Noise in Hadronic Reconstruction Resolution of DIS Q^2, x, y,

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Update

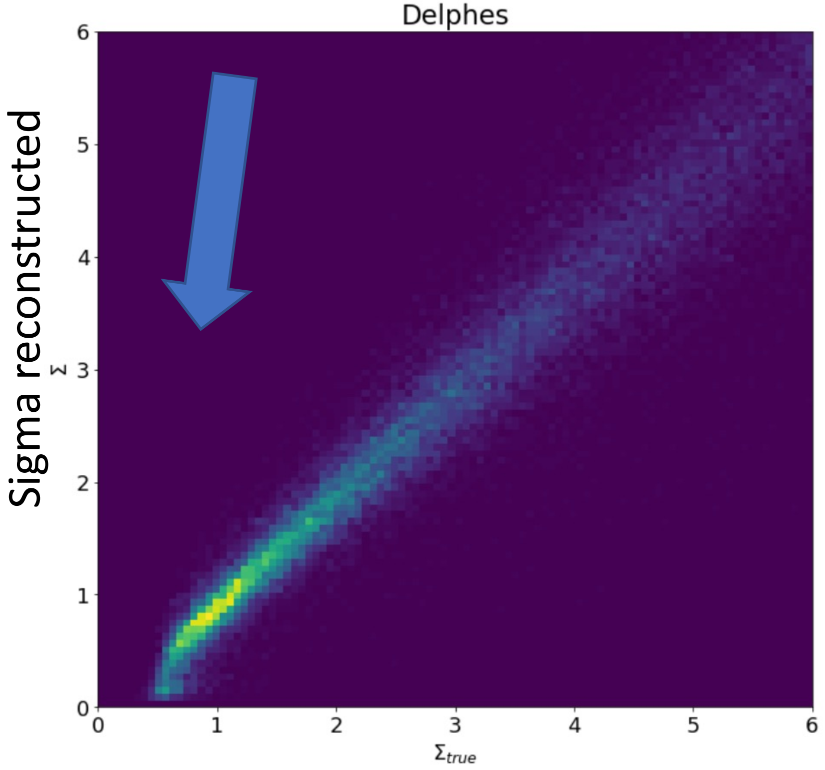
- Found that the missing tail in x resolution at low y in fastsim (Delphes) may be due to a lack of noise / backgrounds.

- Adding in a simple noise model can bring fastsim into reasonable agreement with fullsim (for H1).

Importance of Noise / Background at low y

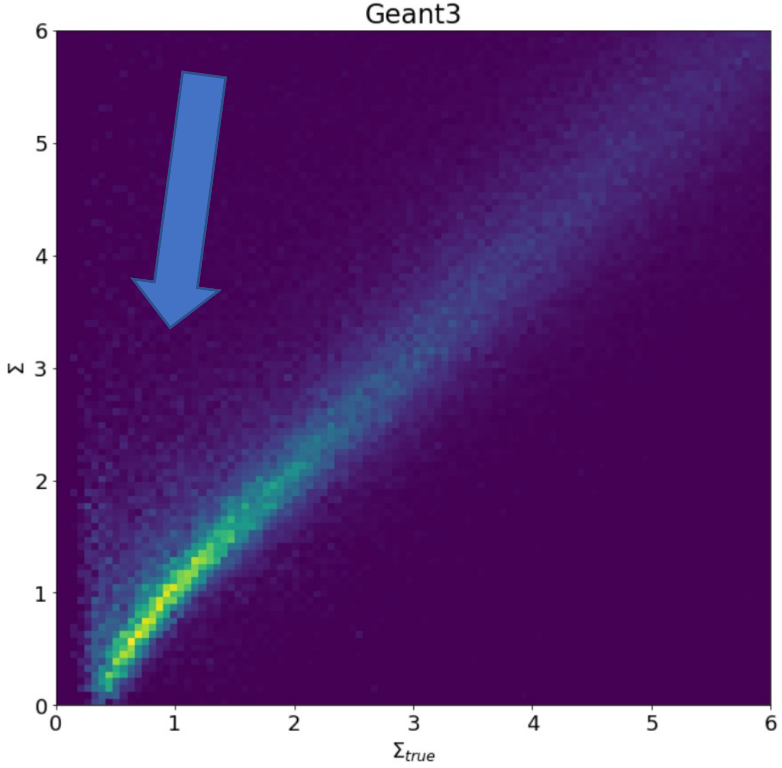
$$\Sigma = \sum_h (E_h - p_{z,h})$$

Fastsim

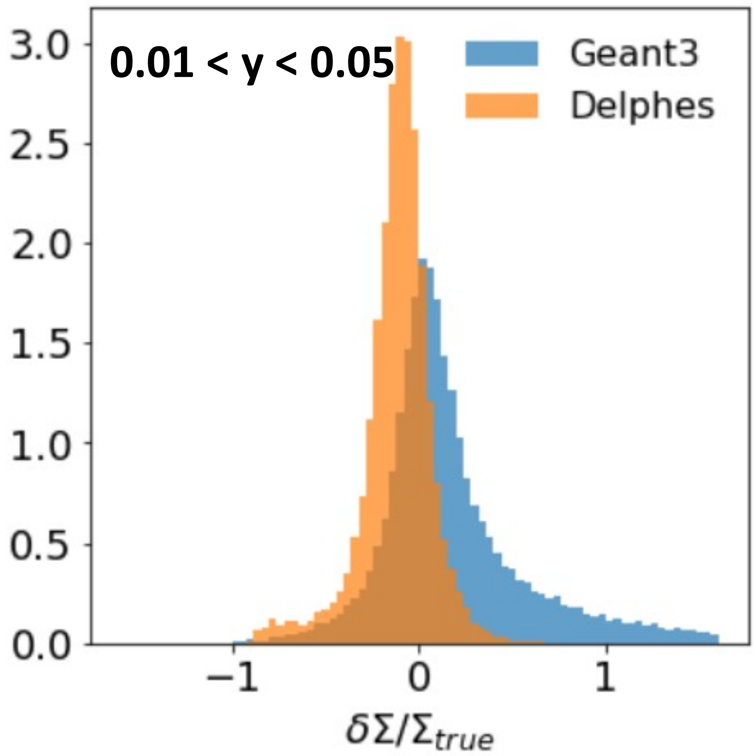


Sigma true

Fullsim

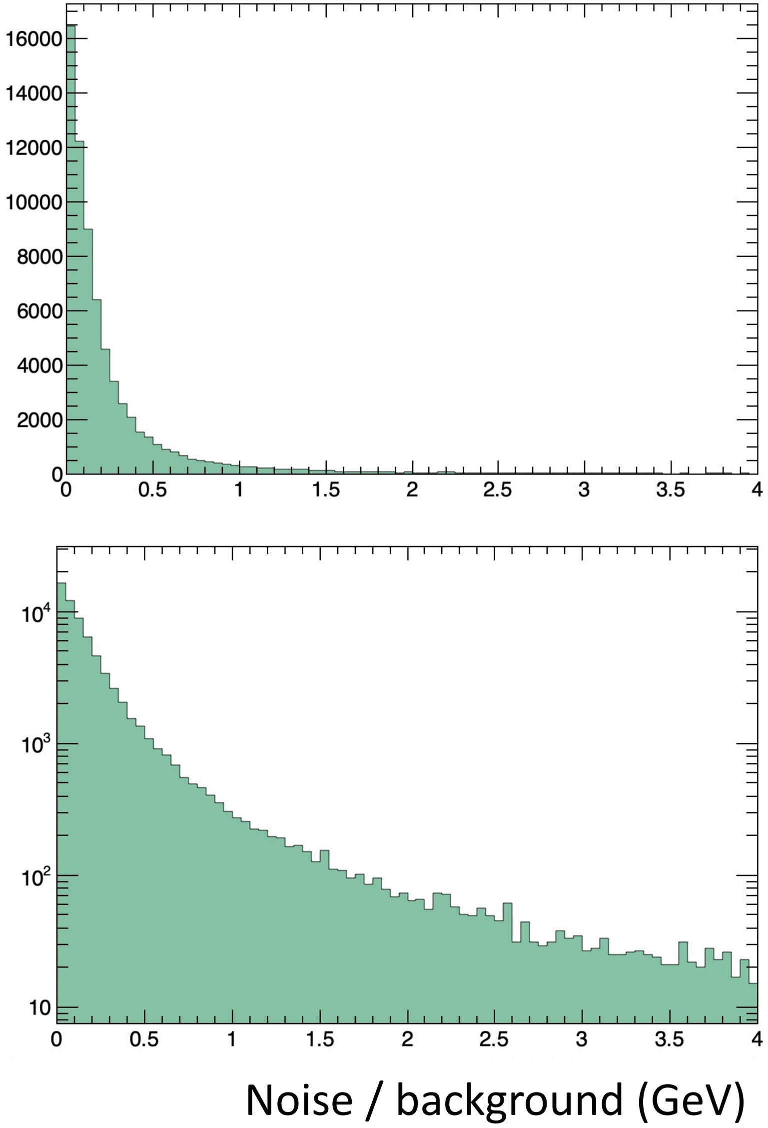


Sigma true



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



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.

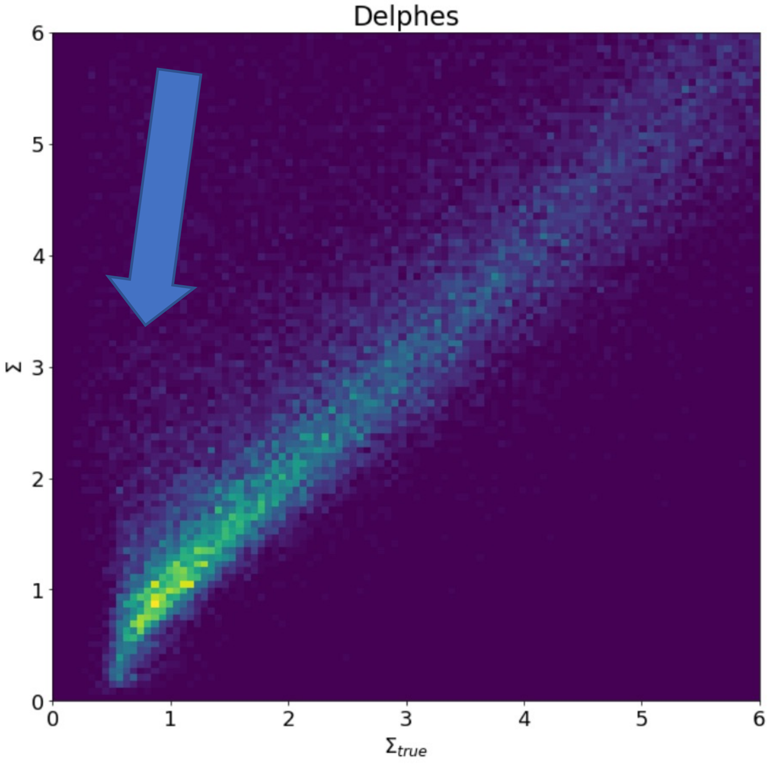
Add sqrt(Npx^2 + Npy^2 + Npz^2) to HFS E.

Importance of Noise / Background at low y

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

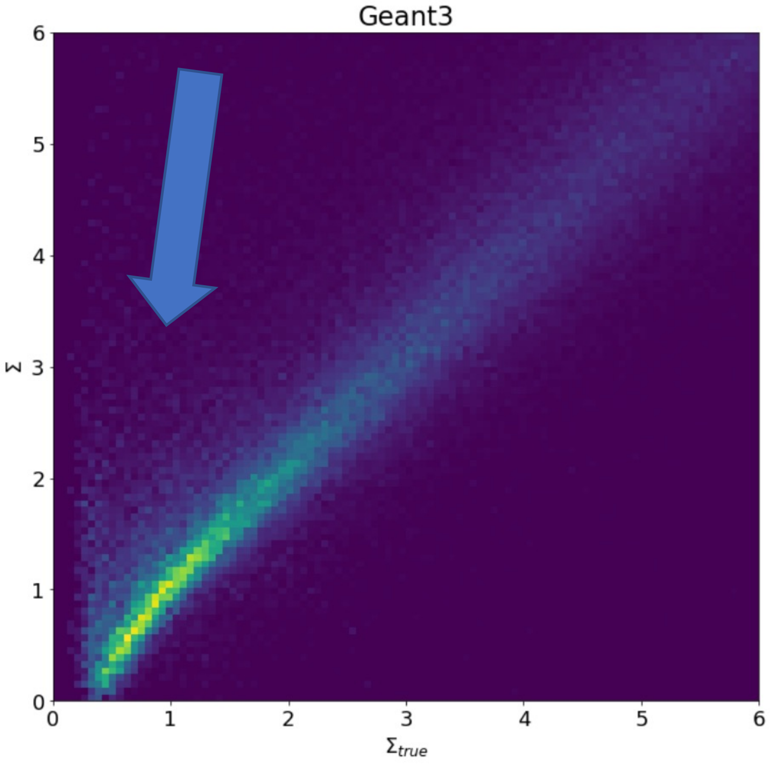
Fastsim + noise

Sigma reconstructed

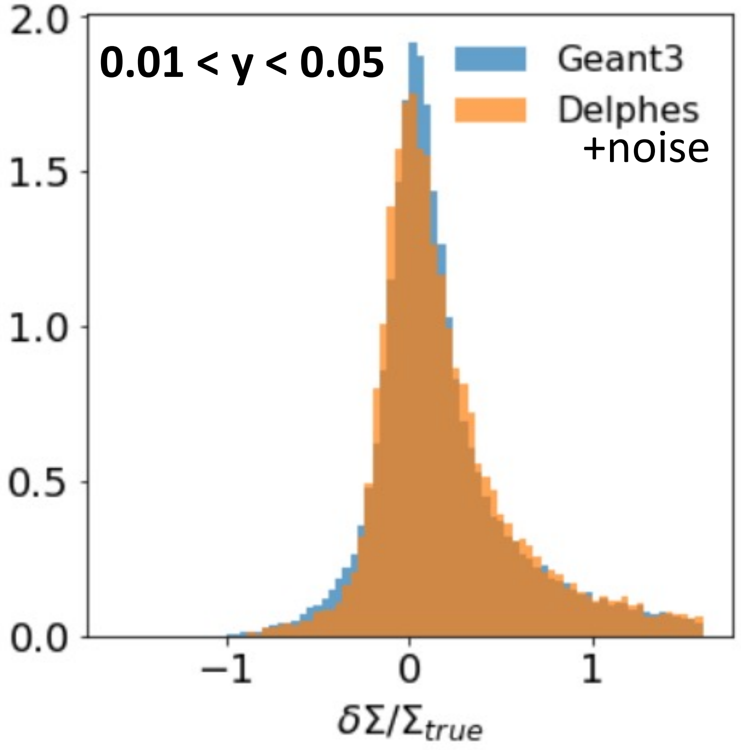


Sigma true

Fullsim



Sigma true



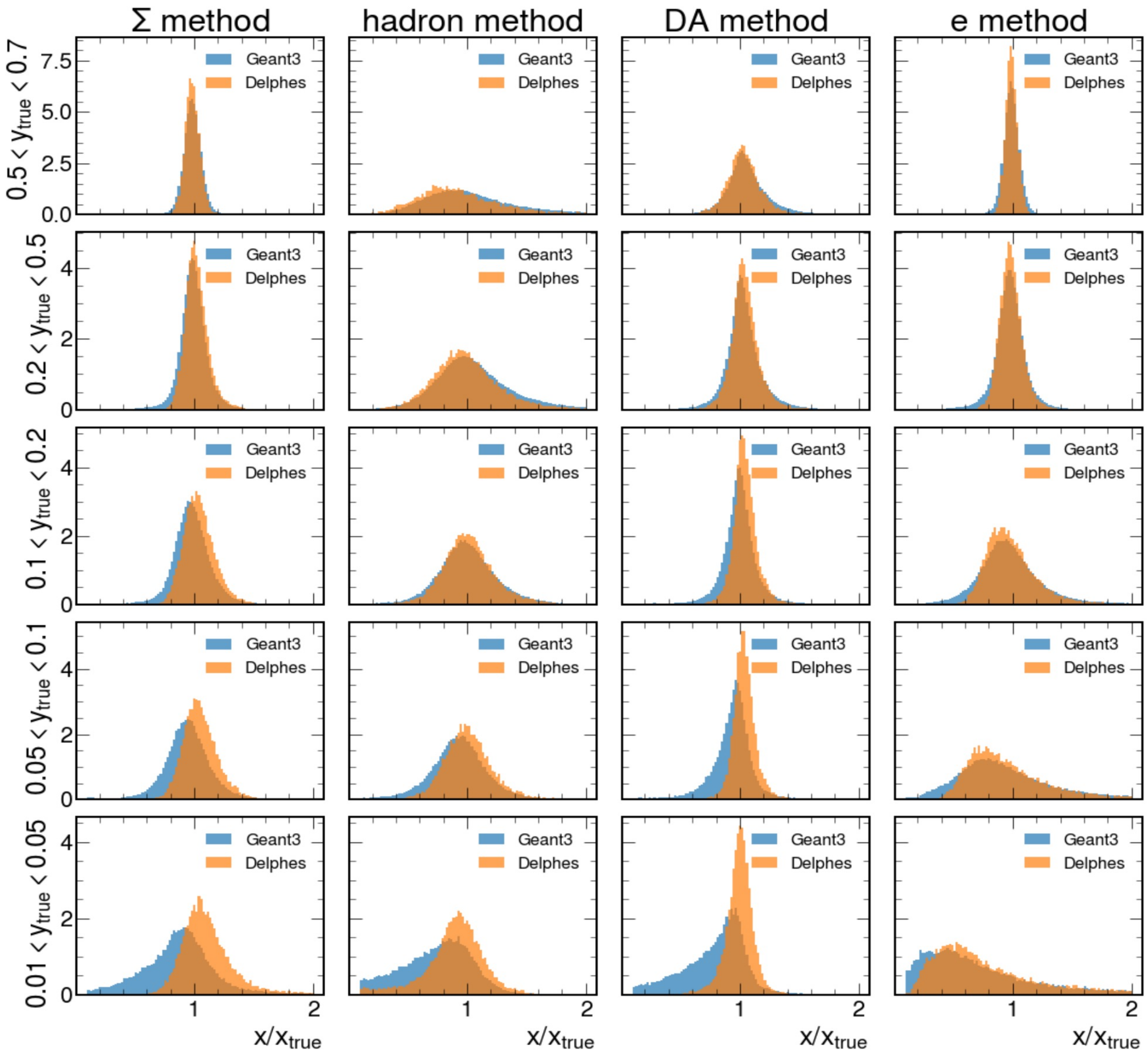
Much better agreement between fullsim and fastsim after adding noise to fastsim!

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

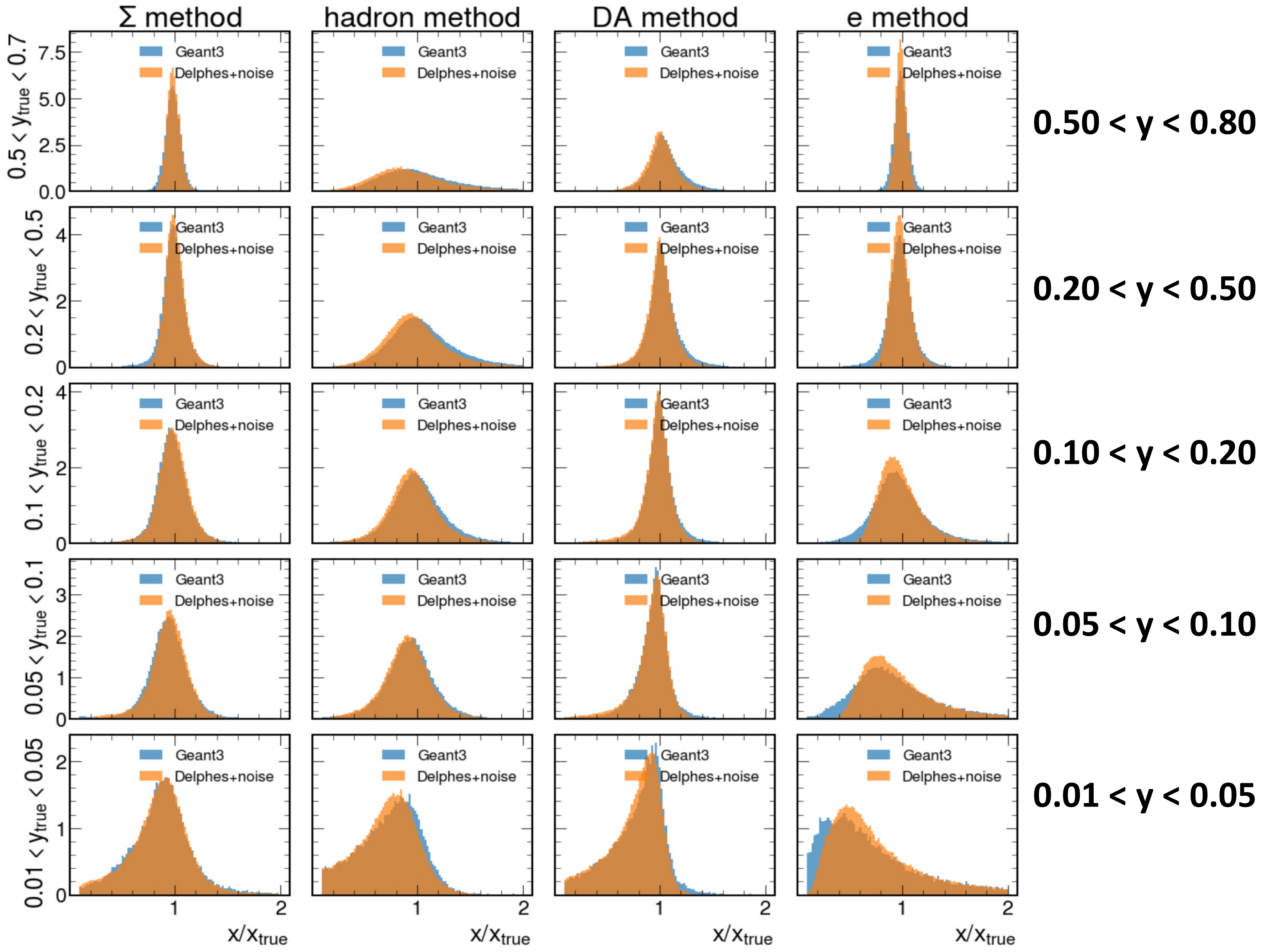
0.05 < y < 0.10

0.01 < y < 0.05

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.



ATHENA fastsim

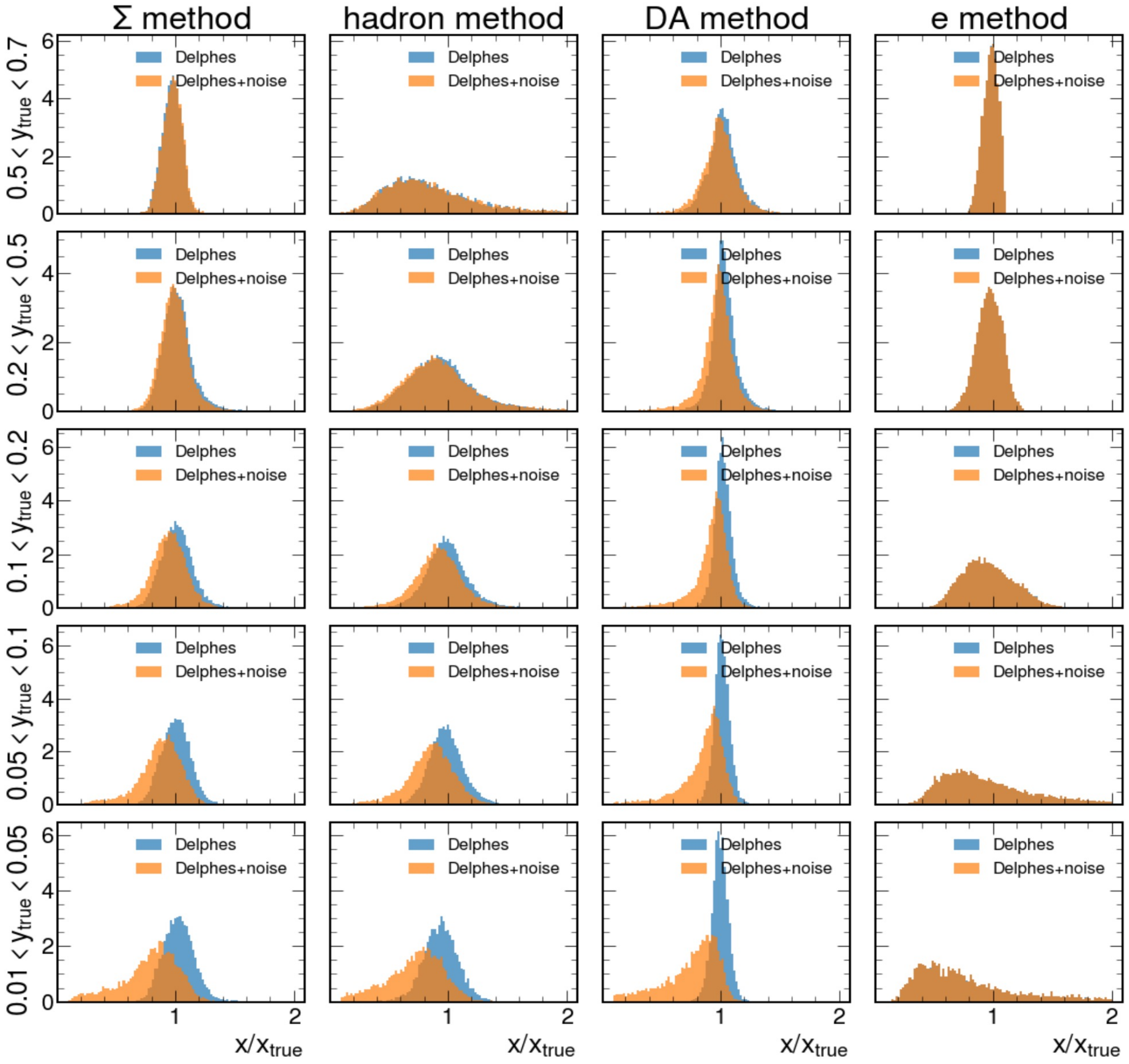
Tried adding the same noise to ATHENA fastsim (Delphes).

For HFS reconstruction, using Energy Flow candidates (tracks, photons, NH), though results with calo Towers looks similar.

ATHENA, with and without added noise

Resolution with noise is very similar to H1 fullsim or H1 fastsim+noise.

Noise completely dominates the resolution at low y in hadronic methods.



0.50 < y < 0.80

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0.05 < y < 0.10

0.01 < y < 0.05

Some conclusions

Noise / backgrounds are very important if you want to get the x resolution correct at low y.

We haven't ruled out that this is due to non-Gaussian resolution tails.

It's probably some complex combination of all 3 (noise, backgrounds, non-Gaussian tails).

What do we do?

Can we come up with realistic, reasonable estimates or bounds for electronics noise, especially in the ECAL? This is important for both fastsim and fullsim.

Would be interesting to model any non-Gaussian tails seen in fullsim and try to include those in Delphes, if that's possible.

Are there important physical backgrounds that should be examined? For example, is pileup totally negligible? Beam backgrounds? Cosmics? This could be important for both fastsim and fullsim.

Extra Slides

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.

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

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

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

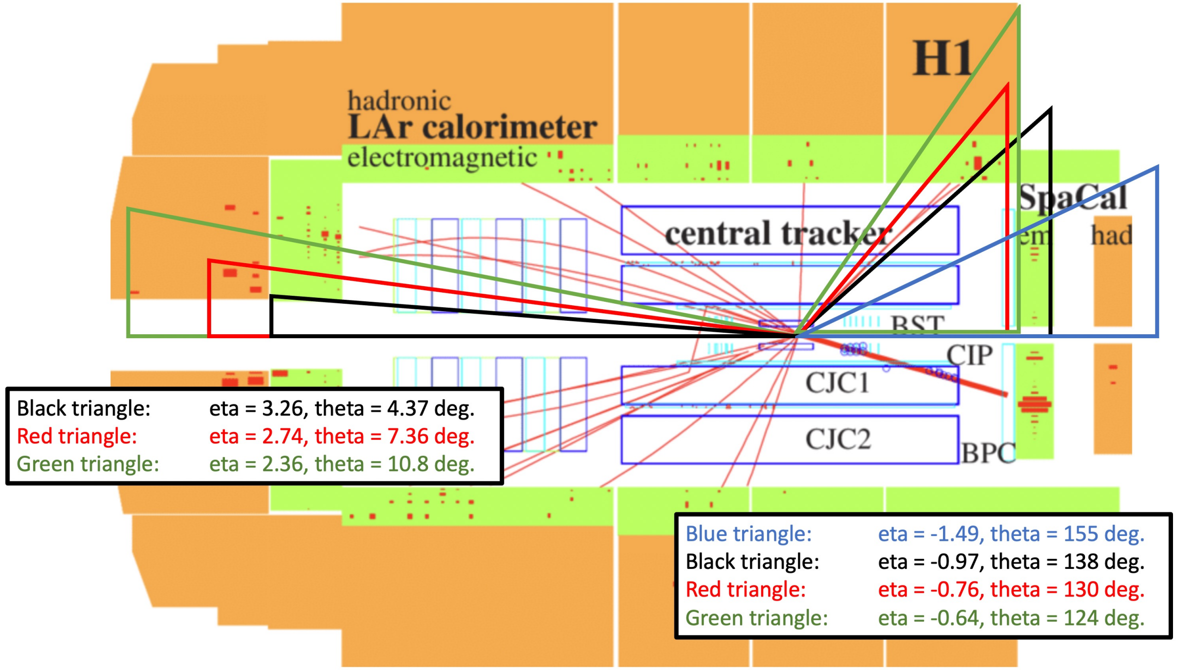
Appendix: y, Q^2 and x formulae

method	y	Q^2	x	
e	$1-\frac{E}{E^e}\sin^2\frac{\theta}{2}$	$4E^eE\cos^2\frac{\theta}{2}$	Q^2/ys	*Electron*
h	$\frac{\Sigma}{2E^e}$	$\frac{T^2}{1-y_h}$	Q^2/ys	*Hadron*
m	y_h	Q_e^2	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_Σ^2	$\frac{E}{E^p}\ \frac{\cos^2\theta/2}{y_\Sigma}$	

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%.

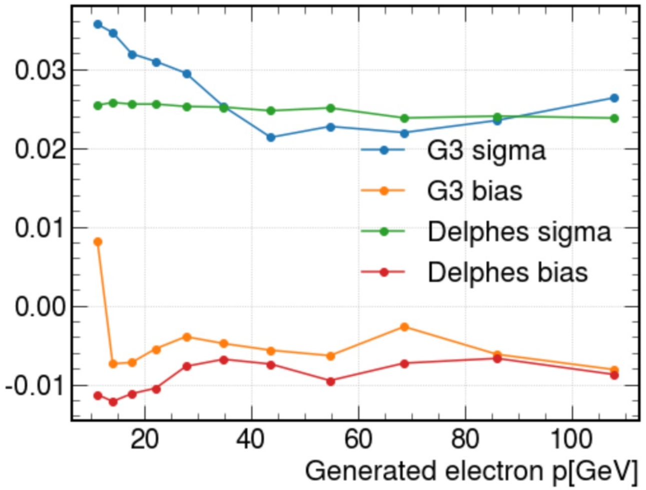


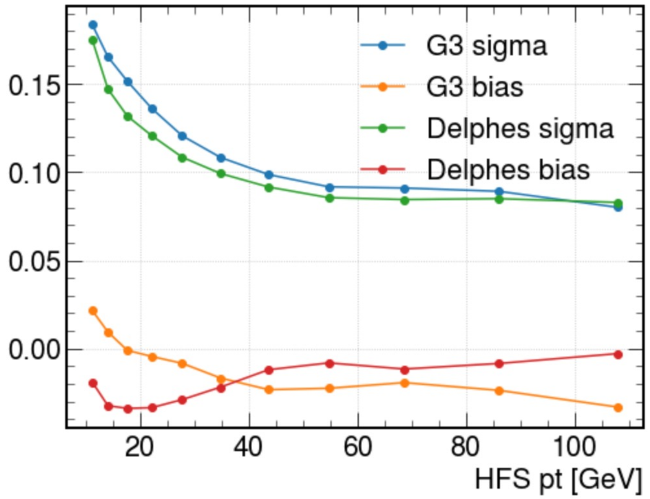
Detector	Acceptance	Resolution
Tracking	|eta| < 2.0	**3.5% + pT*cosh(eta)*0.002**
ECAL	|eta| < 3.35	Barrel: -1.46 < eta < 3.35 **2.5% + 11%/sqrt(E)** Endcap: -3.35 < eta< -1.46 **3.0% + 10%/sqrt(E)**
HCAL	-0.96 < eta < 3.35	Core: -0.64 < eta < 3.20 **20% + 50%/sqrt(E)** Edges: 3.20 to 3.35 and -0.97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

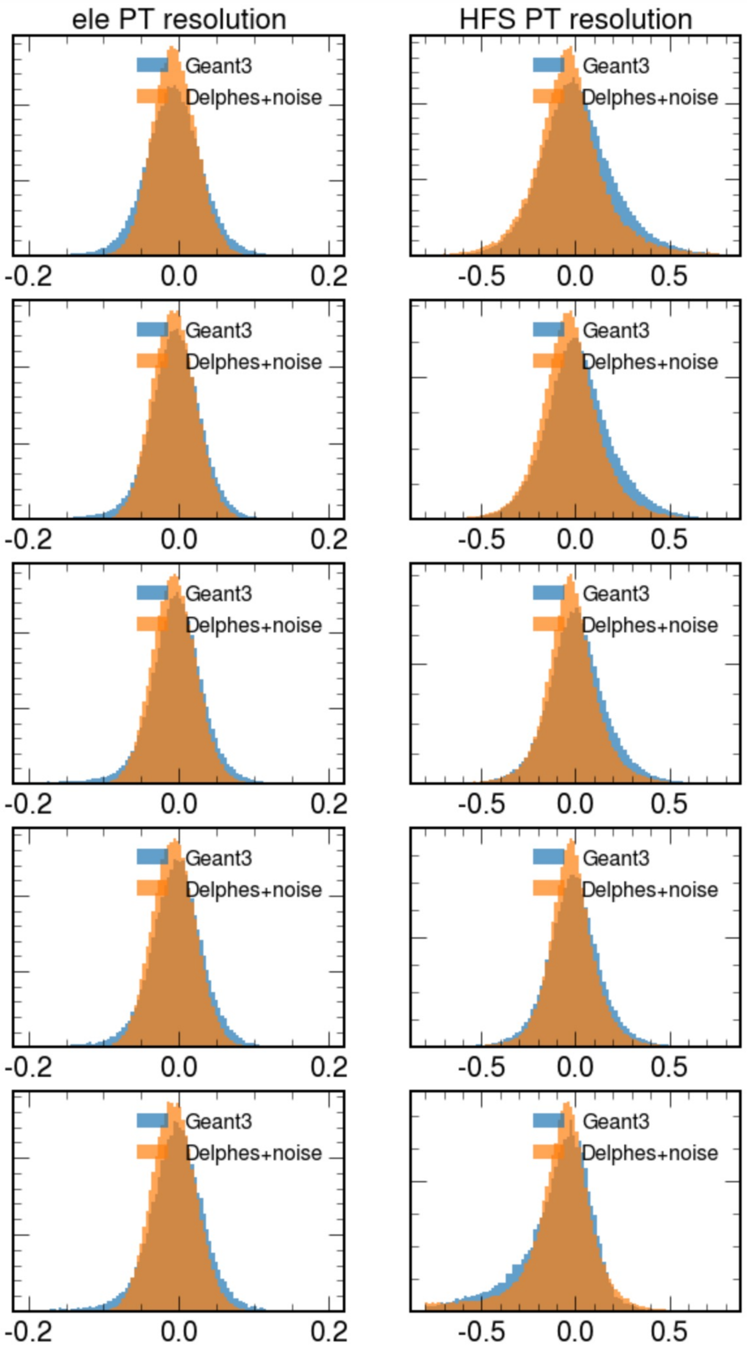
Resolutions based on NIM A 386 (1997) 310 with very rough adjustments from trial and error (not a systematic tuning yet).

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

Resolution for both electron and HFS in pretty good agreement.







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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.