MAORY design trade-off study: tomography dimensioning

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Multi-conjugate Adaptive Optics RelaY for the ~~E~~-ELT

Outline: phase B design trade-off

1- Analysis of dimensioning parameters constrained by tomographic and generalized fitting error

- Number of post-focal DMs conjugated in altitude
- DM pitch
- DM altitudes
- LGS asterism angle
- Number of LGS
- LGS and NGS asterism geometry - *not shown in this talk*

under some constraints

- Seeing
- Cn2 profile
- Zenith distance
- Telescope phase 1 / phase 2
  - Number of LGSs: 4/6
  - M1 central obstruction: 28%/57%

Driver: MAORY main specifications

- **Performance in best conditions**
  - Q1 seeing (0.234 m) and wind, as close to zenith as possible
  - Over 20” FoV
  - SR > 50% @ 2.2 microns (goal 60%)
  - Sky coverage requirement not applicable
- **Performance in median conditions**
  - median seeing (0.157 m) and wind, as close to zenith as possible
  - Over 1’ FoV
  - SR > 30% @ 2.2 microns (goal 50% @ 2 microns)
- **Performance in sub optimal conditions**
  - Q3 seeing (0.139 m) and wind, zenith distance 30 degrees
  - Over 2’ FoV
  - SR > 15% @ 2.2 microns (goal 30%)
- **SR uniformity** < 10% absolute PTV across FoV of interest
- **Sky coverage** > 50%

OCTOPUS® end-to-end simulation

Simulated MCAO WFE terms

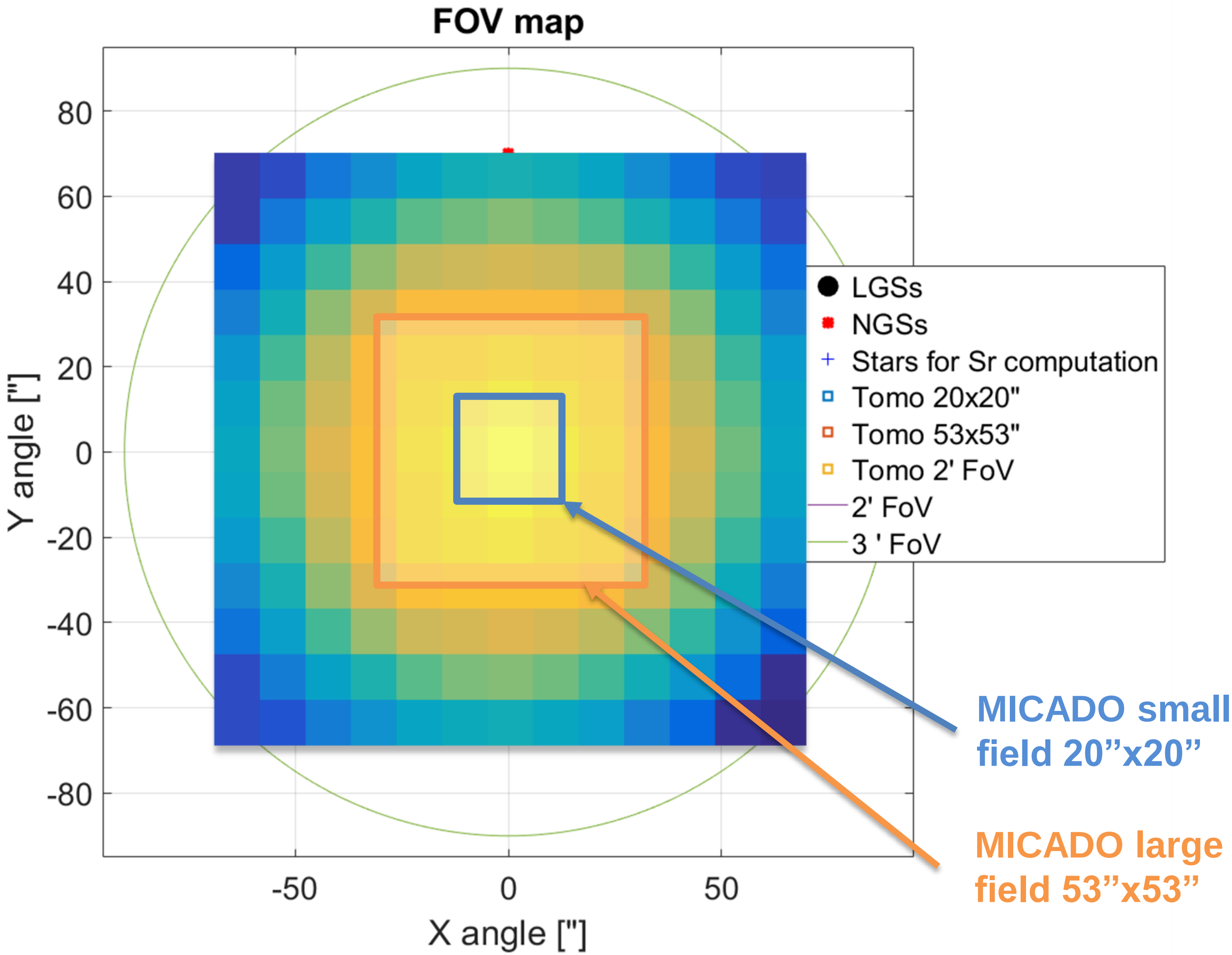
- Generalized fitting
- Spatial aliasing
- Temporal error
- ~~LGS WFS noise~~ high flux and no spot elongation
- ~~NGS WFS noise~~ high flux
- Tomographic error cone effect and anisoplanatism but optimal reconstruction of 35 layers

Command computation:

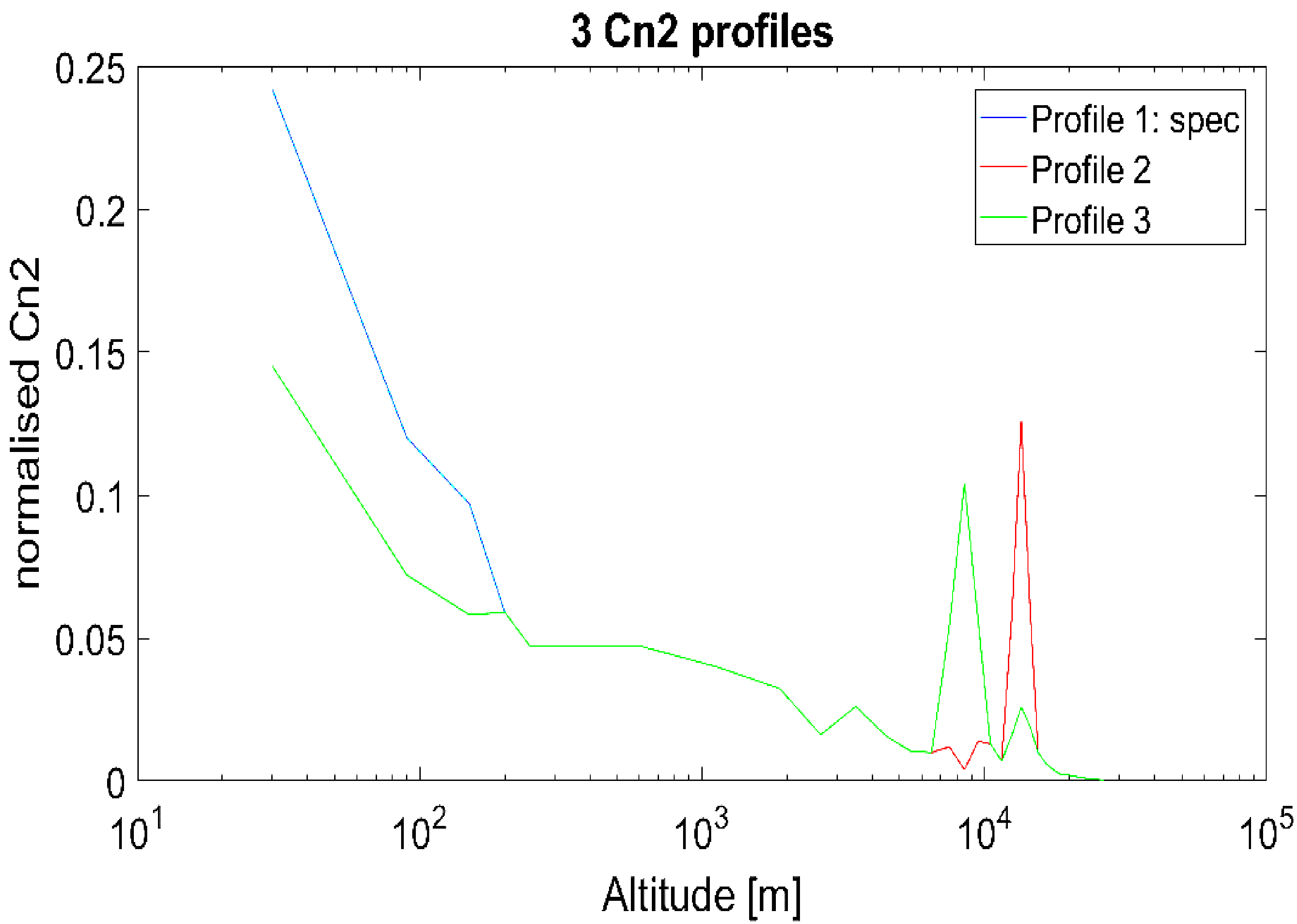
- Tomographic reconstruction to estimate the multi layer turbulent phase: FRIM3D/POLC with perfect priors on Cn^2 profile
- Projection of the estimated 3D phase onto the DMs space. The projection is optimized on a specific FoV

No other error budget term

Typical simulated FoV

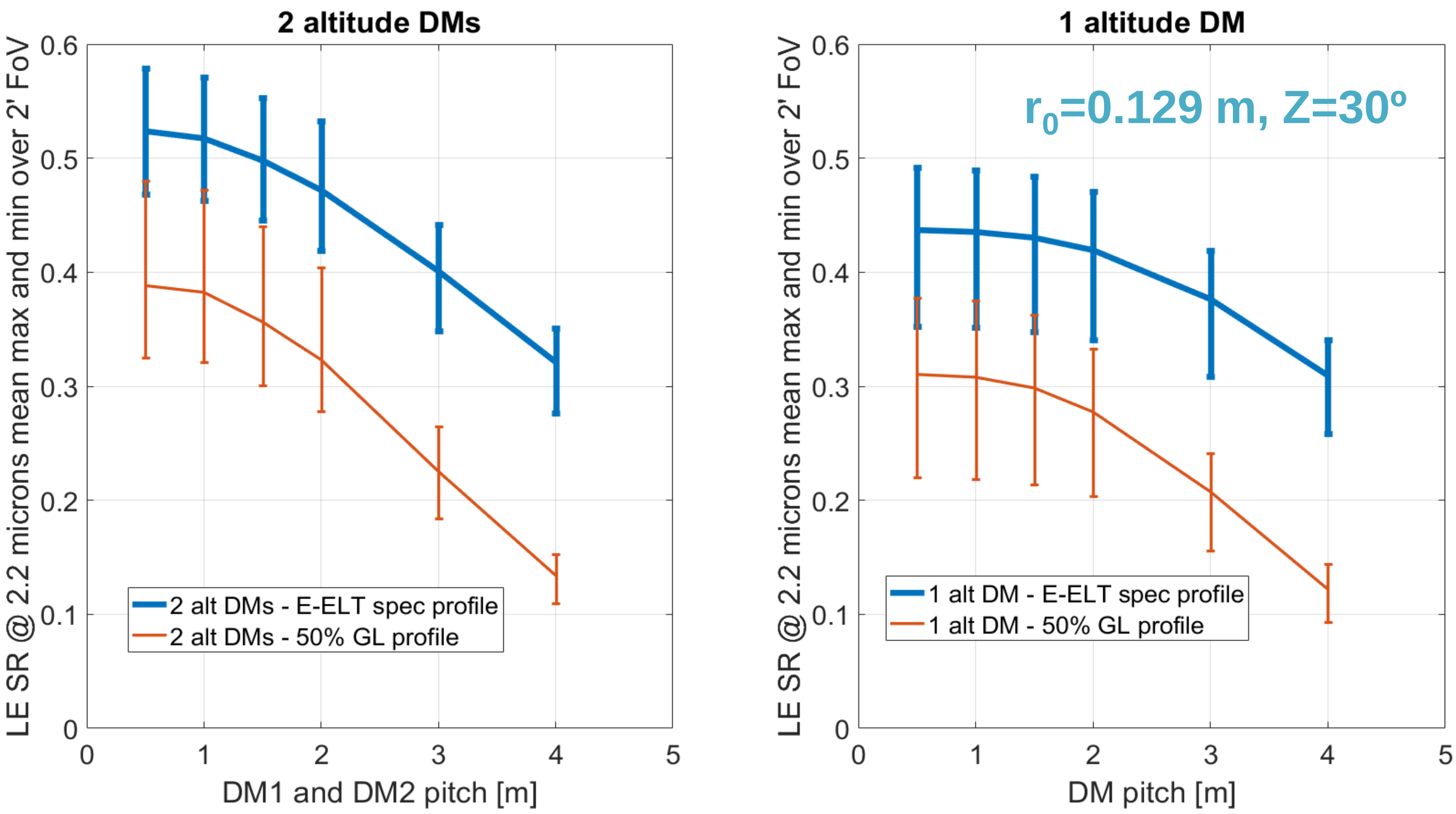


Cn^2 profiles



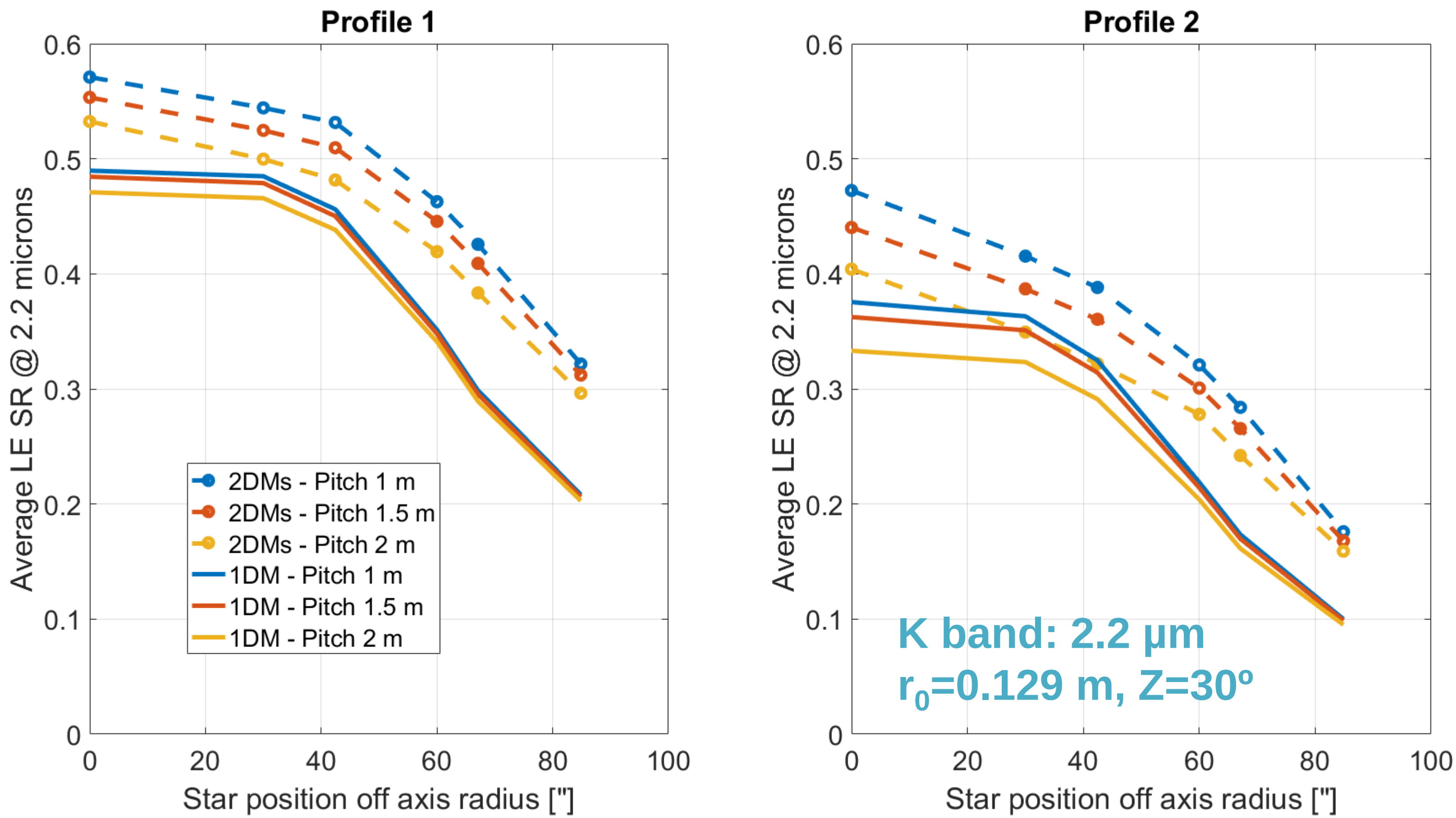
+ other profiles measured by stereo scidar

Gen. fitting: N DMs and pitch



- 2 post-focal DMs: performance flat for pitch < 1.5 m
- 1 post-focal DM: performance flat for pitch < 2 m
- Strong impact from Cn2 profile

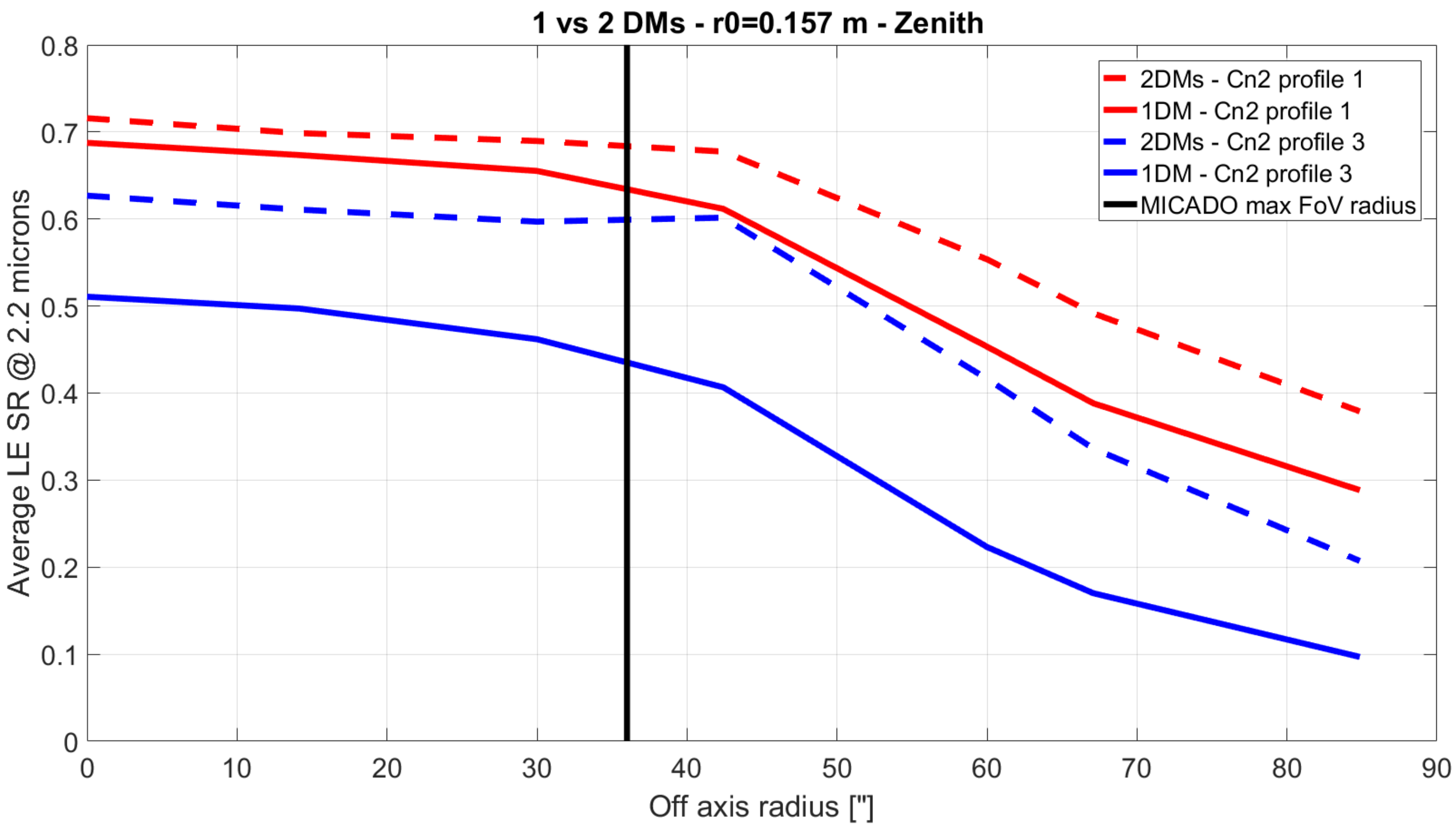
Benefit 2 vs. 1 post-focal DM(s)



- **2 post-focal DMs provide performance improvement of up to 25% in the science field and 100% in the technical field in K band, 250% in J band**

- **2 post-focal DMs desirable to increase sky coverage**

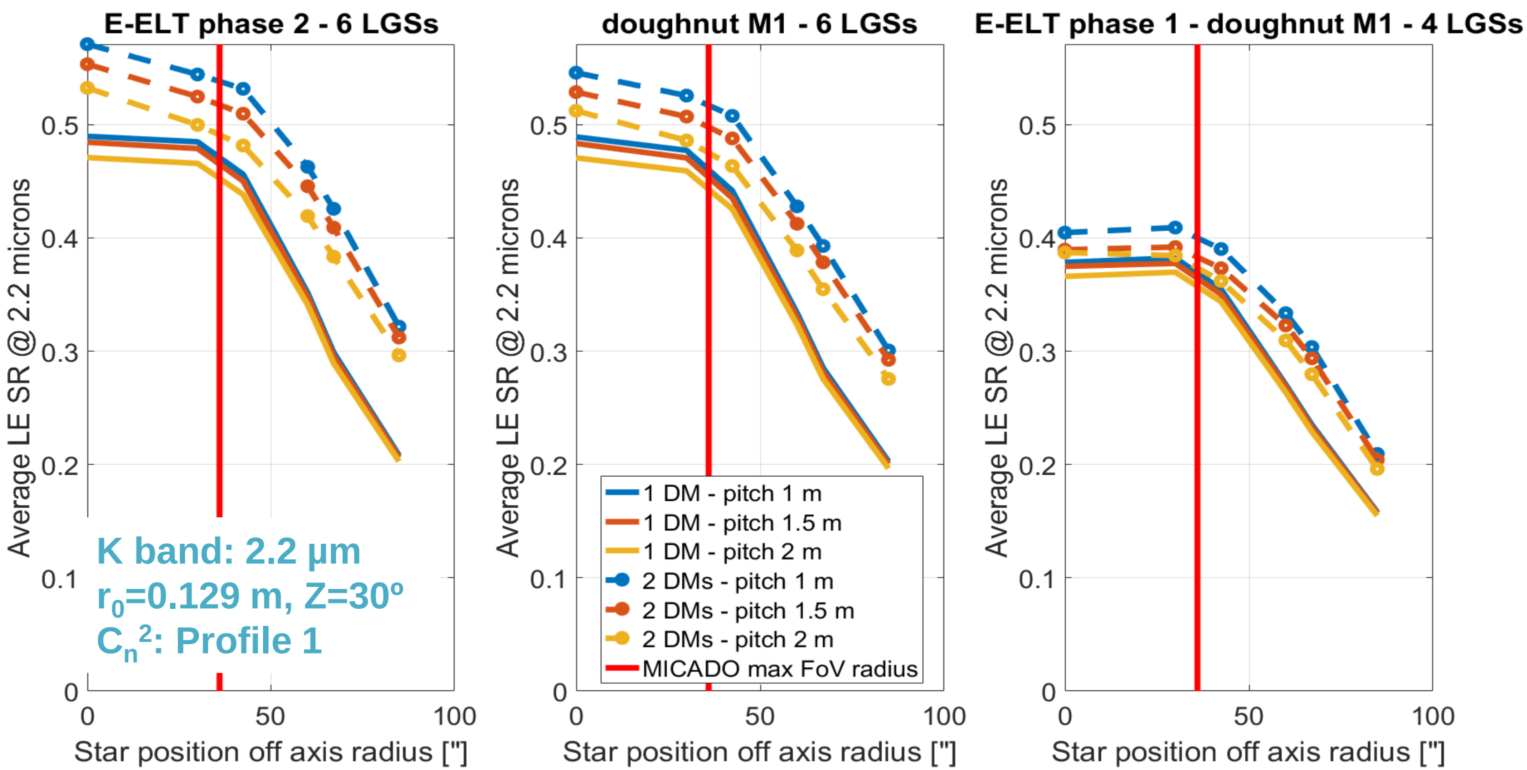
Benefit 2 vs. 1 post-focal DM(s)

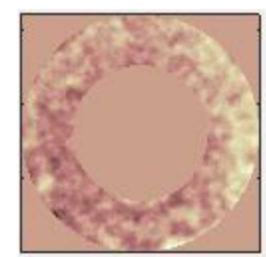


- 2 post-focal DMs improve tolerance to Cn2 profile variation

E-ELT phase 1 / phase 2 – K band

- ❑ M1 doughnut impact on Sr is marginal. How about NGS sky coverage ?
- ❑ **Significant impact 6 LGSs → 4 LGSs**
- ❑ E-ELT phase 1: limited by tomographic error → DM pitch irrelevant
- ❑ 6 LGSs enable benefit from 2 post-focal DMs and finer pitch



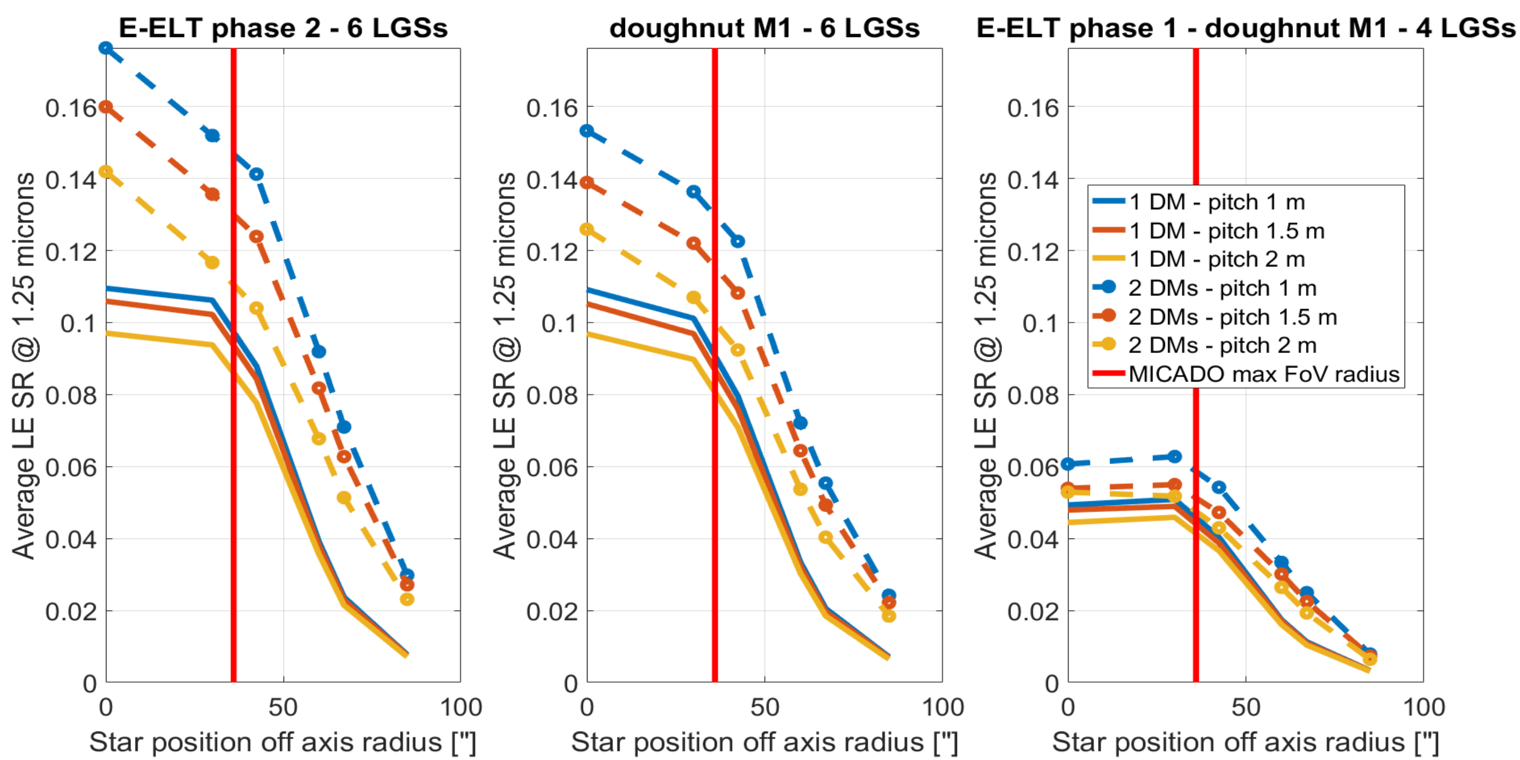


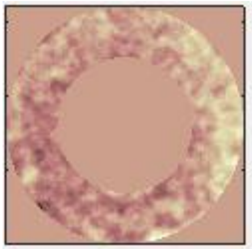
Photon noise σ^2
x3.8 long axis

E-ELT phase 1 / phase 2 – J band

- M1 doughnut impact on Sr is not significant. How about NGS sky coverage ?
- **Dramatic impact 6 LGSs → 4 LGSs**
- **Lower wavelength performance pushes for:**
  - **<u>6 LGSs</u>**
  - **2 post-focal DMs**
  - **finer DM pitch**

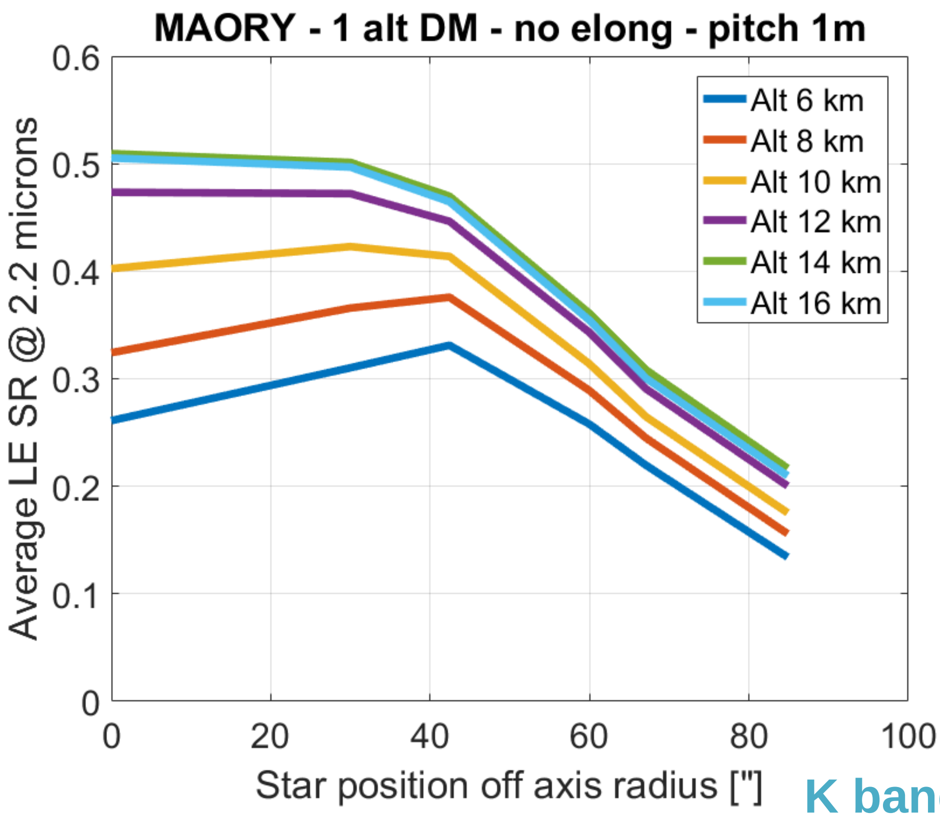
K band: 2.2 µm
r_0=0.129 m, Z=30º
C_n^2: Profile 1

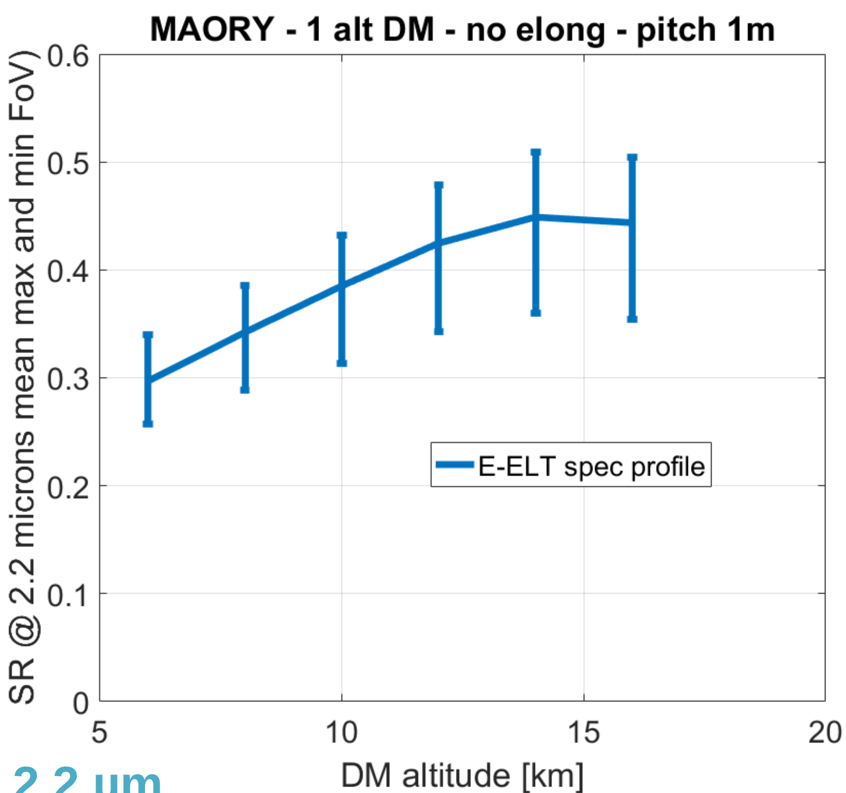




Photon noise σ^2 x3.8 long axis

Post-focal DM altitude: single DM

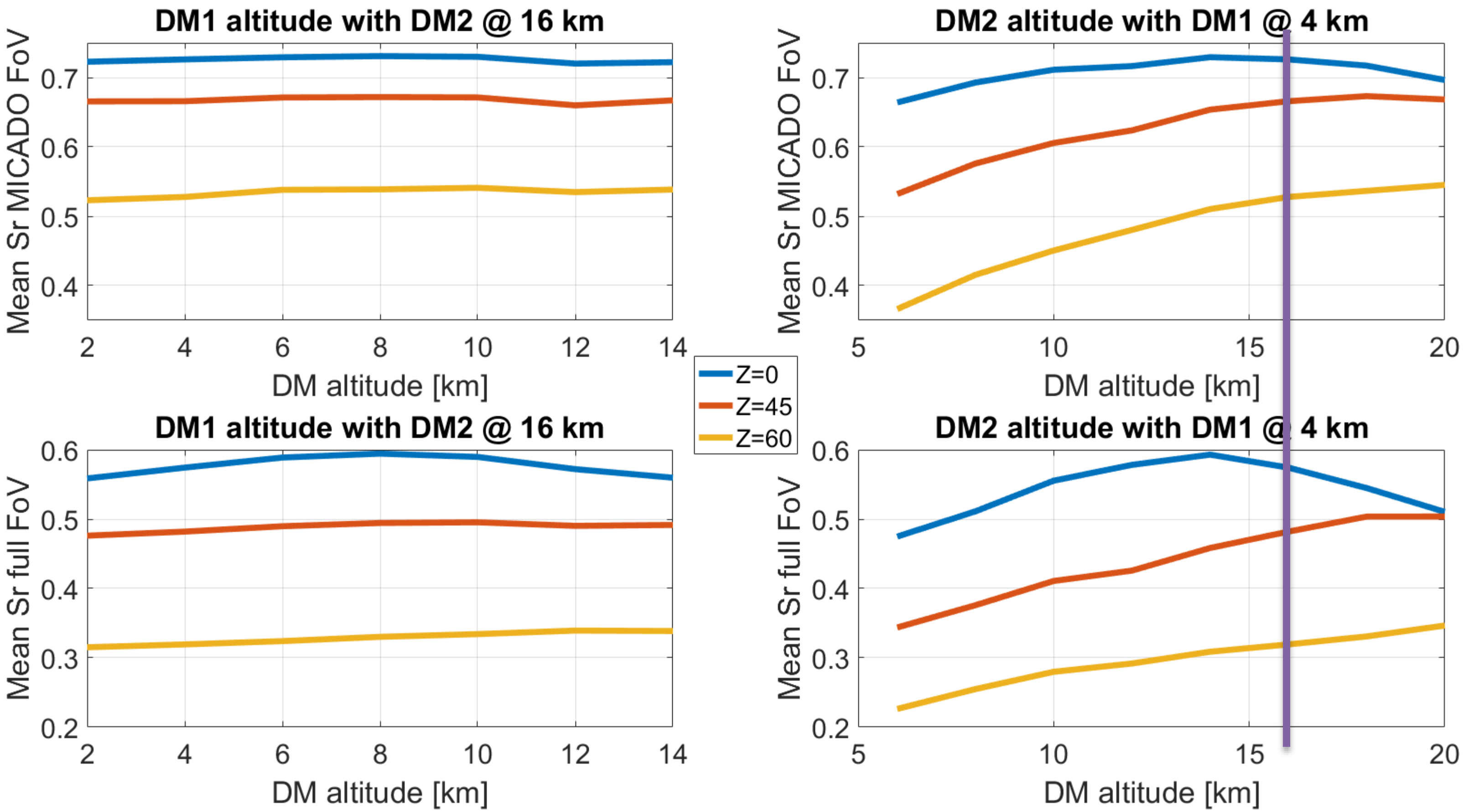




K band: 2.2 µm
r_0=0.129 m, Z=30º
C_n^2: Profile 1

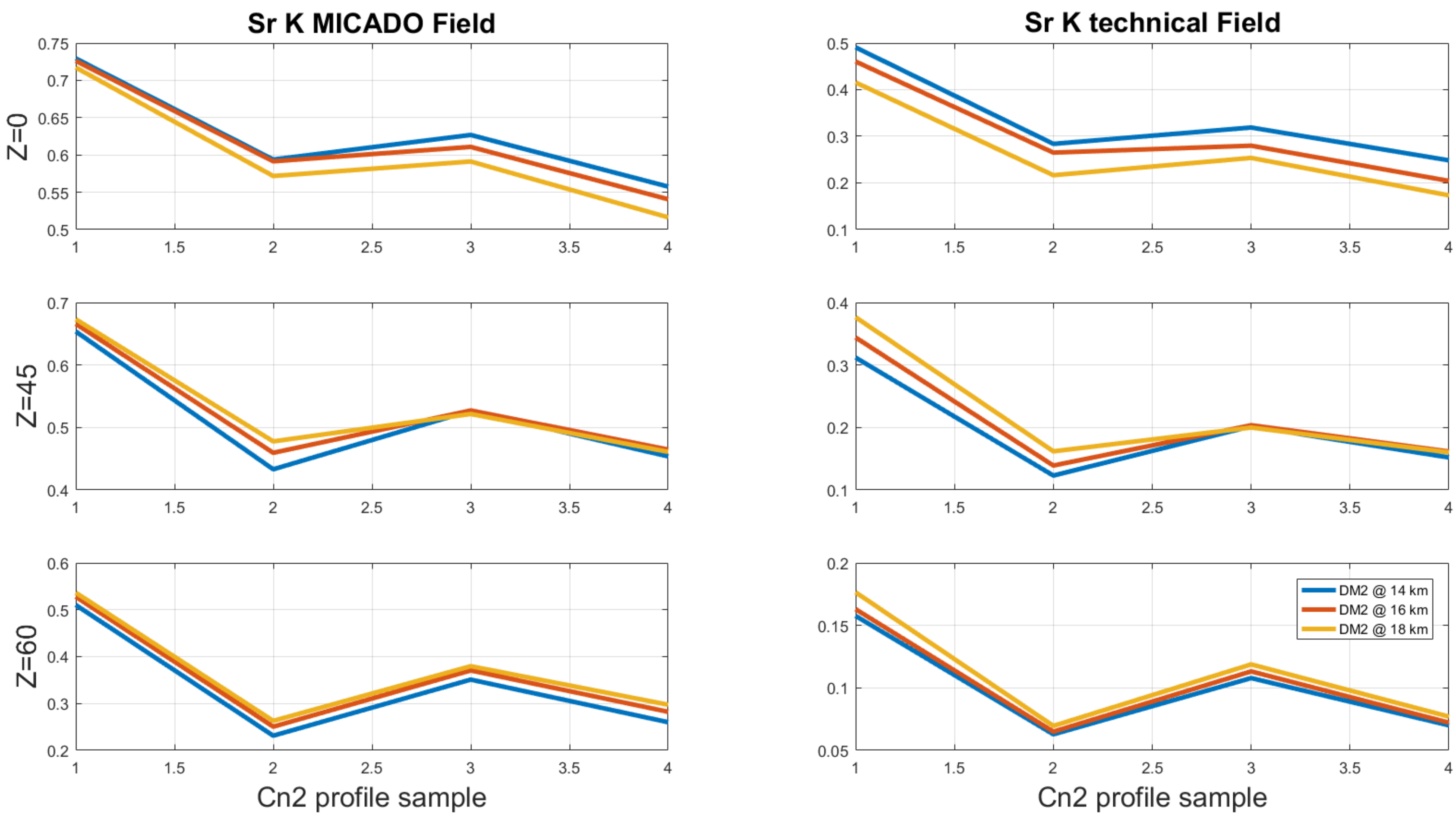
- ❑ 1 post-focal DM: conjugation **altitude** matters and should be > 14 km
- ❑ The conjugation altitude should be higher to cope with larger airmass cases

Post-focal DM altitude: 2 DMs case



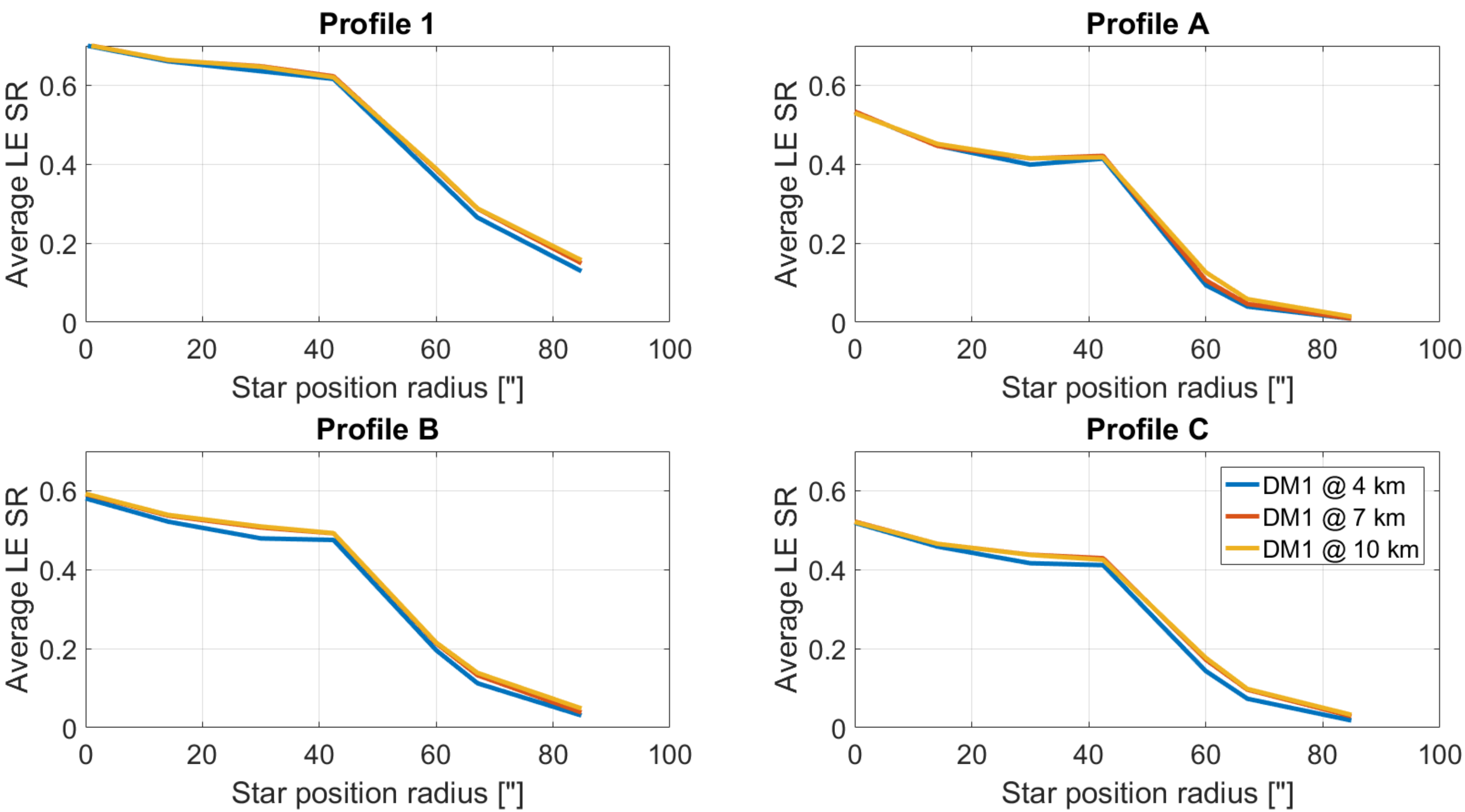
- ❑ **Results confirmed by Cn^2 sensitivity study**
- ❑ **Performance insensitive to DM1 altitude**
- ❑ **DM2 optimal altitude naturally increases with airmass**
- ❑ **16 km conjugation is a good trade-off**
- ❑ **16 km is also close to optimal for a single post-focal DM → Upgradability**

Sensitivity Cn^2 profile: DM2 altitude



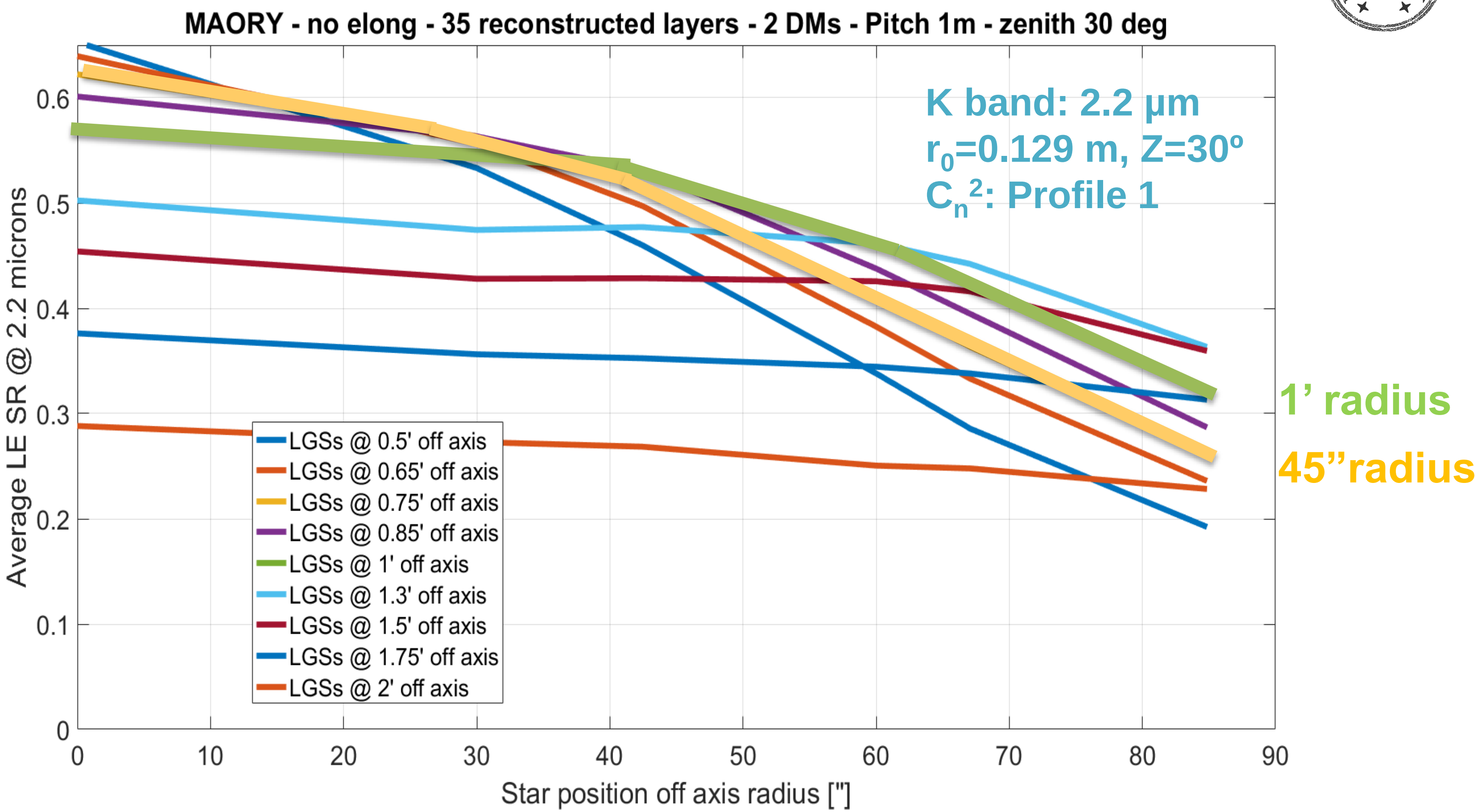
- ❑ **DM2 altitude should obviously be increased at larger airmass**
- ❑ **Dependency on profile is not significant**
- ❑ **Again 16 km conjugation looks like a good compromise**

Sensitivity Cn² profile: DM1 altitude



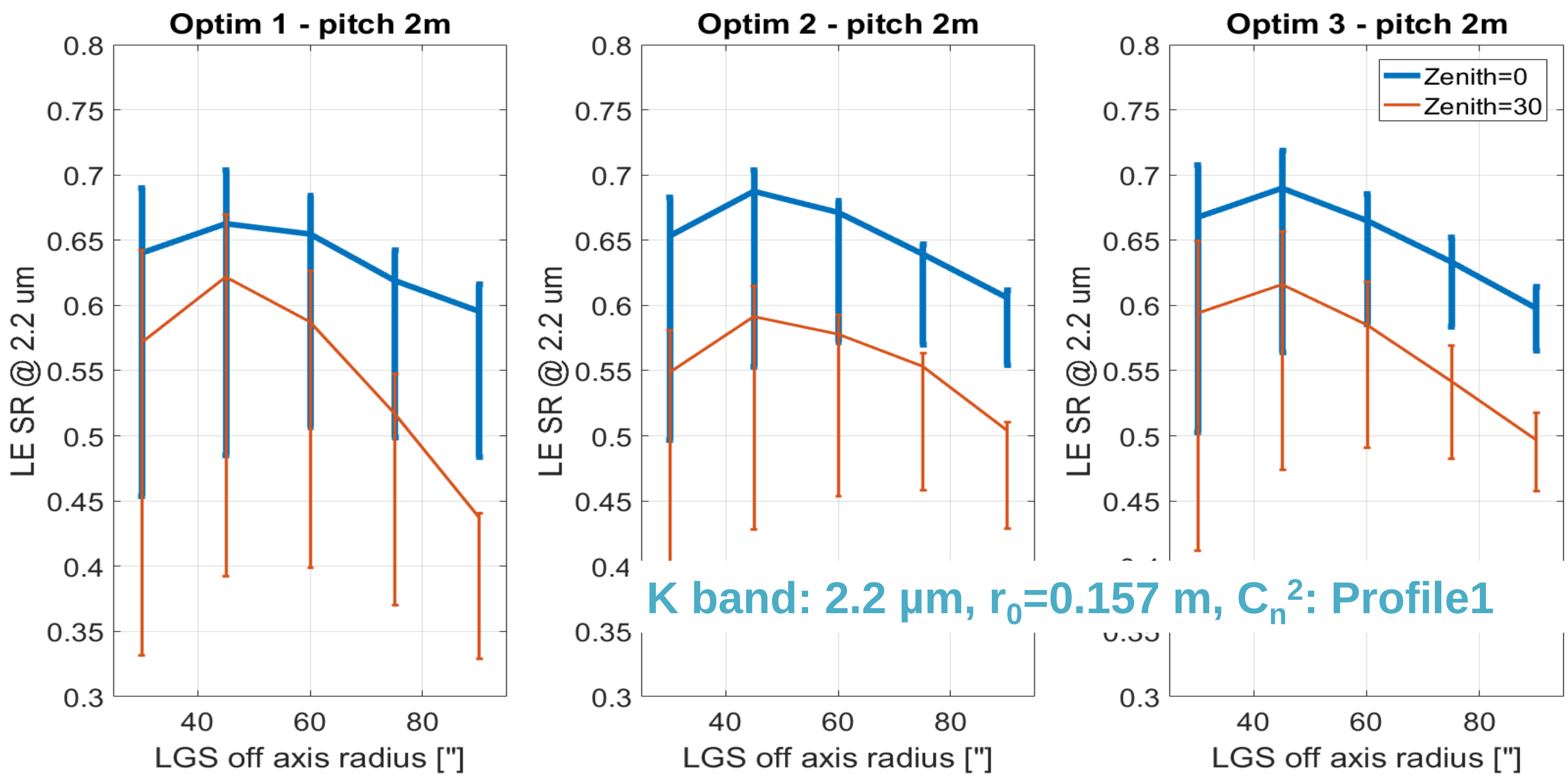
- ❑ **DM1 altitude has a weak influence**
- ❑ **No clear dependency on Cn2 profile**
- ❑ **The opto-mechanical design should drive the DM1 altitude**

LGS asterism angle – full field optim



- ❑ **Tomography reconstruction maximizes performance in full field here**
- ❑ **Closer LGSs improve Sr on axis, decrease uniformity across the MICADO field and decrease the Sr in the technical field**
- ❑ **Trade-off between 45" and 1' radii → other FoV optimization to check**

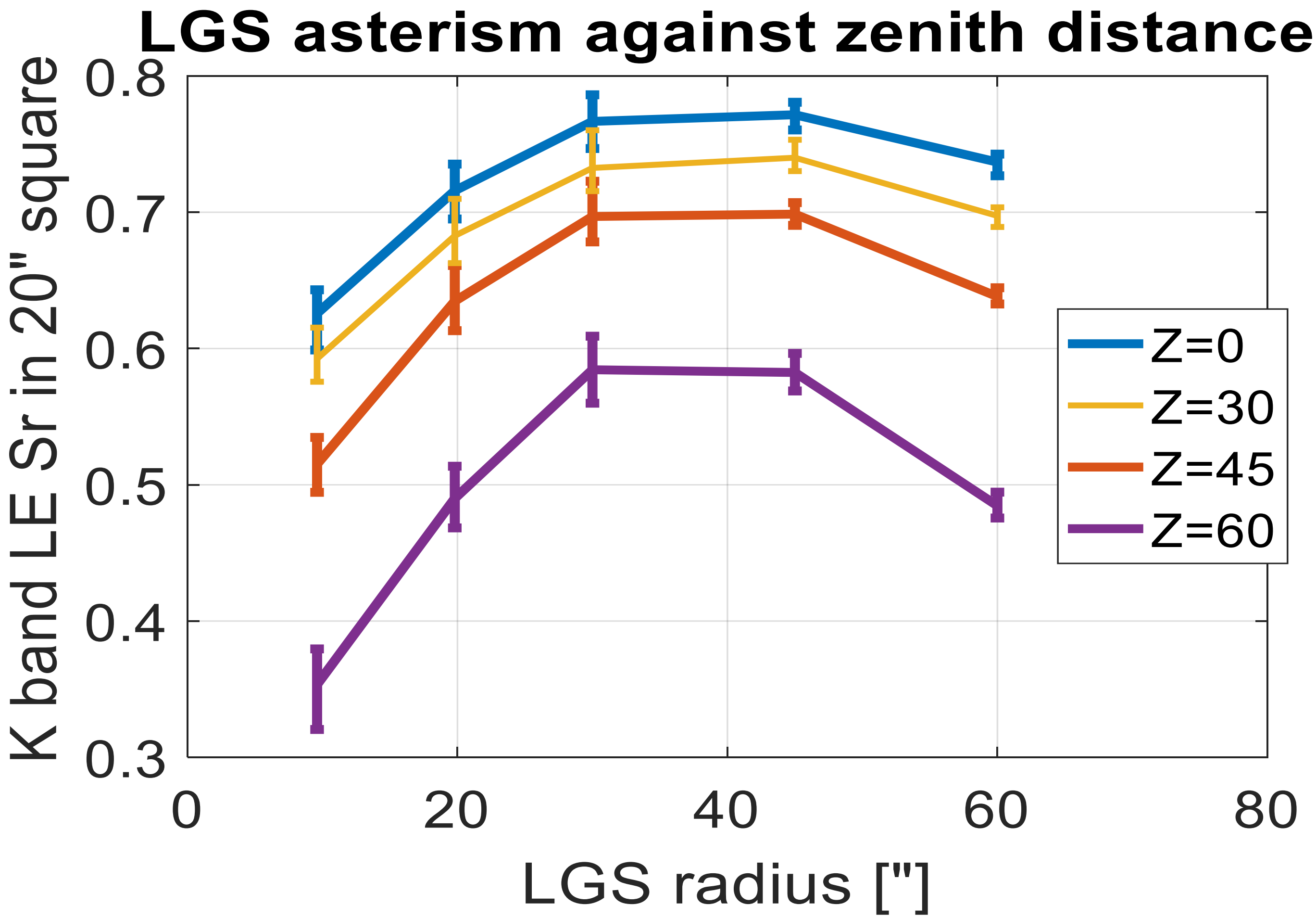
LGS angle – projection optimization



K band: 2.2 µm, r_0=0.157 m, C_n^2: Profile1

- ❑ **Tomography reconstruction maximizes performance in 3 different FoVs with NGS @ 70'' off axis**
- ❑ **Maximum and average Sr in MICADO field highest for LGS @ 45'' off axis**
- ❑ **Average performance in 2' FoV highest for LGS @ 1' off axis**
- ❑ **Baseline: 45'' radius**

Ultimate performance in 20” square



- ❑ Best performance on axis (LTAO with on axis NGS) is achieved with 20” radius @ Z=60
- ❑ NGS cannot be closer than 30” radius without vignetting the science FoV
- ❑ Confirmation that a fixed 45” radius is almost optimal for MICADO at any airmass for both small field and wide field: one single asterism configuration → less complexity

Conclusions on design trade-off

- **2 post-focal DMs (baseline: 1) are desirable in order to enhance:**
  - **Performance in the technical field → sky coverage and robustness (acquisition)**
  - **Performance in the blue for NGS sky coverage and MICADO performance**
  - **Robustness to Cn2 profile variation and zenith distance**
- **DM pitch between 2m and 1.5m → better for worse seeing and with 2 DMs**
- **Post-focal DMs altitude: 4-6 and 16 km to be robust to larger airmass and accommodate 2 post-focal DMs later**
- **LGS asterism angle: fixed @ 45" radius + optimization of tomography projection depending on FoV of interest**
- **E-ELT phase 1 / phase 2:**
  - **M1 doughnut main impact on sky coverage and PSF shape: TBC**
  - **6 LGSs are highly desirable**

Thank you for your attention !