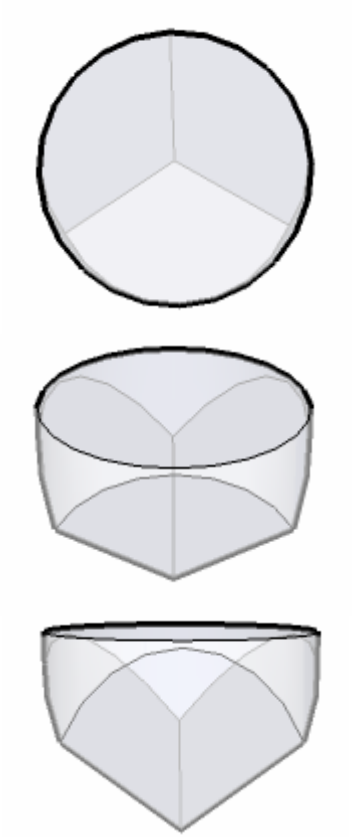
Centre-of-mass corrections of sub-cm-precision targets, STARELTTE and LARES



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NATURAL ENVIRONMENT RESEARCH COUNCIL

GFZ Helmholtz-Zentrum POTSDAM

18th International Workshop on Laser Ranging , Fujiyoshida, 14 Nov 2013

Target Signature Effect goes to **mm**

More retros & Large satellite → Easy observations

Fewer retros & Small satellite → Precise observations

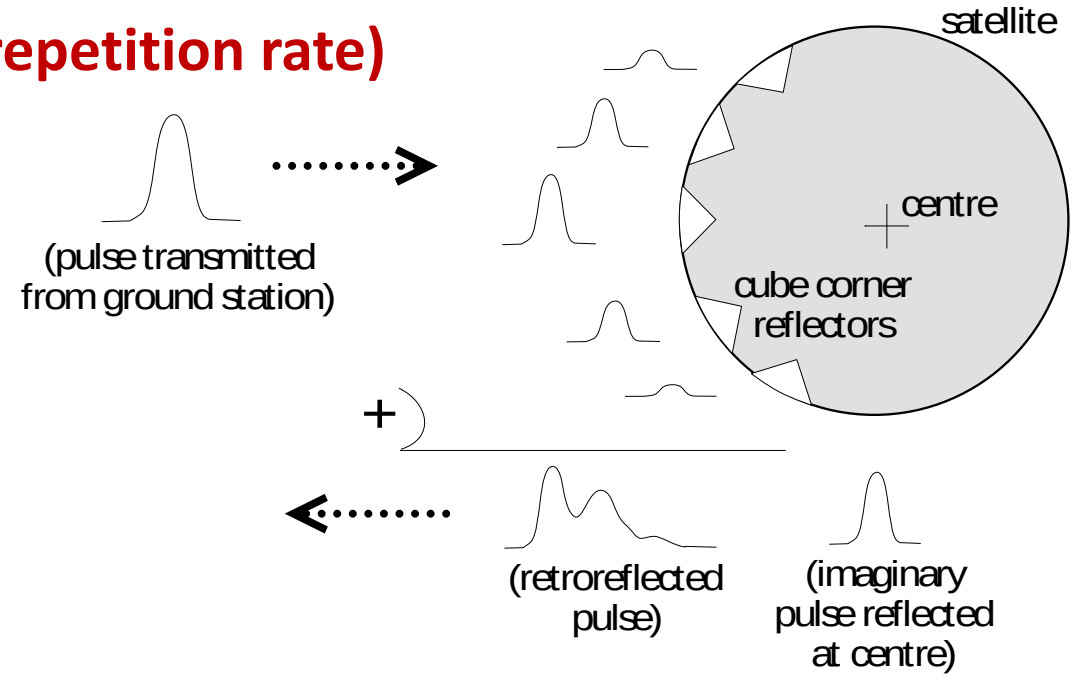
4-5 cm for AJISAI & ETALON, 1 cm for LAGEOS (Otsubo & Appleby, JGR, 2003)

a few cm for GNSS

less than 1 cm for "small targets"

← not negligible for the state-of-the-art systems

(with high accuracy & high repetition rate)



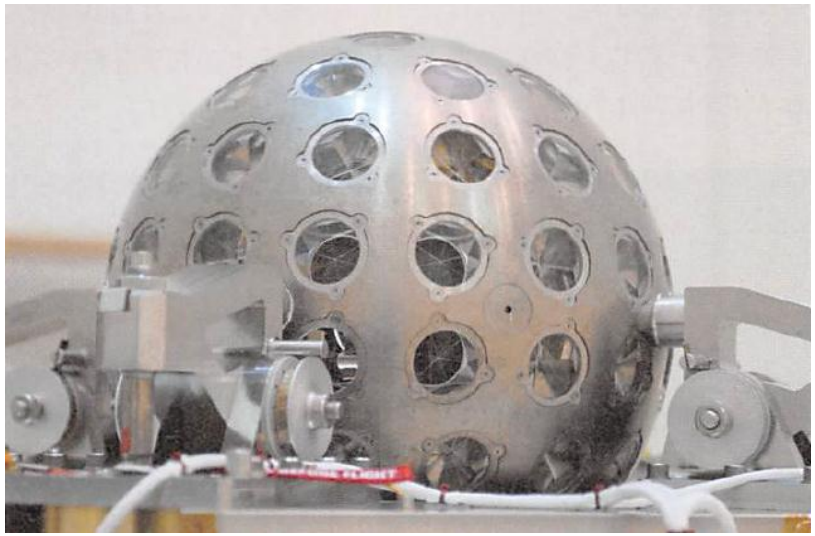
Starlette and LARES, and …

Starlette & its twin Stella

# of reflectors = 60
R = 120 mm

CCR backfaces:
Coated
→ Wide acceptance angle

LARES



# of refletors = 92
R = 182 mm

Uncoated
→ Narrow acceptance angle

BLITS

# of reflectors = 1
R = 85.16 mm

Luneburg lenz,
Single
→ Zero signature

“Standard” Centre-of-mass Corrections

Starlette & Stella :

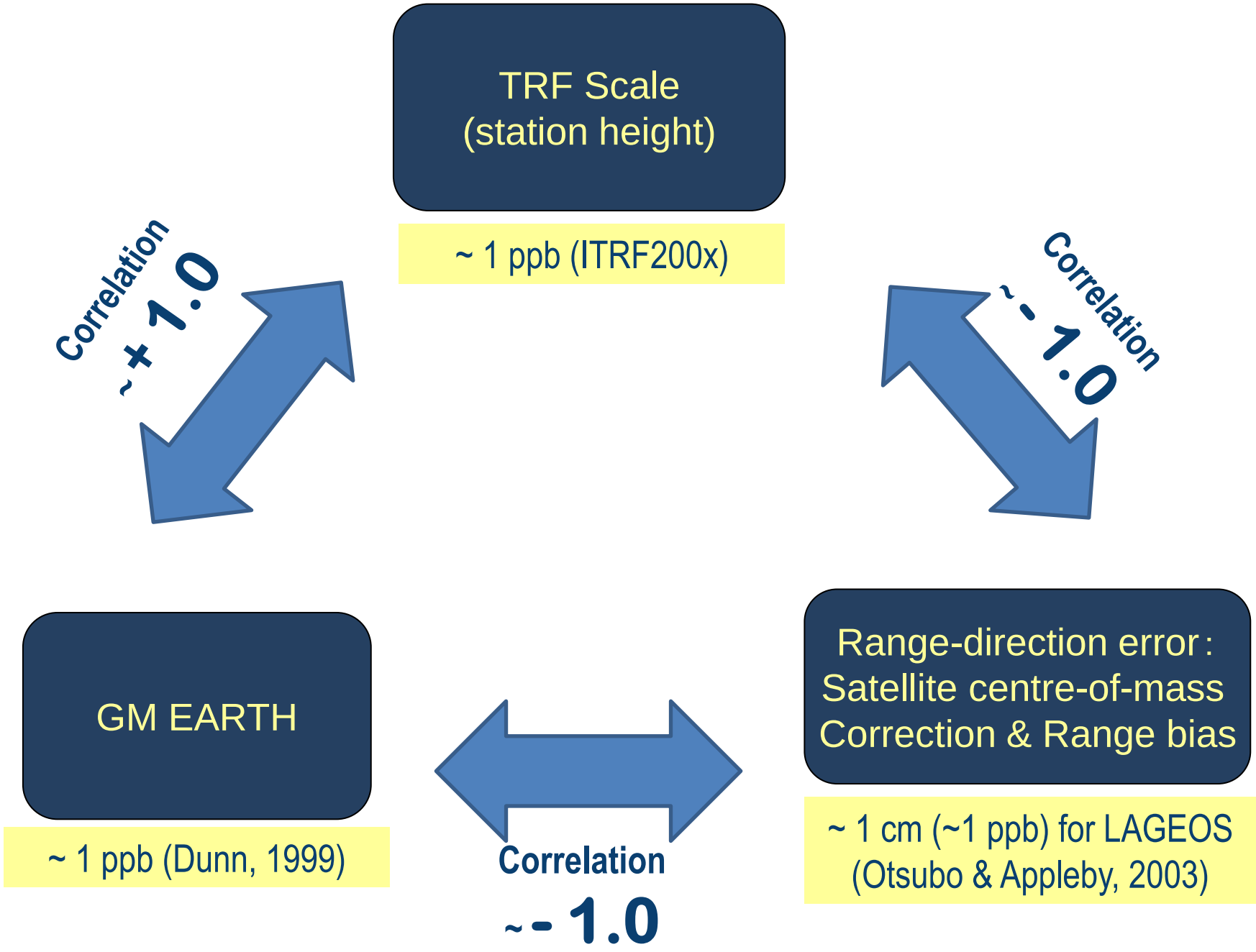
“Standard Value” 75 mm (Arnold, 1975) ← centroid

LARES:

System-dependent range

131 to 137 mm (prelaunch; Otsubo, 2012 & Neubert, 2012)

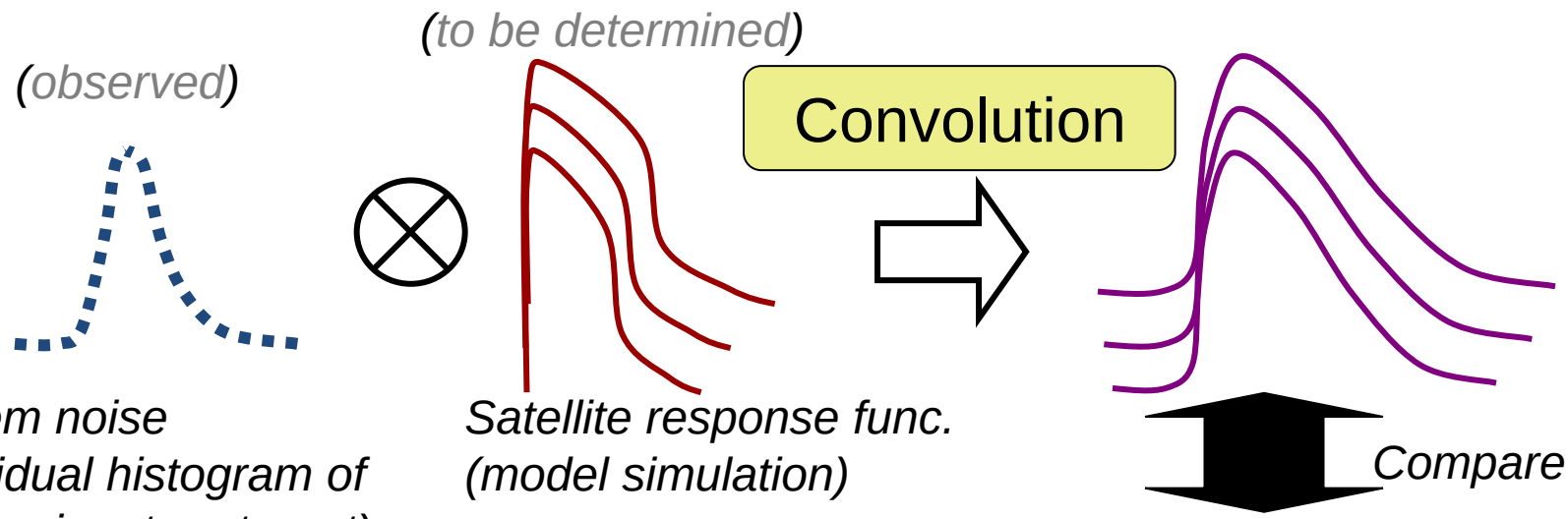
→ **“Provisional Value” 133 mm**


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)

Convolution → Estimation of sat response func

System noise ⊗ Satellite response function

The result is compared with the residual scatter of single-photon ranging.



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

Satellite response func. (model simulation)

based upon the detailed optical computation.

$Intensity = a^p e$

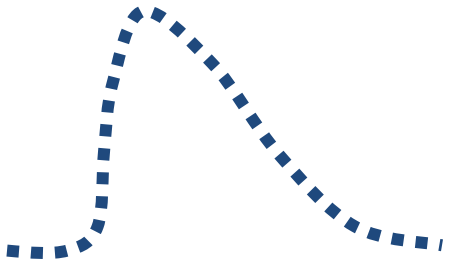
where

a : effective reflection area

e : reflectivity

→ *Find the best-fit p value*

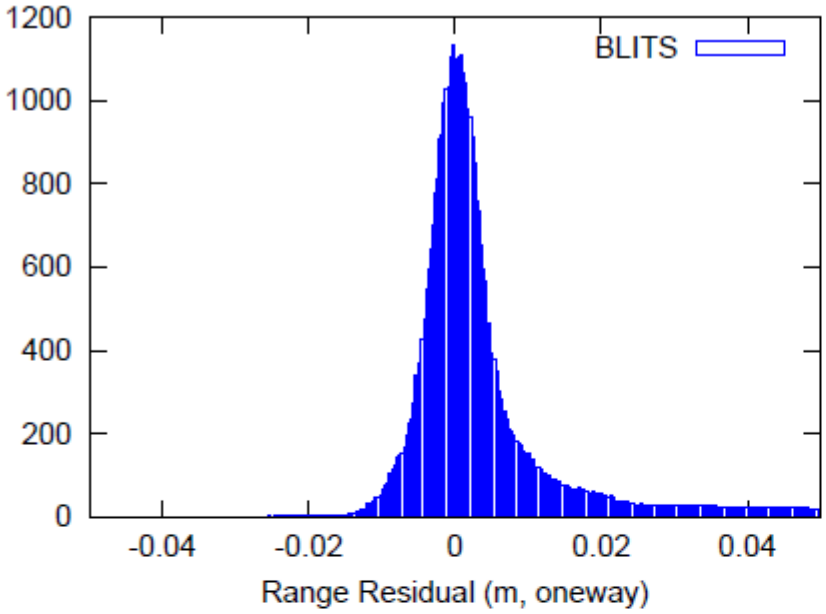
(observed)

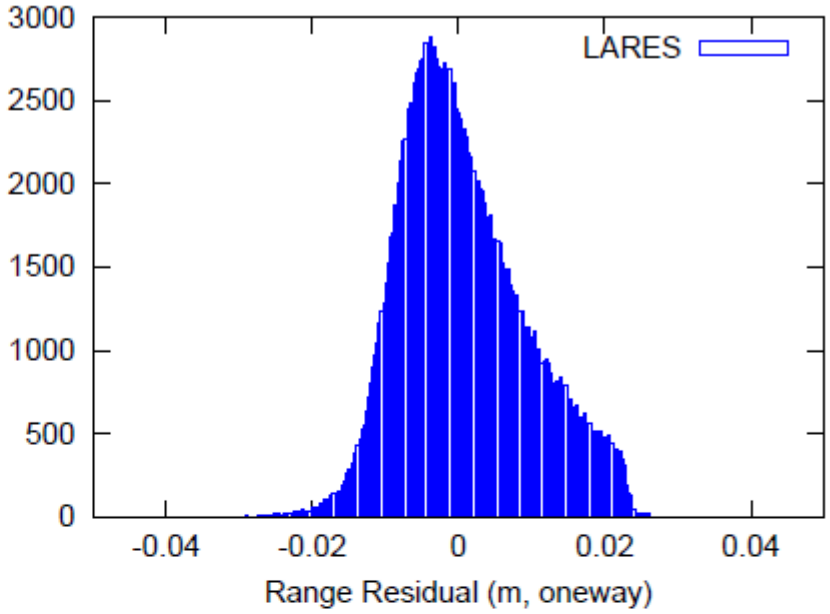


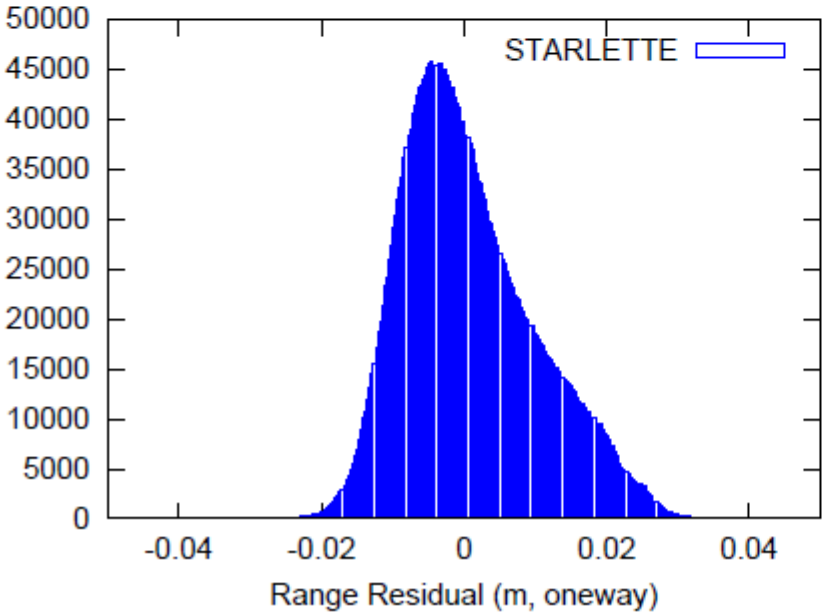
Residual histogram of satellite returns.

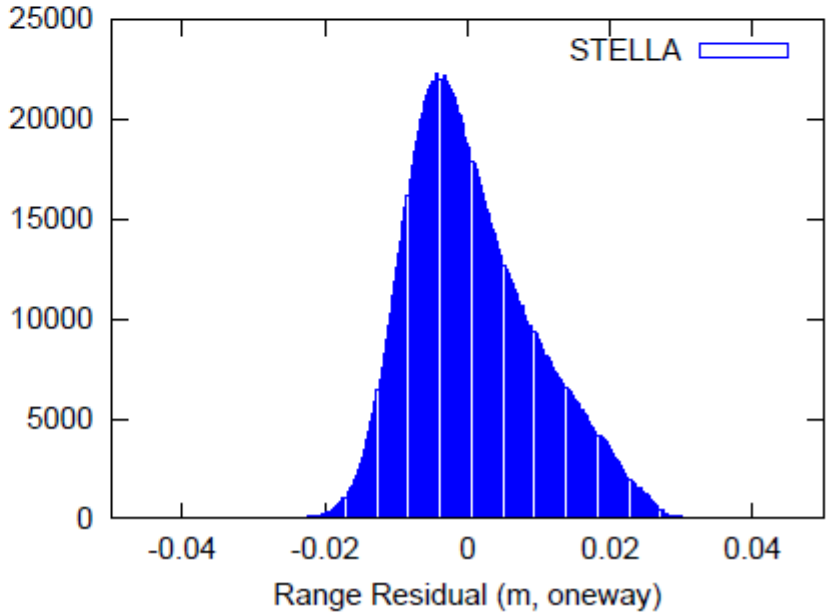
Range residual plots

Herstmonceux (UK) 2009-12
kHz Single-photon ranging



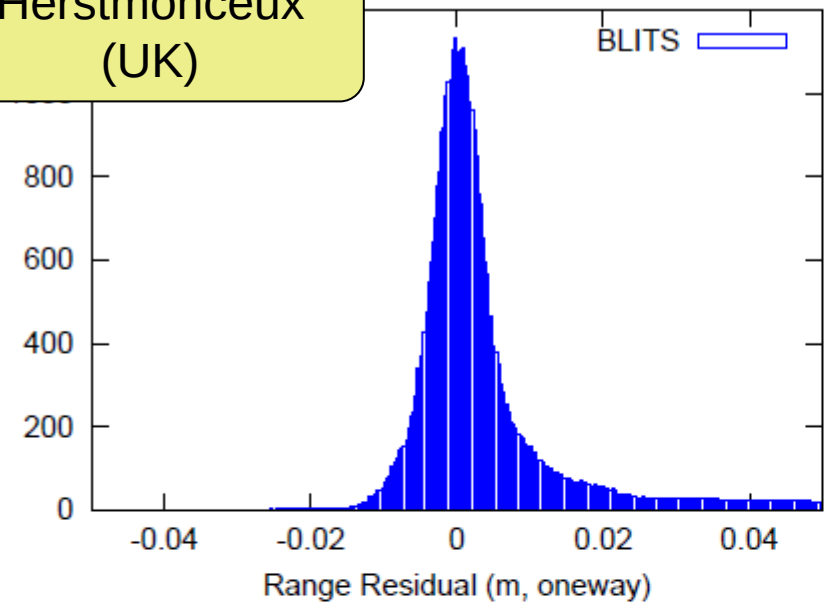


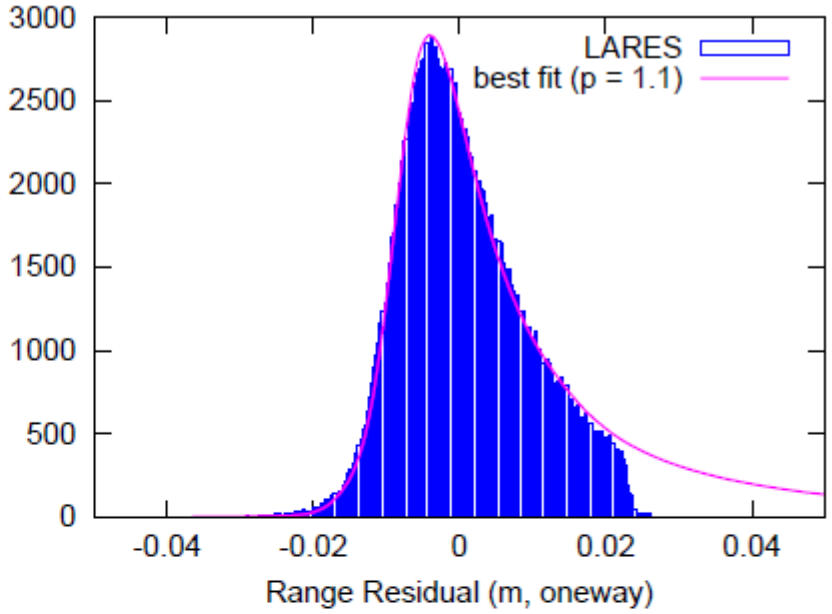


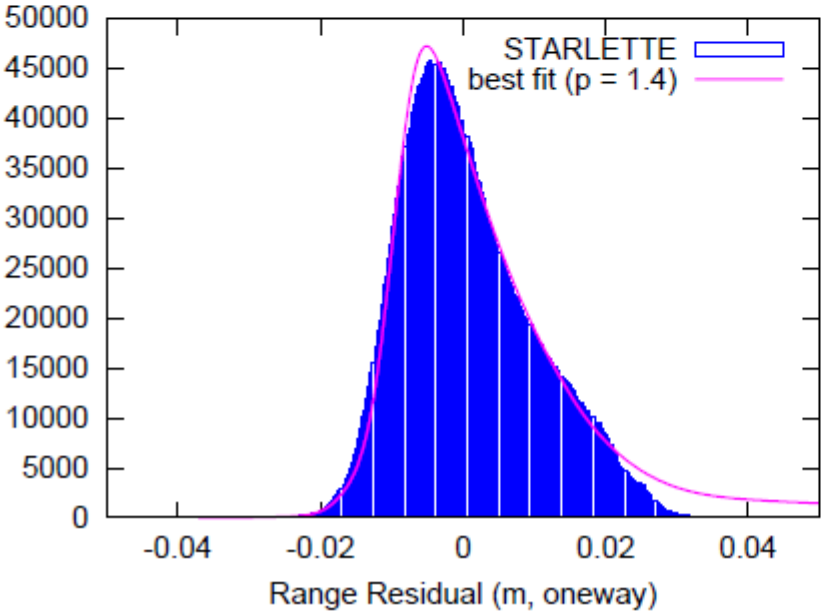


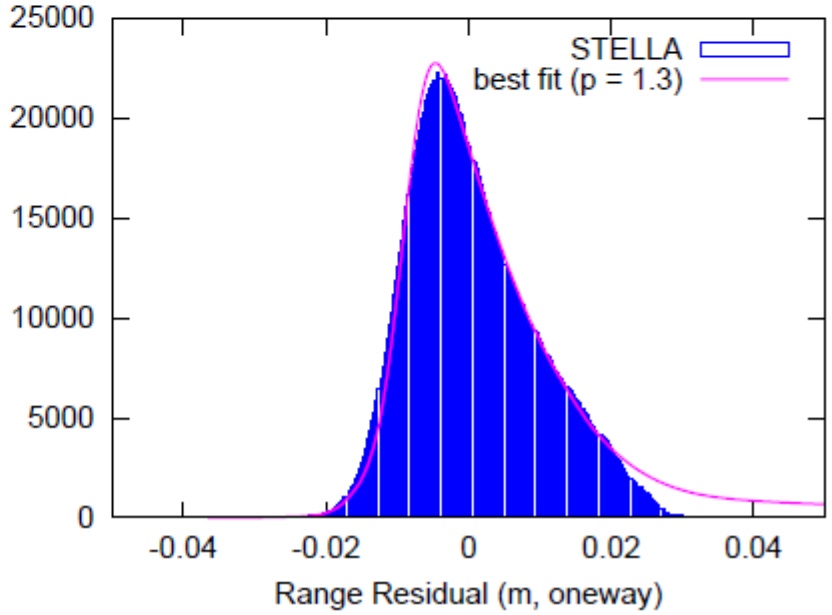
Range residuals & best-fit convolved functions

Herstmonceux (UK)



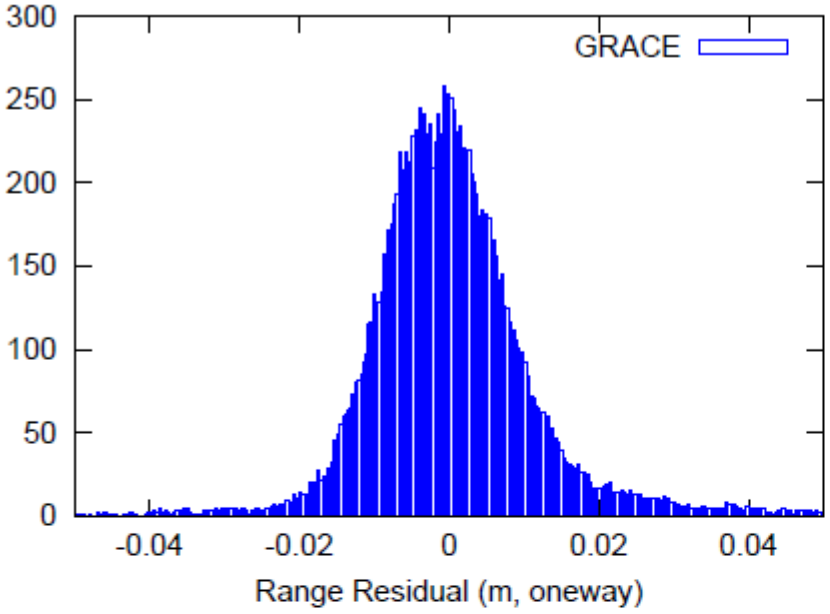


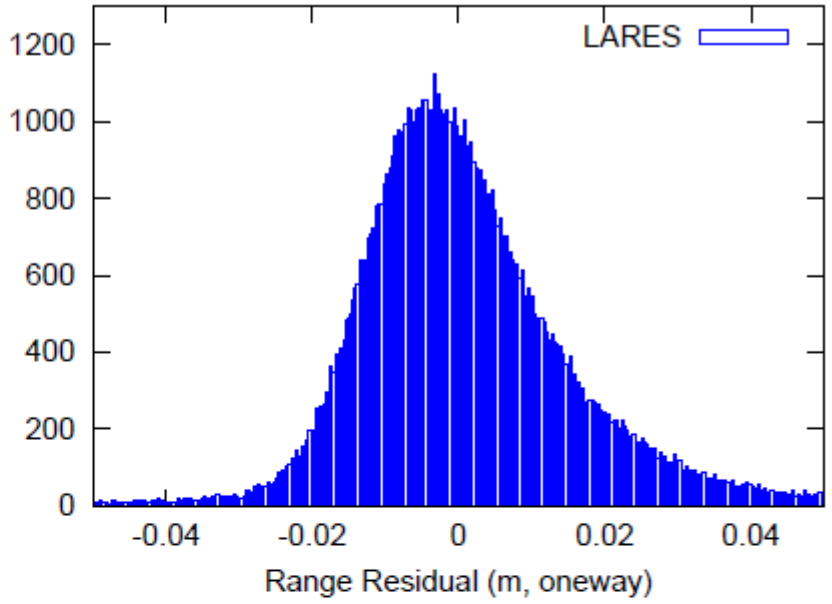


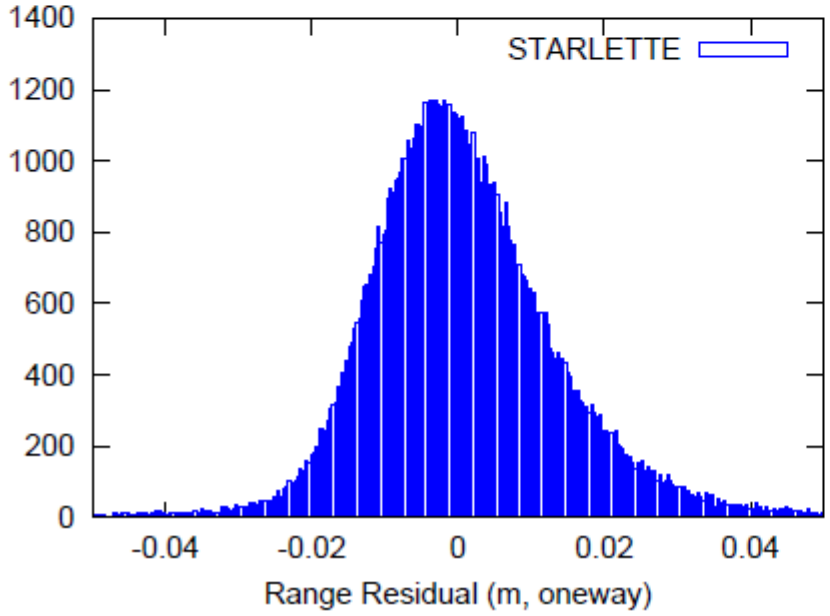


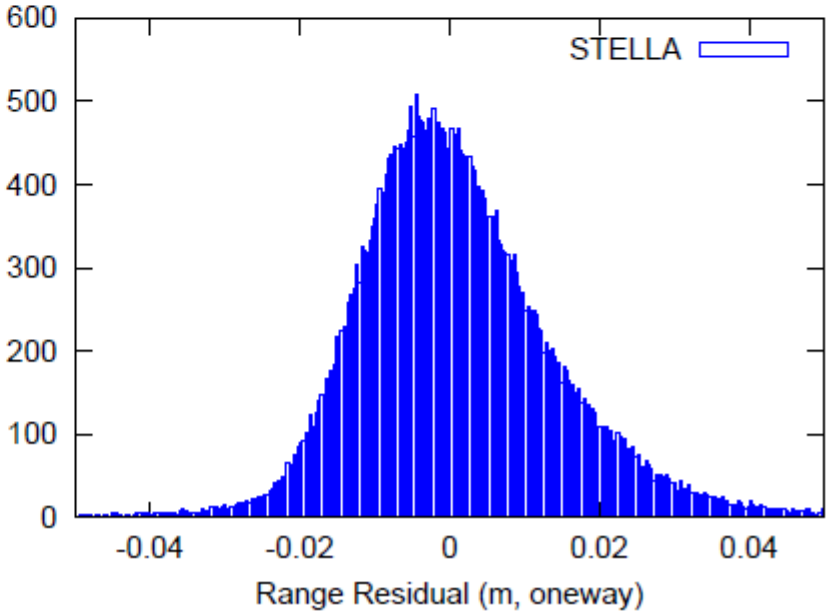
Range residual plots

Potsdam (Germany) 2013
kHz Single-photon ranging



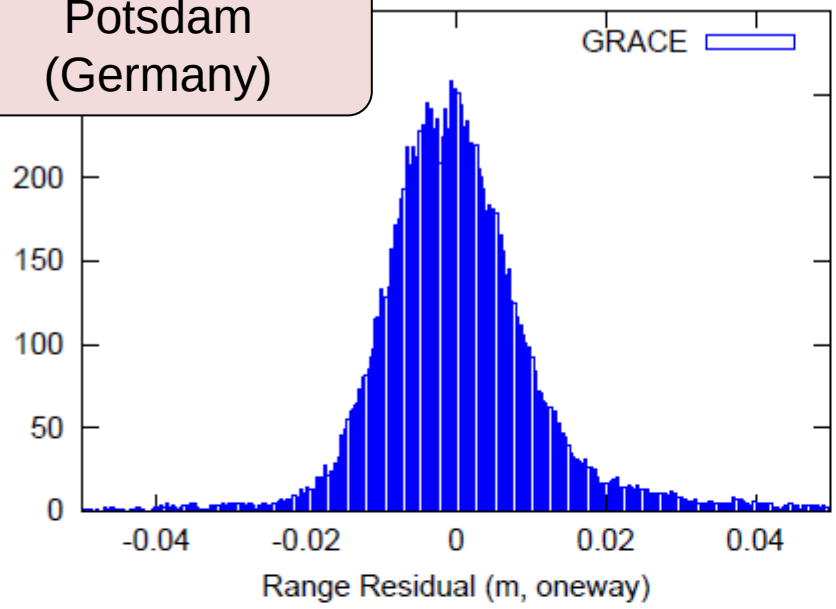


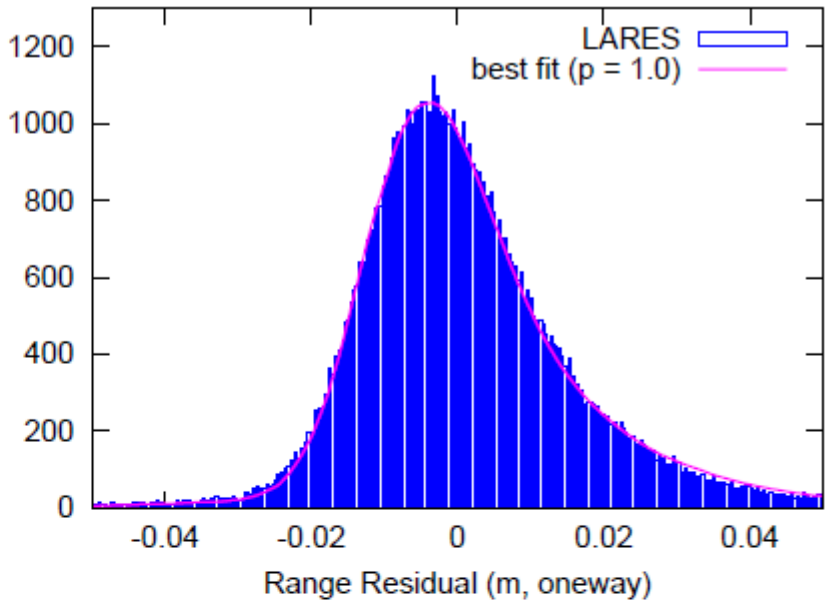


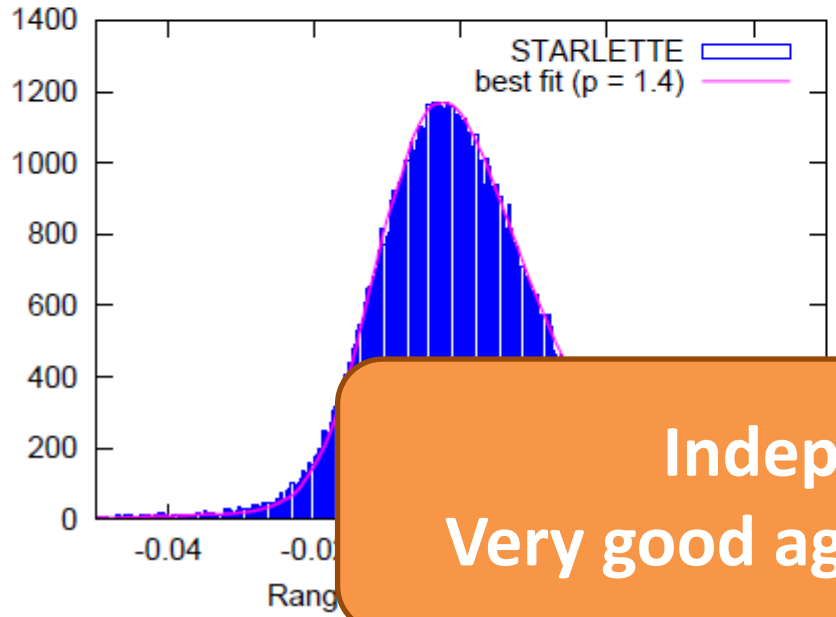


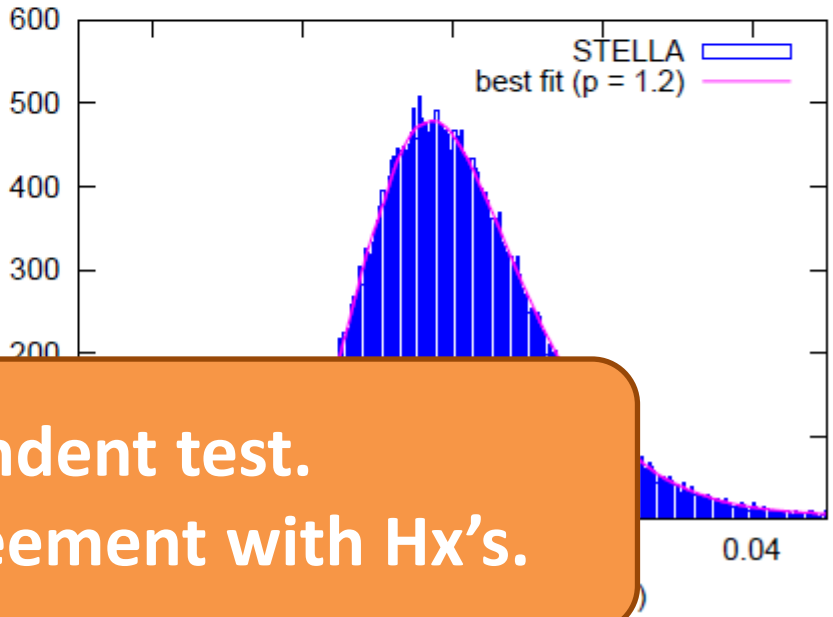
Range residuals & best-fit convolved functions

Potsdam (Germany)



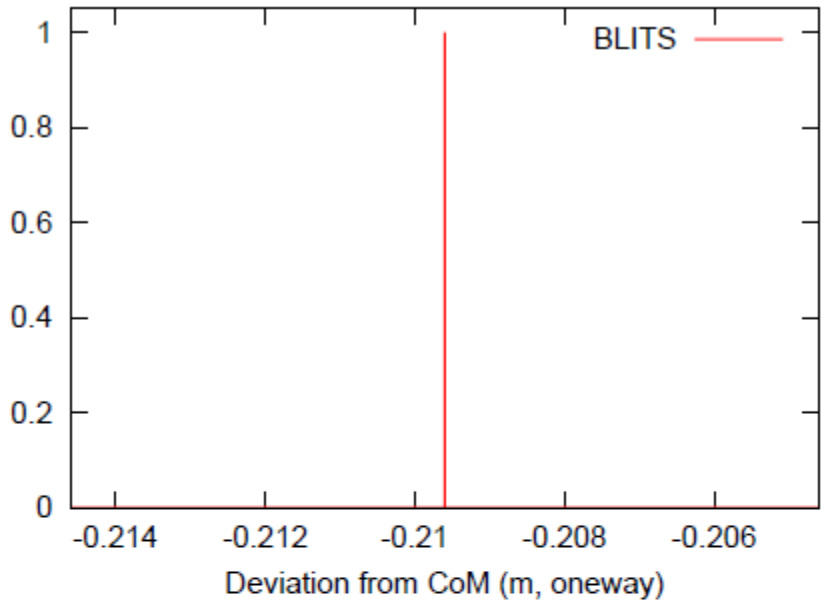


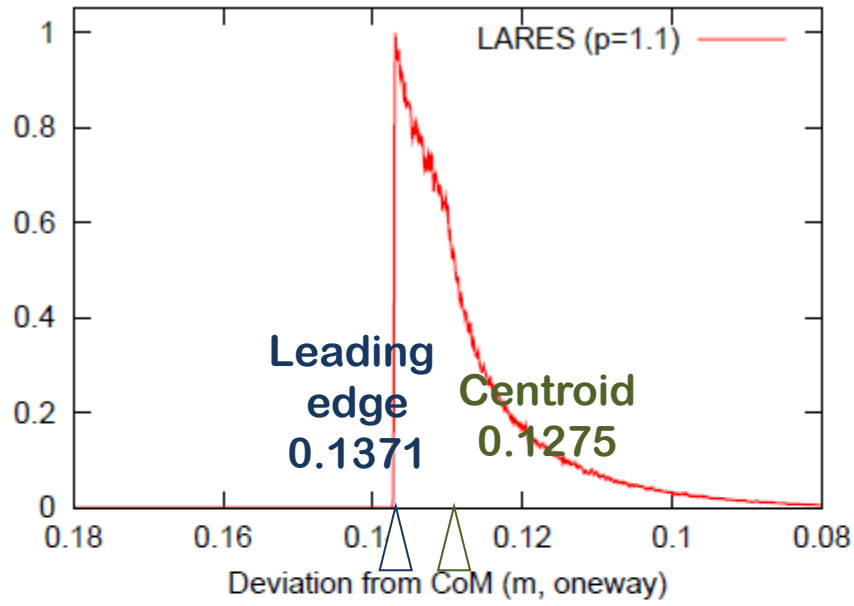


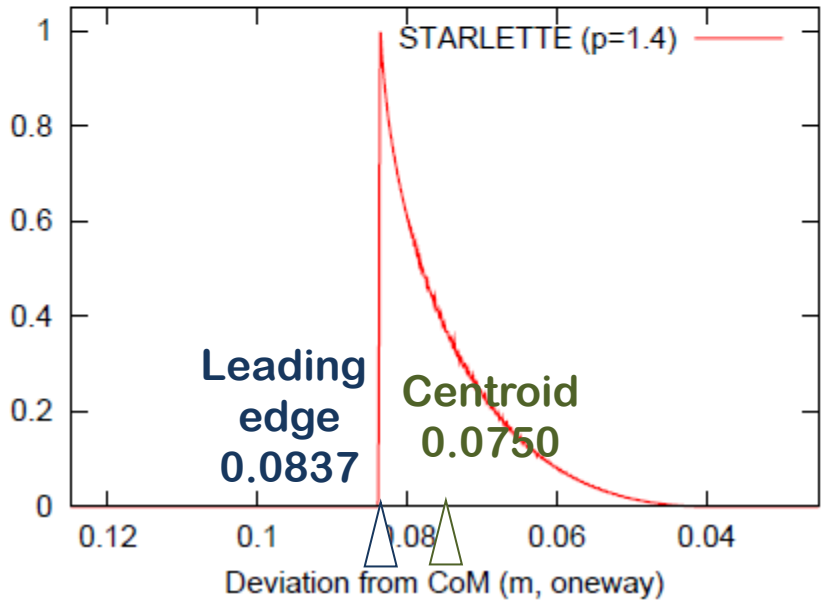


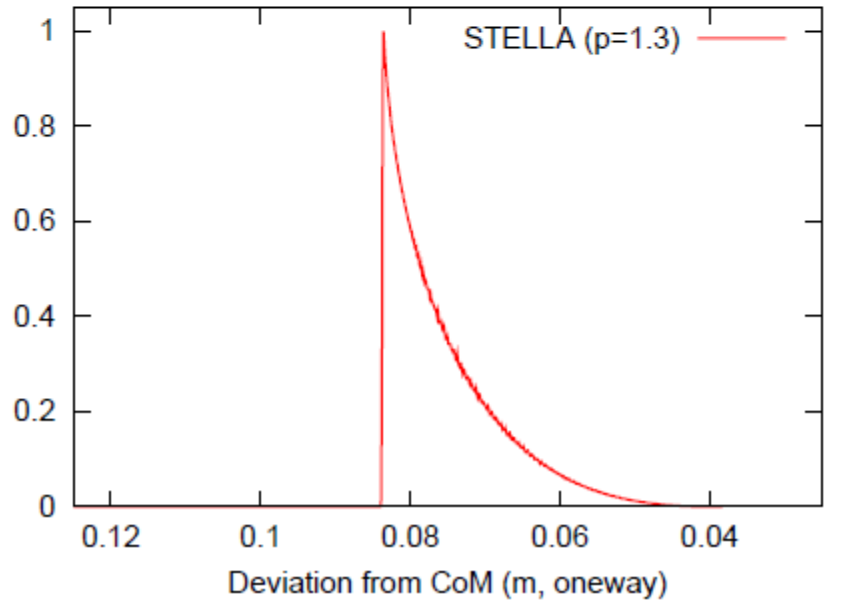
Independent test.
Very good agreement with Hx's.

Response functions



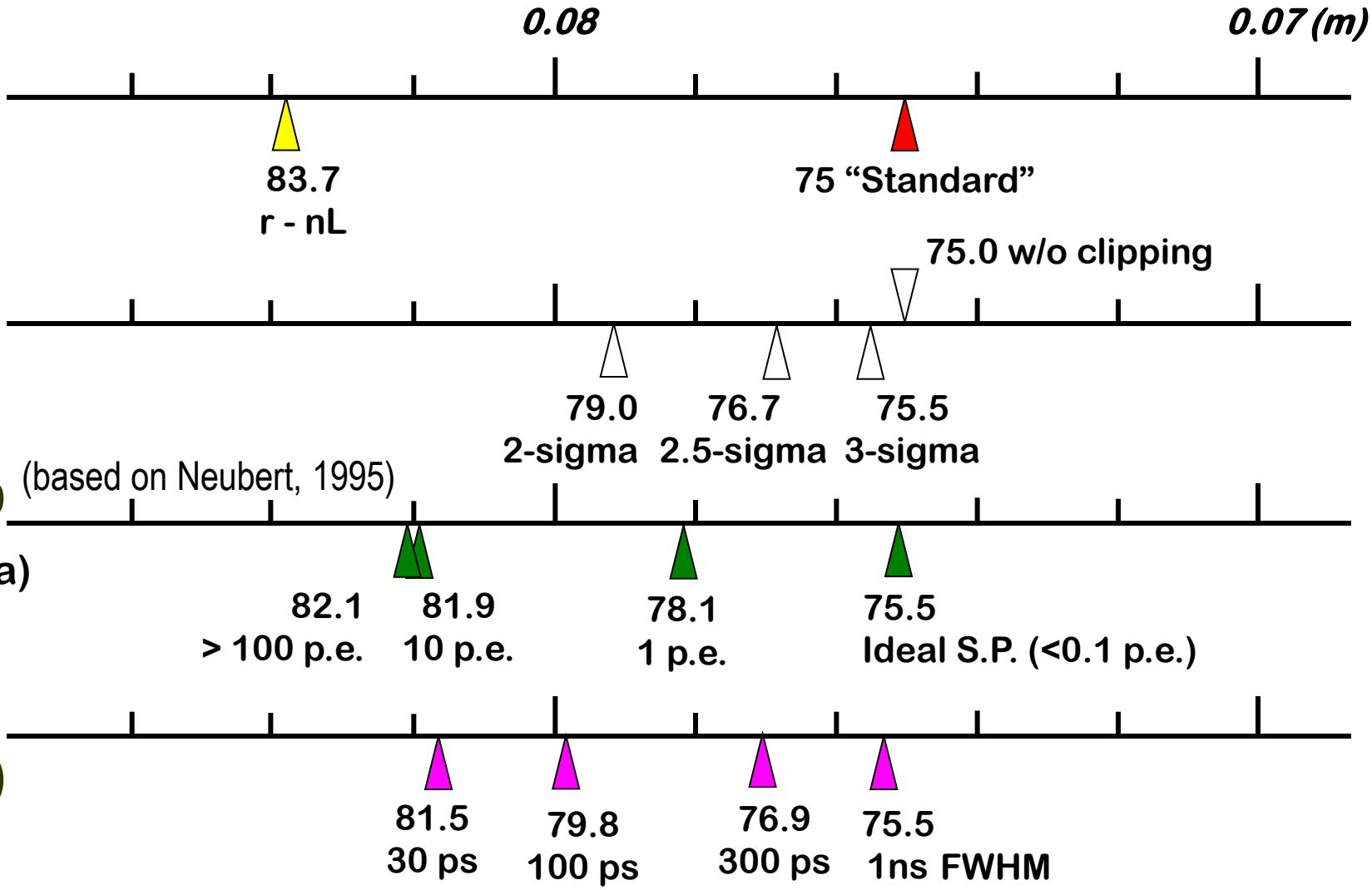






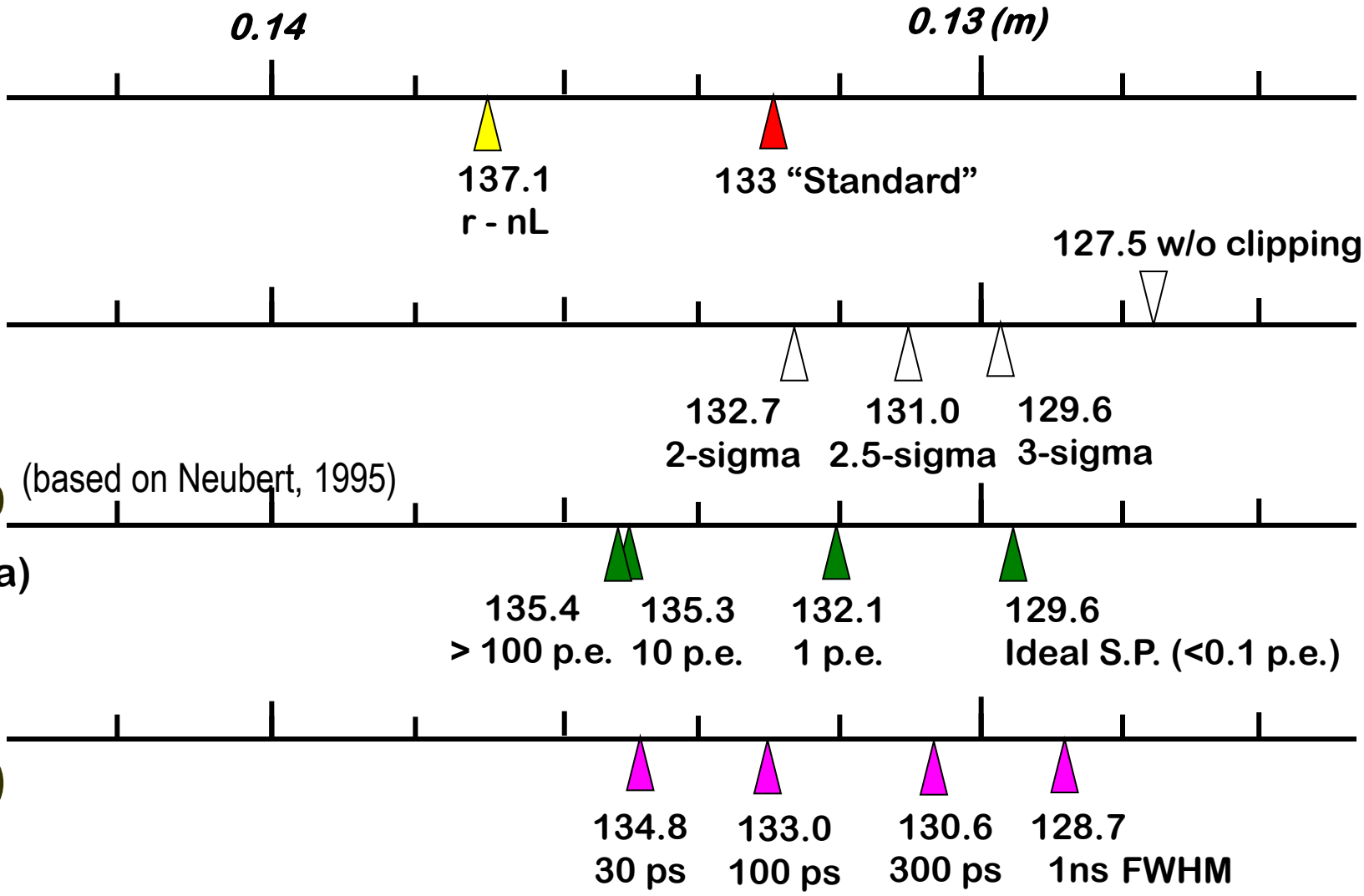
PROVISIONAL but almost FINAL
(Do not use these values for critical purposes)

STARLETTE p~1.4

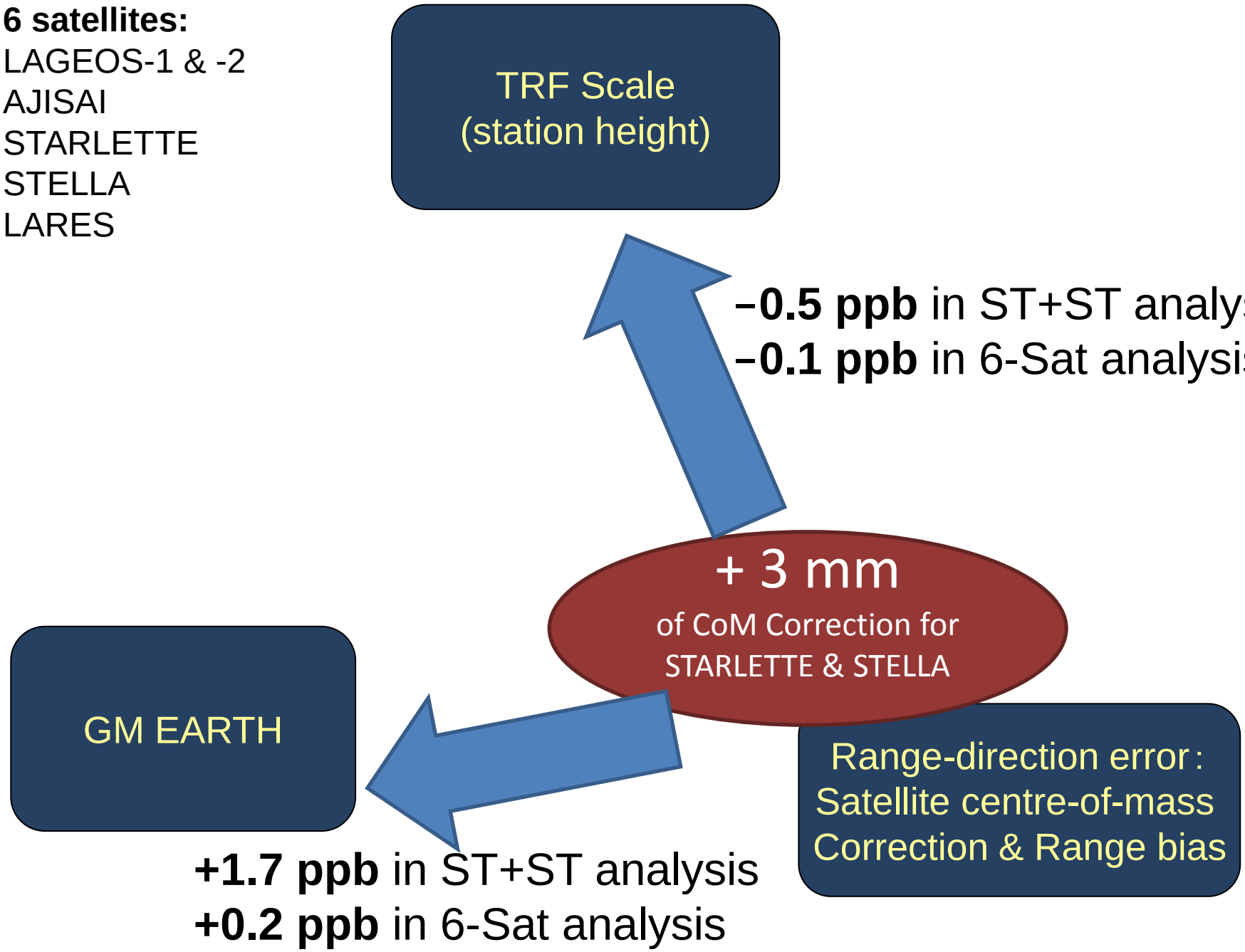


PROVISIONAL but almost FINAL
(Do not use these values for critical purposes)

LARES p~1.1



6 satellites:
LAGEOS-1 & -2
AJISAI
STARLETTE
STELLA
LARES



Possible Long-term Trend of CoM Corrections

Early days (1970s & 80s)

System response >> Signatur

→ CoM Correction ~ Centro

Modern Multi-photon

Leading edge or C-SPAD

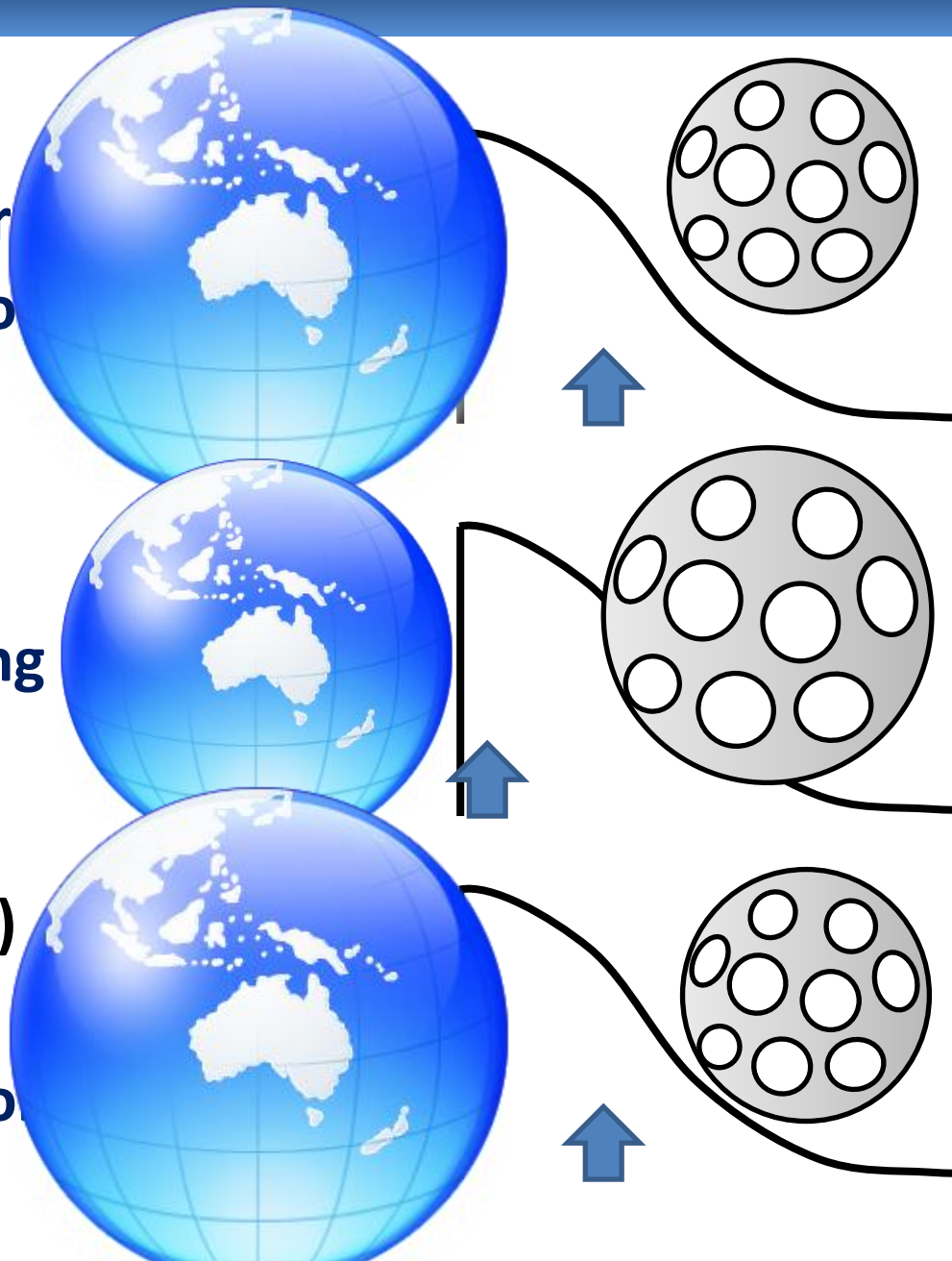
→ CoM Correction ~ Leading

Modern Single-photon

(incl. kHz ranging to high sats)

Mean of the residual profile

→ CoM Correction ~ Centro



Conclusions and Future Studies

Center-of-mass correction of Starlette (& Stella) and LARES

- kHz single photon data (Herstmonceux & Potsdam): useful for this study.
- System-dependence: up to 6-7 mm for both.
- Starlette: "Standard" 75 mm too small. 75 to 82 mm

  (Very good agreement with Arnold (1975) at the centroid (= 75 mm))
- LARES: "Standard" 133 mm reasonable. 129 to 135 mm.

Impacts to geodetic parameters → sub-ppb global params

- 3 mm offset error in Starlette:

  ← Already pointed out by some analysts (Ries, 2008; Sosnica, 2012)

  0.1 to 0.5 ppb bias in TRF (although it is not often used for this purpose)

  0.2 to 1.7 ppb bias in GM ($3.986004\underline{15} \times 10^{14}$ km^3s^{-2})
- Key factor for future geodetic missions. Possibly having affected the long-term TRF scale and GM?