Hadronic Reconstruction Resolution of DIS Q^2, x, y, Fastsim vs Fullsim

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Motivation and Overview

- In some regions of DIS phase space, using the Hadronic Final State (HFS) to reconstruct the DIS variables (Q2, x, y) is superior to using the scattered electron only.
- Hadronic reconstruction resolution is sensitive to detector acceptance, resolution, and noise/backgrounds.
- We may have to rely on fast simulation (Delphes) for physics studies for the Athena proposal, due at the end of the year.
- We can use Fullsim – Fastsim comparisons of the H1 detector to learn how to tune the fast simulation of Athena to make it more realistic.

Definitions

- Fastsim reconstruction of Hadronic Final State (HFS)
  - HFS is everything except the scattered electron (NC DIS).
  - Sum of px, py, pz, E of all calorimeter towers.

- With HFS and scattered electron, you can compute everything.

$$\Sigma = \sum_h (E_h - p_{z,h})$$

$$T = \sqrt{(\sum_h p_{x,h})^2 + (\sum_h p_{y,h})^2}$$

$$\tan\frac{\gamma}{2} = \frac{\Sigma}{T}$$

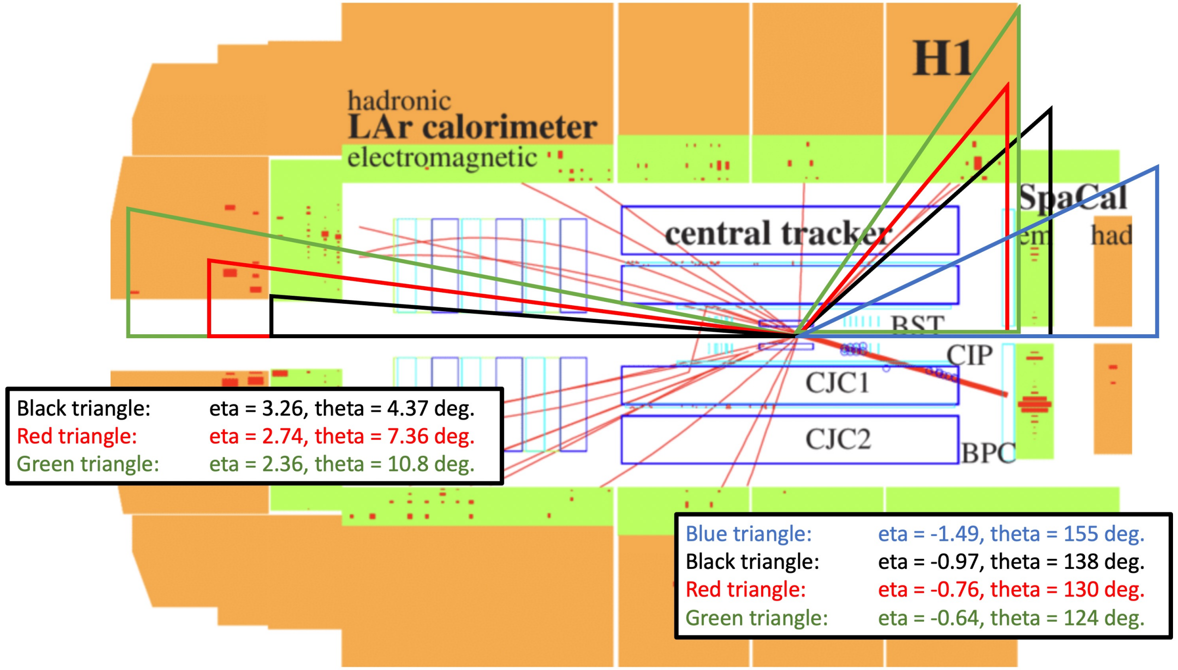
Appendix: y, Q^2 and x formulae

method	y	Q^2	x	
e	$1-\frac{E}{E^e}\sin^2\frac{\theta}{2}$	$4E^e E\cos^2\frac{\theta}{2}$	Q^2/ys	*Electron*
h	$\frac{\Sigma}{2E^e}$	$\frac{T^2}{1-y_h}$	Q^2/ys	*Hadron*
m	y_h	Q^2_e	Q^2/ys	
DA	$\frac{\tan\gamma/2}{\tan\gamma/2+\tan\theta/2}$	$4E^{e2}\frac{\cot\theta/2}{\tan\gamma/2+\tan\theta/2}$	Q^2/ys	*Double Angle*
Σ	$\frac{\Sigma}{\Sigma+E(1-\cos\theta)}$	$\frac{E^2\sin^2\theta}{1-y_\Sigma}$	Q^2/ys	*Sigma*
IDA	y_{DA}	$E^2\ \tan\frac{\theta}{2}\frac{\tan\gamma/2+\tan\theta/2}{\cot\theta/2+\tan\theta/2}$	$\frac{E}{E^p}\frac{\cot\gamma/2+\cot\theta/2}{\cot\theta/2+\tan\theta/2}$	
IΣ	y_Σ	Q^2_Σ	$\frac{E}{E^p}\ \frac{\cos^2\theta/2}{y_\Sigma}$	

From the paper that introduced the Sigma method.
U. Bassler and G. Bernardi, NIM A361 (1995) 197-208.

H1 Fastsim

- Recently implemented in Delphes.
- We had to adjust the calorimeter resolution a bit in order to get agreement in the HFS p_T resolution. Main adjustment was to increase the HCAL constant term to 20%.



Detector	Acceptance	Resolution
Tracking	|eta| < 2.0	**3.5% + pT*cosh(eta)*0.002**
ECAL	|eta| < 3.35	Barrel: -1.46 < eta < 3.35 **2.5% + 11%/sqrt(E)** Endcap: -3.35 < eta< -1.46 **3.0% + 10%/sqrt(E)**
HCAL	-0.96 < eta < 3.35	Core: -0.64 < eta < 3.20 **20% + 50%/sqrt(E)** Edges: 3.20 to 3.35 and -0.97 to -0.64 **40% + 90%/sqrt(E)**

Resolutions based on NIM A 386 (1997) 310 with very rough adjustments from trial and error (not a systematic tuning yet).

H1 Hadronic DIS Reconstruction

This figure is from the paper that introduced the Sigma method.

[U. Bassler and G. Bernardi, NIM A361 (1995) 197-208](#).

Event selection: $Q^2 > 200$

Shows how the HFS and the electron are complementary.

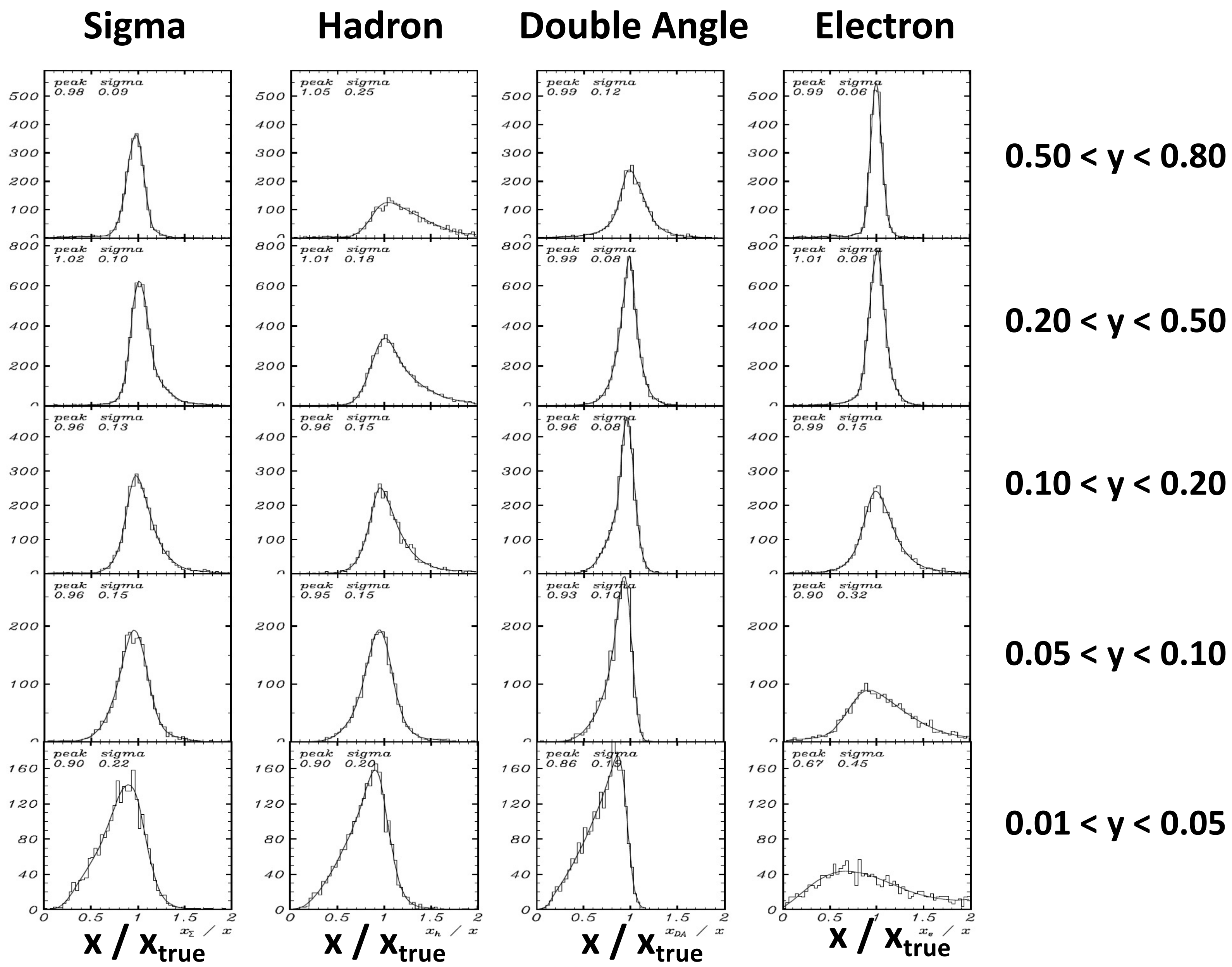
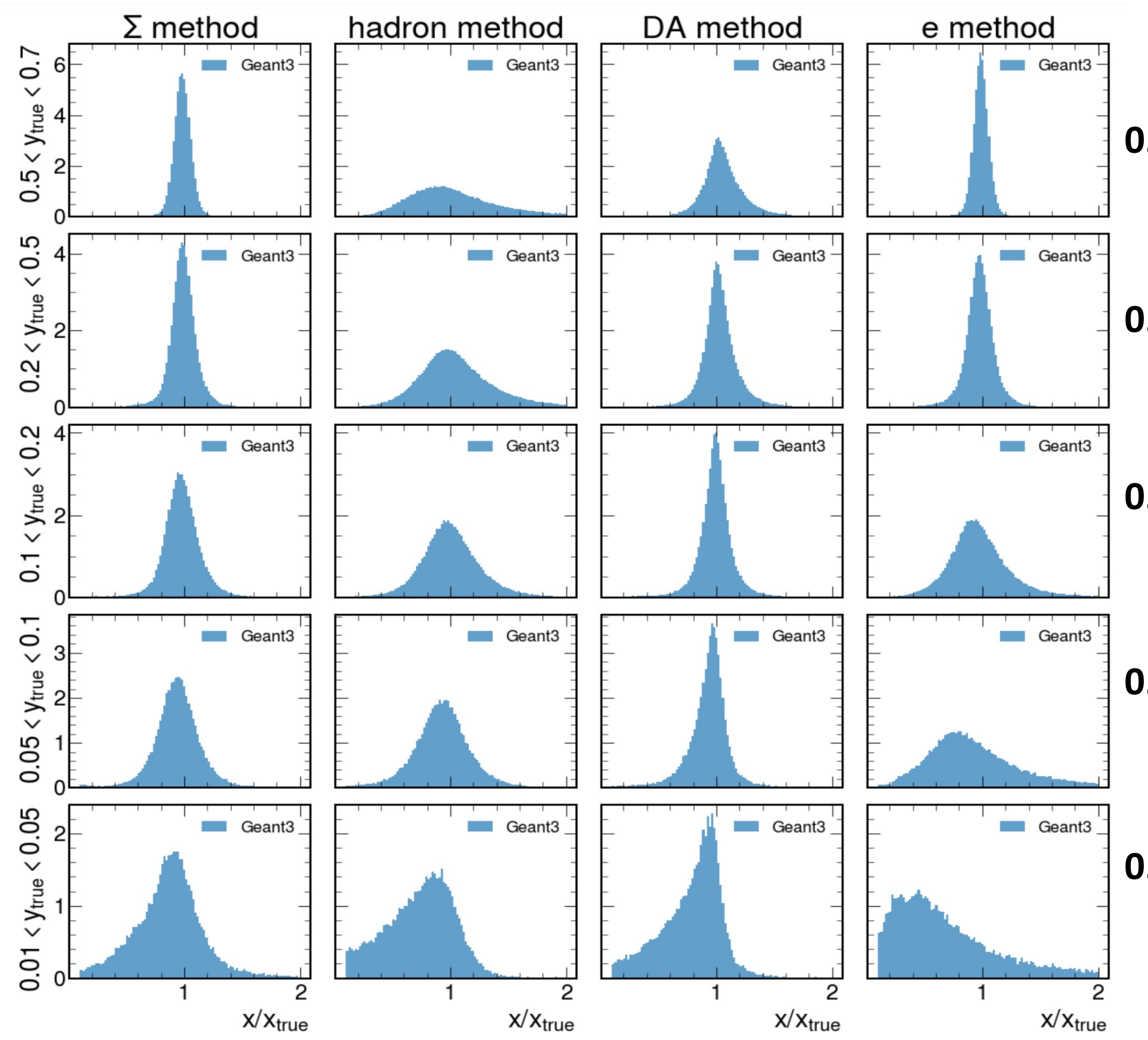


Figure 4: Comparison x_{method}/x at high Q^2 ($Q^2 > 200$ GeV^2) for the Σ, mixed , DA and e methods. From top to bottom, each row represent a bin in y: very high (0.5-0.8), high (0.2-0.5), medium (0.1-0.2), low (0.05-0.1), very low (0.01-0.05).

H1 Fullsim MC

We can reproduce the figure from the paper with Fullsim (Django+G3).



0.50 < y < 0.80

0.20 < y < 0.50

0.10 < y < 0.20

0.05 < y < 0.10

0.01 < y < 0.05

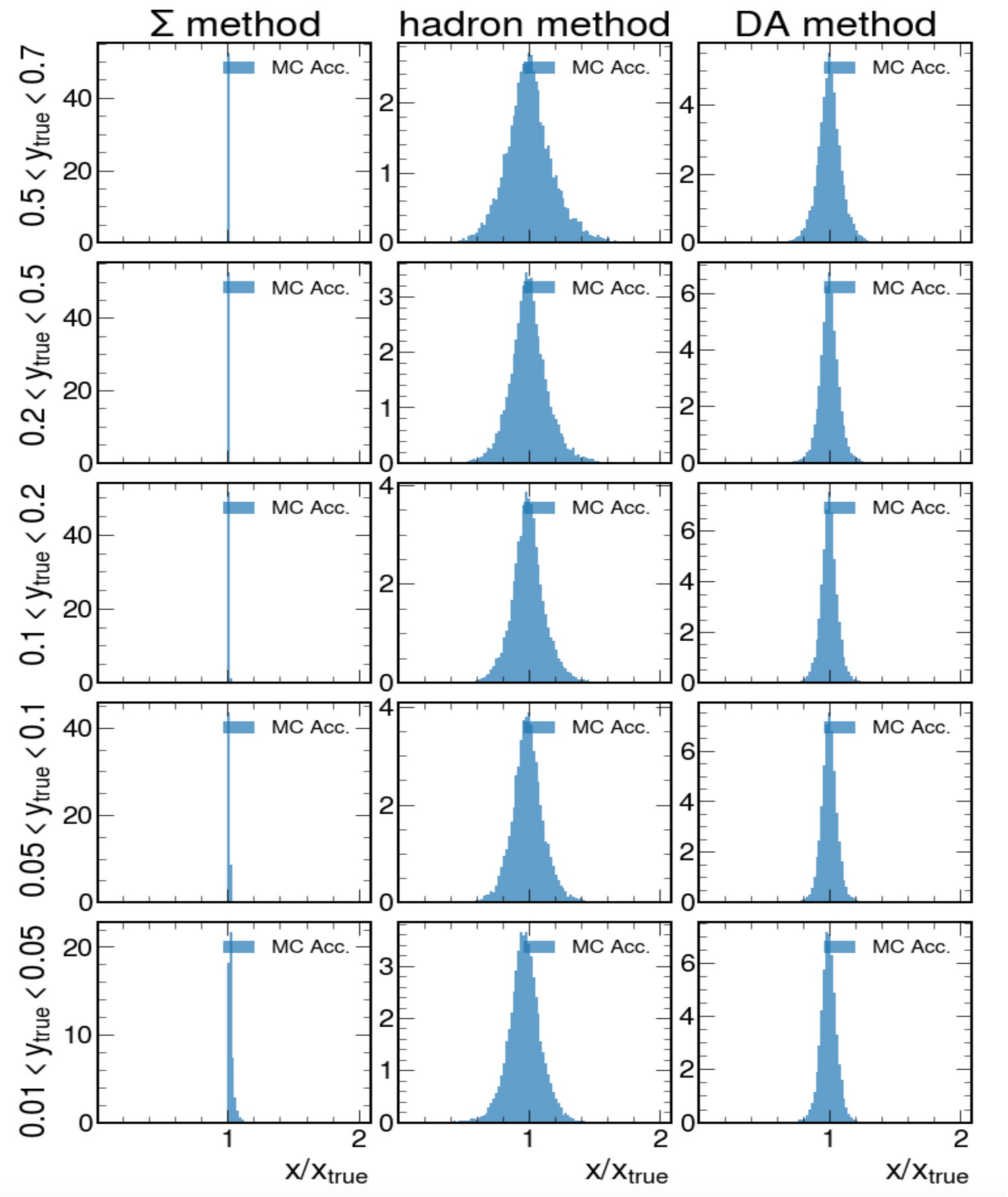
H1 Geometric Acceptance

This shows the resolution effect of the geometric acceptance *only*.

All generated status=1 MC particles from Pythia that are within |eta|<4 are summed up to make this cheat reconstruction.

Sigma method is robust against acceptance losses, but hadron method is not!

We initially thought this might be a bug, but it's real. See the Extra Slides.



0.50 < y < 0.80

0.20 < y < 0.50

0.10 < y < 0.20

0.05 < y < 0.10

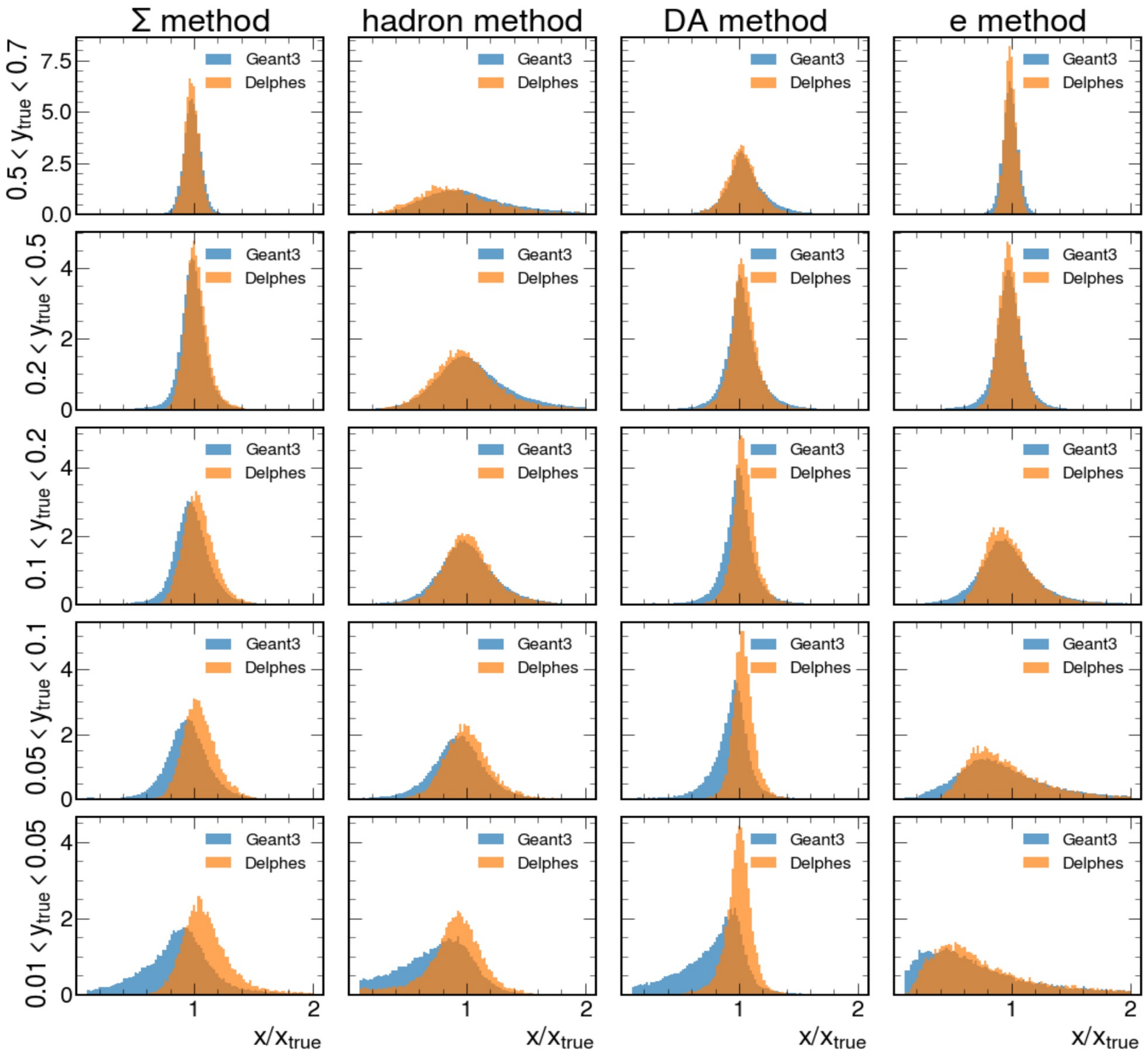
0.01 < y < 0.05

H1 Fullsim vs Fastsim

Fastsim agreement with fullsim isn't too bad for the electron.

Agreement is ok at high y for hadronic methods, but not so good at low y.

Clearly still missing something important at low y.



0.50 < y < 0.80

0.20 < y < 0.50

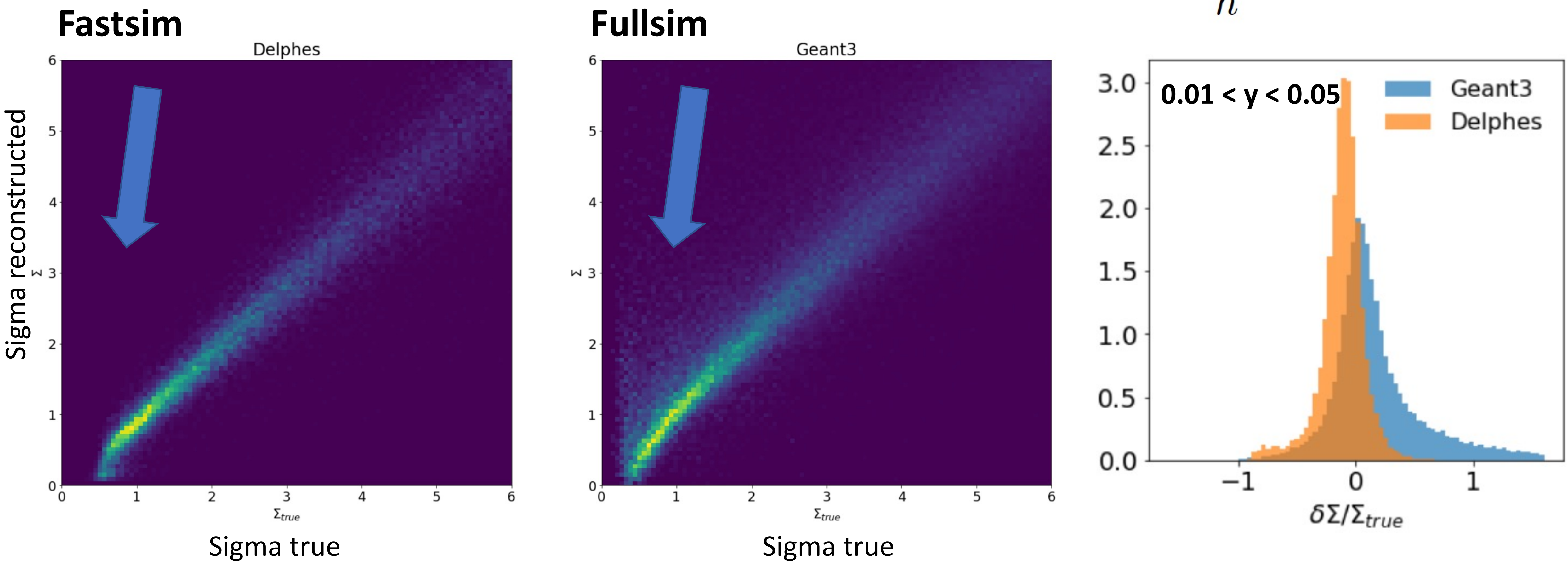
0.10 < y < 0.20

0.05 < y < 0.10

0.01 < y < 0.05

Importance of Noise / Background at low y

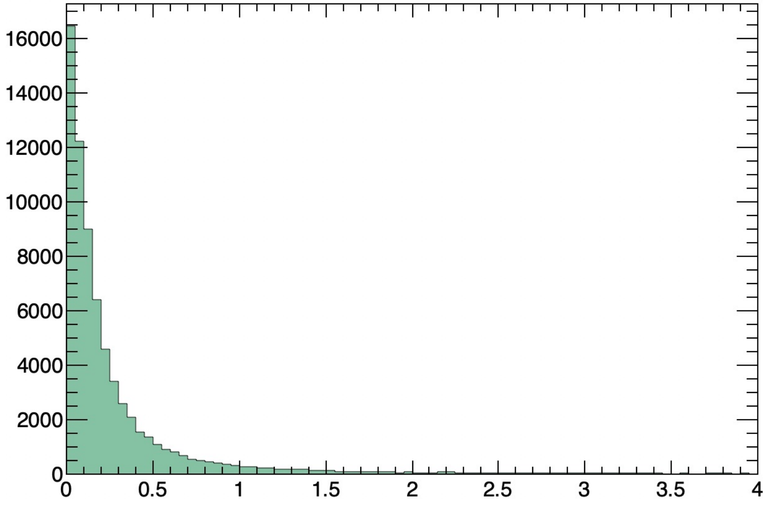
$$\Sigma = \sum_h (E_h - p_{z,h})$$

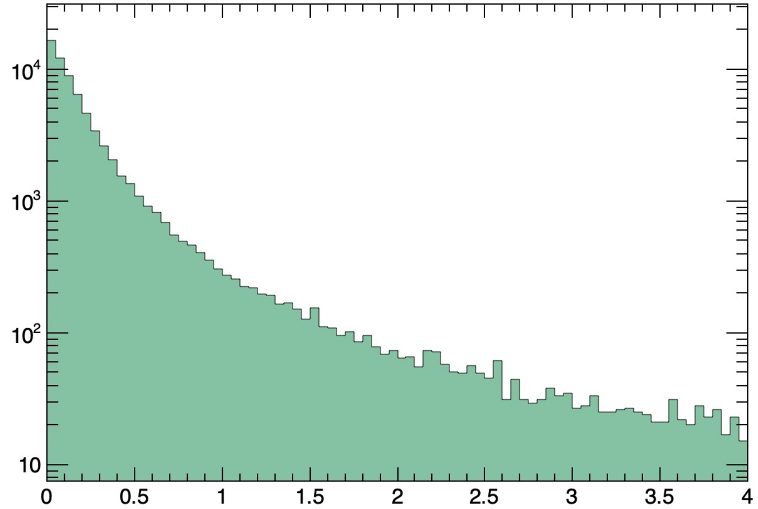


Sigma goes to zero as y goes to zero.

Any background or electronics noise can easily throw off the balance between E and pz required at low y.

Educated guess at the missing HFS noise / background in fastsim





Noise / background (GeV)

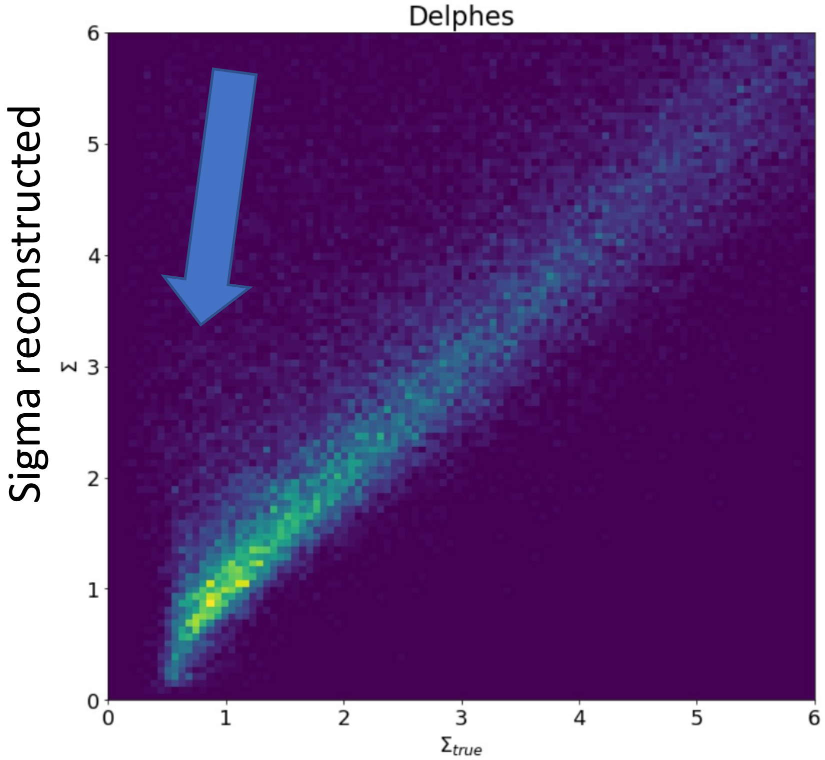
For each of HFS px, py, and pz, pick random numbers (Npx, Npy, Npz) using TRandom::Landau with mu = 0 and sigma = 0.05, randomize the sign (+/-), and add it to sum.

Add sqrt(Npx^2 + Npy^2 + Npz^2) to HFS E.

Importance of Noise / Background at low y

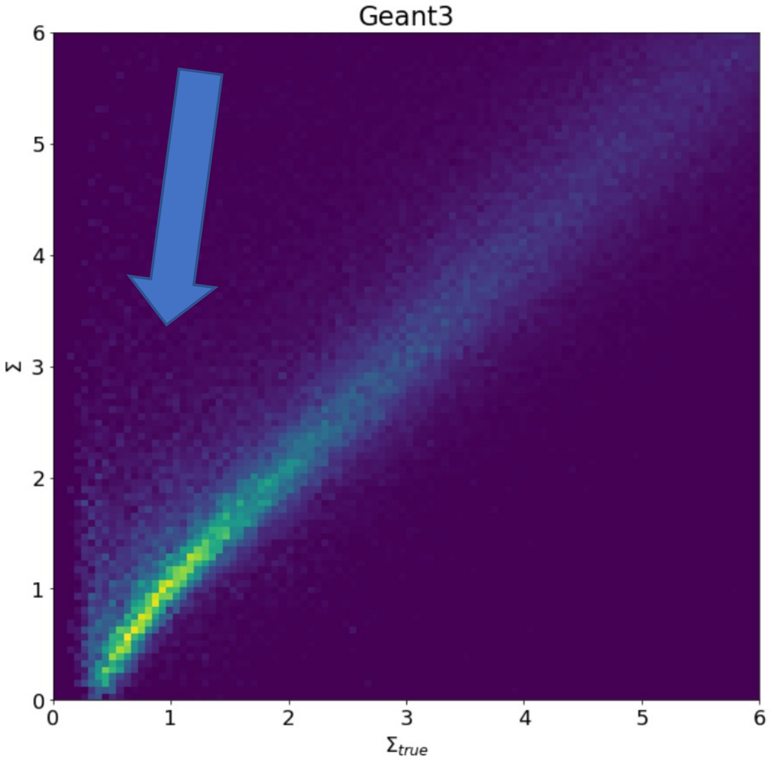
$$\Sigma = \sum_h (E_h - p_{z,h})$$

Fastsim + noise

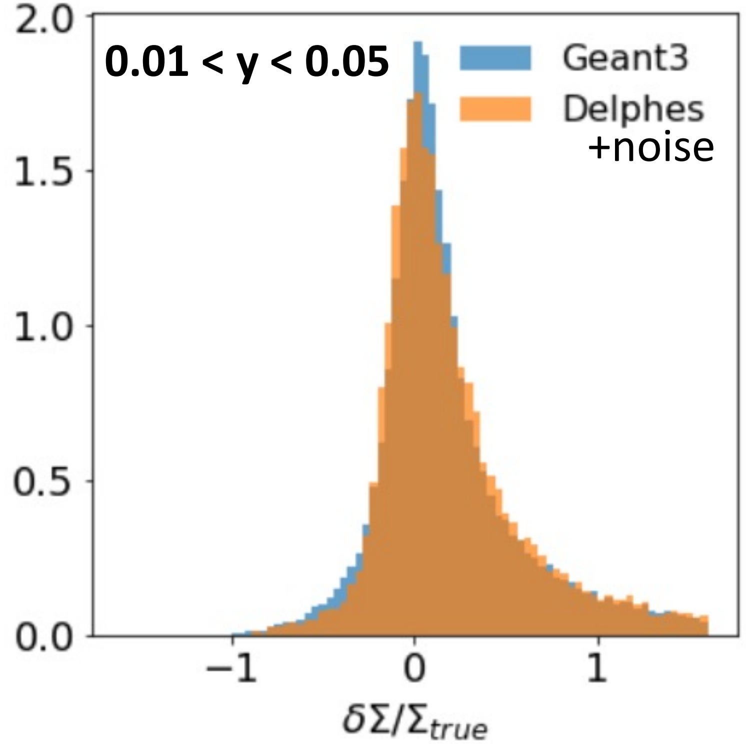


Sigma true

Fullsim



Sigma true

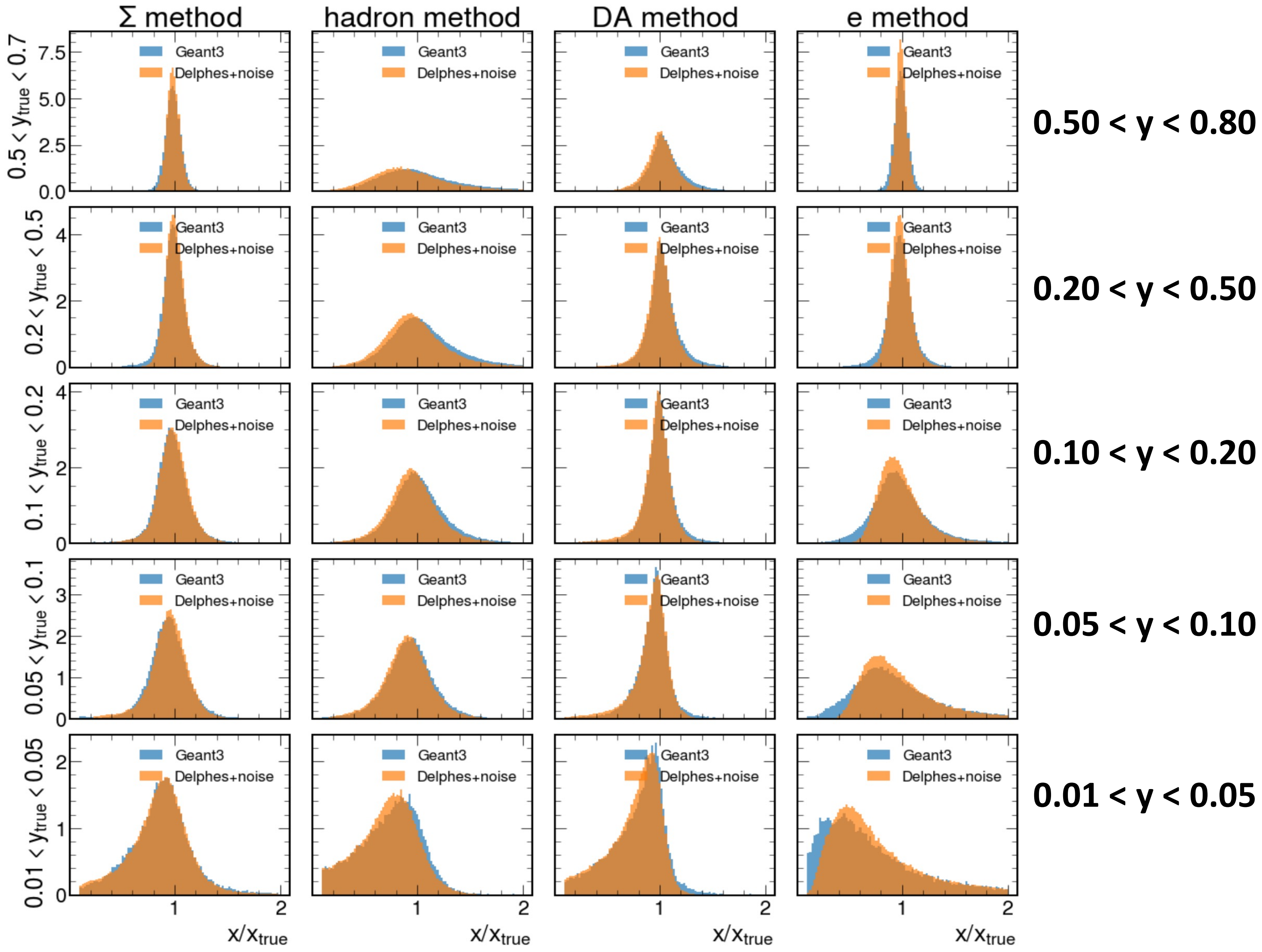


Much better agreement between fullsim and fastsim after adding noise to fastsim!

H1 Fullsim vs Fastsim+noise

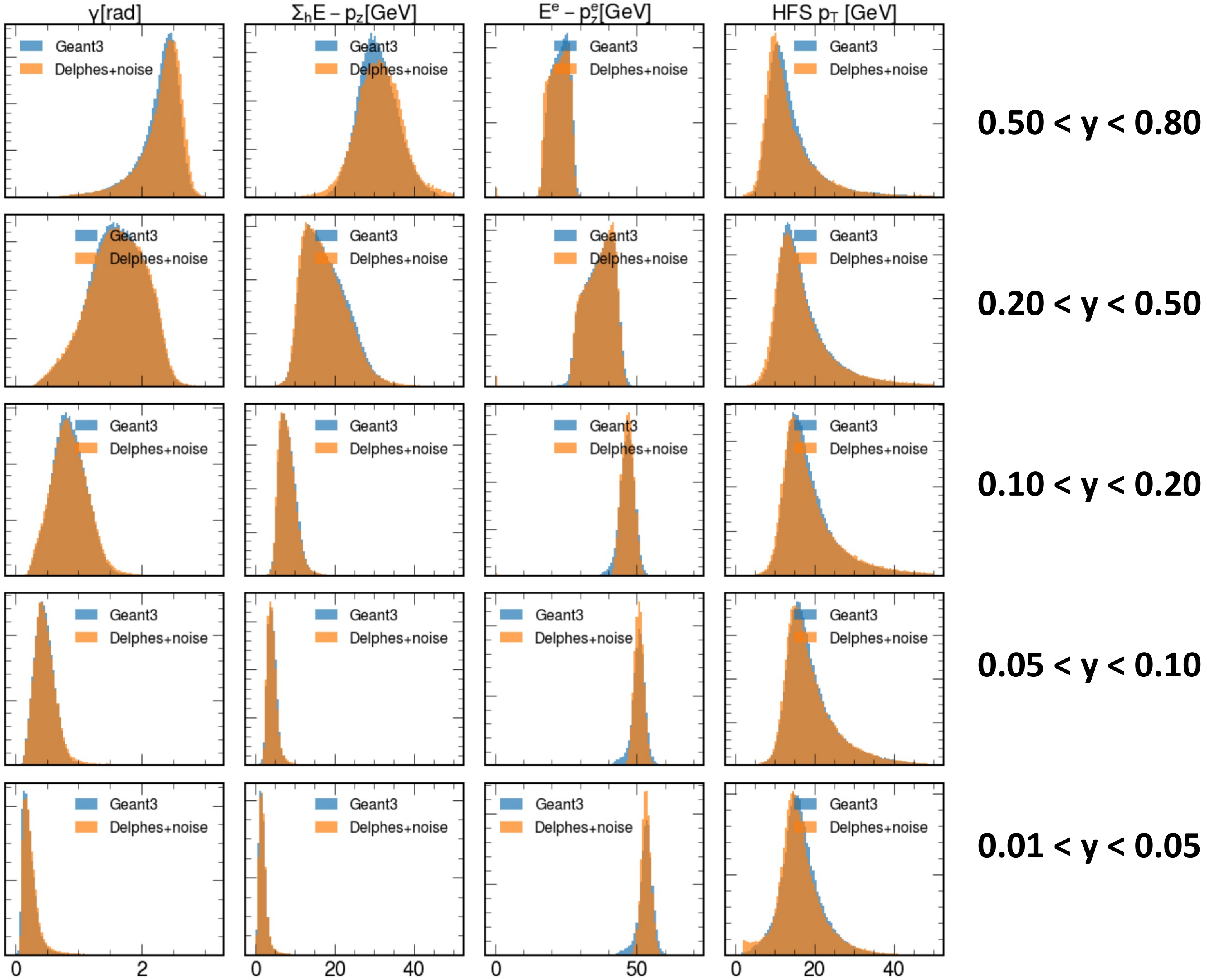
Much better agreement in hadronic reconstruction resolution!

Shows that the low-side tail at low y is very likely entirely due to noise / background in HFS.



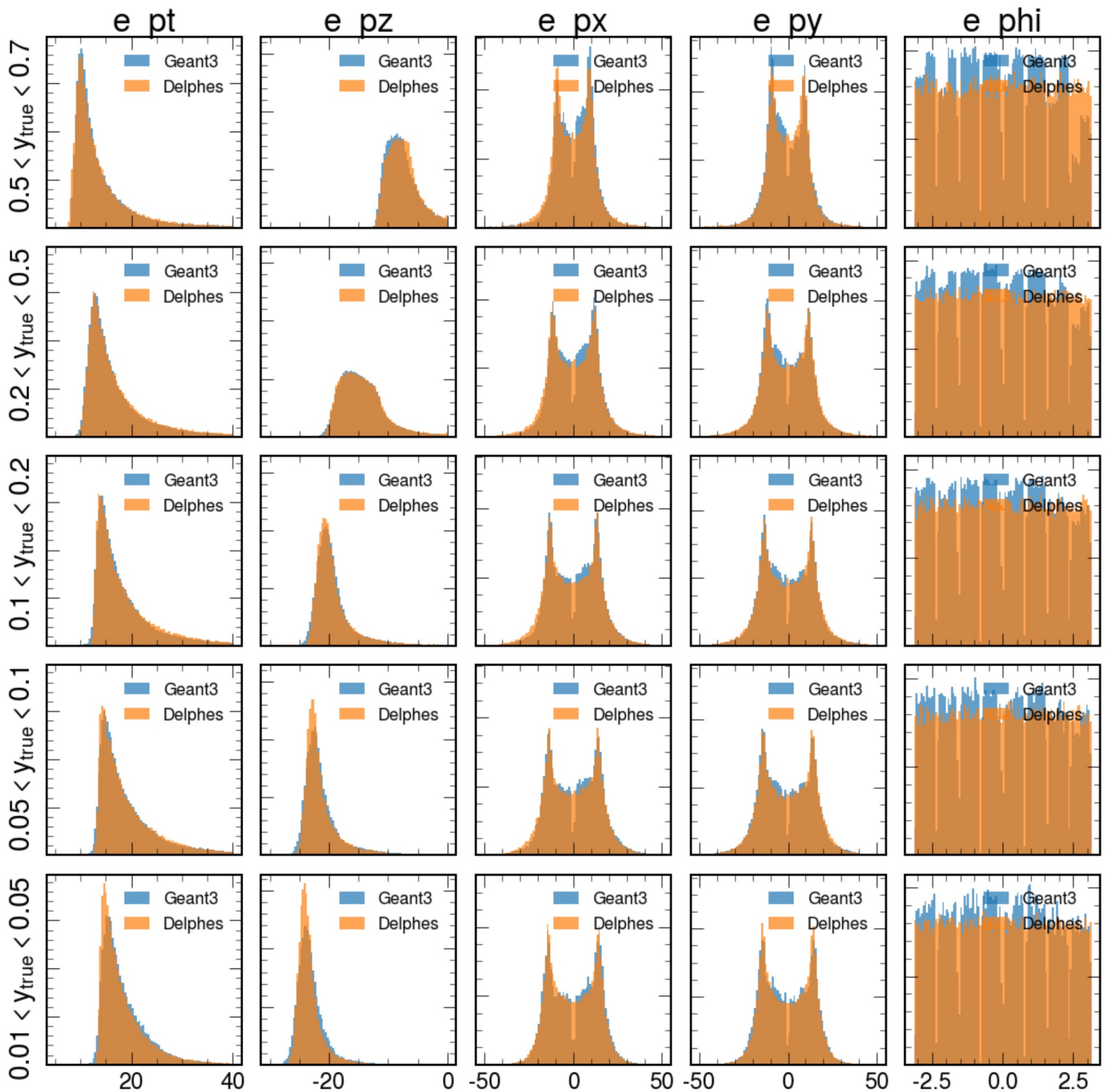
HFS reconstruction distributions, Fullsim vs Fastsim+noise

Surprisingly good agreement.



Electron reconstruction distributions, Fullsim vs Fastsim

Looks pretty good.



0.50 < y < 0.80

0.20 < y < 0.50

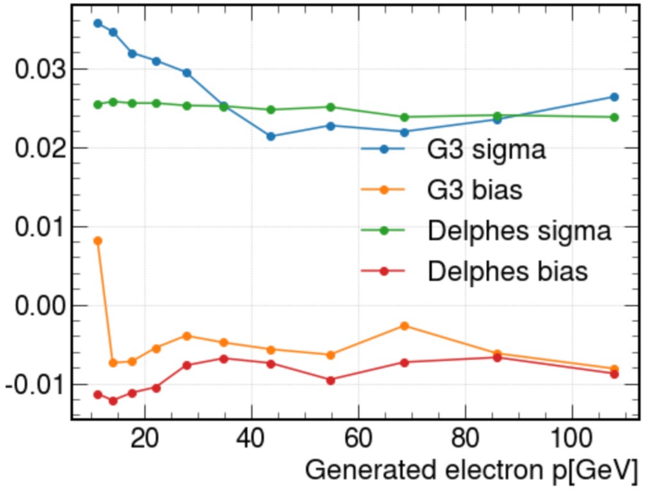
0.10 < y < 0.20

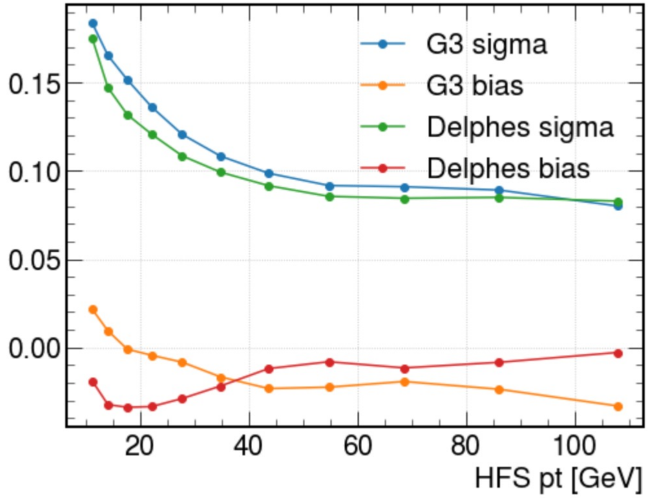
0.05 < y < 0.10

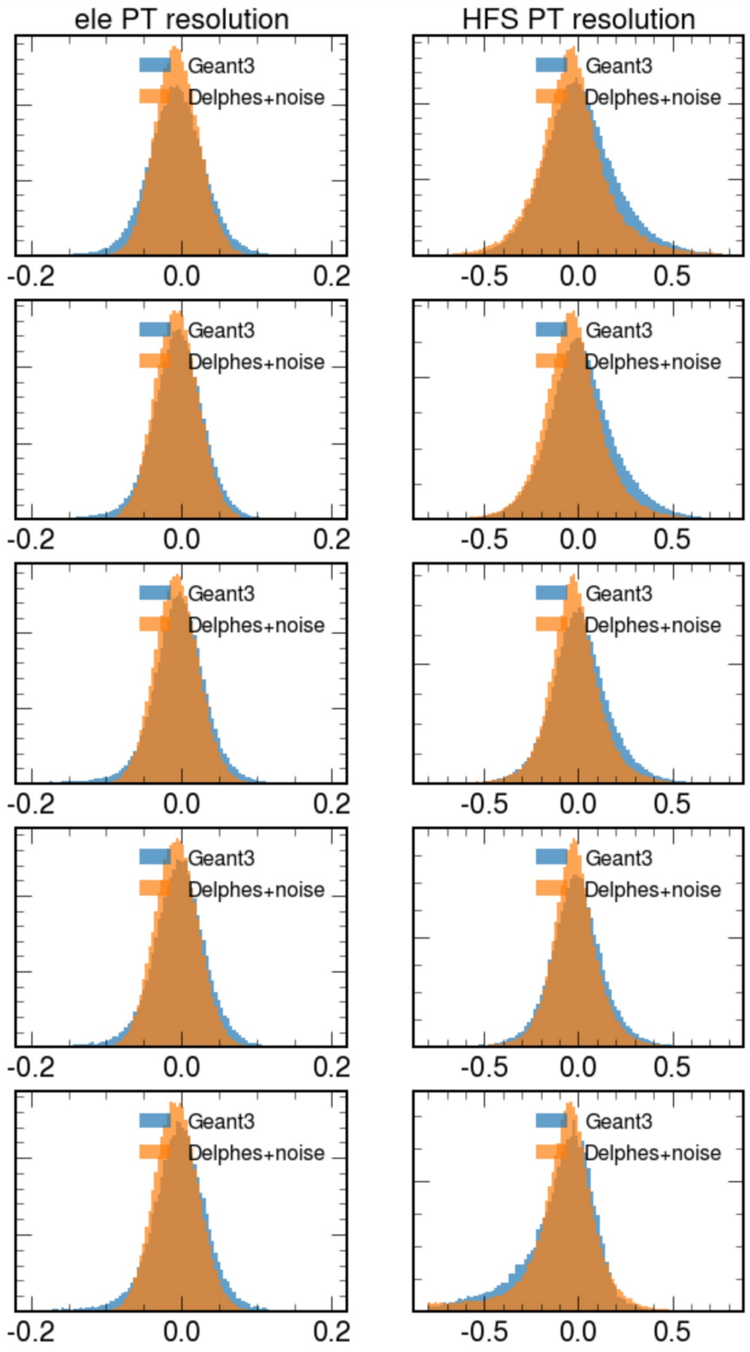
0.01 < y < 0.05

H1 Electron and HFS PT resolution, Fastsim+noise vs Fullsim

Resolution for both electron and HFS in pretty good agreement.







$0.50 < y < 0.80$

$0.20 < y < 0.50$

$0.10 < y < 0.20$

$0.05 < y < 0.10$

$0.01 < y < 0.05$

What have we learned from this?

Geometric acceptance can be an important factor in hadronic reconstruction resolution.

Noise / background in HFS is *very* important at low y.

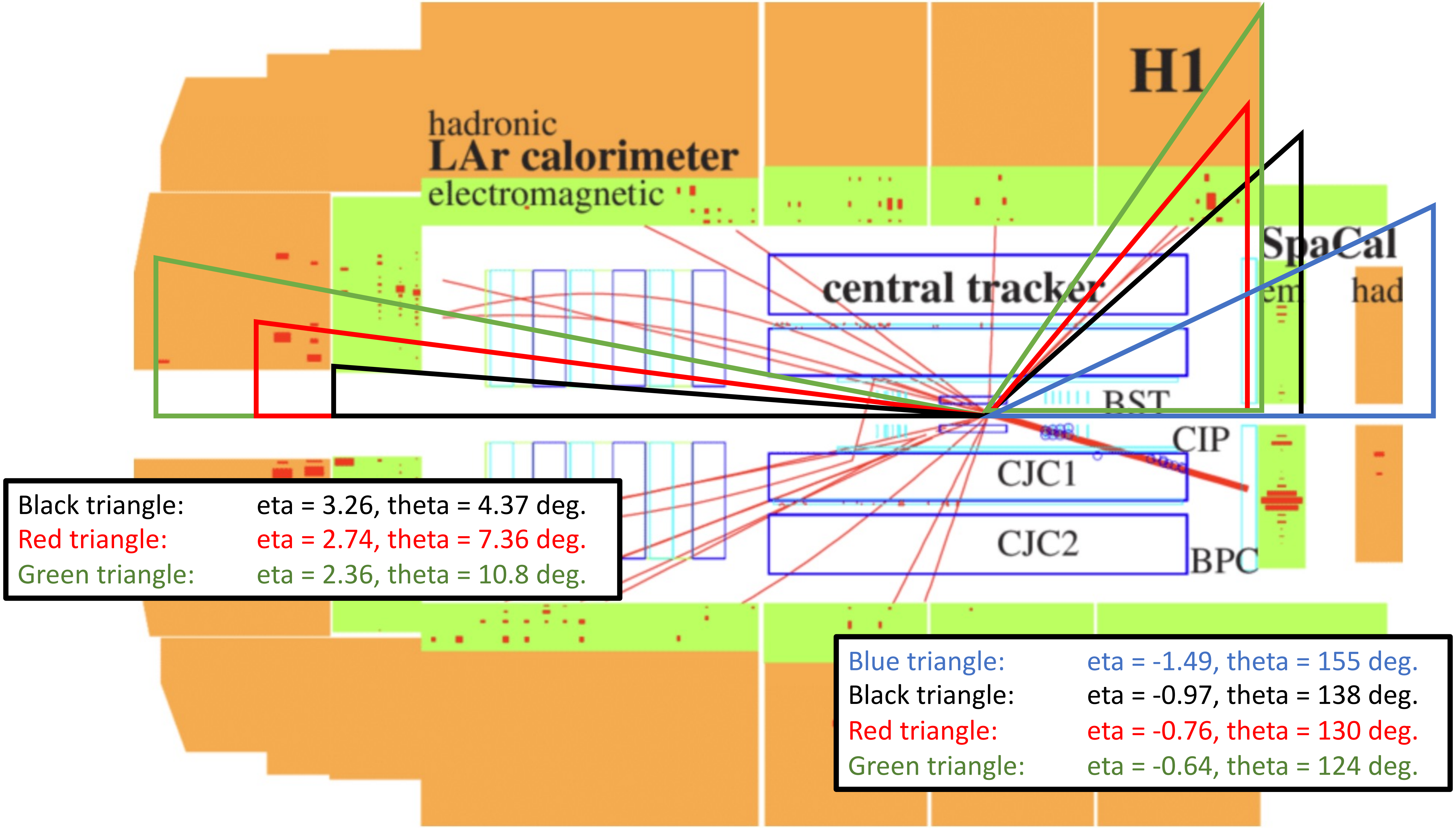
Taking these two factors into account, a *rough* tuning of Delphes fastsim, with noise added agrees pretty well with full-blown Geant3 simulation (of H1).

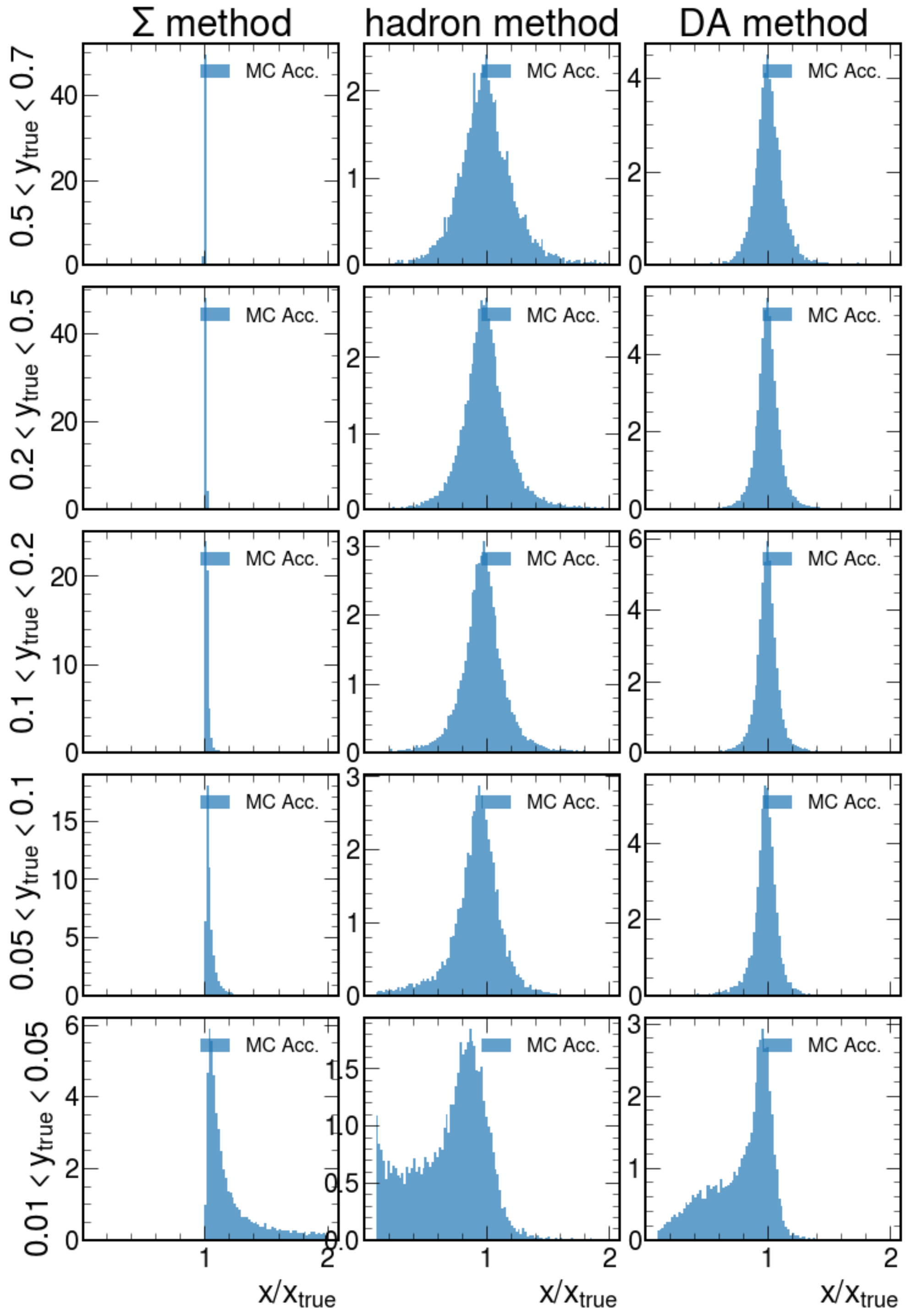
What does this mean for ATHENA?

Including realistic noise / background is essential.

With some tuning, it’s likely that the Delphes fastsim (plus noise) can capture the essential factors for the hadronic reconstruction resolution for ATHENA.

Extra Slides


H1
hadronic
LAr calorimeter
electromagnetic
central tracker
SpaCal
em
had
BST
CIP
CJC1
CJC2
BPC
Black triangle: eta = 3.26, theta = 4.37 deg.
Red triangle: eta = 2.74, theta = 7.36 deg.
Green triangle: eta = 2.36, theta = 10.8 deg.
Blue triangle: eta = -1.49, theta = 155 deg.
Black triangle: eta = -0.97, theta = 138 deg.
Red triangle: eta = -0.76, theta = 130 deg.
Green triangle: eta = -0.64, theta = 124 deg.

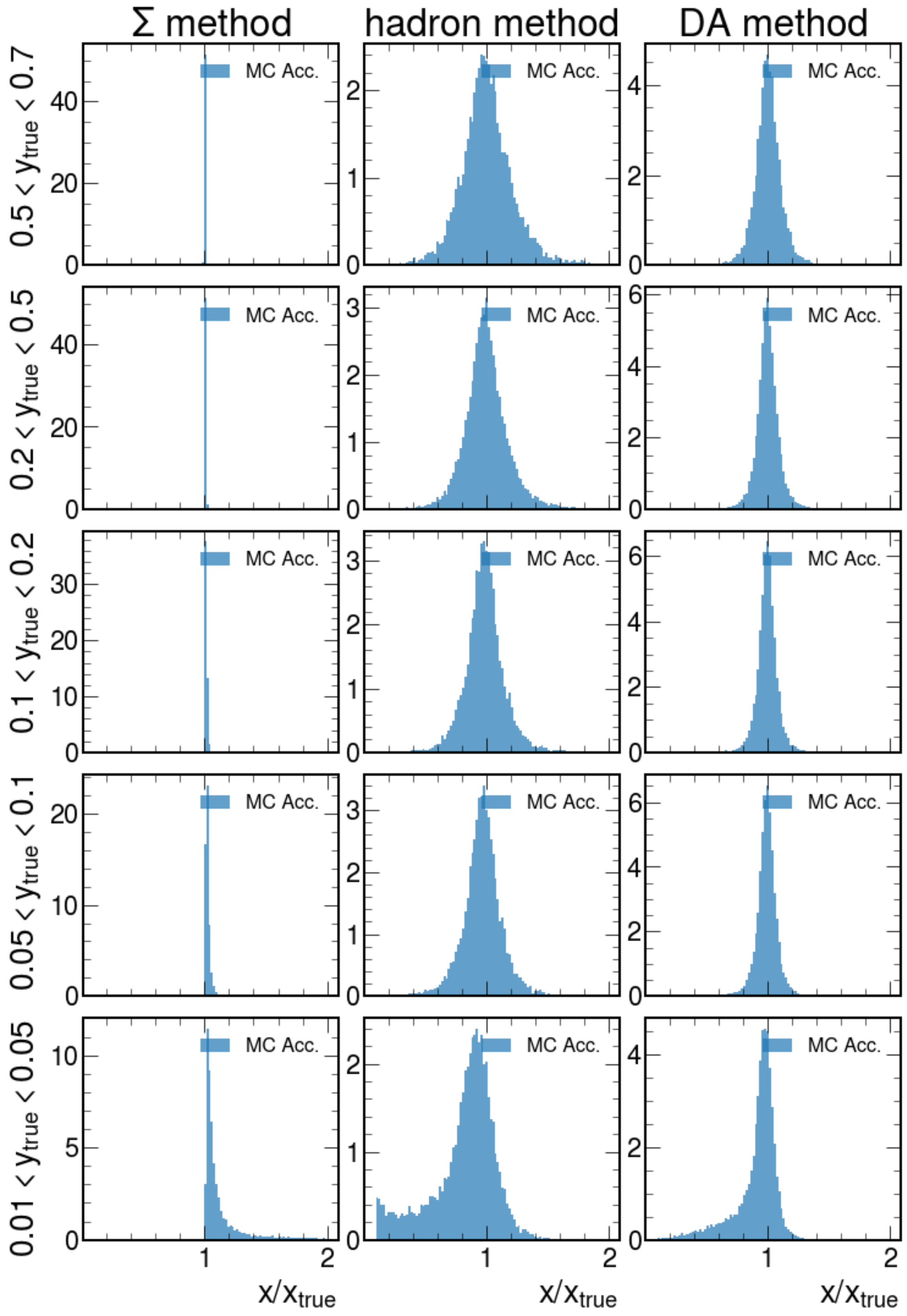


Generator-level MC HFS, |eta|<2.5

This is a cheat using all HFS status=1 MC particles.

The only requirement is on the |eta| of the particles.

This models acceptance effects only with a perfect-response detector.

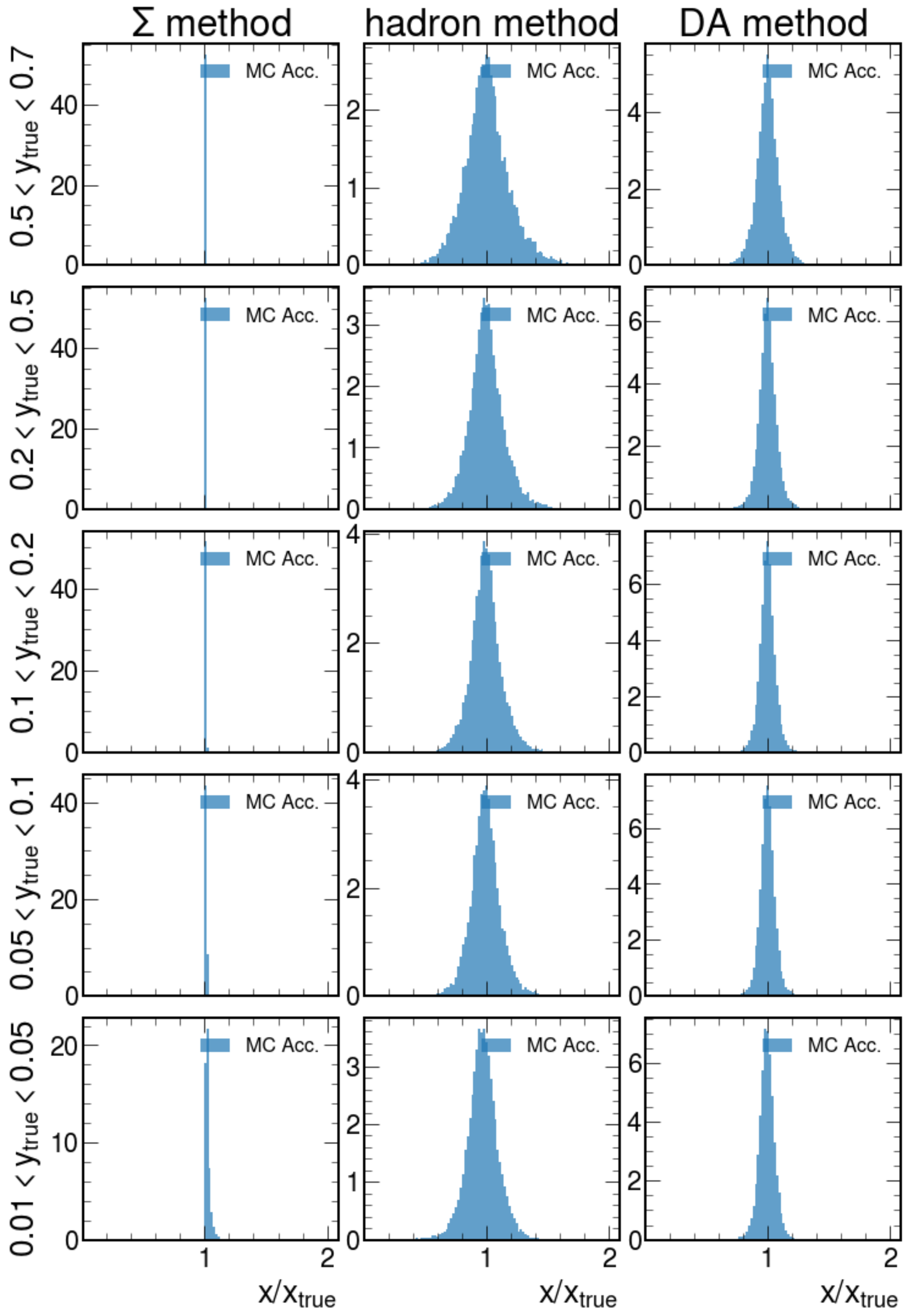


Generator-level MC HFS, |eta|<3.0

This is a cheat using all HFS status=1 MC particles.

The only requirement is on the |eta| of the particles.

This models acceptance effects only with a perfect-response detector.

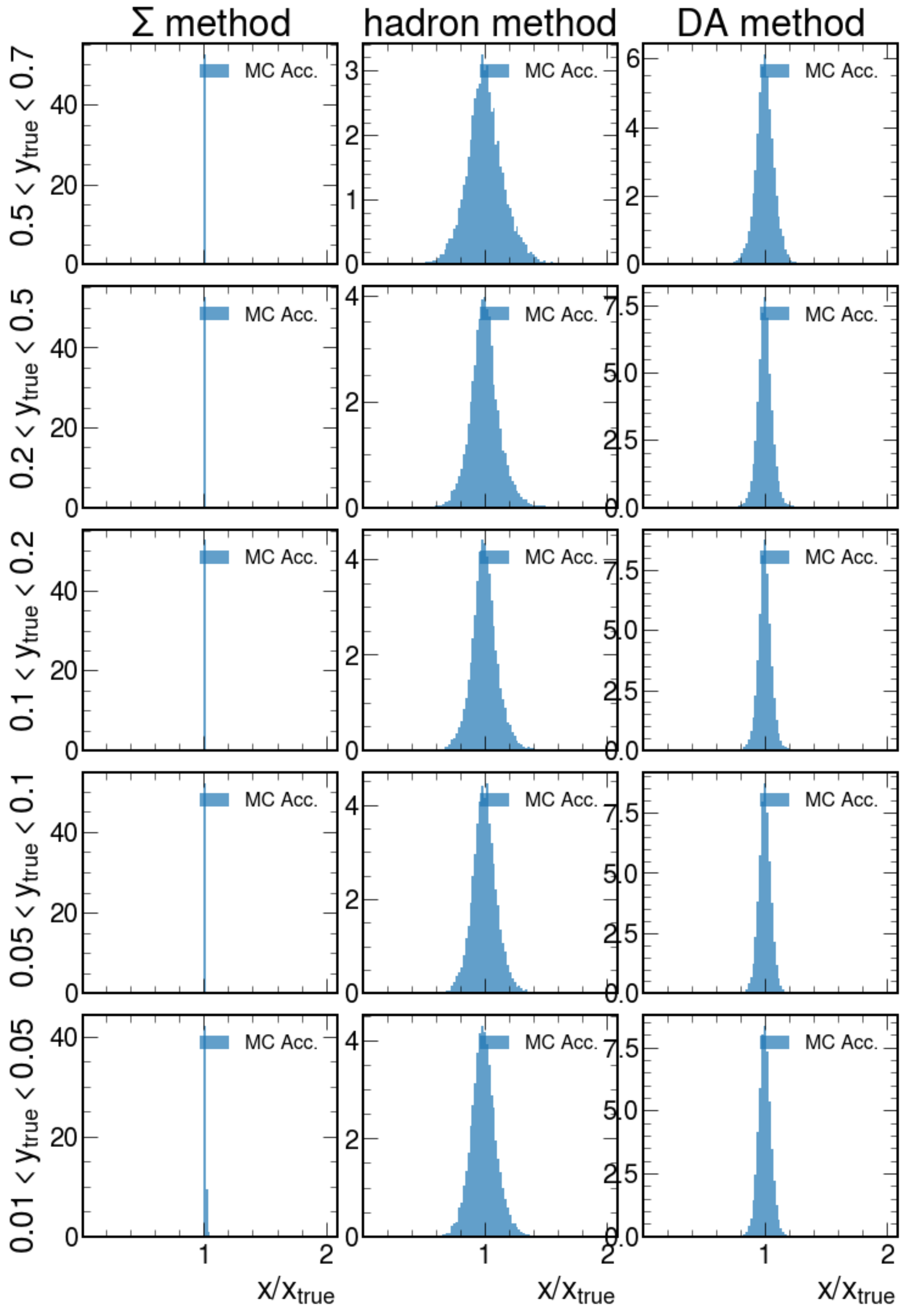


Generator-level MC HFS, |eta|<4.0

This is a cheat using all HFS status=1 MC particles.

The only requirement is on the |eta| of the particles.

This models acceptance effects only with a perfect-response detector.

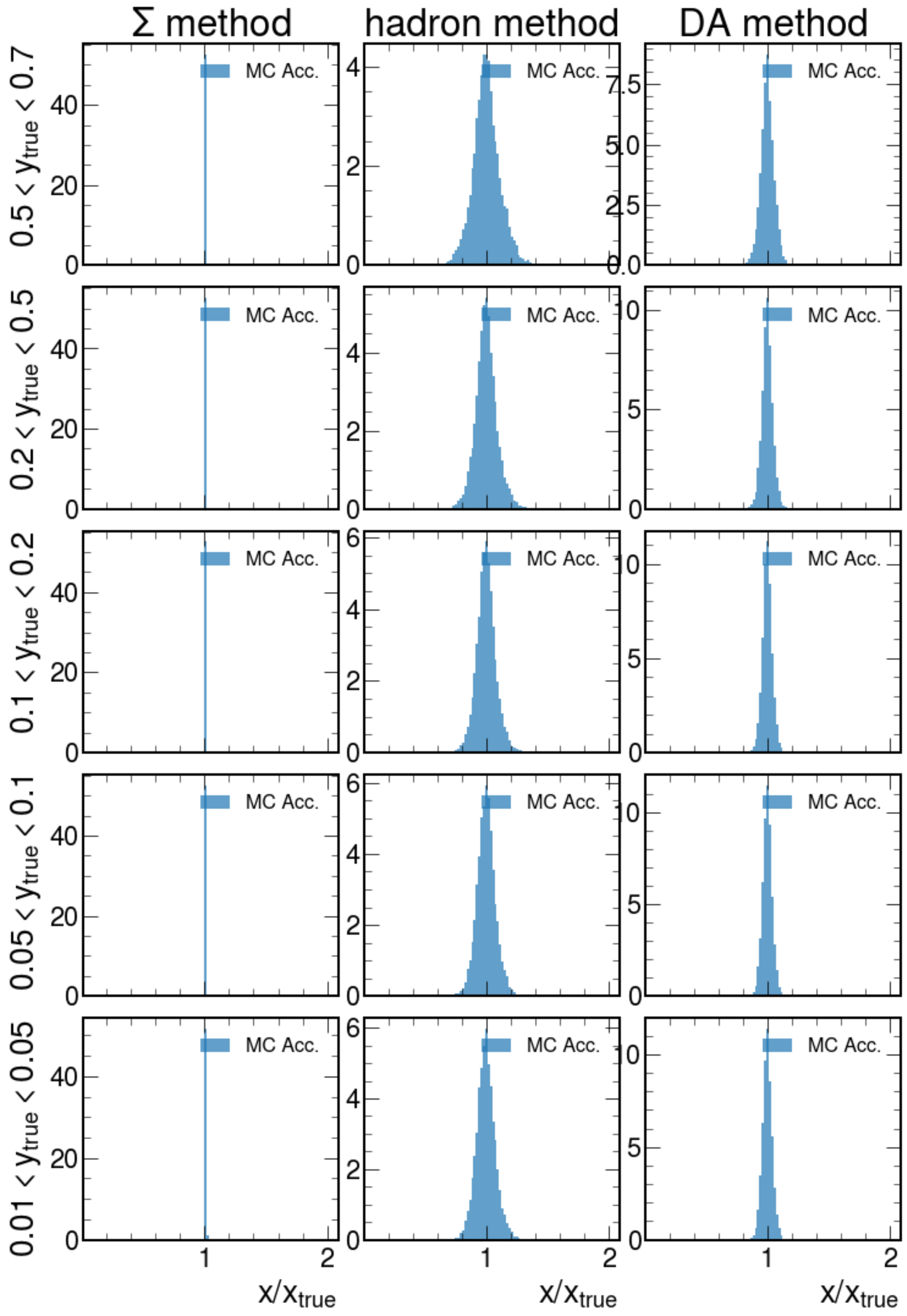


Generator-level MC HFS, |eta|<5.0

This is a cheat using all HFS status=1 MC particles.

The only requirement is on the |eta| of the particles.

This models acceptance effects only with a perfect-response detector.

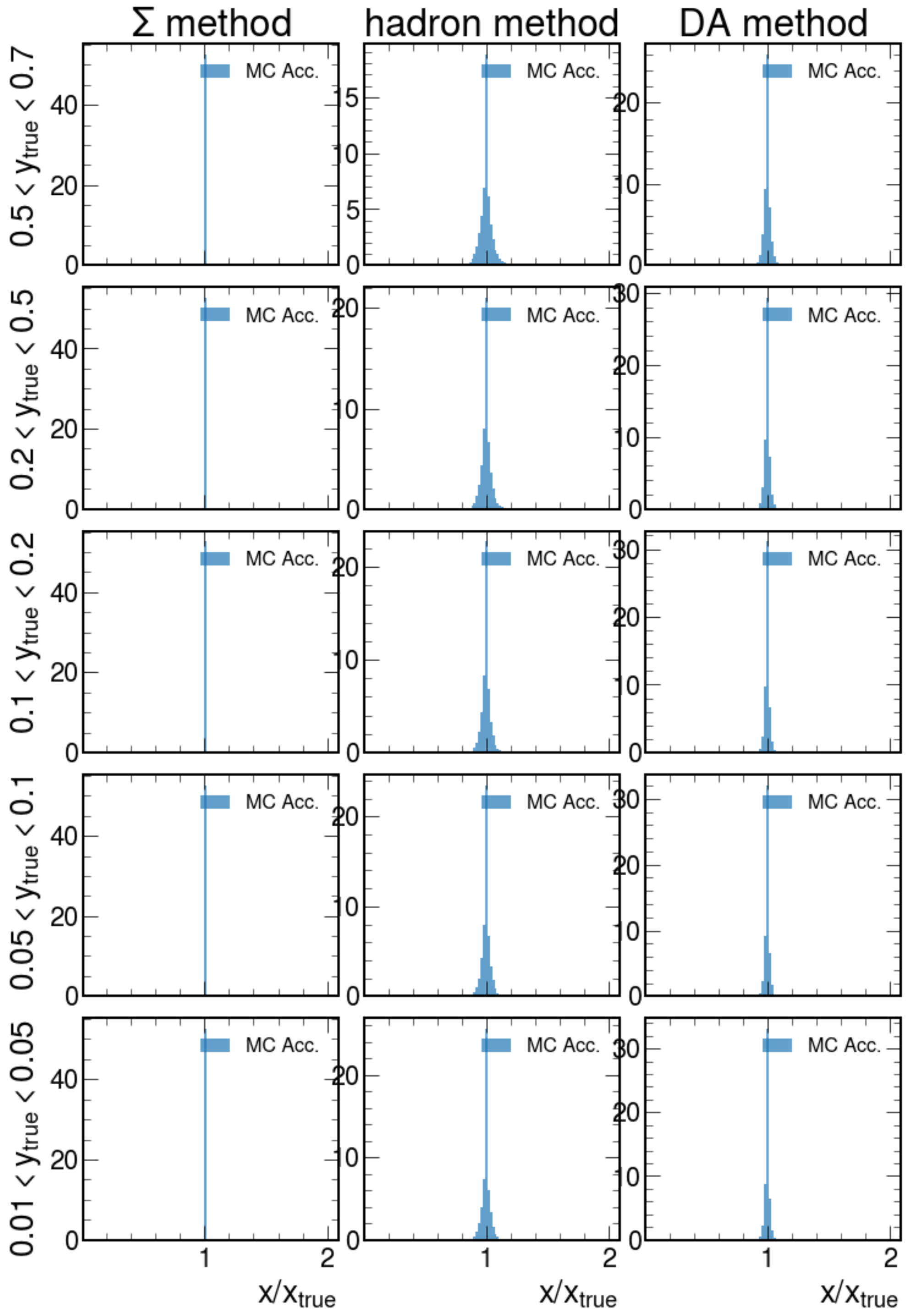


Generator-level MC HFS, |eta|<6.0

This is a cheat using all HFS status=1 MC particles.

The only requirement is on the |eta| of the particles.

This models acceptance effects only with a perfect-response detector.

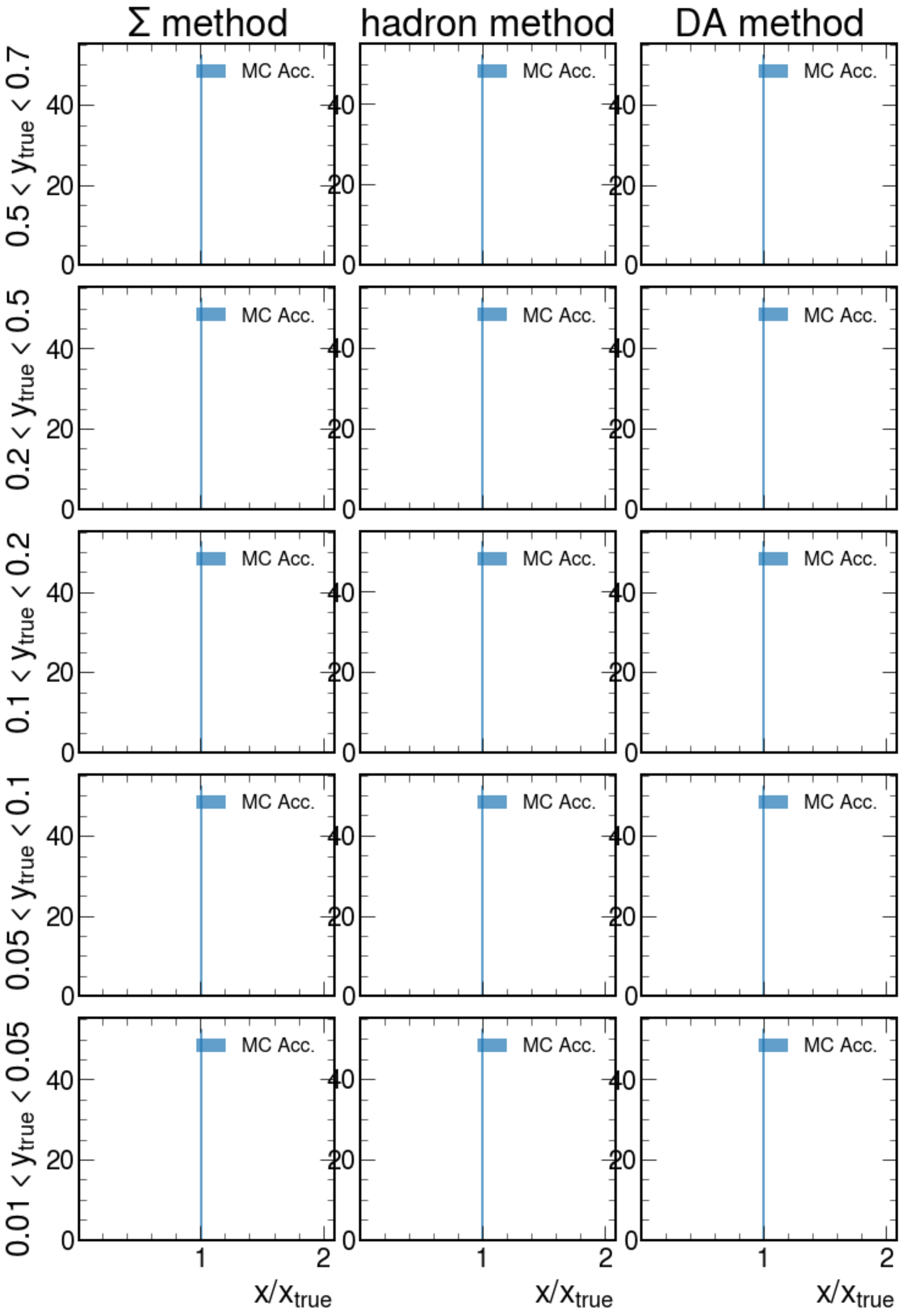


Generator-level MC HFS, |eta|<7.0

This is a cheat using all HFS status=1 MC particles.

The only requirement is on the |eta| of the particles.

This models acceptance effects only with a perfect-response detector.



Generator-level MC HFS, |eta|<9.0

This is a cheat using all HFS status=1 MC particles.

The only requirement is on the |eta| of the particles.

This models acceptance effects only with a perfect-response detector.