Combination of cluster number counts and two-point correlations

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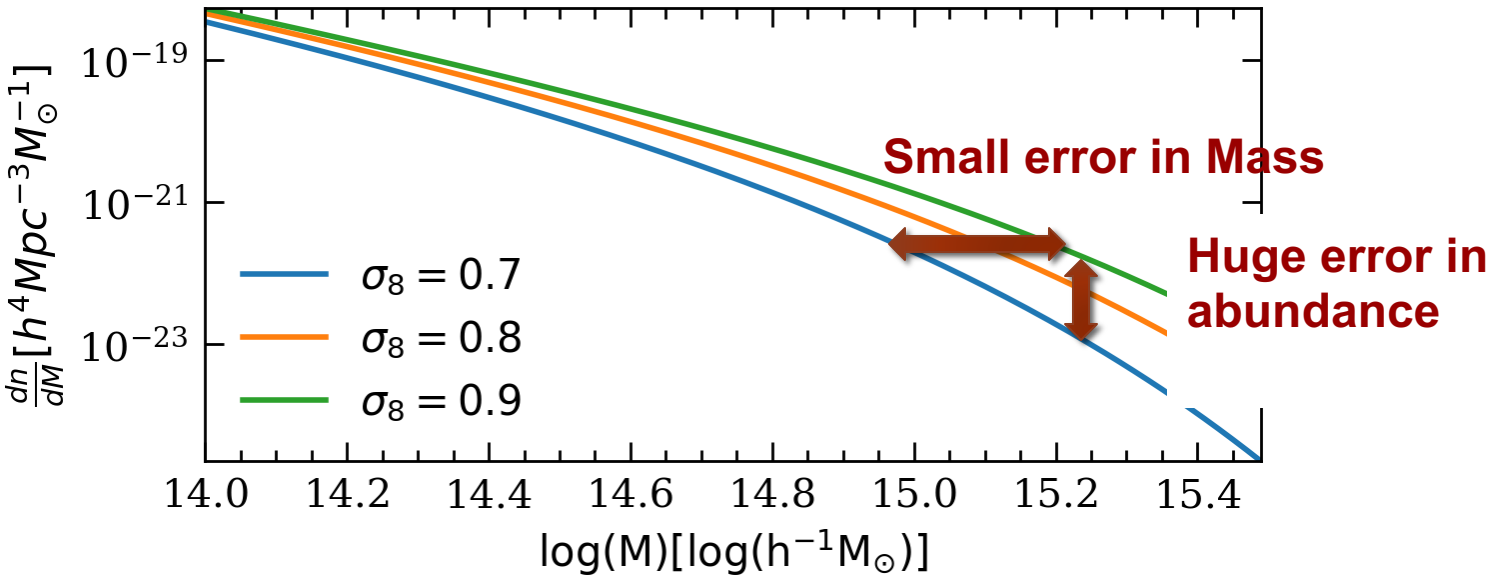
To&Krause et al. 2020 (in prep.)

Motivation

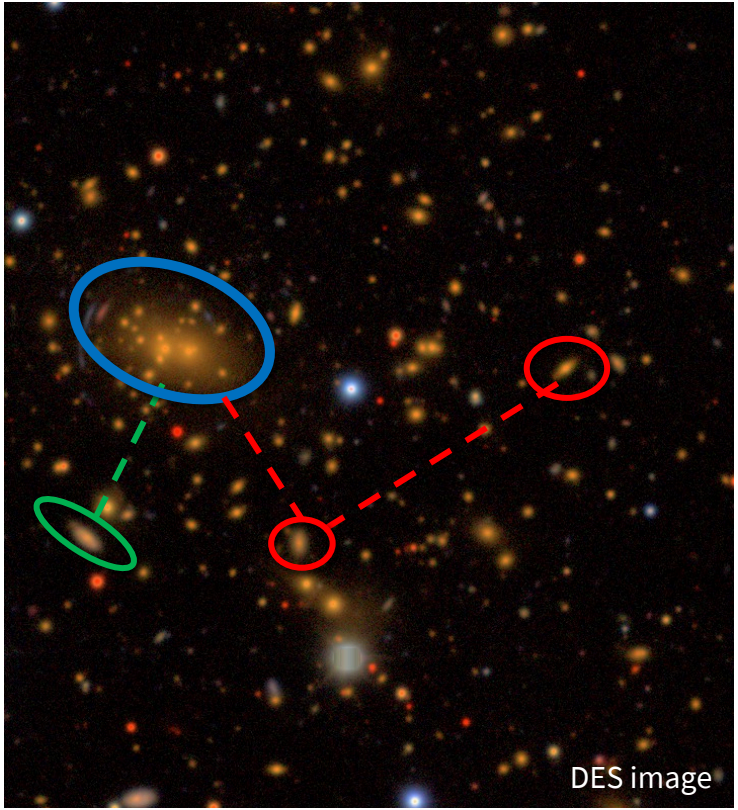
- The abundance of galaxy clusters are sensitive to σ_8 and Ω_m .
- Accurate mass calibration is essential for cluster cosmology.



Motivation

- Bias of a galaxy cluster is sensitive to its mass.

- Measuring cluster mass:
  - ➢ Cluster lensing $\propto b_c(M)$
  - ➢ Cluster x galaxy + galaxy x galaxy $\propto b_c(M)b_g$ + $\propto b_g^2$
  - ➢ Cluster clustering $\propto b_c^2(M)$

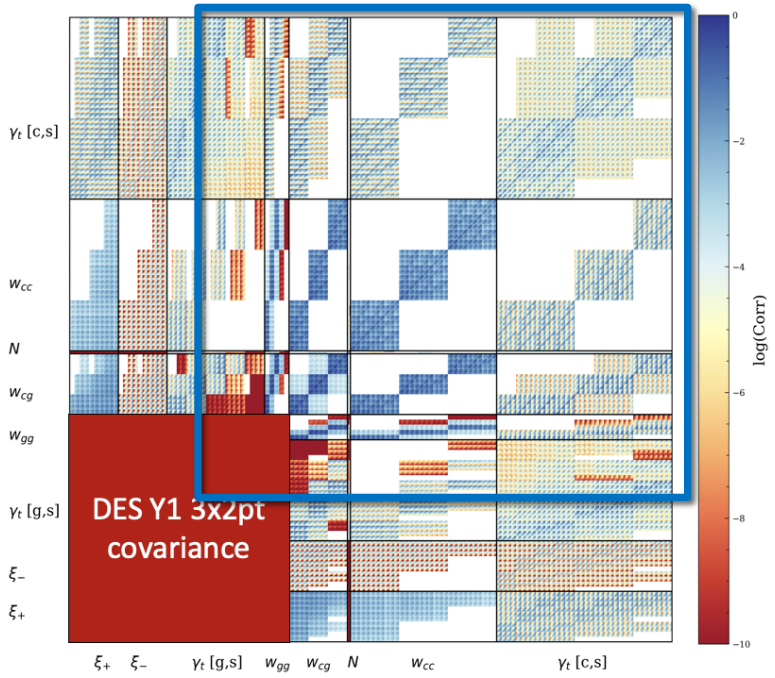


Outlines of the data vector

- We present a method of combining cluster number counts and two-point correlations.

Category	Data vector
DES Y1 3x2pt	➢ Galaxy clustering (w_{gg})
Cluster related two-points	➢ Cluster-galaxy cross correlation (w_{cg}) ➢ Cluster clustering (w_{cc}) ➢ Cluster lensing ($\gamma_t[c,s]$)
Cluster Abundance	➢ Cluster abundance (N)

- Samples:
  - ➢ Cluster samples: redMaPPer clusters
  - ➢ Galaxy samples: redMaGiC galaxies



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Difference from DES Y1 cluster cosmology analysis

Analysis in comparison		Pros of this analysis
DES Y1 cluster analysis [DES collaboration 2020]	This analysis	
• Two step analysis: Weak lensing → mass + N → Cosmology	• One step analysis: Data vector → Cosmology	Easy to be combined with other cosmological probes (e.g. 3x2pt)
• Small scale	• Large scale, 2-halo regime	Safe from many systematics (e.g. baryonic effects, mis-centering)

However, using only large-scale information degrades cosmological constraints
→ Saved by combining multiple two-point correlation functions (w_{cg} and w_{cc})

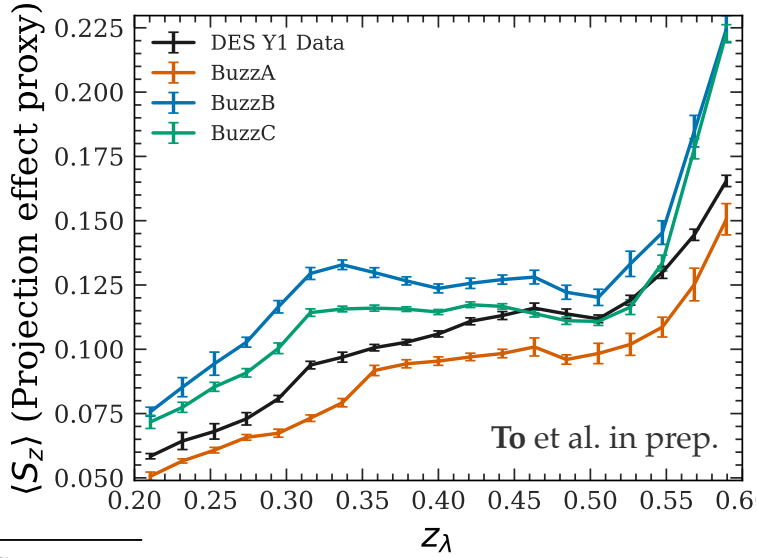
Simulation tests

- Philosophy:
  Simulated galaxy catalogs are treated as plausible universes

Simulation setups

- The projection effect is one of the most important systematics for optical cluster cosmology.

- We create special versions of the Buzzard simulation.
  → The range of projection effects in simulations well spans the data.

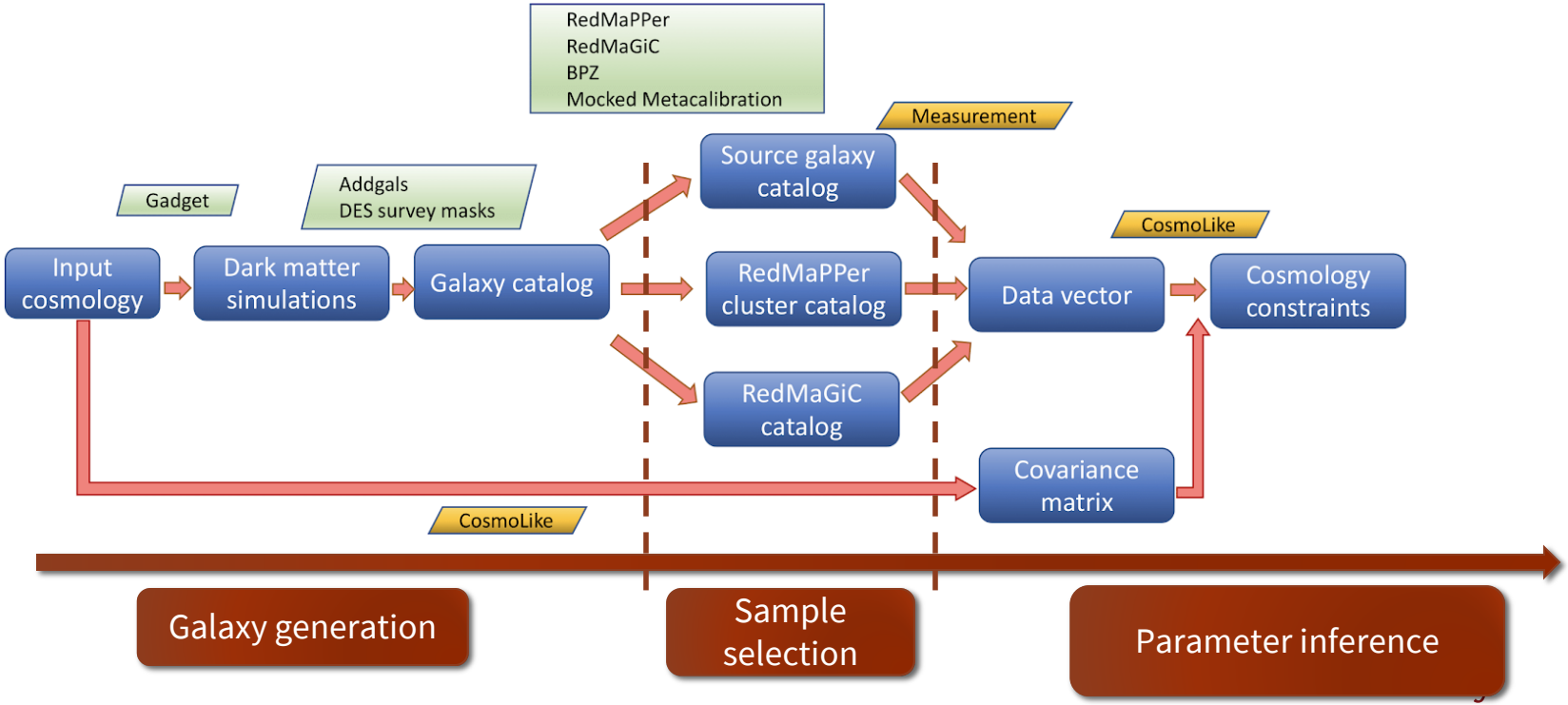


Simulation name	BuzzA	BuzzB	BuzzC
Buzzard version number	v1.9.2	v1.9.2+2	v1.9.8
RedMaPPer mode	Fullrun/Halorun	Fullrun/Halorun	Fullrun/Halorun
Footprint	DES Y1	DES Y1	DES Y3
Survey depth	DES Y1	DES Y1	DES Y3
Number of realizations	10	10	1

BuzzA: least amount of projection
BuzzB: largest amount of projection

End-to-end simulation tests

- We perform the first end-to-end validation of a cluster abundance analysis on catalog-level simulations.



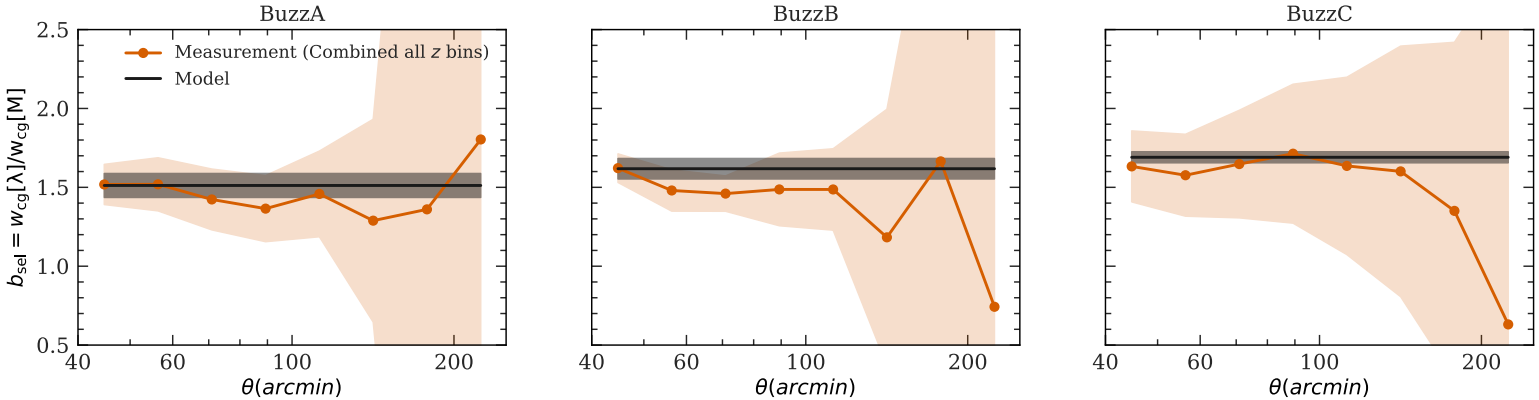
Results

Large-scale selection effect biases

- Existence of correlations between richness and large-scale correlation functions at a fix cluster mass leads to an addition bias → The selection-effect bias ($b_{\rm sel}$).
- Measurement in simulation:

  $b_{\rm sel}$ = wcg [redmapper clusters] / wcg [random halos]
- On large scale, it is scale independent.

  ➢ Relatively simple model: normalization and mass dependence [2 free parameters]



Results

- No significant systematics in the cosmological parameter inferences at DES Y1 accuracy. (Null hypothesis with p-value=3.8%, 7.1% and 2.6% in BuzzA, BuzzB, BuzzC respectively.)
  - ➢Note that different versions (BuzzA and BuzzB) of the Buzzard simulation have the same dark matter distributions → cosmic variances are correlated.

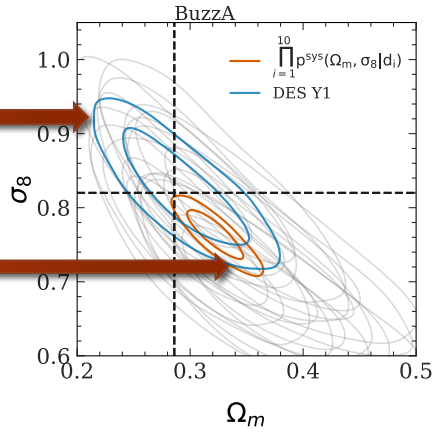
Expected constraining power from DES Y1 data

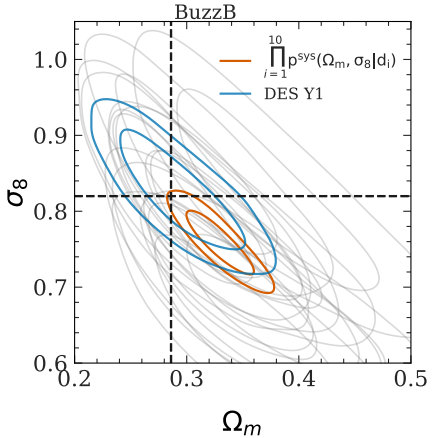
Combination of 10 realizations

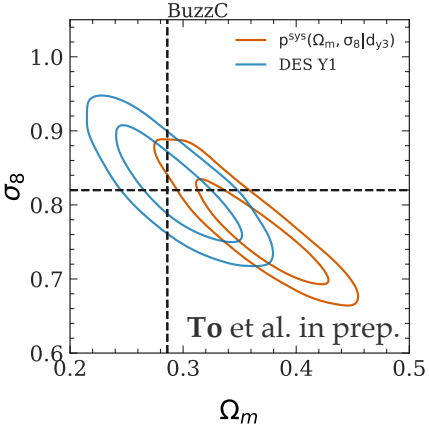
Least projection

Largest projection

1 DES Y3 realization

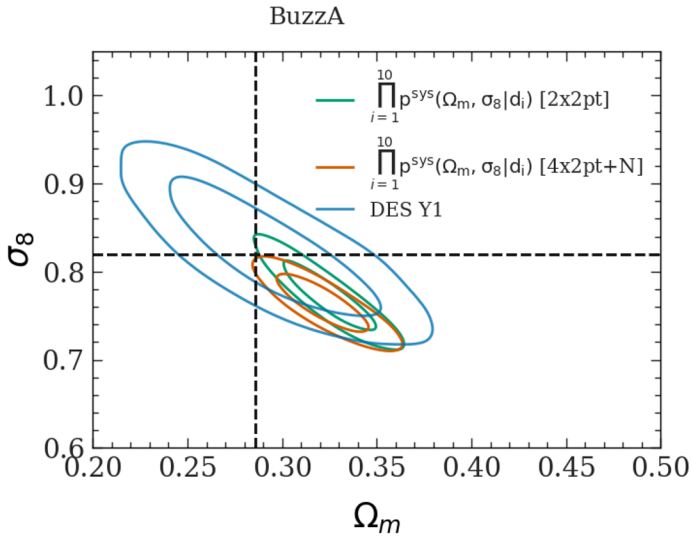


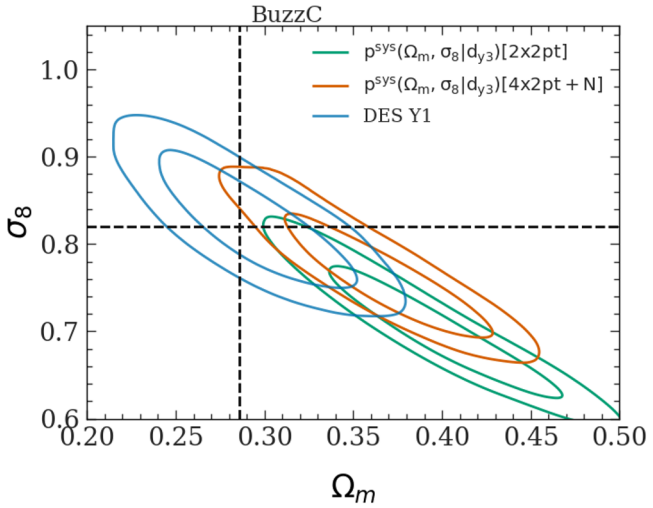




Results

- To check whether the 2 σ level discrepancy is due to flaws in the cluster analysis, we perform the 2x2pt (galaxy clustering + galaxy-galaxy lensing) analysis on BuzzA and BuzzC.
- 2x2pt and our analysis yield consistent cosmological constraints
  → The deviation does not come from flaws in the cluster analysis.

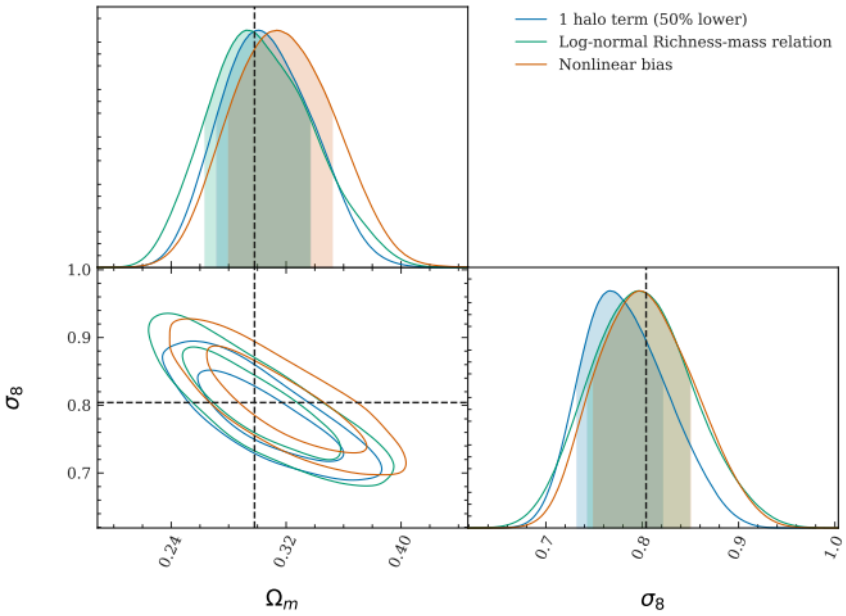




versity

Results

- Analyzing systematic-contaminated theory data vector.
- Systematics:
  - ➢ Cluster lensing one-halo term is 50 % lower than the expected value (DES Collaboration 2020.)
  - ➢ Non-linear bias.
  - ➢ Functional form of the richness-mass relation.
- None of the systematics can bias the cosmology constraints by more than 0.5 sigma.



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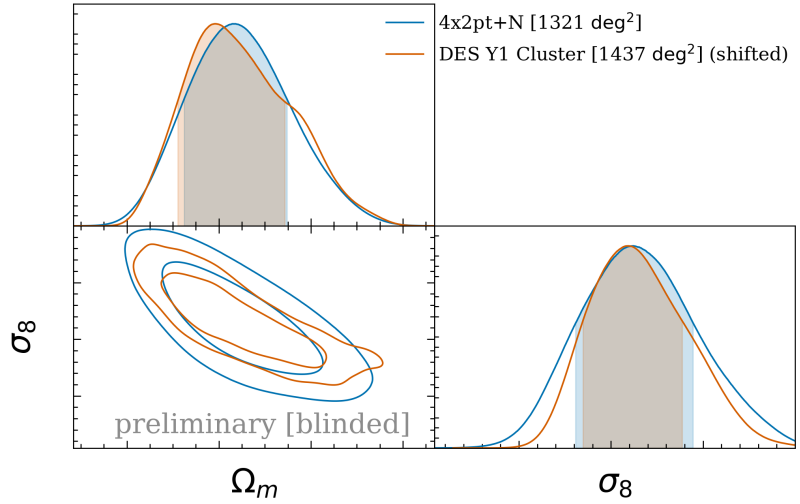
Prospects

- We run the same analysis on the DES Y1 data. [Result is still blinded]

- The method is expected to have a **similar constraining power** as the standard cluster analysis.

[Note: the area and redshift range of this analysis is smaller than the DES Y1 cluster analysis (DES collaboration 2020).]



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Conclusion

- We build a method of combining cluster abundance and two-point statistics.
- We validate the pipeline on three versions of Buzzard simulations, showing no significant systematics.
- We stress test the model by various systematics to show the robustness.

Highlight of this work:

✓ Safe from small-scale systematics (mis-centering, baryonic physics)
✓ Yielding competitive cosmological constraints.
✓ Relatively easy to combine with other cosmological probes.