Testing response of detectors with high-energy protons at CCB

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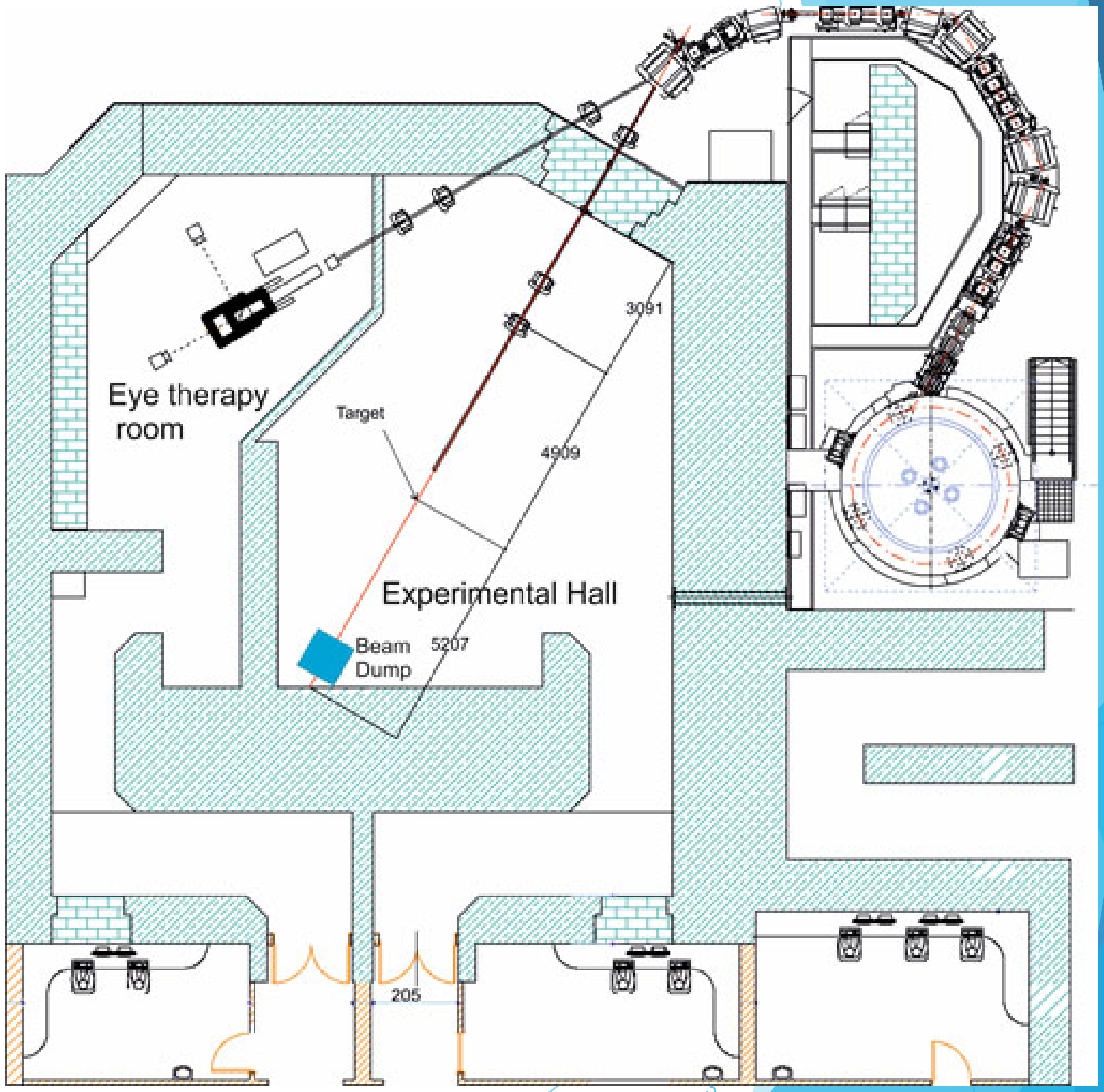
„PRZYSZŁOŚĆ FIZYKI JĄDROWEJ NISKICH ENERGII W POLSCE
A ROZWÓJ KRAJOWEJ INFRASTRUKTURY BADAWCZEJ”
14-15 stycznia 2019 r. ŚLCJ UW

OUTLINE

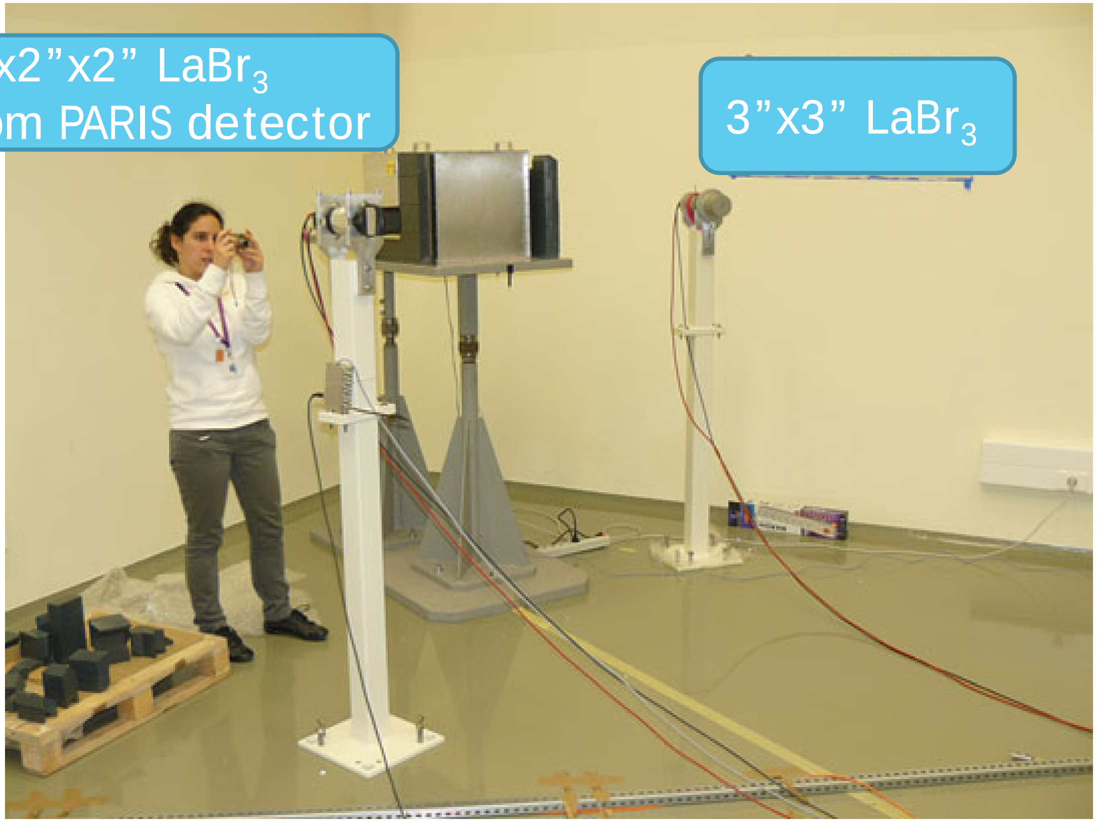
- CCB experimental hall and expected technical constraints
- First tests of $LaBr_3$ detectors
- Test of CALIFA components
- FAZIA and Garfield CsI detector tests
- Conclusion

Experimental Hall in CCB

- Compromise between Eye therapy room and experiment hall - thin wall to save a place,
- Room 9m wide , but only 7m^2 for detectors,
- Door only 2m wide but enough for forklift truck,
- 2T bridge crane at 6m in height,
- Beam pipe closed with 50um Ti foil often use as a target

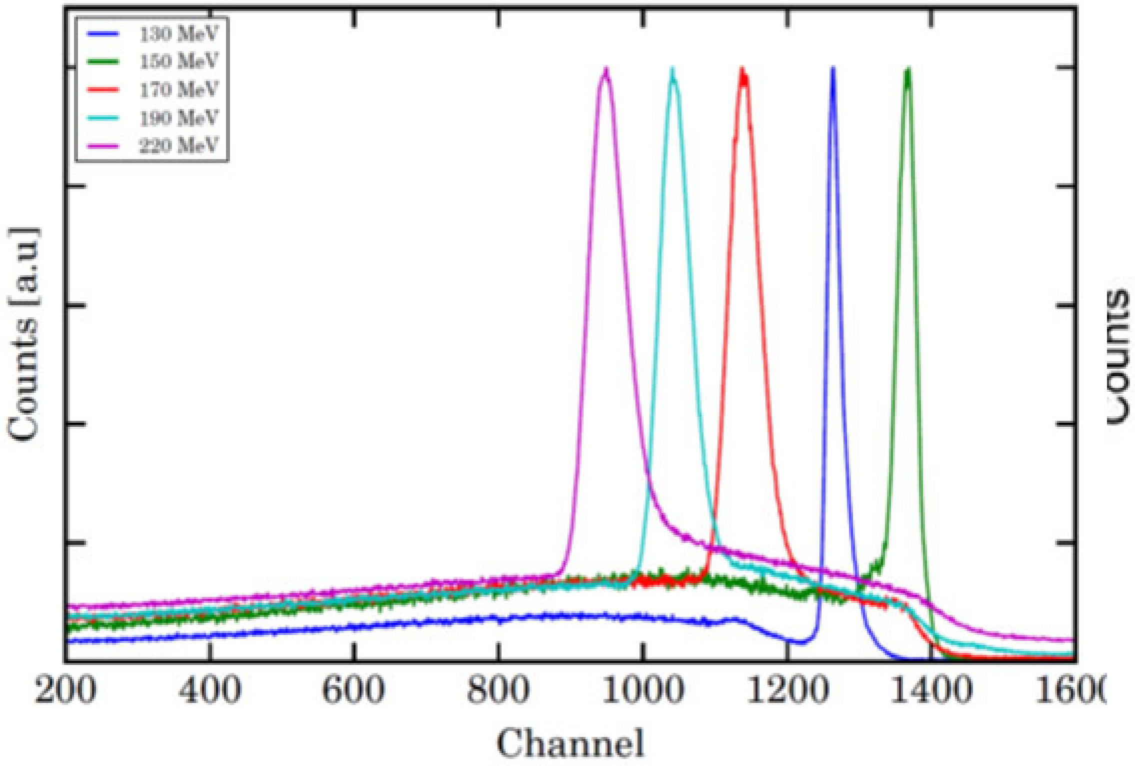


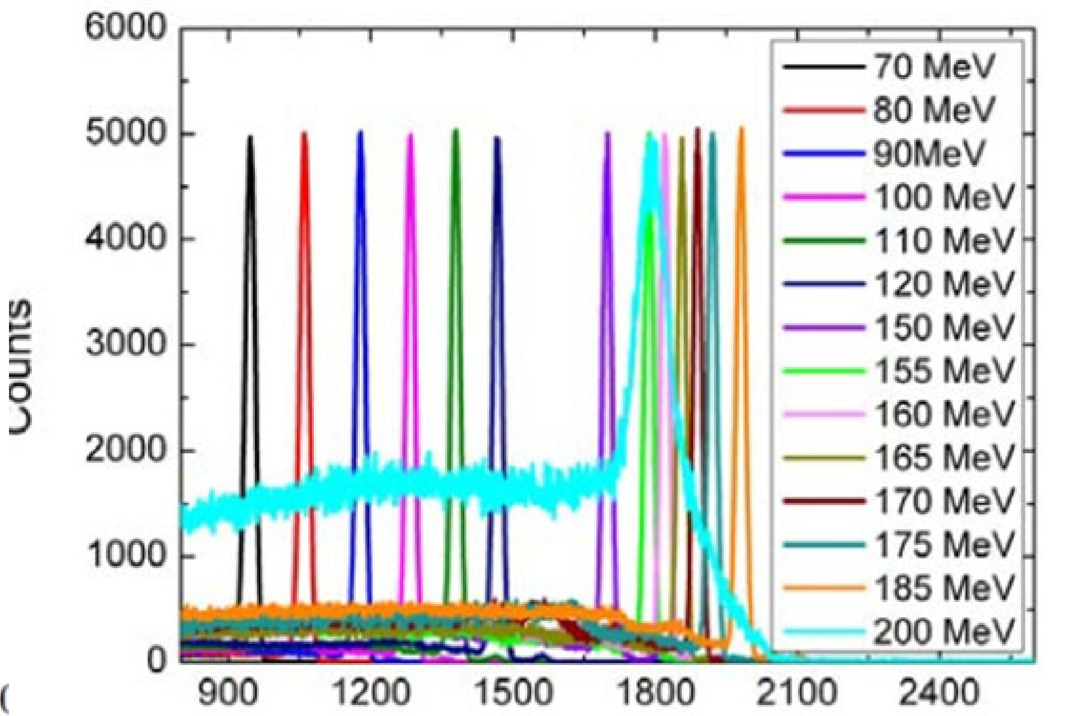
First experiment to find the response of $LaBr_3$ to protons



Investigation of the energy resolution, the proton quenching factor with respect to the gamma rays

Spectra $LaBr_3$ where effect of a punch-through is visible



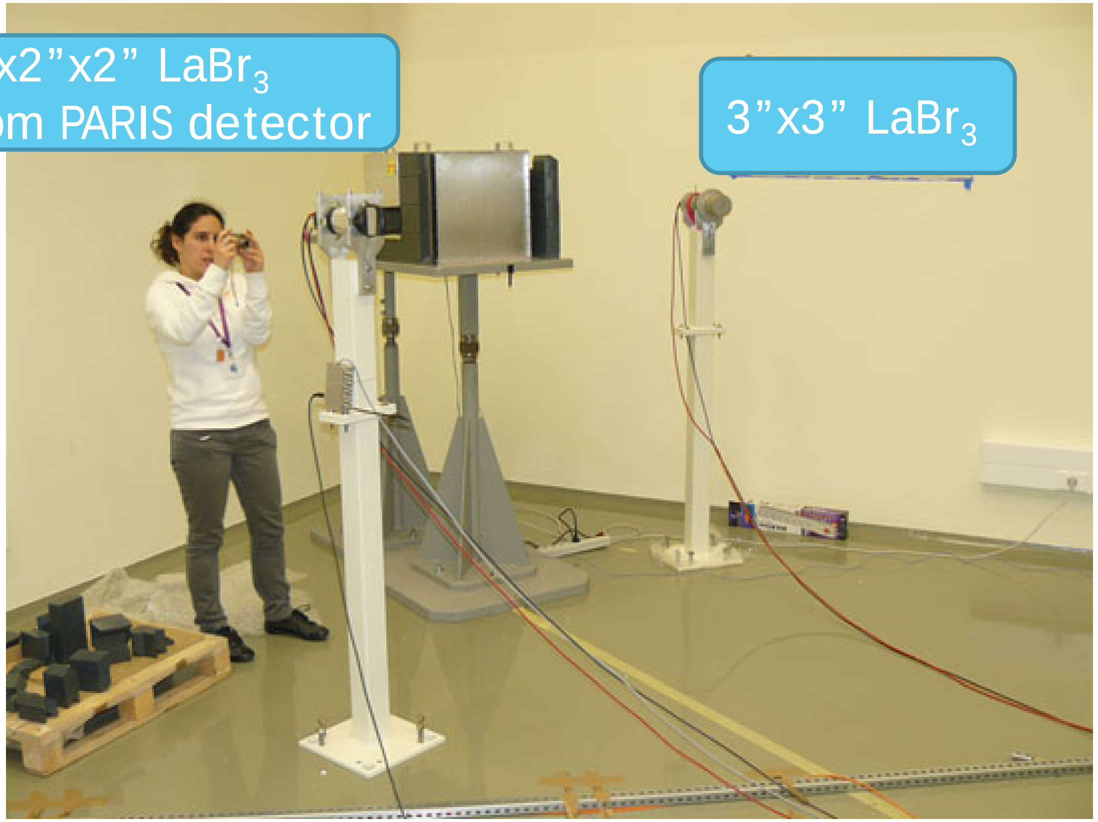


2”x2”x2” $LaBr_3$ – protons of energy above 145MeV are punch-through the detector. The spectrum for the 130 MeV protons is shown for comparison.

3”x3” $LaBr_3$ – protons of energy 70-185MeV are stopped inside the detector

Courtesy of A. Giaz

First experiment to find the response of $LaBr_3$ to protons (March 2013)



Investigation of the energy resolution, the proton quenching factor with respect to the gamma -rays

Conclusions:

- The signal shapes in case of gamma-rays and high-energy protons seem to be very different.
- The distortion of the pulses for protons increases with beam energy.
- The measured FWHM is larger than the one extrapolated from gamma - rays.
- The measured quenching factor for protons is 1.2 for 70 MeV protons and increase with proton energy up to 1.75 for 185 MeV protons.

CALorimeter **I**n **F**light detection of γ rays and charged p**A**rticles - CALIFA

is :

- a calorimeter dedicated to the detection tracking and energy determintion of light charged particles and gamma rays from R^3B experiments at FAIR facillity

It will:

- operate in coincidence with a dedicated target recoil tracking detector.
- cover polar angles between ~7 and 140 degrees
- have good energy resolution for individual gamma rays and for total gamma ray sum energy
- have >75% total absorption efficiency.
- detect protons with energies up to hundreds of MeV

Design is dominated by the kinematics of particles emitted at relativistic energies

Granular detector consisting of thousands of finger-like crystals needed for effective Doppler corrections

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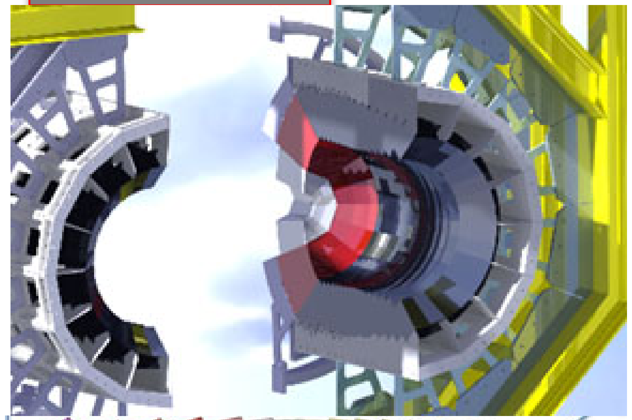
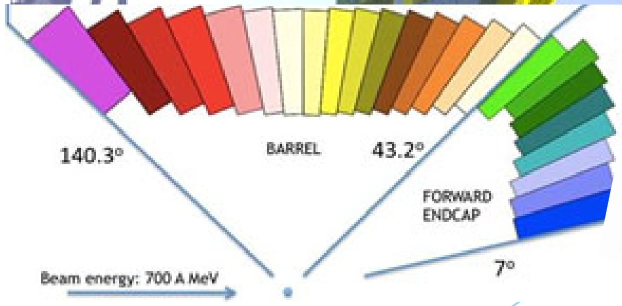
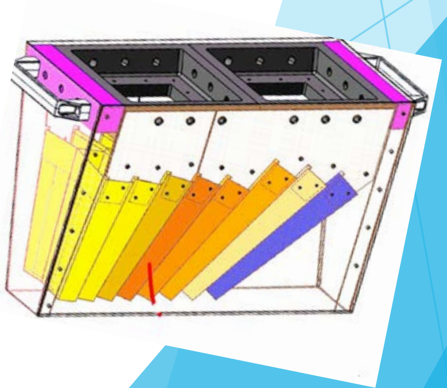
Detector split in two main sections :

BARREL







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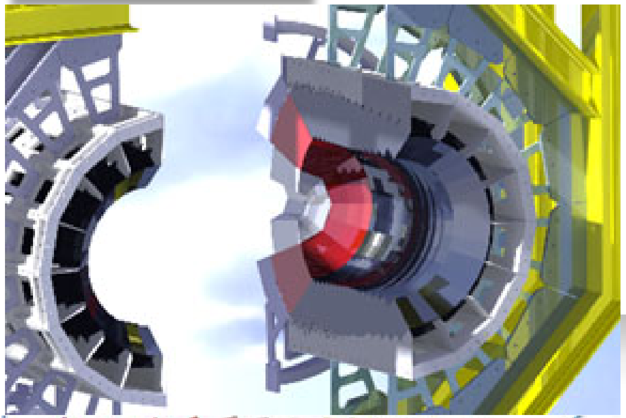
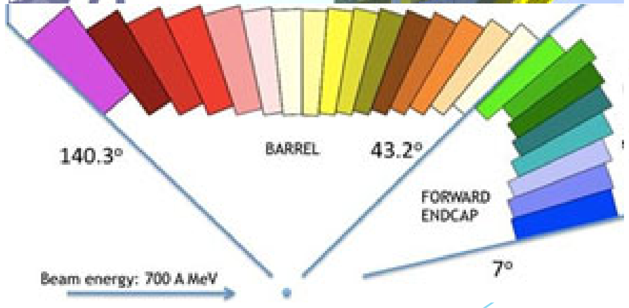
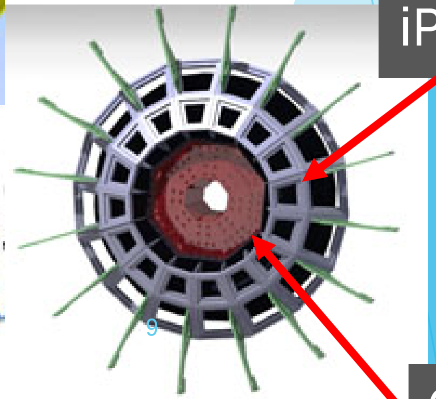
Forward Endcap





CsI(Tl) + LAAPD :
Intrinsic "phoswich"
two components of the scintillation light



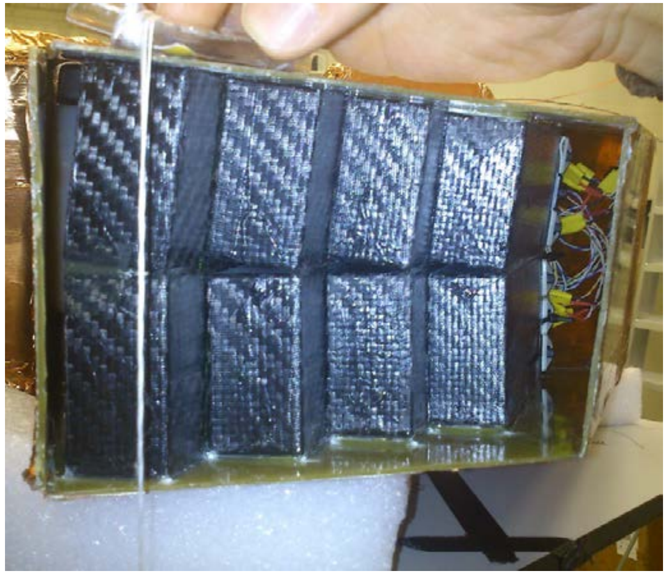
iPhos

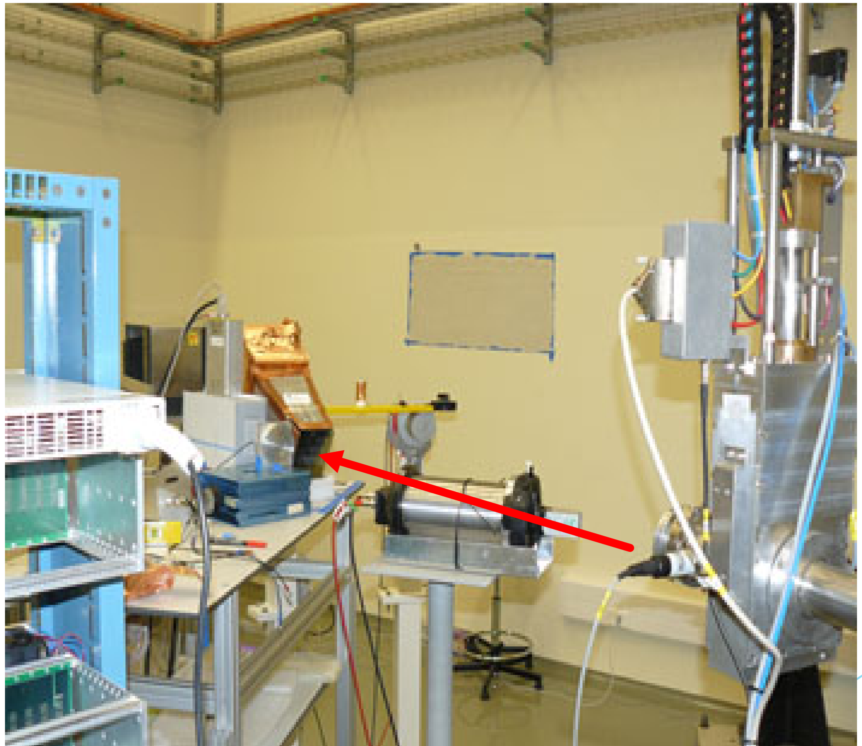
$LaBr_3/LaCl_3$) + PMT
Classical phoswich from the two materials

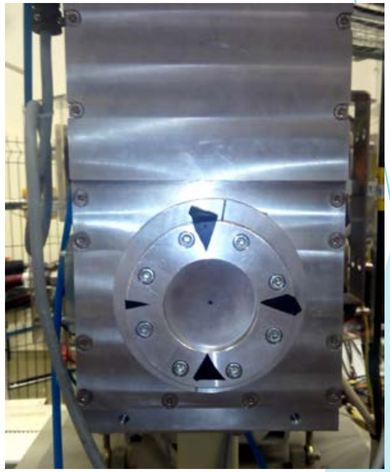
CEPA

Tests of CALIFA components in 2013

A prototype consisting of 32 CsI(Tl) trapezoidally shaped crystals was tested. An entirely new energy reconstruction method (iPhos), for charged particles detected in CsI(Tl) crystals, was developed based on pulse shape analysis. Due to a specific signature punch-through protons can be identified and the full energy reconstructed from the specific energy loss.



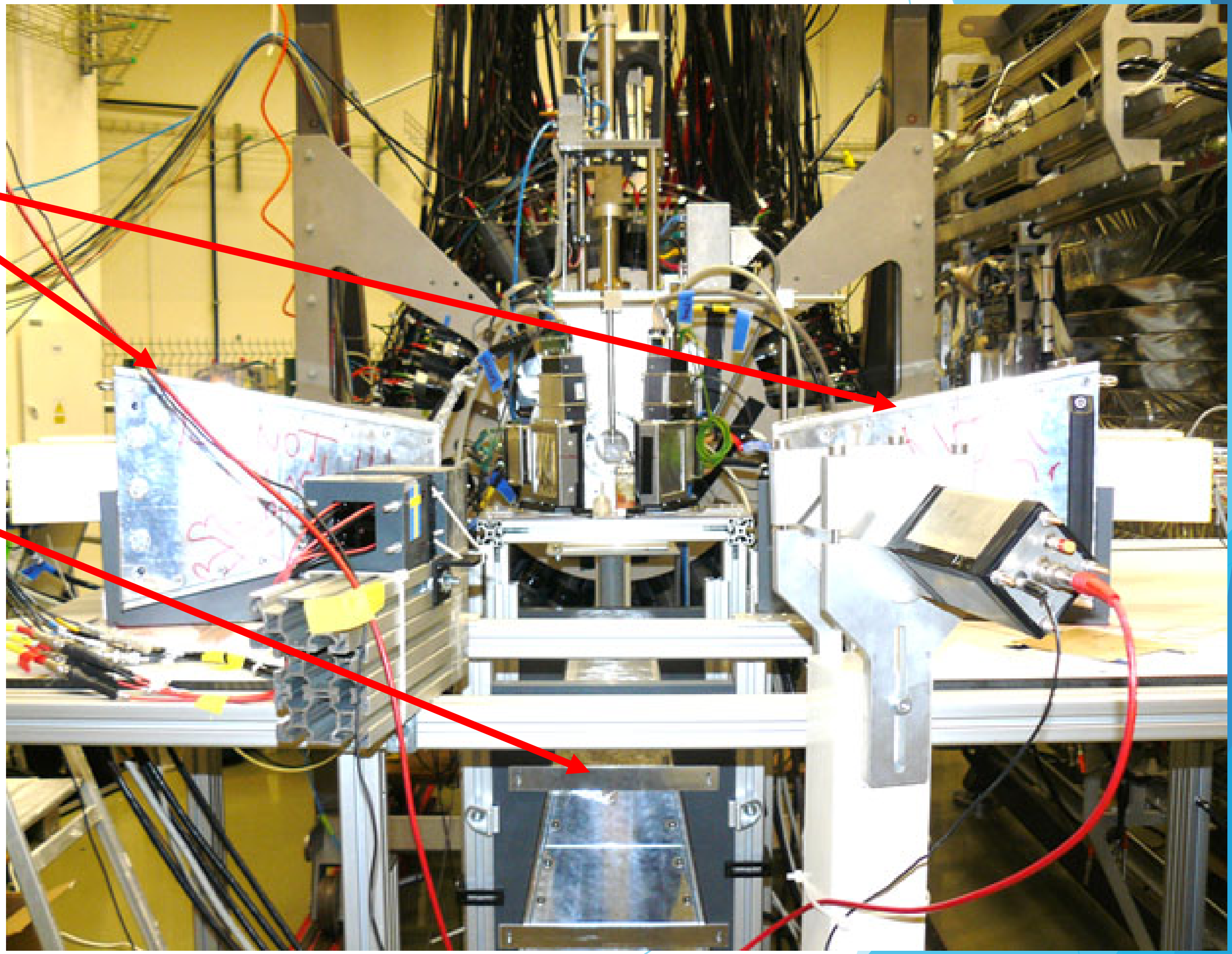


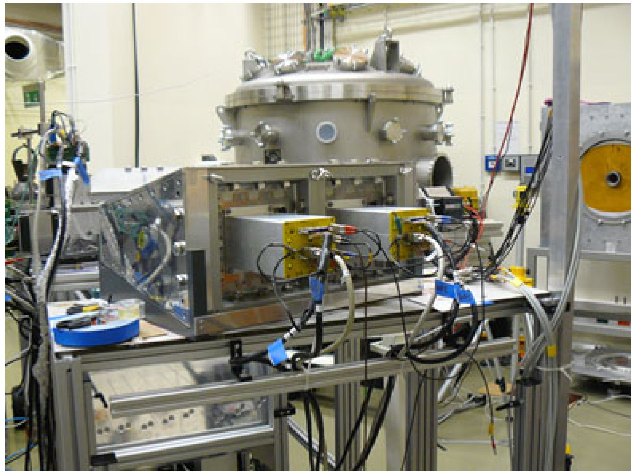


Protons scattered on the 50 um thick titanium foil of the beam-line exit window were used.

Experimental setup 2017

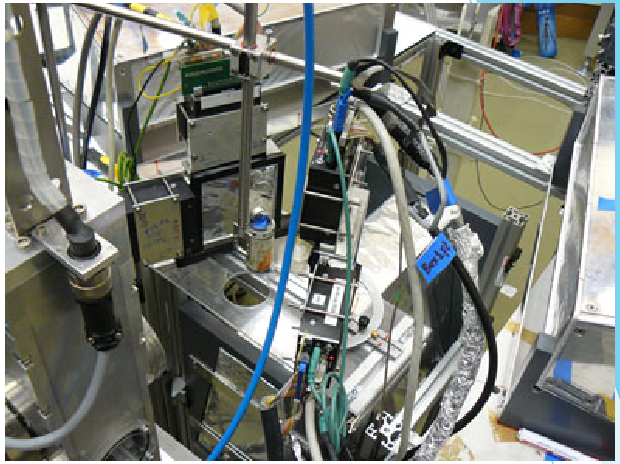
- Two petals were positioned on a horizontal plane with a polar angular coverage of 25° < θ < 58° to detect the scattered particles.
- One petal was deployed at its nominal CALIFA position (43° < θ < 82°) to detect γ -rays.

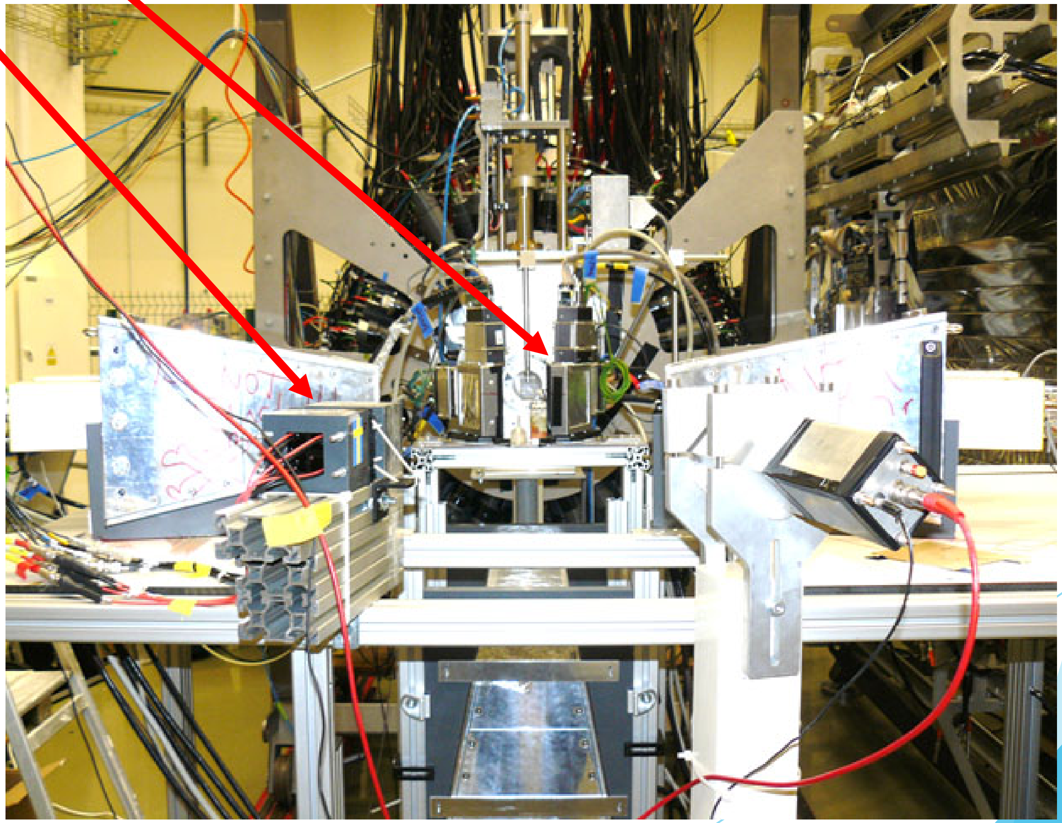




Experimental setup 2017

DSSSD – tracker box





- Two double sided silicon strip detectors (DSSSDs) were also employed as particle trackers.
- A CEPA4 prototype detector for the CALIFA Forward Endcap was placed at θ ~11° for its performance test.
- Data from the petals and the DSSSD trackers were read out with the MBS system featuring FEBEX3B cards
- The LED calibration system was tested with a larger setup under in-beam conditions.

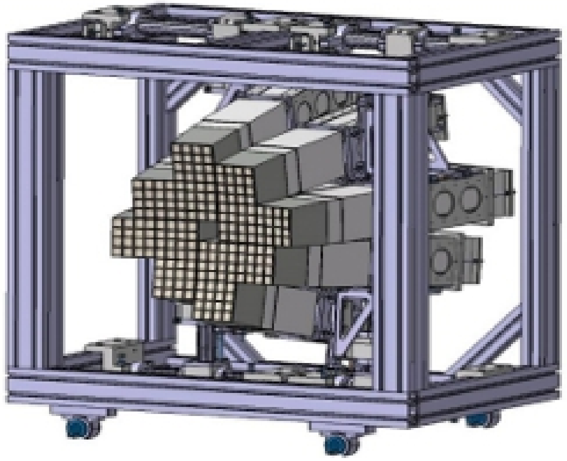
  The long term behavior of detector elements were investigated by proton irradiation of a few elements used in previous tests

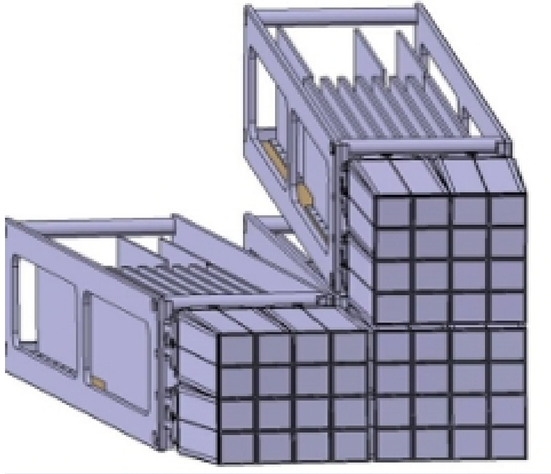
FAZIA

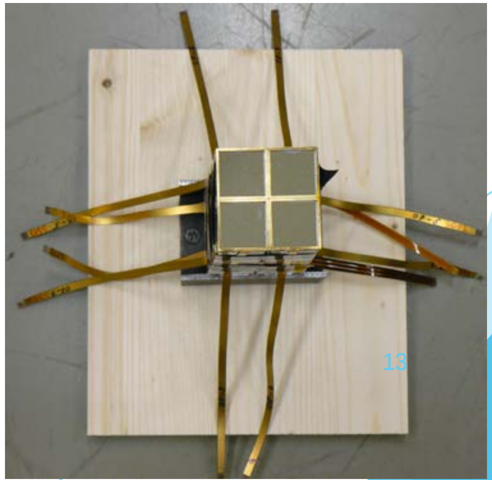
- FAZIA is designed to detect and identify within a large range of charge and mass reaction products coming from heavy-ion induced reactions within the Fermi energy domain (10-100AMeV).
- The expected energy resolution by using FAZIA Si-Si-CsI telescopes
  - 300 µm reverse-mounted Si detector;
  - 500 µm reverse-mounted Si detector;
  - 10 cm CsI(Tl) cristal read by a photodiode

is better than one percent in the range from few MeV to few GeV.

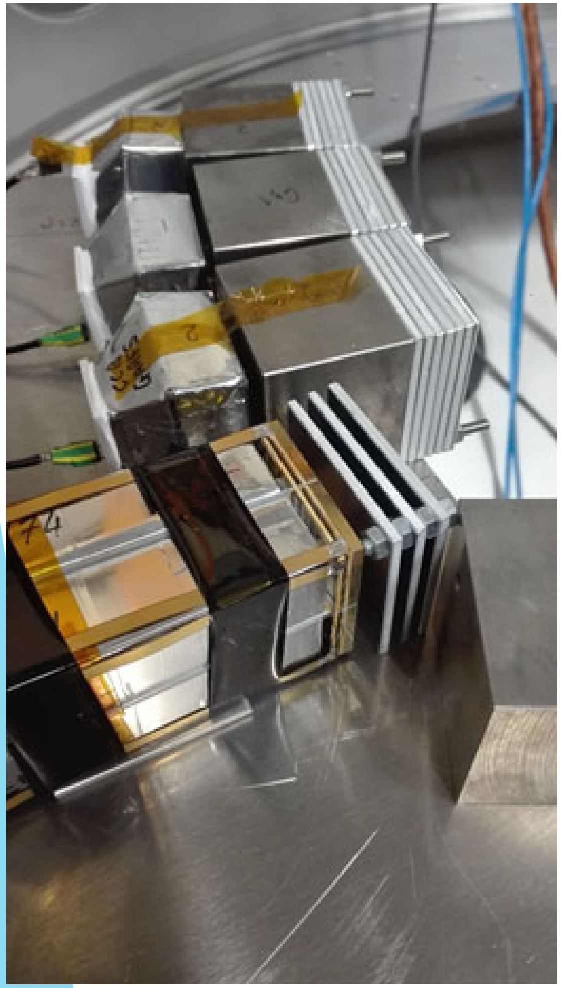
- FAZIA will have the maximal coverage at least 90% of 4Π, in order to efficiently perform event-by-event reconstruction of exclusive measurements.



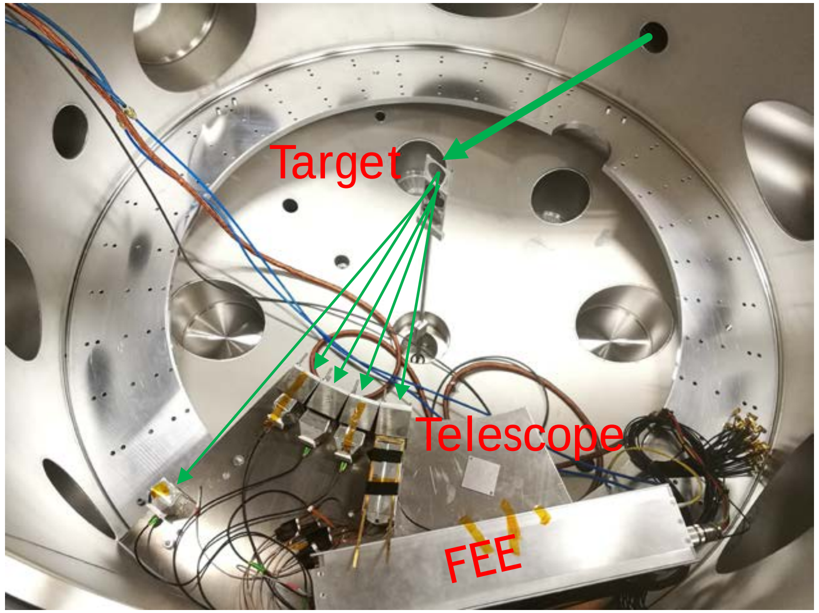




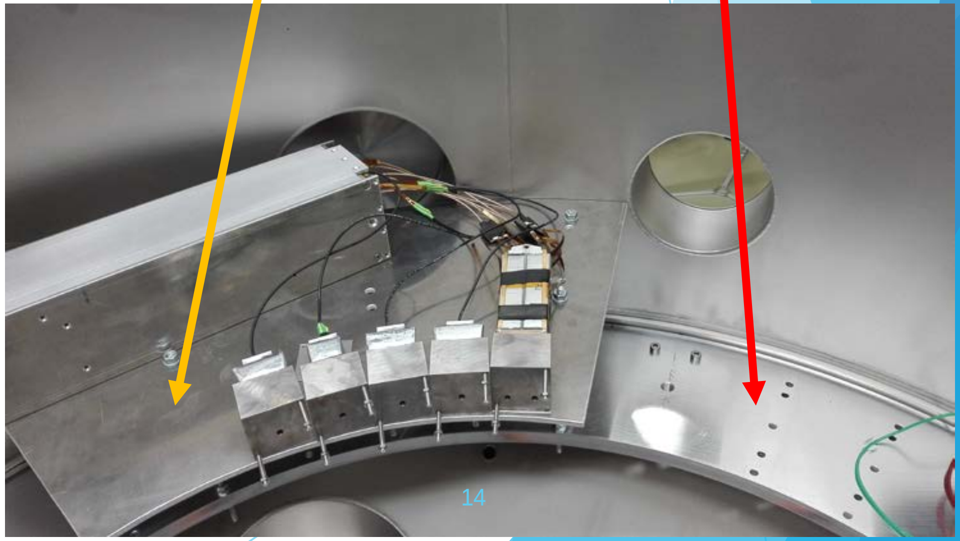
FAZIA and Garfield CsI detector in vacuum chamber



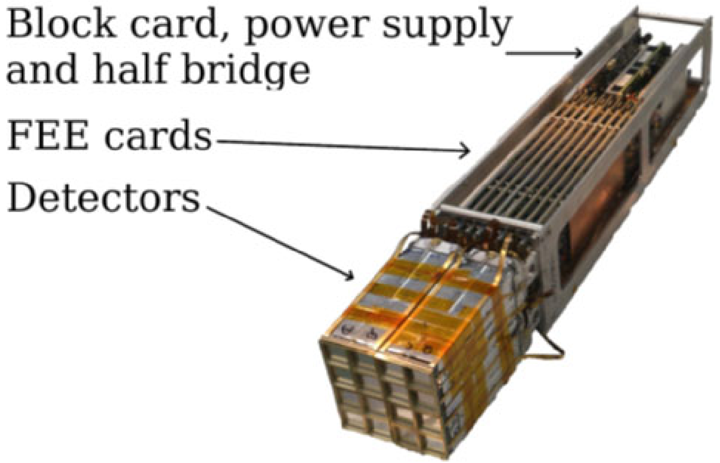
Degrader and colimators for CsI detectors



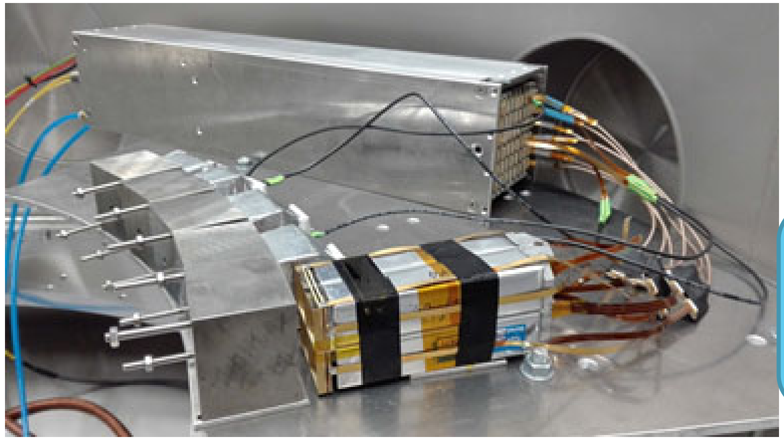
Special ring prepared by UJ spallation group as a base for a shelf where we can put detectors



How to put FAZIA detectors under vacuum

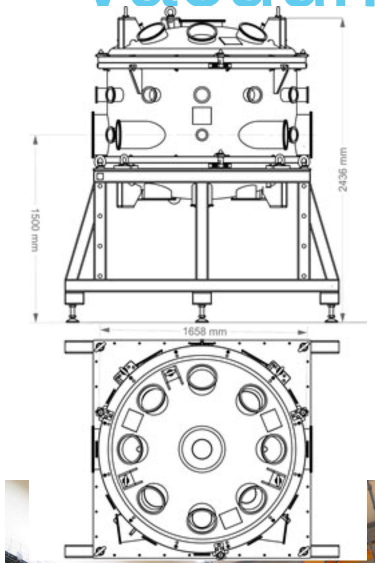


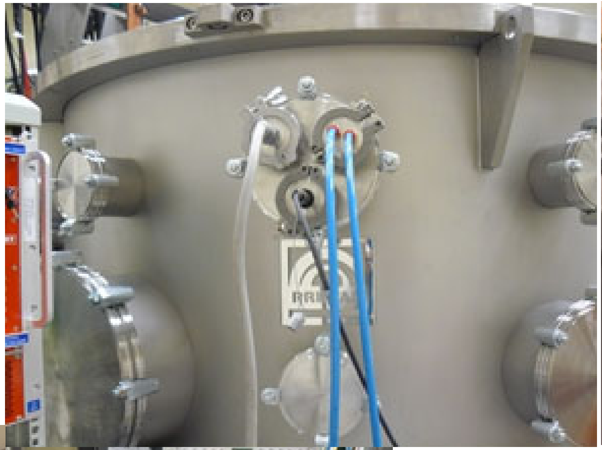
High power voltage conversion from 48 V DC input: 22 V (14 A) DC 5.5 V (70 A) DC
Power Supply Converts 22 V to 13 V, −9 V, ±5 V

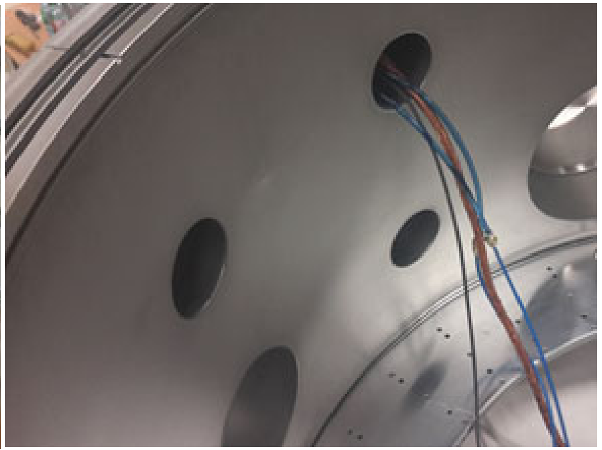


Block is mounted on a copper base in which water flows to provide cooling

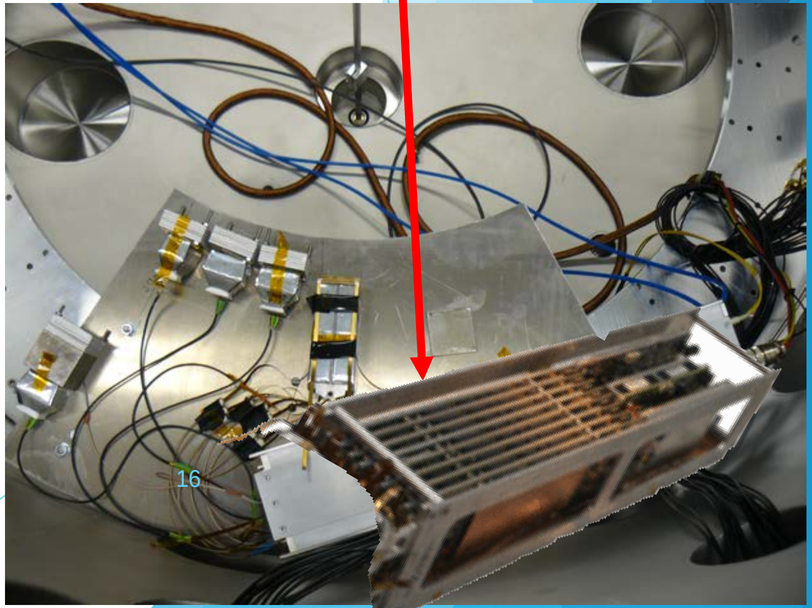
Technical problems to fit detector to vacuum







All the equipment needed for the correct operation of the detector, such as the HV supply or the pulser test signals, is integrated in the FEE



Only a 48V power supply is needed together with a chiller to keep under control the temperature of the FEE using a recirculating water circuit

Evaluator of new detectors as a client

Common requirements :

- Place for detectors min 4 m^2
- Stand or table with variable height next to beamline
- Laser system to set up direction and angel of equipments
- „Clean” power supply
- Ethernet connection between experimental hall and control room
- Crane with maximum load to 2T
- Easy access to the workshop

Conclusion

- It is a strong requirement for nuclear physics community to have a source of high-energy protons with easy adjustable current, and energy
- CCB in Kraków is an ideal facility to characterise newly constructed detectors for the new facility

I would like to thank PARIS, CALIFA and FAZIA collaboration for a fruitful cooperation

References:

- A. Giaz *et al.*, 3”x 3” $LaBr_3$:Ce detector response to monochromatic protons 2013
- M. Bendel *et al.*, iPhos, a new technique for the CALIFA CsI(Tl) calorimeter

  J. Phys.: Conf. Ser. **587** 012049 2015
- E. Nacher *et al.*, Proton response of CEPA4: A novel $LaBr_3$(Ce)-$LaCl_3$(Ce) phoswich array for high-energy gamma and proton spectroscopy

  NIM A 769 2015
- B. Pietras *et al.*, First testing of the CALIFA Barrel Demonstrator

  NIM A 814 2016
- J. Park *et al.* Tests of CALIFA Barrel modules at CCB in Kraków

  GSI Scientific Report 2017

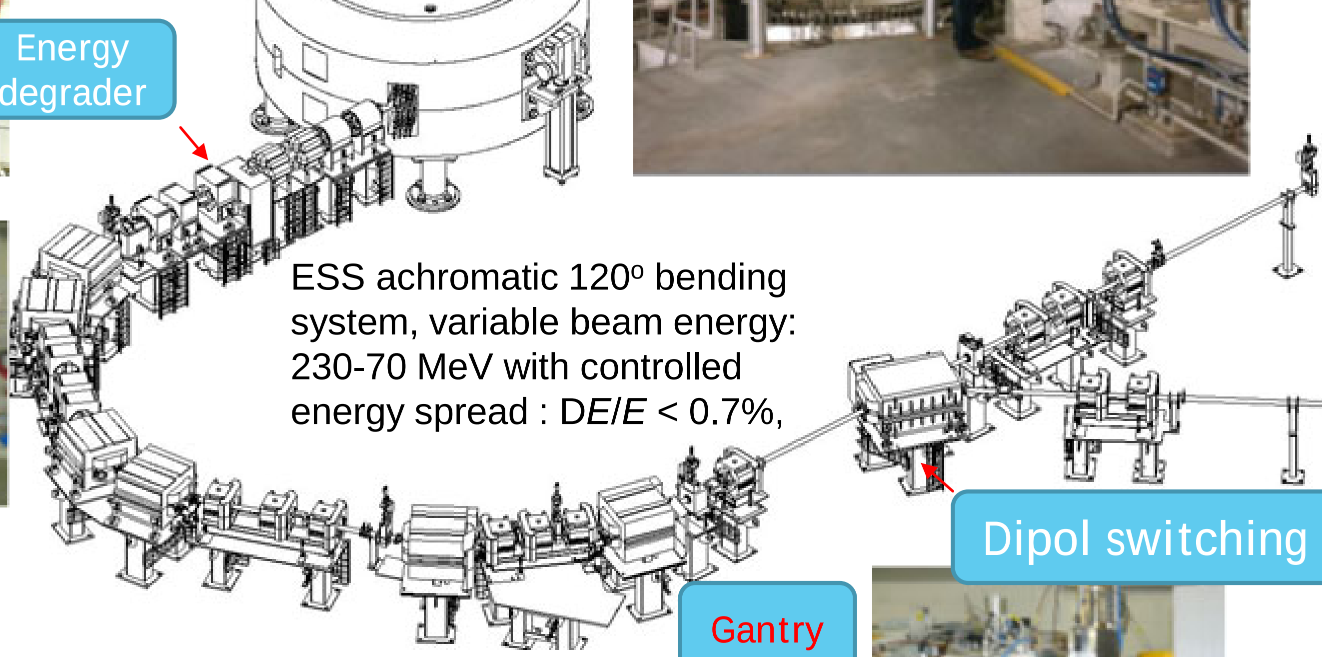
Thank you for your attention

How looks CCB elements

Extracted beam intensity:
Max 600 nA (4.0 x 10^{12} p/s)
Min 0.1 nA (6.6 x 10^{8} p/s)

Proteus C-235

Energy degrader



ESS achromatic 120° bending system, variable beam energy: 230-70 MeV with controlled energy spread : $DE/E < 0.7\%$,

Experimental Hall

Eye Therapy Room

Dipol switching 45

Gantry

BTS
Beam Transport System

Courtesy of W. Męczyński