Pixel TPC simulations

Kees Ligtenberg

Nikhef lepcol gridpix meeting

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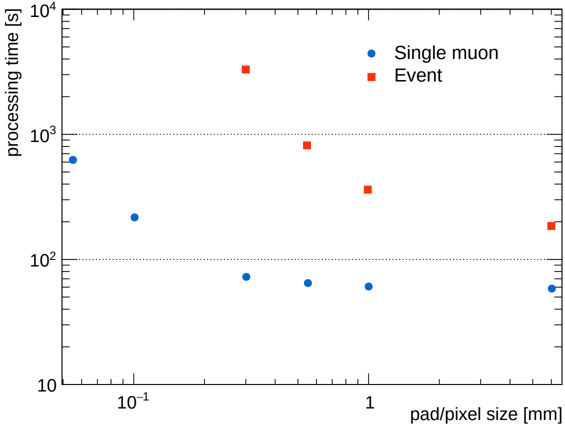
Outline

1. Faster pixel simulation
   - Interpolation curve
   - Deposition of hits
2. Updated event displays

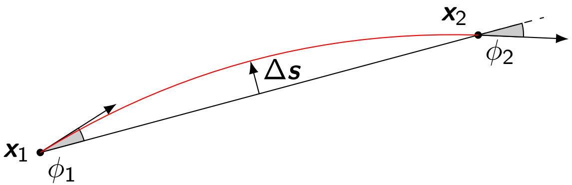
Full 55 × 55 μm^2 pixel simulation takes too much time



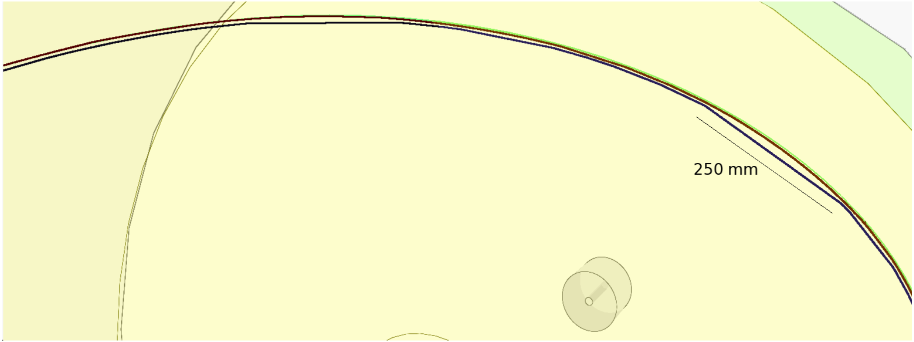
- Processing time increases rapidly at smaller pixel sizes

Interpolate pixels in larger volumes

- The processing time can be sped up by approximating the $55 \times 55\ \mu\text{m}^2$ pixels over larger, e.g. $1 \times 1\ \text{mm}^2$, volumes
- Register point and direction at entry and exit of volume
- Approximate the circular track with a parabola within the volume



Linear and parabolic interpolation

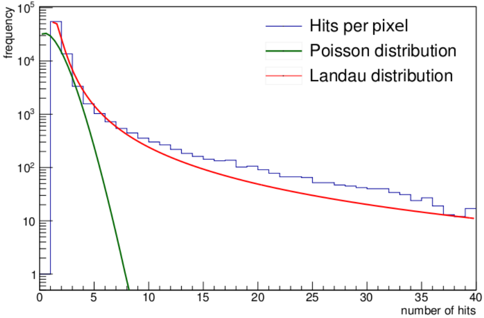


1 GeV muon with large step size for demonstration purposes

- Parabolic interpolation follows track closely

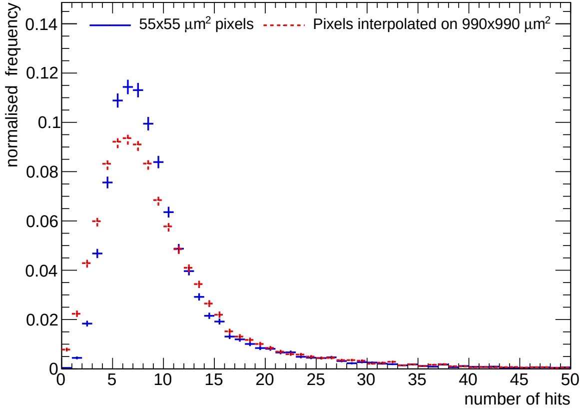
Distribution of hits along the track

- Besides shape, the distribution of hits along the track is another important parameter



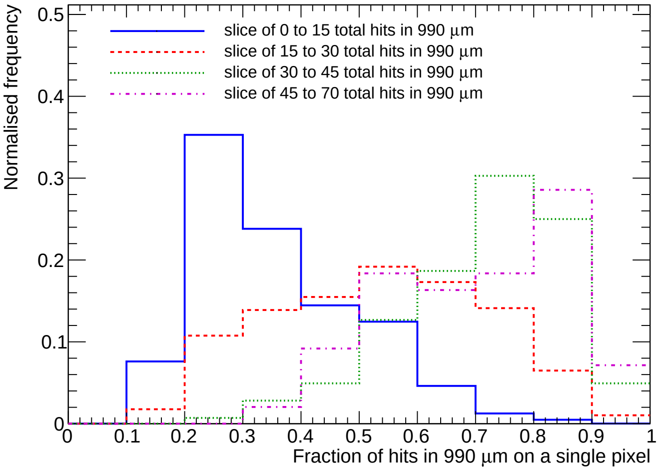
- Ionization in gas follows roughly a Landau distribution
- Hits closer than 55 μm are simulated as multiple hits per volume

Number of hits per 990 μm layer



- 18 steps of 55 μm do not have the same hit distribution as one step of 990 μm
  - The larger step size has a widened distribution

Distribution of hits within 990 μm

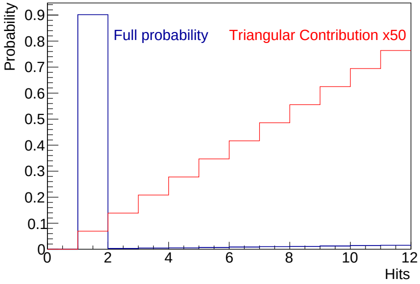


- If there are many hits in 990 μm, most of them are on a single pixel
- If there are few hits, there is a Poisson like distribution

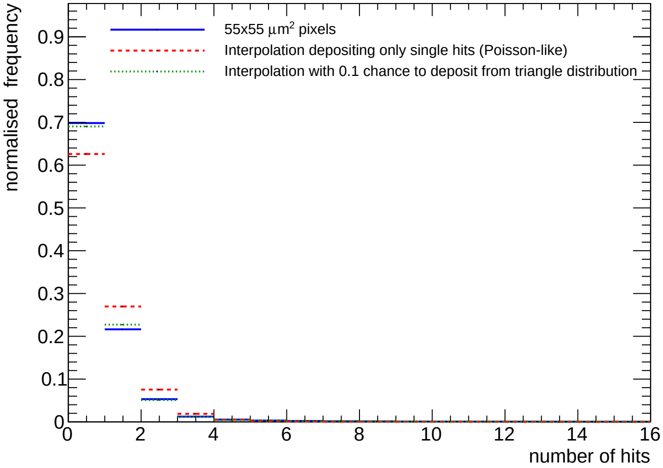
Approximation of distribution

Deposit hits randomly on track segment with a small chance to deposit multiple hits. The chance to deposit N out of N_{total} hits is given by

$P(N_{\text{hits}} = 1) = 0.9$	Poisson like
$P(N_{\text{hits}} = N) \simeq 0.1 \cdot \frac{2N}{N_{\text{total}}^2}$	Triangle between 1 and N_{total}

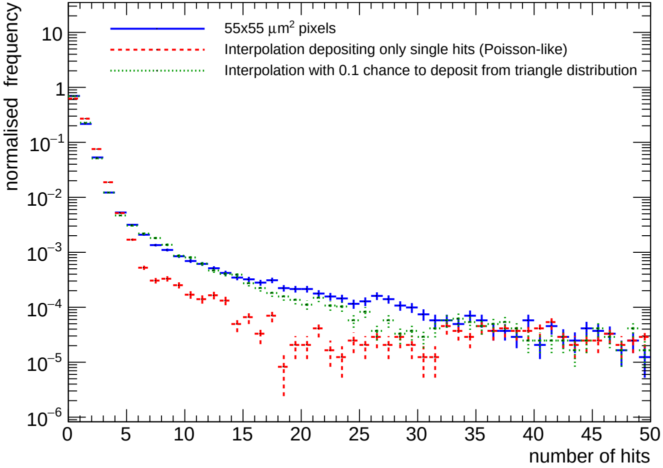


Number of hits per 55 μm layer



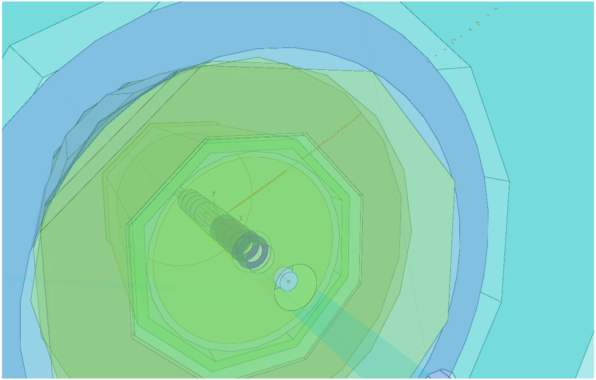
The distribution with a chance to deposit multiple hits agrees better than a pure Poisson distribution

Number of hits per 55 μm layer



The distribution with a chance to deposit multiple hits agrees better than a pure Poisson distribution

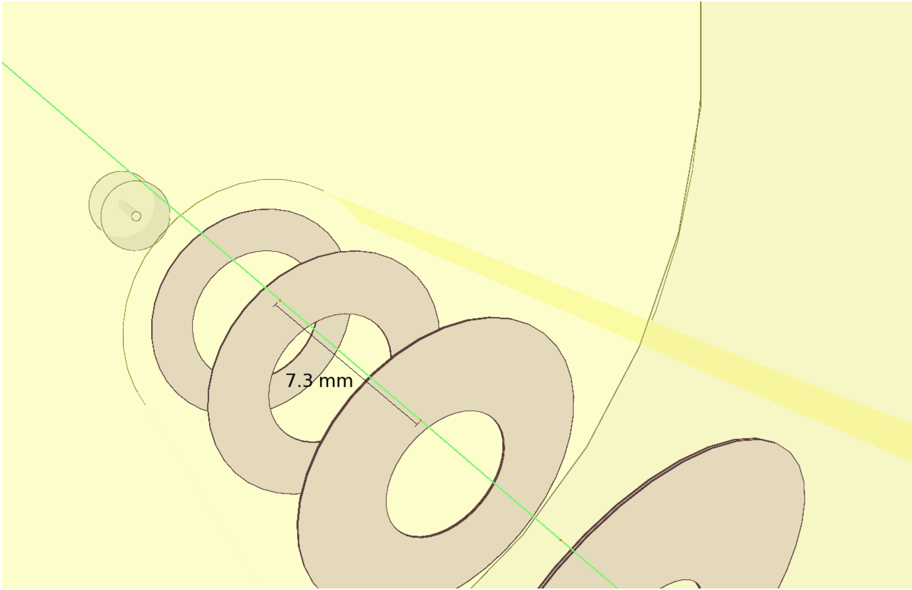
Event displays



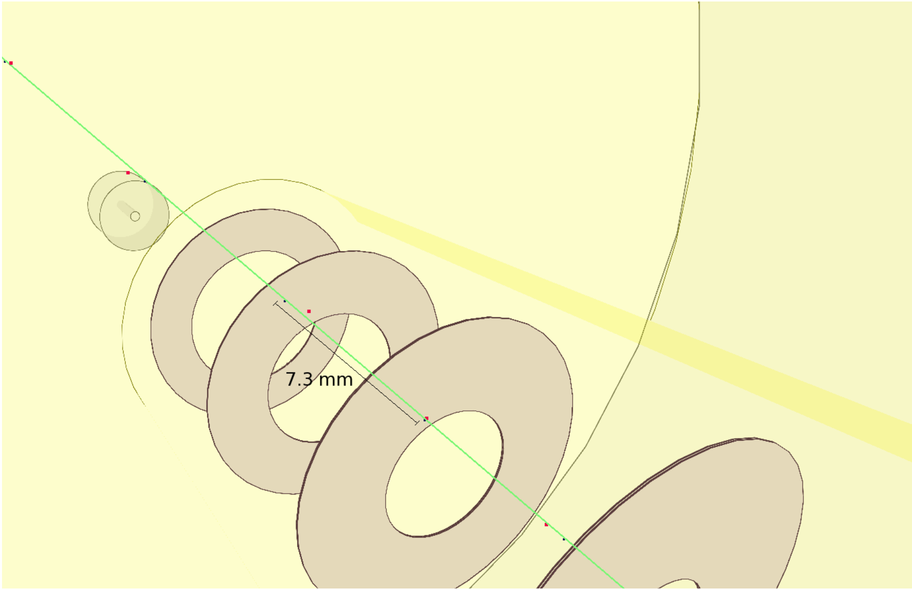
Simulate track of a 50 GeV muon for

- 6×1 mm^2 pad simulation
- 55×55 μm^2 pixel simulation
- interpolation over 990 μm

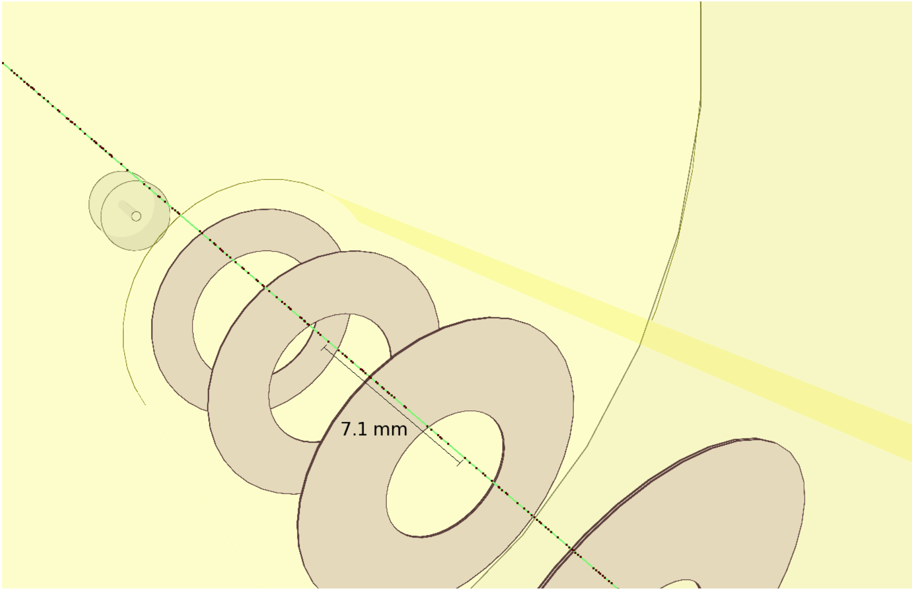
6×1 mm^2 pads



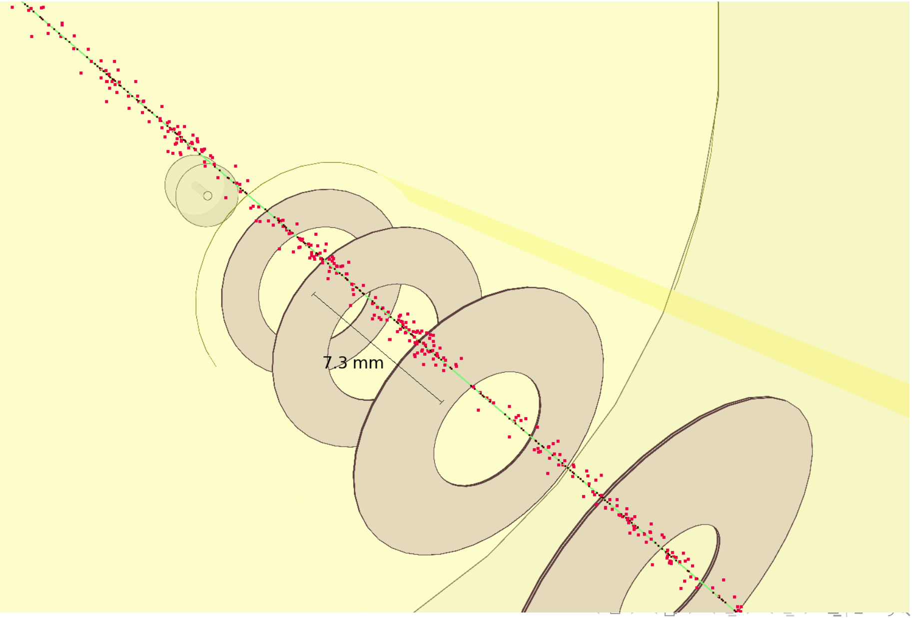
6×1 mm^2 pads



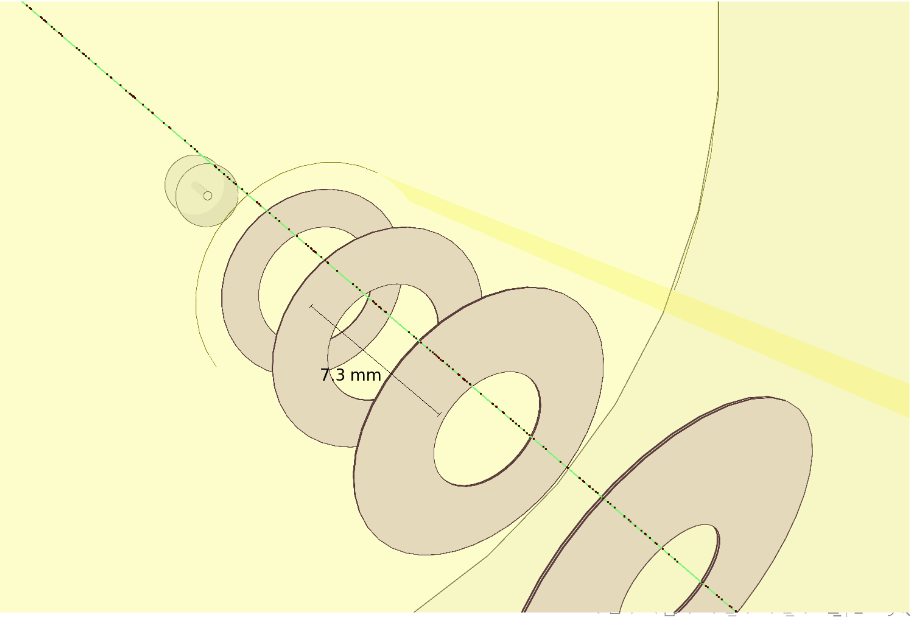
$55 \times 55\ \mu m^2$ pixel



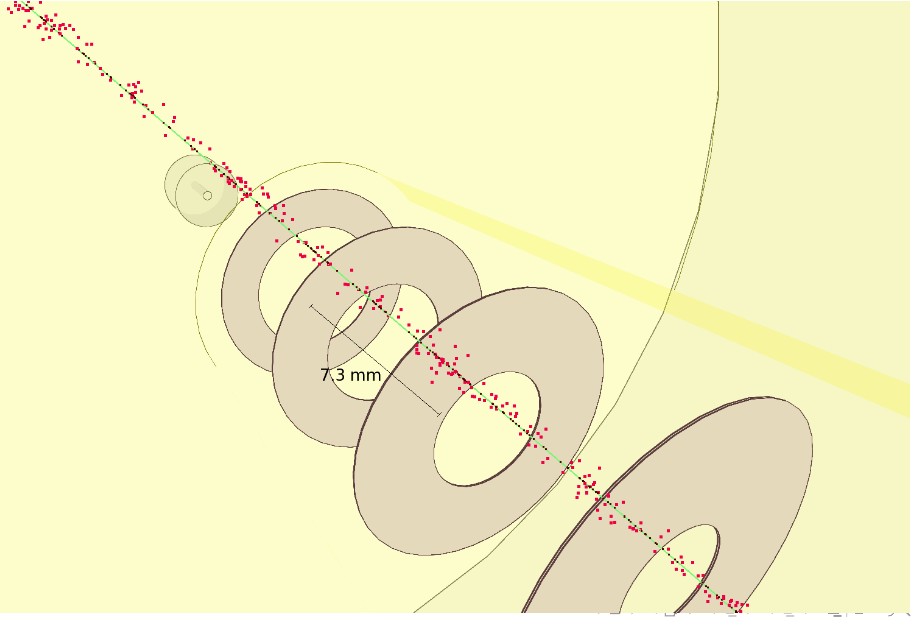
$55 \times 55\ \mu m^2$ pixel



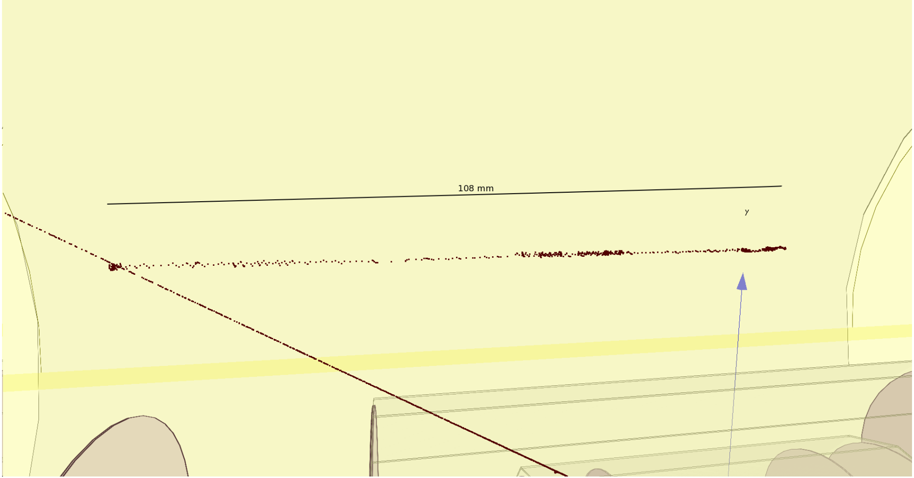
Interpolation over 990 μm



Interpolation over 990 μm

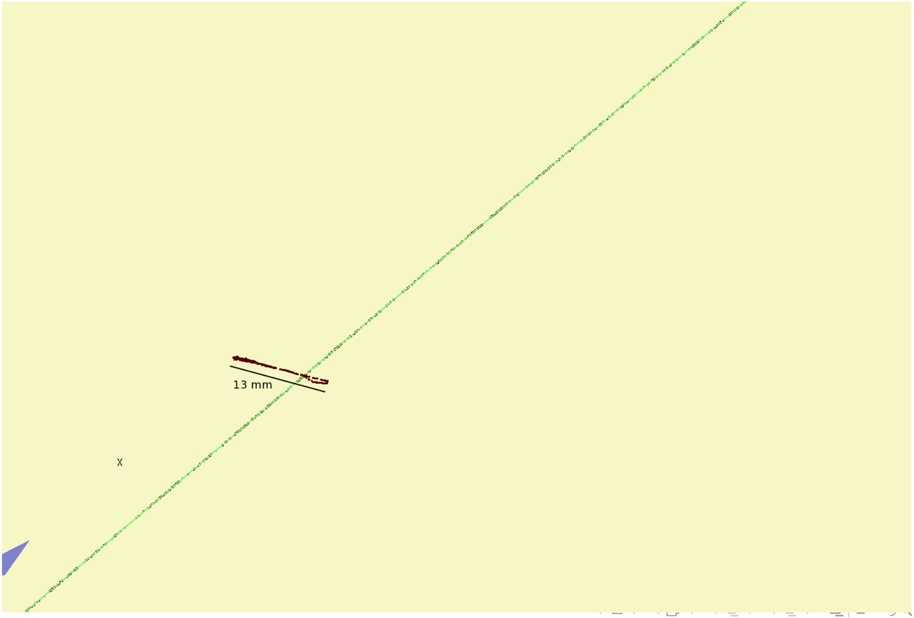


Delta particle in $55 \times 55\ \mu m^2$ pixel simulation

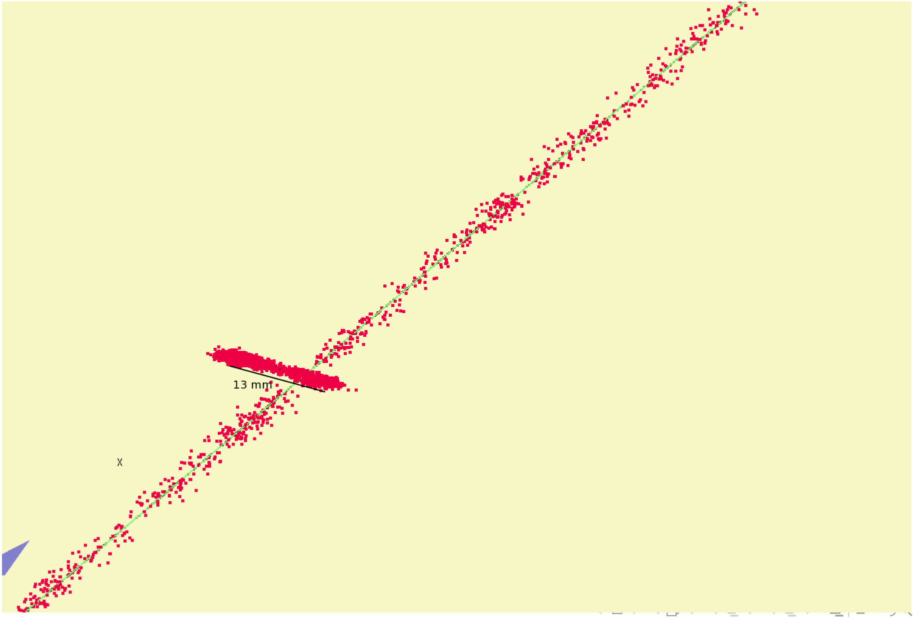


Delta particle in 55 × 55 μm^2 pixel simulation

Delta particle in interpolation over 990 μm



Delta particle in interpolation over 990 μm



Conclusion

- Approximated pixel simulation is made with interpolation
  - parabolic segments make a smooth track
  - The distribution of hits from the full pixel simulation is parametrized
- Next steps:
  - Summarize and document steps until now
  - Look further into reconstruction
  - Go from single particles towards events

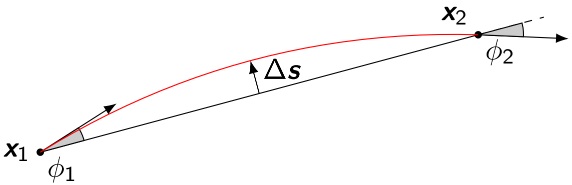
Parabolic interpolation

The position $\boldsymbol{x}(t)$ between the points $\boldsymbol{x}_1$ and $\boldsymbol{x}_2$ is parametrised as a function of $0 \geq t \geq 1$

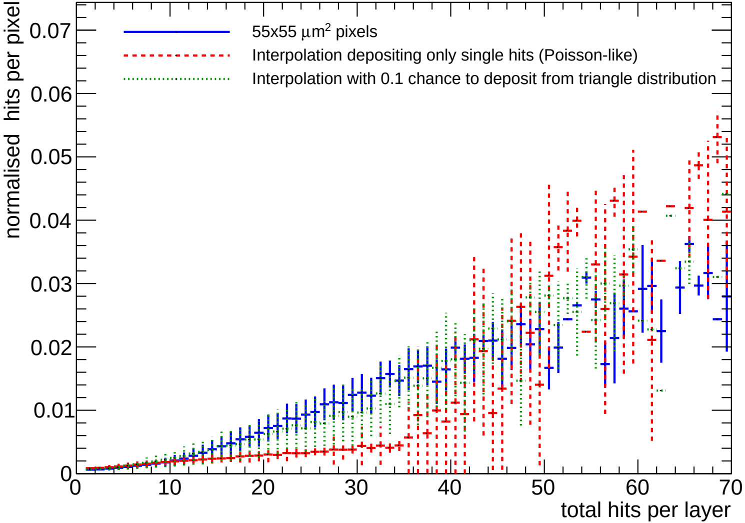
$$\boldsymbol{x}(t) = \boldsymbol{x}_1 + t(\boldsymbol{x}_2 - \boldsymbol{x}_1) + 4t(1-t)\Delta\boldsymbol{s}, \tag{1}$$

where $\Delta\boldsymbol{s}$ is the deflection midway given by

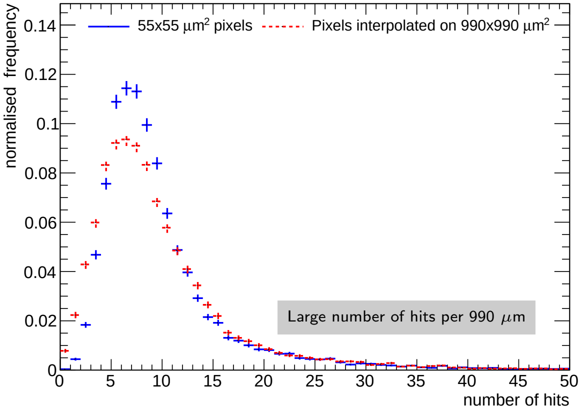
$$|\Delta\boldsymbol{s}| = \frac{|\boldsymbol{x}_2 - \boldsymbol{x}_1|}{4}\sin(\Delta\phi_{12}/2). \tag{2}$$



Profile of maximum 1 against total hits per 990 μm

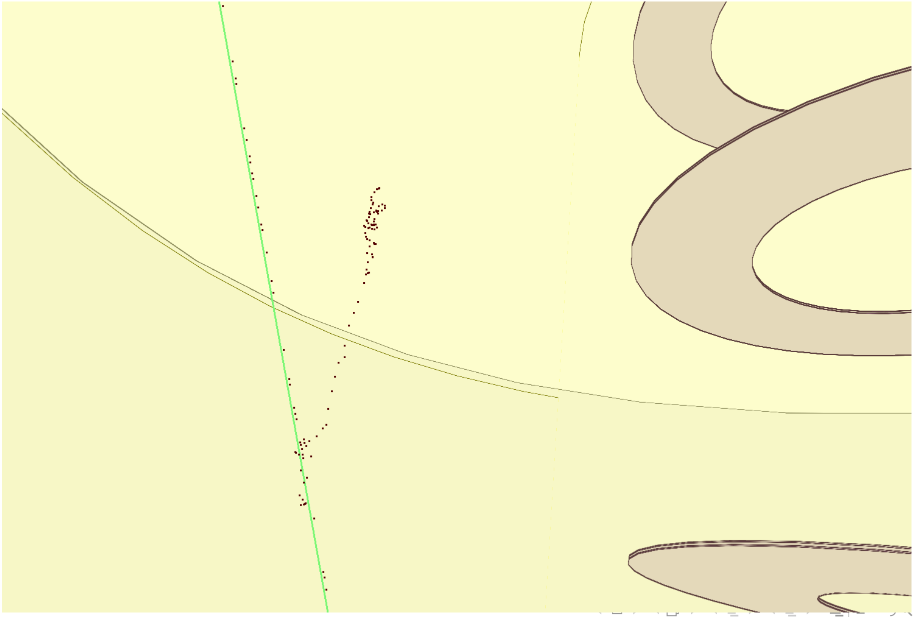


Number of hits per 990 μm layer



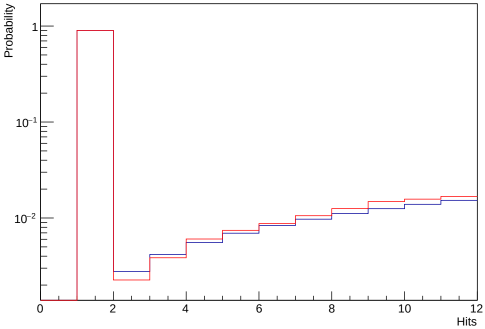
- A large number of hits per 990 μm is can be from many hits in one pixel.

Delta particle in pixel simulation



Hit distribution is actually not a function but generated by the statement:

$$N_{\text{hits}} = \text{int}(N_{\text{min}} + (N_{\text{max}} - N_{\text{min}}) \cdot \text{random}()) \tag{3}$$



Todo:

find function that agrees with generated distribution