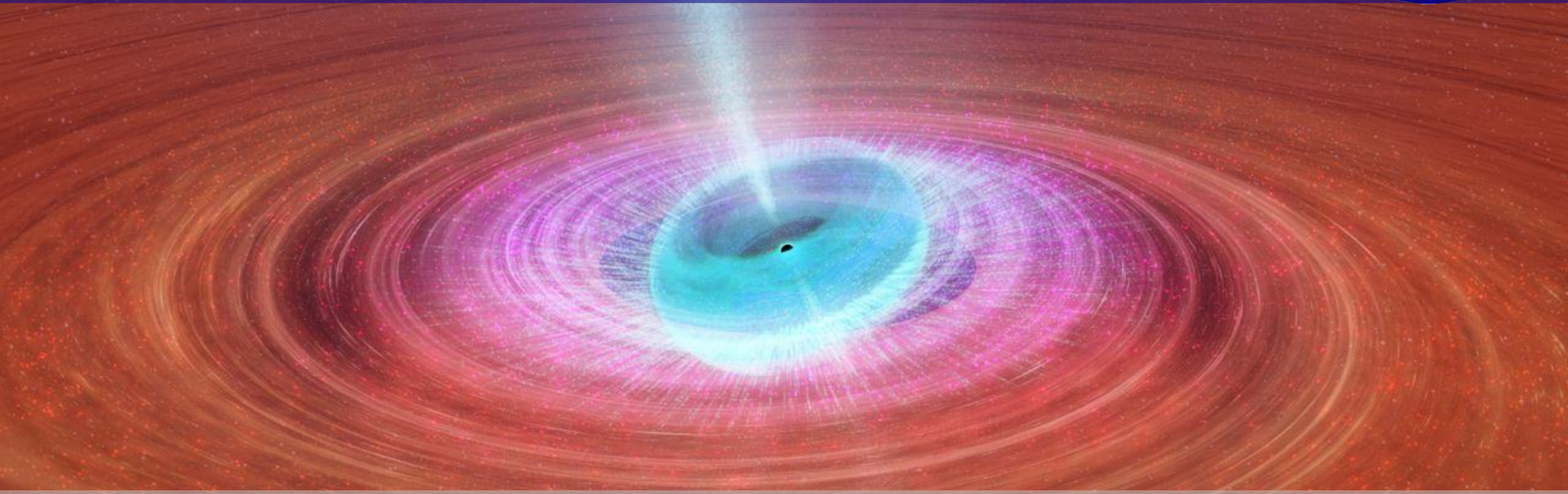
# Picosecond Intensity Interferometry to resolve accreting sources



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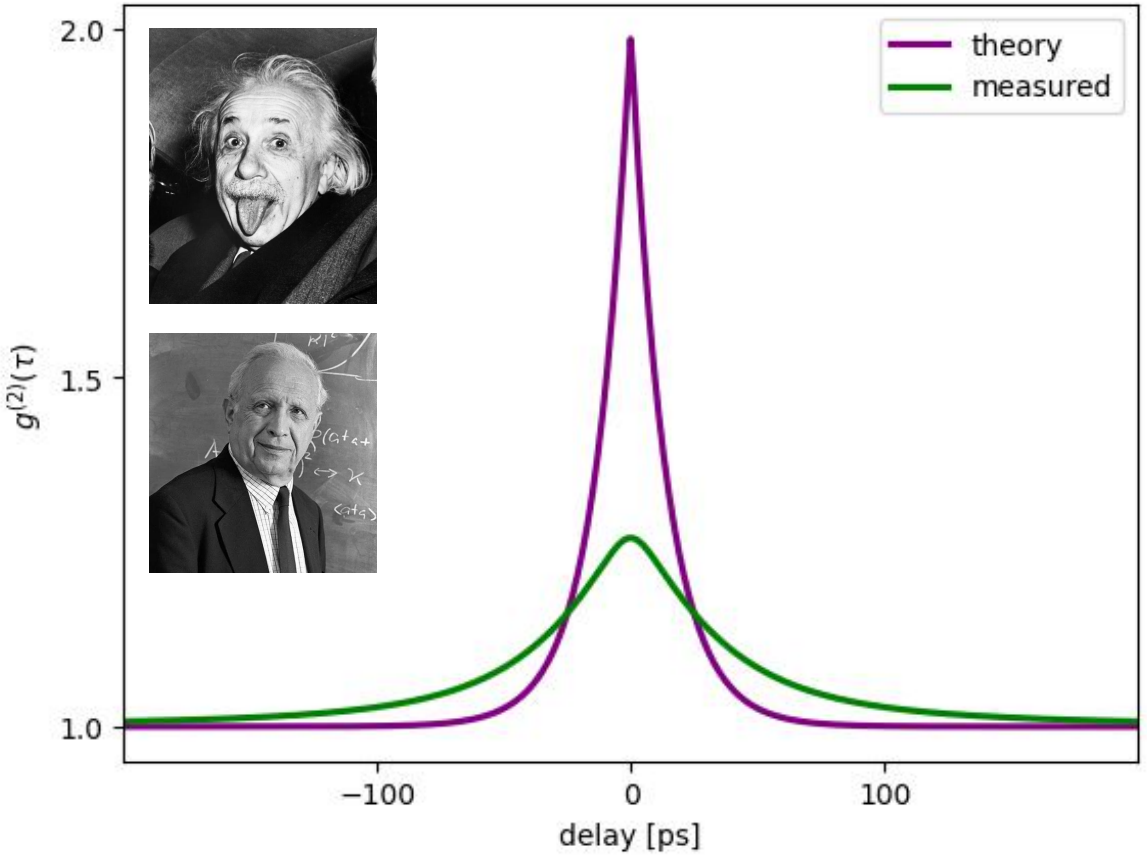
UNIVERSITÉ DE GENÈVE

# History



$$g^{(2)}(\tau, d) \propto \langle I_1(t) I_2(t+\tau) \rangle$$
$$\vdots$$
$$= 1 + |\mathcal{F}(f)|^2 \cdot |V(d)|^2$$

- First experimental proof : R.Hanbury Brown & R.Q.Twiss (1956 )
- Measurement of angular diameter of Vega



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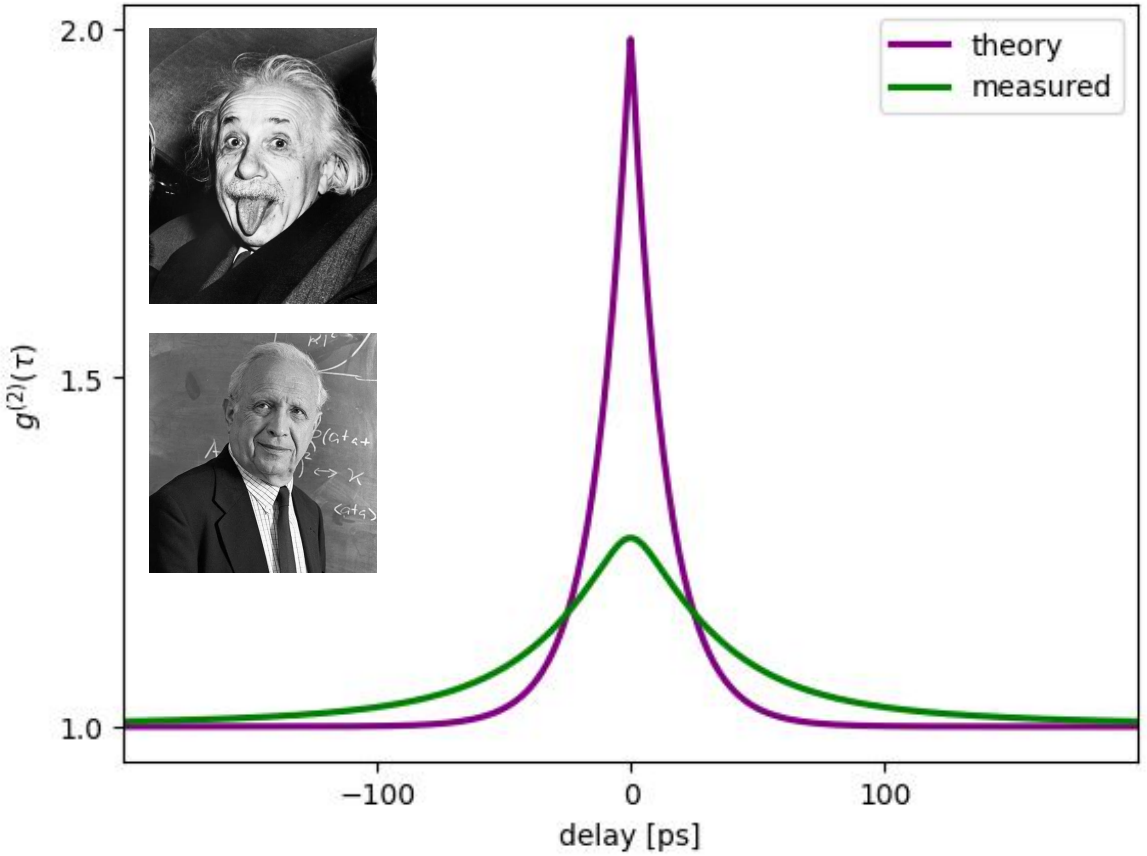
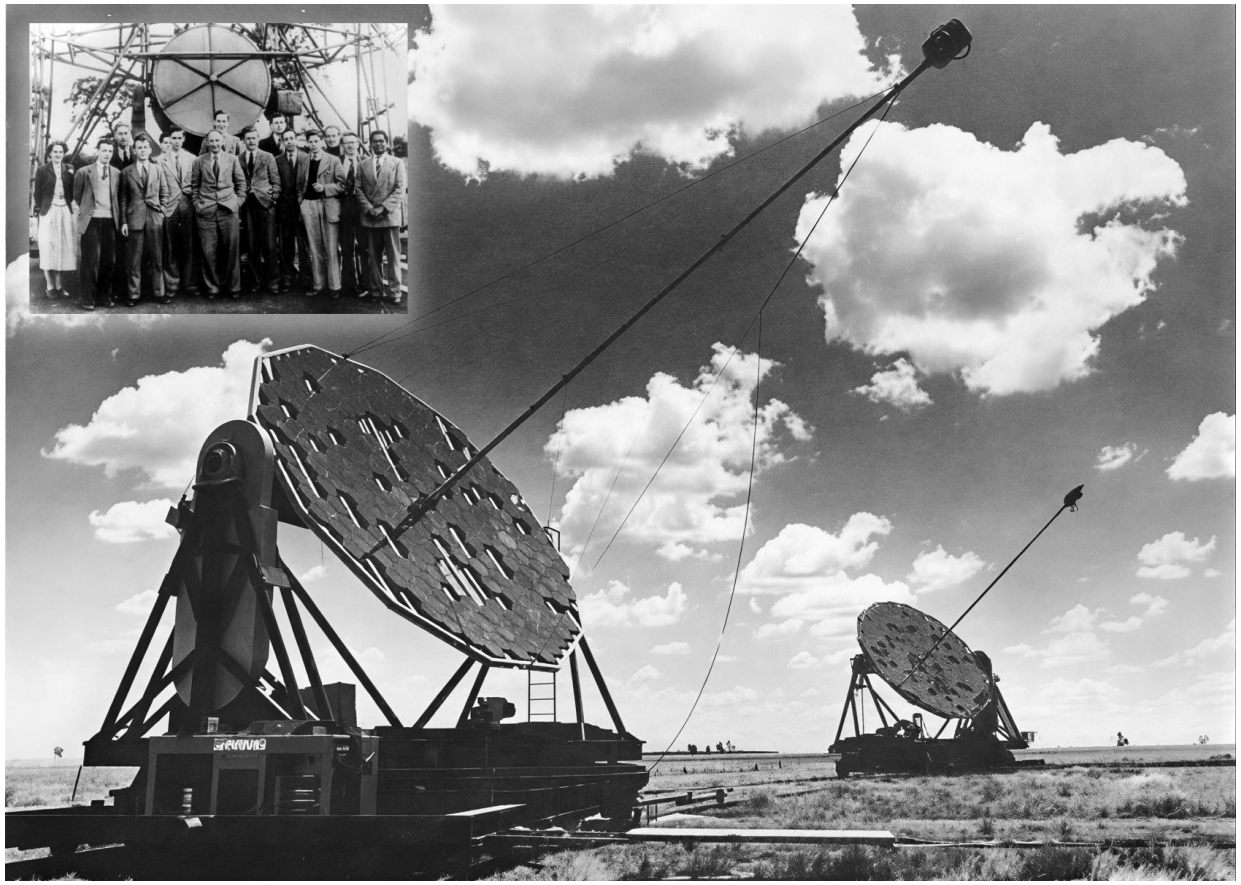
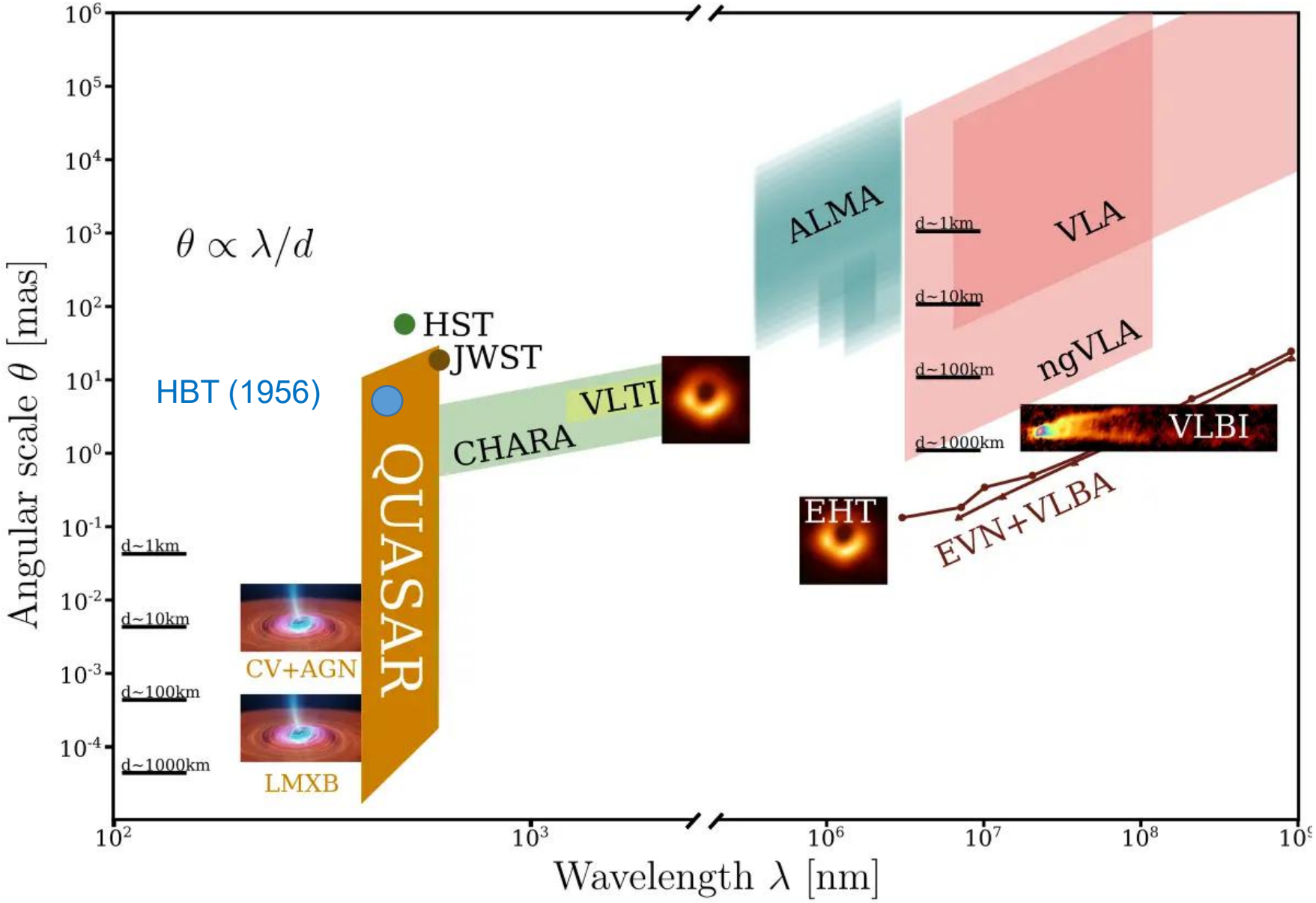


# QUASAR project



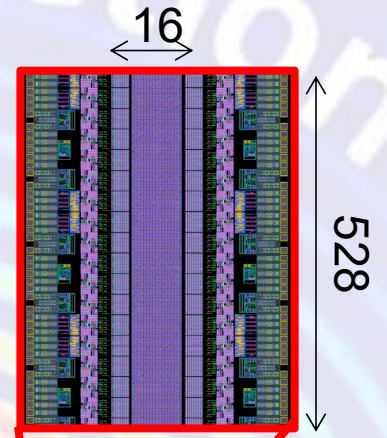


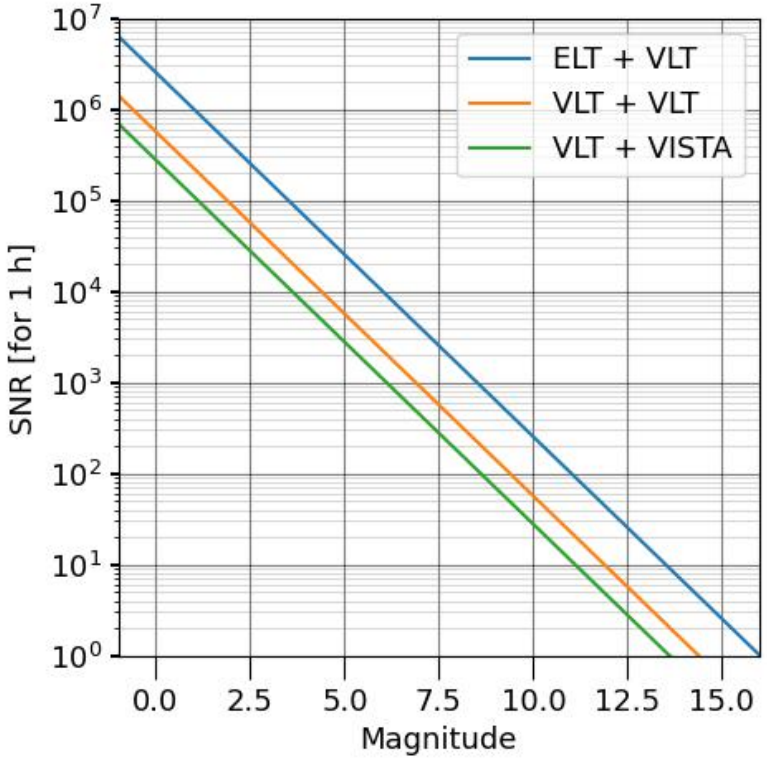
# QUASAR key improvements



$$\mathrm{SNR} \sim \sqrt{A_1 A_2}\sqrt{N_{chan}}\sqrt{\frac{T_O}{\sigma_t}}$$

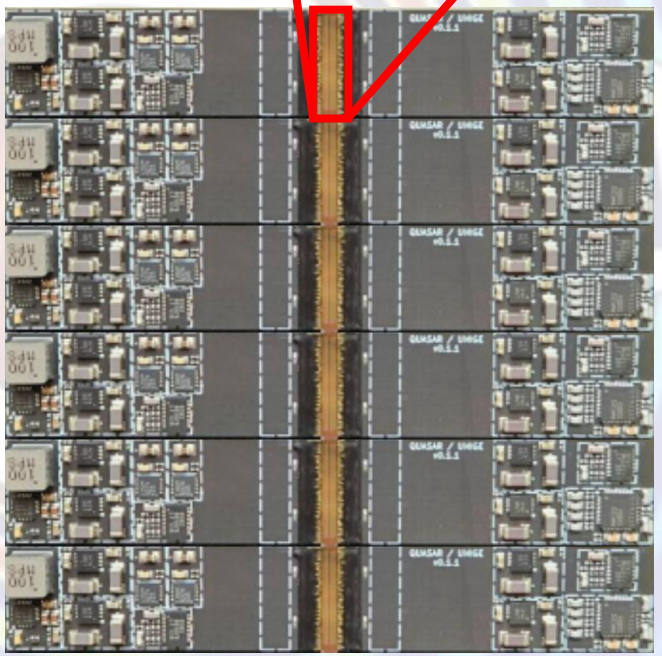
- 60% fill factor
- ~3ps LSB
- 40% QE
- 41Gb/s




| Targets | Size (θ) | Baseline (λ/tan θ) |
|---|---|---|
| 0.01AU astrometry on α Centauri AB | 2 μdeg | 10 m |
| Decretion disks | μdeg | 50m |
| Stars and stellar systems | μdeg to ndeg | 50m-km |
| Micro to nano structures on the Sun | μdeg to ndeg | m-km |
| White dwarfs **VLT-Vista 2027** | 8 ndeg | 2.5 km |
| Accretion disks around white dwarfs | 5 ndeg | 2 km |
| Broad line region in quasars, $H_0$ | 1-100 ndeg | 0.1-20 km |
| Tidal disuption events | 1-100 ndeg | 0.1-20 km |
| Stripped supernova @ 50Mpc **VLT-ELT 2030** | ndeg | 20 km |
| Supermassive star | ndeg | 20 km |
| Accretion disks of quasars | ndeg | 20 km |
| Disk & jet connexions | ndeg | 20 km |
| Binary black-holes | ndeg | 20 km |
| Lensing (differential astrometry: light halo, DM) | 0.3 ndeg | 60 km |
| Black-hole horizons | 100 pdeg | 200 km |
| Accretion disks around neutron stars | 30 pdeg | 600 km |
| Pulsar magnetosphere **ELT++ 2040** | pdeg | 10'000 km |

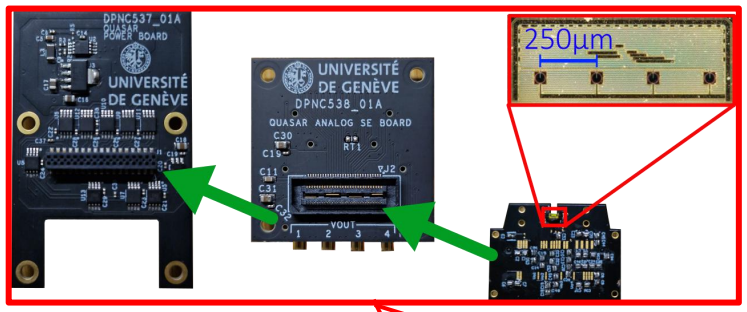
ELT+ 2040



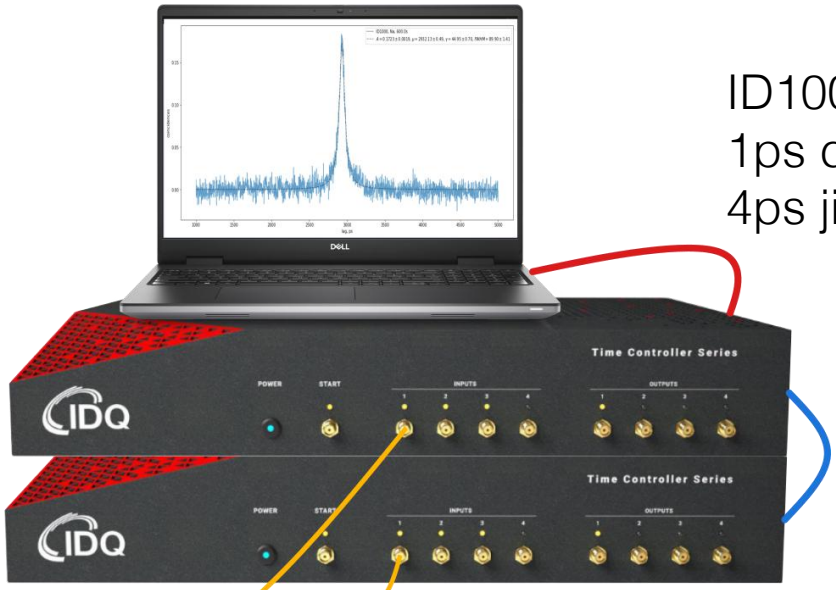
Recieved, tested now

# Current setup



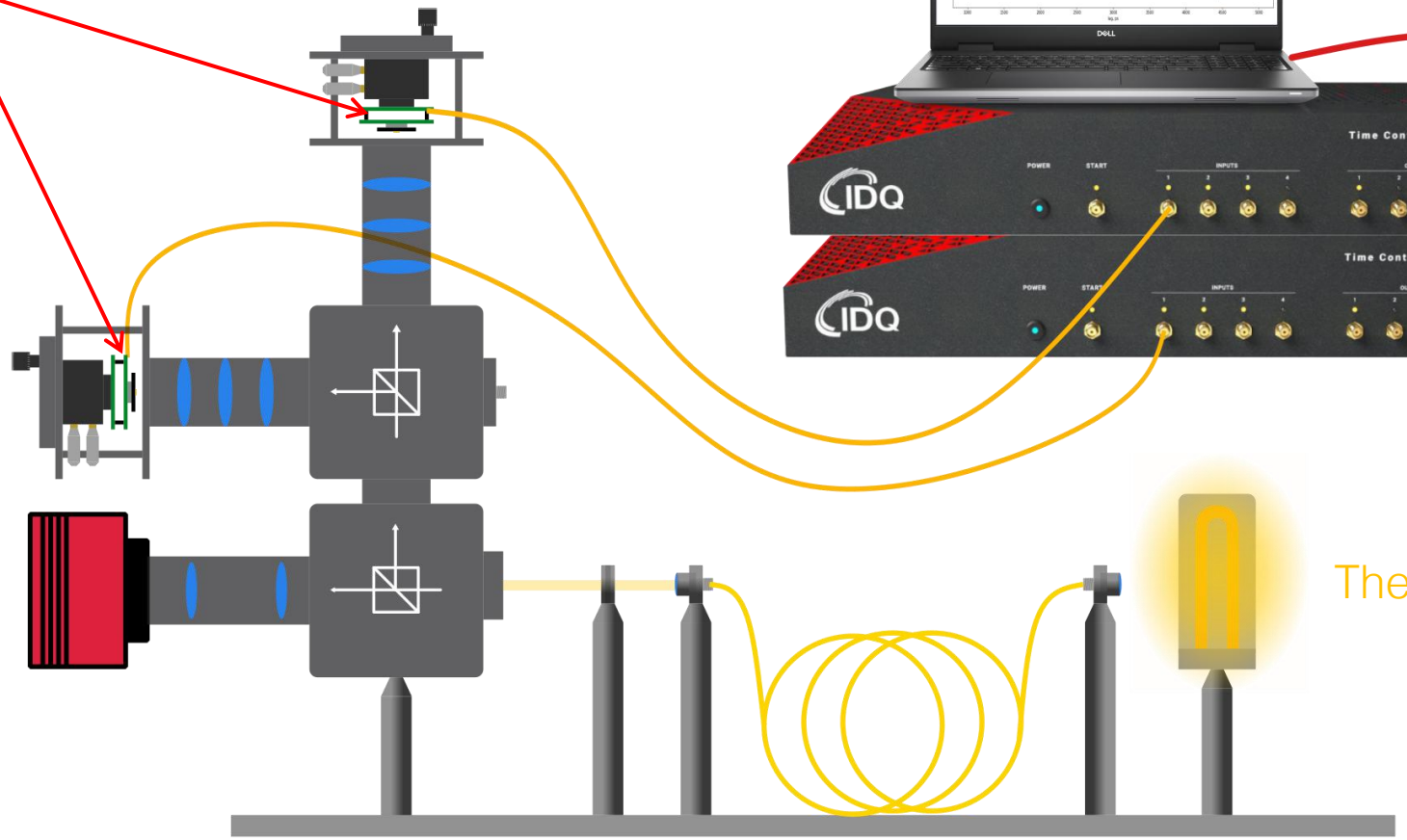



Offline correlations




ID1000 TDC
1ps digital res.
4ps jitter

Sync



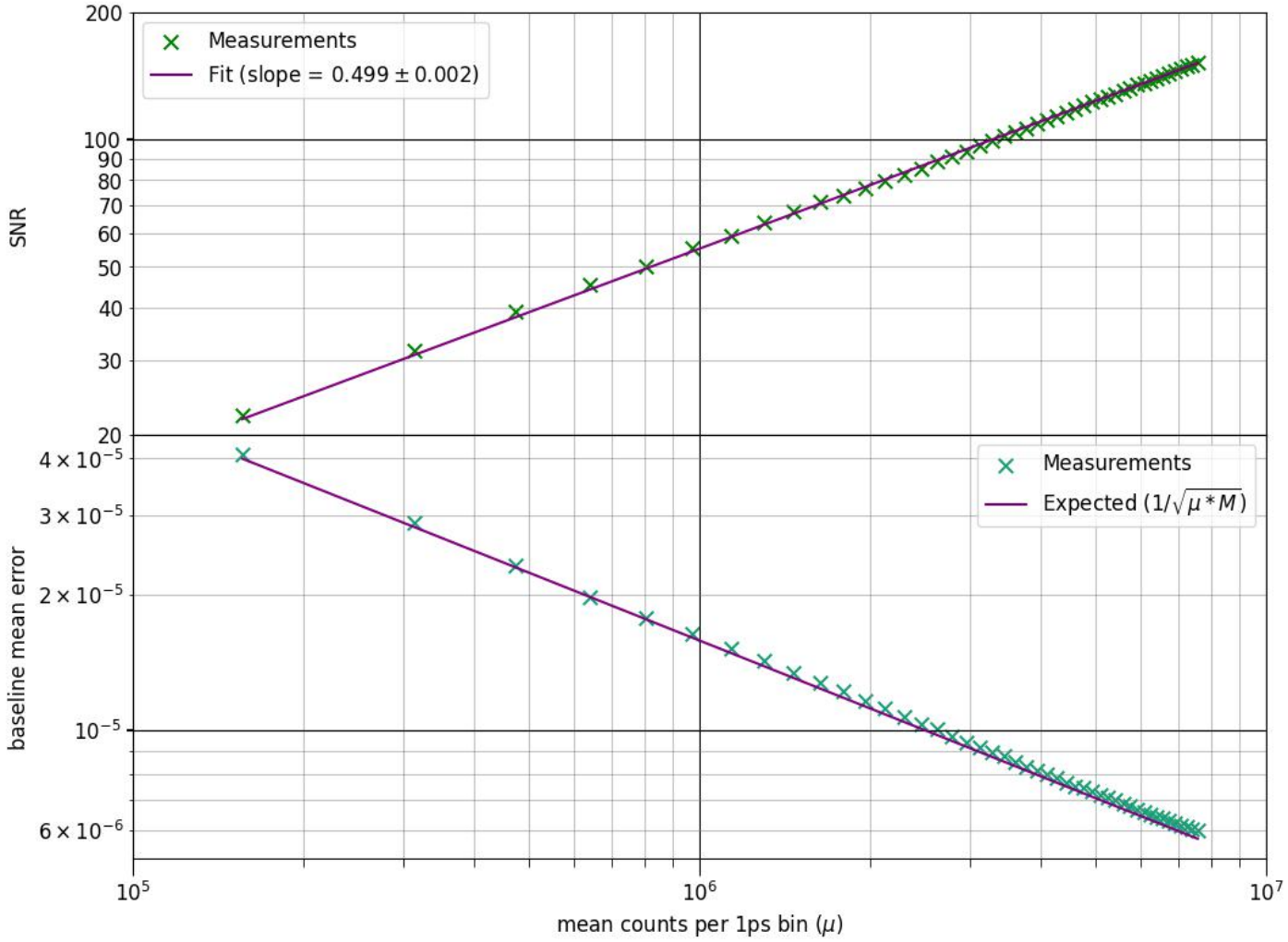
Thermal source + filter

# Current status & results: Specs



- Time resolution (fill system) : **10.4ps RMS**
- SNR grows as $\sqrt{\mu}$
- No systematics up to 7e6 cts/ps bin

$\mu$ = mean(random coincidence)

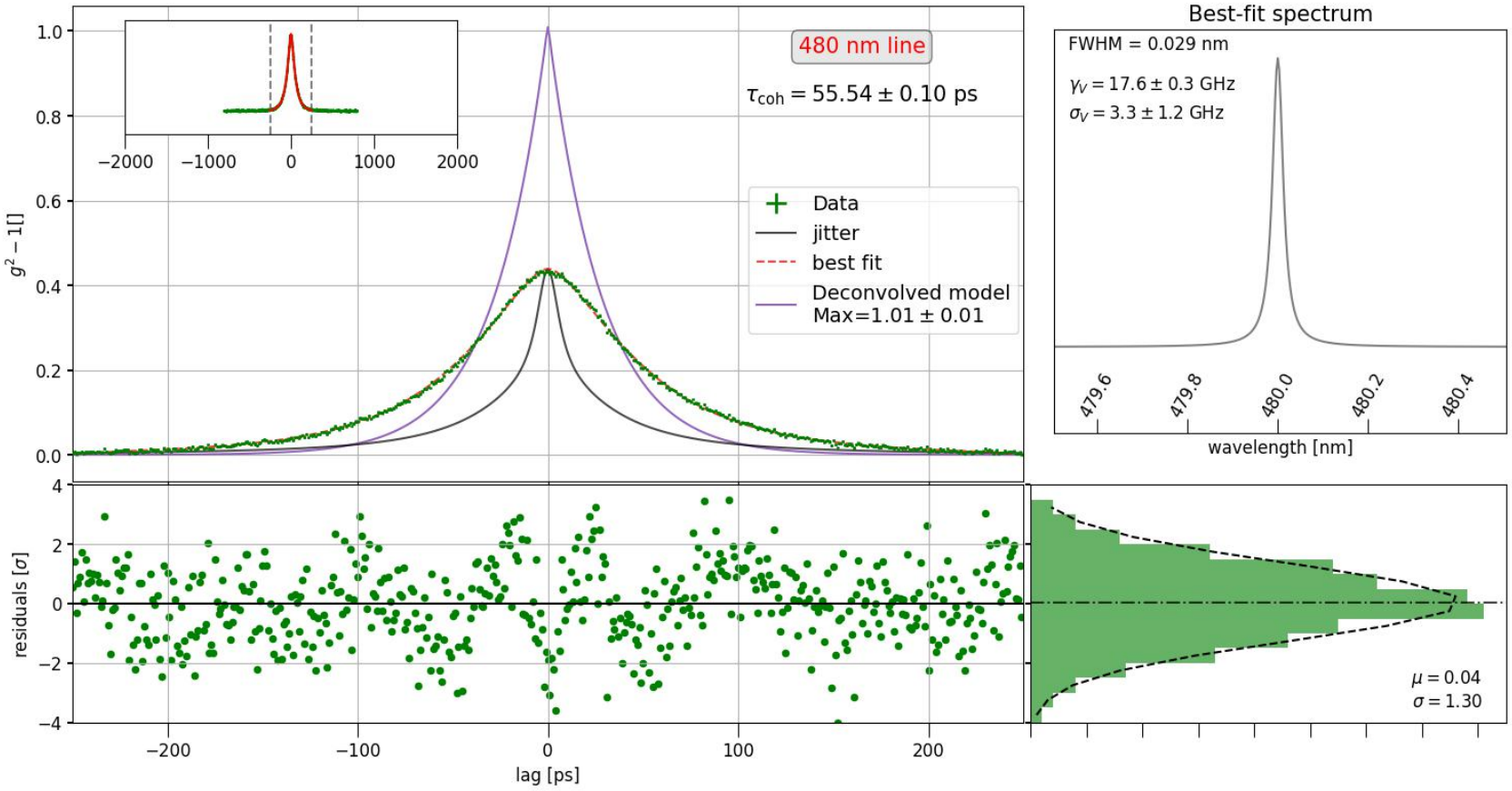


# Current status & results: Spectrum



$$g^{(2)} = 1 + |\mathcal{F}(f)|^2 \cdot |V(d)|^2$$

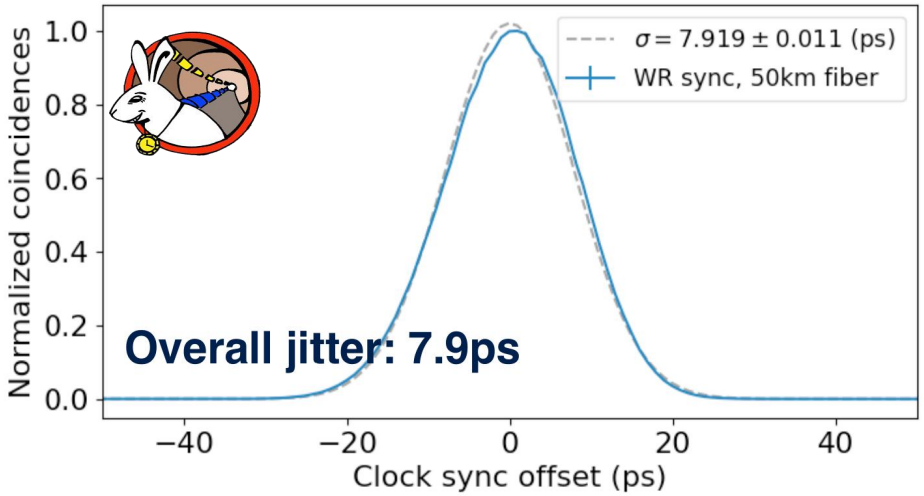
- Narrow line : higher coherence time
  - SM Amplitude recovered
  - Linewidth reconstructed (30pm)
  - Residuals excess (lineshape, lamp)

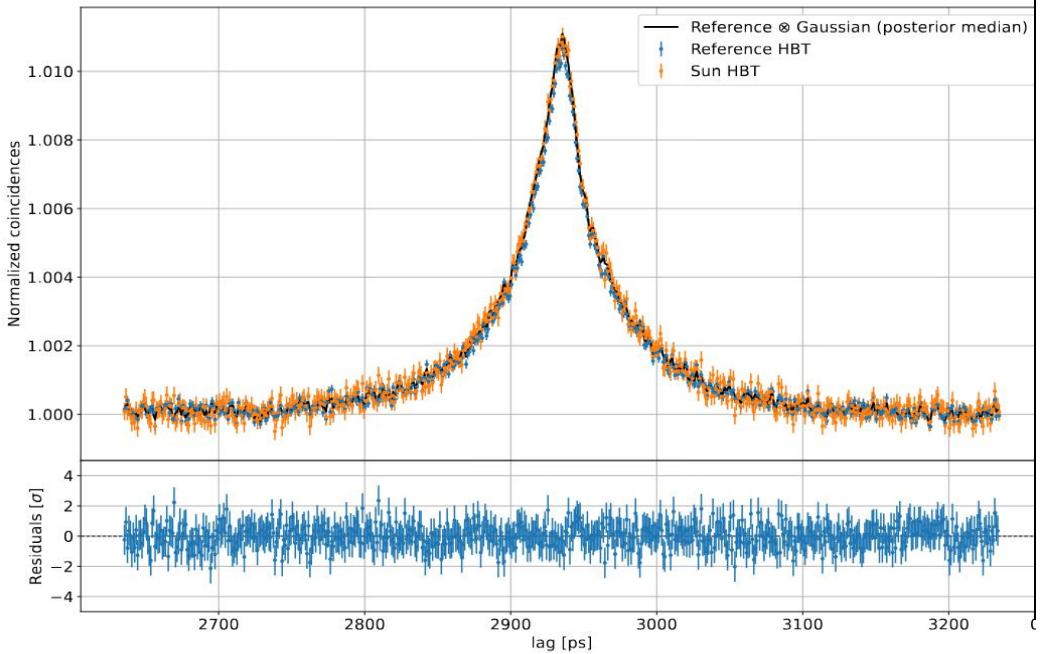


# Current status & results: Timing



- Spool in thermal chamber :0.2°C/h cycles
- Monitor mastaer-slave 10MHz sync
  - **7.9ps** time sync jitter



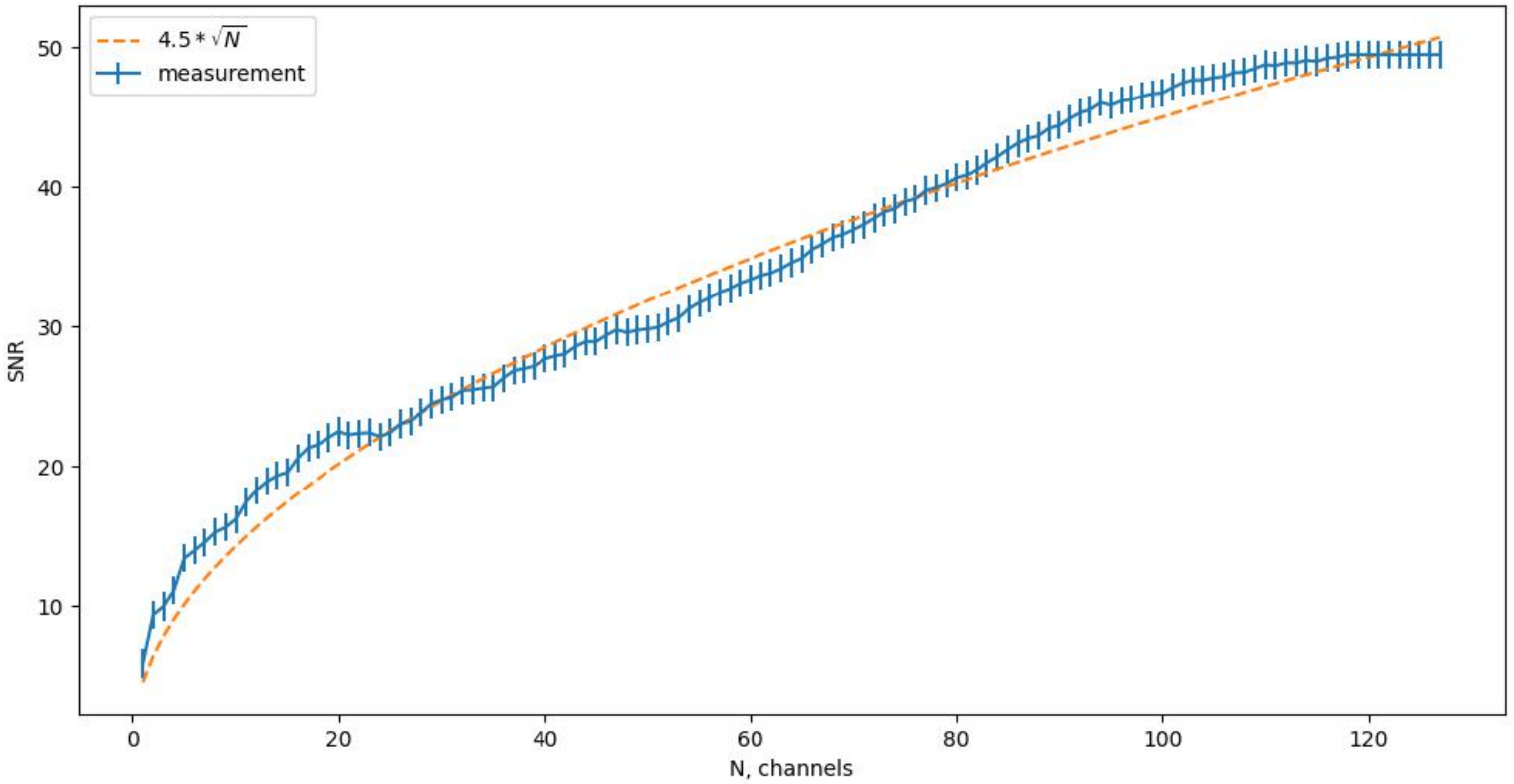



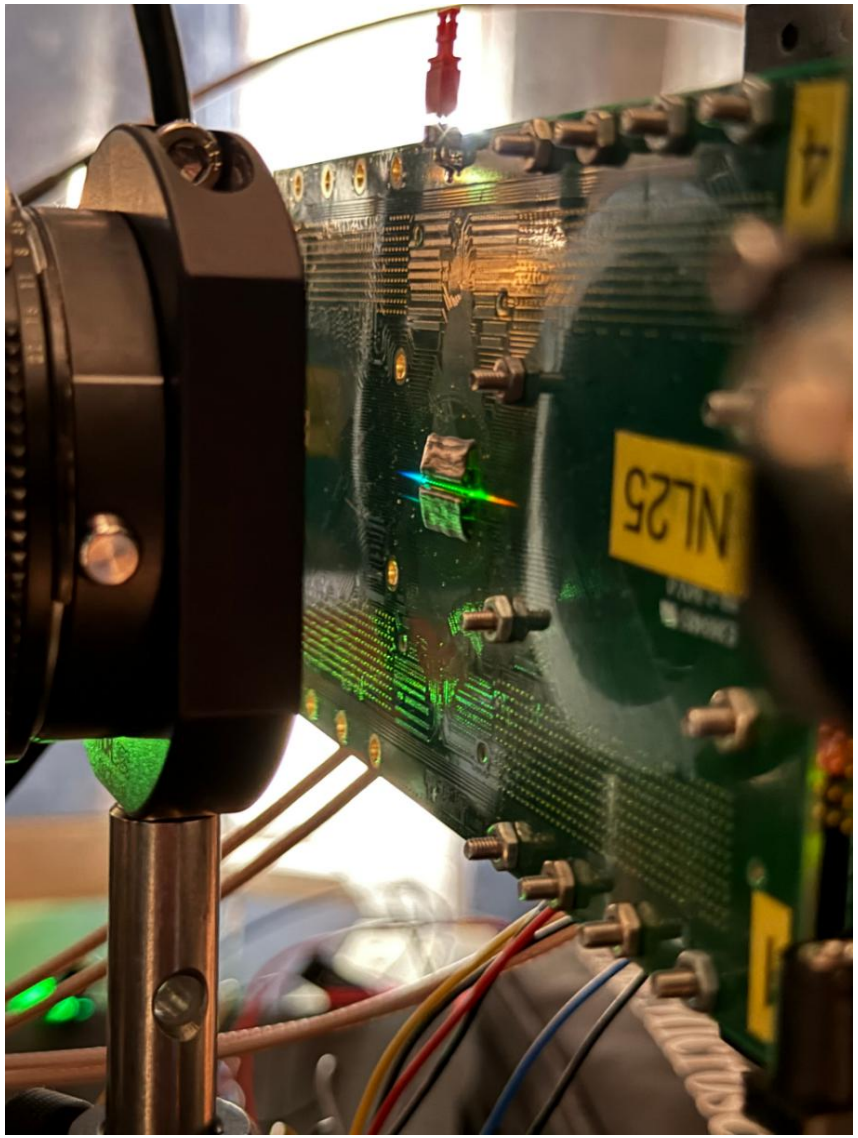

- Models : 30ps broadening
- Measure reference (led) VS sun
  - Measured broadening : **0.65 ps**

# Current status & results: Multiplexing



- Disperse the light on 2x128 channels
  - Spectrometer made in Geneva
  - Older version of detectors (~50ps)

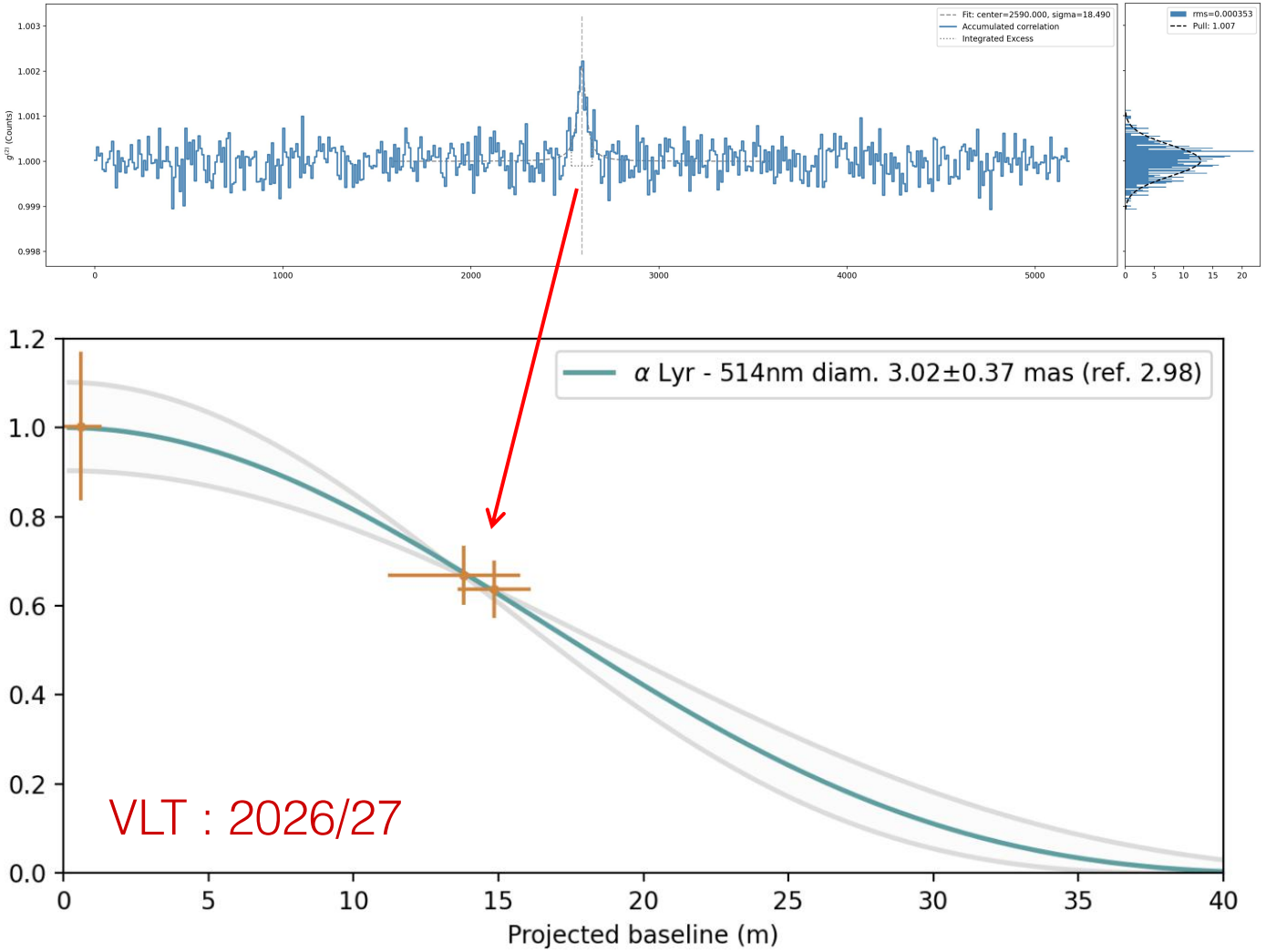


# Current status & results: Vega



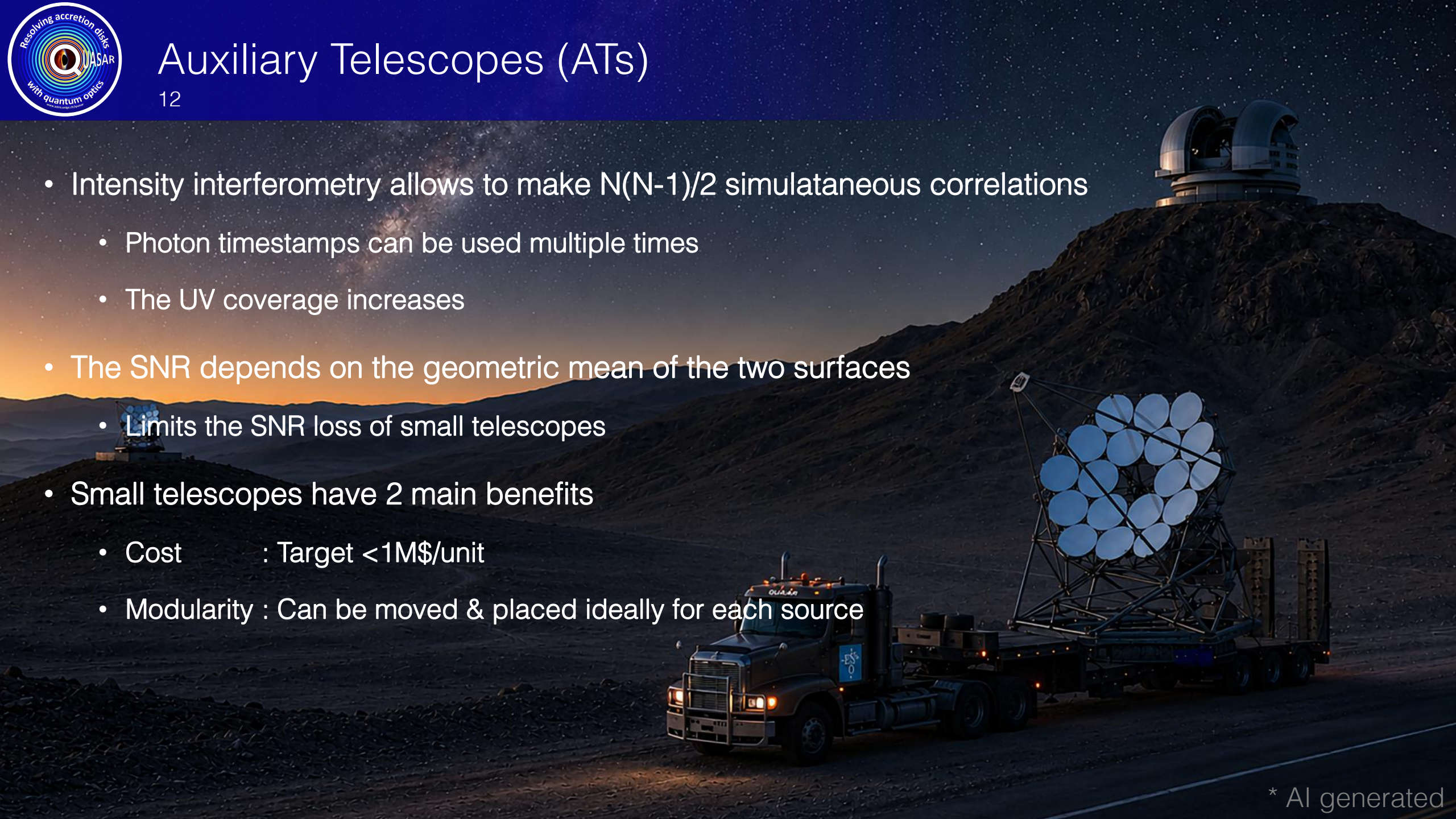
- Skinakas (Crete) + Calern (France)
- Bad weather for the full week
  - 4h of usable data

# Auxiliary Telescopes (ATs)



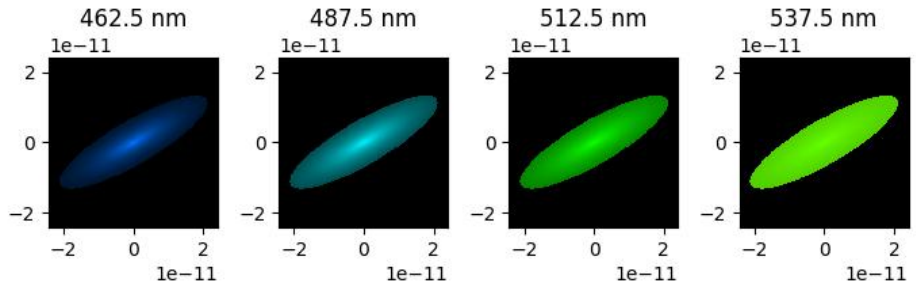
- Intensity interferometry allows to make N(N-1)/2 simulataneous correlations
  - Photon timestamps can be used multiple times
  - The UV coverage increases
- The SNR depends on the geometric mean of the two surfaces
  - Limits the SNR loss of small telescopes
- Small telescopes have 2 main benefits
  - Cost : Target <1M$/unit
  - Modularity : Can be moved & placed ideally for each source

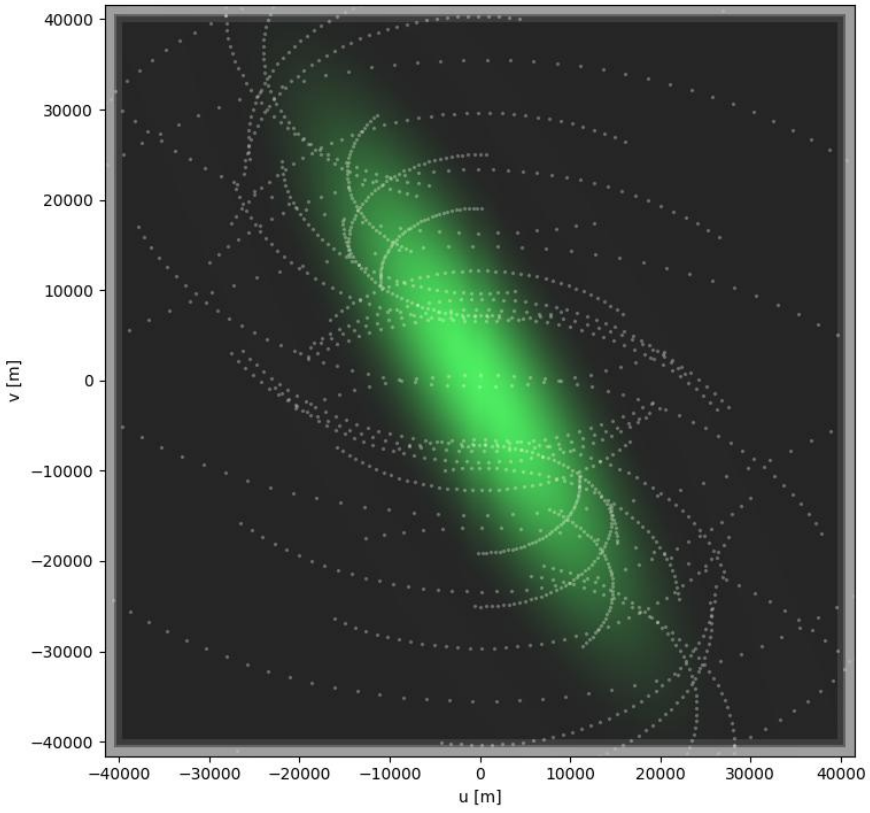


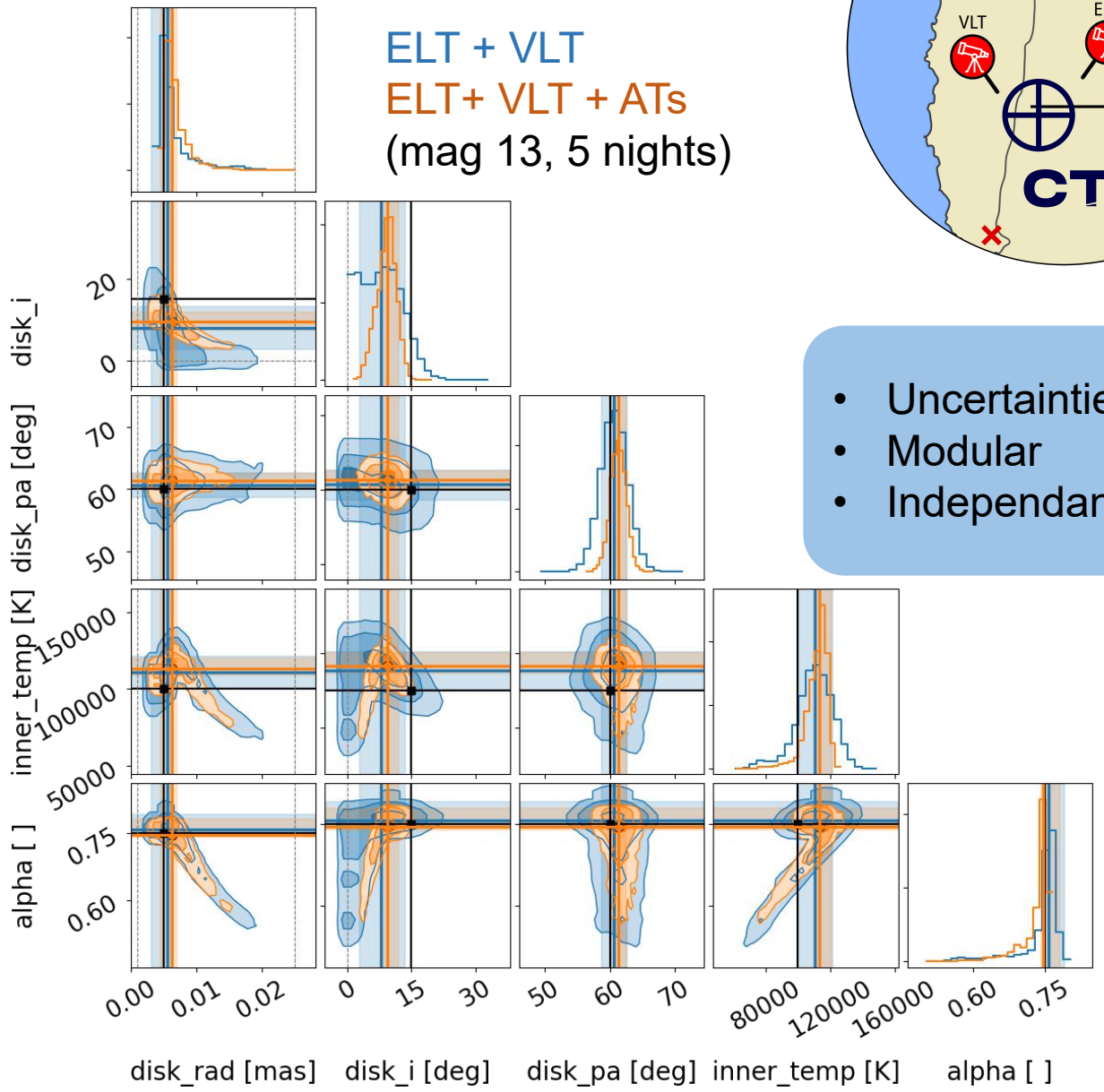
* AI generated

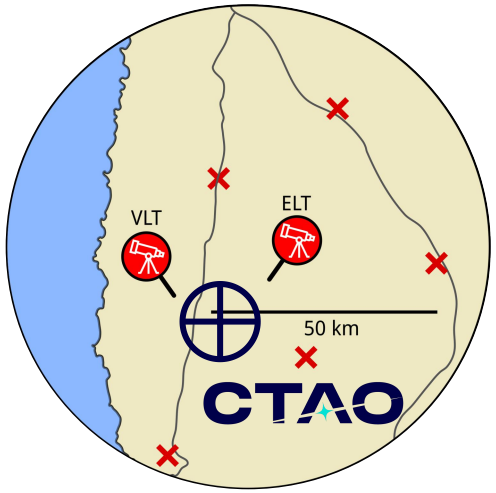
# Scientific benefits





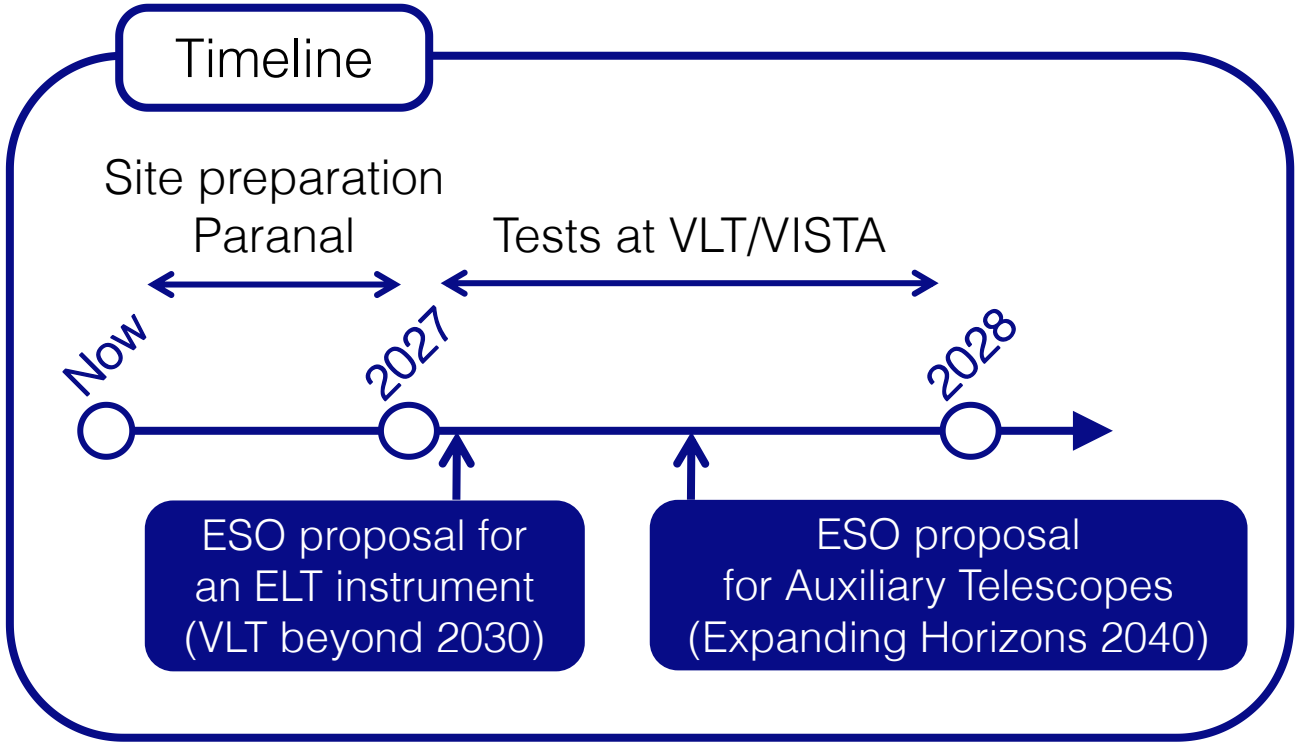




- Uncertainties /3
- Modular
- Independant

# Take home messages



- QUASAR aims at reaching microarcsecond resolution in the visible
  - Chip is being tested
  - First results expected next year
  - Low cost & modular auxiliary telescopes can improve the uncertainties a lot




Richard Feynman jumped up and said 'It can't work!'

In his inimitable style, Hanbury responded, 'Yes, I know. We were told so. But we built it anyway, and it did work'.

Late that night, Feynman phoned and woke Hanbury up to say 'you are right'. He also wrote a letter in which he magnanimously admitted his mistake and acknowledged the importance of this phenomenon that, at first sight, appears counter-intuitive, even to quantum theorists.