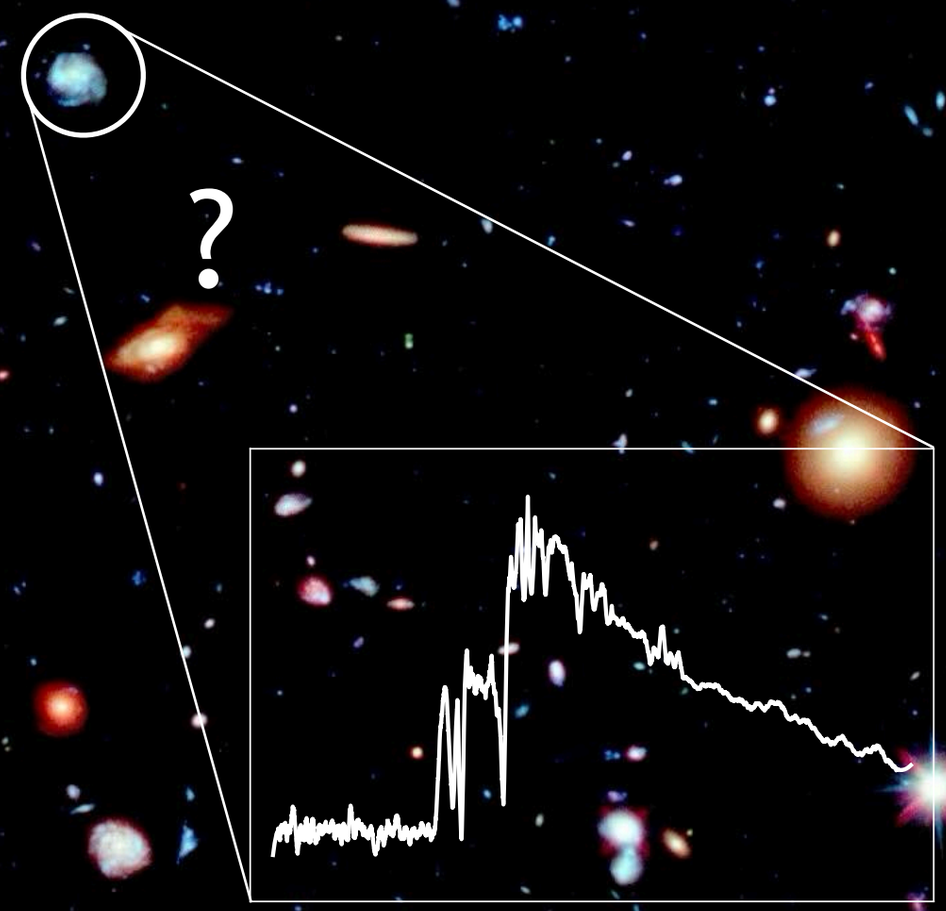
Rubin LSST France - APC 11/2024

High-redshift LBG selection for wide spectroscopic surveys



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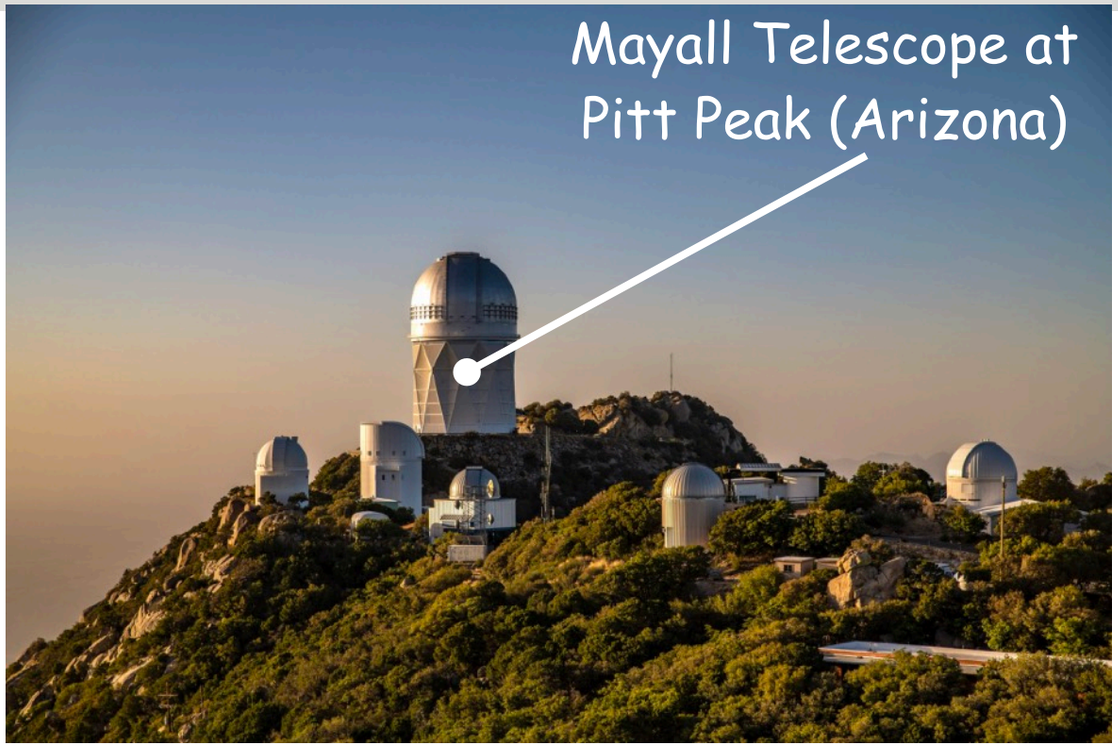
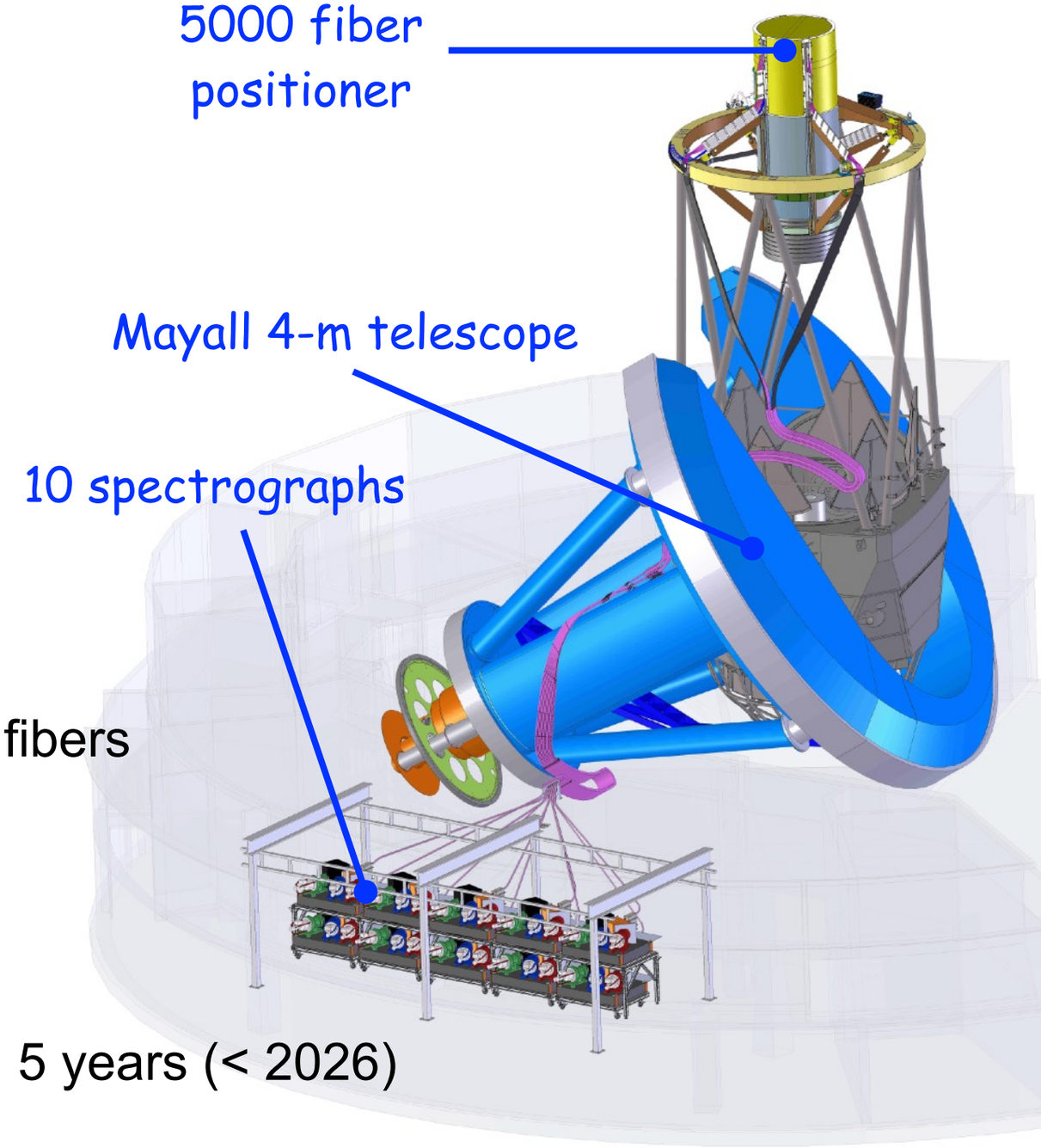
The Dark Energy Spectroscopic Instrument





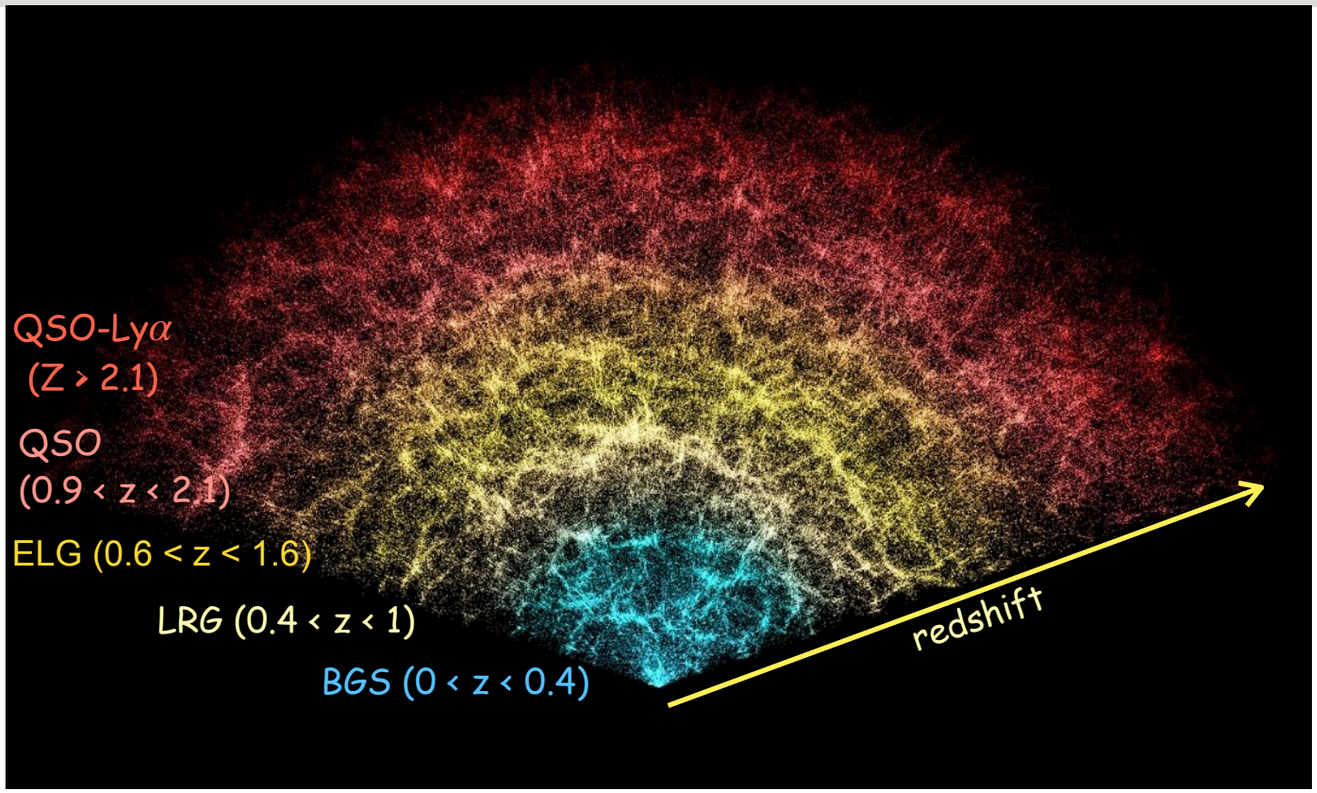
Instrument

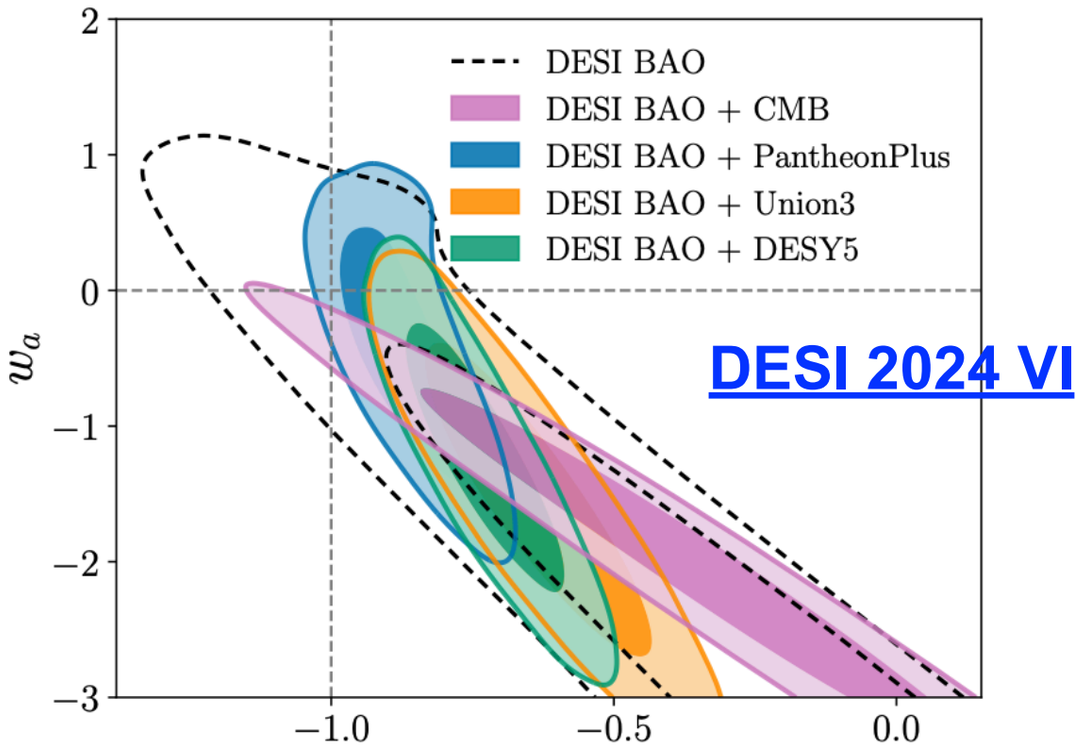
- Wide field of view (8 deg2)
- Automated robotic positioners with 5000 fibers
- Spectrograph from 320 to 1020 nm

DESI Science project

- 14,000 deg^2 survey
- **~40 million spectroscopic redshifts** in 5 years (< 2026)
- For different tracers for $0 < z < 4$
- International collaboration (650 members, 69 institutions, 46 non-US)

Cosmology with DESI and DESI-II





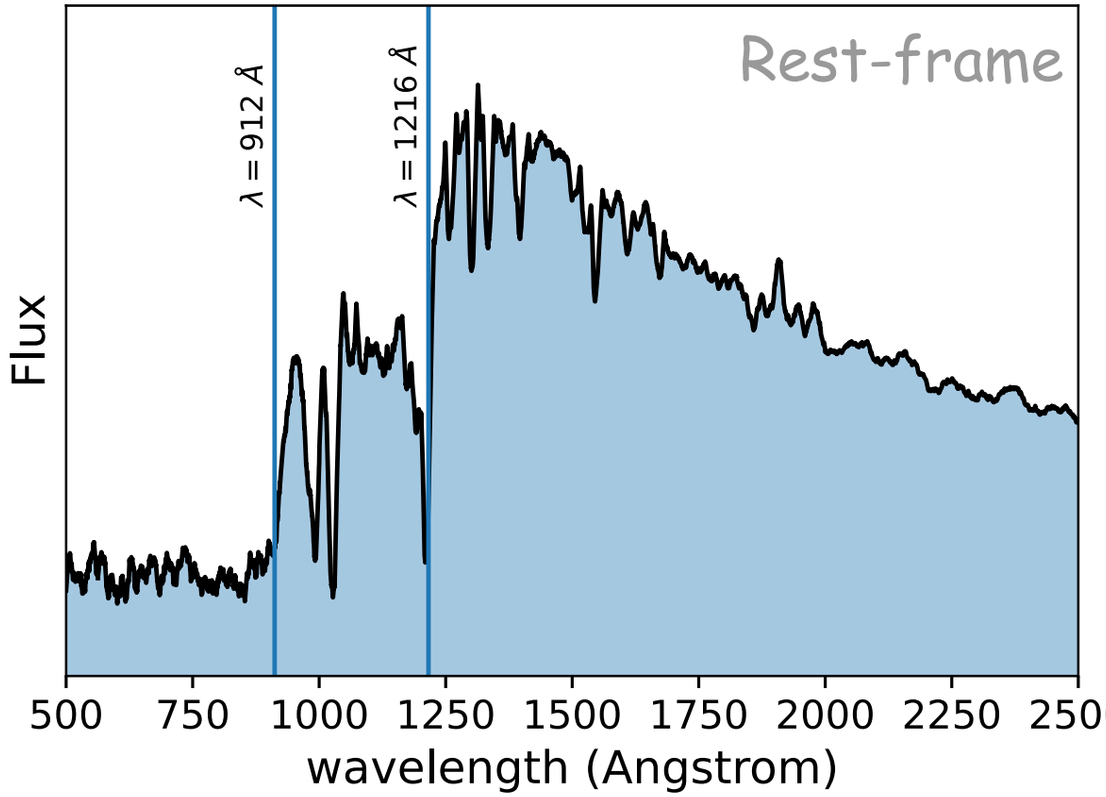
DESI-Y1 results in 2024 !

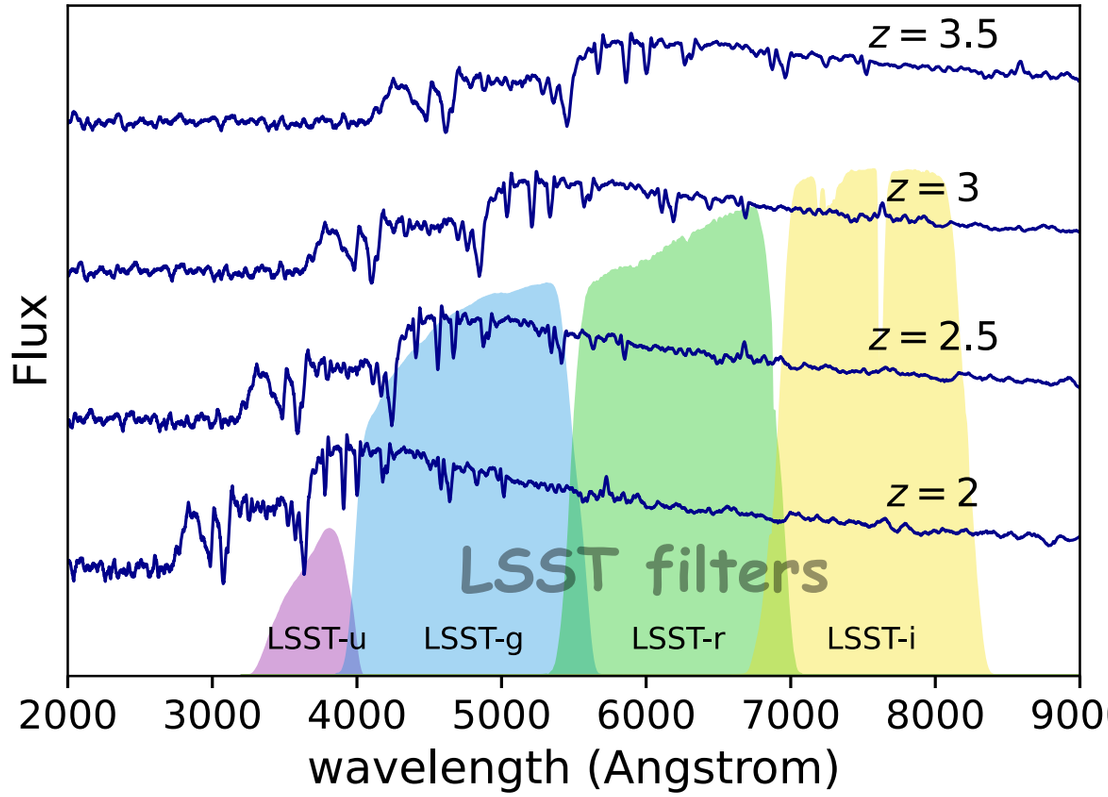
- **DESI 2024 VI:** From the measurement of the BAO peak
  - z < 2.1: clustering of tracers
  - z > 2.1: QSO-Lyα forest
- **DESI 2024 VII:**« full-shape » (+RSD)
- Evidence of time varying $w_{\rm DE}$
- PNGs from LRGs+QSOs = $\sigma(f_{\rm NL}) \sim 10$ (**Chaussidon+2024**, yesterday on arXiv !)

DESI-II (> 2029): « High-z » cosmology

- Will focus on the high-z Universe (2 < z < 4.5)
  - Inflation: $\sigma(f_{\rm NL}) \sim 1$ (distinguish single and multi-field inflationary models)
  - σ(Sum neutrino mass) < 20 meV
  - DE fraction at 2% in the deep matter-dominated regime - Rule out Early DE models

Target selection for Lyman Break Galaxies





LBGs

- Are most of z > 1.5 star-forming galaxies
- Show distinct flux decrement
  - Below the Lyman limit (912 A)
  - Below the Ly-α line (1216 A)
  - Possible Ly-α emission

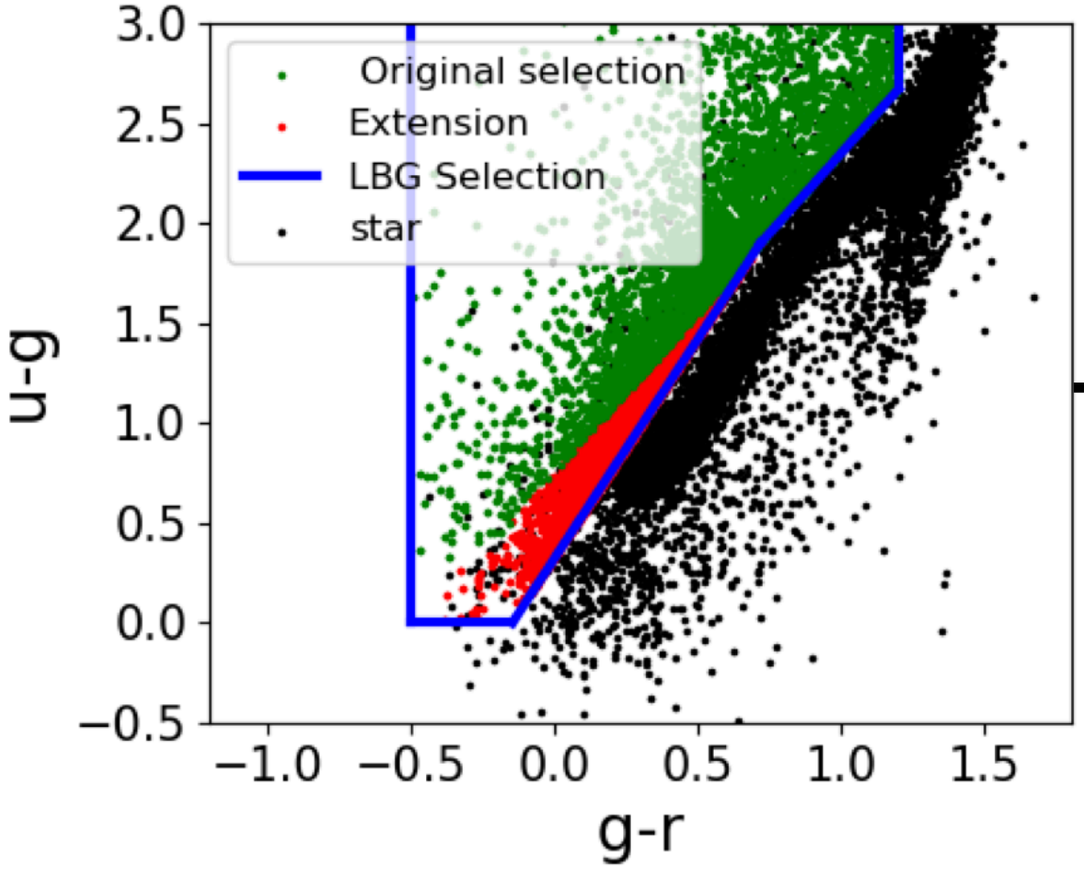
Why LBGs to study the z > 2 Universe ?

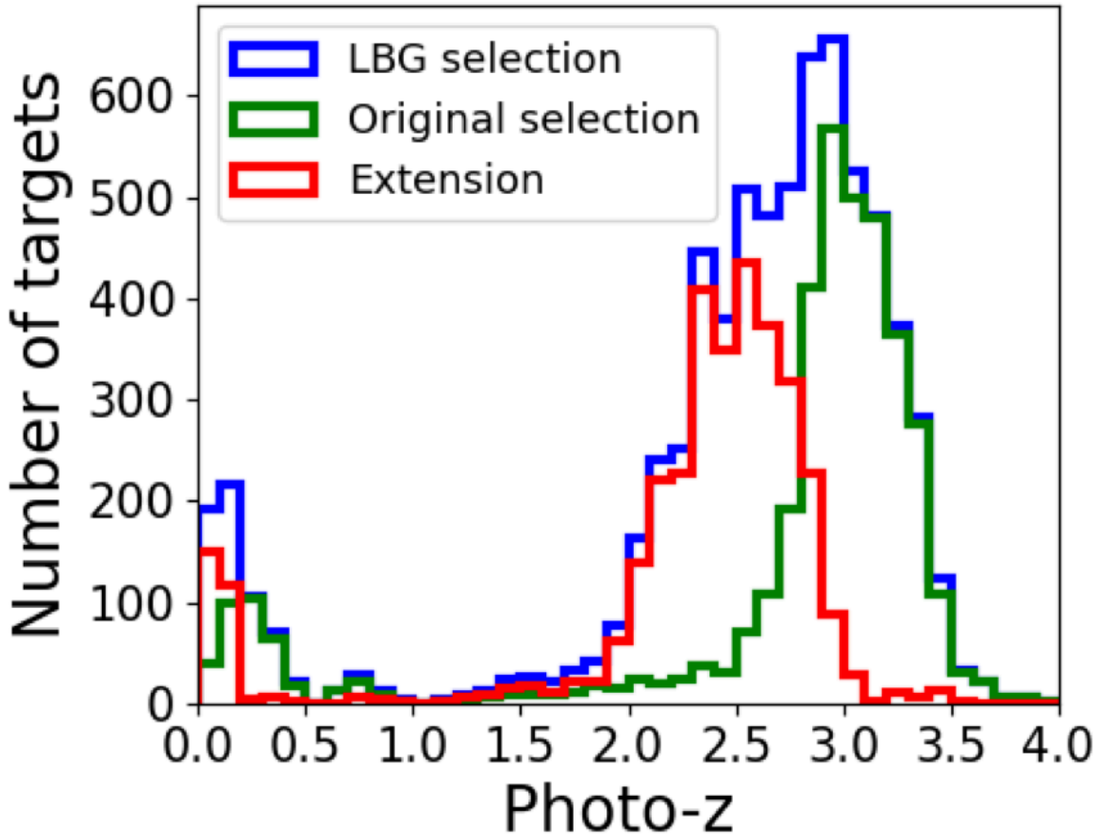
Target selection

- $z > 2.5$, Ly-Break(s) lie in optical range
- $2.5 \leq z_{\mathrm{LBG}} \leq 3.5$ - lack of flux in the U-band
- **Target selection: u-dropout $u - g > 0$**
- Privileged tracers for z > 2 ! So far only explored by QSO-Lyα forests
- **Relies on high-quality *U*-imaging !**

LBG samples from deep imaging

CLAUDS+HSC: *Ruhlmann-Kleider et al.* *arXiv:2404.03569*





Target selection with deep imaging

- LBG selection on ~ 4 deg^2 fields
- Using
  - CLAUDS (u-band, depth = 27.1)
  - HSC (grz, 27.4; 27.1; 26.3)
- **U-dropout + ugr cuts + cut in r < 24.2**

Results

- TS retained $\sim$ 1100 targets per deg^2
- **620 LBGs per squ. degrees** after DESI spectro-z confirmation in 2.3 < z < 3.4
- **So far, deep imaging data are available for 10-100 sq. degrees only**

LBG target selection for DESI-II

DESI Legacy Surveys

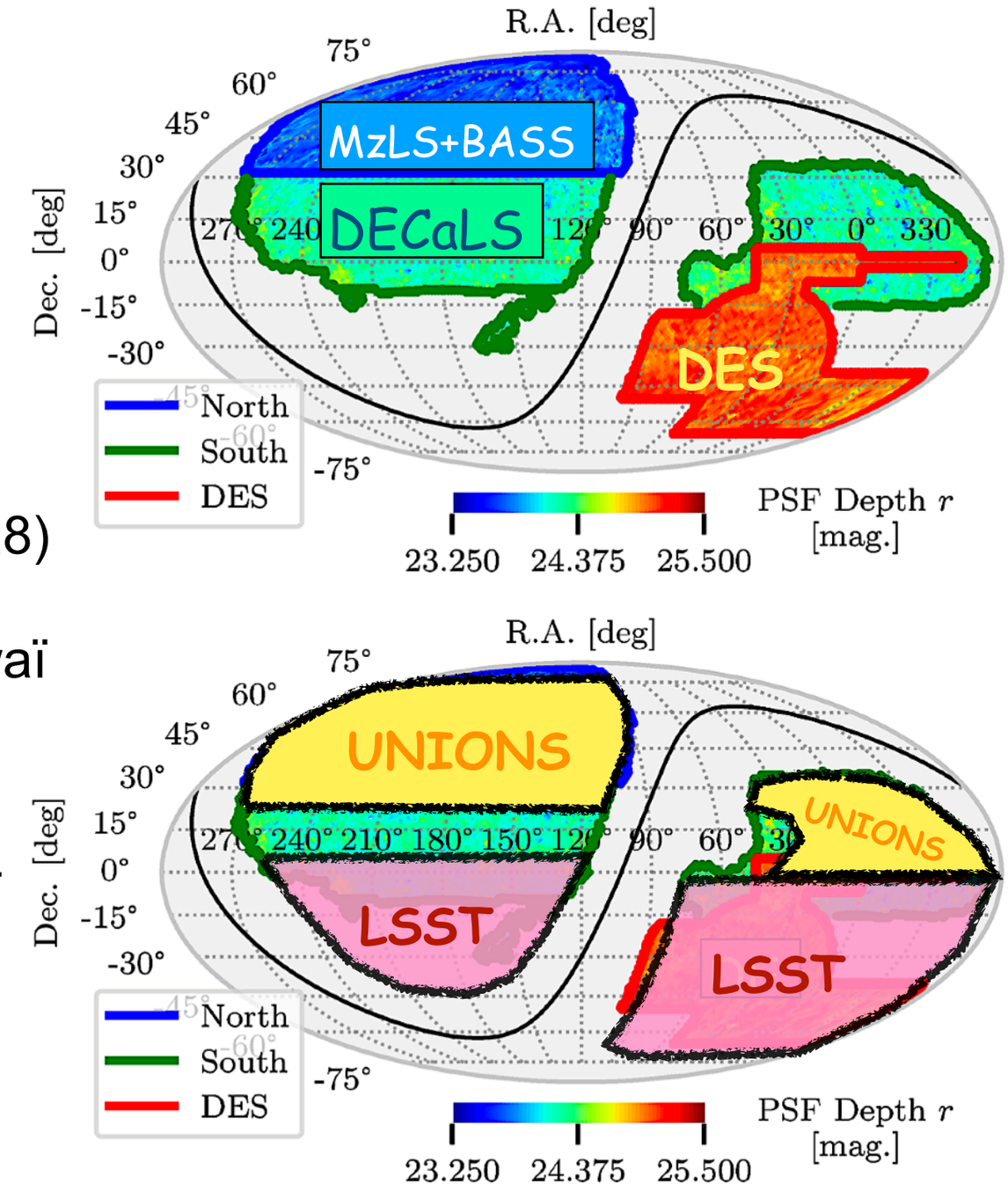
- Grz data: available with DES, DeCALS, MzLS+BASS
- **For LBGs: Missing U-band imaging !**

Wide (*U*-band + …) photometric surveys

- **Rubin LSST (∼soon !)**
  - Overlap with DESI in the South (DR1> 2028)
- **UNIONS**
  - CFHT+Pan-STARR+Subaru (*ugriz*) in Hawaï
  - 5,000 deg^2 compatible with DESI
  - Deepest wide survey until ∼ LSST-Y1/2
  - ***ugriz*** depth = {24.6; 25.5; 25.5; 24.2; 24.4}
- More challenging target selection at shallower depth !

  ⟶ *Payerne et al. arXiv:2410.08062*

DESI Legacy Imaging Surveys



Random Forest approach

Beyond u-dropout

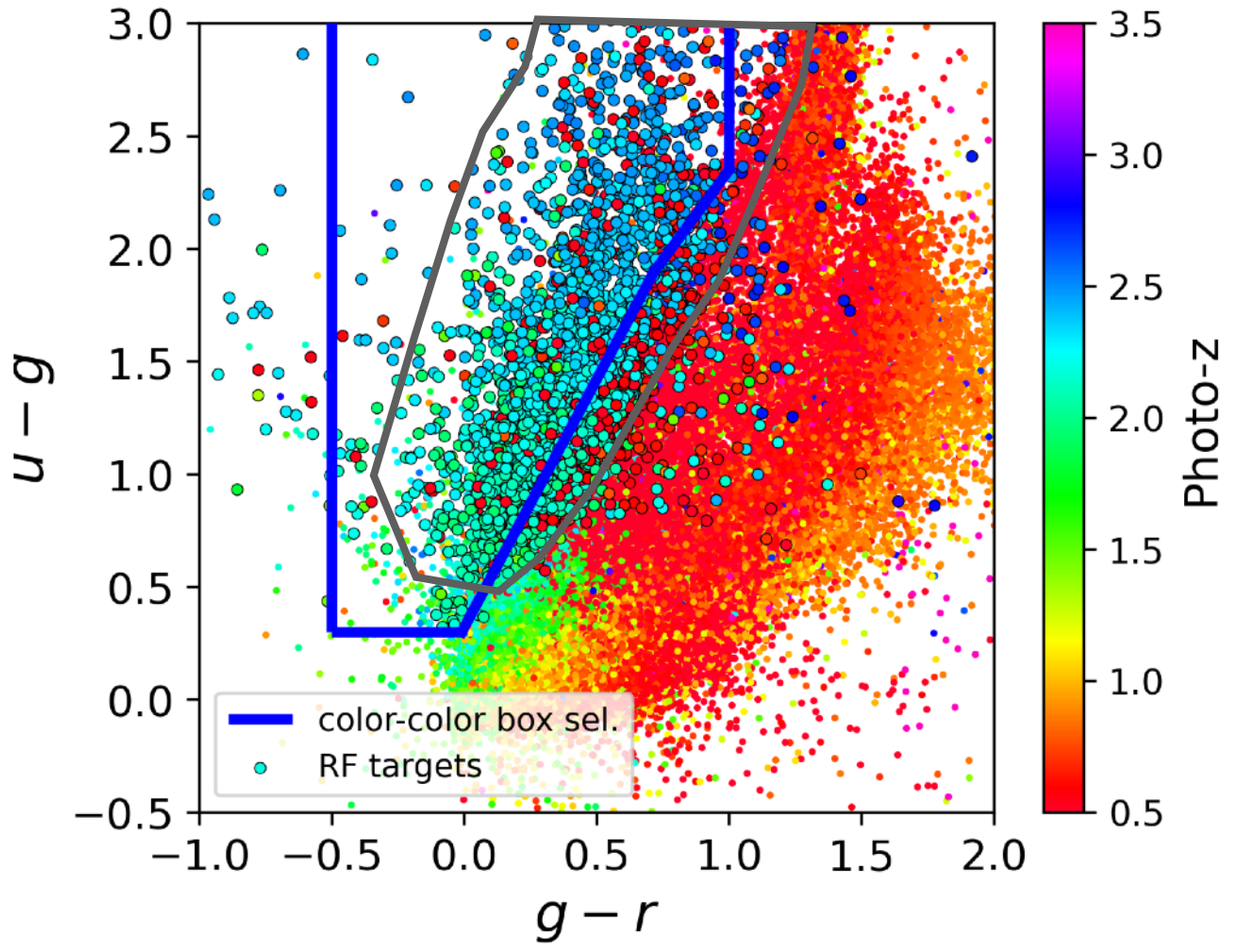
- We can use Random Forest for classification $z \in [2.5,3.5]$ (i.e. « LBGs »)
- Learn best splitting conditions (decision tree)
- **Improve *U*-dropout by 10-15% (tested on CLAUDS)**

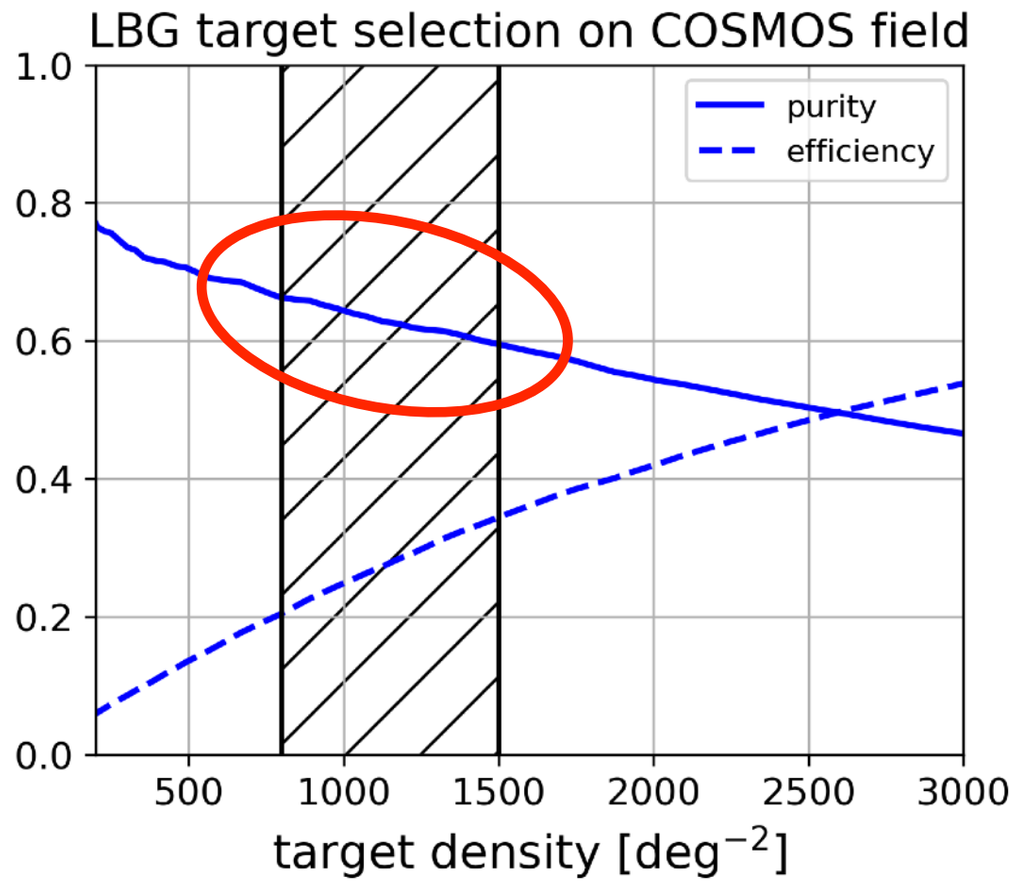
In practice

- **UNIONS data not available at this time !**
- Degrade CLAUDS to UNIONS depth
- Classification: we use LePhare photoz's on COSMOS
- RF Features: 5 colors {*u, g, r, i, z*} $\rightarrow p_i$
- After RF, « quality threshold » cut:
  - Targets for DESI = $\{p_i > P_{\rm lim}\}$
  - Target density $\sim$ 800 - 1500 $\deg^{-2}$

Results

- **Purity stable between 70% and 60%**
- **For $n_{\rm target} = 1{,}100$ per deg^2**
  - $n_{\rm RF}(2.5 < z < 3.5) = 683$ per deg^2
  - $\langle z \rangle_{\rm RF} = 2.85$

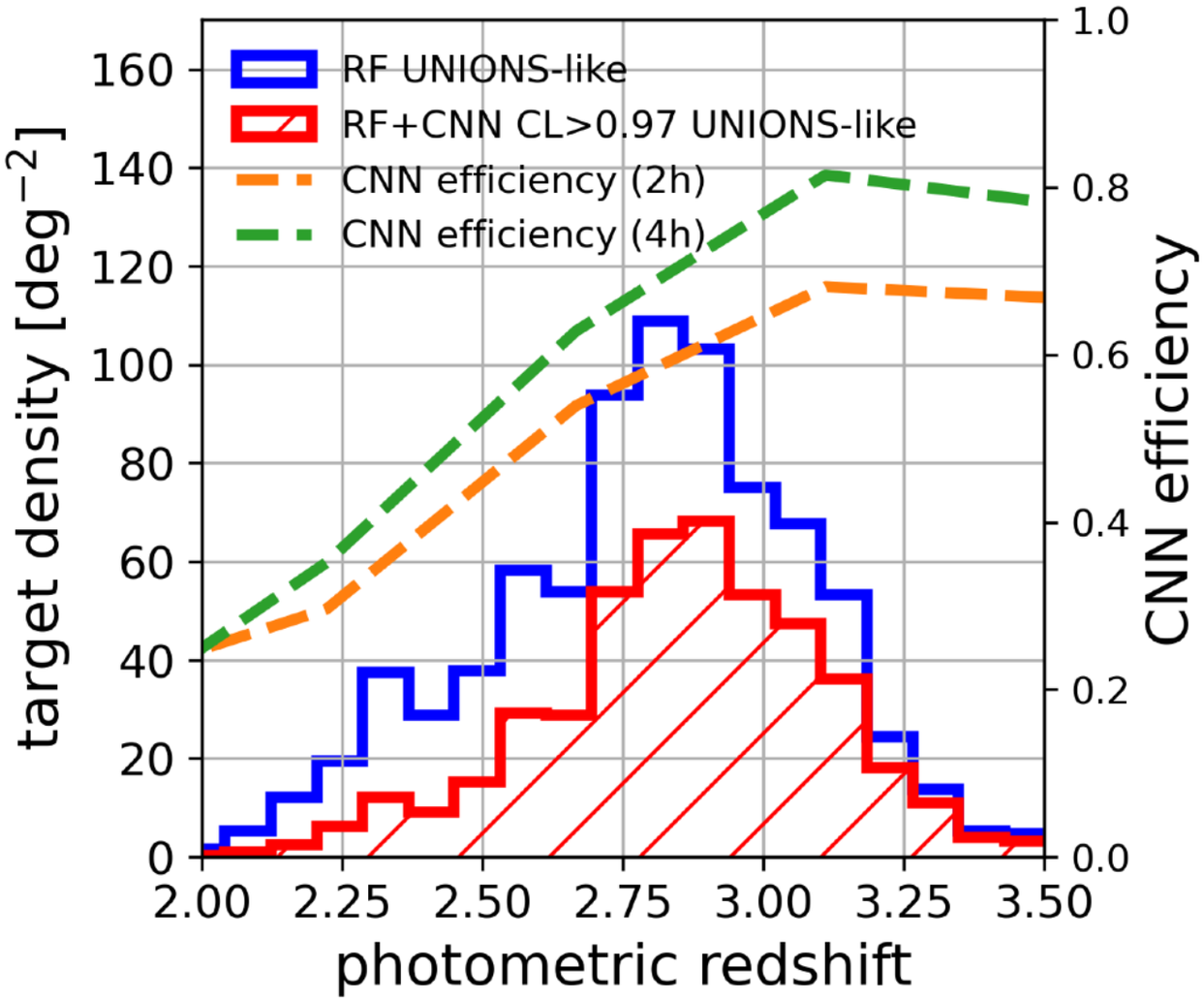




Spectroscopic efficiency

Spectroscopic redshift efficiency

- i.e. our ability to recover LBG redshifts
- Spec-z determined with CNN + template fitting
  - Calibrated from DESI obs. in 2021 (CLAUDS+HSC TS)
  - Efficiency is 20% at z=2, and 80% at z=3.5
  - ∼10% improvement from 2 to 4h of exposure time

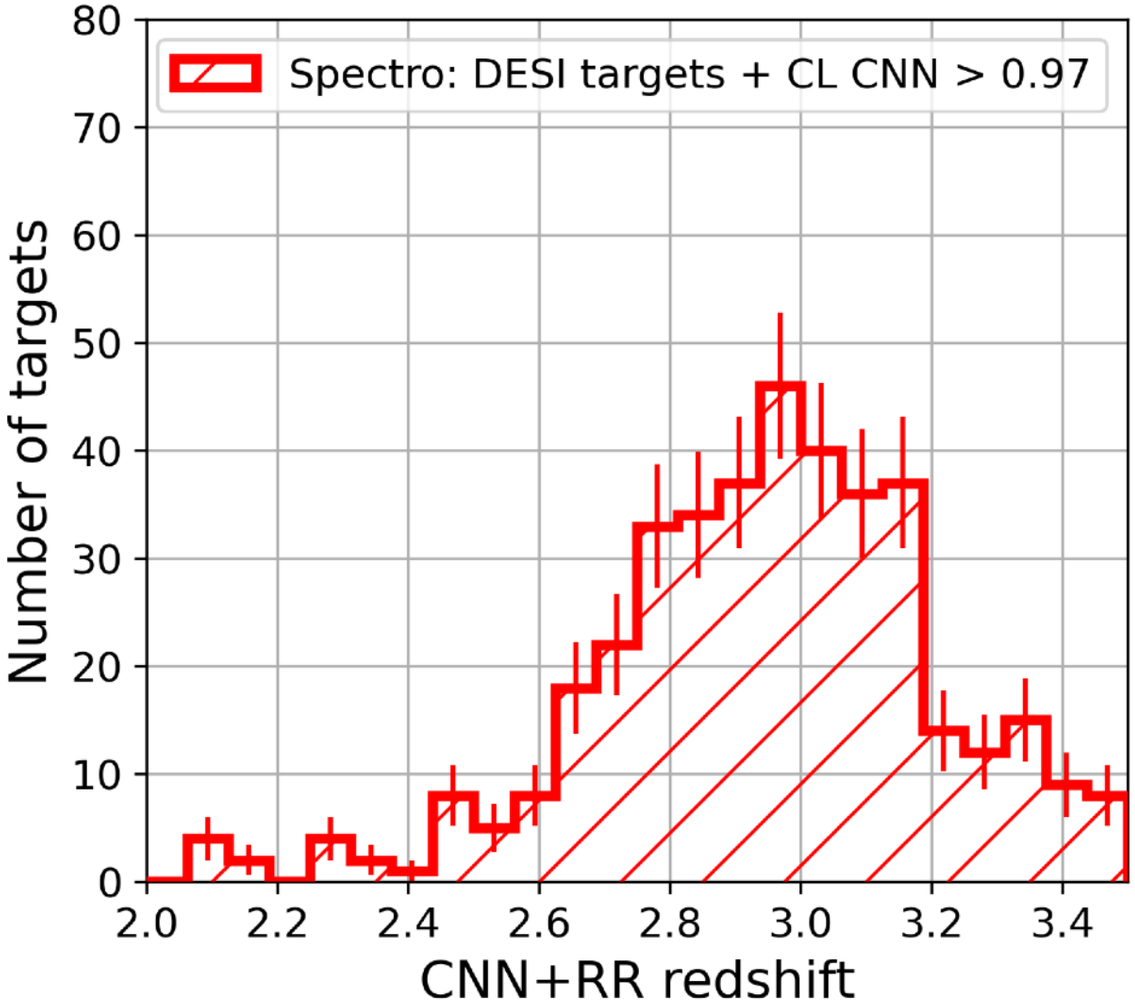


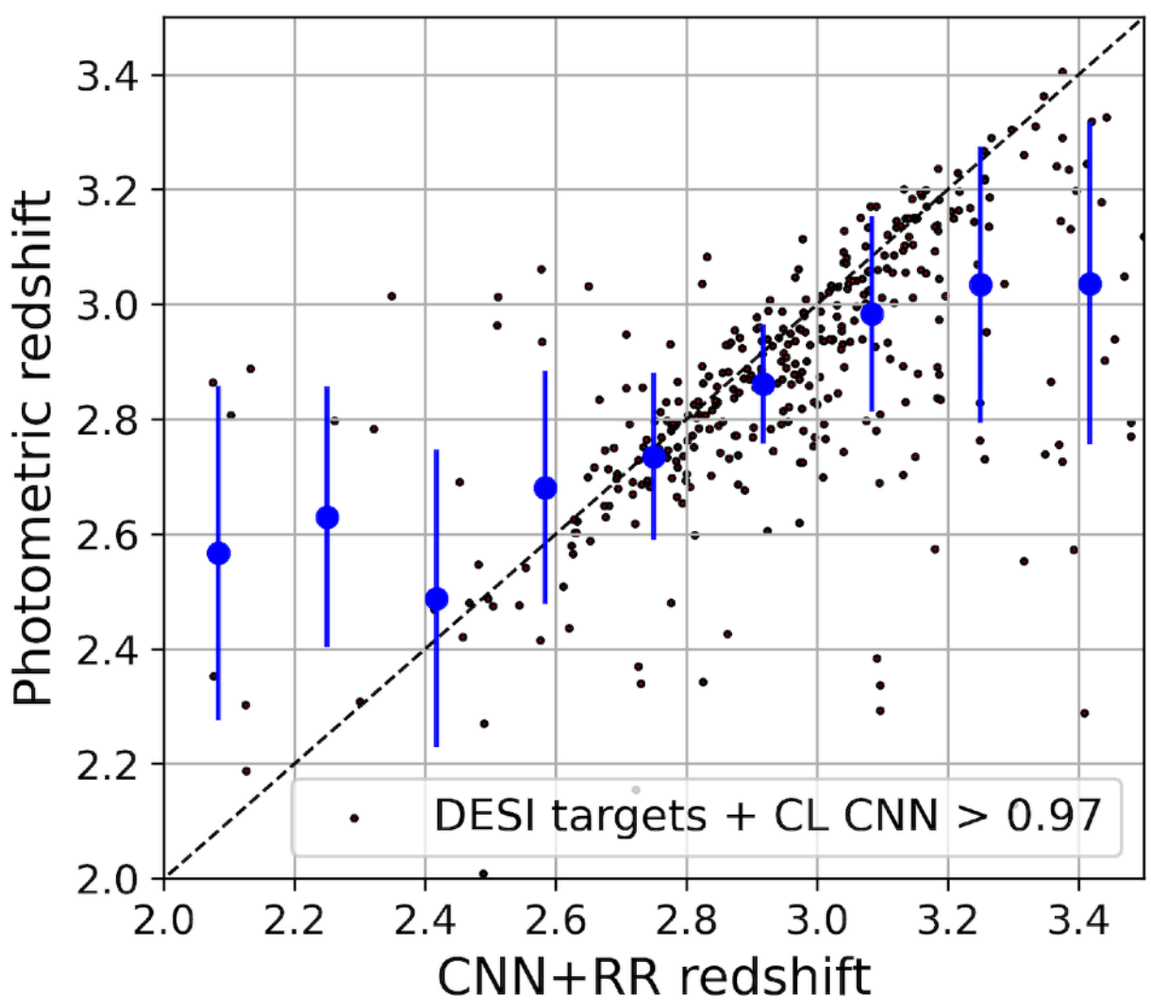
For $n_{\mathrm{target}} = 1{,}100$ per deg^2

- $n_{\mathrm{RF}}(2.5 < z < 3.5) \sim 680$ per deg^2
- $\langle z \rangle_{\mathrm{RF}} = 2.85$
- $n_{\mathrm{spec}}(z > 2) \sim 430$ **per deg^2**
- $\langle z \,|\, z > 2 \rangle_{\mathrm{spec}} = 2.83$

← **45% - For LBG science with DESI !**

DESI observations on COSMOS in 2024 !



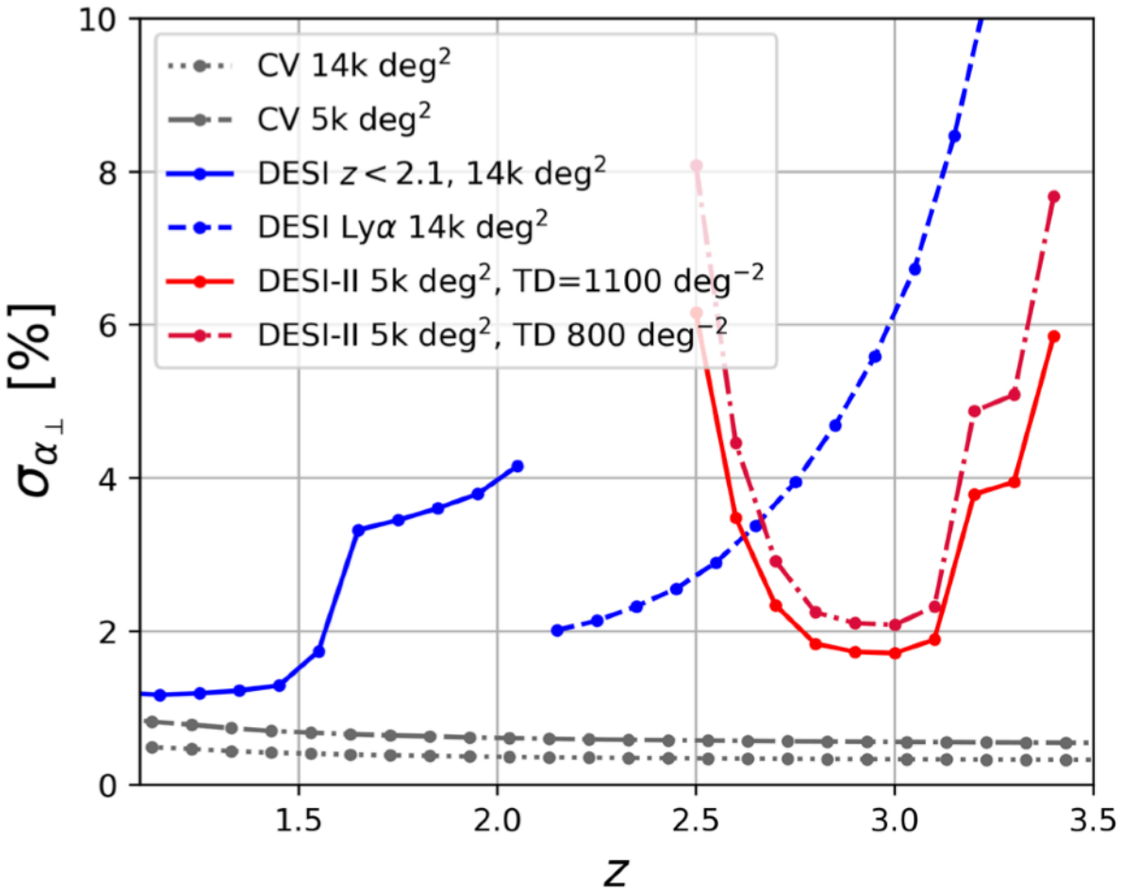


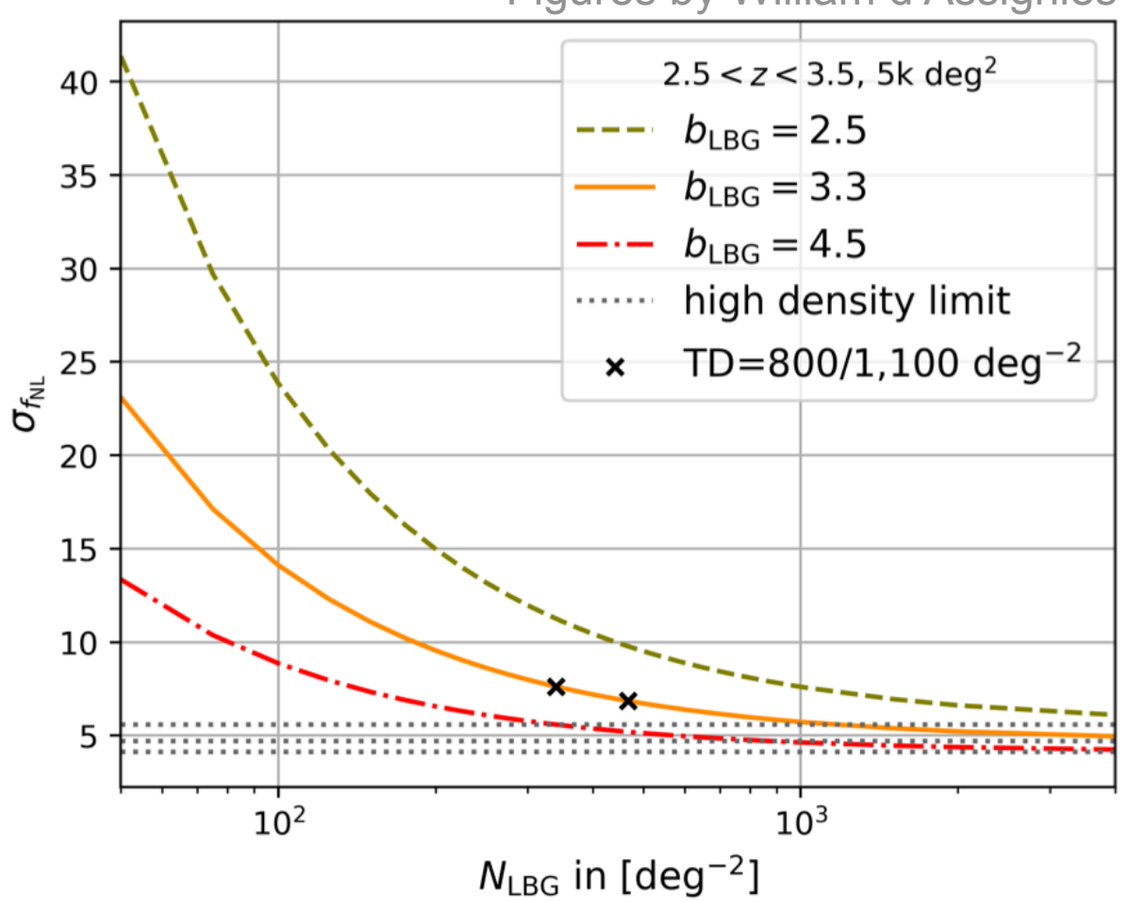
DESI observations in 2024

- TS provided with a purity = 0.6 (similar to 1,100 deg^{-2})
- DESI observed 1000 targets
- **420 LBG with secure spec-z**
- Compatible with forecasts (approx 40%: spectro-z efficiency)
- $\langle z_{\mathrm{spec}} \rangle = 3.0 \pm 0.3$

Forecasts

Figures by William d'Assignies





Forecasts (FishLSS)

- Redshift-space power spectrum
- Bias $b_{\rm LBG}$=3.3
- DESI-II footprint=5,000 $\deg^2$
- Redshift bin = 0.1
- Comparison with DESI main (blue)

Results

- $\sim 0.7\%$ precision for $\alpha_\perp$ and $\alpha_{||}$ in 2.6 < z < 3
- **$\rightarrow$ 2% precision on z > 2 DE fraction**

Primordial Universe

- Through the large-scale dependent bias
- $\sigma_{f_{\rm NL}} \approx 7$ (CMB: $f_{\rm NL} = 0.9 \pm 5.1$)

Summary

Lyman Break Galaxies

- Are promising tracers to study the high-z Universe (z > 2)
- *U*-imaging is crucial to detect LBGs
  - **Deep imaging CLAUDS+HSC**: *Ruhlmann-Kleider et al. arXiv:2404.03569*
  - *U-dropout* **620 LBG/deg^2** after DESI spectro-z confirmation in 2.3 < z < 3.4

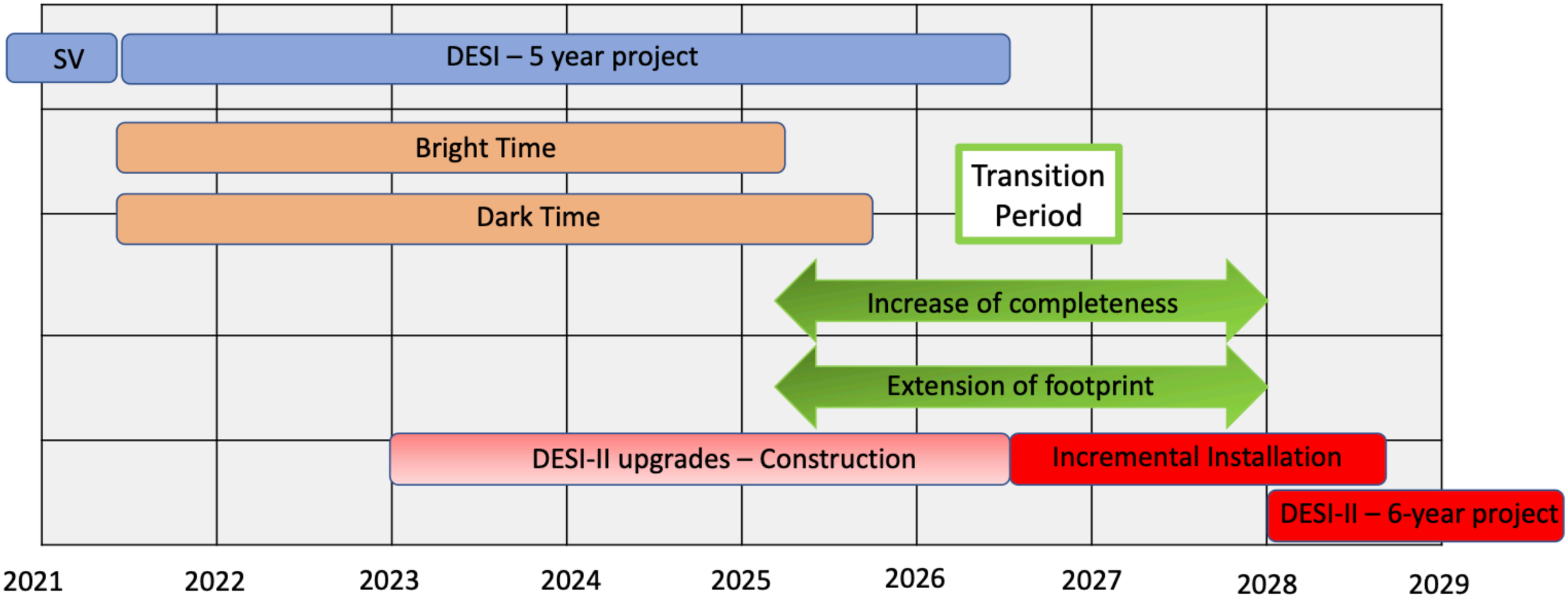
Target selection of LBGs for DESI-II

- **Wide *U*-band (LSST; South, UNIONS; North)** are essential for Stage-V spectro. surveys
- UNIONS-like: *Payerne et al. arXiv:2410.08062*
  - Degraded photometry to UNIONS depths
  - RF: **430 LBG/deg^2 for z > 2** with secure spectro. redshifts
  - Confirmed with DESI dedicated observations on COSMOS
- LSST-like (simple rescaling of LSST-Y10 depths)
  - LSST-Y1: **470 LBG/deg^2 for z > 2** with secure spectro. redshifts
  - LSST-Y5: **660 LBG/deg^2 for z > 2** with secure spectro. redshifts

Forecasts on cosmology with DESI-II (UNIONS-based TS)

- Strong constraining power at $z \sim 2.8 - 3$
- Competitive constraints on A. P. parameters wrt to Lyα (same z range), and on $f_{\rm NL}$
- **LSST focus: Calibration of photoz methods with high-z samples**
- **LSST focus: n(z) for LBG magnification - high-z Cluster mass calibration !**

DESI timeline



Neutrinos in cosmology