GEM backgrounds from GEM copper

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GEM materials budgets

From a presentation a couple years ago

Error in gas X0 corrected

EIC Forward Tracker with standard GEM foil

	Quantity	Thickness μm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	5	8.96	14.3	1	0.0350	0.0045
Kapton	1	50	1.42	286	1	0.0175	0.0071
GEM Foil							
Copper	6	5	8.96	14.3	0.8	0.1678	0.0215
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	5	8.96	14.3	0.2	0.0070	0.0009
Copper-350	1	5	8.96	14.3	0.75	0.0262	0.0034
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO_2)	1	15000	1.84E-03	~~18310~~	~~1~~	~~0.0819~~	~~0.0028~~
					Total	~~**0.471**~~	**0.090**
				141270	1	0.0106	
					Total	0.400%	

EIC Forward Tracker with Copperless GEM foil

	Quantity	Thickness μm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	0	8.96	14.3	1	0.0000	0.0000
Kapton	1	50	1.42	286	1	0.0175	0.0071
GEM Foil							
Copper	6	0	8.96	14.3	0.8	0.0000	0.0000
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	0	8.96	14.3	0.2	0.0000	0.0000
Copper-350	1	0	8.96	14.3	0.75	0.0000	0.0000
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO_2)	1	15000	1.84E-03	~~18310~~	~~1~~	~~0.0819~~	~~0.0028~~
					Total	~~**0.235**~~	**0.060**
				141270	1	0.0106	
					Total	0.164%	

Fully copperless GEM probably NOT viable for SoLID, but maybe for 1st two GEM foil layers

μRWELL materials budget

μRWELL					
Layer	Material	Thickness (μm)	RL (mm)	area fraction	RL %
Gas window	Al	2	89.0	1.000	0.0022%
	Kapton	25	285.8	1.000	0.0087%
Gas layer	70Ar30CO2	3000	141,270.0	1.000	0.0021%
Cathode	Kapton	25	285.8	1.000	0.0087%
	Al	2	89.0	1.000	0.0022%
Gas layer	CO2	3000	141,270.0	1.000	0.0021%
μRWELL foil	Cu	5	14.4	0.800	0.0279%
	Kapton	50	285.8	0.800	0.0140%
	DLC	0.1	214.0	1.000	0.0000%
	Prepreg (G10)	50	194.0	1.000	0.0258%
Readout	Cu	25	14.4	0.200	0.0348%
	G10	50	194.0	1.000	0.0258%
	Cu	25	14.4	0.850	0.1480%
	G10	100	194.0	1.000	0.0515%
Gas layer	CO2	3000	141,270.0	1.000	0.0021%
Gas window	Kapton	25	285.8	1.000	0.0087%
	Al	2	89.0	1.000	0.0022%
Total					**0.367%**
Reference	https://solid.jlab.org/DocDB/0001/000114/001/SoLID_GEM_SoLID_collab_June_2018.pdf (p. 13) and emails				

μRWELL prototype has fewer layers than (full Cu) GEM, but only 10% smaller radiation thickness!

Mainly because readout Cu layers are 25 μm, much thicker than figure used for GEM.

Why? In μRWELL prototype thickness is not critical, could be reduced.

However, per Kondo, SoLID readout strip layers will need vias holes for conducting paths, and this ends up making thicker readout layers necessary. Maybe more like 12 μm, not 25. *But same would be true for SoLID GEMs: they would need to be thicker than current simulation model.*

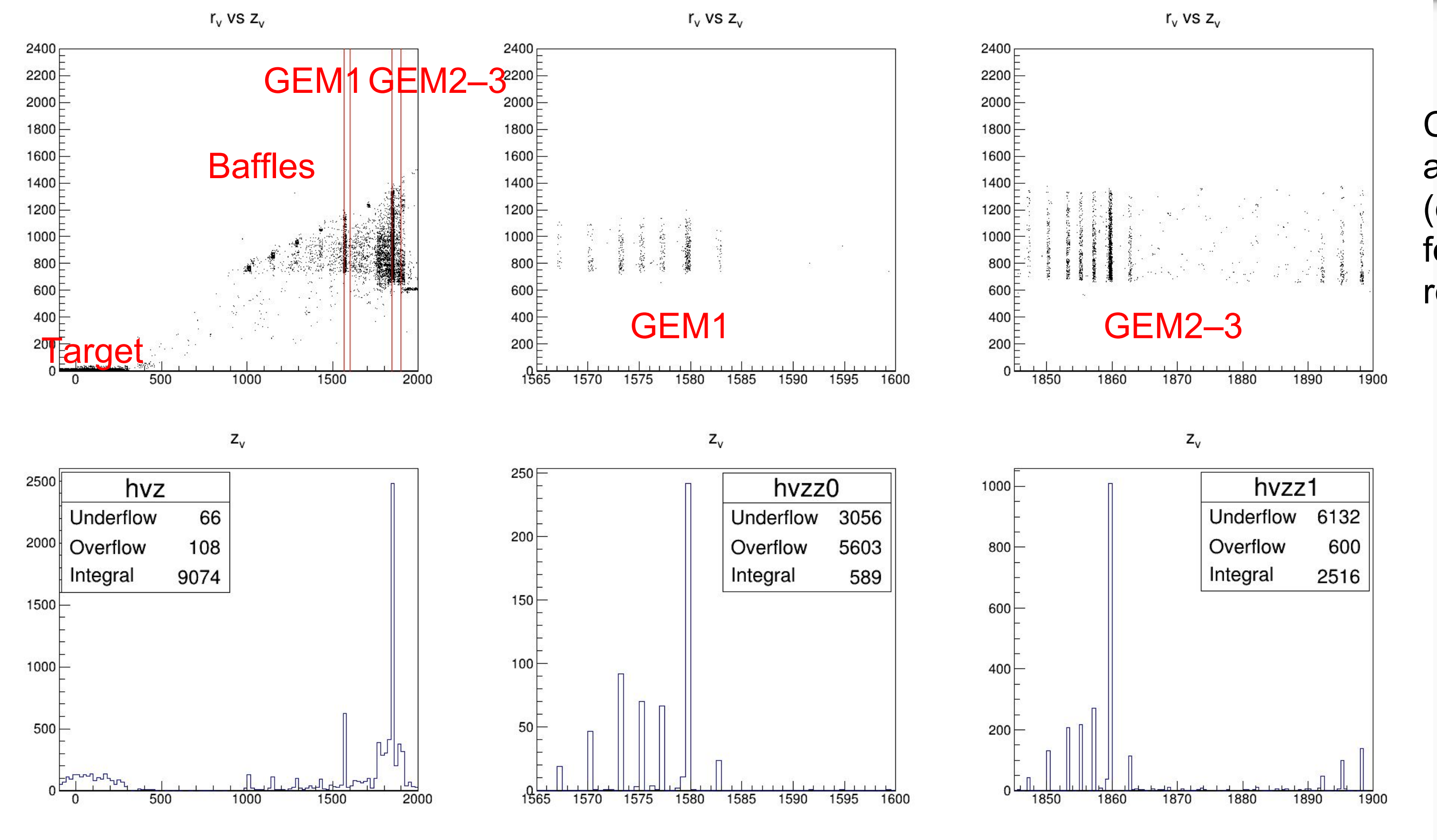
⇒ Actual tracker thicknesses cannot be estimated without a good deal more R&D.

What impact does Cu thickness have on backgrounds?

- Energy deposition in GEMs mainly from e^-/e^+ in gas produced by tracks entering GEM
- Simulation does not provide a direct way to get photon vertex associated with GEM energy deposition
- However, we can look for hit in flux detector that is closest (within ~12 mm) to each energy-depositing hit in GEM, and plot its vertex
- Results do not depend strongly on size of energy deposition. Shown, $E_{dep} > 0$:

Signal in	Vtx in GEM1	Vtx in GEM2–3	Vtx in GEM4–5	Vtx anywhere	%vtx in GEM
GEM1	1218	147		22310	6%
GEM2	1759	936		11830	23%
GEM3	589	2516		9074	34%
GEM4	8	40	361	5437	8%
GEM5	7	34	1824	5917	32%

GEM3 (immediately downstream of GEM2 and upstream of LGC)



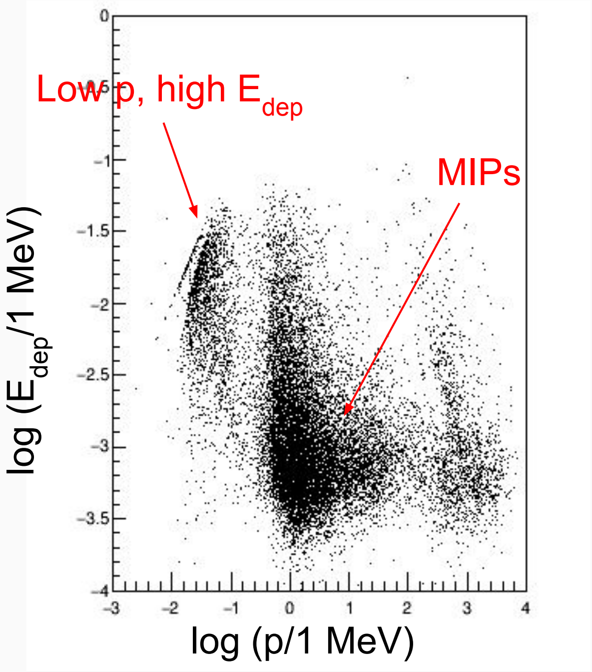
Cu layers are visible (cathode, 3 foils, readout)

Energy deposition

What matters for DAQ is not just rate but also energy.

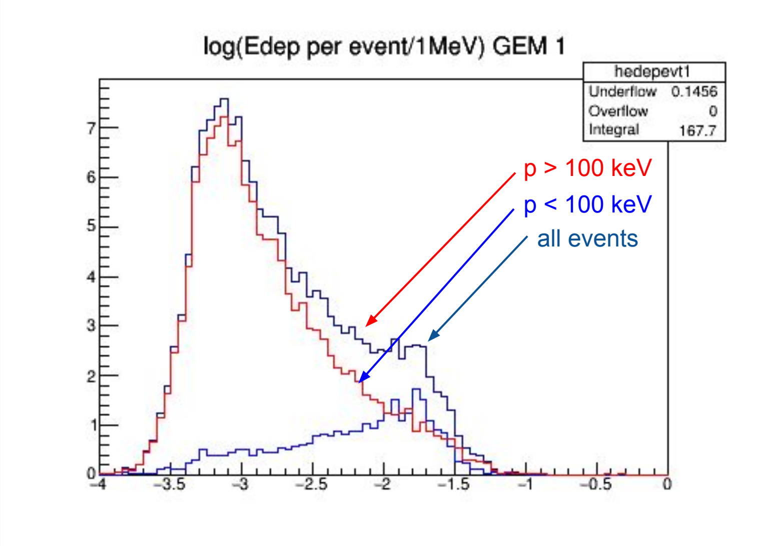
Low energy photons (10–100 keV) are associated with high energy deposition in the GEMs.

This in turn deposits charge on larger numbers of strips, increasing occupancy more than higher energy photon hits.

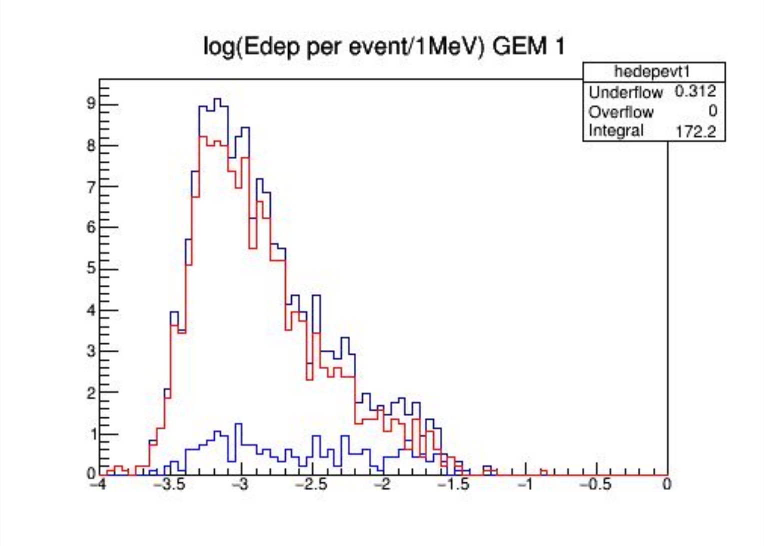


Energy deposition with/without copper

With Cu



Without Cu



Significant reduction in high E_{dep} events

Edit: Normalized y axis to rate in MHz/sector

Occupancy

Occupancy for three data sets:

- Standard
- No Cu in GEMs
- Cut tracks with E < 100 keV

(Latter two are smaller statistics -> noisier)

For GEM1 u strips, see ~30% reduction in occupancy with E cut; maybe ~20% with no Cu.

For GEM1 v strips, see ~10% reduction in peak occupancy (70–80%) but larger reductions away from peak.

High occupancy is hard to reduce (if >>1 hit per event, even a large rate reduction doesn’t much change probability of hit)

Smaller reductions in GEMs 2–3.