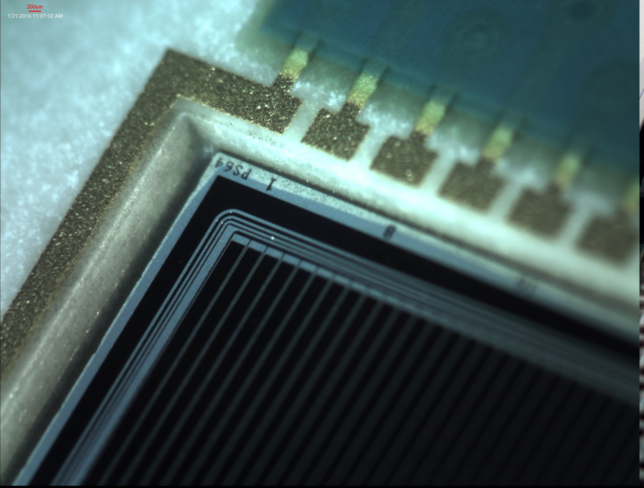
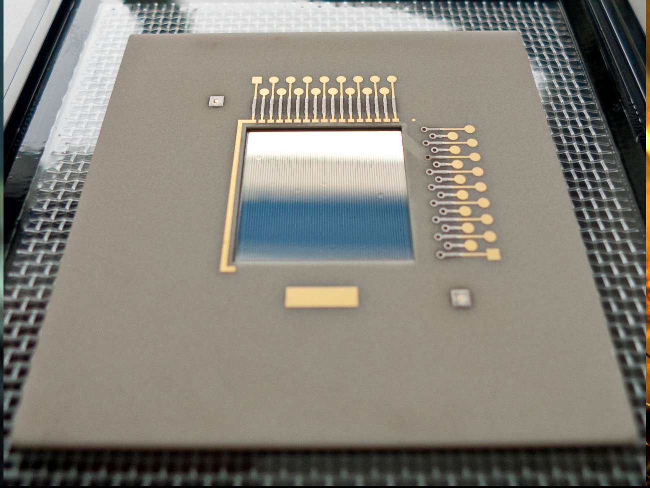
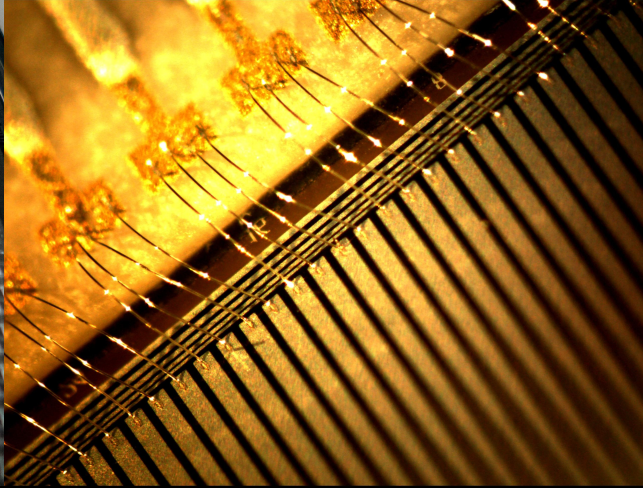




Implementation of Silicon Detector Arrays in the UHV Environment of Storage Rings

Branislav STREICHER

for the EXL collaboration

8th International Conference on Nuclear Physics at Storage Rings - STORI'11

9 - 14 October 2011, Laboratori Nazionali di Frascati

Part 1
Motivation & Physics Background

EXL* Project @ FAIR

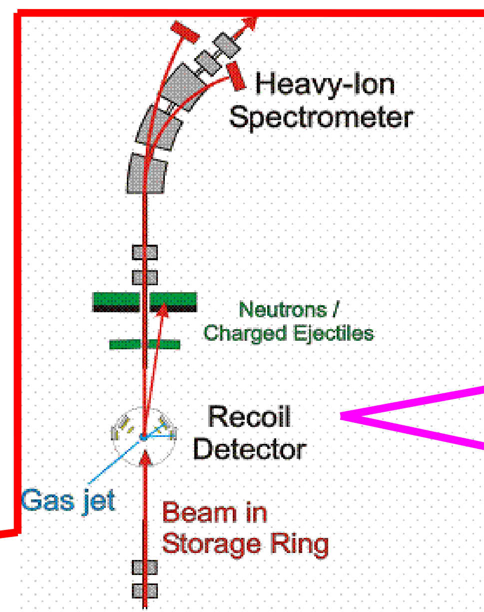
Advantages:

- High intensities in the ring
- Little energy loss in the target
- No target window (no background)
- Small energy/momentum spread of the beam (cooling)

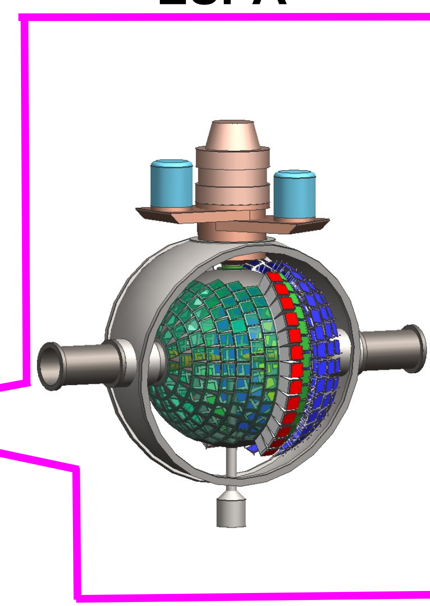
Challenges:

- Very small recoil energies for small q
- Thin targets
- Ultra high vacuum (UHV)

EXL



ESPA

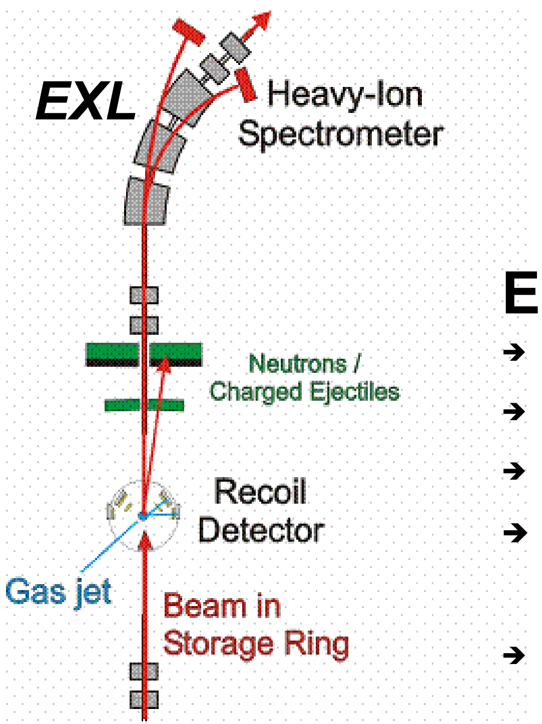


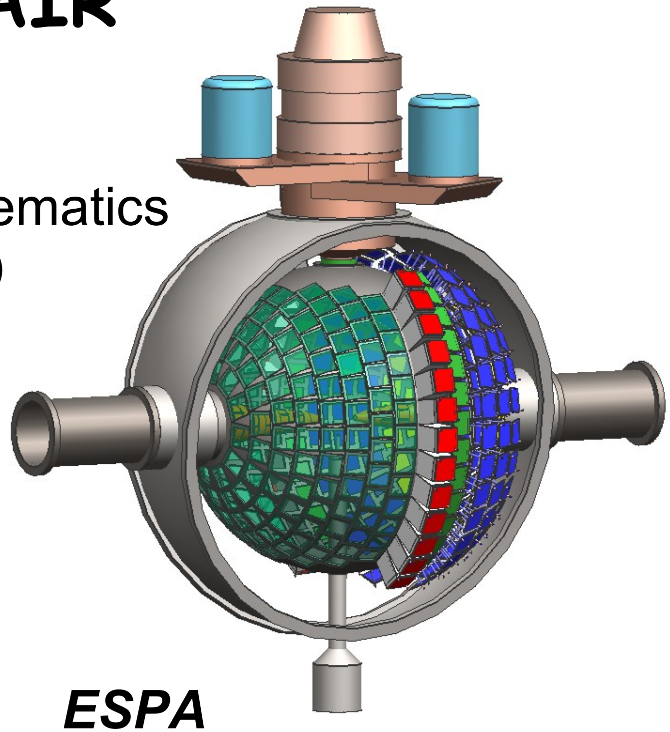
*EXL = EXotic nuclei studied in Light ion induced reactions at the NESR storage ring

EXL Project @ FAIR

EXL Project @ NESR*:

- Reactions with radioactive beams in inverse kinematics
- Recoil detector **ESPA** (**E**XL's **S**ilicon **P**article **A**rray)
- Hundreds of DSSDs planned
- Placement in storage ring environment





ESPA Development:

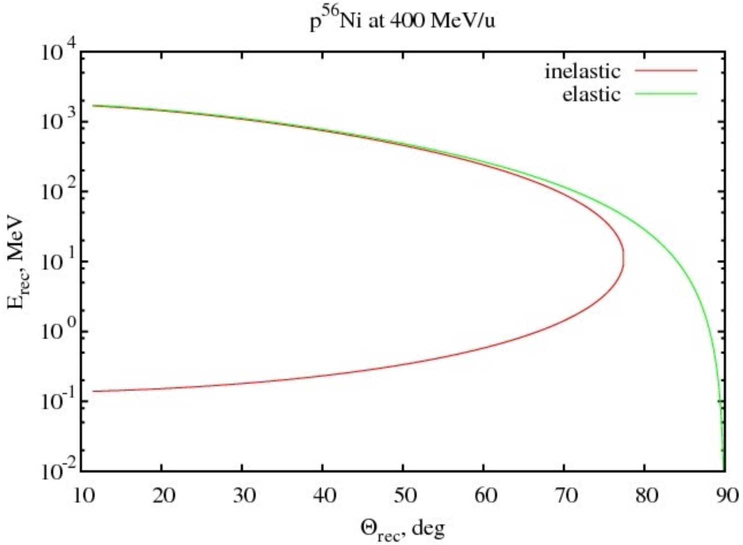
- Performance tests using α-sources at GSI, Edinburgh
- EXL telescope demonstrator tests at GSI, KVI
- PSD experiment at TU München
- Construction of DSSD prototypes at GSI from chips manufactured at PTI St. Petersburg
- UHV vacuum prototype tests

*** downscaled version planned @ ESR**

EXL's Detector Requirements

Detection of light particles (p, d, t, α):

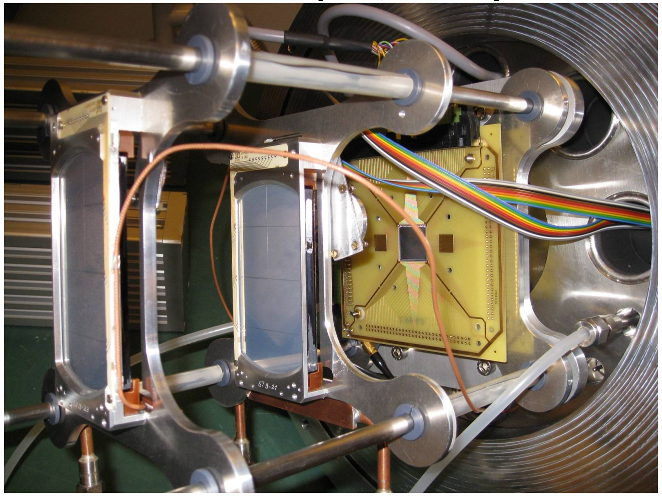
- transmission detectors
- good energy resolution
- good position resolution
- low detection threshold (< 100 keV)
- high dynamic range (100 keV – 25 MeV)



Telescopes of DSSD – Si(Li) – CsI

- total energy reconstruction
- distinguish between low-energy vs. passing-through particles
- separation of different reaction channels

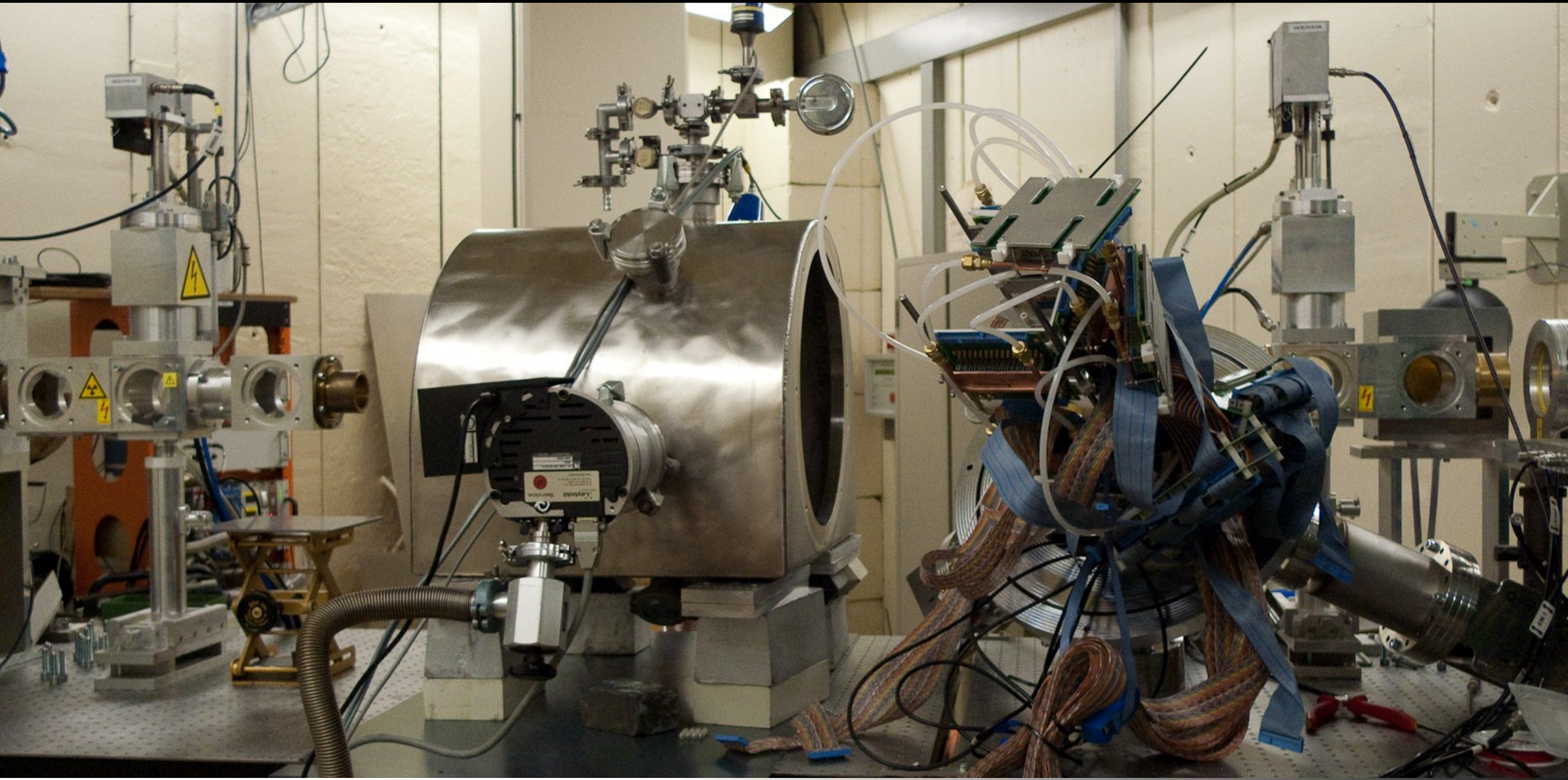
Telescope setup



Ultra High Vacuum (UHV) compatibility:

- low outgassing materials – PCB, connectors, electronics etc.
- reasonable pumping-baking times after ESPA installation in ESR/NESR

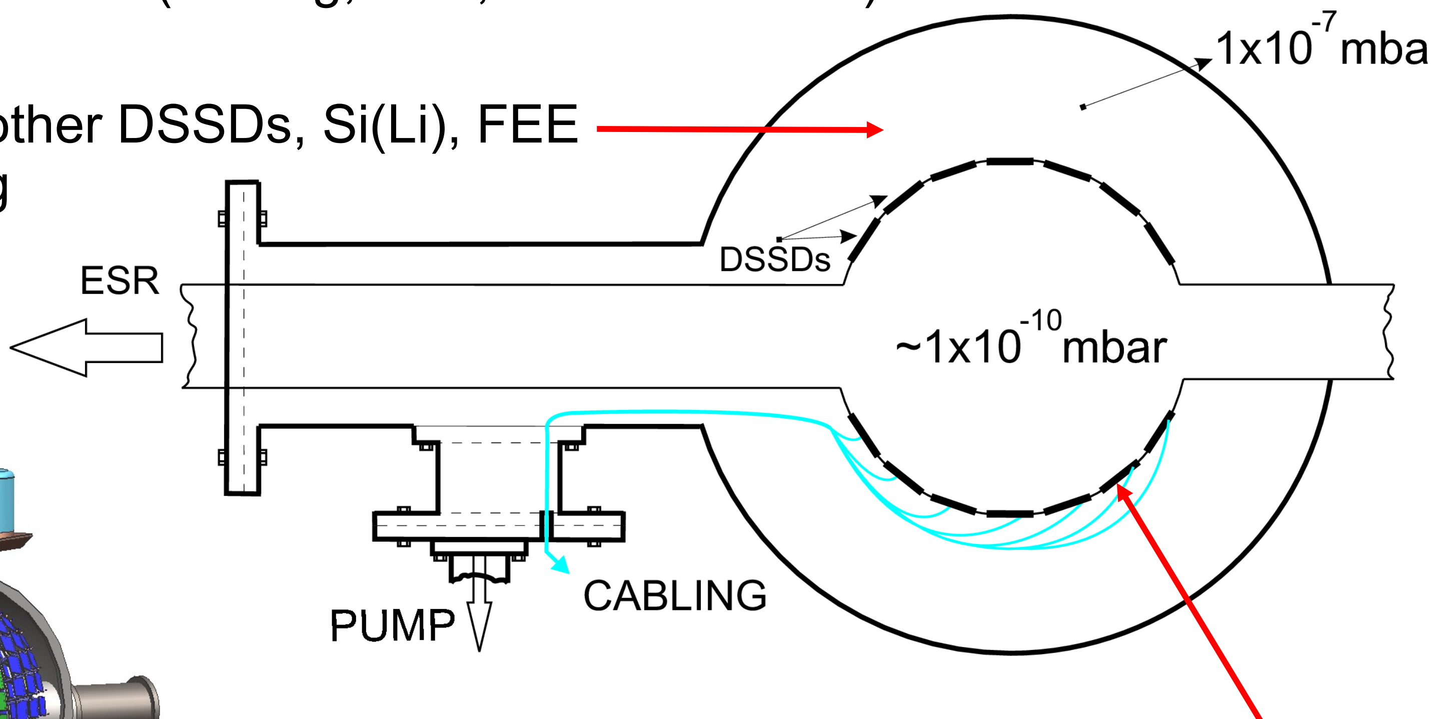
Part 2
Windowless Telescope @ the UHV of the Storage Ring

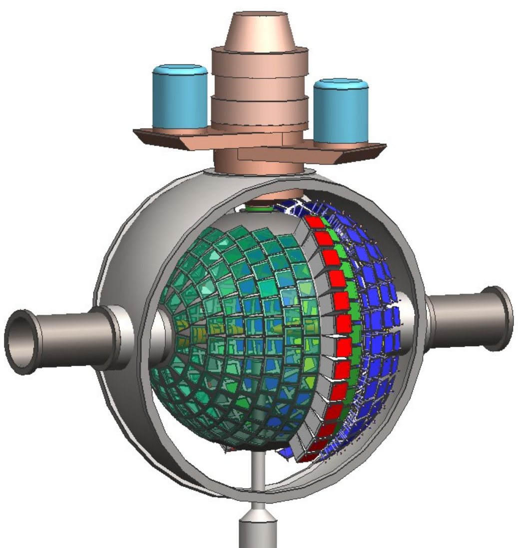


Using DSSDs as High-Vacuum Barrier

- Differential pumping proposed to separate NESR vacuum from EXL instrumentation (cabling, FEE, other detectors)

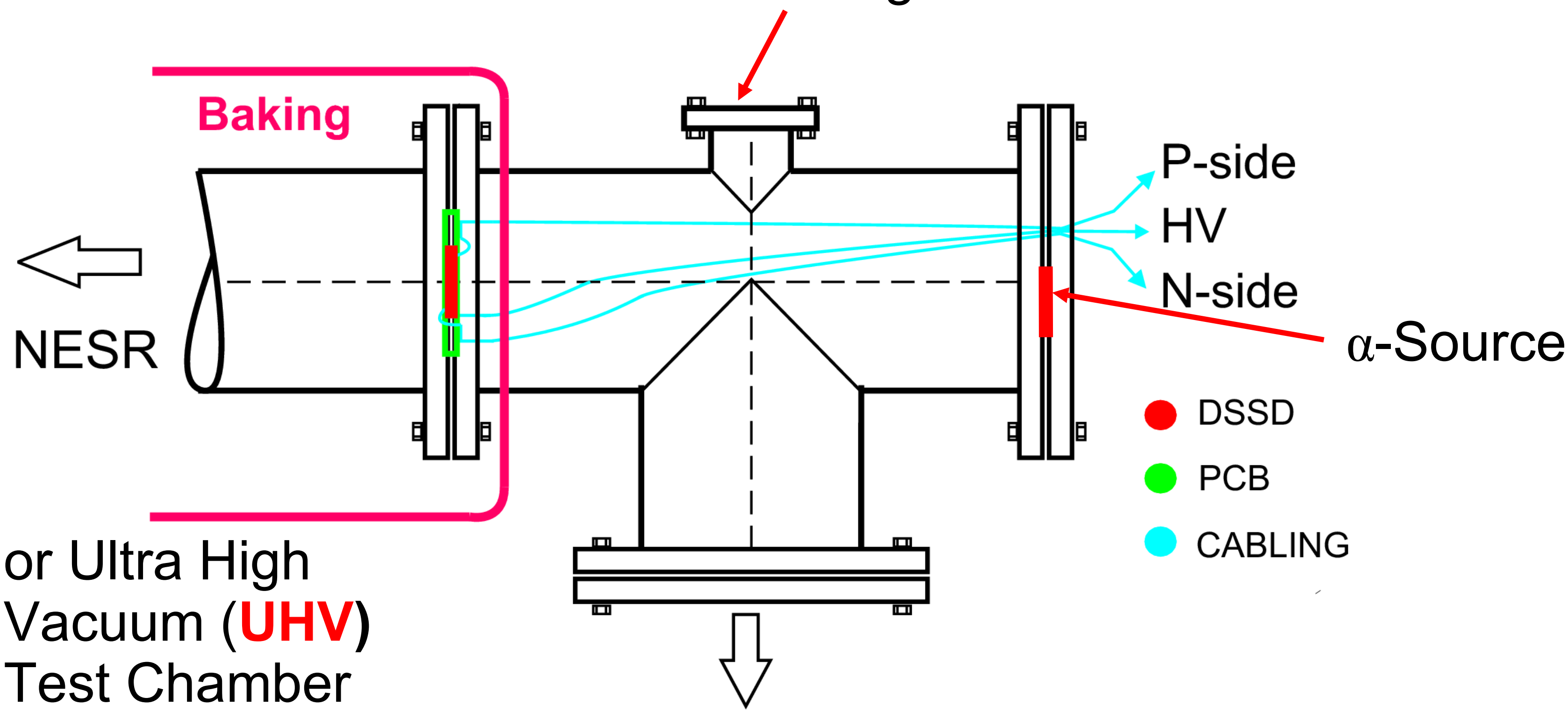
Space for other DSSDs, Si(Li), FEE and cabling





Inner shell of DSSDs on support frame forms (bakeable) vacuum barrier

Vacuum Barrier Demonstrator



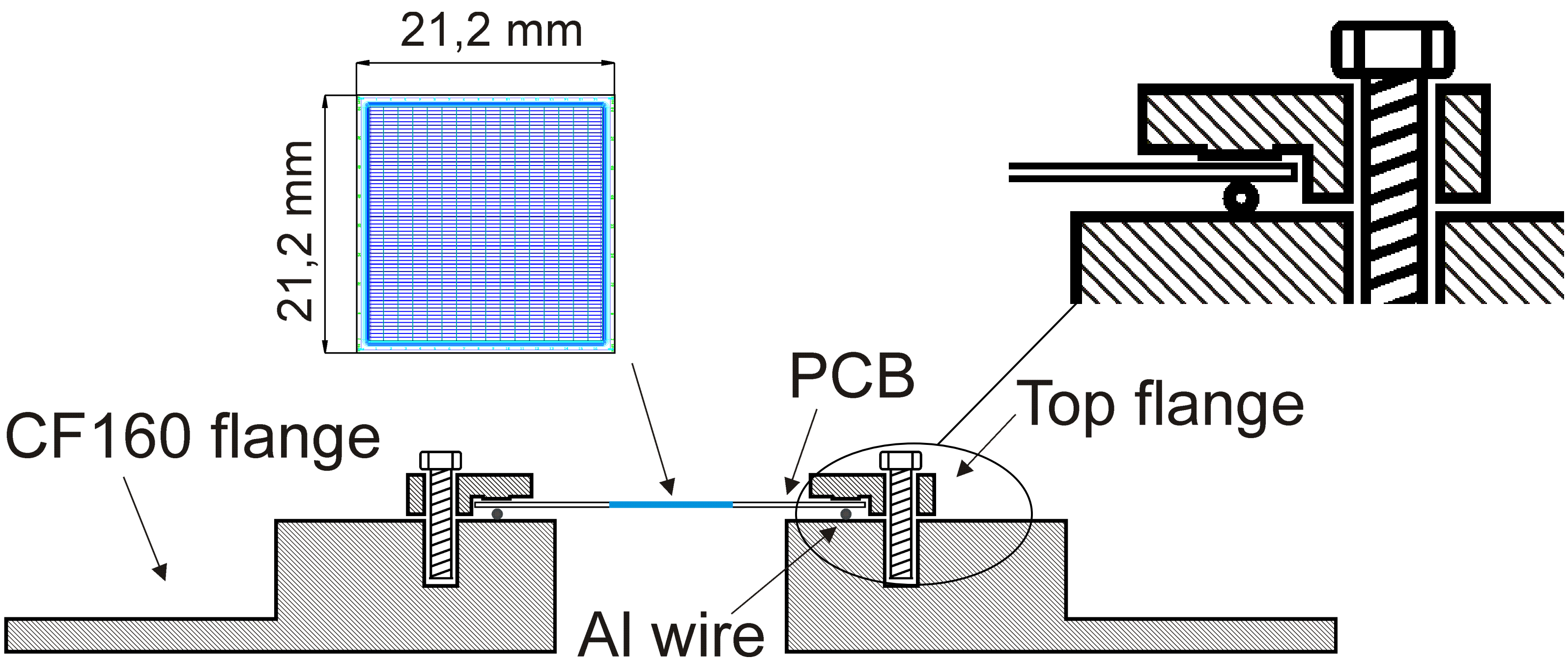
or Ultra High Vacuum (**UHV**) Test Chamber

$p < 10^{-10}$ mbar

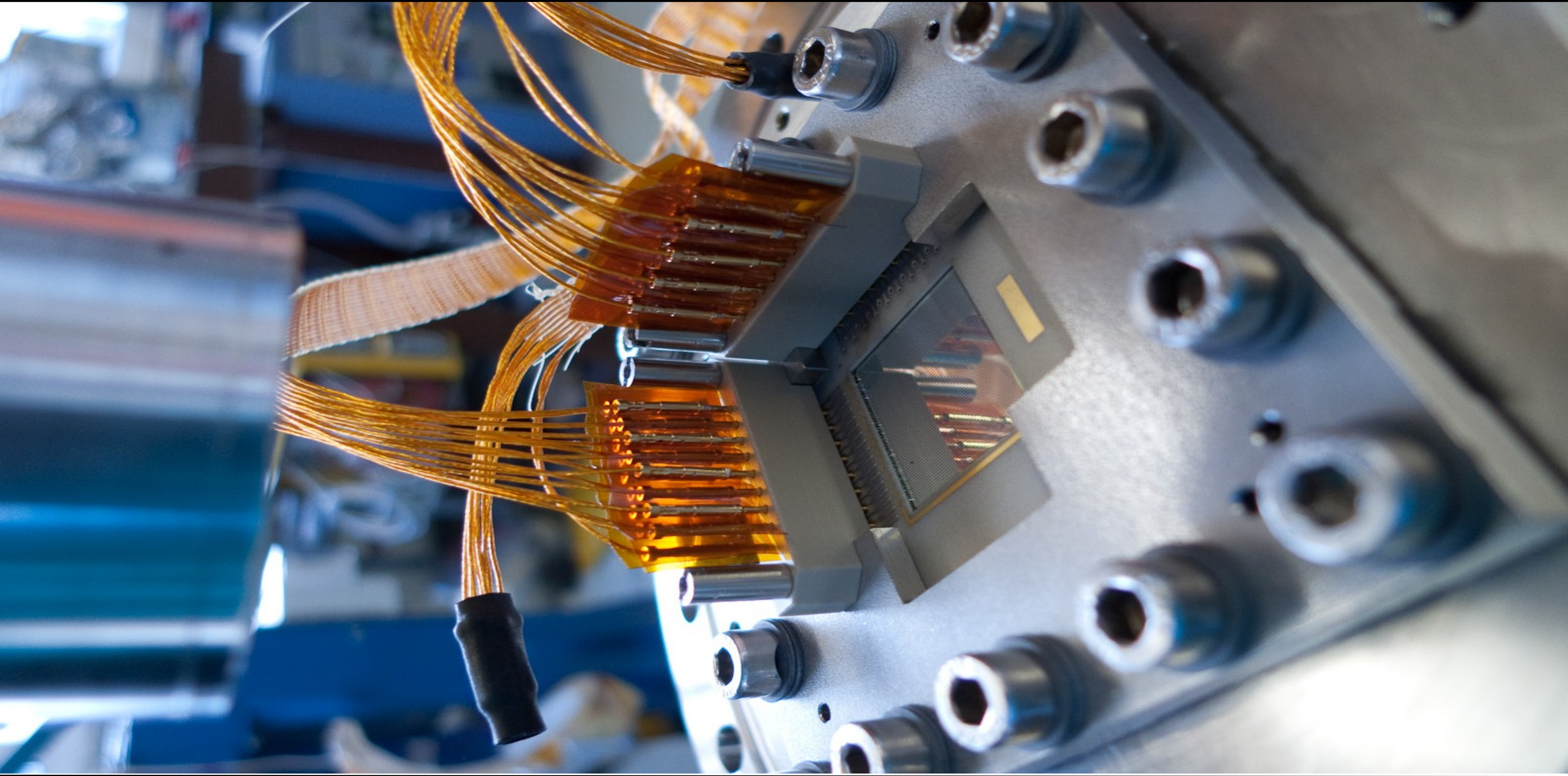
Auxiliary Vacuum (**AV**)
$p \sim 10^{-6}$ mbar

Mechanical Requirements and Separation Principle

- PCB with one “clean” side – no connectors, soldering etc.
  - connections from one side of DSSD must be driven on the other side
- Bakeability up to at least 200°C
  - restricted choice of materials
  - matched thermal expansion coefficients
- PCB should be easily replaceable from the frame

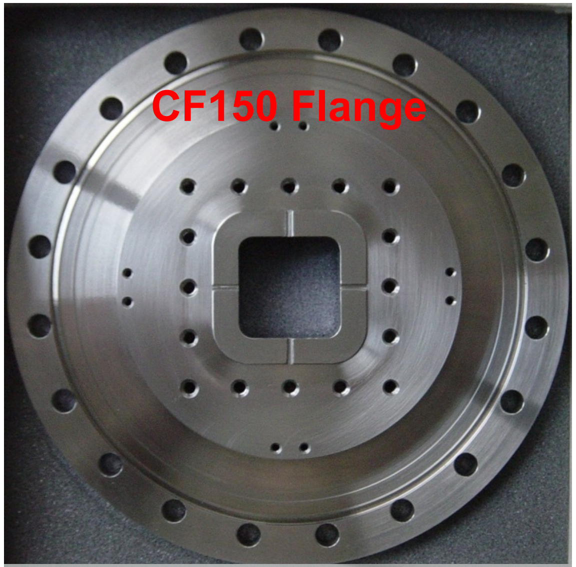


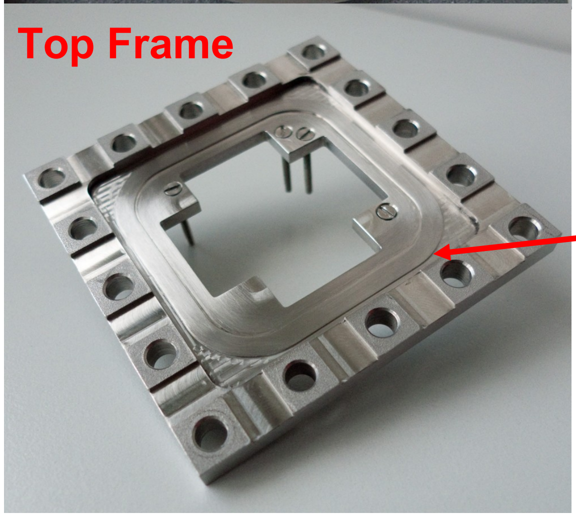
Part 3
Differential Vacuum Demonstrator Construction

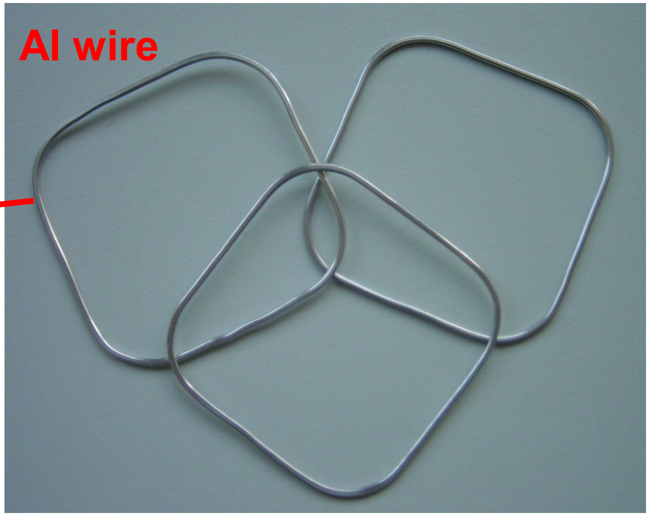


Mechanical Construction

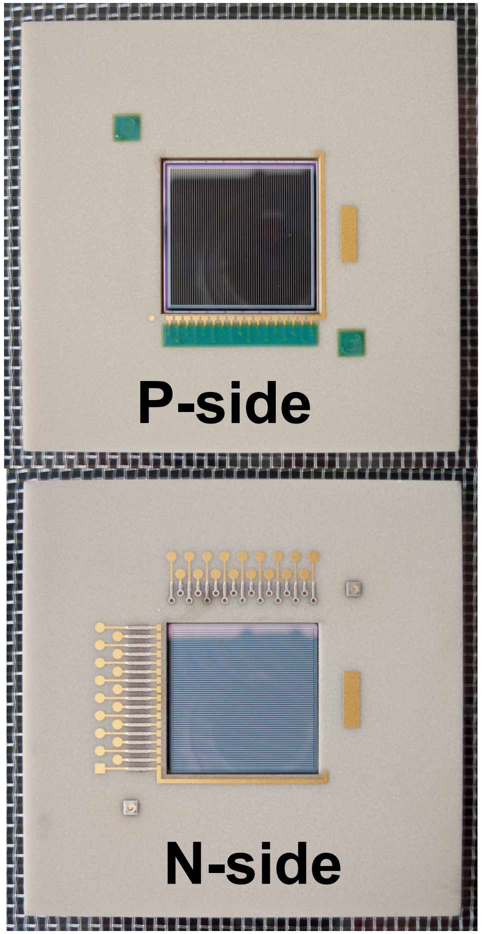
- Aluminum wire used as a vacuum seal
  - welded wire
- Base frame machined from CF150 flange
  - holds Al wire on top of which PCB is placed
  - has α-source holder
- Top frame from stainless steal
  - has groove that fixes top Al wire
  - has mounts for connectors







Ceramic PCB and Connectors

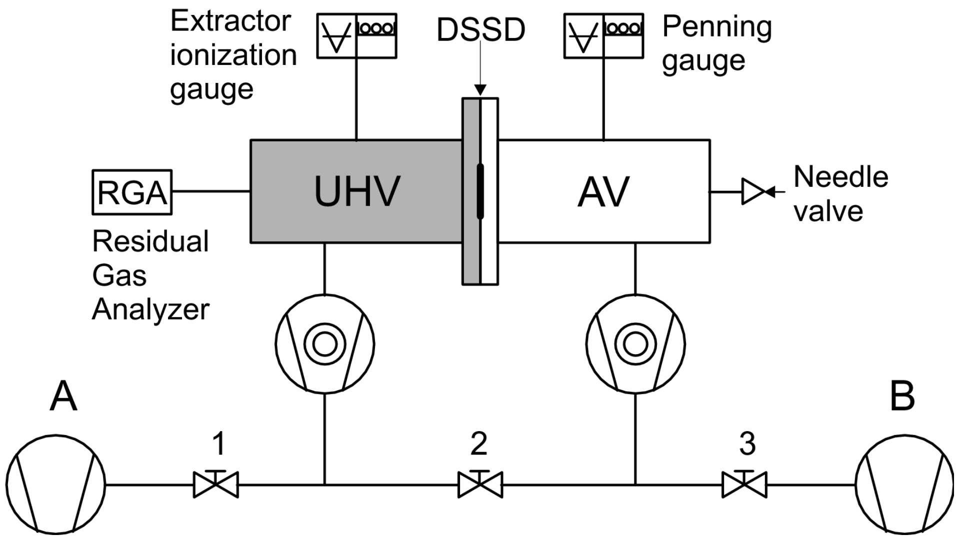


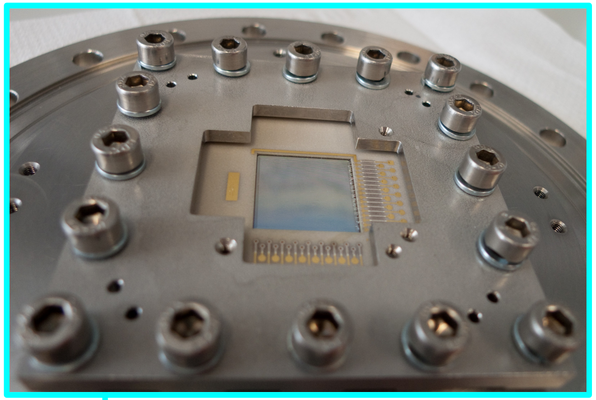
- PCB designed to have "through-board" contacts
  - laser drilled holes for routing P-side contacts to N-side
  - holes hermetically sealed with glass layer
- Manufactured from Aluminum Nitride (AlN)
  - ultra low-outgassing + bakeable to > 200°C
  - expansion coefficient close to Silicon
  - high thermal conductivity
- DSSD glued with EPO-TEK®H77S low-outgassing glue

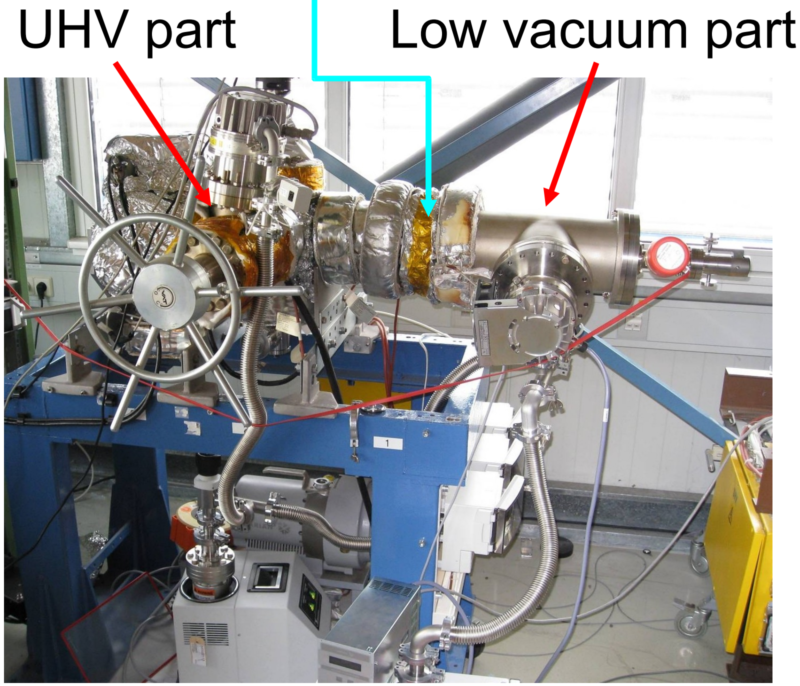
- Connectors machined from PEEK®
- Spring pins of 0.52 mm diameter used
- Kapton coated bakeable cables used

Test Stand @ GSI

- Two vacuum volumes separated by DSSD-PCB barrier
- Each volume equipped with a vacuum meter
- UHV side – Residual Gas Analyzer
- Needle valve on AV side to introduce artificial air leak

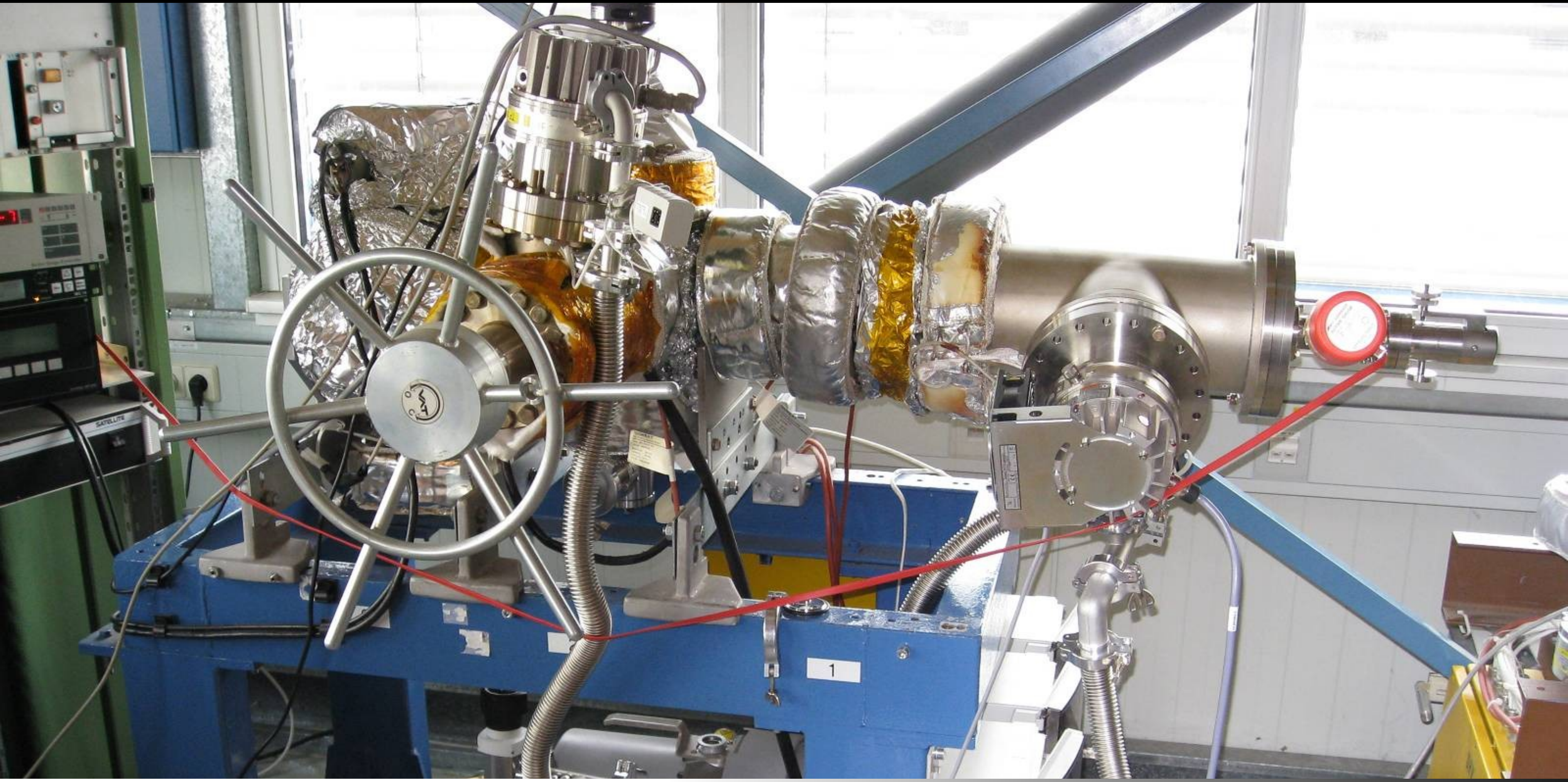






Part 4
Differential Vacuum Demonstrator Results

B. Streicher et al., Nucl. Instrum. Methods Phys. Res. A 654 (2011) 604-607

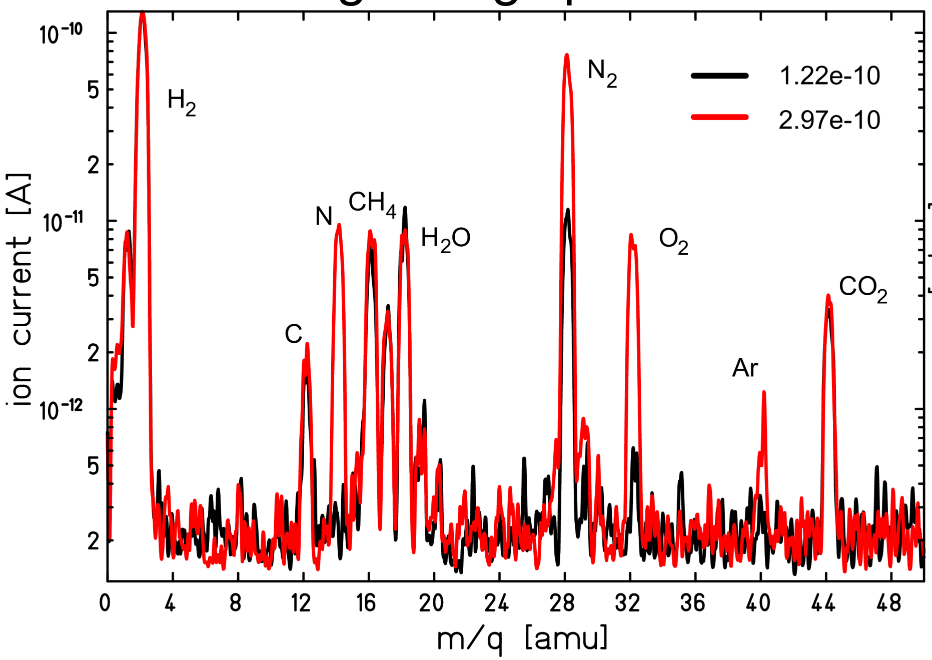


Differential Vacuum Tests

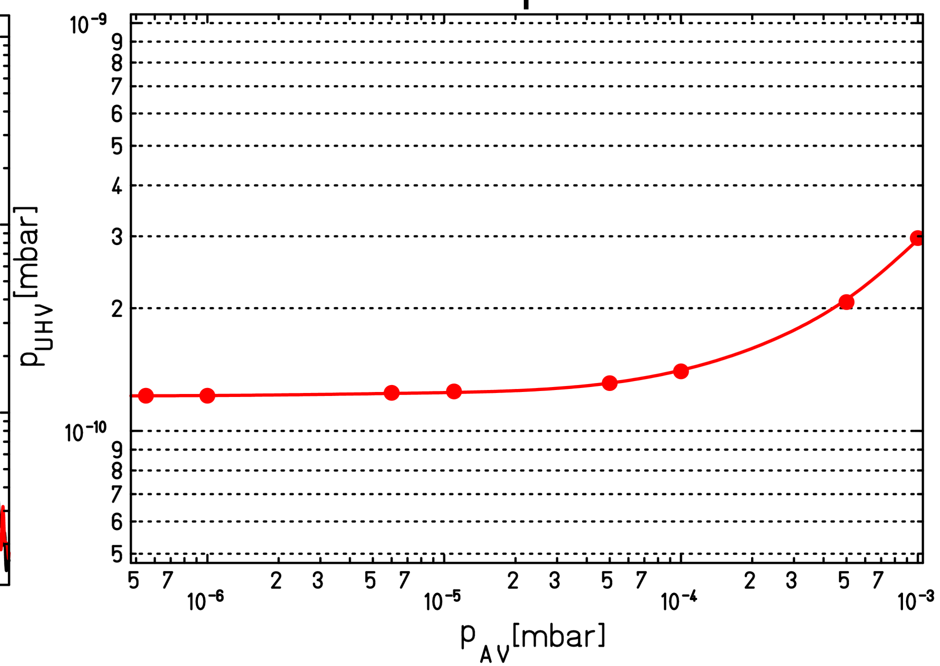
- Low rate of outgassing and residual gas spectra clear of contaminants for glued DSSD
- DSSD as a vacuum barrier could hold 6 orders of magnitude difference between low and UH vacuum in wide pressure region

1.2×10^{-10} mbar for UHV – limit of the test stand

outgassing spectrum



Vacuum separation

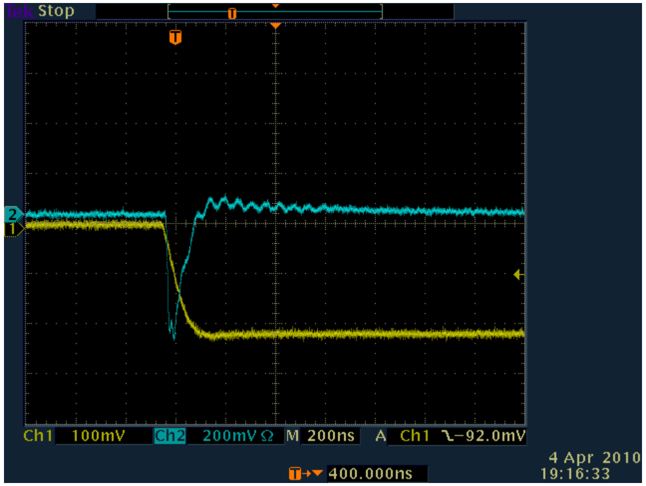


Spectroscopic Performance

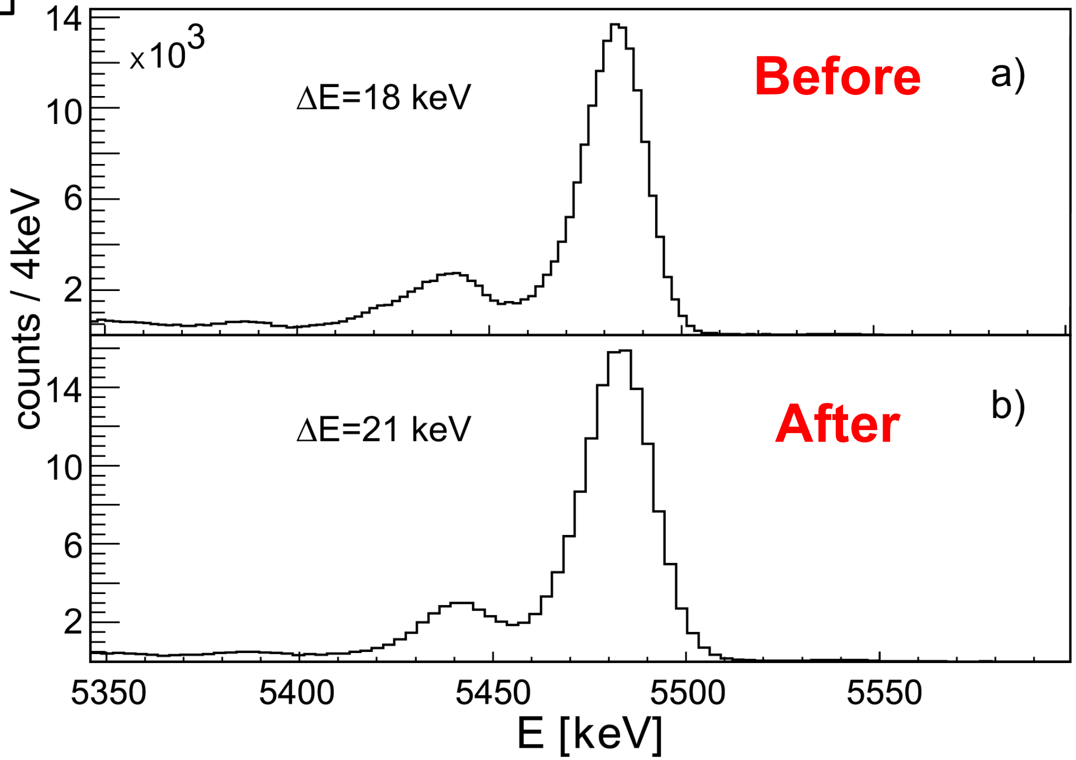
- Does the bake-out cycle influences DSSD chip performance?
- Basic functionality test done by measuring 16 x 16 channels (4 channels coupled together on PCB) for P-side injection
- Leakage current unchanged (~ 5-20 nA)

No noticeable influence

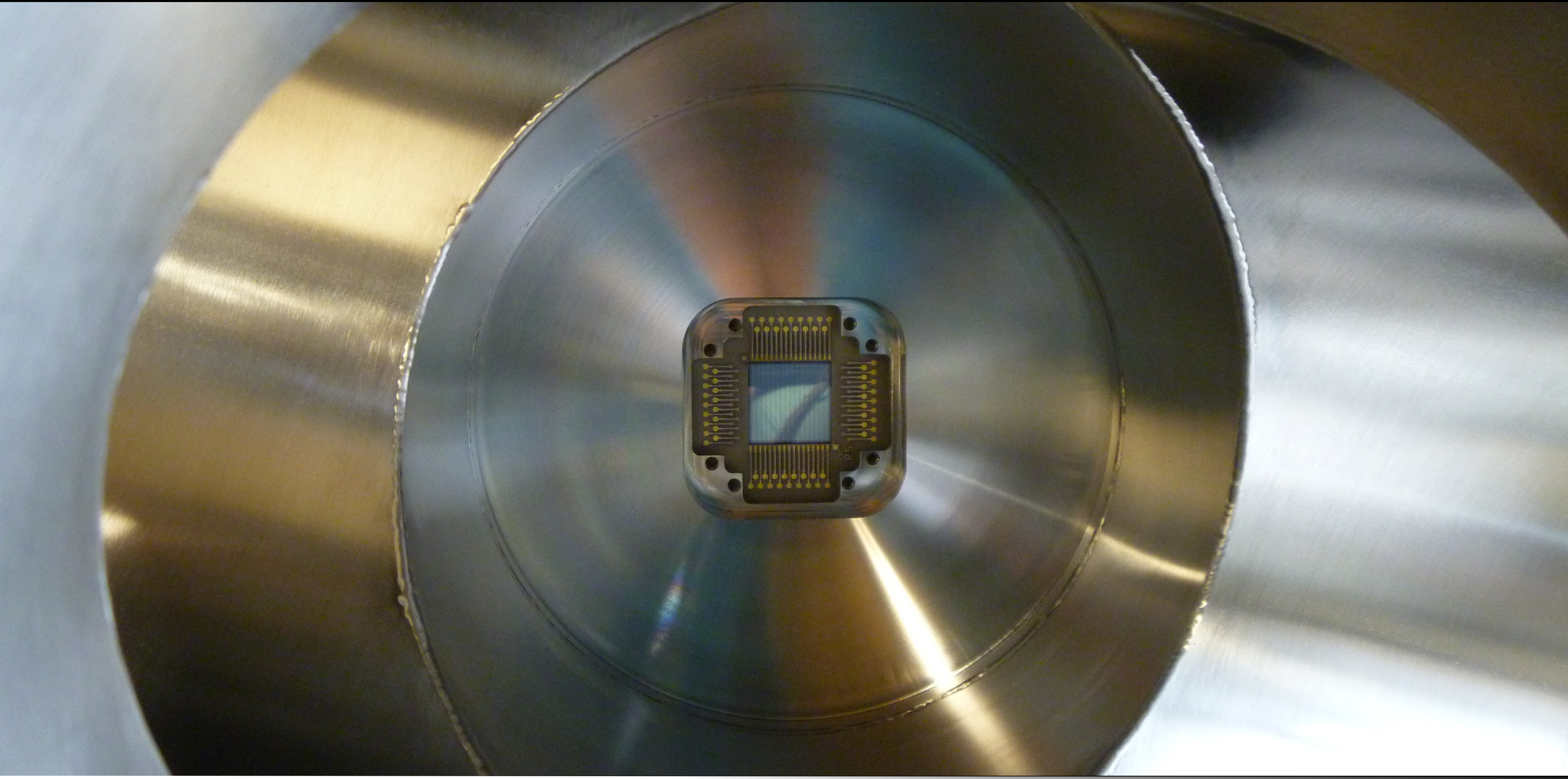
- **Energy**
- **Time**



^{241}Am alpha spectrum

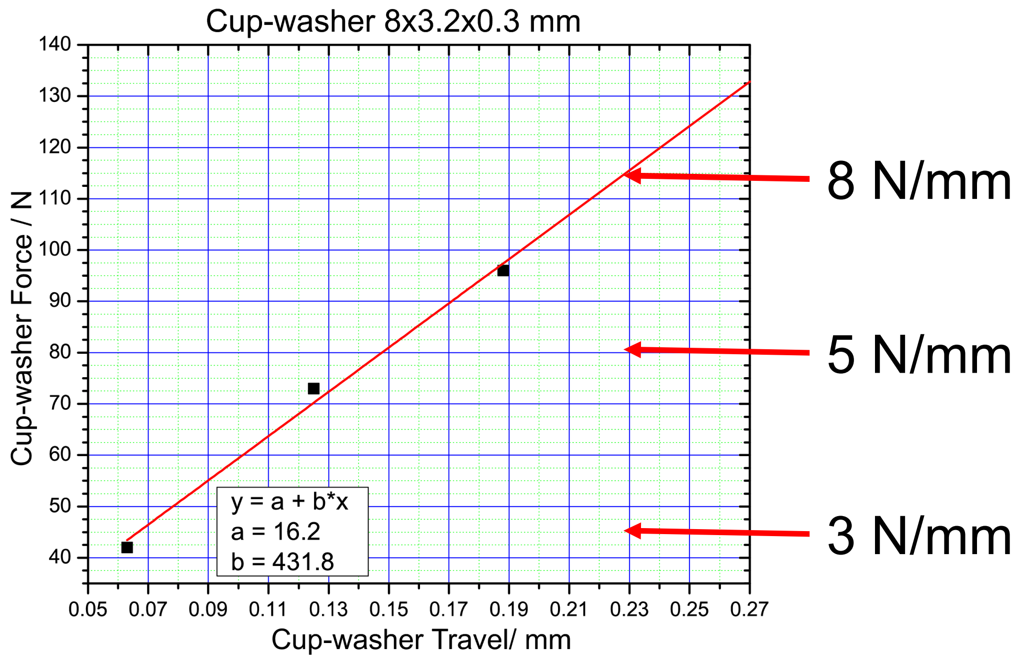


Part 5
Improvements, Current Development & Future Perspectives

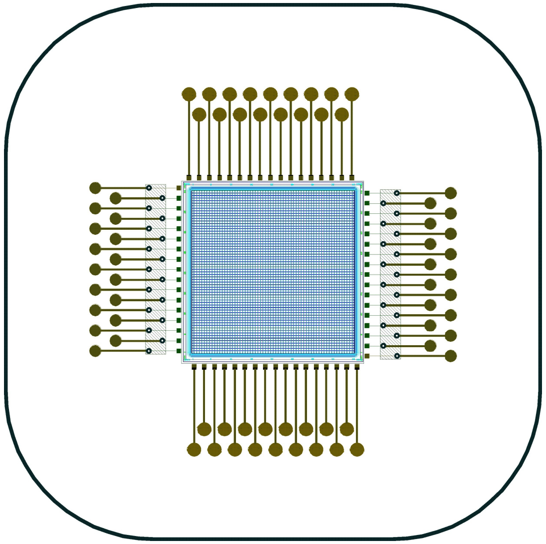


Mechanical Stability Improvement

Test of UHV vacuum vs. press force range



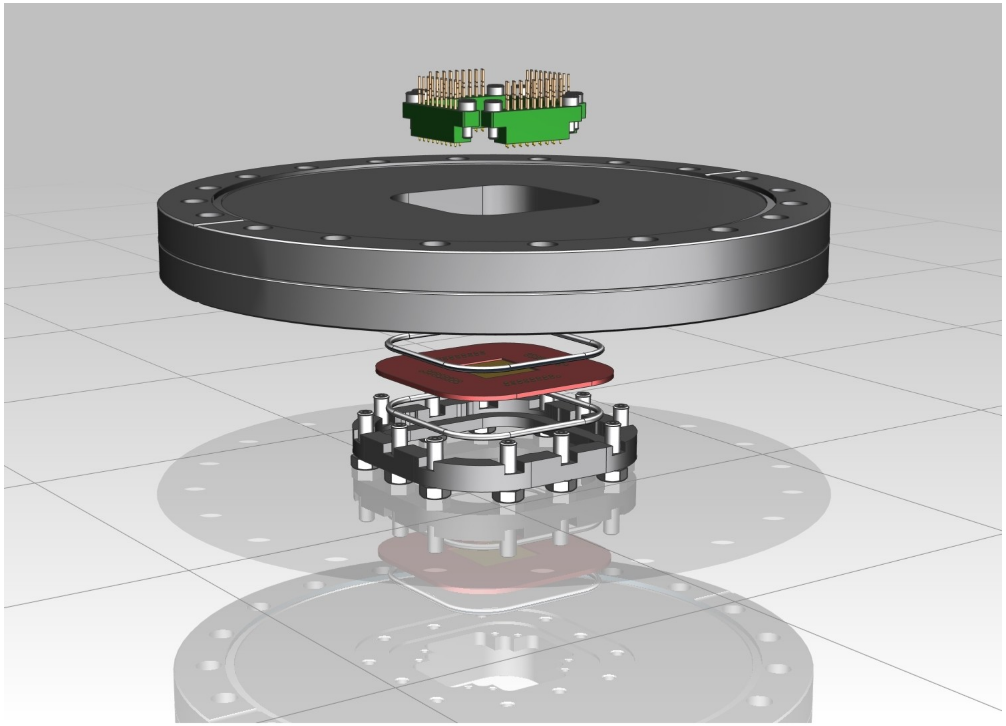
64x64 DSSD

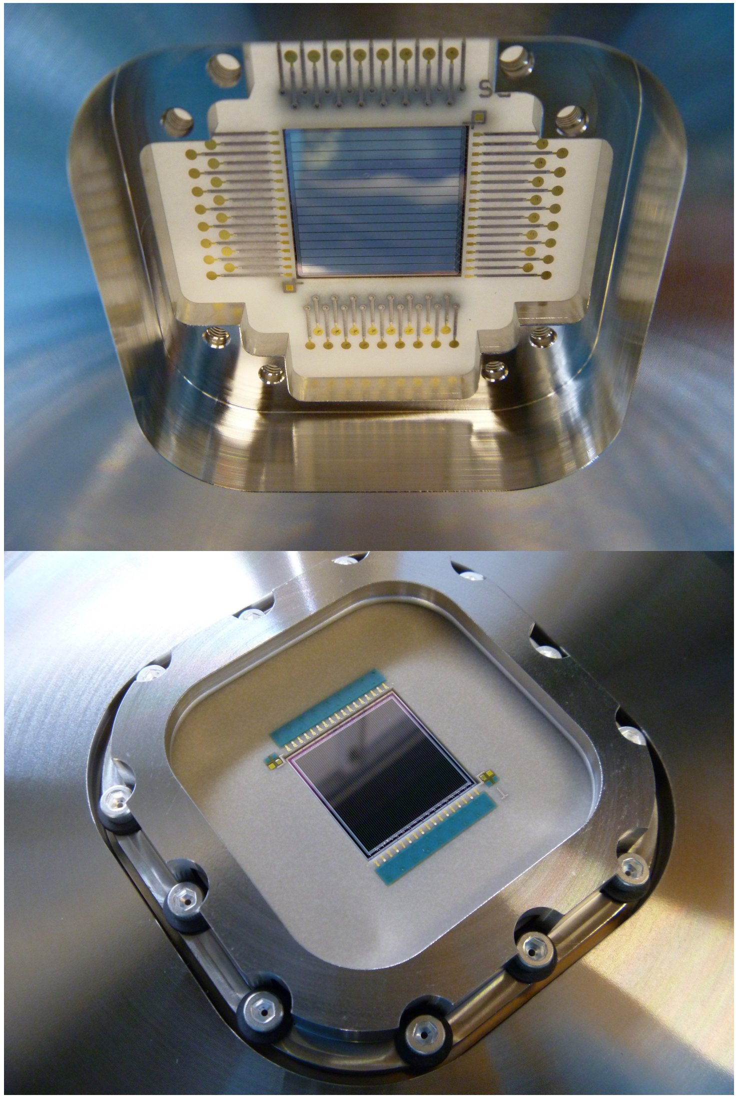


- Improved PCB layout
  - polished surface
  - rounded corners
  - 32 x 32 readout

- New Helicoflex® Delta rings – flat shape, small contact area with the PCB
- Reduction of shear stress on the PCB
  - Industry standart – 30 – 200 N/mm
- All mechanics from the UHV side – screws, cup washers – required for final ESR design

Further Prototyping (32x32 DSSD)

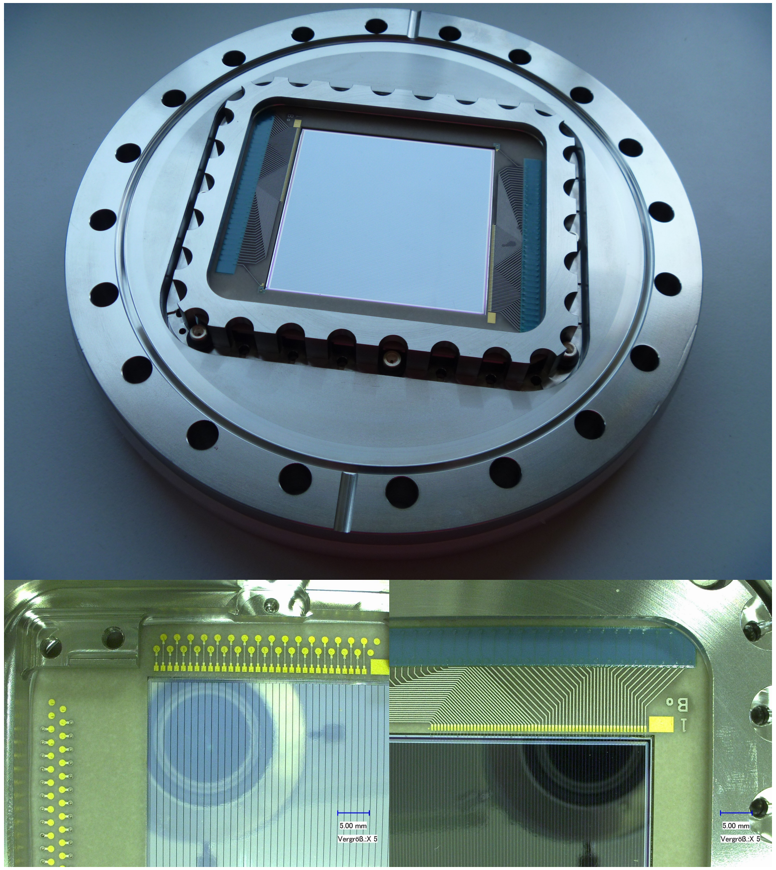


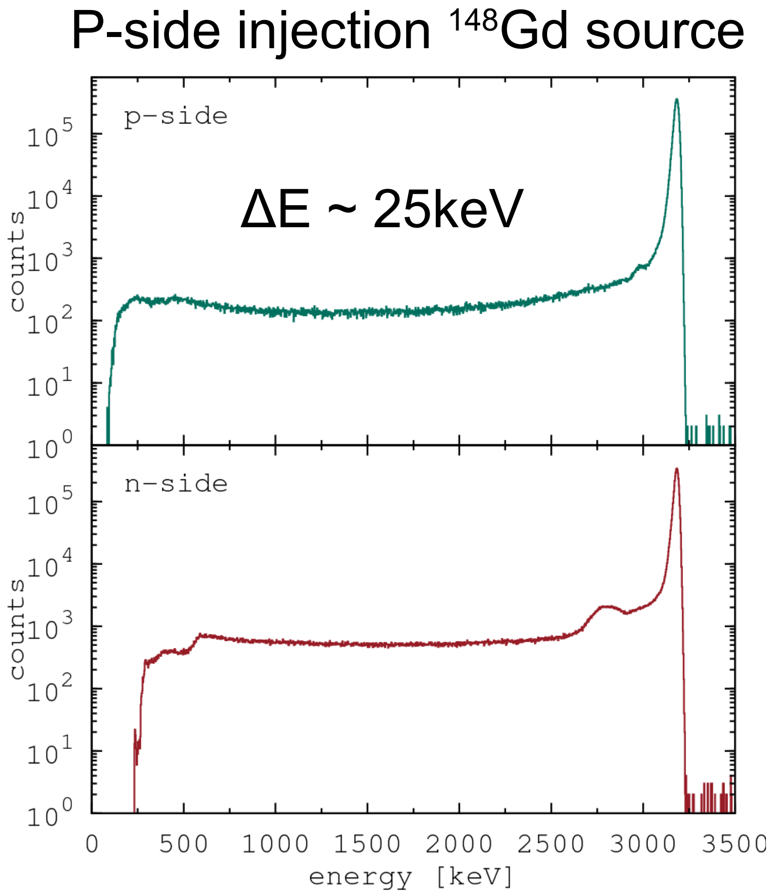


- Improved UHV Test stand (10^{-11} mbar)
  - New 300 l/s turbo pump
  - New Titanium sublimation pump
- **Tests are currently running at GSI**

Further Prototyping (128x64 DSSD)

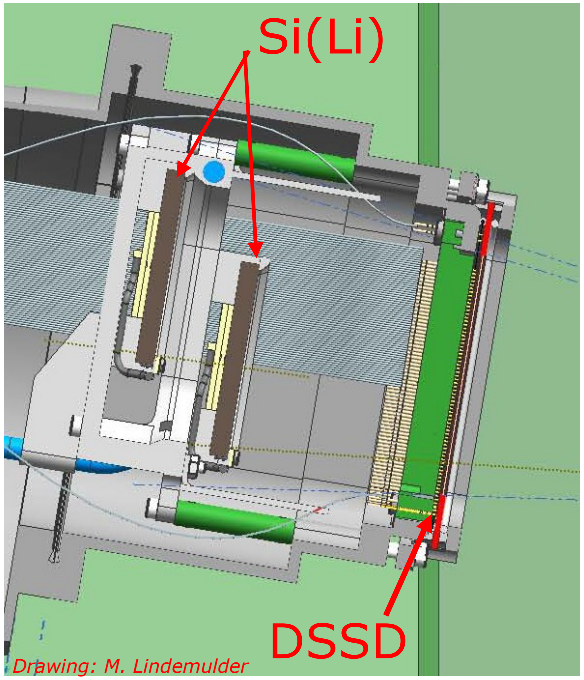
- New 128x64 strip DSSD (64x66 mm^2) constructed for the approved experimental proposal E105 @ ESR, GSI
- Full spectroscopic test performed @ GSI

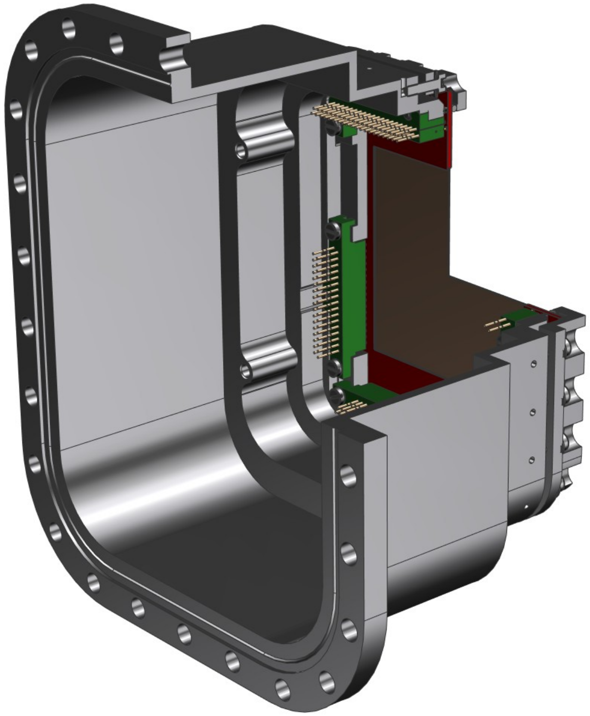




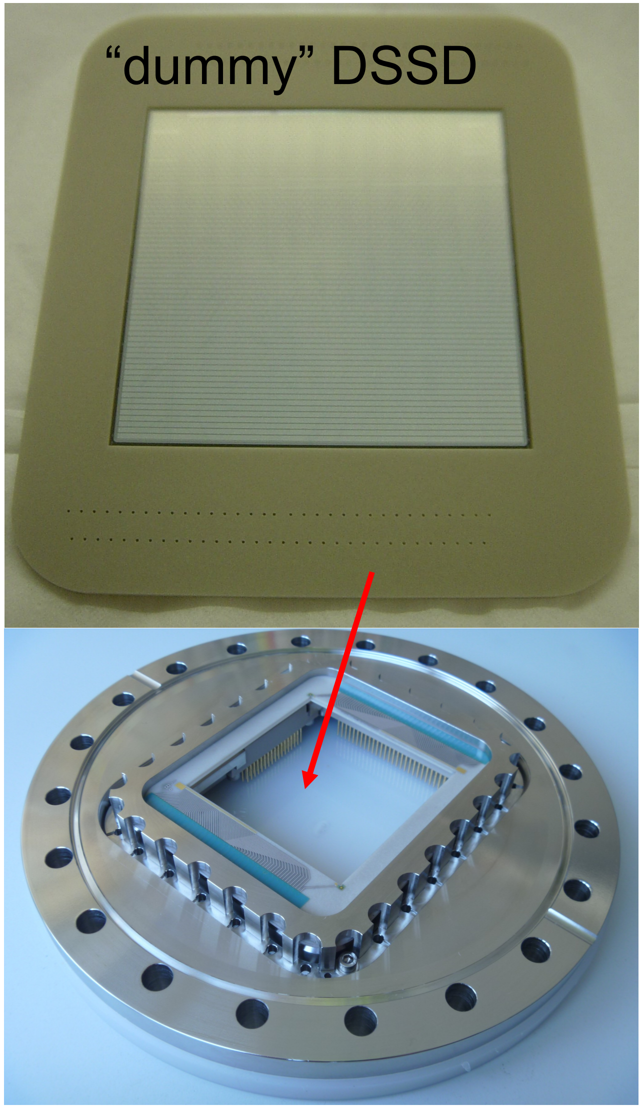
Further Prototyping (128x64 DSSD)

- Vacuum tests by the end of 2011
  - First using “dummy” DSSD
  - With real DSSD
- Resulting in the manufacture of the detector “pocket head”

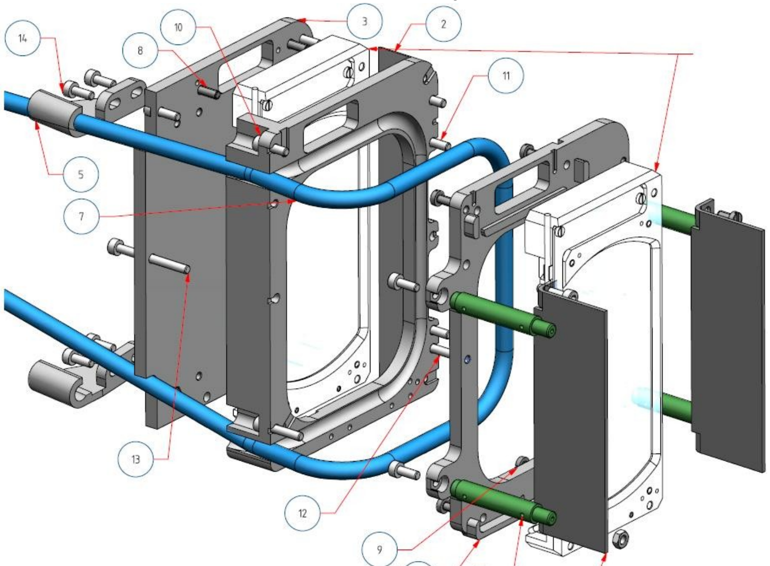




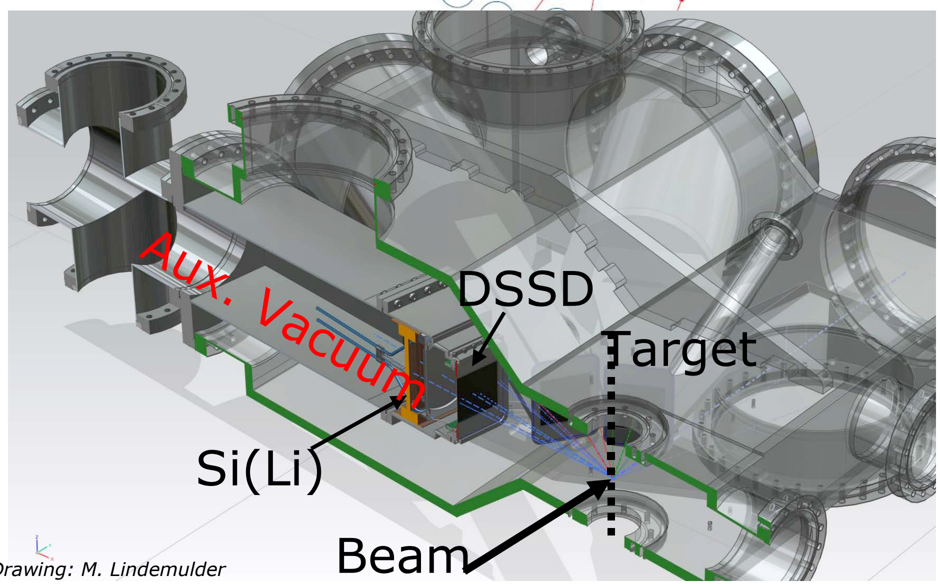
Detector “pocket head”



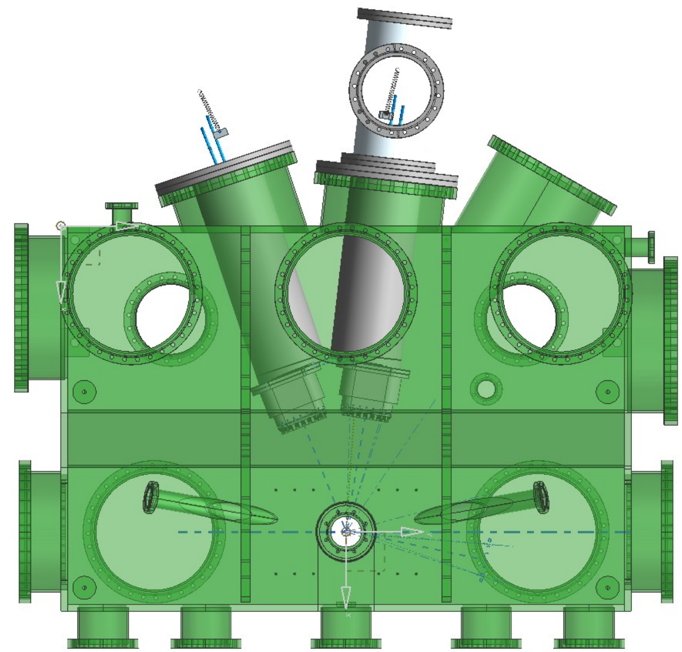
Assembly of the EXL's ESR Chamber



- Thermal tests using the real pocket
  - SiLi cooling vs. pocket baking
- Assembly of a vacuum system
  - Backup system required
- ASIC development + cabling
  - Interconnecting DSSDs with ASIC
  - Proper signal propagation



Drawing: M. Lindemulder



Summary

- Proposed UHV solution for using telescopic detector setup inside the ESR / NESR with an active window - DSSD
- Constructed and tested small UHV prototype using 32x32 DSSD
- Vacuum of 1.2×10^{-10} mbar reached for UHV side
- Difference bigger than 6 orders of magnitude between AV / UHV
- Air-leak like outgassing spectra clear of contaminants

Perspectives

Improved 32x32 DSSD & 128x64 DSSD UHV solution
  - better PCB surface
  - better sealing
  - changed PCB shape
- Thermal tests of the SiLi detectors in the ring environment
- Assembly of the EXL's ESR pocket/s and chamber
  - construction in progress
- Preparation of the E105 experiment @ ESR (possibly in 2012)
- Produce TDR for the EXL project @ NESR (possibly ESR) by the end of 2012

List Of Participants

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Annelie GLAZENBORG-KLUTTIG[2)], Holger KOLLMUS[1)], Thorsten KRÖLL[3)],
Michel LINDEMULDER[2)], Gerhard MAY[1)], Manfred MUTTERER[1,2)],
Nasser KALANTAR-NAYESTANAKI[2)], Mirko von SCHMID[3)],
Branislav STREICHER[1,2)], Michael TRÄGER[1)]

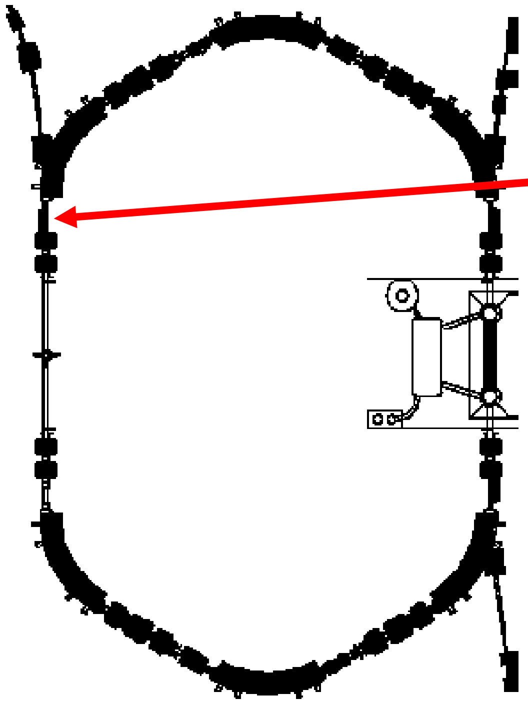
1) GSI Darmstadt, Germany
2) KVI Groningen, The Netherlands
3) TU Darmstadt, Germany
4) PTI St. Petersburg, Russia

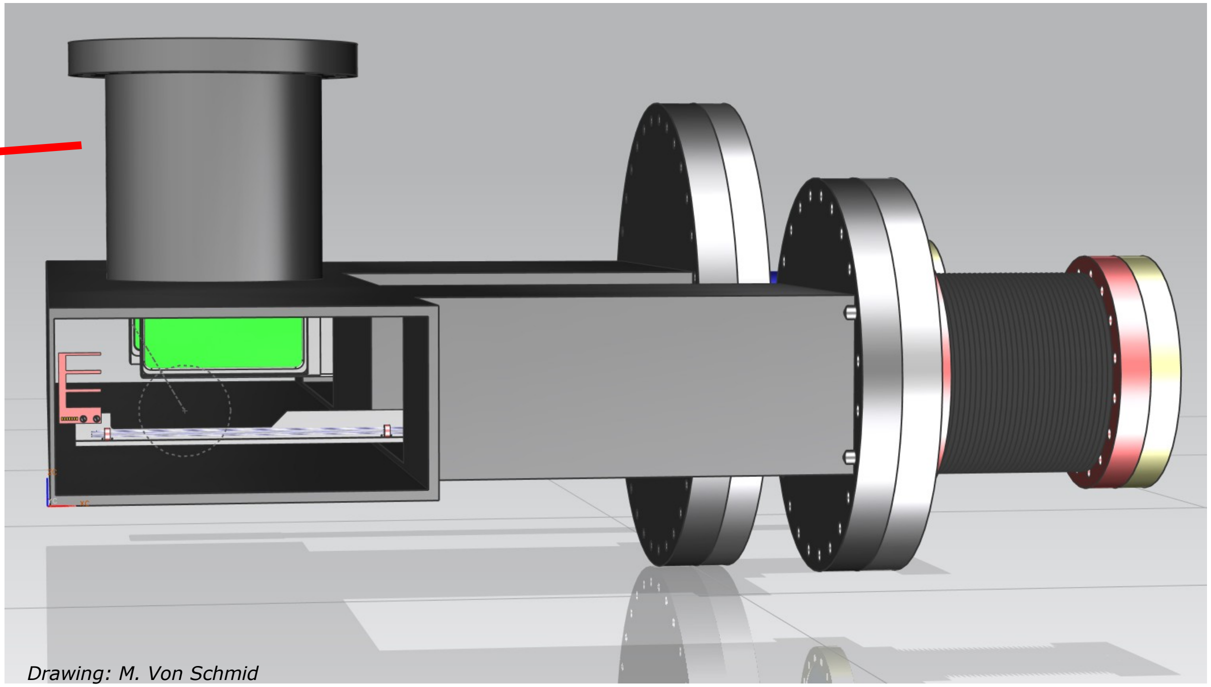
Thank You!

EXL Experiment @ Present ESR – In-ring detectors

- In-ring detectors for coincidence measurement of beam-like particles before the first dipole
- 2 detectors: 1 x in UHV, 1 x in auxiliary vacuum

Pocket and PIN diode arm built @ KVI





In-ring detectors: UHV detector

- Six (1x1 cm^2) PIN-diodes (300μm thick) on the AlN PCB
- Bakeable to 250 °C
- Passed outgassing tests
- New prototype with improves cabling due till the end of 2011