Edgeless detectors with CTS: the 1st year successful operation in TOTEM

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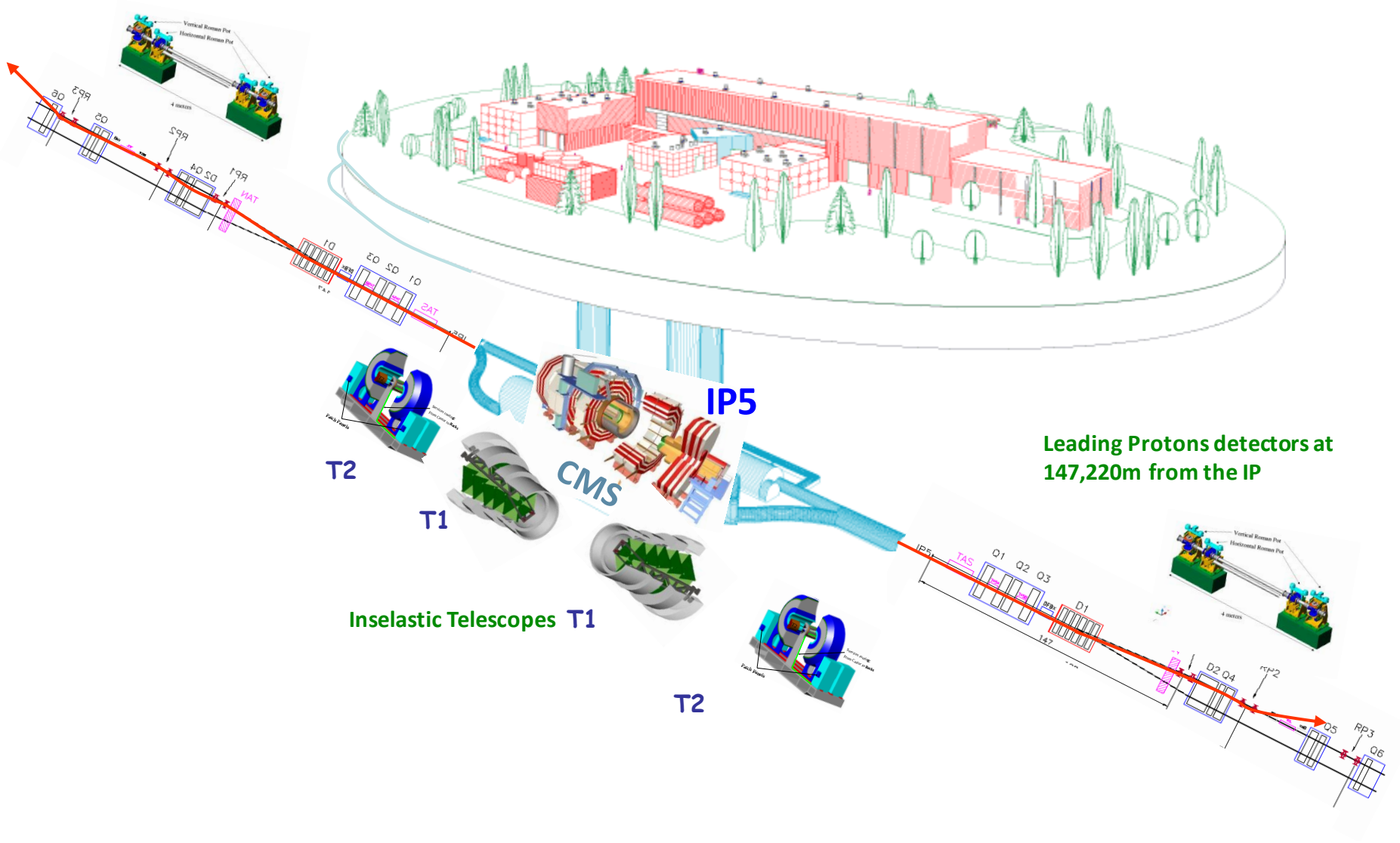
CERN, TOTEM collaboration

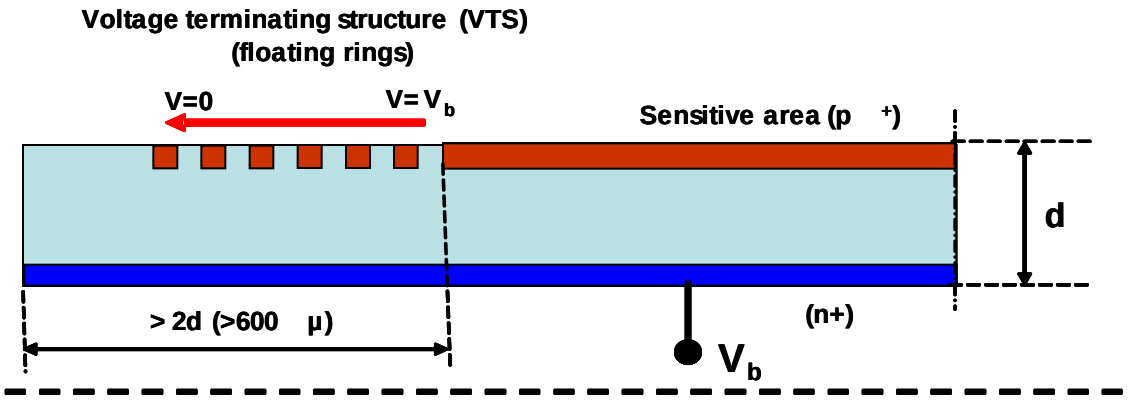
19-th RD50 meeting, CERN, November 21 – 23, 2011

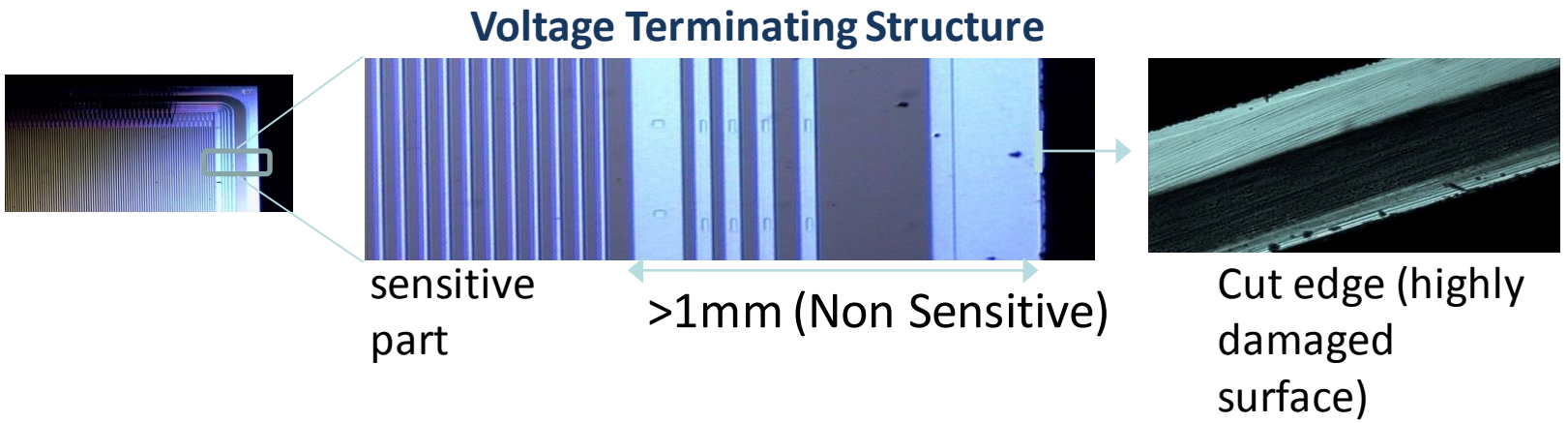
Experimental layout

Leading Protons detectors at
147,220m from the IP



Regular planar detectors





1. G. Ruggiero et al. IEEE Trans. Nucl. Sci. 52 (2005) 1899.
2. E. Noschis et al. Nucl. Instr. and Meth. A 563 (2006) 41.

Requirements for TOTEM Edgeless Strip Detectors

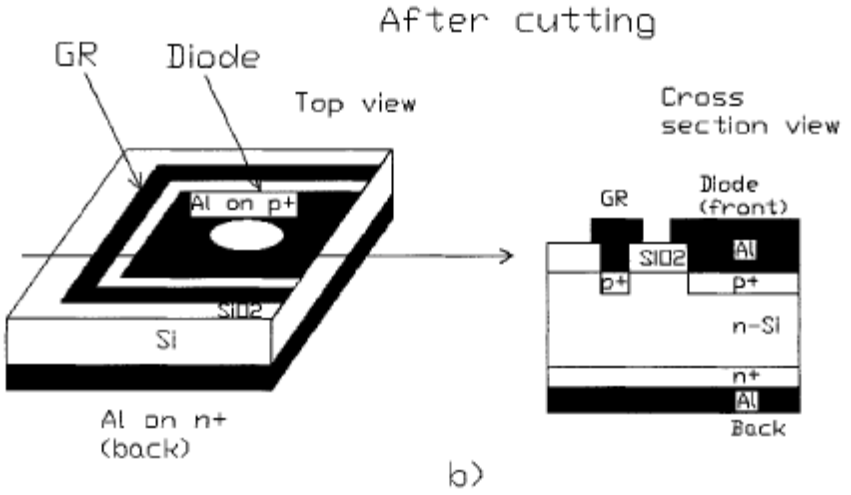
- The production yield providing fabrication hundreds of the detectors
- Low strip capacitance and current for appropriate signal to noise ratio
- Stable properties of the sensitive edge along the years detectors operation.

The choices:

- N-on-P planar
- 3D technology

Prehistory

Z. Li et al., IEEE Trans. Nucl. Sci. NS-49 (2002) 1040-1046



I-V improvement:
- Dicing from the back side
- One day "annealing" at RT

3D active edge detectors

C. Da Via et al., NIM A587 (2008) 243-249

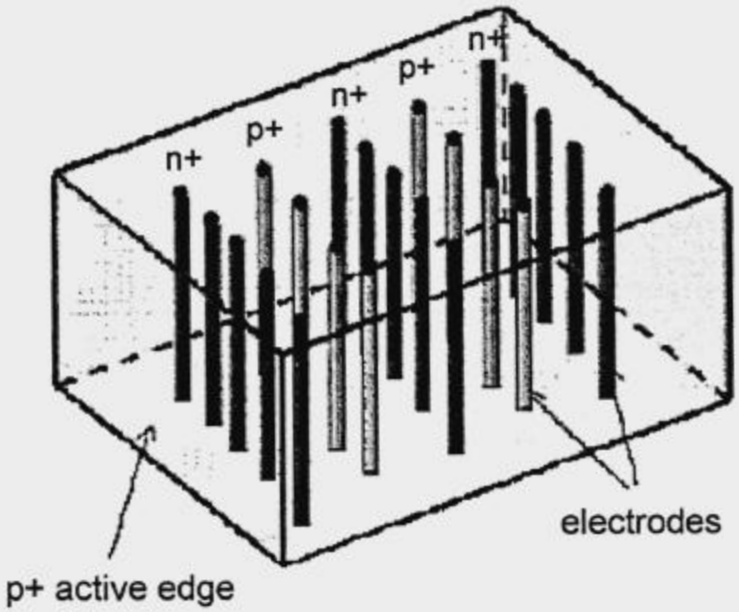


Fig. 1. Sketch of a full-3D sensor where the p+ and n+ electrodes are processed throughout the entire thickness of the silicon bulk. The edges are trench electrodes (active edges) and surround the sides of the 3D device making the active volume sensitive to a few μm from the physical edge.

Main features of design:

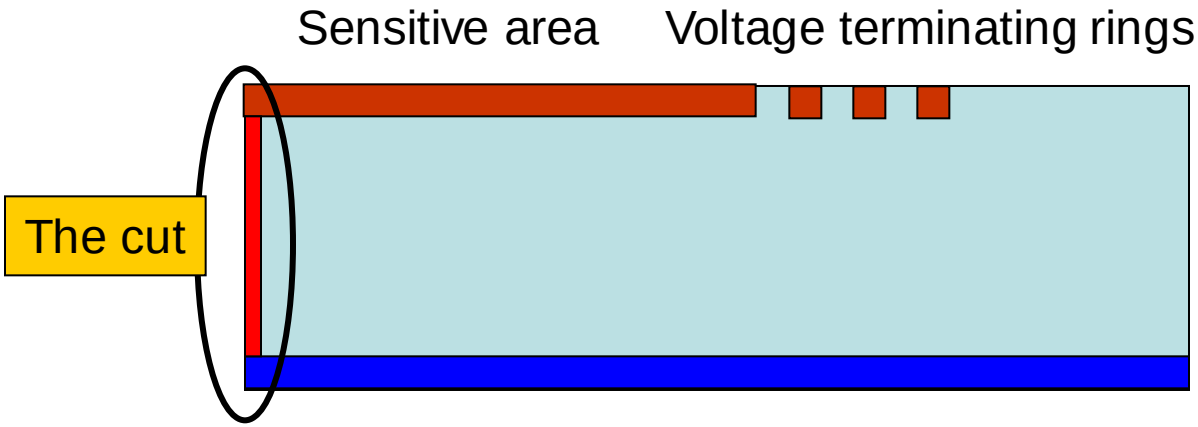
- p^+ and n^+ through entire bulk
- p^+ active edge

✓ collection distance ≤ 50 μm
✓ fast response
✓ higher electric field due to cylindrical geometry
✓ radiation hardness

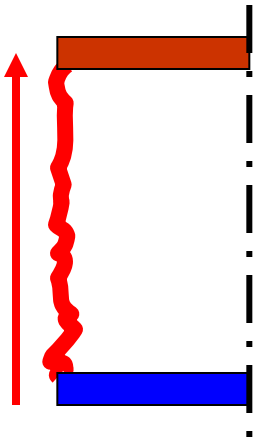
but

✓ Complicated technology – low yield

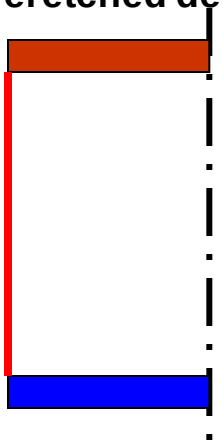
Planar approaches



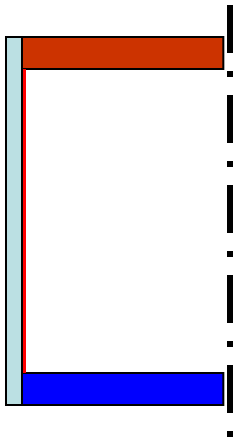
Conductive cut



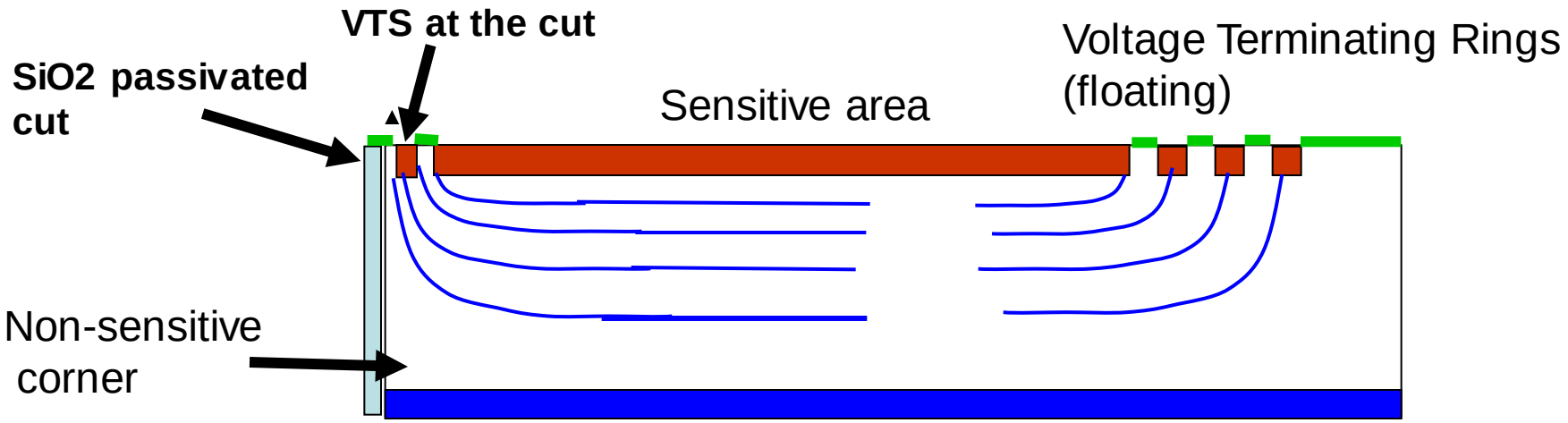
Insulating cut
(exploited in silicon power devises – bevel etched devises)



Passivated cut



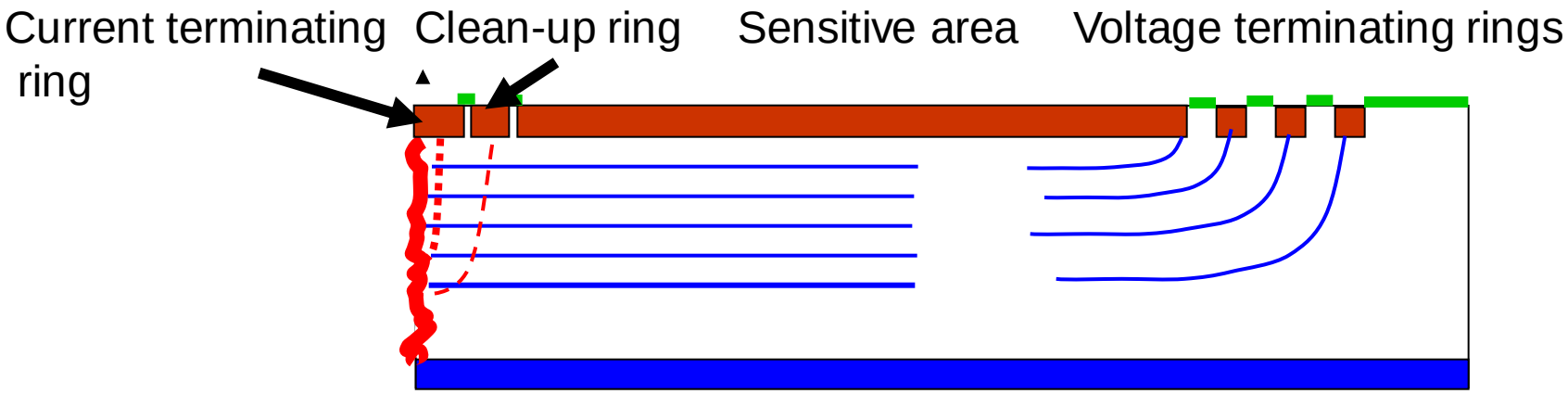
EDL detector with passivated cut



Complicate technology
Low operational voltage
Low operational fluence
Low production yield

Detector with CTS

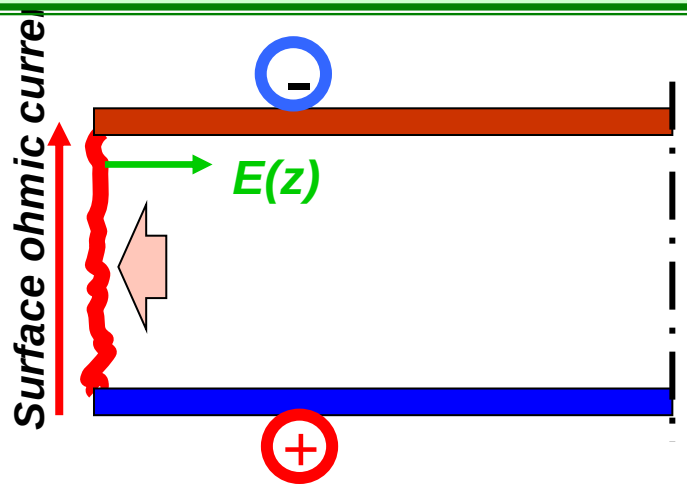
(TOTEM edgeless design)



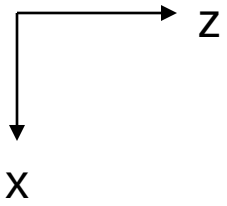
Effect of the Current Terminating Structure

- The potential distribution along the cut similar to the potential in the bulk
- The current of CTR: Injected Ohmic current along the cut
- The current of CUR: Diffusion current from the cut to the bulk
- The current of sensitive area: mainly the bulk generated current
- No potential drop along the CTS rings

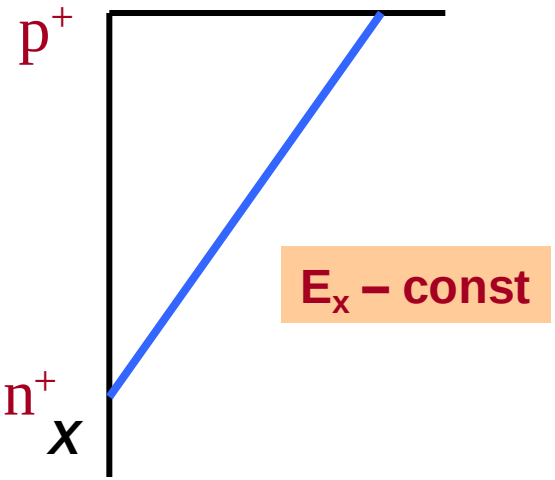
Conductive cut – the main part of EDL detectors



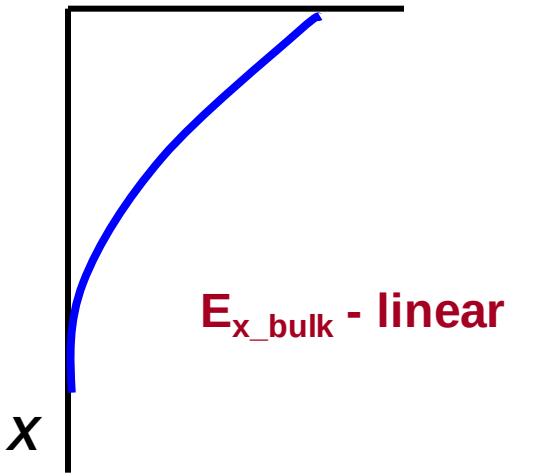
Damaged cut surface has high concentration of defect levels and high recombination rate



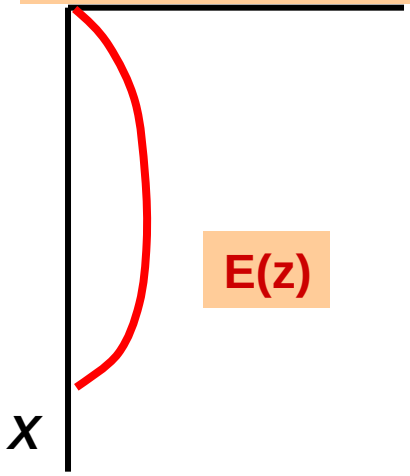
Potential at the cut



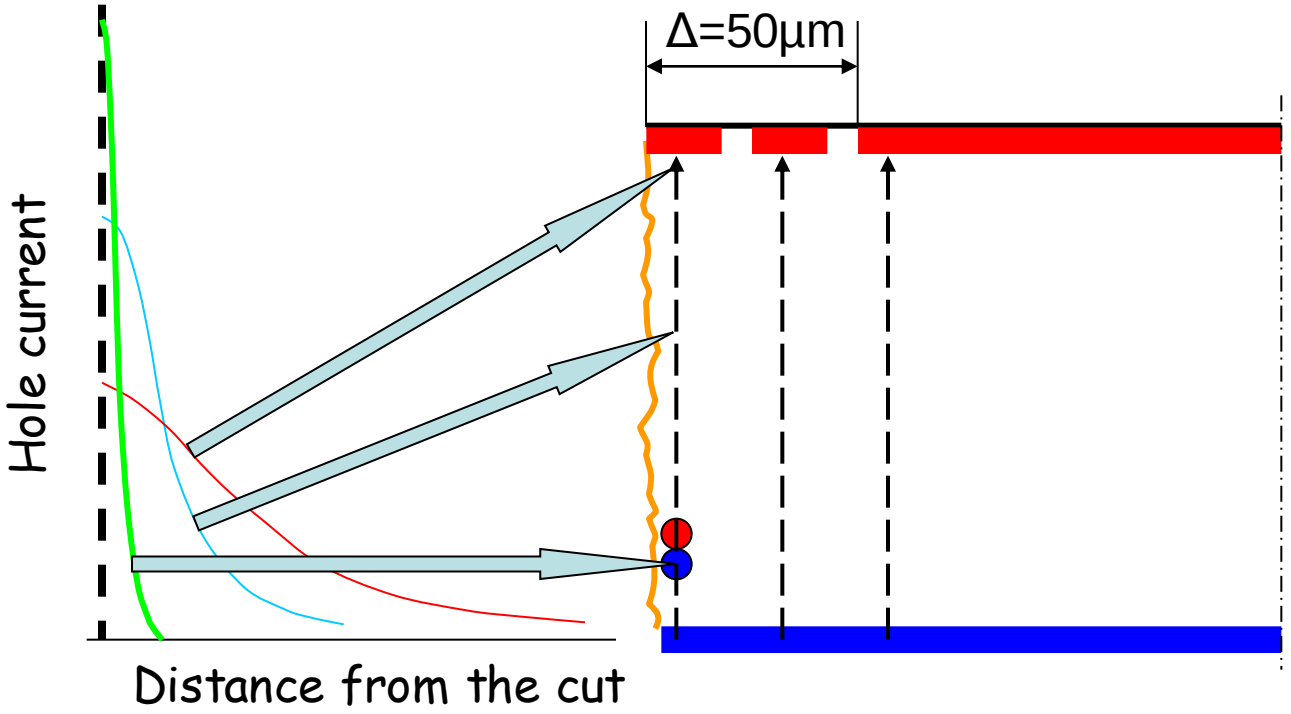
Potential in the bulk



Electric field at the cut



Current at the detector sensitive area (diffusion model)



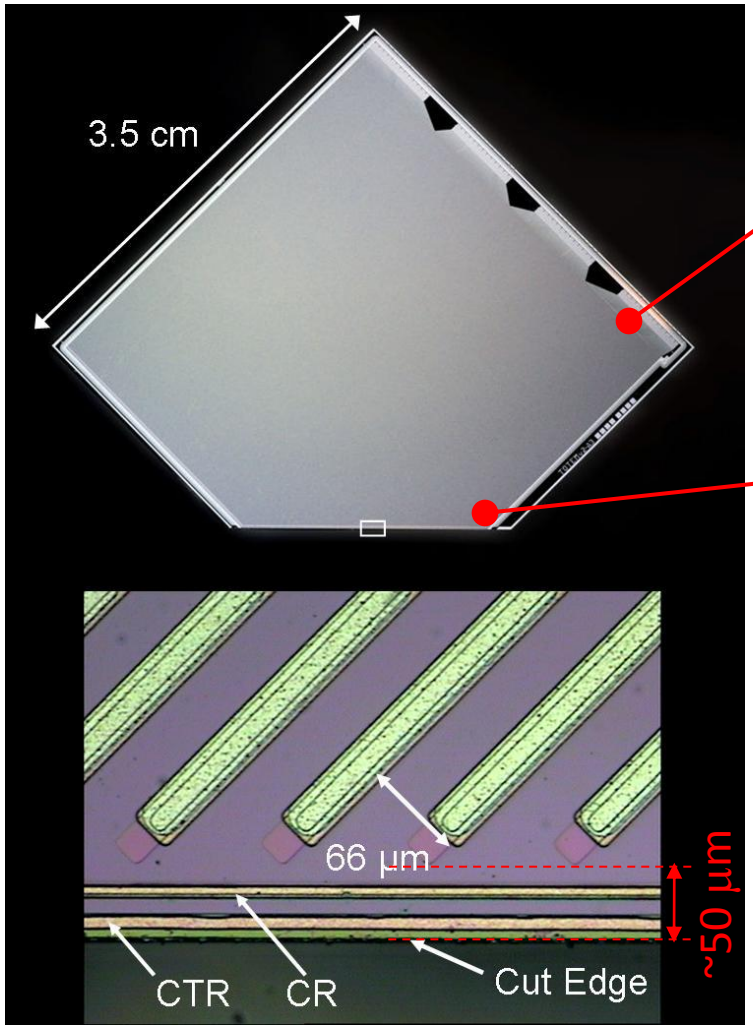
$$L_{dif} = \sqrt{D \cdot t_{dr}} = 4\mu m$$

at : D= 16cm;
t_{dr}= 10ns

I_{bulk}= Igen exp(-Δ/L_{dif})= Igen*2.3e5

at : I_{CTR}= 1e-3A;
I_{bulk}= 2.3e-8A

Final design

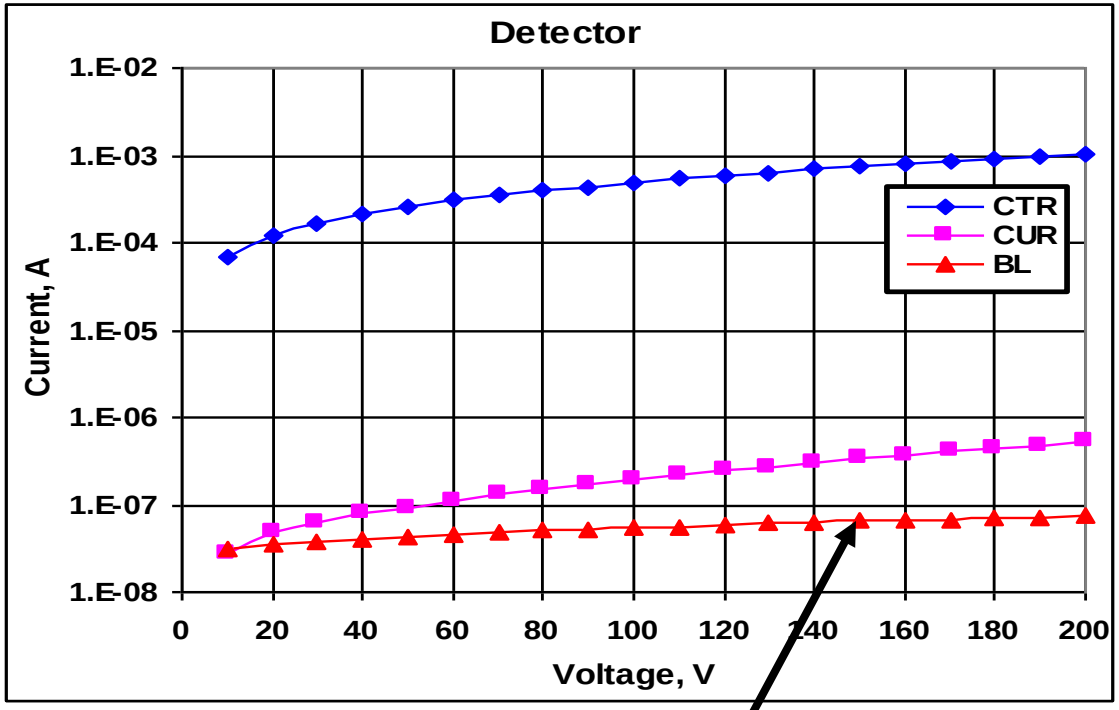


Very High Resistivity Si n-type <111>, 300um thick, Vdep ~20V

- Standard planar technology fabrication
- AC coupled strip (punch-through)
- Single sided detector, 512 microstrips (pitch 66um)
- strips at 45° from the "sensitive" edge
- Voltage Terminating Structure on non sensitive edges
- Current Terminating Structure on sensitive edges

Only 50µm from end of strip to end of sensor!!!

Experimental I-V characteristics

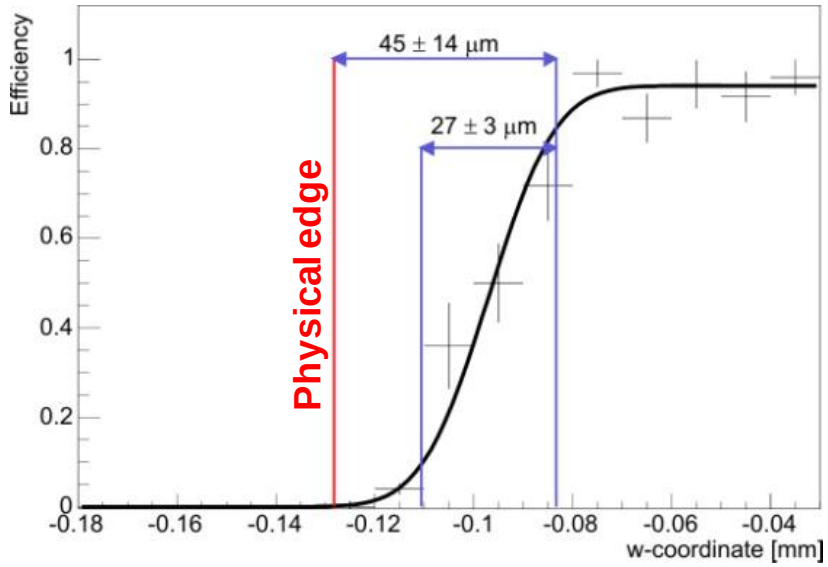


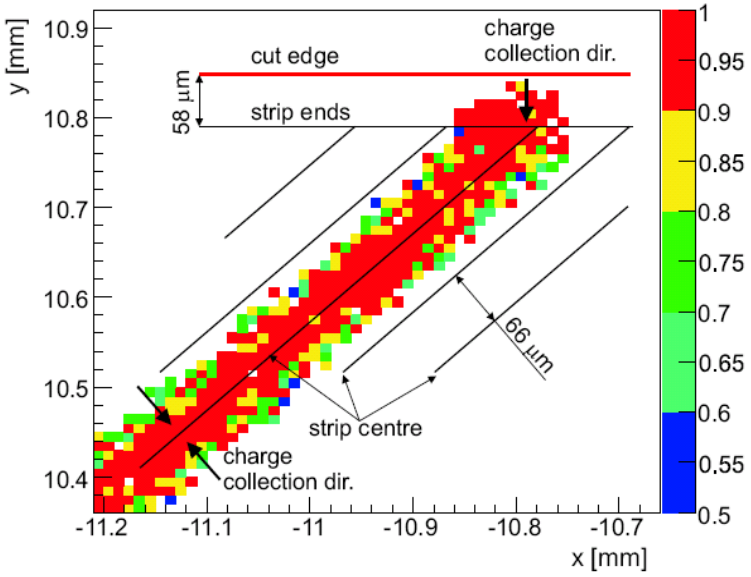
23nA (Icut) + 57nA(Ibulk) = 80nA

Good agreement with the predictions !

Recent experimental results on CCE in p-on-n edgeless detectors with CTS

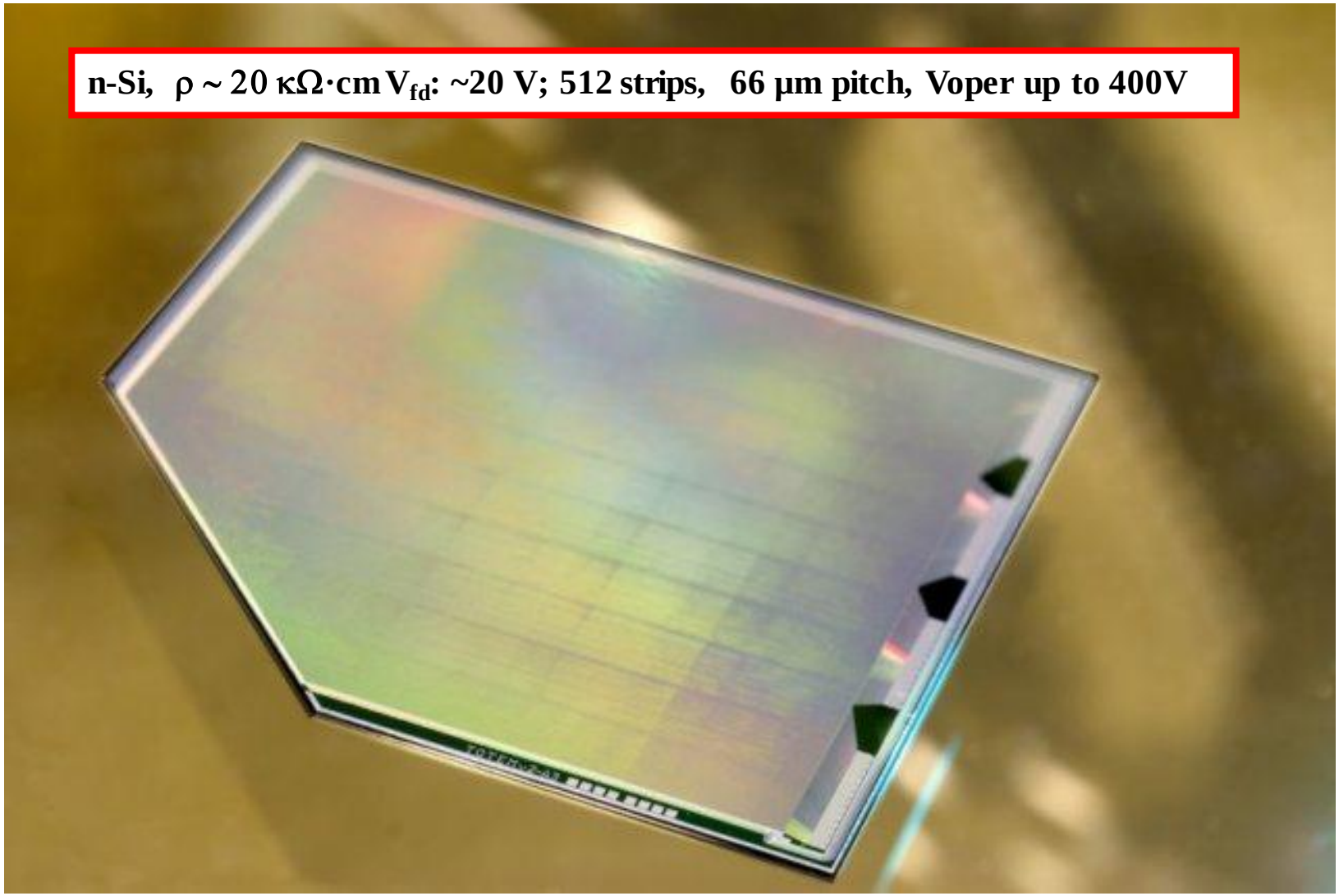
Efficiency of CTS detector at the sensitive edge



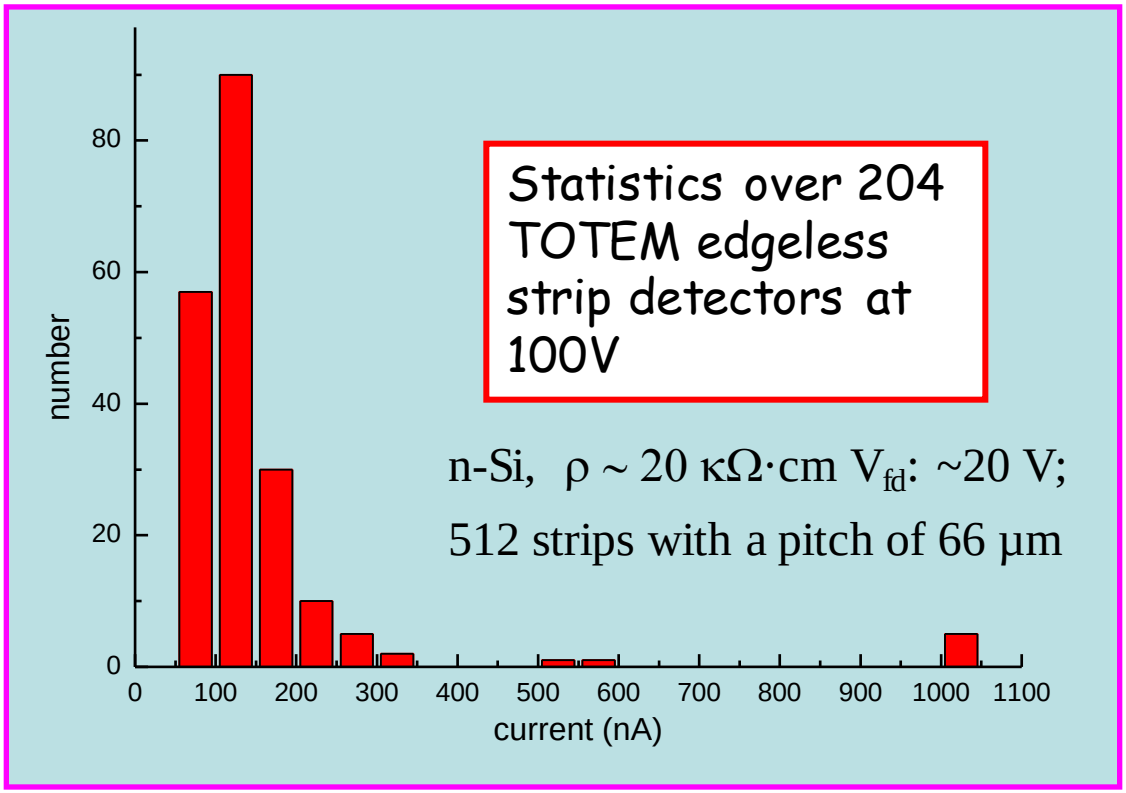


G. Ruggiero et al. Planar Edgeless Silicon Detectors for the TOTEM Experiment. Pres. 8th Intern.Conf. on Position Sensitive Detectors (PSD8), Glasgow, Sept 1-5, 2008, Nucl. Instr. and Meth. A (in press).

The TOTEM Roman Pot Silicon Sensor

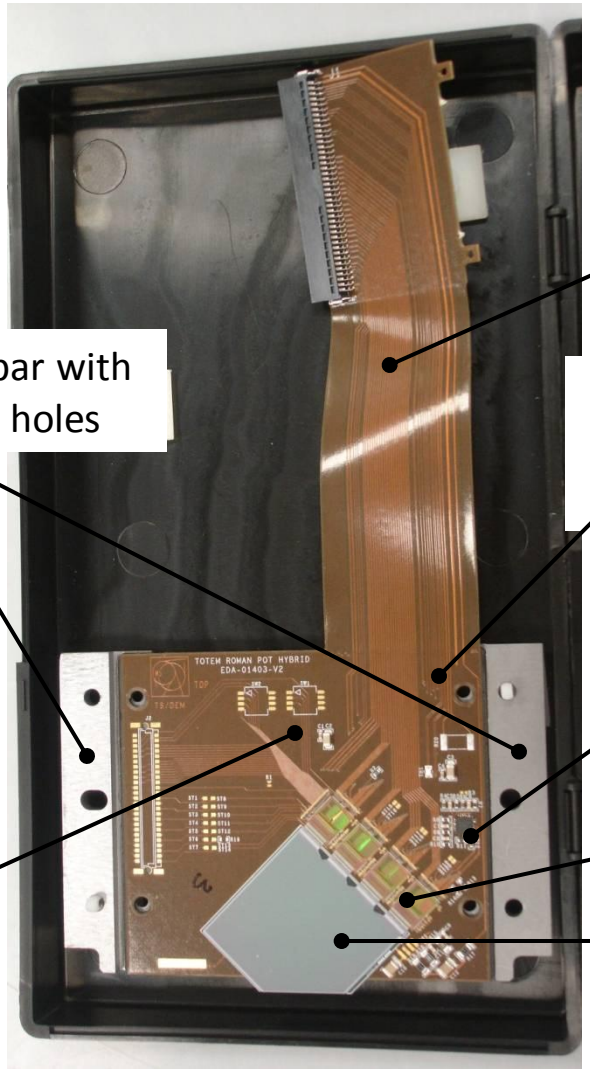


TOTEM Edgeless Detectors Technology Monitoring



Detector area 10cm^2
Averaged current density: 12nA/cm2/300μ

The Hybrid



Kapton Flex PCB

CE07 side bar with mounting holes

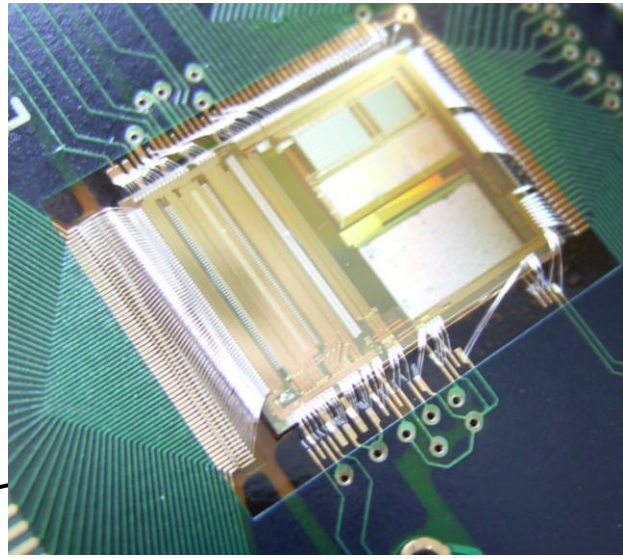
CE07 support plate

DCU

pt100

Si microstrip edgeless detector

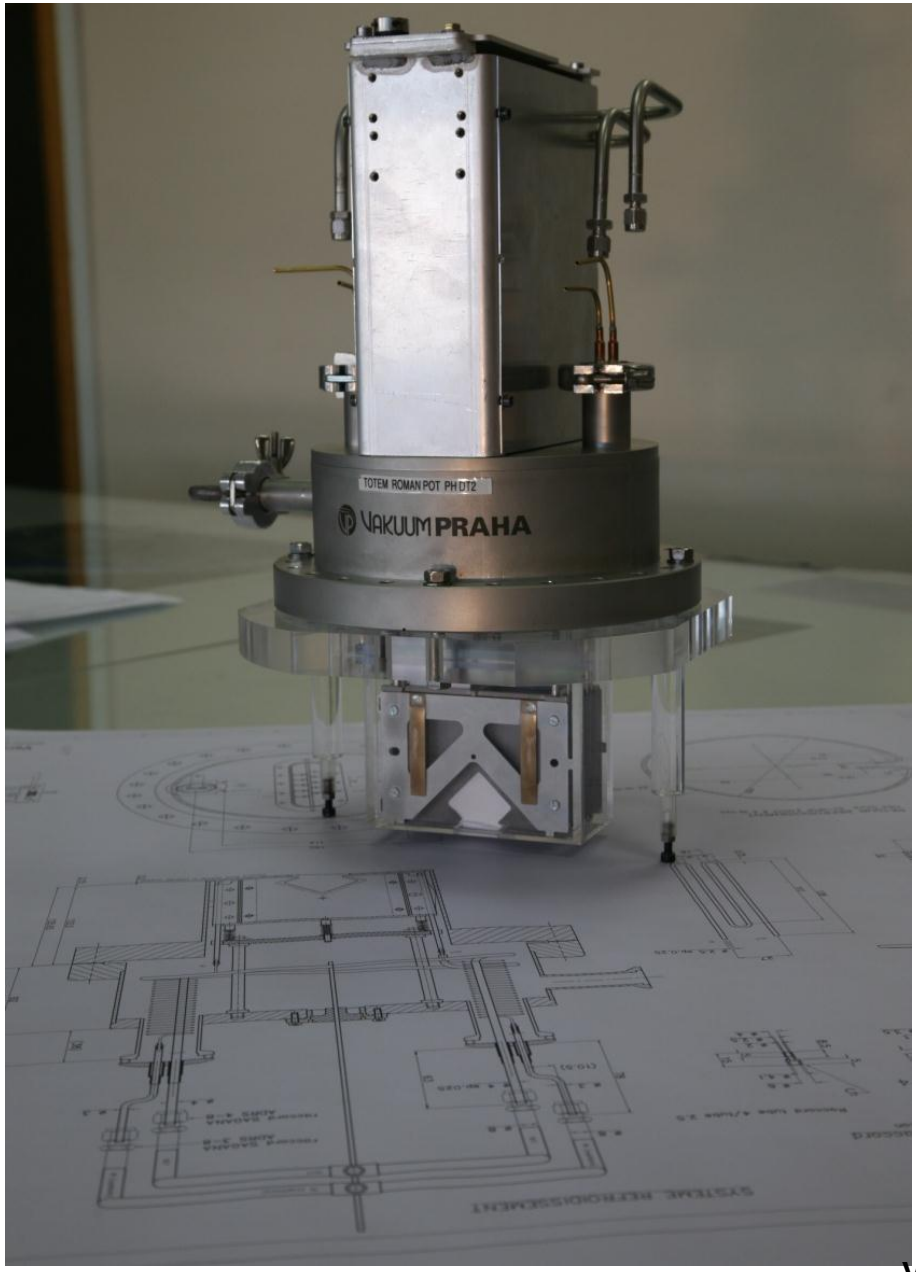
VFAT chip

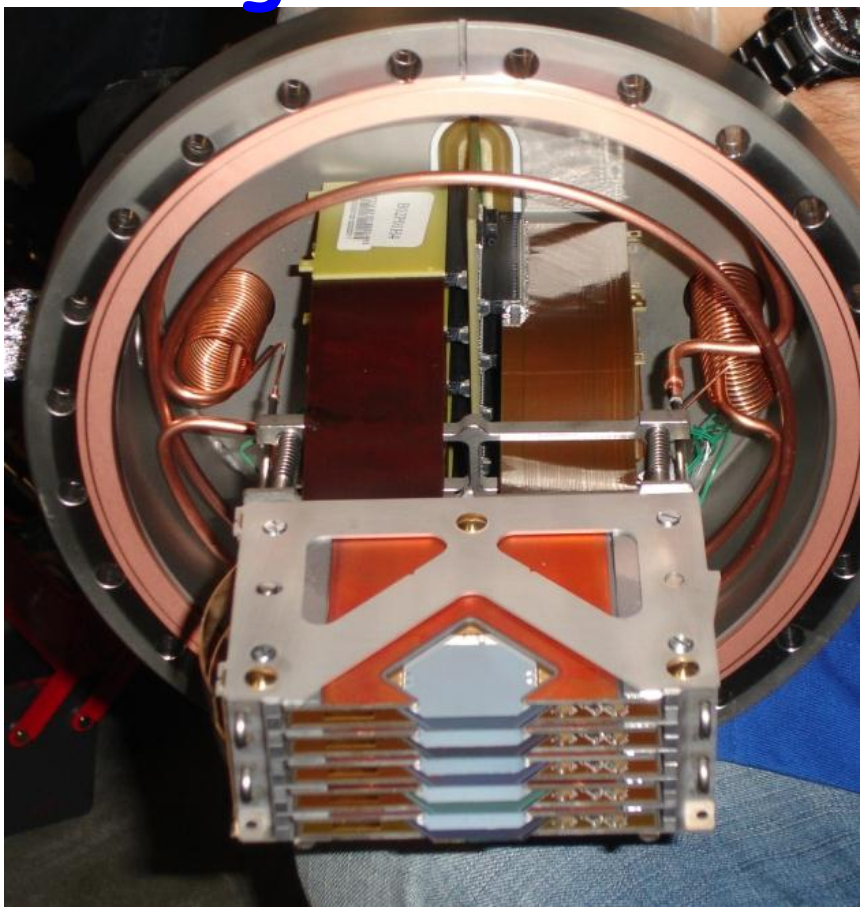


128 channels of tracking front end with digital storage and data transmission

8 programmable trigger outputs , radiation hard design

Detector Package





24 Detector Packages over >440m

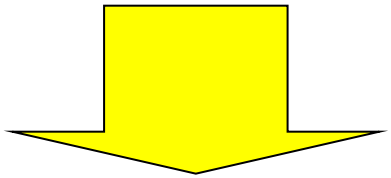
122880 r/o channels

240 sensors (.3m^2)

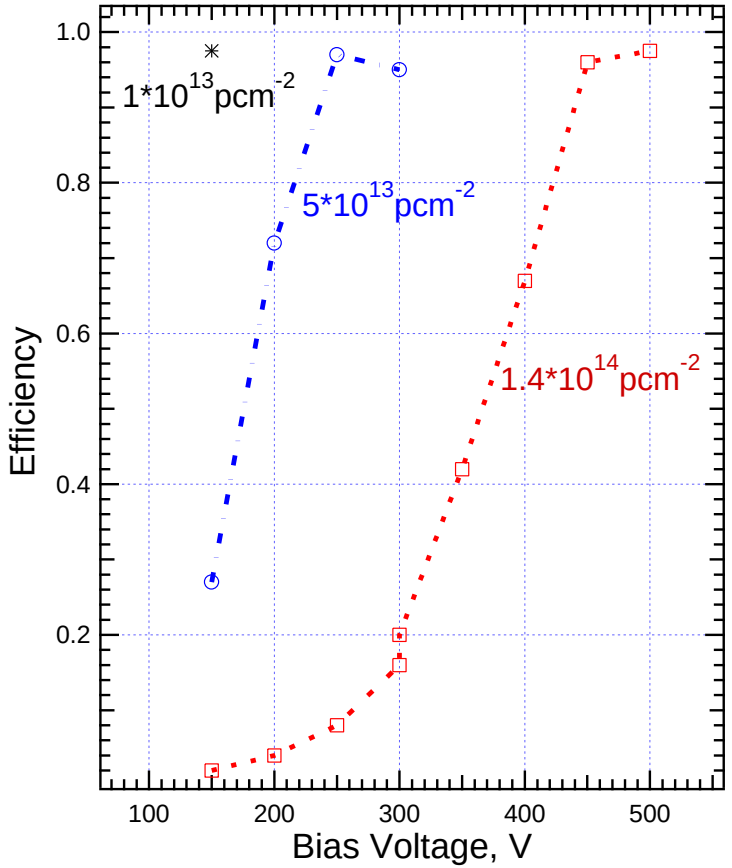
Radiation hardness of the edgeless sensor with CTS

- Real, full size, devices tested
- Uniformly irradiation with 24 GeV protons
- Readout with VFAT
- Operating temperature: -20°C

- 100% Efficiency at >1x10^{14}pcm^{-2} (at 500V)

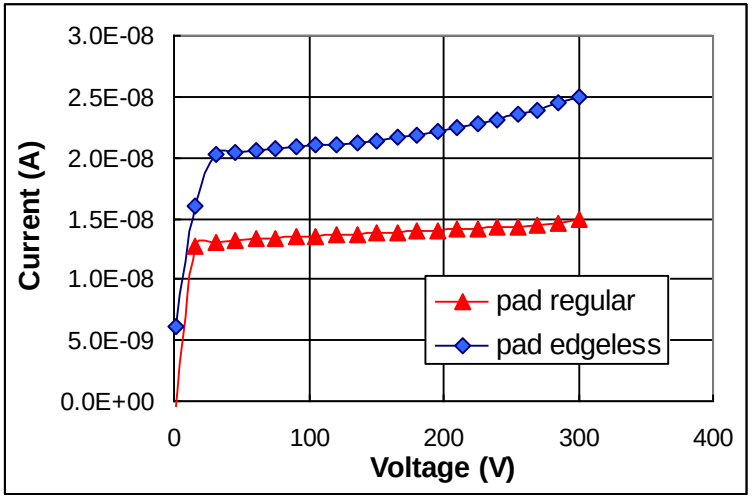


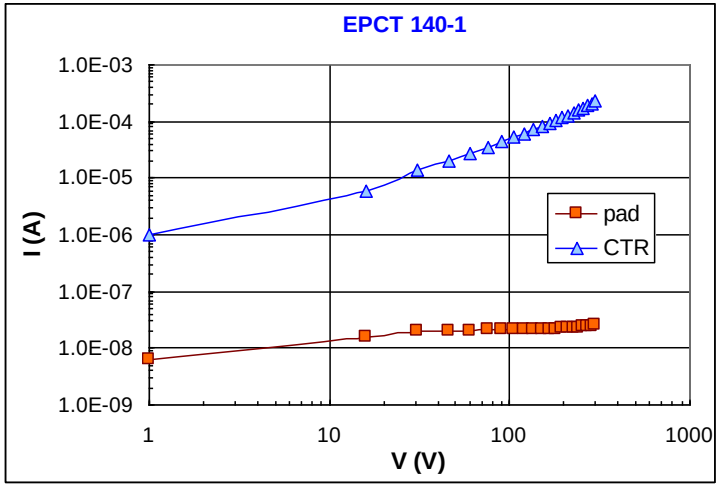
Radiation hard N-on-P edgeless detectors

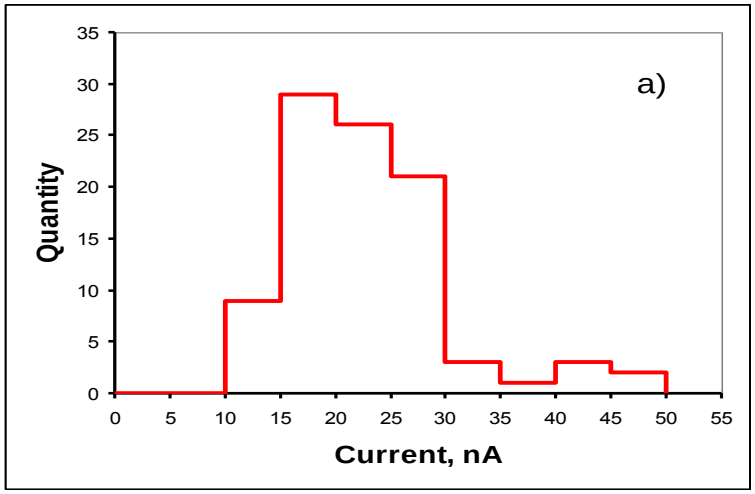


Electrical characteristics of test edgeless n-on-p detectors

Pad detectors as-processed





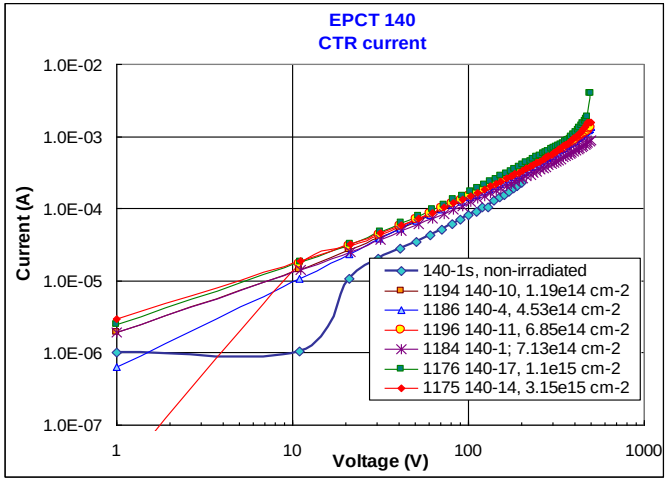


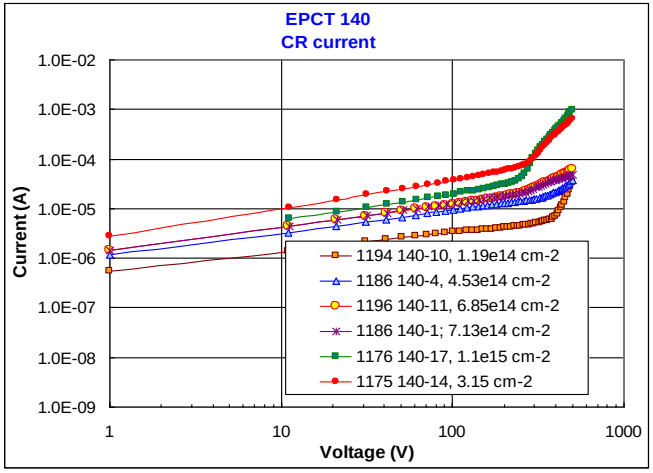
84 samples

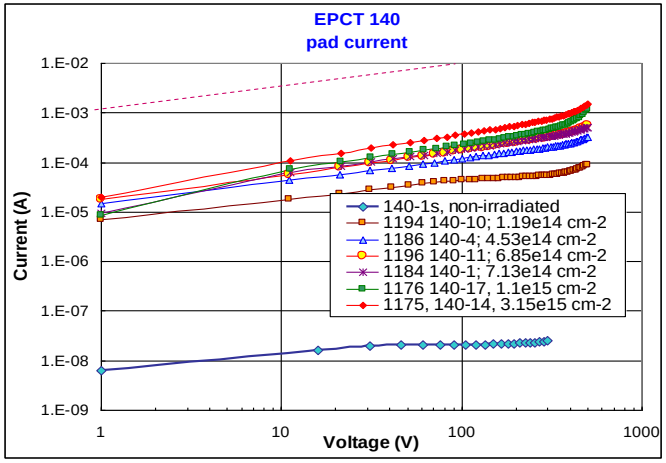
J_{mean} = 30 nA/cm^2

$I_{pad} \approx 10^{-4} I_{CTR}$ -
as in p-on-n

Current vs. fluence in n-on-p edgeless detectors with CTS

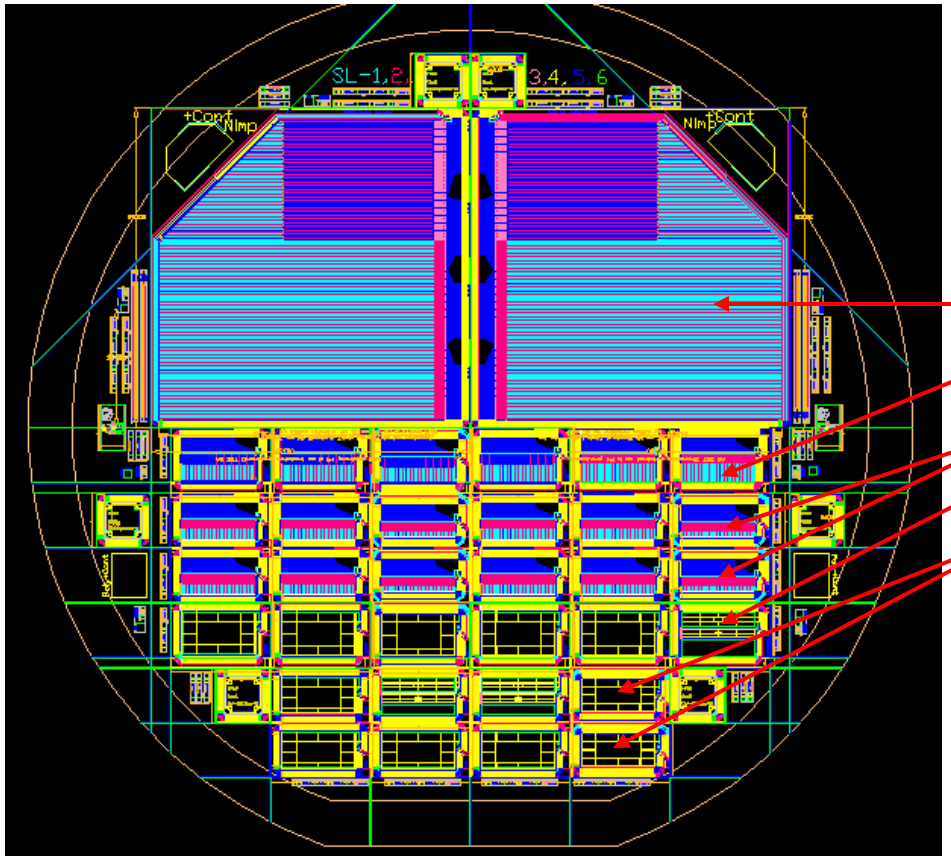






- Dark current is bulk generation current
- dark (pad) current is still less than CTR current
- CTR current is only slightly dependent on F_p
- CR currrent is affected by bulk current

Wafer layout with N-on-P edgeless detectors

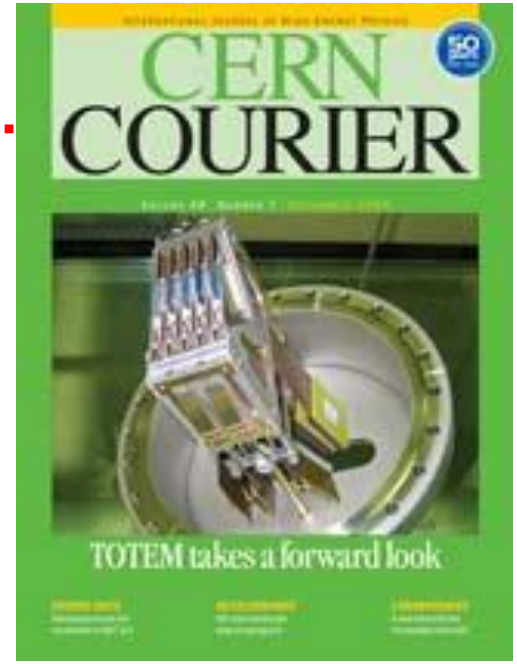


Large strip EDL
Baby strip EDL
Test strip regular
Pad EDL
Pad regular
Small regular

Summary

- A novel approach for the edgeless detectors was developed and successfully realized in TOTEM experiment

  (R&D and TDR in 2004 first data taking in 2009)
- The 1 year stable operation of 240 TOTEM EDL detectors proved completely the physical background of the new development and motivates to follow this line for advancing the EDL detectors radiation hardness.
- The story is not over…



September 2009

October 2011

Thank you for your attention