Dark Energy Survey Supernovae

Report on SN Working Group Activities

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DES Collaboration Meeting

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Outline

- Introduction to SNANA light curve simulating & fitting
- Basic simulation inputs
  - zeropoints & skynoise
  - weather, the moon, & community time overview
- Survey options & example simulations
  - depth & field options, filters, & exposure times
  - light curves
  - peak magnitudes & maximum signal to noise
  - latest filter and cuts choices
- SN statistics for different survey depths
- Default survey
  - Effect of SN rates
  - Errors in μ, A_V, Δ

Outline

- Bias studies
  - μ bias and effect of simulation efficiency and cuts
  - A_V and Δ biases
- Spectroscopic Strategy
- Photometric redshifts
- Systematics
  - zeropoint shifts
  - R_V smearing & fitting A_V/R_V
- Cosmology fits
- Infrared simulations
- Comparison to other surveys, e.g., SNLS

SNANA Software Package for DES

R. Kessler (U. Chicago), J. P. Bernstein, S. Kuhlmann, & H. Spinka (ANL)

- Also used by SDSS & LSST
- Software suite for simulating and fitting SN light curves
- Goal is a more accurate and complete study of DES Supernovae capabilities including DES CCD and filter characteristics, CTIO sky fluctuations using Essence data inputs, dust extinction effects, etc.
- Publicly available: http://www.hep.anl.gov/des/snana

Simulator Description

- Computes rest-frame model magnitudes using various models
- Applies random color/luminosity fluctuations
- Includes host galaxy dust extinction
- Applies K-corrections
- Offers a choice of cosmologies
- Applies Milky Way dust extinction via Schlegel maps*
- Uses survey zero-points to convert magnitudes to flux
- CCD gain, noise, and sky noise added

Fitter included for resulting light curves

*Schlegel, Finkbeiner, Davis 1998, ApJ, 500, 525

Multicolor Light Curve Shape Model

(MLCS2k2; Jha, Riess, Kirshner 2007, ApJ, 659, 122)

- Light curve model magnitude m_x for passband x at given epoch:

$$m_x = M_x + \mu_0 + \Xi_{x,MW} + \Xi_{x,H}(R_v,A_{v0}) + P_x\Delta + Q_x\Delta^2$$

- 4 free parameters:
  - t_0: epoch of maximum light in B-band
  - μ_0: distance modulus
  - Δ: luminosity/light curve shape parameter
  - A_{v0}: extinction in magnitudes by host dust; $R_v = A_{v0} / E(B-V)$, initially set to 3.1*
- Provided by MLCS2k2 SN data training (Jha,Riess,Kershner 2007):
  - M_x: rest-frame magnitude w/ $\Delta = A_{v0} = 0$
  - P_x & Q_x: describe change in shape & luminosity as function of Δ
  - Ξ_x: extinction functions; “MW” for Milky Way & “H” for host galaxy

*Cardelli, Clayton, Mathis 1989, ApJ, 345, 245, and references therein

Spectral Adaptive Lightcurve Template Model

(SALT2; Guy et al. 2007, ApJ, 466, 11)

- Light curve model flux F:

  $$F(p, \lambda) = x_0 \times [M_0(p, \lambda) + x_1 M_1(p, \lambda) + . . .] \times \exp[c CL(\lambda)]$$

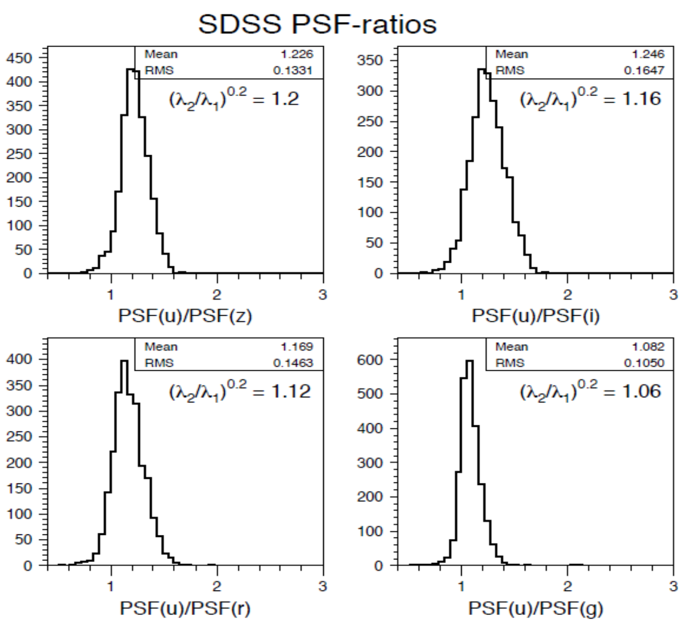
  - p is the rest-frame time since the date of maximum B luminosity
  - λ is the wavelength in the SN rest-frame
  - x_0 is normalization of the SED sequence
  - $x_{k>0}$ are the intrinsic parameters of SN (such as a stretch)
  - $M_0(p, \lambda)$ is the average spectral sequence
  - $M_{k>0}(p, \lambda)$, are additional components describing main variability
  - $CL(\lambda)$ is average color correction law
  - $c = (B - V)_{MAX}$ MAX – (B – V) = color offset wrt max B luminosity
- M_k and CL are properties of the global model
- x_k and c are parameters of a given SN

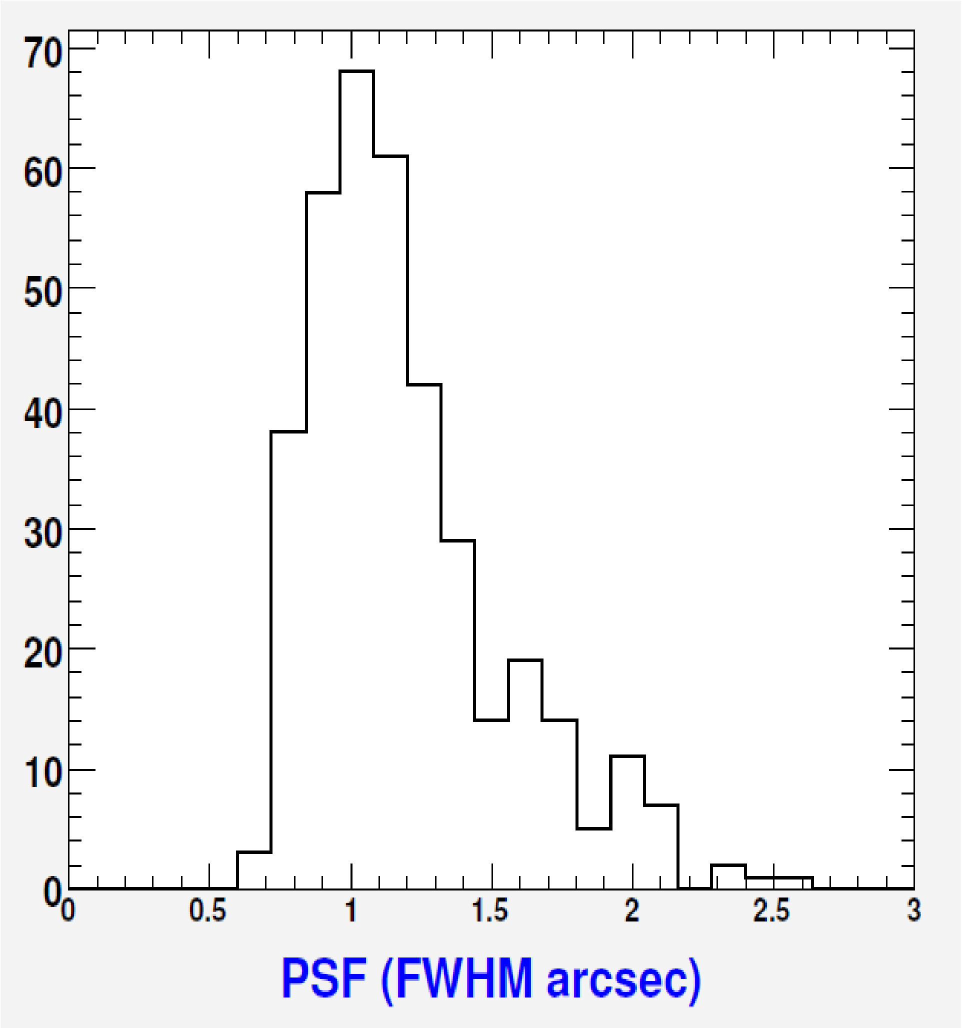
Variation Of The Point Spread Function

Approximation:
PSF_DES = $A^{0.6} \times L^{0.2} \times$ PSF_Essence

A = $\text{airmass}_{DES}/\text{airmass}_{Essence}$
L = $\text{lambda}_{DES}/\text{lambda}_{Essence}$

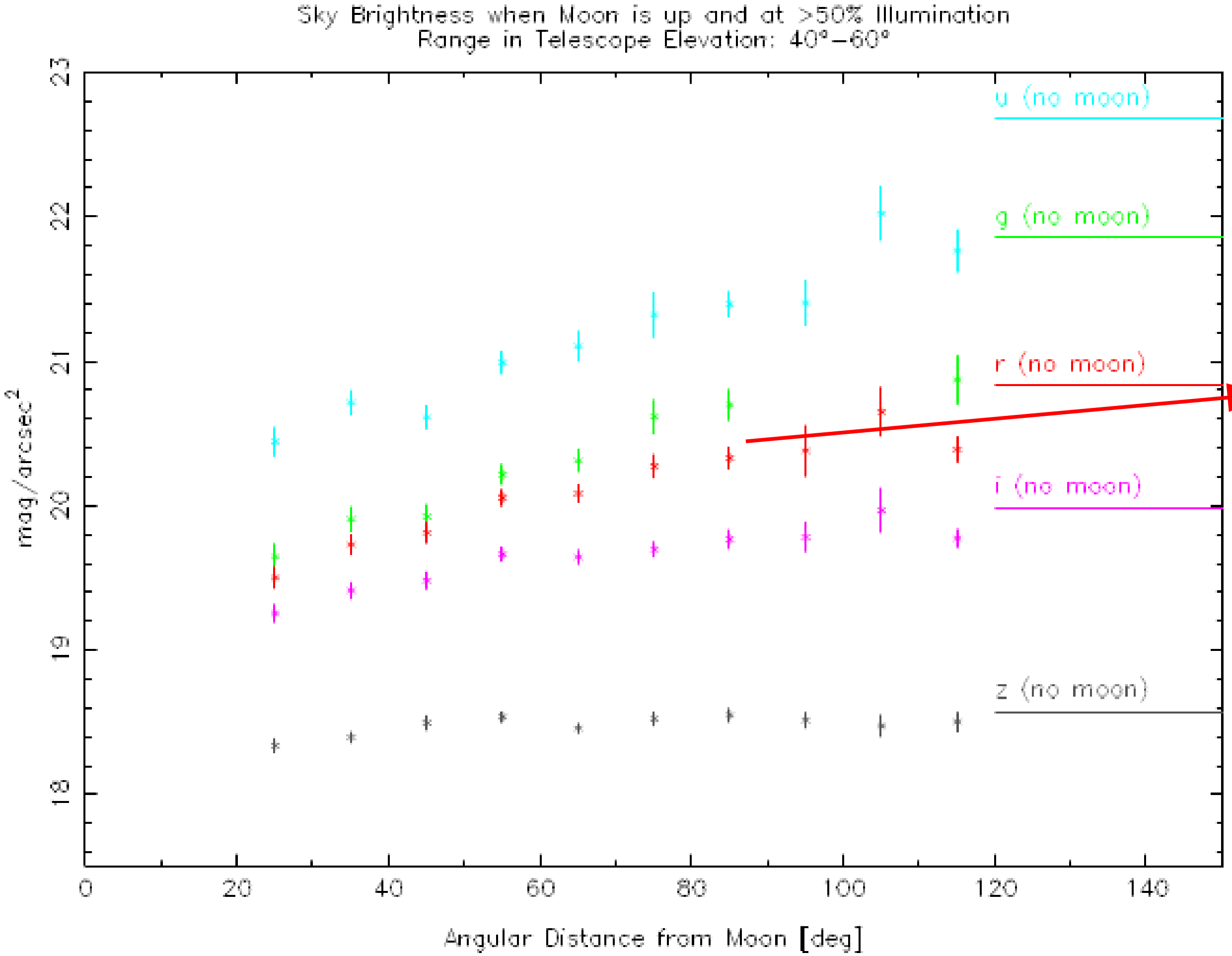
Checked by R. Kessler with SDSS:

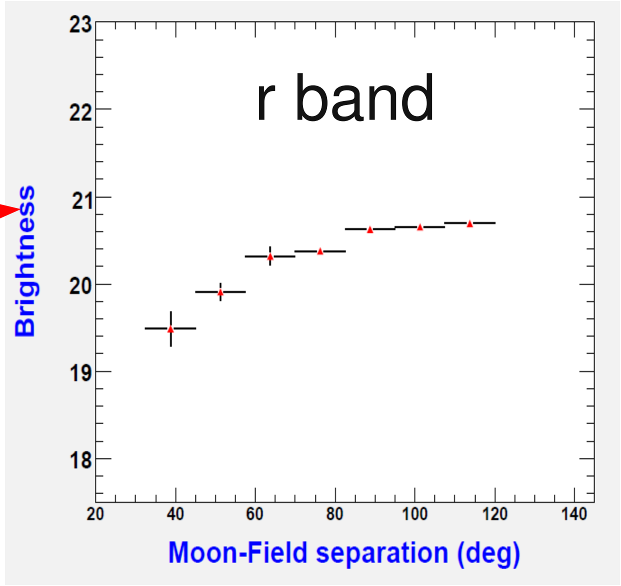




Moon: Implemented Brightness Fits

From J. Marriner and skycalc positions



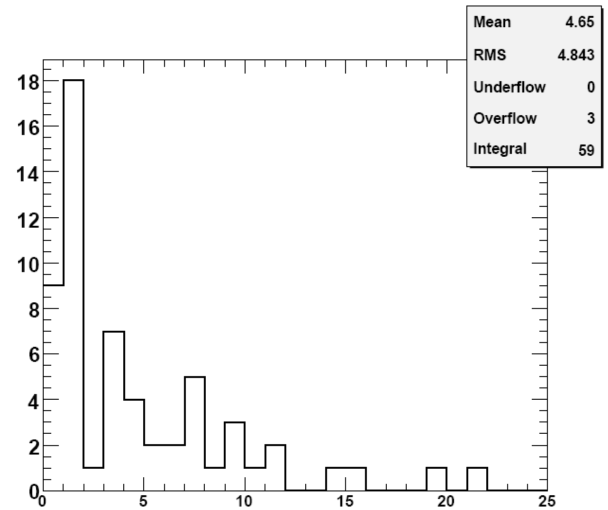


Current Survey Cadence

Uses 100% of DES non-photometric time, Jim Annis' community time proposal, and photometric criteria: 1) 7 day trigger, 2) only 2nd half of night, and 3) 1 field/night.

Results SN survey with 1015 non-photometric and 360 photometric hours

Tail of distribution in Jan/Feb half-night running, but length not understood (also tail events in Jim Annis code)



Gaps Between Observations (z filter)

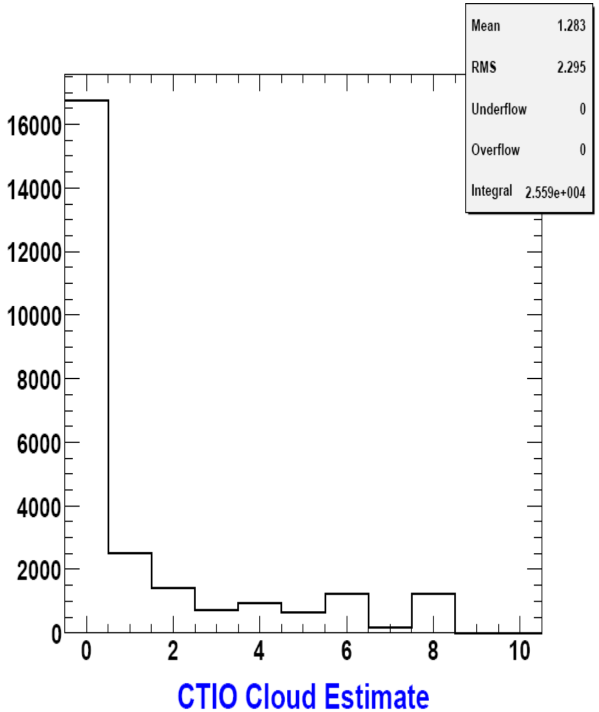
Jim Annis proposed community time distribution

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
September	D	D	N	N	N	D	D	D	D	D	N	N	N	D	D	D	D	D	D	D	D	D	D	D	D	N	N	N	D	D
October	D	D	N	N	N	N	D	D	D	D	N	N	N	D	D	D	D	D	D	D	D	D	D	D	N	N	N	D	D	D
November	N	N	N	D	D	D	D	D	N	N	N	D	D	D	D	D	D	D	D	D	D	D	D	N	N	N	D	D	D	D
December	N	N	N	N	D	D	D	D	N	N	N	D	D	D	D	D	D	D	D	D	D	D	N	N	N	D	D	D	D	D
January	N	N	S	S	S	S	S	N	N	N	S	S	S	S	S	S	S	S	S	S	S	N	N	N	S	S	S	S	S	N
February	N	N	S	S	S	N	N	N	S	S	S	S	S	S	S	S	S	S	S	N	N	N	S	S	S	S	S	S	S	

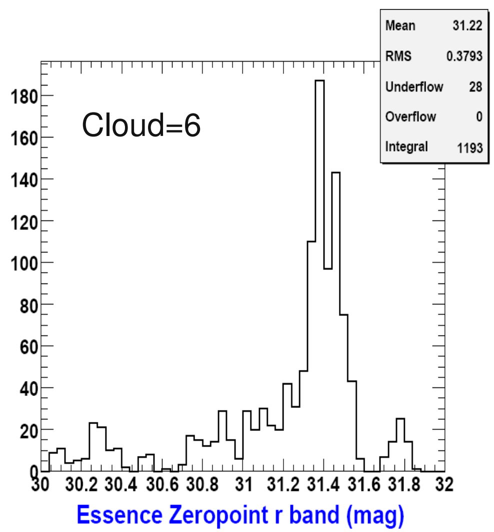
D: DES full night N: NOAO community time S: split night

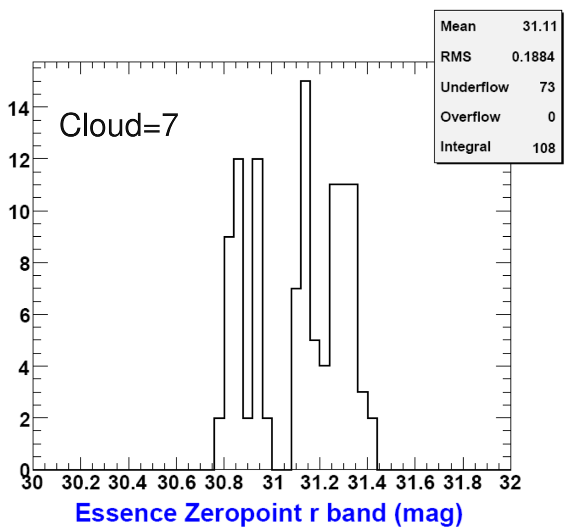
Cloud<5

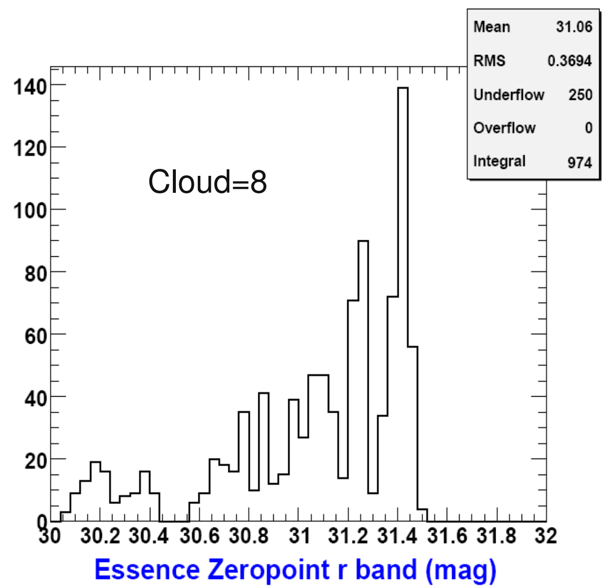
Weather: Clouds



Using all Essence data independent of cloud







RA: 52.500000 DECL: -27.500000 NOBS: 130 MWEBV: 0.000 PIXSIZE: 0.270

#	MJD	IDEXPT	FLT	CCD GAIN	CCD NOISE	SKYSIG	PSF1 (pixels)	PSF2	PSF2/1 RATIO	ZPTAVG	ZPTSIG	MAG
S:	52889.191	10000000	g	1.00	10.00	79.89	2.26	0.00	0.000	32.97	0.033	1.000
S:	52892.312	10000001	g	1.00	10.00	142.97	2.58	0.00	0.000	32.71	0.033	1.000
S:	52900.172	10000002	g	1.00	10.00	47.63	1.57	0.00	0.000	32.92	0.033	1.000
S:	52902.281	10000003	g	1.00	10.00	47.63	2.21	0.00	0.000	31.72	0.032	1.000
S:	52907.305	10000004	g	1.00	10.00	47.63	1.48	0.00	0.000	32.94	0.033	1.000
S:	52915.238	10000005	g	1.00	10.00	57.17	1.35	0.00	0.000	33.04	0.033	1.000
S:	52928.254	10000006	g	1.00	10.00	80.51	1.14	0.00	0.000	33.07	0.033	1.000
S:	52934.148	10000007	g	1.00	10.00	47.63	2.44	0.00	0.000	31.82	0.032	1.000
S:	52935.160	10000008	g	1.00	10.00	47.63	1.86	0.00	0.000	32.19	0.032	1.000
S:	52941.121	10000009	g	1.00	10.00	47.63	1.53	0.00	0.000	32.67	0.033	1.000
S:	52942.102	10000010	g	1.00	10.00	50.21	1.68	0.00	0.000	32.57	0.033	1.000
S:	52943.105	10000011	g	1.00	10.00	53.16	1.49	0.00	0.000	32.79	0.033	1.000
S:	52944.129	10000012	g	1.00	10.00	58.26	1.29	0.00	0.000	32.81	0.033	1.000
S:	52948.109	10000013	g	1.00	10.00	106.51	2.82	0.00	0.000	32.87	0.033	1.000
S:	52949.109	10000014	g	1.00	10.00	125.68	2.81	0.00	0.000	32.87	0.033	1.000
S:	52950.109	10000015	g	1.00	10.00	146.40	2.05	0.00	0.000	32.94	0.033	1.000
S:	52951.094	10000016	g	1.00	10.00	167.13	1.85	0.00	0.000	32.94	0.033	1.000
S:	52956.070	10000017	g	1.00	10.00	47.63	2.21	0.00	0.000	32.93	0.033	1.000
S:	52957.070	10000018	g	1.00	10.00	47.63	2.19	0.00	0.000	32.93	0.033	1.000
S:	52958.070	10000019	g	1.00	10.00	47.63	1.54	0.00	0.000	32.95	0.033	1.000
S:	52959.098	10000020	g	1.00	10.00	47.63	1.61	0.00	0.000	32.85	0.033	1.000
S:	52960.266	10000021	g	1.00	10.00	55.45	1.31	0.00	0.000	32.77	0.033	1.000
S:	52971.125	10000022	g	1.00	10.00	50.39	1.27	0.00	0.000	32.90	0.033	1.000
S:	52974.082	10000023	g	1.00	10.00	67.07	1.16	0.00	0.000	32.19	0.032	1.000
S:	52986.160	10000024	g	1.00	10.00	77.16	1.50	0.00	0.000	32.90	0.033	1.000
S:	52994.160	10000025	g	1.00	10.00	47.63	1.28	0.00	0.000	32.87	0.033	1.000
S:	53001.152	10000026	g	1.00	10.00	47.63	1.49	0.00	0.000	32.94	0.033	1.000
S:	53002.199	10000027	g	1.00	10.00	47.63	1.44	0.00	0.000	32.94	0.033	1.000
S:	53030.043	10000028	g	1.00	10.00	52.36	2.81	0.00	0.000	32.94	0.033	1.000
S:	53034.125	10000029	g	1.00	10.00	78.09	1.37	0.00	0.000	32.50	0.032	1.000
S:	53046.086	10000030	g	1.00	10.00	47.63	1.45	0.00	0.000	32.93	0.033	1.000
S:	53054.055	10000031	g	1.00	10.00	47.63	1.94	0.00	0.000	32.94	0.033	1.000
S:	53063.070	10000032	g	1.00	10.00	67.94	2.24	0.00	0.000	32.98	0.033	1.000

Example Simulation Library File (g-band section only)

Effect of

Moon

ESSENCE PSF variation

ESSENCE Zeropt variation

DES Supernova Survey Field Options

- Time per field or number of fields can be simulation optimized
  - Ultra-deep strategy (3 square degrees = 1 DES field)
  - Deep strategy (9 square degrees)*
  - Shallow but wide strategy (27 square degrees)
  - Hybrid, e.g. 2 deep and 3 wide (15 square degrees)
- Recall total DES survey is 5000 square degrees

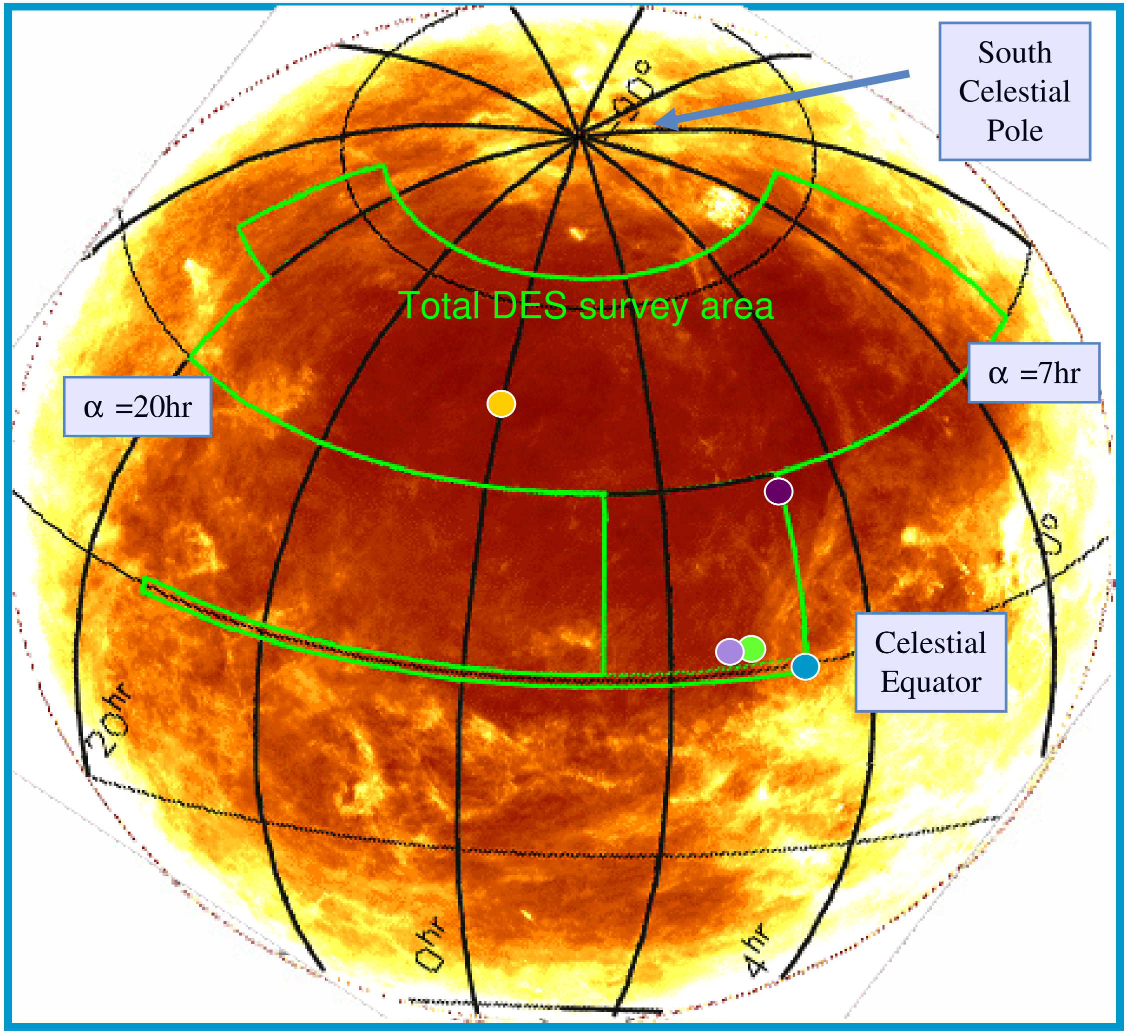
* Highlighted in DES DOE proposal

Current Favored DES *Supernova* Fields

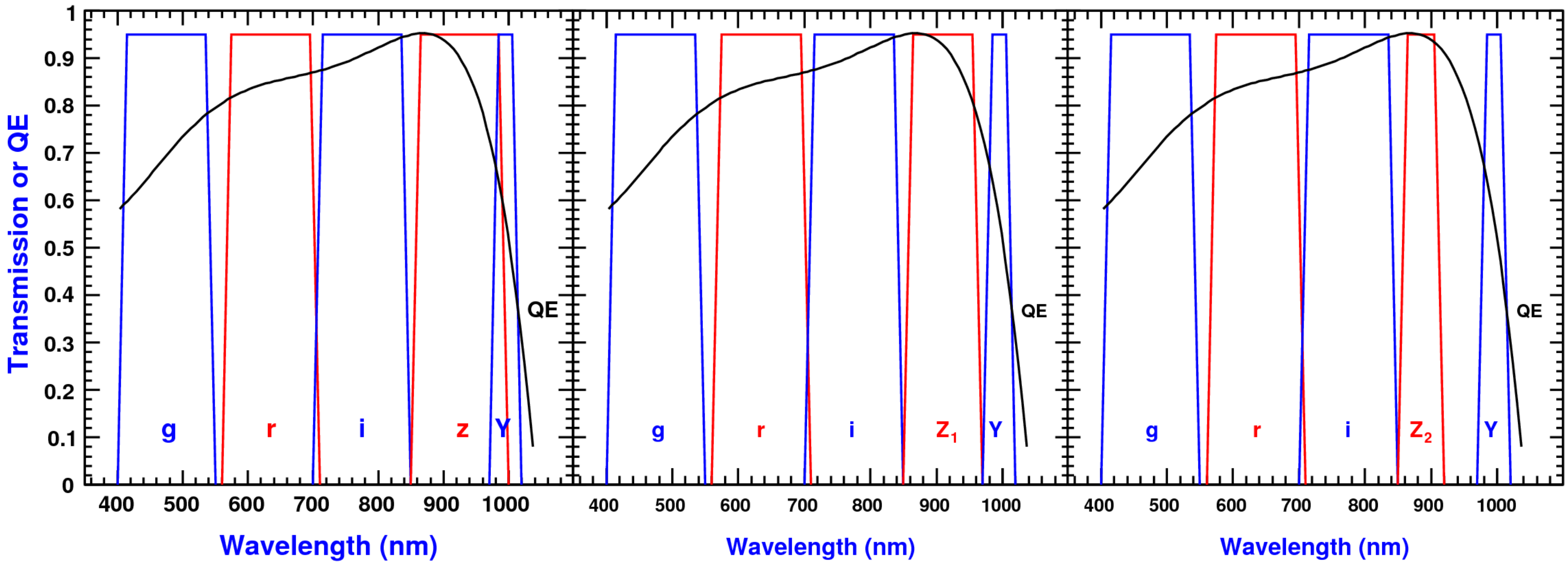
- Chosen to maximize:
  - visibility from DES site
  - past observation history
  - visibility from, e.g, Hawaii

Chandra Deep Field – South
Sloan Stripe 82
SN Legacy Survey (SNLS) D1
XMM-Newton LSS
ELIAS S1

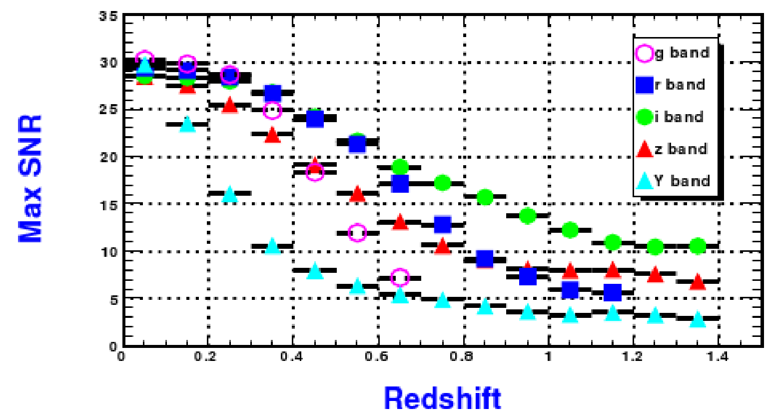
From a study by Peter Nugent



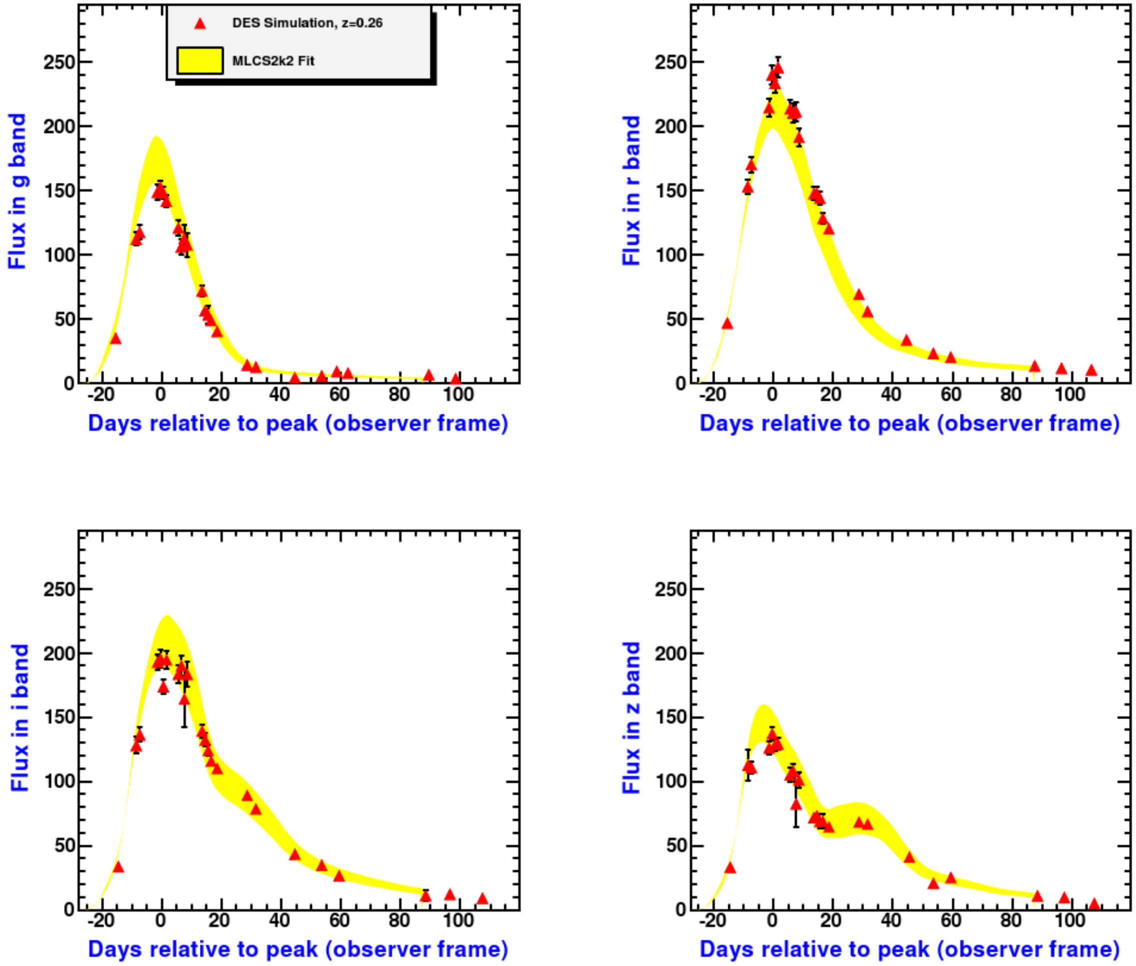
Original DES Filter Options



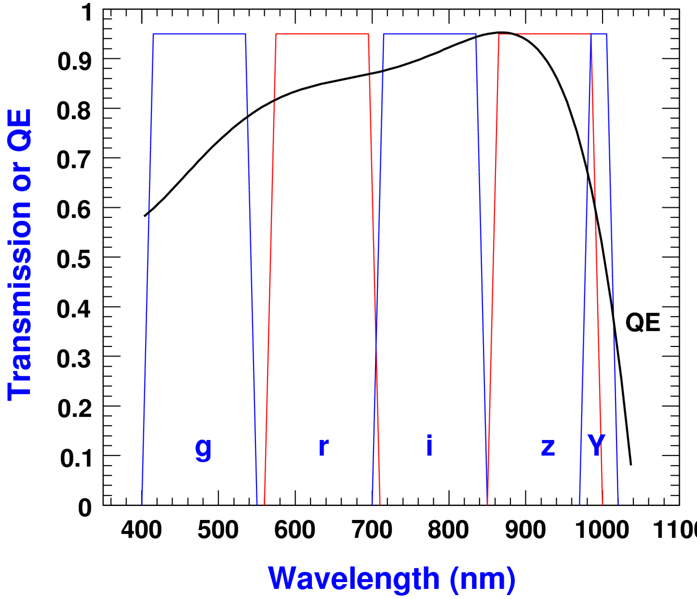
- SN Filters: g, r, i, z or Z_1 or Z_2 , Y ?
- DES has selected z & DES SN will NOT use Y
- Hybrid deep field griz exposure times: ~300s, 1200s, 1800s, 4000s
- Hybrid wide fields have 1/3 exposure times



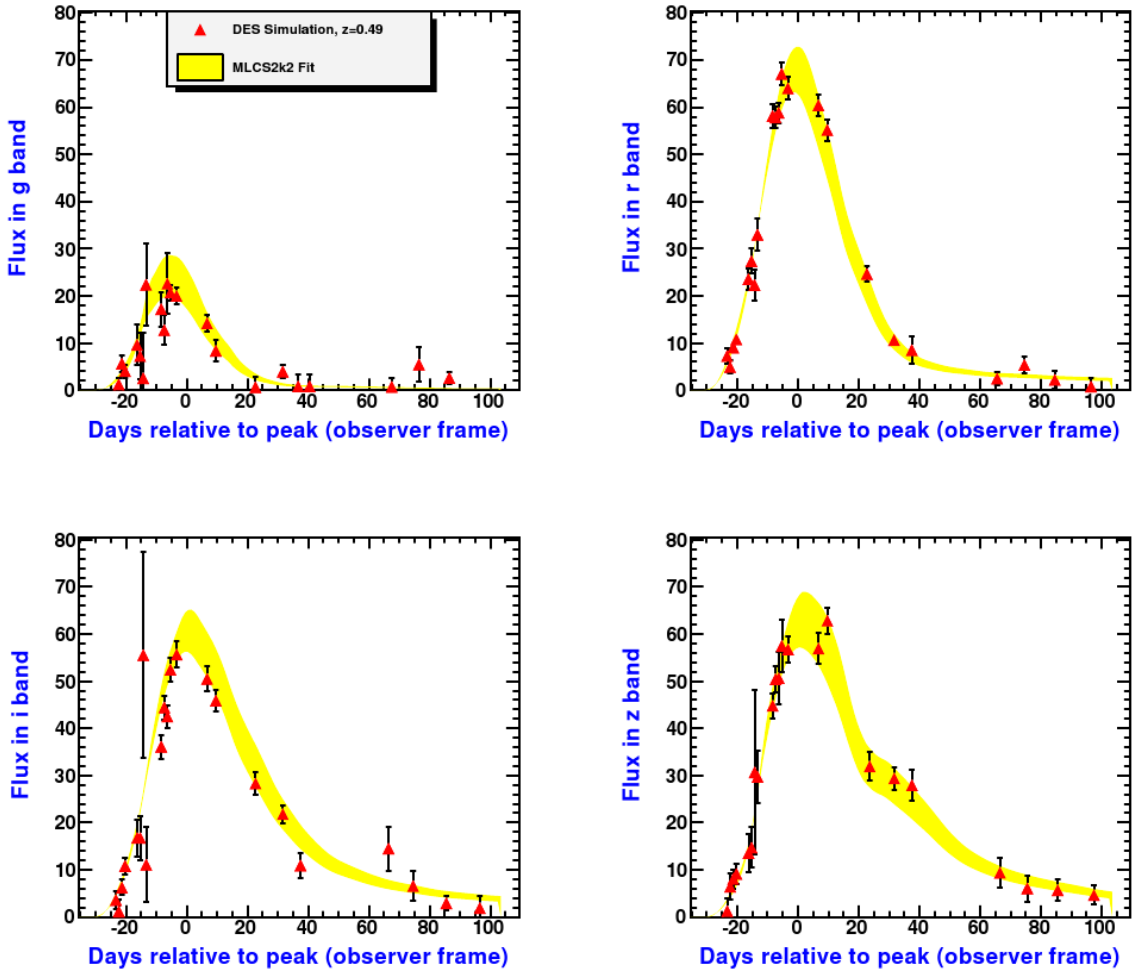
Simulated DES Light Curves



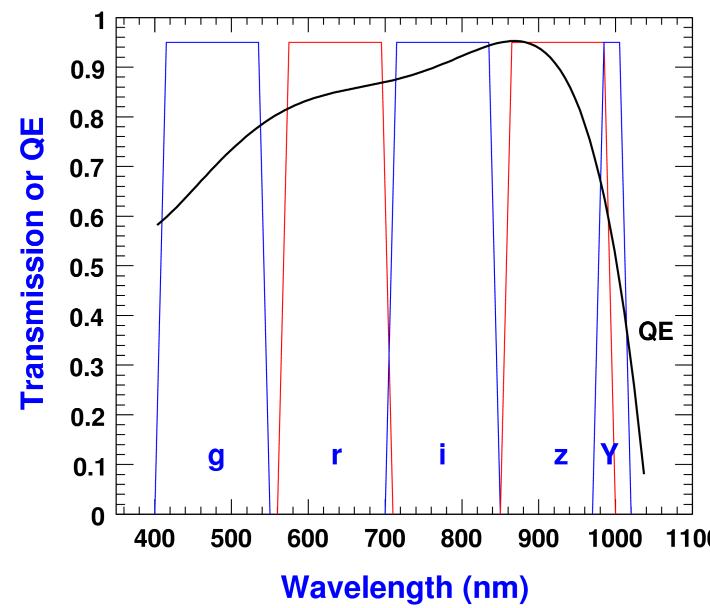
Example light curve at z~0.26 for a hybrid survey (15 sq. deg.) using the griz filter set. Note 2nd bump unique to SN type Ia.



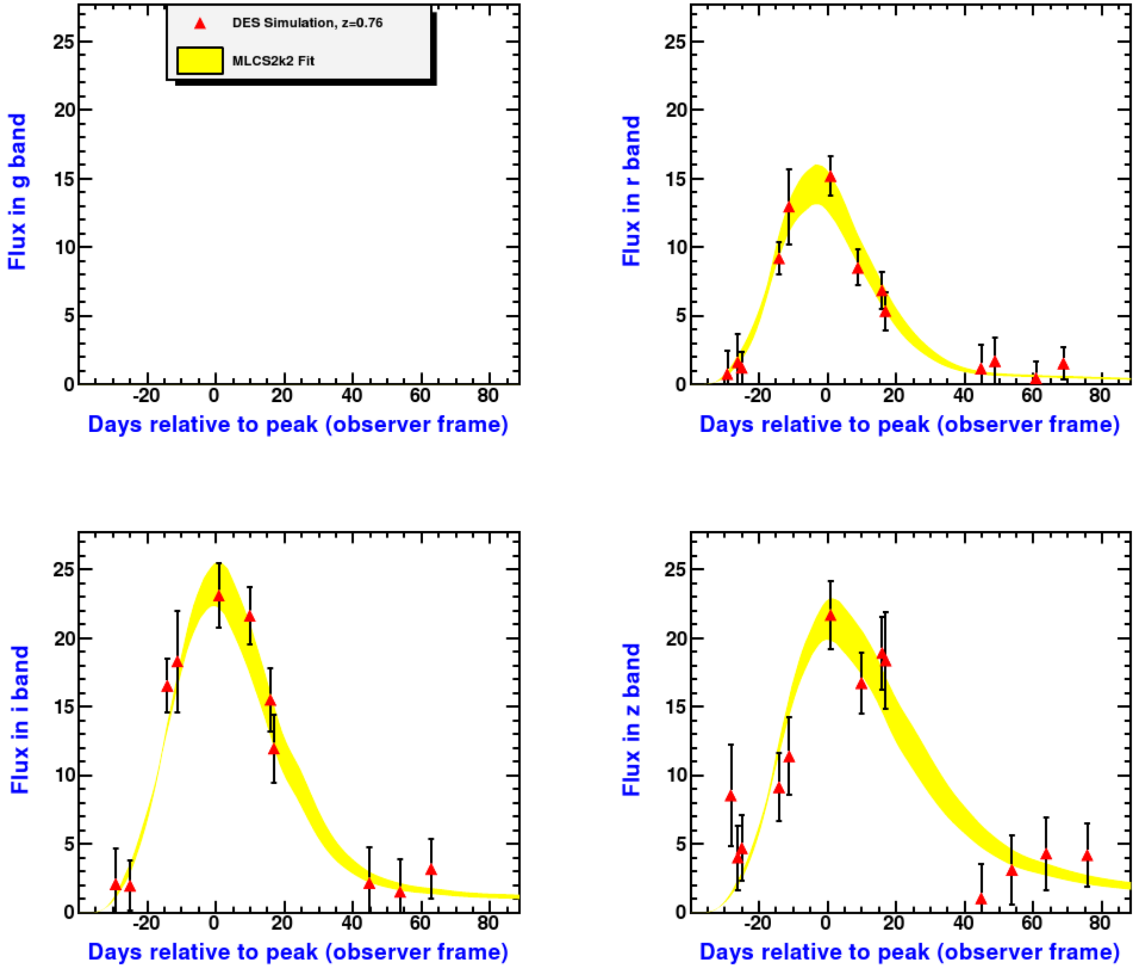
Simulated DES Light Curves



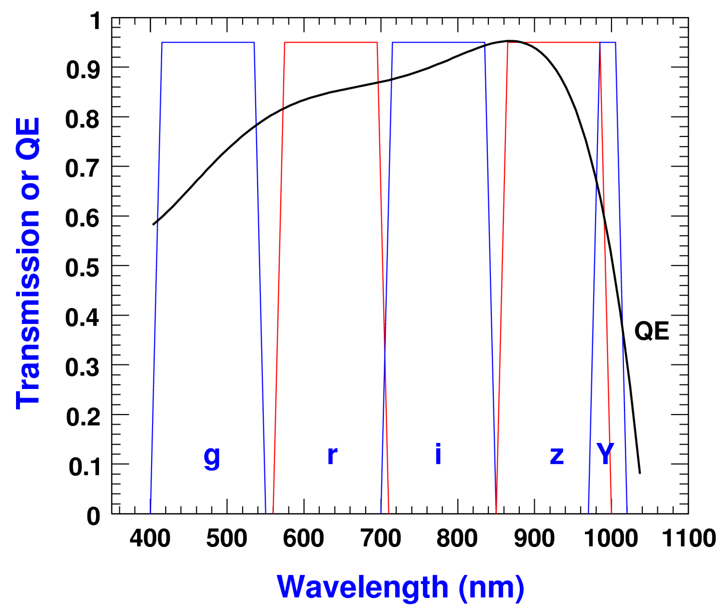
Example light curve at z~0.49 for a hybrid survey (15 sq. deg.) using the griz filter set. Note 2nd bump fade and decreased g-band flux.



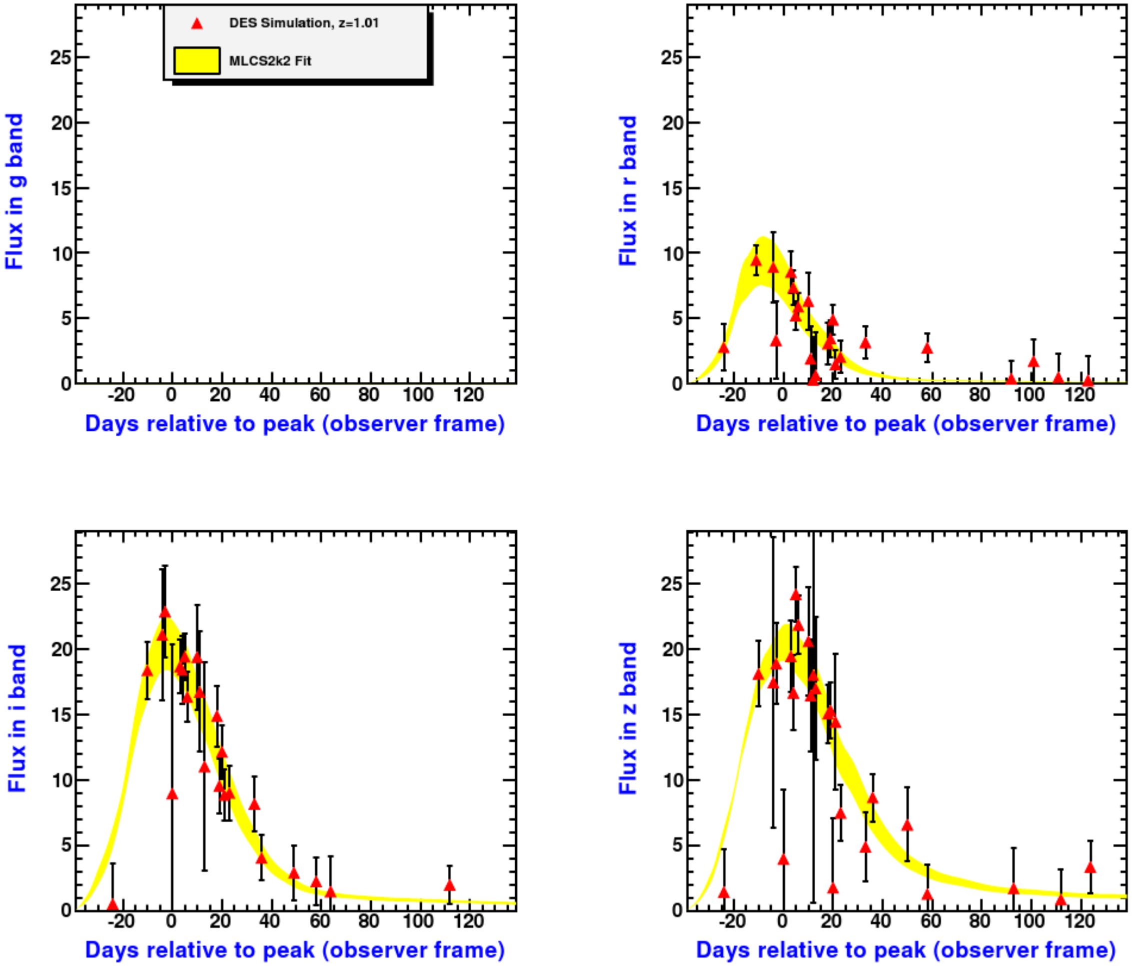
Simulated DES Light Curves



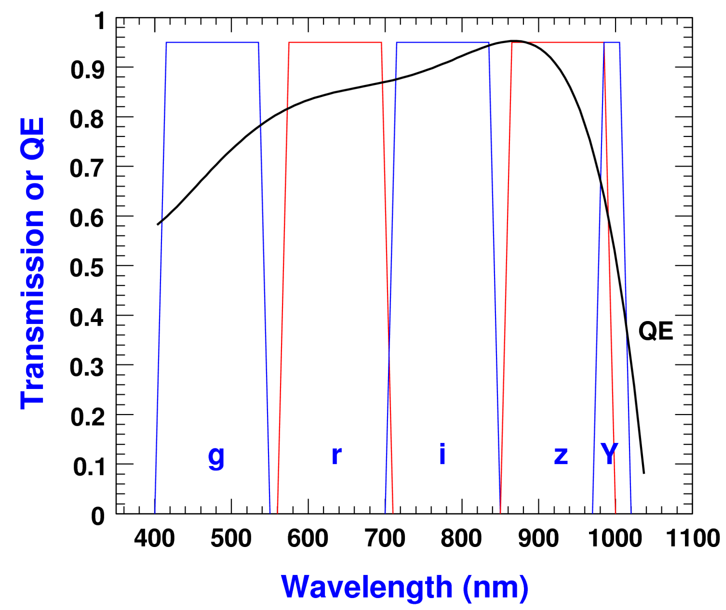
Example light curve at z~0.76 for a hybrid survey (15 sq. deg.) using the griz filter set. Note lack of 2nd bump, lack of g-band, and large gap.



Simulated DES Light Curves



Example light curve at z~1.01 for a hybrid survey (15 sq. deg.) using the griz filter set. Note lack of 2nd bump, lack of g-band, and lower S/N.

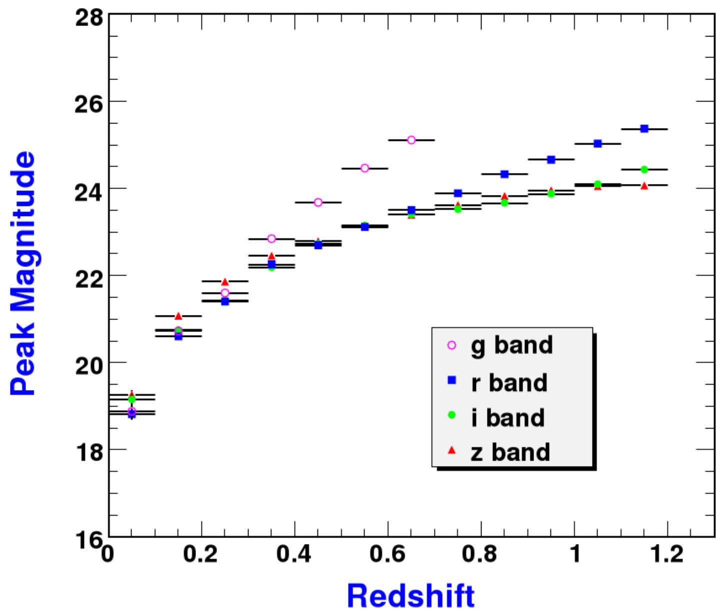


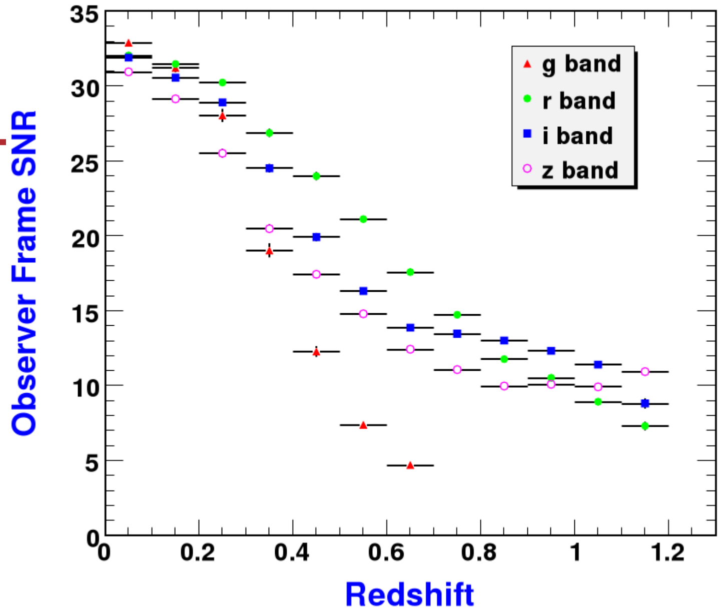
Default Cuts For Each SN

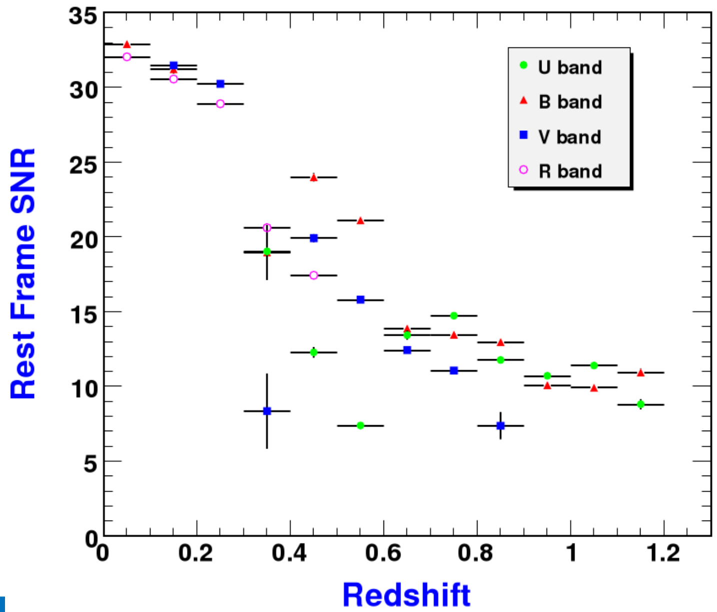
- At least 1 epoch before peak
- At least 1 epoch >10 days after peak
- 5 total epochs (no S/N requirement)
- 1 filter (griz) with S/N > 10 measurement
- 2 additional filters (griz) with S/N > 5 measurement

Peak Magnitudes & Maximum S/N

Hybrid (15 sq. deg) griz – cuts of 1 filter > 10 and any 3 > 5 S/N

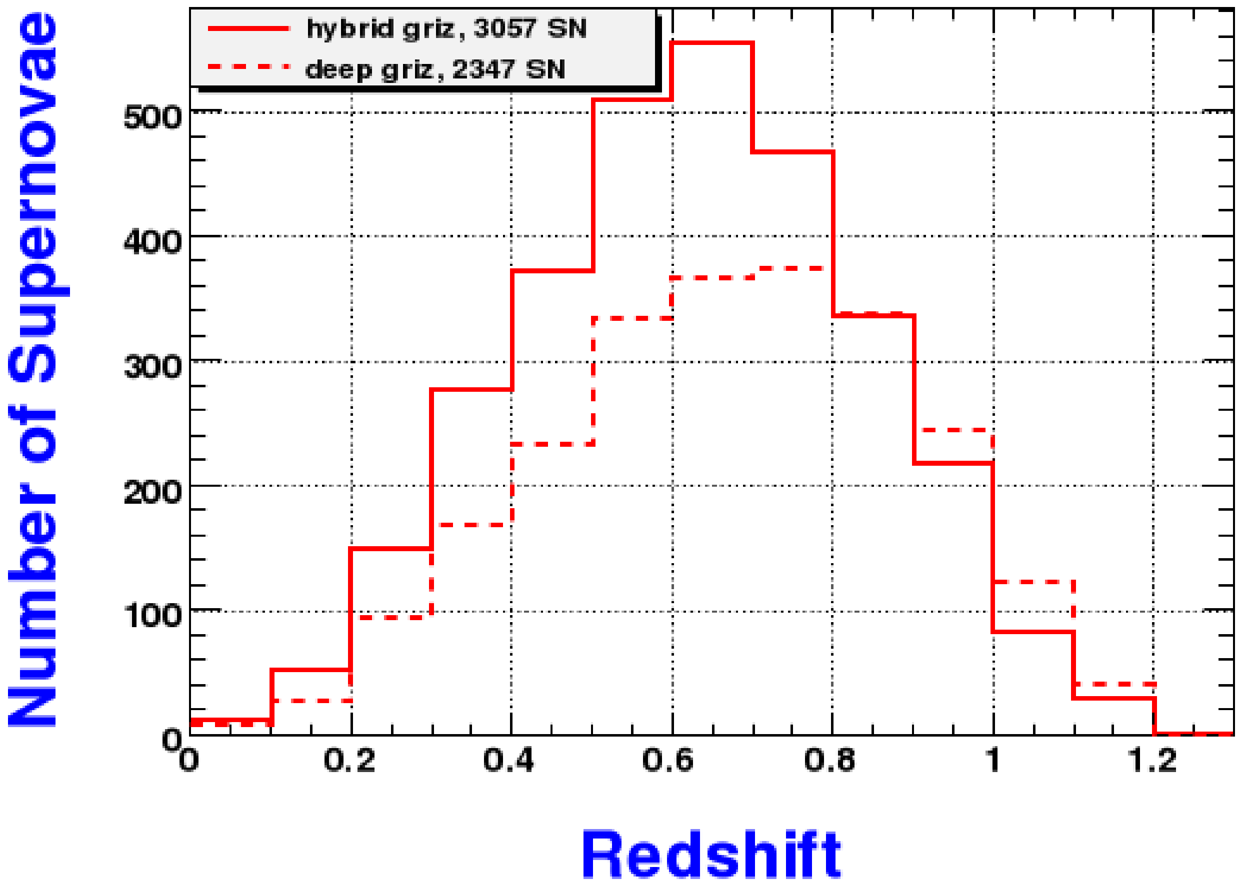






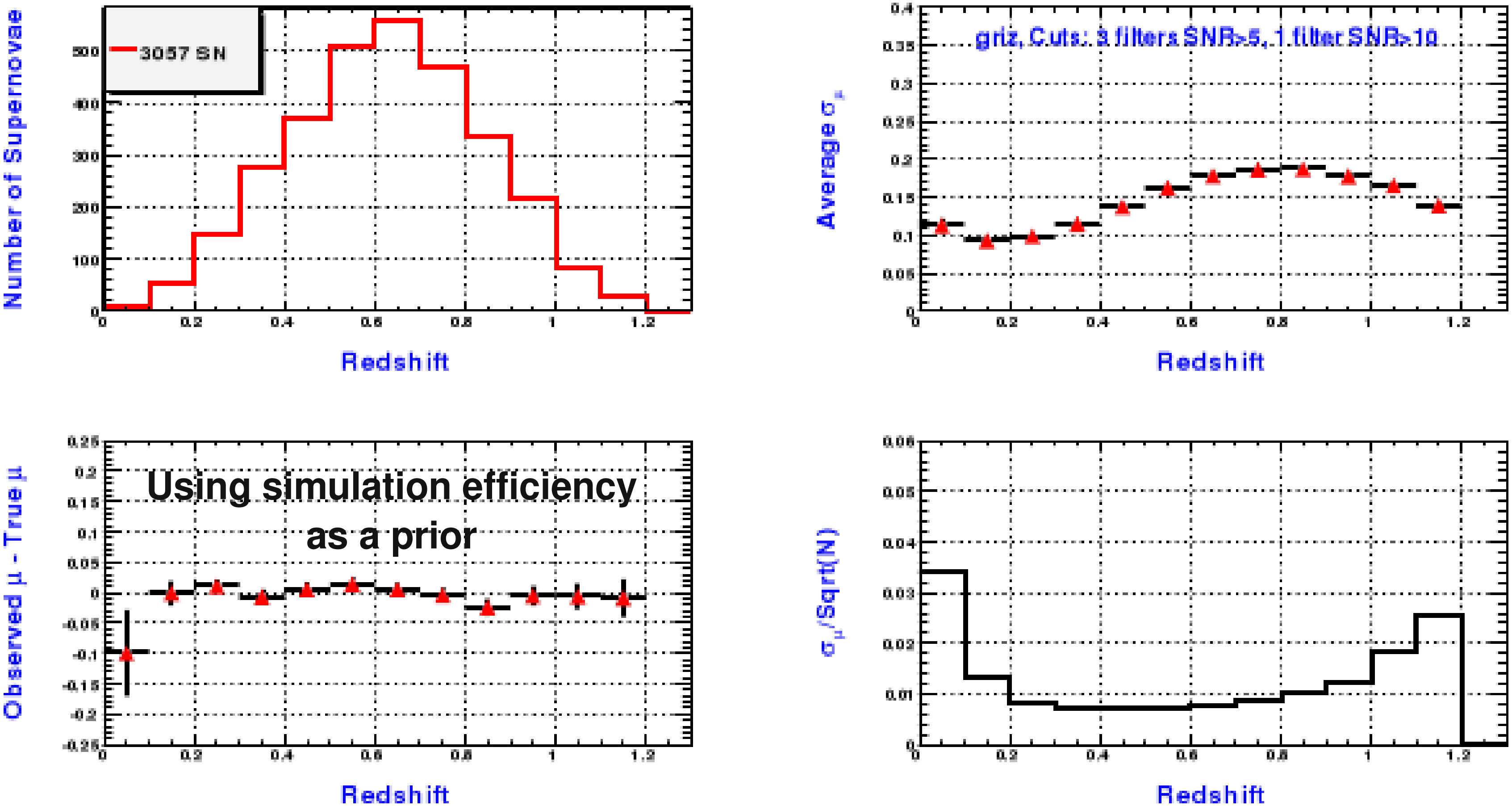
Hybrid vs. Deep Comparison

Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set

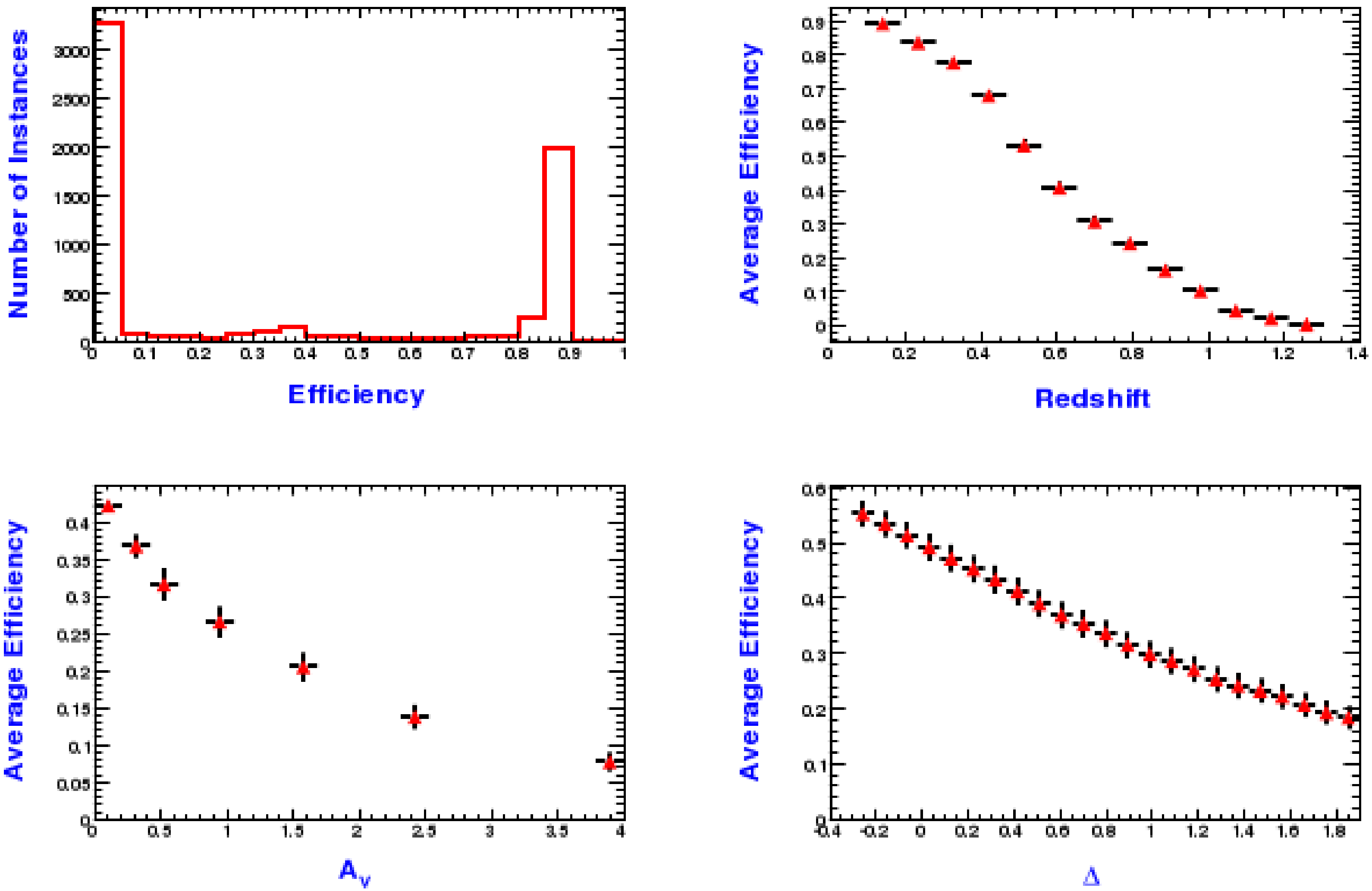


Default Survey: Hybrid griz

Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set

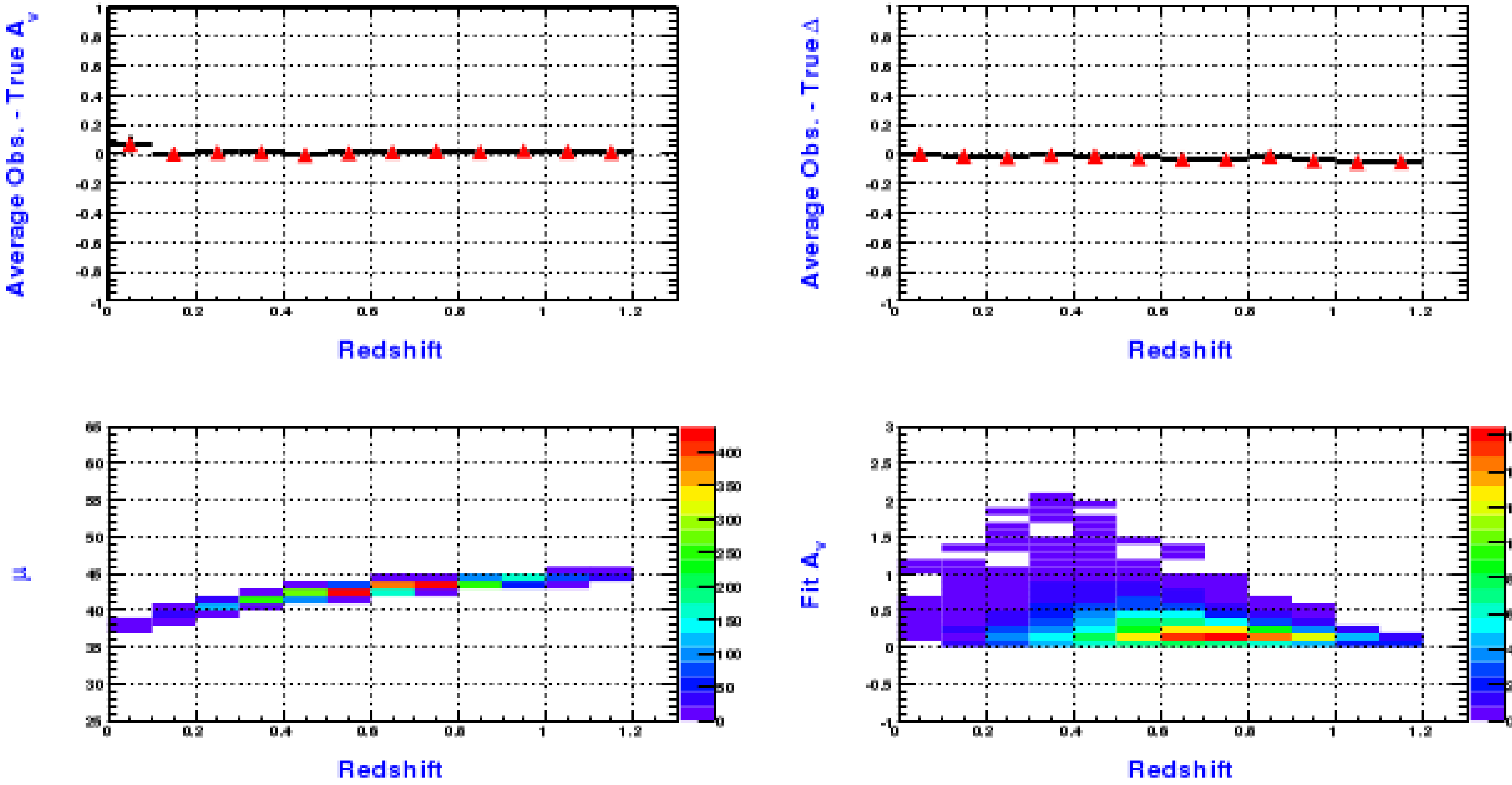


Default Survey: Run Of Simulation Efficiency

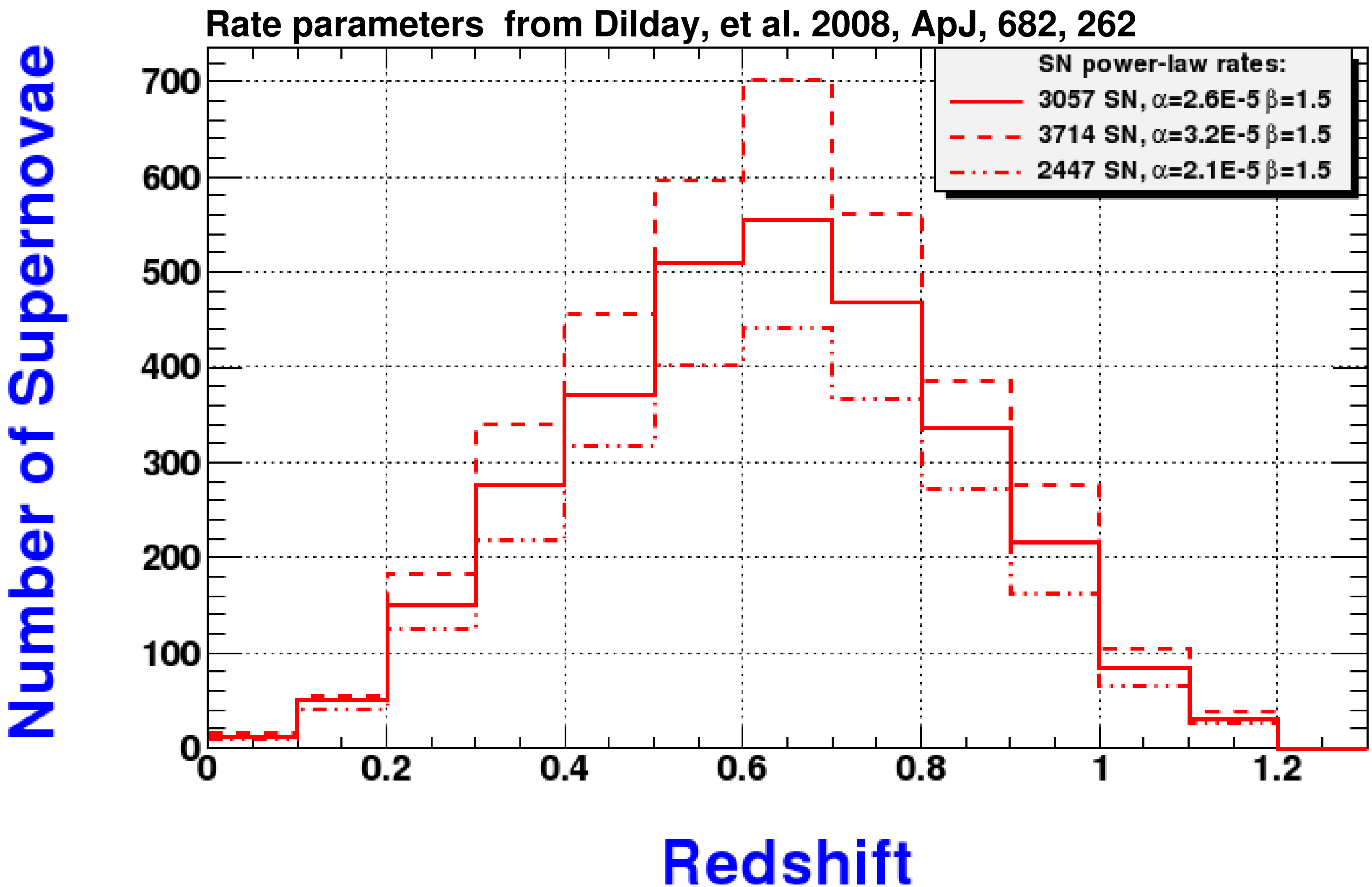


Default Survey: A_V, Δ

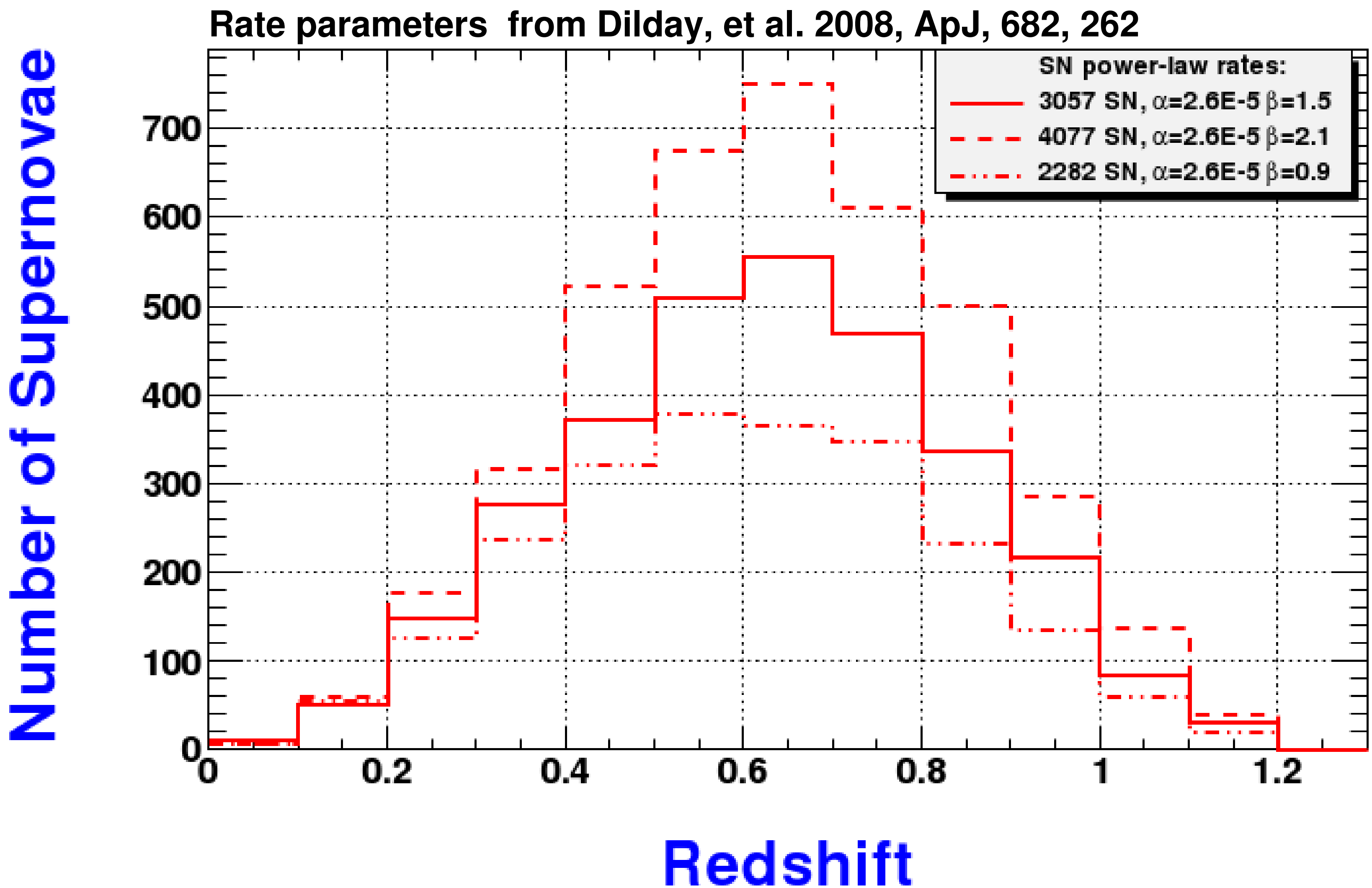
Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set



SN Rates: power-law $\alpha(1+z)^{\beta}$

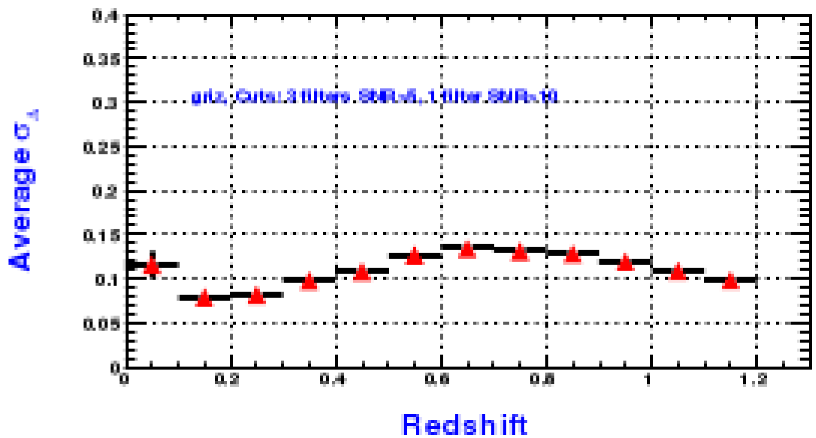


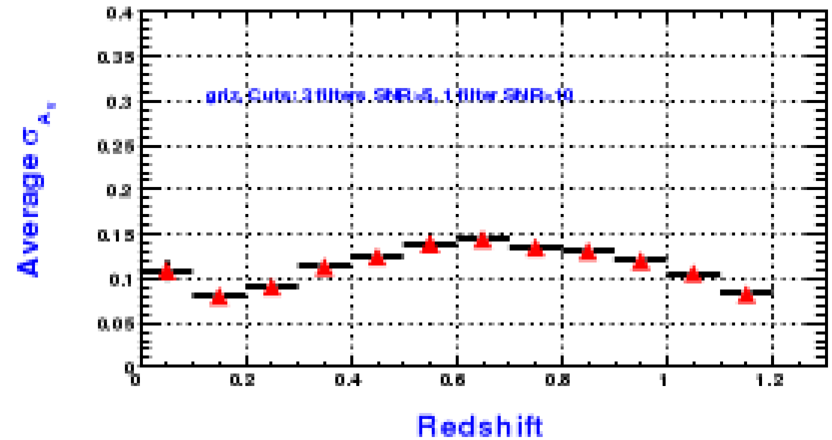
SN Rates: power-law $\alpha(1+z)^{\beta}$

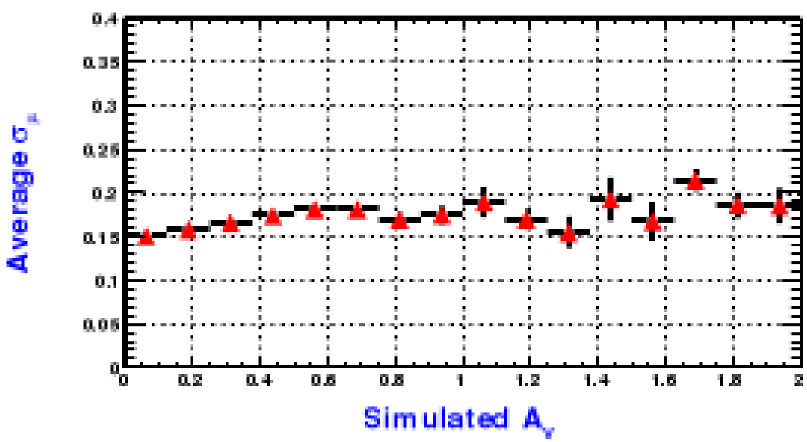


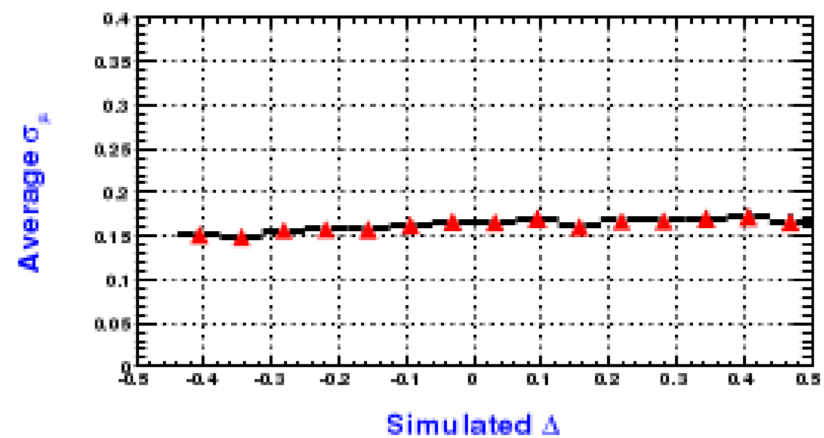
Default Survey: Additional Error Plots

Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set

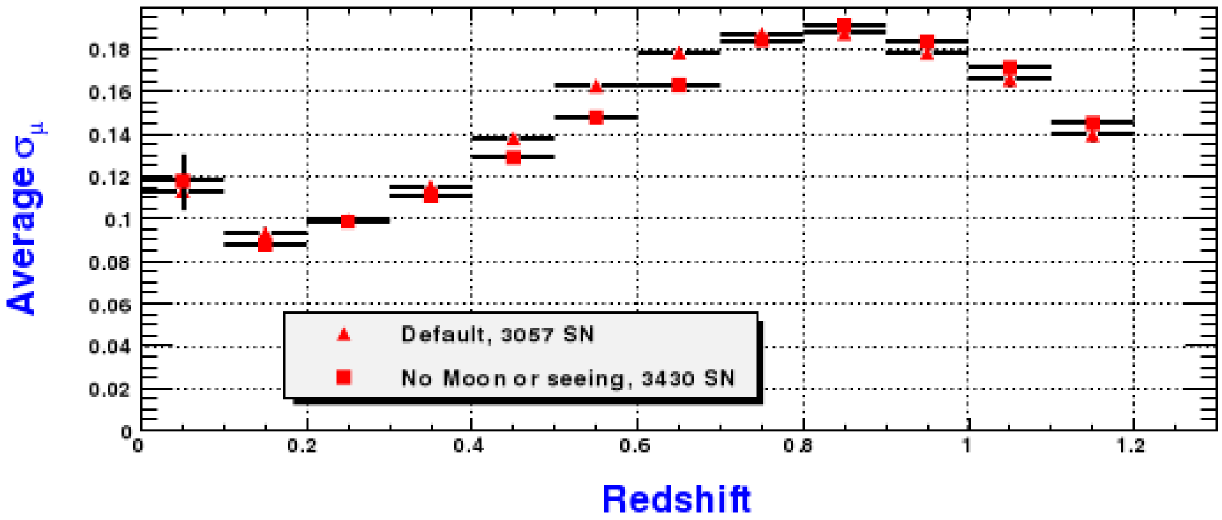


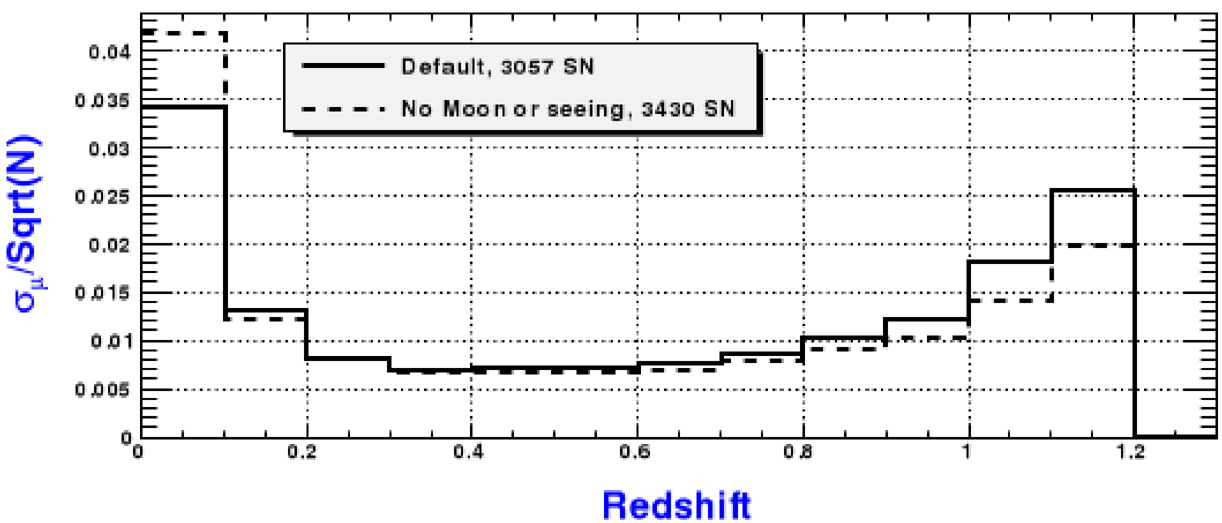






No Moon or Seeing Variation

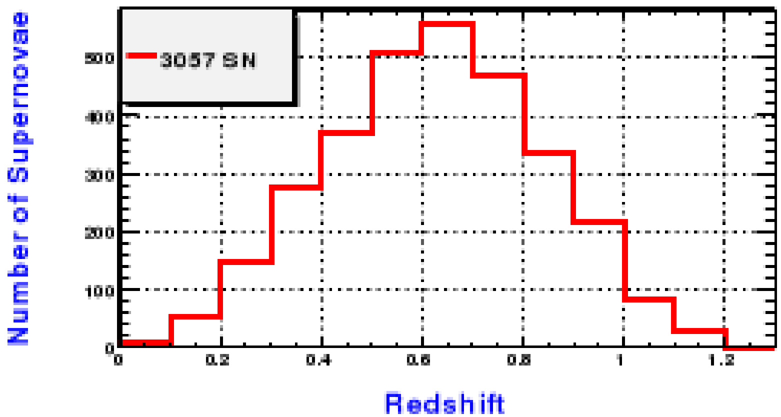


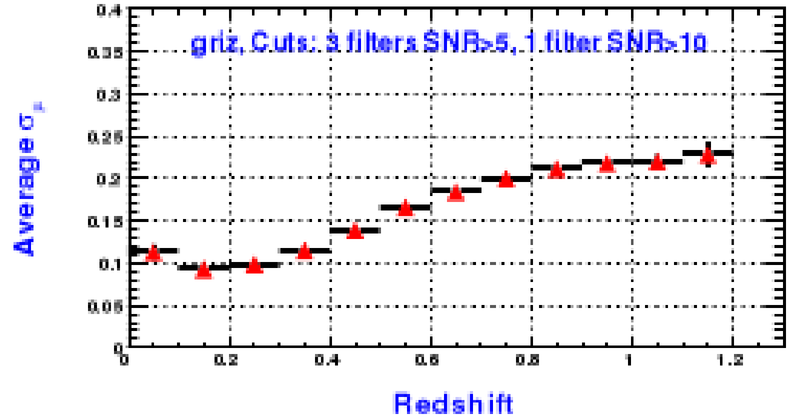


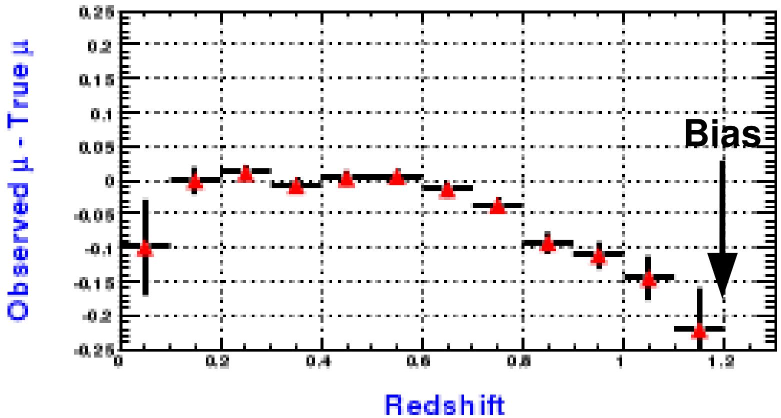
Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set

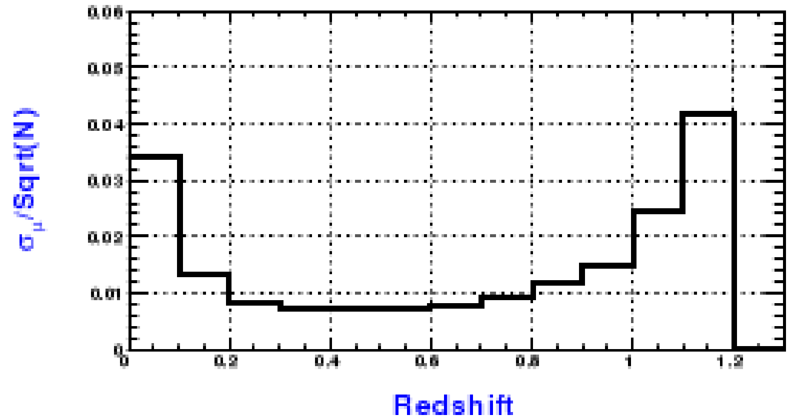
Bias In μ w/o Simulation Efficiency

Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set





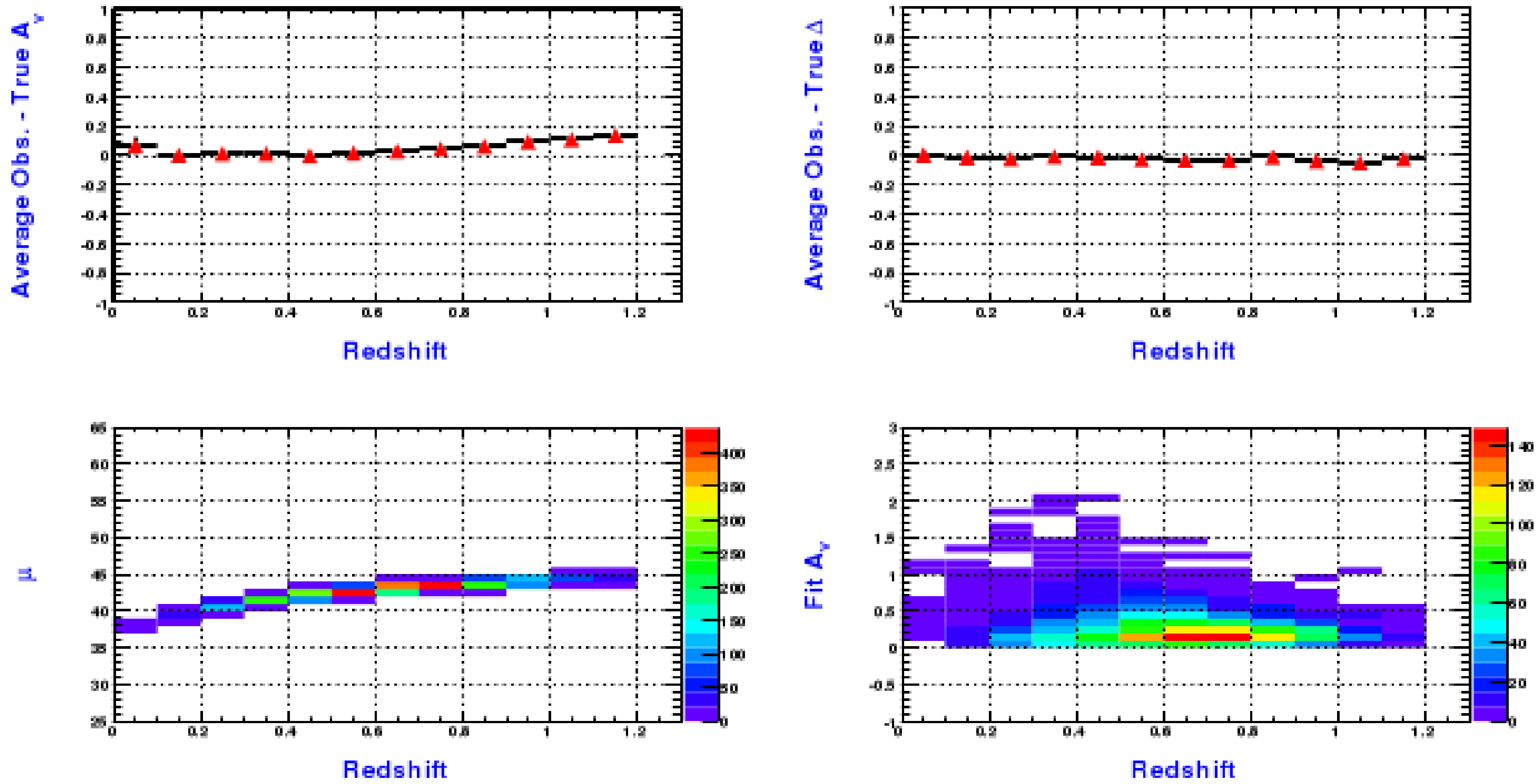




A bias in μ is evident in the difference in the fitted and simulated values arises when selection efficiencies are not taken into account and illustrates the magnitude of the μ-correction that will be needed.

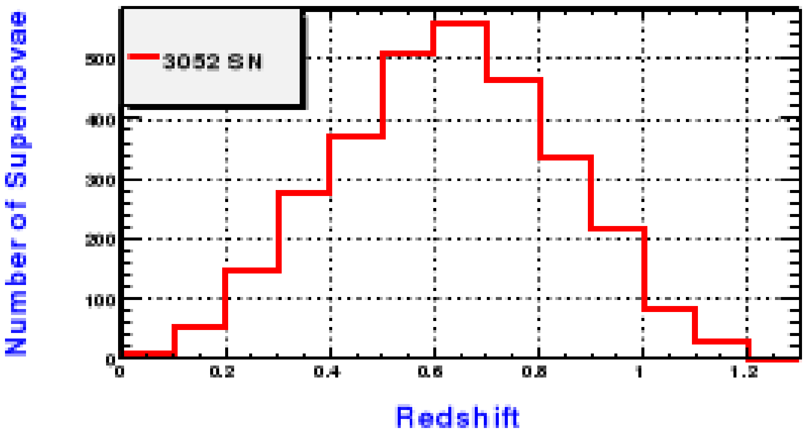
Bias In A_V, Δ w/o Simulation Efficiency

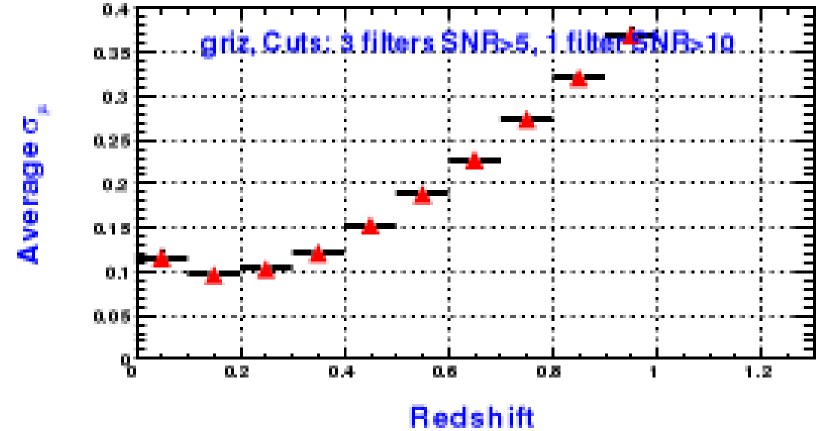
Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set

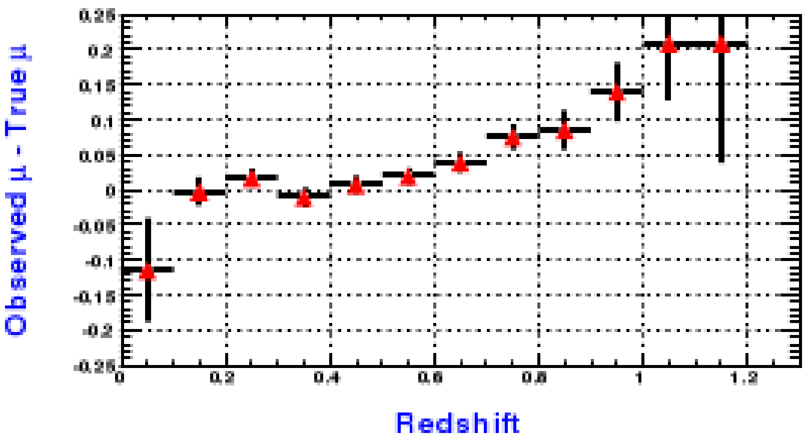


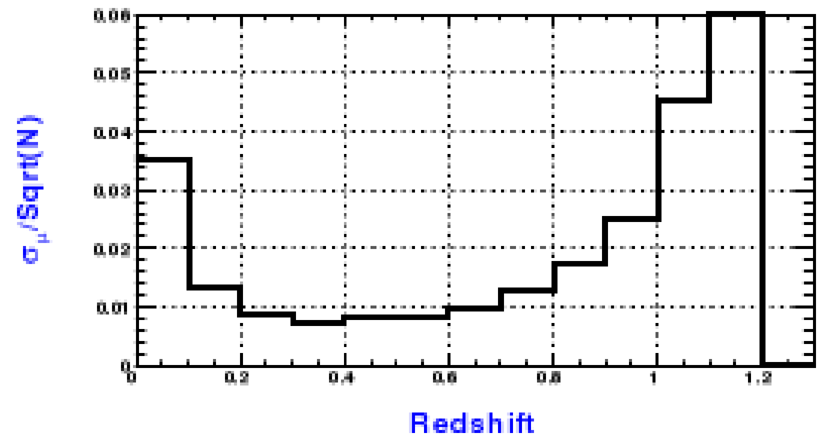
Bias In μ w/o A_V Prior Or Simulation Efficiency

Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set



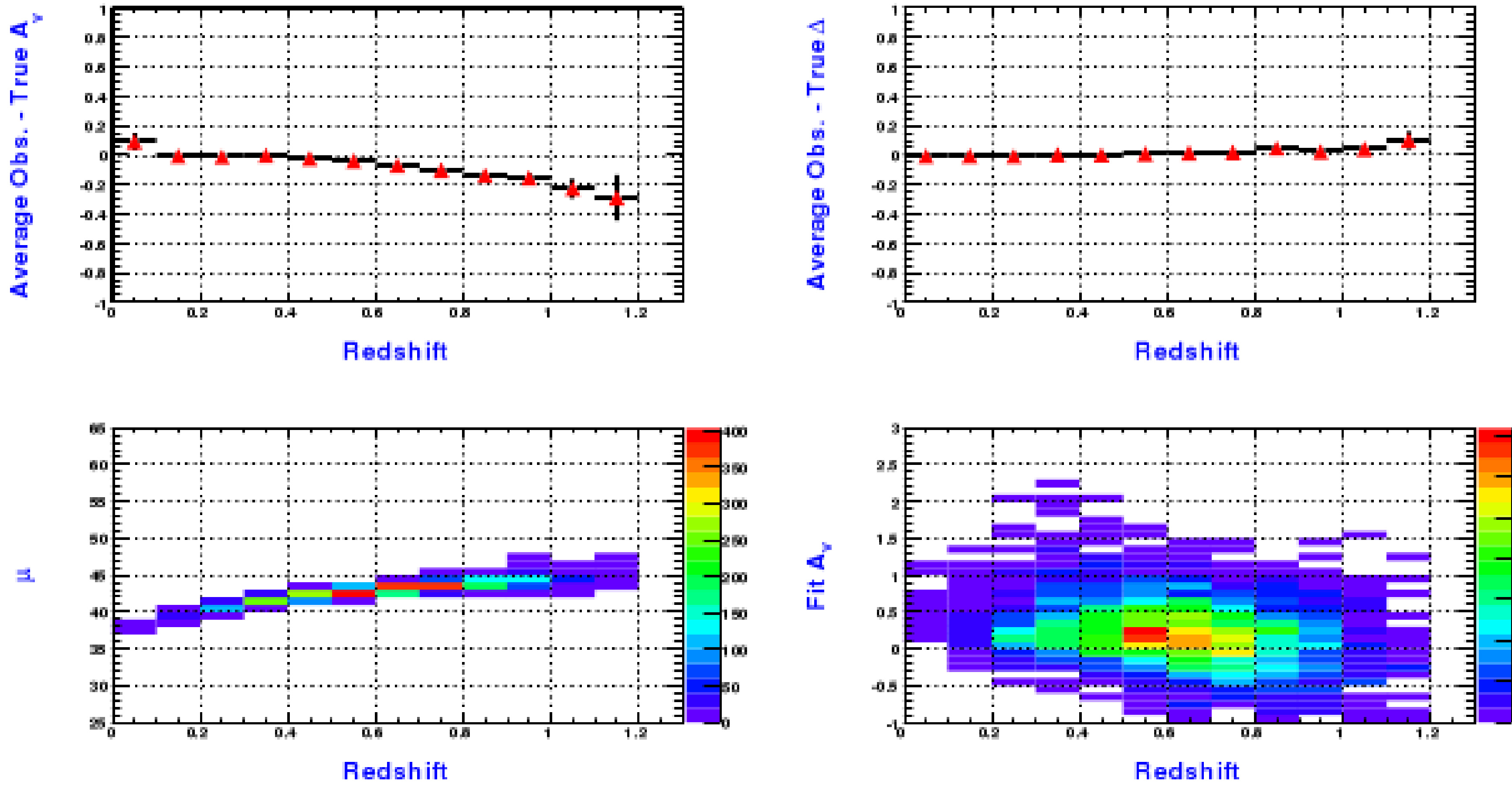






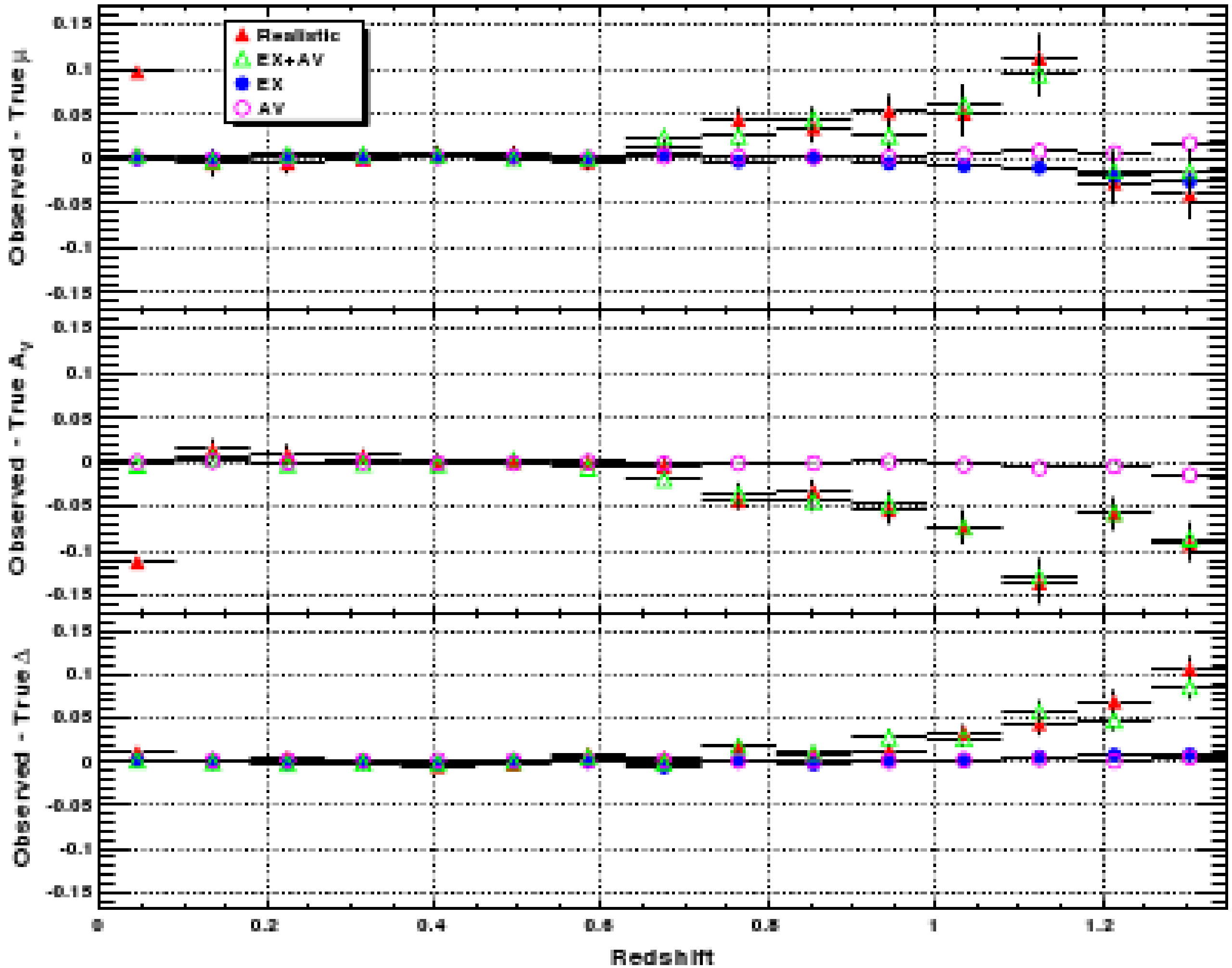
Bias In A_V, Δ w/o A_V Prior

Cuts of 1 filter > 10 and any 3 > 5 S/N have been applied for the griz filter set



Fitter Bias For Minimal Cuts (Nepoch) > 1

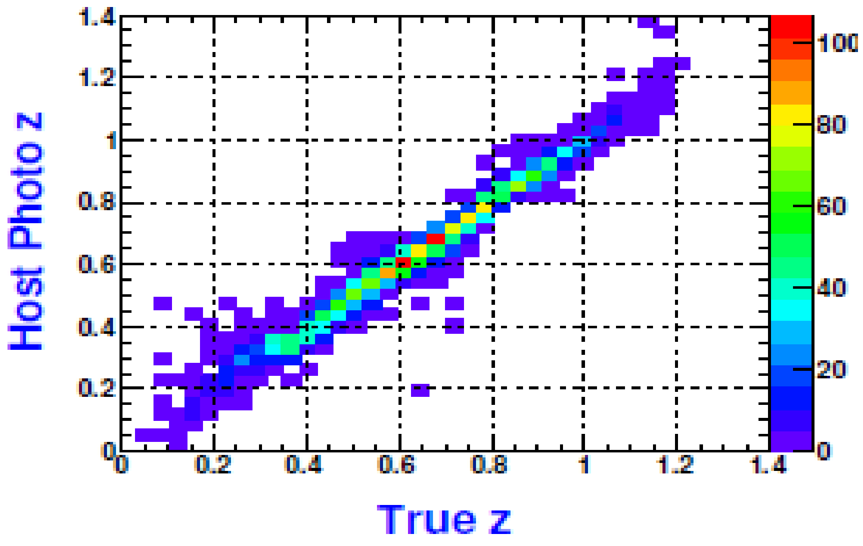
Ultra-deep (3 sq. deg) griz – min cuts

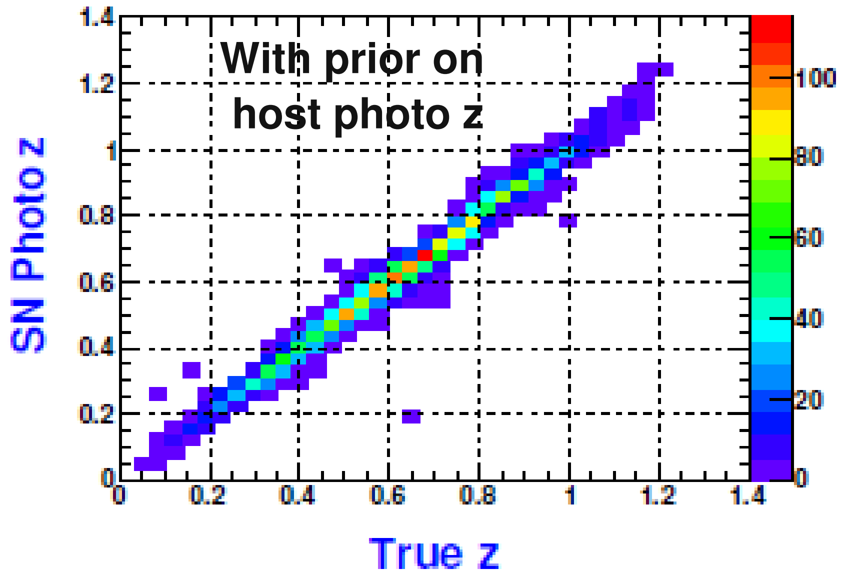


Spectroscopic Strategy

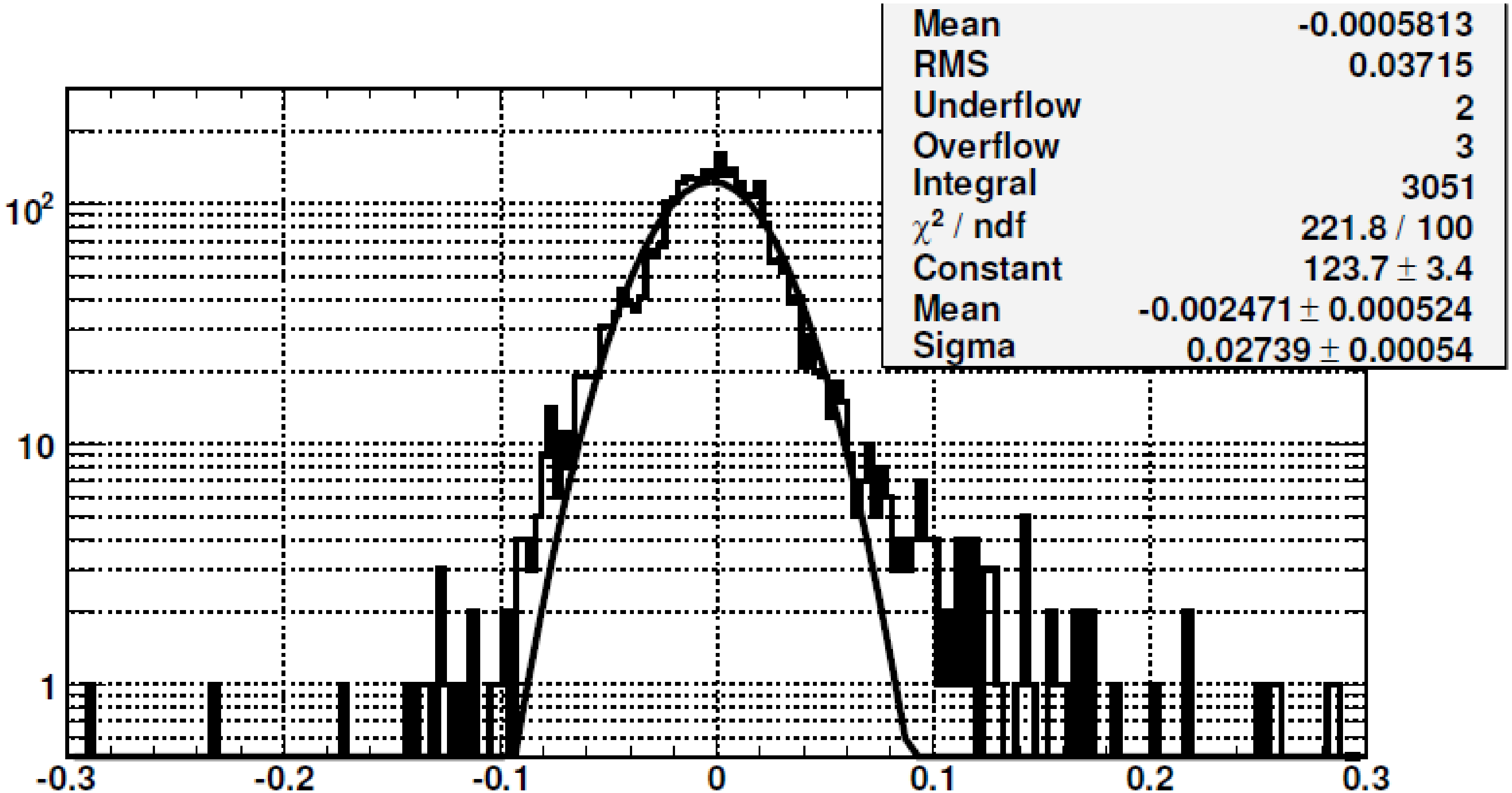
- Spectroscopy of full SNe sample
  - expensive (observing time)
  - large telescopes follow-up for 10 – 25% of SN sample
- Full host galaxy follow-up more feasible
  - negligible redshift errors ($\Delta z < 0.001$ – J. Marriner)
  - redshift enables distinguishing type Ia & II light curves & spectra
- Photometric redshifts

Photometric Redshifts vs. True z





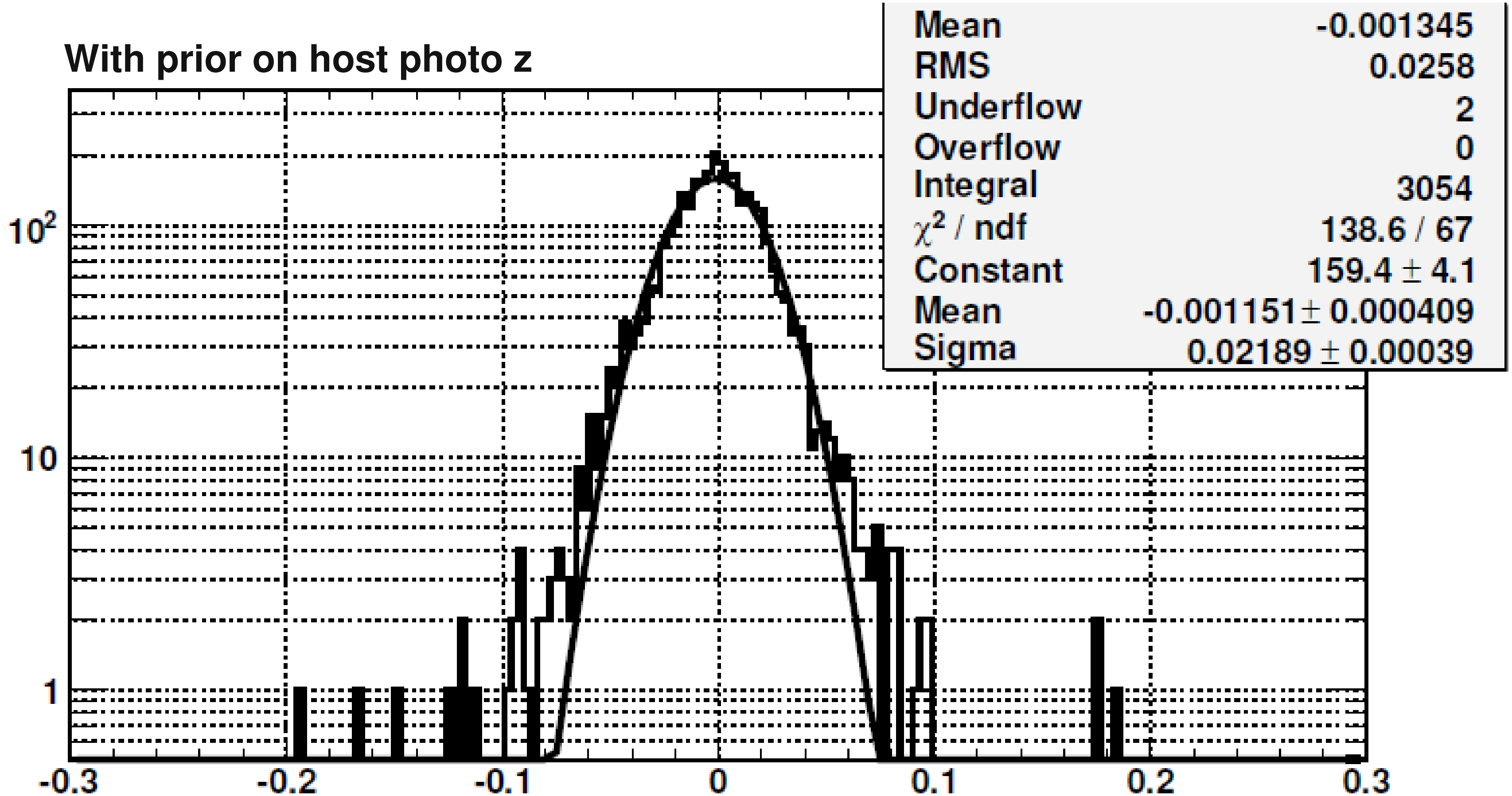
Photometric Redshifts: Host z



Host photo z - True z

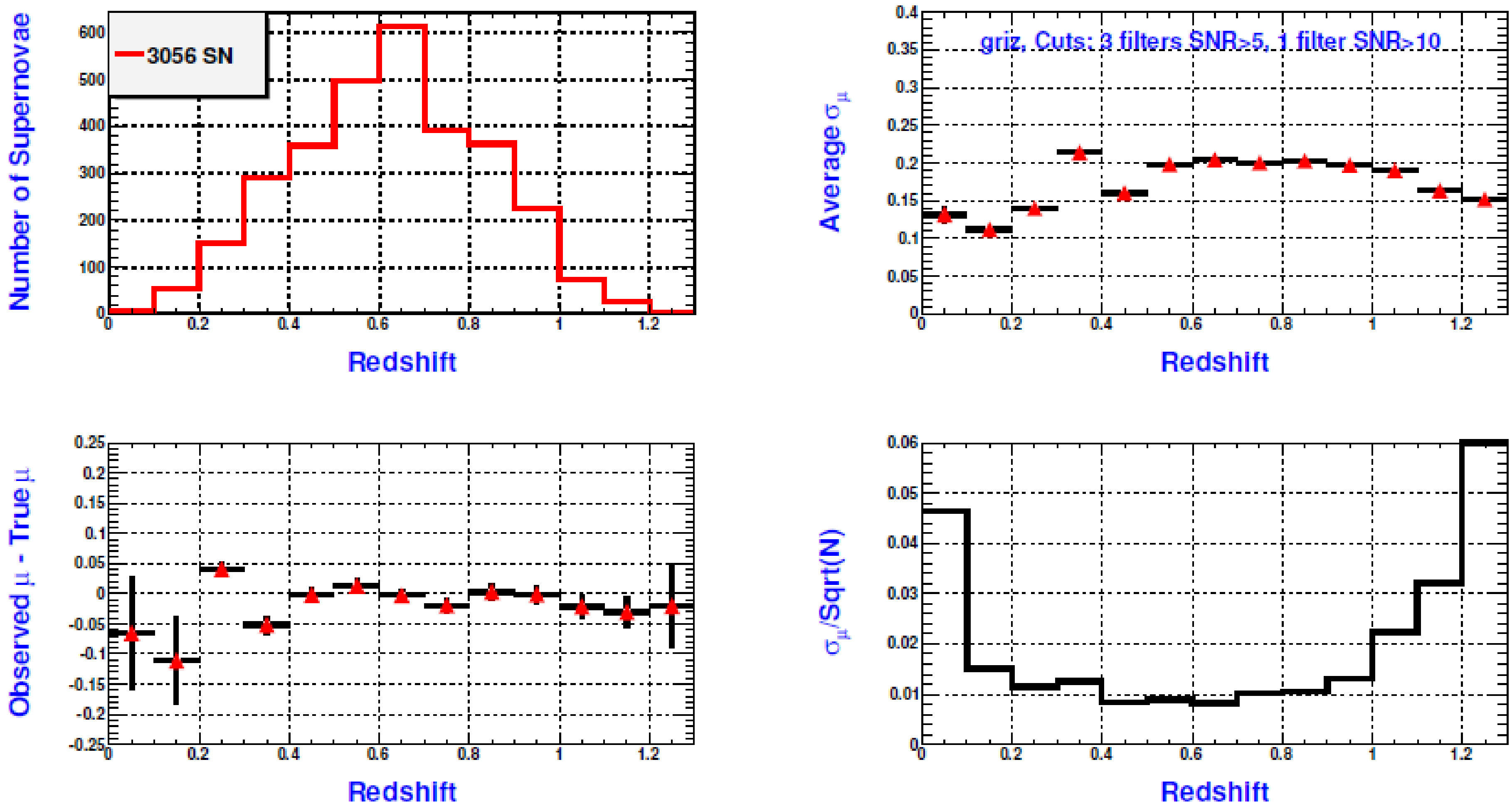
Photometric Redshifts: SN z

With prior on host photo z



SN photo z - True z

Photometric Redshifts: Hybrid Run

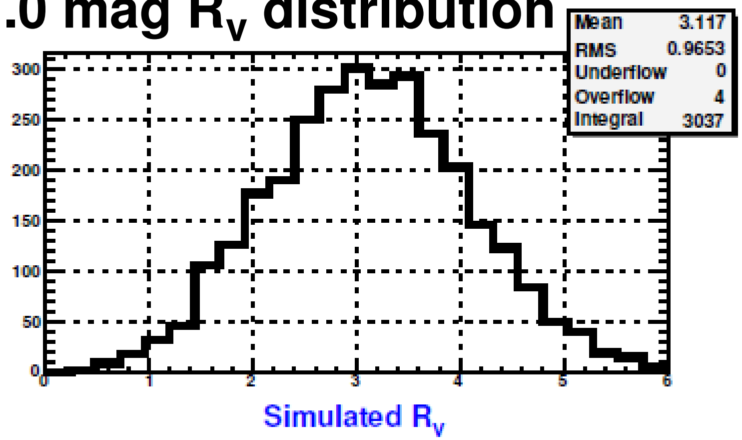


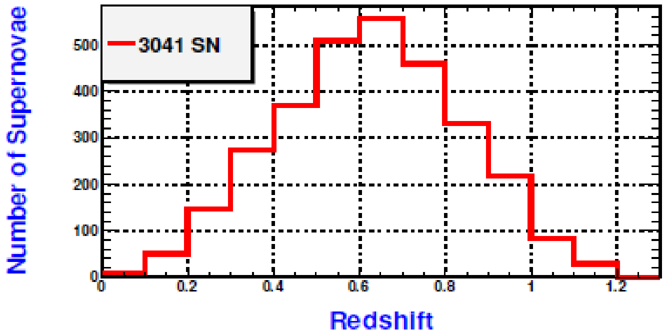
Systematics Studies

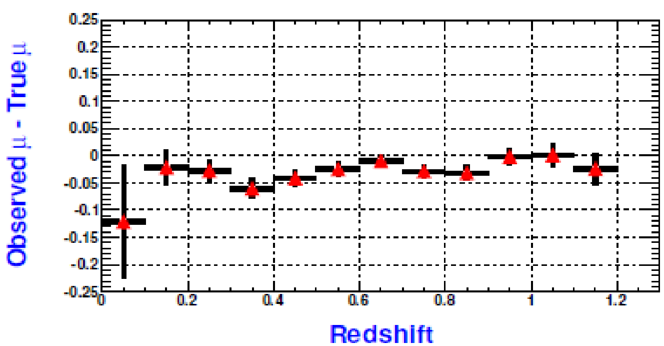
- Current
  - Ribamar Reis: zeropoint shift in r-band by 0.1
    - gives $\Delta\mu$ of 0.04 to -0.16 from z = 0.0 to 1.2
    - expected zeropoint shift is 10x smaller
  - Ribamar Reis: filter centroid shifts
  - R_V smearing
- Future: progressive change in simulated R_V from 1.5 to 3.1 over z = 0 to 1.2
  - fitting A_V/R_V in each redshift bin
  - vary R_V in light curve fitter to determine best chisq in each redshift bin (SDSS-like procedure)

Hybrid griz Systematics

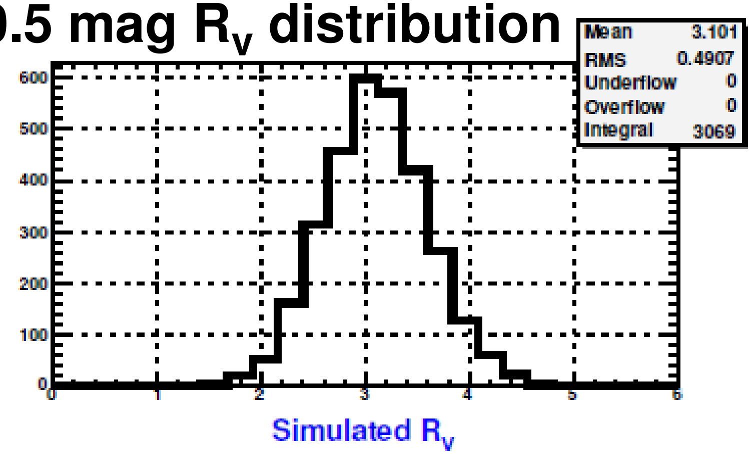
1.0 mag R_V distribution

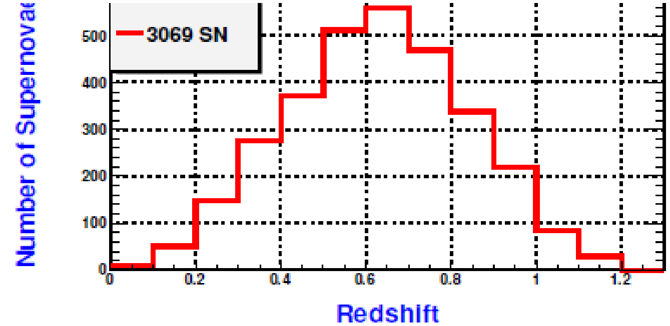


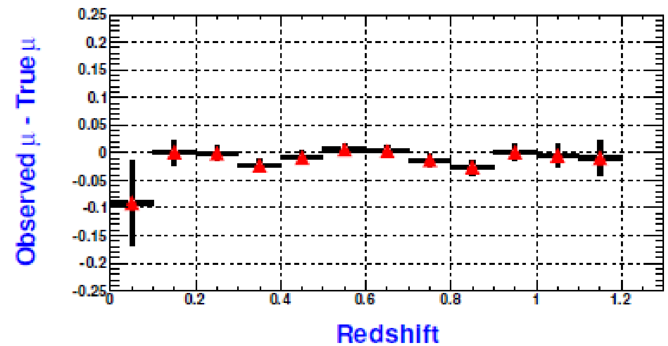




0.5 mag R_V distribution



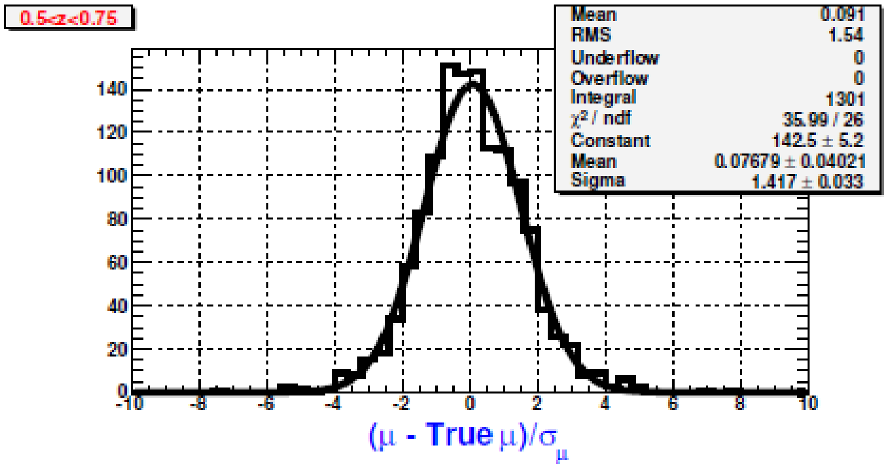




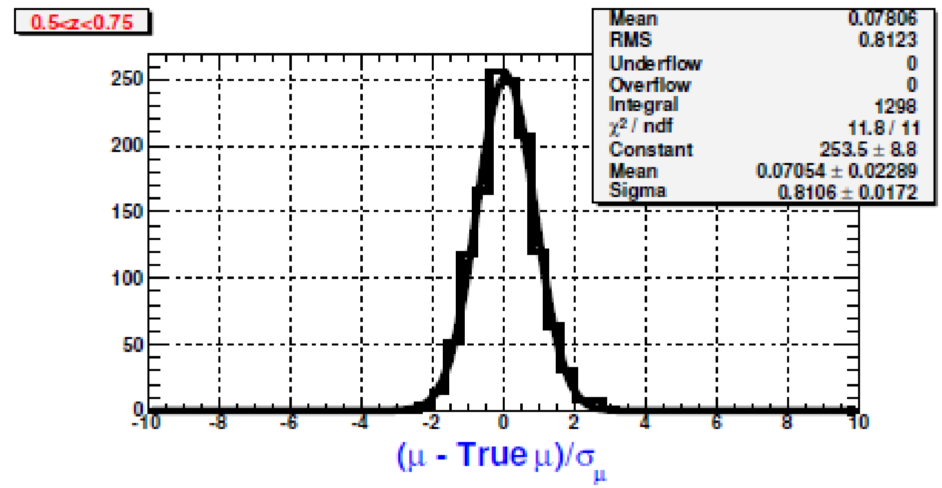
Dominance Of Color Fluctuation

The Dark Energy Survey

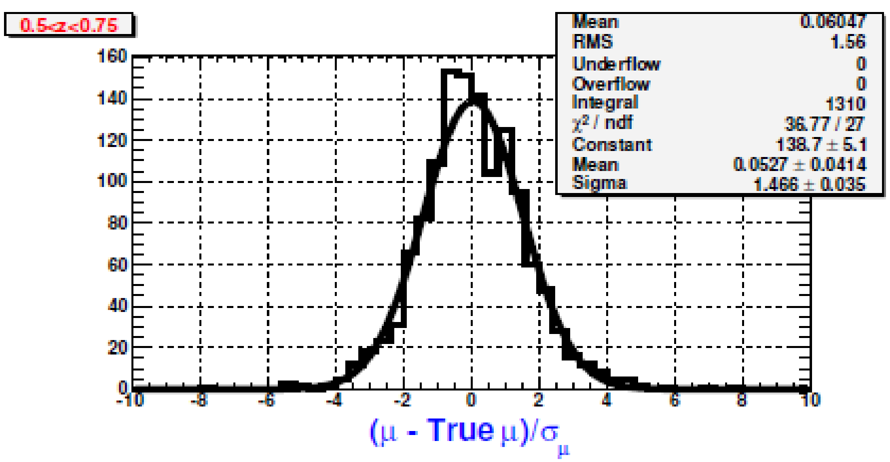
Fixed RV=3.1+color fluct. (default survey)



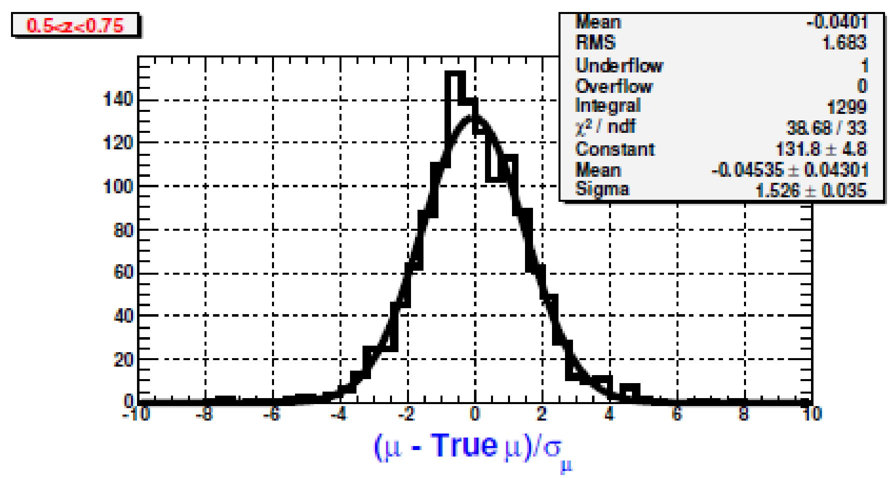
Fixed RV=3.1+ no color fluct.



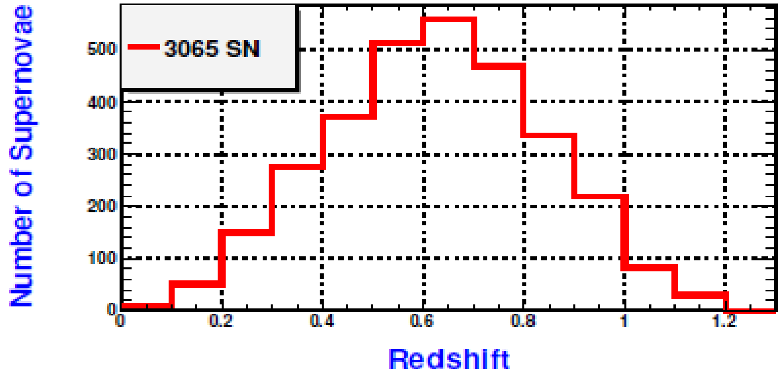
RV smeared 0.5 mag + color fluct.



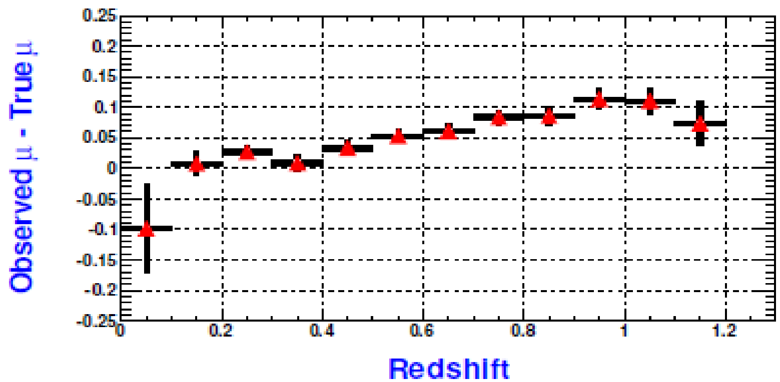
RV smeared 1.0 mag + color fluct.

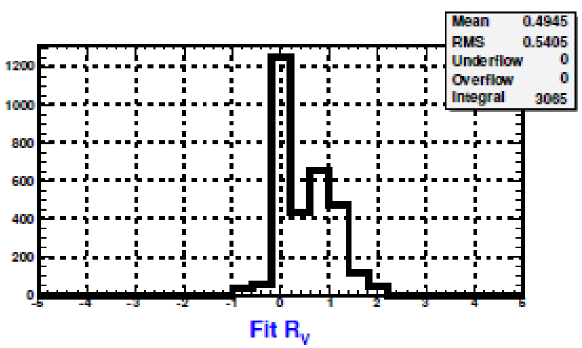


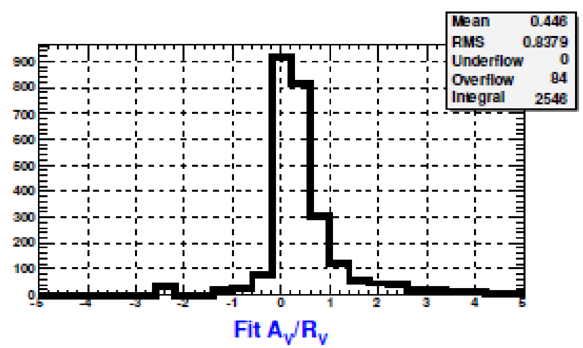
Tuning Up For Full R_V Systematics: Fitting A_V/R_V To Entire Sample

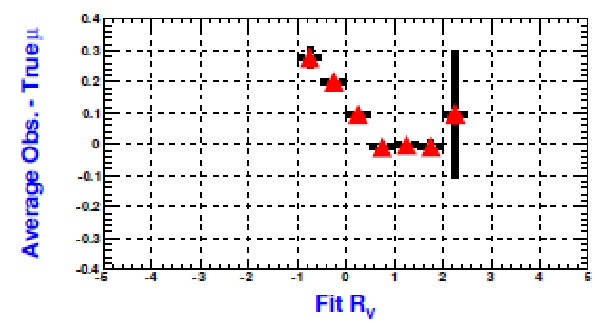


Simulation efficiencies NOT yet updated!!!



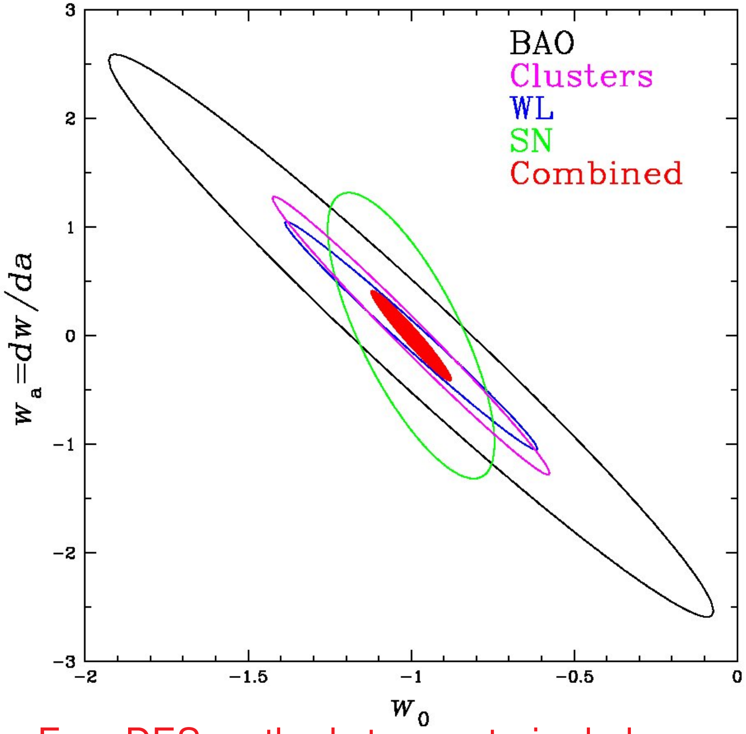






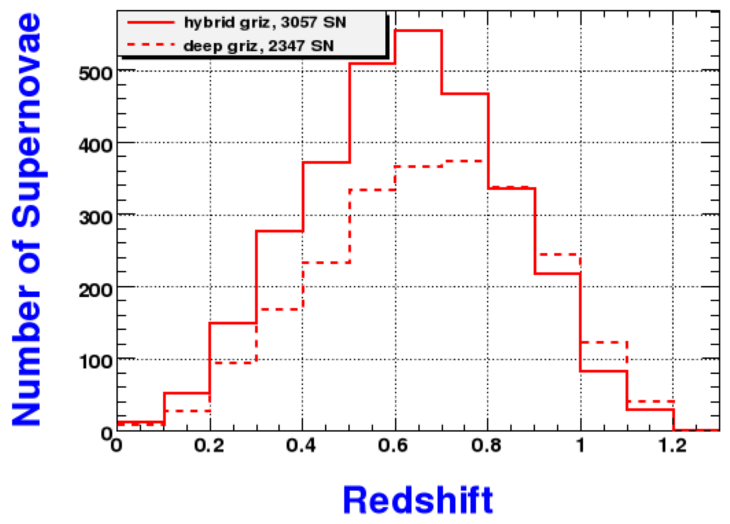
Survey Figure Of Merit (FoM)

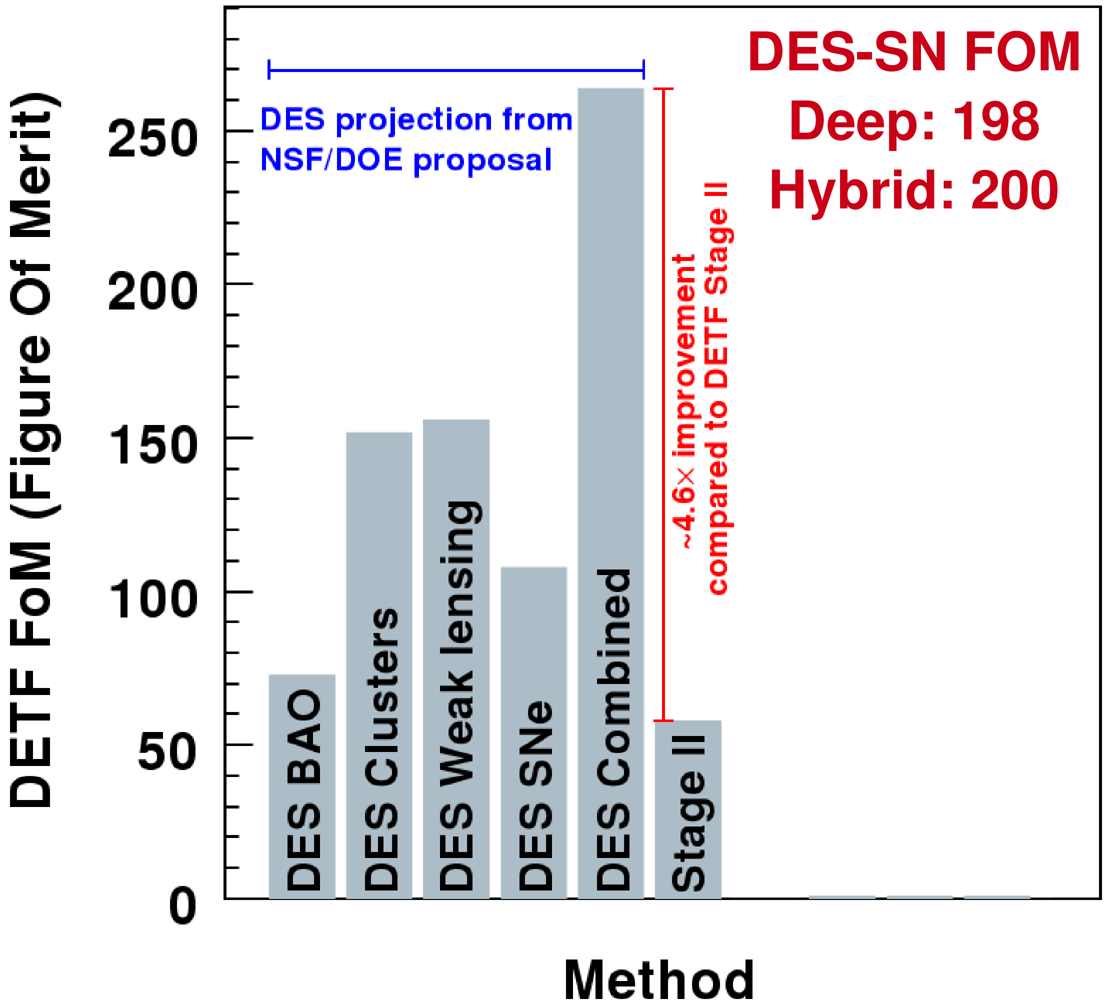
- Dark Energy Task Force (DETF) FoM: inverse size of $w_a - w_o$ error ellipse
  - $w(a) = w_o + (1-a)\,w_a$
  - a = scale factor
  - w_o = w at present epoch
  - w_a = rate of change of w with a
- Inverse area means bigger is better



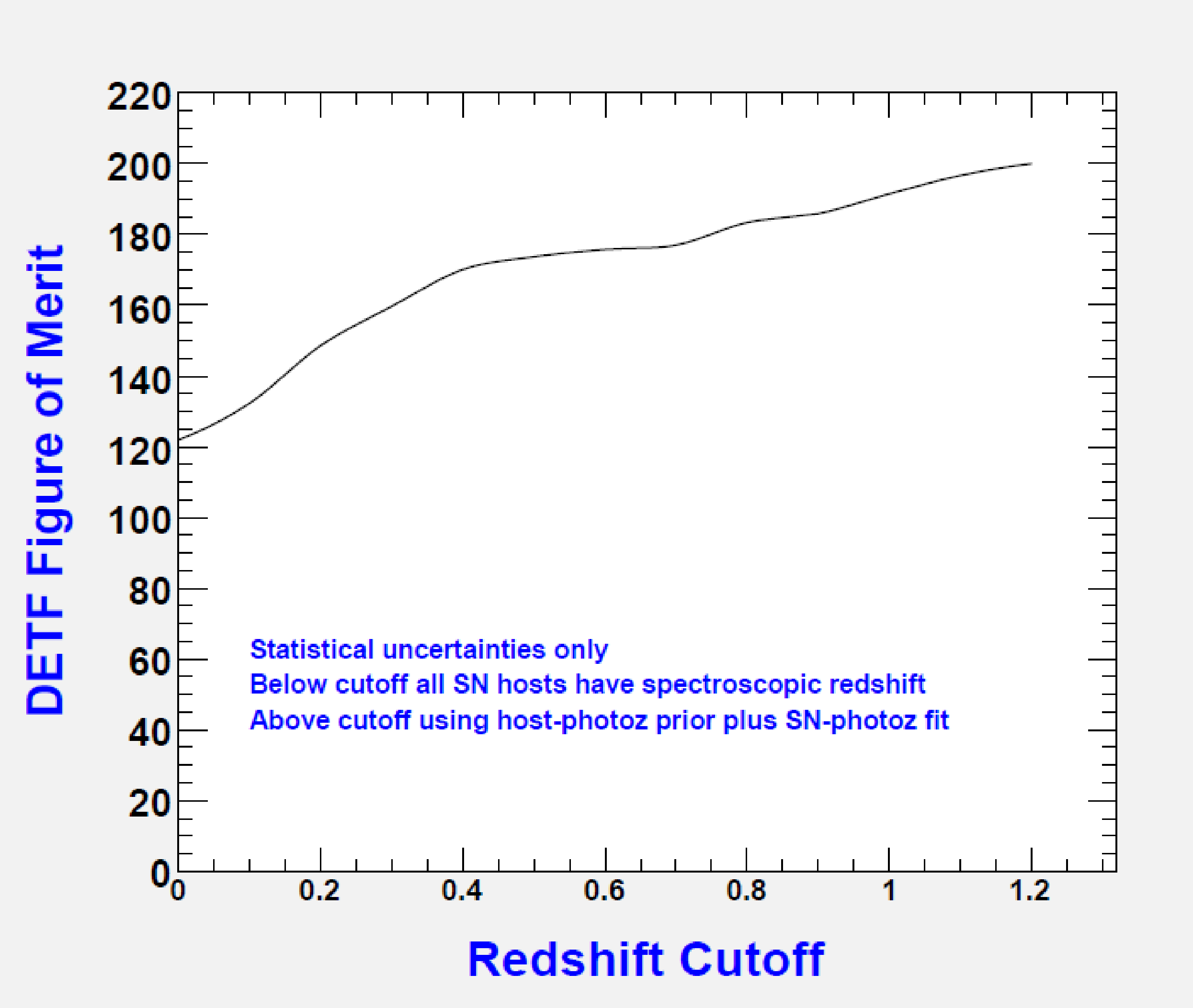
Four DES methods to constrain dark energy (plot from NSF/DOE proposal including Planck priors but NOT the DETF Stage II constraints)

DETF FoM for DES





DETF FoM vs. Spectroscopic z Cutoff



SNANA IR Simulations

- Motivation: simulate VISTA light curves
  - 4-m class wide field survey telescope
  - southern hemisphere
  - near IR camera (1.65 deg diam FOV)
  - 67 million pixels of mean size 0.339"
  - broad band filters at Z, Y, J, H, K_s
  - narrow band filter at 1.18 micron
- Status
  - updated SNANA model light curve code to use 8 filters
  - currently debugging
  - has been dormant but is active again

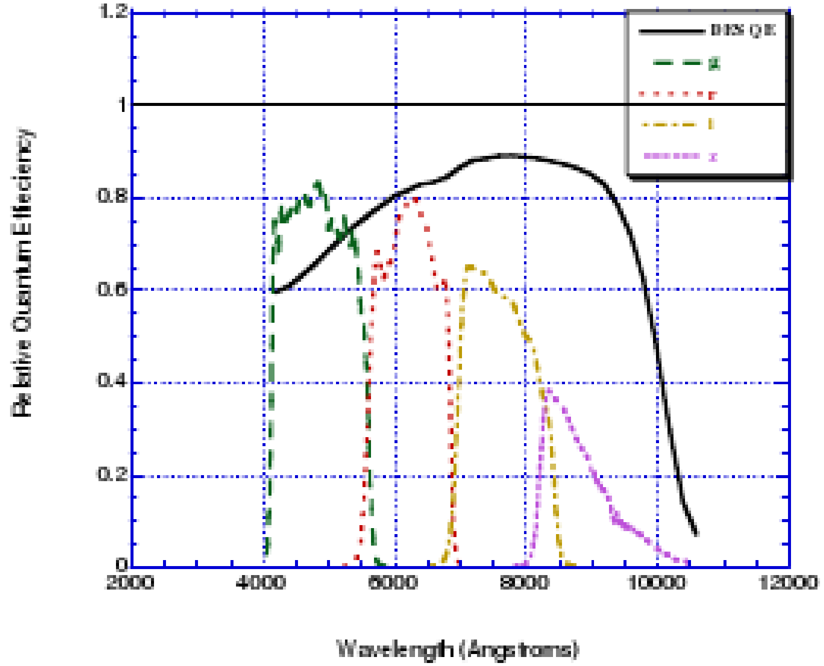
http://www.vista.ac.uk

DES vs. SNLS: General

	SNLS	DES	Units
# Fields	4	2.5	~6 months/year
FoV	1	3	sq deg
Imaging total	1380	750	hr
Photometric?	75-80	50	%
Spectroscopy	1500	?	hr

From John Marriner

DES vs. SNLS: Quantum Efficiency



From John Marriner

DES vs. Pan-Starrs I (roughly)

Factor	DES-SN	PS1 SN	Ratio
Aperture	12.6 m^2	2.5 m^2	5.0
Time Share	3%	30%	0.1
FOV	3 deg^2	7 deg^2	0.4
Seeing	~3/4 arcsec	~3/4 arcsec	~1
Sky Brightness	minimal pollution	modest pollution	~1
Useful Time	80%	60%	~1.3
Edge effects	~3.5/5	~6.5/8	~0.9
NET			**0.2**

On paper PS1 is ~5x faster, and starts ~2 years earlier.
But, not $N^{1/2}$ - systematics control completely dominates.

From John Marriner

To Do List

- Run wide survey for the current survey options
- Add host galaxy noise to simulation
- Finish full R_v systematic study
- Update comparisons to other surveys
- Suggestions?

Backup Slides

DES Zeropoints, etc., Moonless

(mag=-2.5*LOG(Flux in ADU) + Zeropt) (1 ADU = 1 e-) (1 arcsec -> 30.1 Npixels)

	e-/100s for 20th mag	Zeropt for 100s, 100s, 200s,200s, 200s	SQRT(SKY) for 100s, 100s, 200s, 200s, 200s	Our Limiting Magnitude for 10 sigma for 100s, 100s, 200s, 200s, 200s	Table 8 Vista Proposal (Limiting Mag for 10 sigma)
g	49800	31.7	149	23.8	23.8
r	49400	31.7	236	23.3	23.3
i	36940	32.2	400	23.2	23.3
z	38000	32.2	735	22.5	22.6
Y	7600	30.5	520	21.2	21.2