Planar Edgeless Detectors for the TOTEM Experiment

- Introduction
- Edgeless Detectors in the TOTEM Roman Pots
- Planar Edgeless Detector & the Current Terminating Structure
- From the initial idea… …to the mass production
- Device Physics and Simulations
- Experimental confirmations
- Radiation Studies
- Outlook

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CERN, PH Department

VERTEX06
15th INTERNATIONAL WORKSHOP ON VERTEX DETECTORS
Perugia, Italy
September 25 - 29, 2006

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http://totem.web.cern.ch/Totem

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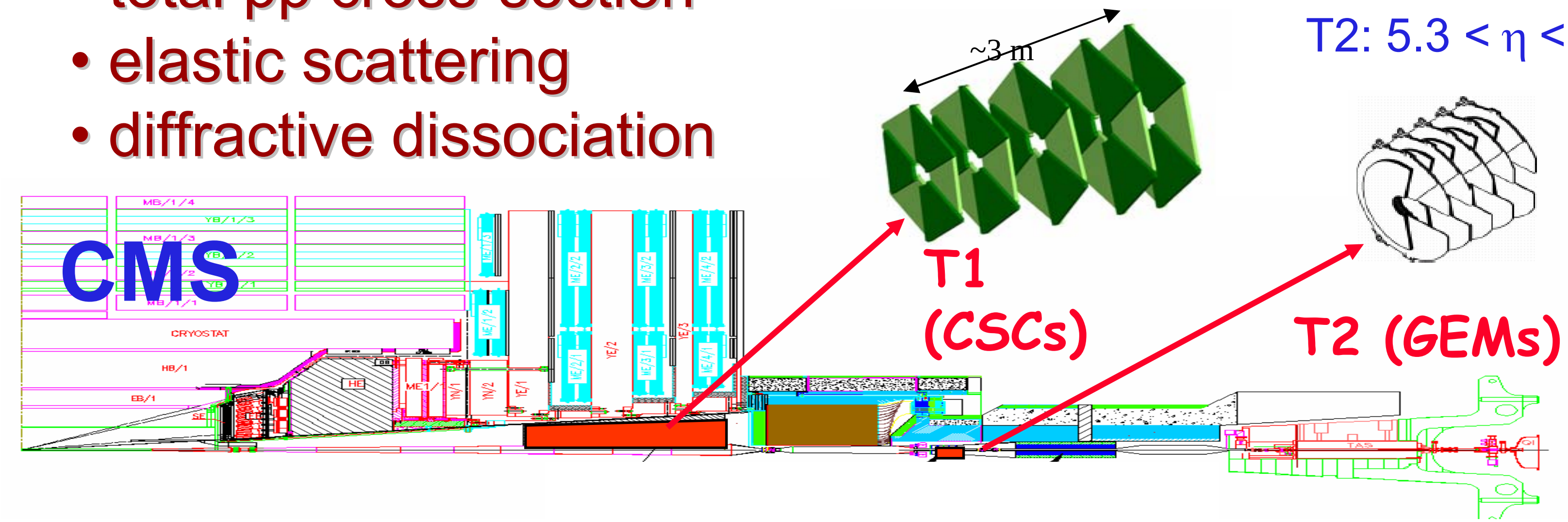
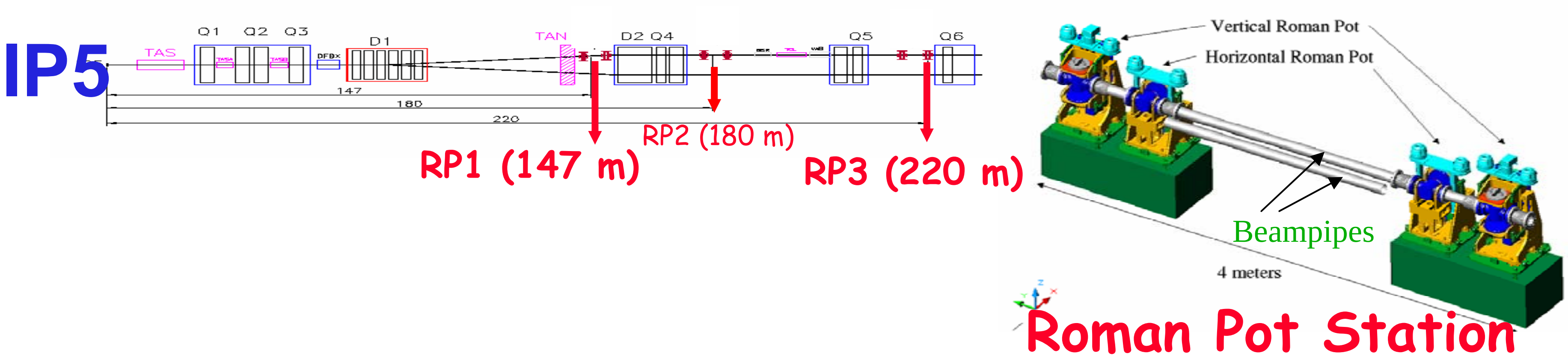
The TOTEM Experiment

- total pp cross-section
- elastic scattering
- diffractive dissociation

T1: $3.1 < \eta < 4.7$

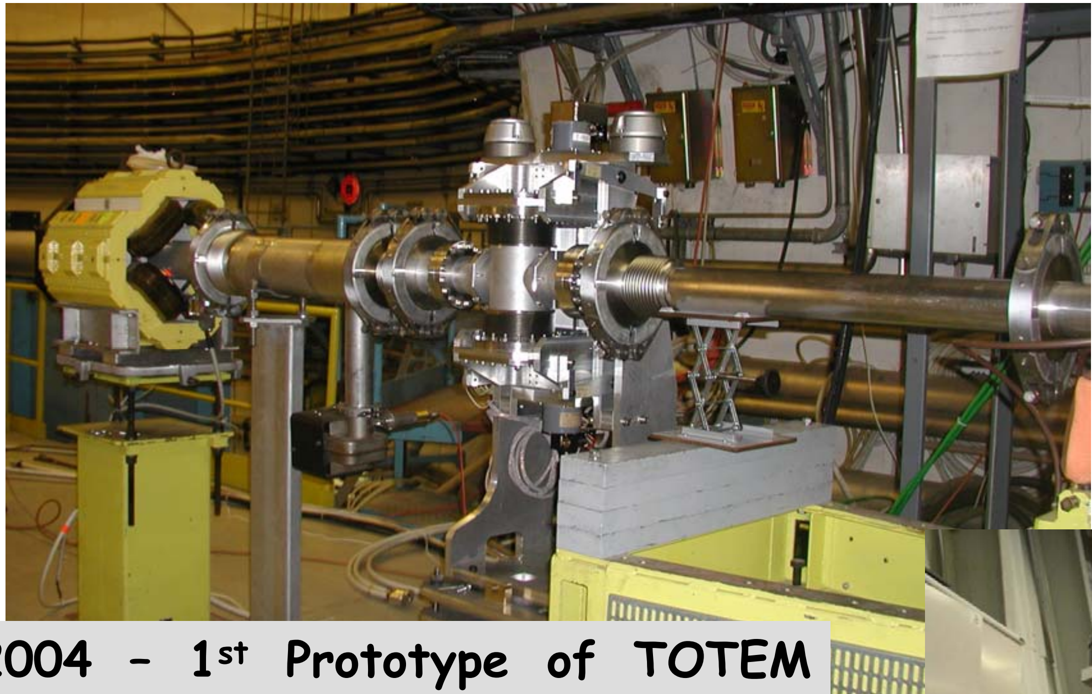
T2: $5.3 < \eta < 6.5$





The Roman Pots

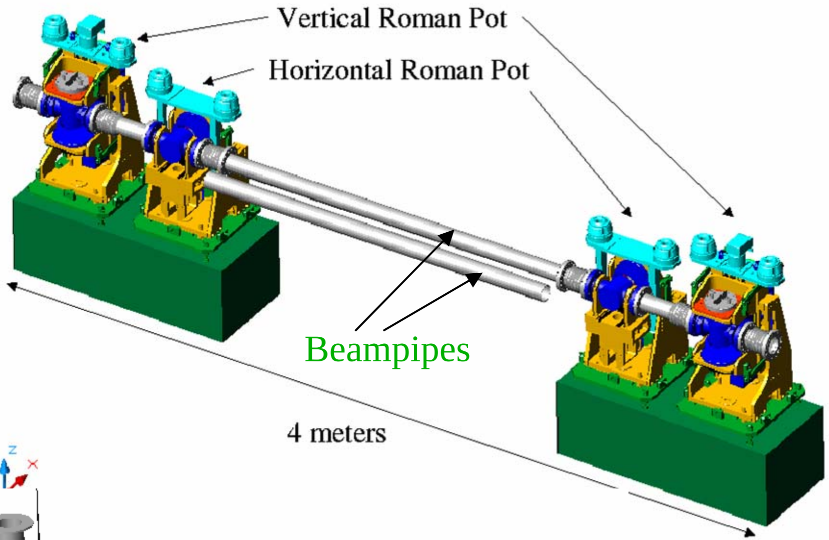
Special beam insertion that allow to approach the detector very close to the beam, with the detector in secondary vacuum, separated by the machine vacuum

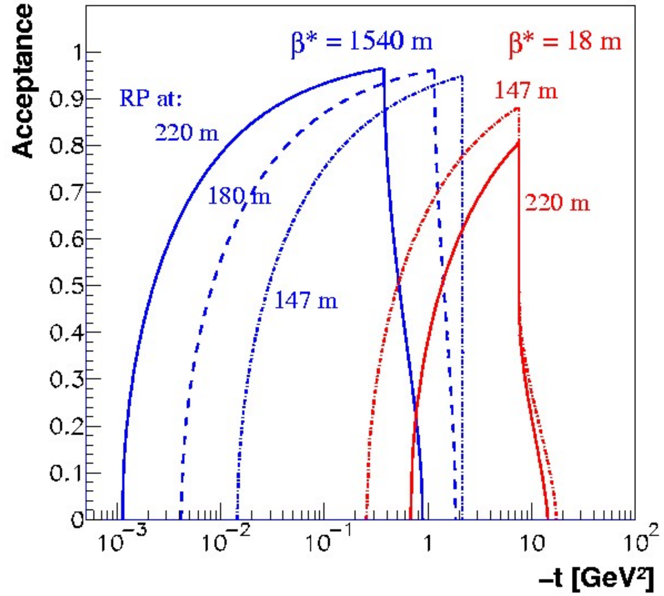


2004 – 1st Prototype of TOTEM ROMAN POT in the Coasting SPS BEAM

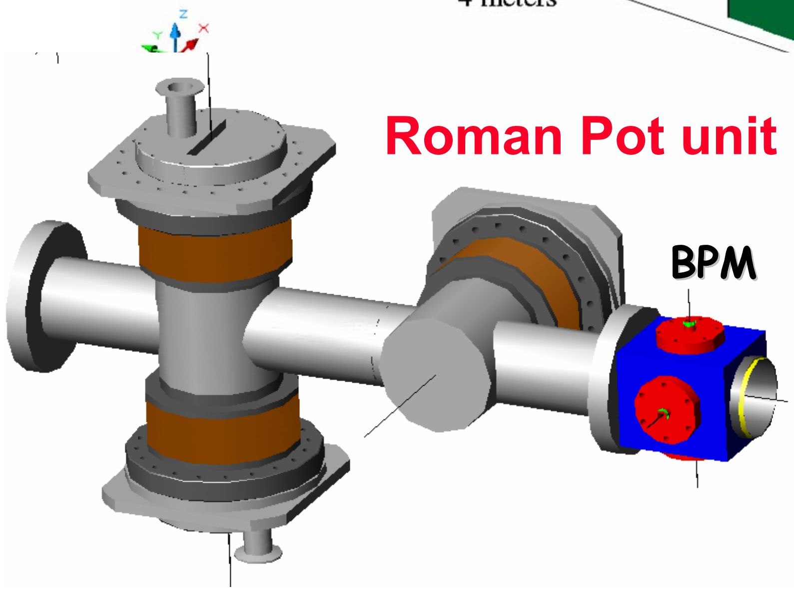
Spring 2006 – 1st TOTEM ROMAN POT to install in the LHC Tunnel in March 2007

Roman Pot stations

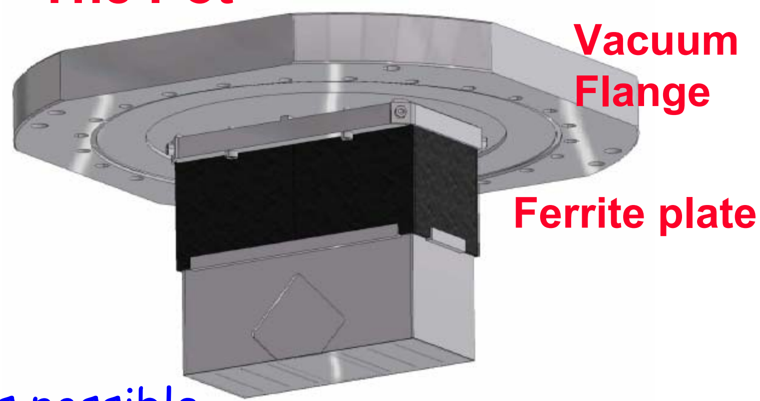




Roman Pot unit

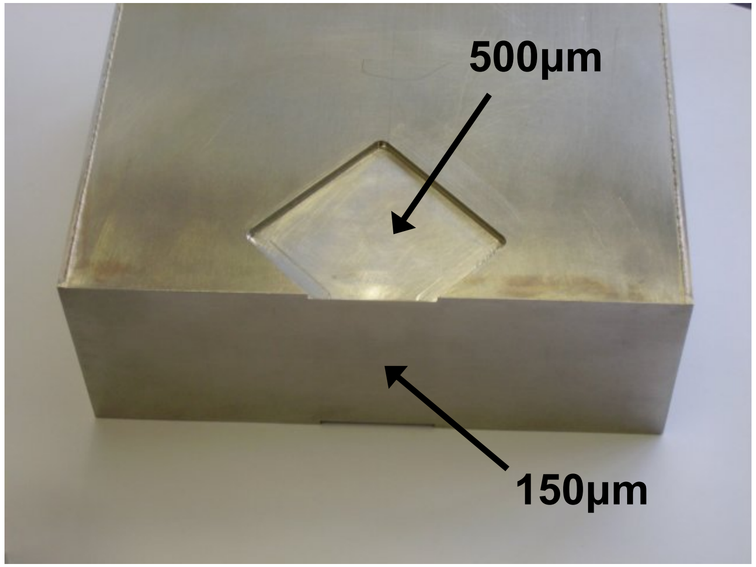


The Pot



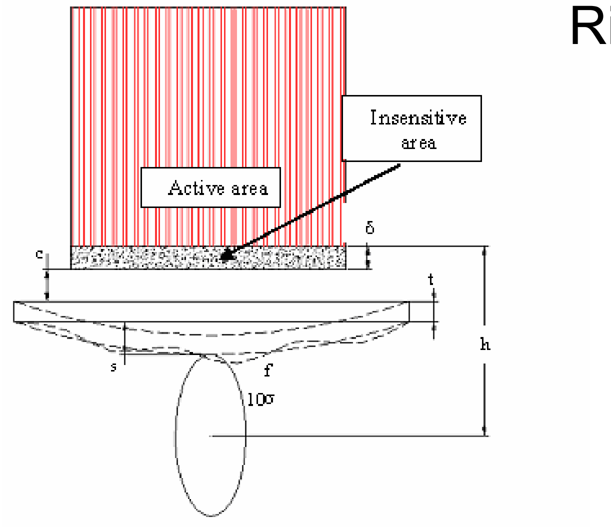
-Vertical and horizontal pots mounted as close as possible
-BPM fixed to the structure gives precise position of the beam
-Compensation system allows the movement from garage position to data taking position
-Ferrite plates mounted on the pot to reduce RF Interference

The Pot and Thin Window

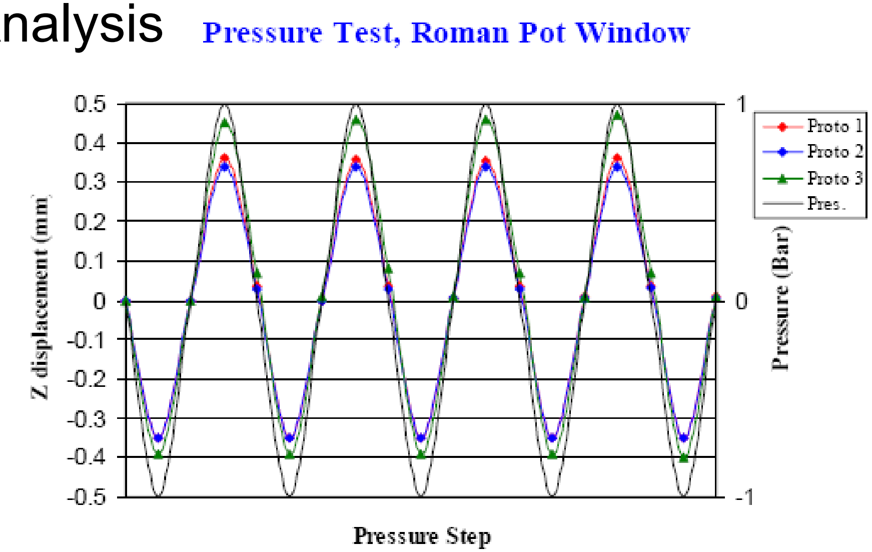


The Pot is a stainless steel box. It's thin window 150 µm thick with planarity of 20 µm will approach the 10σ of the beam when the RP is in the Data taking position

The thin window, brazed on the bottom of the pot separates the secondary vacuum of the detectors from the vacuum of the machine

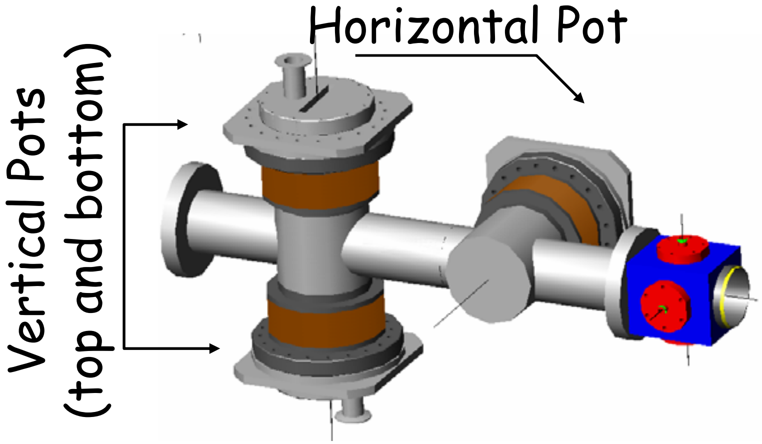


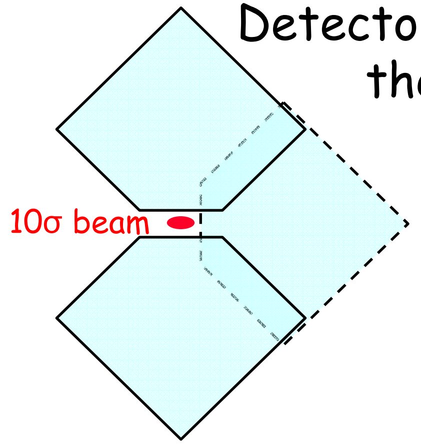
Risk Analysis



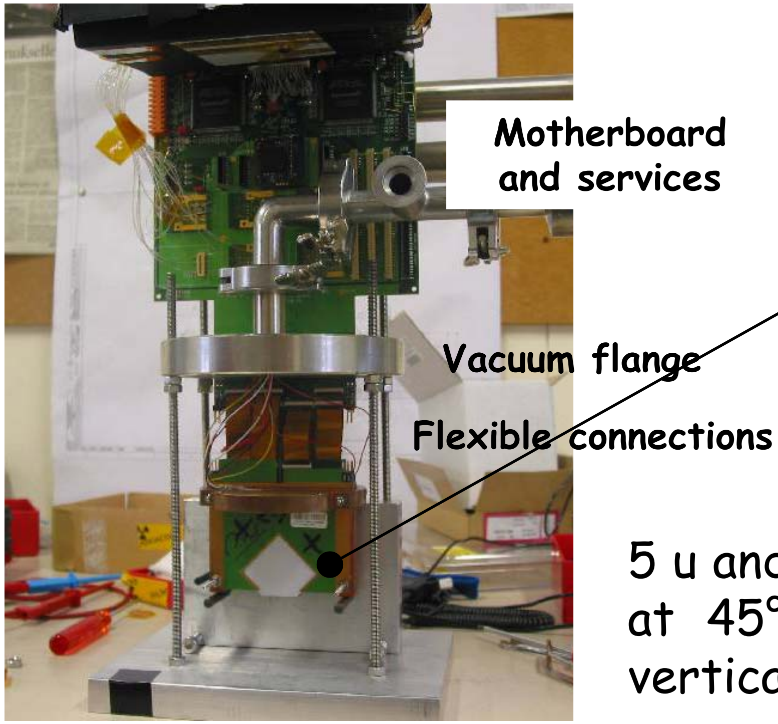
The Roman Pots Detectors

Roman Pots Unit

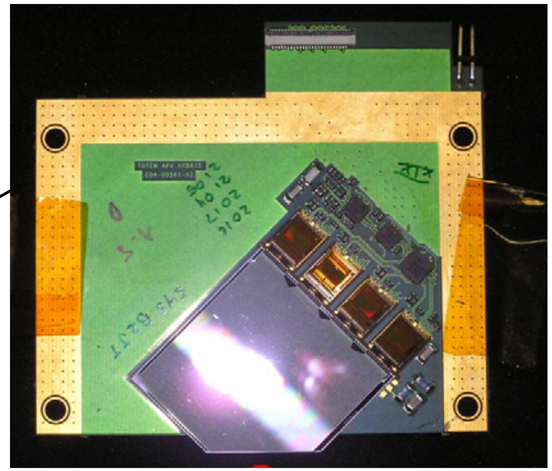




Detectors overlap in the data taking position

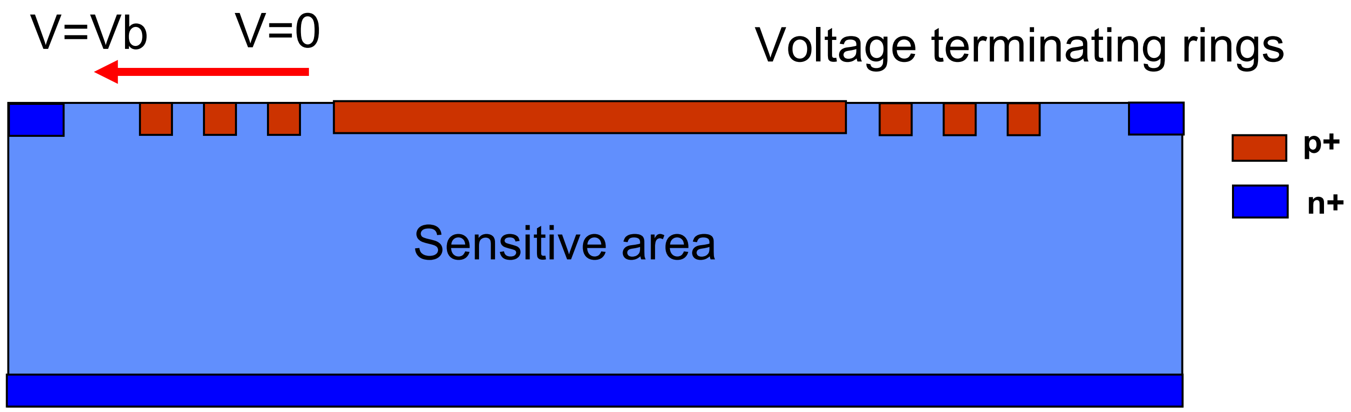


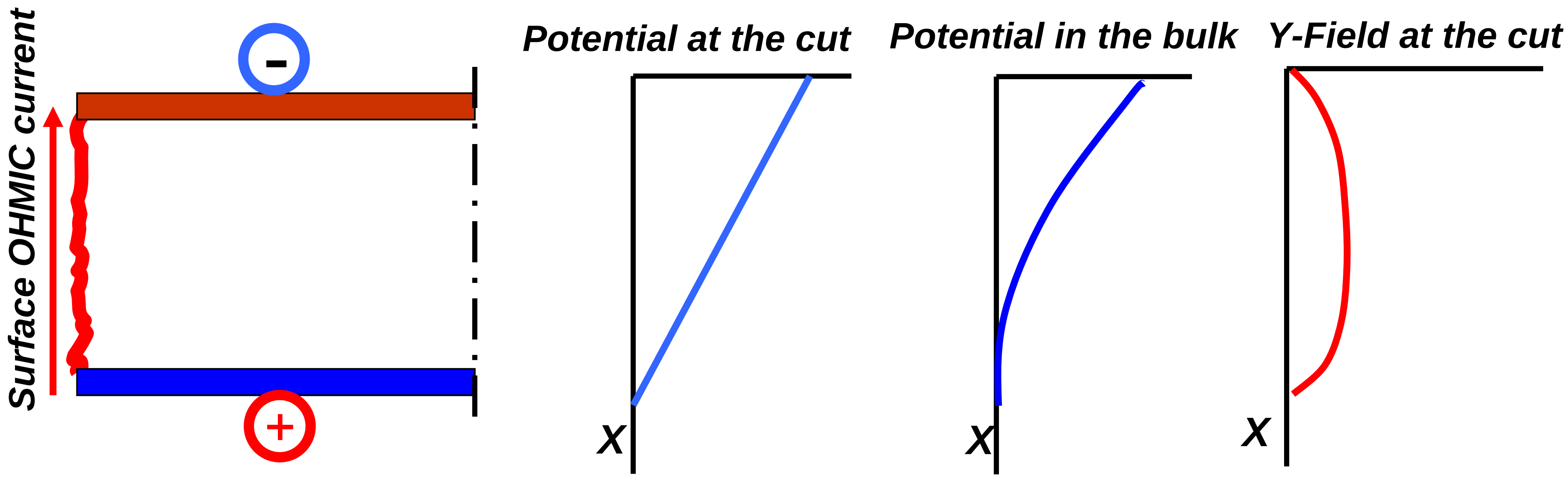
RP detectors with APV25 readout



5 u and 5 v planes in each pot. The detectors have strips at 45° from the sensitive edge. Flipping around the vertical axis yields strips reorienthed orthogonally

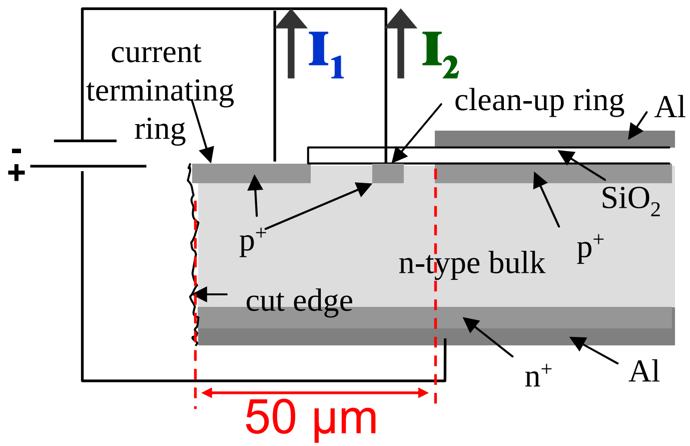
Standard Planar Silicon detectors have an edge…

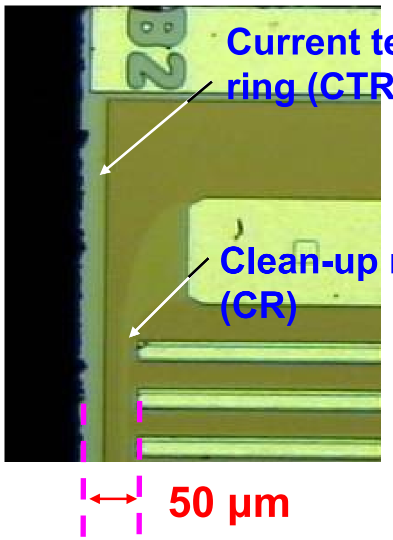


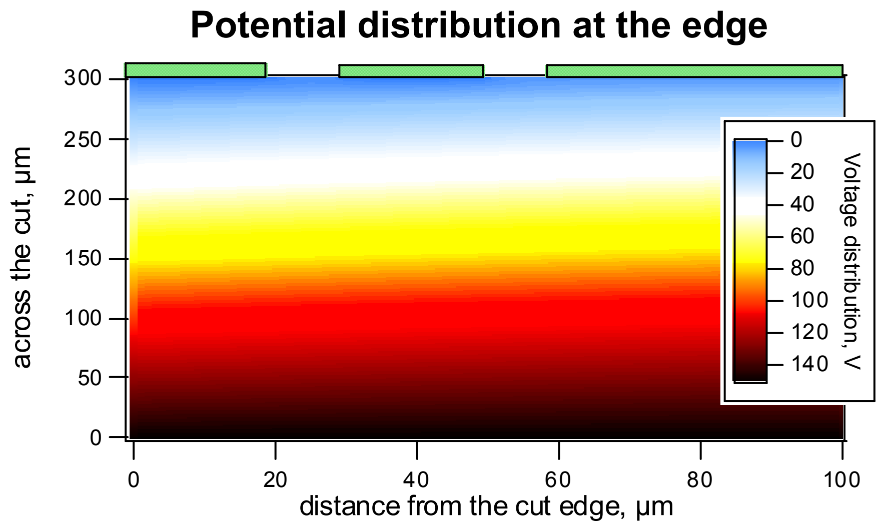


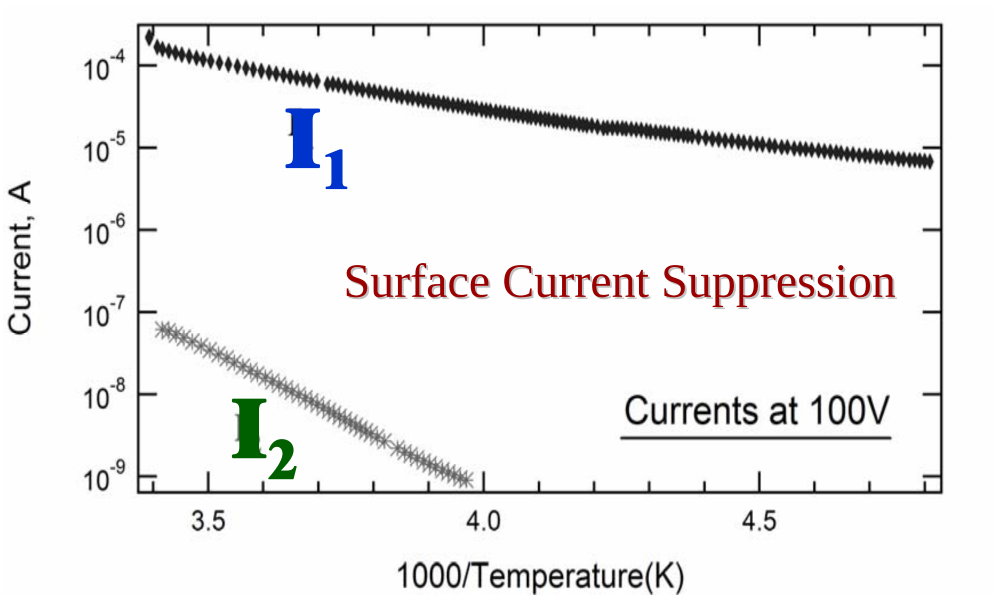
Current Terminating Structure

the idea…



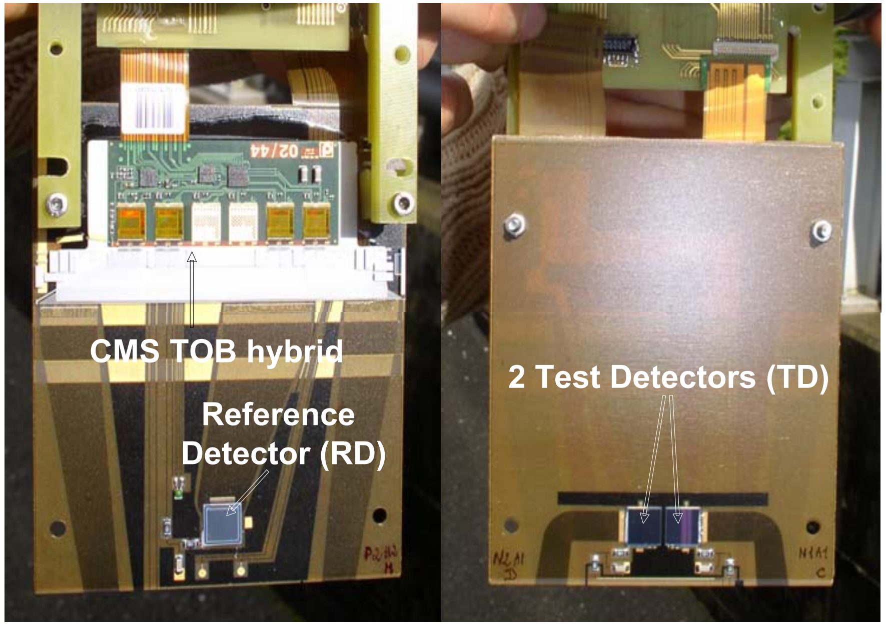






Developed by: CERN/PH-TOT, Ioffe PTI, St. Petersburg and RIMST/ELMA, Zelenograd

First test-beam with APV25 readout

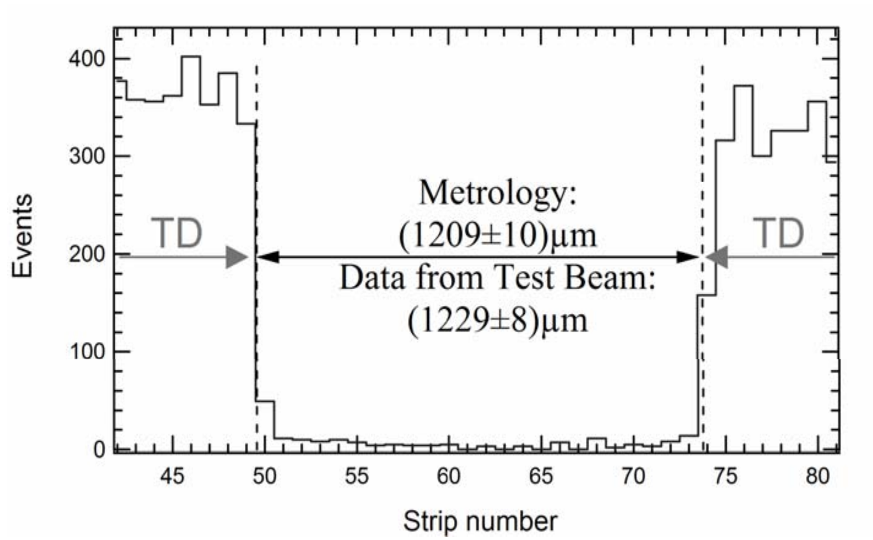


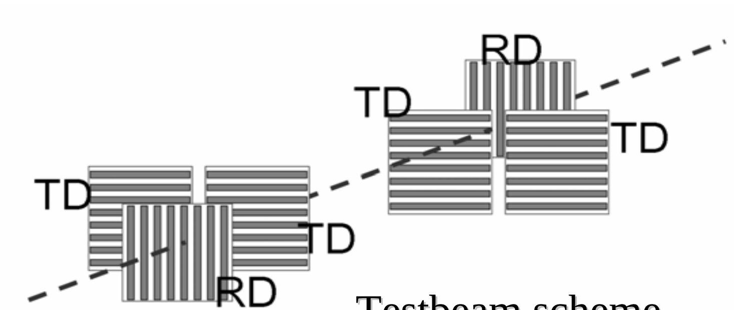
Front Side

Back Side

Detectors produced from very high resistivity 300µm thick, <111> silicon wafers from Topsil. AC coupled strips via punch-through, with a pitch of 50 µm

Efficiency at the edge



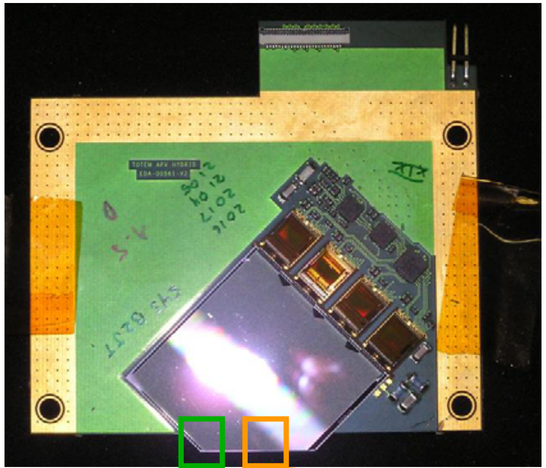


Testbeam scheme
(X5, Summer '03)

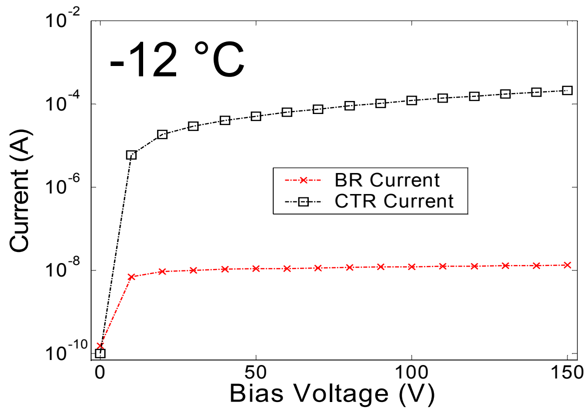
…the proof!!!

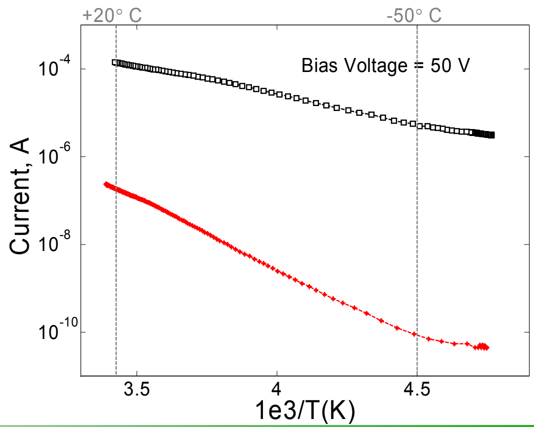
1^{st} Prototype of the Edgeless Detector

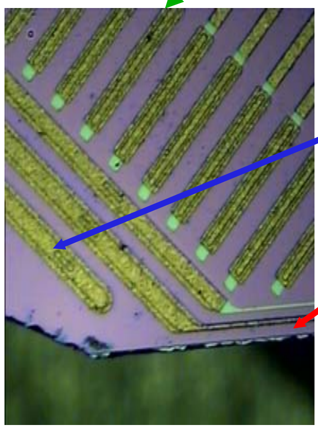
from test size to full size



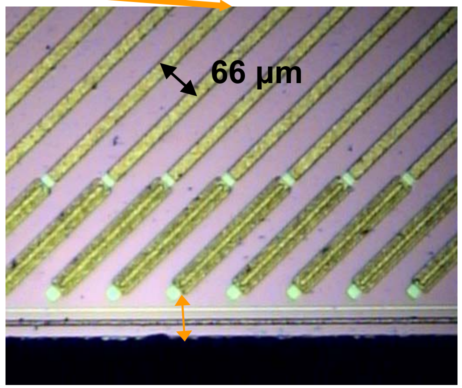
Surface Current Suppression





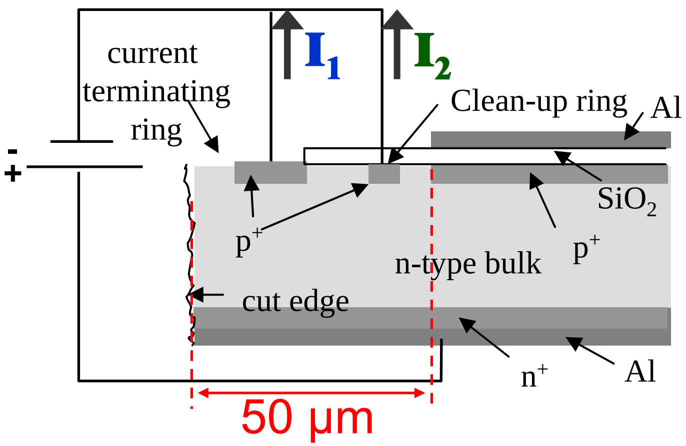


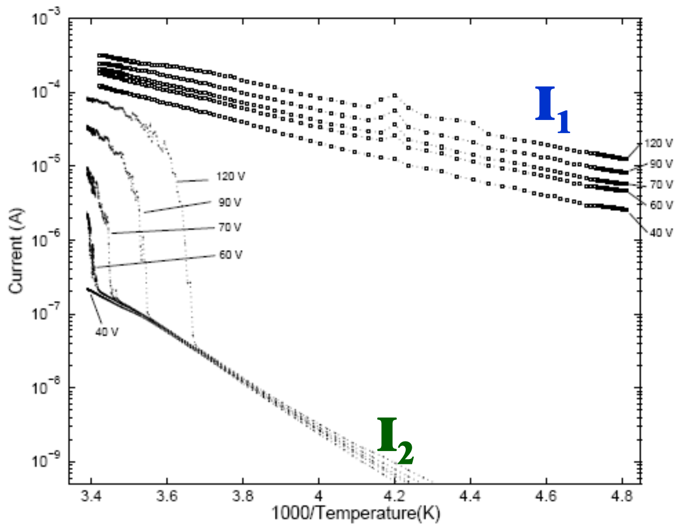
Integration of traditional voltage terminating structure with the Current Terminating Structure

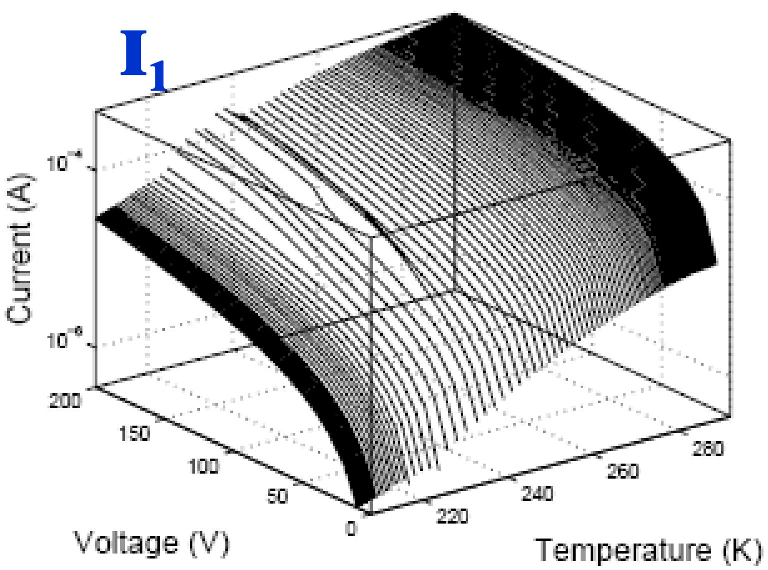


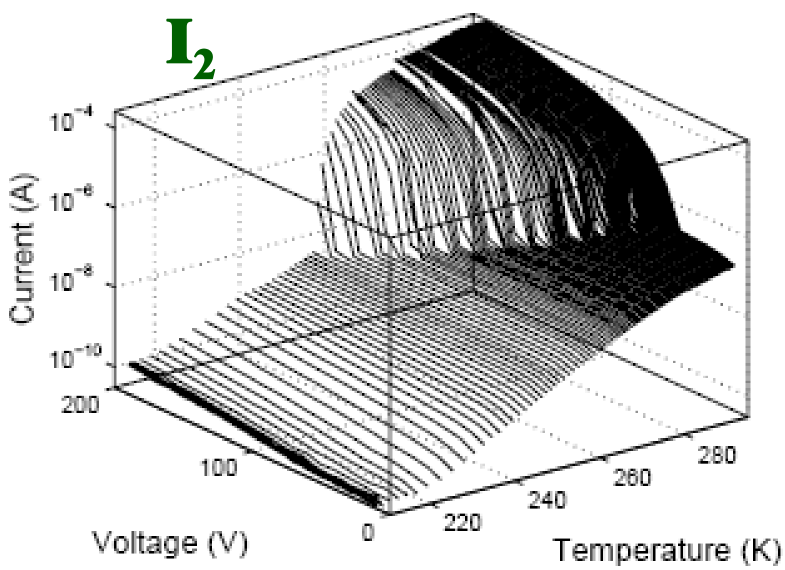
Strips' end 50 µm away from the cut

IV Characteristics at different T

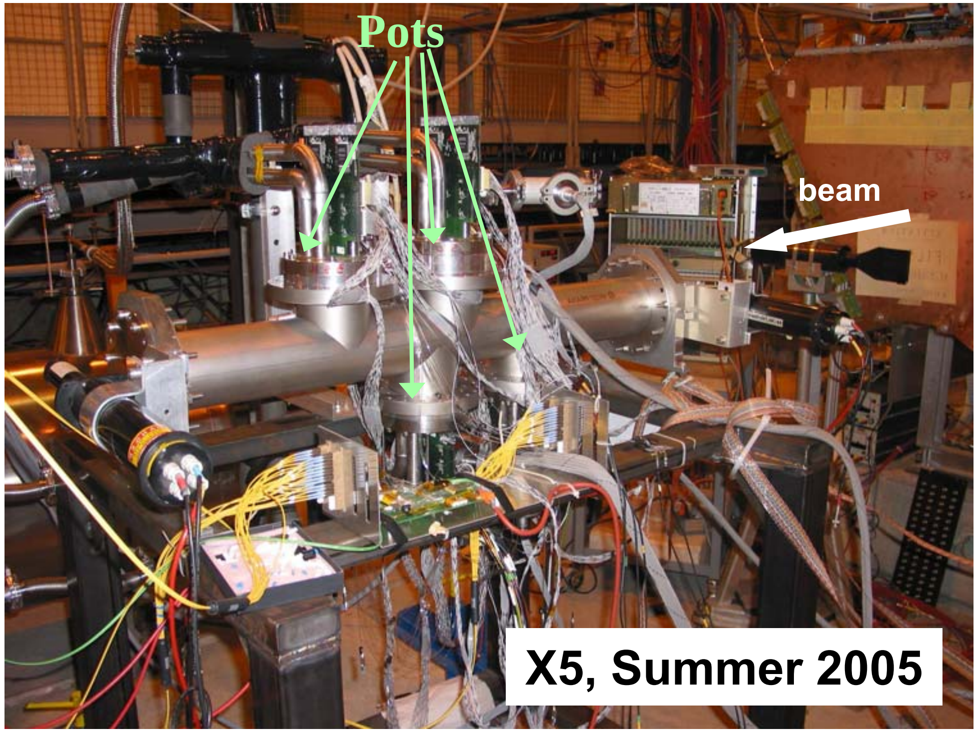




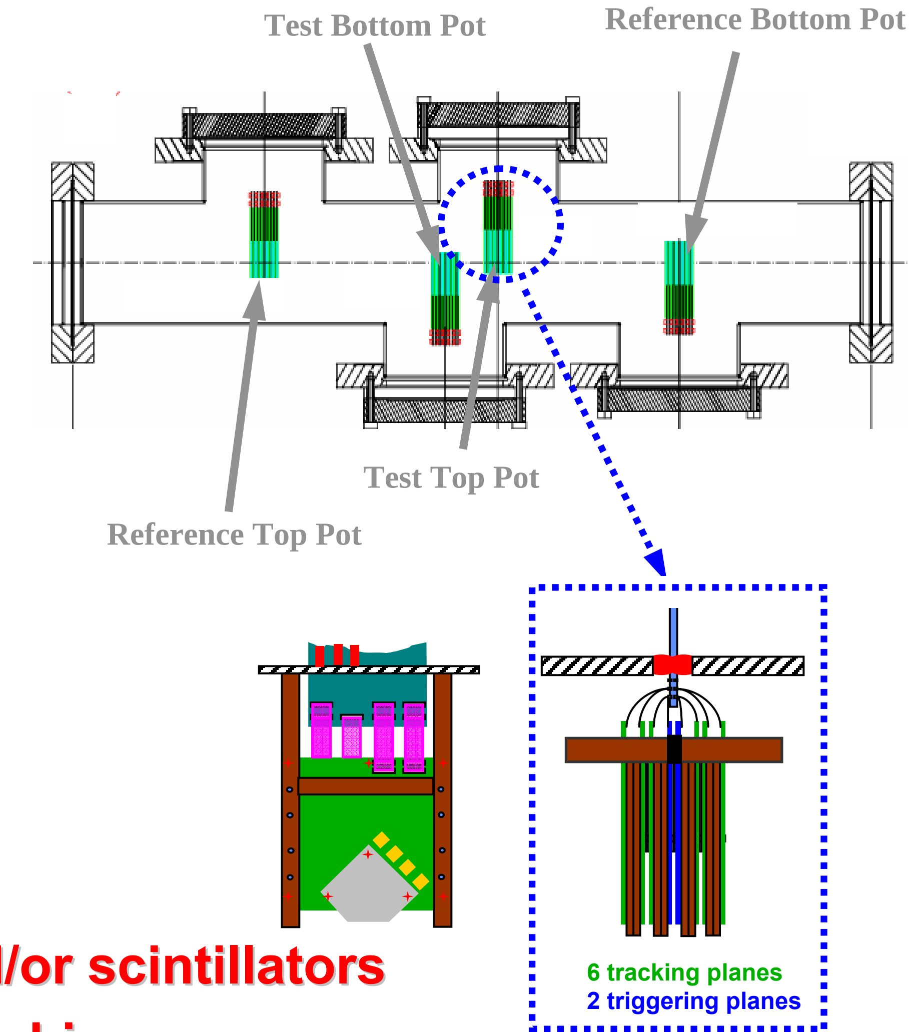




Detector performance in X5 (muon beam)



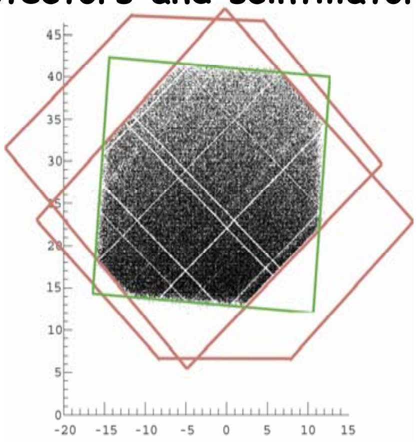
Set-up used in a high energy (120 GeV) muon beam

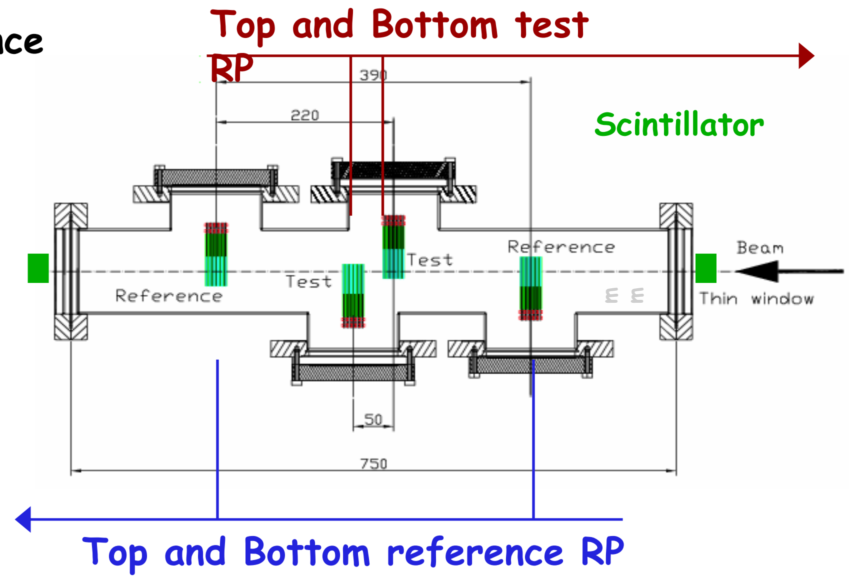


- Triggering: VFAT digital chip and/or scintillators
- Tracking readout: APV25 analog chip

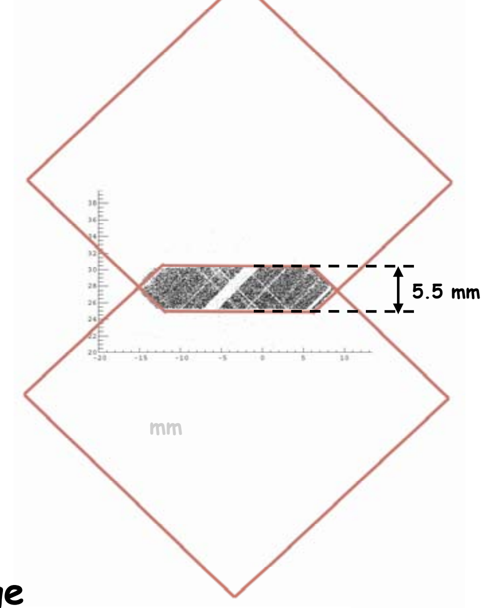
Hit distributions of reference and test detectors

Coincidence plot of reference detectors and scintillators

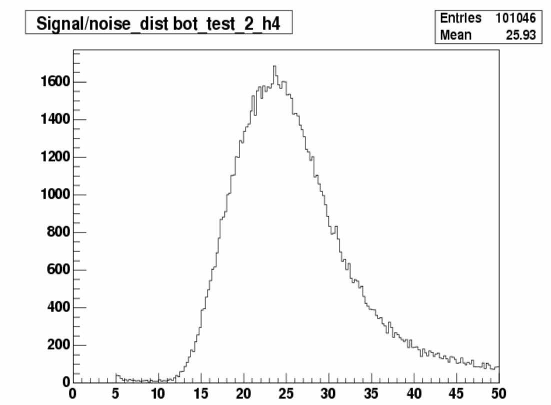




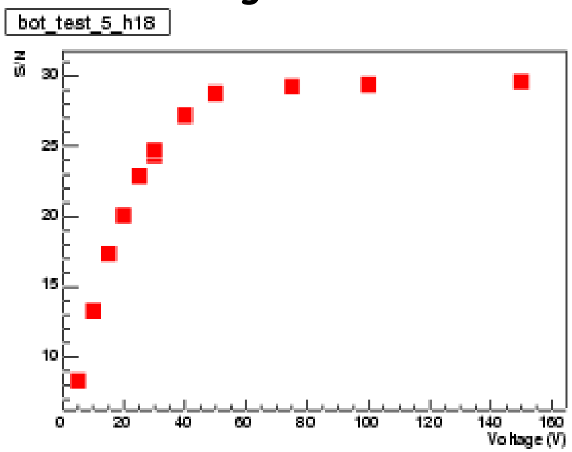
Coincidence plot of test detectors and scintillators



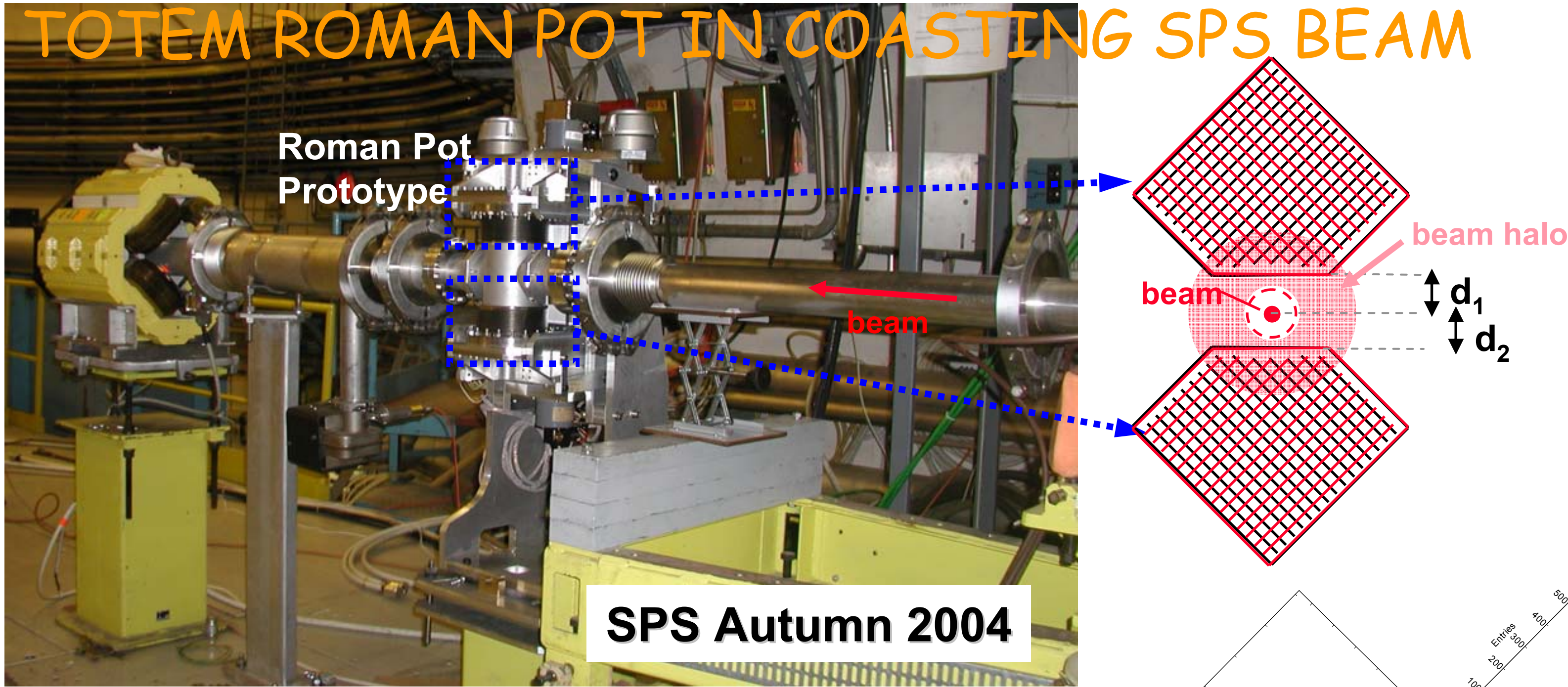
Typical S/N distribution



S/N vs Bias Voltage

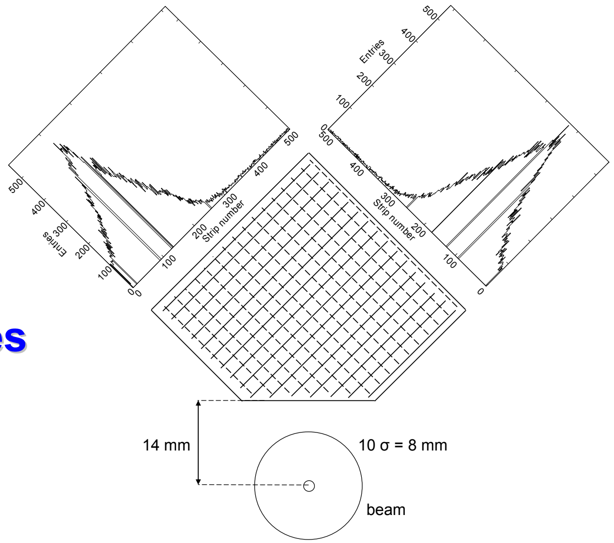


Full size detectors test setup in coasting beam



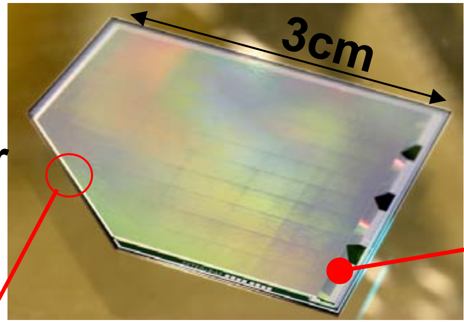
Tests of full size detectors in coasting beam:

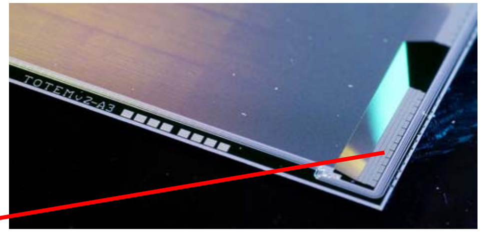
- **High energy (200 GeV) proton beam**
- **Beam halo particles detected for various d_1, d_2 distances**
- **Typical event rate of 3 kHz**



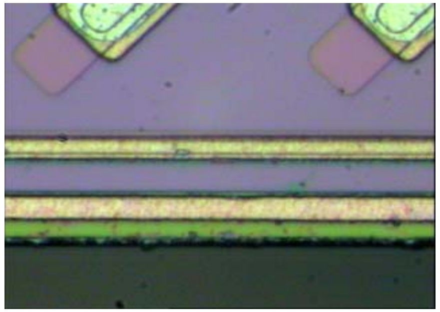
Pre-series run and Mass Production

Roman Pot
Si Edgeless detector



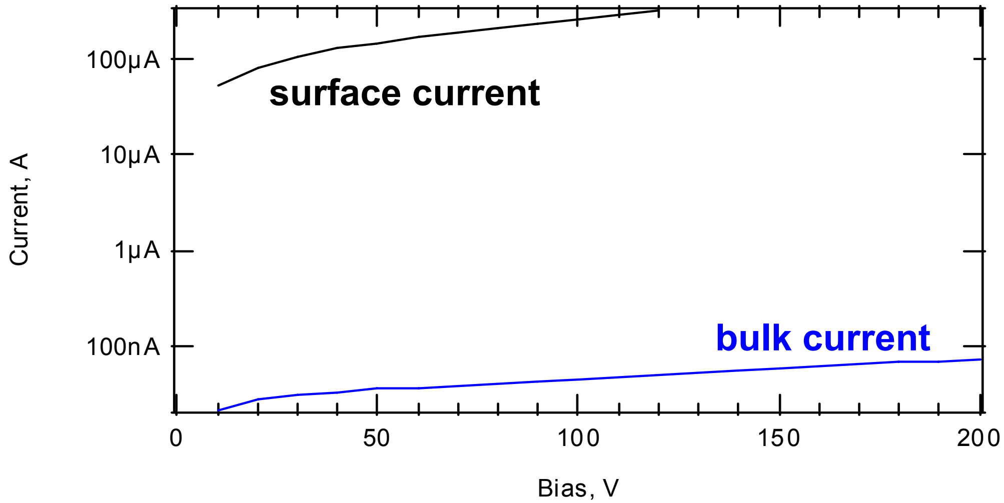


Pitch adapter on detector



47 mm
dead area

planar technology with CTS
(Current Terminating Structure)

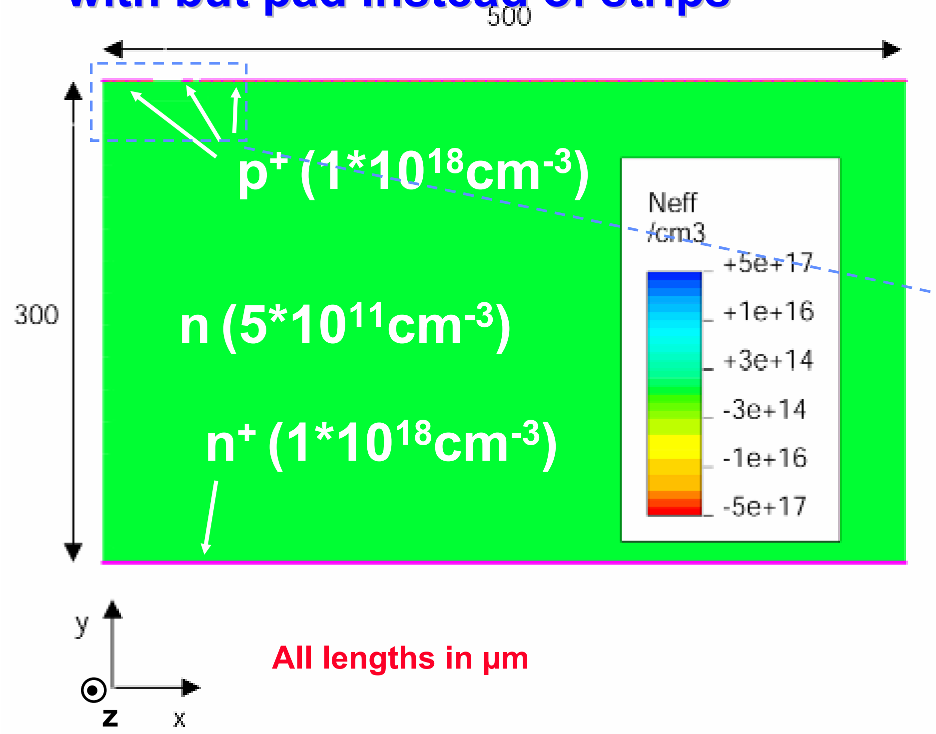


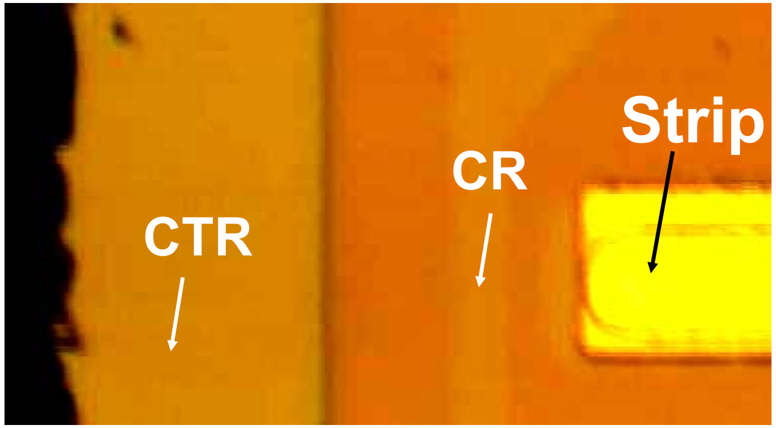
Measurement of leakage (bulk) current: 70 nA at 200 V

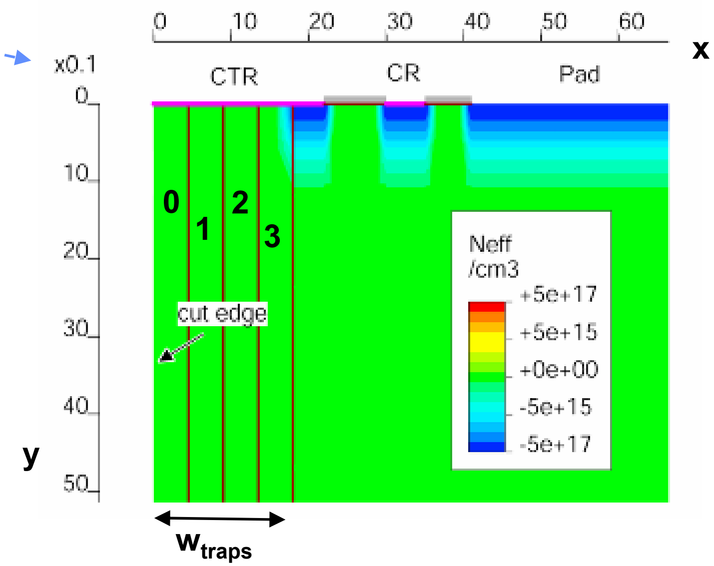
- **The mass production has started (we need 240 good detectors + spares…)**
- **We will try hard to install the Detectors in the Roman Pot by August 2007**

Simulation Studies with ISE-TCAD

The simulated structure corresponds to the one of a CTR detector prototype but with but pad instead of strips





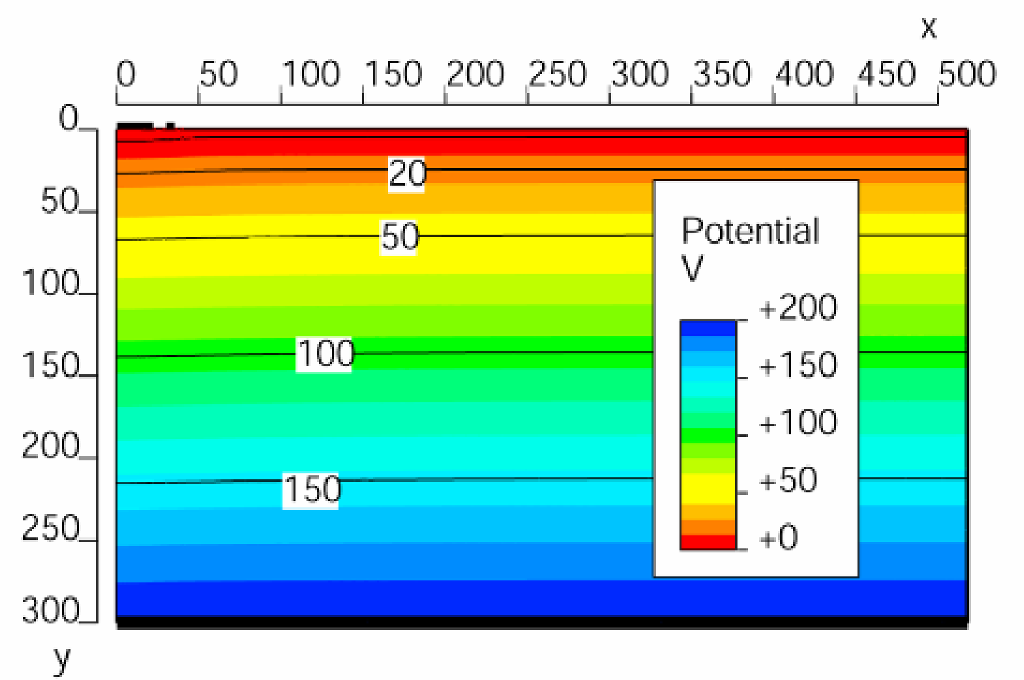


Amorphous Silicon Trap Distribution

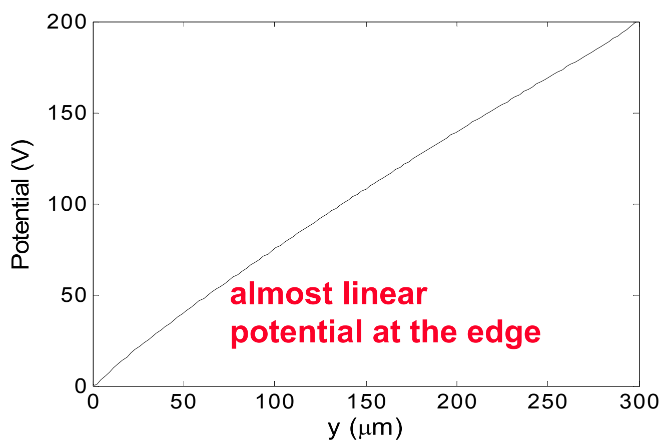
$$f_t(E) = N_1\left(e^{-\left|\frac{E-E_V}{\sigma_{E1}}\right|} + e^{-\left|\frac{E-E_C}{\sigma_{E1}}\right|}\right) + N_{e2}e^{-\left|\frac{E-E_C}{\sigma^e E2}\right|} + N_{h2}e^{-\left|\frac{E-E_V}{\sigma^h E2}\right|}$$

Amorphous silicon at the edge, then concentration of traps decreases exponentially

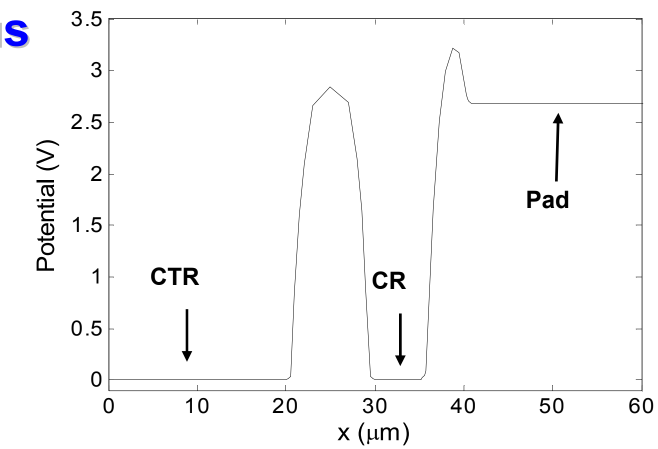
Simulated potential distribution



Potential distribution along y (x=0)



Potential distribution along x (y=0)



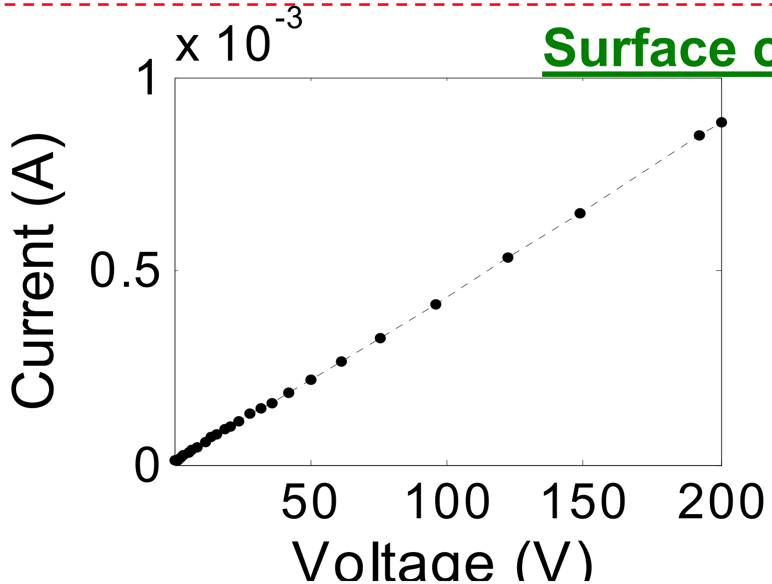
Potential distribution calculated for amorphous silicon-like material close to the cut edge

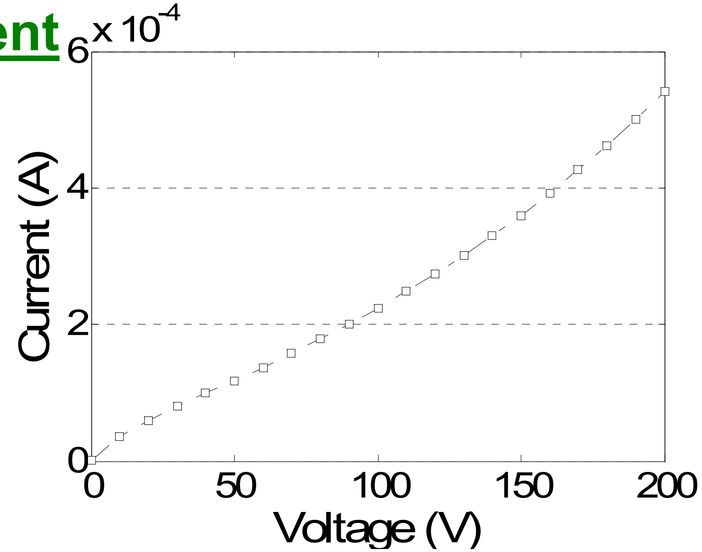
Simulations vs. experimental results: surface and bulk current

SIMULATION

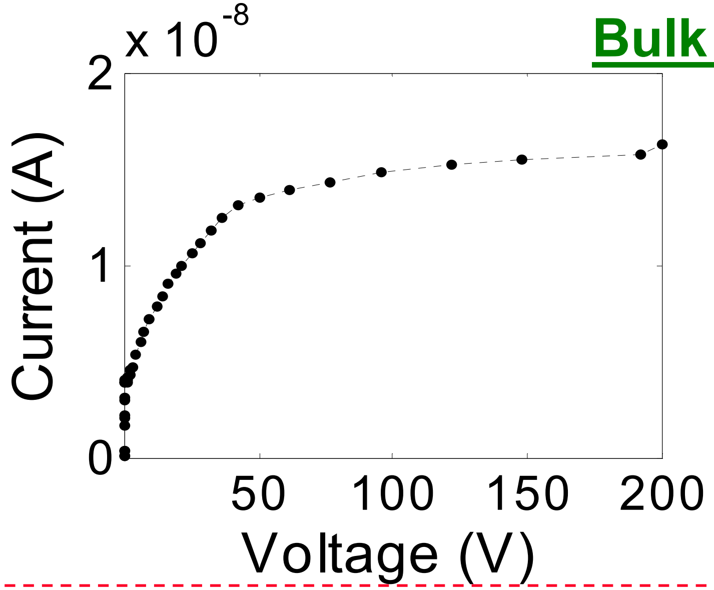
EXPERIMENT

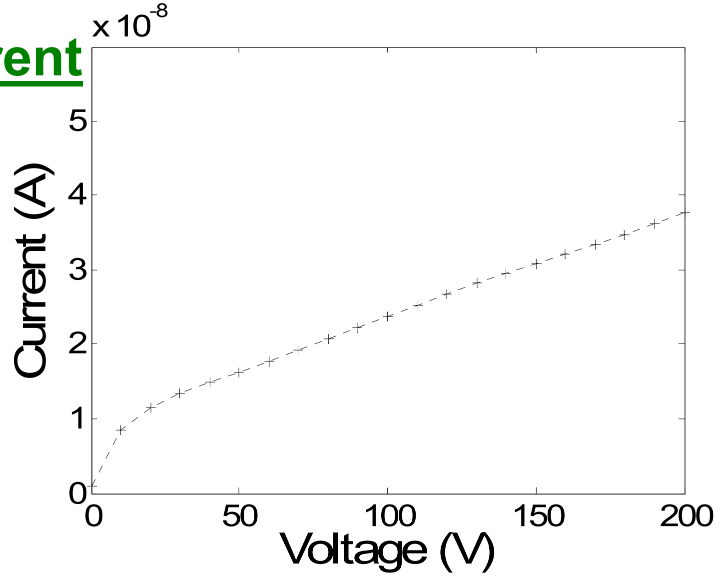
Surface current





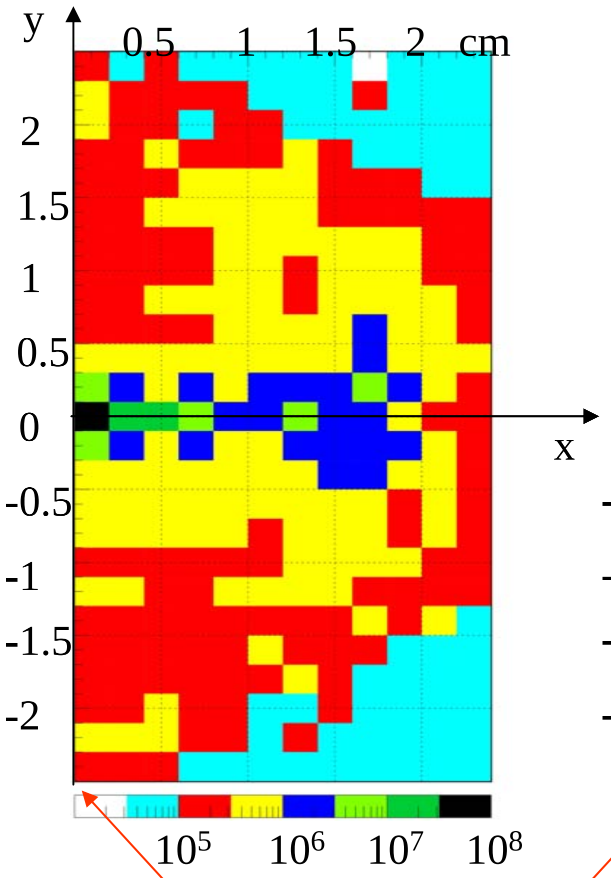
Bulk current



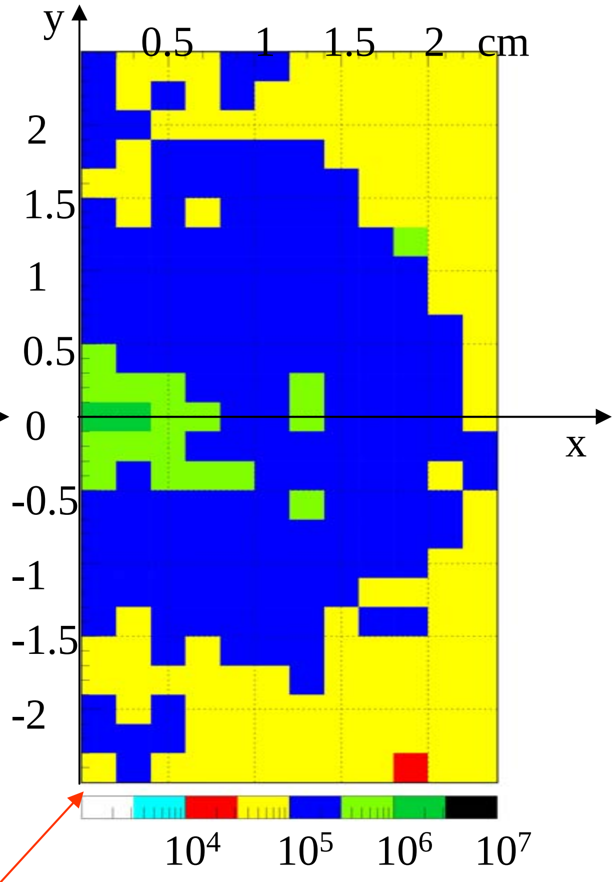


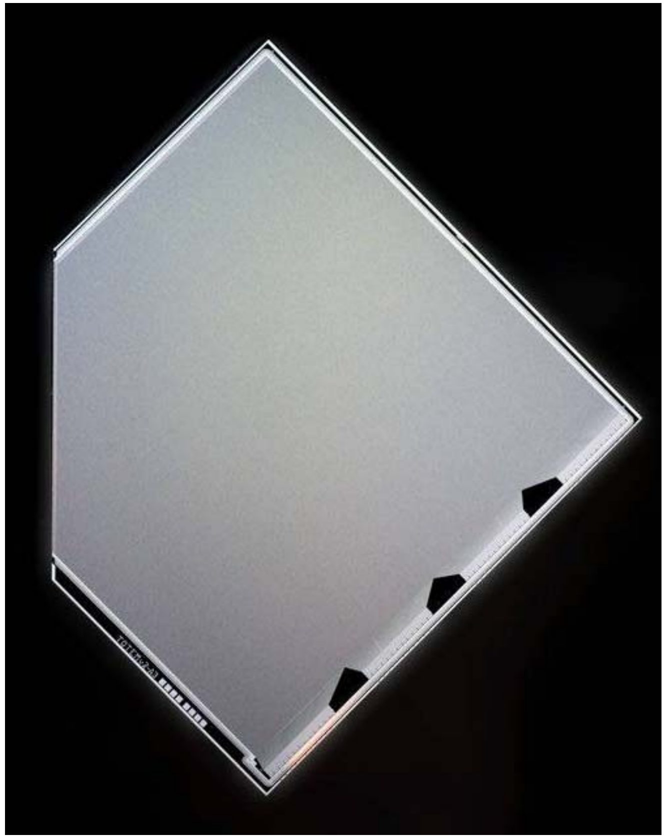
Simulated Flux of Charged Hadrons and Neutrons at 220 m, $L = 10^{33}\ cm^{-2}\ s^{-1}$, $\beta^* = 0.5$ m (MARS code, N. Mokhov)

charged hadrons (incl. diffract. protons)



neutrons



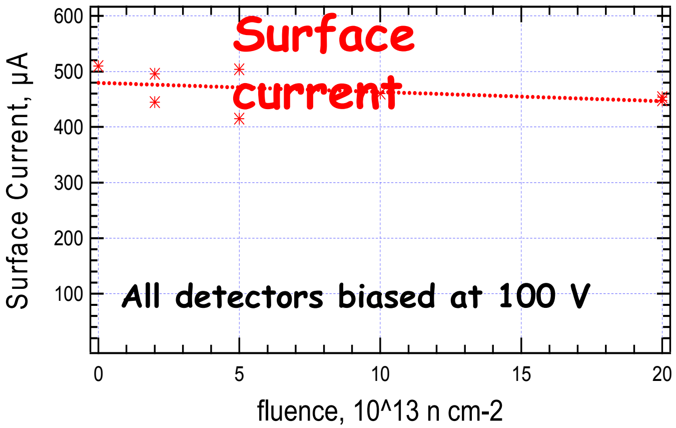


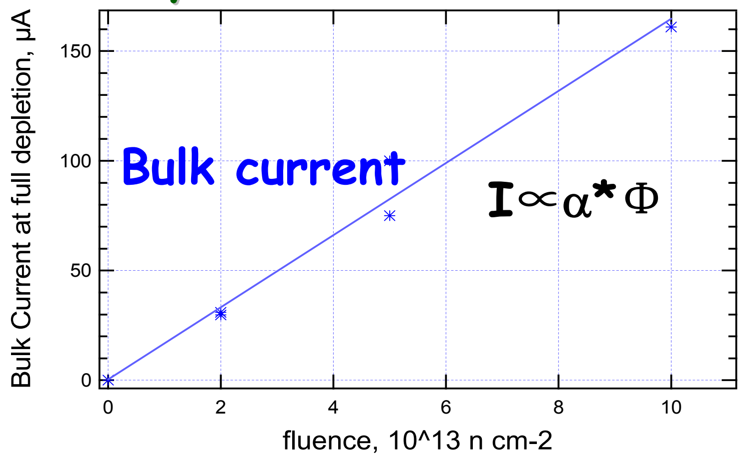
detector's edge

Radiation Tests on Edgeless Planar Detectors

- Expected fluence in the silicon detectors after the 3 years of operation will be ~$10^{12}{}_{1MeV}$n cm^{-2} (calculations with MARS code).

- However accidents and unforeseen beam losses in the neighbourhood of the detector could lead to drastically enhanced radiation level.





Damage Factor $$\alpha = \frac{\text{Current}}{\text{Volume} \times \text{Fluence}} = 5\times10^{-17}\ \text{A/cm}$$

These data suggest a radiation hardness for the Edgeless Planar detectors equal to the standard planar detectors up to $10^{14}{}_{1MeV}$n cm^{-2}.

Outlook

- The Planar Edgeless Detectors with CTS are an "easy and simple" solution to dramatically reduce the "insensitive region at the edge".
- Further studies on radiation hardness are ongoing. Lately a Consortium under INTAS umbrella (CERN, Lappeenranta TU, Bologna U, Barcelona CNM, Ioffe St. Petersburg, RIMST Zelenograd) has joined together to mainly address radiation issues for PED with CTS (TOSTER Project).
- This development has raised interest also in groups working on medical applications (CT, X-ray applications with "edge on" detectors) for it's clear advantages.
- Regarding the production of the Edgeless Detectors for the Roman Pots. Mass production of all the components is ongoing but we are still finalizing the RP hybrid. We are doing our best to install the RP Detectors by August 2007.

Further readings

- G. Ruggiero et al, "Planar edgeless silicon detectorsfor the totem experiment", IEEE Trans. On Nucl. Sci. 52 (2005) 1899.
- E. Noschis et al., " Final size detectors for the TOTEM experiment" to be publish. In NIMA
- "TOTEM TDR", the TOTEM Collaboration , CERN-LHCC-2004-002 (2004), Addendum CERN-LHCC-2004-020 (2004)

TOTEM