6th Trento Workshop on Advanced Silicon Radiation Detectors (3D and P-type Technologies)
FBK-irst, Trento (IT) 2-4/3/2011

Overview of Si n-in-p Pixel Detectors characterization for ATLAS Upgrade

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on behalf of

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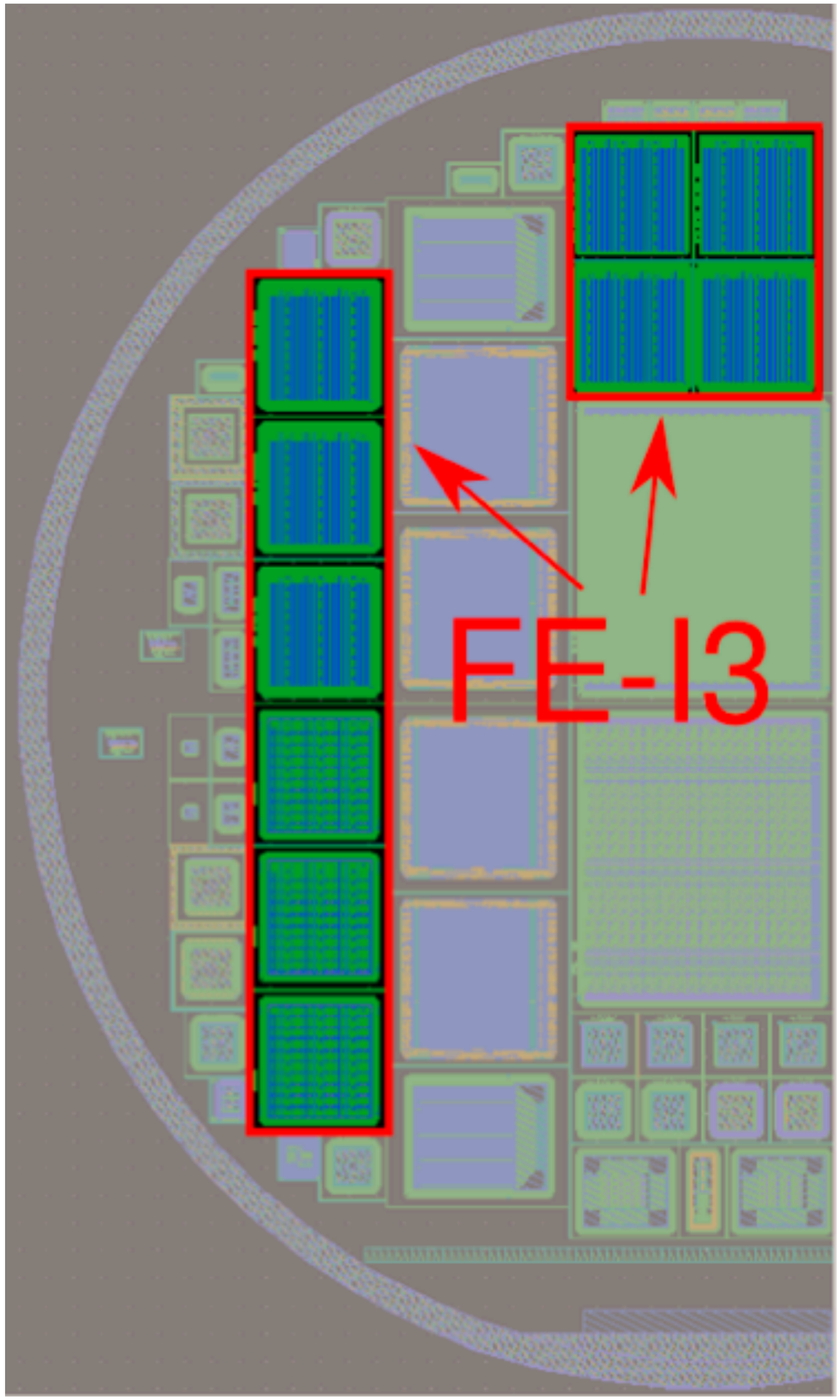
Overview

- CiS n-in-p pixel sensor production
- Lab-test measurements with unirrad devices
  - Leakage current vs Bias voltages
  - Threshold and Noise measurements
  - Gamma and Beta source tests
- Irradiation campaign
- Lab-test measurements with irrad devices
  - Leakage current vs Bias voltages
  - Threshold and Noise measurements
  - Gamma and Beta source tests
- Highlights from 2010 beam tests at CERN

Part of these results have been already presented at RESMDD10 Conference (by P. Weigell)

Publications on going: P. Weigell et al., *Characterization and performance of Silicon n-in-p Pixel Detectors for the ATLAS Upgrades*. In press in NIM A (e-printed: arXiv:1012.3595v1)

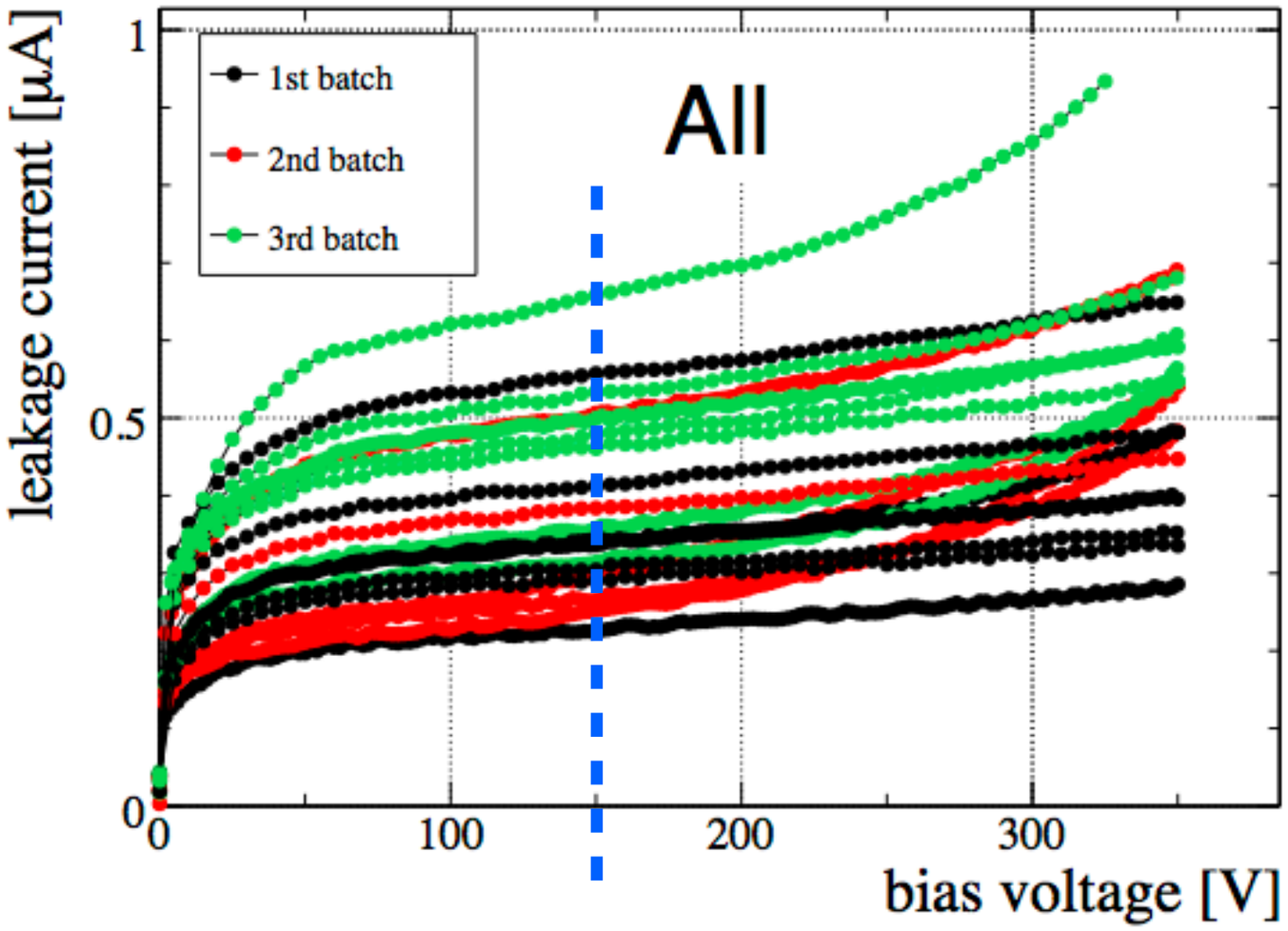
CiS Production (n-in-p Batch)



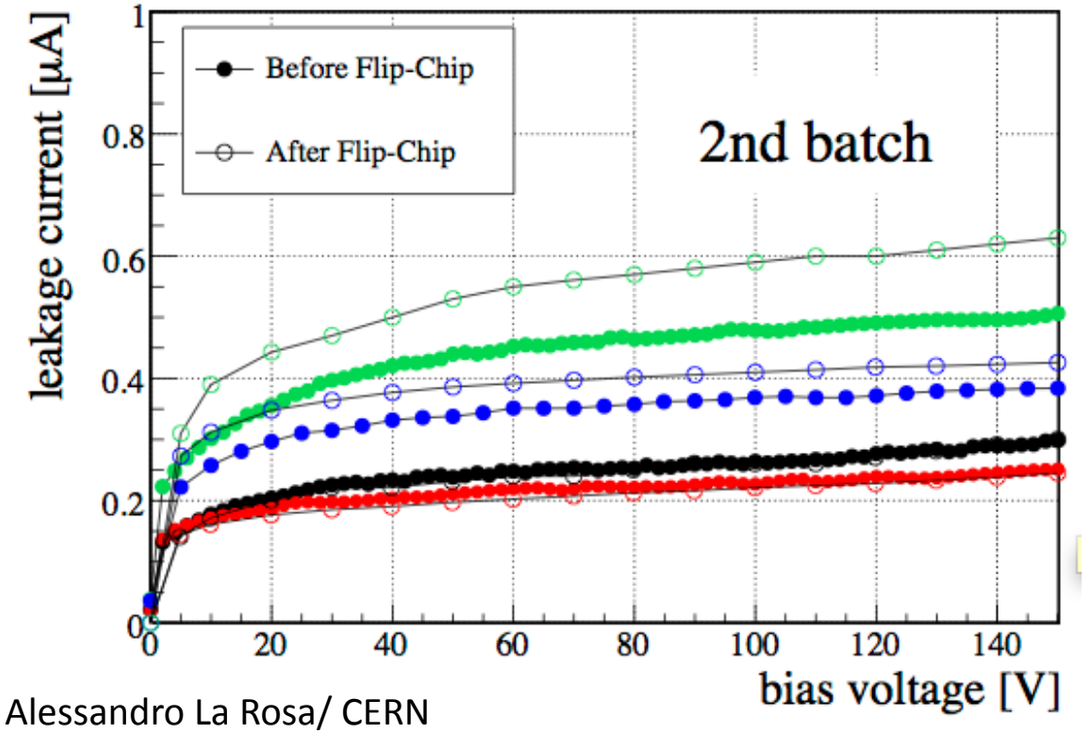
- Production within RD50 and ATLAS Planar Pixel Sensor Collaborations
- Technology
  - Fz n-in-p, 300um thick delivered by CiS
  - 18 wafers available
- Advantage of technology
  - Single side process => Simpler and less expensive
- Structures

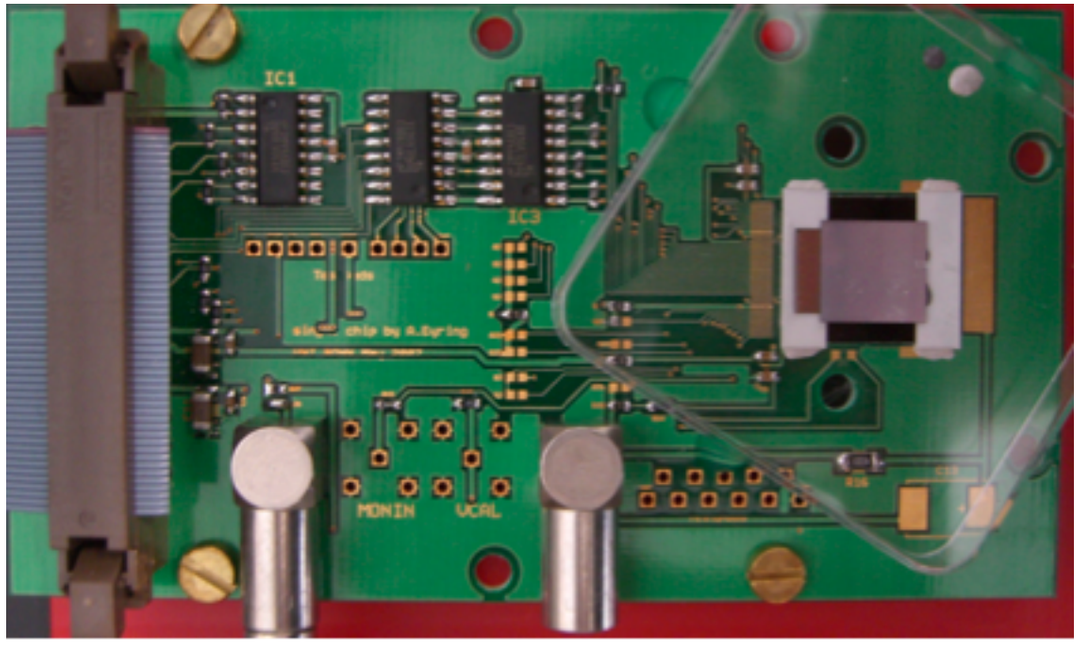
  10 x FE-I3 Single Chip Assembly (SCA) with different Guard Ring (GR) and isolation schemes:
  - 2x 8 GRs, homogeneous p-spray
  - 2x 15 GRs, homogeneous p-spray
  - 3x Standard (19) GR, homogeneous p-spray
  - 3x Standard (19) GR, moderated p-spray
- Wire-bonded on ATLAS Pixel Bonn Cards

Leakage currents



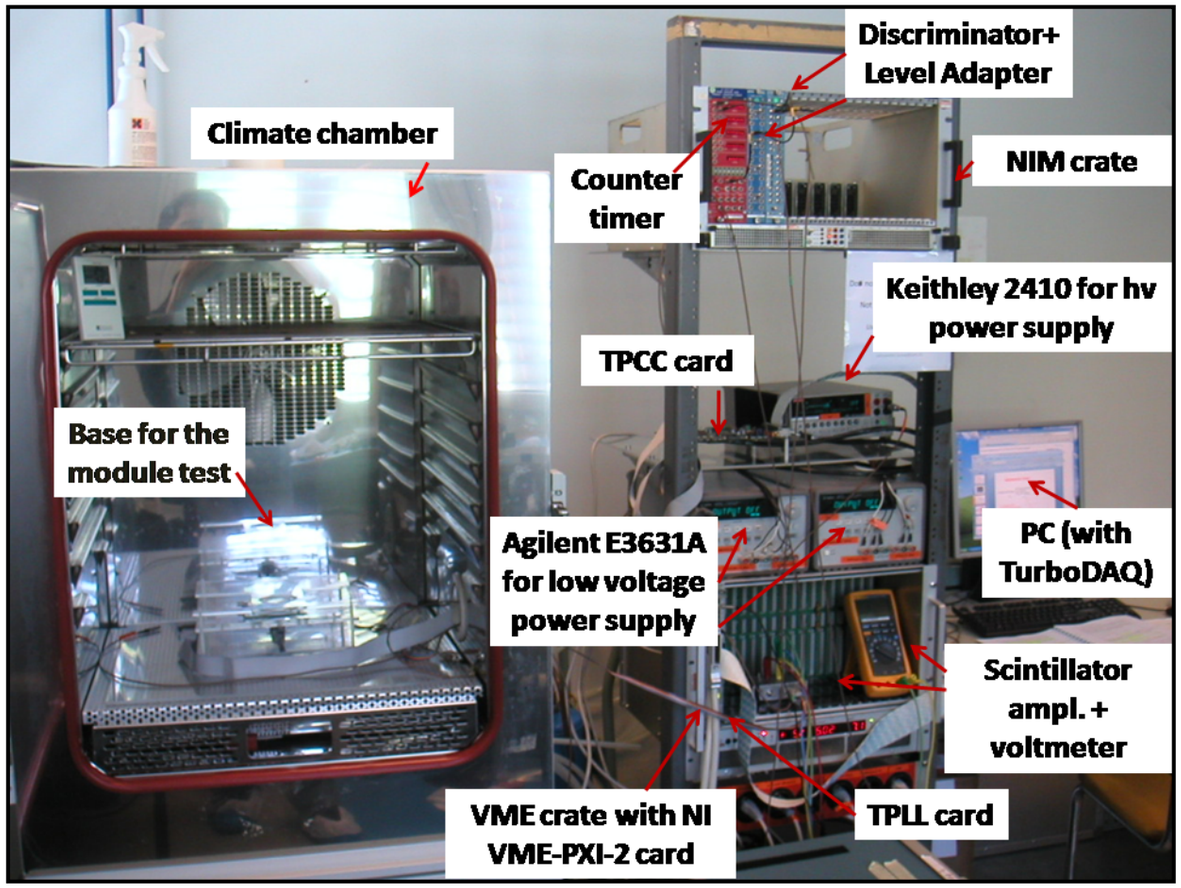
- Flip-chip done by IZM in three batches
  - May (FE rotated by 180º w.r.t. sensor)
  - August and September
- Assembly wire-bonded by Bonn ATLAS Group
- For unirrad devices working point at 150V



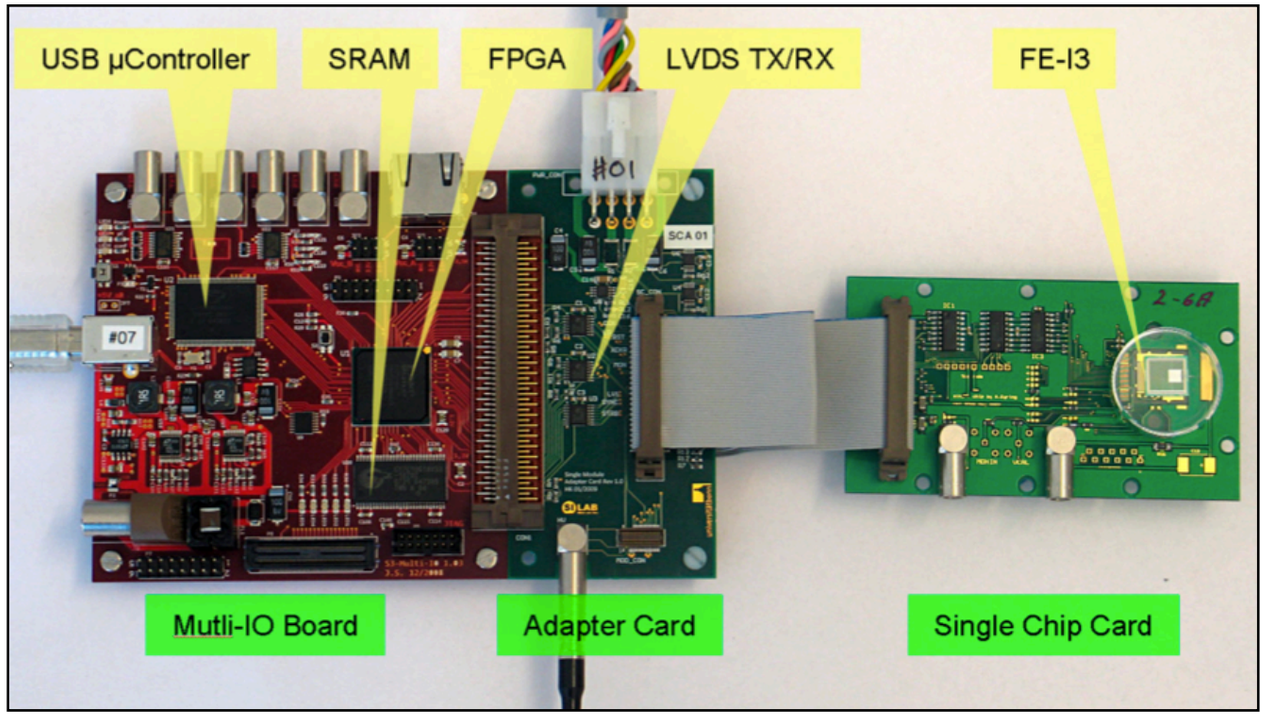


ATLAS FE-I3 experimental setup

- Two different DAQ-system have been used to perform Lab-measurements:
  - TurboDAQ (based on PC-to-VME interface)
  - USBPix (based on USB interface)



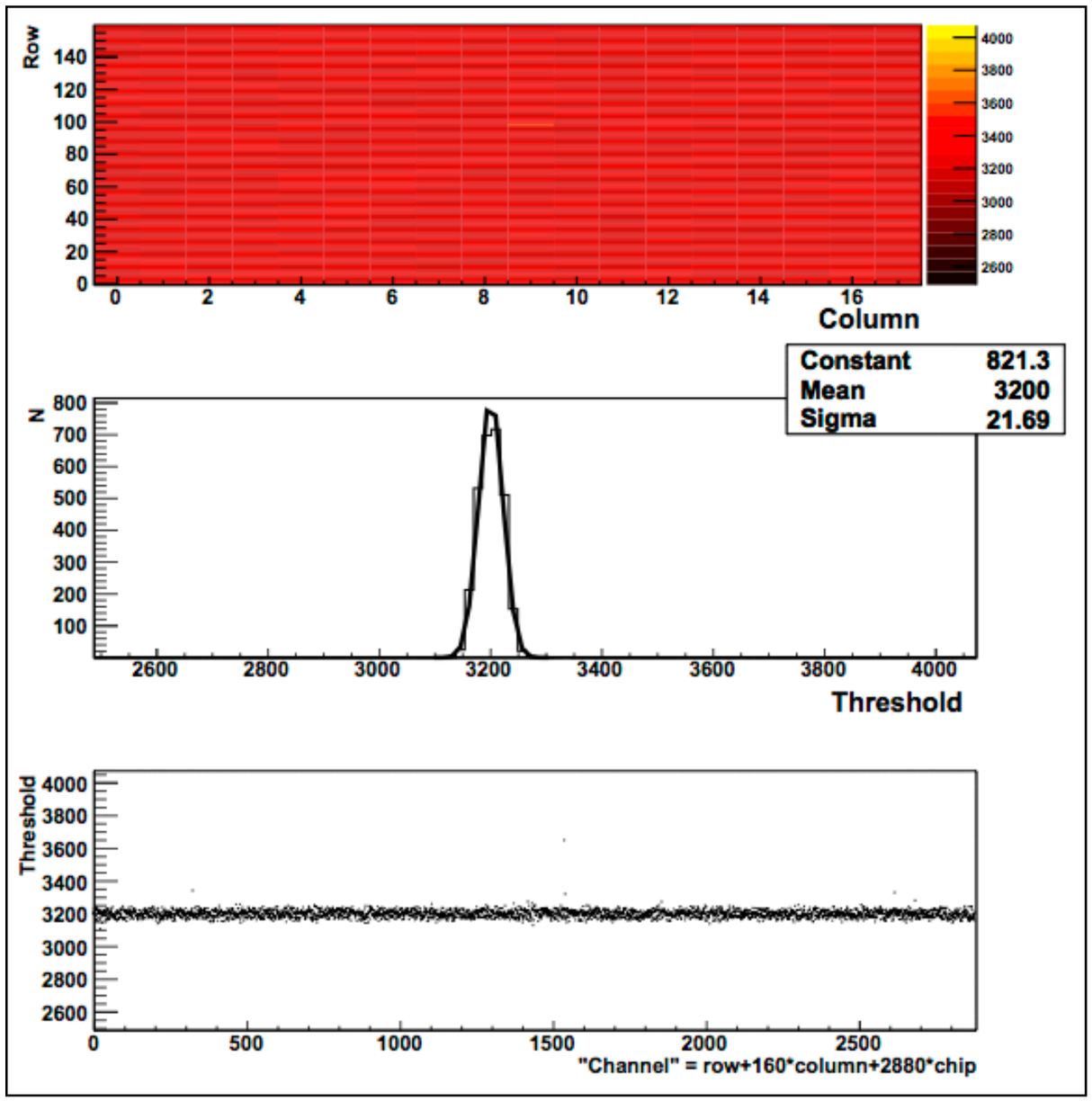
TurboDAQ
for FE-I3 readout system



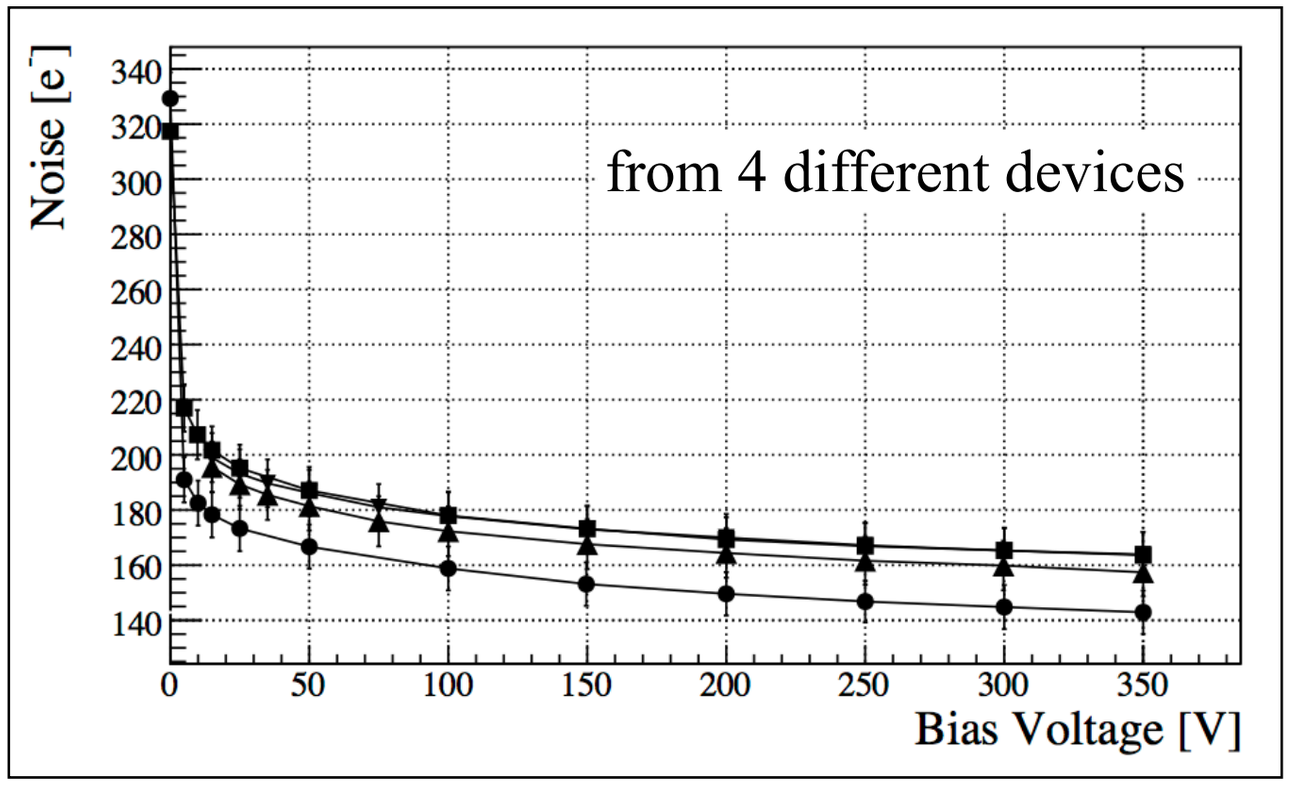
USBPix
for FE-I3 (and FE-I4) readout system

Threshold and Noise measurements

With unirrad device

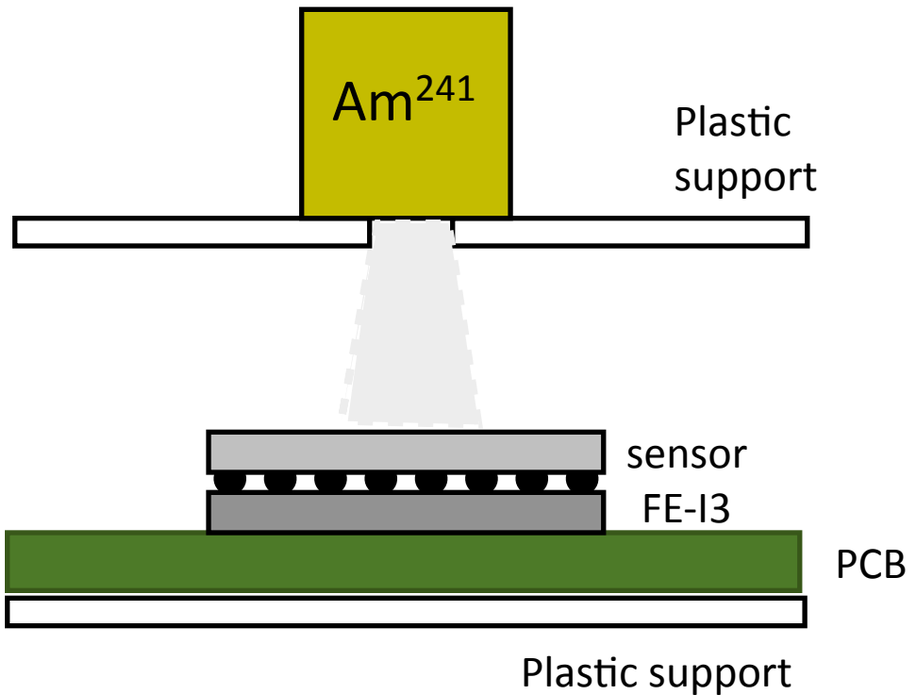


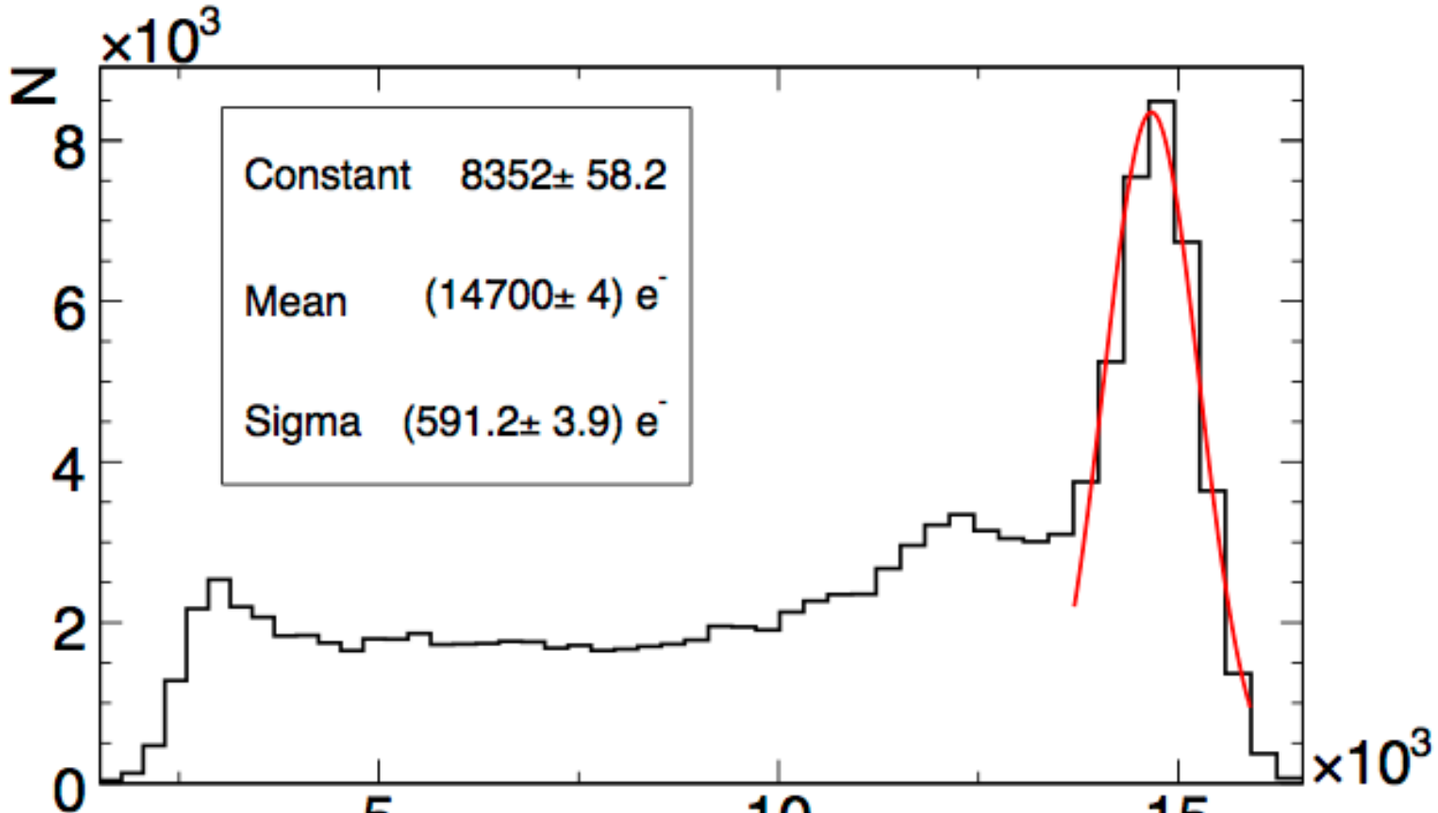
Target Threshold: 3,200 e-



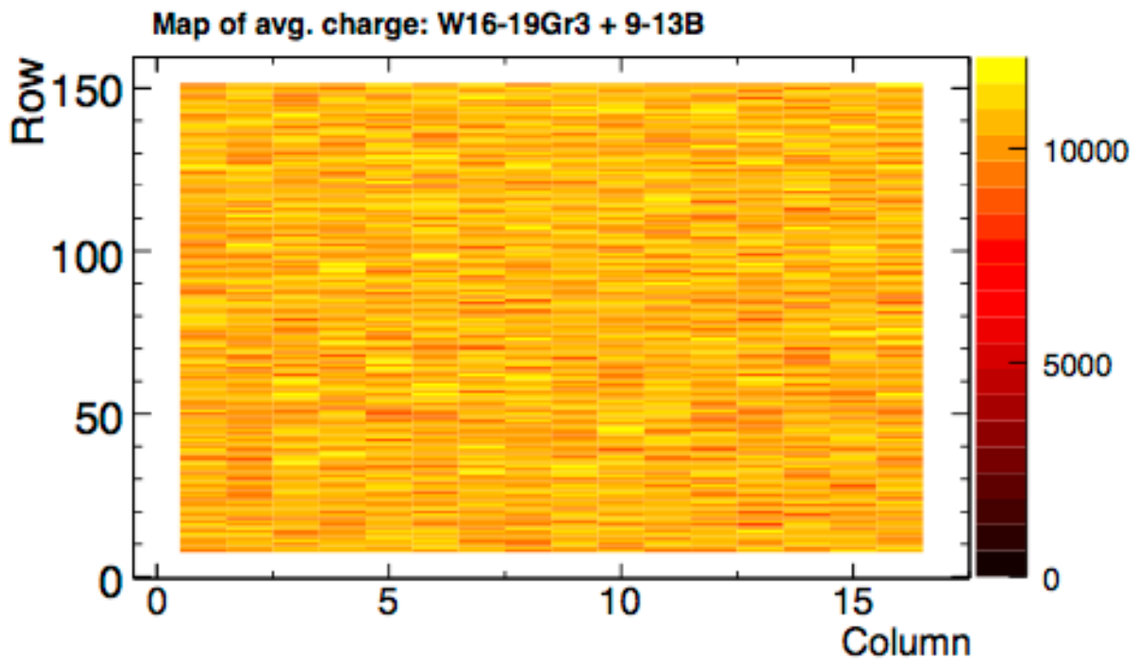
- Very narrow tuning
- Results comparable over all devices
- Noise goes down with rising HV according with theory

Self-trigger operation with Am^{241} source

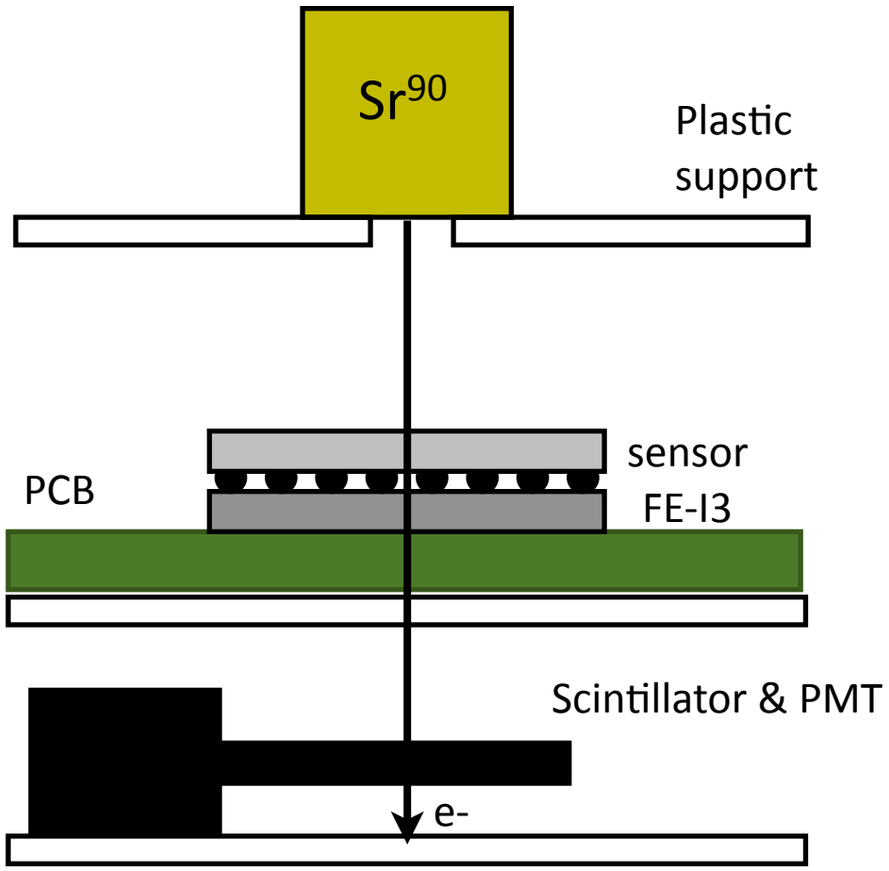


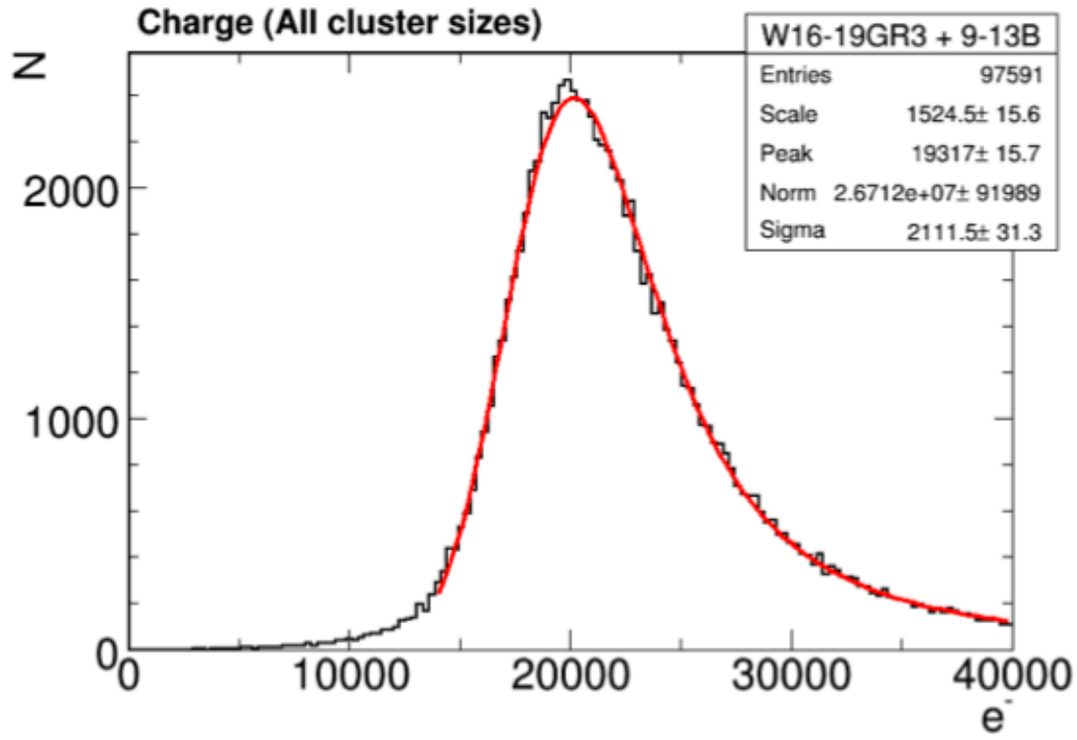


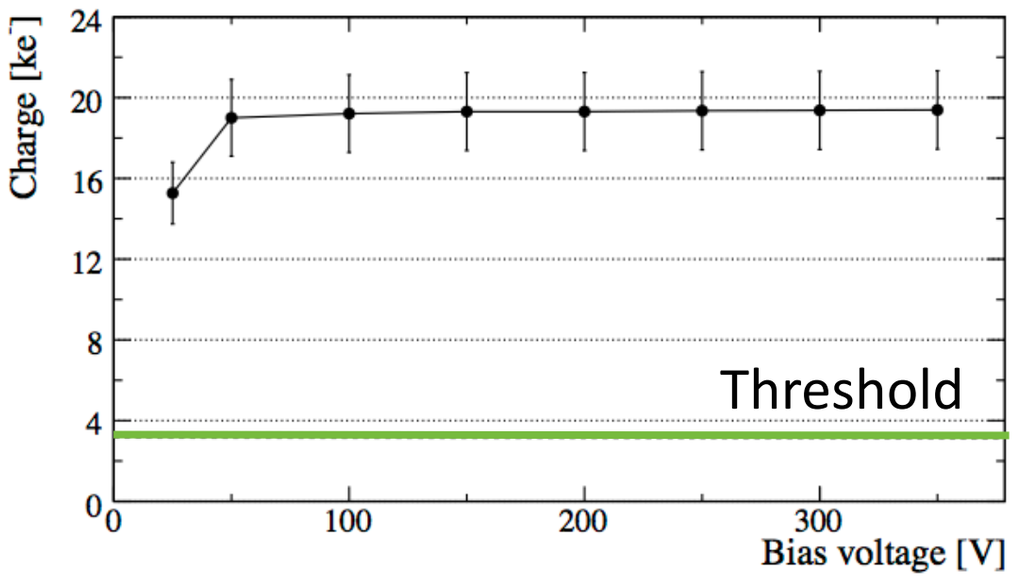
- Seen expected peak at 60KeV
- Measurement performed at 350V (14.7ke-)
- (14.2 ± 0.7)ke-: average of collected charge over all SCAs at bias voltage above 150V
- ~ 10-15% uncertainty from ToT-calibration

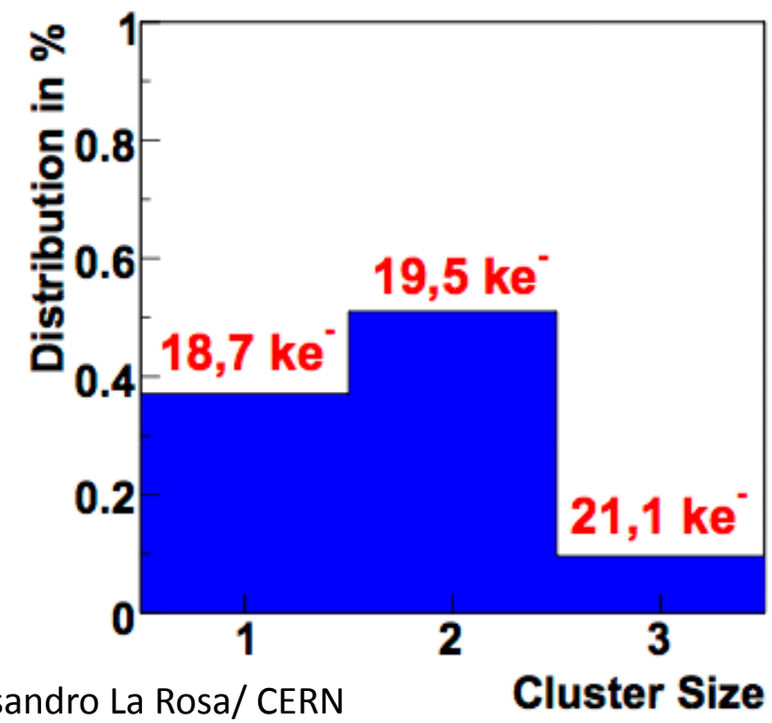


External-trigger operation with Sr^{90} source









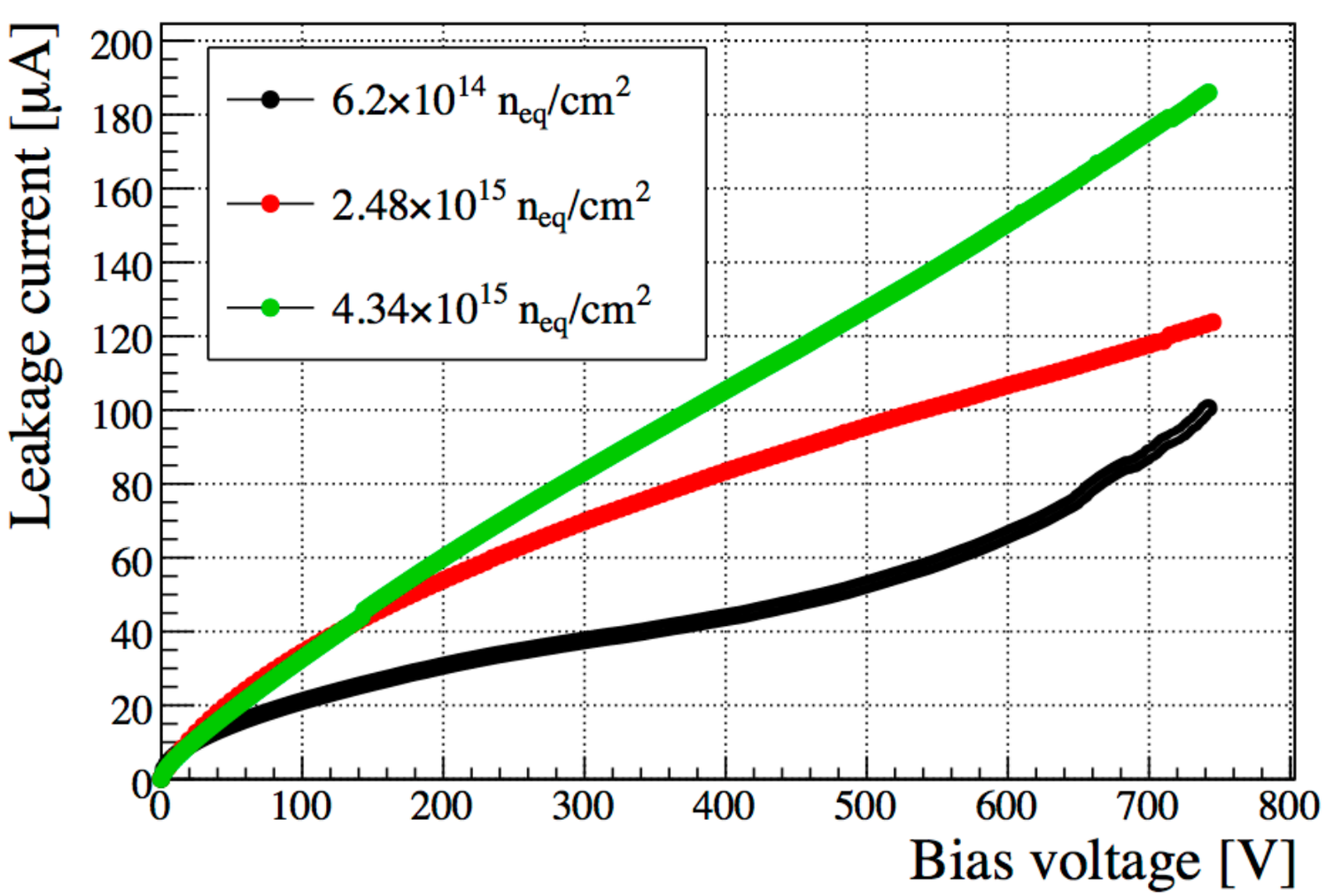
- Most probable Value (MPV): 19.3ke-
- Threshold: 3.2ke-

Irradiation campaign

- Facilities:
  - CERN PS protons at 24 GeV (thanks to M. Glaser)
  - Karlsruhe protons at 25 MeV (thanks to A. Dierlamm & Helmholtz Alliance)
  - Ljubljana neutrons (thanks to V. Cindro)

- Bare sensors irradiation (performed at CERN PS)
  - 1x at 0.6×10^{15} n_{eq}/cm^2
  - 1x at 2.5×10^{15} n_{eq}/cm^2
  - 1x at 4.4×10^{15} n_{eq}/cm^2

IV-measurements performed at -10°C



Irradiation campaign

- Single Chip Assemblies irradiation:
  - 2x SCAs at 1x10^{15} n_{eq} (1x KA and 1x LJ)
  - 2x SCAs at 2x10^{15} n_{eq} (LJ)
  - 1x SCAs at 2x10^{15} n_{eq} (LJ+KA)
  - 2x SCAs at 3x10^{15} n_{eq} (1x LJ and 1x PS)
  - 2x SCAs at 5x10^{15} n_{eq} (1x LJ and 1x PS)

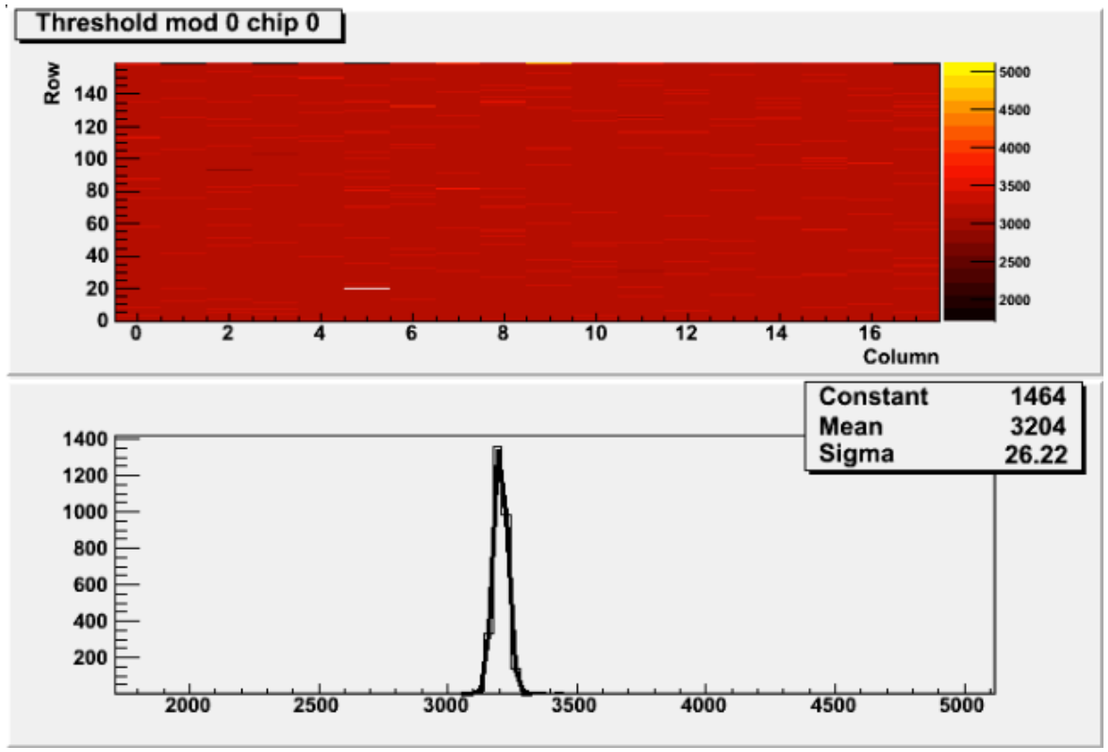
Mixed irradiation:
1x10^{15} n_{eq} with 25MeV p-beam
1x10^{15} n_{eq} with n-beam

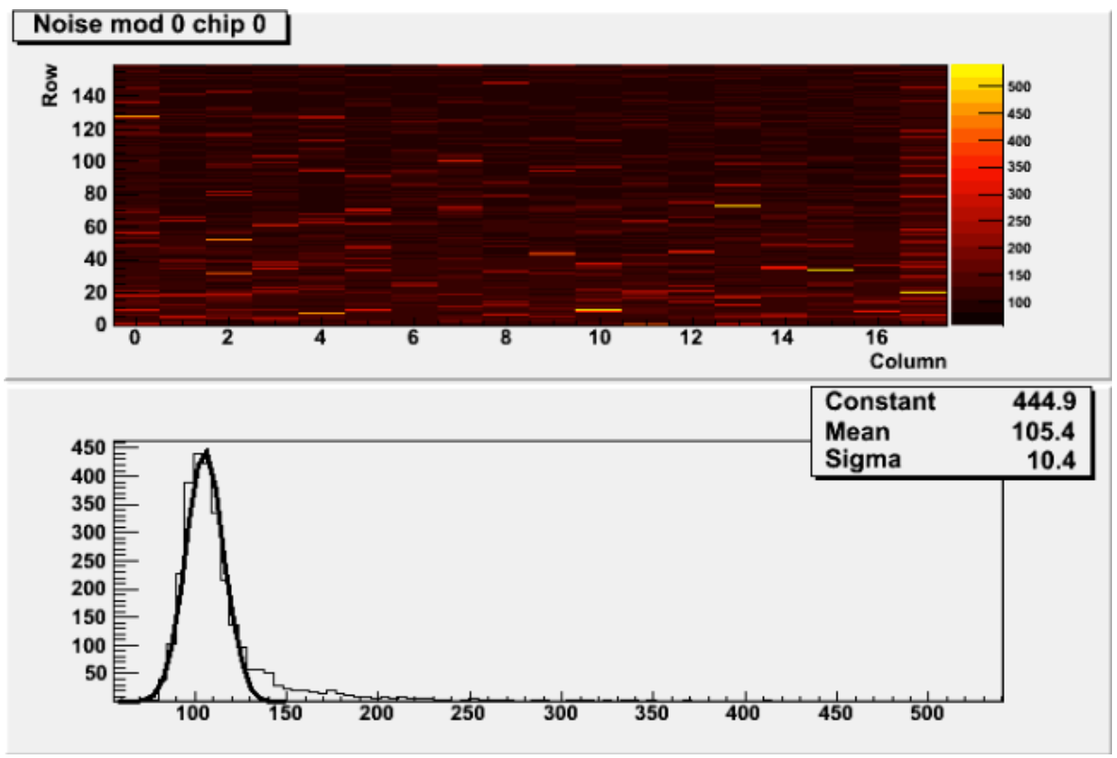
ATLAS IBL Target fluence

Threshold and Noise measurements

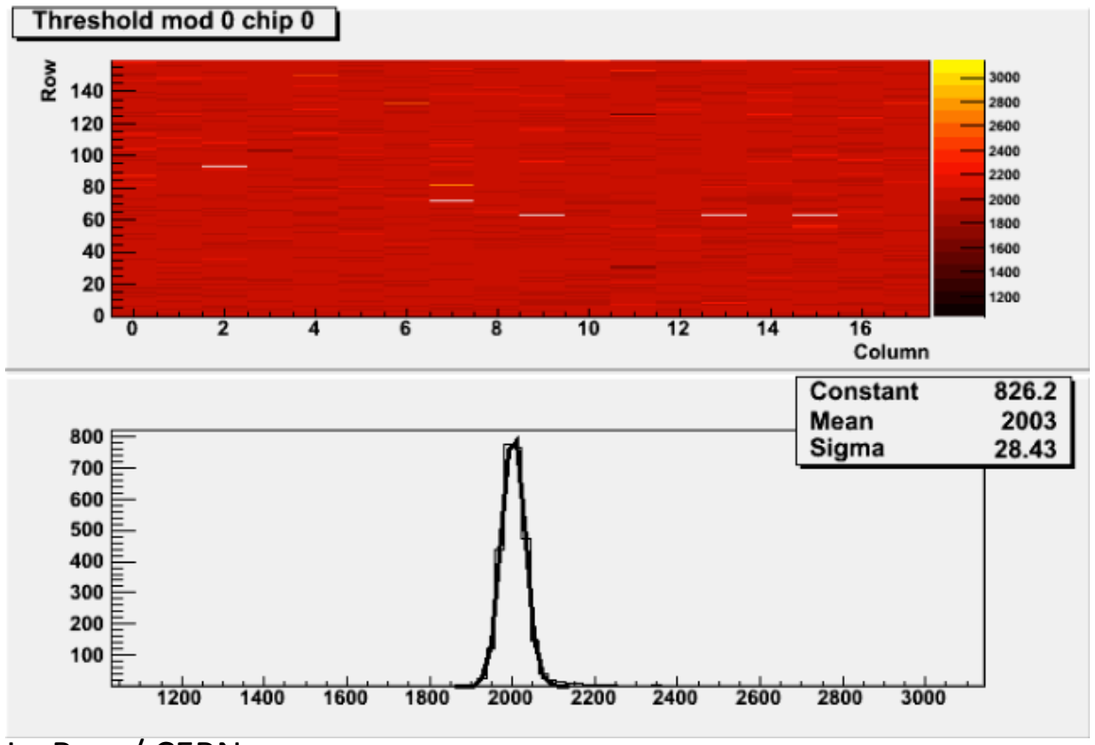
- Measurements from mixed (KA & LJ) irrad devices tot. fluence $2x10^{15}n_{eq}$
  - performed at 700V and at -50 °C

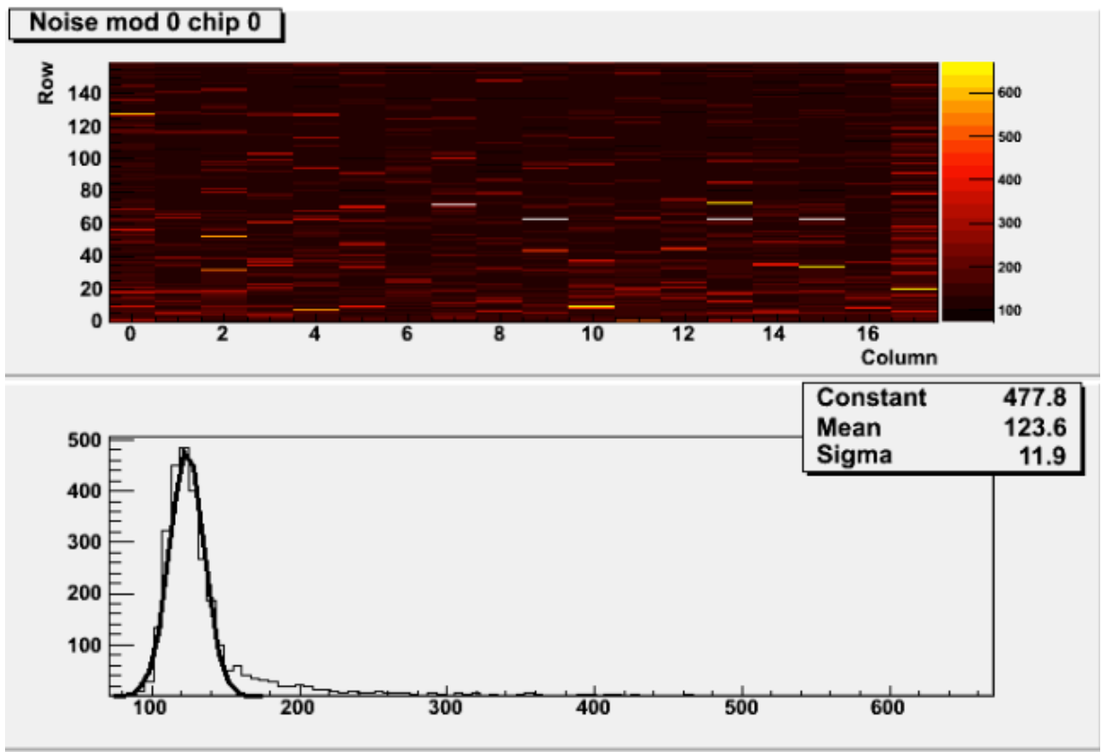
Tuned at 3,200e





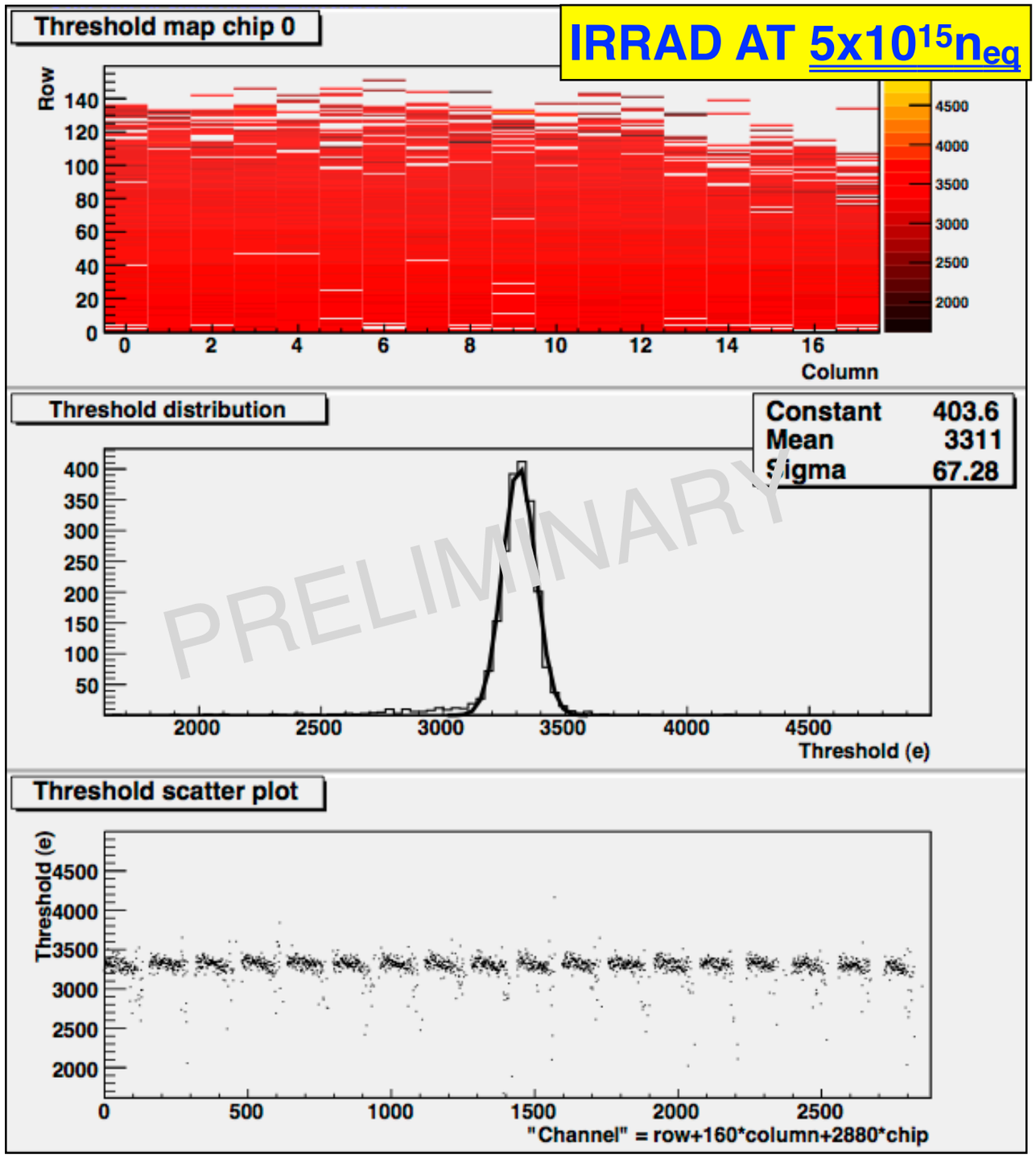
Tuned at 2,000e

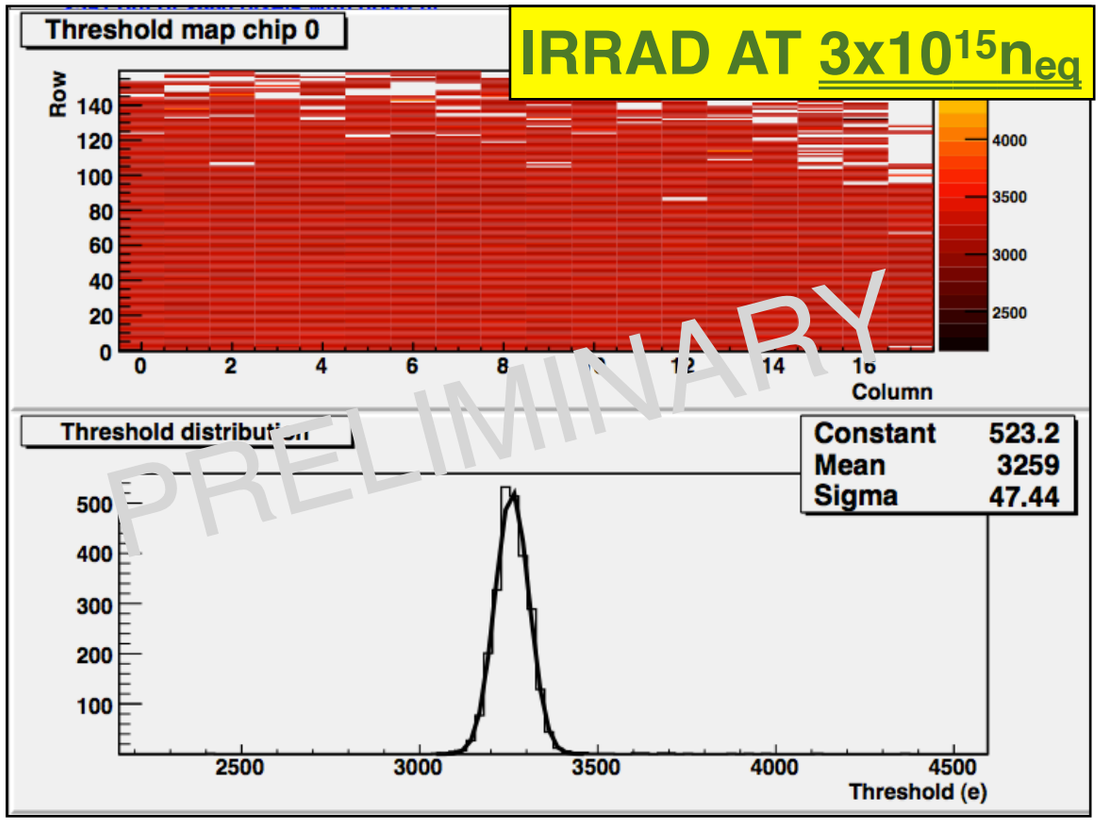




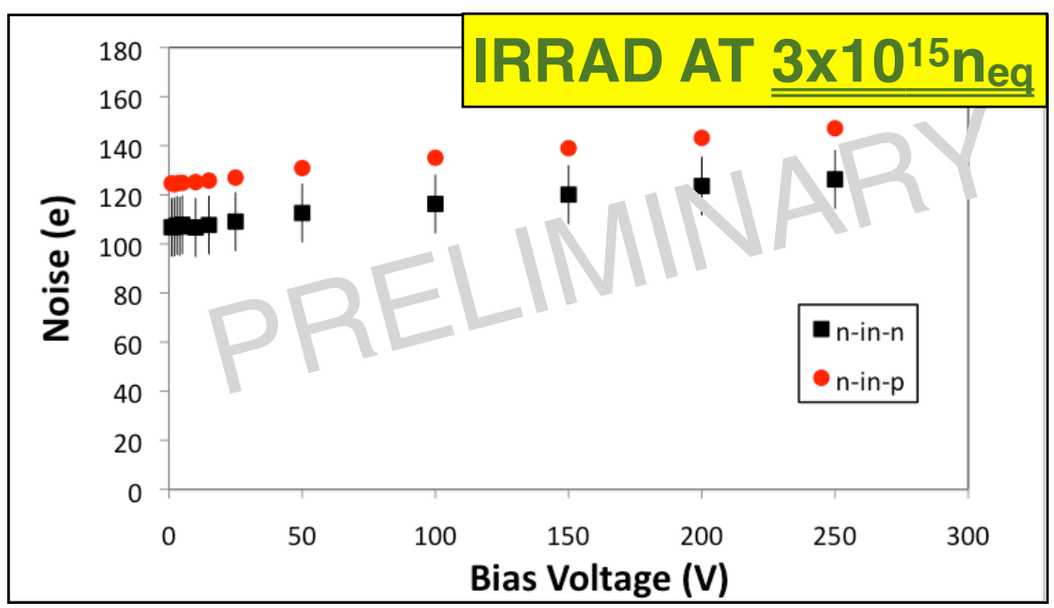
Threshold and Noise measurements

- Measurements from irradiated devices at CERN PS (24GeV)
  - performed at -20 °C



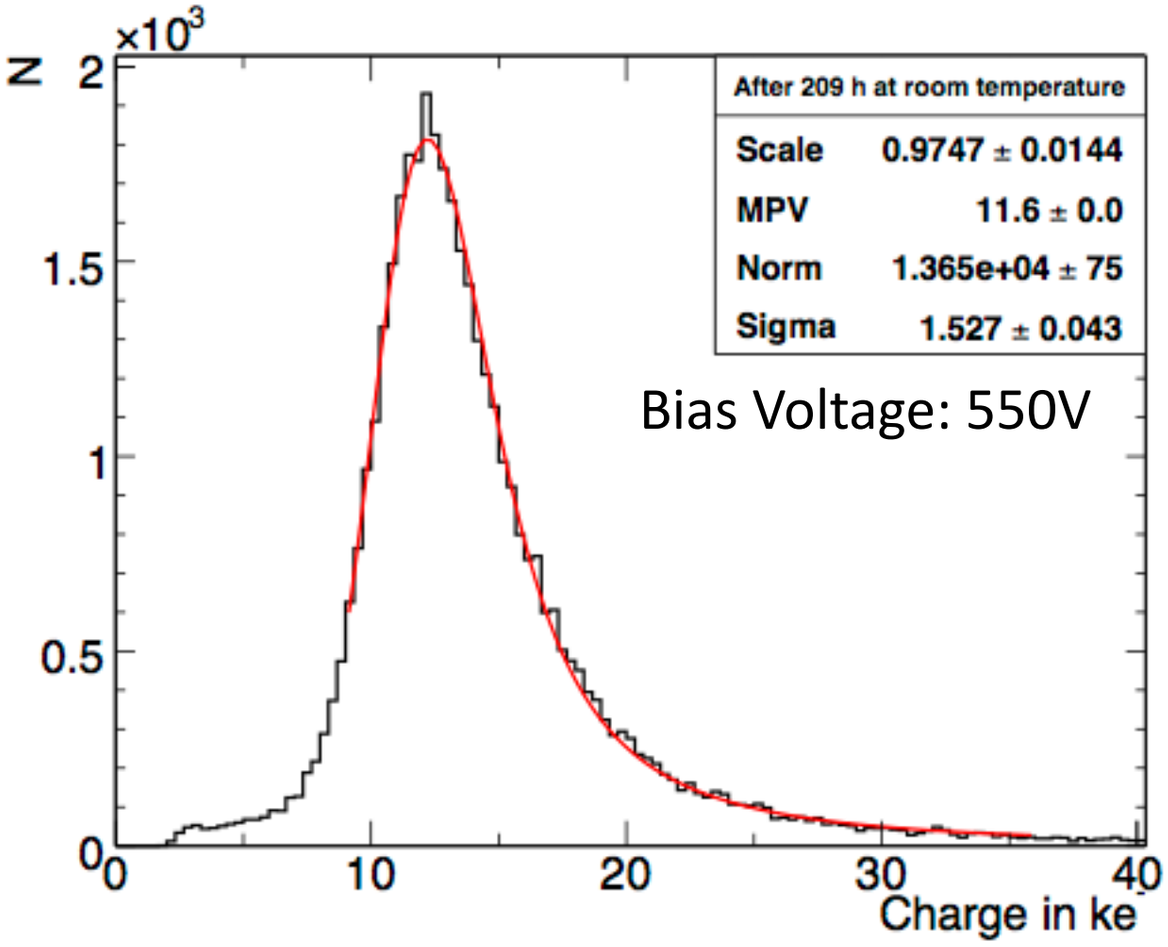


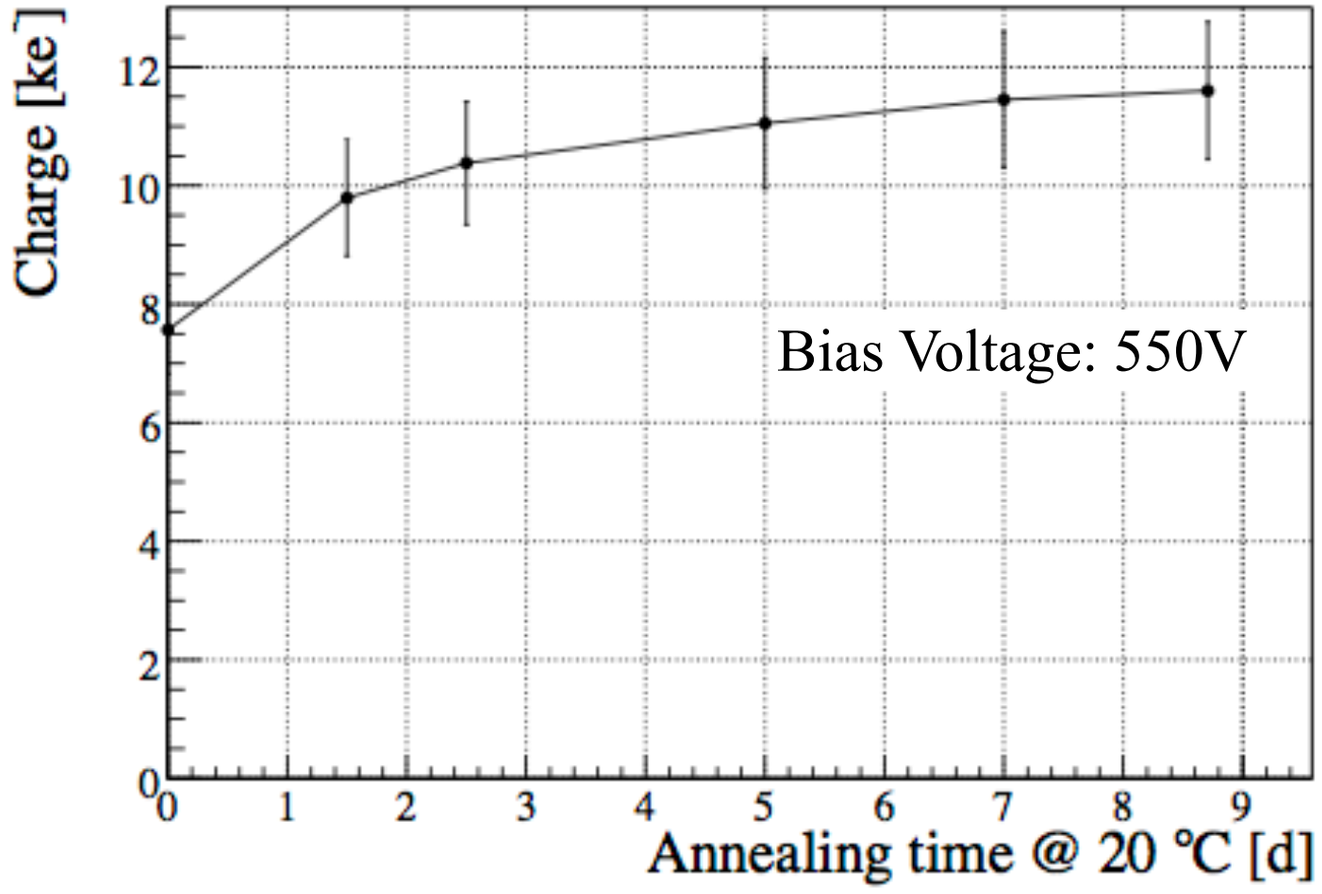
- Noise vs HV Comparison between n-in-p and reference n-in-n SCAs (@ -20°C)



External-trigger operation with Sr^{90} source

- Measurements performed with irradiated device up to **1x10^{15} n_{eq}** (25MeV p-beams)

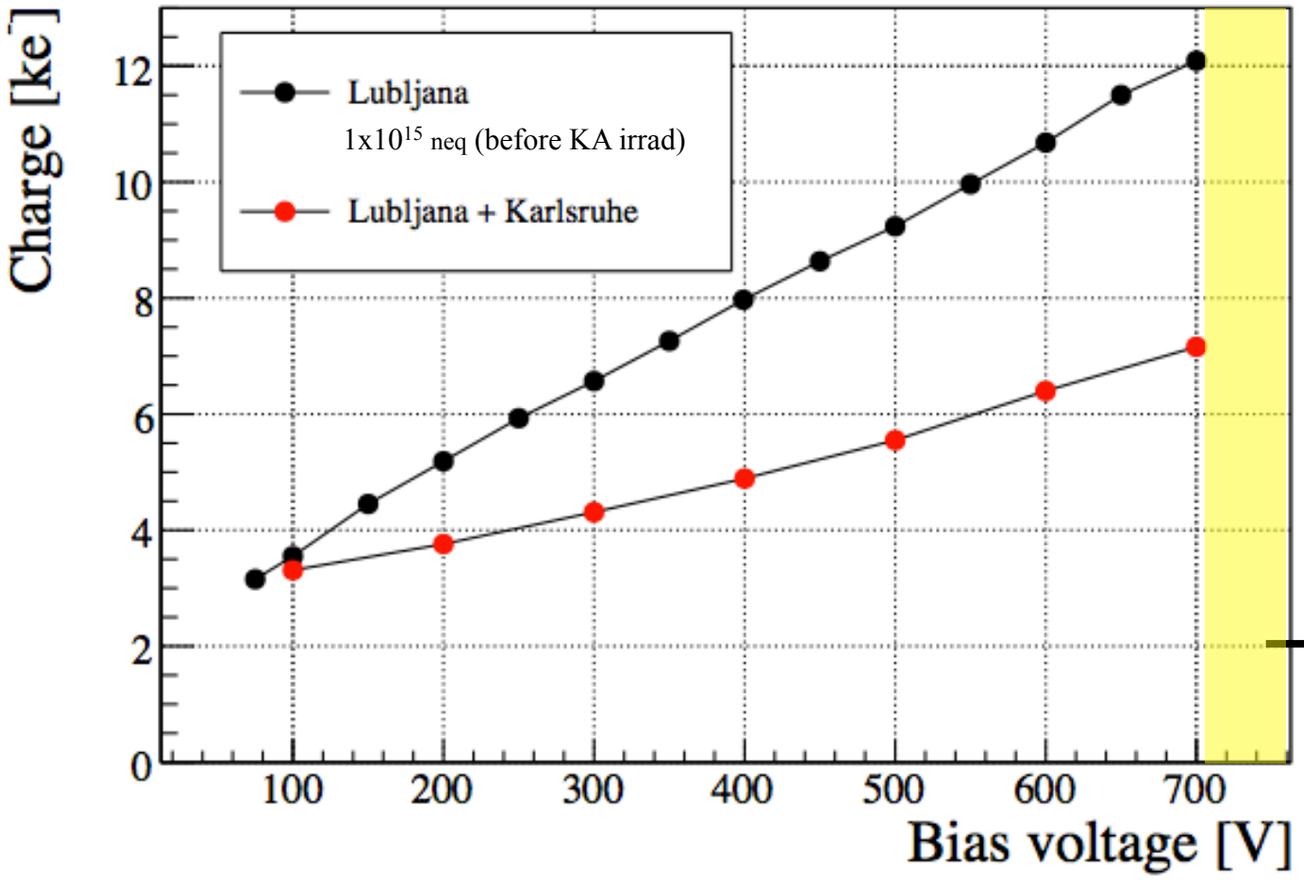


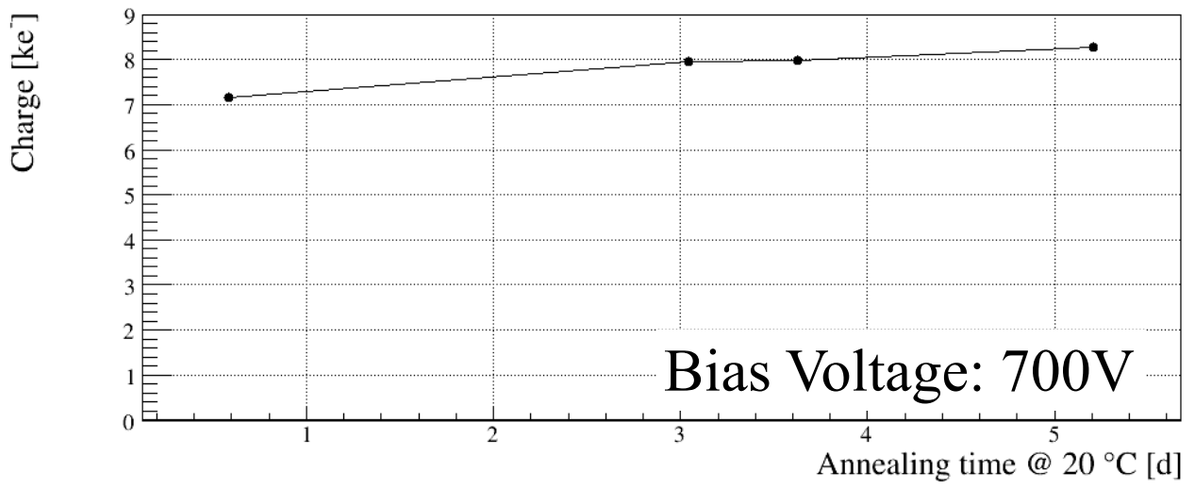


- Source-test at different HV up to 550V --> no saturation for collected charge
- Beneficial annealing:
  - SCA kept at 20°C over a period of almost 9 days --> MPV: 11.6ke- (@550V)
  - About 40% charge lost w.r.t. unirrad SCA

External-trigger operation with Sr^{90} source

- Measurements performed with irradiated device up to **$2x10^{15}$ n_{eq}** (mixed irradiation)



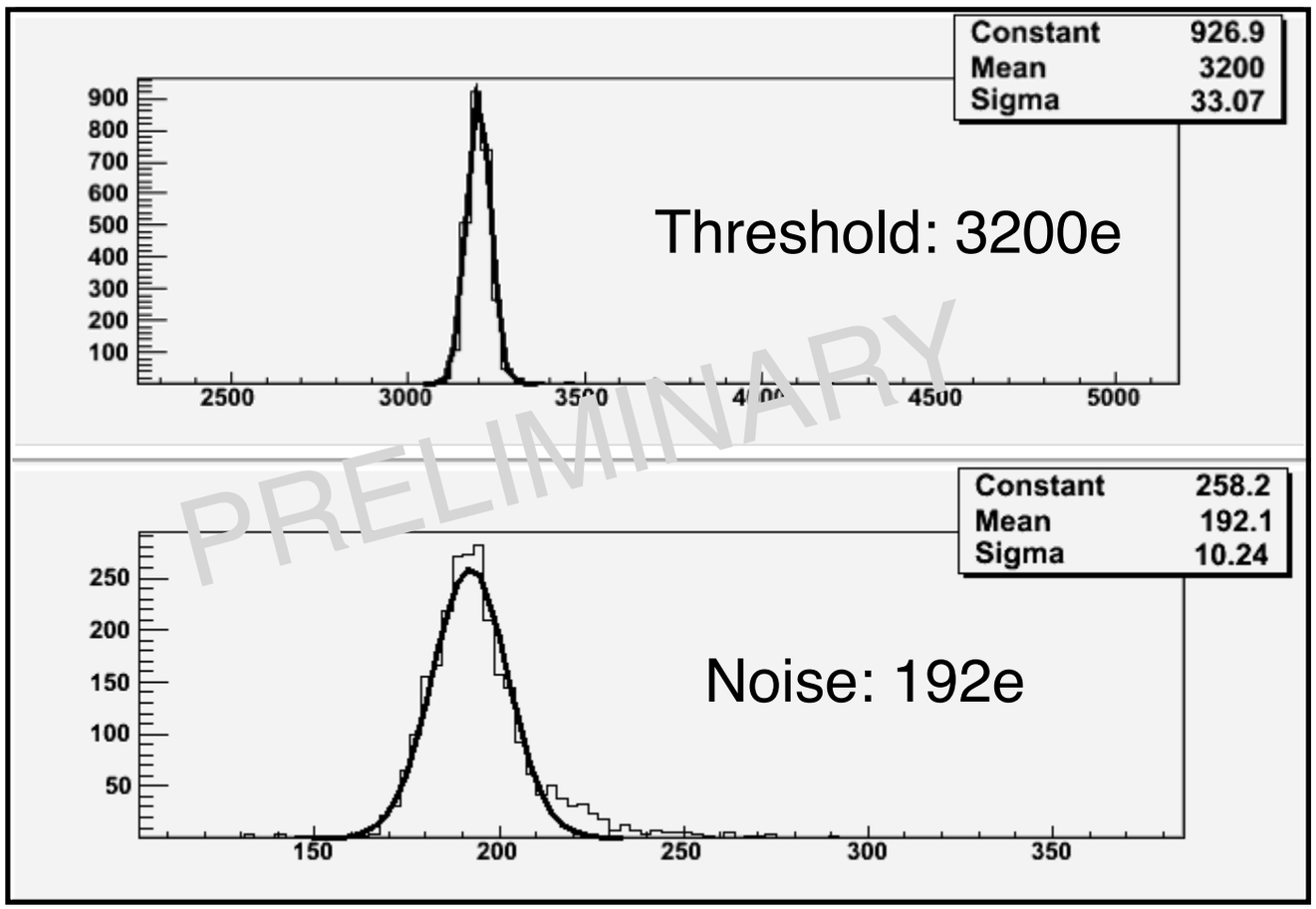


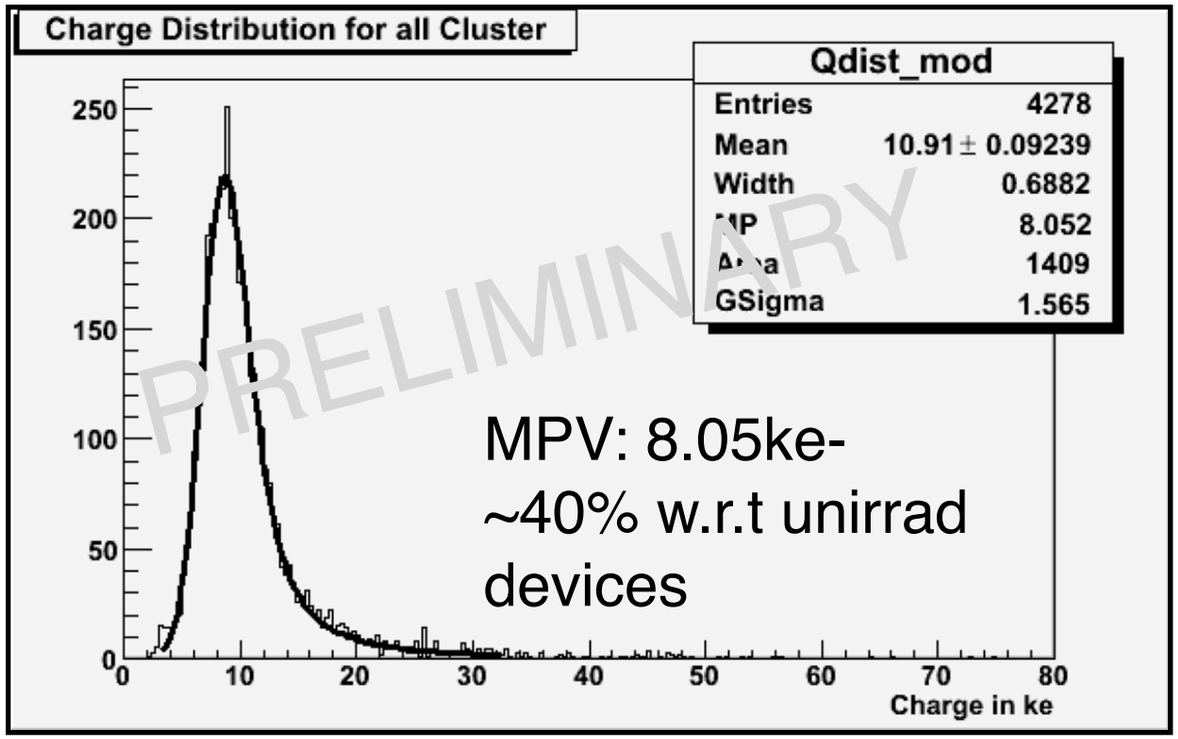
Higher measurements limited by HV capabilities of PCB

- Source-test at different HV up to 700V --> no saturation for collected charge
- Beneficial annealing:
  - SCA kept at 20°C over a period of almost 6 days --> MPV: 8.5ke (@700V)

External-trigger operation with Sr^{90} source

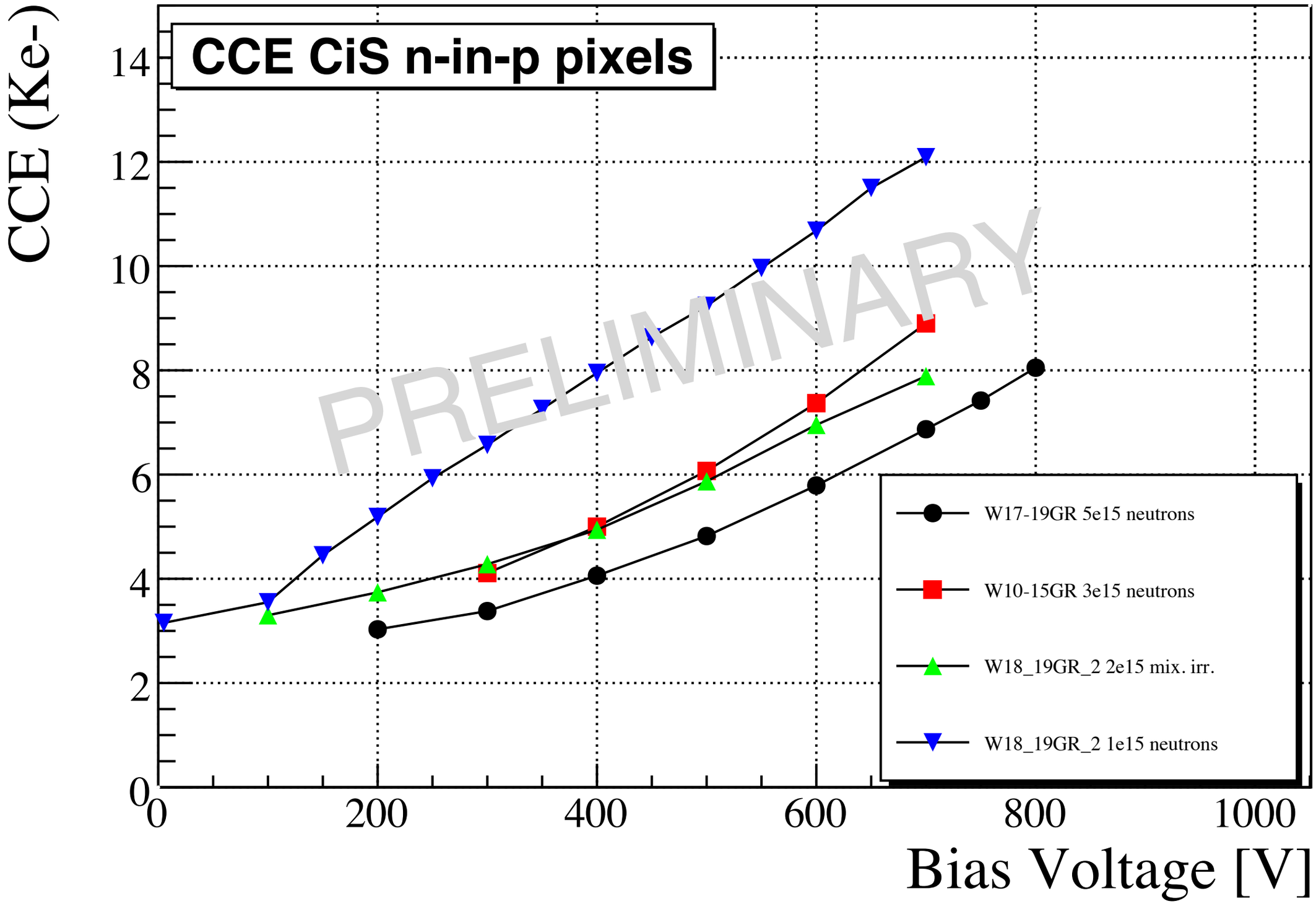
- Measurements performed with irradiated device up to **$5x10^{15}$ n_{eq}** (LJ)
  - modified PCB to allow high HV capabilities (1000V)
  - test performed at -50 ^{o}C
  - bias voltage:





- Very preliminary results. Measurements are on-going

Overview of MPV collected charge for irrad SCAs



Highlights from 2010 beam tests at CERN SPS

- CERN SPS 180GeV pions beam
- H6/B beam line
- Reference Telescope: EUDET
- DAQ based on TurboDAQ System
- About 9 weeks of beam over July and October

ATLAS PPS Testbeam Teams:

in July:

M. Benoit, C. Gallrapp, M. George, S. Grinstein, Z. Janoska, J. Jentsch, A. LaRosa, S. Libov, D. Muenstermann, G. Piacquadio, B. Ristic, I. Rubinsky, A. Rummler, D. Sutherland, C. Troska, S. Tsiskaridze, P. Weigell, J. Weingarten and T. Wittig

in October:

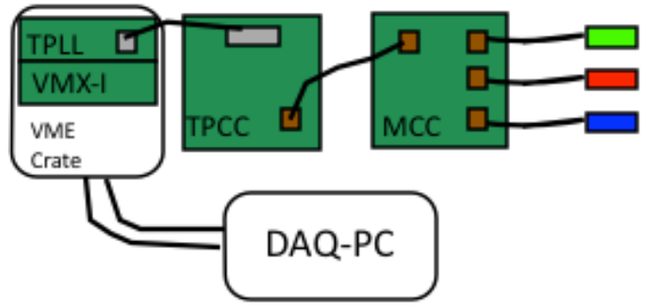
M.Beimforde, M. Benoit, M. Bomben, G. Calderini, C. Gallrapp, M. George, S. Gibson, S. Grinstein, Z. Janoska, J. Jentsch, O. Jinnouchi, T. Kishida, A. LaRosa, S. Libov, A. Macchiolo, G. Marchiori, D. Muenstermann, R. Nagai, G. Piacquadio, B. Ristic, I. Rubinsky, A. Rummler, Y. Takubo, C. Troska, S. Tsiskaridze, I. Tsurin, Y. Unno,P. Weigell, J. Weingarten and T. Wittig

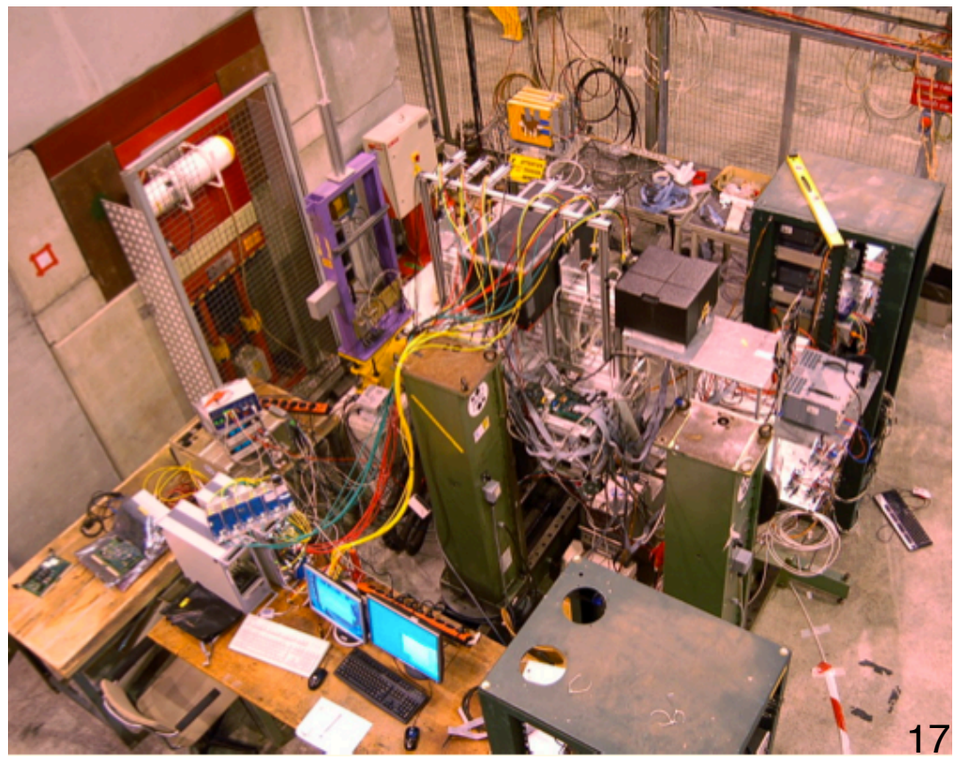
EUDET Telescope

(default telescope for H6/B beamline)

- 6 telescope planes Mimosa_26
- 1152x576 pixels, 21x11 mm^2
- zero-suppressing binary readout
- ~ 3um tracking resolution

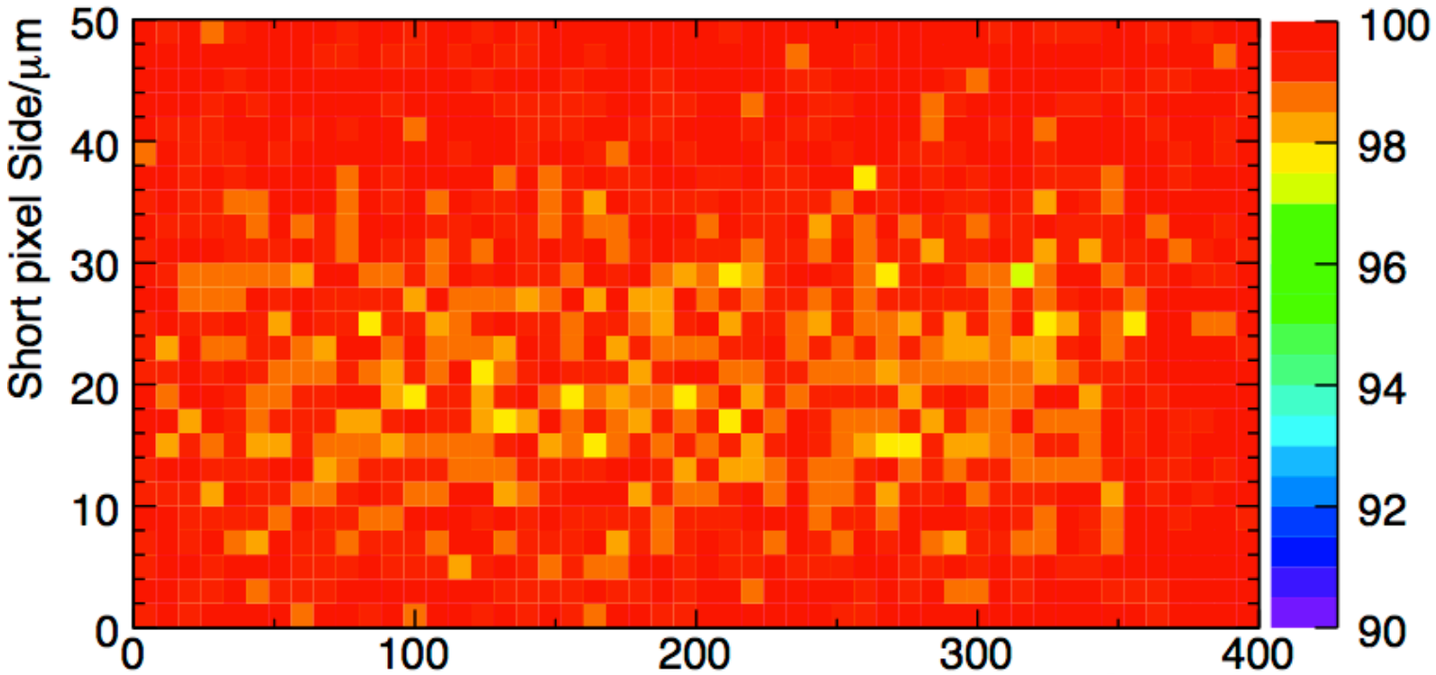
DAQ based on TurboDAQ





From unirrad devices ...

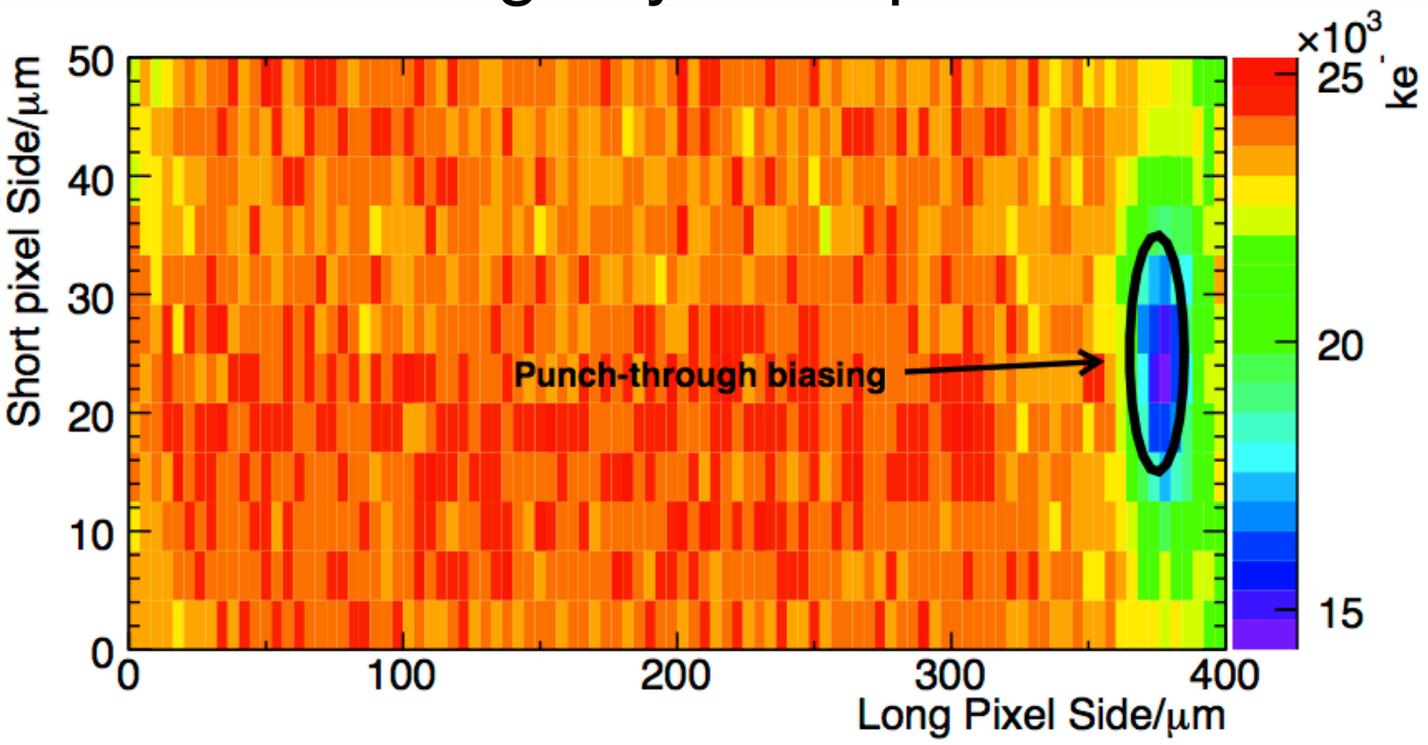
Tracking efficiency map



Measurements performed at 150V

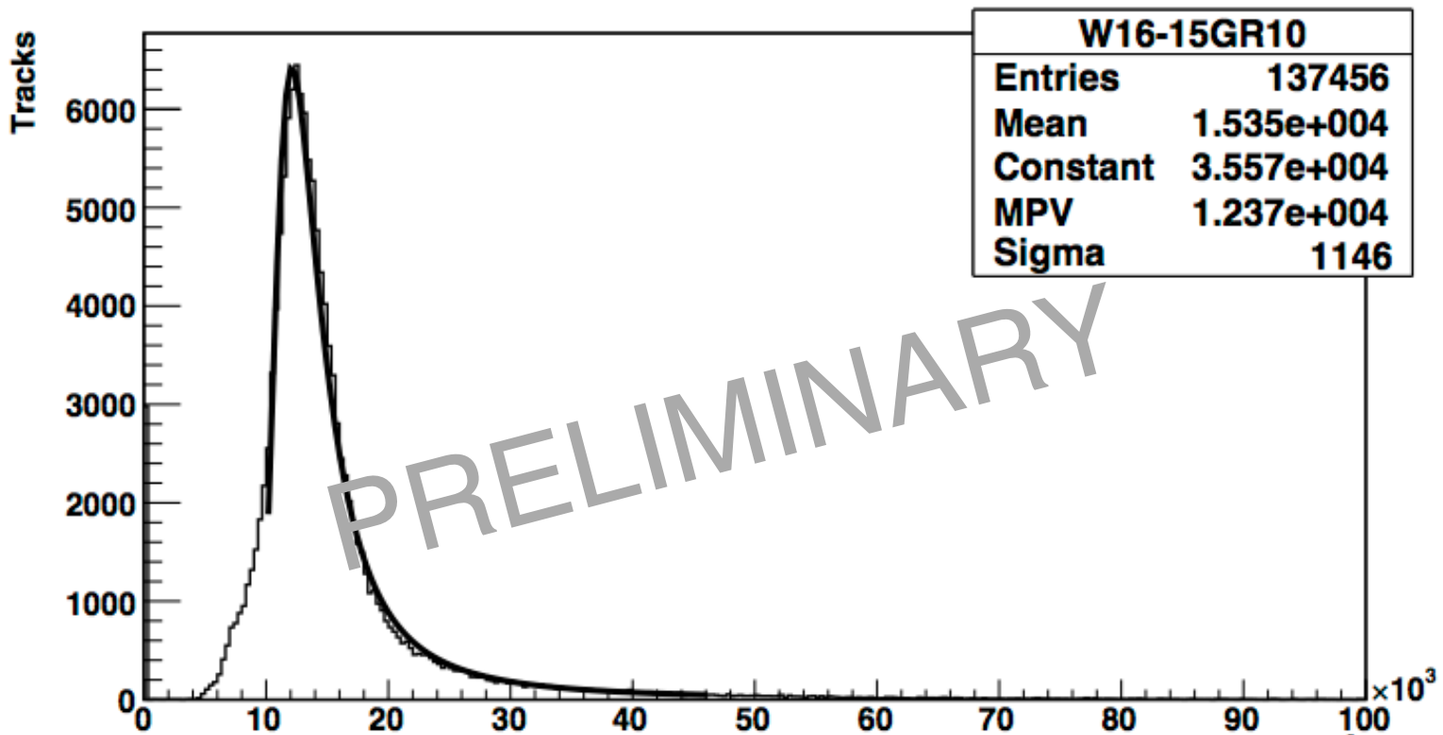
- High Tracking efficiency: 99.3%

Collected charge by track position



- Good collected charge in the punch-through region (well above threshold)

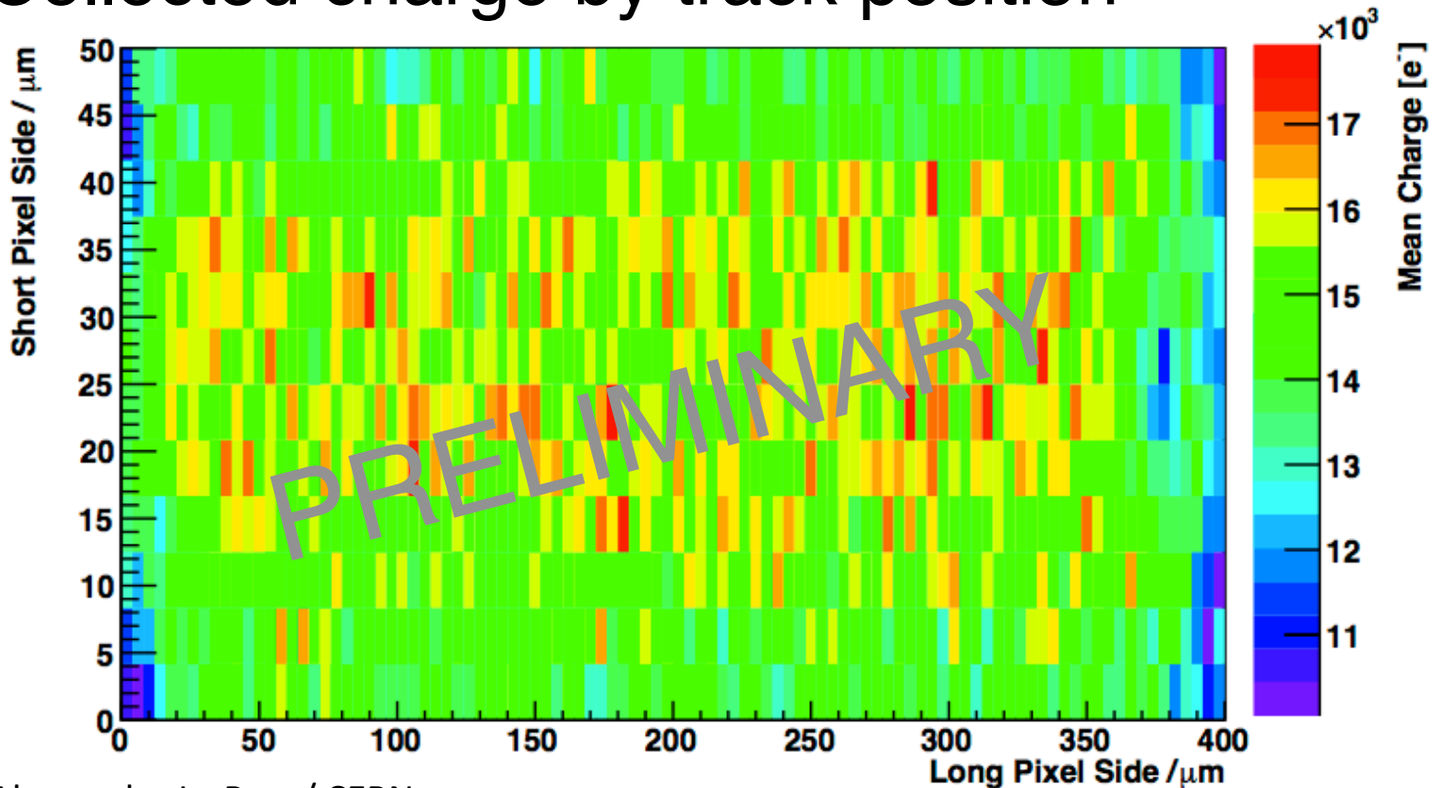
From proton (25MeV) irrad devices at 1x10^{15}n$_{eq}$



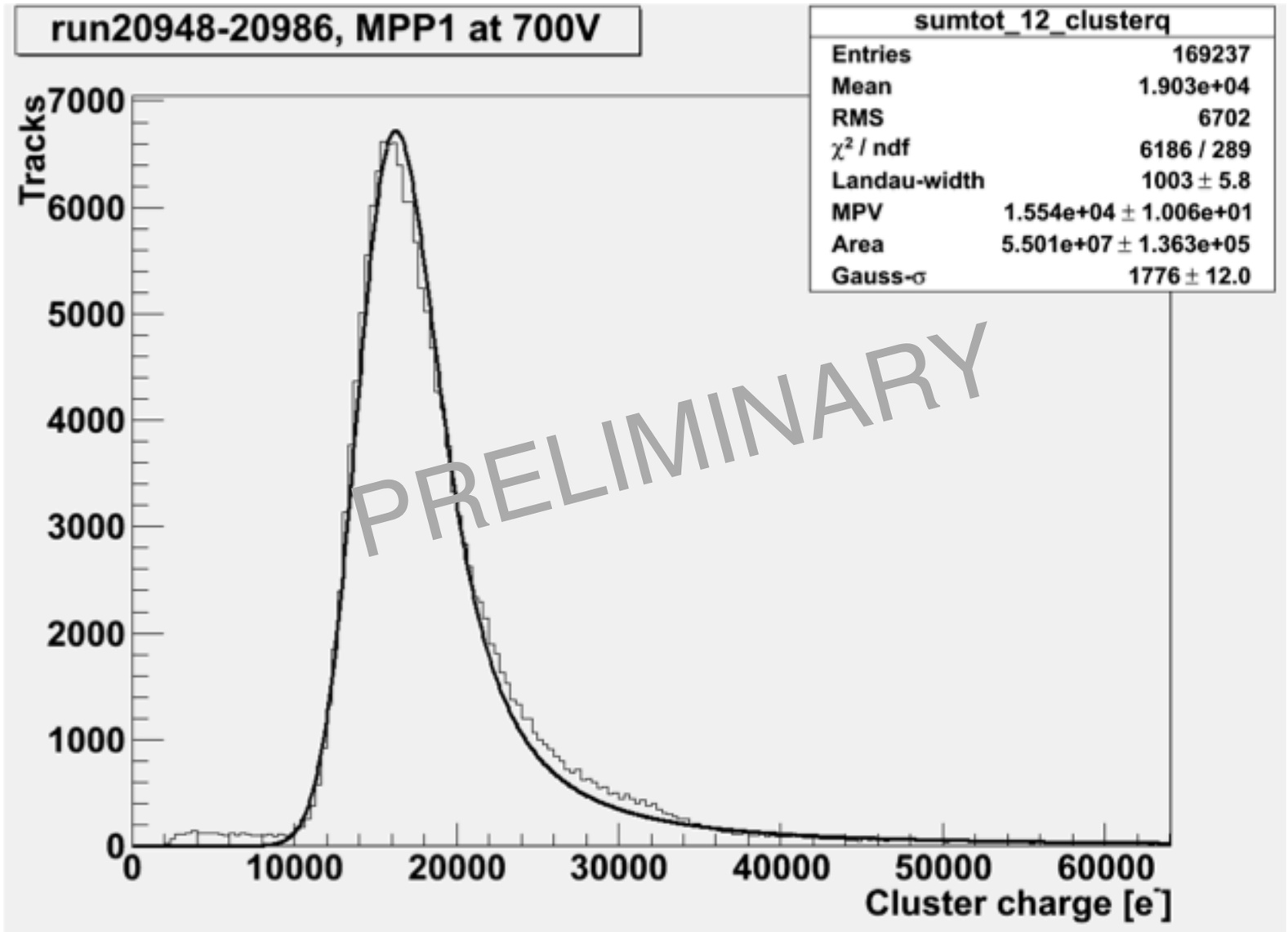
Measurements performed at 500V

- Collected charge in agreement with the Lab-measurements

Collected charge by track position



From neutron irradiated devices at $1x10^{15}$ n_{eq}



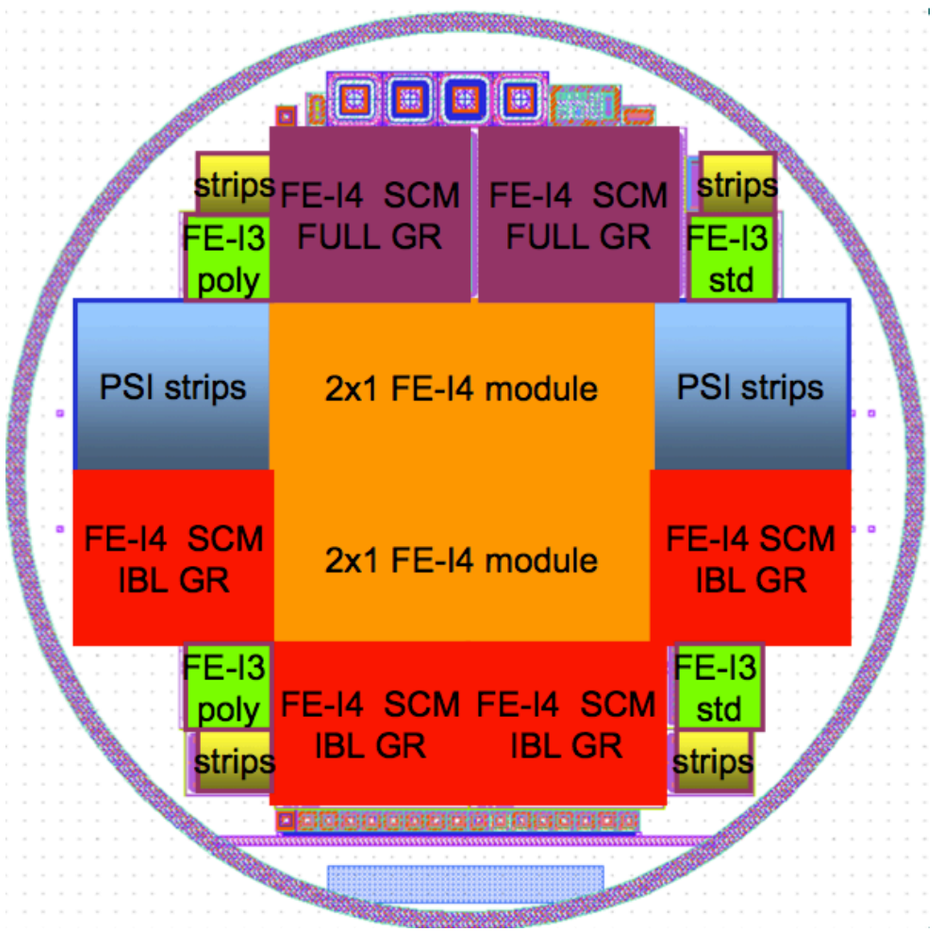
Measurements performed at 700V

- Stable performance for several days at 700V (BCB applied) !!!
- Good collected charge (15.5ke-) above threshold (3.2ke-)

Summary and outlook

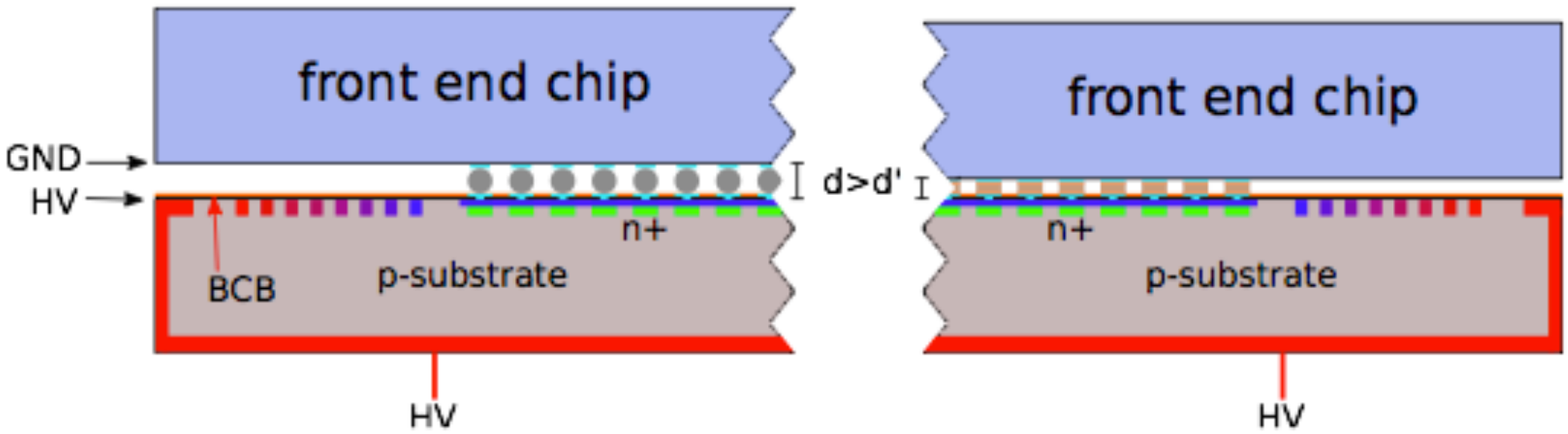
- Several devices have been tested before and after irradiation
  - Good signal to threshold ratio above 16ke/3.2ke for unirrad devices
  - Good charge collection ~7ke after $2x10^{15}$ n_{eq} (Operational bias voltage 700V) => still well above threshold (3.2ke)
  - Lab-test measurement with $5x10^{15}$ n_{eq} irrad devices are on-going

- A second production of n-in-p pixels at CiS is in preparation, this time focusing on FE-I4 compatible sensors
  - 3 batches of different thickness on 4” wafers
    - 300um (for reference), 200um and 150um
  - with several flavors of pixels



Backup

HV Stability with Benzo Clyclo Butene (BCB)

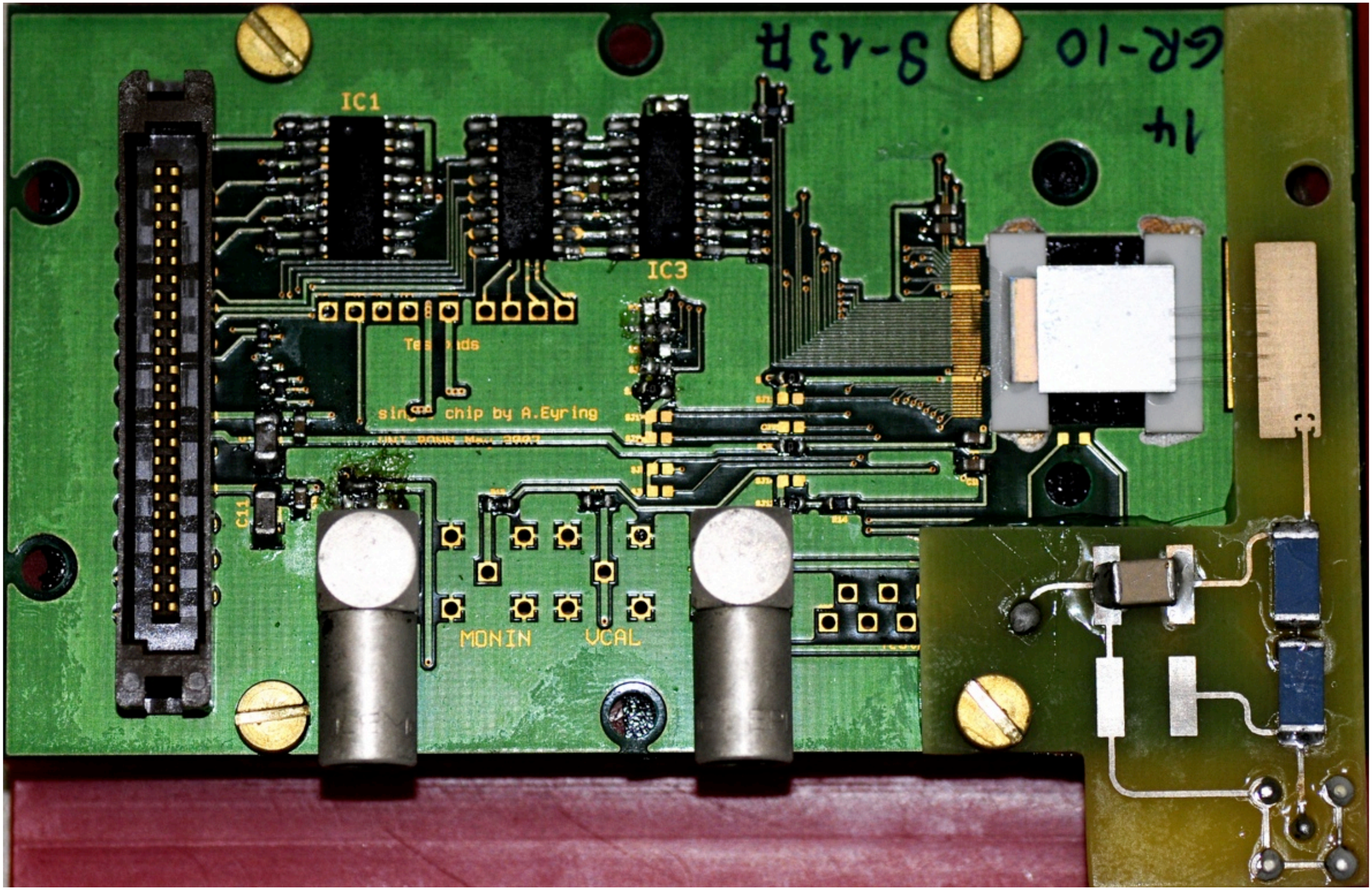


- n-in-p: HV is on sensor side facing the chip (sparks ?)
  - ➡ Cover sensor with a thin layer of BCB

- Tested up to 750V with stable operation for several day
  - ➡ No sparks seen

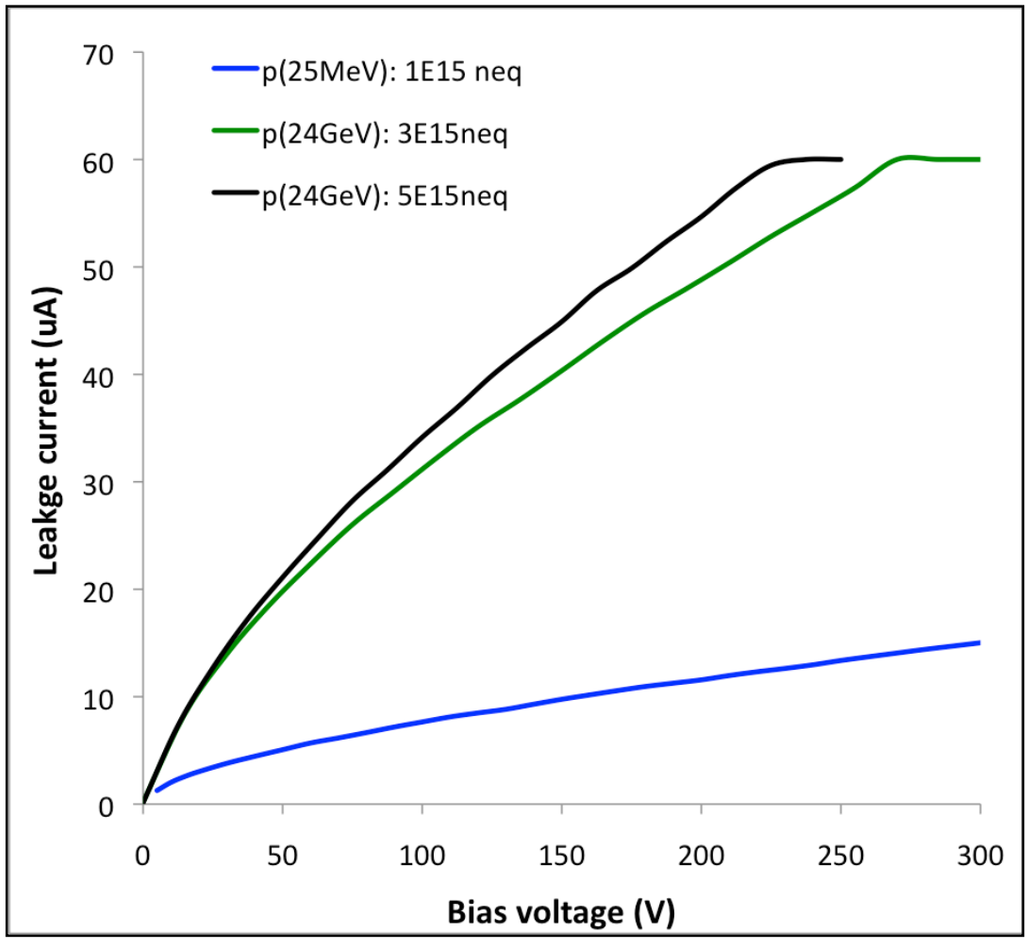
- Further tests at higher voltage planed

Modified PCB



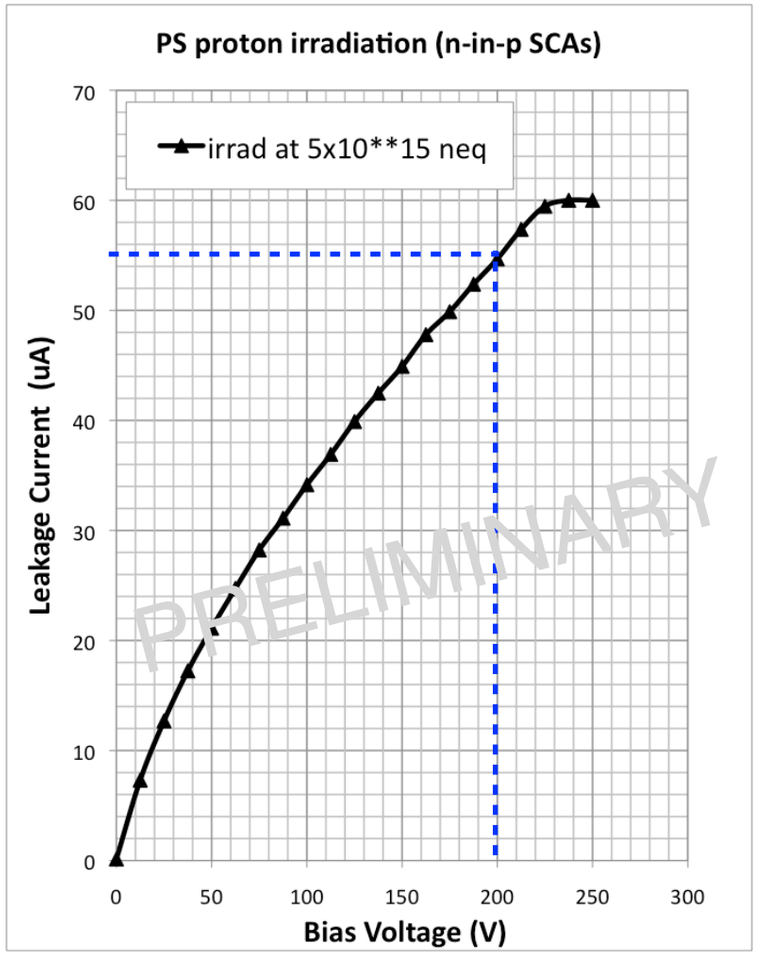
Leakage current

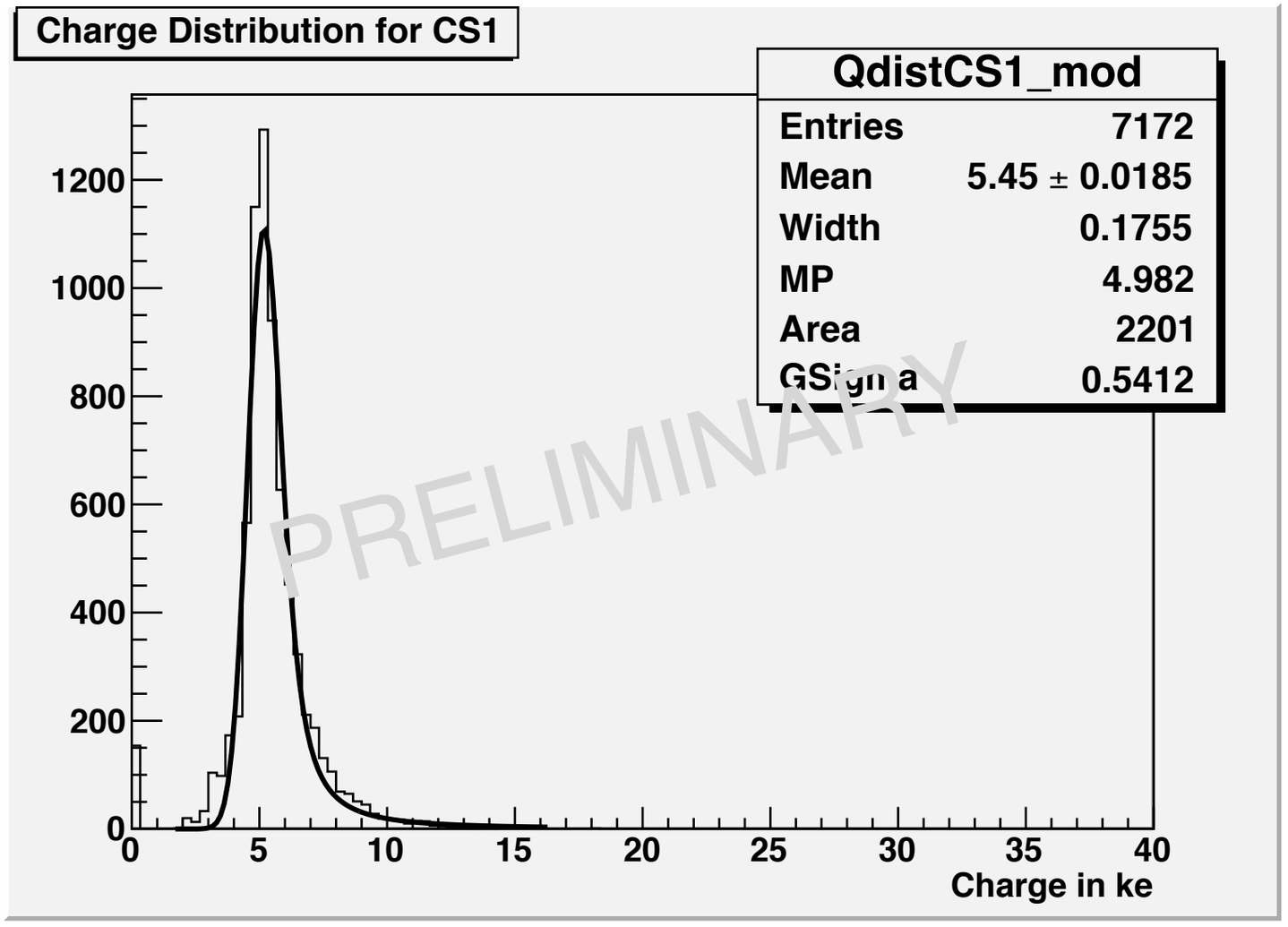
- Measurements performed (or scaled) at -20^{o}C



External-trigger operation with Sr^{90} source

- Measurements performed with irradiated device up to **$5x10^{15}$ n_{eq}** (24GeV p-beams)





- Test performed at -20 ^{o}C with 200V
  - Need to reduce temperature & increase bias voltage to study charge collection