DARK ENERGY SURVEY

Overview and recent results from the Dark Energy Survey

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On behalf of the DES redshift working group

esp.
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Ramon Miquel

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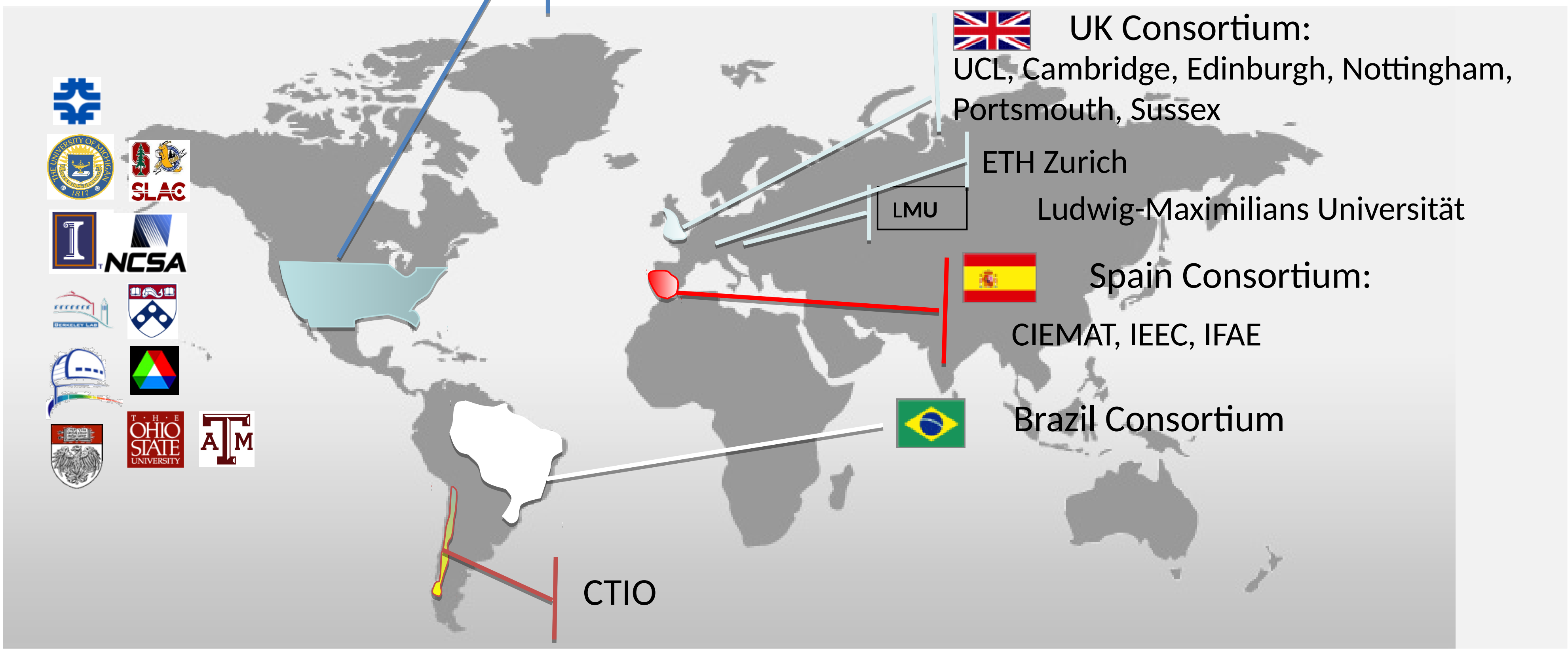
Dark Energy Survey Collaboration

~500 scientists

Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Lab, Ohio State University, Santa-Cruz/SLAC/Stanford, Texas A&M



Credit: Josh Friedman

Dark Energy Survey Collaboration

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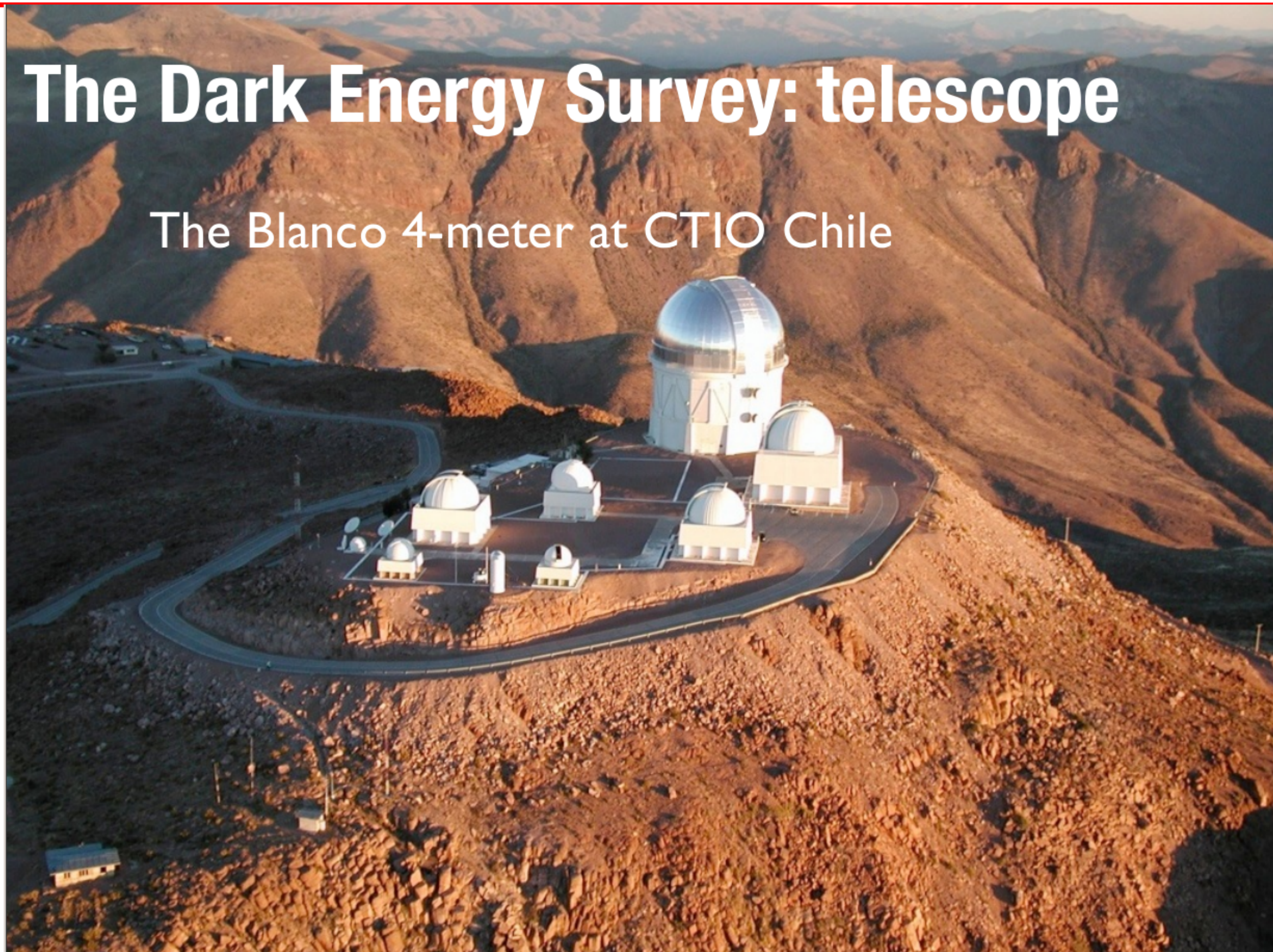

Dark Energy Survey Collaboration

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Built new camera for CTIO Blanco telescope

570 Mpixels

3 deg^2 FOV

Facility instrument

- Five-year Survey

525 nights (Aug - Feb)

Science Verification (SV)

- Nov 2012-Feb 2013

Year 3 started August 2015

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Survey strategy

Wide-Field Survey (c. 5000 sq deg)

- 90 sec exposures in *griz*;
- 45 sec exposures in *Y*
- **Multiple overlapping tilings (layers) to optimize photometric calibrations**
- Typically 2 survey tilings/filter/year

Supernova Survey (c. 30 sq deg)

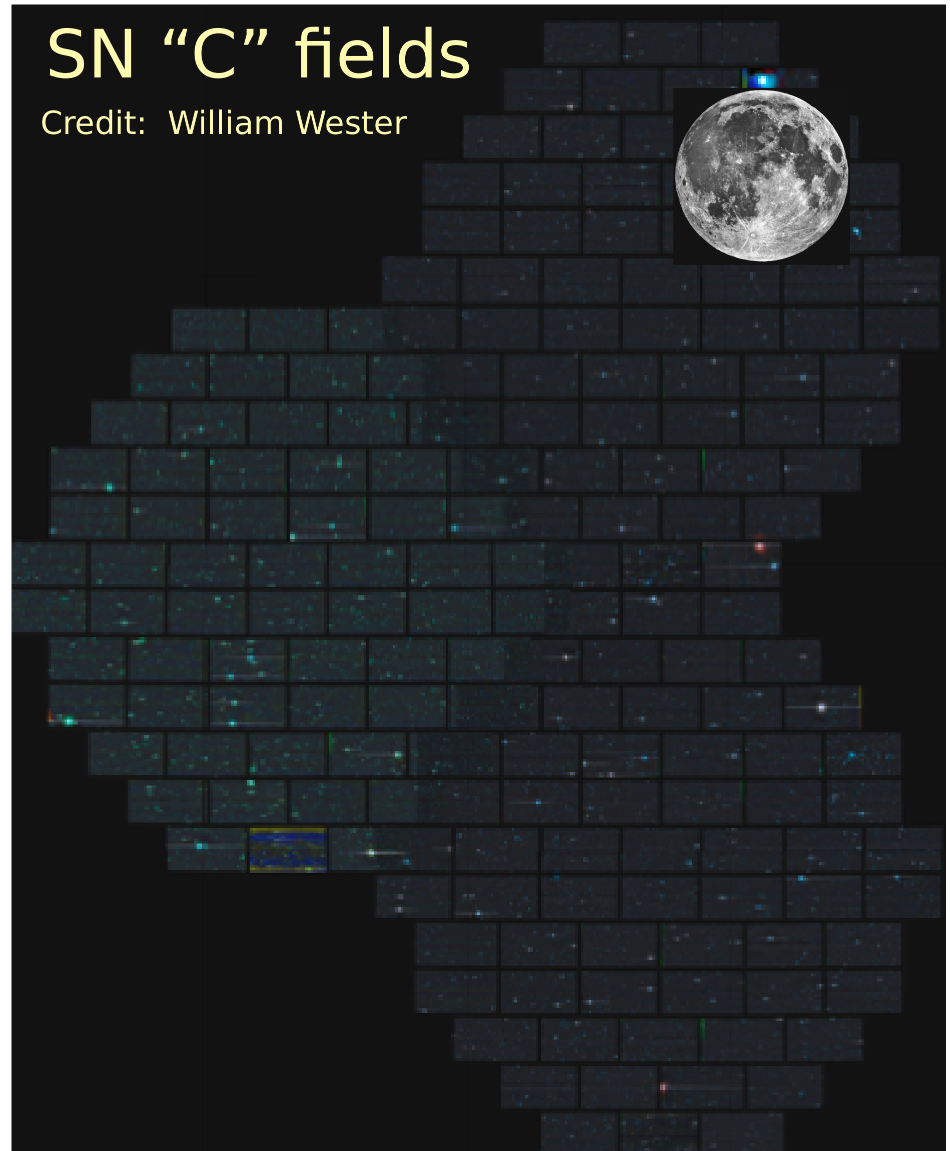
- 150-200 sec exp's in *griz* (shallow)
  200-400 sec exp's in *griz* (deep)
- ***Many*** repeat observations

Supernova vs. Wide-Field

- Observe SN fields during poor image quality or if an SN field has not been observed in 6 nights
- Otherwise do wide-field fields

Photometric Requirements (5-year)

- All-sky internal: 2% rms (Goal: 1% rms)
- Absolute Color: 0.5% (*g-r*, *r-i*, *i-z*); 1% (*z-Y*)
- Absolute Flux: 0.5% in *i*-band



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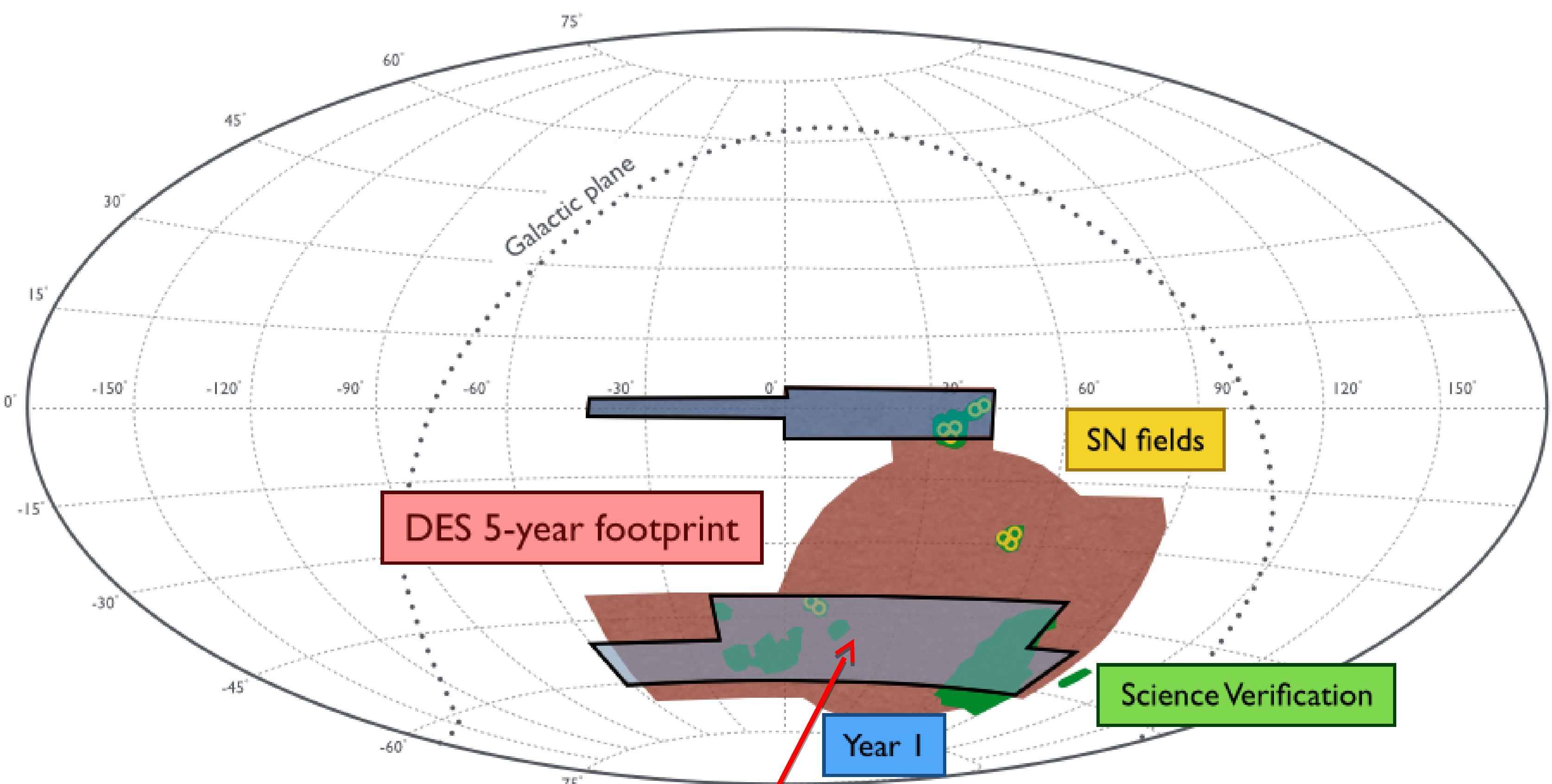


Overlap with the South Pole Telescope Survey (SPT)

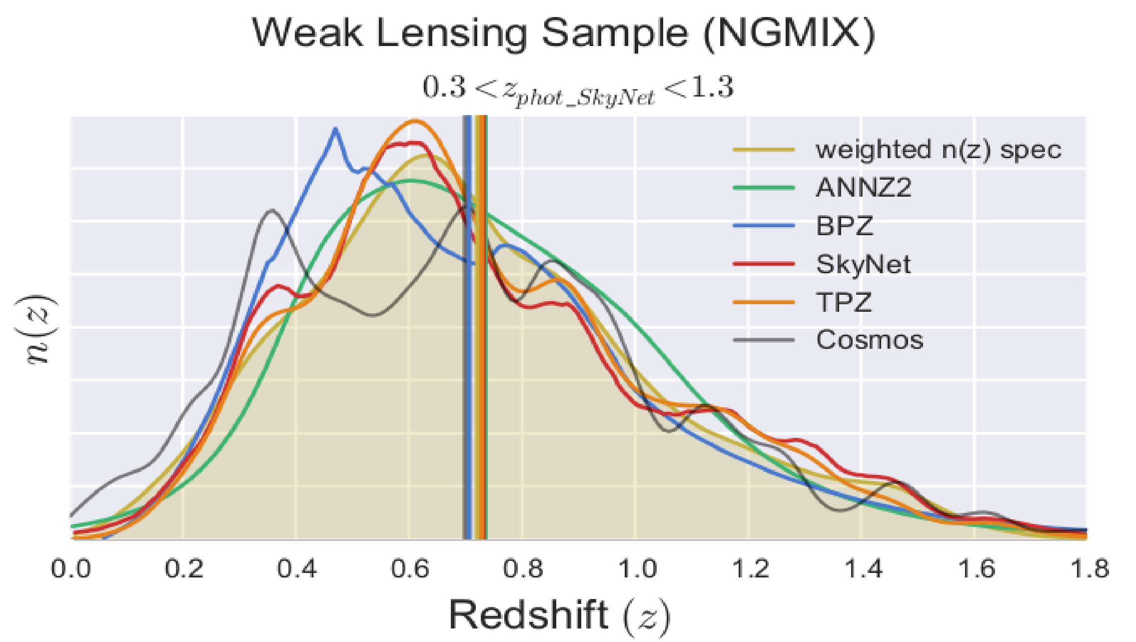
Credit: A. Merson

DES SV WL results

DES SV WL results

Redshift distribution inferred via six methods:

3 Machine learning methods
1 model-based approach
2 direct calibrations



	DES SV -WL sample	Validation sample
Spectra	0.72 (weighted)	0.64
ANNZ2	0.73	0.65
SKYNET	0.73	0.65
TPZ	0.73	0.64
BPZ	0.71	0.64
Matched COSMOS	0.70	-

Bonnett, Troxel, Hartley, Amara & DES (2016)

DES SV WL results

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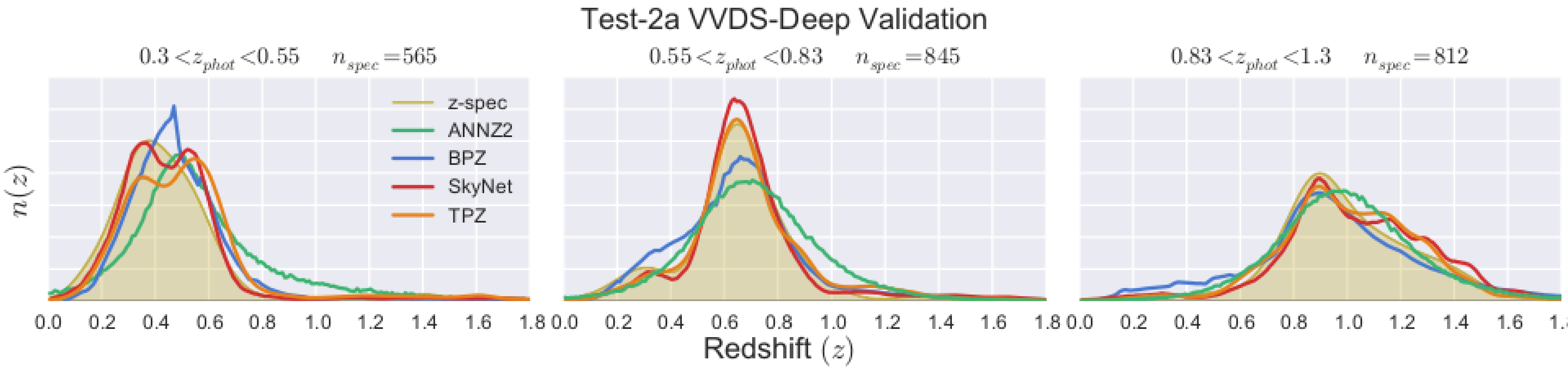
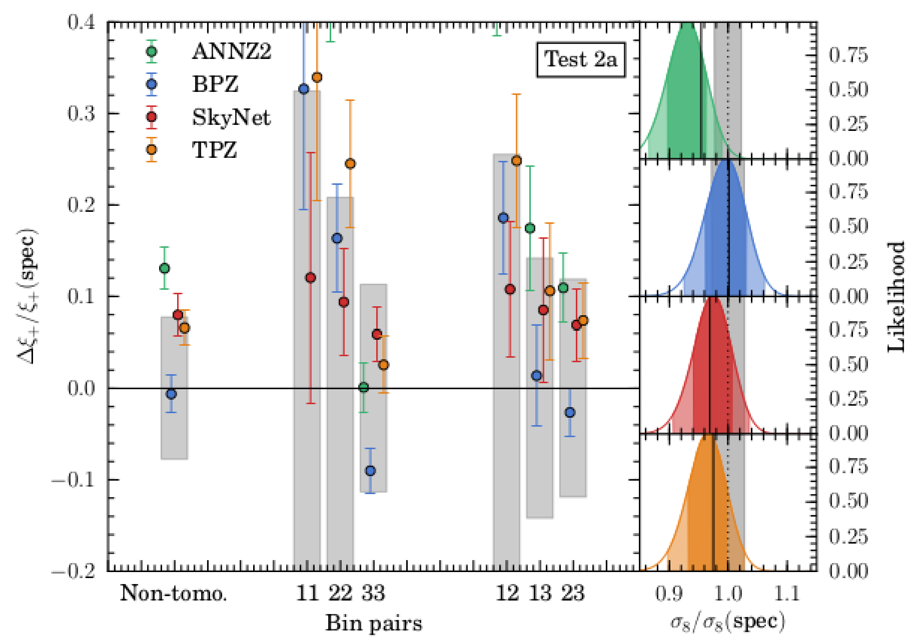


Four photo-z codes, validated against spectra.

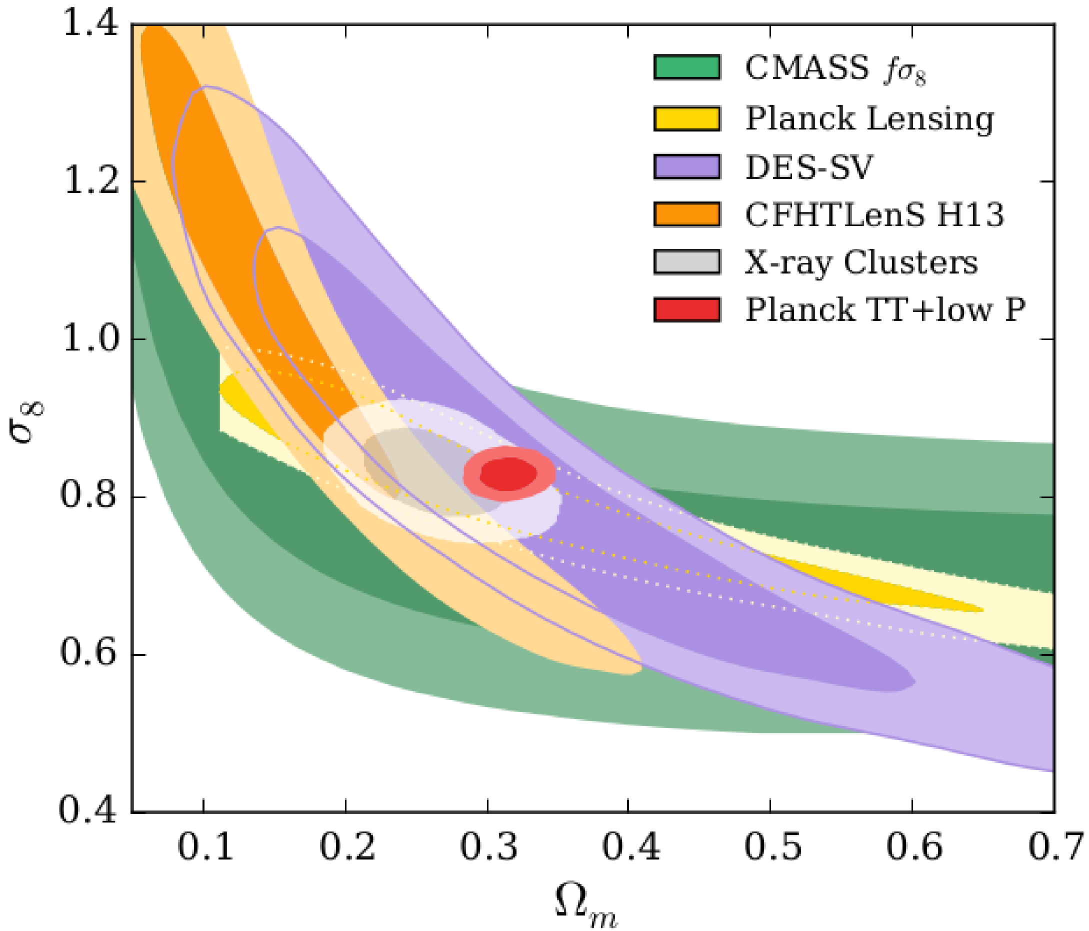
Dispersion → prior on a nuisance param., δ<z>

(one param. per tomo bin)



Bonnett, Troxel, Hartley, Amara & DES (2016)

DES SV cosmology results



The DES collaboration (2016)

DES SV cosmology results

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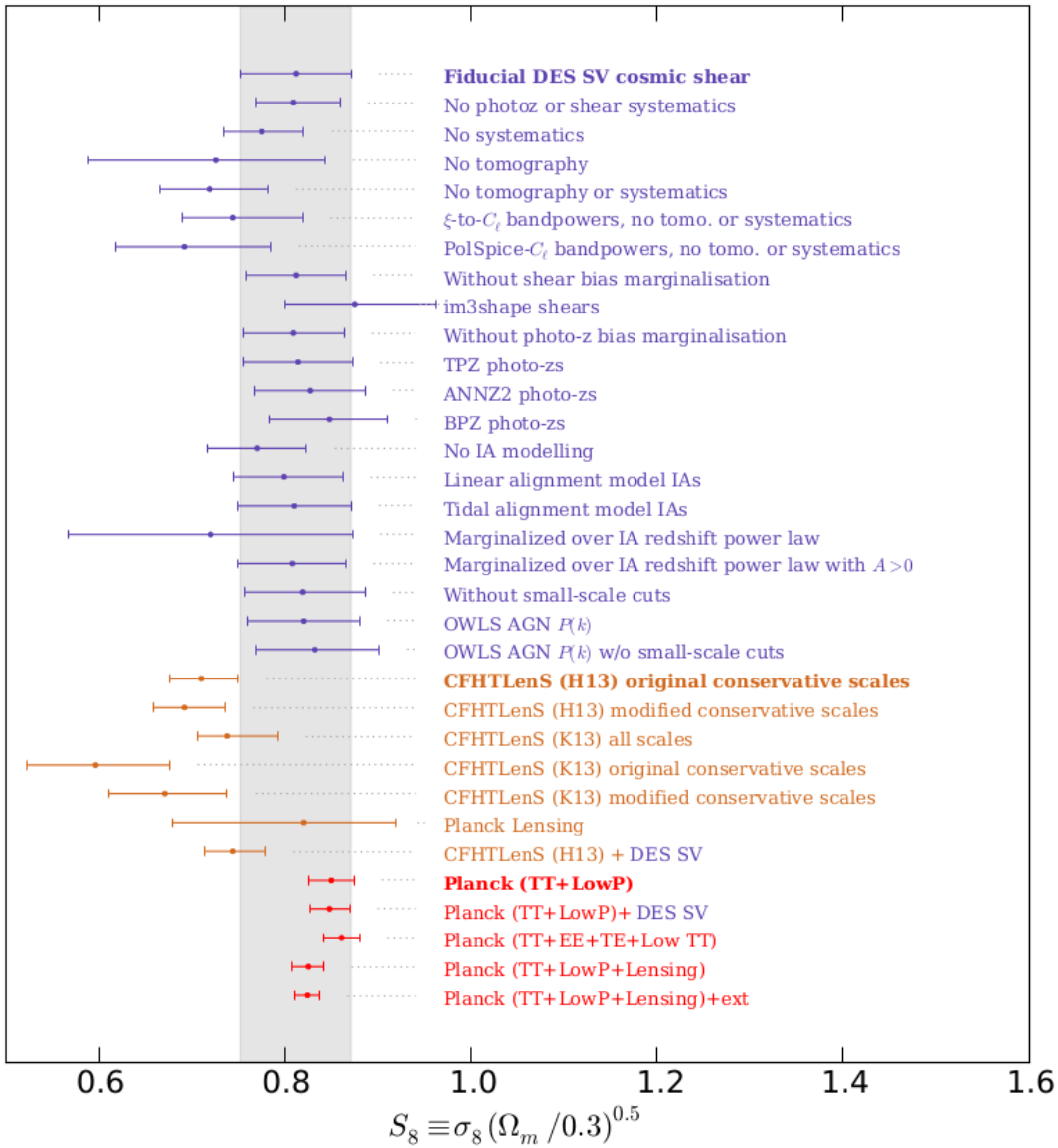
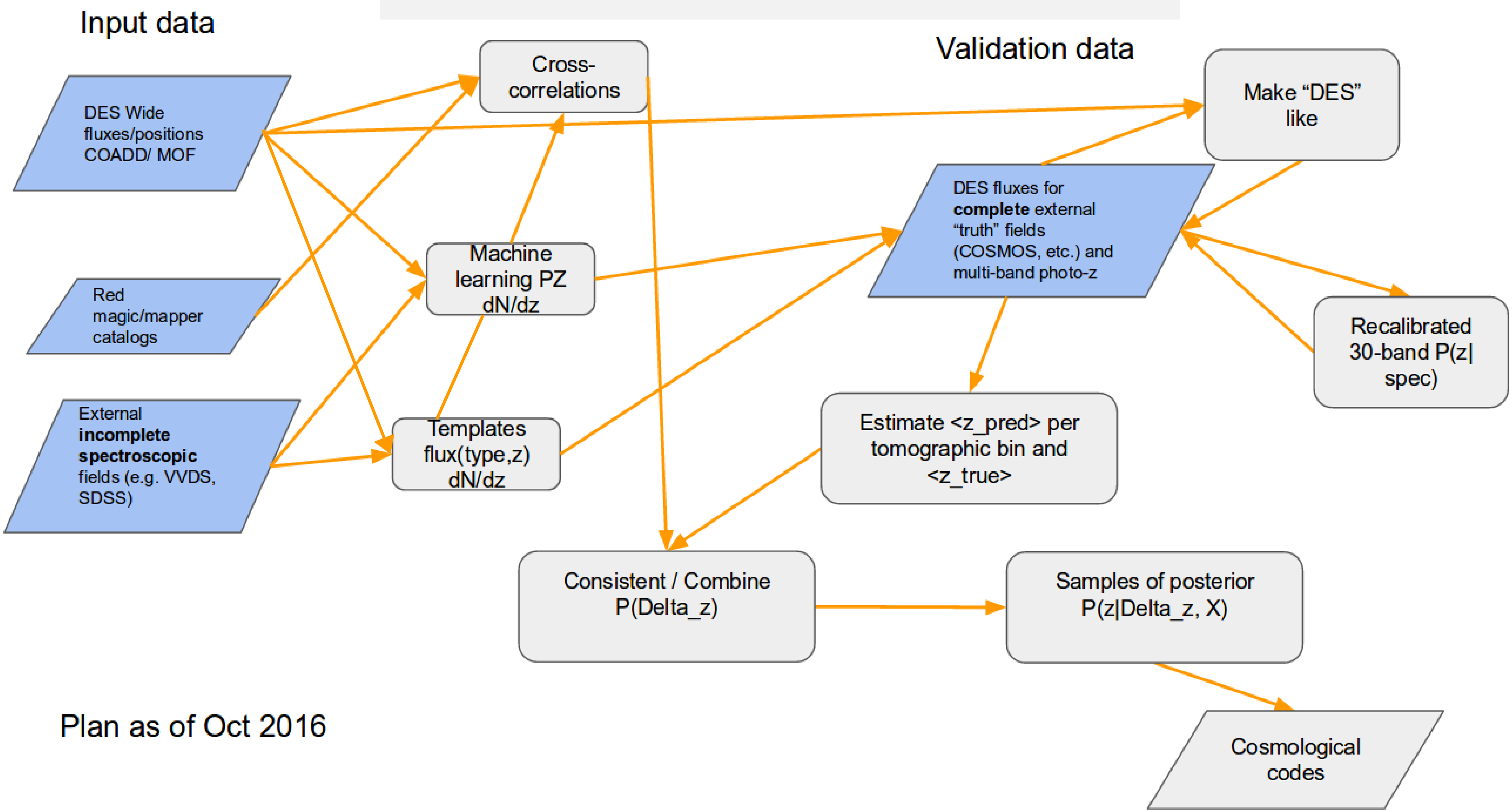


The DES collaboration (2016)

DES Y1 strategy

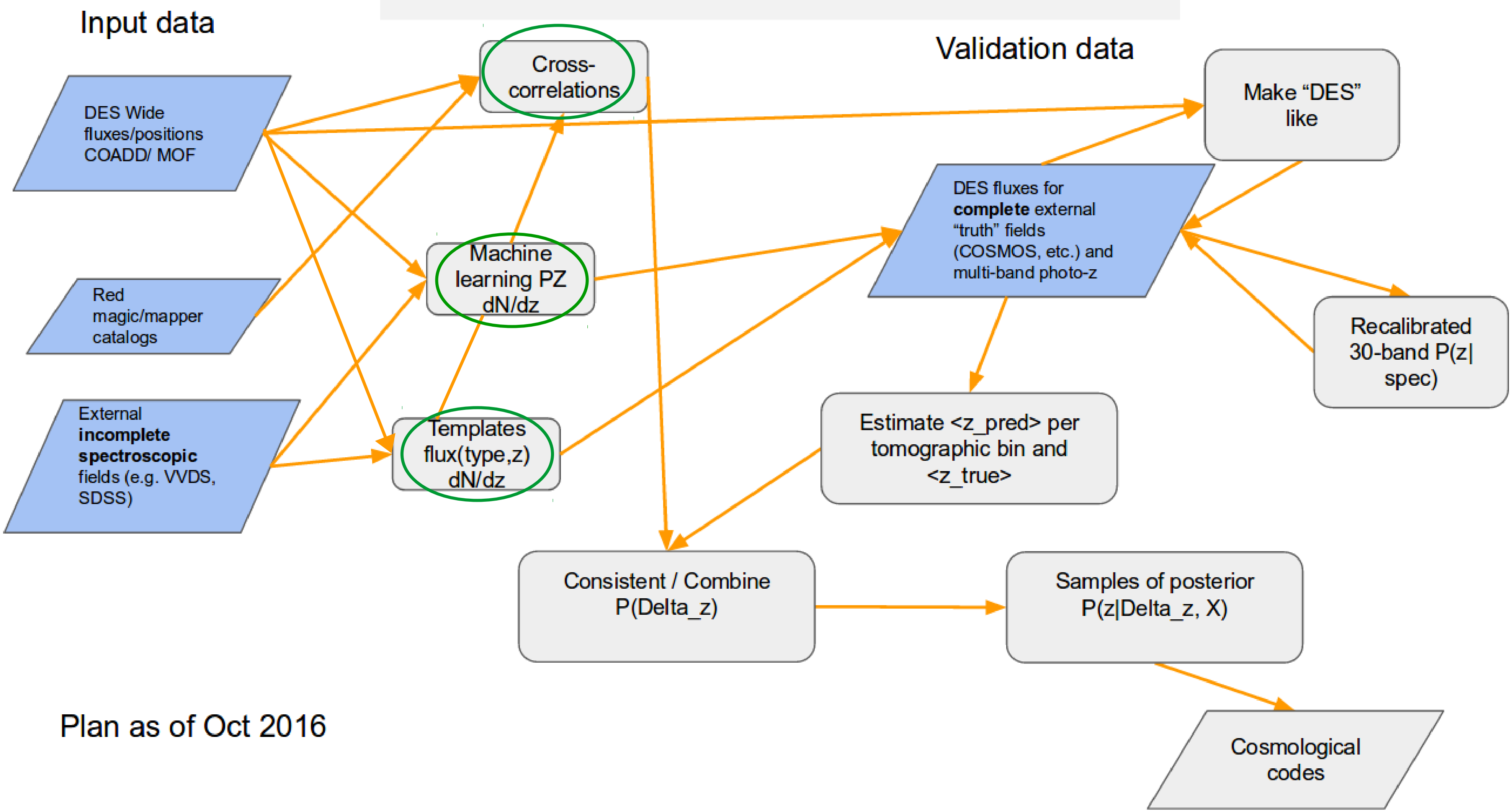
$$\Delta_z = < z_{true} > - < z_{red} >$$



Plan as of Oct 2016

DES Y1 strategy

$$\Delta_z = < z_{true} > - < z_{red} >$$



Plan as of Oct 2016

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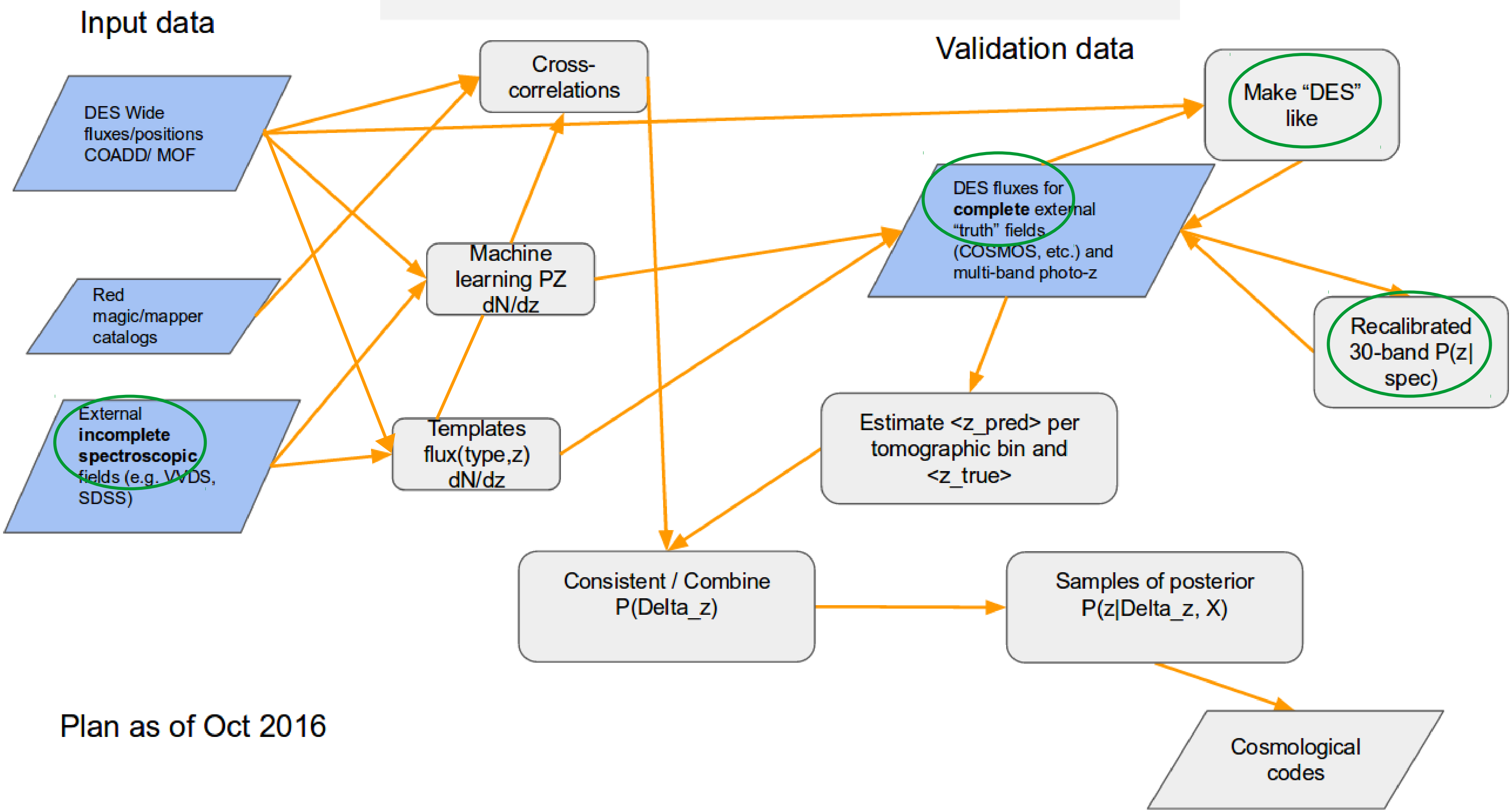

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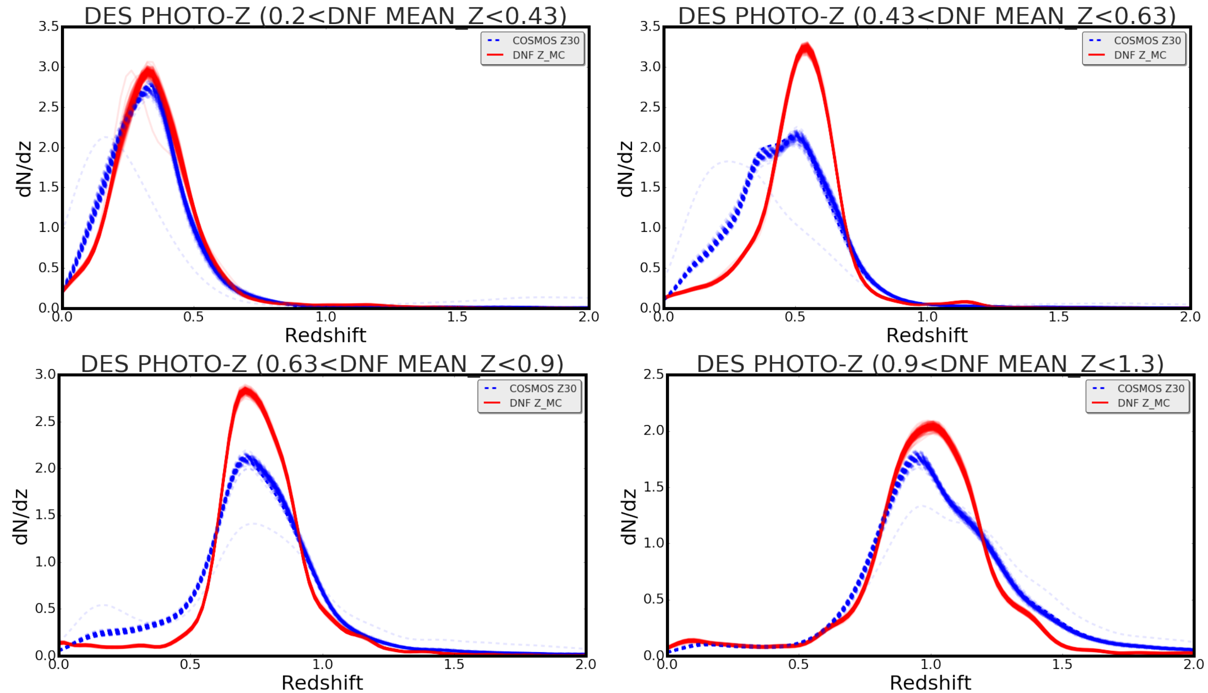
Machine learning in DES Y1

Three codes:

DNF (Juan de Vicente)
ADAboost (Ben Hoyle)
HLF (Markus Rau)

Trained with all available spec-z, except those in COSMOS

Only one code pushed through the full validation (DNF)



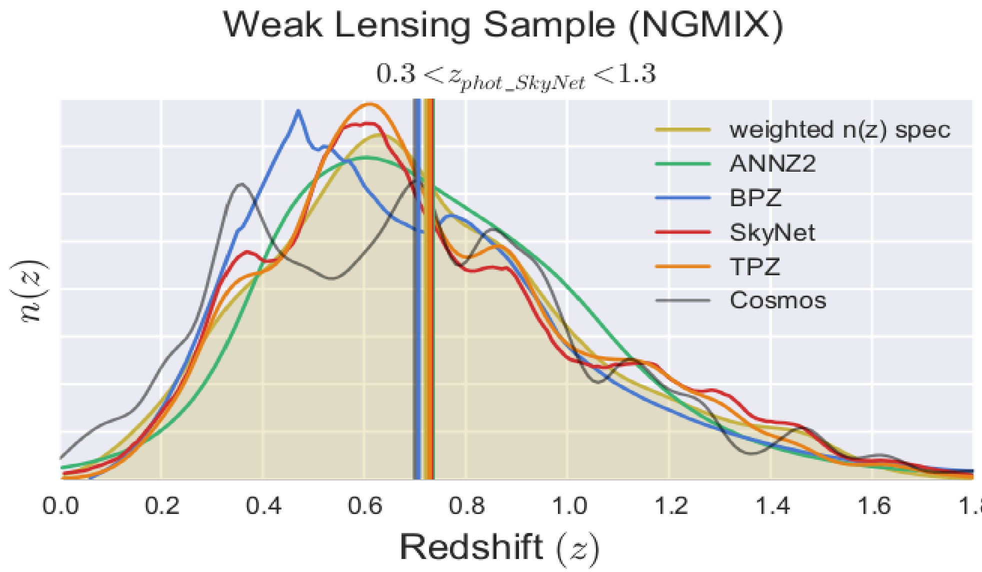
→ Problem of obtaining representative spectra remains

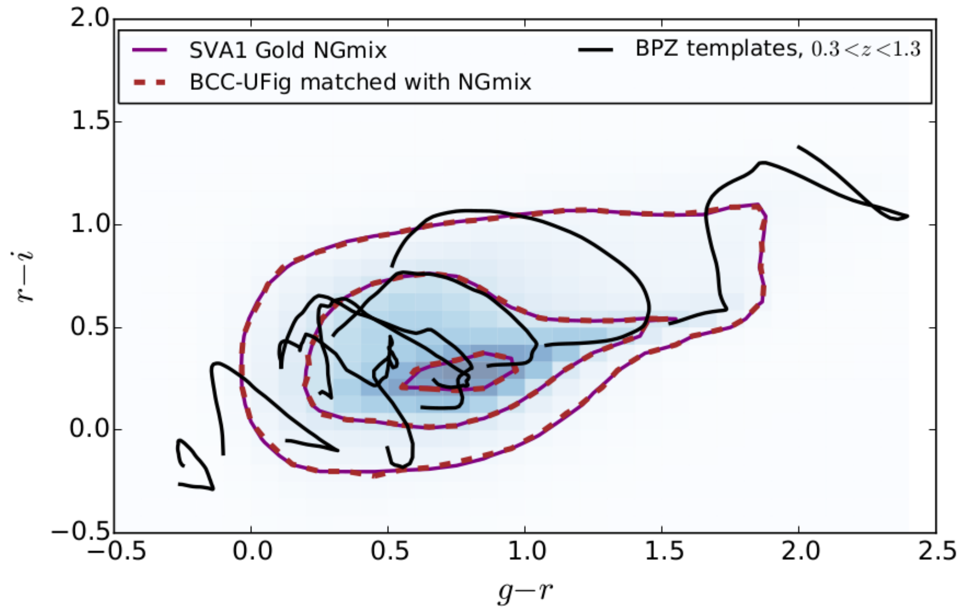
BPZ; SV → Y1

SV:

Models used to infer redshift distribution are limited

→ biases, peculiar features





Bonnett, Troxel, Hartley, Amara & DES (2016)

BPZ; SV → Y1

DARK ENERGY SURVEY

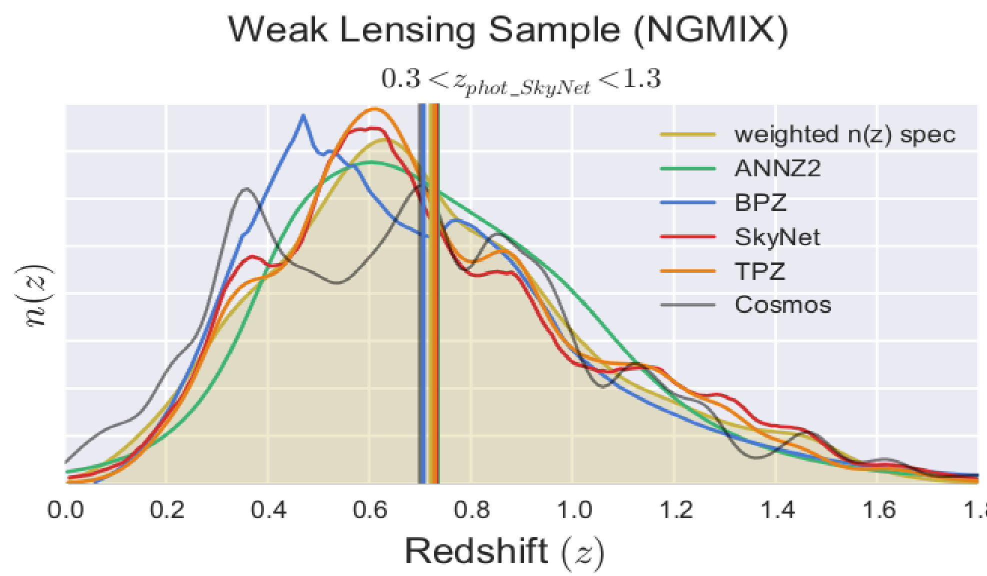
SV:

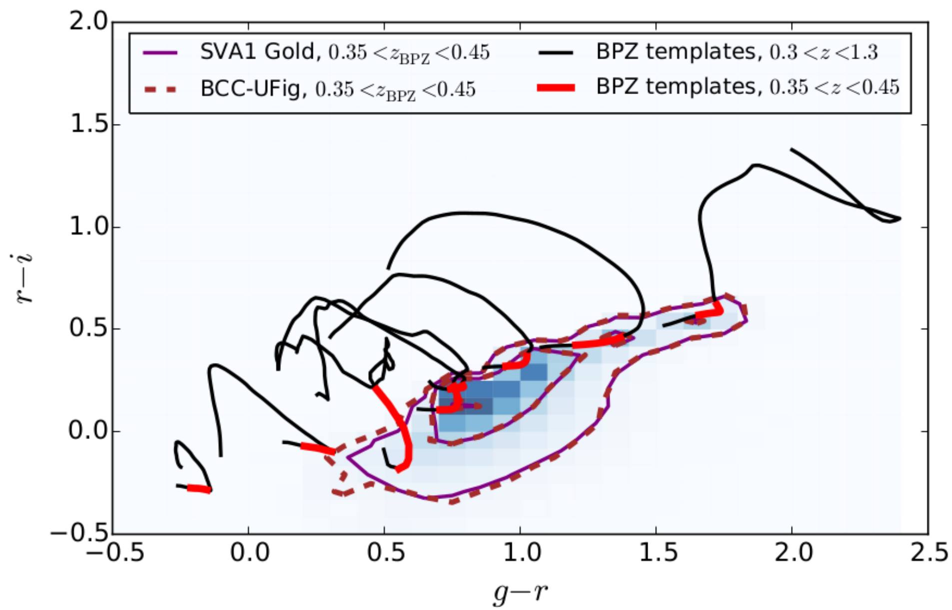
Models used to infer redshift distribution are limited

→ biases, peculiar features

Replicate in image simulation data

→ derive correction: Δz = 0.05





Bonnett, Troxel, Hartley, Amara & DES (2016)

BPZ; SV → Y1

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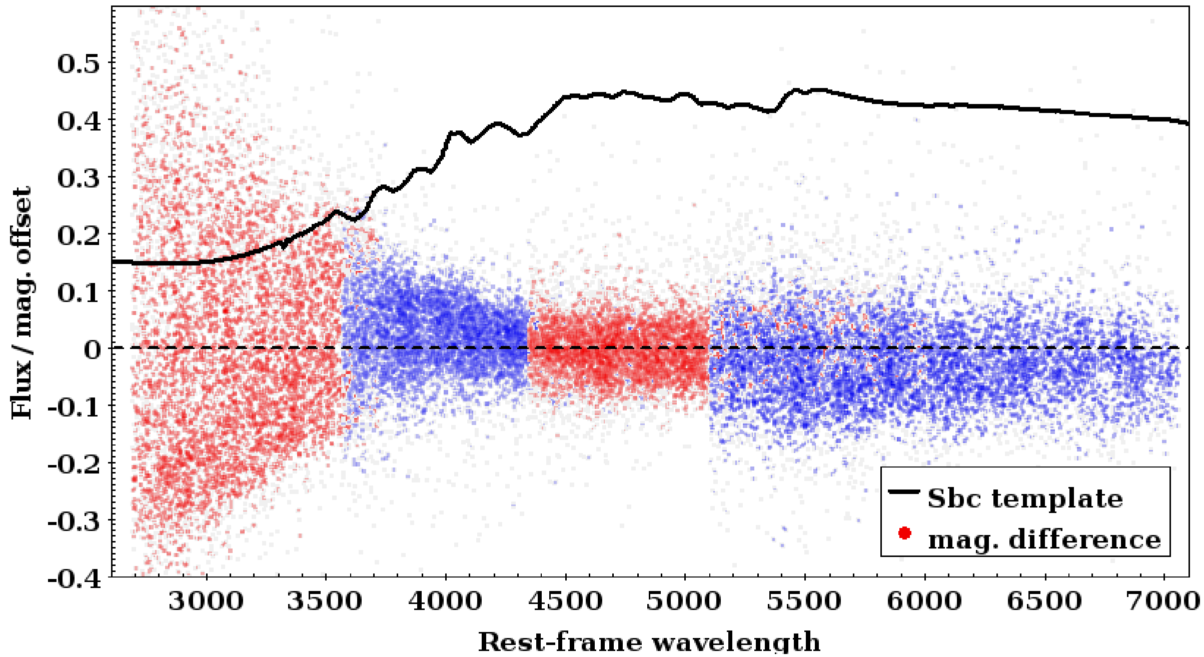
Y1:

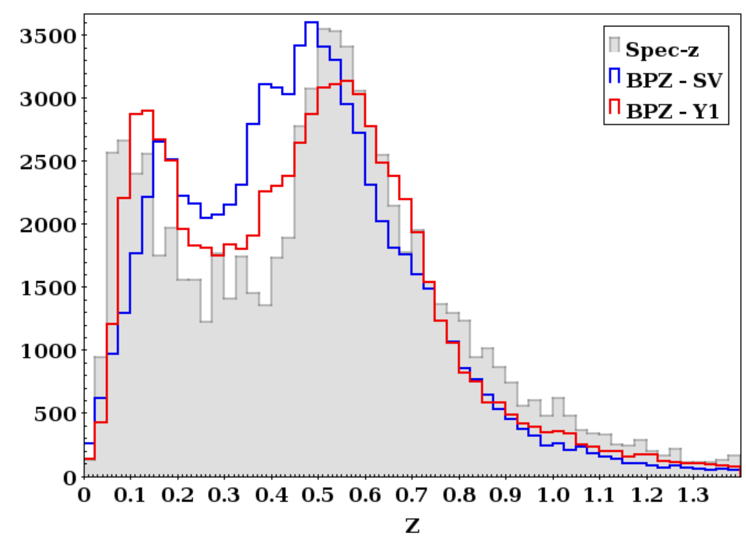
→ correct templates for z (PRIMUS)

→ train prior with complete data (COSMOS)



→ need careful cross-calib w. cosmos etc.

→ what is the best base SED set?



Lead: Will Hartley

Y1 validation strategy: clustering-z
(→ Ramon's talk)

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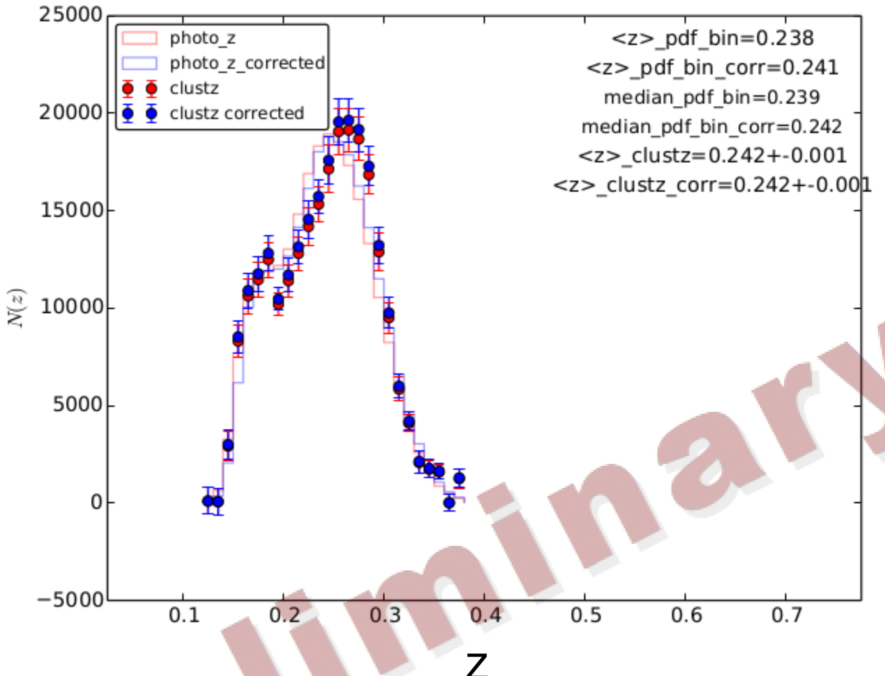
Tracer sample: redMagic (Rozo et al., 2015)

→ calibrated and tested vs SDSS spec-z
(Lead: Ross Cawthorn)

→ systematics and estimators tested in sims
(Leads: Marco Gatti, Pauline Vielzeuf)

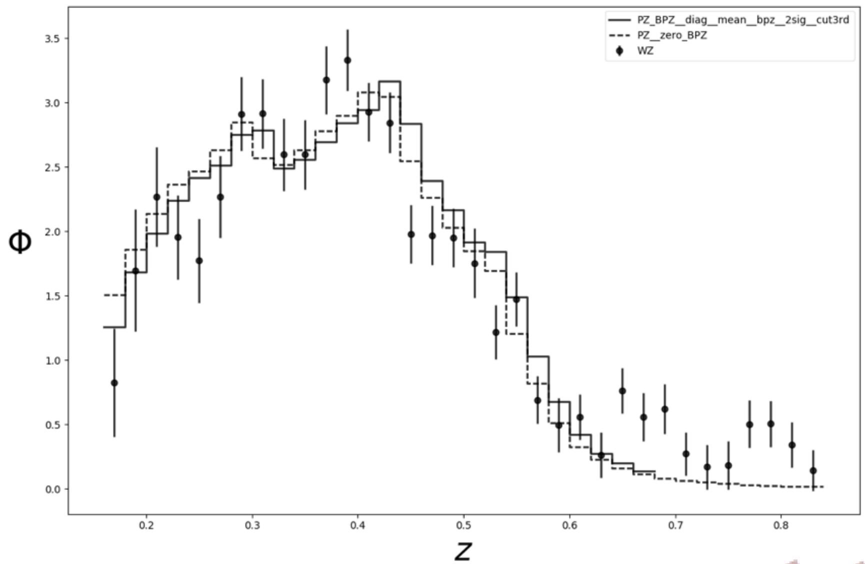
Principal systematics: PDF shape, bias evol.

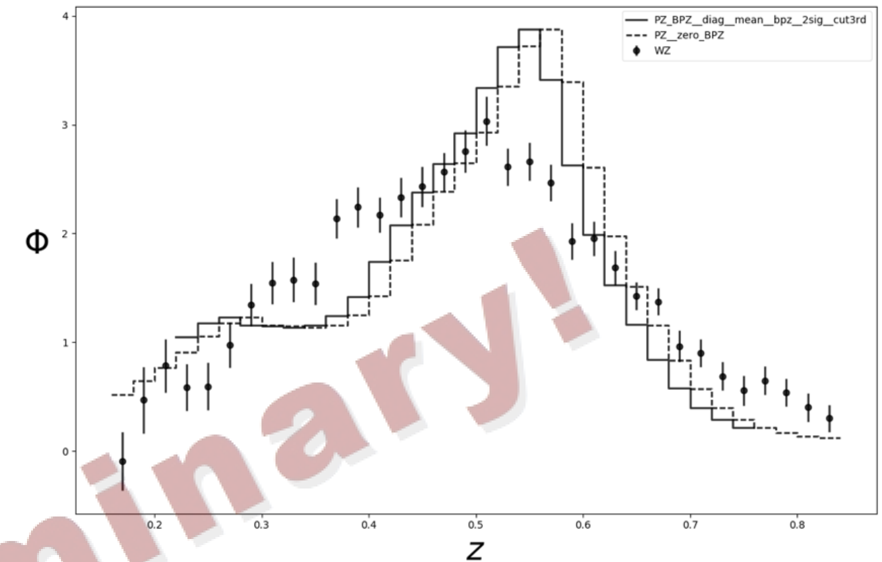
Results for BPZ:
(…) averaged over 3 codes – BPZ, DNF, ADAboost



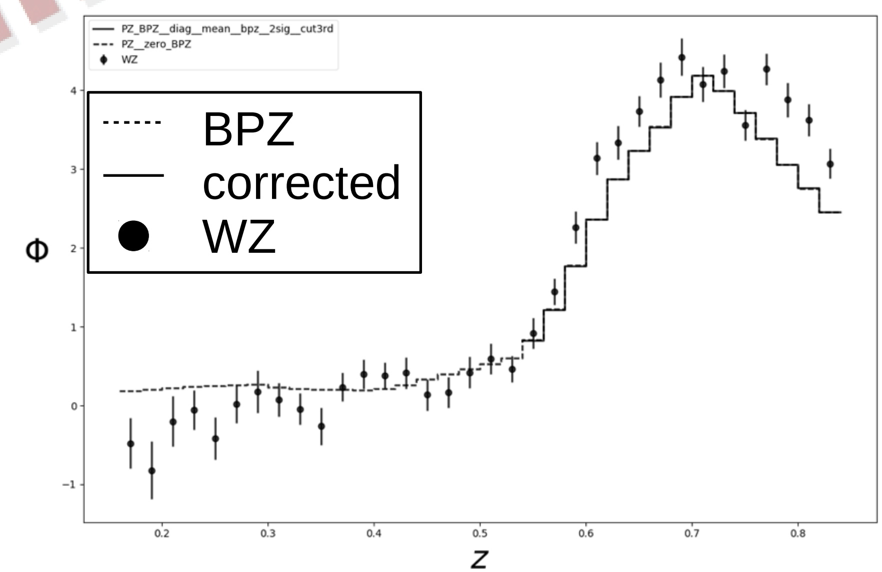
	1st tomo bin	2nd tomo bin	3rd tomo bin
bias evolution	0.02 (0.014)	0.01 (0.011)	0.008 (0.009)
Red magic photo-z	0.009 (0.007)	0.001 (0.004)	0.001 (0.002)
photo-z shape	0.011 (0.009)	0.012 (0.008)	0.004 (0.011)
mean-matching	0.005	0.005	0.005
total (in quadrature)	**0.025 (0.019)**	**0.016 (0.015)**	**0.010 (0.015)**

Y1 validation strategy: clustering-z
(→ Ramon's talk)





Bin	WZ shift	WZ uncert.
1	1,14E-02	2,60E-02
2	-1,95E-02	2,20E-02
3	1,00E-04	2,20E-02



Lead: Chris Davis

Spectroscopic incompleteness
(→ Will's talk)

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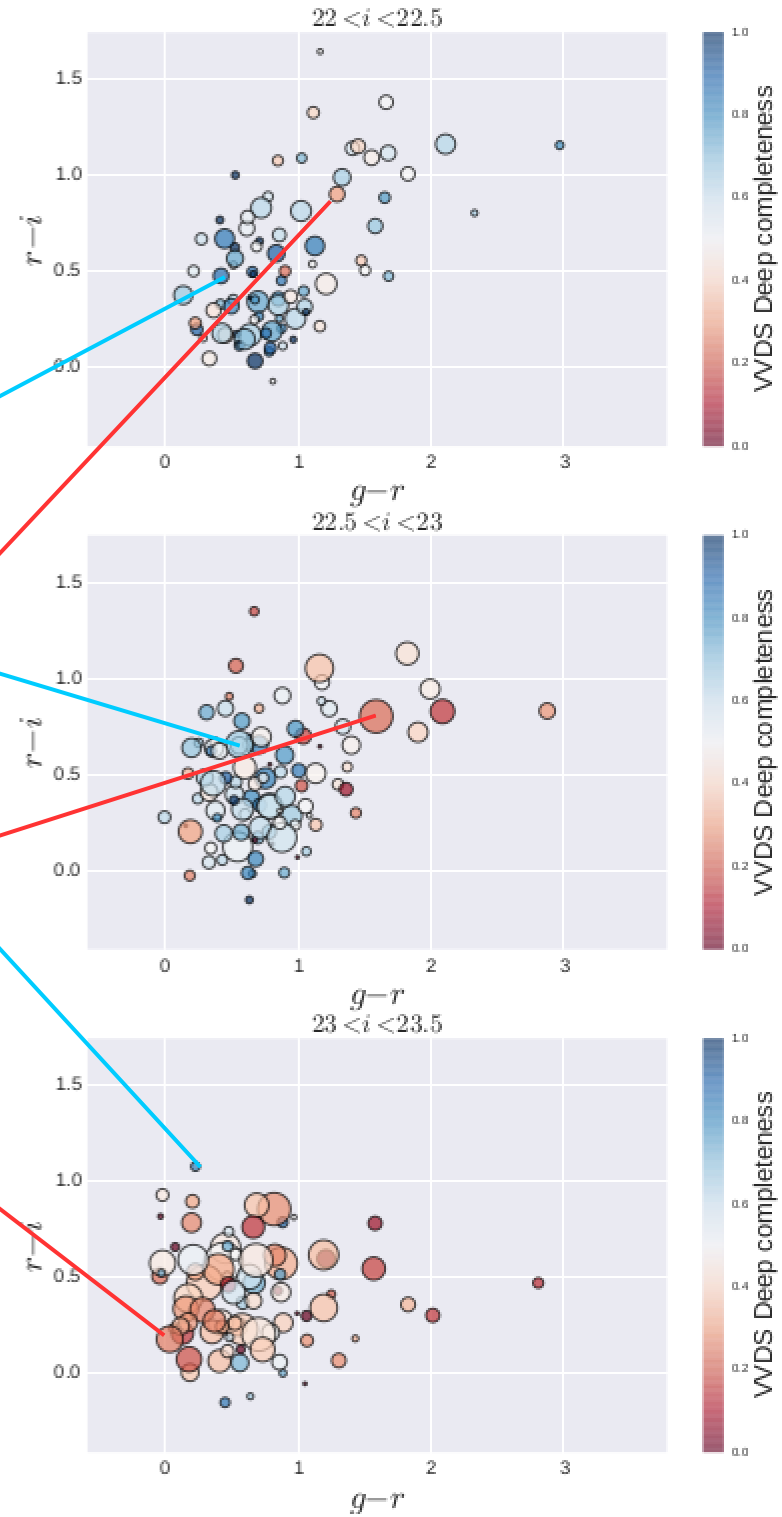
'Good' cells (high completeness):
< z (cosmos) > – < z (spec.) > = 0.01

'Bad' cells (low completeness):
< z (cosmos) > – < z (spec.) > = 0.03

Offsets ~ level of expected sample variance for VVDS Deep, COSMOS.



Bonnett, Troxel, Hartley, Amara & DES (2016)

Spectroscopic incompleteness (→ Will's talk)

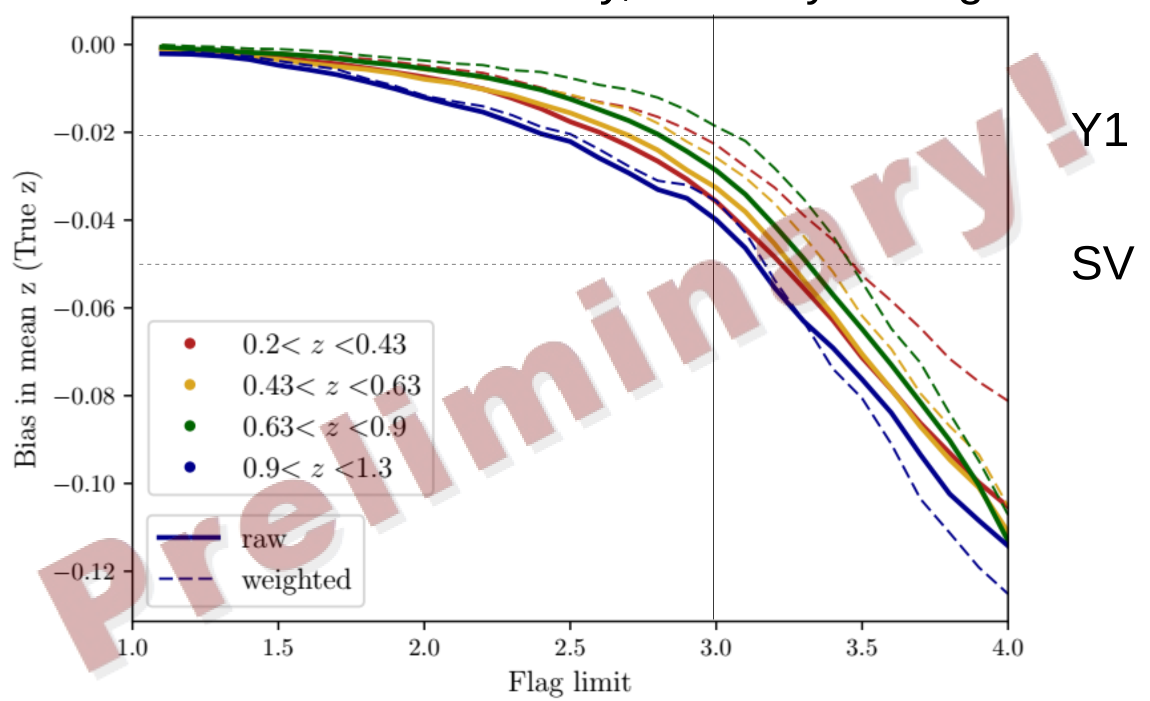
Leads: Will Hartley, Chihway Chang

Bias in mean redshift due to incompleteness

→ within SV budget

→ ~ to **total** budget for Y1 in 3 bins

→ greater than allowed in highest tomo bin



→ Is this situation recoverable? (e.g. via culling bad data)

→ Will we be able to use spec-z for precision cosmology validation in future?

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Y1 validation strategy: COSMOS

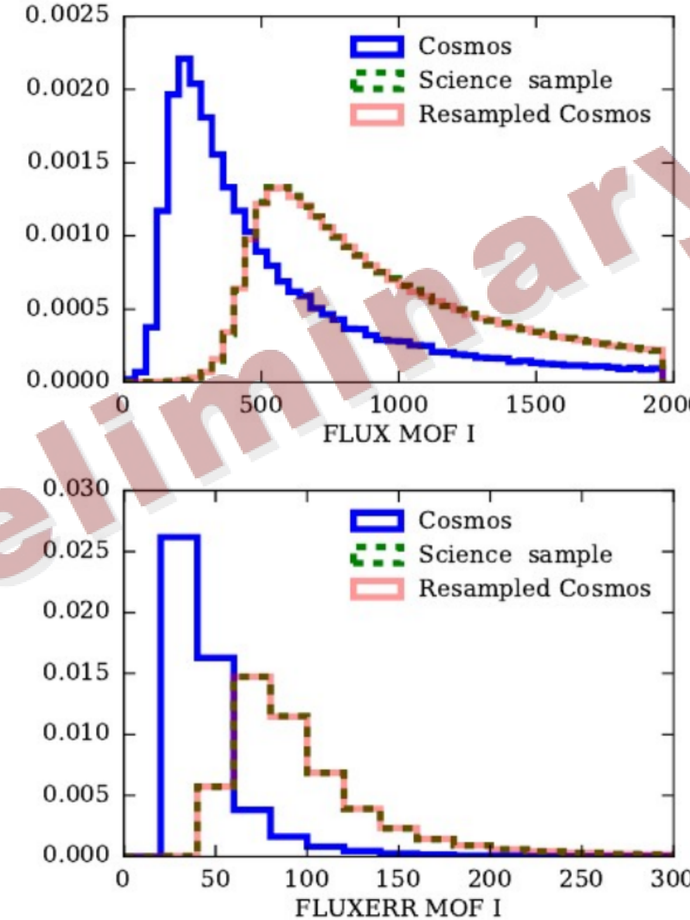
→ COSMOS PDFs rescaled (a la Bordoloi et al., 2010)

→ Random sample of 200,000 science objects chosen.

→ COSMOS DECam photometry degraded (and perturbed) to reflect each object's image depth.

→ COSMOS object selected to match target (in flux, flux error and pre-seeing size).

→ Redshift drawn from (rescaled) COSMOS PDF.



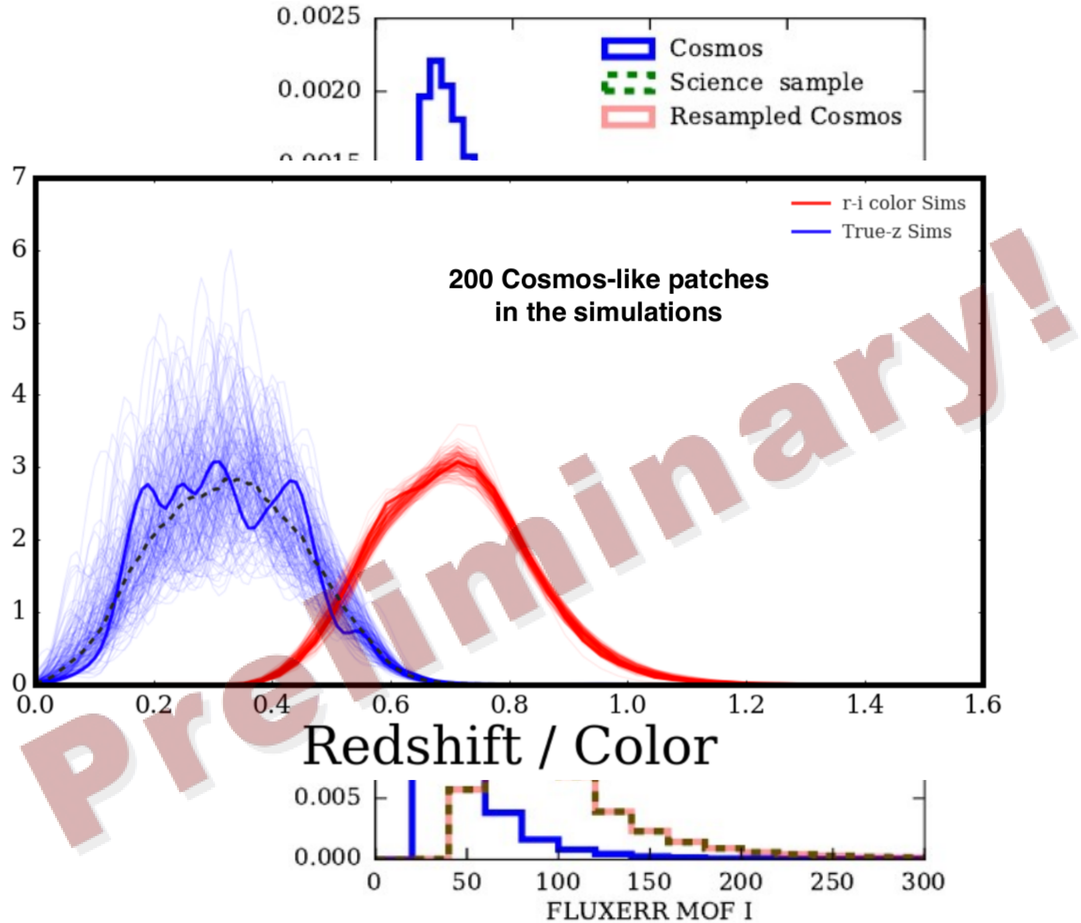
Lead: Ben Hoyle

Y1 validation strategy: COSMOS

COSMOS is subject to field-to-field var.

→ significant uncert. in global mapping of col. → z; and therefore in <z>

→ f-to-f var. error: 1.2%
(after col-mag reweighting)



Lead: Ben Hoyle

Y1 validation strategy: COSMOS

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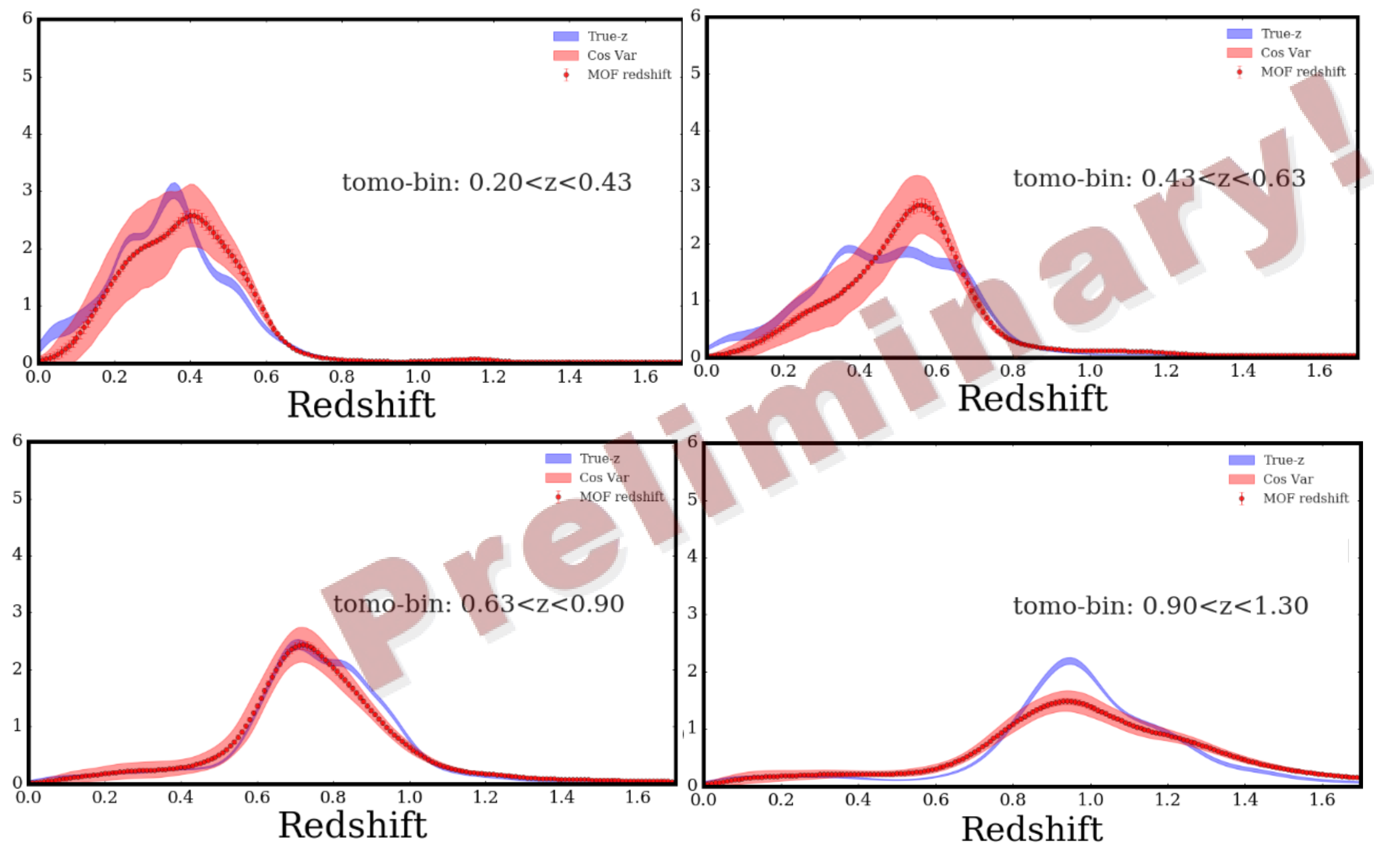
BPZ validation with COSMOS

→ **Not optimising PDF shape in Y1**

→ Not dramatically incosistent with COSMOS



Leads: Ben Hoyle, Daniel Gruen

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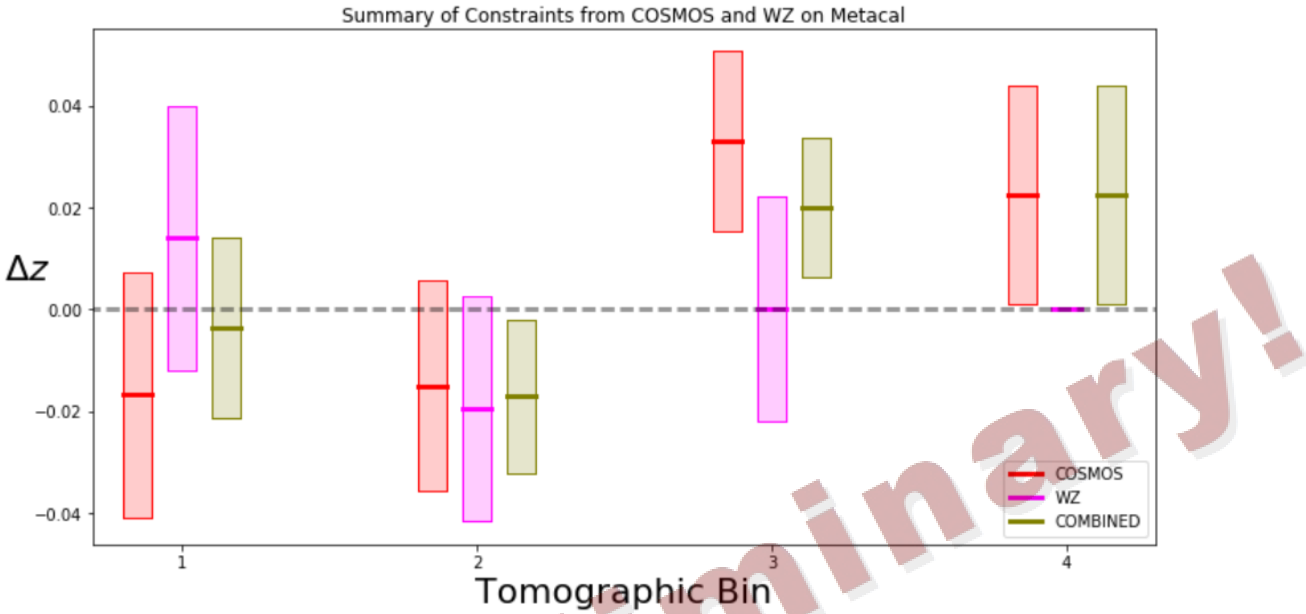
	Bin1	bin2	bin3	bin4	total
COSMOS resampling stat. uncertainty	0.0009	0.0017	0.0018	0.0030	0.0011
COSMOS resampling systematic uncertainty	0.0073	0.0073	0.0073	0.0073	0.0073
COSMOS resampling morphology uncertainty	0.0062	0.0062	0.0062	0.0062	0.0062
COSMOS cosmic variance	0.0073	0.0077	0.0039	0.0070	0.0047
COSMOS photometric calibration	0.0030	0.0040	0.0039	0.0059	0.0021
COSMOS uncertainty sum in quad.	**0.0153**	**0.0130**	**0.0112**	**0.0136**	**0.0109**

Preliminary!

→ Are we already reaching the useful limits of this approach?

Current constraints on Y1 WL



Main sources of error:

- Photo-z PDF shape
- Field-to-field var. in deep photometric fields
- Bias evolution in target samples

Bin	Δz (comb. wz, pz)	$\sigma_{\Delta z}$ (for Gaussian prior)
1	-0.0037	0.0177
2	-0.0171	0.0150
3	0.0200	0.0138
4	0.0224	0.0215

Outlook for Y3+
(→ Gary's talk)

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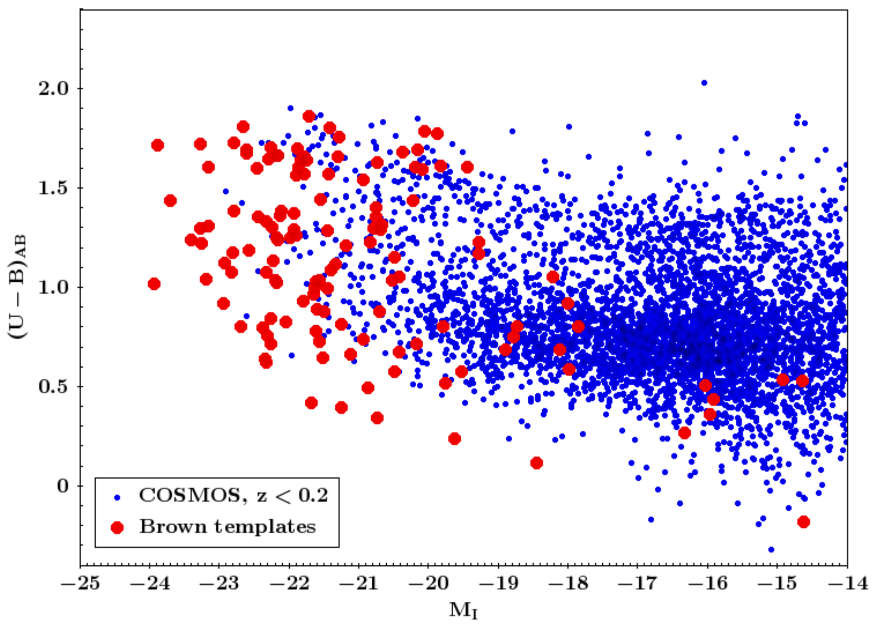
Substantial improvements needed, going from Y1 → Y3:

- Y3 has ~3x the area of Y1.
- Photo-z is already a major part of Y1 error budget!

Data:

→ Further photometric fields (Alhambara)
→ More spectroscopy (esp. C3R2)
→ Larger RedMagic sample



Methods:

→ Move to colour-space sample, tomo bin selection
→ Revamp SEDs for model photo-z (urgent)
→ Demand accuracy in PDF shape, not just Δz

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=== Main Issues ==

Prediction/training/calibration:

1.1) Machine learning codes: What happens when the training data is not the representative of the science sample.

1.2) Template codes: What happens when the templates are not representative of the data.

1.3) Are the flux errors realistic enough?

1.4) Is there an optimal method to obtaining pdfs for ML?

Direct validation of redshift predictions for single galaxies and samples of galaxies.

2.1) Tests of representativeness of the validation data and the science sample data

2.3) What should we do when the spectroscopic data is not longer bias free (in redshift) and unrepresentative of the science sample.

2.4) Do multi photometric surveys provide accurate enough redshifts, and cover large enough area.

Data-driven validation methods

3.1) Do we trust the correlation-redshifts methods more than the color-redshift relation? E.g. galaxy-db bias [and evolution] of samples.

Science from photo-z

4.1) How are the dndz uncertainties propagated and marginalised over. Are they characterised with enough nuisance parameters?

4.2) How do we know trust photo-z predictions of small numbers of objects (e.g. z=7 galaxies in a pencil beam survey!)