Planar Edgeless Silicon Detectors for the TOTEM Experiment

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on behalf of the TOTEM collaboration

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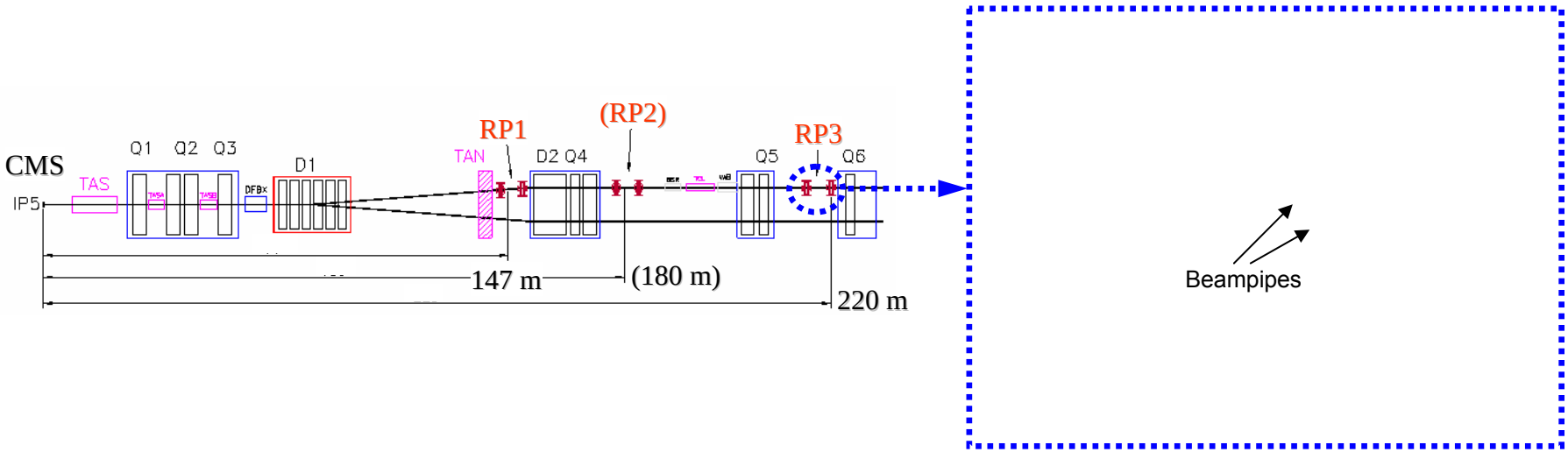
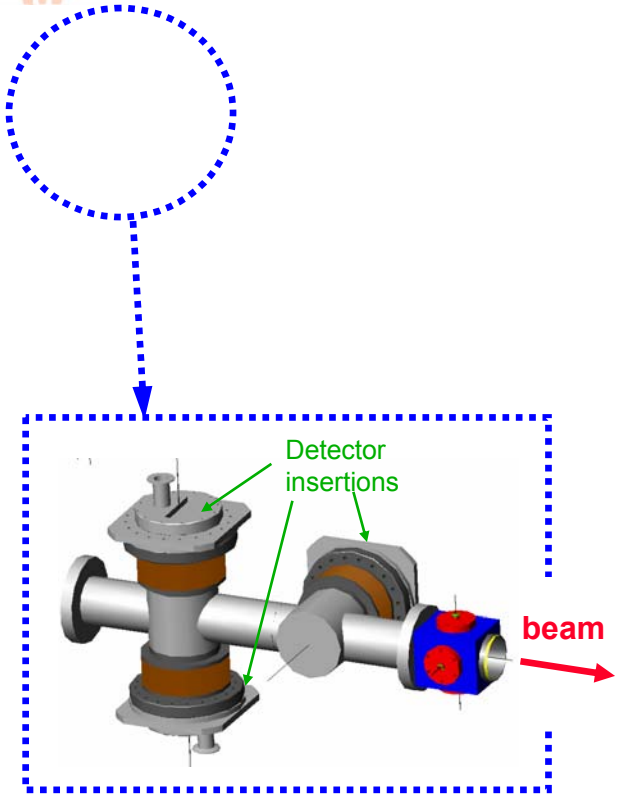
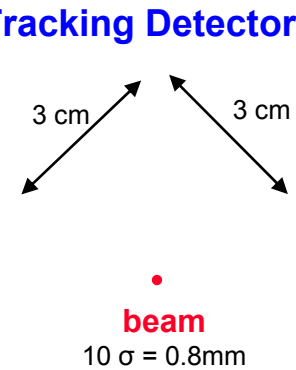
1. The TOTEM experiment

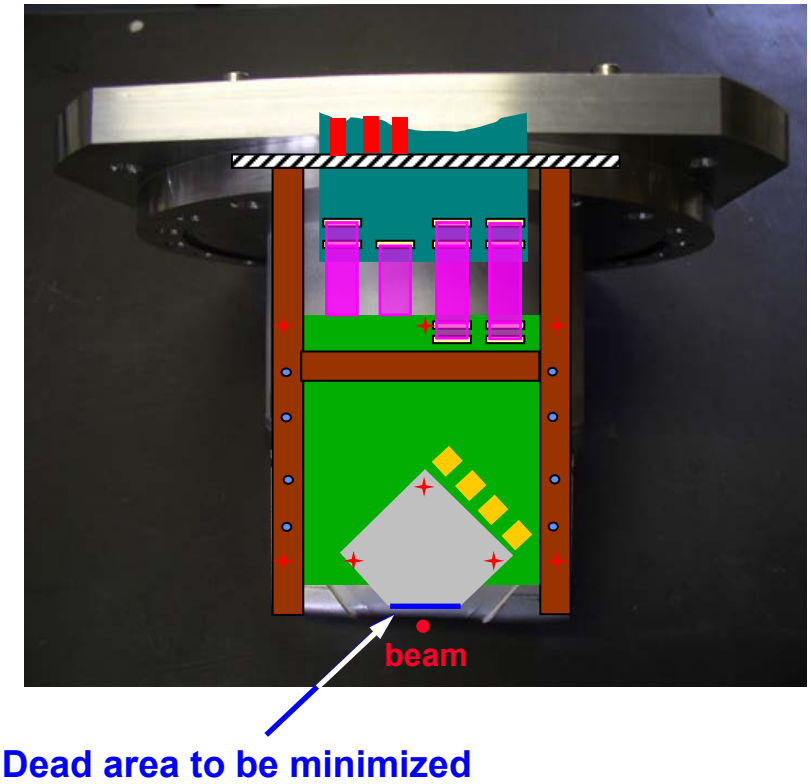
In order to determine the total cross section of pp interactions with 1% uncertainty at $\sqrt{s}$ = 14 TeV, the TOTEM experiment will detect leading protons scattered in angles of microradians. This is achieved using tracking detectors with a minimized insensitive edge not exceeding 50 μm inserted into Roman Pots (RP).



1.1 Roman Pot Stations







The tracking detectors must be placed as close as possible to the 10 σ envelope of the beam

1.3 Requirements on the “edgeless” tracking detectors

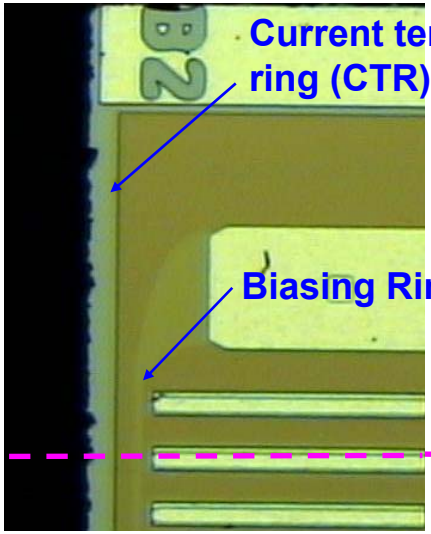
The detectors must fulfill the following requirements:

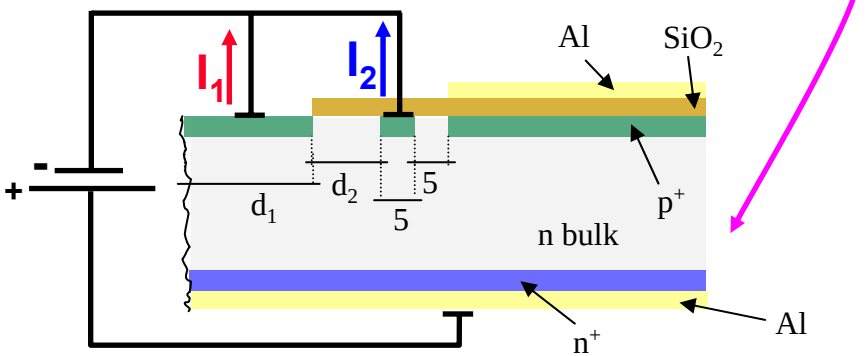
- **Spatial resolution of 10-20 μm**
- **Charge collection time not exceeding 25 ns**
- **Radiation hardness up to 10^{14} “n”/cm^2**
- **Operational temperature not below -20°C**
- **Inactive edge not exceeding 50 μm**

Two different technologies are being considered:

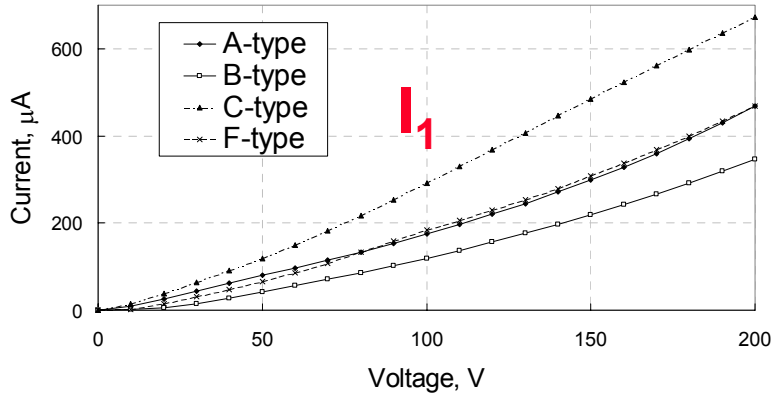
- **planar “edgeless” detectors**
- **planar “edgeless” detectors with 3D edges**

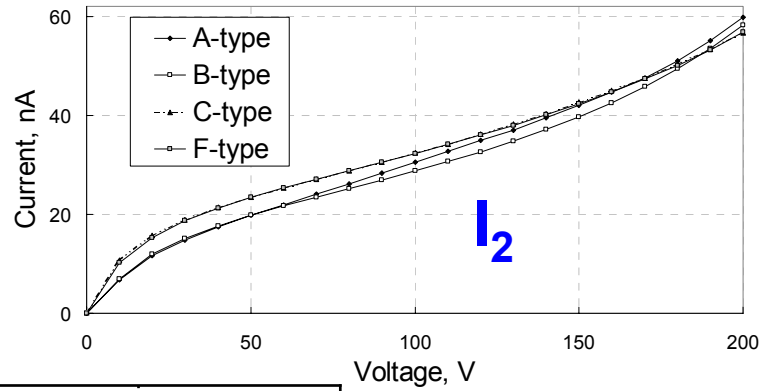
2. Basic Principle of Planar Edgeless Detectors





TOTEM Technical Design Report
CERN-LHCC-2004-002 (2004)
G. Ruggiero et al., *"Planar edgeless Silicon Detectors for the TOTEM experiment", Accepted for publication in IEEE Trans. Nucl. on Sci.*

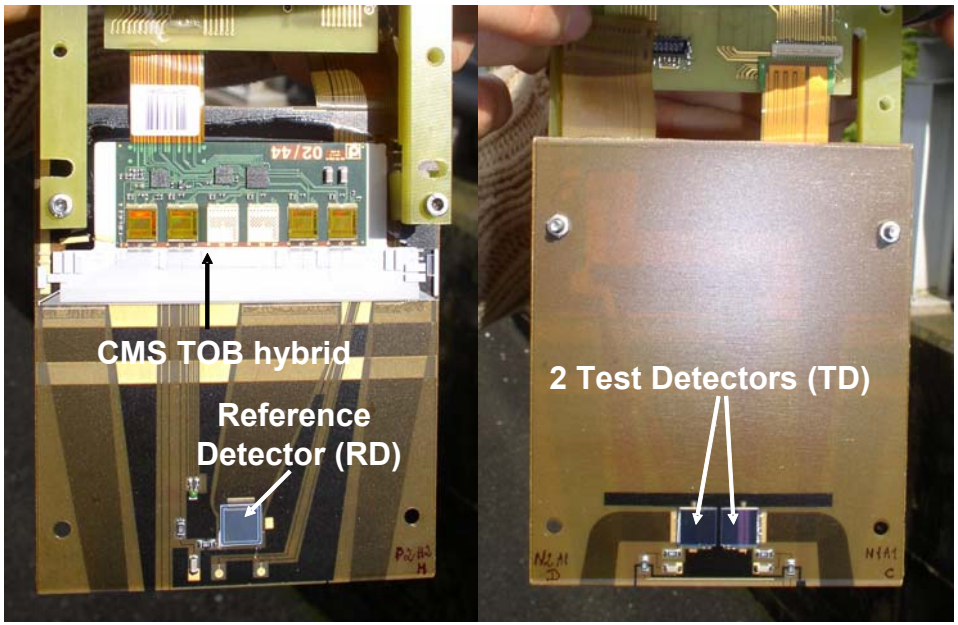




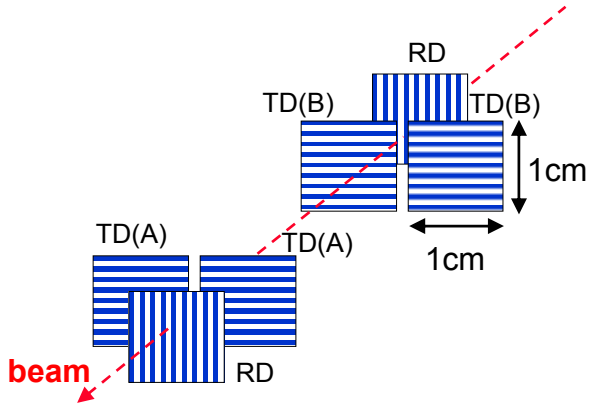
Type	d_1+d_2 (μm)
A	20+10
B	20+20
C	40+10
F	60+20

This design allows full separation of surface and bulk generated current

2.1 Small size detector test setup



Front Side Back Side



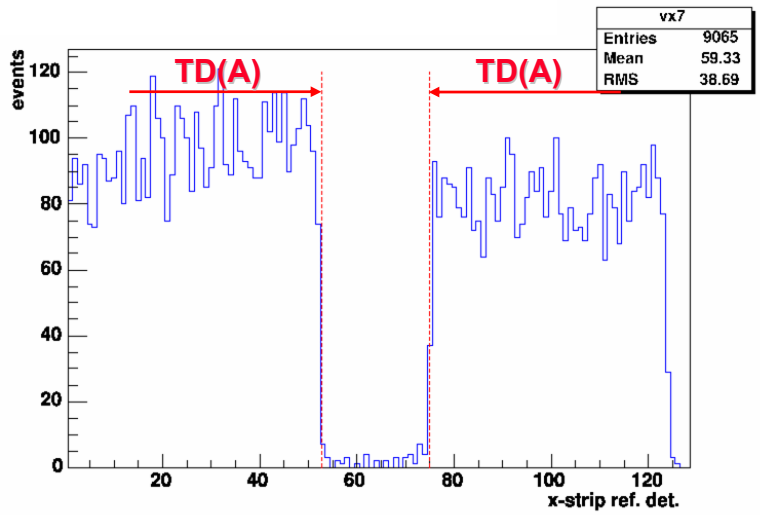
Arrangement of the detectors along the beam line

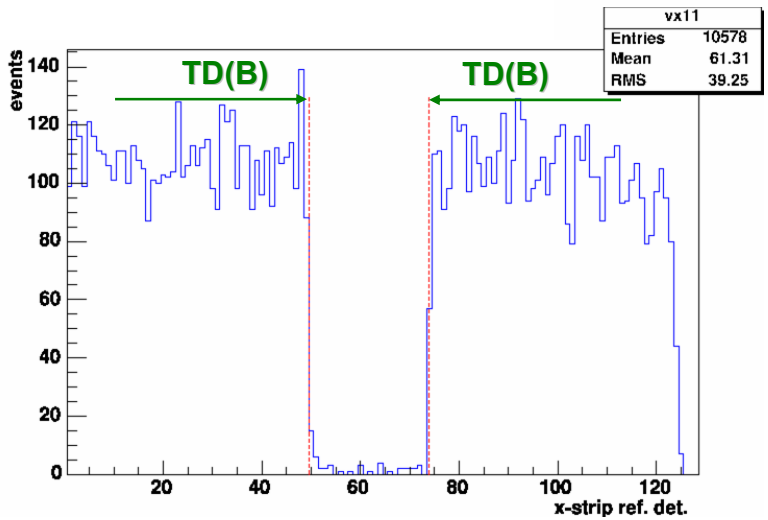
Module with detectors and readout electronics:

- Test Detectors placed edge-to-edge, reference detector pitch 50 μm
- APV25 chips used for read-out

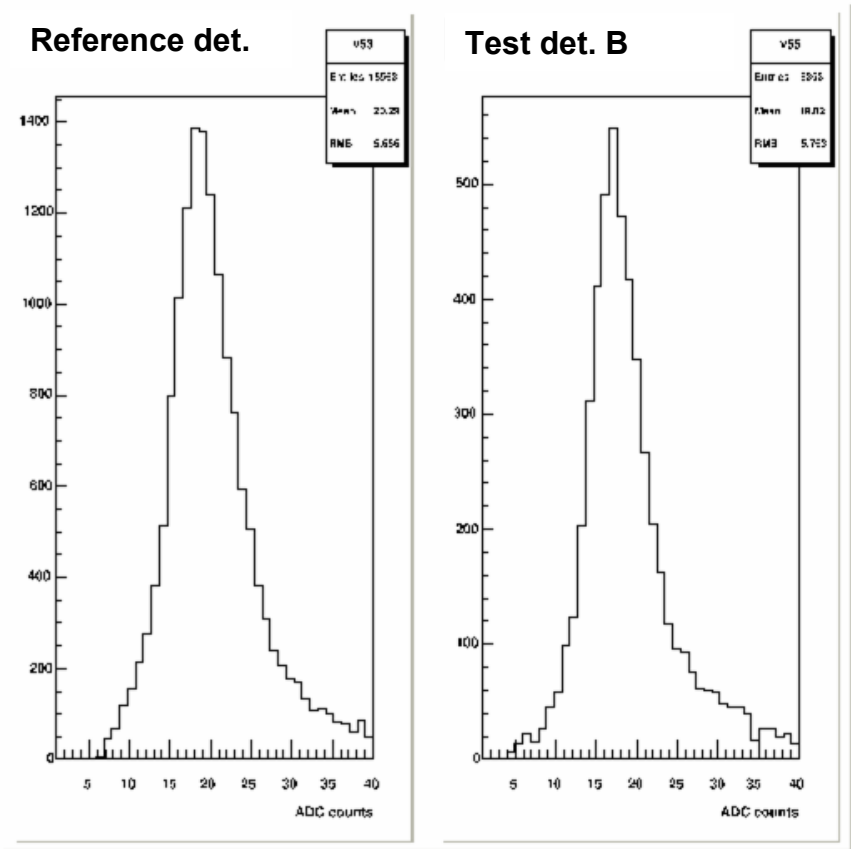
The small size detectors were tested in a high energy muon beam at CERN

2.2 Small size detector performance





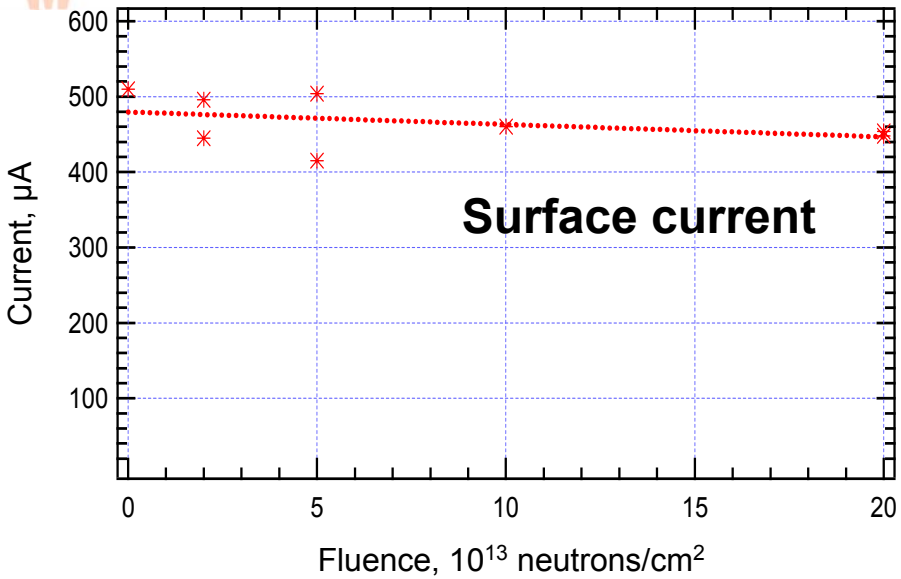
Signal-to-noise ≈18 for a detector thickness of 300μm

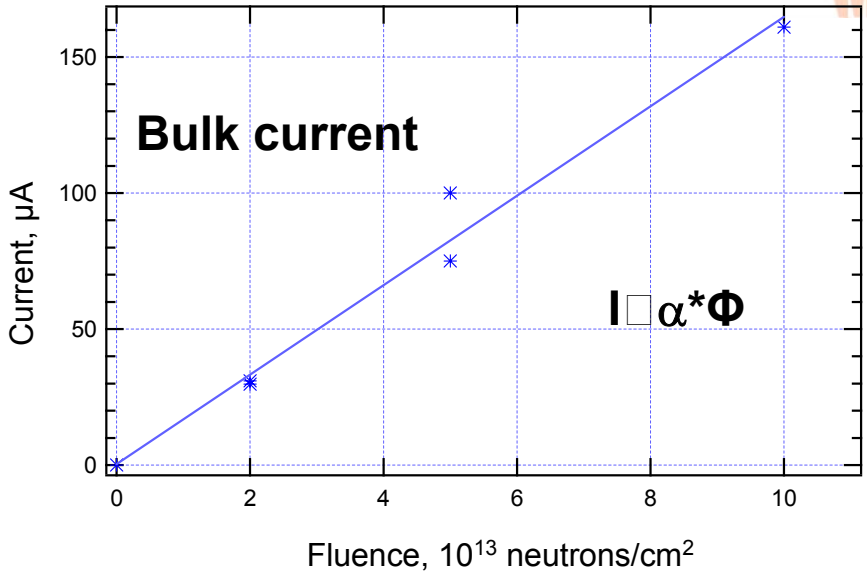


Detectors fully sensitive up to 60 μm from the edge

2.3 Radiation Tests on Edgeless Planar Detectors

All detectors fully depleted





Studies on irradiated silicon detectors:

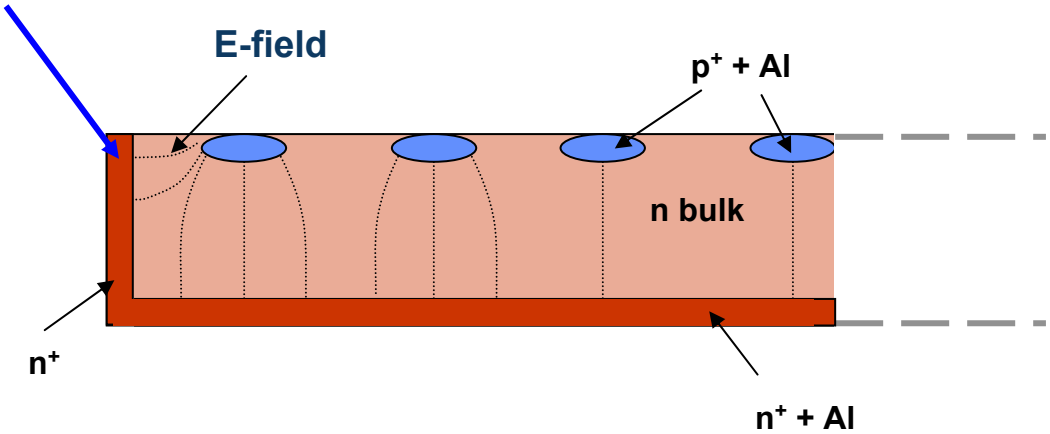
- No increase in the surface current with fluence (as expected)
- Bulk current increases with fluence in agreement with what is observed in standard planar detectors

(damage factor $\alpha = \frac{\text{Current}}{\text{Volume} \times \text{Fluence}} = 5 \times 10^{-17}$ A/cm)

These data suggest a radiation hardness for the Edgeless Planar detectors equal to the standard planar detectors up to 10^{14} "n"/cm^2

3. Basic principle of planar 3D detectors

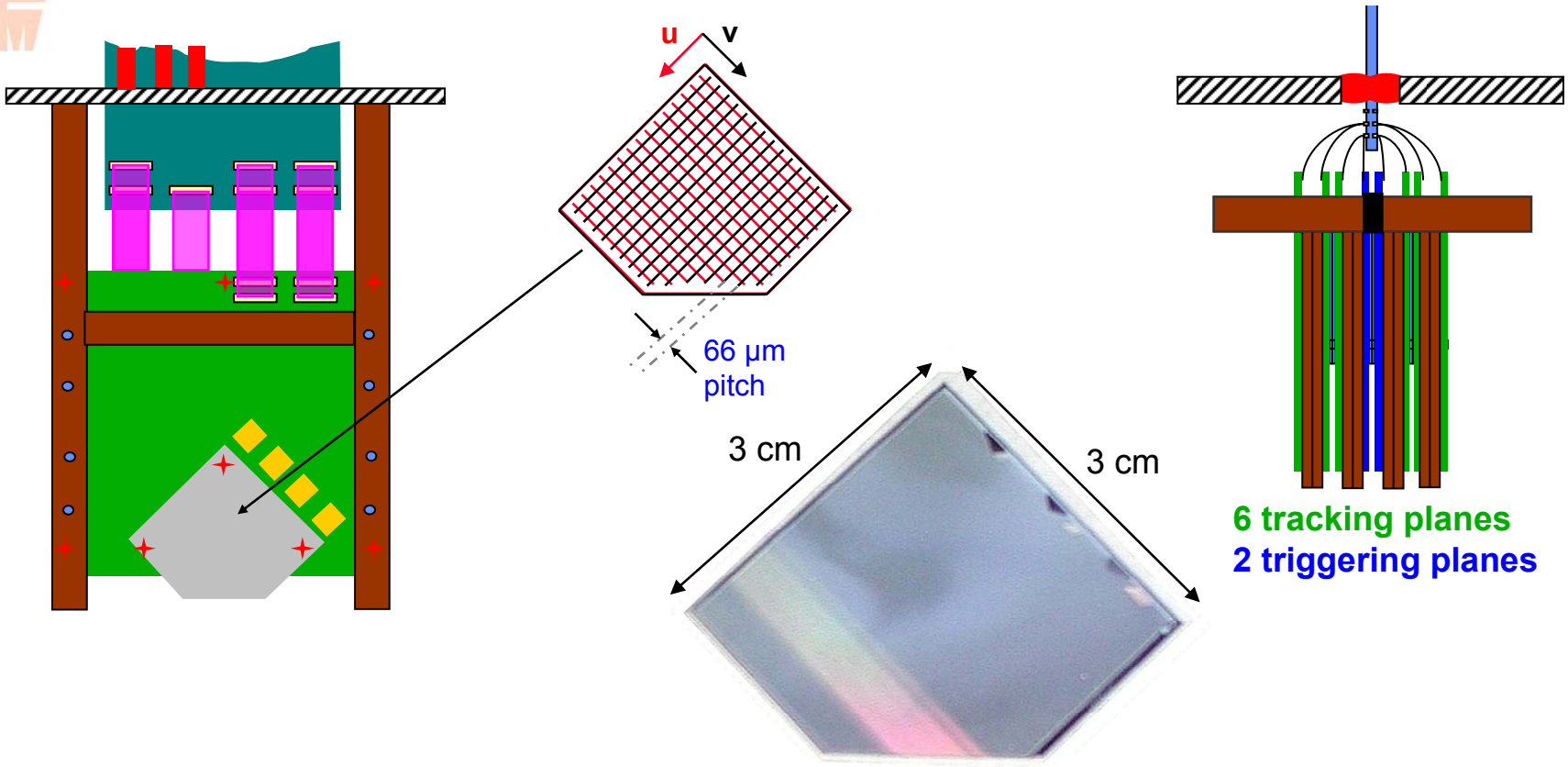
Traditional planar detector + deep etched edge filled with doped polysilicon



TOTEM Technical Design Report
CERN-LHCC-2004-002 (2004)
C.J. Kenney et al.,
IEEE Trans. on Nucl. Sci. 48 (2) 189 (2003)

Smaller dead area than for planar technology

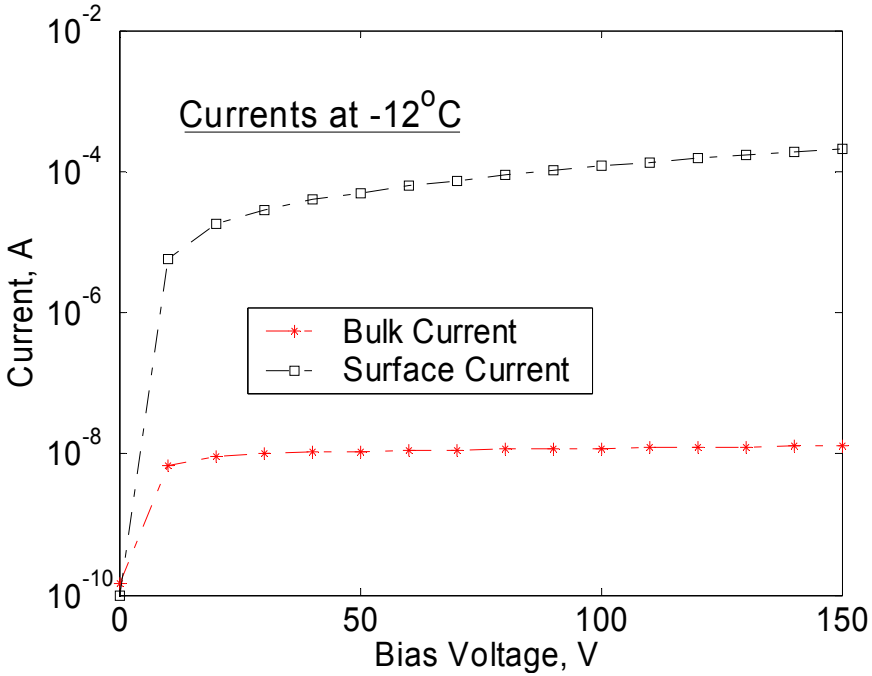
4. Final size Edgeless Planar Detectors

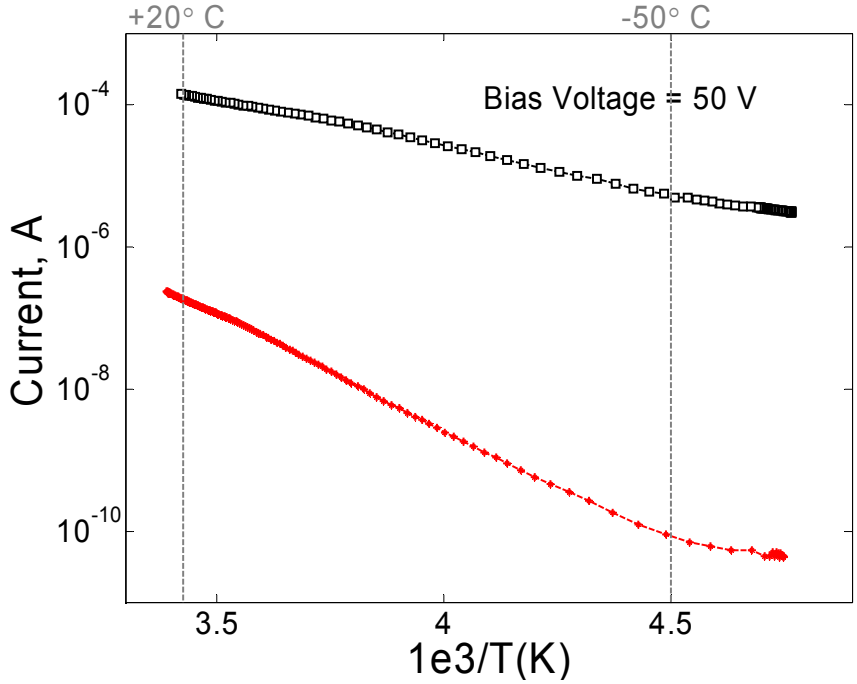


Final size edgeless detectors were produced and tested in 2004 :

- In a fixed target experiment with high energy muons
- In a coasting beam experiment with high energy protons

4.1 Temperature performance of the final size detectors

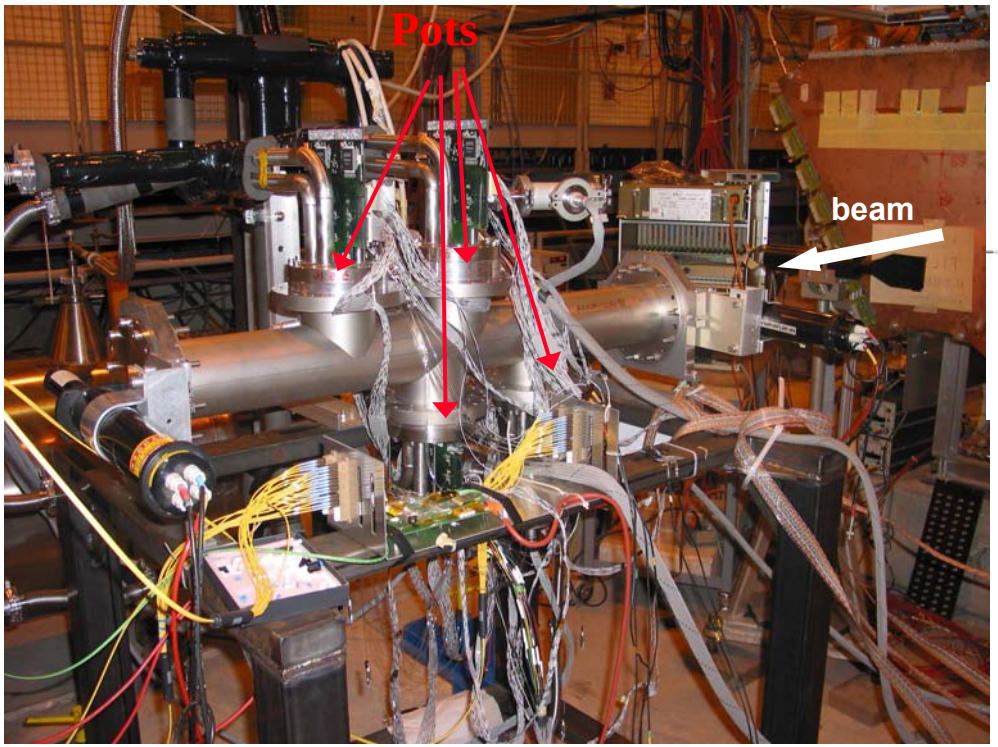




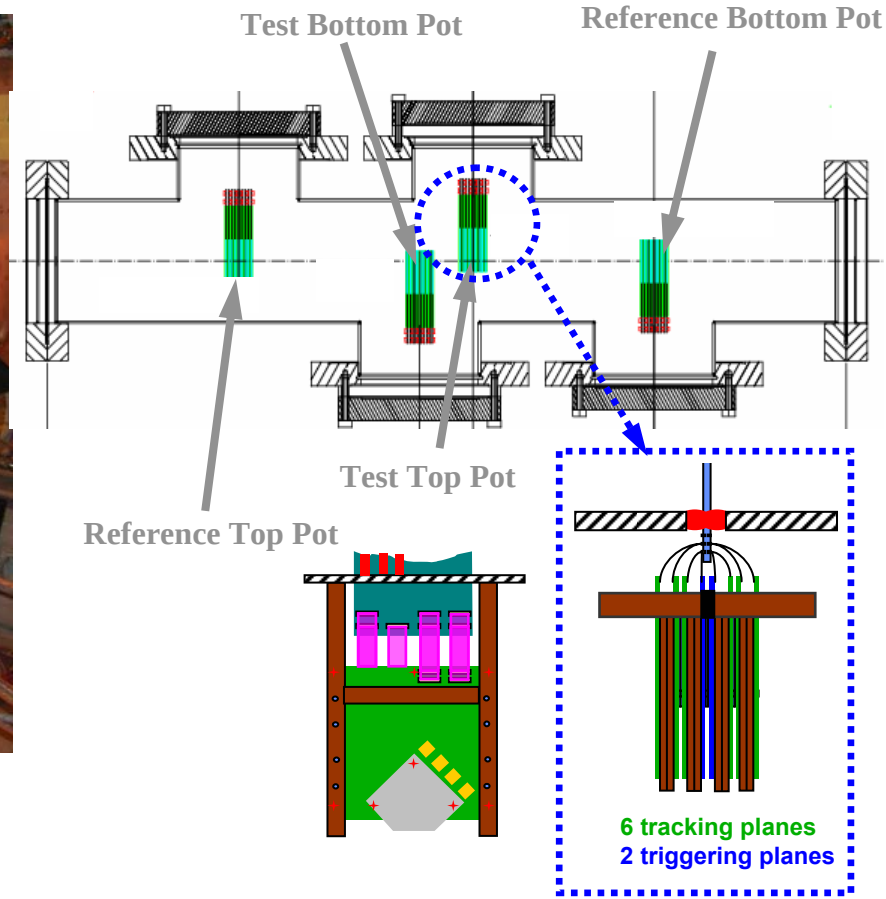
Detector overdepleted (V_{fd} = 20 V)

Surface current less reduced than bulk current by cooling

4.2 Detector performance test in fixed target experiment

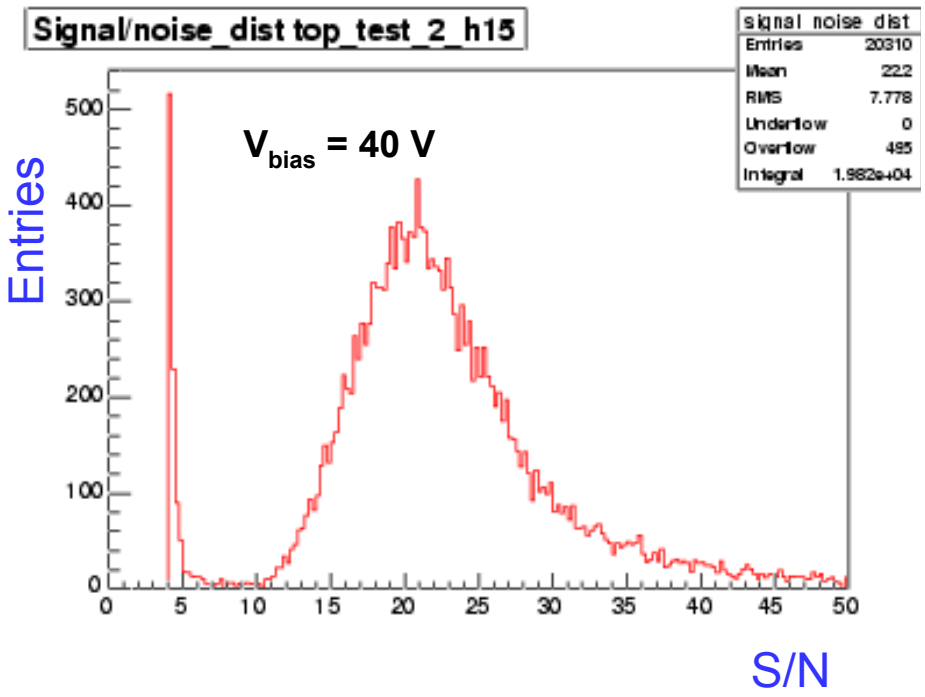


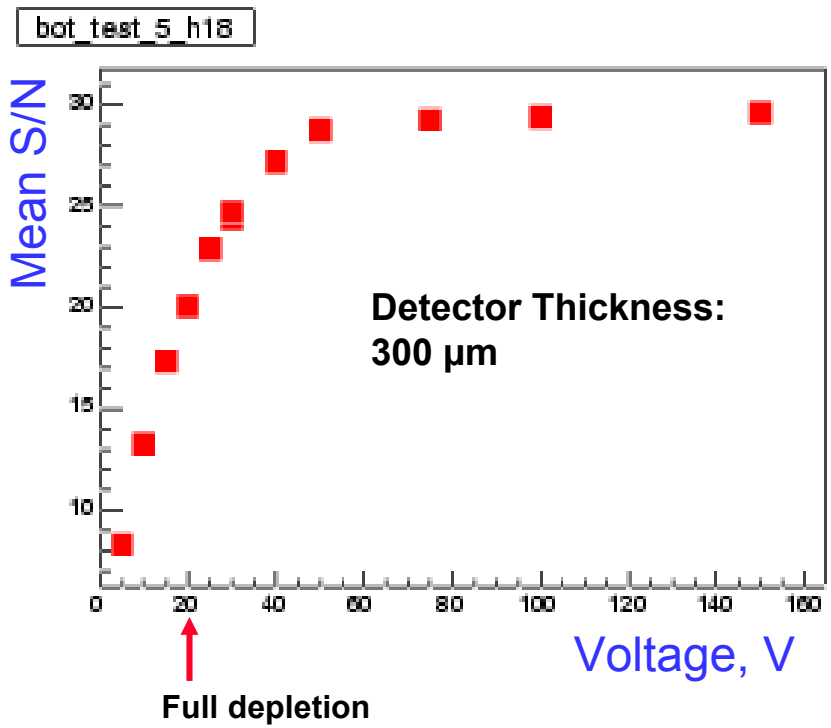
Set-up used in a high energy (120 GeV) muon beam



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

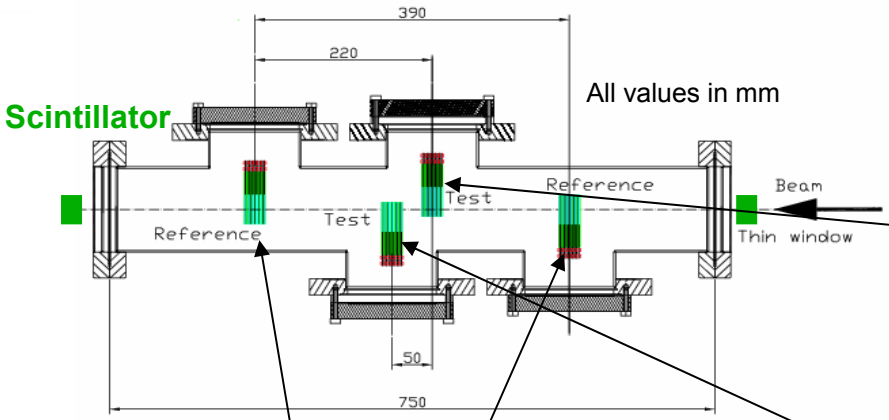
4.3 Detector response





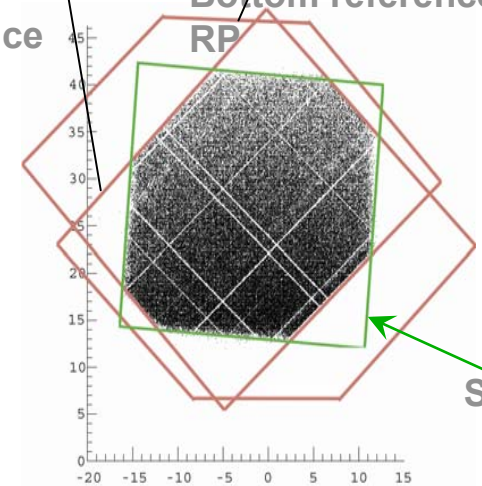
Faster collection time with increasing voltage, signal-to-noise ratio allows high signal selection efficiency

4.4 Hit distributions of reference and test detectors



Top reference RP

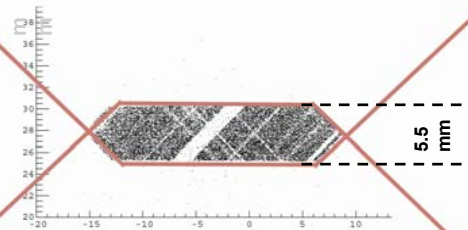
Bottom reference RP



Scintillator

Coincidence plot of reference detectors and scintillators

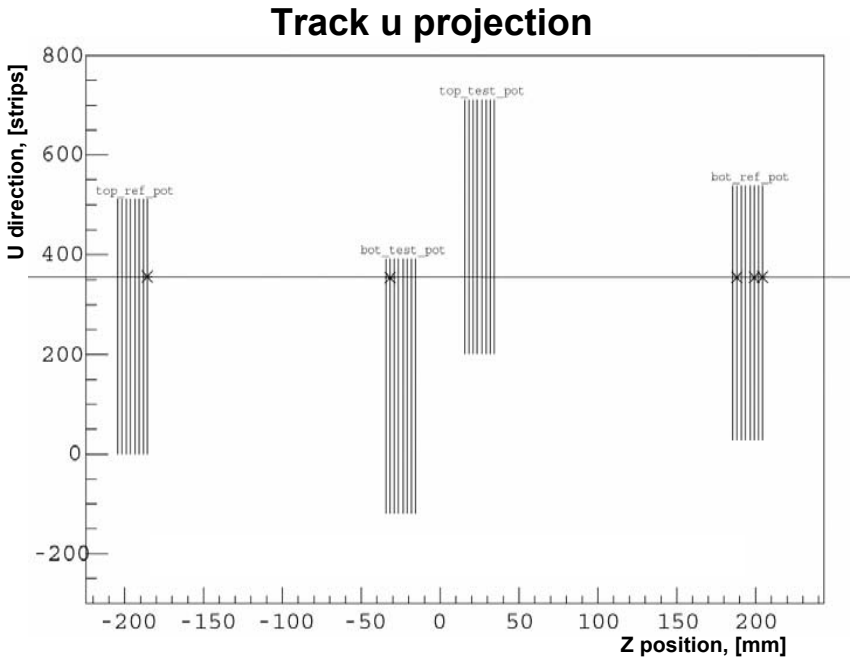
Top test RP

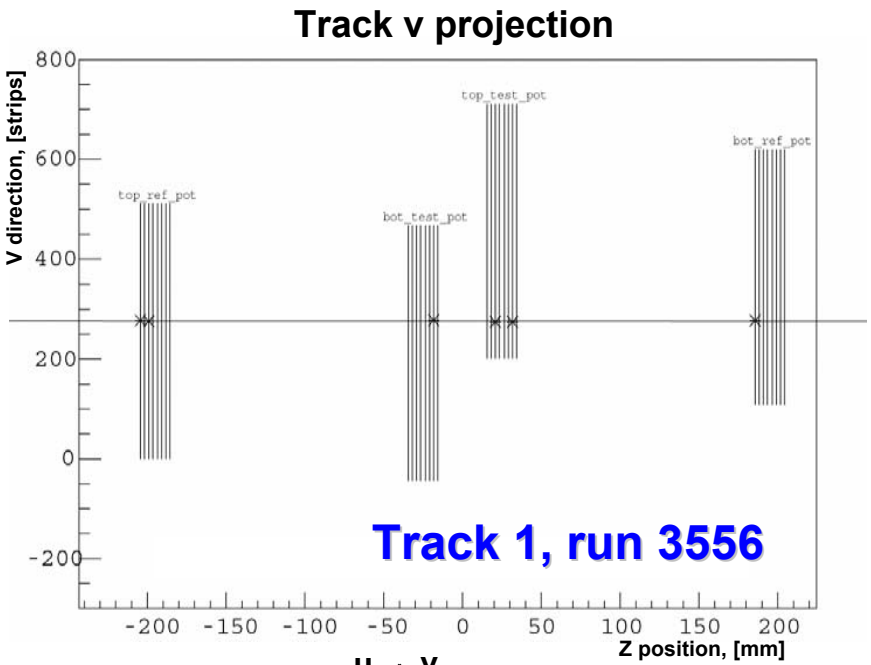


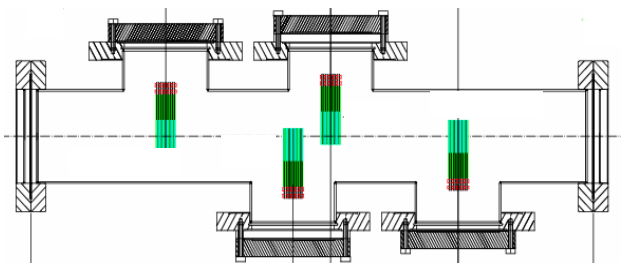
Bottom test RP

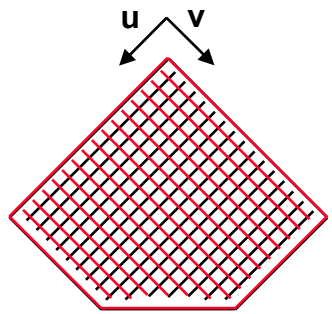
Coincidence plot of test detectors and scintillators

4.5 Track reconstruction

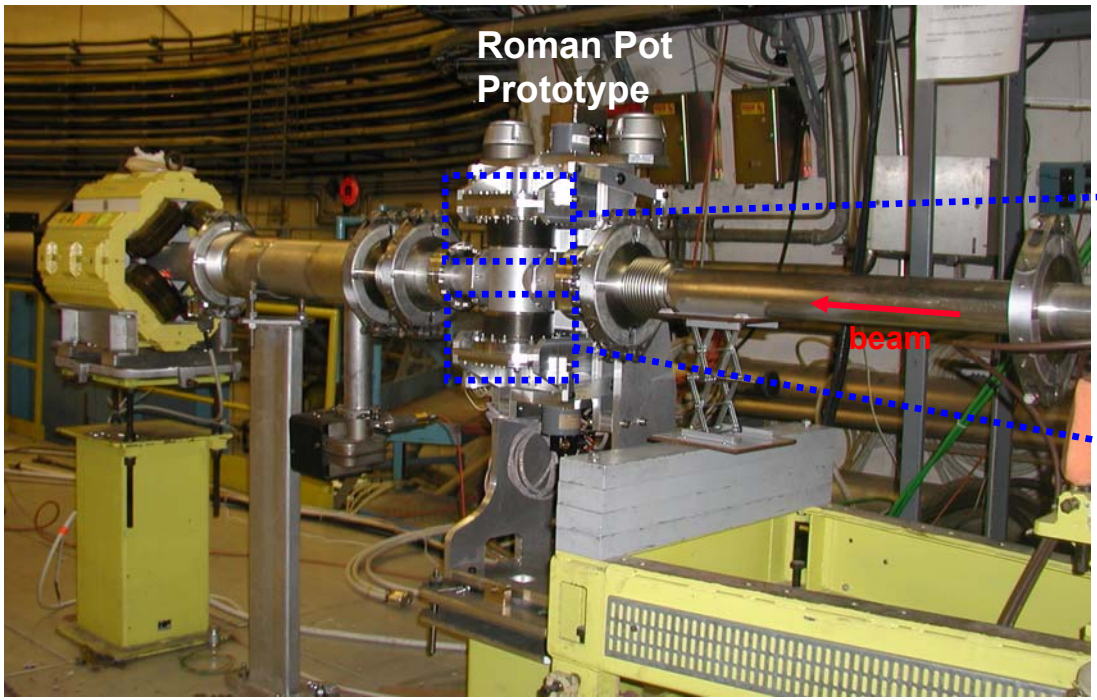


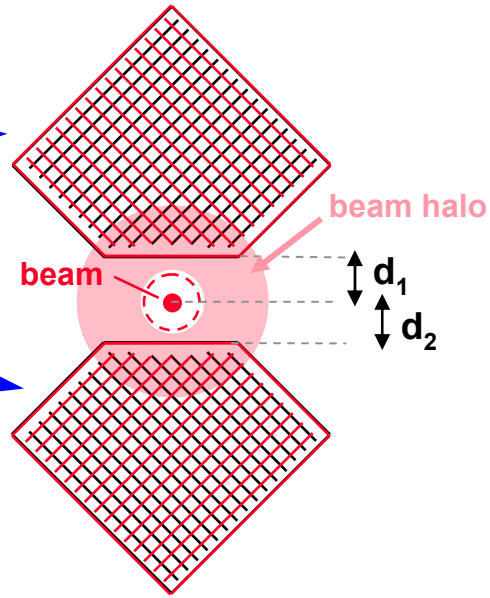






4.6 Full size detectors test setup in coasting beam

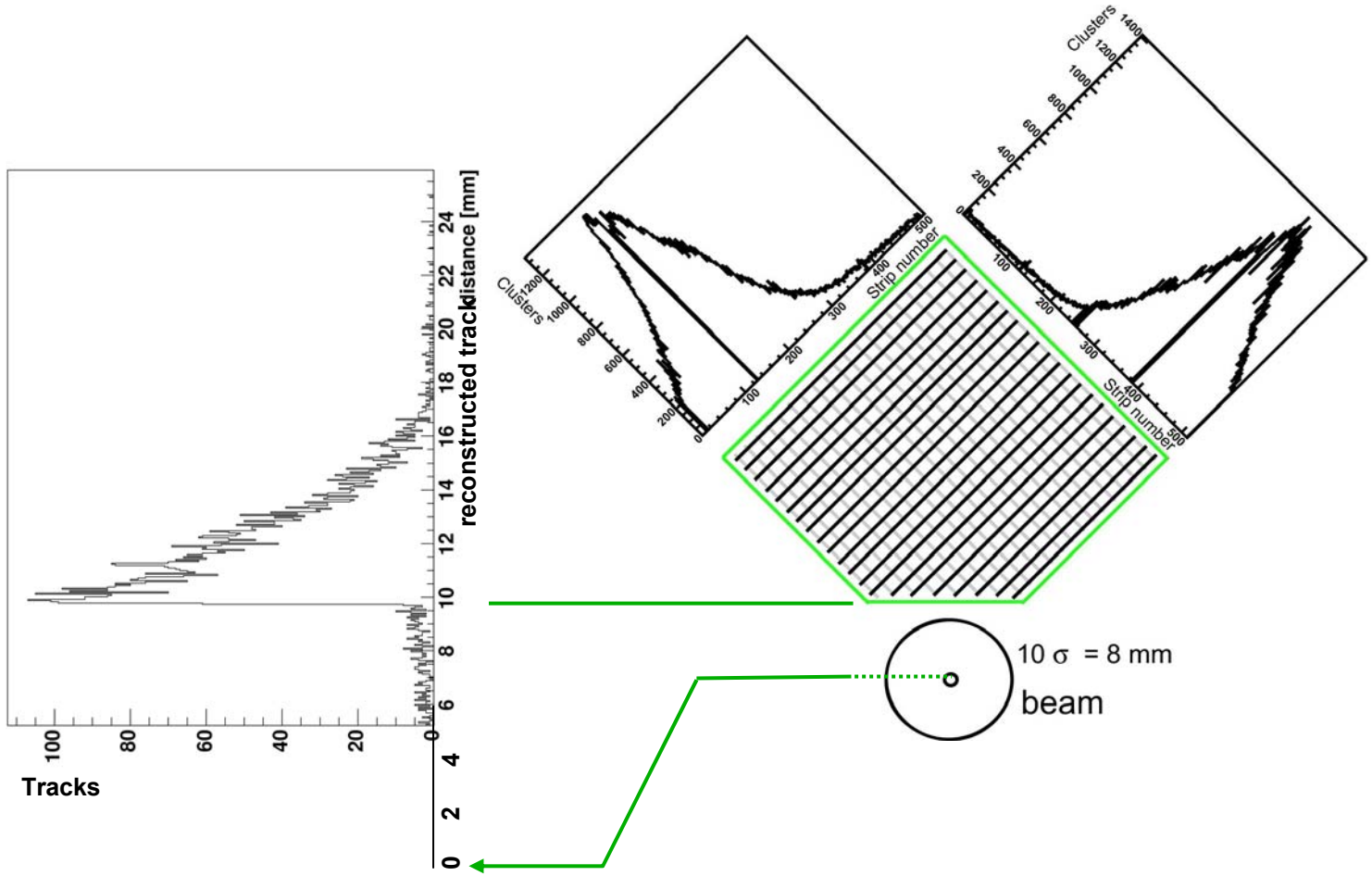




Tests of full size detectors in coasting beam:

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

4.7 Final Size Detector Performance in coasting beams



5. Conclusion

The edgeless planar detectors fulfill following criteria:

- **Sensitivity up to 60 μm from the edge**
- **Charge collection time below 25 ns**
- **Radiation hardness up to fluences of 10^{14} "n"/cm^2**
- **Operational temperature not below -10°C**

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