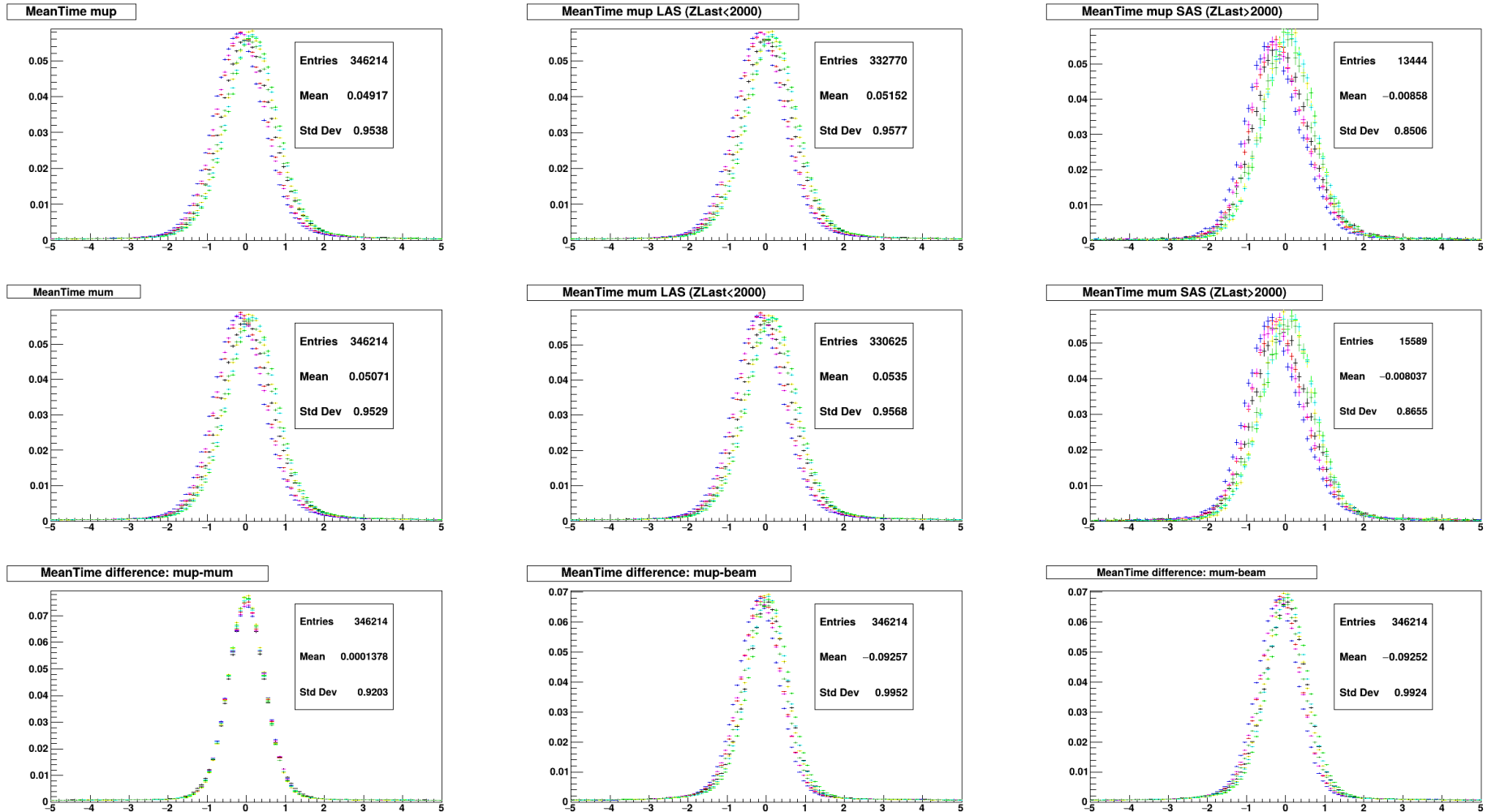


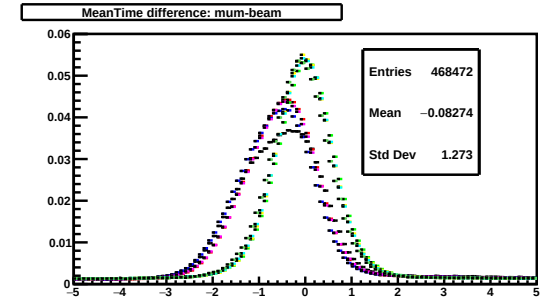
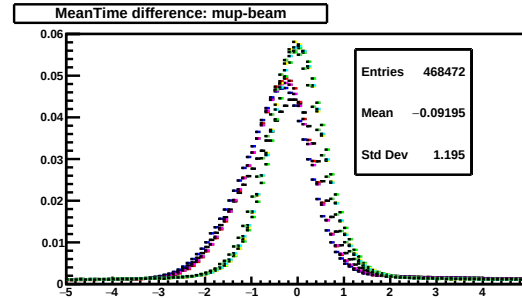
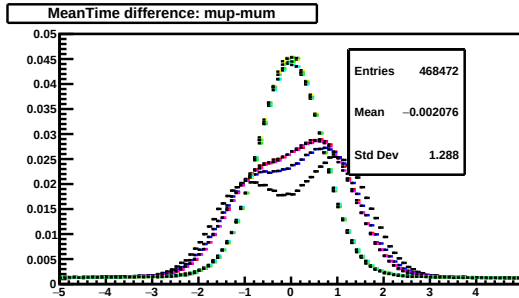
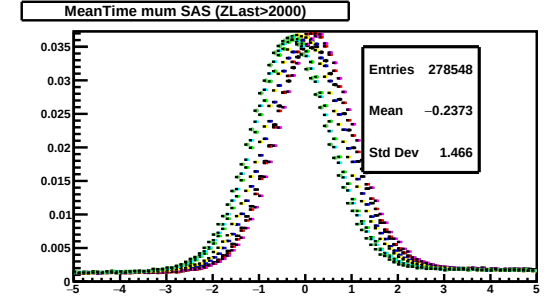
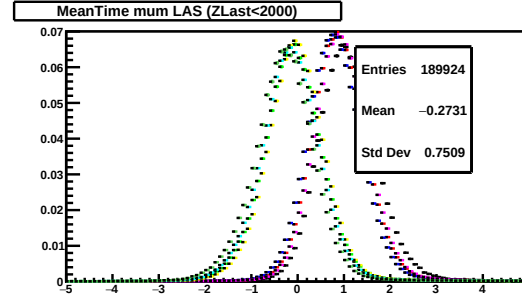
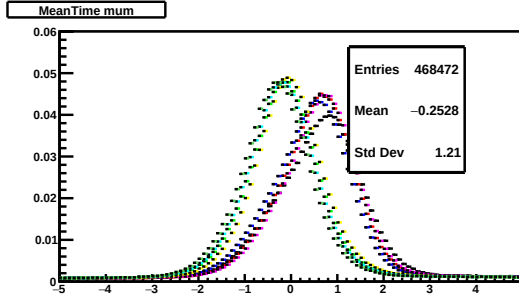
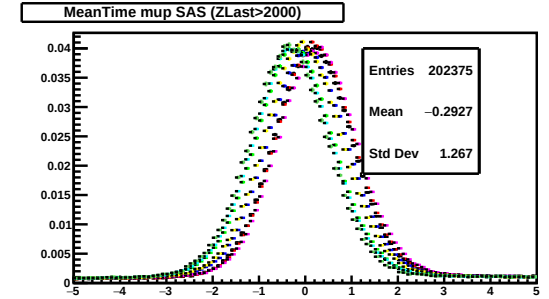
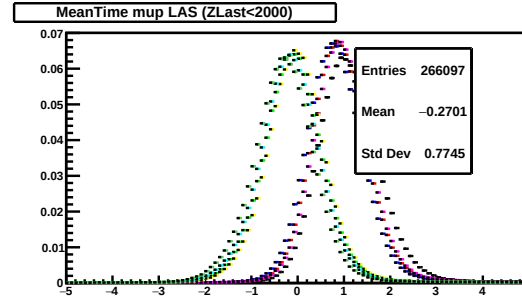
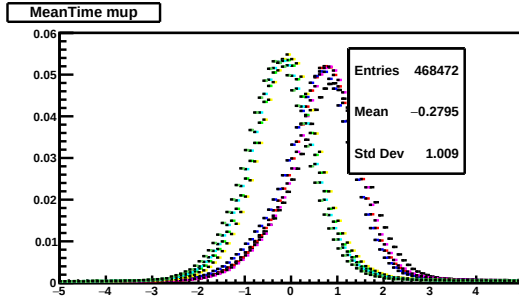
Evidences of differences between periods (RD)

LAS-LAS events $M > 1.5 \text{ GeV}/c^2$



Evidences of differences between periods (RD)

LAS-OT events $M > 1.5 \text{ GeV}/c^2$



In the first 4 periods there is a timing problem affecting the muons (but the window of timing cuts is in principle wide enough to accommodate this: $[-3, 3] \text{ ns}$).

LAS-LAS	P1	P2	P3	P4	P5	P6	P7	P8
PT1: RD fraction that pass time cuts	96%	96%	97%	96%	97%	97%	98%	95%
PT1: MC fraction that pass time cuts	97%	99%	97%	96%	96%	96%	96%	97%
PT1: MC/RD	122	133	148	131	134	123	113	144
W: RD fraction that pass time cuts	96%	96%	96%	96%	95%	96%	95%	95%
W: MC fraction that pass time cuts	97%	99%	97%	96%	97%	96%	96%	96%
W: MC/RD	56	59	66	59	58	60	59	68

MC: HMDY

All other cuts are applied, except time cuts being tested.

$$4.3 < M < 8.5 \text{ GeV}/c^2$$

LAS-OT	P1	P2	P3	P4	P5	P6	P7	P8
PT1: RD fraction that pass time cuts	94%	94%	94%	94%	95%	95%	95%	96%
PT1: MC fraction that pass time cuts	97%	99%	96%	96%	96%	96%	96%	96%
PT1: MC/RD	133	127	143	128	134	127	122	142
W: RD fraction that pass time cuts	92%	94%	93%	92%	94%	95%	94%	95%
W: MC fraction that pass time cuts	97%	99%	96%	96%	96%	96%	96%	96%
W: MC/RD	63	65	70	63	65	64	61	78

Amount of HMDY data in each period: RD versus MC

	P01	P02	P03	P04	P05	P06	P07	P08
MC HMDY PT1 LAS-LAS	9.1%	20.2%	17.2%	14.2%	9.5%	9.1%	14.7%	6.1%
MC HMDY PT1 LAS-OT	9.3%	19.2%	16.5%	13.6%	9.3%	9.6%	15.8%	6.7%
MC HMDY W LAS-LAS	9.1%	19.5%	16.4%	13.5%	8.4%	10.0%	16.3%	6.8%
MC HMDY W LAS-OT	9.0%	18.8%	16.0%	13.2%	8.8%	10.3%	16.8%	7.1%
MC (Vincent slides)	8.4%	19.4%	15.1%	14.2%	9.3%	9.9%	17.0%	6.7%
RD after select PT1 LAS-LAS $4.3 < M < 8.5$	9.7%	19.8%	15.1%	14.1%	9.2%	9.6%	16.9%	5.5%
RD after select PT1 LAS-OT $4.3 < M < 8.5$	9.2%	19.8%	15.1%	13.8%	9.1%	10.0%	16.8%	6.2%
RD after select W LAS-LAS $4.3 < M < 8.5$	9.8%	19.9%	14.9%	13.9%	8.7%	10.0%	16.8%	6.0%
RD after select W LAS-OT $4.3 < M < 8.5$	9.3%	19.0%	14.8%	13.6%	8.8%	10.5%	18.0%	6.0%

When looking at selected good HMDY events, we see a good reproduction of proportions of periods in MC wrt RD (P03 and P07 are a bit worse).

Comparing x-sections: with global acceptance versus period acceptance PT1 LAS-LAS

(only statistical errors are shown)

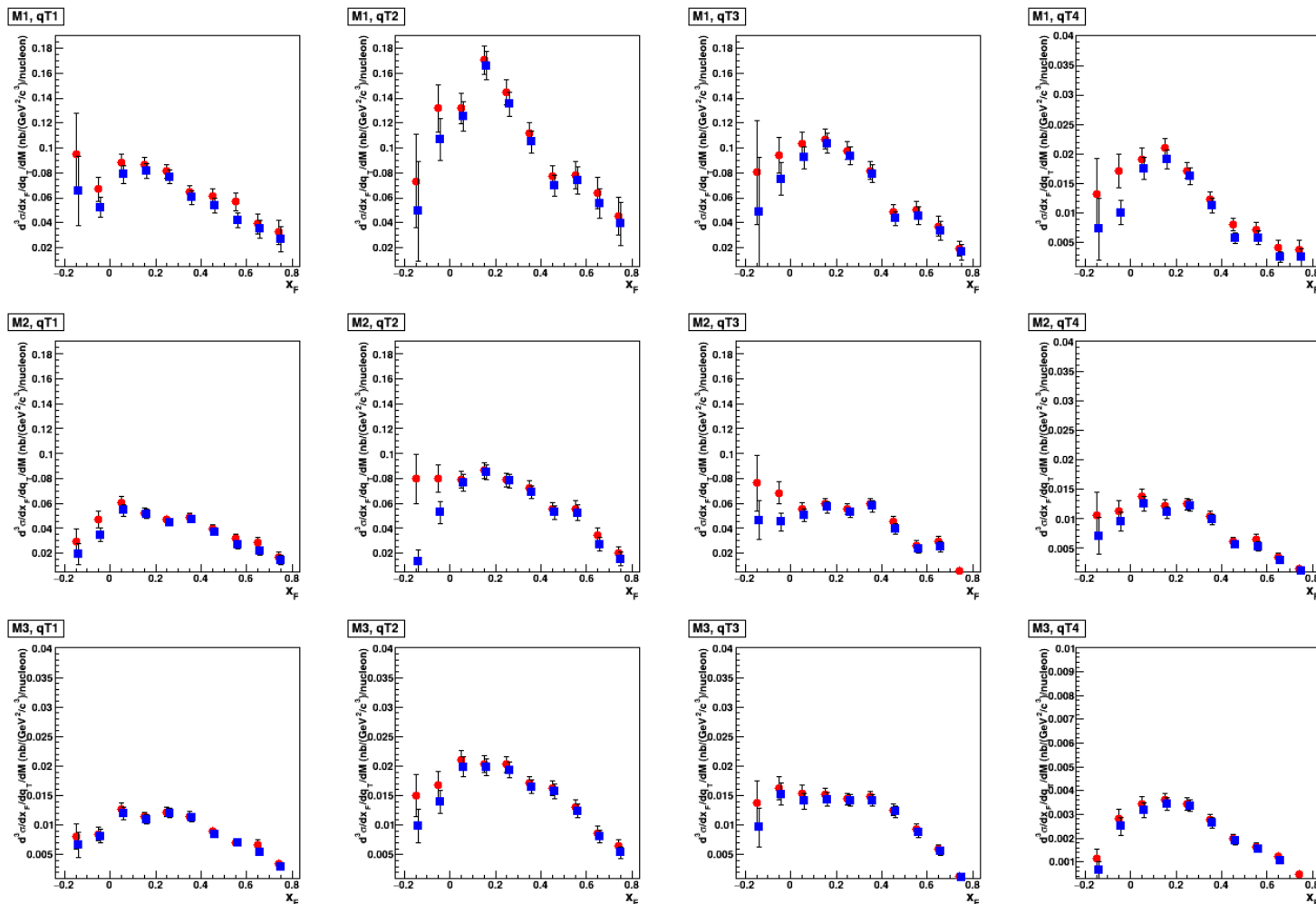
$$\sigma \pm \delta\sigma$$

If using period acceptances, the x-sections tends to be systematically lower. Larger differences are visible at the low x_F .

For the x-section with period acceptance, the weighted-average of x-sections per period is done, using statistical error as weight:

$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$



x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

PT1 LAS-LAS

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using weights by errors, the x-sections tend to be systematically lower. Larger differences are visible at the low xF.

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

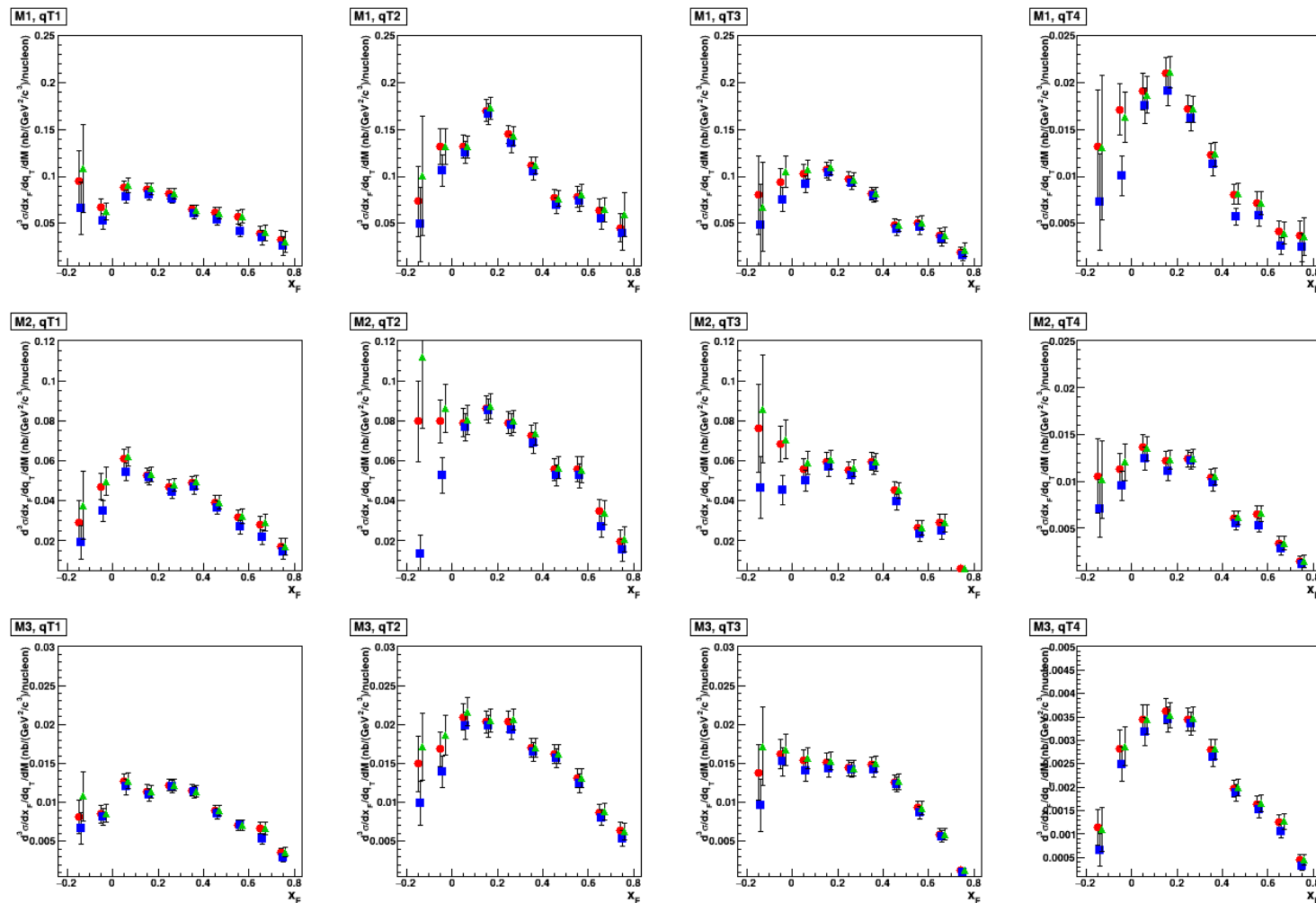
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

PT2 LAS-LAS

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using weight by errors, the x-sections tend to be systematically lower. Larger differences are visible at the low xF.

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

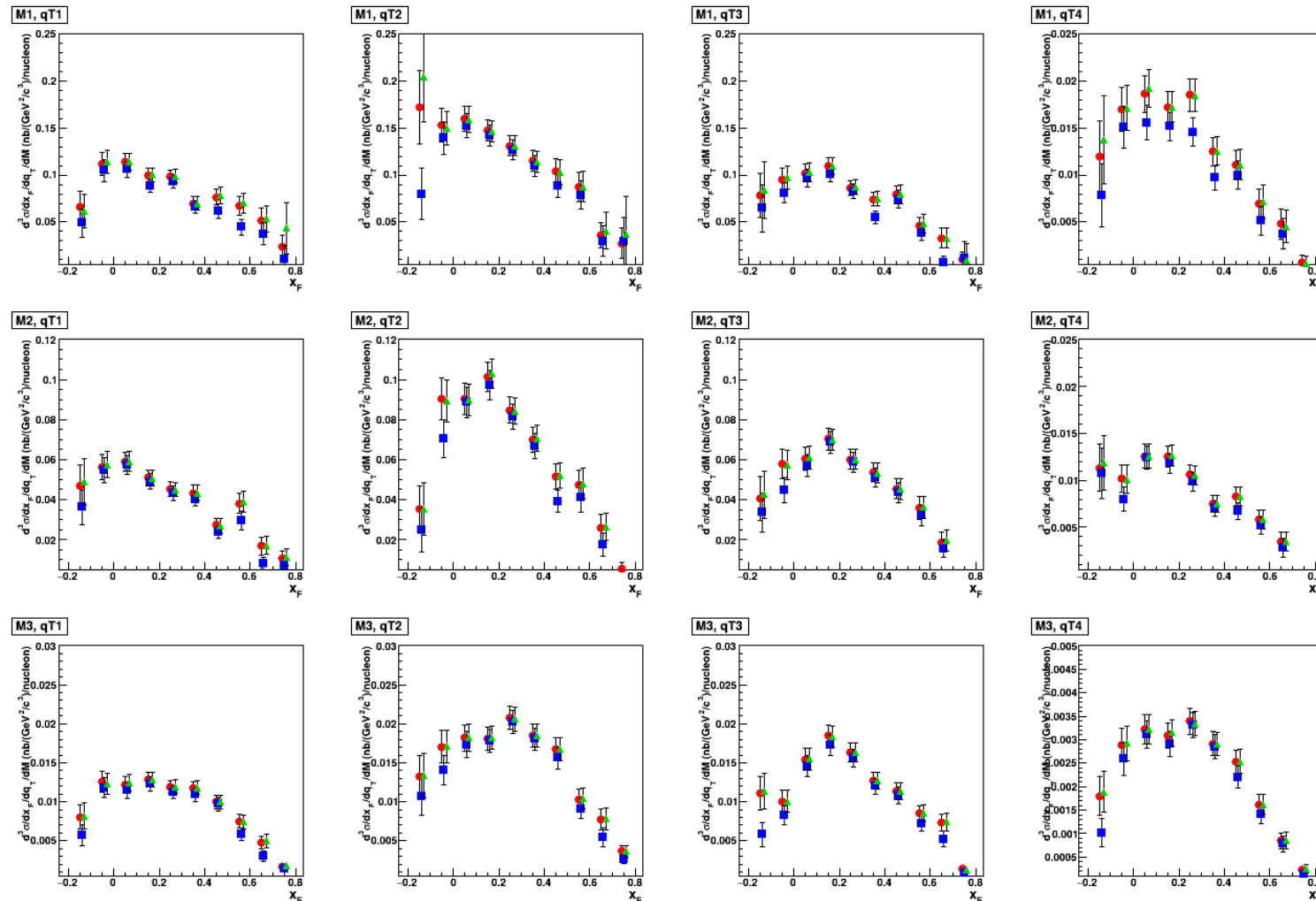
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

AL LAS-LAS

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using period acceptances, the x-sections tends to be systematically lower. Larger differences are visible at the low xF.

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

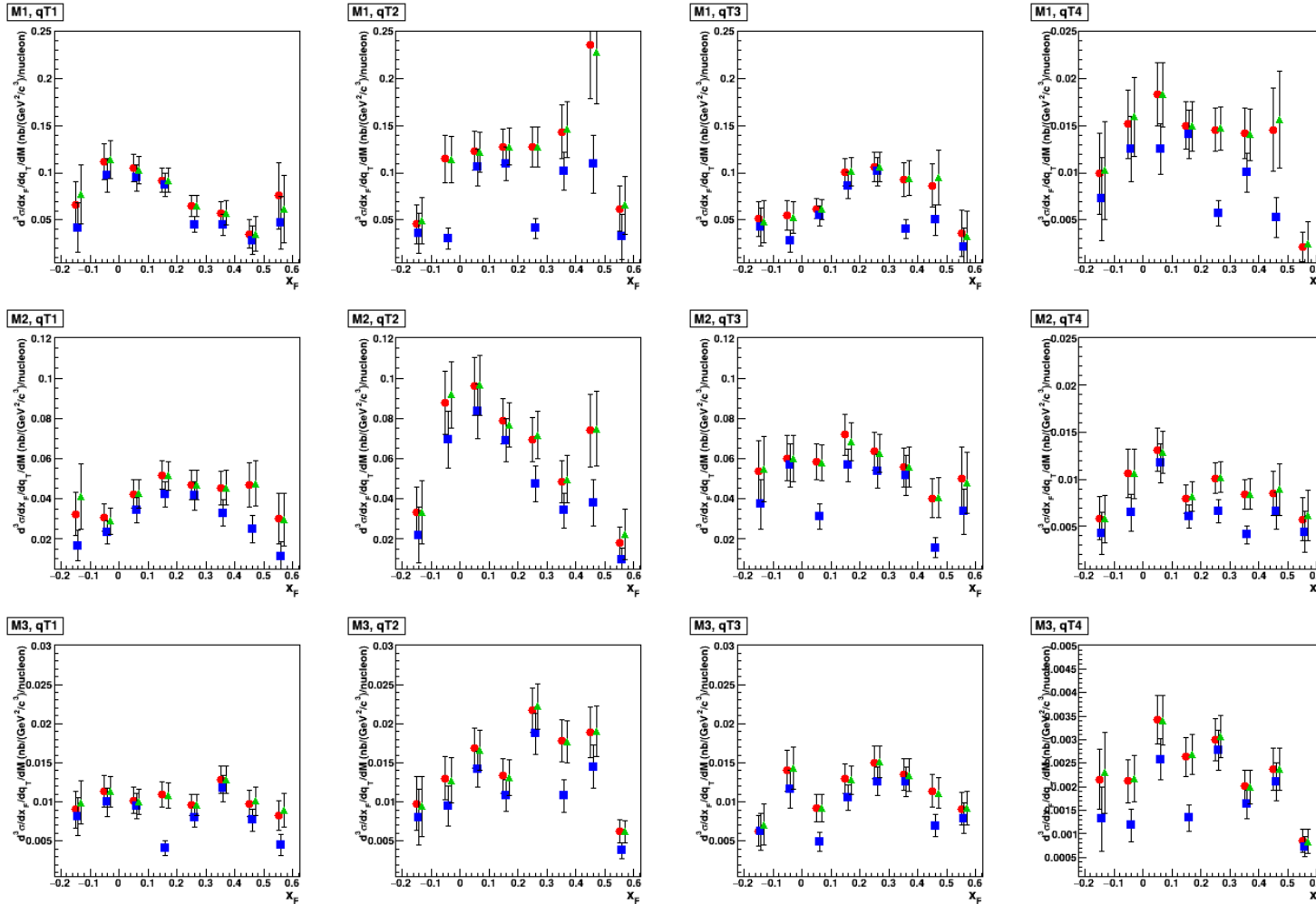
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

W LAS-LAS

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using period acceptances, the x-sections tends to be systematically lower. Larger differences are visible at the low xF.

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

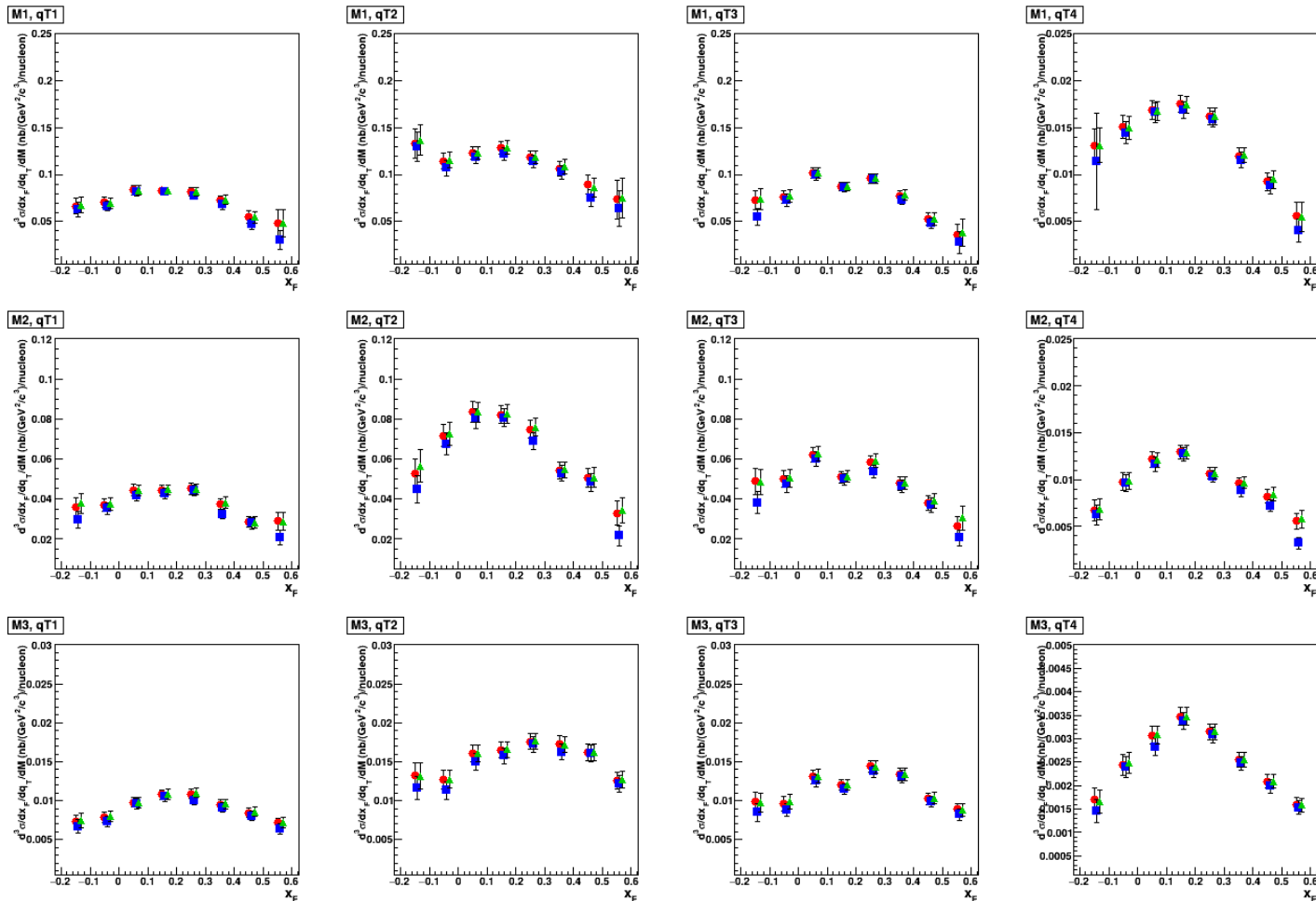
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



When obtaining the DY cross section in 3D bins, separately per trigger and target, and per period, it happens sometimes to have empty bins, because the binning was optimized for the global analysis (all periods together).

Although a bin with zero event counts means zero cross-section, this **does not** mean that the uncertainty is null. To evaluate the approximate error of such bins, I use the proportion between the error of counts: $\text{SQRT}(N)$ in a bin with global measured cross-section, to obtain the error in x-section from the zero count error $= 3 * \text{SQRT}(1)$.

all calculations are in the google sheet at this [link](#)

x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

PT1 LAS-OT

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using period acceptances, The x-sections tends to be systematically lower. Larger differences are visible at the low xF.

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

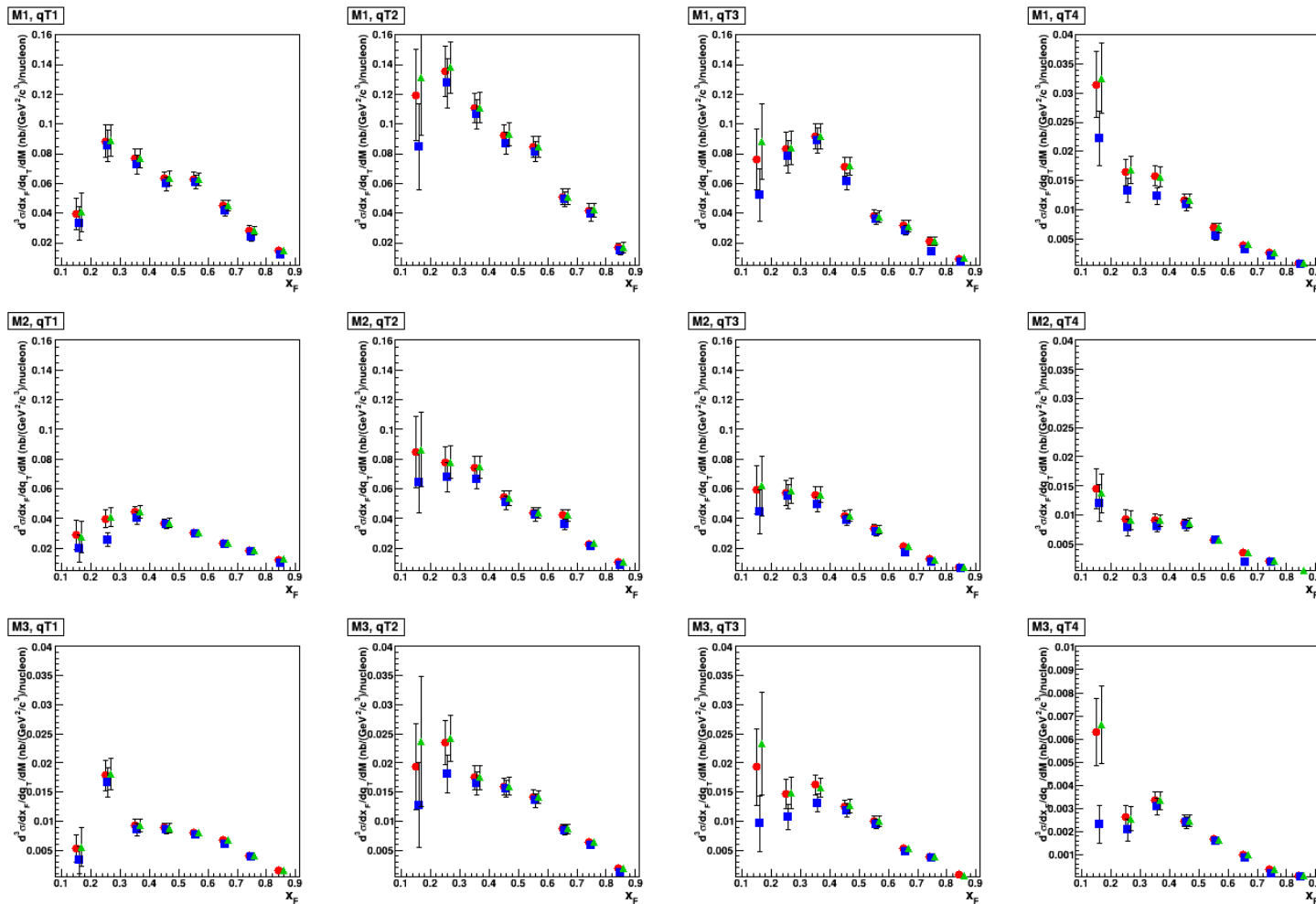
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

PT2 LAS-OT

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using period acceptances, The x-sections tends to be systematically lower. Larger differences are visible at the low x_F .

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

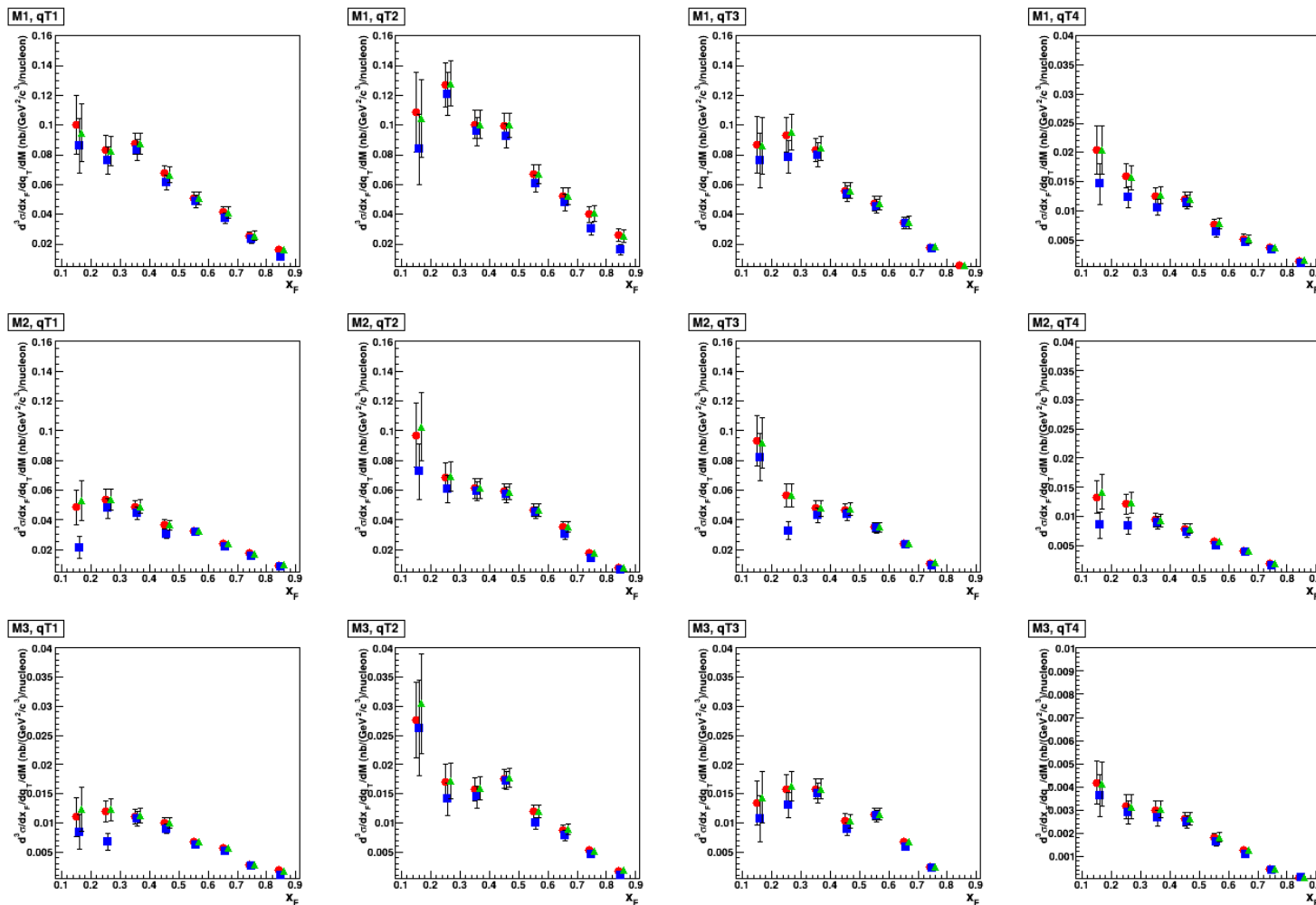
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

ALAS-OT

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using period acceptances, The x-sections tends to be systematically lower. Larger differences are visible at the low xF.

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

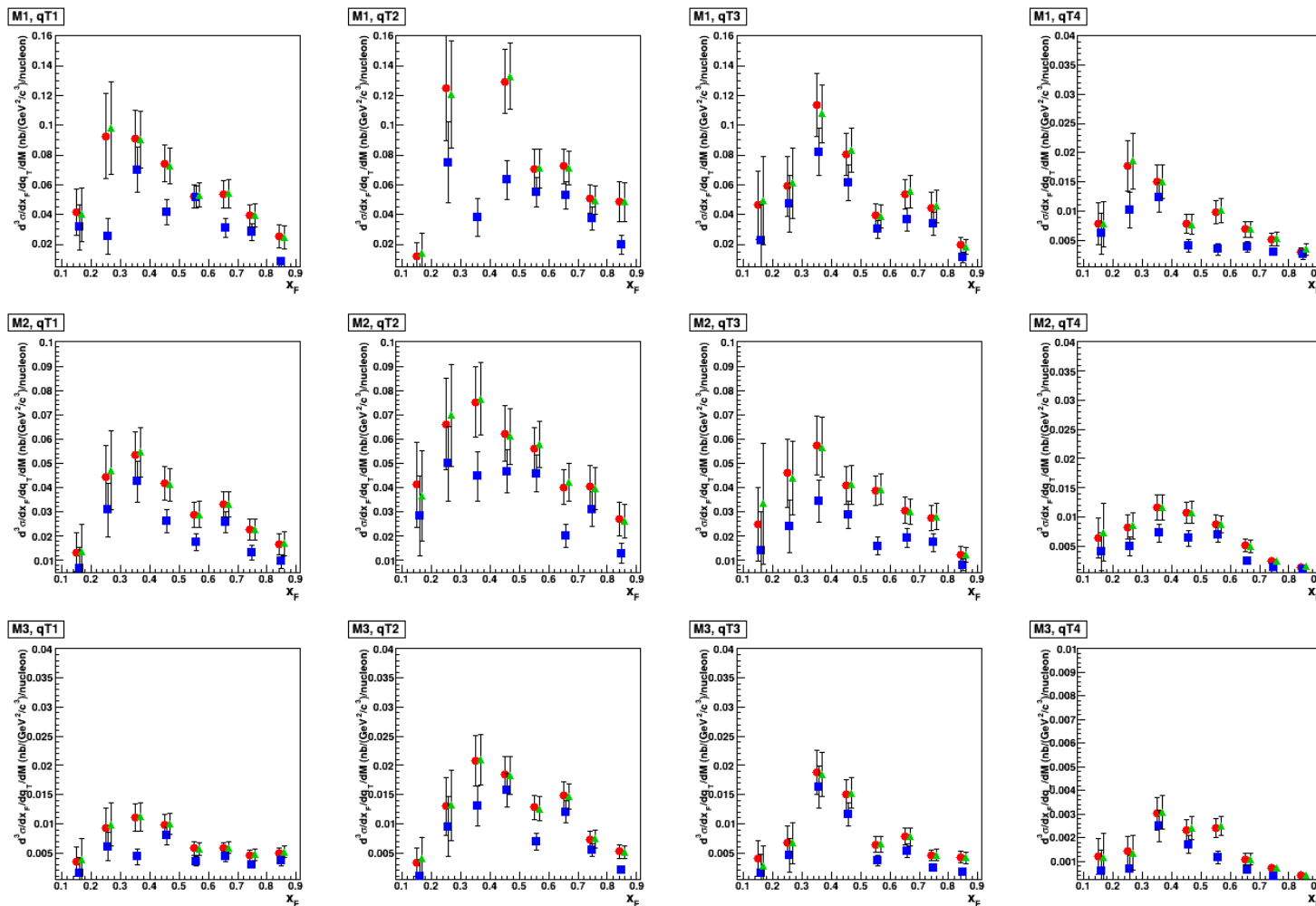
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



x-sections: **global acceptance** versus periods, using **stat error** or **beam flux** as weight

W LAS-OT

(only statistical errors are shown)

$$\sigma \pm \delta\sigma$$

If using period acceptances, The x-sections tends to be systematically lower. Larger differences are visible at the low xF.

For the x-section with period acceptance, the weighted-average of x-sections can be done **using statistical error as weight**:

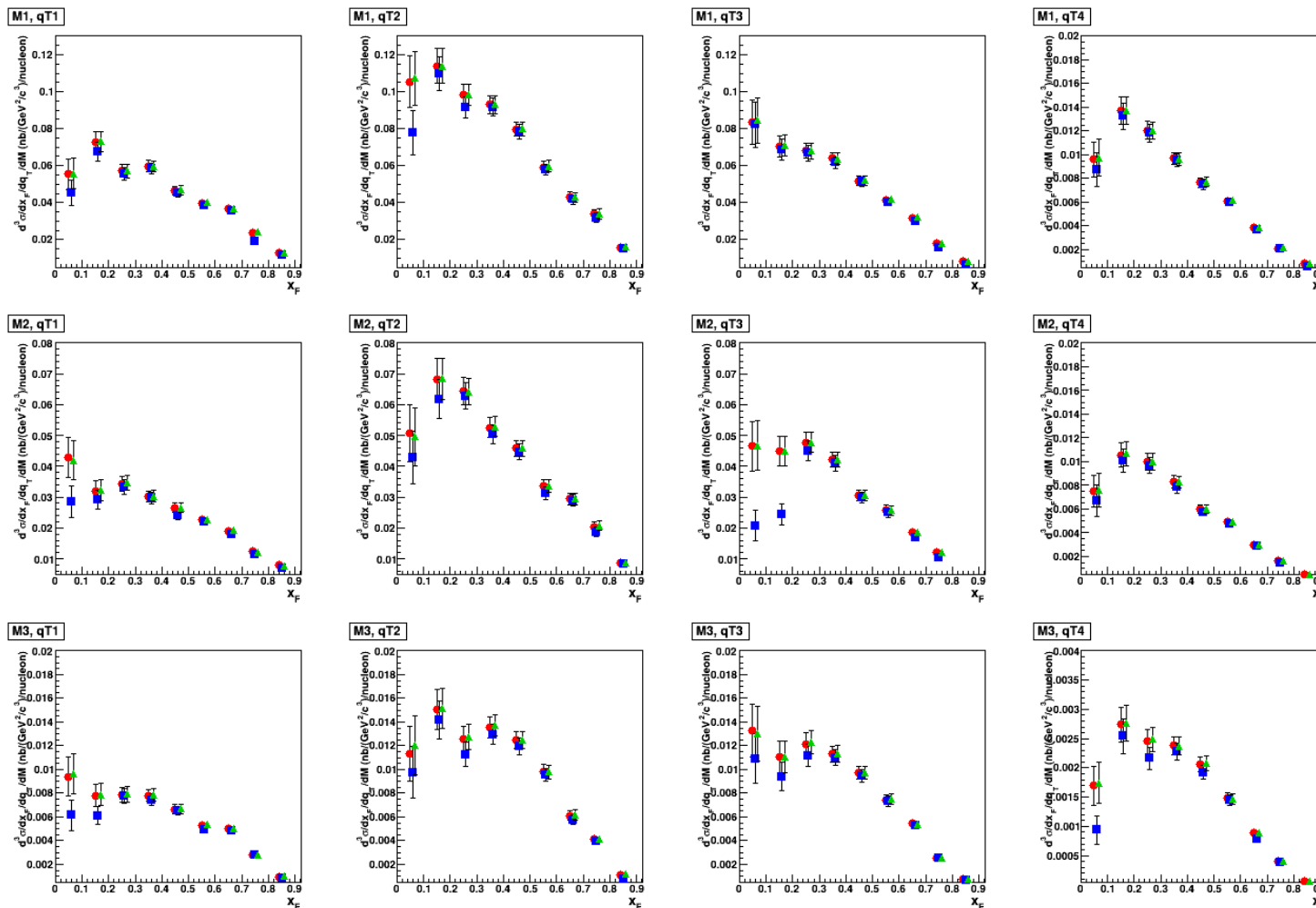
$$\sigma_{\text{mean}} = \sum (\sigma_i / \delta\sigma_i^2) / (1 / \delta\sigma_i^2)$$

$$\delta\sigma_{\text{mean}} = \sum 1 / \sqrt{(1 / \delta\sigma_i^2)}$$

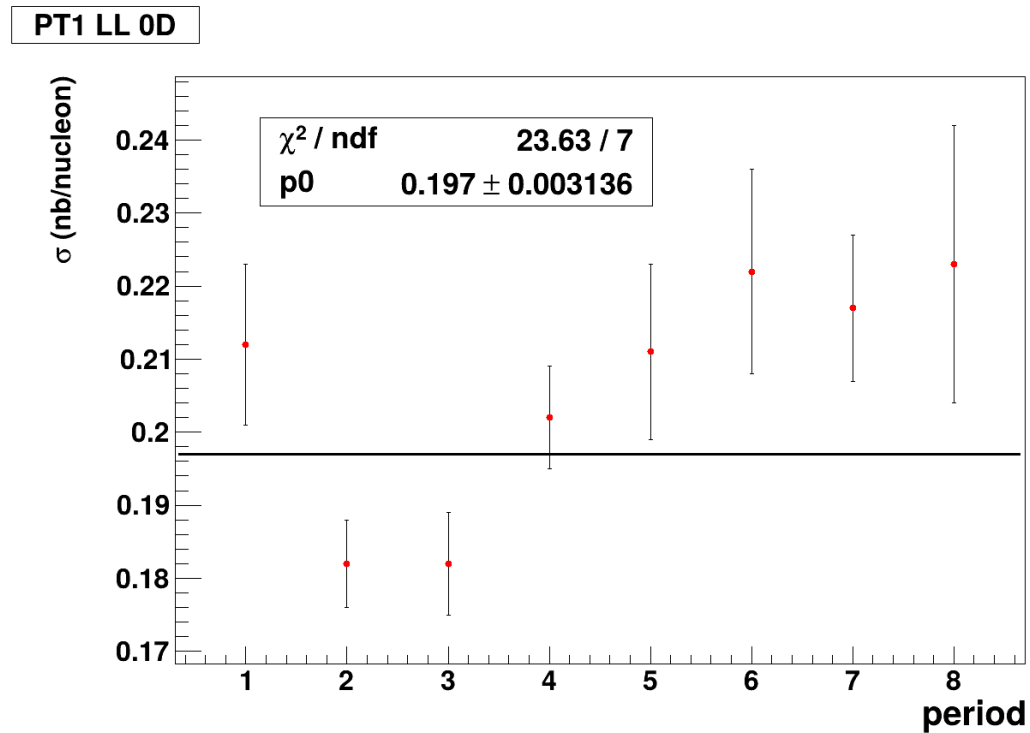
It can also be done **using the beam flux as weight**:

$$\sigma_{\text{mean}} = \sum (\sigma_i * \mathcal{L}_i) / (\mathcal{L}_{\text{tot}})$$

$$\delta\sigma_{\text{mean}} = 1 / \mathcal{L}_{\text{tot}} * \sqrt{\sum \delta(\sigma_i^2 * \mathcal{L}_i^2)}$$



Cross sections per period: compatibility (only statistical error)



From global analysis (all periods together): $\sigma = 0.198 \pm 0.003$ nb/nucleon

From weighted average of periods, using statistical error in the weights: $\sigma = 0.197 \pm 0.003$ nb/nucleon

From weighted average of periods, using beam flux per period in the weights: $\sigma = 0.203 \pm 0.003$ nb/nucleon

Pulls of cross section per period in 3D analysis

12 pulls are build, per target (PT1 & PT2, Al, W) and per trigger (LAS-LAS, LAS-OT) separately.

Each pull contains:

- 16 points for (NH3+He)
- 8 point for Al
- 8 points for W

Each point (x-section $\sigma \pm \delta\sigma(\text{stat})$, where $\delta\sigma(\text{stat})$ stands for the statistical error only) in the pull is calculated using the usual formula:

$$(\sigma_i - \bar{\sigma}) / \sqrt{\delta\sigma_i^2 - \delta\bar{\sigma}^2}$$

The ideal pull behaves as a normalized gaussian with mean value $\mu_{\text{pull}}=0$ and sigma $\sigma_{\text{pull}}=1$. The spectrometer behaviour varies with time, namely with detectors efficiency, trigger efficiency and global alignment that vary from period to period. The pull is used here to evaluate the compatibility of periods, by resulting in a systematic error in the cross section, due to acceptance variations

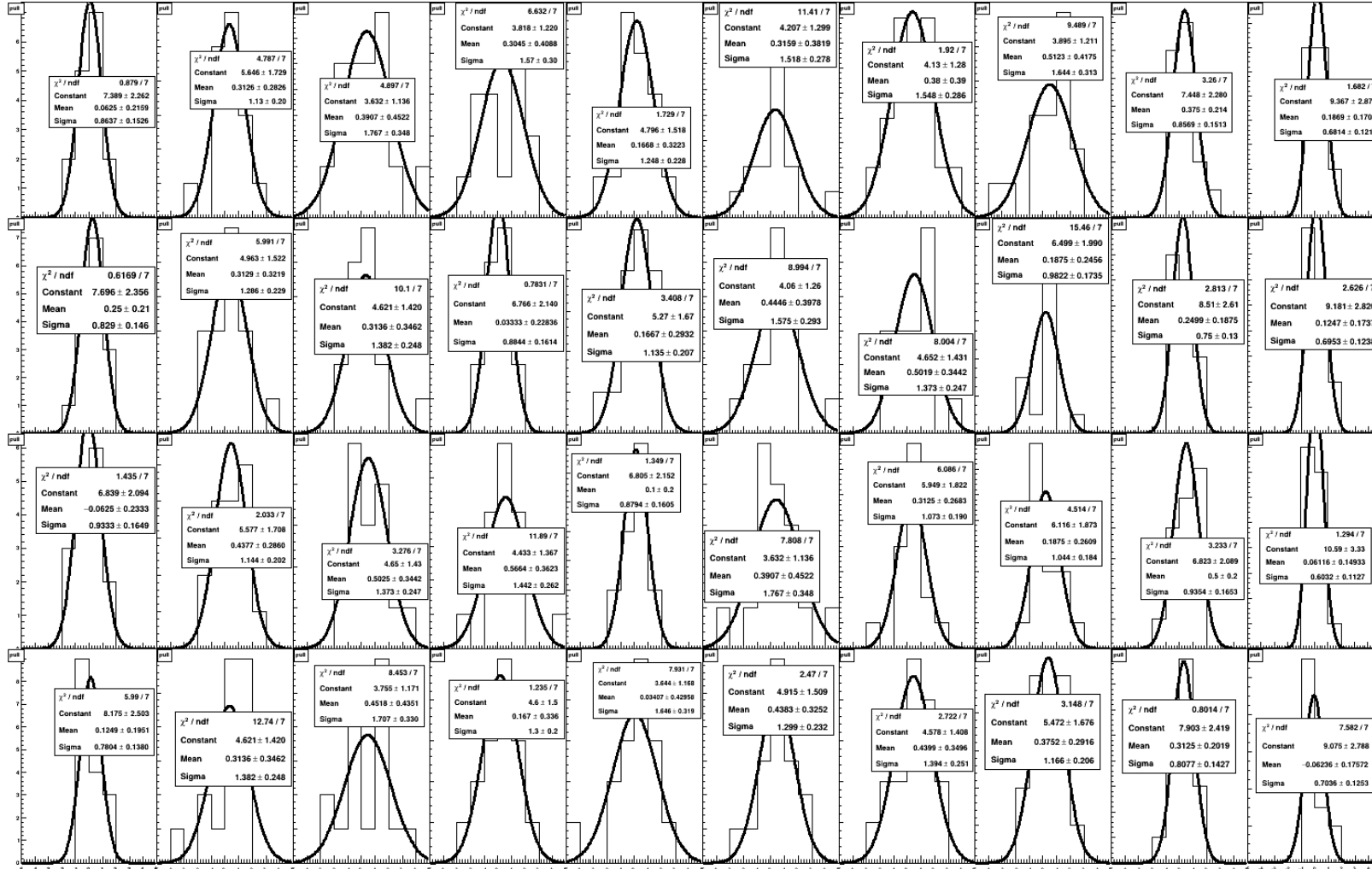
$$\delta\sigma_{\text{acc}}(\text{syst}) / \delta\sigma(\text{stat}) = \sqrt{(\sigma_{\text{pull}}^2 - 1) + |\mu_{\text{pull}}|}$$

Systematic from “acceptance” variations over time: pulls

Example: (NH3+He) LAS-LAS, 3D, $4.3 < M < 4.7 \text{ GeV}/c^2$

The systematic error is a multiplicative factor wrt the statistical error of the respective bin. given by

$$\sqrt{(\sigma_{\text{pull}}^2 - 1) + |\mu|}$$

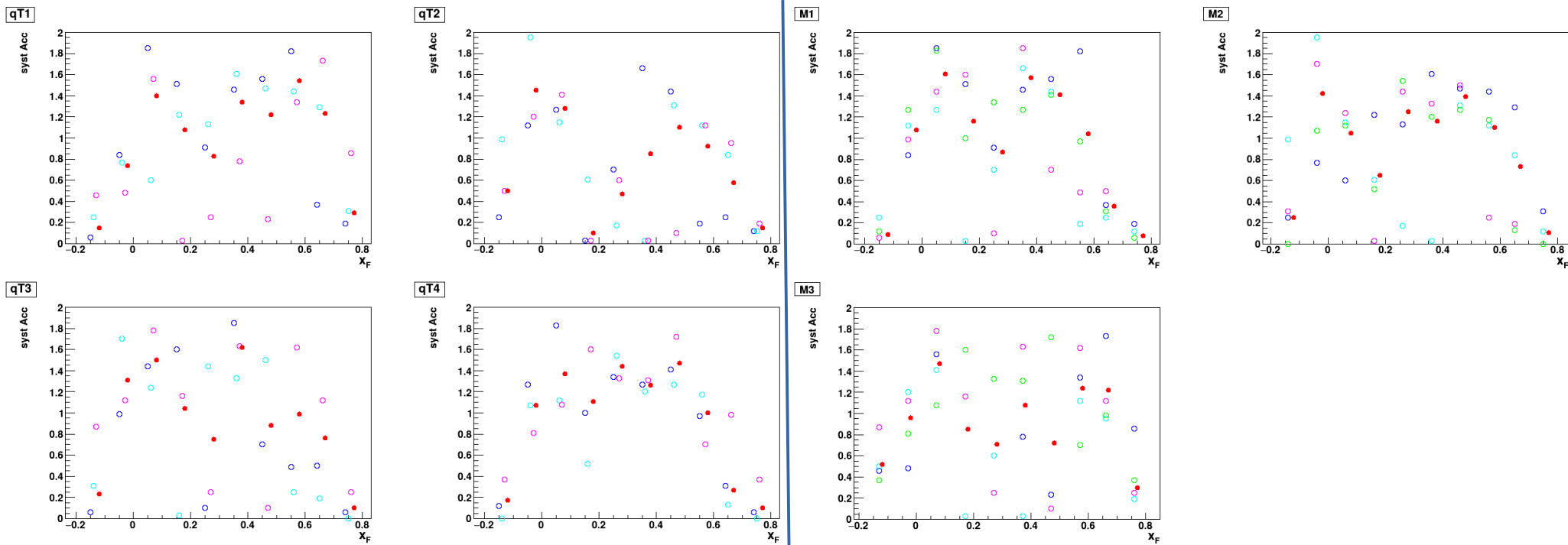


Bins with 0 x-section do not have 0 statistical error!

Systematic from “acceptance” variations over time: pulls

Using pulls in this way leads to too few entries in each pull (worse for AI and W, with only 8 per pull), and large variations. Can we assume that, since the acceptance is almost flat in M and q_T , this systematic error is only dependent on x_F ?

Example: (NH3+He) LAS-LAS, 3D vs 2D



Red full points: all mass bins together

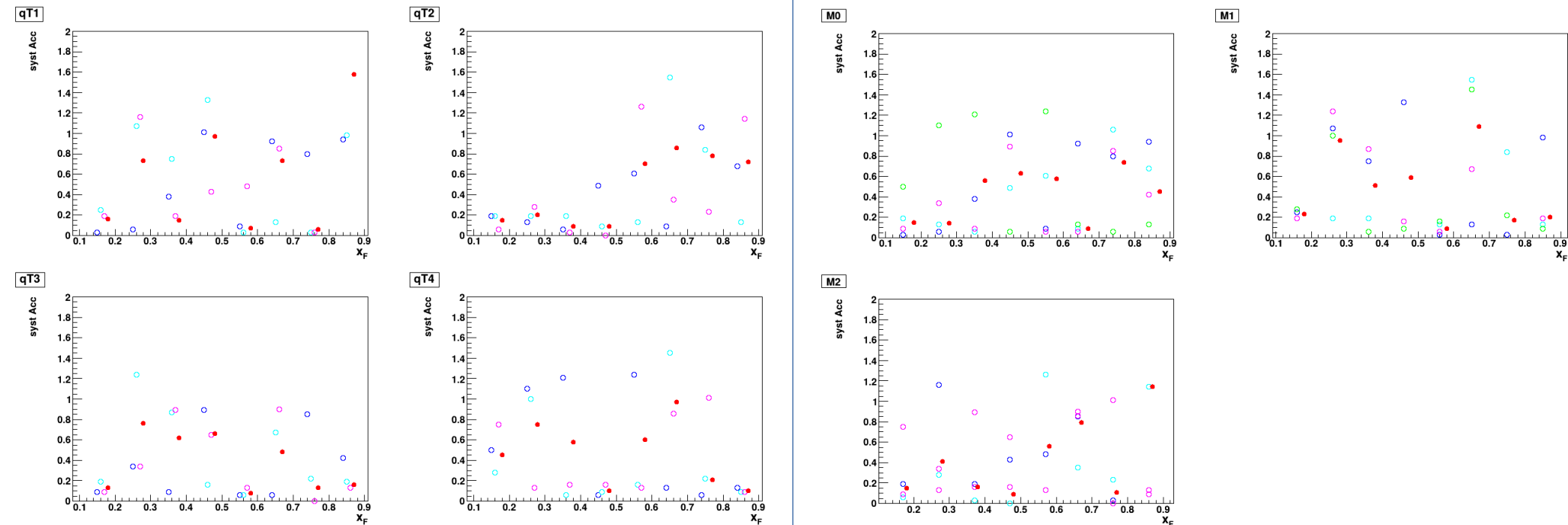
Red full points: all q_T bins together

Similar pattern. Yes, this error seems independent from M and q_T , but not from x_F .

Systematic from “acceptance” variations over time: pulls

Using pulls in this way leads to too few entries in each pull (worse for AI and W, with only 8 per pull), and large variations. Can we assume that, since the acceptance is almost flat in M and qT, this systematic error is only dependent on xF?

Example: (NH3+He) LAS-OT, 3D vs 2D



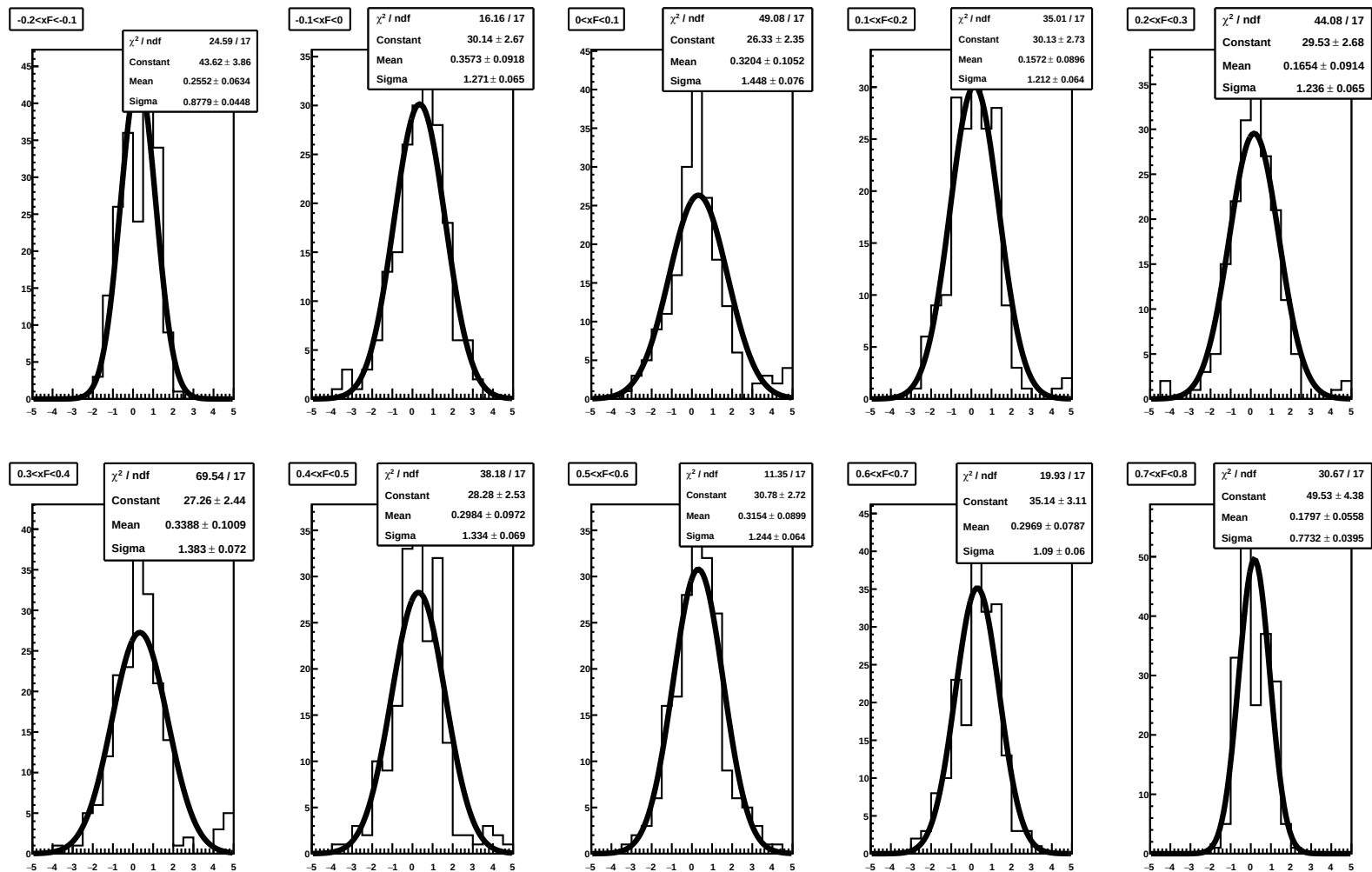
Red full points: all mass bins together

Red full points: all qT bins together

Similar pattern(?) The error seems independent from M and qT, not clear from xF.

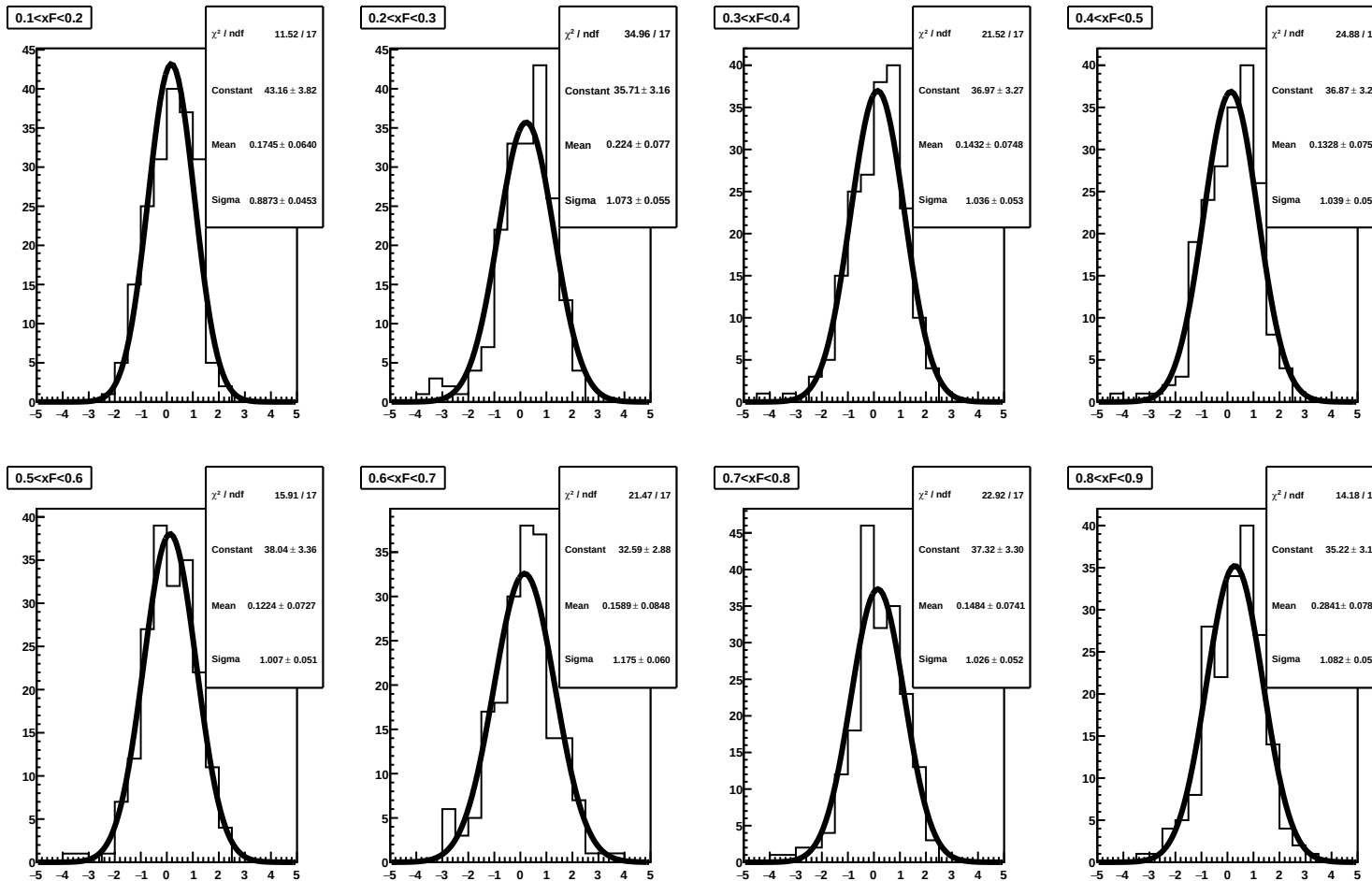
Systematic from “acceptance” variations over time: pulls

Example: (NH₃+He) LAS-LAS, xF dependence



Systematic from “acceptance” variations over time: pulls

Example: (NH₃+He) LAS-OT, xF dependence



Systematic from “acceptance” variations over time: pulls

(NH3+He) LAS-LAS	mean[192]	sigma[192]	Syst(acc[192])
-0.2 < xF < -0.1	0.255	0.878	0.26
-0.1 < xF < 0	0.357	1.271	1.14
0 < xF < 0.1	0.320	1.448	1.37
0.1 < xF < 0.2	0.157	1.212	0.84
0.2 < xF < 0.3	0.165	1.236	0.89
0.3 < xF < 0.4	0.339	1.383	1.29
0.4 < xF < 0.5	0.298	1.334	1.18
0.5 < xF < 0.6	0.315	1.244	1.06
0.6 < xF < 0.7	0.297	1.090	0.73
0.7 < xF < 0.8	0.180	0.773	0.18

(NH3+He) LAS-OT	mean[192]	sigma[192]	Syst(acc[192])
0.1 < xF < 0.2	0.177	0.887	0.17
0.2 < xF < 0.3	0.224	1.072	0.61
0.3 < xF < 0.4	0.143	1.036	0.41
0.4 < xF < 0.5	0.133	1.039	0.41
0.5 < xF < 0.6	0.122	1.007	0.24
0.6 < xF < 0.7	0.159	1.175	0.78
0.7 < xF < 0.8	0.148	1.026	0.38
0.8 < xF < 0.9	0.284	1.082	0.70

This systematic, proportional to the statistical error, is larger for LAS-LAS than for LAS-OT.