PFS instrument and the SSP survey

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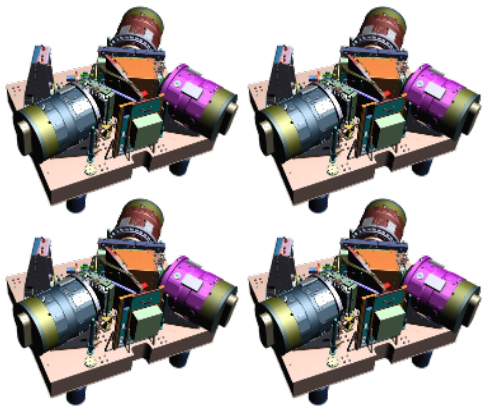
This talk includes the following topics:

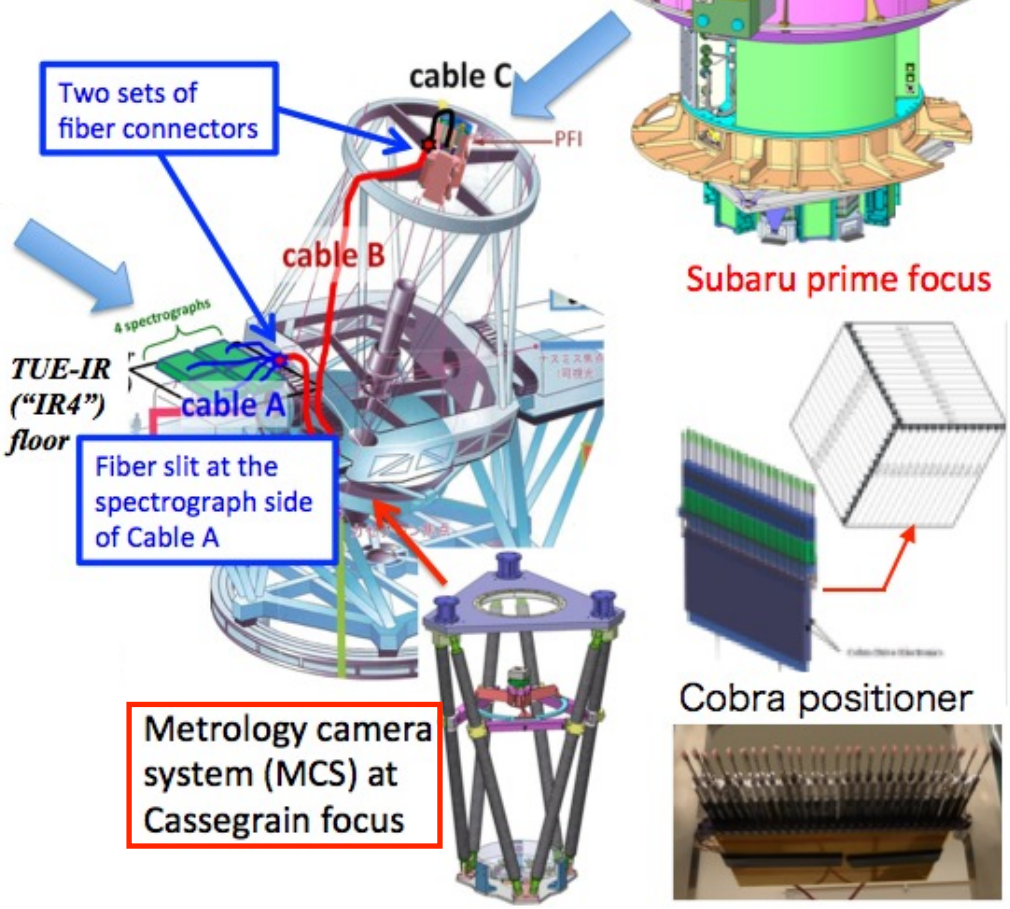
- Brief summary of PFS instrument
- Brief summary of PFS SSP survey
- PFS instrument details
- SSP survey plan & simulations

Summary of PFS instrument: overview

Spectrograph System (SpS)



Prime Focus Instrument (PFI)



Minowa+16 (modified)

Subaru prime focus

POpt2

Cobra positioner

PFS specification:

- ~1.3 deg diameter (hexagonal FoV)
- 2394 science fibers
- Quick fiber configuration by MCS (~60-120 sec.)
- Spectral coverage: 380 nm - 1260 nm with R~2000-4000
- System throughput: ~20-30 %

PFS expected performance (5σ, 1 hour integration):

- Continuum (3 pix binning) : ~22.5 AB (blue), ~22.4 AB (red), ~21.4 AB (NIR)
- Emission line (σ=70 km/s): ~1 x 10^{-17} erg/s/cm^2

PFS software development:

- Instrument Control Software (ICS)
- Exposure Targeting Software (ETS)
- Data Reduction Pipeline (DRP)
- Survey Planning & Tracking (SPT)

Summary of PFS instrument: information

PFS Instrument Parameters

Prime Focus Instrument				
Field of view	~1.38 deg (hexagonal - diameter of circumscribed circle)			
Field of view area	~1.25 deg^2			
Input F number to fiber	2.8			
Fiber core diameter (1)	127 μm (1.12 arcsec at the FoV center, 1.02 arcsec at the edge)			
Positioner pitch	8 mm (90.4 arcsec at the FoV center, 82.4 arcsec at the edge)			
Positioner patrol field	9.5 mm diameter (107.4 arcsec at the FoV center, 97.9 arcsec at the edge)			
Fiber minimum separation (2)	~30 arcsec			
Fiber configuration time	~60-120 sec. [TBC]			
Number of fibers	Science fibers	Fixed fiducial fibers		
	2394	96		
Fiber density	~2000 deg^{-2} / ~0.6 $arcmin^{-2}$			
Number of A&G camera (3)	6			
Field of view of A&G camera	~5.1 $arcmin^2$ per one camera			
Sensitivity of A&G camera	r'~20.0 AB mag for S/N~30 (100) in 1 (10) sec. exposure			
Spectrograph				
Spectral arms	Blue	Red		NIR
		Low Res.	Mid. Res.	
Spectral coverage	380 - 650 nm	630 - 970 nm	710 - 885 nm	940 - 1260 nm
Dispersion	~0.7 Å/pix	~0.9 Å/pix	~0.4 Å/pix	~0.8 Å/pix
Spectral resolution	~2.1 Å	~2.7 Å	~1.6 Å	~2.4 Å
Resolving power	~2300	~3000	~5000	~4300
Spectrograph throughput (4)	~53% (@500nm)	~57% (@800nm)	~54% (@800nm)	~33% (@1100nm)

(1) This is a diameter of the sky projected on to the fiber core not directly but through a microlens with a magnification of 1.28. According to the plate scale without microlens, 100um subtends ~ 1.1 arcsec on the sky.

http://pfs.ipmu.jp/research/parameter.html

PFS Expected Performance

The sensitivity information below is still preliminary and is subject to change in the future.

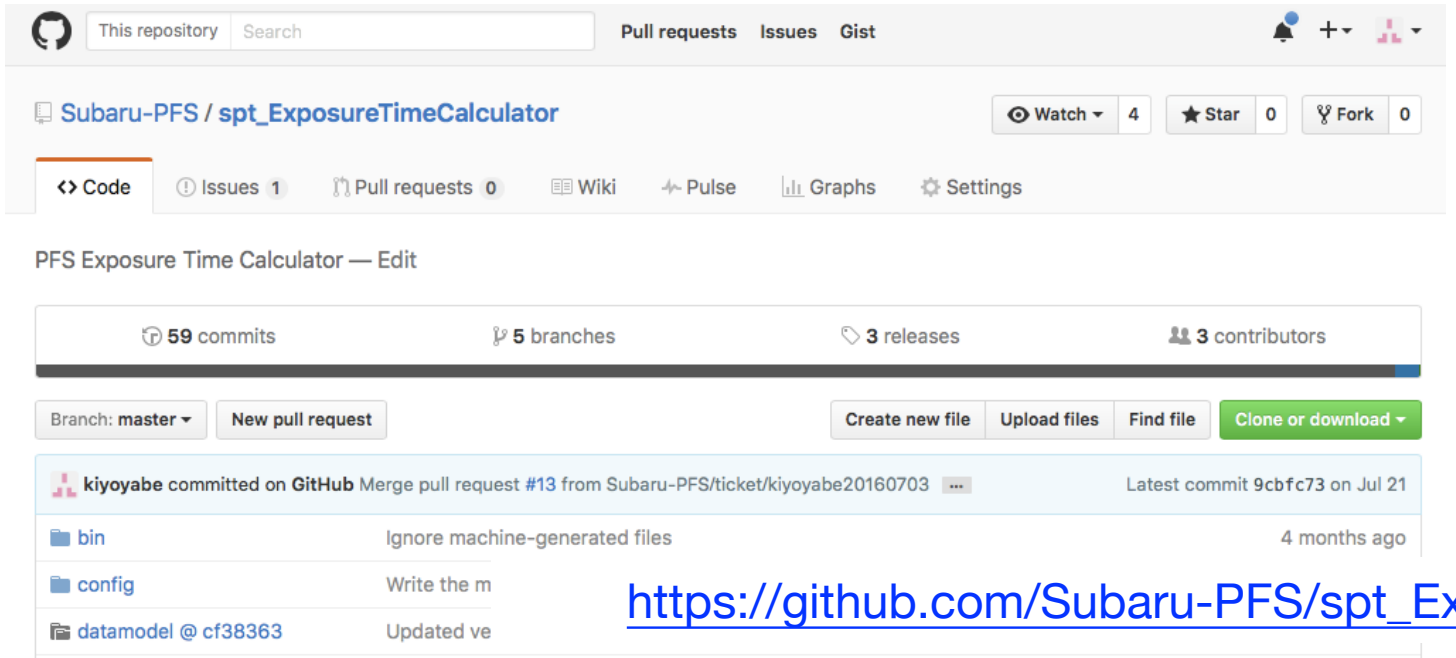
- Basic Information
- Moonlight Effects

Basic Information

Arm		Wavelength range [nm]	Throughput(1)	Resolving Power	Continuum sensitivity(2) [AB mag] mean(4)	Continuum sensitivity(2) [AB mag] representative(5)	Emission line sensitivity(3) [10^{-17} erg/s/cm^2] mean(4)	Emission line sensitivity(3) [10^{-17} erg/s/cm^2] representative(5)
Blue		380 - 450	14%	~2300	22.0	22.1 (@415nm)	2.9	2.8 (@415nm)
		450 - 550	24%		22.4	22.5 (@505nm)	1.5	1.4 (@505nm)
		550 - 650	23%		22.1	22.2 (@605nm)	1.5	1.3 (@605nm)
Red	Low Res.	630 - 750	29%	~3000	22.2	22.5 (@680nm)	1.2	1.0 (@680nm)
		750 - 850	30%		22.0	22.4 (@796nm)	1.1	0.9 (@796nm)
		850 - 970	27%		21.6	22.1 (@912nm)	1.2	0.9 (@912nm)
	Mid. Res.	710 - 775	26%	~5000	21.6	21.8 (@741nm)	1.3	1.1 (@741nm)
		775 - 825	28%		21.6	21.8 (@796nm)	1.1	1.0 (@796nm)
		825 - 885	27%		21.5	21.7 (@856nm)	1.2	1.0 (@856nm)
NIR		940 - 1050	17%	~4300	20.9	21.5 (@993nm)	2.0	1.3 (@993nm)
		1050 - 1150	19%		21.0	21.4 (@1100nm)	1.6	1.2 (@1100nm)
		1150 - 1260	17%		20.9	21.3 (@1208nm)	1.5	1.2 (@1208nm)

Note: These estimates are based on the PFS exposure time calculated developed by C. Hirata arXiv:1204.5151 under the following assumptions:

http://pfs.ipmu.jp/research/performance.html

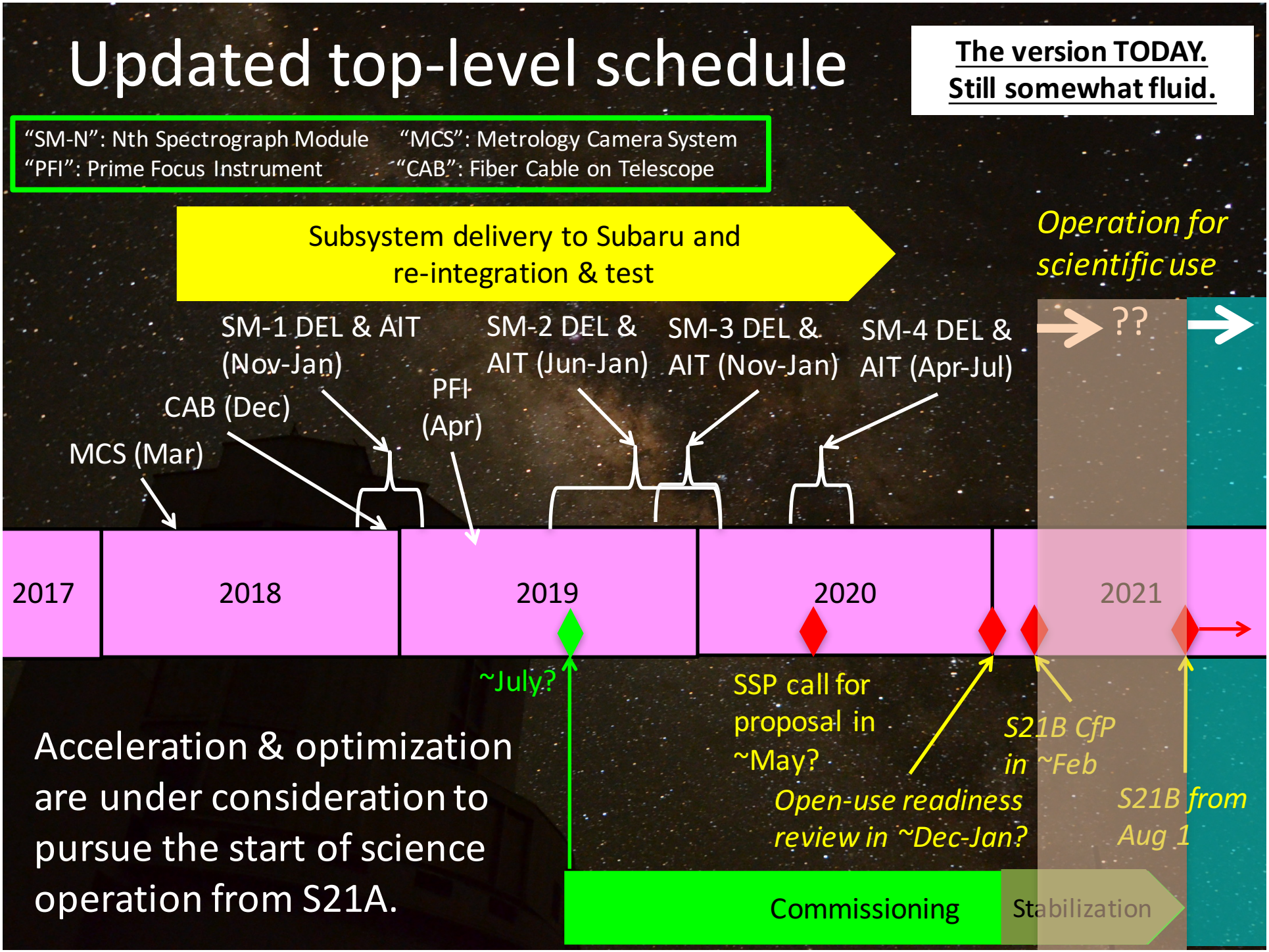


https://github.com/Subaru-PFS/spt_ExposureTimeCalculator

Summary of PFS SSP survey: overview

- PFS Subaru Strategic Program
  - 300 nights (a possibility of +60 nights)
  - 3 science groups are now working
- Cosmology:
  - ~1400 deg^2 of HSC wide foot prints (TBD)
  - Targeting emission line galaxies at z=0.6-2.4 (TBD)
  - Main scientific goals
    - ✓ Rule out the inverted hierarchy of neutrino masses
    - ✓ Rule out the standard ΛCDM model by finding a time evolution of Ω_Λ
- Galactic Archaeology:
  - MW dwarf satellites / Andromeda halo stars / MW halo,stream,disk (TBD)
  - Measuring radial velocity & chemical abundances of stars in these targets
  - Main scientific goals
    - ✓ Measuring radial velocity & chemical abundances of stars in these targets to constrain the nature of dark matter and its role in the formation of galaxies
- Galaxy/AGN Evolution:
  - Low-z (z=0.7-2) component / High-z (z=2-7) component
  - ~14 deg^2 of HCS deep foot prints (TBD)
  - Main scientific goals:
    - ✓ Measuring physical parameters of galaxies/AGNs residing in various environments and various redshifts
    - ✓ Large-scale structures traced by HI gas and galaxies

Summary of PFS SSP survey: timeline

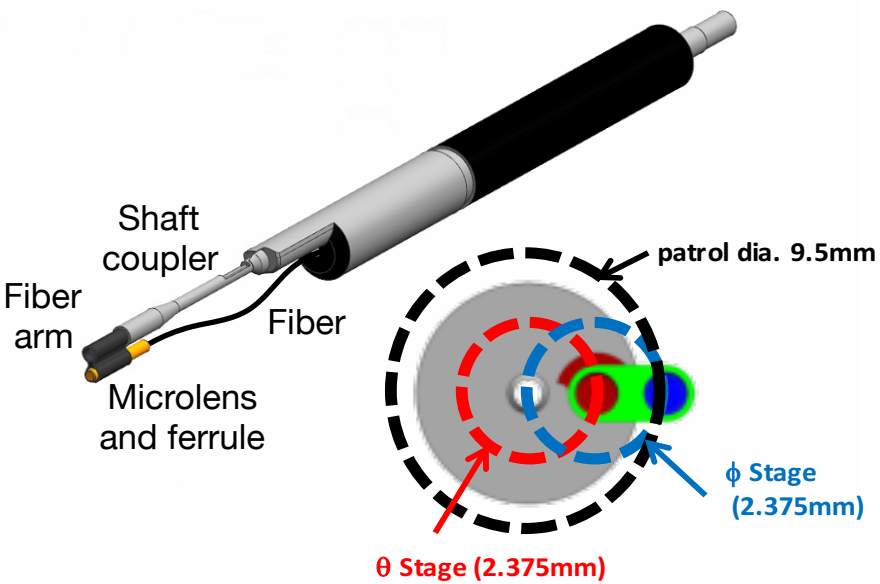


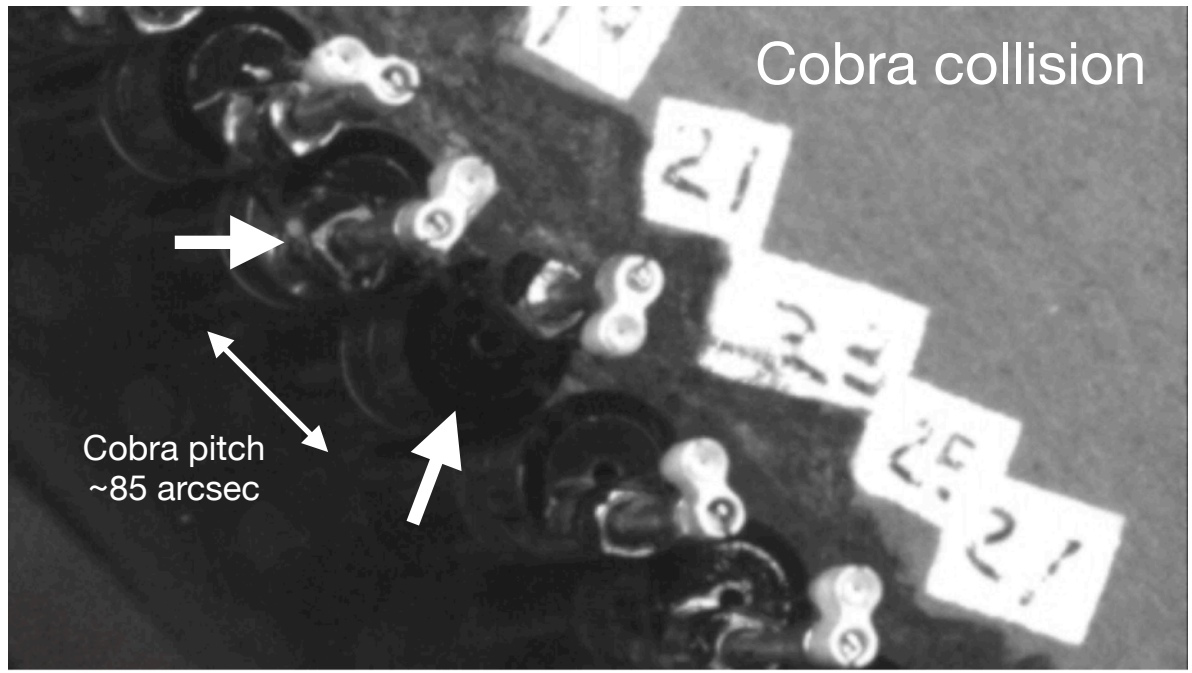
PFS instrument details: fiber configuration

- **Fiber configuration requirements**:
  - The configuration is finished in <105 sec. for 95% of all 2394 fibers
  - The positioning error is <5 μm (~0.04 arcsec)

- **Cobra collisions**:
  - There are some collision patterns (see below)
  - Some tests on the collision avoidance are in progress
  - Minimum separation of cobras ~30 arcsec (including margins)

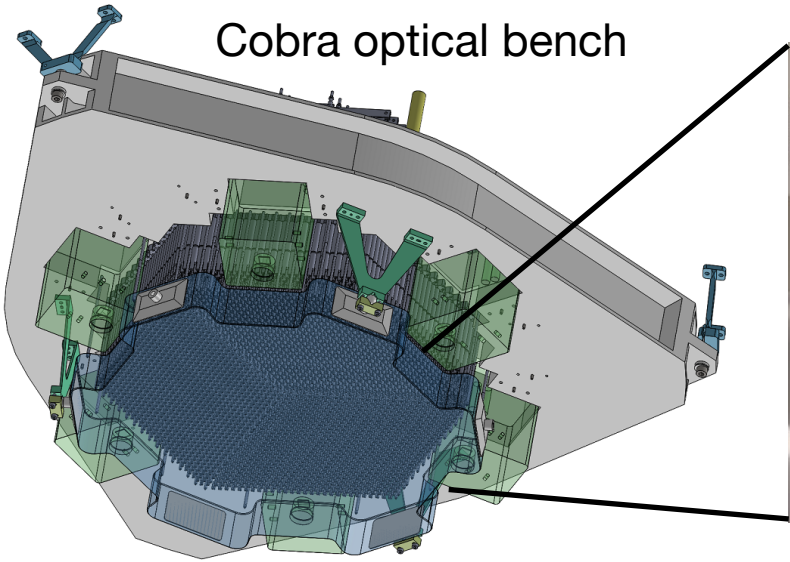
PFS fiber positioner "Cobra"

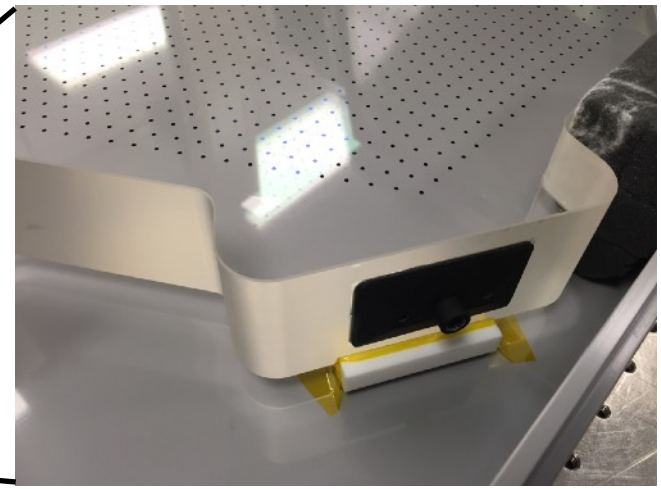




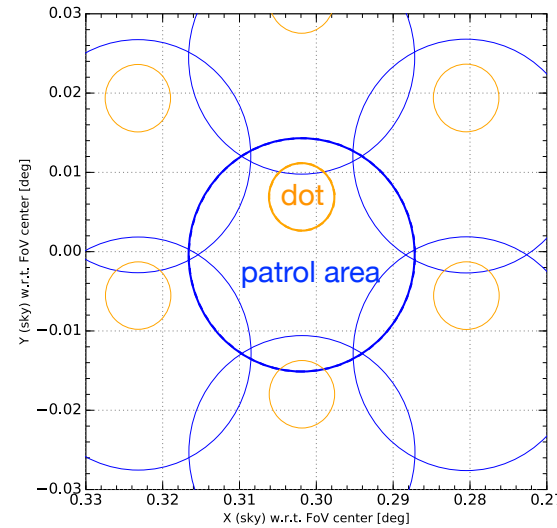
PFS instrument details: dot coverage

- **Masked regions called as "dots" on the focal plane**:
  - Used for the purpose of hiding some fibers when calibration images are taken (e.g., PSF reconstruction using arc images)
    - ✓ Diameter of 1.5 mm and coating reflectance of ~20%
    - ✓ Minimum distance from dot to fiber without light loss is 1.375mm
    - ✓ The blocked region is 2.75 mm diameter (~30 arcsec; ~8% of patrol area)
  - We cannot observe objects in the blocked region



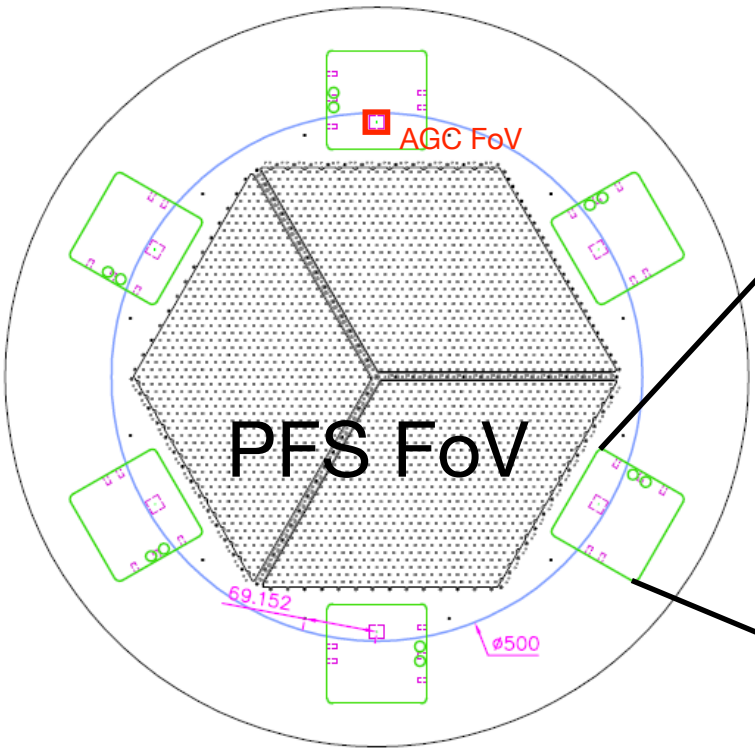


Field element

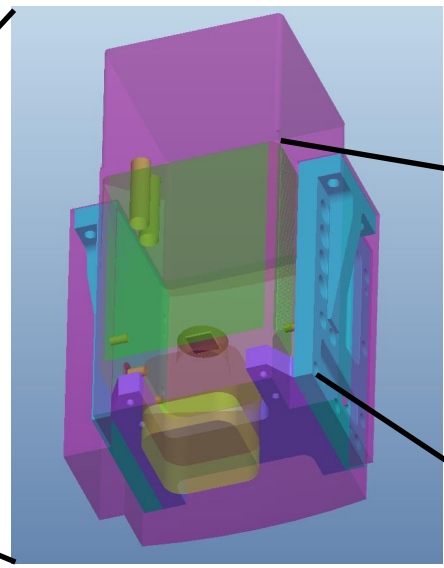


PFS instrument details: auto guiding system

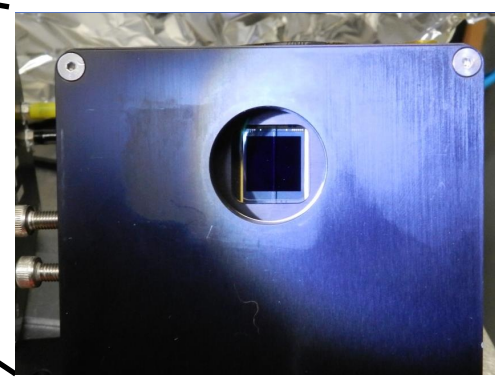
- **Auto guiding system**:
  - The auto guiding by 6 AG cameras around the FoV
    - ✓ Area of each camera: ~5 arcmin^2
    - ✓ Wavelength coverage: 400 - 800 nm
  - We expect to detect >4 guide stars with SNR>30 with 1 sec exposure anywhere on the sky (based on SDSS data)
  - Pointing and position angle may be somewhat restricted (especially in high Galactic latitude)



PFS AG camera

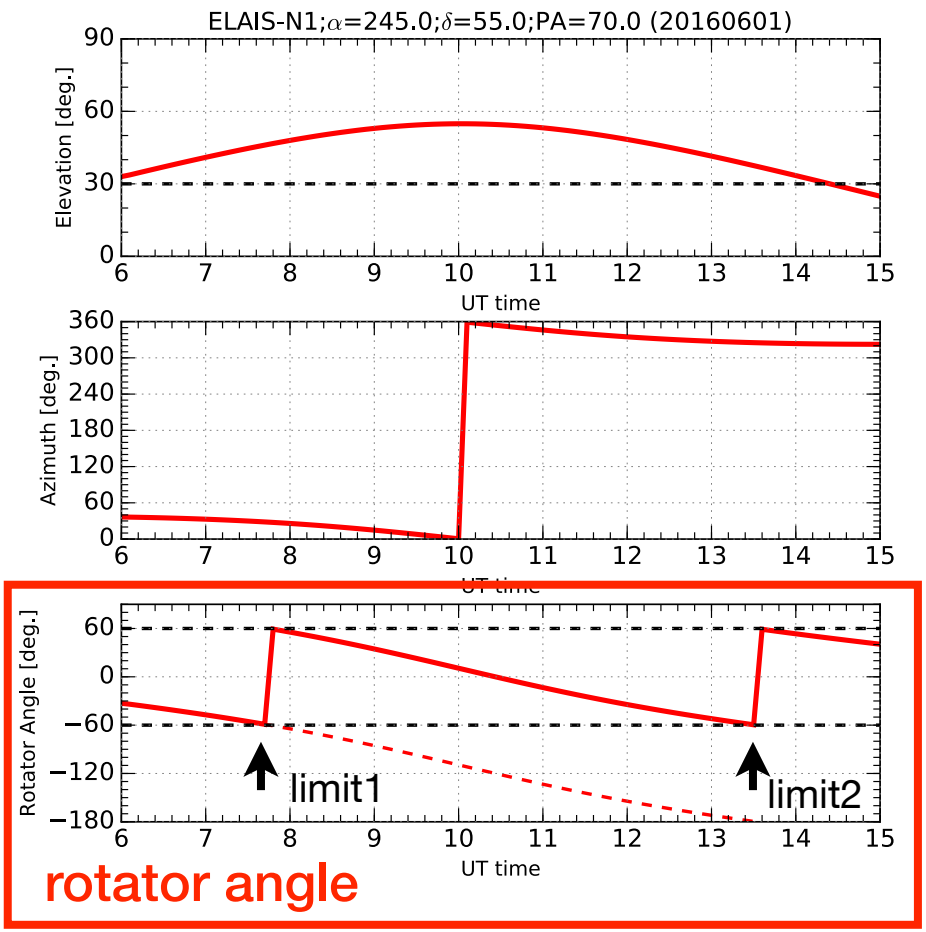


AG camera CCD



PFS instrument details: instrument rotator

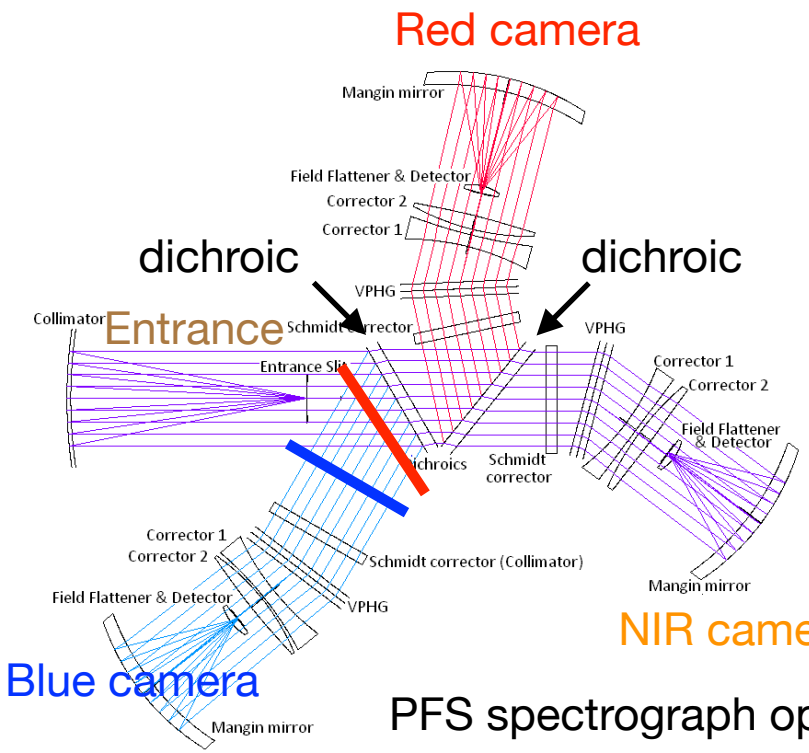
- **Instrument rotator angle:**
  - The mechanical limitation of the instrument rotator angle is ±276 deg.
  - We assume to operate the instrument with the rotator angle between -60 deg. and +60 deg. to minimize the impact of fiber FRD
  - The position angle (PA) of the FoV and the duration of the exposure in a fixed configuration therefore may be limited



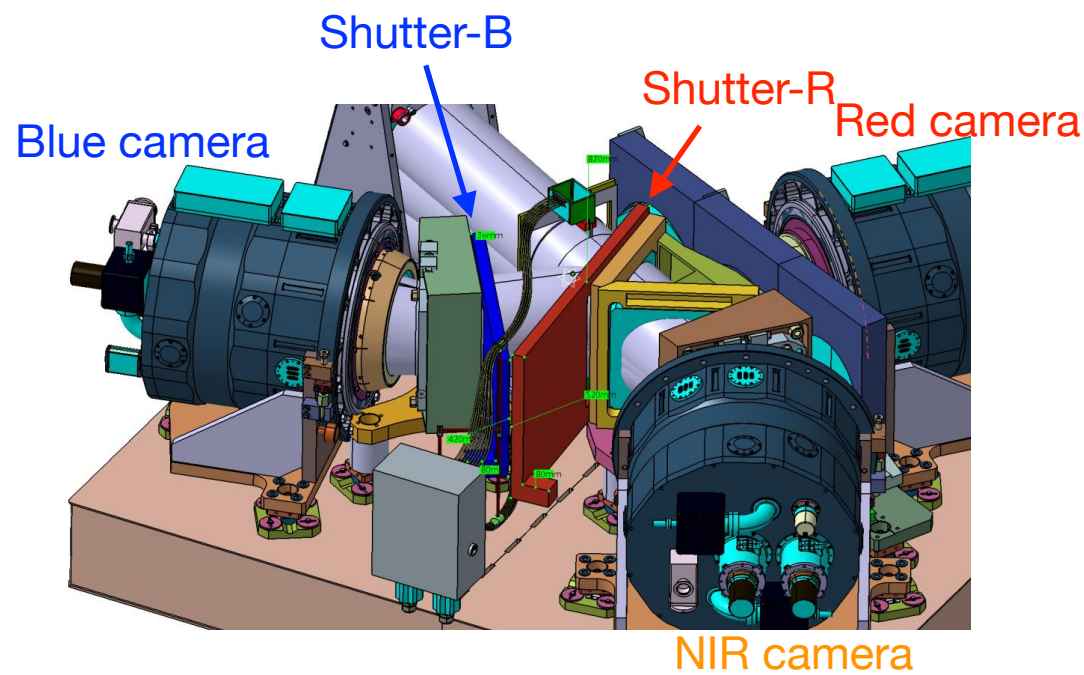
- If the rotator angle hits the limit during the observation, we need to rewind the rotator so that the angle is within the available range
- Rewinding angle is 60 or 120 deg. taking into account the symmetry
- (c.f.) The maximum rotator speed is 1.5 deg. s^{-1}

PFS instrument details: spectrograph

- **Exposure time**:
  - Requirement of the exposure time: SpS shall be capable of taking exposure longer than 2 sec. and shorter than 30 min.
    - ✓ The longest exposure time limit is due to various factors such as cosmic ray, OH line saturation, differential atmospheric refraction
    - ✓ The shortest exposure time limit is required for taking calibration data (c.f., requirement of the shutter speed: ~1 sec. for open/close)
  - Different exposure time for blue and red/NIR can be possible, but we can control the exposure of only blue arm (blue < red/NIR); no scientific merit?



PFS spectrograph optics



PFS instrument details: others

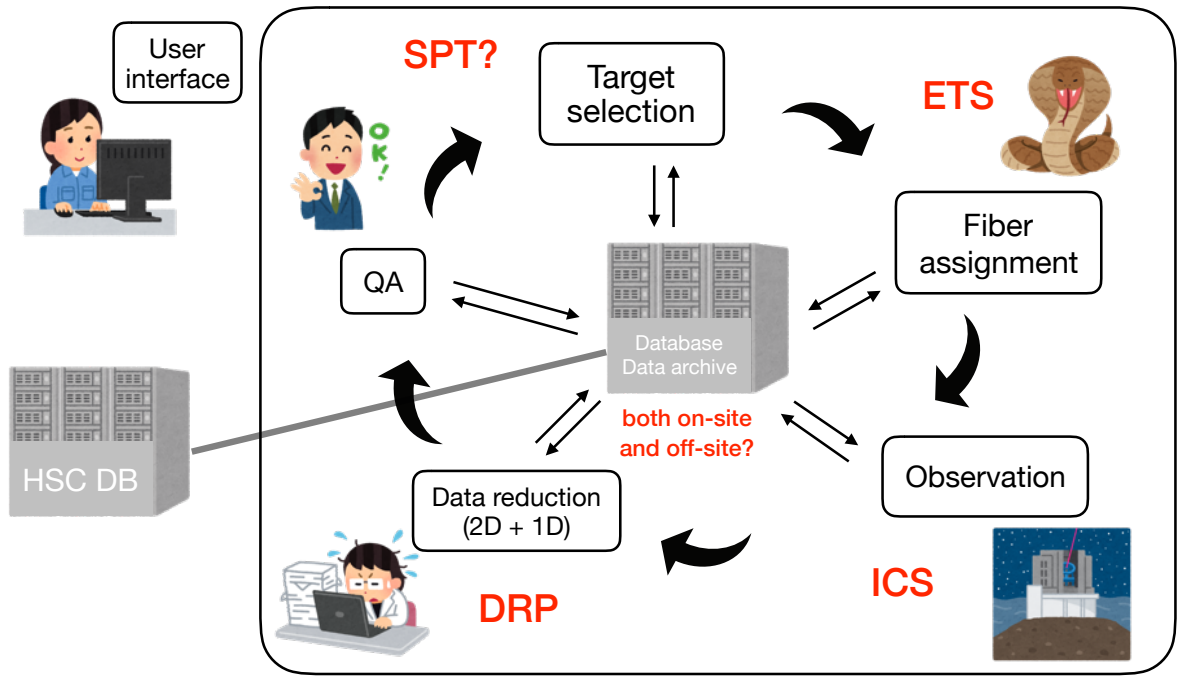
- **Operational mode**:
  - Currently, we suppose to operate without "beam-switching" mode
  - Sky fibers and science fibers are observed simultaneously
  - No limitation to the beam-switching from hardware perspective
  - Any development of DRP for the beam-switching mode is not considered currently

- **Taking calibration data**:
  - Calibration data for each fiber configuration is necessary
  - It takes about ~5 mins. for one configuration (TBC)
  - The data acquisition in the morning after the observation and the evening in the other day if necessary
  - The number of fiber configuration per night may be limited

Summary of PFS SSP survey: basic concept

- Basic concept of the PFS survey operation is executing the following observation loops, in which each software component plays an important role
  - *Exposure Targeting Software (ETS)* calculates the fiber configuration for a given target list
  - *Instrument Control Software (ICS)* controls each instrument component
  - *Data Reduction Pipeline (DRP)* reduced obtained data for a scientific usage
  - *Survey Planning & Tracking (SPT)* manages the overall survey operation
  - All data are stored in *PFS database system* (operational + science)
- Development of each software component is in progress (see our GitHub; https://github.com/Subaru-PFS)

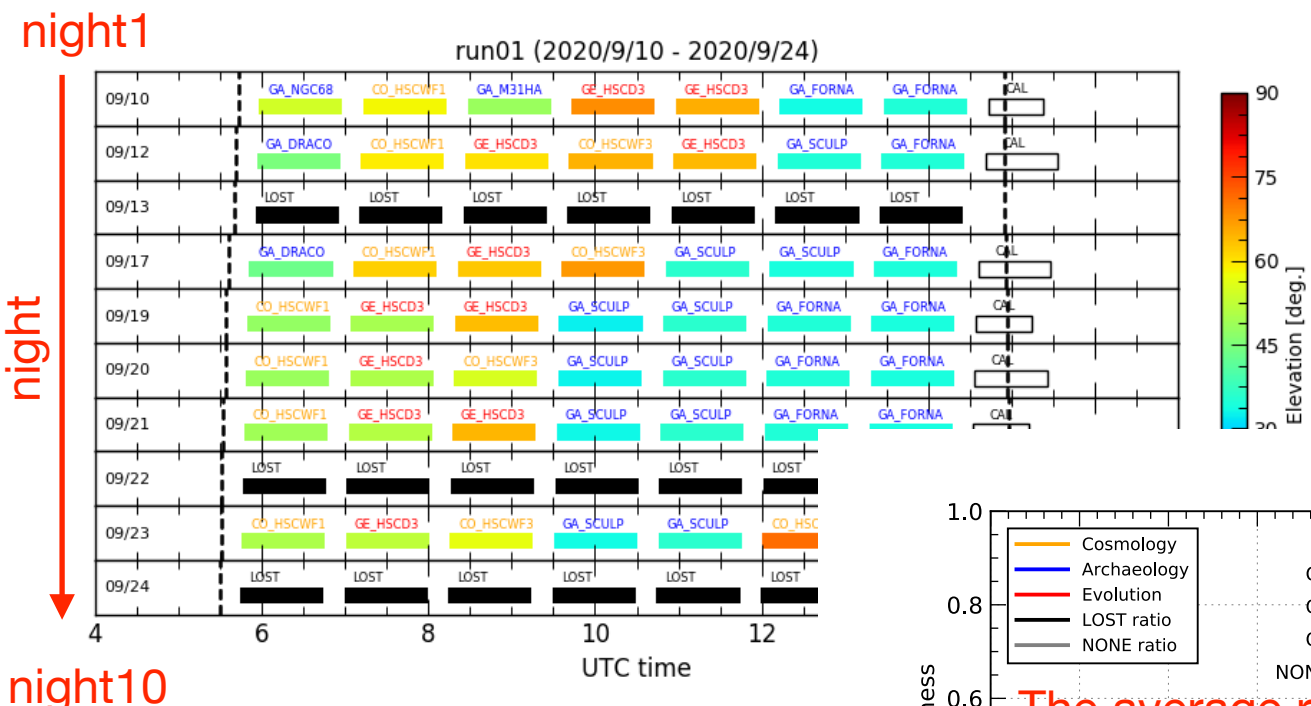
PFS survey procedure

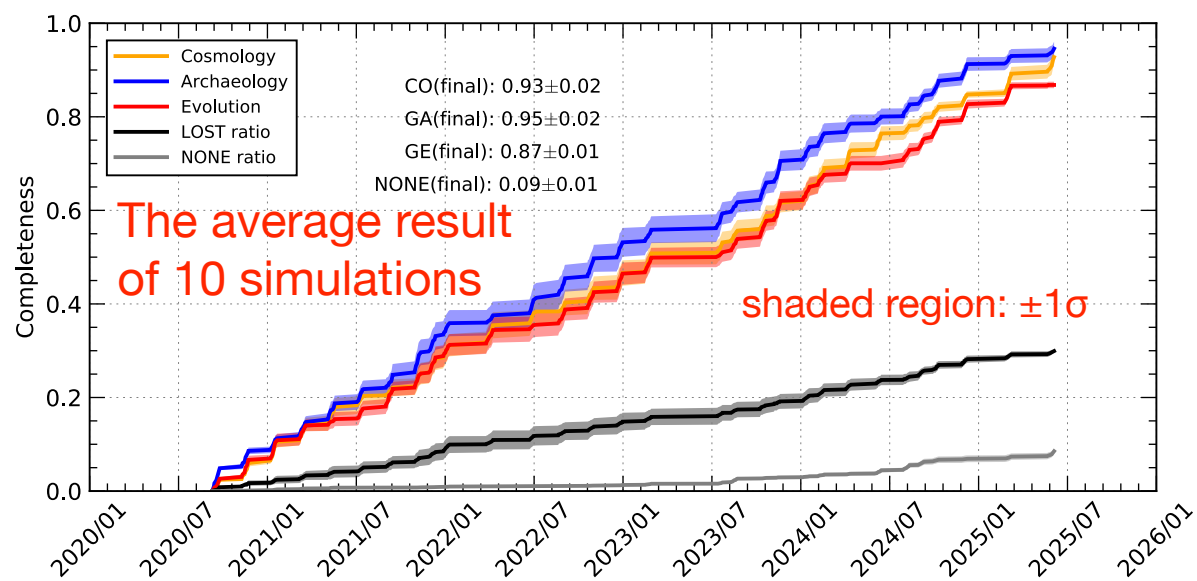


Repeating the observing cycle connecting to each other

Summary of PFS SSP survey: planning & simulation

- We have many targets for 3 different science goals, with different required exposure time, in different fields on the sky, and so on
- We should include them into one survey package in 300 nights
- The overall survey strategy is not clearly defined yet actually
- Survey simulation is now ongoing to see what happens in the actual survey

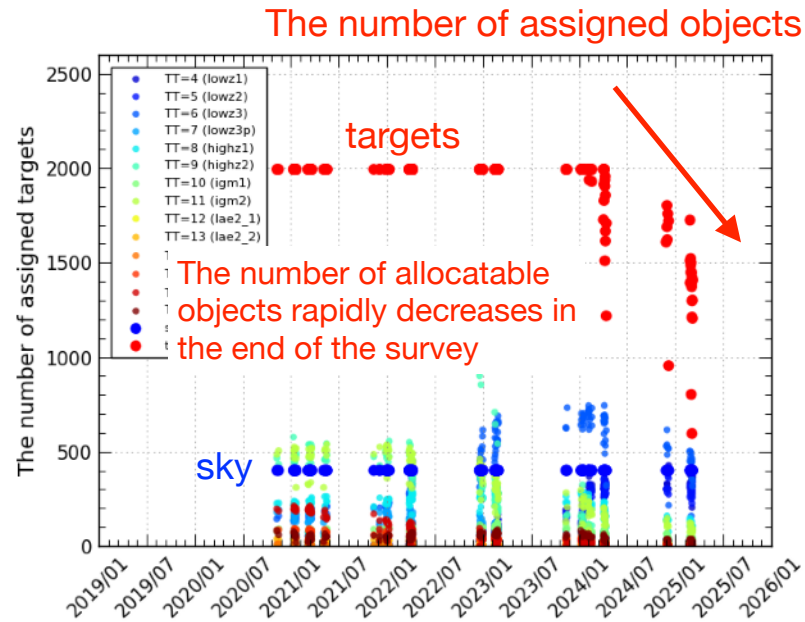


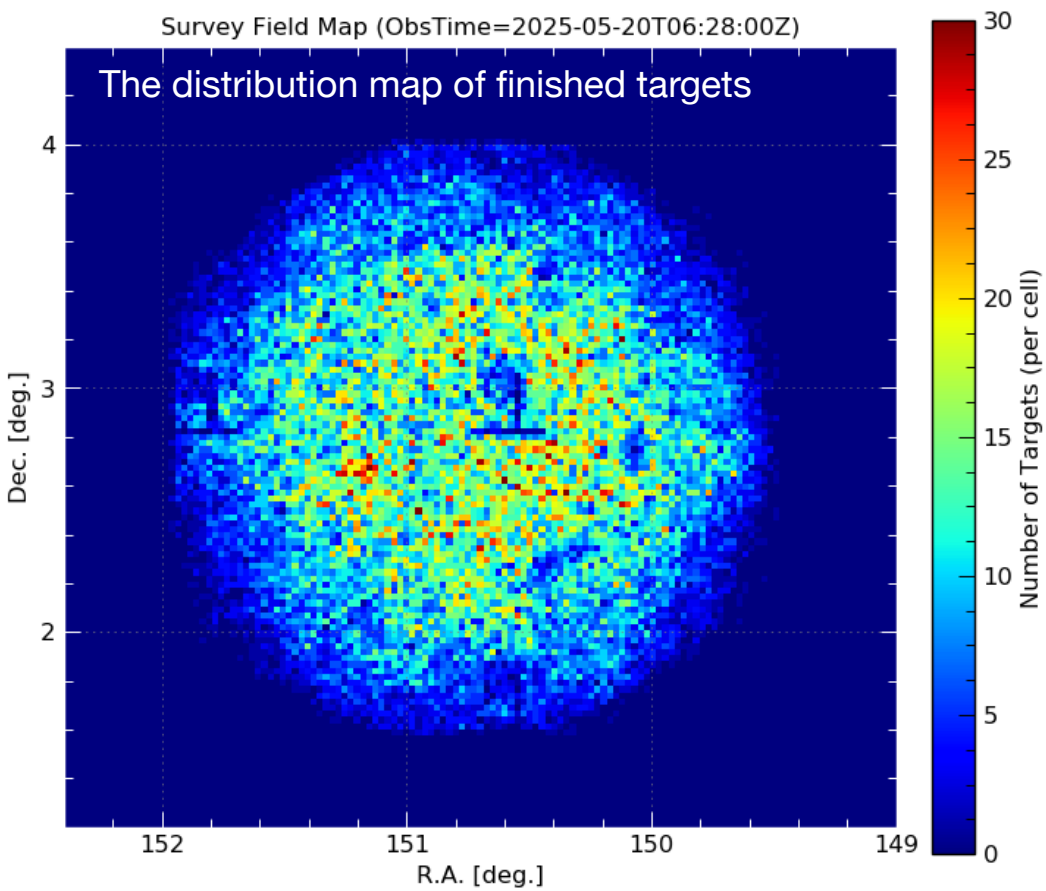


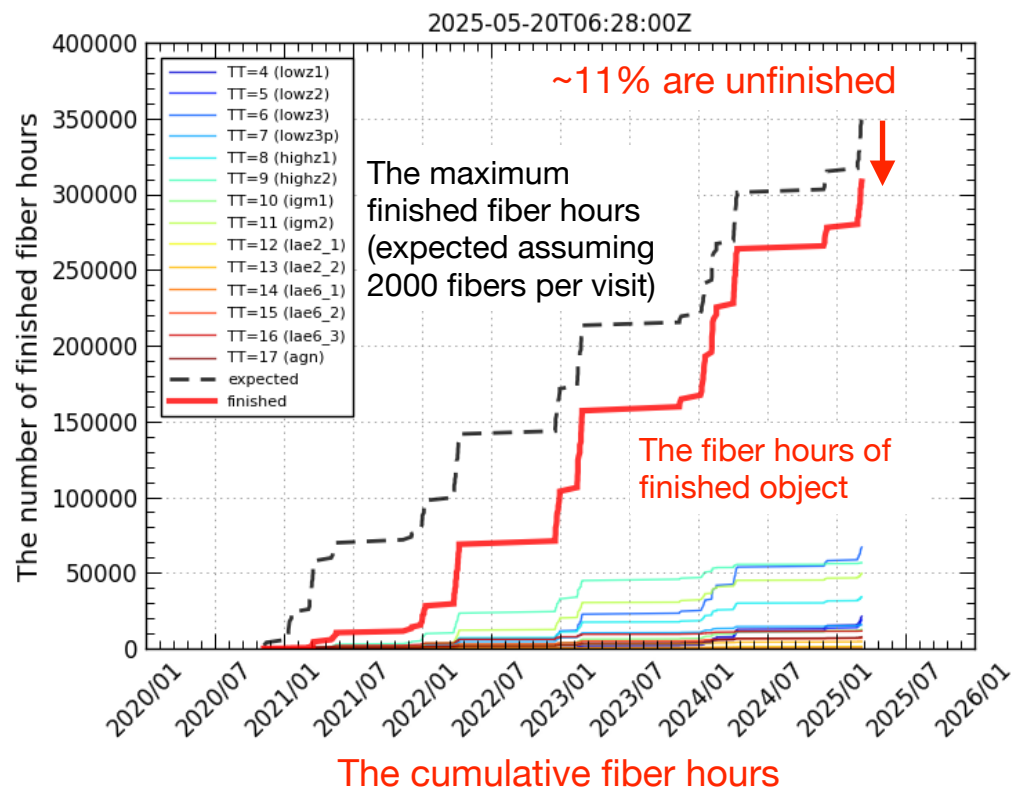
In addition to the overall scheduling simulation, end-to-end simulation using realistic target lists and some actual software components is in progress

Summary of PFS SSP survey: planning & simulation

- Simulation for Galaxy/AGN Evolution survey
- COSMOS mock catalog (total coverage is ~5 deg^2)
- If the observed exposure time reaches the expected one, the observation of the target is stopped
- The number of assigned objects rapidly decreases in the end of the survey
- ~25% fibers may be open in the very end of the survey
- But we still have additional sources (e.g., fainter targets)

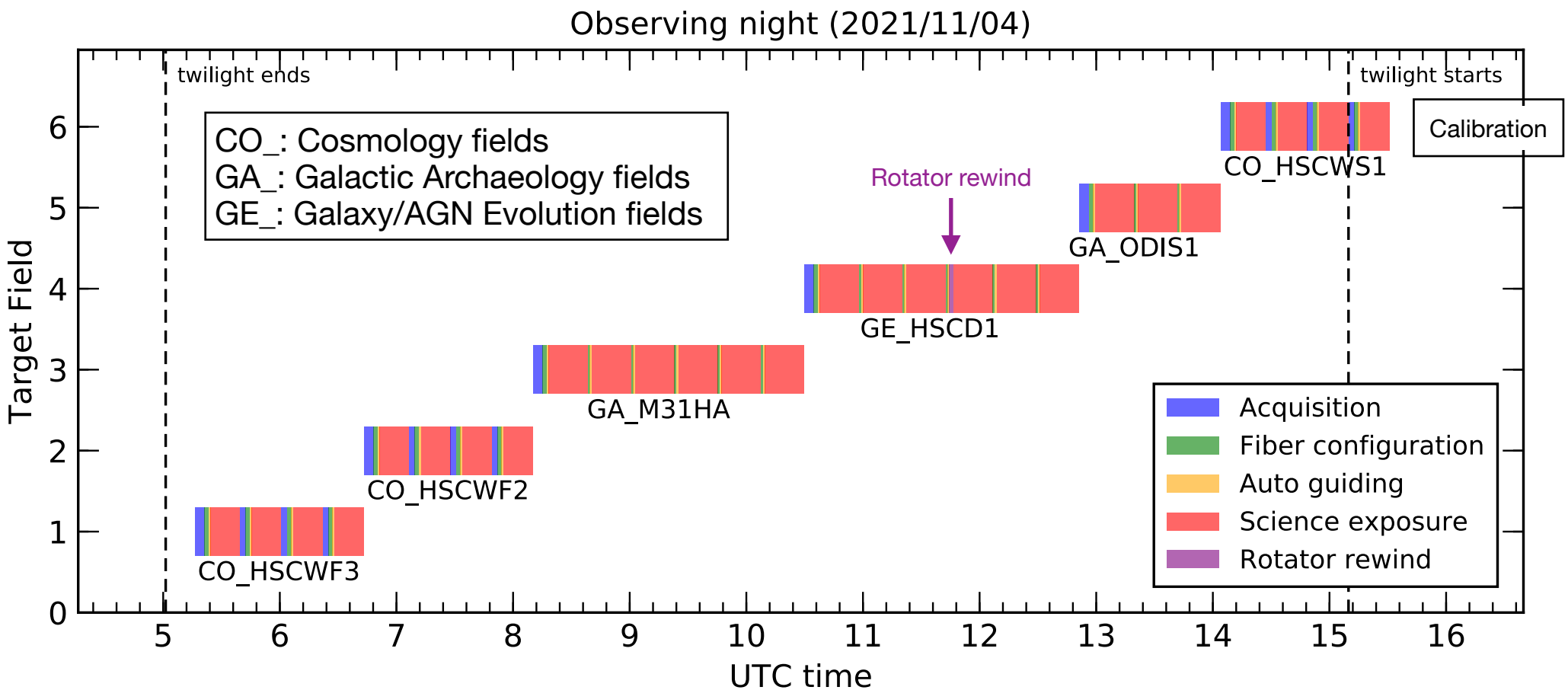






Summary of PFS SSP survey: example operation

- The design of the operational model in the actual survey is ongoing
- The assumed overheads:
  - Field acquisition: ~5 min. (large offset) / ~3 min. (small offset)
  - Fiber configuration: ~2 min. (full) / ~1 min. (tweak)
  - Starting auto guides: ~1 min.
  - Rewinding instrument rotator (if necessary): ~2 min.
- Typical overhead ratio (overheads / exposure time) is ~0.25



Summary:

- PFS is an instrument with a wide field (~1.3 deg.), a large multiplicity (~2400 fibers), and a wide wavelength coverage (3800Å-1.26μm)
- PFS SSP survey is 300 nights survey for 3 major science topics (Cosmology, Galactic Archaeology, Galaxy/AGN Evolution)
- The detailed design of the instrument operation and the SSP survey operation is actually under development
- We are happy to hear feedbacks from potential users in open use