JULIAN GERATZ

MAY 17, 2021

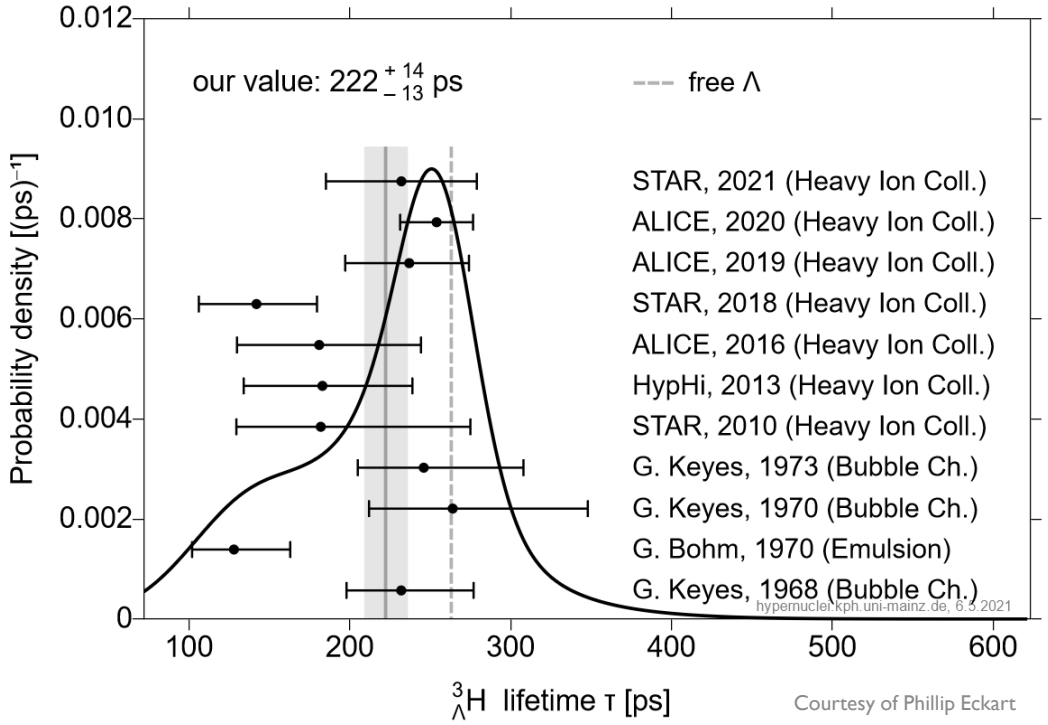
BACHELOR THESIS PRESENTATION

DESIGN OF A THERMAL IMAGING SYSTEM FOR THE HYPERTRITON EXPERIMENT AT A1

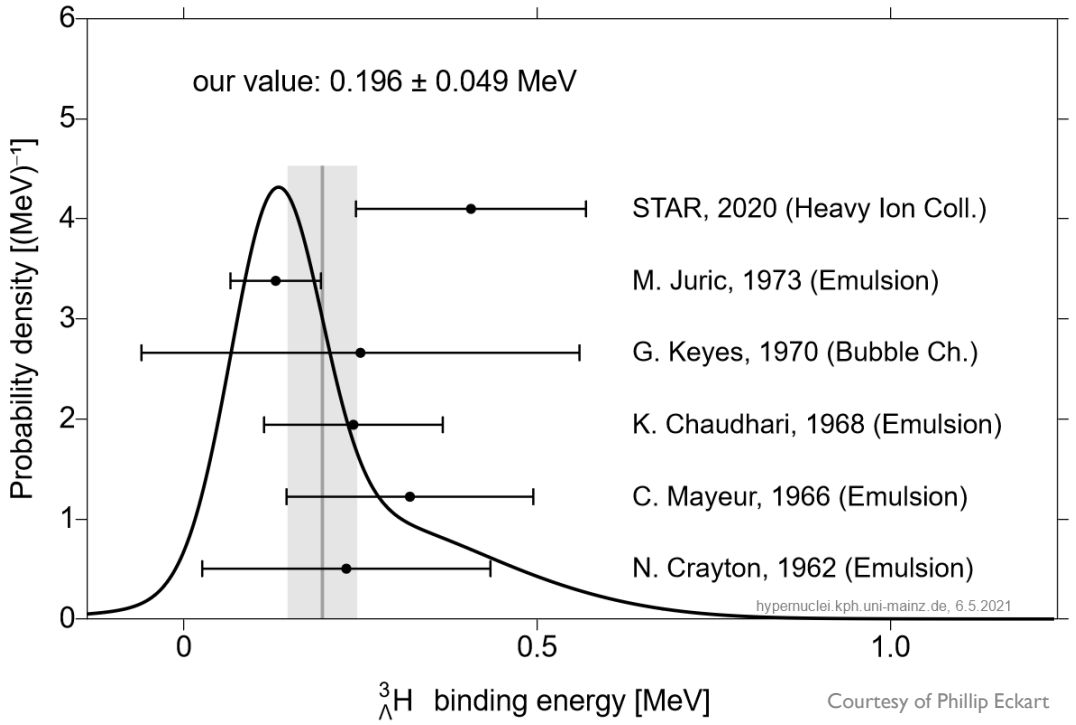
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

CONTENTS



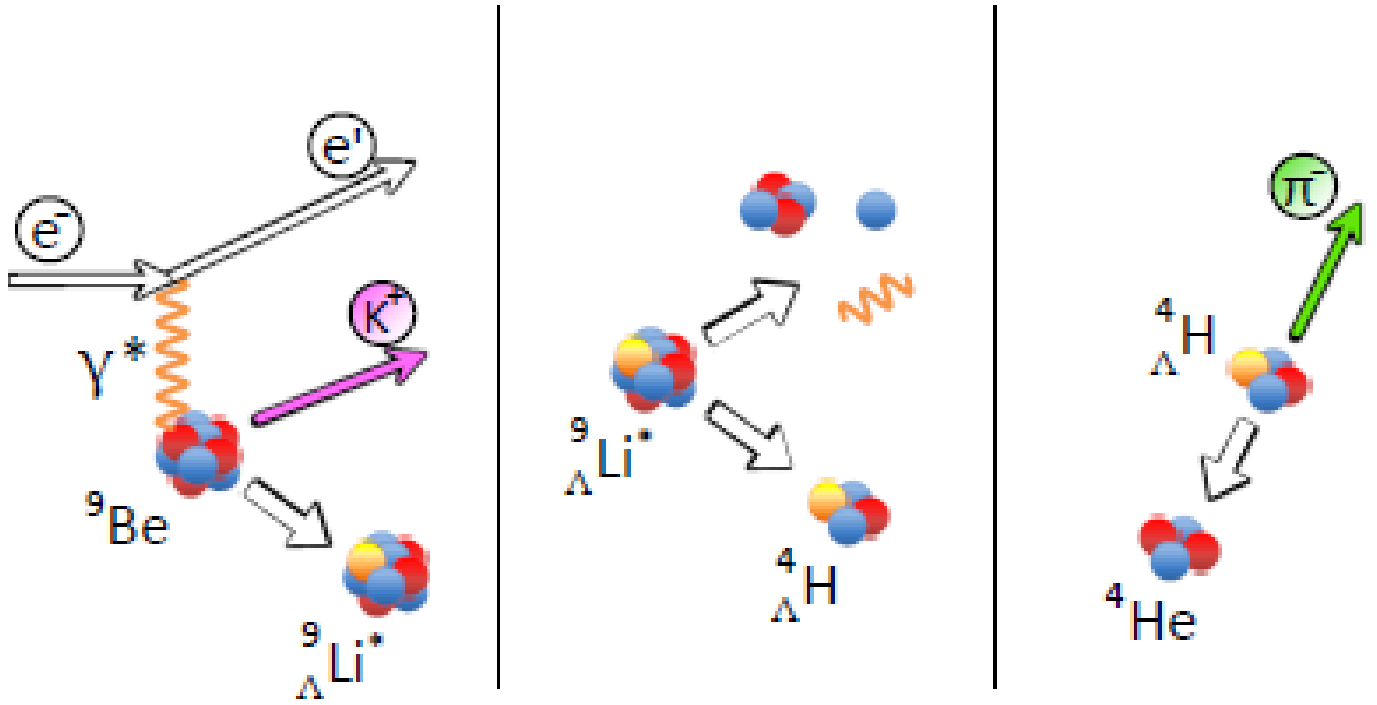
Courtesy of Phillip Eckart



Courtesy of Phillip Eckart

${}^{3}_{\Lambda}H$ THE HYPERTRITON

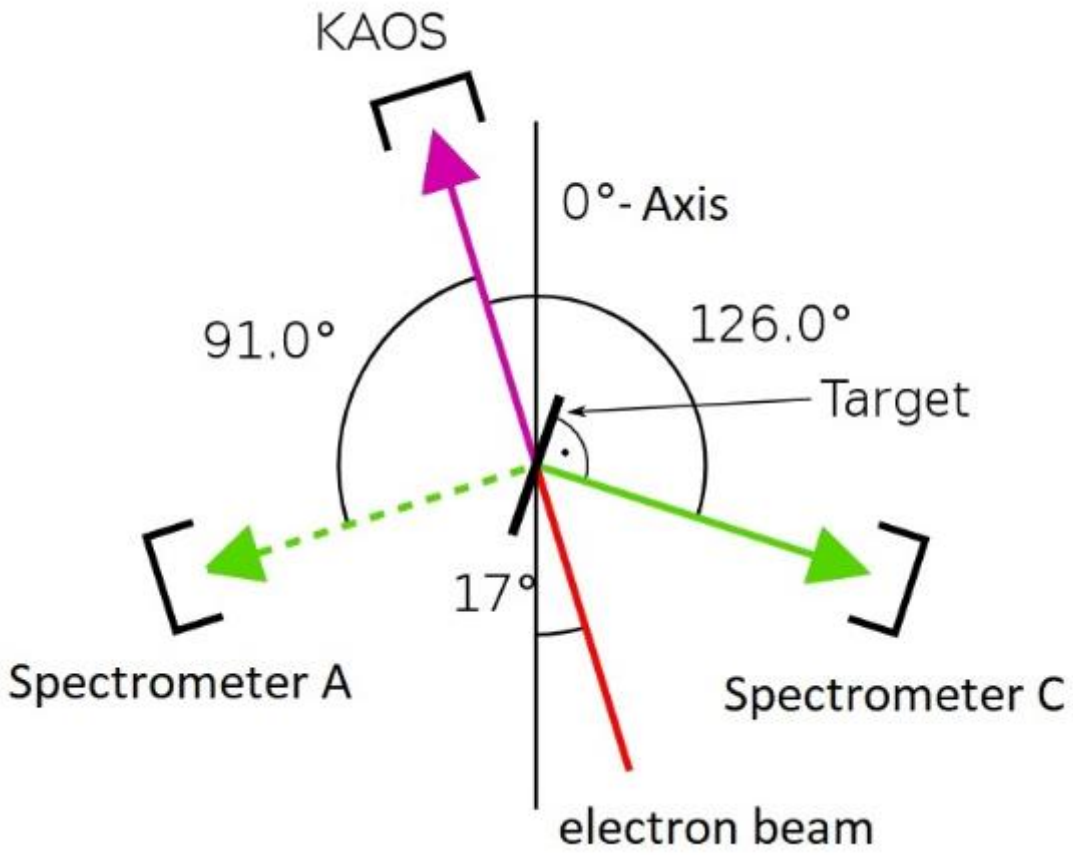
- Current measurements of binding energy and lifetime inconclusive
- Further study required



Präzisionsmessung der Λ-Separationsenergie von ${}^{4}_{\Lambda}H$ am Mainzer Mikrotron, Dissertation, Florian Schulz, Dez. 2015

PRODUCTION REACTION

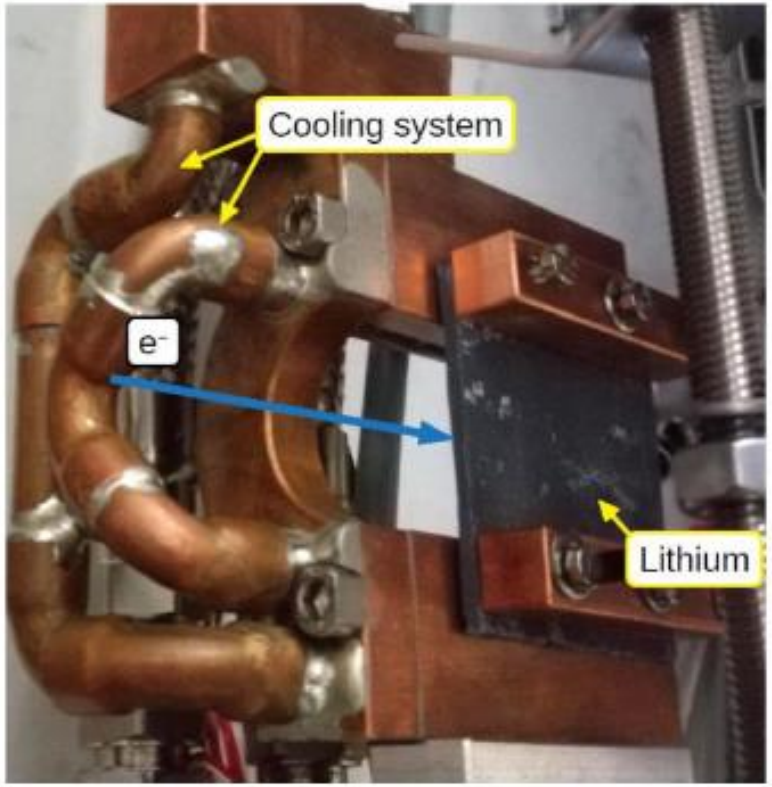
- Excite target
- Fragmentation into light hypernuclei
- Two-body decay

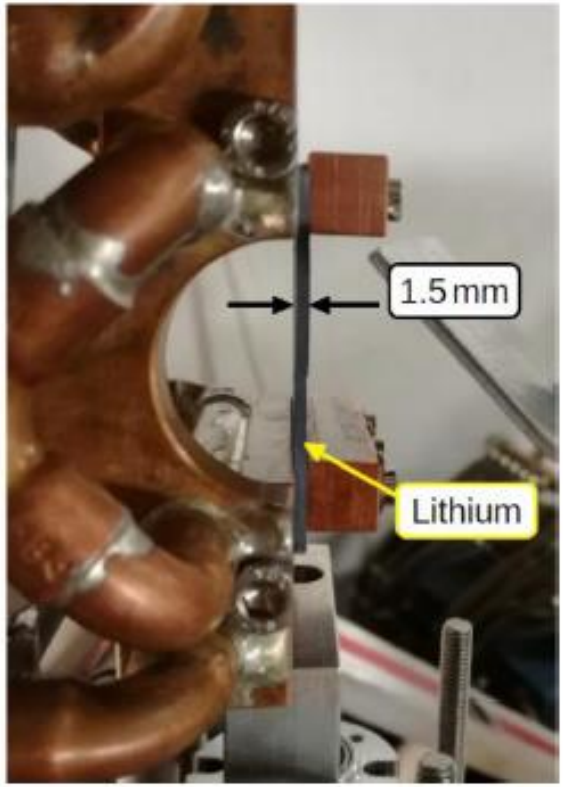


Präzisionsmessung der Λ-Separationsenergie von $^{4}_{\Lambda}H$ *am Mainzer Mikrotron*, Dissertation, Florian Schulz, Dez. 2015

BERYLLIUM TARGET AT MAMI

- Produce light hypernuclei in Beryllium
- ^{9}Be target used to observe $^{4}_{\Lambda}H$
- Yield of $^{3}_{\Lambda}H$ to $^{4}_{\Lambda}H$ about 10 times smaller
- Increasing luminosity is difficult
- $^{6/7}Li$ ideal for $^{3/4}_{\Lambda}H$ observation

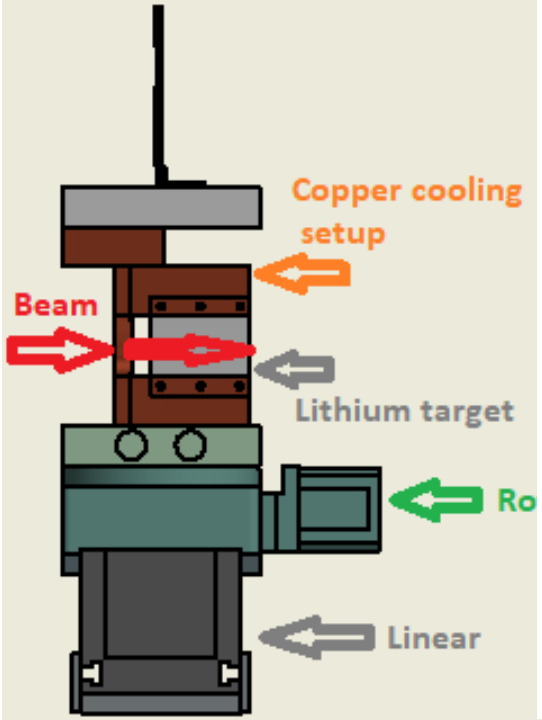


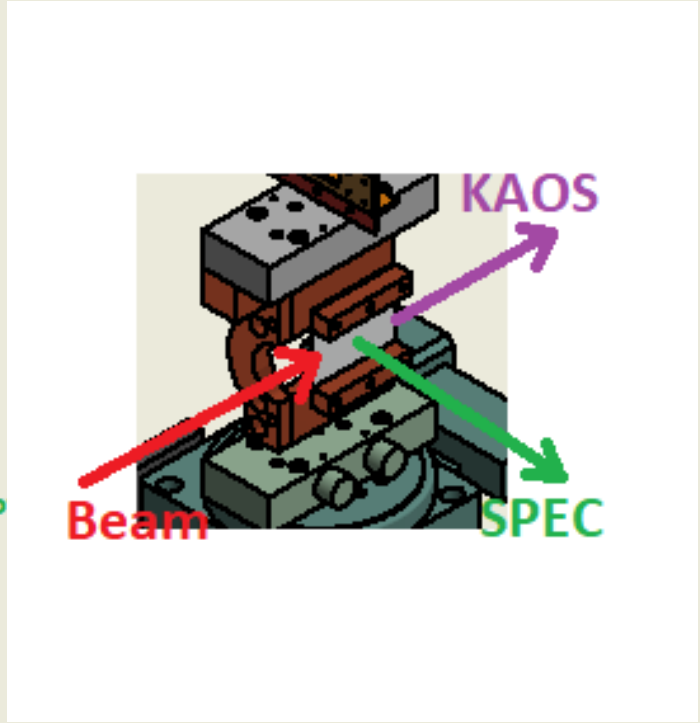


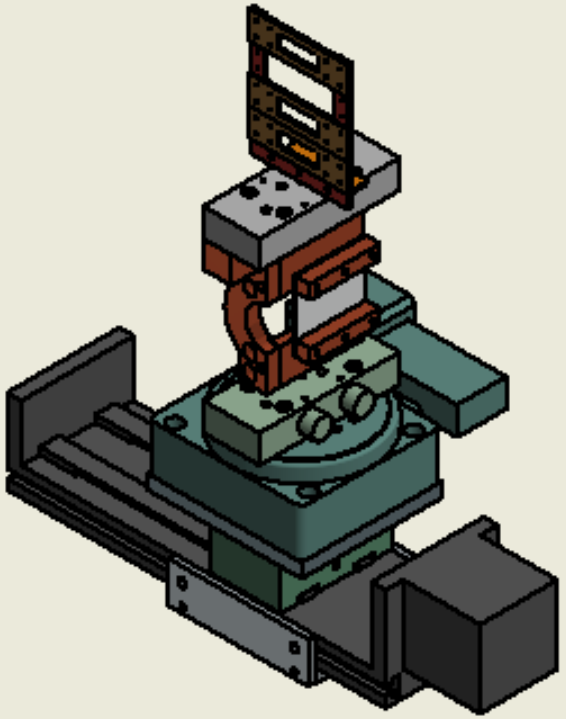
Vorarbeiten für genaue und präzise Messungen leichter Hyperkernmassen mit der A1-Spektrometeranlage am MAMI, Dissertation, Philipp Herrmann, 2021

LITHIUM TARGET

- 50x50x1.5 mm Lithium Sheet
- Increased luminosity with minimal momentum smearing
- Low melting point ($180^{\circ}C$) requires liquid cooling

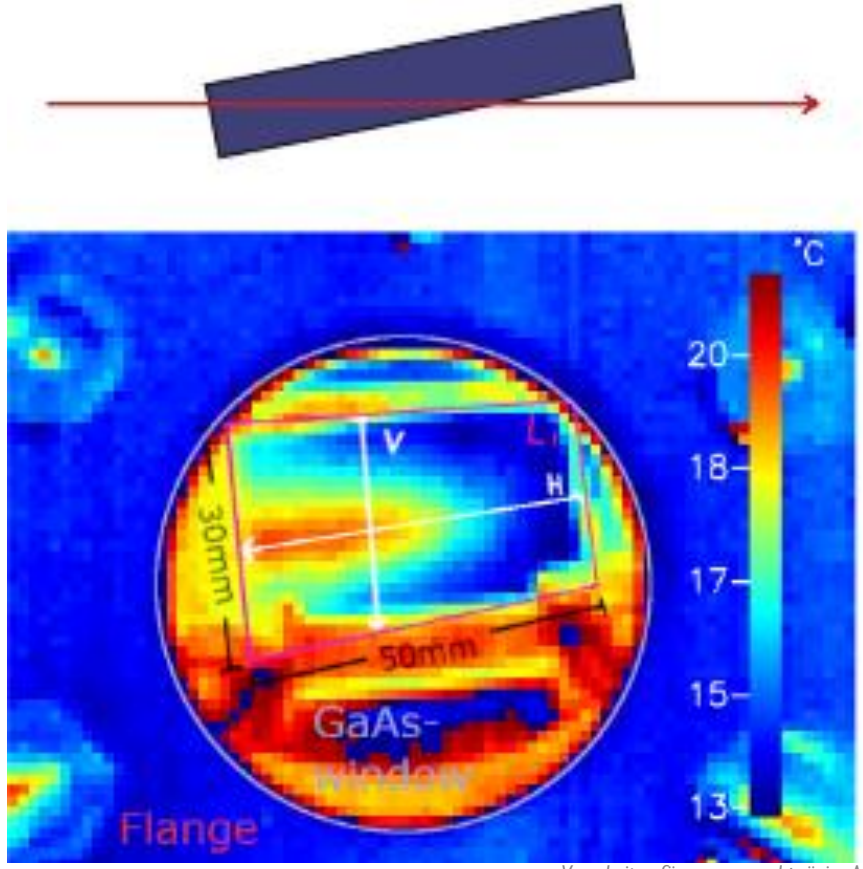


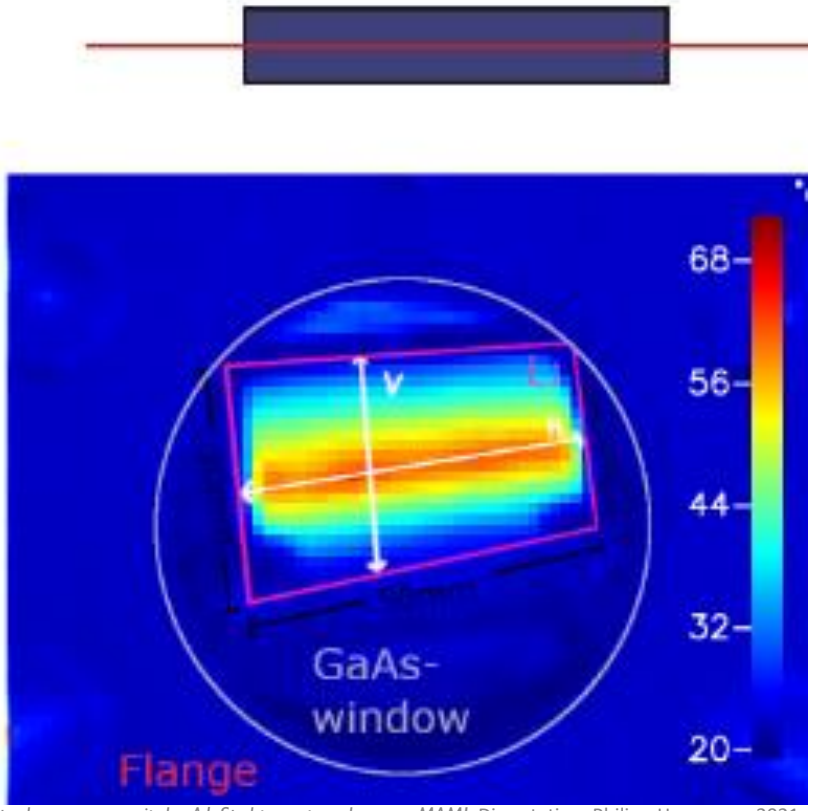




LITHIUM TARGET

- No problems with 10μA (planned for 5μA)
- Temperature did not come close to melting point

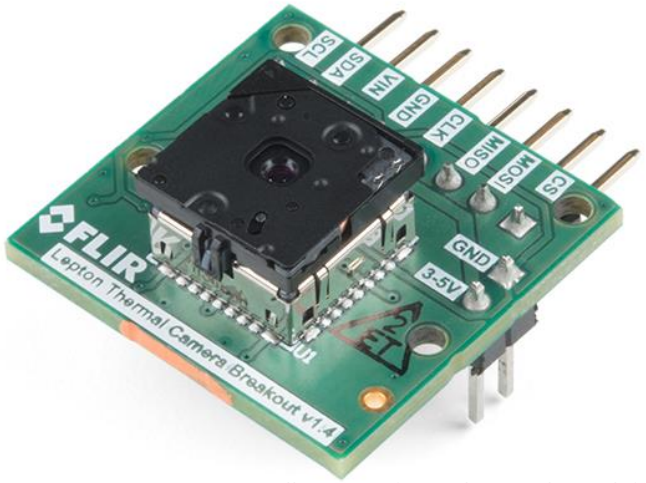




Vorarbeiten für genaue und präzise Messungen leichter Hyperkernmassen mit der A1-Spektrometeranlage am MAMI, Dissertation, Philipp Herrmann, 2021

TARGET ALIGNMENT

- Use thermal camera to observe beam trajectory
- Use translation and rotation stage to align target and beam



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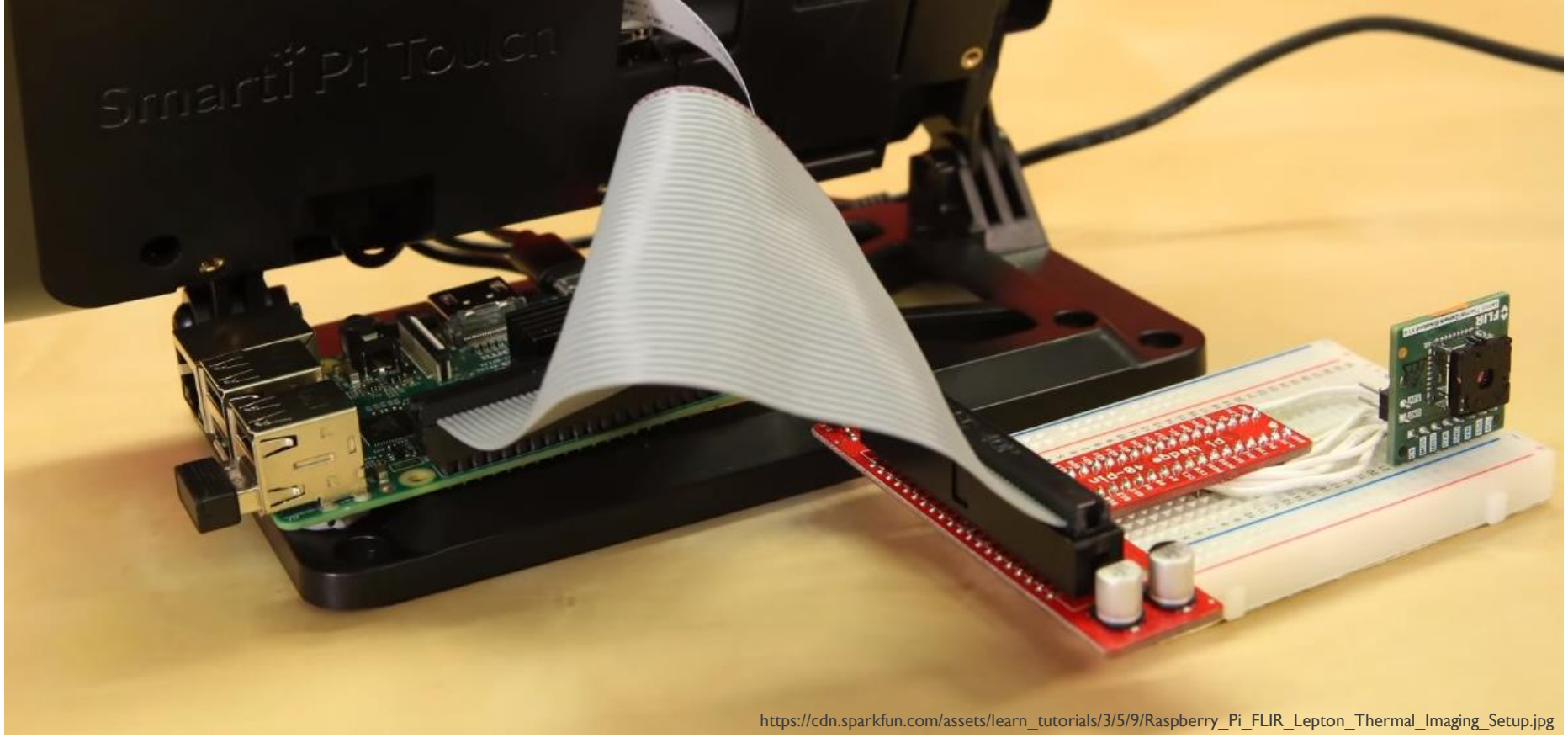
THE FLIR LEPTON 2.5 THERMAL IMAGING MODULE

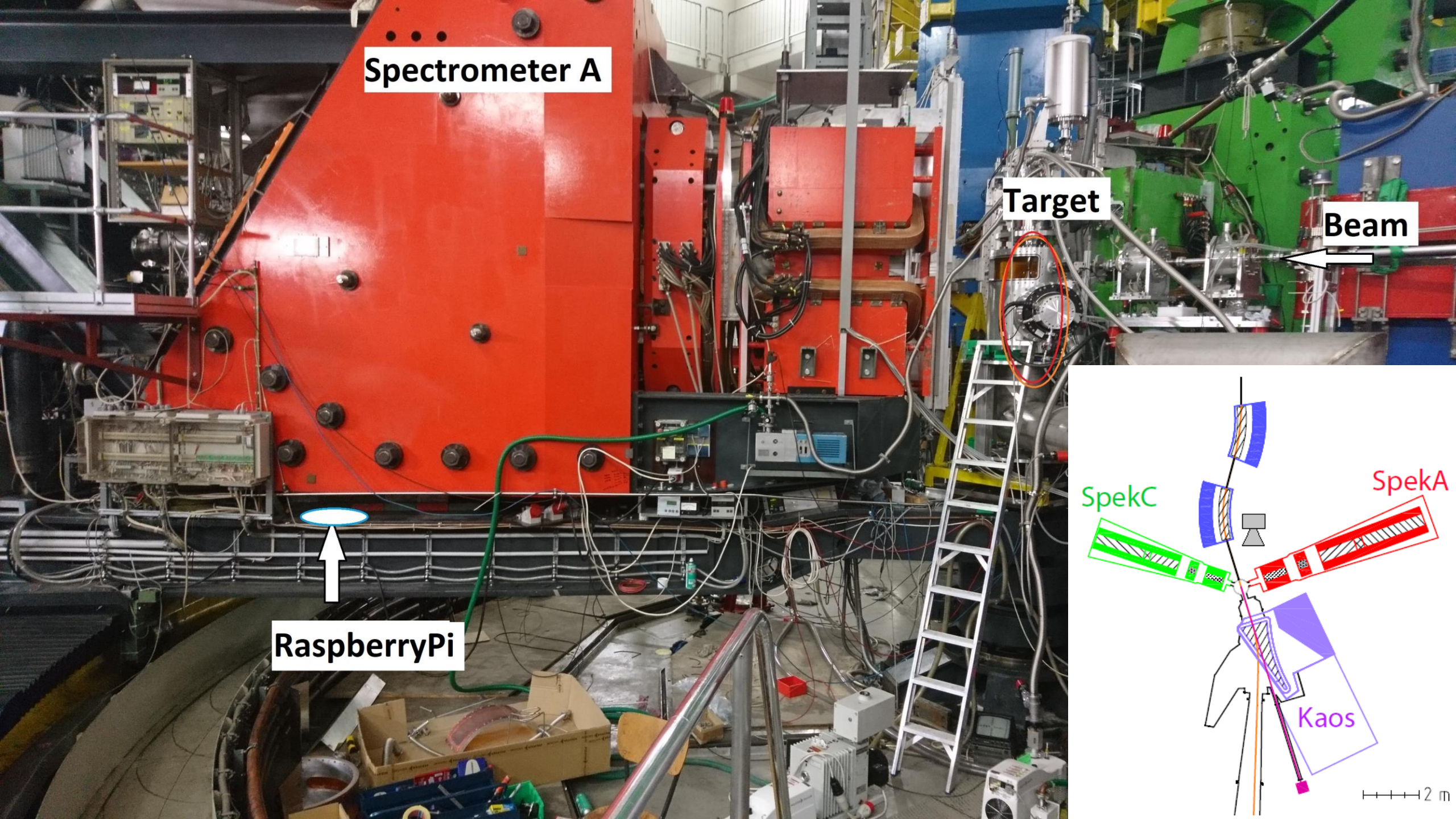
- Surprisingly good radiation resistance
- Inexpensive to replace
- Uses microbolometers (thermistors) for thermal imaging

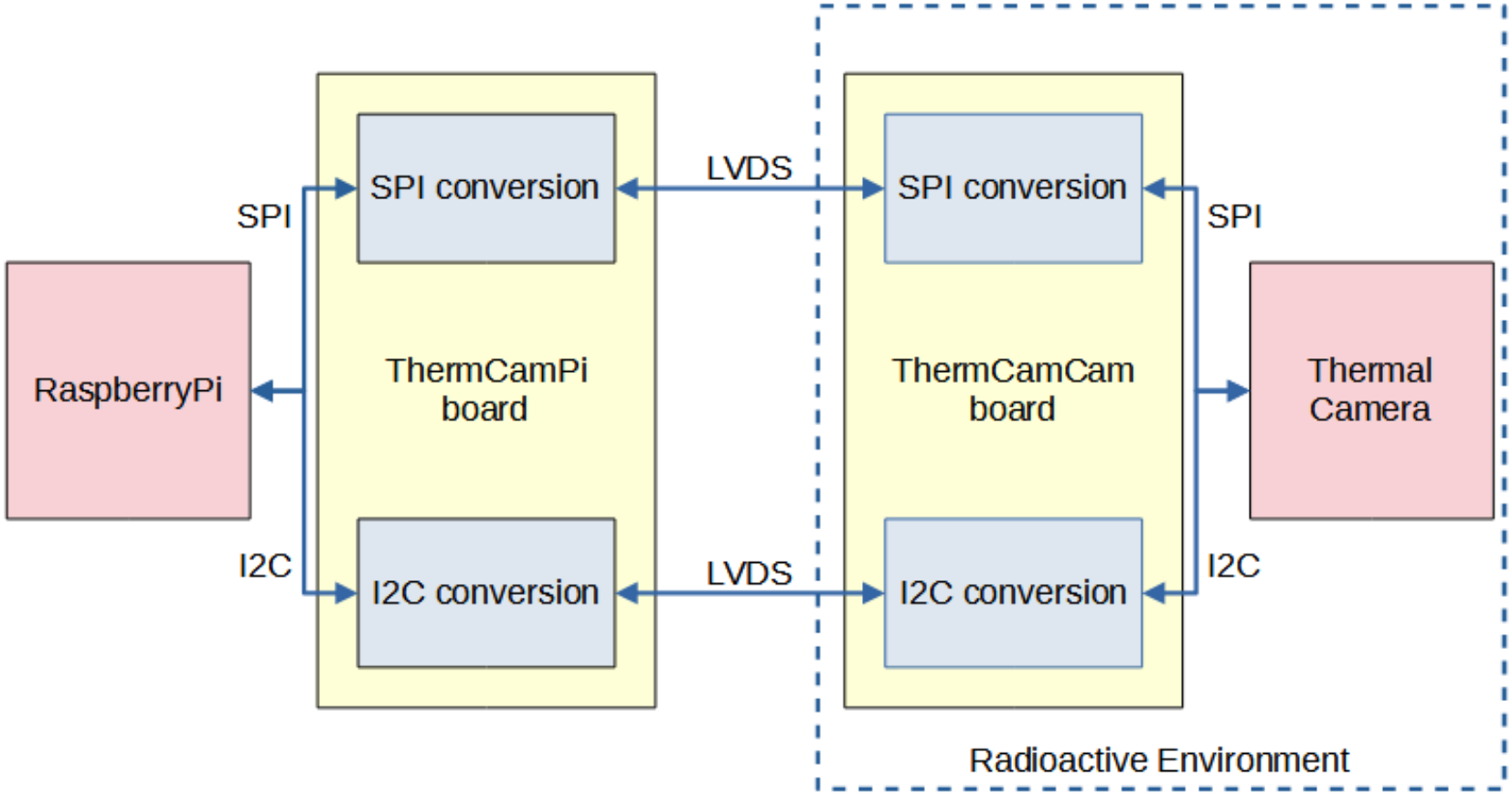


https://cdn.sparkfun.com/assets/learn_tutorials/3/5/9/Raspberry_Pi_FLIR_Lepton_Thermal_Imaging_Setup.jpg

THE FLIR LEPTON 2.5 THERMAL IMAGING MODULE

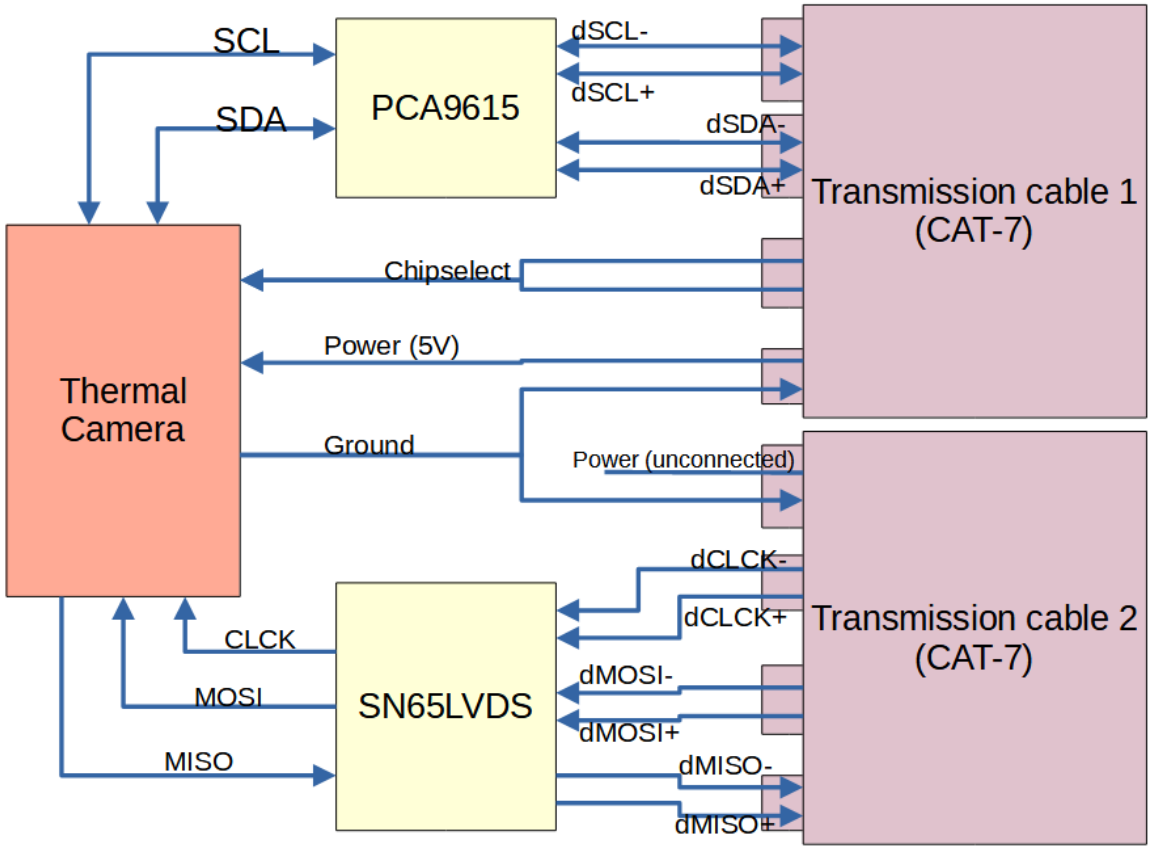
- Camera is controlled with a RaspberryPi
- I2C and SPI signal protocols are short ranged
- Radiation causes the RaspberryPi to crash frequently


Spectrometer A
Target
Beam
RaspberryPi
SpekC
SpekA
Kaos
2 m



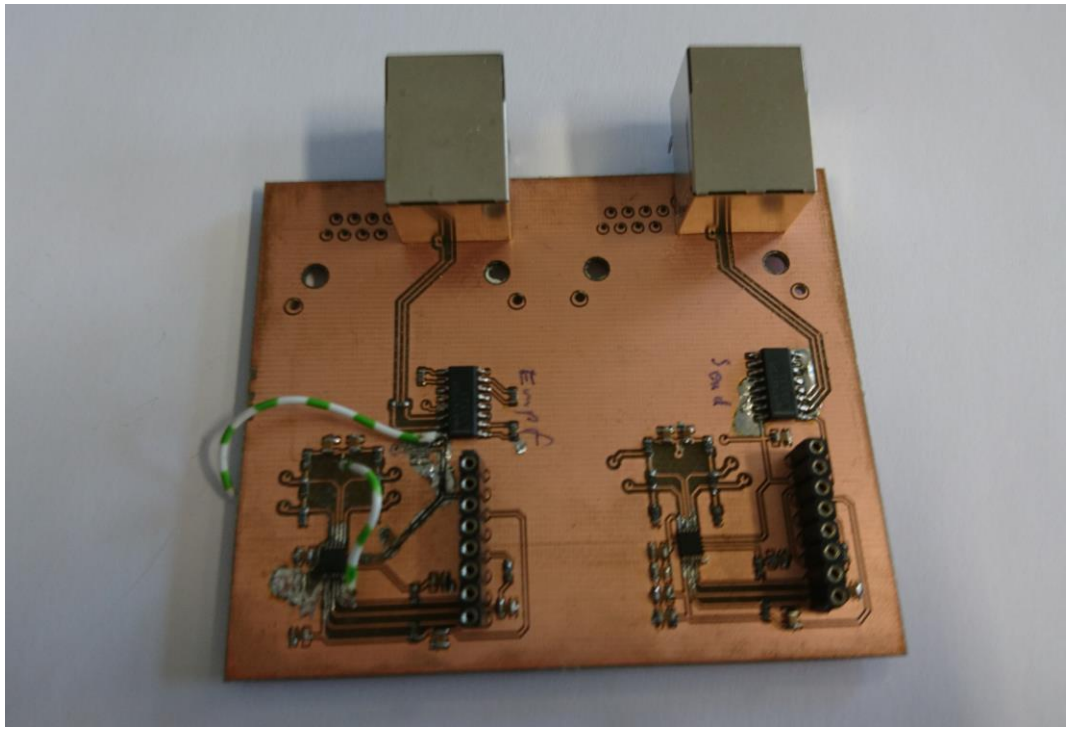
TRANSMISSION SETUP

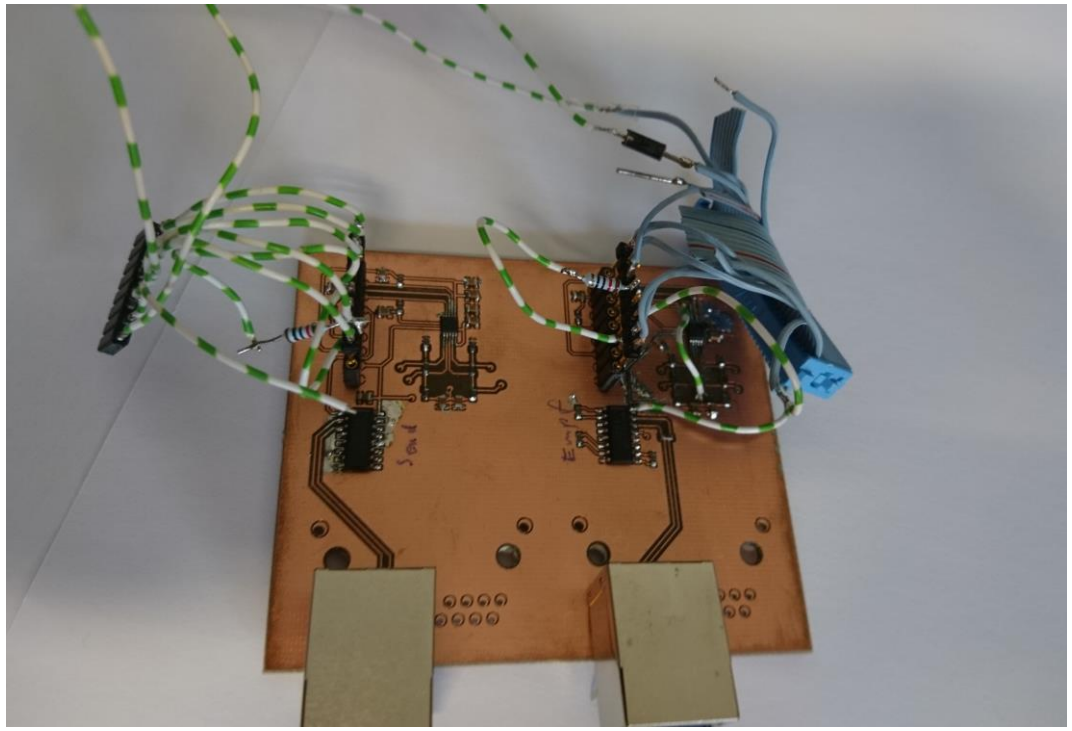
- LVDS retains signal integrity over long distances
- With more distance, the RaspberryPi is exposed to less radiation



TRANSMISSION SETUP

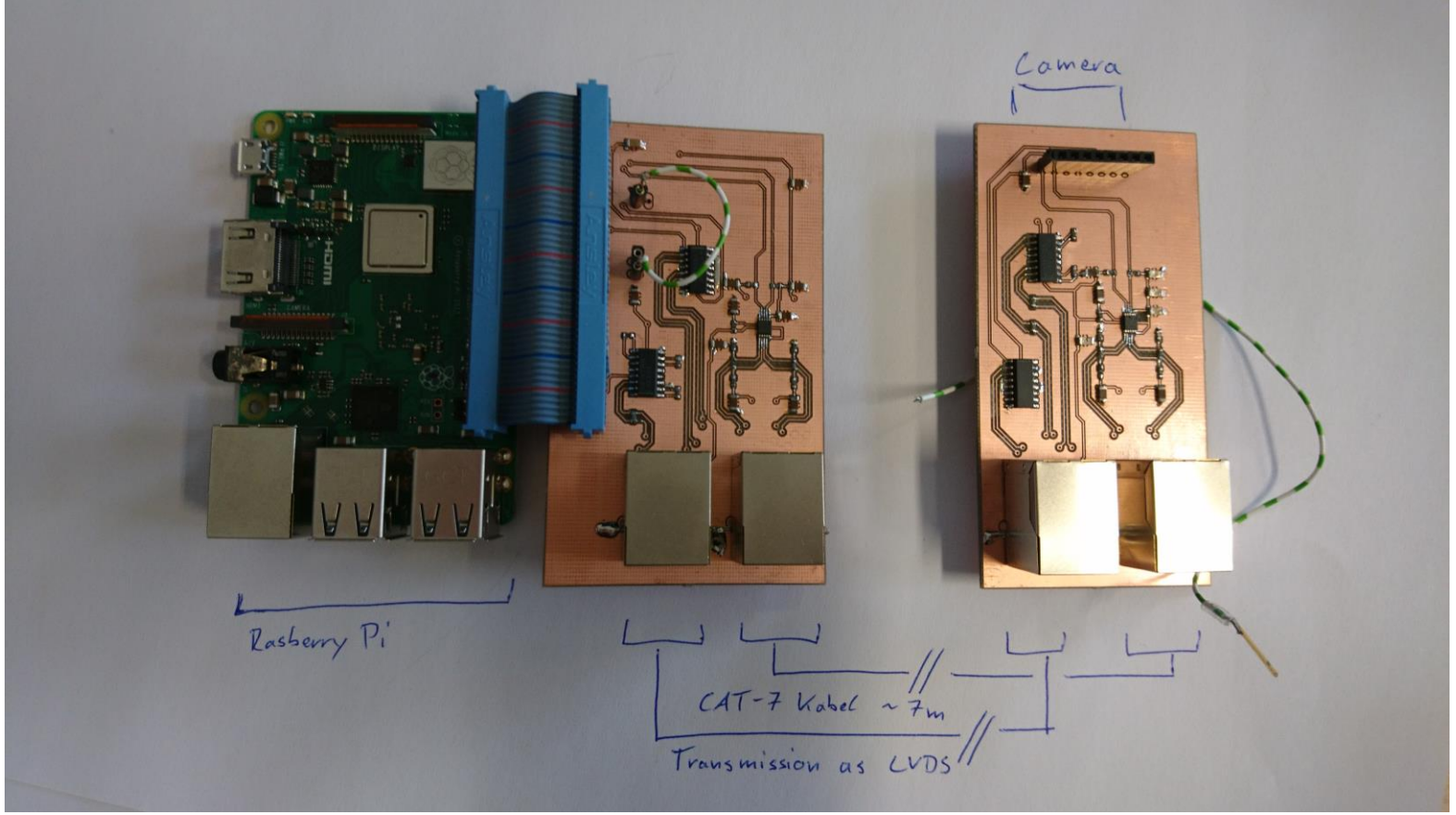
- One CAT-7 cable carries 4 twisted pairs (8 channels)
- A set of differential signals (e.g. dSCL+/-) on one twisted pair (2 channels)
- Both cables carry Ground, only one carries Power
- For complete operation of the camera two CAT-7 cables are required





THE TEST BOARD

- Manufactured at the University, hand soldered
- Test of conversion components

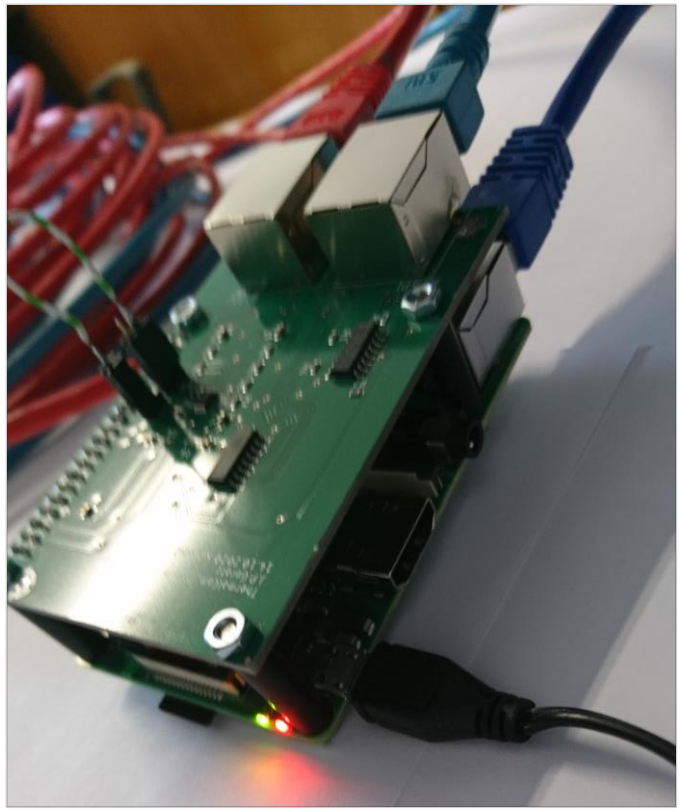


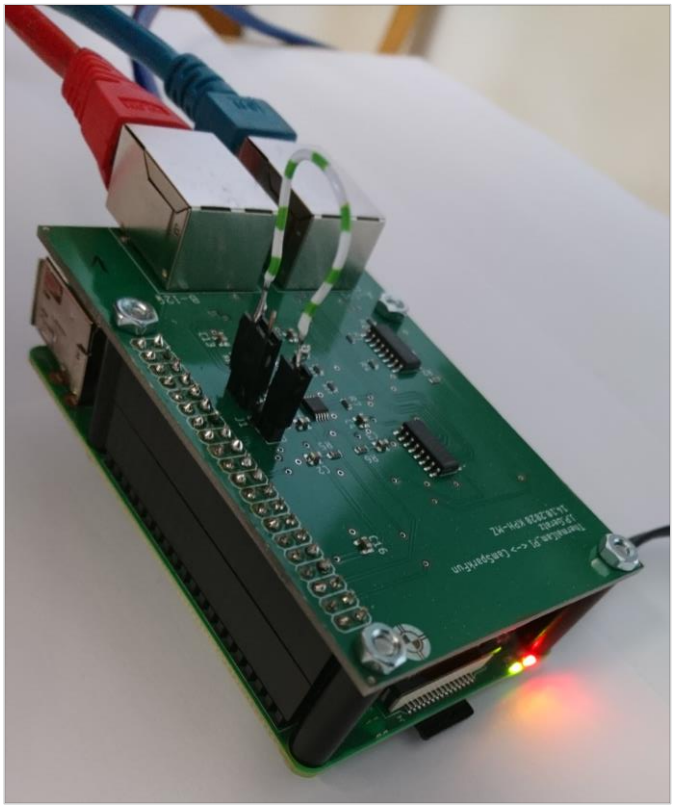
THE FULL SCALE PROTOTYPE

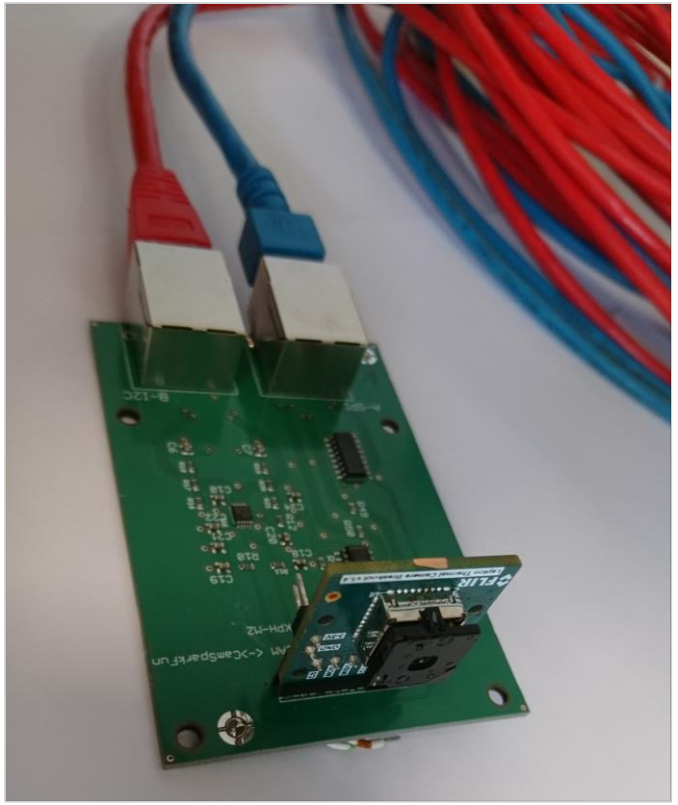
- Fully functional set of converter boards
- Successfully tested with a transmission distance of 7 m

THERMCAM_V1

- Industrially manufactured
- Ordered 4 sets together with a mask for assembly machine
- Remote viewing from the control center established

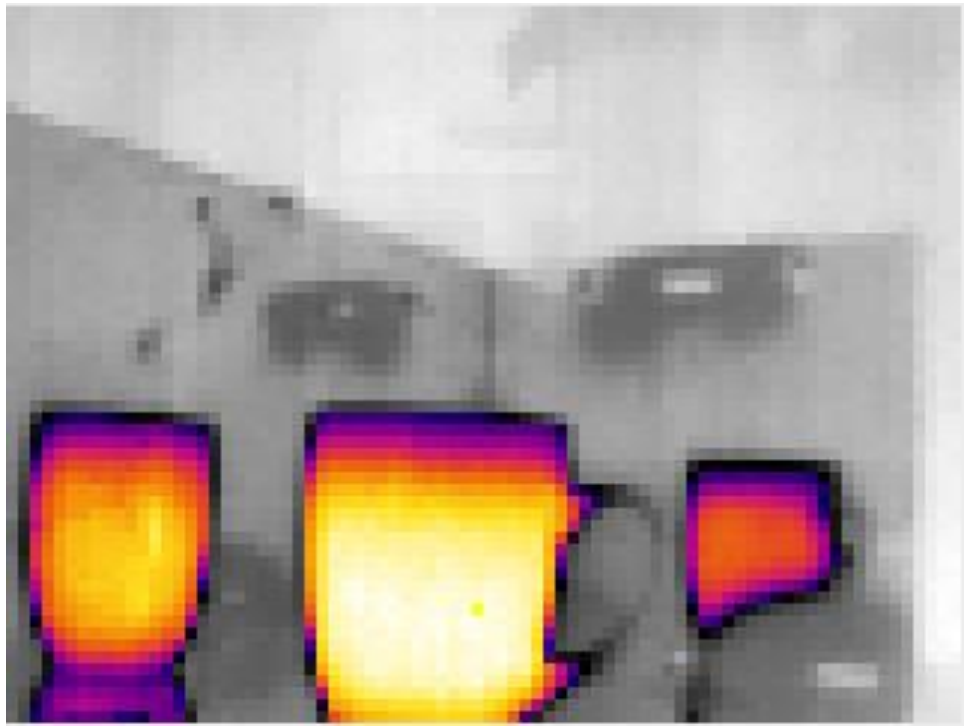






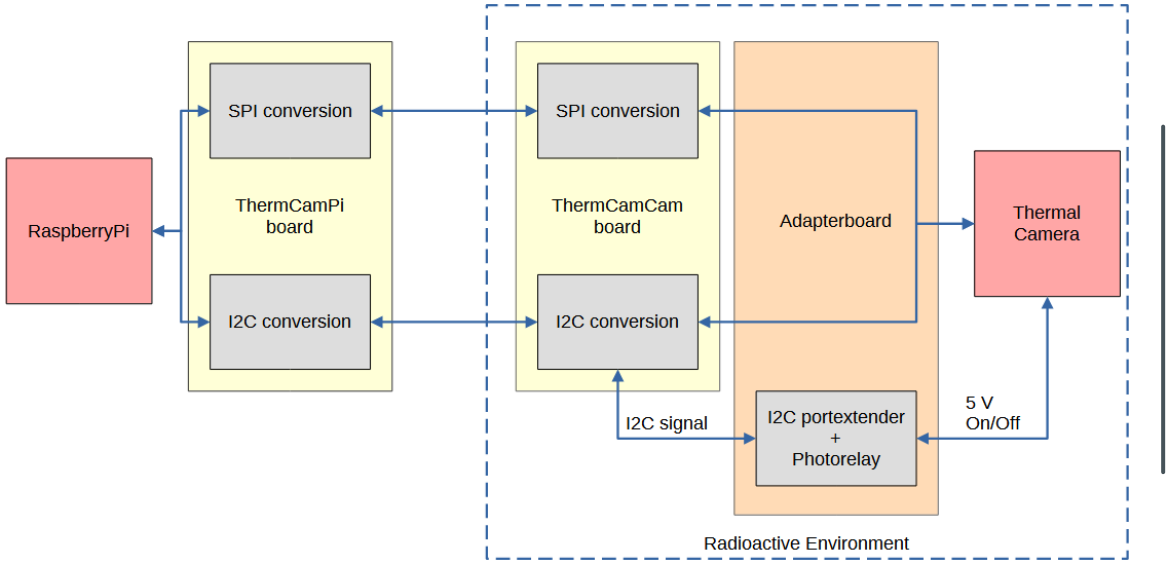
THERMCAM_V1

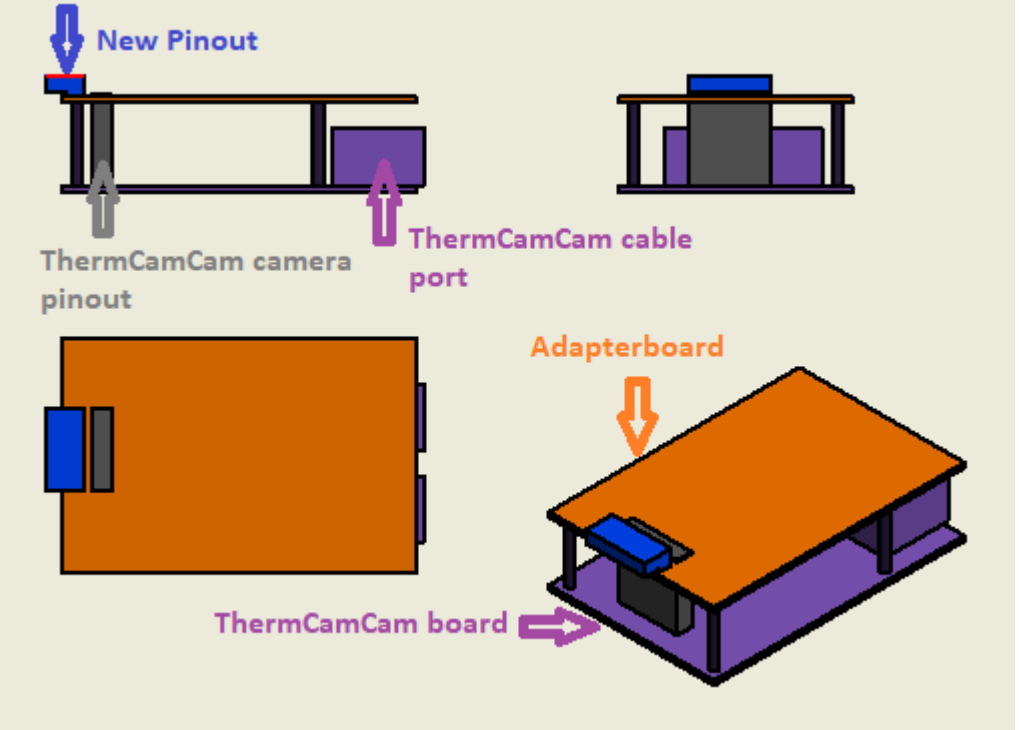
- Preliminary tests were successful (5μA, 855MeV, 3 days)
- Proper stress test not yet available



THERMCAM_V1

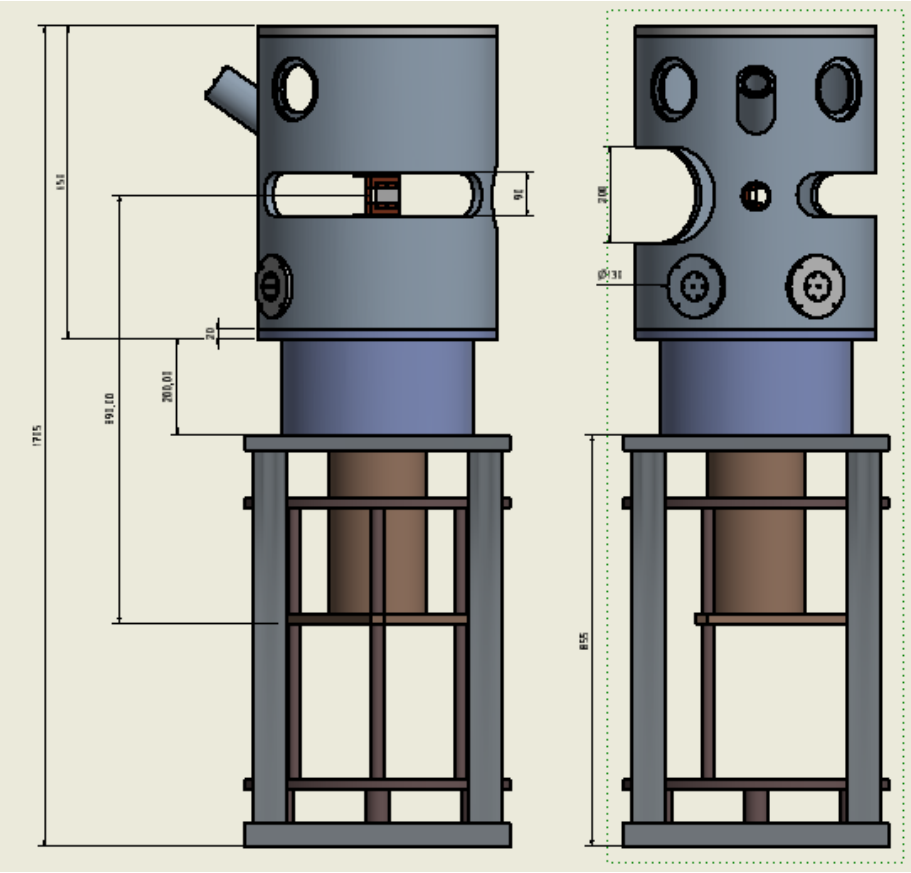
- Cup with hot water
- Thermal camera sees reflections of heat on aluminum walls

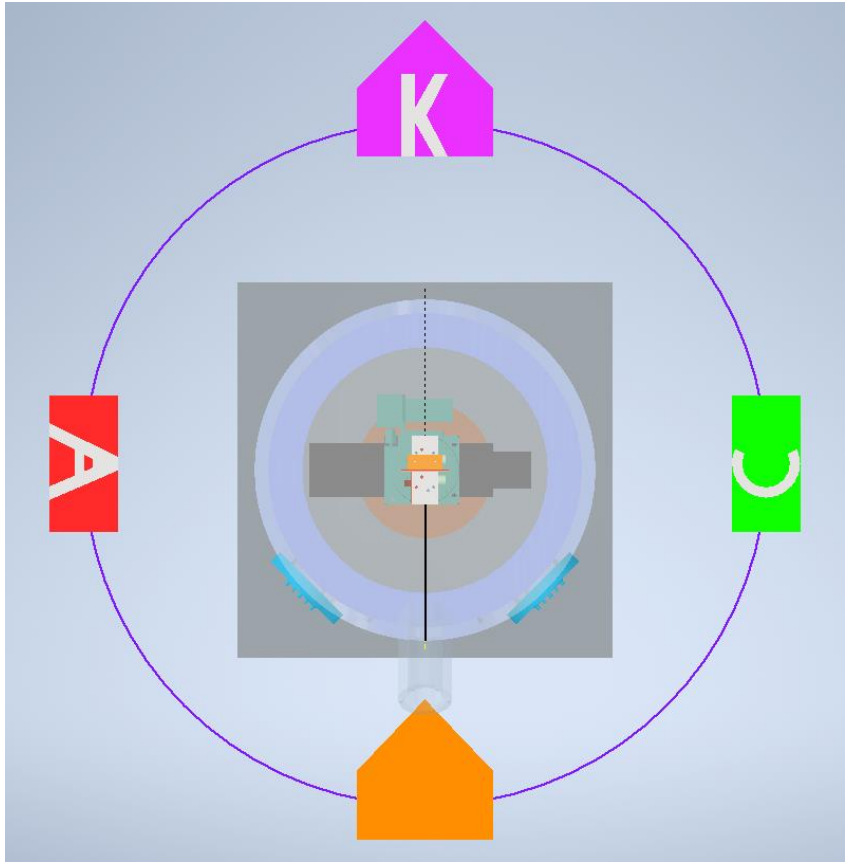




POSSIBLE UPGRADES

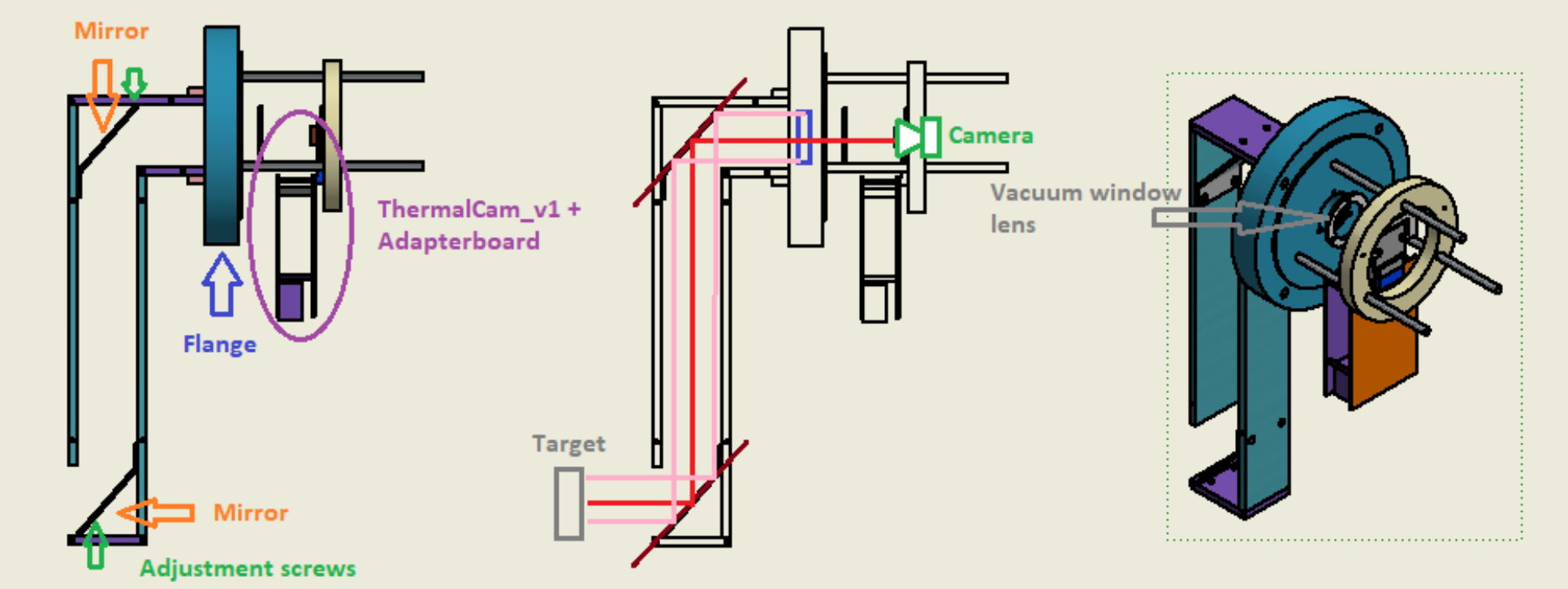
- Camera On/Off
- Compatibility with new breakout boards





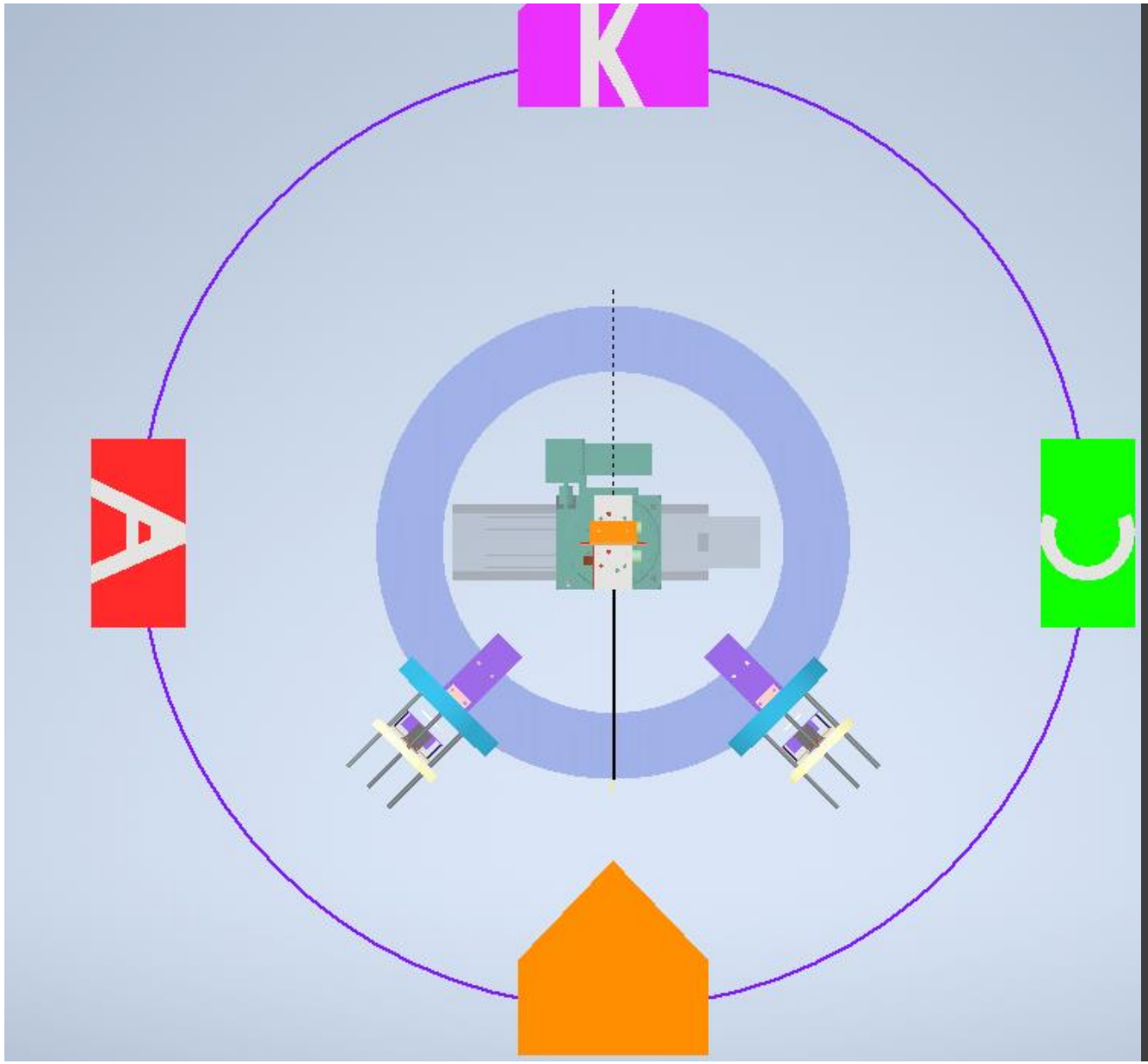
SETUP AT THE TARGET CHAMBER

- Flanges at 135° (45°)
- Periscope to bridge height difference
- Offers good view without obstructing spectrometers



THE PERISCOPE

- GaAs lens as vacuum window
- Aluminum sheets as mirrors



SUMMARY

- Lithium target difficult to calibrate
- Beam trajectory visualization with thermal camera
- RaspberryPi for camera operation cannot be close to sources of radiation
- Signal transformation into LVDS for long distance operation
- Successful operation of thermal camera tested over 7m

THANK YOU FOR YOUR ATTENTION

SOURCES

- *Präzisionsmessung der Λ-Separationsenergie von* ${}^{4}_{\Lambda}H$ *am Mainzer Mikrotron*, Dissertation, Florian Schulz, Dez. 2015
- *Vorarbeiten für genaue und präzise Messungen leichter Hyperkernmassen mit der A1-Spektrometeranlage am MAMI*, Dissertation, Philipp Herrmann, 2021
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- Wolfgang Demtröder, *Experimentalphysik 3*, Springer Verlag, 5. Auflage, 2015, ISBN 978-3-662-49093-8
- https://en.wikipedia.org/wiki/Microbolometer
- Texas Instruments, SNx5LVDSxx High-Speed Dierential Line Drivers, SLLS261M {JULY 1997{REVISED DECEMBER 2014, Product data sheet.
- NXP Semiconductors, PCA9615, 2-channel multipoint Fast-mode Plus dierential I2C-bus buer with hot-swap logic, Rev. 1.1 | 10 May 2016, Product data sheet.
- https://learn.sparkfun.com/tutorials/i2c
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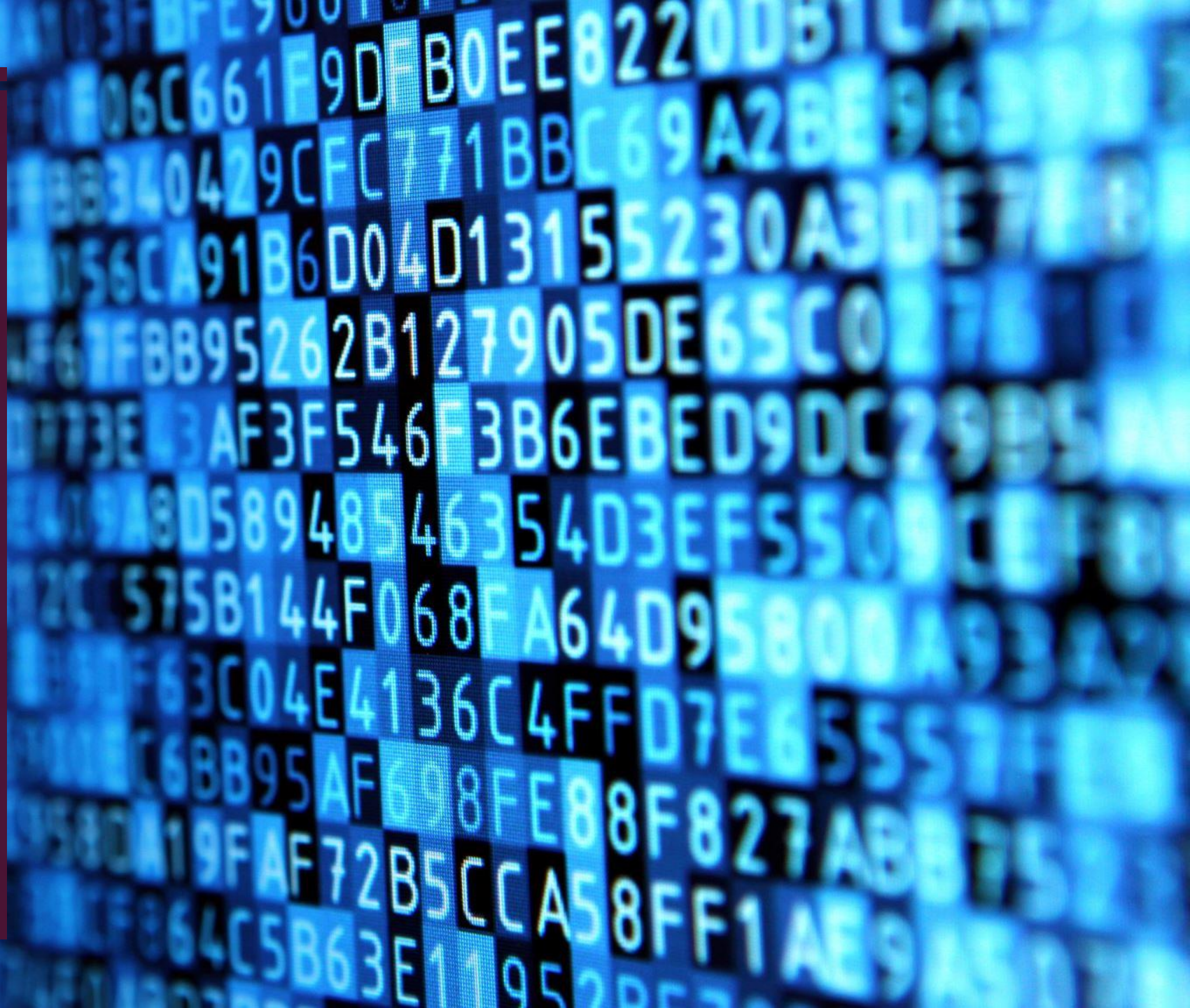
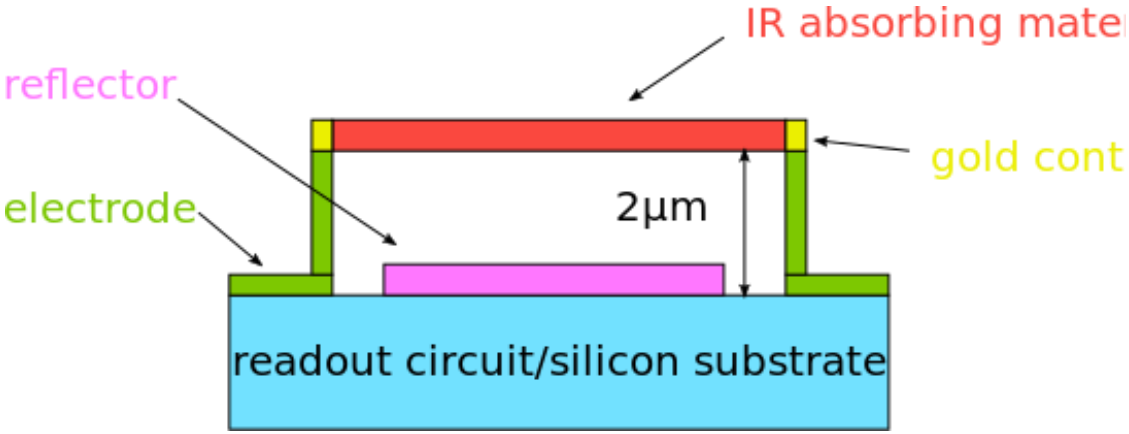
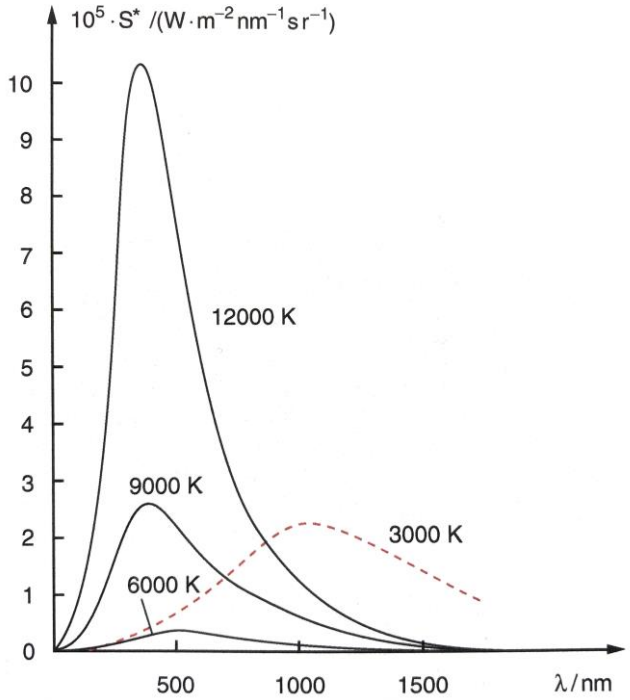
- https://www.sparkfun.com/
- Patrick Achenbach, Sergio Alves Garre, Philipp Eckert, Saül Garcia Orrit, Philipp Herrmann, Pascal Klag, Marten Mildeberger, Josef Pochodzalla, on behalf of the A1 Collaboration, Masashi Kaneta, Yoshihiro Konishi, Sho Nagao, Satoshi N. Nakamura, Yuichi Toyama and Toshiyuki Gogami, *Status of hypertriton binding energy measurements at the Mainz Microtron*, https: //www.worldscientific.com/doi/abs/10.1142/9789811219313_0123
- https://www.autodesk.de/products/inventor/overview

BACKUP





https://en.wikipedia.org/wiki/Microbolometer

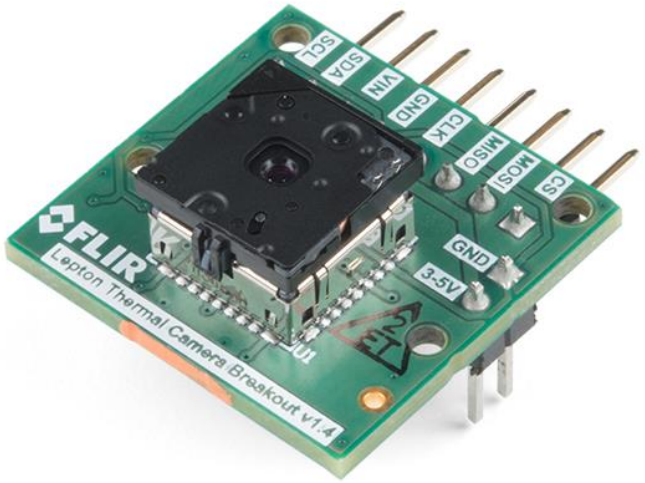


Wolfgang Demtröder, *Experimentalphysik 3*, Springer Verlag, 5. Auflage, 2015, ISBN 978-3-662-49093-8

THERMAL RADIATION

- Cross section of microbolometer
- Spectral distribution of a perfect black body
- 3000 K curve magnified by 100
- Amount of power radiated scales with T^4

https://www.sparkfun.com/products/15948



https://www.sparkfun.com/products/retired/14654

BREAKOUT BOARD VERSIONS

- New breakout board features double lined pinout
- Setup was designed for single pinout of old version