Dark matter axion search in IBS-DMAG

Saebyeok Ahn

Postdoctoral researcher

On behalf of ***IBS Dark Matter Axion Group (DMAG)***
Y. Nakamura, University of Tokyo, RIKEN

Institute for Basic Science (IBS)

Dark Matter Axion Group (DMAG)

Daejeon, South Korea

April 27, 2025

CUBES 2025, Gurye

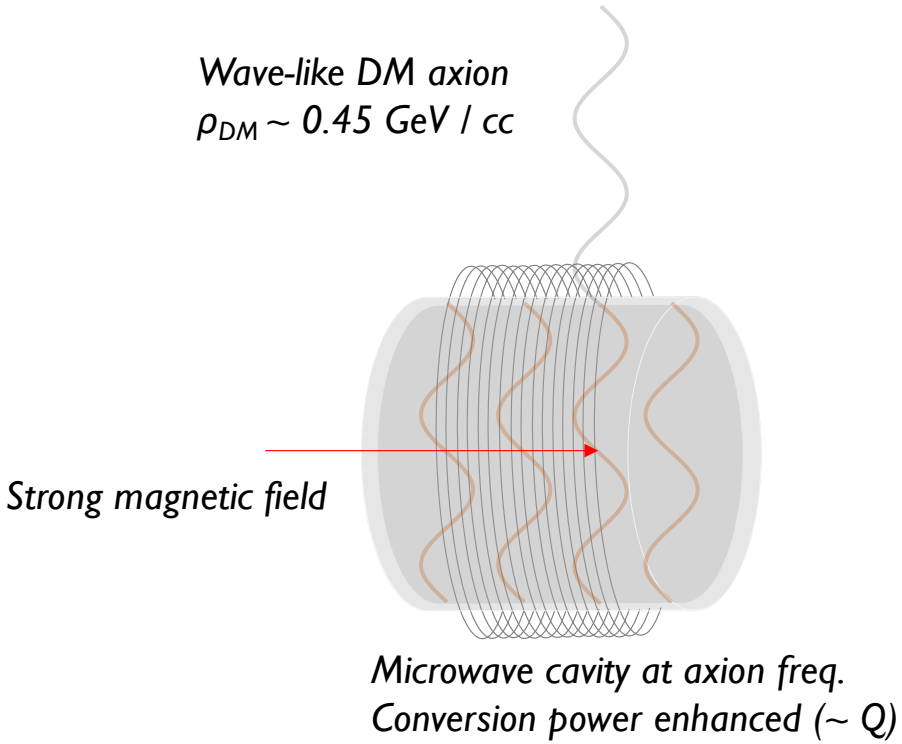
Axion haloscope

- Search for dark matter (DM) axions around the Milky way galaxy

Wave-like DM axion
$\rho_{DM} \sim 0.45$ GeV / cc

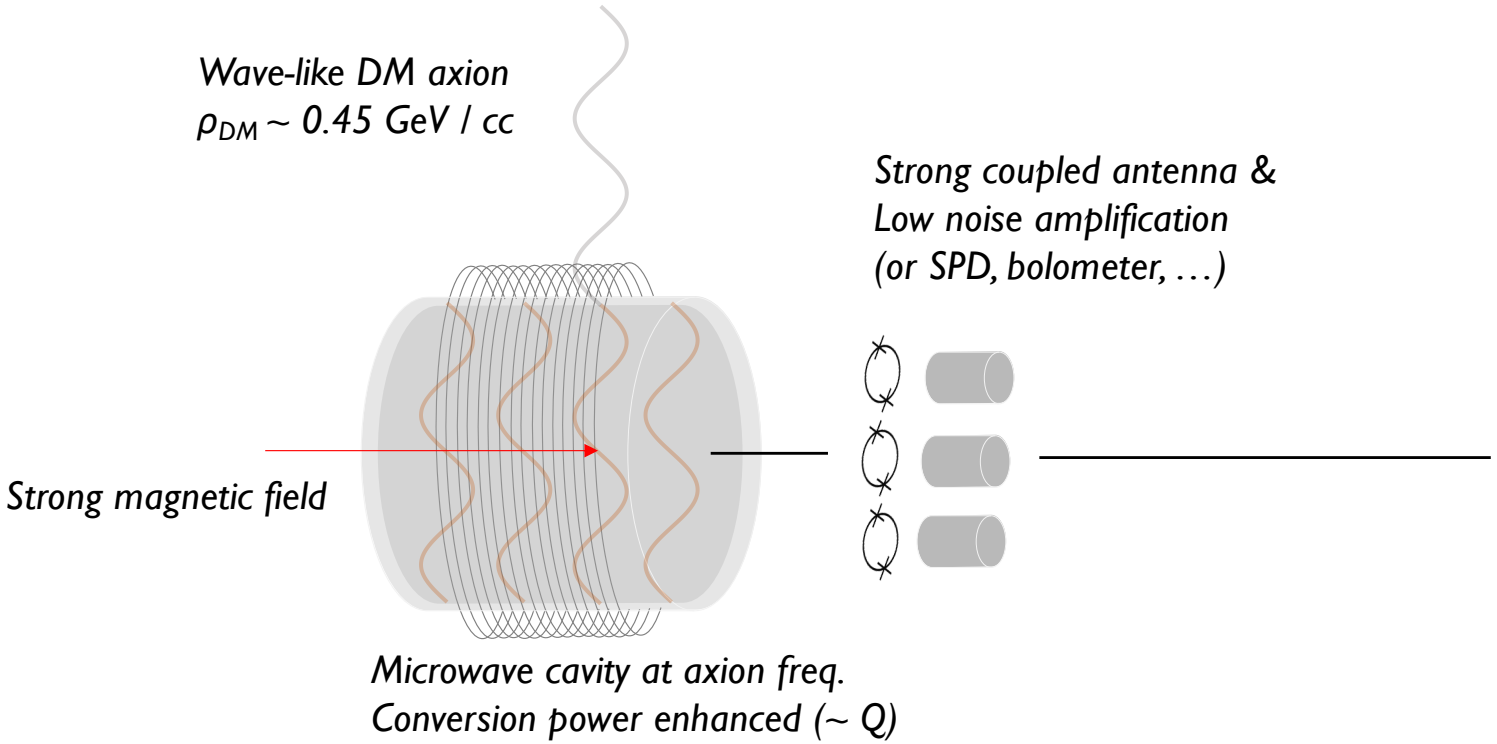
Axion haloscope

- Search for dark matter (DM) axions around the Milky way galaxy



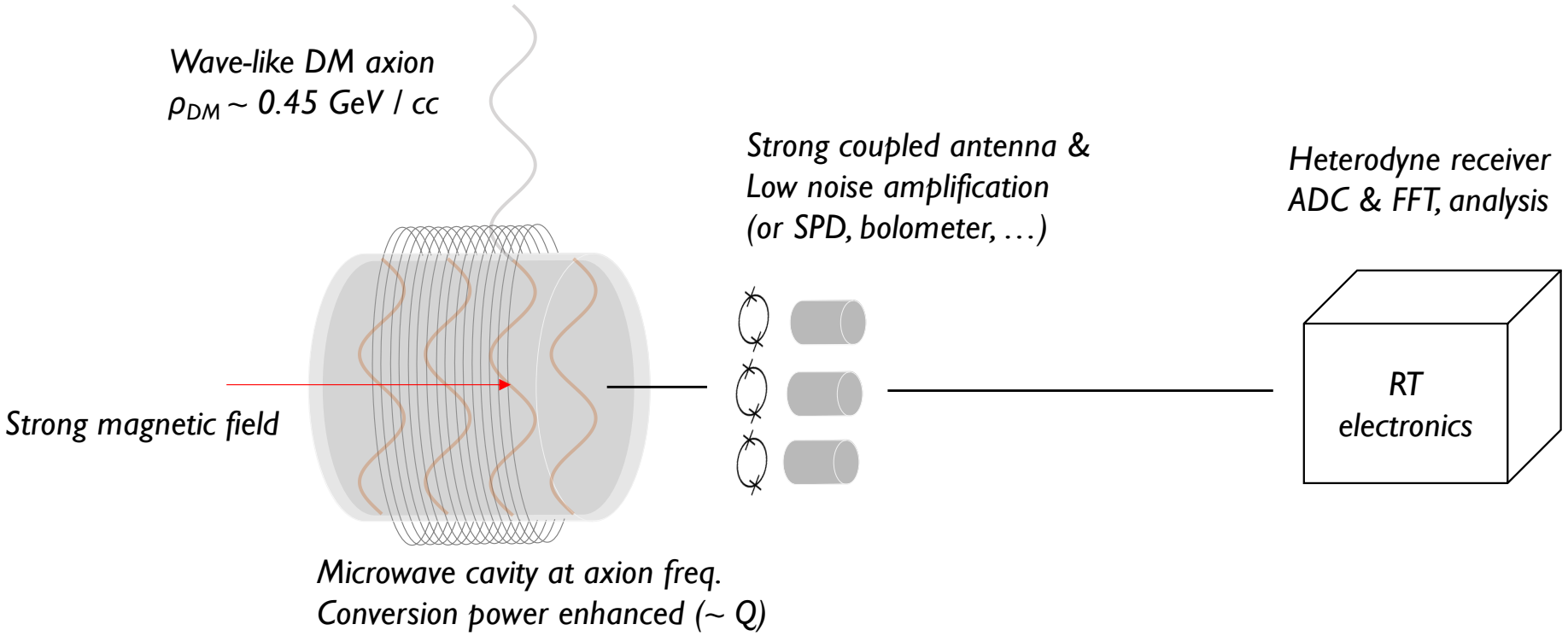
Axion haloscope

- Search for dark matter (DM) axions around the Milky way galaxy



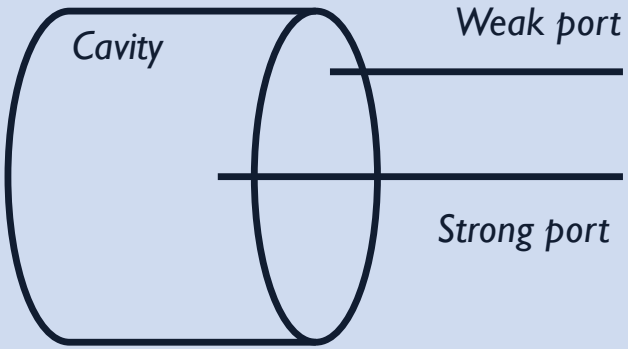
Axion haloscope

- Search for dark matter (DM) axions around the Milky way galaxy



Axion haloscope receiver chain

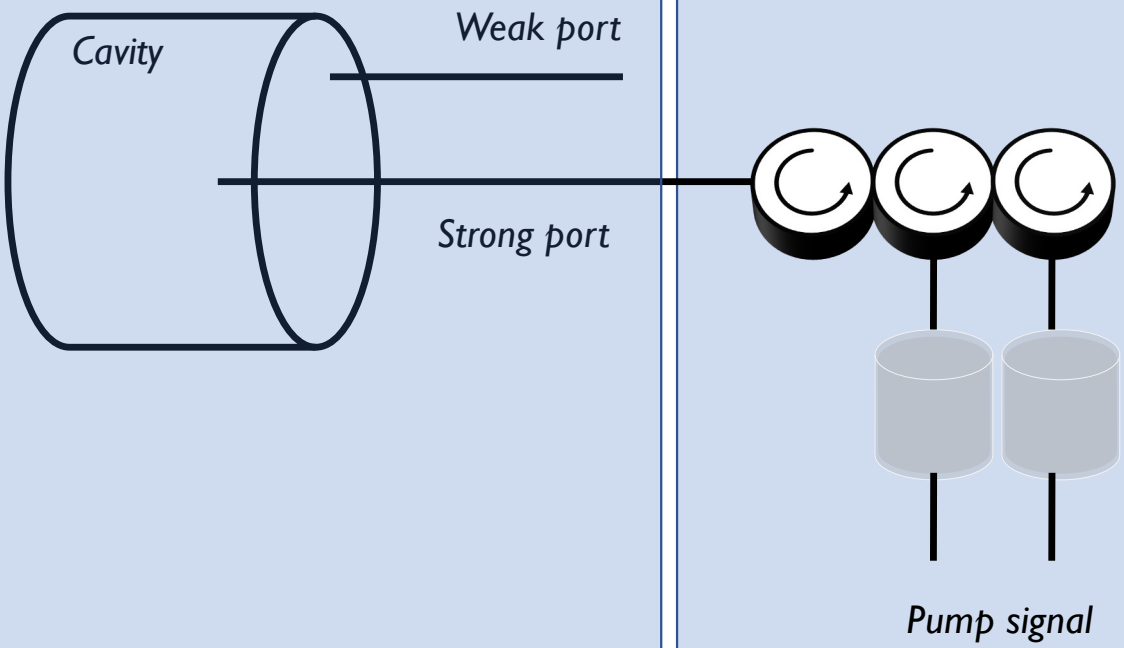
- *Signal resonated in the cavity*
- *Typical temperature ~ 30 mK*



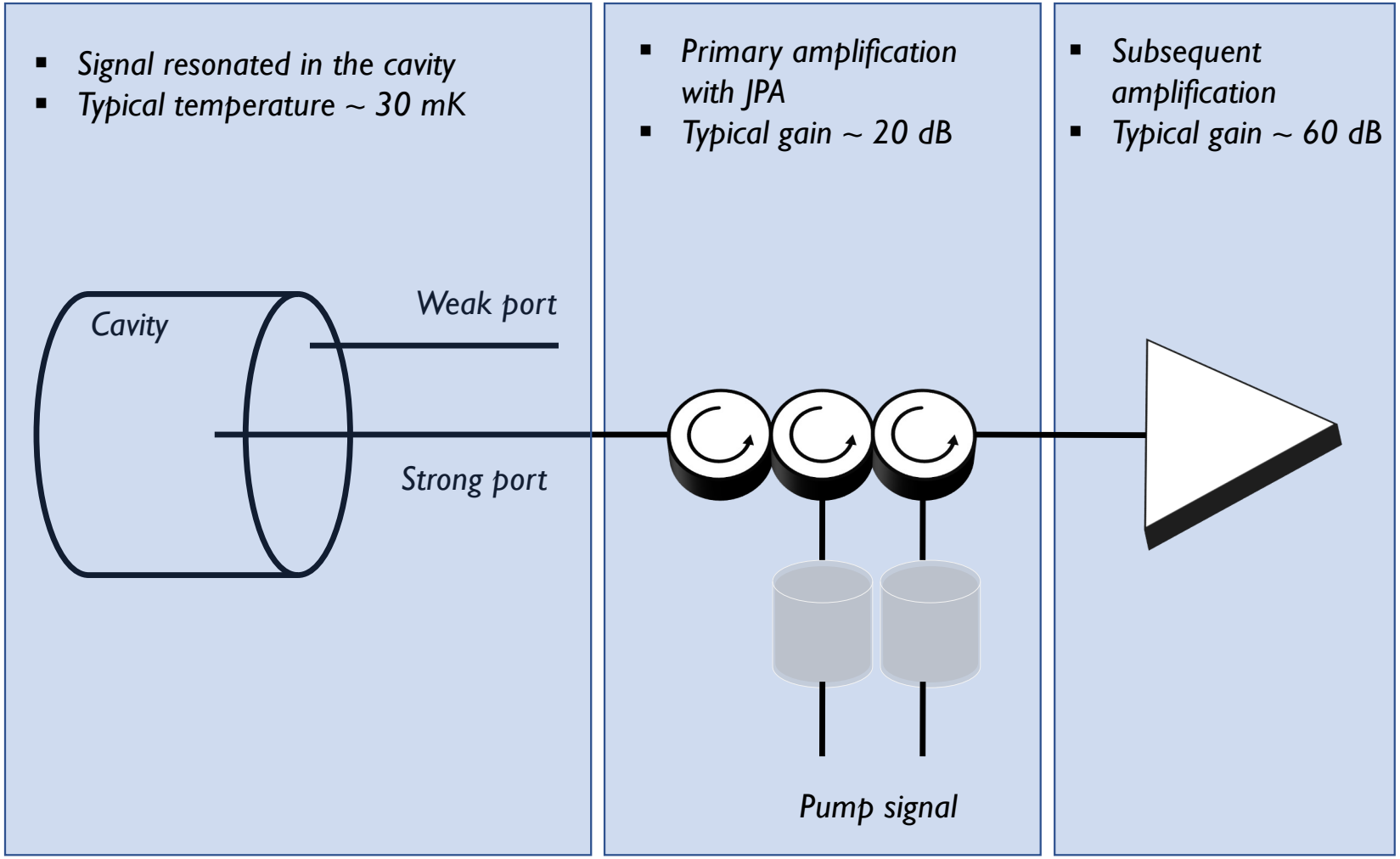
Axion haloscope receiver chain

- *Signal resonated in the cavity*
- *Typical temperature ~ 30 mK*

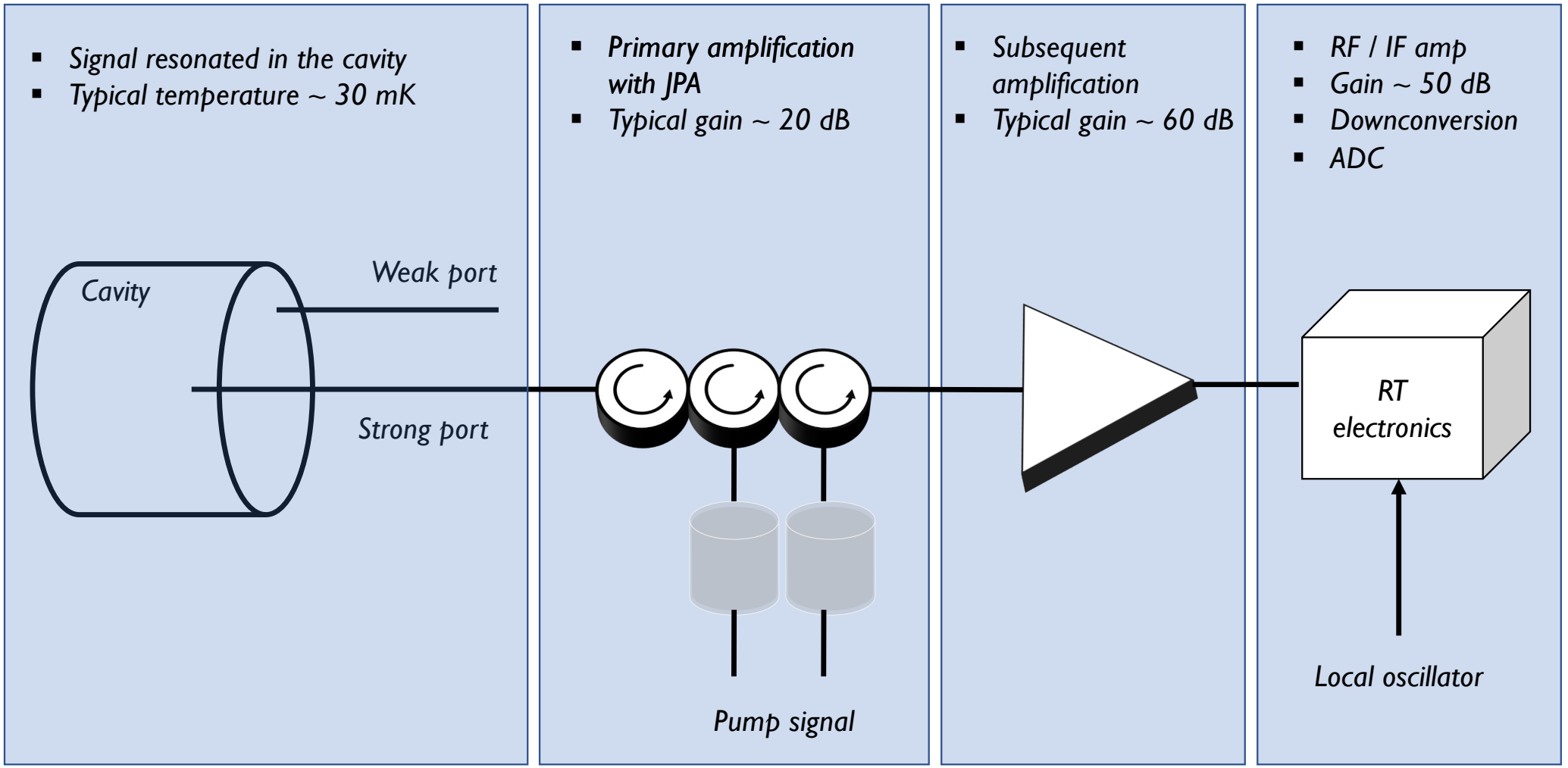
- *Primary amplification with JPA*
- *Typical gain ~ 20 dB*



Axion haloscope receiver chain



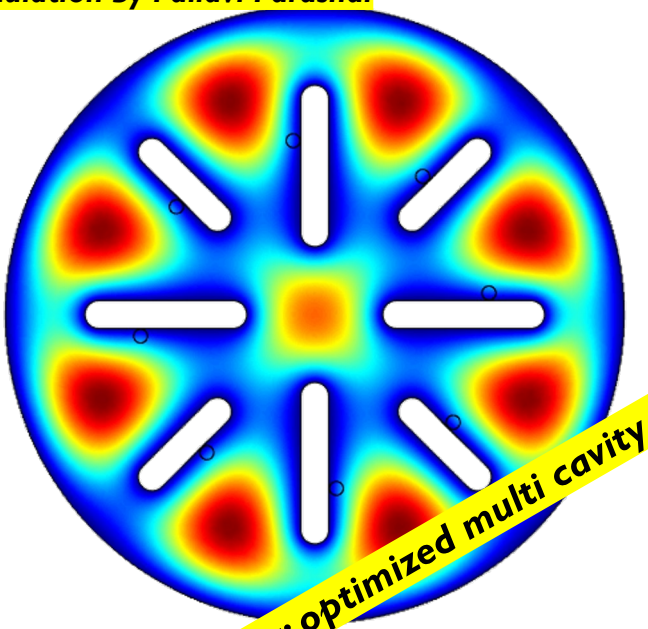
Axion haloscope receiver chain



DMAG cavities: high frequency

SungWoo Youn, Jinsu Kim

Simulation by Pallavi Parashar



Pizza / Kiwi cavity: optimized multi cavity system

IBS – DMAG (former CAPP)

Former CAPP, now Dark Matter Axion Group (DMAG)

Cavity-based dark matter axion experiments

SungWoo Youn *the group leader (Chief Investigator)*

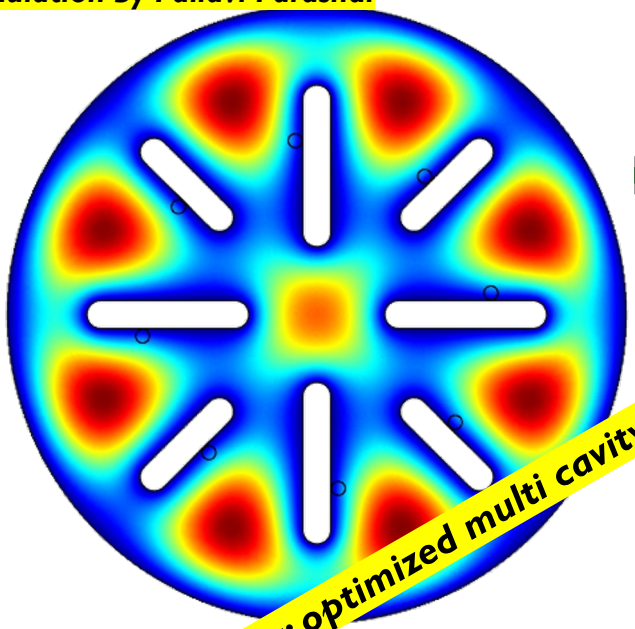
- *3 (dry) + 1 (wet) fridges with superconducting magnets (8 T, 12 T) as axion haloscopes*
- *A dry fridge for quantum sensor testbed*

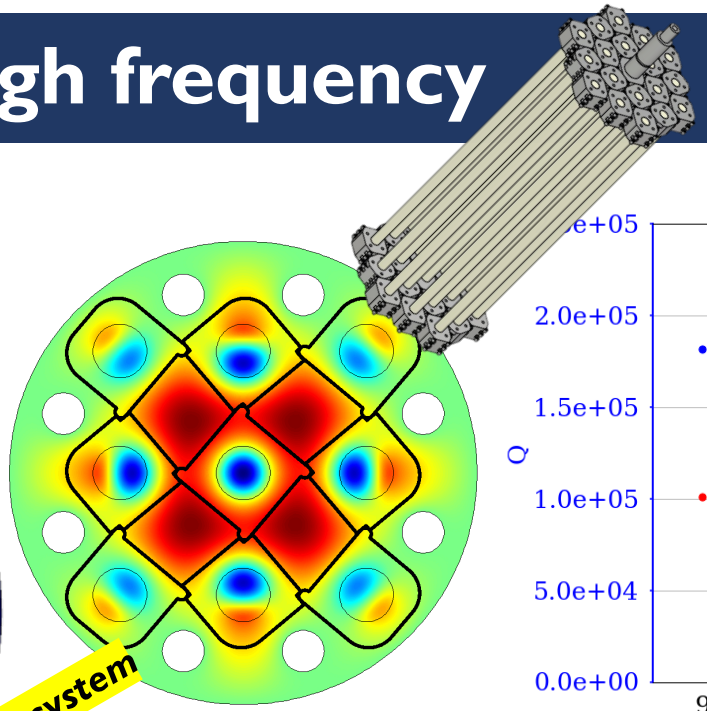
- *3 postdocs, 3 researchers/fellows, 2 students, 3 research engineers, a visiting professor (emeritus of KAIST)*
- ***High frequency techniques / High Q cavities with HTS films***
- ***1 – 6 GHz scan with KSVZ/DFSZ sensitivity in 4 years***

DMAG cavities: high frequency

SungWoo Youn, Jinsu Kim

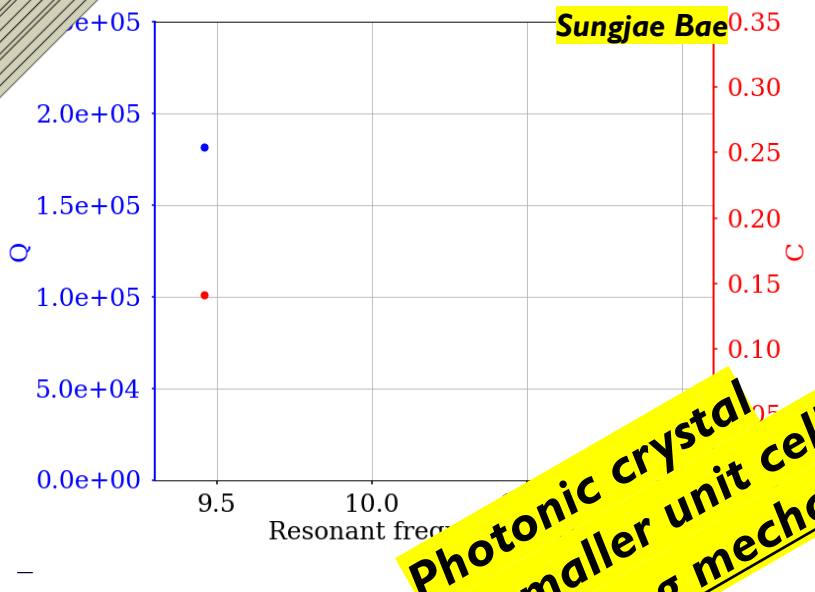
Simulation by Pallavi Parashar





Pizza / Kiwi cavity: optimized multi cavity system

Sungjae Bae



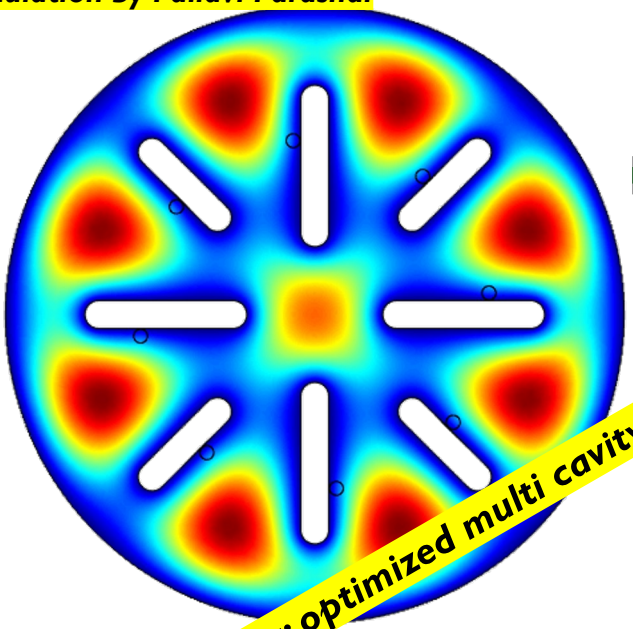
Photonic crystal (even smaller unit cell)

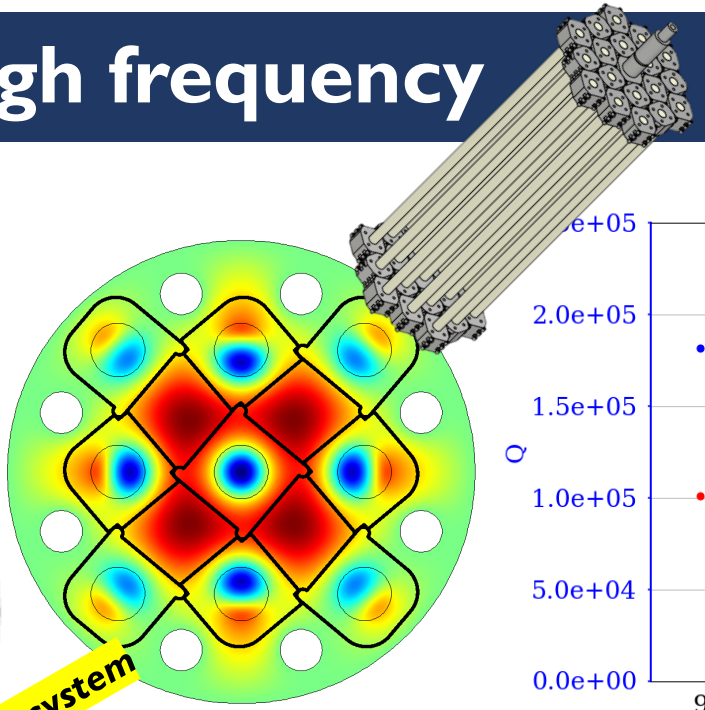
Kirigami tuning mechanism

DMAG cavities: high frequency

SungWoo Youn, Jinsu Kim

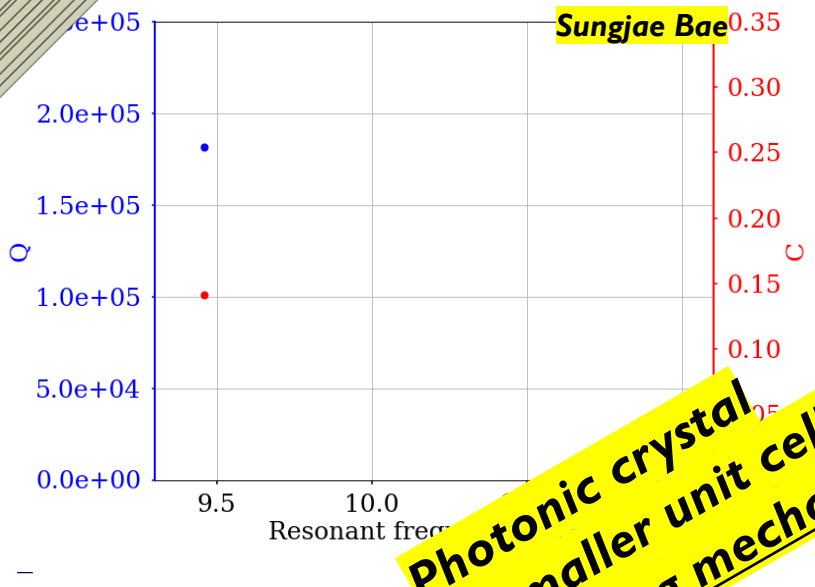
Simulation by Pallavi Parashar



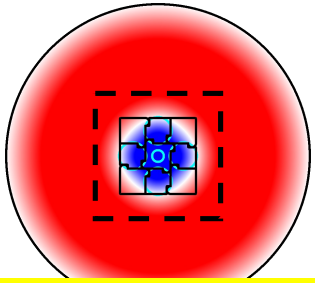


Pizza / Kiwi cavity: optimized multi cavity system

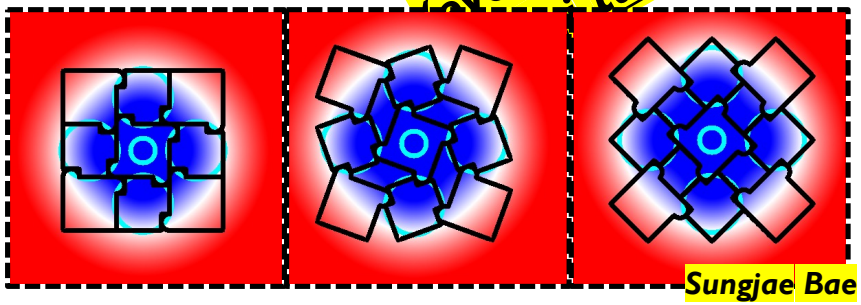
Sungjae Bae



Photonic crystal
aven smaller unit cell)
tuning mechanism



TM_{020} cavity

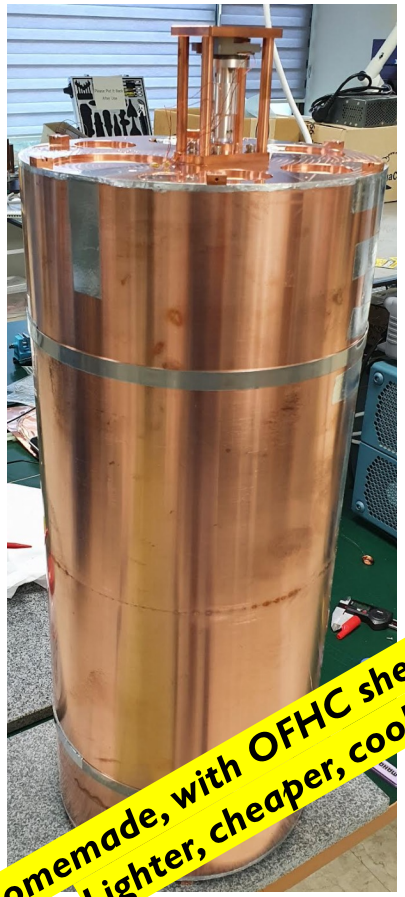


Sungjae Bae

CUBES 2025, Gurye

DMAG cavities: ULC and HTS cavity

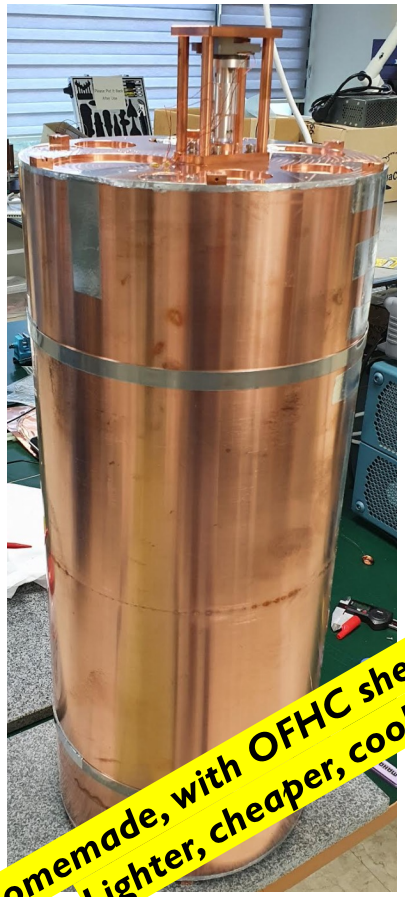
Ohjoon Kwon
Danho Ahn
Jiwon Lee
Prof. Dojun Yeom



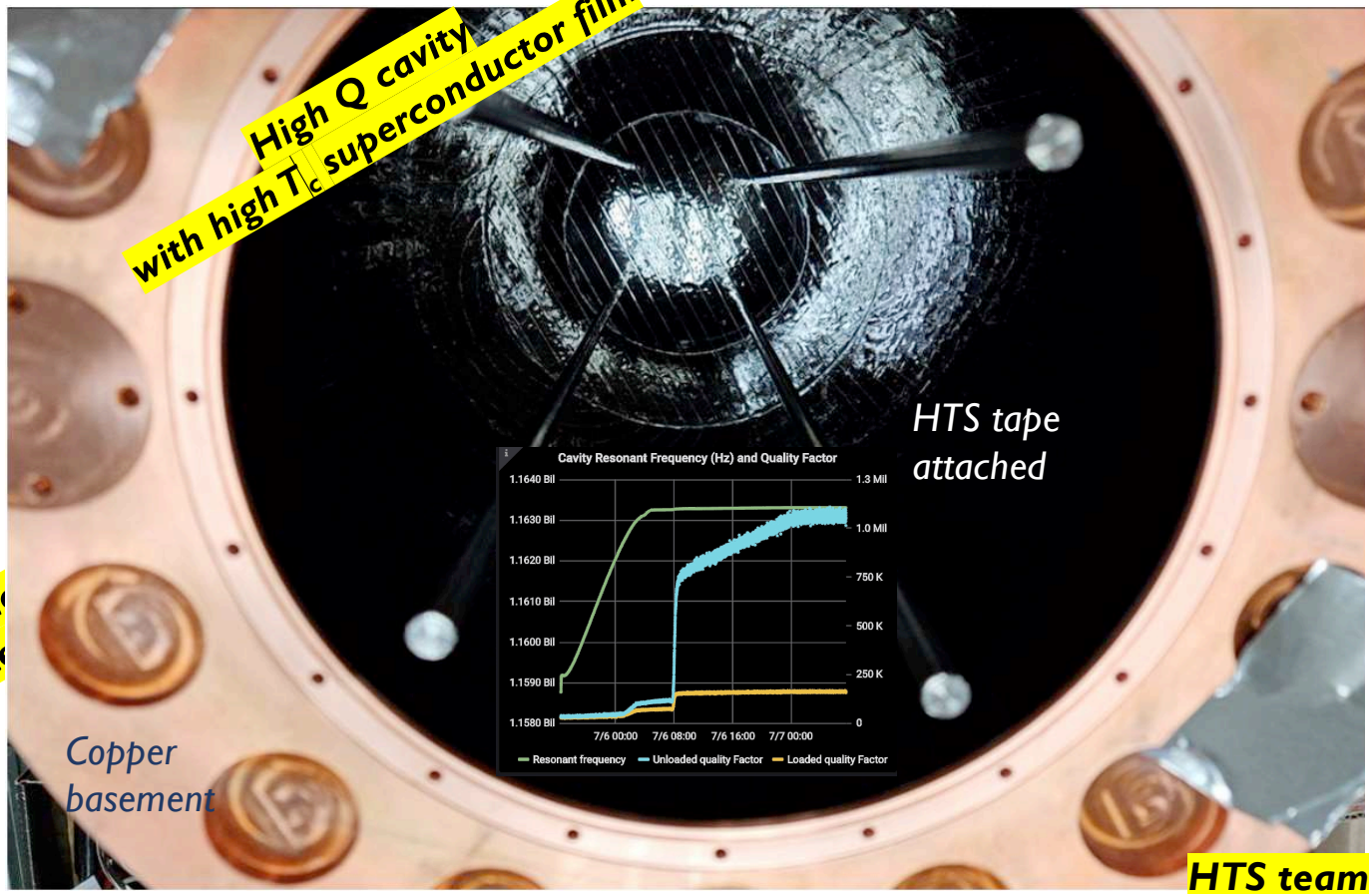
Homemade, with OFHC sheets (sidewall)
Lighter, cheaper, cooler, faster

DMAG cavities: ULC and HTS cavity

Ohjoon Kwon
Danho Ahn
Jiwon Lee
Prof. Dojun Yeom



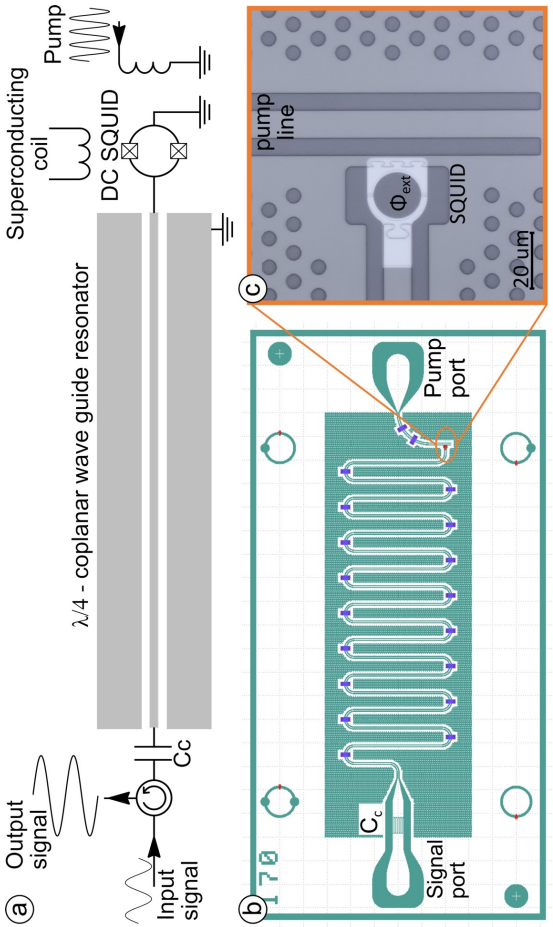
Homemade, with OFHC sheets (sid
Lighter, cheaper, cooler, faste



DMAG receiver chains

Uchaikin SV, Kim J, Kutlu C, Ivanov BI, Kim J, van Loo AF, Nakamura Y, Ahn S, Oh S, Ko M and Semertzidis YK (2024), Front. Phys. 12:1437680. doi: 10.3389/fphy.2024.1437680

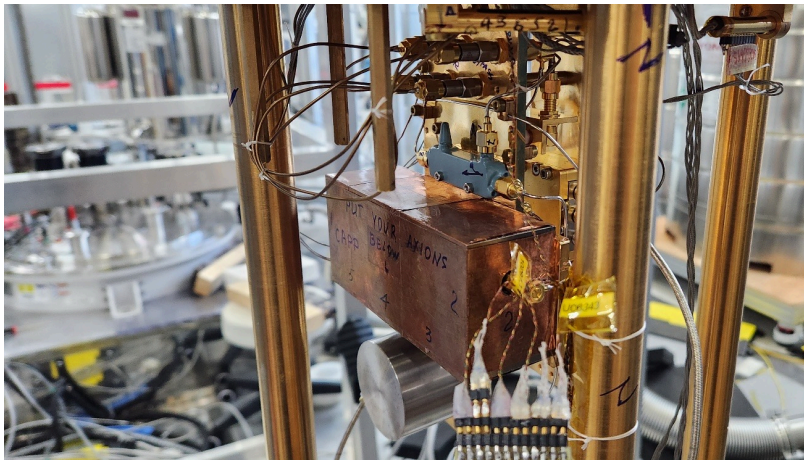
Sergey Uchaikin
Boris Ivanov
QLNA team

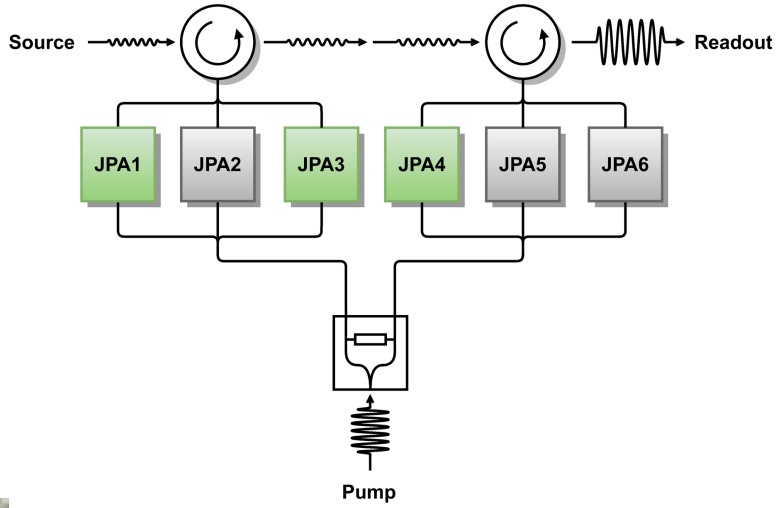


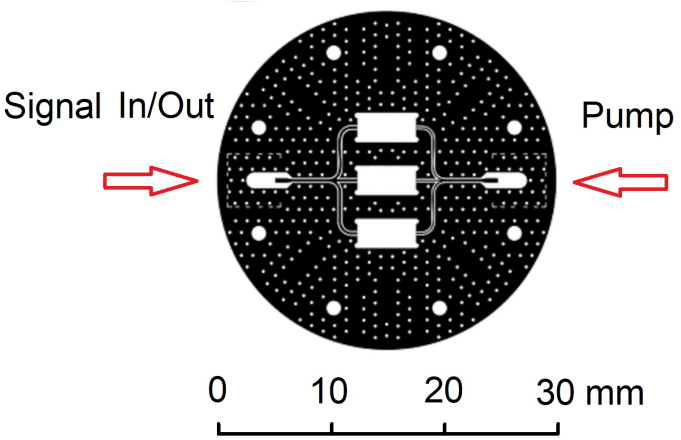
- *Flux-driven JPAs*
- *Collaborating with U. of tokey*

Parallel JPAs

- *3 JPAs bundled up*
- *Single holder / flux bias / pump*
- *Extending the amplifier's frequency range*



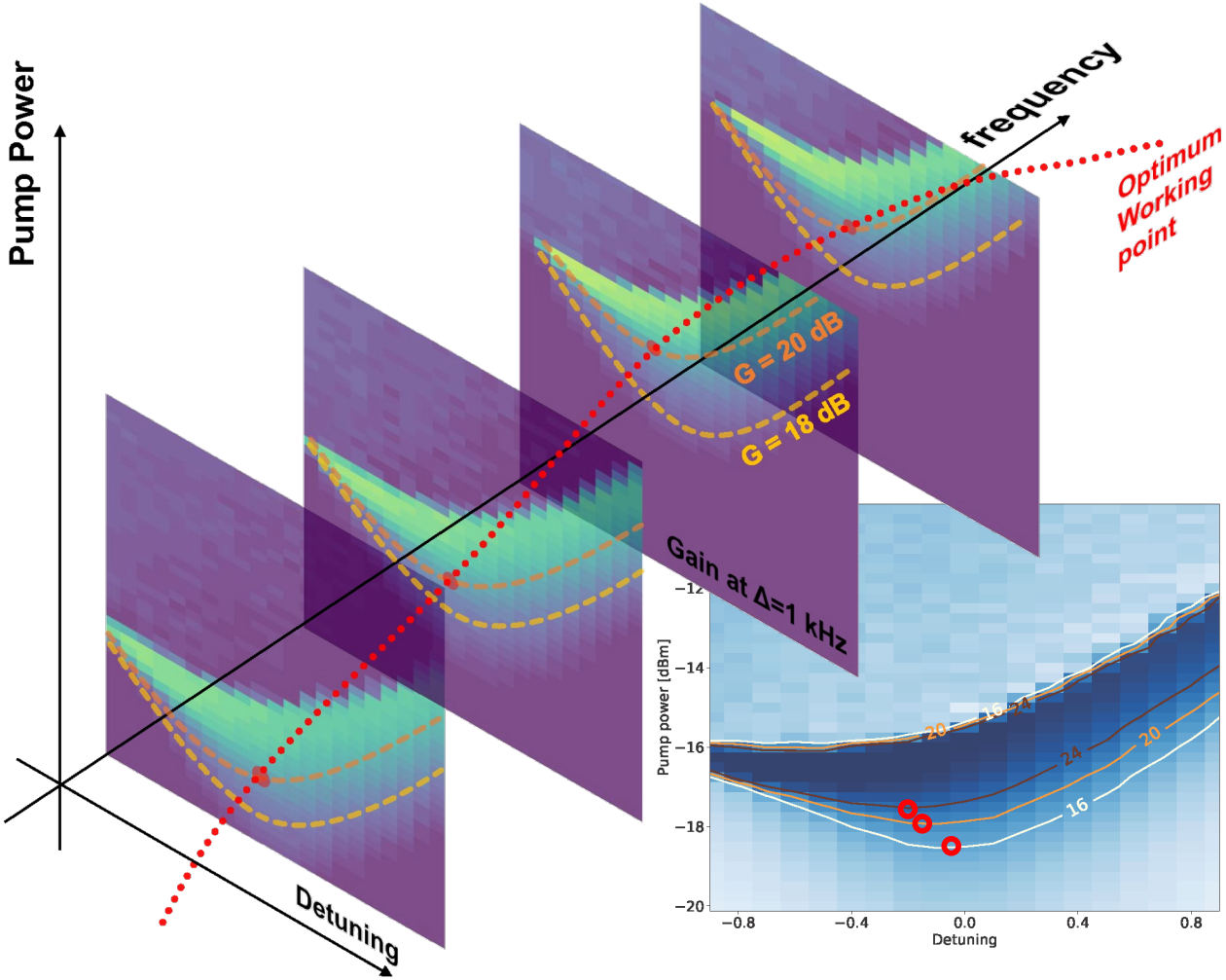




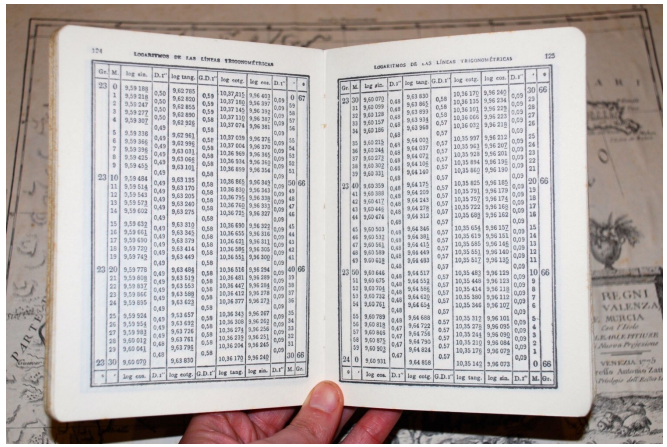
More discussion in Sergey's talk

DMAG receiver chains

Uchaikin SV, Kim J, Kutlu C, Ivanov BI, Kim J, van Loo AF, Nakamura Y, Ahn S, Oh S, Ko M and Semertzidis YK (2024), Front. Phys. 12:1437680. doi: 10.3389/fphy.2024.1437680

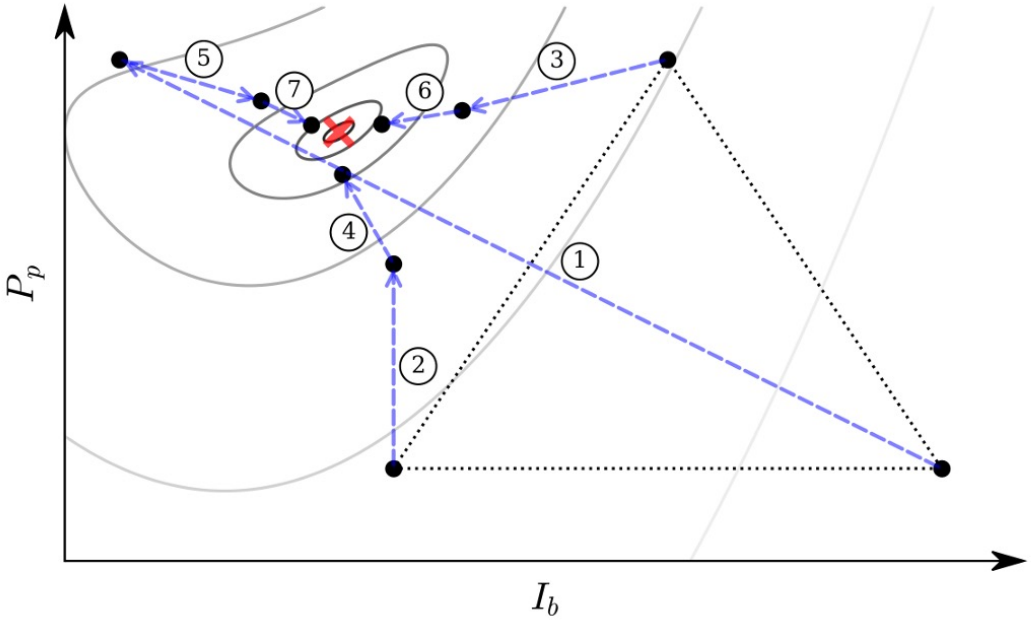


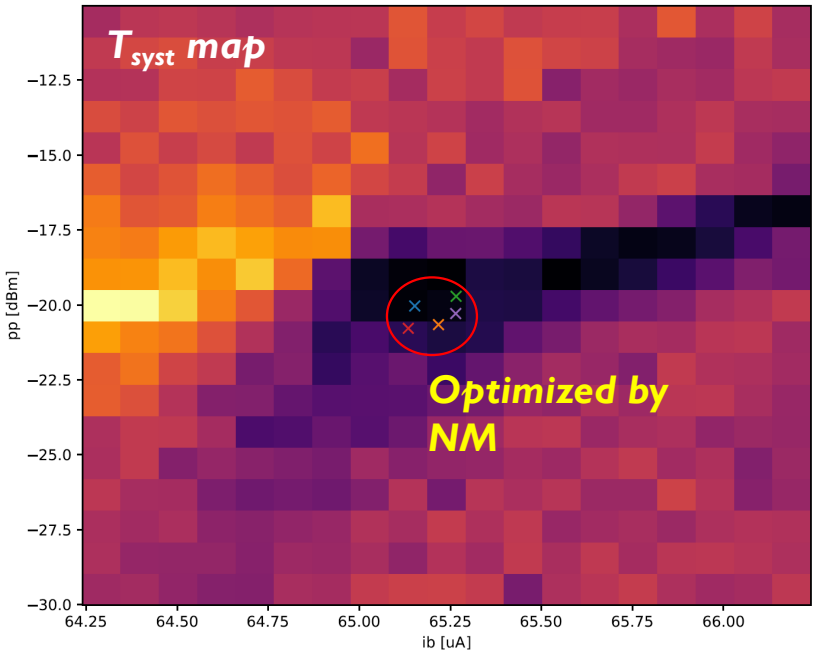
- *2D JPA Paramap ($f_{passive}$, P_{pump})*
- *Gain contour*
- *Lower pump power → Lower added noise*
- *Get the lowest P_{pump} in the contour of given target gain (typically 20 dB)*
- *Every 0.2 ~ 0.5 MHz, interpolated for each tuning step*



DMAG receiver chains

Kim, Y.; Jeong, J.; Youn, S.; Bae, S.; van Loo, A.F.; Nakamura, Y.; Uchaikin, S.; Semertzidis, Y.K. Electronics 2024, 13, 2127. https://doi.org/10.3390/ electronics13112127

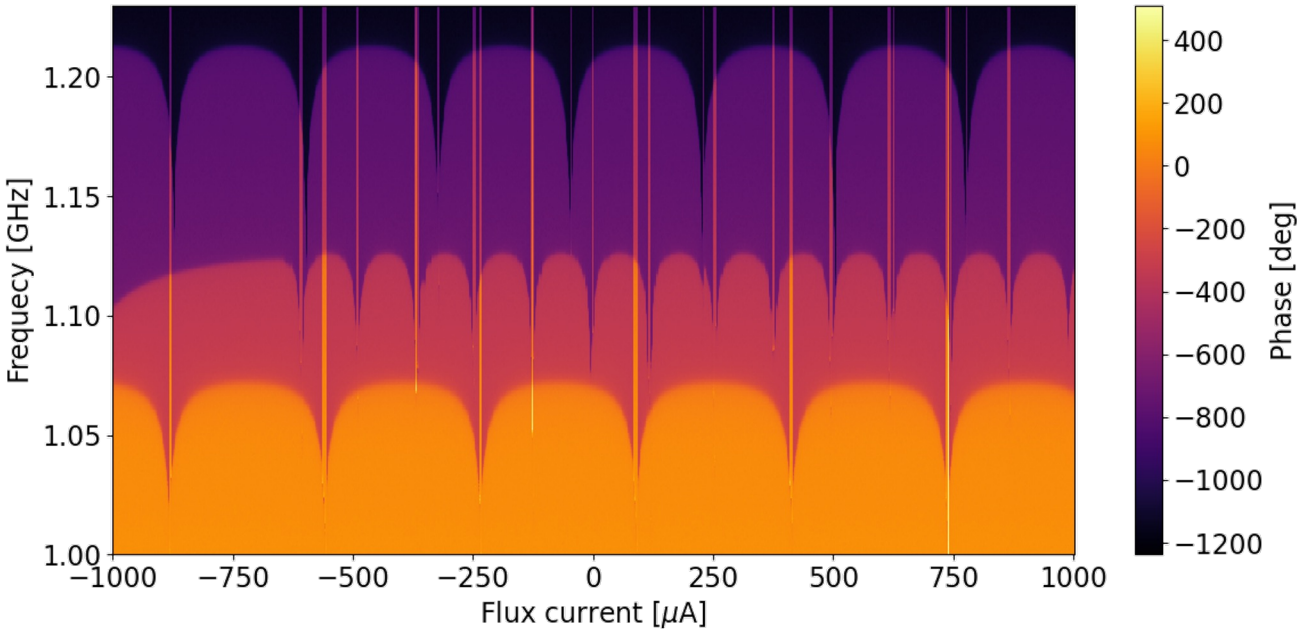




Numerical optimization of T_{syst} with Nelder-Mead (NM) algorithm

- *Optimize the SNR improvement by JPA*

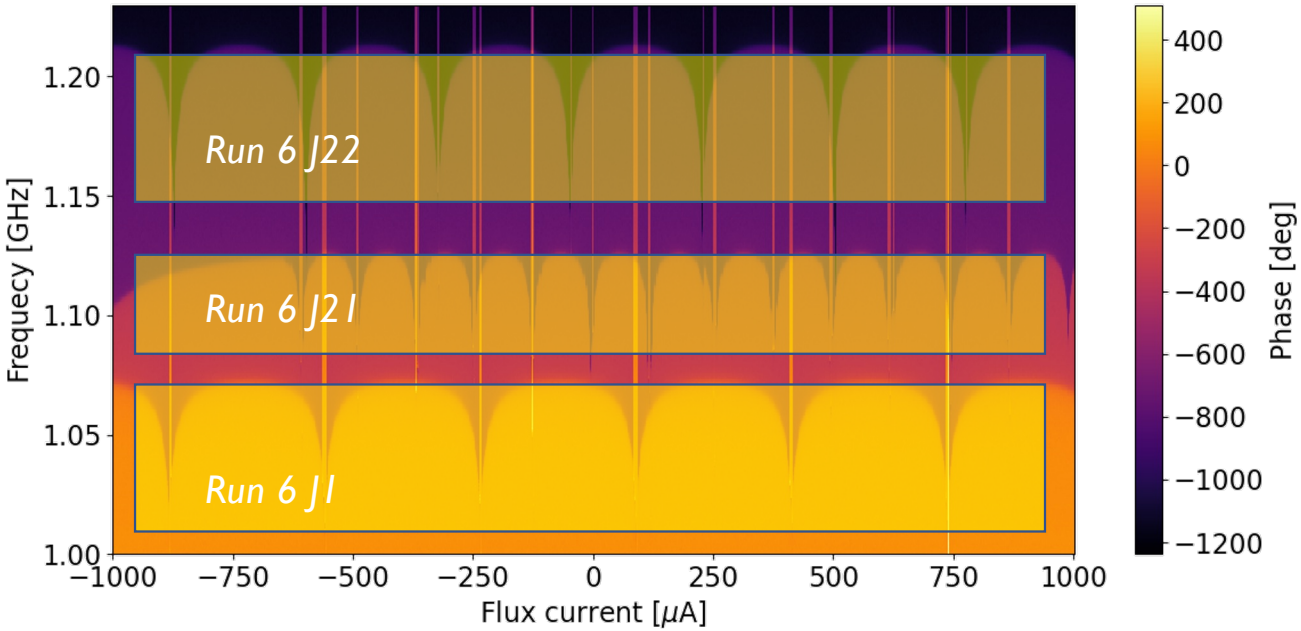
DMAG receiver chains



3 Parallel JPA calibration

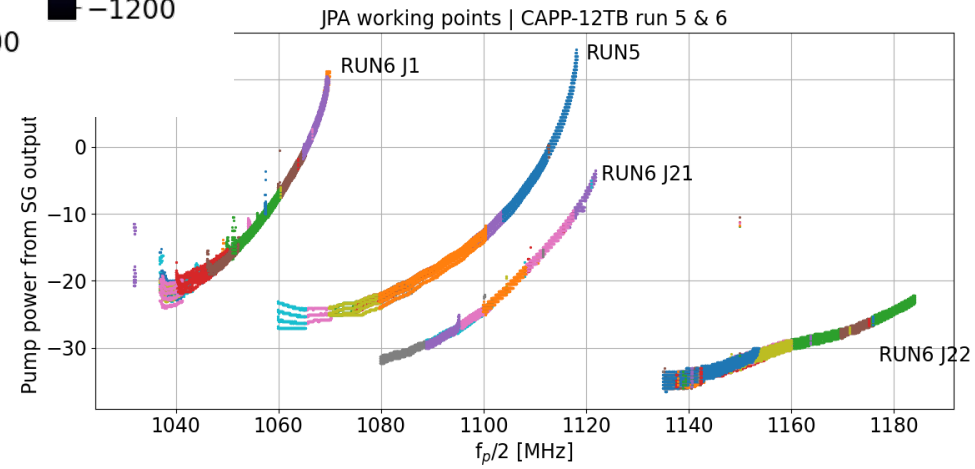
- *All tuned with one bias current circuit*
- *Frequency ranges are separated, no interference among them (mostly)*

DMAG receiver chains



3 Parallel JPA calibration

- *All tuned with one bias current circuit*
- *Frequency ranges are separated, no interference among them (mostly)*



Successfully utilized in the science run

- *CAPP-MAX run 6*
- *No degradation in noise / gain performance of JPAs*