Session 6 LiteBIRD (3): System and agency contribution

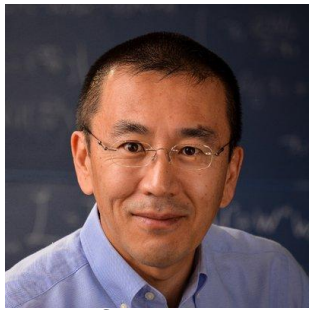
Kavli IPMU at the University of Tokyo

T. Matsumura on behalf of Kavli IPMU team

2019-7-2

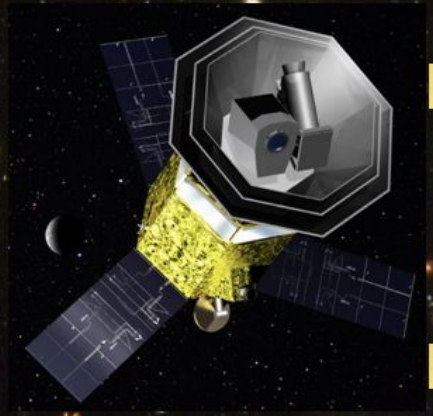
Kavli Institute for the Physics and Mathematics of the Universe

We bring together physicists, mathematicians, and astronomers under one roof to solve most fundamental questions about the Universe



slide from Hirosi Ooguri

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE



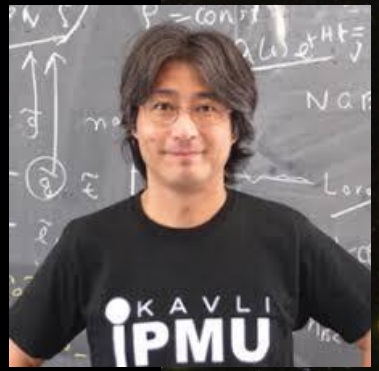
How did the Universe begin?

What is its fate?

What is it made of?

How does it work?

Where do we come from?



slide from Hitoshi Murayama

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

KEK

KAVLI IPMU INSTITUTE FOR THE P MATHEMATICS OF TH

東京大学
THE UNIVERSITY OF TOKYO

JAXA ISAS

JAXA 宇宙科学研究所相模原キャンパス

Outline

- IPMU
- Role of IPMU in LiteBIRD
- Pre-PhaseA2 development
- Future plan

Kavli IPMU is a proposer of the LiteBIRD project to the Master Plan 2020 of the Science Council of Japan.

【物理学】 LiteBIRD（ライトバード） ― 熱いビッグバン以前の宇宙を探索する宇宙マイクロ波背景放射偏光観測衛星

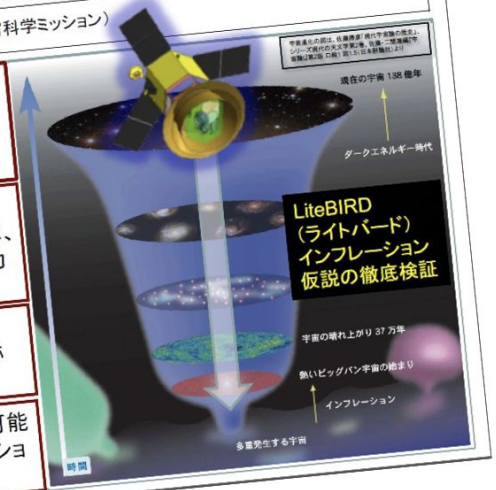
計画期間	2019~2034（2022プロジェクト化、2027打ち上げ、2034最終結果発表）
実施機関等	宇宙航空研究開発機構宇宙科学研究所、東京大学国際高等研究所カブリ数物連携宇宙研究機構、高エネルギー加速器研究機構素粒子原子核研究所を中心とした国際・学際グループ
所要経費（億円）	JAXAの総予算約300億円（戦略的中型宇宙科学ミッション）

人類にとって根源的な問いに答える
- ◆ 宇宙誕生の瞬間とは？
- ◆ 宇宙・時空を創るルールブック（究極理論）とは？

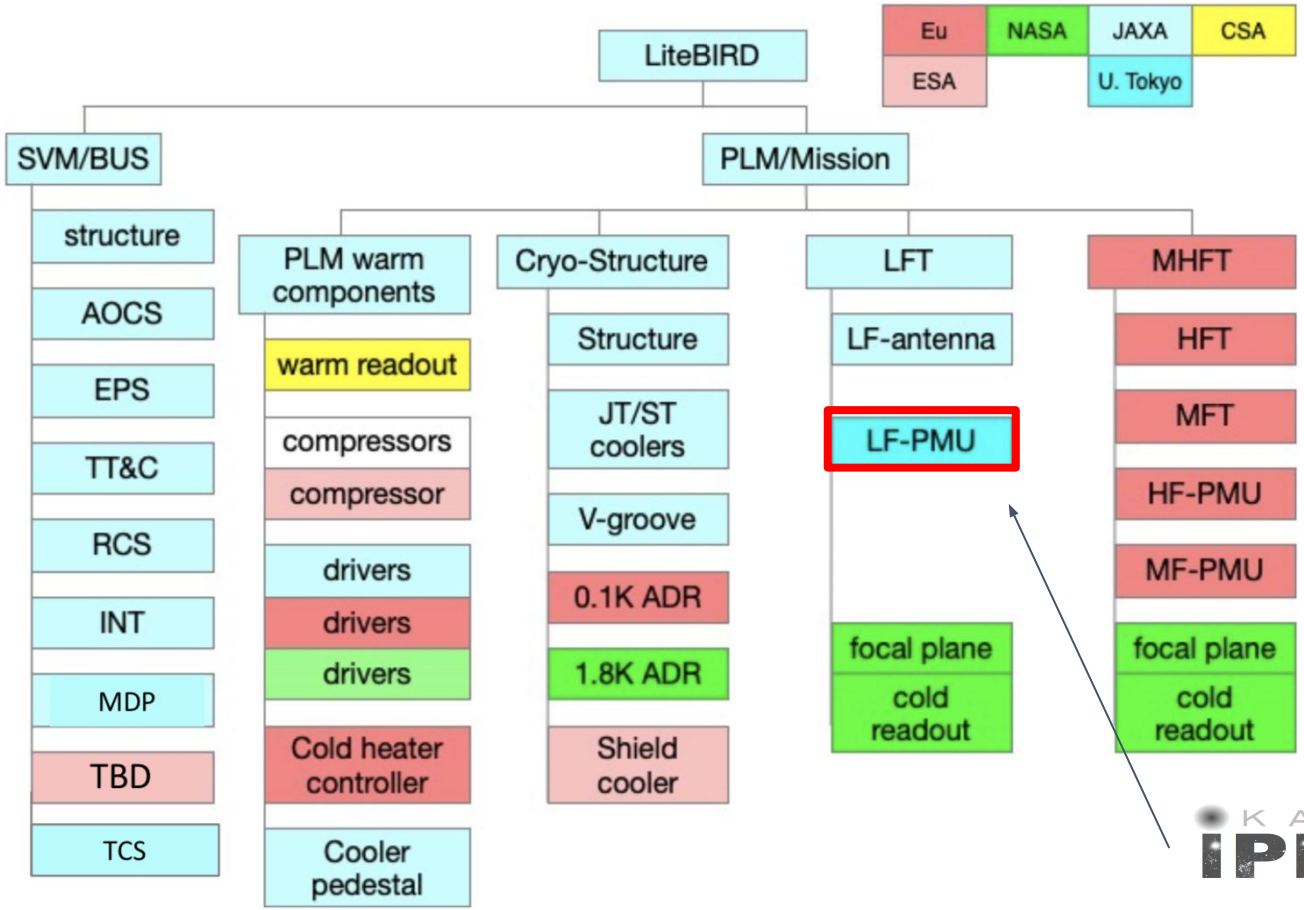
「宇宙のインフレーション仮説」（佐藤勝彦東京大学名誉教授等が提案）は、熱いビッグバン以前の宇宙に関する最有力仮説。原始重力波の存在を予言。

原始重力波は宇宙マイクロ波背景放射（CMB）の偏光マップに「指紋」の様な痕跡（Bモードと呼ばれる）を残す。

LiteBIRDはスペースからの観測でのみ可能な「指紋」の全天精査を行い、インフレーション仮説を徹底検証する。



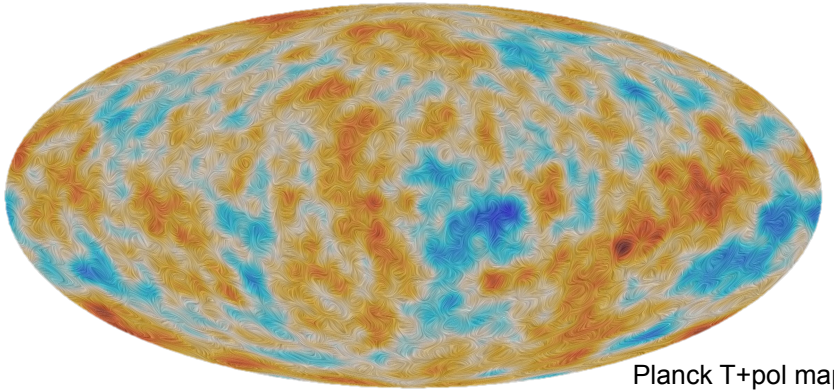
Role of IPMU in LiteBIRD product tree



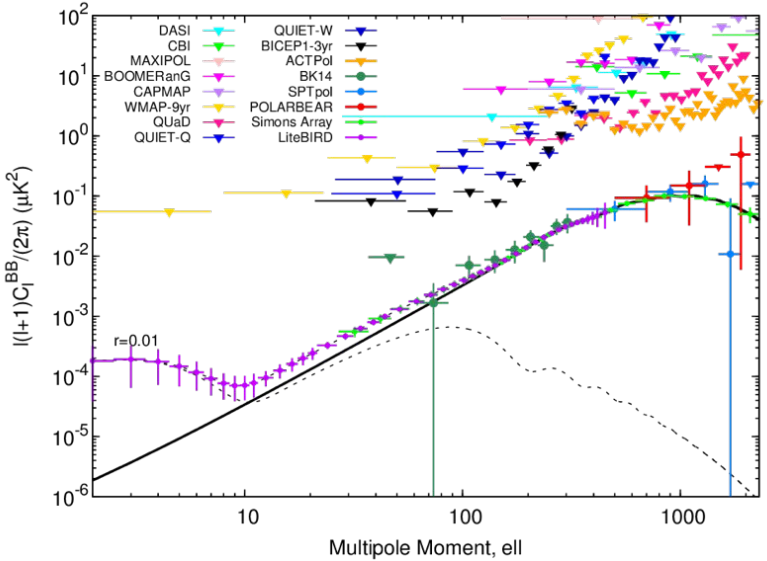
KAVLI IPMU INSTITUTE FOR THE F MATHEMATICS OF TH

Why modulator for LiteBIRD?

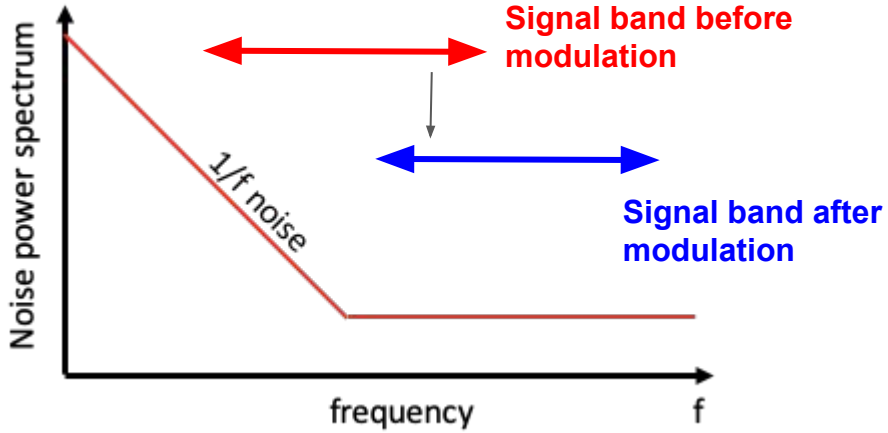
Talk from yesterday by Masashi



Planck T+pol map



- The goal is to measure the fluctuation of the polarization signal at nano-Kelvin level over the large angular scale.
- The instrument is required to
  - be stable enough to make a distinction between the fluctuation from the sky signal and fluctuation from the instrument.
  - minimize the conversion from the temperature signal leaking into the B-mode signal.



Pre-PhaseA2 development

- 2016 July
  - Pre-PhaseA2 started
- 2017 mid May
  - Pre-PhaseA2a midterm review
- 2017 mid Nov
  - Pre-PhaseA2b review
- 2018 Nov.-2019 March
  - Pre-PhaseA2c exit review
- 2019 July
  - Kickoff symposium

Pre-PhaseA2 development

- 2016 July
  - Pre-PhaseA2 started
- 2017 mid May
  - Pre-PhaseA2a midterm review
- 2017 mid Nov
  - Pre-PhaseA2b review
- 2018 Nov.-2019 March
  - Pre-PhaseA2c exit review
- 2019 July
  - Kickoff symposium

The polarization modulator scheme is identified as one of the high risk items in LiteBIRD. As a result, the team is requested to focus on this R&D to demonstrate **TRL5**.

Pre-PhaseA2 development

- 2016 July
  - Pre-PhaseA2 started
- 2017 mid May
  - Pre-PhaseA2a midterm review
- 2017 mid Nov
  - Pre-PhaseA2b review
- 2018 Nov.-2019 March
  - Pre-PhaseA2c exit review
- 2019 July
  - Kickoff symposium

The polarization modulator scheme is identified as one of the high risk items in LiteBIRD. As a result, the team is requested to focus on this R&D to demonstrate **TRL5**.

We carried out the rest of the development with the momentum built from Pre-PhaseA2a.

Pre-Phase2 goals

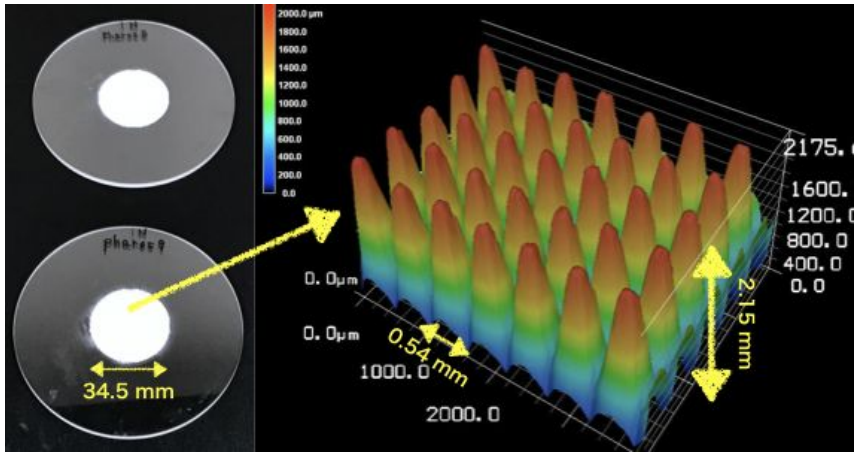
What's the path toward TRL5?

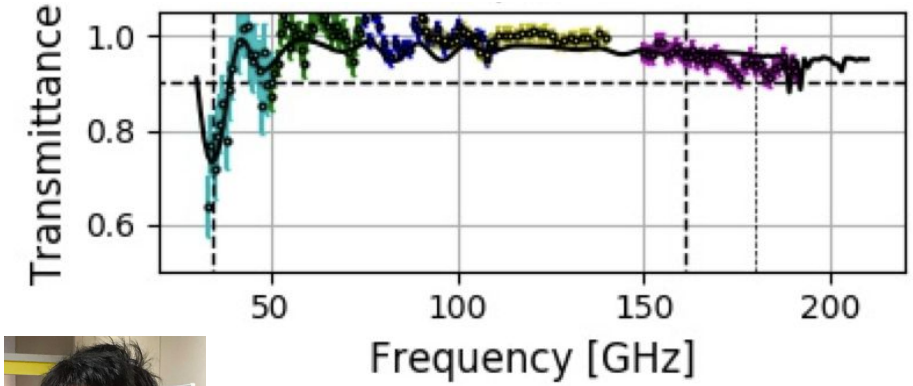
1. Broadband AR
2. Broadband modulation efficiency — **$\Delta\nu$ = 35-161 GHz, $\Delta\nu/\nu$=1.3**
3. Measurement capability over LFT band

4. Feasibility of keeping the HWP temperature: **HWP below 20 K**
5. Cryogenic Holder mechanism: **hold in place at cryogenic temperature and cool the HWP**
6. Drive mechanism: **spin at 88 RPM, possibly slower**
7. Encoder feasibility: **encode the HWP position with accuracy < 10^{-3} degs**
8. Magnetic shield plan: **suppress B field less than 1% of NET**
9. Launch lock plan: **survive the launch**

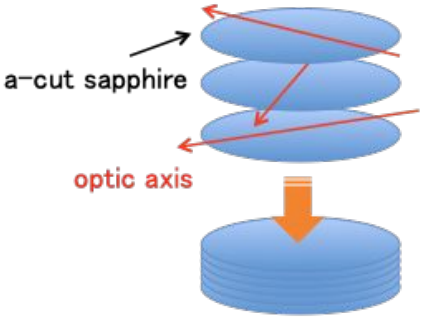
Development results

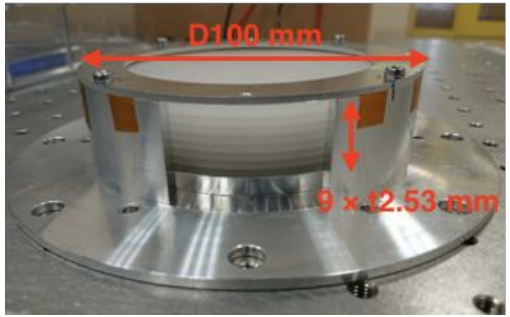
Broadest AR and achromatic HWP using sapphire

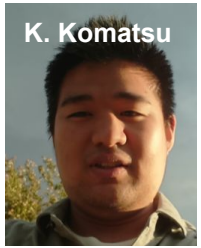




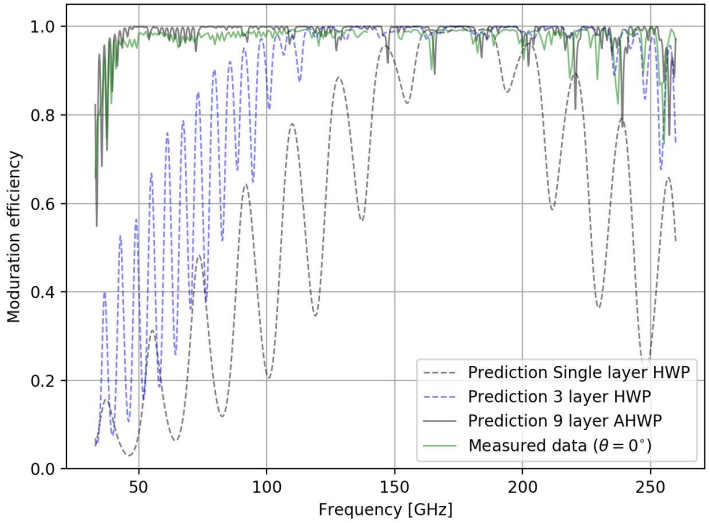
Univ. of Tokyo



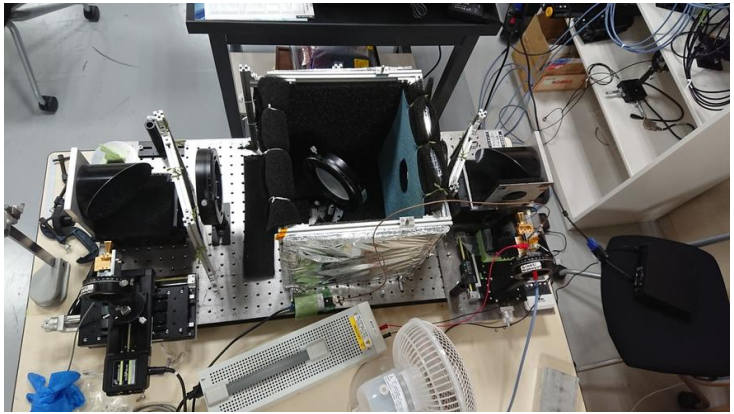


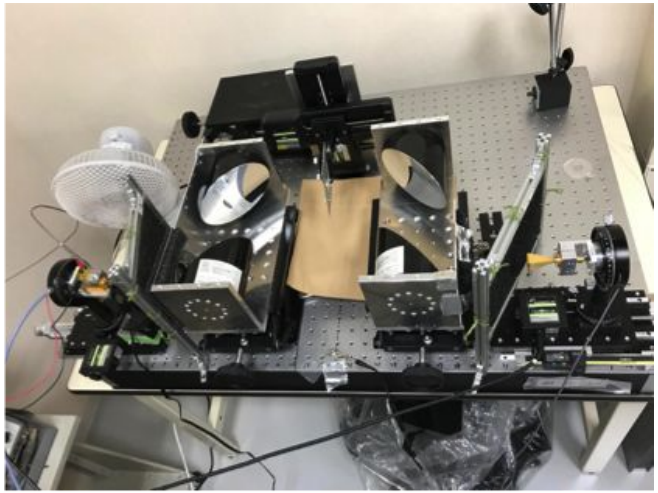


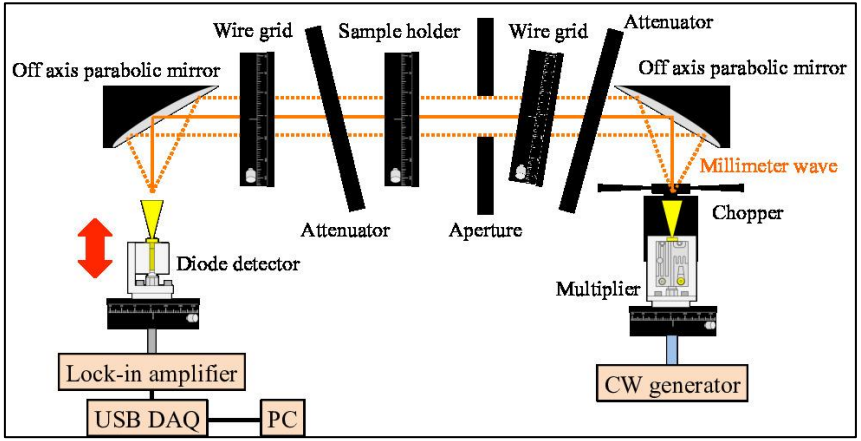
Okayama Univ.

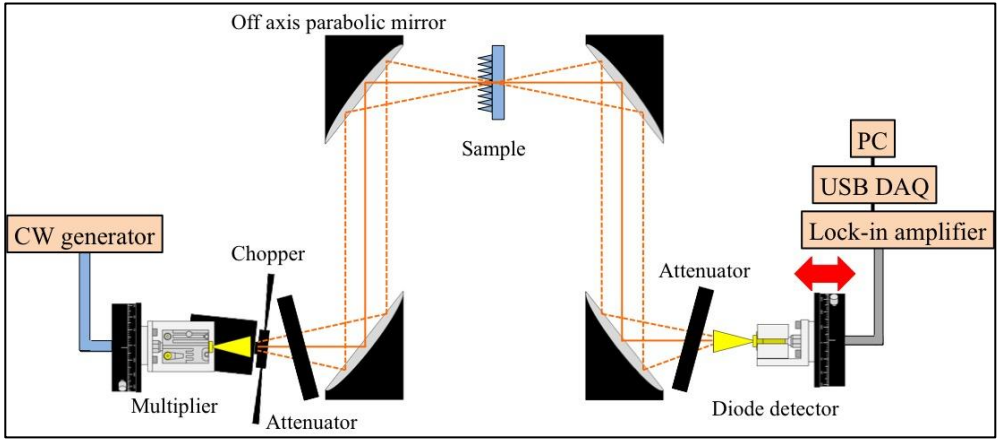


Measurement system

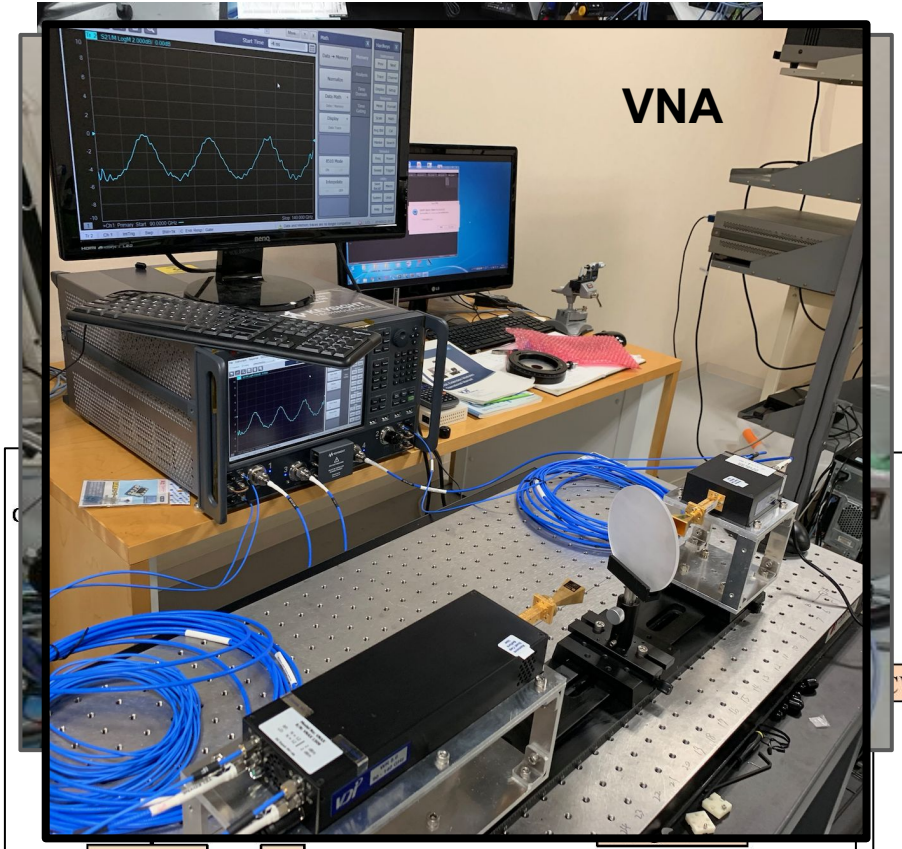


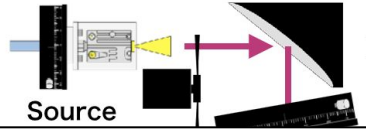






Measurement system



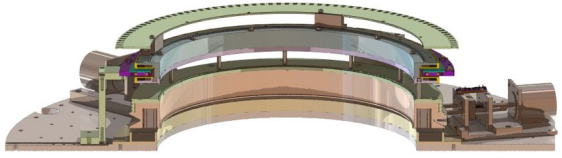


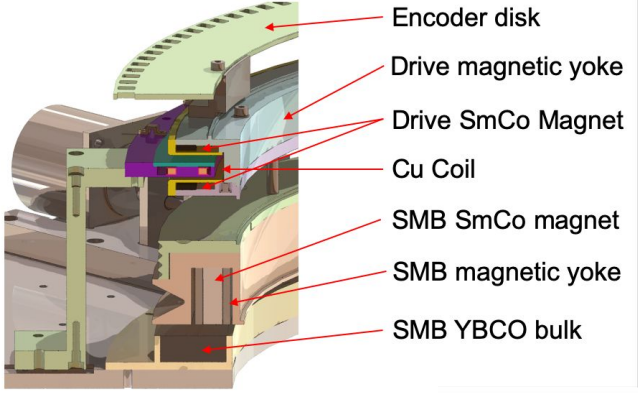
- WR 3.4 : 220-330 GHz
- WR 5.1 : 140-220 GHz
- WR 8.0 : 90-140 GHz
- WR12+ : 55-95 GHz
- WR 19 : 40-60 GHz
- WR 28 : 26.5-40 GHz

Cold Head

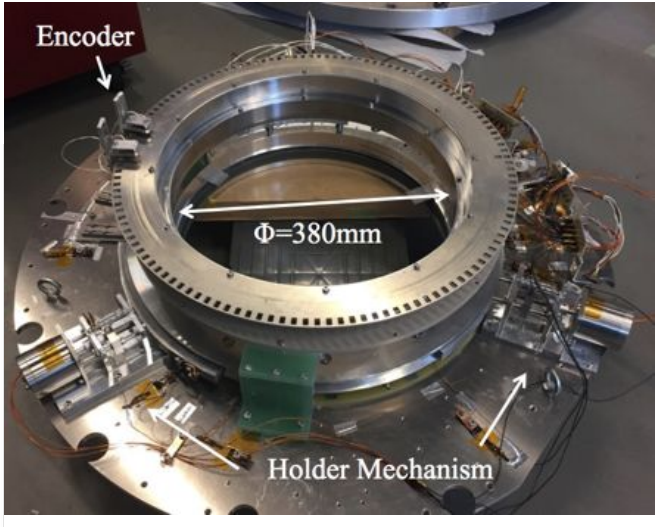
USB DAQ — PC

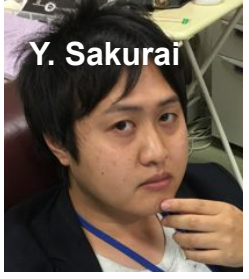
Zero contact. rot. mechanism

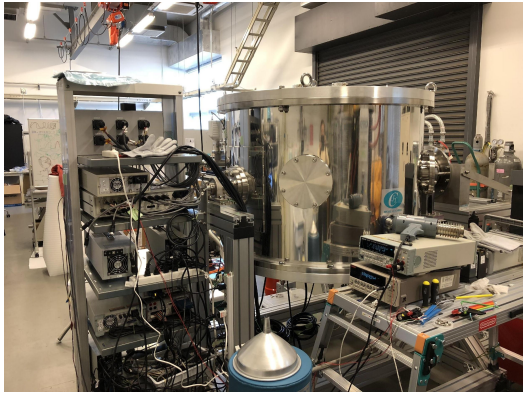


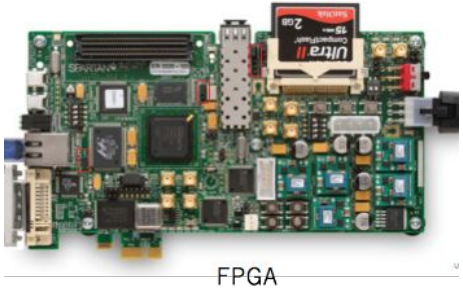


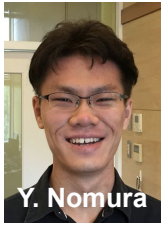
BBM PMU for a lab demonstration





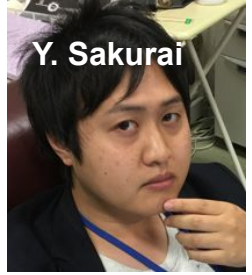


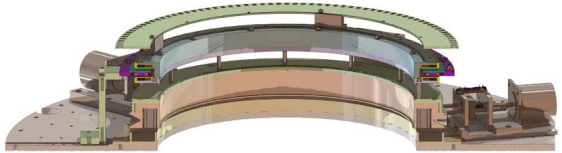


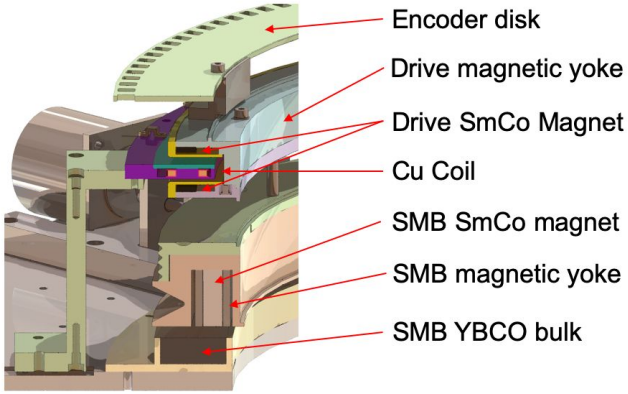


Saitama Univ.

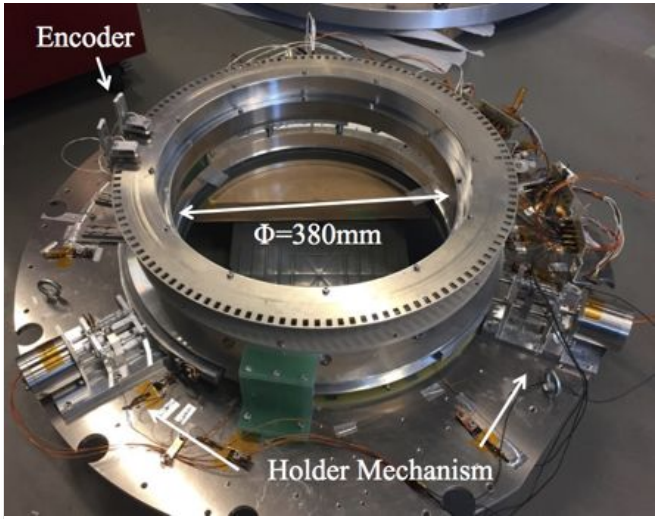
Zero contact. rot. mechanism



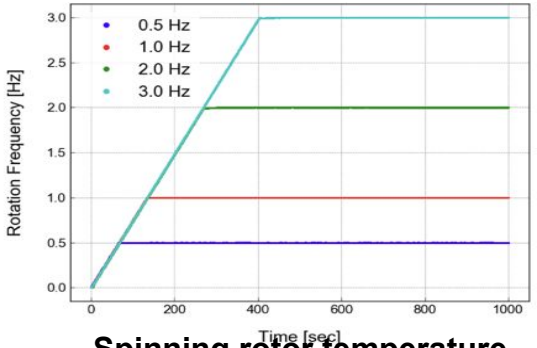


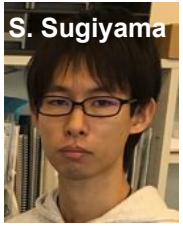


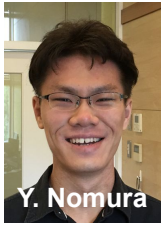
BBM PMU for a lab demonstration



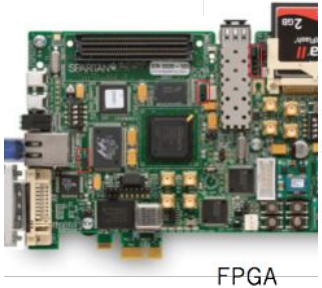
Rotational performance using the cryo. drive mech. operating below 20 K

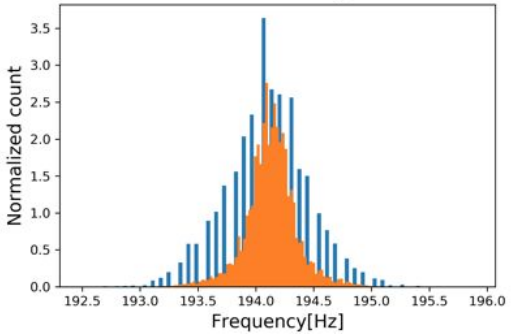




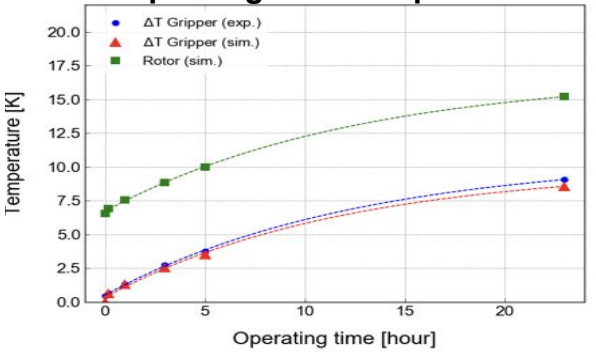


Saitama Univ.



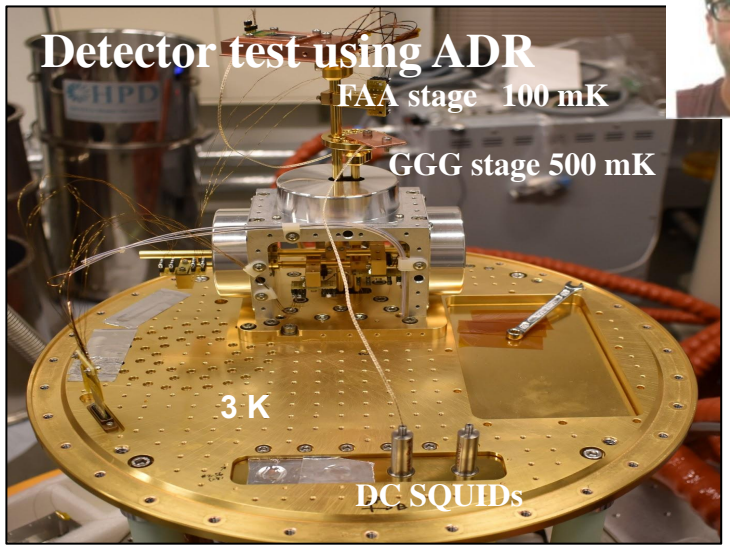


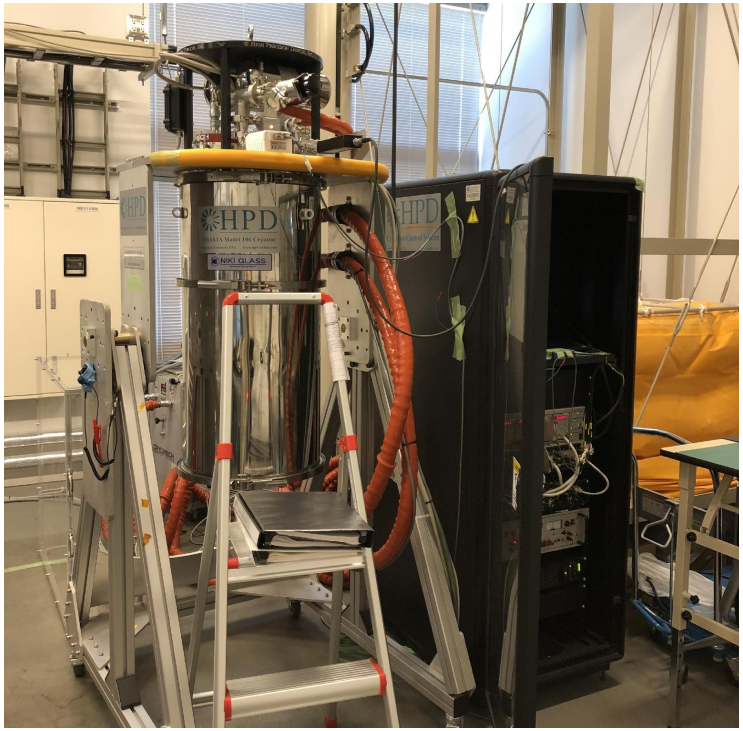
Spinning rotor temperature



Detector test

IPMU/Oxford

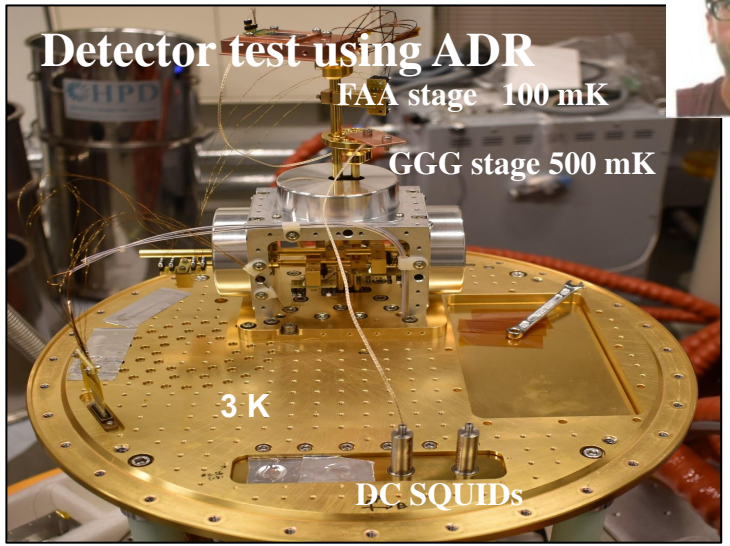




The aims of the study is to address

- Present: Detector parameters, noise and response cross-check.
- Future: Check possible interference between detector/readout with
  - HWP magnetic bearing.
  - Cosmic ray testing at 100 mK with radioactive source.

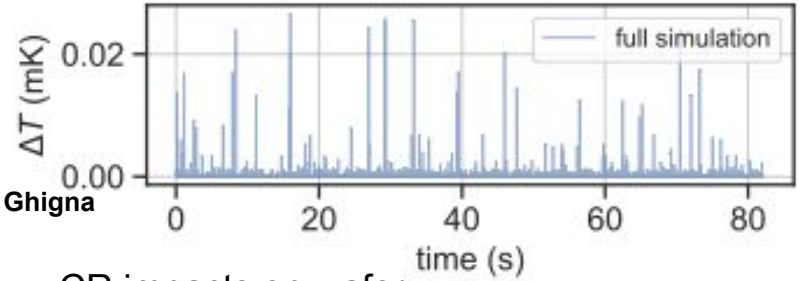
Detector test



IPMU/Oxford

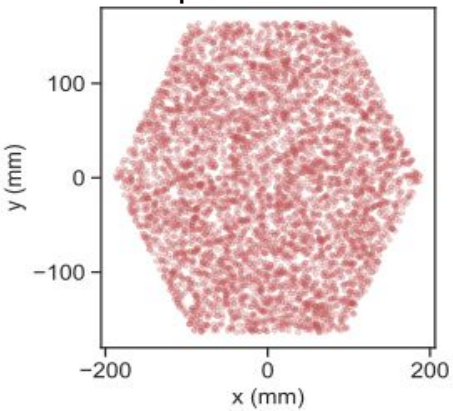
Tommaso Ghigna

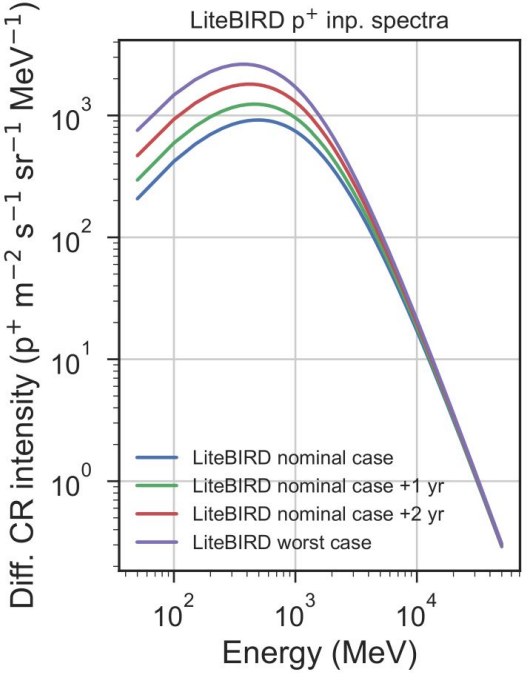
simulated cosmic ray temperature fluctuation on wafer



Samantha Stever

CR impacts on wafer



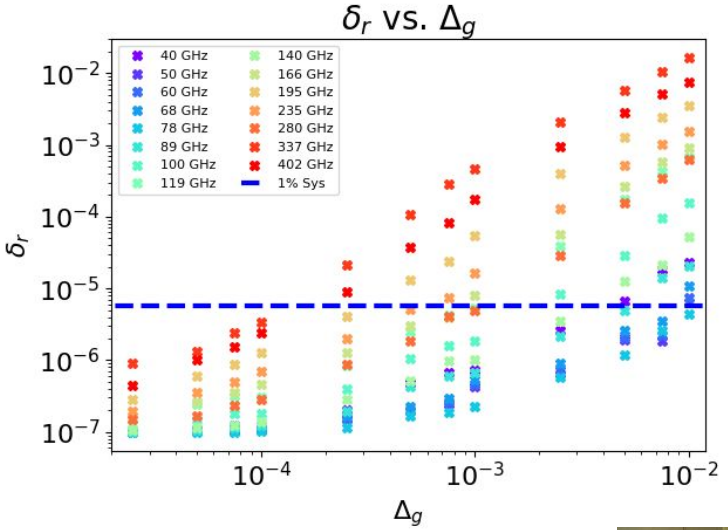


The aims of the study is to address

- Present: Detector parameters, noise and response cross-check.
- Future: Check possible interference between detector/readout with
  - HWP magnetic bearing.
  - Cosmic ray testing at 100 mK with radioactive source.

Systematics and calibration

Inter-frequency gain calibration



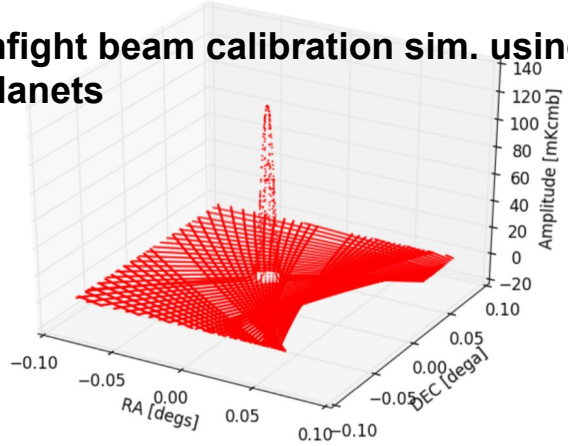
IPMU/Oxford

Tommaso Ghigna

Collaboration with G. Patanchon (APC), H. Ishino (Okayama U.), D. Poletti (SISSA) et al.

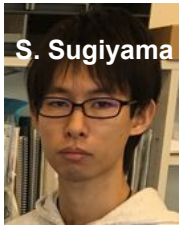
Hajime Sugai
Calibration JSG convener

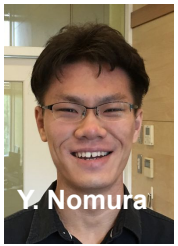
Infight beam calibration sim. using planets



S. Takakura

H. Ochi
Yokohama
National University





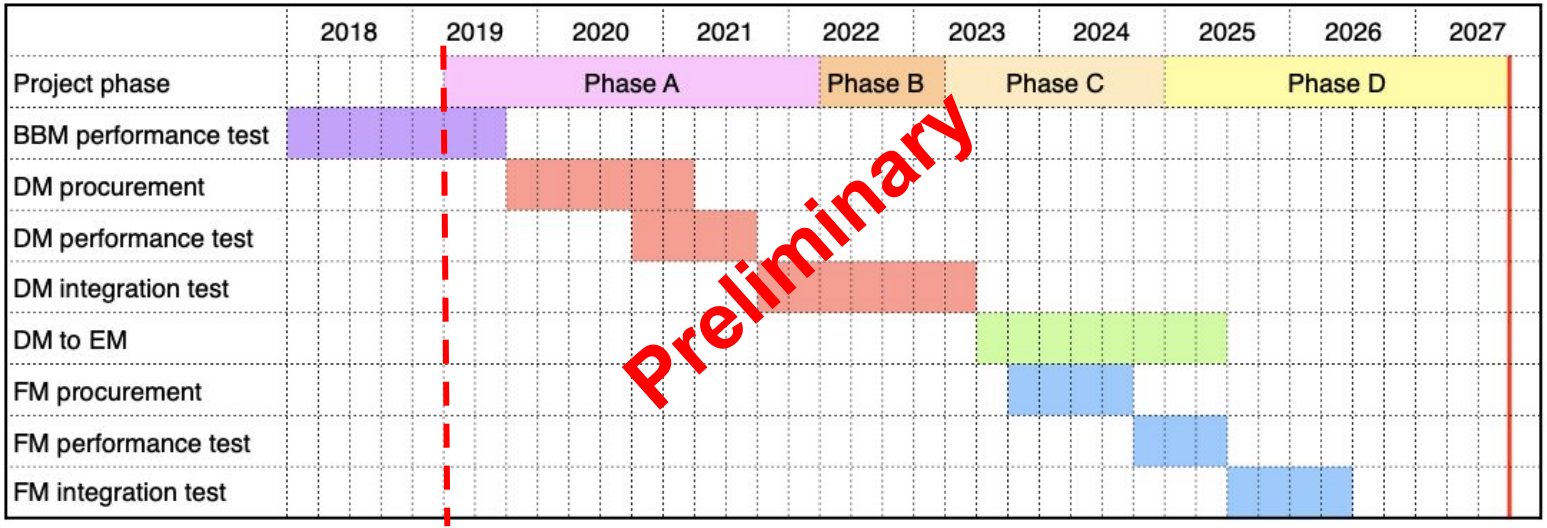
Saitama Univ.

- More items are in progress
  - Cosmic ray modeling and sim.
  - detector non-linearity due to the HWP
  - HWP modeling
  - Science with the HWP systematics

Science Data Analysis Center

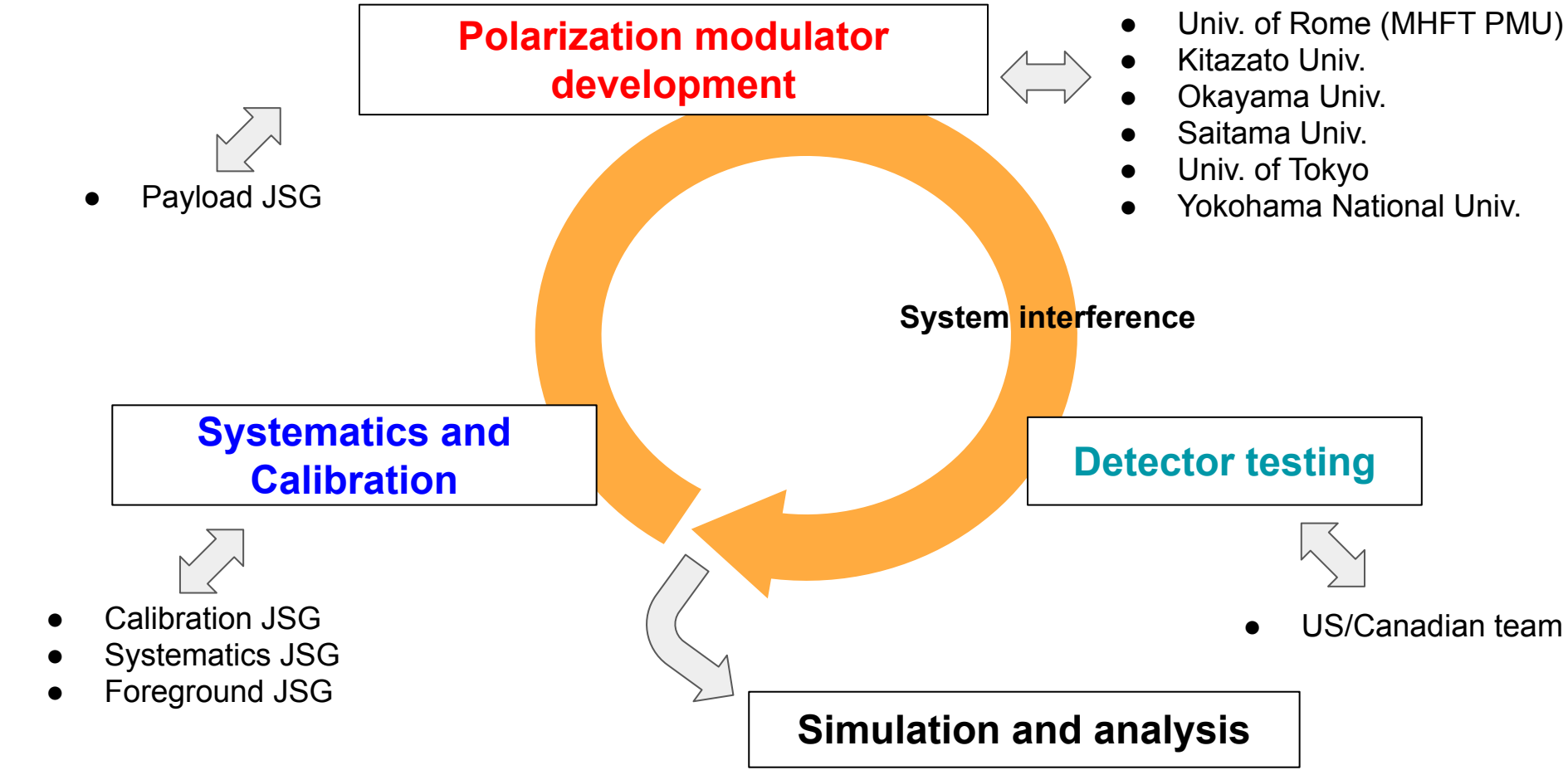
- Kavli IPMU will be responsible for science data analysis to meet the success criteria of the LiteBIRD mission (i.e. measure r)
- We will set up a team at Kavli IPMU to work on establishing the science data analysis center working with the data management steering group of LiteBIRD
- Although we have experiences and have modest amount of computing resources for Hyper Suprime Cam. We will NOT build an on-premise computing center at Kavli IPMU.
- We will use hardware resources at existing supercomputing center at universities in Japan and/or in the clouds

Moving forward



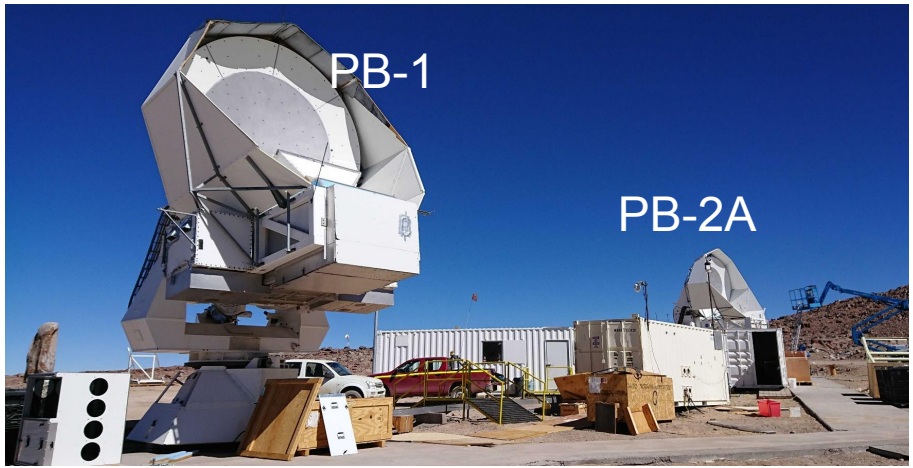
- **Near term**
  - PMU
    - A cryogenic optical performance test is under way.
    - Prep. toward the FM size HWP AR
    - Start contacting with the industrial partners toward DM
  - Detector
    - Prep. toward the study of the interference between the PMU and the detector system
  - Systematics/Calibration study
    - Many effects to be further addressed.

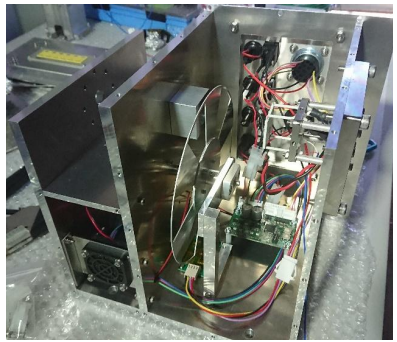
Defining the ICD for PMU!


Polarization modulator development
Univ. of Rome (MHFT PMU)
Kitazato Univ.
Okayama Univ.
Saitama Univ.
Univ. of Tokyo
Yokohama National Univ.
Payload JSG
System interference
Systematics and Calibration
Detector testing
Calibration JSG
Systematics JSG
Foreground JSG
US/Canadian team
Simulation and analysis

Other CMB activities at IPMU

Kavli IPMU is also an active member of POLARBEAR, POLARBEAR2/Simons Array, and Simons Observatory.



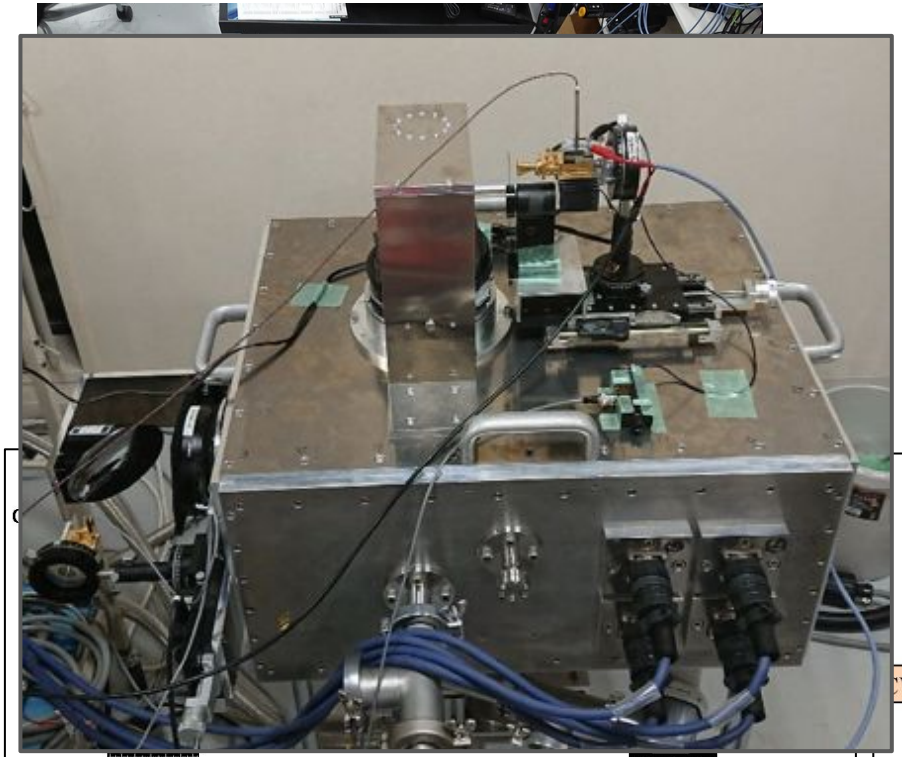


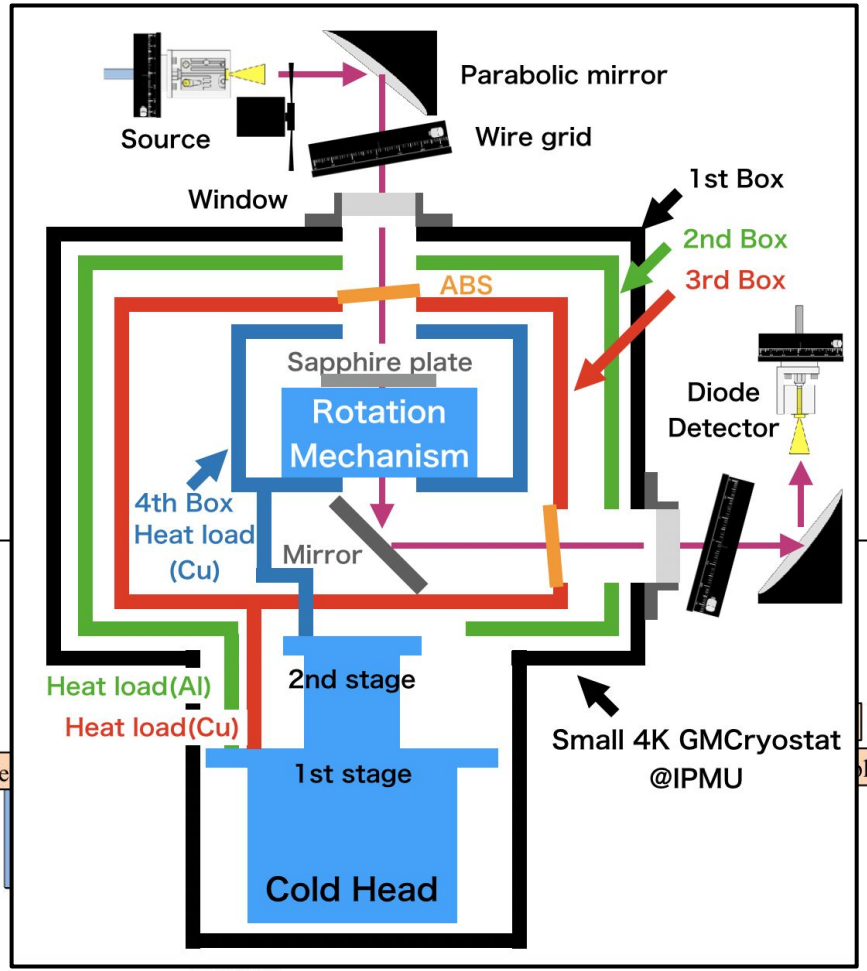
Summary

- Kavli IPMU brings together physicists, mathematicians and astronomers under one roof to solve most fundamental questions about the Universe.
- Kavli IPMU is in role of LFT polarization modulator and data analysis.
- We went through the extensive Pre-PhaseA2 in focus of the polarization modulator development.
- The activities expand toward the detector testing with the external interference sources.
- We are active participants to the systematics JSG and two conveners organize the calibration JSG. This effort will lead to the simulation and analysis.

Future

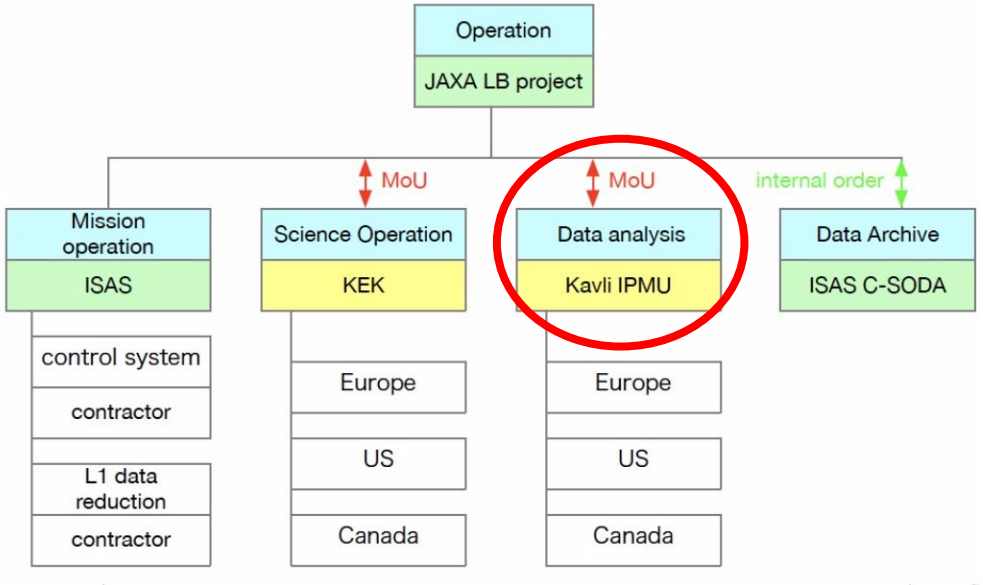
Measurement system





Science Data Analysis Center

- Kavli IPMU will be responsible for science data analysis to meet the success criteria of the LiteBIRD mission (i.e. measure r)
- We will set up a team at Kavli IPMU to work on establishing the science data analysis center working with the data management steering group of LiteBIRD
- Although we have experiences and have modest amount of computing resources for Hyper Suprime Cam. We will NOT build an on-premise computing center at Kavli IPMU.
- We will use hardware resources at existing supercomputing center at universities in Japan and/or in the clouds



From LiteBIRD procurement management plan

Role of IPMU in LiteBIRD

- Payload module
  - LFT
  - LFT-HWP
  - LFT-FP
  - Warm electronics
  - MHFT
  - MHFT-HWP
  - SubK
  - MHFT-FP

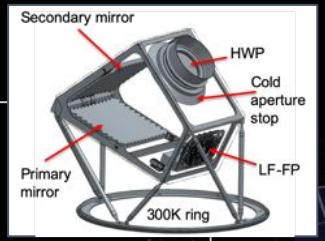
Kavli IPMU is a proposer of the LiteBIRD project to the Master Plan 2020 of the Science Council of Japan.

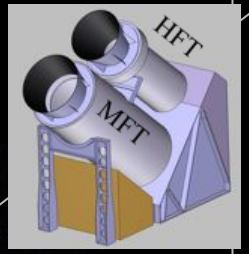
Role of IPMU in LiteBIRD

JAXA
- Launch
- Satellite system
- Low frequency telescope (LFT)

Kavli IPMU
- **Polarization modulator for LFT**
- **Data analysis lead in Japan**

KEK
- Ground calibration

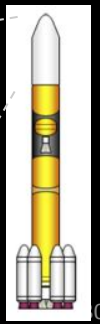




Europe
- Middle and high frequency telescope
- Sub-K cooler

US
- Superconducting detector (TES) array
- Sub-K cooler

Canada
- Warm readout electronics



JAXA
H3 rocket