EXL recoil detector and R3B Active Target - status and R&D

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I. Si detectors for EXL recoil detector

II. Setup with Si detectors – experiment E105 EXL@ESR

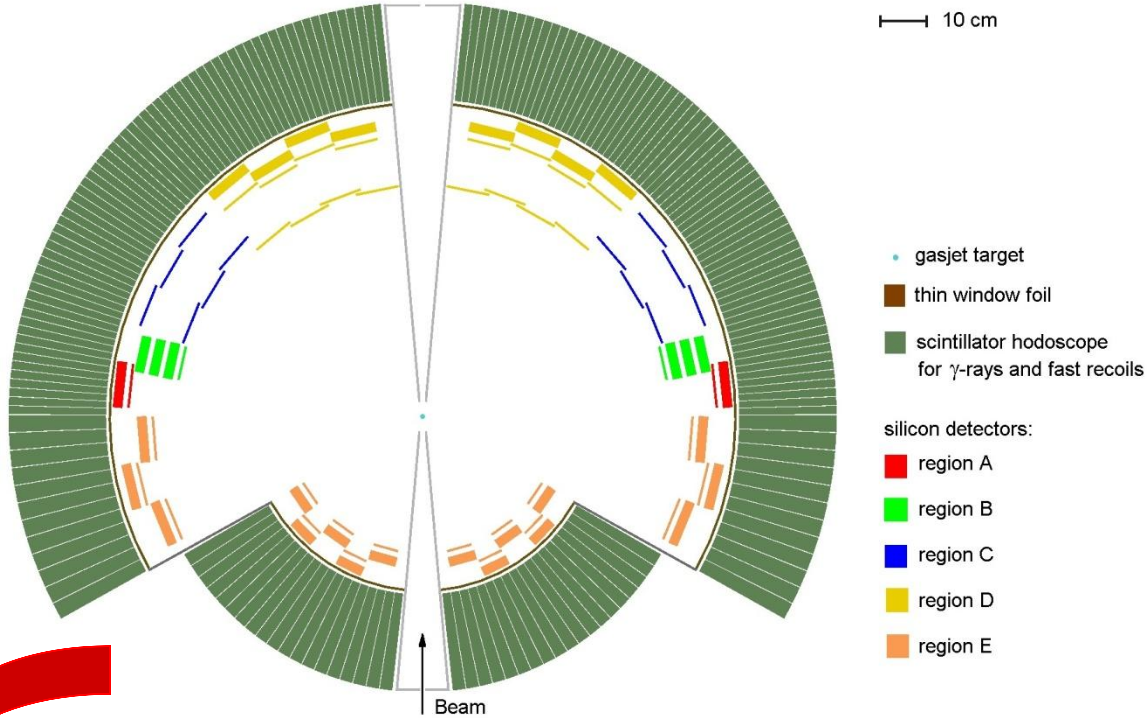
III. Performance in realistic conditions and further development towards larger EXL setup

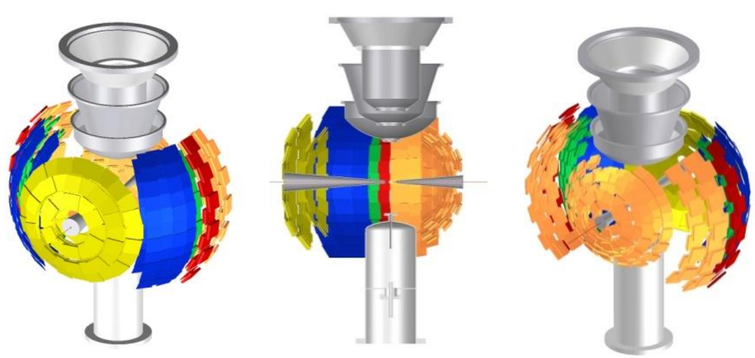
IV. Possible experiments with Active Target and requirements

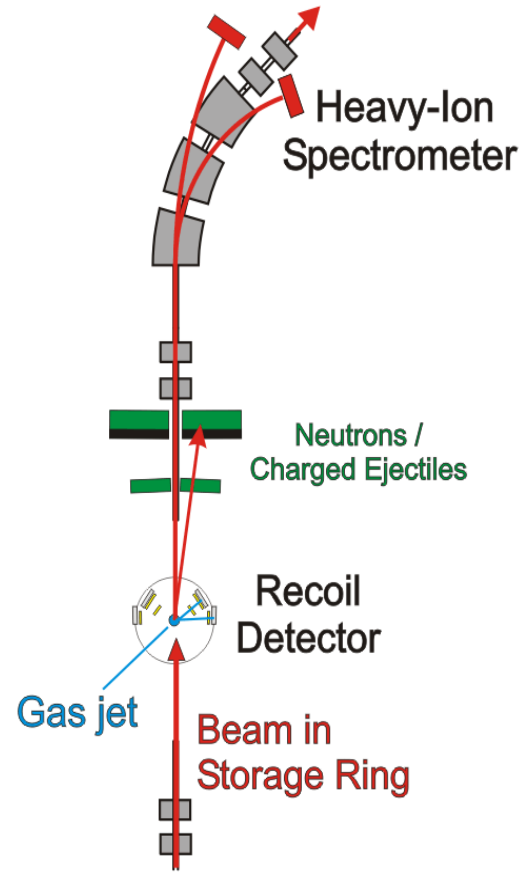
V. R&D towards first experiment with Active Target/R3B setup

NUSTAR Week, 07-11 October, 2013, Helsinki, Finland

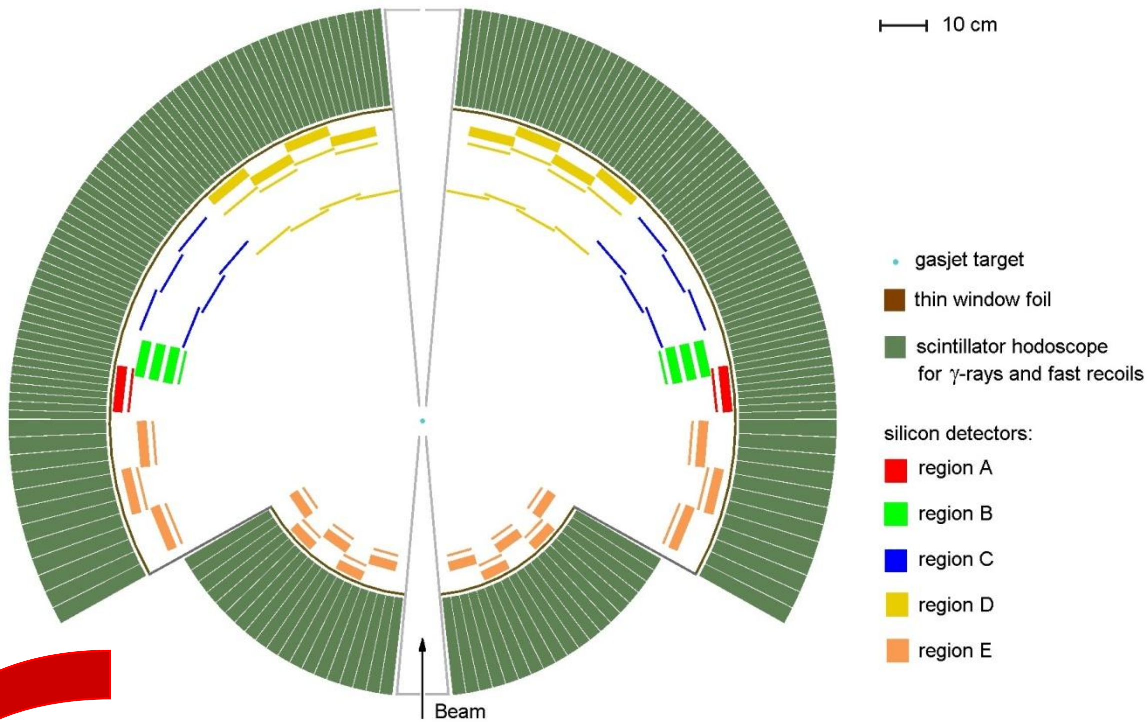
I. Si detectors for EXL recoil detector

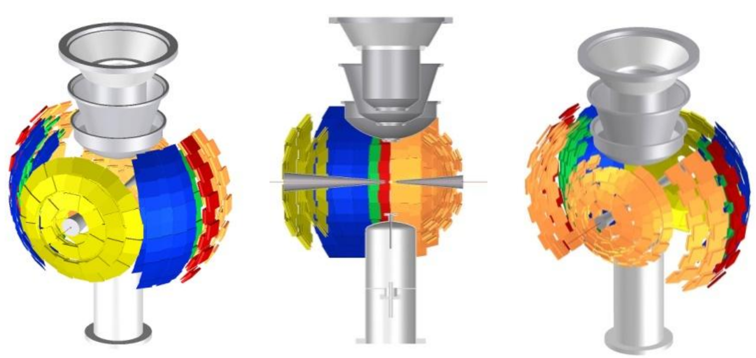






I. Si detectors for EXL recoil detector





Si DSSD ⇨ **ΔE, x, y**
300 μm thick, spatial resolution better than 500 μm in x and y,
ΔE = 30 keV (FWHM)

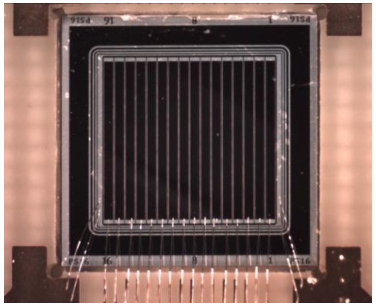
Thin Si DSSD ⇨ **tracking**
<100 μm thick, spatial resolution better than 100 μm in x and y,
ΔE = 30 keV (FWHM)

Si(Li) ⇨ **E**
6-9 mm thick, large area
100 x 100 mm^2,
ΔE = 50 keV (FWHM)

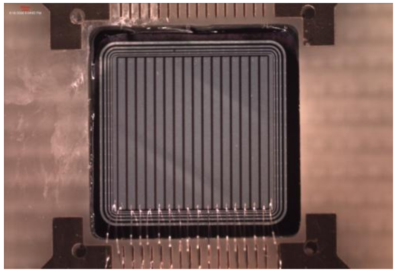
CsI crystals ⇨ **E, γ**
High efficiency, high resolution, 20 cm thick

I. Si detectors for EXL recoil detector

Aim: determine spectroscopic properties: ΔE, efficiency, PSD
precision of total energy reconstruction
UHV capability



Detectors: 1st series of small size DSSDs from PTI St. Petersburg
(8 sensors delivered April 2008/ September 2009)
2nd series of DSSD`s with larger size (65 x 65 mm^2)
(5 sensors delivered January 2010)

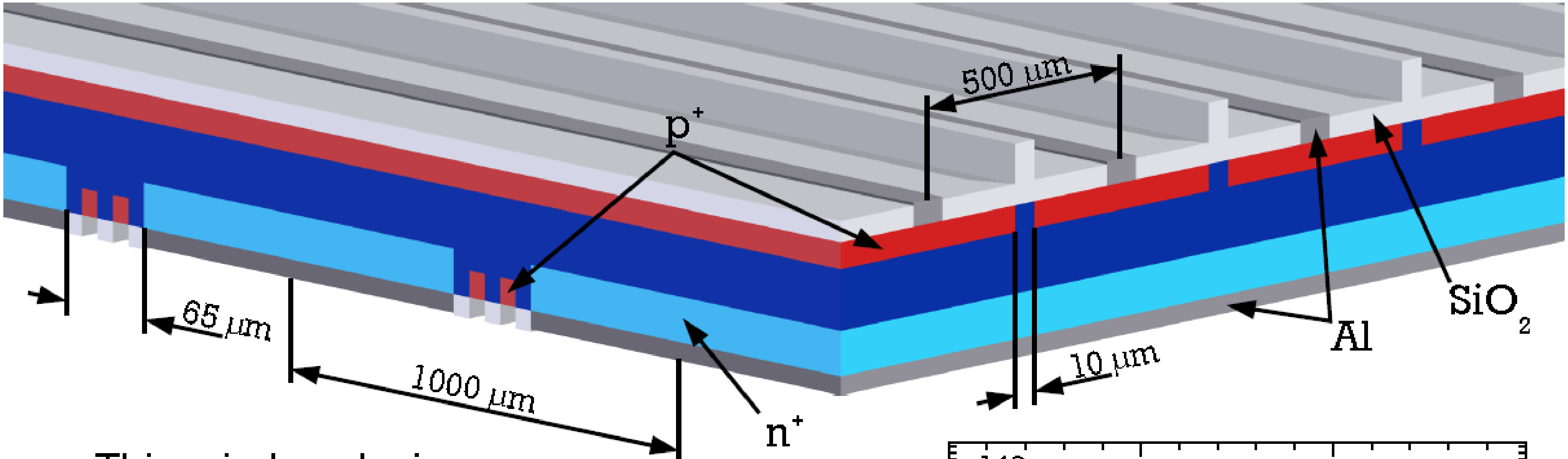


Thin entrance window < 50 nm

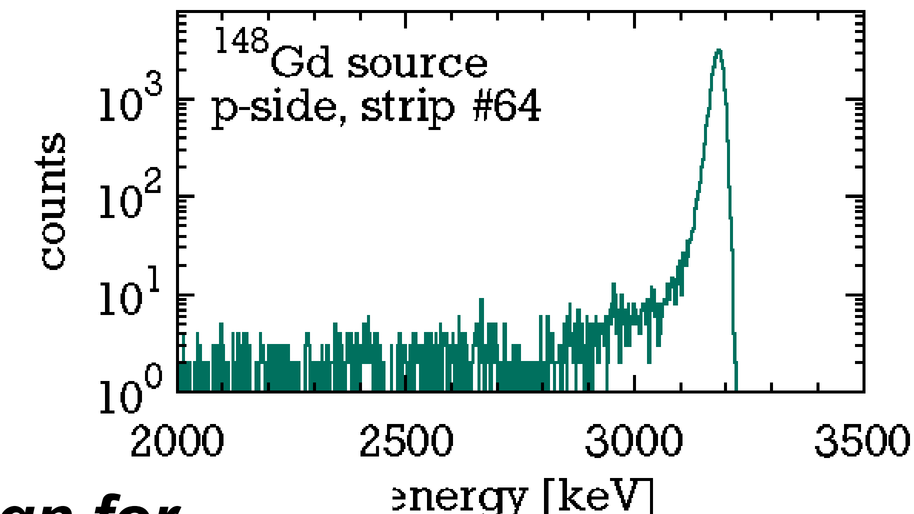
Tests:

2008/2009: GSI: α sources
2008: Edinburgh: α sources
April 2009: KVI Groningen: protons of 50 MeV
July 2009: TU München: α particles E < 30 MeV
September 2009: GSI: protons of 100 and 150 MeV
April 2010: KVI Groningen: protons of 135 MeV
January 2011: TU Tübingen: protons of 1.5 MeV down to 70 keV

I. Si detectors for EXL recoil detector

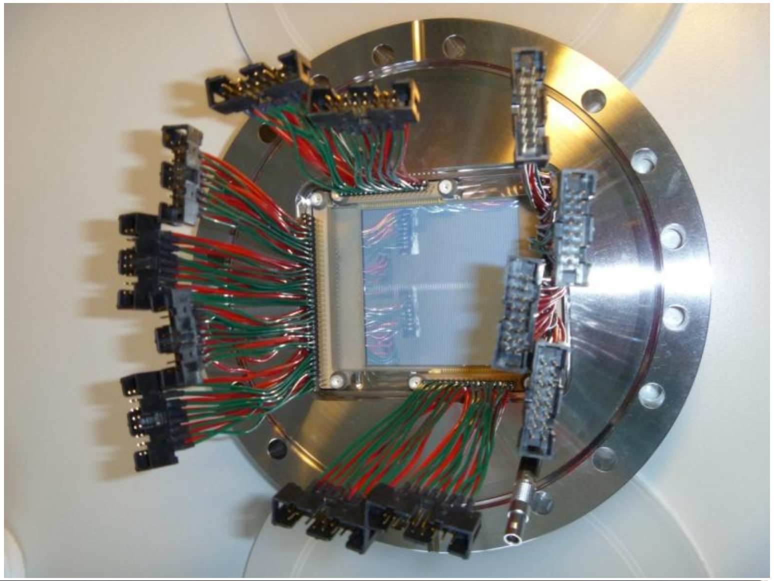


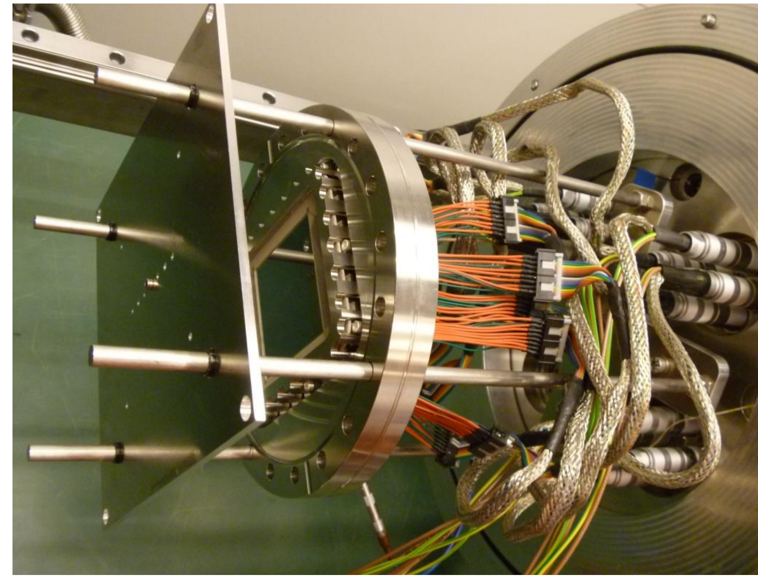
- Thin-window design:
  - p^+-implant on p-side: 500 Å thick
  - Al metallization: 600 Å thick
  - thin SiO_2 layer: 500 Å thick
- Compensation of different energy losses for low-energy particles



"Compensated" window design for very thing and uniform detector window

2nd Series of DSSD`s from PTI St. Petersburg: 64 X 64 mm^2



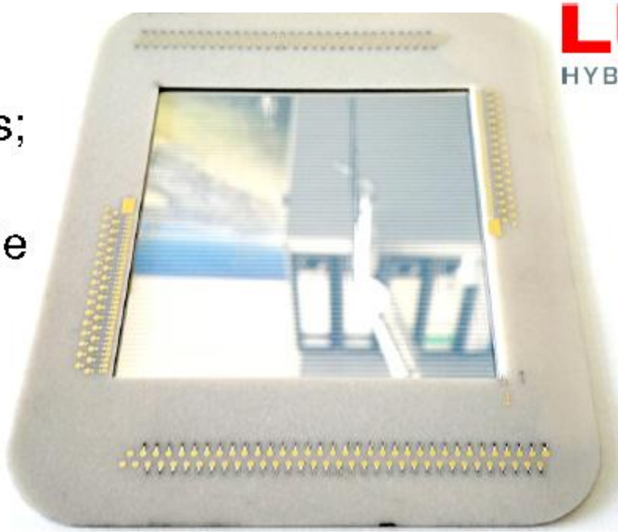


New 128 x 64 strip DSSDs are fully tested
DSSDs + PCB is bakeable up to 200 °C
Spectroscopic and mechanical properties fully suited for the experiments at ESR/EXL

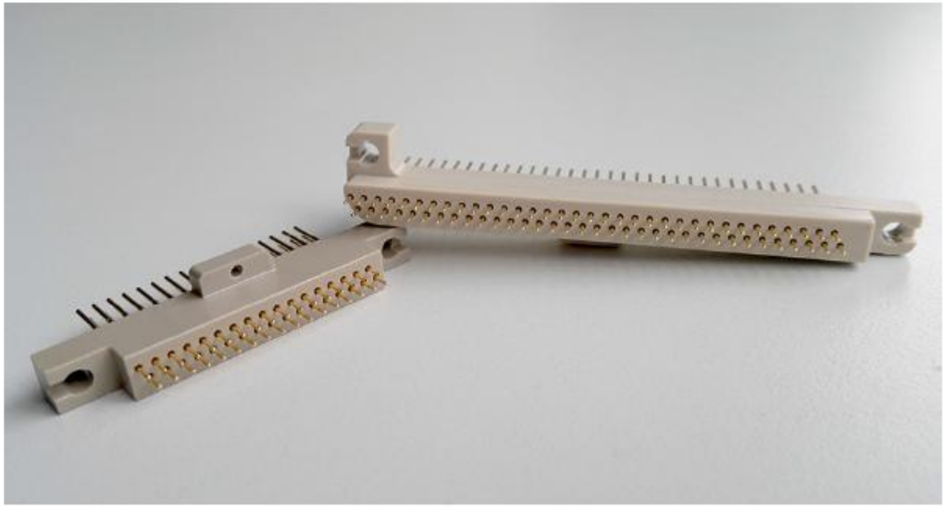
I. Si detectors for EXL recoil detector

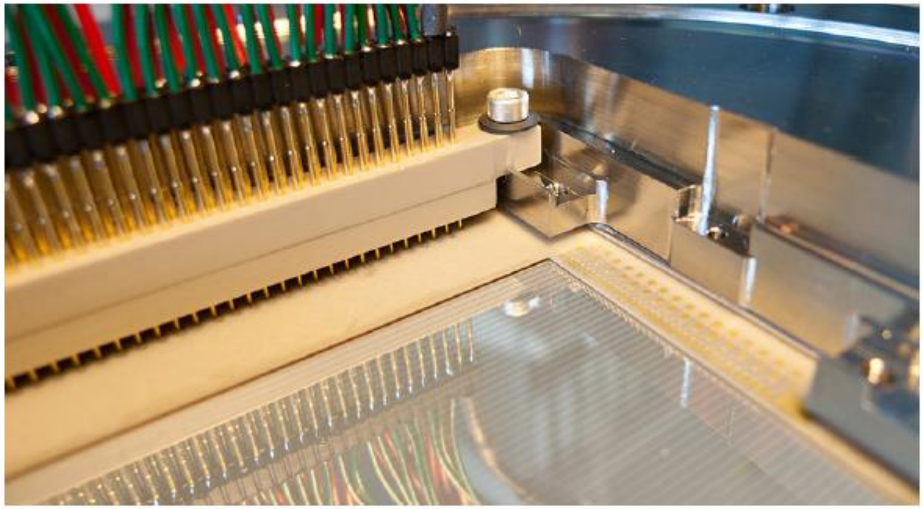
UHV compatible PCB, temperature expansion like Si, readout from the back side

- DSSD on AlN PCB
  - “clean“ UHV side with sealed feedthroughs; no soldering, no connectors etc.
  - Readout of all 192 strips from the back side



- Reversible contacting via spring pins in custom made connector made of PEEK
  - heat resistant till 160°C at least



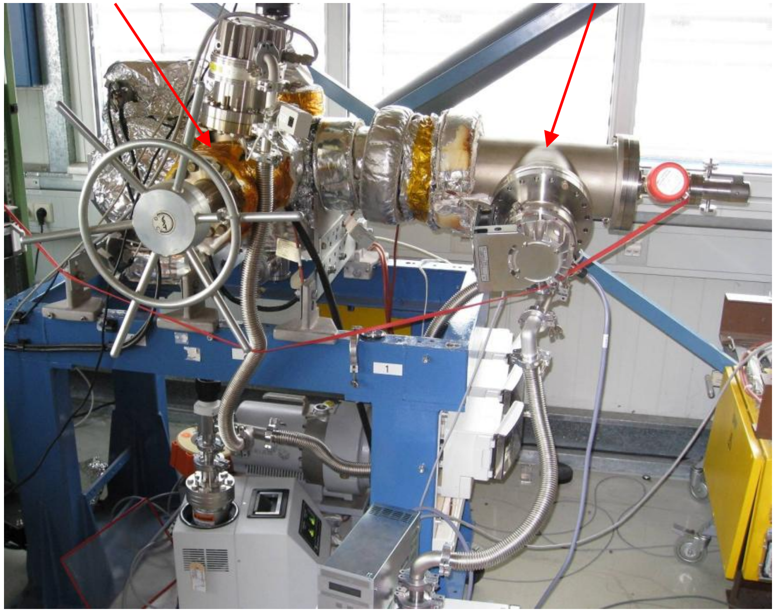


I. Si detectors for EXL recoil detector

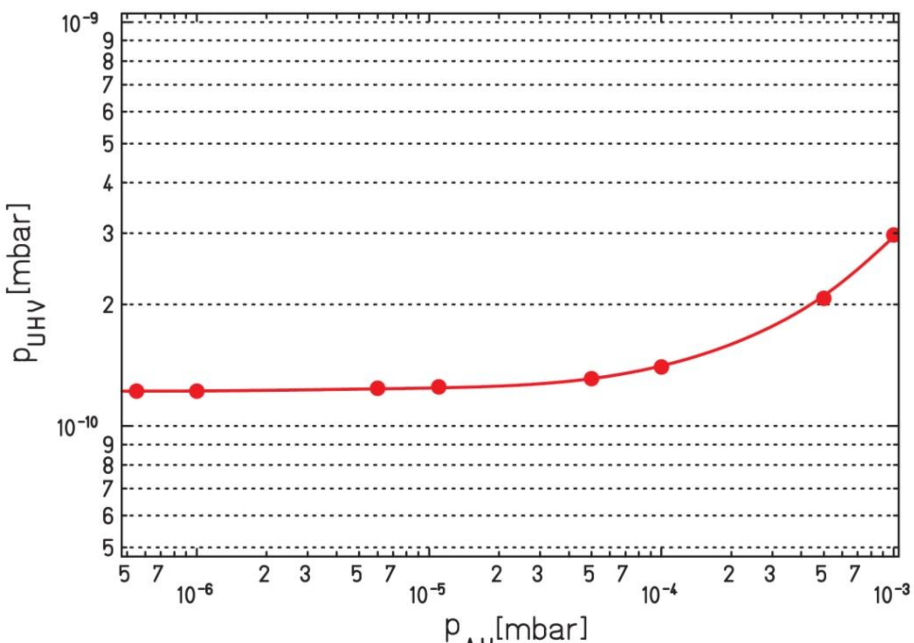
Differential Vacuum Test

- Differential vacuum test using **real DSSD** as a vacuum barrier
  - 6 orders of magnitude difference between low and UH vacuum in wide pressure region
- Vacuum of **1.2 * 10^{-10} mbar** reached (pumping limit of the station)

UHV part Low vacuum part



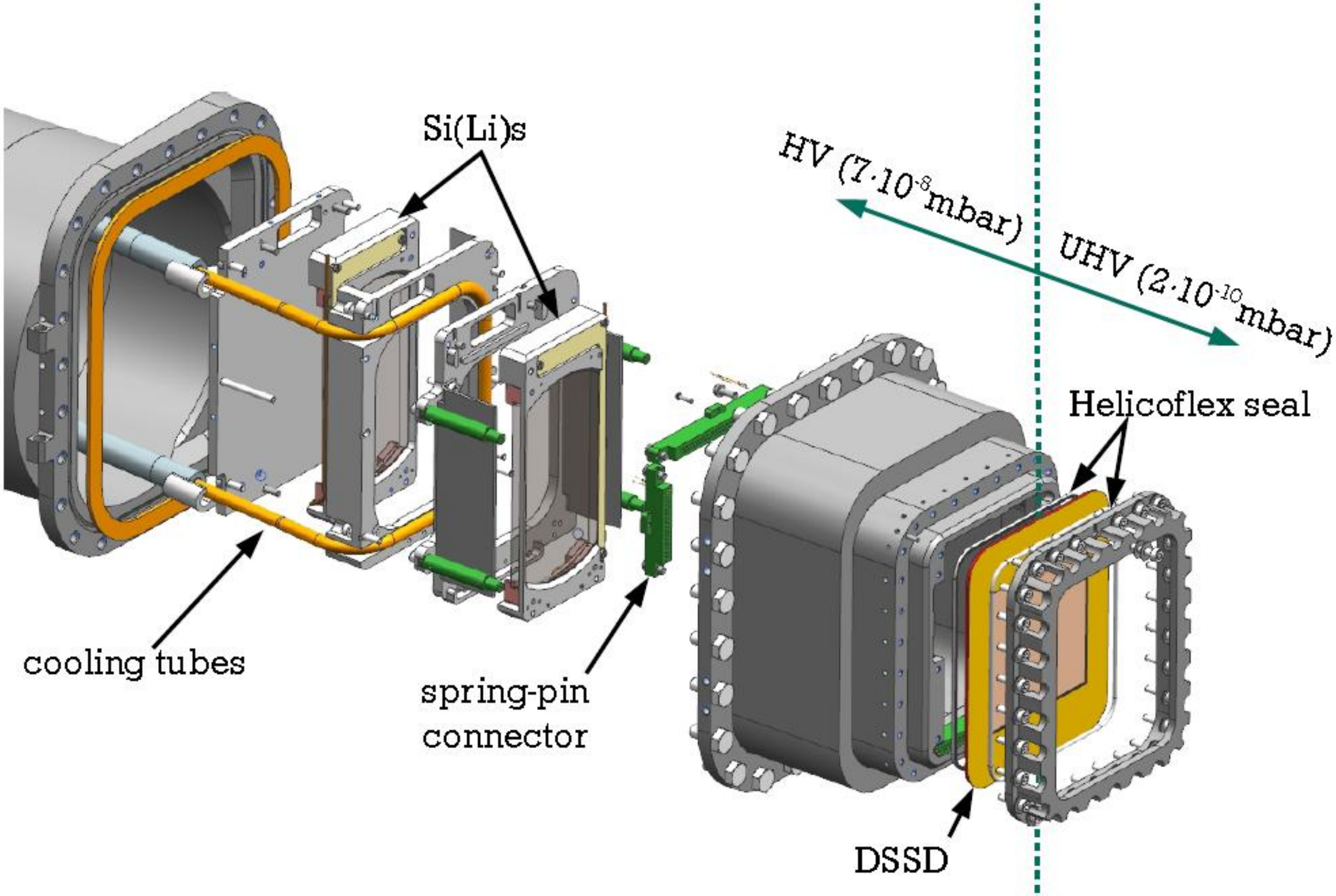
Vacuum separation



B. Streicher et al., NIM A654 (2011)604

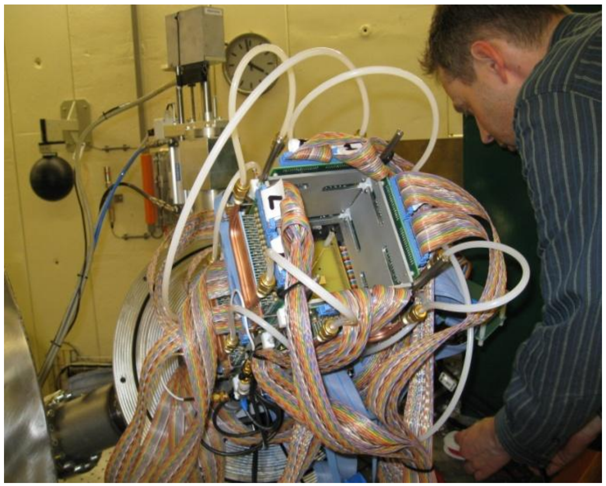
I. Si detectors for EXL recoil detector

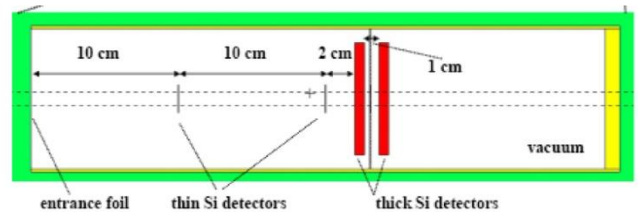
DSSDs as an active window - mounting scheme



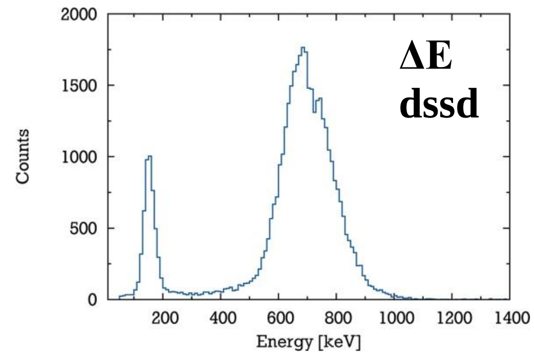
Picture: M. Lindemulder

In-Beam Test at KVI Groningen with 50 MeV Protons

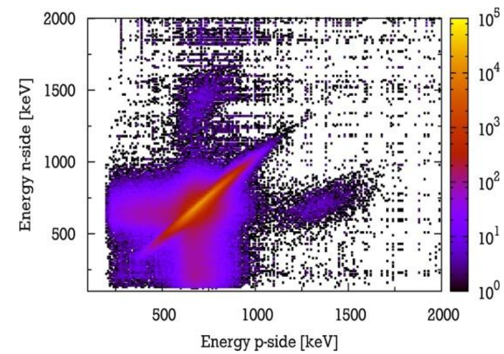


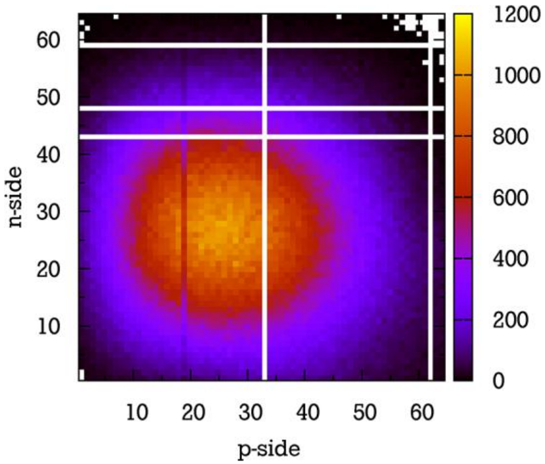


set-up



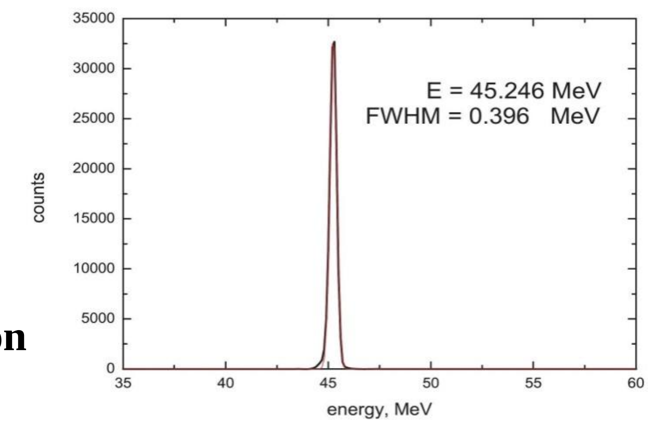
N/P





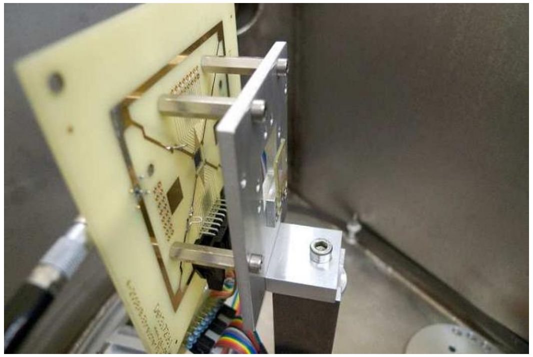
Beam profile

Total energy reconstruction

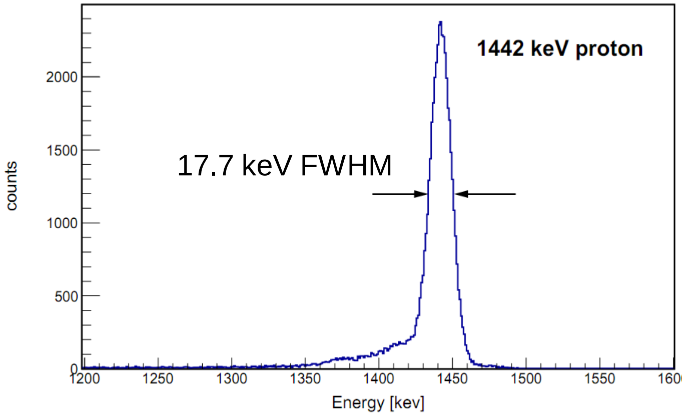


Response of Si detectors to very low energy particles

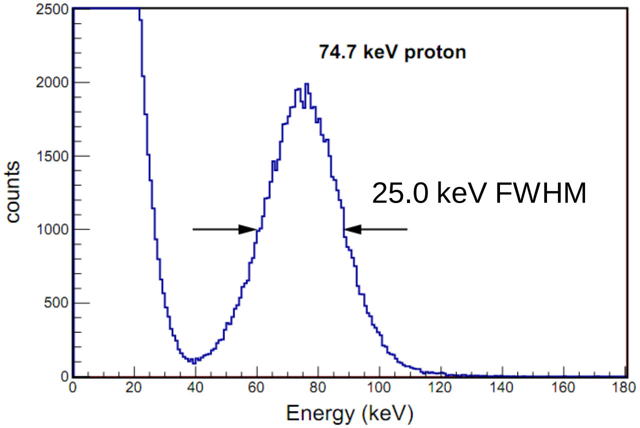
proton beams from the
Tübingen van de Graaf Accelerator



- 1503 keV protons scattered from C target (37µg/cm²)
- Spectrum shown for one strip on p side

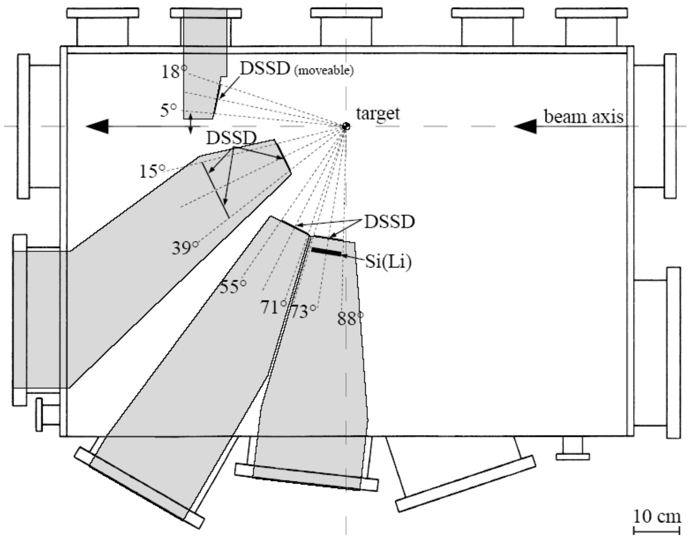


- 818 keV H_2 scattered from C target (37µg/cm²), ~3.5 µm Mylar degrader in front of DSSD
- Spectrum shown for one strip on p side



II. Setup with Si detectors – experiment E105 EXL@ESR

(p,p), (α,α`), (^{3}He,t) reactions with ^{58}Ni and ^{56}Ni beams



Comparison to the experiment performed recently at GANIL with MAYA active target

reactions with ^{58}Ni:

proof of principles and feasibility studies:

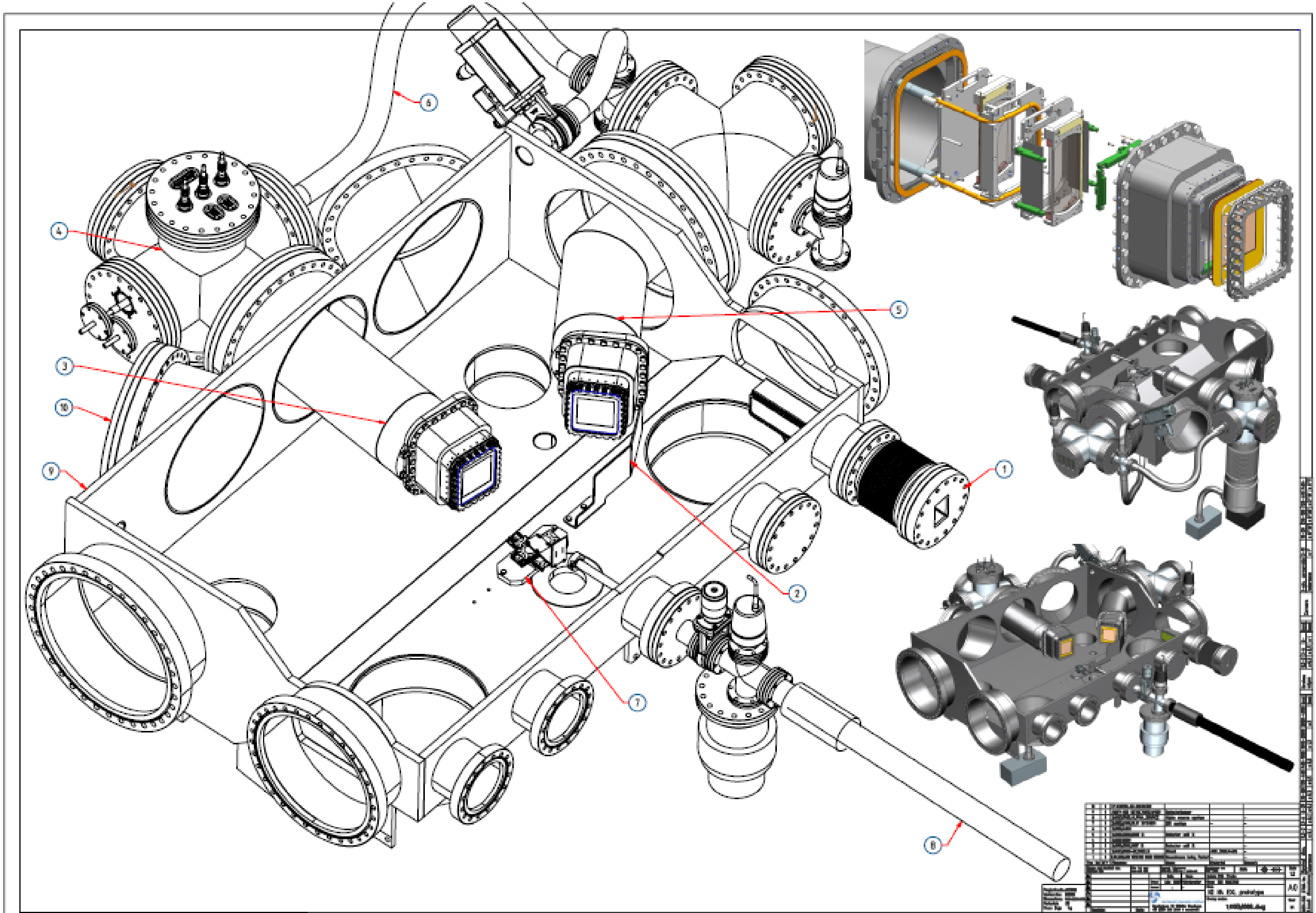
- background conditions in the environment of an internal target
- low energy threshold
- target extension and density
- performance of in-ring detection system

reactions with ^{56}Ni:

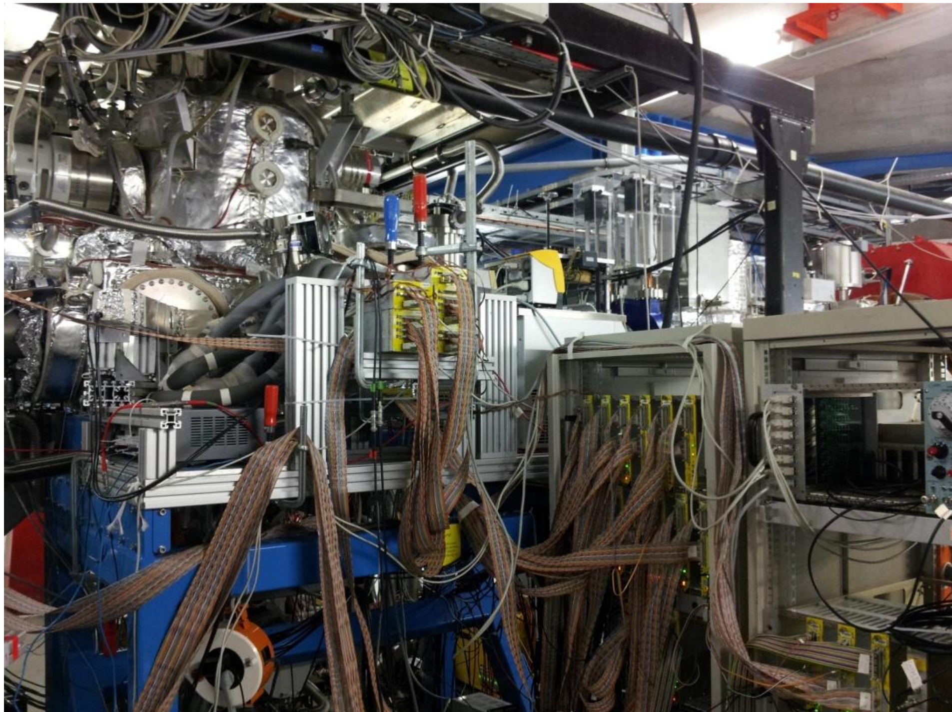
^{56}Ni: doubly magic nucleus!!

- (p,p) reactions: nuclear matter distr.
- (α,α`) reactions: giant resonances ISGMR, IVGDR, parameters of the EOS
- (^{3}He,t) reactions: Gamow-Teller matrix elements, important for astrophys.

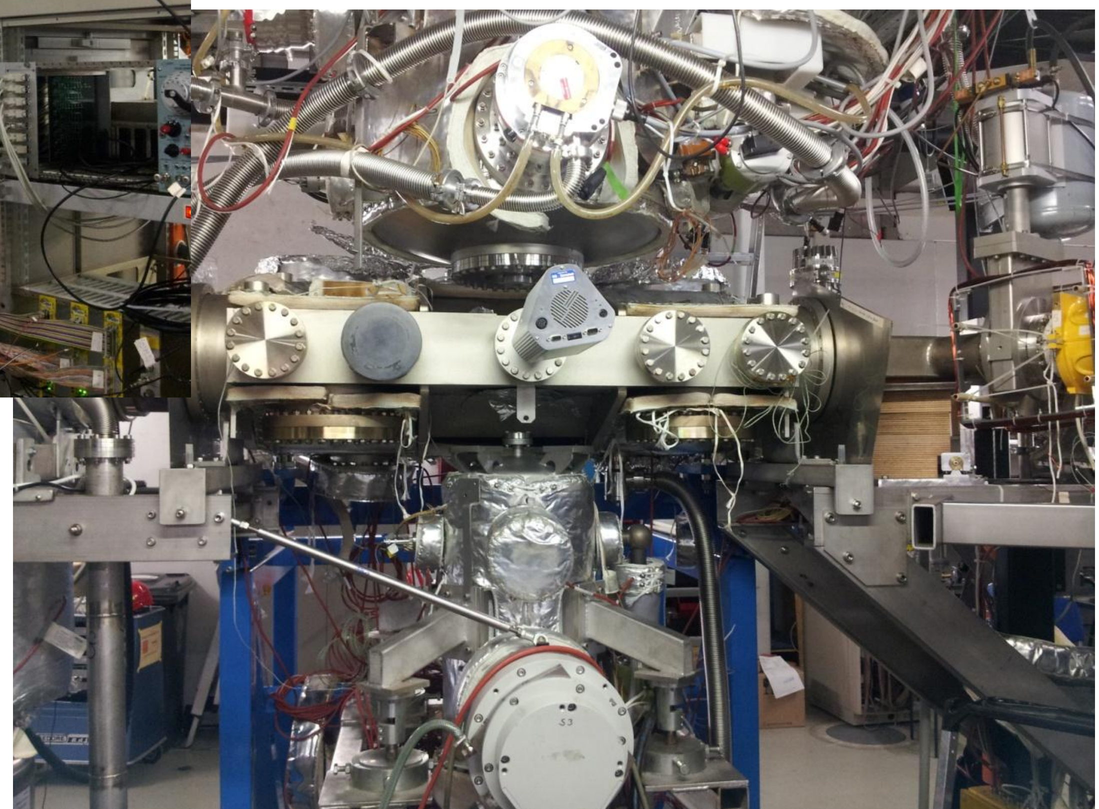
Detector Setup



Detectors and components in UHV

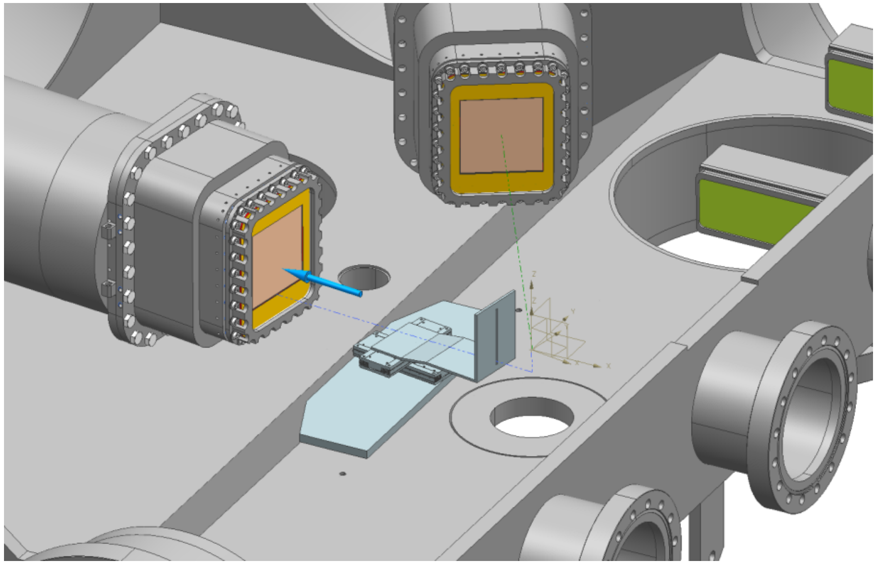


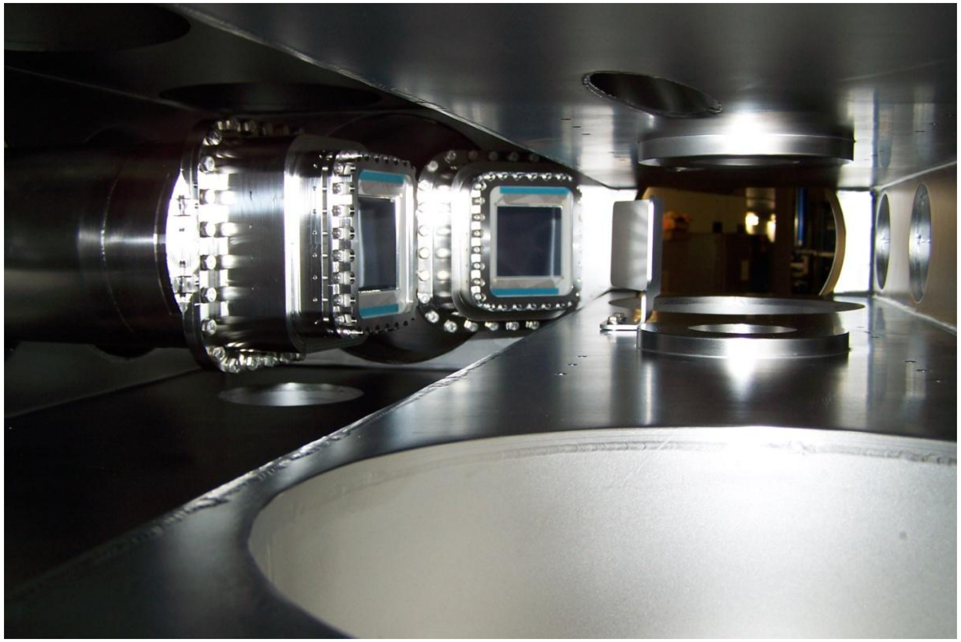
- *Complex environment of a storage ring*
- *DSSDs in UHV*
- *Active cooling of SiLi detectors in auxiliary vacuum*



First experiment worldwide having Si DSSDs as a window between UHV (10^{-10} – 10^{-11} mbar) and auxiliary vacuum (10^{-7} mbar)

Challenges of the experiment





Additional technical challenges: piezomotors directly inside UHV for X-Y slit movement, calibration of the DSSDs on site

Safety: power-fail protected electrical system, constant monitoring of vacuum, pressure difference, temperature, pumps status with alarm system (Emal and SMS sending)

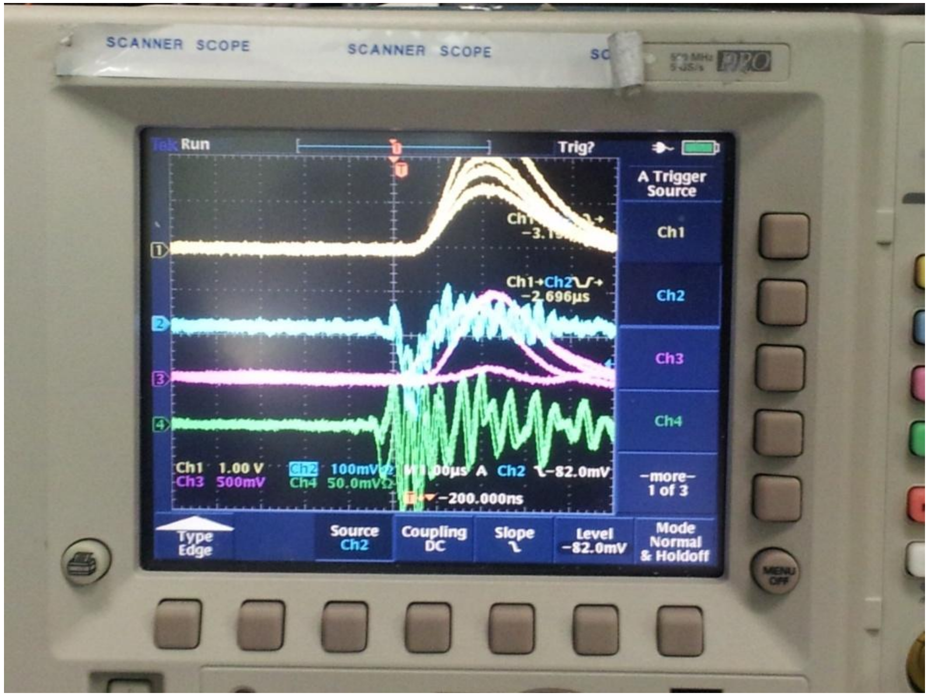
III. Performance in realistic conditions and further development towards larger EXL setup

All experimental systems worked well for a whole period of experiment!

Many systems have been used for a first time in such conditions, like the piezomotors in UHV

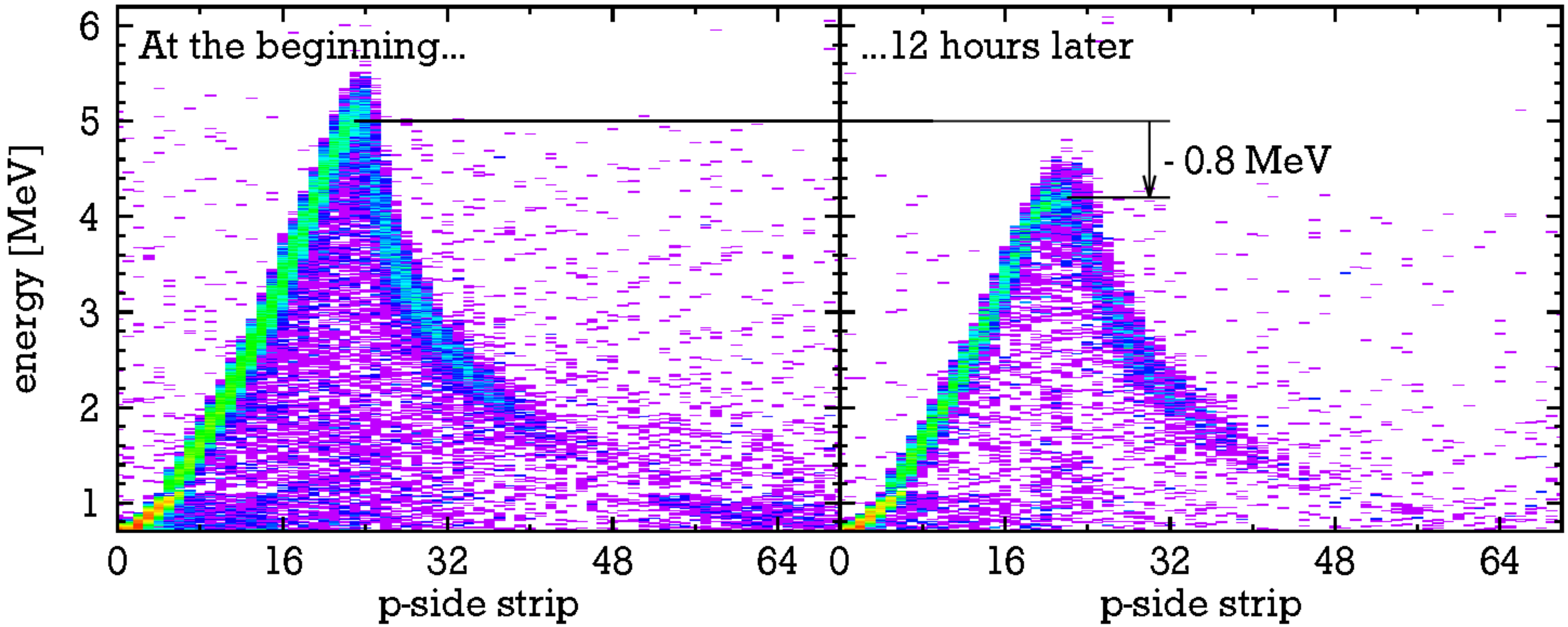
Several tests before the experiment and careful selection of the components ensure the success of experiment

Few aspects of the setup, nevertheless, need to be improved



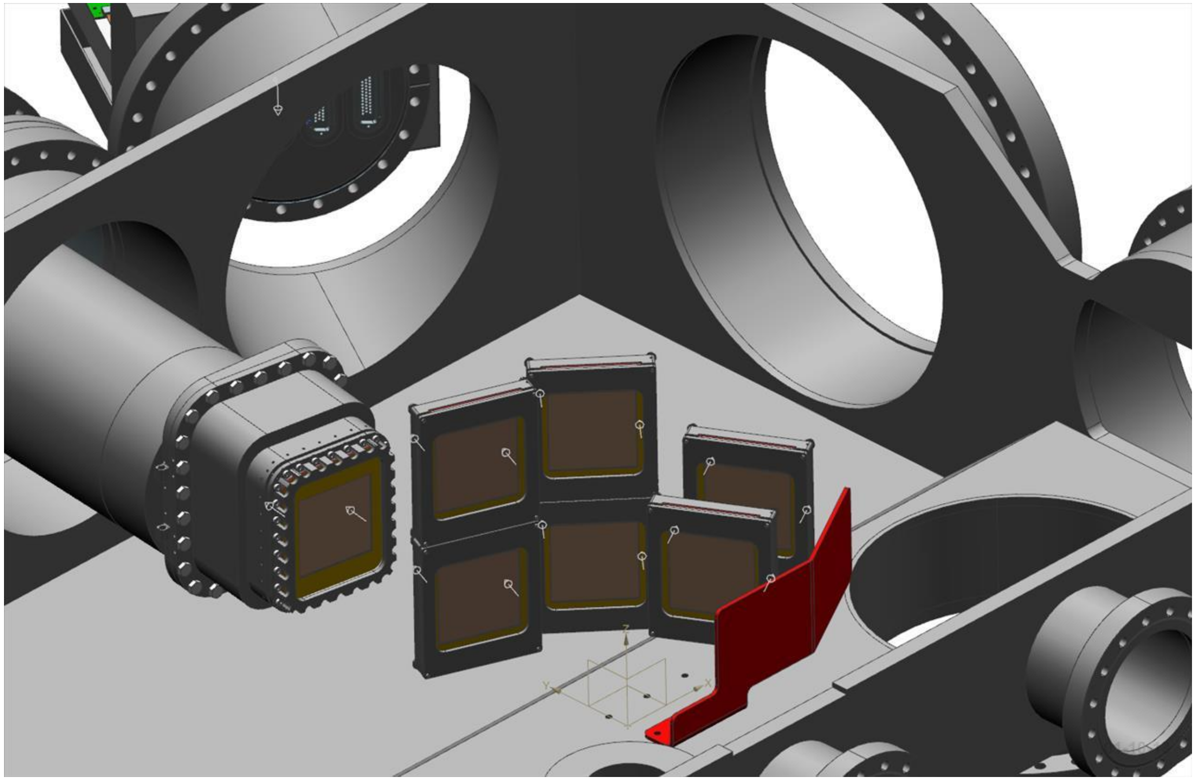
Effect of depletion change of DSSD under irradiation

- Beam intensity of stable ^{58}Ni beam $\approx$ 25 times higher.
- Observed deterioration of detector performance over time:
  - Leakage current increasing
  - Maximum energy decreasing $\rightarrow$ decreased depletion depth



Not a “classical” radiation damage – proton rate is very small
Most probable reason – low-energy electron or/and γ-irradiation
Design of DSSDs changed, new detectors should be more radiation-hard

Larger recoil detector – design towards full-scale EXL



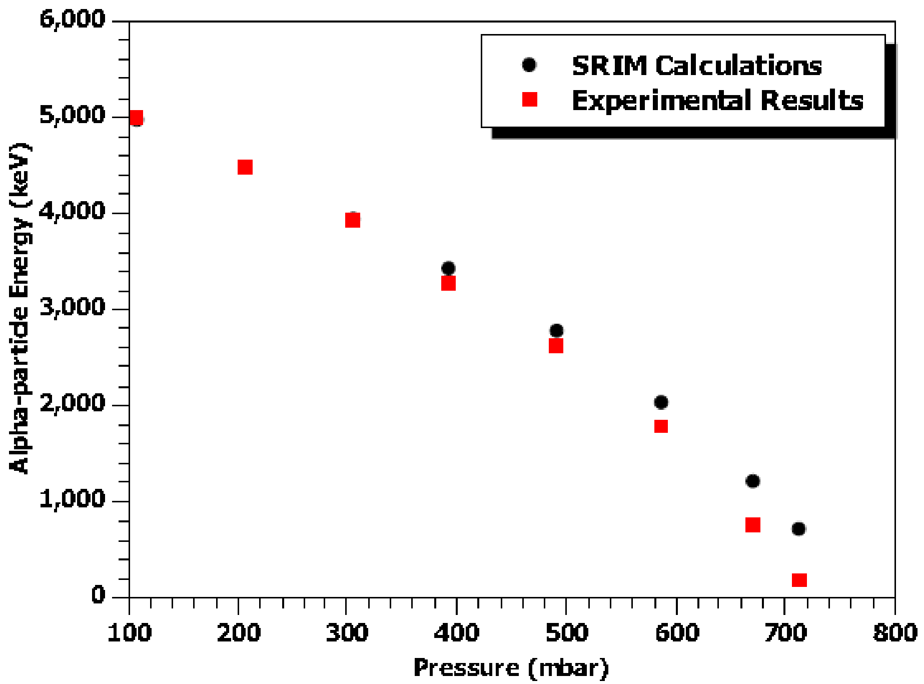
- ✓Test of cables, connectors in UHV is positive ⇒ ***DSSD can be operated fully in UHV***
- ✓First design of detector mounting is available
- ✓Modular and scalable scheme
- ✓New readout with ASICs – 256 channels per PCB, energy and timing
- ✓Possible use of new thick Si detectors for calorimetry

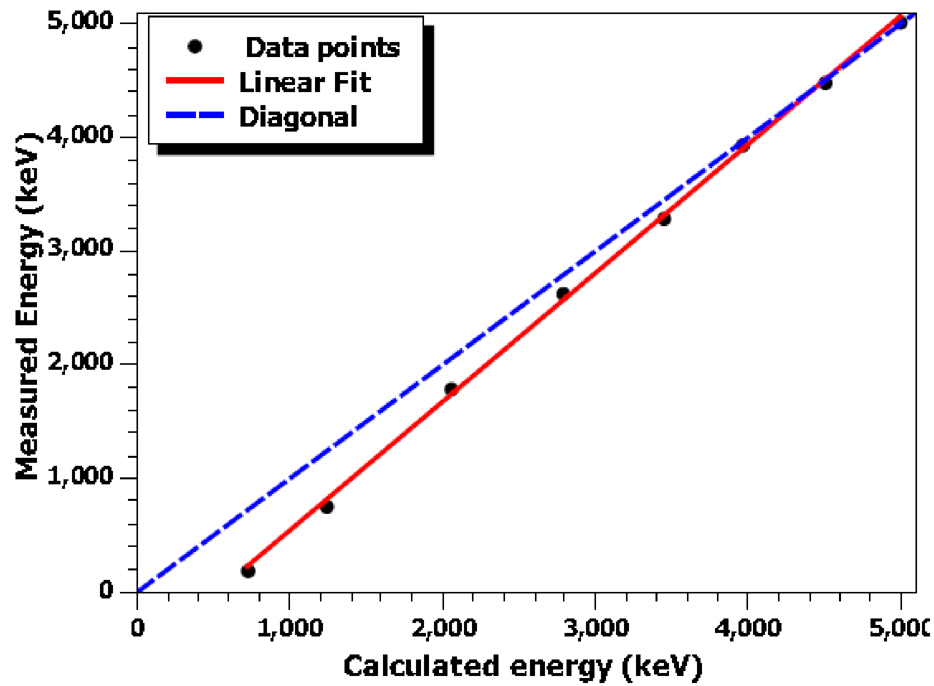
Aims:

1) prepare an experiment ^{56}Ni(α,α') at ESR at the middle of 2014

2) Prove solutions applicable for a larger system

Calibration of Si detectors with low-energy α-particles



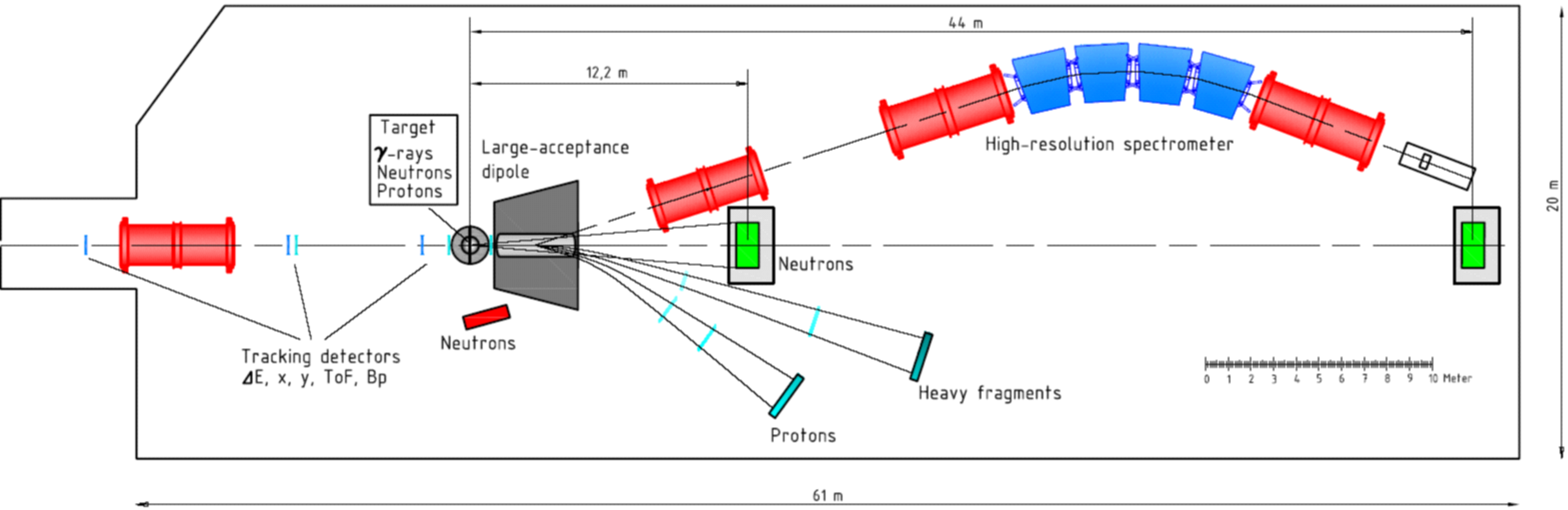


- ✓Aim – establish method for calibration of DSSDs with α-particles, E = 200-1000 keV
- ✓Technique – decelerating 5.5 MeV α-particles in gas
- ✓Varing pressure one can vary final energy
- ✓Mehtod established, measurements done and compared with SRIM calculations
- ✓***Precision needs to be improved – better pressure and temperature control plus better range calculation***

Conclusions

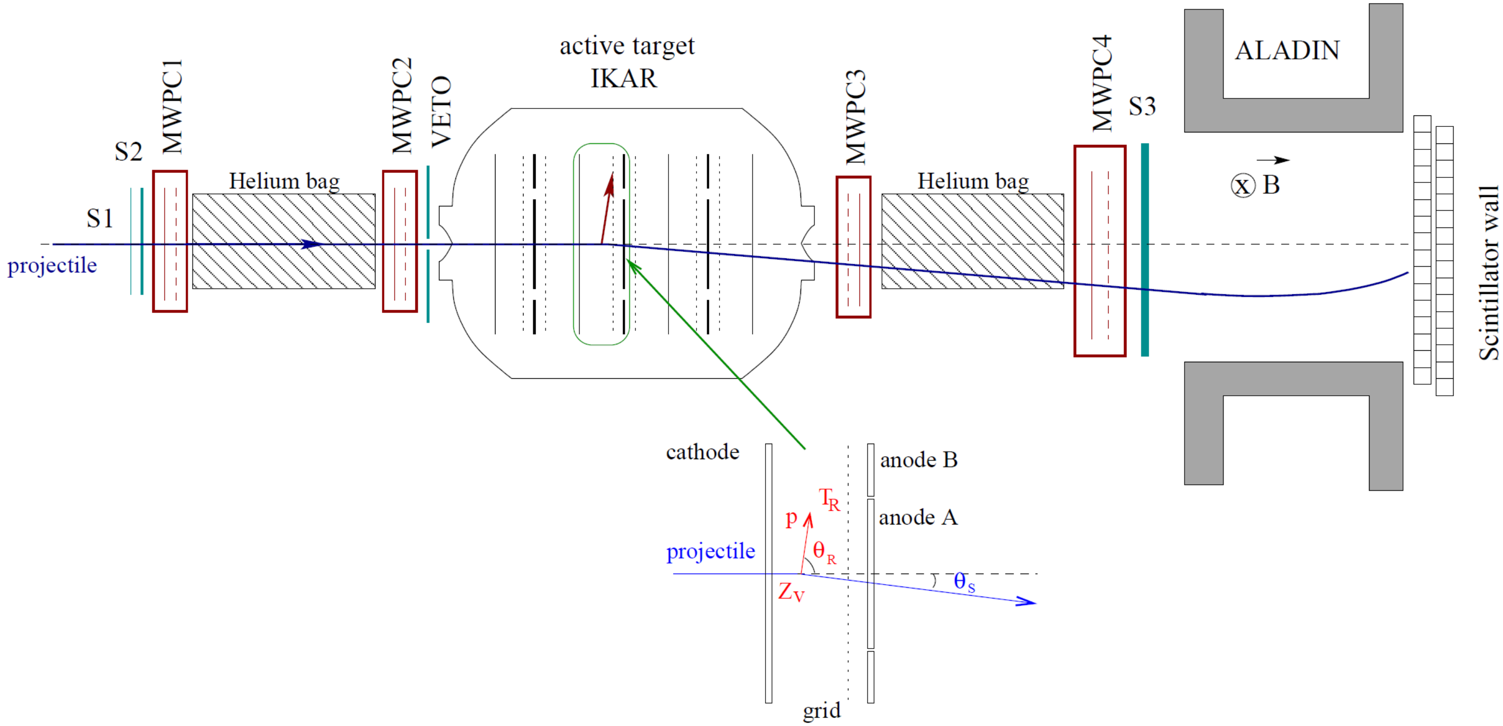
- The EXL setup is designed as universal detection system providing high resolution and large solid angle coverage for measurements at low momentum transfer - a world wide unique.
- The realization of EXL UHV compatible Si recoil detector is most challenging.
- A lot of R&D and feasibility studies are done. All major technical problems are solved.
- ***First scattering experiment with radioactive nuclei and a down-scaled setup at storage ring has been successfully performed in October-November 2012 at GSI Darmstadt.***
- New design of the detectors made, should improve radiation hardness
- New compact readout electronics should be usable for a larger system
- **Design of modular and scalable detector system – a real step towards a full EXL detector**

IV. Possible experiments with Active Target and requirements



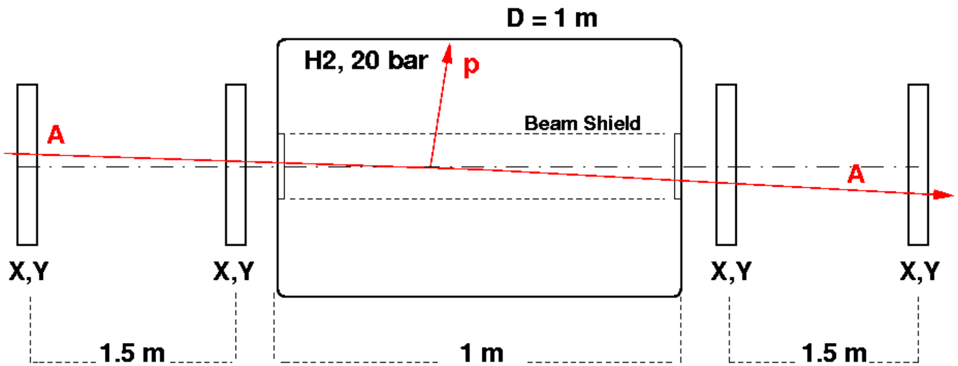
- Alternative option to the „standard“ R3B target setup –> specific experiments
- It allows experiments when low-energy charged recoils need to be measured – p or α elastic scattering, p,p‘, α,α‘, giant resonances, charge exchange
- High efficiency (~100%) for low energy reaction products
- Relatively thick target → study of rear reactions
- Very low energy threshold (~1 MeV)
- Good angular and position resolution, particle identification, high dynamic range
- Experiments with light to heavy ions

Experience with Active Target technique

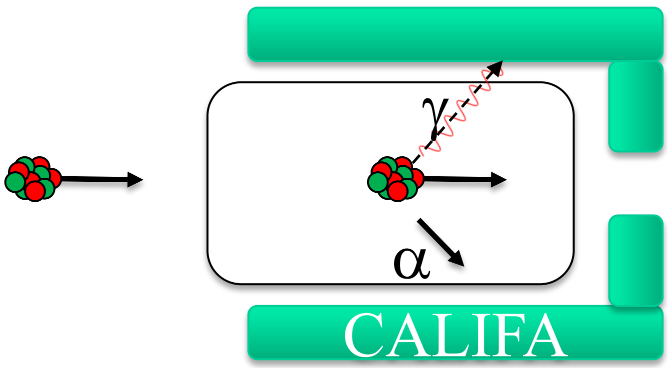


- Ionization chamber with axial symmetry, built at PNPI
- Diameter of inner anodes – 20 cm, of outer – 40 cm
- Normally filled with pure H_2; D_2, He also possible, pressure up to 10 bar
- 6 independent detection modules in the same gas volume
- Many successful experiments with stable and radioactive ions are performed
- **Limited to light ions up to Carbon**

Two types of Active Targets for R3B

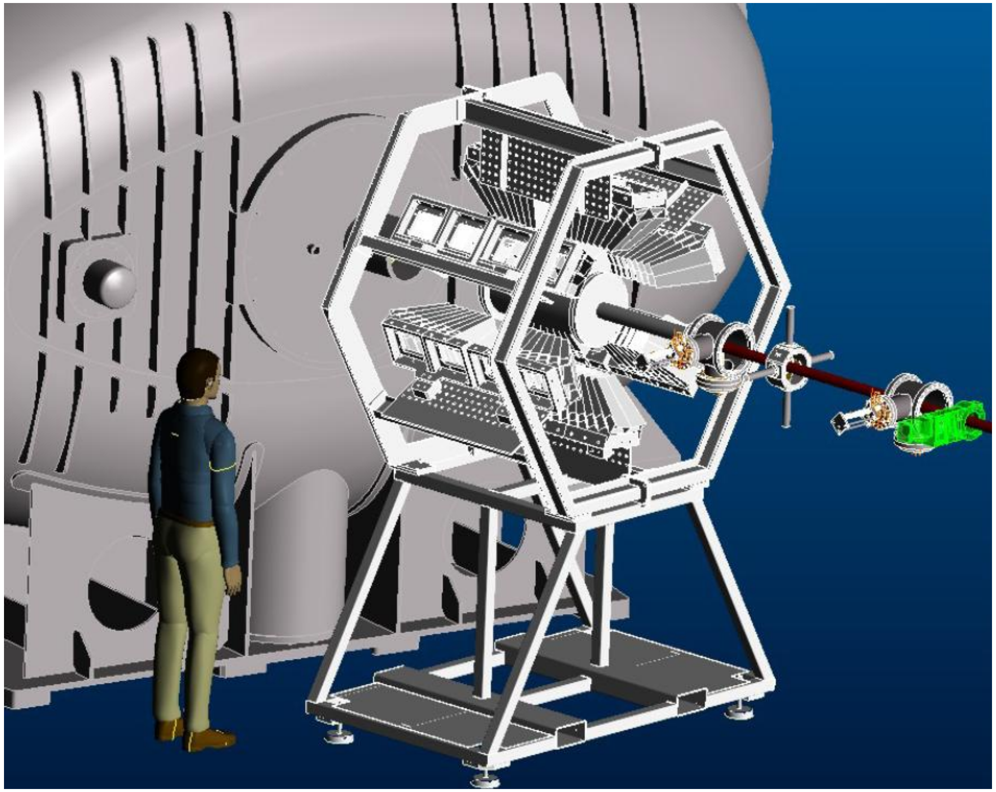


- Mainly p,p and α,α scattering
- Design based on IKAR chamber
- Gas – H_2, D_2, ^3He, ^4He, CH_4, Ar, pressure – up to 25 bar
- Beam shielding electrodes
- High segmentation of electrodes



- Investigation of low-lying dipole strength in inelastic α scattering
- Smaller chamber inside CALIFA
- Gas – H_2, D_2, ^3He, ^4He, CH_4, Ar, pressure – up to 10 bar
- Beam shielding electrodes
- High segmentation of electrodes

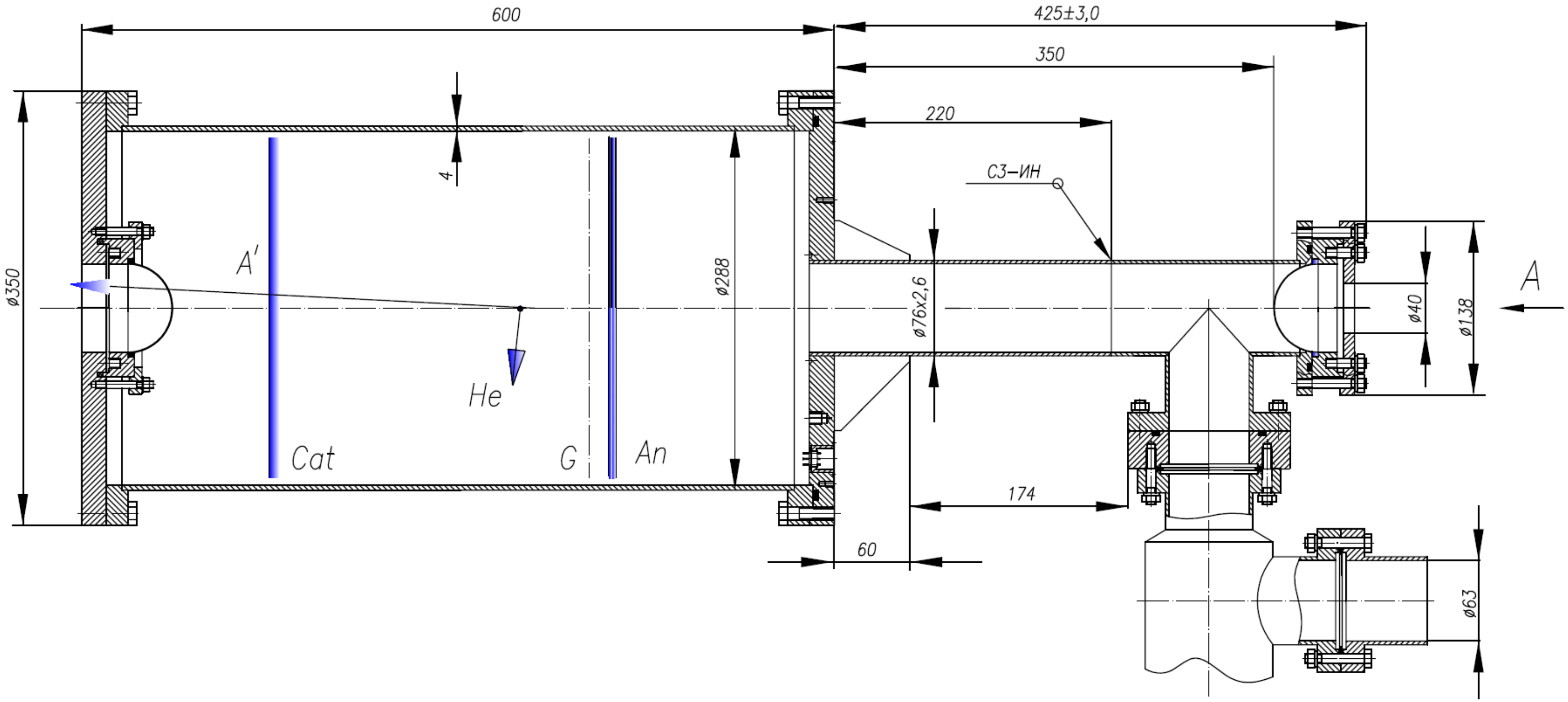
Active Target inside CALIFA



Possible arrangement of the active target, CALIFA demonstrator, tracking detectors and GLAD magnet

Existing cylinder of ionization chamber and vacuum parts at PSI, Switzerland
Fits inside CALIFA
Transported to GSI in May 2013

V. R&D towards first experiment within R3B setup

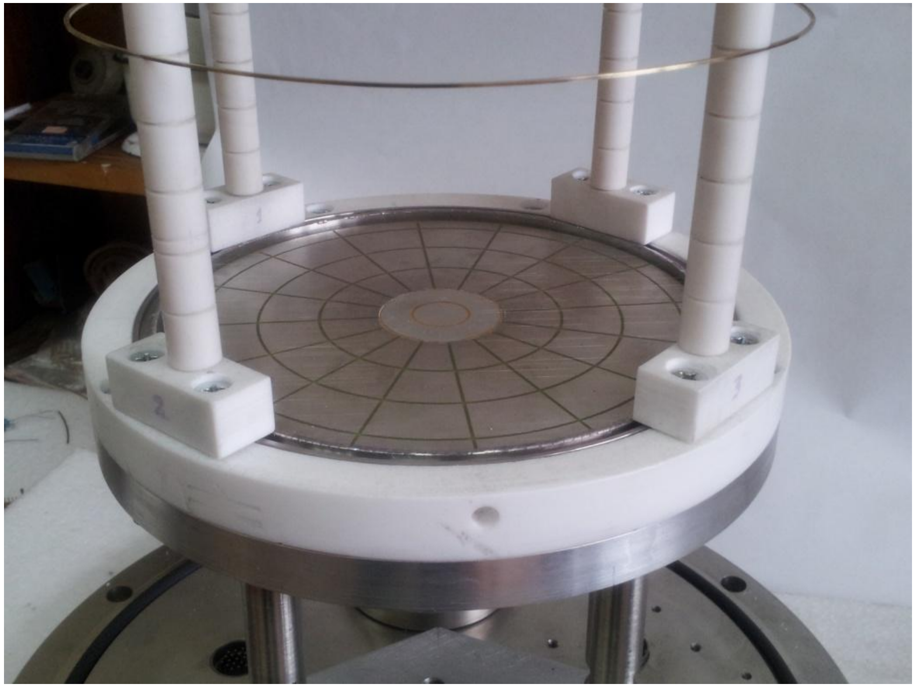


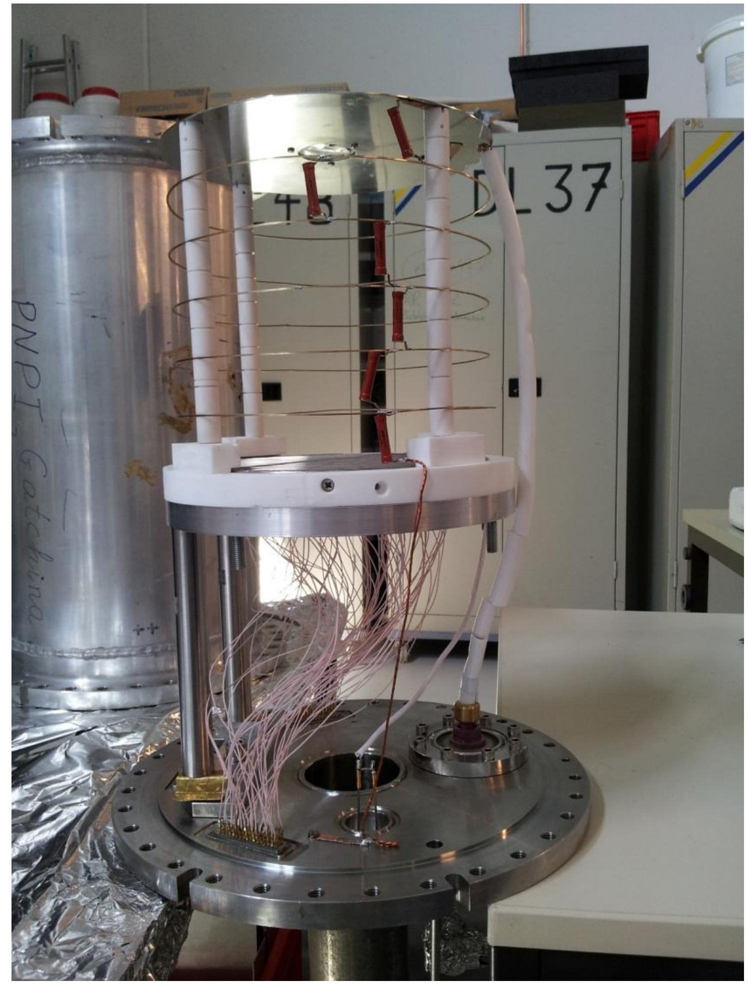
New design of the beam pipe, vacuum system and support frame with rails for insertion inside CALIFA is available; production started

Entrance and exit windows – Be, 0.5 mm, tested up to 13 bar

Working pressure – up to 10 bar

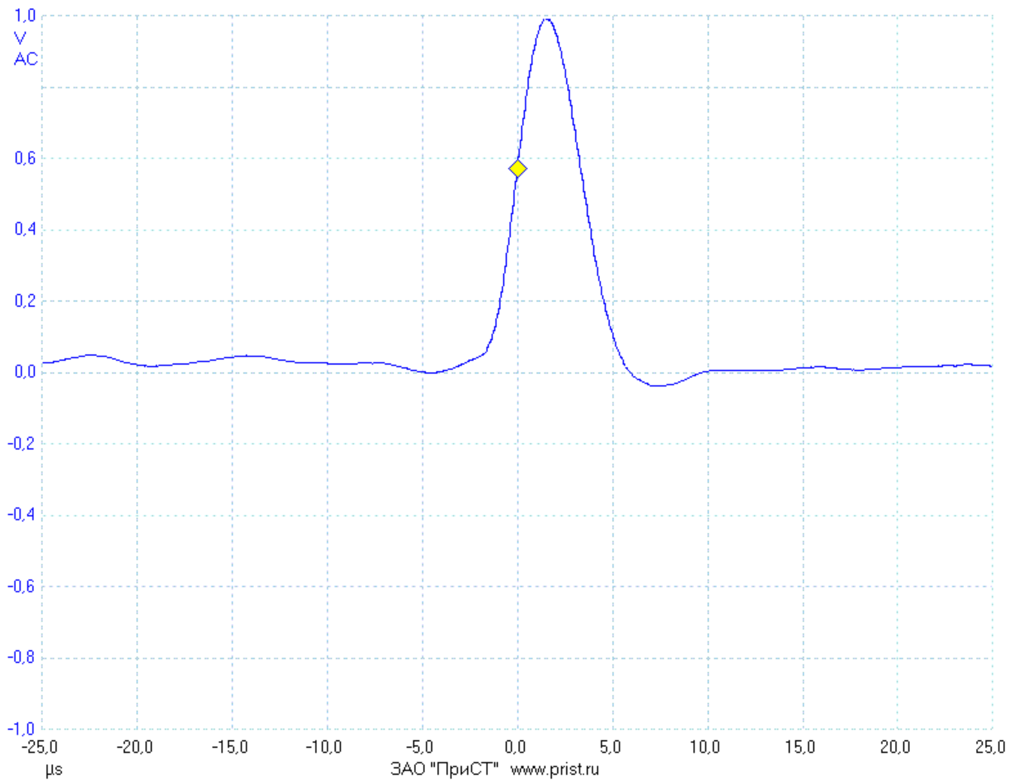
New electrodes of the Active Target





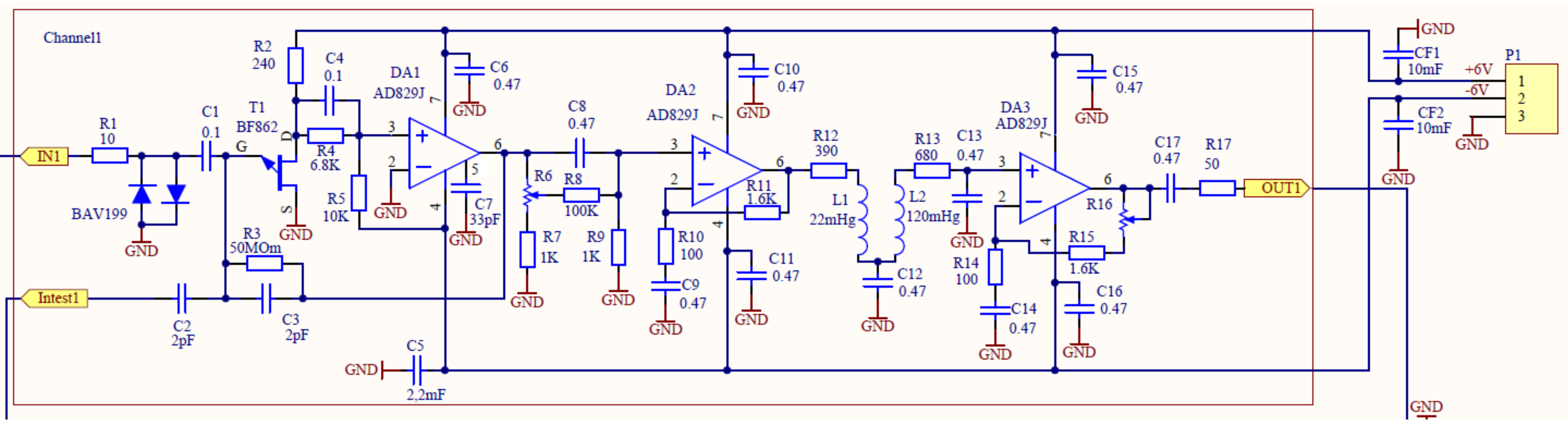
New electrodes made at PNPI
In the middle – electrodes for beam shielding
Field cage with voltage dividers
Assembled at GSI detector lab

First signals from the new Active Target



- ✓New electrode structure inside test chamber at PNPI
- ✓Gas – Ar at 10 bar
- ✓^{241}Am source on cathode (22 cm drift path)
- ✓Signals digitized with 14-bit FADC
- ✓Very low noise

New amplifiers for Active Target



PNPI contribution

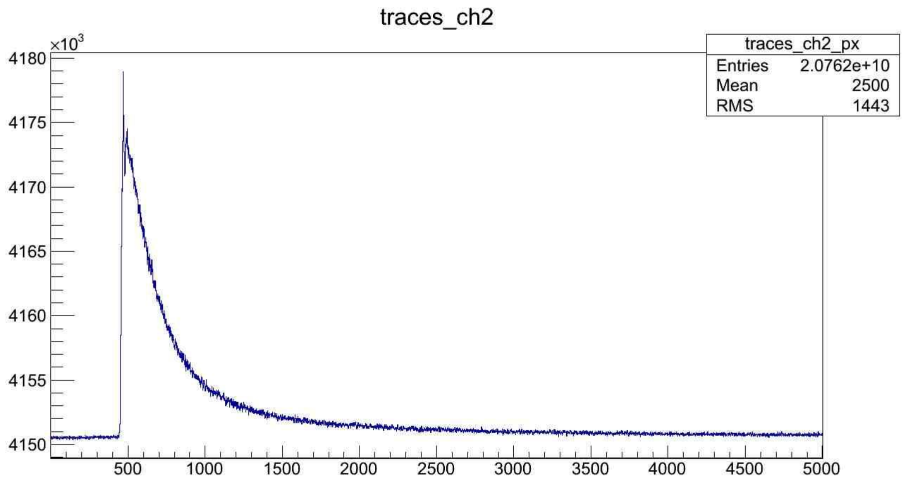
✓16 independent channels
✓Preamplifier based on N-channel JFET transistor
✓Amplifier used one of the best low-noise operational amplifier
✓Changeable gain
✓Diode protection against sparks
✓Energy resolution ≅15 keV @ realistic input capacity ≅20 pF – 2-3 times better than IKAR amplifiers
✓First board is available, two more are expected in November 2013

New digitizers for new Active Target

FADC SIS3316 from Struck GmbH
16 independent channels,14-bit resolution
Up to 250 MS/s per channel
64 MSamples memory/channel
Two programmable input ranges
Offset DACs
125 MHz analog bandwidth
Internal/External clock
Multi event mode
Readout in parallel to acquisition
Pre/Post trigger capability
Trigger OR output (16 individual thresholds)
Gigabit Ethernet and Multi-Gigabit optical link
Modules for smaller and larger chambers are available (240 channels)

GSI contribution

New digitizers for new Active Target



First code for MBS DAQ written at TU Darmstadt
Developed further at GSI/EMMI

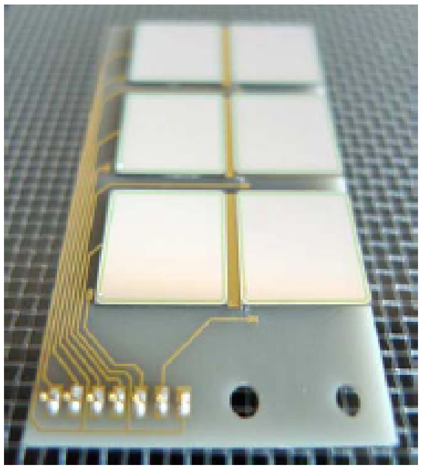
All parameters (thresholds, digitization speed, are written in external file and easily changeable)
LAND/R3B software used for the data analysis
Tested with Cristall Ball electronics and signals
Readout code is called by the LAND/R3B DAQ
Should be easy to implement in the DAQ with CALIFA Demonstrator, tracking detectors

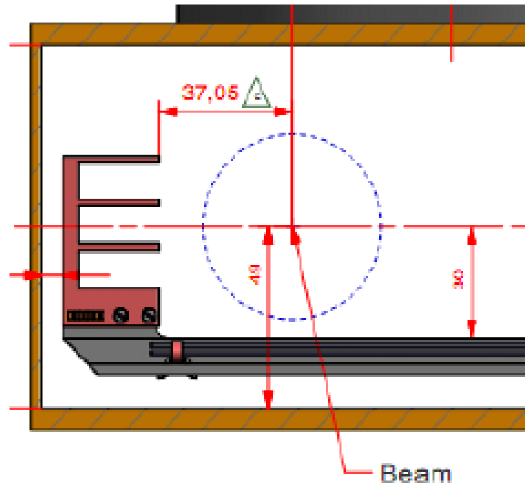
Status and plans - Active Target

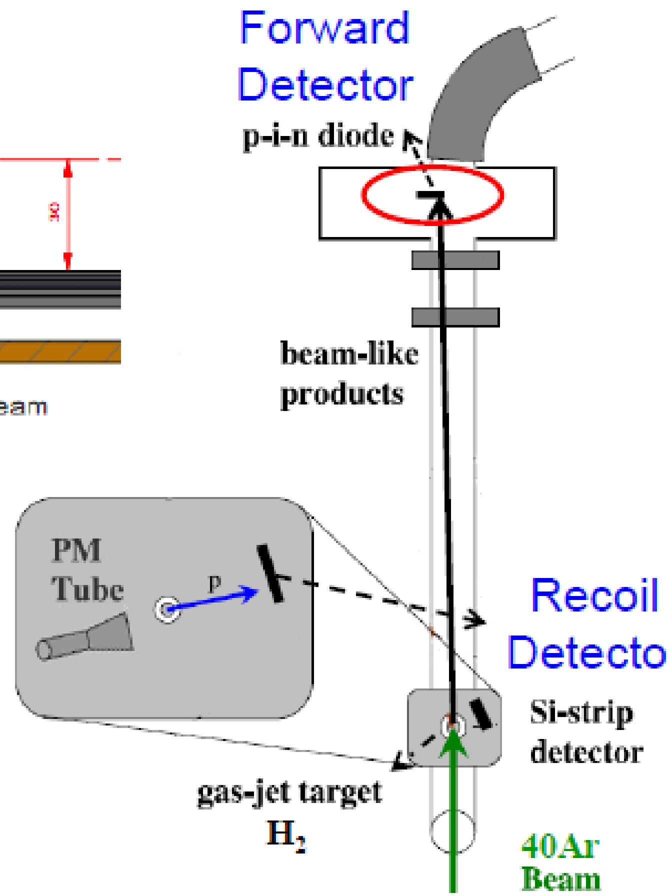
- Chamber body is available
- New electrodes are ready
- New amplifiers are ready, characteristics better than those used for IKAR
- New signal digitizers are available and working
- Design of the vacuum system and support ready, production of mechanical parts started
- First tests with α-source are positive
- ***Readiness for a beam test with CALIFA demonstrator – March 2014***

Backup

UHV capable Tagging Detector







- Forward detector before the first dipole, detection of beam like reaction products in coincidence with recoils.
- 6 PIN diodes (1 x 1 cm²) on AlN PCB, directly in the UHV
- Small dead edge, could be very close to the beam
- Baked at 250° C, passed vacuum Test.