ΔOSI: A Prototype Microstrip Dosimeter for Characterisation of Medical Radiotherapy and Radiosurgery Systems

PPARC & Department of Health fund ΔOSI

- What do we want to measure and why?
- Device description
- Beam tests at Weston Park Hospital, Sheffield

NHS Sheffield
Sheffield Teaching Hospitals NHS Trust
University of Glasgow
CCLRC
electron tubes
MICRON SEMICONDUCTOR ltd

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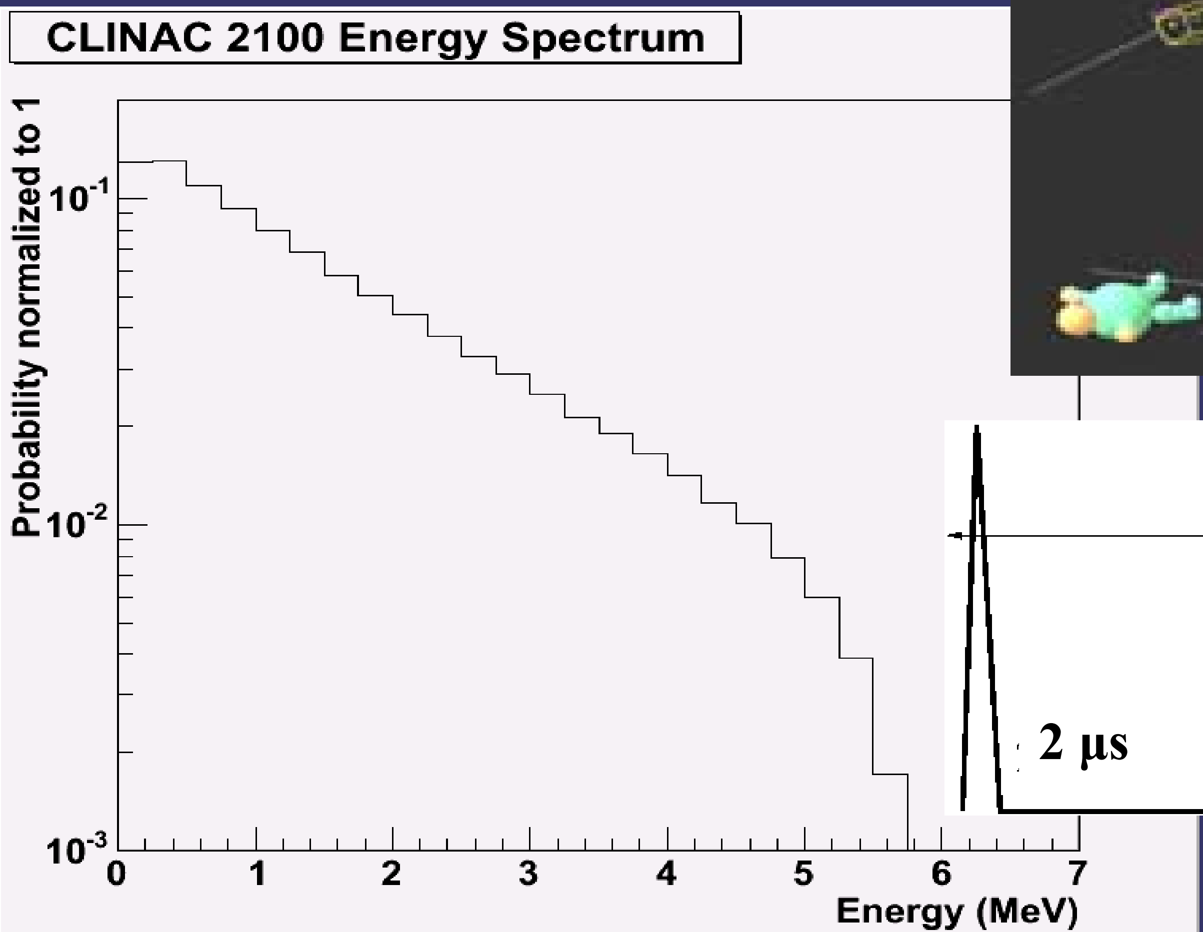
University of Glasgow

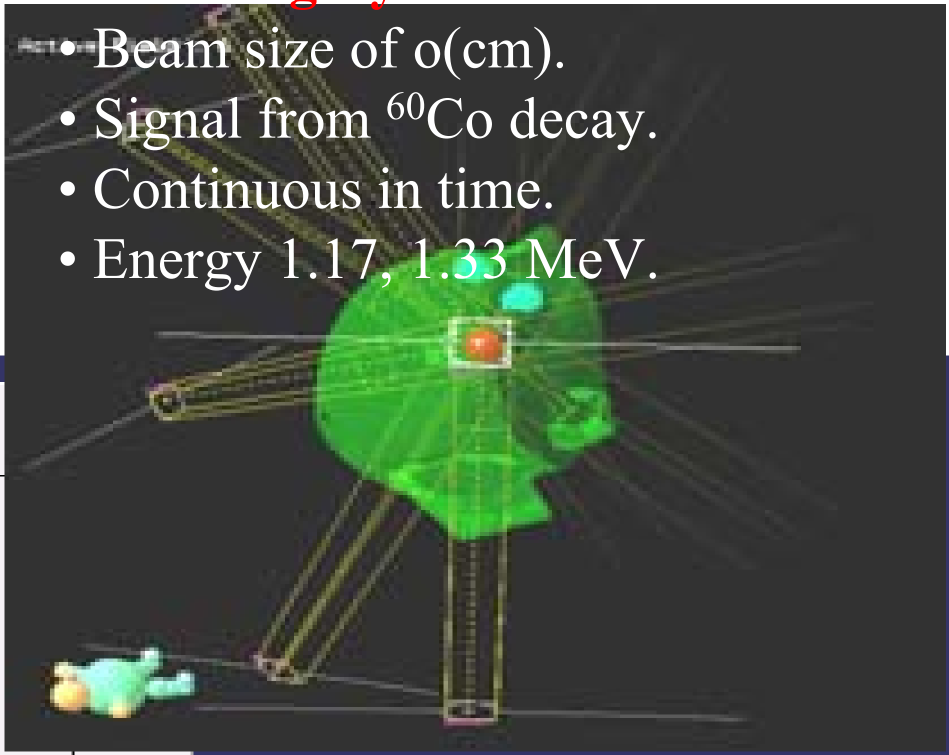
IMRT with Clinical Linac Beams:

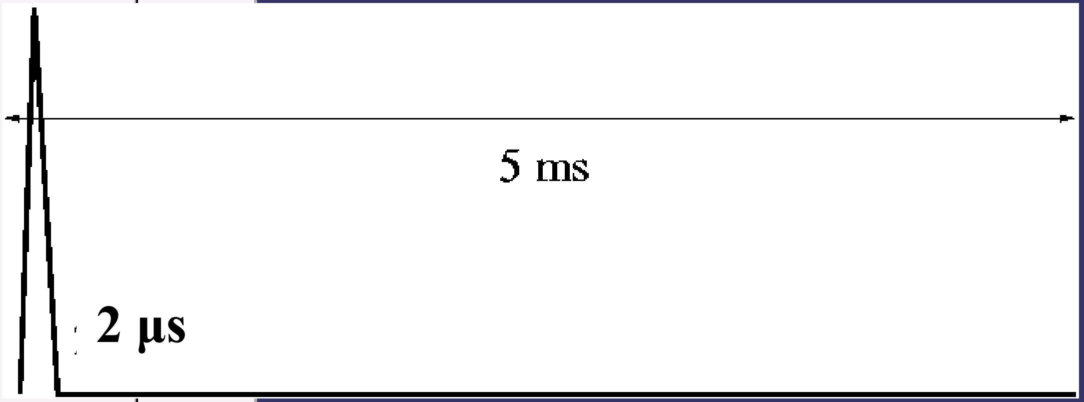
- Beam size of o(few cm).
- Photons from bremstrahlung .
- Pulsed signal: 50-300 Hz.
- Max. Energy 4-25 MeV.
- Speed of MLC leafs o(cm/s)

Radiosurgery with Gamma Knife:

- Beam size of o(cm).
- Signal from ^{60}Co decay.
- Continuous in time.
- Energy 1.17, 1.33 MeV.

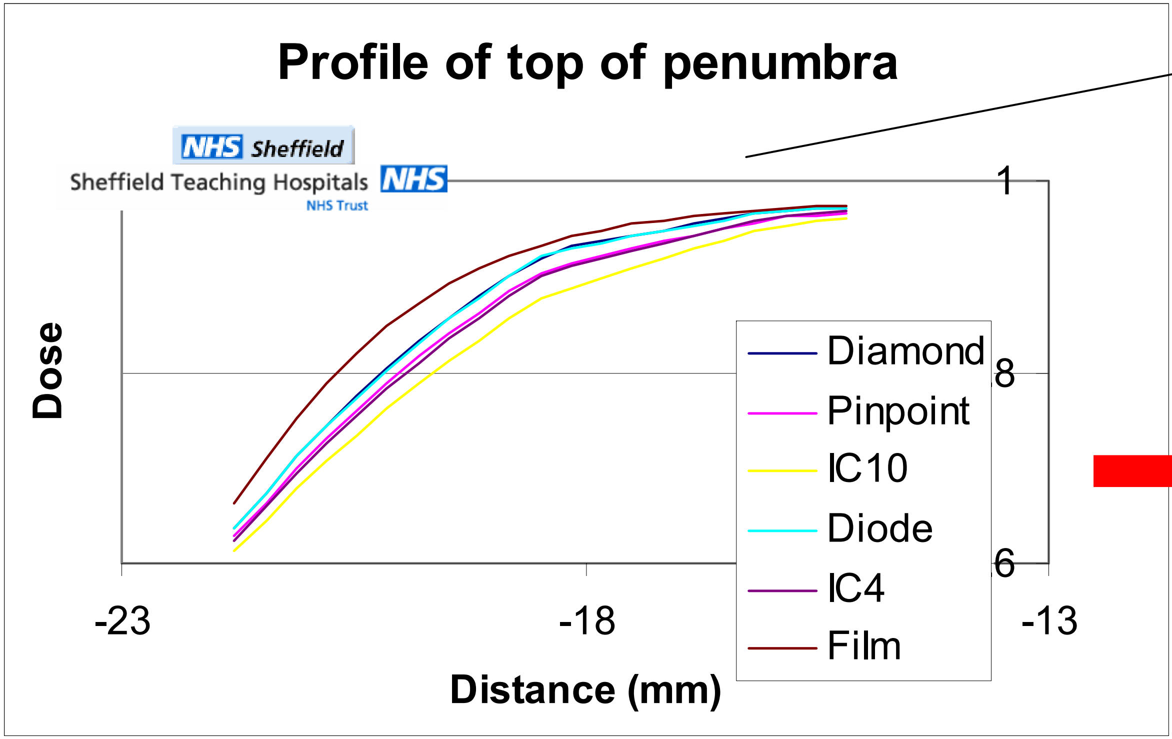


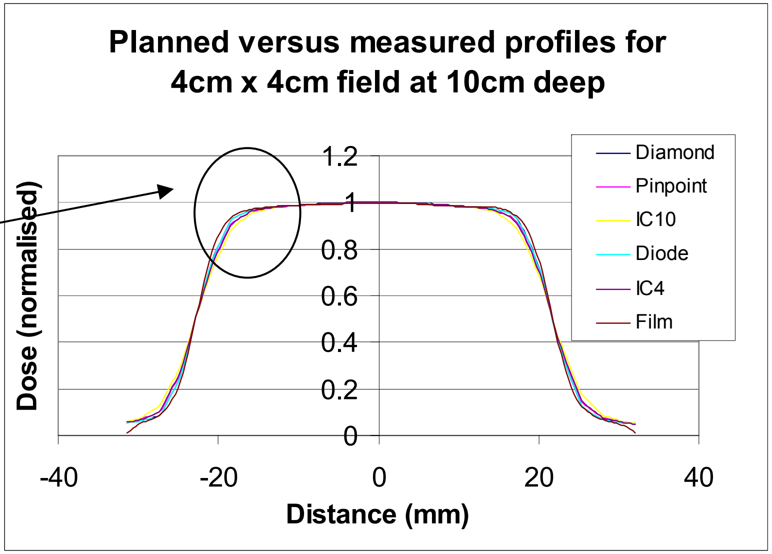




Large dose gradients & small fields (4-40 mm)

Example of measurement of a high dose gradient using different dosimeters





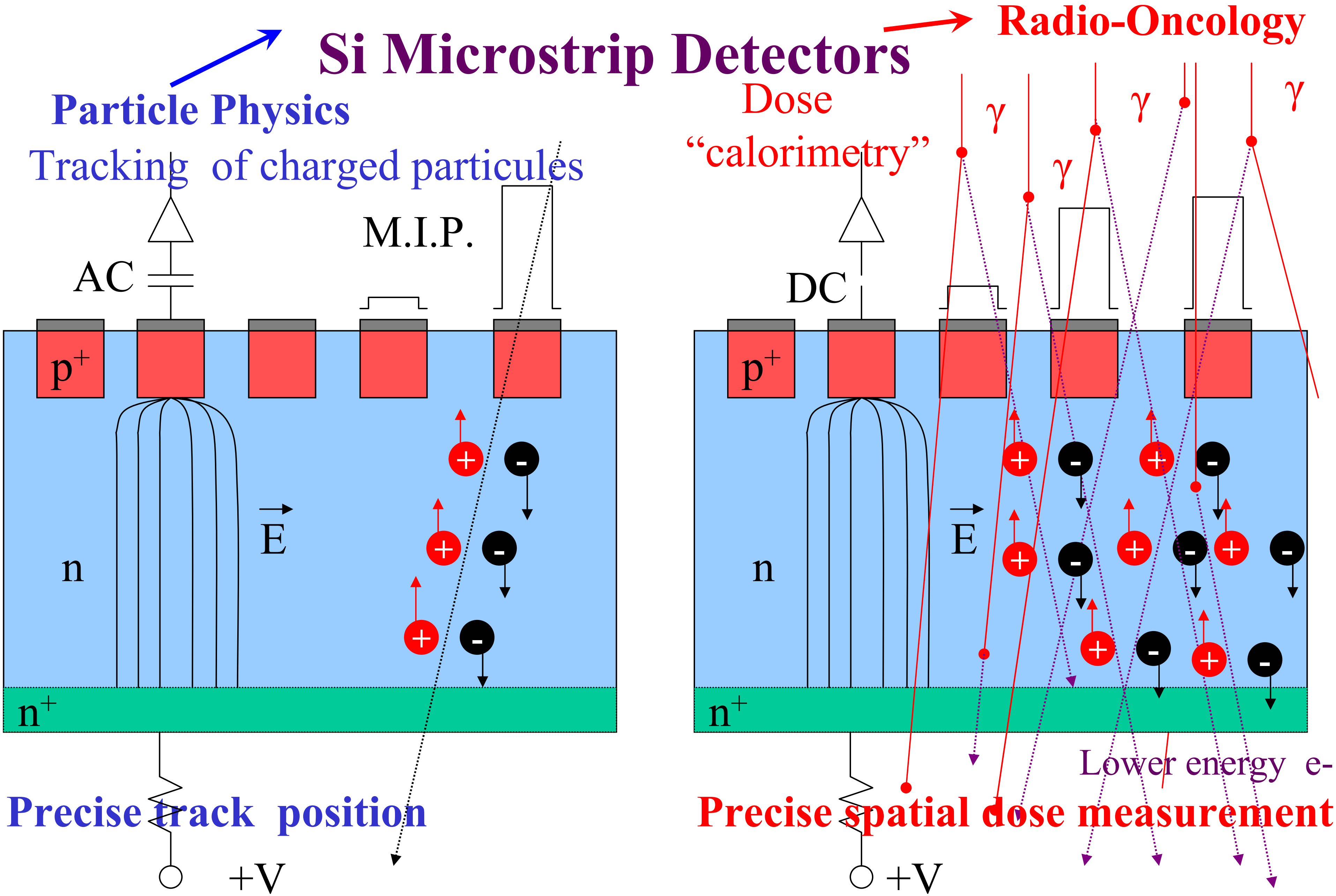
Planning system prediction depends on the accuracy of this measurment

- Film is best...but it is film.
- Scanning devices not appropriate for dynamic measurements.
- EPIDs not suitable for phantom work

ΔOSI goals:

- To develop devices to be used for commissioning of IMRT and Radiosurgery
- To develop both 1D and 2D silicon detector arrays that provide spatial resolution comparable with film dosimetry and provide simultaneous direct readouts of all channels

Si Microstrip Detectors



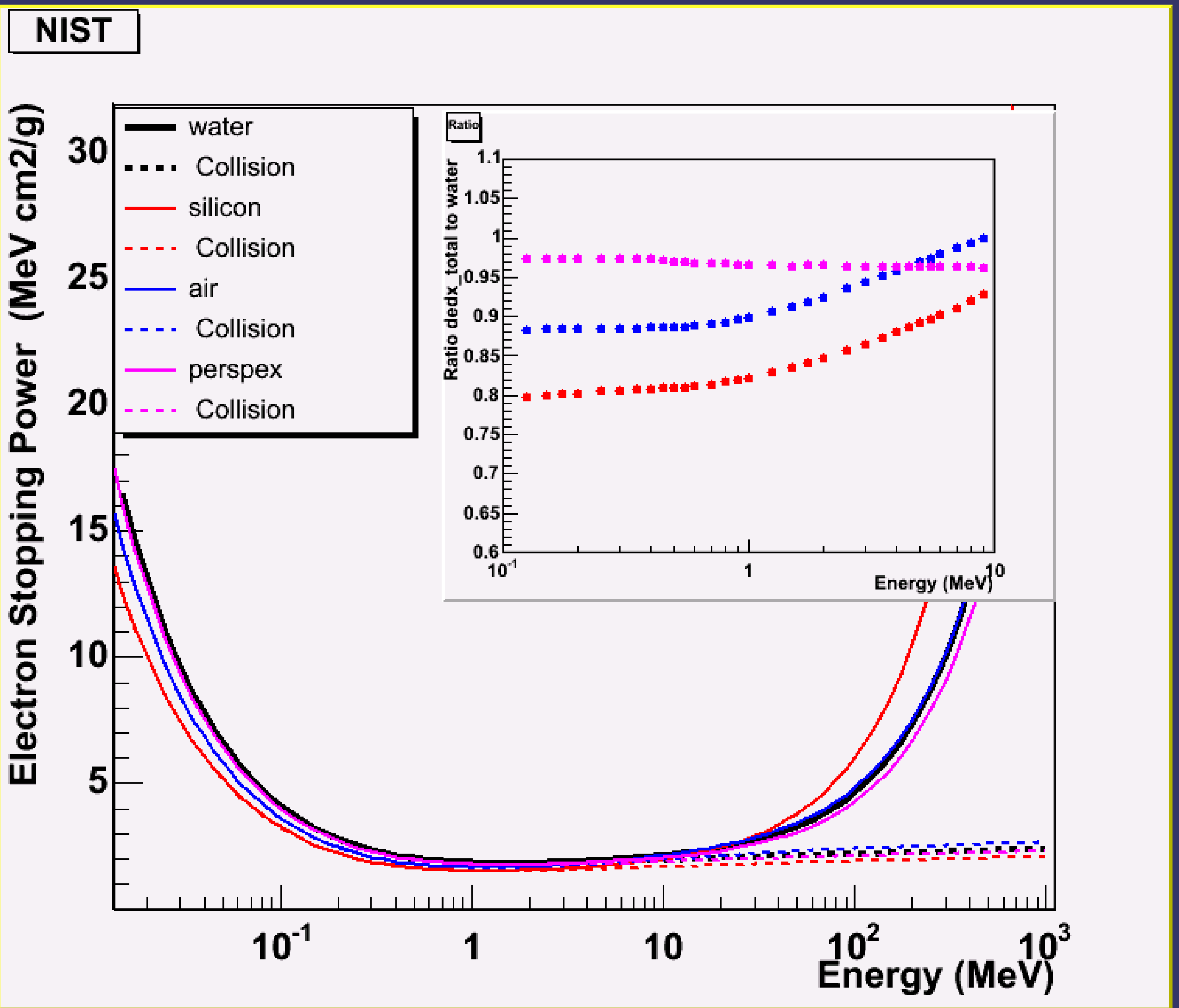
Created charge is a good measure of dose (deposited energy).
Dosimetry is not imaging

Pre-iradiated p-type is industry standard for in vivo diodes because:

- Lower sensitivity degradation rate,
- n-type lose linearity after irradiation

Rikner&Grusell 1987

How tissue equivalent is Si?



Most of the ionization comes from compton interactions in tissue, outside the Si

...although diamond would be best

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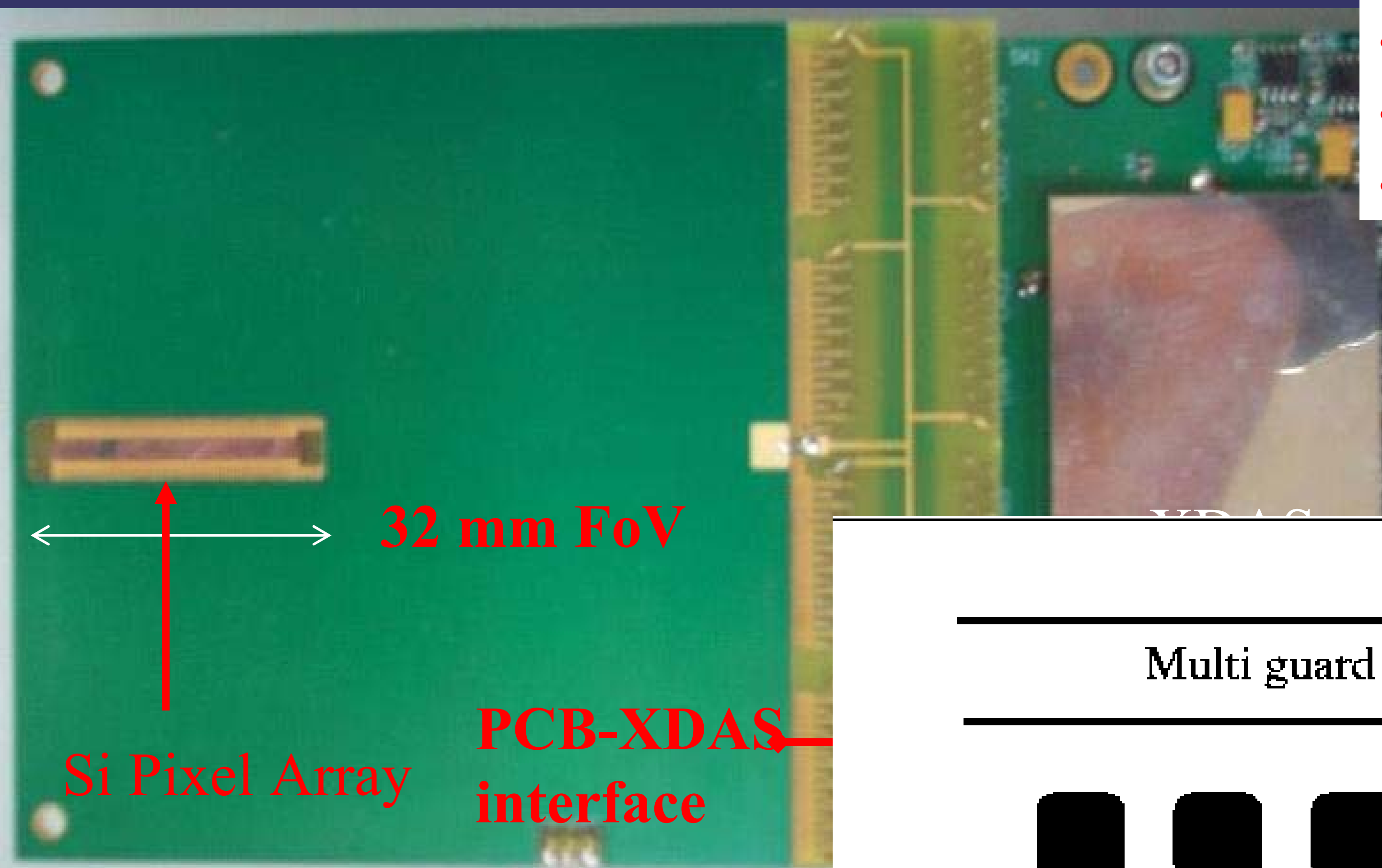
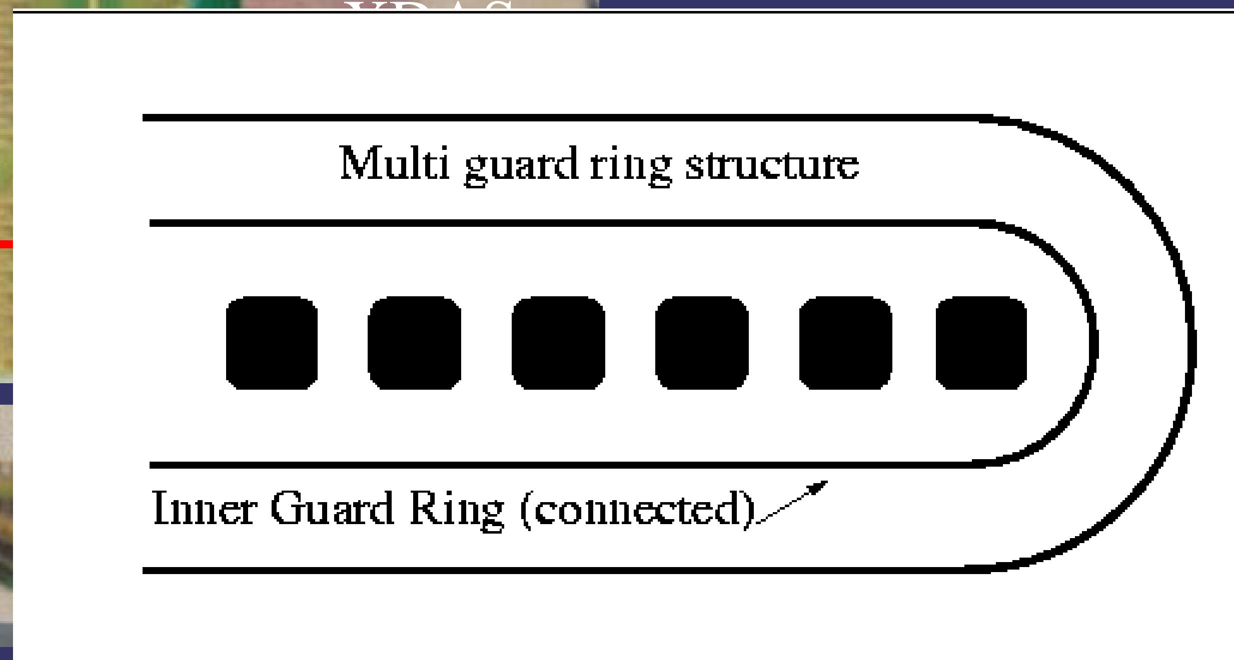
ΔOSI IMRT Prototype: 1d-Pixel Array

MICRON SEMICONDUCTOR ltd

- Single crystal n-Si
- 128 channels (1 x XDAS)
- Area = 32 mm x 0.2 mm
- 0.25 mm pitch
- 0.2 mm x 0.2 mm pixel size



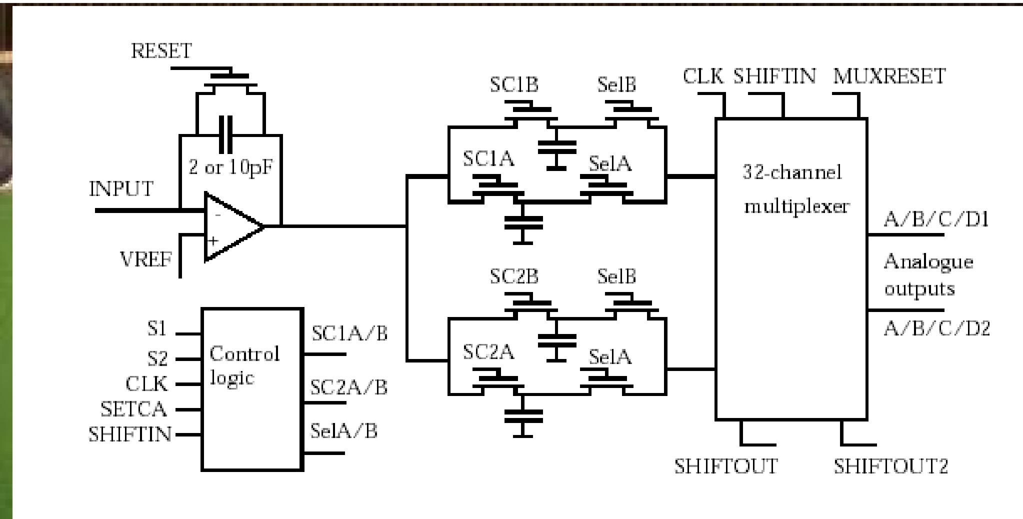
Thin encapsulated detector easy to

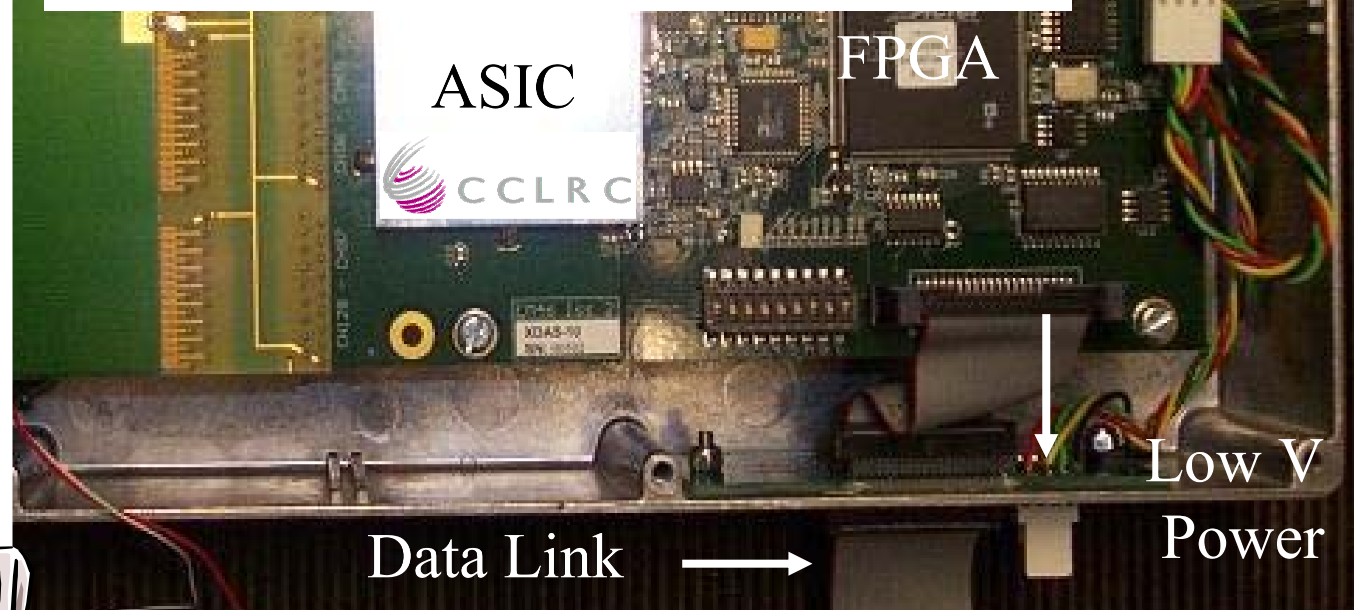


XDAS Data Acquisition

XDAS spec's

- 128 channels
- Q_{max} = 15 pC/3 pC
- t_{int} (min) = 10 μs
- t_{int} (max) = 10 s
- t_{dead} = 1 μs
- 14 bit ADC
- $t_{digitization}$ = 100 μs
- S/n = 30000
- 5 Mb/sec
- 1000 frames/sec
- Average until 256 events
- Modular (x 64 boa





PC disc

- Parallel port
- PCI card
- NI framegrabber

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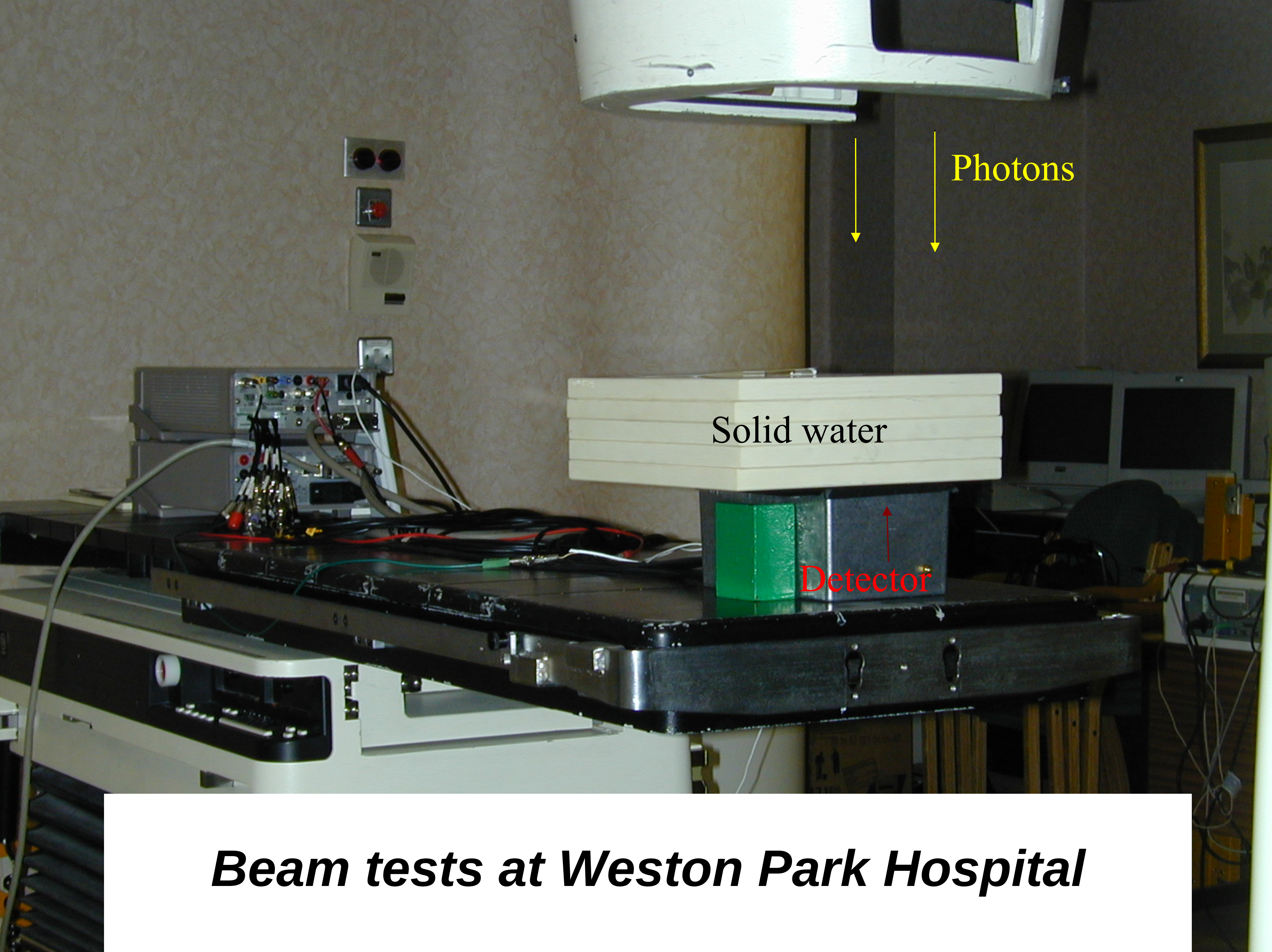


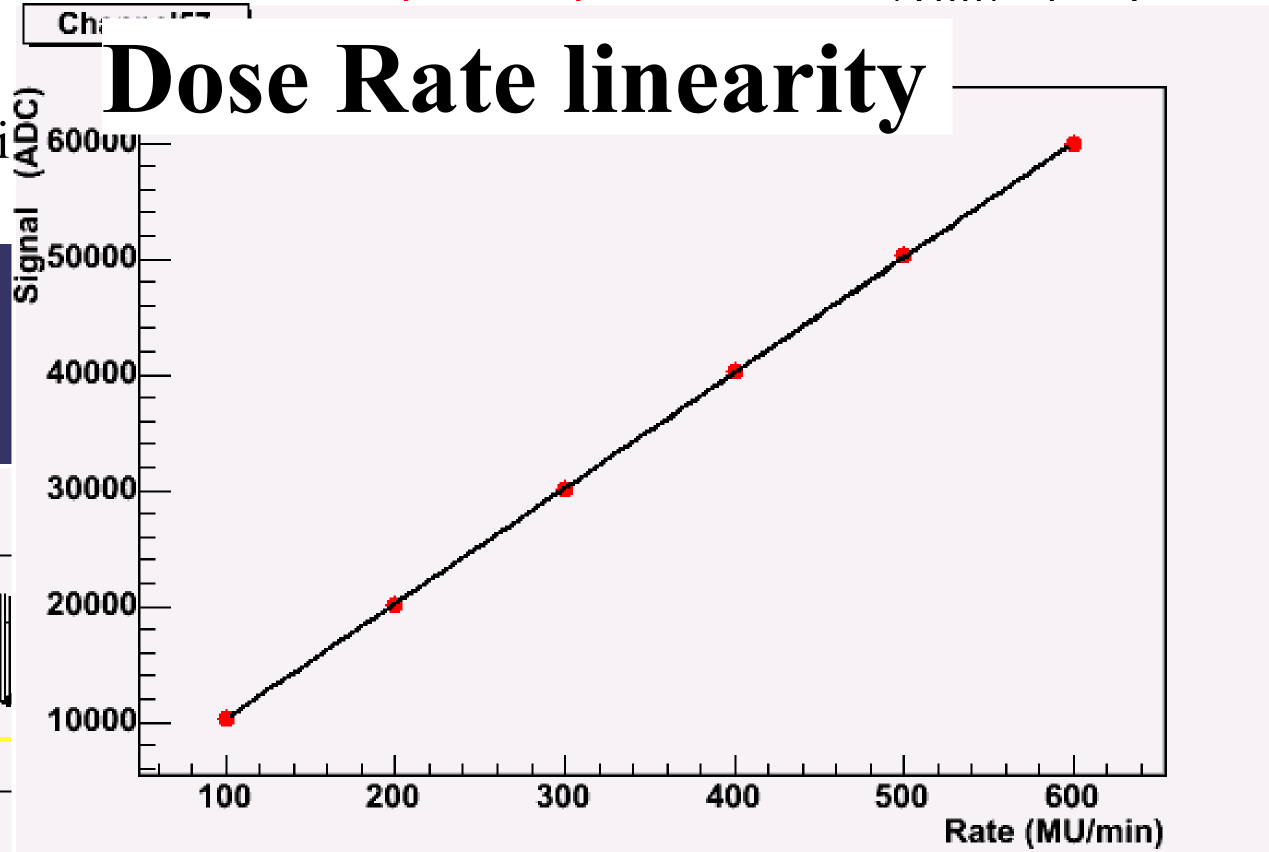
Beam tests at Weston Park Hospital

At Hospitals, in vivo diodes are typically operated unbiased and

Advantages:

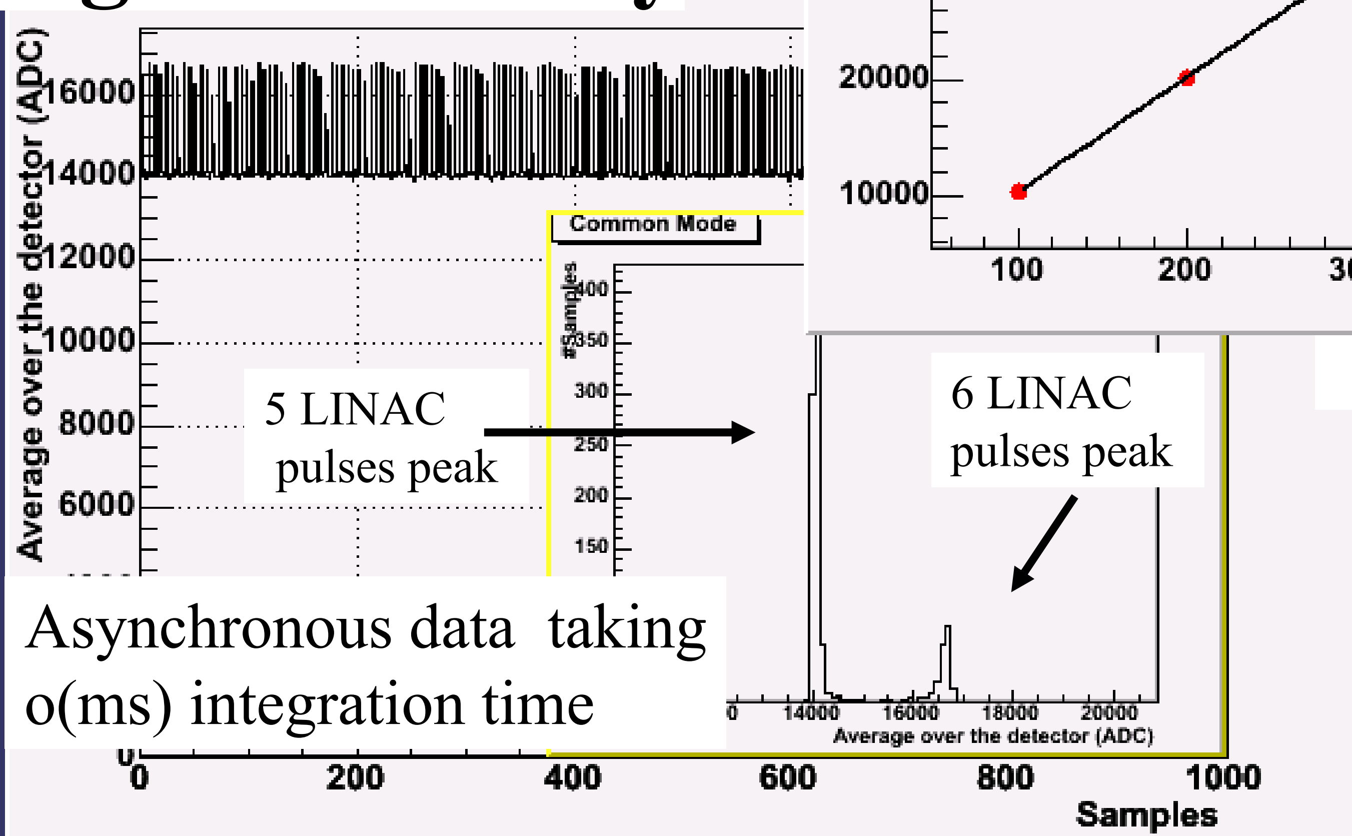
- No need to get the trigger signal whi
- No extra power supply

Dose Rate linearity

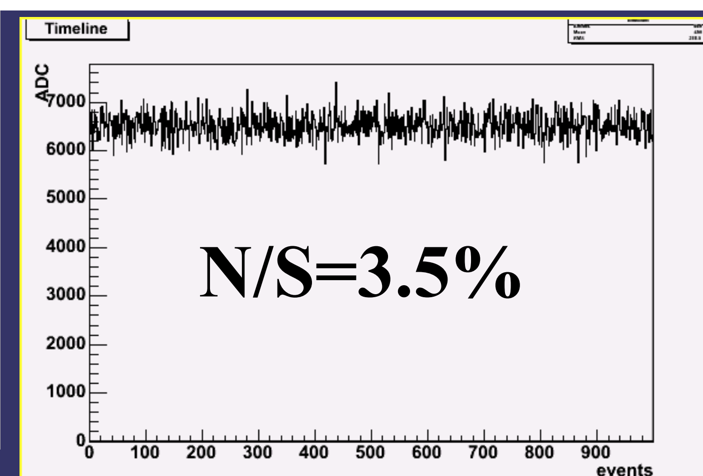


(XDAS minimum)

Signal Stability



Asynchronous data taking
o(ms) integration time



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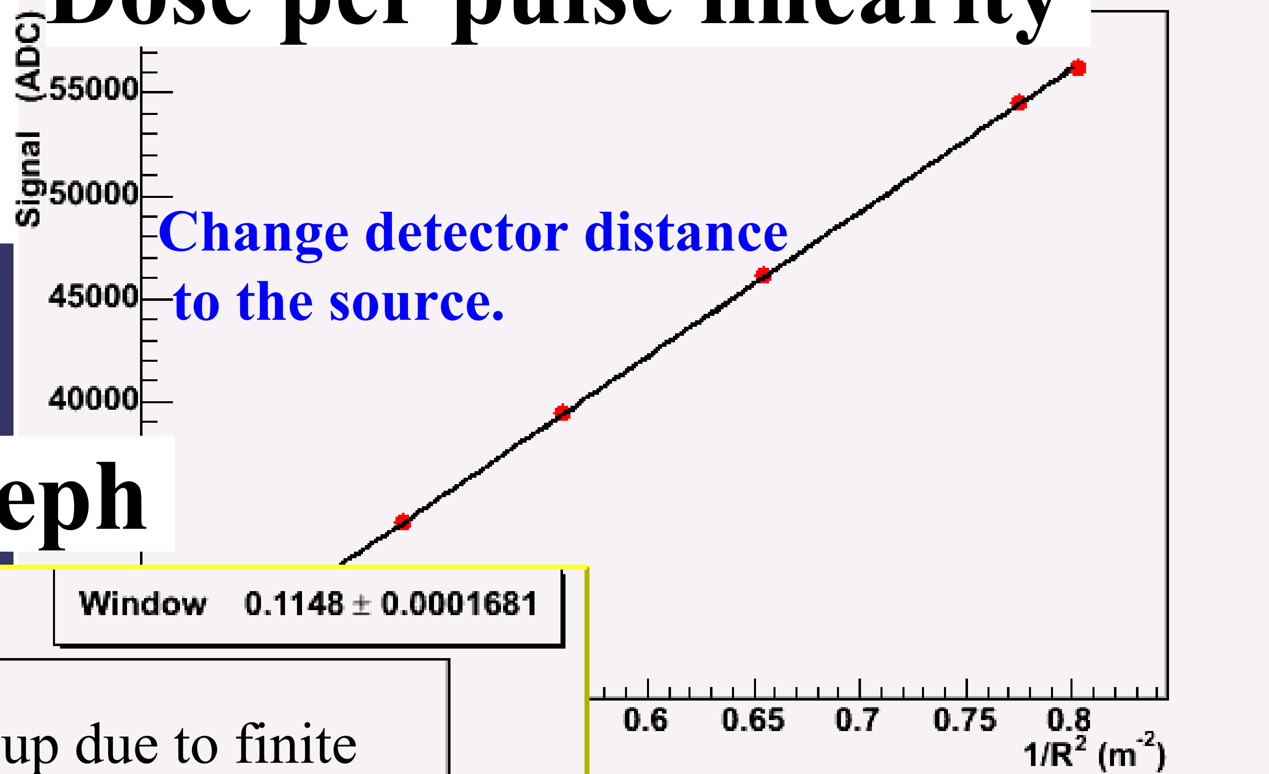
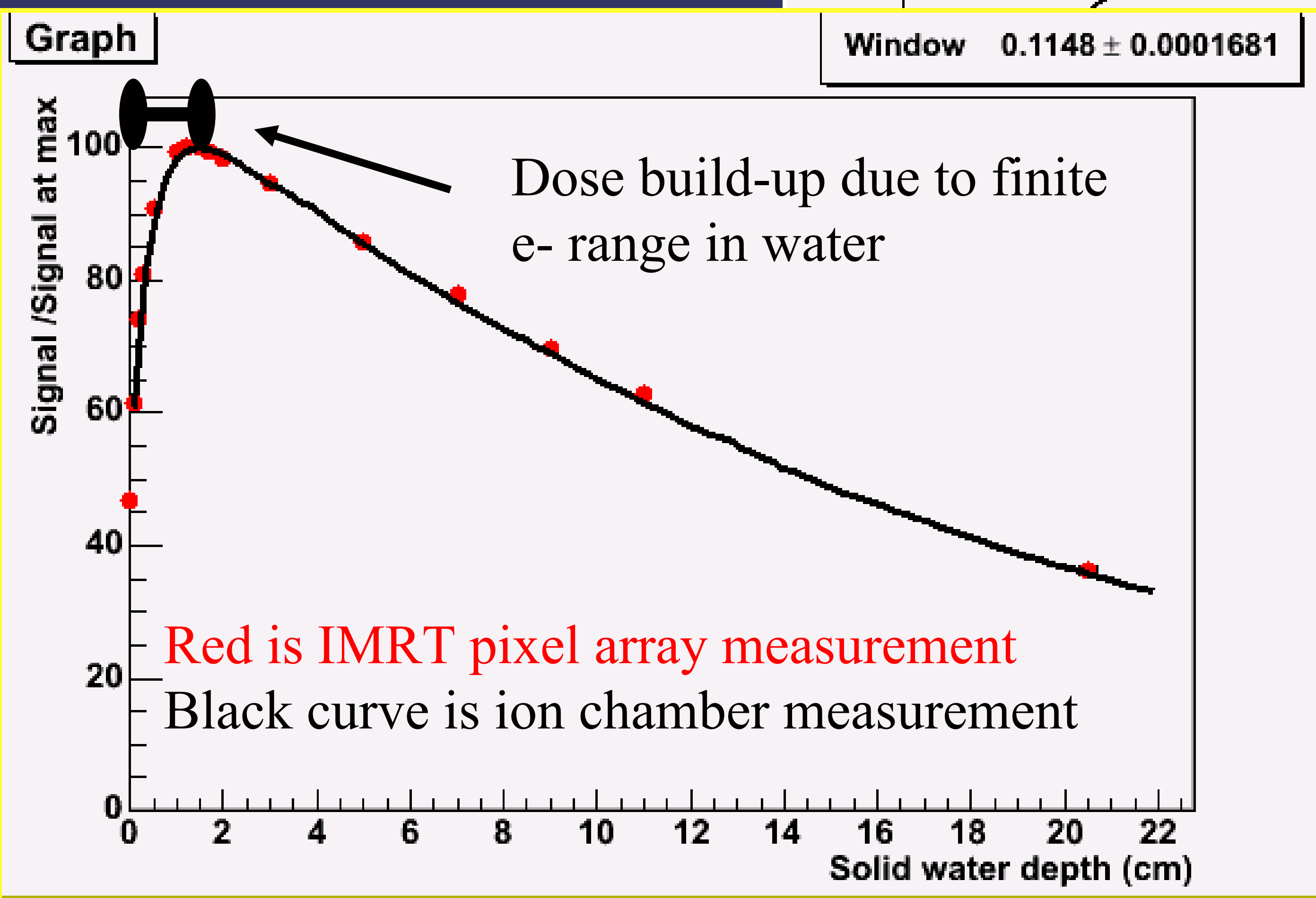
Dosimetry

Dose per pulse linearity



Percentage Dose Deph



Change build up in front of the detector and compare to ion chamber data .

Allow for depth shift to account for window

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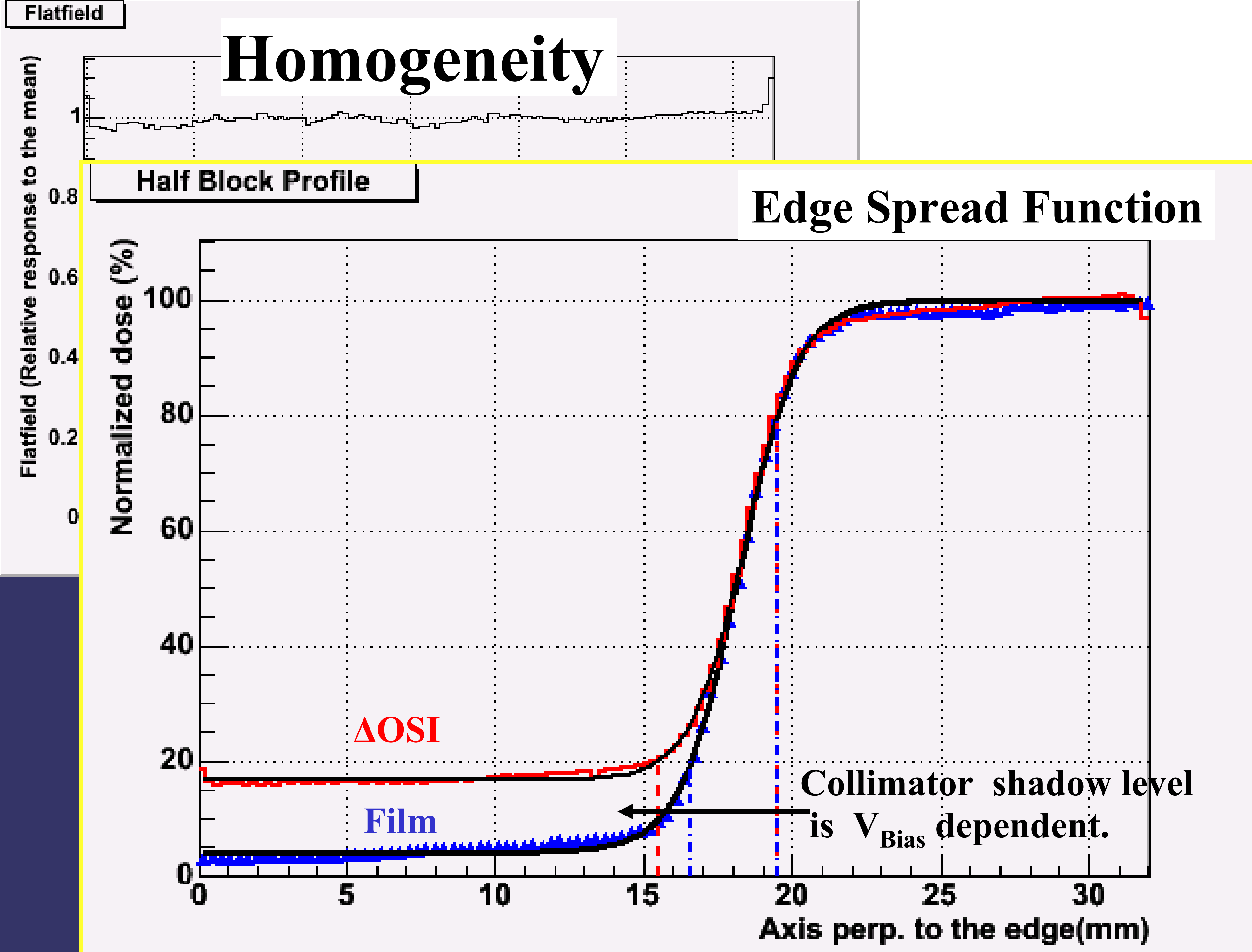
Homogeneity

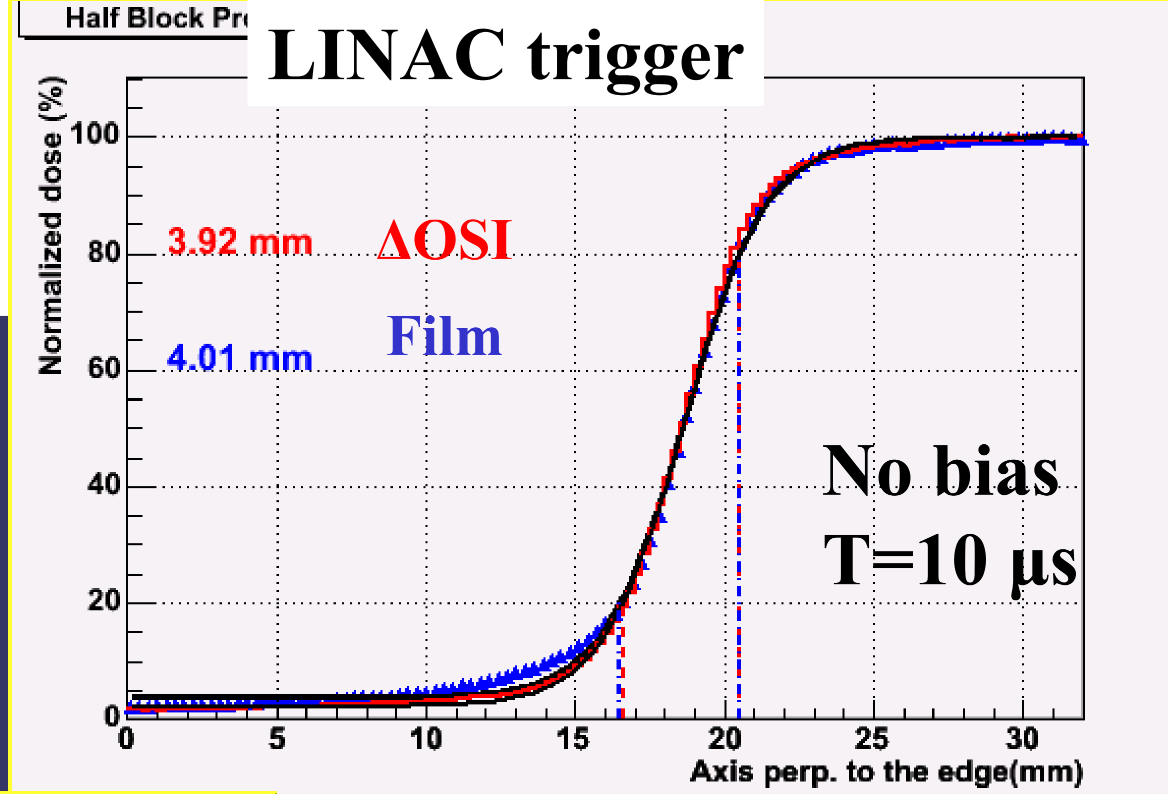
Edge Spread Function

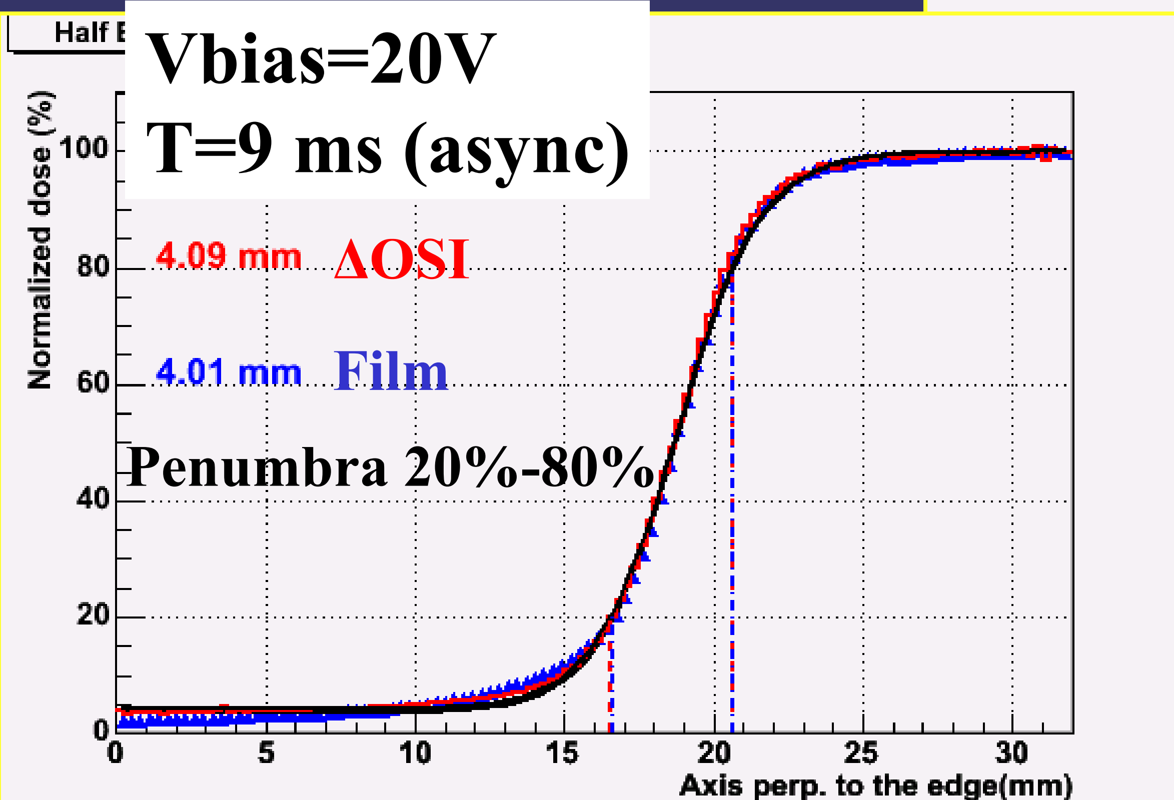


Two solutions

Increase Vbias

Trigger





Get rid of the diffussion tail by integration of the begining of the pulse only

Film-like spatial resolution ...without scanning

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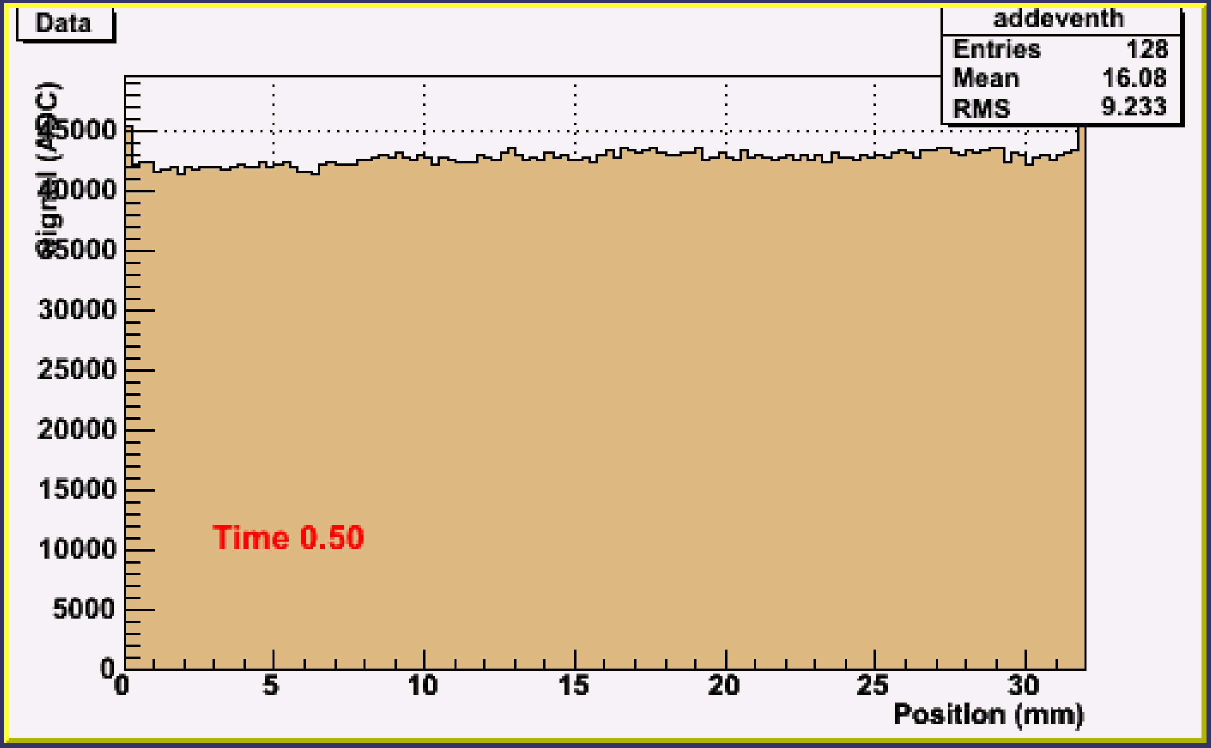
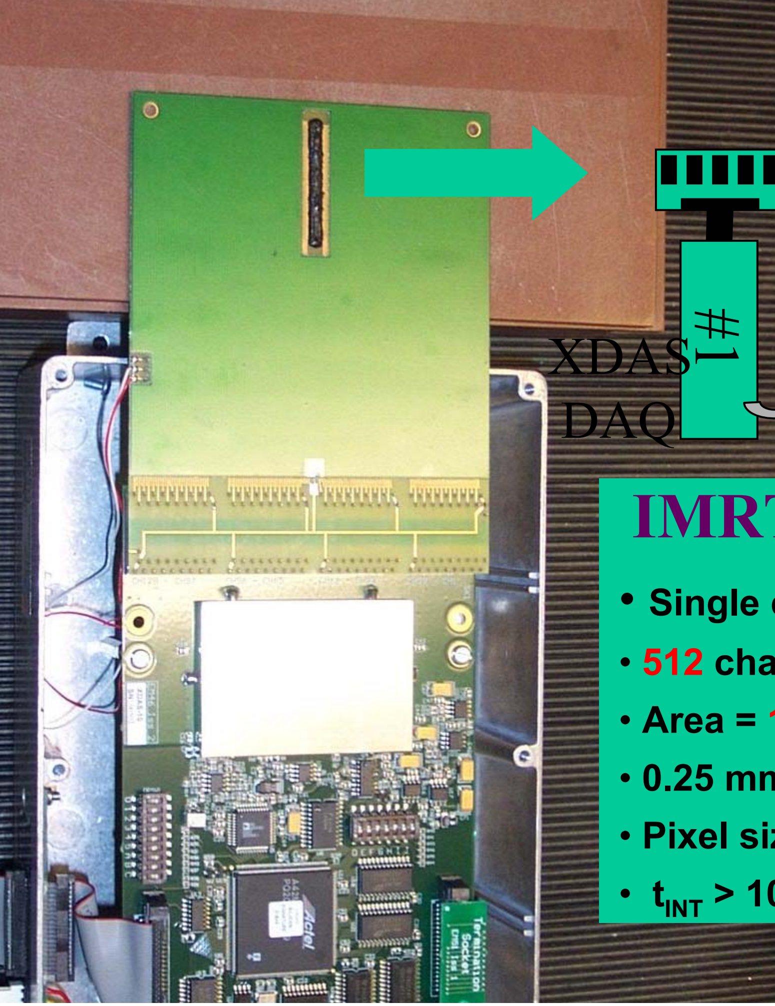
Dynamic Wedge



Online dose measurement with film-like spatial resolution

Projects



IMRT pixel array

- Single crystal n-Si
- 512 channels (4 x XDAS)
- Area = 128 mm x 0.2 mm
- 0.25 mm pitch
- Pixel size 0.2 mm x 0.2 mm
- t_{INT} > 10 msec

SRS/IMRT 2d pixel detector

- Single crystal n-Si
- 22 x 22 channels (4 x XDAS)
- Area = 22 mm x 22 mm
- 1 mm pitch
- SRS (IMRT): 0.9(0.2) mm x 0.9(0.2) mm pixel size
- SRS (IMRT): t_{INT} > 0.01 (10) msec

SUMMARY

- Good dose per pulse linearity
- Dose vs rate linearity

→ **Dosimetry**

- Homogeneous and stable response

→ **Film-like penumbra**

covering whole field of view

Dynamic measurements

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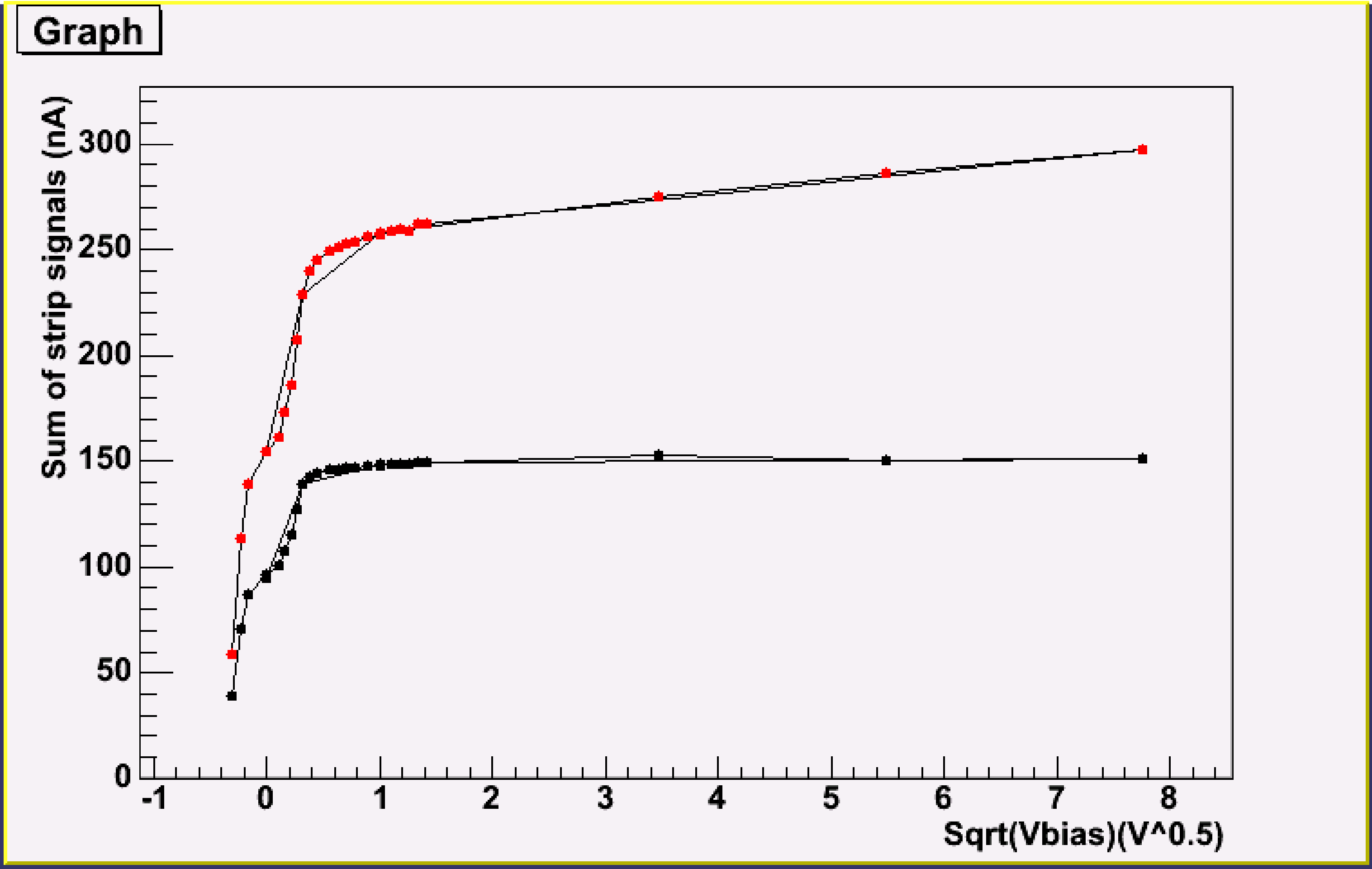
- How do these radiation detectors compare for measuring radiotherapy beams?

DETECTOR	APPLICATION	VOLUME (cc)	Smallest dimension (mm)
Ion chambers (Farmer)	Radiotherapy Calibration	0.6	7.0
Ion chambers (sealed)	Radiotherapy beam scanning	0.14	6.0
Pin-point chamber	Radiosurgery	0.015	2.0
Diamond	Radiotherapy beam scanning	1.8×10^{-3}	0.26
Diode	Radiotherapy beam scanning	0.3×10^{-3}	0.06
Film	Quality Assurance & Verification	10^{-6}	0.10
ΔOSI 1d pixel array	Facility Commisitioning &...	0.02	0.25

What is inadequate with the present technology? <u>IFs and BUTs</u>

- Film has the best spatial resolution and field of view – but film is unreliable and requires processing and scanning
- Small ion chambers have poor signal/noise
- Scanned single detectors can provide high resolution dose maps – but are unsuitable for dynamic MLC beams
- Electronic Portal Imaging Devices (EPIDs) can be used for portal dose prediction – but cannot be used for phantom work.

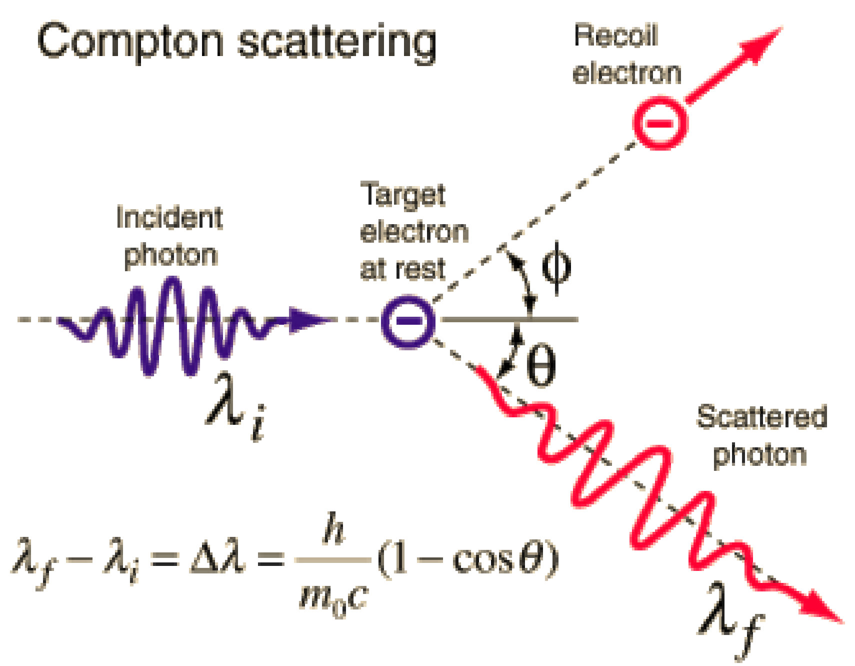


Marginal increase above 100 mV due to side strips

Signal does not depend on depleted volume

<=>Recombination larger than the order of detector thickness

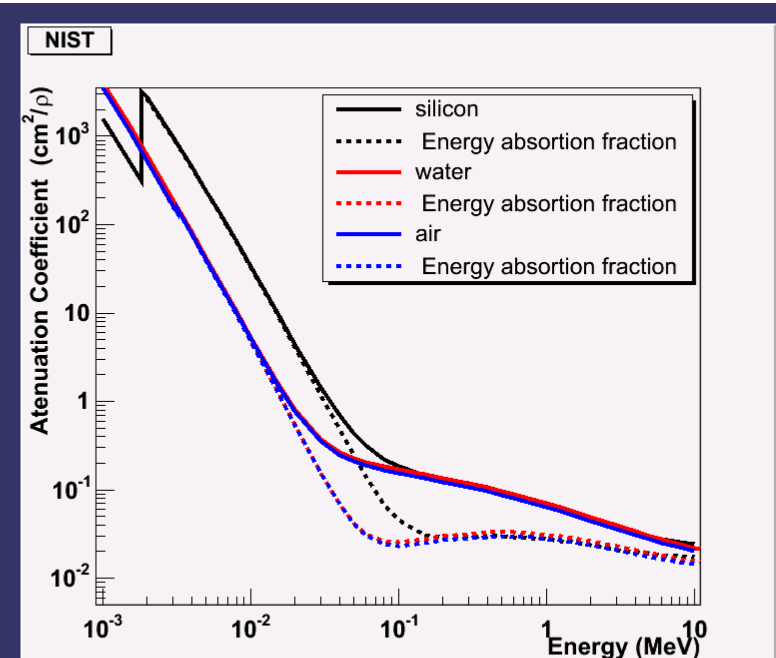
Compton cross section dominates at MeV energies in tissue/water



Ionize the medium depositing energy for a range of 0(1 cm) and suffers strong multiple scattering(backscatter).

Energy deposition is non local

Travels for O(10 cm) beforethe next compton scatter...until the photon is absorbed producing a photoelectron



How tissue equivalent is Si?

Water and Si agree above 200 keV + density ratio=2.33

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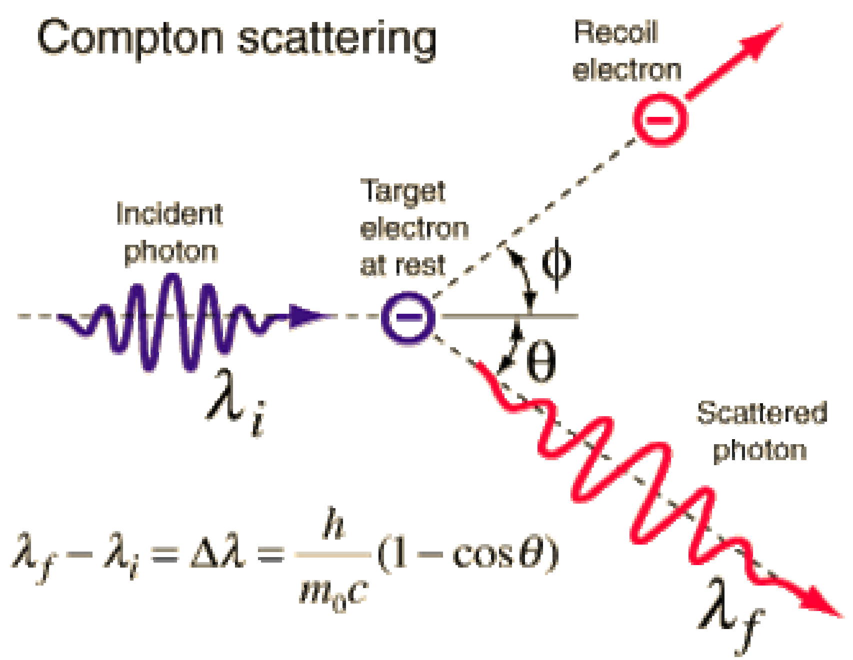
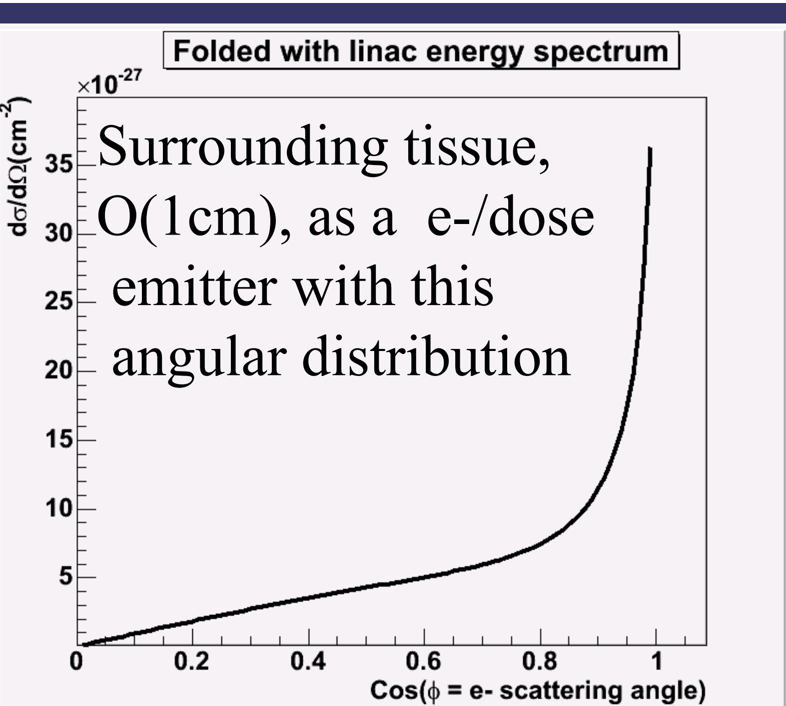
Dosimetry is not Imaging



Ionize the medium depositing energy for a range of O(1 cm) and suffers strong multiple scattering(backscatter).

→ Energy deposition is non local

Travels for O(10 cm) before the next compton scatter...until the photon is absorbed producing a photoelectron



Surrounding tissue, O(1cm), as a e-/dose emitter with this angular distribution

Not interested in tracking primary photon fluence but...

Absorbed energy in the medium i.e. **Dose**

Detector should be:

- **encapsulated in water equivalent material;**

- **the thinner the better...**

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