ScCVD diamond detector for MIPs and heavy ions

- radiation damage for heavy ions
- timing and position measurements for MIPs

J. Pietraszko[a],

[a] GSI Helmholtz Centre for Heavy Ion Research GmbH Planckstrasse 1, D-64291 Darmstadt, GERMANY

Radiation damage in scCVD diamond material measured with relativistic Au ions for future CBM/HADES experiments at FAIR

J. Pietraszko[a], A. Draveny[b] ,T. Galatyuk, V. Grilj[c], W. Koenig[a], M. Träger[a]

[a] GSI Helmholtz Centre for Heavy Ion Research GmbH Planckstrasse 1, D-64291 Darmstadt, GERMANY
[b] Ecole Centrale de Lyon
[c] Ruđer Bošković Institute, Zagreb
[d] Technische Universität Darmstadt, Darmstadt, Germany

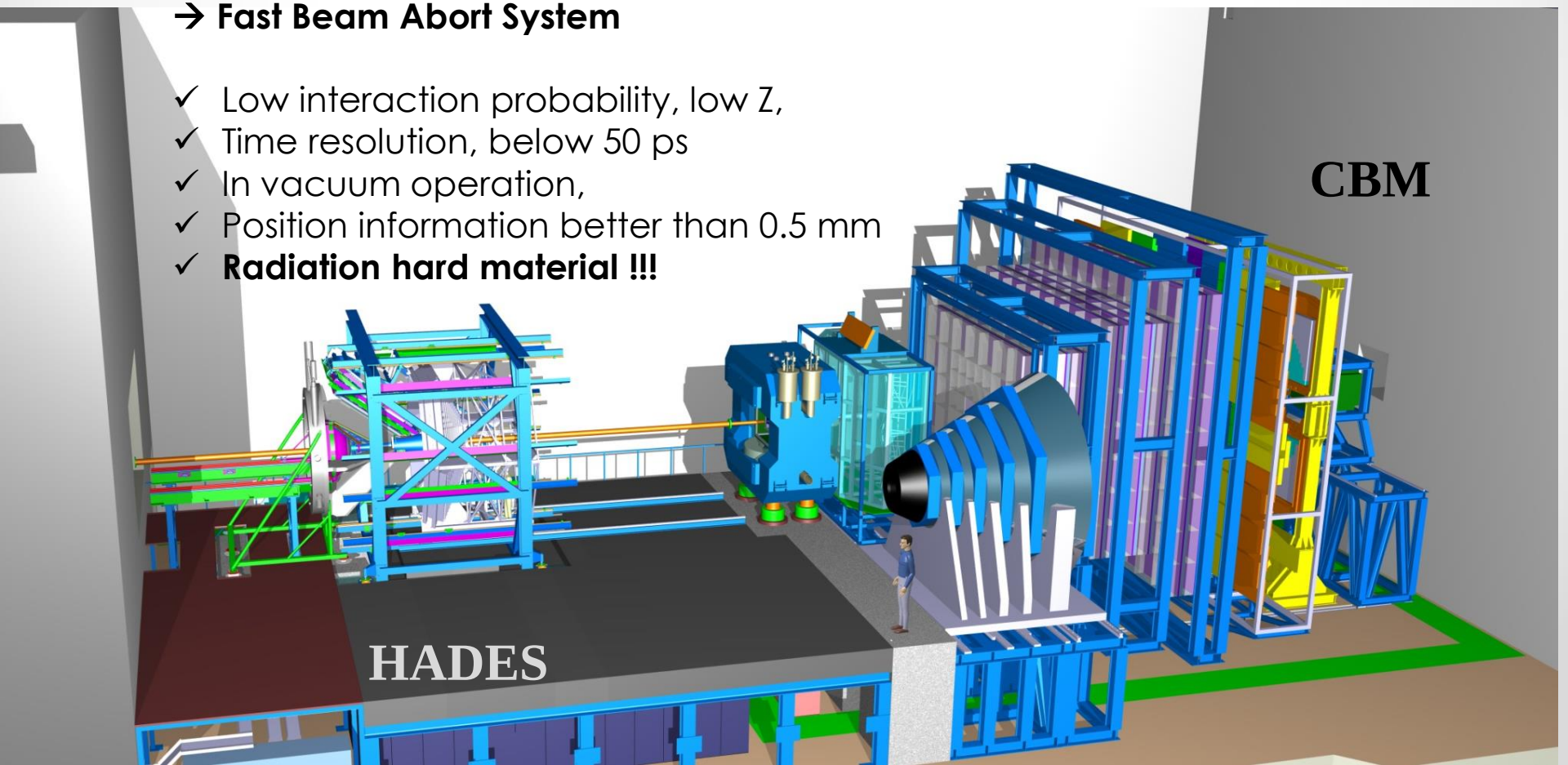
T0 and beam monitoring detector requirements

Applications:

- ✓ high rate CBM experiment at FAIR: beam intensity 10^9 ions/s
- ✓ HADES at SIS100: beam intensity 10^7 ions/s

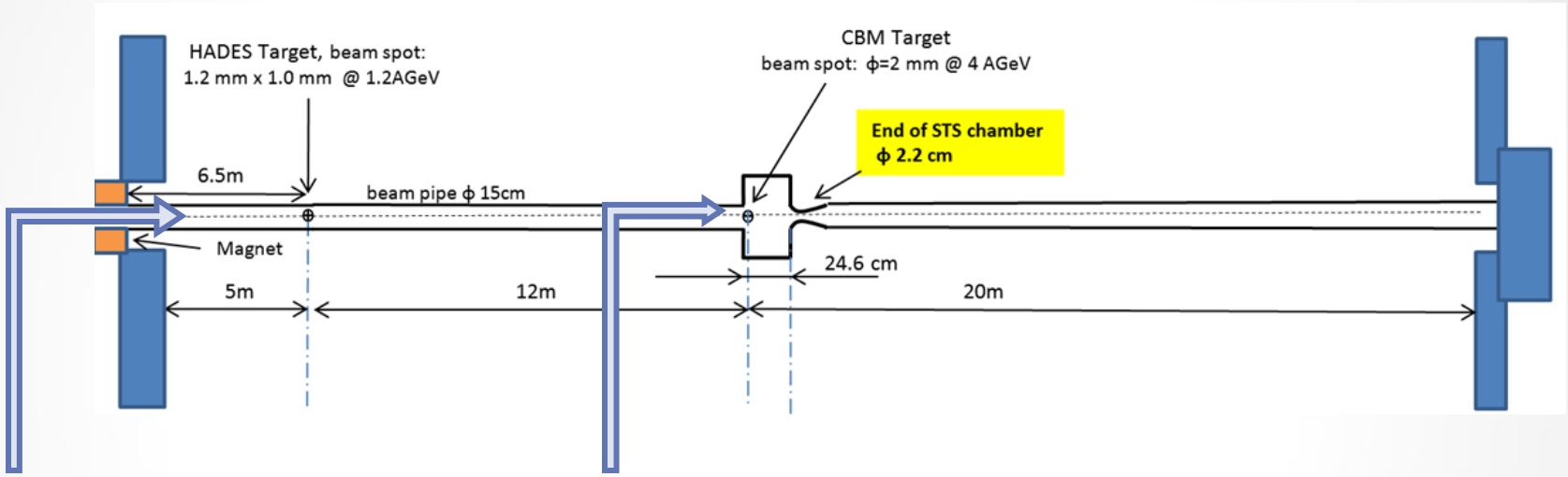
→ **Single particle mode**
→ **T0 determination**
→ **Beam monitoring**
→ **Fast Beam Abort System**

- ✓ Low interaction probability, low Z,
- ✓ Time resolution, below 50 ps
- ✓ In vacuum operation,
- ✓ Position information better than 0.5 mm
- ✓ **Radiation hard material !!!**



HADES/CBM beam line

- CBM beamline aperture



Just behind the magnets:

1.2×10^5 parts/s/mm^2
Beam diameter: 100 mm
Area: 7850 mm^2

Bigger detector required

At the target point:

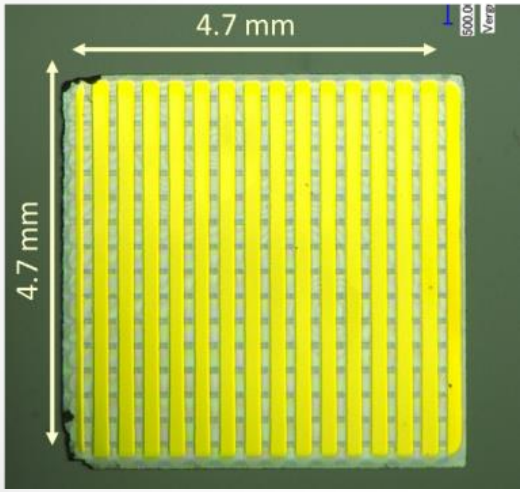
10^9 parts/s/mm^2
Beam diameter: 1 mm
Area: 0.8 mm^2

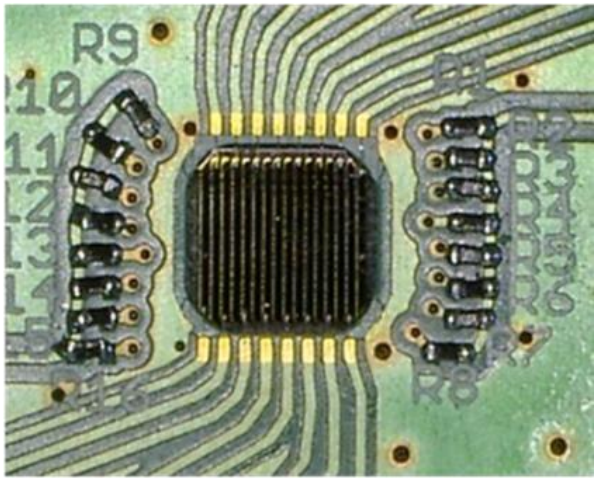
Electronic limitation

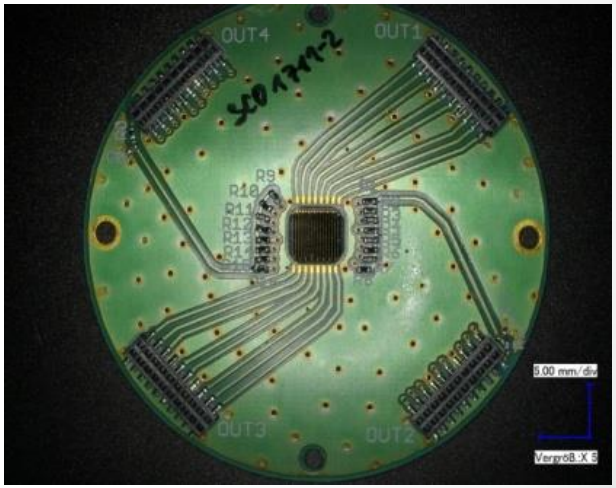
Prototype diamond detector

The key features:

- ✓ Double-sided multi-strip diamond based sensor for HI
  (16 channels on each side)
- ✓ Strip width: 200 μm, gap: 90 μm, det. thickness: 60 μm
- ✓ Fast, high rate readout electronics, up to 10MHz/channel
  - Multihit TDC, 17 ps intrinsic time res
  - Det. resolution < 50 ps



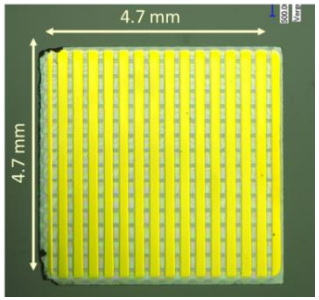


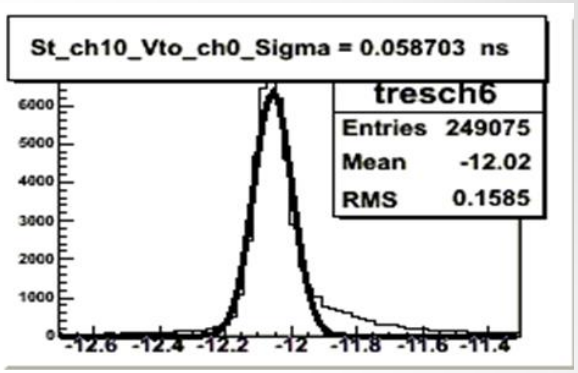


Prototype detector performance

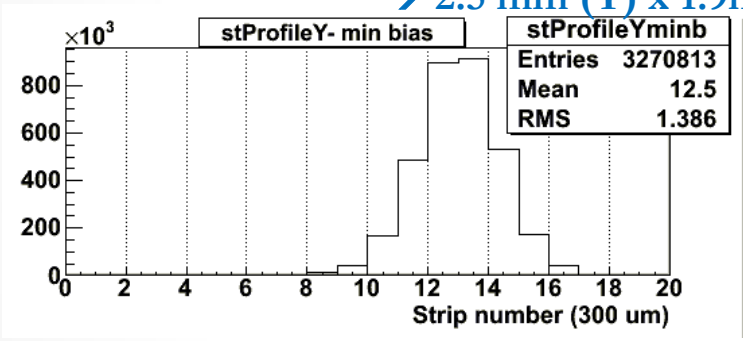
Beam monitoring and T0 for Au beam @ 1.25 A GeV:

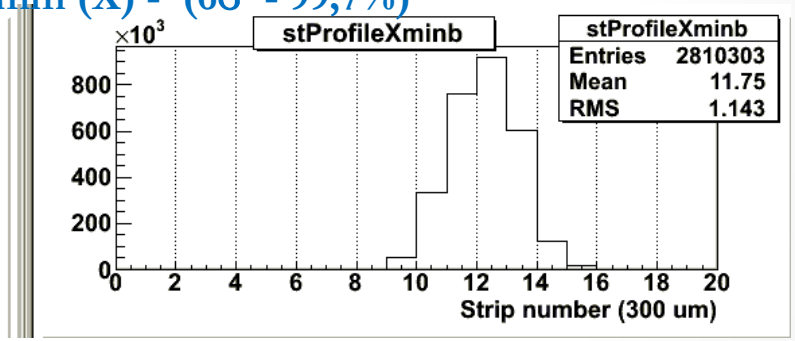
- ✓ Single partilce mode up to 10^7 ions/s per channel
- ✓ Precise beam profile in X and Y
- ✓ Beam HALO measuerment
- ✓ T0 with $\sigma < 50$ ps



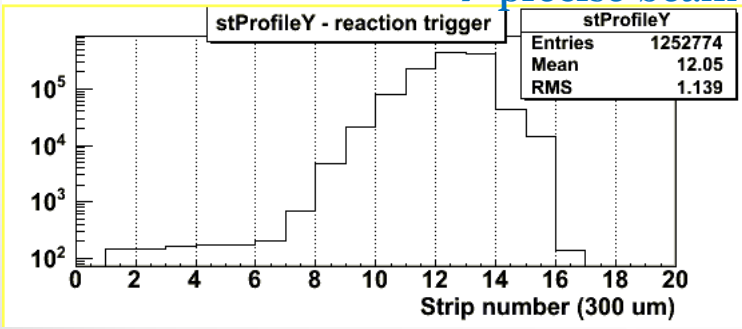


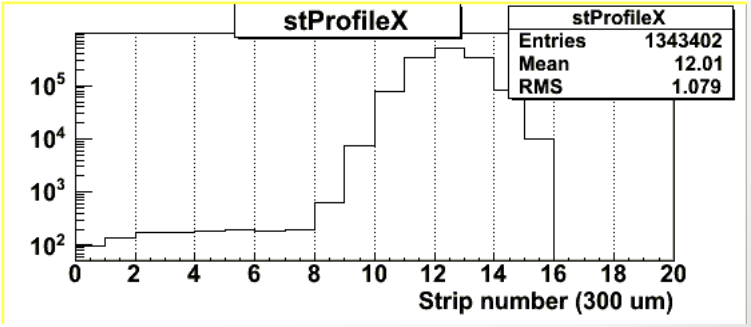
→ 2.5 mm (Y) x 1.9mm (X) - (6σ - 99,7%)





→ precise beam halo measuerment

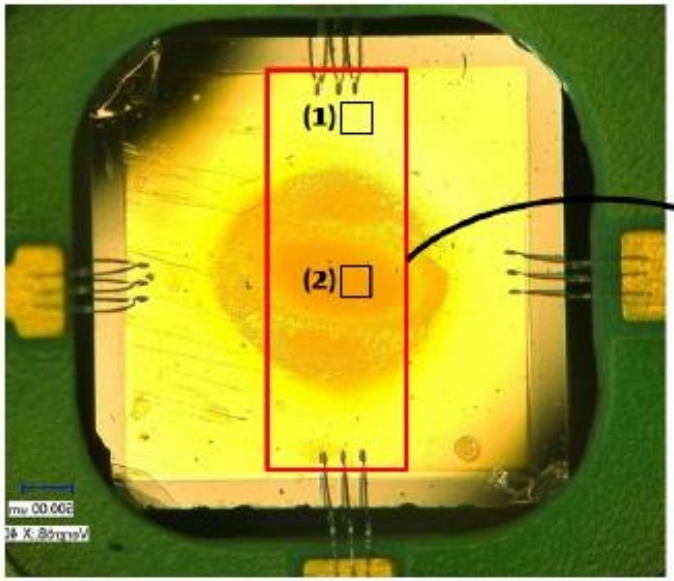




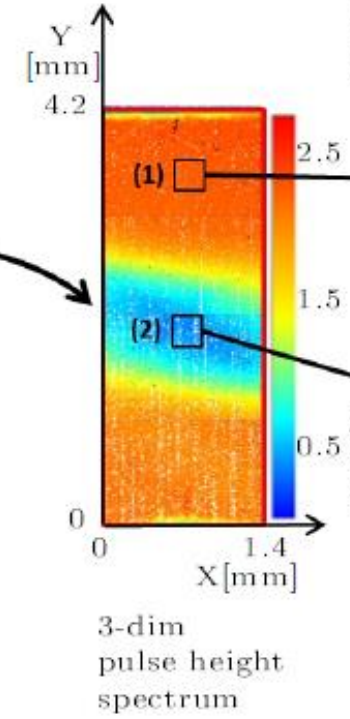
Radiation damage – part 1

- ✓ Sample irradited at GSI with Au @ 1.23 A GeV (3 x 10^{11} ions)
- ✓ Pulse height scan with 4.5 MeV μ-beam of protons
- ✓ Ion Beam Induced Current (IBIC) method at the Laboratory for ion beam interactions at the Ruđer Boskovic Institute in Zagreb

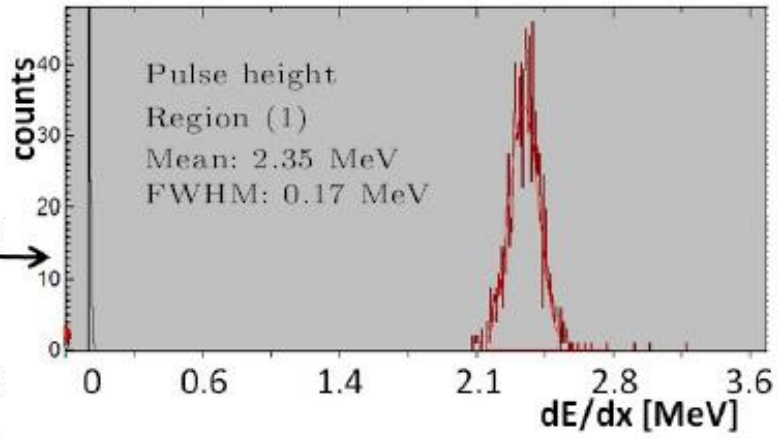
Sample irradiated at GSI with Au@1.23A GeV
3 x 10^{11} Au ions

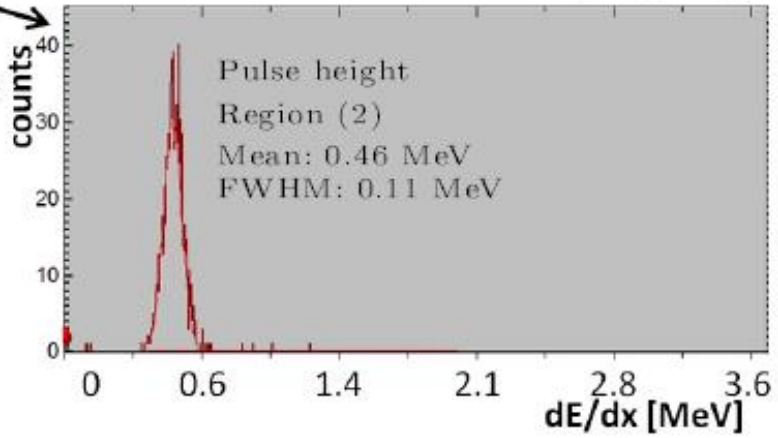


IBIC scan
Zagreb



3-dim
pulse height
spectrum





→ pulse height spectrum reduced by a factor of 5.1 at absorbed dose of about 87 MGy

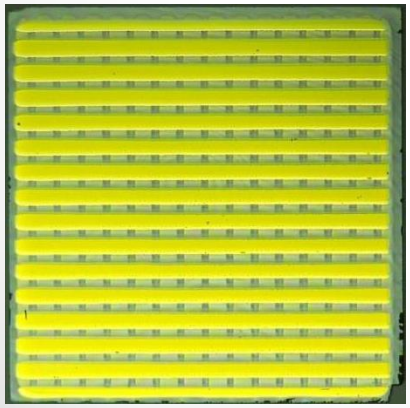
Radiation damage – systematic study for Au beam

Detector has been irradiated in 7 places with focused 1.23 AGeV Au beam. the particle fluence for each spot has been precisely measured.

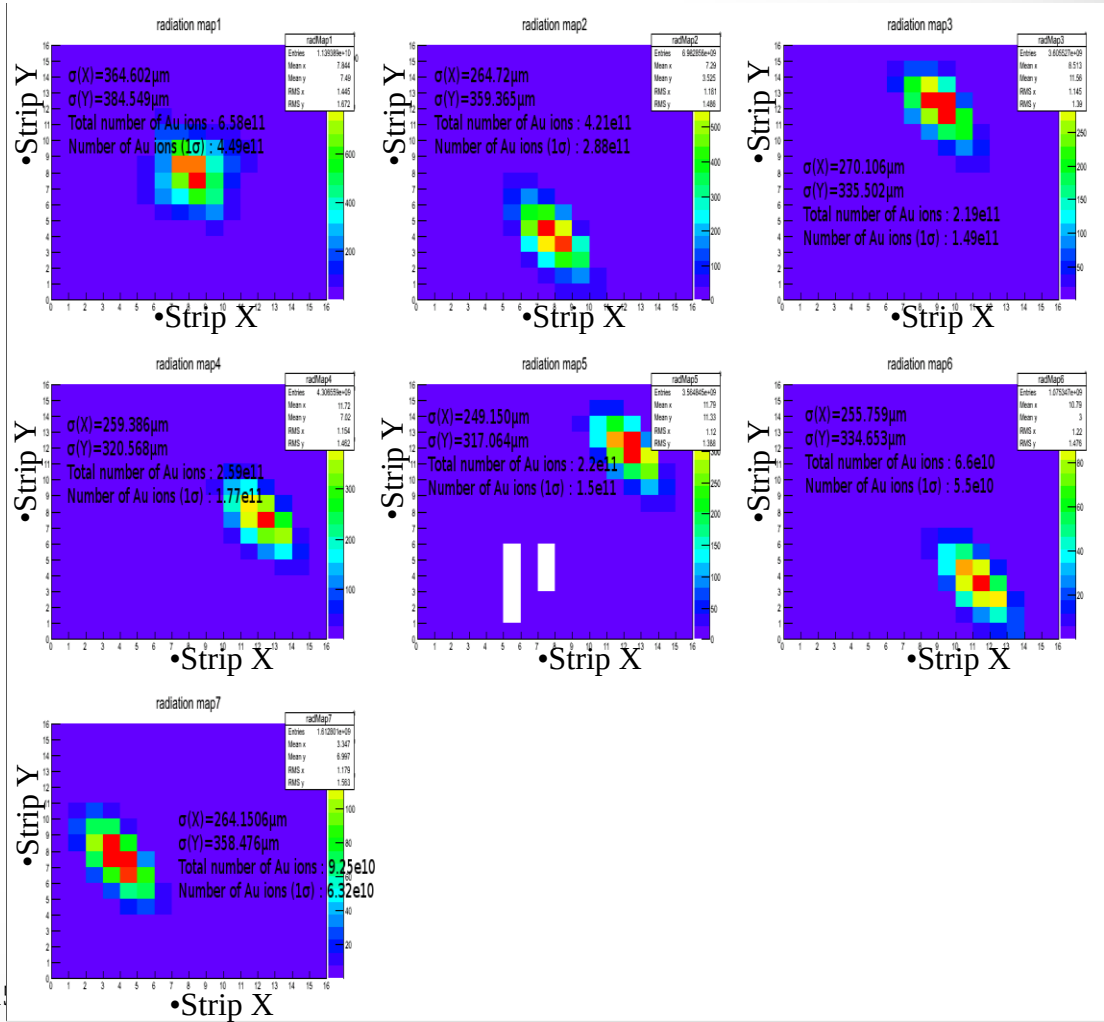
Detector under test:

- 60 um thick , scCVD diamond
- 16 readout strips on each side, 200 um + 90 um spacing
- pixel size: 290 um x 290 um

photo of the metallized sensor before mounting on the PCB



Fluence map for each irradiation period



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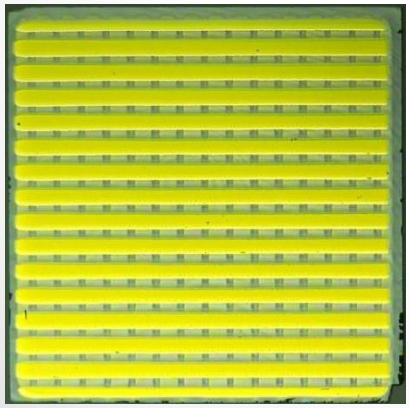
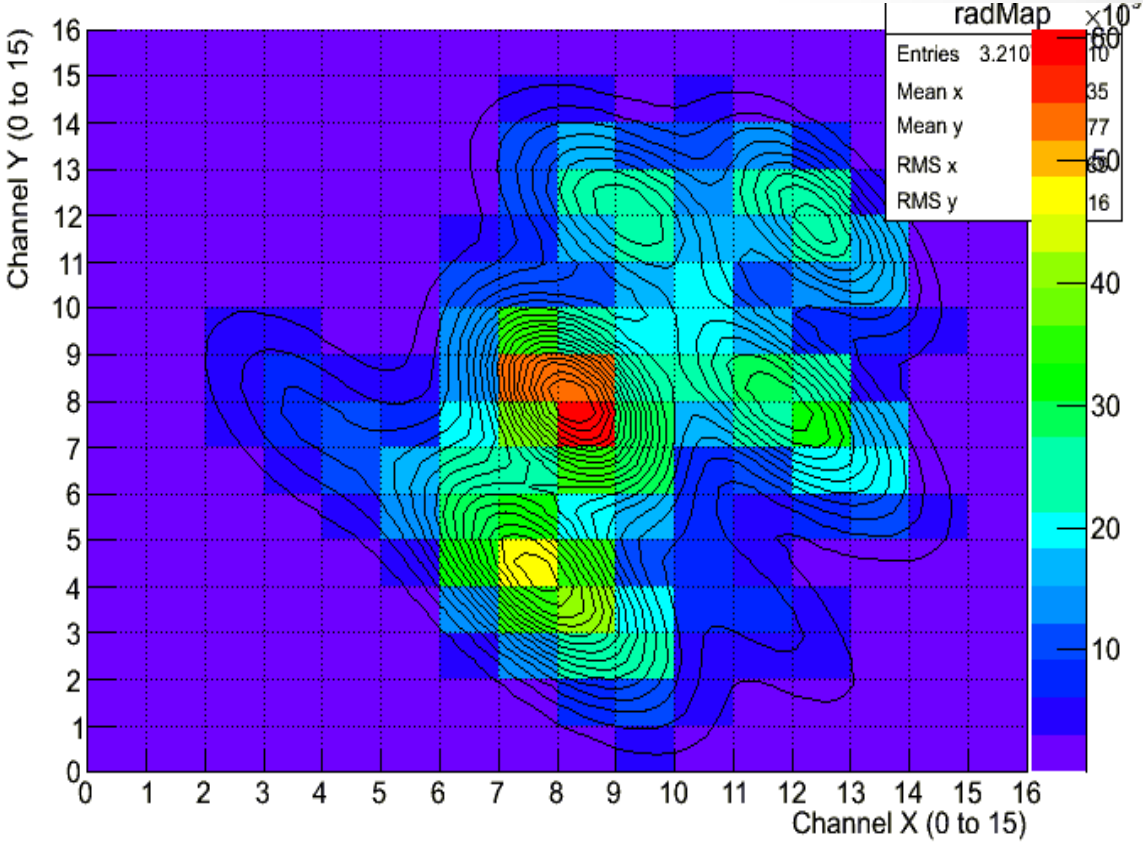


Fluence map in one histogram fitted with seven 2d functions



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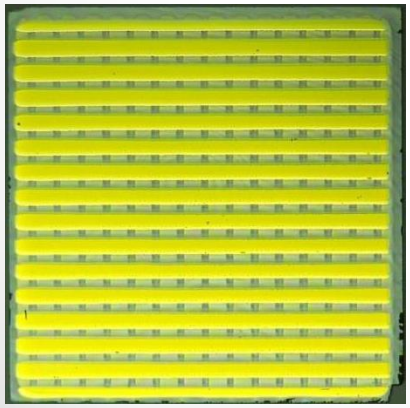

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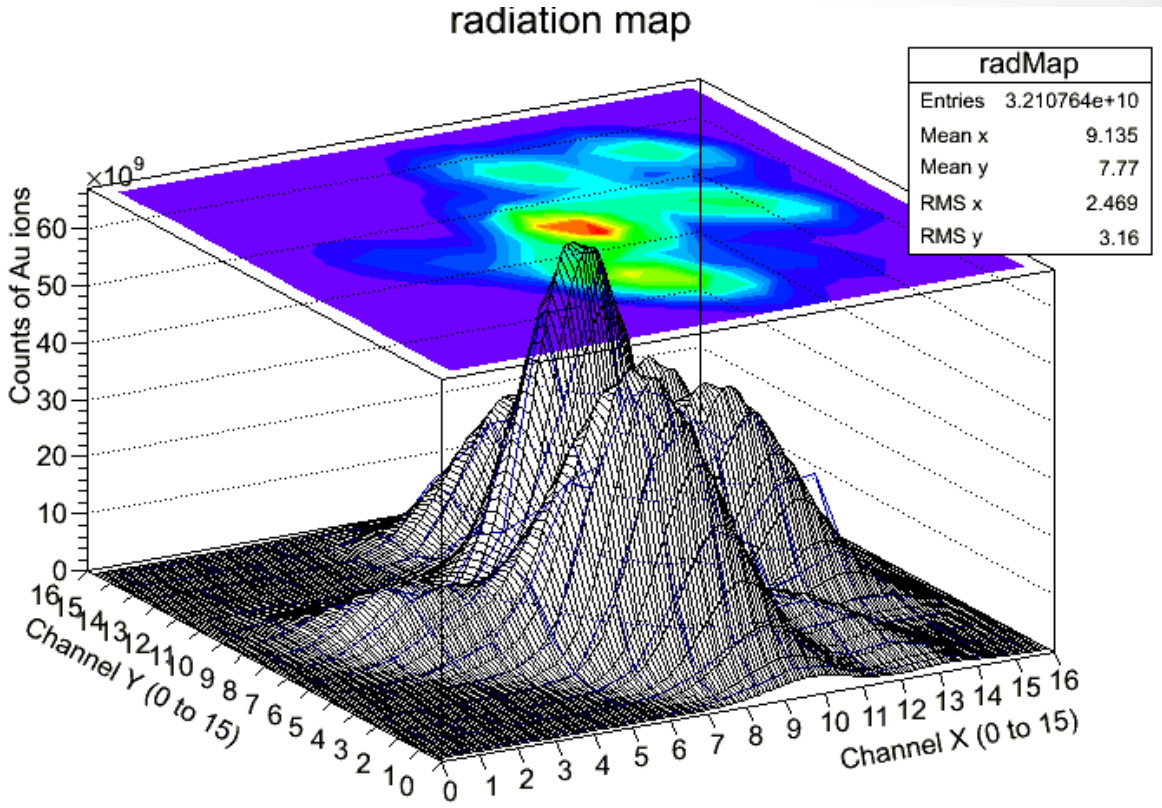

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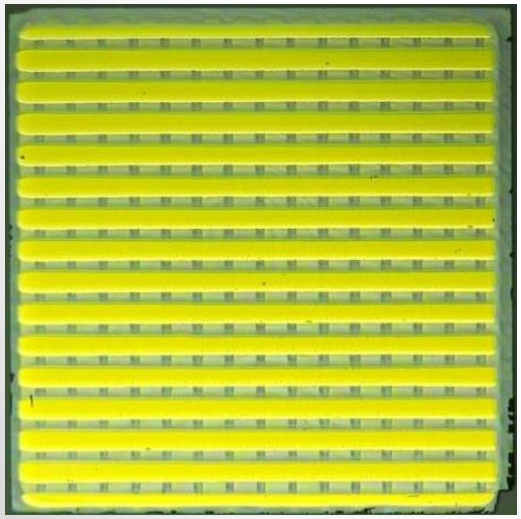
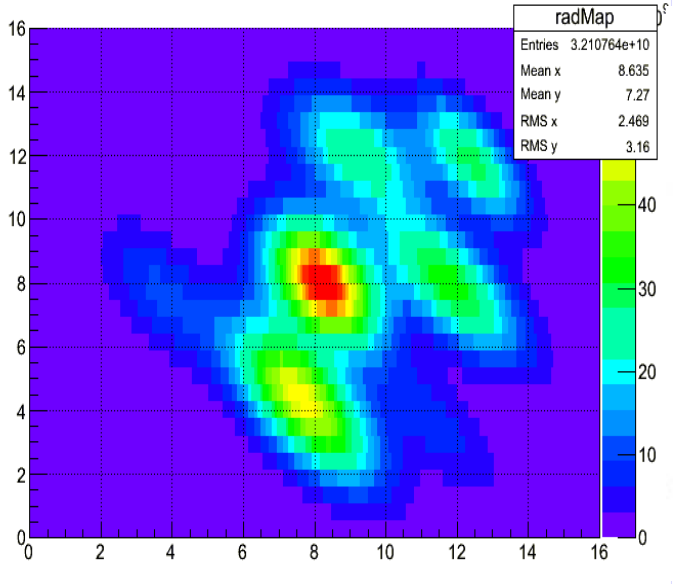
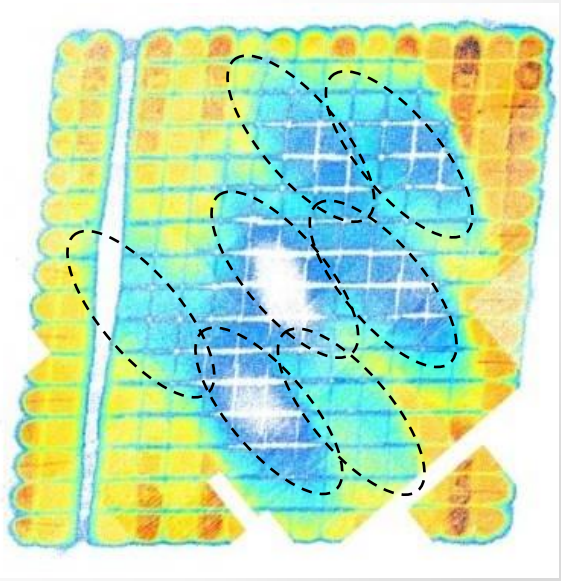


Fit **result** to the fluence: seven 2-dim functions.



First try:

uBeam scan, Zagreb, unfortunately two most important spots are not properly measured **– noise !!**



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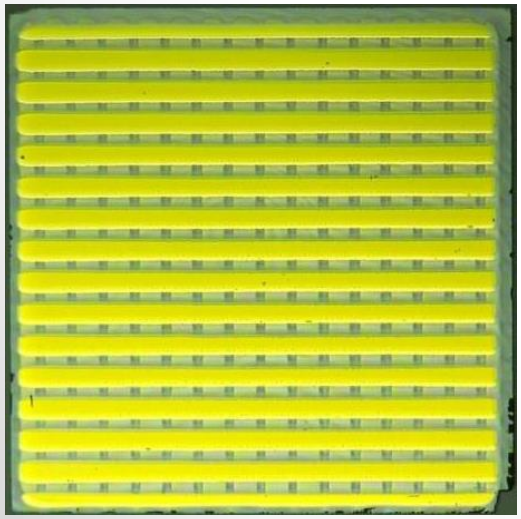

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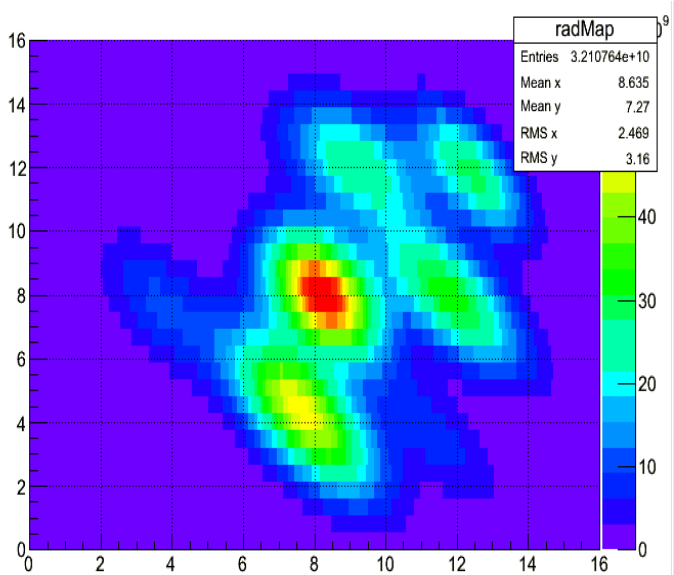
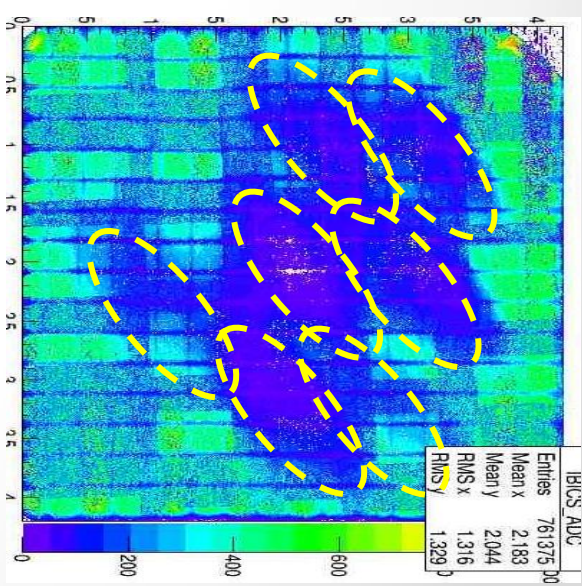


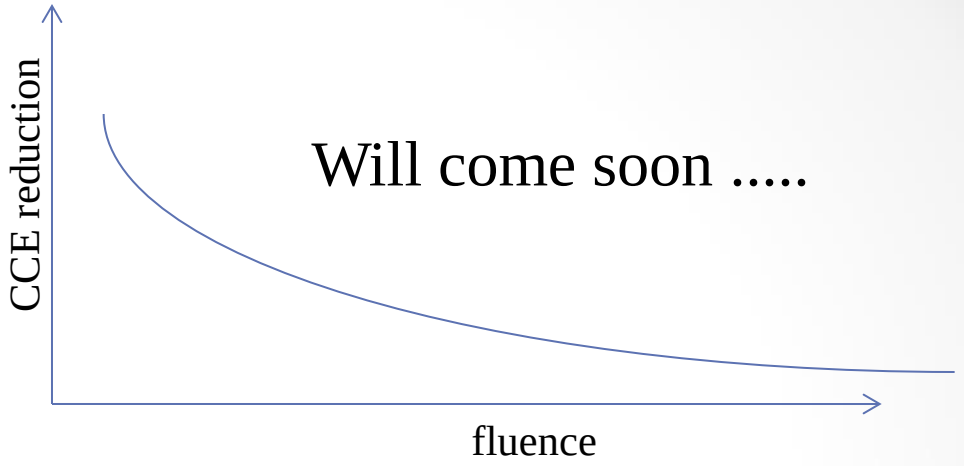
Second try – online picture:

uBeam scan, Zagreb,
Whole detecotr measuered



Radiation damage – systematic study for Au beam

The final result .....



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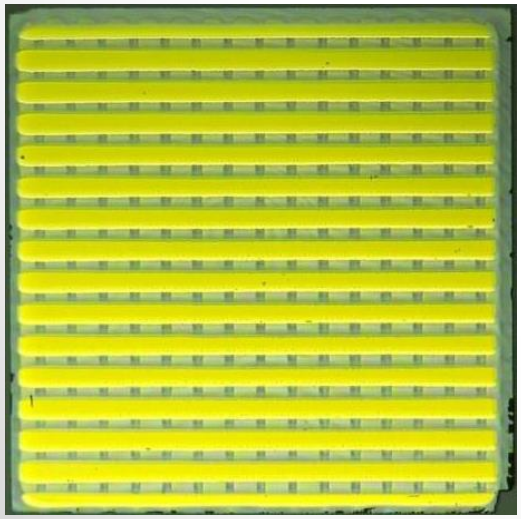

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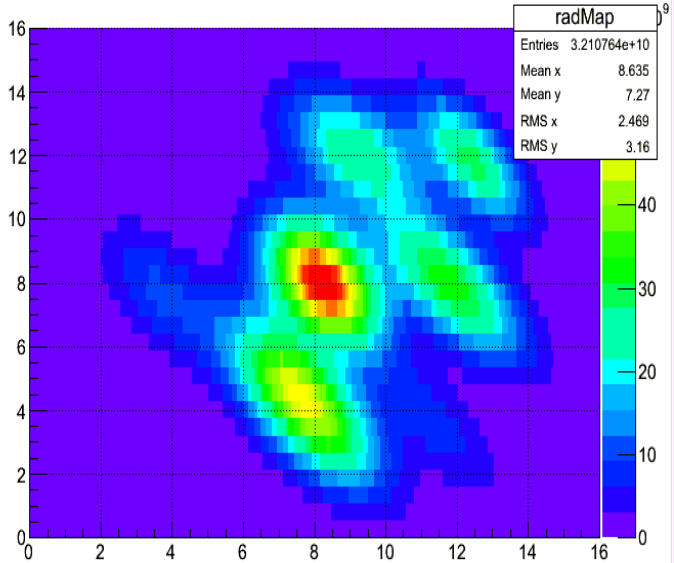

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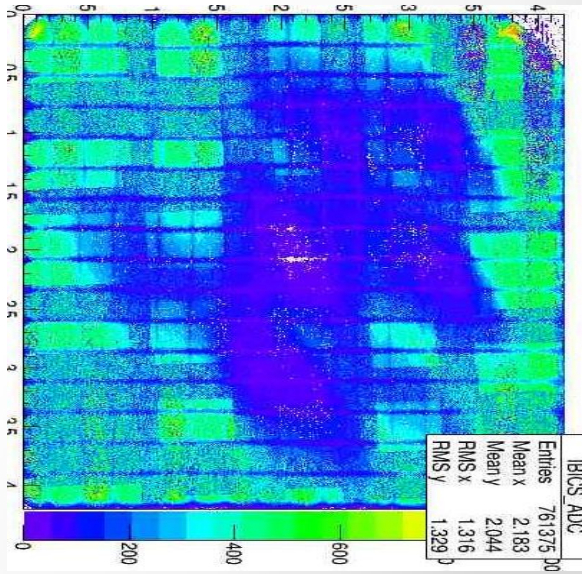
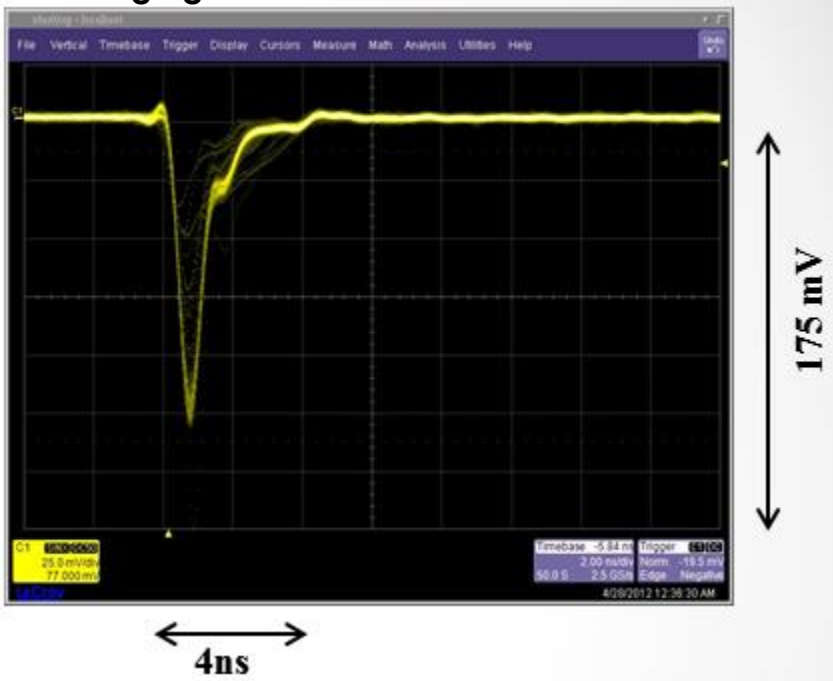


Radiation damage study for Au beam: outcome

Very stable detector behavior after irradiation (~10^{12} Au ions / mm^2):

- Leakage current below 10 nA
- Time resolution below 60 ps

Analog signal for Au ions before irradiation



Possible long term solution:

- original signal amplitude: 150 mV
- radiation damage: reduction by a factor of 6 ?
- additional amplification x 10

→ **very long running period**

Acknowledgements

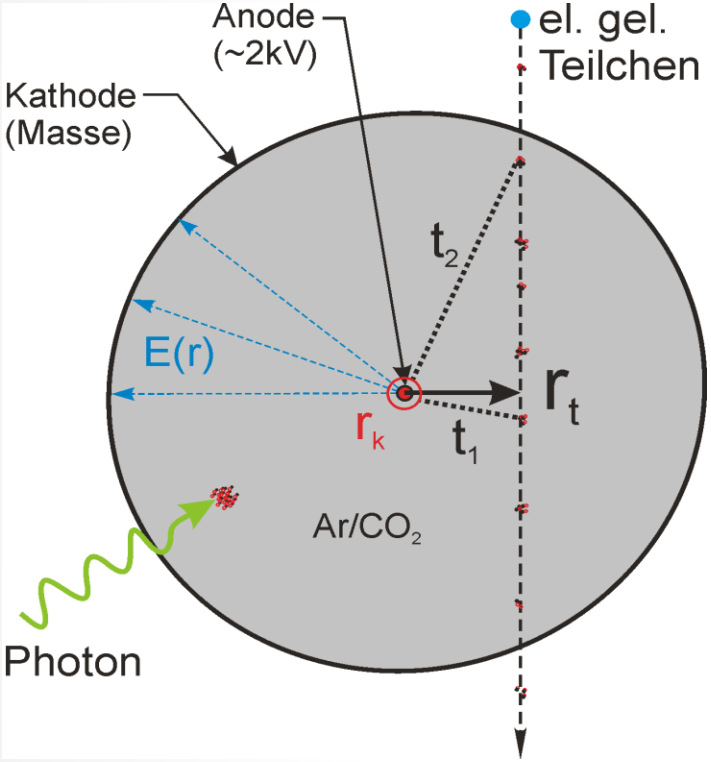
1. GSI Detector Lab: M. Träeger, R. Visinka, M.Kis et al.
2. GSI Target Lab: A. Hübner et al.
3. Ruđer Bošković Institute (μ-beam), Zagreb: V. Grilj, N. Skukan,
4. AIDA-2020 access program

Diamonds for MIPs.
Diamonds for high precision tracking - PADI for straw tube readout

beam test – Jülich, Feb. 2015

Jerzy Pietraszko, Michael Träger, Mircea Ciobanu, Jochen Frühauf

Aim of the test



PADI6 ASIC for straw tube readout

(M. Ciobanu, m.ciobanu @ gsi.de)

- 4 channel per ASIC, differential inputs
  8 channel on FEET-PADI6_Hda
- conversion gain: 35(17.5*)mV/fC
- voltage gain: 244
- BW: 416MHz
- time constant in setup: ~20ns

Straw tube detector

- CBM MUCH prototype
  6mm diameter, ~22cm length
- detector gas: Ar/CO_2 (70/30)
- gas pressure: 1bar
- HV: 1800V
- AC coupling to PADI input:
  400pF(straw), 2.2nF(PCB)

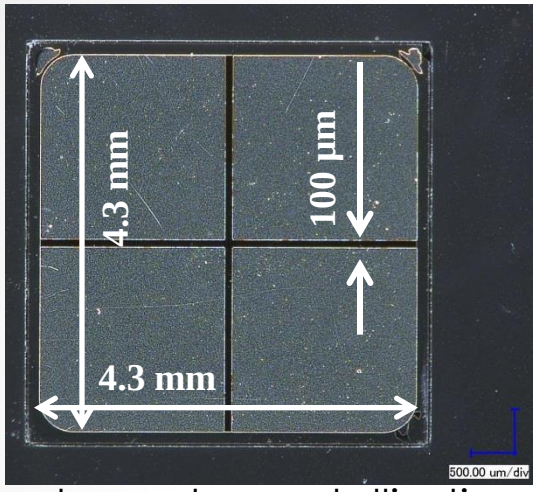
Needed a reference detector:

- **position resolution below 50 µm**
- **time resolution better 100 ps**
- **single particle mode for MIPs**

→ scCVD diamond

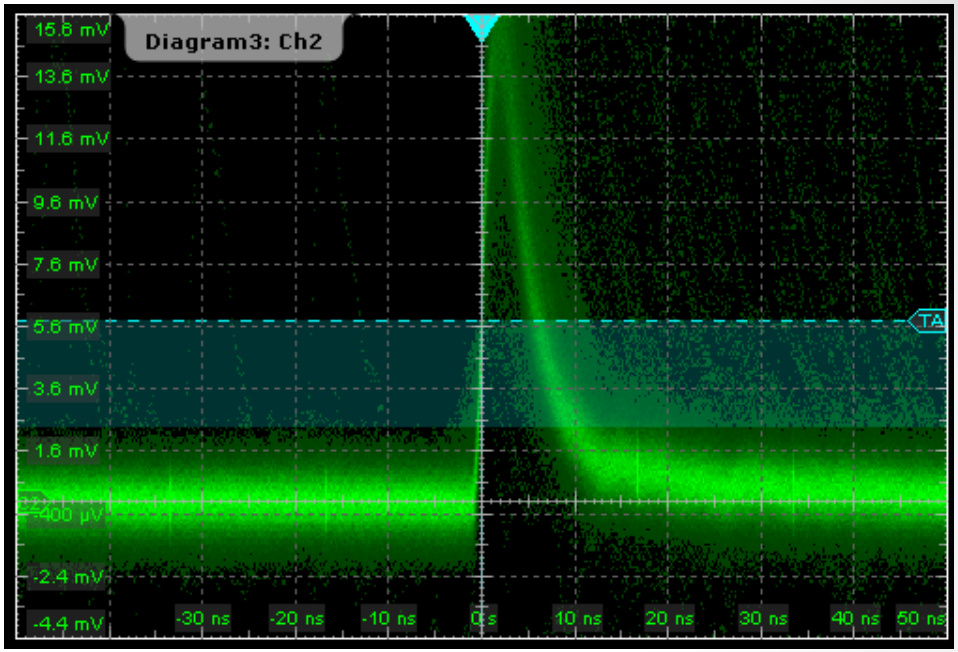
Experimental setup – reference detector

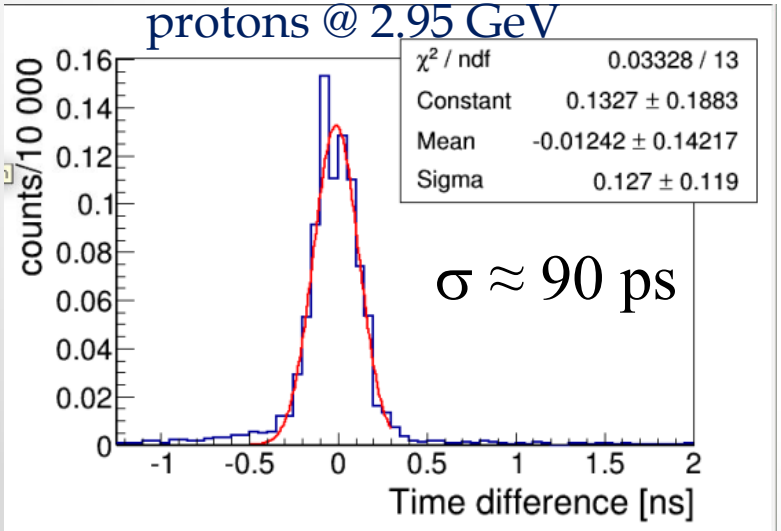
Reference, tracking, scCVD detector



- four channels – metallization
- 100µm space between electrodes
- time resolution below 100 ps

scCVD diamond signal for MIPs

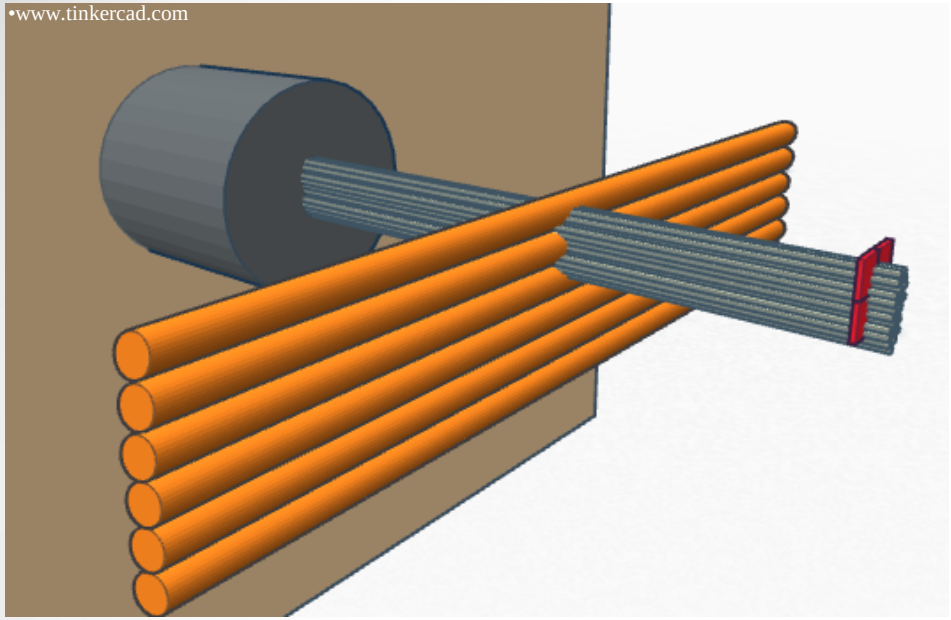




Used threshold: 7mV on each channel

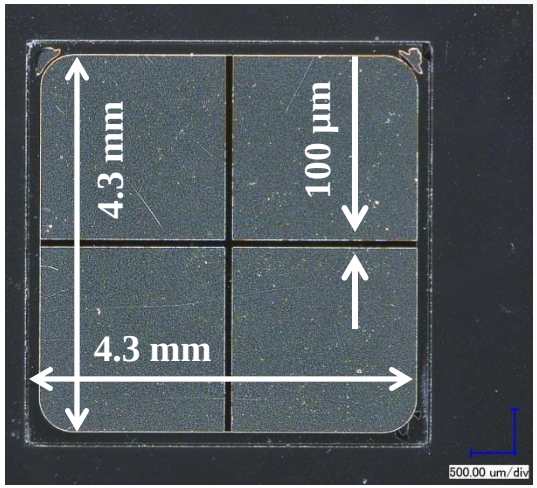
→ position better than 50µm

Experimental setup



- straw tubes connected to the PADI v6
- straw diameter: 6 mm
- Ar/CO_2: 70%/30%
- HV: 1800 V

Reference, tracking, scCVD detector

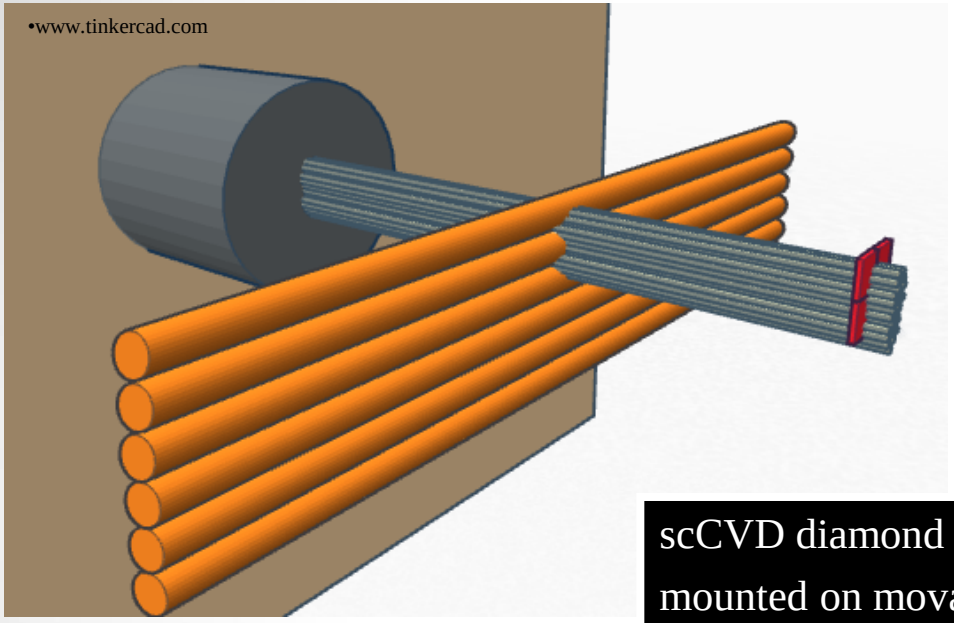


- four channels – metallization
- 100µm space between electrodes
- time resolution below 100 ps
- attached to a movable table,
  (µm step precision)

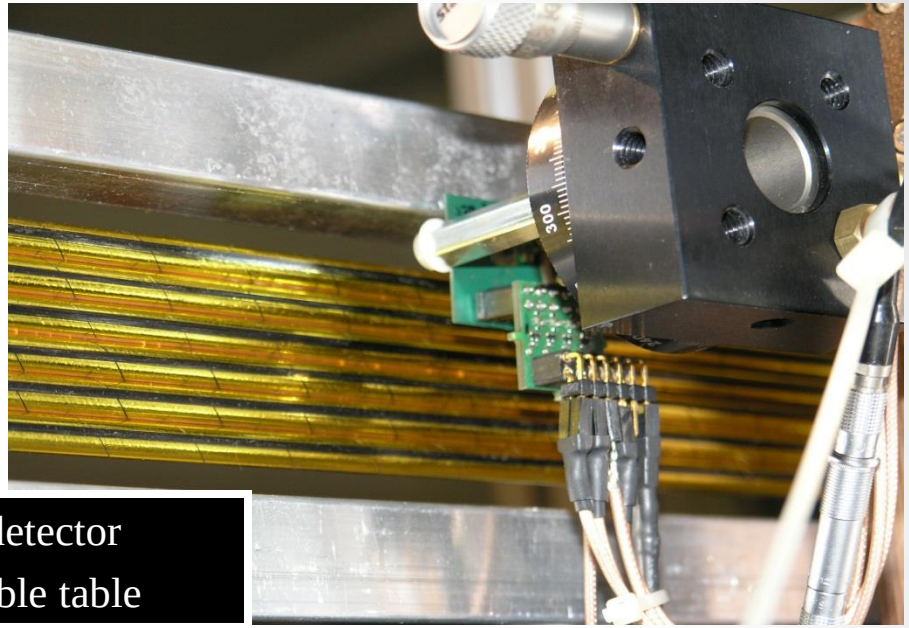
DAQ /Trigger:

- Oscilloscope used as a DAQ (R&S 1044)
- correlated signal in two diamond electrodes used as a trigger
  → proton in the 100µm gap between electrodes.

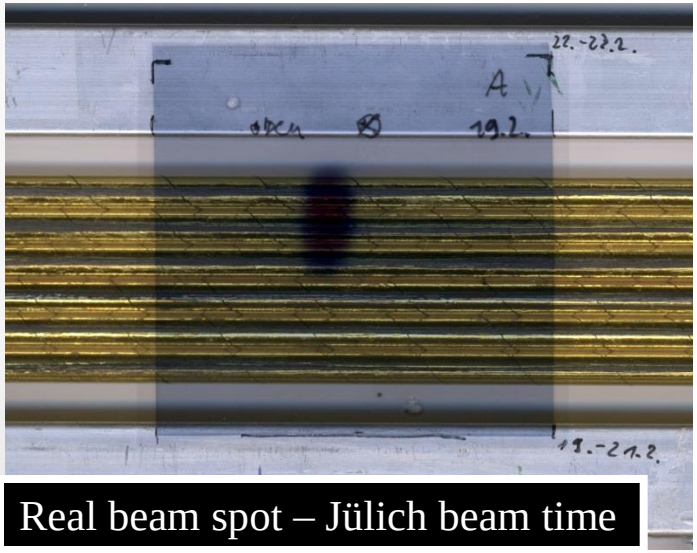
Experimental setup



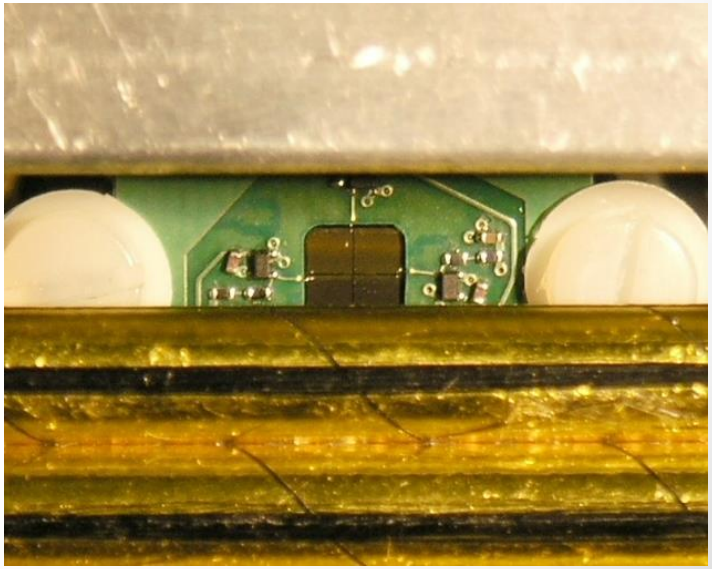
•www.tinkercad.com



scCVD diamond detector mounted on movable table



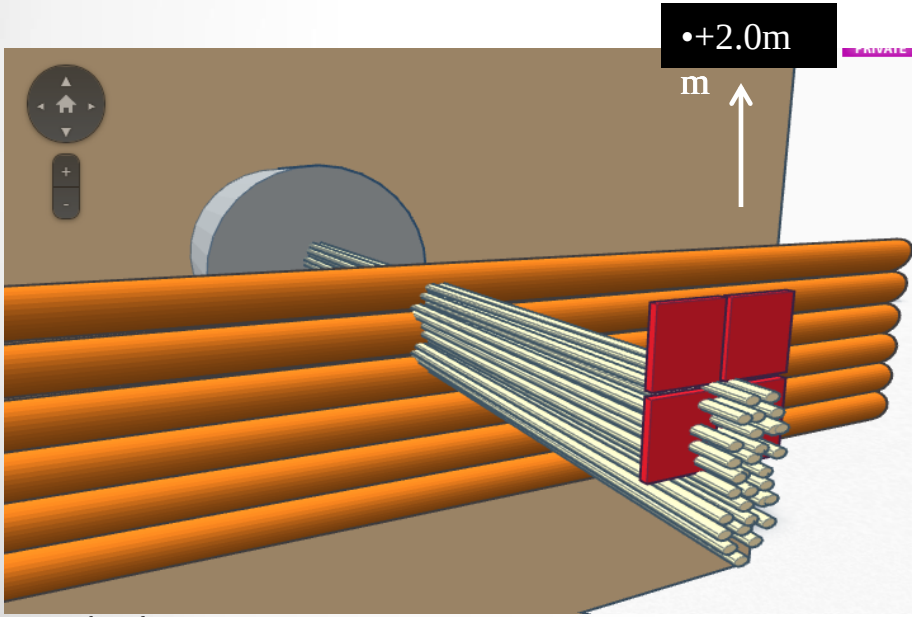
Real beam spot – Jülich beam time



Drift time measurement

Time difference between the scCVD diamond detector and Straw Signal from the PADI discriminator.

→ Drift time spectra (example for 5 positions)



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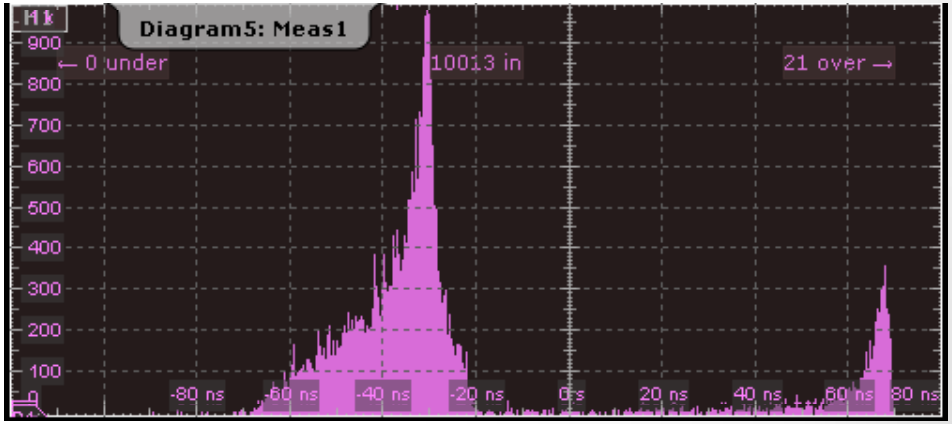
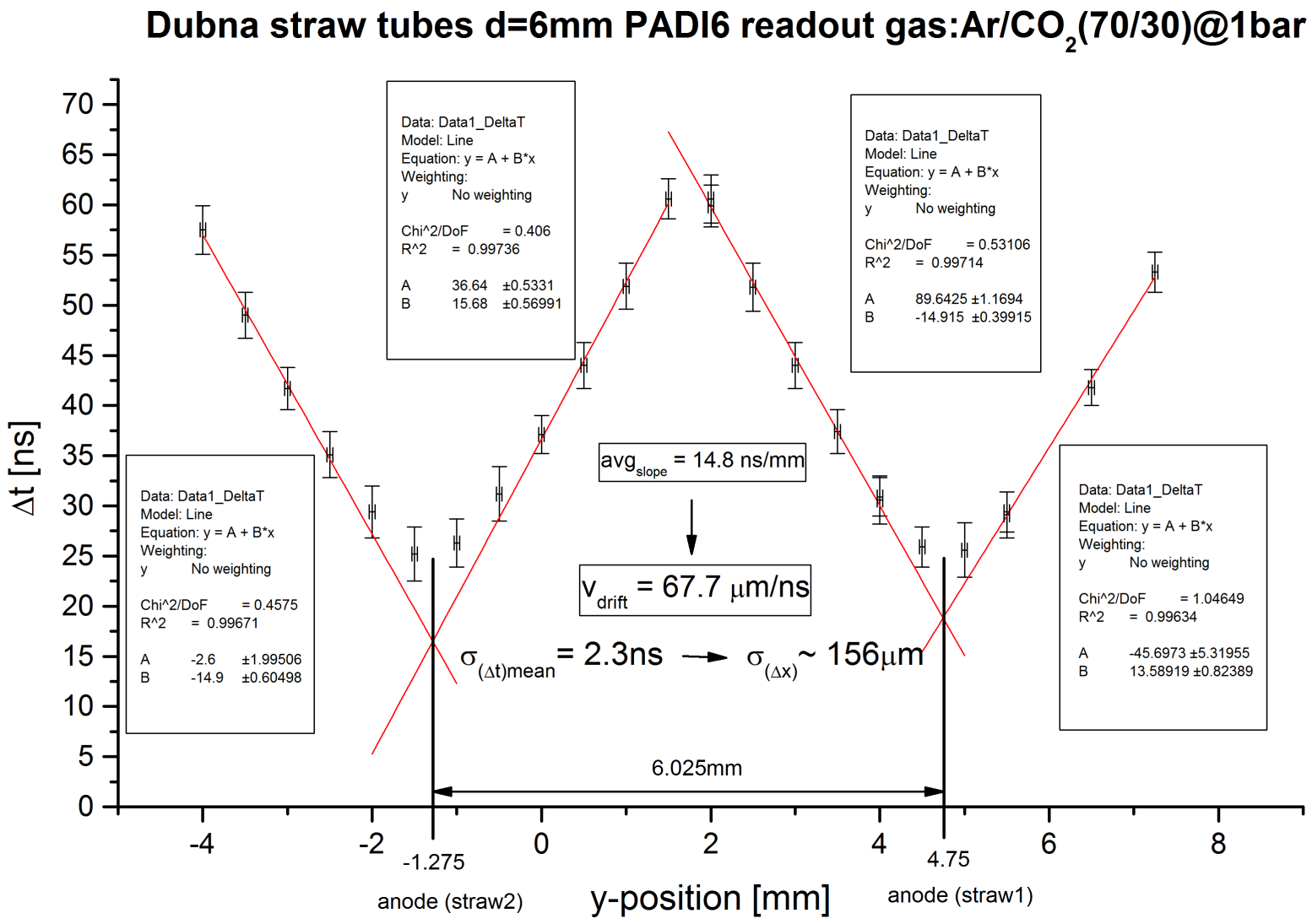


Drift velocity estimation



Summary

Radiation damage

- Stable diamond operation after irradiation above 10^{11} Au ions/mm^2
- Leakage current below 10nA
- Time resolution below 60 ps
- Significant CCE reduction, more than a factor of 6 !
- Can be compensated by additional amplification x 10

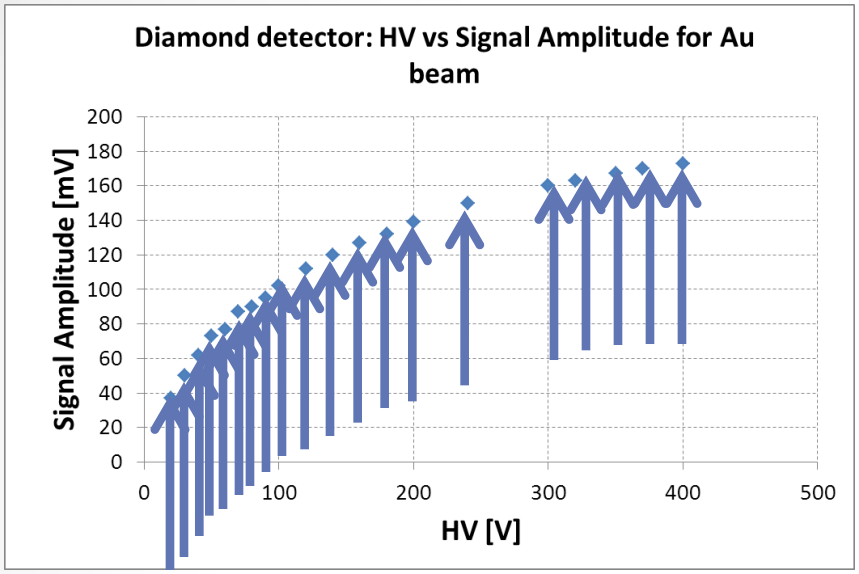
Diamonds for MIPs

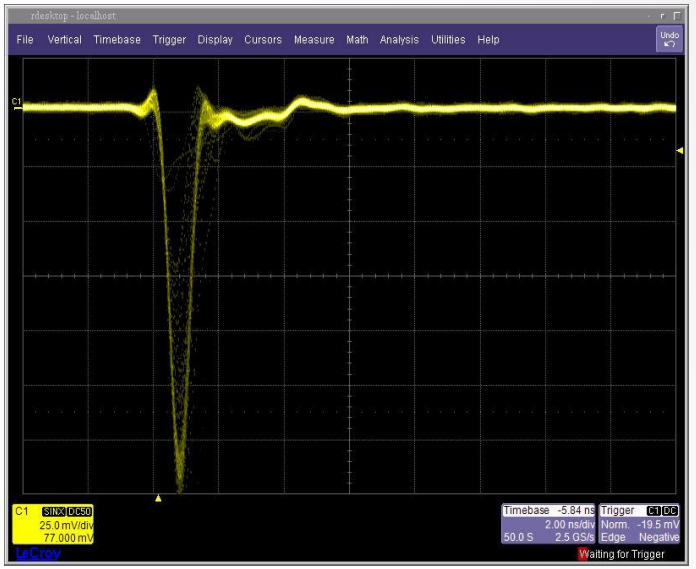
- Excellent time resolution for MIPs, below 100ps
- Position resolution better than 50 μm and can be improved

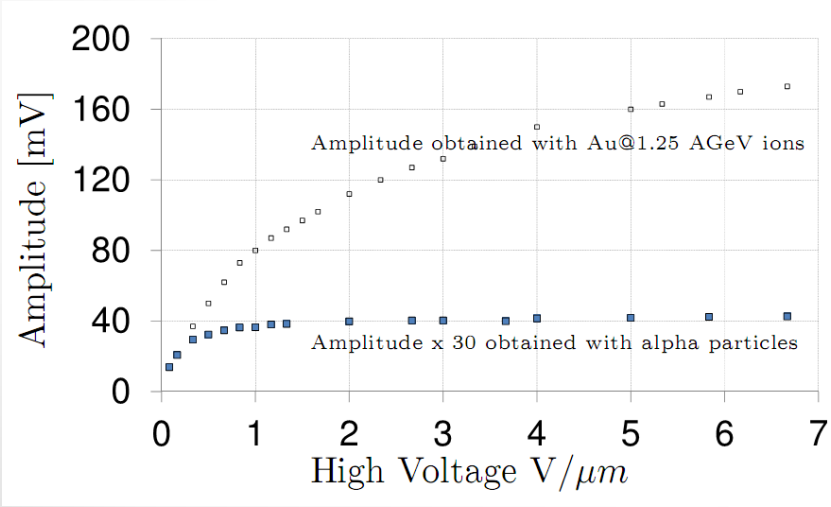
Thank you

Diamond signal properties for Au ions

(^{197}Au at 1.25 A GeV) and alpha particles



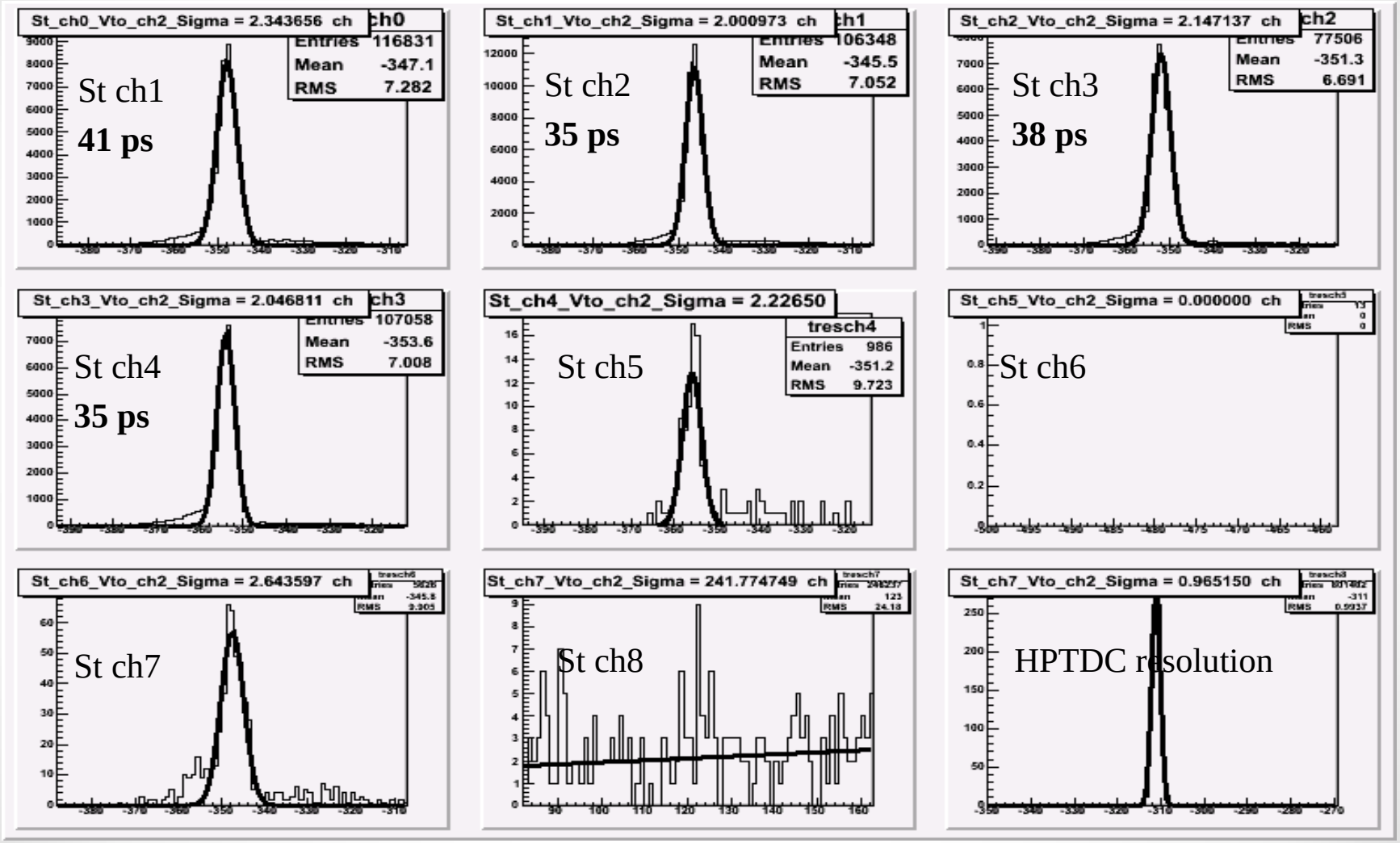




→ Fast signal: rise time < 100 ps, base width < 2ns.

→ differently amplitude/HV characteristics for Au ions and by Alpha particles

Time resolution – test with Fe beam at 1V/μm



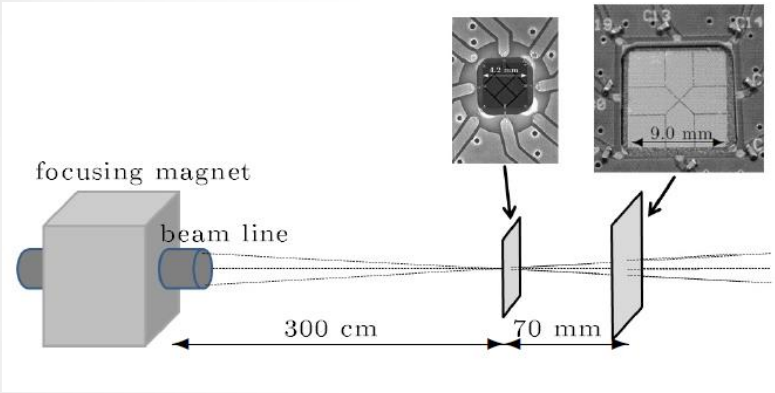
→ **Time resolution below 50 ps**

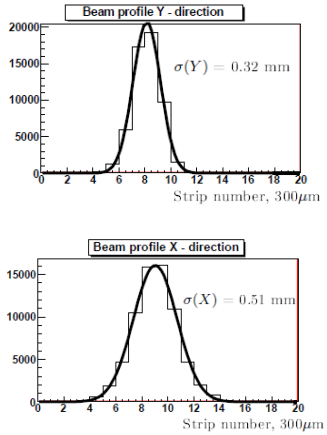
Radiation hardness test with Au beam

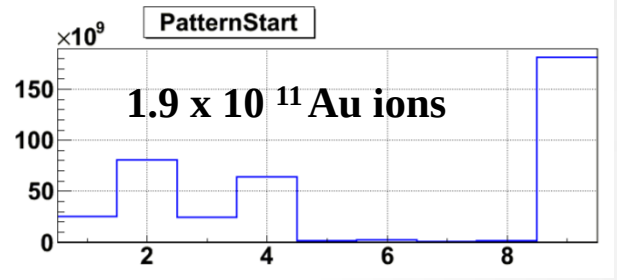
→ several days with well focused beam

→ 10^6 ^{197}Au ions/s (^{197}Au at 1.25 A GeV)

→ single particle readout → total number of particles measured





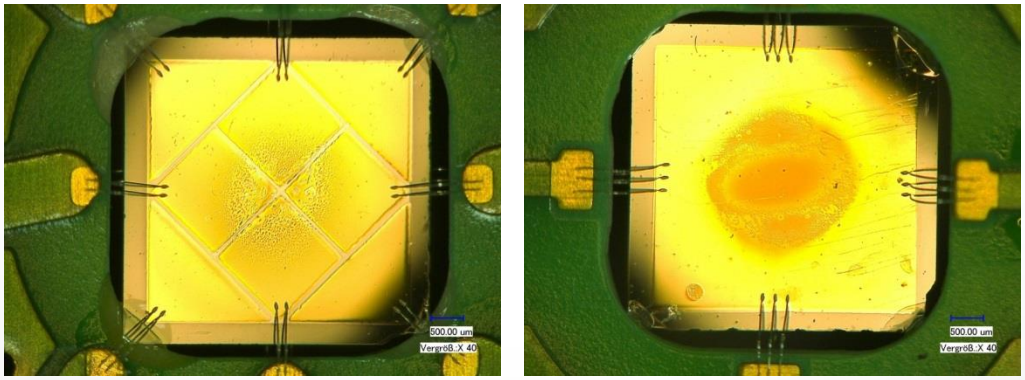


+ 30 % DAQ off + 30 % beam times in 2010

→ **3.04 x 10^{11} Au ions**

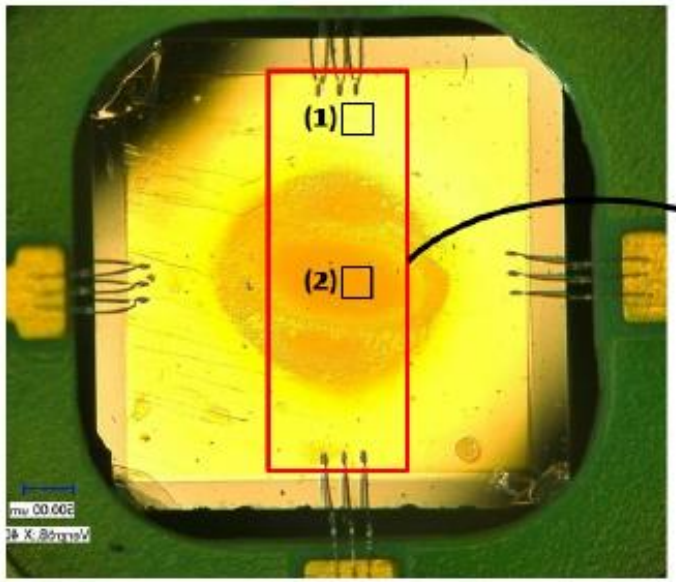
→ **total absorbed dose: 87 MGy**

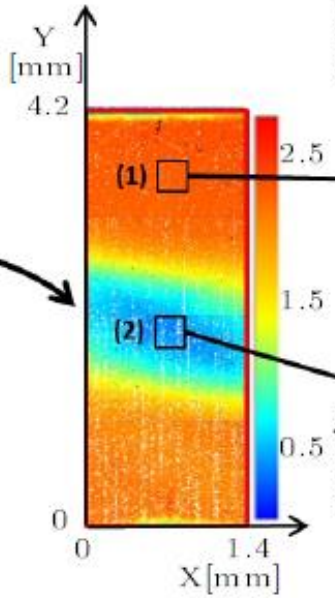
Dismounted detector:



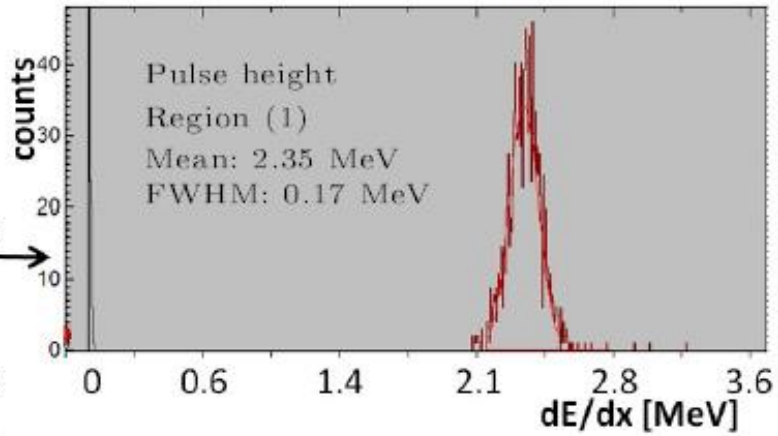
Radiation hardness test with Au beam - results

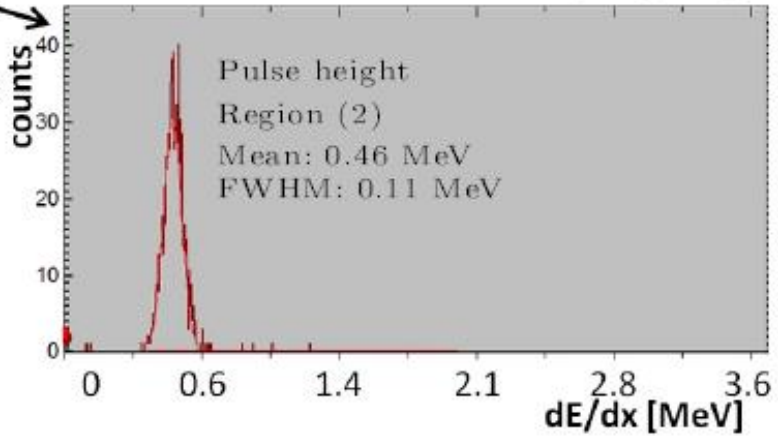
- ✓ Pulse height scan with 4.5 MeV µ-beam of protons
- ✓ Ion Beam Induced Current (IBIC) method at the Laboratory for ion beam interactions at the Ruđer Boskovic Institute in Zagreb





3-dim pulse height spectrum





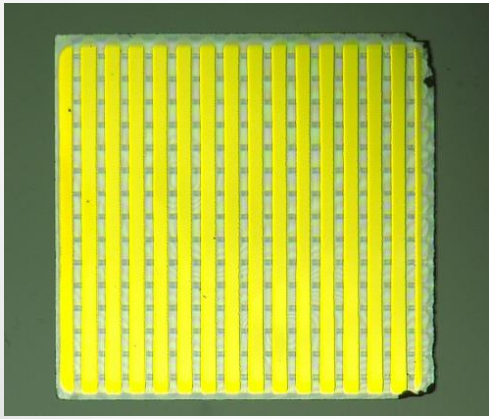
→ pulse height spectrum reduced by a factor of 5.1 at absorbed dose of about 87 MGy

Outlook

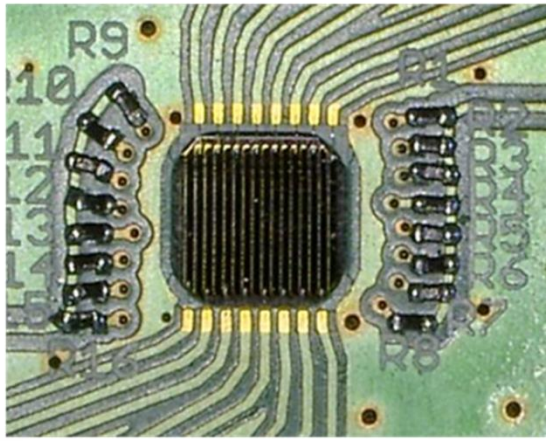
scCVD diamond strip detector irradiated with ^{197}Au

- ✓ Strip scCVD diamond: 16 strips on each side → position information
- ✓ Several beam spots → different absorbed doses
- ✓ Preliminary pulse height scan with 4.5 MeV μ-beam of protons → improvement needed
- ✓ Ion Beam Induced Current (IBIC) method at the Laboratory for ion beam interactions at the Ruđer Boskovic Institute in Zagreb

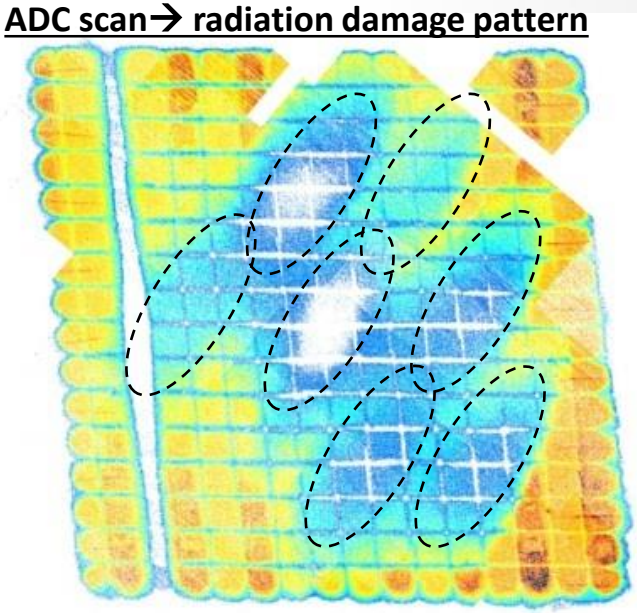
Metallized diamond



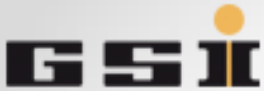
Bonded to the PCB

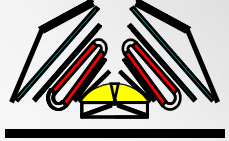


ADC scan→ radiation damage pattern



→ ongoing analysis, results come soon





Thank you