KIT TA Status

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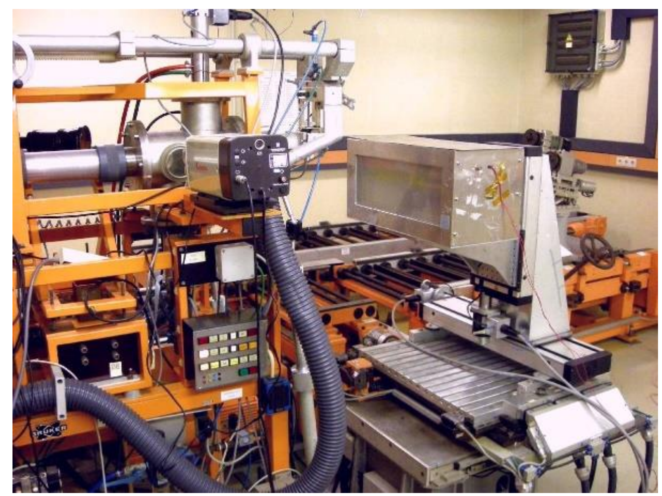
INSTITUT FÜR EXPERIMENTELLE KERNPHYSIK



The infrastructure

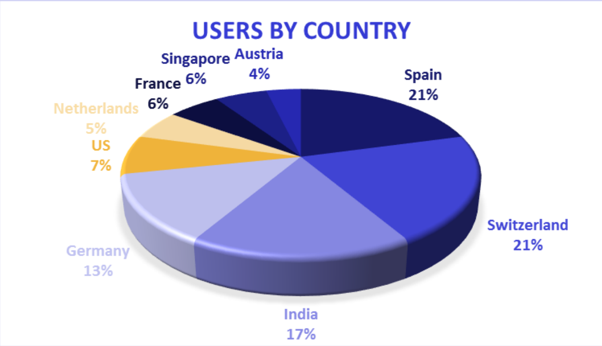
- Description on http://www.ekp.kit.edu/english/irradiation_center.php
- Cyclotron parameters:
  - Proton energy ~23 MeV (25.3MeV at extraction)
  - Proton current ~2.0µA (100nA - 20µA)
  - Max. object width 44cm
  - Max. object height 17cm
  - N_2-cooling temperature -30°C
- On average 4-5h slot every second week
  - up to 6 weeks turn-around time
- E.g., irradiating one sensor of 20mm x 20mm to $5x10^{15}$ n_{1MeV}/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!

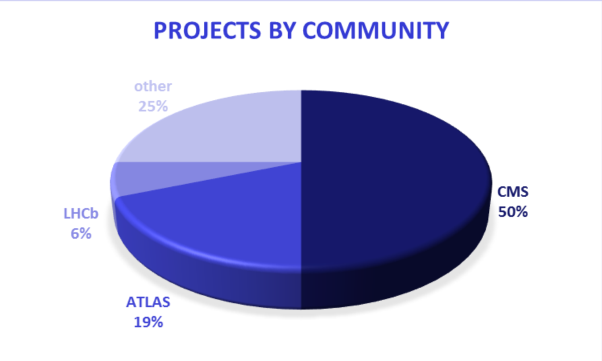
- Initial contact and infos: irradiations@lists.kit.edu

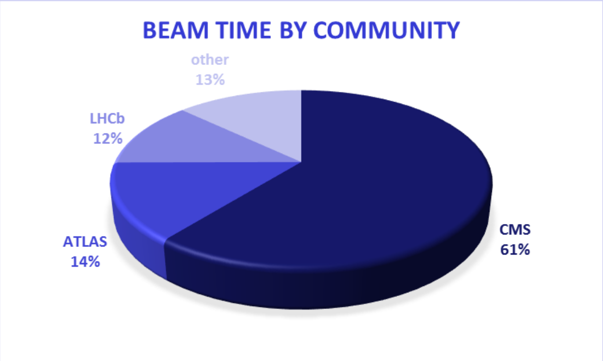
Projects so far

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

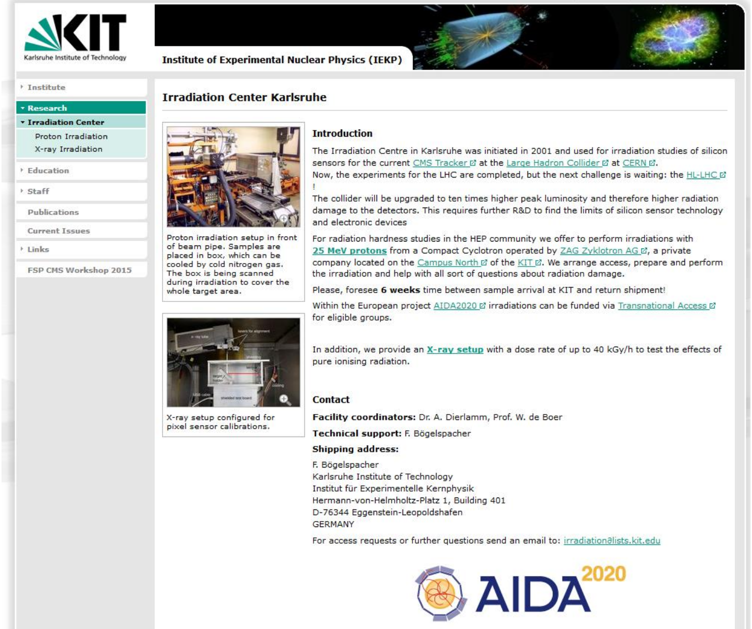


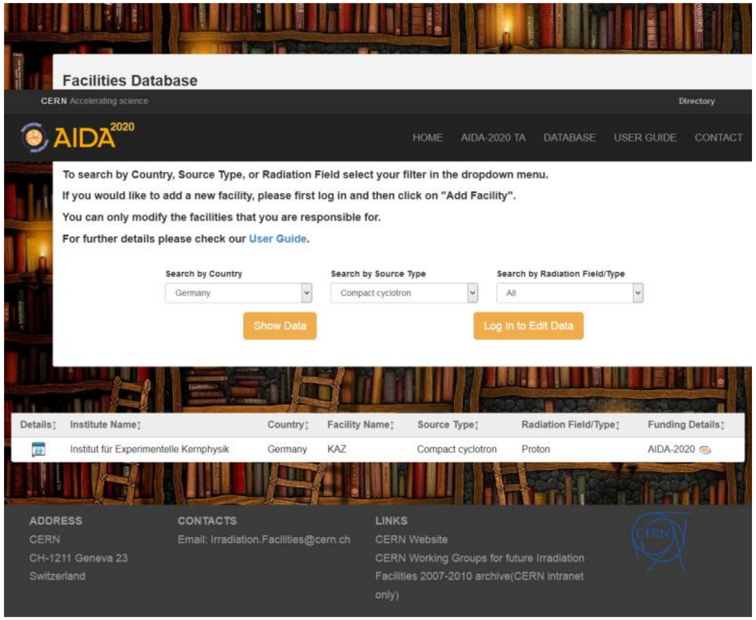




Publicity

- 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





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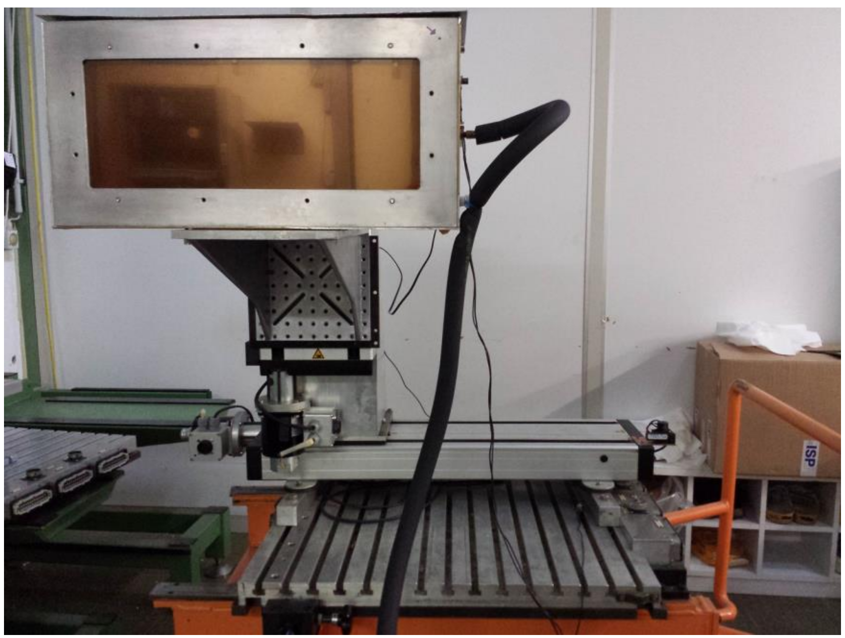
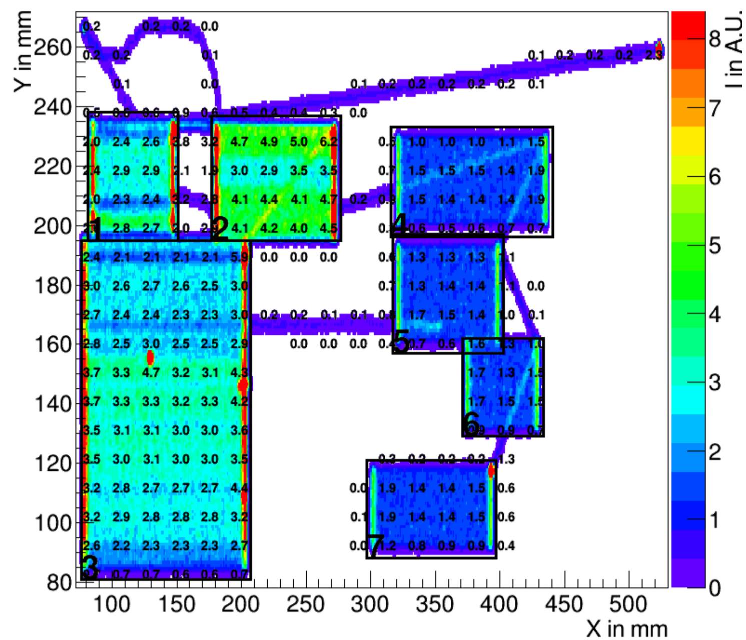
Upgraded monitoring

- 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





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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 / 10^{14}p/cm² in SiO_2

- Rate capability maintained after 1.2MGy

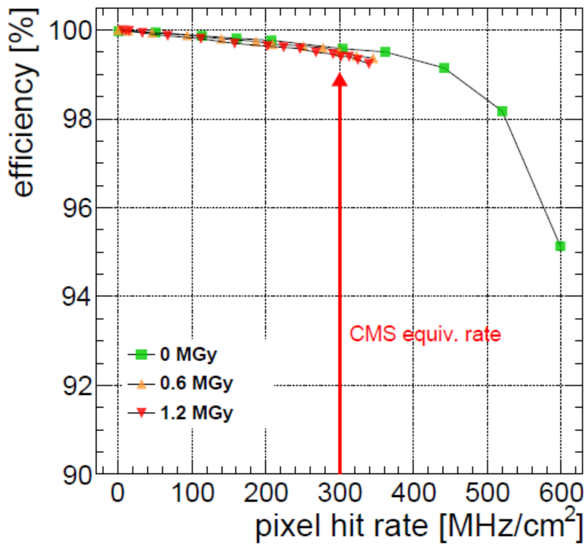

Figure 5. Efficiency of PROC600 before and after irradiation.

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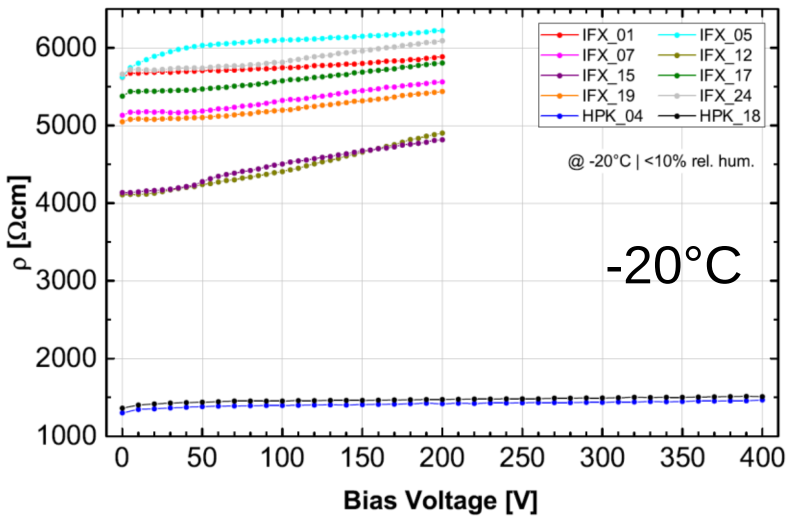
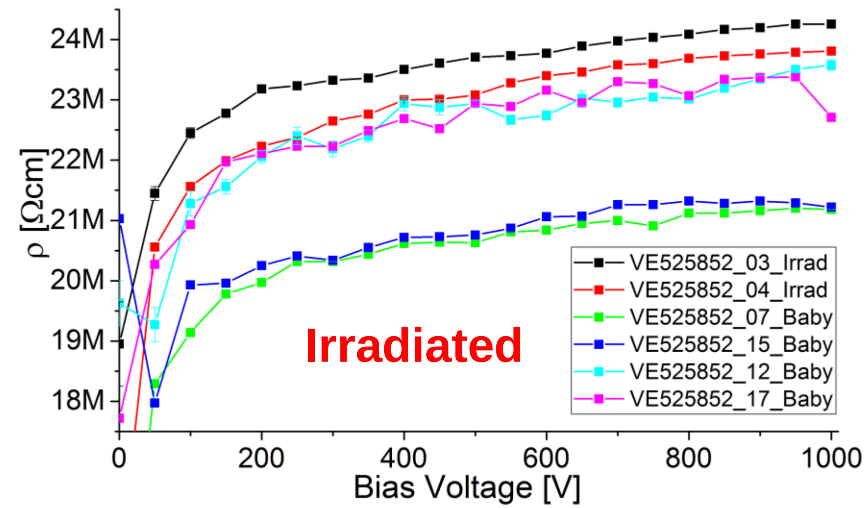
CMS tracker upgrade: front-side biasing with IFX sensor

- 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 (>6x$10^{14}n_{eq}/cm^2$)
  → not useful for HL-LHC due to large voltage drop and power dissipation
- Publication in preparation

Sample	Fluence (neq/cm2)	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



Resistivity @ T= (-20±0,1) °C



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Conclusion

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

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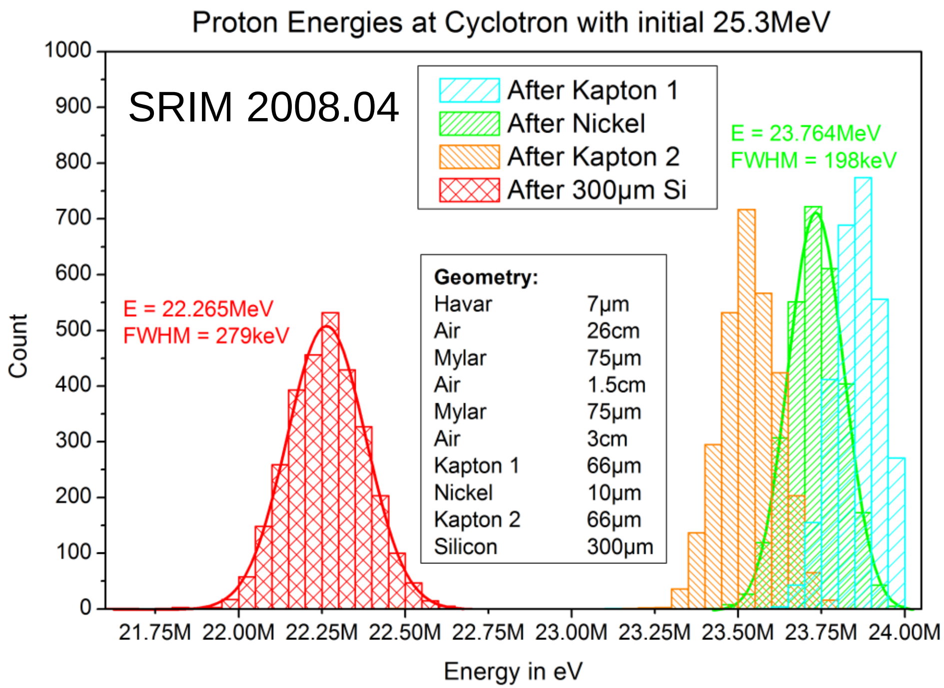
SPARES

Energy at Target

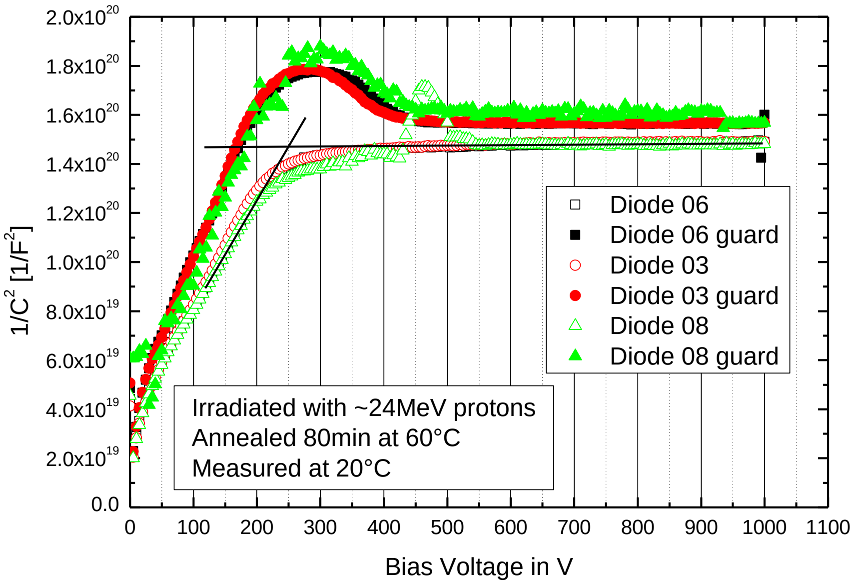
- 25.3MeV is the energy in the beam line
- Protons have to pass several materials until they hit the samples
- SRIM gives us a proton energy entering the samples of about 23.8MeV and on average in the sample: **22.9MeV**
- Samples covered by Nickel foils see lower energy ~22.8MeV

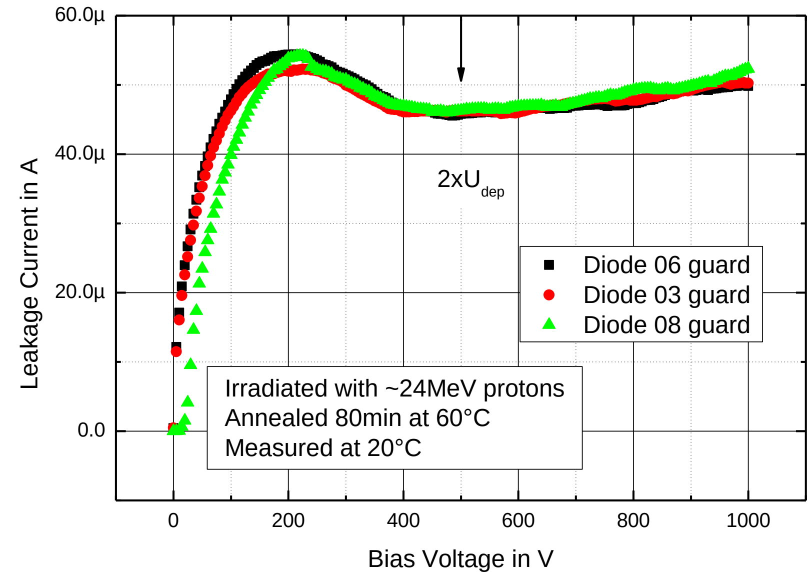


Calibration with Diodes

- 3 ELMA diodes from HH
  - Diode 03:
    U_{dep} = 44V, I_{dep} = 0.2nA, $I(2*U_{dep})$= 5nA, V=0.25cm² x 374µm = 9.36e-3cm³
  - Diode 06:
    U_{dep} = 46V, I_{dep} = 2nA, $I(2*U_{dep})$= 5nA, V=0.25cm² x 375µm = 9.37e-3cm³
  - Diode 08:
    U_{dep} = 45V, I_{dep} = 0.2nA, $I(2*U_{dep})$= 0.4nA, V=0.25cm² x 374µm = 9.36e-3cm³
- Irradiation with I_{beam} =1.04µA, v_x=115 mm/s, n_{scans}=5
  - **F_{est} = (0.56 ± 0.06)e14 p/cm²**
- Ni-foils:
  - **F_{Ni} = (0.60 ± 0.07)e14 p/cm²**

Calibration with Diodes

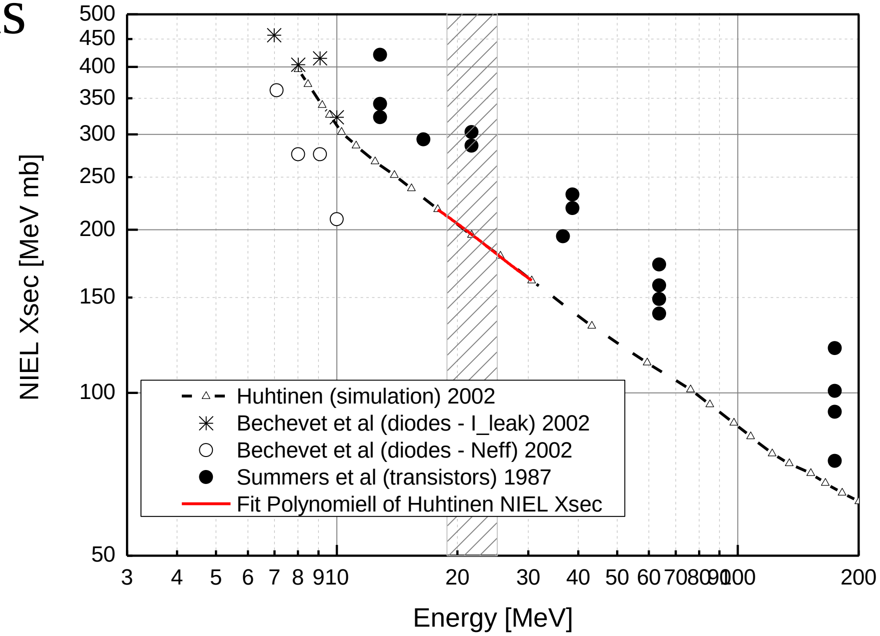




- Specific leakage currents after irradiation:
  - Diode 03: $I(2xU_{dep})$ = 46.2µA, ΔI/V = 4.925e-3 A/cm³
  - Diode 06: $I(2xU_{dep})$ = 45.8µA, ΔI/V = 4.888e-3 A/cm³
  - Diode 08: $I(2xU_{dep})$ = 46.3µA, ΔI/V = 4.947e-3 A/cm³
- Including a 1°C error for temperature measurement we get ΔI/V = (4.9±0.5)e-3 A/cm³
- And finally with α = 3.99±0.3e-17 A/cm² at 20°C after annealing for 80min at 60°C:
  $\mathbf{F_{diode}}$ = (4.9±0.5)e-3 A/cm³ / α = **(1.23±0.22)e14 n_{eq}/cm²**

Hardness Factor κ

- The hardness factor could be derived by
  $$\kappa = F_{diode}/F_{Ni} = \mathbf{2.05 \pm 0.61}$$
- Previous assumption was **1.85** for **26MeV** protons
- Hardness factor was derived from simulated NIEL data by Huhtinen[1]
- Assuming about 22.9 MeV protons on average in the sample, we get **κ = 2.00±??**
- 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% !**