Diamond activities in Karlsruhe

Projects:
Beam Loss Monitor for LHC (issue rad.hardness)
Diamond Beam Exit Window (issue leak tightness)

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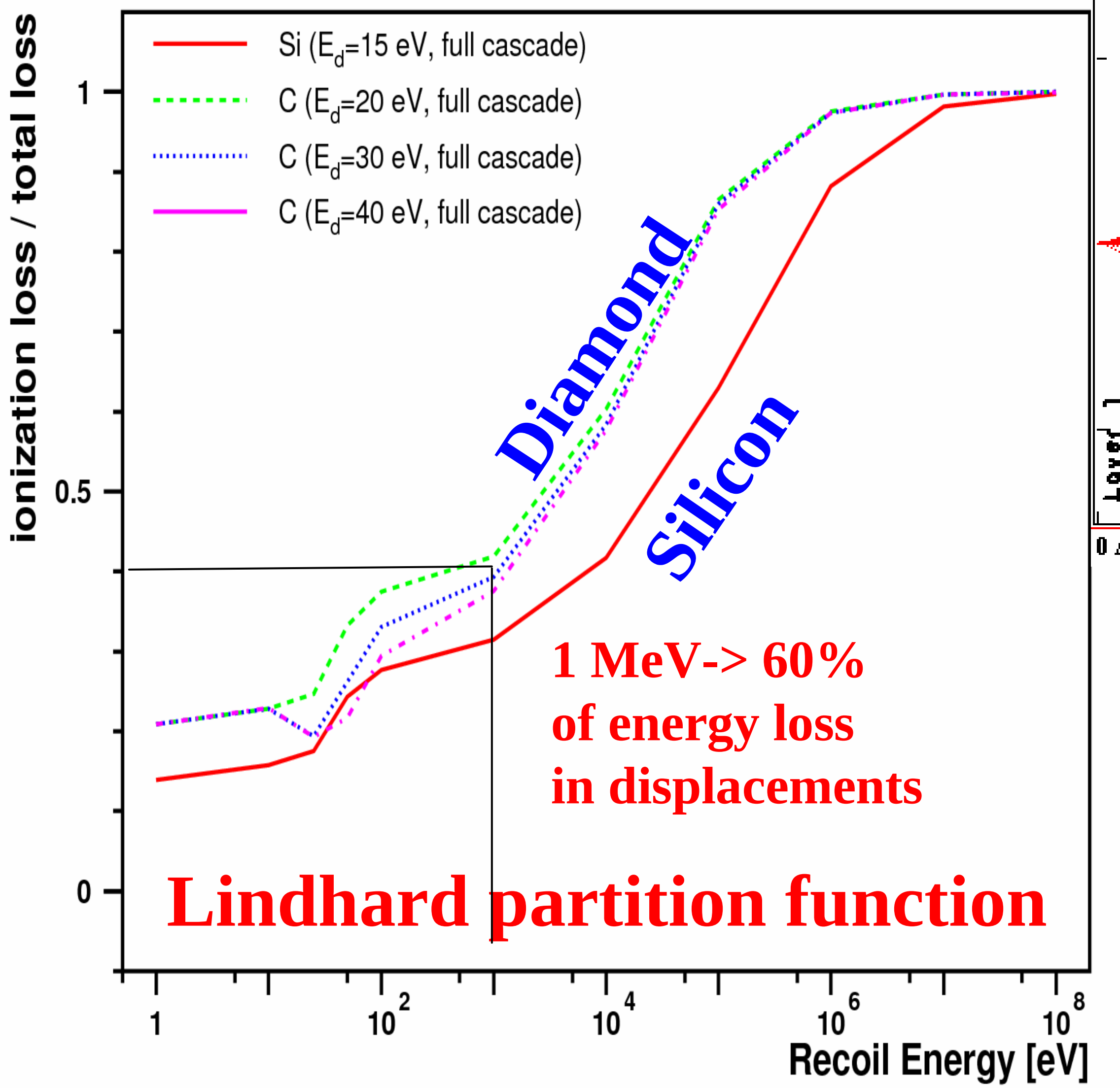
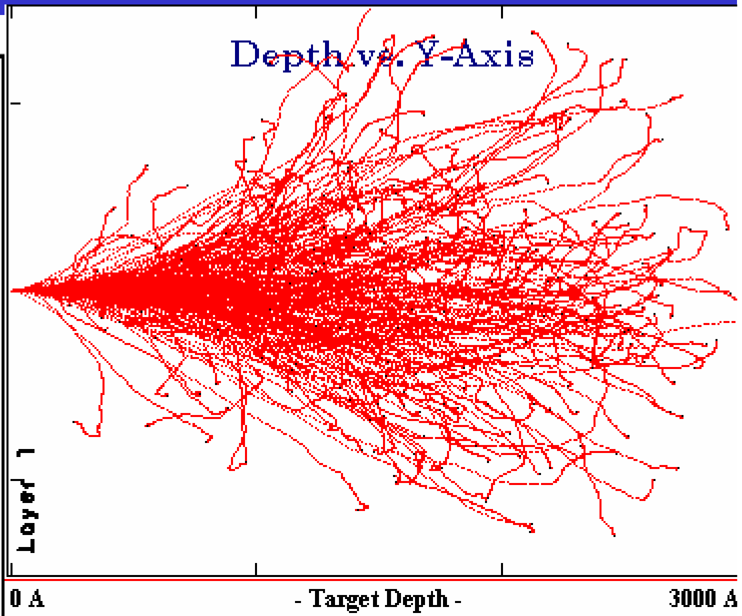
Definition of NIEL hypothesis (used sofar for Si)

NIEL= Non-Ionizing-Energy Loss
(given by Lindhard partition function)
Hypothesis: Sensor signal loss $\propto$ nr. of defects $\propto$
NIEL damage cross section in [MeVmb]

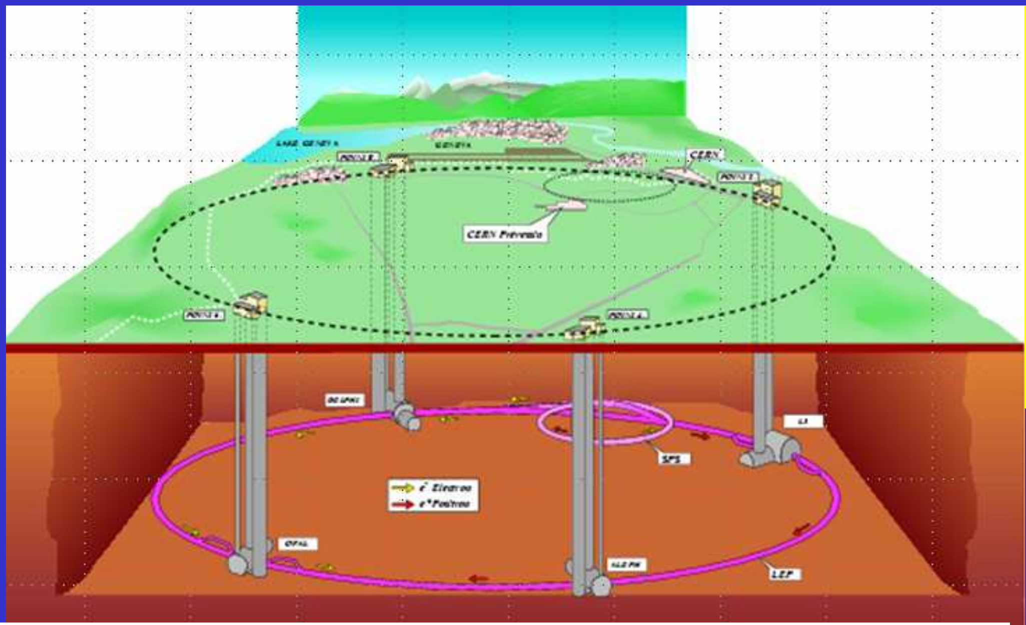
NIEL mainly by low energy impinging particles





Scattering of
0.1 MeV Al (Z=13)
nuclear fragments
in Si (Z=14)
(simulation by SRIM
www.srim.com)

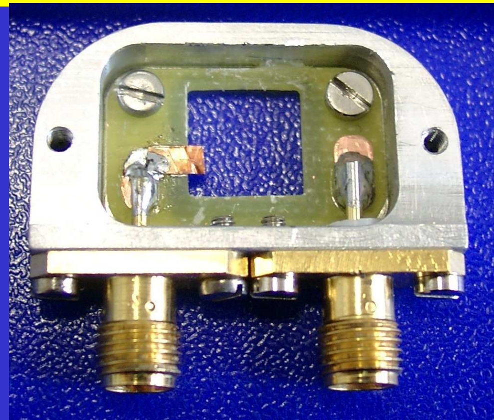
Beam loss monitoring at the LHC 14 TeV pp collider



Expected flux on LHC beampipe: 10^{15} p/cm^2 per yr

Expected radiation damage (RD42 Coll.):

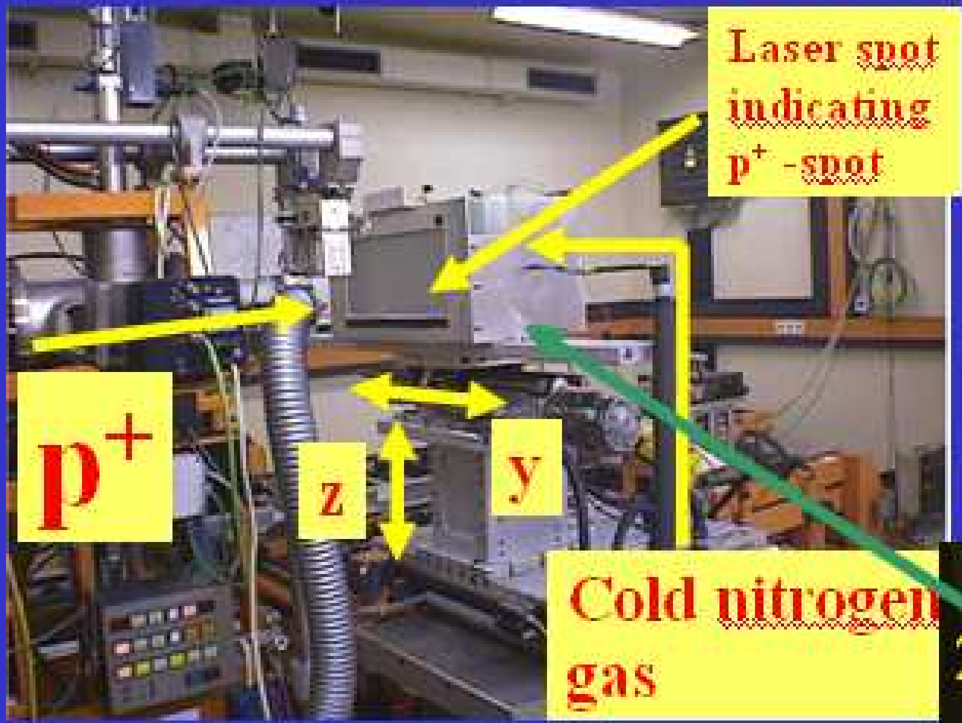
$\Phi_{1/2} = 2.\ 10^{15}$ (24 GeV p)/cm^2



27 km long LHC tunnel filled with SC magnets. Beam loss monitoring by 3700 ionization chambers, which are replaced in experimental area with diamond sensors.

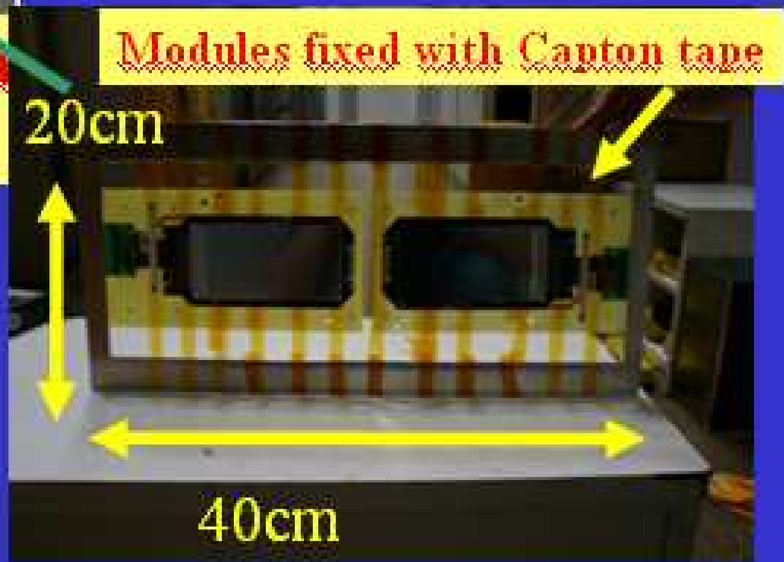
Problem: measured
$\Phi_{1/2}$ = (3-5). 10^{14} (26 MeV p)/cm^2

26 MeV proton irradiation in Karlsruhe



Compact Cyclotron

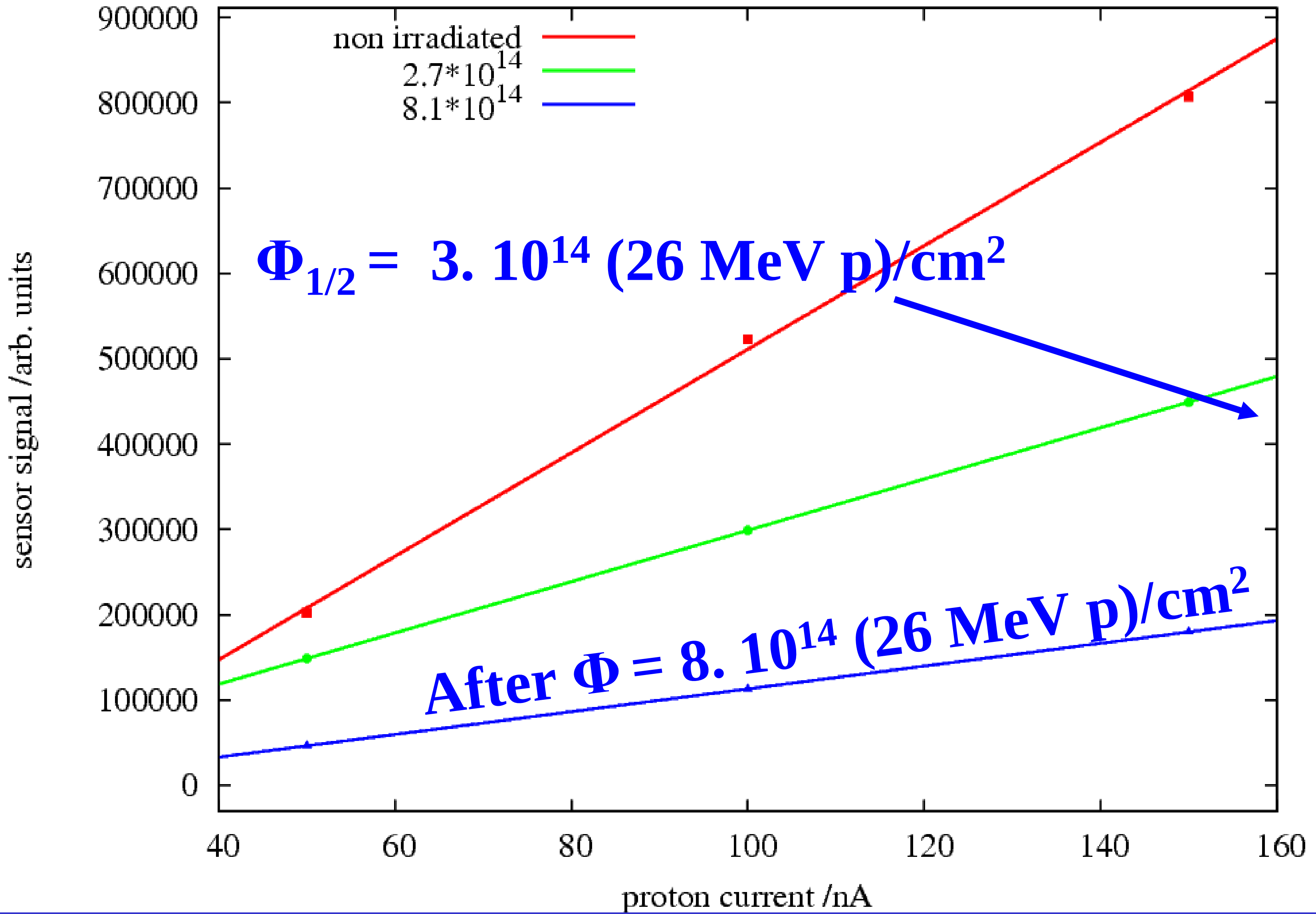
- protons with 19 MeV up to 40 MeV
- beam currents up to 100μA (1μA up to 2μA used)
- 26 MeV protons → κ=1.85
- $1.2\cdot10^{14}$p/cm² for 100cm² in ~15 min
- Temperature during irradiation: -40...+25 °C



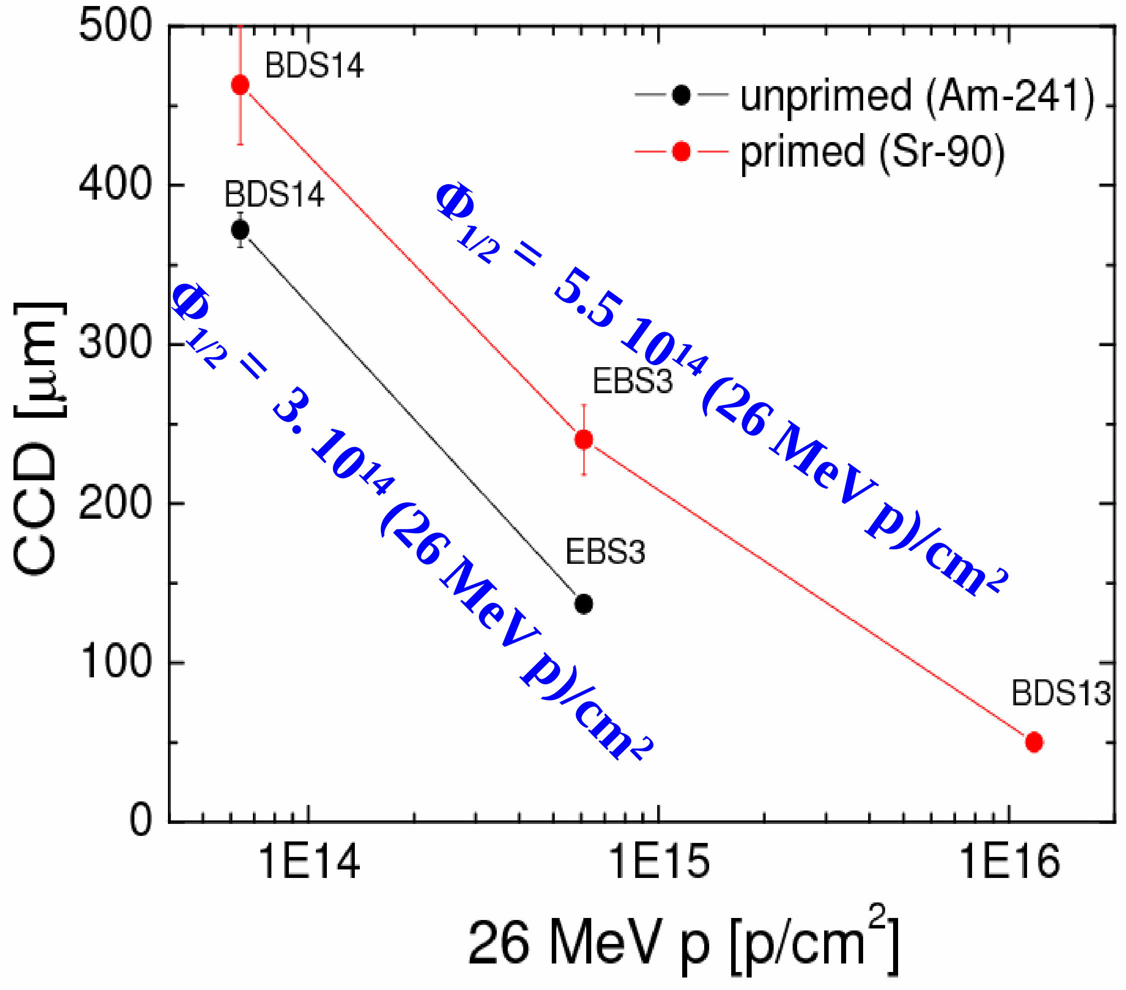
Scans perpendicular to p+

→ Areas of 40x20cm² possible, to be irradiated at once !

Ionization current vs beam current for 26 MeV protons after several fluences



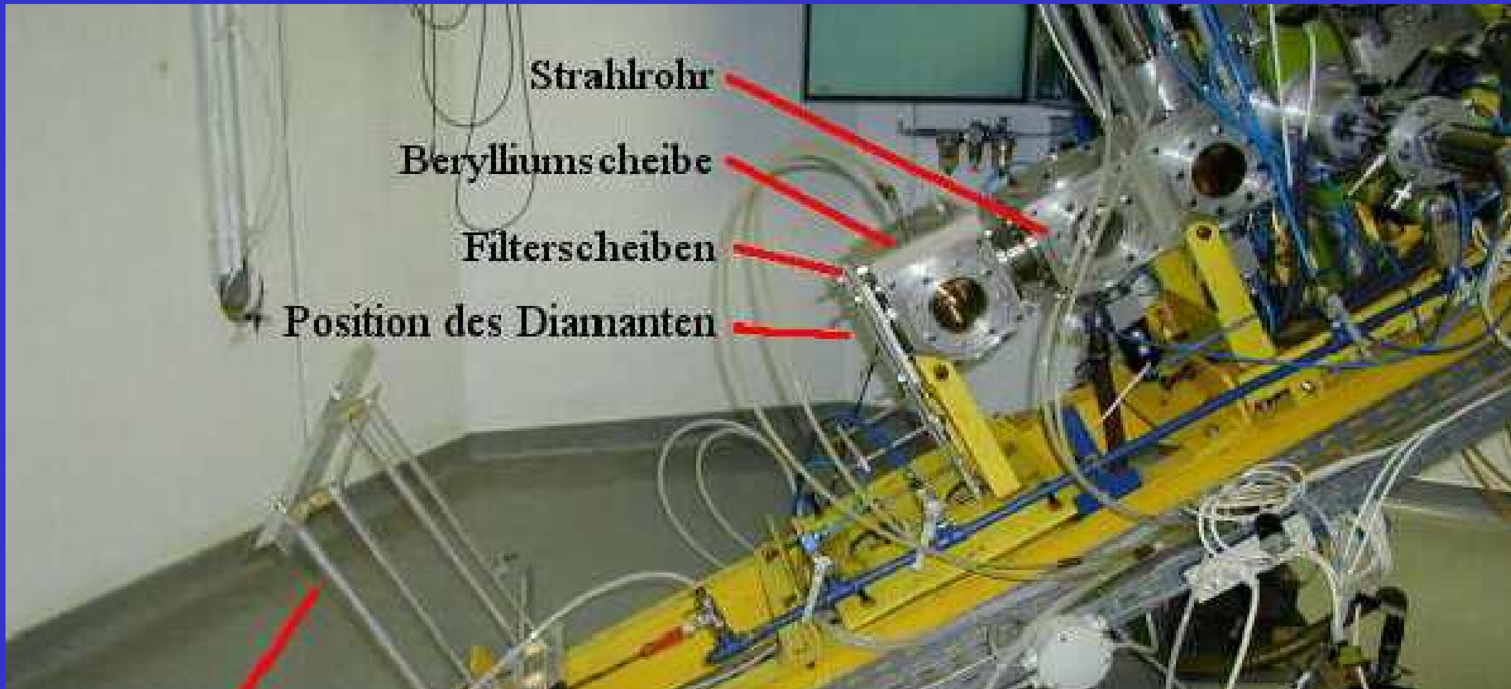
sCVD sensors same results as pCVD sensors (E6)

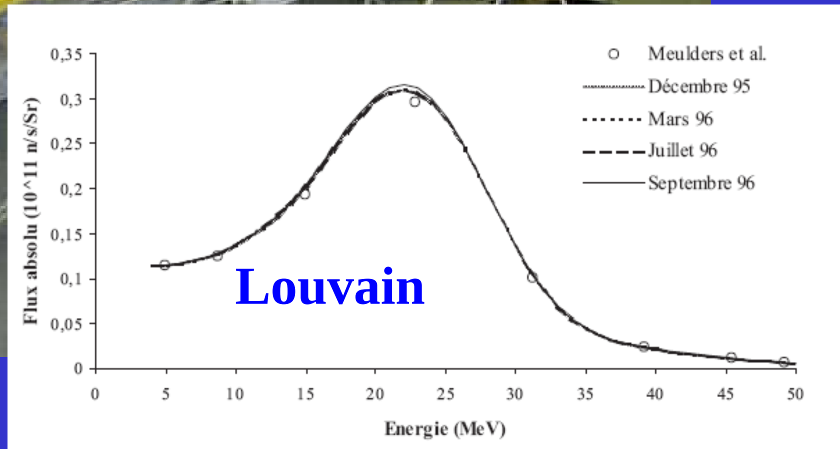


These measurements done with real CCD measurements with source characterization instead of beam current.
(M. Pomorski, GSI)

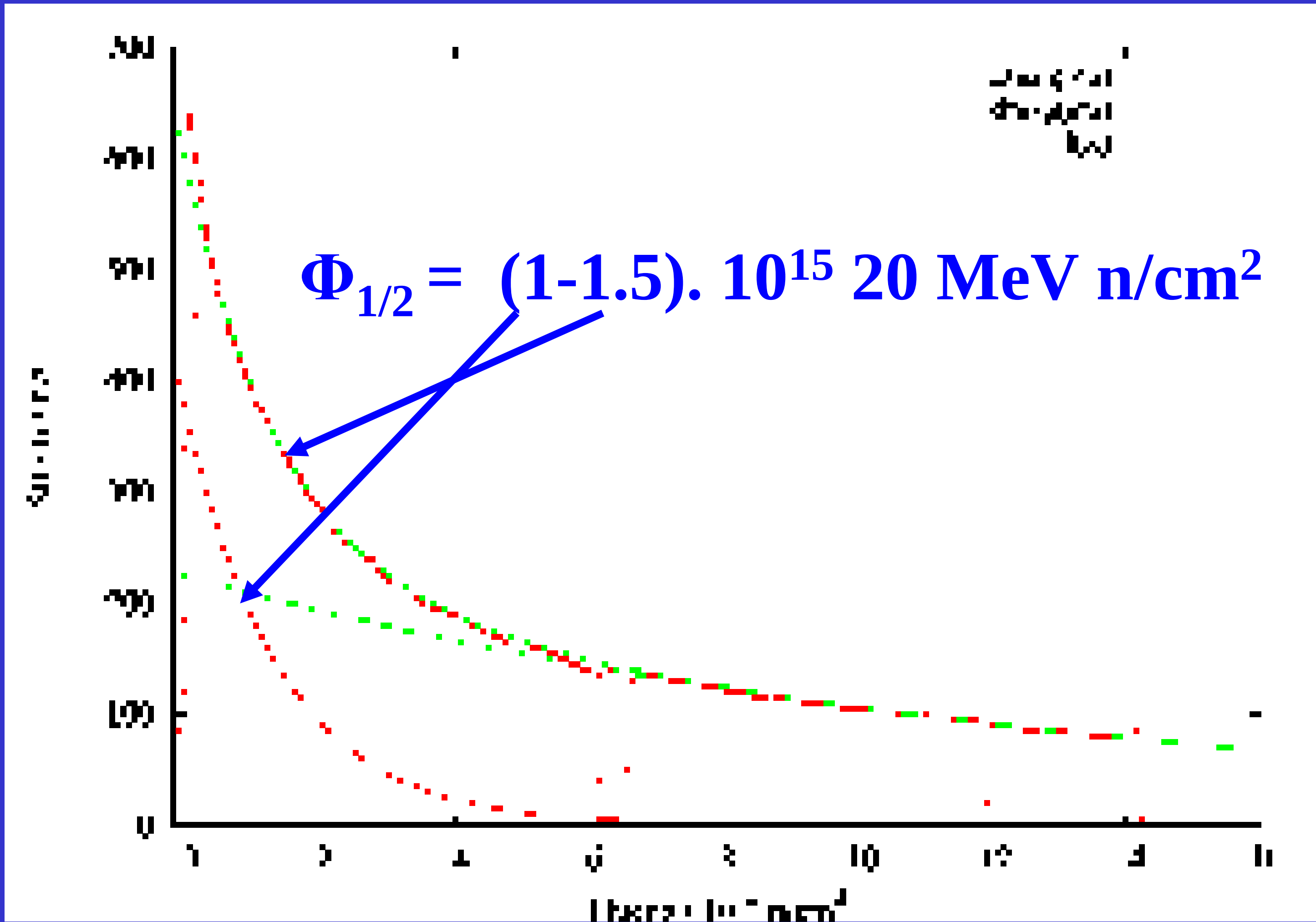
So results independent of method and crystal type (sCVD or pCVD). Intrinsic property of diamond!

<20 MeV> n-irradiation at Louvain





Decay of CVD signal during neutron irradiation



Calculation of NIEL curve

Conclusion: diamond radiation hardness not as high as expected for low energy protons

Reason?

First question: does NIEL hypothesis work?

Implying: signal loss $\propto$ defects.

Can be calculated by SRIM package by Ziegler et al.
(SRIM = Stopping and Range of Ions in Matter)
(freely available from internet)

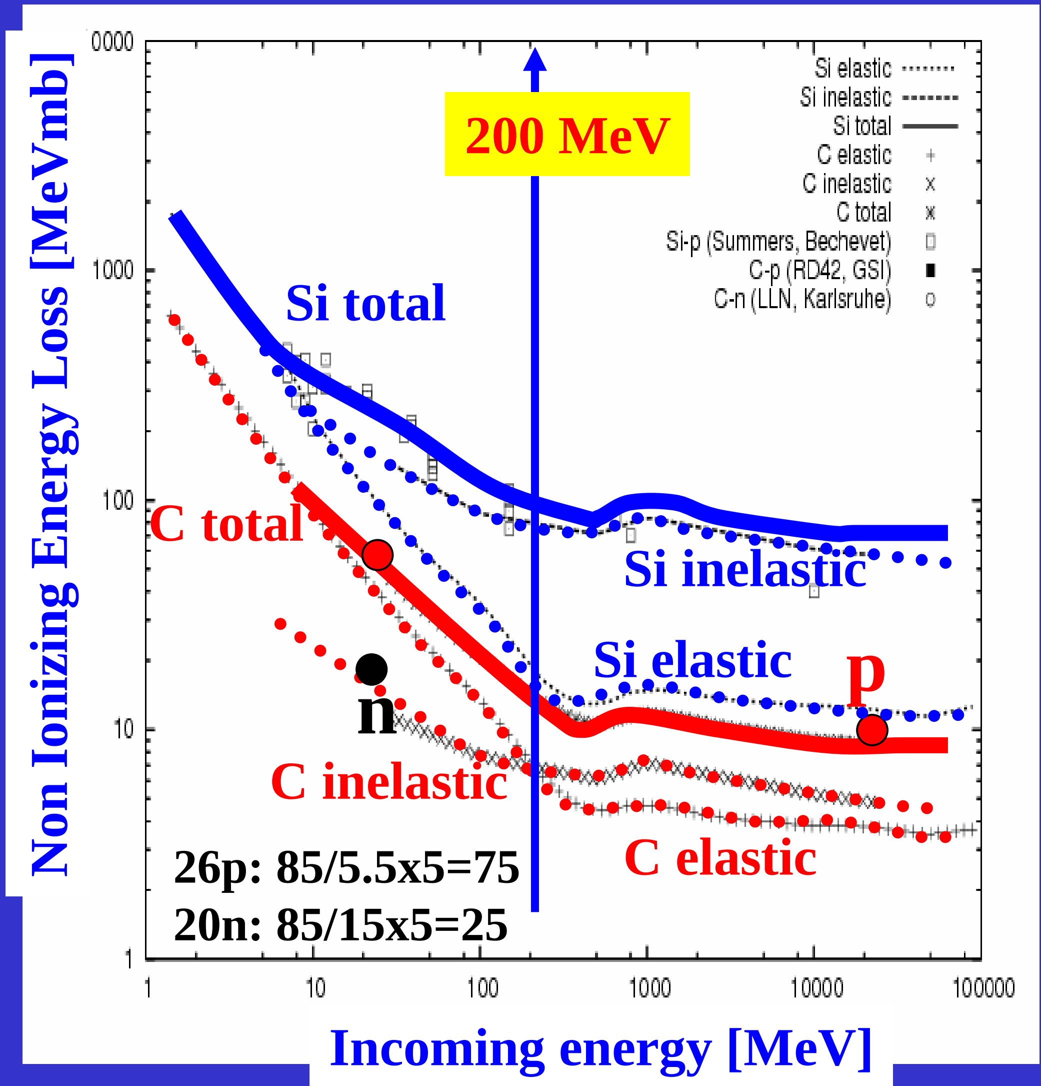
Disadvantage: SRIM calculates only Coulomb scattering

Solution: use FLUKA to

1) calculate nuclear interactions to elastic scattering

2) calculate fragments with energy spectrum
Calculate damage from fragments by SRIM again

NIEL damage cross section in Diamond



Si

Z	Ions	NIEL
14	417	4.2
13	910	9.06
12	1384	12.47
11	1021	8.86
10	1225	8.45
9	265	1.41
8	493	2.09
7	398	1.31
6	909	2.36
5	270	0.55
4	383	0.66
3	662	0.67
2	11152	4.4
1	46107	0.9
Total	65590	57.38

10 GeV protons

C

Z	Ion	NIEL
6	698	0.8
5	869	0.77
4	584	0.44
3	1133	0.55
2	10625	2.01
1	30465	0.24
Total	44374	4.81

Conclusion

Radiation damage
at HIGH energy
dominated by inelastic cross sections.
C-nuclei smaller and more stable than Si.
Diamond order of magnitude better than Silicon.

Radiation damage
for LOW energy protons (O(MeV)) dominated by elastic scattering
C-nuclei have factor two smaller Z than Si and higher displacement energy (≈40 eV vs 20 eV).
Diamond for low energy protons factor 3-4 better than silicon, but order of magnitude worse than expected from high energy measurements. For neutrons C order of magnitude better than Si.

NIEL hypothesis seems to be working!!

Future

Measure with more types of diamond
with more particle beams
at different energies.

Would like to get samples from FP7
and money for irradiation.
Would like to have radiation hard preamp
to drive long cables needed for accelerator exp.

Do not need personnel from FP7
Contribute with 2.5 FTE from Karlsruhe