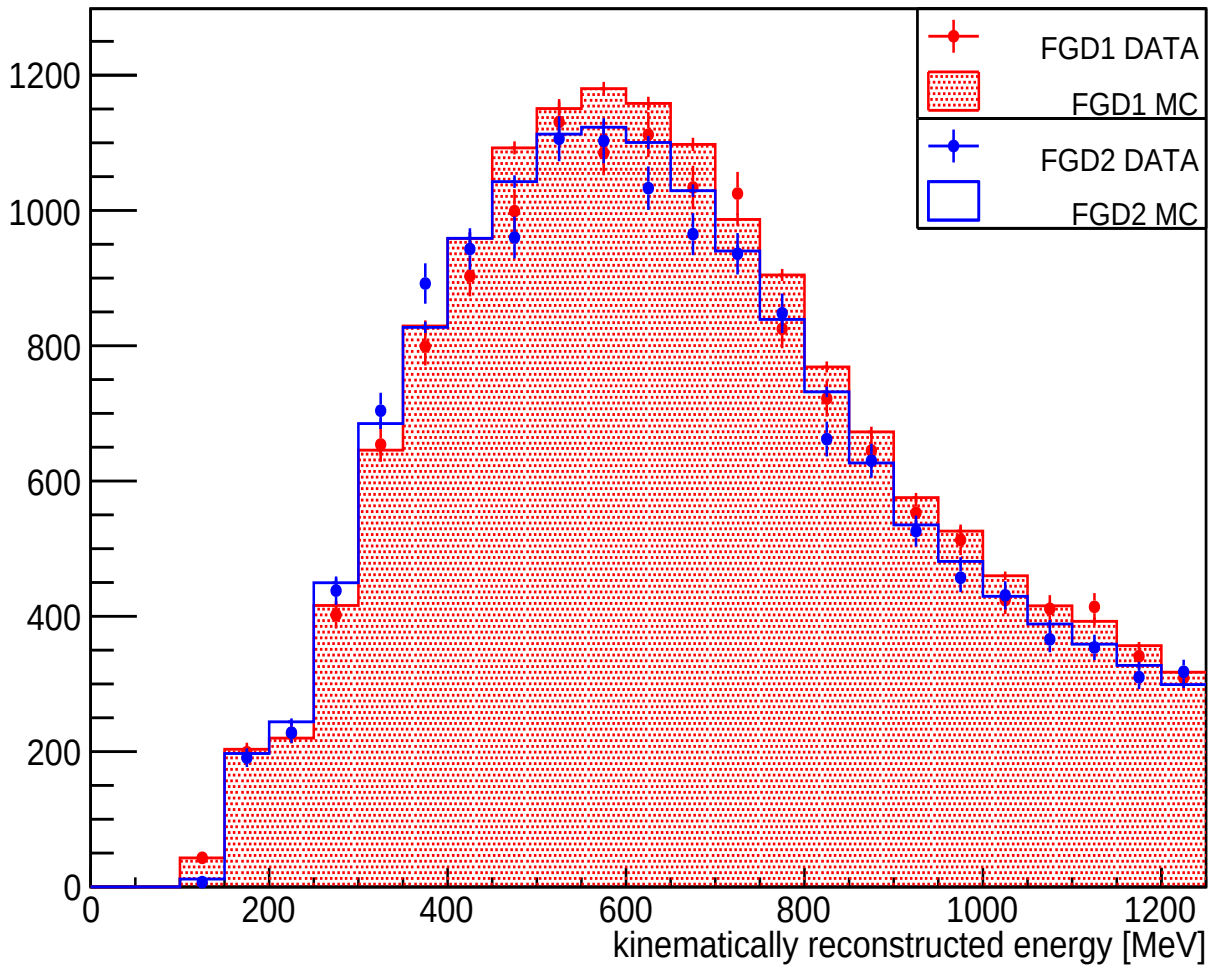
numu CC inclusive selection, FORWARD candidates

FGD1 MC		FGD1 DATA	
Mean	667.097 ± 0.631165	Mean	667.684 ± 2.1113
RMS	254.609	RMS	256.59
Integral	15370.9	Integral	14770
FGD2 MC		**FGD2 DATA**	
Mean	659.778 ± 0.637005	Mean	658.696 ± 2.13448
RMS	254.816	RMS	256.209
Integral	14739.1	Integral	14408

$\text{Mean}^{\text{FGD1 DATA}}$ - $\text{Mean}^{\text{FGD1 MC}}$ = 0.59 ± 2.2
$\text{Mean}^{\text{FGD2 DATA}}$ - $\text{Mean}^{\text{FGD2 MC}}$ = -1.1 ± 2.2
1.7 ± 3.1

$\text{Mean}^{\text{FGD1 MC}}$ - $\text{Mean}^{\text{FGD2 MC}}$ = 7.3 ± 0.89
$\text{Mean}^{\text{FGD1 DATA}}$ - $\text{Mean}^{\text{FGD2 DATA}}$ = 9 ± 3
-1.7 ± 3.1

FGD1 χ^2/ndof = 44.4 / 22 (pvalue 0.0032)
FGD2 χ^2/ndof = 35.6 / 22 (pvalue 0.034)



$\sigma_k^{H_2O}$

T^{fgd2H_2O} = number of targets in the H_2O component of FGD2
T^{fgd2CH} = number of targets in the CH component of FGD2
T^{fgd1} = number of targets in FGD1

Estimated number of events in H_2O (pure water) (in bin k):

$$\hat{N}_k^{H_2O} = \hat{N}_k^{fgd2} - \hat{N}_k^{fgd2CH}$$

$$\hat{N}_k^{H_2O} = \hat{N}_k^{fgd2} - \sigma_k^{CH} \cdot T^{fgd2CH} \cdot \phi$$

We can estimate σ_k^{CH} using FGD1: $\sigma_k^{CH} = \frac{\hat{N}_k^{fgd1}}{T^{fgd1} \cdot \phi}$

$$\hat{N}_k^{H_2O} = \hat{N}_k^{fgd2} - \frac{\hat{N}_k^{fgd1}}{T^{fgd1} \cdot \phi} \cdot T^{fgd2CH} \cdot \phi$$

$$\sigma_k^{H_2O} = \frac{\hat{N}_k^{H_2O}}{T^{fgd2H_2O} \cdot \phi} = \frac{\hat{N}_k^{fgd2}}{T^{fgd2H_2O} \cdot \phi} - \frac{\hat{N}_k^{fgd1}}{T^{fgd1} \cdot \phi} \cdot \frac{T^{fgd2CH}}{T^{fgd2H_2O}}$$

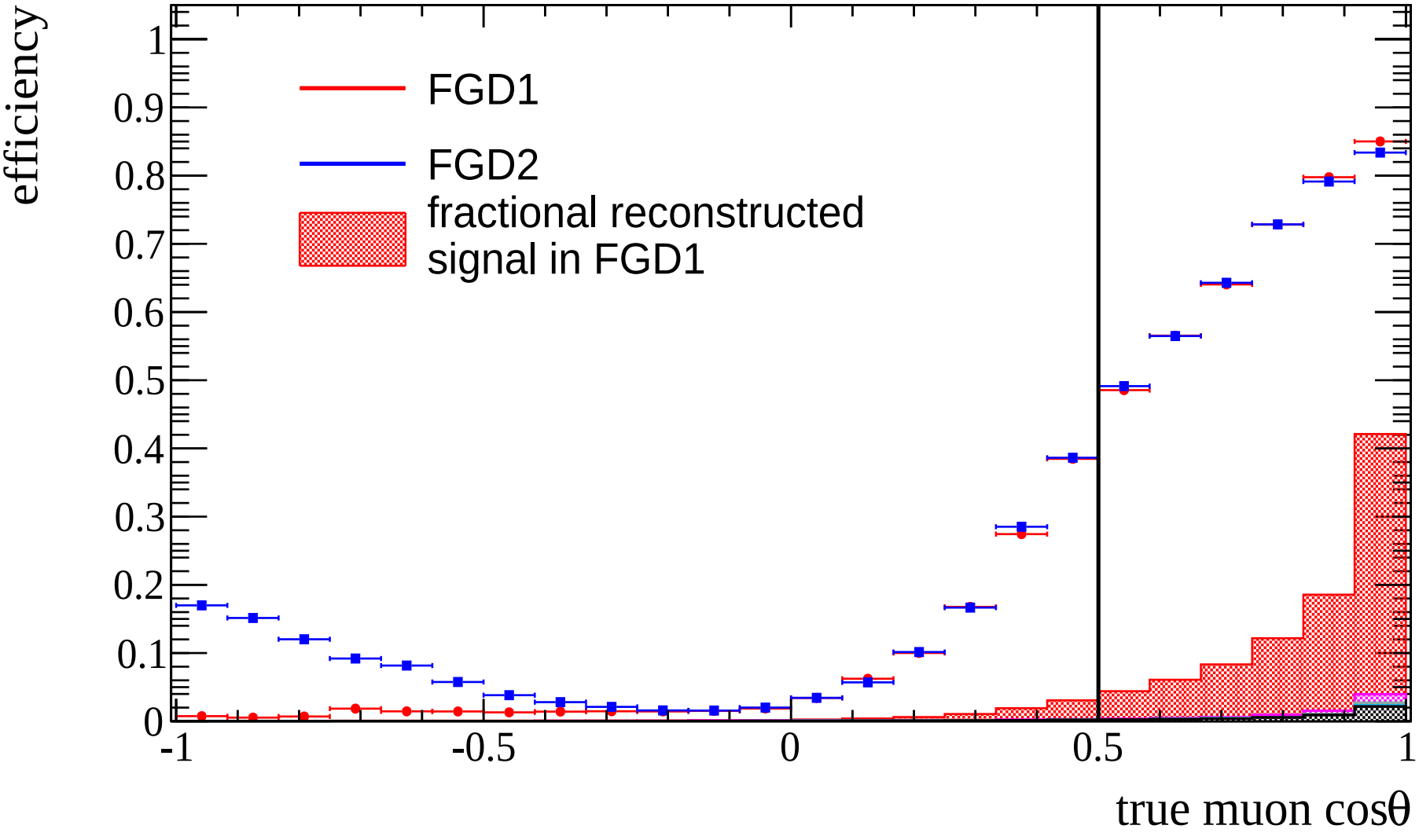
$\sigma_k^{H_2O} / \sigma_k^{CH}$

$$\sigma_k^{H_2O} = \frac{\hat{N}_k^{fgd2}}{T^{fgd2H_2O} \cdot \phi} - \frac{\hat{N}_k^{fgd1}}{T^{fgd1} \cdot \phi} \cdot \frac{T^{fgd2CH}}{T^{fgd2H_2O}} \qquad \sigma_k^{CH} = \frac{\hat{N}_k^{fgd1}}{T^{fgd1} \cdot \phi}$$

$$\frac{\sigma_k^{H_2O}}{\sigma_k^{CH}} = \frac{\frac{\hat{N}_k^{fgd2}}{T^{fgd2H_2O} \cdot \phi}}{\frac{\hat{N}_k^{fgd1}}{T^{fgd1} \cdot \phi}} - \frac{T^{fgd2CH}}{T^{fgd2H_2O}} = \frac{\hat{N}_k^{fgd2}}{\hat{N}_k^{fgd1}} \cdot \frac{T^{fgd1}}{T^{fgd2H_2O}} - \frac{T^{fgd2CH}}{T^{fgd2H_2O}}$$

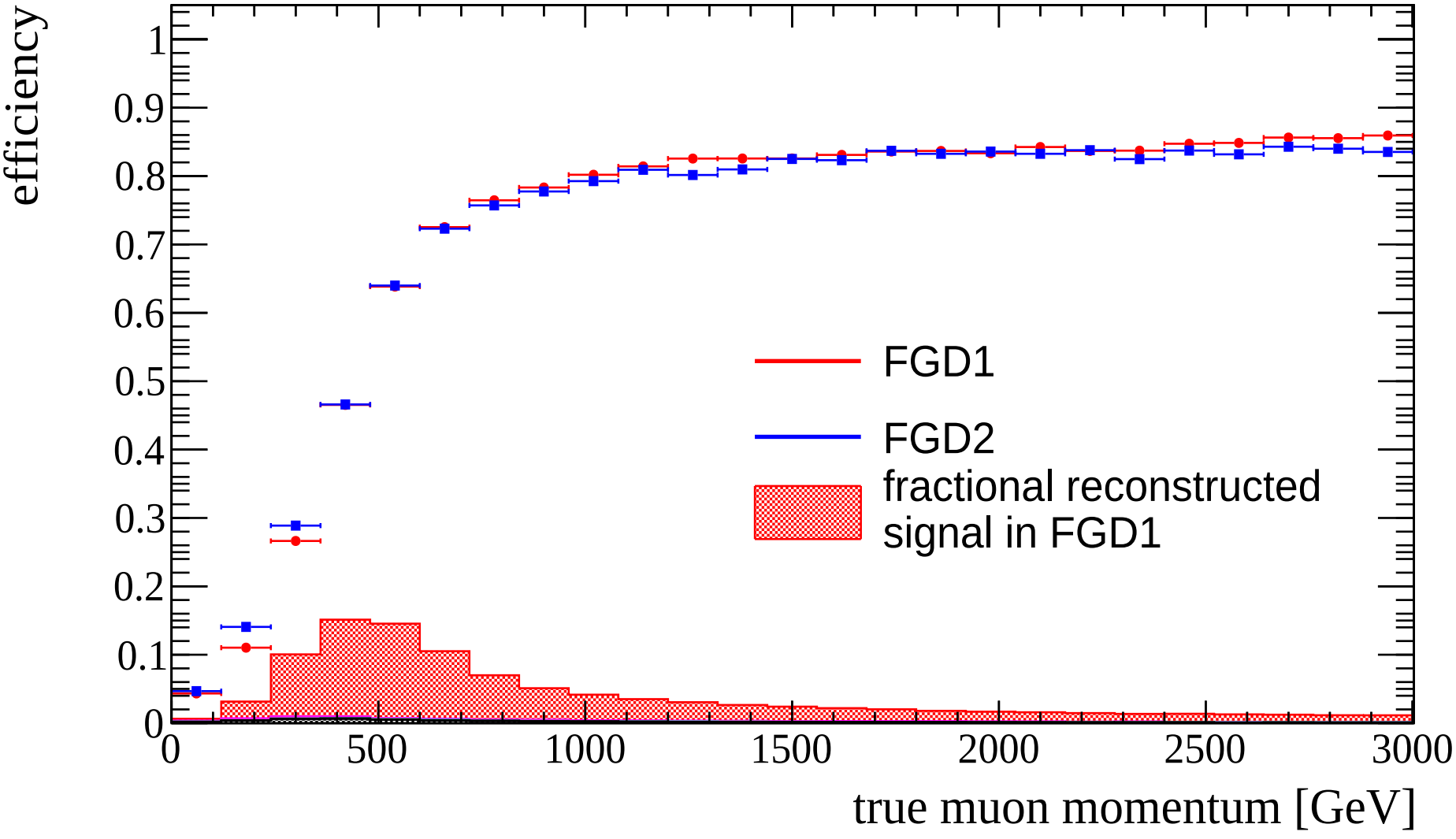
Efficiency in $\cos\theta_\mu$

- phase space cut: true muon $\cos\theta_\mu > 0.5$



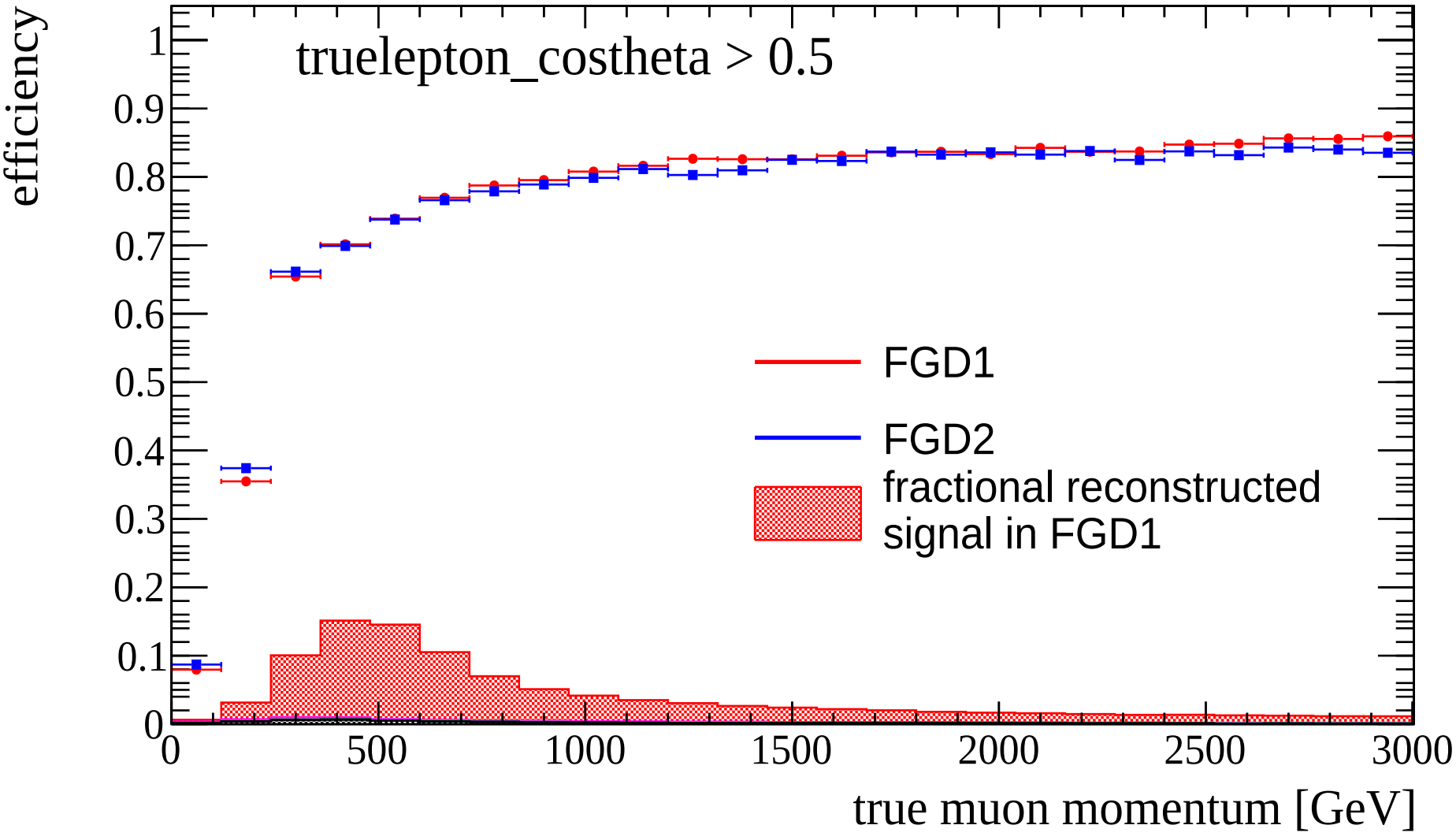
Efficiency in p_μ

- p_μ efficiency WITHOUT phase space cuts



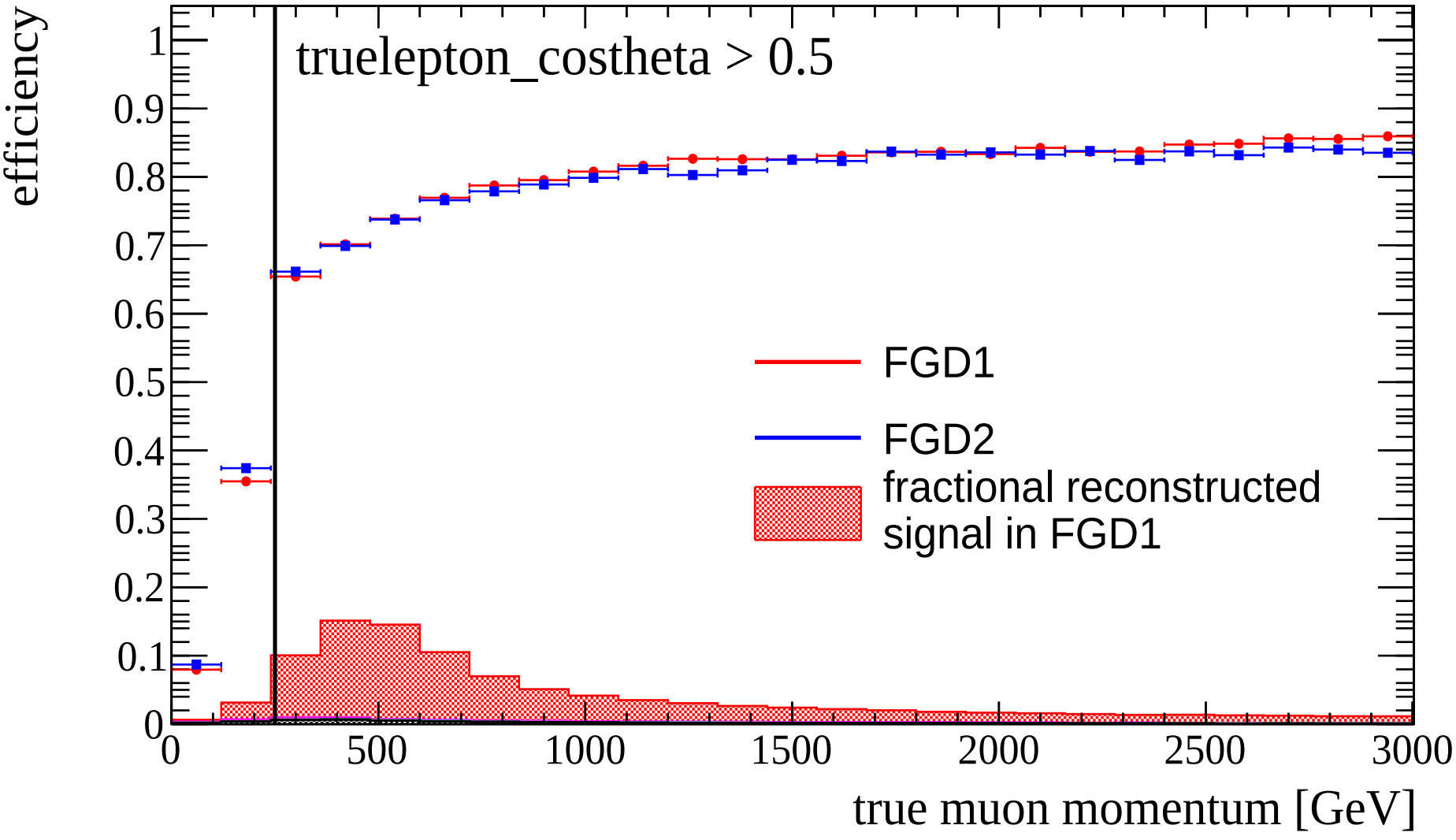
Efficiency in p_μ

- p_μ efficiency WITH phase space cut on true muon $\cos\theta_\mu > 0.5$



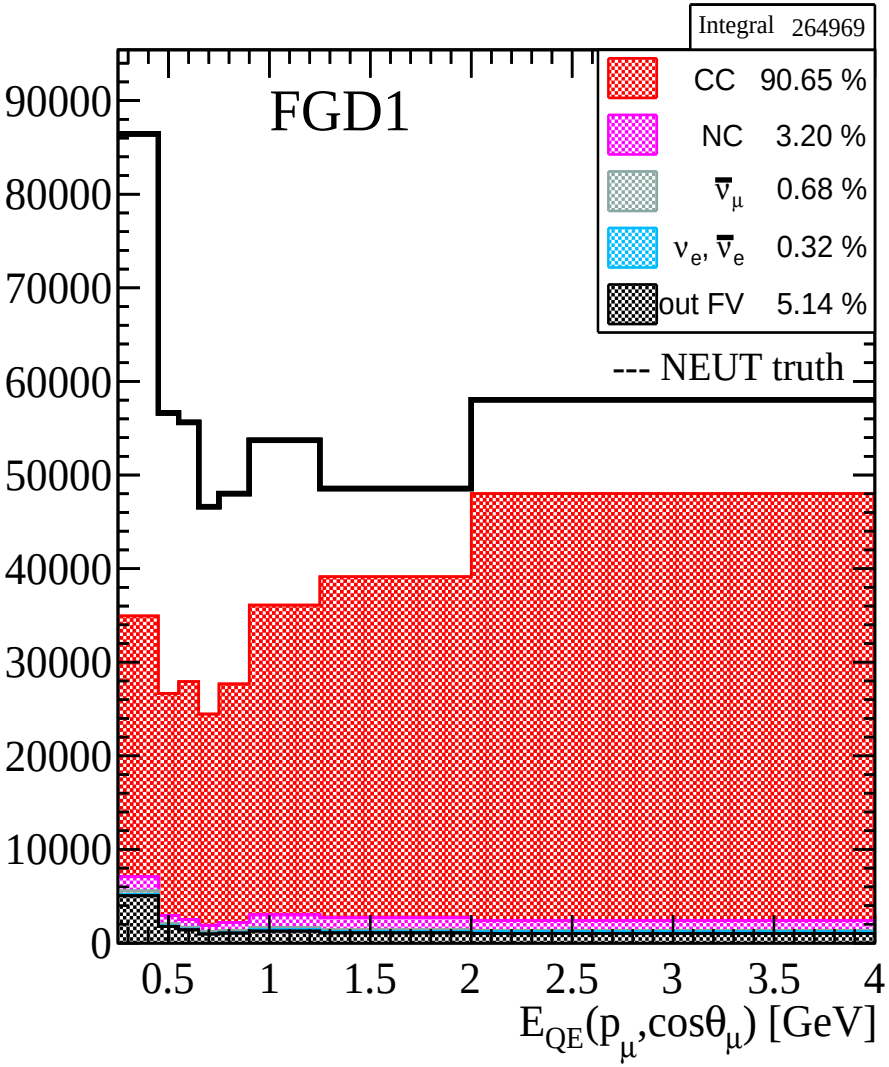
Efficiency in p_μ

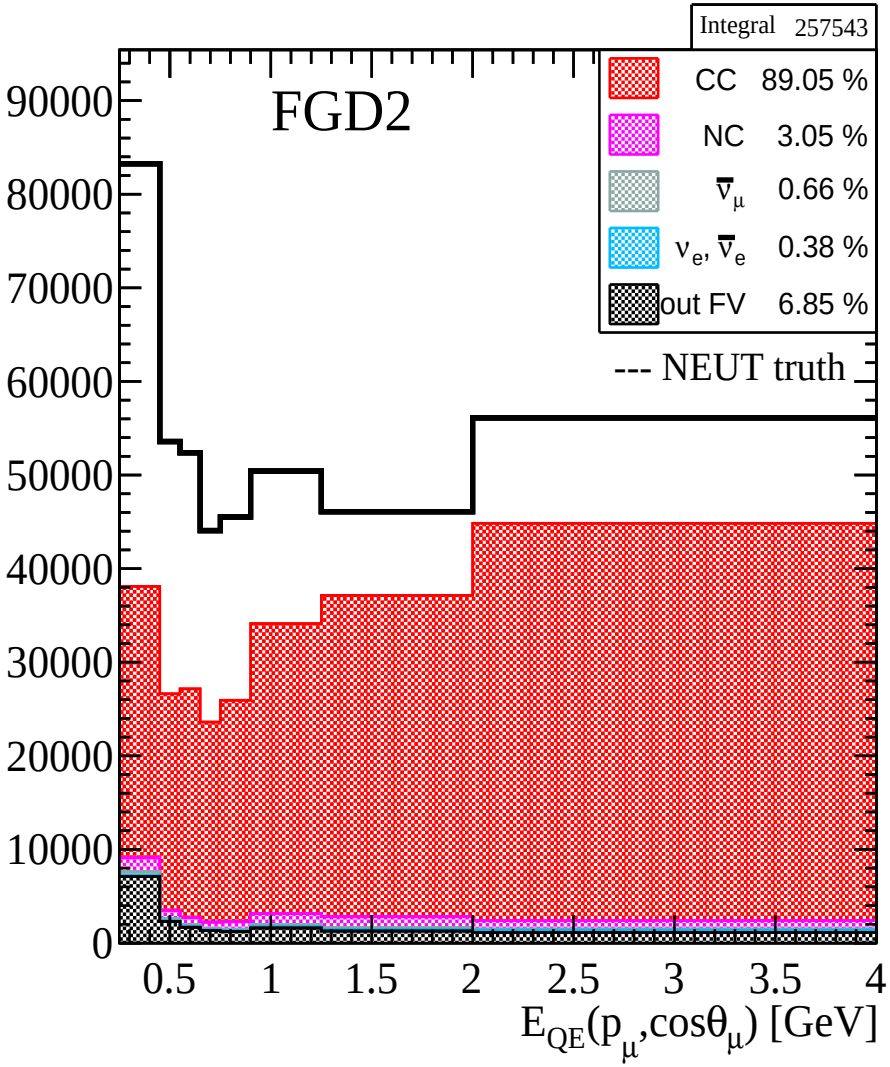
- 2nd phase space cut: true momentum $p_\mu > 250 MeV$



$E_{QE}(p_\mu, \cos\theta_\mu)$ spectra

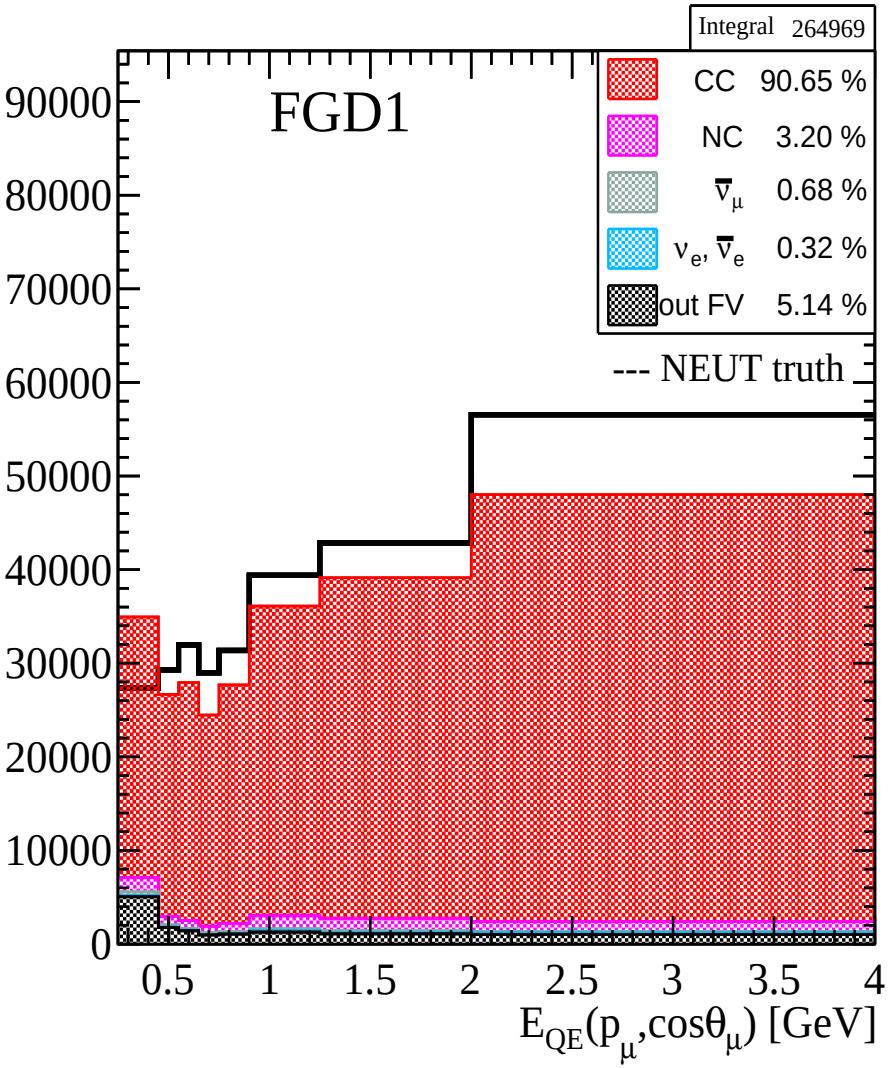
- WITHOUT phase space cuts

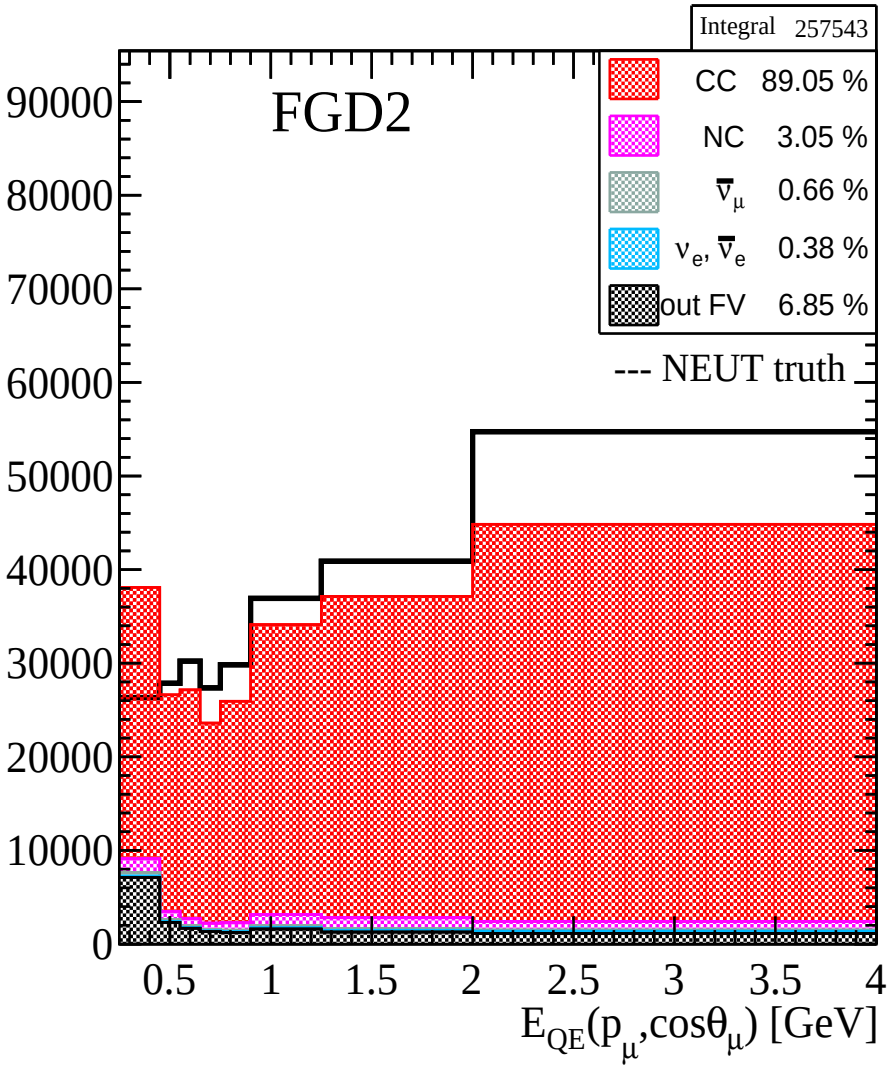




$E_{QE}(p_\mu, \cos\theta_\mu)$ spectra

- WITH phase space cuts: true $\cos\theta_\mu > 0.5$ && true momentum $p_\mu > 250 MeV$

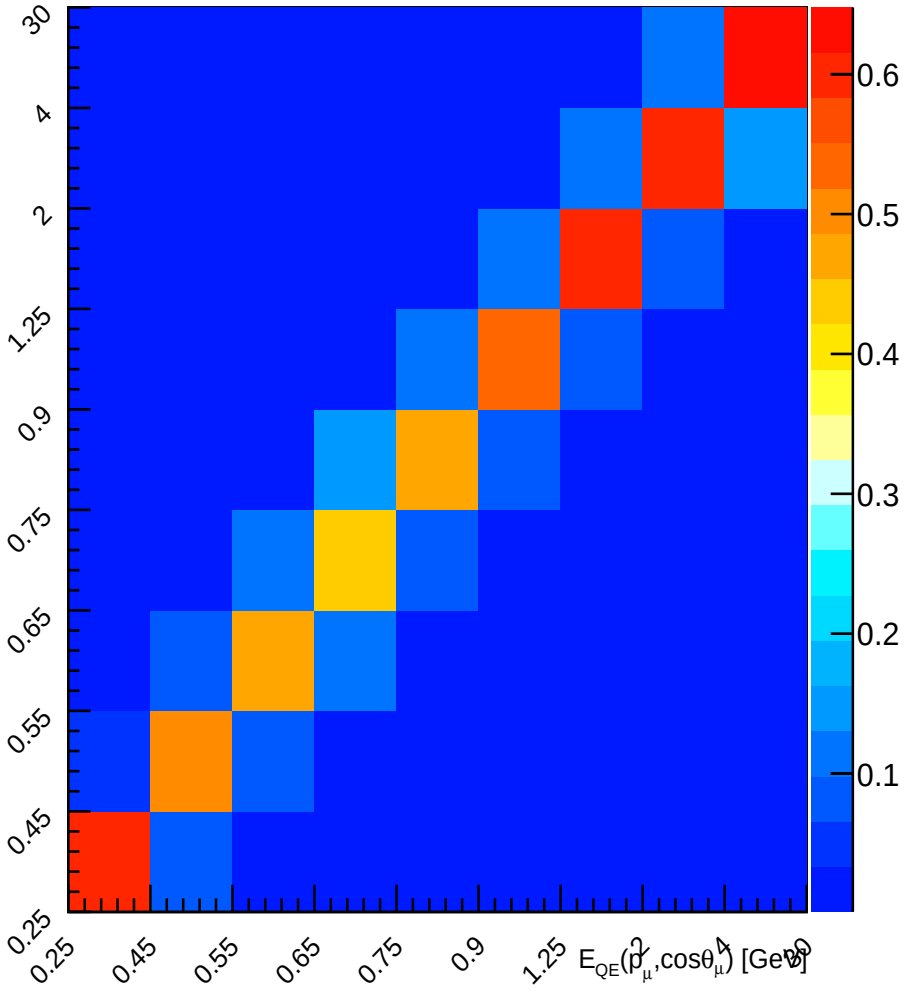




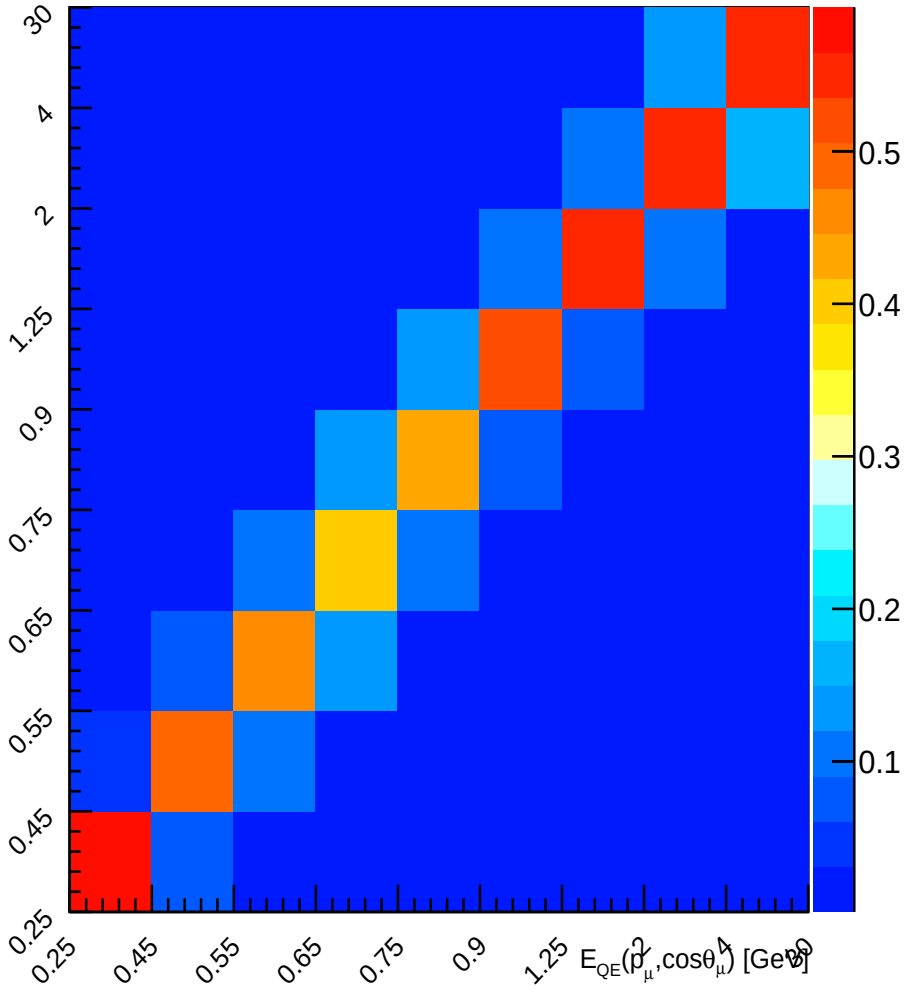
Smearing matrices

- Quite diagonal!

Smearing matrix FGD1



Smearing matrix FGD2



Samples and software

- Full Prod 6B NEUT MC sample
- Fake data: full Prod 6B GENIE MC sample scaled to 5.82 POT (run II-III-IV)
- nd280Highland2 v2r7
- xsTool v2r4, trying several unfolding method, subtracting the background before unfolding
- xsTool/T2KReWeight v2015p1r5 with NIWG parameters for OA 2015
- 500 toys for detector and model systematics, 2000 for statistics mc and data

Signal definitions

- Selection: current psyche FGD1 and FGD2 ν_μCC inclusive selections
  - select FGD+TPC muon candidates

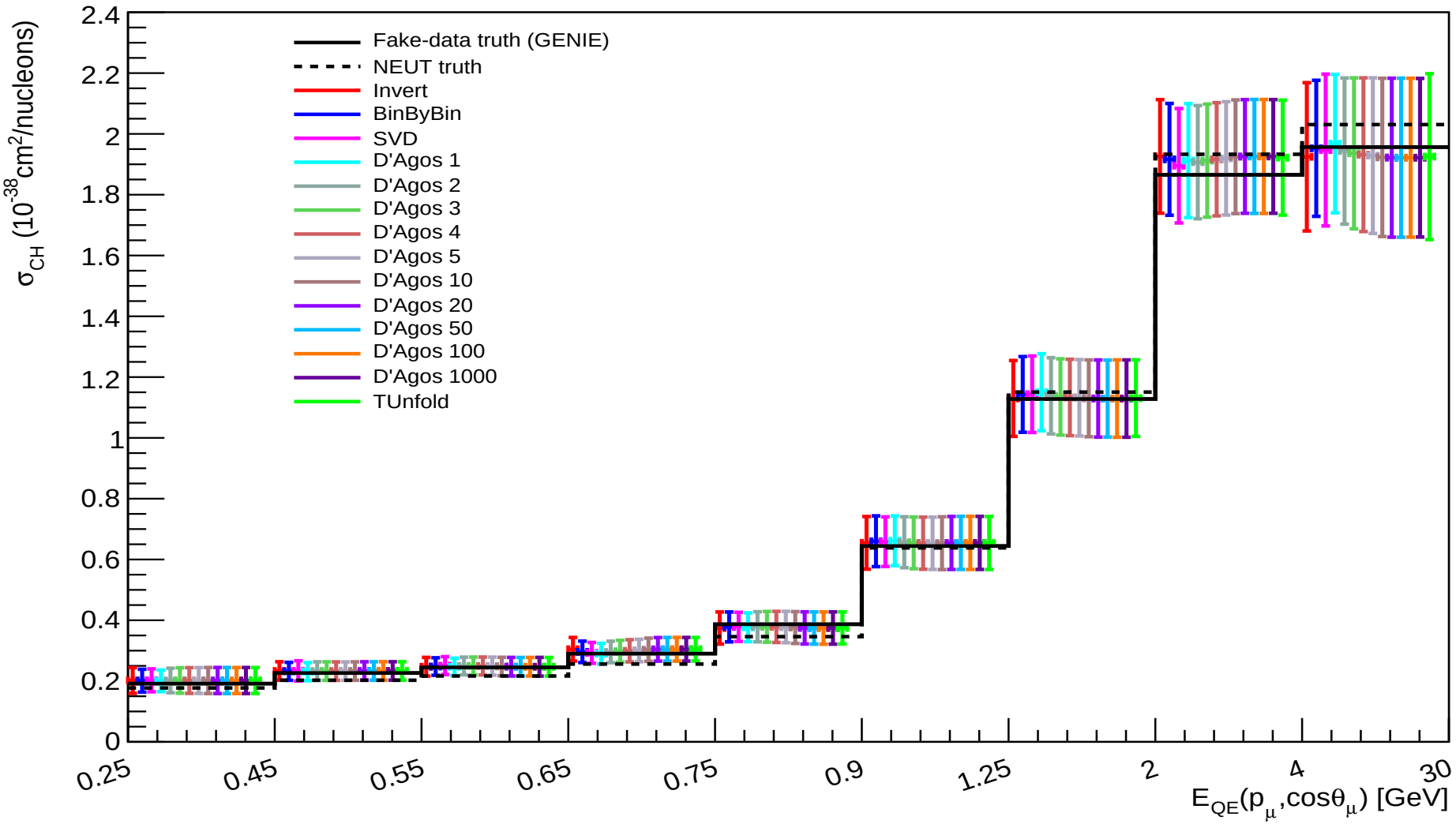
- Signal: ν_μCC inclusive NEUT interactions
  && true muon $\cos\theta > 0.5$
  && true muon momentum > 0.25 GeV

- Unfolding (several method) in bins of $E_{QE}(p_\mu, \cos\theta_\mu)$. Binning [GeV]:

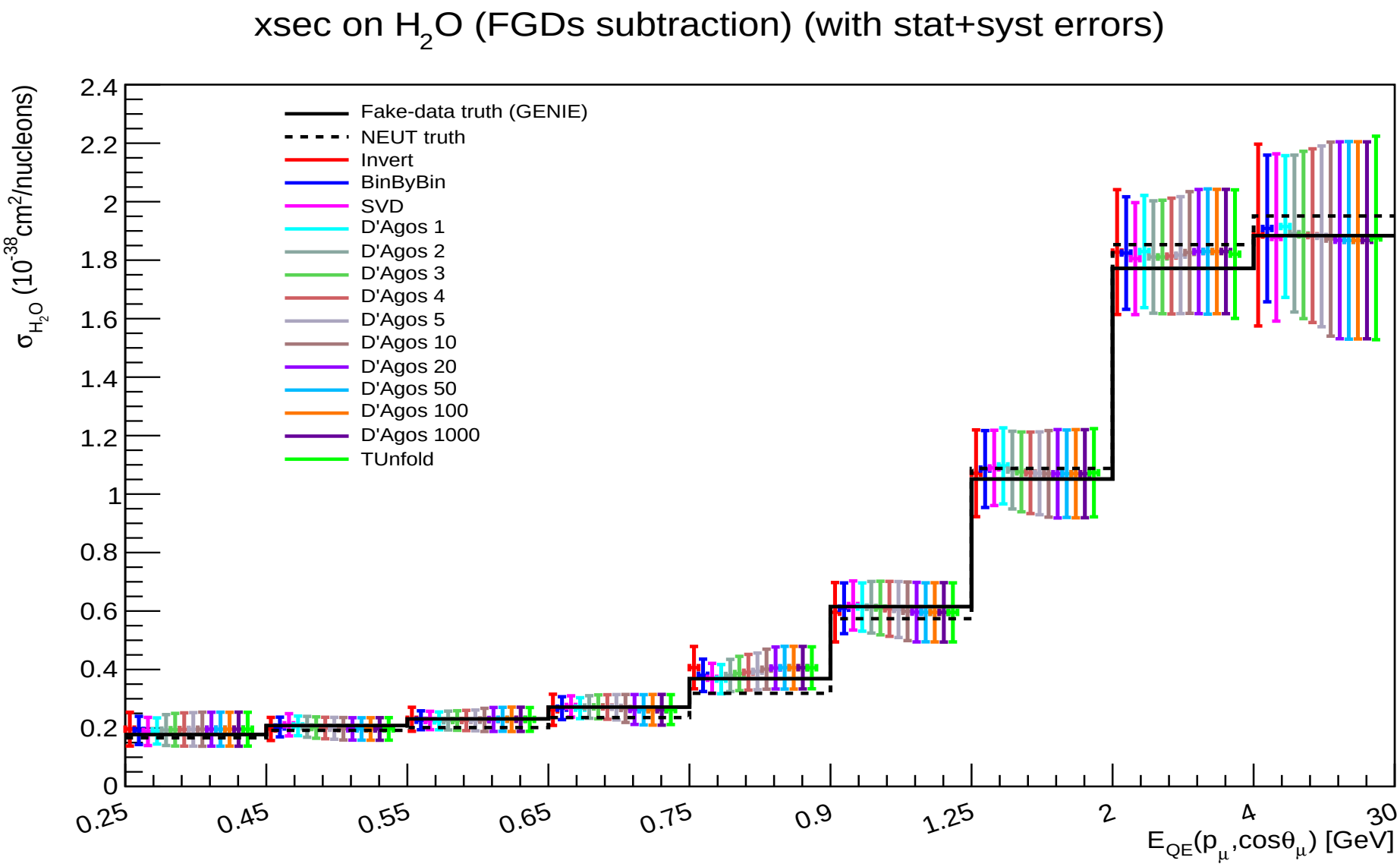
  0.25 - 0.45 - 0.55 - 0.65 - 0.75 - 0.9 - 1.25 - 2.0 - 4.0 - 30.0

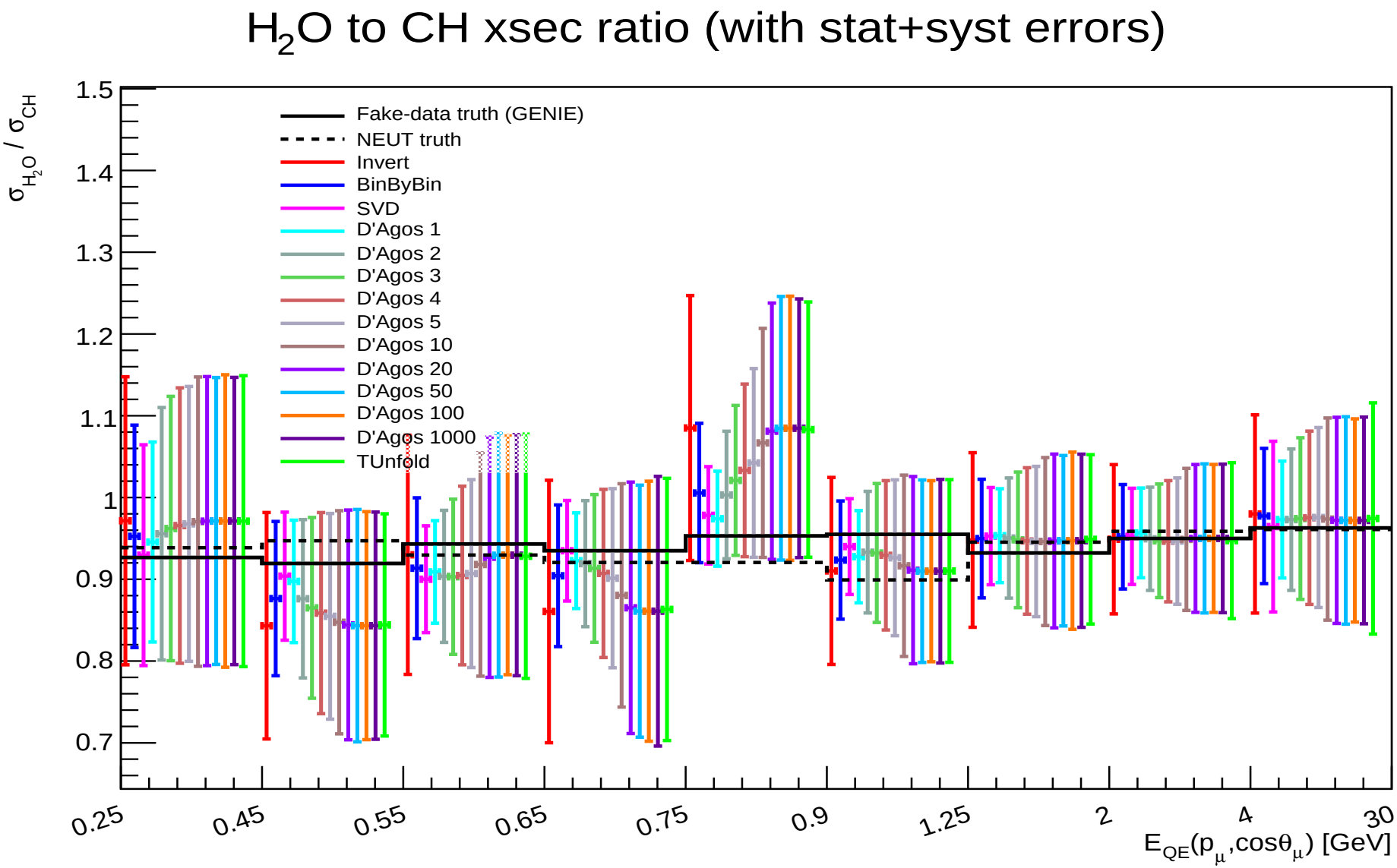
- Normalization:
  - flux folded (divided by the average of the flux in each bin)
  - cross-sections per nucleon (number of targets: p+n)

xsec on CH (in FGD1) (with stat+syst errors)

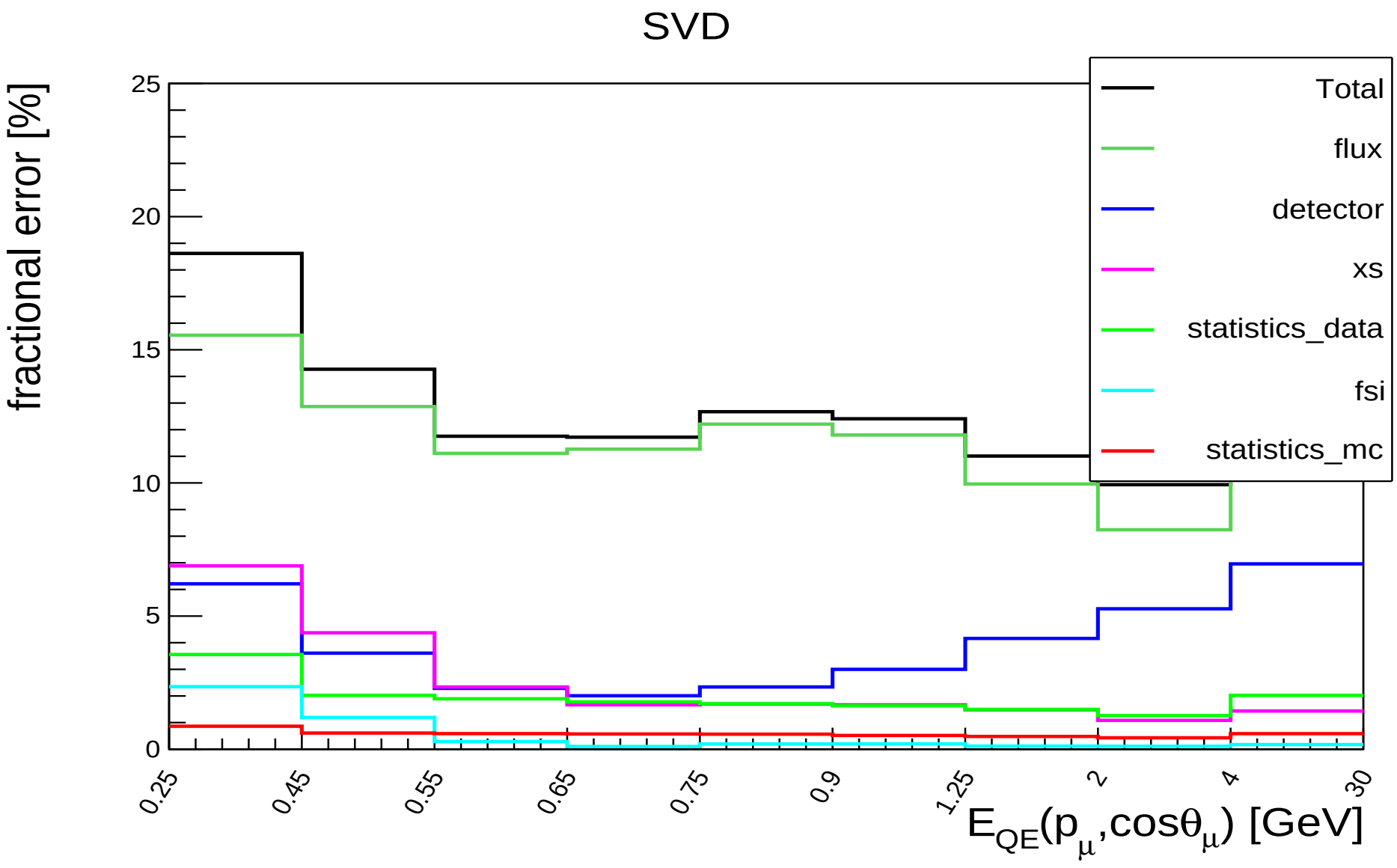


σ_{H_2O}

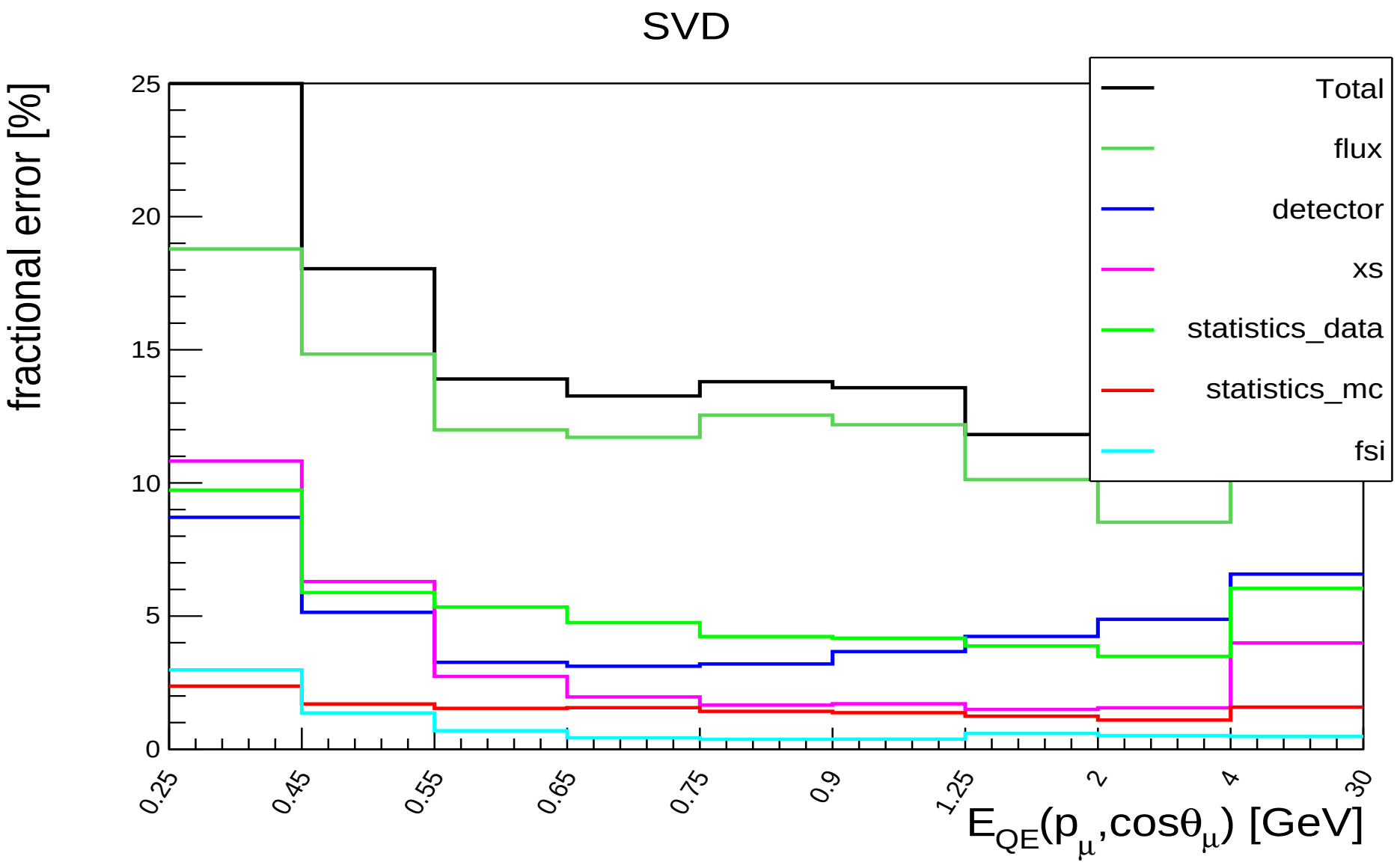

xsec on H2O (FGDs subtraction) (with stat+syst errors)
σH2O (10-38cm2/nucleons)
Fake-data truth (GENIE)
NEUT truth
Invert
BinByBin
SVD
D'Agos 1
D'Agos 2
D'Agos 3
D'Agos 4
D'Agos 5
D'Agos 10
D'Agos 20
D'Agos 50
D'Agos 100
D'Agos 1000
TUnfold
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
0.25
0.45
0.55
0.65
0.75
0.9
1.25
2
4
30
EQE(pμ,cosθμ) [GeV]


H2O to CH xsec ratio (with stat+syst errors)
σH2O / σCH
Fake-data truth (GENIE)
NEUT truth
Invert
BinByBin
SVD
D'Agos 1
D'Agos 2
D'Agos 3
D'Agos 4
D'Agos 5
D'Agos 10
D'Agos 20
D'Agos 50
D'Agos 100
D'Agos 1000
TUnfold
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.25
0.45
0.55
0.65
0.75
0.9
1.25
2
4
30
EQE(pμ,cosθμ) [GeV]

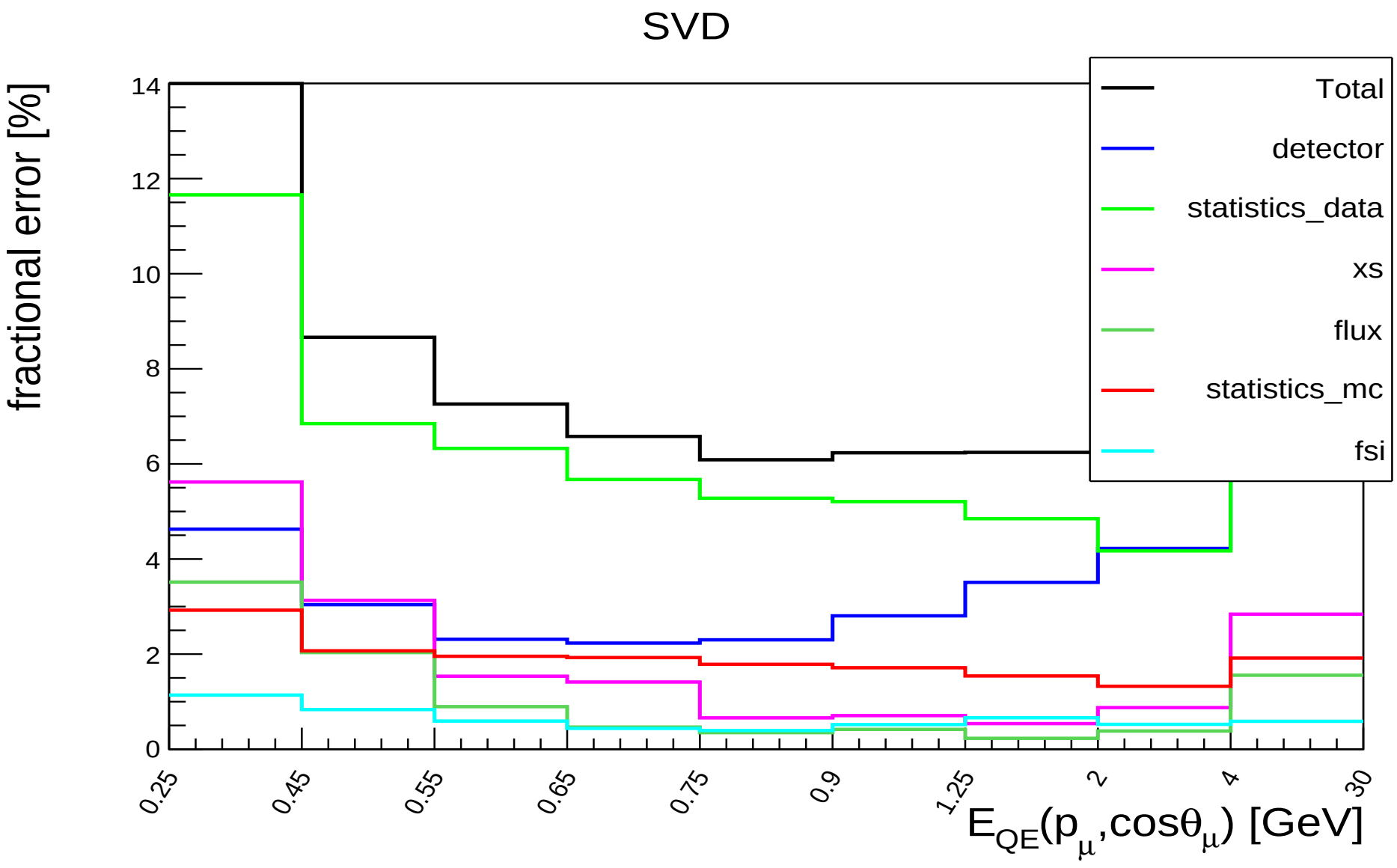
errors on σ_{CH}

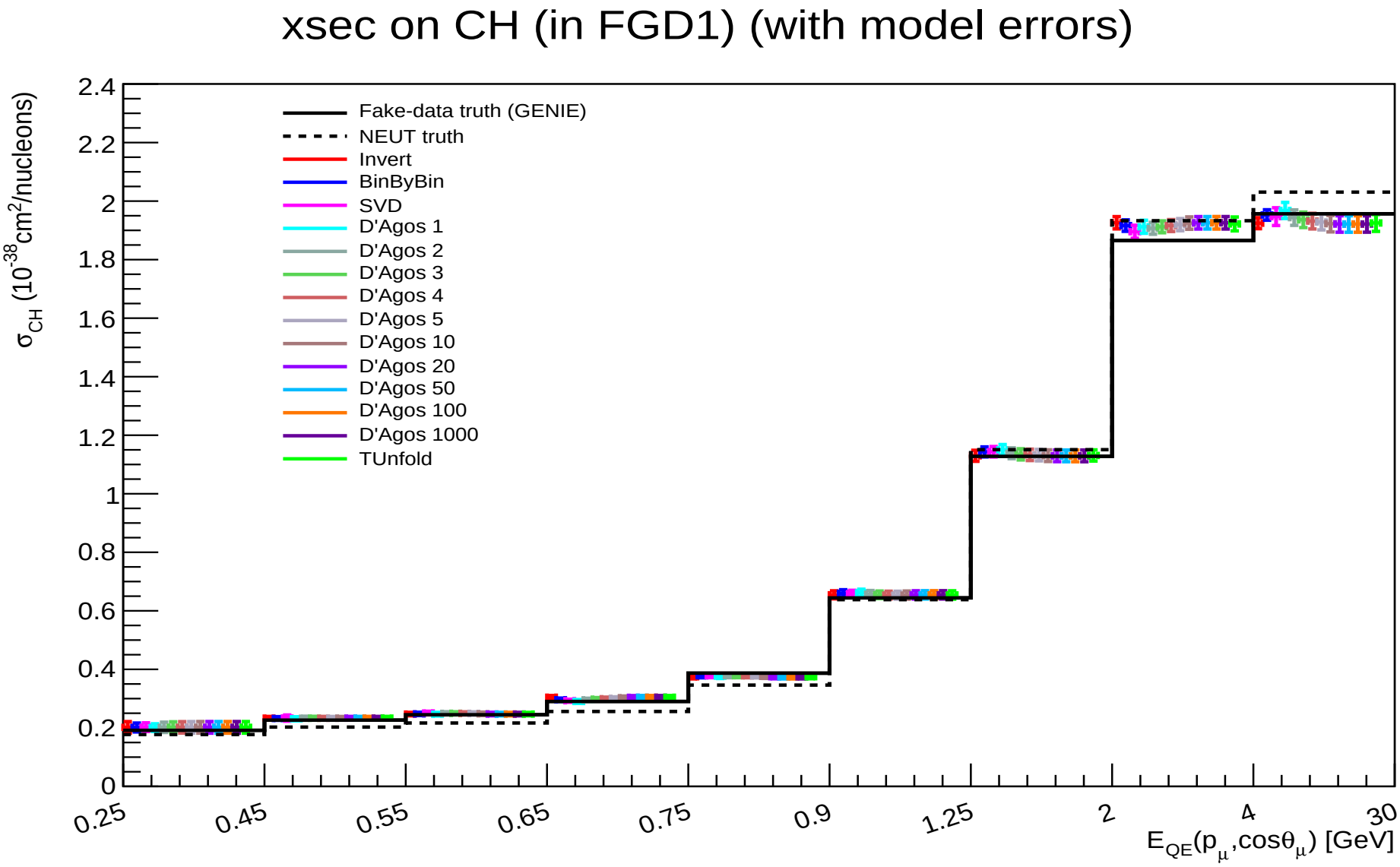


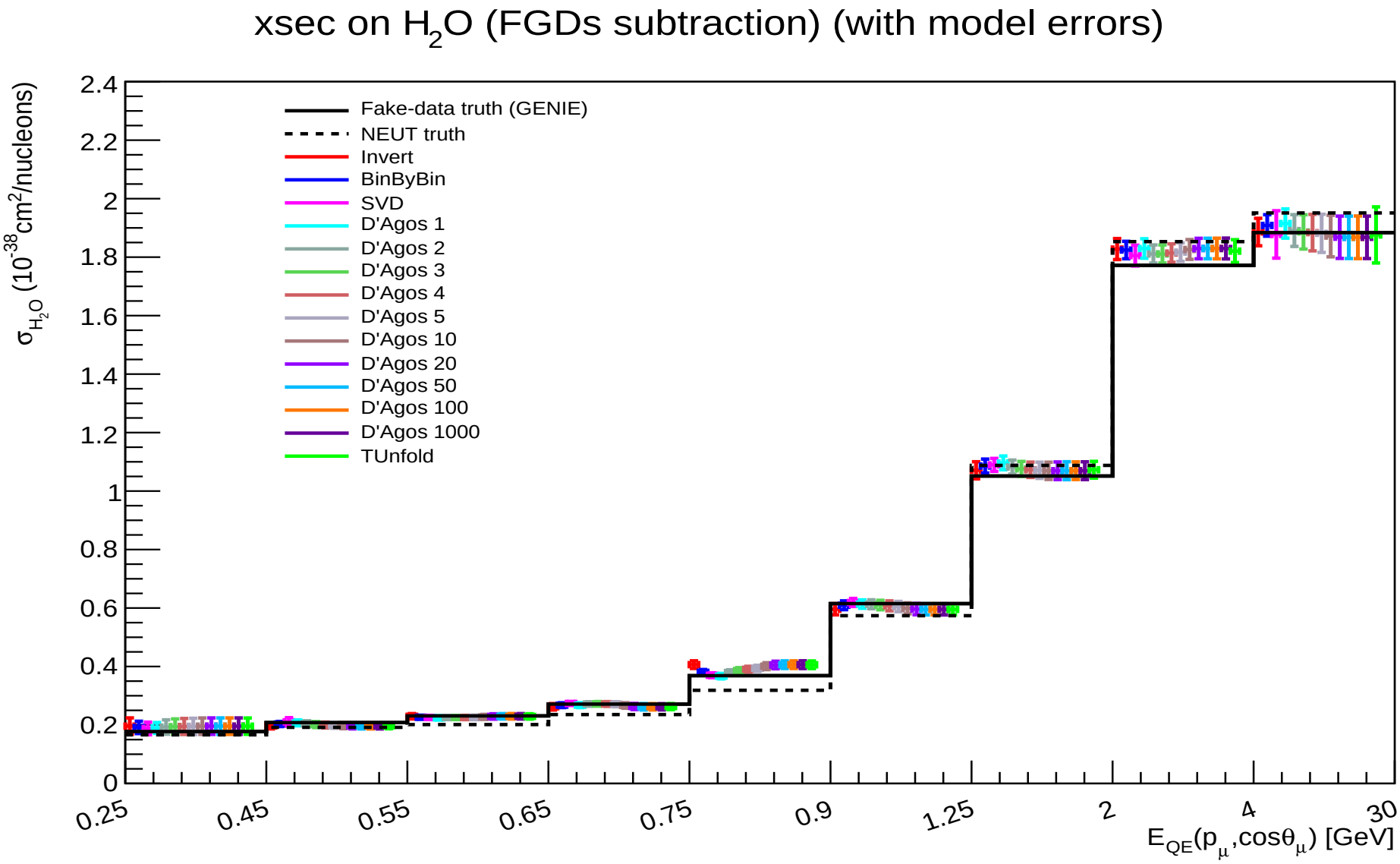
errors on σ_{H_2O}

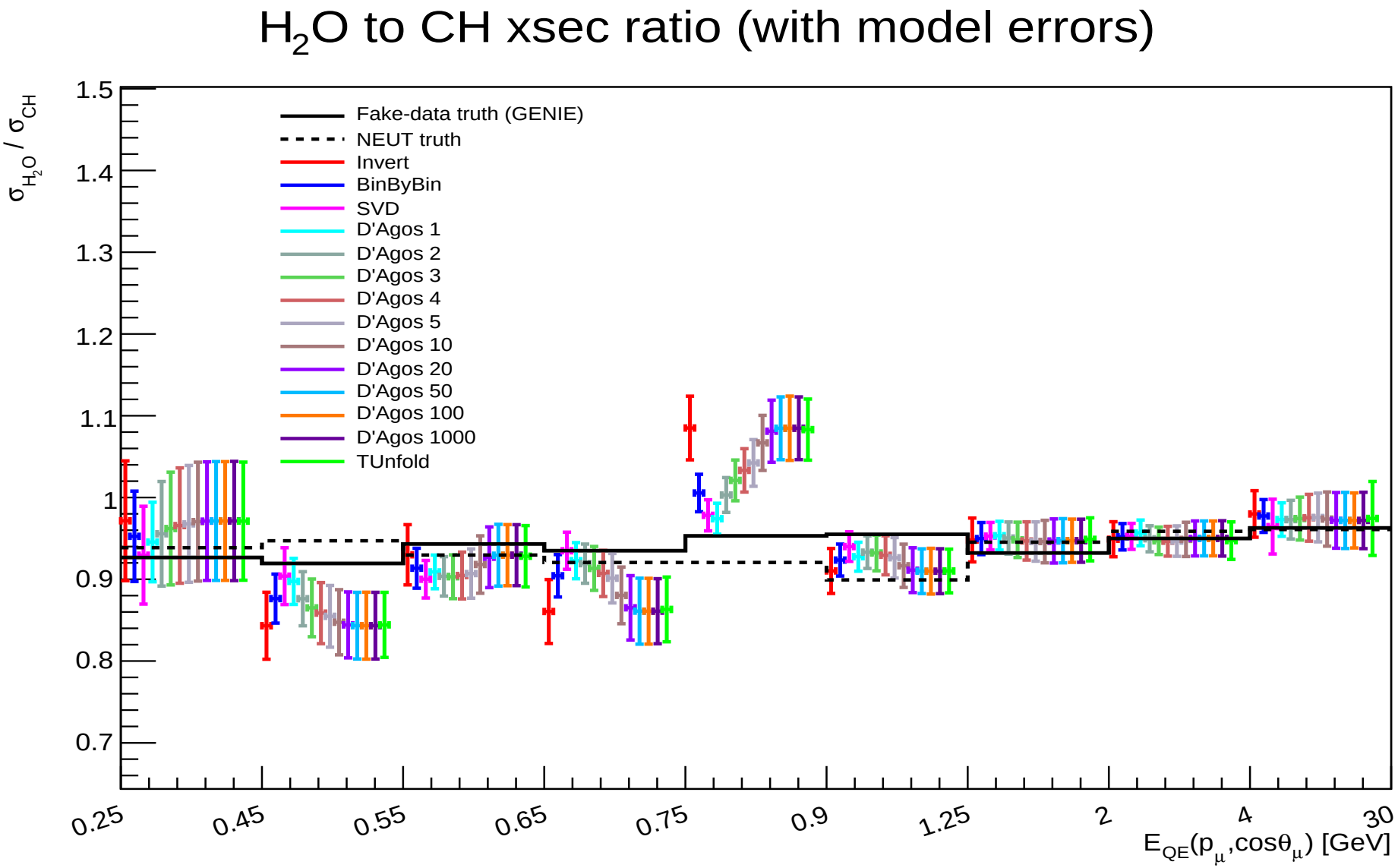


errors on $\sigma_{H_2O}/\sigma_{CH}$



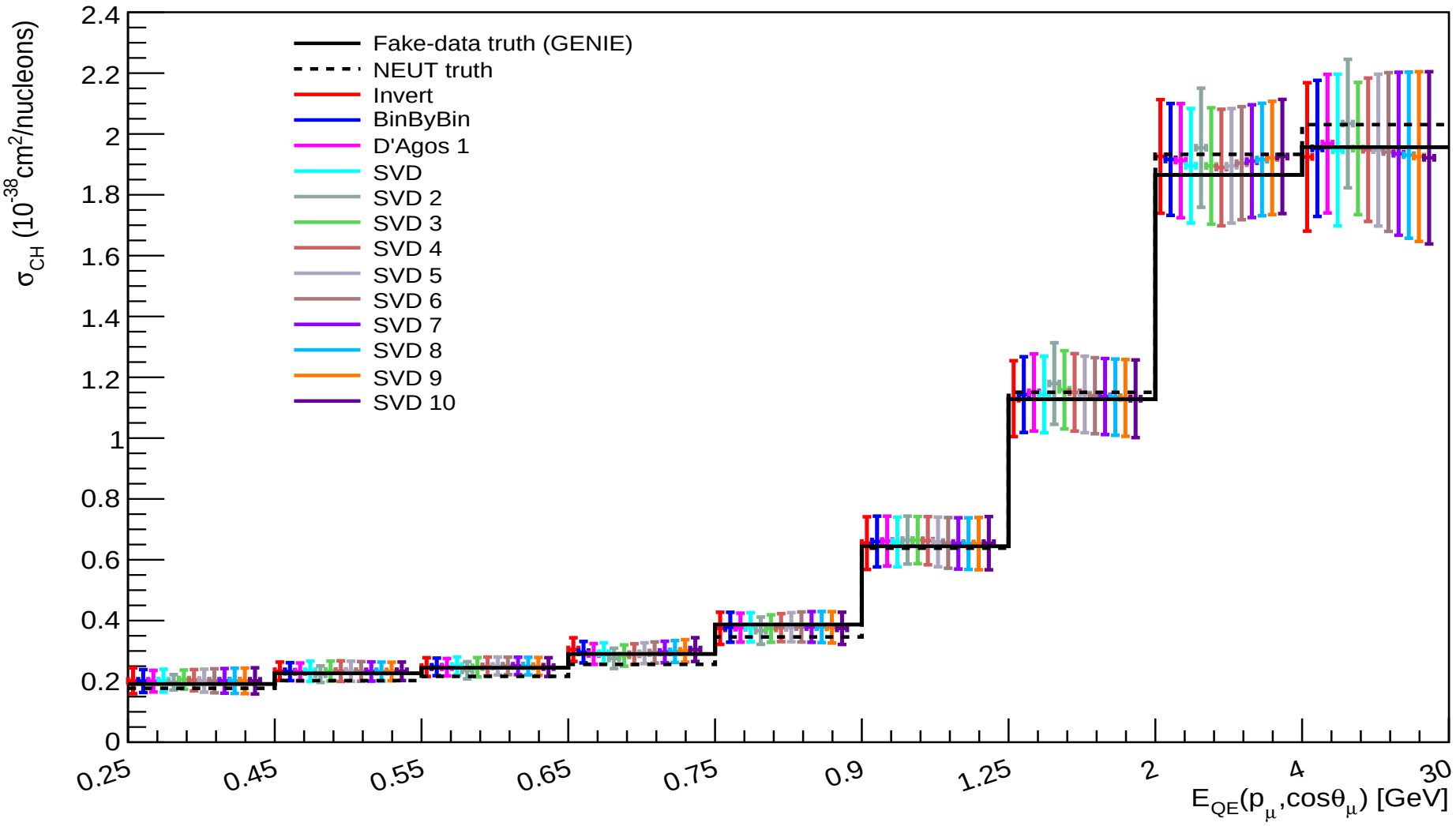

xsec on CH (in FGD1) (with model errors)
Fake-data truth (GENIE)
NEUT truth
Invert
BinByBin
SVD
D'Agos 1
D'Agos 2
D'Agos 3
D'Agos 4
D'Agos 5
D'Agos 10
D'Agos 20
D'Agos 50
D'Agos 100
D'Agos 1000
TUnfold
σ_{CH} (10^{-38}cm^2/nucleons)
$E_{QE}(p_\mu,\cos\theta_\mu)$ [GeV]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
0.25
0.45
0.55
0.65
0.75
0.9
1.25
2
4
30

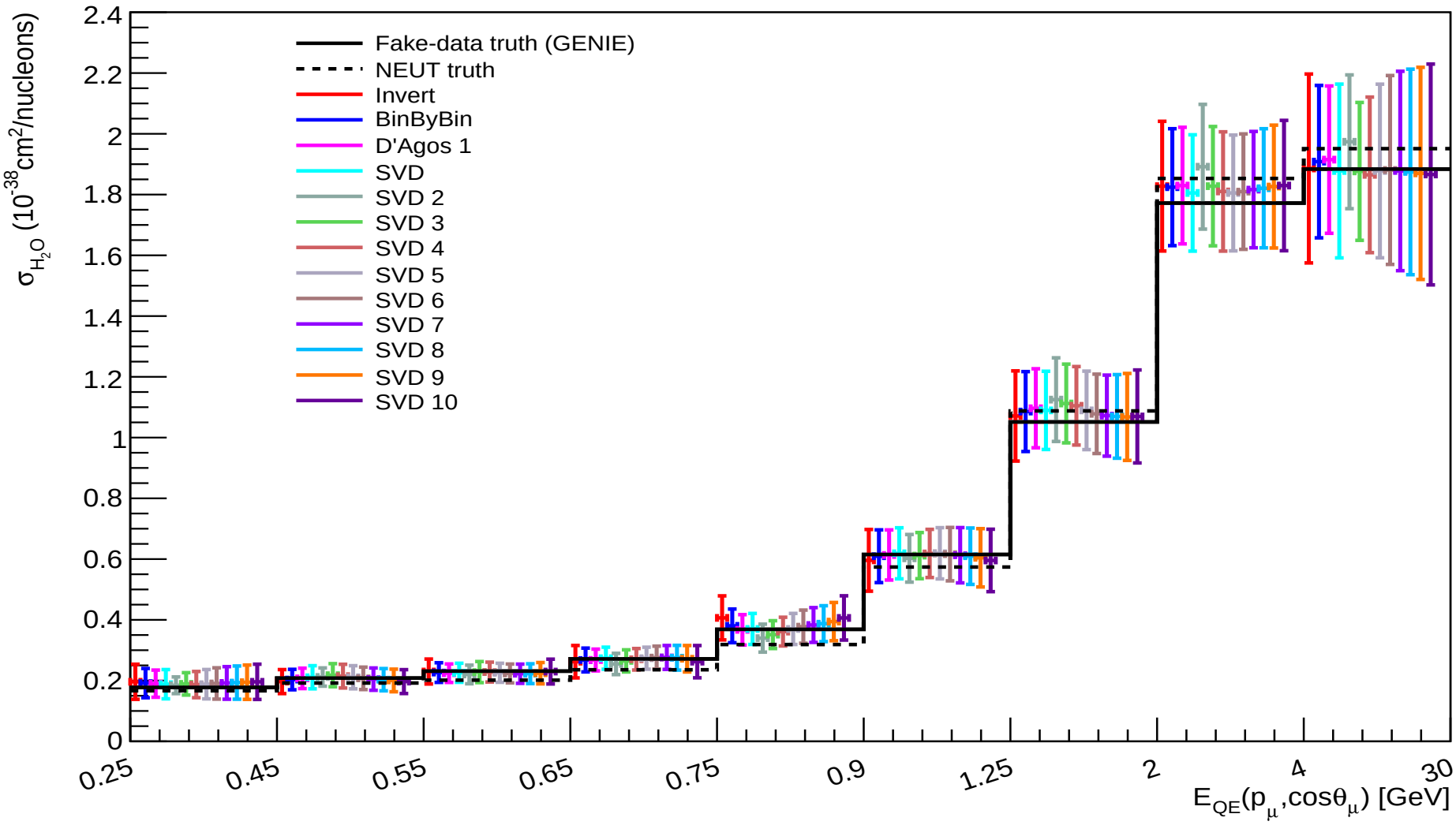

xsec on H_2O (FGDs subtraction) (with model errors)
σ_{H_2O} (10^{-38}cm^2/nucleons)
Fake-data truth (GENIE)
NEUT truth
Invert
BinByBin
SVD
D'Agos 1
D'Agos 2
D'Agos 3
D'Agos 4
D'Agos 5
D'Agos 10
D'Agos 20
D'Agos 50
D'Agos 100
D'Agos 1000
TUnfold
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
0.25
0.45
0.55
0.65
0.75
0.9
1.25
2
4
30
$E_{QE}(p_\mu,\cos\theta_\mu)$ [GeV]

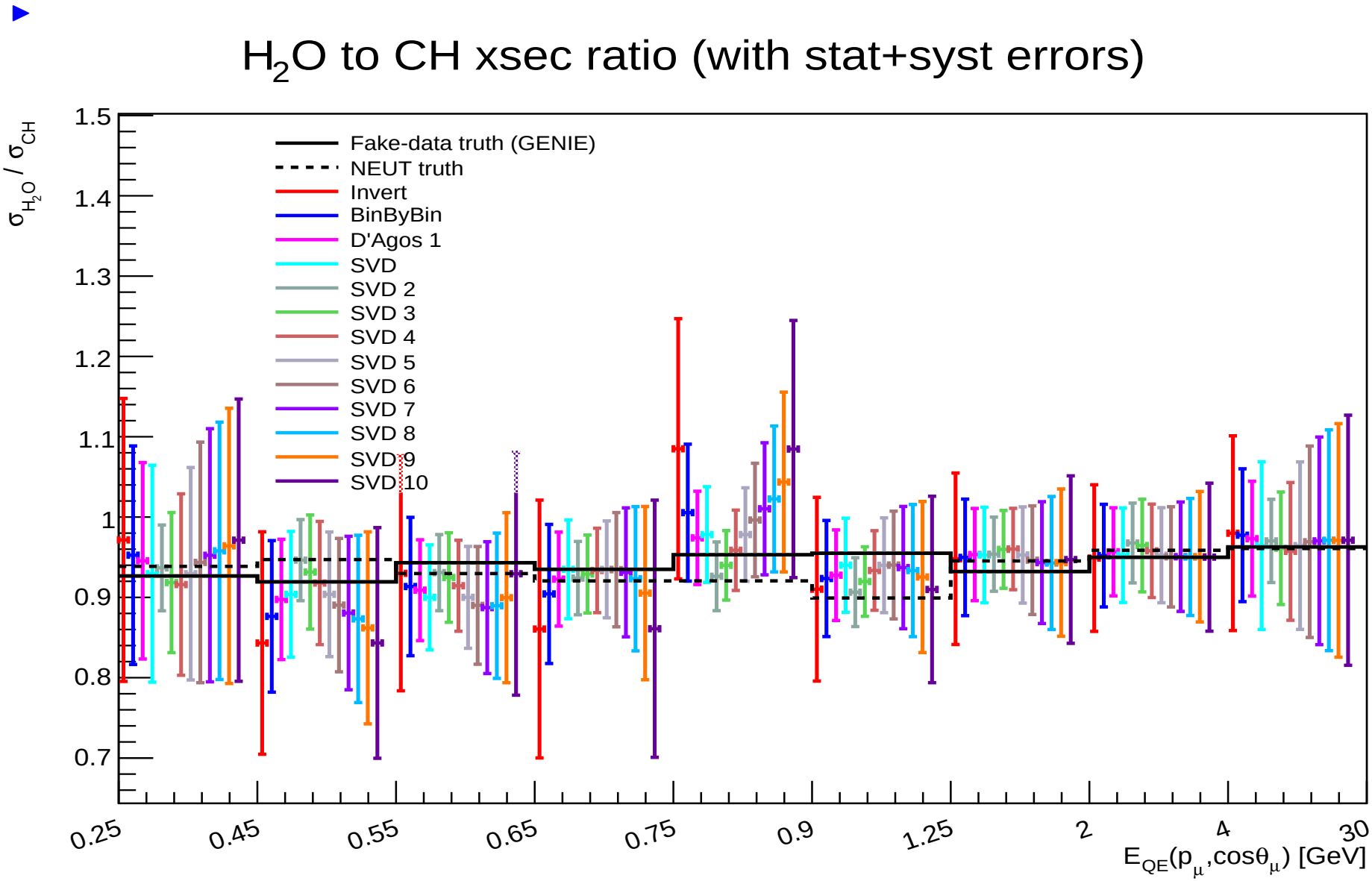

H2O to CH xsec ratio (with model errors)
σH2O / σCH
Fake-data truth (GENIE)
NEUT truth
Invert
BinByBin
SVD
D'Agos 1
D'Agos 2
D'Agos 3
D'Agos 4
D'Agos 5
D'Agos 10
D'Agos 20
D'Agos 50
D'Agos 100
D'Agos 1000
TUnfold
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.25
0.45
0.55
0.65
0.75
0.9
1.25
2
4
30
EQE(pμ,cosθμ) [GeV]

BACKUP

xsec on CH (in FGD1) (with stat+syst errors)




xsec on H_2O (FGDs subtraction) (with stat+syst errors)
σ_{H_2O} (10^{-38}cm^2/nucleons)
Fake-data truth (GENIE)
NEUT truth
Invert
BinByBin
D'Agos 1
SVD
SVD 2
SVD 3
SVD 4
SVD 5
SVD 6
SVD 7
SVD 8
SVD 9
SVD 10
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
0.25
0.45
0.55
0.65
0.75
0.9
1.25
2
4
30
$E_{QE}(p_\mu,\cos\theta_\mu)$ [GeV]


H2O to CH xsec ratio (with stat+syst errors)
σH2O / σCH
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
Fake-data truth (GENIE)
NEUT truth
Invert
BinByBin
D'Agos 1
SVD
SVD 2
SVD 3
SVD 4
SVD 5
SVD 6
SVD 7
SVD 8
SVD 9
SVD 10
0.25
0.45
0.55
0.65
0.75
0.9
1.25
2
4
30
EQE(pμ,cosθμ) [GeV]