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UNIVERSITÉ PARIS

l'Observatoire de Paris | GEPI
Galaxies Étoiles Physique et Instrumentation

cnrs
dépasser les frontières

SPIAKID

erc
European Research Council
Established by the European Commission

Goals of the project

- Build a spectro-imager based on MKIDs technology
- Deploy it on the ESO-NTT 3.5m telescope
- Demonstrate that the technology is mature for real science application and brings a plus-value with respect to existing detectors
- Perform a detailed study of the stellar populations of at least one Ultra Faint Dwarf galaxy in the Local Group

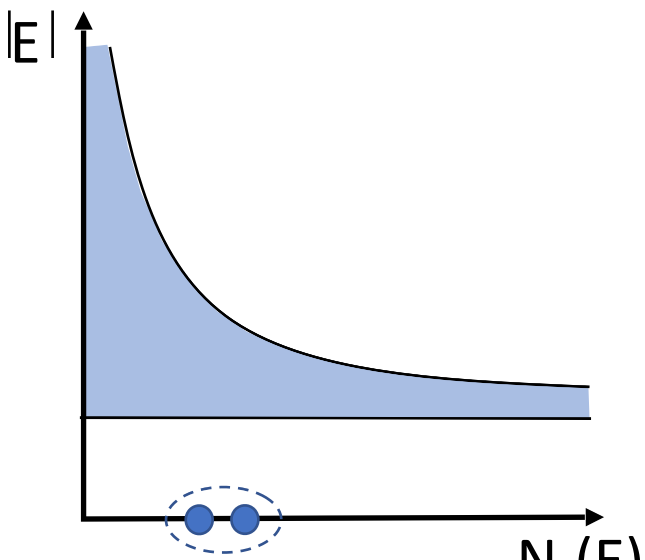
The team

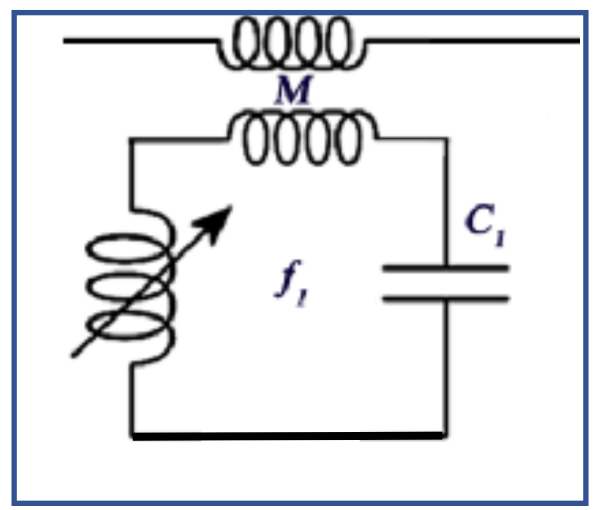
- P. Bonifacio (GEPI) PI
- F. Boussaha (GEPI) PM & KIDs development
- P. Jagourel (GEPI) Deputy PM
- E. Caffau (GEPI) IS
- S. Gauffre (LAB) Instrument Electronics
- M. Dekkali (LESIA) Characterisation Electronics

- S. Mignot (GEPI) DRS
- J. Hu (GEPI) Cryostat & Test Bench
- D. Horville (GEPI) Optics
- J.-P. Amans (GEPI) Mechanics
- G. Fasola (GEPI) Instrument Control Electronics
- T. Vacelet (LERMA) AIT

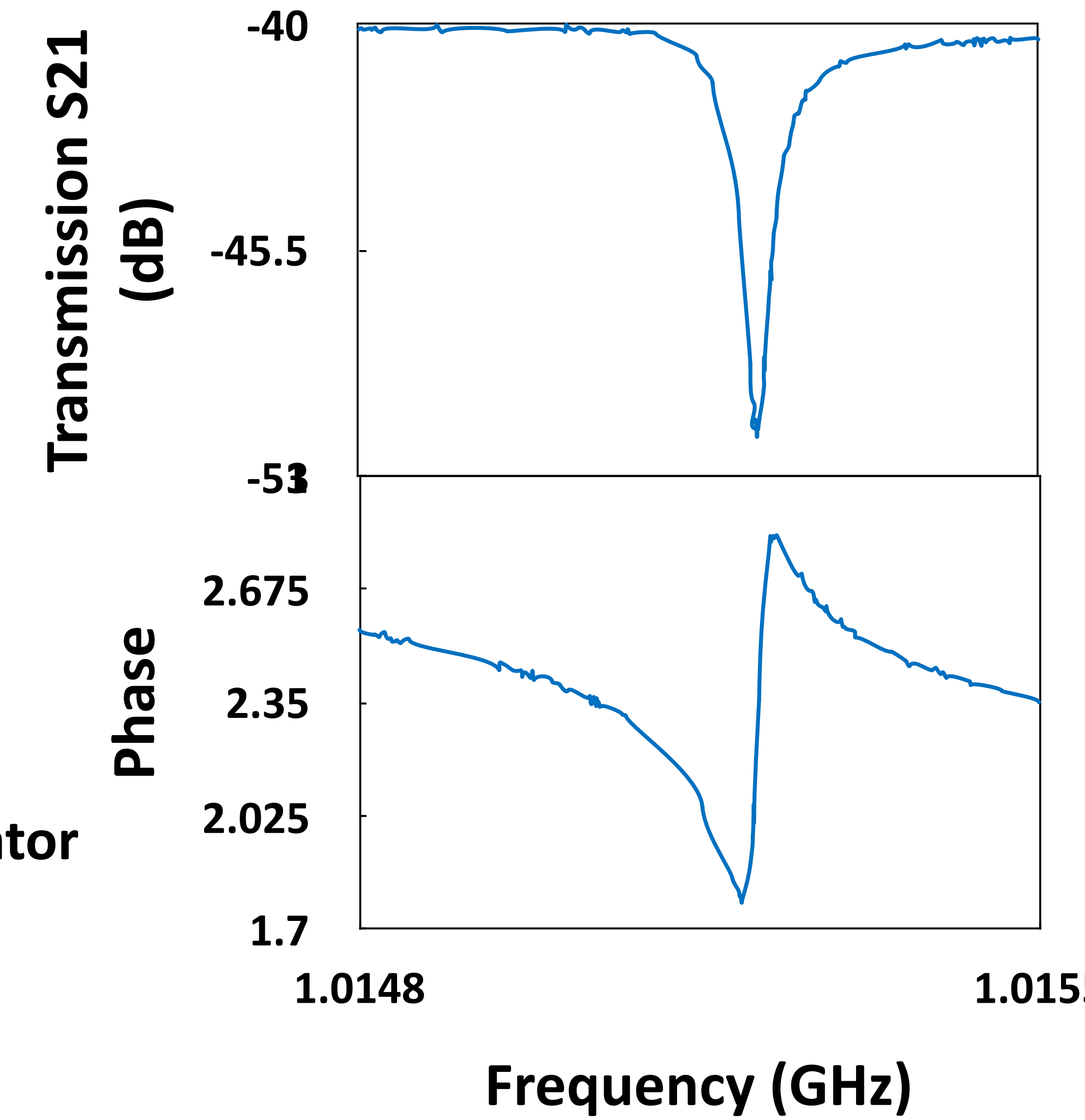
MKID : detection principle

P. Day et al, Nature 2003 (Caltech, JPL-NASA)





Superconducting LC Resonator



$$L_k = \frac{m_e}{n_s e^2}$$

$$f_0 = \frac{1}{2\pi\sqrt{(L_{geo} + L_k)C}}$$

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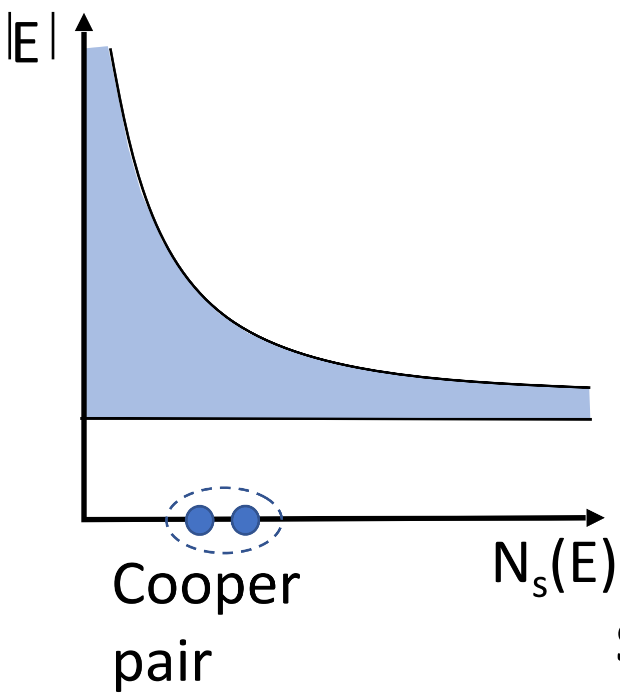

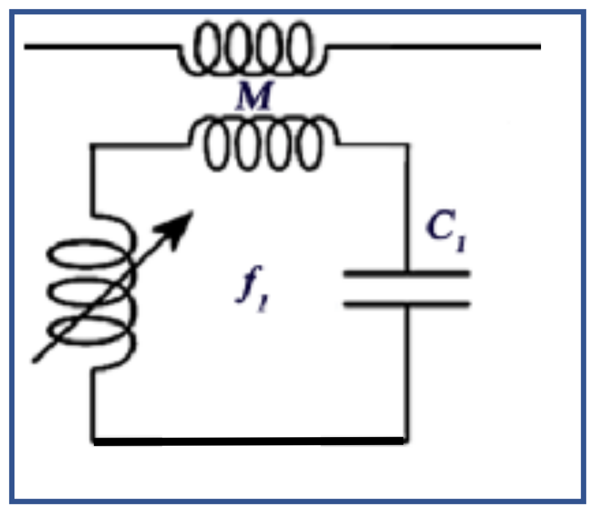

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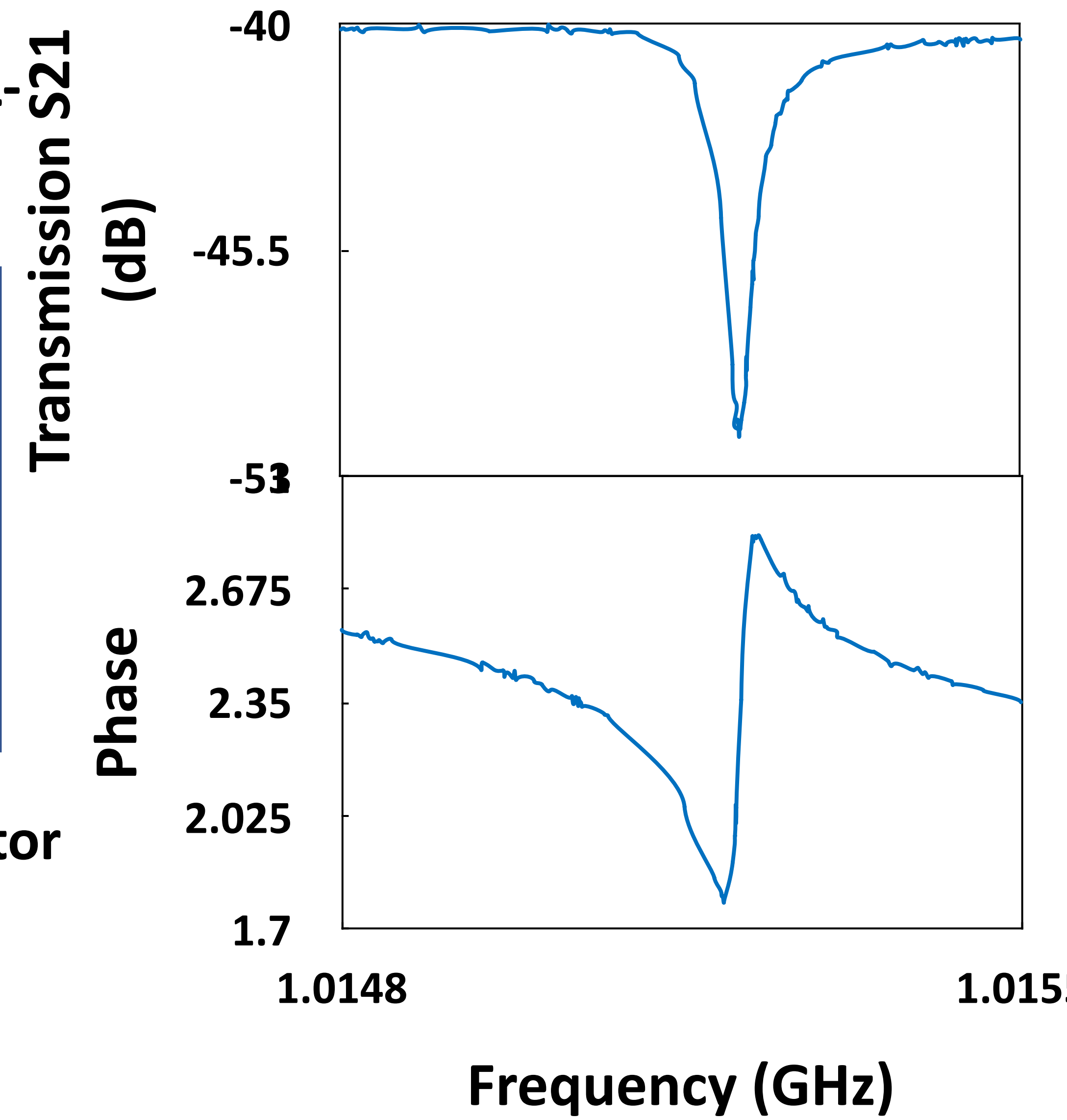

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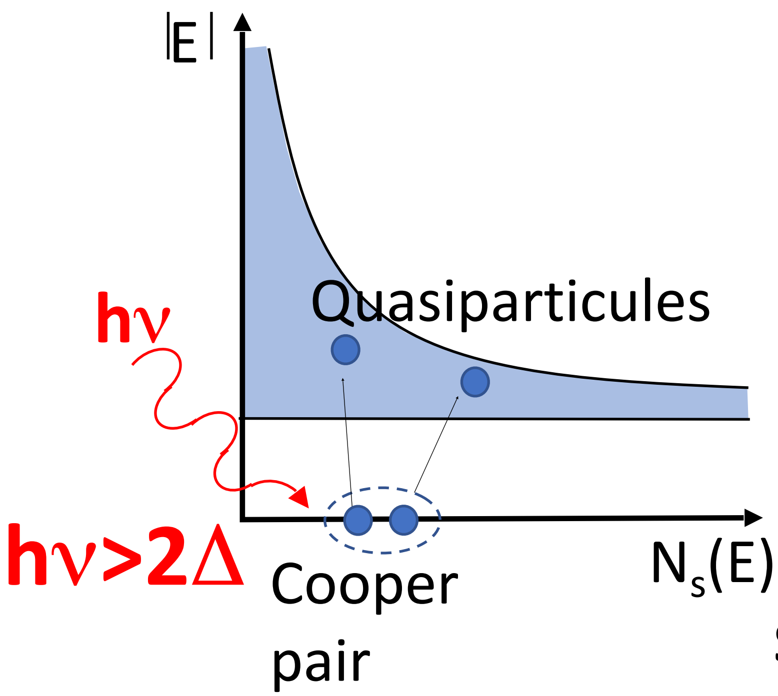

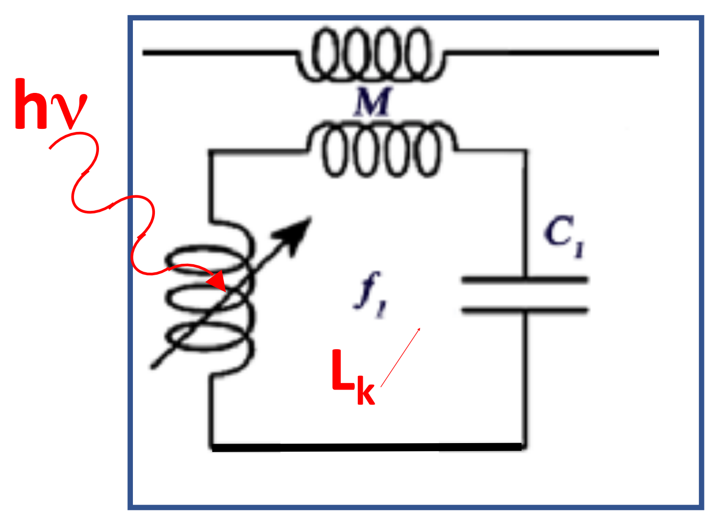

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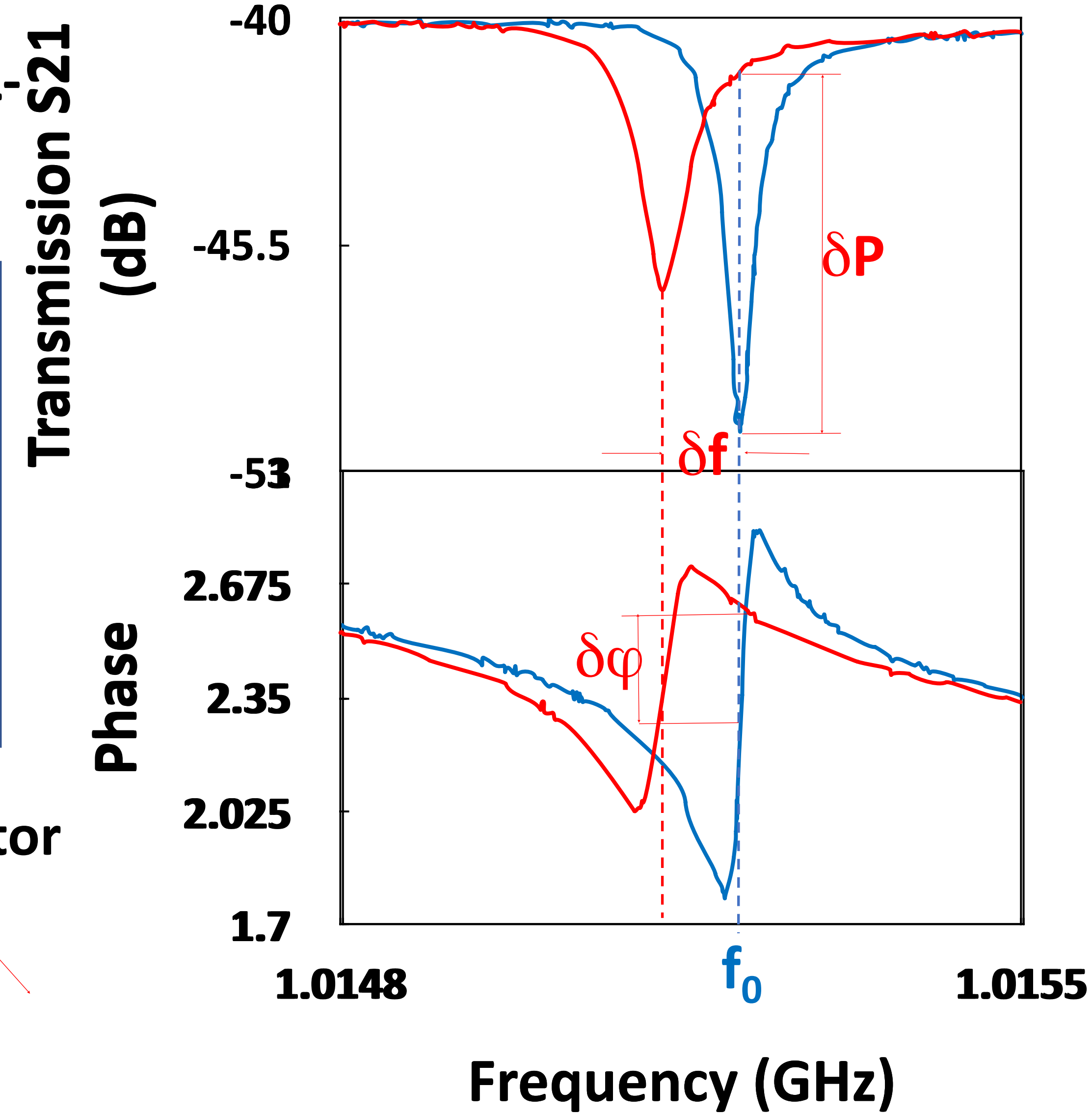

$$n_s \searrow \;\Rightarrow\; L_k = \frac{m_e}{n_s e^2} \nearrow \;\Rightarrow\; f_0 = \frac{1}{2\pi\sqrt{(L_{geo} + L_k)C}} \searrow$$

Key advantages of KIDs over traditional detectors

- Energy resolution R~10 without use of filters/dispersers
- Photon counting, zero read-out noise
- Fast read-out (μs), simultaneous reading of all the array

Unknowns

- precision of flat-fielding (5% - 1% ???)
- quantum efficiency (?)
- Operate a 100mK cryostat at NTT (never done), but..CONCERTO is working on APEX, so…
- Can we obtain spectrophotometry with 0.02 mag accuracy ?

SPIAKID science cases

- **Populations of Ultra Faint Dwarf galaxies**
- **Follow-up observations of sources of gravitational waves.**
- **Folllow up of afterglows of GRBs**
- Redshifts for high-redshift QSOs and galaxies.
- High speed photometry.
- Follow up of transients (SNe, Novae, …)
- Characterisation of minor bodies of the solar system.
- Detection of exoplanet transits and exoplanet transit spectroscopy.

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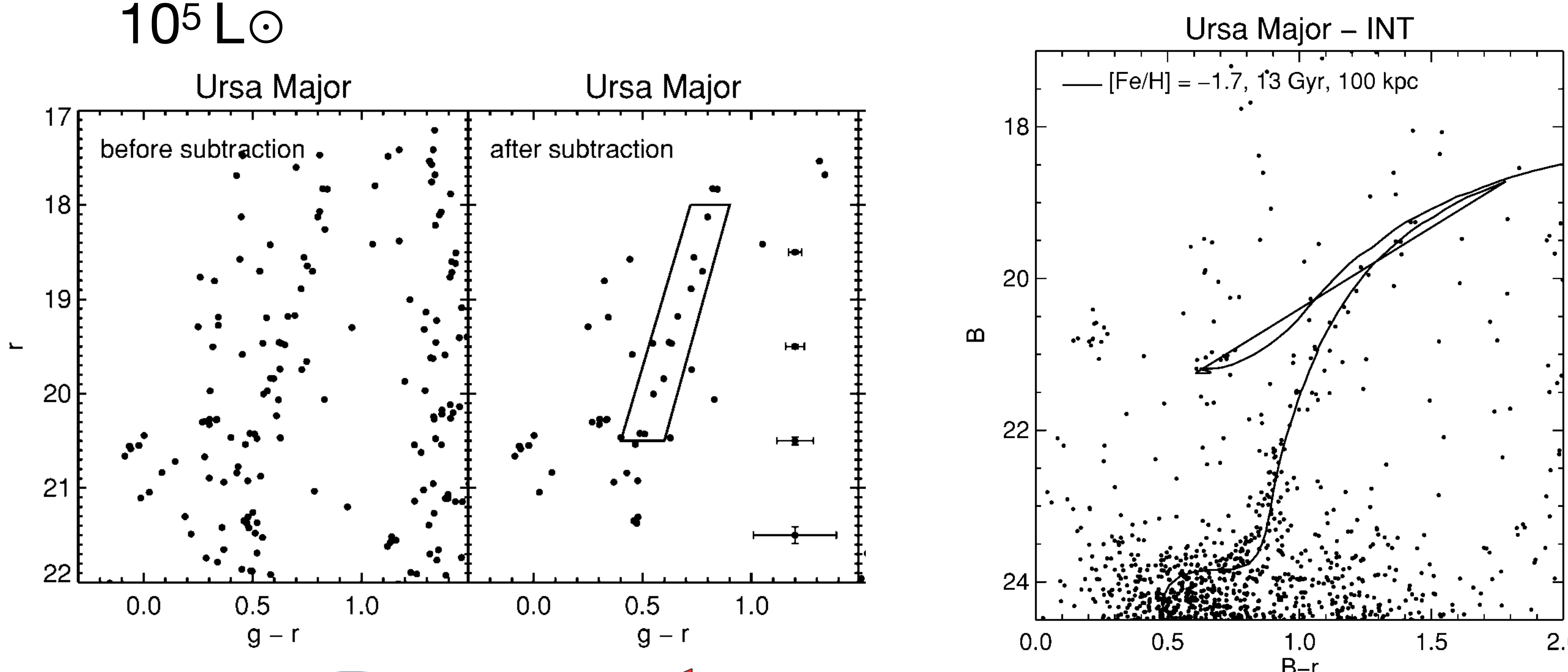
Driving Science Case: UFDs

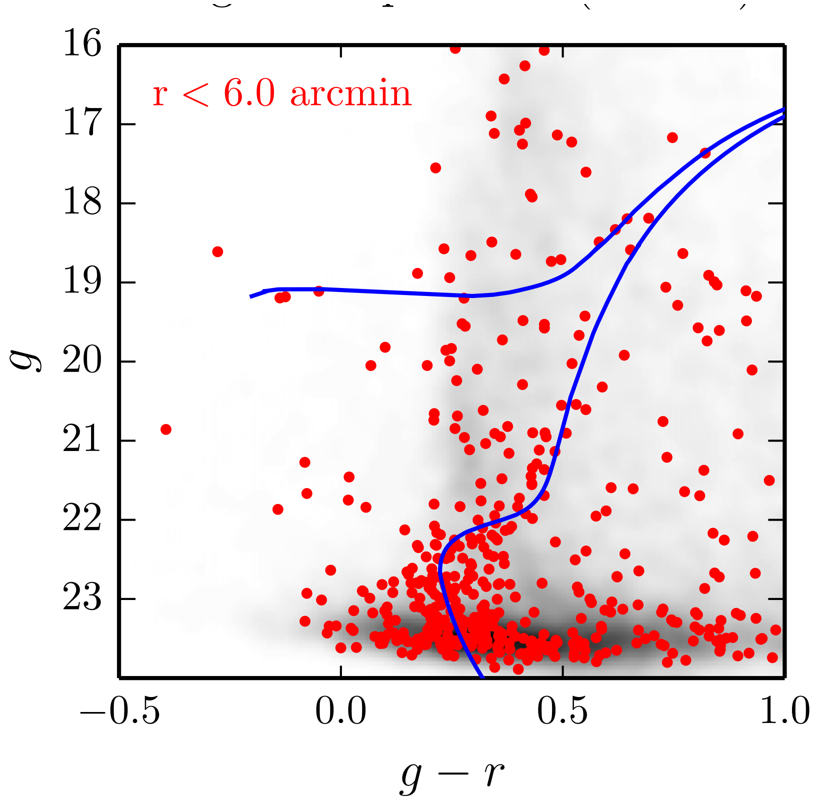
- In 2005 using the multicolour SDSS data two new LG galaxies were discovered (Willman-1 and UMa; Willman et al. 2005a,b)

- These were fainter than “classical” dwarf galaxies with L< 10^5 L$\odot$

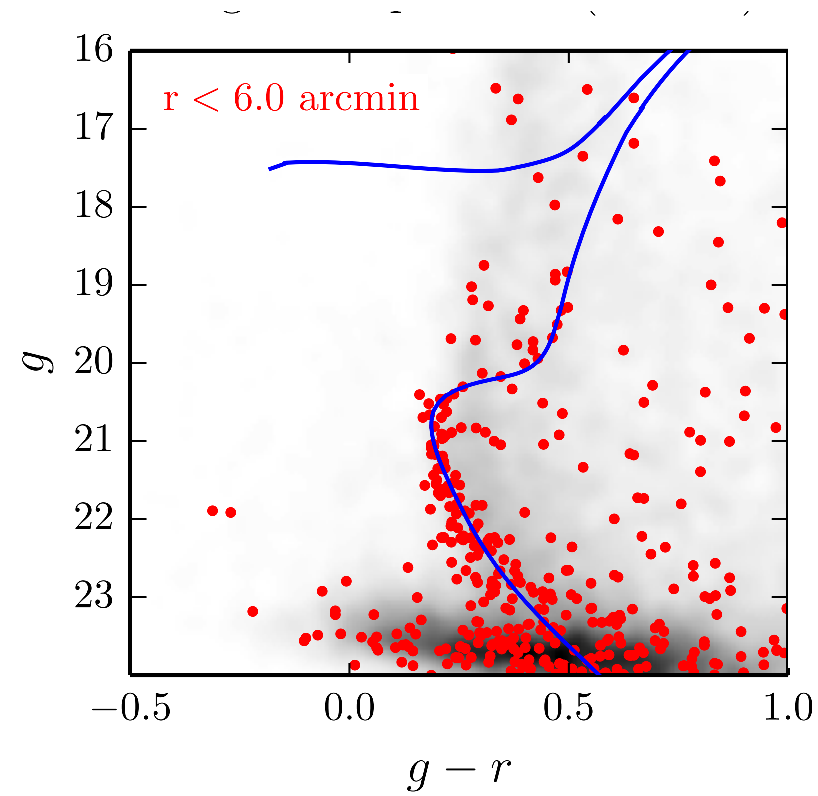


Very active field of research: 116 refereed papers since 2015

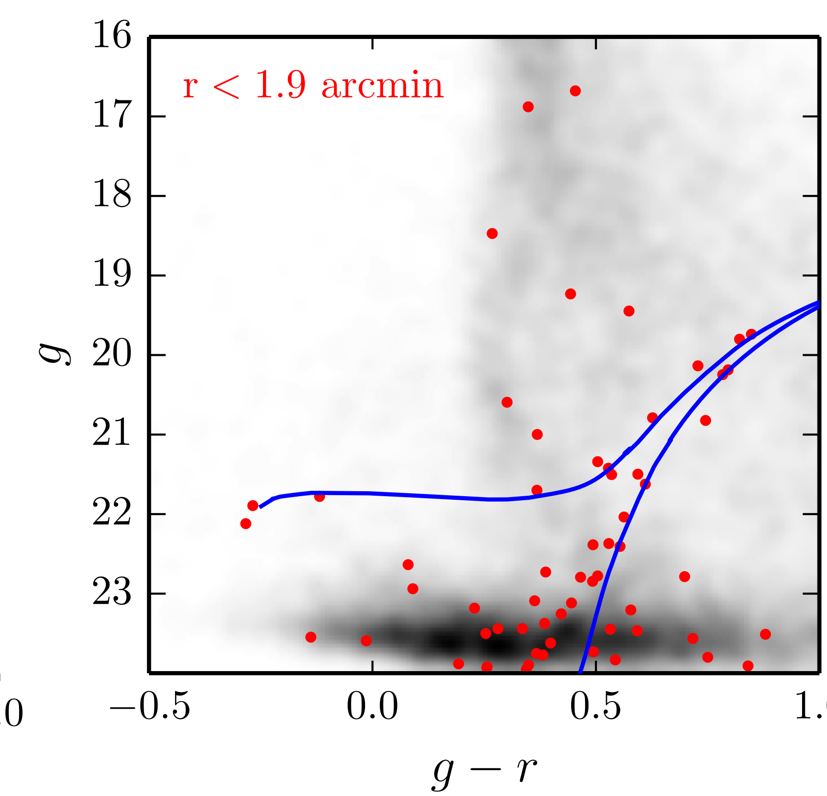
Grus II



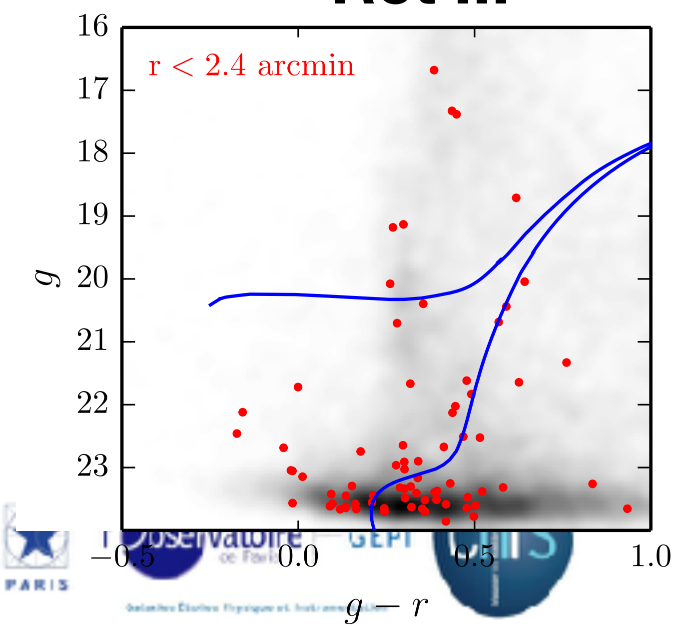
Tuc III



Columba I

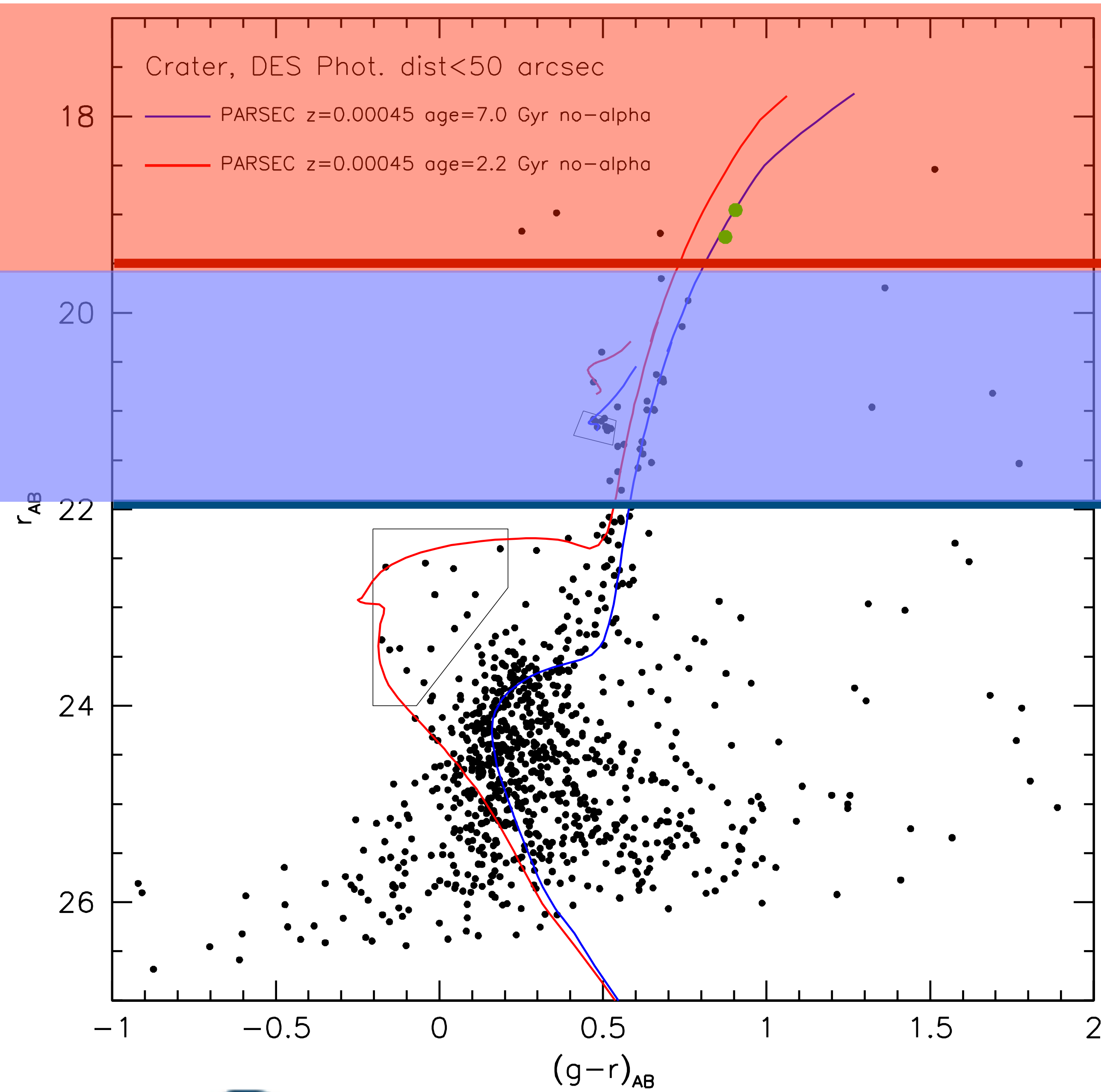


Ret III



- **The nearest UFDs have the TO around r=20**
- **the most distant for which TO has been observed r=25**
- **Many have only been observed in the RGB even though photometric observations were pushed to r=23**

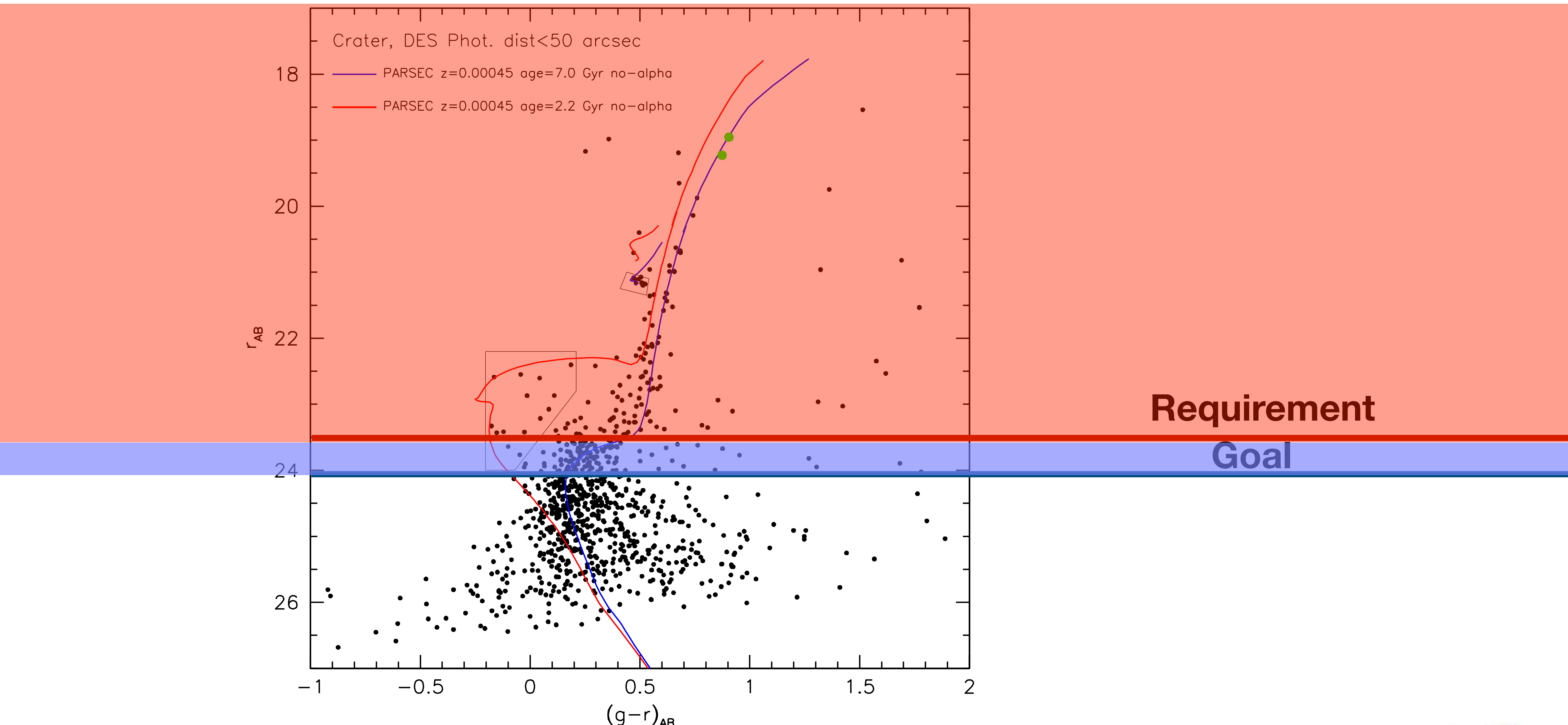
The classical view of what can be done observationally

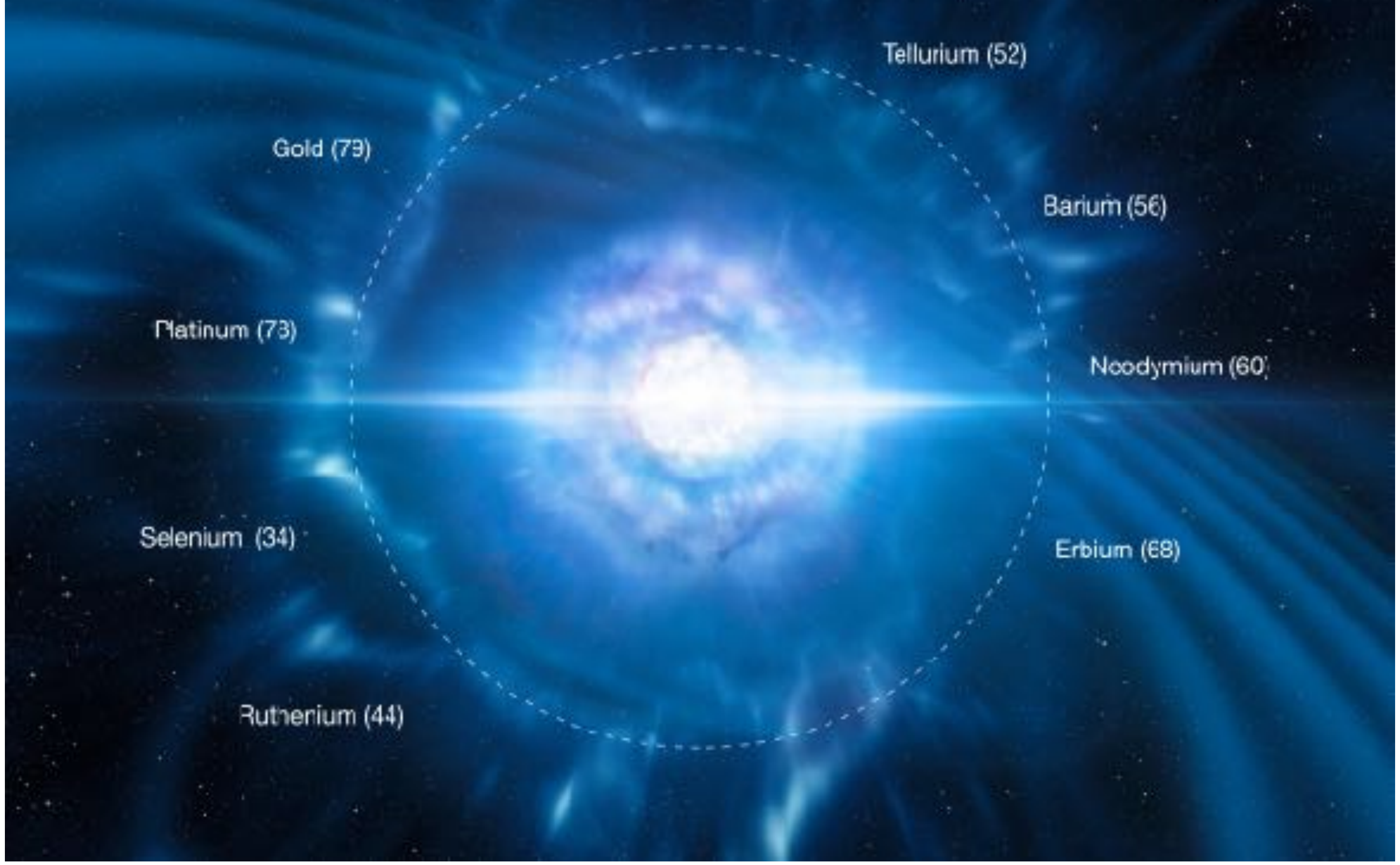


High resolution spectroscopy
R≳10000

Low resolution spectroscopy
R≃2000

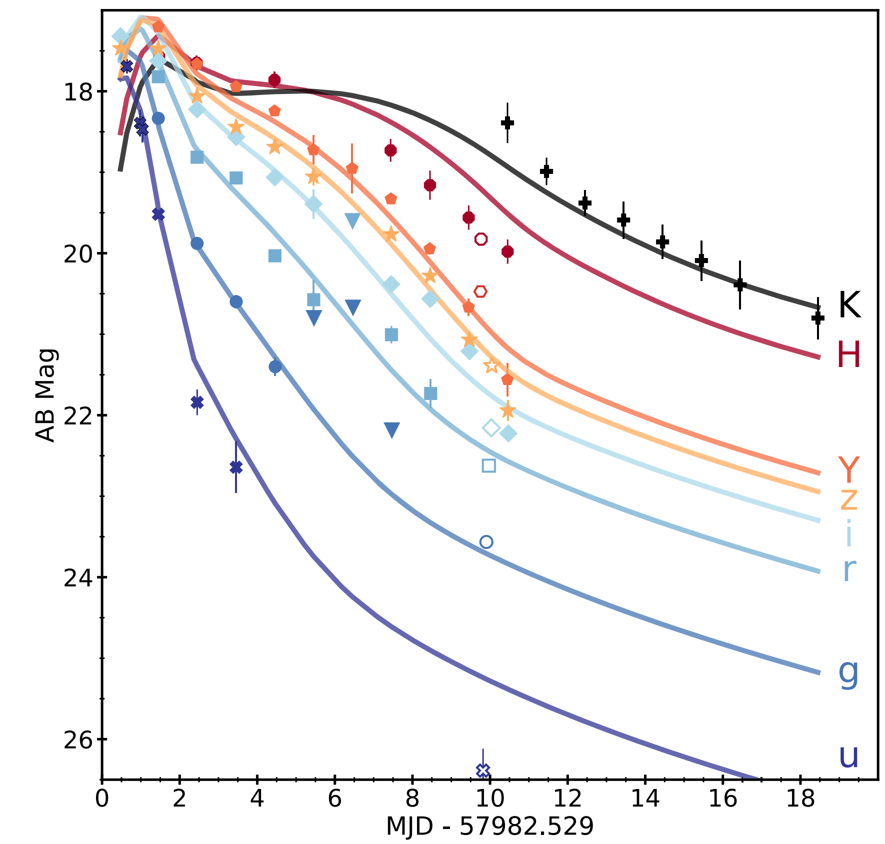
The SPIAKID view of what can be done observationally

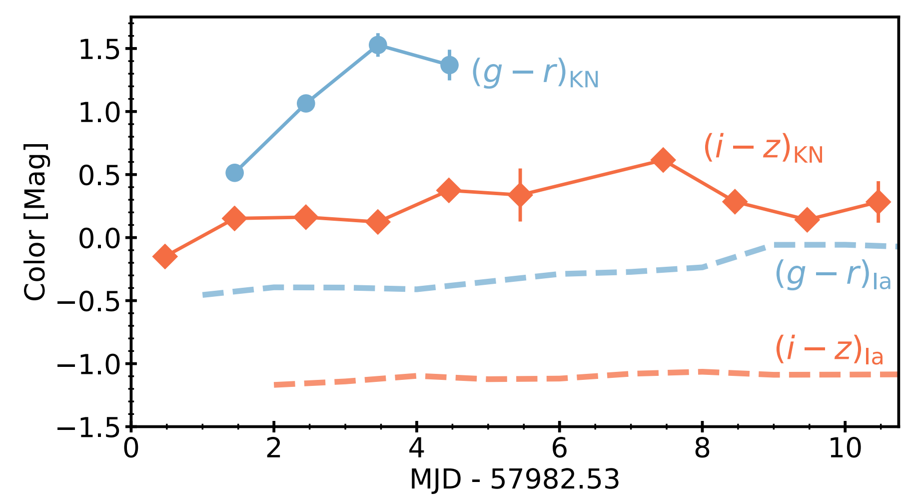


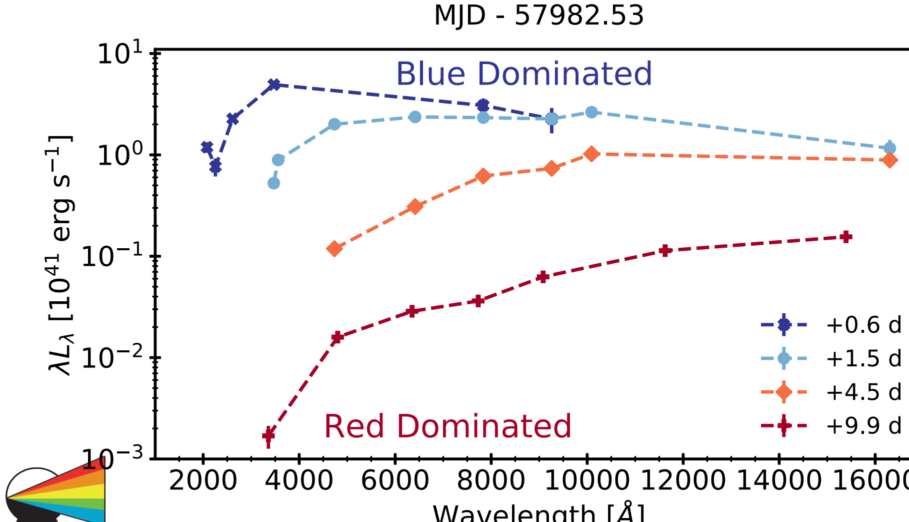


Credit: ESO/L. Calçada/M. Kornmesser

Cowperthwaite et al. 2017







Gravitational Wave sources

Artist's view of GW170817, an event that results form the merging of two neutron stars. It is an important site of production of heavy elements through rapid neutron capture. Modelling of the light curve, especially in the NIR provides important iformation on this process

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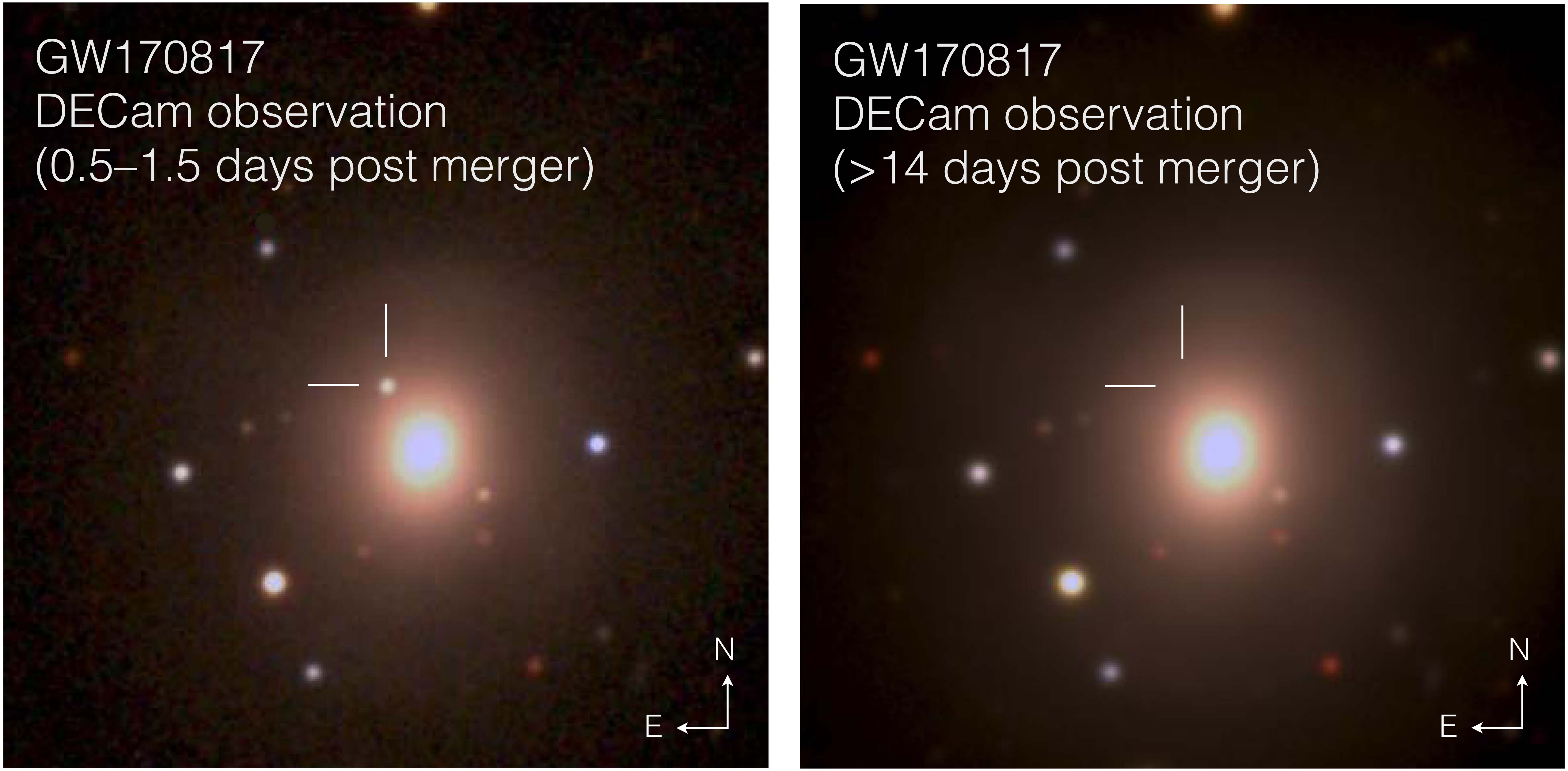
Soares-Santos et al. 2017, grz composite images



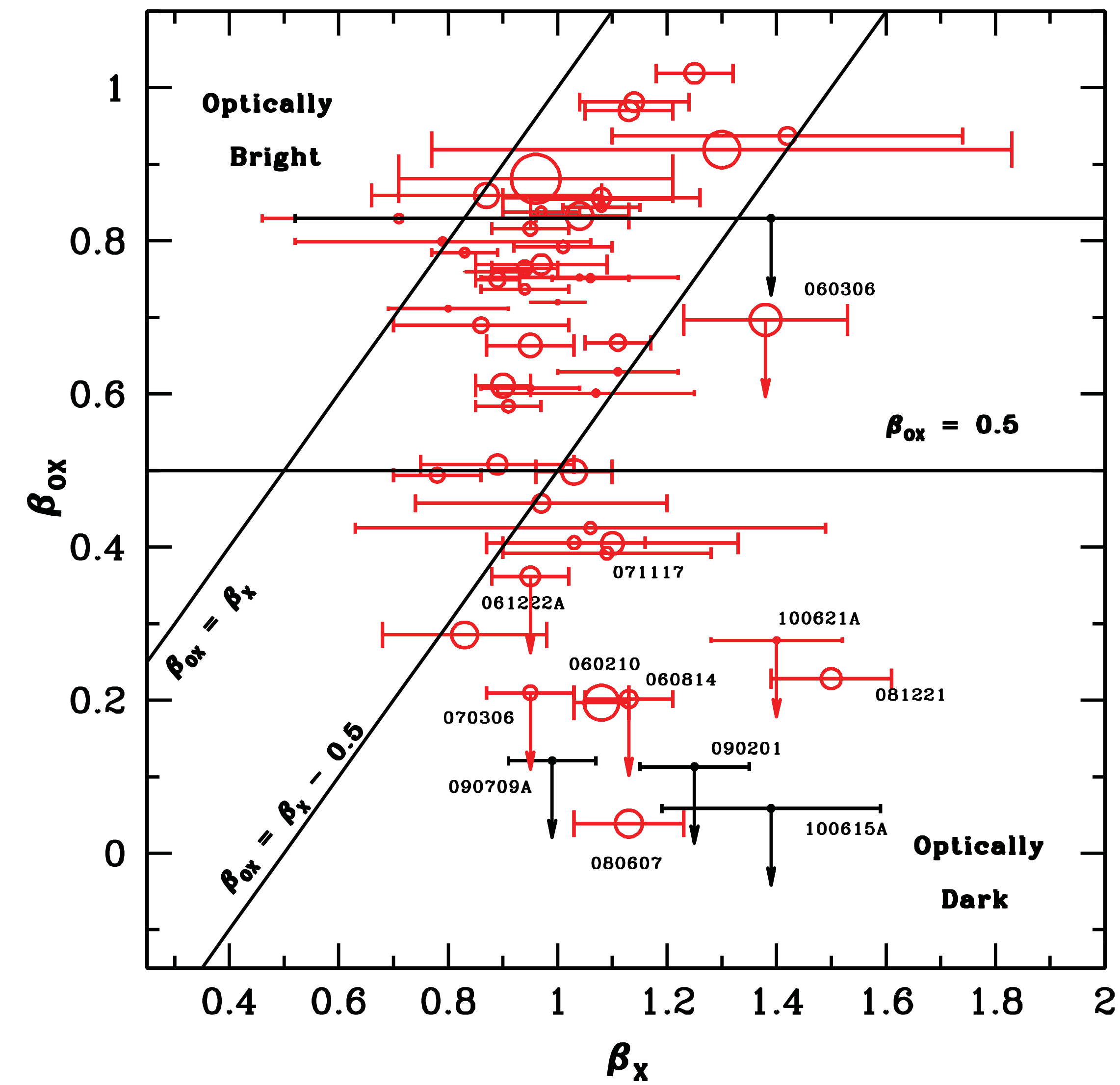
1.5’ x 1.5’ image

It is also extremely important to characterize the host galaxy and its host populations, for this reason UV-to-NIR spectrophotometry is also essential

Gamma Ray bursts

brief and intense flashes of high-energy gamma-rays, originating at cosmological distances and oftenassociated with radiation emitted at longer wavelengths for longer periods, identified as the afterglow. (Melandri et al. 2012)

- "cosmological distances" implies high red-shift, thus NIR data is important
- some GRBs are "dark" (low optical flux compared to X-ray flux). Most likely reason is local dust extinction, again a good reason to have NIR data.



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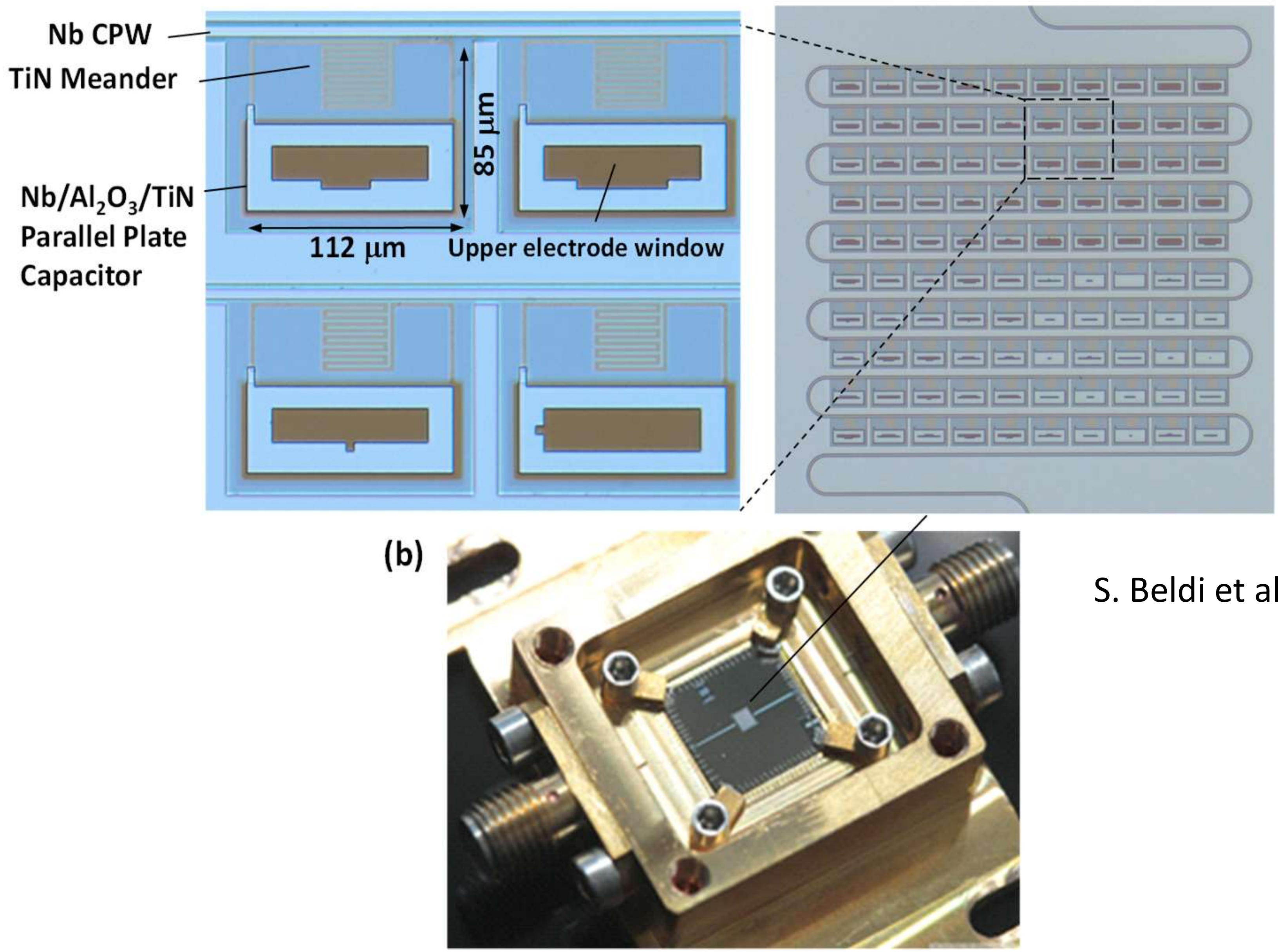
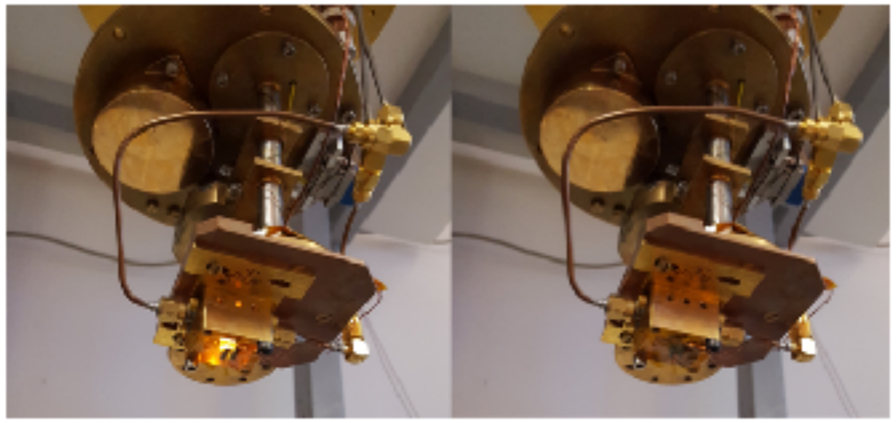
Small pixel size



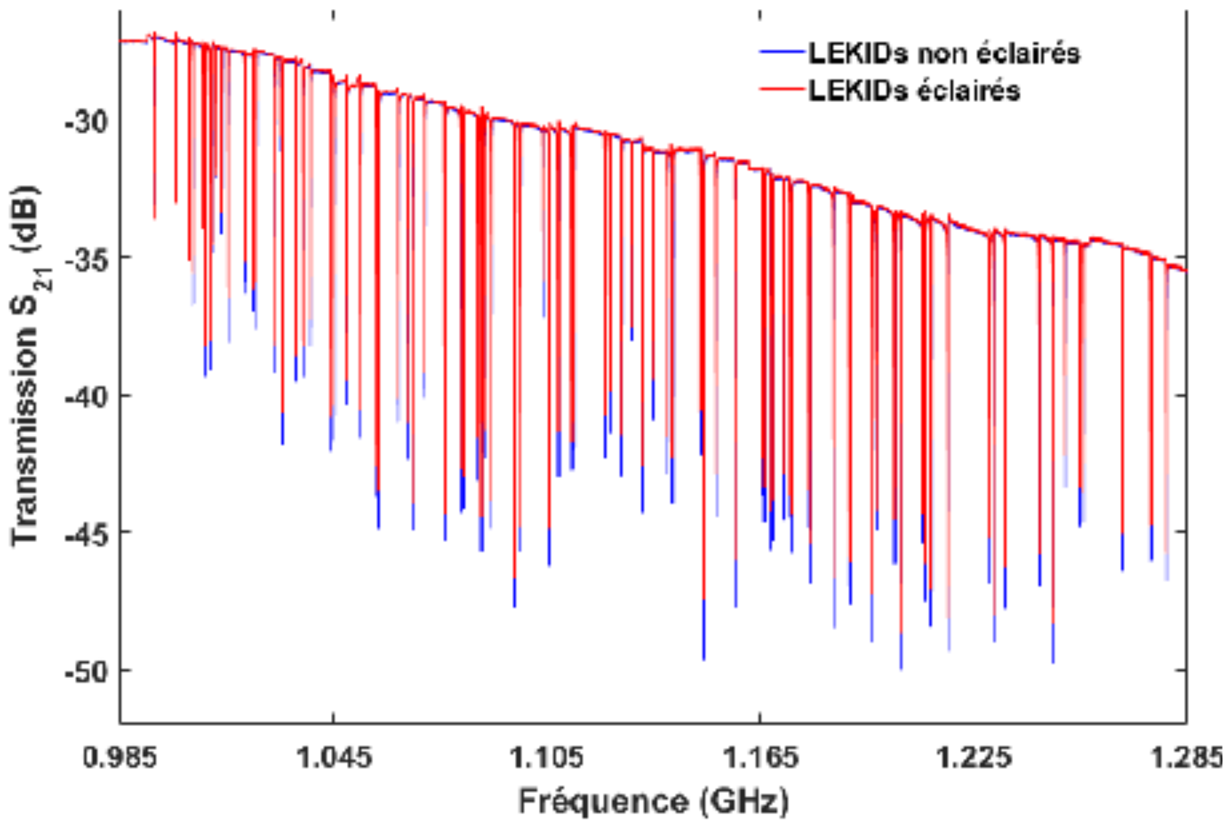
10x10 pixels

S. Beldi et al, Optics Express 2019

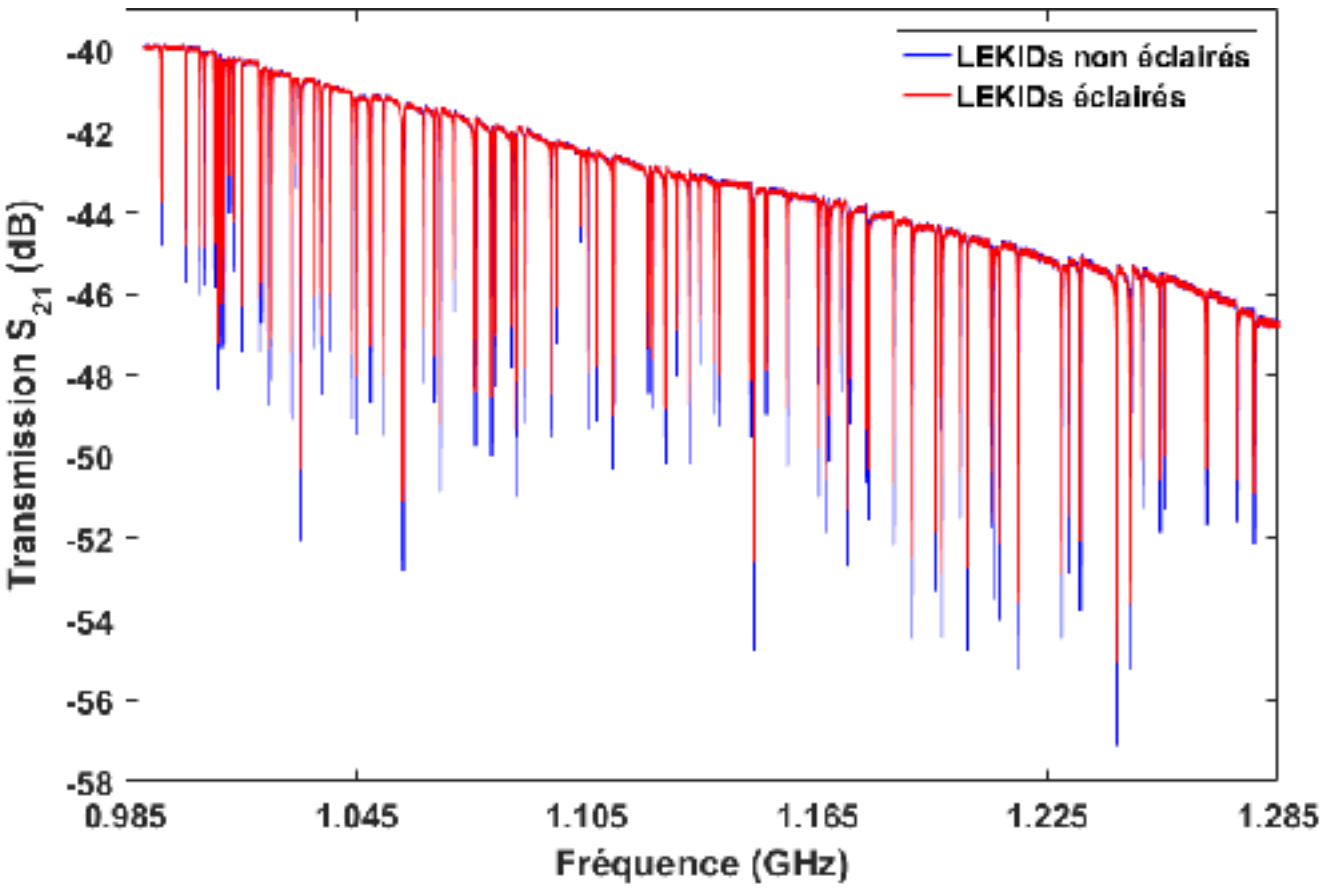
Measure in the laboratory (APC cryostat)



LED visible (450 nm)



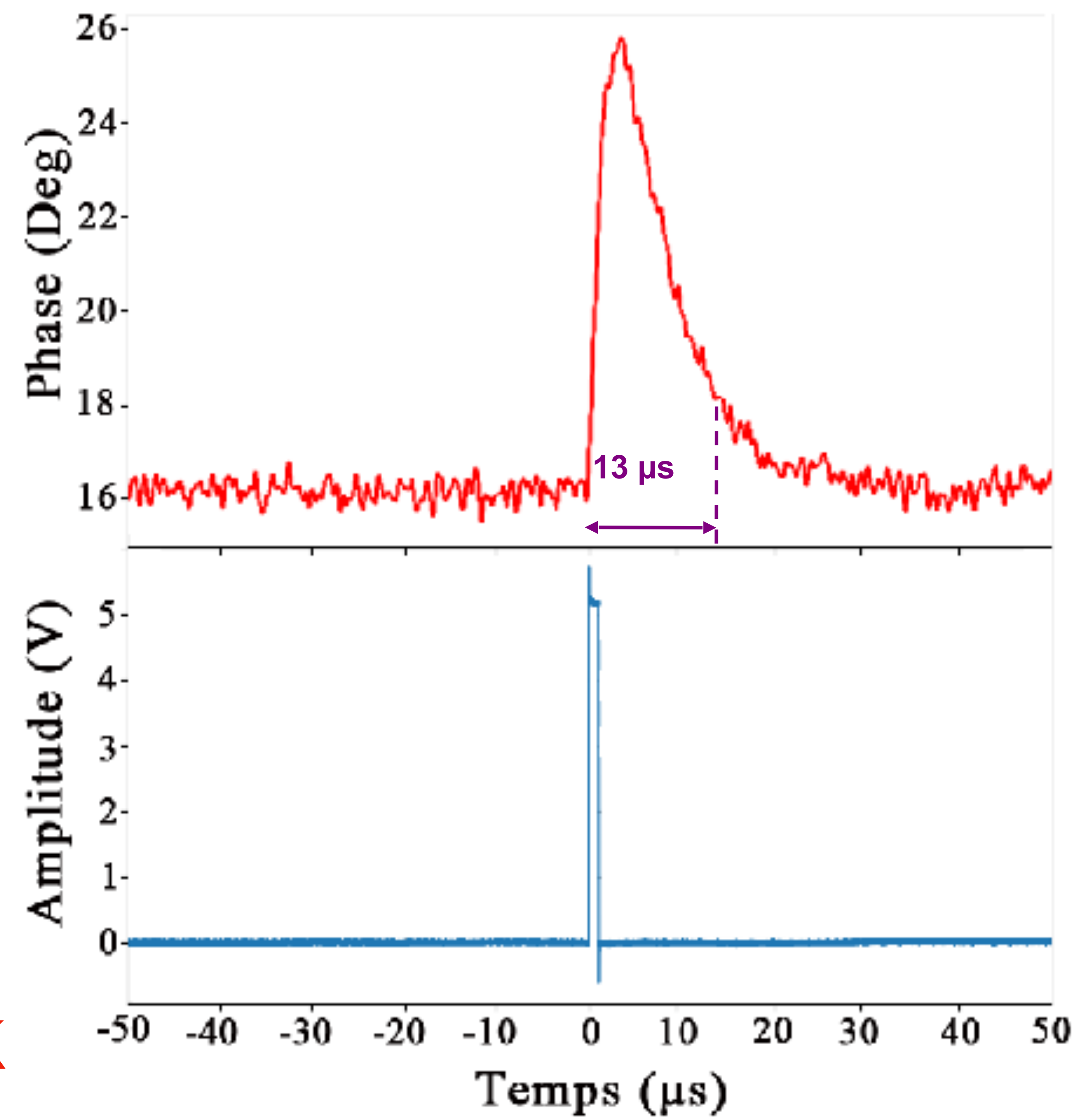
LED I-R proche (890 nm)



Figures courtesy of S. Beldi

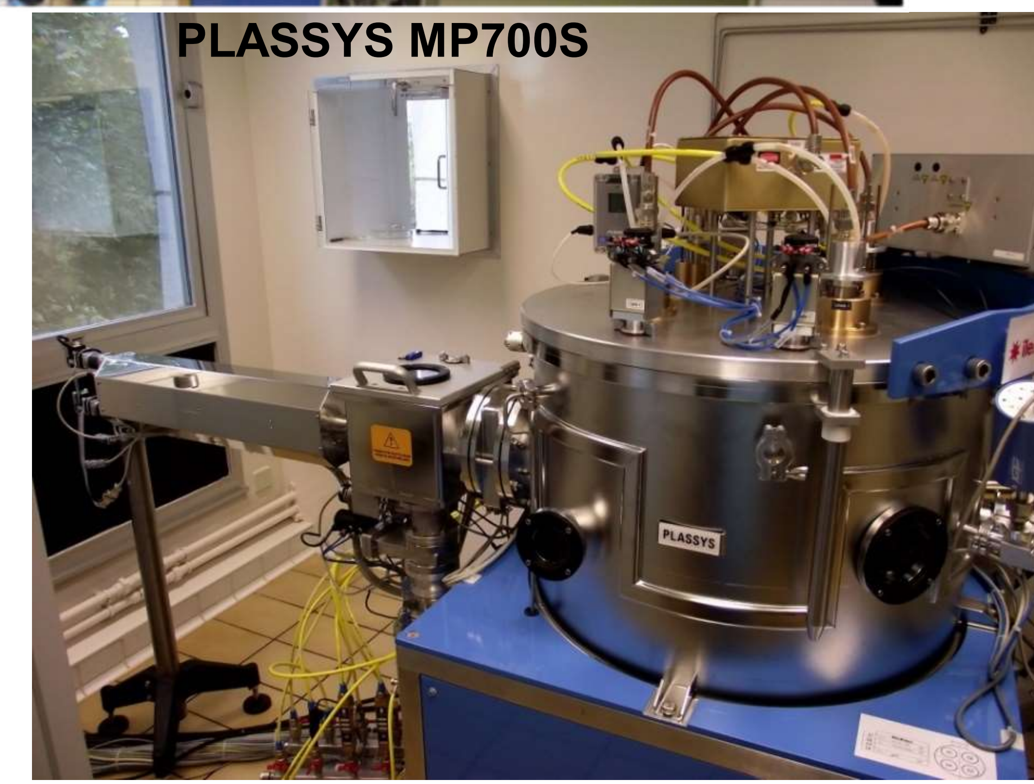
Lifetime of quasi-particules for TiN (Tc = 4.6 K)

- **Measurement of the phase allows to determine the lifetime of the quasiparticules**
- **In TiN the lifetime is inversly proportional to the Tc (Leduc et al. 2010)**
    - ✦**15 µs @ 4K**
    - ✦**100 µs @1.1K**
    - ✦**200 µs @0.8K**



Goal: produce TiN with Tc ~ 1 K

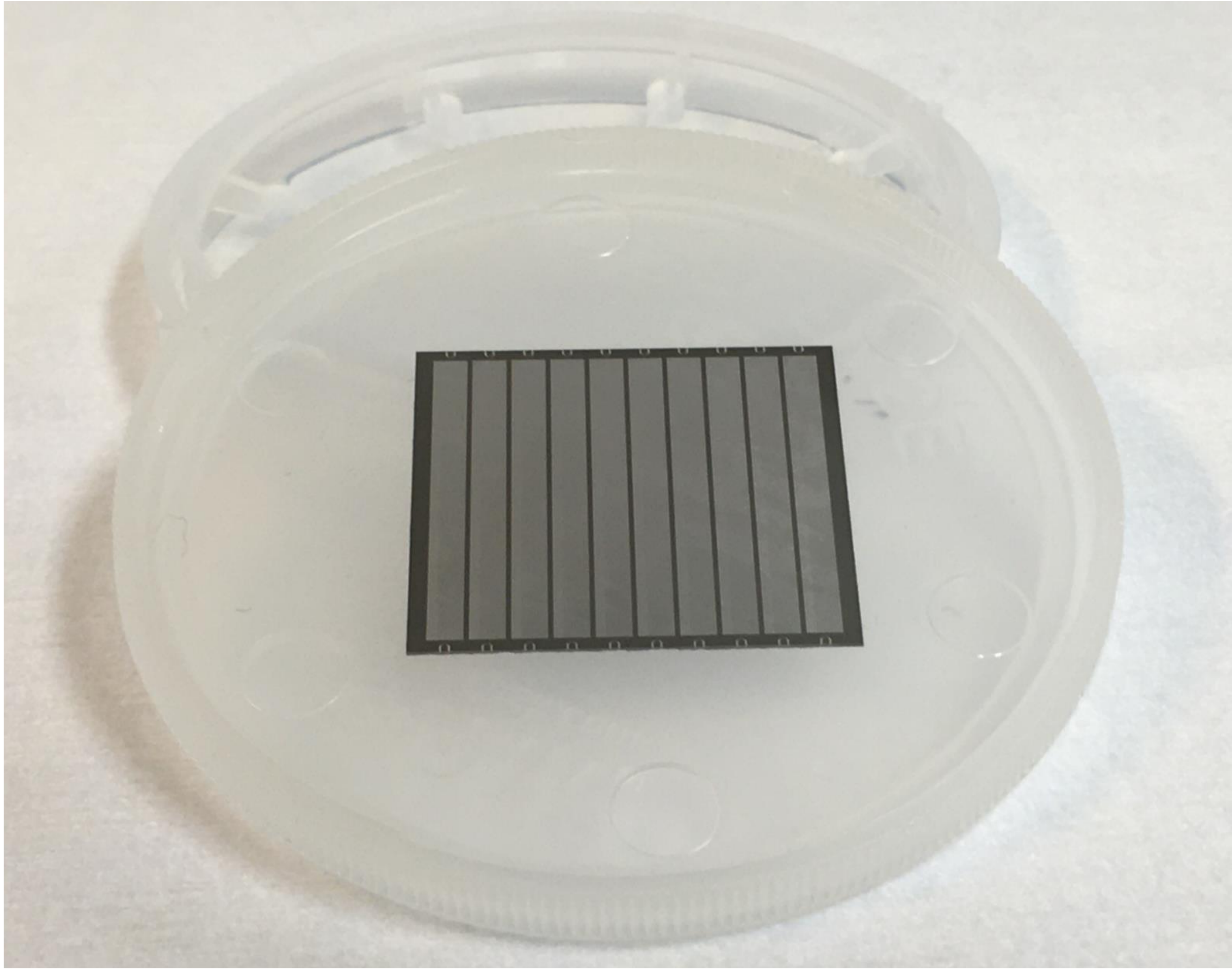
Superconducting devices at Observatoire de Paris



Sputter deposition, a physical vapor deposition (PVD) : Nb, Al, AlO_x, AlN, AlN, NbN, Ti and TiN

SPIAKID_10x2002p_IDC_Sapphire_TiN4.6K_02102020_ver1

(Design: S. Beldi,F. Boussaha / Fabrication: C. Chaumont / Cutting out: F. Reix)



R&T Group – Pôle Instrumental – GEPI, F. Boussaha 02/10/2020

Focal plane geometries

- Field of view: 2’
- pixel size 0.45”
- Mosaic of 4 independent detectors
- Number of pixels is dimensioning
- Uniform sensitivity

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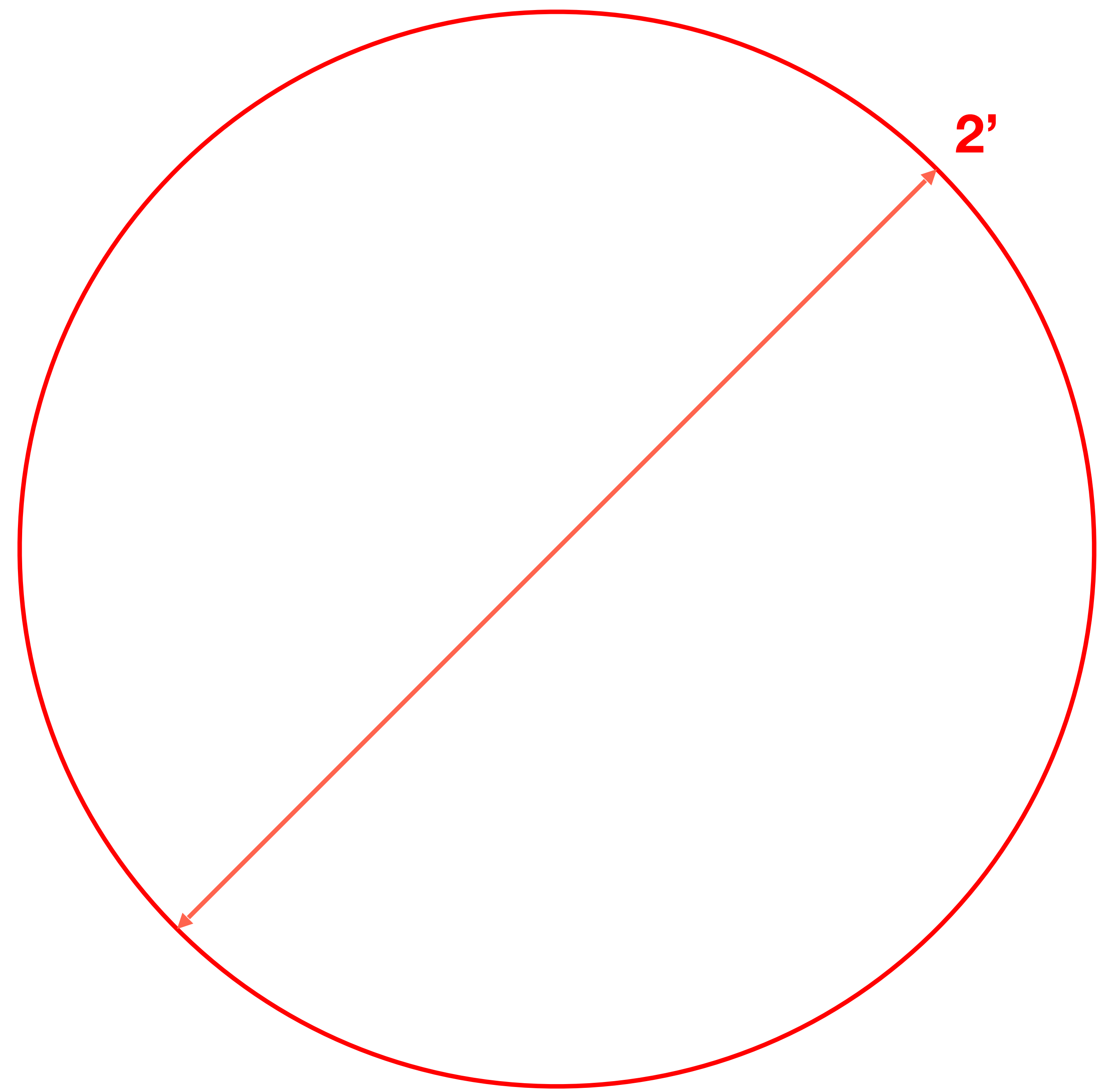

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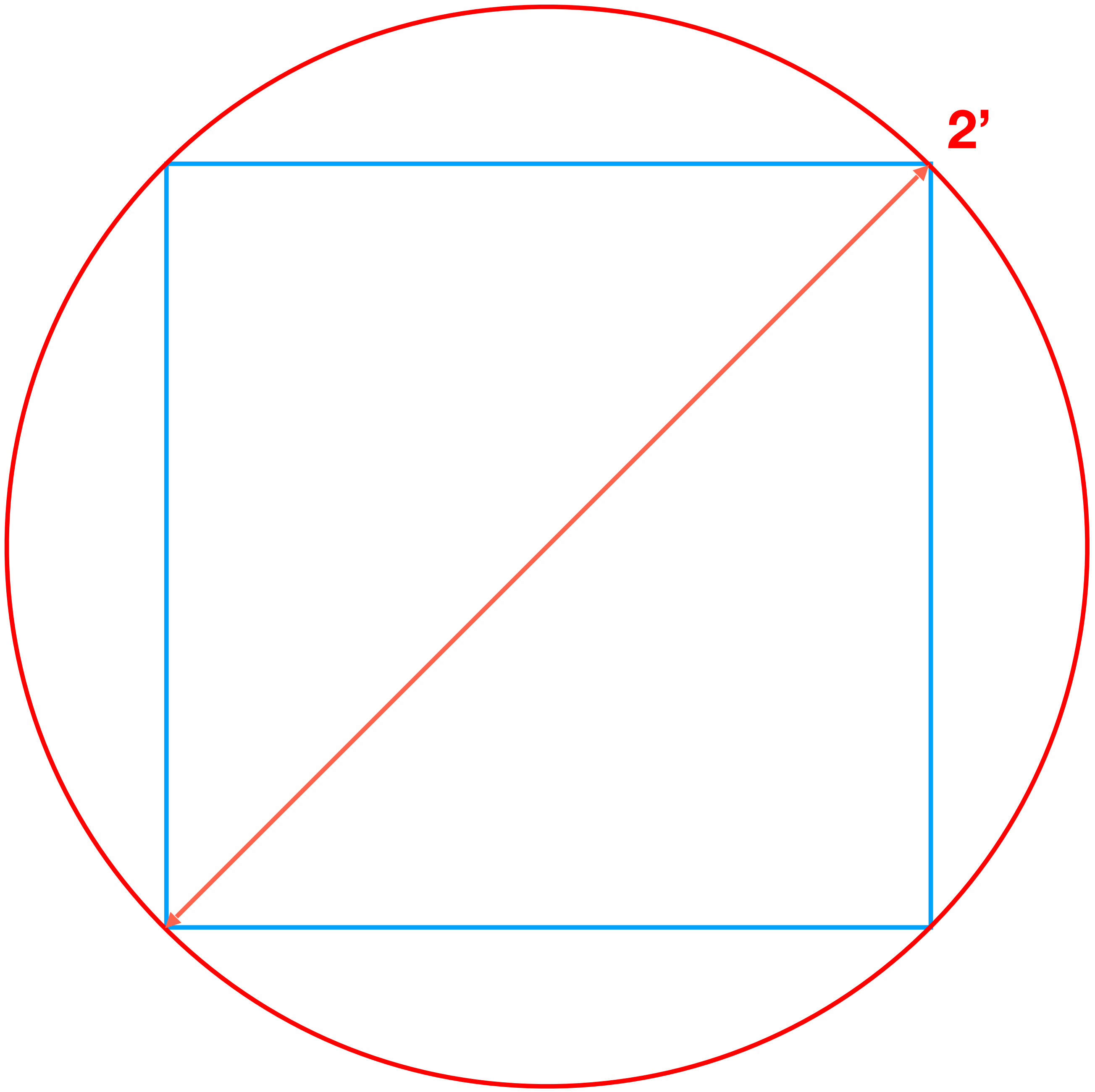

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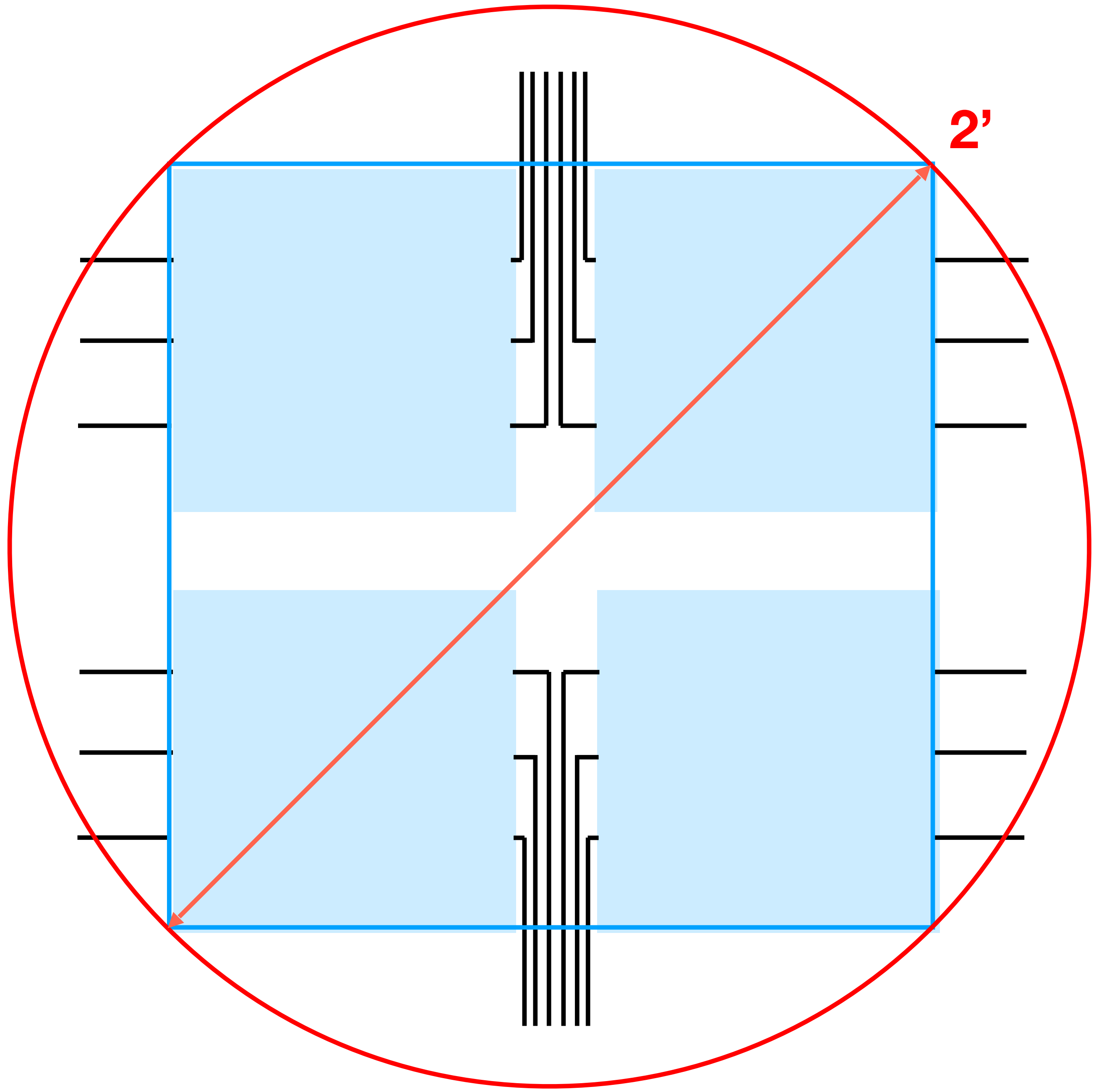

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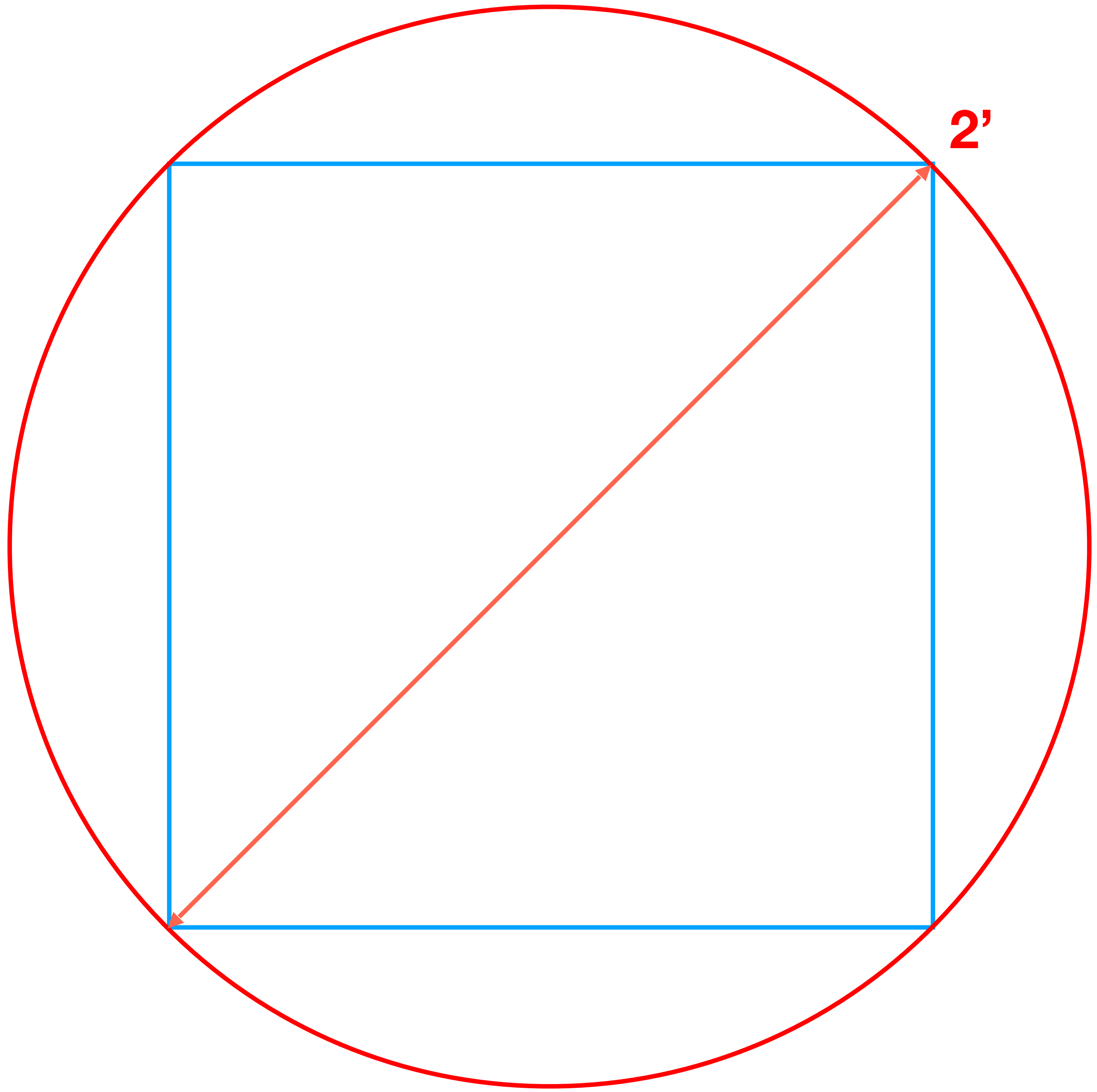

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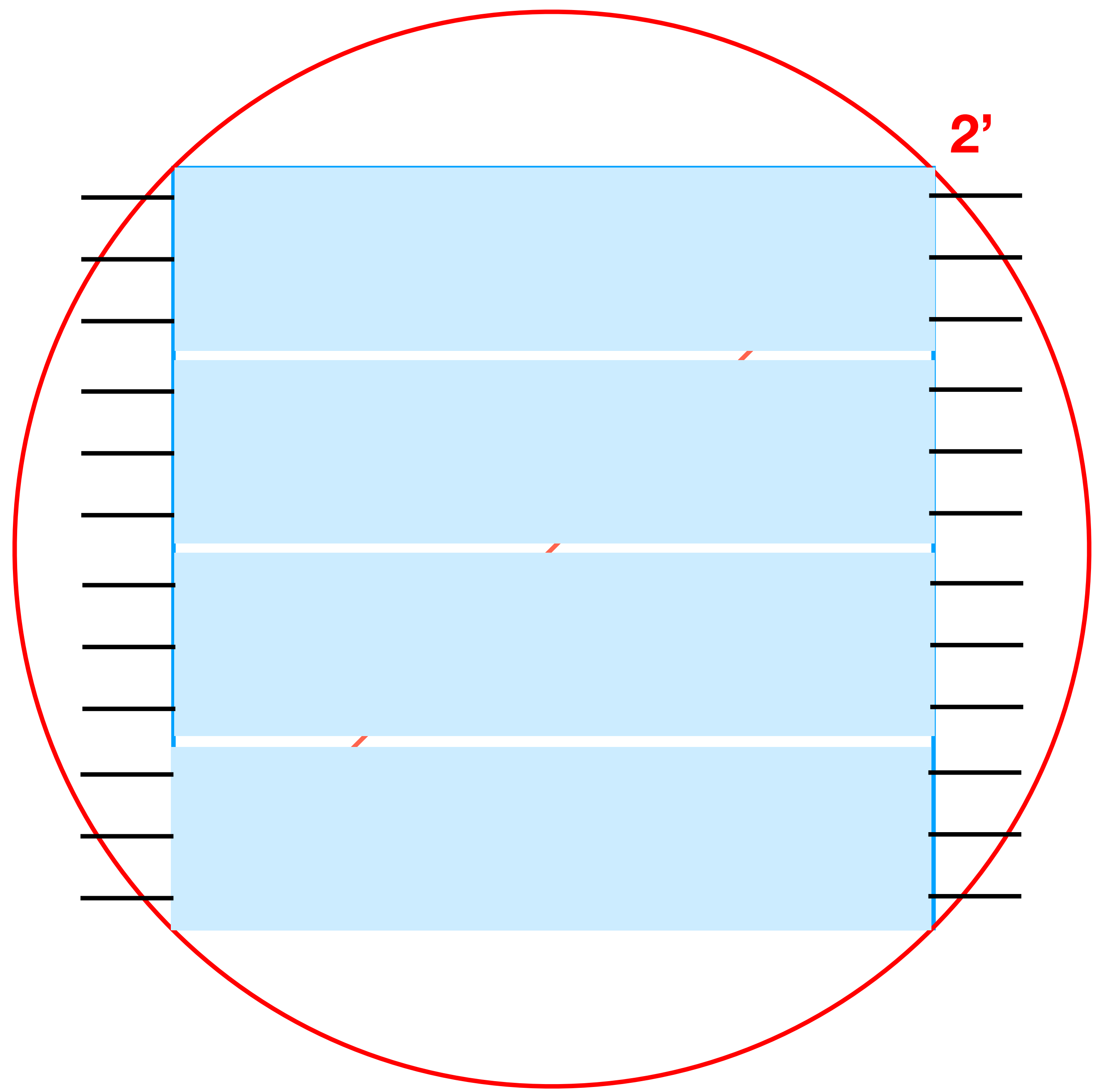

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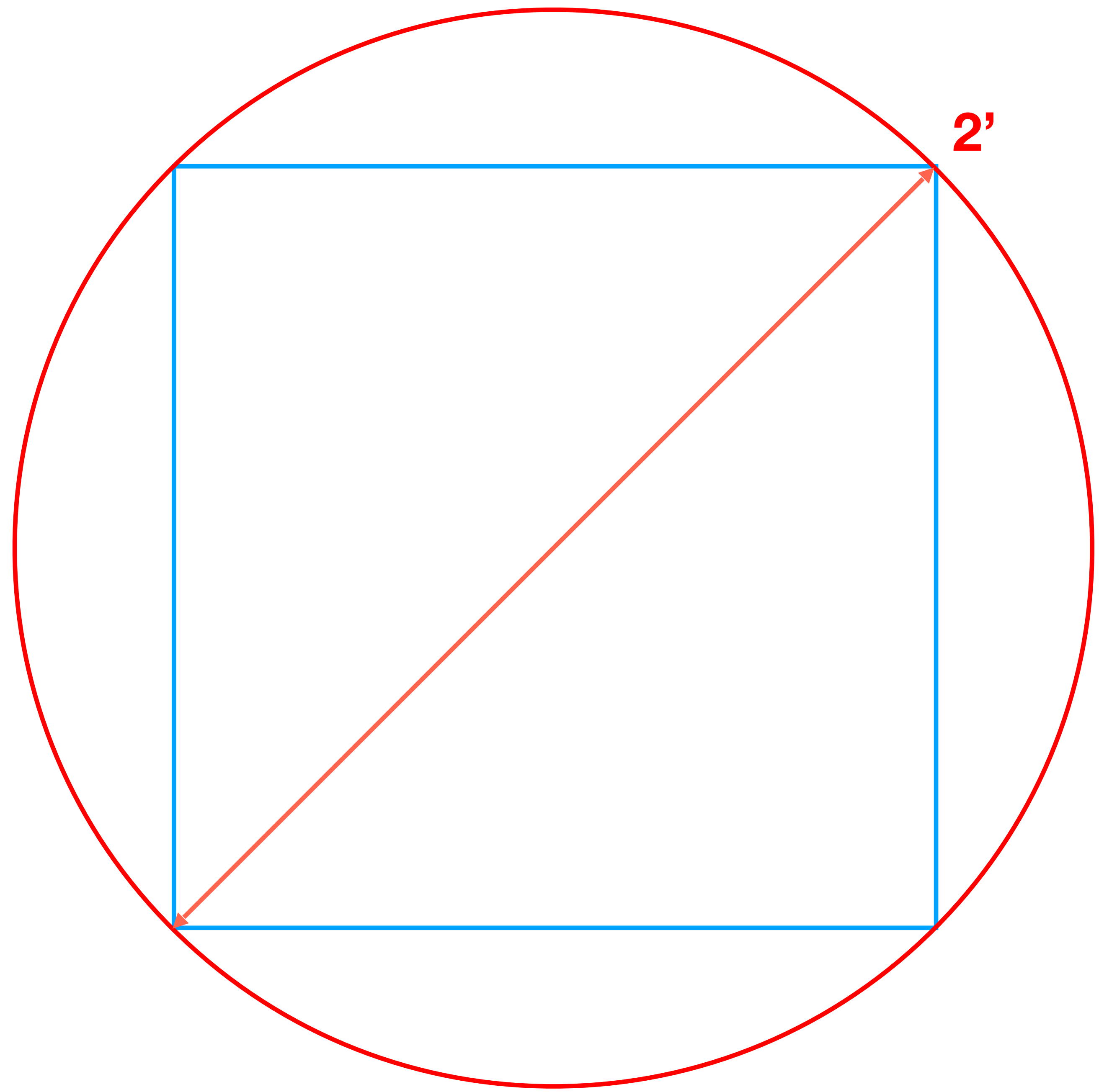

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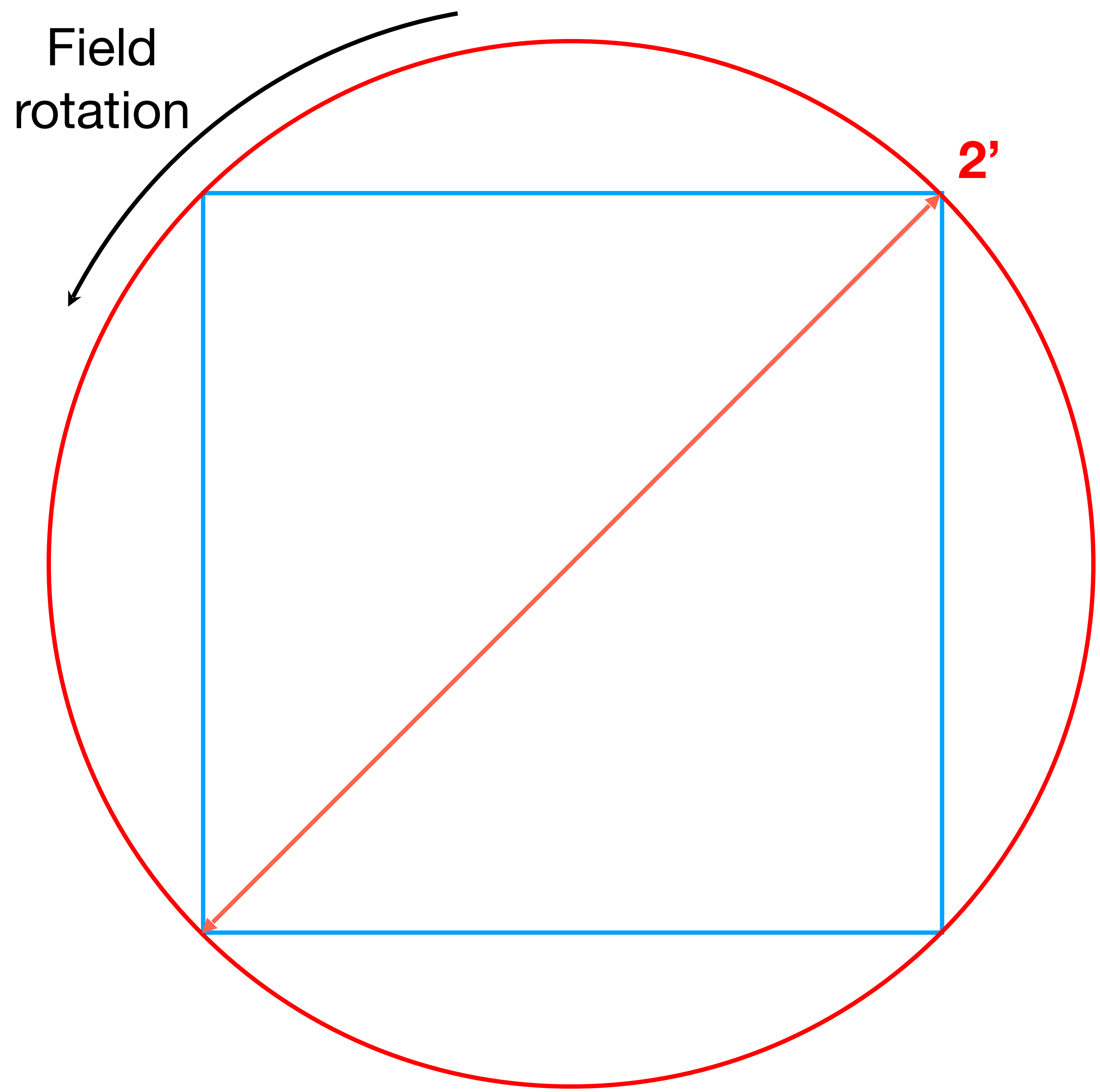

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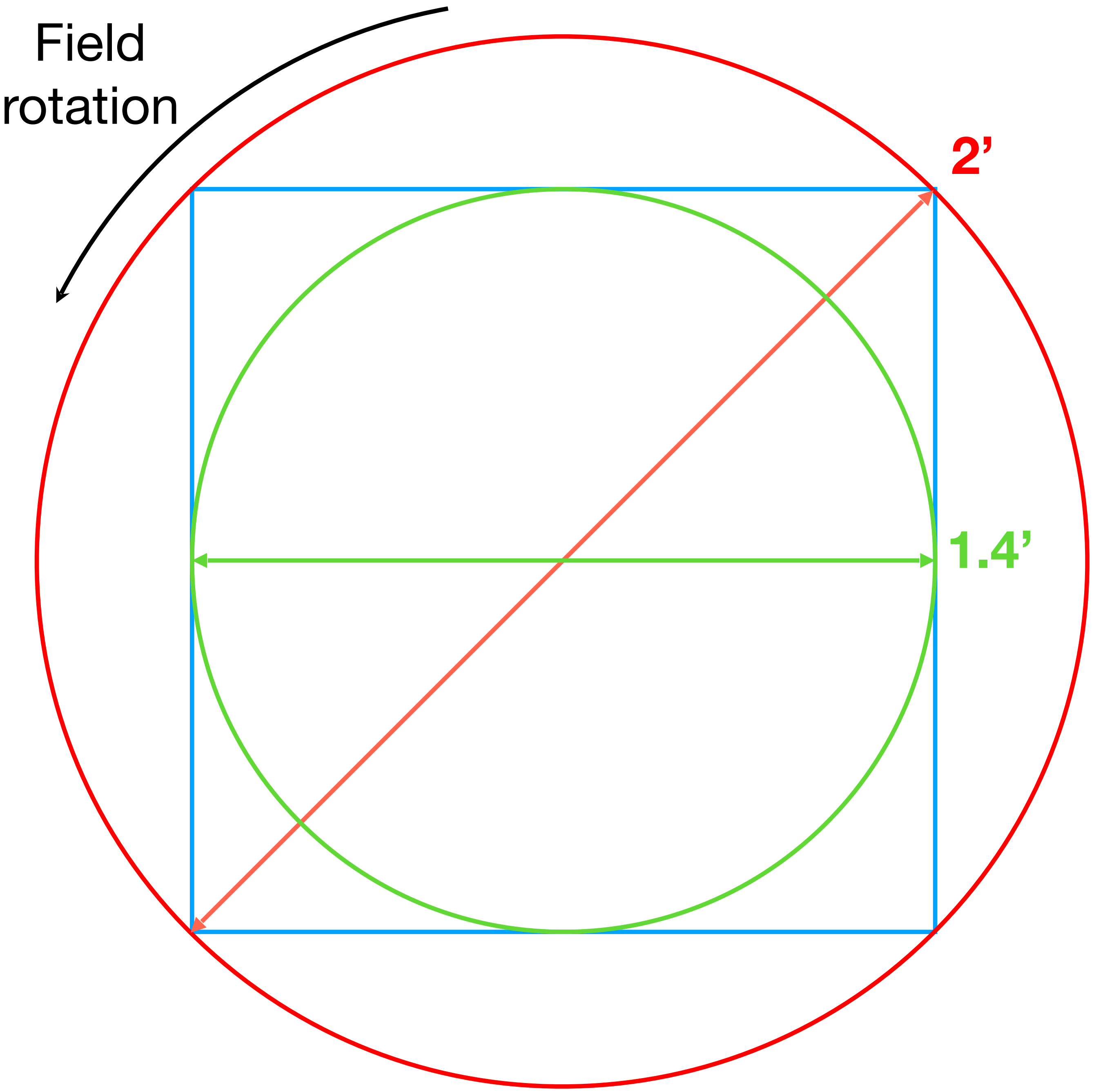

SPIAKID

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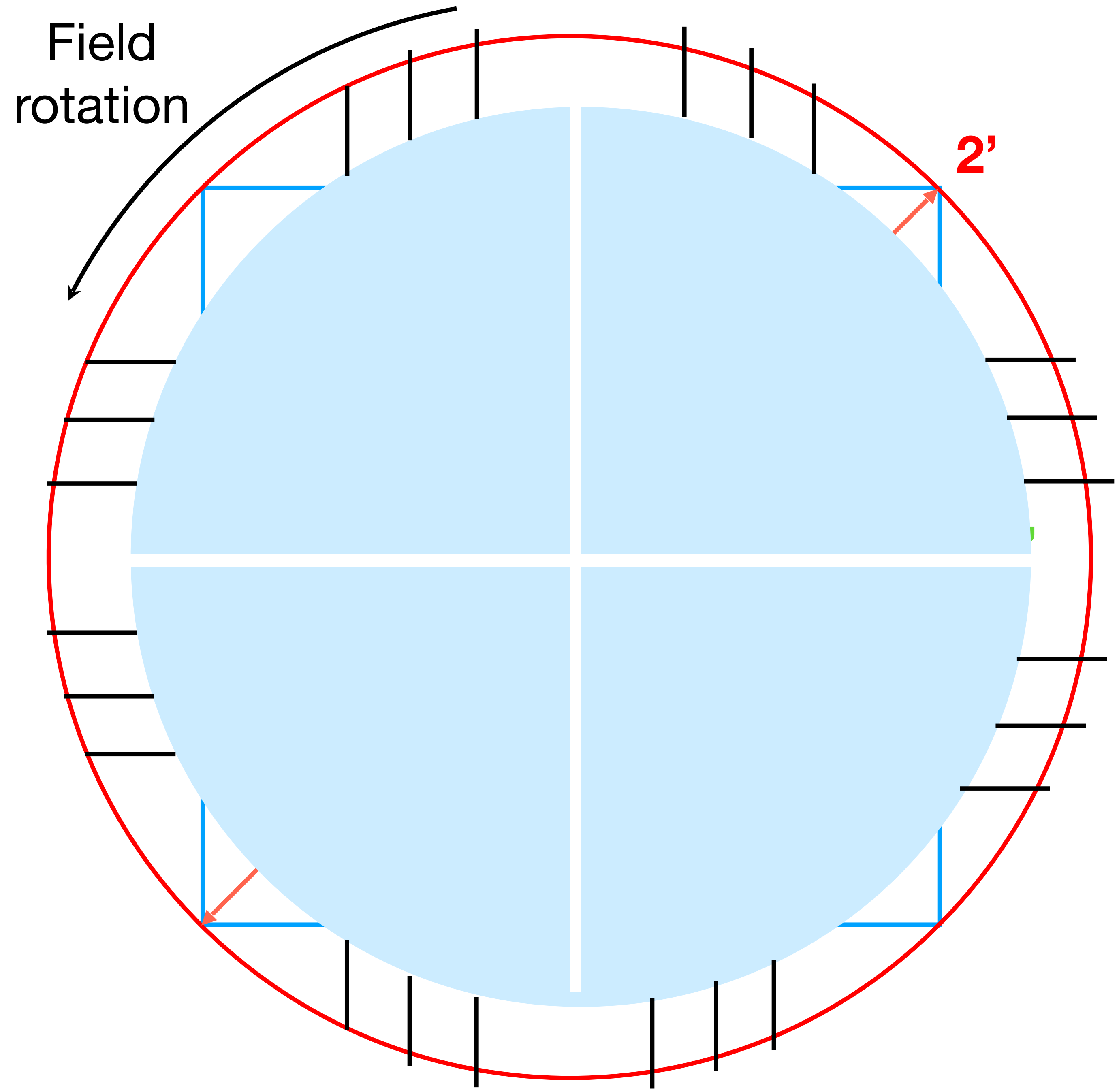
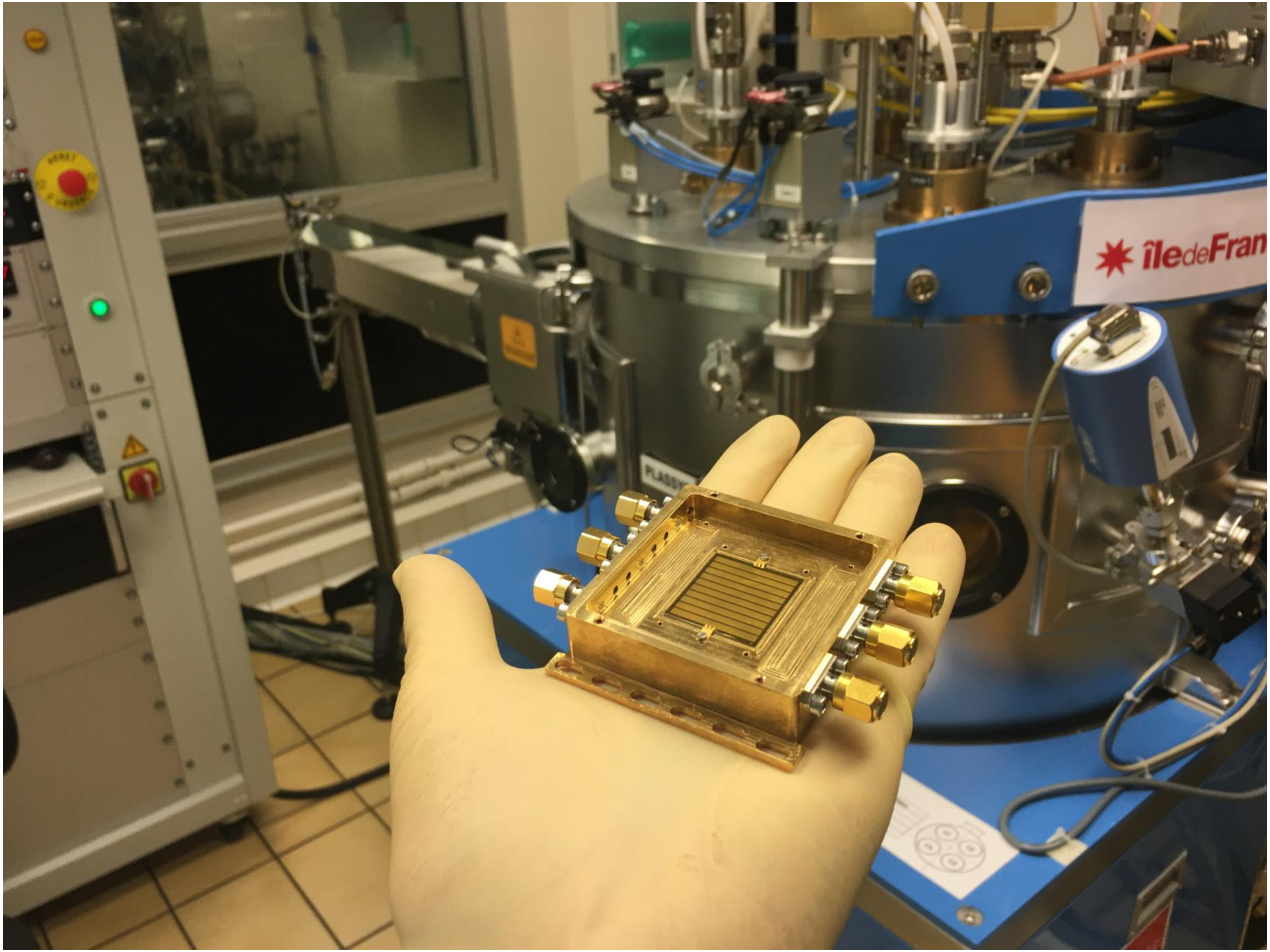
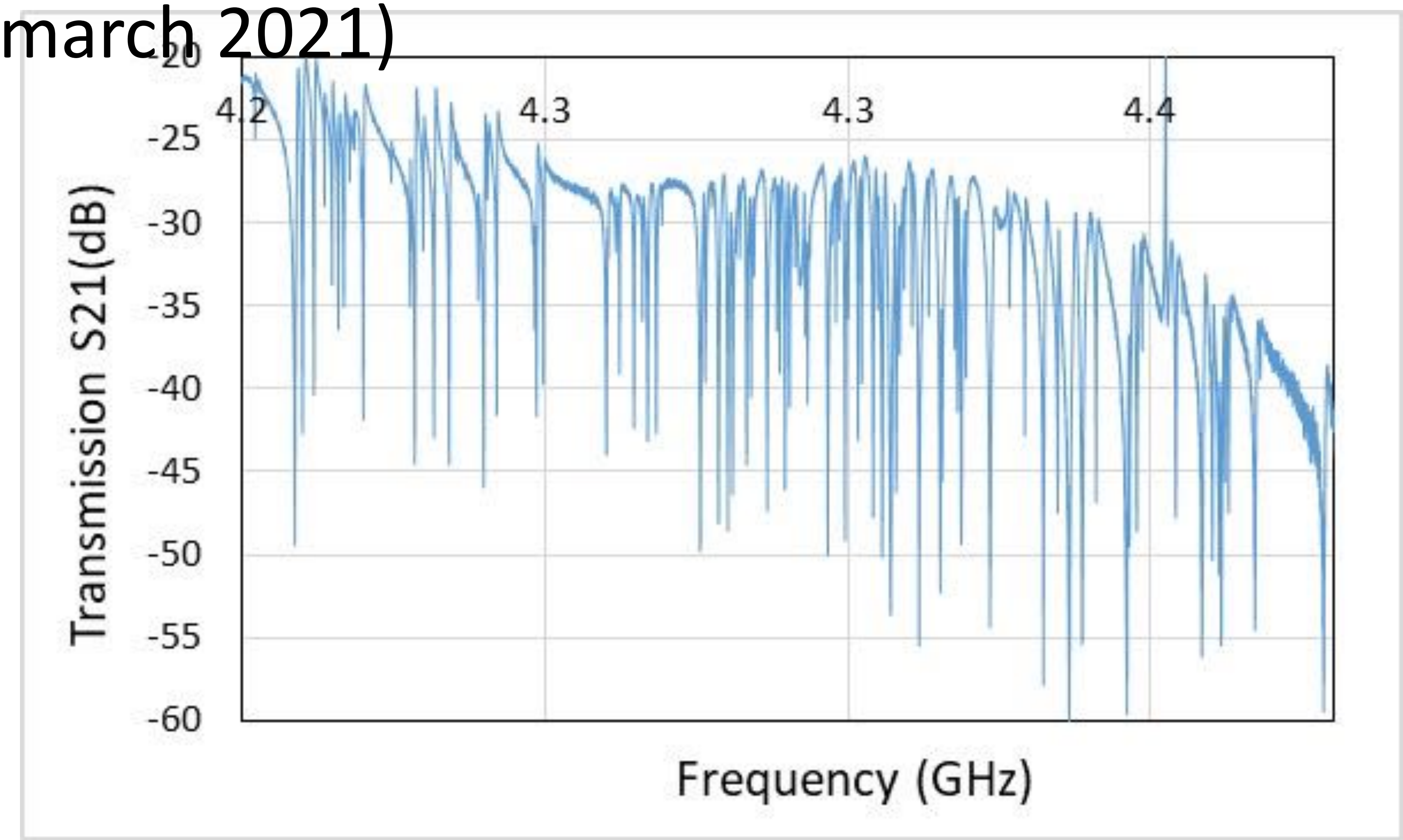


SPIAKID

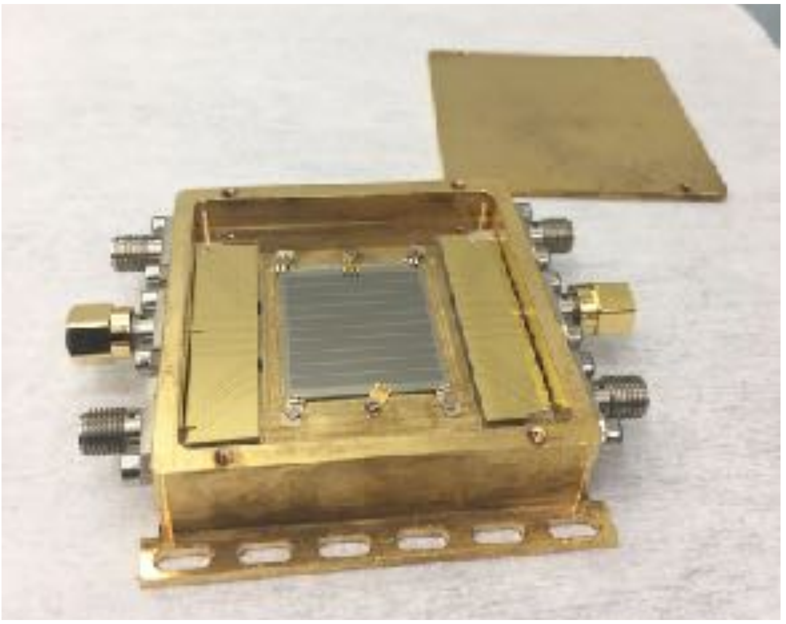
20 020-pixel device + holder_26112020



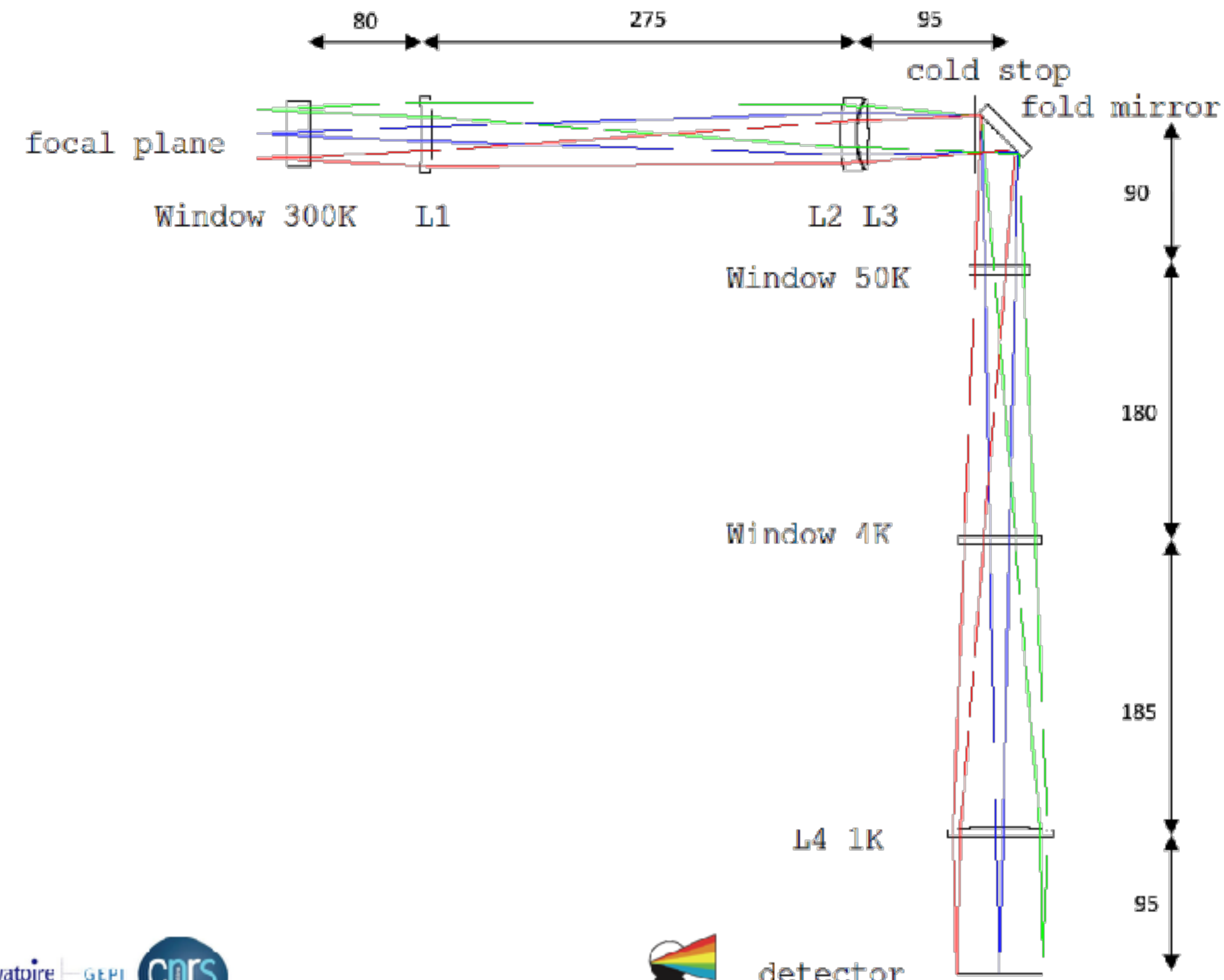
First measured resonances of a 2002-pixel array (march 2021)



A small part of the transmission S_{21}



Opto-mechanics



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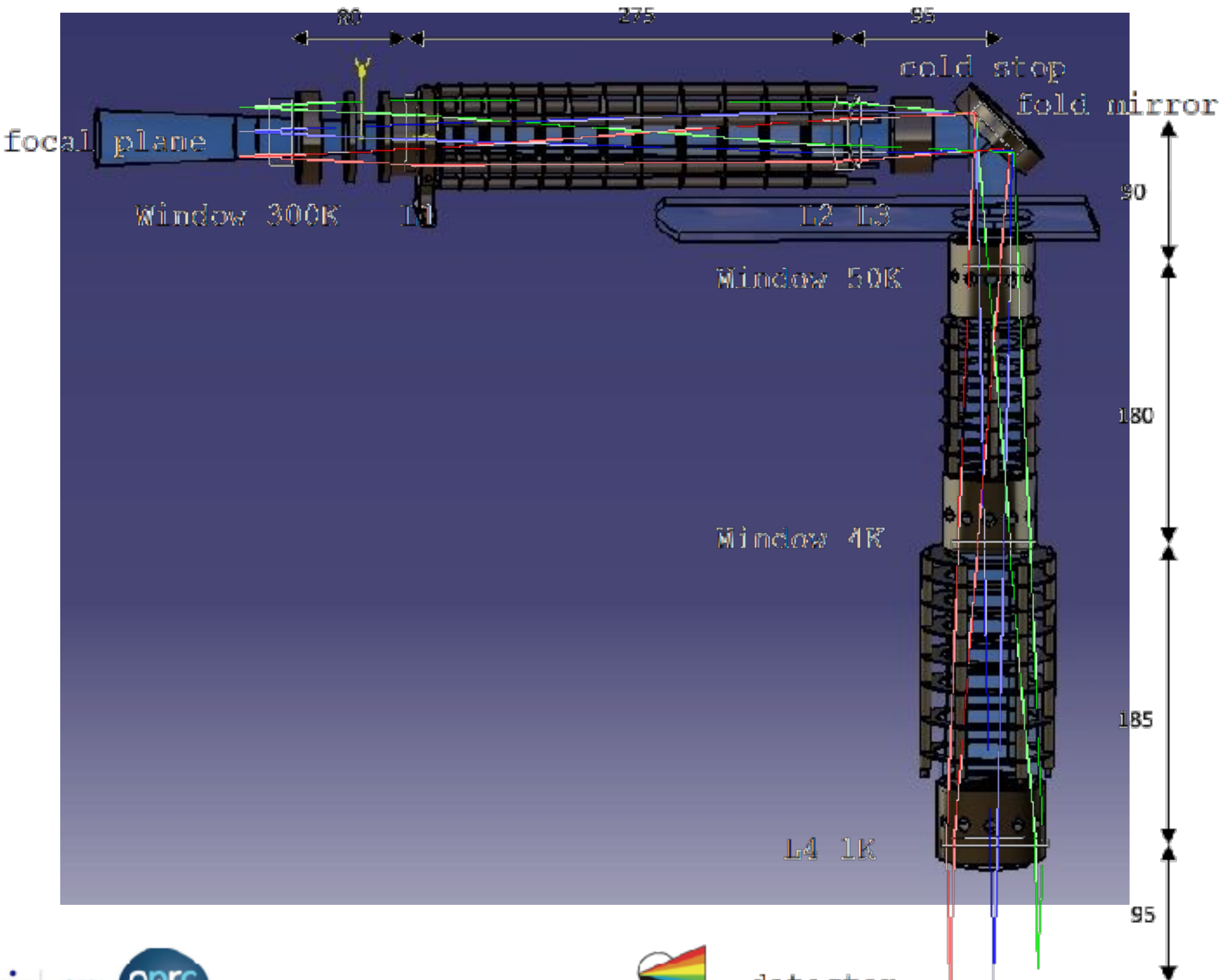
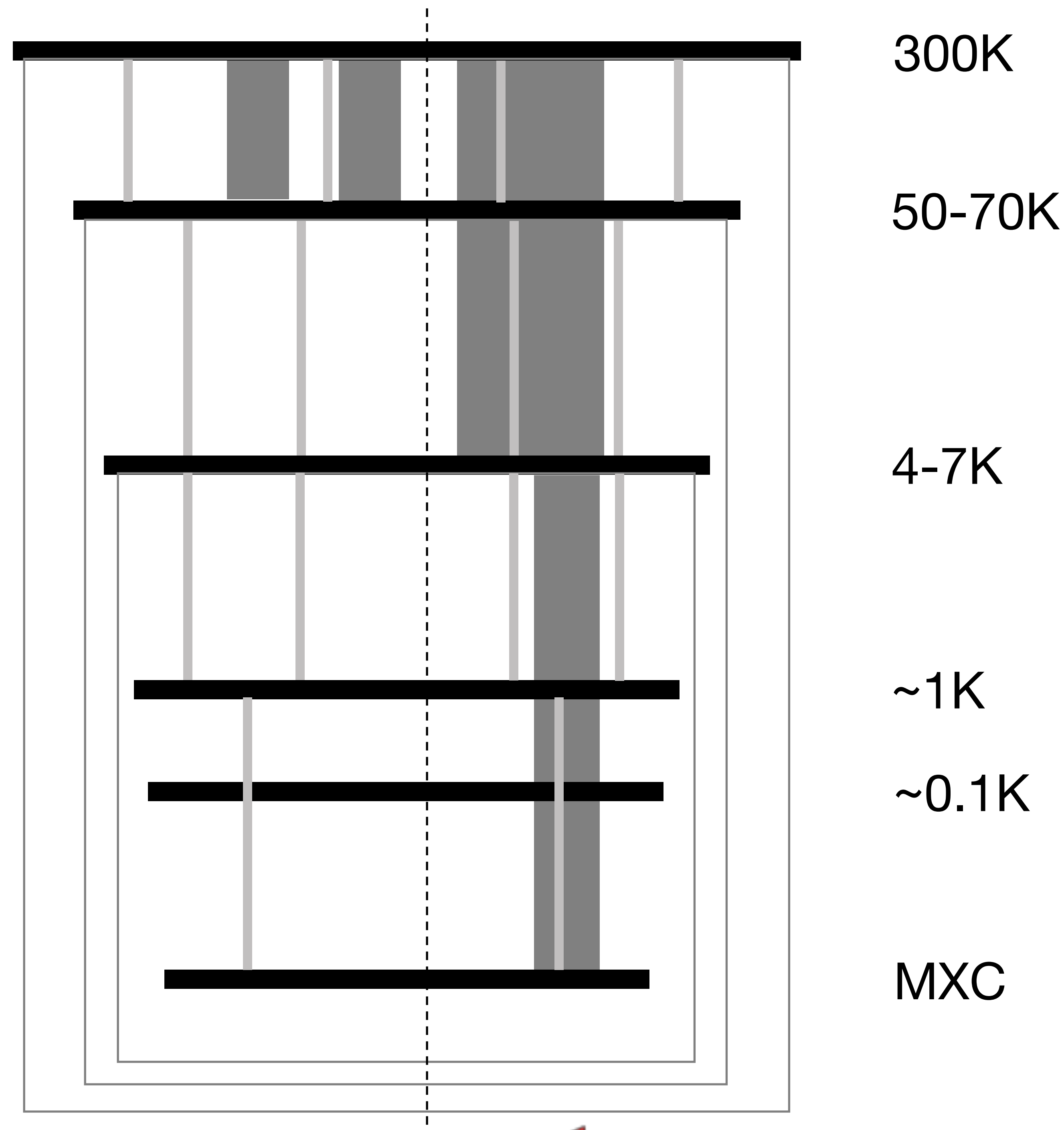


Cryostat assembly



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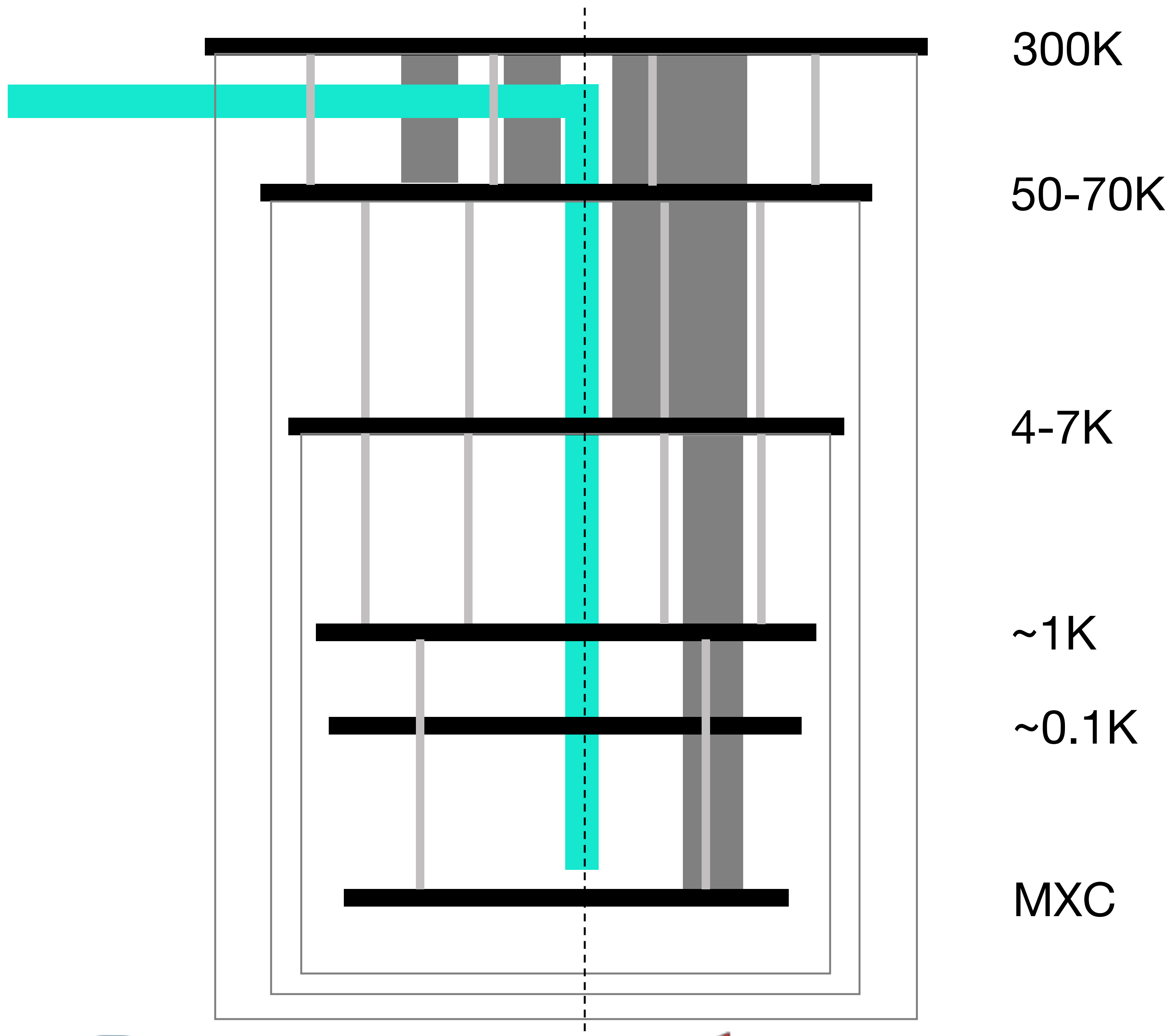

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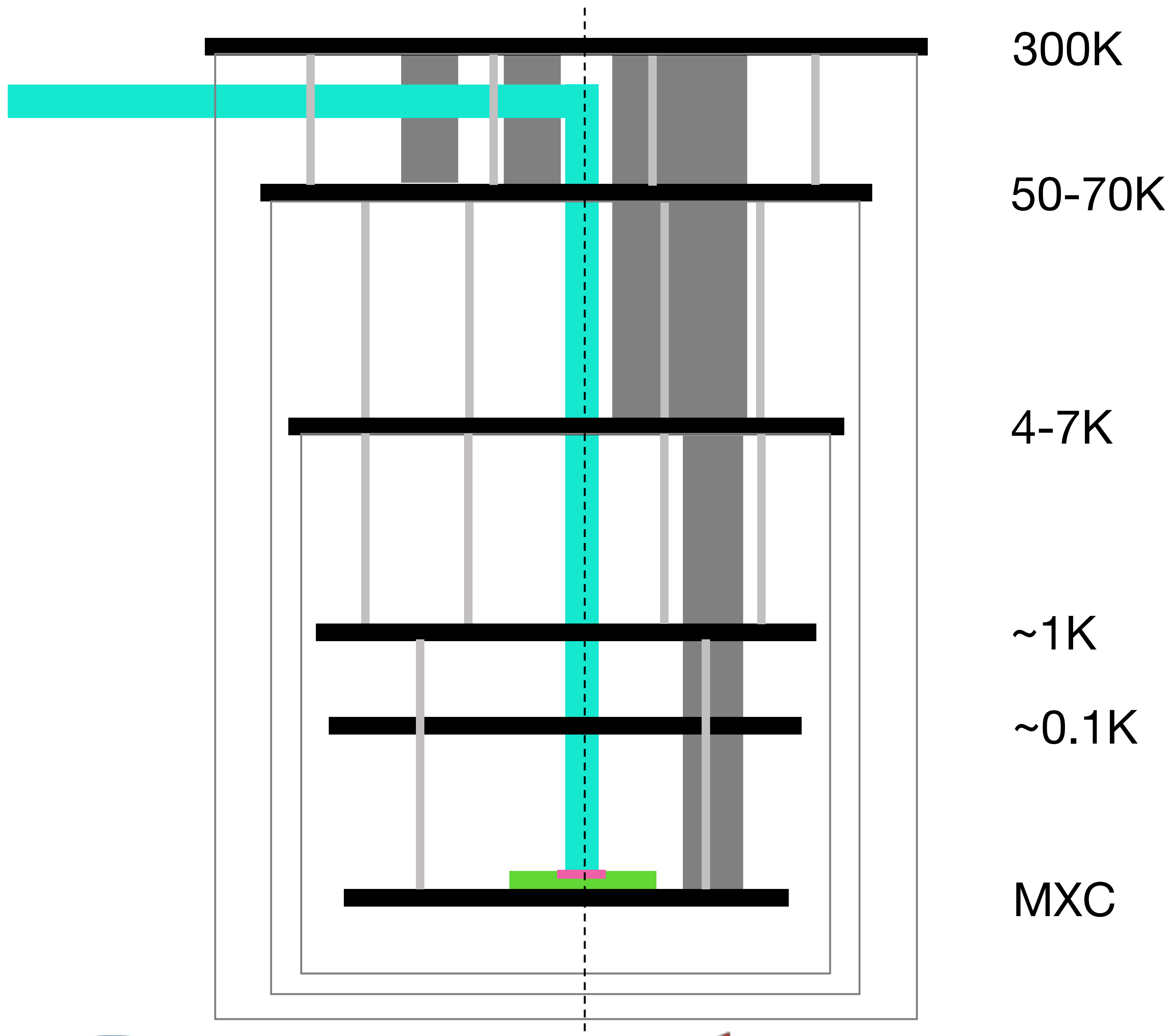

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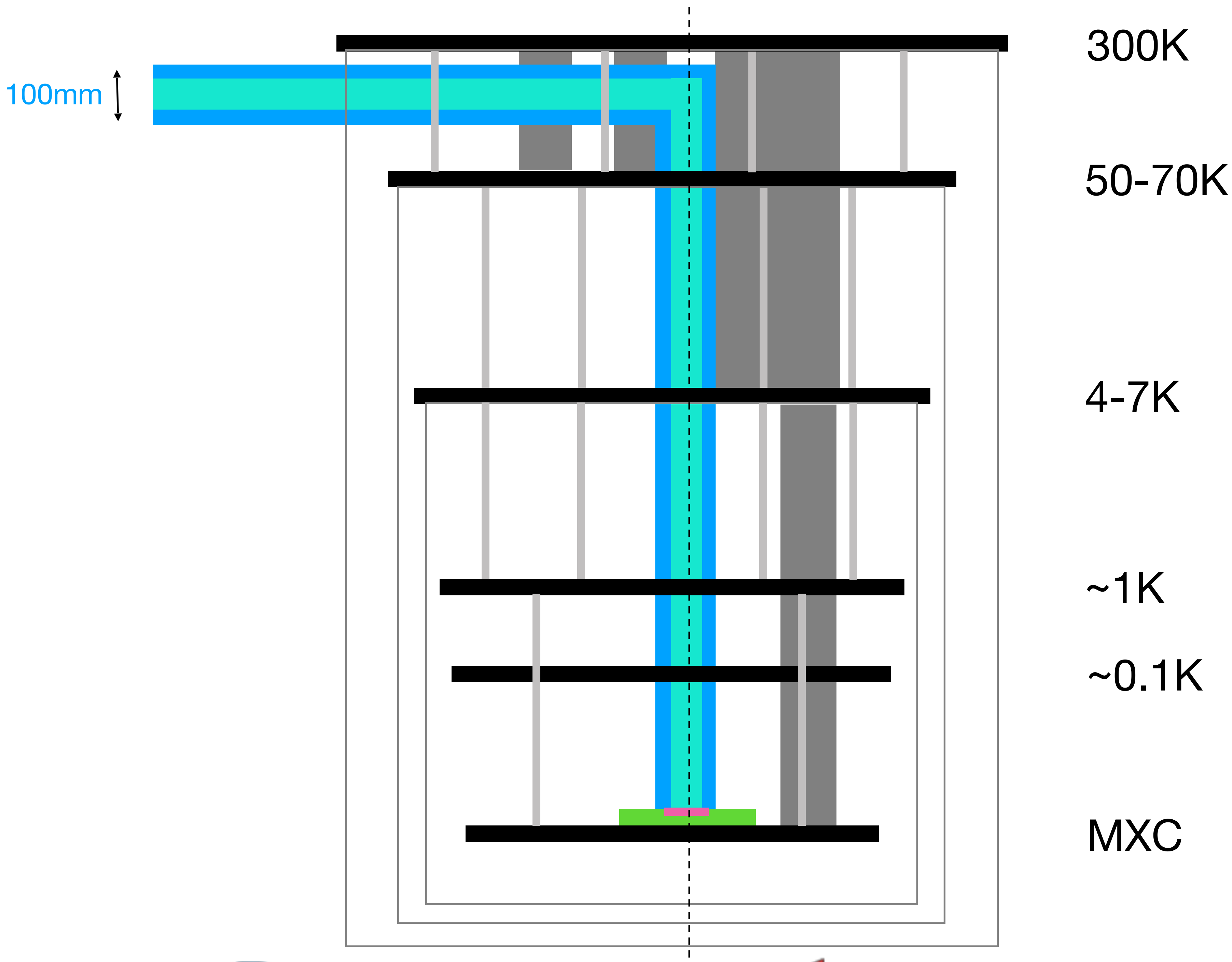

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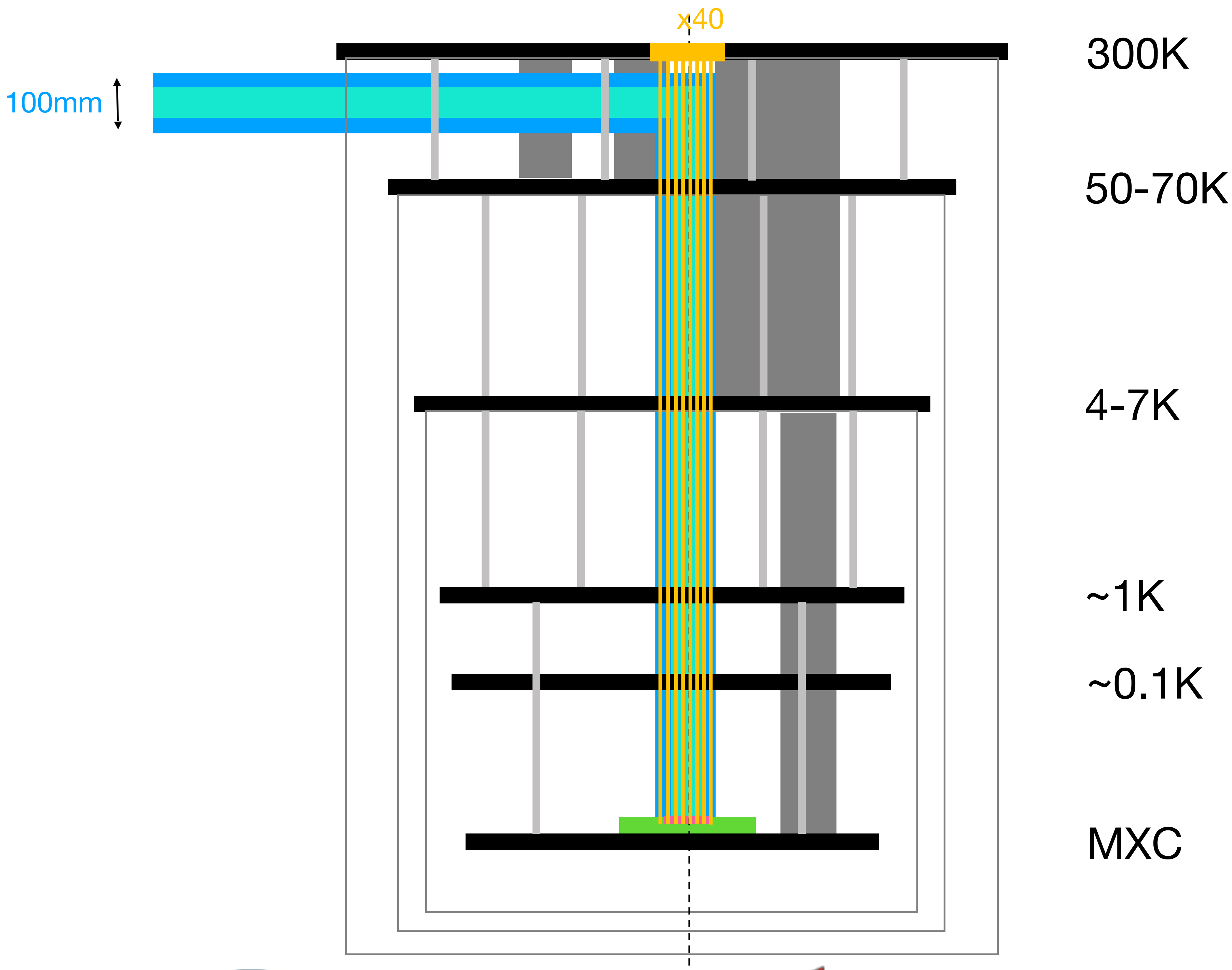

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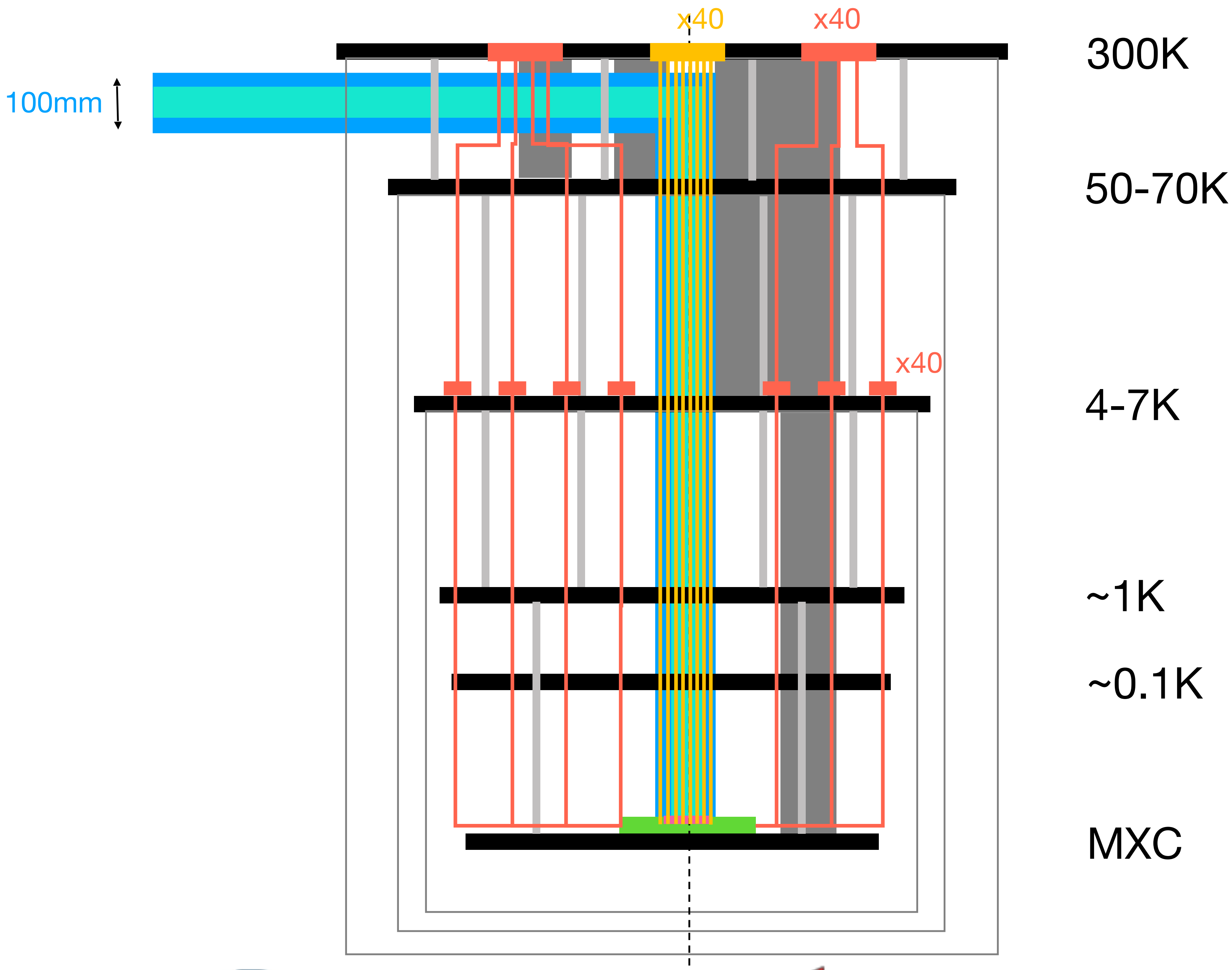

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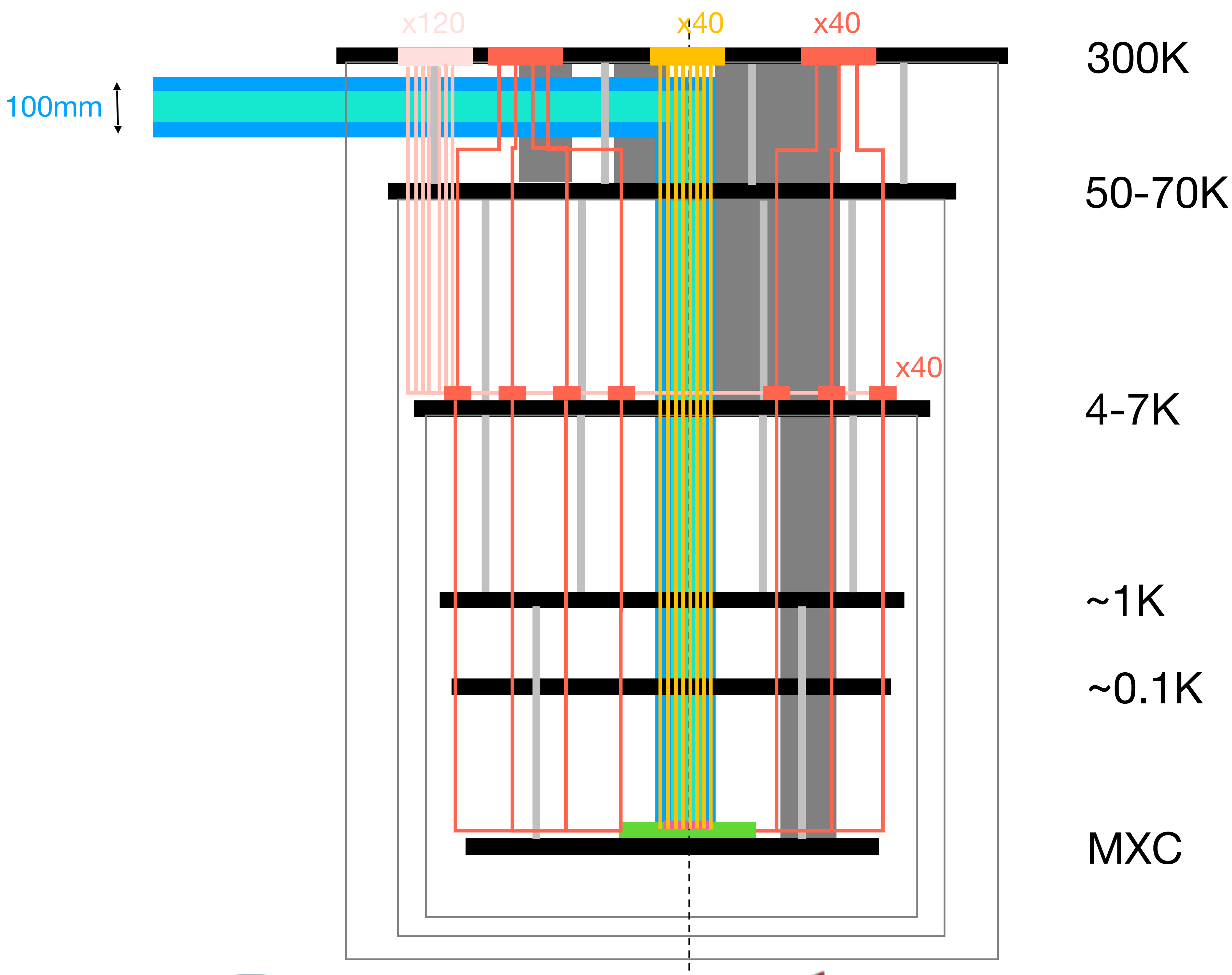

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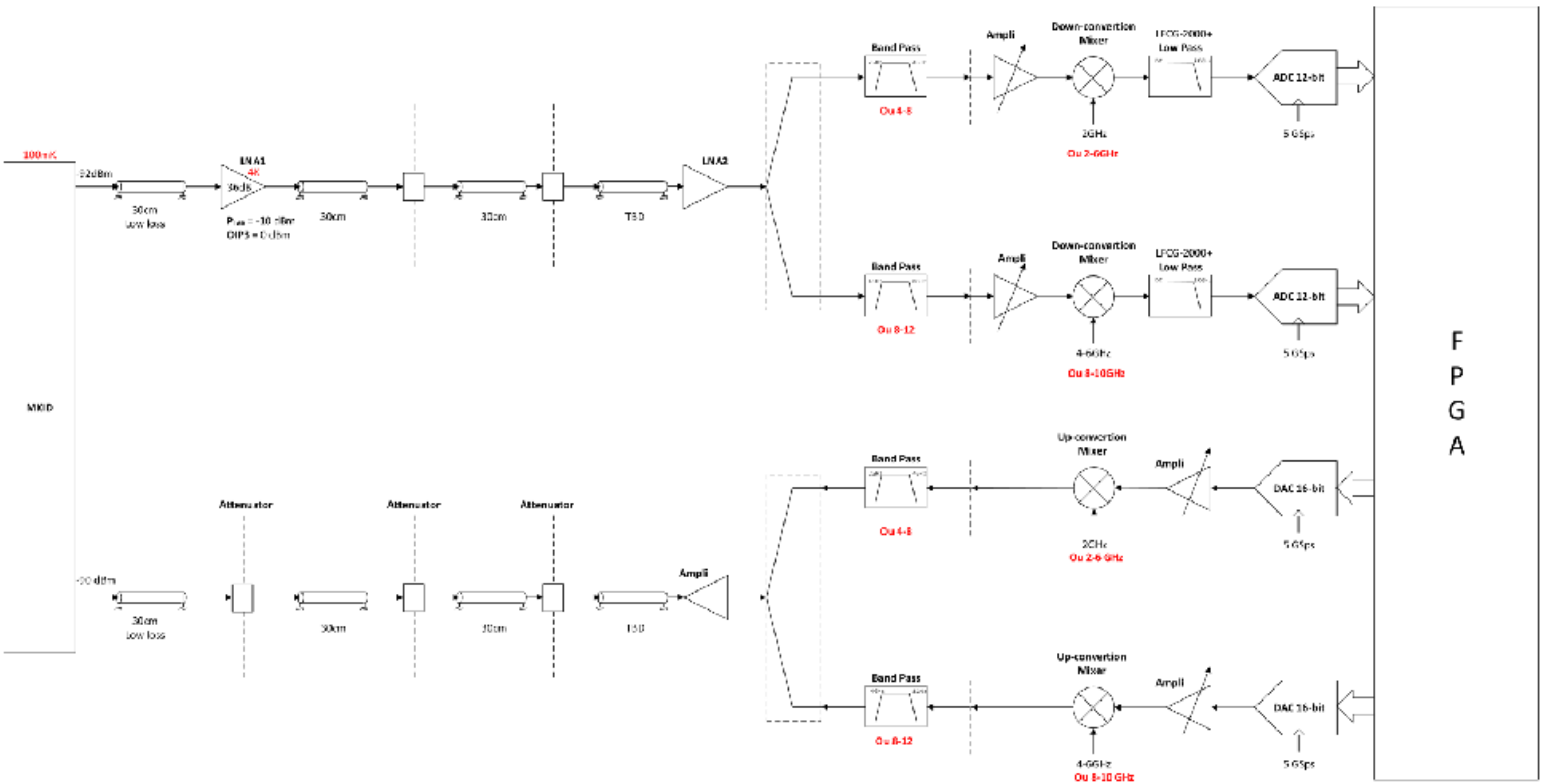
Read-out electronics



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SPIAKID Deployment

1. Laboratory, test bench

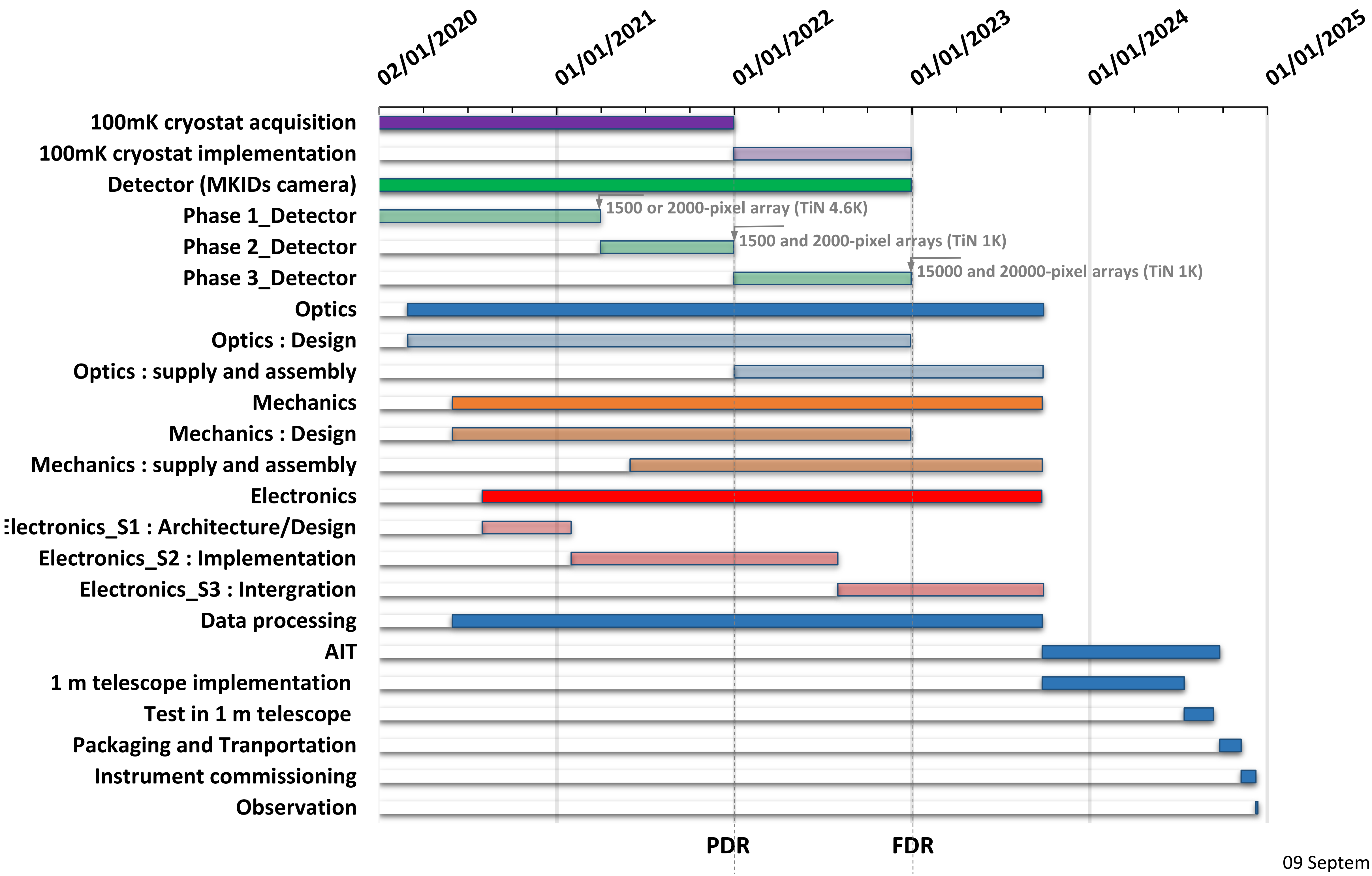
2. 1m telescope Meudon. SPIAKID fed by a custom fibre IFU. No scientific goal, system check. Opportunity for students to be involved in the instrument testing.

3. 3.5m NTT telescope

    a. Commissioning (technical time ?) 2-3 nights

    b. Visitor Instrument, offered through OPC. Open for the community. SPIAKID team will take care of observations and data reduction.

SPIAKID SCHEDULE



09 September 2020

MERCI !