DES – Type Ia SNe Selection Part 2: Figure of Merit for Cosmology Constraints

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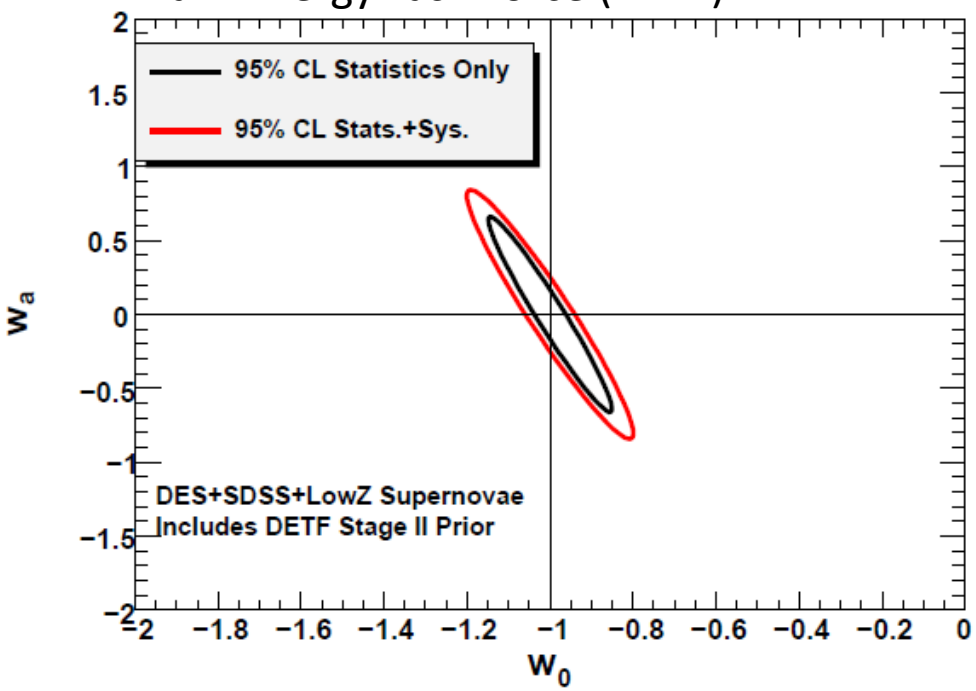
Outline

- Definition of Figure of Merit (FoM) from the *Dark Energy Task Force*
- Factors affecting the FoM
- Hubble scatter plots for Ia and Core Collapse
- FoM Results for a range of SNR cuts, and for MLCS and SALT

Figure of Merit (FoM)

- L is the probability distribution of SN Ia
- F is the Fisher Matrix, a statistical tool

Figure of Merit as advocated in the Dark Energy Task Force (DETF)



$$L(\mu|\Theta); \quad \Theta = (w_0, w_a, \Omega_\Lambda, \Omega_k, \ldots)$$

$$F \approx \left\langle \frac{\partial^2(-\ln L)}{\partial\theta_i\theta_j} \right\rangle;$$

$$FoM \propto \frac{1}{Area_{ellipse}}$$

Left: 95% confidence contour: constrains the values of w_a and w_0, parameters that model the time dependency of Dark Energy. The FoM is proportional to the reciprocal of the ellipse area.

Factors contributing to the FoM

- Number of Supernovae
- Distance Modulus error
- Core Collapse contamination
  - How? Fitting $\langle \mu_{cc} \rangle - \langle \mu_{Ia} \rangle$ in z bins
  - $f_{cc} \rightarrow$ probability that SN is CC, i.e. (1-purity)
  - We use 100% of the value of f_{cc} as its uncertainty, this uncertainty is used as a prior for the FoM.

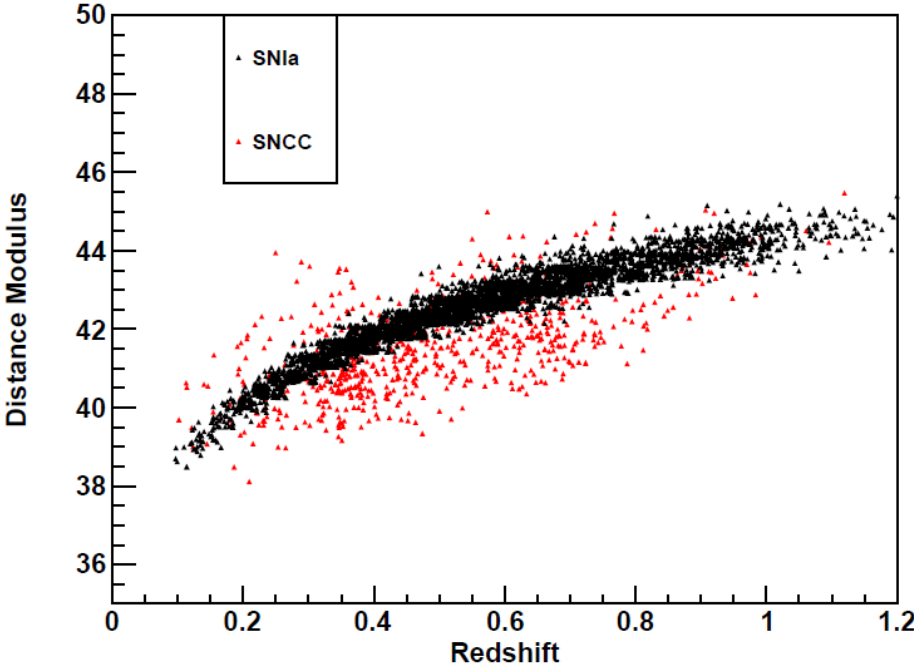
Signal to Noise ratio cuts affect all of the above

Hubble scatter plots

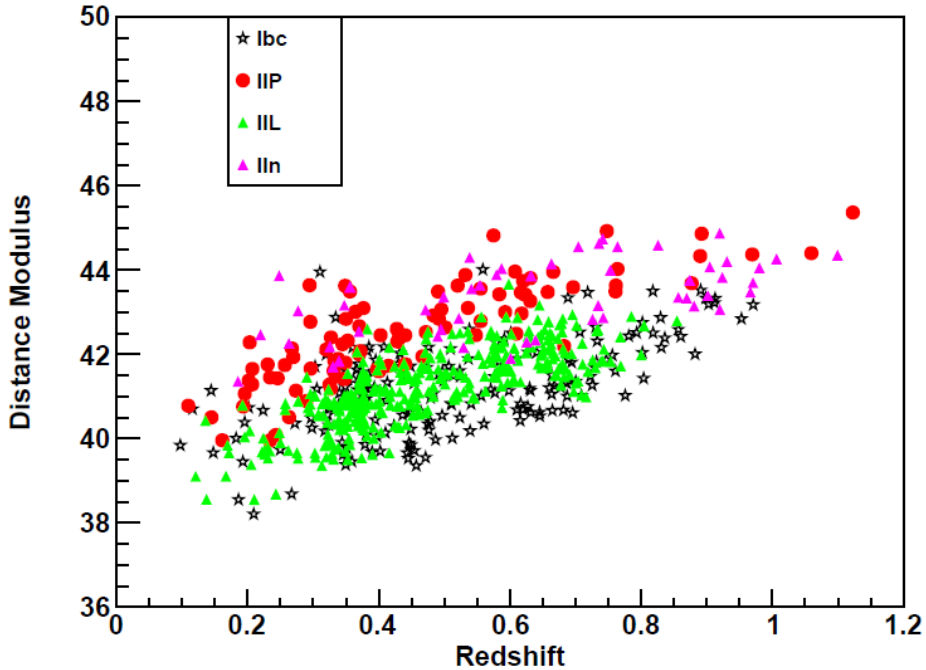
SALT simulations with SALT fits

SNR 5_5_5

SN Ia and SN Core Collapse



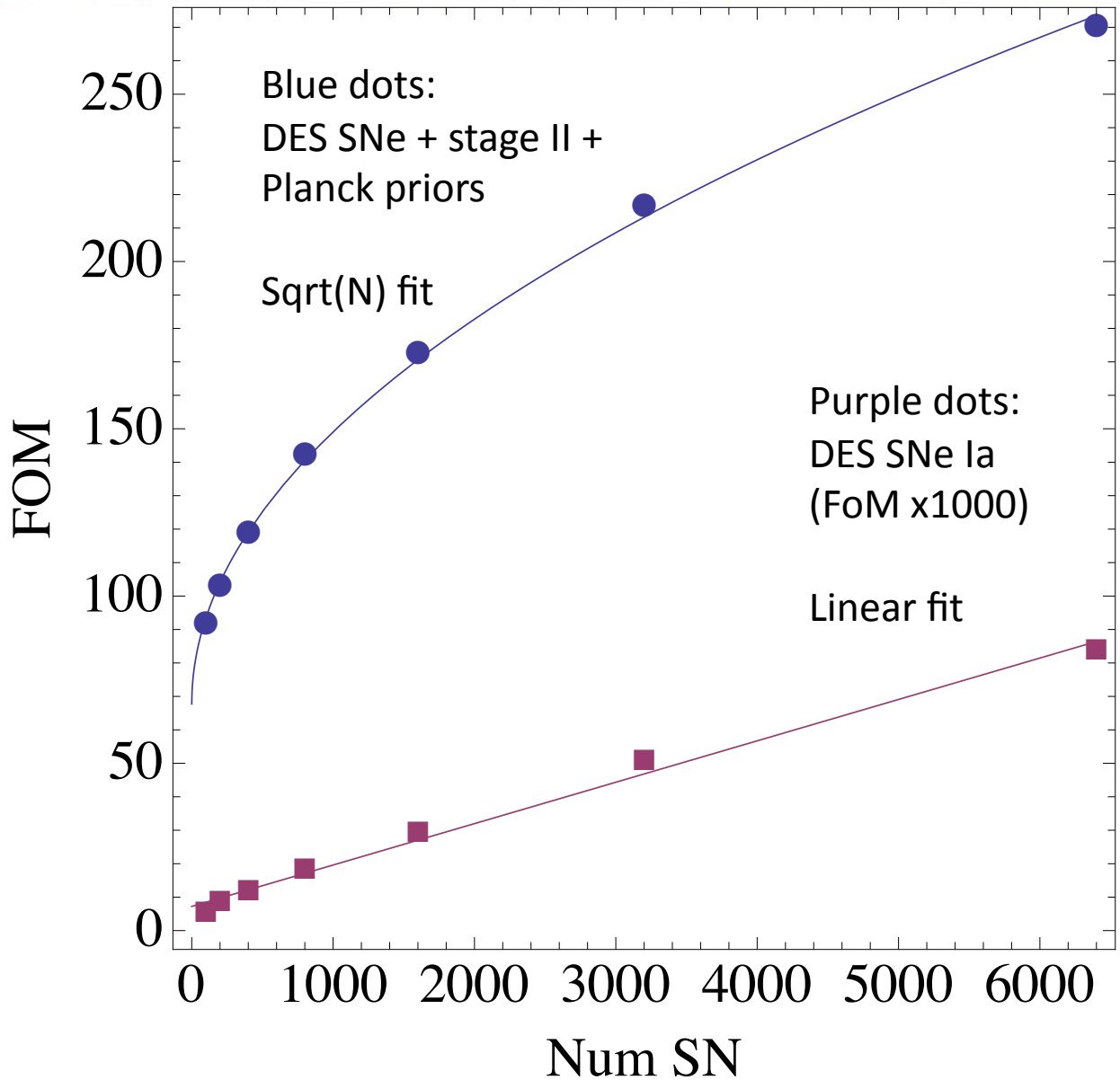
SN Core Collapse Types



SN Type	M_R
IIP	-15.66 ± 0.16
Ib/c	-16.09 ± 0.23
IIL	-17.44 ± 0.22
IIn	-16.86 ± 0.59

Li et. Al. (2011a), R-band magnitudes

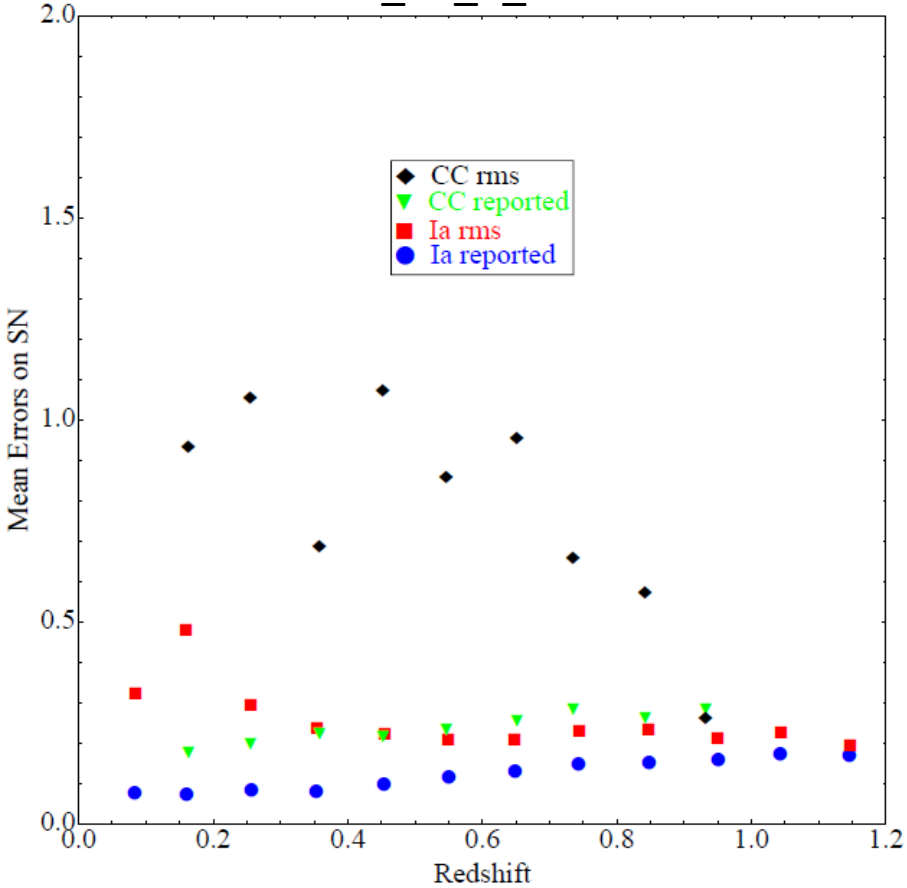
FoM vs Number of SN



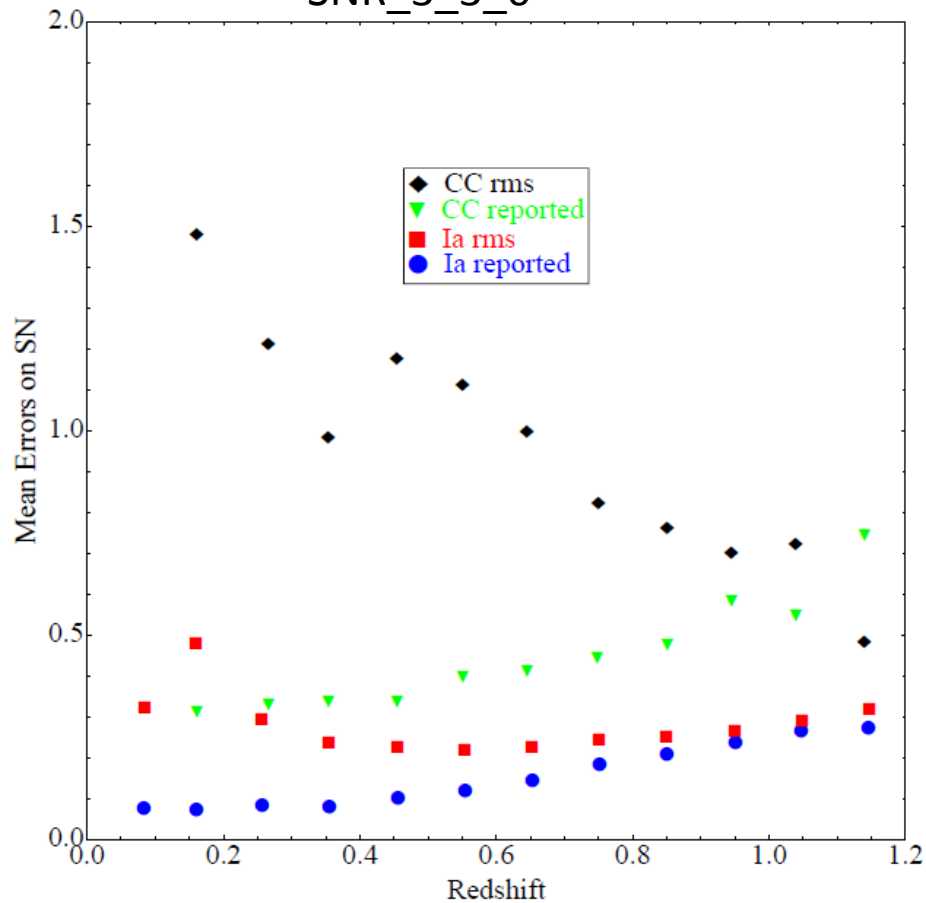
Average mu error for Ia and CC

MLCS sim and fit

SNR_10_5_5



SNR_3_3_0



CC mu reported error ~ 2 times Ia error

CC mu reported error ~ 4 times Ia error

FoM scaling mu error x2 or x4

- FoM decreases from 250 to 188 with mu err x2
- FoM decreases from 250 to 133 with mu err x4

(SNR_10_5_5 – Ia only)

FoM vs fpMLCS cut

SNRMAX cuts	ID algorithm	FoM SNIa only	FoM SNIa and SNCC
SNR-3-3-0	f_pMLCS> 0.05	332.8	139.2
SNR-3-3-0	f_pMLCS> 0.1	316.4	137.2
SNR-3-3-0	f_pMLCS> 0.2	306.2	136.7
SNR-10-5-5	f_pMLCS> 0.05	251.7	238.3
SNR-10-5-5	f_pMLCS> 0.1	250.4	244.9
SNR-10-5-5	f_pMLCS> 0.2	247.5	245.0

Table 5. The Dark Energy Task Force Figure of Merit is presented for a variety of MLCS fit probability selection criteria.

FoM is fairly insensitive to precise fpMLCS cut

Example: scaling of FoM, including CC

- SNR_3_3_0 – loosest cuts (MLCS)
  - FoM for Ia (only) = 303
  - FoM for Ia + CC (with Ia mu error) = 354
  - FoM for Ia + CC (no systematics) = 316
  - FoM for Ia + CC + CC systematics = 137

- Dispersion in mu of CC is not included in DETF FoM. Our plan is to change the intrinsic dispersion amount to match the total sample Ia +CC RMS. This will increase our sensitivity to purity.

FoM with/without Core Collapse

When only Ia considered, number of SN is most relevant variable for FoM

Best FoM Including Core Collapse for both MLCS and SALT are with the tightest SNR cuts.

SNRMAX cuts	SNIa ID	SNIa	Pur.	FoM SNIa only	FoM SNIa + SNCC
SNR-10-5-5	f_pMLCS>0.1	3694	97%	250.3	244.9
SNR-5-5-5	f_pMLCS>0.1	4800	94%	268.0	232.0
SNR-5-5-0	f_pMLCS>0.1	6151	91%	285.7	183.9
SNR-3-3-0	f_pMLCS>0.1	9200	74%	316.4	137.2
SNR-10-5-5	f_pSALT>0.1	3267	91%	194.5	145.3
SNR-5-5-5	f_pSALT>0.1	4345	87%	210.8	131.8
SNR-5-5-0	f_pSALT>0.1	5748	81%	229.7	117.4
SNR-3-3-0	f_pSALT>0.1	8848	63%	257.4	120.8

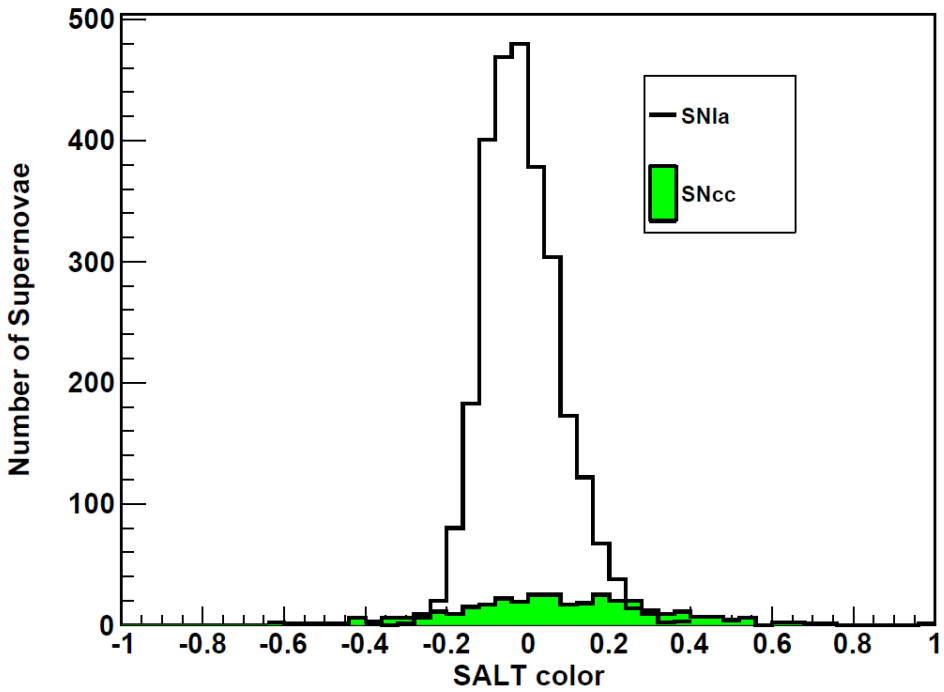
- **Overall, FoM is extremely sensitive to purity.**
- **For example for MLCS, 97% → 91% change in purity is a drop of 61 in FoM.**
- **Comparable to largest systematic uncertainty in Bernstein et al. (2011).**

Additional variables to improve purity

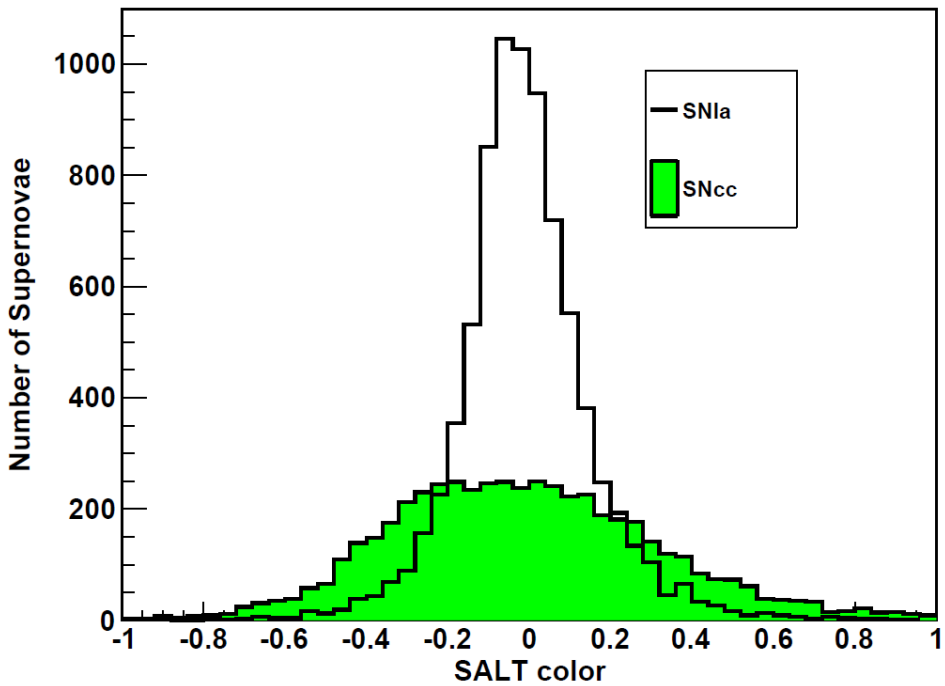
- SALT color
- SALT x_1
- Hubble residuals

SALT color

10_5_5

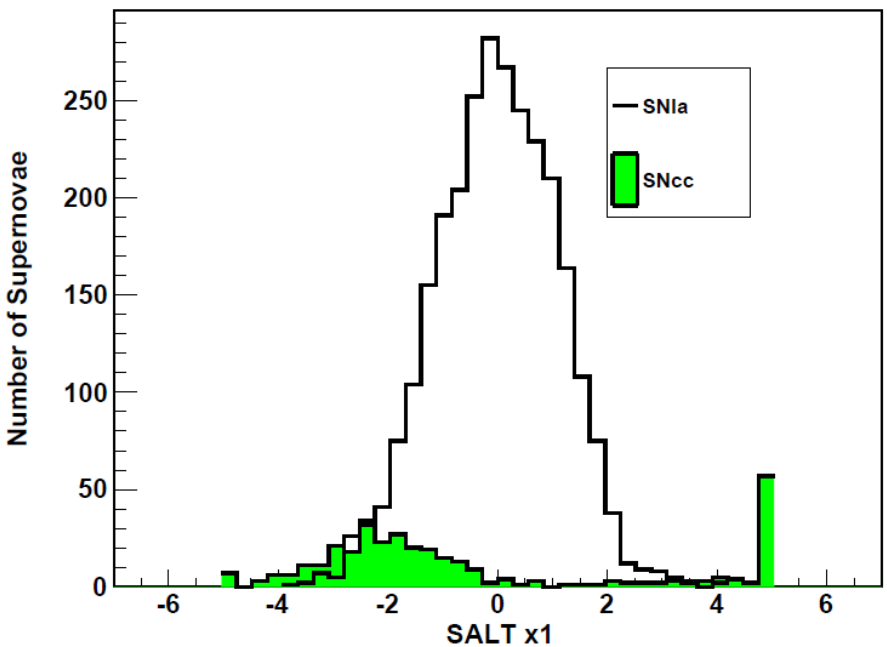


3_3_0

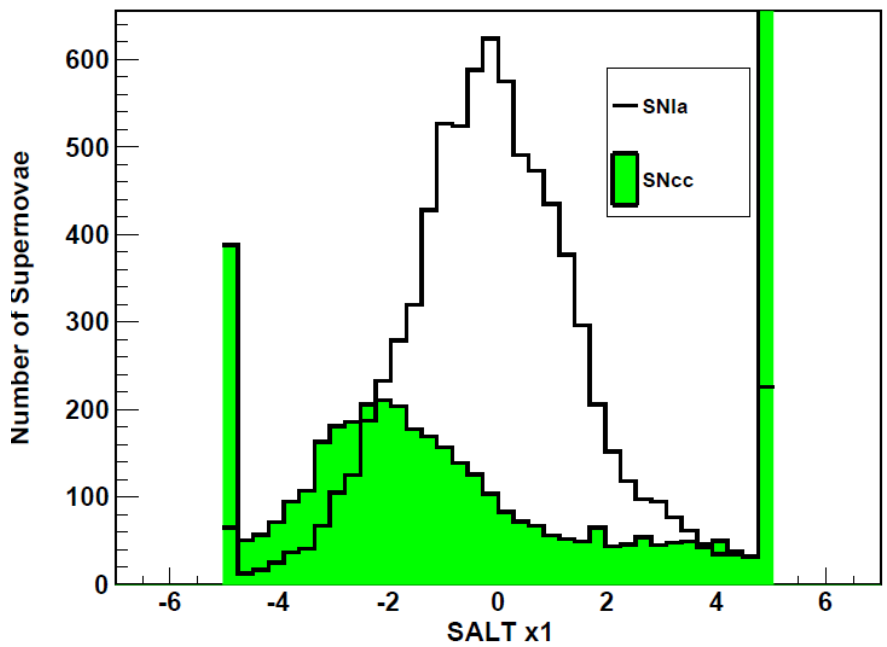


SALT x_1

10_5_5

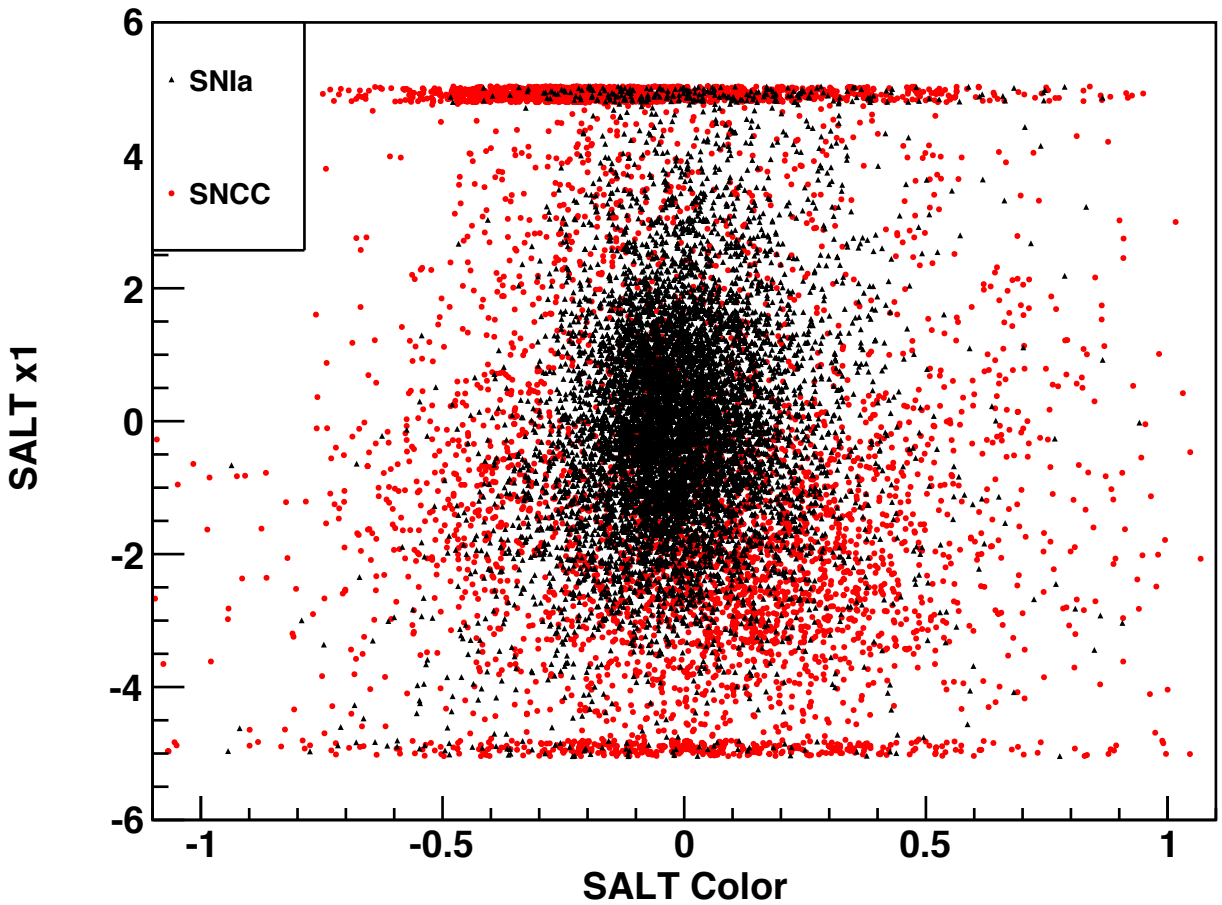


3_3_0



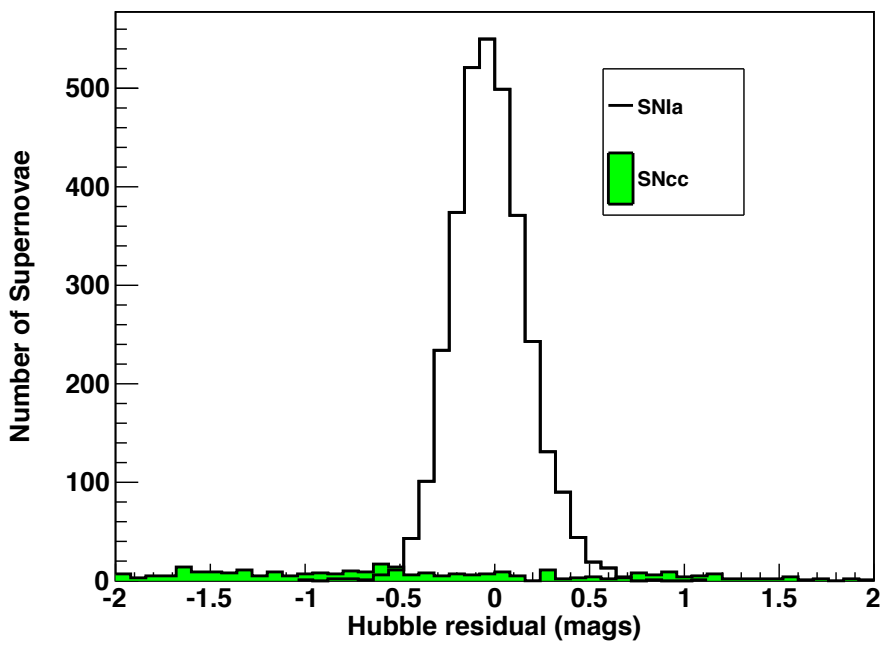
SALT x_1 vs color

SNR_3_3_0

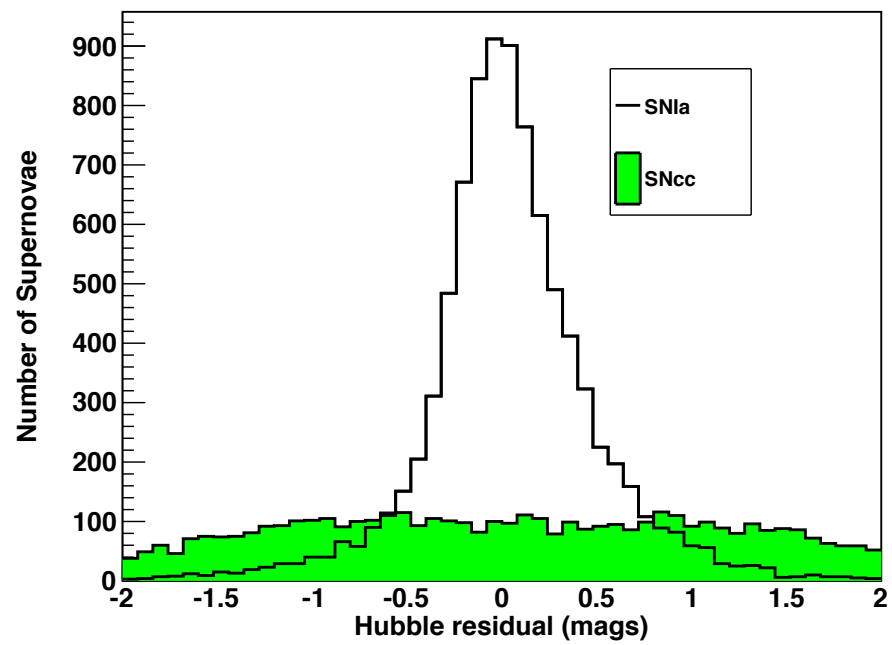


Hubble residuals

10_5_5

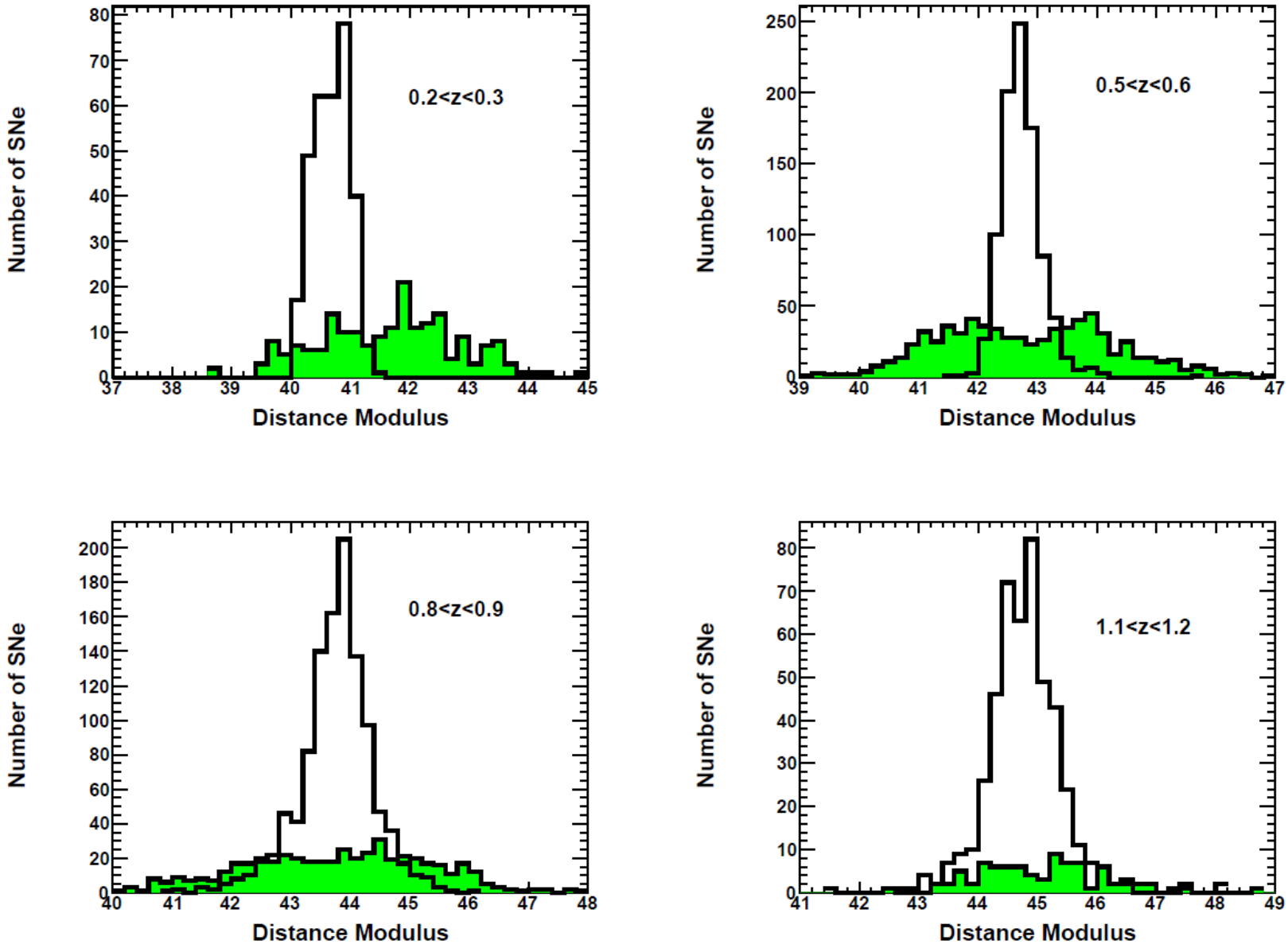


3_3_0



Would like to apply a cut that is very insensitive to cosmology (next slide…)

Binned Distance Modulus



If we trust the Ia widths from the simulation, cutting at peak +- 1 mag in each bin would be insensitive to cosmology and efficient.

3_3_0

Conclusions

- In our analysis, the DETF Figure of Merit drops quickly for purities below 95%.
- SALT fitting allows more core collapse SNe to have decent fit probabilities, leading to lower purities than MLCS.
- Additional cuts being investigated to improve purities.