Status of Silicon Charge Detector Simulation in HerdSoftware

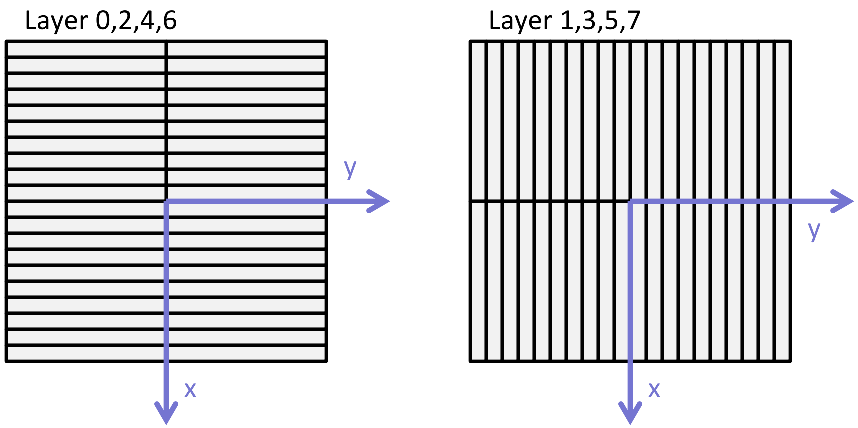
08/02/2021

Current Layout of SCD in HerdSoftware

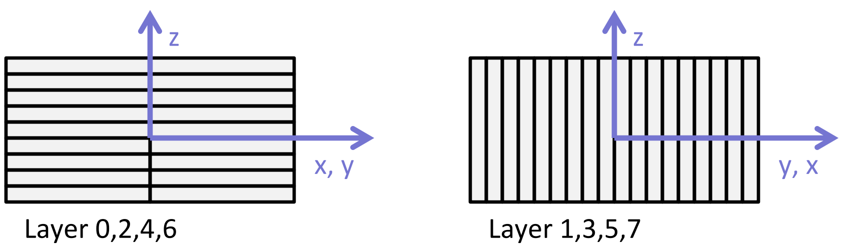
All geometry (number of planes, thicknesses, gaps, support structures) are decided in production.
For the rest of this work we use this layout without any extra material.
This design is not realistic (too light and thin), but it is still **good for basic estimations** of resolution.

Current Layout of SCD in HerdSoftware

SCD Top: 190 × 190 cm^2, 20 × 20 ladders



SCD Top: 98 × 175 cm^2, 2 × 9 or 1 × 18 ladders



Wafer 9.5 × 9.5 cm^2
SCD Top Ladder with 10 wafers (2 halves)
SCD Side Ladder with 9 wafers (1/2 halves)
896 ladders of 9 or 10 wafers
8284 wafers
75.7 m^2 active area

With 50 μm implantation pitch, 1900 strip/wafer:

- 1.7M readouts, with 0 floating strips
- 850k readouts, with 1 floating strips
- 600k readouts, with 2 floating strips
- 430k readouts, with 3 floating strips

With 200 μm implantation pitch, 475 strip/wafer:

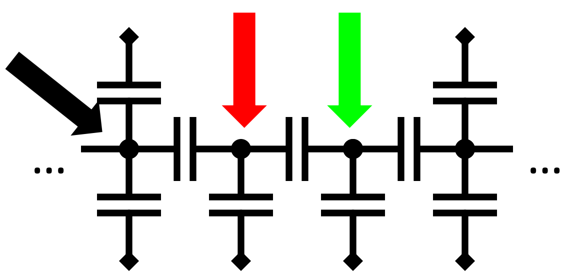
- 430k readouts, with 0 floating strips
- 210k readouts, with 1 floating strips
- 140k readouts, with 2 floating strips
- 110k readouts, with 3 floating strips

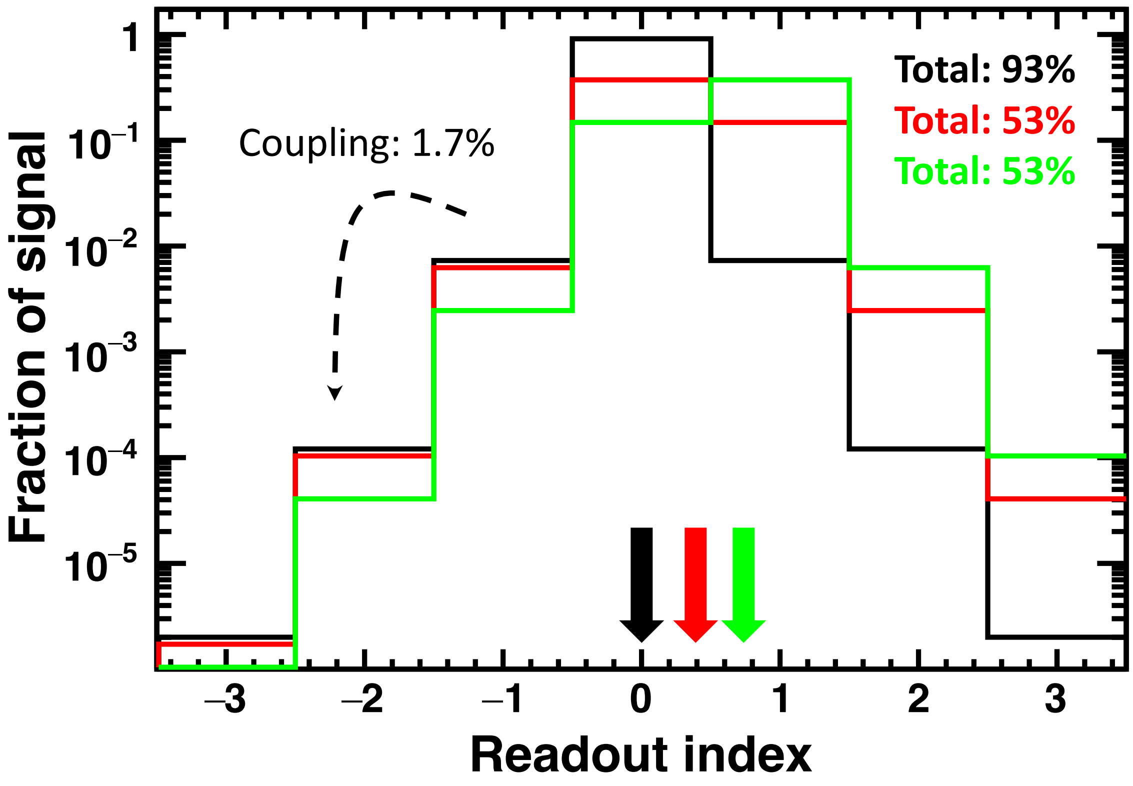
These are just some of the many possible sensor/ladder/strip designs.
Wafer sizes, number of layers, placement can be changed in production.
Ladder association (bonding), strip implantation, readout pattern can be changed in digitization.

Capacitive Net

Capacitances are calculated with simple model and assumptions (C_{IS}~C_{bck}~pF/cm, C_{IS2}~$0.1C_{IS}$, C_{dec}~$10\ C_{IS}$).
Then we simulate the capacitance net with SPICE injecting charge on each single strip.

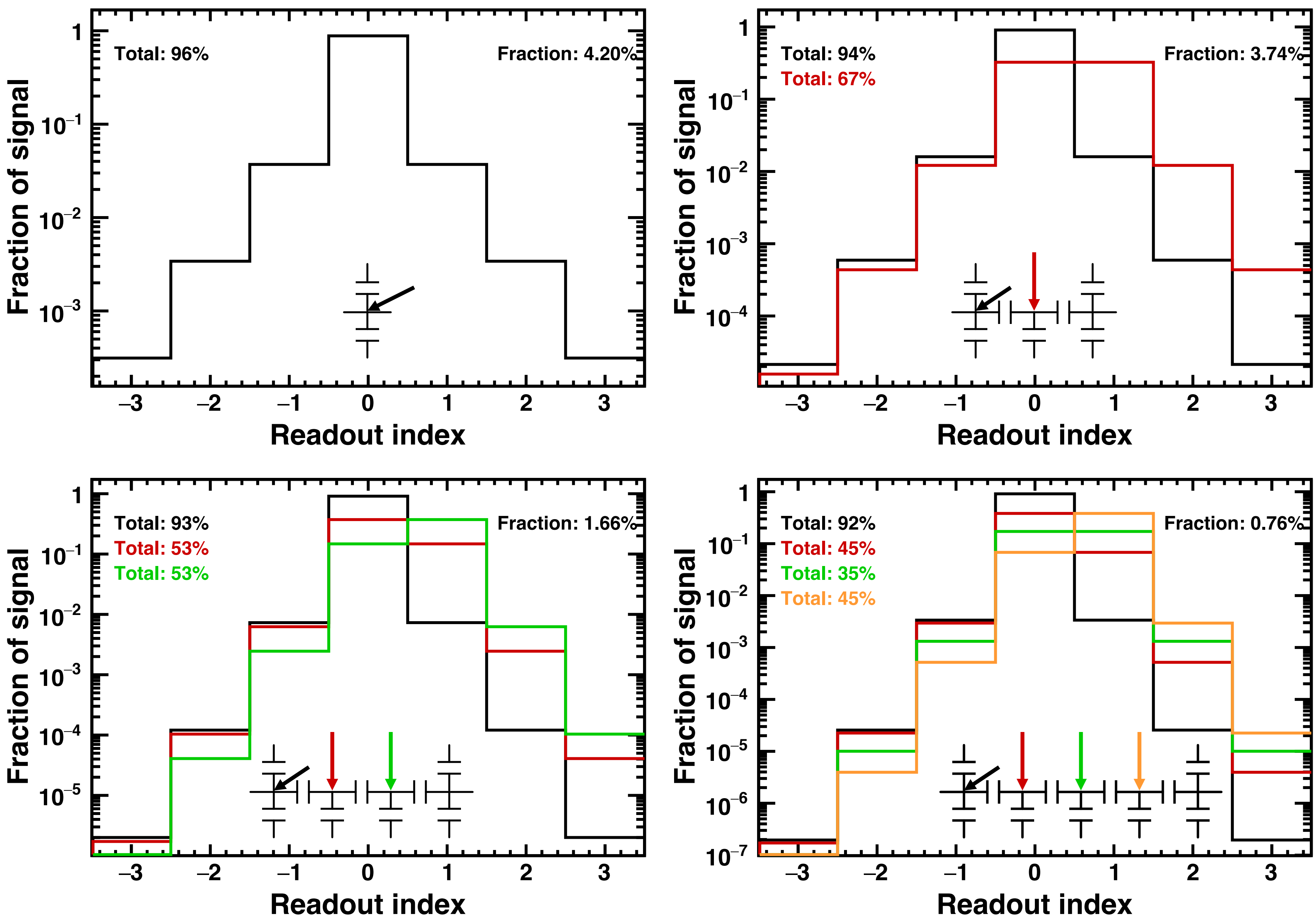
Thickness: 150 µm
Pitch: 50 µm
Width: 10 µm
N. Floating: 2



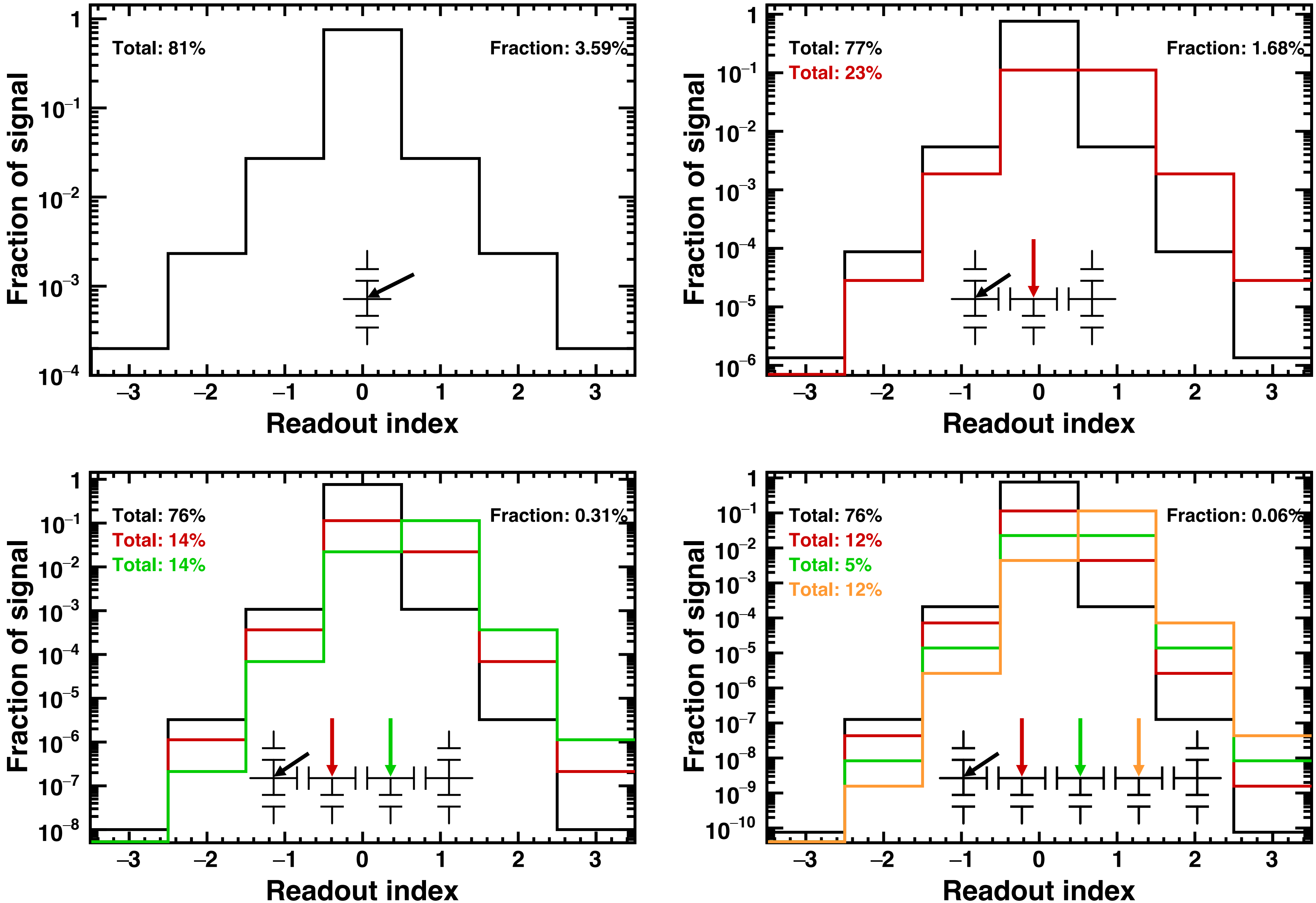


Energy loss: amount of signal lost for energy deposit in between strips with respect to readout (~57%).
Coupling: ratio of contiguous strips outside of the signal region (~1.7%).

Signal Injection (150 μm Thickness, 50 μm Pitch)



Signal Injection (150 μm Thickness, 200 μm Pitch)



Analysis

Geant4 MC has been produced at CNAF with GGSPenny for proton, alpha, ^{12}C, ^{16}O, ^{18}Si and ^{56}Fe at several energy point (10, 100, 1000, 10000 GeV/A) from an hemisphere of 2m. With TRD, PSD_v2, CALO_v2, but no CSS and no extra material (foam, or meteorite shield).

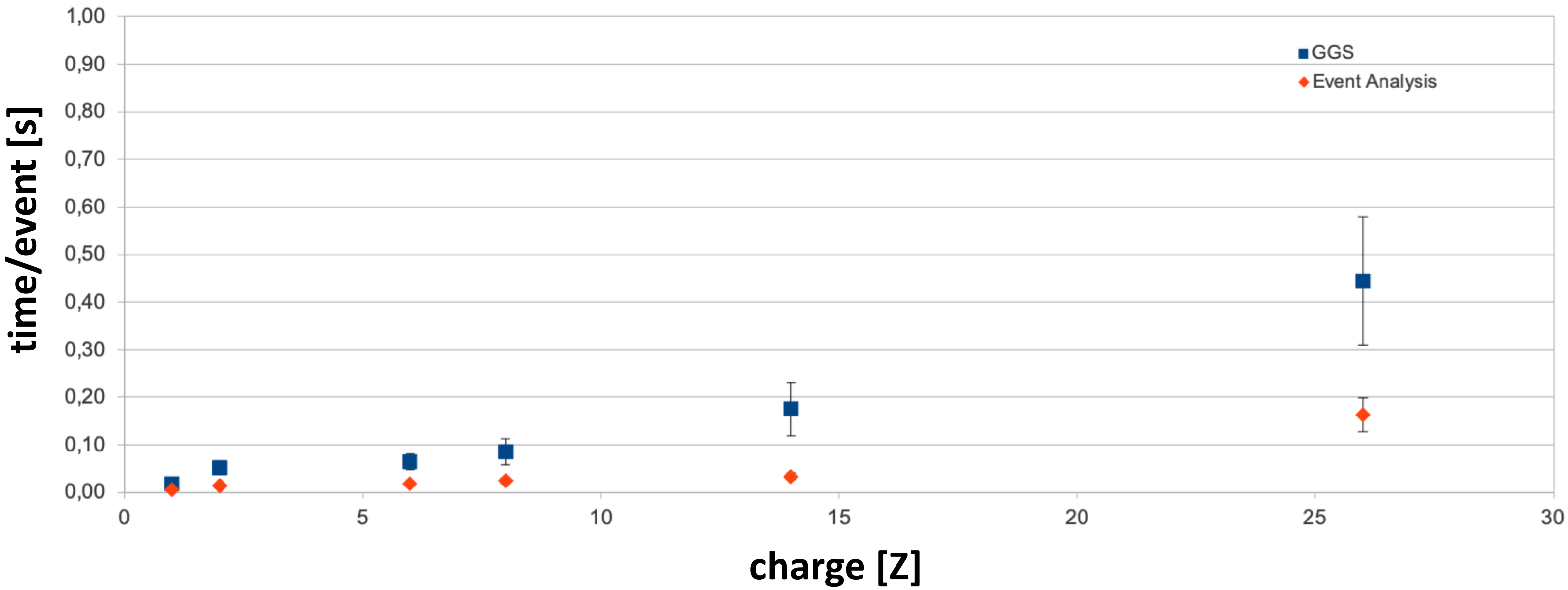
From GGS files we produced **"half-baked"** with fully digitized FIT, MC hits of CALO and PSD, and full MC information (particle hits) for the SCD.

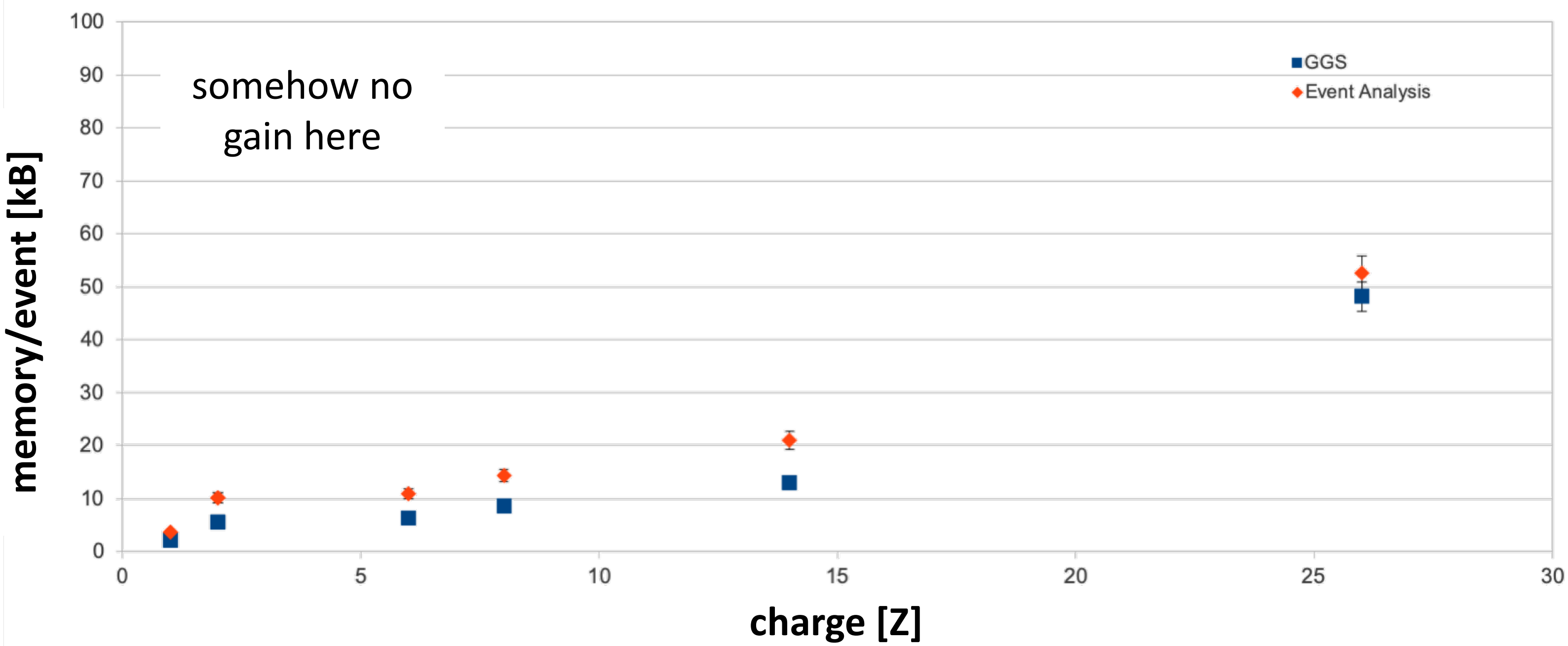
Main performances in terms of **CPU time** and **disk space** of this processing are detailed in the next slides (…).

Starting from "half-backed" we perform **SCD digitization** (drift-diffusion, capacitive-net, bonding) for all the configurations (**implantation pitch, readout pitch**) that we wanted to test.

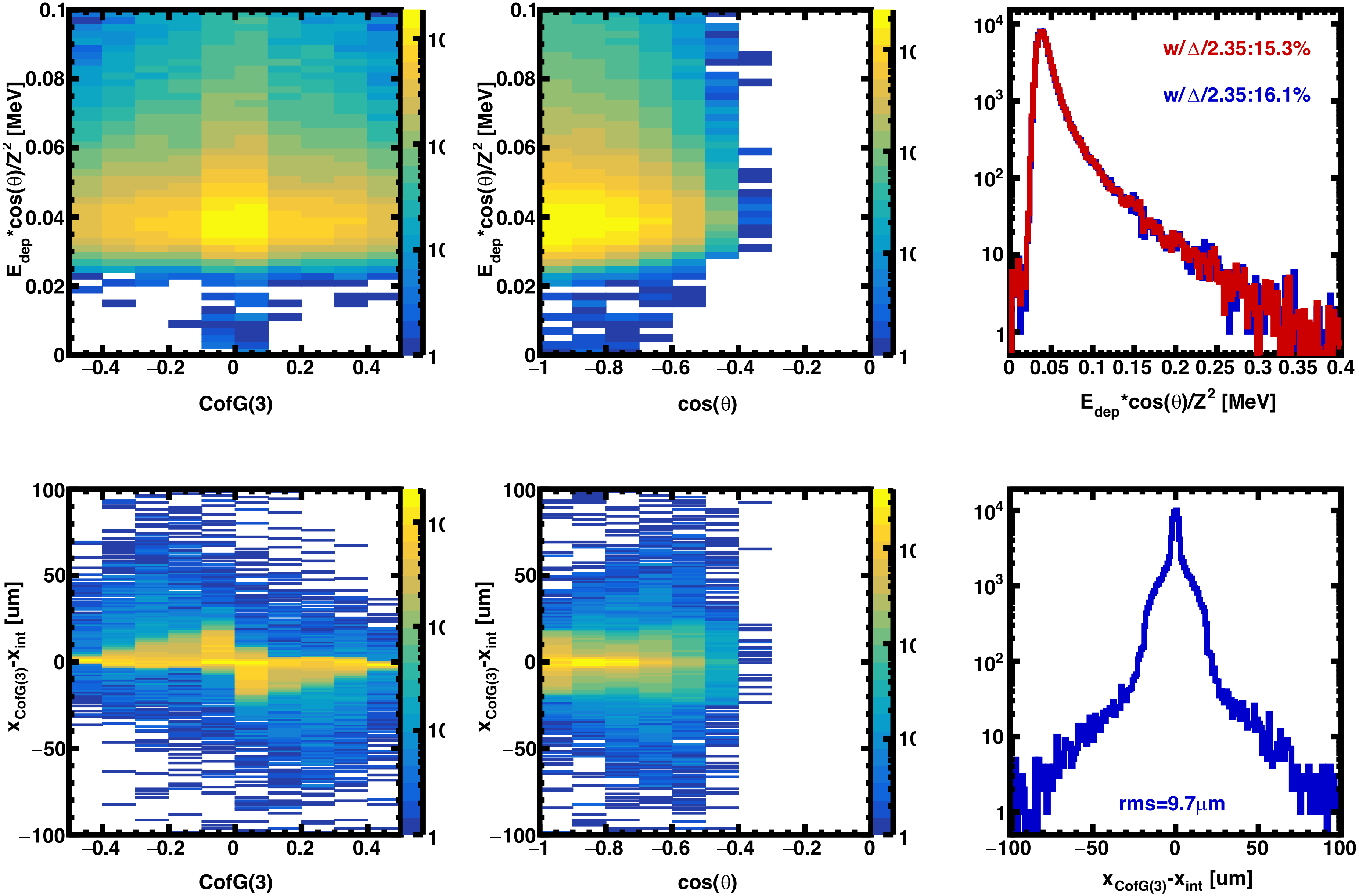
Eventually, an analysis program creates clusters starting from the strips, and using the MC truth, the closest clusters to the track are found and performances in terms of charge distribution and spatial resolution are evaluated.

Production @ 10 GeV/n

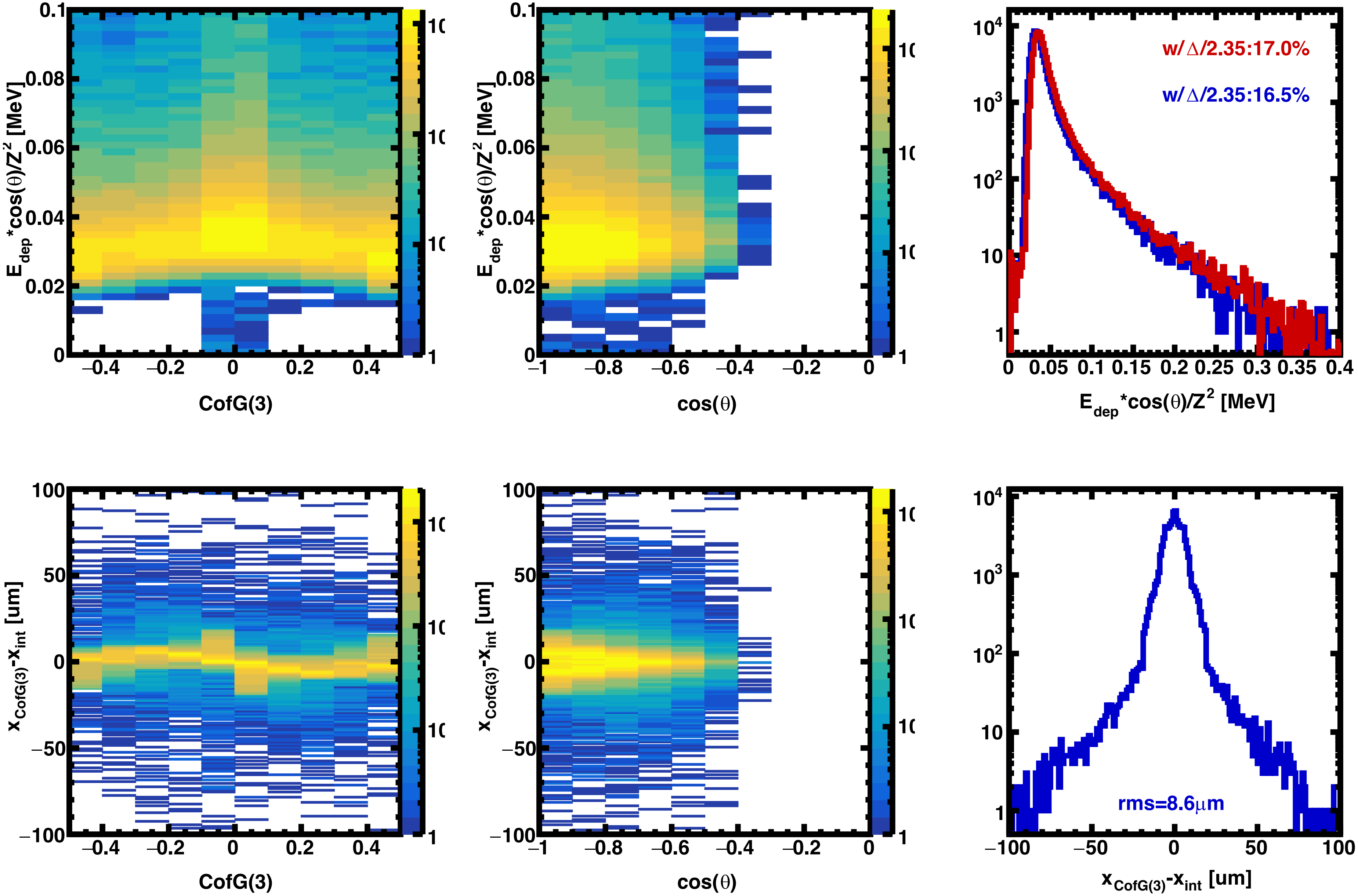




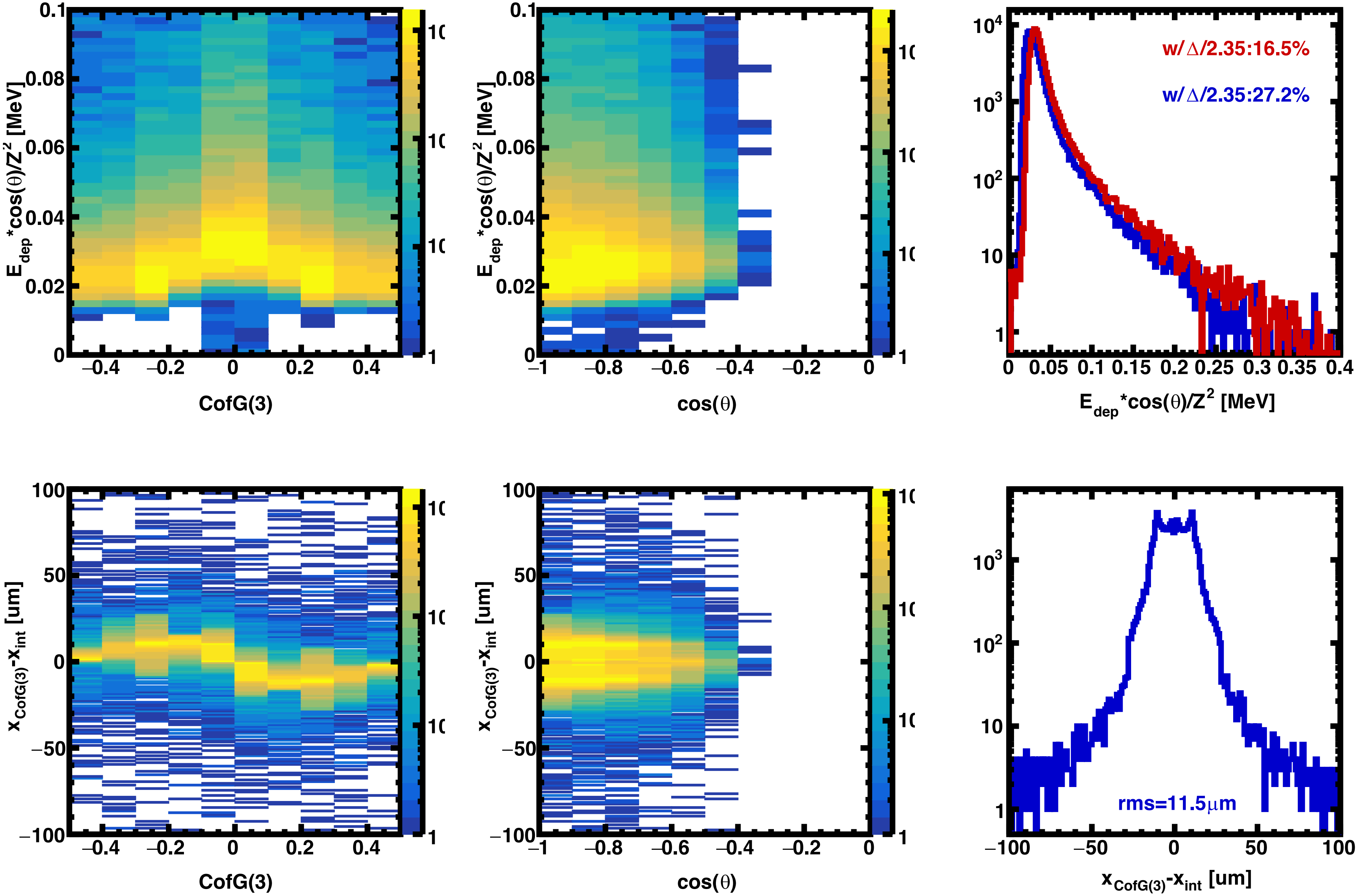
10 GeV proton, 0 floating



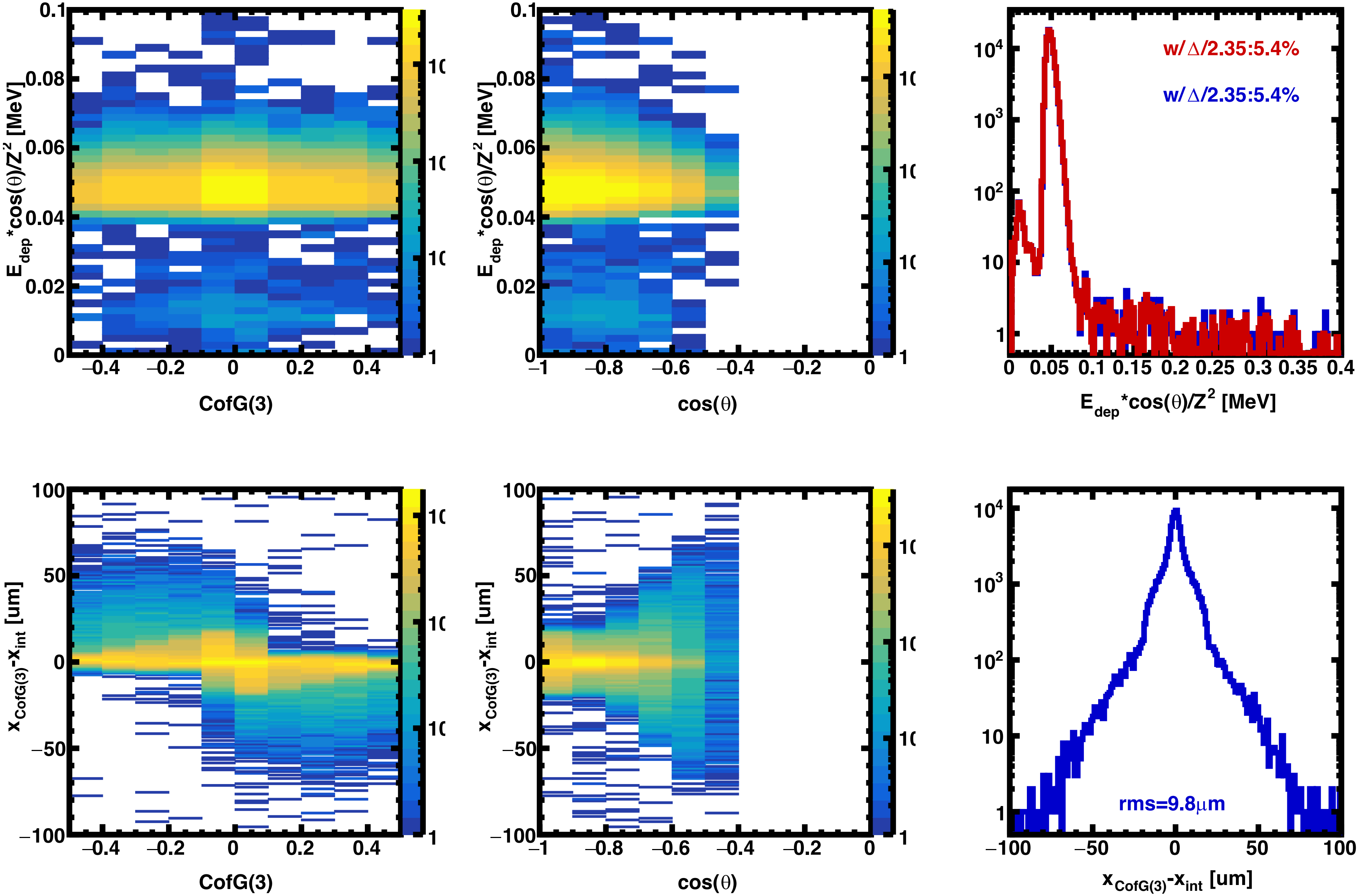
10 GeV proton, 1 floating



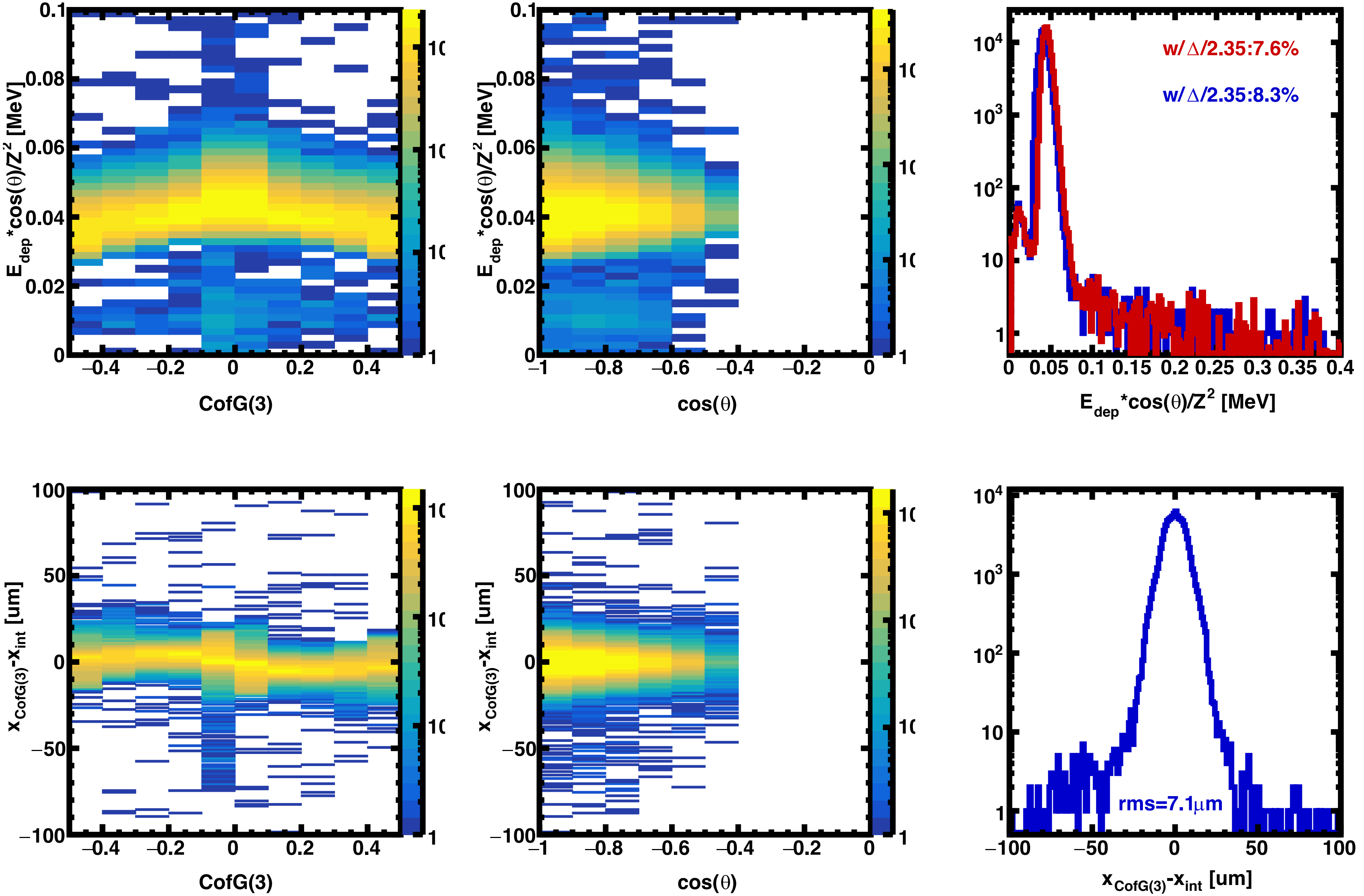
10 GeV proton, 2 floating



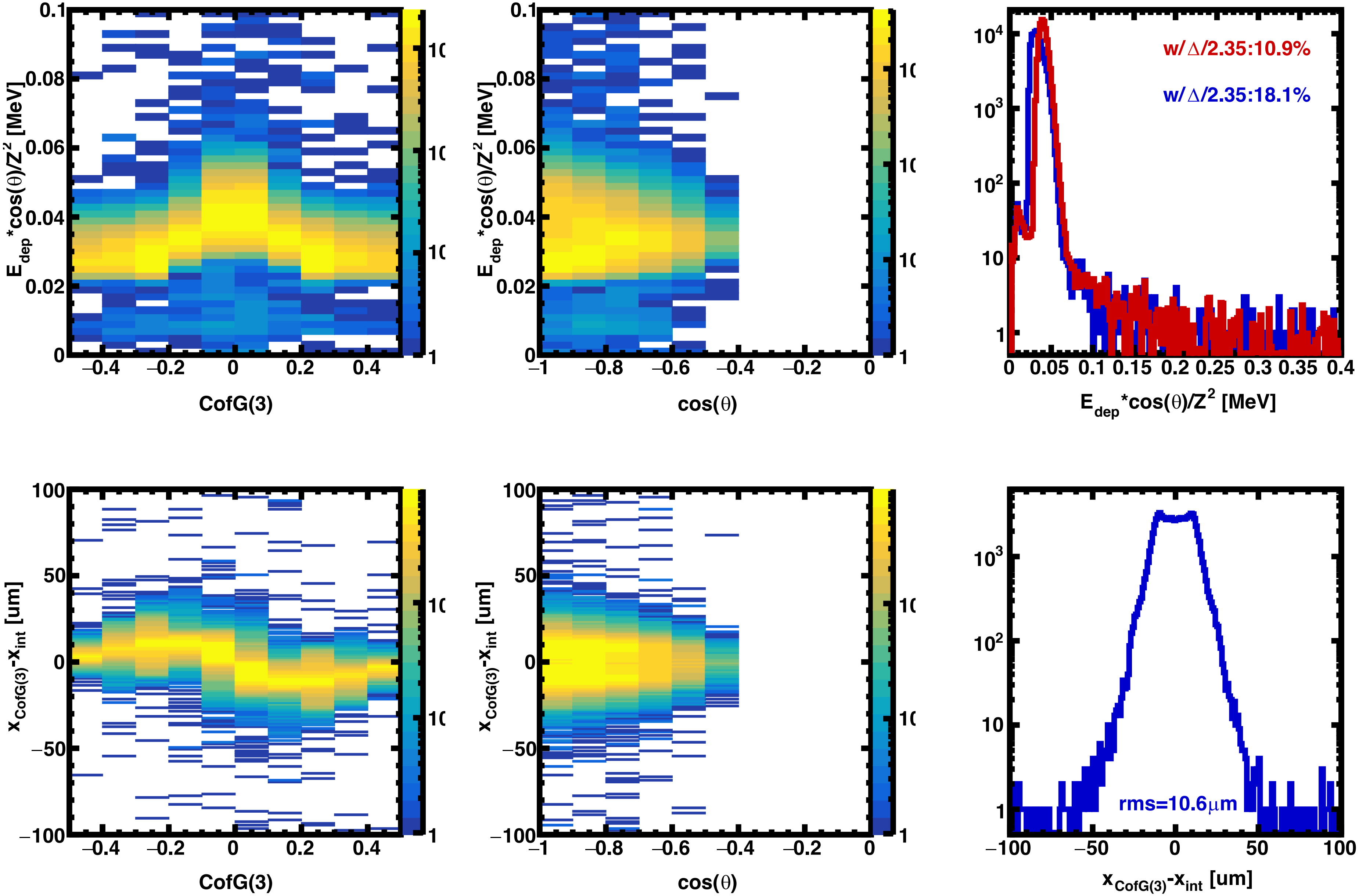
10 GeV/n ^{12}C, 0 floating



10 GeV/n ^{12}C, 1 floating

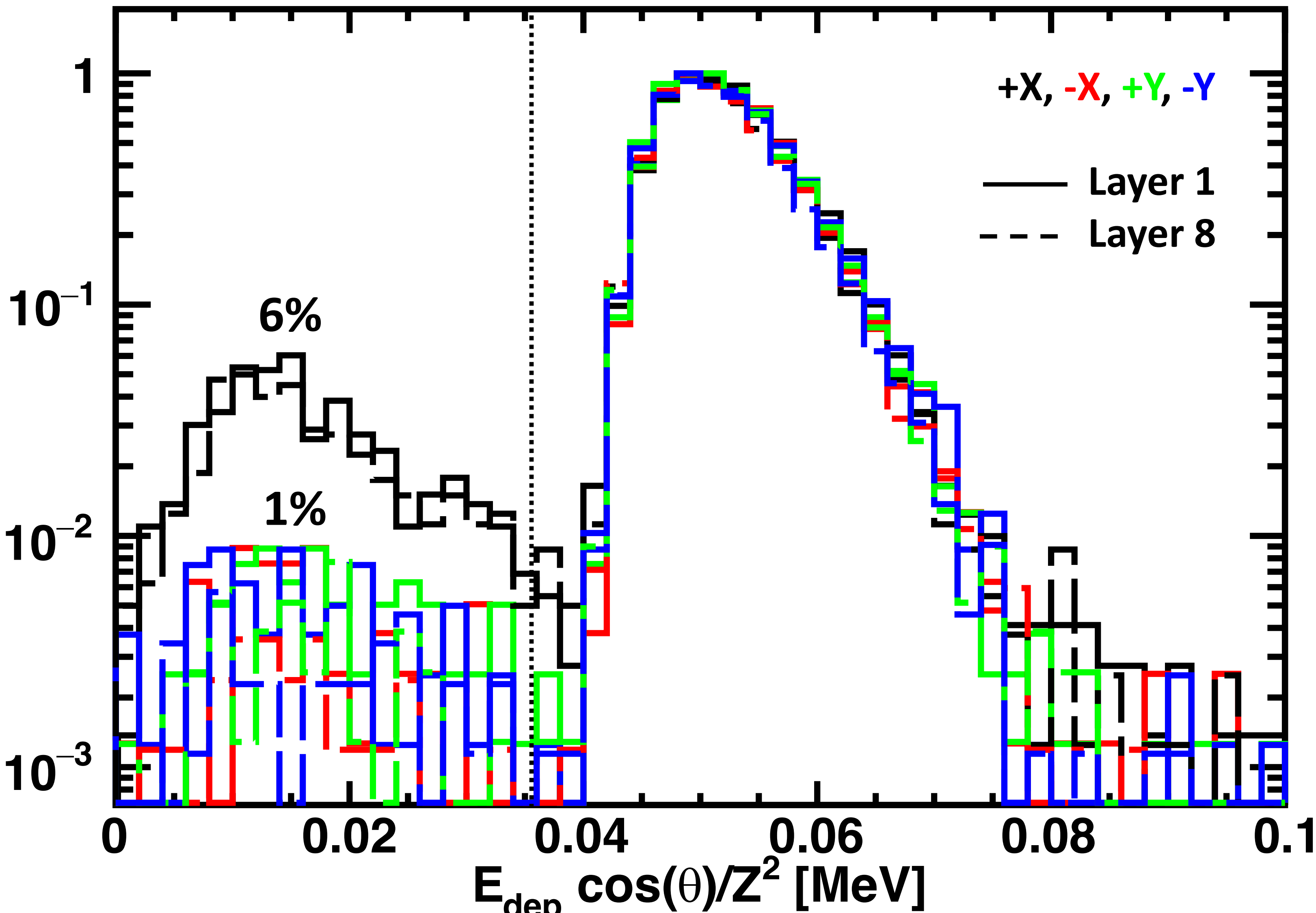


10 GeV/n ^{12}C, 2 floating



Interactions in SCD and TRD for ^{12}C @ 10 GeV/n

The average interaction level is about 6% for TRD and about 0.5% for L1 to L8.



Conclusions

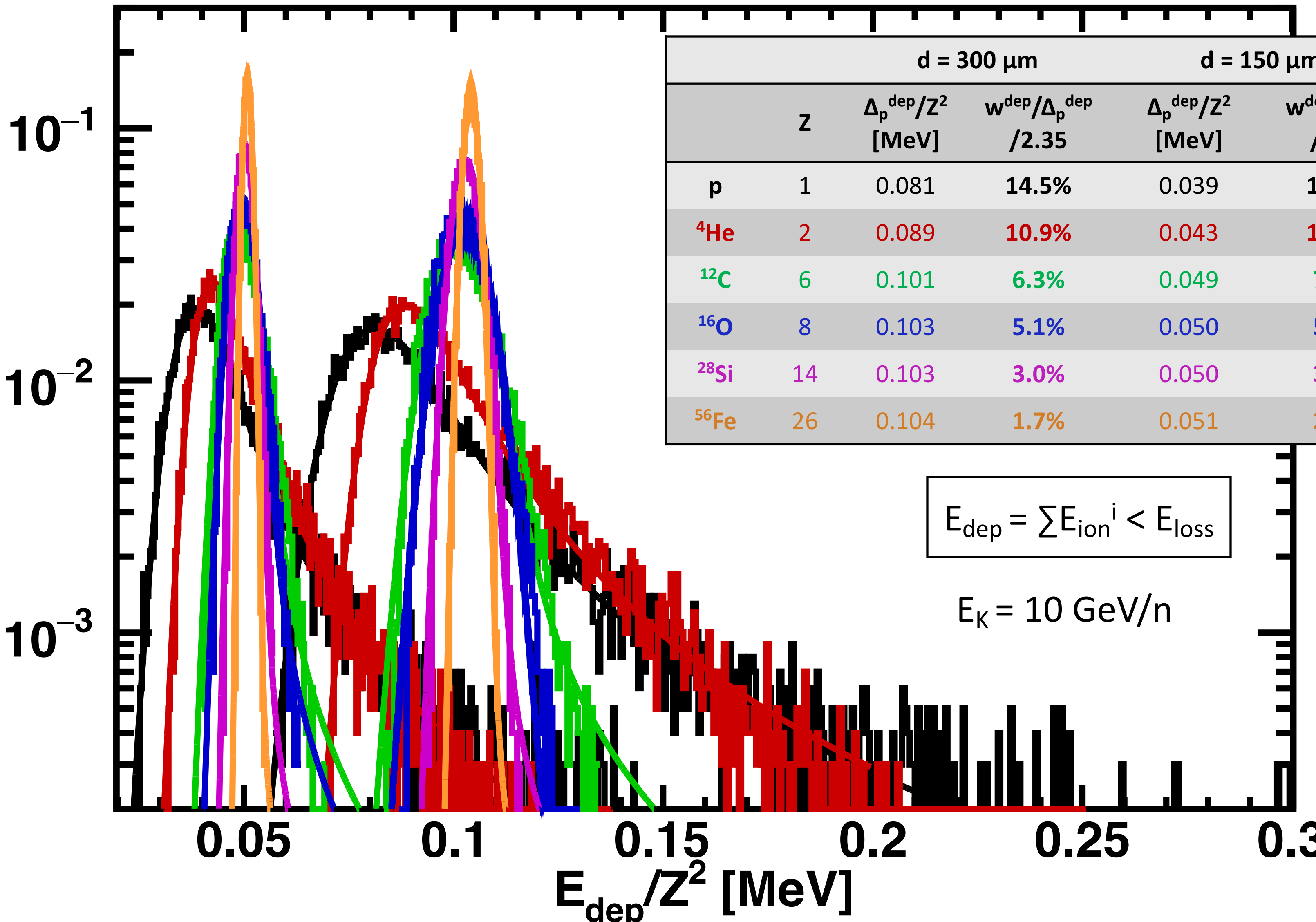
Simulation chain has been tested and we got what we put inside.

We miss some steps to have a full simulation/reconstruction chain (add noise, correct some bug in clustering, and test everything with the already present track reconstruction algorithm). We need to finish this and test also track reconstruction.

Performances studies (charge resolution, spatial resolution, TRD interactions, …) are under development.

To have a realistic simulation/reconstruction, that's a complete different business. For that we will have to wait for inputs from lab data and test beams.

Energy Deposit



		d = 300 µm		d = 150 µm	
	Z	Δ_p^{dep}/Z^2 [MeV]	w^{dep}/Δ_p^{dep} /2.35	Δ_p^{dep}/Z^2 [MeV]	w^{dep}/Δ_p^{dep} /2.35
p	1	0.081	**14.5%**	0.039	**17.0%**
^{4}He	2	0.089	**10.9%**	0.043	**12.3%**
^{12}C	6	0.101	**6.3%**	0.049	**7.0%**
^{16}O	8	0.103	**5.1%**	0.050	**5.7%**
^{28}Si	14	0.103	**3.0%**	0.050	**3.6%**
^{56}Fe	26	0.104	**1.7%**	0.051	**2.0%**

Due to the existing asymmetry in the signal

- $w/\Delta \sim c_1/[c_2+\log(d)]$, slow improvement with thicker materials (less than $\mathrm{sqrt}(d_2/d_1)$).
- Combination of N independent measurement may give a better resolution than a thick sensor.