Session 3&4 Introduction

Target signatures of existing sub-cm targets and prospects for future SLR constellations

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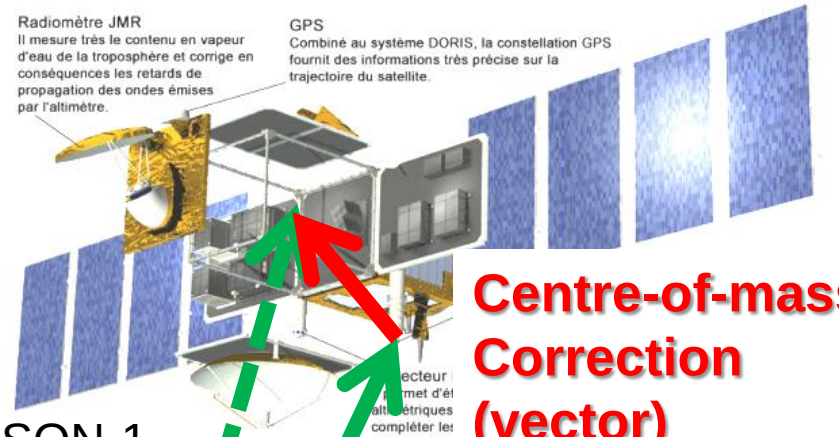
International Technical Laser Workshop
Frascati, 6 Nov 2012

Session 3&4: Introduction

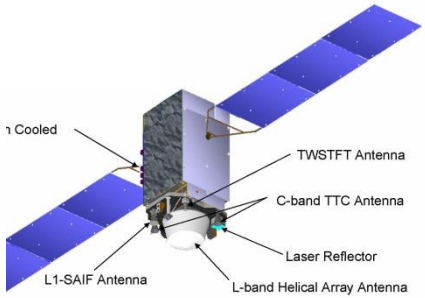
SLR cannot reach satellites' centre of mass.



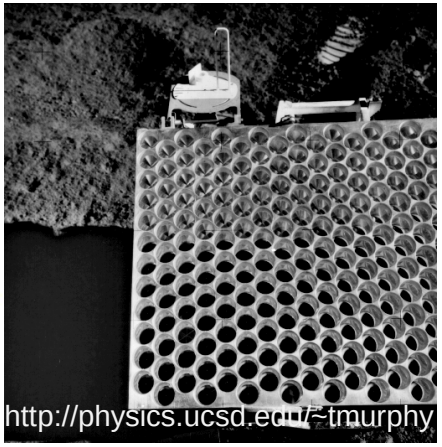
Centre-of-mass Correction (vector)

JASON-1
(1500 km alt)

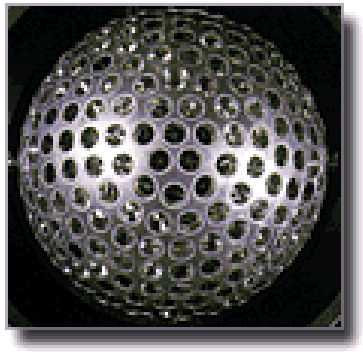
SLR Measurement



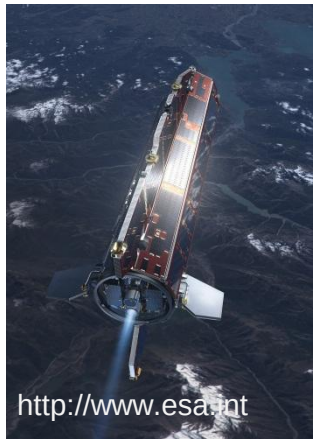
QZS-1
(36000 km alt)



Apollo-15
(380000 km alt)



LAGEOS-1
(6000 km alt)



GOCE (250 km alt)

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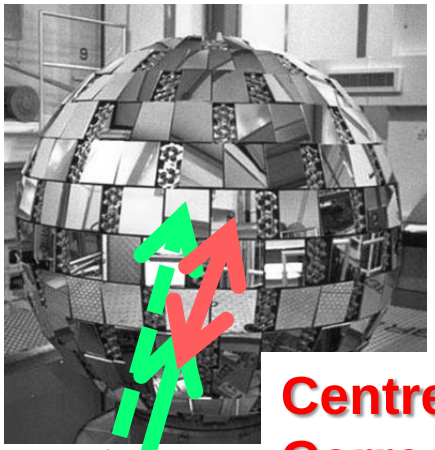
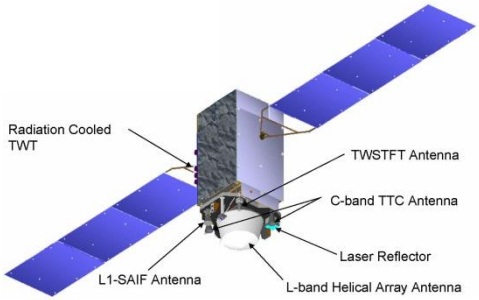
SLR cannot reach satellites' centre of mass.



AJISAI
(1500 km alt)

Centre-of-mass Correction (scalar)

SLR Measurement



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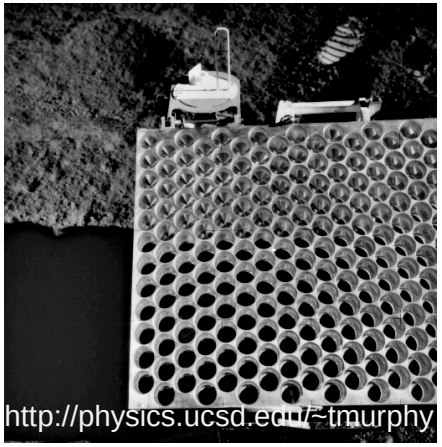

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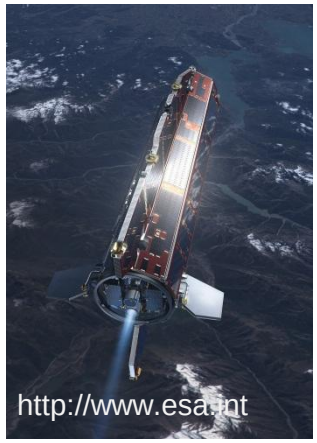
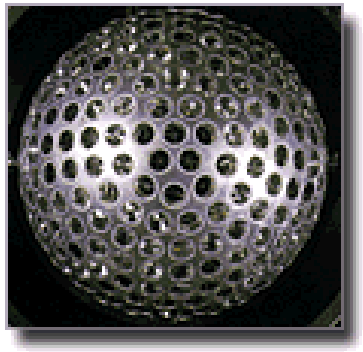


GOCE (250 km alt)



LAGEOS-1
(6000 km alt)

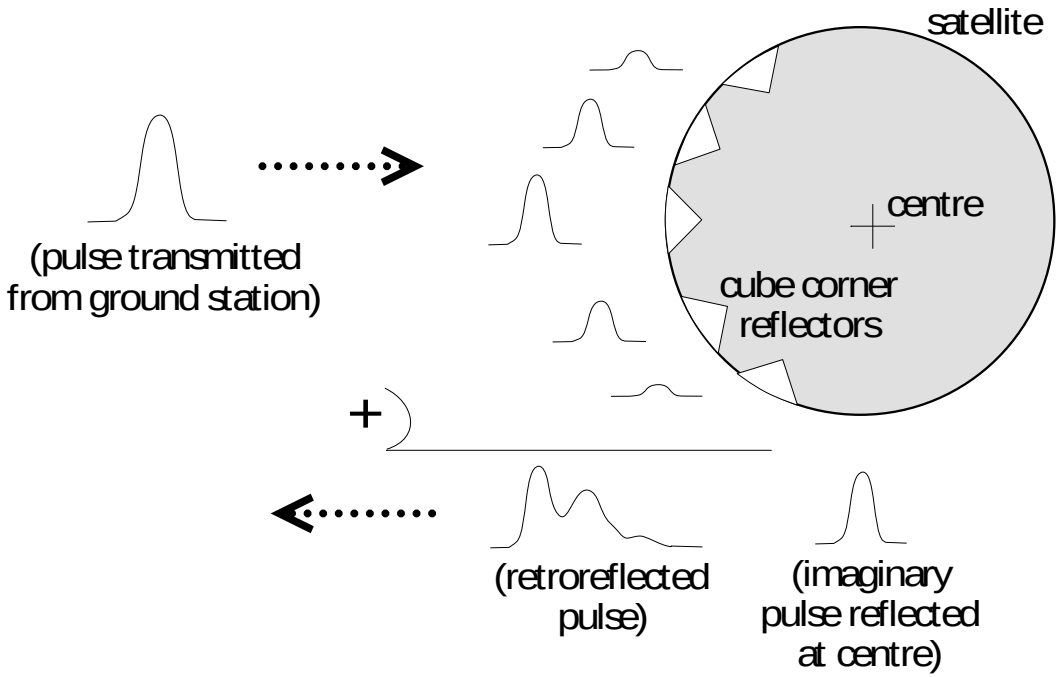
Target Signature Effect

More retros, less accurate!

4-5 cm for AJISAI, ETALON, 1 cm for LAGEOS (Otsubo and Appleby, JGR, 2003)

a few cm for GNSS

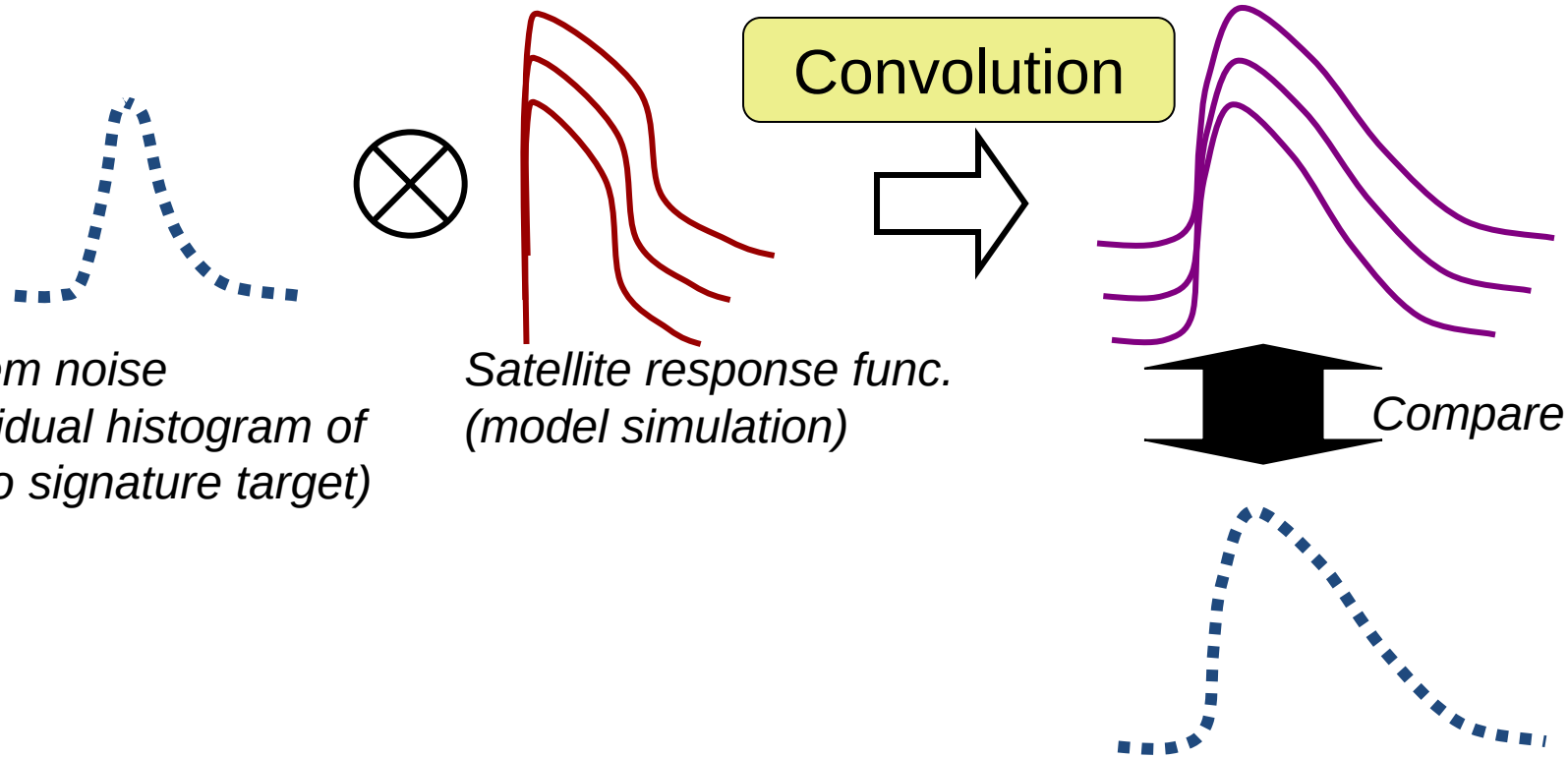
< 1 cm for “small targets”



Convolution

System noise ⊗ Satellite response function

The result compared with Residual scatter



System noise (=residual histogram of a zero signature target)

Satellite response func. (model simulation)

Residual histogram of satellite returns.

1992: 20 Years ago

Appleby, LW8, Annapolis, 1992.

Satellite Signatures in SLR Observations

G.M. Appleby
Royal Greenwich Observatory

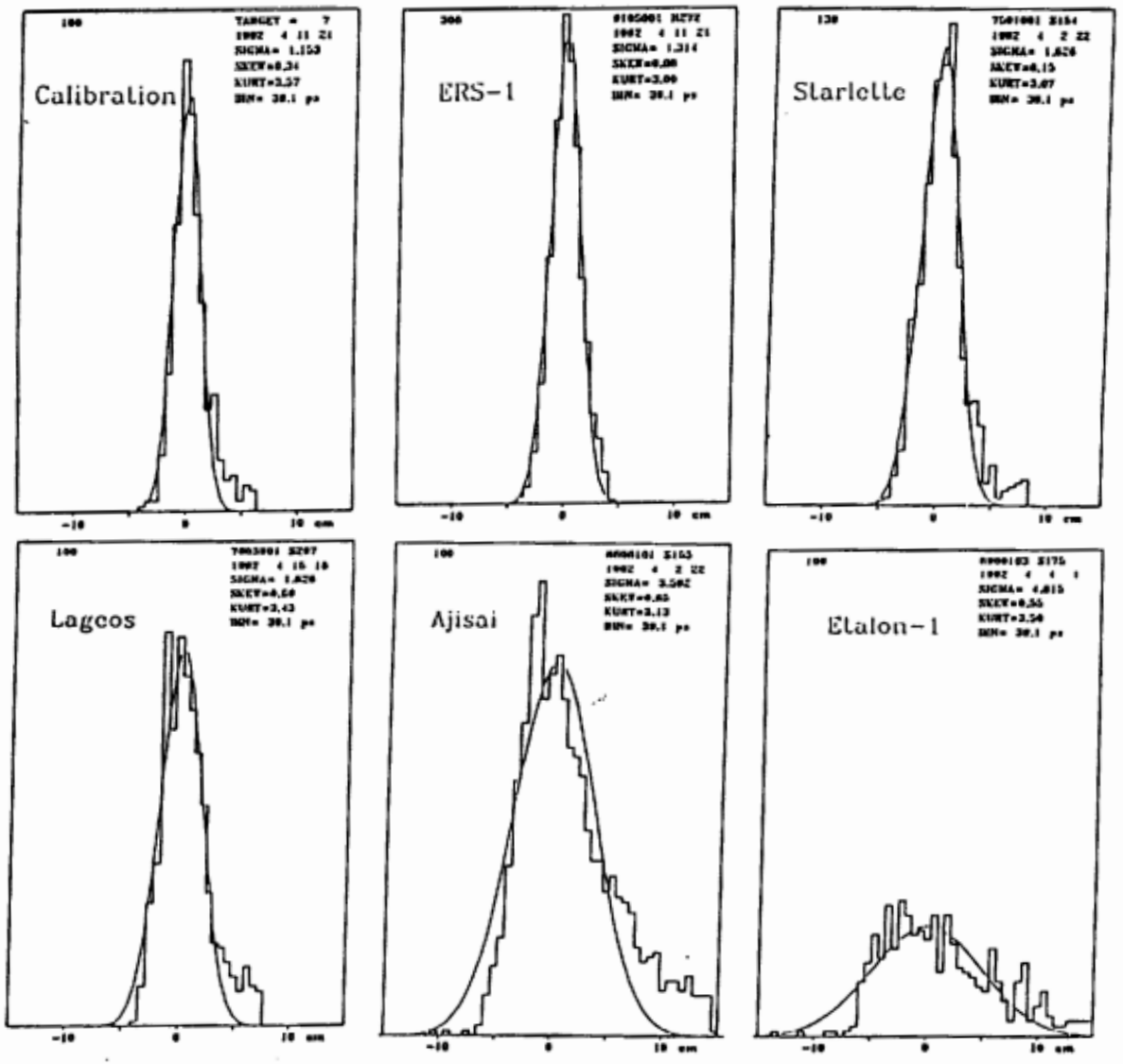
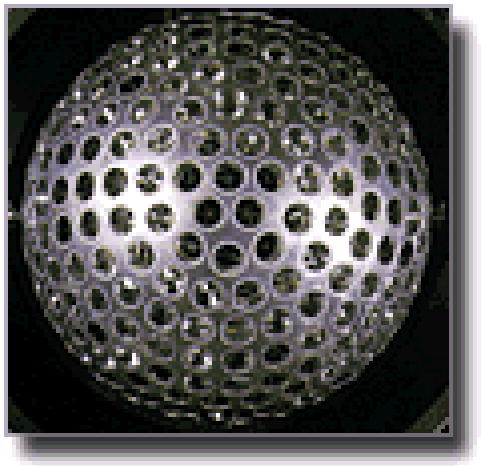
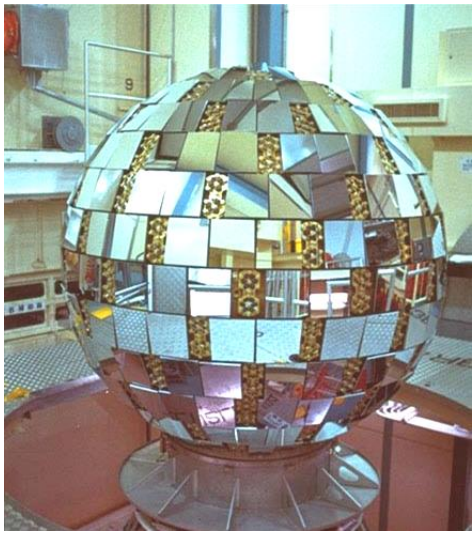


Figure 1. Observed distributions of range residuals from calibration and satellite targets.

2002: 10 Years ago



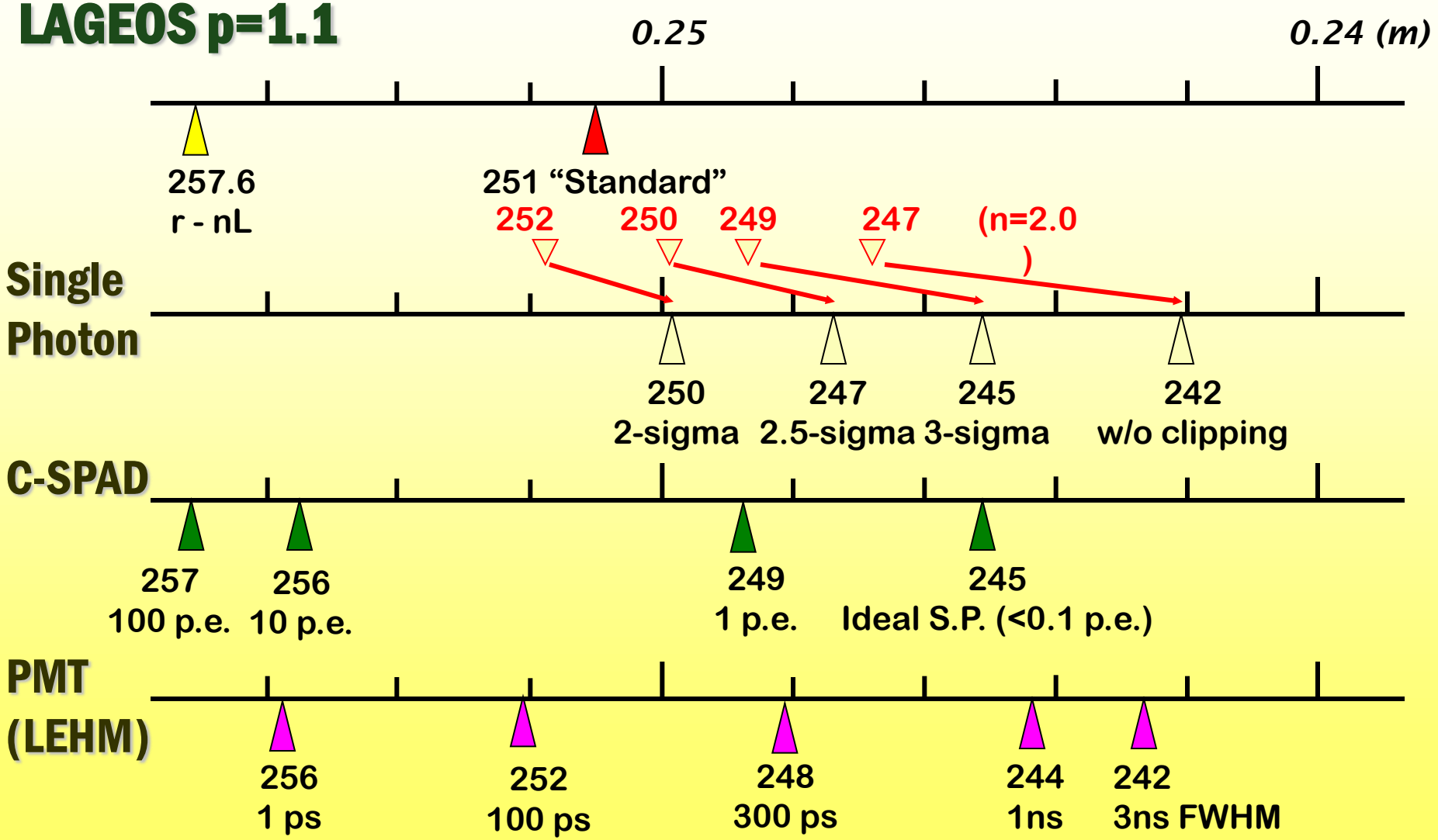


NATURAL ENVIRONMENT RESEARCH COUNCIL

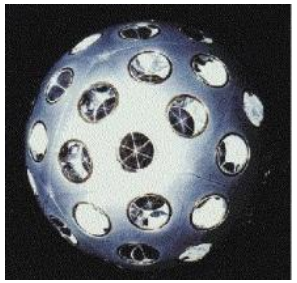
Otsubo & Appleby, LW13, Washington, 2002. (later published in JGR, 2003)

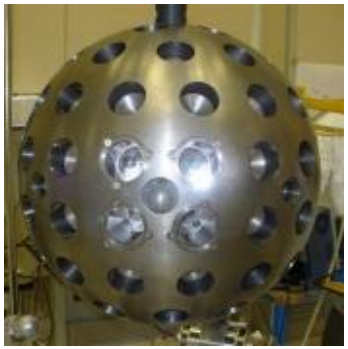
CRL

Centre of mass correction



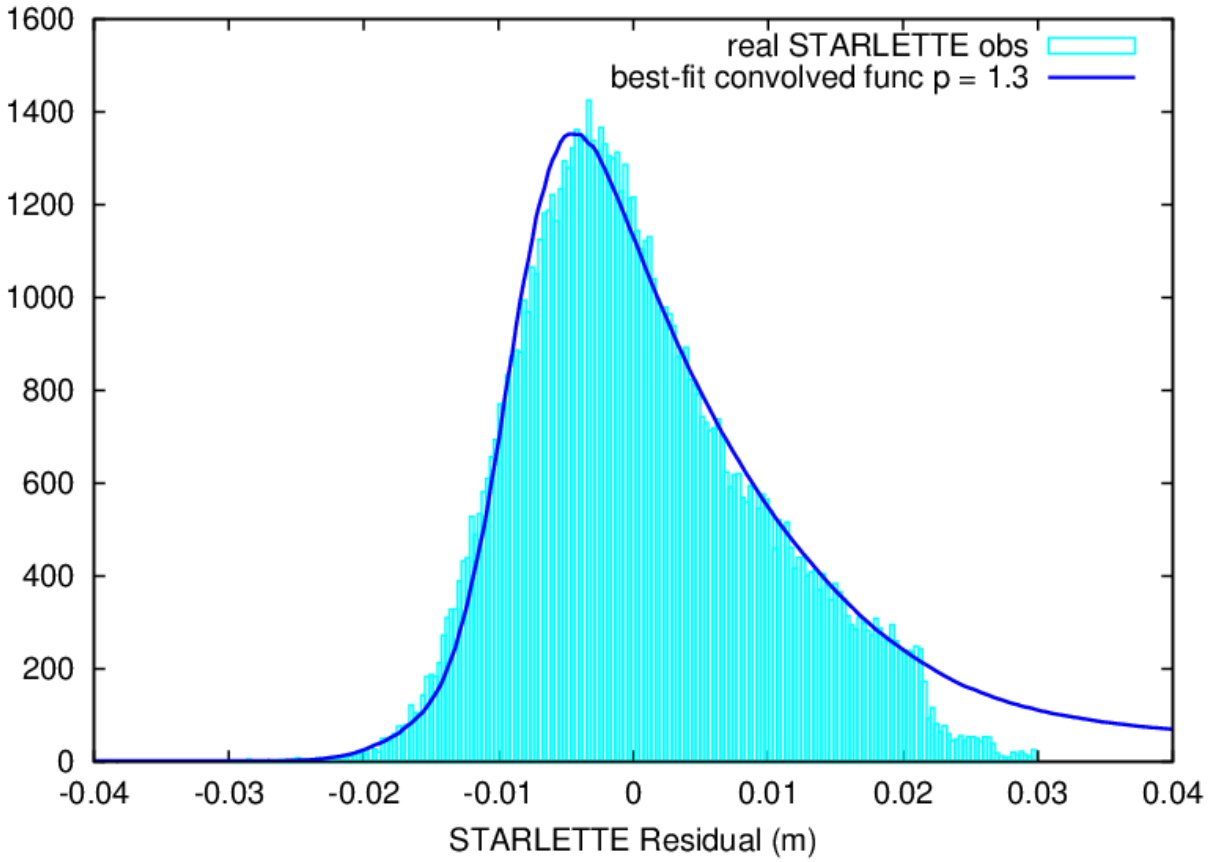
And now





STARLETTE

Diameter = 24 cm
60 x 33-mm retro, backface coated

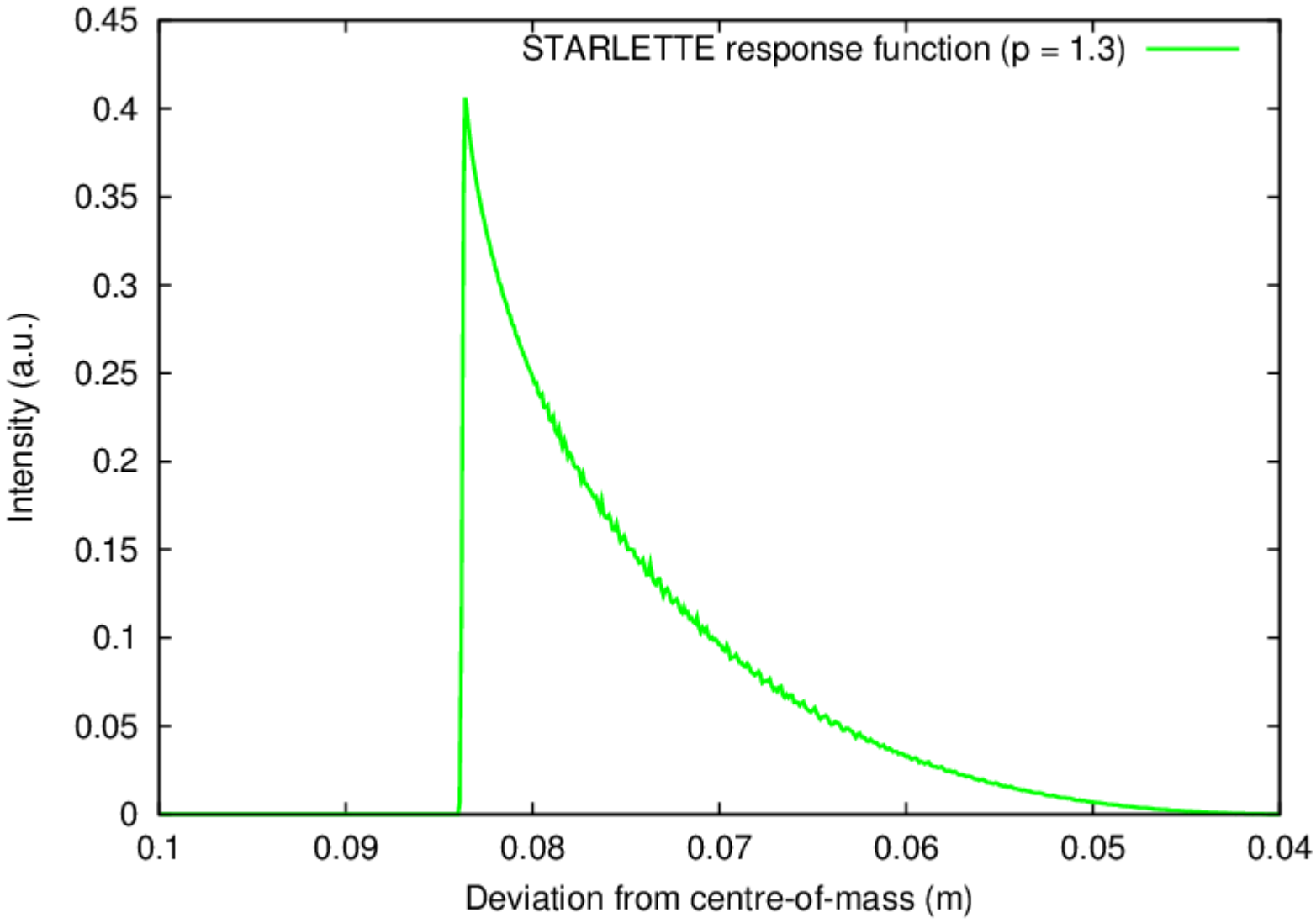


kHz single photon data, Herstmonceux, May-Jun 2012

$Intensity = a^p\ e$
where
a **: effective reflection area**
e **: reflectivity**

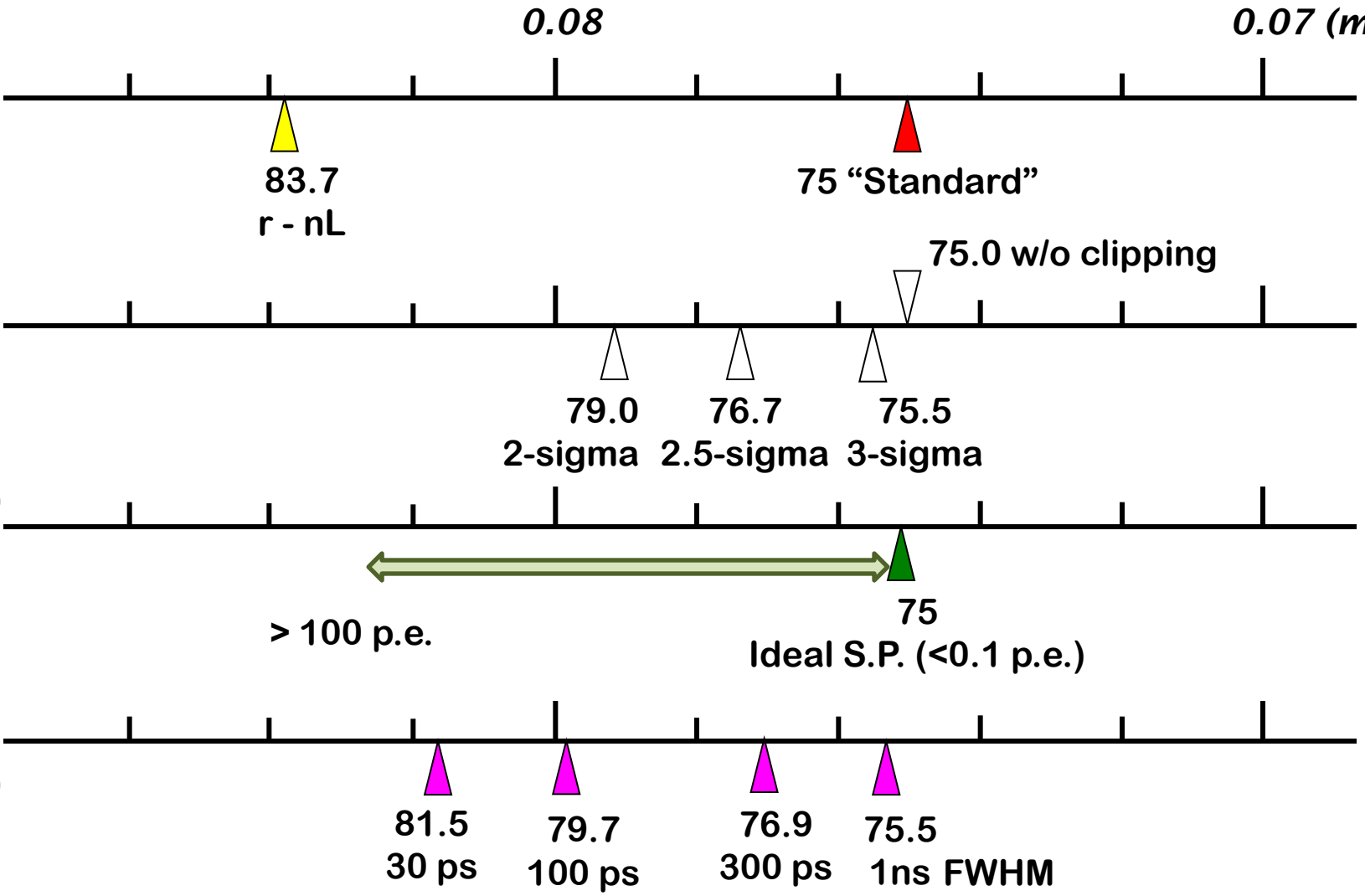
See Neubert's talk for LARES.

(Provisional) Best-fit response function STARLETTE



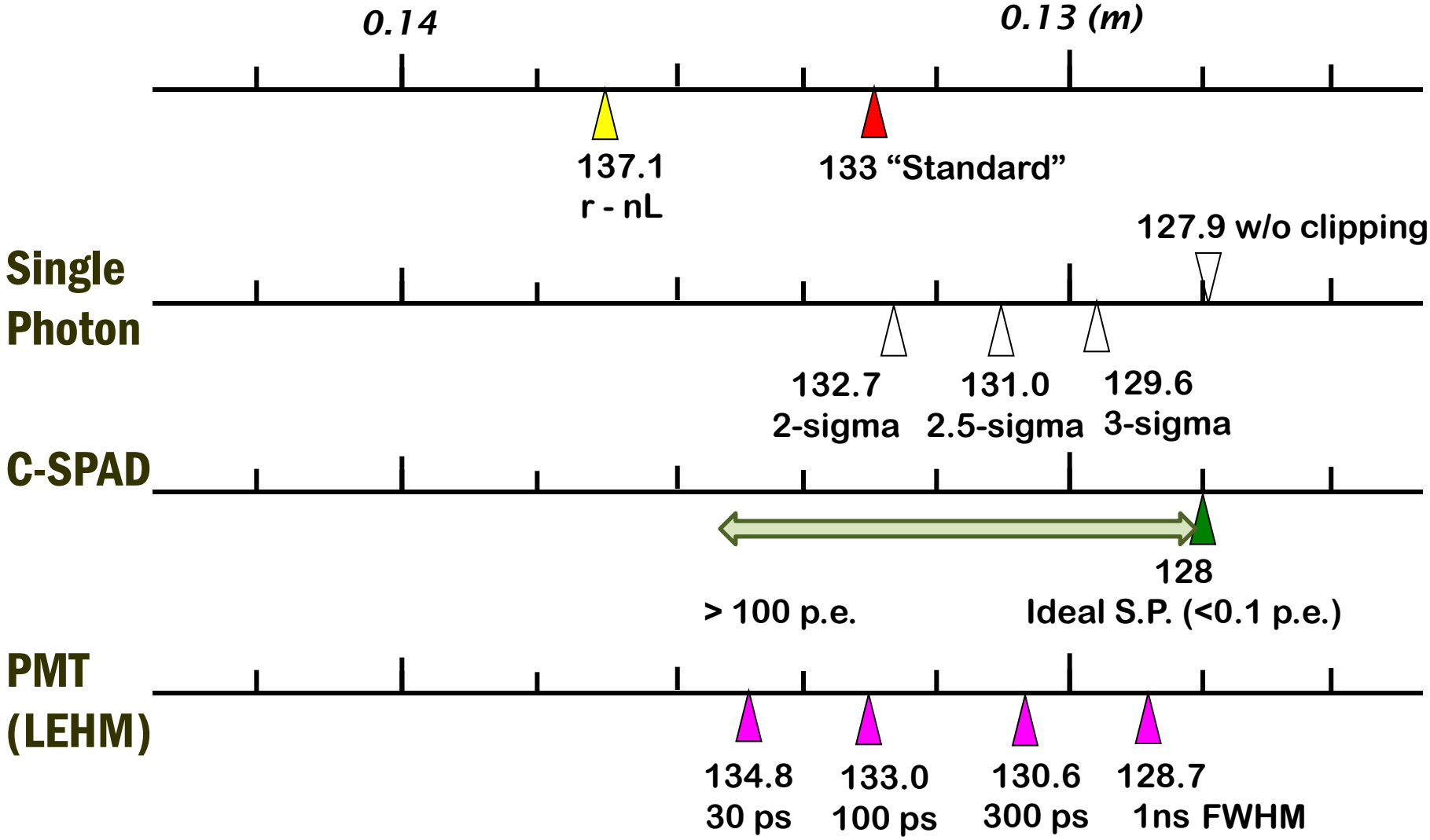
PROVISIONAL
(Do not use these values for critical purposes)

STARLETTE p~1.3



PROVISIONAL
(Do not use these values for critical purposes)

LARES p~1.0

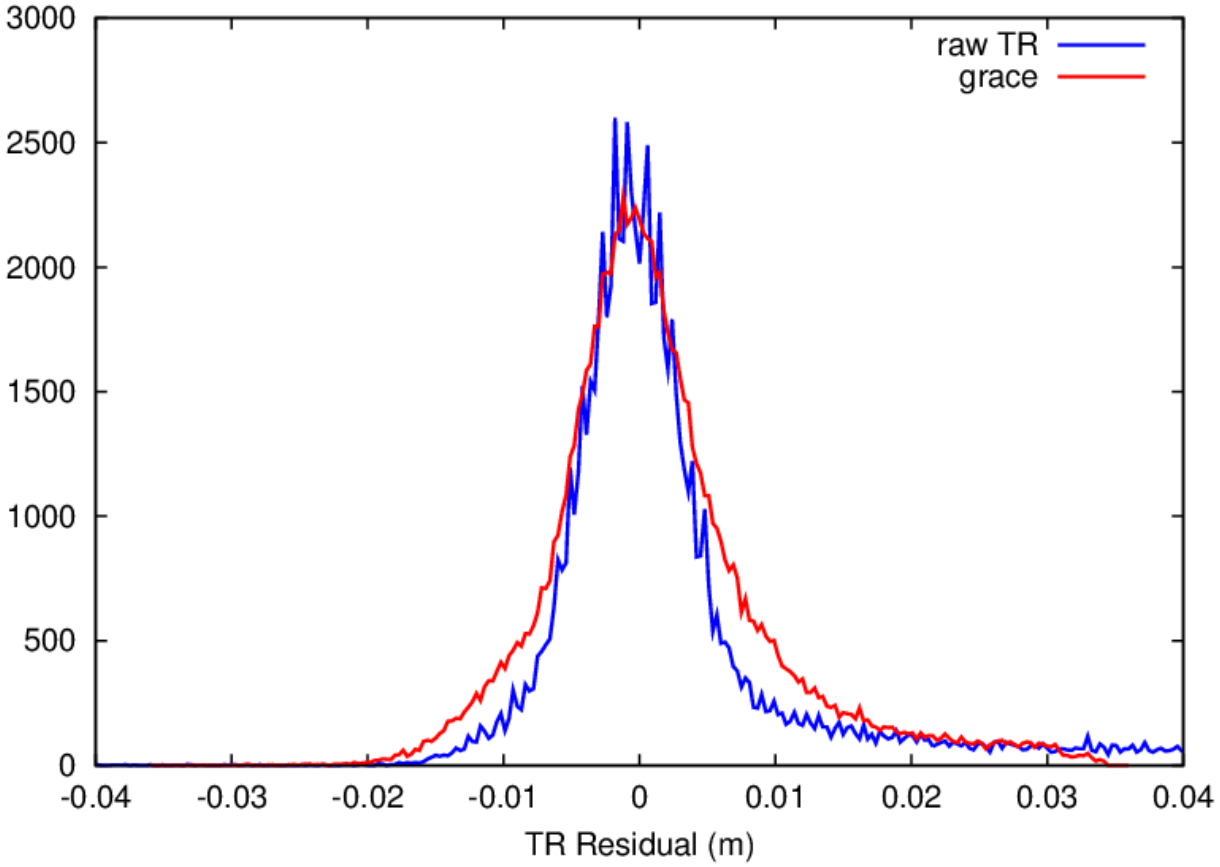


Why provisional? TR vs Small-sig targets

System noise

How much will the atmosphere broaden a pulse?

Or any other causes?



kHz single photon data, Herstmonceux, Jun 2012

(Even BLITS residual broader than TR)

Part II:
Future SLR Constellation for mm-accurate TRF scale (just a very rough idea)

ITRF2008 origin & scale

ITRF2008 webpage:
http://itrf.ensg.ign.fr/ITRF_solutions/2008/datum_ITRF2008.php

- **The ITRF2008 origin is defined in such a way that there are null translation parameters at epoch 2005.0 and null translation rates between the ITRF2008 and the ILRS SLR time series.**
- **The ITRF2008 scale is defined in such a way that there null scale and scale rate between ITRF2008 and the average of VLBI and SLR scales/rates.**

ITRF2008 scale: VLBI vs SLR

J Geod (2011) 85:457–473
DOI 10.1007/s00190-011-0444-4

ORIGINAL ARTICLE

ITRF2008: an improved solution of the international terrestrial reference frame

Zuheir Altamimi · Xavier Collilieux · Laurent Métivier

" the level of the scale agreement between VLBI and SLR solutions is not better than 1 ppb."

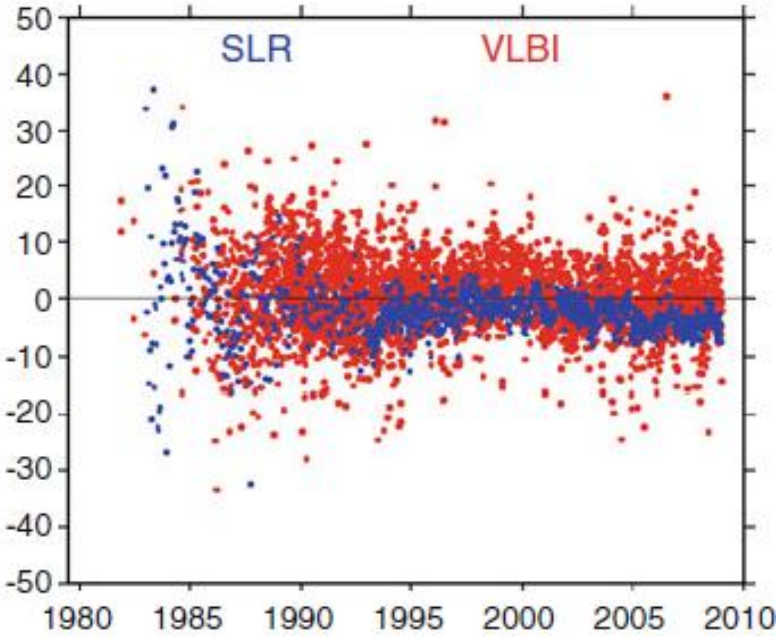


Fig. 6 Scale factors, in millimeters, of the VLBI, SLR and DORIS solutions with respect to ITRF2008

Space geodesy always poor at vertical

ALL

TRF Scale
(station height)

~ 1 ppb (ITRF200x)

Note: Not all of these parameters are always solved for.

Range-direction error

Satellite-based

GM EARTH

< 1 ppb (Dunn, 1999)

ALL (very small for SLR)

Atmosphere
Ionosphere

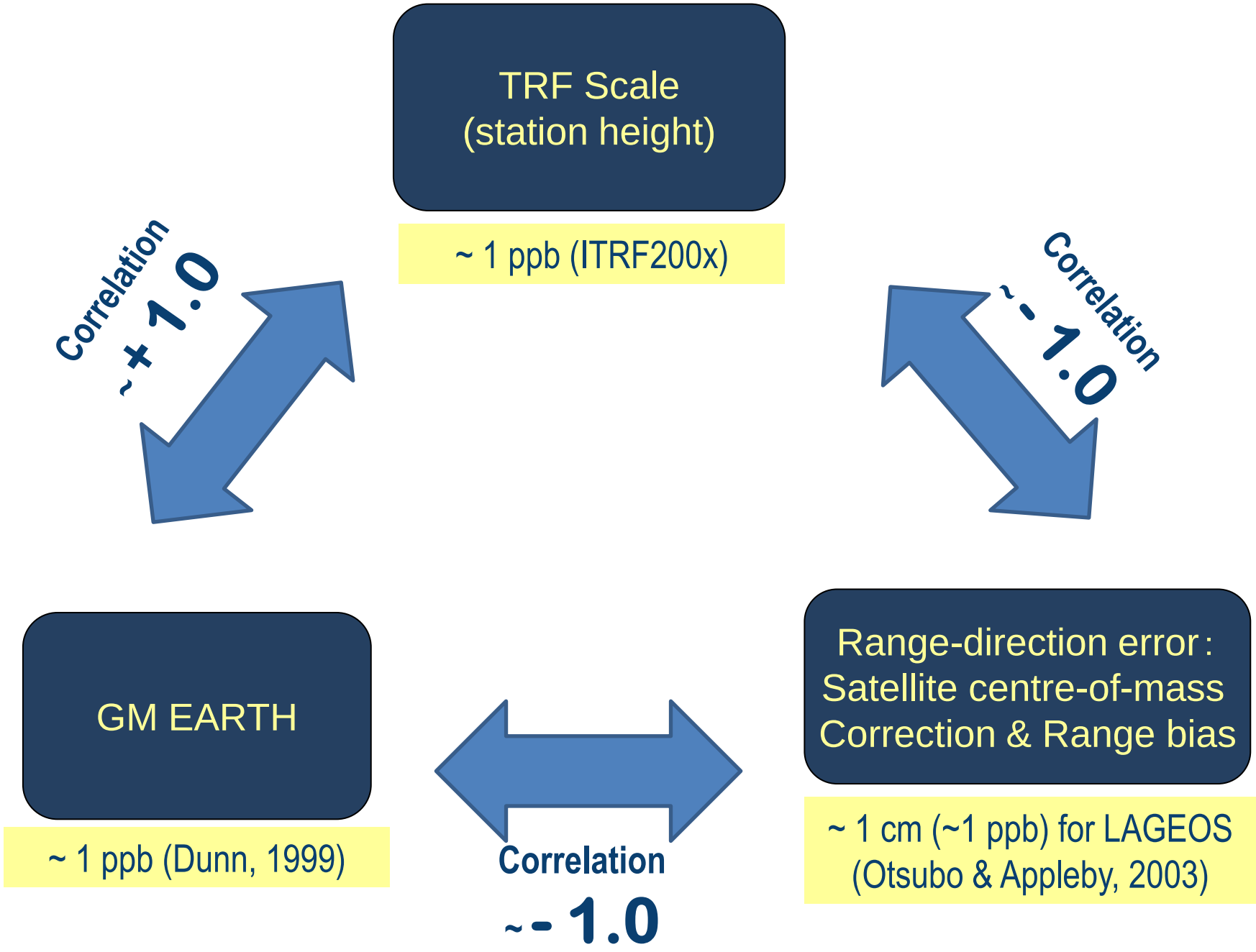
SLR

Satellite centre-of-mass
Correction & Range bias

~ 1 cm (~1 ppb) for LAGEOS
~ 5 cm (~2 ppb) for ETALON
(Otsubo & Appleby, 2003)

VLBI/GNSS

Clock, Ambiguity,
Cycle slip, etc.


TRF Scale
(station height)
~ 1 ppb (ITRF200x)
Correlation
~ + 1.0
Correlation
~ - 1.0
GM EARTH
~ 1 ppb (Dunn, 1999)
Correlation
~ - 1.0
Range-direction error :
Satellite centre-of-mass
Correction & Range bias
~ 1 cm (~1 ppb) for LAGEOS
(Otsubo & Appleby, 2003)

Precision and Accuracy

millimetre precise?

Single-shot prec. 3 mm / Sqrt (Obs. =10000)

= NP prec. 0.03 mm !!! ← kHz station

millimetre accurate?

Not just target signatures, a large number of error sources hidden in a SLR system.

No evidence of being at 1 mm.

1 mm accuracy achievable?

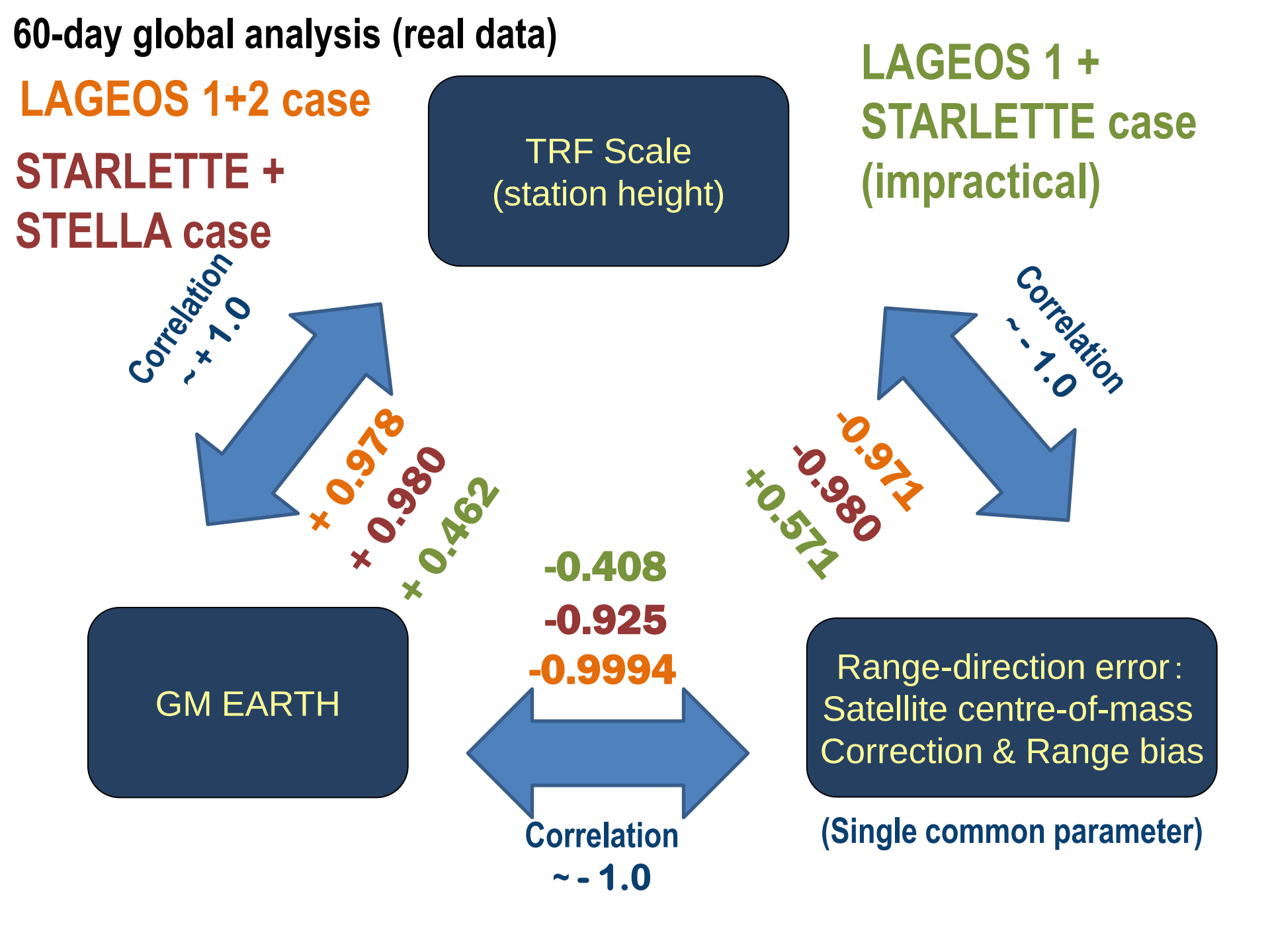
→ Range bias estimation inevitable to claim better accuracy (assuming a constant bias).

How to relax the high correlations

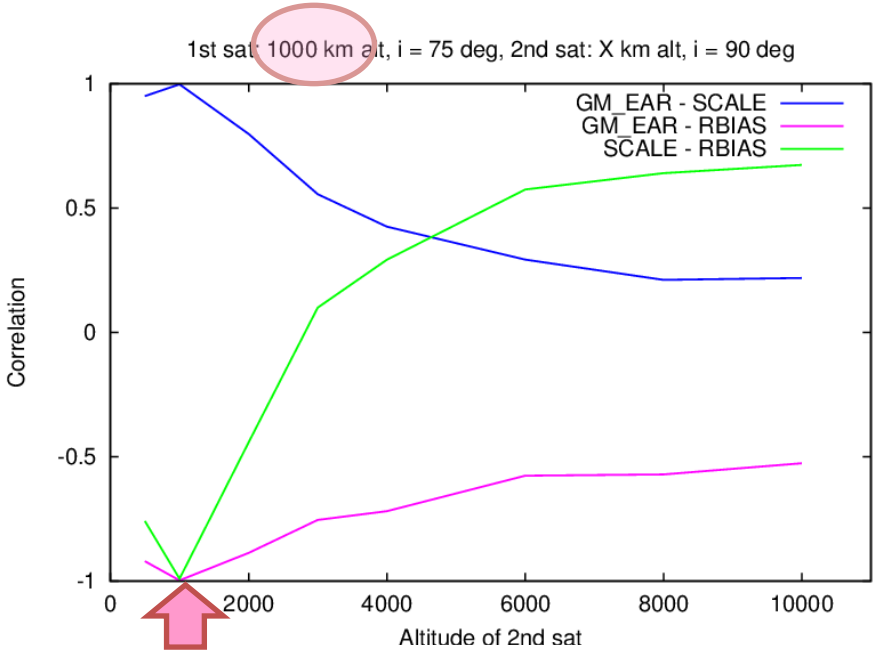
[1] Use multiple satellites at different altitudes.

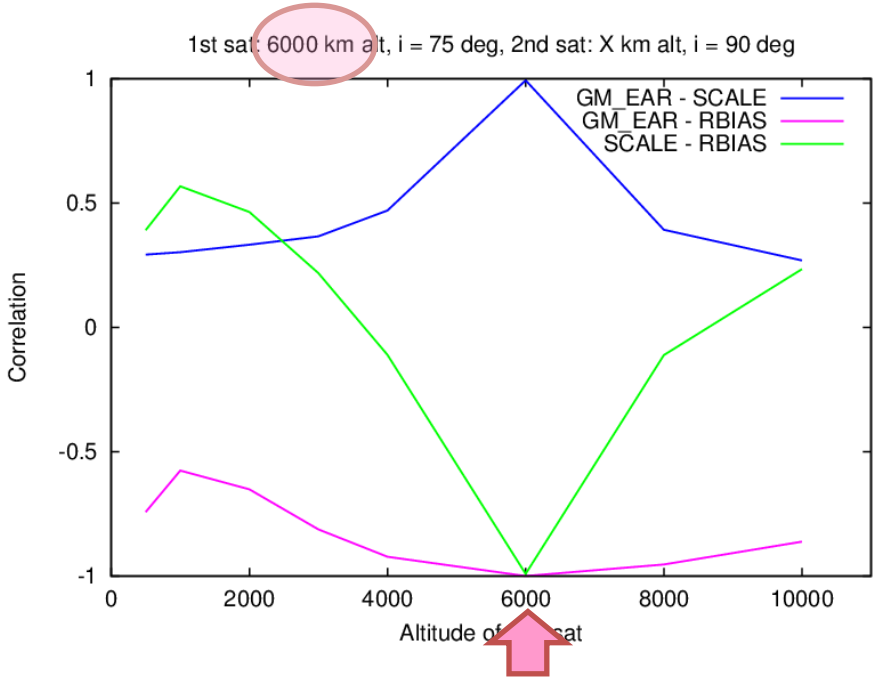
[2] Estimate a common range bias for different satellites.

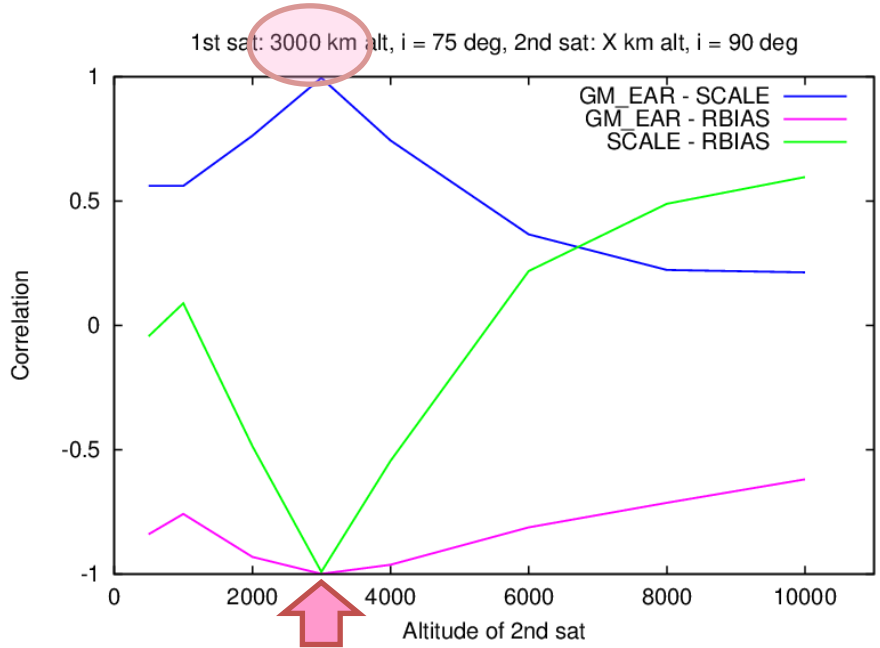
- **Existing satellites: Different target signatures for different altitudes → Range bias should be solved for separately. Or rely on the CoM table.**
- **Future scenario: A twin/sister satellite system that has a common signature effect possible?**


60-day global analysis (real data)
LAGEOS 1+2 case
STARLETTE + STELLA case
LAGEOS 1 + STARLETTE case (impractical)
TRF Scale (station height)
Correlation ~ + 1.0
+ 0.978
+ 0.980
+ 0.462
Correlation ~ - 1.0
-0.971
-0.980
+0.571
GM EARTH
-0.408
-0.925
-0.9994
Correlation ~ - 1.0
Range-direction error : Satellite centre-of-mass Correction & Range bias
(Single common parameter)

60-day global analysis (simulation data)

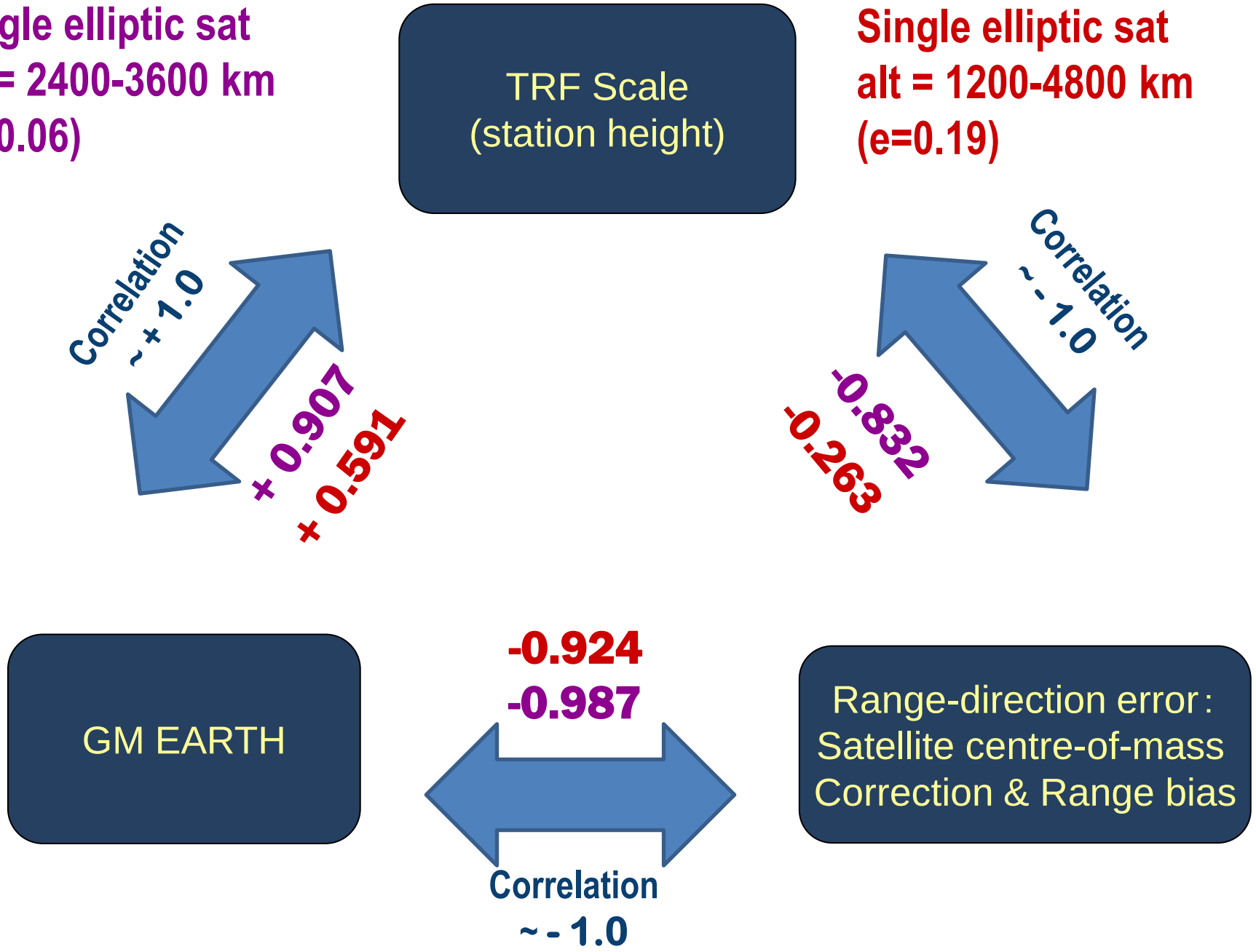






Formal errors also get worse by > 10 times when the two sats are at the same altitude.

60-day global analysis (simulation data)



Summary

Satellite signature of sub-cm targets

- STARLETTE (+STELLA):

  "75 mm" is the centroid point. Probably too small for the average value.

  Range: 75 to 82 mm (provisional).

- LARES:

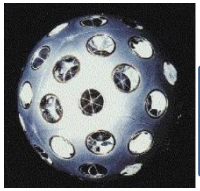
  Expected behaviour. Provisional "133 mm" reasonable.

  Range: 128 to 135 mm (provisional).

SLR Constellation for Earth scale parameters

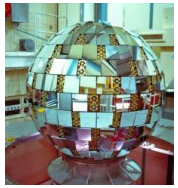
- Correlation: GM, TRF Scale, and Range Bias.
- Problem solved with "sister satellite combination" or "eccentric orbits".
- Possible with "LARES + LAGEOS"? "LARES-2" different alt.?
- Common/shared range bias is the key. x10 improvement?

[to do] more simulation studies!!!

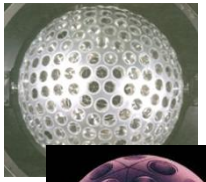


1975- STARLETTE

1976- LAGEOS-1



1986- AJISAI



1992- LAGEOS-2

1993- STELLA

2012- LARES