Systematic study of radiation hardness of single crystal CVD diamond material investigated with an Au beam and IBIC method.

J. Pietraszko[a], A. Draveny[b] ,T. Galatyuk[d], V. Grilj[c], M. Kis[a], W. Koenig[a], C.J.Schmidt[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

for the CBM and HADES Collaborations

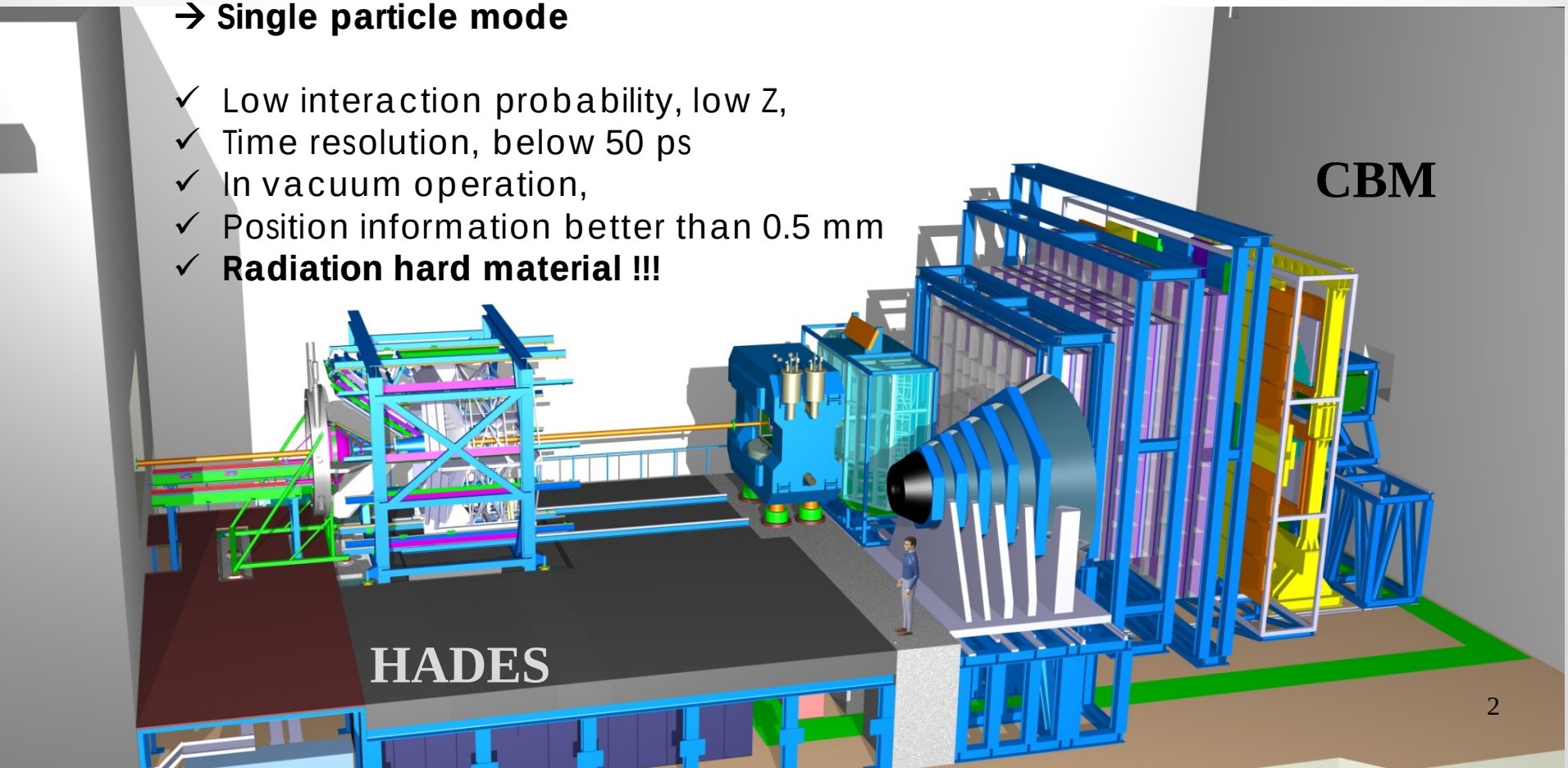
T0 and beam monitoring detector requirements

Applications:

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

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

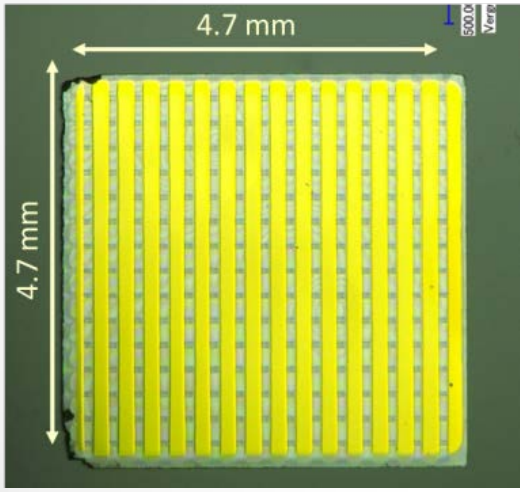
- ✓ Low interaction probability, low Z,
- ✓ Time resolution, below 50 ps
- ✓ In vacuum operation,
- ✓ Position information better than 0.5 mm
- ✓ **Radiation hard material !!!**

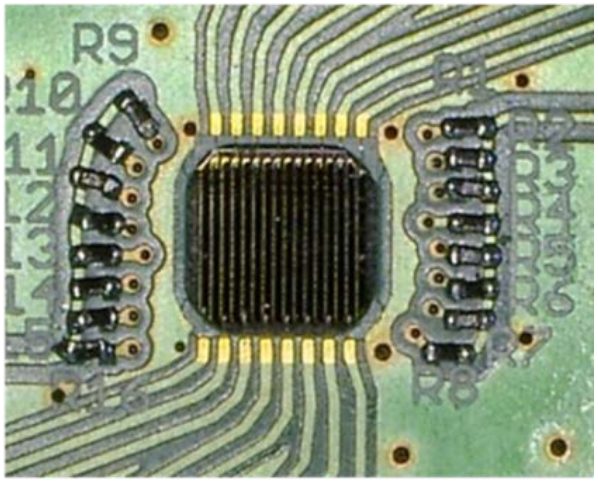


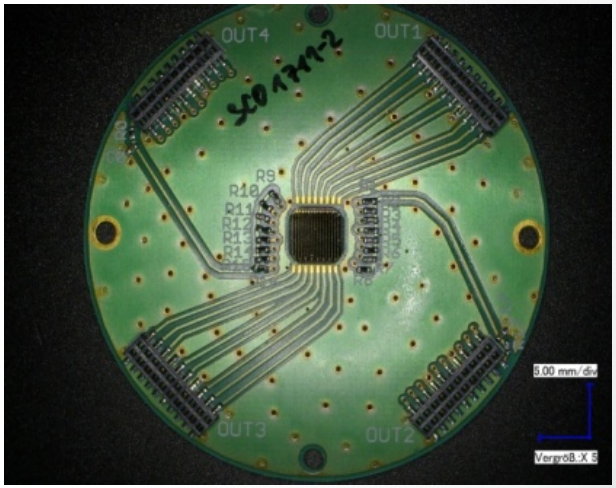
Prototype diamond detector

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



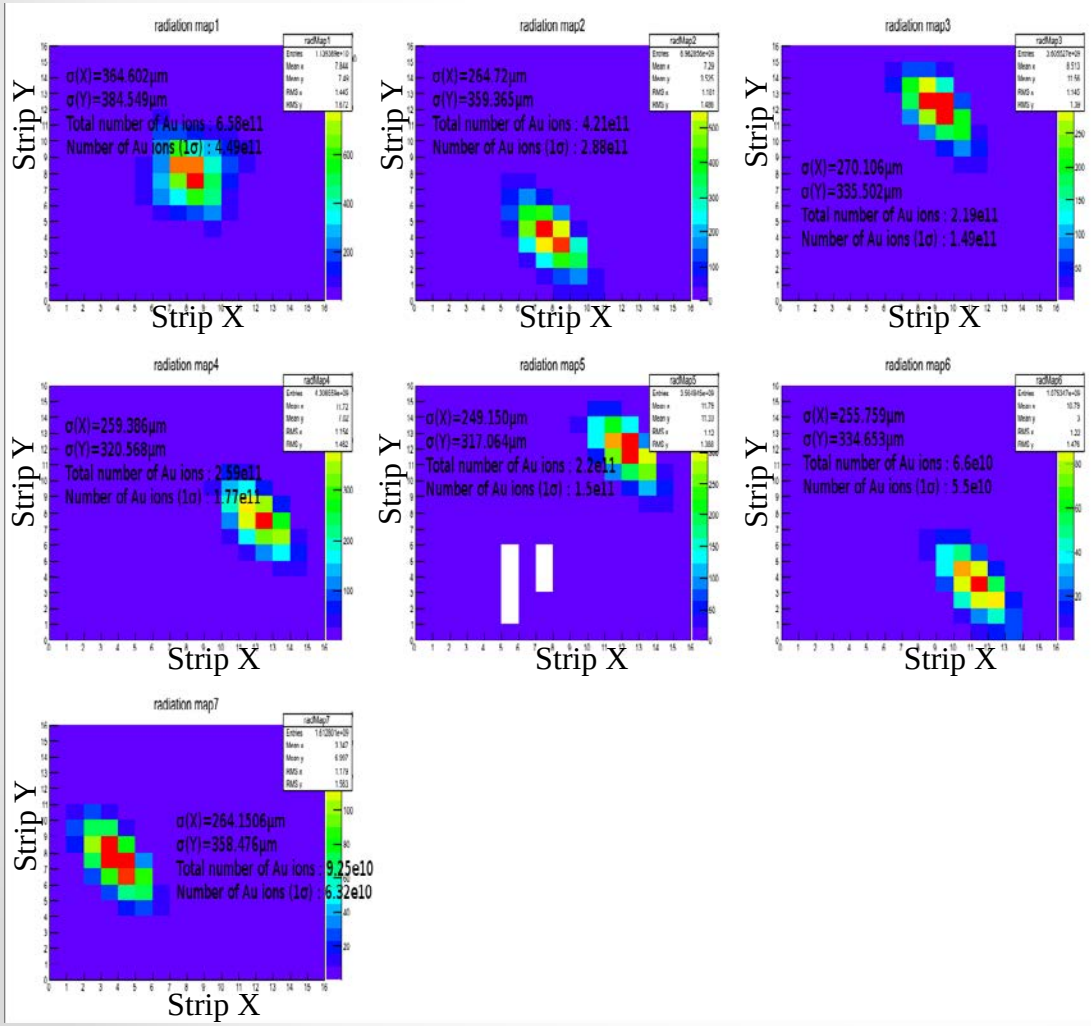




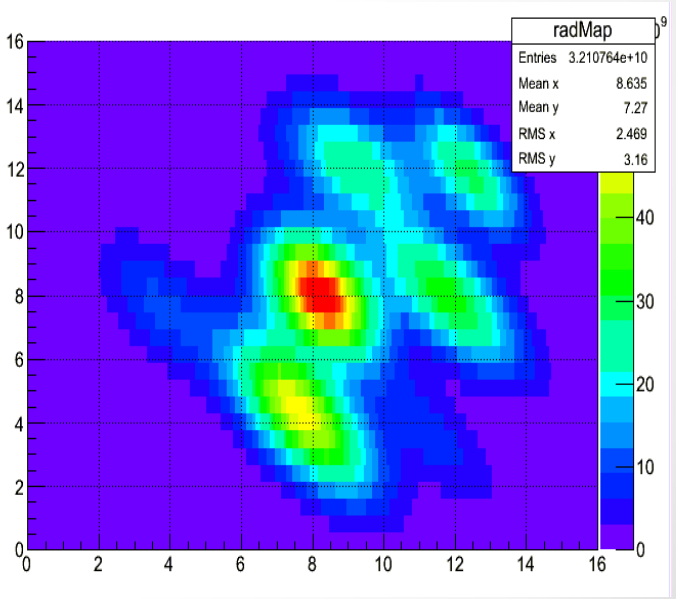
Radiation damage – systematic study for Au beam

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

Fluence map for each irradiation period

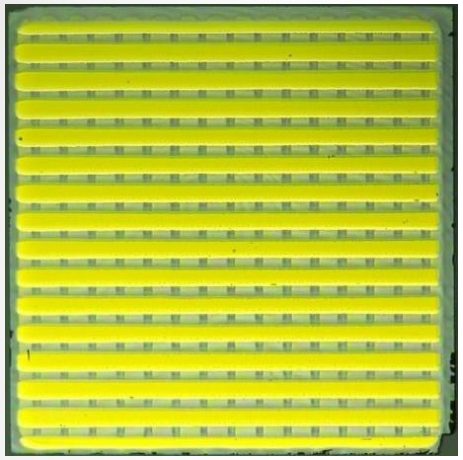


Shown in one histogram

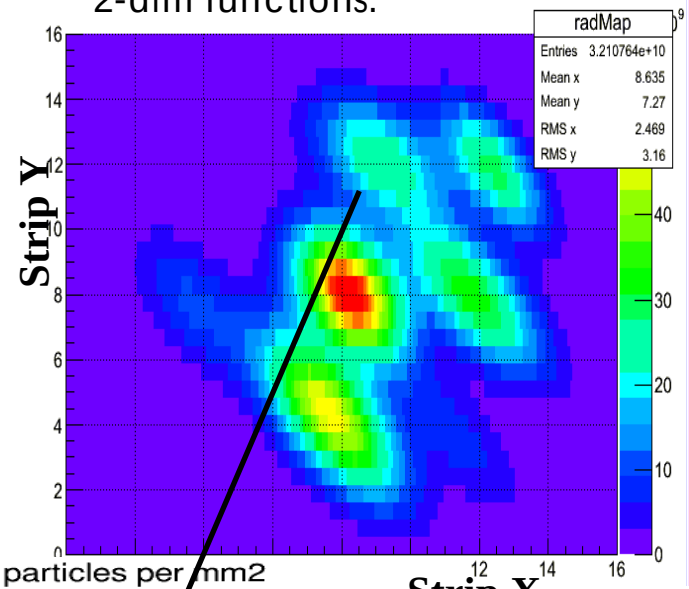


Radiation damage – systematic study for Au beam

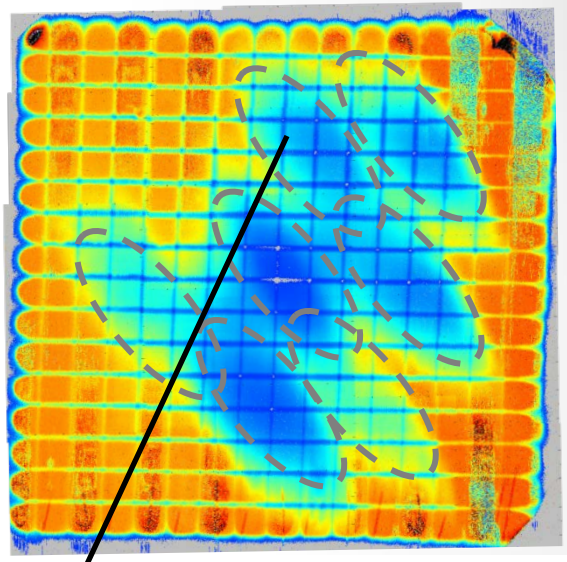
photo of the metallized sensor before mounting on the PCB

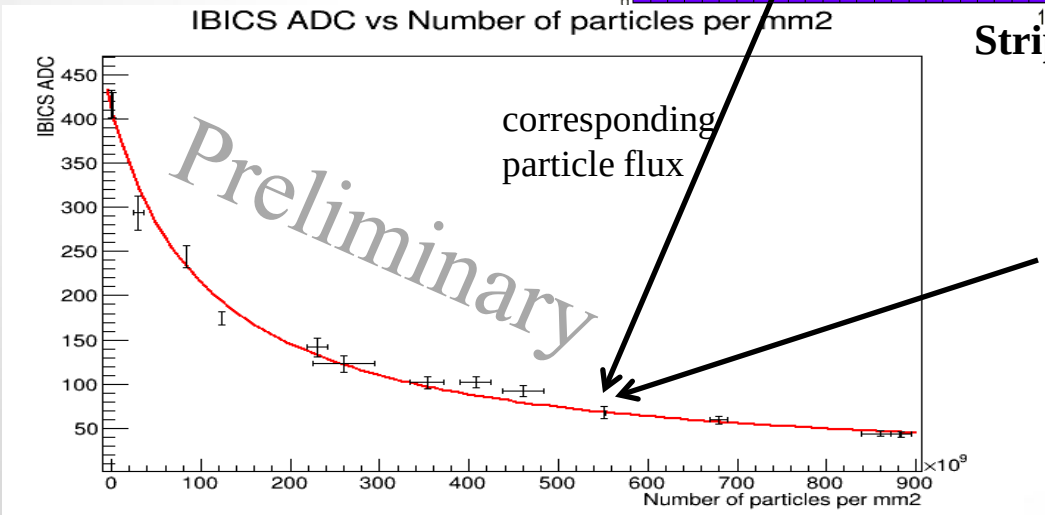


Fit **result** to the fluence: seven 2-dim functions.



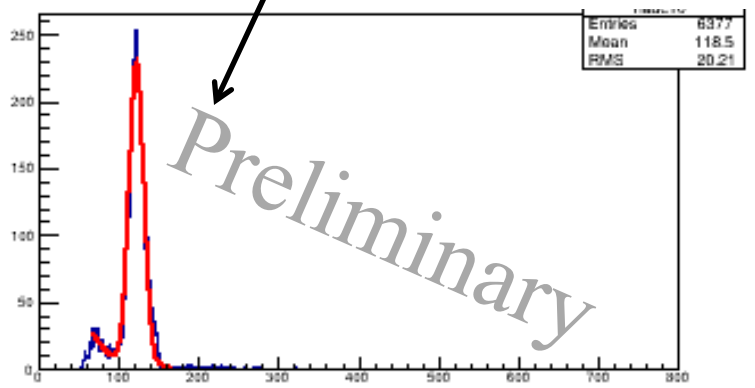
IBIC - µBeam scan, Zagreb, Proton beam @ 4.5 MeV





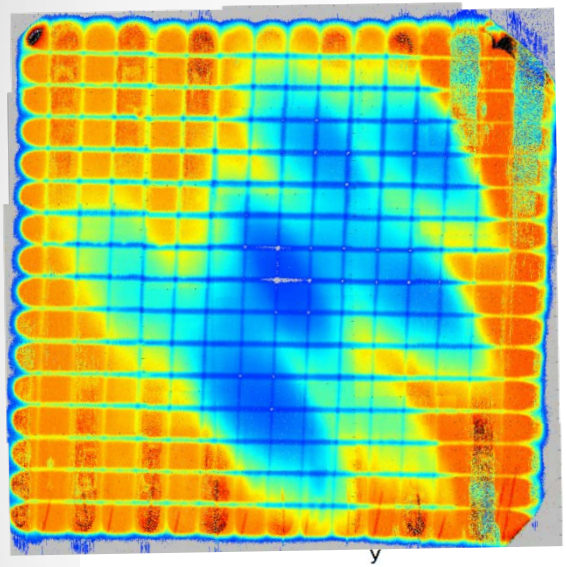
corresponding particle flux

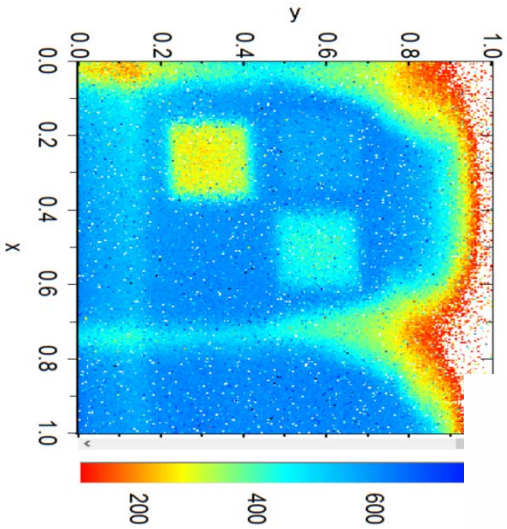
Example ADC IBIC spectra

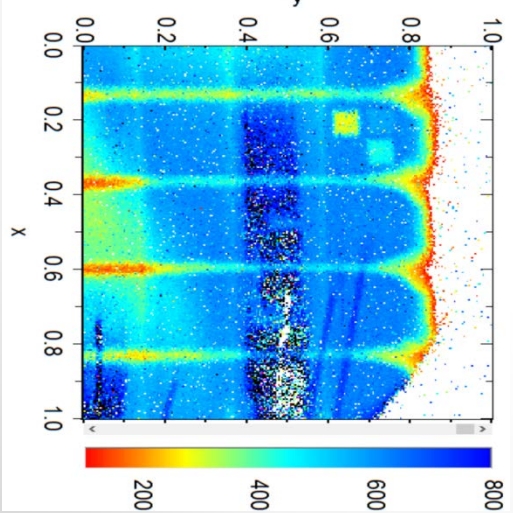


Irradiation with 4.5 MeV protons

- ✓ 3 irradiated areas, 100 x 100 μm^2
- ✓ Fluencies: 4.6x10^{11} ions/mm^2, 1.5x10^{12}ions/mm^2, 3.4x10^{12} ions/mm^2
- ✓ IBIC done at +100 V

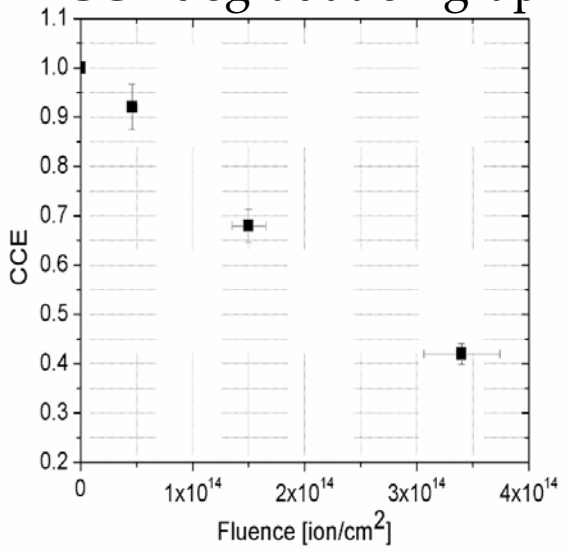




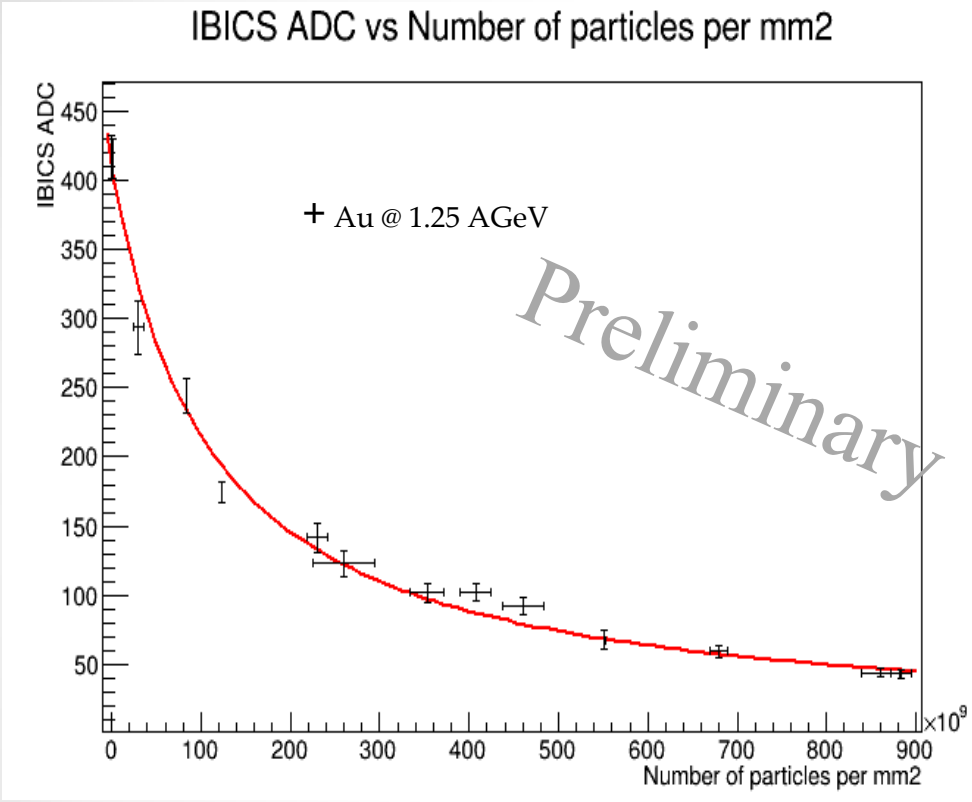


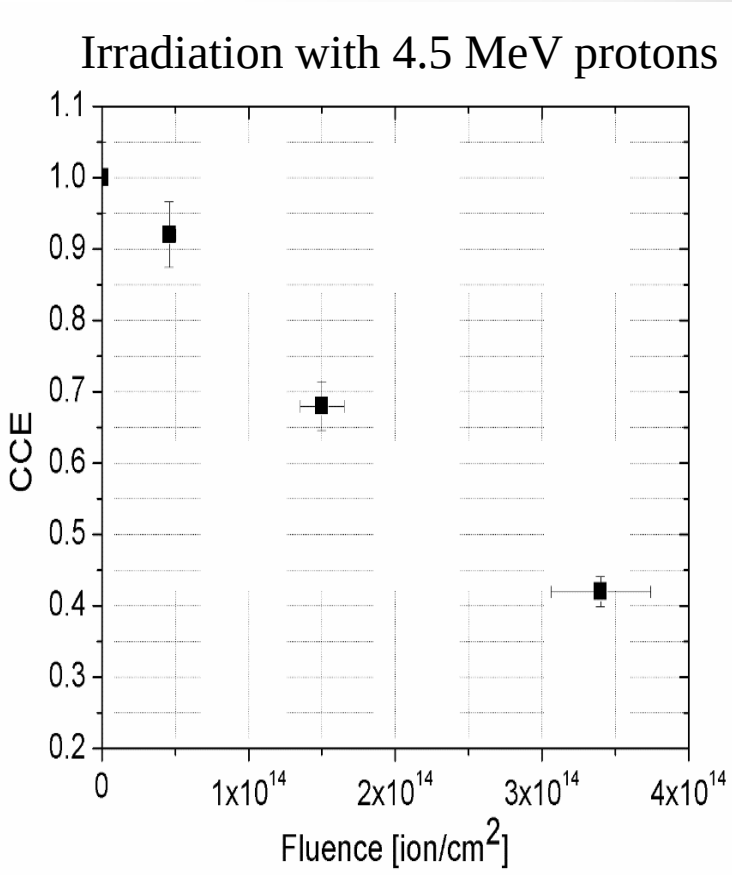
Fluence [mm^2]	ADC [MeV]	CCE
0	430	1
4.6E11	395	0.92
1.5E12	292	0.68
3.4E12	180	0.42

CCE degradation graph



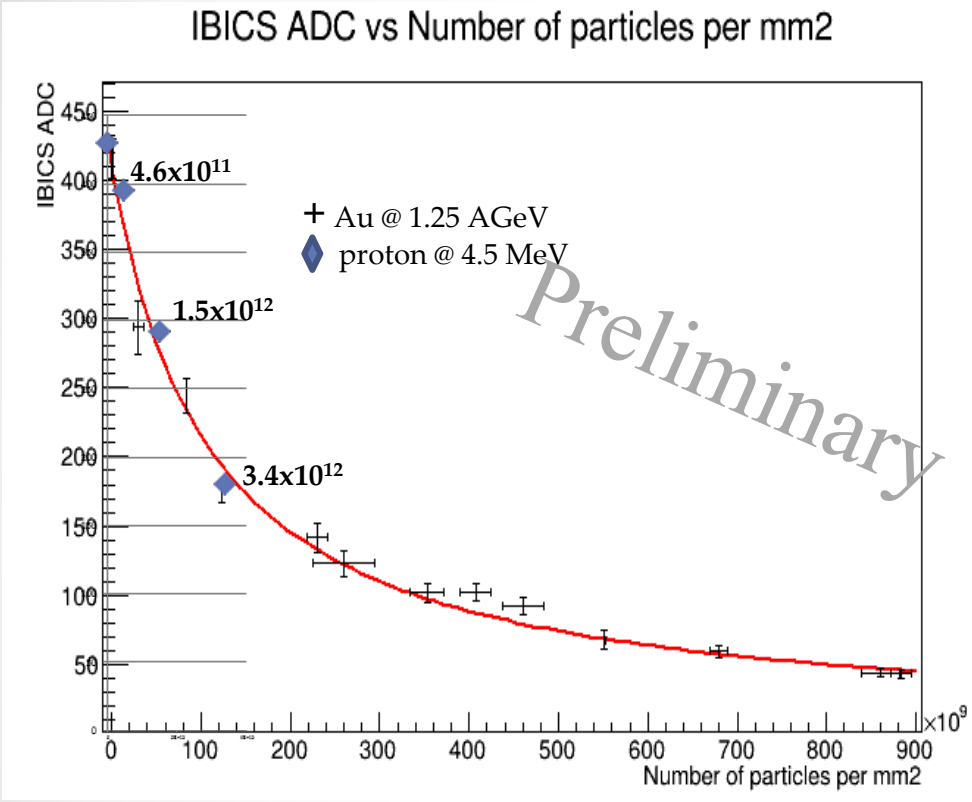
Radiation damage – systematic study for Au beam comparison to protons@4.5 MeV

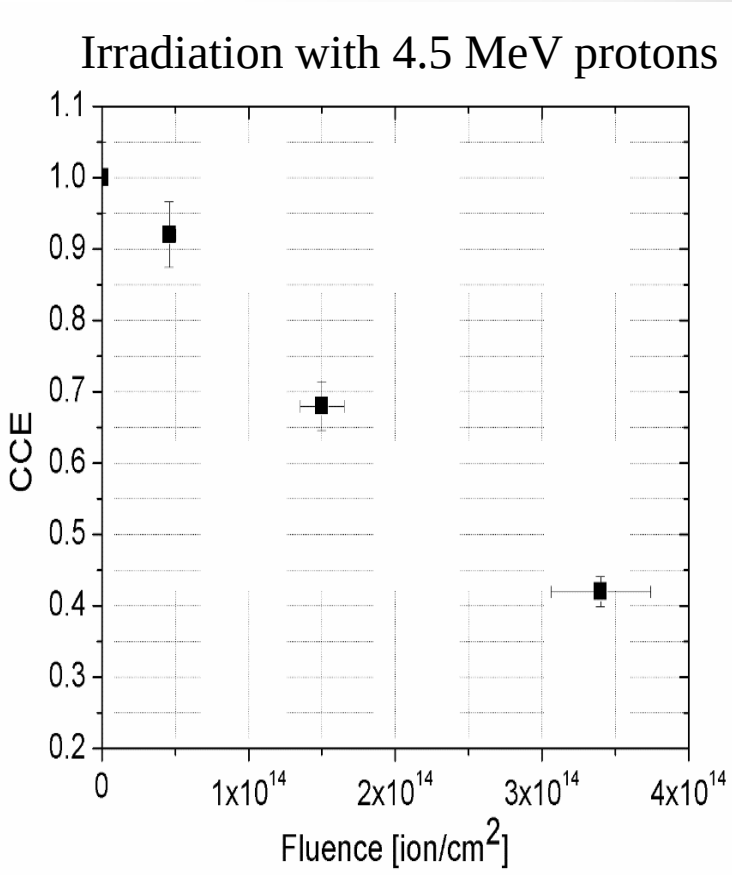




The same detector irradiated with Au ions and protons !

Radiation damage – systematic study for Au beam comparison to protons@4.5 MeV

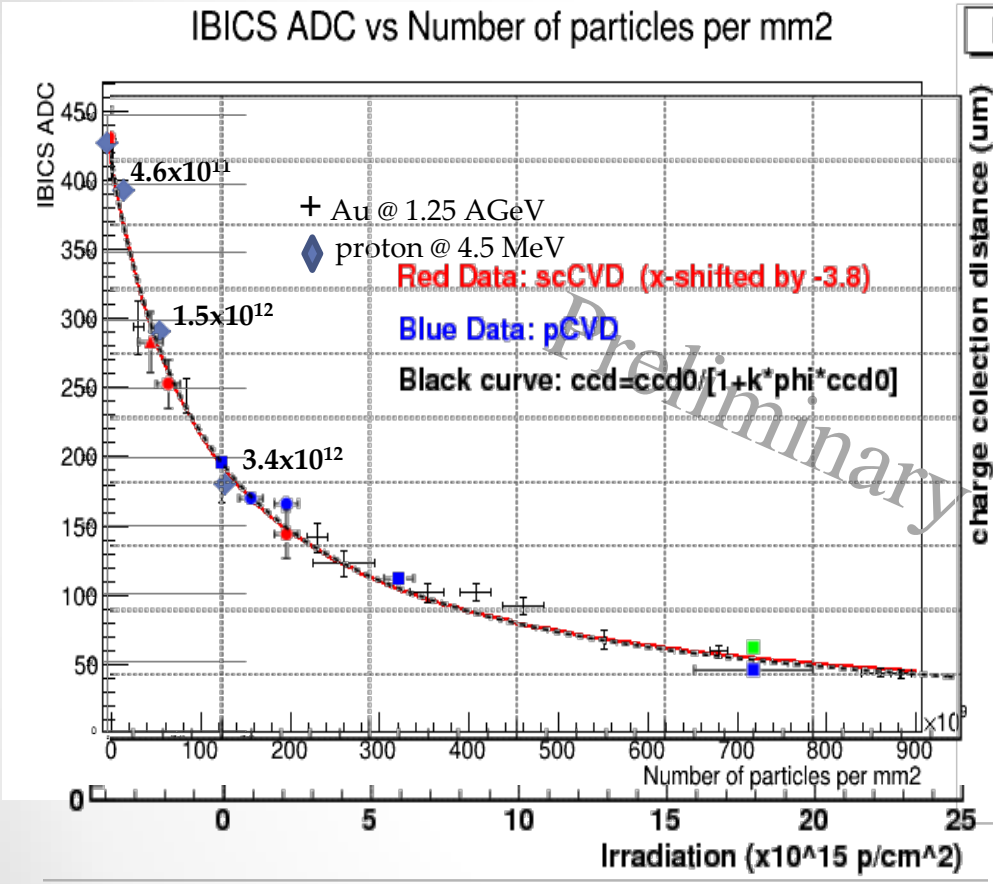


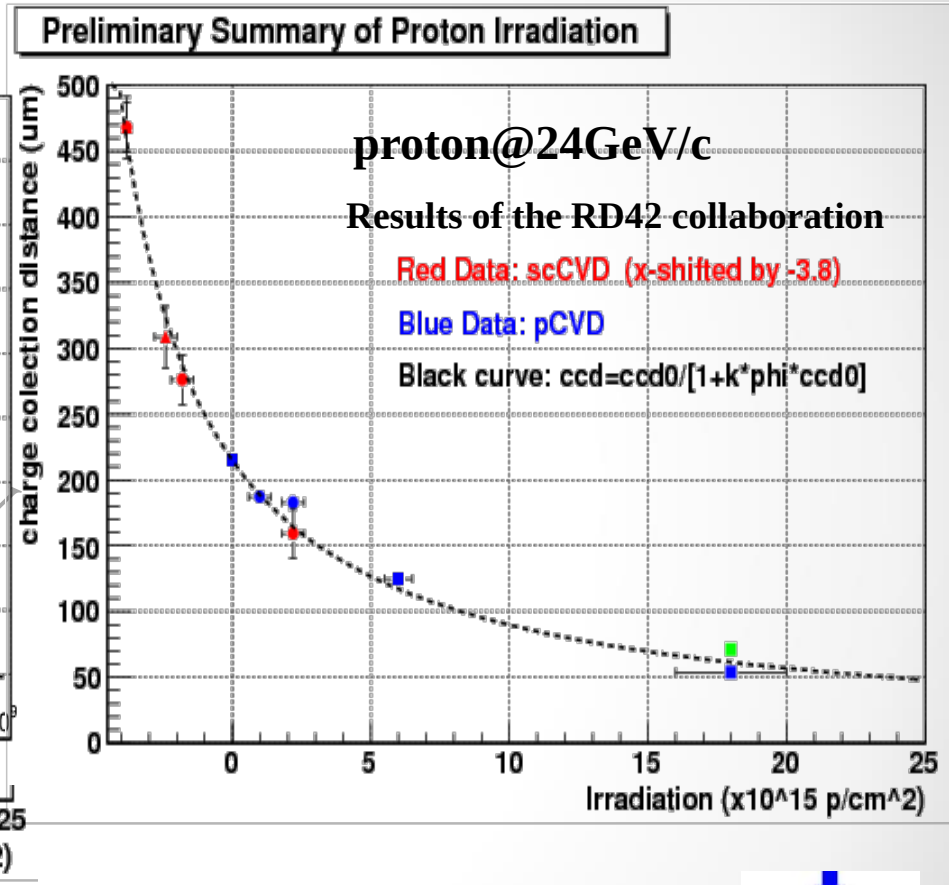


The same detector irradiated with Au ions and protons

→ **detailed comparison possible**

Radiation damage – systematic study for Au beam comparison to protons@4.5 MeV and proton@24GeV/c





Compare Au @ 1.25 AGeV to p @ 4.5 MeV and p @ 24 GeV
RD42 old fit was: ccd = ccd0 / (1 + k * phi * ccd0)

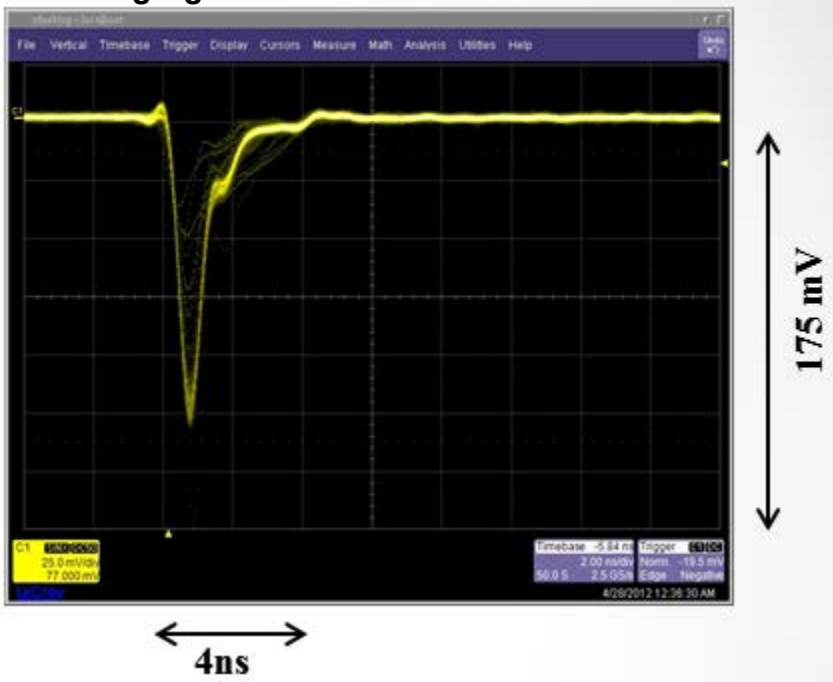
→ k parameter is used for comparison

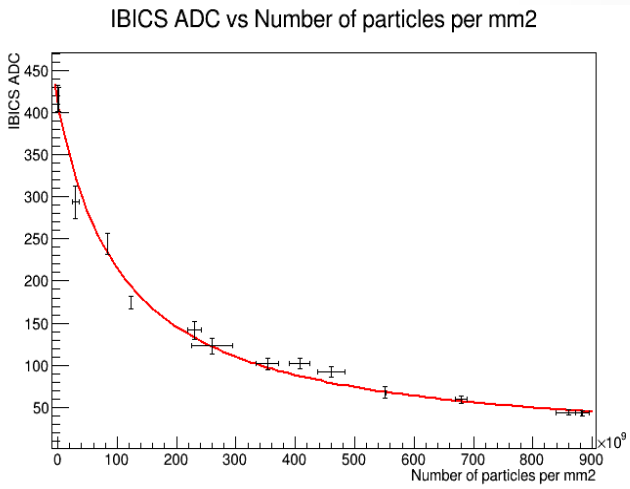
Radiation damage study for Au beam: outlook

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

- Leakage current below 10 nA
- Time resolution below 60 ps - **J.Pietraszko, et al., NIMA 763 (2014) 1–5**
- Ongoing comparison of Au@1.25 AGeV to p@4.5 MeV and p@24 GeV (RD42 data)

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: N. Skukan,
4. AIDA-2020 access program

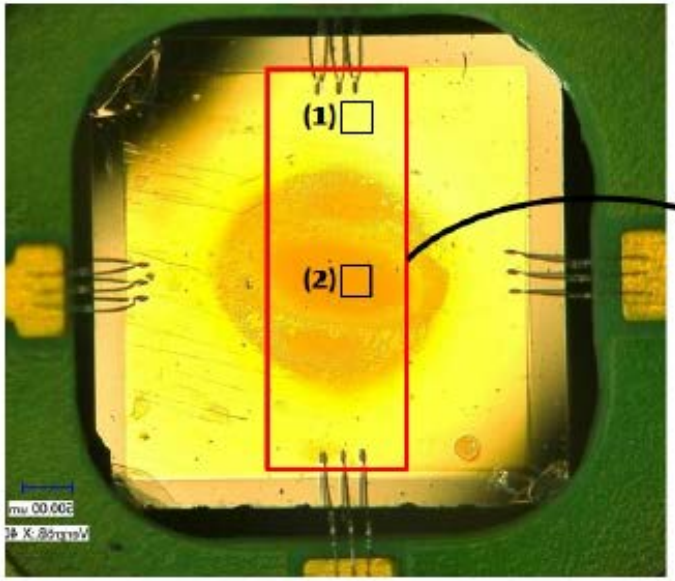
Thank you

Radiation damage – part 1 (EBIC from 2010)

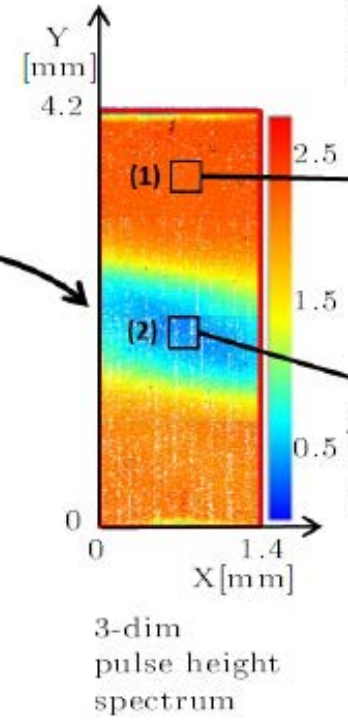
J.Pietraszko, et al., NIMA 763 (2014) 1–5

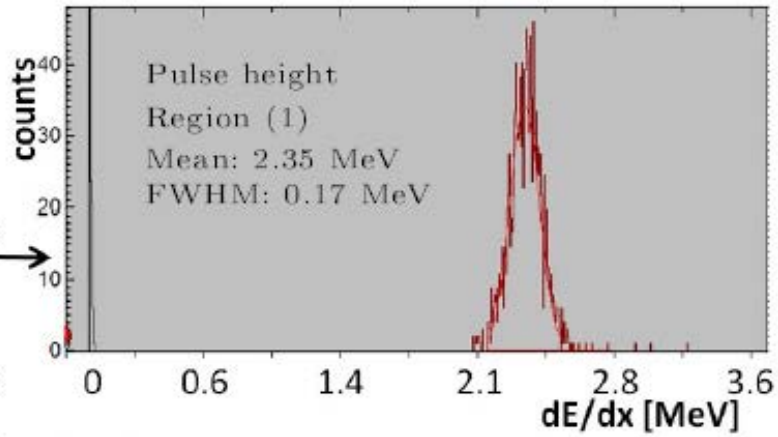
- ✓ Sample irradited at GSI with Au @ 1.23 A GeV (3 x 10^{11} ions)
- ✓ Pulse height scan with 4.5 MeV μ-beam of protons
- ✓ Ion Beam Induced Current (IBIC) method at the Laboratory for ion beam interactions at the Ruđer Boskovic Institute in Zagreb

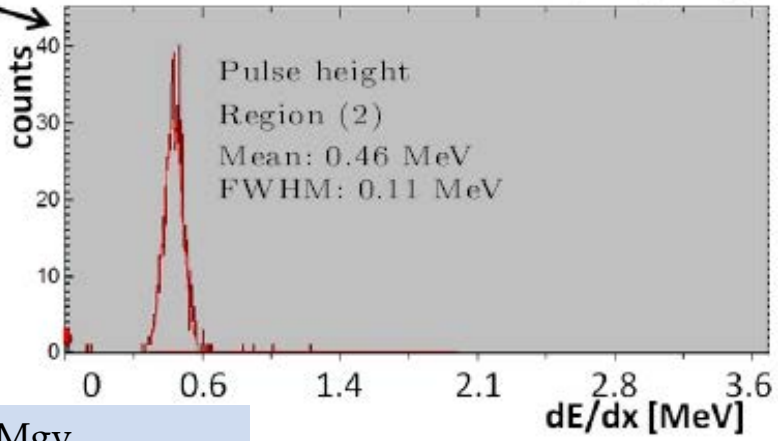
Sample irradiated at GSI with Au@1.23A GeV
3 x 10^{11} Au ions



IBIC scan Zagreb







→ pulse height reduced by a factor of 5.1 for dose of about 87 Mgy
→ measured for one dose only ! Systematic study needed !