Silicon 3D detectors irradiated with pions and protons

UNIVERSITY
of
GLASGOW

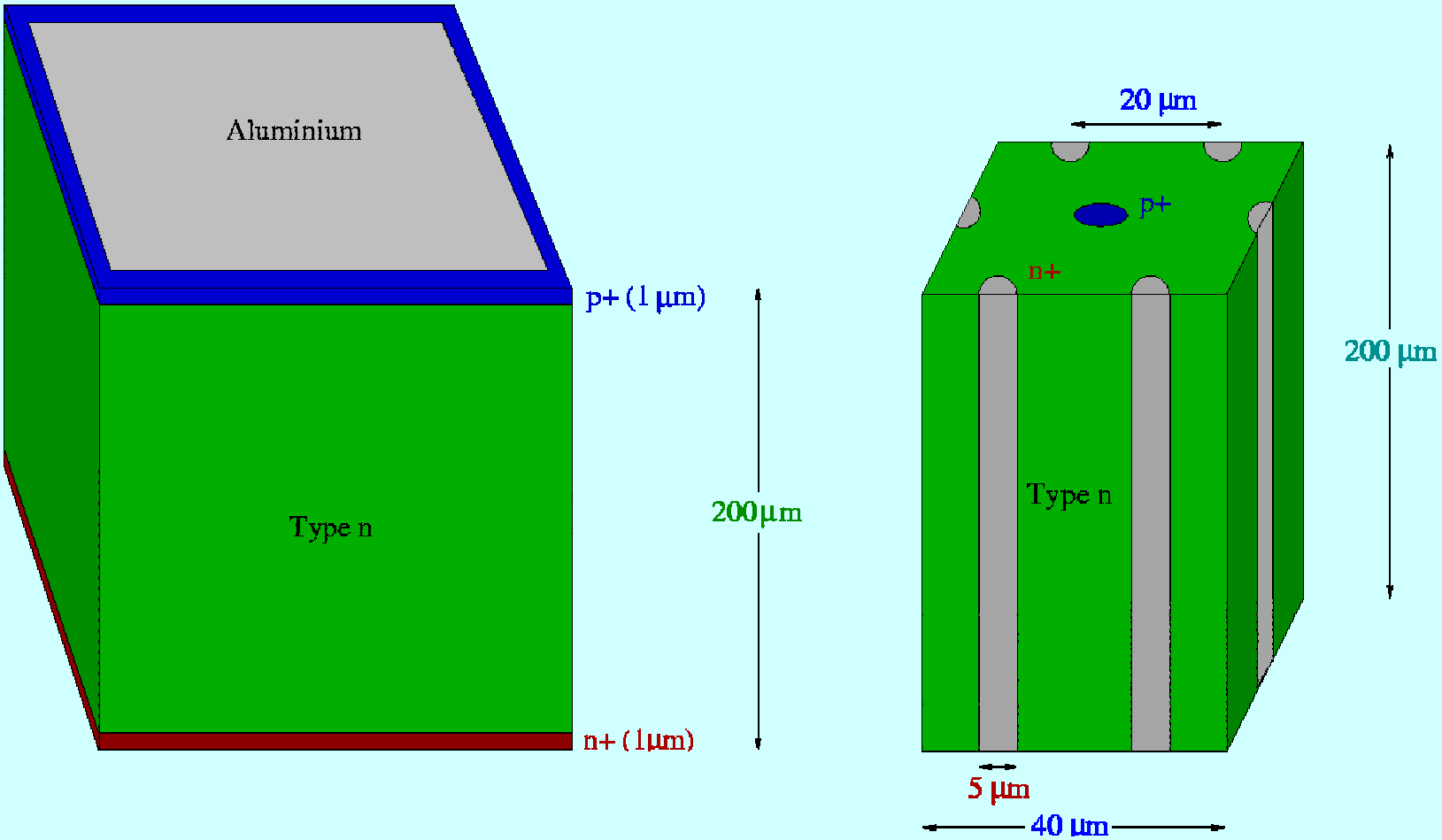
Patrick Roy

G. Pellegrini, V. Wright, R. Bates, L. Haddad,
J. Melone, V. O'Shea, K.M. Smith, M. Rahman

Overview

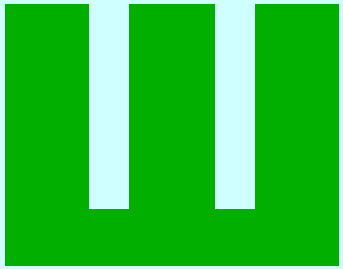
- **Introduction**
- **Results from irradiation:**
  - **-Pions**
  - **-Protons**
- **What is next?**
- **Conclusion**

Introduction



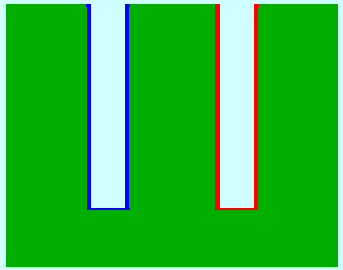
Fabrication steps

- **Creation of the vias**



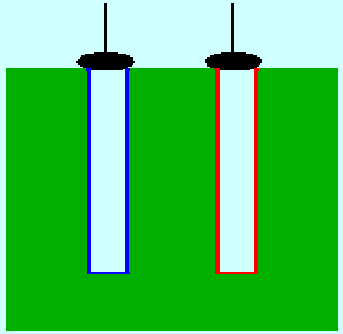
Dry etching
Laser drilling
PEC etching

- **Creation of the electrodes**



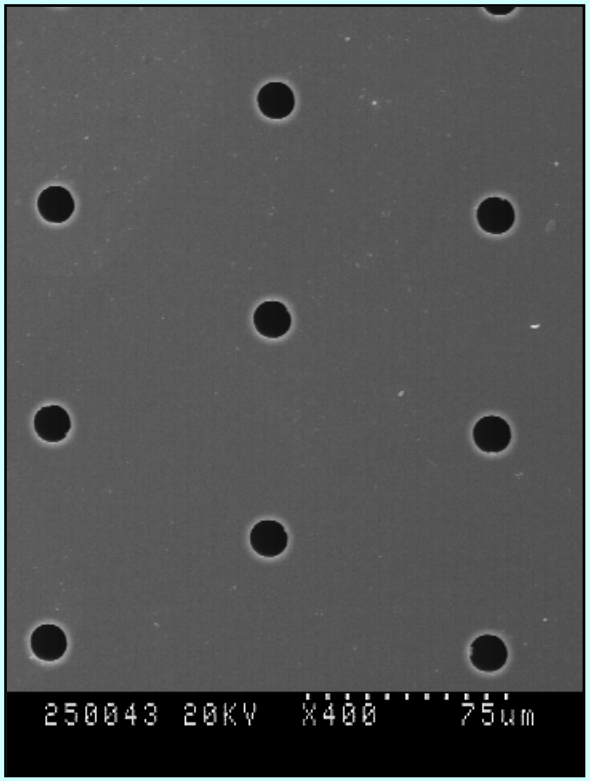
Shottky-Schottky
p-n junction

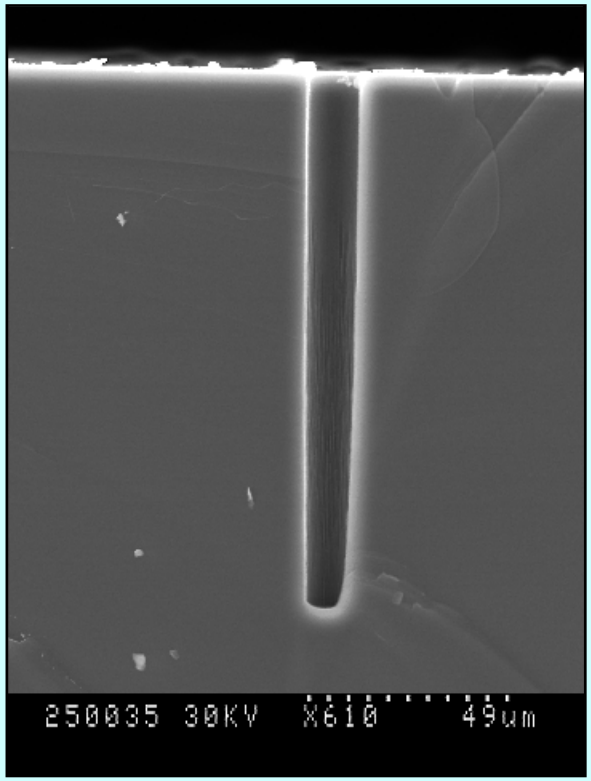
- **Connection to the electronics**



Wire bonding
Bump bonding

Dry etching





Inductively Coupled Plasma

- **Mask**: photoresist
- **Gas**: SF_6
- **Coating**: C_4F_8

- **Diameter**: 10 μm
- **Spacing**: 85 μm
- **Depth**: 130 μm
- **Etch time**: 100 minutes

Aspect ratio 13:1

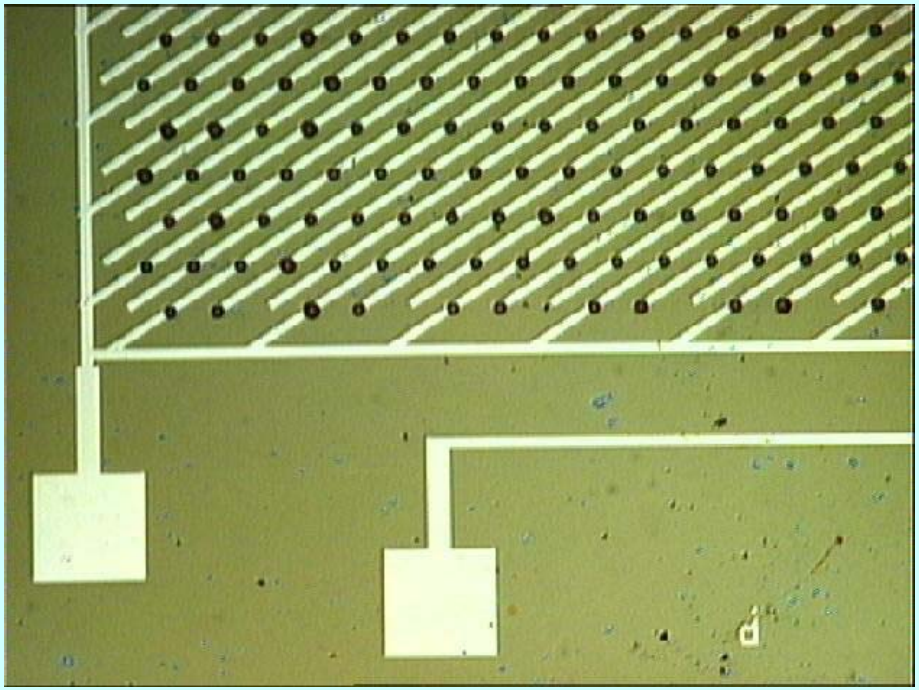
Electrical contacts

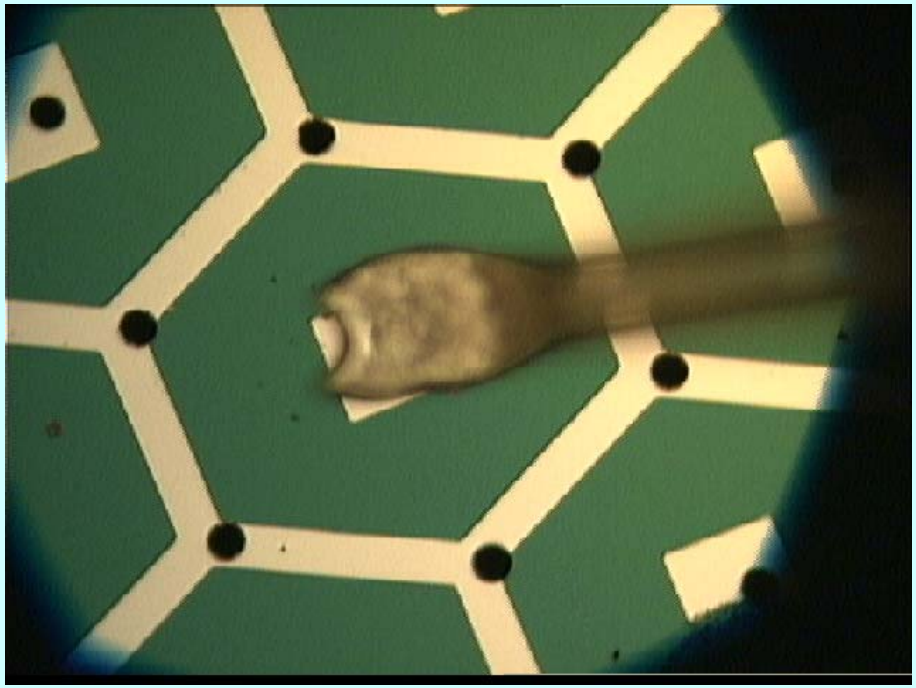
- **Metal evaporation:**

  Ti (50 nm)
  Au (105 nm)

- **Tracks of Al (150 nm)**
  (over the SiO_2 layer)

- **Wire bonding**
  (25 μm wire)



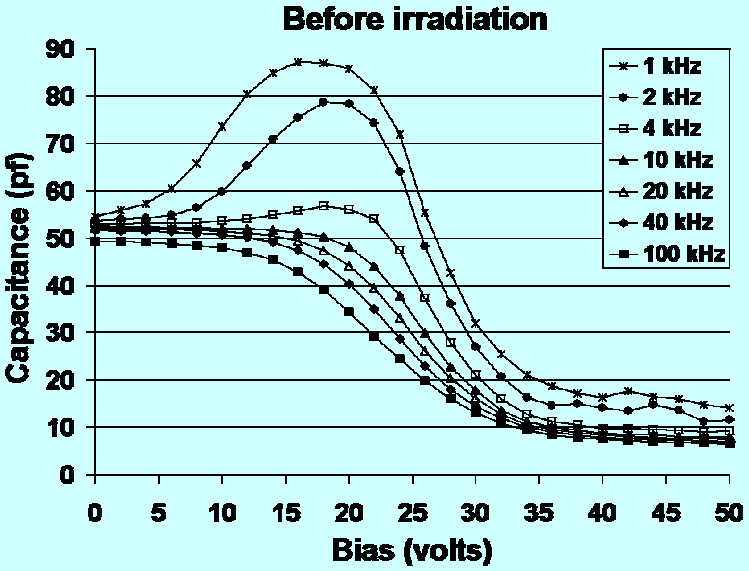


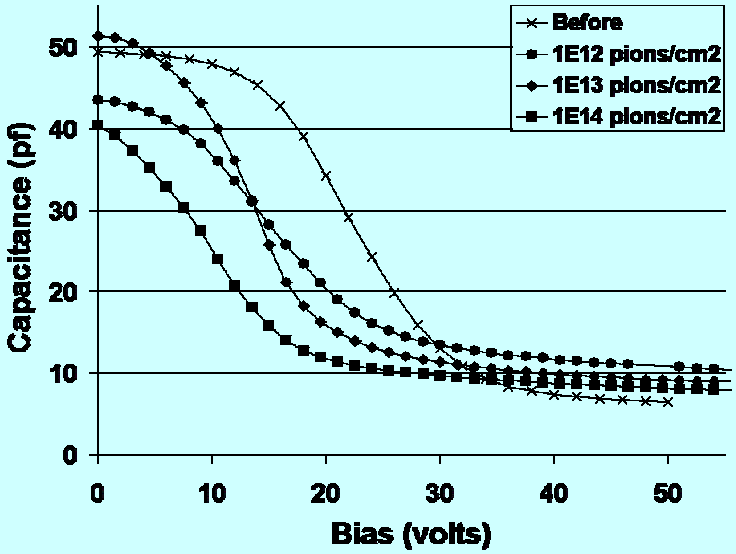
Irradiation at PSI*

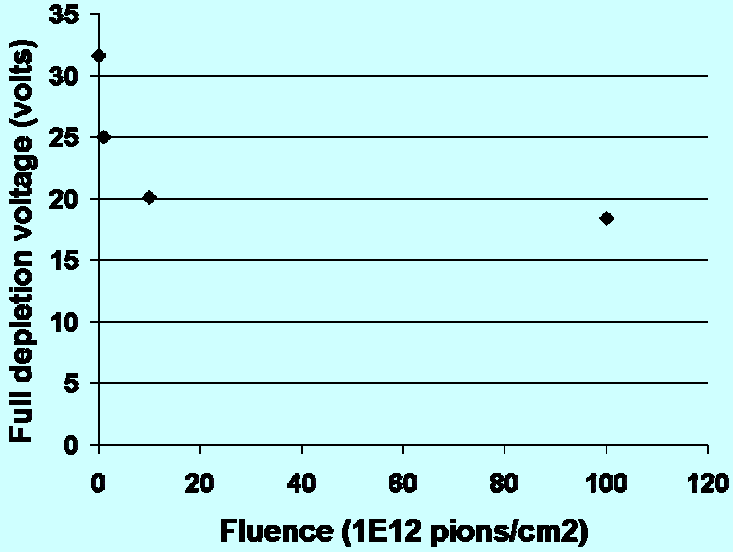
- **Irradiation with 300 MeV/c π at PSI (Villigen)**
- **Bunch of 1 ns every 19 ns**
- **Flux of 10^{14} π/cm^2/day**
- **3 fluences: 10^{12}, 10^{13} and 10^{14} π/cm^2**
- **4 low resistivity n-type silicon samples**

*** Irradiation performed by K. Gabathuler, M. Glaser and M. Moll.**

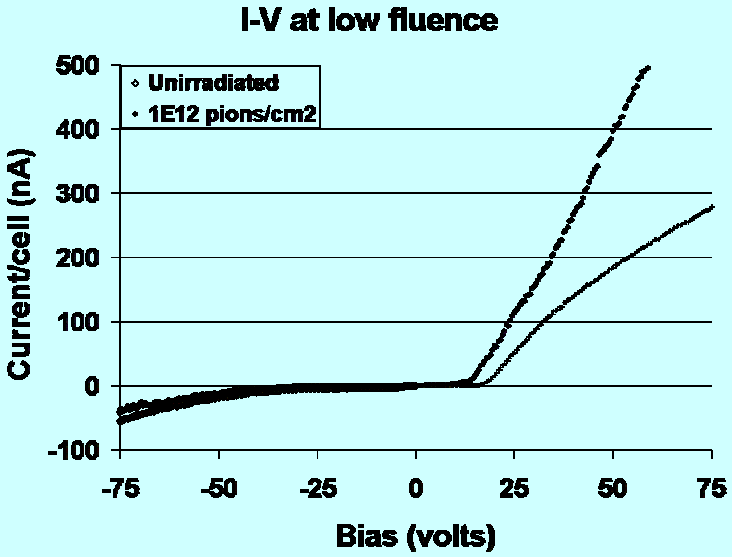
Capacitance measurements (pions)

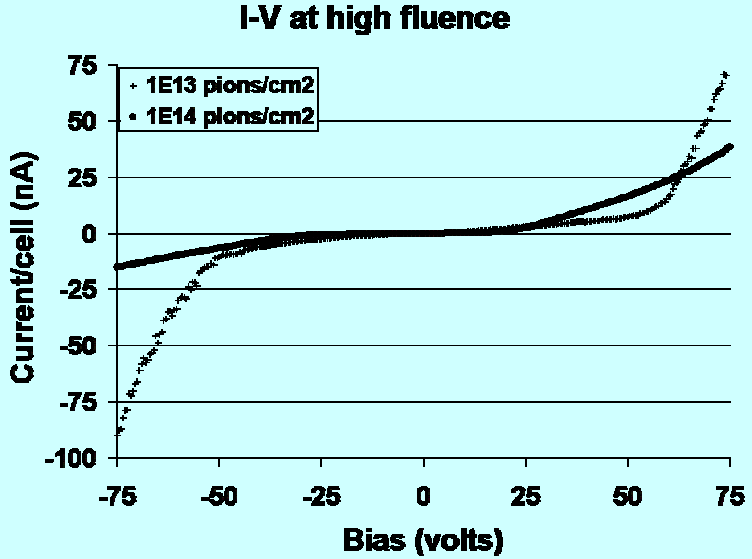


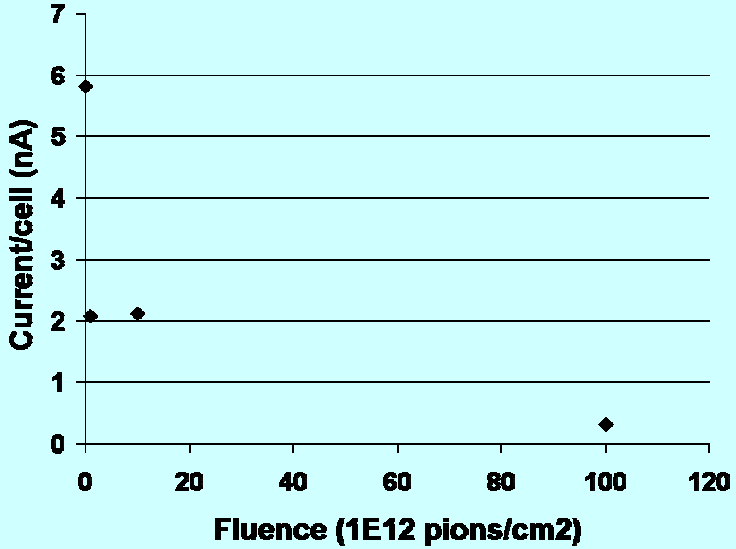




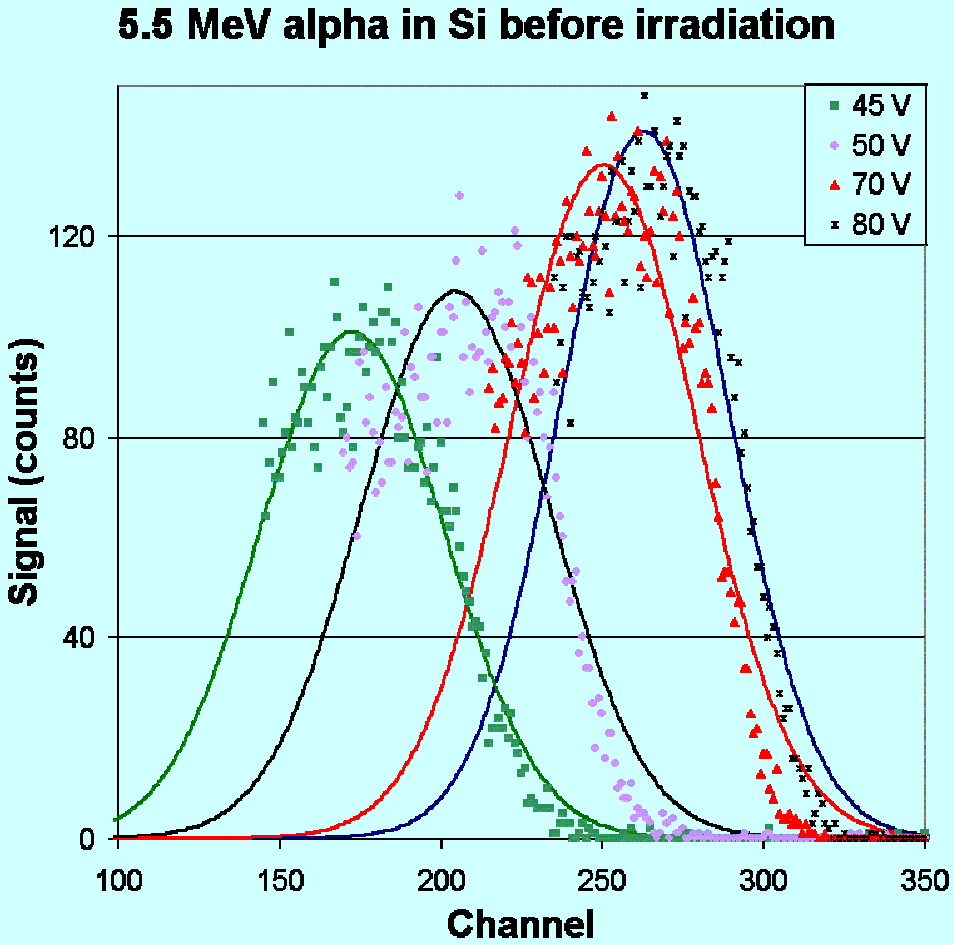
Leakage current (pions)

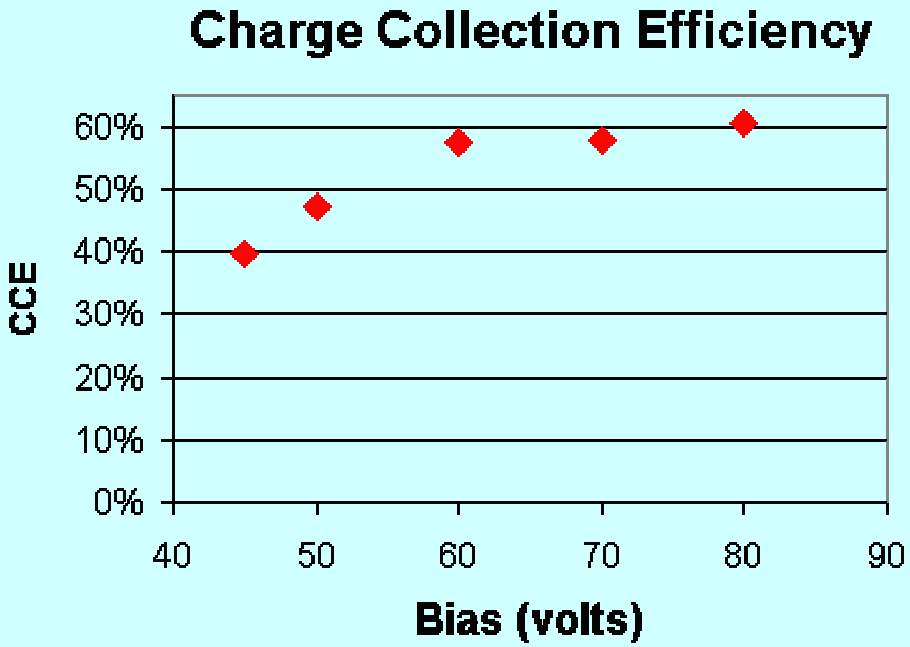




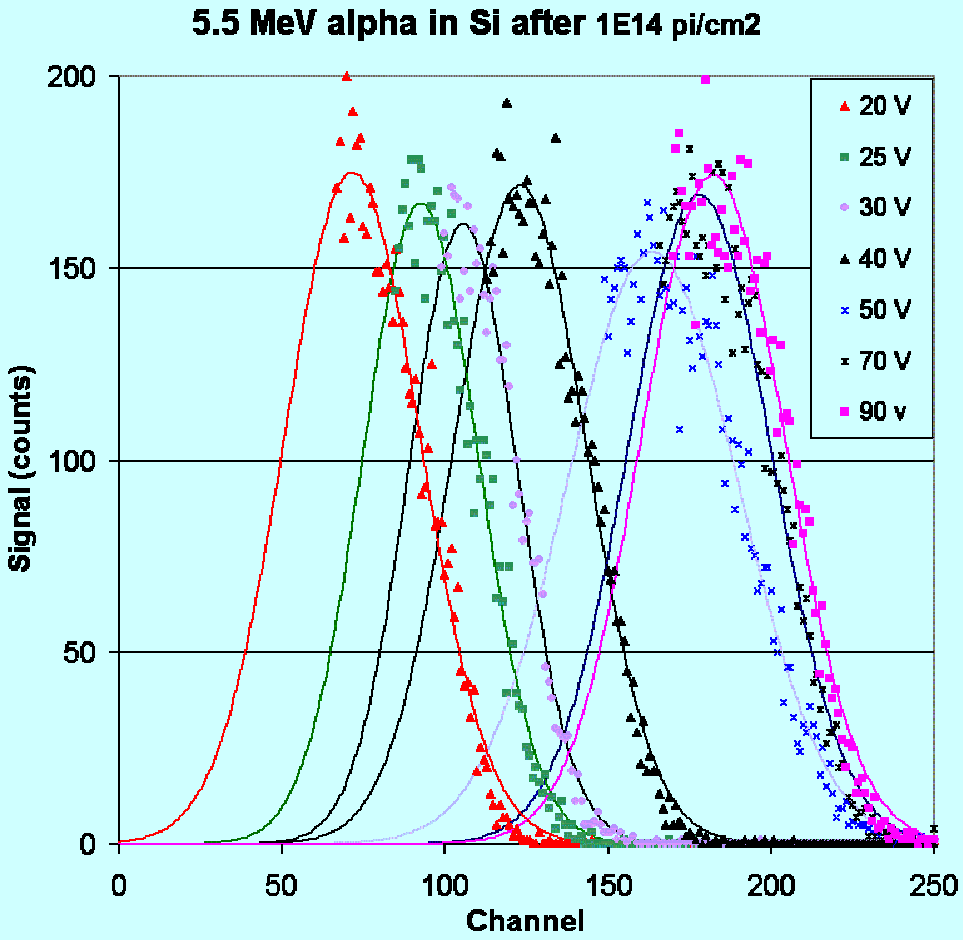


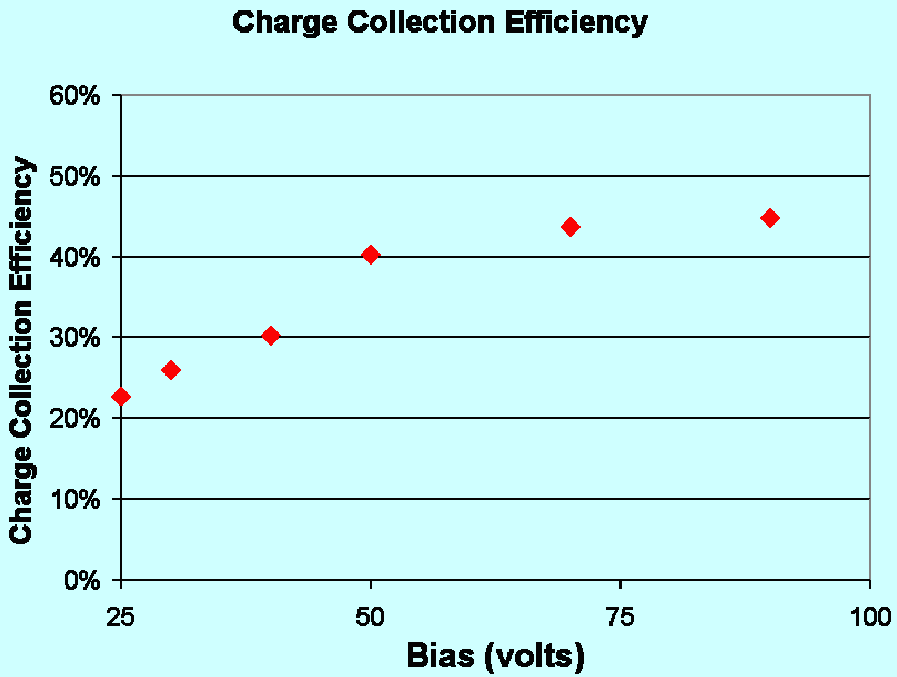
Alpha spectroscopy





Alpha spectroscopy
(irradiated)



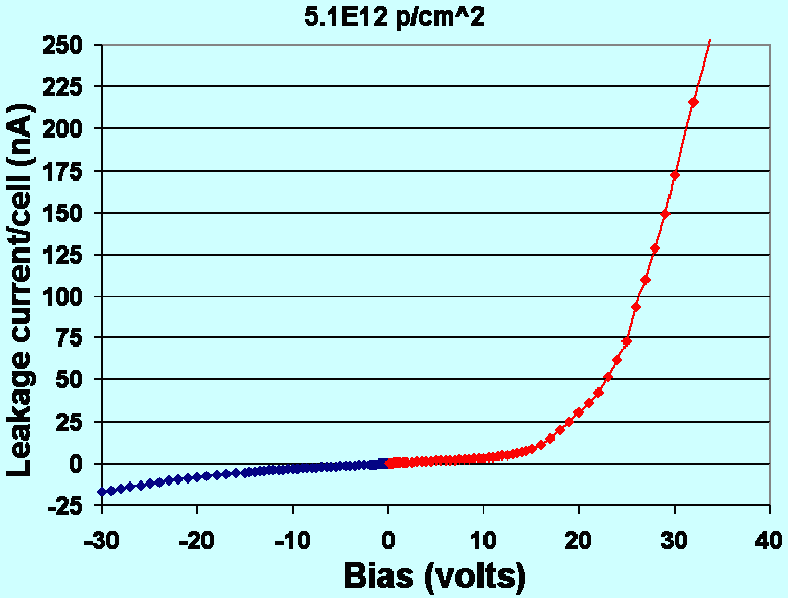


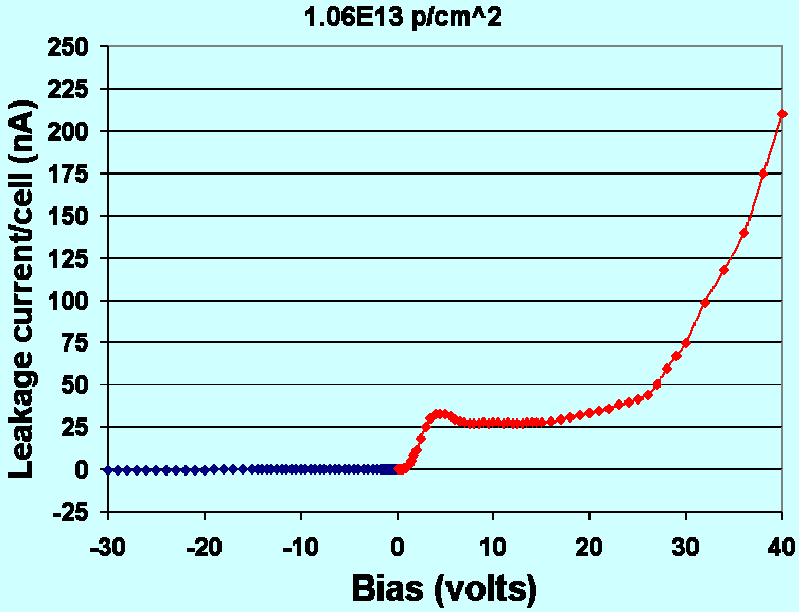
Irradiation at CERN*

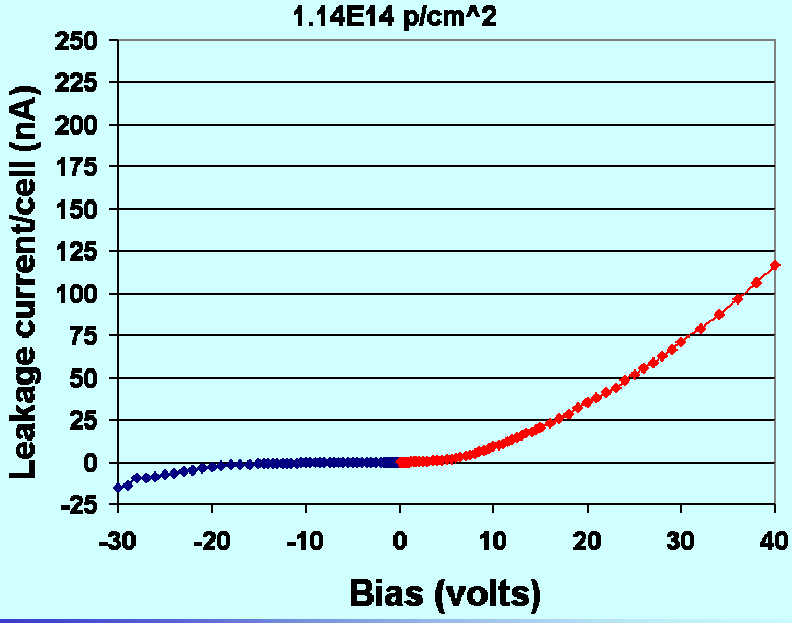
- **Irradiation with 24 GeV/c protons at CERN**
- **Flux of 1-3 x 10^{13} p/cm^2/h**
- **7 fluences between 5 x 10^{12} and 5 x 10^{14} p/cm^2**
- **13 high resistivity n-type silicon samples**

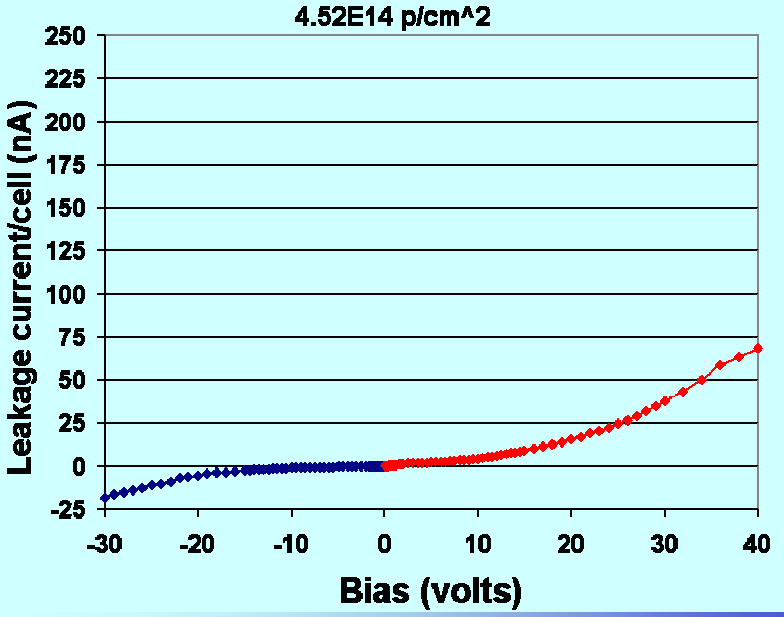
*** Irradiation performed by M. Glaser and M. Moll.**

Leakage current (protons)



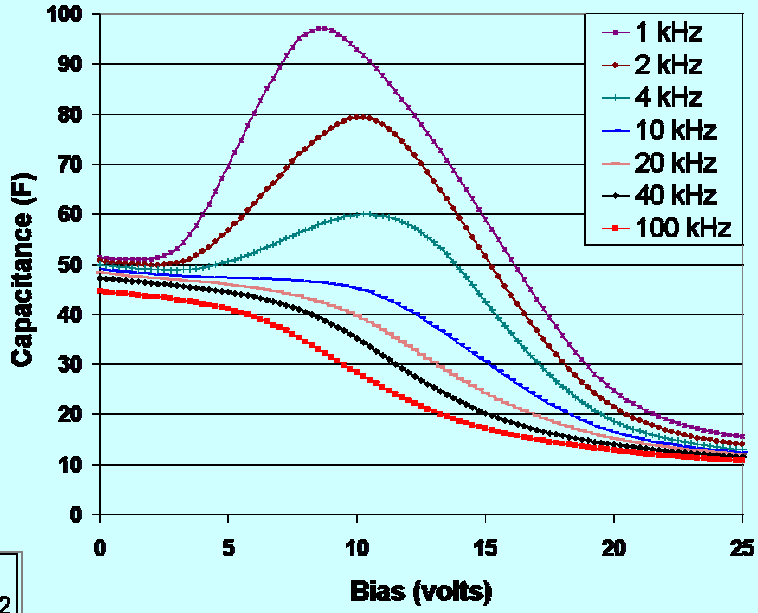


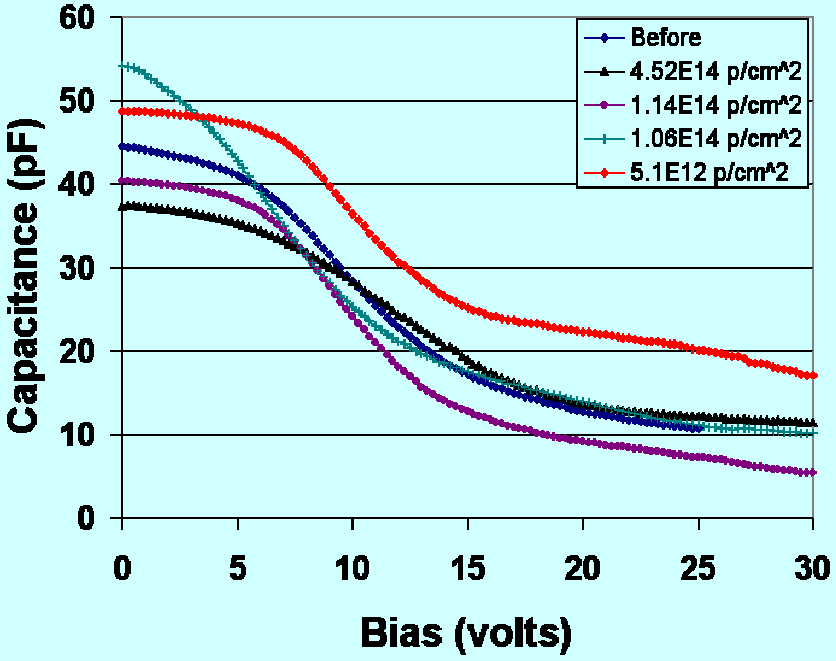


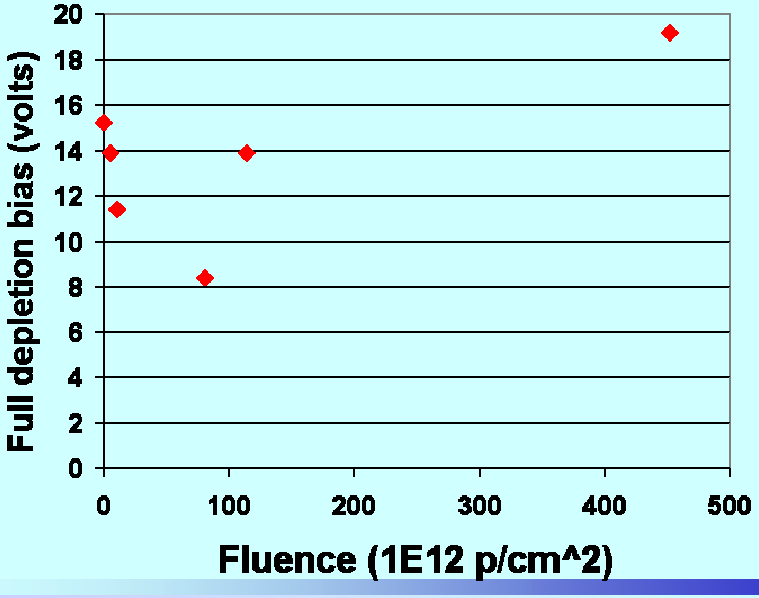


Capacitance measurements (protons)

Before irradiation







In development

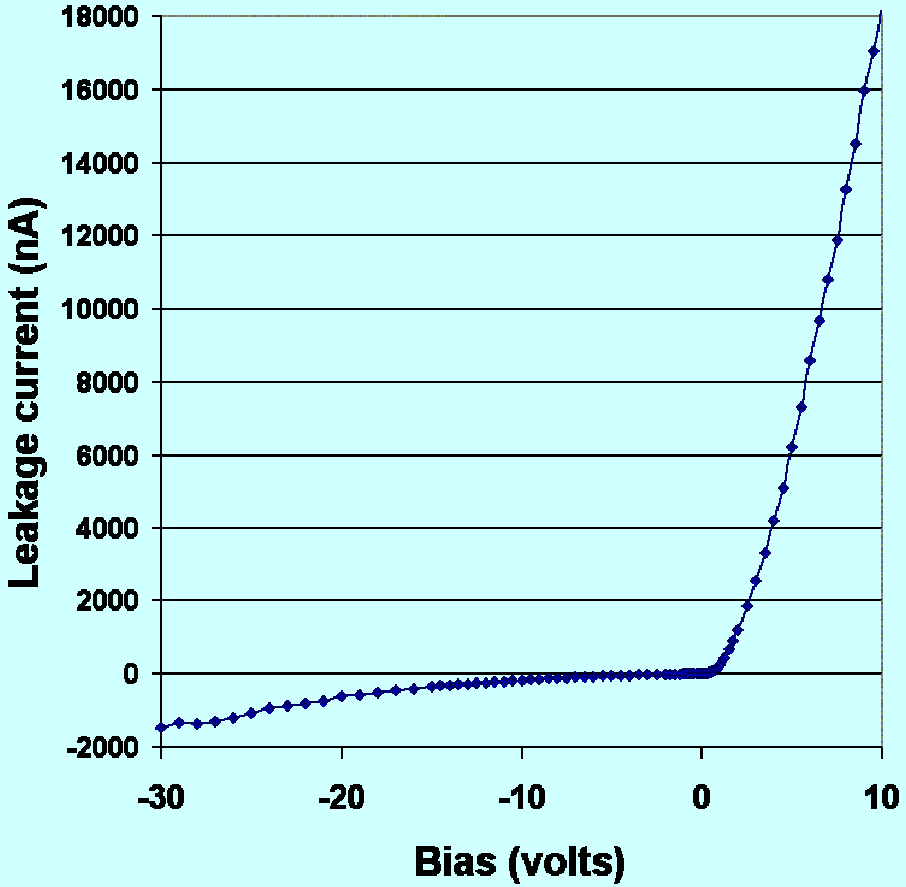
- **Improved aspect ratio of vias**
  - **-Dry etching (~30:1*)**
  - **-PhotoElectroChemical etching (>30:1*)**
- **Improved electrodes**
  - **-pn junction**
- **Improved readout electronics**
  - **-MEDIPIX1***
  - **-LHCb VELO**
  - **-ATLAS SCT**

*** 3D-RID collaboration: ppewww.ph.gla.ac.uk/3D-RID**

pn junction

Sample's preparation:

-creation of central via
-boron doping
-creation of surrounding vias
-metal evaporation



3D MEDIPIX1*

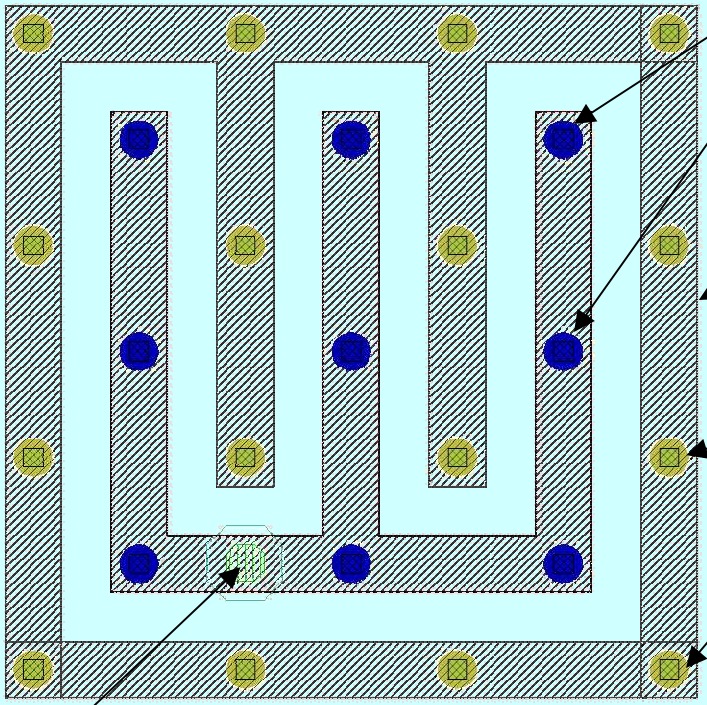
MEDIPIX chip

-Pixels per chip
-64 x 64

-Pixel size
-170 x 170 μm²

-Leakage current compensation

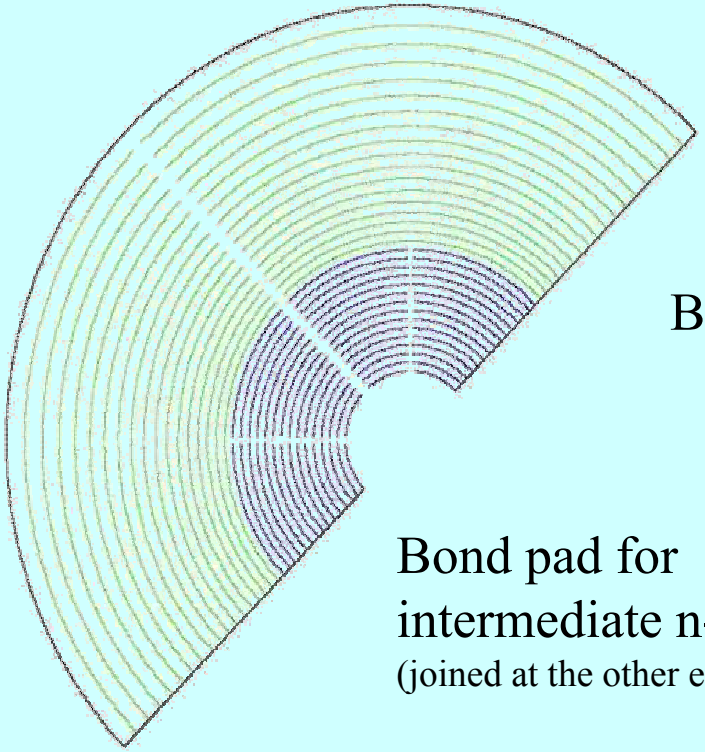
-Sensitive to positive input charge only



Vias diameter: 10 μm
Width of metal strips: 15 μm
Pitch: 56.67 μm
Cell pitch: 170.01 μm

*** 3D-RID collaboration: ppewww.ph.gla.ac.uk/3D-RID**

LHCb -VELO*



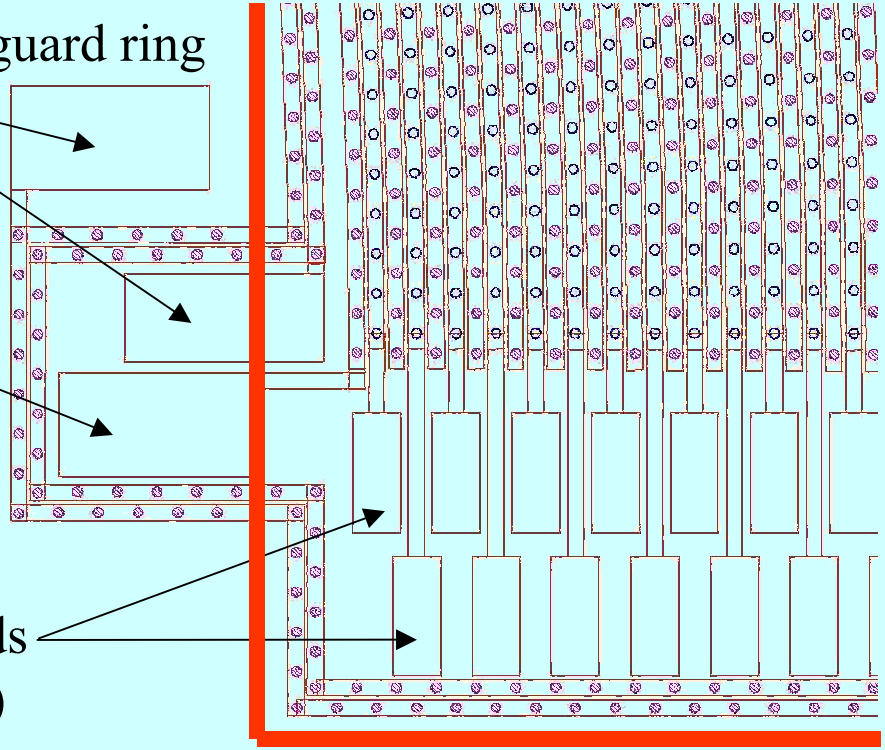
Constant via spacing of 50 μm along the strip.
Via spacing varies with radius.

Bond pads for guard ring

Bond pad for
intermediate n-type strips
(joined at the other end of the strips)

Pitch varies linearly from
45 μm at the innermost
region to 90 μm at strip 128

Main bond pads
(p-type strips)



*** Designed in collaboration with C. Parkes**

ATLAS SCT

Microstrips design (barrel)

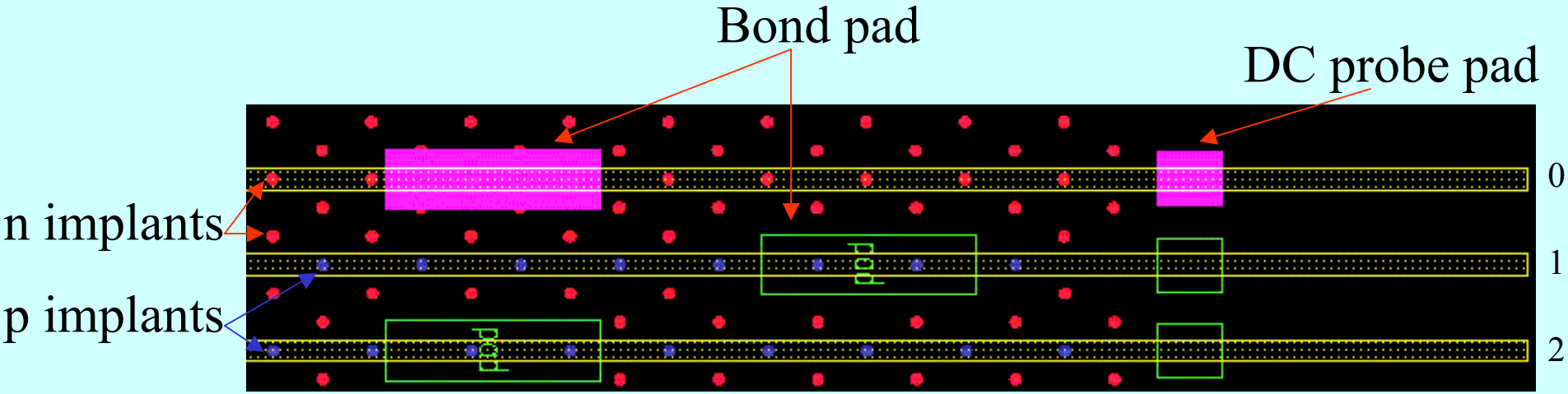
-Small version (~1 cm^2)

-Channel: 128 + 2

•Strip: 20 μm x 1 cm
80 μm pitch

•Hexagonal cells

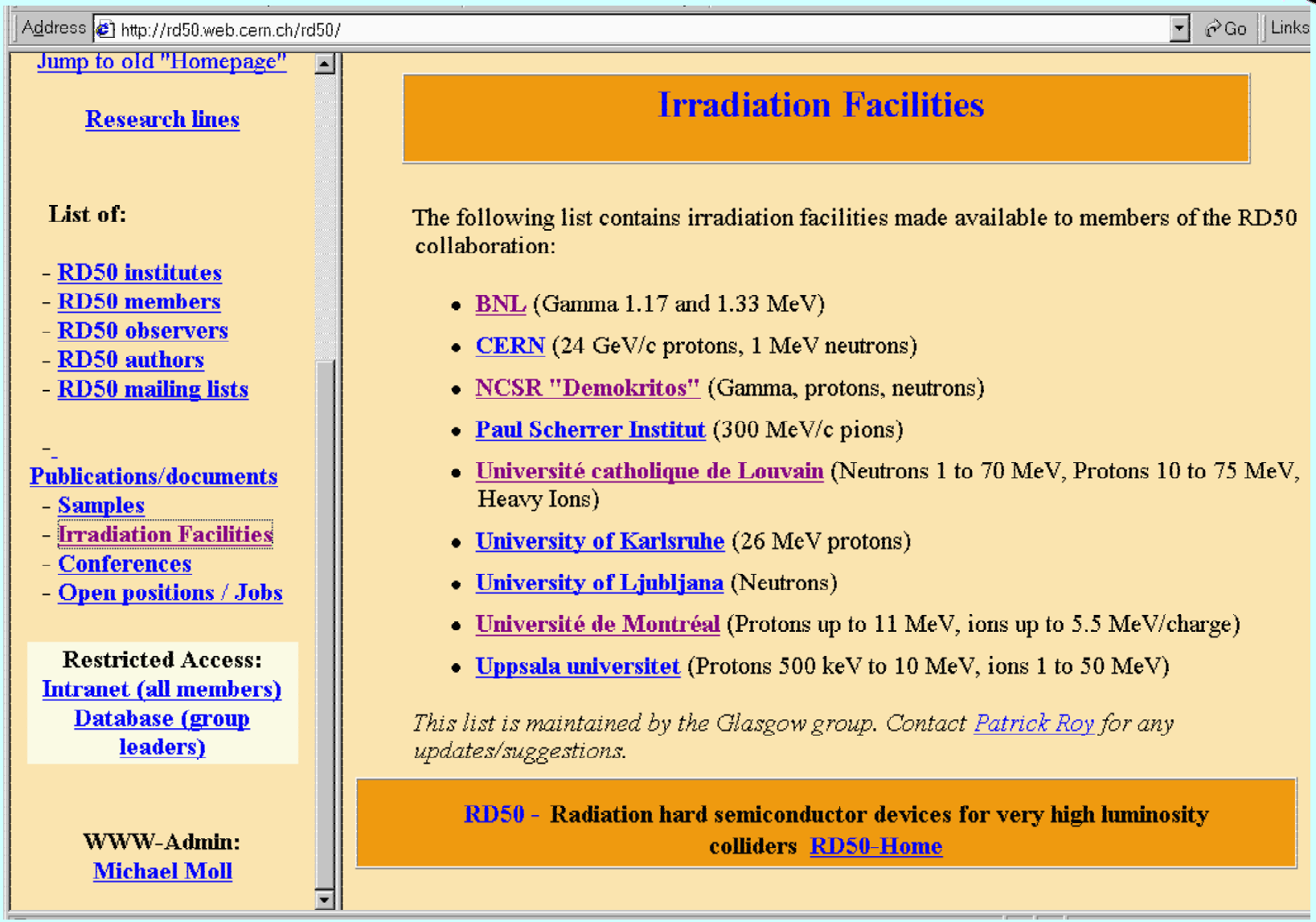
•Vias: 10 μm diameter
53.3 μm pitch



Conclusion

- **Working 3D test structures**
- **Results from irradiation:**
  - **-Pions**
  - **-Protons**
- **In development:**
  - **-pn junctions**
  - **-proper readout electronics**

Reminder


Address
http://rd50.web.cern.ch/rd50/
Go
Links
Jump to old "Homepage"
Research lines
List of:
- RD50 institutes
- RD50 members
- RD50 observers
- RD50 authors
- RD50 mailing lists
Publications/documents
- Samples
- Irradiation Facilities
- Conferences
- Open positions / Jobs
Restricted Access:
Intranet (all members)
Database (group leaders)
WWW-Admin:
Michael Moll
Irradiation Facilities
The following list contains irradiation facilities made available to members of the RD50 collaboration:
• BNL (Gamma 1.17 and 1.33 MeV)
• CERN (24 GeV/c protons, 1 MeV neutrons)
• NCSR "Demokritos" (Gamma, protons, neutrons)
• Paul Scherrer Institut (300 MeV/c pions)
• Université catholique de Louvain (Neutrons 1 to 70 MeV, Protons 10 to 75 MeV, Heavy Ions)
• University of Karlsruhe (26 MeV protons)
• University of Ljubljana (Neutrons)
• Université de Montréal (Protons up to 11 MeV, ions up to 5.5 MeV/charge)
• Uppsala universitet (Protons 500 keV to 10 MeV, ions 1 to 50 MeV)
This list is maintained by the Glasgow group. Contact Patrick Roy for any updates/suggestions.
RD50 - Radiation hard semiconductor devices for very high luminosity colliders RD50-Home