

KIT TA Status

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INSTITUT FÜR EXPERIMENTELLE KERNPHYSIK



The infrastructure

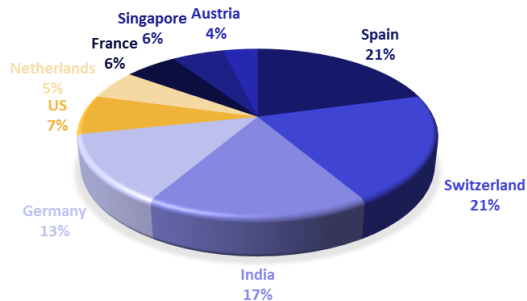
- Description on http://www.ekp.kit.edu/english/irradiation_center.php
- Cyclotron parameters:
 - Proton energy ~23 MeV (25.3MeV at extraction)
 - Proton current ~2.0 μ A (100nA - 20 μ A)
 - Max. object width 44cm
 - Max. object height 17cm
 - N₂-cooling temperature -30°C
- On average 4-5h slot every second week
 - up to 6 weeks turn-around time
- E.g., irradiating one sensor of 20mm x 20mm to $5 \times 10^{15} \text{ n}_{1\text{MeV}}/\text{cm}^2$ takes about 90 minutes.
- Min. quantity of access to be provided: 100h beam time
- Samples can be shipped to us, we irradiated and send them back
 - No visitors expected!
- Initial contact and infos: irradiations@lists.kit.edu

Projects so far

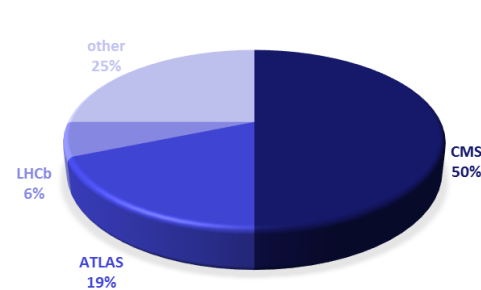
TA Project Acronym	Project Title	Communities involved (CMS, ATLAS, Neutrino...)	Continuation from previous reporting periods		Access Units
			Project completed (yes/no)	Date - when project completed	
AIDA-2020-KIT-2015-01	LHCb VELO upgrade	LHCb	yes	19 August 2015	2.13
AIDA-2020-KIT-2015-02	Irradiation of a LPNHE/FBK active edge pixel module	ATLAS	yes	11 August 2015	0.42
AIDA-2020-KIT-2015-03	Radiation-hard Si sensors development at India for the CMS Experiment	CMS	yes	16 November 2015	2.62
AIDA-2020-KIT-2015-04	Irradiation study of the CMS upgrade pixel detector readout chip	CMS	yes	12 May 2016	5.99
AIDA-2020-KIT-2015-05	Embedded Pitch Adapters		yes	10 December 2015	2.92
AIDA-2020-KIT-2016-01	High voltage sensor contacts in high radiation environment		yes	08 September 2016	1.22
AIDA-2020-KIT-2016-02	CMS tracker upgrade: front-side biasing with IFX sensors	CMS	yes	01 September 2016	5.43
AIDA-2020-KIT-2016-03	Finding a HV insulation for the future ATLAS strip tracker	ATLAS	yes	01 March 2017	1.67
AIDA-2020-KIT-2016-04	Radiation test for domain wall device		yes	08 September 2016	0.17
AIDA-2020-KIT-2016-05	Proton irradiation of a new generation of 3D sensors developed for the HL-LHC	ATLAS	yes	22 September 2016	2.62
AIDA-2020-KIT-2016-06	LHCb VELO upgrade	LHCb	yes	18 November 2016	1.92
AIDA-2020-KIT-2016-07	Investigation of radiation damage in CMS FPix sensors	CMS	yes	29 September 2016	4.08
AIDA-2020-KIT-2016-08	Study of Radiation hardness of small pixel Si sensors for CMS phase 2	CMS	no		
AIDA-2020-KIT-2016-09	Radiation-hard Si sensors development at India for the CMS Experiment	CMS	no		0.08
AIDA-2020-KIT-2016-10	TID dependence study of a readback mechanism calibration of the CMS pixel readout chip	CMS	no		1.73
AIDA-2020-KIT-2017-01	Proton irradiation of AMS H35Demo chips	CMS	no		0.33

Total: 16 projects, 53 users, 33.33h

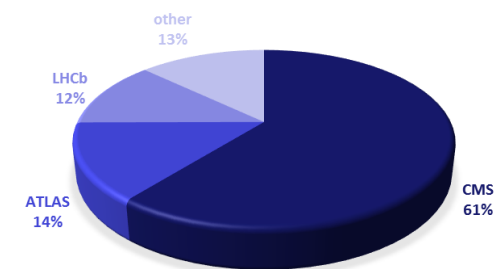
USERS BY COUNTRY



PROJECTS BY COMMUNITY



BEAM TIME BY COMMUNITY



Publicity

- Dedicated web page
- Link to AIDA TA on RD50 web page
- Listed in <http://irradiation-facilities.web.cern.ch/publicDB.php>
- TA video online
- Presentation at the 4th Beam Telescopes and Test Beams Workshop 2016 (3.2.2016, Orsay) with 60 participants
- Personal reminders to previous customers

KIT
Karlsruhe Institute of Technology

Institute of Experimental Nuclear Physics (IEKP)

Irradiation Center Karlsruhe

Introduction

The Irradiation Centre in Karlsruhe was initiated in 2001 and used for irradiation studies of silicon sensors for the current [CMS Tracker R](#) at the [Large Hadron Collider R](#) at [CERN R](#). Now, the experiments for the LHC are completed, but the next challenge is waiting: the [HL-LHC R](#). The collider will be upgraded to ten times higher peak luminosity and therefore higher radiation damage to the detectors. This requires further R&D to find the limits of silicon sensor technology and electronic devices.

For radiation hardness studies in the HEP community we offer to perform irradiations with [25 MeV protons](#) from a Compact Cyclotron operated by [ZAG Zyklotron AG R](#), a private company located on the [Campus North R](#) of the [KIT R](#). We arrange access, prepare and perform the irradiation and help with all sort of questions about radiation damage.

Please, foresee **6 weeks** time between sample arrival at KIT and return shipment!

Within the European project [AIDA2020 R](#) irradiations can be funded via [Transnational Access R](#) for eligible groups.

In addition, we provide an [X-ray setup](#) with a dose rate of up to 40 kGy/h to test the effects of pure ionising radiation.

Contact

Facility coordinators: Dr. A. Dierlamm, Prof. W. de Boer
Technical support: F. Bögelspacher

Shipping address:
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Karlsruhe Institute of Technology
Institut für Experimentelle Kernphysik
Hermann-von-Helmholtz-Platz 1, Building 401
D-76344 Eggenstein-Leopoldshafen
GERMANY

For access requests or further questions send an email to: irradiation@lists.kit.edu

AIDA 2020

Facilities Database

CERN Accelerating science

AIDA 2020

HOME AIDA-2020 TA DATABASE USER GUIDE CONTACT

To search by Country, Source Type, or Radiation Field select your filter in the dropdown menu.
If you would like to add a new facility, please first log in and then click on "Add Facility".
You can only modify the facilities that you are responsible for.
For further details please check our [User Guide](#).

Search by Country: Germany | Search by Source Type: Compact cyclotron | Search by Radiation Field Type: All

Show Data | Log in to Edit Data

Details	Institute Name	Country	Facility Name	Source Type	Radiation Field Type	Funding Details
	Institut für Experimentelle Kernphysik	Germany	KAZ	Compact cyclotron	Proton	AIDA-2020

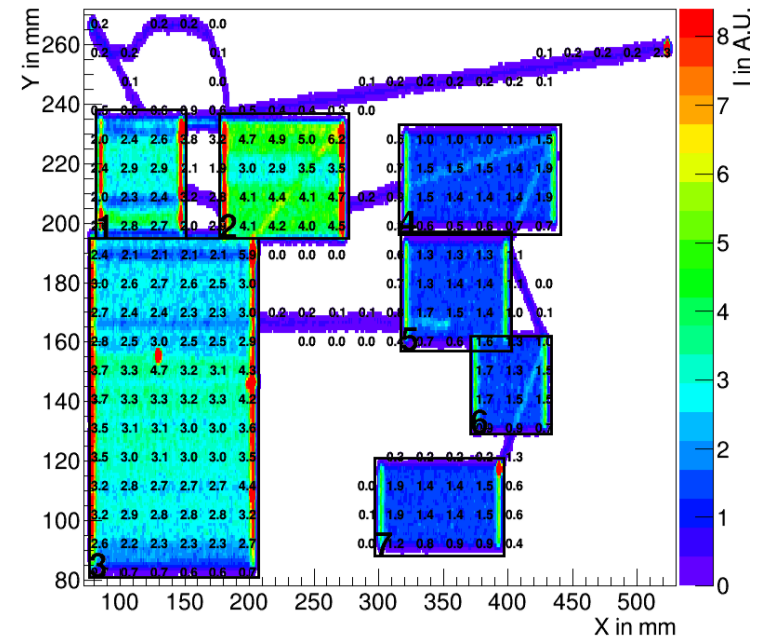
ADDRESS
CERN
CH-1211 Geneva 23
Switzerland

CONTACTS
Email: Irradiation.Facilities@cern.ch

LINKS
CERN Website
CERN Working Groups for future Irradiation
Facilities 2007-2010 archive/CERN intranet only

Upgraded monitoring

- Rare SEU in controller memory generate random changes in scanning pattern
- Detailed logging of scanning available now
 - alarm issued when deviations from expectation arise
- Working on online monitoring of beam current for fast feedback



TWO EXAMPLES OF PROJECTS

Irradiation study of the CMS upgrade pixel detector readout chip

- AIDA-2020-KIT-2015-04
- PROC600 designed for 600MHz/cm²
- To be confirmed after irradiation
- Publication: 2017 JINST 12 C01078

- 23MeV protons
→ 300kGy / 10¹⁴p/cm² in SiO₂

- Rate capability maintained after 1.2MGy

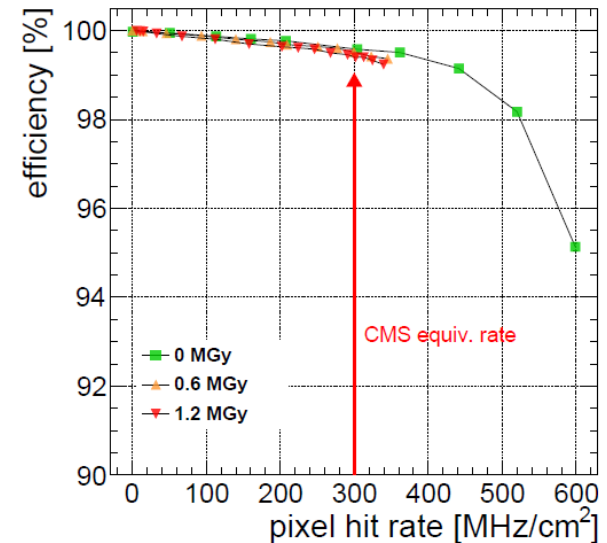
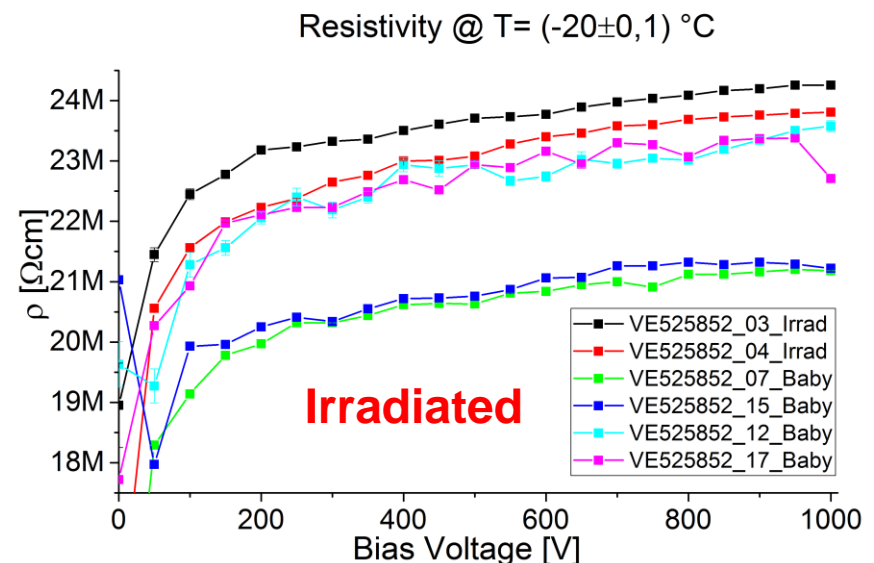
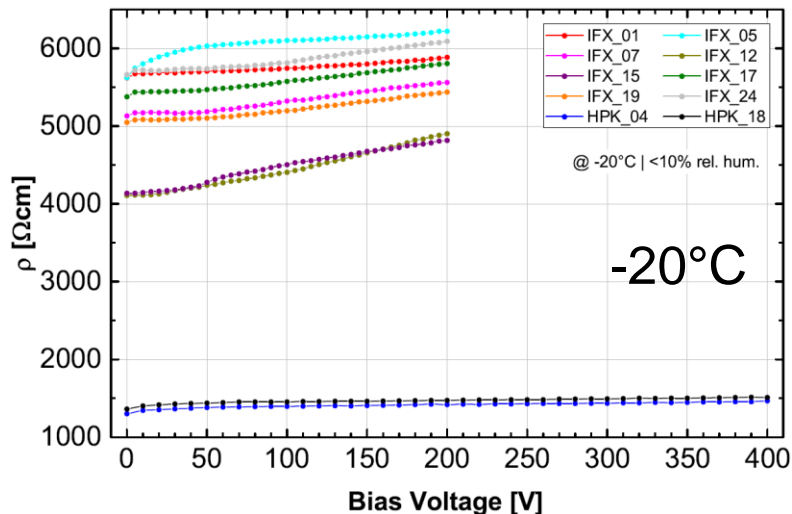


Figure 5. Efficiency of PROC600 before and after irradiation.

CMS tracker upgrade: front-side biasing with IFX sensor

- AIDA-2020-KIT-2016-02
- Evaluation of front-side biasing for strip sensors at HL-LHC, which would very much simplify module assembly
- Edge resistivity increases dramatically for high fluence ($>6 \times 10^{14} n_{eq}/cm^2$)
 → not useful for HL-LHC due to large voltage drop and power dissipation
- Publication in preparation

Sample	Fluence (neq/cm ²)	Annealing
VE525852_03_Irrad	6.07E14	10 min @ 60°C
VE525852_04_Irrad	6.07E14	10 min @ 60°C
VE525852_07_Baby	6.82E14	10 min @ 60°C
VE525852_12_Baby	2.10E15	10 min @ 60°C
VE525852_15_Baby	6.82E14	10 min @ 60°C
VE525852_17_Baby	2.10E15	10 min @ 60°C
VE525852_19_Baby	6.82E14	0 min @ start



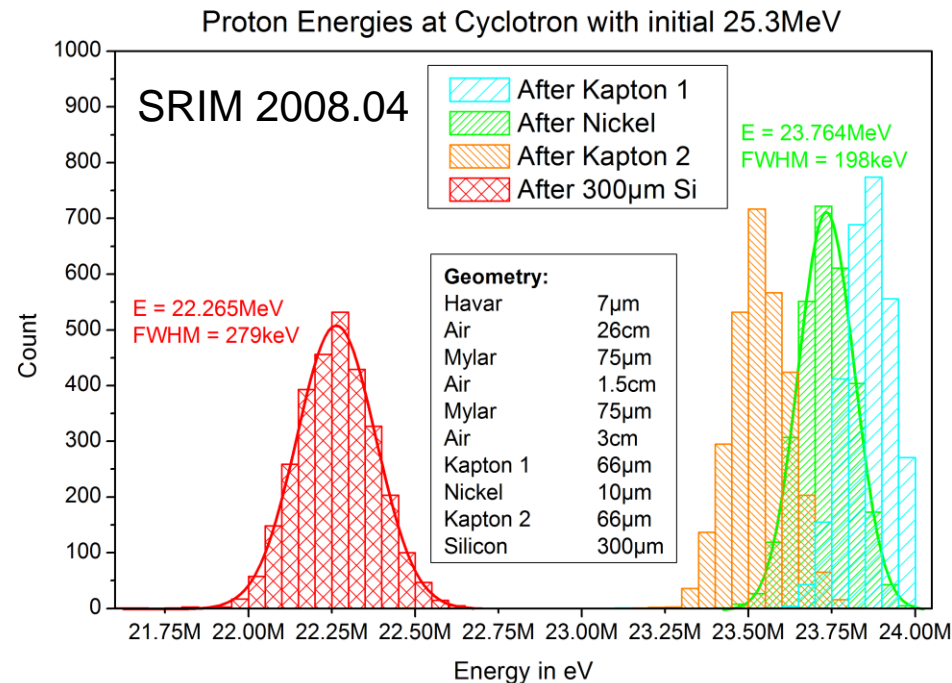
Conclusion

- Irradiations running smoothly
- Upgrading control system
- Slightly behind AIDA schedule
- Very tedious to find/get publications from users

SPARES

Energy at Target

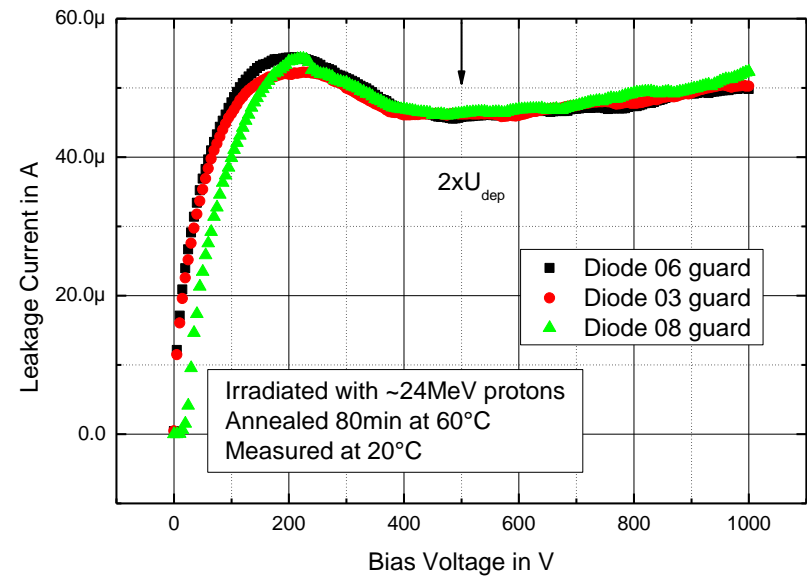
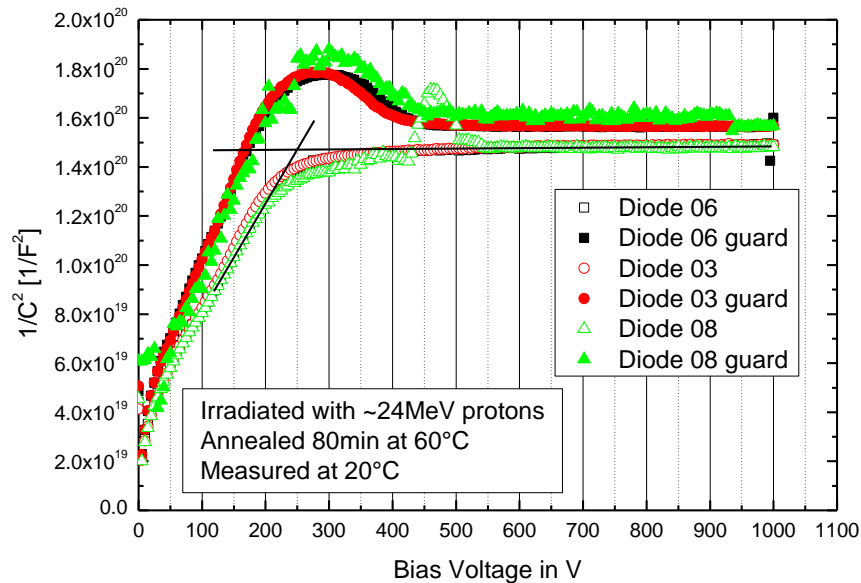
- 25.3MeV is the energy in the beam line
- Protons have to pass several materials until they hit the samples
- SRIM gives us a proton energy entering the samples of about 23.8MeV and on average in the sample: **22.9MeV**
- Samples covered by Nickel foils see lower energy $\sim 22.8\text{MeV}$



Calibration with Diodes

- 3 ELMA diodes from HH
 - Diode 03:
 $U_{\text{dep}} = 44\text{V}$, $I_{\text{dep}} = 0.2\text{nA}$, $I(2*U_{\text{dep}}) = 5\text{nA}$, $V = 0.25\text{cm}^2 \times 374\mu\text{m} = 9.36\text{e-}3\text{cm}^3$
 - Diode 06:
 $U_{\text{dep}} = 46\text{V}$, $I_{\text{dep}} = 2\text{nA}$, $I(2*U_{\text{dep}}) = 5\text{nA}$, $V = 0.25\text{cm}^2 \times 375\mu\text{m} = 9.37\text{e-}3\text{cm}^3$
 - Diode 08:
 $U_{\text{dep}} = 45\text{V}$, $I_{\text{dep}} = 0.2\text{nA}$, $I(2*U_{\text{dep}}) = 0.4\text{nA}$, $V = 0.25\text{cm}^2 \times 374\mu\text{m} = 9.36\text{e-}3\text{cm}^3$
- Irradiation with $I_{\text{beam}} = 1.04\mu\text{A}$, $v_x = 115\text{ mm/s}$, $n_{\text{scans}} = 5$
 - **$F_{\text{est}} = (0.56 \pm 0.06)\text{e}14\text{ p/cm}^2$**
- Ni-foils:
 - **$F_{\text{Ni}} = (0.60 \pm 0.07)\text{e}14\text{ p/cm}^2$**

Calibration with Diodes



- Specific leakage currents after irradiation:
 - Diode 03: $I(2xU_{dep}) = 46.2 \mu A$, $\Delta I/V = 4.925e-3 A/cm^3$
 - Diode 06: $I(2xU_{dep}) = 45.8 \mu A$, $\Delta I/V = 4.888e-3 A/cm^3$
 - Diode 08: $I(2xU_{dep}) = 46.3 \mu A$, $\Delta I/V = 4.947e-3 A/cm^3$
- Including a $1^\circ C$ error for temperature measurement we get $\Delta I/V = (4.9 \pm 0.5)e-3 A/cm^3$
- And finally with $\alpha = 3.99 \pm 0.3e-17 A/cm^2$ at $20^\circ C$ after annealing for 80min at $60^\circ C$:

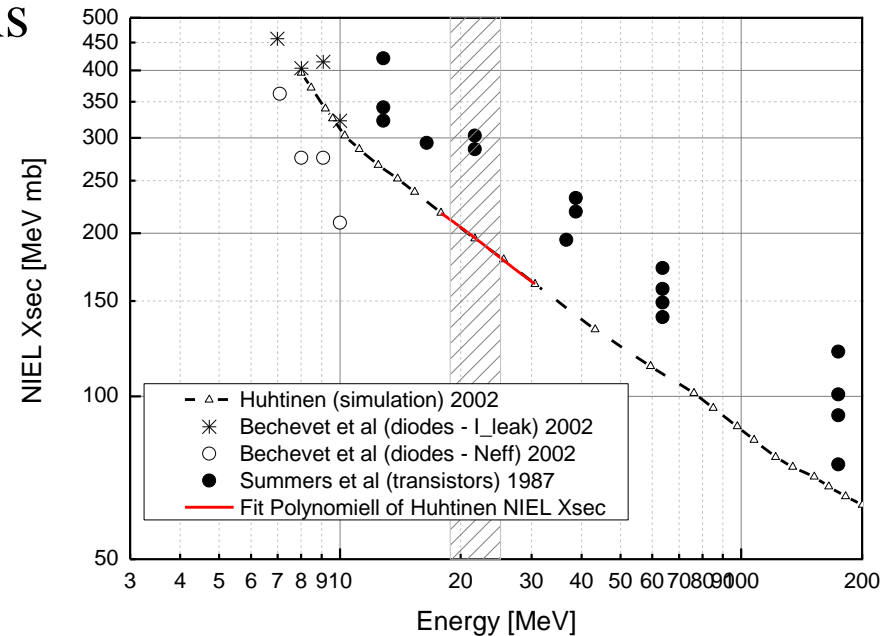
$$F_{diode} = (4.9 \pm 0.5)e-3 A/cm^3 / \alpha = (1.23 \pm 0.22)e14 n_{eq}/cm^2$$

Hardness Factor κ

- The hardness factor could be derived by

$$\kappa = F_{\text{diode}}/F_{\text{Ni}} = \mathbf{2.05 \pm 0.61}$$

- Previous assumption was **1.85** for **26MeV** protons
- Hardness factor was derived from simulated NIEL data by Huhtinen¹
- Assuming about 22.9 MeV protons on average in the sample, we get **$\kappa = 2.00 \pm ??$**
- Alternative measurements of NIEL show quite a spread...



¹ M. Huhtinen, "Simulation of non-ionising energy loss and defect formation in silicon", NIM A 491 (2002) 194-215

Considering the Errors

- With the used value of 1.85 one still gets an agreement of the equivalent fluence from the different methods considering the errors !
- Considering the nice agreement of measured hardness factor and derived hardness factor from NIEL simulation one could claim the hardness factor for our protons to be **more like 2.0** (+10% to prev. value).
- In general, the stated fluence is **not better than 20% !**

