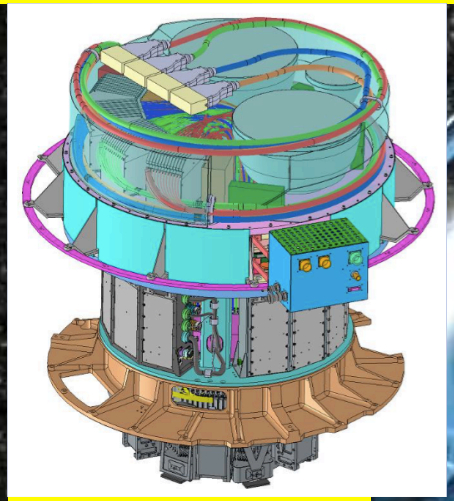
SUBARUPRIMEFOCUSSPECTROGRAPH

A status report by:
Naoyuki Tamura (Kavli IPMU)

On behalf of PFS collaboration

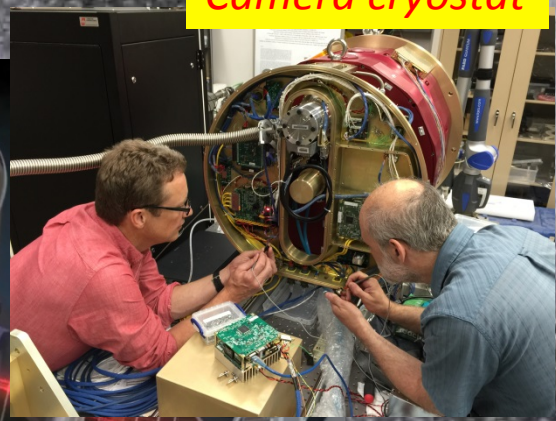
Prime Focus Instrument "PFI"



Fiber connectors

"Cobra" engineering model module

Camera cryostat

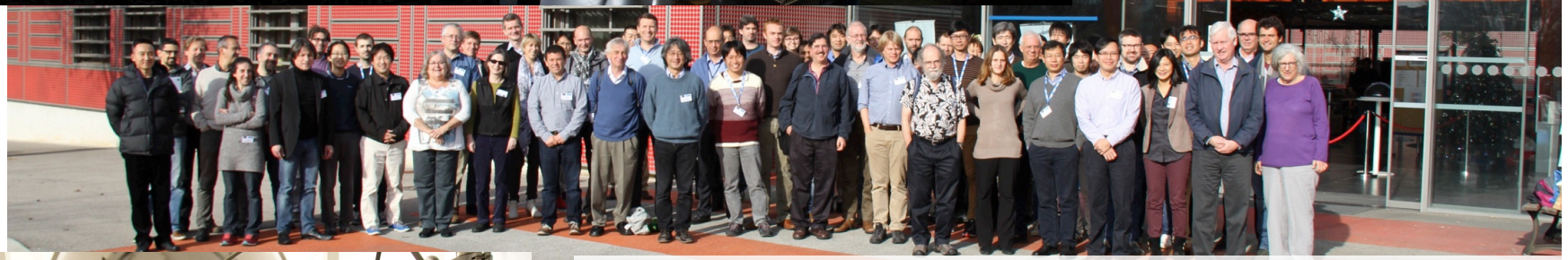


Spectrograph system

Subaru Users Meeting@Atami, Jan 19-21, 2016 JST

7th PFS collaboration meeting (Dec 14-18 at LAM, Marseille)

- 16th & 17th: Joint session with all participants
- 14th, 15th & 18th: Break-out sessions



- Two reports from the project & many others:
  - ~30min for management aspects
  - ~30min for technical & system aspects + various ~15-30min updates from collaborators

These are squeezed into 15min today, highlighting latest/major updates …

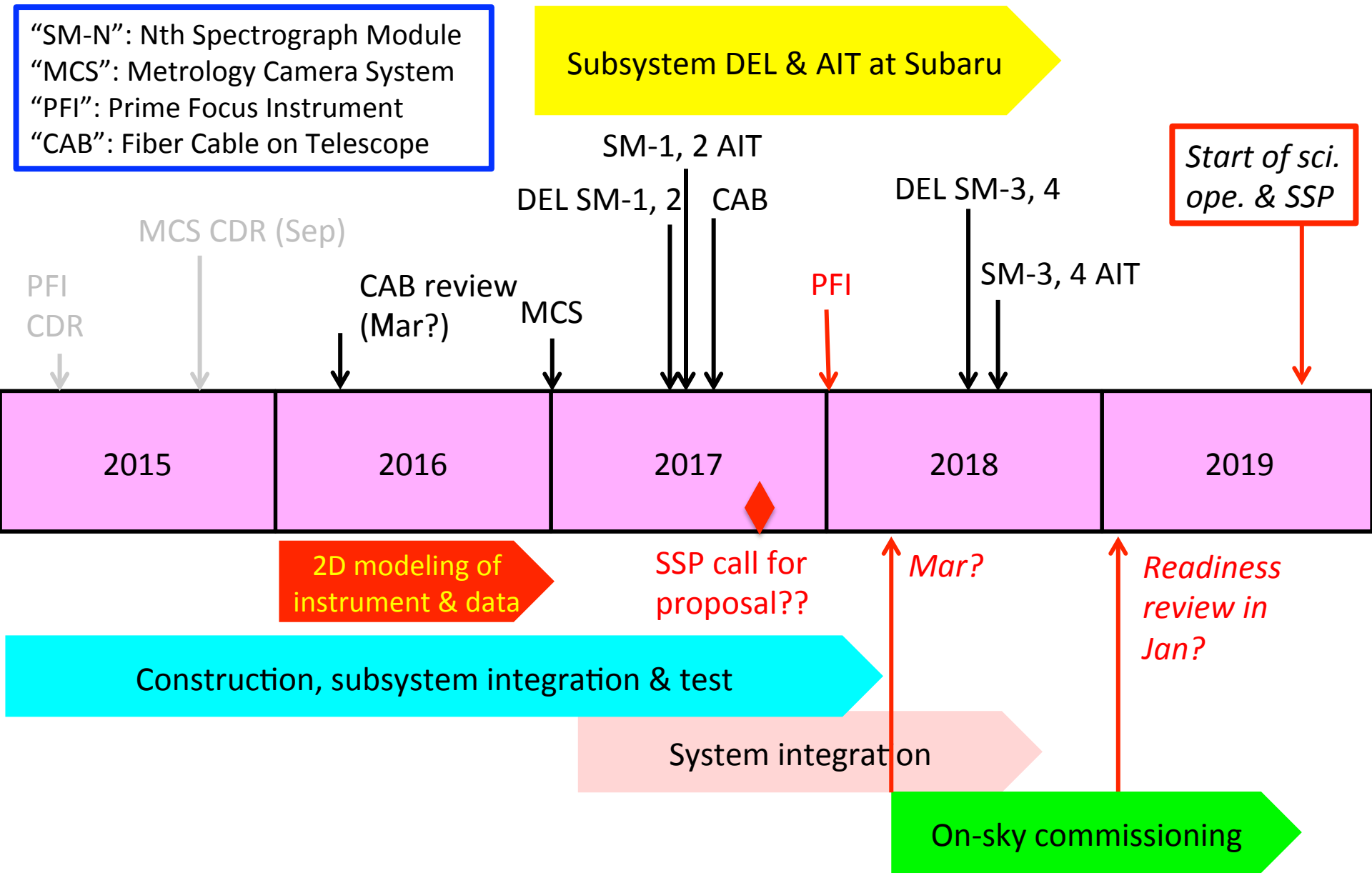
“PFS” – Fast facts

- Subaru *Prime Focus Spectrograph*
  - “SuMIRe” (Subaru Measurement of Images & Redshifts)
    = Large sky survey of imaging (HSC) AND spectroscopy (PFS)
  - Wide field: *~1.3 deg* diameter
  - Highly multiplexed: *2394 fibers*
  - Quick fiber reconfiguration: *~60-100 sec* (TBC)
  - Optical-NIR coverage: *380-1260nm simultaneously*
- Developed by *international* collaboration, under the initiative of *Kavli IPMU*
- ***Cosmology, Galaxy/AGN evolution, Galactic Archaeology*** as the key science areas in the PFS collaboration
- Aiming to start science operation from *2019*, as a *facility instrument* on Subaru.

Project history

- Apr 2011: Project Office was established. Design study activities were formalized.
- Mar 2012: Conceptual Design Review (CoDR: 概念設計会議) @ Hilo
- Feb 2013: Preliminary Design Review (PDR: 基本設計会議) @ Hilo
- Mar 2013 – Present: A hybrid phase of critical/final design studies & production. Critical Design Review (CDR: 詳細設計会議) is held at subsystem level (instead of no entire project CDR).
  - Mar 2014: Cable A & Spectrograph System (SpS) CDR – ***Done!***
  - Mar 2015: PFI, fiber positioner system, Cable C CDR – ***Done!***
  - Sep 2015: Metrology camera system CDR (with a delta review in Dec) – ***Done!***
  - Early 2016: Cable B (TBC)

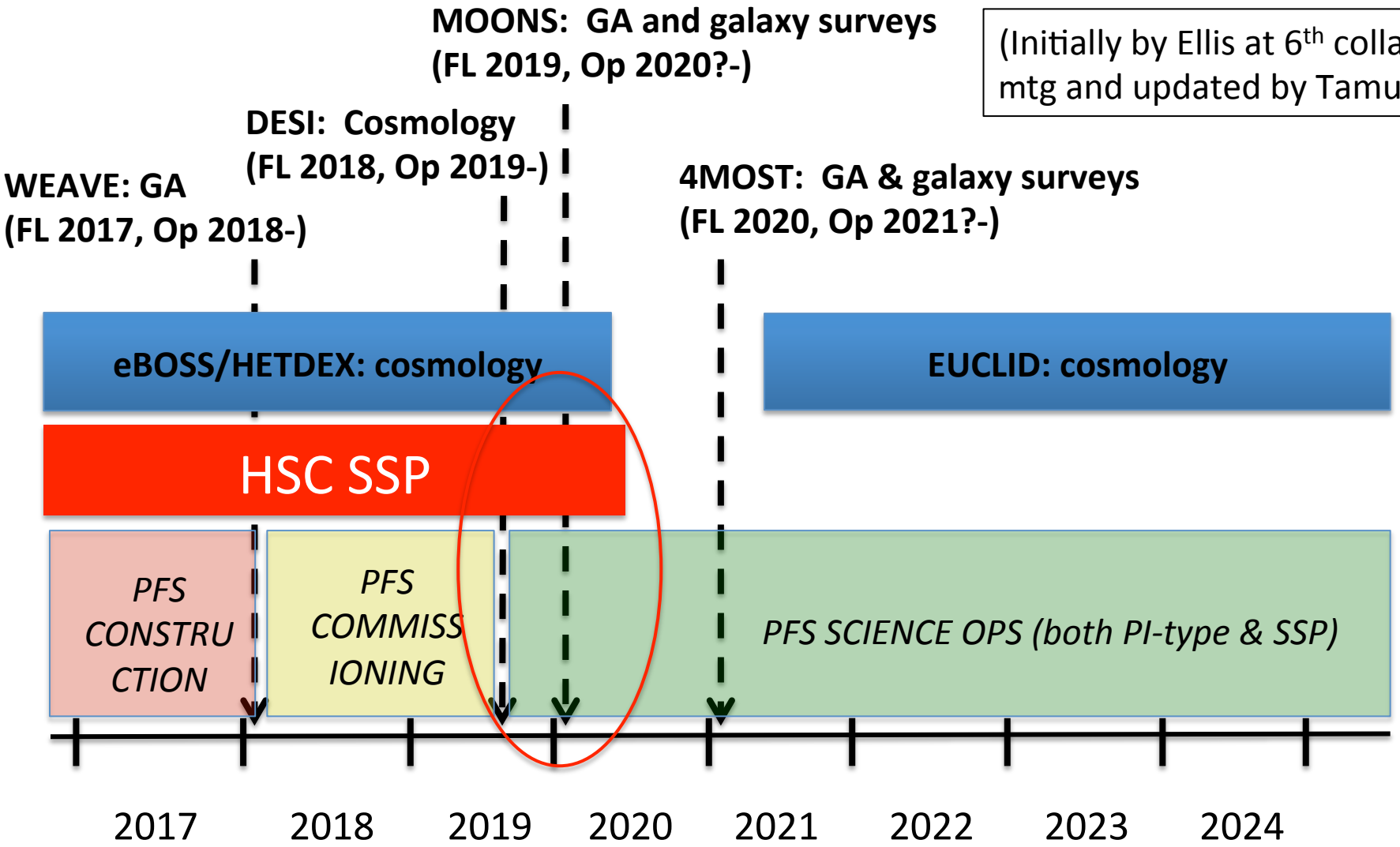
PFS project top-level schedule



The Competition: Schedules

Note: The schedules of the competitors are based partly on the information in the official websites etc but partly on informal information, so may be inaccurate.

(Initially by Ellis at 6th collab. mtg and updated by Tamura)



Breakdown Still preliminary

Planning the details of engineering observation
Y. Moritani (Kavli IPMU) et al.

- Run 1: 2 days
  - M1 – 4: MCS performance and study of Coordinate Transform
- Run 2: 2 days
  - M4: study of Coordinate Transform
- Run 3: 6 days
  - P1—P8: check of PFI functions, alignment of WFC, and refining fiducial fibers position
- Run 4 : 3 days
  - P9—P13: TPA and measurement of distortion of focal plane
- Run 5 : 4 days
  - F1,2&A1,2: validate Cable system and PSF characterization, calibration of positioner
- Run 6 : 8 days
  - F1,2&A1,2: validate Cable system and PSF characterization, calibration of positioner, improve of fiber positioning
- Run 7 : 5 days
  - improve of fiber positioning, performance verification
- Run 8, 9: 3 days
  - performance verification
- SM1,2 verification : 6 month
- SM3,4 verification : 2 month

Table 1: Expected days for commissioning.

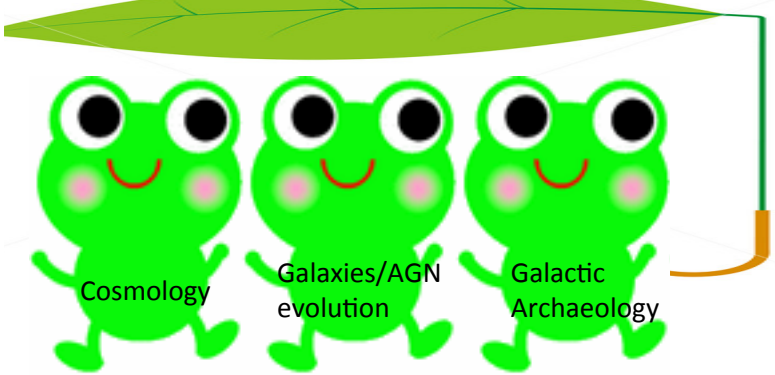
Run	seq.	daytime is OK	night-sky is needed	total
1	M1–3	1*	0	2
	M4	1	0	
2	M4	2	0	2
3	P1–P3	1	0	6
	P4	1	0	
	P5	1	0	
	P6	0	2	
	P7	1	0	
4	P8–P10	0	1.5	3
	P11	0	1.5	
5	F1 (SM1,2)	0.5	0	4
	F2 (SM1,2)	1.5	0	
	A1 (SM1,2)	1	0	
	A2 (SM1,2)	1	0	
6	P11	0	2	8**
	F1 (SM3,4)	0.5	0	
	F2 (SM3,4)	1.5	0	
	A1 (SM3,4)	1	0	
	A2 (SM3,4)	1	0	
	A3	0	2	
7	A3	0	2	5
	A4	0	1	
	A5	0	2	
8	A4	0	1	3
	A5	0	2	
9	A4	0	1	3
	A5	0	2	
			total	36

** daytime and night time are counted individually

Co-chaired by Ellis (ESO) & Takada (IPMU)

Why draft the SSP now?

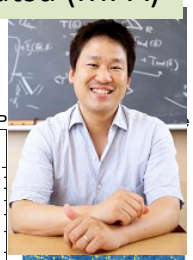
- A draft SSP effectively summarizes the current science goals of the partnership
  - It serves as the basis of documents which can be presented to prospective partners (and now MSIP assessors !) and the Japanese community
  - It is good discipline to succinctly update and record our discussions with compelling figures and scientific plans
- More importantly, the envisaged SSP also is intended to summarize the arguments for a particular survey strategy



→ Intended to maximize observing efficiencies and scientific outputs.

Komatsu (MPA)

Cosmology

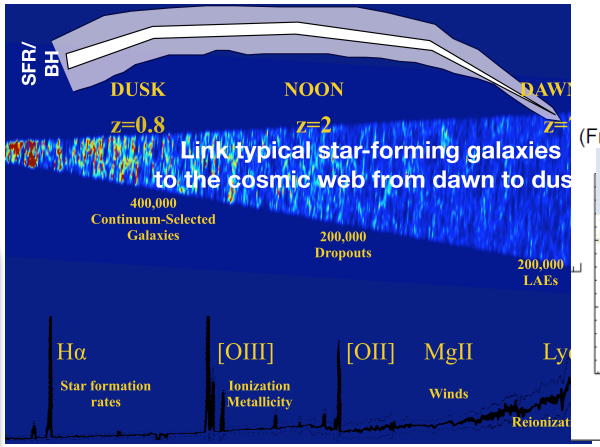


PFS can also weigh neutrino, which is now Japanese national particle!

Takada (IPMU)

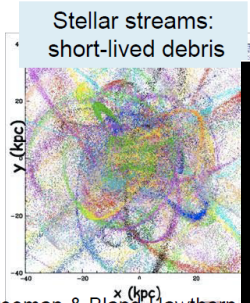
Galaxies/AGN evolution

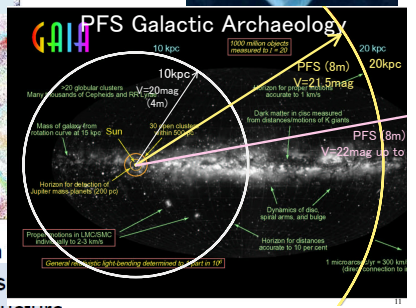
Greene (Princeton)



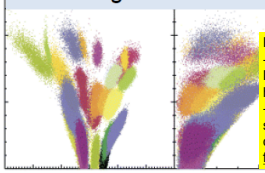
Chiba (Tohoku)

Galactic Archaeology



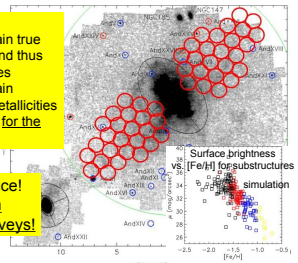


Halo stars in phase s
full of long-lived substructure



PFS survey of Andromeda halo

PFS survey
- Enables to obtain true M31 members and thus halo substructures
- Enables to obtain spectroscopic metallicities over large areas for the first time

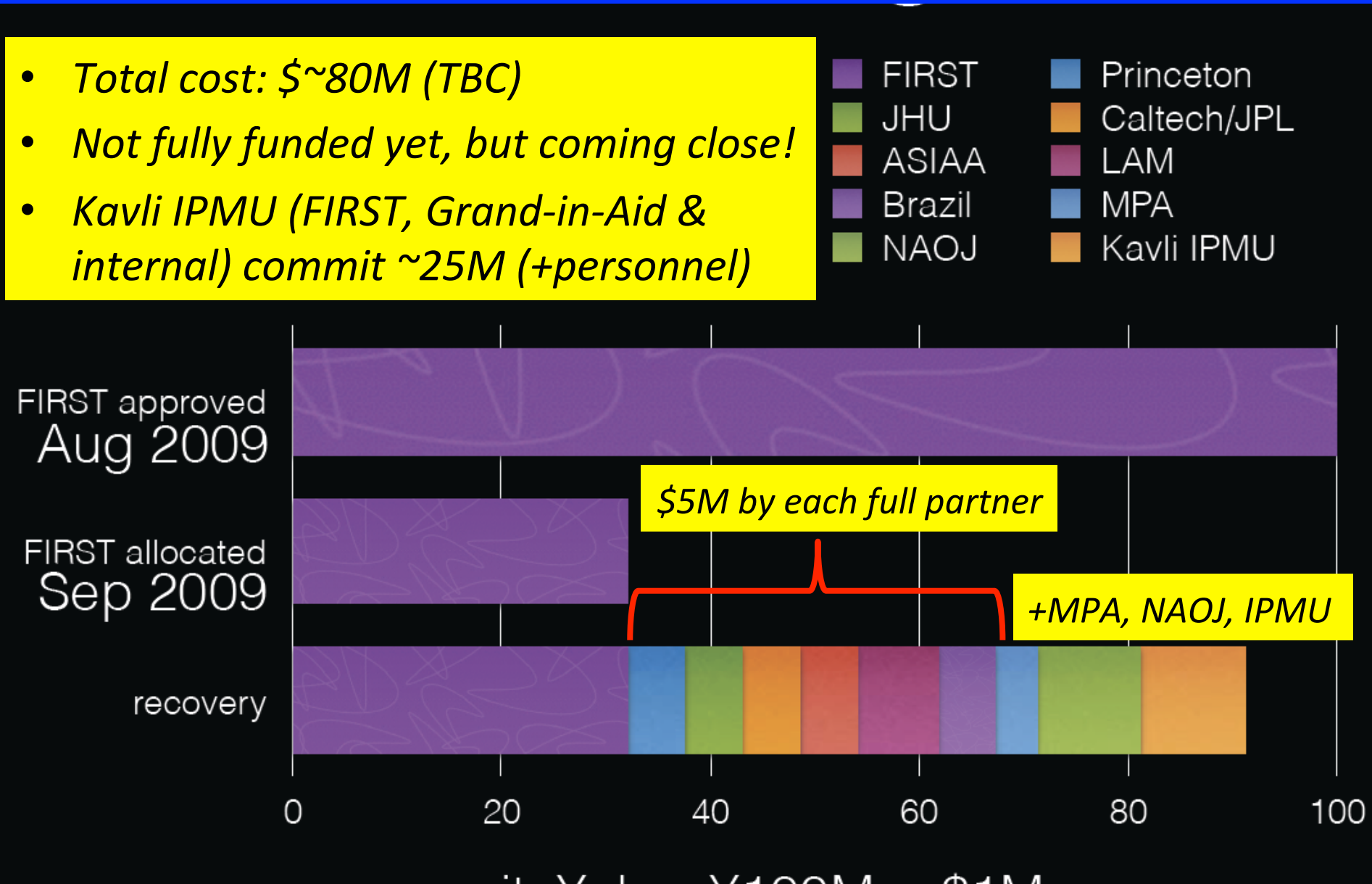


(Helmi & de Zeeuw 20

Unique science! Impossible in other 4m surveys!

A rough sketch of funding situation

- *Total cost: $~80M (TBC)*
- *Not fully funded yet, but coming close!*
- *Kavli IPMU (FIRST, Grand-in-Aid & internal) commit ~25M (+personnel)*



The PFS collaboration

*The Chinese consortium (Y. Jing from Shanghai Jiao Tong Univ. is the leader) has newly joined in **Dec 2015!**, at the initiative of **Takada & Tamura**, firstly negotiated in **Apr 2015. So efficient!!***

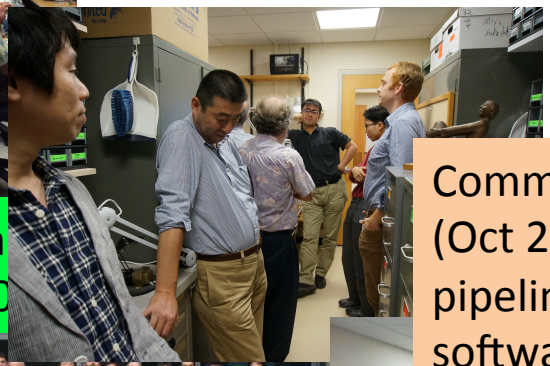
We will propose an SSP survey with "all Japan" elements in the team. Please join & commit !!

The PFS collaboration

- Annual collaboration meetings
- Roughly monthly various face-to-face meetings by a subset of the team
- PFS science workshops

PFS science WS at NAOJ (Jul 2015)

Spectrograph interfaces & integration details at Subaru Hilo (Aug 2015)



6th collaboration m
at ASIAA (Dec 20

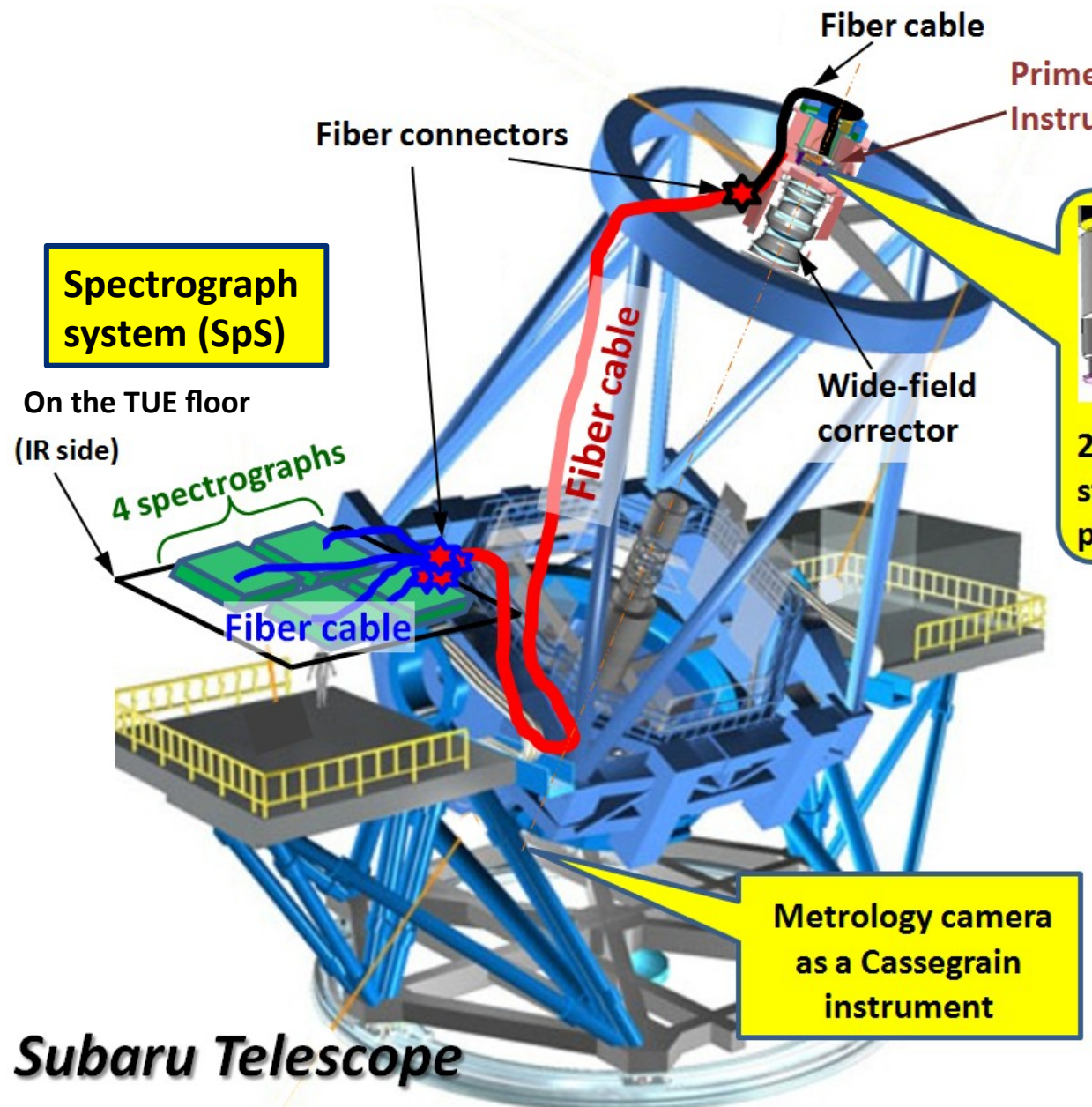
Commissioning p
(Oct 2015) & rec
pipeline, control
software (Jan 20
Princeton

PFS galaxy WS at IPMU (Nov 2015)

Thanks to Matsuoka(NAOJ)-san's initiative:

- PFS AGN WS at NAOJ (May, Oct 2015)
- HSC AGN WS at Kagoshima U. (Dec 2015)

PFS subsystems distribution



… in Prime focus unit "POpt2" with Wide Field Corrector "WFC".

Calibration system

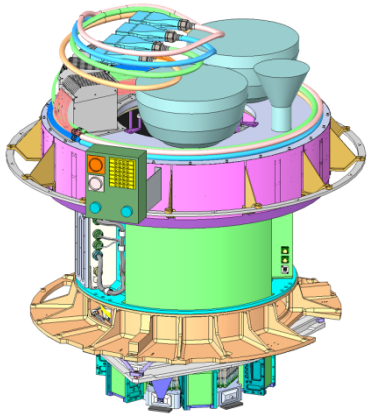
POpt2 & WFC will be shared with Hyper Suprime Cam (HSC).

Software system

Subaru Telescope

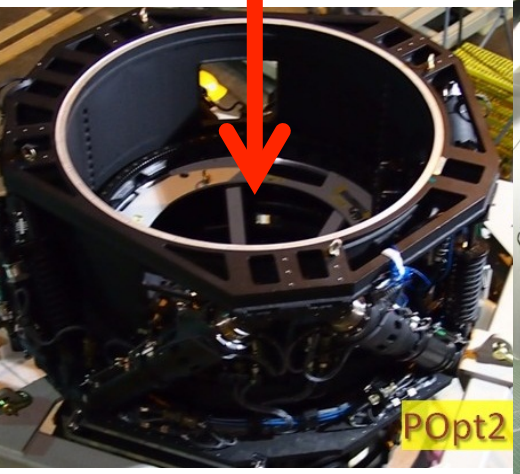
Prime Focus Instrument (PFI)

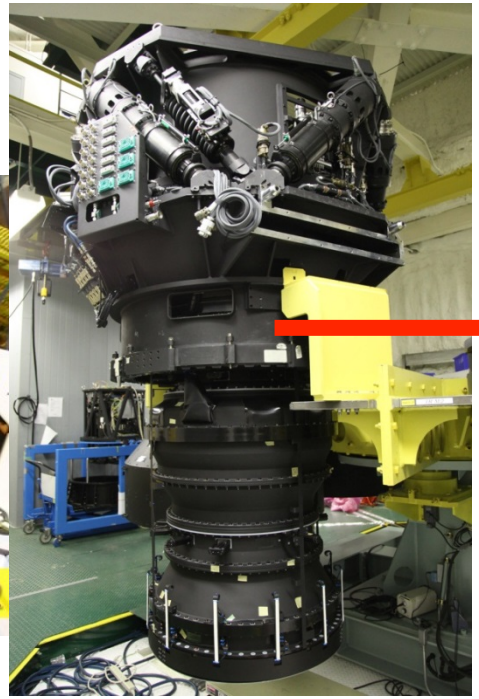
Sits in the prime focus unit “POpt2” and installed to the telescope

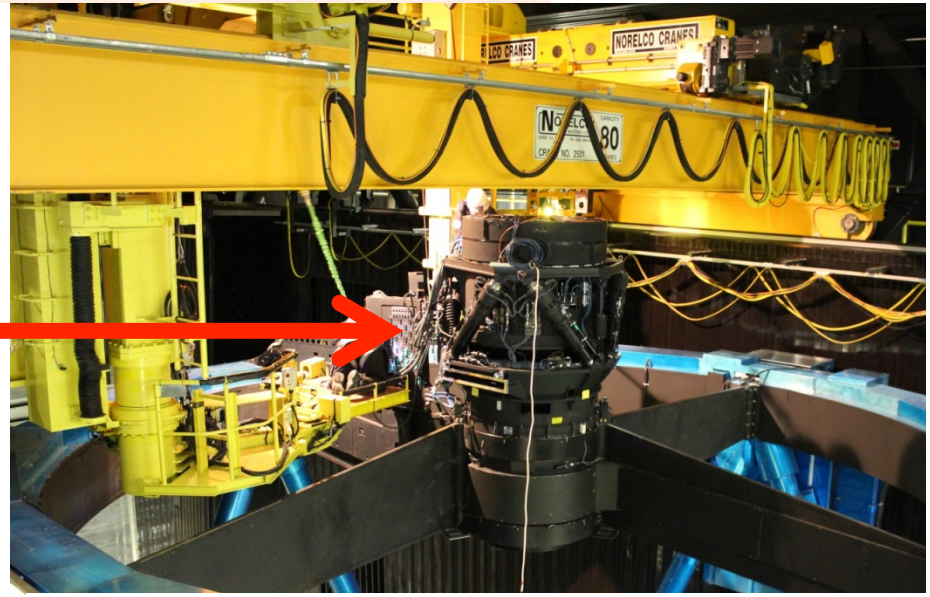


- Fiber positioner system
- Acquisition & Guide (AG) camera
- Fiber cable: “Cable C” & fixed fiducial fibers
- Fiducial fiber illuminator
- Field element (cf. Filter+dewar window@HSC)
- Cable wrapper
- Calibration lamp system

Caltech-JPL
LNA
ASIAA
IPMU/Princeton







HSC builder’s blog
http://anela.mtk.nao.ac.jp/hscblog/builder/

PFI CDR (Mar 10-11, at Caltech)

- Review board
  - External x 6: T. Huang (ASIAA), F. Leger (Washington), K. Seaman (JPL), M. Colavita (JPL), R. Foehner (JPL), K. Aaron (JPL)
  - Internal x 4: N. Takato (NAOJ), J. Gunn (Princeton), G. Murray (Durham), N. Tamura (Kavli IPMU, chair)

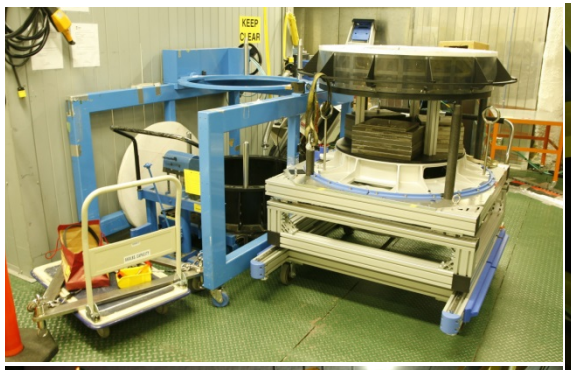
2 Executive summary

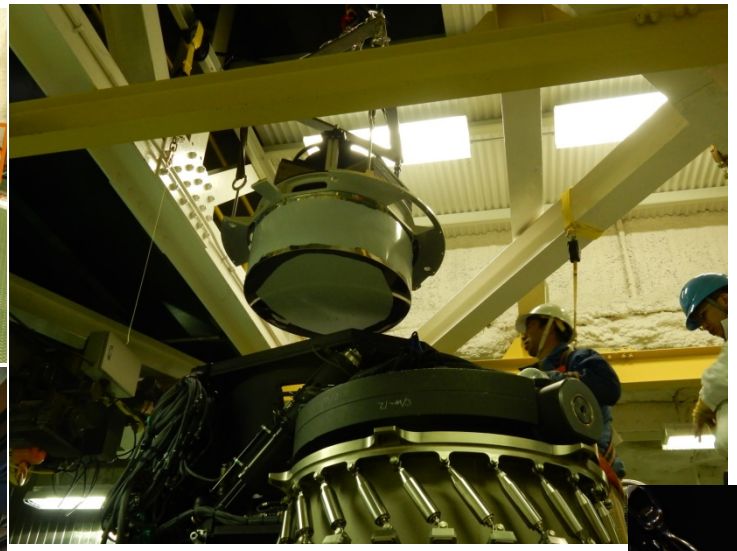
The review board was very pleased to see such an impressive amount of achievement and progress in spite of the complexity in the system to be developed and the diversity of the team in various senses. Although the team still needs to continue their effort and finalize the design, the review material was at a sufficient level to understand the issues and risks the project will face moving forward through delivery. We congratulate the team on having brought the design study to its current status. Below we assemble feedbacks from the board members that range from general comments to high-level issues to inputs and advices for specific areas. The board expects the team to take them into account in the final design studies for successful fabrication of subcomponents and integration of the PFI system.

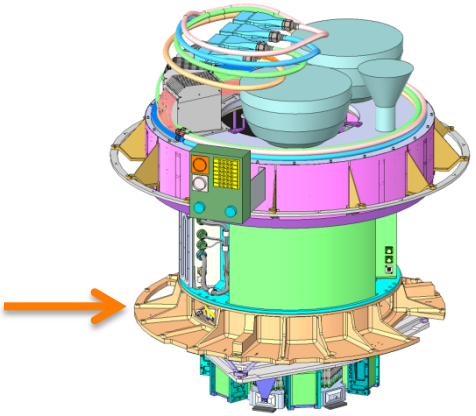
- The JPL-Caltech team successfully passed the fiber positioner system delta CDR on Jun 22.
- The life-time test results of pre-production units are good. The team should agree *(this week*) on the target convergence before going into the mass production.

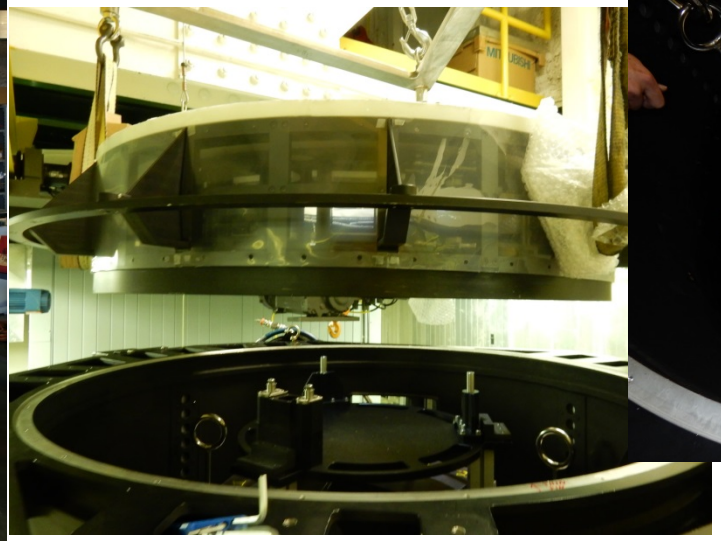
PFI – Positioner frame fitting test by Subaru & ASIAA (June 15, 2015)

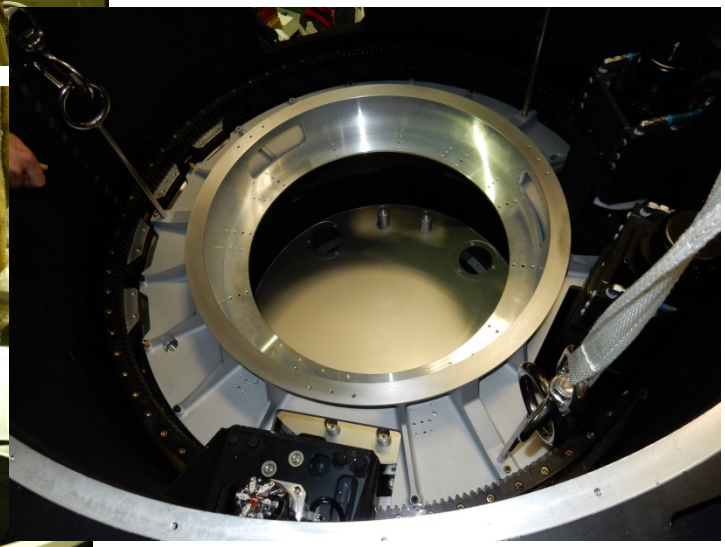
Positioner frame, Cable wrapper, dummy weight, installation tools & jigs → POpt2





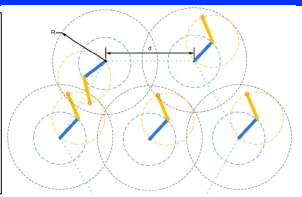


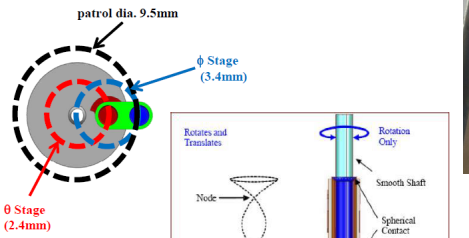




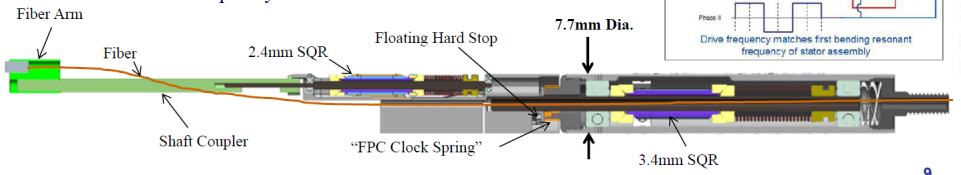
Focal plane: Fiber positioner "Cobra"

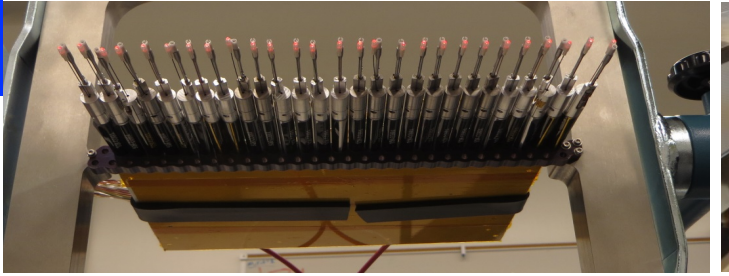
8mm pitch vs. 9.5mm diameter patrol area → Patrol areas are overlapped.

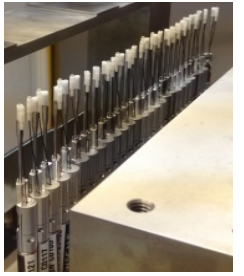


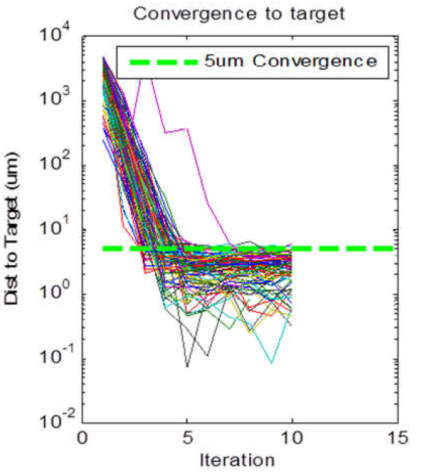


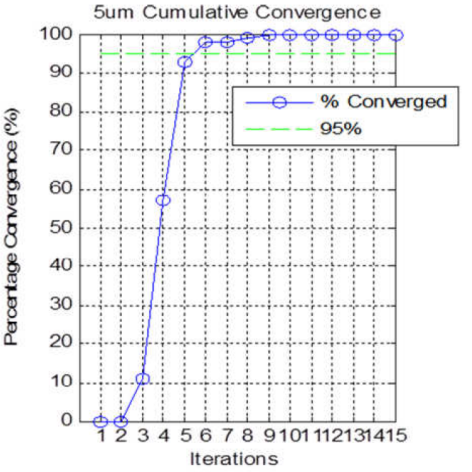
- Fiber is routed from the arm on the phi-stage through the center of the Cobra
  - Stages utilize hard stops to allow for full range of motion, yet prevent over twisting of the optic fiber
  - Protects fiber during handling and operation
- Piezo motors use phase shifted signals to excite the motor body at the first bending resonant frequency





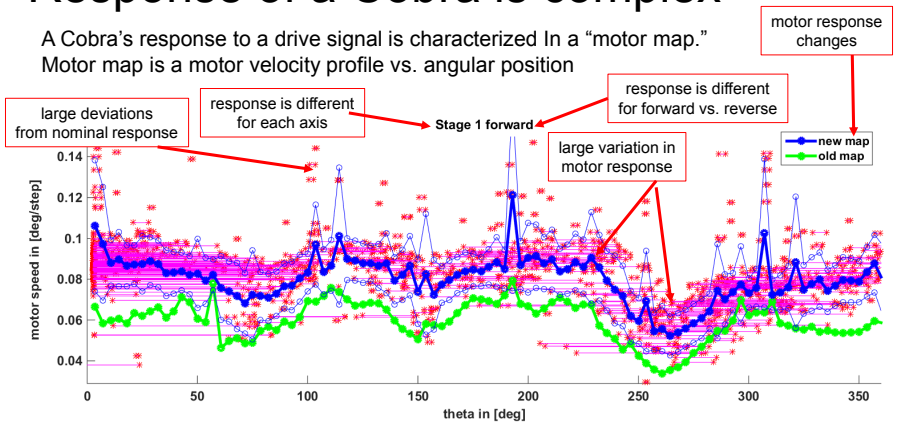






Response of a Cobra is complex

A Cobra's response to a drive signal is characterized In a "motor map."
Motor map is a motor velocity profile vs. angular position



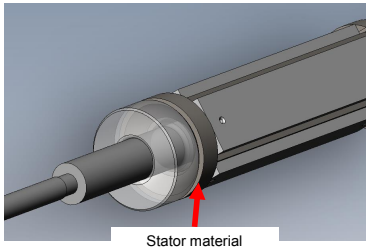
Each positioner has a complex, unique profile.
This complexity is hidden from the observer.
Obtaining excellent convergence with this complexity constitutes a lot of our work.
See Johannes's report for more detail.

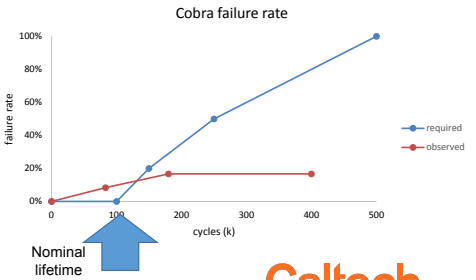
Caltech

Lifetime problem appears to be solved

Troubleshooting considered: materials, drive signal, design, & re-evaluating requirements

Outcome:
- reasonable consensus on requirements
- slight change in design
- reasonable performance in lifetest (needs discussion across the project)
- now in production contract
- production is awaiting test of convergence





Caltech

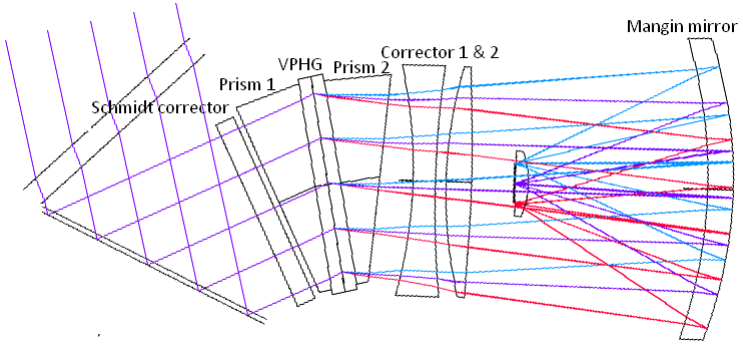
Spectrograph System (SpS)

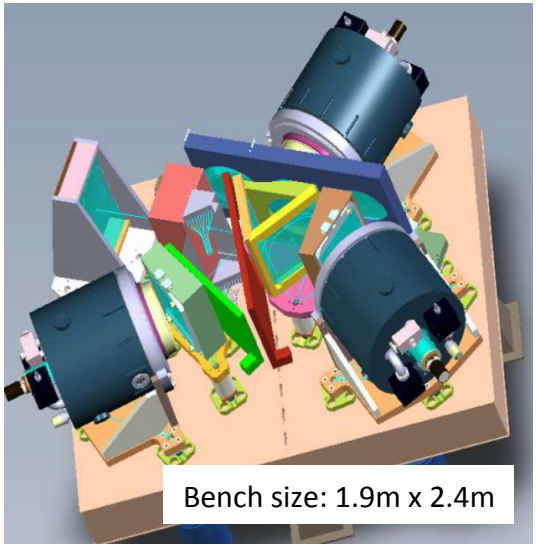
-- CDR in Mar 2014 at LAM.
-- Subassemblies have started coming to LAM.

"Red"

Mangin mirror
Field Flattener & Detector
Corrector 2
Corrector 1
VPHG
Collimator
Schmidt Corrector
Entrance Slit
VPHG
Corrector 1
Corrector 2
Field Flattener & Detector
Dichroics
Schmidt corrector
Corrector 1
Corrector 2
Schmidt corrector (collimator)
Field Flattener & Detector
VPHG
Mangin mirror
"NIR"
"Blue"
Mangin mirror

Mid. Res mode in the red arm





Spectrograph System (SpS)

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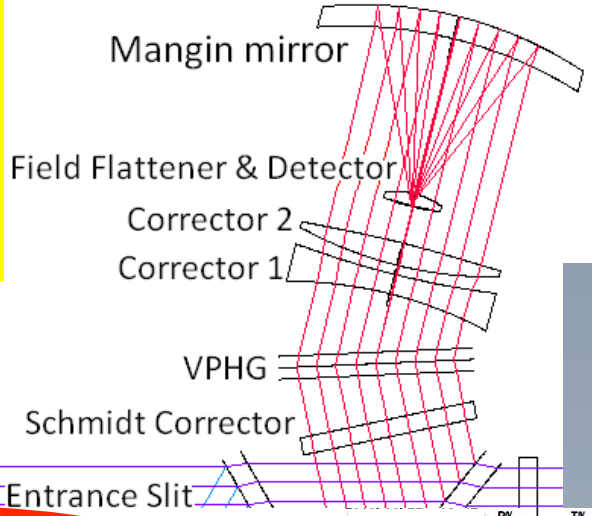
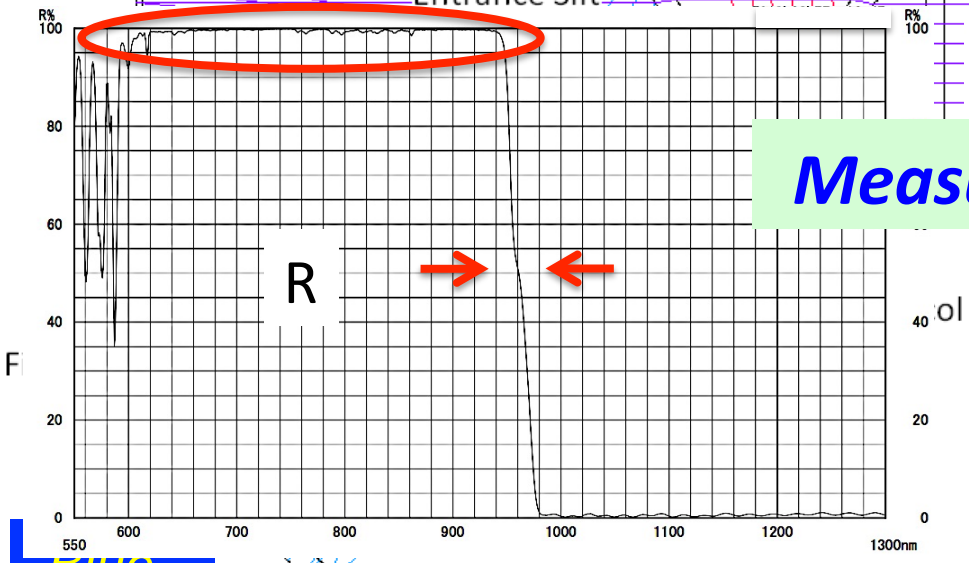
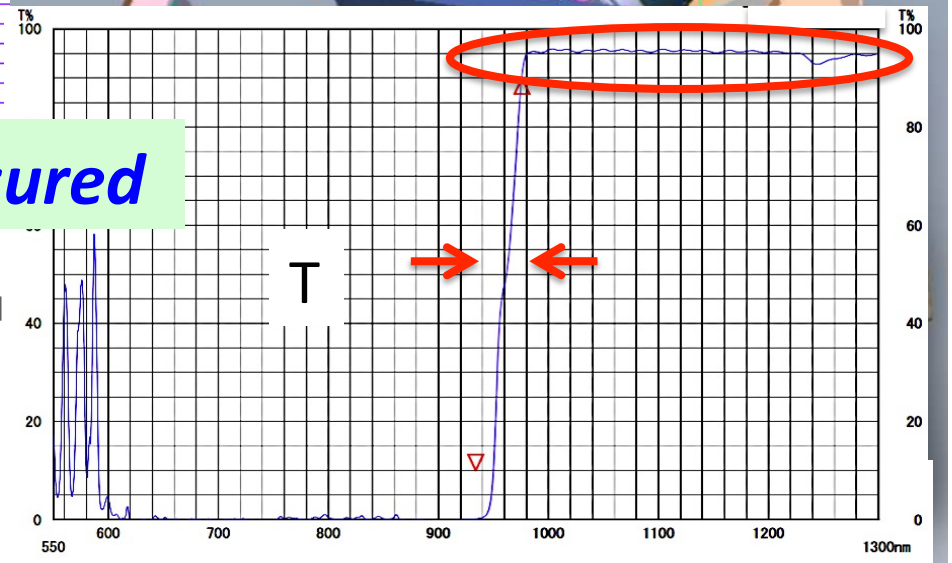
"Red"

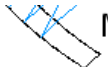


Measured

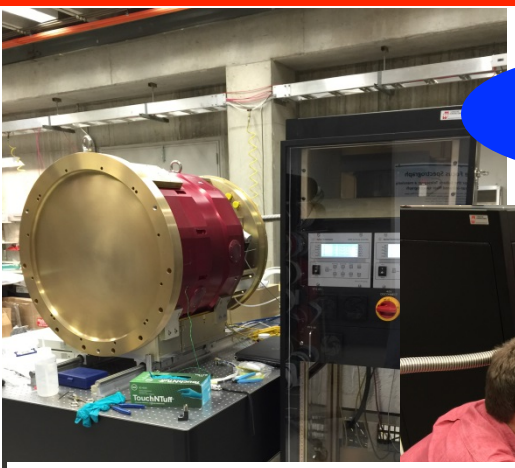


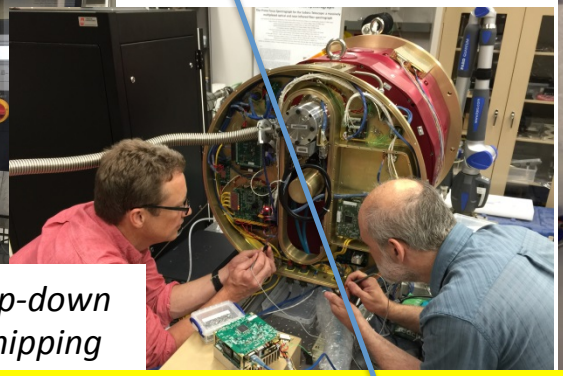


Blue



SpS – What's happening now

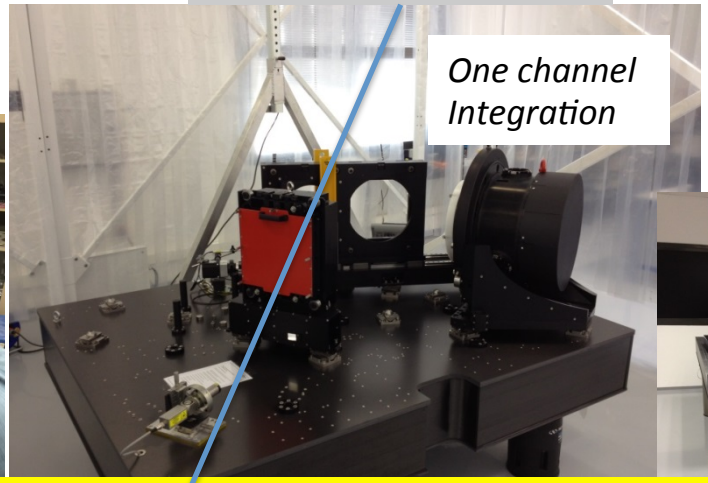




Cryostat assembly, pump-down and cool-down before shipping

JHU

Subcontractor

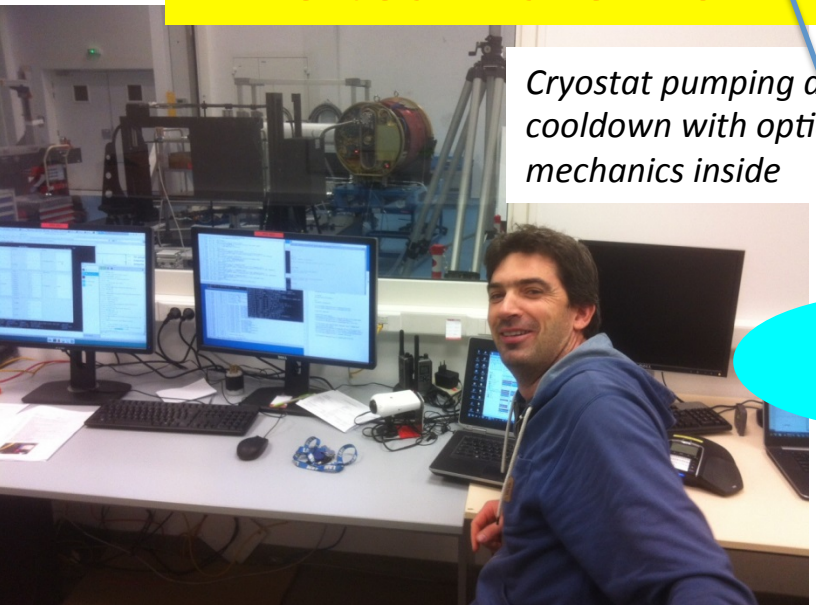


One channel Integration

Mangin

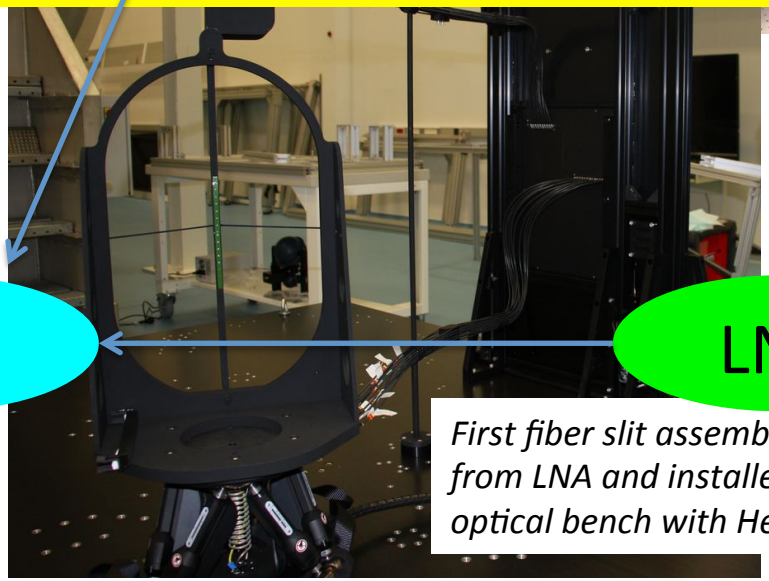
Collimator

The team are working hard to get first lab spectra.



Cryostat pumping and cooldown with optics & mechanics inside

LAM

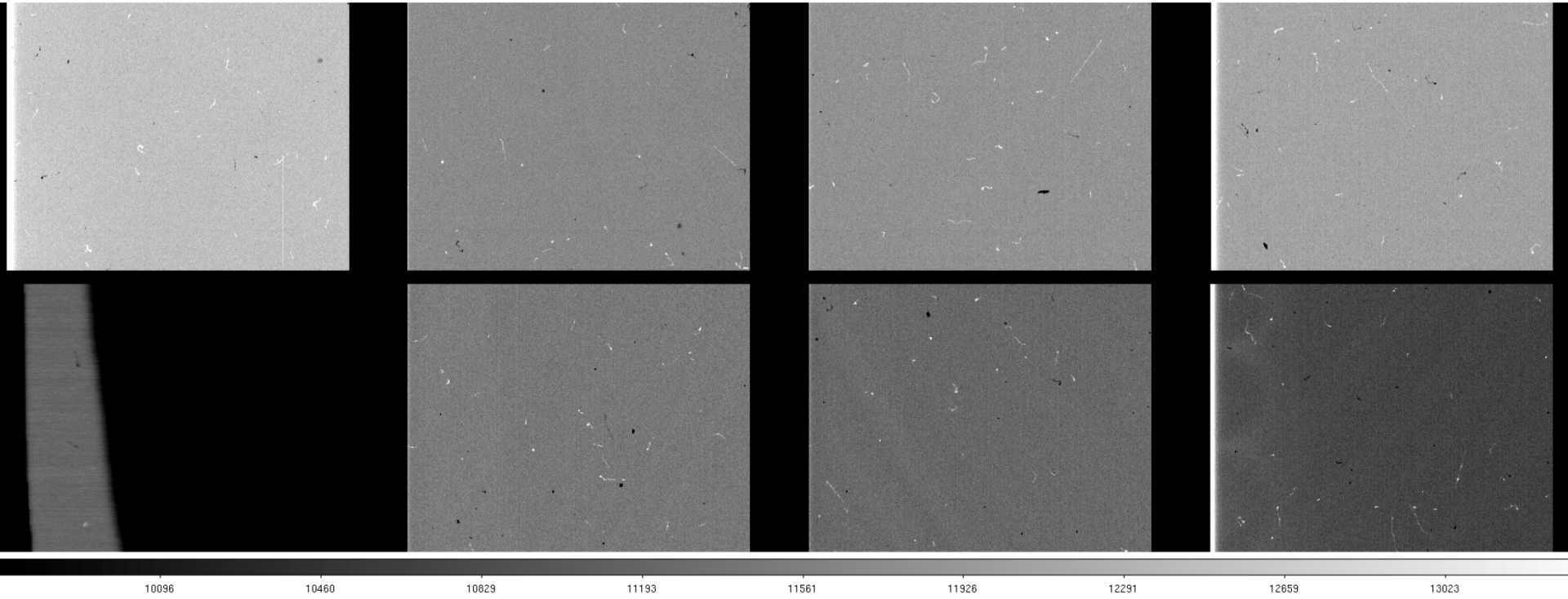


LNA

First fiber slit assembly arrival from LNA and installed on the optical bench with Hexapod.

SpS – What's happening now

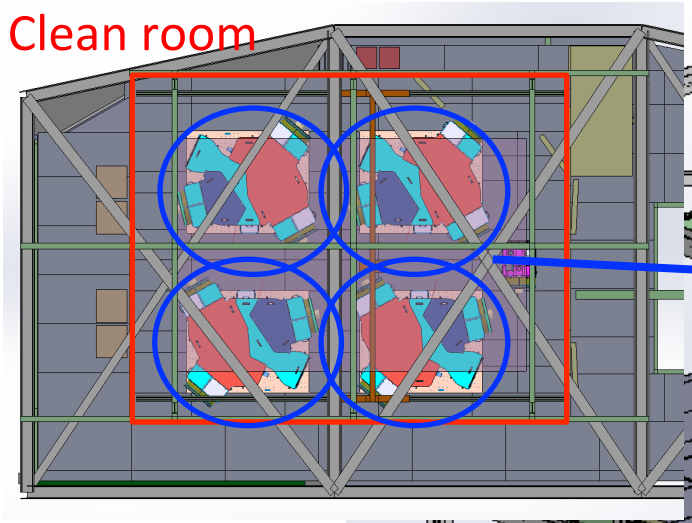
First images with the engineering CCDs reported on Oct 31
(2 chips, 4 channels per each)



The first science-grade H4RG array has been completed and delivered in Dec 2015.
The other three will be coming in 2016.

SpS: Configuration at Subaru

4x spectrograph modules (SM) are accommodated in a temperature-controlled clean room.



“IR4” floor

“IR3” floor

IR-side Nasmyth floor
(not shown here)

Takato & T. Tamura (Subaru)

Funding situation

- *Improving!* ~90% of the total cost ($~80M) has been secured (cf. $~20M shortfall at the time of PDR in 2013).
- *Good news!* The Murayama, Takada, Komatsu et al.'s application to Grant-in-Aid for Scientific Research on Innovative Areas (科研費新学術) was approved last year!
  → $~1.8M for the PFS development (NIR cameras) over 5 years.
- Looking for new partners to the collaboration:
  - The Chinese consortium joined → +US$5M.
- *"Meaningful" cost increase (e.g. Cobra durability)*
- Continuing funding applications:
  - Other candidates for new partners in contact
  - NSF MSIP by PFS US team ($~5M): Passed the 1st step. Going to 2nd stage.
  - Budget request for PFS to Ministry/Government via U. Tokyo (概算要求)
  - Grand-in-Aid (科研費) applications:
    - As a part of "S"-type PI'd by W. Aoki (NAOJ)
    - Other small ones ("C"-type, 新学術公募研究, etc)

New members of the PFS project office from Apr 2015

Dr. Kiyoto Yabe

- They are astronomers, but also are experienced in instrumentation (FMOS, WISH, Kyoto3.8m, Kanata).
- They are a part of the FMOS core team and played key roles in the FMOS eng. obs.

Will be good liaisons to the science WGs:

← Galaxy/AGN GA→

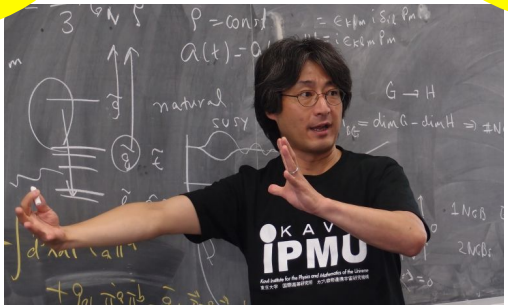
Dr. Yuki Moritani

- Commitments are expected in the areas as follows:
  - On-sky performance estimations & background information surveys
  - Survey simulations & feedbacks to SSP proposal
  - Software development support
  - System integration & engineering observation planning

PFS@Kavli IPMU

Scientists

Murayama [PI]



Takada [PS]

Suzuki

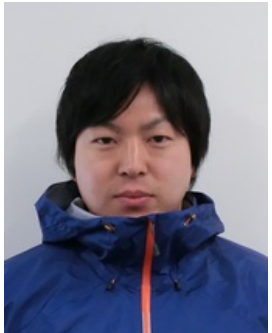
Silverman

Ishigaki

Yasuda

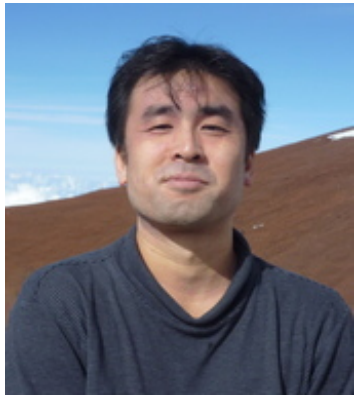
Yabe

Hayashi



Project Office

Tamura [PM, SE]



Moritani

Shimono

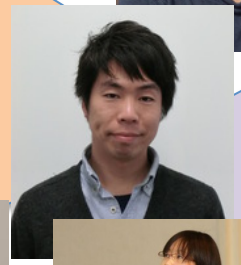
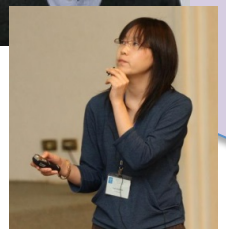
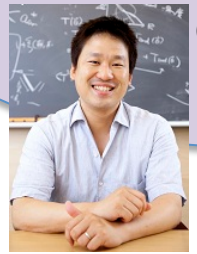
Software development





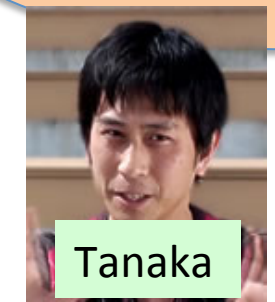








Software integration & management telecon (Subaru & Project office)

SpS control software telecon (Princeton, LAM, Project office)

PFI-MCS control software telecon (JPL, ASIAA, Subaru, Project office)

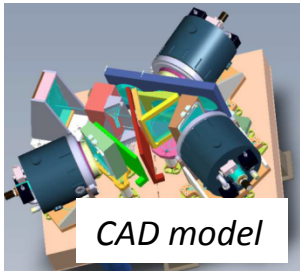
Data reduction pipeline (Princeton, LAM, IPMU, Project office)

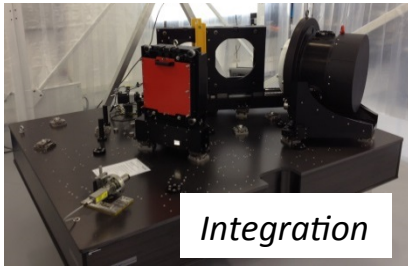
Database & data archive system (IPMU, NAOJ)

Observation planning (MPA, IPMU, Project office)

A summary about PFS

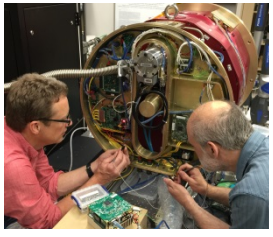
- The project passed Conceptual Design Review in 2012 and Preliminary Design Review in 2013.
- The Spectrograph System (SpS) & the Prime Focus Instrument (PFI) also passed the subsystem Critical Design Review in 2014 & 2015, respectively.
- Now finalizing the design studies and proceeding with production, integration & test.


CAD model


Integration


Optics

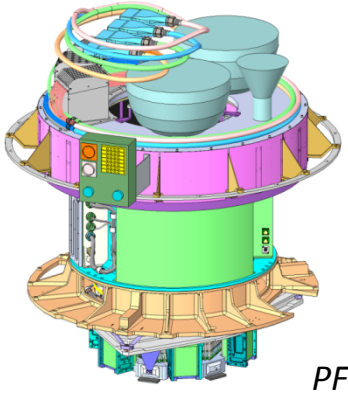
Cryostat

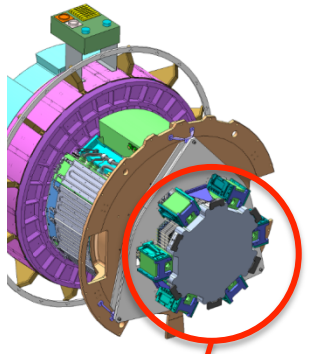


- Aiming at engineering observation from early 2018 & science operation from mid-late 2019.
- ***Unique capability of Subaru for unique science via synergy with Euclid, TMT, JWST, LSST, WFIRST …***

Refer to PFS web & blog for more detailed information and updates.

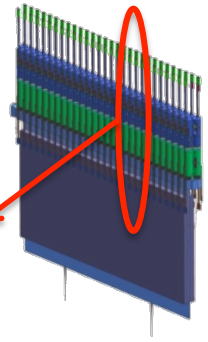
PFI CAD model

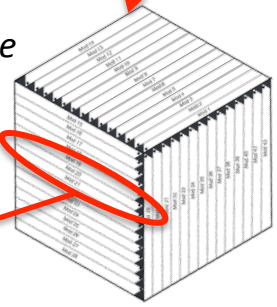




PFI focal plane

"Cobra" positioner module





"Cobra" engineering model module

Individual "Cobra" positioners