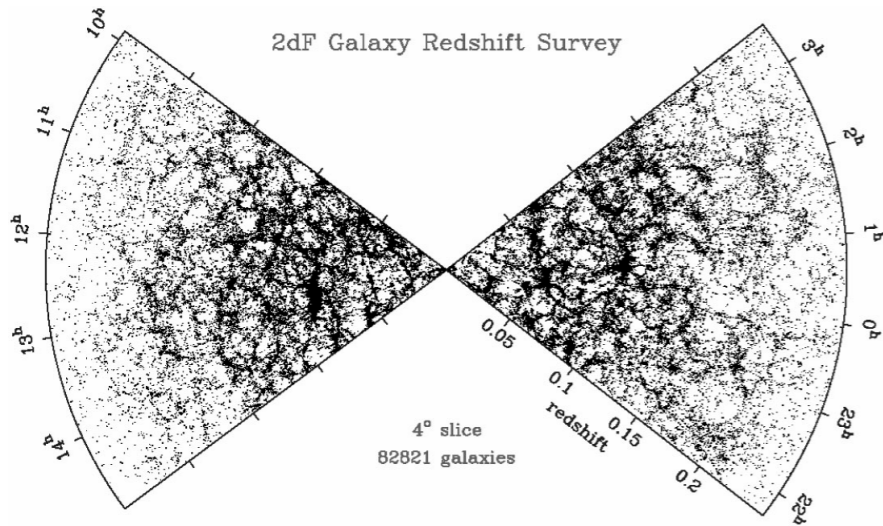


# Open questions in LSS parameter inference

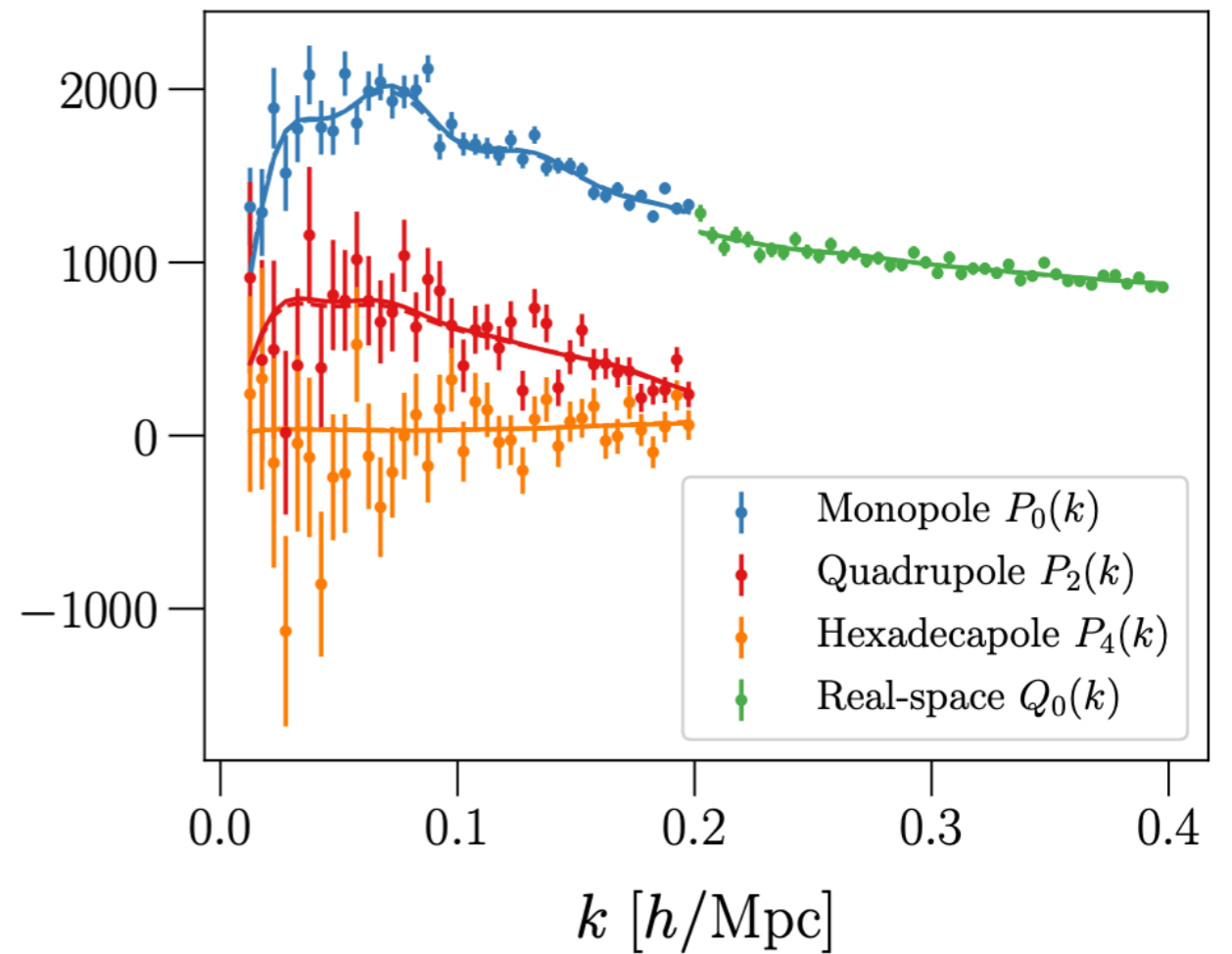
Marko Simonović  
University of Florence

# Standard analyses

galaxy map



$kP_l(k) [h^{-2}\text{Mpc}^2]$

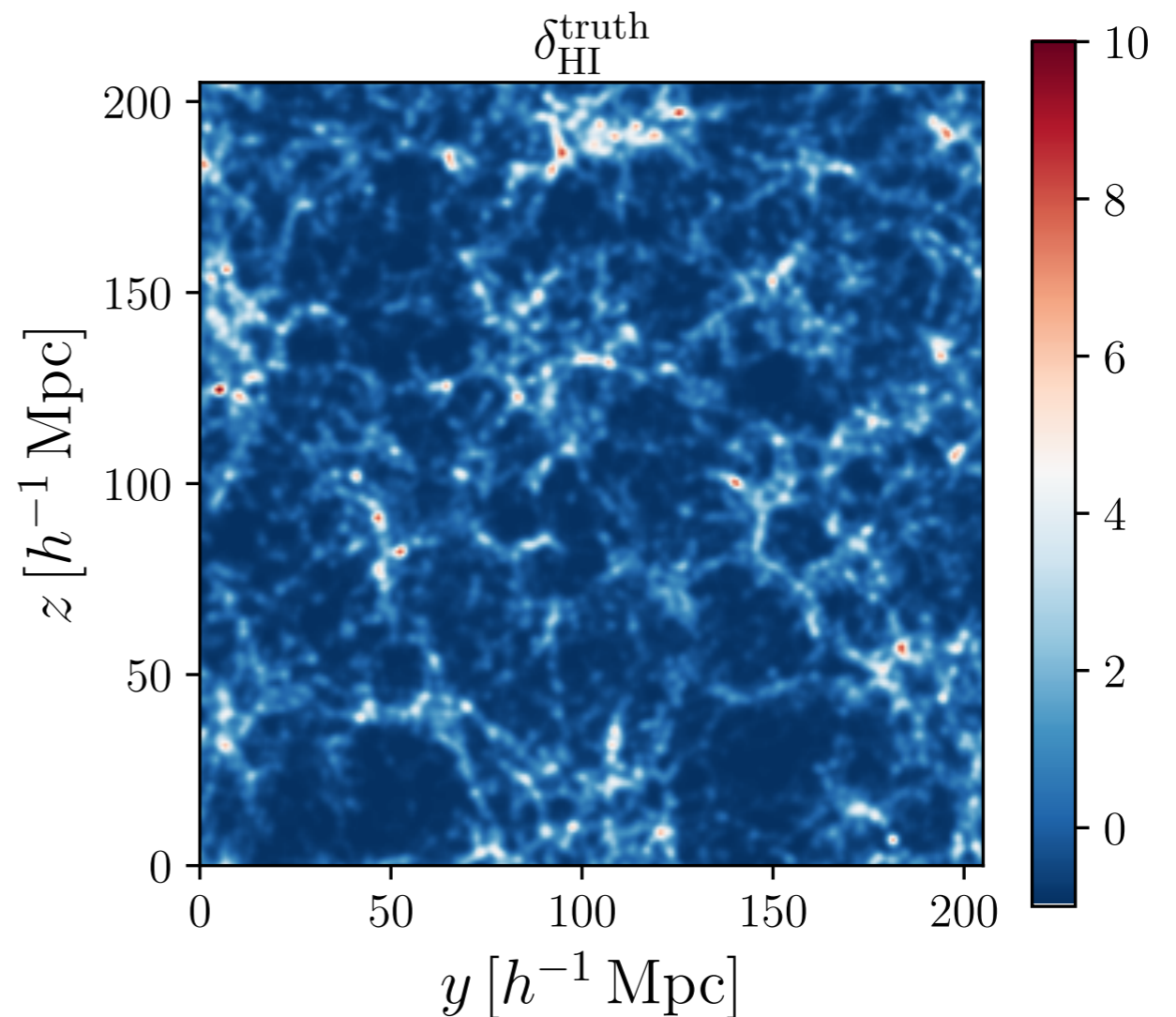
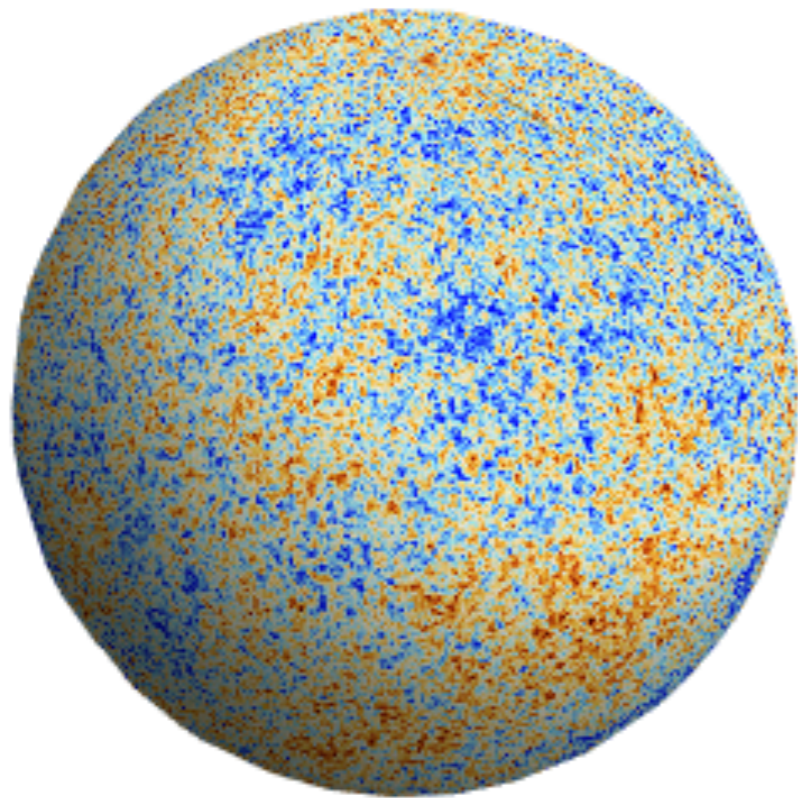


Full-shape analysis

# Field-level inference

Fit the whole map, not statistics

This is an optimal analysis



At the moment, not possible for LSS using sims.

# Field-level inference

## Perturbative forward modeling

IC



nonlinear density field using PT

$$\delta_g = \delta_g[\delta, \boldsymbol{\theta}] + \epsilon_g$$

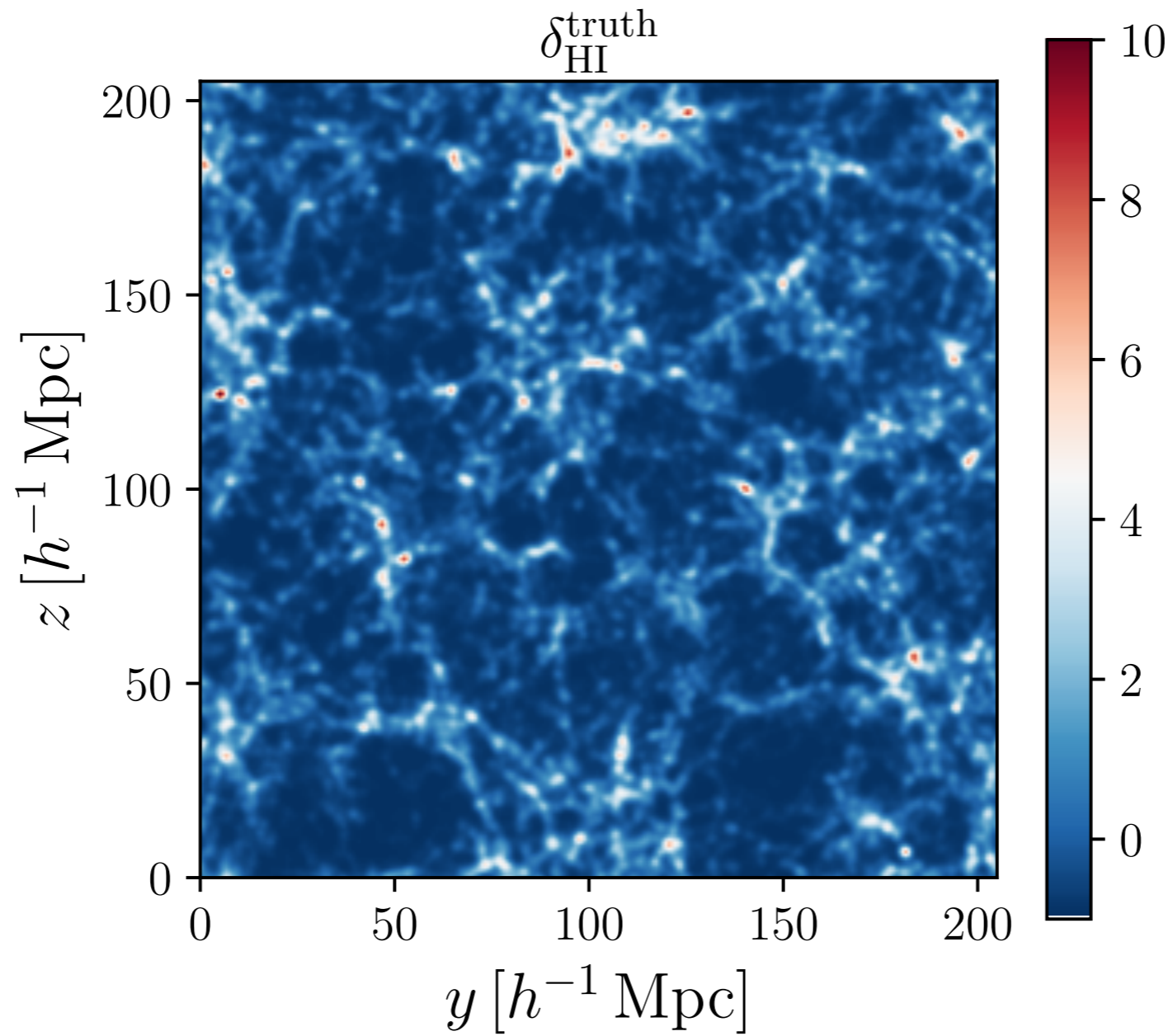
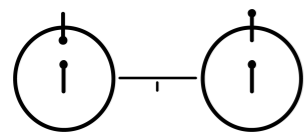
$$\tilde{\mathcal{O}}(\mathbf{k}) \equiv \int d^3\mathbf{q} \mathcal{O}(\mathbf{q}) e^{-i\mathbf{k}\cdot(\mathbf{q}+\psi_1(\mathbf{q}))}$$

$$\psi_1(\mathbf{q}) = \int_{\mathbf{k}} e^{i\mathbf{k}\cdot\mathbf{q}} \frac{i\mathbf{k}}{k^2} \delta_1(\mathbf{k})$$

$$b_1^L \delta_1(\mathbf{q}) + b_2^L (\delta_1^2(\mathbf{q}) - \sigma_1^2) + b_{\mathcal{G}_2}^L \mathcal{G}_2(\mathbf{q}) + \dots$$

# Field-level inference

Obuljen, MS, Schneider, Feldmann (2022)

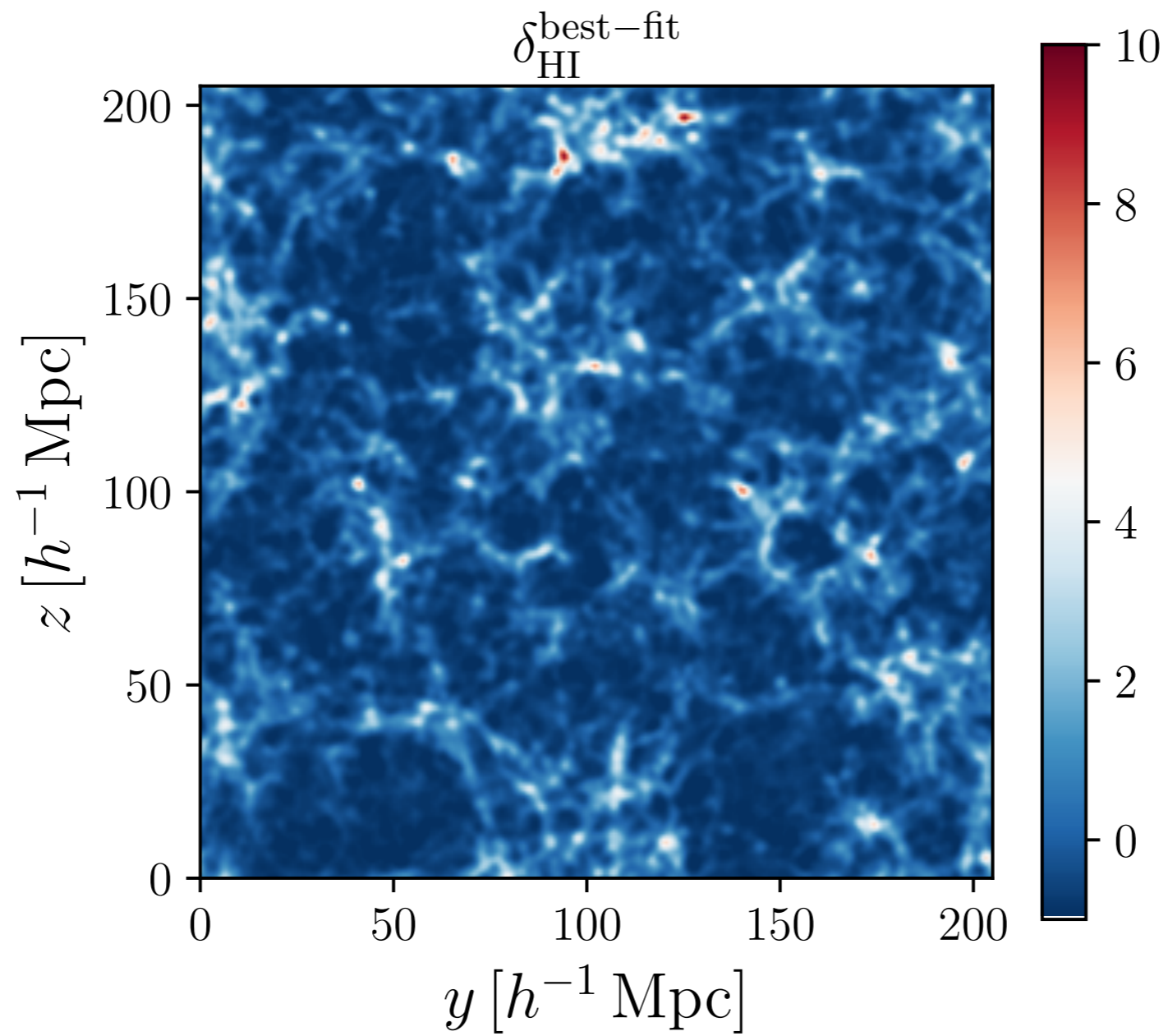
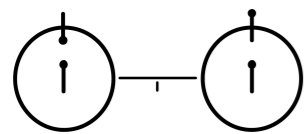


Hydro code



# Field-level inference

Obuljen, MS, Schneider, Feldmann (2022)



PT map

# Field-level inference

## Likelihood and posterior

$$\mathcal{L}[\hat{\delta}_g | \delta, \boldsymbol{\theta}] = \text{normalization} \times \exp \left( -\frac{1}{2} \int_{\mathbf{k}} \frac{|\hat{\delta}_g(\mathbf{k}) - \delta_g[\delta, \boldsymbol{\theta}](\mathbf{k})|^2}{P_\epsilon} \right)$$

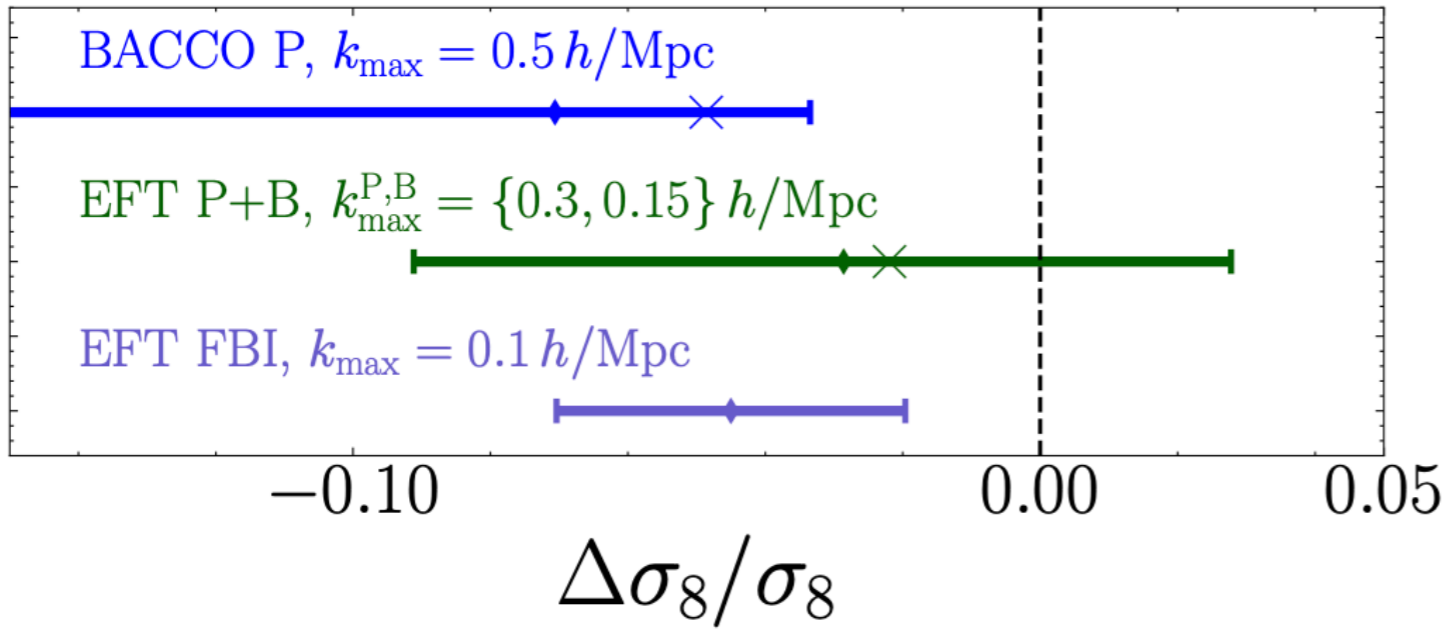
$\sim 10^7$  params.



$$\mathcal{P}[\boldsymbol{\theta} | \hat{\delta}_g] = \mathcal{N} \times \int \mathcal{D}\delta \exp \left( -\frac{1}{2} \int_{\mathbf{k}} \frac{|\delta(\mathbf{k})|^2}{P(k)} - \frac{1}{2} \int_{\mathbf{k}} \frac{|\hat{\delta}_g(\mathbf{k}) - \delta_g[\delta, \boldsymbol{\theta}](\mathbf{k})|^2}{P_\epsilon} \right) \times p(\boldsymbol{\theta})$$

# Field-level inference

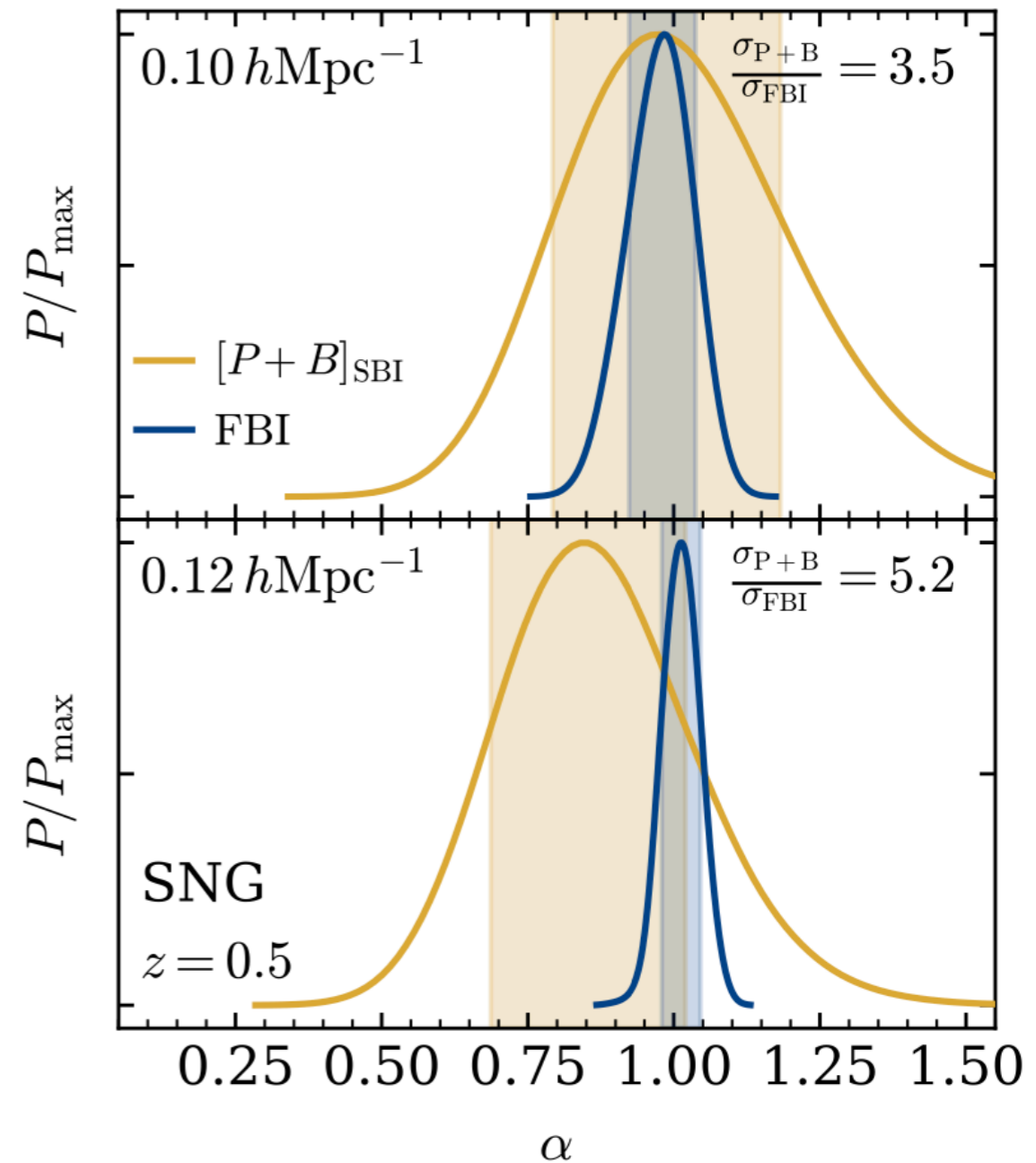
real-space snapshots (mean of 10 realizations), fixed  $\omega_m, \omega_b, n_s, h$



Krause et. al. (2024)  
Beyond 2-pf collaboration

$\sigma_8$  important for BSM

Nguyen, Schmidt, Tucci, Reinecke, Kostic (2024)

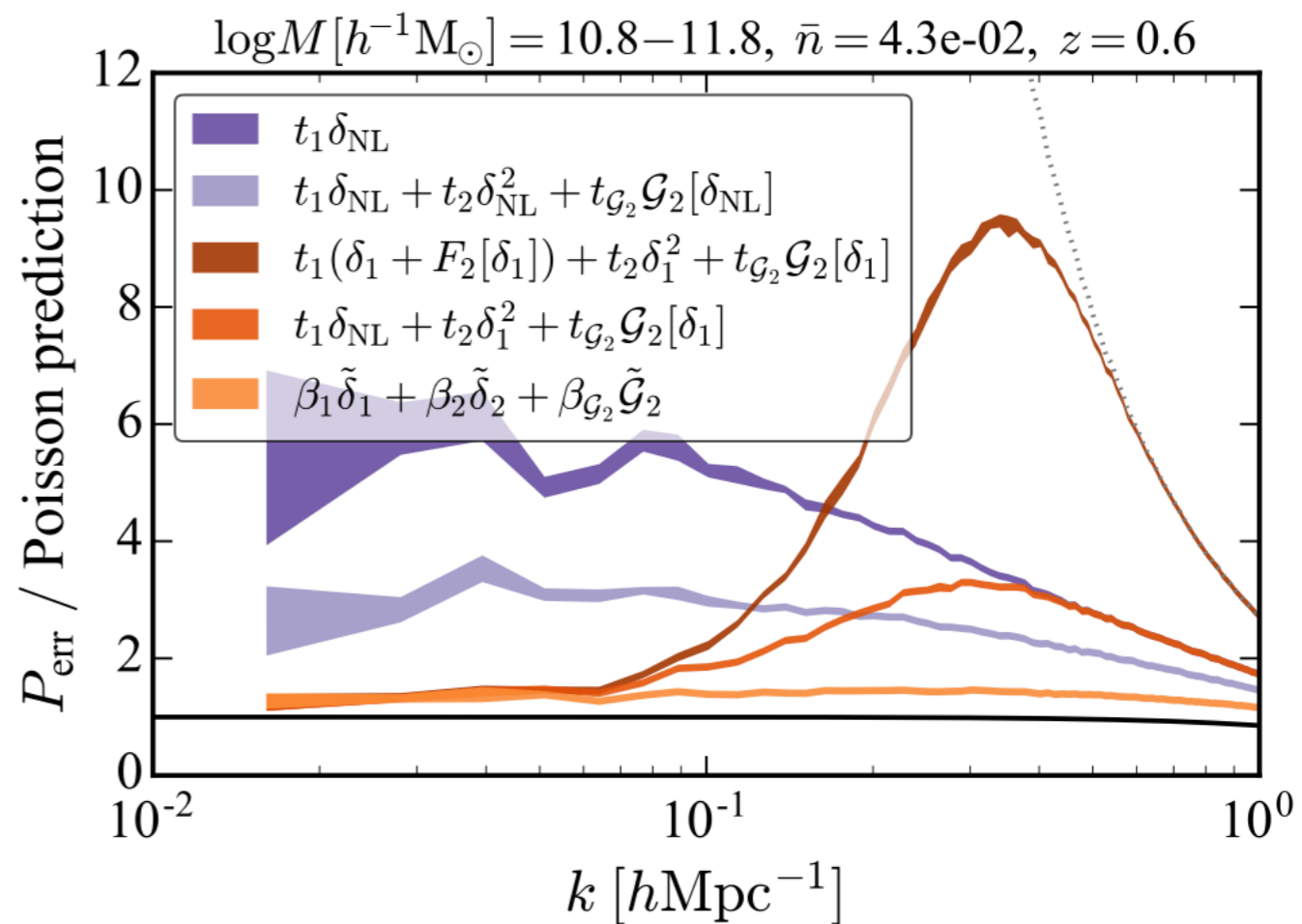
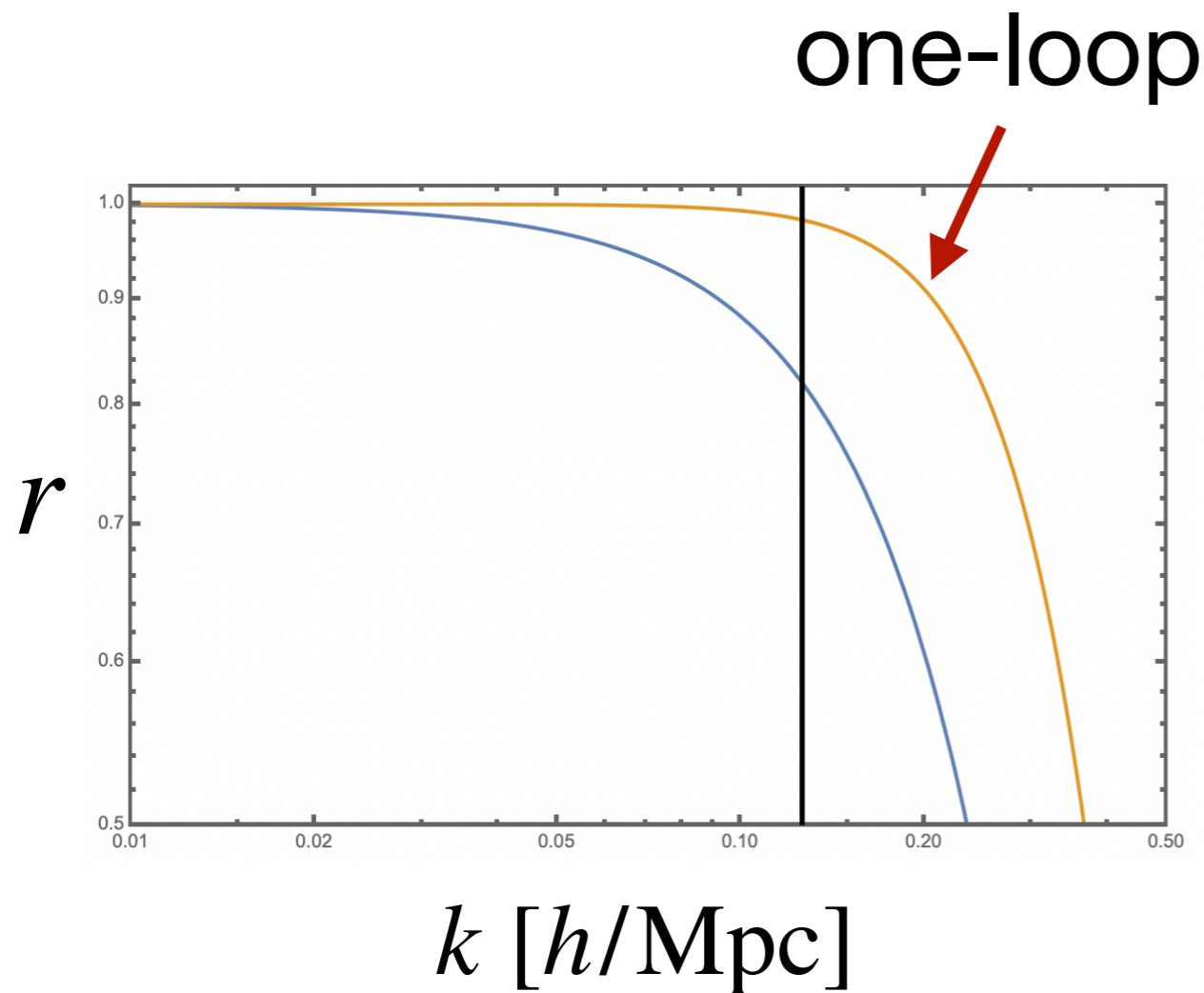




# Why is this puzzling?

On largest scales dynamics simplifies

$$\delta_g(\mathbf{k}) = \sum_{n=1}^{+\infty} \int_{\mathbf{p}_1, \dots, \mathbf{p}_n} (2\pi)^3 \delta_D^{(3)}(\mathbf{k} - \mathbf{p}_1 \dots \mathbf{p}_n) X_n(\boldsymbol{\theta}; \mathbf{p}_1, \dots, \mathbf{p}_n) \delta(\mathbf{p}_1) \cdots \delta(\mathbf{p}_n)$$



# Why is this puzzling?

Cabass, MS, Zaldarriaga (2023)

$$\delta_g(\mathbf{k}) = \sum_{n=1}^{+\infty} \int_{\mathbf{p}_1, \dots, \mathbf{p}_n} (2\pi)^3 \delta_D^{(3)}(\mathbf{k} - \mathbf{p}_{1\dots n}) X_n(\boldsymbol{\theta}; \mathbf{p}_1, \dots, \mathbf{p}_n) \delta(\mathbf{p}_1) \cdots \delta(\mathbf{p}_n)$$

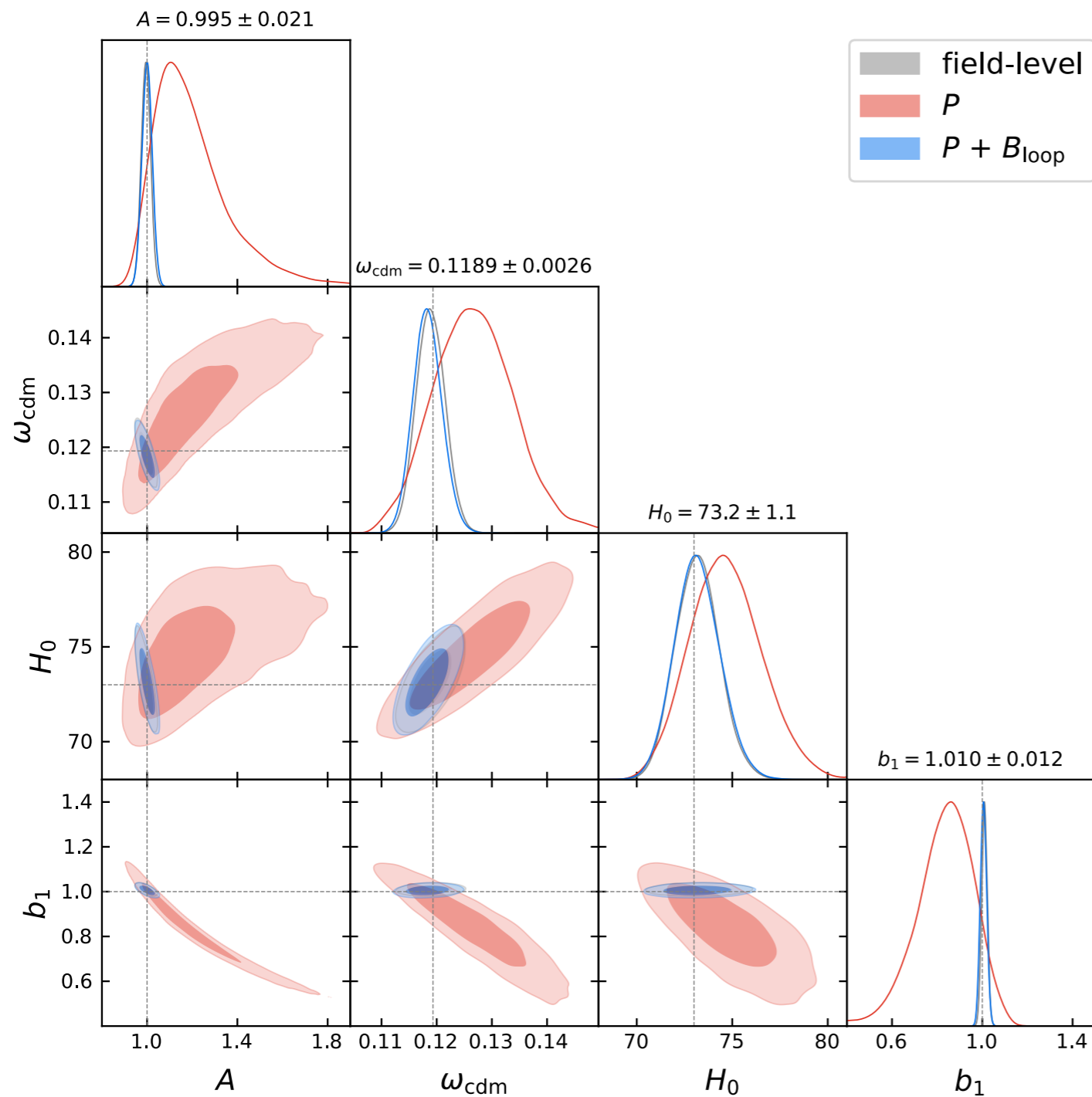
Model with b1 and A only:

$$\frac{1}{\sigma_A^2} = 2V \int_{\mathbf{k}, \mathbf{p}} \left[ X_2^2(\mathbf{p}, \mathbf{k} - \mathbf{p}) \frac{P(p)P(|\mathbf{k} - \mathbf{p}|)}{P(k)} + 2X_2(\mathbf{p}, \mathbf{k} - \mathbf{p})X_2(-\mathbf{p}, \mathbf{k})P(p) \right]$$

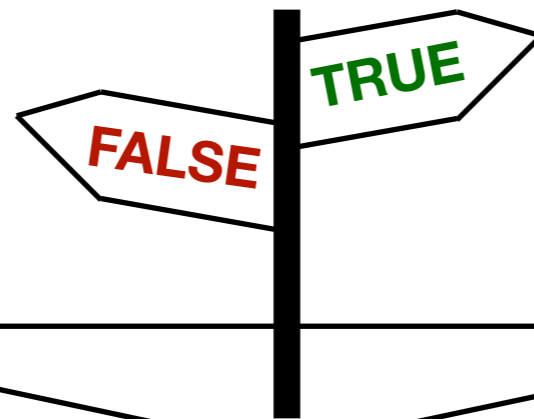
The exact same error as for P+B analysis  
in the same model!

# Why is this puzzling?

Preliminary!



It is interesting to understand this





It is interesting to understand this

