Telescope Intercalibration: Extension to timing

CCF Meeting, Barcelona 27/10/15

A. Mitchell & M. Punch

Cross Calibration of Optical Efficiencies

http://arxiv.org/abs/1510.06526

Cross Calibration of Telescope Optical Throughput Efficiencies using Reconstructed Shower Energies for the Cherenkov Telescope Array

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Abstract

For reliable event reconstruction of Imaging Atmospheric Cherenkov Telescopes (IACTs), calibration of the optical throughput efficiency is required. Within current facilities, this is achieved through the use of ring shaped images generated by muons. Here, a complementary approach is explored, achieving cross calibration of elements of IACT arrays through pairwise comparisons between telescopes, focussing on its applicability to the upcoming Cherenkov Telescope Array (CTA). Intercalibration of telescopes of a particular type using eventwise comparisons of shower image amplitudes has previously been demonstrated to recover the relative telescope optical responses. A method utilising the reconstructed energy as an alternative to image amplitude is presented, enabling cross calibration between telescopes of varying types within an IACT array. Monte Carlo studies for two plausible CTA layouts have shown that this calibration procedure recovers the relative telescope response efficiencies at the few percent level.

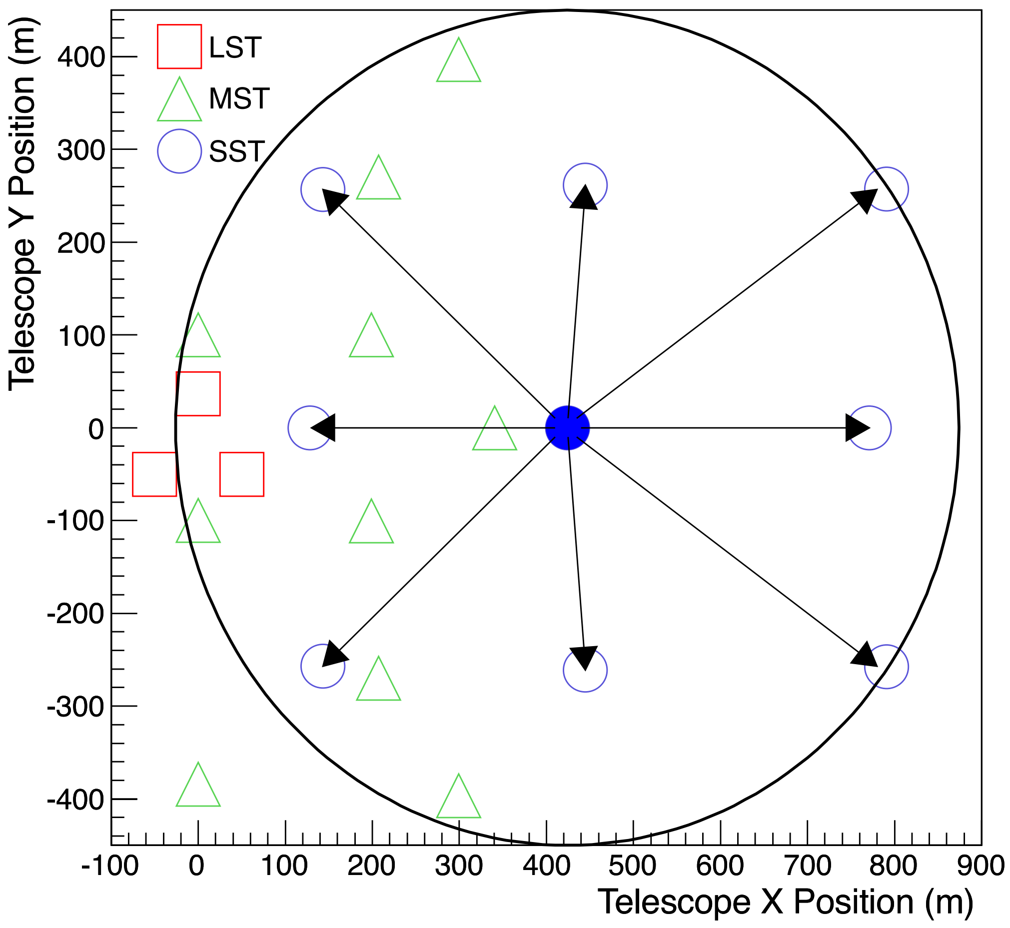
Keywords: IACT technique, Calibration, Cherenkov telescopes, Gamma rays

Reclassified from consortium to technical;
accepted for publication in Astroparticle Physics

Thank you for your feedback

Reminder: Intercalibration Principle

- Principle of pairwise comparisons between telescopes
- Number of pairs grows with N telescopes as ~N^2
- Many pairwise comparisons enable calibration of the entire array



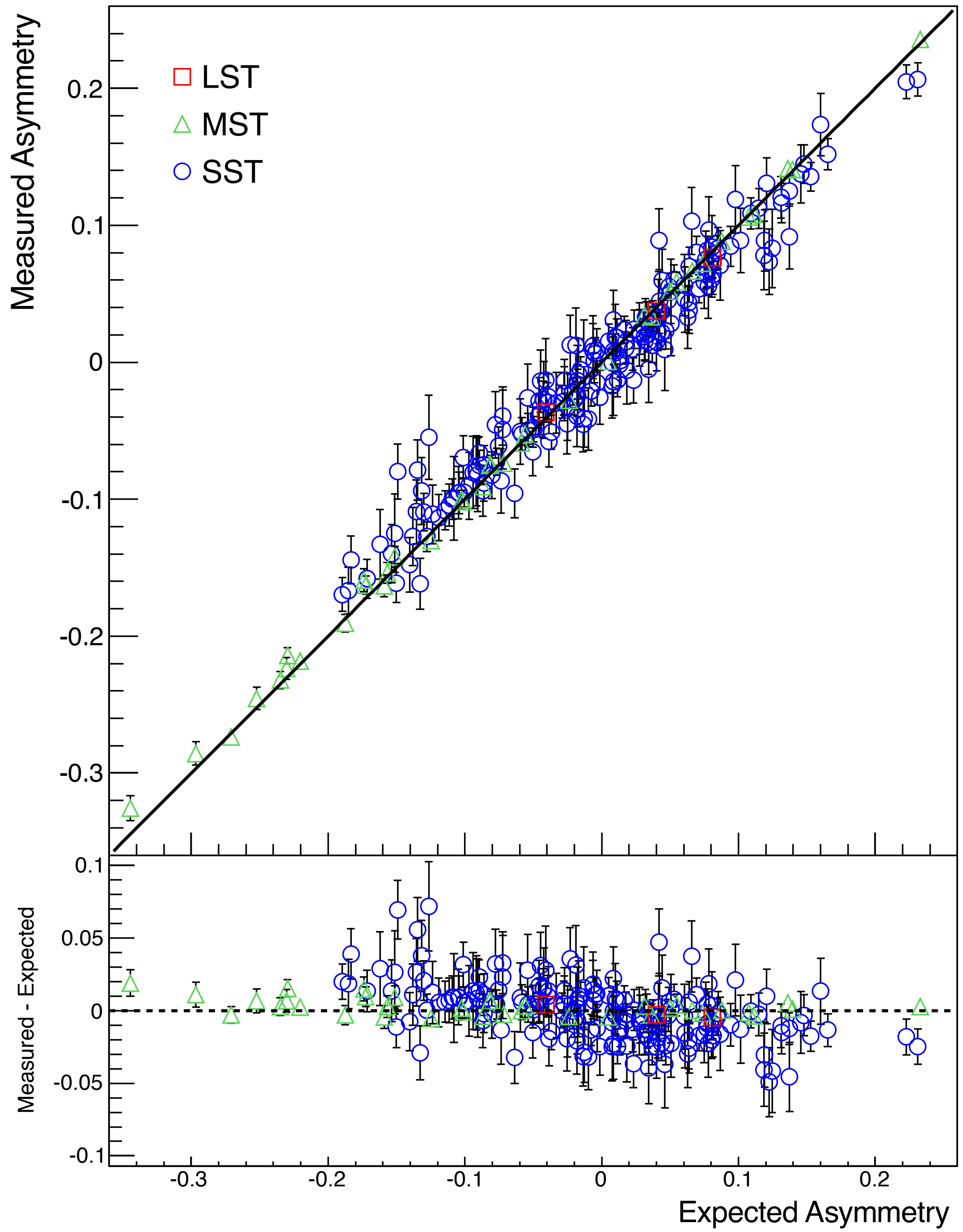
Reminder: Intercalibration

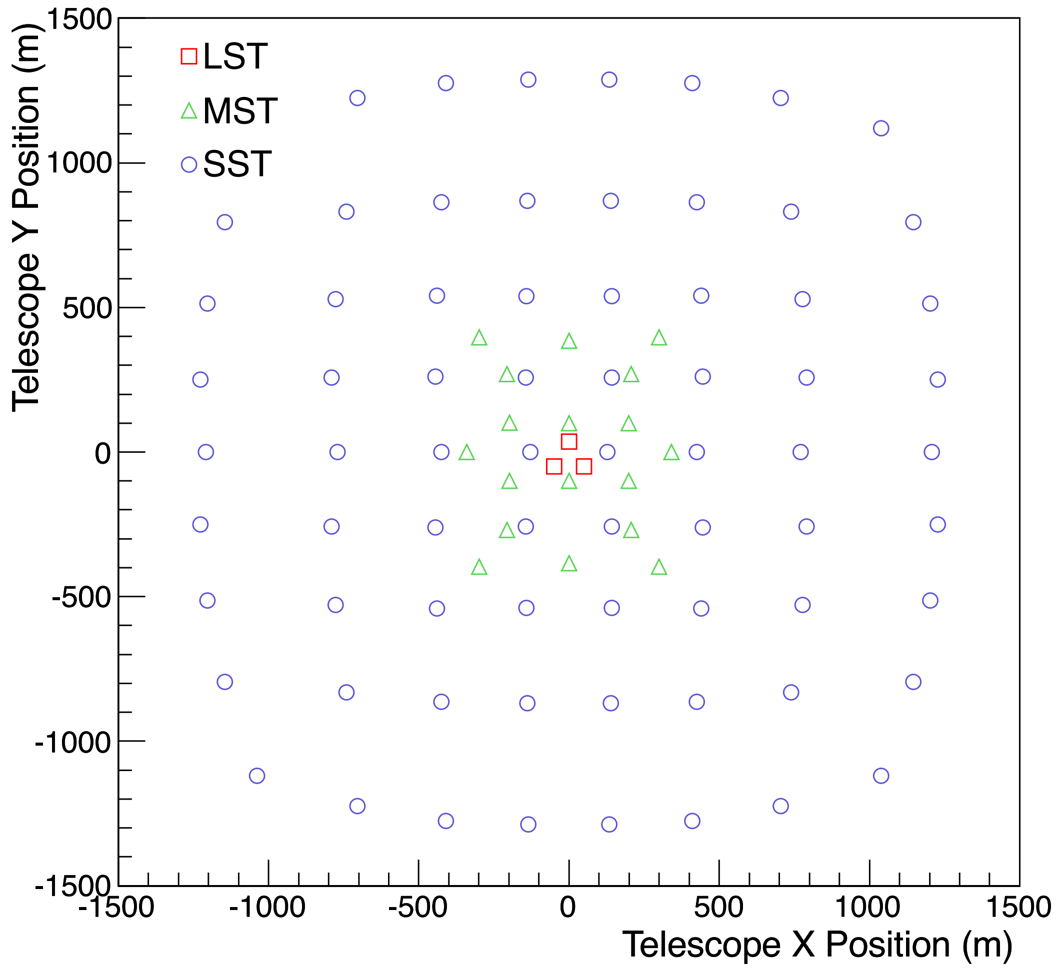
- Comparison via an asymmetry parameter in reconstructed energy (rather than image size) as a probe of optical efficiency

$$a_x = \frac{x_i - x_j}{x_i + x_j}$$

- On MC, measured energy asymmetries agree with input random optical efficiencies

- Tested two layouts, 2B shown





Reminder: Intercalibration

- A chi-square minimisation for each telescope sub type was performed to recover the individual telescope coefficients.

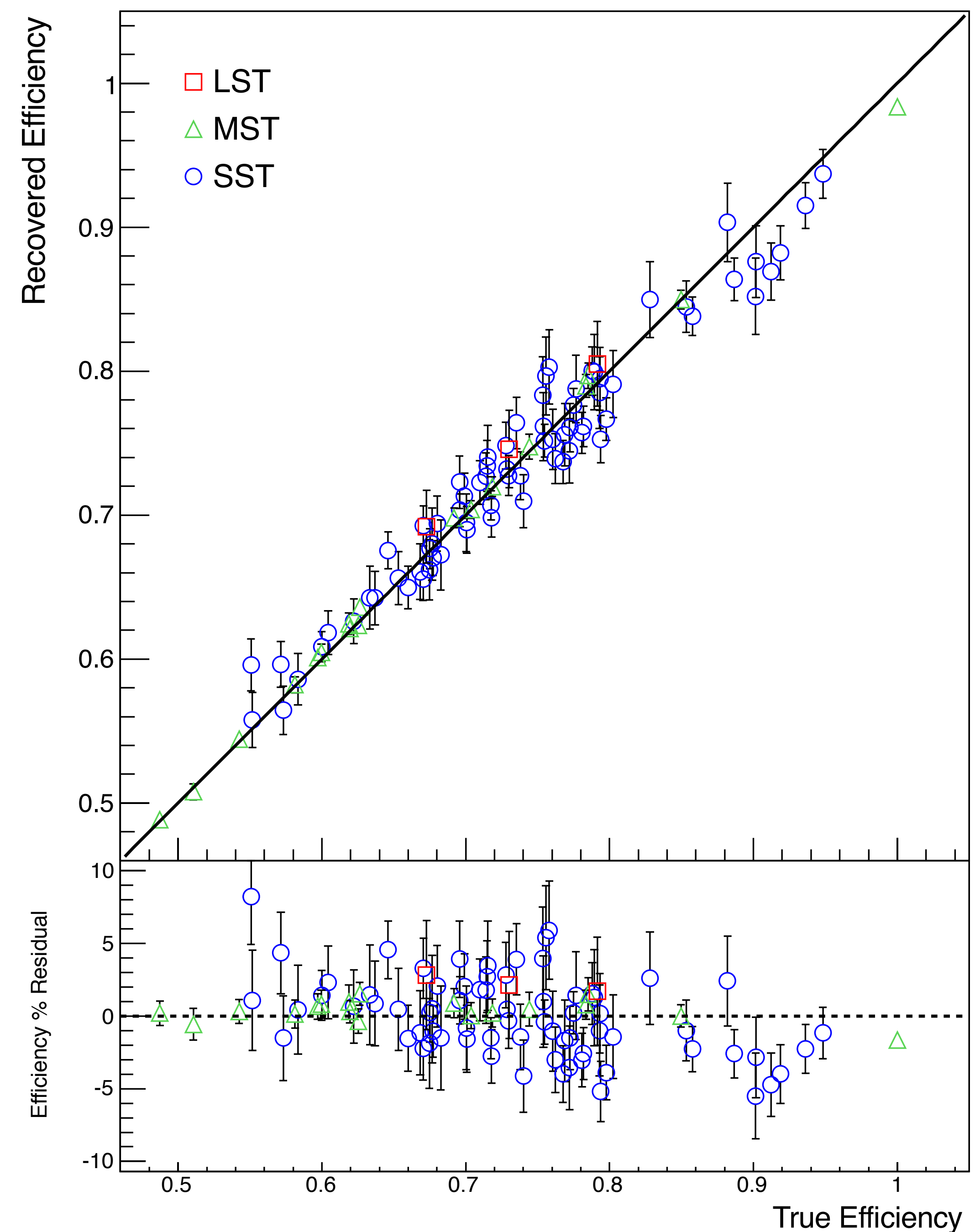
$$\chi^2 = \sum_{i=1,j>i}^{N} \frac{\left(a_{ij} - \frac{c_i - c_j}{c_i + c_j}\right)^2}{\sigma_{ij}^2}$$

- Different telescope subsystems were normalised

- Good agreement between recovered efficiencies and input values

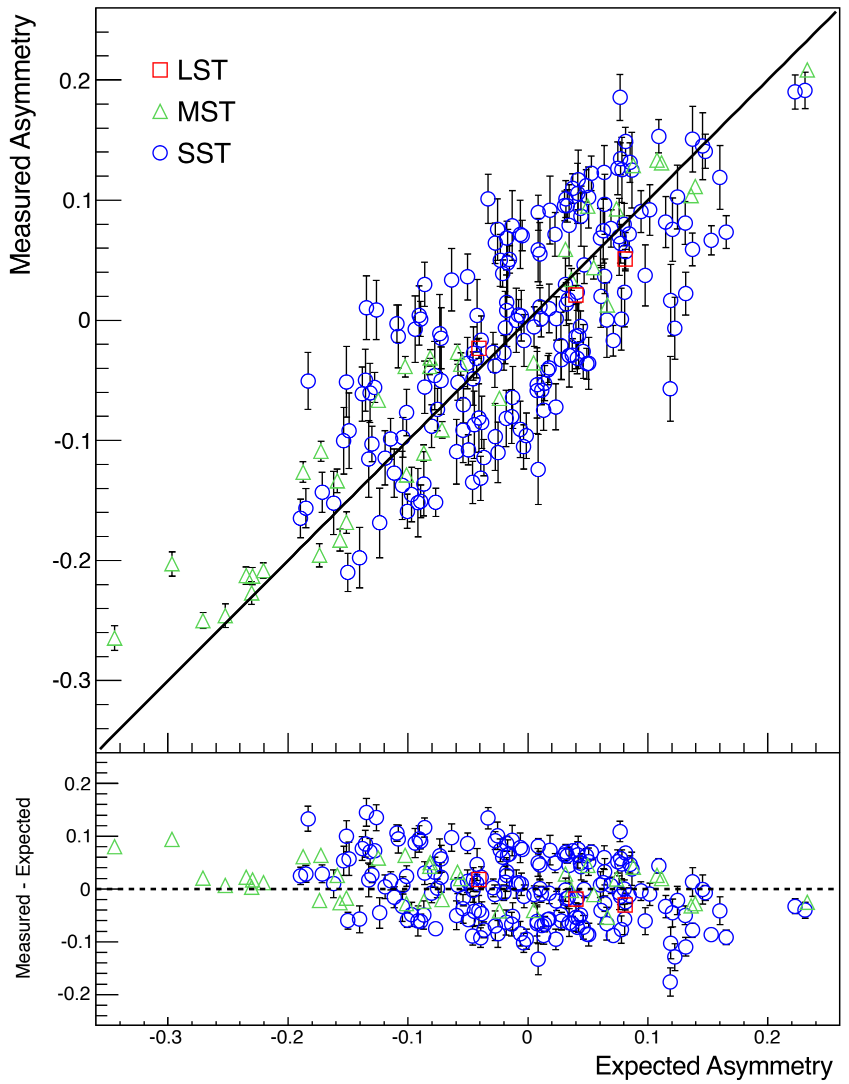
- Results after MC <=> 13 hours on a source with 10% Crab flux:

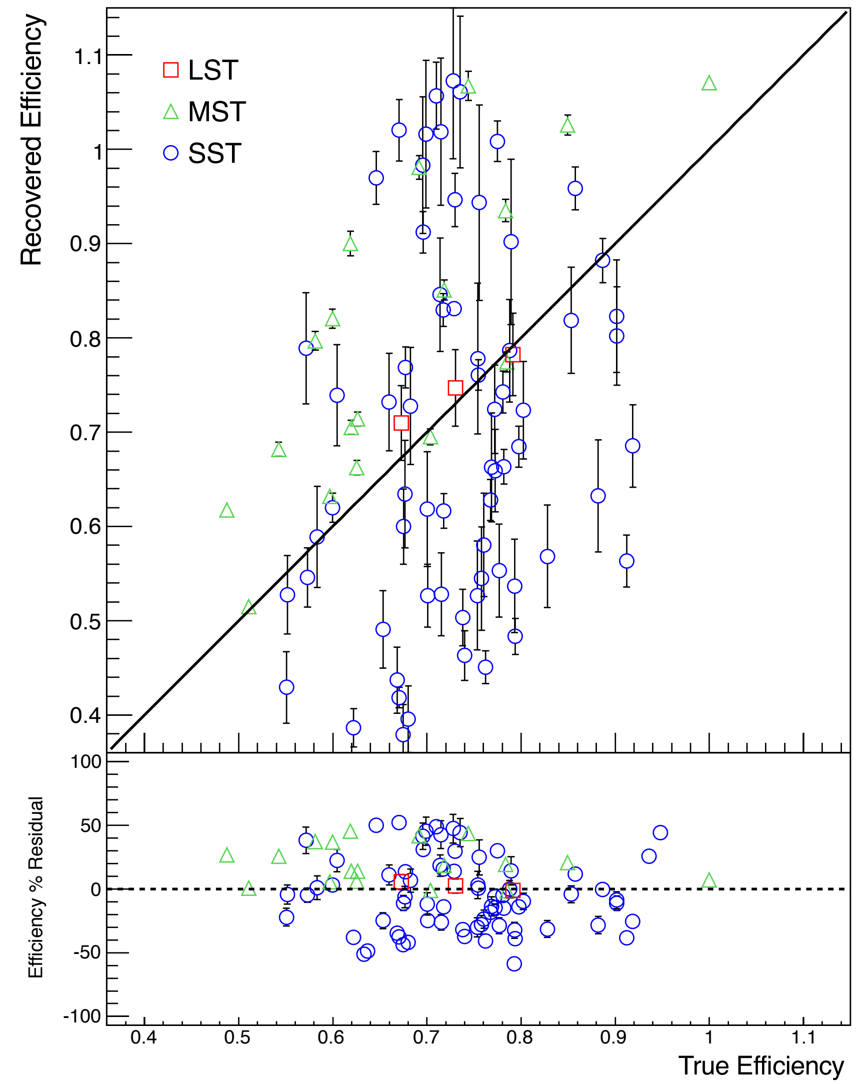
Array Component	2A	2B
LSTs	0.2%	0.5%
MSTs	0.9%	0.7%
SSTs	1.2%	2.8%
Full array	1.7%	2.5%



Cross Calibration on hadronic background

- Protons
- good correlation in asymmetries
- low statistics; ~O(10^{-3}%) survive cuts
- large scatter for smallest telescopes
- Results after MC <=> 23s livetime

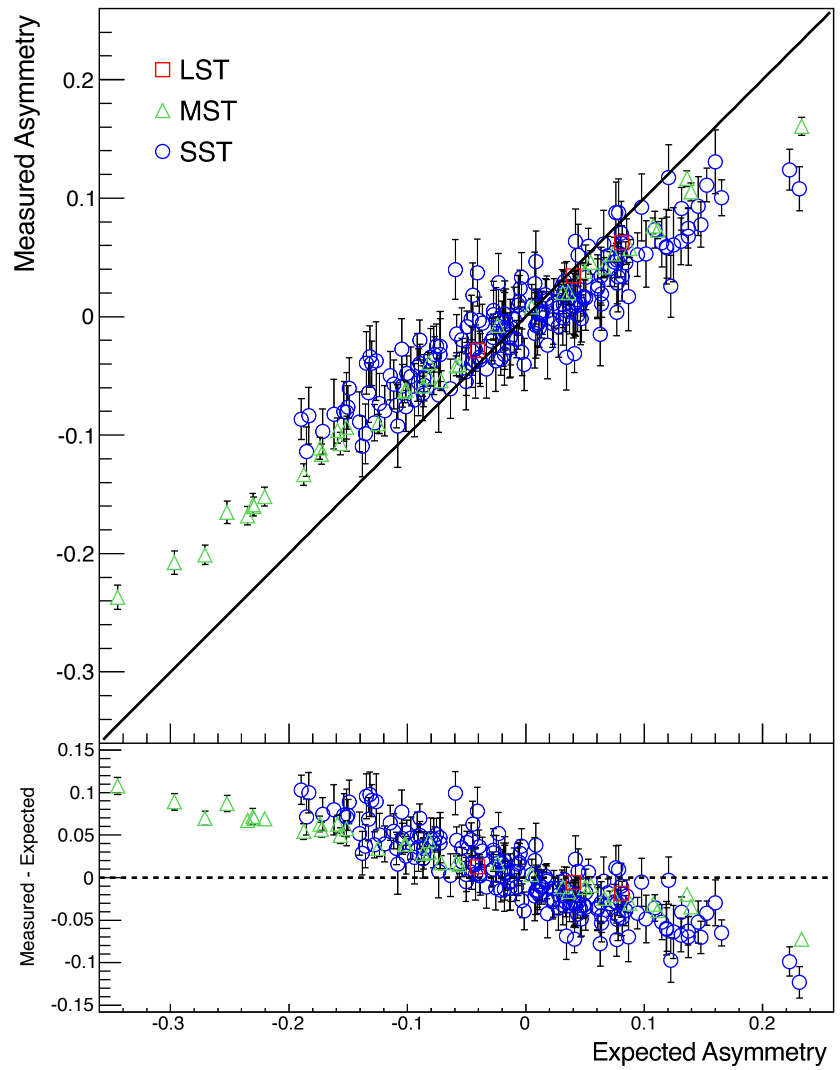


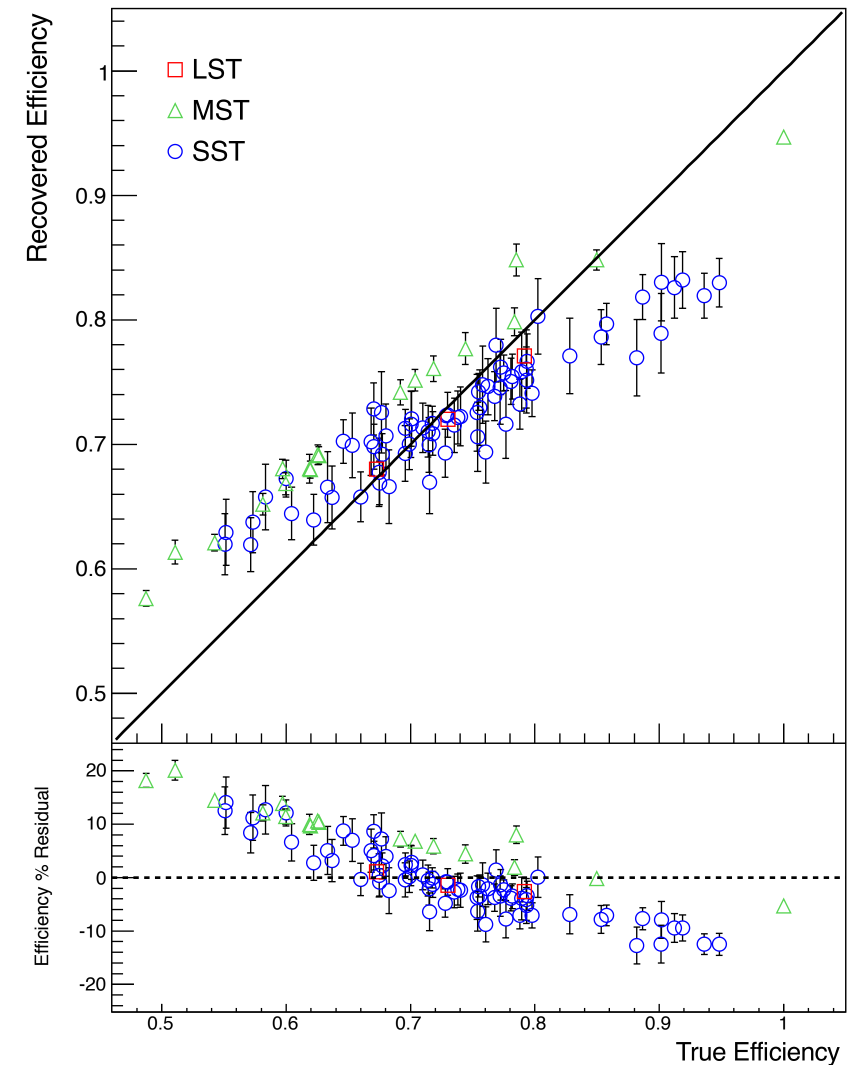


Array Component	2A	2B
LSTs	1.3%	2.7%
MSTs	11.3%	12.8%
SSTs	25.0%	30.2%
Full Array	21.3%	27.9%

Dealing with biased energy reconstruction

- Deliberately biased energy reconstruction with core distance
- Bias factor (200/d) applied
- subsystem scaling factors difficult (not applied)





Array Component	2A	2B
LSTs	0.9%	1.6%
MSTs	3.9%	5.7%
SSTs	5.0%	6.4%
Full Array	4.7%	7.3%

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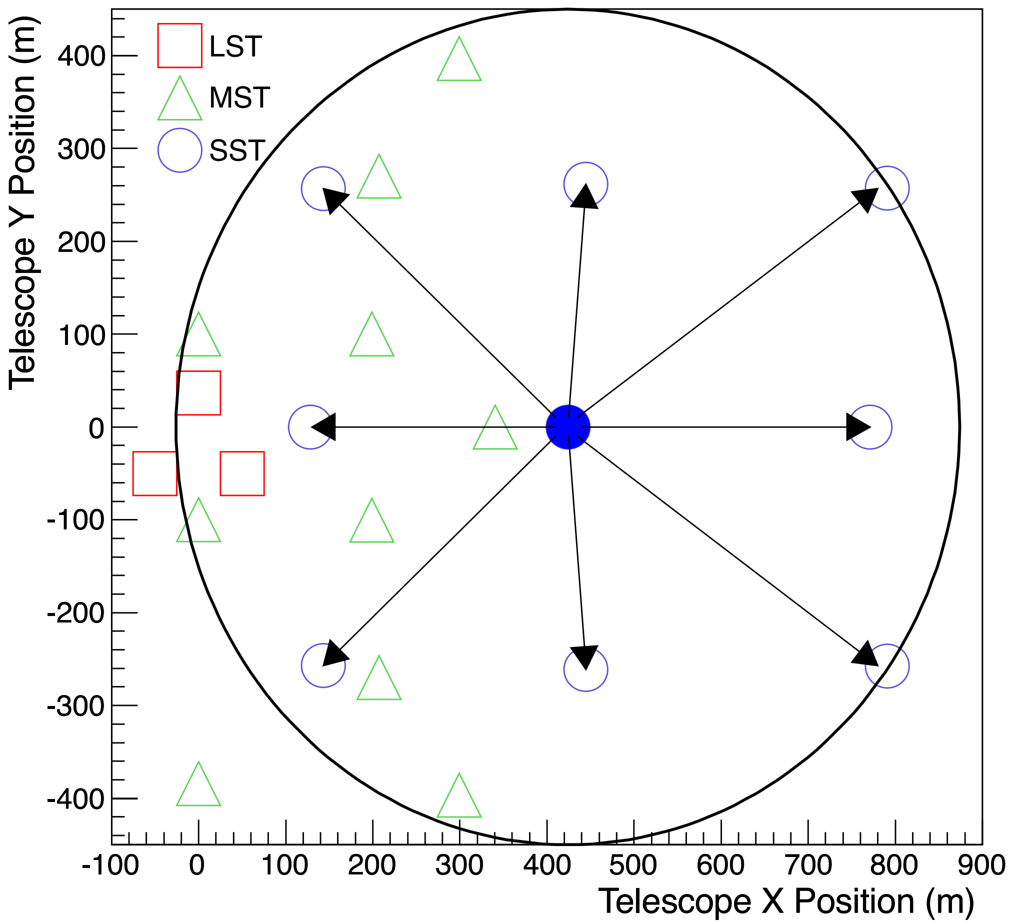
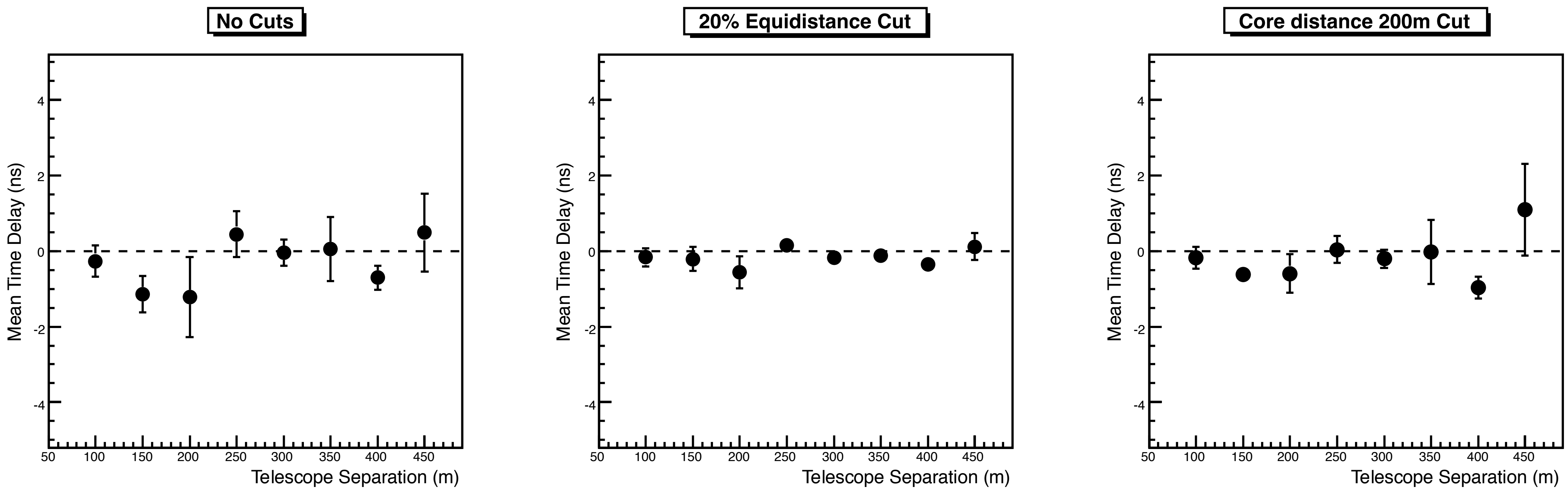


- Obtained from data (no extra equipment)
- Intrinsically uses the correct Cherenkov light spectrum
- Potentially available nightwise
- Good precision demonstrated

- Suggestion from M. Punch: Extend this to calibration of central trigger times

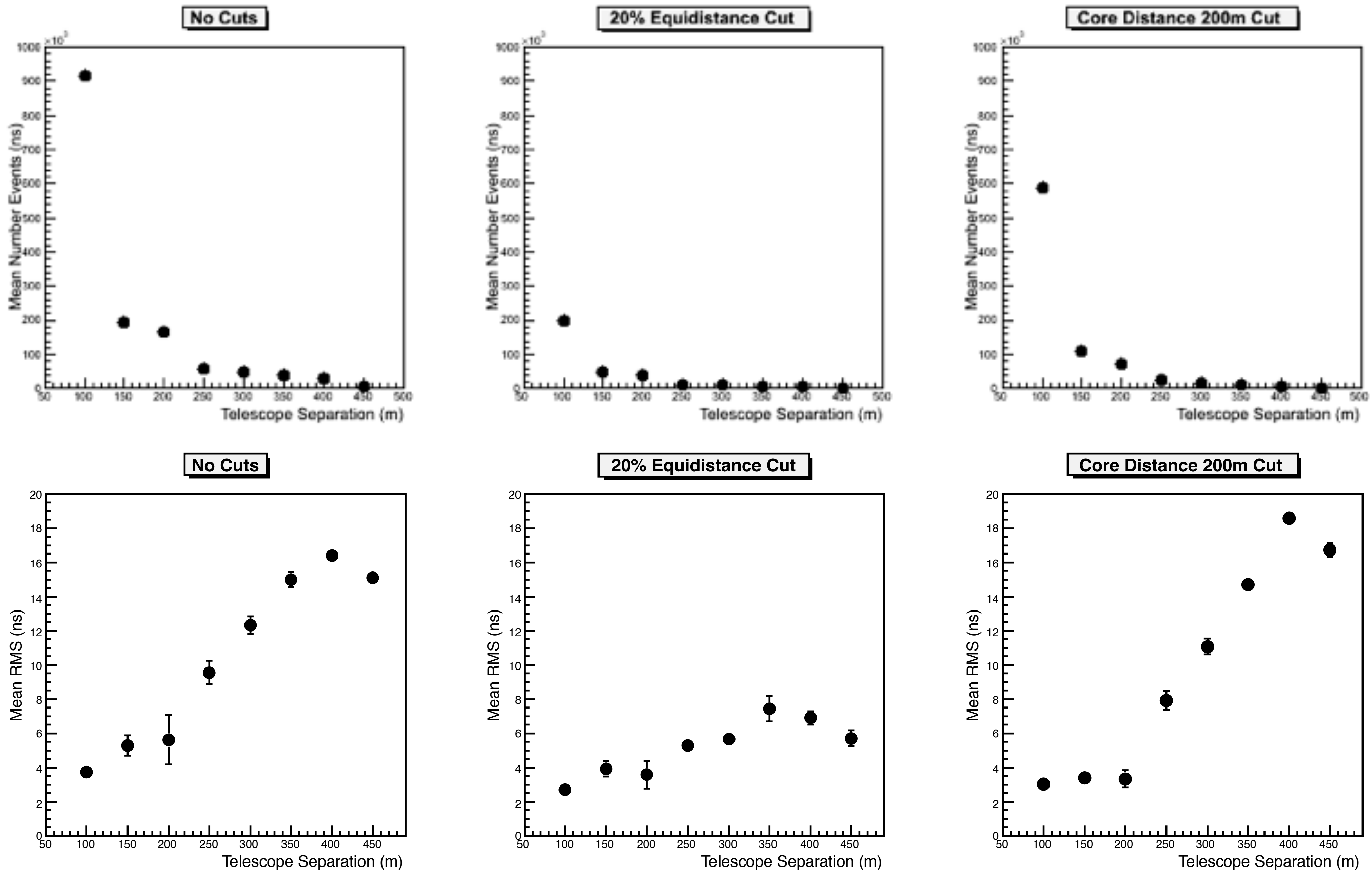
Same type comparisons



Difference in central trigger time,
Averaged per telescope separation
Calibrate to within 10ns, 2ns with cuts (meets requirements)

γ- MC only

Number of events and RMS spread



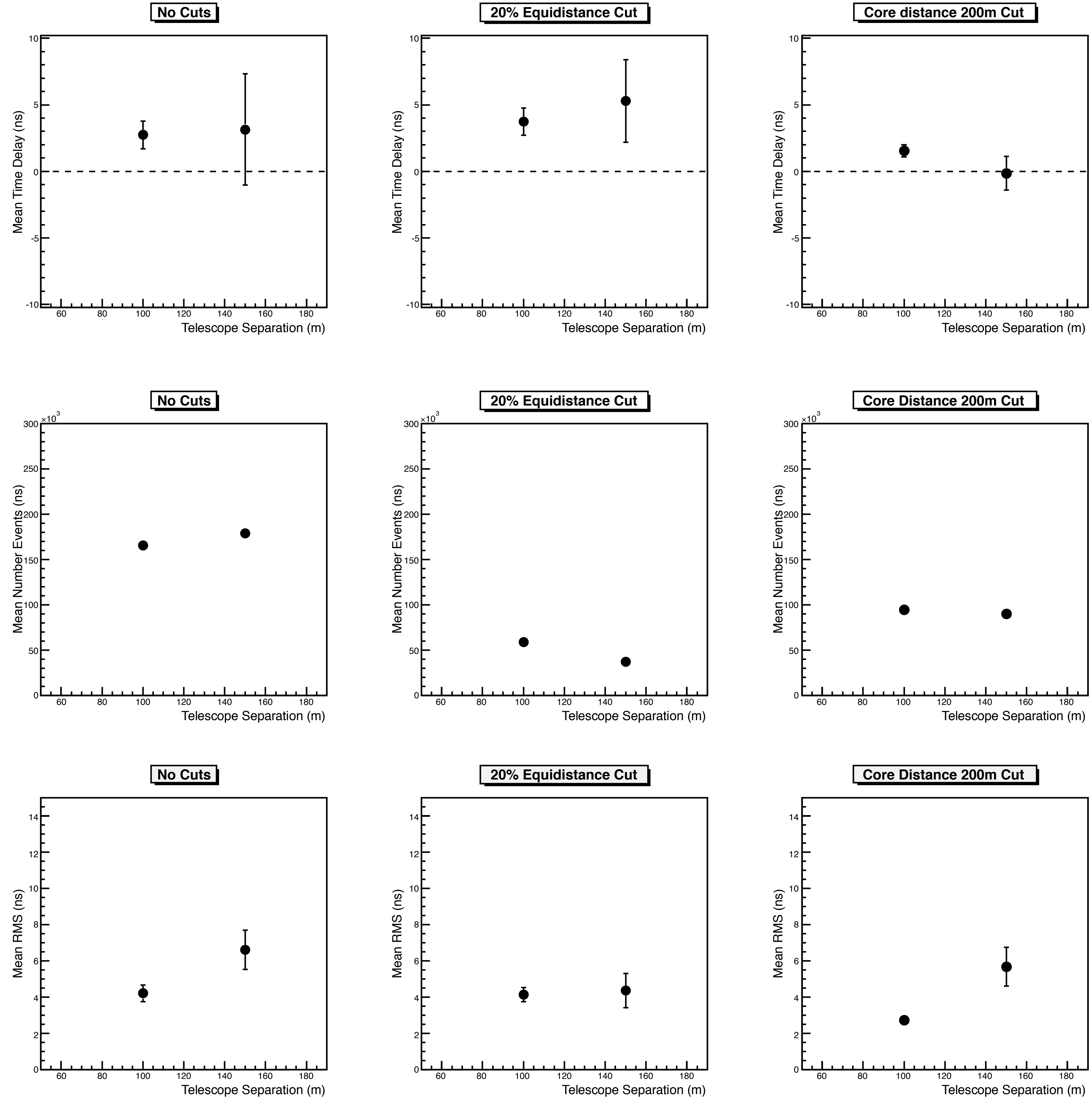
Same type comparisons

Equidistance cut reduces rms

(cuts on image size and shape - no significant effect)

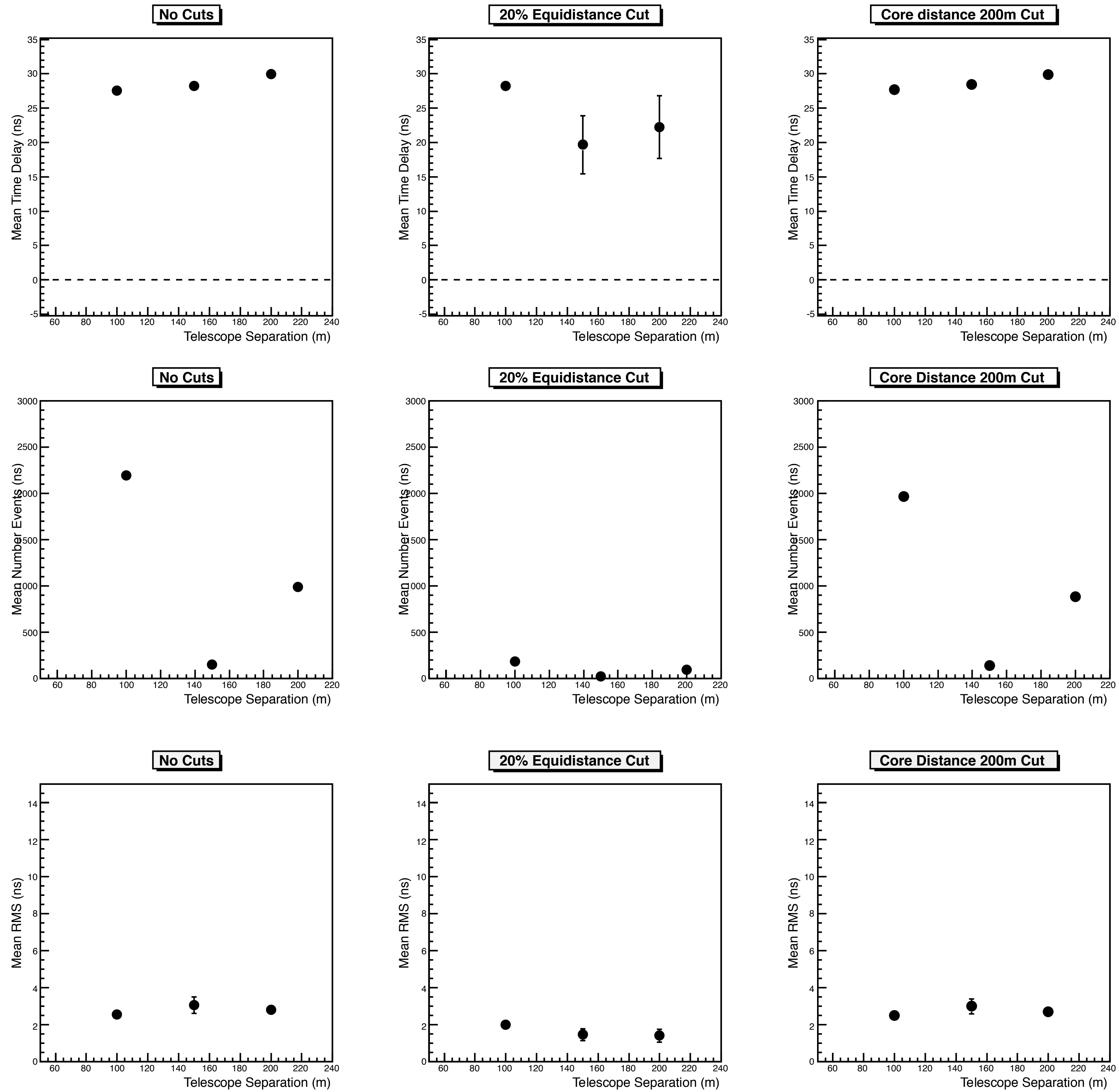
LST - MST

- Systematic offset of ~3ns
- Reduced by core distance cut



MST - SST

- SC-SSTs
- Systematic offset ~30ns
- core distance cut did not remove many events



Potential & Further work

- Systematic offset between types is not unexpected
- Contributing factors include: read out rates, electronics optics, shower front & telescope geometry - lead to different definitions of t=0
- Location of telescope within array - repeat test with diffuse gammas?
- Difference is between telescope trigger signal delays.
- Where to account for this? At central trigger? Or through calibration?
- Complementary to but not competitive with White Rabbit schemes
- Investigate source of & understand offset
- May also wish to compare absolute time stamp

Thank you for your attention

Any Questions?