Roman Pot background studies in TOTEM
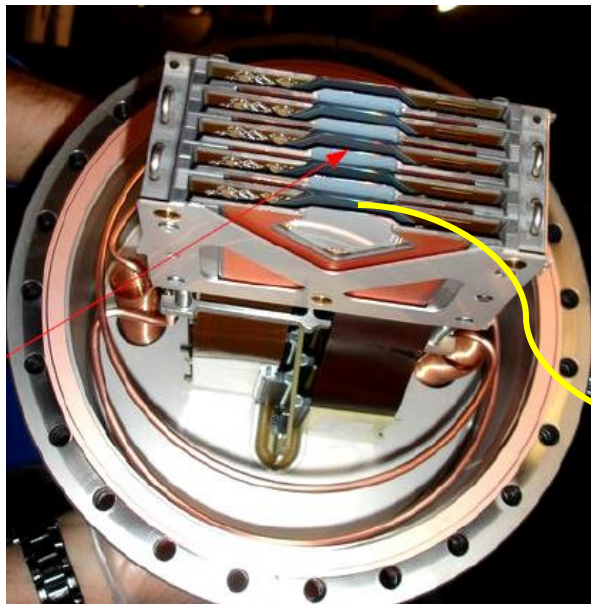
Geant4 simulations
Preliminary results

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5/15/2013
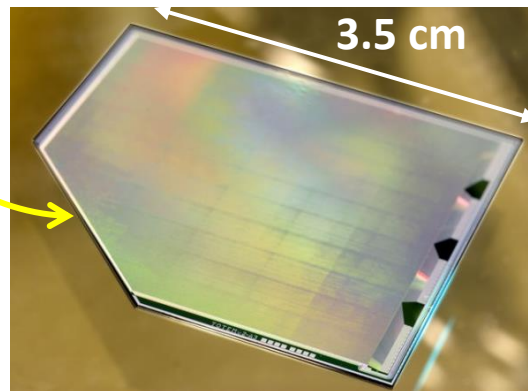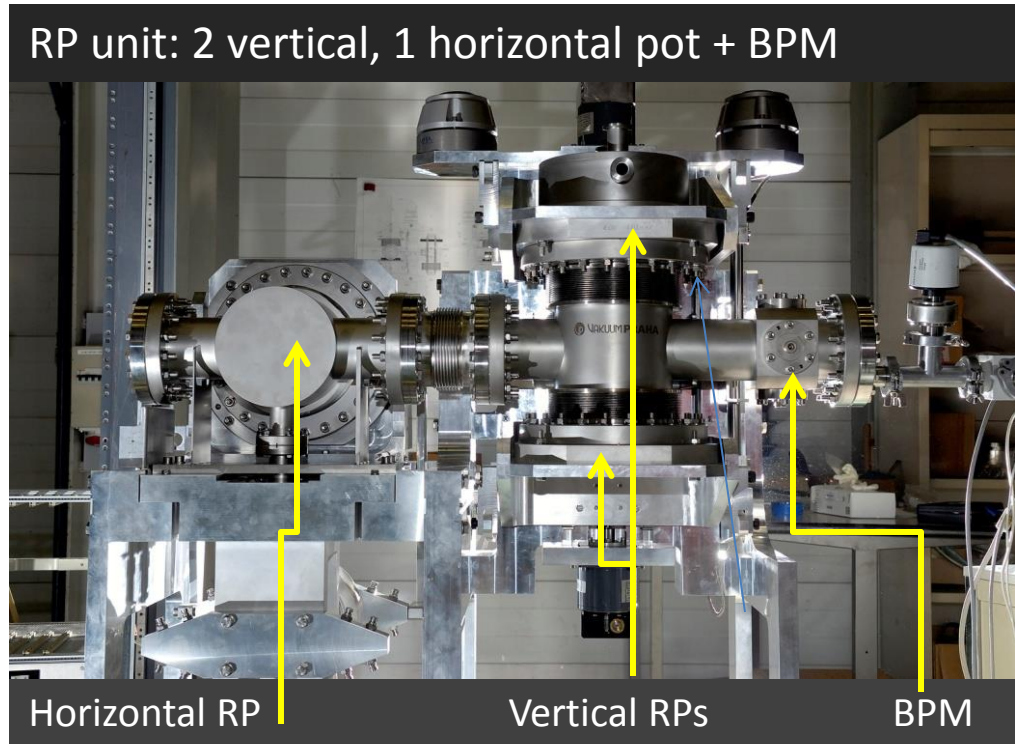
Roman Pots

RP stations:

◆ 2 units at about 5 m distance

◆ Measurement of very small proton scattering angles (few µrad)

◆ Vertical and horizontal pots mounted as close as possible to the beam

Horizontal RP   Vertical RPs   BPM

10 planes of edgeless detectors

3.5 cm

Si edgeless detector

1 Roman Pot

Main objectives of the Geant4 study

- ## Secondary particle production study of RPs:
  - Comparison of different Roman Pot geometries
    - Box (present)
    - Cylindrical (RF optimized for upgrade)
  - Comparison of different RP parts
    - Bottom, thin window, …

- ## Study of realistic scenarios:
  - With input particle distribution, "debris" profile, measured by Roman Pots
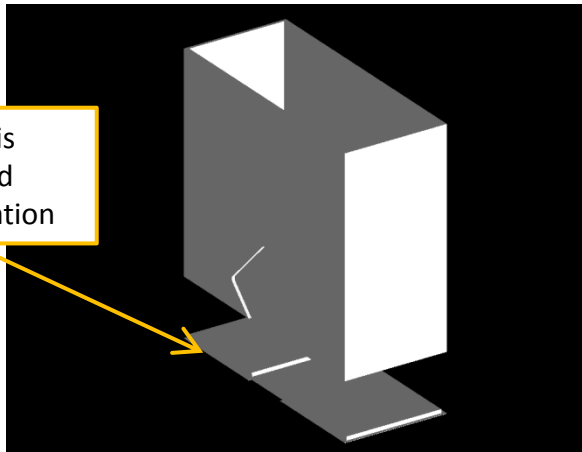 - Multiple pot effects: avalanche, …

Particle generator & RP geometries
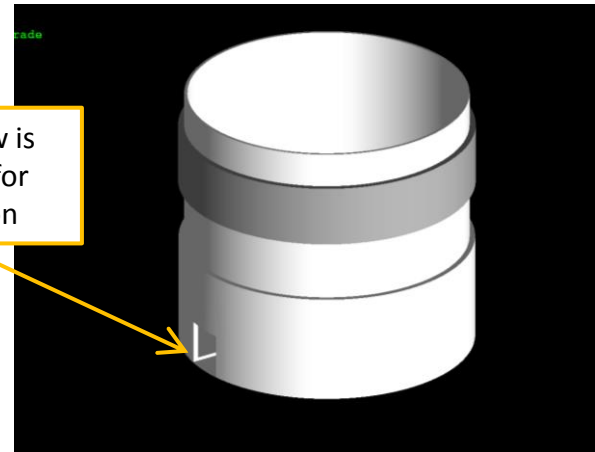
Particle generator:

- 2×10^3 protons
- $p_z = 7$ TeV/c, with $p_x = p_y = 0$
- $z = 0$, Dirac-δ profile in (x,y) plane
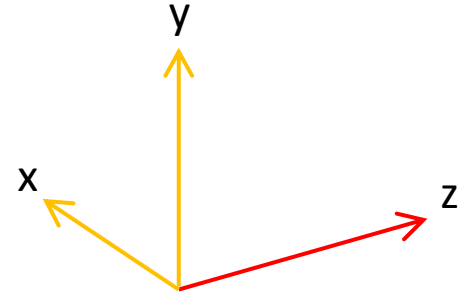
Bottom is detached for visualization

Thin window is uncovered for visualization

Box shape (present)
Material : Steel
l_x = 128 mm
l_z = 54 mm
height = 111.2 mm
$d_{BottomThinWall}$ = 150 μm

Cylindrical (RF opt., production drawing, 07/5/2013)
Material : Steel
d_{outer} = 145 mm
d_{inner} = 139 mm
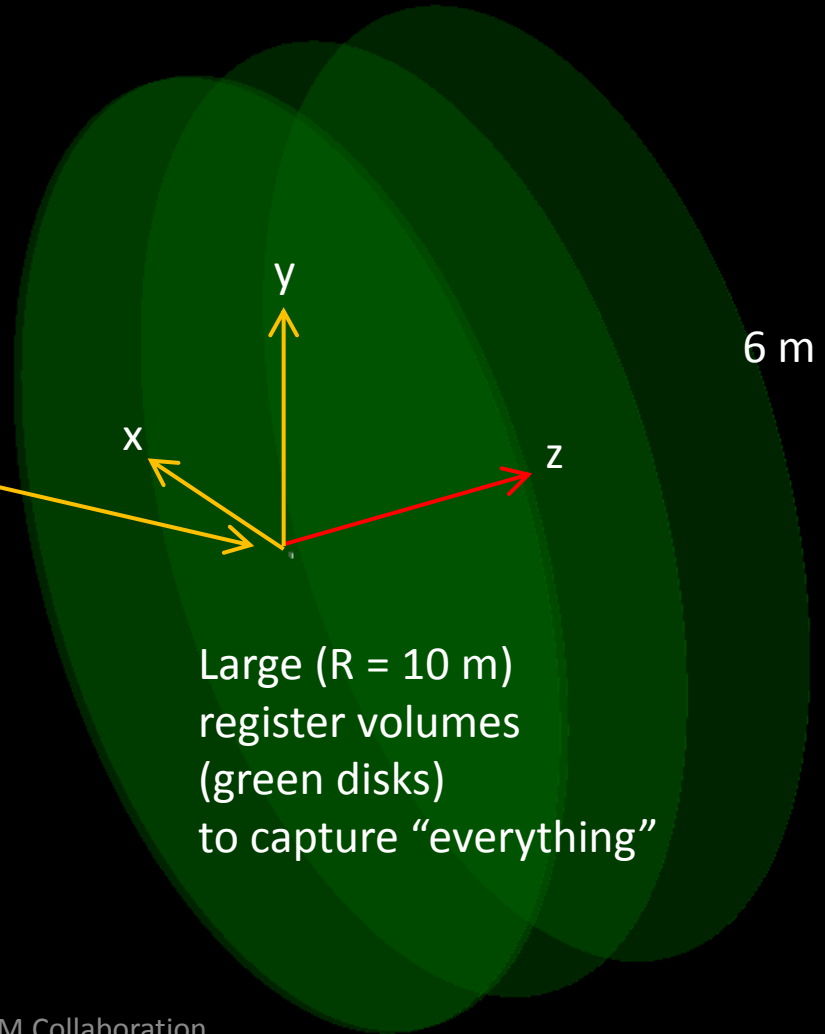**height** = 130.5 mm
$d_{BottomThinWall}$ = 300 μm

Single Roman Pot studies

Register volumes, geometry
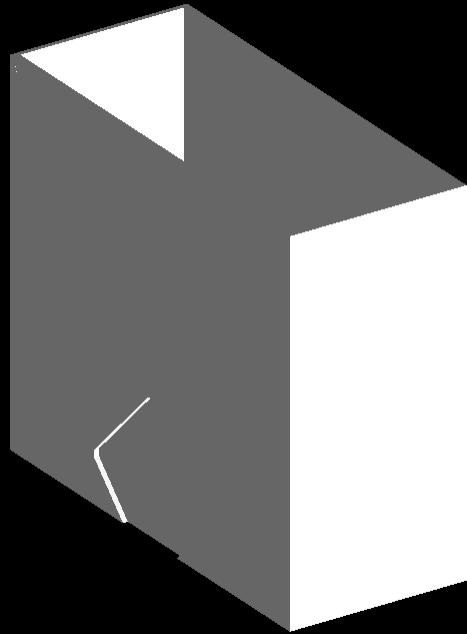
Pot is There.

Bottom boundary at x = y = 0 z = 150 mm

6 m

y

x

z
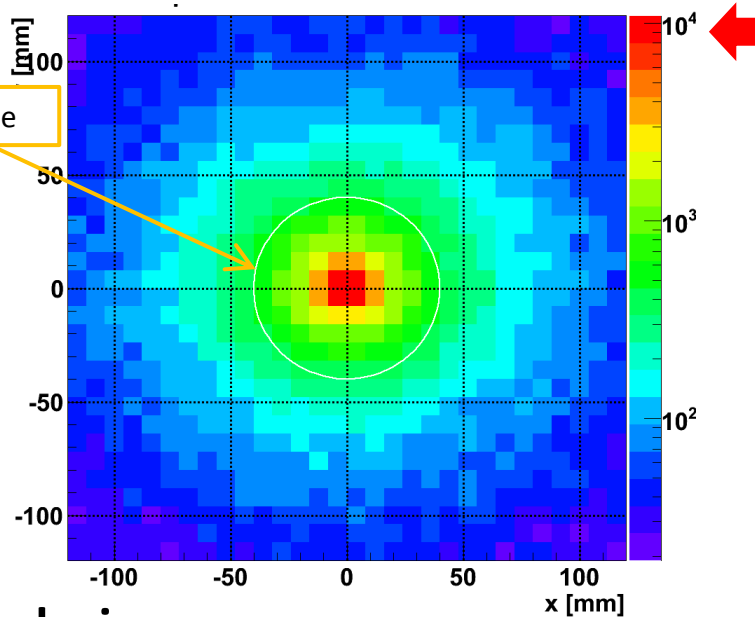
Large (R = 10 m) register volumes (green disks) to capture "everything"
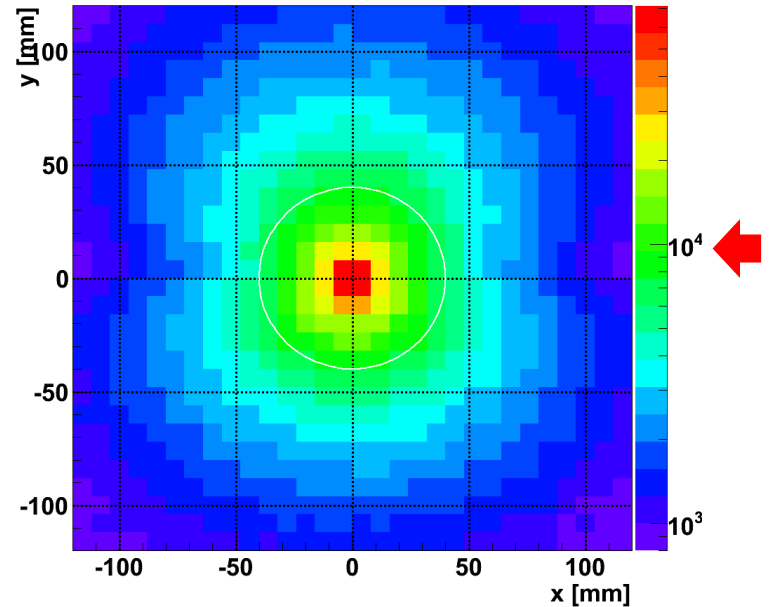
Secondary particle hit distributions

Secondary particles produced by 2×10^3 protons:

- Bottom part of Roman Pot is tested
- Register volume:
  - at 6 meters in the transverse (x,y) plane
  - the rectangle ($\pm$ 120 mm, $\pm$ 120 mm) is shown

Box shape

Cylindrical shape

Beam pipe

Conclusion:
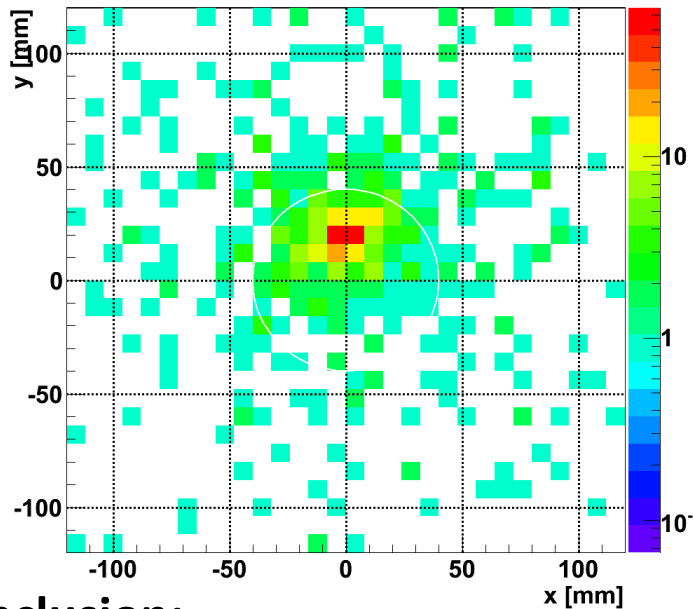
- More secondary particles from cylindrical Roman Pot, $N_{cylinder} \approx 7 \times N_{box}$
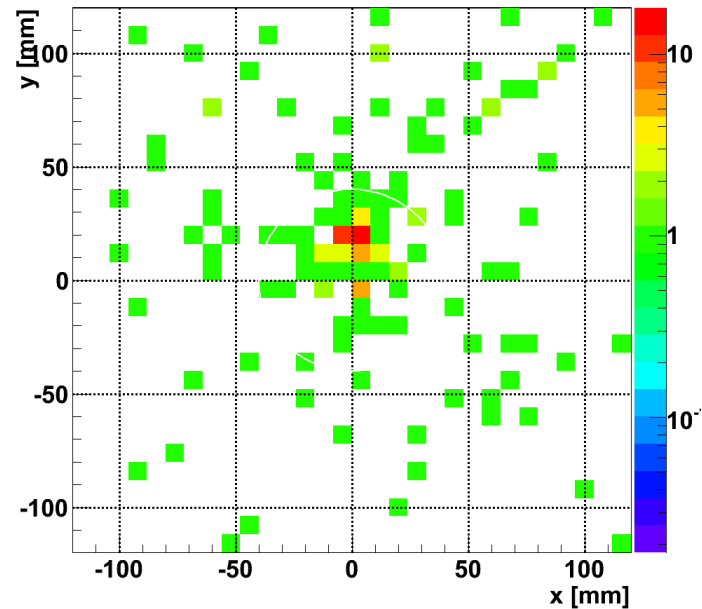
Secondary particle hit distributions

For comparison:
- Front thin window of Roman Pot is tested
- Thickness of **front** thin window
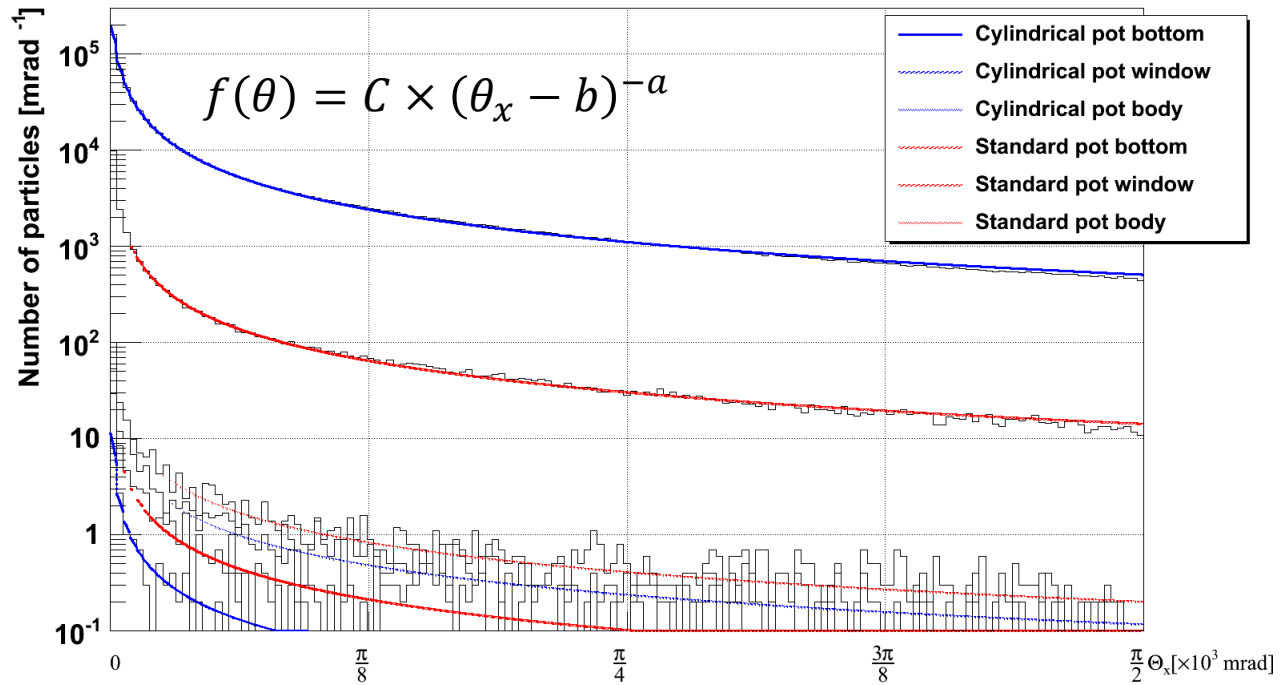 - Box shape : 500 µm
  - Cylindrical : 300 µm

Box shape

Cylindrical shape

Conclusion:

- Negligible contribution with respect to the bottom part.

Θ_x distribution of secondary particles

$$f(\theta) = C \times (\theta_x - b)^{-a}$$

Legend:
- Cylindrical pot bottom
- Cylindrical pot window
- Cylindrical pot body
- Standard pot bottom
- Standard pot window
- Standard pot body

Results:

- $a \approx 1.0$
- $b \approx 0$ mrad

C [mrad^{-1}]			
Shape	Bottom	Window	Body
Cylindrical	8.5×10^5	23	185
Box	2.3×10^4	79.3	318

Θ$_y$ distribution of secondary particles

$$f(\theta) = C \times (\theta_y - b)^{-a}$$

Results:

- a ≈ 1.0
- b ≈ 0 mrad
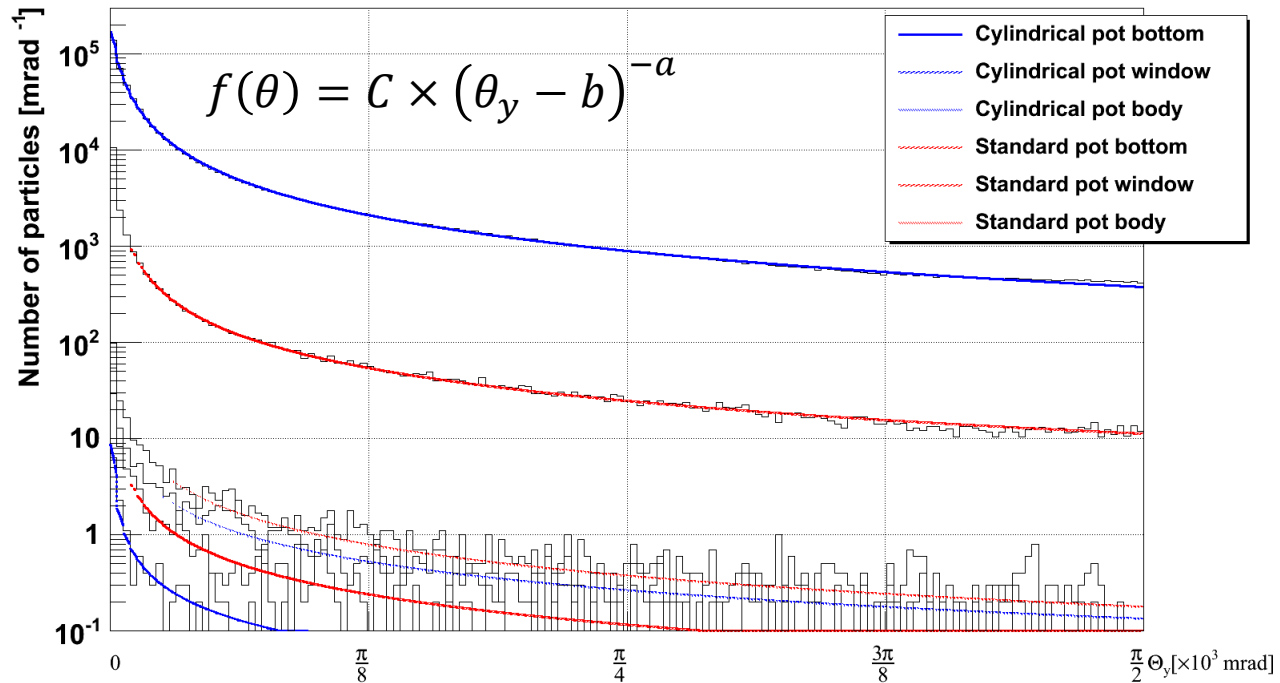
C [mrad^{-1}]			
Shape	Bottom	Window	Body
Cylindrical	6.7×10^5	28.8	209
Box	1.9×10^4	90.3	289

Simulation with measured rate profile
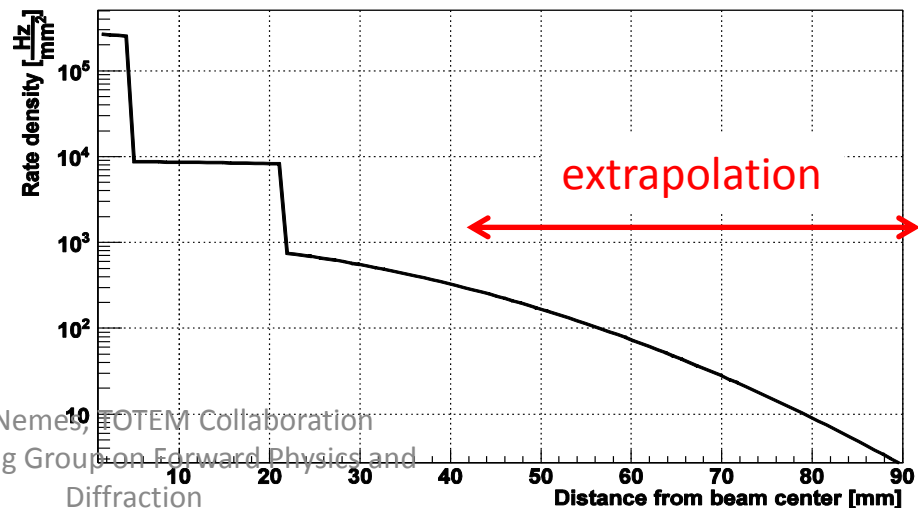
- Particle generator "debris"
  - 6×10^4 protons
  - $p_z = 7$ TeV/c, with $p_x = p_y = 0$

  Shape:
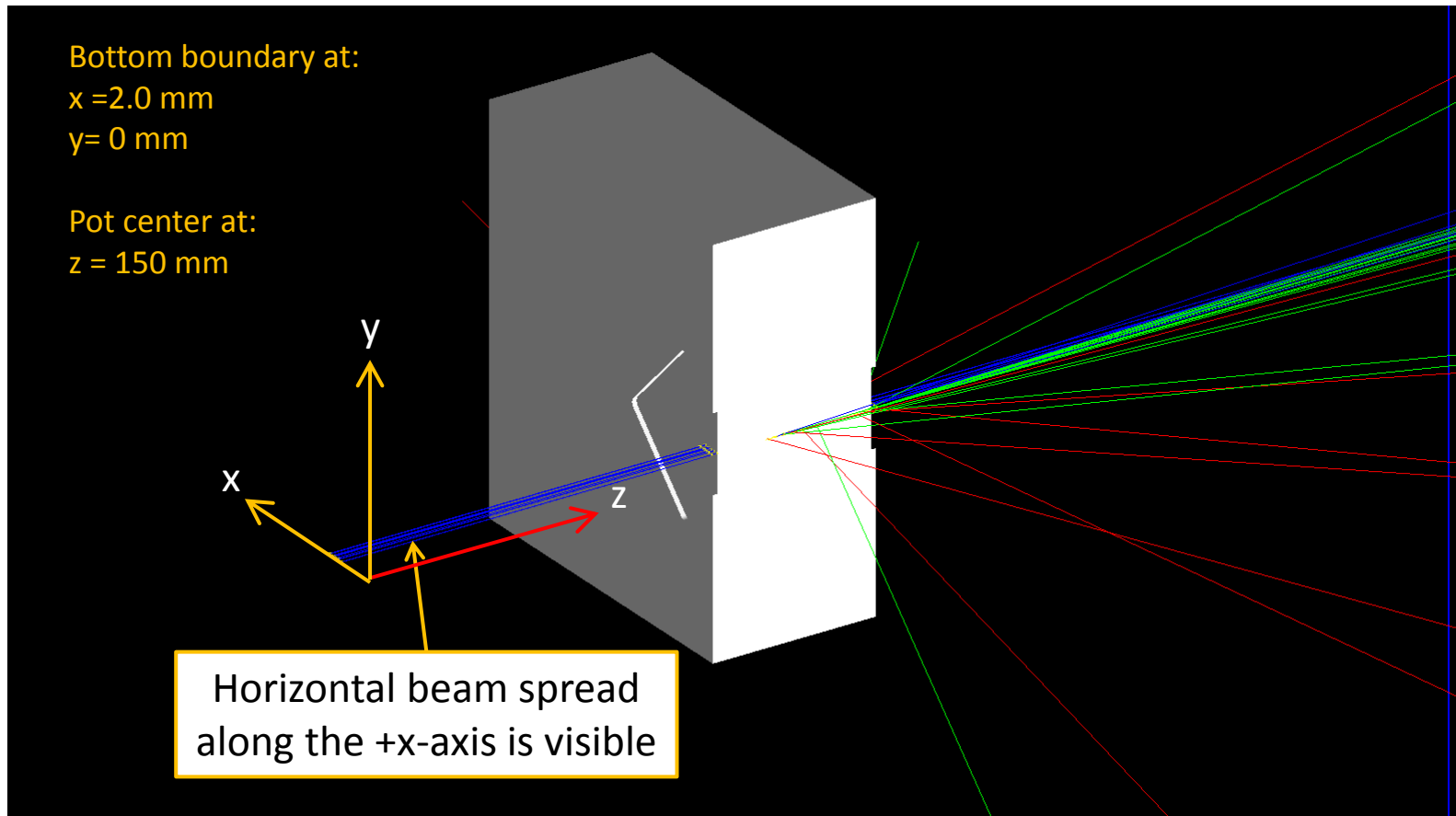 - $z = 0$
  - y : Gaussian profile
    - σ_y(4.0 mm)
    - $\approx 10 \times \sigma_y$ of $\beta^* = 0.55$ m @220m
  - x : rate density profile
    - Fit with measured rate
    - 45-220-N-H, 15/11/2012
    - 10% errors : $\chi^2 / ndf = 0.75$
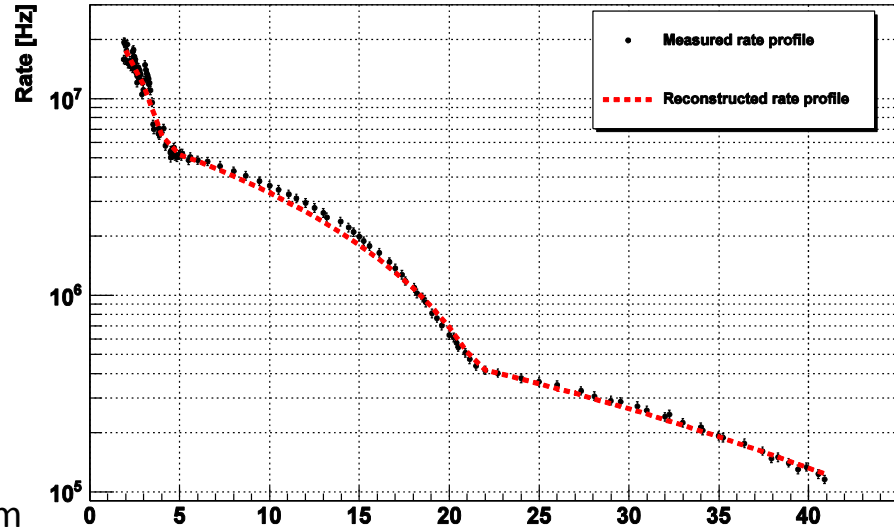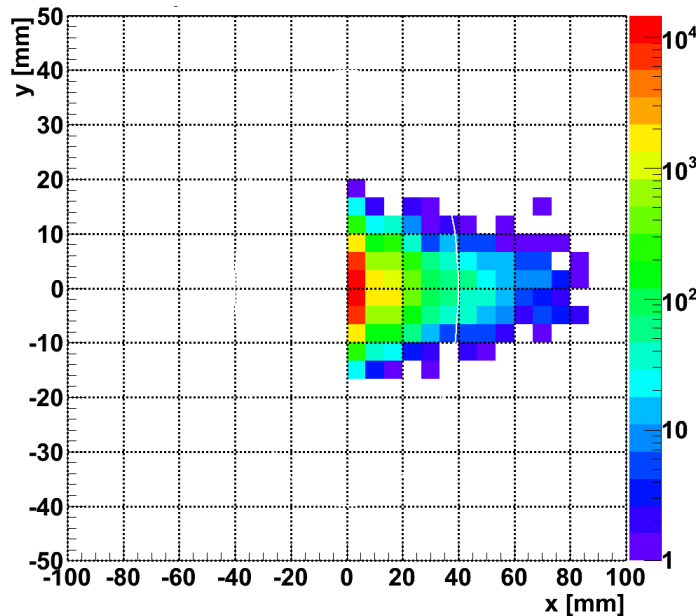

Convolution with Si detector plane

extrapolation

Horizontal Roman Pot

Bottom boundary at:
x =2.0 mm
y= 0 mm

Pot center at:
z = 150 mm
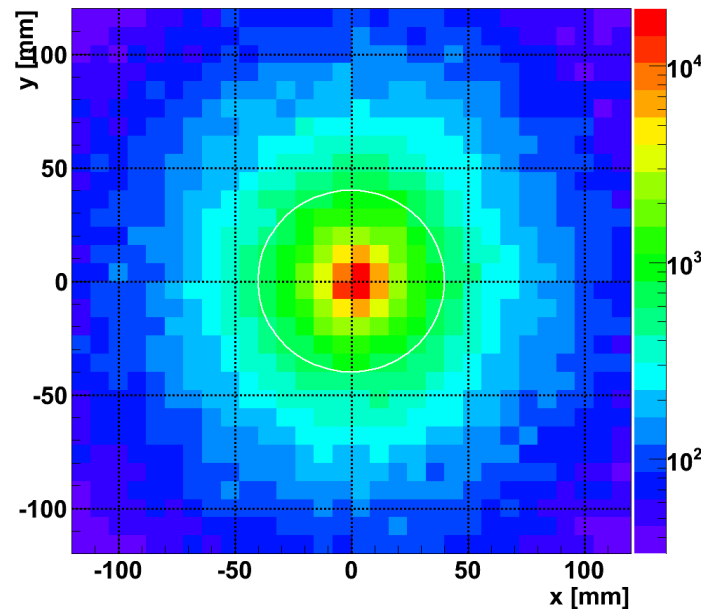
Horizontal beam spread along the +x-axis is visible

Secondary particle hit distribution

- 51687 protons detected by the (model) Si detector
  → conversion factor to Hz ≈ 290.2

**Input (primary particles)**

Output at 6 m

Conclusion:

- bottom part remains the most intensive source

Conclusions

- Bottom part produces the majority of the secondary particles:
  - $N_{bottom} > 10^2 \times N_{other}$
  - longer path in material

- Cylindrical pot produces more secondary particles

- Angular distribution of secondary particles: $N(\Theta) \sim 1 / \Theta$
  - Many particle stay in the beam pipe (even @ 6m)
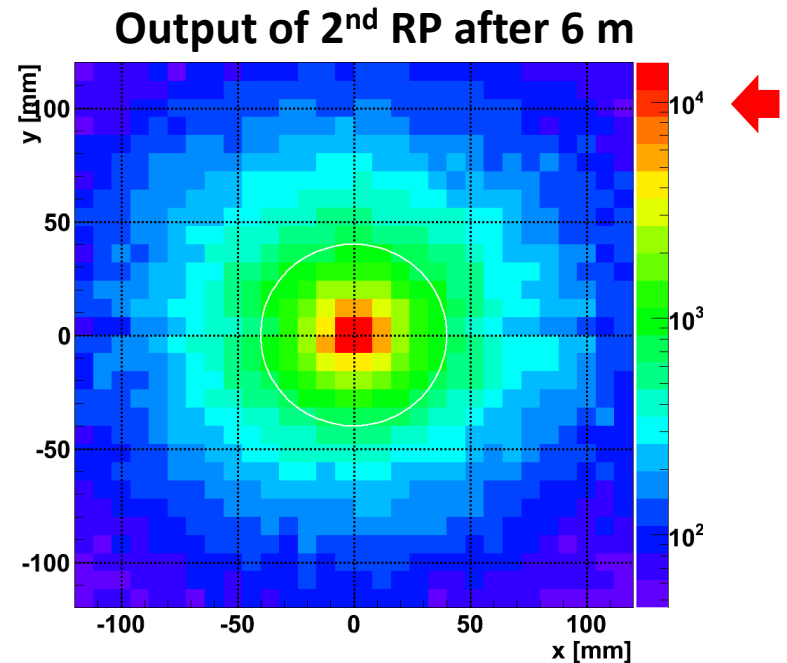
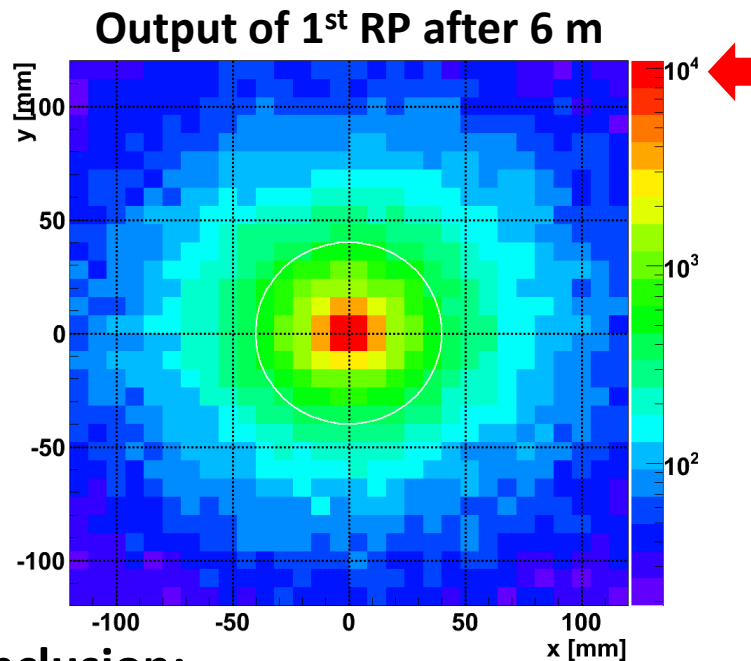# **Multiple Roman Pot studies**

Avalanche effects
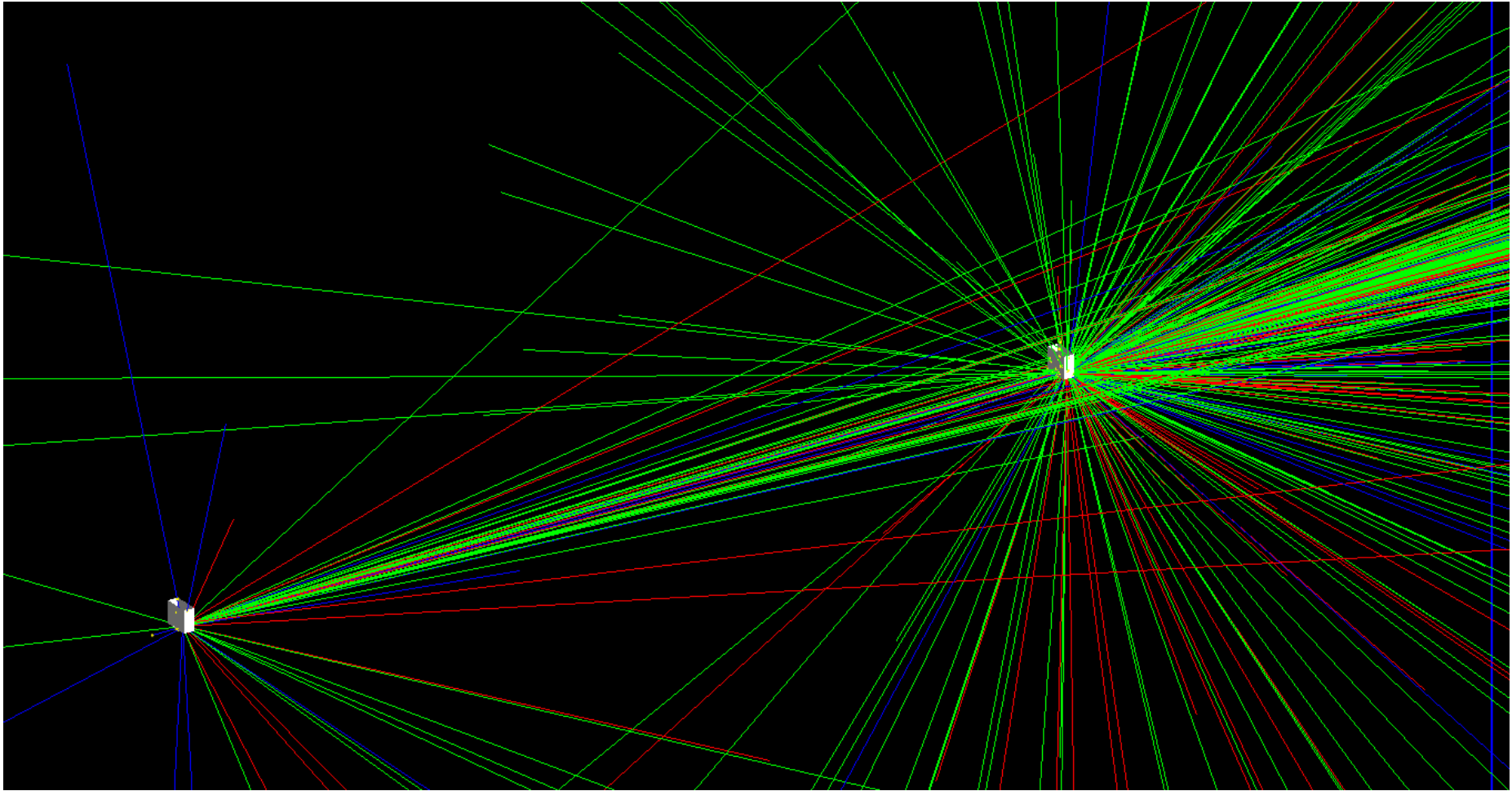
Avalanche effects

Study:

- Dirac-δ generator (2×10^3 protons)
- Box shaped Roman Pot, bottom part
- 1st RP $\rightarrow$ 2nd RP is tested

Output of 1st RP after 6 m

Output of 2nd RP after 6 m

Conclusion:
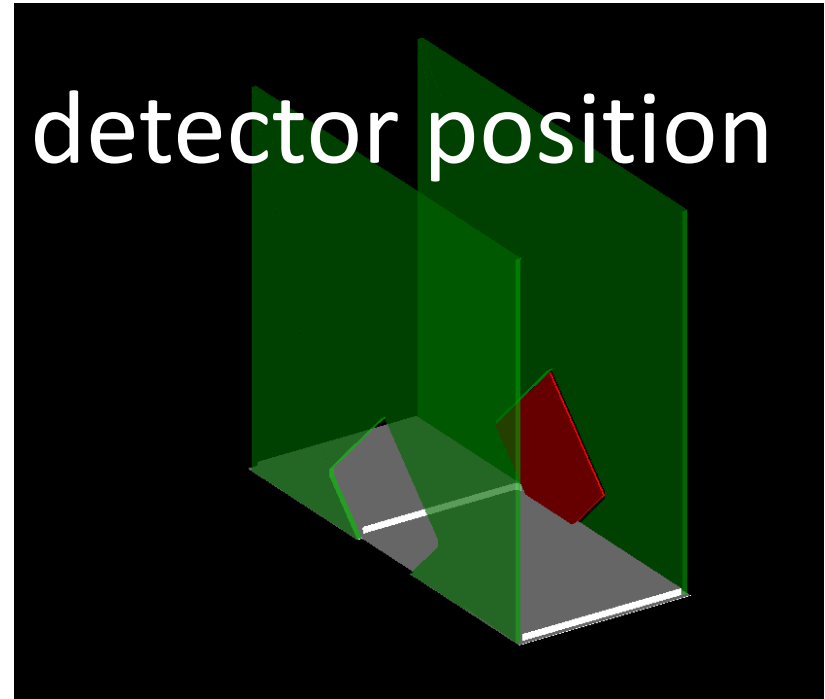
- Increase with a factor of ≈ 2

The effect of the Si detector position

$$R = \frac{\text{charged particles detected by far RP}}{\text{charged particles detected by near RP}}$$

Measured ratio, $R_{measured} \approx 3 - 4$

Geant4 simulation:
- Particle generator "debris"
- Si detector position inside the 2nd RP has a strong effect

Conclusion:

Detector plane position	Behind front wall	Middle	Before back wall
$R_{simulated}$	1.6	1.7	2.5

- a relevant part of the background is created inside the 2nd Roman Pot

Conclusions

- The presence of avalanche effects is evident

- Increase with a factor of ≈ 2 from 1st to 2nd RP

- A relevant part of the background detected by the 2nd Roman Pot is created inside the 2nd Roman Pot