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

CEPC

2022年9月-12月工作报告

报告人：　　夏欣
导师　：　　阮曼奇

实验物理中心　高能量组

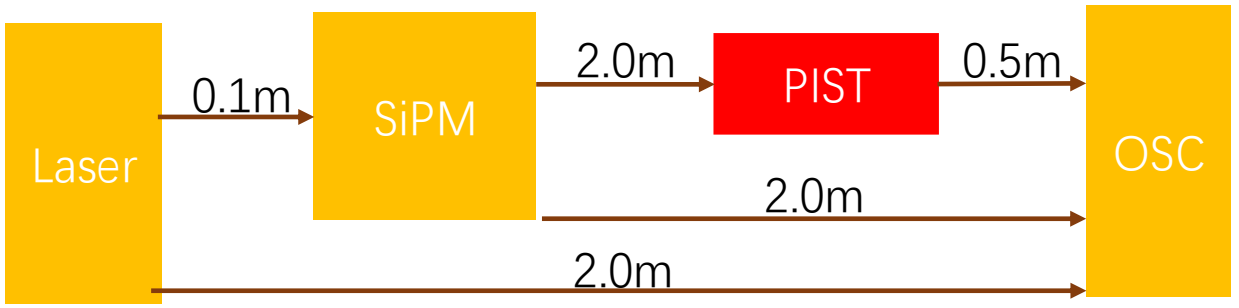
2023年1月6日

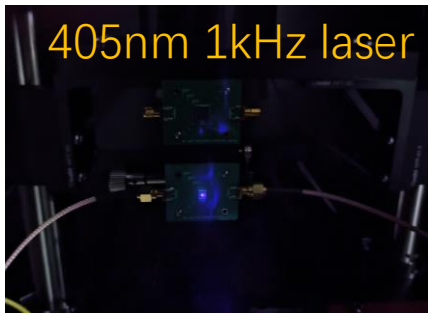
Outline

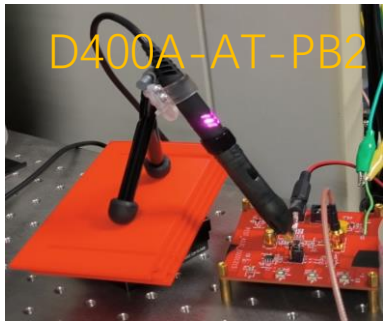
- PIST ASIC Test
- Influence of Multiple Scattering on Track Reconstruction
- dE/dx Measurement based on CEPC Baseline Silicon Tracker
- Summary

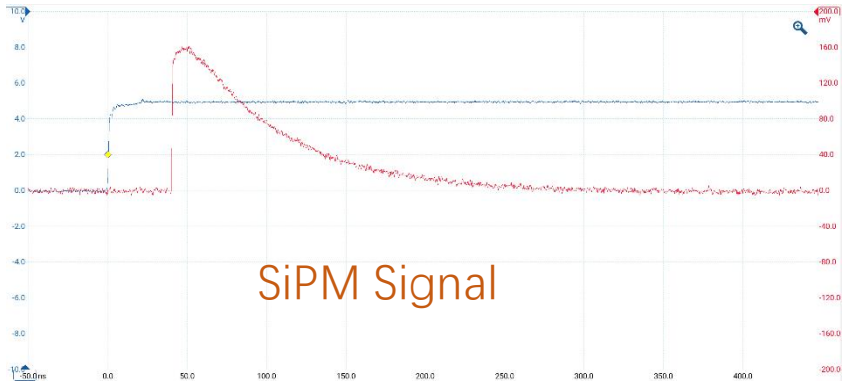
PIST ASIC Test

- Motivation: PIST ASIC主要用于连接CEPC的ECAL的SiPM传感器,有望在200 p.e信号的情况下实现优于10 ps的时间分辨，并具有TOT-like function。
- 工作内容：搭建并优化实验；分析信号波形并改善相关算法。

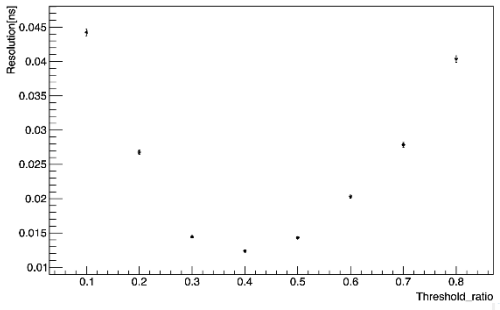


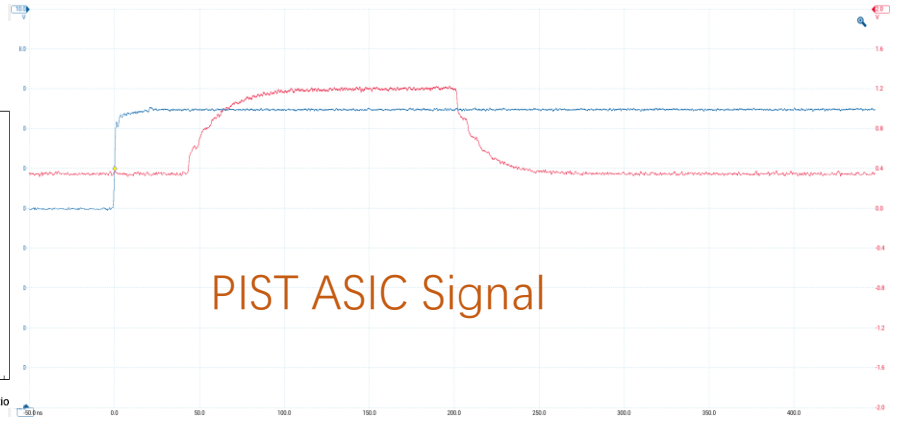






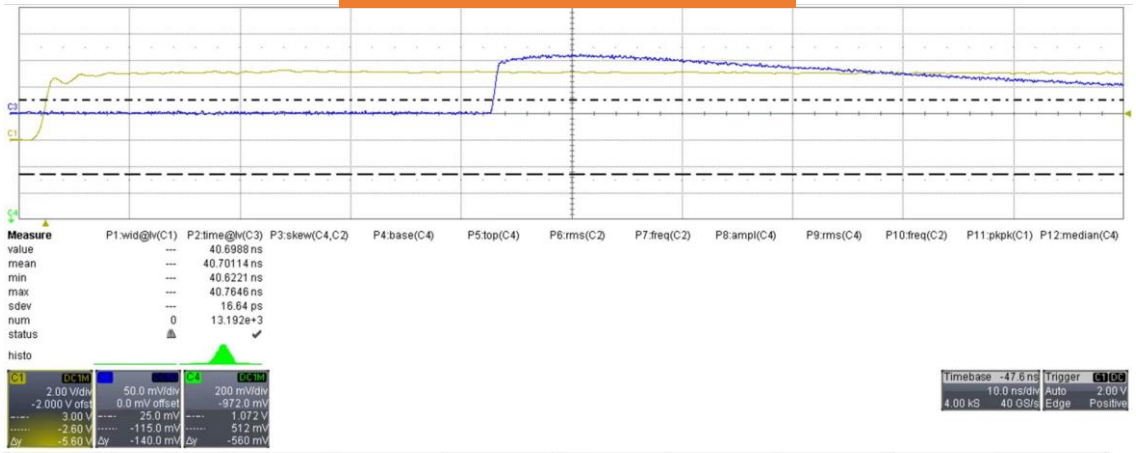
constant ratio Timing of SiPM signal leading edge

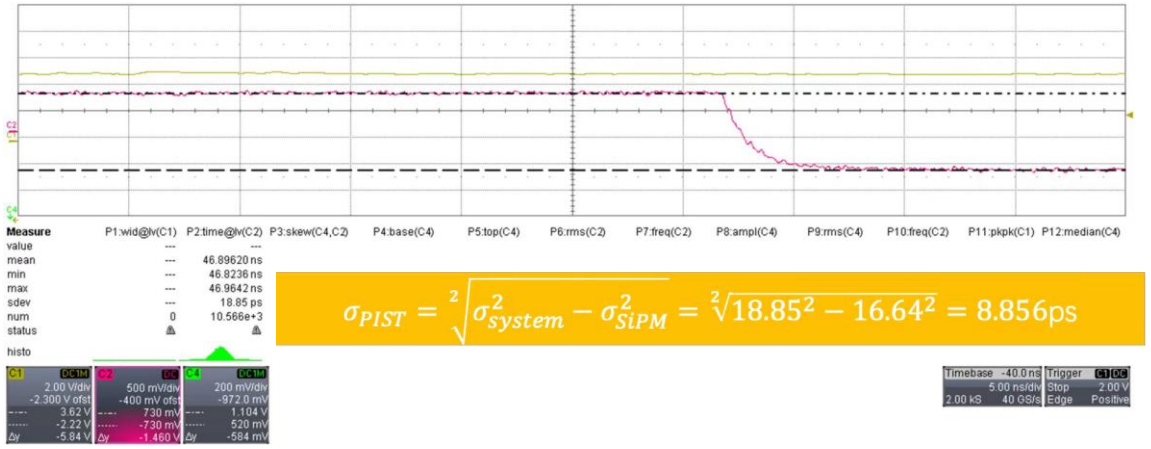




PIST ASIC Test

Time Resolution

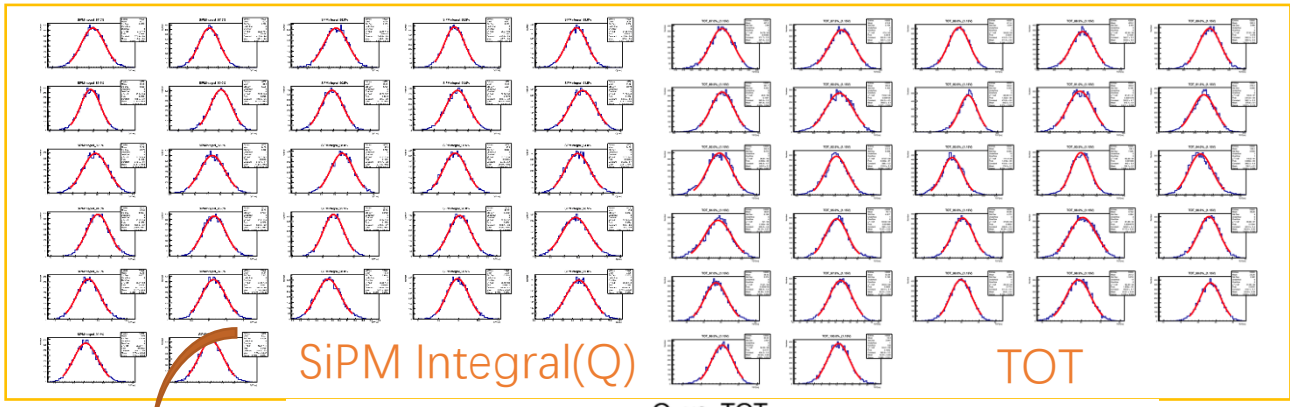


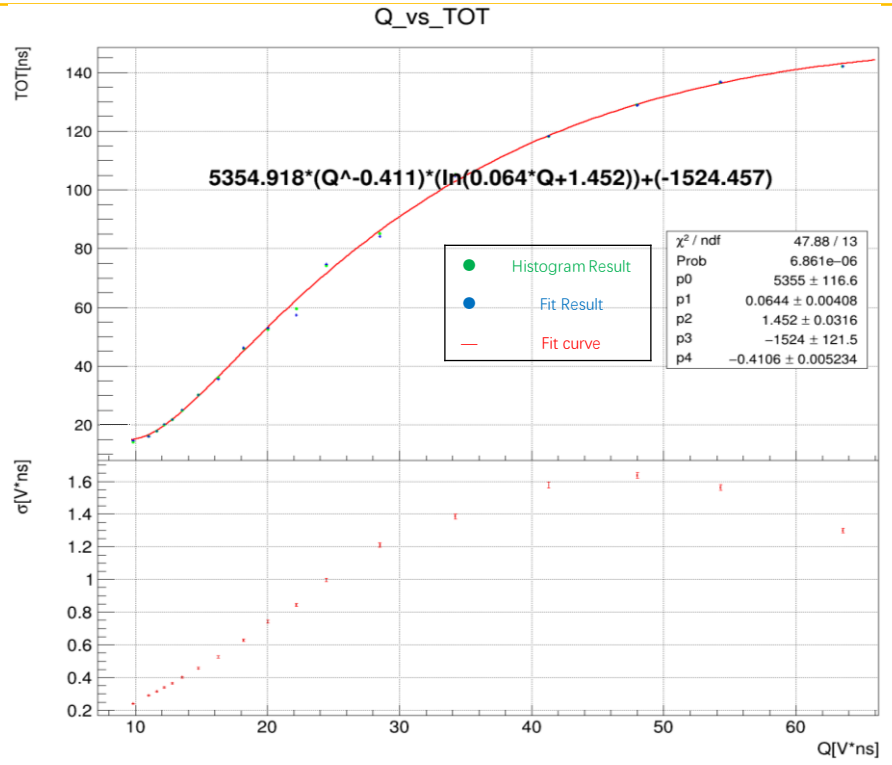


$$\sigma_{PIST} = \sqrt[2]{\sigma_{system}^2 - \sigma_{SiPM}^2} = \sqrt[2]{18.85^2 - 16.64^2} = 8.856\text{ps}$$

Result:系统级时间分辨~19ps；PIST ASIC 时间分辨~9ps

TOT-like Function





Influence of Multiple Scattering on Track Reconstruction

- Motivation：多次散射是影响低能粒子在晶体探测器中入射角度重建上限的关键因素，需要分析不同粒子在材料中的行为以找到上限
- 工作内容：模拟不同粒子在不同材料不同层数下的行为(搭建几何+分析），找到偏转角度与入射粒子的能量和材料厚度的关系

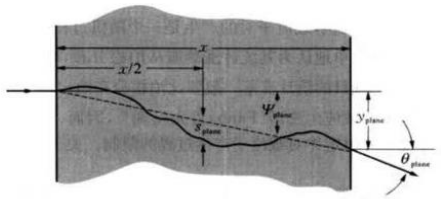


图 2.1.5 带电粒子在物质中的多次散射示意图(粒子沿页面水平入射)

由图 2.1.5，选取页面为参考平面，投影到该平面的入射粒子的散射角(θ_{plane})分布均方根(root mean square，rms)可以近似表述为

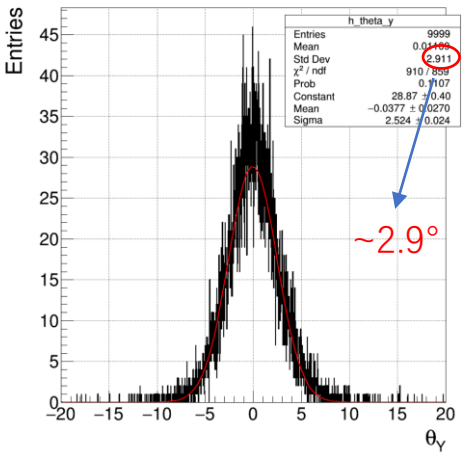
$$\theta_{plane}^{rms} = \sqrt{\langle \theta_{plane}^2 \rangle} = \frac{13.6}{\beta c p} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln \frac{x}{X_0}\right] \quad (2.1.16)$$

其中动量 p 单位为 MeV/c，x/X_0 是以辐射长度为量度的物质厚度。辐射长度 X_0 的定义详见后文。在 $10^{-3} < x/X_0 < 10^2$ 范围内，公式(2.1.16)对所有的纯物质均成立，其误差好于 11%。

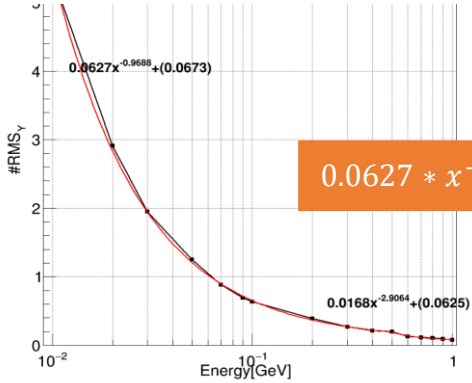
式(2.1.16)还可以进一步简化，对于绝大多数实际应用情况，有

$$\theta_{plane}^{rms} = \frac{13.6}{\beta c p} \sqrt{\frac{x}{X_0}} \quad (2.1.17)$$

0.50GeV的e-在3mm厚的Scintillator中的角度分布

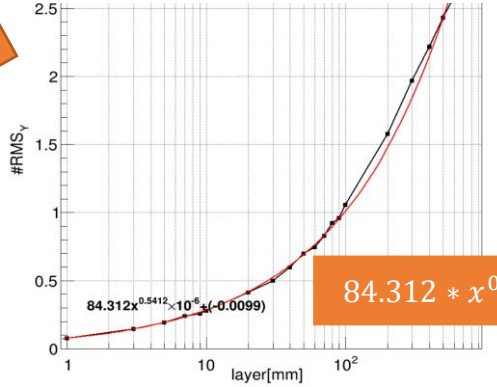


e- 在3mm Scintillator中的角度随能量的变化



$0.0627 * x^{-0.9688} + 0.0673$

0.5GeV的e- 在Scintillator中的角度随厚度的变化



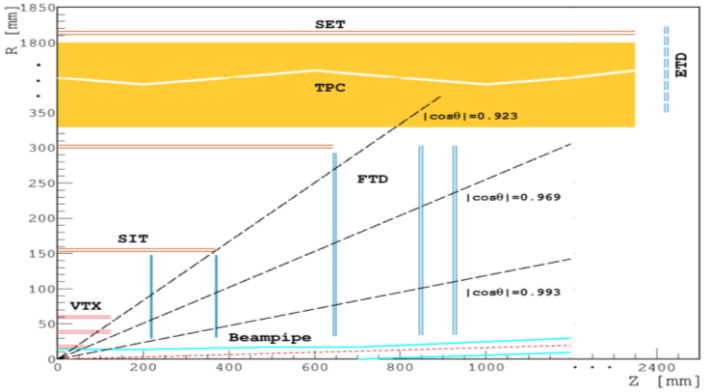
$84.312 * x^{0.5412} - 0.0099$

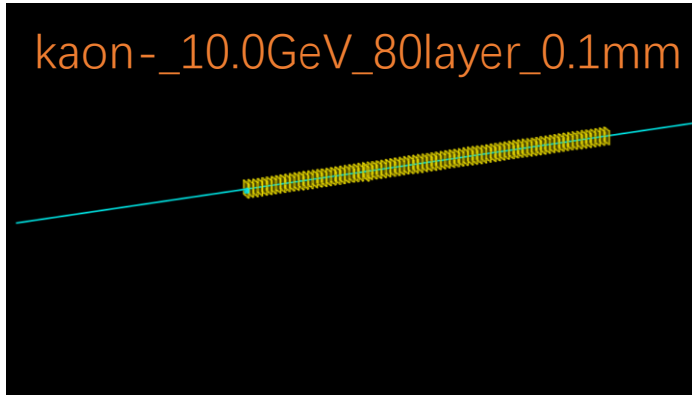
Work with Hengyu Wang

dE/dx Measurement based on CEPC Baseline Silicon Tracker

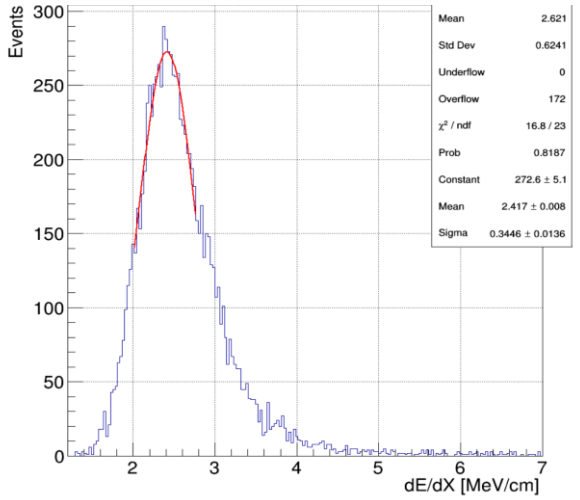
- Motivation：dE/dx的测量对粒子鉴别至关重要，Silicon Tracker具有良好的dE/dx测量潜力
- 工作内容：模拟kaon-在不同尺寸的颗粒度与不同层数下的行为，分析这些参数对dE/dx的测量的影响

Preliminary layout of the tracking system of the CEPC baseline detector

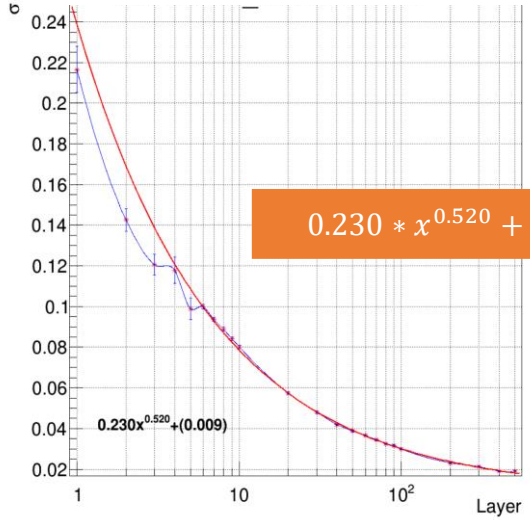




10GeV kaon- 在100μm/layer 2layer 下dE/dx分布



10GeV kaon- dE/dx随厚度的变化（1layer = 100μm）



$0.230 * x^{0.520} + 0.009$

Work with Hengyu Wang

Summary

- PIST ASIC Test: 初步达到目标结果，实现ps量级的时间分辨，以及TOT与能量有很好的对应关系。下一步计划：
  - 精细分析系统时间分辨率中各个仪器所占的比例；
  - 找寻TOT最大动态范围并利用光子数进行刻度。
- Influence of Multiple Scattering on Track Reconstruction：验证在低能粒子入射的情况下，粒子的径迹重建角度与粒子能量和探测器厚度的关系。
- dE/dx Measurement based on CEPC Baseline Silicon Tracker：找到了在固定能量下dE/dx随Si阵列厚度的关系。下一步计划：
  - 回归CEPC Baseline Silicon Tracker，精确量化Silicon Tracker对dE/dx的测量潜力。
- CERN Test Beam Data Analysis

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谢 谢 ！

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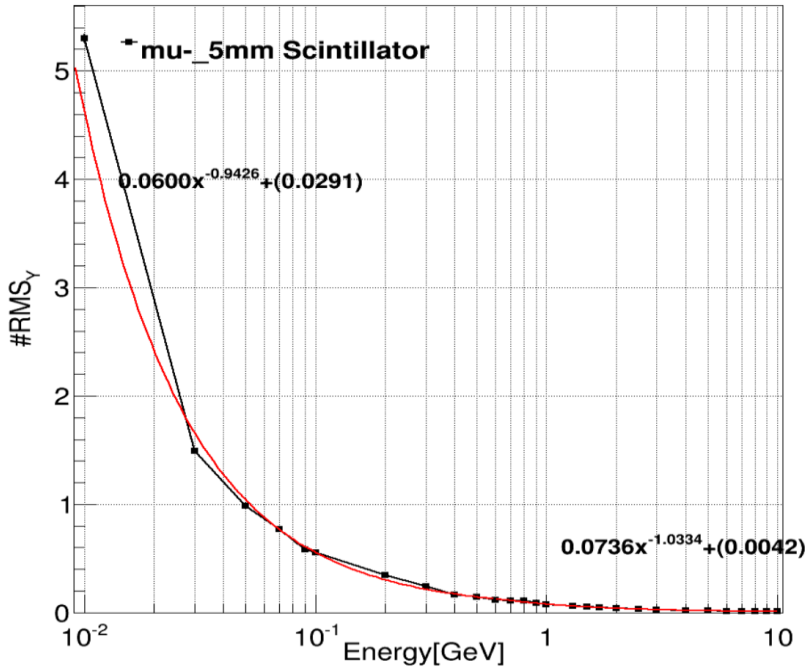
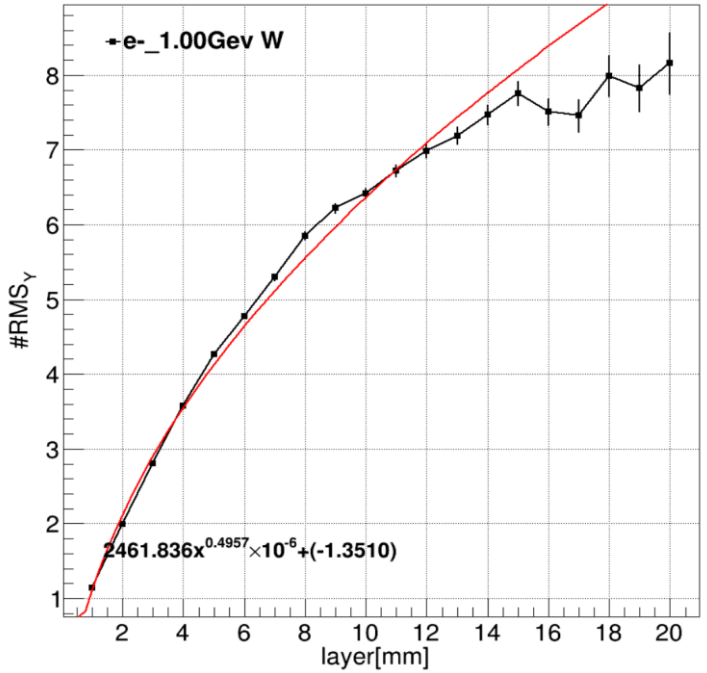
实验物理中心 高能量组
2023年1月6日

Backup

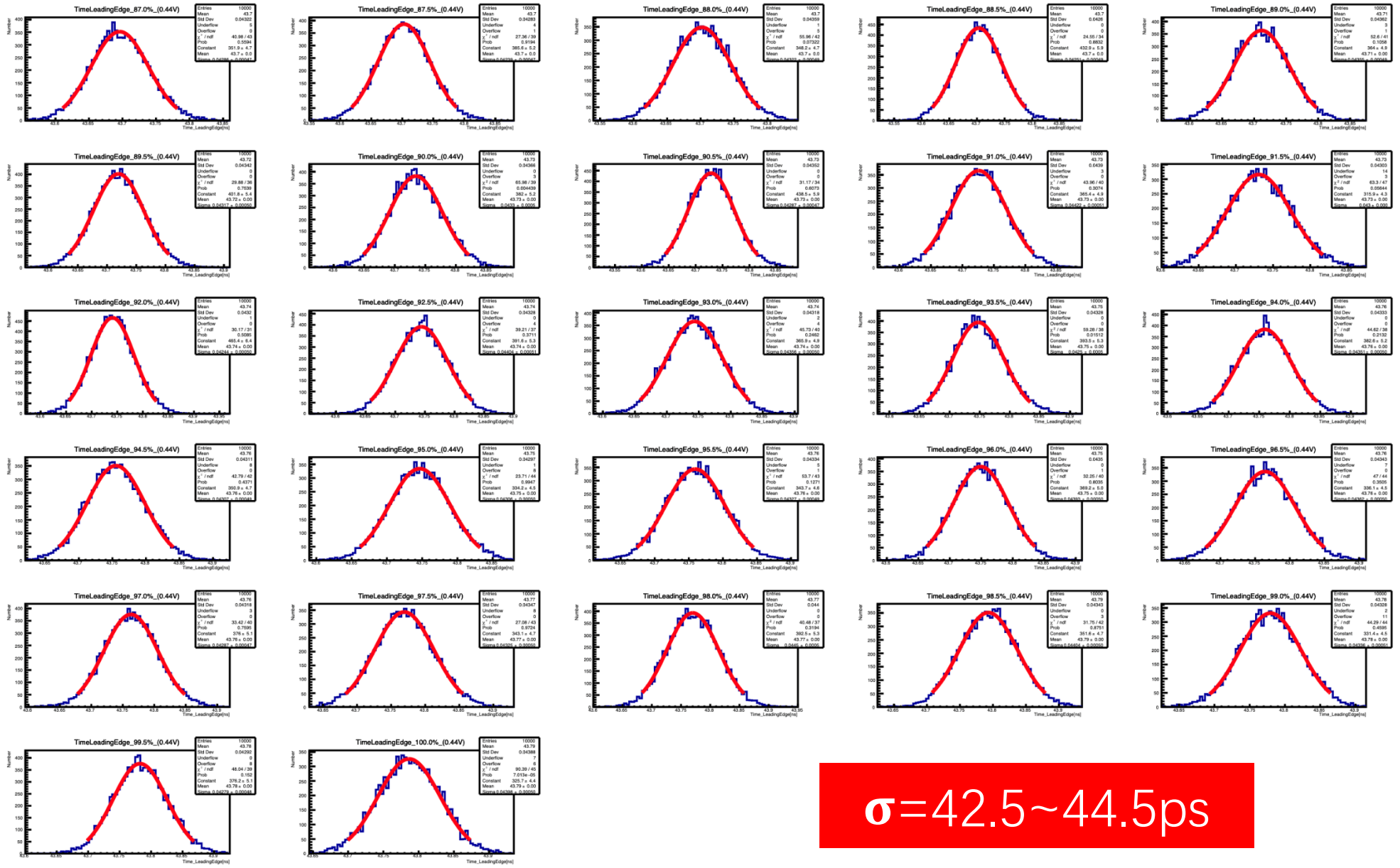
muon- 在5mm Scintillator中的角度随能量的变化



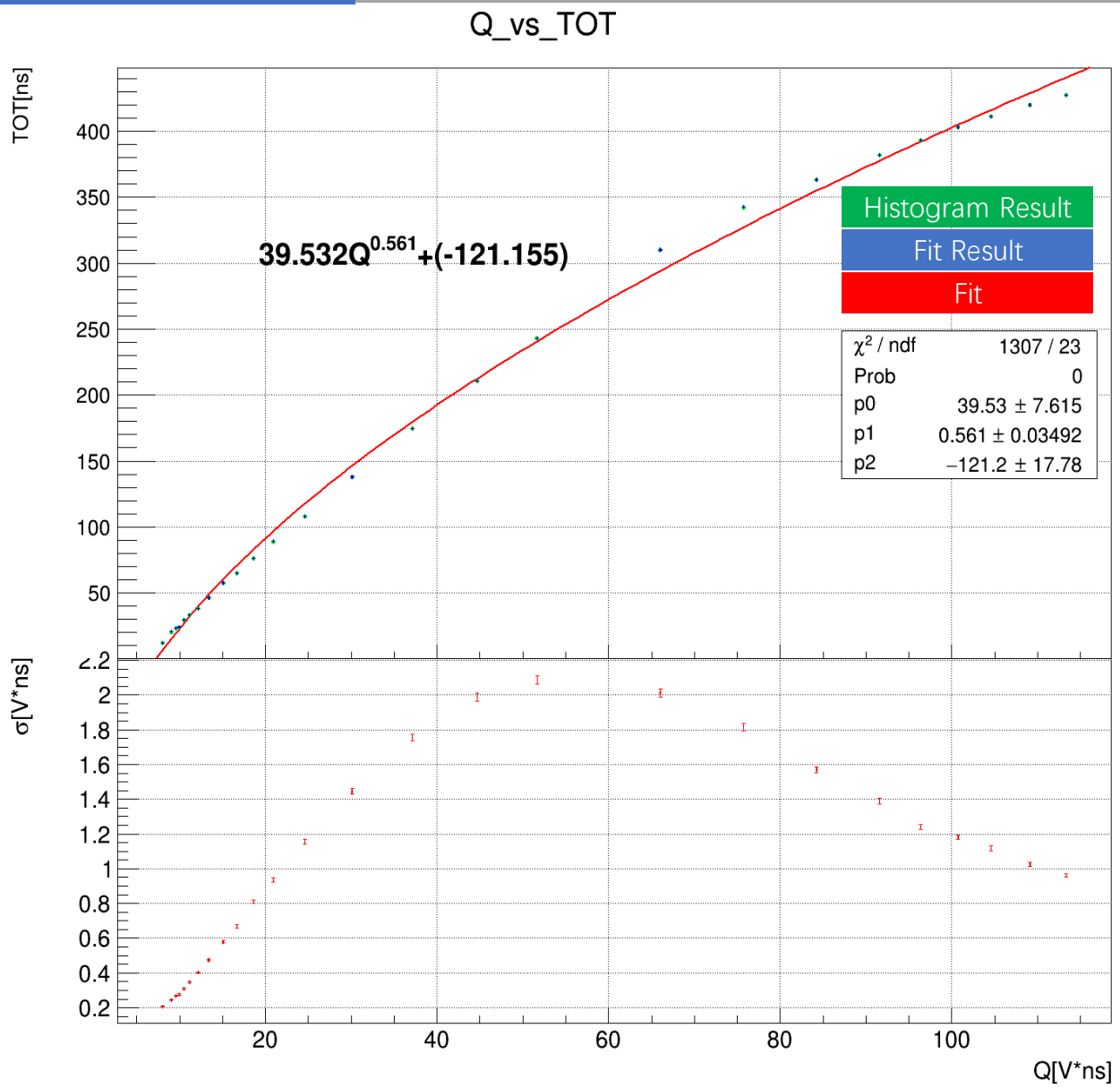
1.0GeV的e- 在W中的角度随厚度的变化

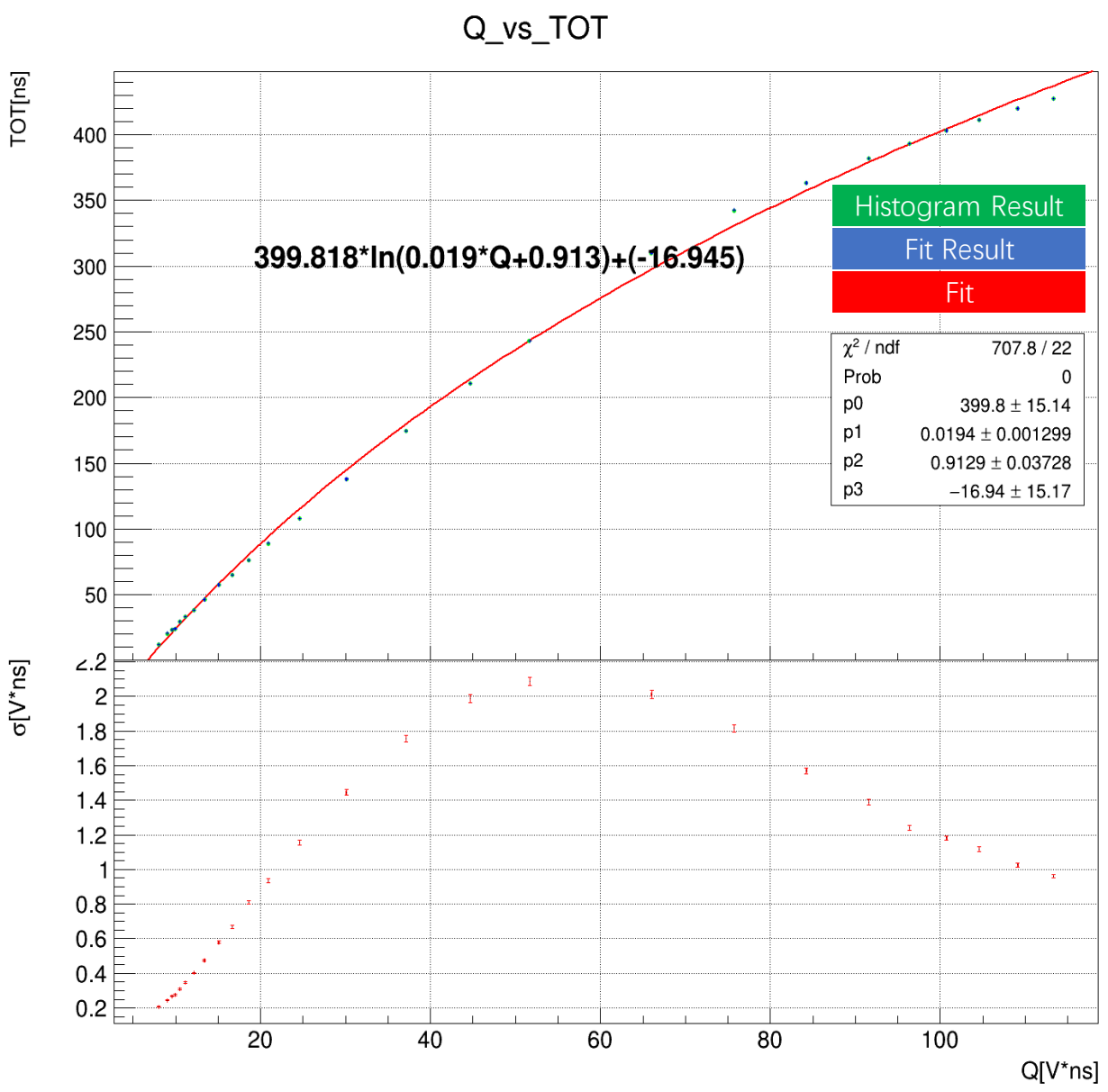


Time Leading Edge Threshold = 0.44V

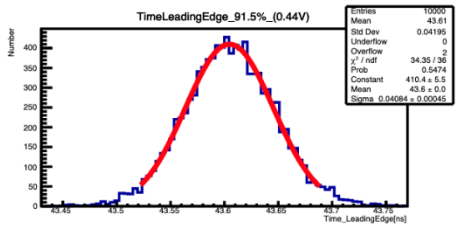


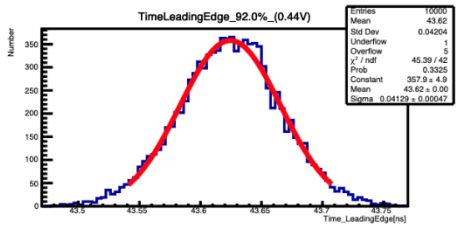
σ=42.5~44.5ps

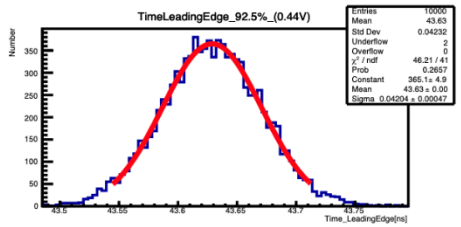

Q_vs_TOT
TOT[ns]
σ[V*ns]
Q[V*ns]
39.532Q^0.561+(-121.155)
Histogram Result
Fit Result
Fit
χ² / ndf 1307 / 23
Prob 0
p0 39.53 ± 7.615
p1 0.561 ± 0.03492
p2 −121.2 ± 17.78

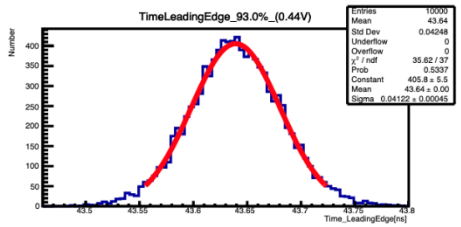

Q_vs_TOT
TOT[ns]
σ[V*ns]
Q[V*ns]
399.818*ln(0.019*Q+0.913)+(-16.945)
Histogram Result
Fit Result
Fit
χ² / ndf 707.8 / 22
Prob 0
p0 399.8 ± 15.14
p1 0.0194 ± 0.001299
p2 0.9129 ± 0.03728
p3 −16.94 ± 15.17

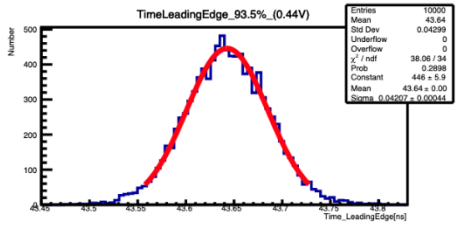
Time Leading Edge Threshold = 0.44V

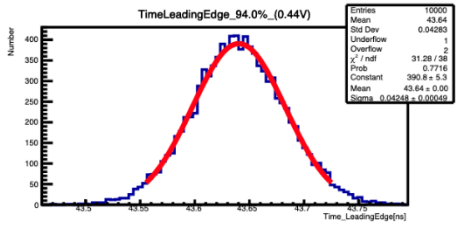


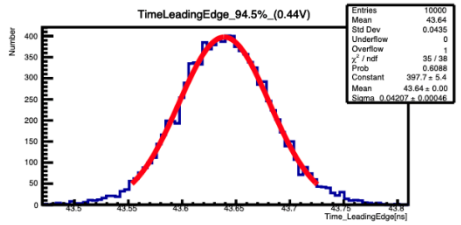


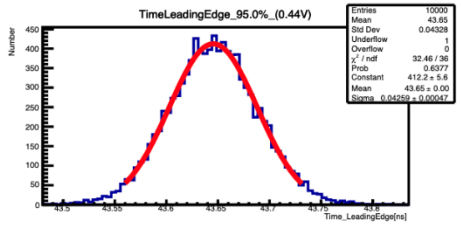


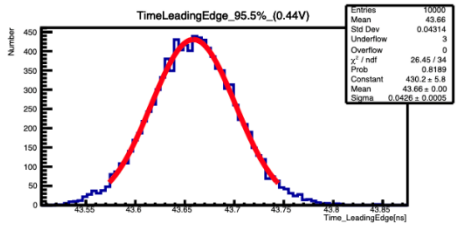


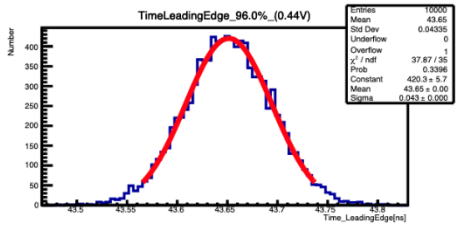


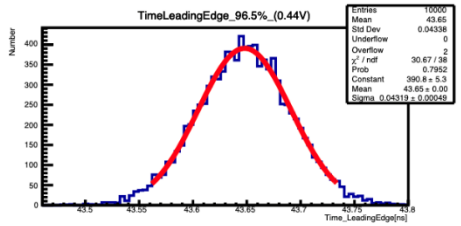


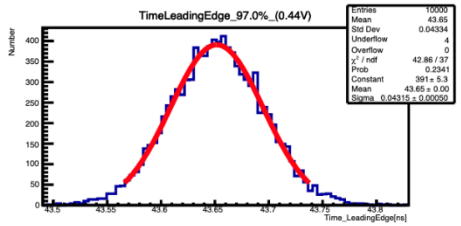


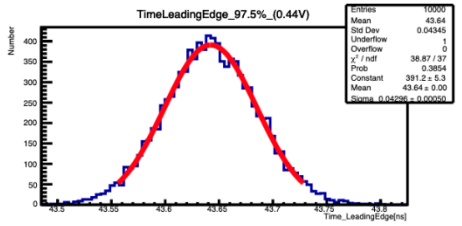


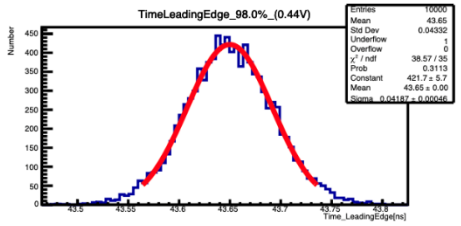


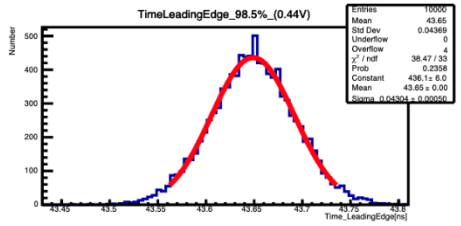


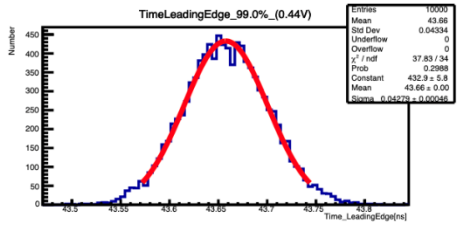


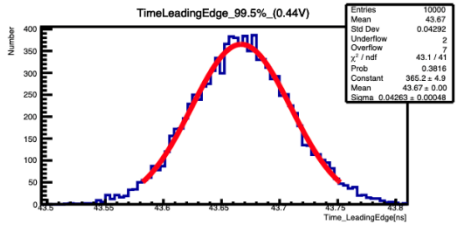


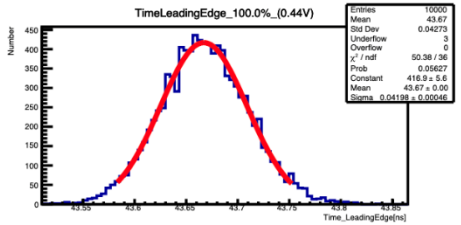




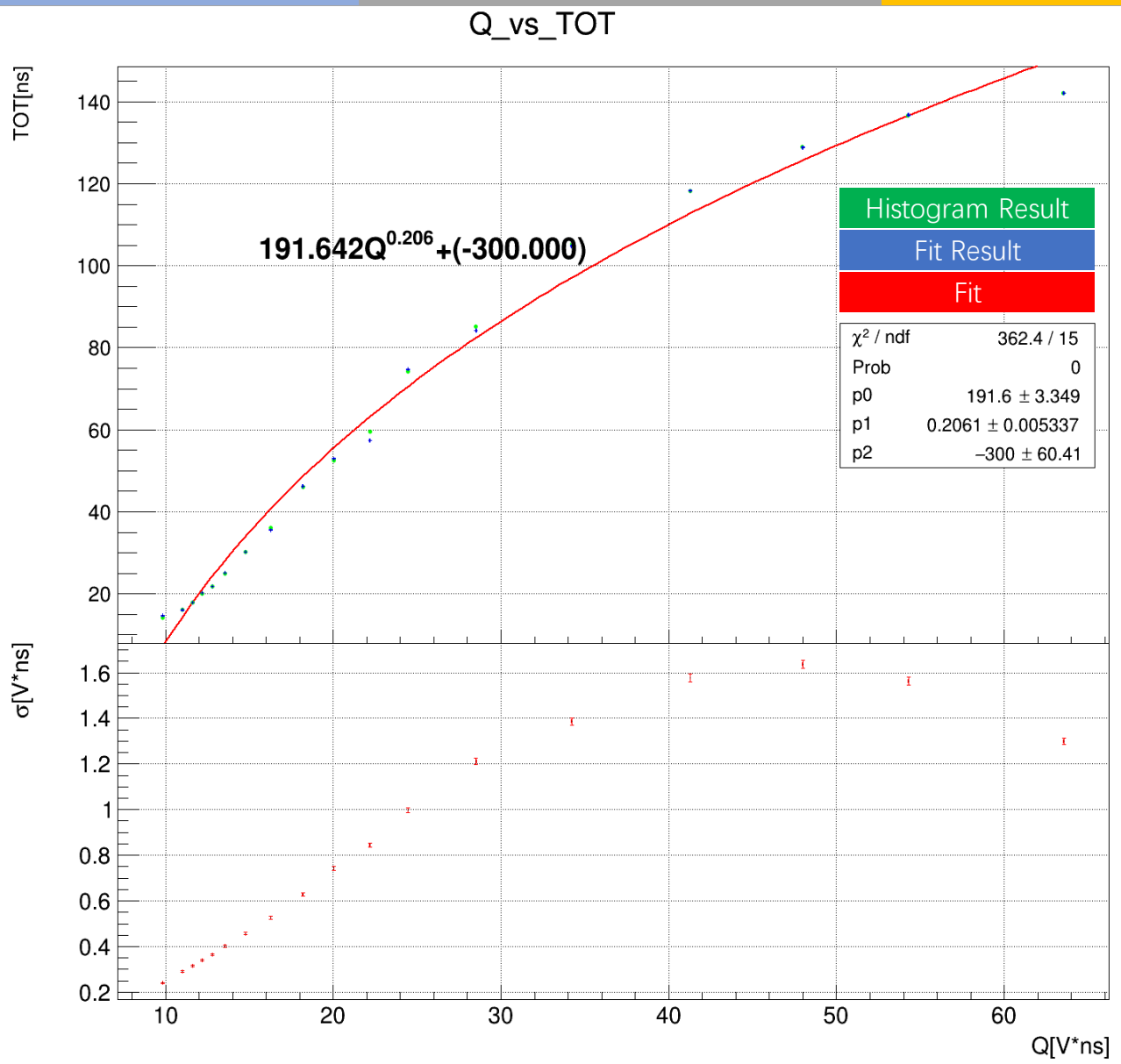


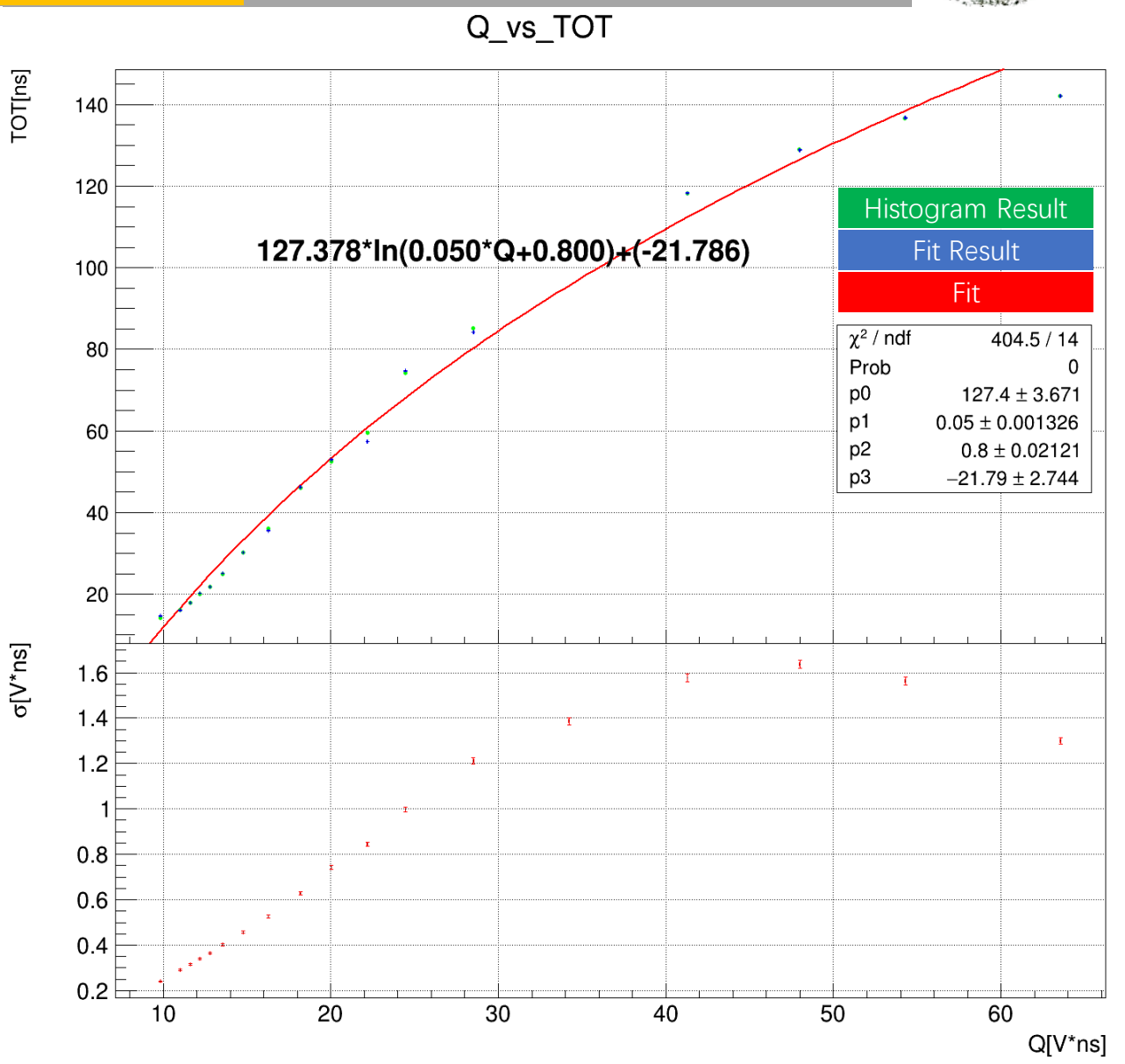






σ=40.5~43.5ps


Q_vs_TOT
TOT[ns]
σ[V*ns]
Q[V*ns]
191.642Q^0.206+(-300.000)
Histogram Result
Fit Result
Fit
χ² / ndf 362.4 / 15
Prob 0
p0 191.6 ± 3.349
p1 0.2061 ± 0.005337
p2 −300 ± 60.41


Q_vs_TOT
TOT[ns]
σ[V*ns]
Q[V*ns]
127.378*ln(0.050*Q+0.800)+(-21.786)
Histogram Result
Fit Result
Fit
χ² / ndf 404.5 / 14
Prob 0
p0 127.4 ± 3.671
p1 0.05 ± 0.001326
p2 0.8 ± 0.02121
p3 −21.79 ± 2.744