I-V & CCE Characterisation of Proton Irradiated 12 Micron Epitaxial GaN Detectors

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Outline

- Status of GaN as a radiation hard material
- New material + fabrication into detectors
- Material characterisation
  - I-V & CCE measurements
- CCE experimental set-up
- I-V & CCE results
- Conclusions & future work

Status of GaN

- SI GaN grown by MOCVD
- Epitaxial layer 2.5μm thick

Fluence (n/p/pions/x-rays)	Max CCE (%)	Voltage @ Max CCE
unirradiated	90	30V
600Mrad X-Rays	90	30V
10^{14}n	79	30V
10^{15}n	7	22V
10^{16}n	4	15V
10^{16}p	13	50V

[1] A.Blue

(4th RD50 Workshop)

➢ Increase statistics i.e. fabricate and irradiate more GaN detectors

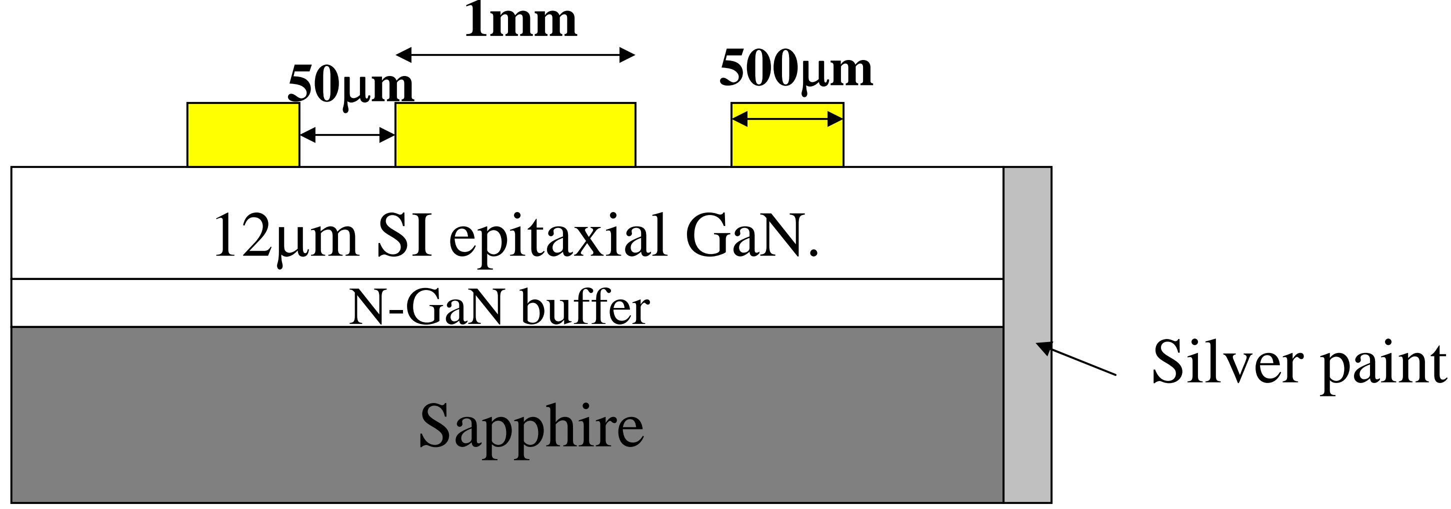
➢ **Need thicker material to increase amount of charge generated and (hopefully!!) collected.**

New Material

- Non doped n-type GaN epilayer of 12 micron thickness grown by MOCVD on sapphire using n-GaN buffer (Lumilog Ltd.) ⇨ 1 wafer (2inch)
- Non doped n-type GaN epilayer of 2.5 micron thickness grown by MOCVD on sapphire using n-GaN buffer (Tokushima University) ⇨ 3 wafers (2inch)

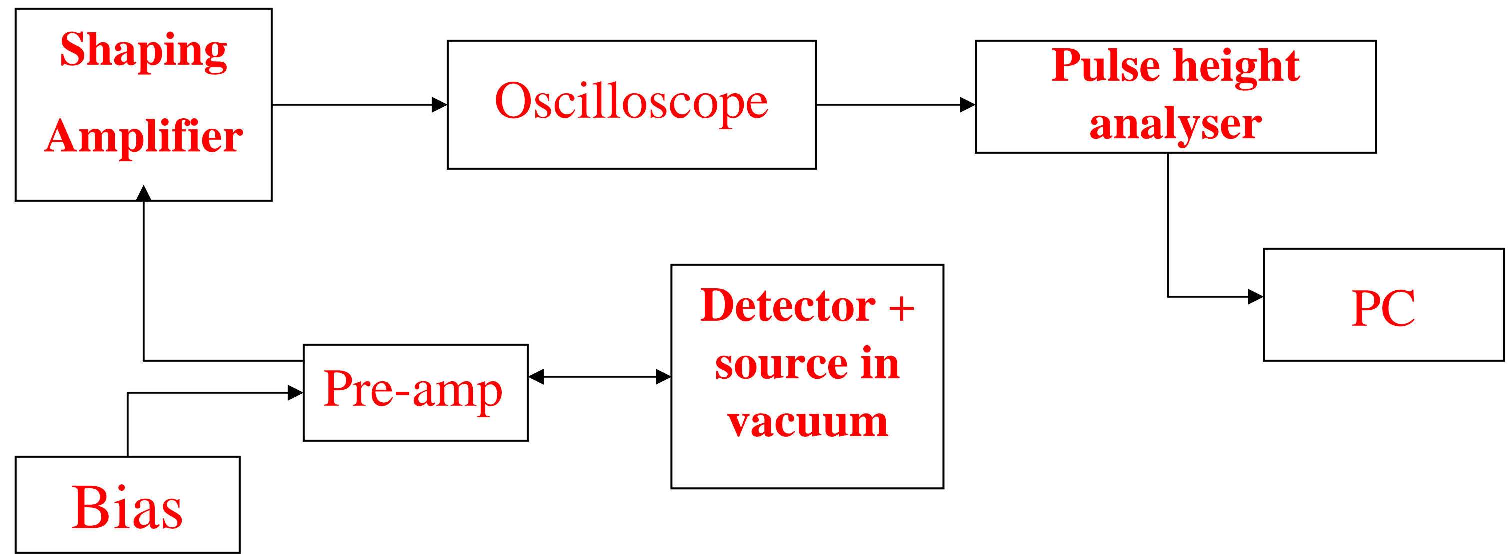
Detector Fabrication

- Fabricated pad/guard ring structures using photolithographic techniques
- Samples 10mm by 5mm. Two Pad/guard ring structures per sample.
- Pad 1mm diameter. 50µm spacing between pad and guard ring. Guard ring 500µm thick
- Deposited 200nm Pd to make Schottky contact. 200nm Au on top of this to make bonding easier.
- Somehow needed to make a contact with buffer layer.
- Coated side of material with silver paint.



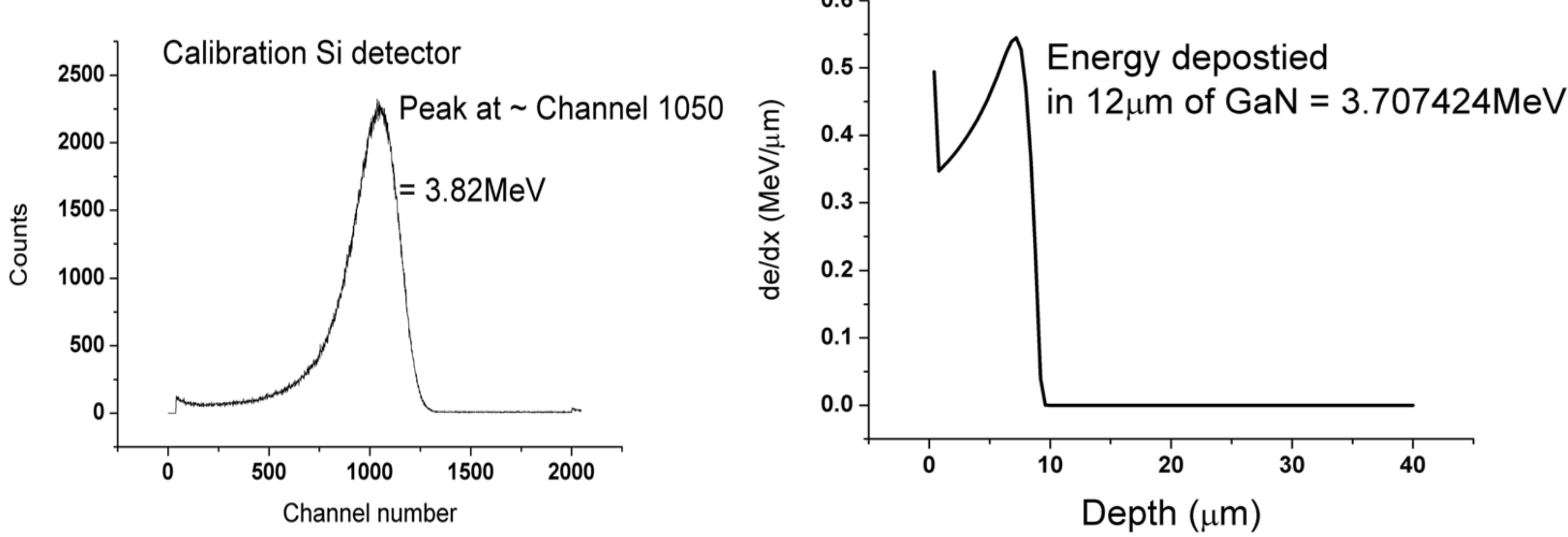
Detector Characterisation

- Detectors characterised pre- and post- irradiated by performing
  - I-V measurements using a Keithley 237 measurement unit
  - CCE measurements using 5.48MeV α particles from an ^{241}Am source
- Detectors left in dark for ~ 2hours before performing I-V's.



CCE Measurement

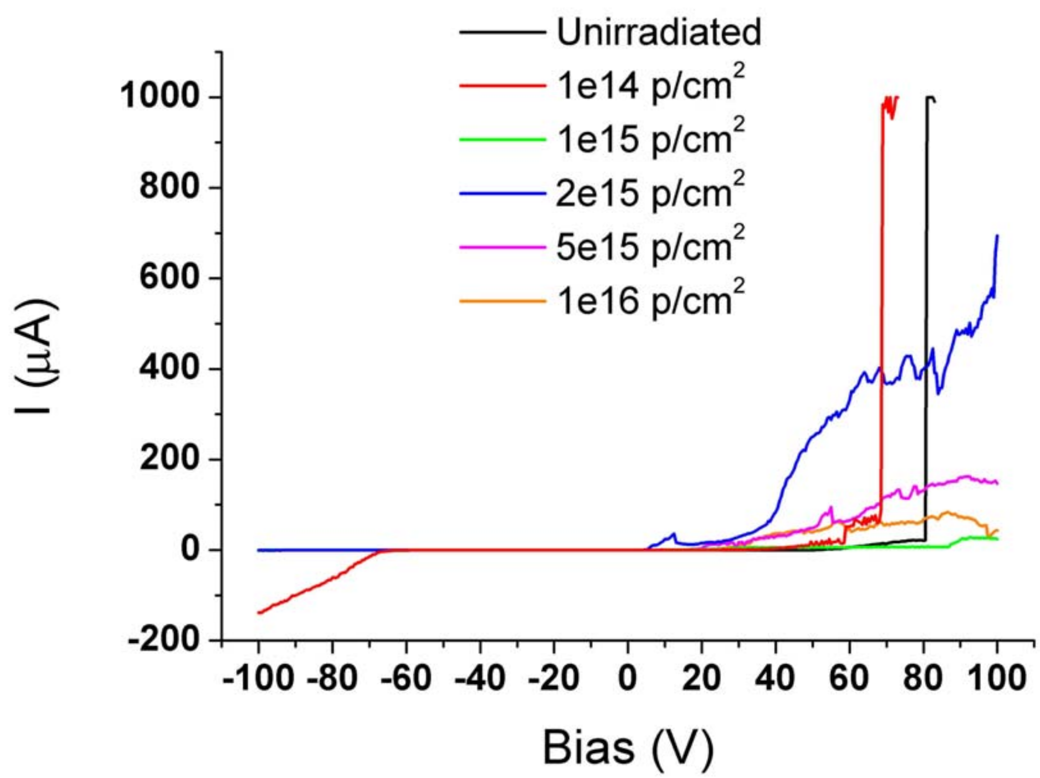
- Calibrate set-up using a Si detector assumed to have 100% CCE
- From observed spectrum (below left) the energy of the α particles emitted from our americium source is taken to be 3.82MeV
- Then use SRIM simulation (below right) to calculate the amount of energy that should be deposited by an α particle with incident energy of 3.82MeV in 12μm of GaN.
- Found to be 3.707MeV



Irradiations Performed

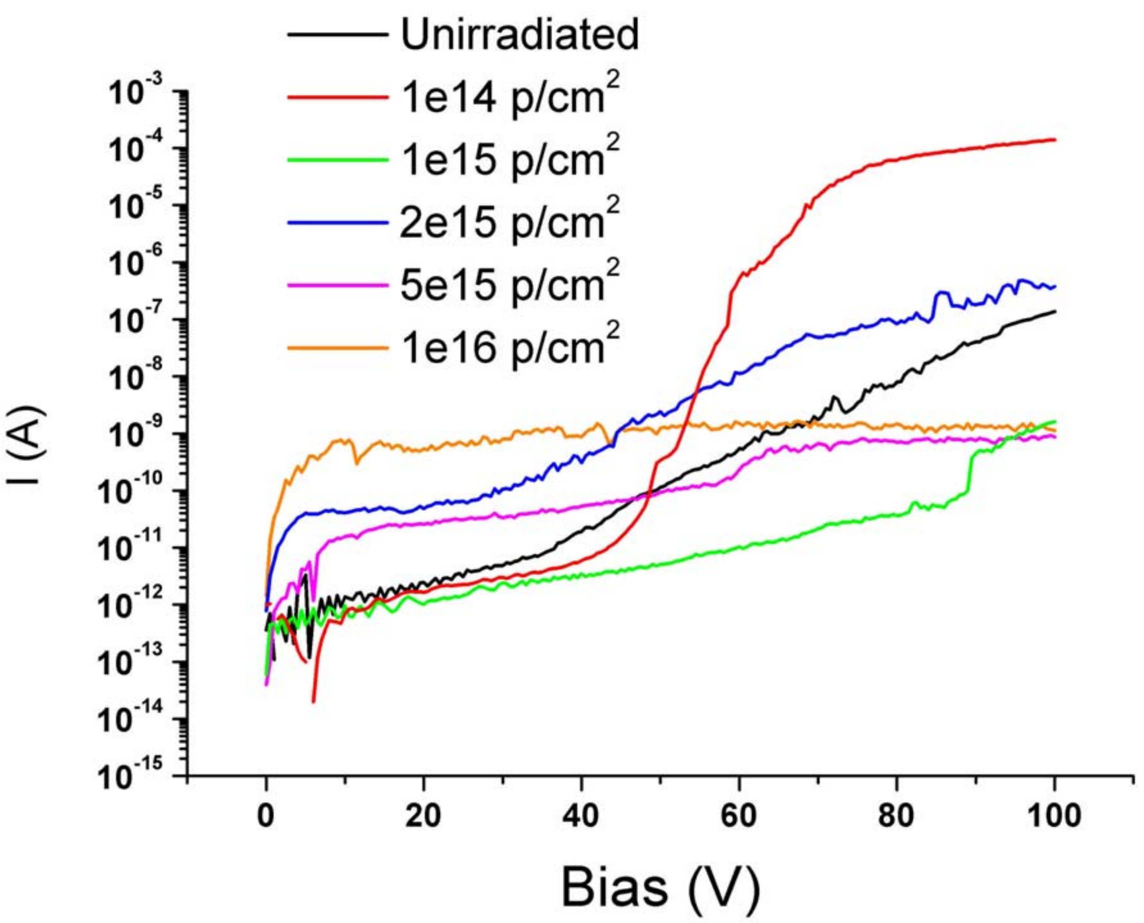
- Detectors irradiated with 24GeV/c protons at CERN
- 5 samples from each wafer = 20 samples irradiated.
- Detectors irradiated to fluences:
  - 1 $x10^{14}p/cm^2$
  - 1 $x10^{15}p/cm^2$
  - 2 $x10^{15}p/cm^2$
  - 5 $x10^{15}p/cm^2$
  - 1 $x10^{16}p/cm^2$
- Detectors stored at –20°C after irradiation
- I-V/CCE Characterisation of 12µm epitaxial GaN done first

I-V's of p Irradiated 12μm GaN



- Detectors show Ohmic/Schottky behaviour
- Following slide shows I-V curves for –ve bias in more depth

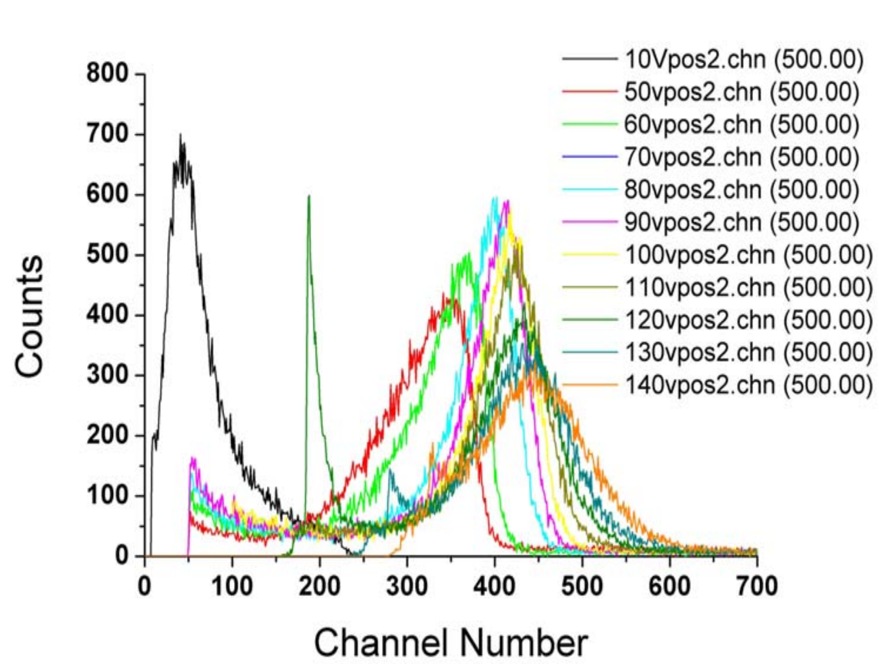
I-V curves (-ve Bias only)

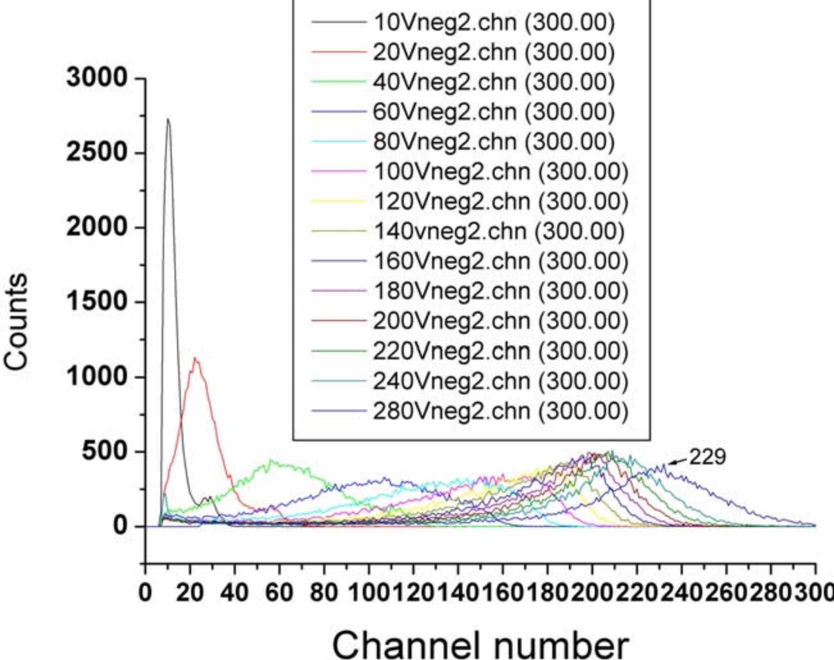


- -ve Bias applied

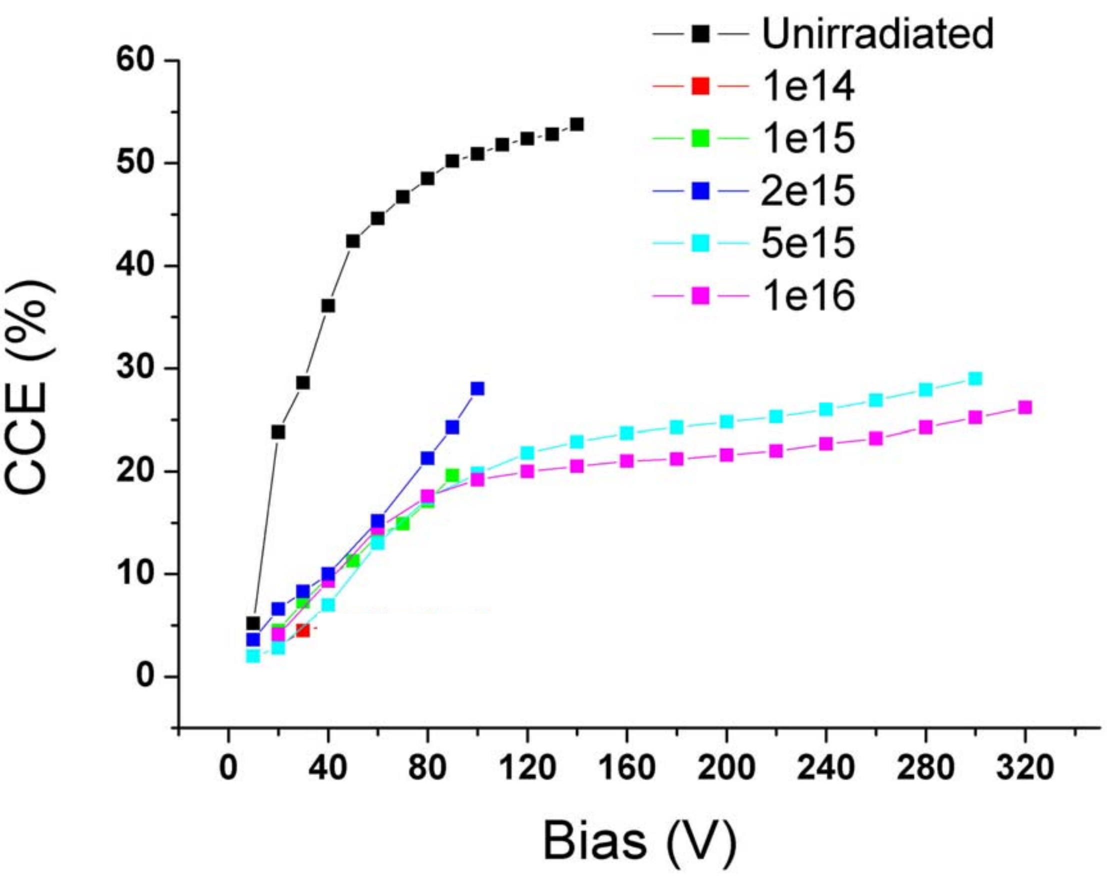
CCE Spectra

- Spectra from an unirradiated detector shown on the left and from the detector irradiated to $5e^{15}$p/cm^2 on the right





CCE Plots



Comparison

Material	D (μm)	Fluence (n/p/pions/cm^2)	CCE_{max} (%)	V@CCE_{max}
SiC [1]	100	unirradiated	60	650V
SiC [1]	100	10^{13}pions	50	600V
FZ Si [2]	50	4.5×10^{14} 1MeV n/cm^2	100	75V
FZ Si [2]	50	8.1×10^{14} 1MeV n/cm^2	100	200V
GaN	12	unirradiated	55	130V
GaN	12	1016p/cm2	25	320V

[1] W.Cunningham et al. (4th RD50 workshop, CERN)

[2] M. Bruzzi et al. (5th RD50 workshop, Florence)

Conclusions + Future Work

- Fabricated detectors on 12µm epitaxial GaN
- Unirradiated detector shows a CCE of ~55%
- After irradiation to 10^{16}p/cm^2 CCE drops to ~26 %

- For the future: Irradiate some 12µm epitaxial GaN with neutrons (also irradiate some 2.5µm epitaxial GaN detectors) at varying fluences.
- ICP etching of 12µm epitaxial GaN. Make a ‘proper’ contact to the buffer layer