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ULTIMATE AO simulations

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Research School of Astronomy and Astrophysics

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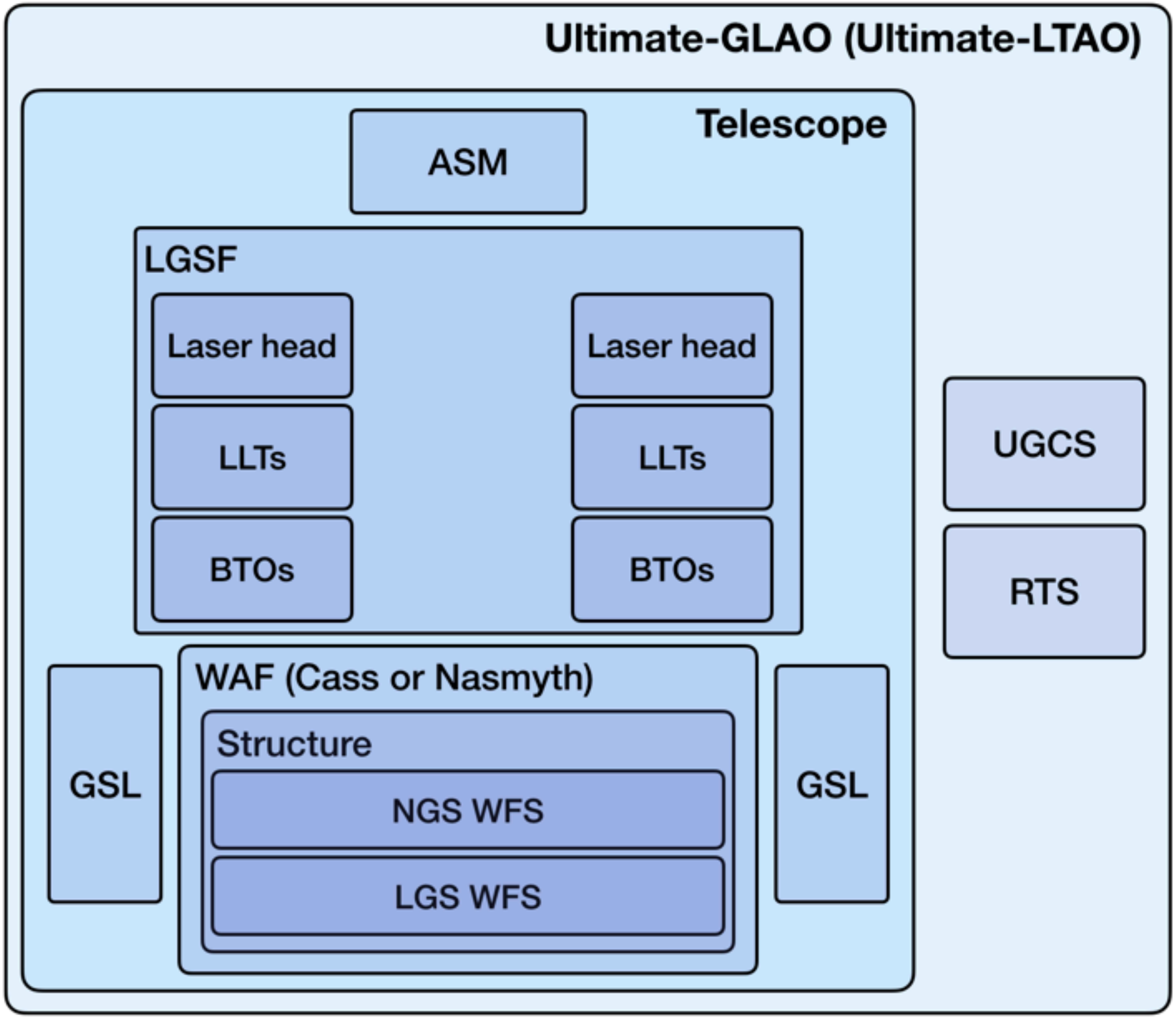
Outline

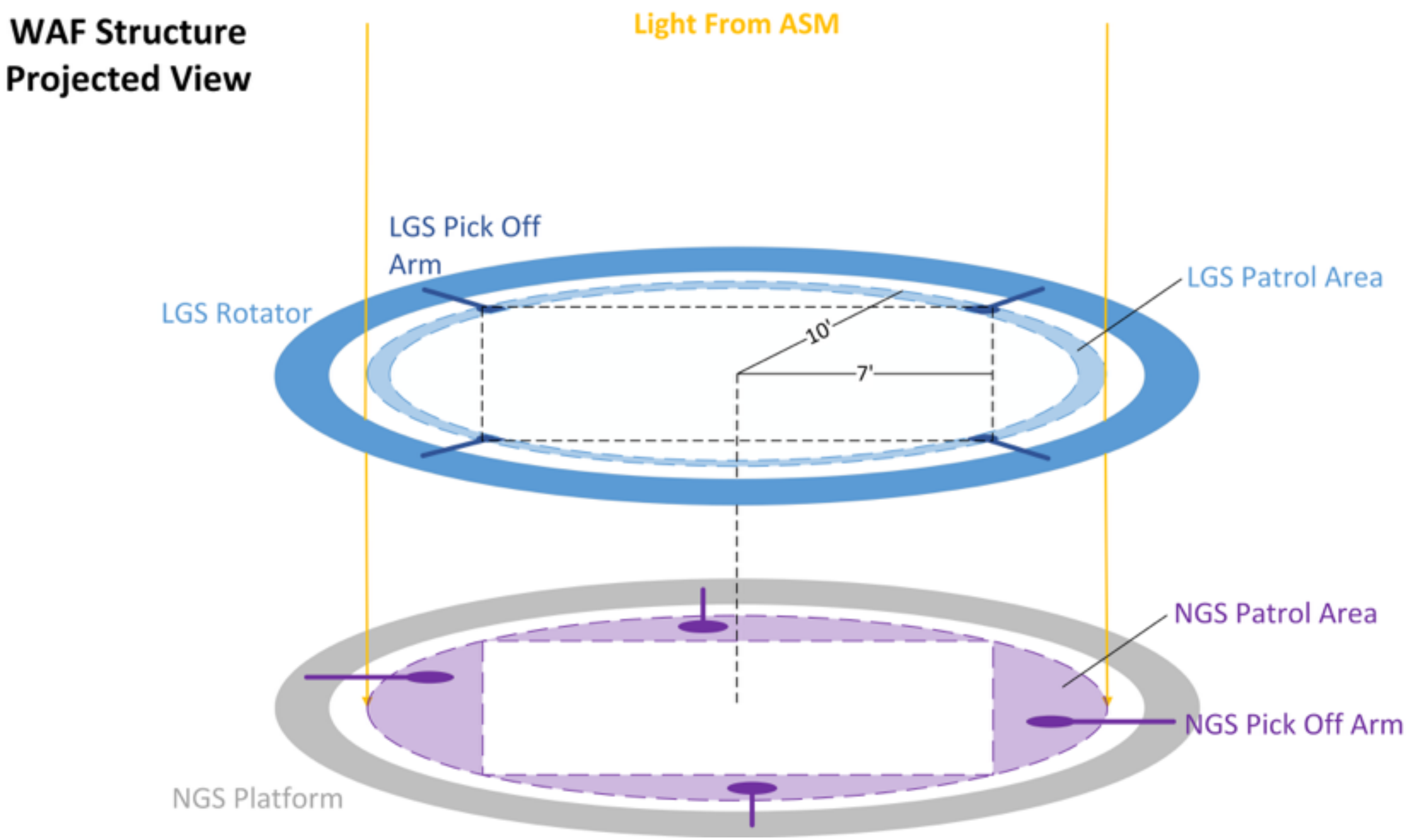
- Introduction & background
- Simulation results
- Next steps
- Conclusions

System diagram



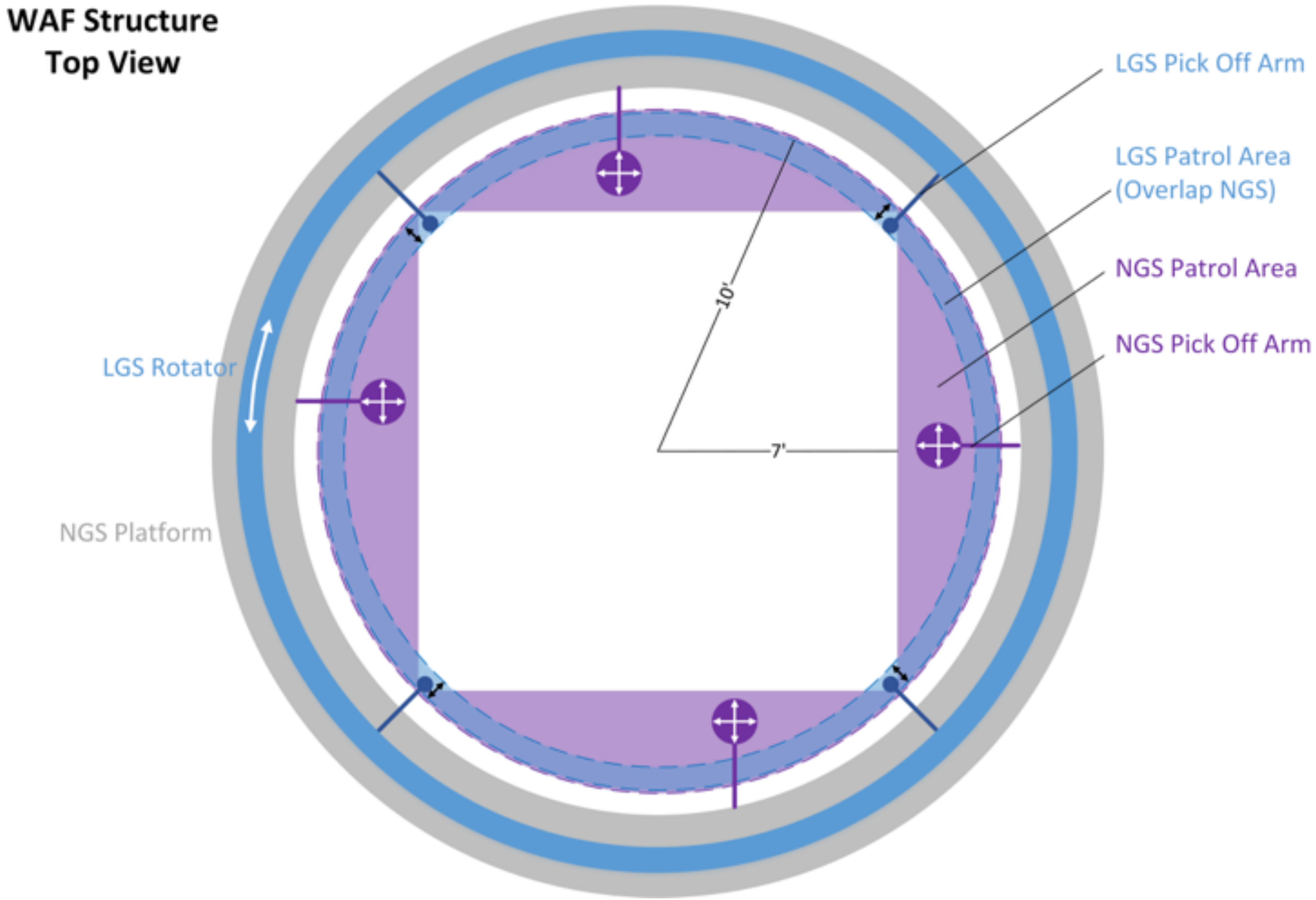
WFS adaptor flange

- Science FOV baseline 14’, but can be smaller
- LGS patrol area in the circle surrounding the science field



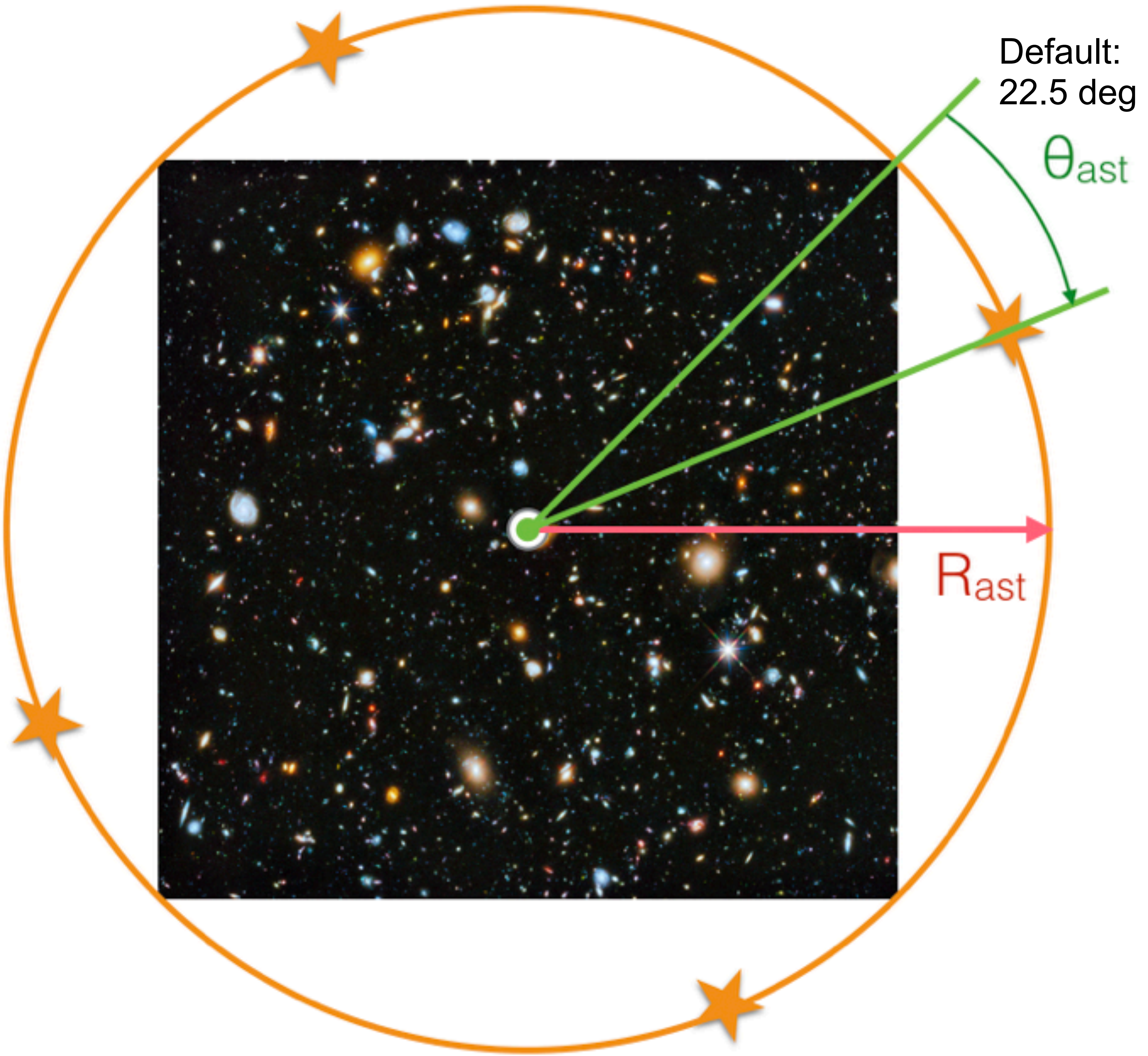
WFS adaptor flange

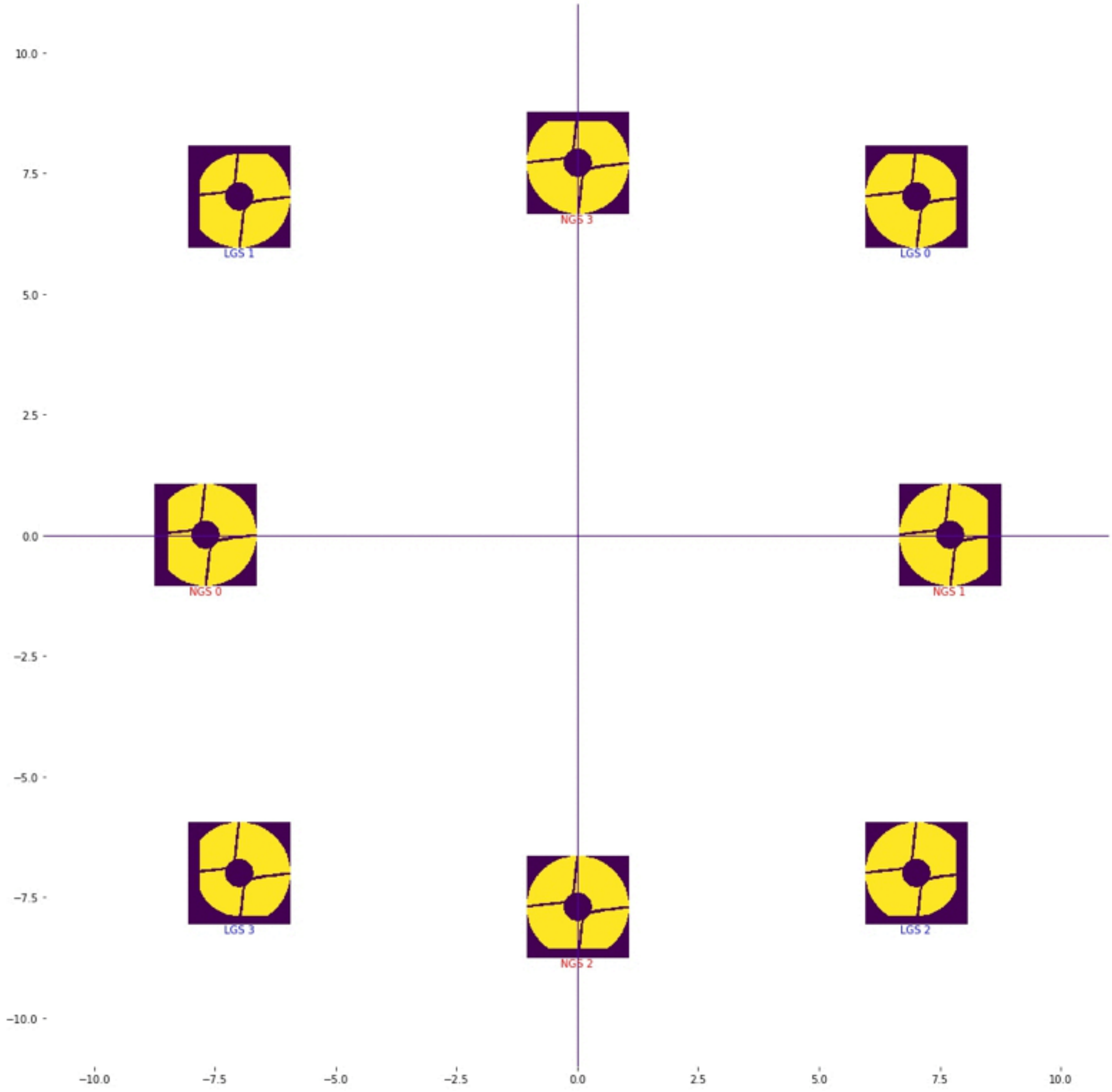
- Pick one GS in each crescent
- Margin of ~2” required



Referentials

- We use instrument coordinates in our simulations
- 1-4 NGS: positions do not depend on clocking, pupil rotation and vignetting change
- 4 LGS: positions change depending on clocking, pupil rotation and vignetting constant
- Science field evaluated over a grid of 7x7 PSFs




LGS 1
NGS 3
LGS 0
NGS 0
NGS 1
LGS 3
NGS 2
LGS 2

Simulations in 3 stages

1. System design optimisation
   - parameters (number of subapertures, WFS pixel size, AO system update rate, controller loop gain) are optimised
2. Final system design performance
   - system performance evaluated using the optimised parameters
3. Full statistical performance prediction
   - Based on a set of actual targets, statistical distribution of the Sodium returns, turbulence profiles, many performance points are evaluated

Simulation parameters: fixed

Subsystem	Parameter	Value	Comment
Telescope	Outer diameter	7.92m	
	Inner diameter	0.277	Cent. cone (350mm) being discussed
	Pupil map		To be generated to a fits image
ASM	Outer diameter	1.265m	Need the drawings
	Number of actuators	924	Not to be optimised
	conjugation altitude	-80m	
LLT	Location	Side Launch	Picked from configs in Mitsubishi analysis
	Diameter	45cm	Assuming filled aperture
	Laser $1/e^2$ ⊘	30cm	
	Tube seeing	$1''$	In addition to atmospheric seeing
	Optical throughput	70%	Includes Beam Transfer Optics + LLT
LGS	Number of LGS	4	On a square geometry
	LGS asterism radius	Sci. FoV $\times\sqrt{2}/2$	R_{ast} in figure 1
	LGS asterism clocking	$22.5°$	θ_{ast} in figure 1
Laser	Type	TOPTICA 20W	+ 10% modulation in side band
	Na return at zenith	See section 4.3	
LGS WFS	Optical Throuhgput	0.448	
NGS WFS	Effective λ visible	650nm	For visible detectors
	Effective λ NIR	1.64μm (H)	For NIR detectors
	Optical Throughput	0.448	Define for visible and NIR
	# of TT+Focus	one or all	Compared to TT only
Operation	Zenith angle	$30°$	Default, see 4
Imager	Wavelength	Ks (2.15μm)	Major science cases

Simulation parameters: turbulence

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- Cn2 profiles in (Oya, 2014), except low altitudes from (Chun, 2009)

Alt [m]	C_n^2 25% [$m^{1/3}$]	C_n^2 50% [$m^{1/3}$]	C_n^2 75% [$m^{1/3}$]
0	1.766E-13	2.924E-13	4.031E-13
15	5.798E-14	5.007E-14	8.773E-14
30	2.155E-14	1.754E-14	1.537E-14
60	7.311E-15	1.279E-14	1.853E-14
119	2.626E-15	6.281E-15	2.050E-14
353	2.171E-14	4.132E-14	7.964E-14
1500	9.804E-15	2.348E-14	6.452E-14
9333	6.022E-14	8.385E-14	1.242E-13
Total	3.578E-13	5.277E-13	8.136E-13
r0(500cm) [cm]	14.9	11.8	9.1

Parameters to scan in phase 1

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- Seeing cases 25, 50 and 75
- FOV: 14’
- Number of WFS subapertures: 26, 32
- LGS WFS pixel size: 0.1”—0.8”
- LGS WFS FOV: at least 5”
- LGS WFS framerate: 100–600 Hz, limited by ORCA Flash

Simulation implementation

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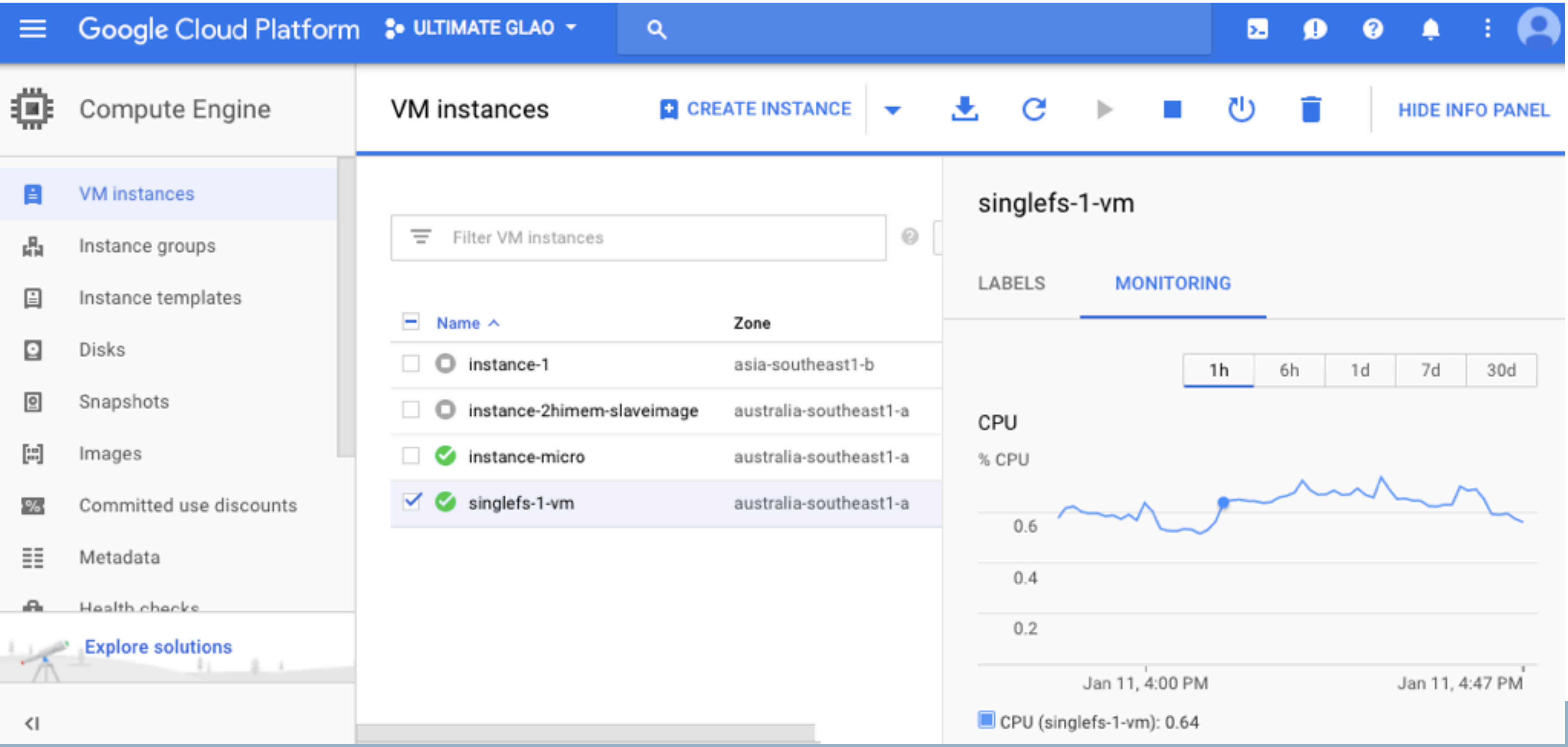
- Use Google Cloud Compute Engine to run YAO simulations
- Low-cost & convenient platform
  - $0.01 for one CPU hour + storage etc. (preemptible, i.e. may be rebooted)
  - Stage 1 simulations of ~23.000 h: AU$800



Performance as a function of FOV

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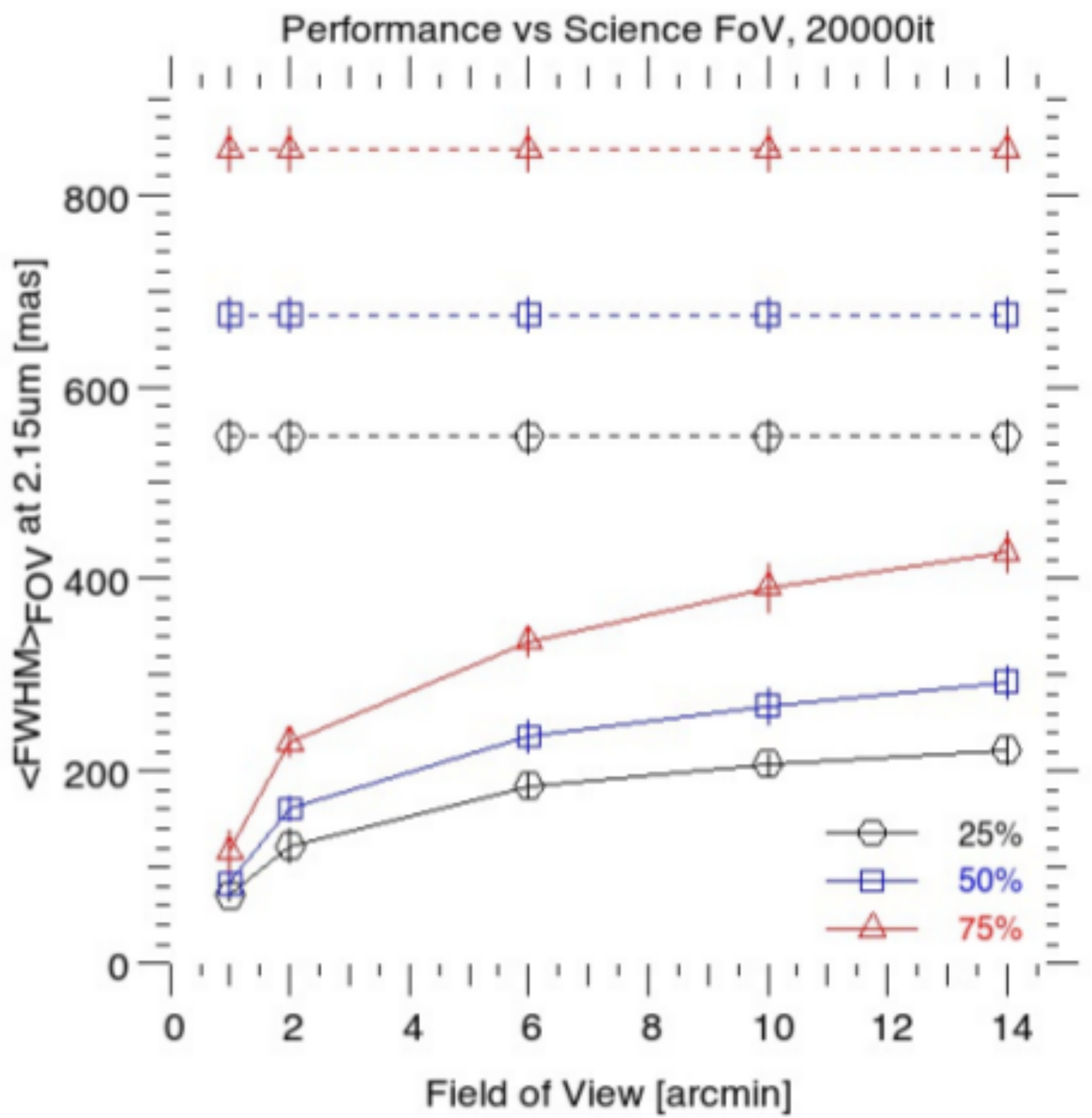
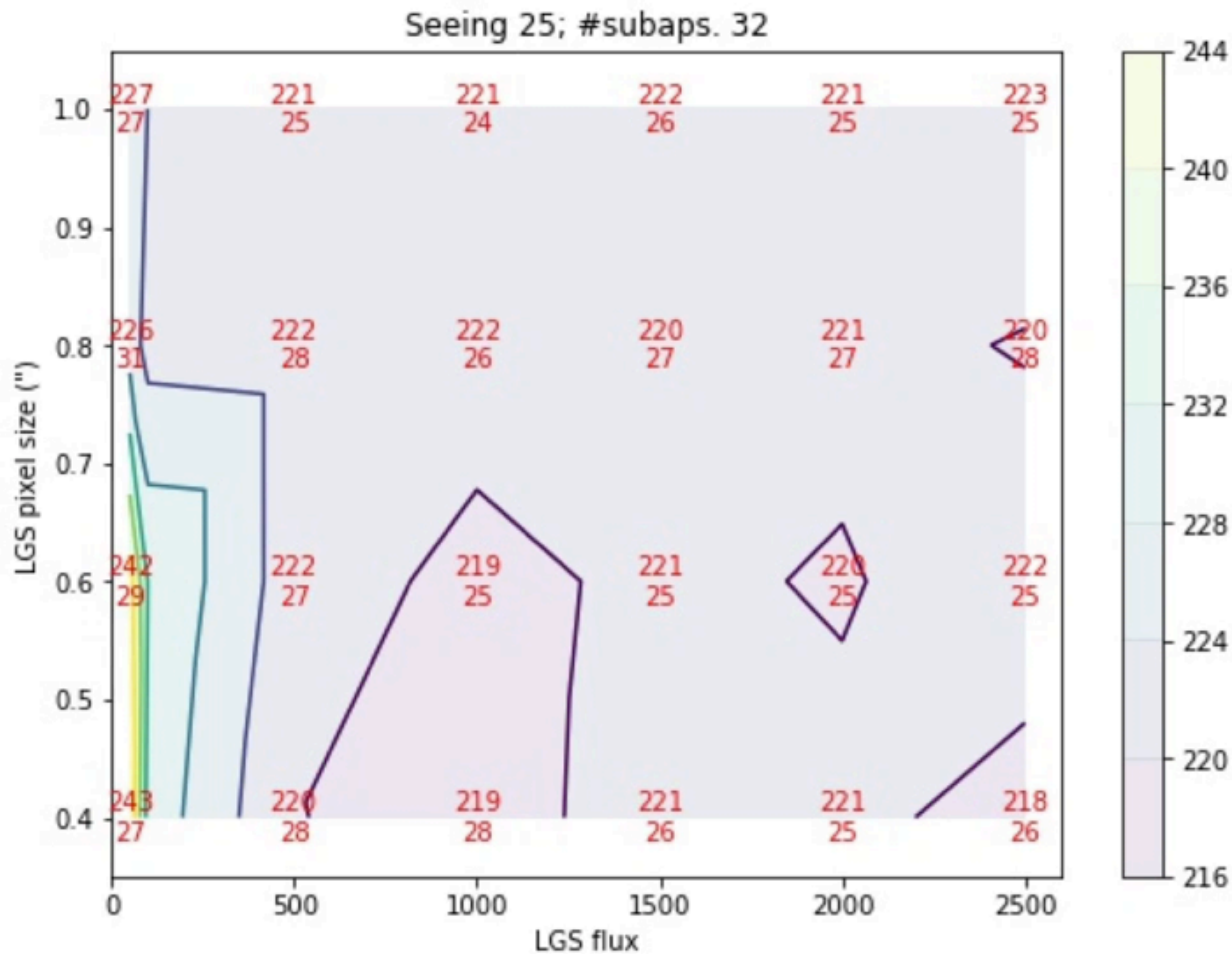
- Preliminary results for FWHM dependency on the corrected FOV
- Reduce baseline FOV of 14' to 10':
  - **Gain 10-20 mas 4% in FWHM**
- Reduce baseline FOV of 14' to 6':
  - Gain 50-80 mas (17%) in FWHM
- Even more significant gains at smaller fields



Optimal LGS WFS pixel size

- Optimise loop gain & system framerate
- FWHM as a function of LGS flux & pixel size
- **Optimal LGS pixel size 0.6”**
- LGS flux can be 25% of expected, before performance reduction

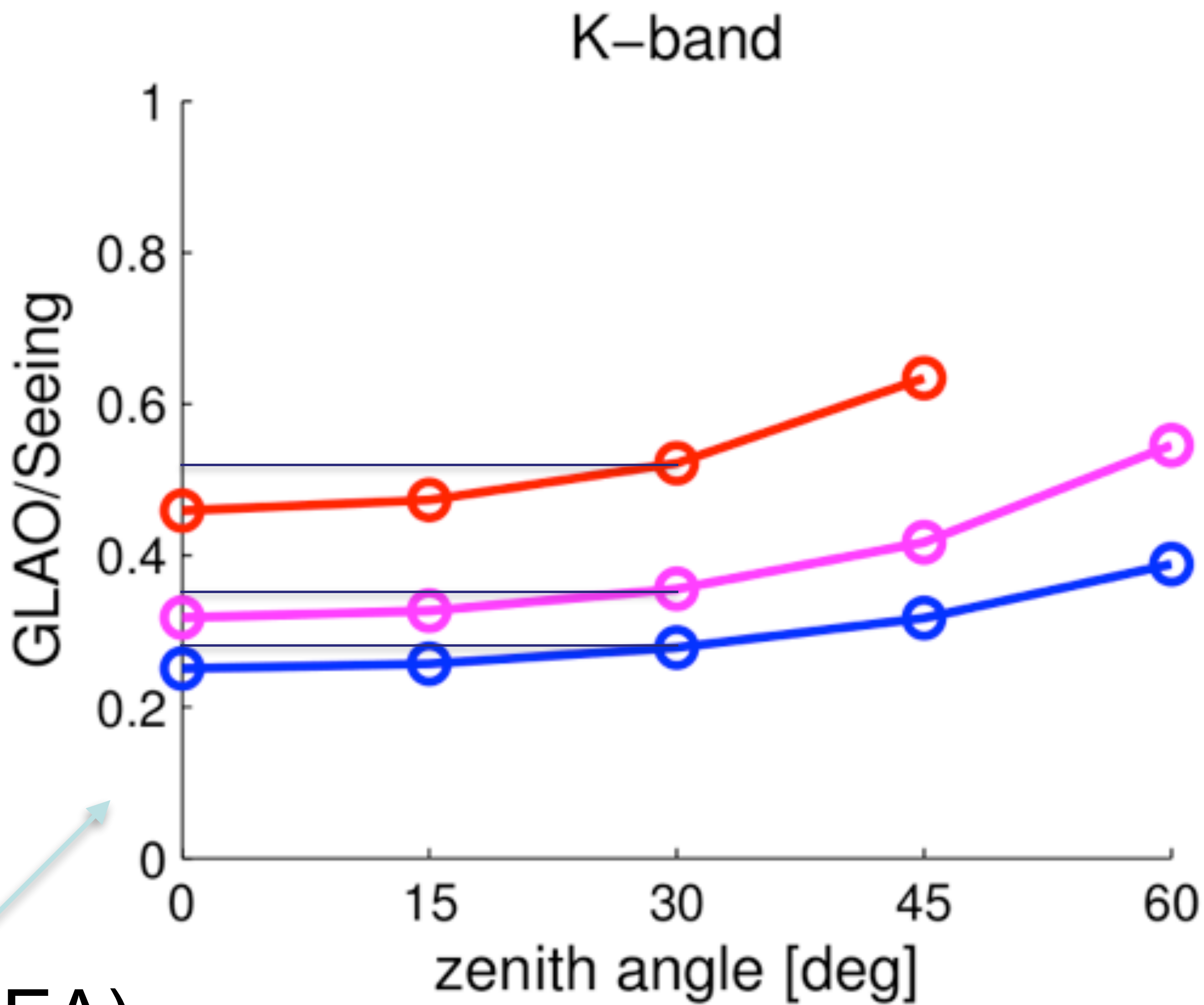


Comparison to earlier simulations

Compare the case with 30 deg zenith angle

Seeing case	Oya NEA ratio	YAO Seeing FWHM	YAO GLAO FWHM	YAO Est. NEA ratio
25	0.3	0.47”	0.23”	0.3
50	0.35	0.60”	0.32”	0.4
75	0.5	0.82”	0.51”	0.4

(Oya, 2014)



Ratios of noise-equivalent-area (NEA)

- Differences between Oya’s and ours:
  - Oya’s coarse turbulence sampling at altitudes of 0—100 m
  - Oya’s FOV of 10’ vs. 14’ in our simulations

Comparison to earlier simulations

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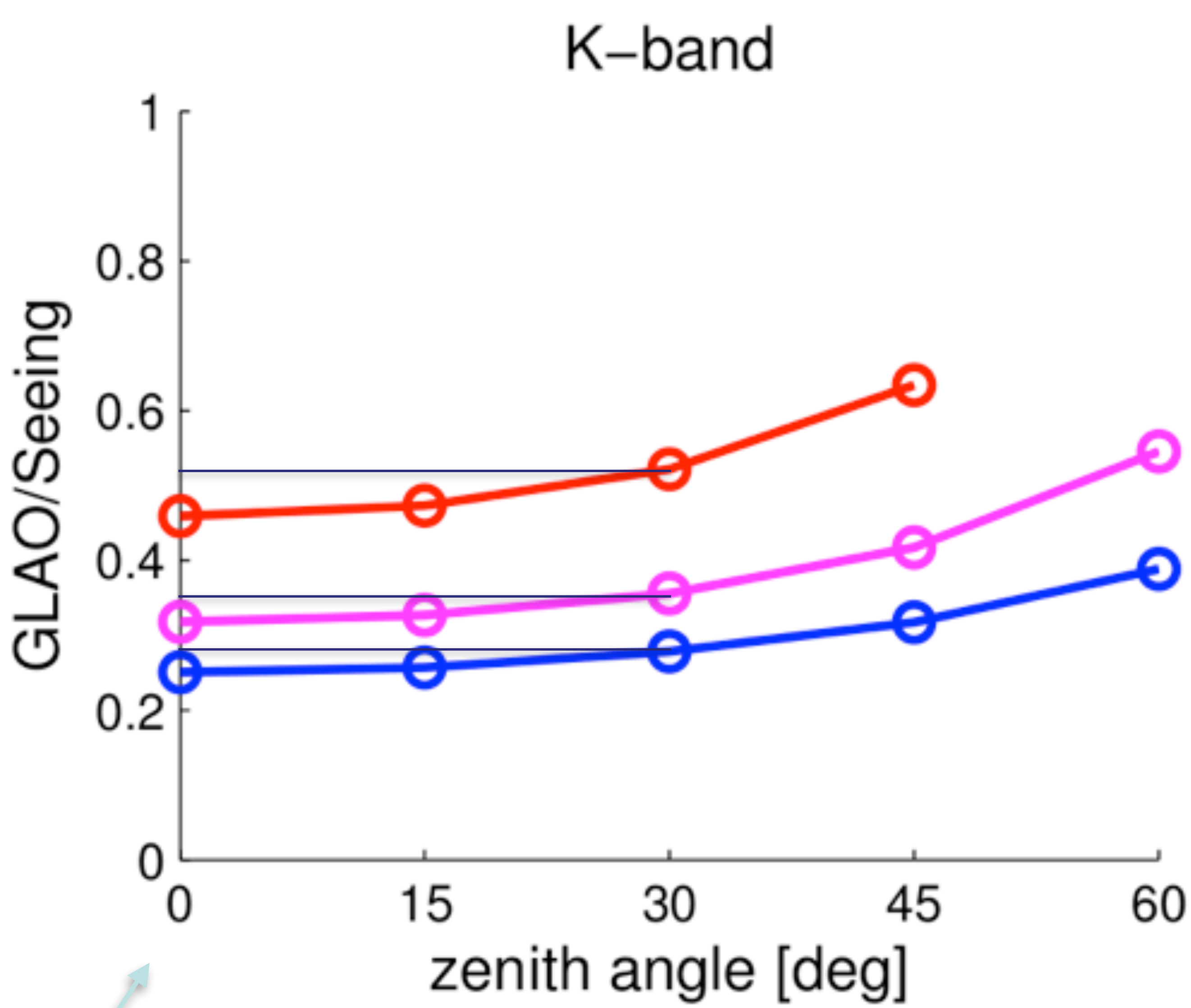
Clear message:

- GLAO reduces FHWM by 50%
- Median seeing GLAO performance: 0.2-0.3”

(Oya, 2014)



Ratios of noise-equivalent-area (NEA)

Next steps

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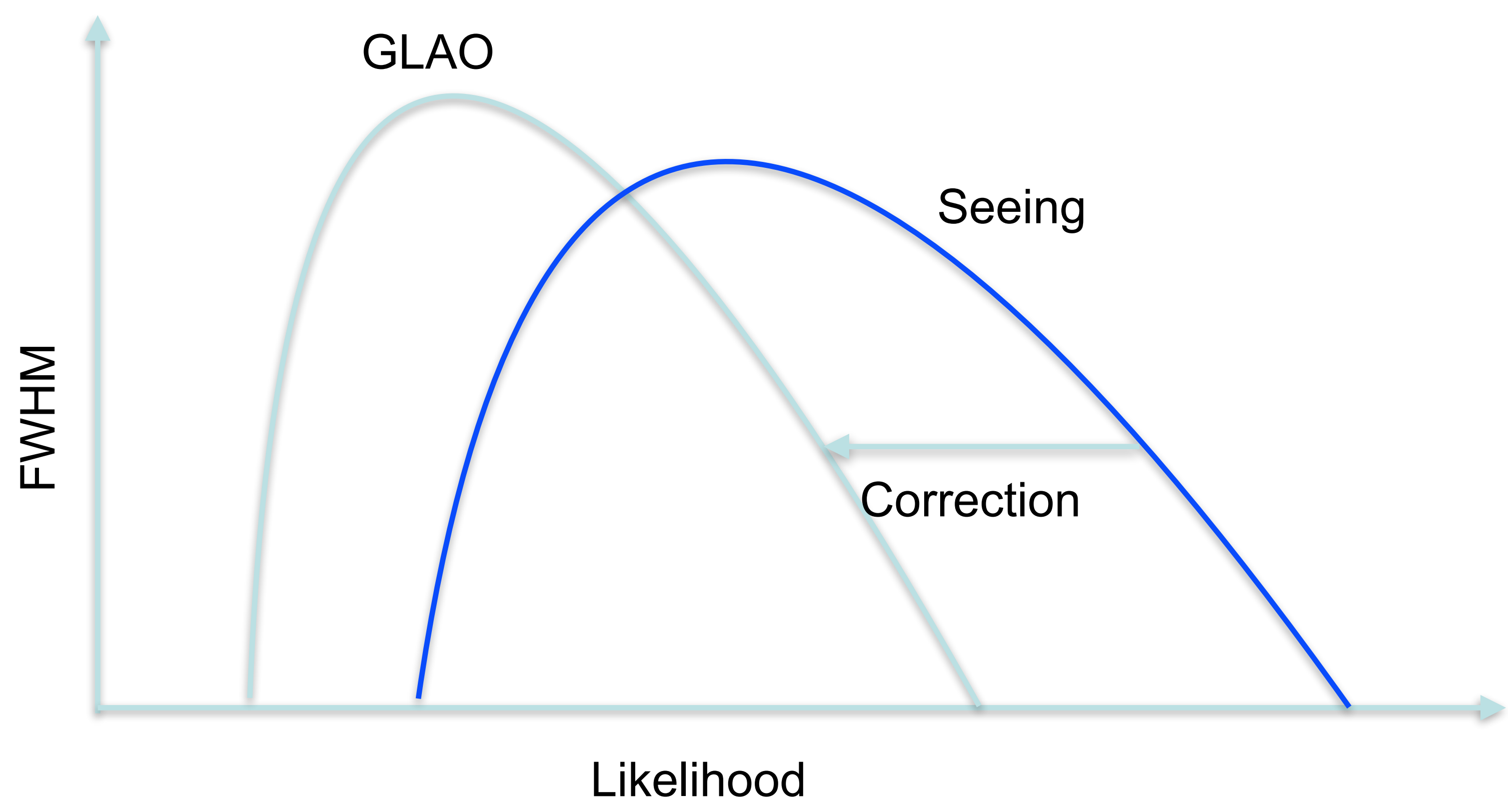
- Discrepancies between YAO & Oya's simulations
  - Clarify turbulence normalisation
- Finish simulation stages 1—2
  - Optimise of NGS WFS pixel size
  - Decide between visible and infrared detector for NGS WFS (based on expected NGS constellations)
- Complete stage 3 of simulations
  - Compile statistical performance estimates using realistic pointings, turbulence profiles and sodium returns

Simulation stage 3: future results

- For final performance estimate, we create 1000 samples using realistic settings
- We obtain:
  - For each sample: performance, e.g., FWHM, for seeing limited & GLAO corrected image
  - Histograms showing the likelihoods for seeing cases and corrections



Conclusions

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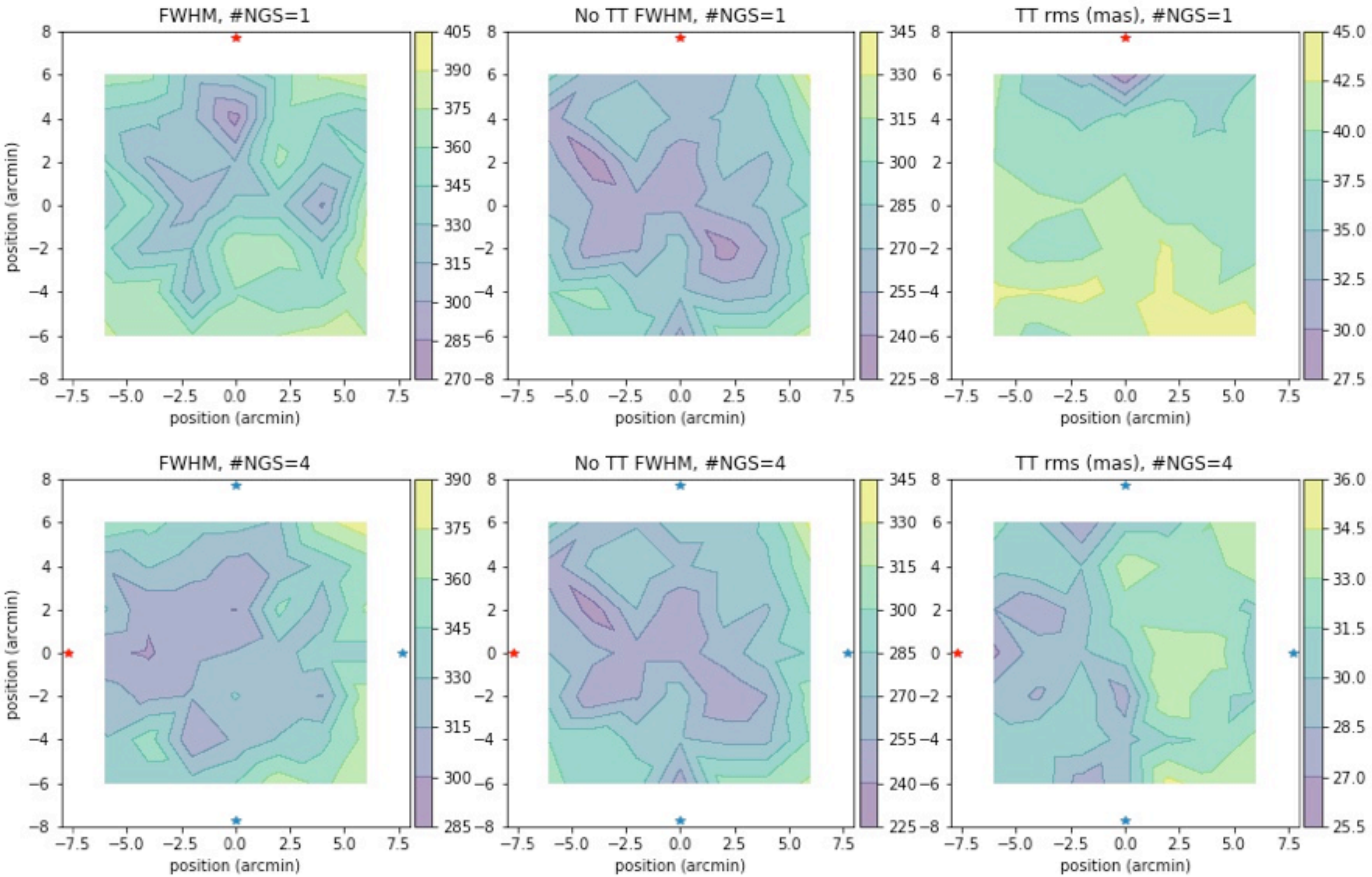
- Most of simulations for stages 1—2 completed (optimised design parameters)
- Good agreement with prior simulations, in particular regarding the ratio that GLAO correction will achieve: FWHM reduced by ~50% in all seeing conditions
- Minor discrepancies to sorted out: make sure our turbulence is not too conservatively scaled (to accurately predict expected absolute GLAO corrected FWHM)
- Minor tasks remain to complete stages 1—2:
  - NGS WFS pixel size & used wavelength
- Simulation stage 3, full fledged performance prediction, will commence shortly

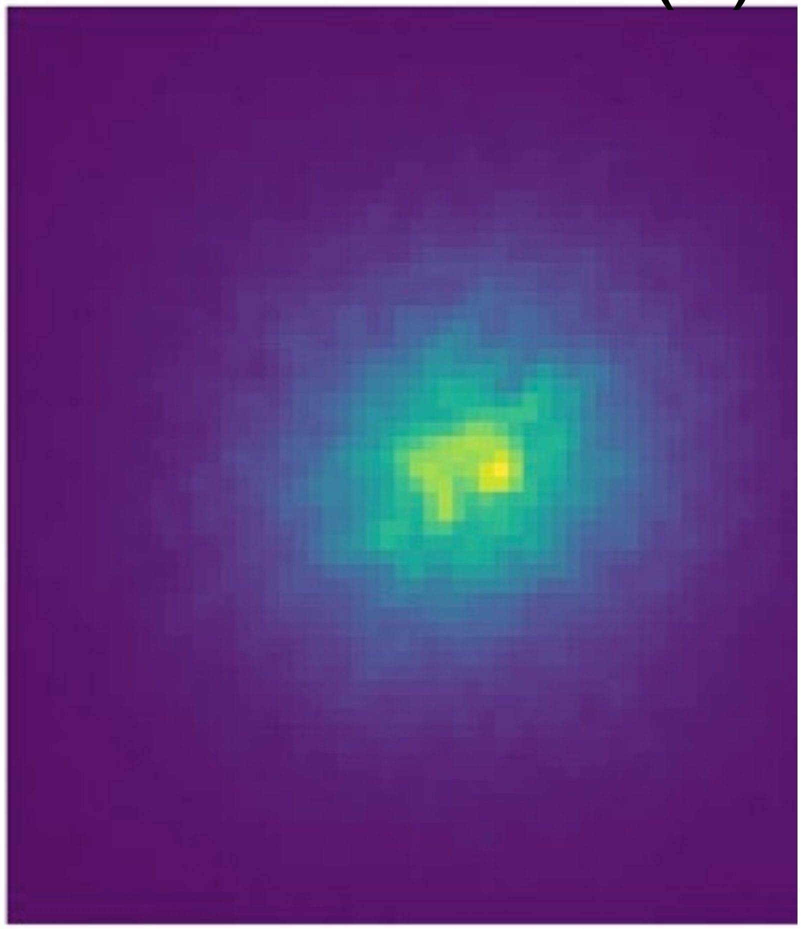
Thank you for your attention!

PSF quality as a function of field position. Seeing 50. 20000 iterations

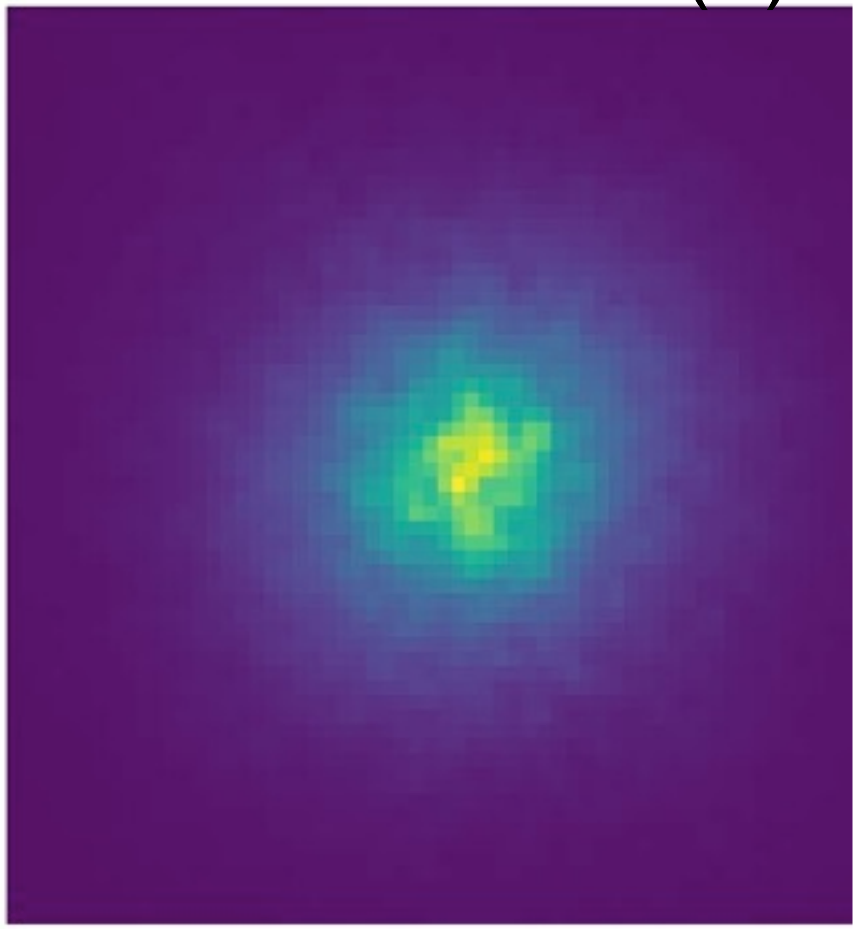


Convergence: PSF quality

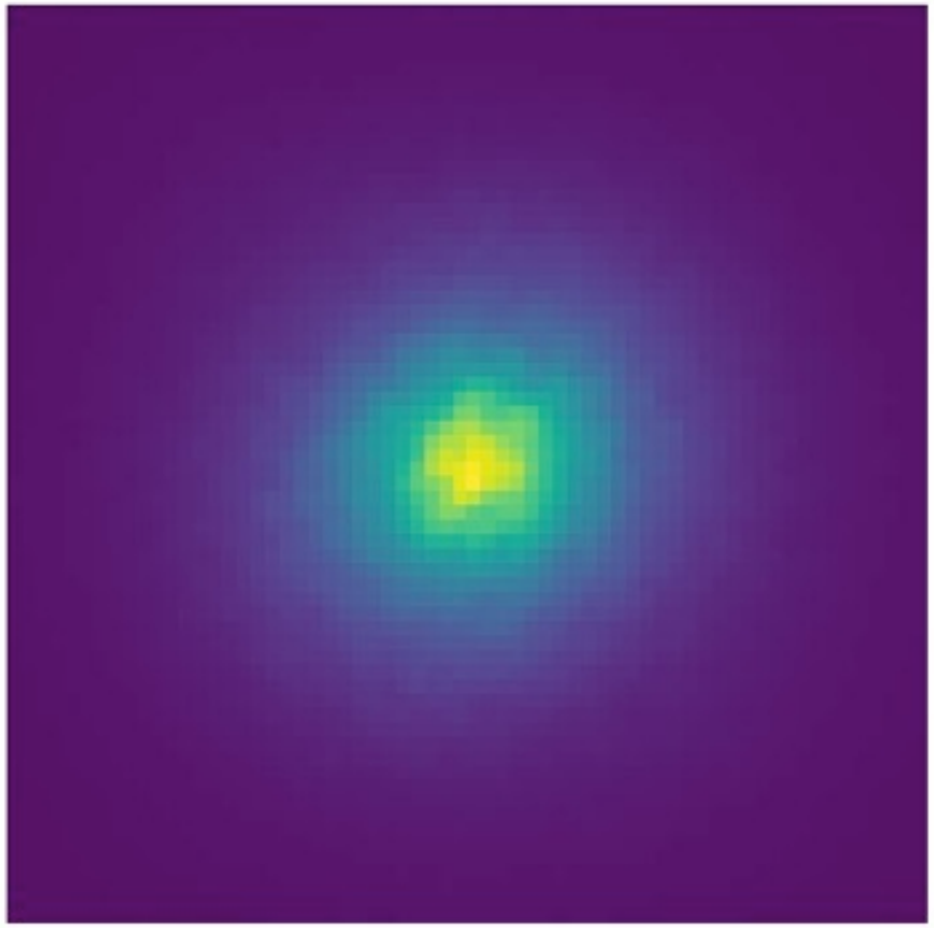
5000 iterations (1)



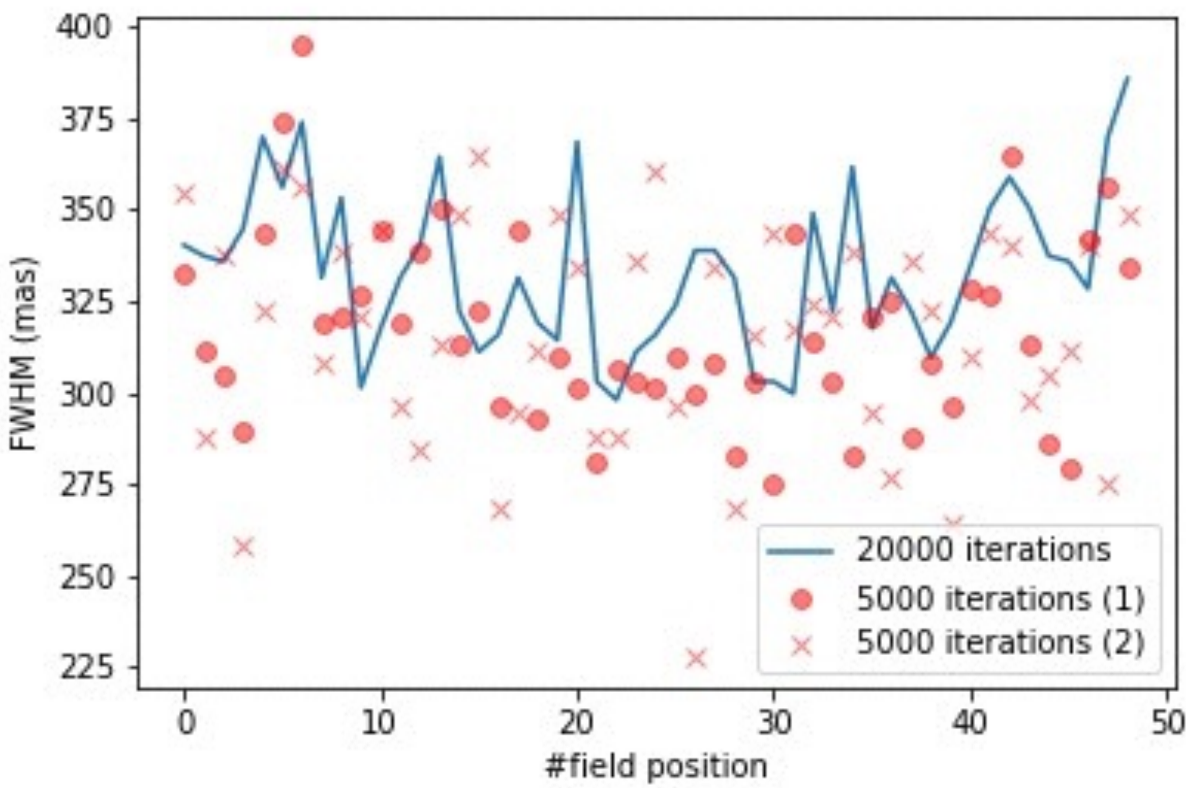
5000 iterations (2)

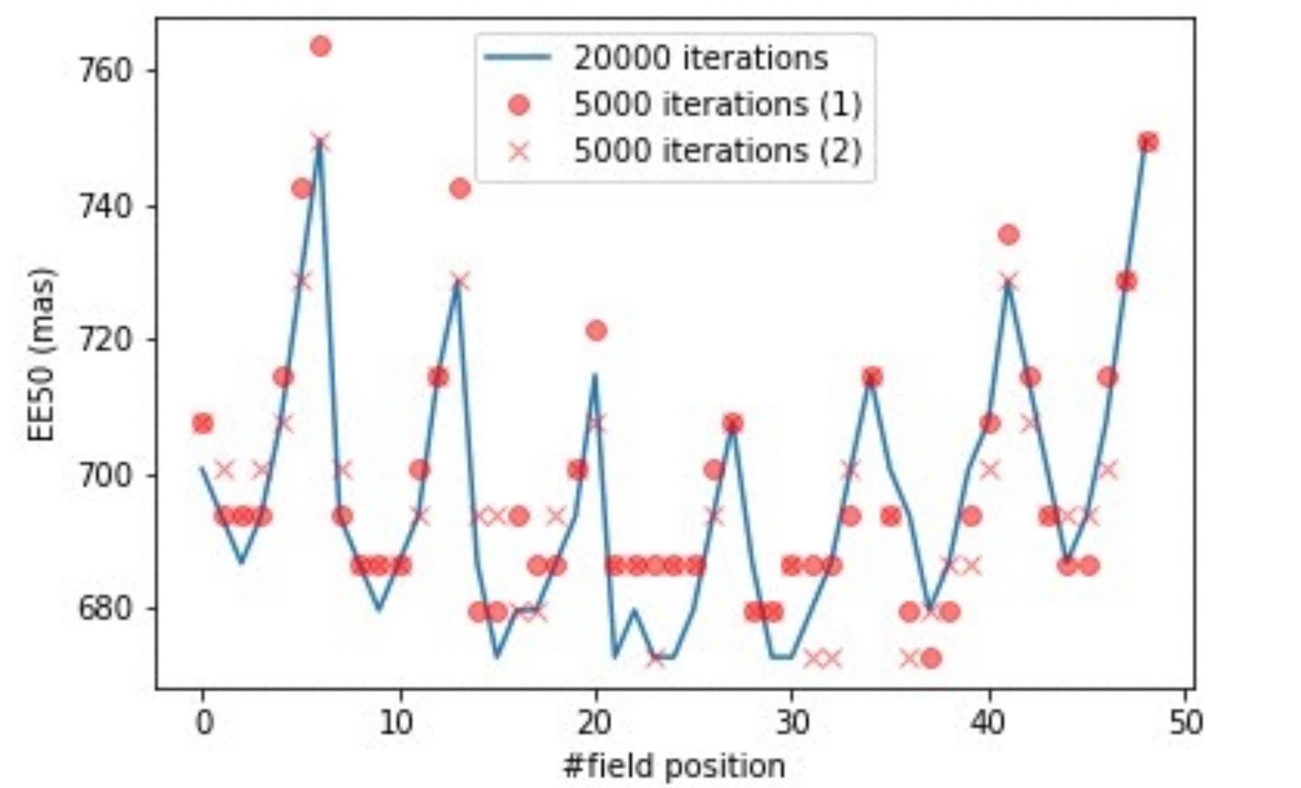


20000 iterations



Simulations: convergence





>20000 iterations for FWHM

>5000 iterations for EE50