

HEIC-Cube 10 layers SPS + PS beam test

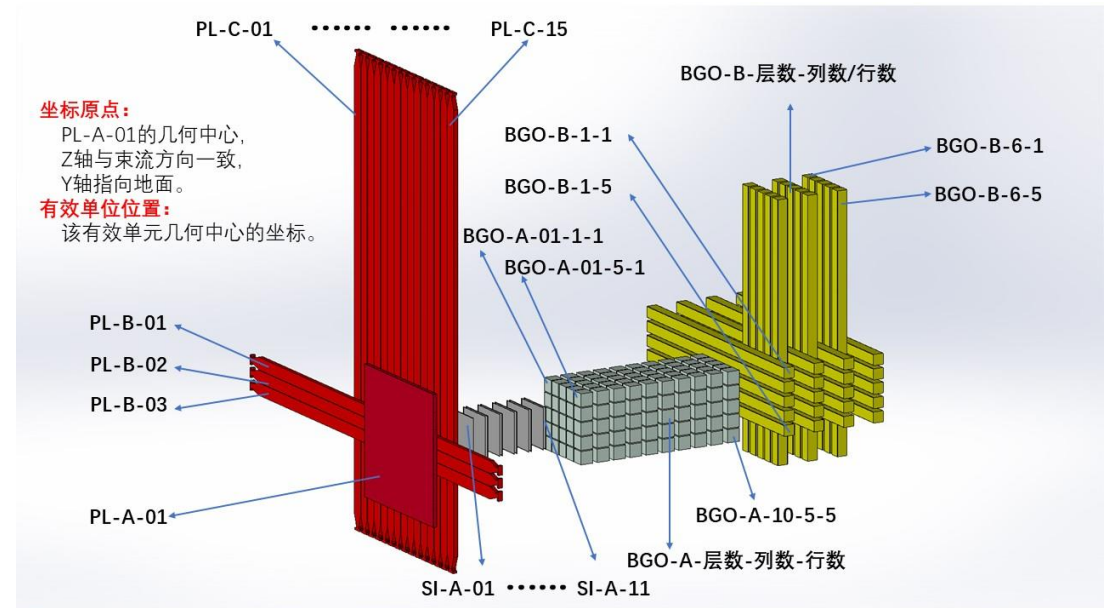
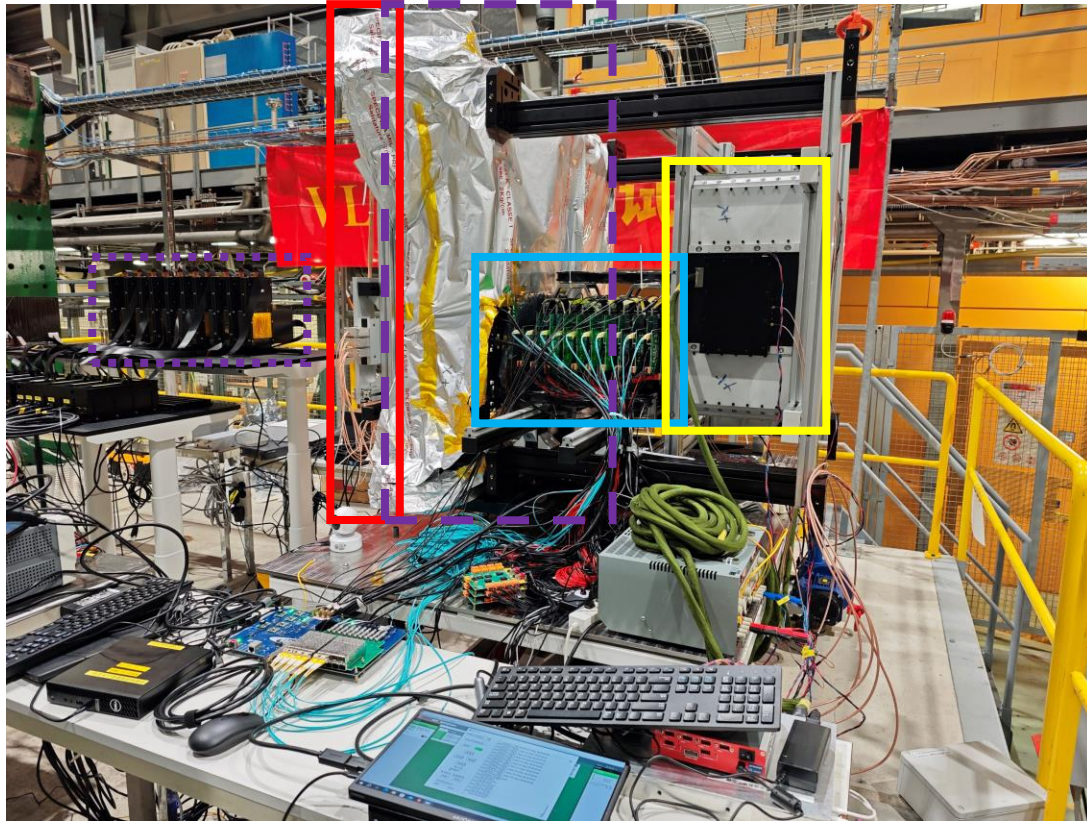
张研硕

2024.06.23

Content

- VLAST prototype, HEIC-Cube prototype and beam test team group;
- SPS beam test items, basic parameters calibration and high energy electron spectrums;
- PS beam test items, basic parameters calibration, electron energy spectrums and APD response to direct ionization;

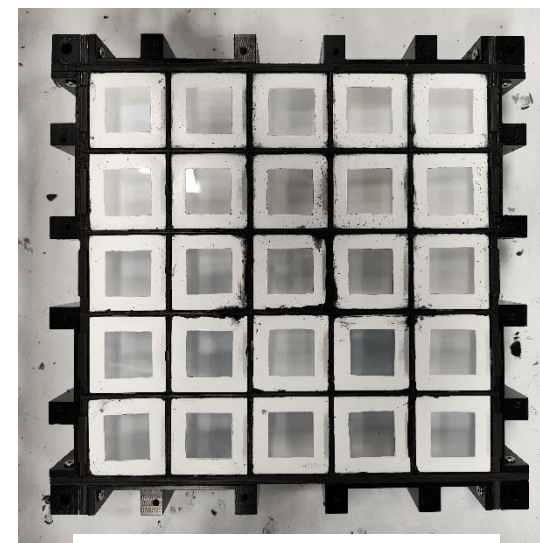
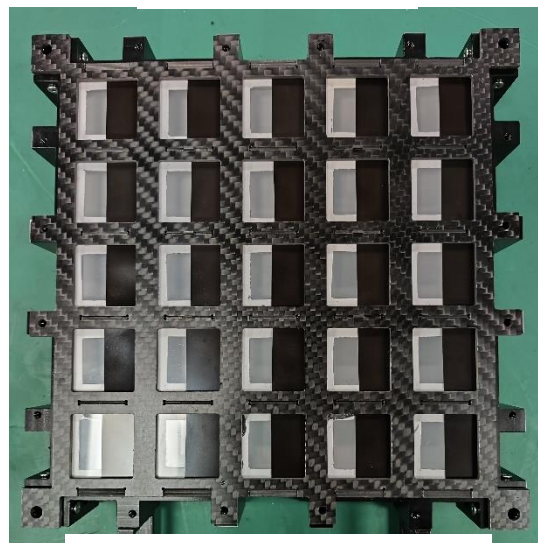
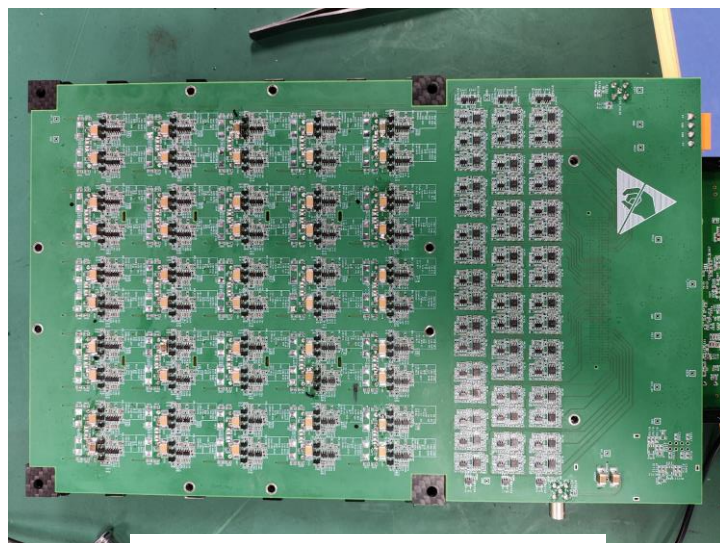
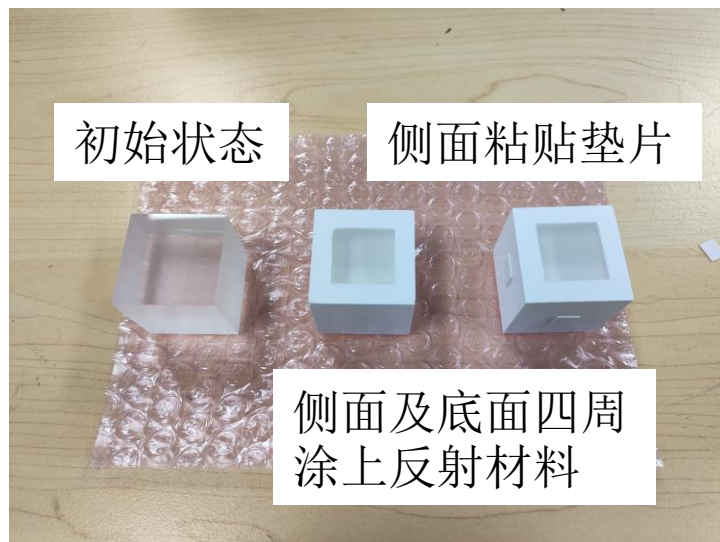
VLAST prototype



Effective detector units

HEIC-Cube 样机—探测器部分

胡一鸣、陈灯意 老师



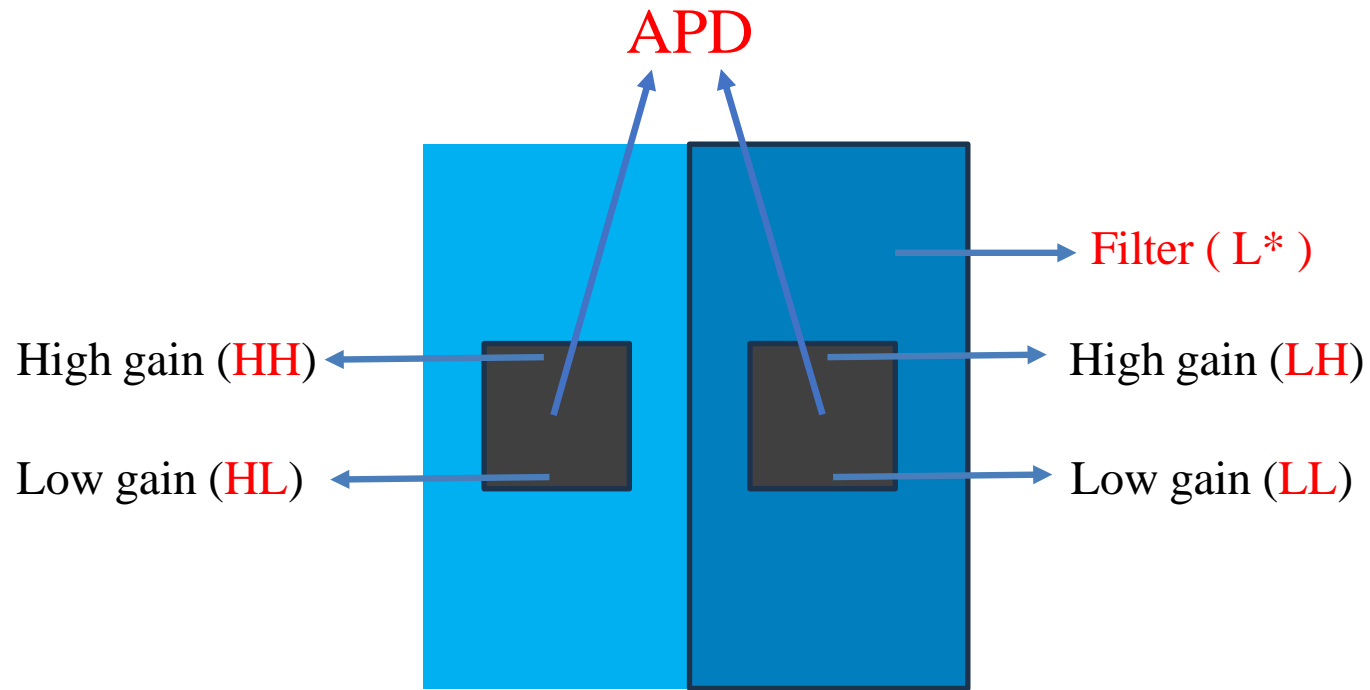
扣合前端板组成一层

盖上遮光片和隔板

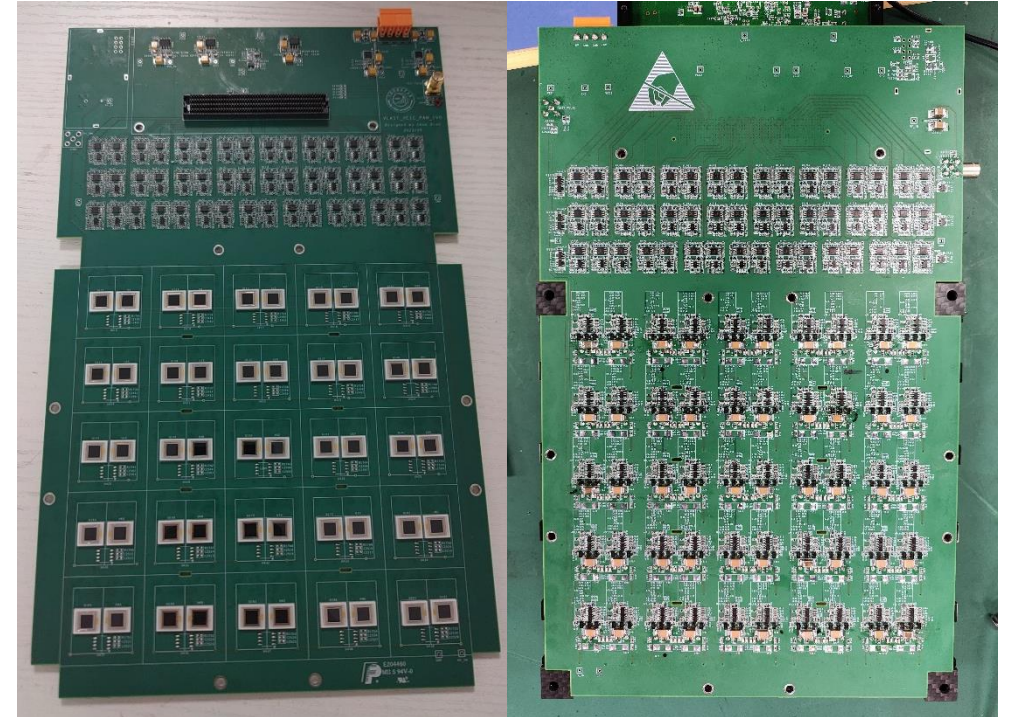
所有晶体粘贴完成

HEIC-Cube 样机—电子学部分

封常青 老师, 陈乾 同学



- HH: 无衰减片 APD 的电子学高增益通道
- HL: 无衰减片 APD 的电子学低增益通道
- LH: 有衰减片 APD 的电子学高增益通道
- LL: 有衰减片 APD 的电子学低增益通道

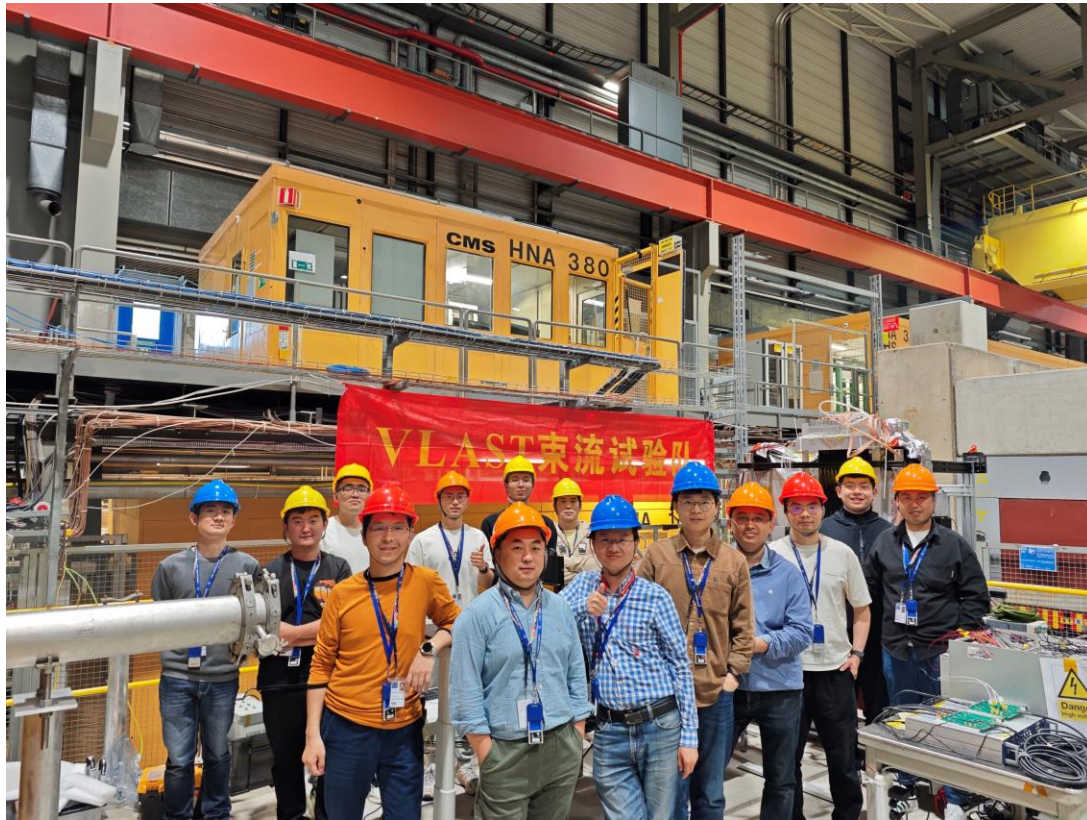


前端电子学的正面及反面照片

HEIC-Cube beam test team group



VLAST prototype beam test team group



SPS – H2, Prevezin site



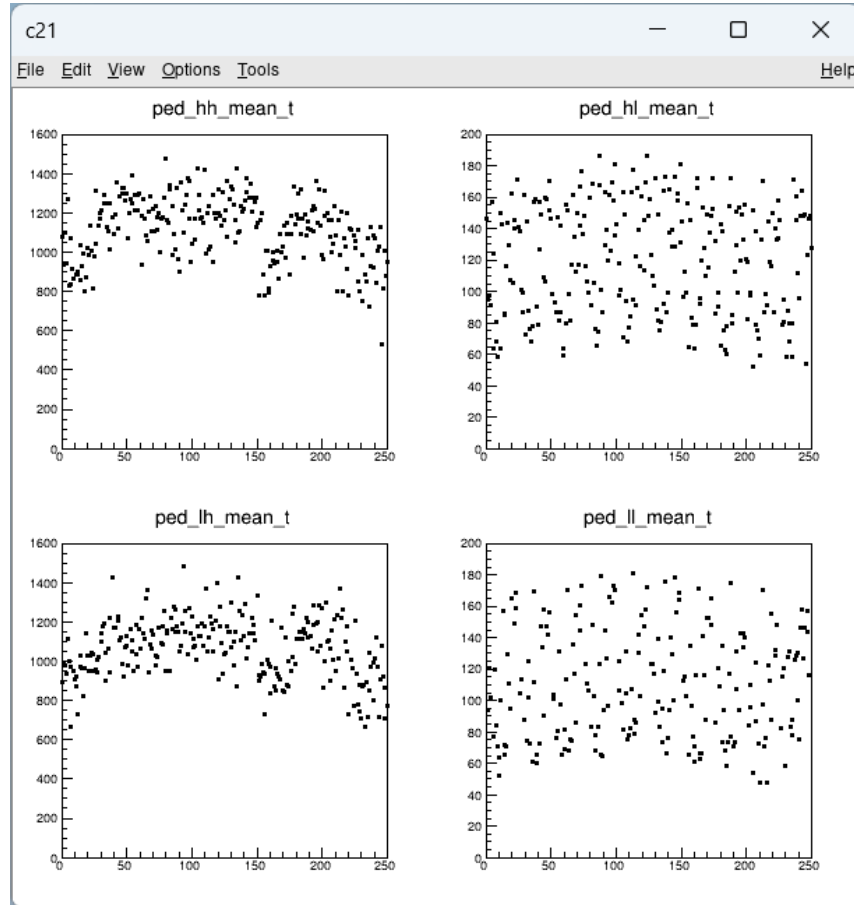
PS – T9, Meyrin site

SPS beam test (5.15 - 5.22)

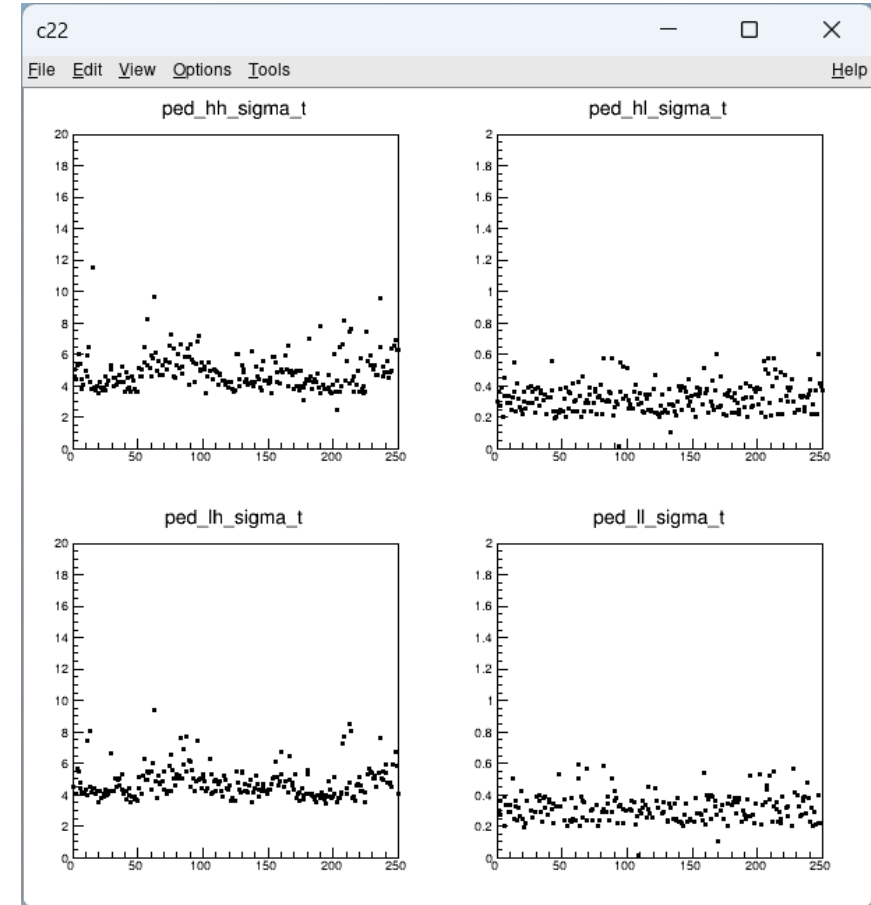
Particle	Momentum (GeV/c)	Counts
μ^-	150	1,950,178
$p + \pi^+$	350	842,425
e^-	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200	457,937; 473,032; 308,943; 320,296; 1,086,973; 325,942; 420,245; 569,088; 428,381; 1,070,706; 508,270; 664,850; 626,896; 866,277; 1,808,245

- RunID10005, 150GeV muon, wide beam;
- Counts: 153710; -- Pedestal, MIPs;
- RunID10008, 350GeV pion + proton;
- Counts: 100959; -- Linear;
- Electron energy spectrum;

150GeV Muon pedestal HH/HL/LH/LL

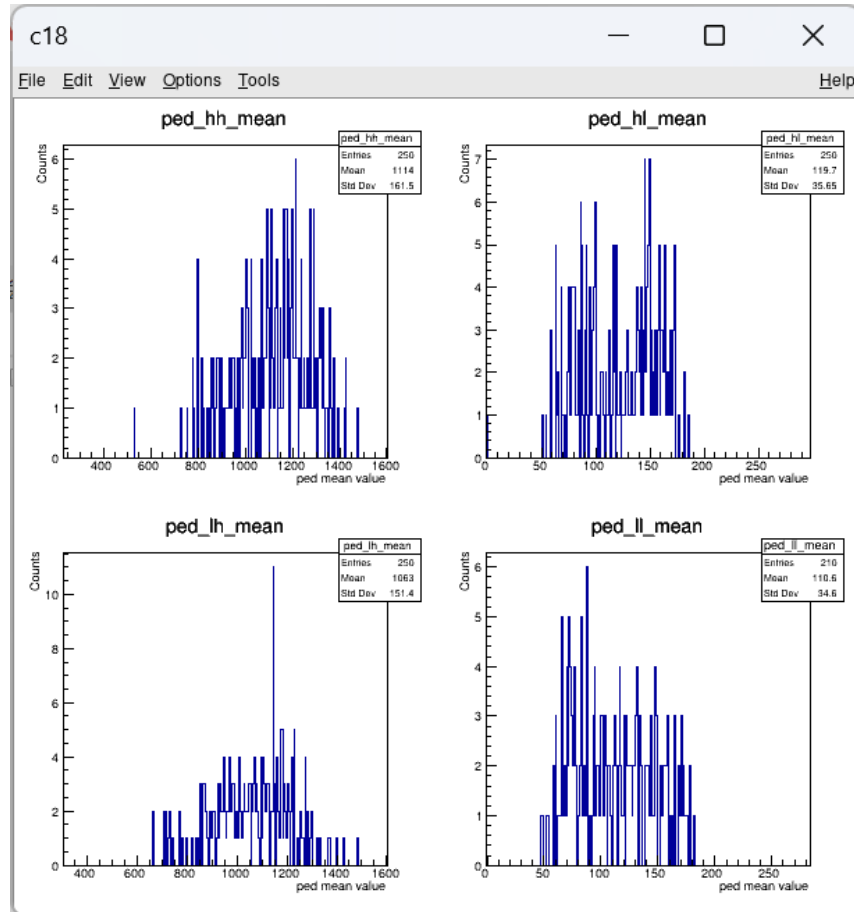


Pedestal HH, HL, LH, LL mean

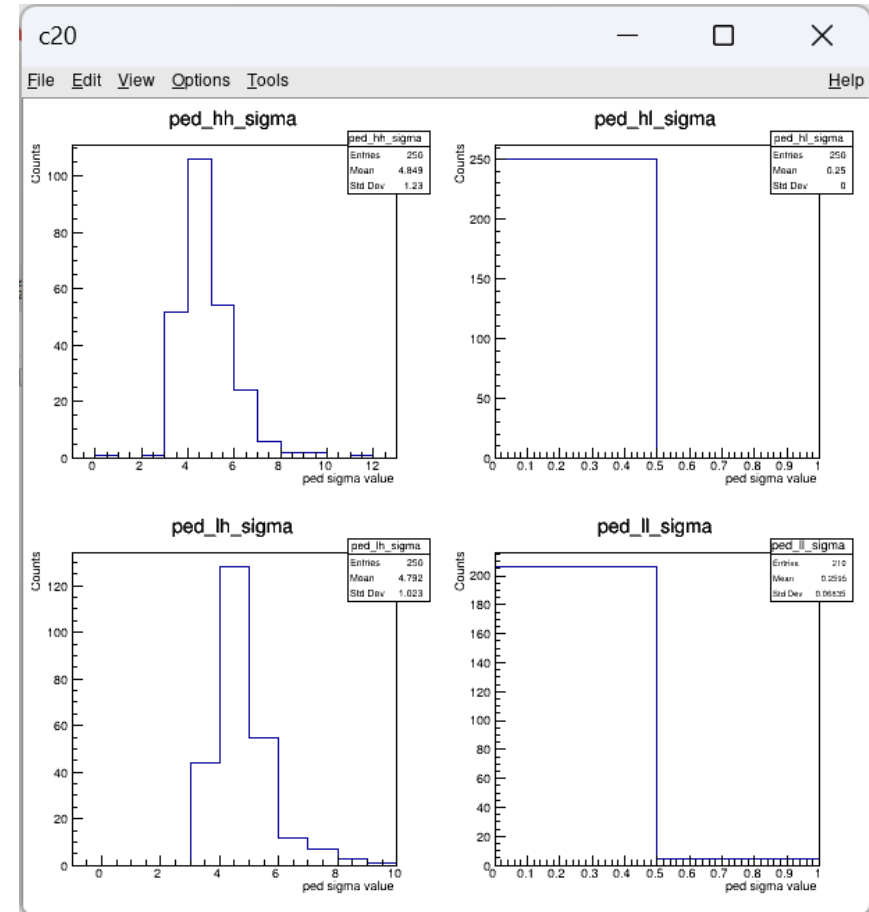


Pedestal HH, HL, LH, LL sigma

150GeV Muon pedestal summary



Pedestal HH, HL, LH, LL mean

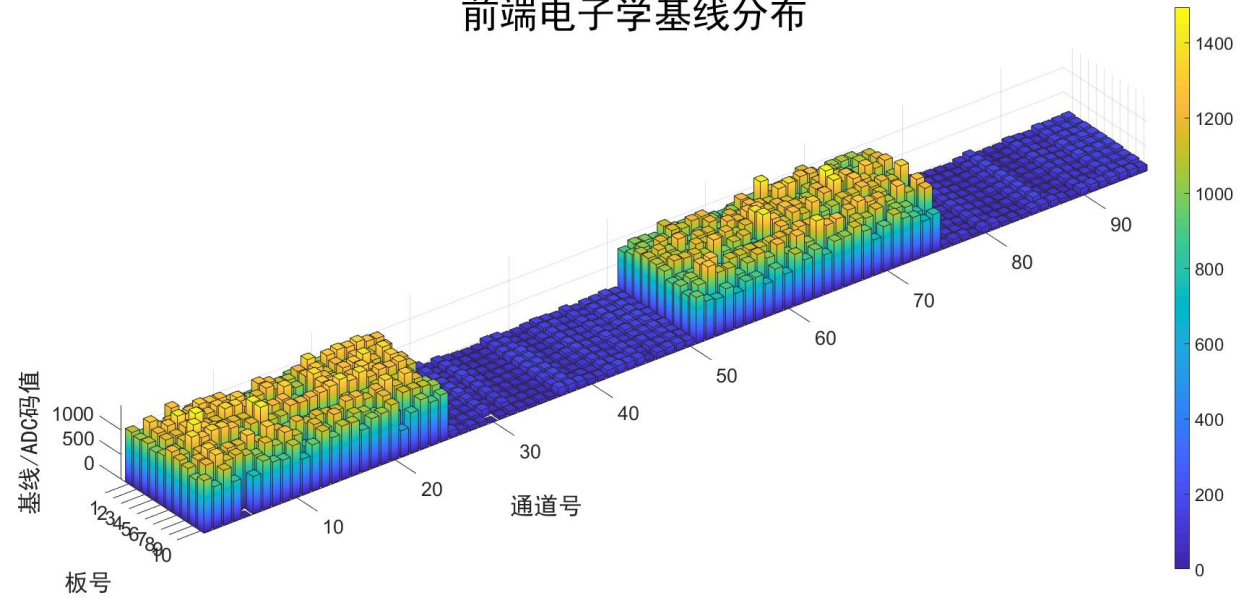


Pedestal HH, HL, LH, LL sigma

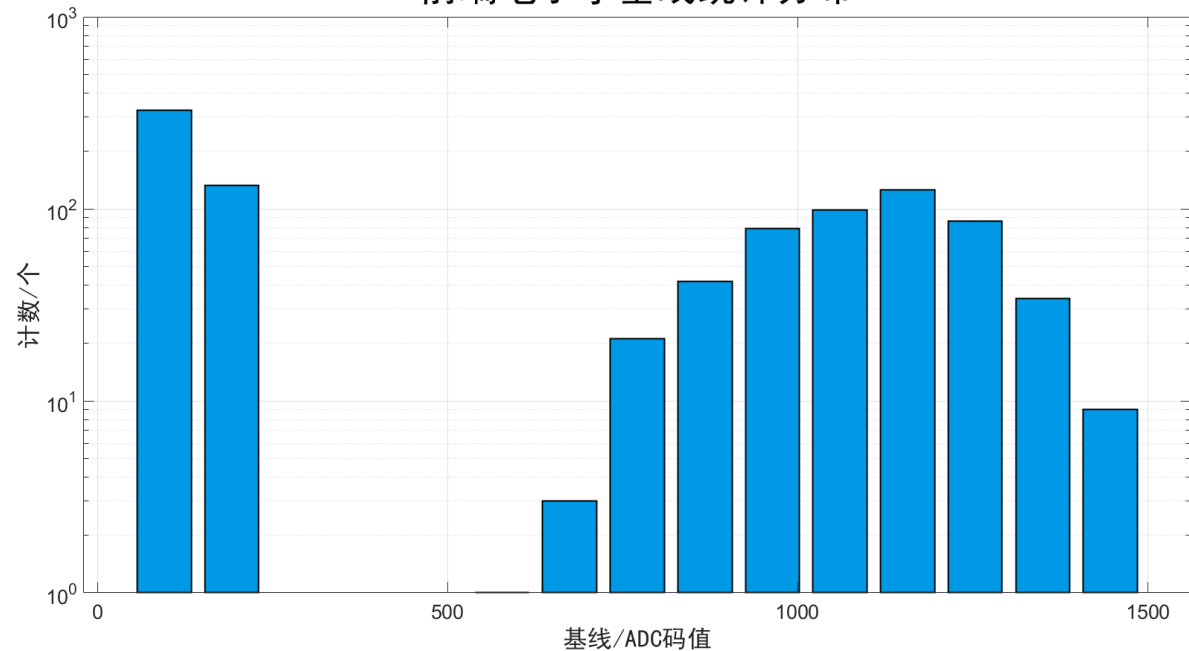
前端电子学基线分布

- 通道号0~24为HH增益
- 通道号25~49为HL增益
- 通道号50~74为LH增益
- 通道号75~96为LL增益

前端电子学基线分布

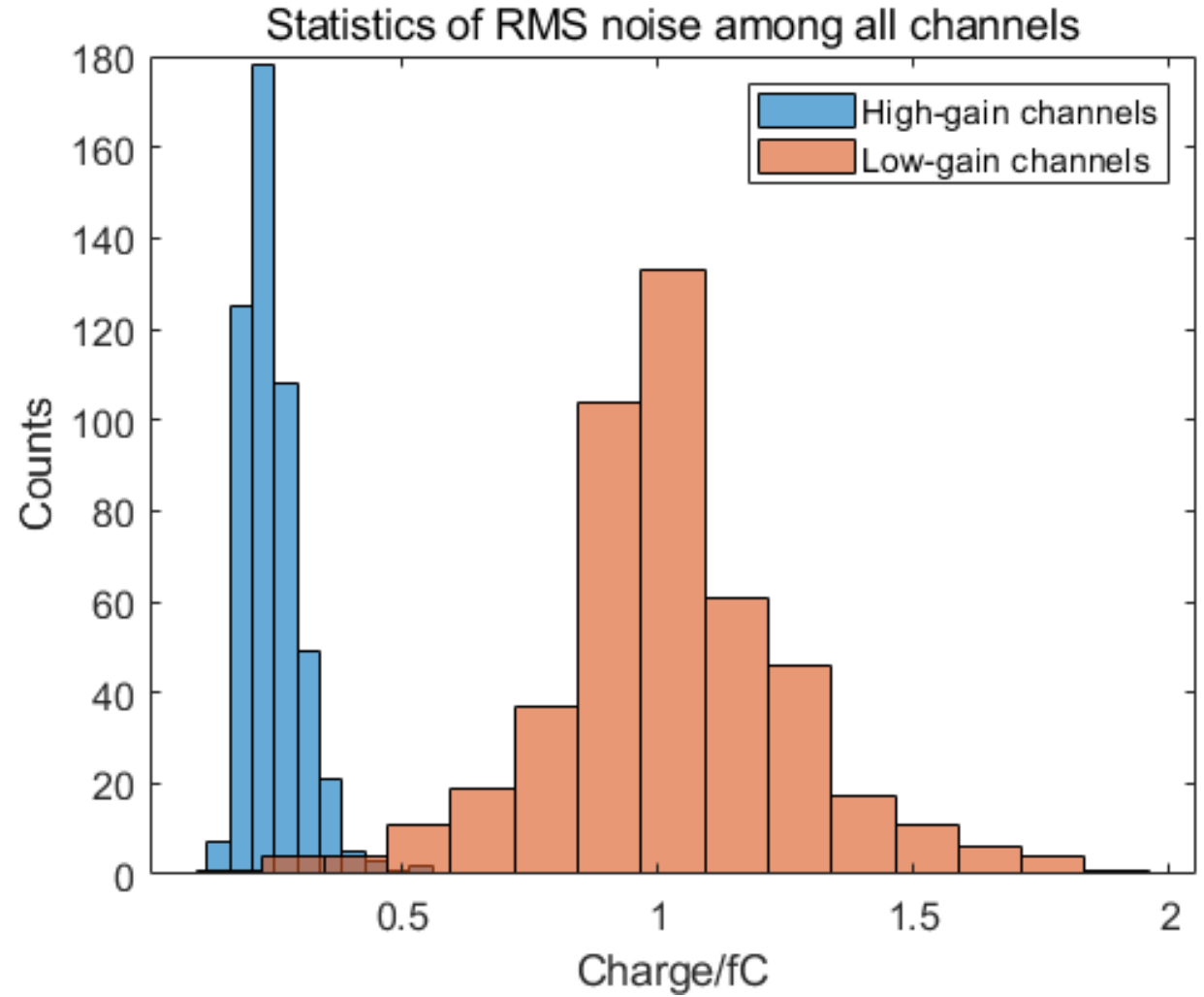


前端电子学基线统计分布



前端电子学噪声

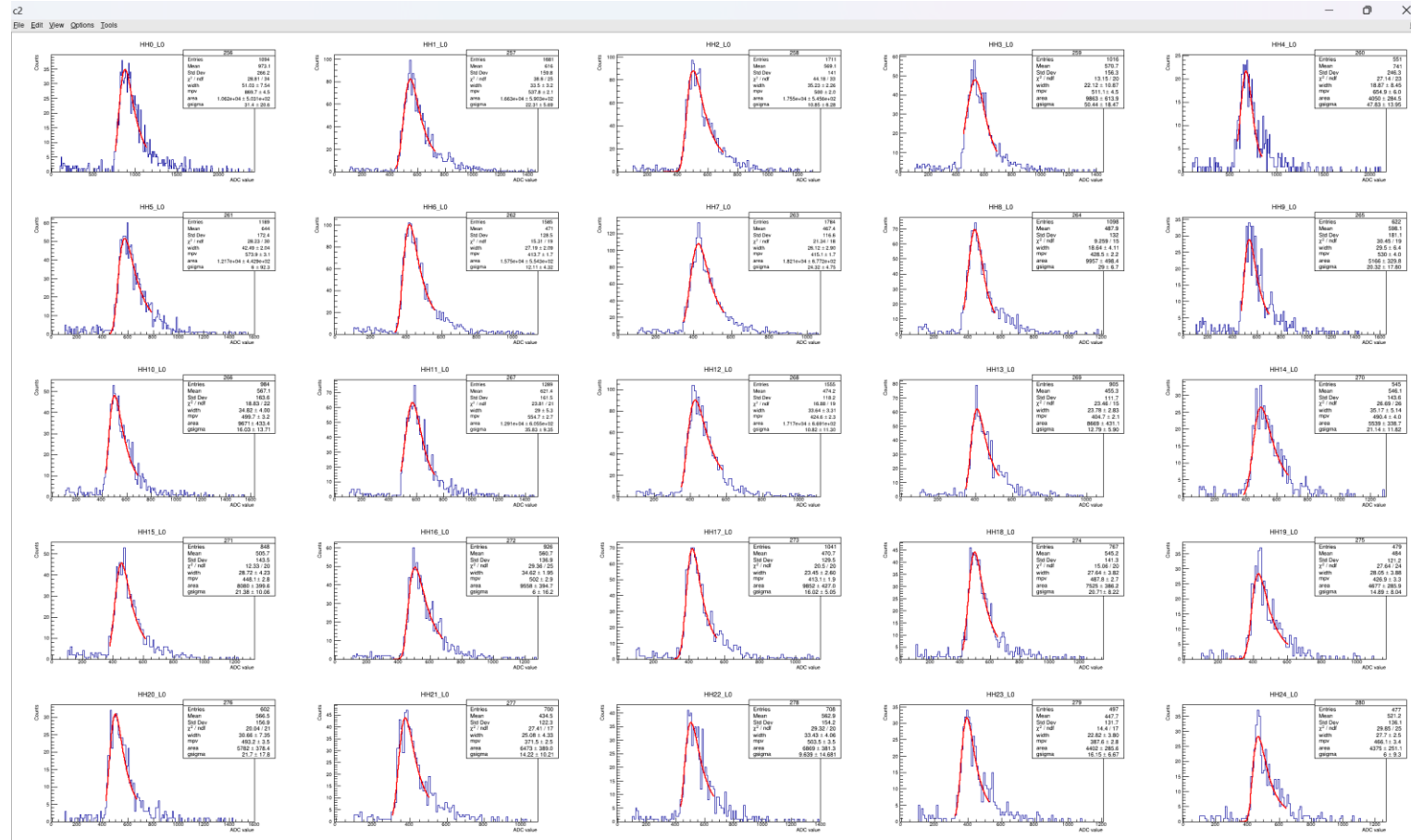
- 电子学低增益通道 (HL和LL)
噪声均**小于 $2fC$**
- 电子学高增益通道 (HH和LH)
噪声均**小于 $0.5fC$**



150GeV Muon MIPs

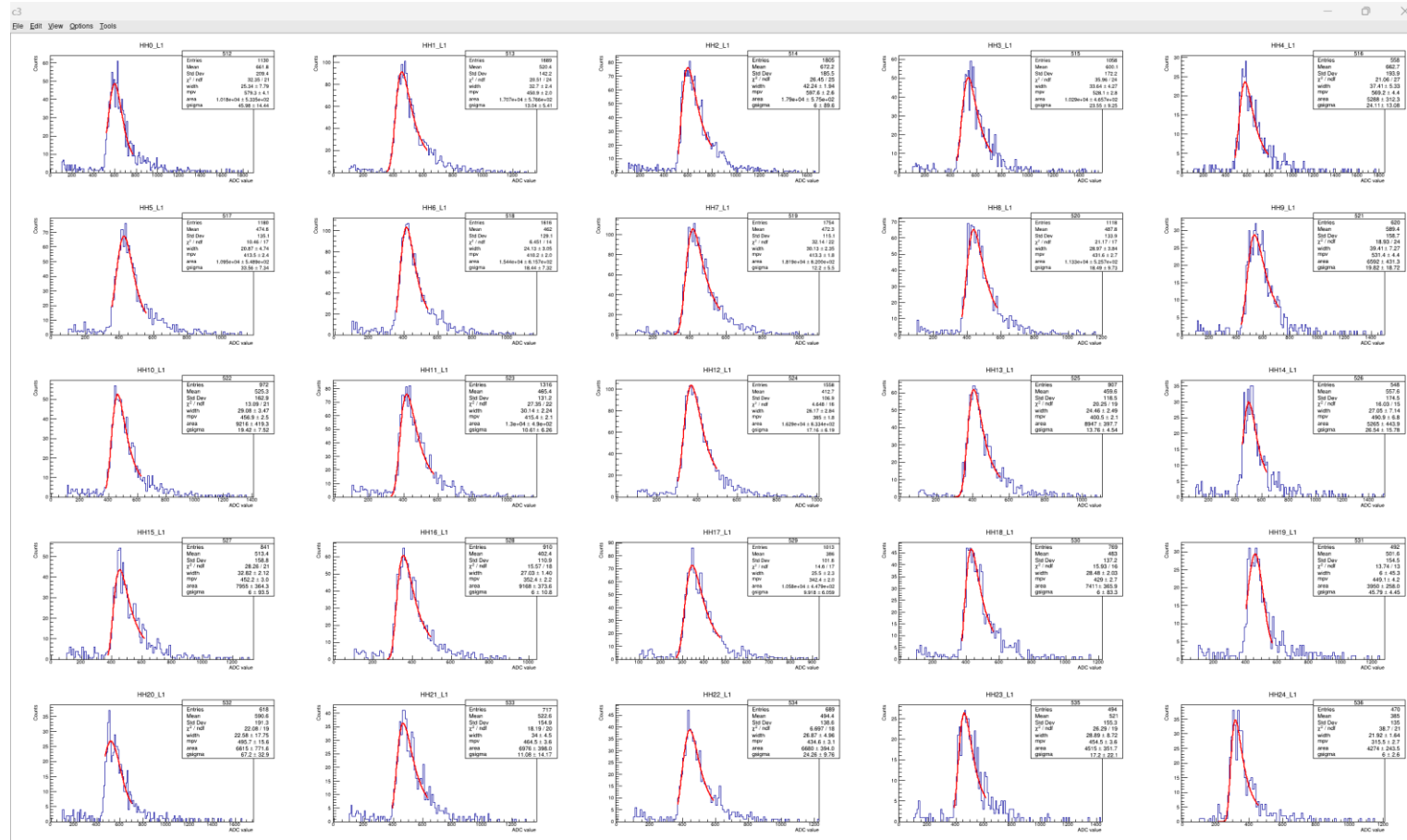
- MIPs 筛选条件：
 - 选取无衰减片高增益通道（HH），要求 $ADC > 25$;
 - 每层有 1 或 2 个 通道被击中;
 - 前3层中至少2层有信号，后3层中至少2层有信号，全部10层中至少7层有信号;

150GeV Muon MIPs layer 0



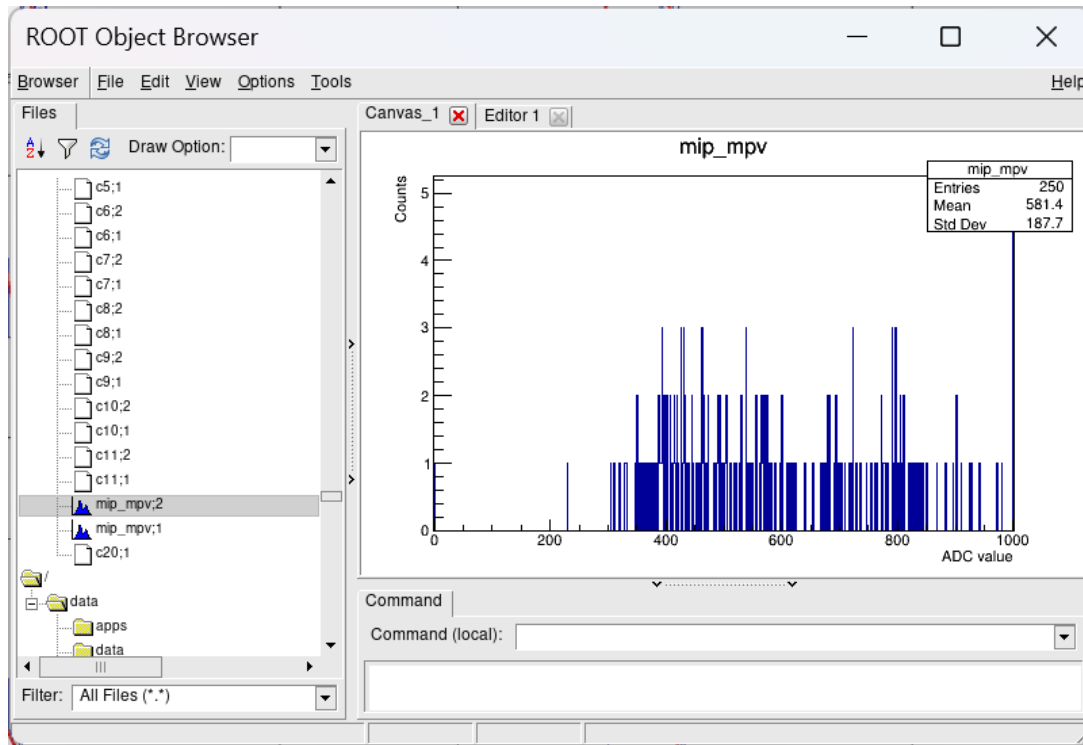
MIPs selection HH0--HH24 layer 0

150GeV Muon MIPs layer 1



MIPs selection HH0--HH24 layer 1

150GeV Muon MIPs summary



MIPs selection mpv collection

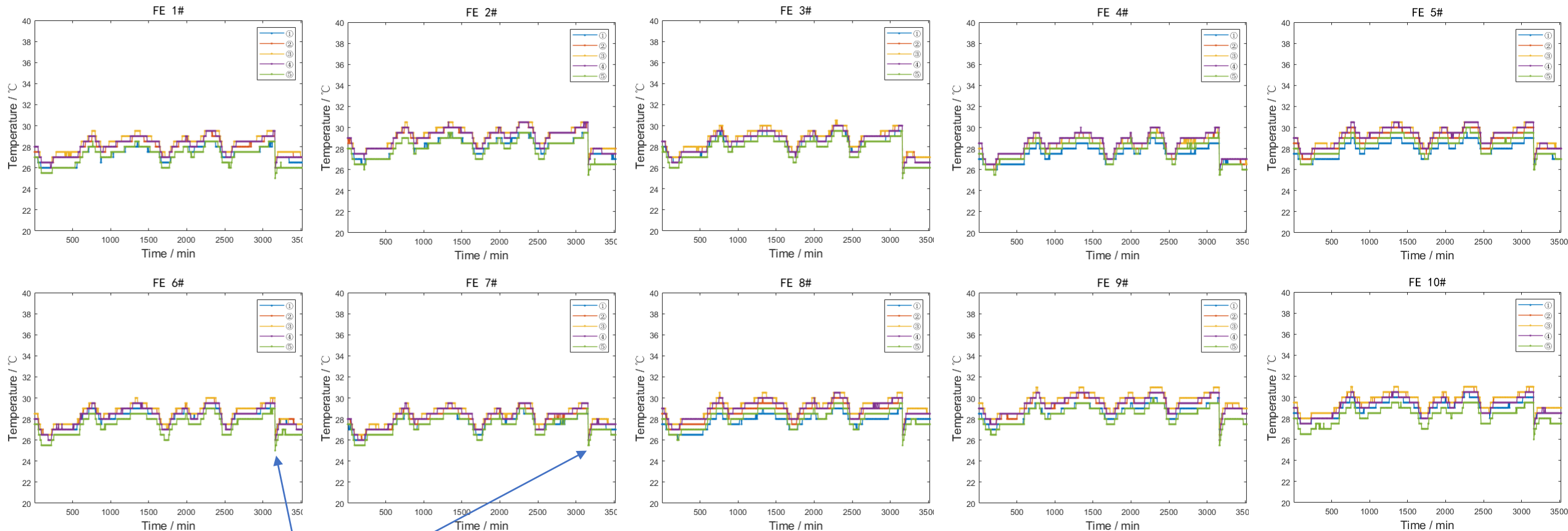
- 拟合得到的所有通道的 MIPs mpv值，分布比较分散；
- 可能与以下因素有关：
 - APD 的温度系数；
 - APD 的工作电压；
 - BGO 晶体的温度系数；

系统温度

➤ SPS测试时温度变化情况

PCB昼夜最大温度变化为4°C

间隔5分钟采集一次温度数据



拆卸安装遮光片后重新装入探测器

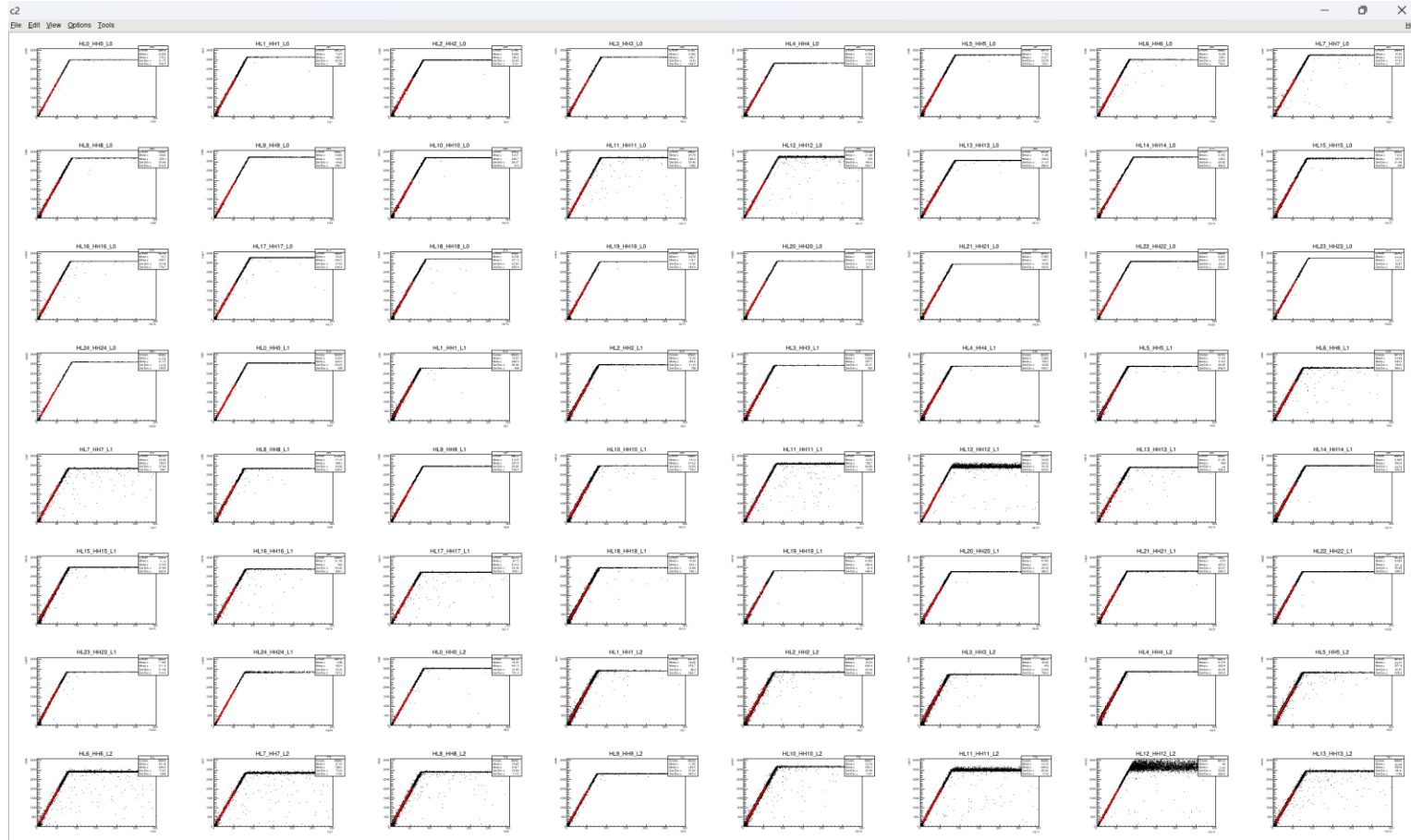
平均温度为27°C

高压电流

➤ 上电稳定后，各层高压电流情况：

板号	1	2	3	4	5	6	7	8	9	10
偏压/V	382	394	385	385	391	382	384	386	388	388
电流/ μ A	0.09	0.09	0.12	0.13	0.12	0.09	0.09	0.08	0.11	0.12

350GeV Pion + proton HL-HH



HL--HH ratio under the same APD

350GeV Pion + proton LH-HL_1

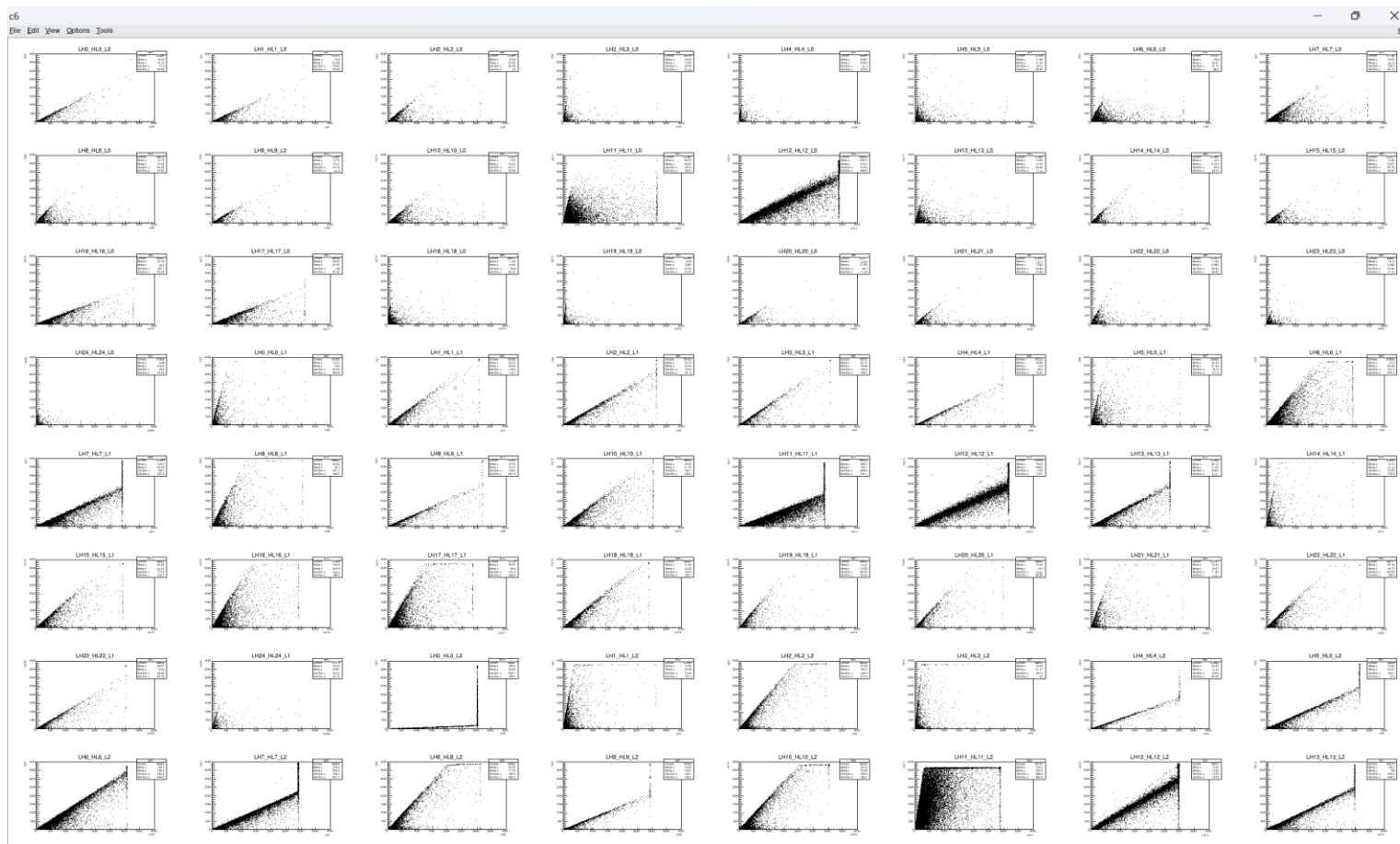
➤ 可以看到明显的主线，但各通道 ratio 不一致，且**主线下方**有很多散点。

➤ Ratio 不一致：

- ① 衰减片衰减倍数不均匀；
- ② 衰减片较软，平展程度不一致，与每块晶体的框架并非完全贴合；
- ③ 部分衰减片位置在安装探测器过程中发生少许移动；

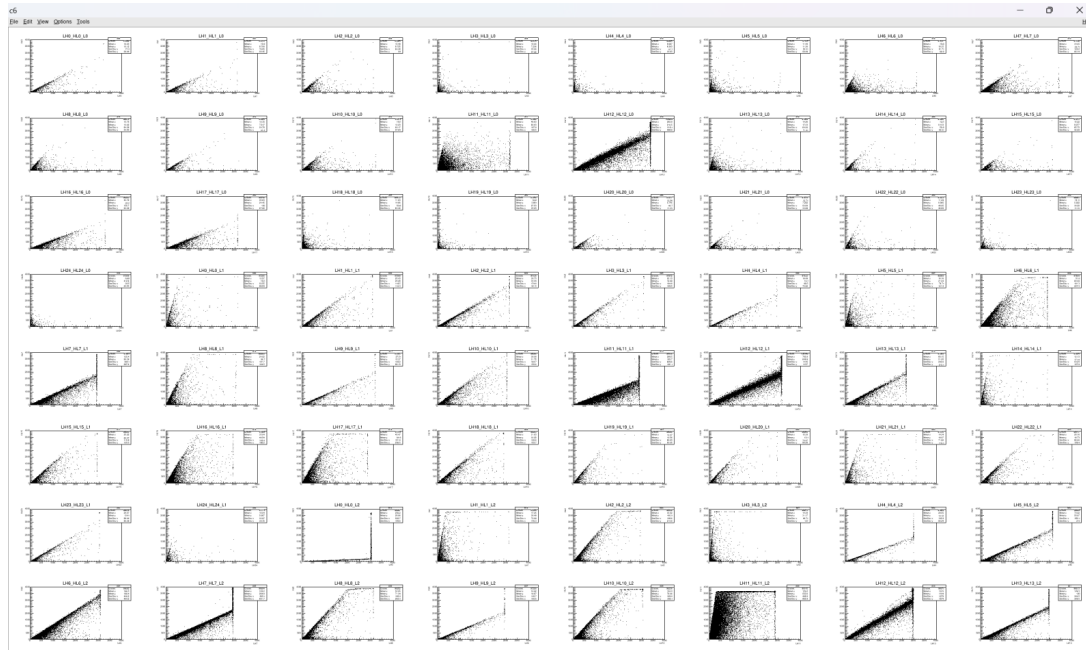
➤ 散点：

- ① **APD被直接电离**，其信号大小相比BGO荧光经衰减后在APD产生的信号不可忽略；
- ② 光衰减片与APD并非紧贴，可能有结构多次反射的荧光；

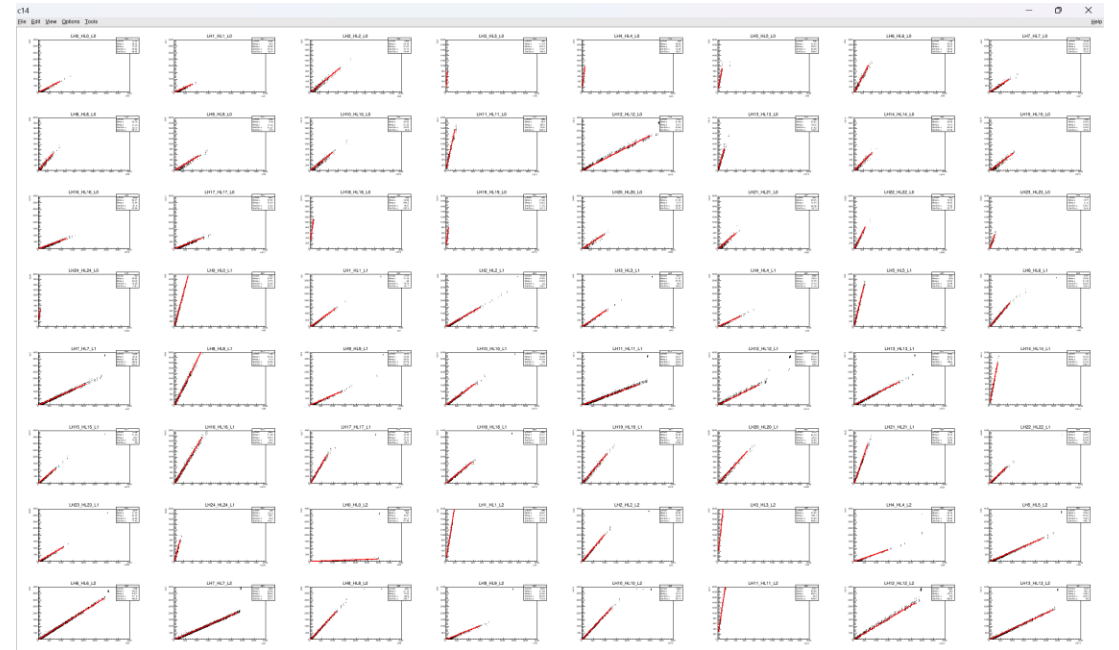


LH--HL ratio between 2 APDs

350GeV Pion + proton LH-HL_2

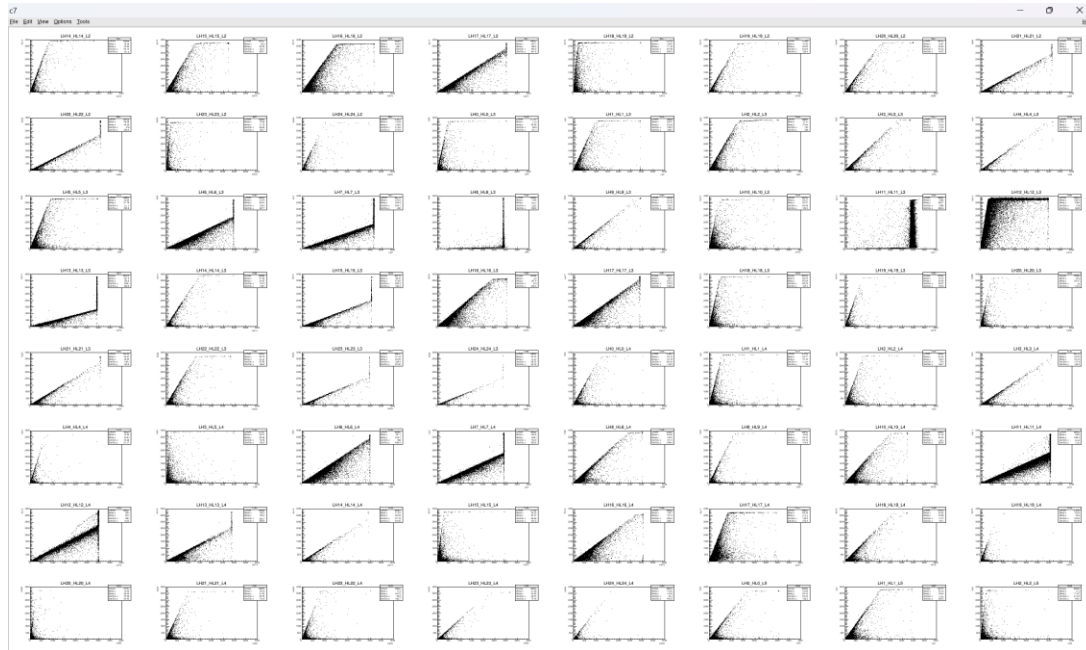


LH--HL ratio between 2 APDs

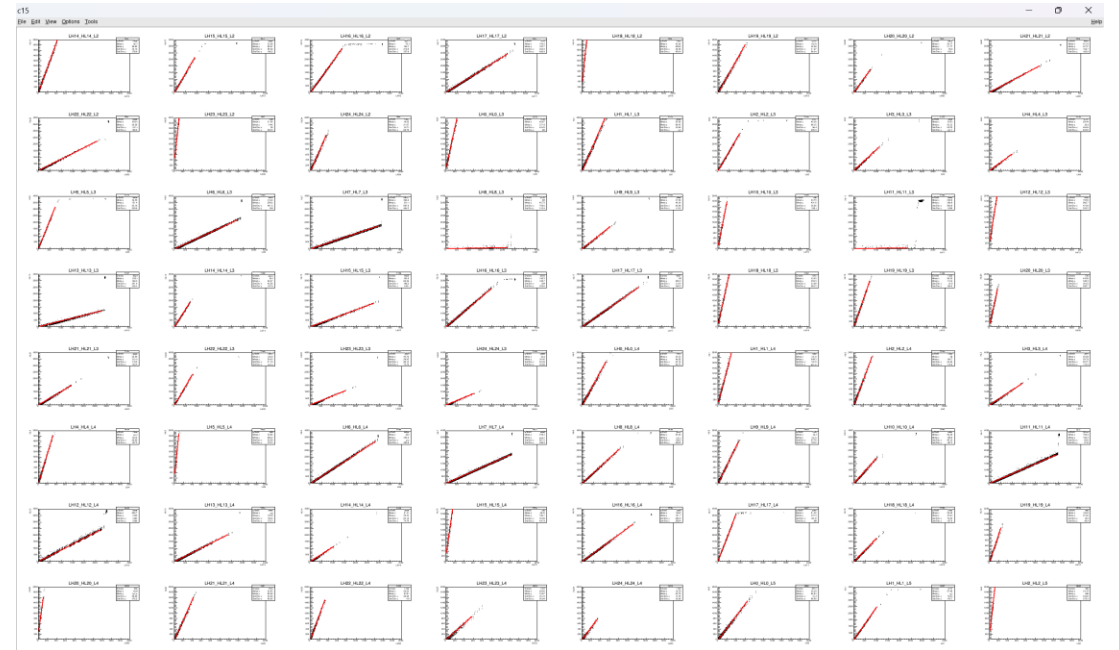


LH--HL ratio after selection

350GeV Pion + proton LH-HL_3

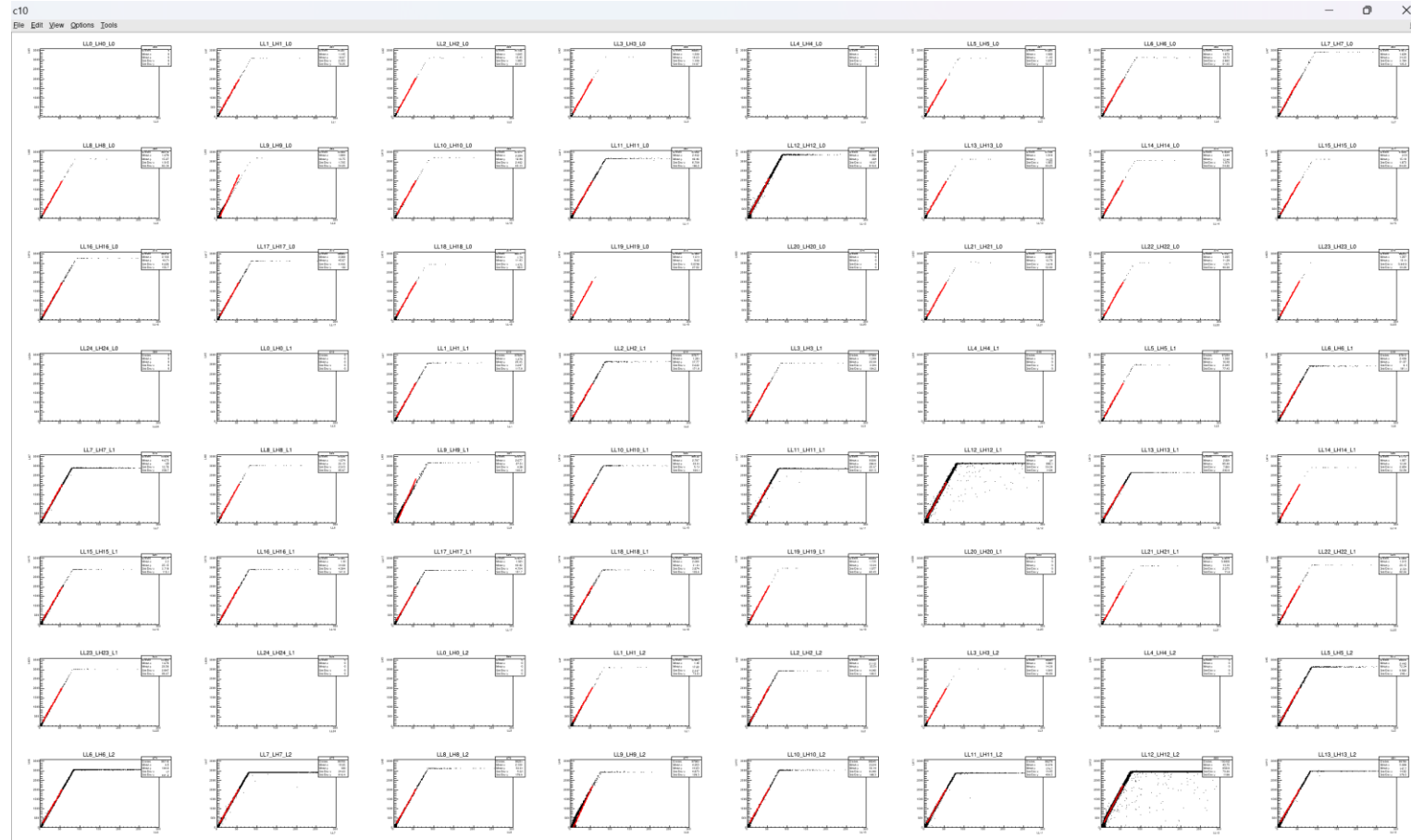


LH--HL ratio between 2 APDs



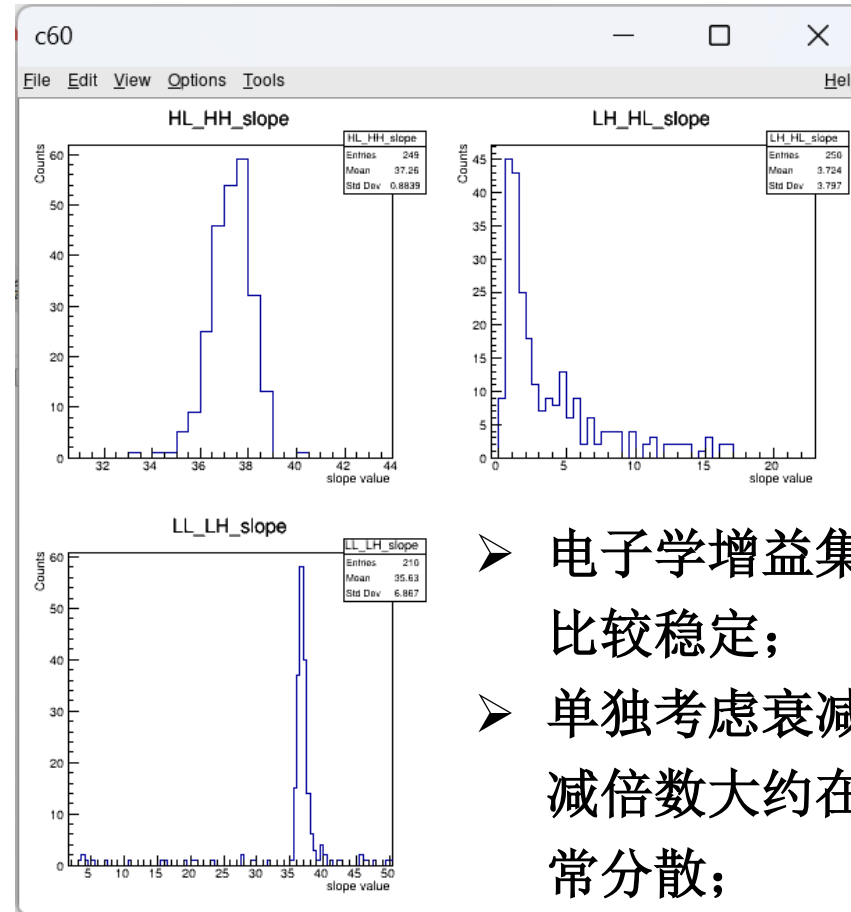
LH--HL ratio after selection

350GeV Pion + proton LL-LH



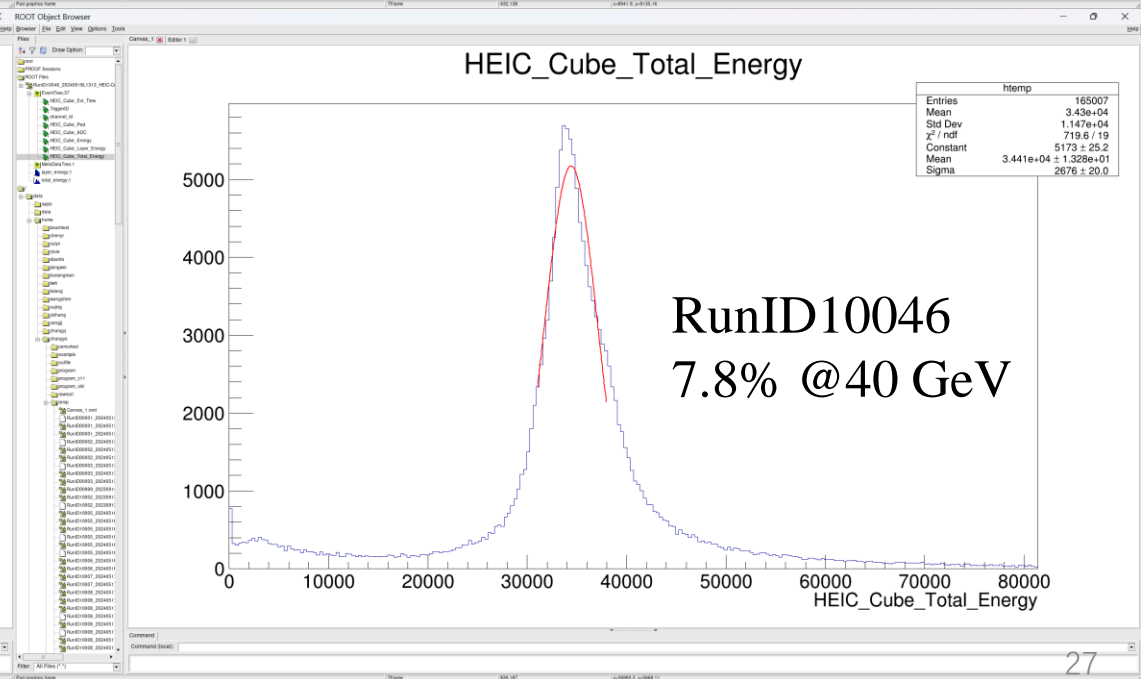
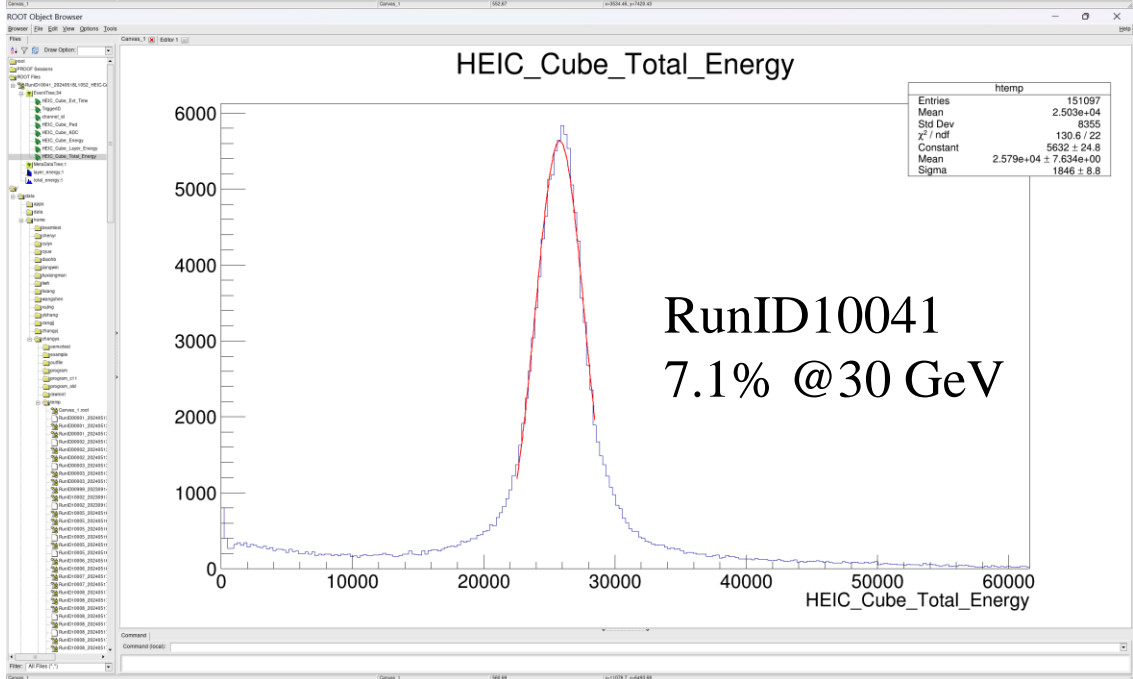
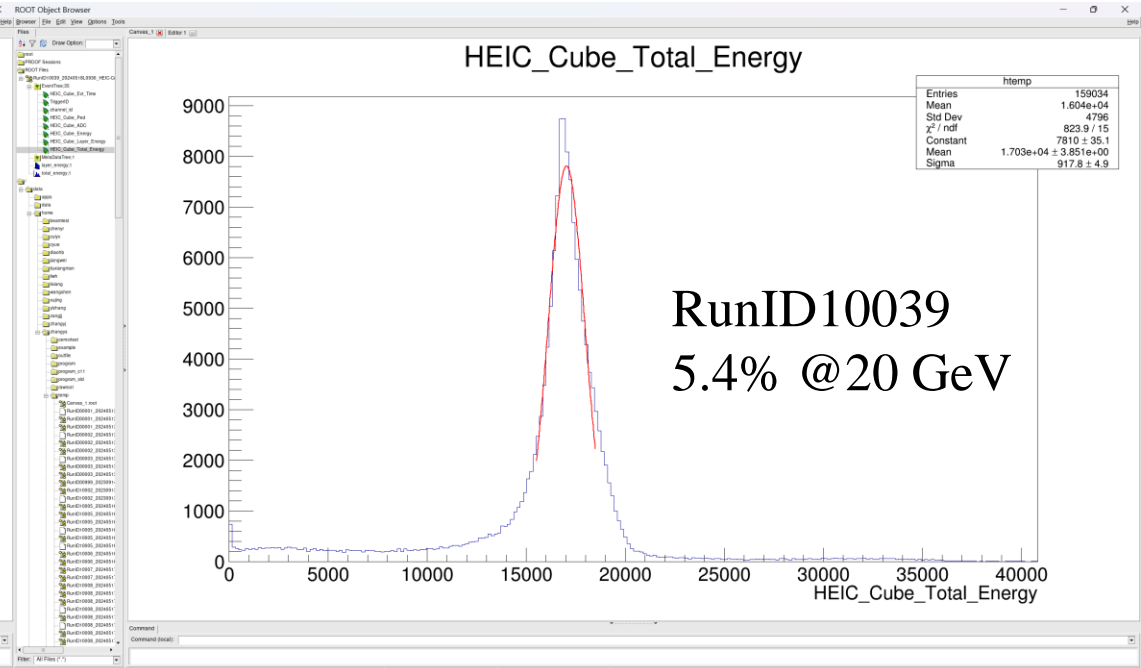
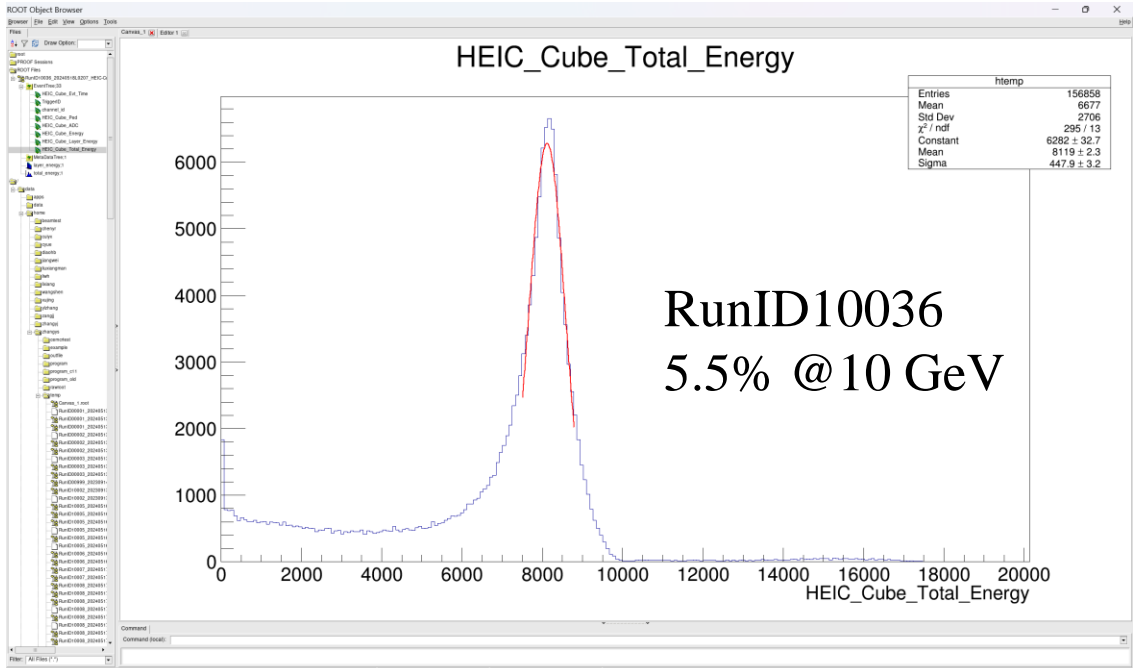
LL--LH ratio under the same APD

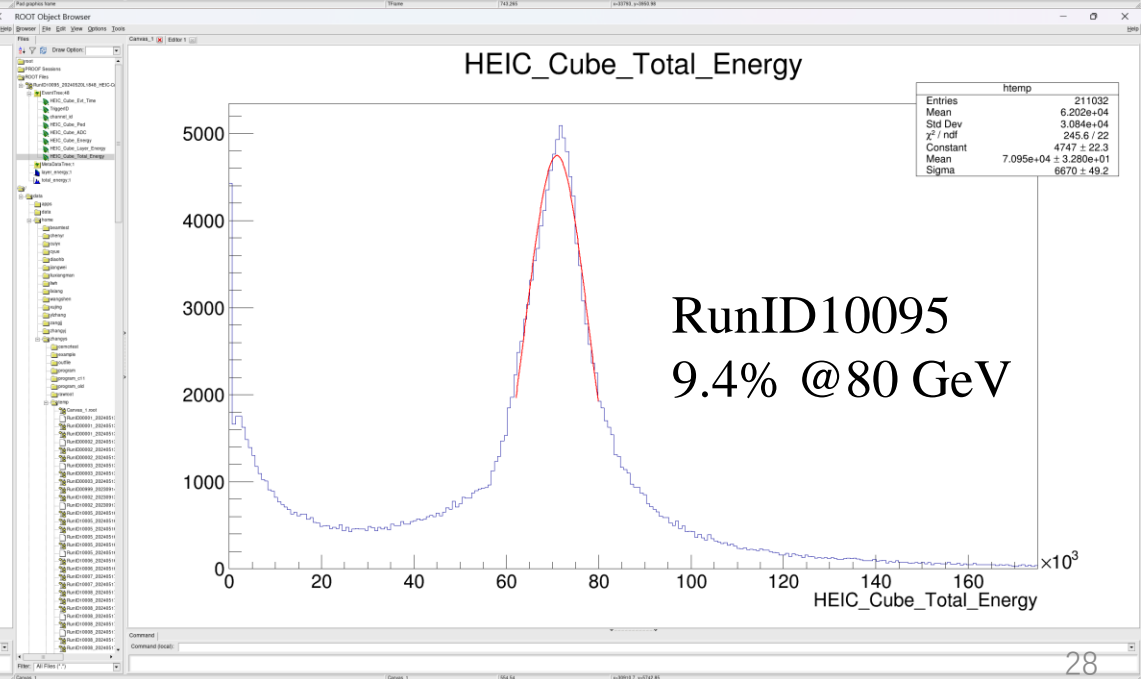
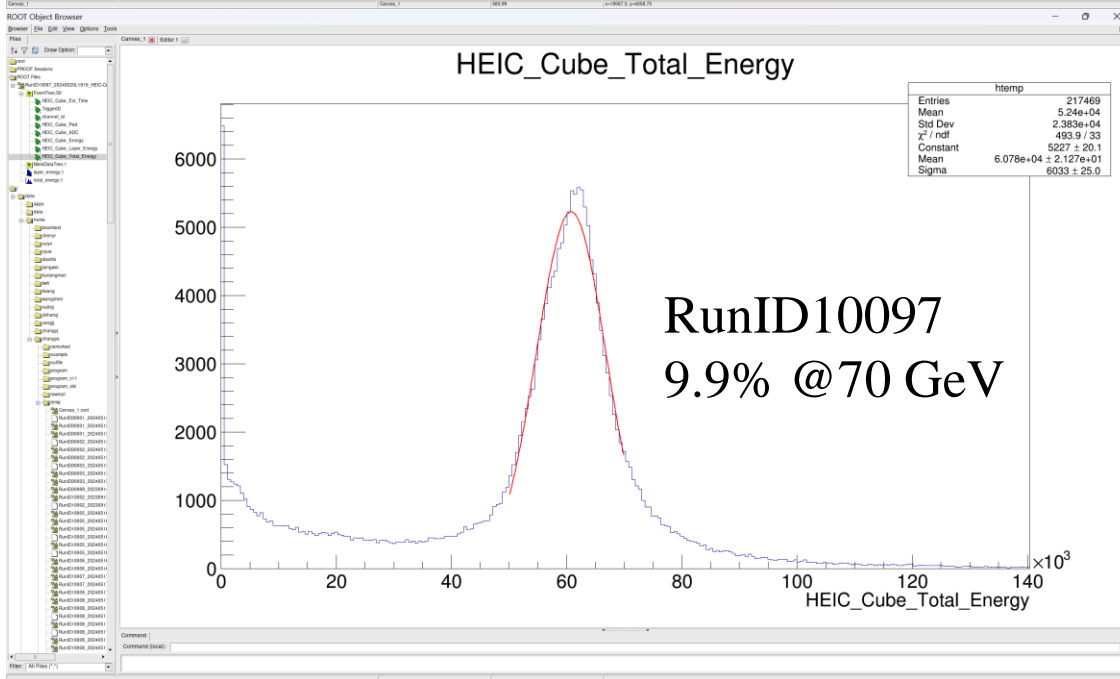
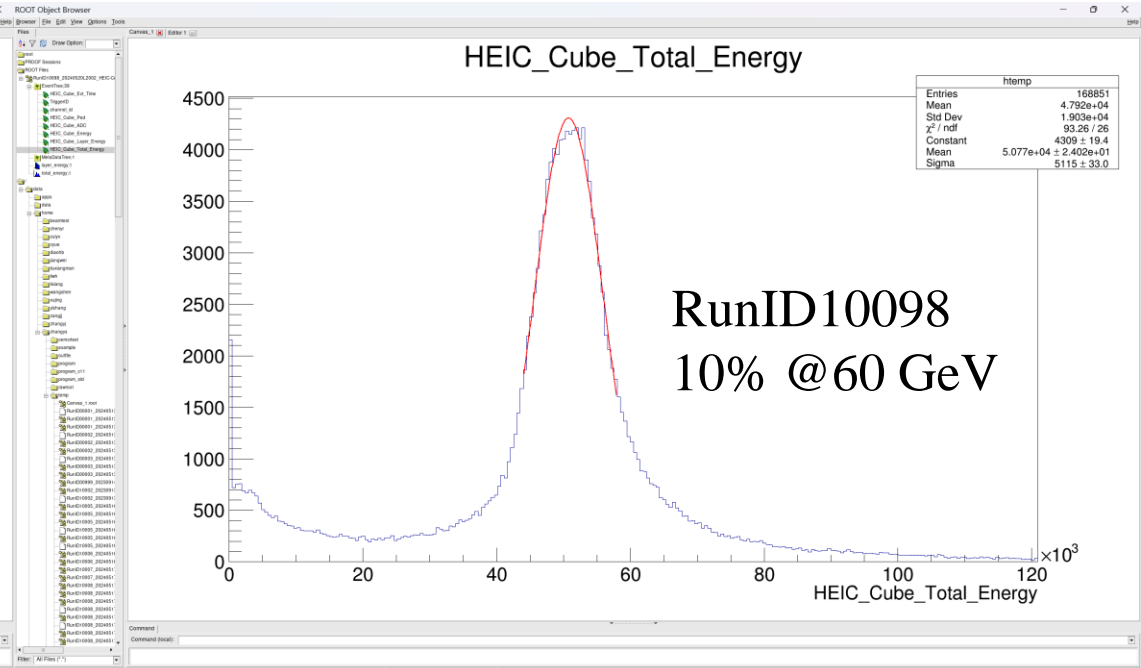
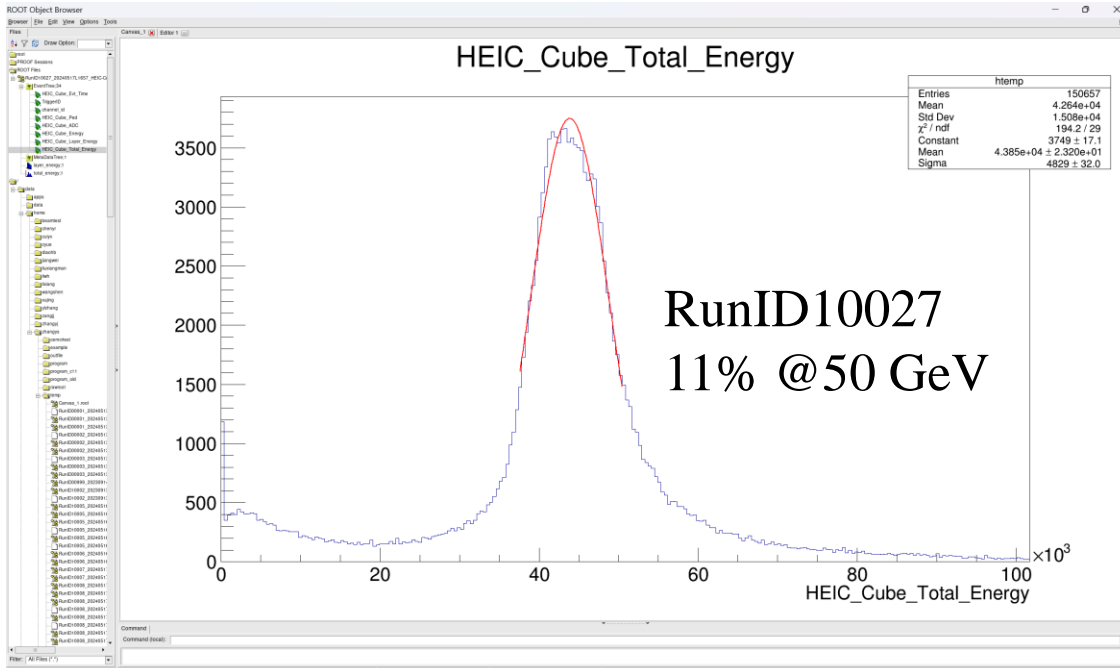
350GeV Pion + proton ratio summary

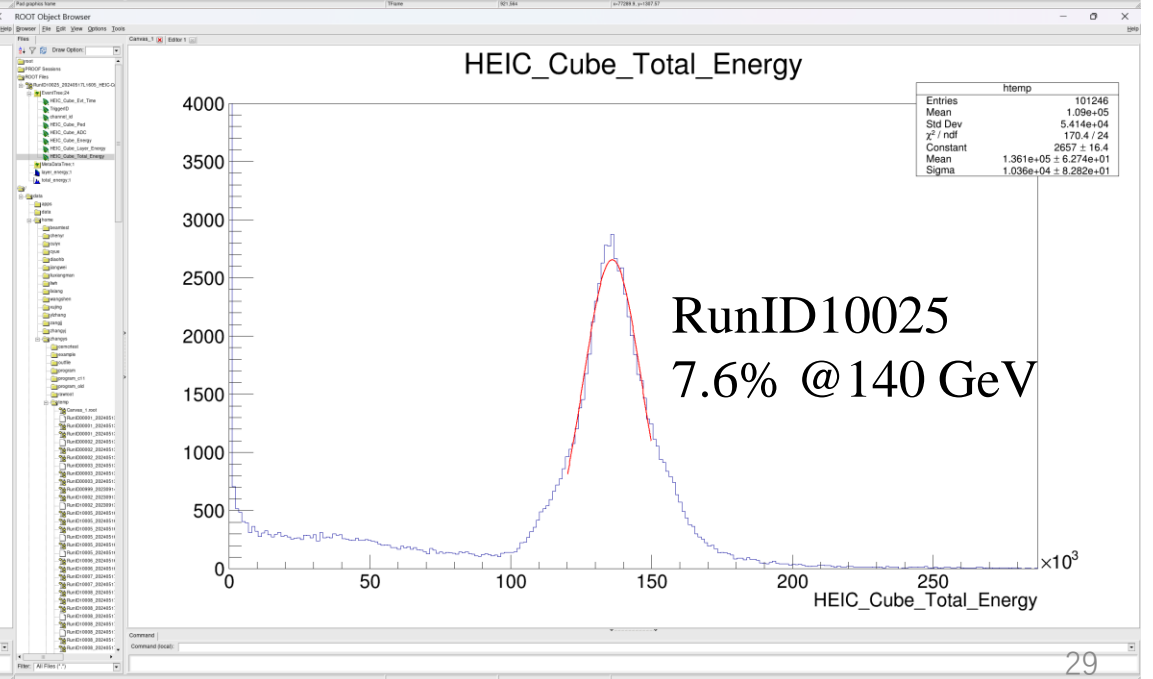
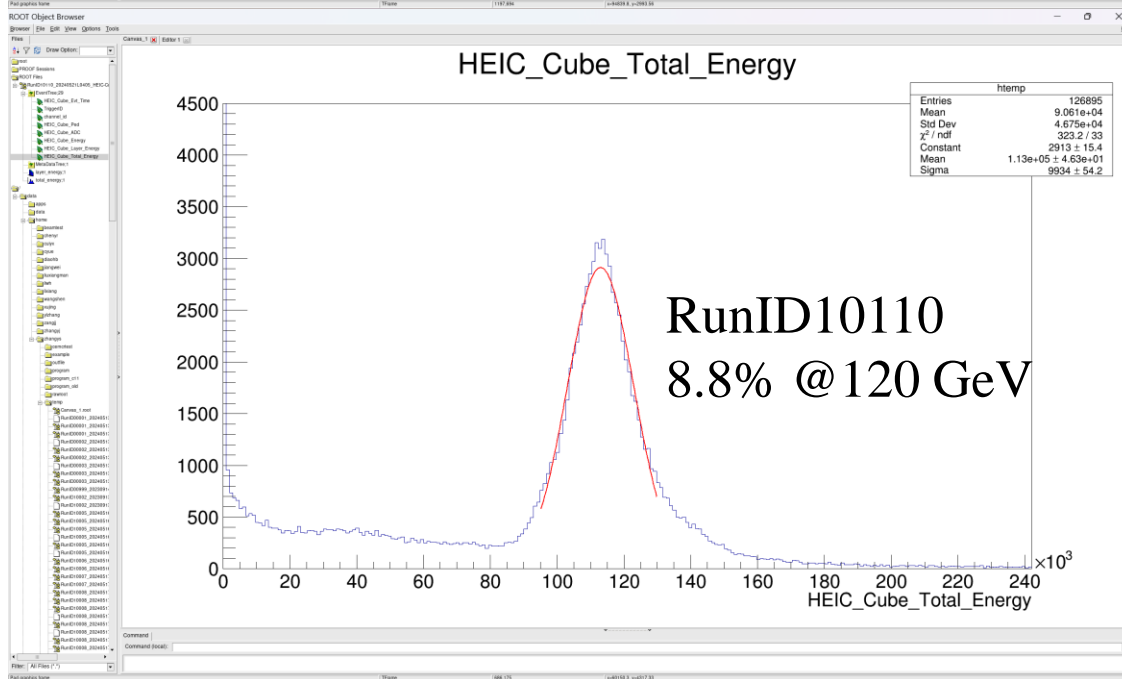
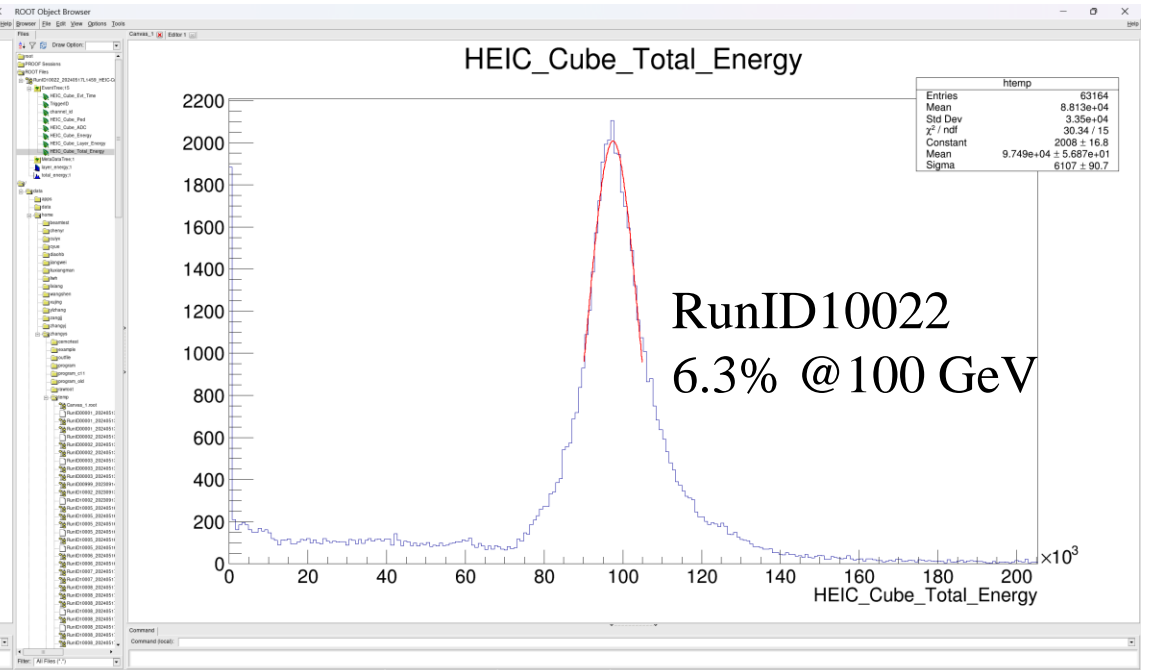
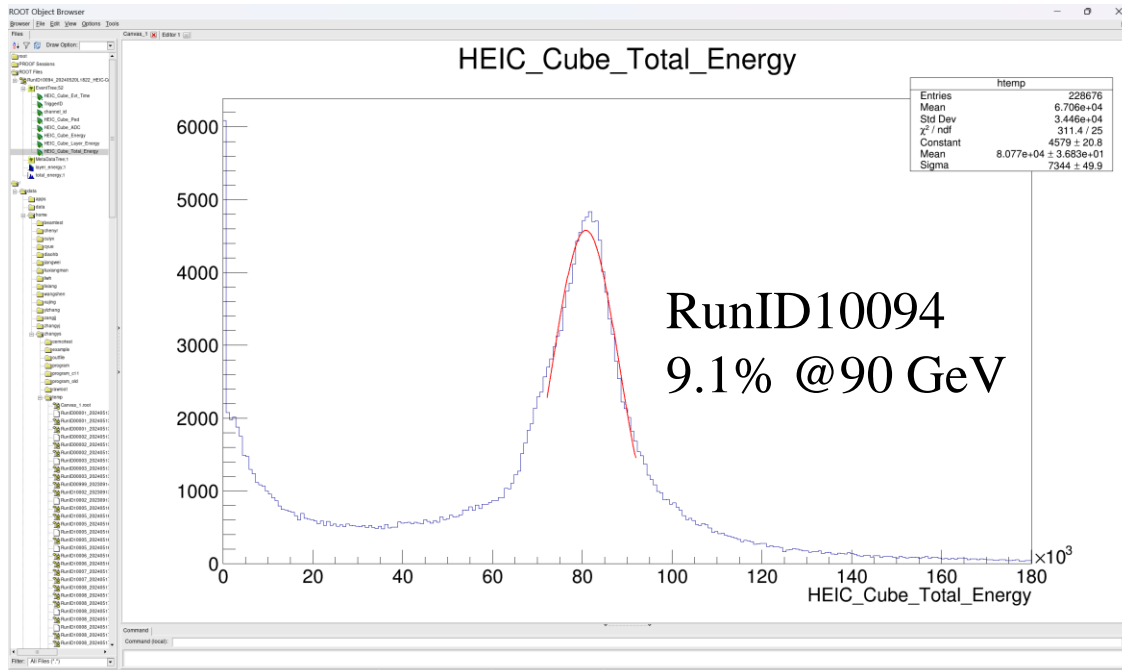


- 电子学增益集中在37倍左右比较稳定；
- 单独考虑衰减片的作用，衰减倍数大约在65倍左右且非常分散；

Linear slope collection



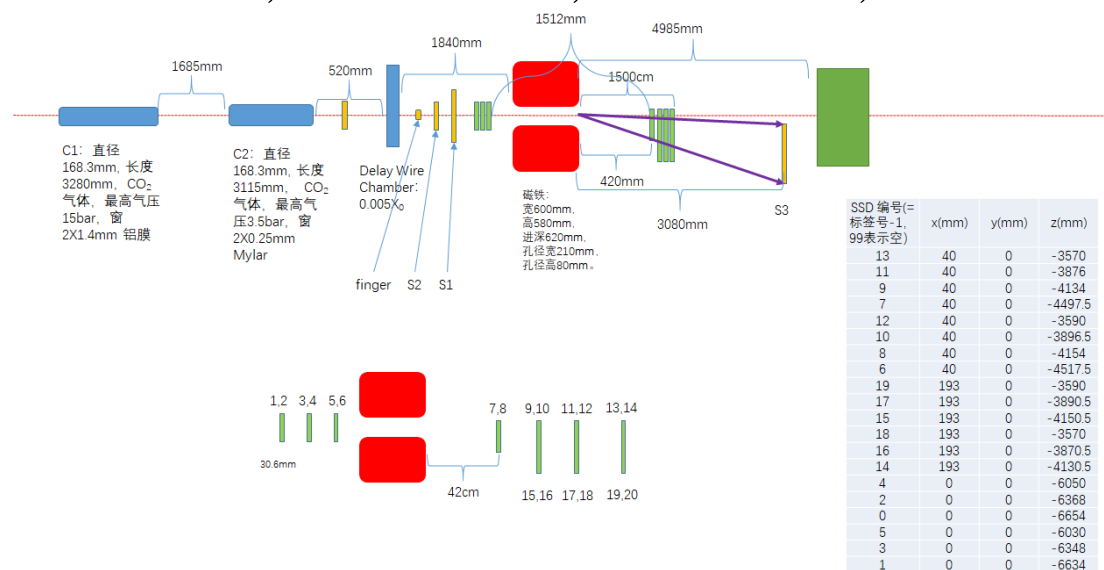




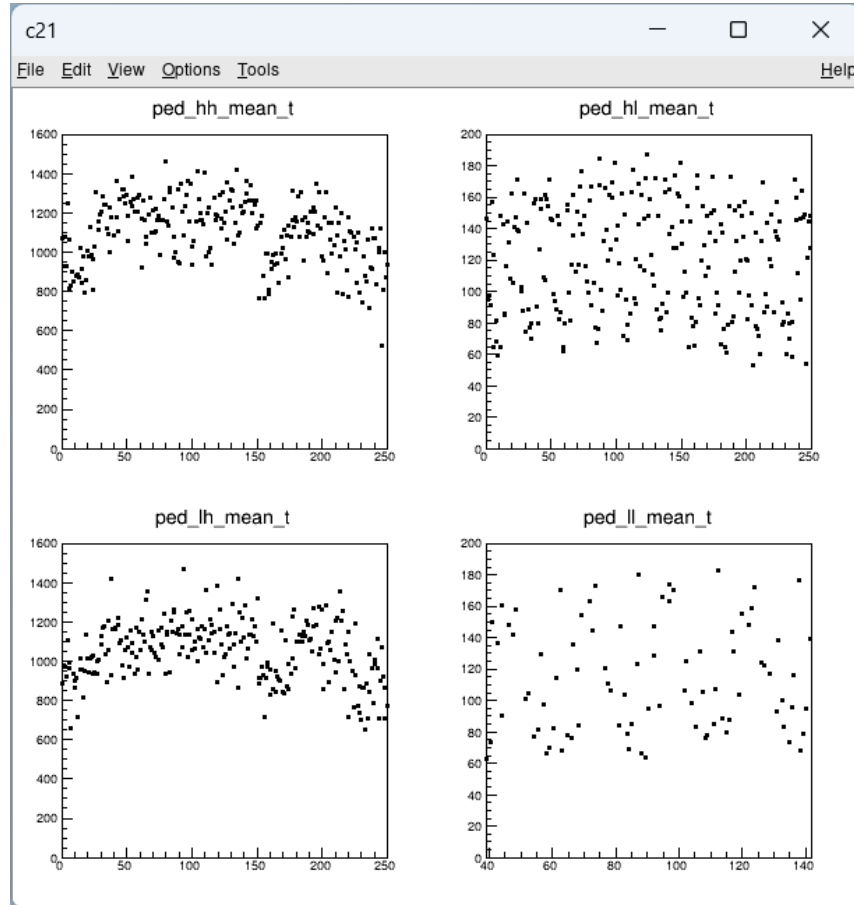
PS beam test (5.22 – 6.5)

Particle	Momentum (GeV/c)	Counts
μ^-	5	1,137,924
π^+	12, 10, 5, 3	106,750; 201,223; 252,583; 64,434
e^-	0.5, 1, 2, 3, 3.5, 4, 4.5, 5	284,254; 846,822; 547,222; 511,386; 40,553; 607,795; 185,920; 790,338
e^- 韧致辐射 产生的 γ	2, 3, 3.5, 4, 4.5	209,374; 202,253; 3,001,876; 1,281,320; 2,546,719

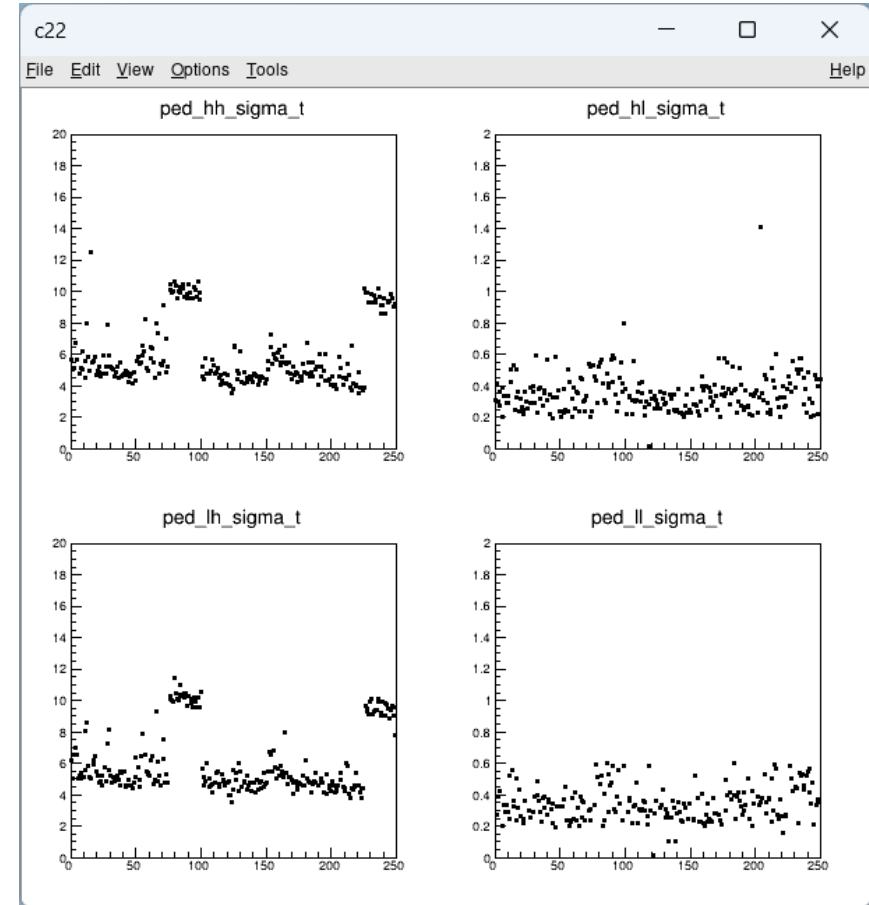
- RunID20140, RunID20142, RunID20143, RunID20144, RunID20145, 5GeV muon, wide beam;
- Counts: 487906; -- MIPs;
- RunID20144, 5GeV muon, wide beam;
- Counts: 140017; -- Pedestal;
- RunID20322, 12GeV pion;
- Counts: 110971; -- Linear;
- Electron energy spectrum;



5GeV Muon pedestal HH/HL/LH/LL

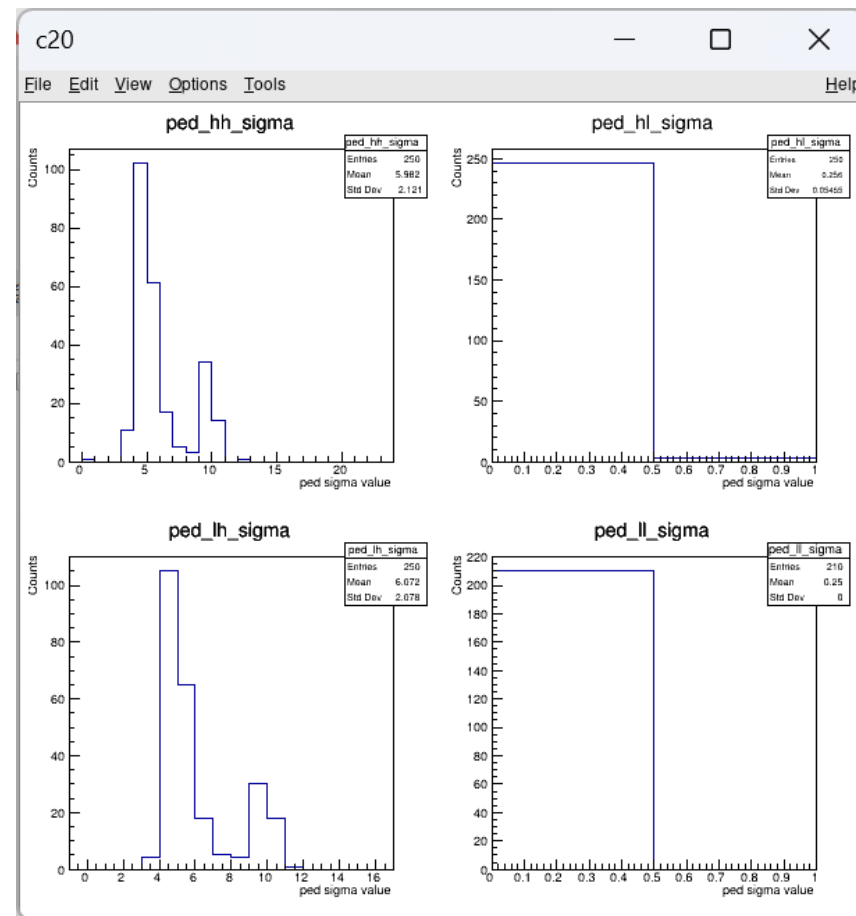
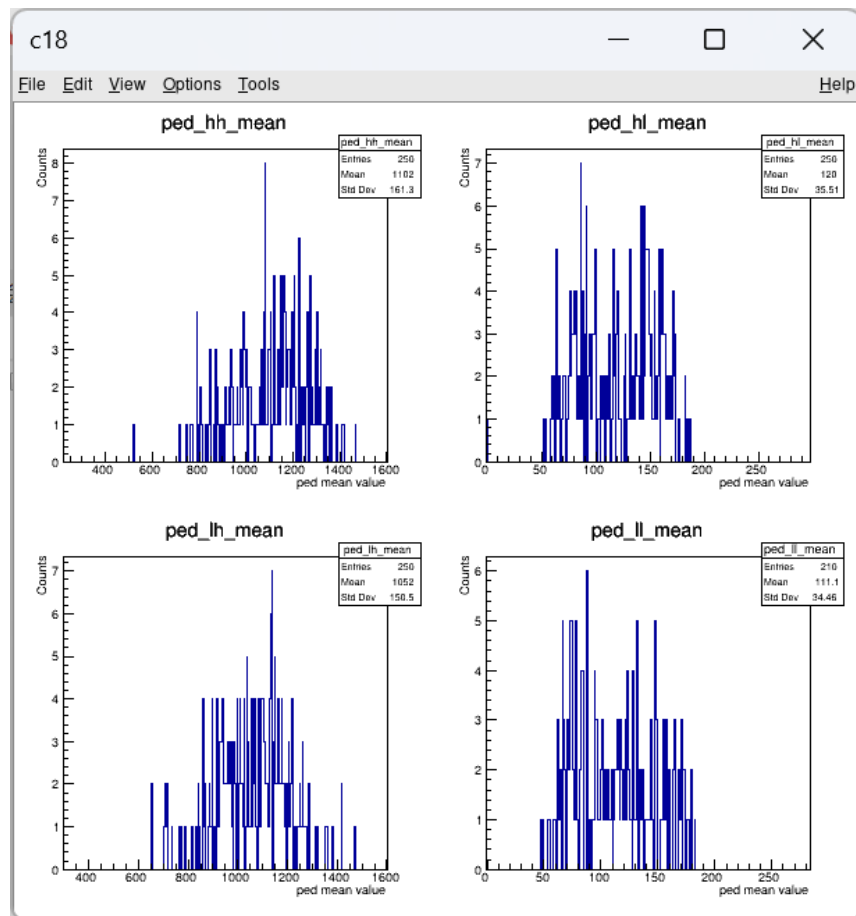


Pedestal HH, HL, LH, LL mean



Pedestal HH, HL, LH, LL sigma

5GeV Muon pedestal summary

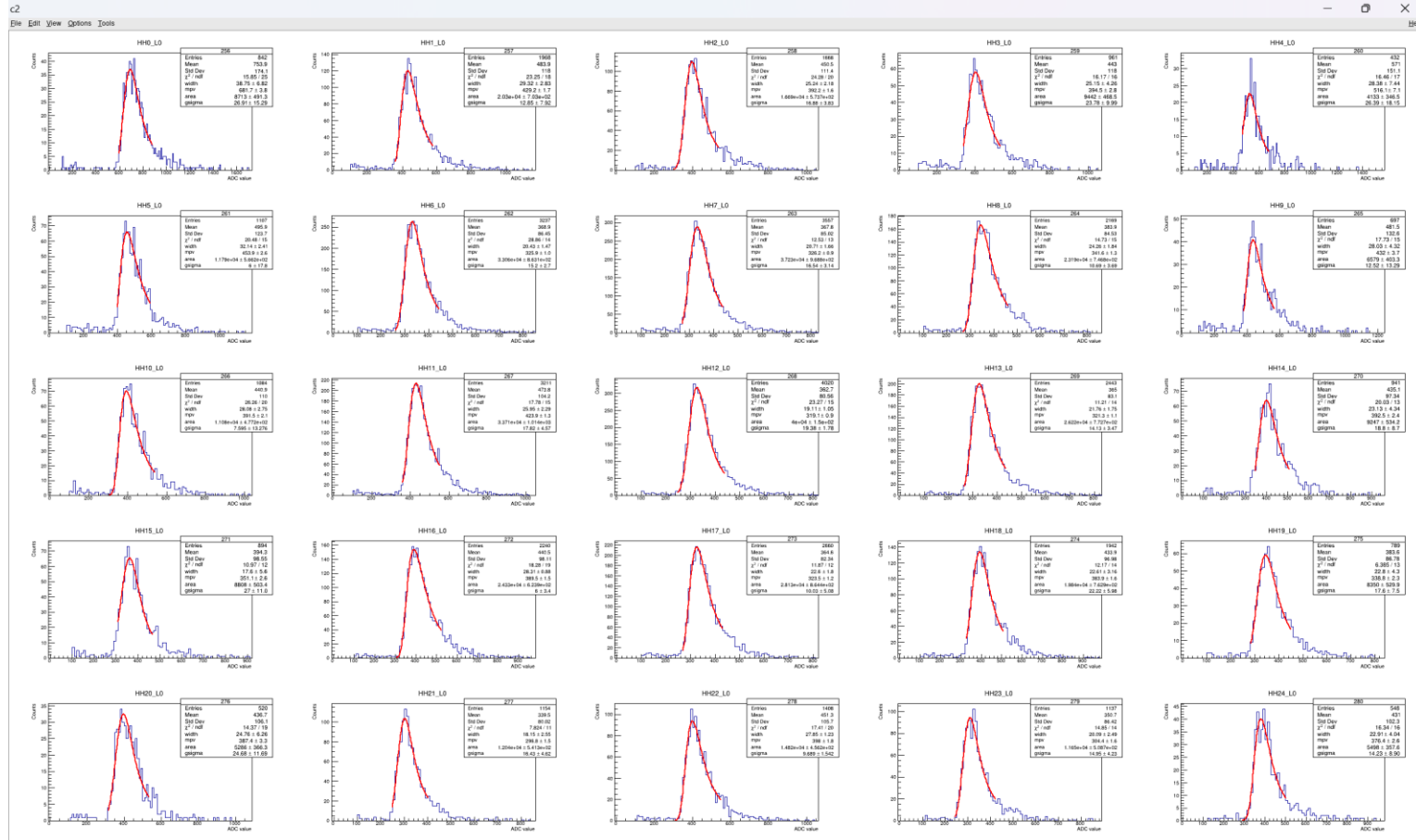


与SPS测试时相比，台基的平均值无明显变化

5GeV Muon MIPs

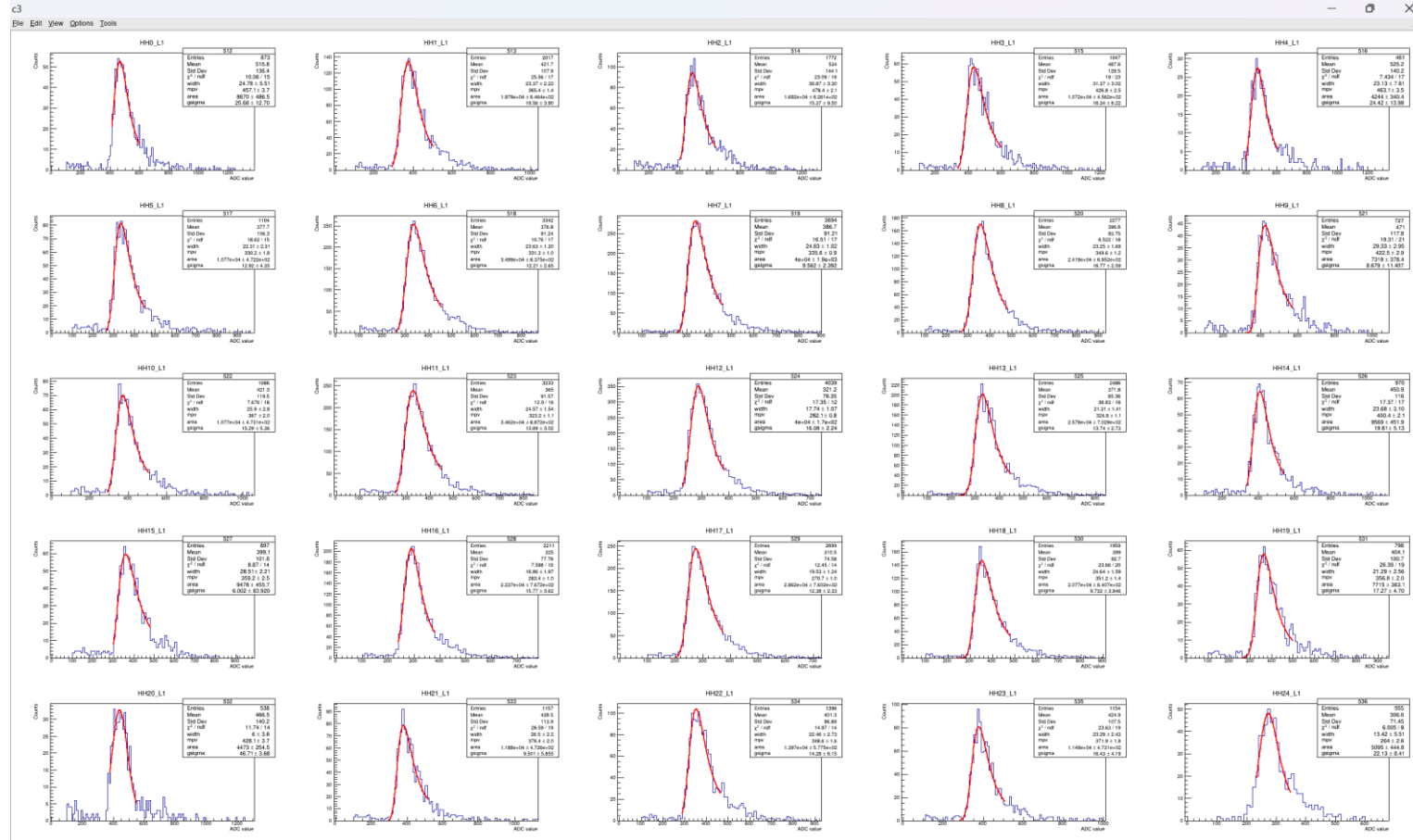
- MIPs 筛选条件：
 - 选取无衰减片高增益通道（HH），要求 $ADC > 25$;
 - 每层有 1 或 2 个通道被击中；
 - 前3层中至少2层有信号，后3层中至少2层有信号，全部10层中至少7层有信号；

5GeV Muon MIPs layer 0



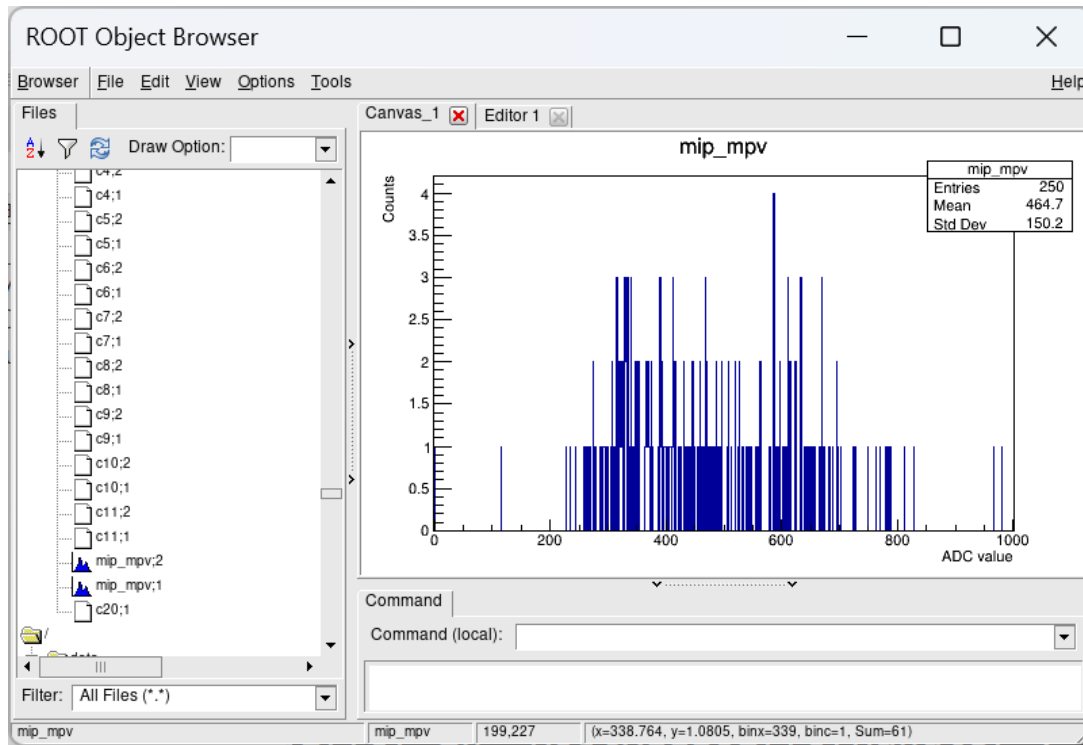
MIPs selection HH0--HH24 layer 0

5GeV Muon MIPs layer 1



MIPs selection HH0--HH24 layer 1

5GeV Muon MIPs summary



MIPs selection mpv collection

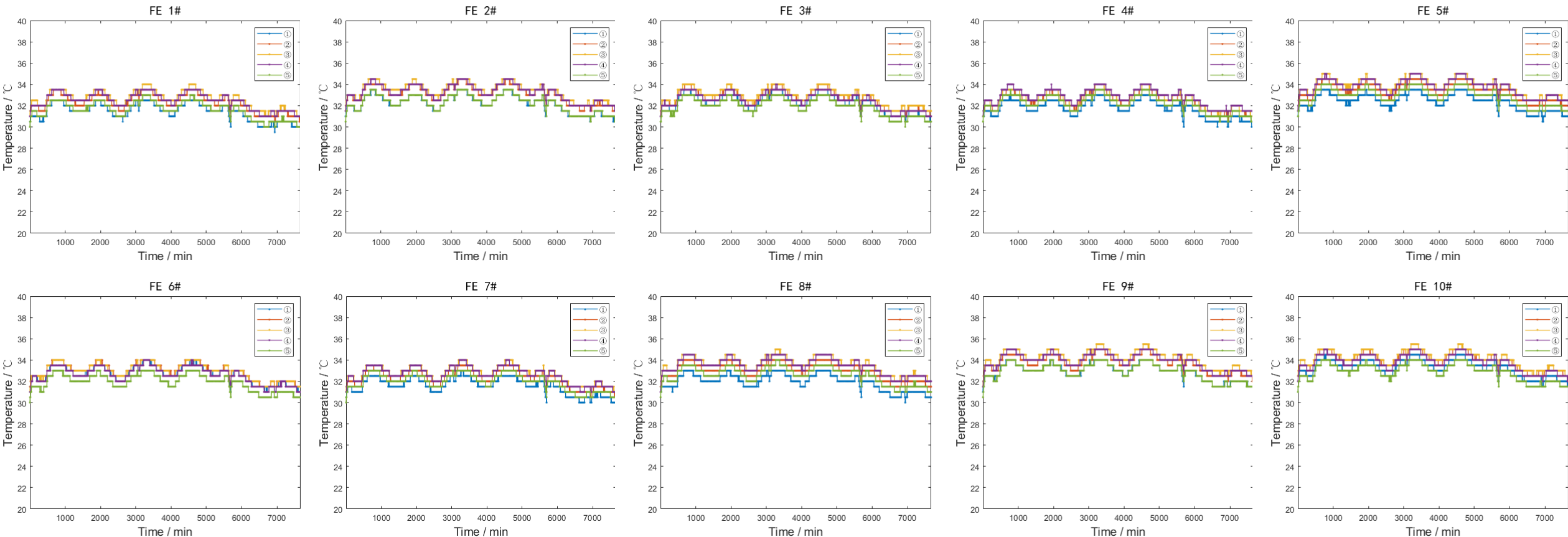
- 拟合得到的所有通道的 MIPs mpv 值，分布比较分散；
- 所有通道的 MIPs mpv，相比 SPS 的测试，整体变小约 120 道；
- PS 测试时系统温度相比 SPS 高了约 6~7°C，APD 的温度系数约为 2.5%，再考虑到晶体光产额的温度系数，约 20% 的幅度变化可以认为是合理的；

系统温度

➤ PS测试时温度变化情况

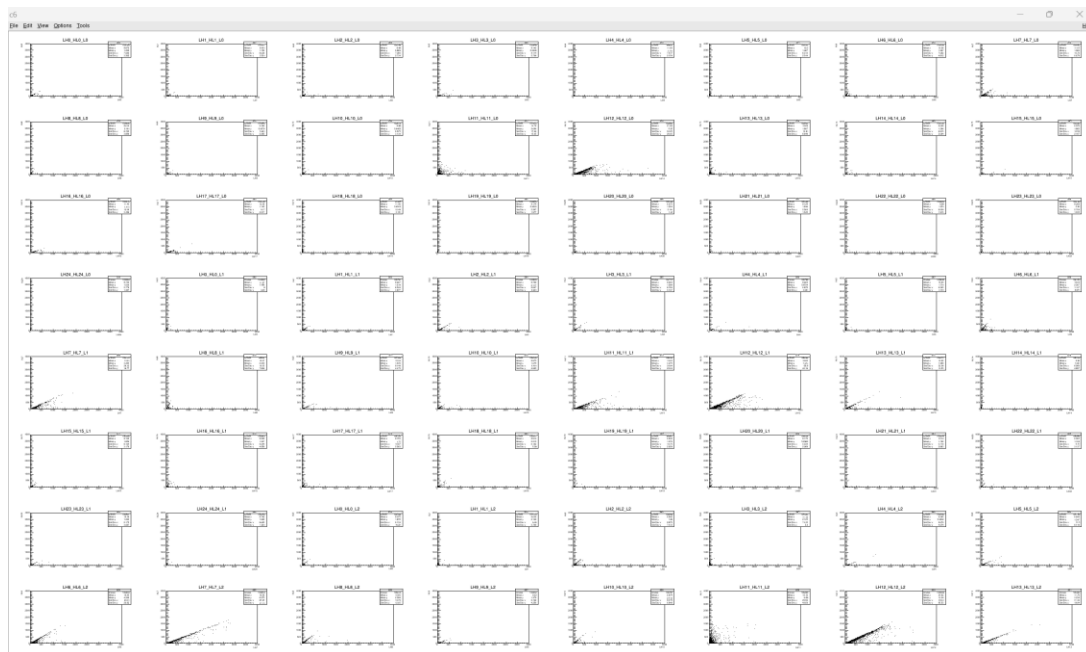
PCB昼夜最大温度变化为3°C

间隔5分钟采集一次温度数据

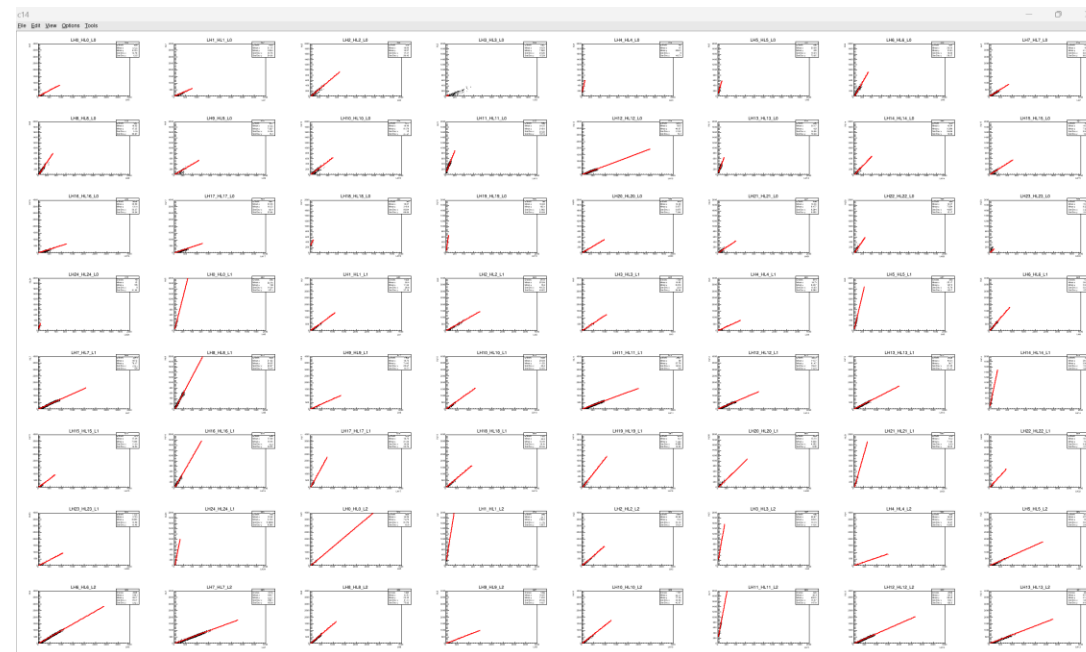


平均温度为33°C，比在SPS高了约7°C

12GeV Pion LH-HL ratio

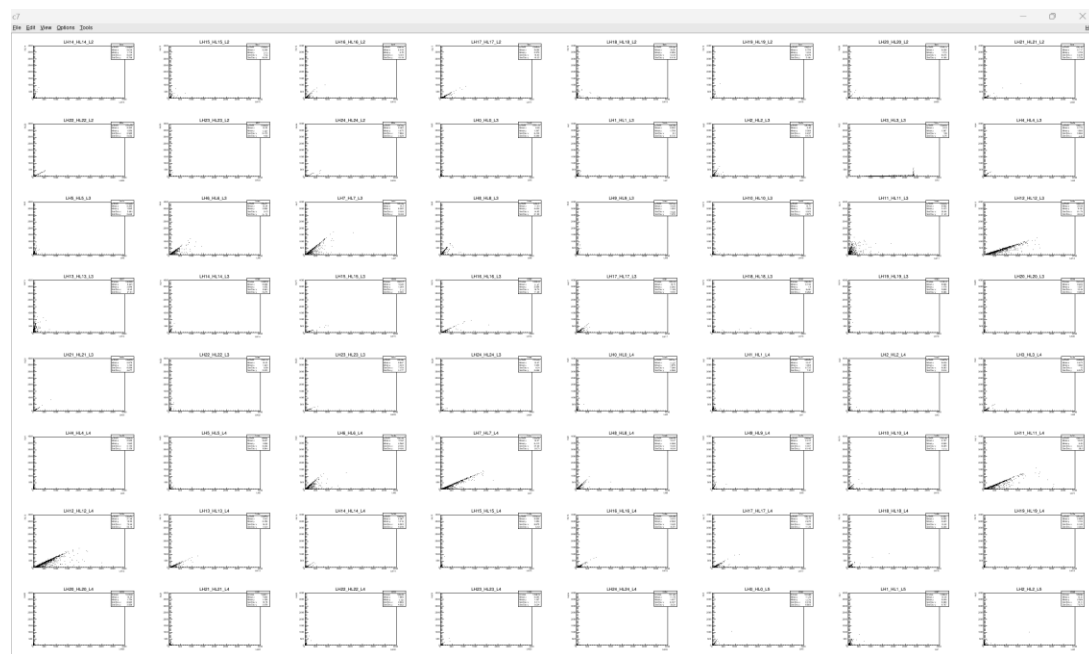


LH--HL ratio between 2 APDs

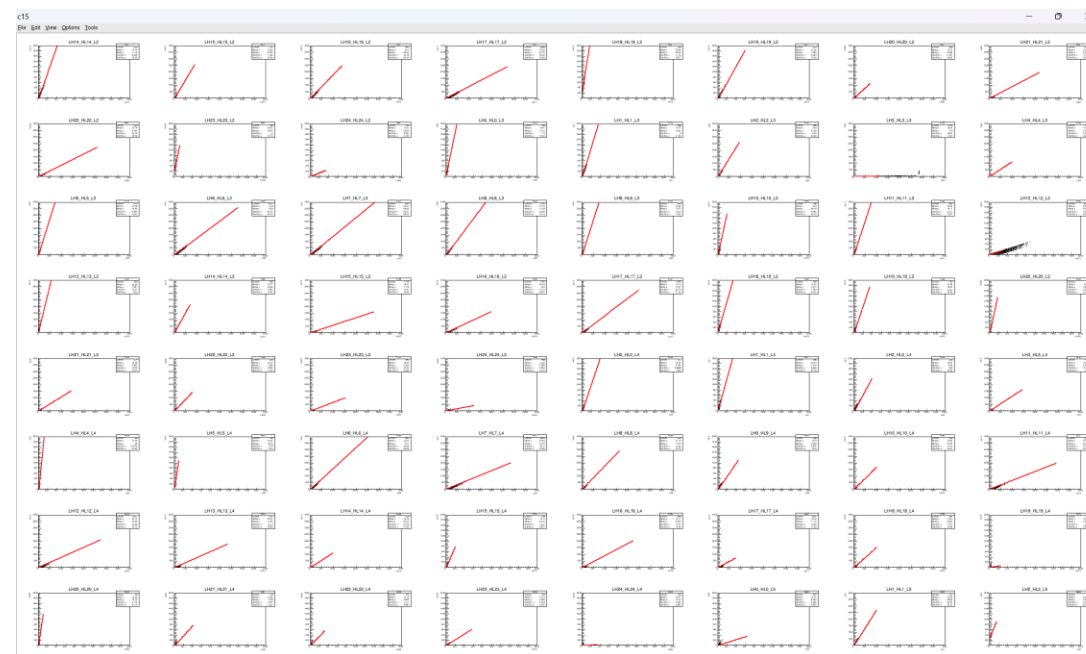


LH--HL ratio after selection

12GeV Pion LH-HL ratio



LH--HL ratio between 2 APDs



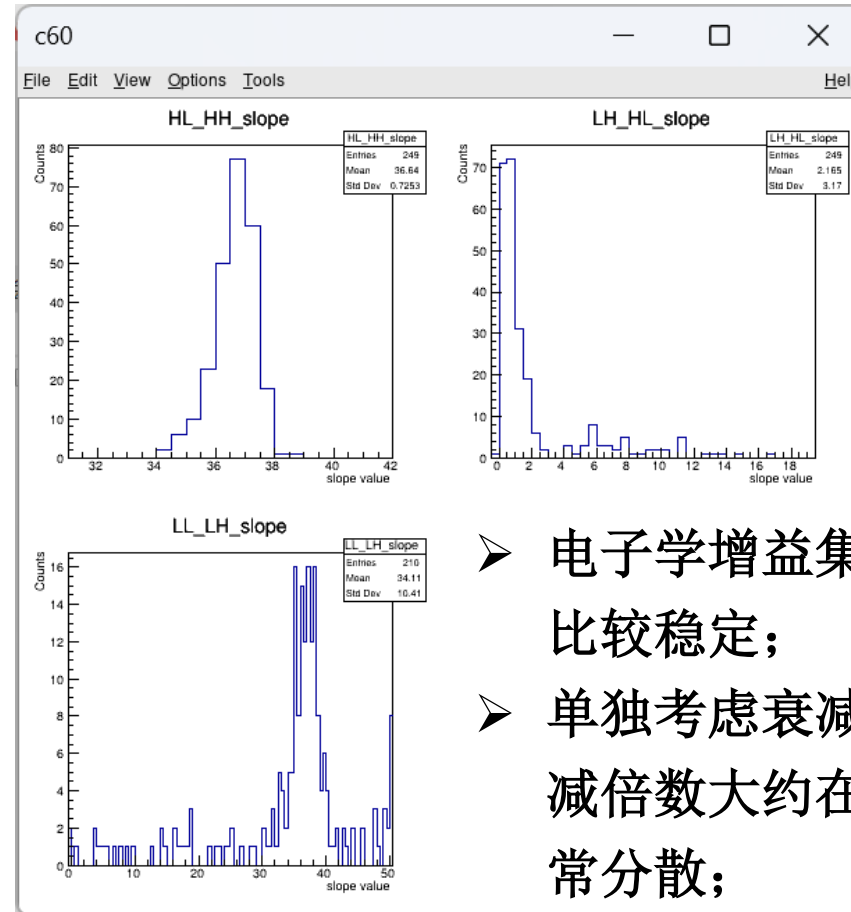
LH--HL ratio after selection

12GeV Pion LL-LH ratio



LL--LH ratio under the same APD

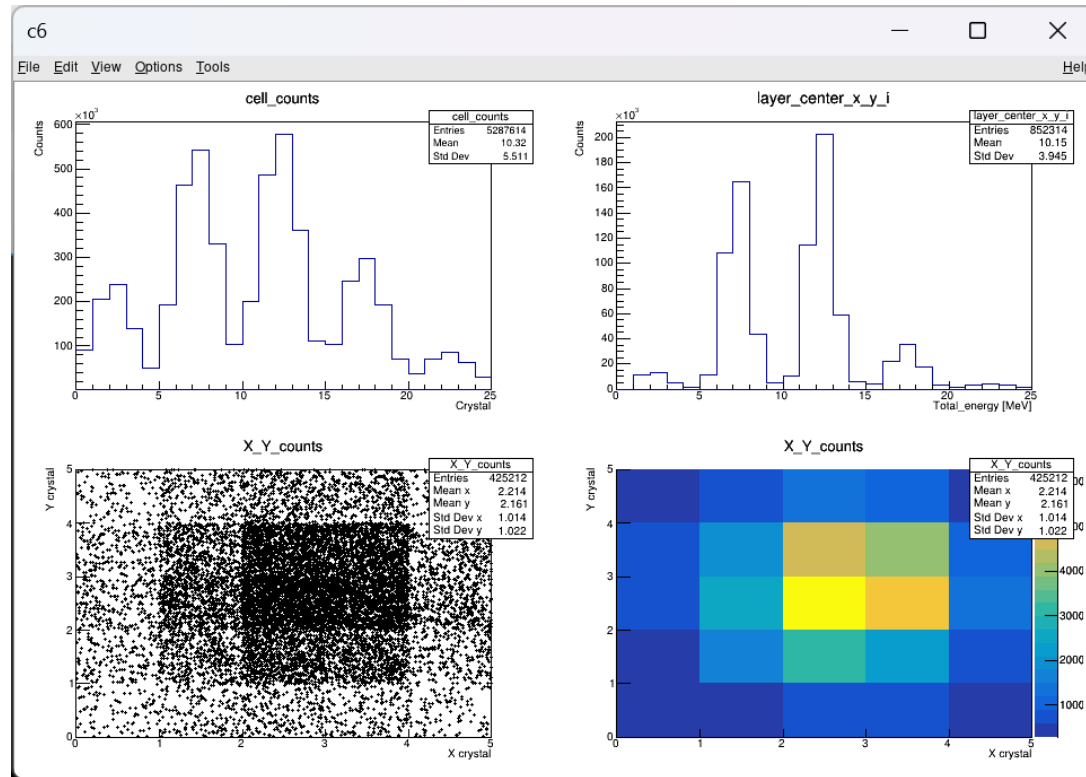
12GeV Pion ratio summary



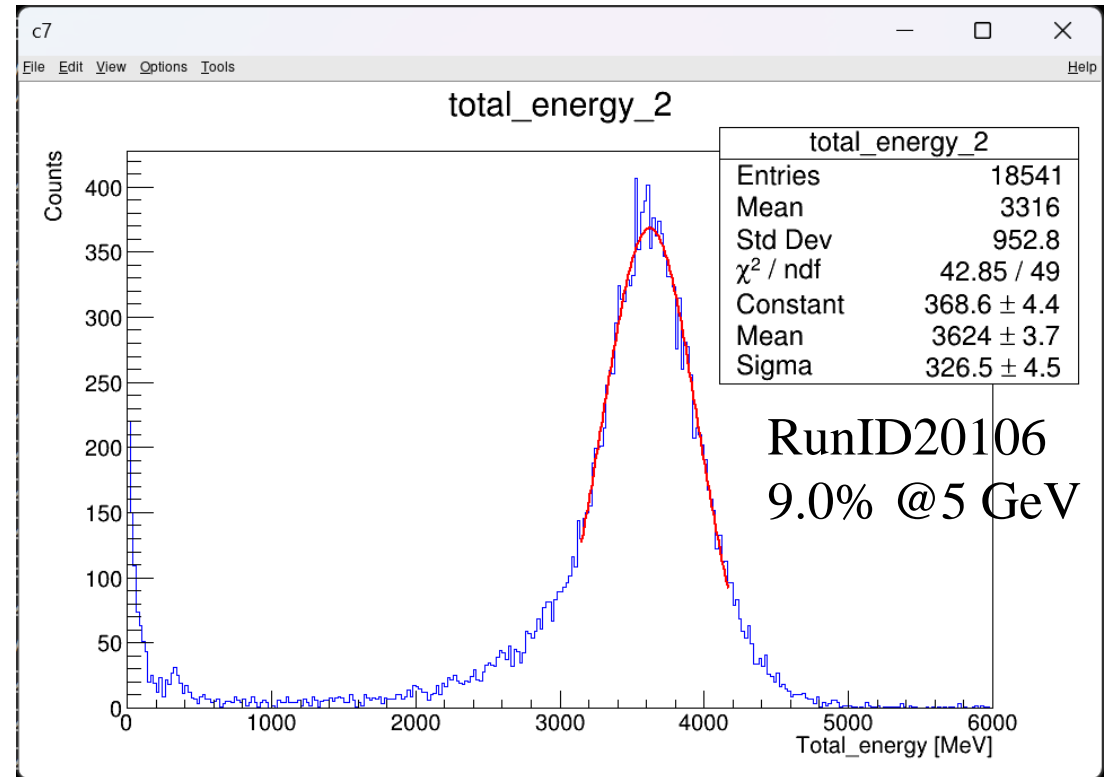
- 电子学增益集中在37倍左右比较稳定；
- 单独考虑衰减片的作用，衰减倍数大约在65倍左右且非常分散；

Linear slope collection

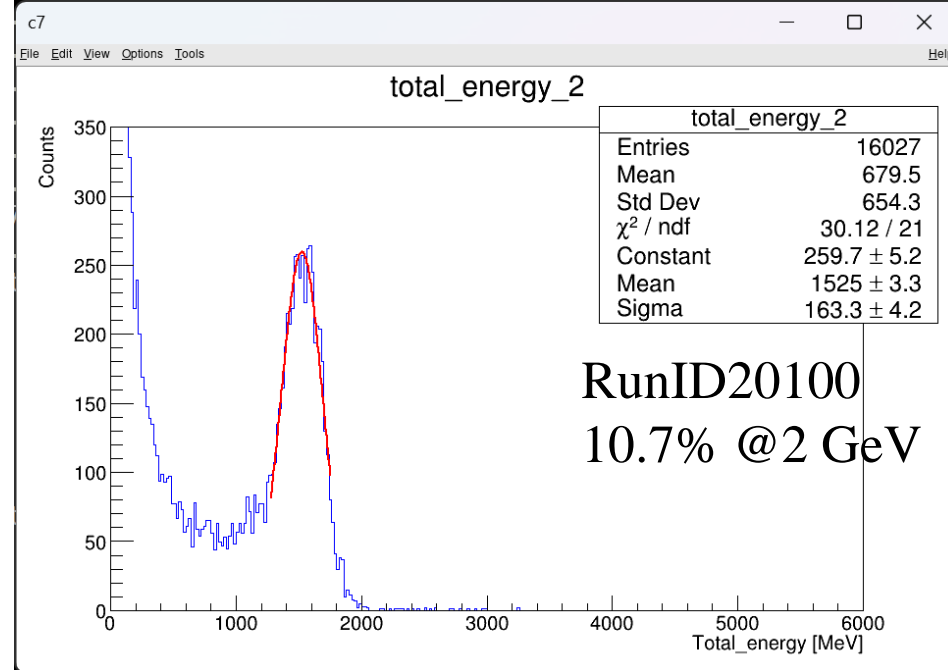
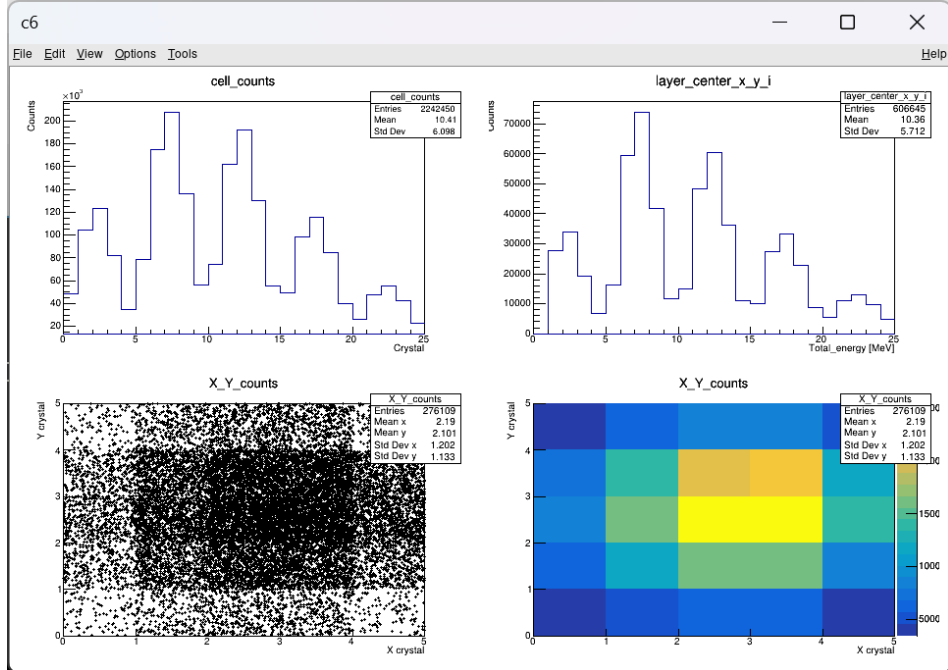
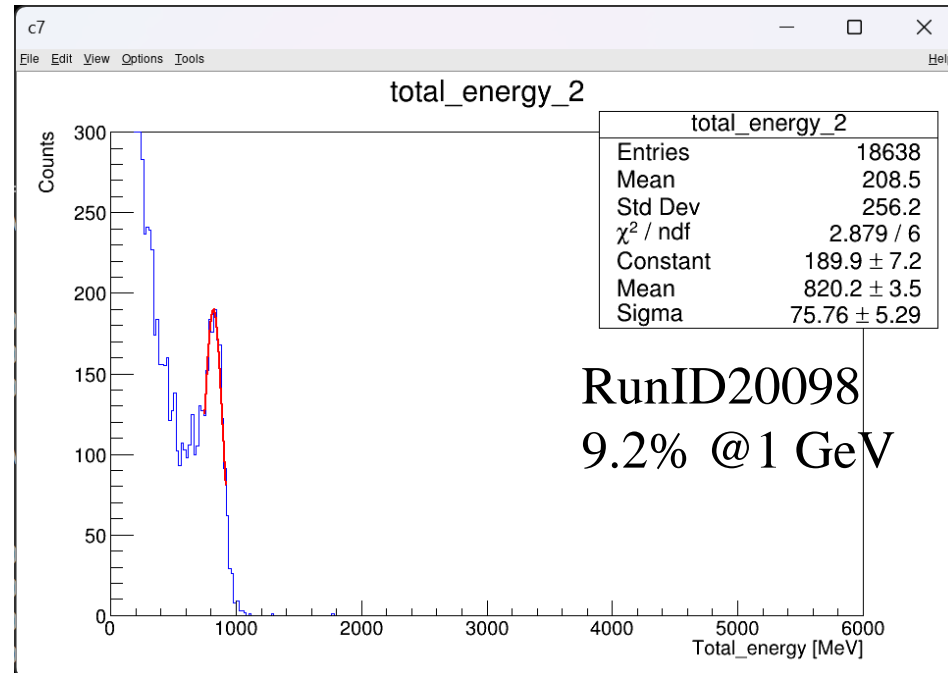
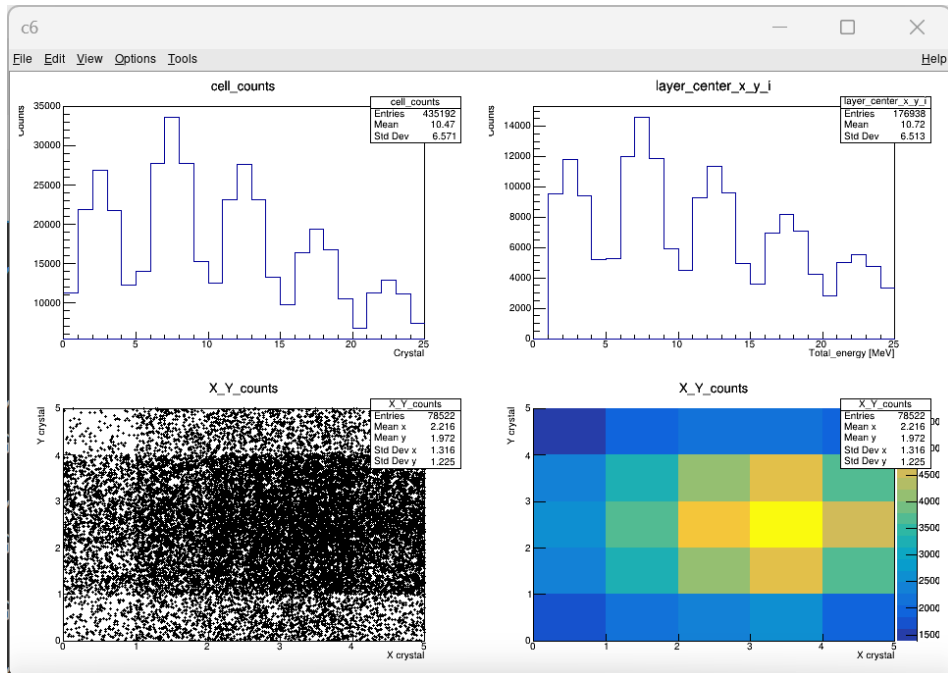
5GeV electron, [max energy=(12)]>=6 layers

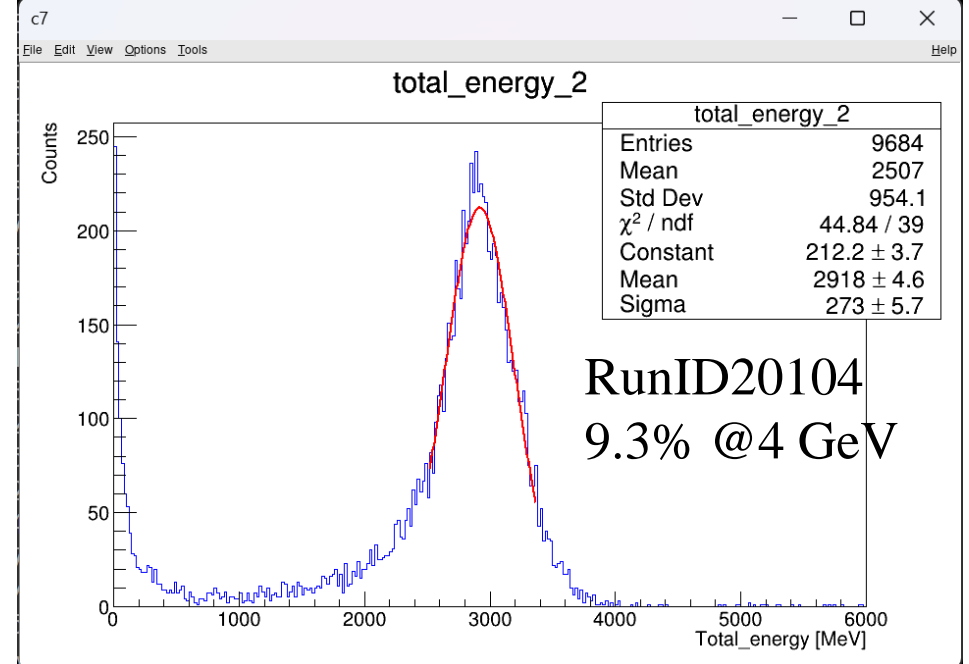
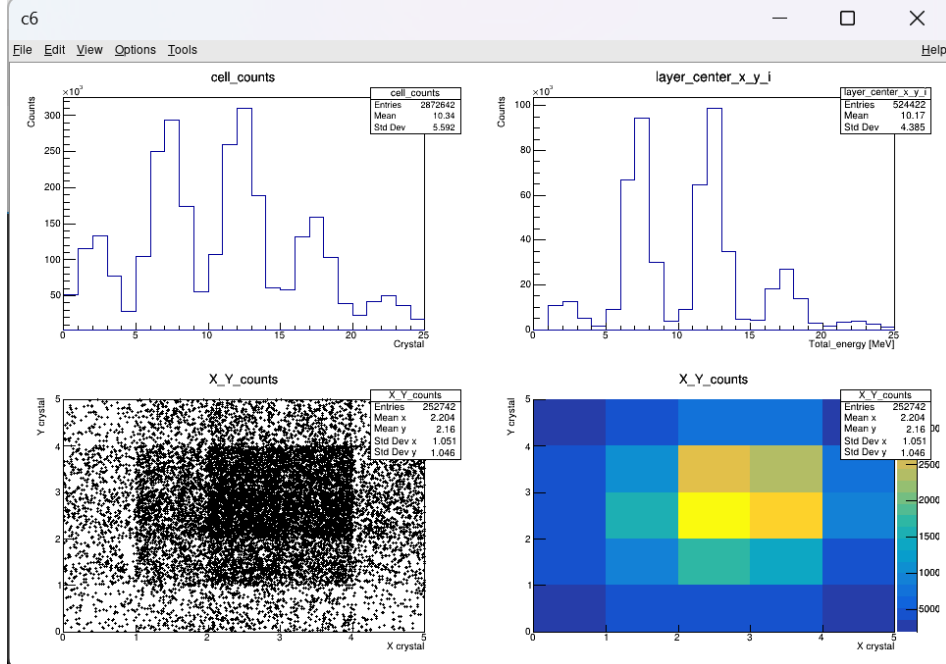
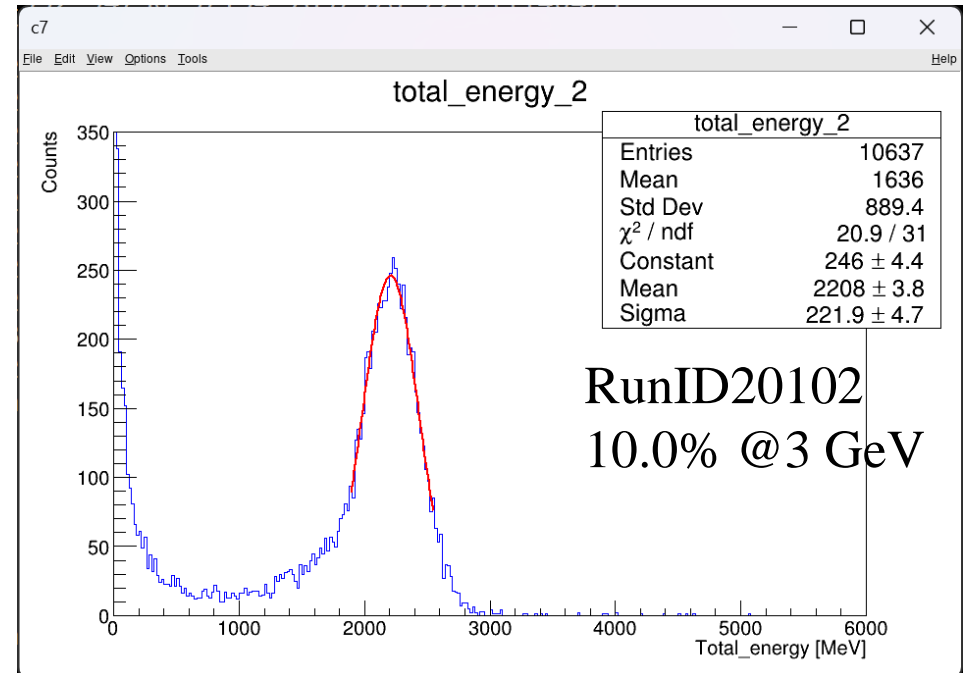
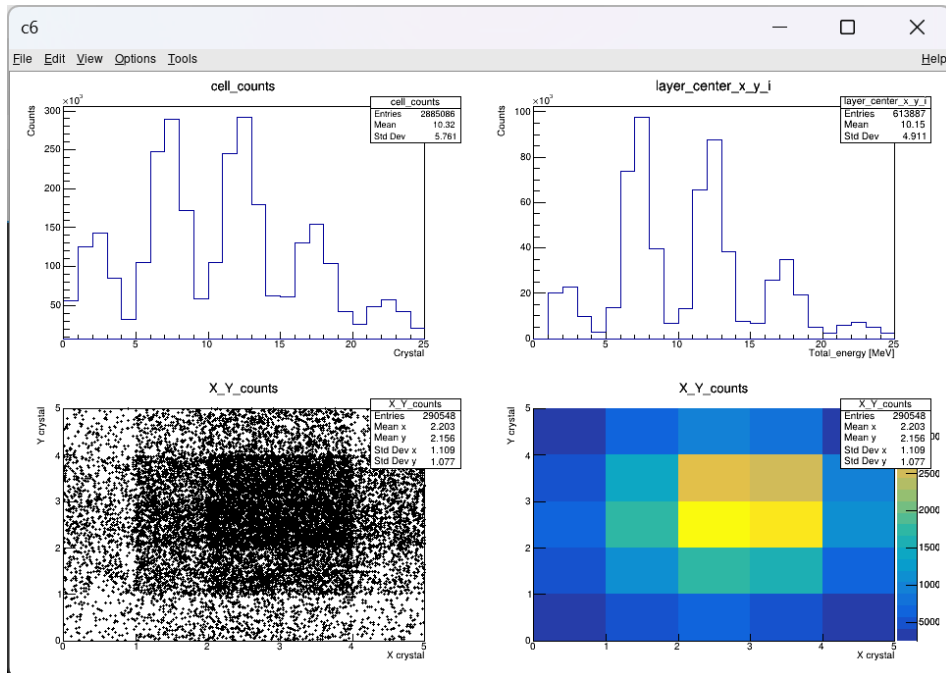


5GeV electron hit position

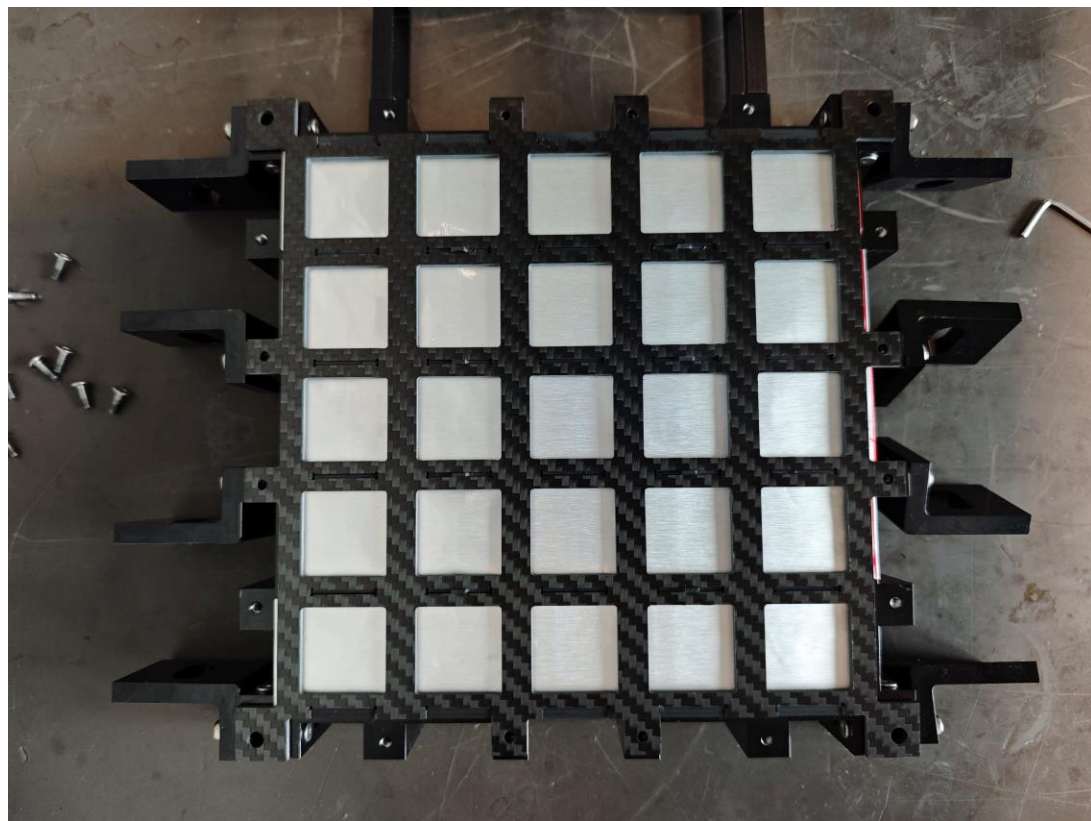


5GeV electron energy spectrum

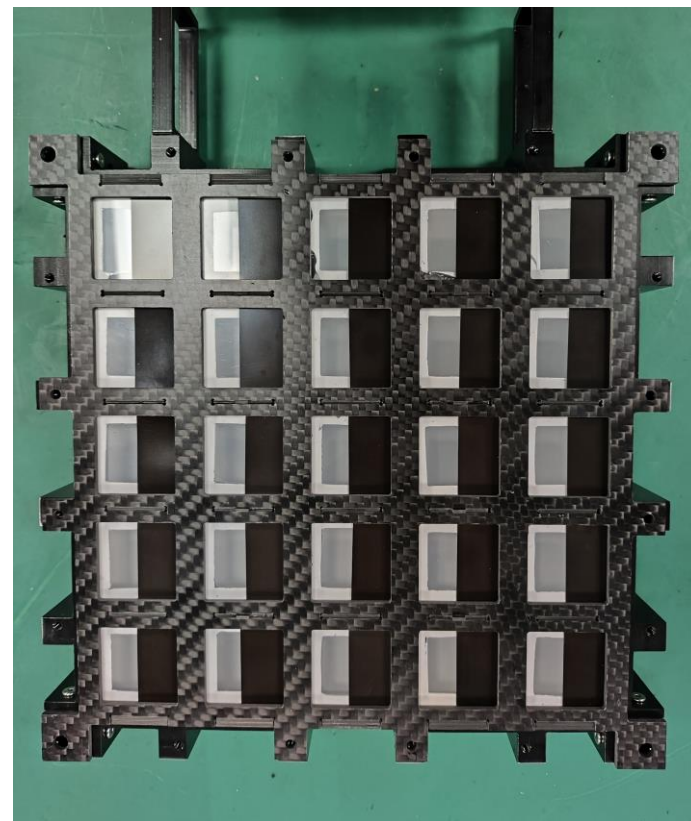




直接电离对 APD 的影响

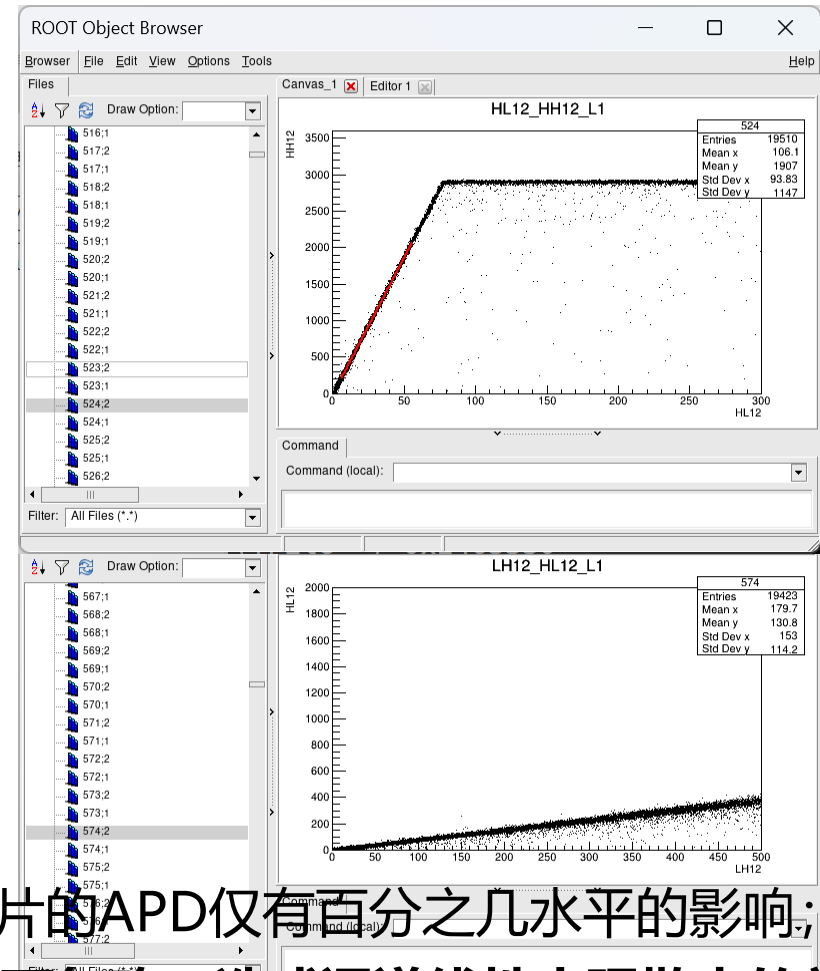
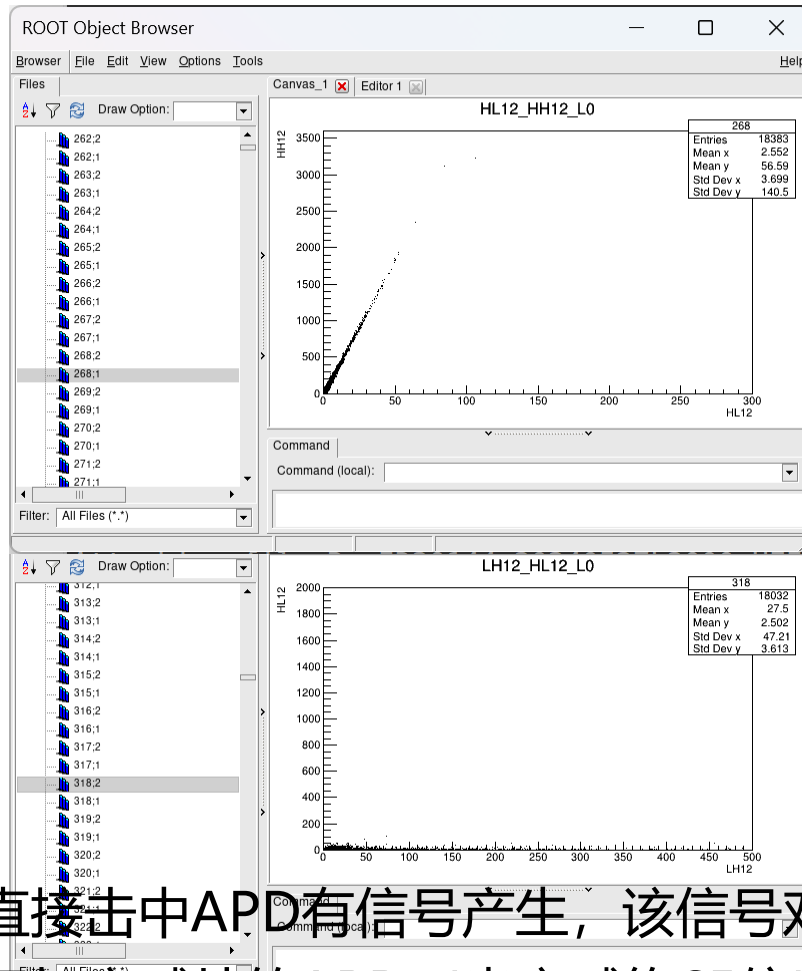


1、3、5、7、9层将晶体用铝箔蒙起来



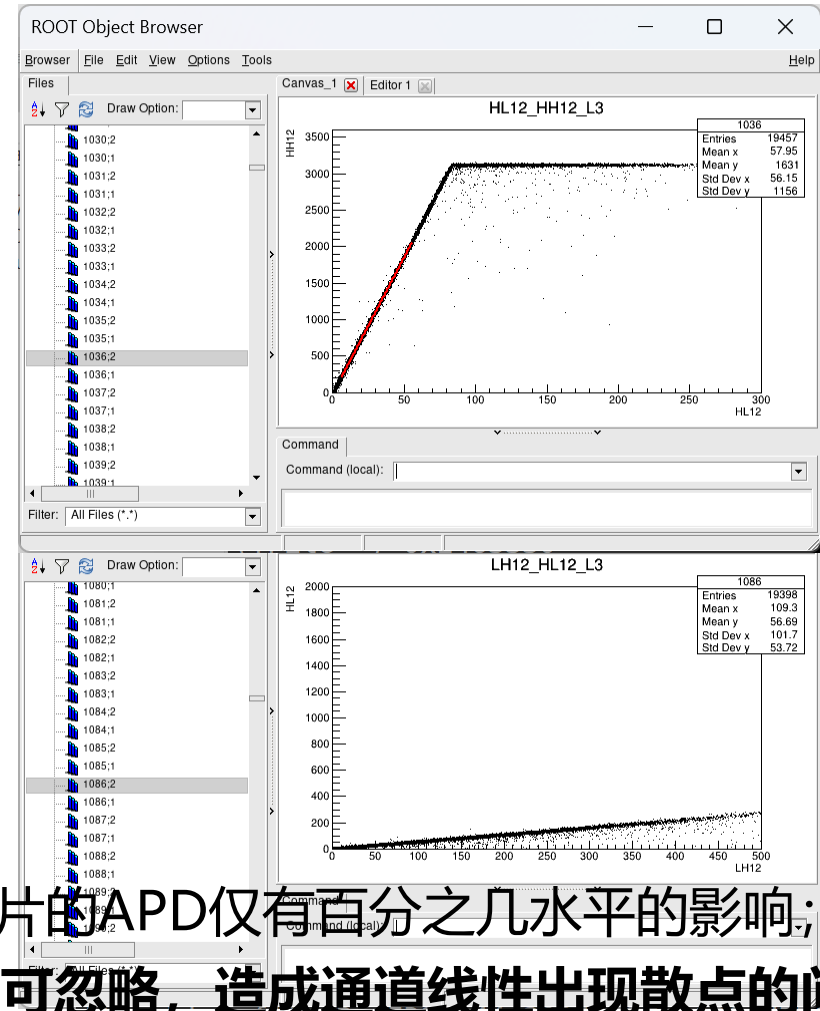
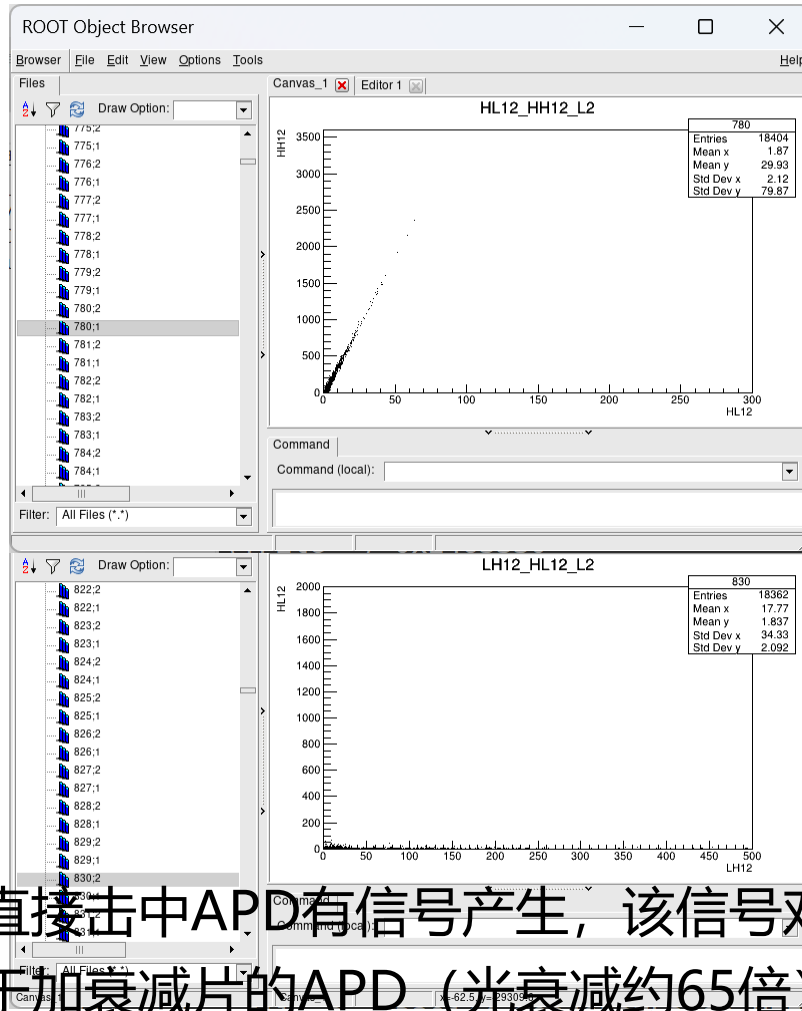
初始状态

RunID20010, 5GeV electron



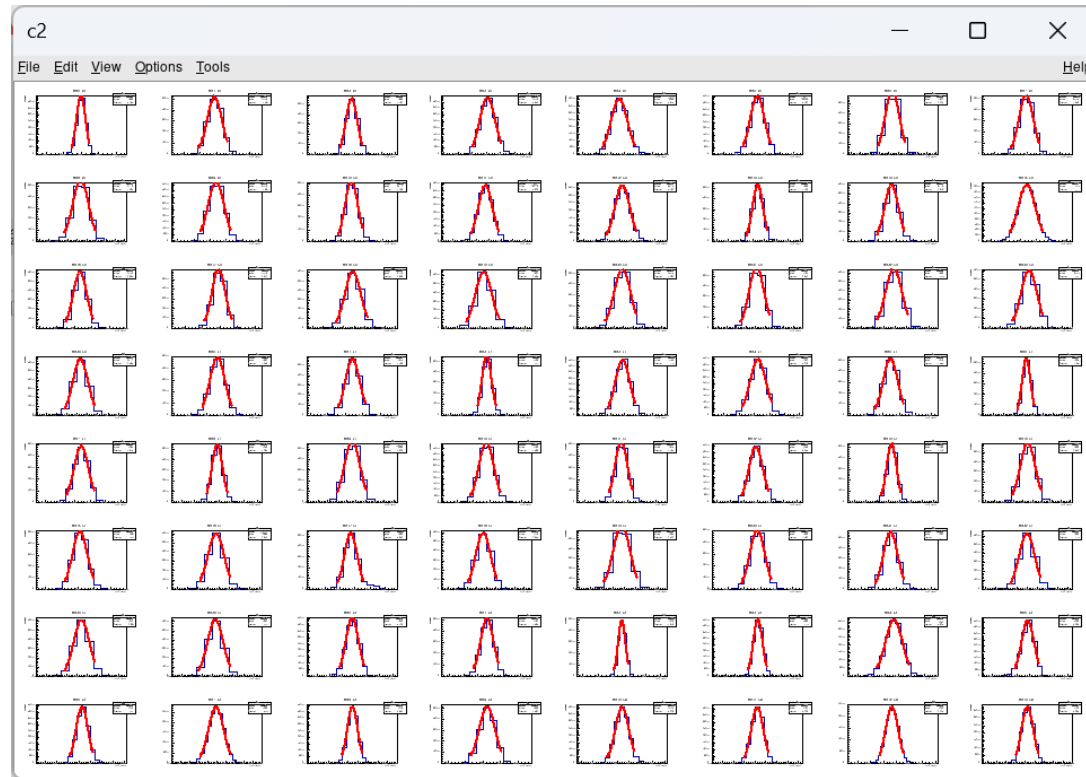
- 电子直接击中APD有信号产生，该信号对于未加衰减片的APD仅有百分之几水平的影响；
- 但对于加衰减片的APD（光衰减约65倍），该影响不可忽略，造成通道线性出现散点的问题；

RunID20010, 5GeV electron

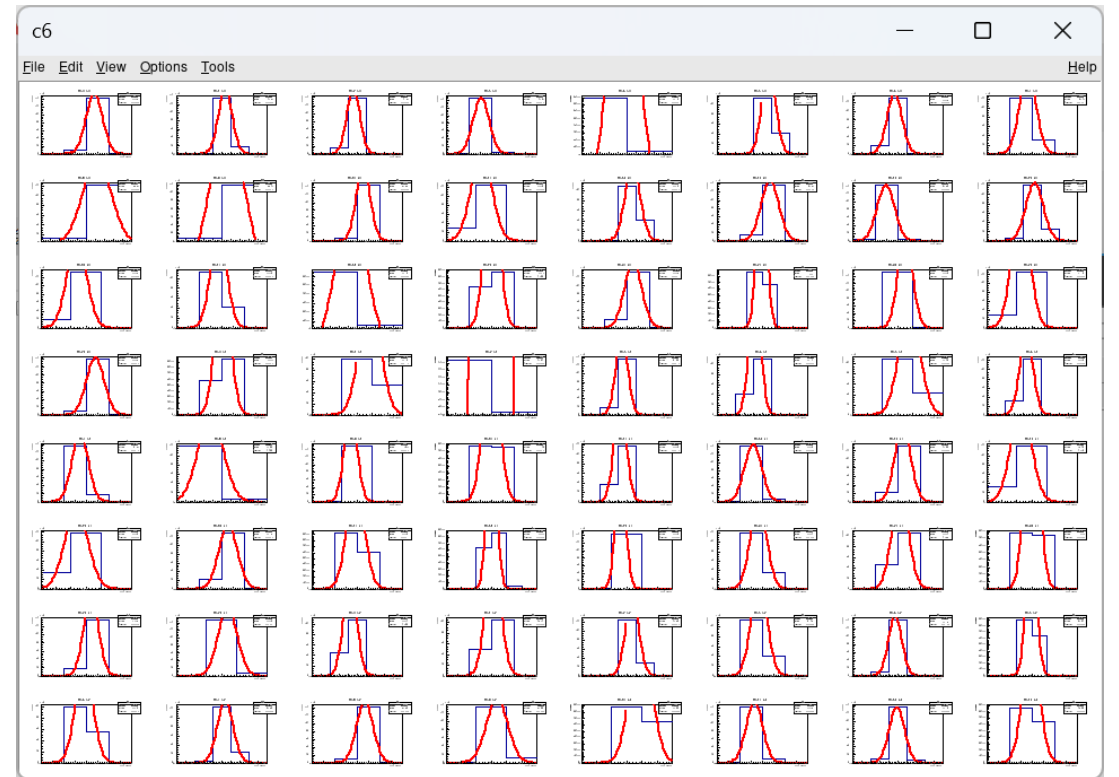


- 电子直接击中APD有信号产生，该信号对于未加衰减片的APD仅有百分之几水平的影响；
- 但对于加衰减片的APD（光衰减约65倍），该影响不可忽略，造成通道线性出现散点的问题；

150GeV Muon pedestal HH / HL

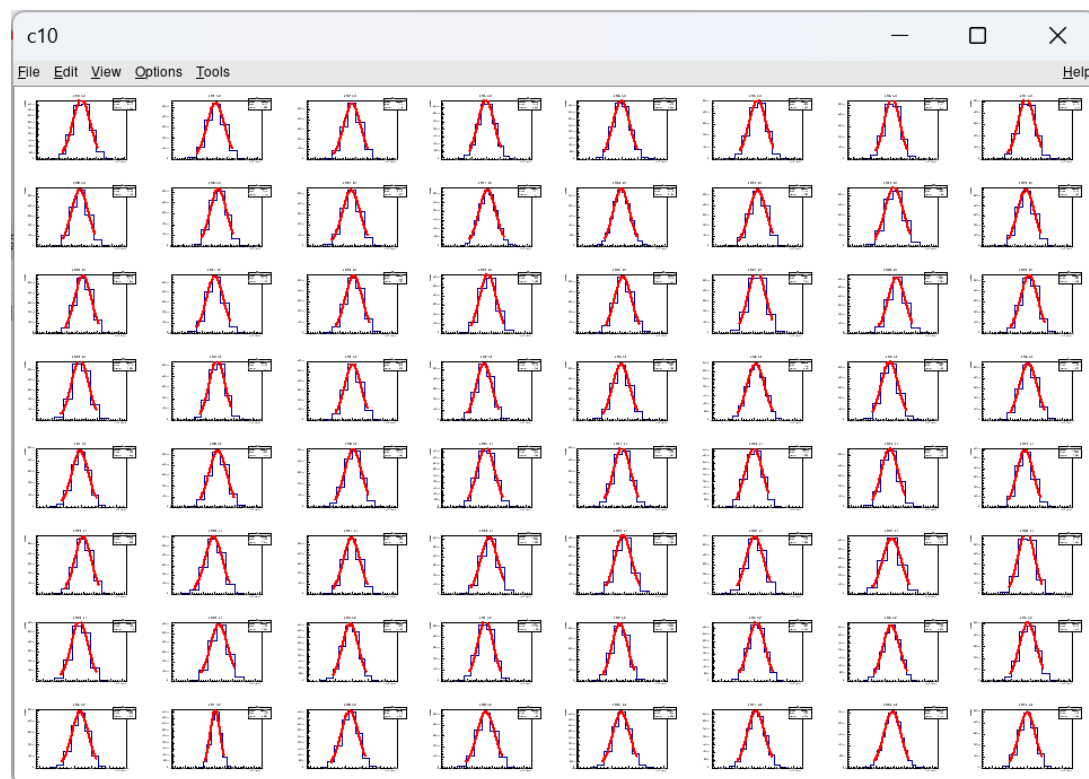


Pedestal HH0_L0--HH13_L2

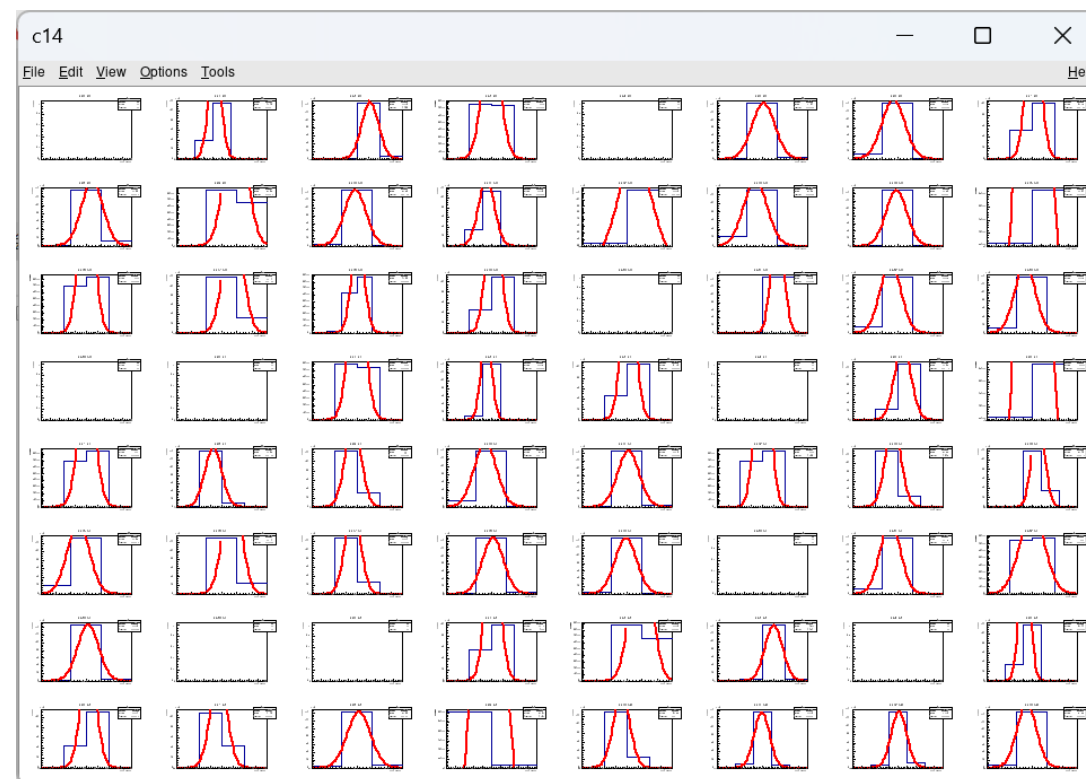


Pedestal HL0_L0--HL13_L2

150GeV Muon pedestal LH / LL



Pedestal LH0_L0--LH13_L2



Pedestal LL0_L0--LL13_L2

5GeV Muon pedestal HH / HL



Pedestal HH0_L0--HH13_L2

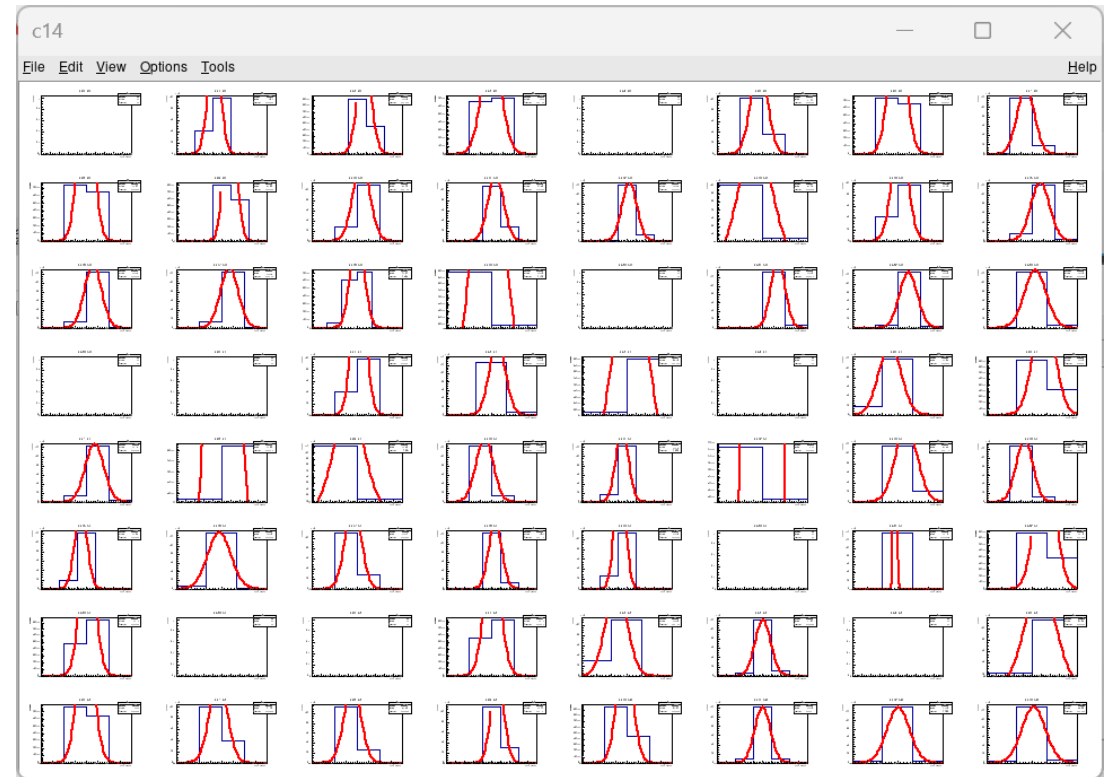


Pedestal HL0_L0--HL13_L2

5GeV Muon pedestal LH / LL



Pedestal LH0_L0--LH13_L2



Pedestal LL0_L0--LL13_L2