



R³B Commissioning Experiments with Final CALIFA Setup



Supported by BMBF 05P15WOFNA and 05P19WOFN1.

The results presented here are based on the experiment s444/s473, which was performed at the beam line/infrastructure Cave C at the GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (Germany) in the frame of FAIR Phase-0.

GEFÖRDERT VOM

Tobias Jenegger

R³B Experiment

PSI Seminar

16.06.2021

CALIFA – Design and Upgrades

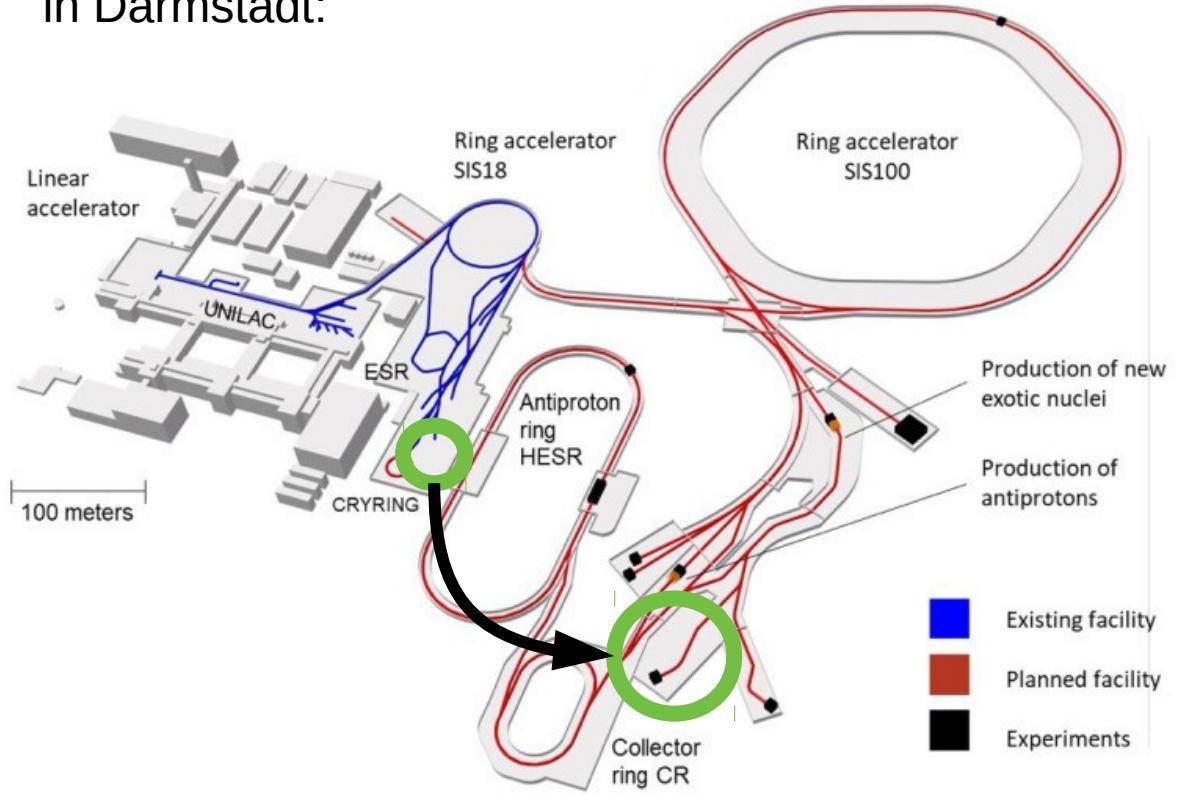
QFS Analysis

R³B @ GSI

TUM Members:

Roman Gernhäuser, Lukas Ponnath, Philipp Klenze, Tobias Jenegger

R³B as part of the
Facility for Antiproton and Ion Research (FAIR)
in Darmstadt:



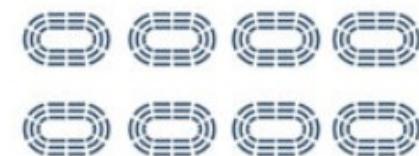
Tobias Jenegger



- 2 mio. m³ of earth excavated
- 600,000 m³ of concrete
- 65,000 tons of steel



5,000 single family homes



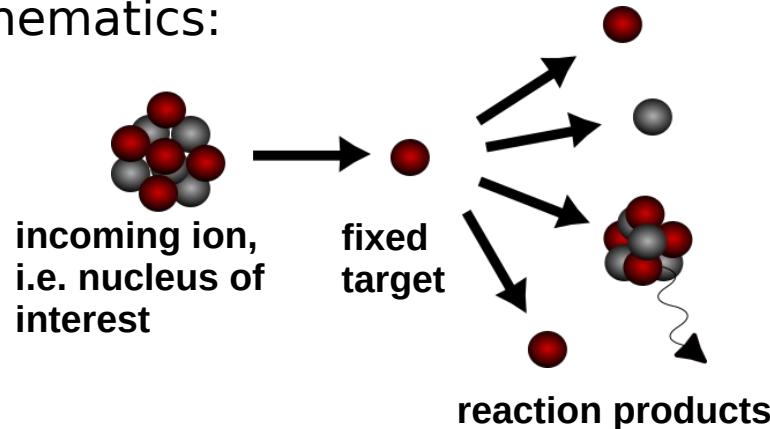
eight Frankfurt soccer stadiums



nine Eiffel Towers

Reactions with Radioactive Relativistic Beams

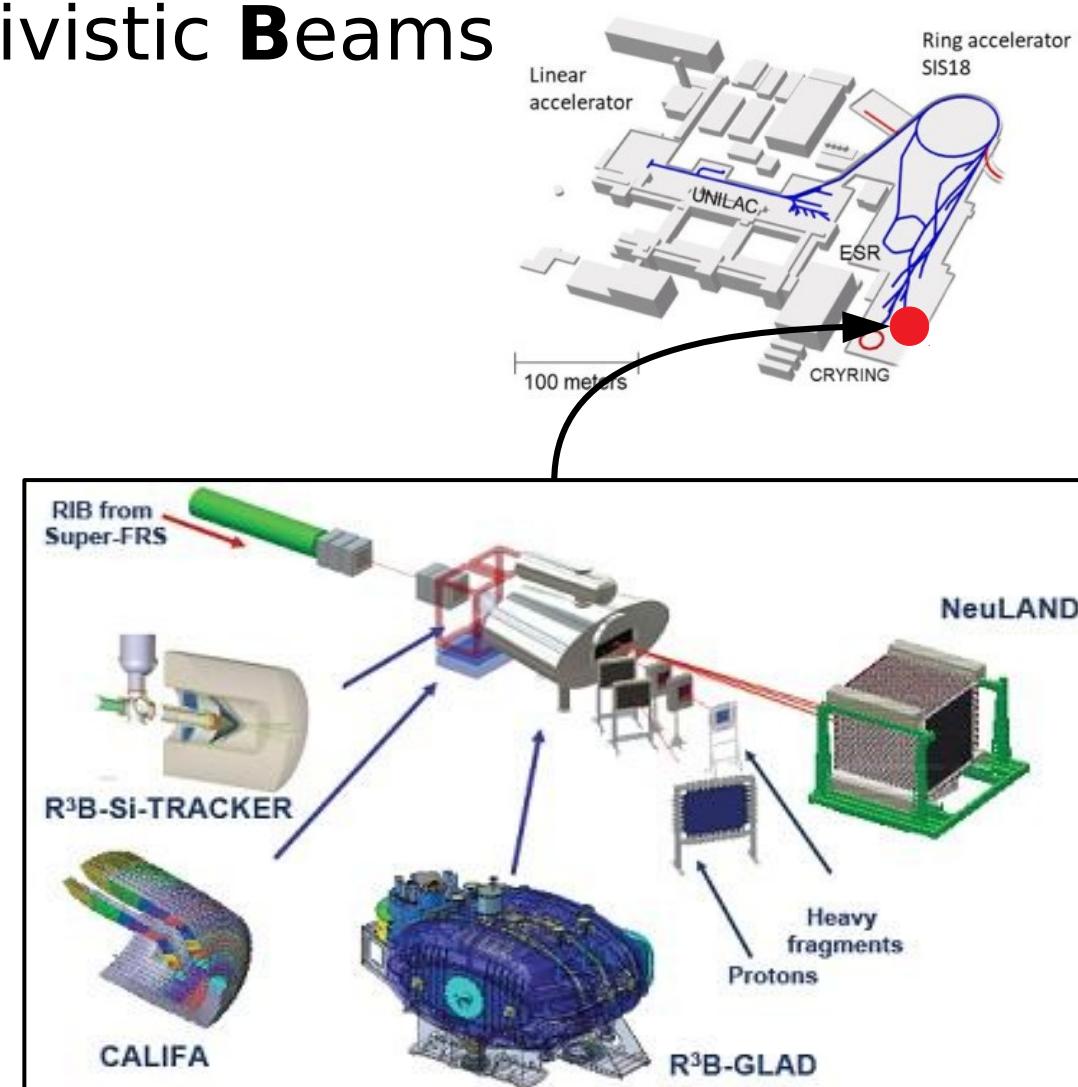
- Physics program on exotic nuclei in inverse kinematics:



- kinematically complete measurements
- In flight production of exotic nuclei from fragment separator Super-FRS
- Flexible setup, extensive physics schedule (despite pandemic restrictions)

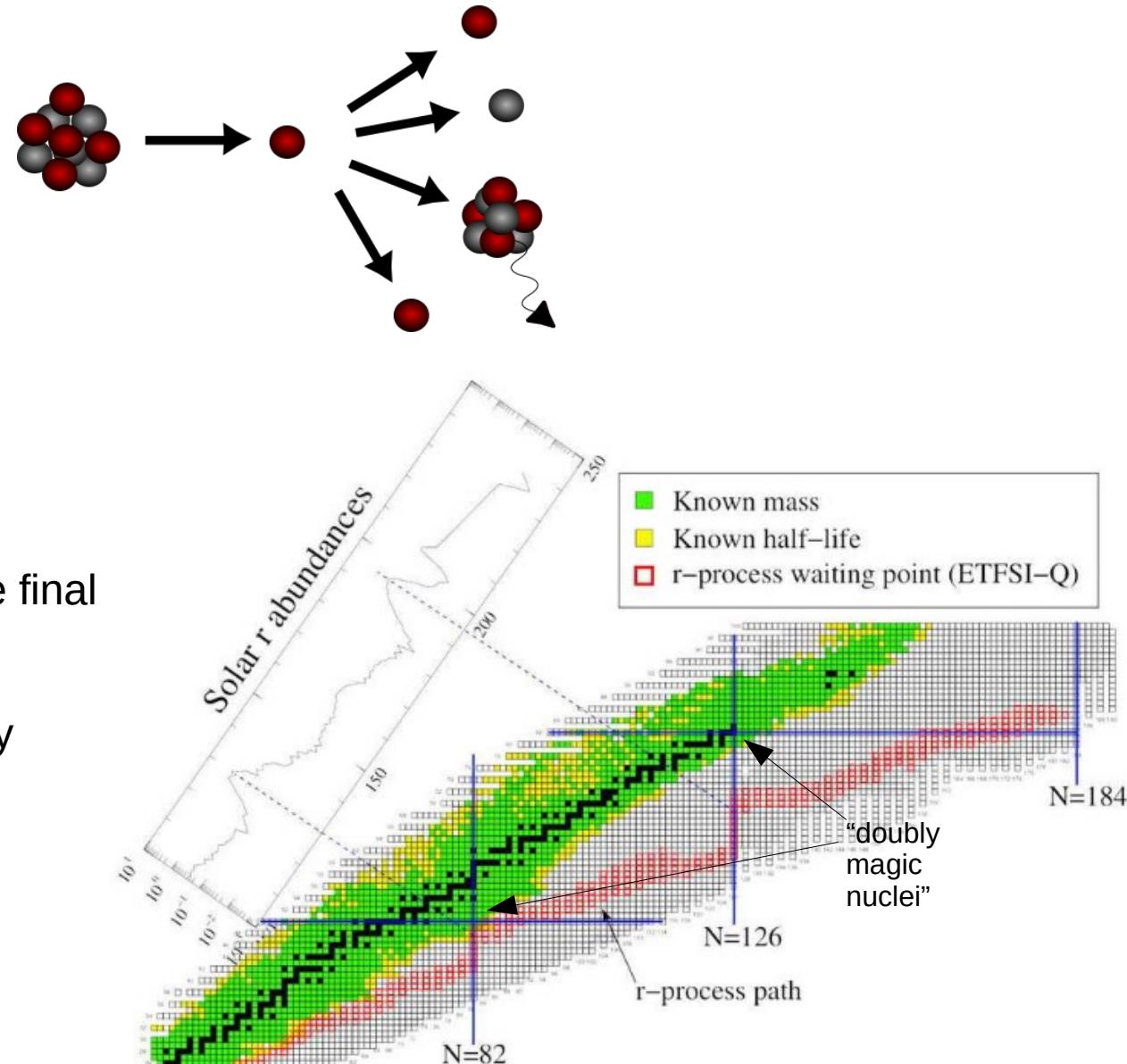


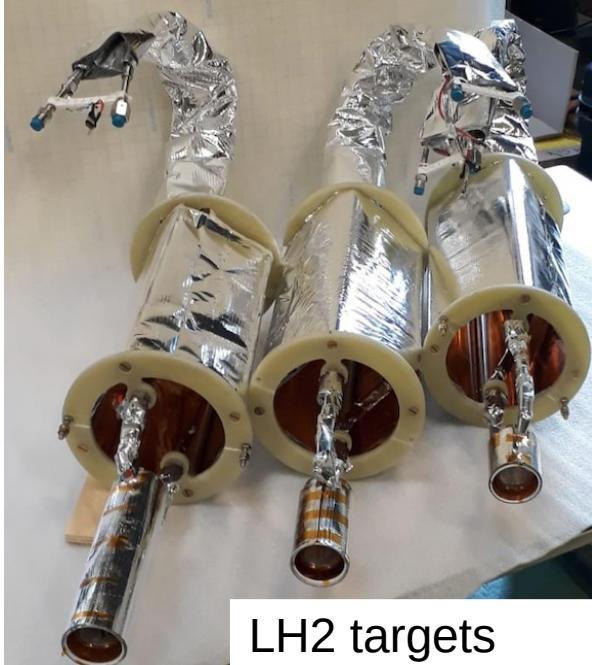
Tobias Jenegger



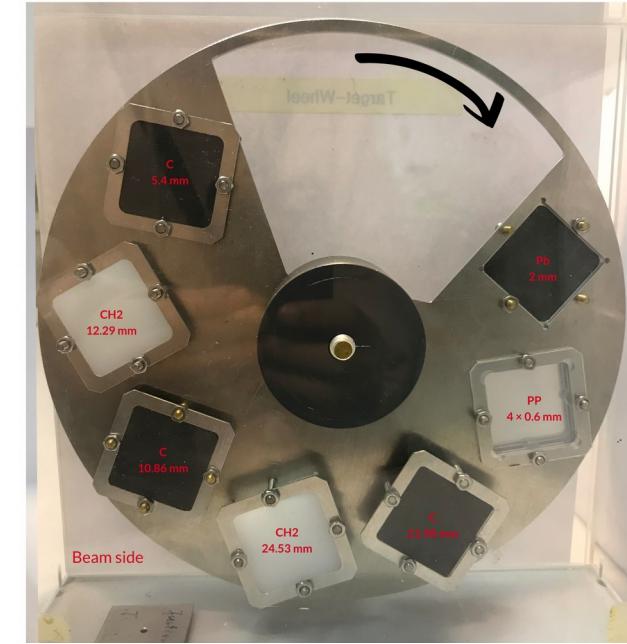
Right now two major physics fields:

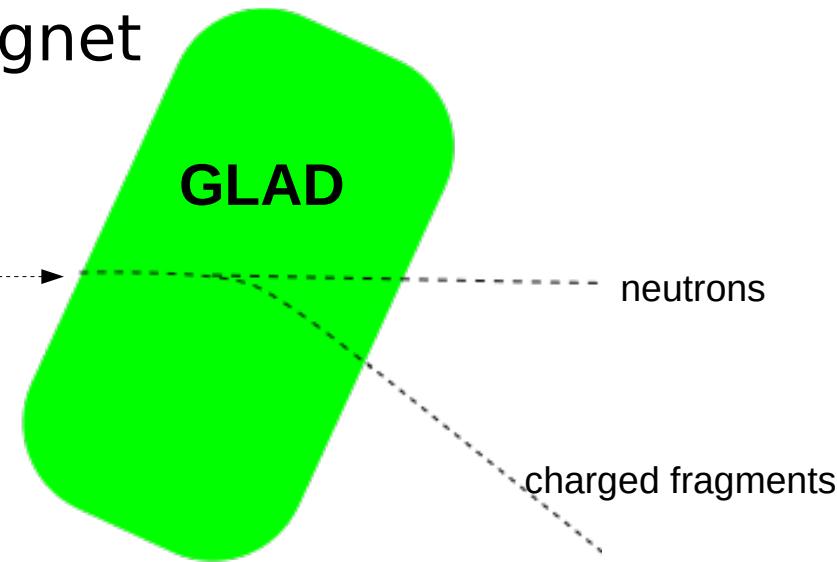
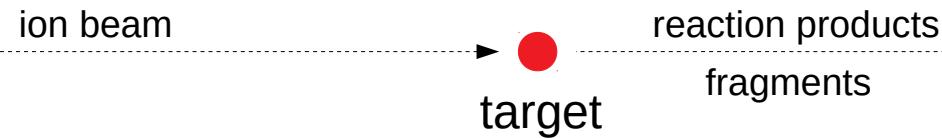
- Quasi Free Scattering (QFS)/Knockout reactions
 - study single particle properties inside nuclei
 - analyze shell evolution far off stability
 - measurement of Fermi-momentum, separation energy
- Fission Studies (up to uranium)
 - fission yields are important to understand e.g. the final r-process abundance
 - measurement of the fission barriers far off stability
 - collective excitations in neutron rich exotic nuclei, e.g. Pygmy dipole – resonance, neutron halos





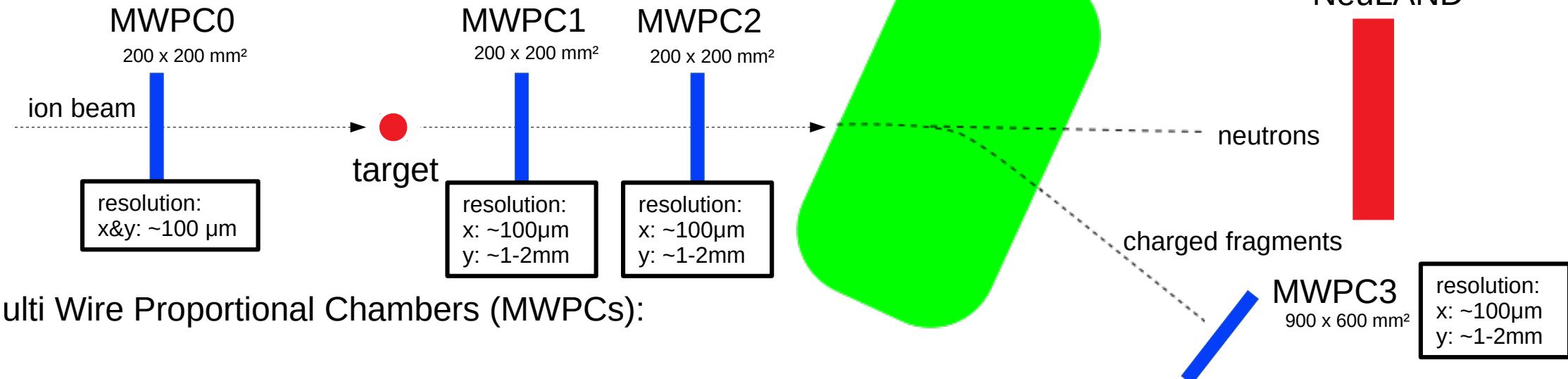
Target Wheel



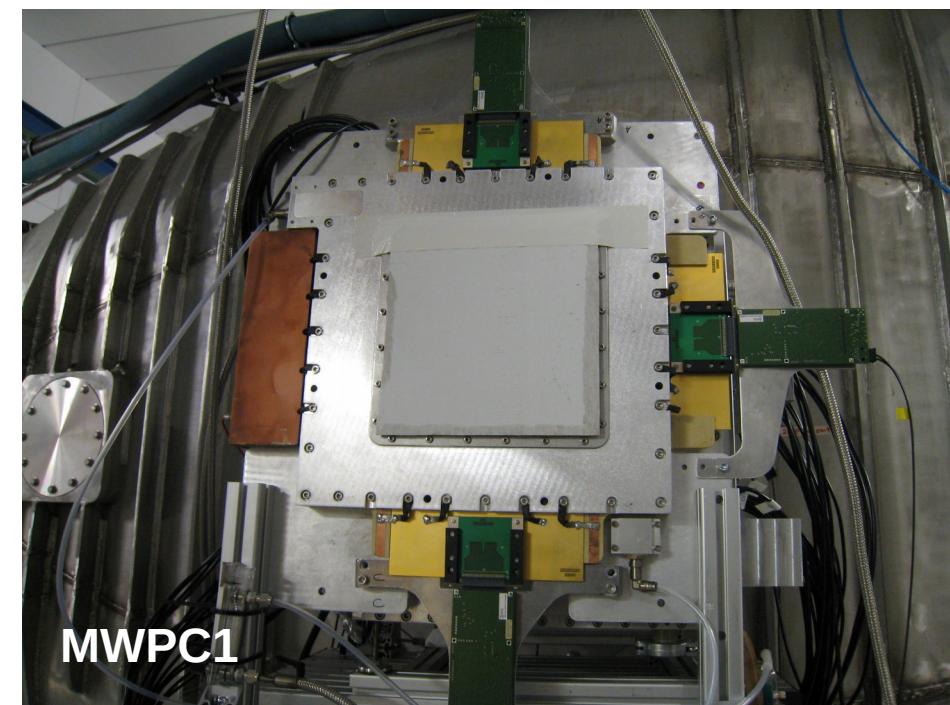
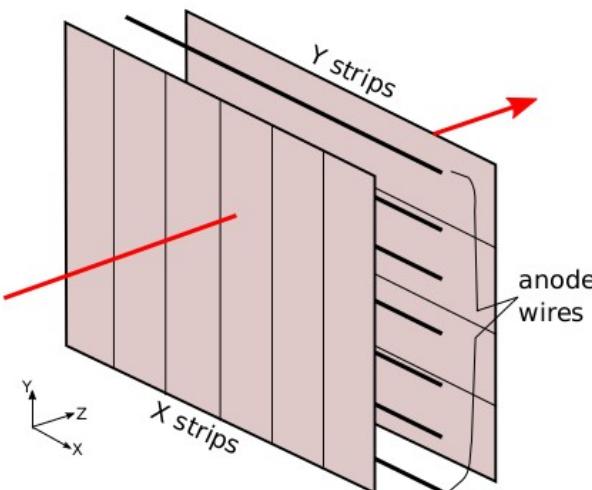


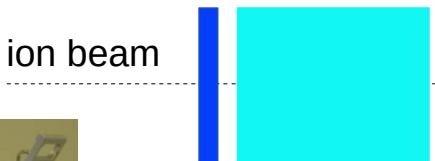
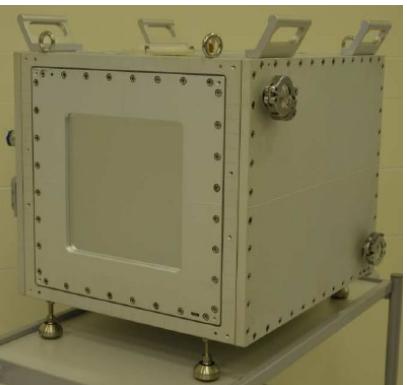
- large vertical gap (+-80 mrad) for neutrons
- High bending angle of 40°
- field integral of about 5 Tm
- momentum resolution $\Delta p/p$ of around 10^{-3}

Tracking Detectors



- vertical/horizontal wires: 50 μm diameter, 2.5 mm spacing
- vertical/horizontal pads:
Al-evaporated on a 12 μm Mylar foil,
5/3.125 mm width (vertical/horizontal)
- gas mixture: 84% Ar, 16% CO₂
- readout signal from influenced pads





R³B MUSIC

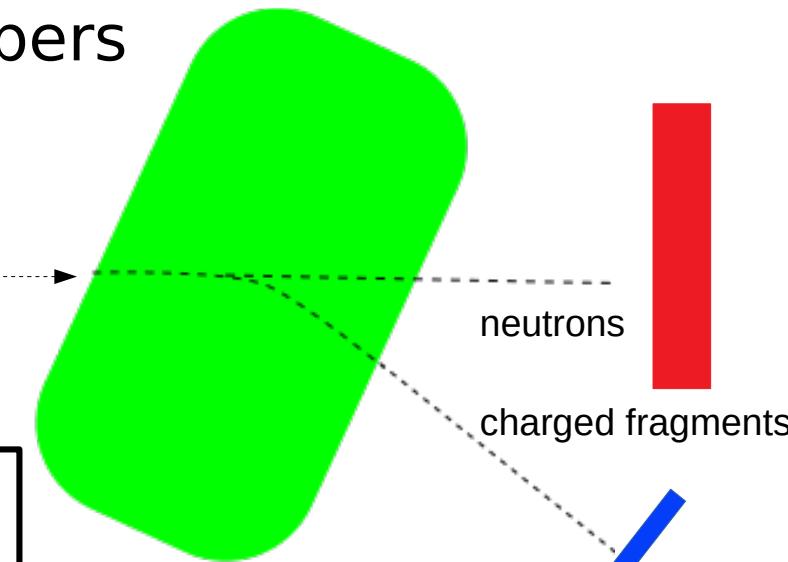
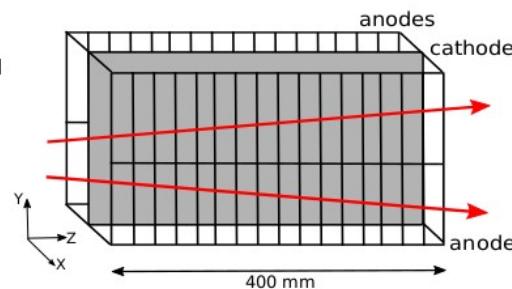
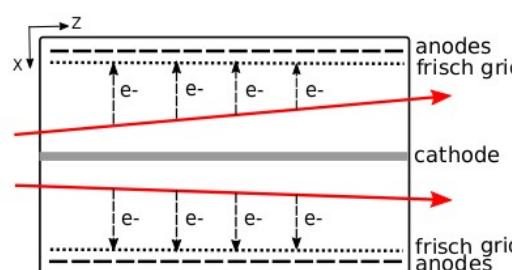
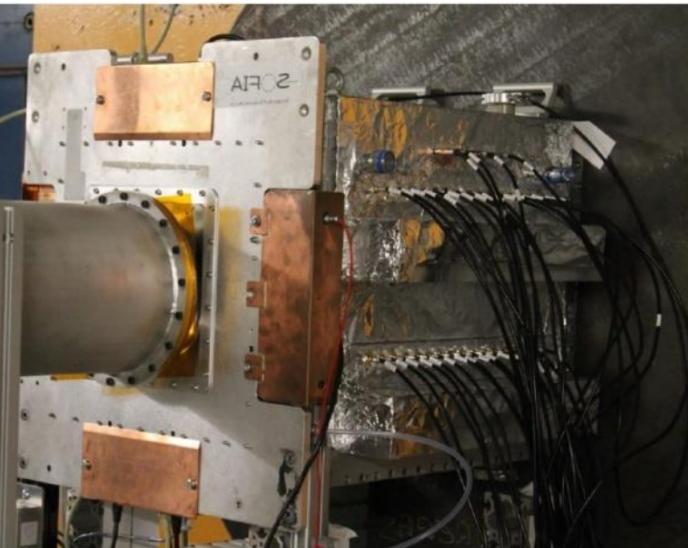
51 x 54 x 53 cm³
Cathode left side -
Anode right side
Gas mixture:
Ar 25%, CH4 75%

target

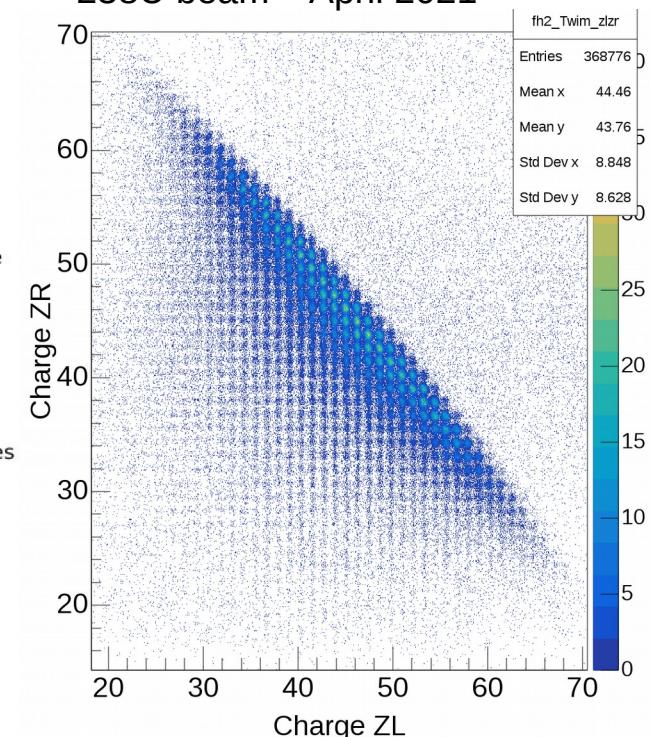


TWIM MUSIC

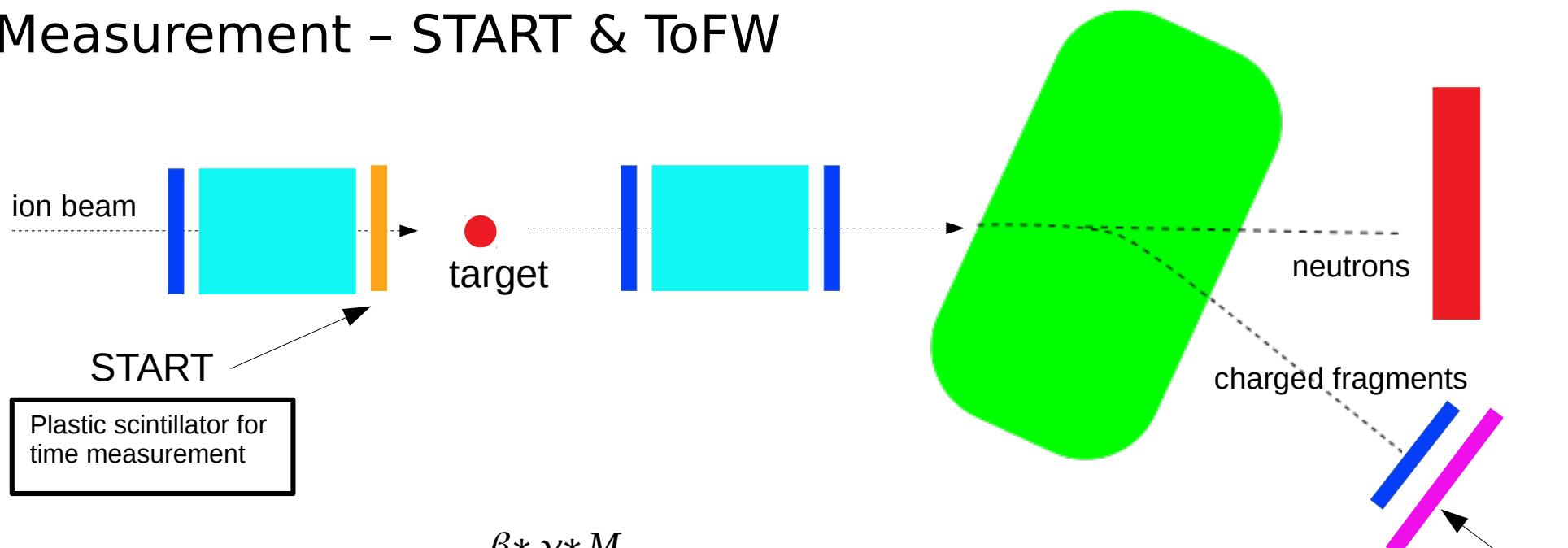
43 x 48 x 55 cm³
Double ionization chamber with
central cathode and two anode
planes
Frisch grid for better signal
quality and time resolution
Gas mixture:
Ar 25%, CH4 75%



238U beam – April 2021



Time Measurement - START & ToFW



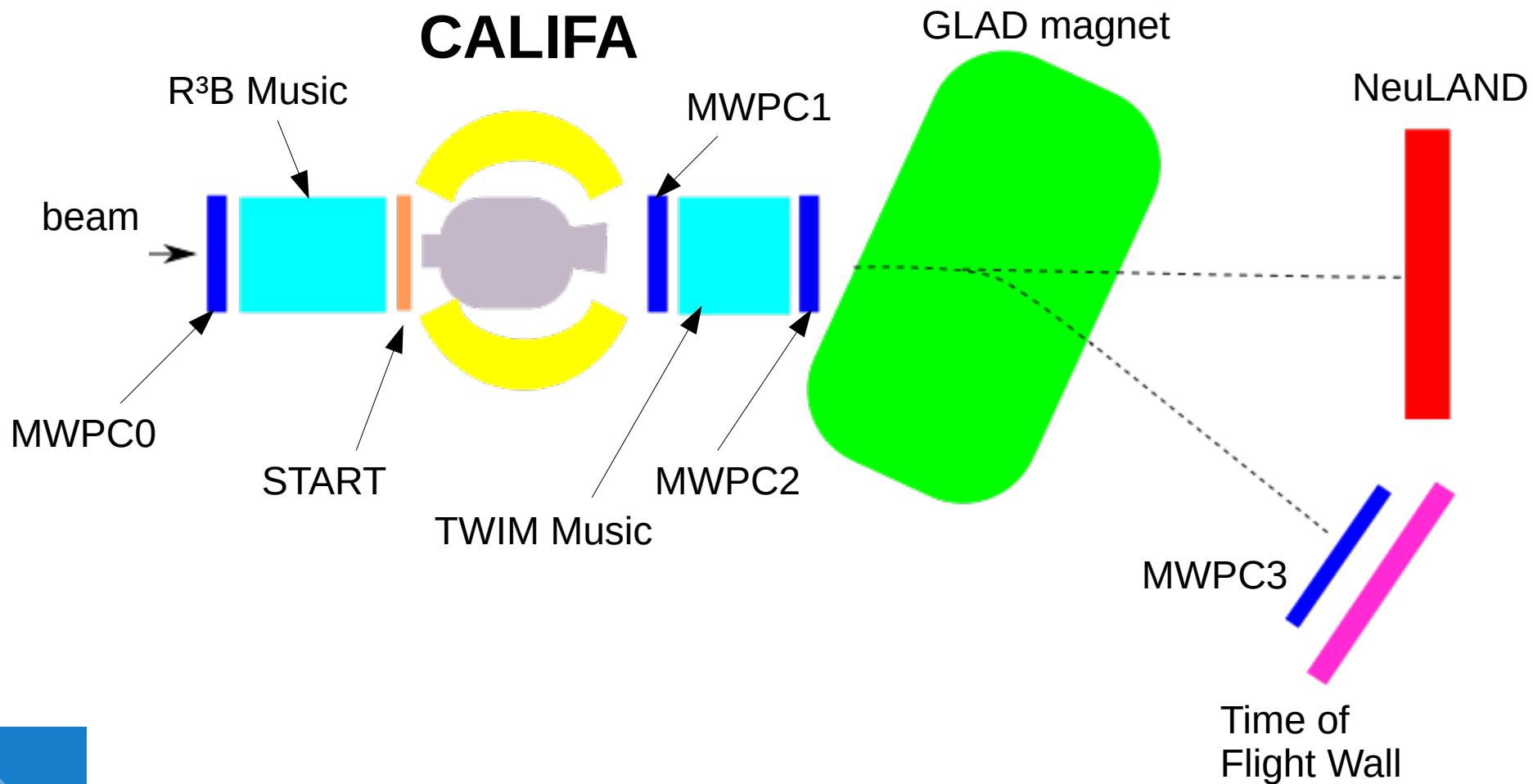
Particle Identification: $B * \rho = \frac{\beta * \gamma * M}{q}$

- ToF measurement: START to TOFW
- flight-path reconstruction: tracking detectors
- charge measurement: TWIM MUSIC



Time of Flight Wall
(ToFW)

27 vertical scintillators
(54 PMTs, up & down)
time and position
measurement



CALIFA Detector @ R³B

CALorimeter for the In Flight detection of γ -rays and light charged pArticles

Endcap:

iPhos:

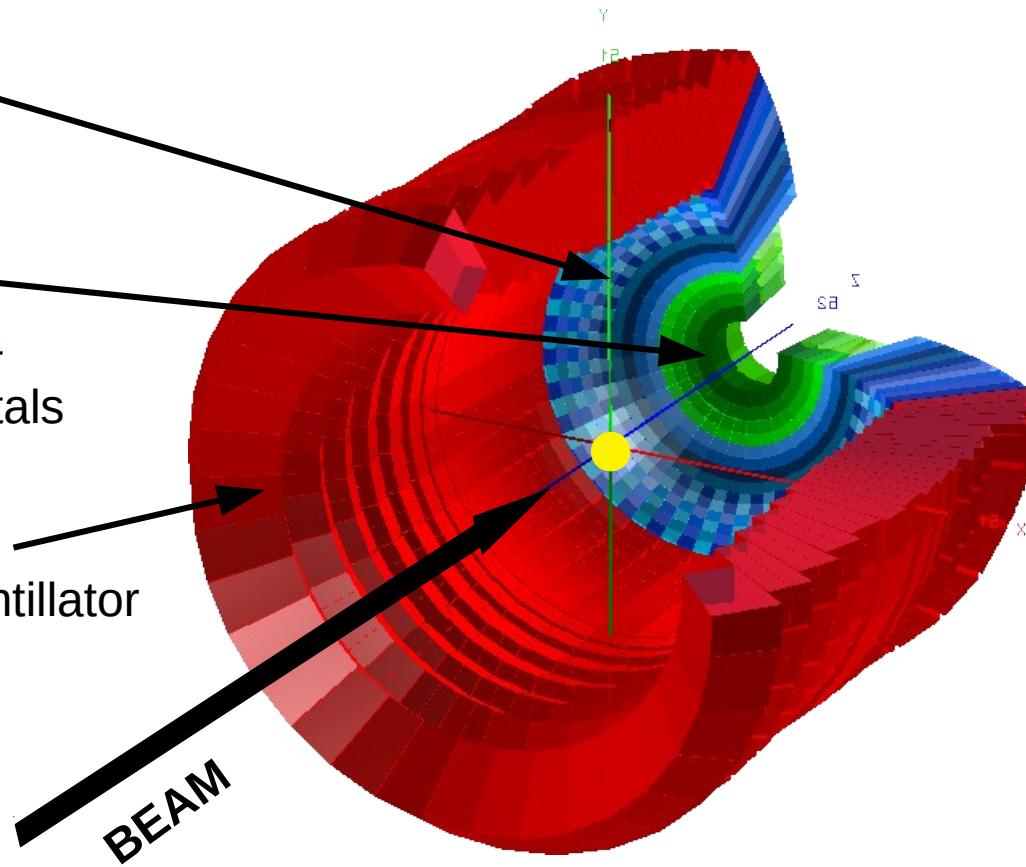
512 CsI(Tl)
crystals

CEPA:

96 LaBr₃ &
LaCl₃ crystals

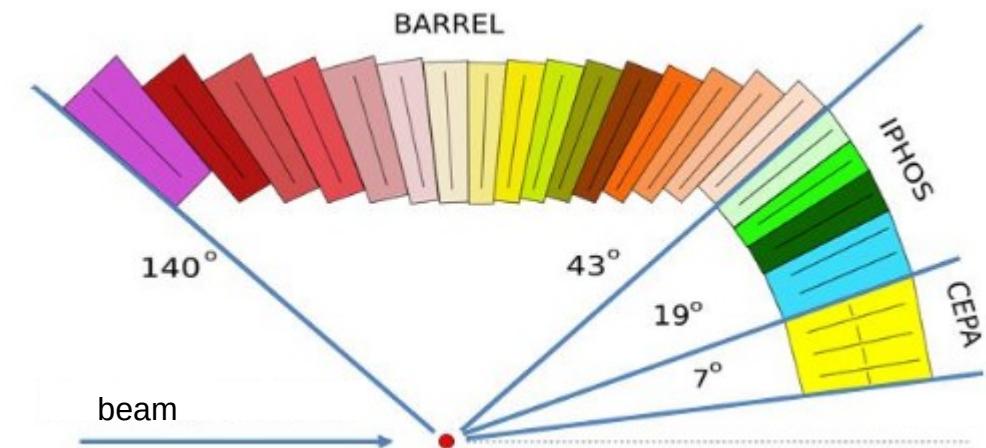
Barrel:

1952 CsI(Tl) scintillator
crystals



Requirements:

- high dynamic range:
100 keV γ -rays – 700 AMeV charged particles
- high efficiency
- high granularity → Doppler correction
- particle identification



Signal Processing @ CALIFA

γ /particle interaction in **crystal** → scintillatorlight (550nm)

Every crystal connected to one **APD** → signal current

APDs connected to preamplifier:

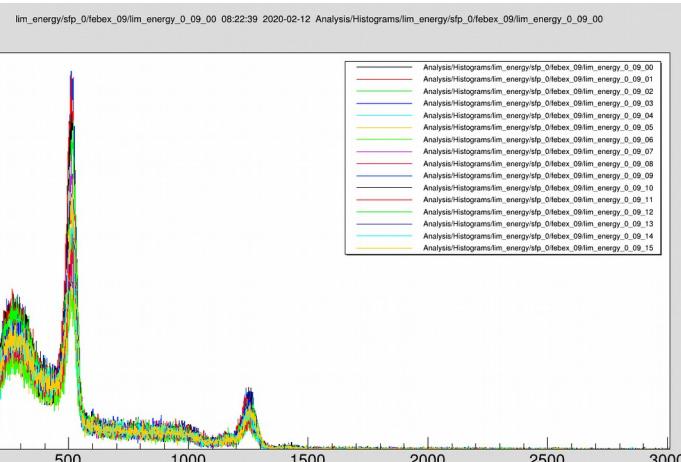
- generates HV for APD bias
- amplifies (integrates) the signal from the APDs

Add-on Board:

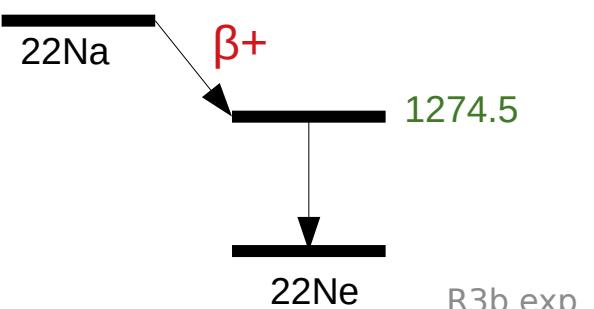
- Nyquist Filtering (<25 MHz)
- DC offset: Signal from preamp is positive, ADC range of FEBEX ADC $\pm 0.9V$

On FEBEX:

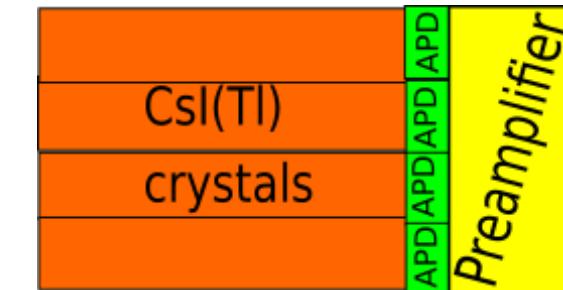
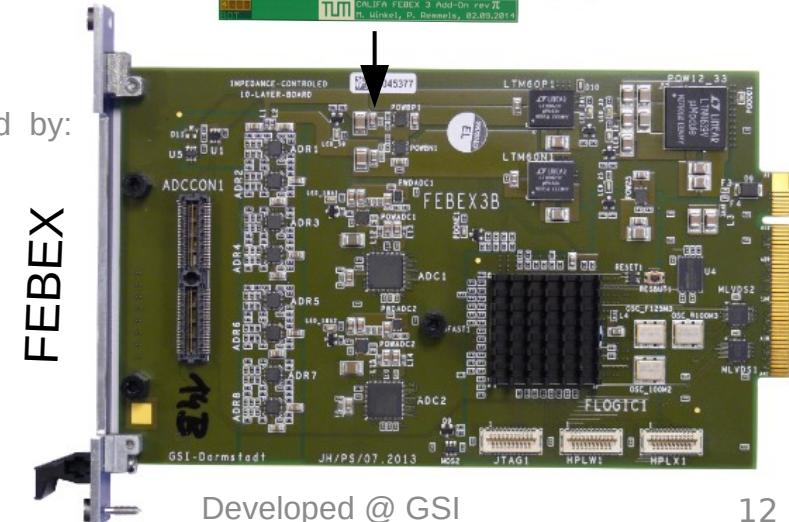
- Energy and particle identification



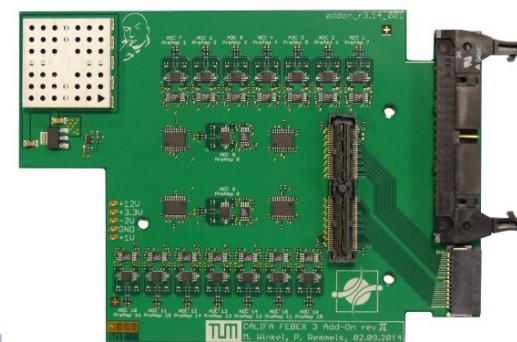
E.g. 22Na decay:



Firmware developed by:
Michael Bendel,
Max Winkel,
Benjamin Heiss,
Philipp Klenze,
Patrick Remmels,
et al.



Add-on Board





Electronics for CALIFA



Each rack:

→ 1024 channels

→ 50 MHz continuous sampling rate

Dead-time free readout design:

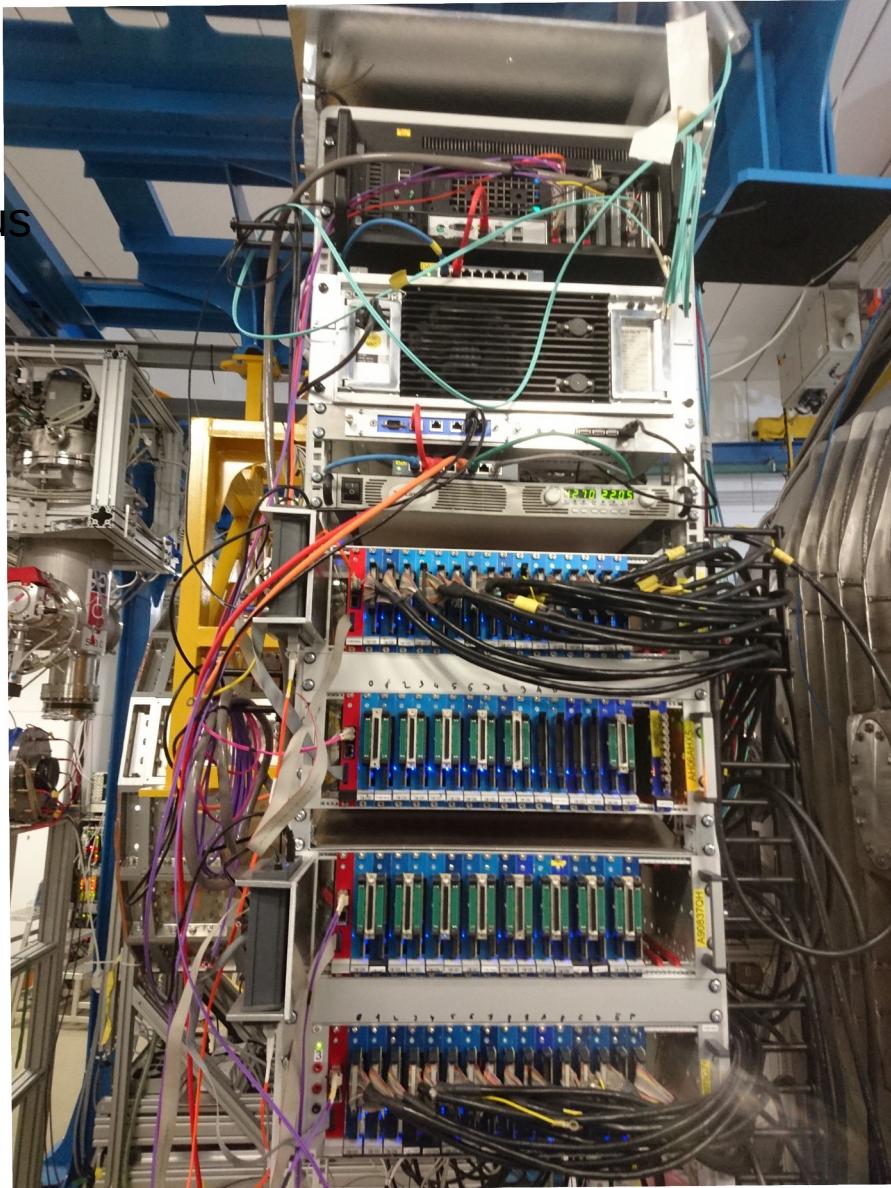
→ PEXOR card

→ TRIXOR card

→ EXPLODER

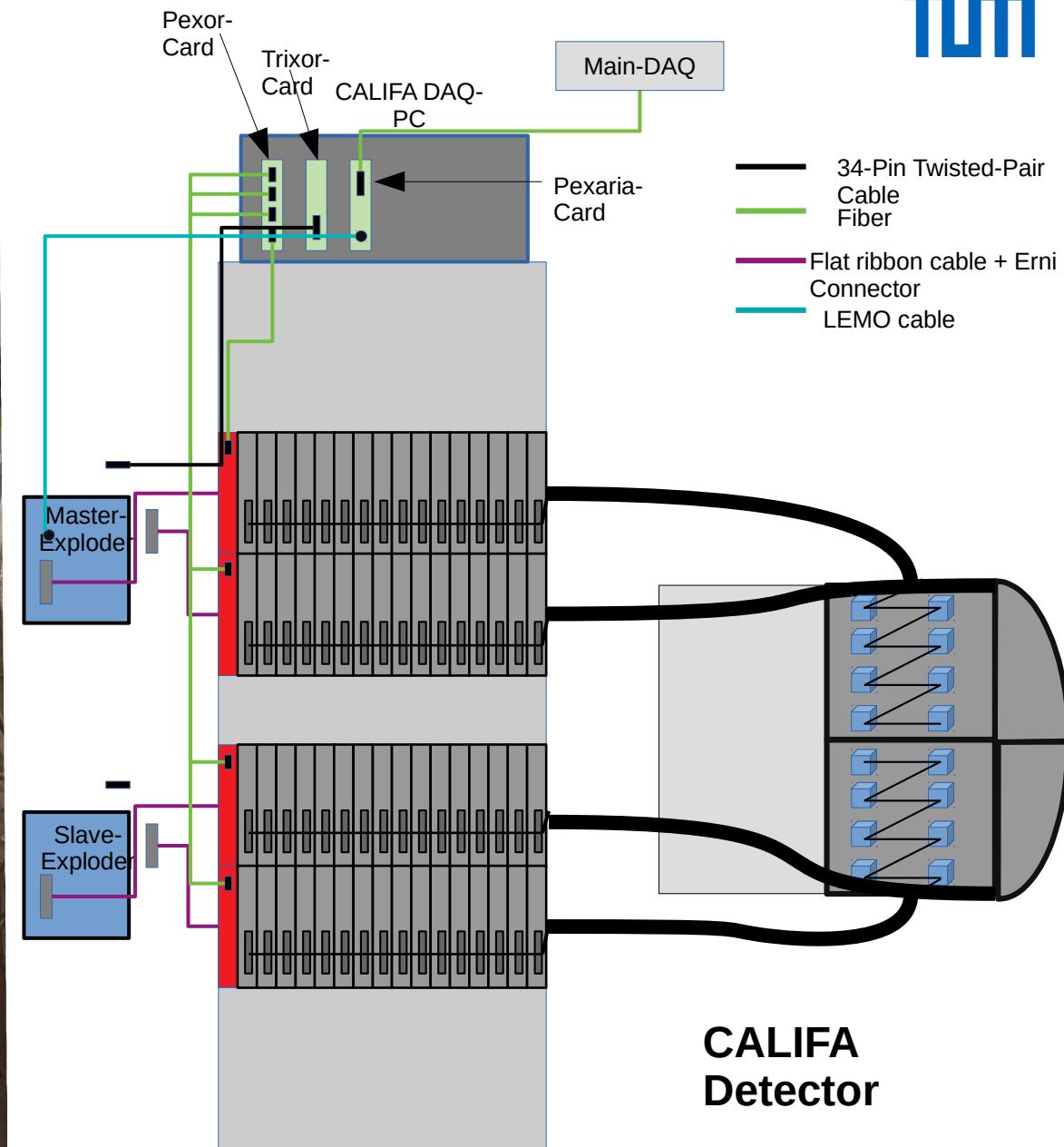
→ PEXARIA (white

Rabbit timestamp)



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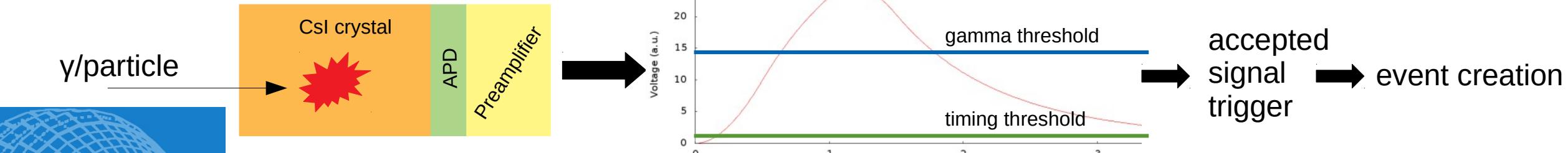
R3b exp



Discriminator-Threshold Logic:

- **Timing Trigger**: event time assignment
 - **Gamma Trigger**: gamma reconstruction
 - **Proton Trigger**: proton reconstruction
-
- discriminators can be used flexibly over trigger matrices
(e.g. timing and proton trigger for external detector triggering)

Intuitive event building logic...



-timing/gamma/proton trigger can be generated internally (exceeding threshold) or externally (trigger signal from other detector)

Trigger Modes:

- free running: each channel has its own signal trigger (e.g. internal timing & gamma trigger)
- synchronous and coincident (e.g. internal timing & external gamma trigger)

Readout Modes:

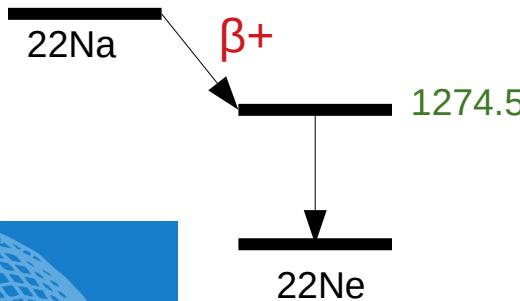
- single event readout: data is read out after each accepted signal trigger
- multi event readout (e.g. for free running trigger mode) :
 - events/data saved on FEBEX modules
 - if one module reaches a certain eventnr. value, all parameters are read out



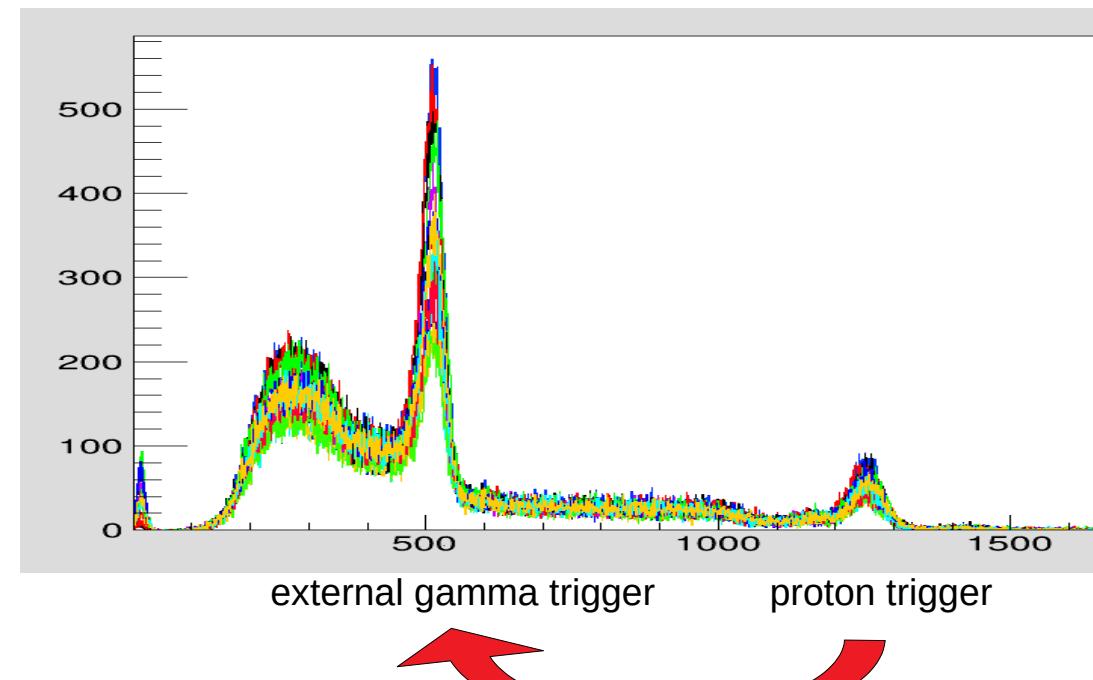
- for experiment in May 2021 with He test beam
- external gamma trigger input from START detector, internal timing trigger
- allows to only select CALIFA events in coincidence with other detector events

Testing:

- 22Na source
- Use γ - 1274.5 keV as proton trigger
- redirect proton trigger as external gamma trigger



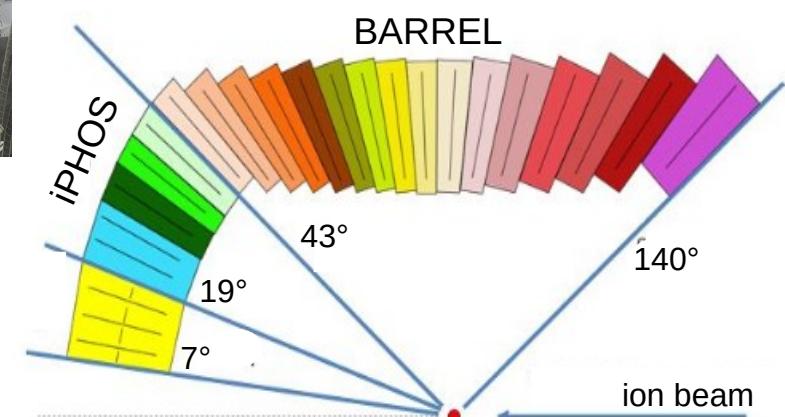
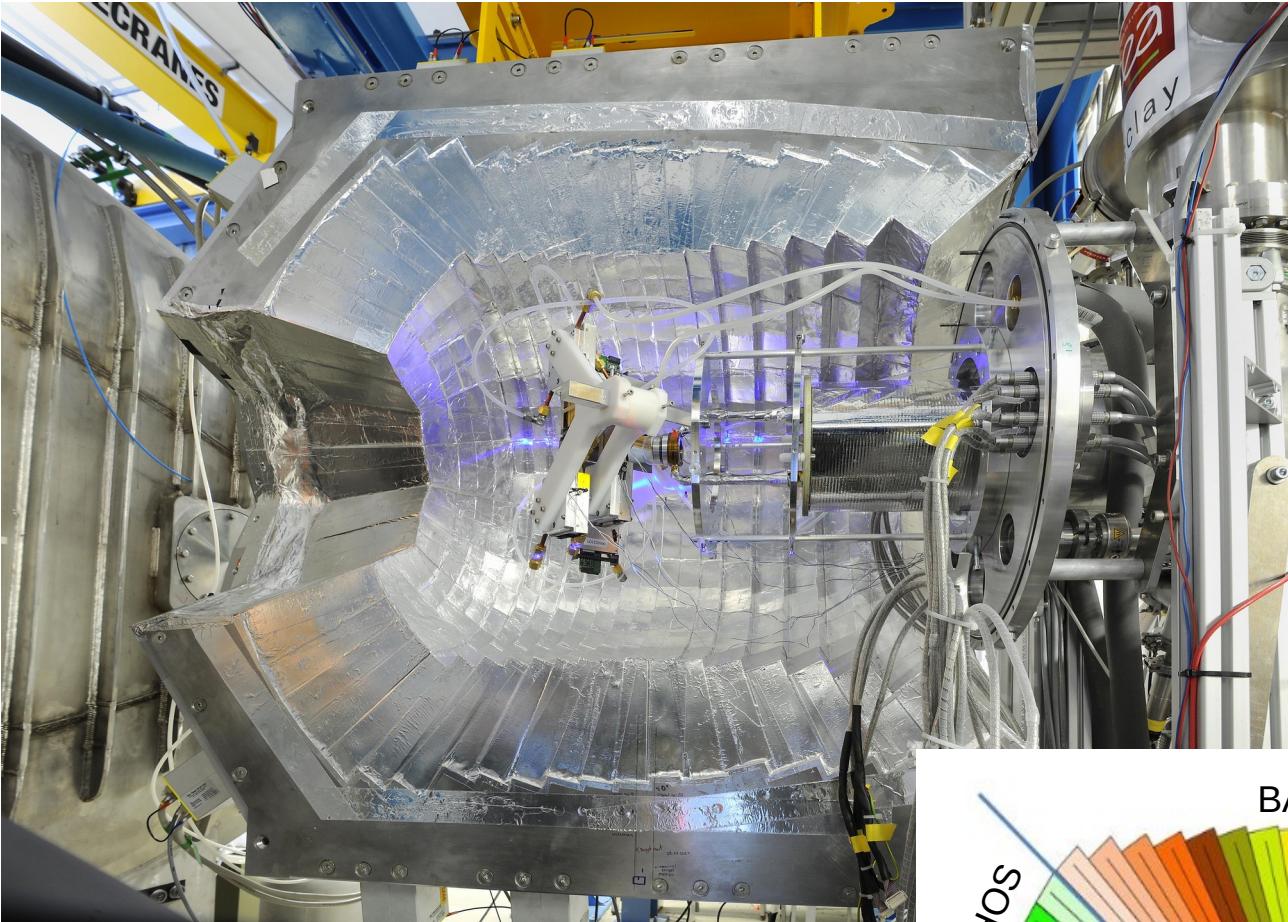
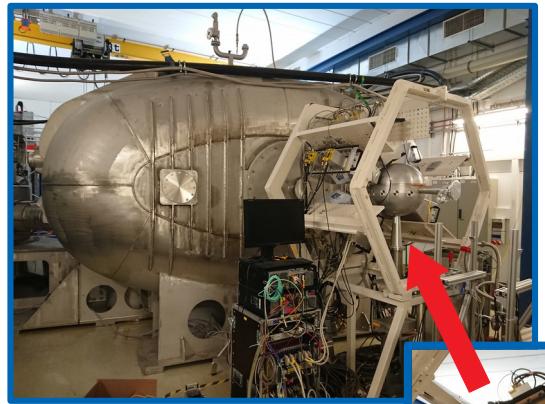
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CALIFA Upgrade 2021

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From Demonstrator to Final Setup



IPHOS region fully filled!



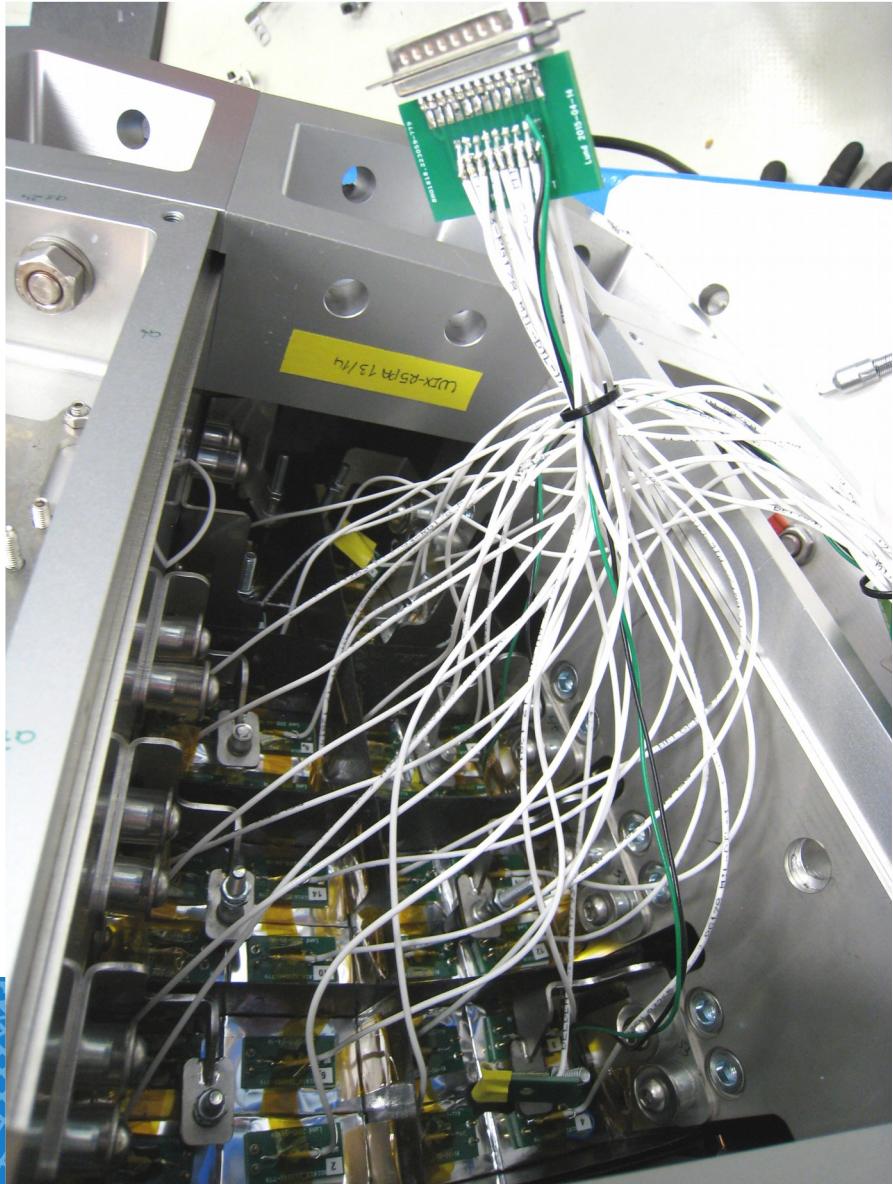
unmounting:



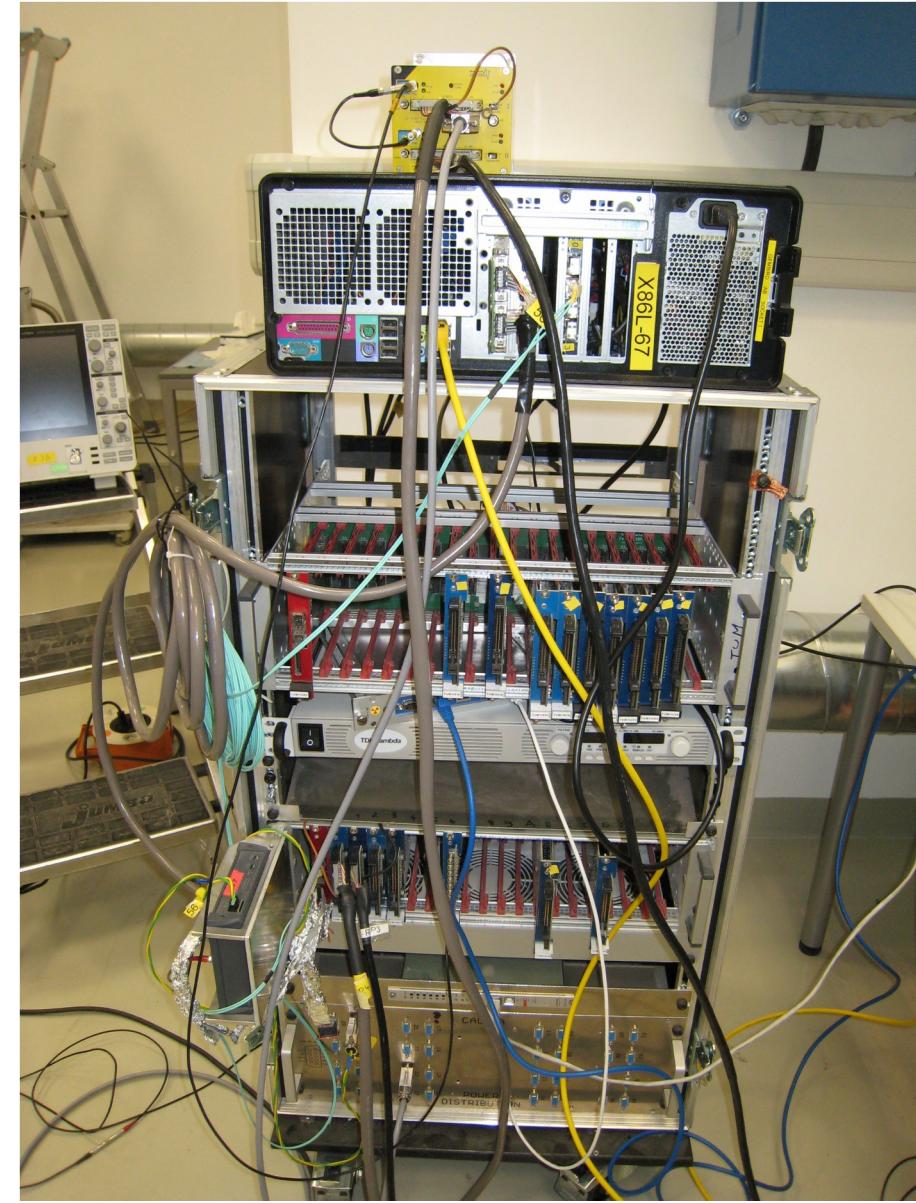
measure crystals & open tiles:



crystal filling:



testing with mobile DAQ:



bring back to Cave C:



mount and align:

