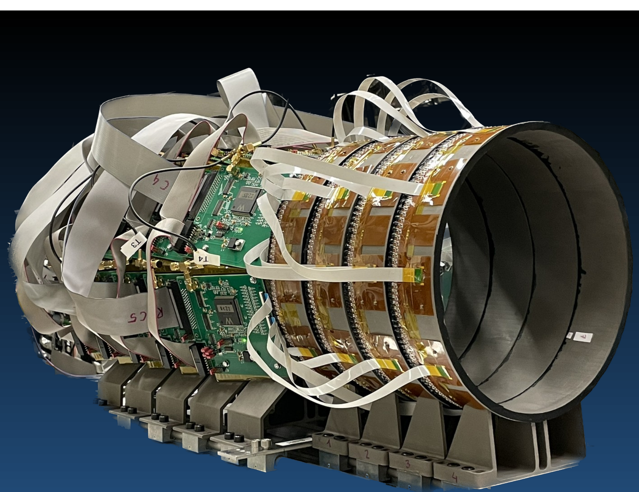

KRAB

detector for the ASY-EOS II experiment

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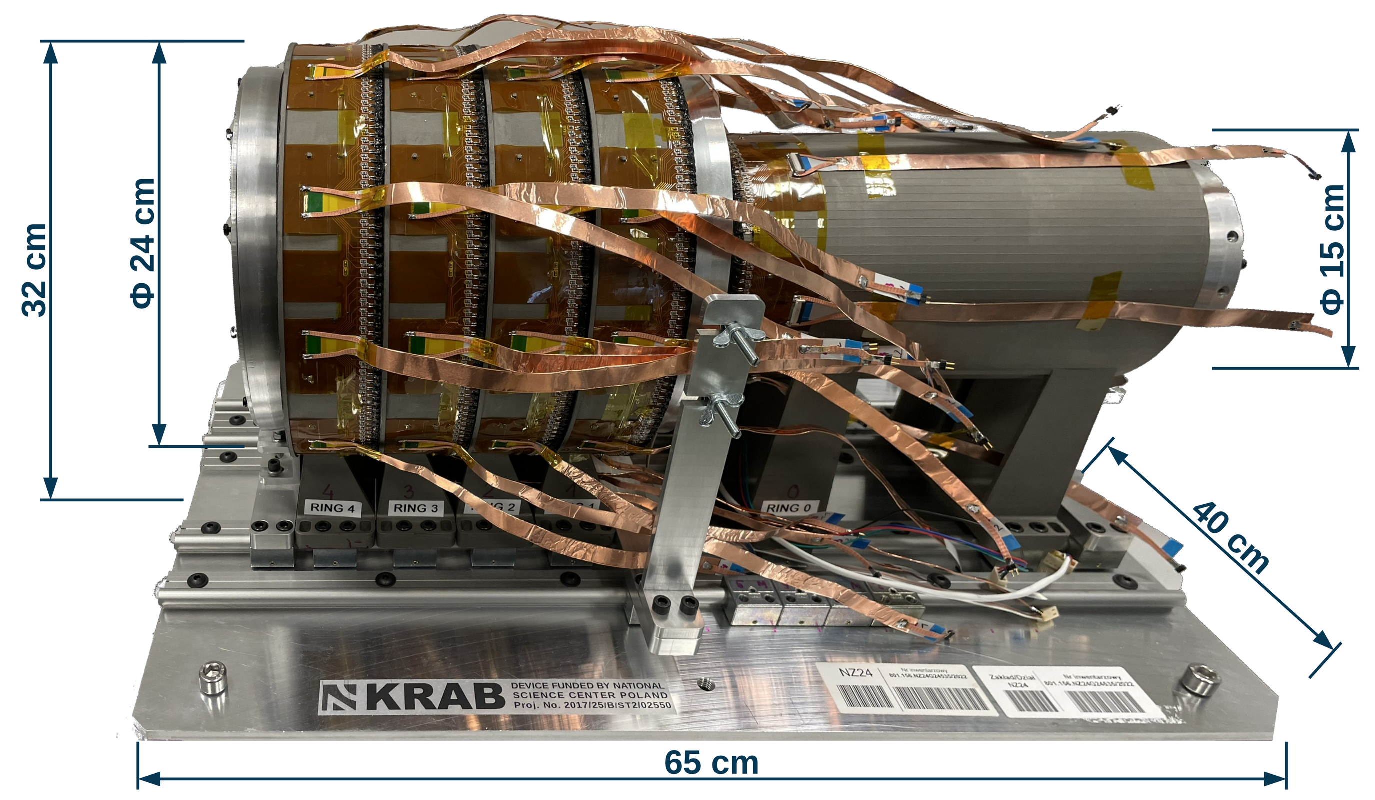
multiplicity trigger, reaction plane and centrality detector [1,2]

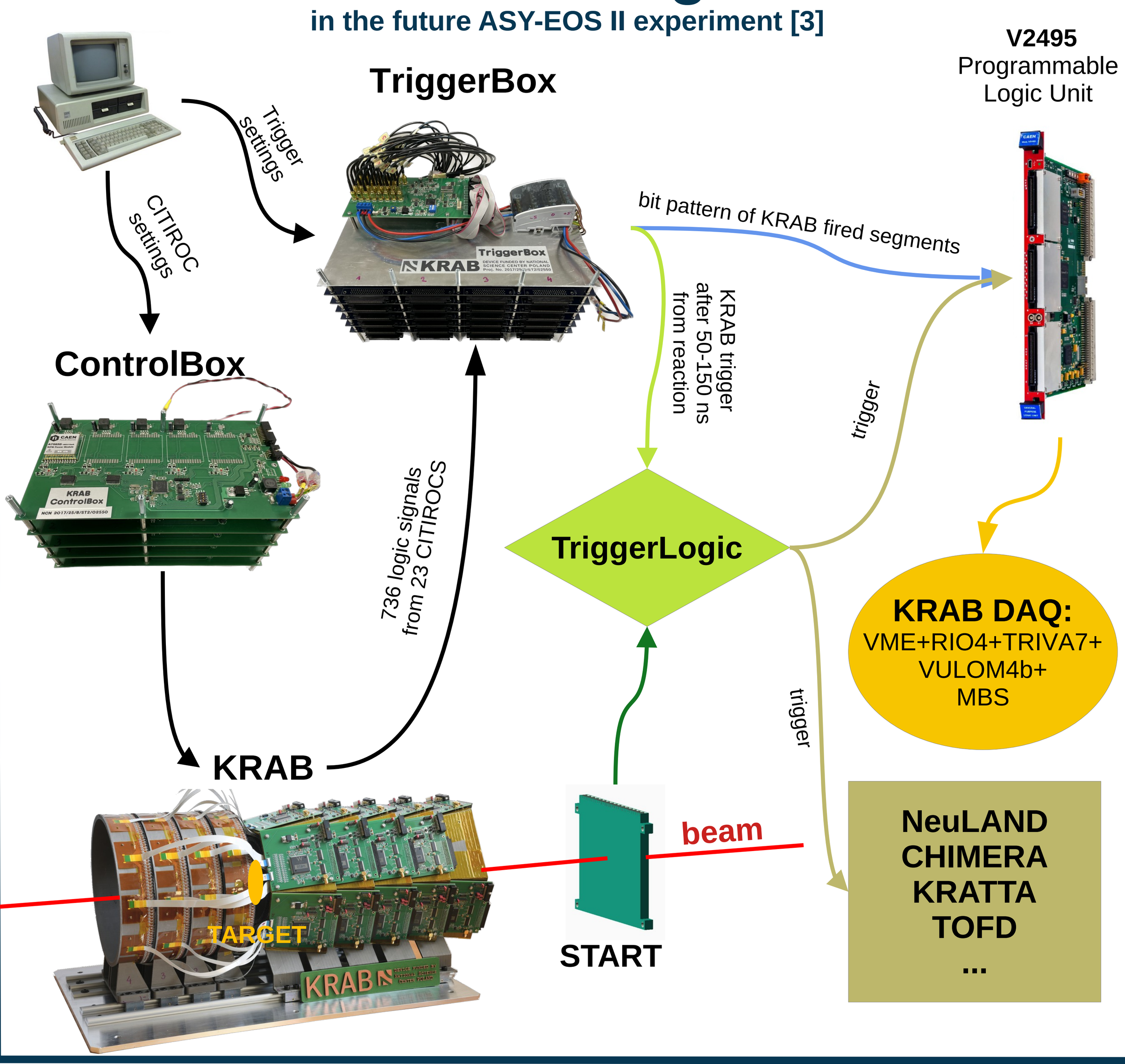


Main characteristics:

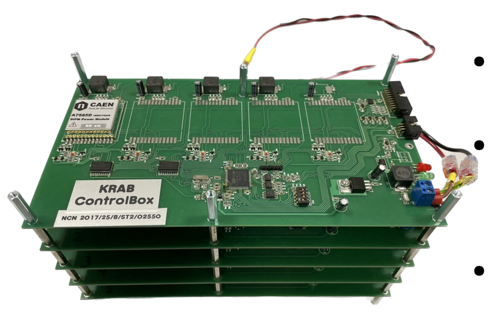
- 3D printed mechanical structure (ABS)
- 5 rings of 4×4 mm² scintillating fibers (BCF-10)
- read out by 3×3 mm2 SiPMs (SensL MicroFJ-30035)
- 4×160 segments in forward and 96 in backward ring
- 736 channels
- 32 ch CITIROC 1A ASICs used for signal processing
- compact A7585D SiPM power modules
- broad coverage from 30° to 165°
- geometrical efficiency ~87% (within covered angles)
- ~5% multihit probability (for 1 AGeV Au+Au reaction)
- sufficiently large for radioactive beams
- sufficiently small and lightweight not to disturb neutrons
- He sleeve to suppress δ-electrons
- remotely controlled target wheel with 4 slots
- ZnS target + camera
- ControlBox to control and setup CITOROCs
- TriggerBox to produce trigger, bit pattern and for
- slow control monitoring (scalers)
- multiplicity based trigger produced after 50 ns
- bit pattern of fired segments sent to V2495 logic module
- RIO4 + MBS based data acquisition
- GUI based remote control software

KRAB related signal flow

in the future ASY-EOS II experiment [3]

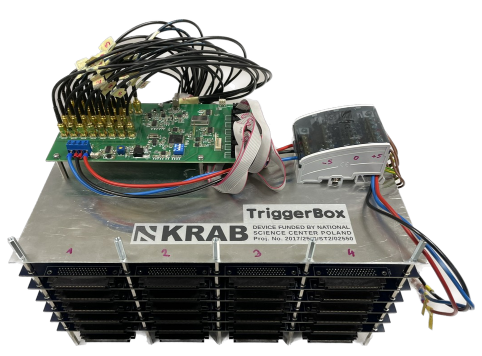


ControlBox



- 5 boards, 1 per ring
- sets LV for CITIROCS and HV for SiPMs,
- uses A7585D SiPM power modules
- used for setting and control of CITIROC parameters: biases, gains, thresholds,
- allows control of analog signal probe

TriggerBox

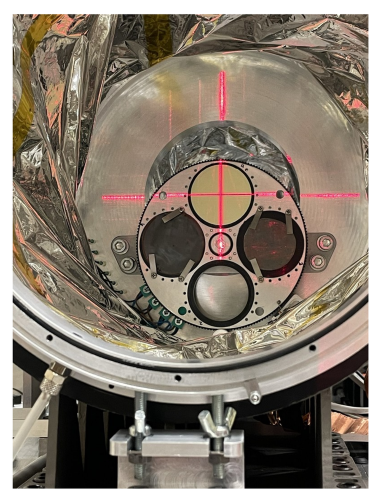


- 6 boards,
- 5 FPGA per board
- generates multiplicity based trigger
- allows setting and control of trigger: threshold, gates
- provides slow control scalers independent of DAQ,
- produces the fired module bit pattern for V2495

Helium sleeve

- fits inside KRAB
- ~13 l volume
- contains target wheel

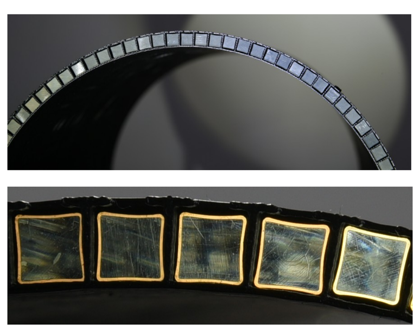
Target wheel



- remotely controlled
- stepper motor driven,
- fits inside sleeve,
- 4 target slots,
- with inductive sensors for position verification
- possible camera preview

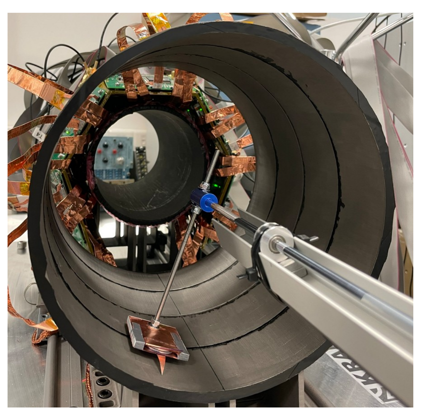
Mechanics

Ring frames and supports were 3D printed with ABS. Below: backward ring filled with SciFi segments

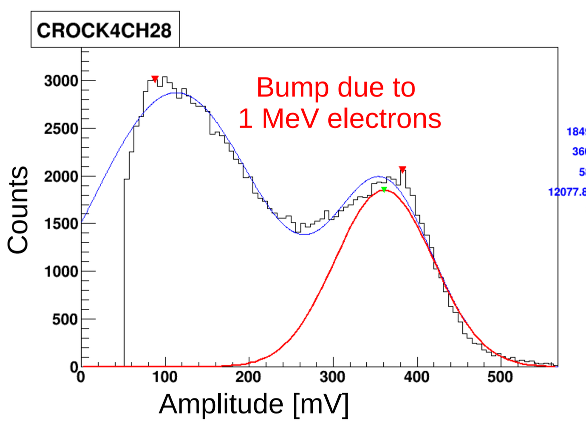


Calibration using ^{207}Bi source

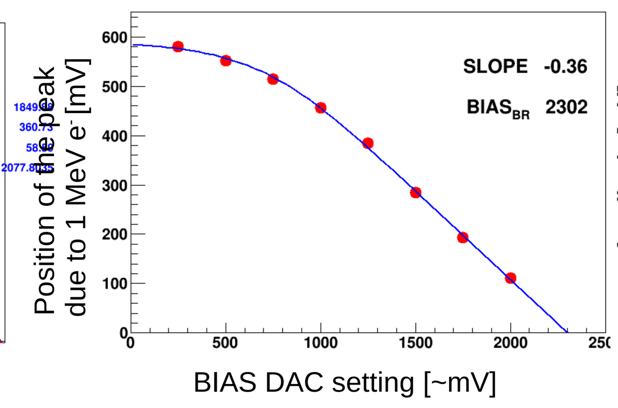
Clock-like mechanism rotating the source placed at the end of the hand that facilitates calibration of each channel



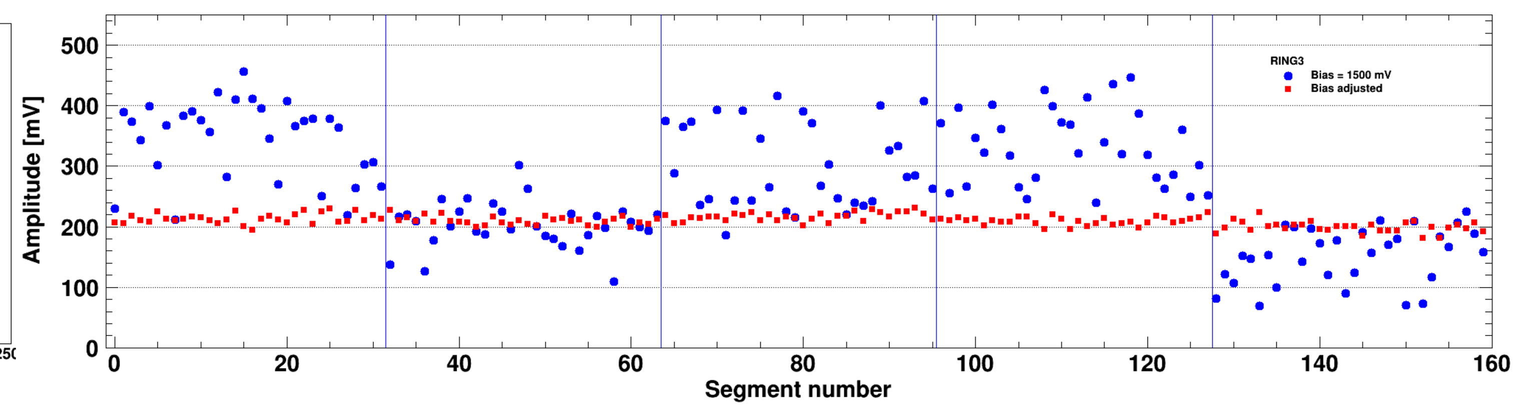
Typical Bi spectrum in air for 1 fiber + SiPM



Typical calibration curve for 1 channel HighGain mode with visible saturation of the preamplifier

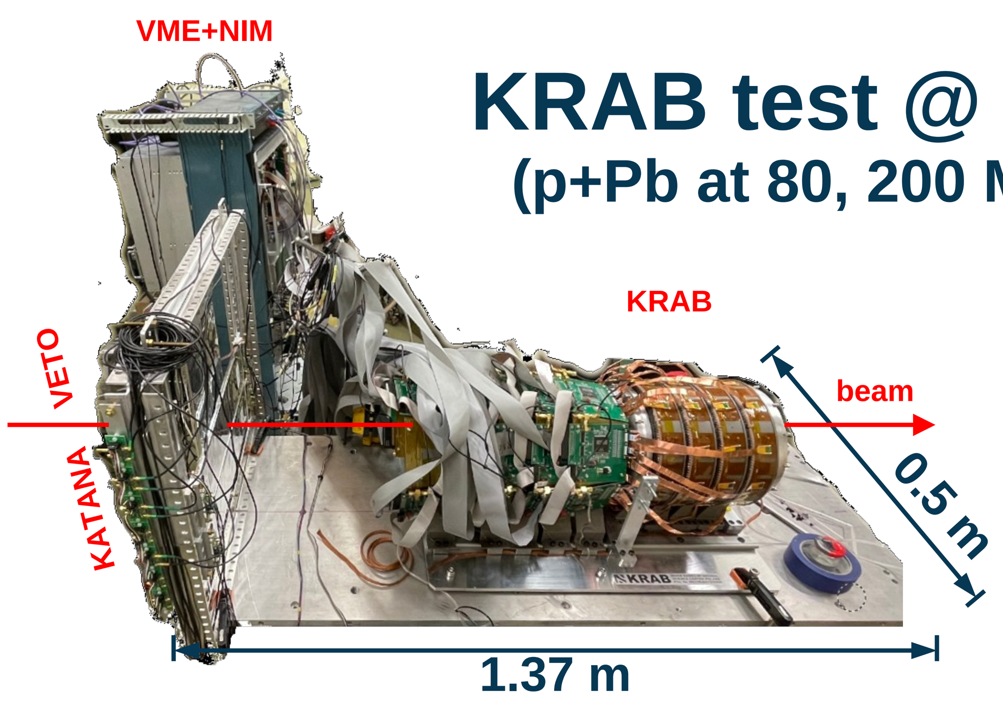


Response of 160 fibers (1 RING, 5 CITIROCS) to 1 MeV e⁻ for single BIAS DAC setting of 1500 mV (blue circles) and the result after BIAS adjustment leading to amplitude alignment at 200 mV (red squares). Spread of the amplitudes due to different SiPM characteristics, due to DAC linearity variation and non uniformity upon different ASICs for a fixed stimulus drops from about 35% before to about 4% after alignment.

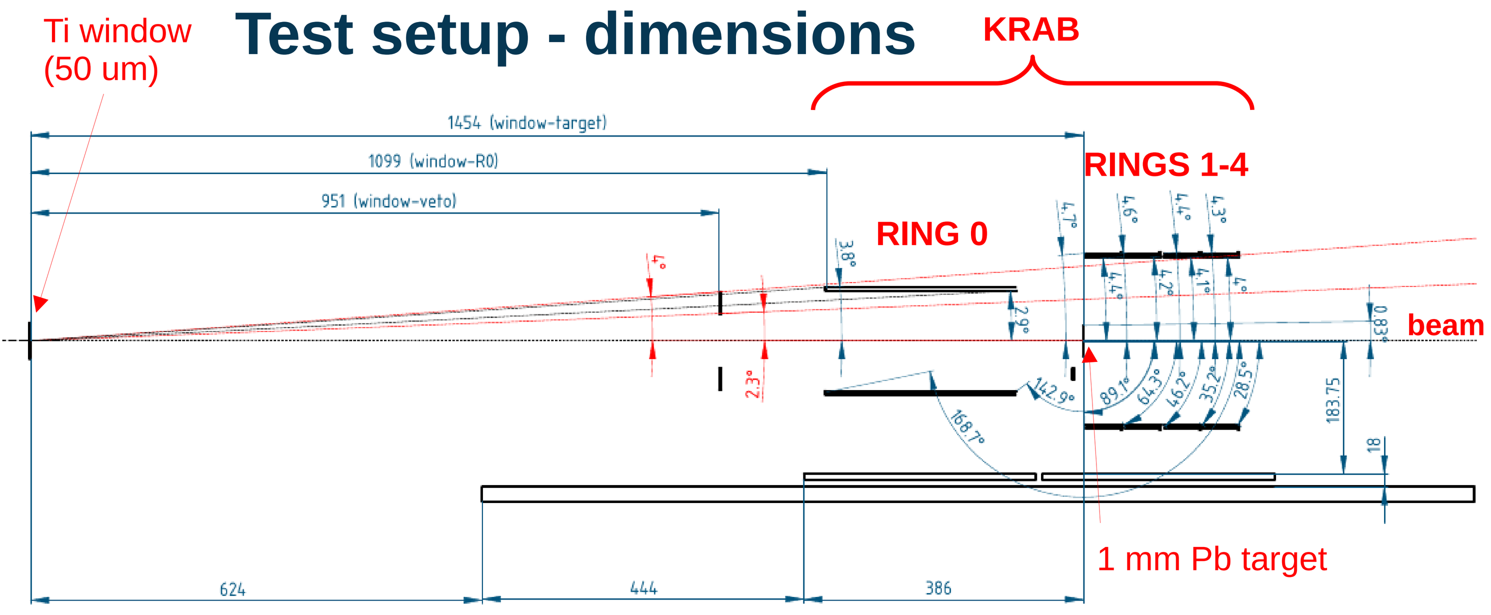


KRAB test @ CCB

(p+Pb at 80, 200 MeV)

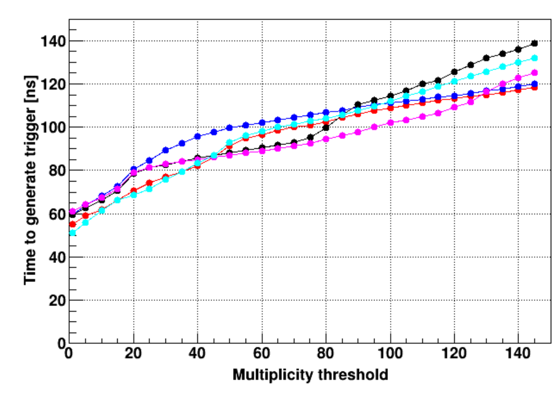


Test setup - dimensions



Trigger timing

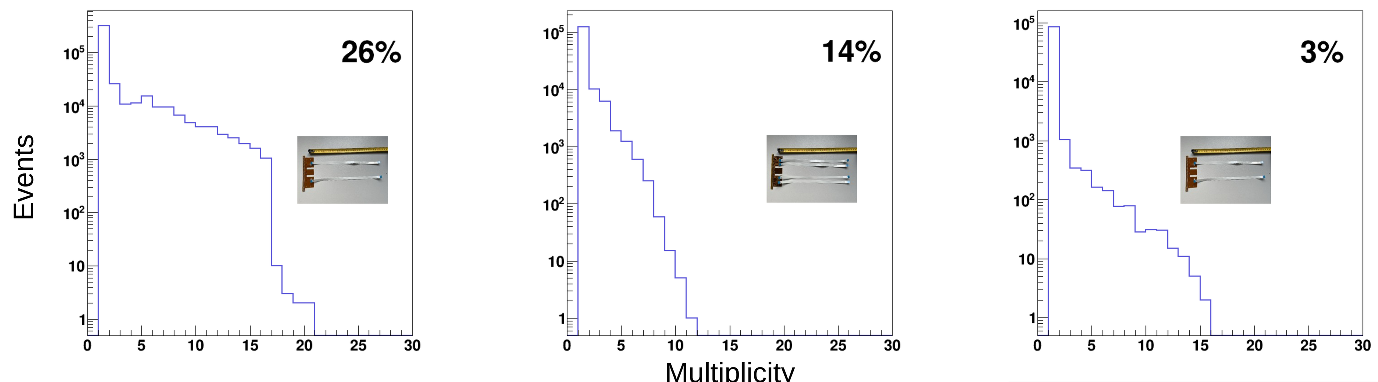
Time to generate trigger in the TriggerBox varies from about 50 to about 140 ns, depending on the threshold setting. Different curves correspond to electromagnetic excitation of different sections of rings.



Cross-talks

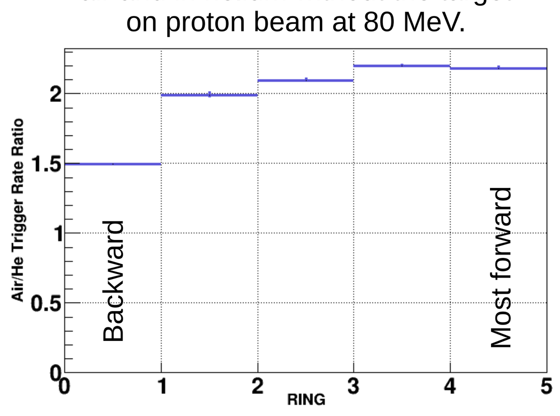
Protons scattered on the Ti window (on the left in the figure above) can cross backward ring (RING 0) at small angles depositing large energy and leading to large amplitude pulses. Forward RINGS (1-4) are less effected because they have shorter scintillators. The cross talks are expected to be most severe for RING 0. It was equipped with 4 FFC cables connecting the SiPMs with CITIROCS, instead of 2, with every other wire grounded, to reduce the cross-talk effect.

Multiplicity distributions and cross-talk probabilities (in %) defined as a ratio of the number of events with multiplicity > 1 to the number of all events are shown below. Ideally there should be no events with multiplicity >1. There are many cases when half of CITIROC channels fire with 2 FFC version of backward ring (left panel). Applying 4 FFCs (middle panel) leads to reduction of cross talks by almost a factor of 2. Forward rings (right panel) are less effected by cross talks even with 2 FFCs per CITIROC. A necessary condition to keep the cross-talks at low level is to bias SiPMs with voltages close to the beak-down voltage and eliminate direct hits of the detector by the scattered beam particles using an efficient veto detector.



Helium effect

Trigger rate ratio for measurement in air and in helium without the target on proton beam at 80 MeV.

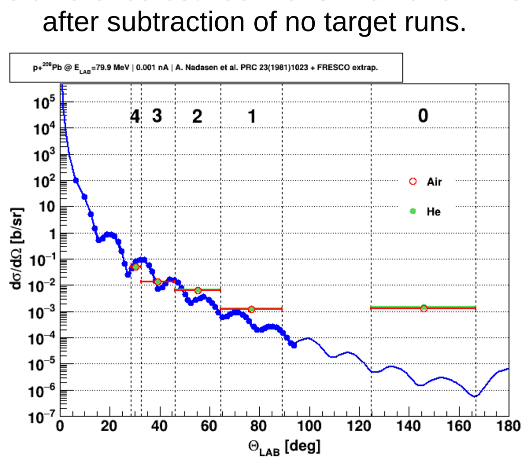


The count rate drops in He by a factor of 2 in forward rings. Multiplicity threshold was set to 1.

Simulations predict the reduction of multiplicity of fired segments for 1AGeV Au beam in He due to δ-electrons by a factor of 20-30 as compared to the beam in air.

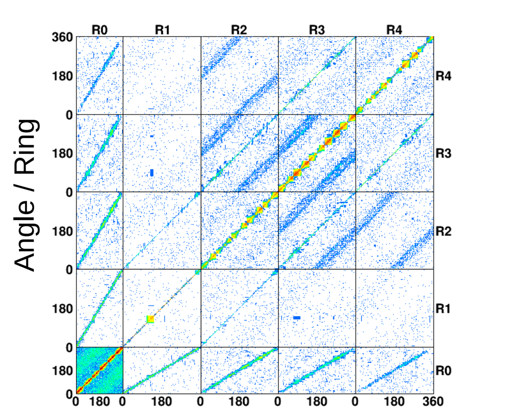
Polar angles

Polar angle distribution for p+Pb at 80 MeV, after subtraction of the no target run yields. Superposed on published data extrapolated with FRESCO. No sizable difference between runs in air and in helium after subtraction of no target runs.



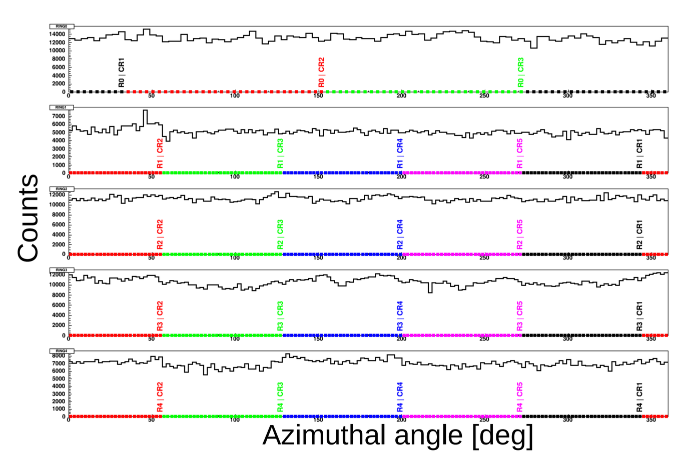
Overestimation by 2 decades in the backward ring is most likely due to hits of beam protons scattered on Ti window and in air upstream, to inefficiency of FRESCO extrapolation or inelastic contribution. Efficient VETO detector is needed to eliminate events and cross talks due to beam scattered on the exit beam pipe window and in air upstream.

Correlations between channels



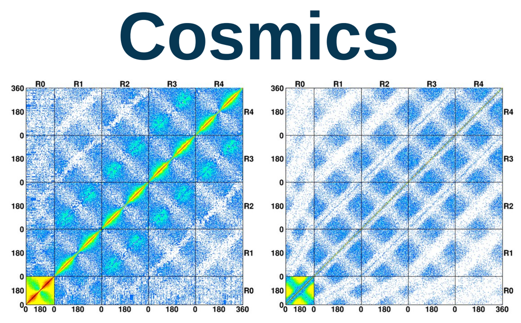
Correlation between KRAB channels for 80 MeV protons on empty target – reactions on Ti window. The non-diagonal lines represent most likely quasi-free scattering, with 2 protons emitted almost back to back. Diagonal lines show single proton tracks.

Azimuthal angles



Azimuthal distributions for p+Pb @ 200 MeV for RINGS 0-4 from top to bottom. Channels covered by different CITIROCS are marked with different colors.

Cosmics



Cosmic rays are emitted mostly vertically as seen from the correlation on the left for MULT>=2 condition. Right plot shows correlation for MULT==2 condition.

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References

[1] J. Łukasik Il Nuovo Cimento C 41 (2019) 182.
[2] P. Russotto, M.D. Cozma, E. De Filippo, A. Le Fèvre, Y. Leifels, J. Łukasik La Rivista del Nuovo Cimento 46 (2023) 1.
[3] P. Russotto, A. Le Fèvre, J. Łukasik et al., arXiv:2105.09233 [nucl-ex] (2021).

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