Radiation monitoring and semiconductor detector upgrade actualities

Juozas Vaitkus

On behalf of VU team in RD39, RD50, AIDA, AIDA-2020 WP15

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My contribution task: to present our team activities to represent us and to search for collaboration

Outline:

- Semiconductor detector problems (with a bit of history)
- Our activities
- Our inventions and proposals

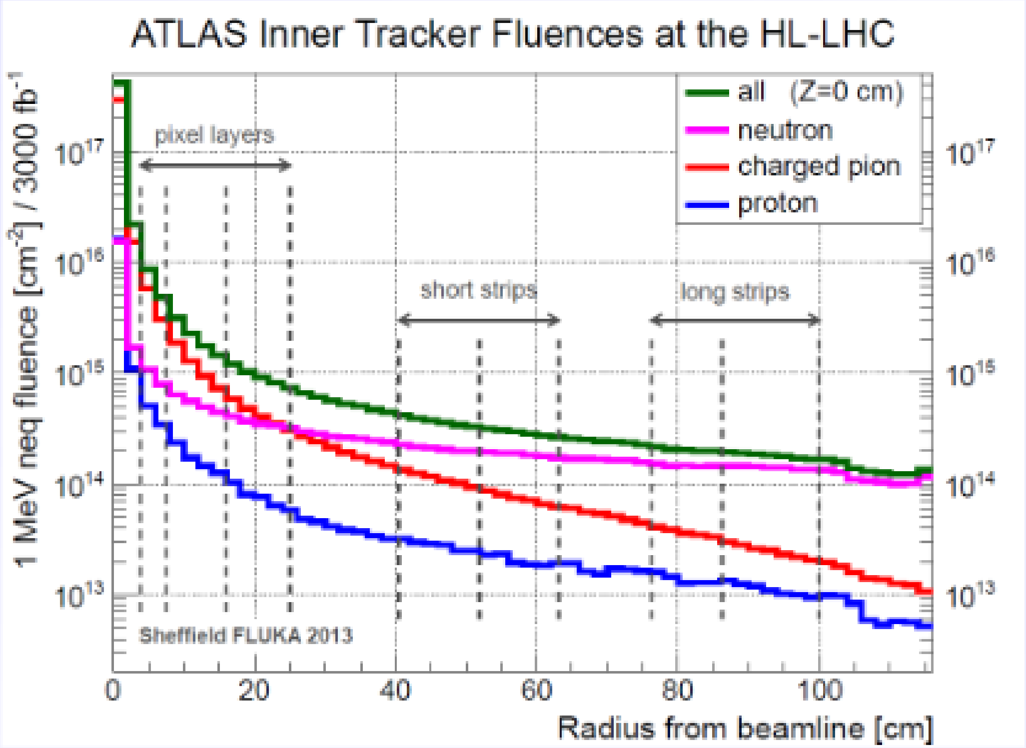
General facts about CERN requests and our team in CERN:

- HEP experiments request the **sensitive, fast, 50-100 μm size and radiation hard ionizing radiation** detectors.
  - 1994-1995 GaAs RD8, Diamond RD42 and Si RD48 were competing up to 1998, 2002 RD50 started.
    - We joined RD8 at 1995 as a part of Glasgow team, and the decision: "GaAs is not recommended for LHC, but it is excellent for X-rays imaging in medicine (CERN-RD-MEDIPIX started.)
    - **2002 we joined as GU team at start of RD50, but registered as VU**
- HEP experiments' technical service requests:
  - the detectors to control the proton beam trajectory that work at cryogenic temperature
    - **We were invited to join RD39 in 2003**
  - The devices for the radiation monitoring in the different places of LHC experiments;
    - **AIDA (2011-2015) and AIDA2020 WP15 (2015-2019) projects represent us in this activity.**

CERN (i.e., LHC future)

LHC upgrade *(and beyond…. HE-LHC, VHE-LHC)*

- **upgrade of the LHC to the High Luminosity LHC (HL-LHC) after LS3 (2022)**
- **expected integrated luminosity: 3000 fb^{-1}**



[I. Dawson, P. S. Miyagawa, Sheffield University, Atlas Upgrade radiation background simulations]

Silicon detectors will be exposed to hadron fluences equivalent to more than 10^{16} n/cm^2

➔ detectors used now at LHC cannot operate after such irradiation

RD50 mission: development of silicon sensors for HL-LHC

LHC schedule beyond LS1

LHC projected performance

Only EYETS (19 weeks) (no Linac4 connection during Run2)
LS2 starting in 2018 (July) 18 months + 3months BC (Beam Commissioning)
LS3 LHC: starting in 2023 => 30 months + 3 BC
injectors: in 2024 => 13 months + 3 BC

LHC schedule approved by CERN management and LHC experiments spokespersons and technical coordinators
Monday 2nd December 2013

13-14 TeV

Phase-1

Total $\mathcal{L}_{int}$(pp) before LS3:
300 – 500 fb^{-1}
$\mathcal{L}_{max}$(pp) ~ 2 10^{34} Hz/cm^2

Phase-2: HL-LHC

GOAL after LS3:
Total $\mathcal{L}_{int}$(pp) 3000 fb^{-1}
$\mathcal{L}_{level}$(pp) ~ 5 10^{34} Hz/cm^2

$\mathcal{L}$ (therefore <PU>) increase affects L1 trigger efficiency
→ TRIGGER UPGRADE

Needed: **HIGH GRANULARITY DETECTORS**
with rad-hard components

Most ambitions :CMS Forward callorimeter needs ~80 m^2 detectors radiation hard up to 10^{17} neutrons/cm^2

The RD50 Collaboration

RD50

- **RD50:** ***48 institutes and 270 members***

40 European and Asian institutes

Belarus (Minsk), Belgium (Louvain), Czech Republic (Prague (3x)), Finland (Helsinki, Lappeenranta), France (Paris), Germany (Dortmund, Erfurt, Freiburg, Hamburg (2x), Karlsruhe, Munich), Italy (Bari, Florence, Padova, Perugia, Pisa, Trento), Lithuania (Vilnius), Netherlands (NIKHEF), Poland (Krakow, Warsaw(2x)), Romania (Bucharest (2x)), Russia (Moscow, St.Petersburg), Slovenia (Ljubljana), Spain (Barcelona(2x), Santander, Valencia), Switzerland (CERN, PSI), Ukraine (Kiev), United Kingdom (Glasgow, Liverpool)

6 North-American institutes

Canada (Montreal), USA (BNL, Fermilab, New Mexico, Santa Cruz, Syracuse)

1 Middle East institute

Israel (Tel Aviv)

1 Asian institute

India (Delhi)

Detailed member list: http://cern.ch/rd50

RD50 - Radiation hard semiconductor devices for very high luminosity colliders

RD50

RD50 Organizational Structure

CERN

Co-Spokespersons

Gianluigi Casse and ***Michael Moll***

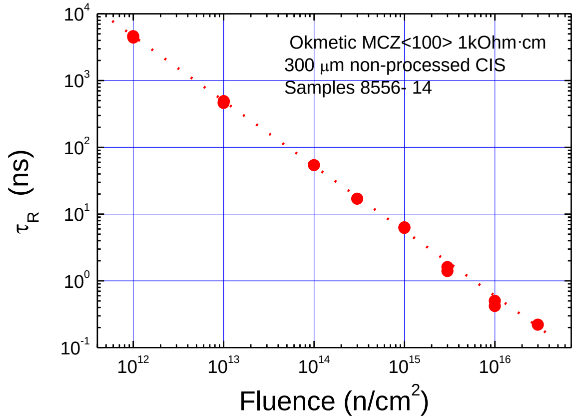
(Liverpool University) (CERN PH-DT)

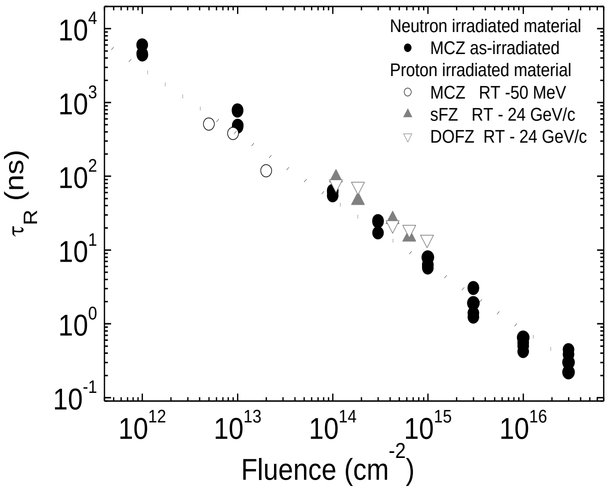
Collaboration Board Chair & Deputy: G.Kramberger (Ljubljana) & J.Vaitkus (Vilnius), Conference committee: U.Parzefall (Freiburg)

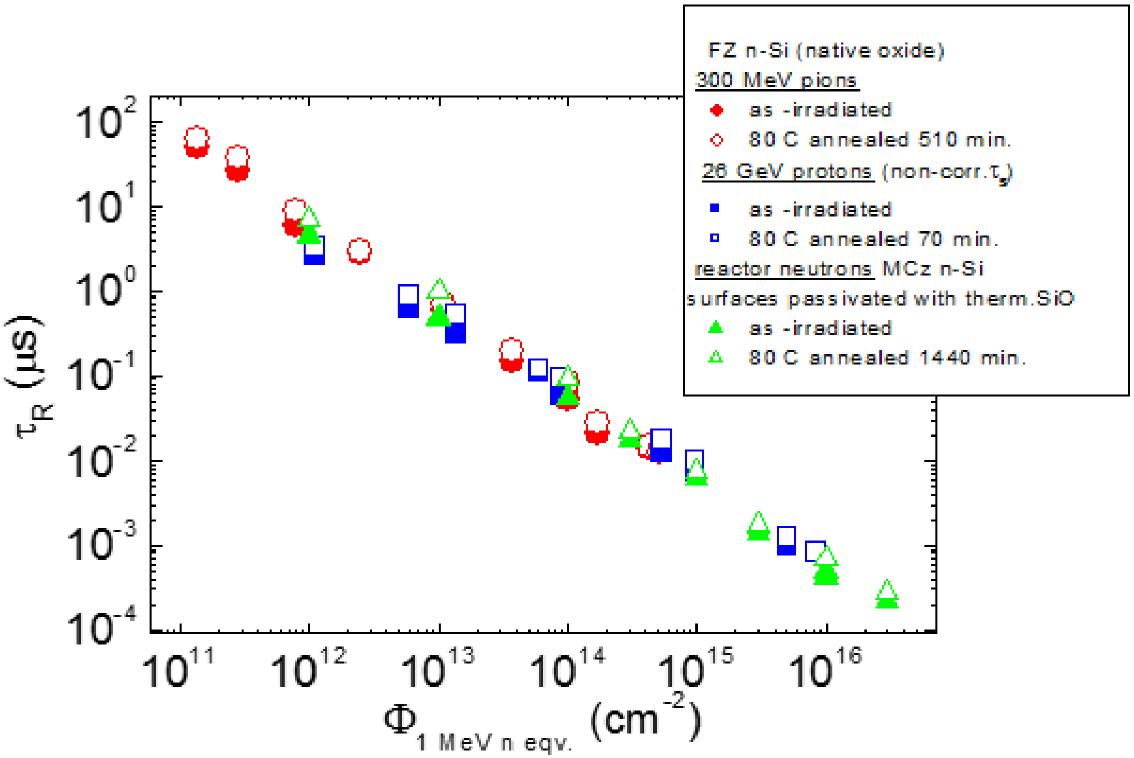
CERN contact: M.Moll (PH-DT), Secretary: V.Wedlake (PH-DT), Budget holder & GLIMOS: M.Glaser (PH-DT)

Defect / Material Characterization *Ioana Pintilie* (NIMP Bucharest)	Detector Characterization *Eckhart Fretwurst* (Hamburg University)	New Structures *Giulio Pellegrini* (CNM Barcelona)	Full Detector Systems *Gregor Kramberger* (Ljubljana University)
• Characterization of microscopic properties of standard-, defect engineered and new materials pre- and post-irradiation • DLTS, TSC, …. • SIMS, SR, … • NIEL (calculations) • WODEAN: Workshop on Defect Analysis in Silicon Detectors (G.Lindstroem & M.Bruzzi)	• Characterization of test structures (IV, CV, CCE, TCT,.) • Development and testing of defect engineered silicon devices • EPI, MCZ and other materials • NIEL (experimental) • Device modeling • Operational conditions • Common irradiations • Wafer procurement (M.Moll) • Device Simulations (V.Eremin)	• 3D detectors • Thin detectors • Cost effective solutions • Other new structures • Detectors with internal gain (avalanche detectors) • Slim Edges • 3D (R.Bates) • LGAD (V.Greco) • Slim Edges (Vitaliy Fadeyev)	• LHC-like tests • Links to HEP • Links electronics R&D • Low rho strips • Sensor readout (Alibava) • Comparison: - pad-mini-full detectors - different producers • Radiation Damage in HEP detectors • Test beams (M.Bomen & G.Casse)

Radiation monitoring is based on the dependence of free carrier lifetime on the fluence.
This dependence was observed in Si from different suppliers and differently grown Si



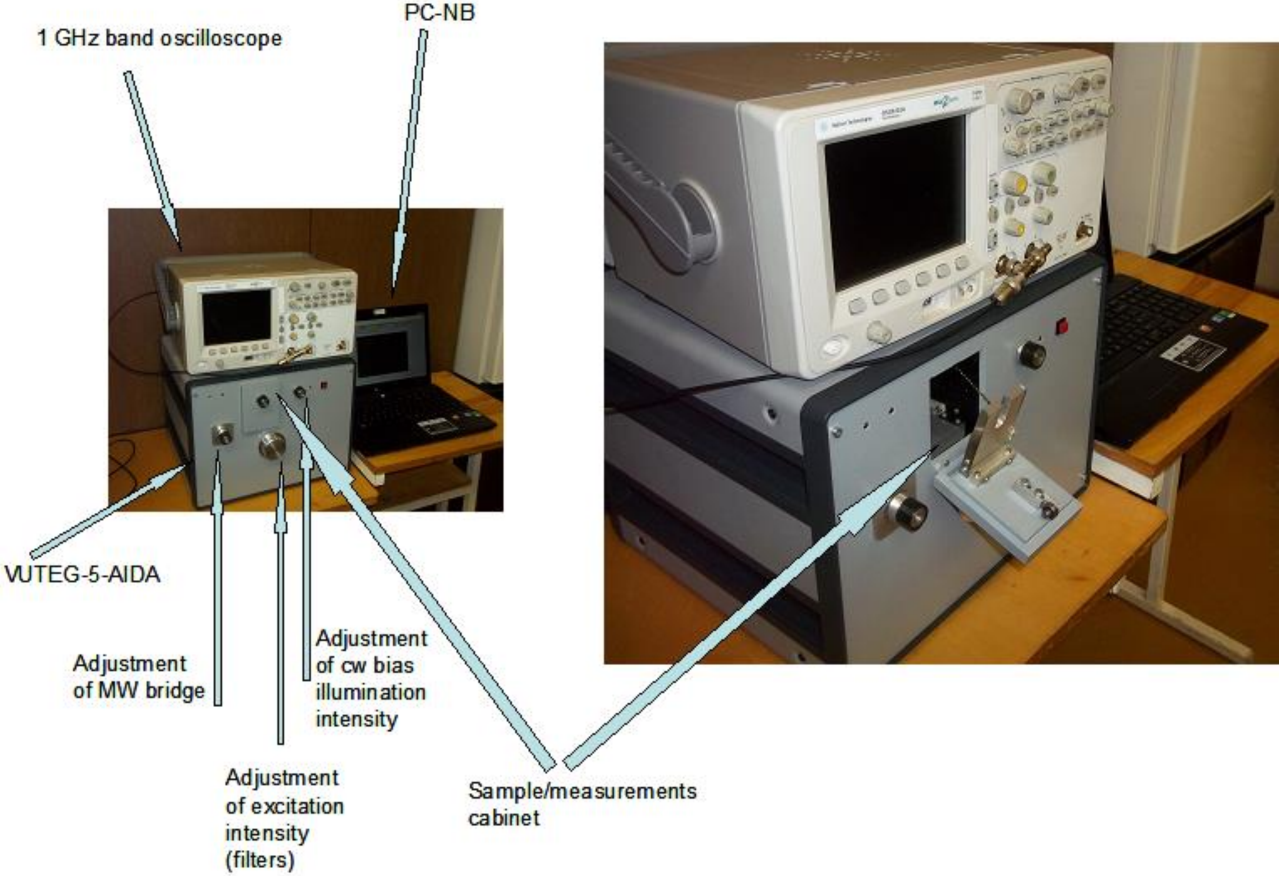




AIDA task: “Design and fabrication of the device for the radiation monitoring (after first test at CERN it was added: and proton beam profiling”

User guide
for manipulations
with dosimeter VUTEG-5-AIDA

2014 Vilnius

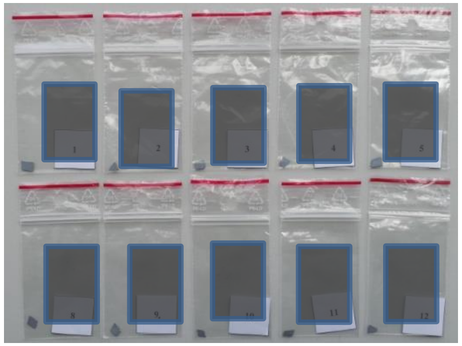


General view of the instrument VUTEG-5-AIDA with sample compartment C1 devoted to rapid fluence monitoring of Si samples of dimensions 10×10 mm^2 placed in plastic bags.

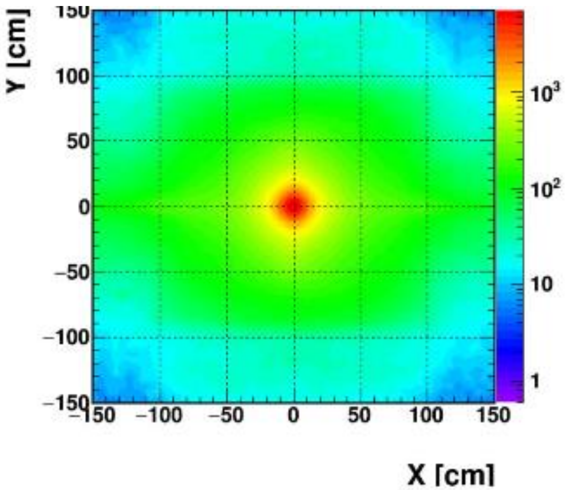
The device for integrated fluence monitoring

General view of the dosimeter with two-type sample chambers

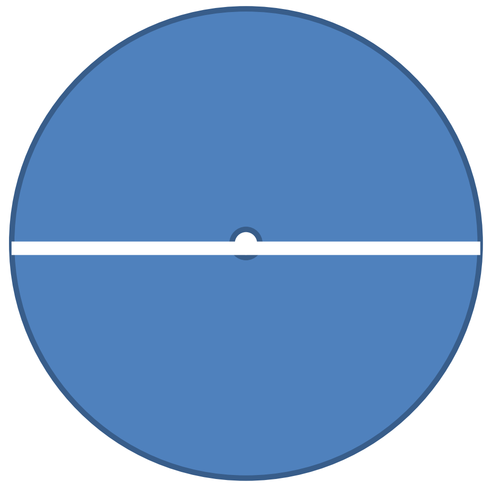
- The device for the contactless fluence monitoring delivered to CERN, the instruction book given, the seminar for the staff members organized, Vilnius team member is ready to come if necessary.
- The calibration procedure has started, and to proton and neutron irradiation the irradiation by pions was added.



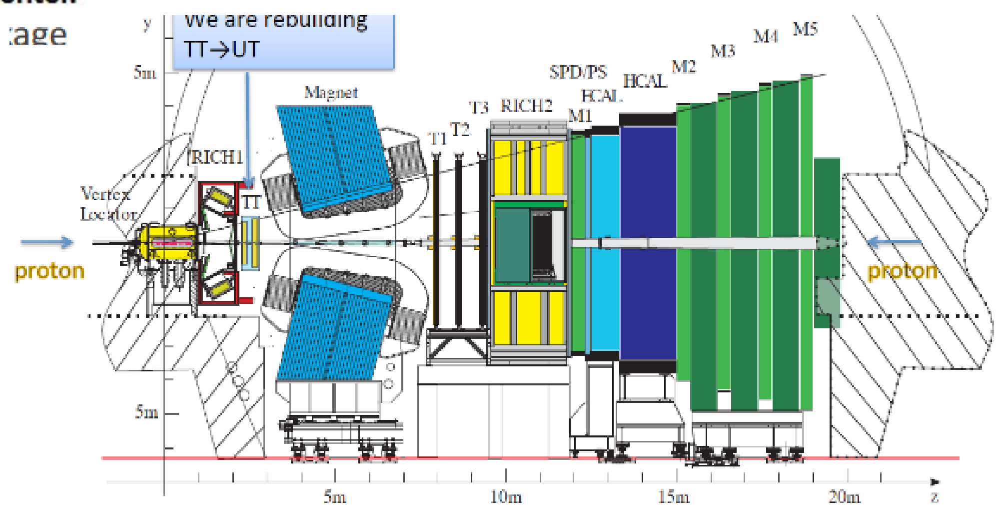
For LHC(b) purpose (our vision):



Non-uniform irradiation profile depending on distance from beam center.



1. Two Si wafer pieces (Fig.) put around the proton beam.
2. Irradiate. Remove.
3. Scan the lifetime distribution across both pieces.
4. Transform the lifetime map to the integrated fluence image.

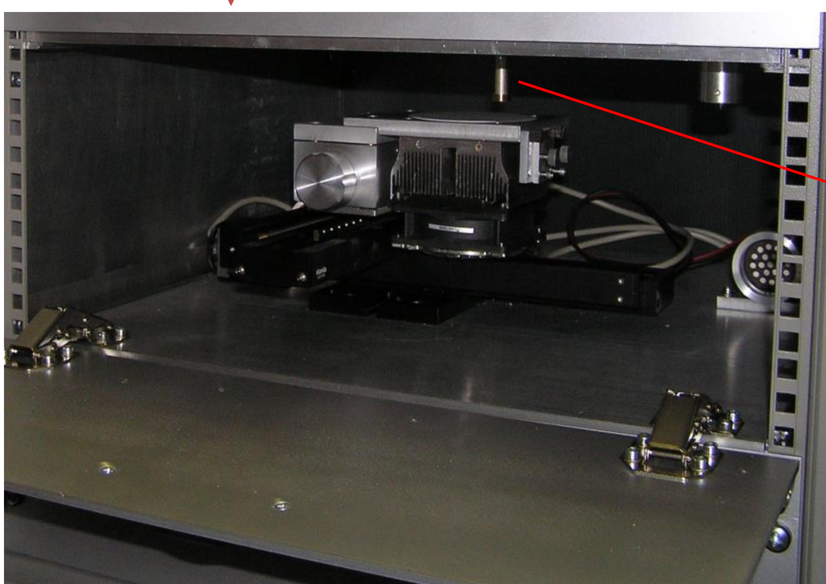


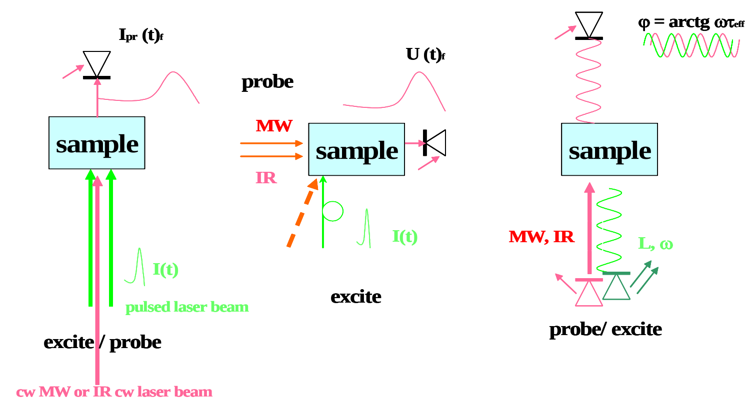
The fluence range 1e12-more that 1e16 hadrons/cm2.

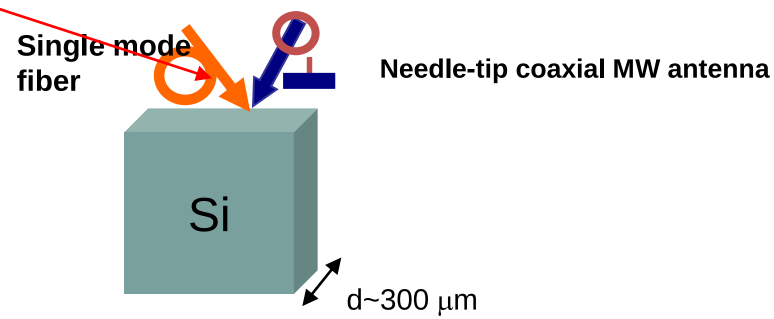
(If the irradiation will be more than 3e16 cm-2, then this area will be necessary to scan by other method, purely optical)

This device for 2D integrated fluence imaging up to 3“.

It can scan sample in different regimes: transmission, reflectance and probe







Our duties and main results:

- Investigation of radiation hardness and parameters of different semiconductors related to LHC experiments (120 scientific papers in ISI data base without the collaboration papers)
- We are responsible (in RD50 WODEAN project) for the lifetime and PC spectra analyze for all types of material.
- We discovered the linear dependence of free carrier lifetime on the irradiation fluence.
- We proved GaN is the extreme radiation hard material for the detectors (and it works at room T)
- We find out the dependence of free carrier mobility on the hadron fluence in Si, that is **important for the irradiated device properties prediction**.
- Our (VU) device for new type of radiation monitoring is implemented in **the Irradiation Facility at CERN**

Acknowledgements: This work covers the long term investigations in a frame of CERN RD50 & RD39 collaborations and during AIDA & AIDA-2020 projects.

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THANK YOU FOR YOUR ATTENTION!