第四届微结构气体探测器研讨会

阻性阳极GEM探测器研究进展

董明义，鞠旭东，欧阳群，修青磊

核探测与核电子学国家重点实验室
State Key Laboratory of Particle Detection and Electronics

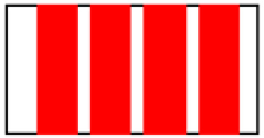
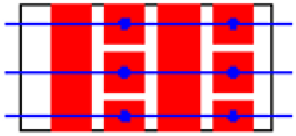
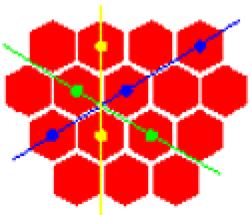
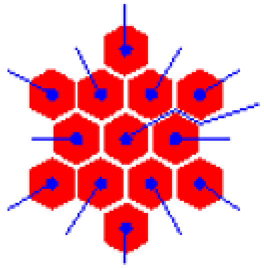
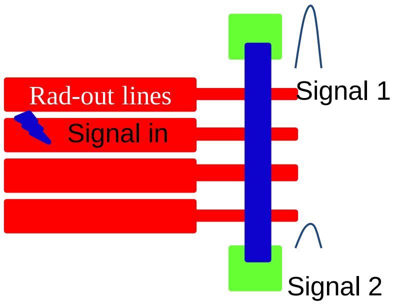
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

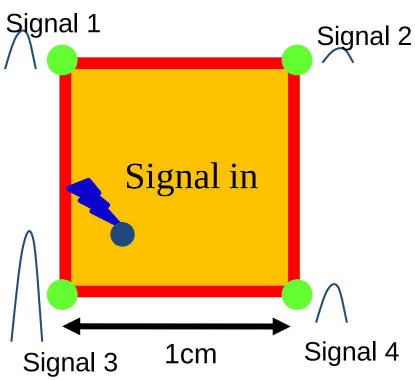
- 探测器基本介绍
- 探测器均匀性研究
- 阻性阳极读出板参数研究
- 总结与计划

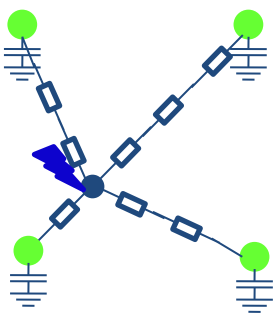
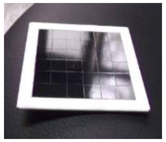
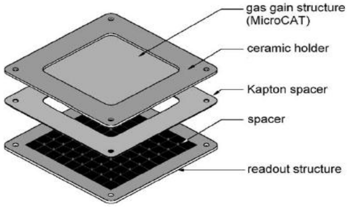
探测器基本介绍

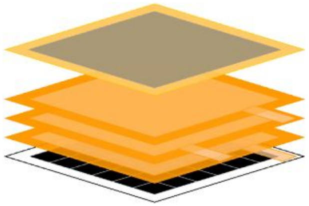
阻性阳极二维插值读出方法

- **目的：**
  - 研究**阻性阳极二维插值**读出方法
  - 用于X射线成像等二维位置灵敏探测器
- **优点：**
  - 有效减少电子学，降低探测器成本
    - 相同的位置分辨率，通道数比像素读出减少**1-2个数量级**
  - 降低GEM探测器连续放电几率，提高稳定性
- **重点：**
  - 阻性阳极读出板
  - 二维插值重建算法
- **应用：**
  - 可用于各种微结构探测器的读出极
  - **Resistive Anode Gas Electron Multiplier**

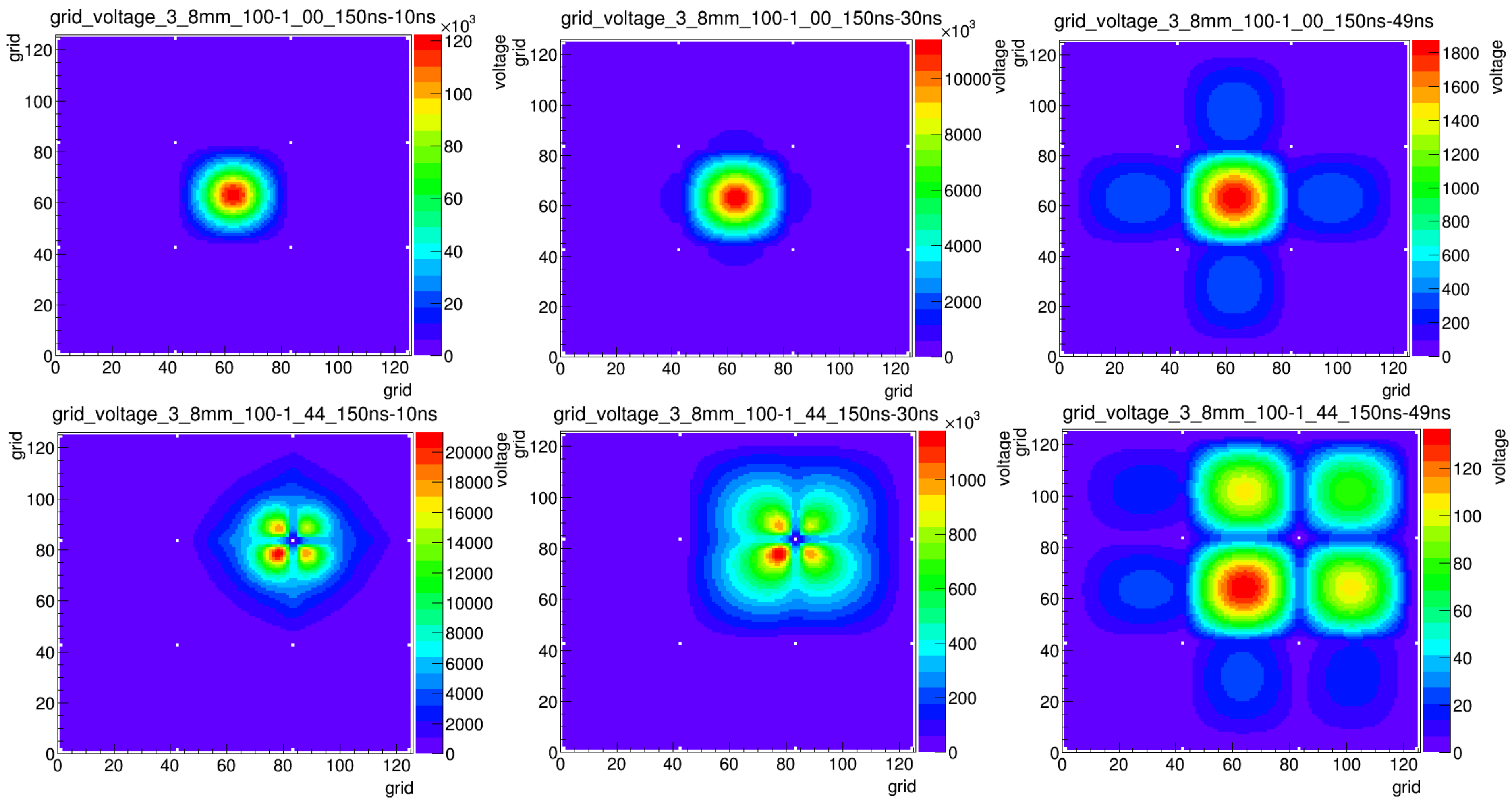




juxd@ihep.ac.cn

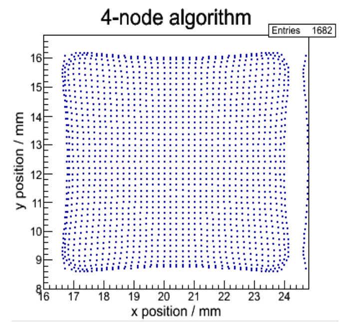
RAGEM读出原理

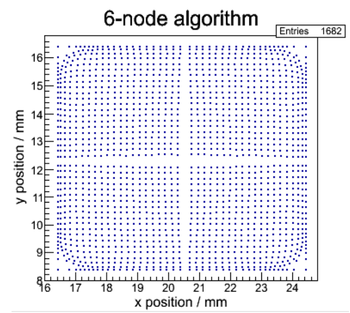


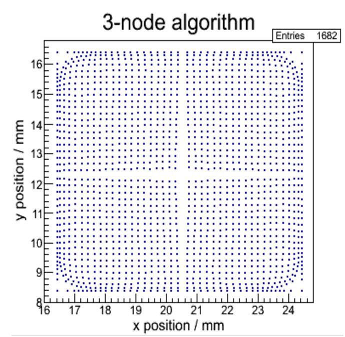
- 原初电离电子经过三级GEM进行**雪崩放大**
- 雪崩放大后的电子向**阻性阳极平面漂移**，并在阻性阳极平面上**感应出电荷**
- **感应电荷**在**阻性阳极平面**上向周围**扩散**，并最终在收集节点处被收集进入前放

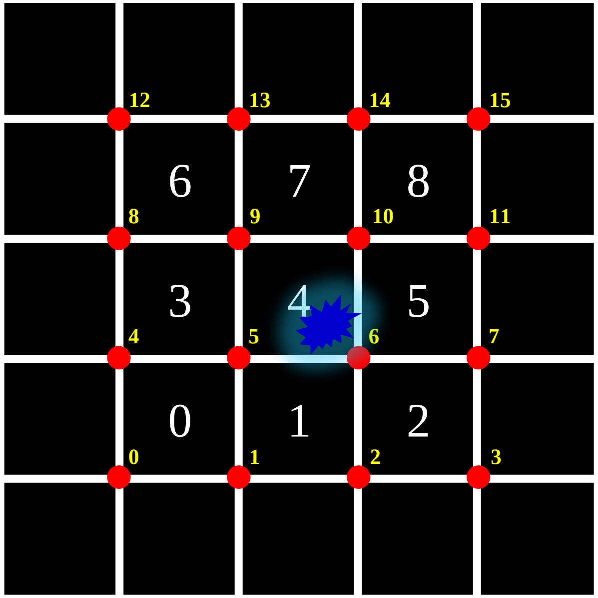
RAGEM重建算法

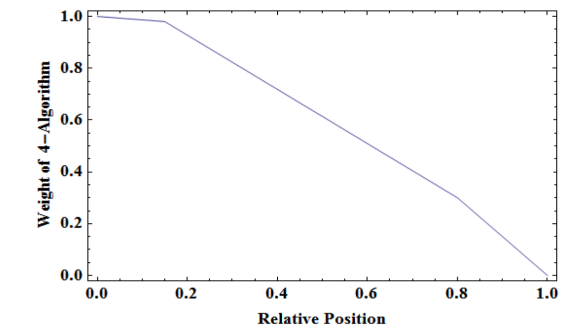
- **4节点方法 -靠近中心**
  - $x_4 = L \times \frac{(Q_{10}-Q_9)+(Q_6-Q_5)}{Q_5+Q_6+Q_9+Q_{10}}$
  - $y_4 = L \times \frac{(Q_{10}-Q_6)+(Q_9-Q_5)}{Q_5+Q_6+Q_9+Q_{10}}$
- **6节点方法 -靠近低阻条**
  - $x_6 = L \times \frac{(Q_{11}-Q_9)+(Q_7-Q_5)}{Q_{11}+Q_{10}+Q_9+Q_7+Q_6+Q_5}$
  - $y_6 = L \times \frac{(Q_{10}-Q_2)+(Q_9-Q_1)}{Q_{10}+Q_6+Q_2+Q_9+Q_5+Q_1}$
- **3节点方法 -靠近节点**
  - $x_3 = L \times \frac{(Q_7-Q_5)}{Q_7+Q_6+Q_5}$
  - $y_3 = L \times \frac{(Q_{10}-Q_2)}{Q_{10}+Q_6+Q_2}$
- **346组合方法 -参数刻度**
  - $x = a_x x_4 + (1-a_x)[b_x x_3 + (1-b_x)x_6]$
  - $y = a_y y_4 + (1-a_y)[b_y y_3 + (1-b_y)y_6]$

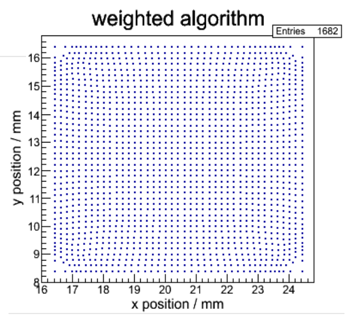


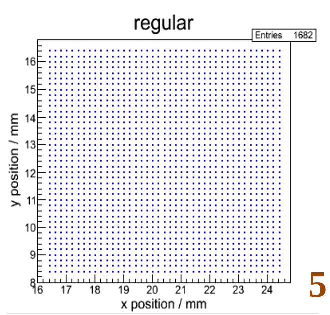






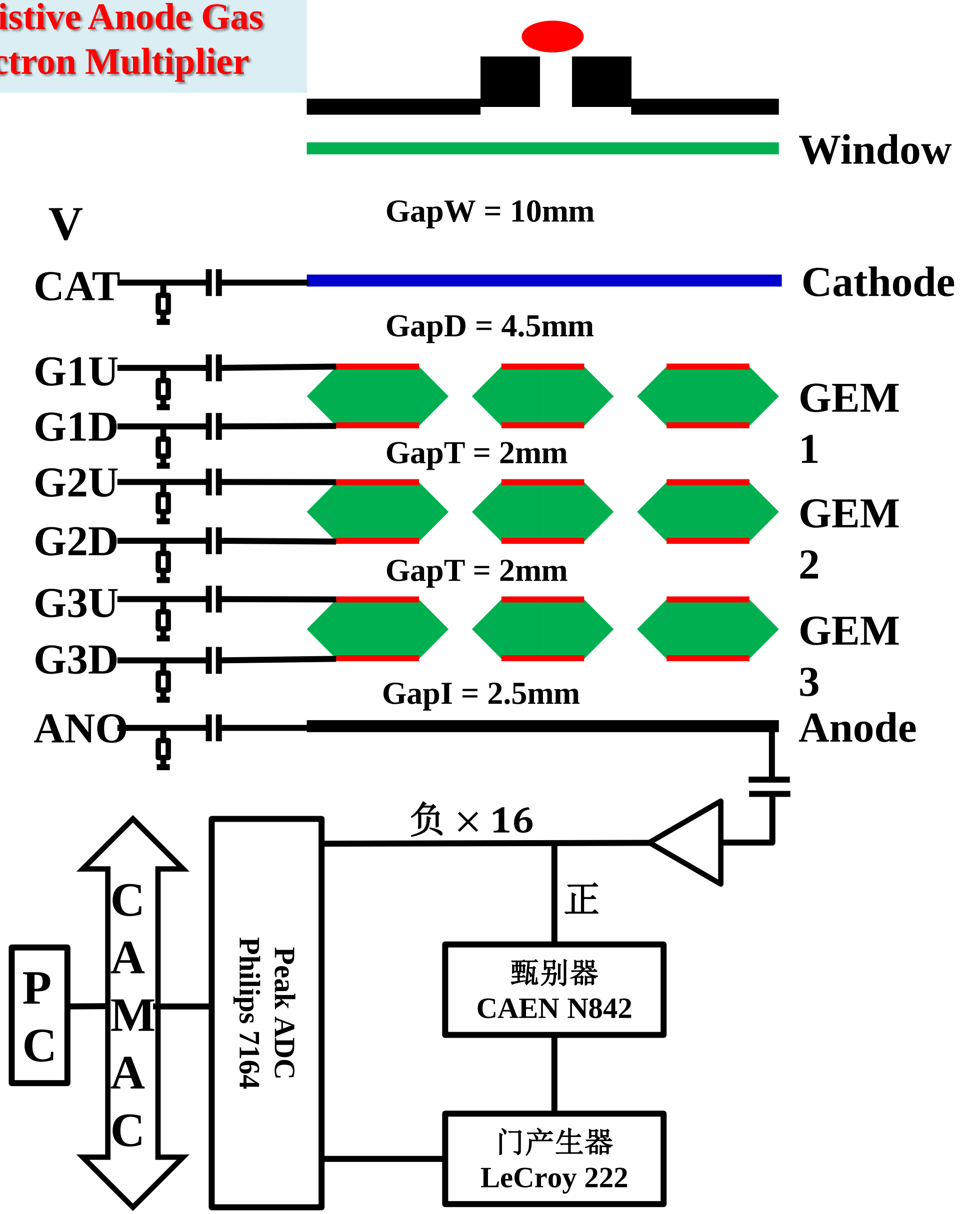


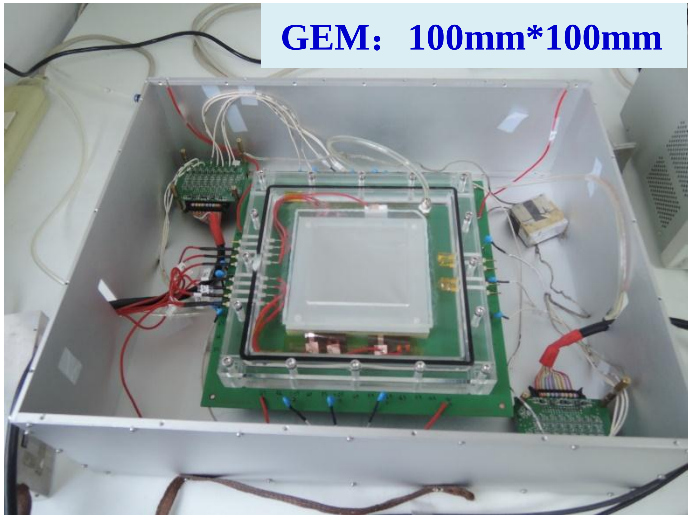


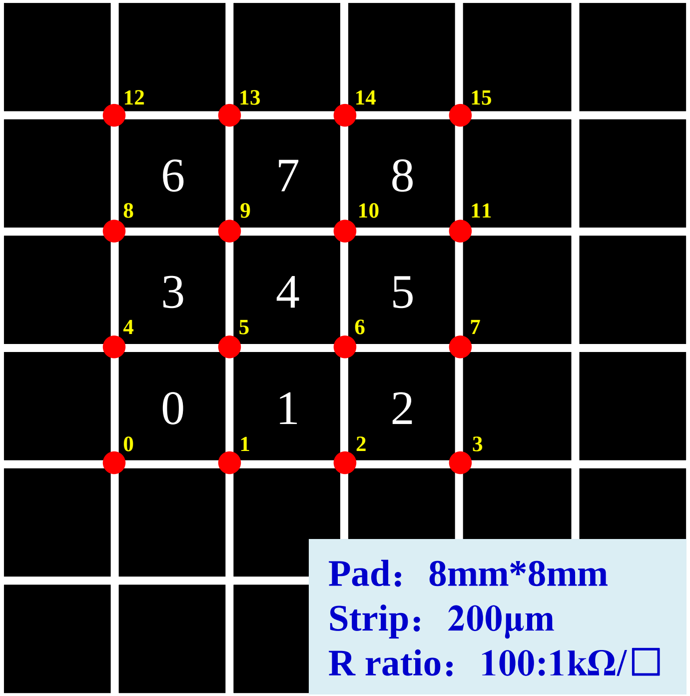


RAGEM原理机

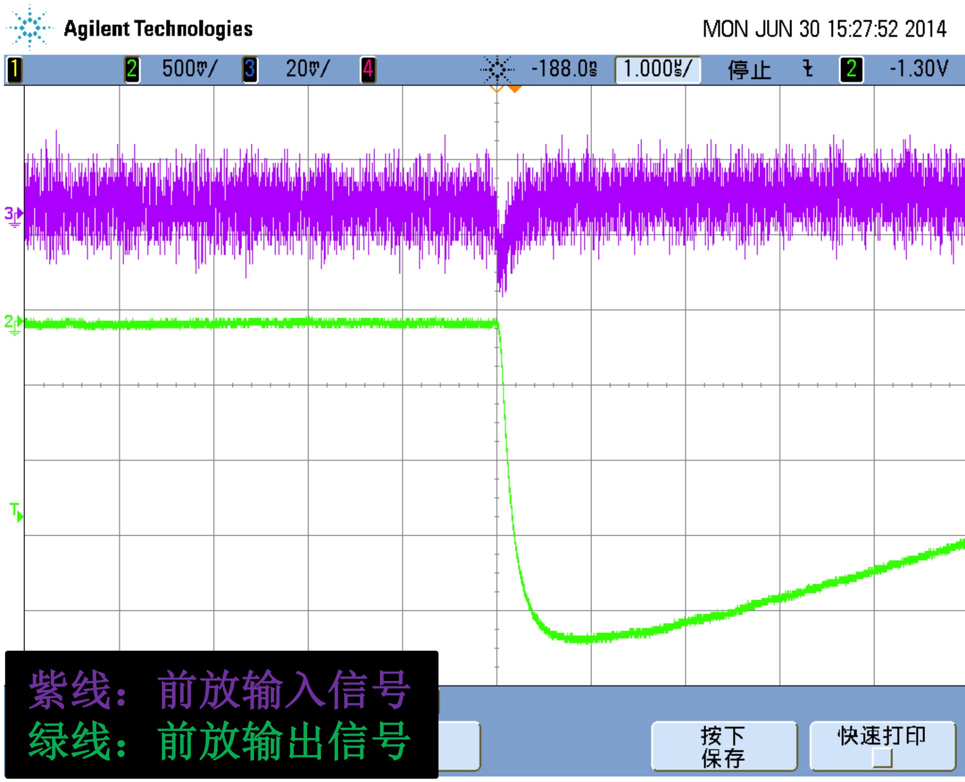
Resistive Anode Gas Electron Multiplier



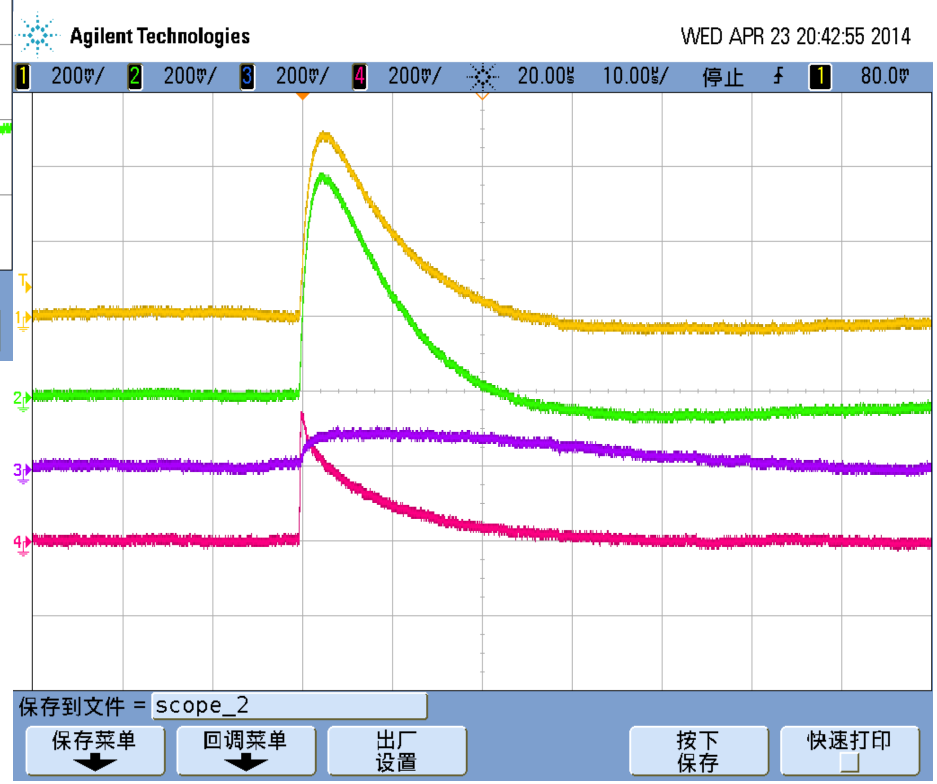




典型的RAGEM信号



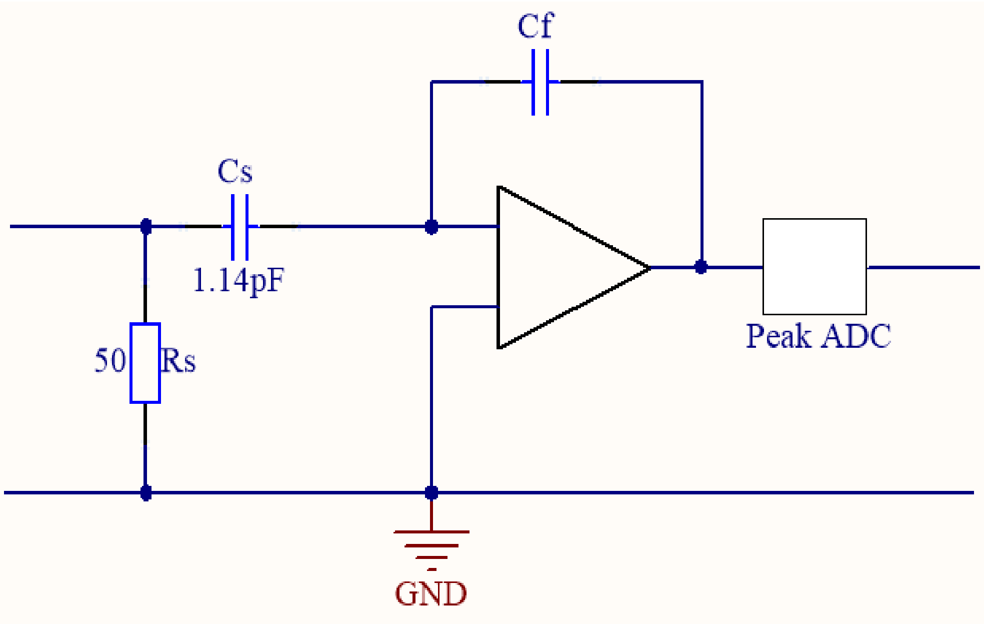
Agilent Technologies
MON JUN 30 15:27:52 2014
500mV/
20mV/
-188.0ns
1.000us/
停止
-1.30V
按下保存
快速打印
紫线：前放输入信号
绿线：前放输出信号



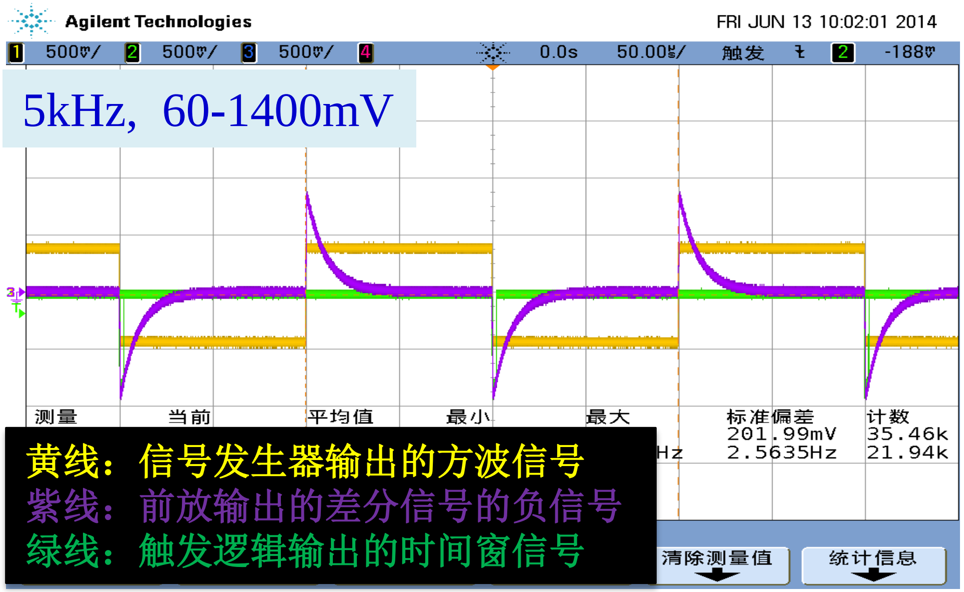
Agilent Technologies
WED APR 23 20:42:55 2014
200mV/
200mV/
200mV/
200mV/
20.00ns
10.00ns/
停止
80.0mV
保存到文件 = scope_2
保存菜单
回调菜单
出厂设置
按下保存
快速打印

RAGEM均匀性研究

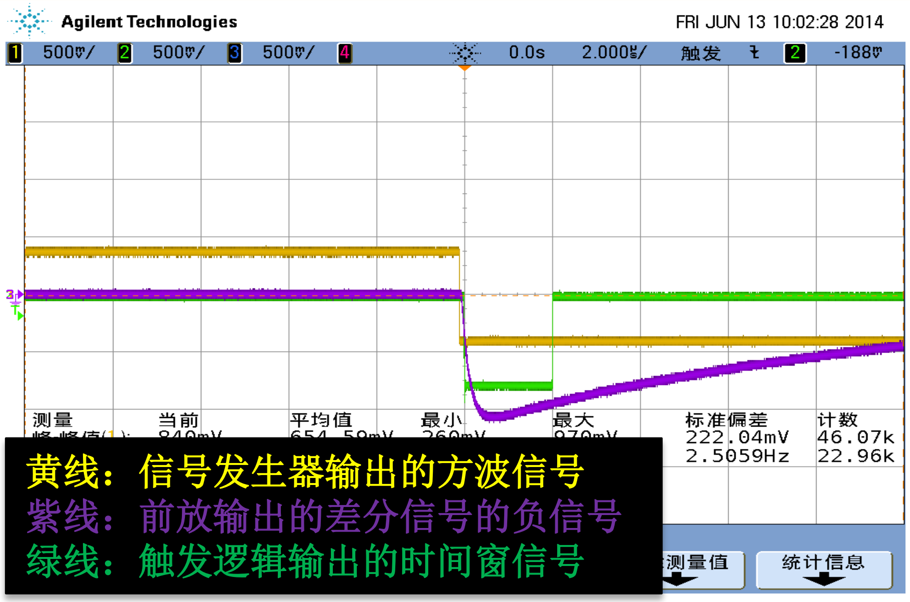
RAGEM电子学刻度



Cf
Cs
1.14pF
50
Rs
Peak ADC
GND

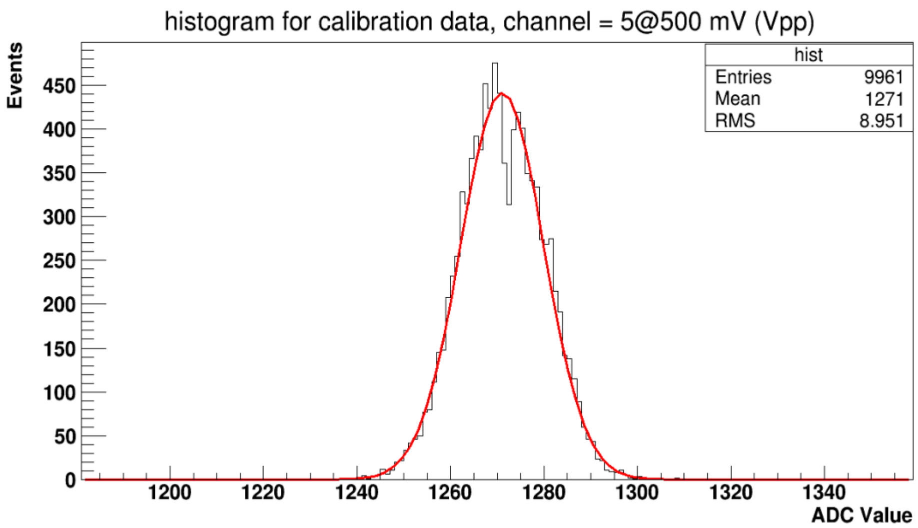


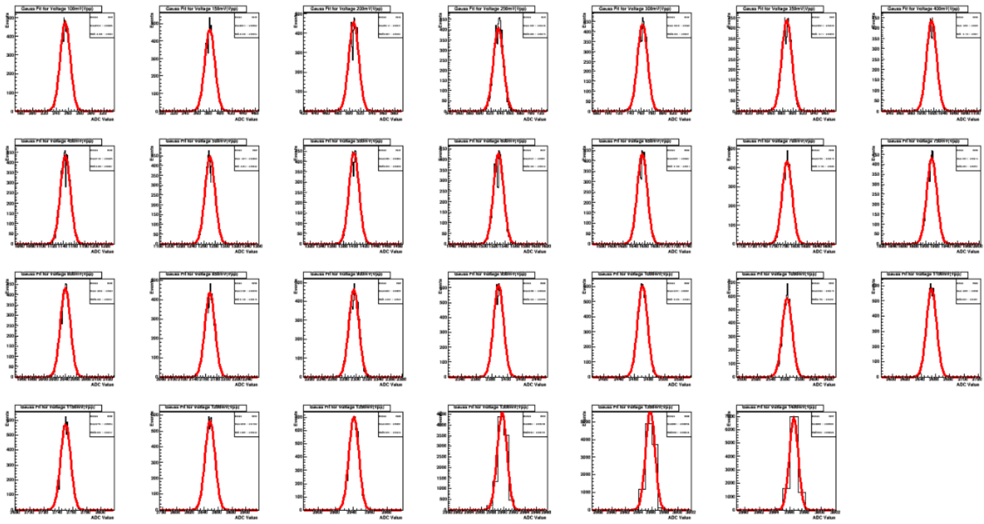
Agilent Technologies
FRI JUN 13 10:02:01 2014
5kHz，60-1400mV
测量 当前 平均值 最小 最大 标准偏差 计数
201.99mV 35.46k
2.5635Hz 21.94k
黄线：信号发生器输出的方波信号
紫线：前放输出的差分信号的负信号
绿线：触发逻辑输出的时间窗信号
清除测量值
统计信息

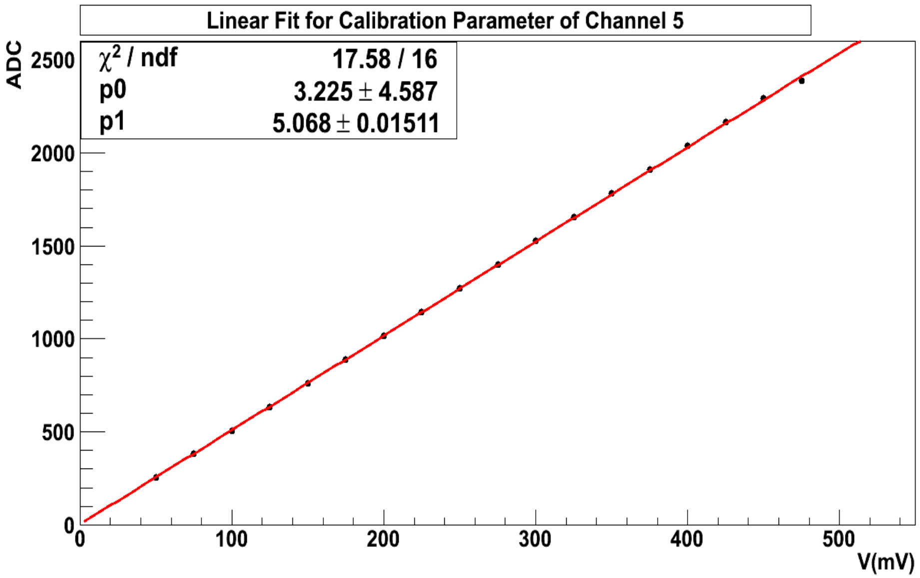


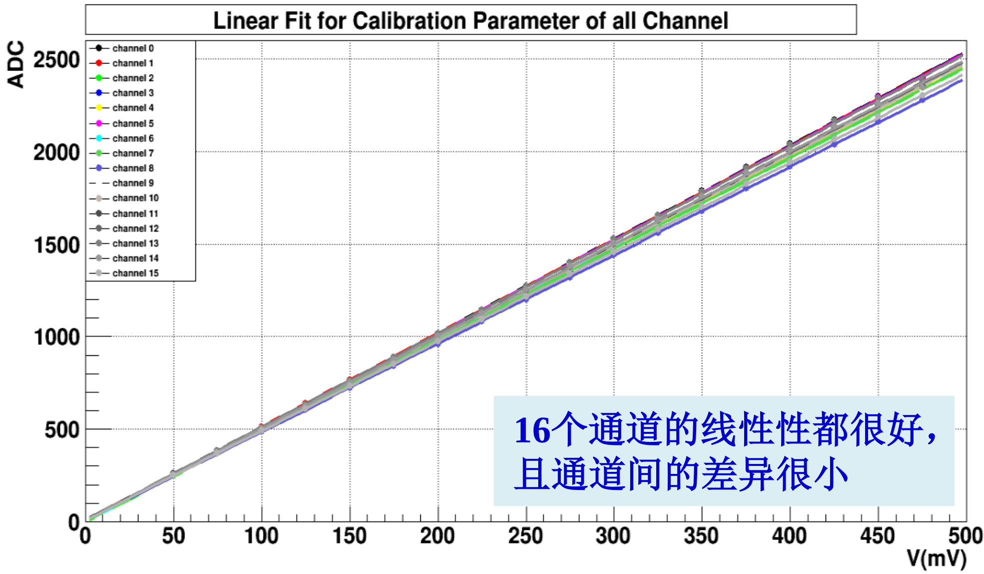
Agilent Technologies
FRI JUN 13 10:02:28 2014
测量 当前 平均值 最小 最大 标准偏差 计数
222.04mV 46.07k
2.5059Hz 22.96k
黄线：信号发生器输出的方波信号
紫线：前放输出的差分信号的负信号
绿线：触发逻辑输出的时间窗信号
统计信息

RAGEM电子学刻度

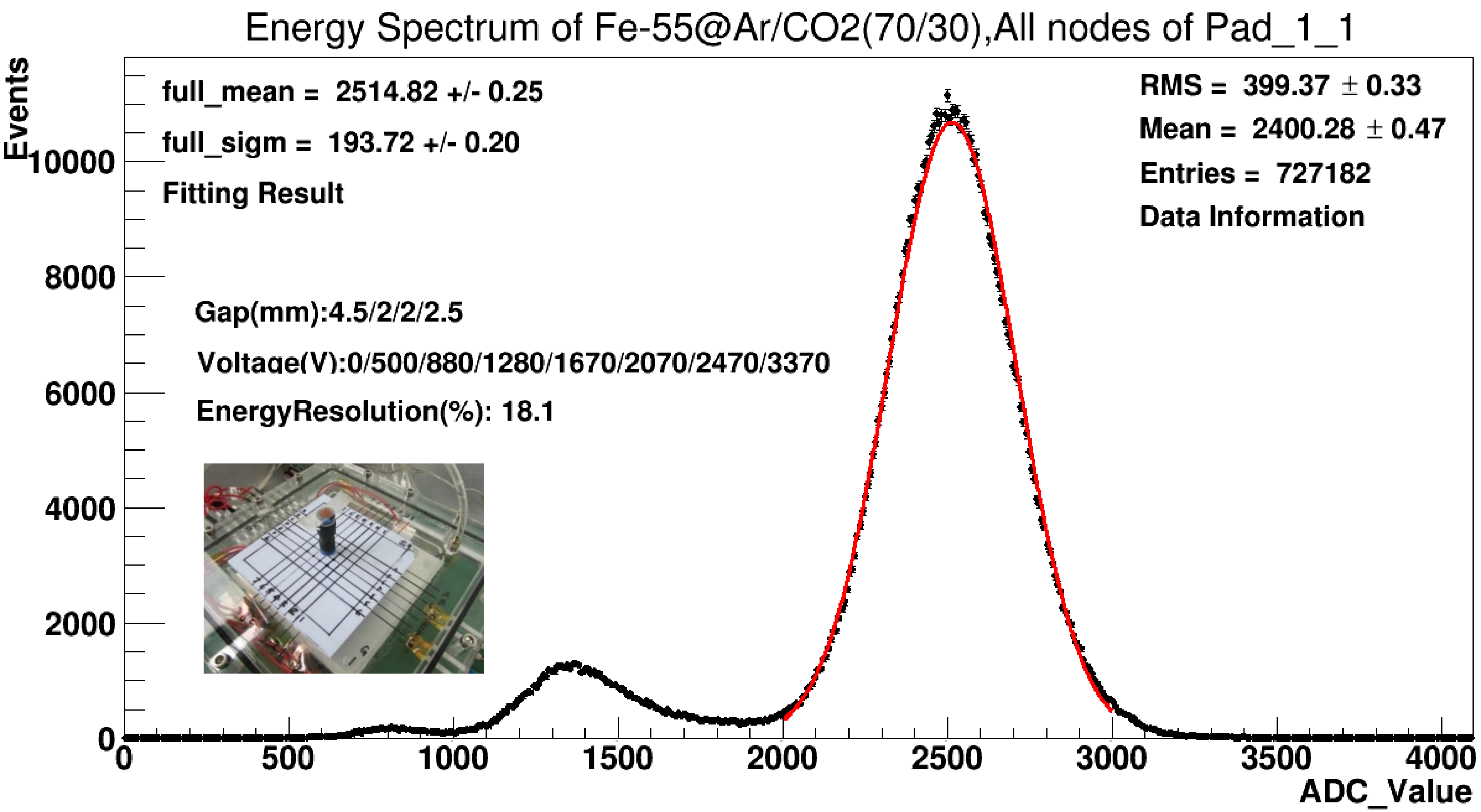

histogram for calibration data, channel = 5@500 mV (Vpp)
hist
Entries 9961
Mean 1271
RMS 8.951
Events
ADC Value



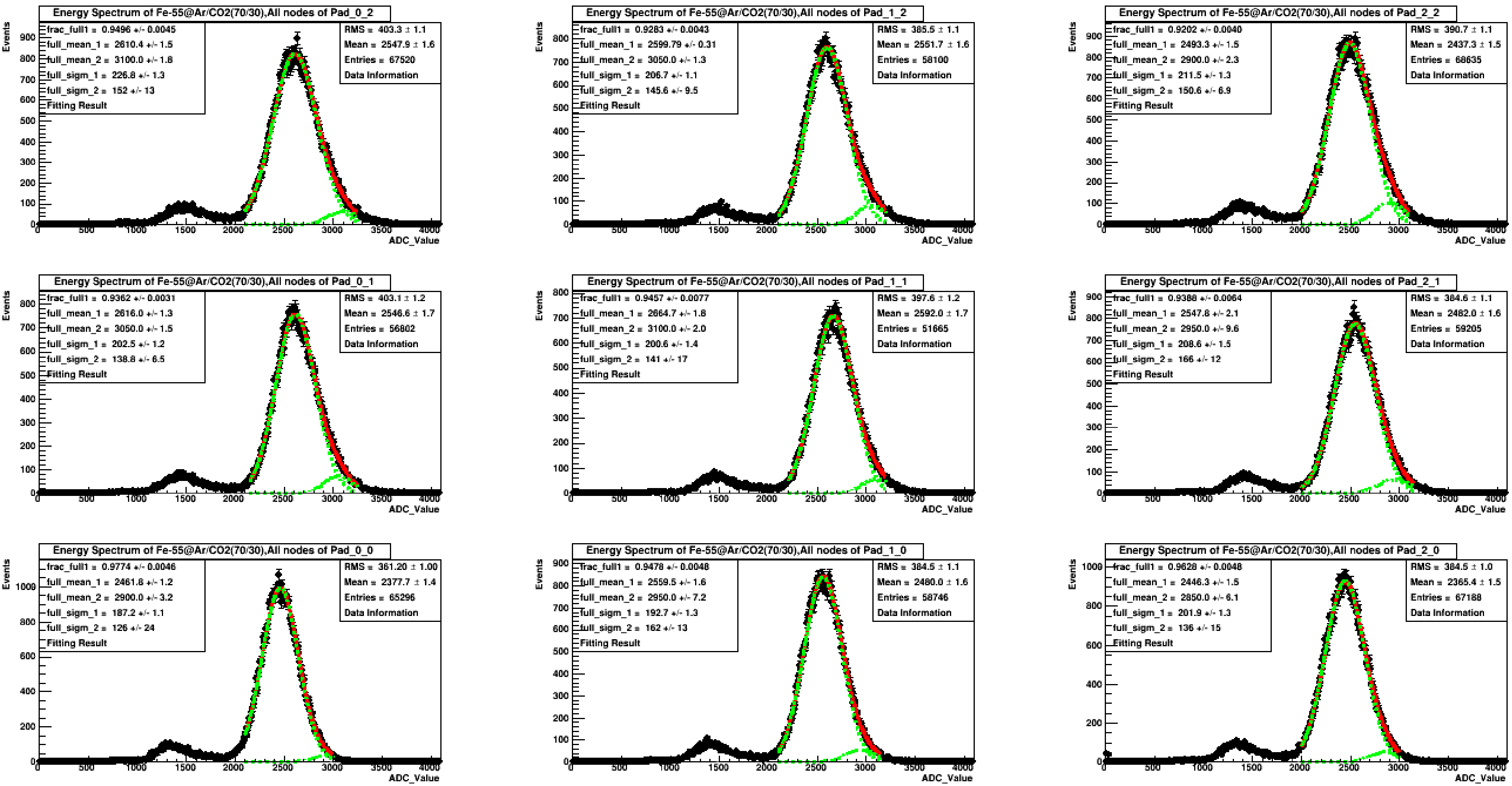

Linear Fit for Calibration Parameter of Channel 5
χ^2 / ndf 17.58 / 16
p0 3.225 ± 4.587
p1 5.068 ± 0.01511
ADC
V(mV)


Linear Fit for Calibration Parameter of all Channel
channel 0
channel 1
channel 2
channel 3
channel 4
channel 5
channel 6
channel 7
channel 8
channel 9
channel 10
channel 11
channel 12
channel 13
channel 14
channel 15
ADC
V(mV)
16个通道的线性性都很好，
且通道间的差异很小

RAGEM能量分辨率

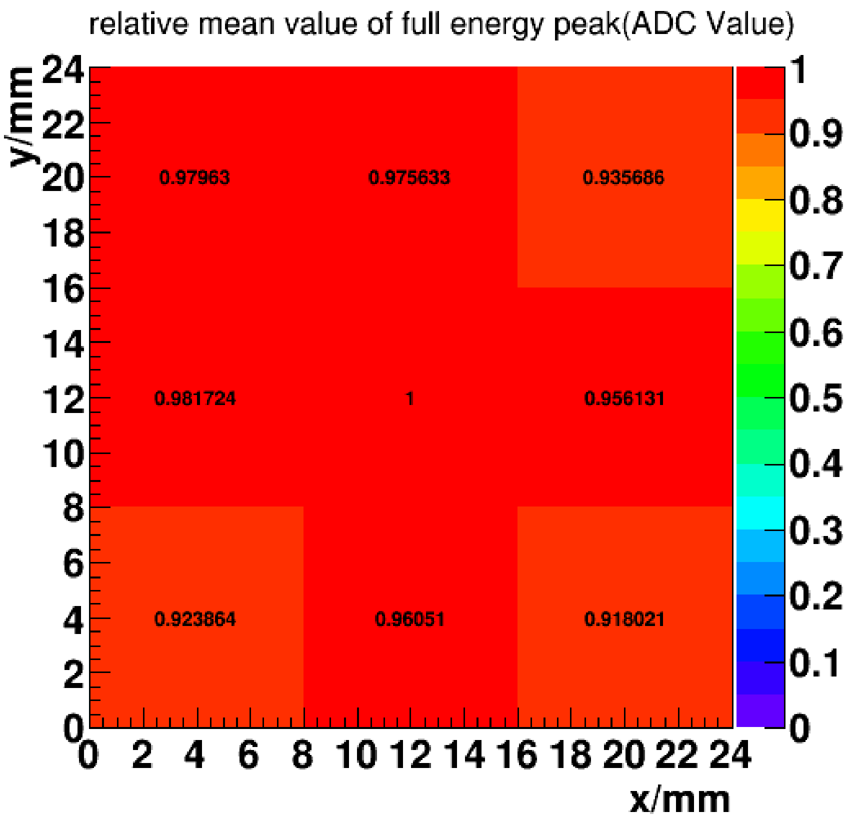

Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_1_1
full_mean = 2514.82 +/- 0.25
full_sigm = 193.72 +/- 0.20
Fitting Result
RMS = 399.37 ± 0.33
Mean = 2400.28 ± 0.47
Entries = 727182
Data Information
Gap(mm):4.5/2/2/2.5
Voltage(V):0/500/880/1280/1670/2070/2470/3370
EnergyResolution(%): 18.1
Events
0
2000
4000
6000
8000
10000
0
500
1000
1500
2000
2500
3000
3500
4000
ADC_Value

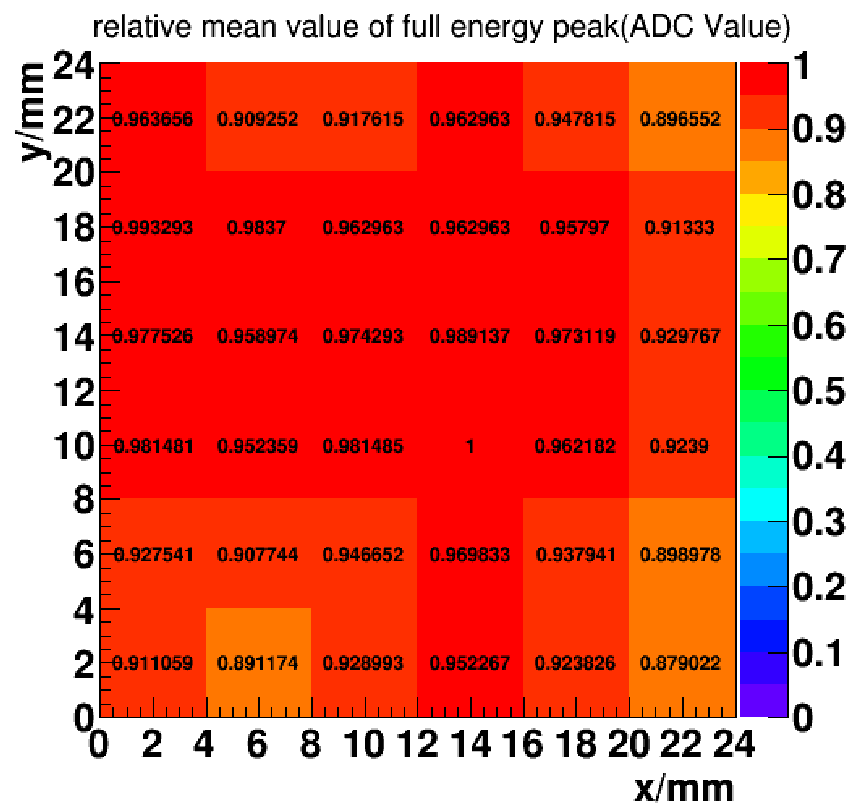
RAGEM能量分辨率



Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_0_2
frac_full1 = 0.9496 +/- 0.0045
full_mean_1 = 2610.4 +/- 1.5
full_mean_2 = 3100.0 +/- 1.8
full_sigm_1 = 226.8 +/- 1.3
full_sigm_2 = 152 +/- 13
Fitting Result
RMS = 403.3 ± 1.1
Mean = 2547.9 ± 1.6
Entries = 67520
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_1_2
frac_full1 = 0.9283 +/- 0.0043
full_mean_1 = 2599.79 +/- 0.31
full_mean_2 = 3050.0 +/- 1.3
full_sigm_1 = 206.7 +/- 1.1
full_sigm_2 = 145.6 +/- 9.5
Fitting Result
RMS = 385.5 ± 1.1
Mean = 2551.7 ± 1.6
Entries = 58100
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_2_2
frac_full1 = 0.9202 +/- 0.0040
full_mean_1 = 2493.3 +/- 1.5
full_mean_2 = 2900.0 +/- 2.3
full_sigm_1 = 211.5 +/- 1.3
full_sigm_2 = 150.6 +/- 6.9
Fitting Result
RMS = 390.7 ± 1.1
Mean = 2437.3 ± 1.5
Entries = 68635
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_0_1
frac_full1 = 0.9362 +/- 0.0031
full_mean_1 = 2616.0 +/- 1.3
full_mean_2 = 3050.0 +/- 1.5
full_sigm_1 = 202.5 +/- 1.2
full_sigm_2 = 138.8 +/- 6.5
Fitting Result
RMS = 403.1 ± 1.2
Mean = 2546.6 ± 1.7
Entries = 56802
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_1_1
frac_full1 = 0.9457 +/- 0.0077
full_mean_1 = 2664.7 +/- 1.8
full_mean_2 = 3100.0 +/- 2.0
full_sigm_1 = 200.6 +/- 1.4
full_sigm_2 = 141 +/- 17
Fitting Result
RMS = 397.6 ± 1.2
Mean = 2592.0 ± 1.7
Entries = 51665
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_2_1
frac_full1 = 0.9388 +/- 0.0064
full_mean_1 = 2547.8 +/- 2.1
full_mean_2 = 2950.0 +/- 9.6
full_sigm_1 = 208.6 +/- 1.5
full_sigm_2 = 166 +/- 12
Fitting Result
RMS = 384.6 ± 1.1
Mean = 2482.0 ± 1.6
Entries = 59205
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_0_0
frac_full1 = 0.9774 +/- 0.0046
full_mean_1 = 2461.8 +/- 1.2
full_mean_2 = 2900.0 +/- 3.2
full_sigm_1 = 187.2 +/- 1.1
full_sigm_2 = 126 +/- 24
Fitting Result
RMS = 361.20 ± 1.00
Mean = 2377.7 ± 1.4
Entries = 65296
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_1_0
frac_full1 = 0.9478 +/- 0.0048
full_mean_1 = 2559.5 +/- 1.6
full_mean_2 = 2950.0 +/- 7.2
full_sigm_1 = 192.7 +/- 1.3
full_sigm_2 = 162 +/- 13
Fitting Result
RMS = 384.5 ± 1.1
Mean = 2480.0 ± 1.6
Entries = 58746
Data Information
Energy Spectrum of Fe-55@Ar/CO2(70/30),All nodes of Pad_2_0
frac_full1 = 0.9628 +/- 0.0048
full_mean_1 = 2446.3 +/- 1.5
full_mean_2 = 2850.0 +/- 6.1
full_sigm_1 = 201.9 +/- 1.3
full_sigm_2 = 136 +/- 15
Fitting Result
RMS = 384.5 ± 1.0
Mean = 2365.4 ± 1.5
Entries = 67188
Data Information
Events
ADC_Value

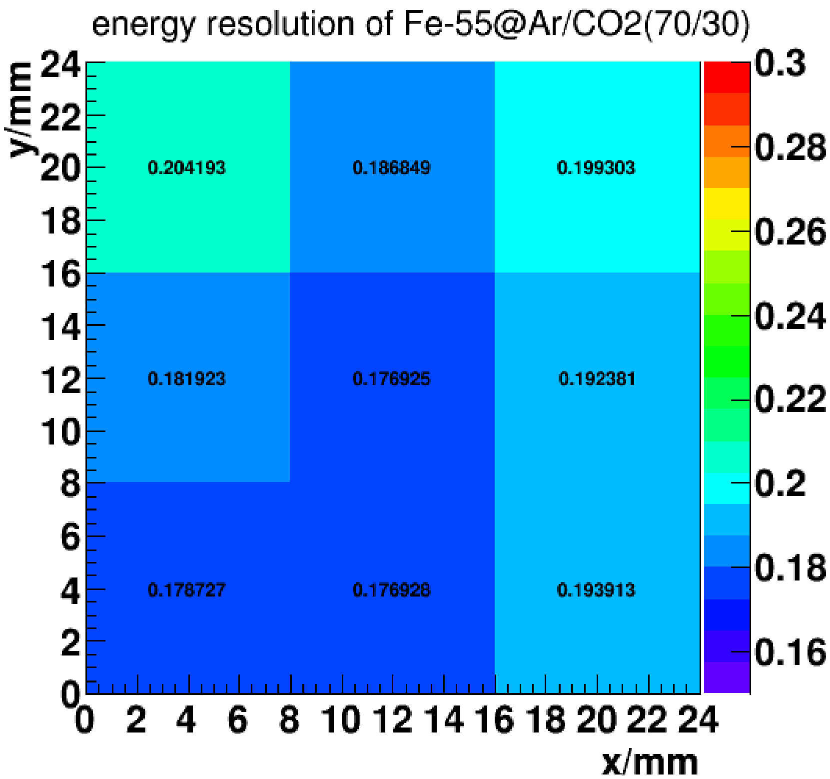
RAGEM增益均匀性

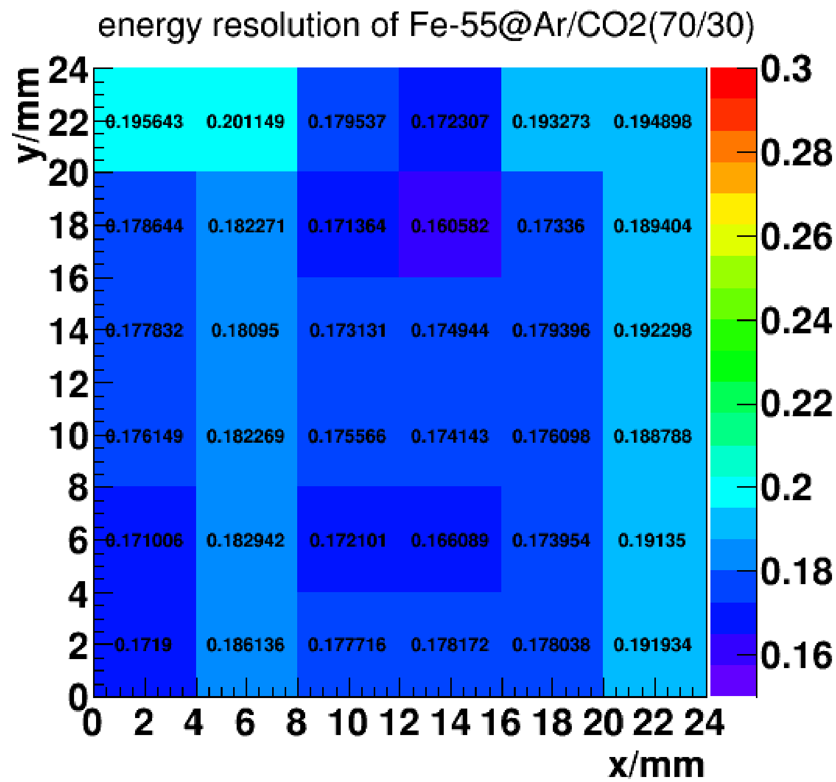




- 增益均匀性 <8% (~2500ADC)，中间Pad最大，周围Pad相对较小
  - 压强和温度的影响，探测器长时间工作的稳定性
  - 阻性阳极Pad本身的不均匀性，以及探测器入射窗不平等带来的影响
  - 周围Pad电荷扩散到了临近的没有电子学的Pad

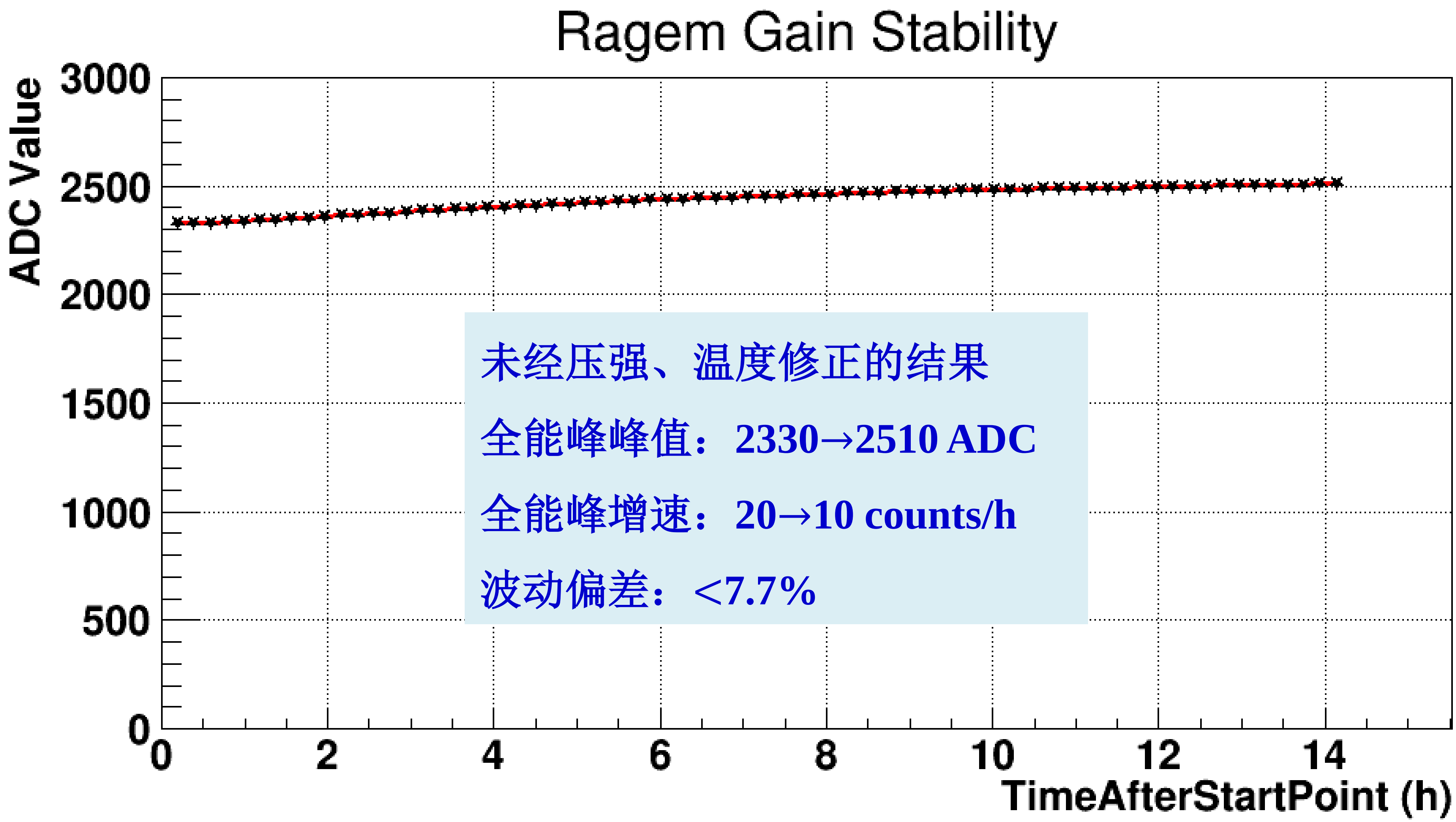
RAGEM能量分辨率均匀性





- 能量分辨率在**17%-20%**之间，气体探测器正常范围值

RAGEM增益稳定性



未经压强、温度修正的结果

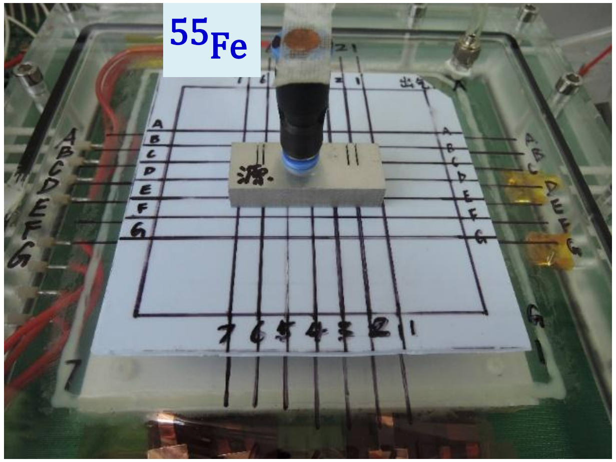
全能峰峰值：2330→2510 ADC

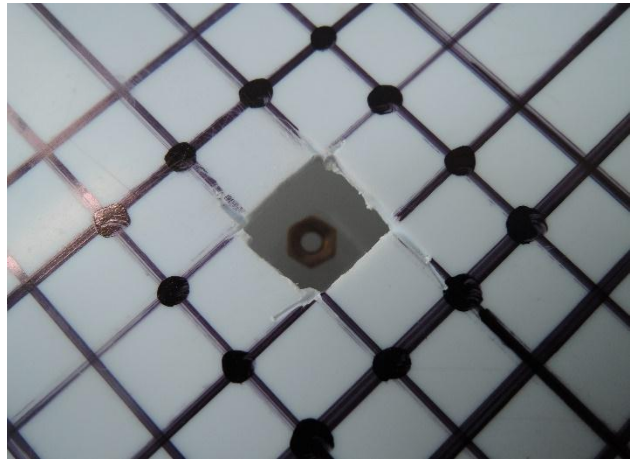
全能峰增速：20→10 counts/h

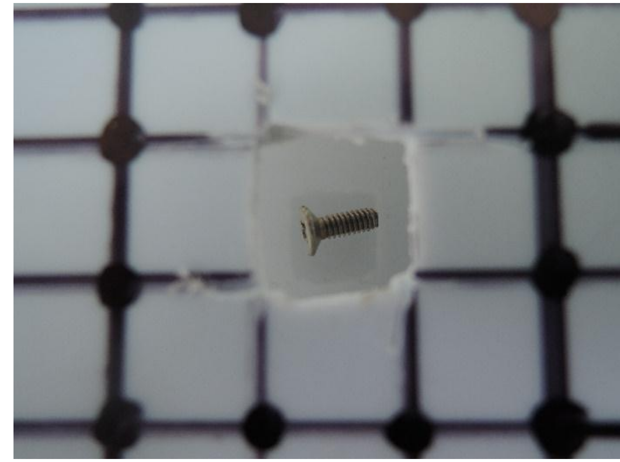
波动偏差：<7.7%

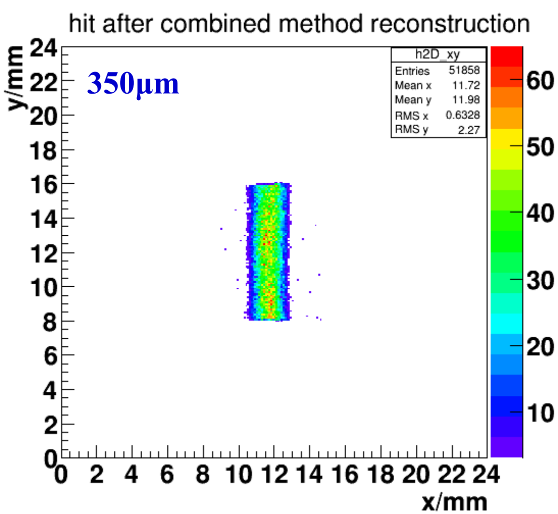
20140709日数据

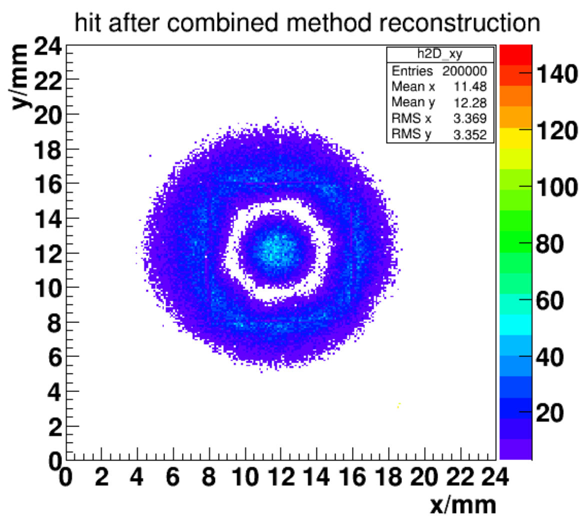
RAGEM初步成像结果

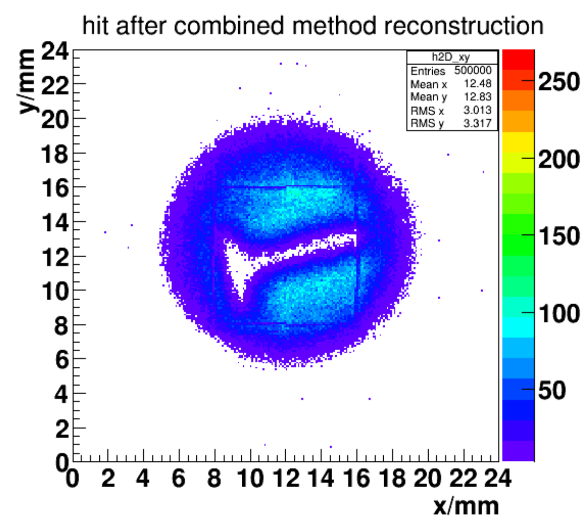






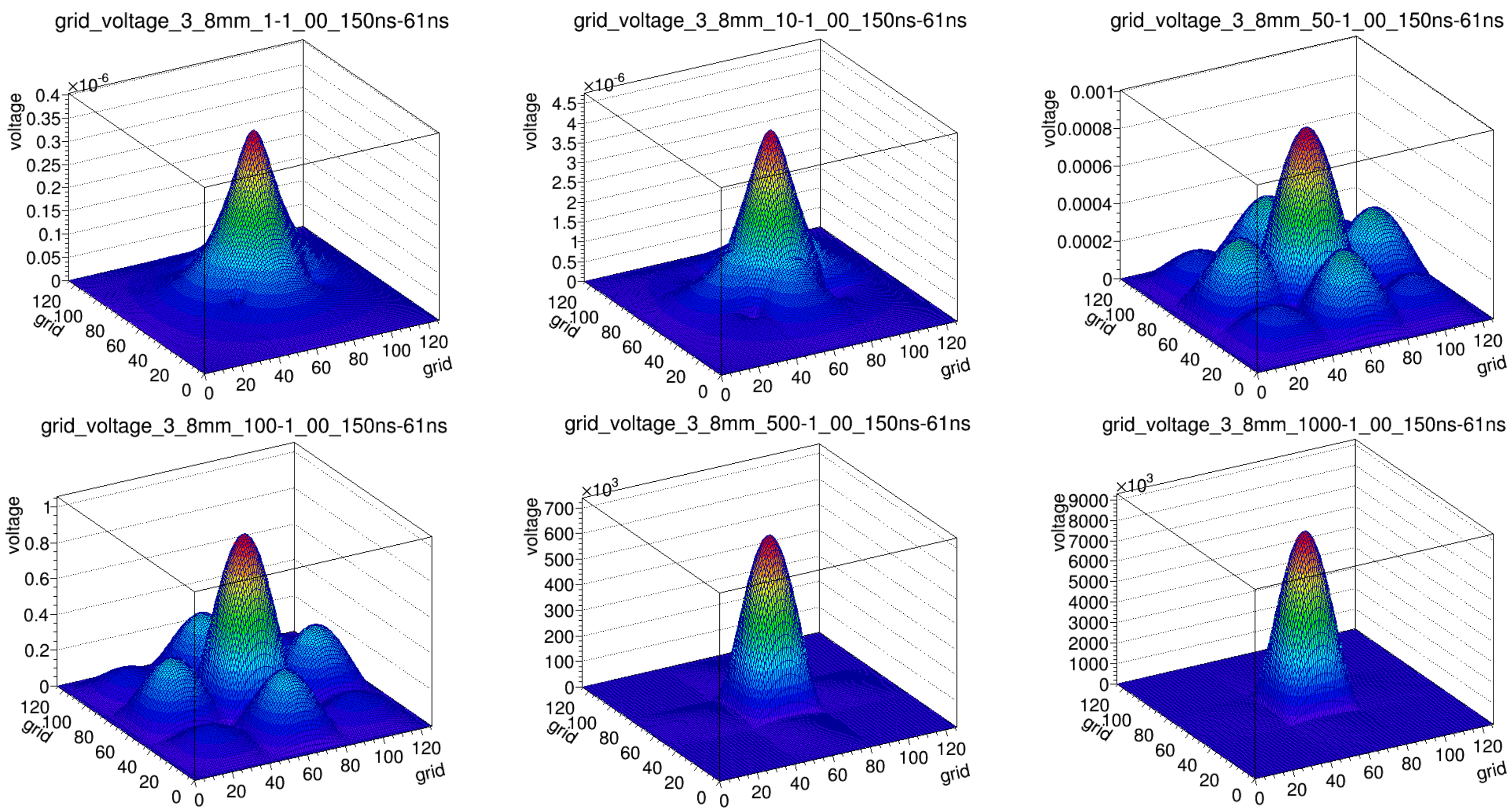






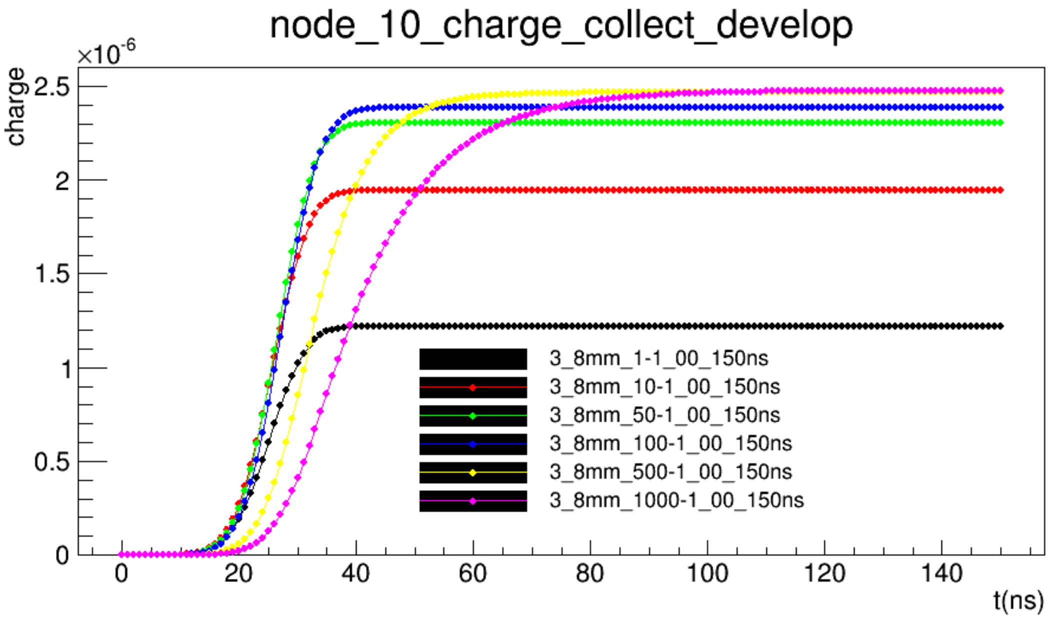
阻性阳极读出板参数研究

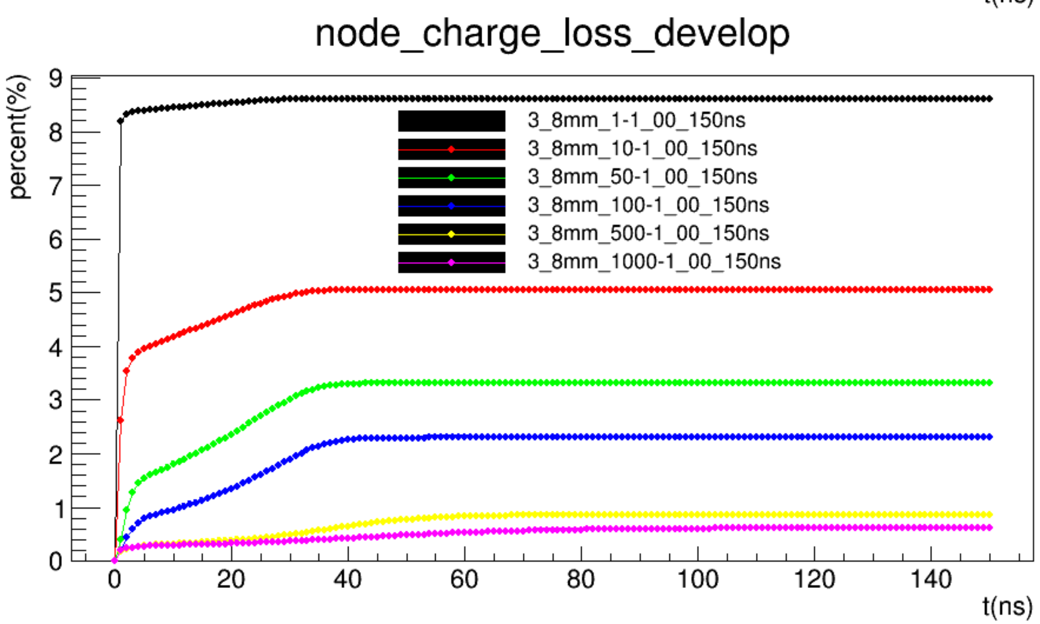
不同面电阻比值对电荷收集的影响



- 不同的面电阻比值，电荷扩散形状不同；且从**形状**上看，面电阻比值**越大**，电荷扩散的**越慢**
- 不同的面电阻比值，电荷收集时间不同；且从**幅值**上看，面电阻比值**越大**，电荷收集的**越慢**

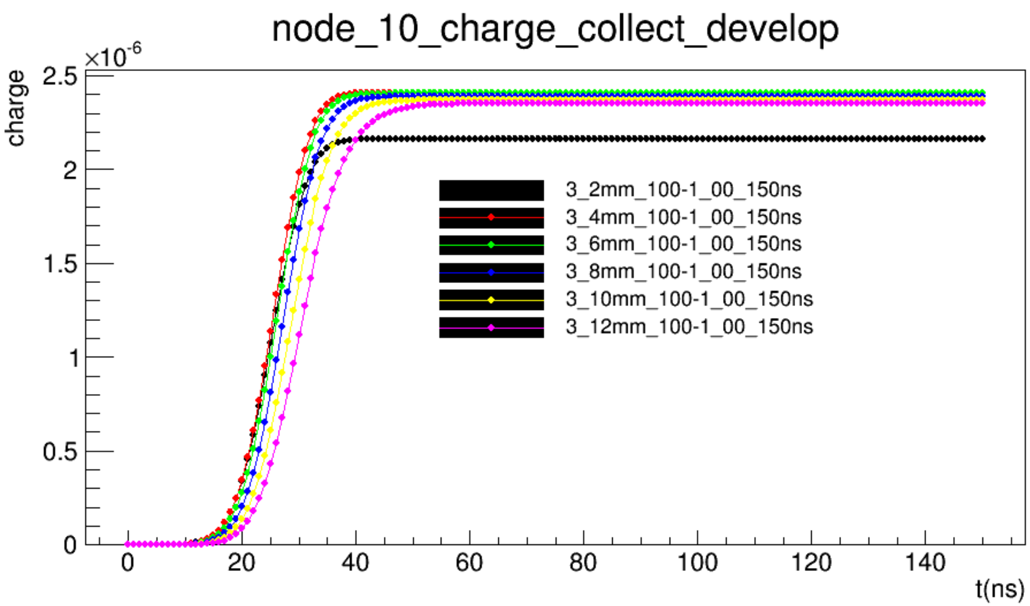
不同面电阻比值对电荷收集的影响

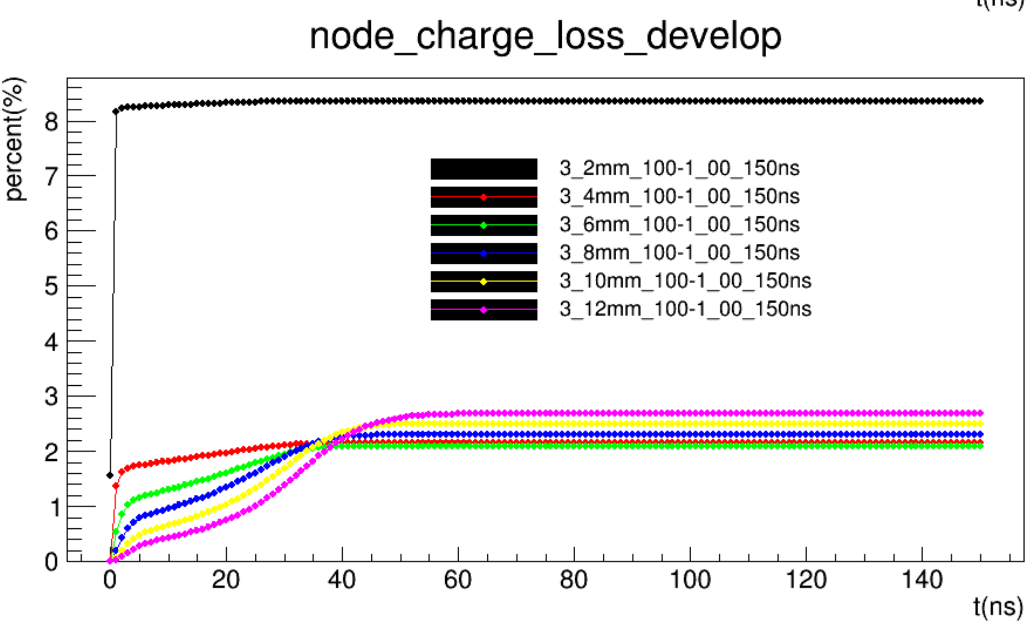




- **条件：**
  - 面电阻比值：不同(1:1–1000:1kΩ/□)
  - **Pad**尺寸：**8mm**
  - 击中位置：**Pad**中心
- **结论：**
  - 节点电荷收集时间：
    - 比值越大，收集越慢
    - **30ns** 到 **80ns**
  - 节点收集到的电荷：
    - 比值越大，收集越多
    - 相差 2 倍
  - **Pad**电荷损失率：
    - 比值越大，损失率越小
    - **0.5%** 到 **8.5%**
  - 比值太小
    - 热噪声大，影响位置分辨
  - 比值太大
    - 限制收集速率，影响计数率

不同Pad尺寸对电荷收集的影响

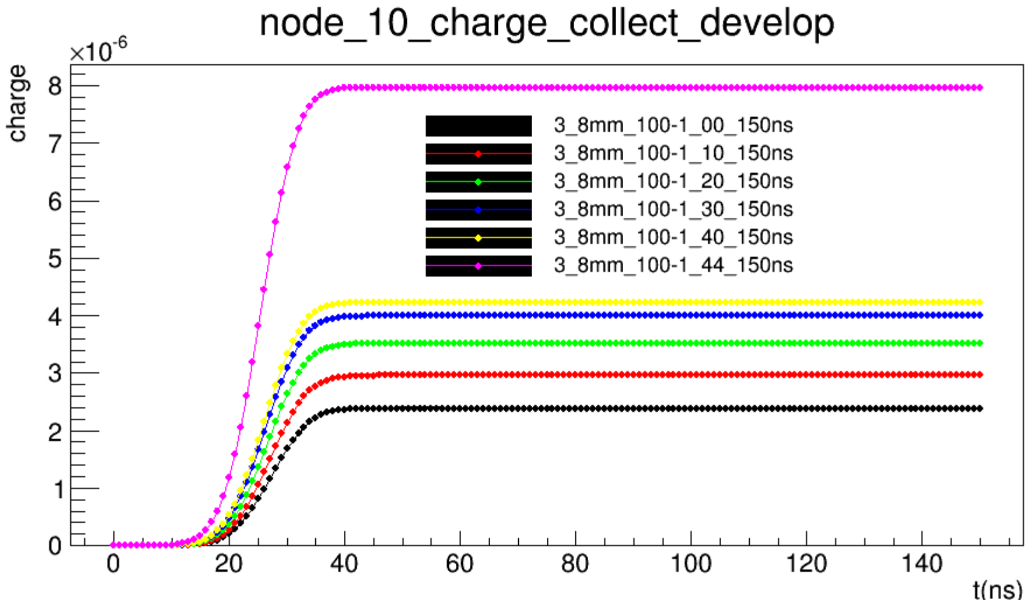


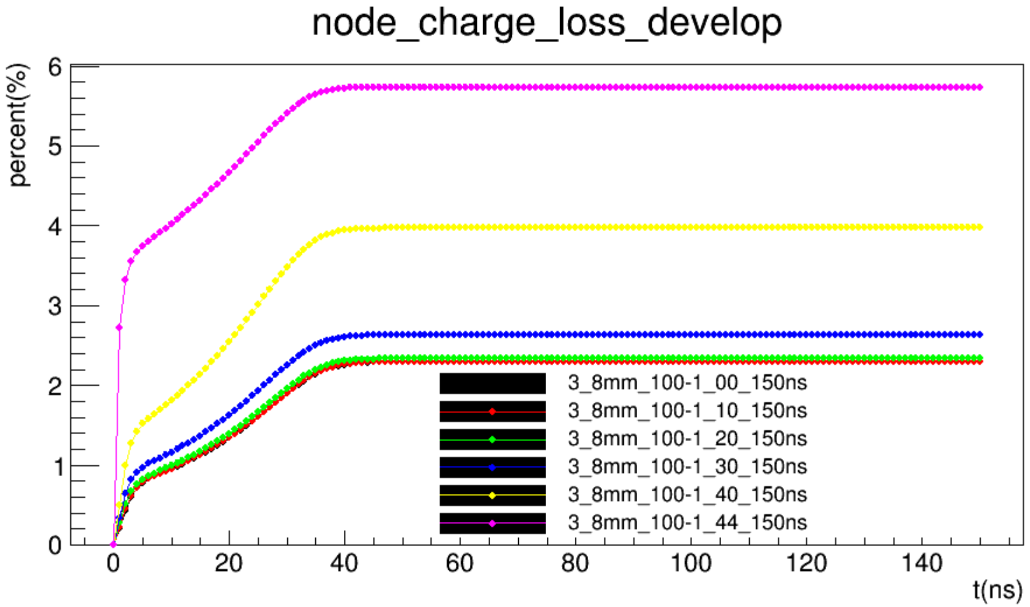


- **条件：**
  - 面电阻比值：**100:1kΩ/□**
  - **Pad尺寸：不同 (2 - 8mm)**
  - 击中位置：**Pad中心**
- **结论：**
  - 节点电荷收集时间：
    - 基本相同，约为 **35ns**
  - 节点收集到的电荷：
    - **Pad越大，收集越多**
    - 相差 很少
  - **Pad电荷损失率：**
    - **Pad大，损失少，有变化**
    - **2.5% 到 8.5%**

  - **Pad尺寸影响位置分辨**

不同击中位置对电荷收集的影响





- **条件：**
  - 面电阻比值：**100:1kΩ/□**
  - **Pad尺寸：8mm**
  - 击中位置：不同(**Pad**中心到边缘)
- **结论：**
  - 节点电荷收集时间：
    - 基本相同，约为 **35ns**
  - 节点收集到的电荷：
    - 越靠近节点，收集越多
    - 相差显著
  - **Pad**电荷损失率：
    - 越靠近节点，损失越多
    - 2.5% 到 6%

- 影响电荷收集时间的是面电阻比值
- **Pad**电荷损失并不显著，即电荷多被所在**Pad**的节点收集
- 电荷扩散过程对信号总得收集时间的限制很小

总结与计划

总结与计划

- 总结
  - 测试了探测器的均匀性，均匀性好于 8%
  - 初步进行了成像实验，（需要好的准直器和准直粒子源）
  - 计算了阻性阳极读出板的不同参数对电荷收集的影响，为探测器制作提供参考
- 计划
  - 新的电子学
    - 全部电子学通道，约 13*13 道
  - 新的原型机制作
    - 铝制室体
    - 测试不同参数的阻性阳极板对探测器性能的影响
  - 模拟和重建算法的优化和改进
    - 位置分辨
    - 大面积，多Seed
    - 新的刻度方法
  - X光机实验
    - 位置分辨
    - 成像

谢谢

Theory is when you know everything but nothing works.
Practice is when everything works but no one knows why.
Since I'm an experimenter, I suggest that you talk with a theorist if you really want to know why.