

MPGD 2DStrip Software Developments

Yann Bedfer

CEA/DPhN Saclay

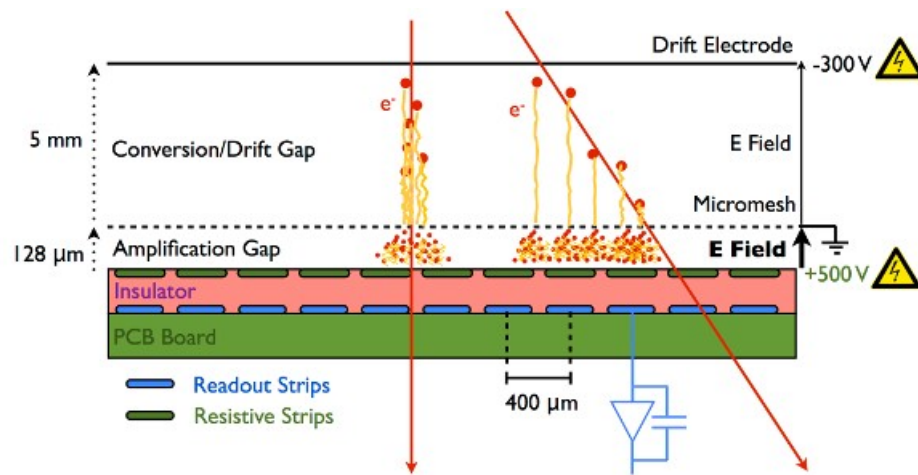
2 April 2026

Two Branches of Development

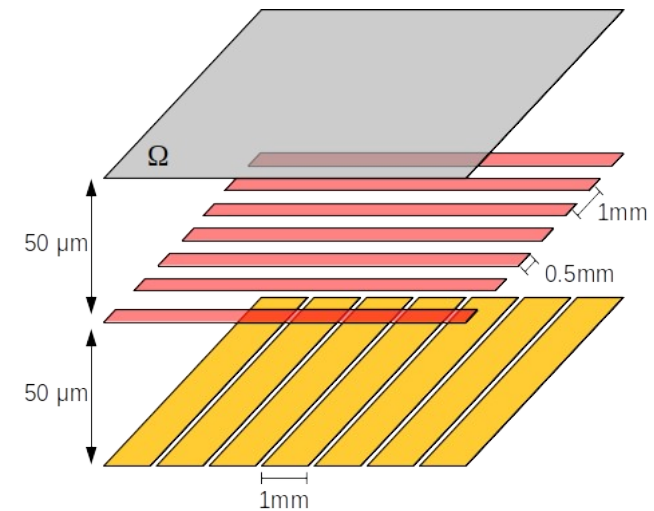
- Multiple Sensitive Volumes
 - Basic idea: One distinct volume *per* Strip Coordinate (*called p and n*).
1 Particle → **2 SimHits**.
 - Need in fact more subdivisions. Implemented: 5 SubVolumes.
1 Particle → **5 SimHits**.
 - PullRequests: EICrecon #2177, epic #1014. **Merged**.
- Clusters (*of size =2, so far*)
 - Digitization: Clusterization = **1 SimHit** → **2 RawHits**.
 - Reconstruction: Clustering = **2 RawHits** → **1 RecHit**.
 - PullRequests: EICrecon #2264, epic #1021. **Open**.

2DStrip Readout

- Barrel: CyMBaL, μ RWELL-BOT. EndCaps: μ RWELL-ECT's.



Class12 Micromegas: 1D-strip Readout



Charge Sharing \Rightarrow 2D-strip Readout

- One Ionization \times Amplification $\xrightarrow{\text{Charge Sharing}}$ Two proto Hits, along strips $u = p, n$
 - Charge Spreading** (enhanced by resistive layer Ω): proto Hit \rightarrow cluster of Hits.
- Strips per se**, no big problem: they are **stretched pixels**. . .
 . . . *i.e.* **2D objects**, w/ **bad precision** ($= \mathcal{O}(\text{size})$) along one of the D's.
- Problem is 2DStrip**, because **One and only one Sensitive Surface per volume** in DD4hep.

Previous Solution: MultiSegmentation + ReSegmentation

- **Original** scheme: **pixel** SimHit → **pixel** RawHit.

```
<segmentation type="CartesianGridUV" grid_size_u="0.150*mm*sqrt(12)"
  grid_size_v="0.150*mm*sqrt(12)" grid_angle="M_PI*rad/4" />
<id>system:8,layer:4,module:12,sensor:2,u:-16,v:-16</id>
```

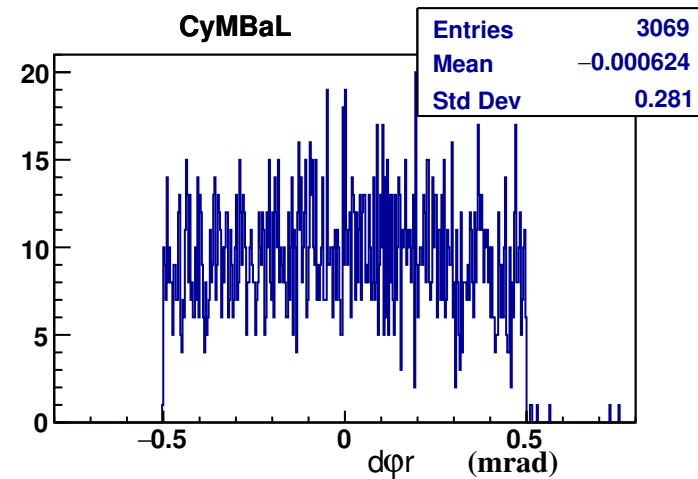
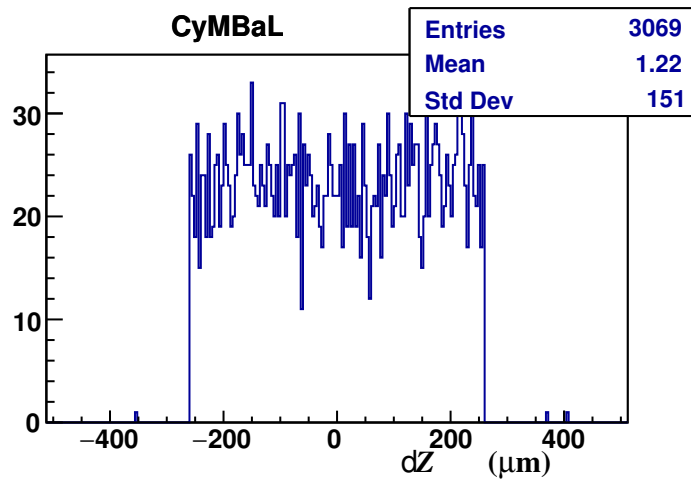
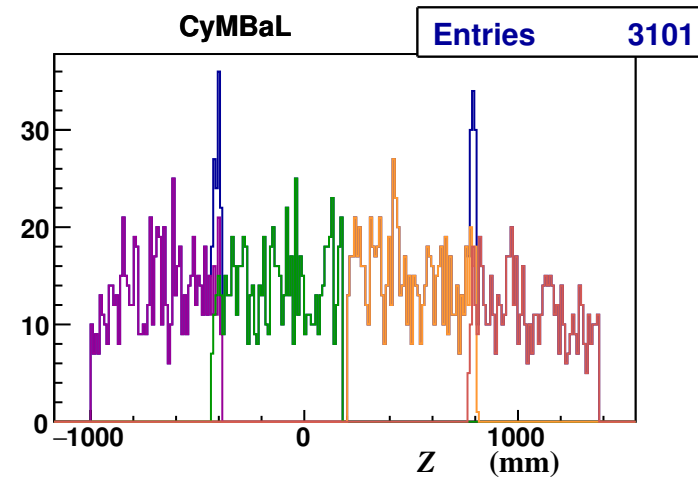
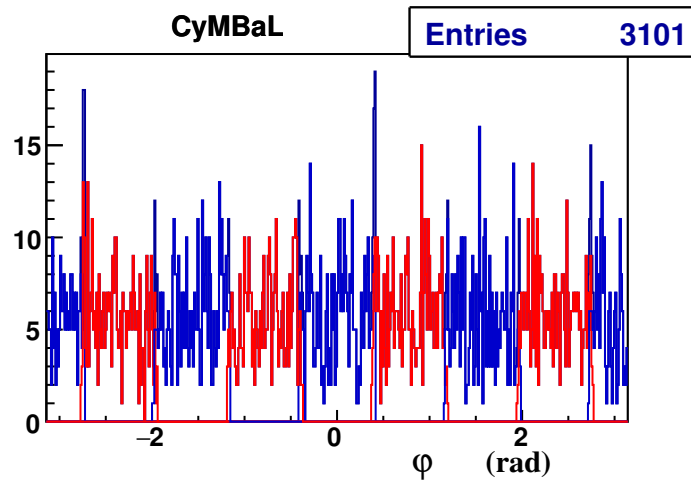
- **2D-strip**: **pixel** SimHit $\xrightarrow[\text{ReSegmentation}]{\text{MultiSegmentation}}$ **2 strip** RawHits.

```
<segmentation type="MultiSegmentation" key="strip" >
  <segmentation name="Pixels" type="CartesianGridUV" key_value="0"
    grid_size_u="0.150*mm*sqrt(12)" grid_size_v="0.150*mm*sqrt(12)" grid_angle= ...
  <segmentation name="USTrips" type="CartesianGridUV" key_value="1"
    grid_size_u="0.150*mm*sqrt(12)" grid_size_v="μRWellStrip_range" grid_angle= ...
  <segmentation name="VStrips" type="CartesianGridUV" key_value="2"
    grid_size_u="μRWellStrip_range" grid_size_v="0.150*mm*sqrt(12)" grid_angle= ...
</segmentation/>
<id>system:8,layer:4,module:12,sensor:2,strip:28:4,u:-16,v:-16 </id>
```

- **Pixel Segmentation** in nspsim.
- **ReSegmentation** done in EICrecon's digitization step *via* MPGDTrackerDigi.

Pixel Residuals: SiliconTrackerDigi

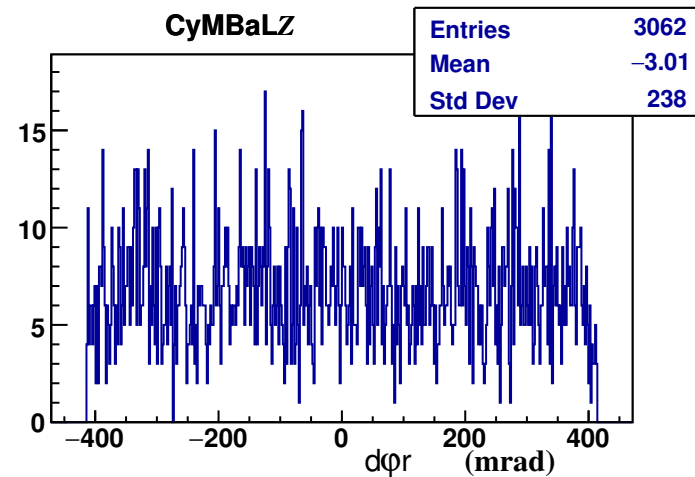
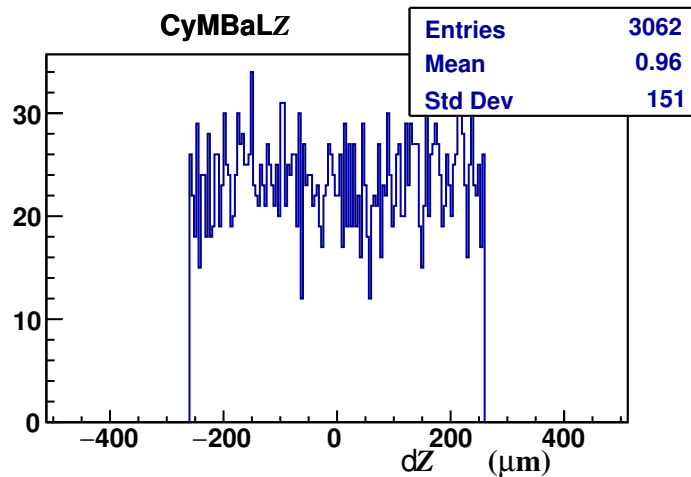
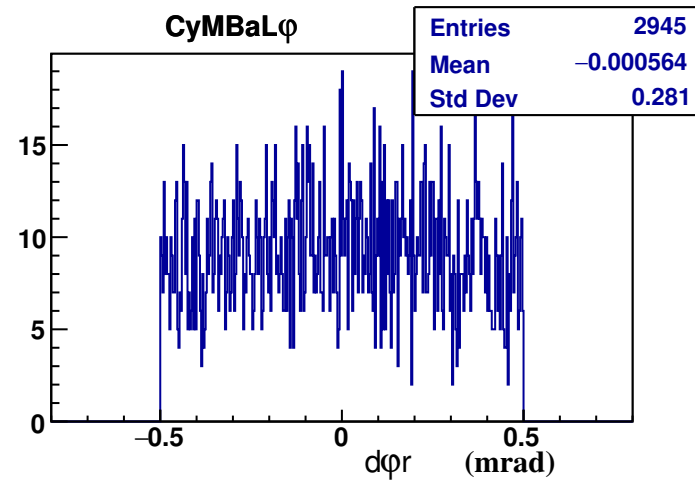
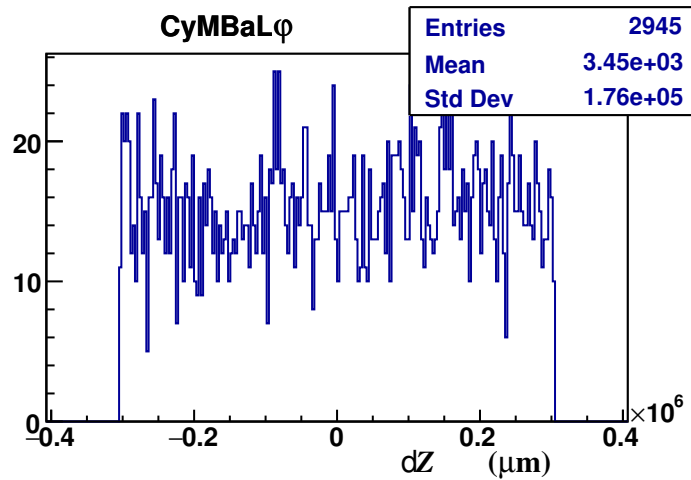
- ddsim: SIM.gun μ^- $15 < \theta < 165$ deg. $P = 10$ GeV
- eicrecon -PMPGD:SiFactoryPattern=0x3(=default) ... \rightarrow SimHits, Residuals (RawHit-SimHit).



- Z: $150 \mu\text{m}$, ϕ : $\sim 1 \text{ mrd} / \sqrt{12}$ ($\simeq 150 \mu\text{m} / R$).

Strip Residuals: MPGDTrackerDigi

- Same simulation as before.
- `eicrecon -PMPGD:SiFactoryPattern=0x0 ...` → Residuals (**RawHit-SimHit**).

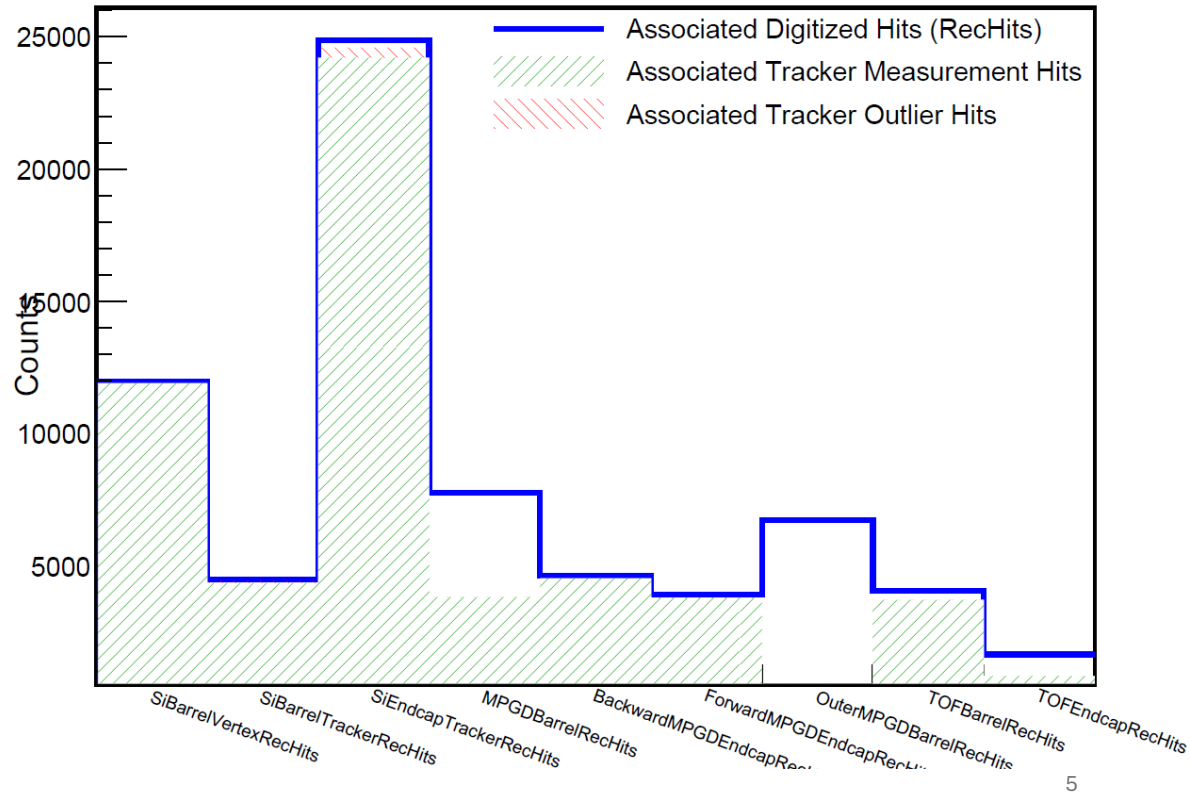


- Strip precision as expected: $150 \mu\text{m} \times \mathcal{O}(\text{size})$.

Problem: 2DStrip Hit-to-Track Association

- Reported by Barak Schmookler at Tracking Meeting of April, 3rd 2025:

Events with 1 reconstructed track



⇒ **Hit-to-Track Association Efficiency:** CyMBaL = **50%**, Outer = **0%**.

Problem: 2DStrip Hit-to-Track Association (*cont'd*)

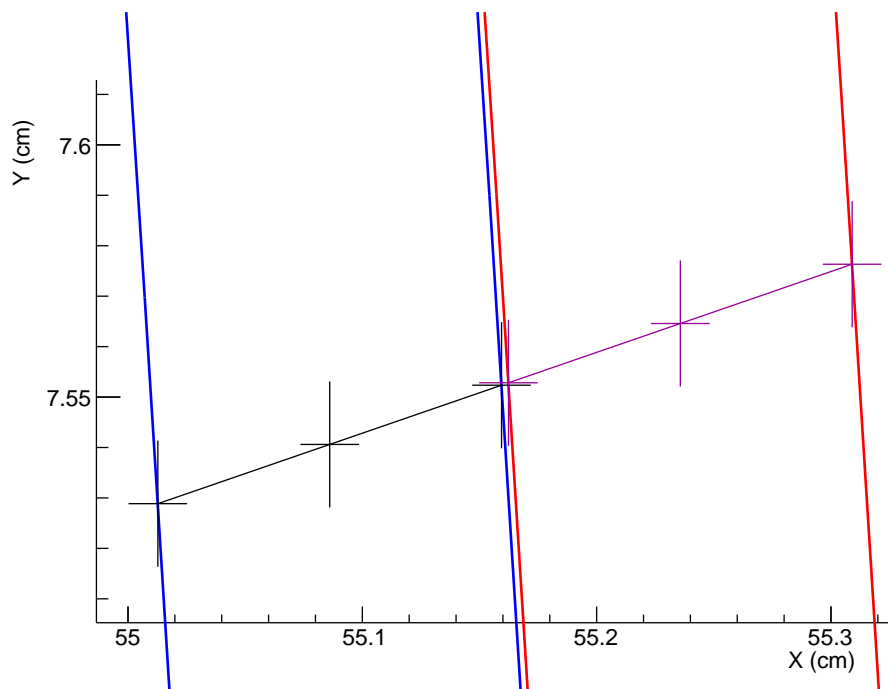
Events with 1 reconstructed track



- Outer: Fix (*Cov.Matrix rotated $\pi/4$, not committed*). \Rightarrow Now behaves as CyMBaL.
- All 2DStrip's: Either *p* or *n* associated. Never both.
One and only one hit associated per Sensitive Surface (*the least χ^2 increment*).

Solution implemented: Multiple Sensitive Volumes

- See PR #2177 on EICrecon github.
- Principle = **Coalescence + Extension + ReSegmentation**
 - **Subdivision** into Sensitive **SubVolumes**: each of p and n gets its own **Sensitive Surface**.
 - **Coalescence** of the **SubHits**: needed to preserve p vs. n **Correlation**.
 - **Only one SubVolume** gets EDep: **Extend SubHit** to fill the gap.



Five **SubVolumes** in all:

- Two **Radiator SubVolumes** (*red and blue*) to collect energy deposit,
- + Two **Readout SubVolumes** (*in central gap*) to which RawHits are eventually assigned.
- + A **Reference SubVolume** (*at exact centre*) to rationalize the source code.

(*Markers @ SubHit position \pm path-length*)

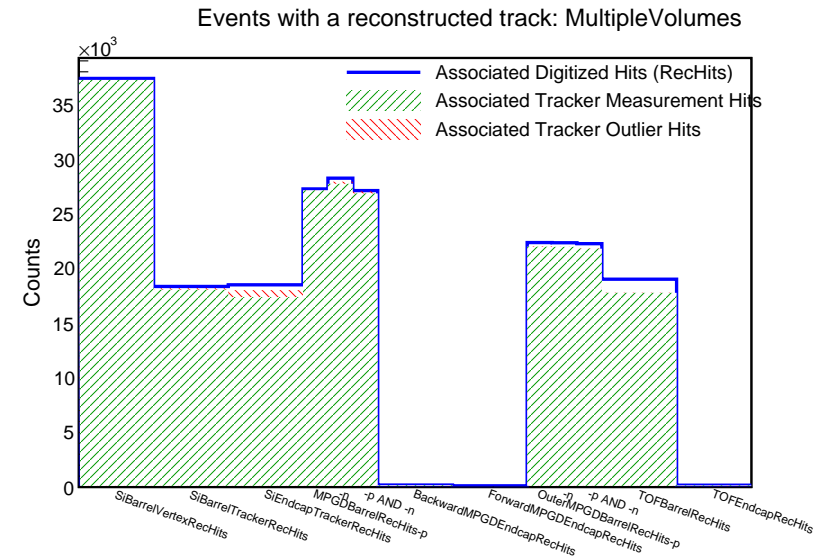
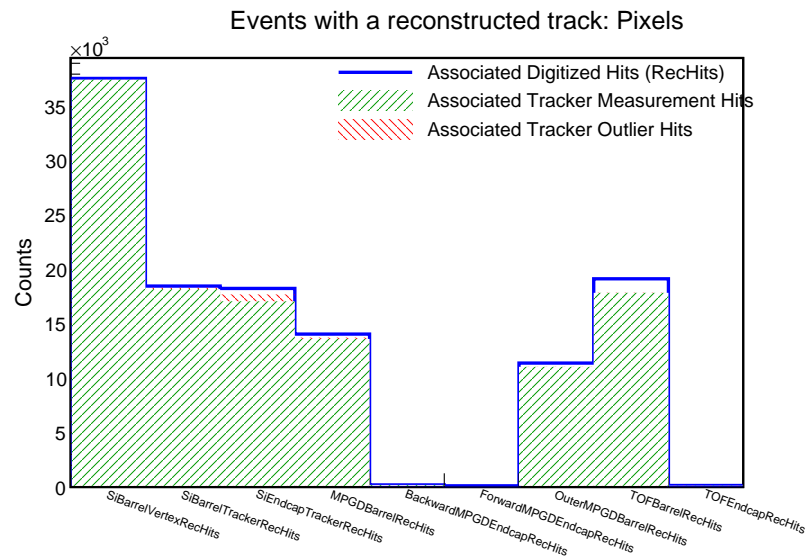
- **Guideline: Reproduce** as exactly as possible **Single Volume** situation, *whether or not it best simulates MPGD inner workings, e.g.: do not coalesce δ -ray w/ primary SubHit.*
 \Rightarrow **Extensive checks** conducted before **coalescing**.

Multiple Sensitive Volumes: ReSegmentation

- `<segmentation type="MultiSegmentation" key="strip" >`
 - `<segmentation name="Pixels" type="CartesianGridUV" key_value="0"`
`grid_size_u="0.150*mm*sqrt(12)" grid_size_v="0.150*mm*sqrt(12)" grid_angle= . . .`
 - `<segmentation name="USTrips" type="CartesianGridUV" key_value="1"`
`grid_size_u="0.150*mm*sqrt(12)" grid_size_v="μRWellStrip_range" grid_angle= . . .`
 - `<segmentation name="VStrips" type="CartesianGridUV" key_value="2"`
`grid_size_u="μRWellStrip_range" grid_size_v="0.150*mm*sqrt(12)" grid_angle= . . .`
 - `<segmentation name="BotRad" type="CartesianGridUV" key_value="3"`
`grid_size_u="0.150*mm*sqrt(12)" grid_size_v="0.150*mm*sqrt(12)" grid_angle= . . .`
 - `<segmentation name="TopRad" type="CartesianGridUV" key_value="4"`
`grid_size_u="0.150*mm*sqrt(12)" grid_size_v="0.150*mm*sqrt(12)" grid_angle= . . .`
- `</segmentation/>`
- `<id>system:8,layer:4,module:12,sensor:2,strip:28:4,u:-16,v:-16 </id>`
- **ReSegmentation** done in EICrecon, based on **Coalesced/Extended SimHit position**.

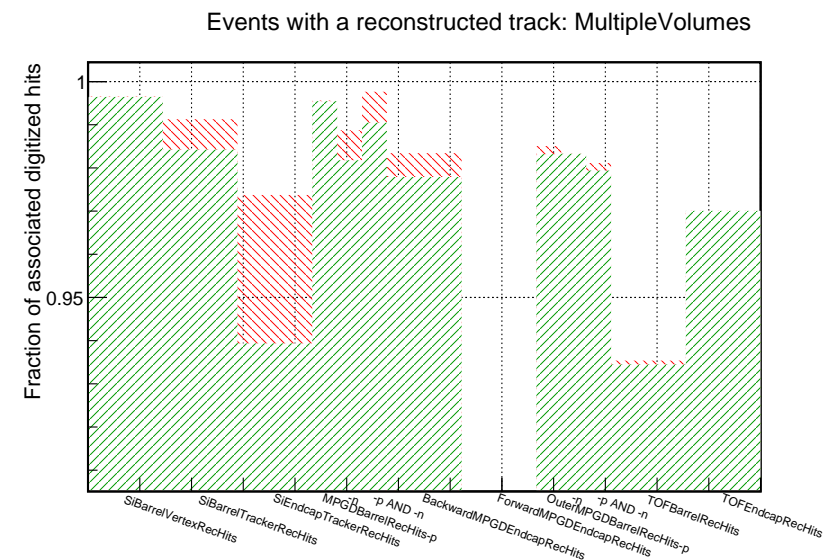
Multiple Sensitive Volumes: Hit-to-Track Association

- Association **Efficiency recovered**:



- Twice (*approx.*) as many SimHits.
- **RawHits** are associated *collection-wise* to all coalesced **SubHits**.

*Note: CyMBaL non **pn**-symmetric*



Multiple Sensitive Volumes: Pros and Cons

- Cons:
 - It's **complicated**: ~1500 lines of code.
 - Coalesced/Extended SimHits not available in podio output.
 - Pros:
 - **It's working!**
 - It's debugged: **Many thanks to Dmitri Kalinkin!**
 - It's available. 3 PRs:
 - MPGDTrackerDigi + *little fix to TrackerMeasurementFromHits*
 - Almost no impact on EICrecon behavior.
 - epic: Actual commit of Multiple Sensitive Volumes.
 - MPGDTrackerDigi and MPGDHitReconstruction: Clusters.
 - Backward compatibility:
 - Each MPGD XML comes in two flavors: `_pixel` and `_2Strip`,
 - A `cmake` command line option allows to install one or the other.
 - It's modular: Can easily be changed, **piece-wise**, any time.
- ⇒ Could now be used to **evaluate accurate rates** and **MPGD impact on tracking**.

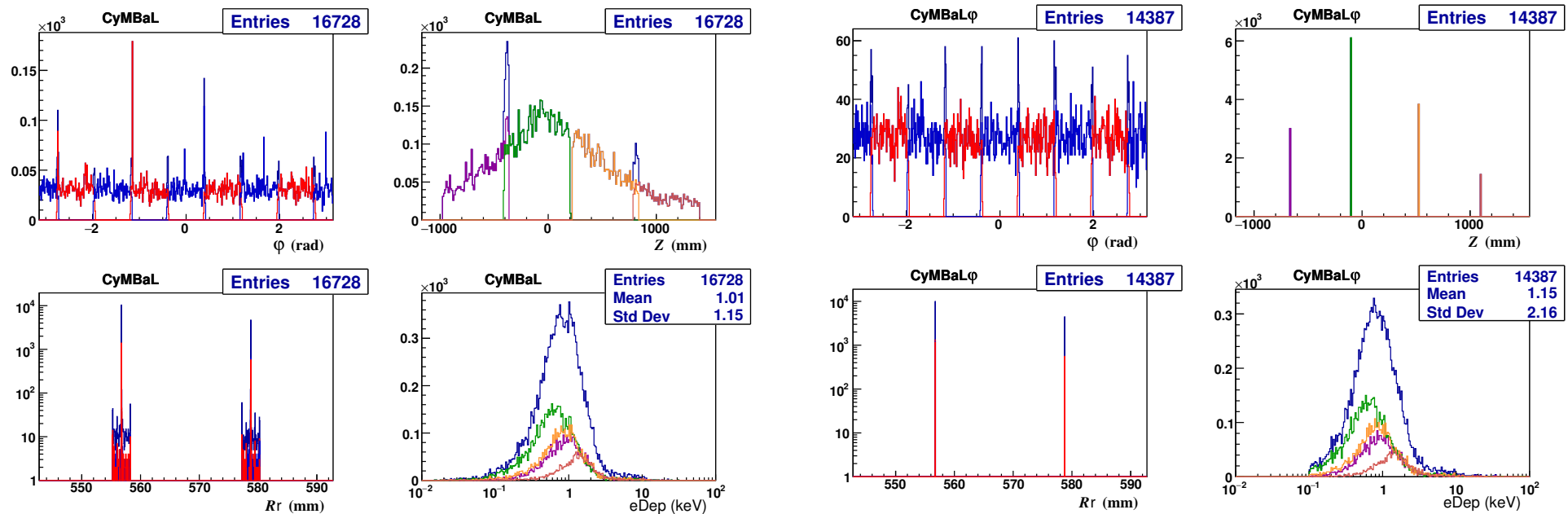
RecHits

- 32-bit channel# ends up split into two 16-bit fields, one of which is =0.

3000e040 0260 fddf \rightarrow 1000e040 0000 fde0 + 2000e040 0260 0000

3 = Inner Radiator SubVolume, **1** = p-strip, **2** = n-strip.

(Note: Same for *RawHits*).



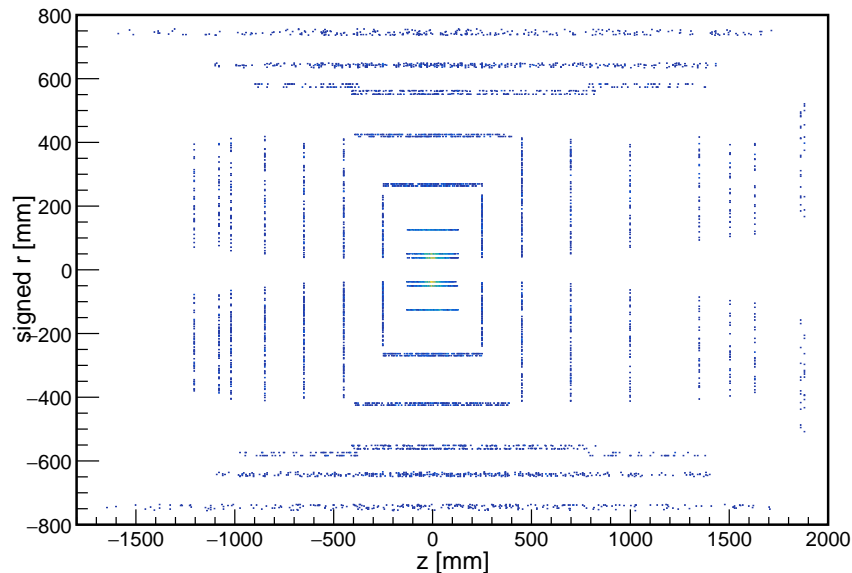
SimHits.

SimHits of ϕ -strips.

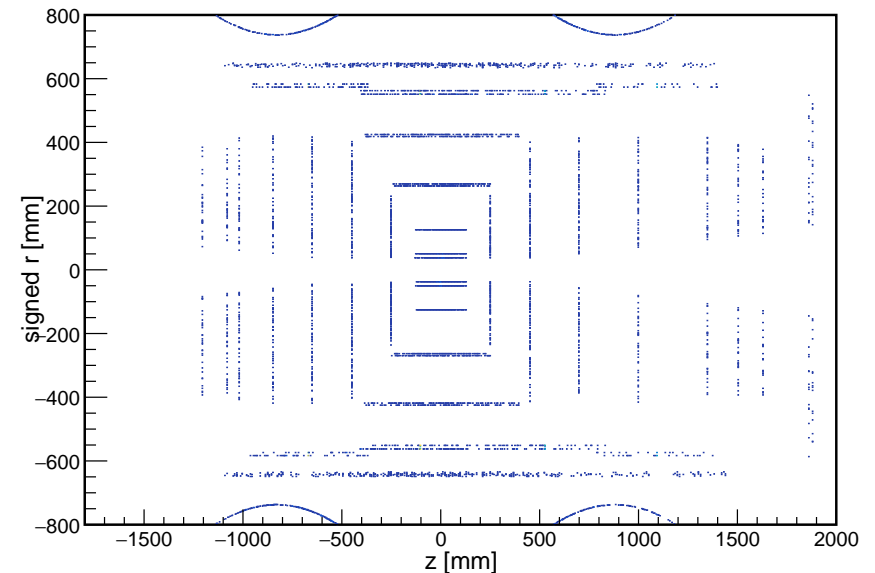
Weird Feature of UV RecHits

- U RecHits sit $V = 0$ (and vice versa).
 \Rightarrow RecHits may sit outside PCB.
 \Rightarrow (X, Y) vs. Z correlation.

All associated digitized hits



All associated digitized hits



- signed- R vs. Z **Fixed** in my private version: Combining U of U-strips and V of V-strips.
- Still expecting some bias in (Track-RecHit) residuals, pulls and χ^2

Also: all strips have same length \Rightarrow Further bias.

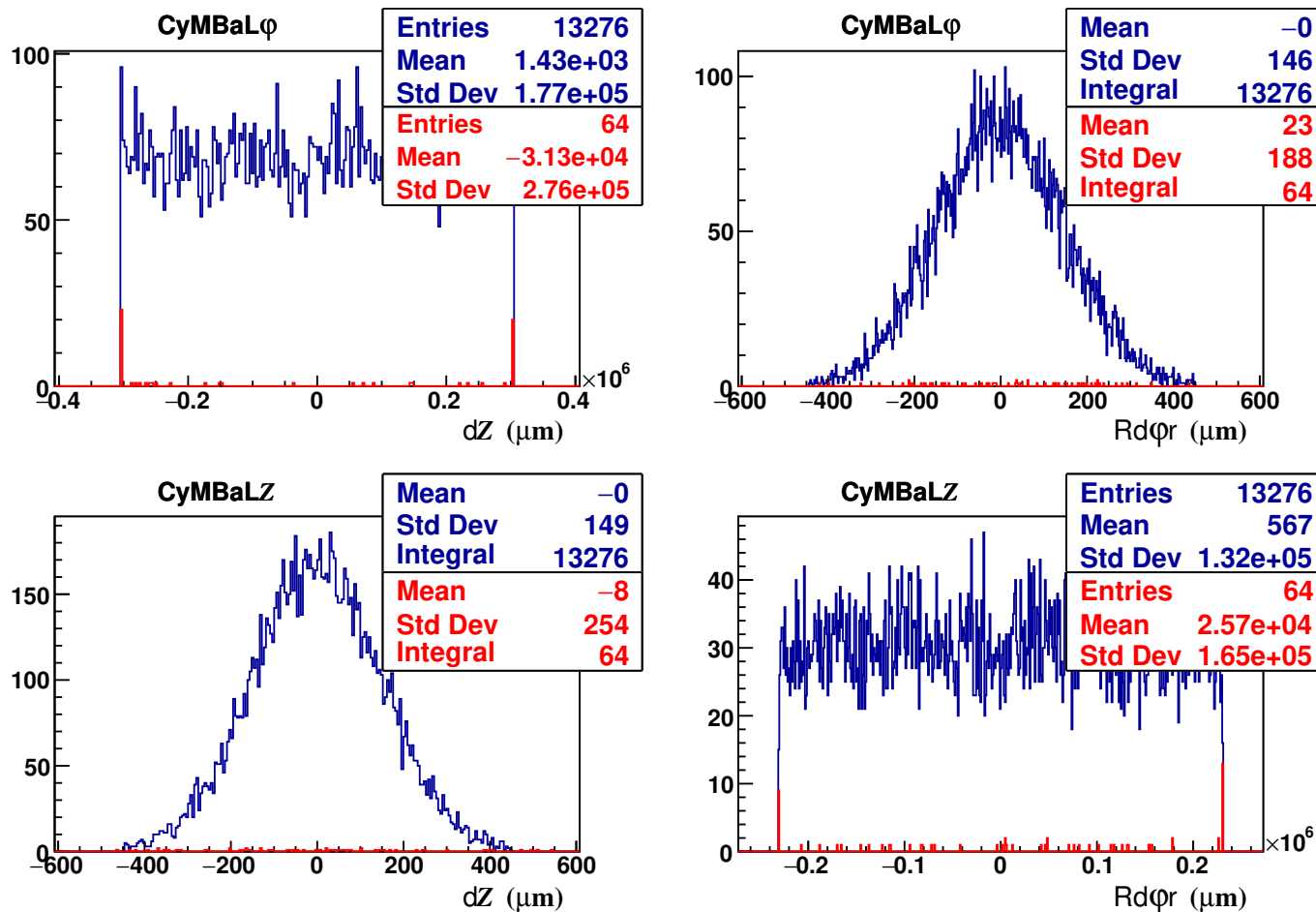
And: CyMBaL's RecHits sit on the cylinder, while on average SimHits sit below.

Clusters

- At present: **2-Hit** Clusters.
 ⇒ Hits right on strip have vanishing, below thresholds eDep.

Truncated 3σ Gaussian.

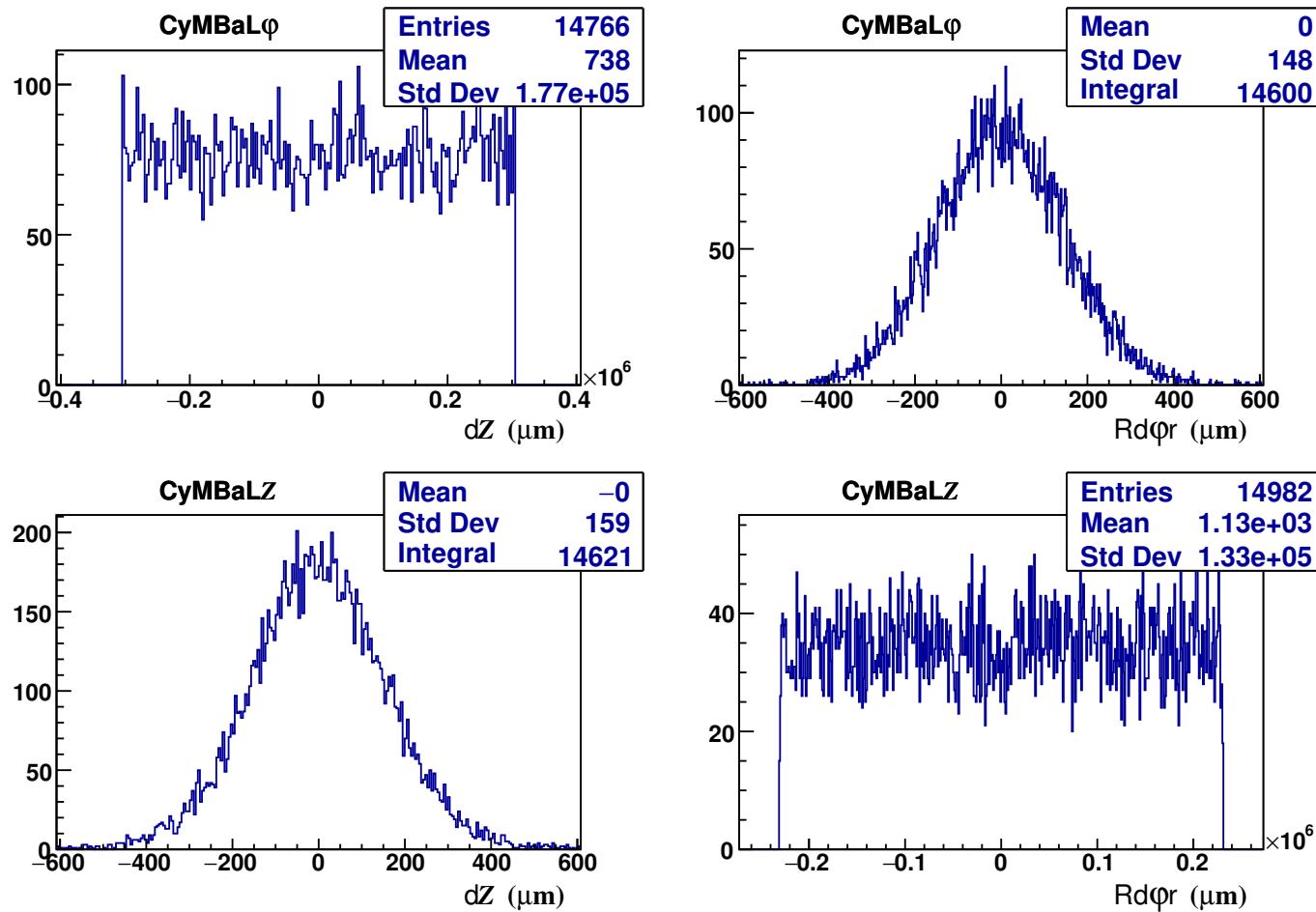
Few hits outside 3σ : because **crossing edge**.



Primary hits, w/o any Secondary (δ -ray) interfering.

Cluster Features

- Counter-intuitively: When δ -rays allowed in, Gaussian sits on top of flat background.



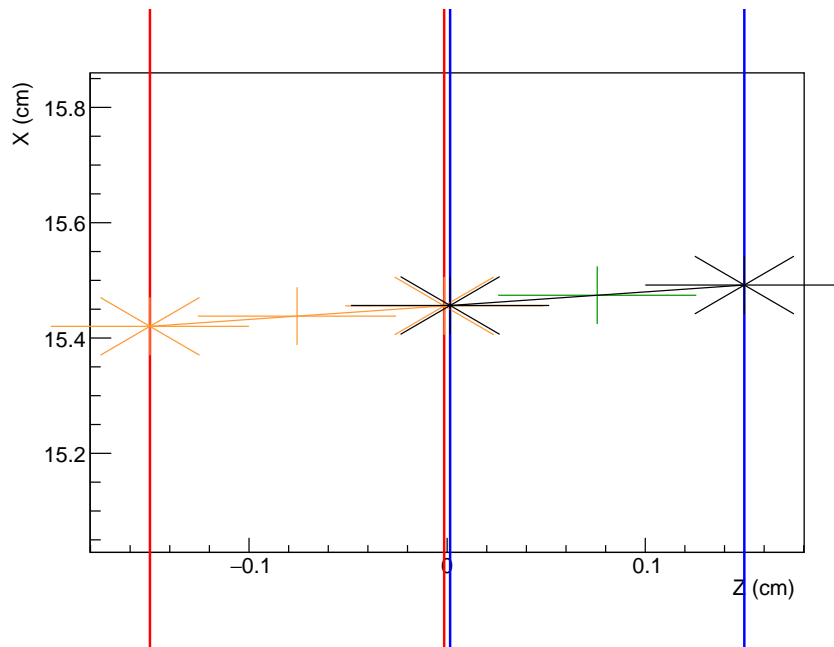
All hits (from primary particles).

Primary vs. Secondary (δ -ray) Hits

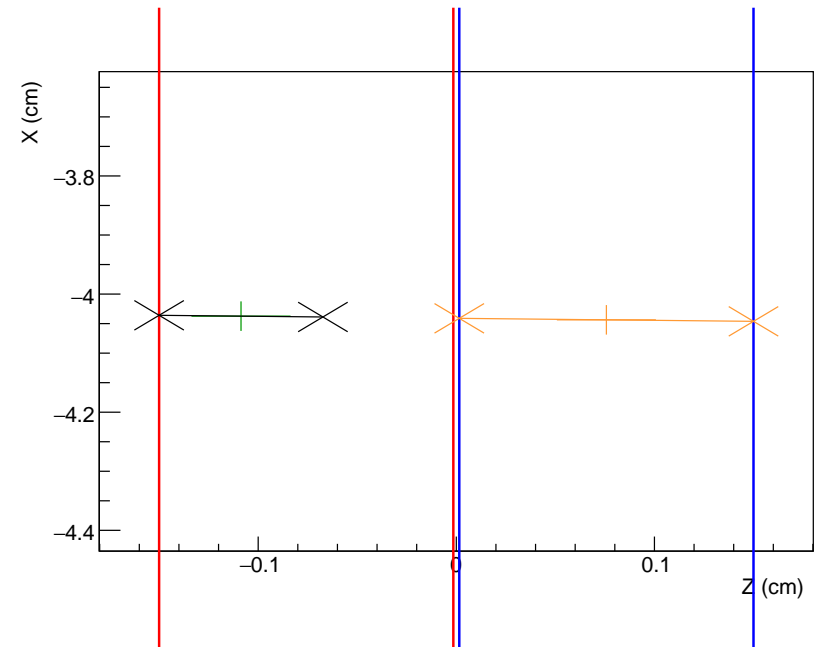
- **SimHits** have position, momentum and pathLength.

Primary-only Hit: position \pm half-pathLength along momentum direction spans (sub)Volume.

Primary accompanied by native Secondary stops prematurely.



Primary-only subHits.



Primary w/ δ -ray (*not drawn*).