Radiation and Background Rate Considerations

Yuan Li, Mingyu Li, Weizhi Xiong
Shandong University

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Key Questions to be Considered

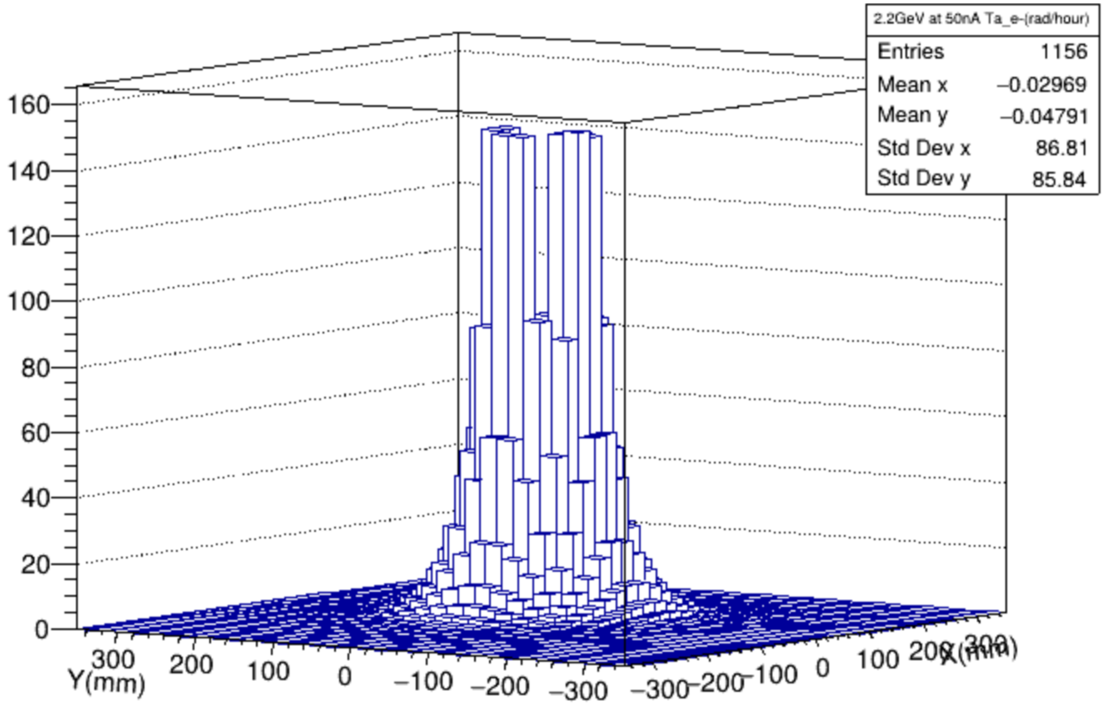
1. Using aluminum beam pipe or He4 bag?
2. Using original HyCal absorber or the new larger absorber?

- What to consider in making decisions:
  - GEM background rate
  - HyCal background rate
  - HyCal Radiation damage

Aluminum Pipe V.S. He4 Bag

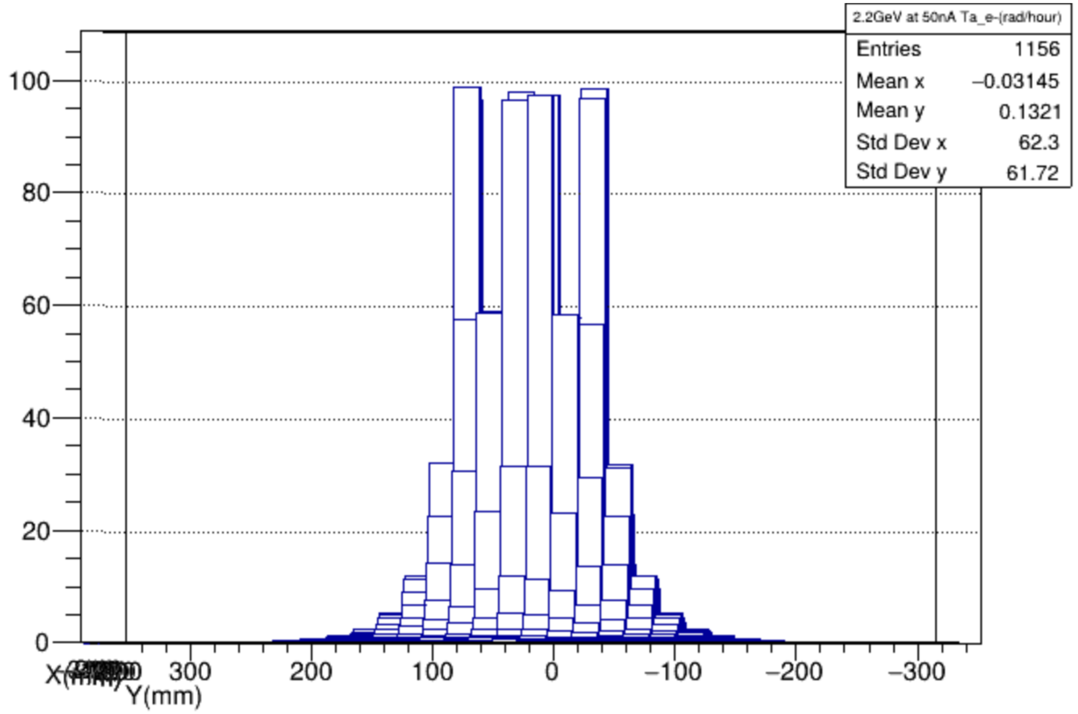
HyCal radiation reduced by 1/3, if using He4 Bag
Condition: 2.2 GeV, 1um Ta, 50nA

Small Absorber – Aluminum Pipe



1st open layer max dose: 150 rad/h
2nd open layer max dose: 50 rad/h

Small Absorber – Helium Bag

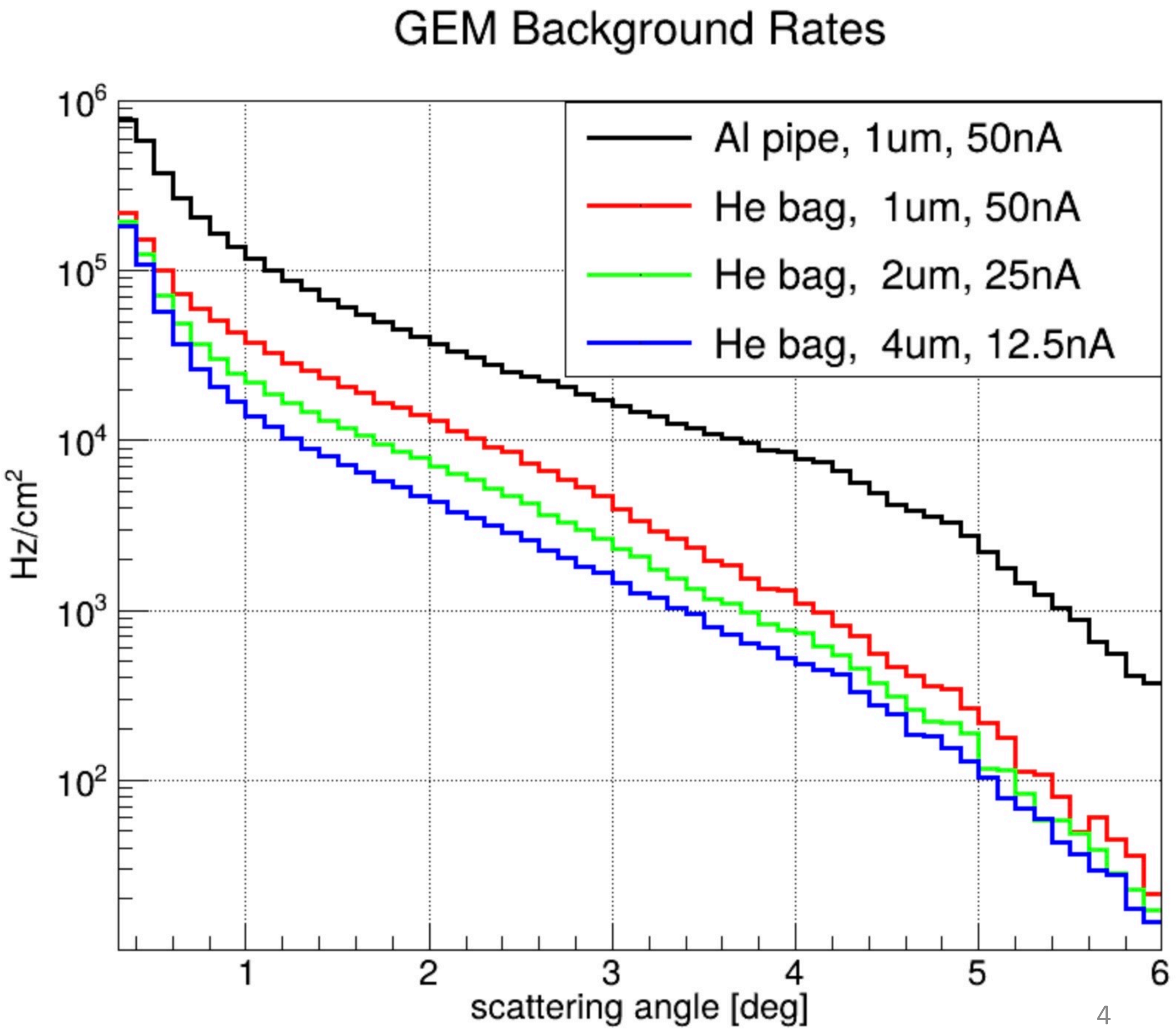


1st open layer max dose: 100 rad/h
2nd open layer max dose: 30 rad/h

Aluminum Pipe V.S. He4 Bag

- GEM background rate increased by ~5 times with aluminum pipe, very decisive factor to use He4 bag, see the next talk by Yuan
- Even with He4 bag, the GEM rate is already very high, bg increasing by another factor of 5 will likely make it useless

We should use the He4 bag



Large or Small Absorber (HyCal Flux Rate)

- Condition: 2.2 GeV, 1um Ta, 50nA
- First open may have ~2MHz flux rate per module if using regular absorber, significant reduction if using larger one
- But with fADC, the flux rate at 2MHz should be manegable, so not a stopper for using the smaller one

E > 20 MeV [MHz]

0.58	1.5	2.3	2.4	1.5	0.6
1.3	Small Absorber He pipe E > 20 MeV [MHz]				1.3
2.2					2.4
2.2					2.3
1.4					1.3
0.59	1.5	2.4	2.3	1.5	0.59

0.19	0.31	0.58	0.69	0.69	0.57	0.30	0.20
0.35	Large Absorber He pipe						0.30
0.50							0.50
0.65							0.66
0.67							0.65
0.50							0.50
0.31							0.31
0.20	0.31	0.57	0.70	0.71	0.58	0.30	0.19

E > 50 MeV [MHz]

0.34	0.9	1.4	1.4	0.93	0.35
0.8	Small Absorber He pipe E > 50 MeV [MHz]				0.78
1.3					1.4
1.3					1.4
0.81					0.74
0.32	0.89	1.4	1.4	0.96	0.34

0.10	0.16	0.32	0.38	0.38	0.32	0.16	0.10
0.17	Large Absorber He pipe						0.16
0.27							0.27
0.36							0.36
0.37							0.36
0.27							0.27
0.16							0.15
0.10	0.16	0.32	0.39	0.40	0.33	0.16	0.10

Large or Small Absorber (HyCal Flux Rate)

- Target Thickness: 1.0 µm
- Beam Current: 50 nA

0.58	1.5	2.3	2.4	1.5	0.6
1.3	Small Absorber				1.3
2.2	He pipe				2.4
2.2	E > 20 MeV				2.3
1.4	[MHz]				1.3
0.59	1.5	2.4	2.3	1.5	0.59

0.34	0.9	1.4	1.4	0.93	0.35
0.8	Small Absorber				0.78
1.3	He pipe				1.4
1.3	E > 50 MeV				1.4
0.81	[MHz]				0.74
0.32	0.89	1.4	1.4	0.96	0.34

- Target Thickness: 2.0 µm
- Beam Current: 25 nA

0.51	1.5	2.2	2.2	1.5	0.51
1.2	Small Absorber				1.2
2.2	He pipe				2.2
2.2	E > 20 MeV				2.1
1.2	[MHz]				1.2
0.51	1.4	2.3	2.3	1.4	0.51

0.3	0.9	1.3	1.3	0.93	0.3
0.72	Small Absorber				0.73
1.4	He pipe				1.3
1.3	E > 50 MeV				1.3
0.74	[MHz]				0.75
0.29	0.85	1.3	1.3	0.85	0.3

- Target Thickness: 4.0 µm
- Beam Current: 12.5 nA

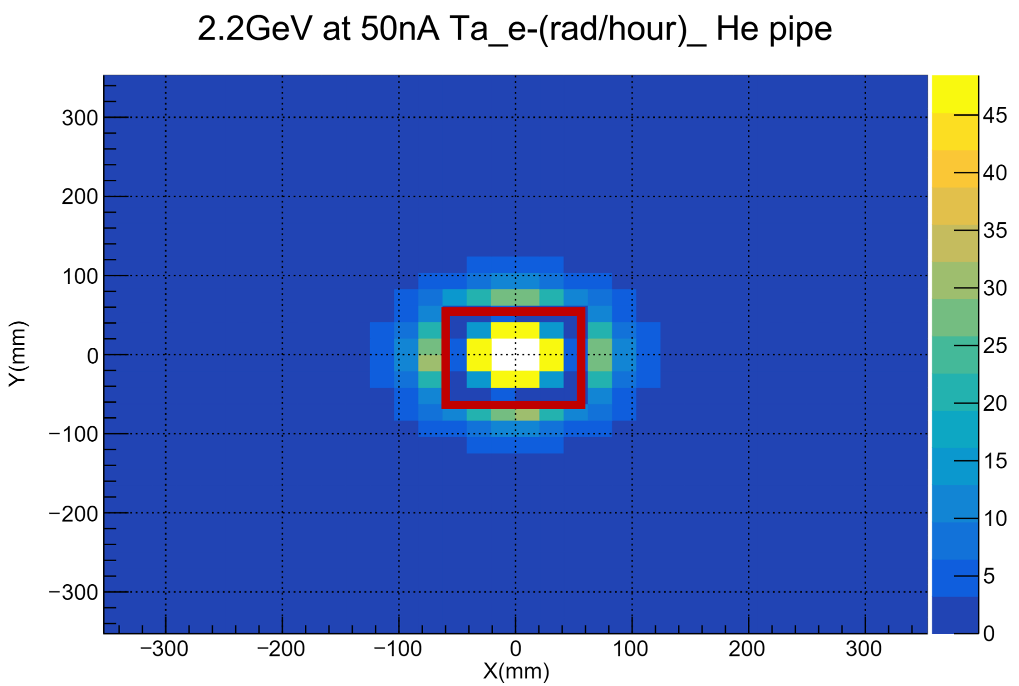
0.5	1.4	2.2	2.2	1.4	0.5
1.2	Small Absorber				1.2
2.1	He pipe				2.2
2.1	E > 20 MeV				2.2
1.2	[MHz]				1.2
0.5	1.4	2.2	2.2	1.4	0.5

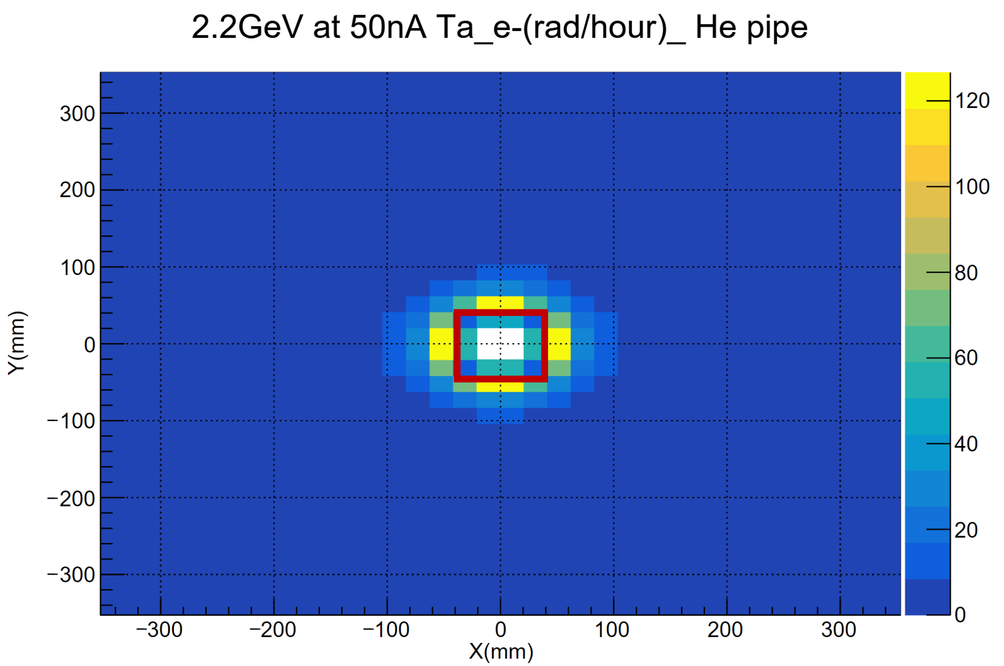
0.3	0.9	1.3	1.3	0.9	0.3
0.7	Small Absorber				0.7
1.3	He pipe				1.3
1.3	E > 50 MeV				1.3
0.7	[MHz]				0.7
0.3	0.9	1.3	1.3	0.9	0.3

- **Beam Energy: 2200 MeV**

Large or Small Absorber (Radiation Damage)

- With the smaller absorber we will have to deal with the high radiation dose on the first open layer crystals
- The hottest module on 1st open layer has:
  - 120 rad/hr for the small absorber
  - 30 rad/hr for the large absorber
- Can HyCal tolerate 120 rad/hr? How much will this affect resolution?

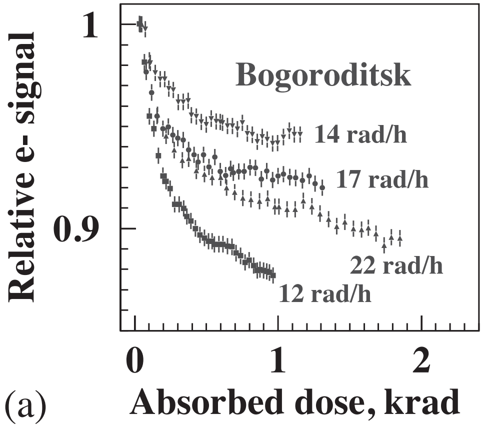


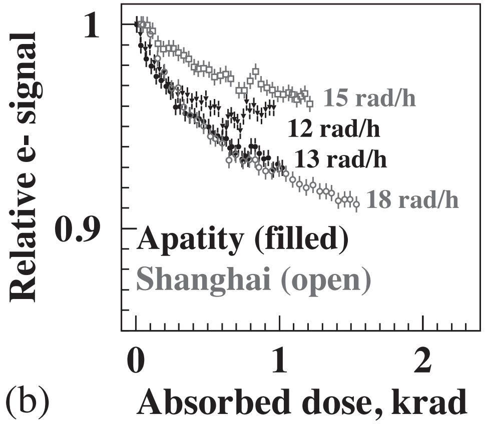


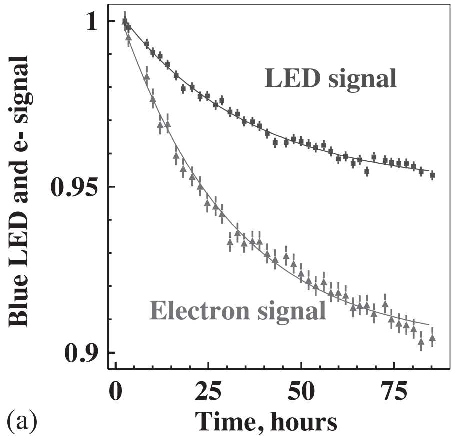
Large or Small Absorber (Radiation Damage)

- HyCal had radiation test before, found stable performance but only at ~10Rad/hr, too low for what we consider here
- Batarin et al, found stable performance at 15 Rad/hr for a few days (PRA 512 (2003) 488–505)

- Previously we consider running X17 before PRad, so we set 15 Rad/hr as bar to protect HyCal as much as possible
- There is no indication that PbWO4 cannot tolerate ~100 Rad/hr







Large or Small Absorber (Radiation Damage)

- In fact, Batarin et al, done measurements with much higher radiation in the same paper (PRA 512 (2003) 488–505)
  - 500 - 1000 rad/hr, 20-25% light output loss
  - 100 krad/hr, cumulated 2.5 MRad, 2/3 of light output loss
  - Nevertheless light loss saturates, if dose rate reduced, light output recovers

- NPS collaboration also reported measurement at 260 rad/hr with 300 krad cumulated dose (https://wiki.jlab.org/cuawiki/images/c/ce/Nps19nov-v2.pdf)
  - No notable damage to the optical properties of $PbWO_4$ was observed within the uncertainty of the transmittance measurements

- There is no strong evidence that our $PbWO_4$ will not survive at 120rad/hr, though resolution might be somewhat affected:
  - Can we do some optical simulation for that?

Large or Small Absorber (Radiation Damage)

- What we can do to safely monitor radiation and resolution during the experiment:
  1. Have a mature online radiation damage monitor system, using LMS to monitor gain
  2. Online reconstruction, using elastic ep and ee to monitor resolution run by run (or event multiple time during a run)
  3. Start the experiment with radiation level below 15 Rad/hr, slowly increase luminosity
  4. Having the LMS signal collected at low rate (~Hz), instead of at the beginning of a run
  5. Lower the luminosity if needed (Rafo's study suggest we may gain with smaller absorber even at high the luminosity)
  6. Using LED light to cure whenever we have down time?
  7. In worse case, we can apply software cut to remove hits from the 1^{st} layer open ones

Summary

- We need He4 bag configuration for the X17 due to background on GEM
- With smaller HyCal absorber, flux rate on 1st open crystal at the level of ~2MHz per module, should be manegable with fADC
- Radiation dose will go beyond 100 Rad/hr with the smaller absorber
    - No strong evidance that crystall will be severely damaged at this level, though light output will certainly get a bit lower, some optical simulation might be helpful
    - Need to develop a mature online monitoring system (in progress) and careful run plan and procedures