Time of Flight (ToF) detector at the EIC Simulation study

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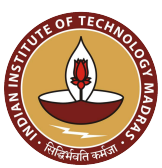
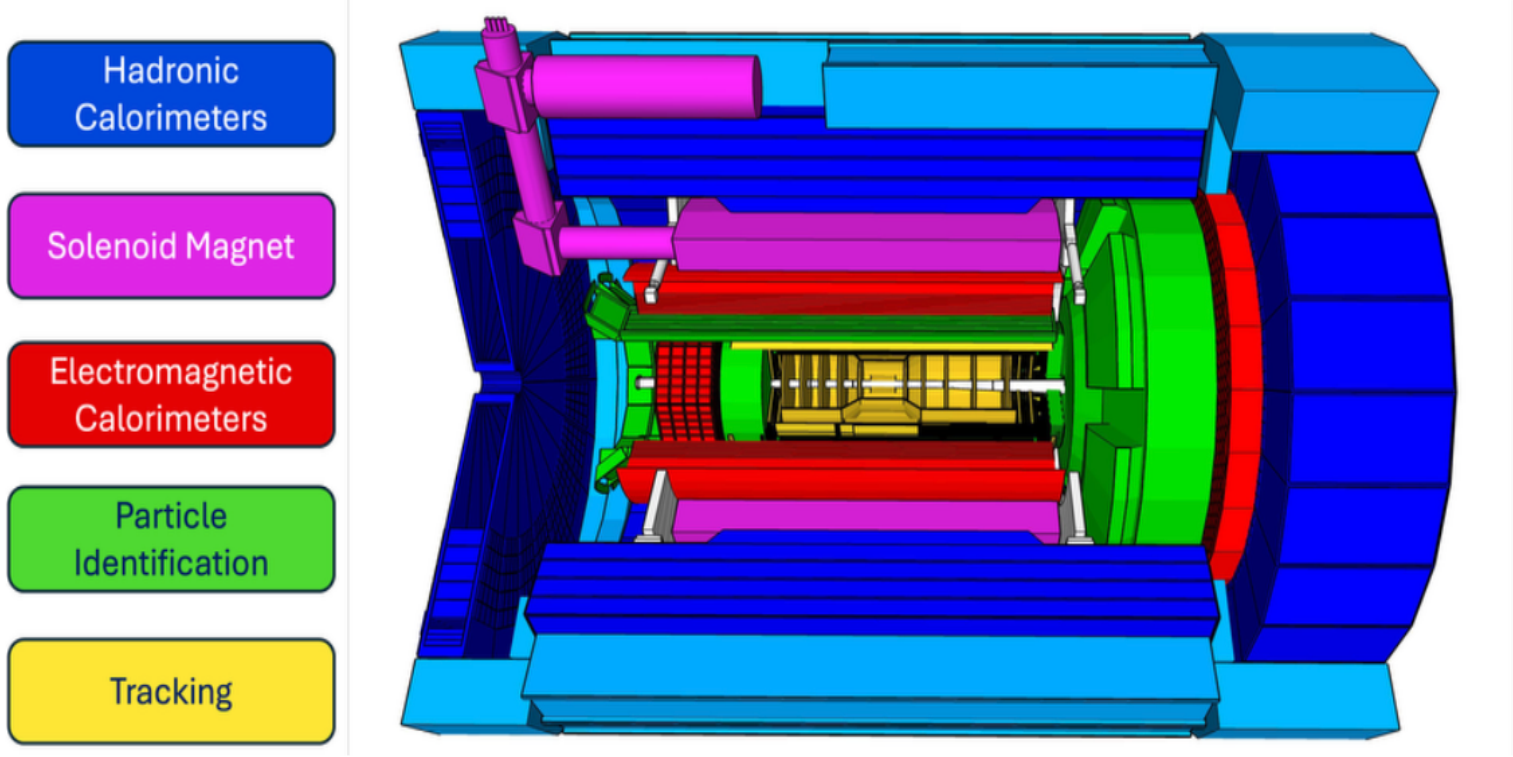


EIC-ToF Detector

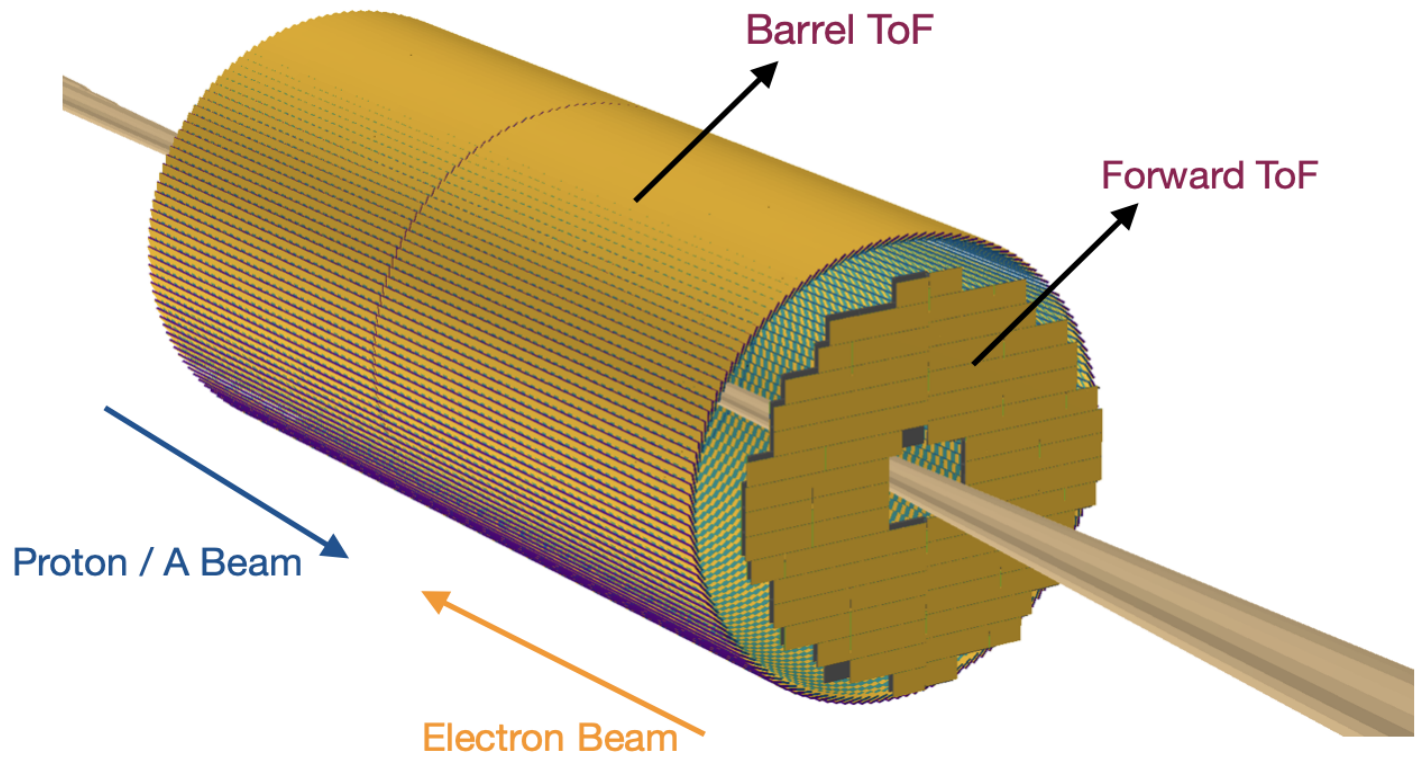
- 3-σ Particle identification with ToF (particularly in low momentum range $p_T < 2.5$ GeV)
- 4-D reconstruction (x,y,z,t) of the events (provides tracking points).



EIC-ToF Detector (Using DD4HEP package)

ToF sub-detectors

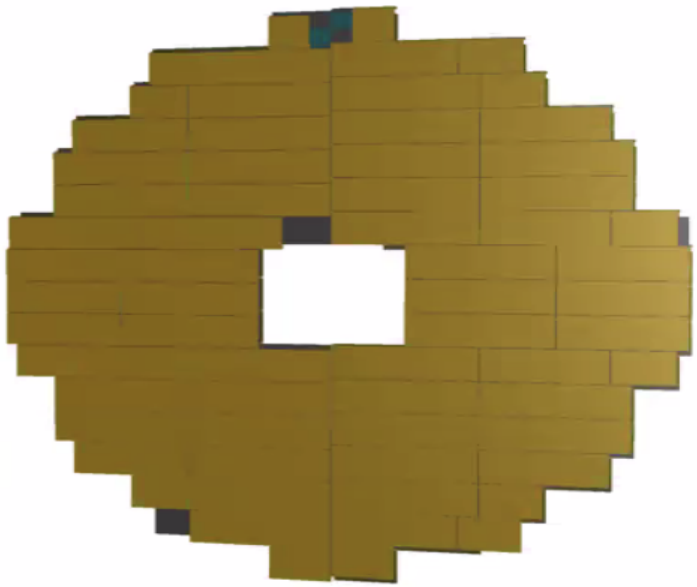
- Barrel ToF
- Forward ToF / Endcap ToF



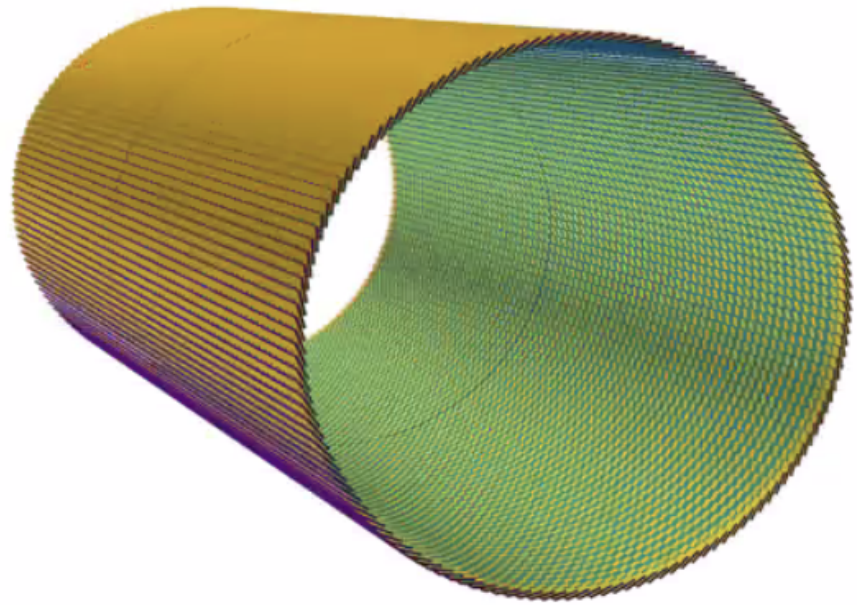
EIC-ToF Detector

Dimensions of BToF and FToF are following:-

Subsystem	z_{min}	z_{max}	inner radius	outer radius
Forward ToF	185 (cm)	192.5 (cm)	10.5 (cm)	60 (cm)
Barrel ToF	-117.5 (cm)	171.5(cm)	62 (cm)	69.5 (cm)



FToF consists of 386 modules of dimensions 4.5 x 3.43 mm^2 on one side.



BToF consists of 144 staves with total length 270 cm, each made up of two half staves.

AC-LGAD sensors

Capacitively-coupled Low-Gain Avalanche Diode

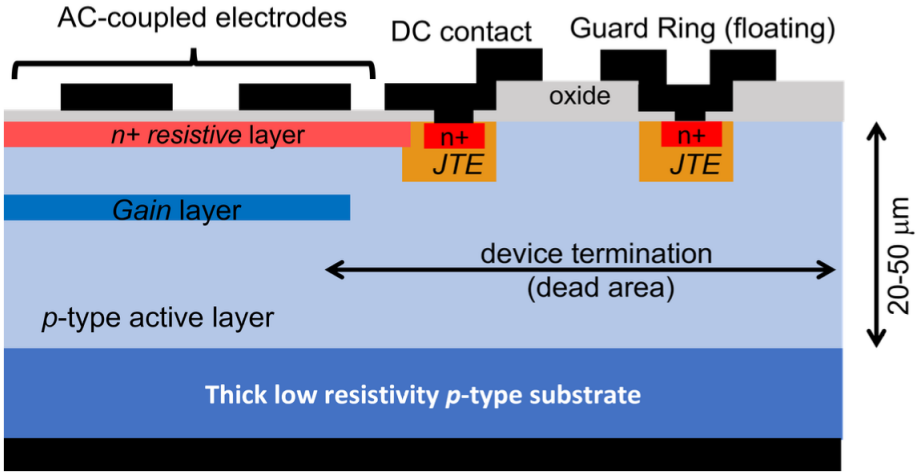


Figure: cross-section of AC-LGAD

Advantages:-

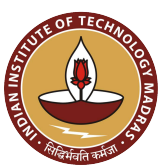
- High timing resolution($\sim$ 30 ps)
- High spatial resolution($<$ 10 μm)
- Higher granularity

- Signal produced by charged particle is amplified by internal p+ layer.
- Internal signal amplification and thin active layer enables precise timing information.
- Charge sharing among the neighboring electrode provides the precise position measurements.

Ref.- "LGAD-Based Silicon Sensors for 4D Detectors by Gabriele Giacomini", Sensors 2023, 23(4), 2132; https://doi.org/10.3390/s23042132.

Specification of the ToF

Subsystem	Barrel ToF	Forward ToF
Timing resolution	35 ps	25 ps
Position resolution	30 μm (r, ϕ)	30 μm (x, y)
Area	12 m^2	1.1 m^2
Channel	2.4 M	3.4 M
Size	3.2 x 2 cm^2	1.6 x 1.6 cm^2
Sensor type	Strips	Pixels
Ch/sensor	128	1024



ToF module and stave assembly

- Each module is mounted with four sensors.
- Each stave (half length = 135 cm) is mounted with 64 sensors on each side.

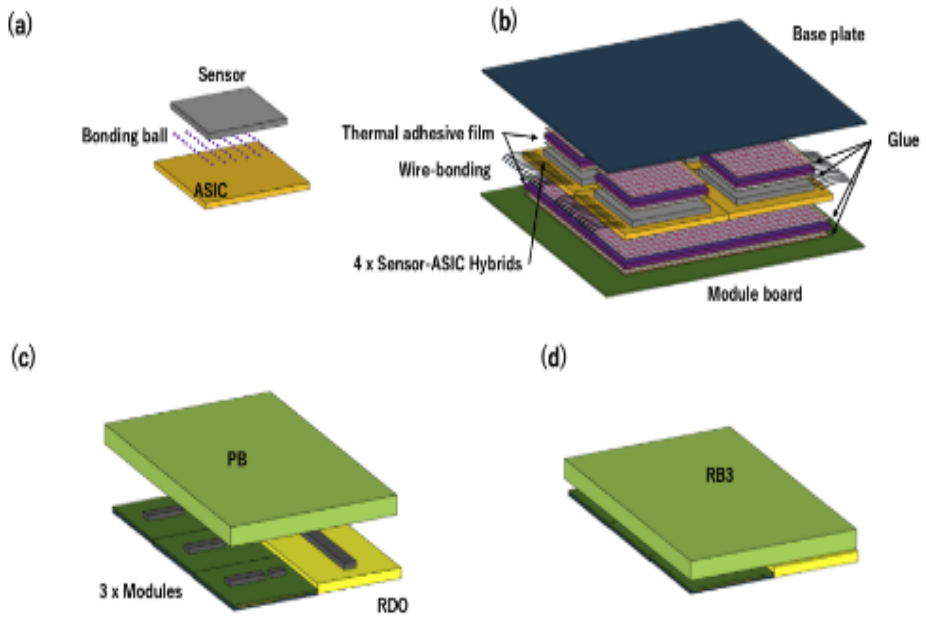


Figure: FToF module assembly

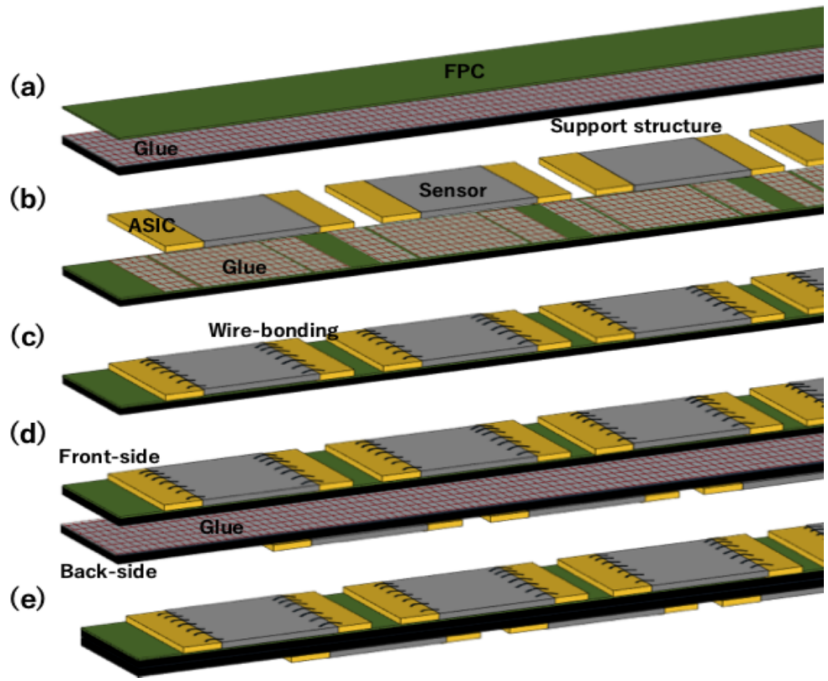
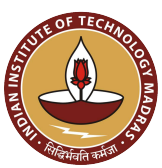


Figure: BToF stave assembly

(Figures are not upto scale.)

Goal of the simulation

1. Extracting hit information from 20 bit cellID.
2. Finding neighbouring cells of the hit Cell.
3. Implementing 2-D gaussian among the neighbouring cell to smear the energy deposited in the hit Cell.
4. Implementation of digitisation of timing and energy information.
5. Adding noise in the simulated data.

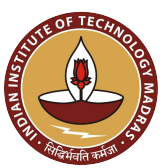


DD4HEP Simulations FToF

- Simulated 100 events with 10-100 GeV e^- (using "npsim" command and particle gun).
- Hit CellID = 18417470709031764346
  64-bit binary conversion -
  1111111110011000000000000000011110101001000000000000000101111010
- Implementation of decoder on 64-bit binary Cell ID is done.
- Decoder is used to extract the information from hit CellID.

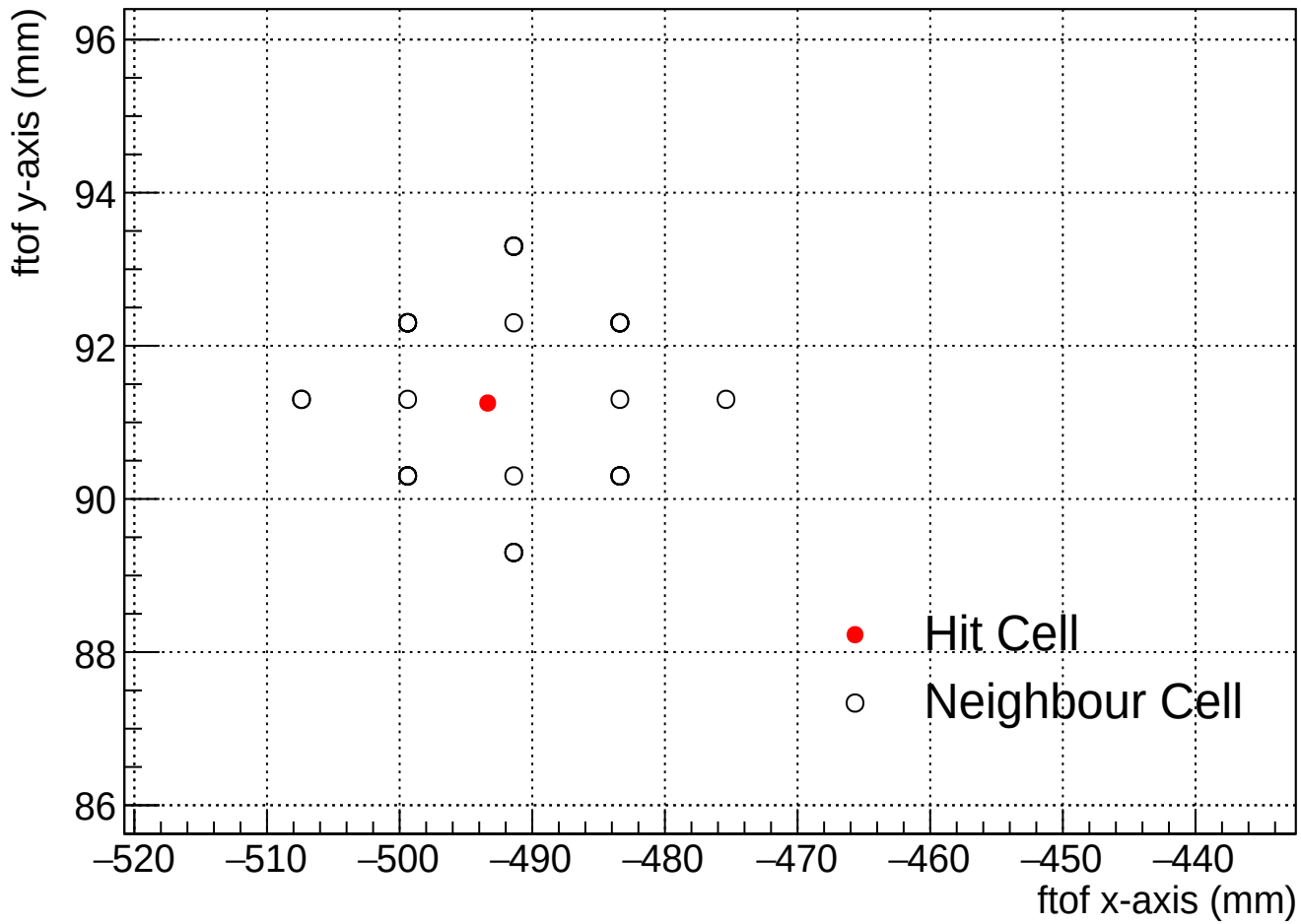
```
<readouts>
  <readout name="TOFEndcapHits">
    <segmentation type="CartesianGridXY" grid_size_x="1*mm" grid_size_y="0.8*cm" />
    <id>system:8,layer:4,module:2,idx:5,idy:5,ids:6,x:36:-12,y:-16</id>
  </readout>
</readouts>
```

- system : 122, layer : 1, module : 0, idx : 16, idy : 21, ids : 2, x : 7, y : 65432



Neighbouring cell finding

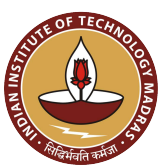
- Using segmentation to get neighbour Cell ID.



2-D Gaussian function parameters

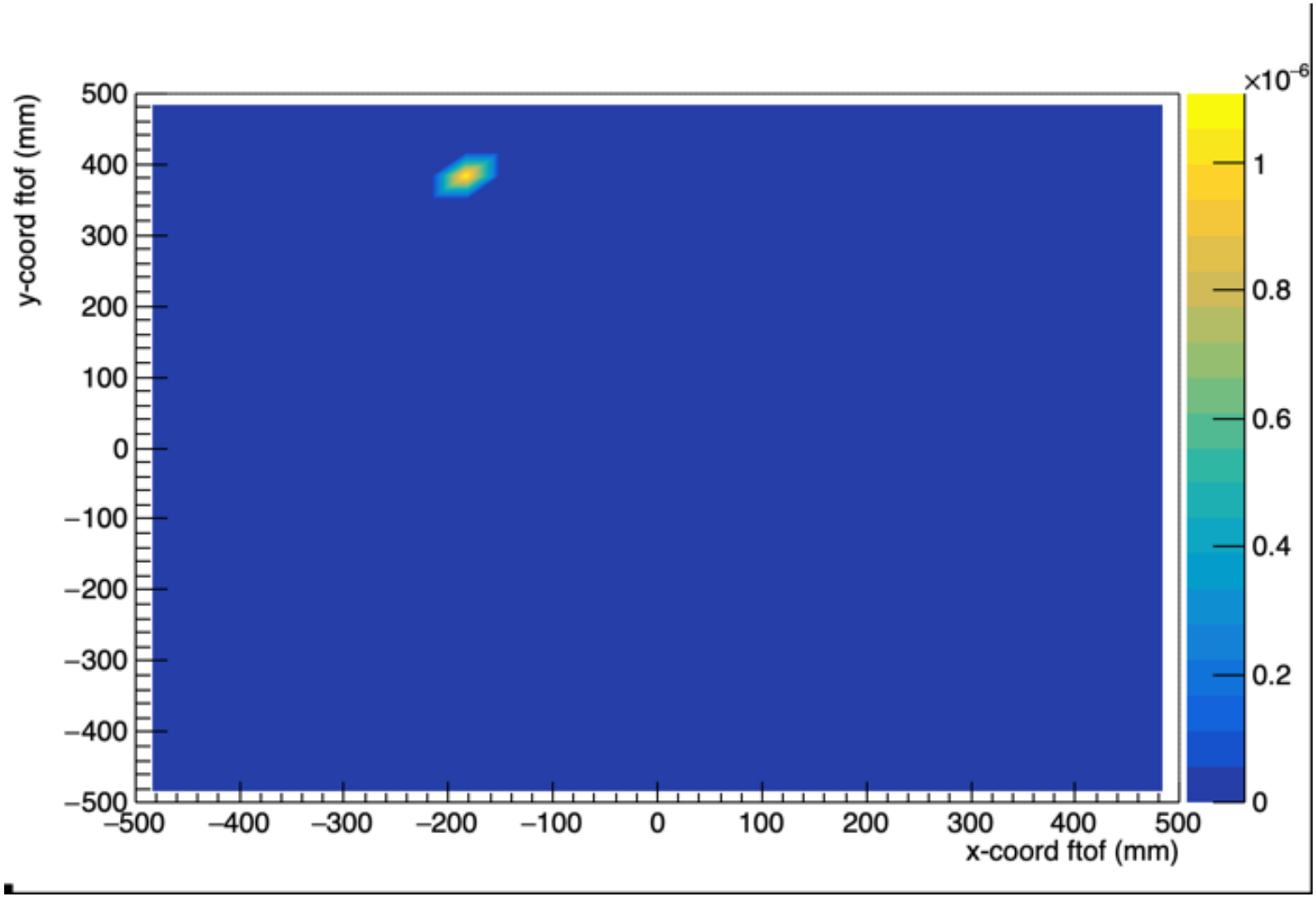
$$f(x,y) = par[0] \times Exp(-\frac{((x - par[1])^2 + (y - par[2])^2)}{2 \times par[3] \times par[4]}) \qquad (1)$$

- par[0] = Amplitude = edep
- par[1] = central position of x = x-pos of hit
- par[2] = central position of y = y-pos of hit
- par[3] = σ_x = 1.0 and 50.0 (same for both x and y)
- par[4] = σ_y = 1.0 and 50.0
- Calculation of Integral of Gaussian and store the information of shared hits.



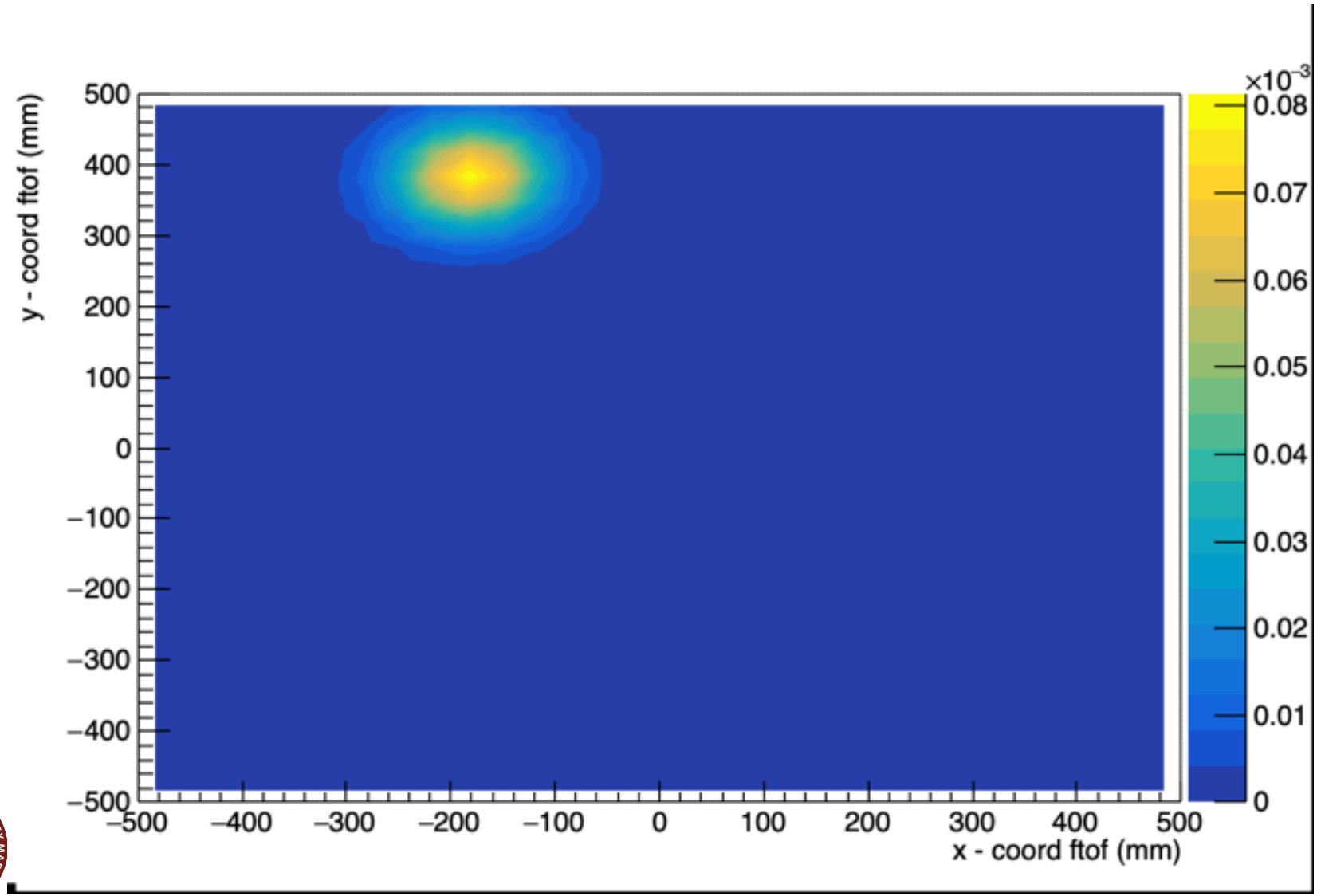
2-D Gaussian distribution (sigma = 1.0)

Energy distribution of a single Hit in ToF Endcap :-



Sigma = 50.0 mm

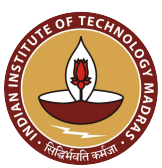
- par[3] = sigma = 50.0



Digitization of events

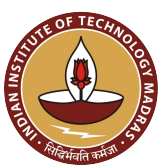
Working on:-

1. Digitizing the hit information (energy and timing) using 10-bit TDC and 8-bit ADC.
2. Adding noise in simulated data.



Summary and Future Plan

1. Extracting information from hit Cell ID.
2. Finding neighbouring cells of the hit Cell.
3. Implementing charge sharing among the neighbour Cells.
4. Using Energy deposited and timing information to implement digitization.
5. Adding noise in simulated data.



THANK YOU.