Fourier Space analysis of LRG sample

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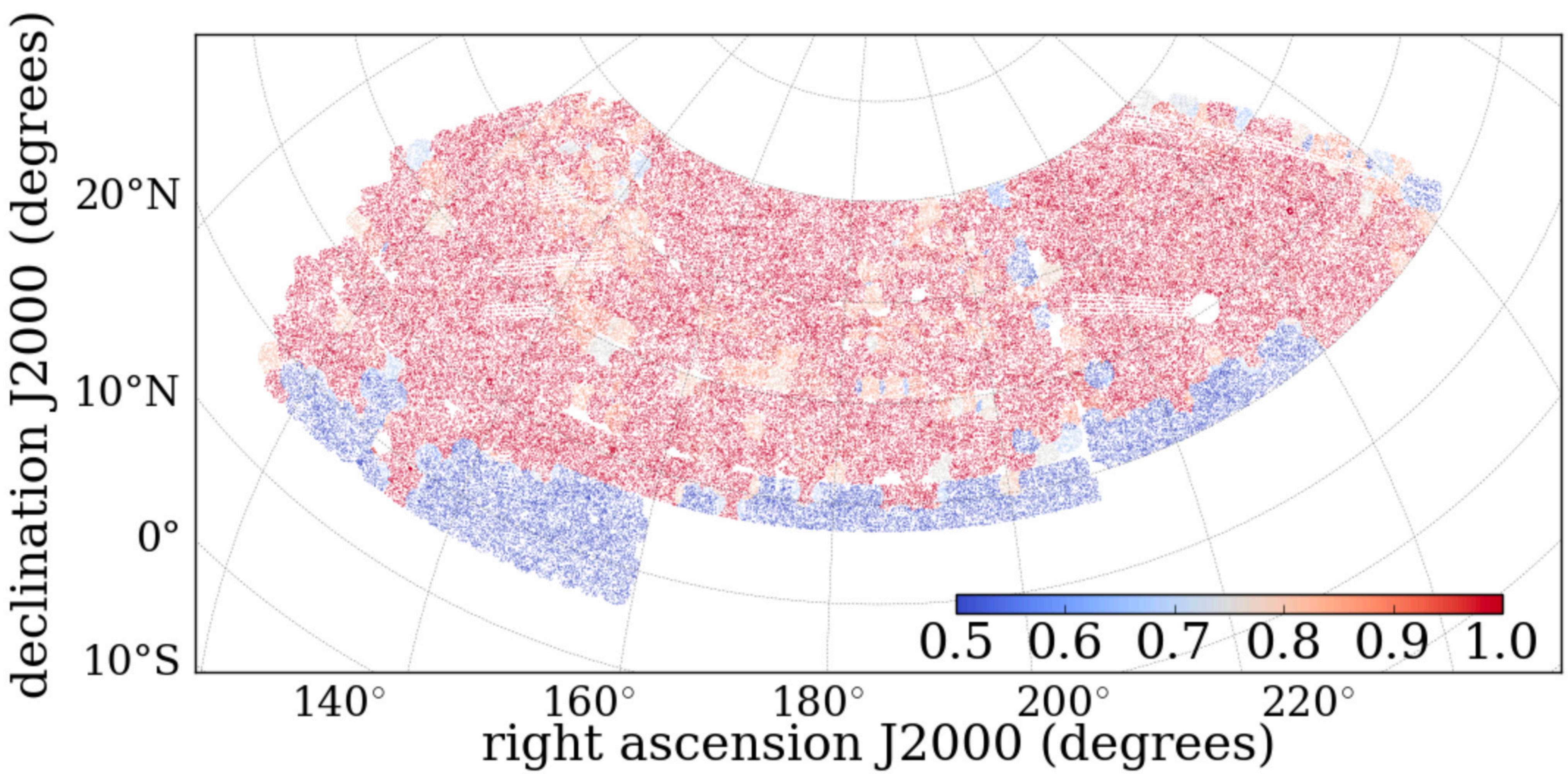
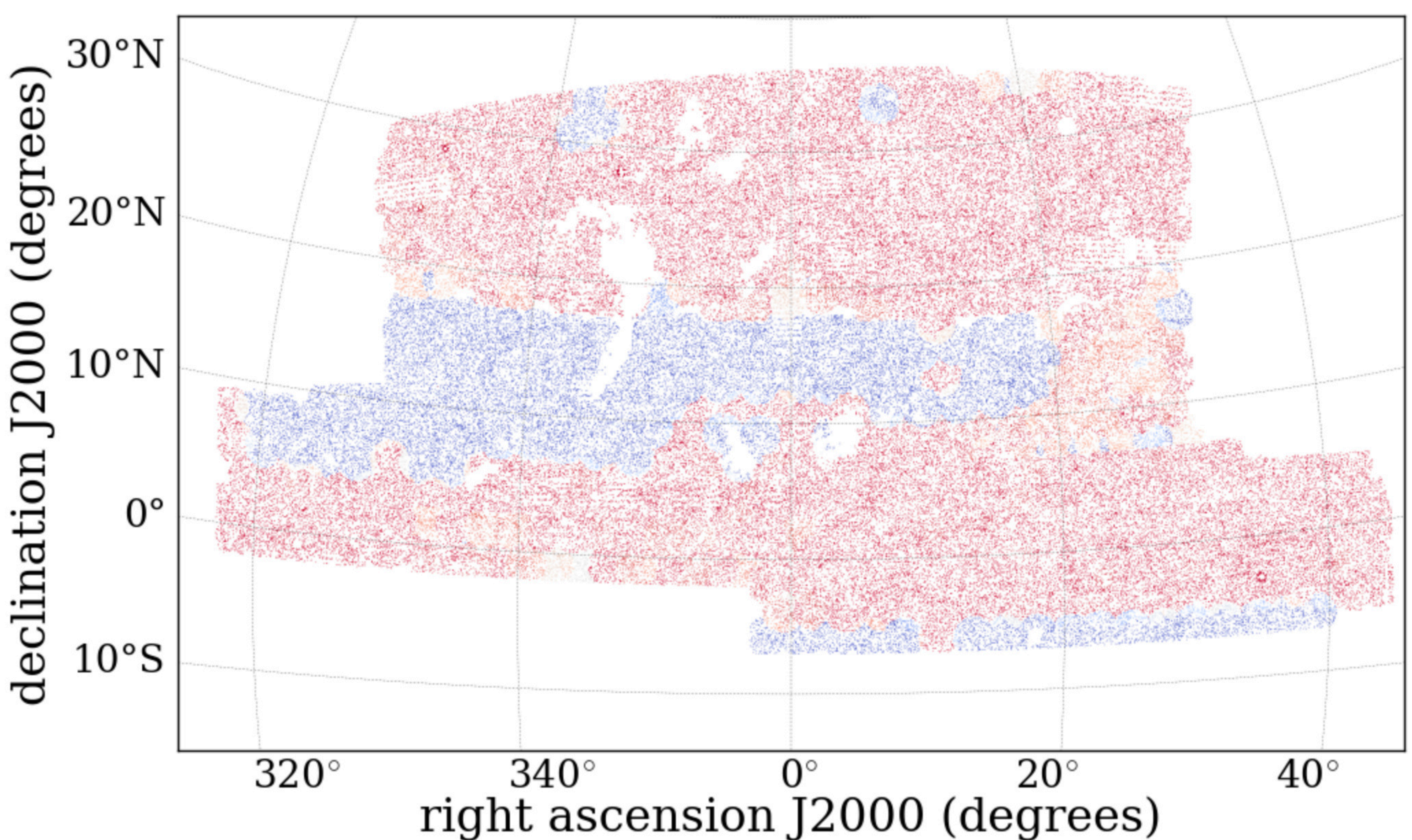
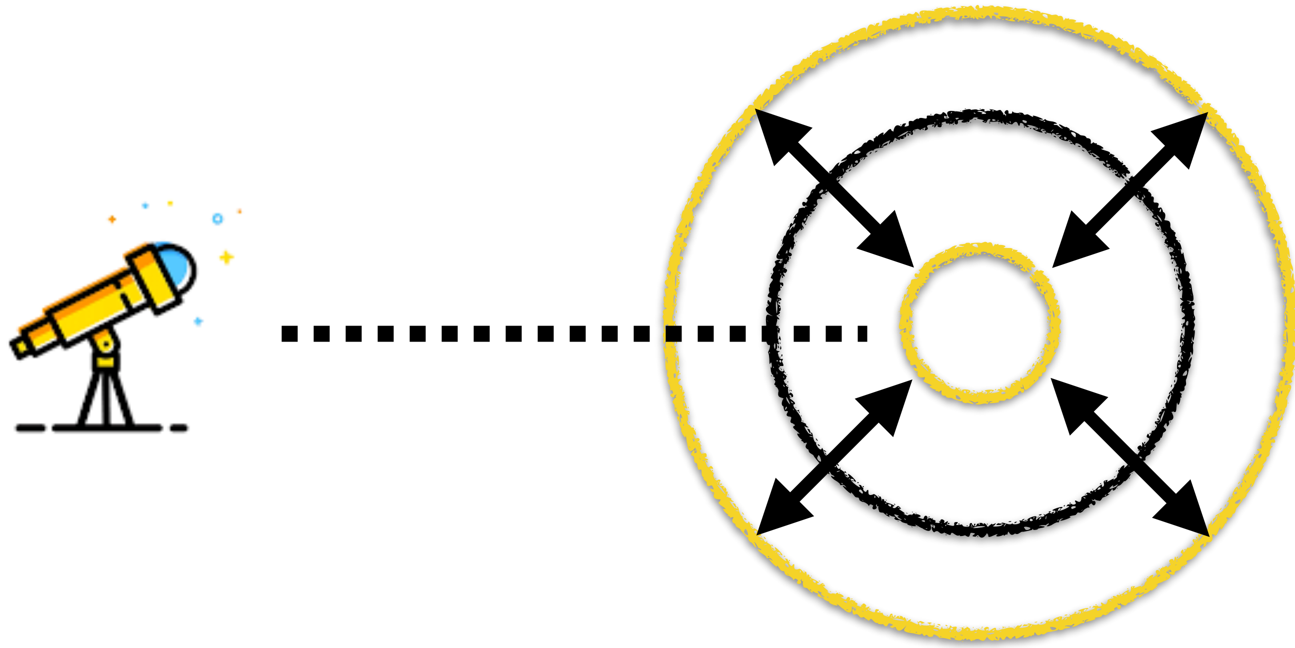
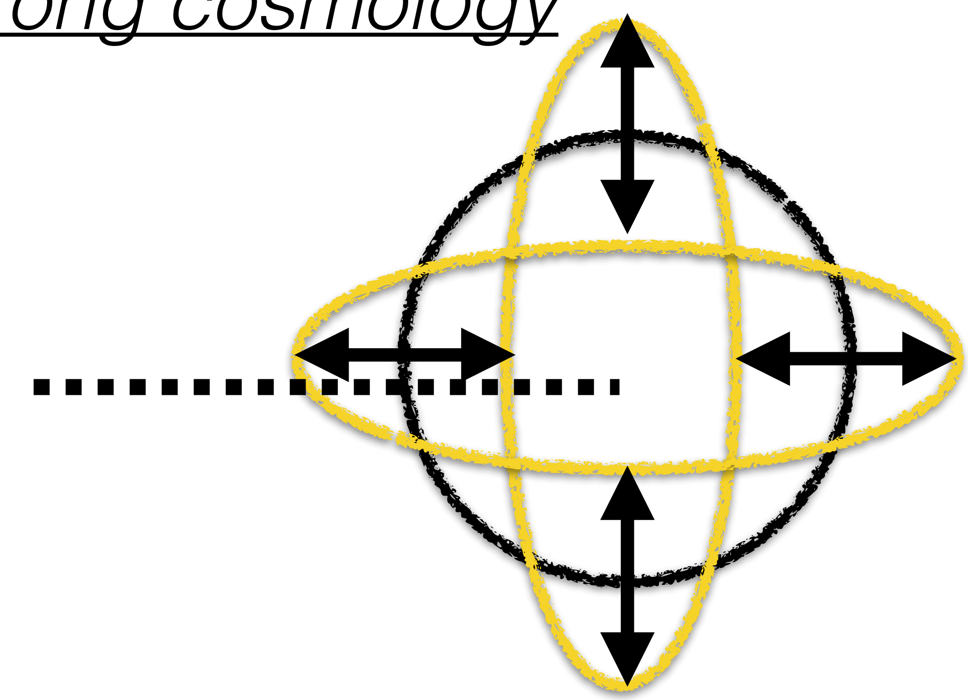

20°N
10°N
0°
10°S
declination J2000 (degrees)
0.5
0.6
0.7
0.8
0.9
1.0
140°
160°
180°
200°
220°
right ascension J2000 (degrees)


30°N
20°N
10°N
0°
10°S
declination J2000 (degrees)
320°
340°
0°
20°
40°
right ascension J2000 (degrees)

Alcock-Paczynski & Redshift Space Distortions

- **AP effect**: Anisotropy induced by transforming redshifts into coming distances assuming a *wrong cosmology*





BAO shift, but no extra anisotropy

$\sim (D_A^2/H)^{1/3} / r_s$

Relative BAO shift along and across the line-of-sight + induced anisotropy

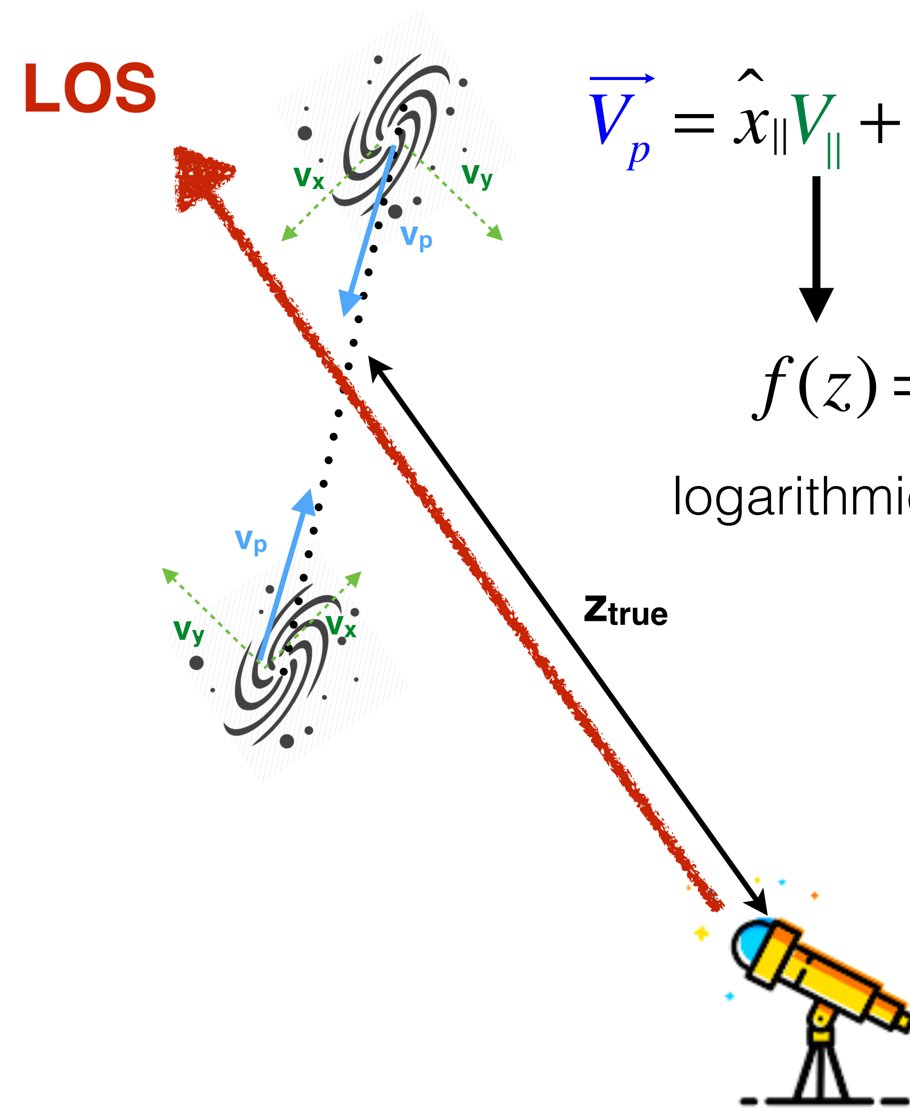
$\sim D_A H$

Redshift Space Distortions

- Universe assumed **isotropic** and **homogeneous**
- **RSD**: Enhancement / reduction of the clustering along the line-of-sight (LOS) direction due to peculiar velocities (Kaiser 1987)

Induces anisotropy but does not shift the BAO

$\sim f\sigma_8$



$$\vec{V}_p = \hat{x}_{\parallel} V_{\parallel} + \hat{x}_{\perp} V_{\perp}$$

$$\downarrow$$

$$f(z) = \Omega_m(z)^{\gamma}$$

logarithmic growth of structur

Modelling the power spectrum: full shape vs. BAO

There are two main kind of complementary analyses:

1. **Full Shape analysis** (aka RSD): Based on the PS full shape and amplitude signal
   - Constrain the growth of structure, $f\sigma_8(z)$, $D_A(z)$ and $H(z)$ through the shape and amplitude of a range of scales.
   - It requires a full modelling of the amplitude and shape of the power spectrum multipoles
2. **BAO analysis**: Based on the position of the BAO-peak
   - Constrain on $D_A(z)$ and $H(z)$ through the BAO-feature only
   - It only requires the modelling of the oscillation, not the shape/amplitude of the broadband signal
   - Usage of reconstruction algorithm to enhance the significance of the peak

Full Shape Analysis

- Non-linear dark matter PS shape
  Perturbation Theory 2-loop
- Galaxy bias,
  Non-linear & non-local
- Redshift Space distortions
  TNS-model

$$P_g^{(s)}(k,\mu) = D_{\rm FoG}^P(k,\mu,\sigma_{\rm FoG}^P[z])\left[P_{g,\delta\delta}(k) + 2f\mu^2 P_{g,\delta\theta}(k)\right.$$
$$\left. + f^2\mu^4 P_{\theta\theta}(k) + b_1^3 A(k,\mu,f/b_1) + b_1^4 B(k,\mu,f/b_1)\right]$$

$P_{\delta\delta},\ P_{\delta\theta},\ P_{\theta\theta} \to$ Dark Matter non-linear models
$D_{\rm FoG}^P \to$ 1-parameter Lorentzian damping term
$A, B \to$ TNS functions

The total number of free parameters of the model is,

- Bias Parameters: $b_1,\ b_2$
- **Cosmology Parameters:** $f,\ \sigma_8$
- **AP parameters:** $\alpha_{\parallel},\ \alpha_{\perp} \to D_A/r_s(z_d)$ and $H(z)r_s(z_d)$
- Fingers-of-God: $\sigma_{\rm FoG}$
- Shot noise amplitude $A_{\rm Noise}$

8 free parameters $\to$ 4 cosmological, 4 “nuissance”

BAO Analysis: Isotropic template

- Reconstruction suppresses RSD & non-linearities
- Quadrupole & Hexadecapole are close to be 0
- Work with monopole and μ^x-moment(s)

$$P^{(\mu^2)} \equiv \frac{2}{5}P^{(2)} + P^{(0)} \qquad P^{(\mu^4)} \equiv \frac{8}{63}P^{(4)} + \frac{4}{7}P^{(2)} + P^{(0)}$$

- BAO-peak position, α, is related to AP-dilation parameters,

$$\alpha_0 = \alpha_\parallel^{1/3}\alpha_\perp^{2/3} \qquad \alpha_2 = \alpha_\parallel^{3/5}\alpha_\perp^{2/5} \qquad \alpha_4 = \alpha_\parallel^{5/7}\alpha_\perp^{2/7}$$

$$P_{\rm bao-iso}(k, \alpha_{0,2,4}) = P_{\rm sm}^{(0,2,4)}(k)\left\{ 1 + \left[\mathcal{O}_{\rm lin}(k/\alpha_{0,2,4}) - 1\right] \exp[-\frac{1}{2}k^2\Sigma_{\rm nl}^{(0,2,4)}] \right\}$$

where,

$$P_{\rm sm}^{(\ell)}(k) = B^{(\ell)}P_{\rm lin,sm}(k) + A_1^{(\ell)}k + A_2^{(\ell)} + \frac{A_3^{(\ell)}}{k} + \frac{A_4^{(\ell)}}{k^2} + \dots$$

Non-linear damping

$$\Sigma_\parallel(z) = [1 + f(z)]10.4\sigma_8(z)$$

$$\Sigma_\perp(z) = 10.4\sigma_8(z)$$

$$\boxed{\begin{aligned} \Sigma_{\rm nl}^{(0)} &= [(\Sigma_\parallel)^4(\Sigma_\perp)^2]^{1/6} \\ \Sigma_{\rm nl}^{(2)} &= [(\Sigma_\parallel)^4(\Sigma_\perp)^6]^{1/10} \\ \Sigma_{\rm nl}^{(4)} &= [(\Sigma_\parallel)^4(\Sigma_\perp)^{10}]^{1/14} \end{aligned}}$$

BAO Analysis: Anisotropic template

Similar to FS modelling,

$$P_{(\ell)}(k,\mu) = P_{\rm sm}^{(\ell)}(k,\mu)\left\{ 1 + \left[\mathcal{O}_{\rm lin}(k) - 1\right] \exp[-\frac{1}{2}k^2(\mu^2\Sigma_\parallel^2 + (1-\mu^2)\Sigma_\perp)] \right\}$$

$$P_{\rm sm}^{(\ell)}(k,\mu) = B^{(\ell)}(1+f\mu^2 R)^2 + A_1^{(\ell)}k + A_2^{(\ell)} + \frac{A_3^{(\ell)}}{k} + \frac{A_4^{(\ell)}}{k^2} + \dots$$

Smoothing scale $R = 1 - \exp(-\frac{1}{2}k^2\Sigma_s^2)$

$$P^{(\ell)}(k) = \frac{2\ell+1}{2\alpha_\perp^2\alpha_\parallel}\int_{-1}^{+1} d\mu \mathcal{L}_\ell(\mu) P_{(\ell)}(k',\mu')$$

AP-dilations

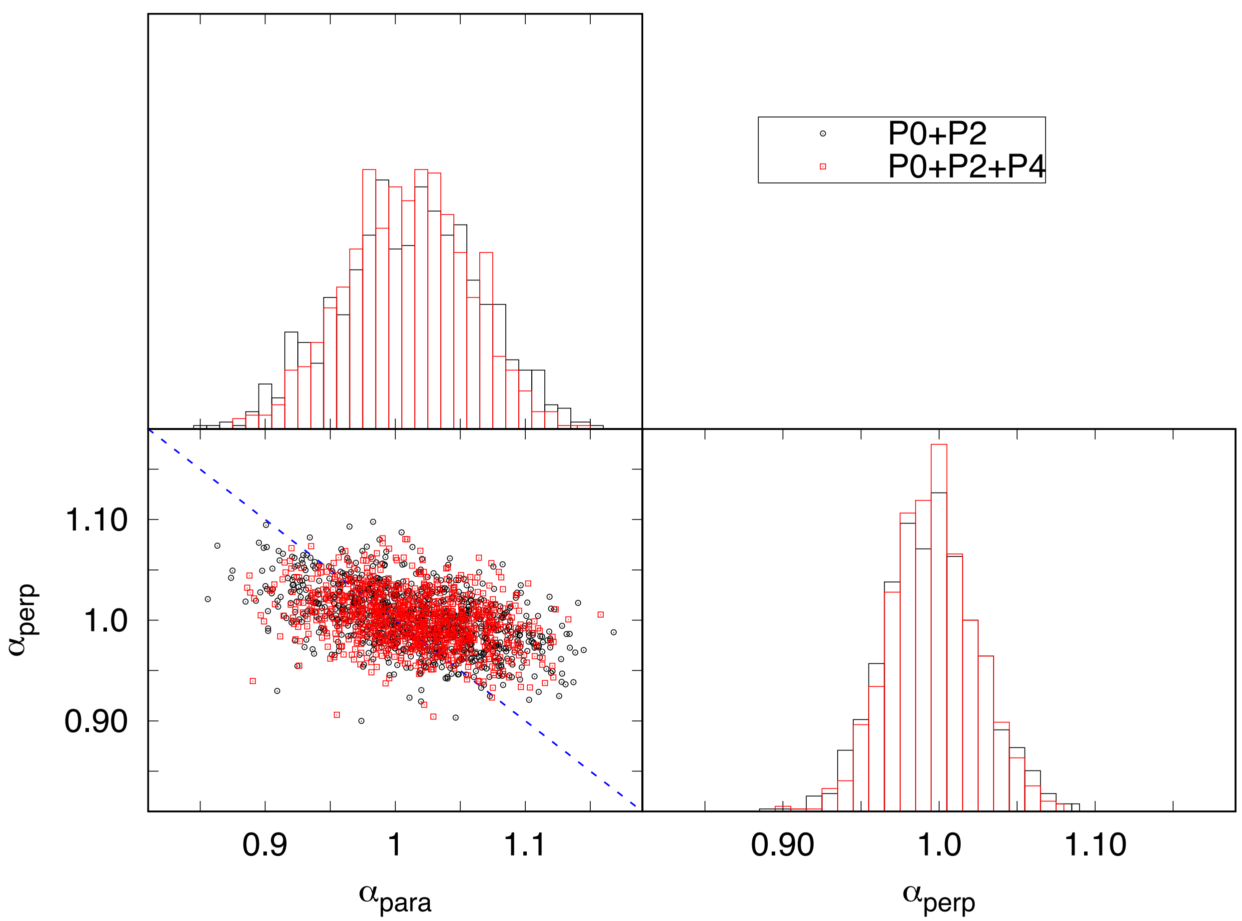
$$\boxed{\begin{aligned} k' &= \frac{k}{\alpha_\perp}\left[1+\mu^2\left(F^{-2}-1\right)\right]^{1/2} \\ \mu' &= \frac{\mu}{F}\left[1+\mu^2\left(F^{-2}-1\right)\right]^{-1/2} \end{aligned}}$$

The difference between BAO iso- and anisotropic template relies in the BAO damping through Σ

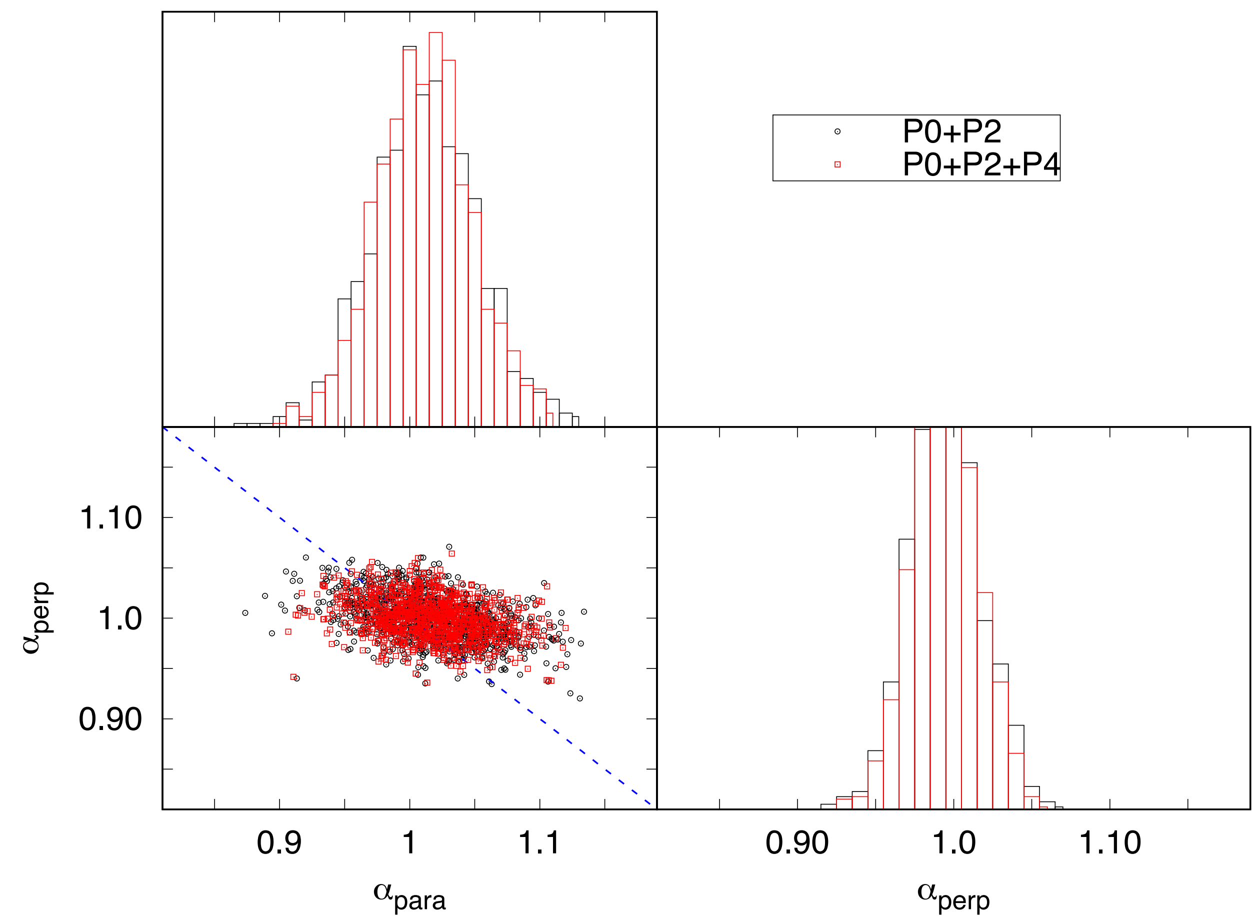
Pros: Better modelling of BAO damping, more physical modelling for post-recon(?)
Cons: Need to perform μ-integration in each step

Mock results v4

Pre-recon



Post-recon

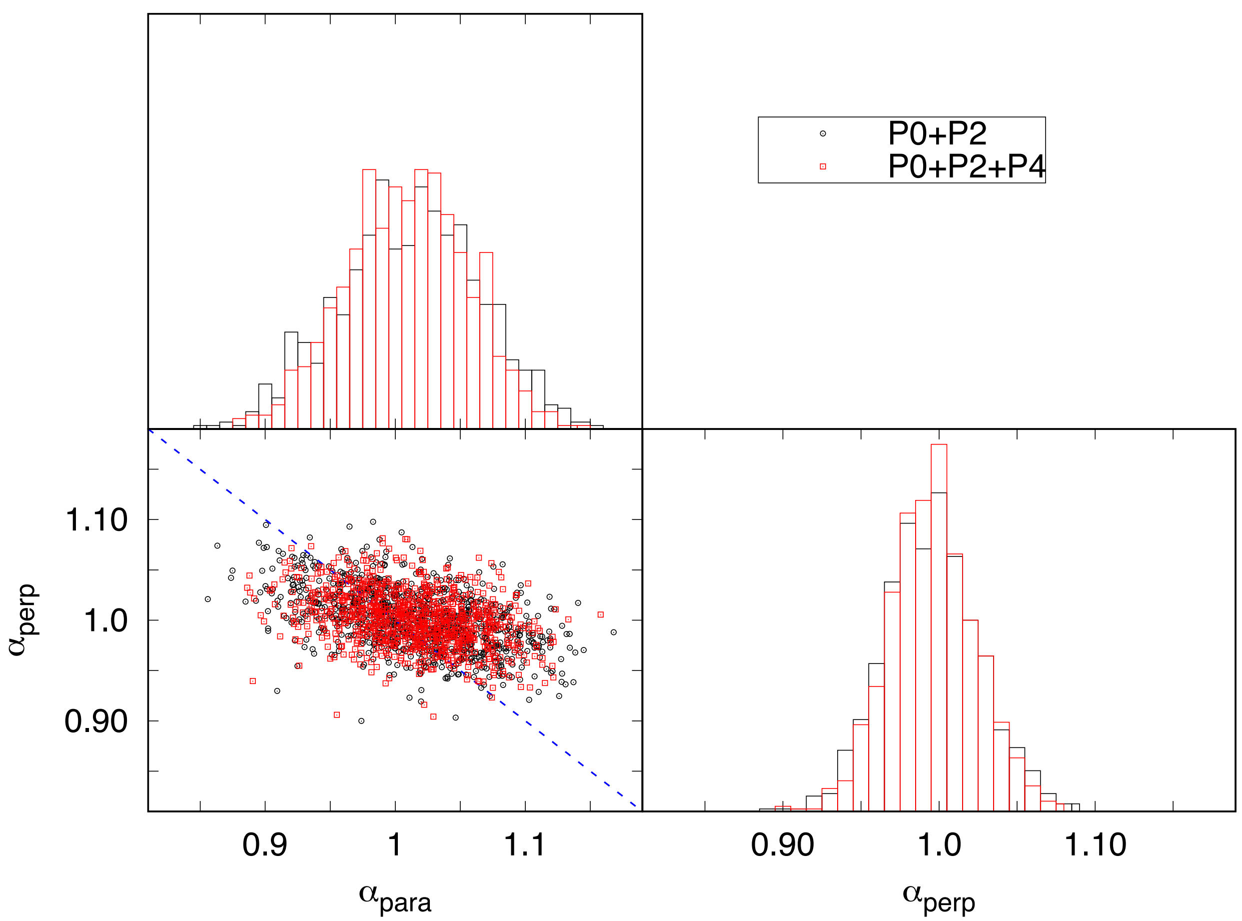


P0+P2 (isotropic template)

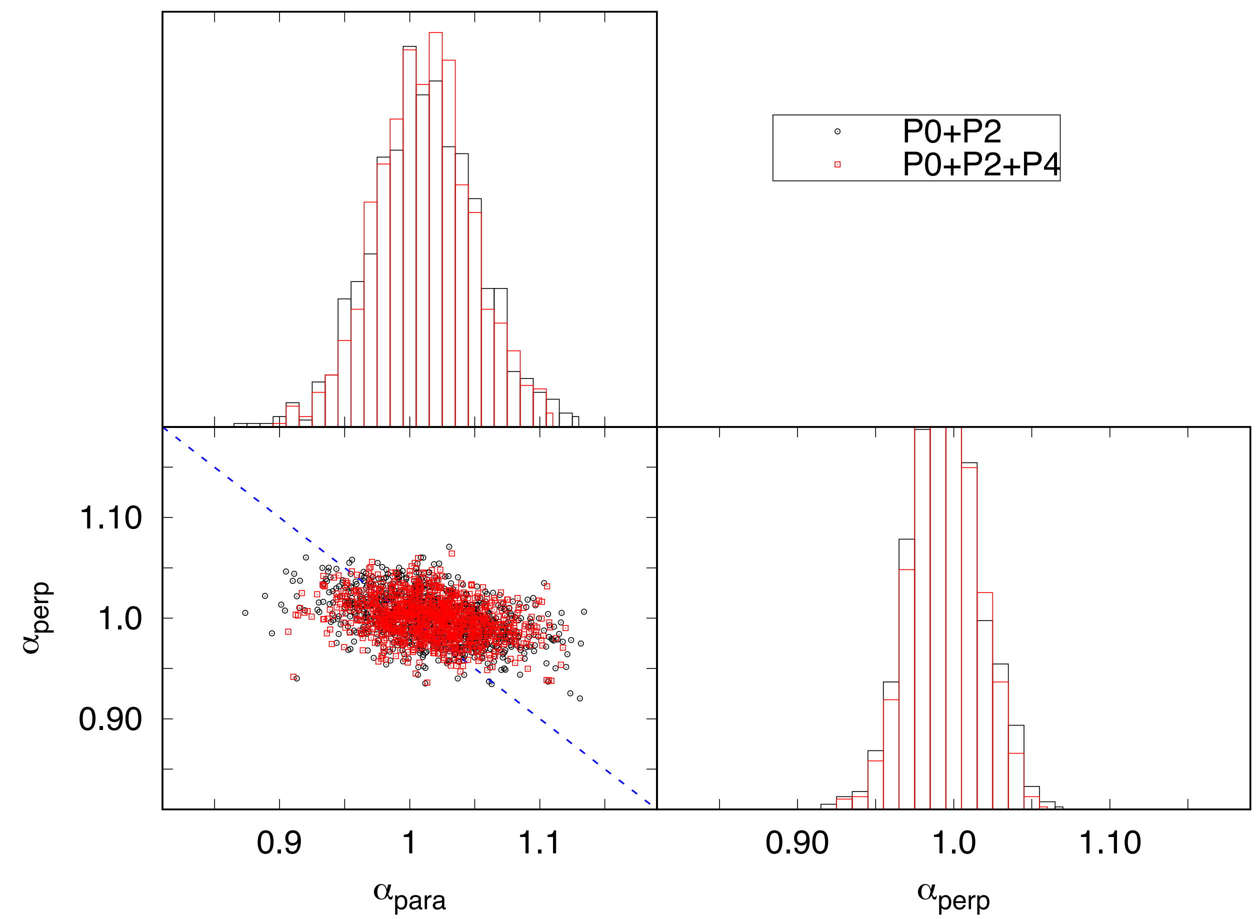
	<α_{para}>	<err>	RMS	<α_{perp}>	<err>	RMS	N_{det}
Pre-recon mocks	1.015704	0.055720	0.053561	1.000503	0.032008	0.030530	887
Post-recon mocks	1.016807	0.039438	0.040530	0.999569	0.023452	0.022757	997

Mock results v4

Pre-recon



Post-recon



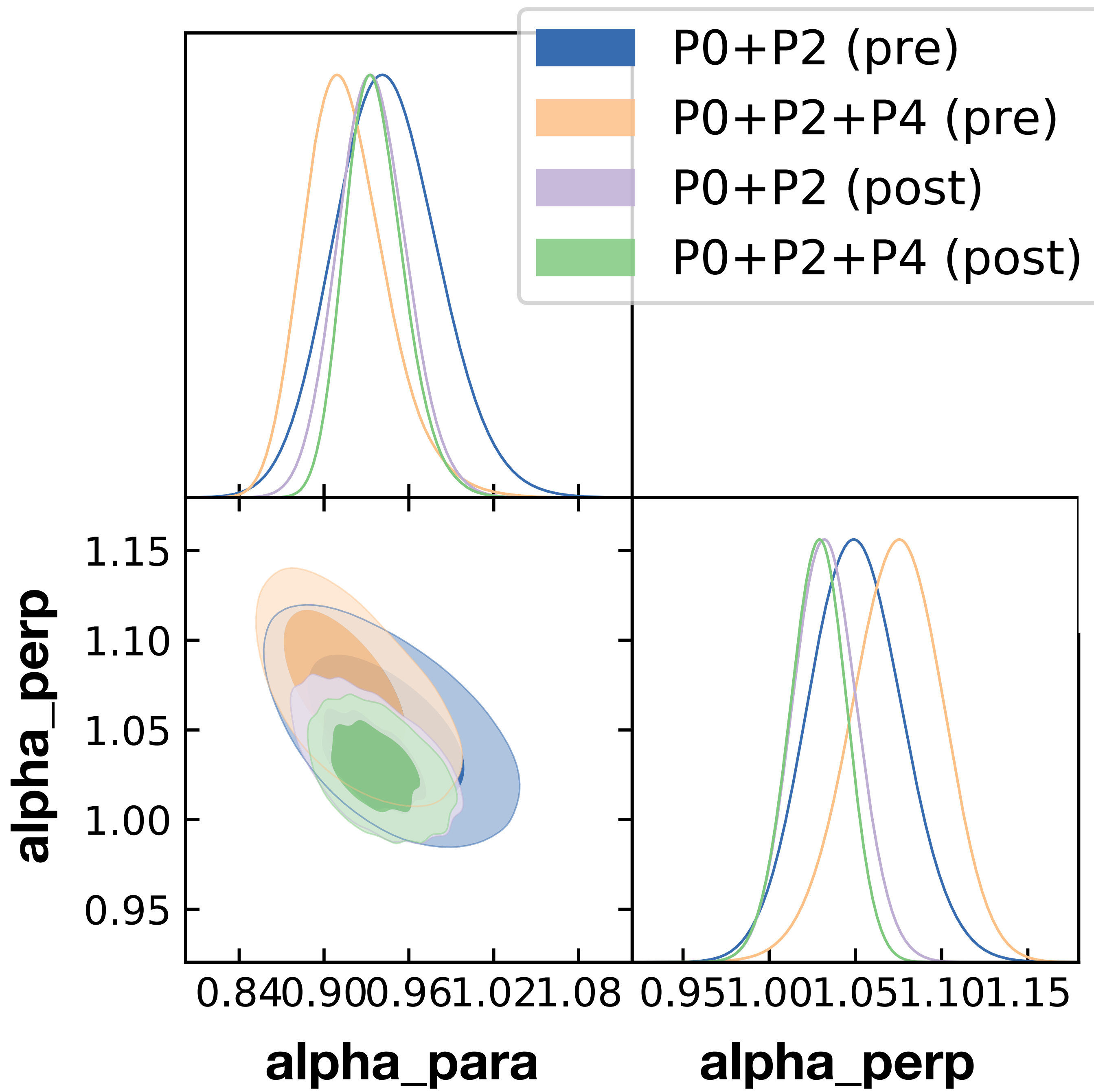
P0+P2+P4 (isotropic template)

	$\langle\alpha_{para}\rangle$	<err>	RMS	$\langle\alpha_{perp}\rangle$	<err>	RMS	N_{det}
Pre-recon mocks	1.013883	0.050755	0.046194	1.000967	0.030122	0.027609	887
Post-recon mocks	1.016383	0.037307	0.036755	0.999491	0.022214	0.020615	997

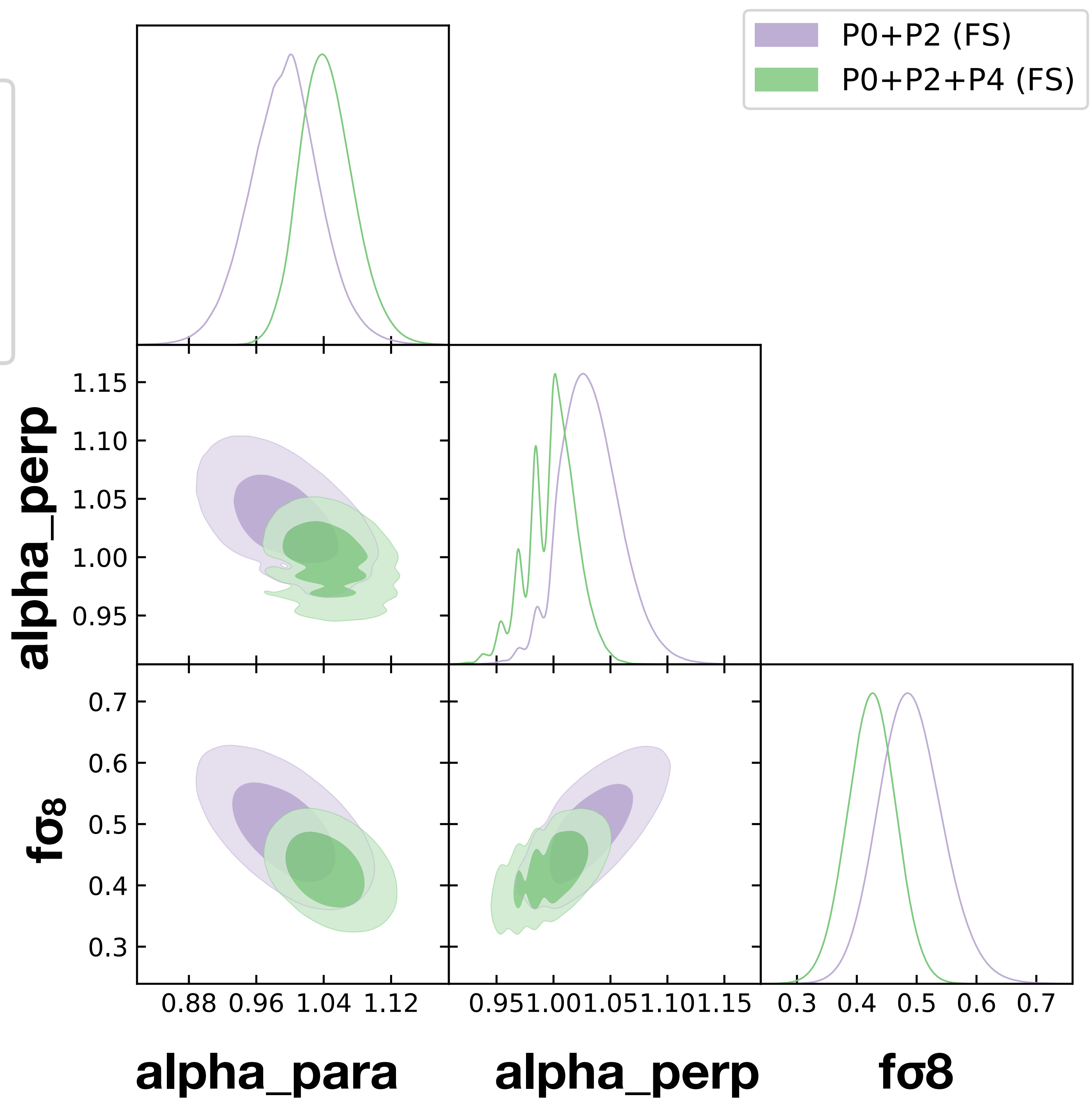
Data results v5

Preliminary

BAO: pre vs. post



FS: P02 vs. P024



BAO post-recon: P0+P2

α_{para}	0.934567	0.024516
α_{perp}	1.037006	0.018854
$f\sigma_8$		

BAO pre-recon: P0+P2

0.943576	0.036901
1.056737	0.027432

FS pre-recon: P0+P2

0.995752	0.042464
1.017227	0.026573
0.467601	0.054158

BAO post-recon: P0+P2+P4

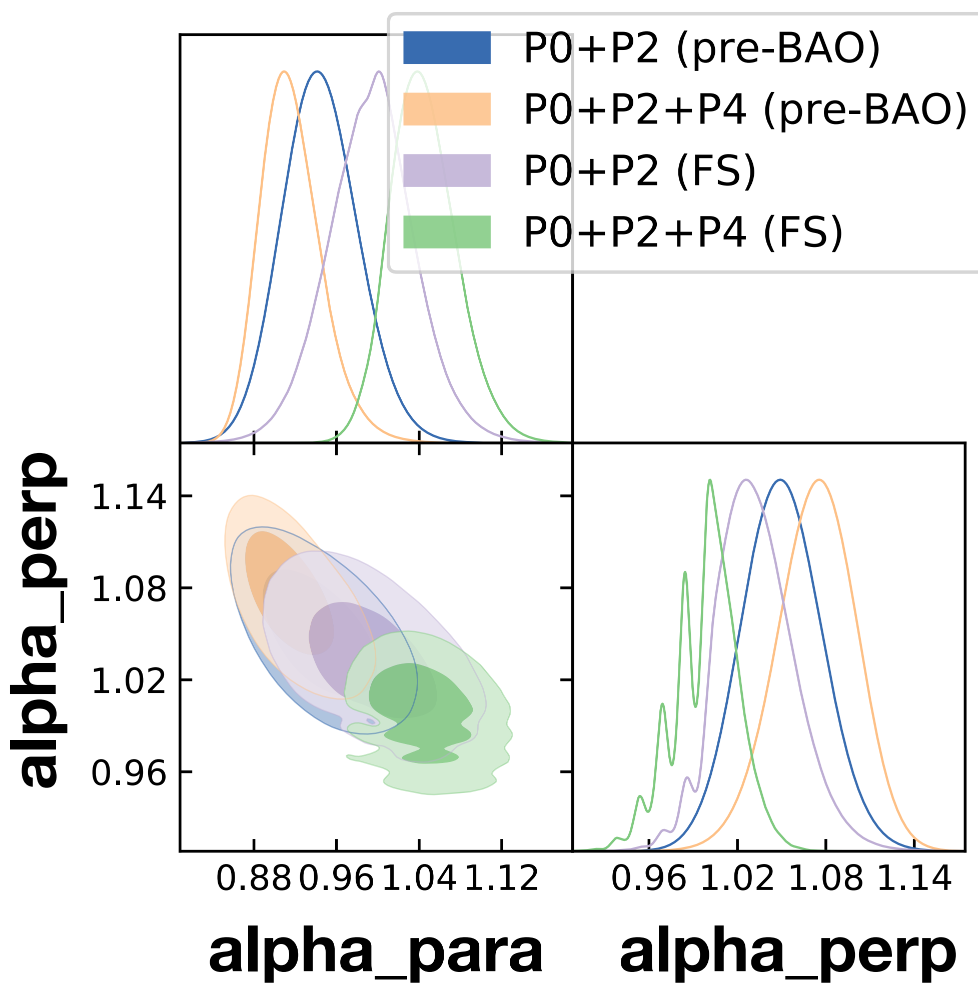
α_{para}	0.923194	,0.021297
α_{perp}	1.031102	0.016554
$f\sigma_8$		

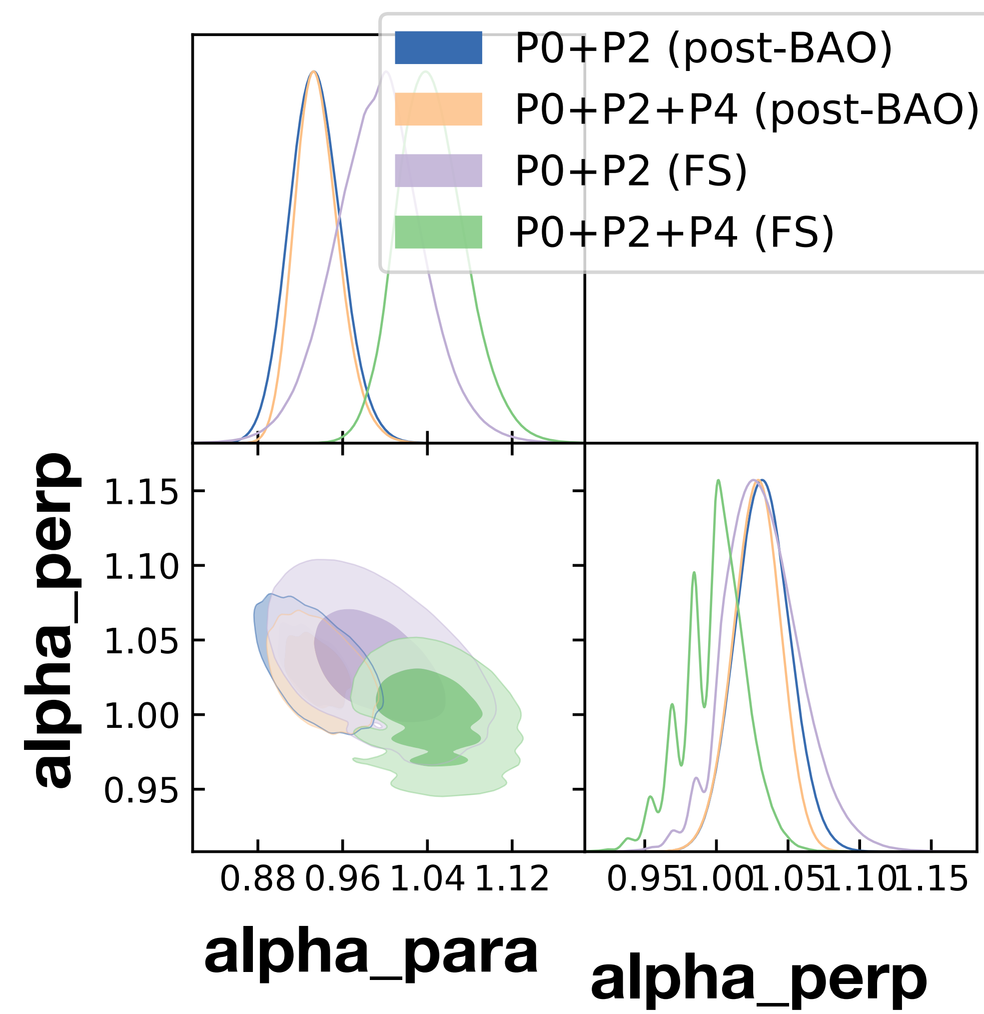
BAO pre-recon: P0+P2+P4

0.902291	0.029877
1.093433	0.026966

FS pre-recon: P0+P2+P4

1.035241	0.032366
0.998880	0.021886
0.423363	0.040738





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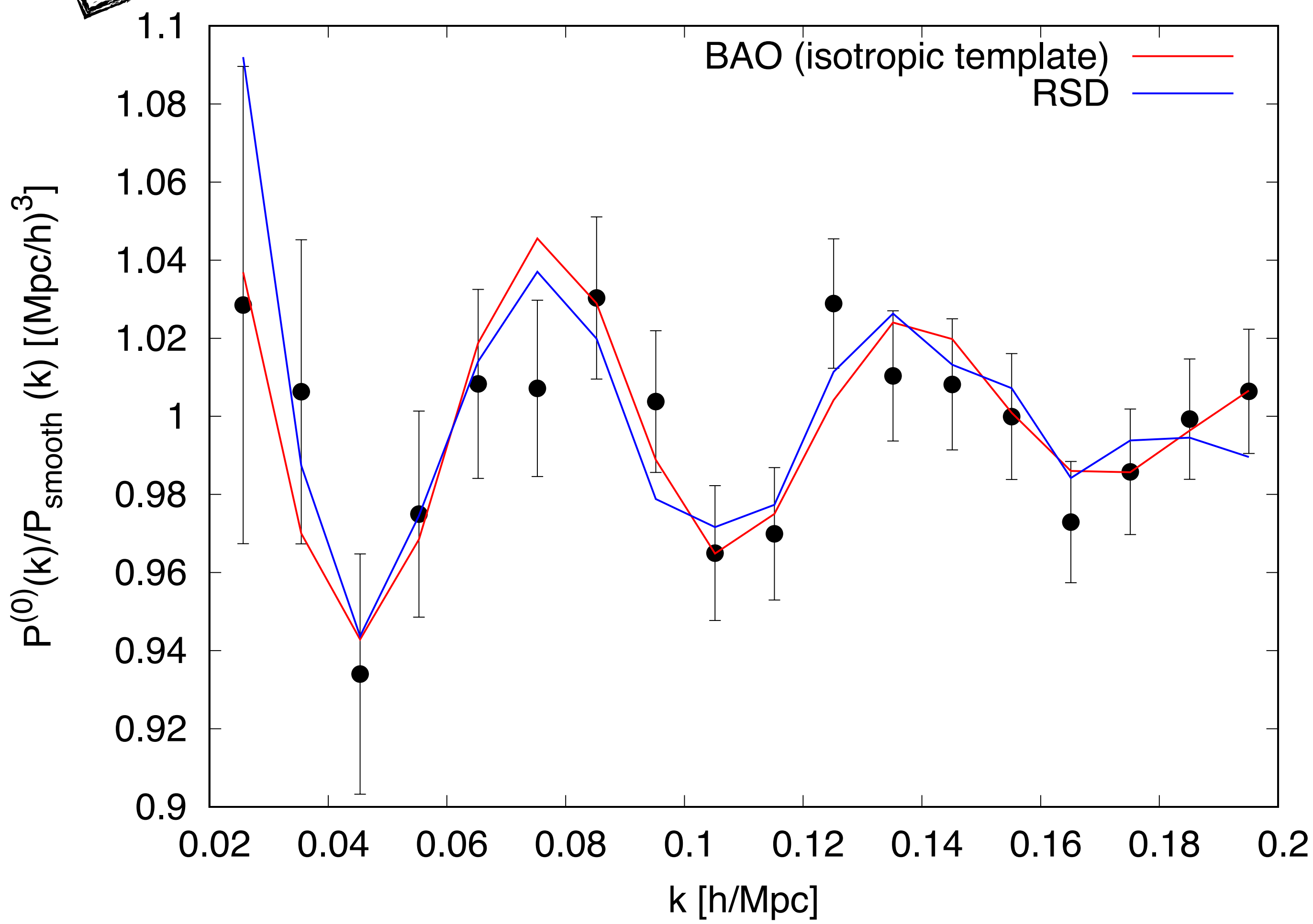
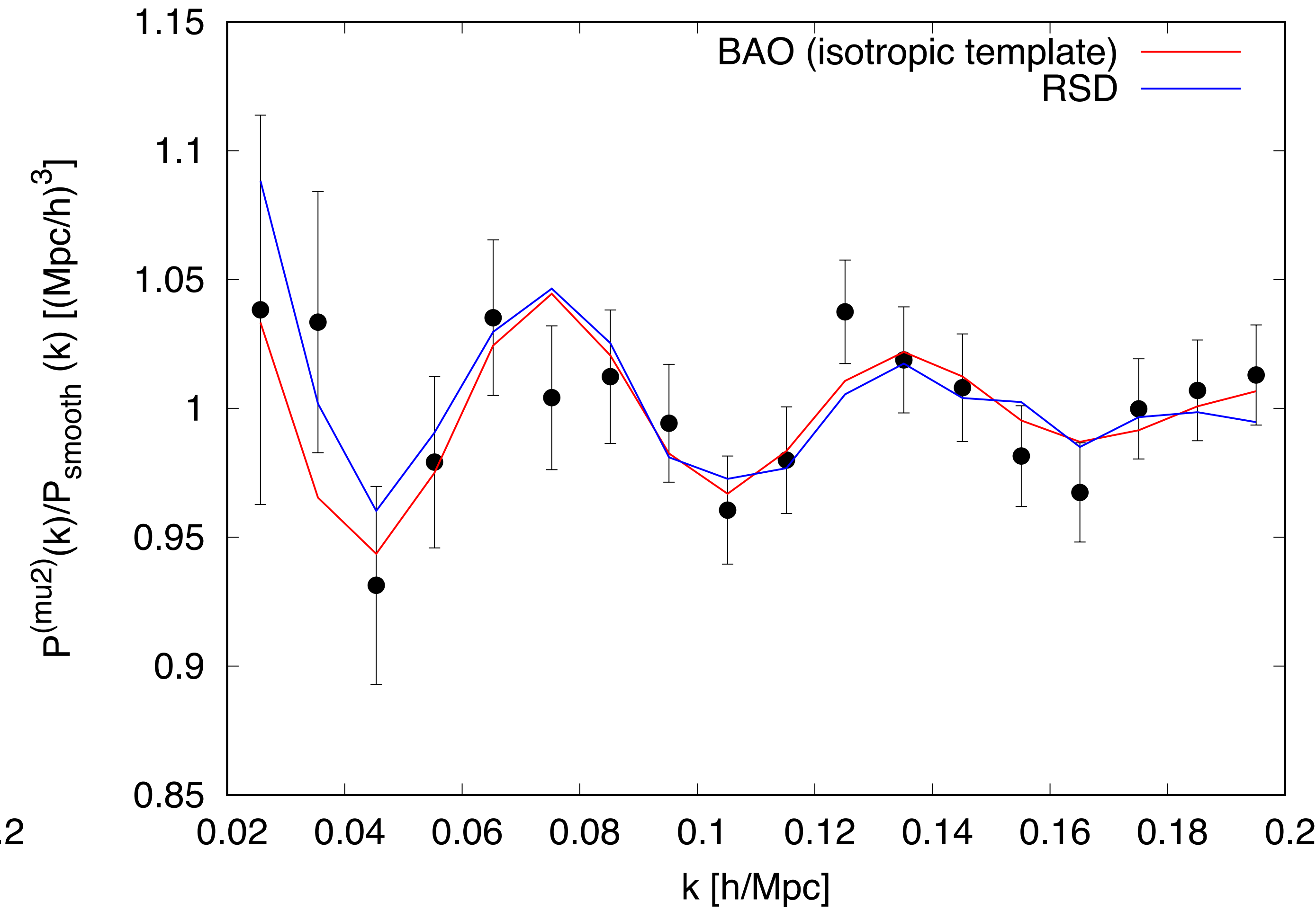
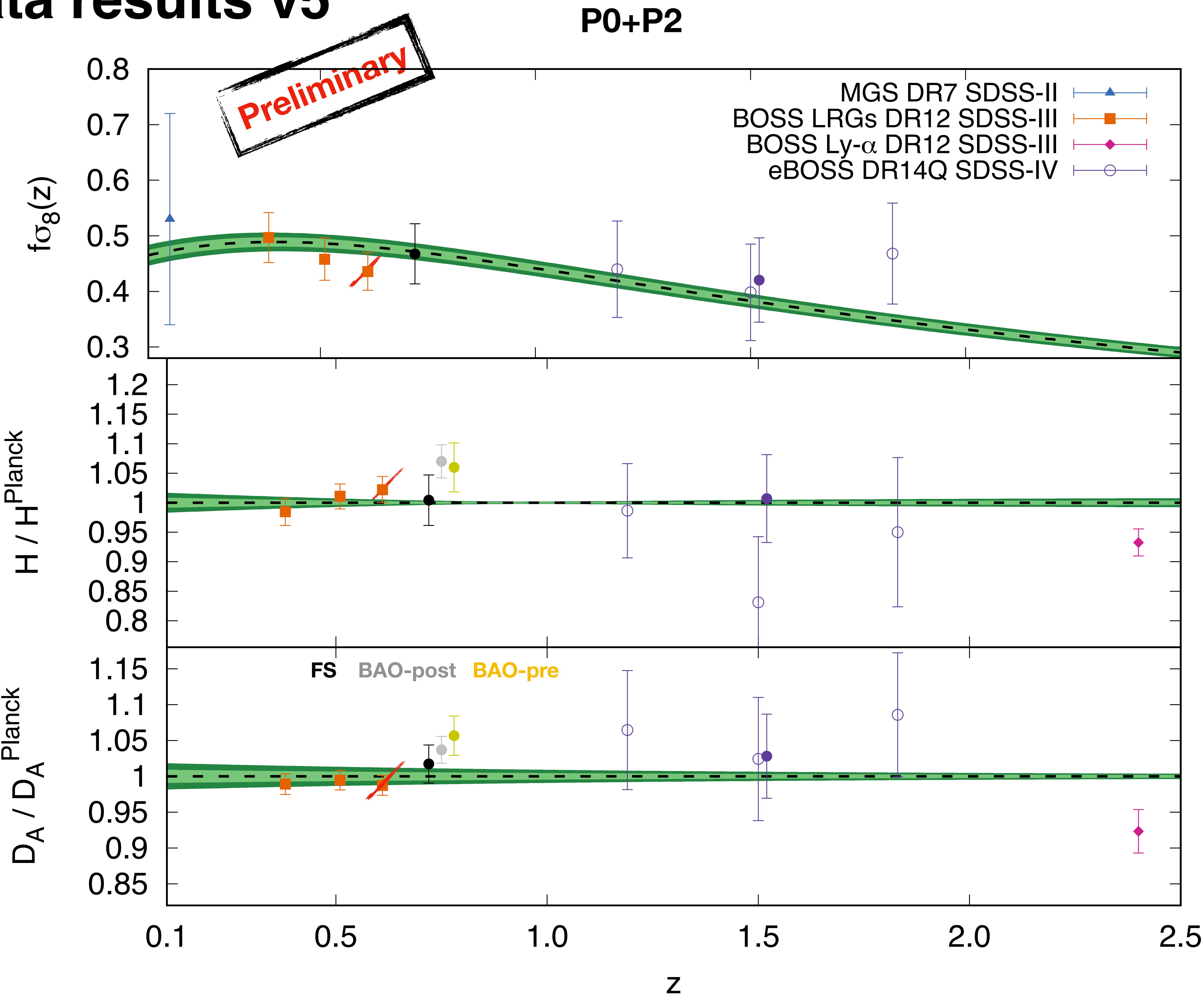
Preliminary

Pre-recon: BAO vs. FS

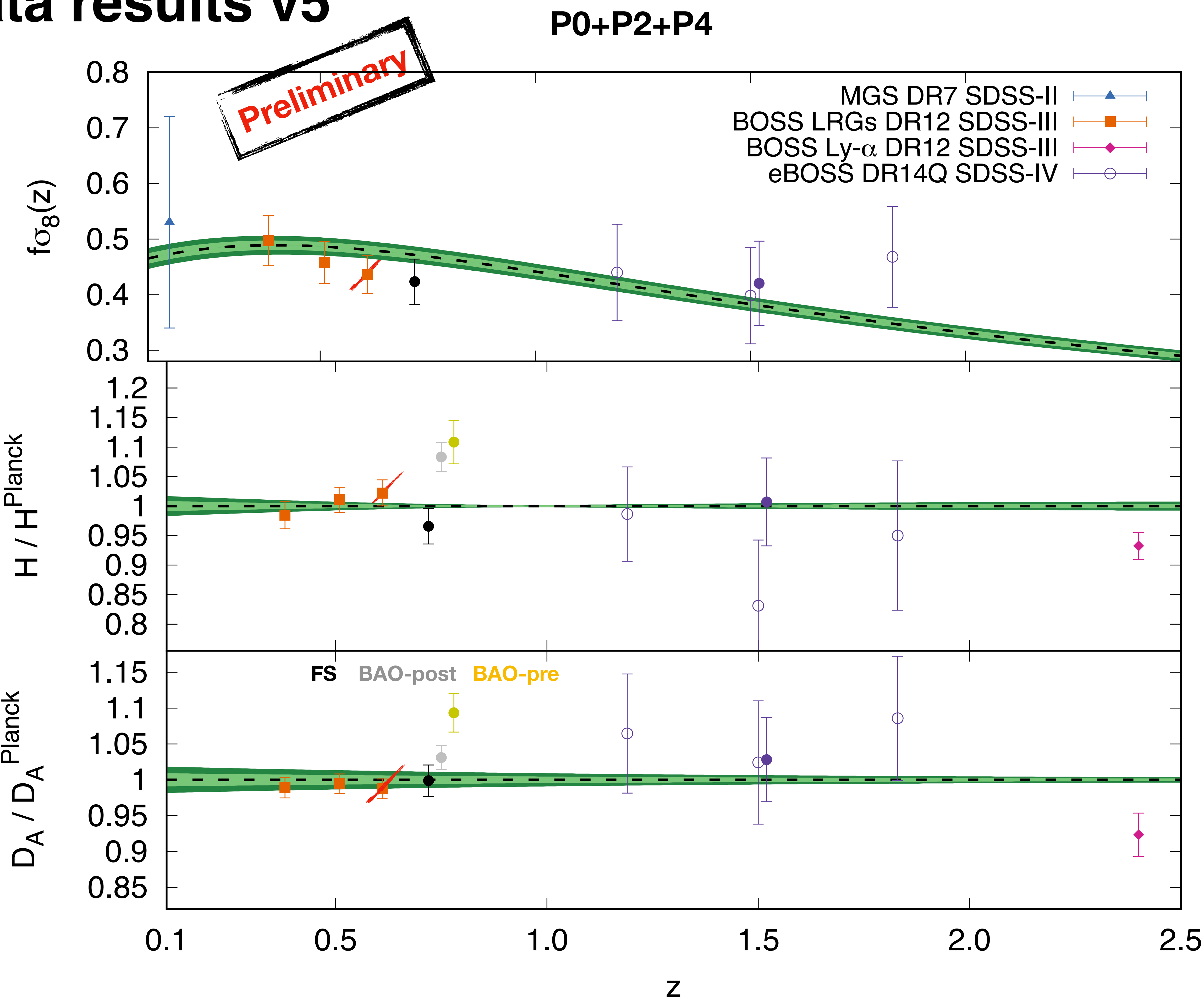


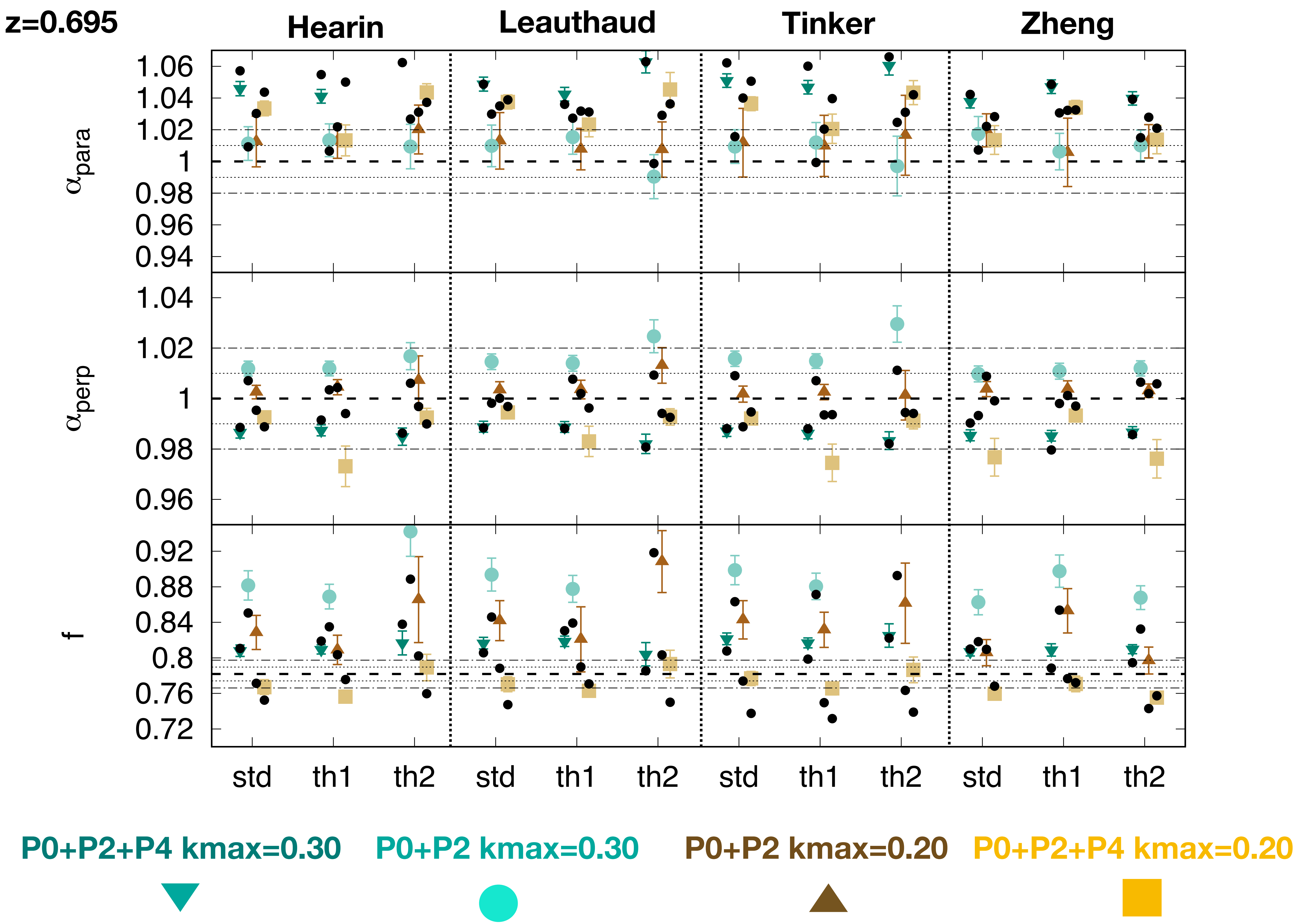


Data results v5

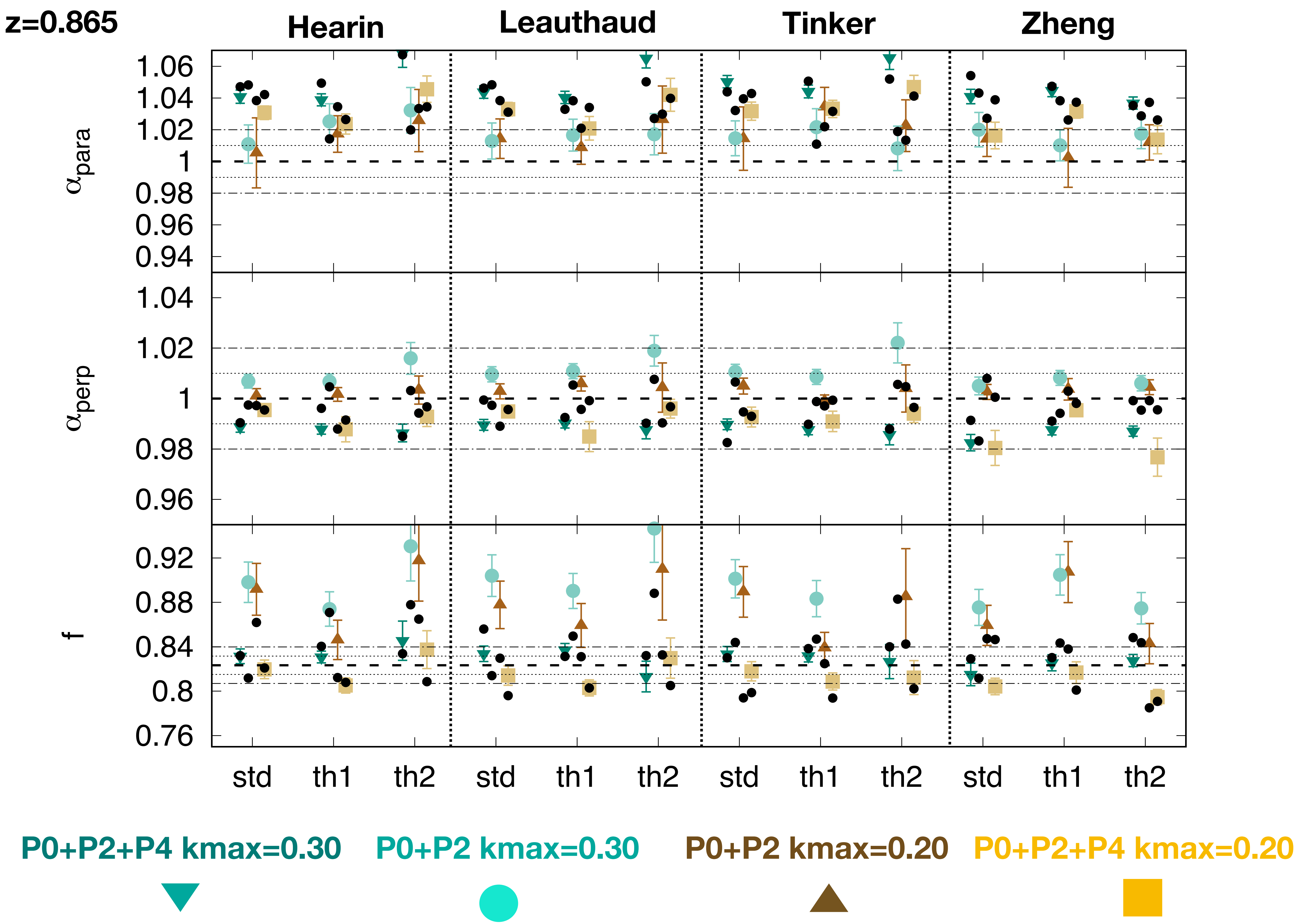


Data results v5





z=0.695
Hearin
Leauthaud
Tinker
Zheng
α_{para}
α_{perp}
f
std
th1
th2
P0+P2+P4 kmax=0.30
P0+P2 kmax=0.30
P0+P2 kmax=0.20
P0+P2+P4 kmax=0.20



z=0.865
Hearin
Leauthaud
Tinker
Zheng
α_{para}
α_{perp}
f
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.88
0.84
0.8
0.76
std
th1
th2
P0+P2+P4 kmax=0.30
P0+P2 kmax=0.30
P0+P2 kmax=0.20
P0+P2+P4 kmax=0.20

Summary / ToDo

- BAO pre & post recon inconsistent with FS in dilation scales?
- Comparison with configuration space?
- Is BAO isotropic template good enough? TBC with BAO anisotropic (in progress)
- Mock challenge (by Graziano) show unclear results on FS analysis.
- BAO only (pre- and post-recon) on mock challenge may shed light.
- Role of hexadecapole? Help in pre-recon data, but doesn’t in post-recon
- Keep improving BAO & FS pipeline.