Target Signature Effects on Laser Ranging Accuracy for the GIOVE Satellites

Toshimichi Otsubo (t.otsubo@srv.cc.hit-u.ac.jp)
Hitotsubashi University, Japan

Philip Gibbs and Graham M Appleby*
NERC Space Geodesy Facility, UK

NATURAL ENVIRONMENT RESEARCH COUNCIL

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kHz & Single Photon !

kHz System:

More shots, More returns

Sharp pulse width (10 ps at Hx)

Single Photon System:

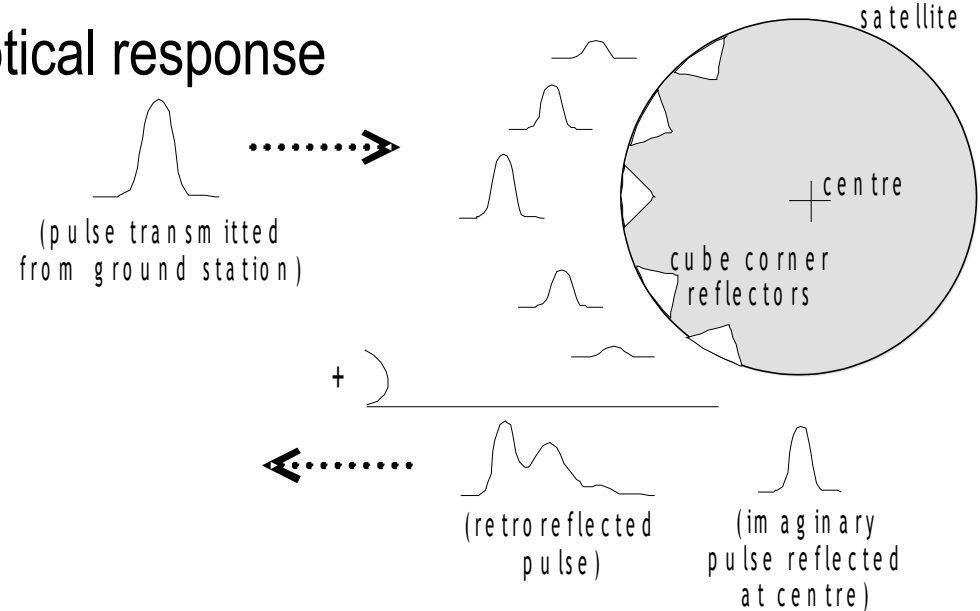
No intensity dependence → Systematic bias minimised

Large scatter, but the average profile of return pulse observable

kHz + Single Photon System:

Ideal tool for retrieving the satellite optical response

Works like a streak-camera



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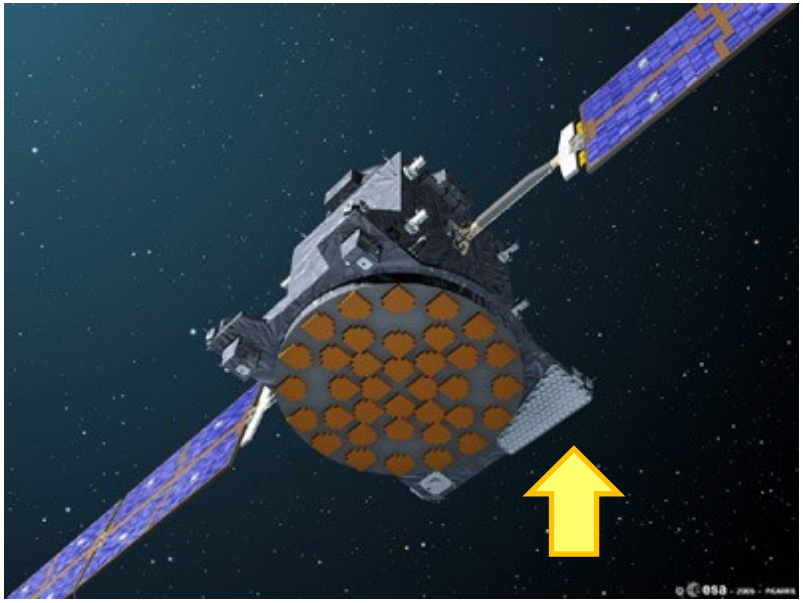
GIOVE-A and GIOVE-B

GIOVE = Galileo In-Orbit Validation Element

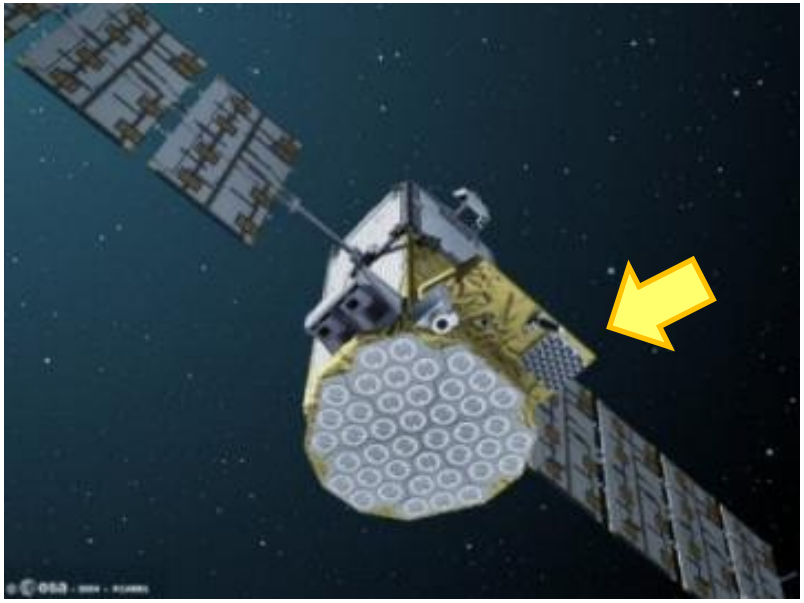
GIOVE-A : launched on 26 Dec 2005.

GIOVE-B: launched on 26 Apr 2008.

Routine SLR Tracking by ILRS Stations. Typ. 5 to 20 passes/sat/week.



GIOVE-A



GIOVE-B

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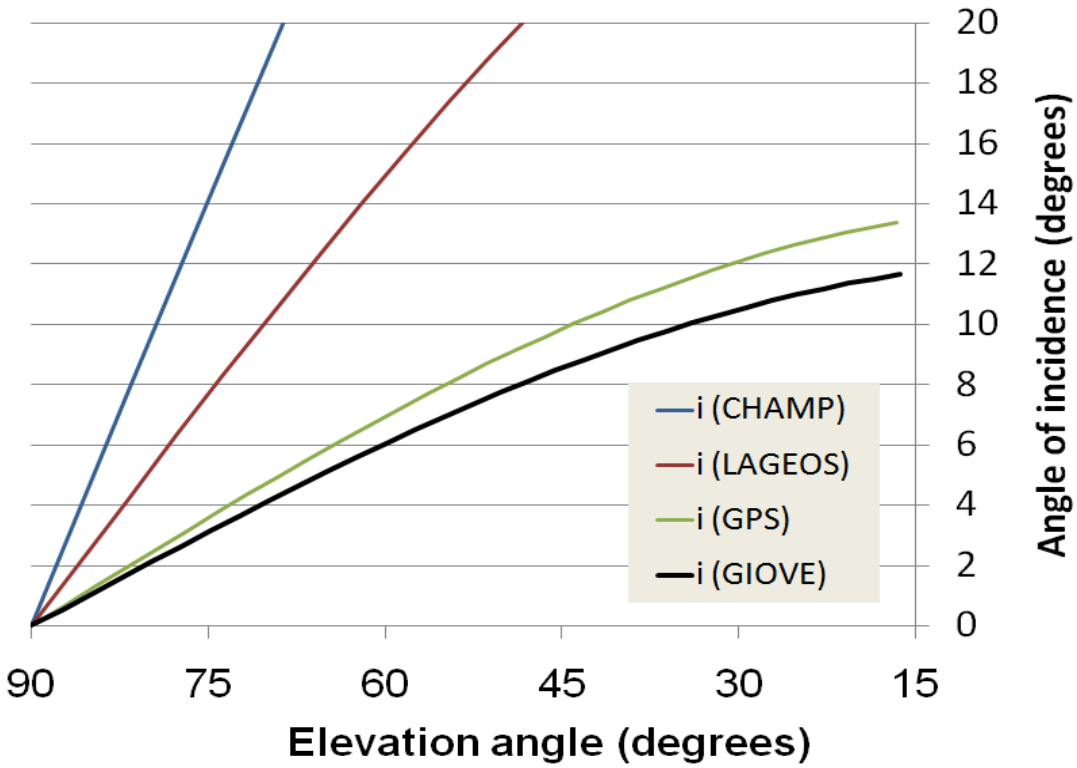
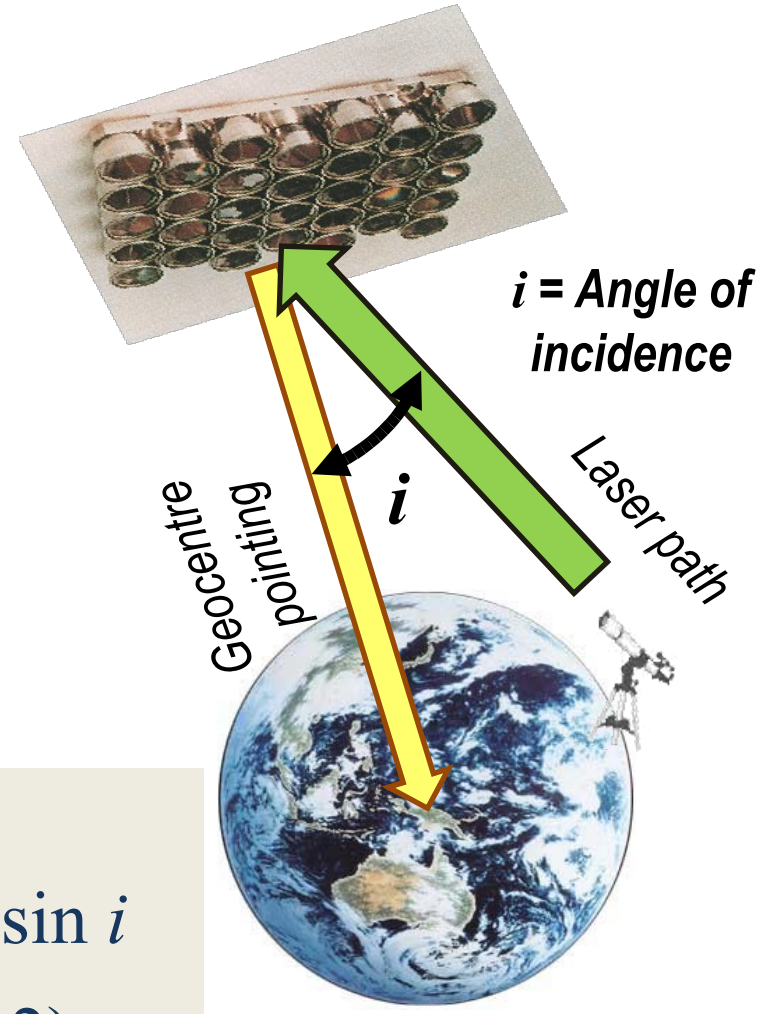
Images: ILRS Website

Angle of incidence toward a planar array





GIOVE (alt. 23900 km)

El = 48° → i = 8°

El = 34° → i = 10°

El = 20° → i = 11.4°

[Pulse spread]
= [Array size] x sin i

$(\sin 11.4^{o} \sim 0.2)$

cf. GLONASS 1.2 m x 1.2 m array
Otsubo, Appleby and Gibbs, Surveys in Geophysics, 2001.

GIOVE-A reflector array

GIOVE-A : Trapezoidal array

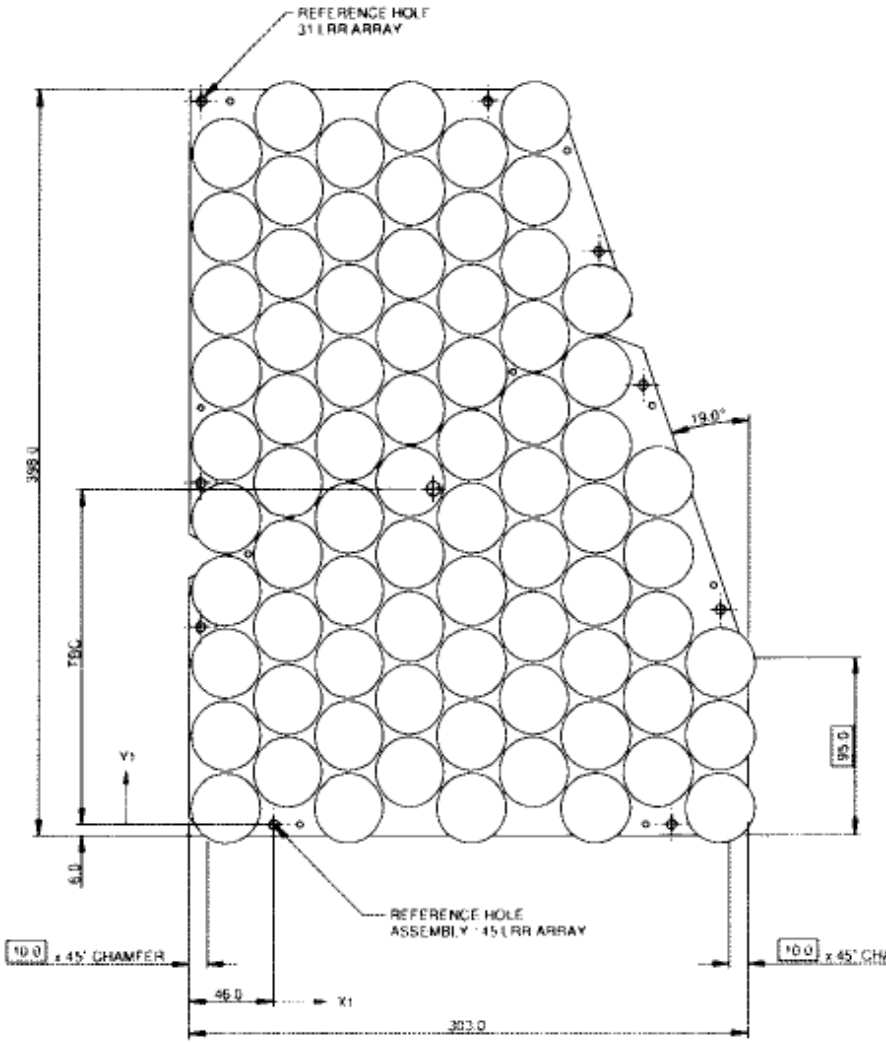
Planar arrangement

Number of retros: **76**

27-mm diameter, al-coated

32 cm (width = x)

x **39 cm** (height = y)



GIOVE-A

Image: ILRS Website

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GIOVE-B reflector array

GIOVE-B : Square array

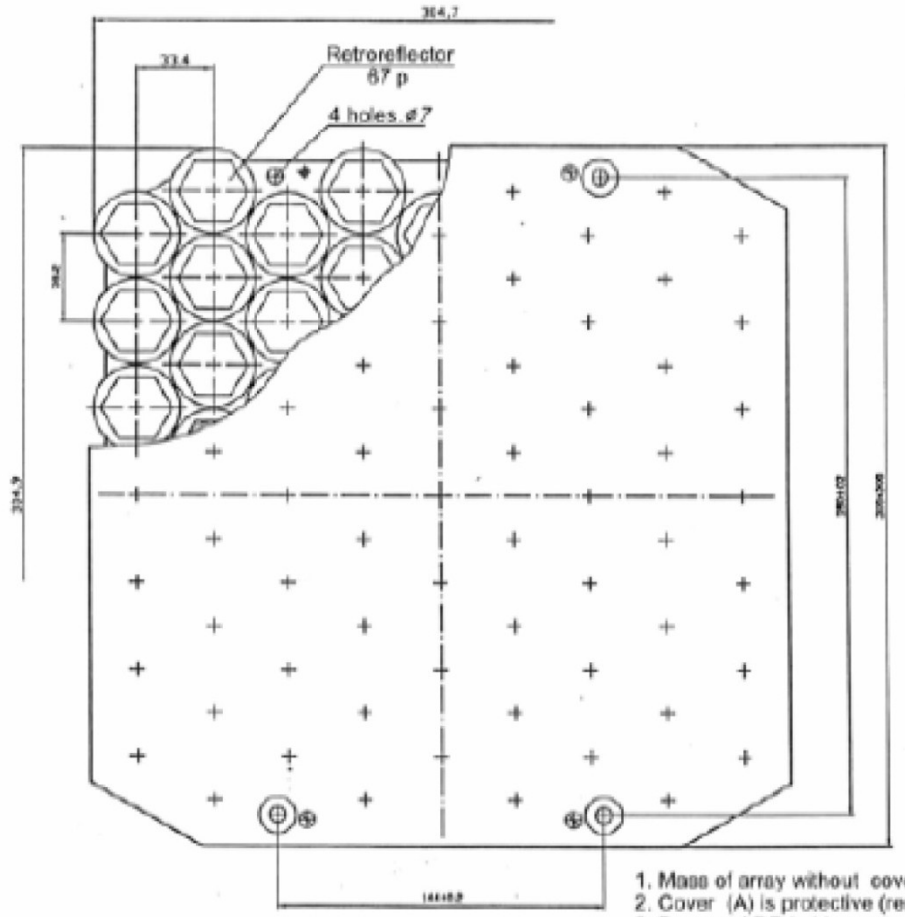
Planar arrangement

Number of retros: **76**

27-mm diameter, al-coated

30 cm (width = x)

x **30 cm** (height = y)



GIOVE-B

Image: ILRS Website

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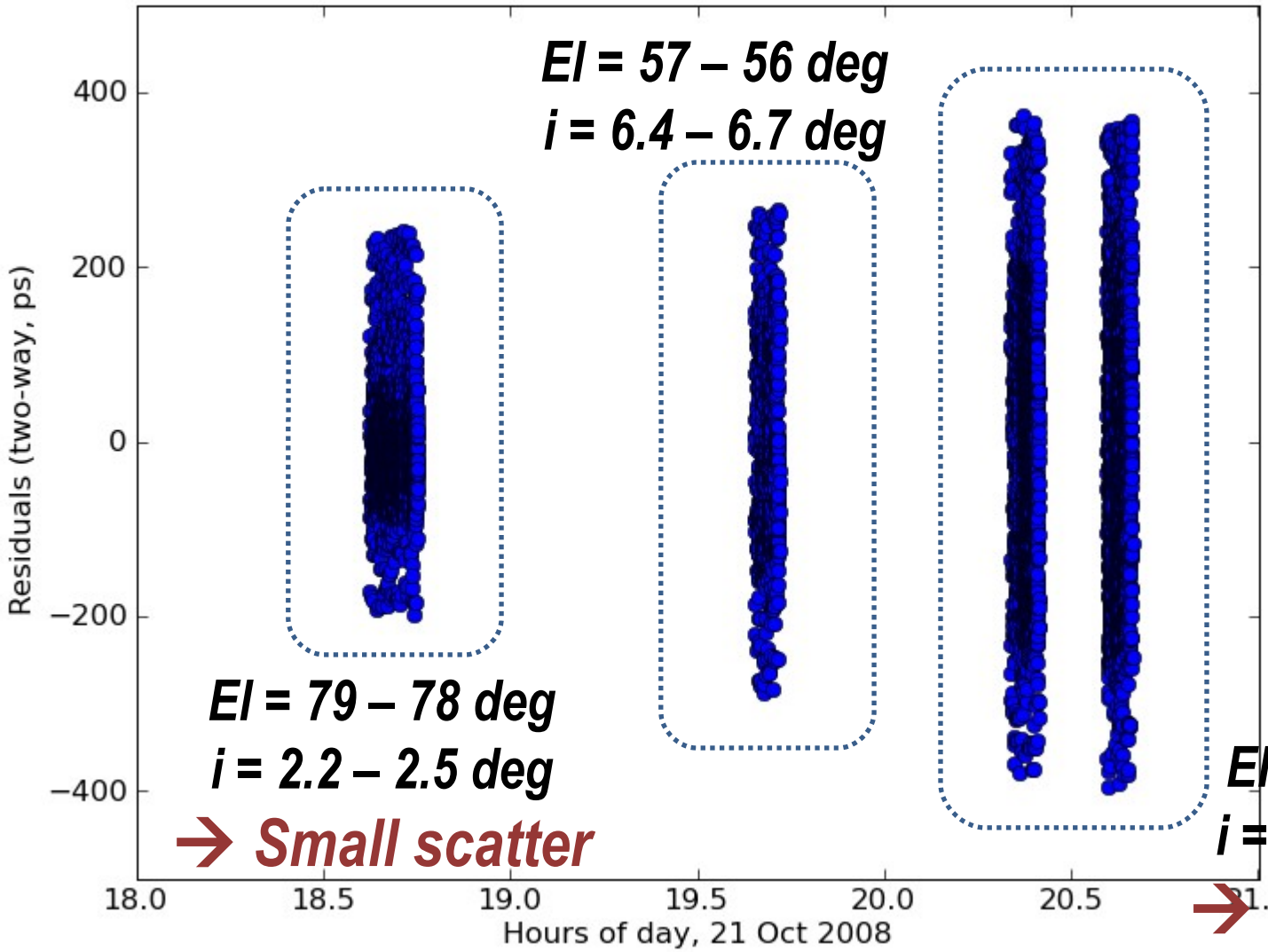
Pulse spread: Hx residual scale



Pulse spread

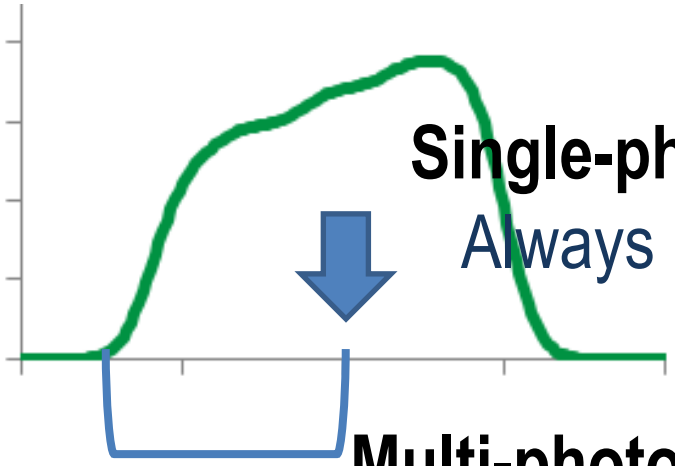
[Pulse spread] = [Array size] x $\sin i$

For instance,

(EI = 34° →) i = 10°, Array size = 30 cm

Pulse spread = 30 cm x sin 10° = 5.3 cm

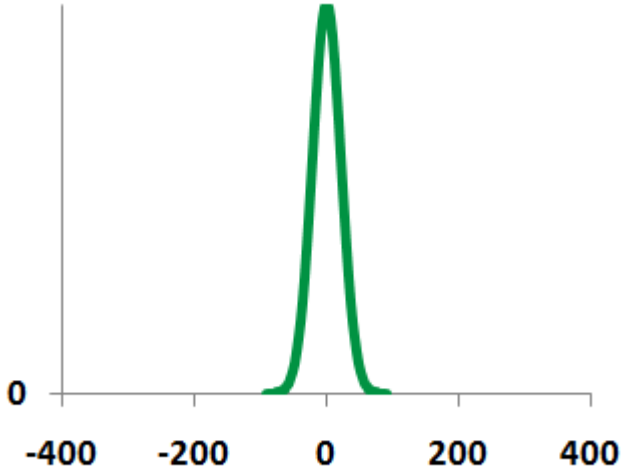
→ Big challenge for "mm-ranging" !!



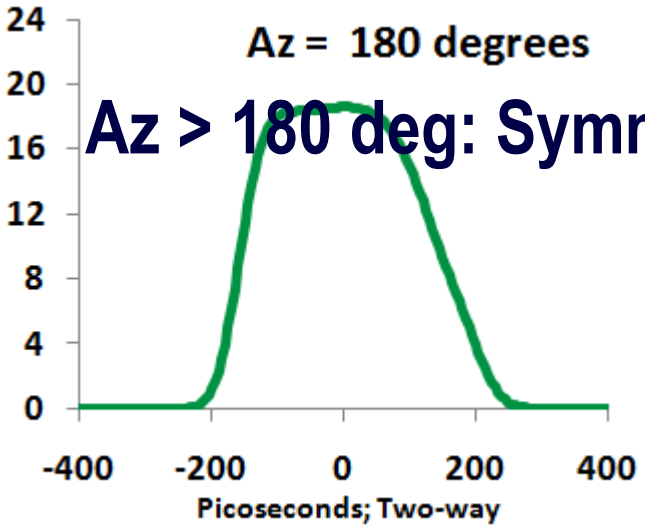
Single-photon systems:
Always refer to the centroid.

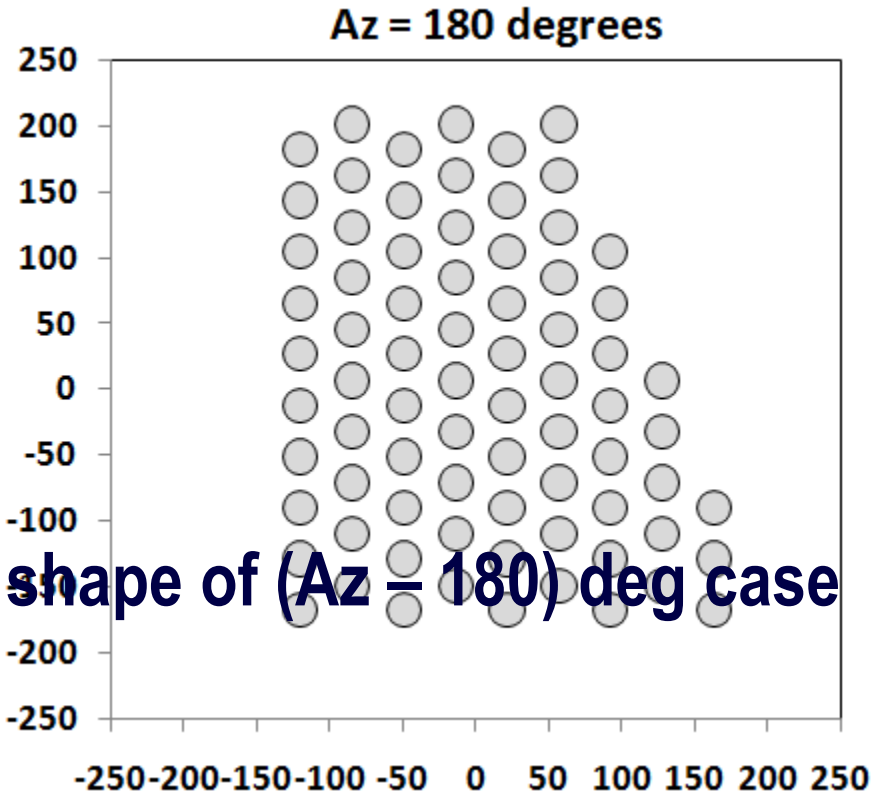
Multi-photon systems:
Refer "somewhere" in this region.

Modeled pulse shape from GIOVE-A



Unit: ps

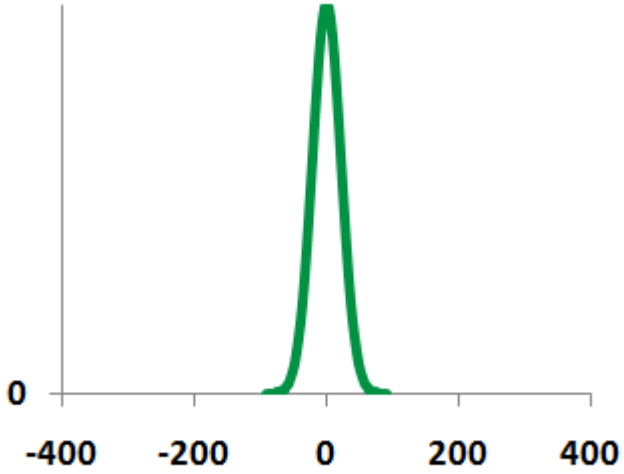




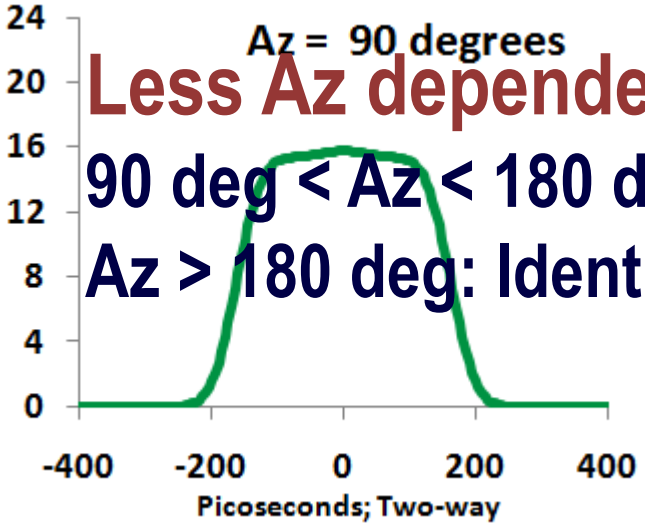
Unit: mm

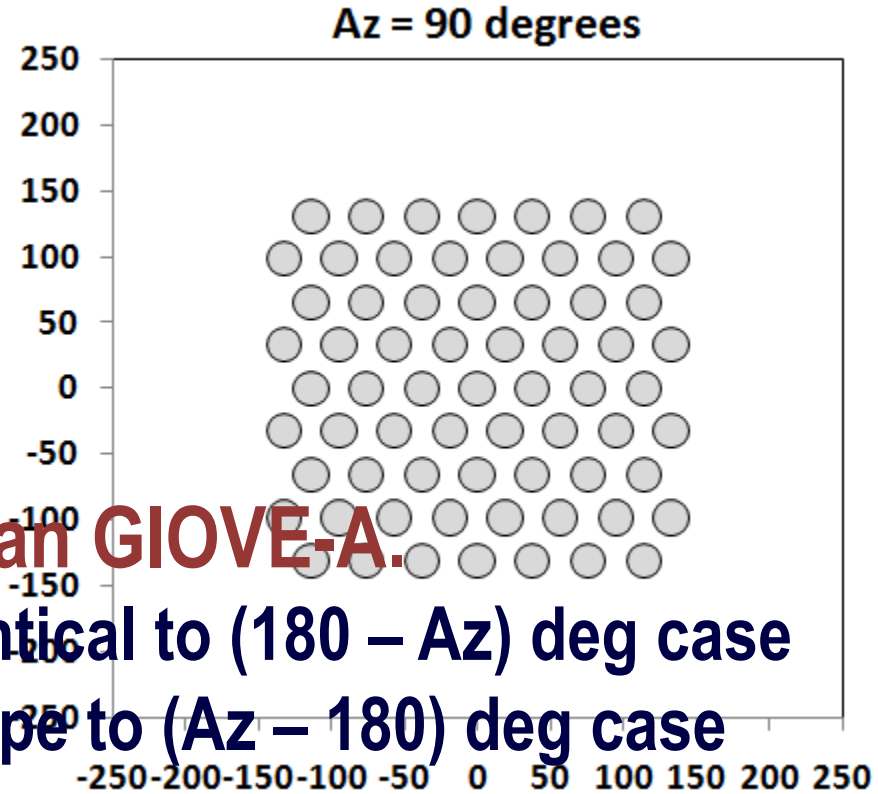
Az > 180 deg: Symmetrical shape of (Az – 180) deg case

Modeled pulse shape from GIOVE-B



Unit: ps





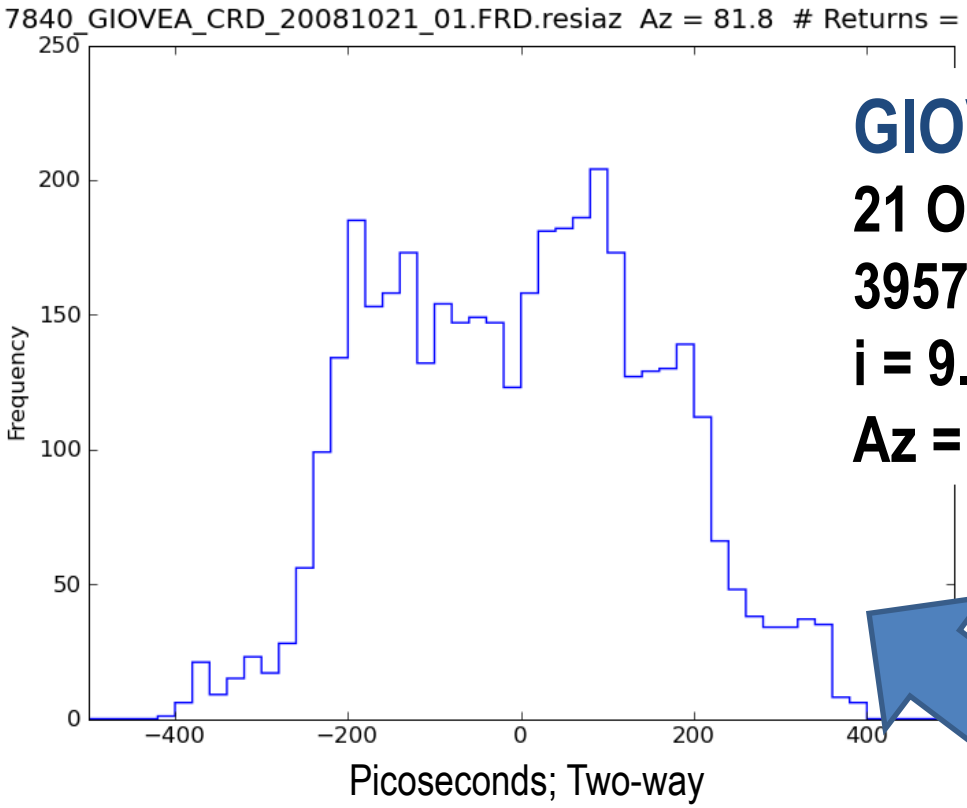
Unit: mm

Less Az dependence than GIOVE-A.

90 deg < Az < 180 deg: Identical to (180 – Az) deg case

Az > 180 deg: Identical shape to (Az – 180) deg case

Pulse shape: Hx Obs. vs Model



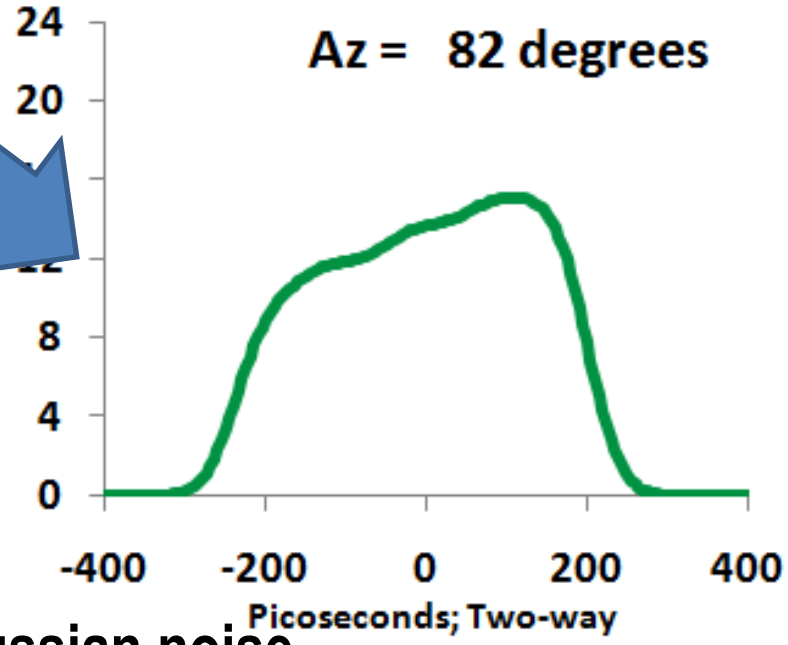
GIOVE-A Residuals (Hx best case)

21 Oct 2008

3957 returns

i = 9.2 — 10.2 deg (scaled to 10 deg)

Az = 85 — 78 deg



GIOVE-A Model

i = 10 deg

Az = 82 deg

Convolved with 30-ps Gaussian noise

Discussion & Future studies

Reflector array size

Was critical for 1.2-m old GLONASS array in 2001.
Is/Will be critical for 30-40 cm GIOVE and other GNSSes.
Intensity-dependent, El-dependent error for multi-photon systems.
Array size vs Intensity: Shouldn't we be more accuracy-oriented?

Reflector shape

Non point-symmetric shape like GIOVE-A (and old GLONASS)
→Az-dependent error for multi-photon systems.

More "kHz single-photon" data required

for more comprehensive research.