Sensor optimisation for the upgrade of the CMS pixel barrel

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Single sided sensors, edge break down
Capacitance measurements
Ministrips, macro-pixels
Radiation hardness of present system, sensors, ¼ micron chip

Single Sided Sensors

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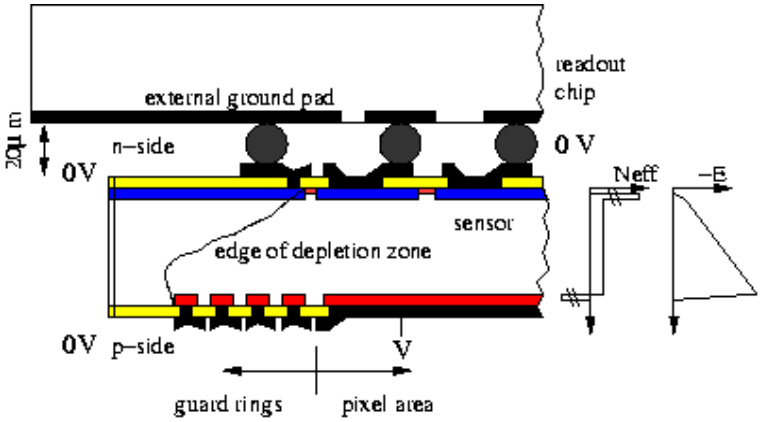
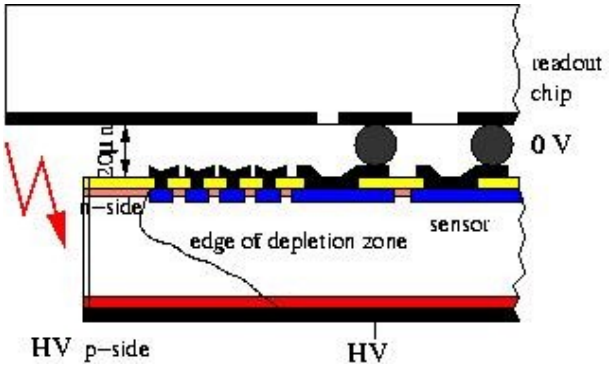
- Present CMS pixel detector uses n-in-n-sensors
  - double sided processing (back side is structured)
  - all sensor edges on ground
  - most expensive part of the module (only bump bonding is more expensive)
- Exploring n-in-p sensors as alternative
  - recent studies show radiation hardness
  - single sided process promise price benefit of factor 2-3
  - Absence of guard rings on back side lead to the risk of (destructive)sparking to the ROC

n-in-n

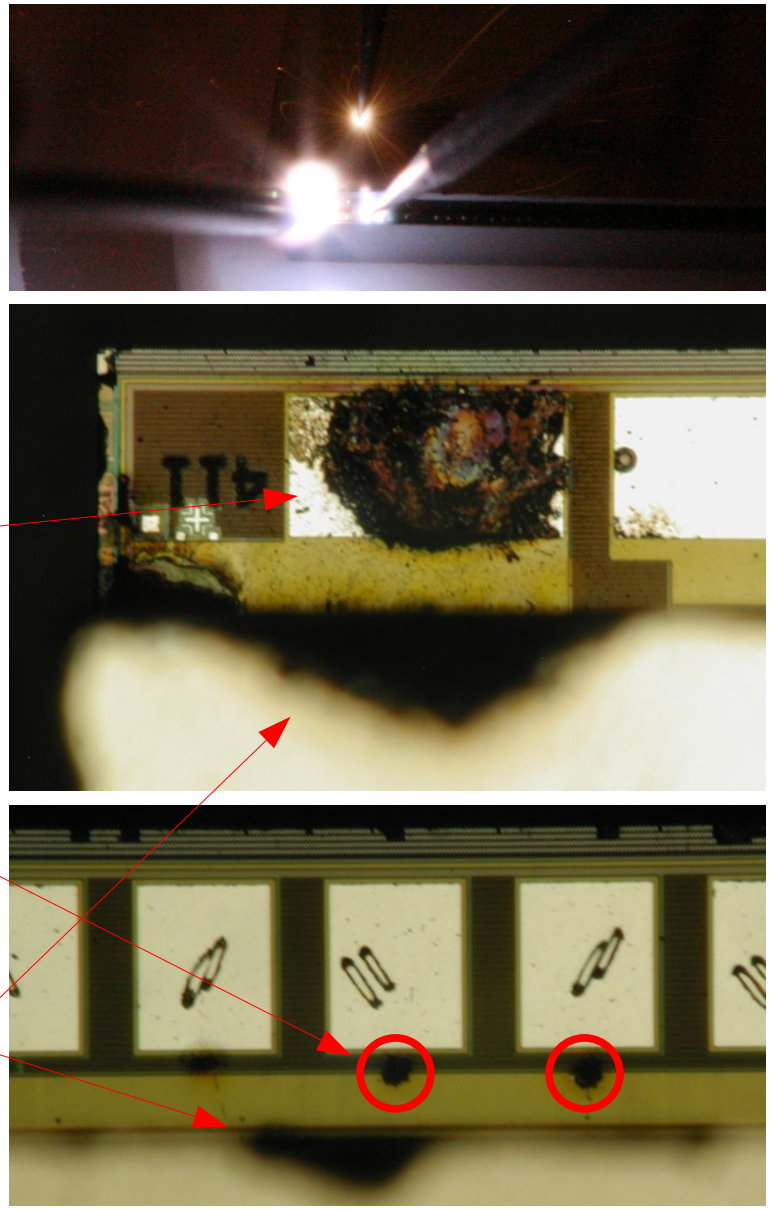


n-in-p



Sparking at Sensor Edge

- Bump bonded rejected material from PSI-PILATUS project (p-in-n sensors and defective ROCs)
- Applied bias voltage to the sensor while ROC was grounded
- Breakdown occurs at ~500V
  - Grounded pad on ROC completely destroyed
  - Other pads also damaged
  - Voltage surprisingly high
    - spark comes from sensor back side?
    - 500V →500µm air?
    - Aluminium also evaporated on sensor backside



Edge Protection

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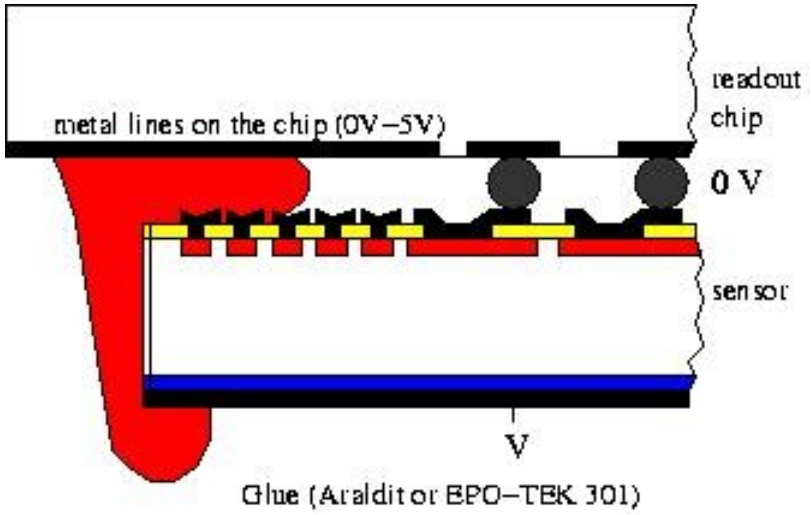
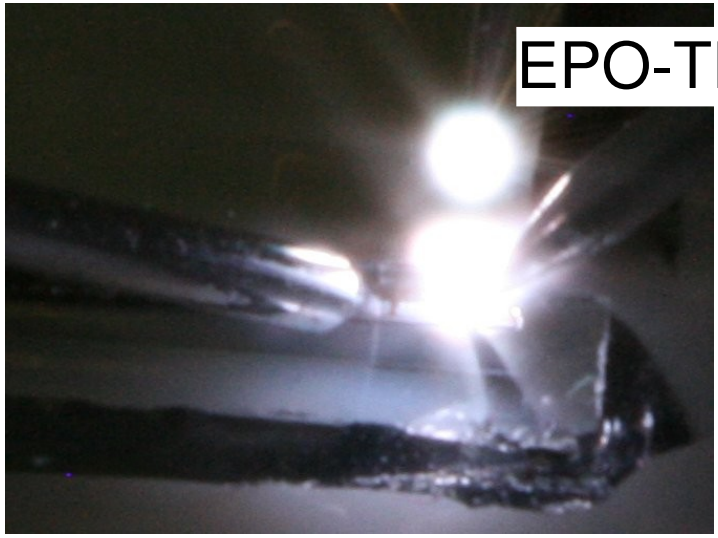
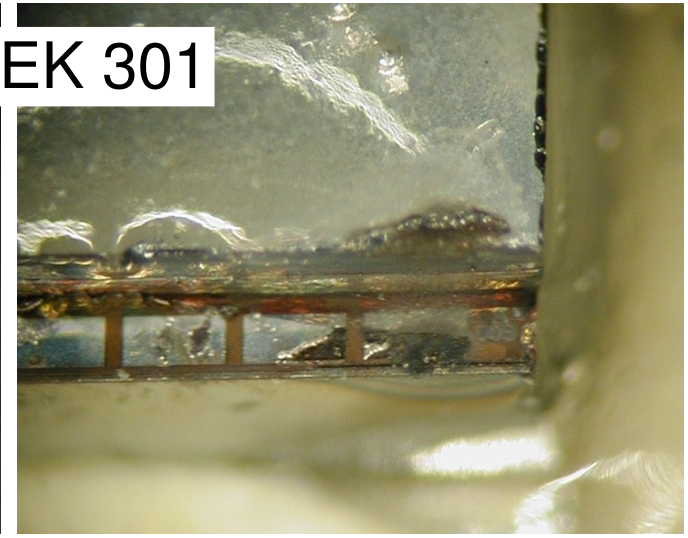
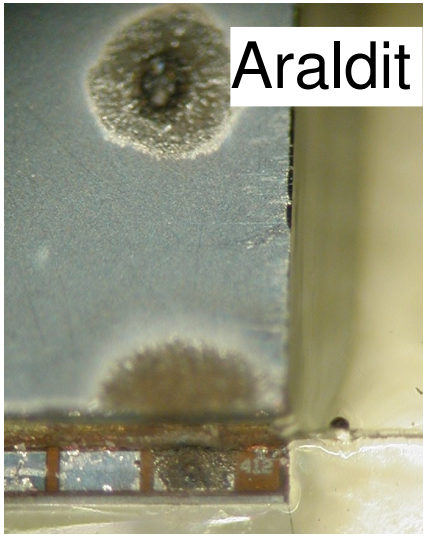
- Tried to passivate edges with glue
  - Araldit (standard)
    - used as underfill and glue in CMS module production
    - no change of break down voltage
  - EPO-TEK 301
    - very liquid, fills part of the gap
    - break down at ~700V



- Investigate further possibilities (Kapton?)







Capacitance measurement

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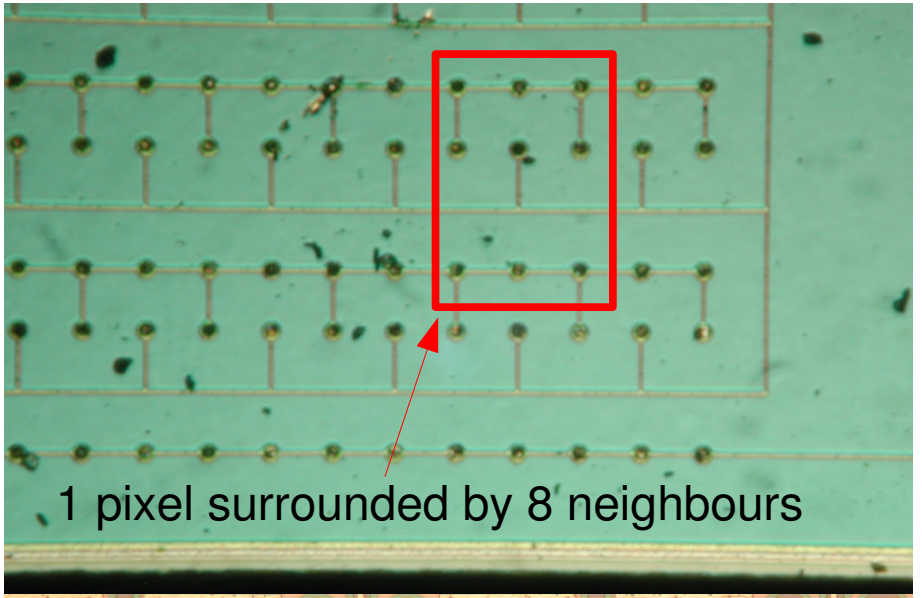
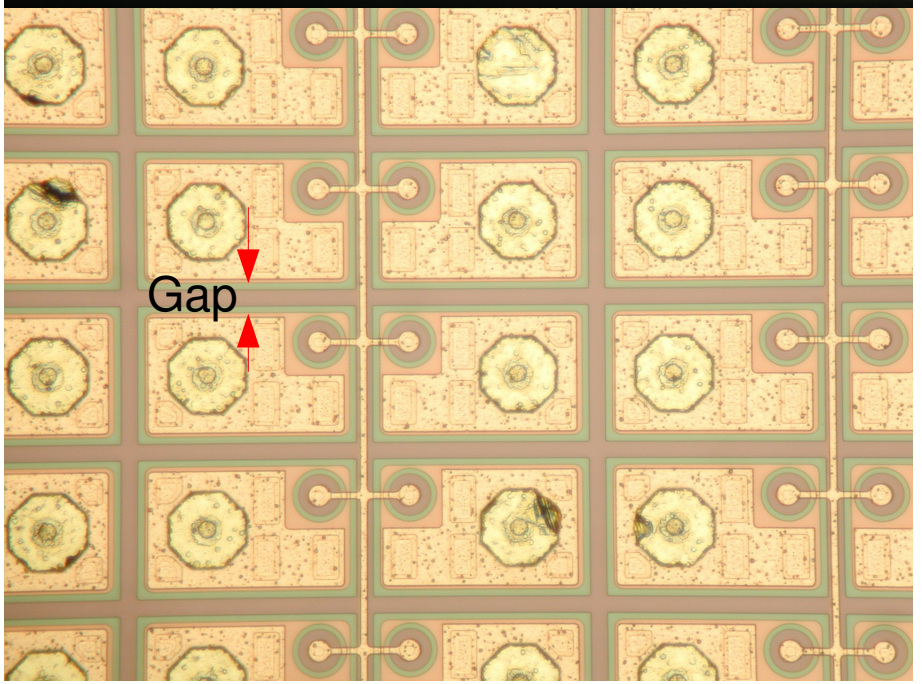
- Inter pixel capacitance is important for
  - time walk of ROC (analogue power)
  - noise
- First trials in 2006 (together with Florian Bechtel, Uni HH)
- Used very small sensors (22×40 pixels, pitch 125×125µm^2)
- **New "fan outs" for "regular" single chip sensors (52×80 pixels) ordered**
  - Better accuracy
  - More samples available
  - Better understanding of
    - Cap vs. gap size
    - Cap vs. bias
    - radiation dependence
  - Apply to all kind of devices





Results from 2006

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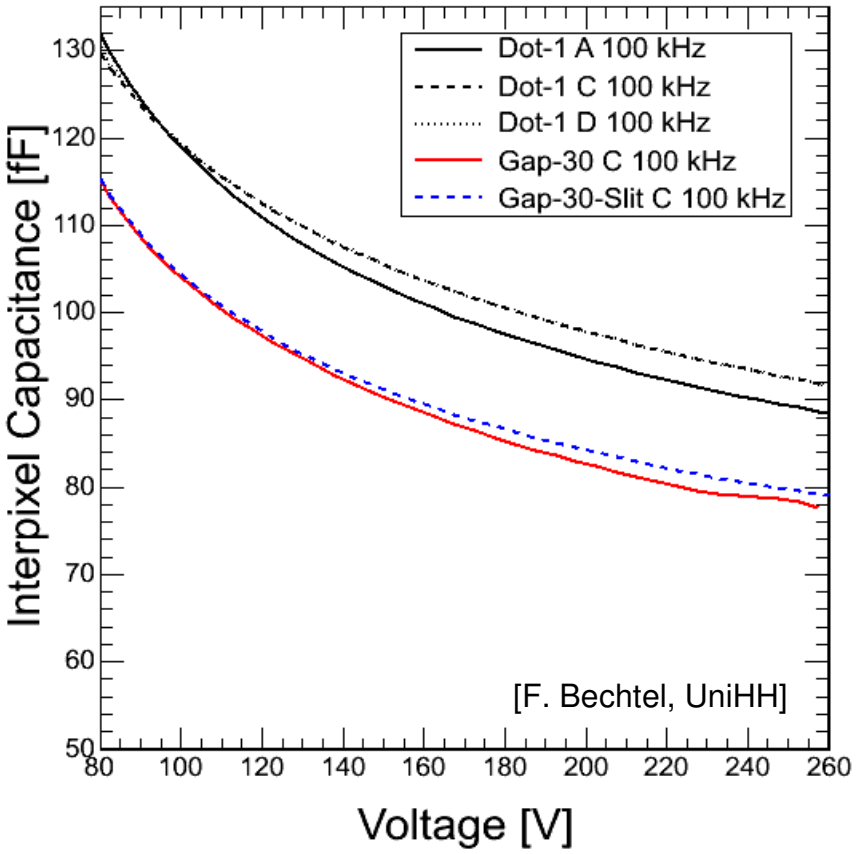
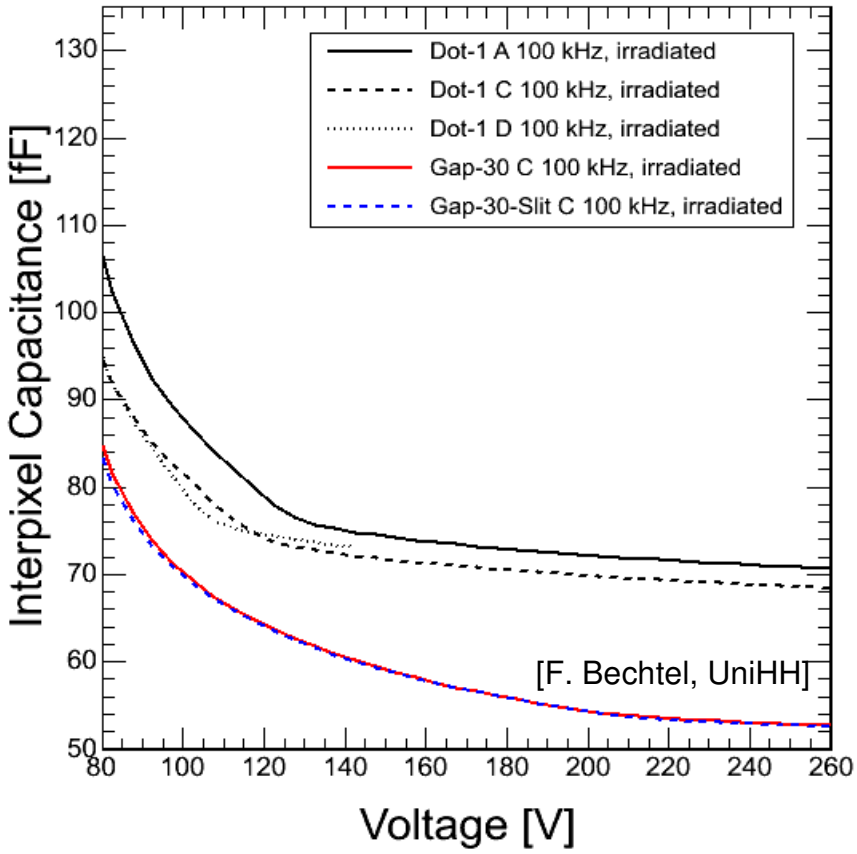
Unirradiated:



- Inter pixel capacitance is bias dependent
- Increasing the gap from 20 to 30 μm results in a drop of C ~105 to 90 fF

Irradiated with 17 kGy ^{60}Co:



- Gamma irradiation establishes surface damage (mostly responsible for capacitance)
- C is slightly lowered and less bias dependent

Other Structures on Wafer

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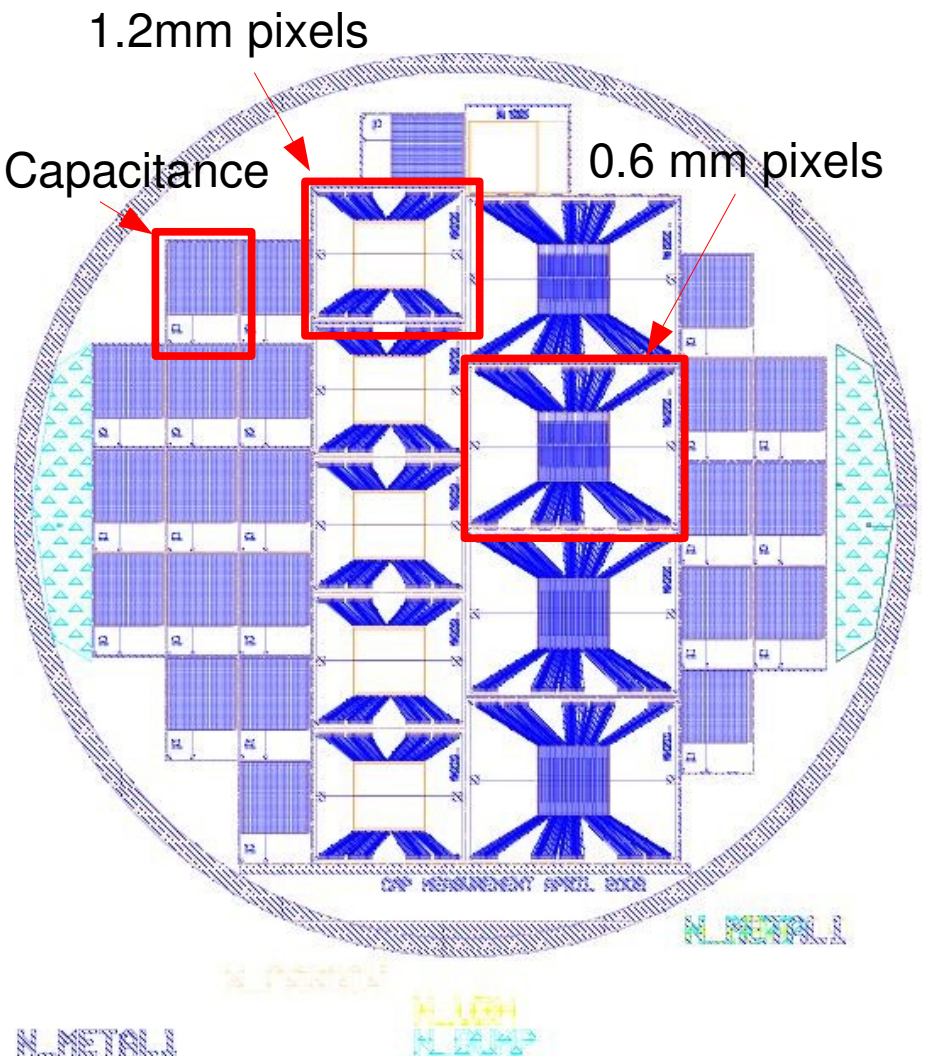
- simple technology with 3 layers only
  - metal
  - passivation
  - bumps
- 23 capacitance measurement structures
- 9 structures “macro-pixels”
  - 4 or 8 pixels are connected together and routed to a wire bond pad
  - bond pattern fits to APV hybrids (kindly provided by Alan Honma)
  - Also “bricked” pattern
- Delivery in June



Present System

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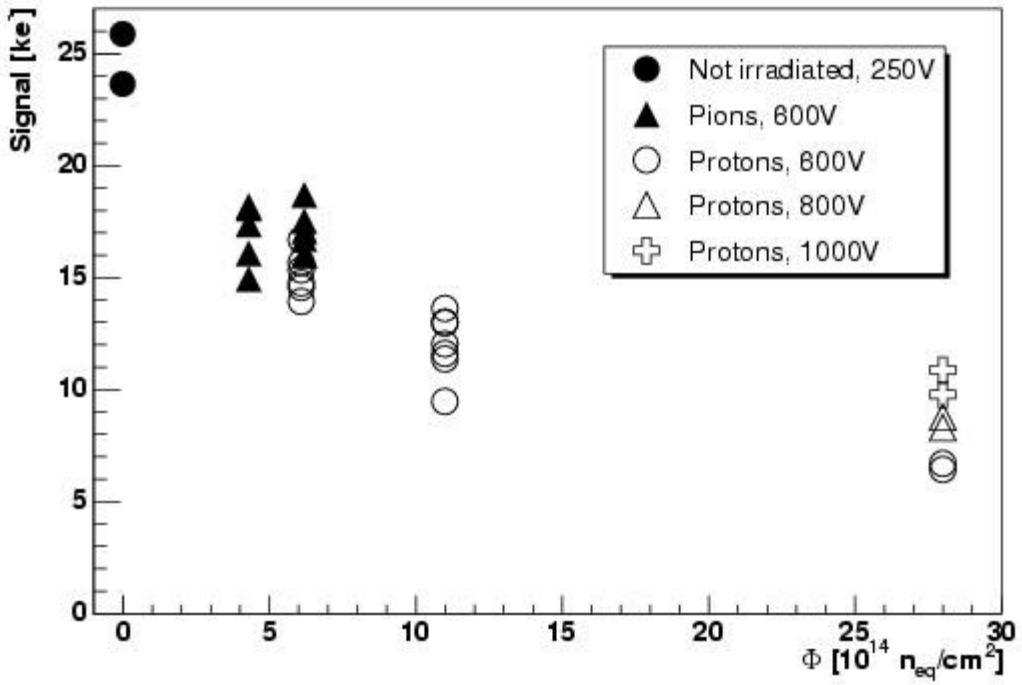
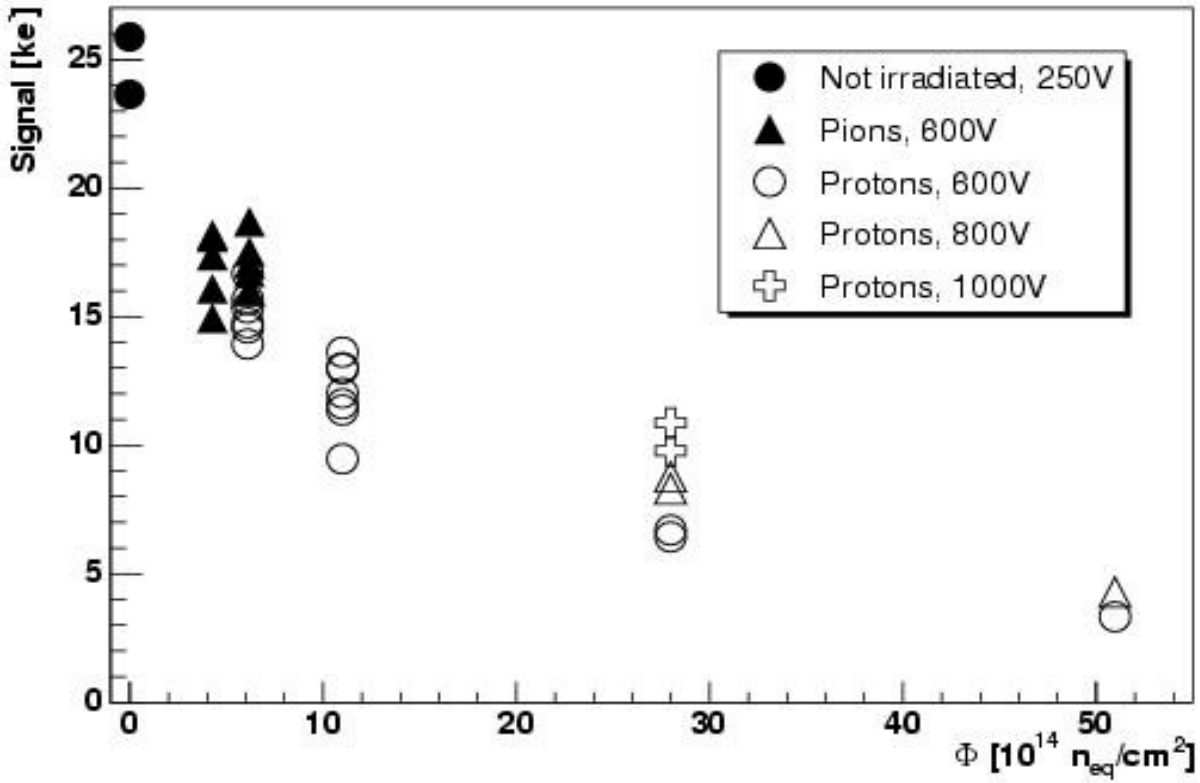
- Could take data with "present-style" single chip modules up to **~3×10^{15}n$_{eq}$/cm^2**
  - double sided sensor ("n-in-n")
  - need bias up to 1000 V
  - **get ~10 k electrons as MPV**
  - ROC works fine with slightly adjusted settings



- Detailed study of chip properties is under way
- **Our modules seem suitable for a phase 1 upgrade**
- Samples with fluences > ~3×10^{15}n$_{eq}$/cm^2 were not yet tested

Very Preliminary!!

- Tested one chip at ~5×10^{15}n$_{eq}$/cm^2
- Can clearly see source, Landau distribution looks good!
- Need more analysis, have several other samples to test at this fluence



New Sr-90 Setup

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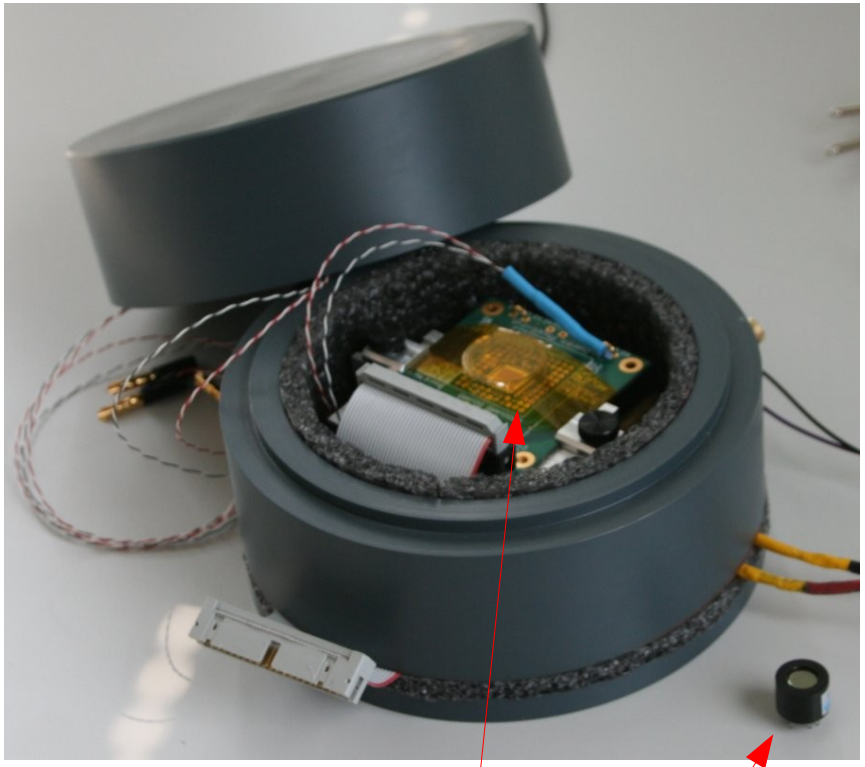
- Improved cooling
  - lower temperature, up to -15C (still room for further improvement if needed)
  - more stable
- Independent scintillator trigger
  - will be used for efficiency measurements
  - very stable and little noise
  - timing still a problem
- Commissioning ongoing



Summary

- Source measurements give very encouraging results with respect to the phase 1 upgrade
  - signal after $3\times10^{15}N_{eq}/cm^2$ ~10000 electrons
- Fan outs to be bump bonded to single chip sensors have been submitted
  - measurement of pixel capacitance
  - connecting several pixels to 0.6 and 1.2 mm long mini-strips (width 100μm)
- Started to investigate “sparking problem” at the edge of single sided pixel sensors