关于本底、电子学工作模式等的初步思考

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内容

- 尼龙袋与钢罐方案本底压制率比较
- 时间常数对分辨的影响
- 宇宙射线μ子产生的次级粒子横向半径分布
- 下一步工作：球外反符合系统研究
- 总结

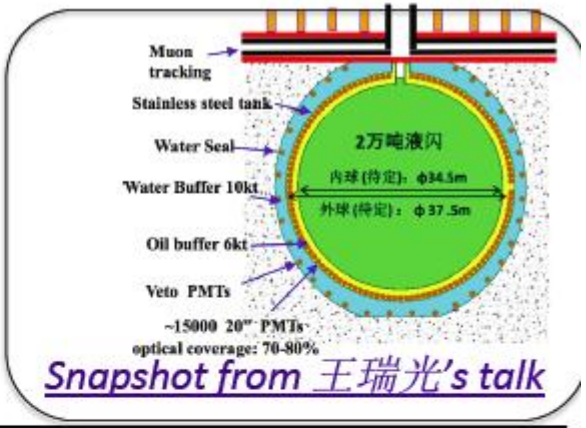
尼龙袋与钢罐方案本底压制率比较

尼龙袋方案 DetSim3

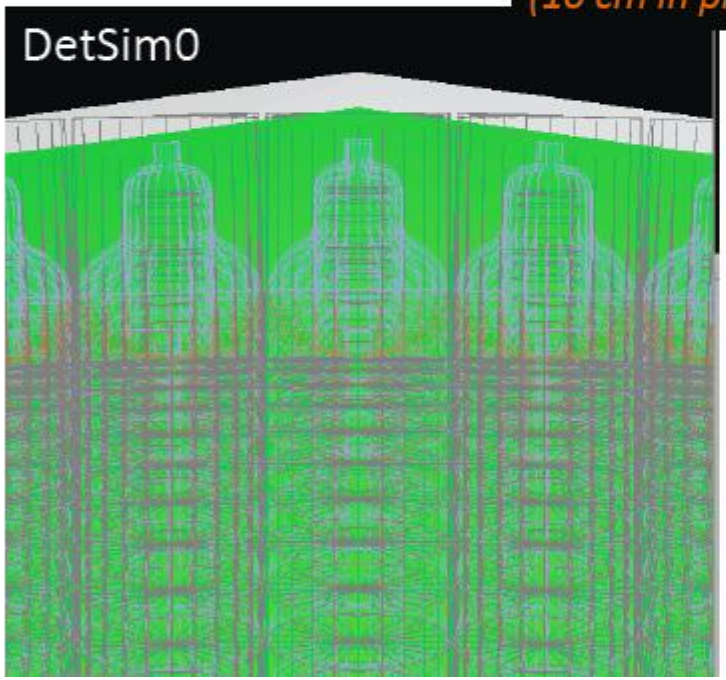
DetSim0 + Nylon balloon + Oil

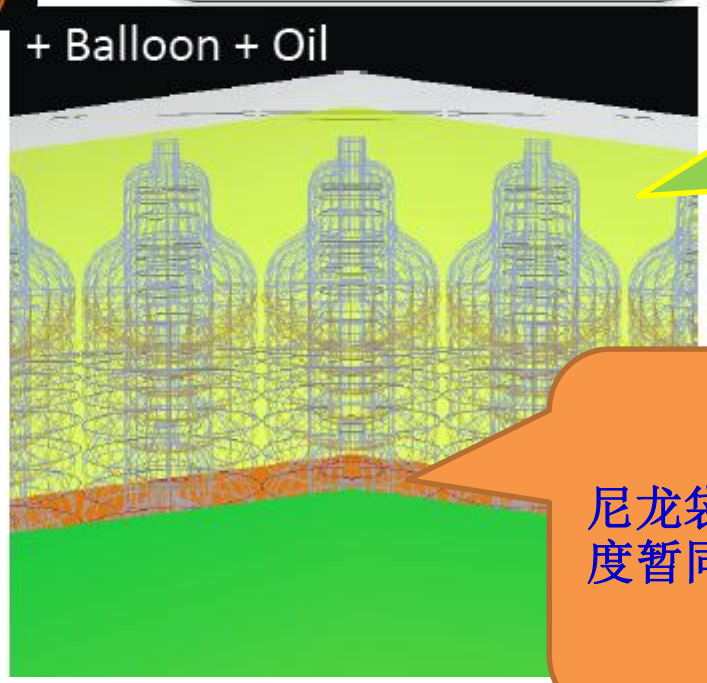
Oil Buffer:
C_7H_{15}
sphere
d=1 m

Balloon:
Nylon66
sphere
d=200 μm
(10 cm in pic.)



Snapshot from 王瑞光's talk





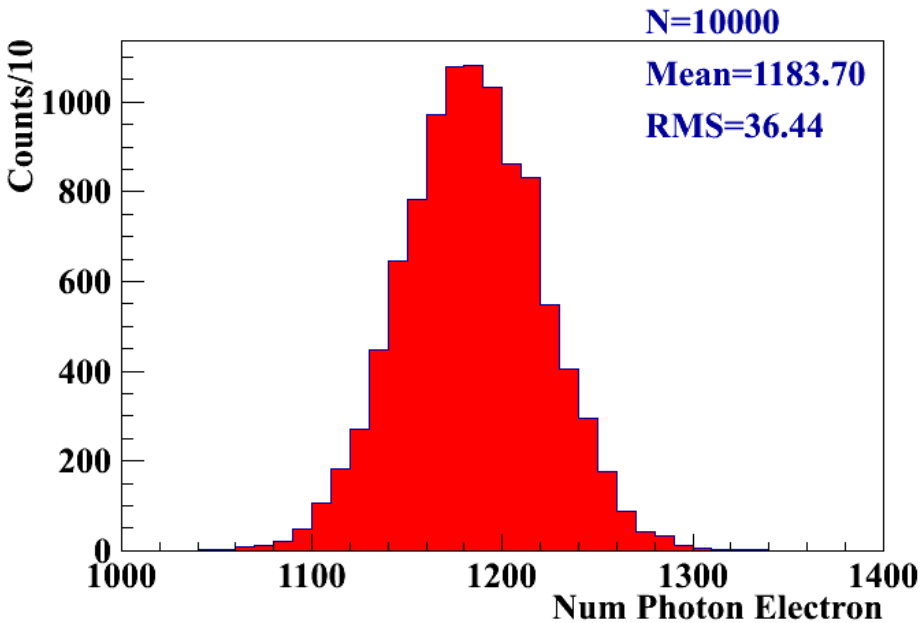
1m oil

尼龙袋衰减长度暂同LS

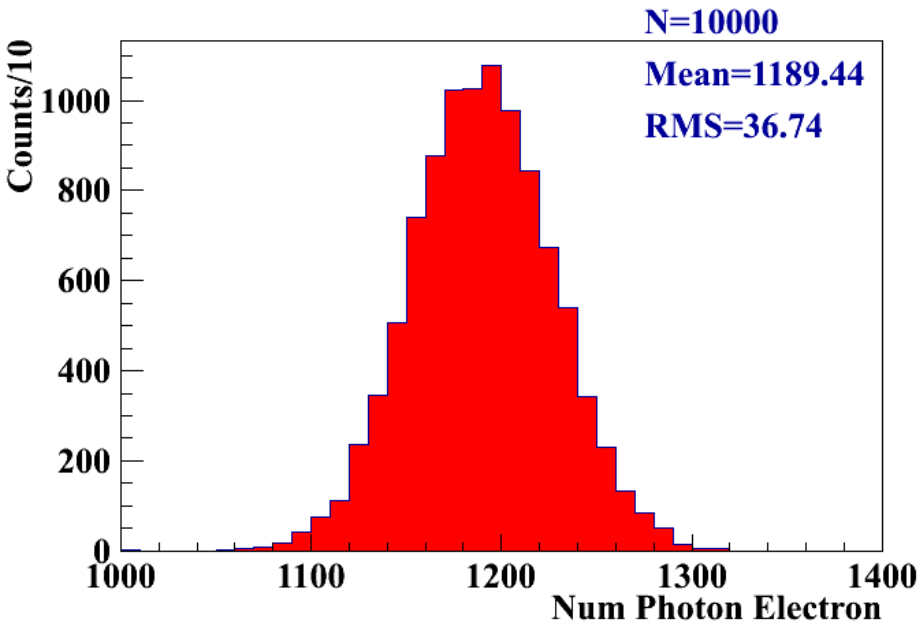
1m厚白油对γ射线能量分辨的影响

在中心点（0,0,0）发出2条0.511MeV的射线

初步结论：
加尼龙袋（衰减常数暂时同LS）后，1米厚的白油对分辨影响不大；

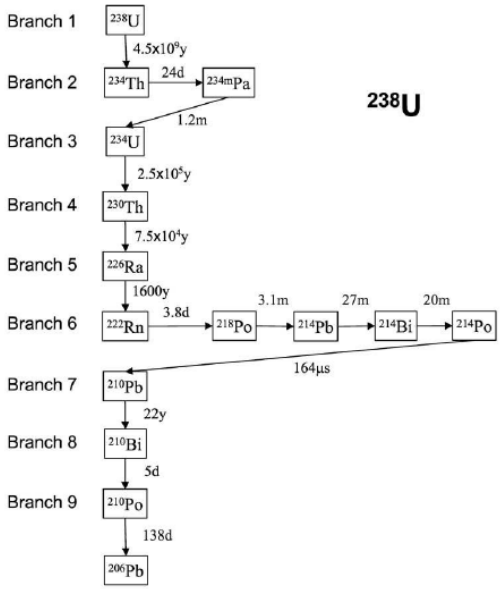


DetSim0: 钢罐直接加PMT



DetSim3: 尼龙袋方案（1m白油，尼龙袋衰减同LS）

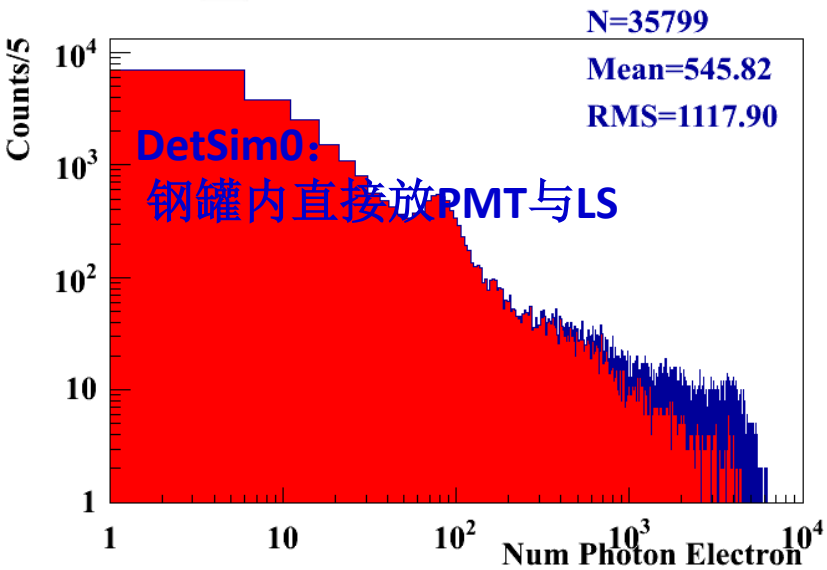
钢罐与尼龙袋模型的^{238}U系本底初步比较

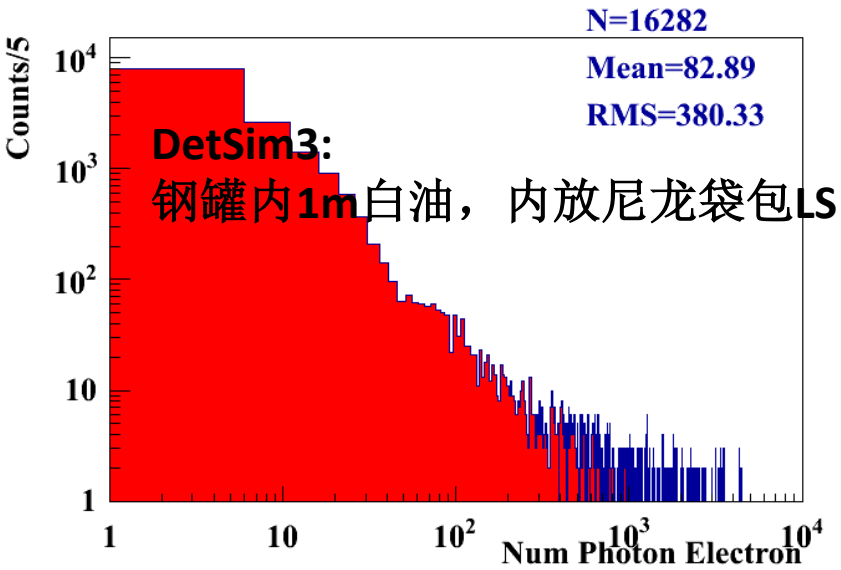


模拟100K次^{238}U系衰变，衰变点随机分布在不同的PMT表面(射线种类α、β、γ，数量及动量用大亚湾1期的产生程序)。

钢罐直接放PMT方案共有35.8K次衰变被探测到光电子，每个探测到的事件的平均光电子数是546个（左下图）

在钢罐内加1米厚的白油，核心为尼龙袋装液闪，共有16.3K个事件被探测到有来自本底的光电子，每一衰变平均光电子数为83（右下图）





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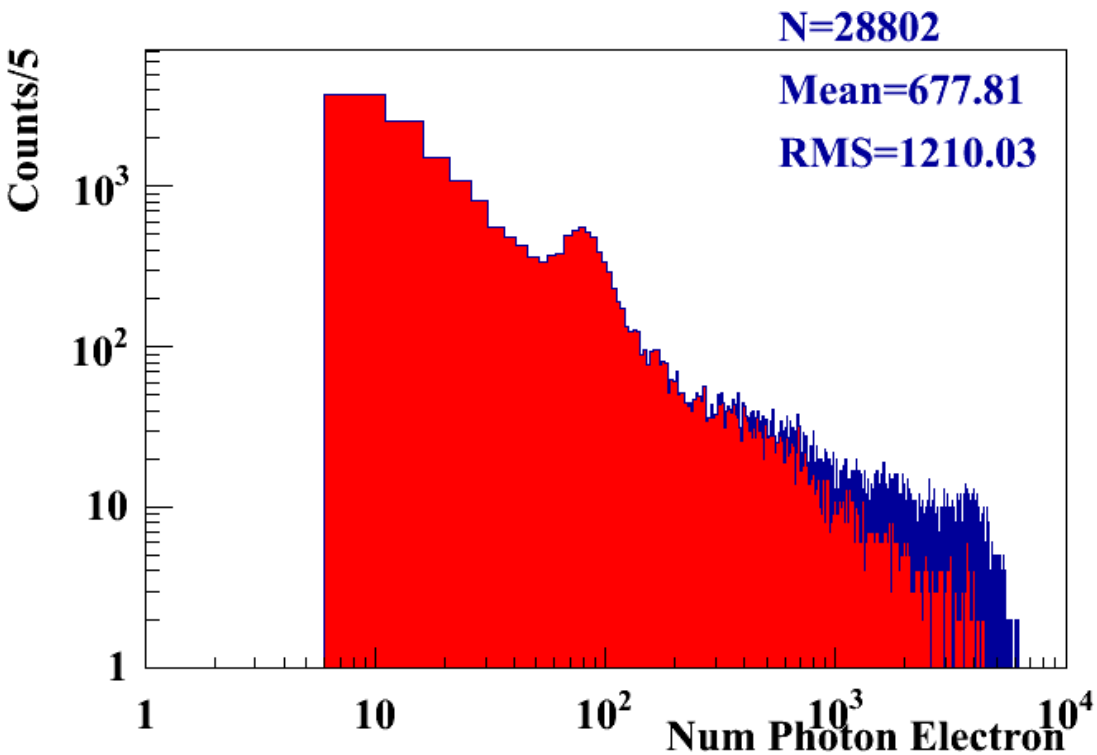
钢罐方案考虑可容忍的本底光子数后^{238}U系本底事件干扰

对于(0,0,0)发出的2*0.511MeV光子

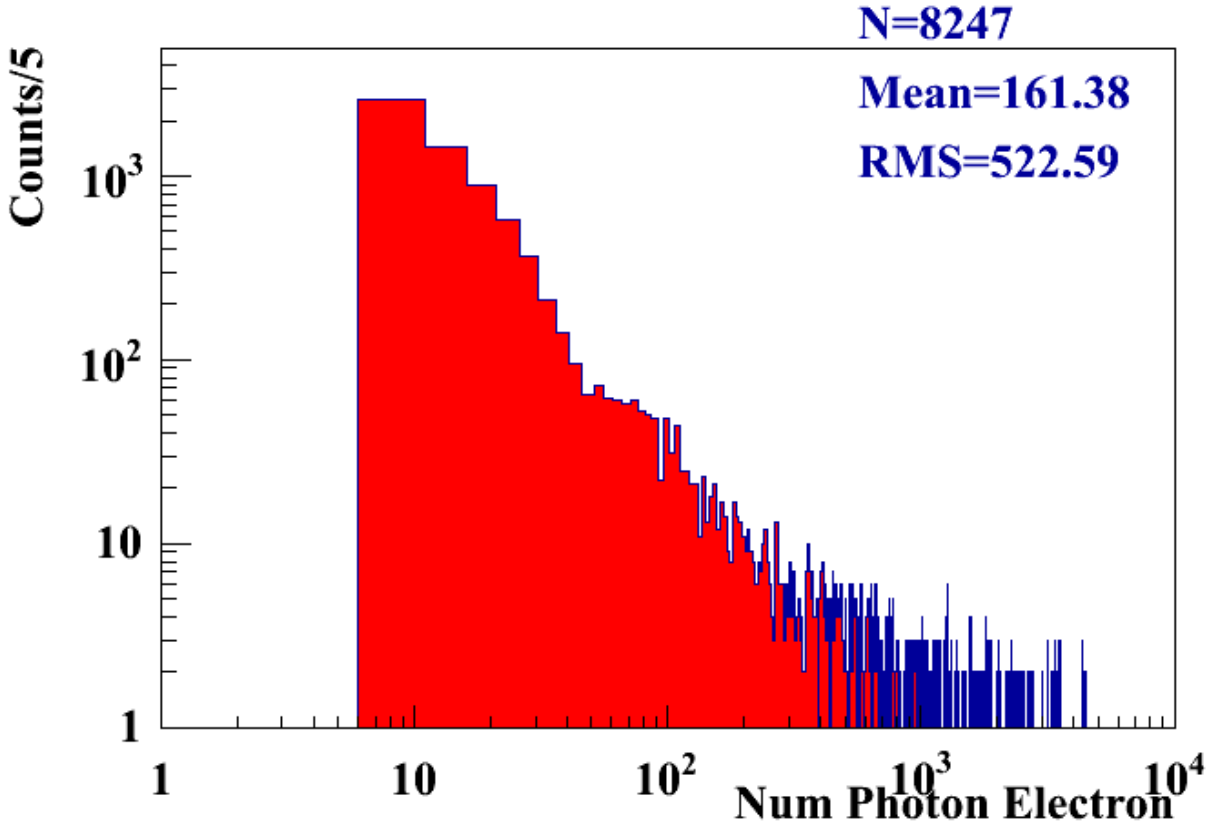
如果容忍5个及以内光子的本底，这时100K次^{238}U系本底事件共28.8K （1个及以上时35.8K ）产生干扰。



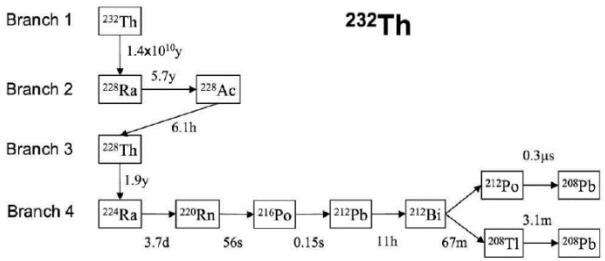
尼龙袋方案考虑可容忍的本底光子数后^{238}U系本底事件干扰

对于(0,0,0)发出的2*0.511MeV光子

如果容忍5个及以内光子的本底，这时100K次^{238}U系本底事件共8.2K （1个及以上时16.3K ）产生干扰。



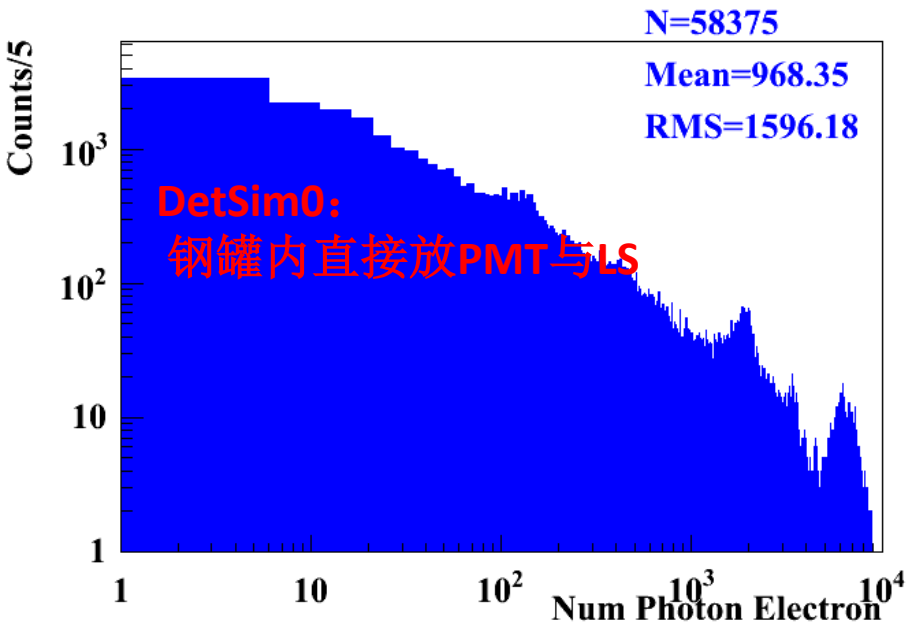
钢罐与尼龙袋模型的^{232}Th系本底初步比较

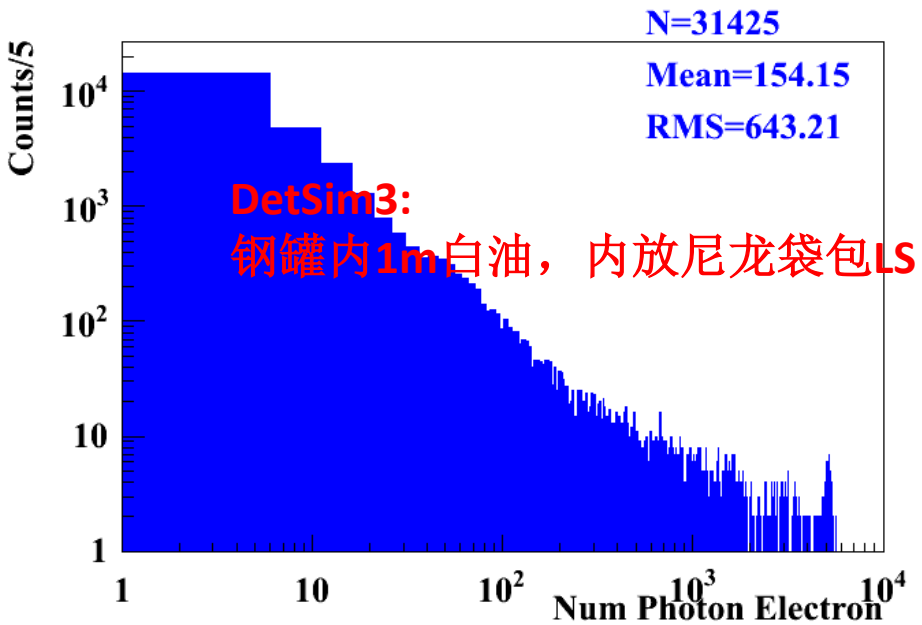


模拟100K次^{232}Th系衰变，衰变点随机分布在不同的PMT表面(射线种类β、γ，数量及动量用大亚湾1期的产生程序)。

钢罐直接放PMT方案共有58.3K次衰变被探测到光电子，每个探测到的事件的平均光电子数是968个（左下图）

在钢罐内加1米厚的白油，核心为尼龙袋装液闪，共有31.4K个事件被探测到有来自本底的光电子，每一衰变平均光电子数为154（右下图）

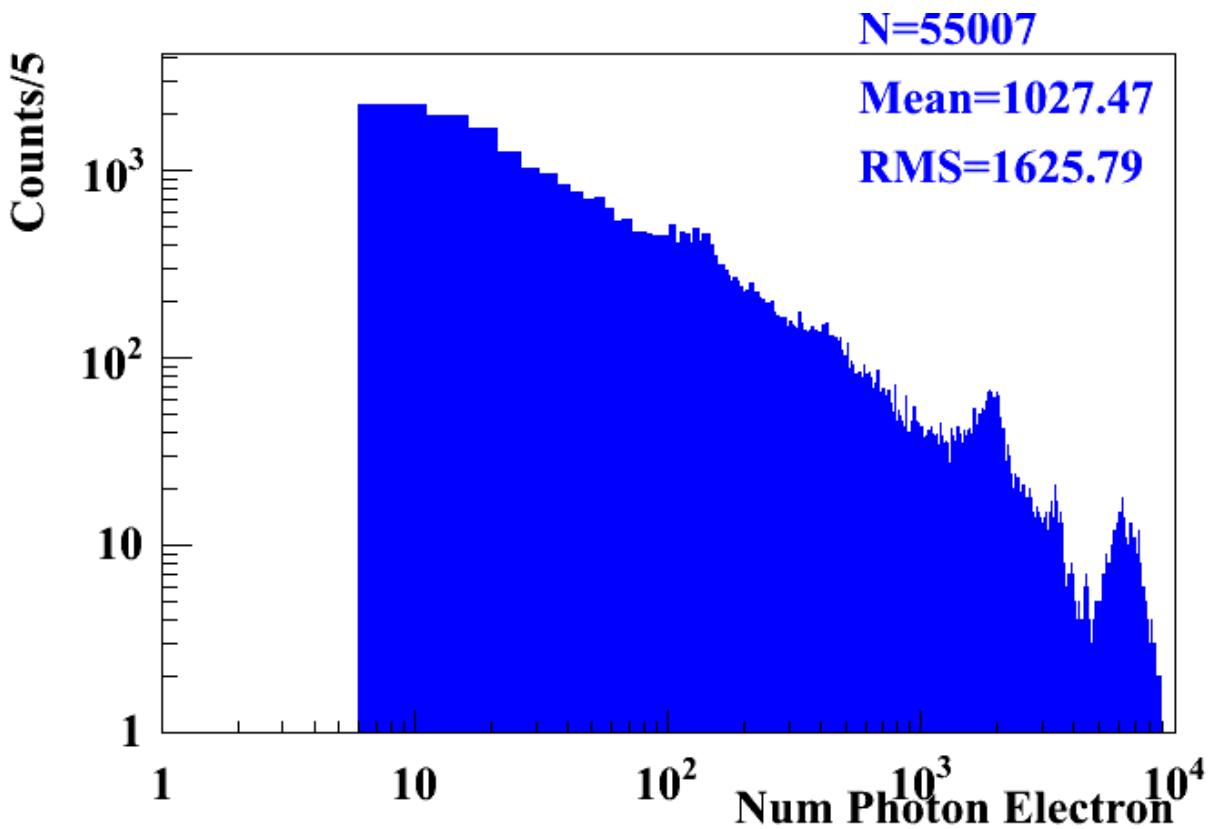




钢罐方案考虑可容忍的本底光子数后^{232}Th系干扰

对于(0,0,0)发出的2*0.511MeV光子

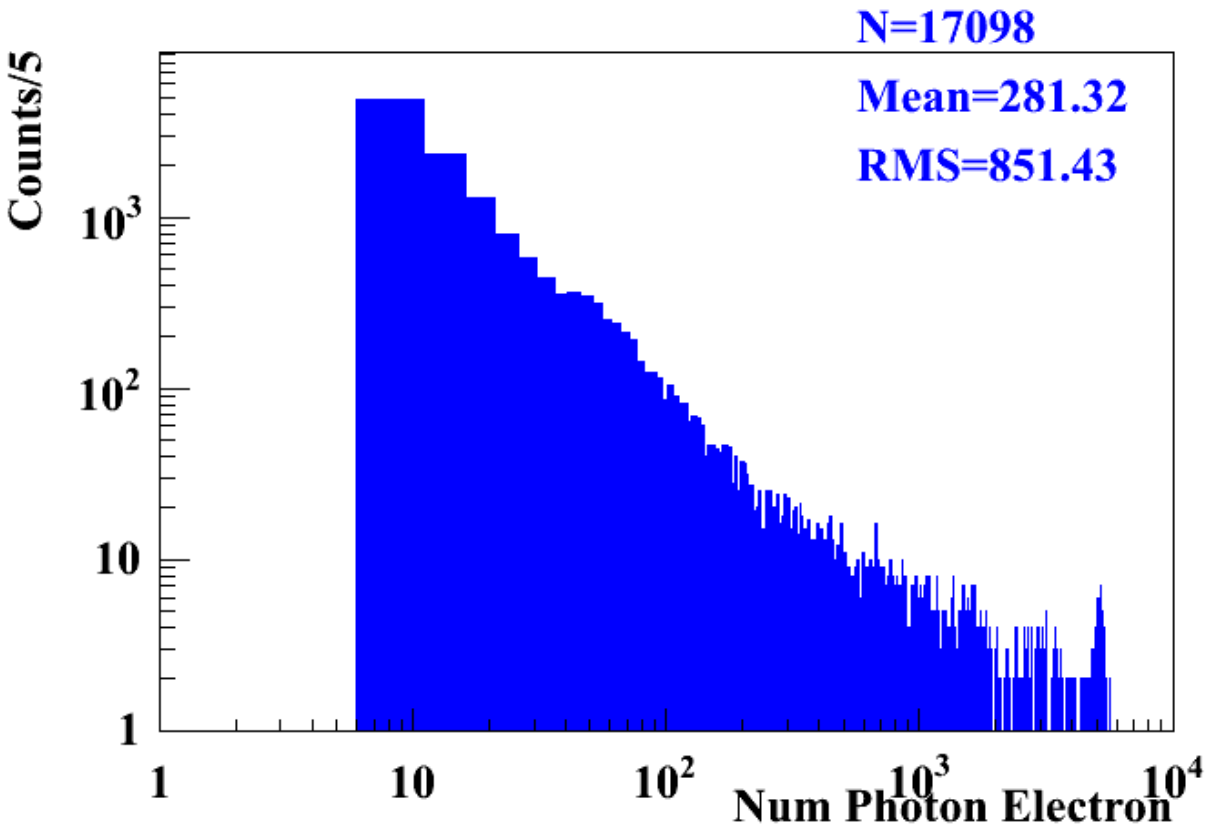
如果容忍5个光子的本底， 这时100K次^{232}Th系本底事件共55K （ 1个及以上时58.3K ）产生干扰。



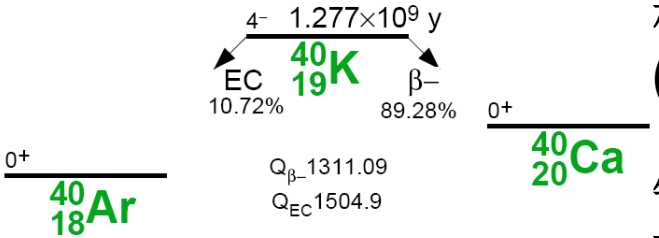
尼龙袋方案考虑可容忍的本底光子数后^{232}Th系本底事件干扰

对于(0,0,0)发出的2*0.511MeV光子

如果容忍5个光子的本底，这时100K次^{232}Th系本底事件共17.1K （1个及以上时31.4K ）产生干扰。

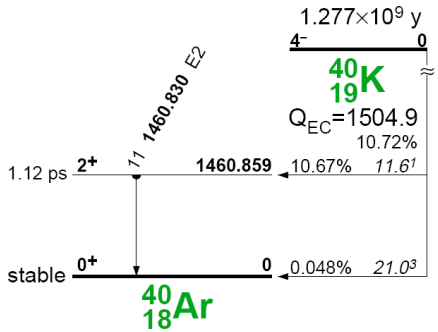


钢罐与尼龙袋模型的^{40}K系本底初步比较

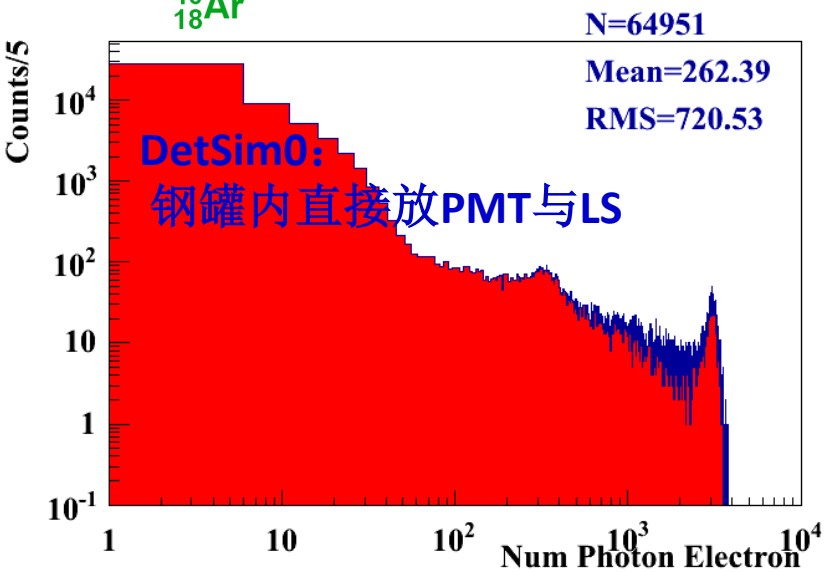


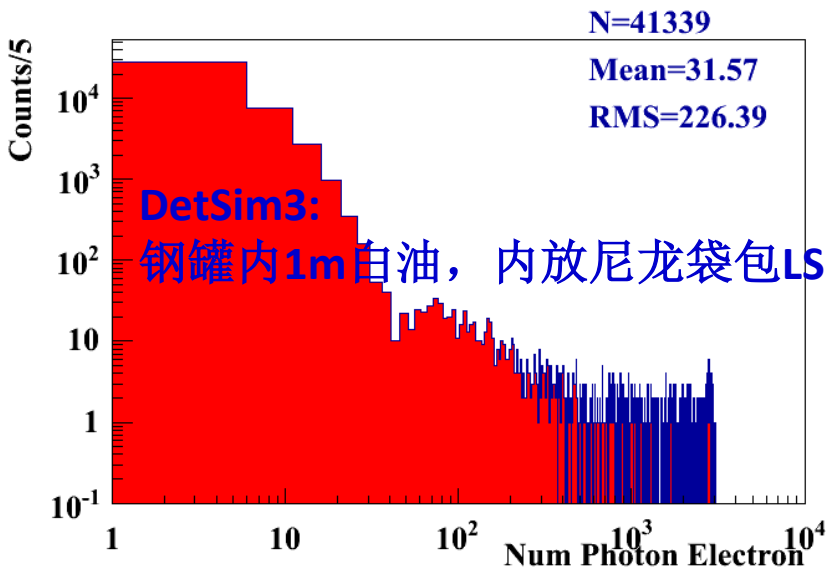
模拟100K次^{40}K系衰变，衰变点随机分布在不同的PMT表面(射线种类β、γ，数量及动量用大亚湾1期的产生程序)。

钢罐直接放PMT方案共有65K次衰变被探测到光电子，每个探测到的事件的平均光电子数是262个（左下图）



在钢罐内加1米厚的白油，核心为尼龙袋装液闪，共有41.3K个事件被探测到有来自本底的光电子，每一衰变平均光电子数为32（右下图）

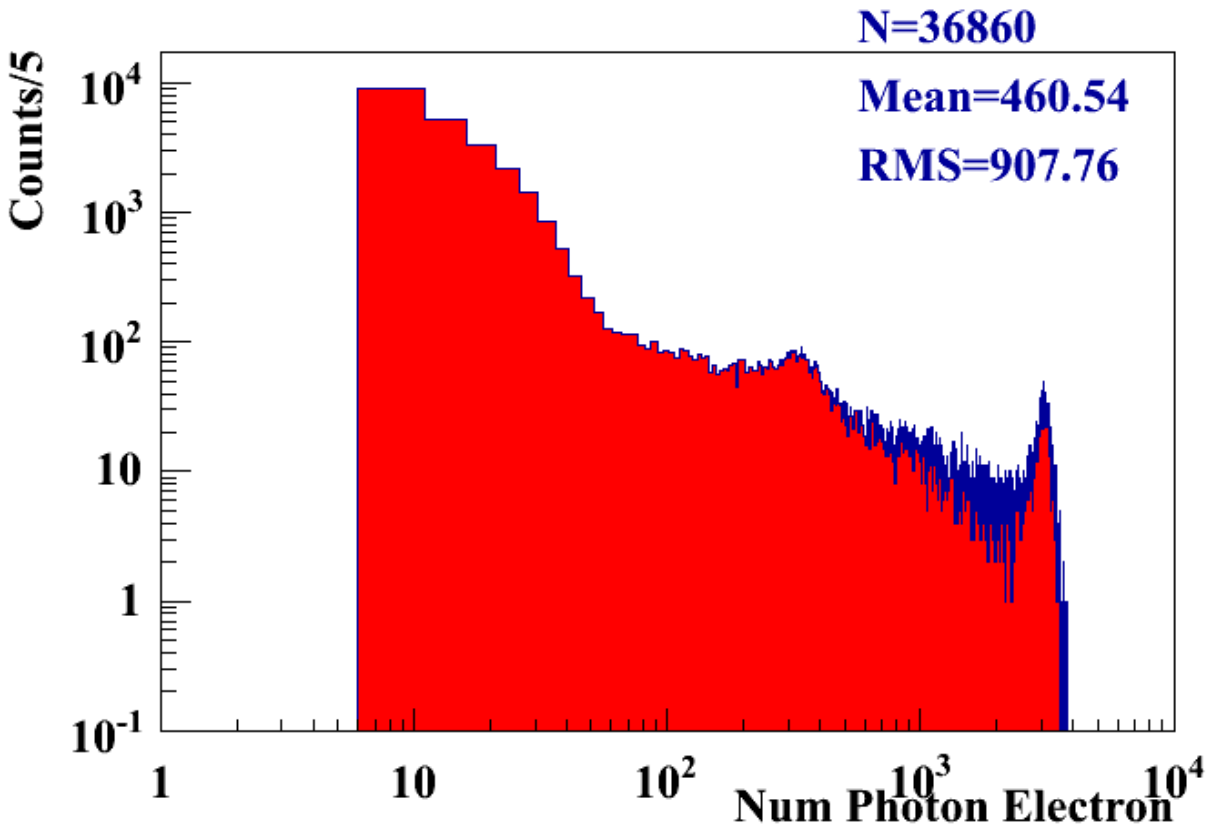




钢罐方案考虑可容忍的本底光子数后^{40}K干扰

对于(0,0,0)发出的2*0.511MeV光子

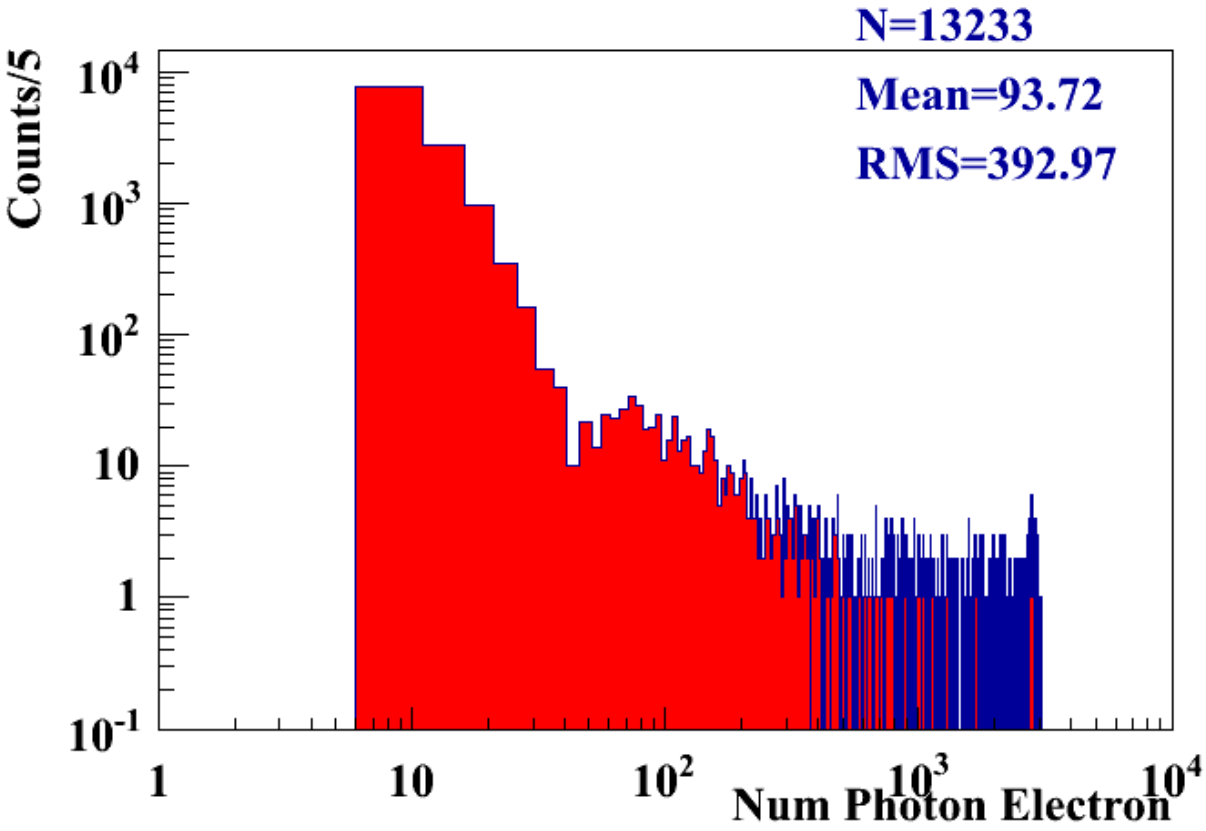
如果容忍5个光子的本底，这时100K次^{40}K系本底事件共36.9K （ 1个及以上时65K ）产生干扰。



尼龙袋方案考虑可容忍的本底光子数后^{40}K系本底事件干扰

对于(0,0,0)发出的2*0.511MeV光子

如果容忍5个光子的本底，这时100K次^{40}K系本底事件共13.3K （ 1个及以上时41.3K ）产生干扰。



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本底小结

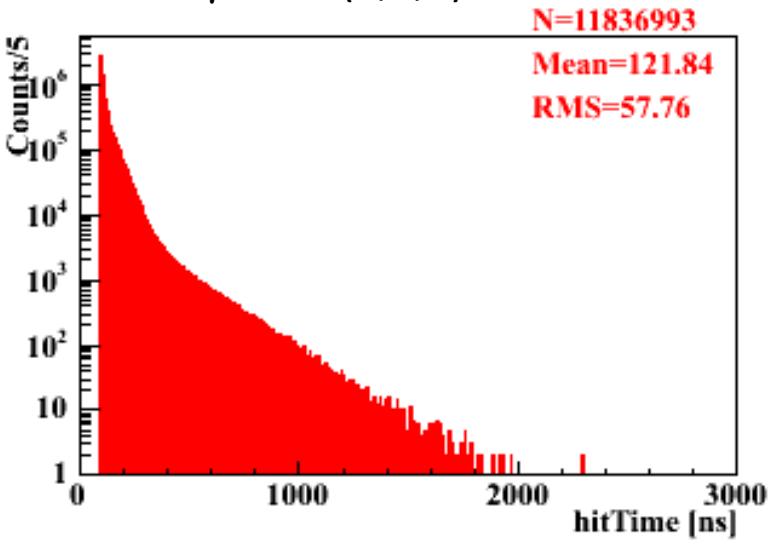
Background Channels	DetSim0	DetSim3	DetSim0 +>5PE	DetSim3 +>5PE
100K ^{238}U	35.8K	16.3K	28.8K	8.2K
100K ^{40}K	65.0K	41.3K	36.9K	13.3K
100K ^{232}Th	58.3K	31.4K	55.0K	17.1K

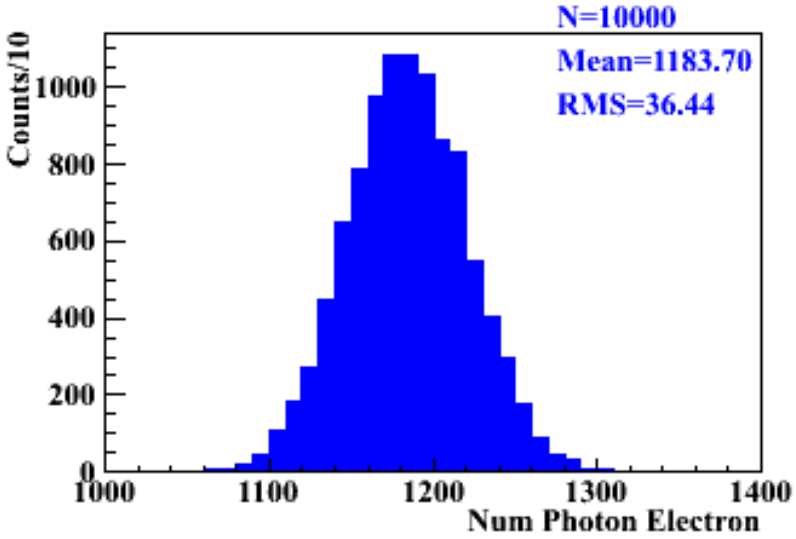
+>5PE 指允许有5个（含）以内的本底光电子

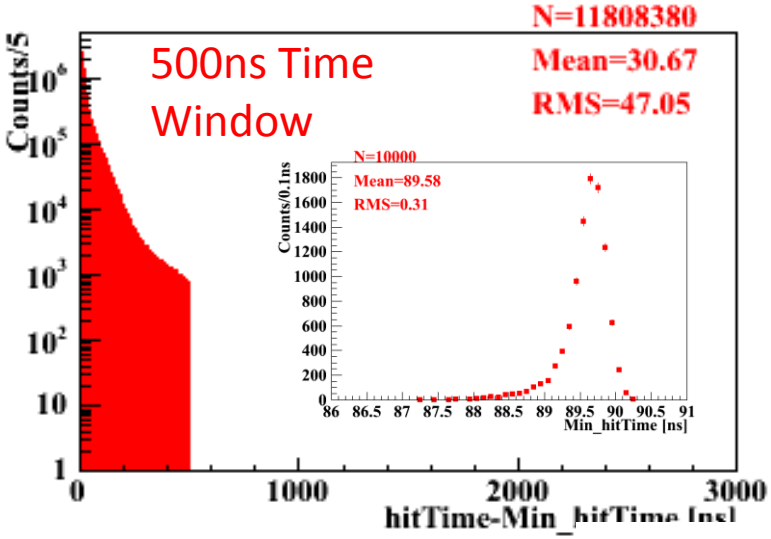
时间常数对分辨的影响

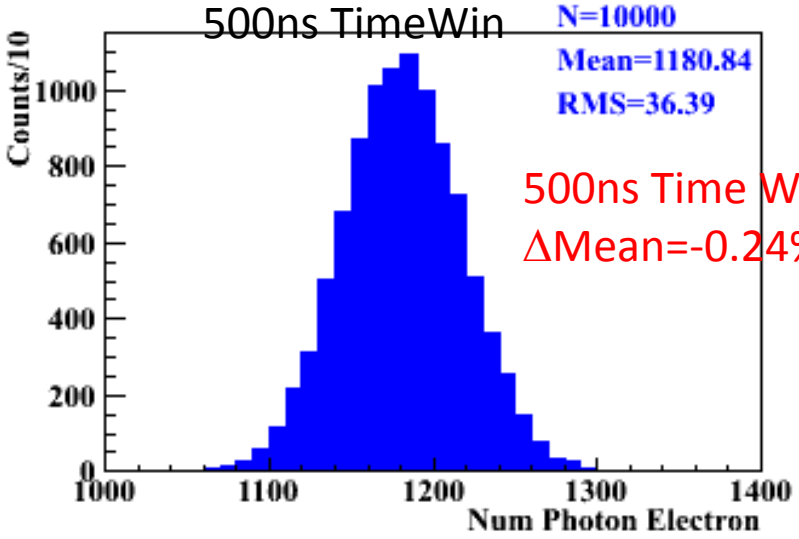
hitTime分布 【DetSim0】

2*0.511 γ from (0,0,0)



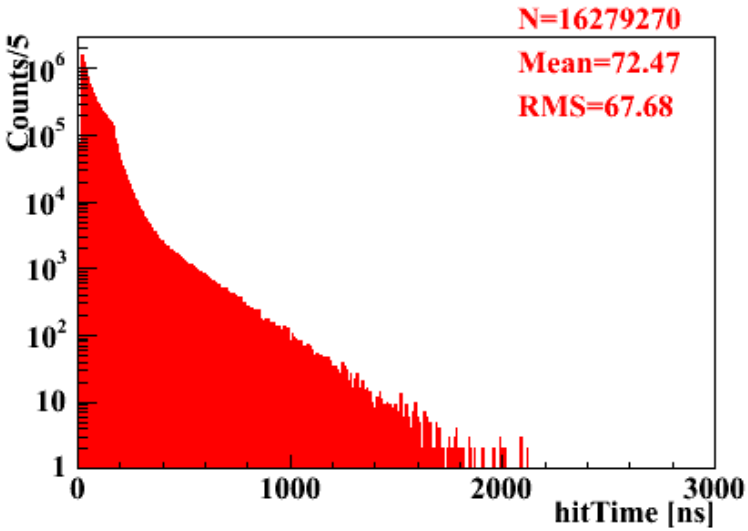


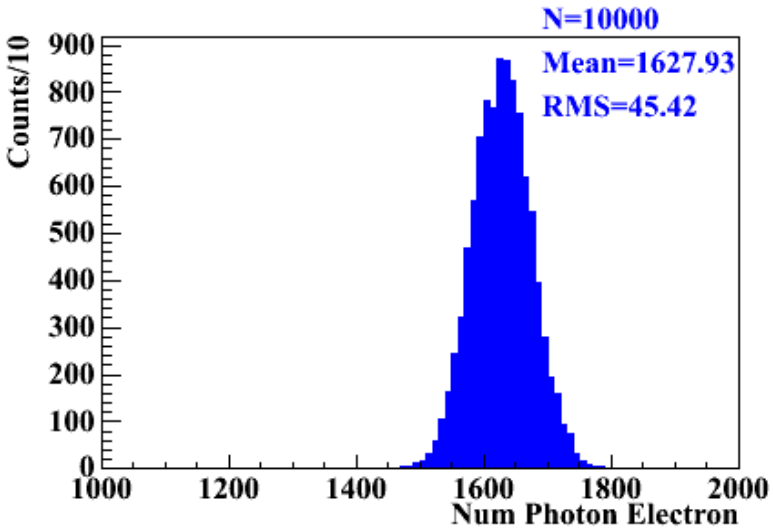


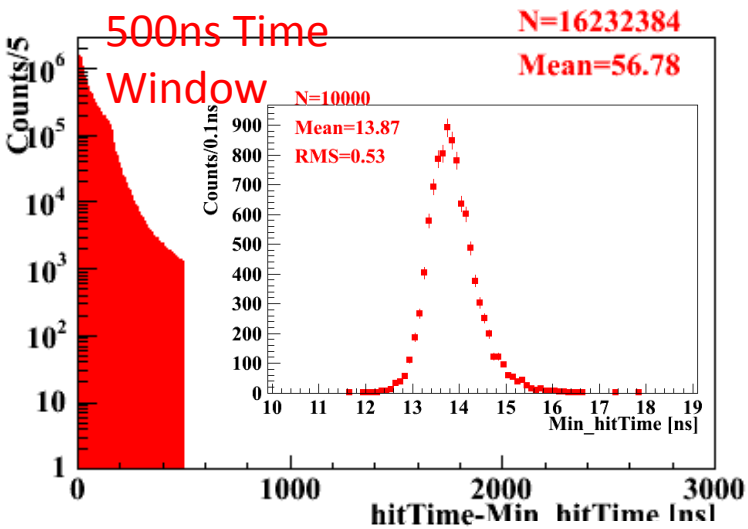


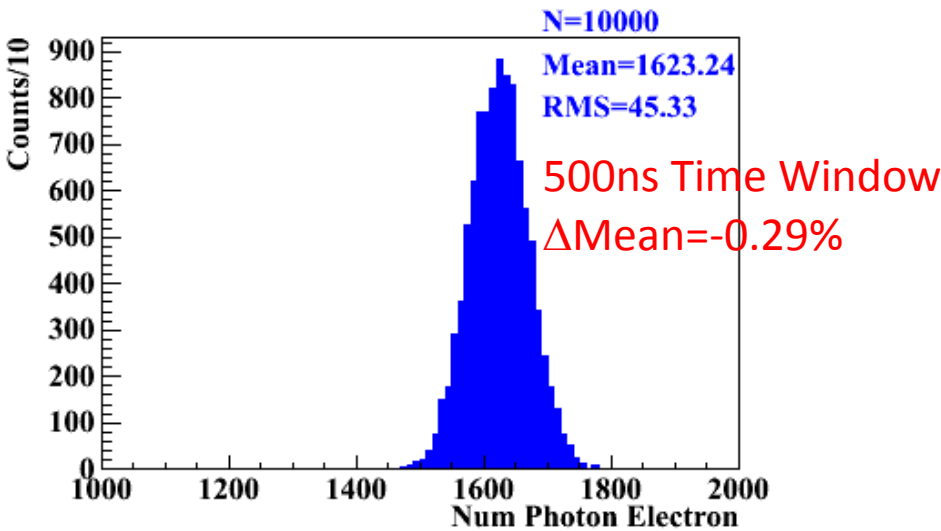
hitTime分布 【DetSim0】

2*0.511 γ from (**15m**,0,0)



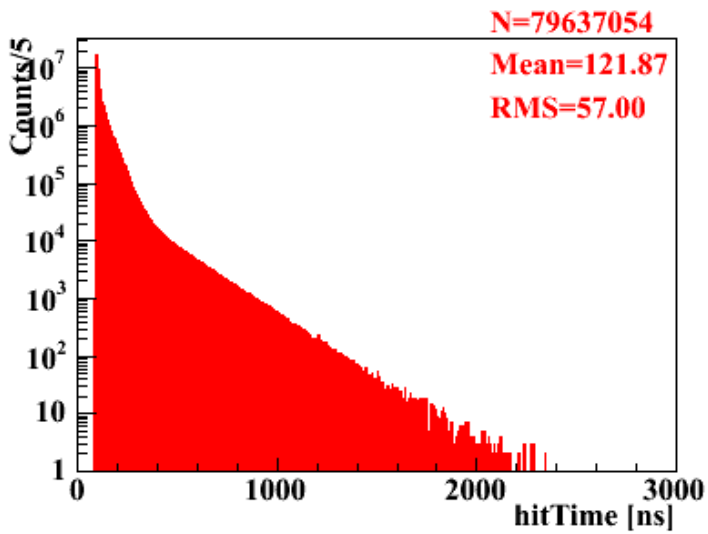


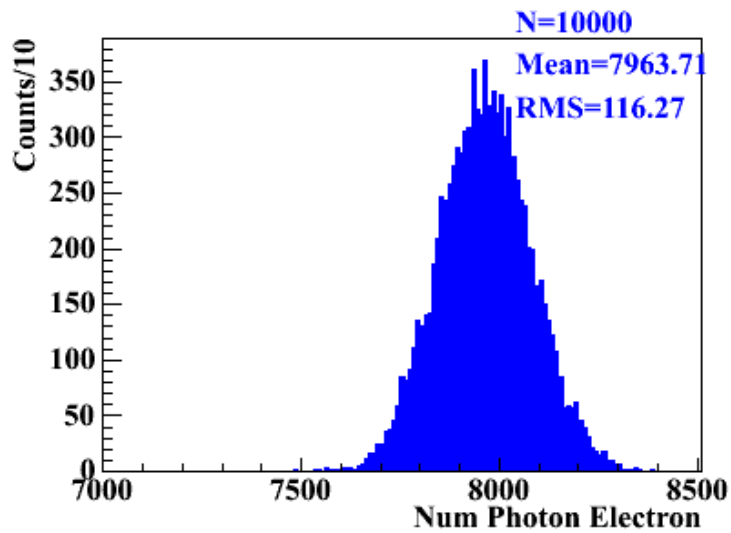


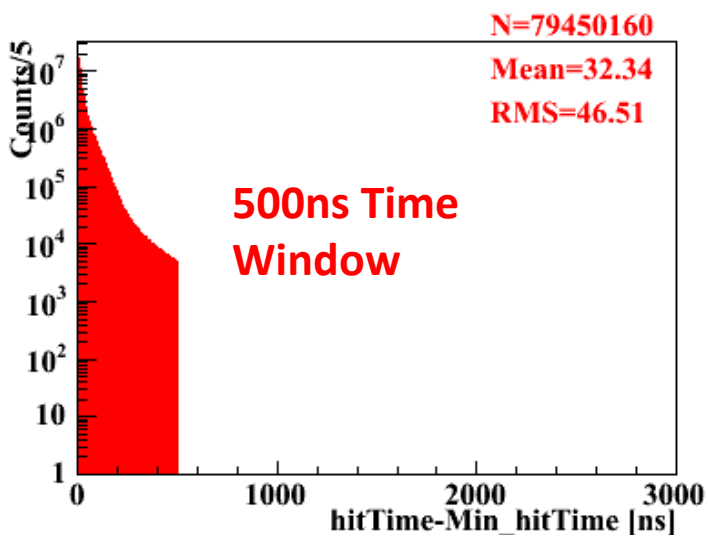


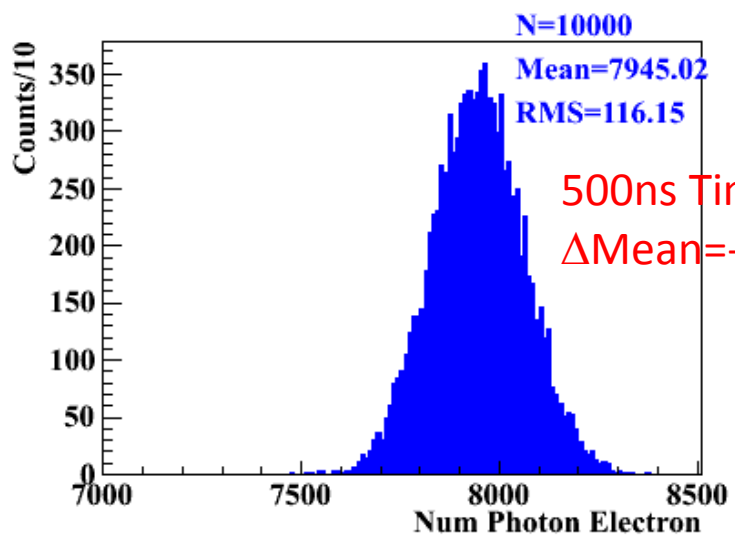
hitTime分布 【DetSim0】

6.13MeV γ from (0,0,0)





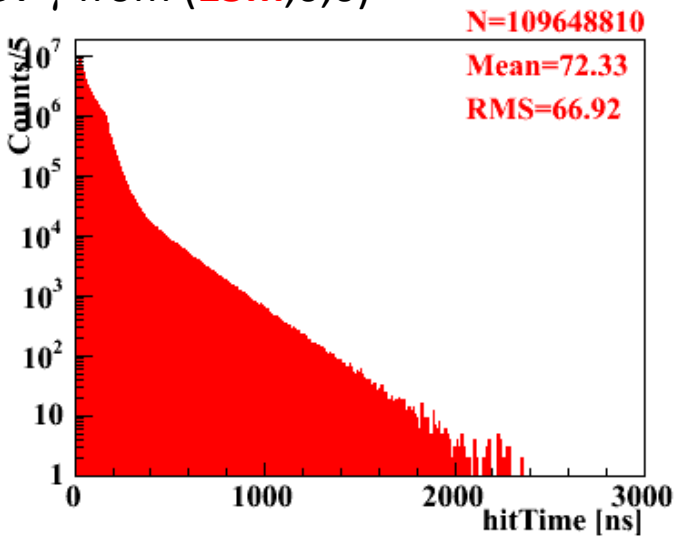


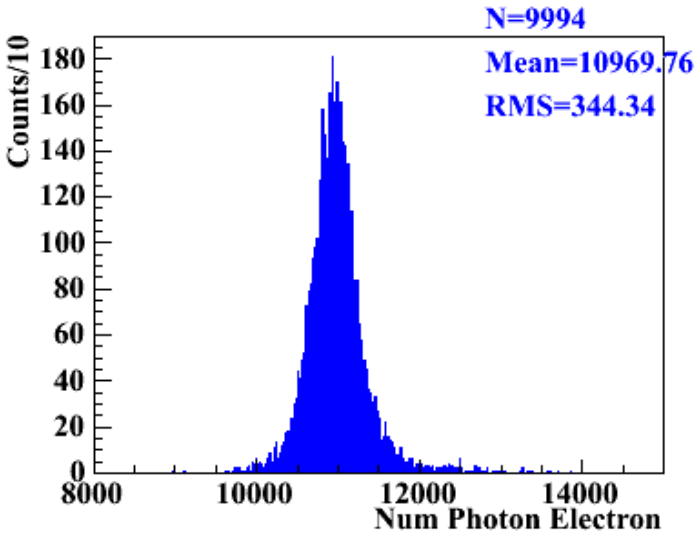


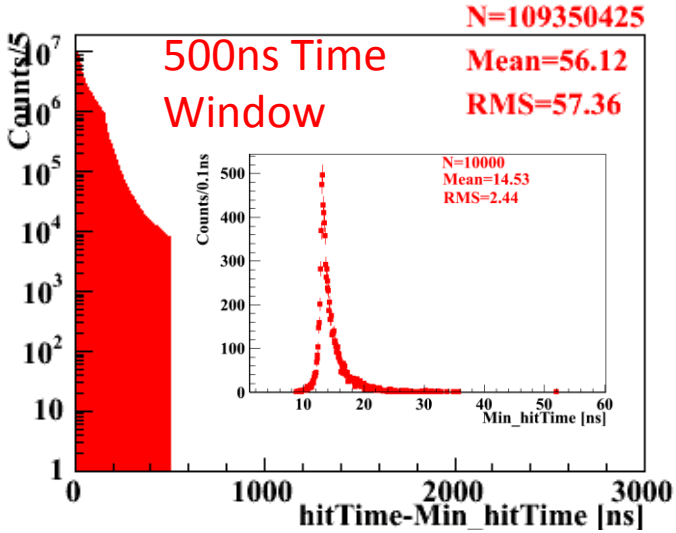
500ns Time Window
ΔMean=-0.23%

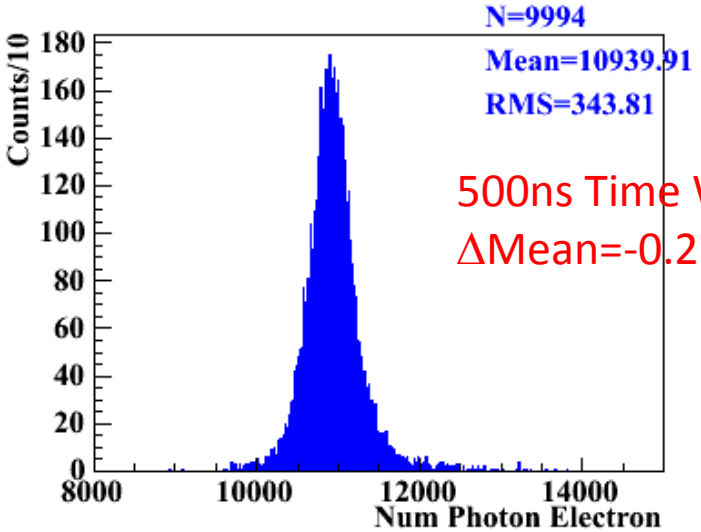
hitTime分布 【DetSim0】

6.13MeV γ from (**15m**,0,0)

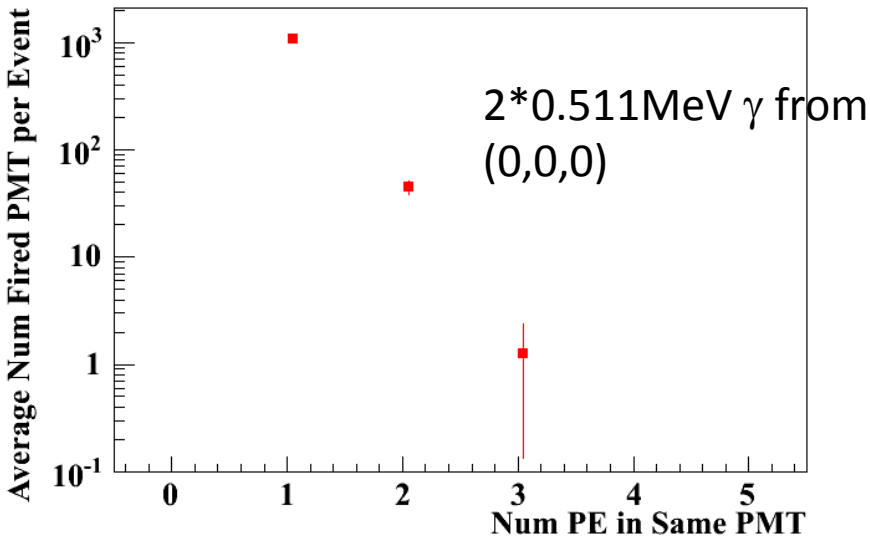


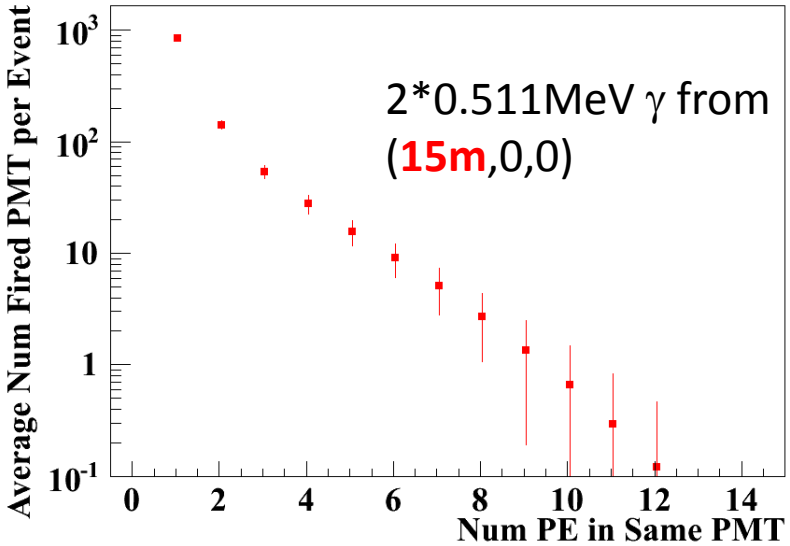


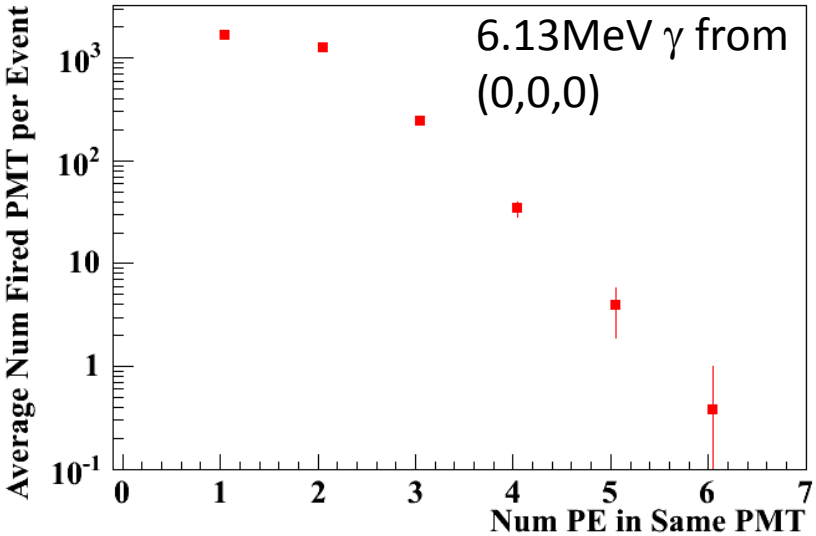


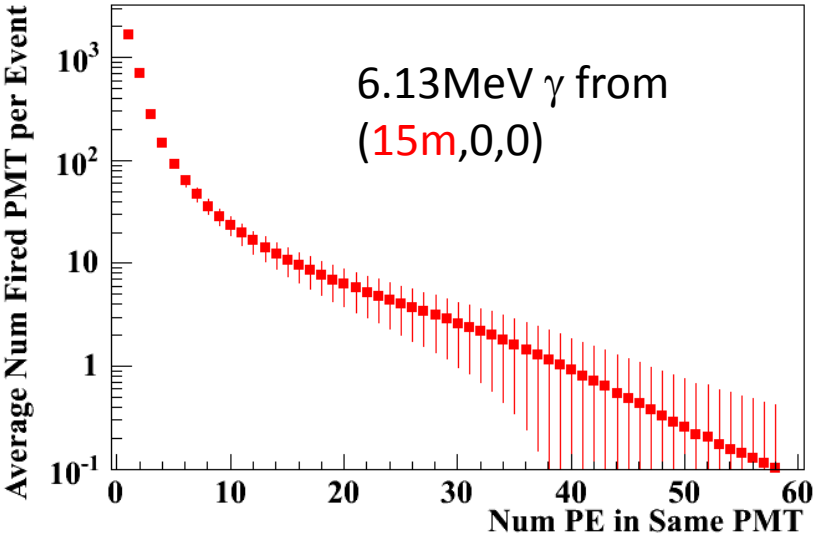


同PMT上光电子数


2*0.511MeV γ from
(0,0,0)
Average Num Fired PMT per Event
Num PE in Same PMT

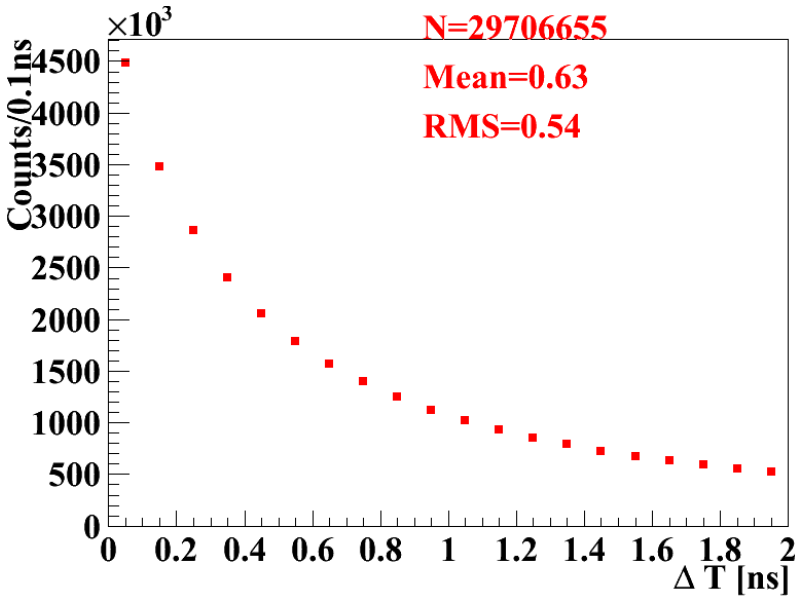

2*0.511MeV γ from
(15m,0,0)
Average Num Fired PMT per Event
Num PE in Same PMT


6.13MeV γ from
(0,0,0)
Average Num Fired PMT per Event
Num PE in Same PMT

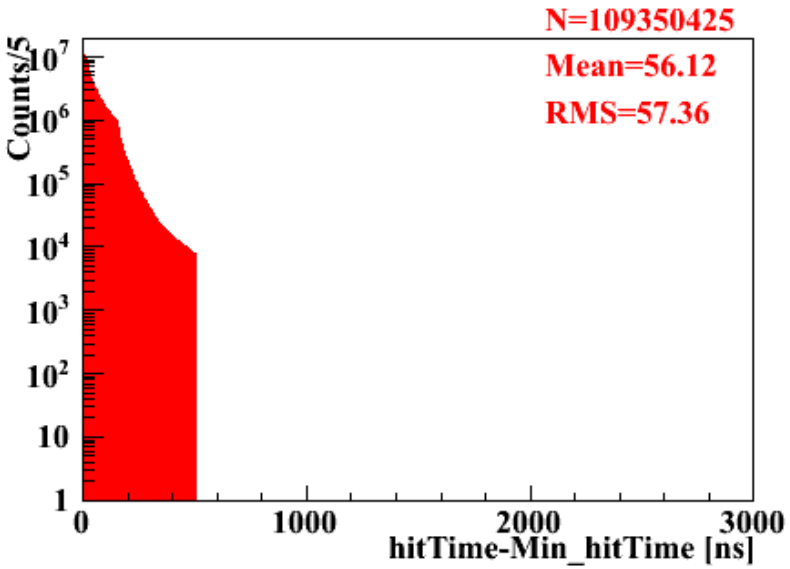

6.13MeV γ from
(15m,0,0)
Average Num Fired PMT per Event
Num PE in Same PMT

同一PMT上前后两光电子时间间隔

（15m,0,0）处的6.13MeV的γ射线



同PMT上前后hitTime时间间隔



500ns时间窗内的光子数

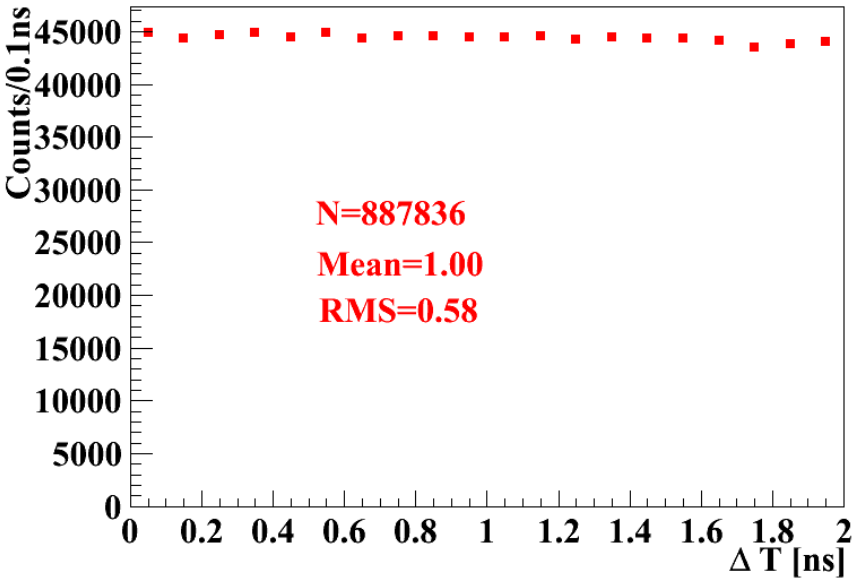
小于2ns的时间间隔数目29.7M（左图）; 500ns内总的光电子数109.4M （右图）

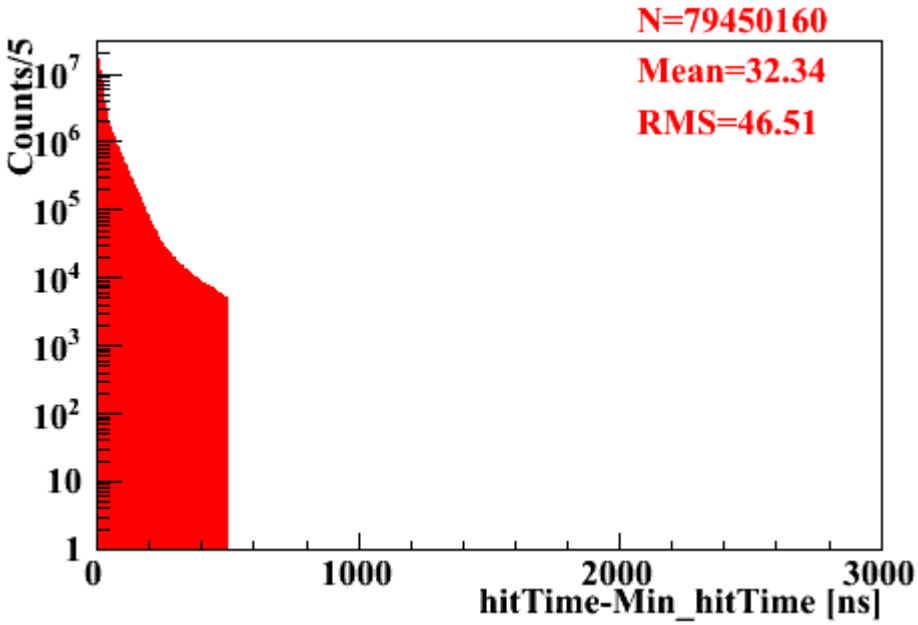
29.7M/109.4M=27.1%

这意味着，如果单光子工作模式不能很好区分2ns内的前后脉冲信号，对于来自（15m,0,0）处的6.13MeV的γ射线将有27.1%的光子丢失（？需要其他同事进一步确认）！

同一PMT上前后两光电子时间间隔

（0,0,0）处的6.13MeV的γ射线





前后时间间隔小于2ns的时间间隔数目

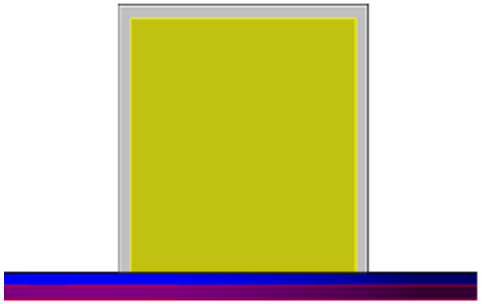
500ns时间窗内的光子数

0.8878M/79.45M = 1.1%

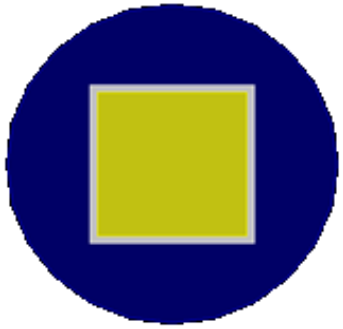
单光子工作模式会因前后时间间隔太短而丢光电子数，
脉冲幅度积分模式怎样受时间间隔的影响？

脉冲幅度积分模式例子

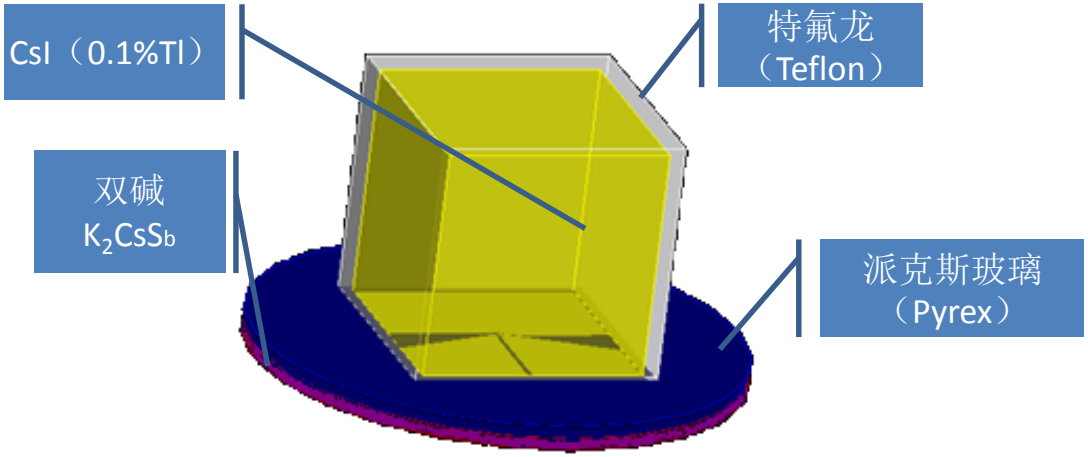
模拟简单的CsI探测器



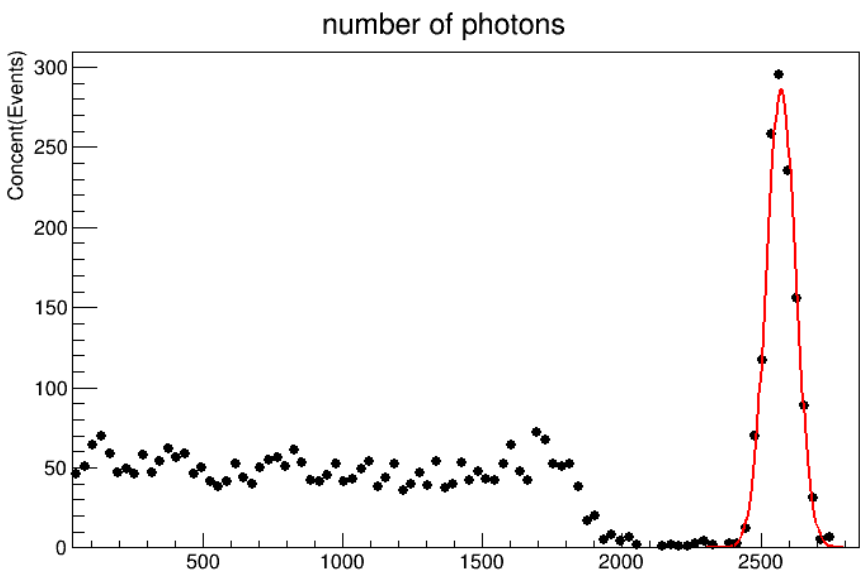
正视图



俯视图

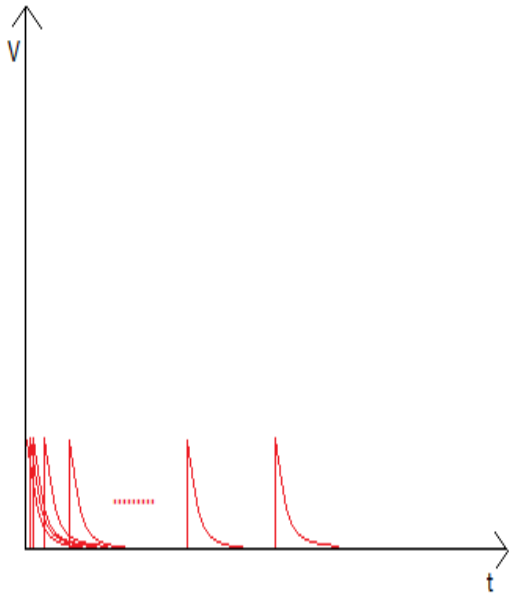


立体图



661KeV的γ射线在光阴极产生的光电子数目（QE=8%）。

能量分辨为4.83%

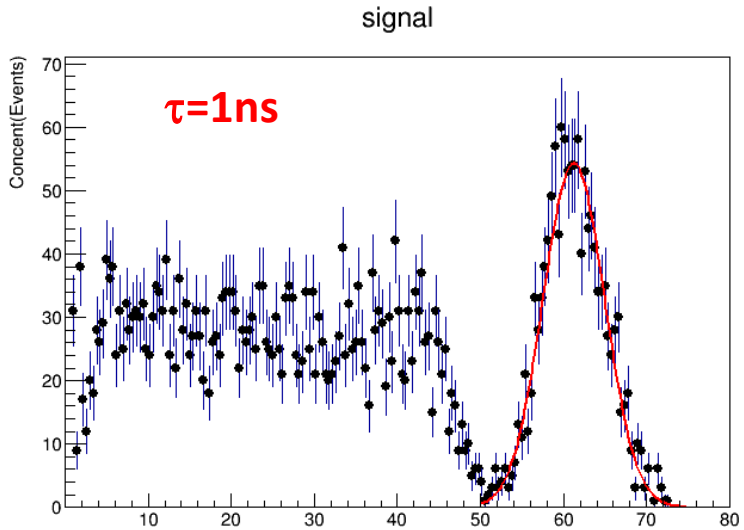


积分工作模式：

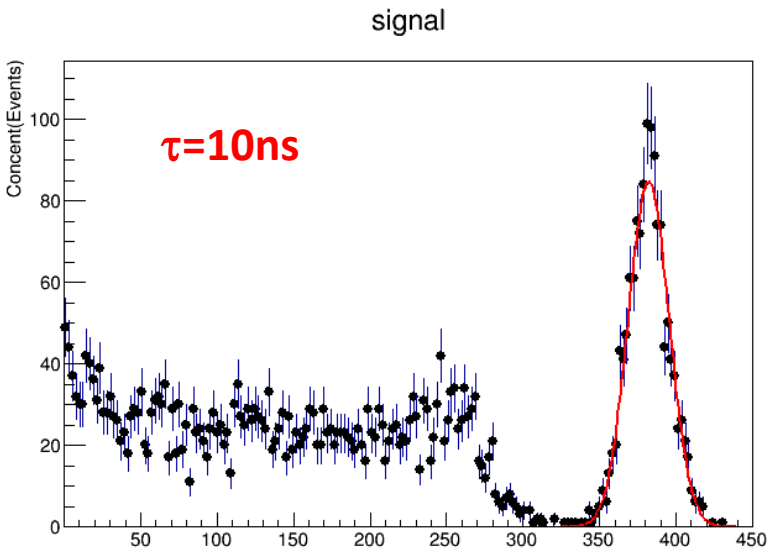
根据光电子放大后脉冲的电荷叠加，累计的脉冲最大值即信号幅度：

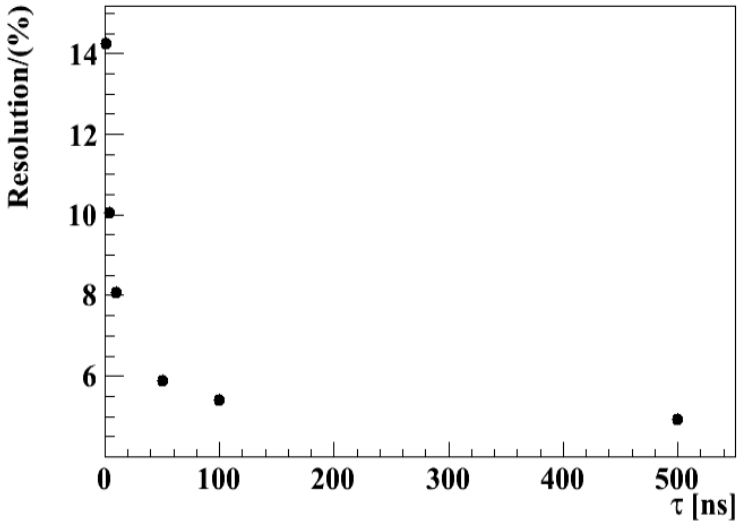
$$H(t) = \sum_{i=1}^{n} h e^{-(t-t_i)/\tau}$$

不同成形常数下的分辨

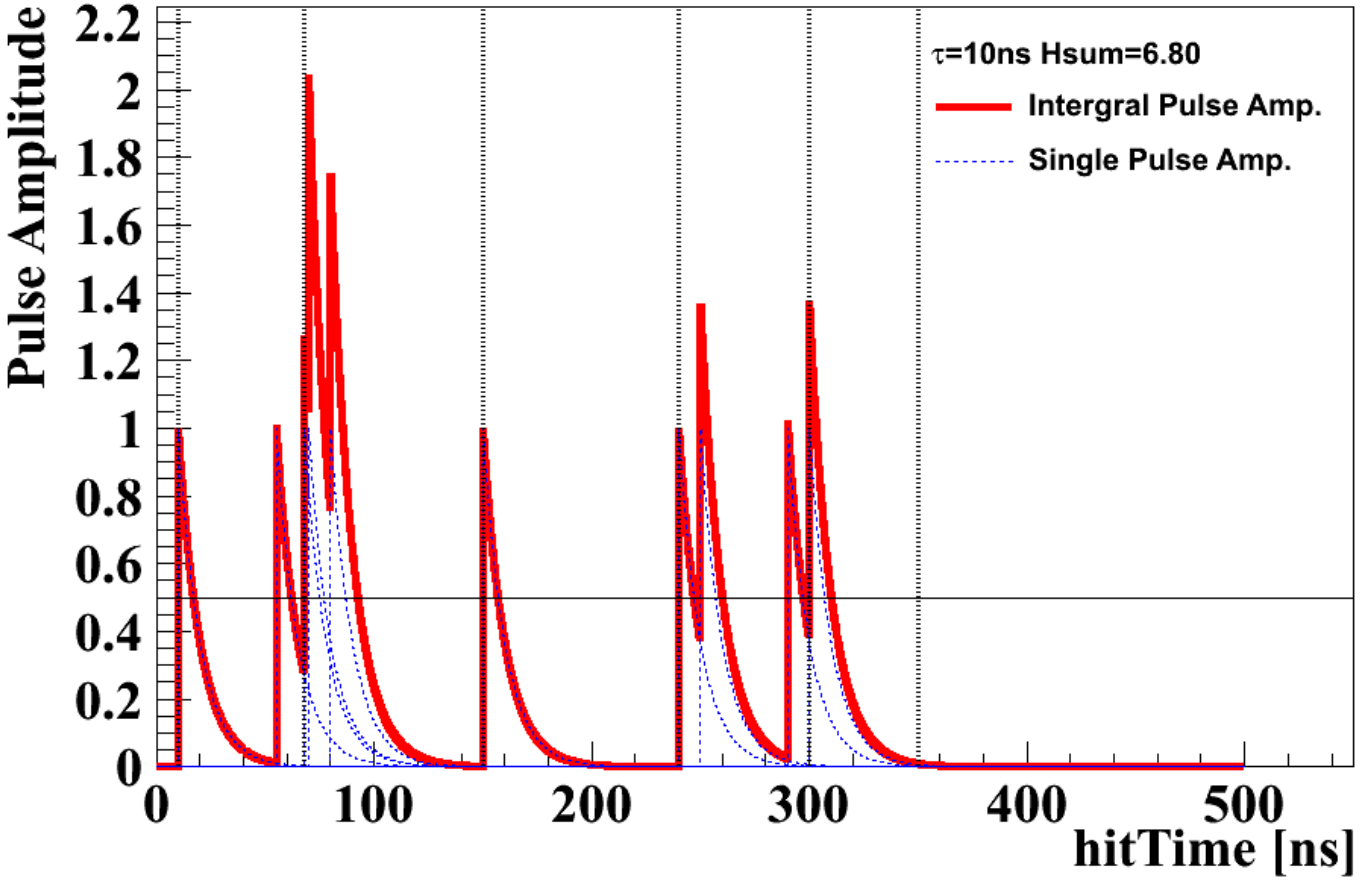


积分常数τ(ns)	分辨率(%)
1	14.25
4.3	10.06
10	8.06
50	5.89
100	5.4
500	4.94
∞	4.83



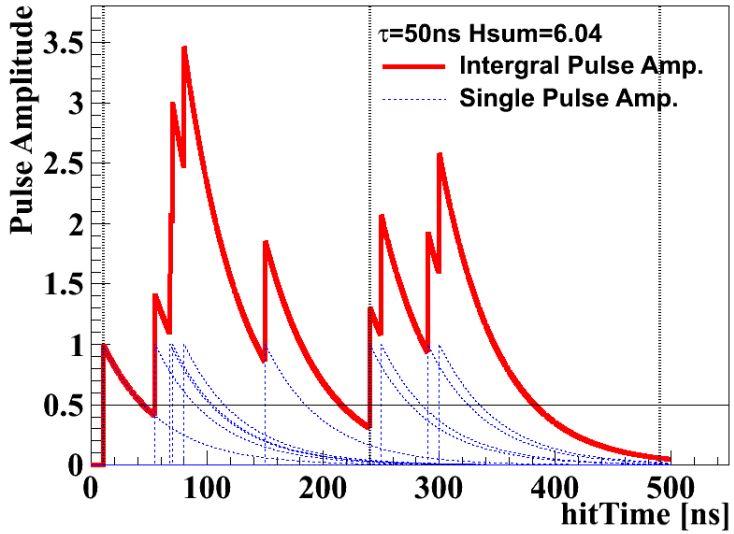


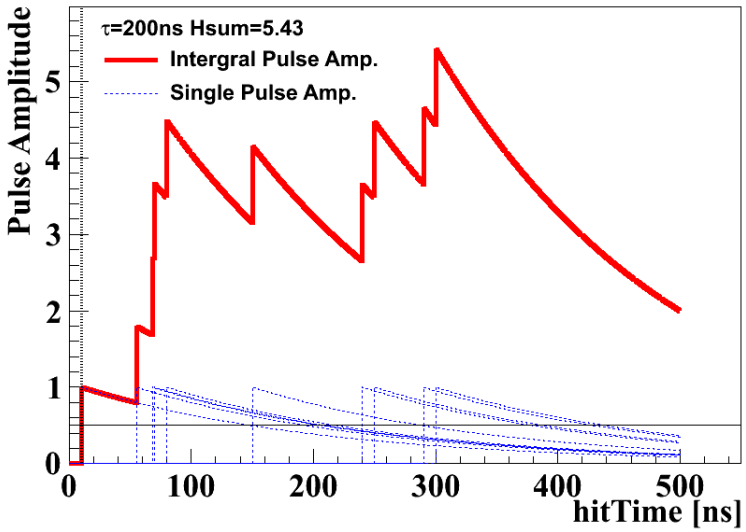
数字化时成形时间τ对幅度的影响

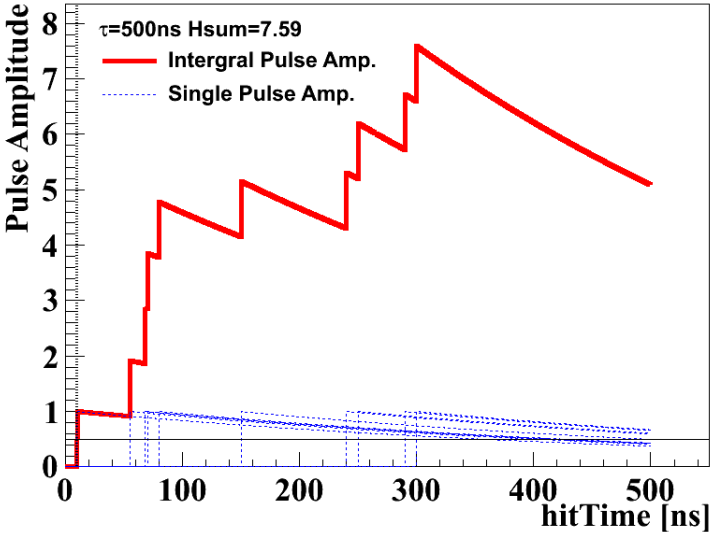


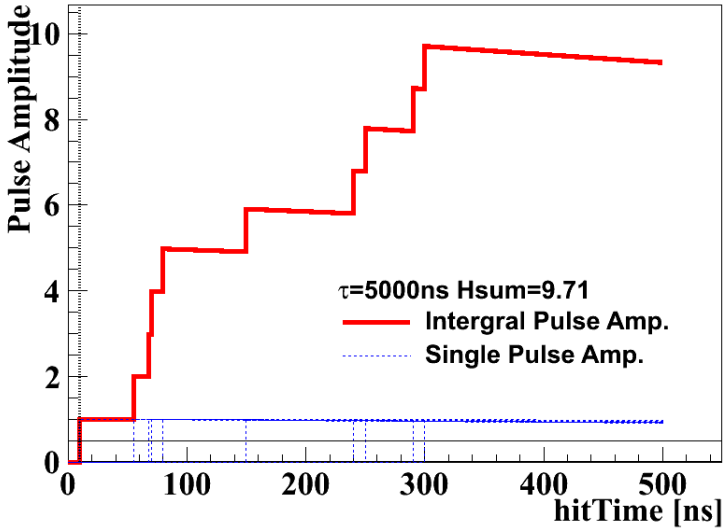
积分脉冲每过1个光电子脉冲幅度的1/2且与上一个区间间隔ADC转换时间以上(假设DAC时间为50ns)为一个新脉冲记录时间开始。最后一个区间的结束为5τ
Hsum为各个区间最高幅度相加之和。

数字化时不同成形时间τ对幅度的影响



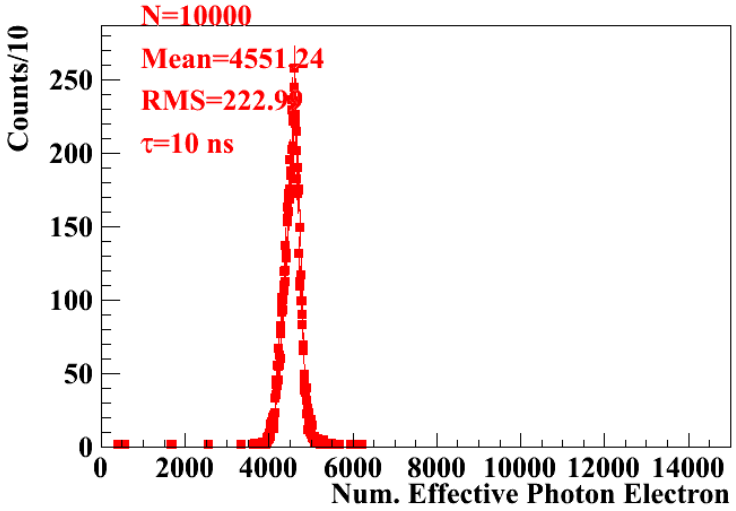


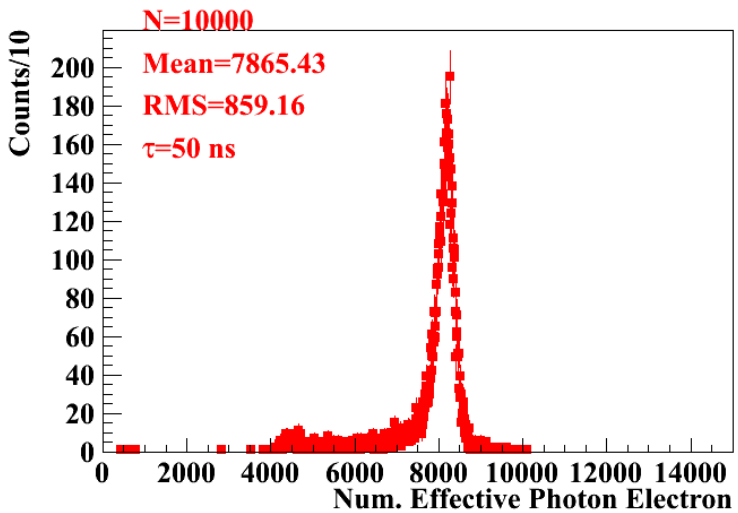


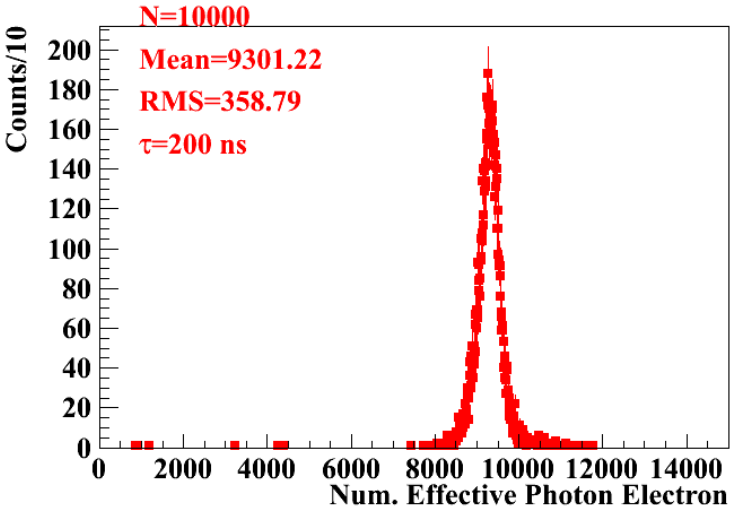


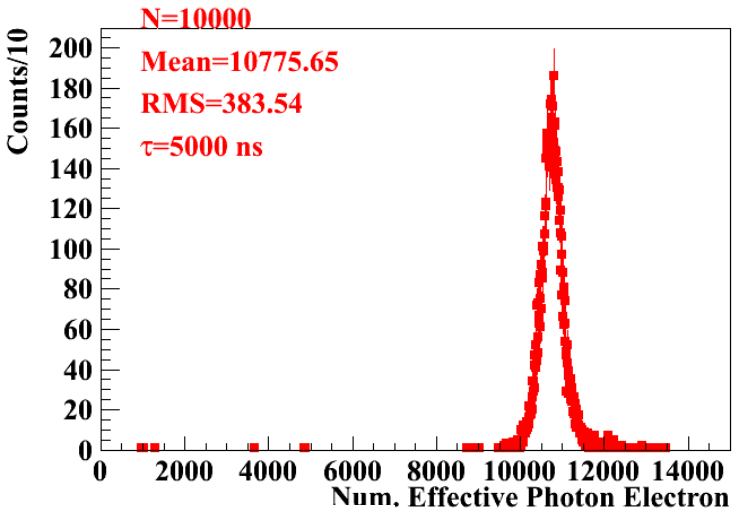
不同时间常数下收集的总脉冲高度

6.13MeV γ from (**15m**,0,0)



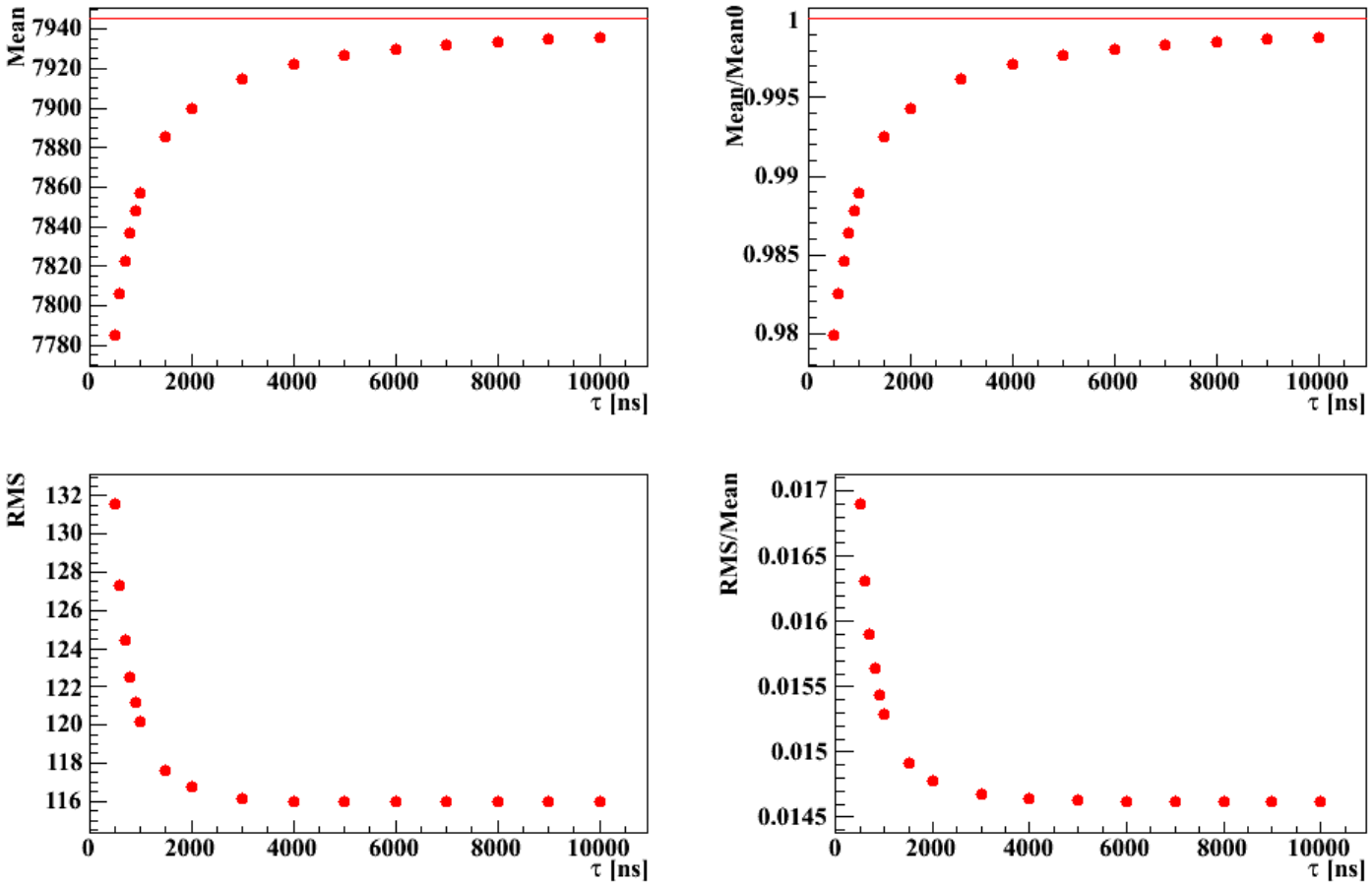






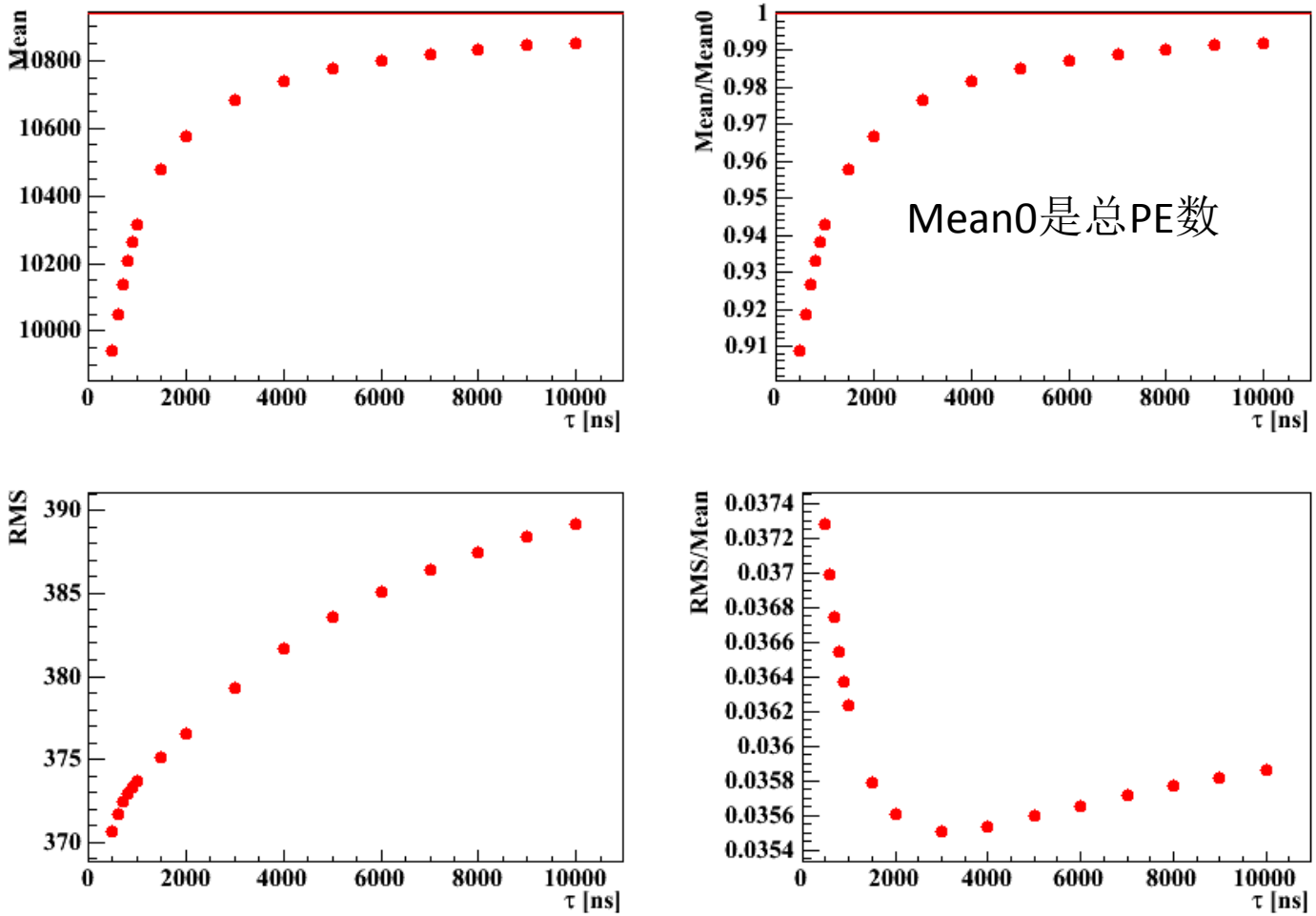
Mean, RMS和分辨随τ的变化

6.13MeV γ from (0,0,0)



Mean, RMS随τ的变化

6.13MeV γ from (15m,0,0)



1） τ要非常长才能保障脉冲高度与实际相符

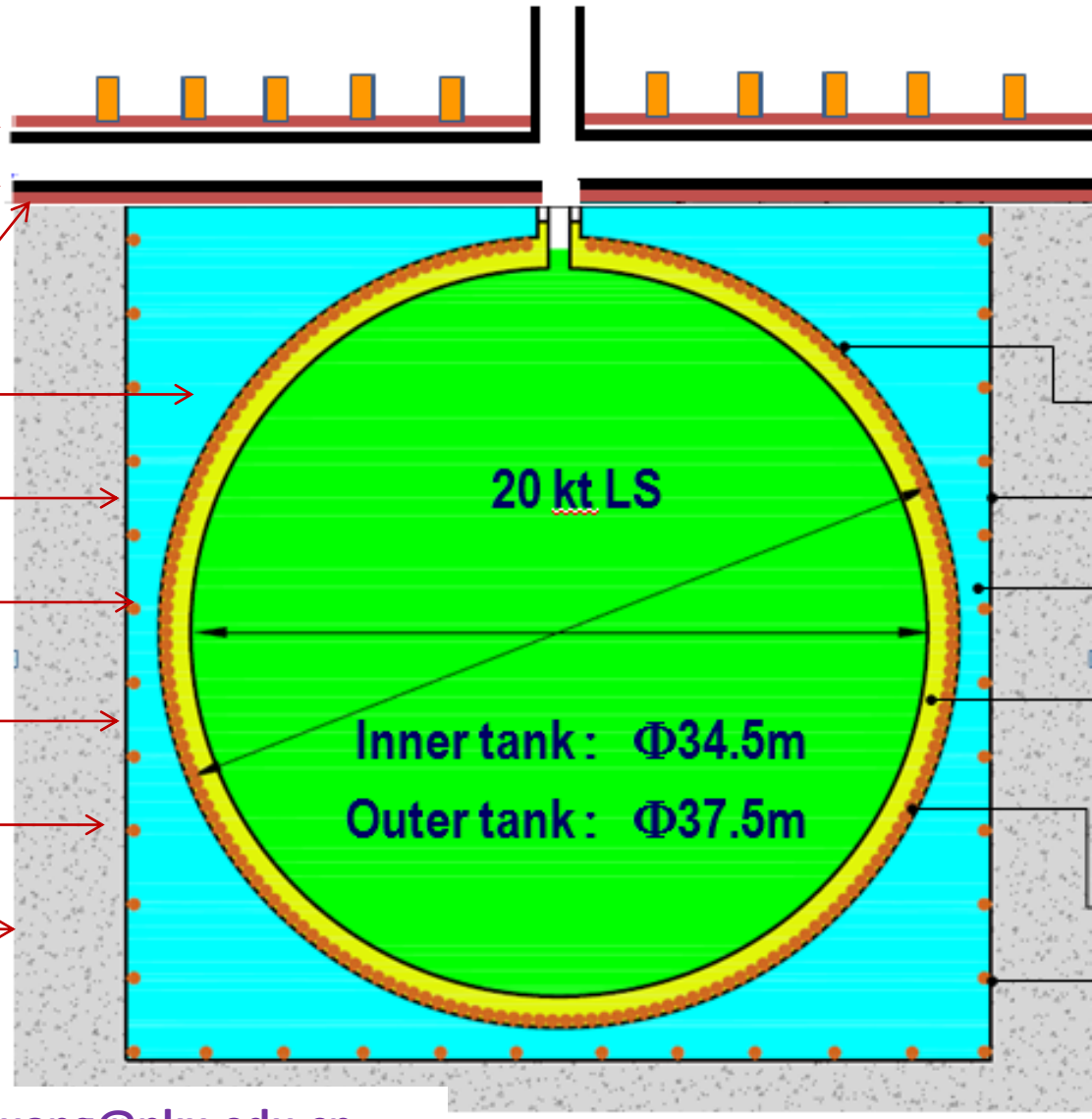
2）在线起始与结束的时间窗选取

宇宙射线μ子产生的次级粒子横向半径分布

反符合探测器系统任务及初步设计

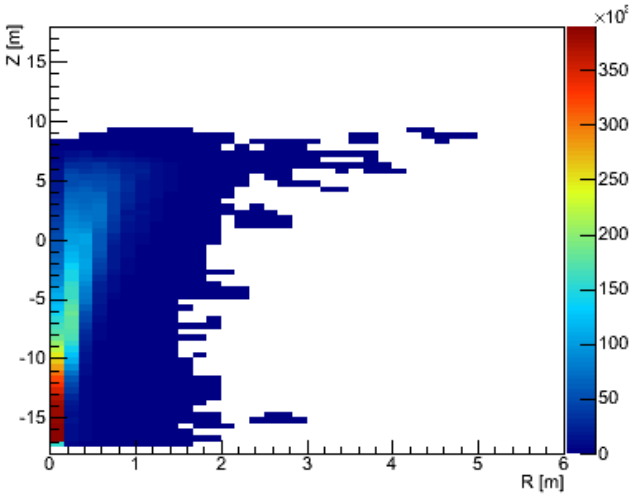
来自杨长根研究员报告

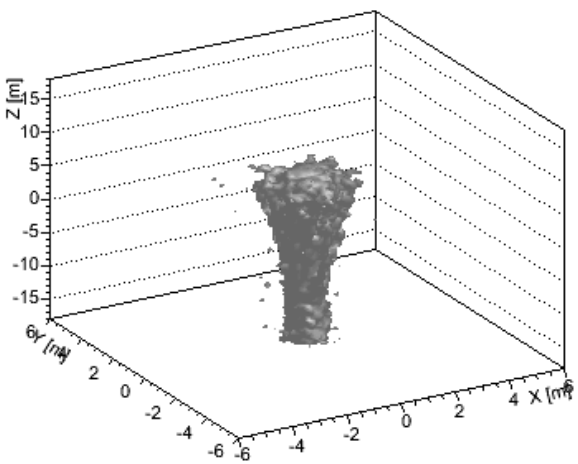
- 顶部径迹探测器
- 顶部径迹探测器支撑结构
- 纯净水系统
- Tyvek反射膜
- PMT支撑结构及安装
- 水池内衬及密封
- 水池保温
- 磁场屏蔽线圈



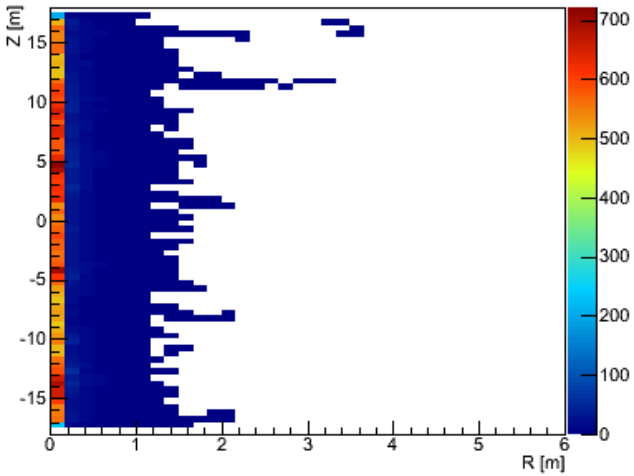
siguang@pku.edu.cn

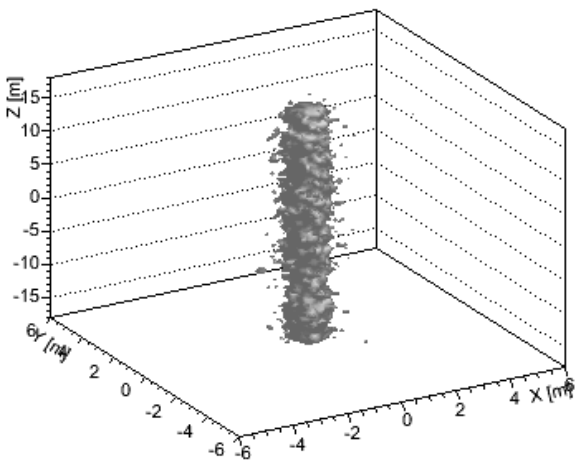
Energy Deposition in LS





5GeV μ along z passing (0,0,0)

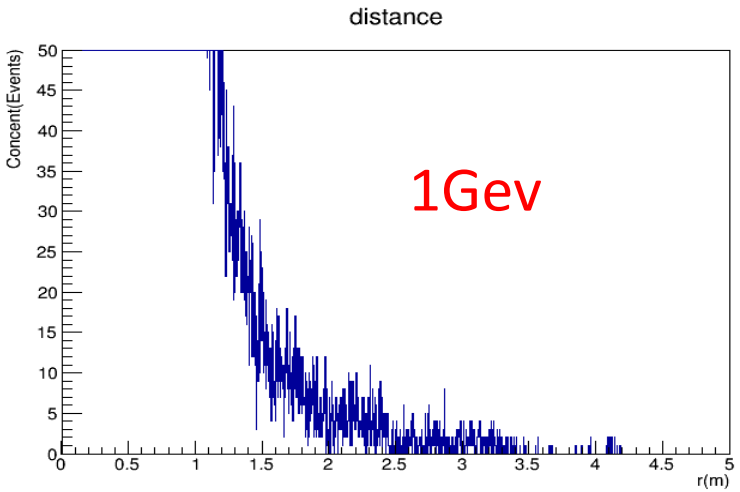


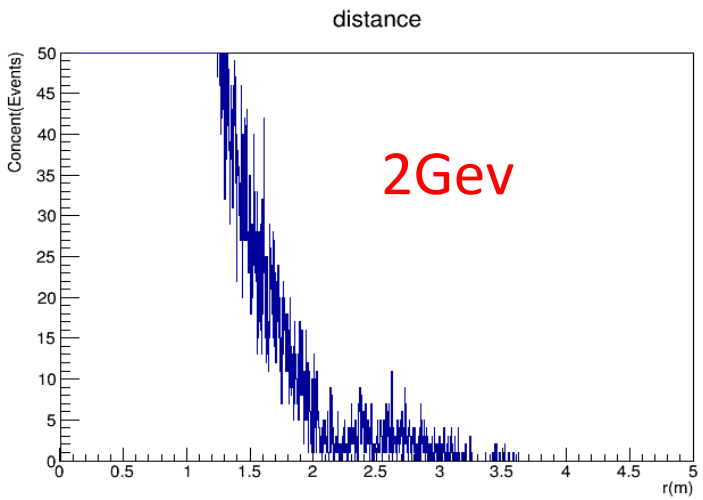


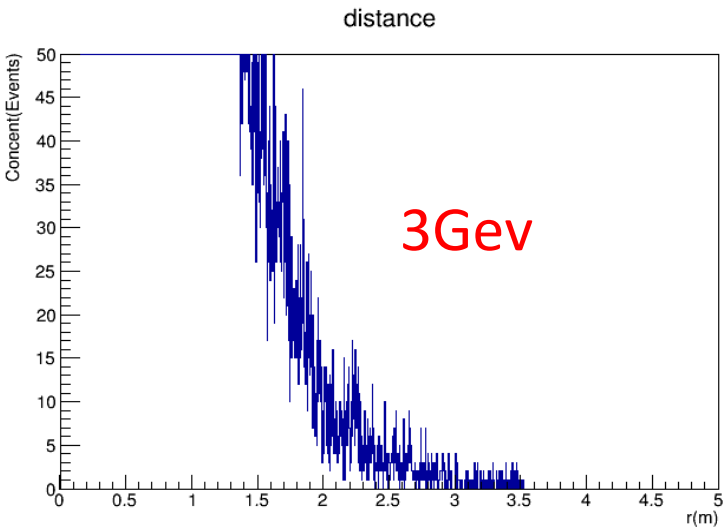
210GeV μ along z passing (0,0,0)

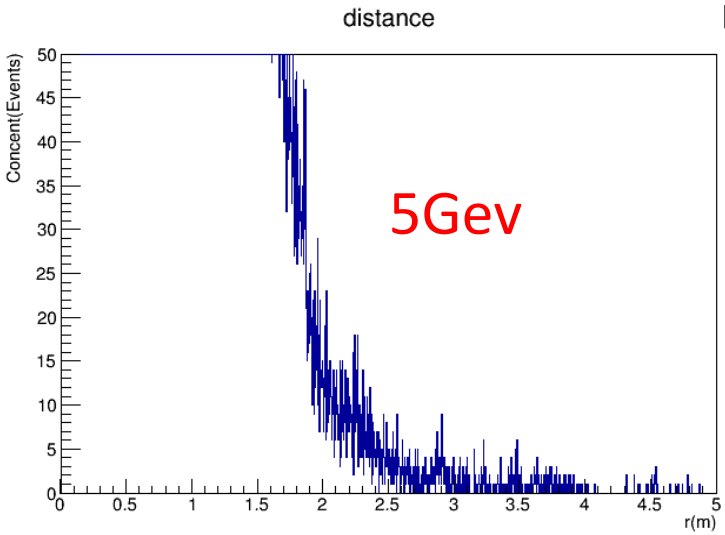
不同能量的μ产生的次级粒子的沉积能量横向分布

μ子垂直向下沿z轴方向过(0,0,0)点





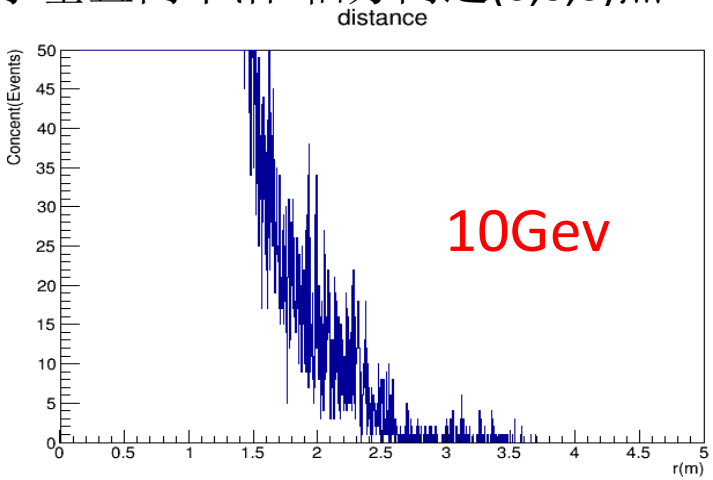


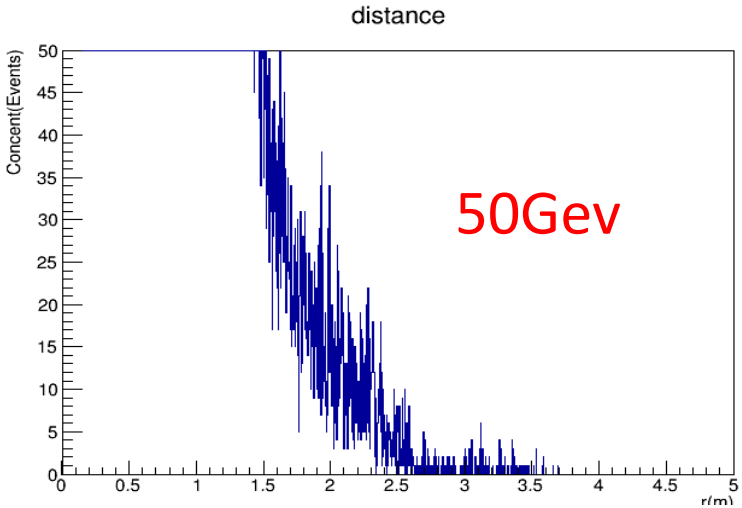


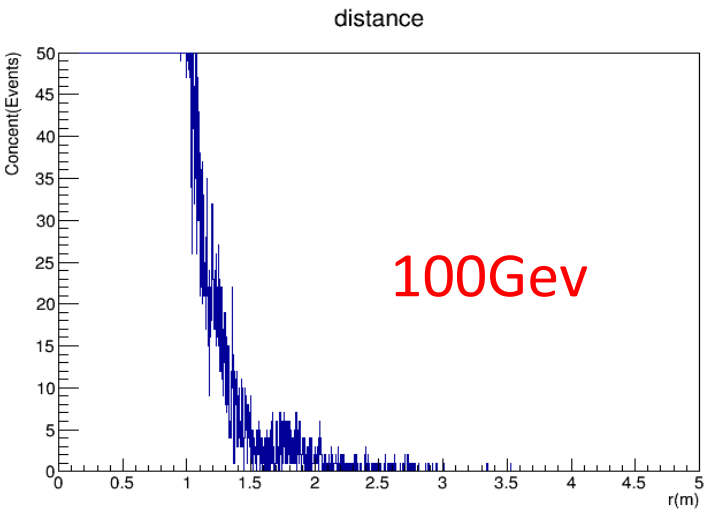
结论：反符合掉R<5m内的信号是合理的

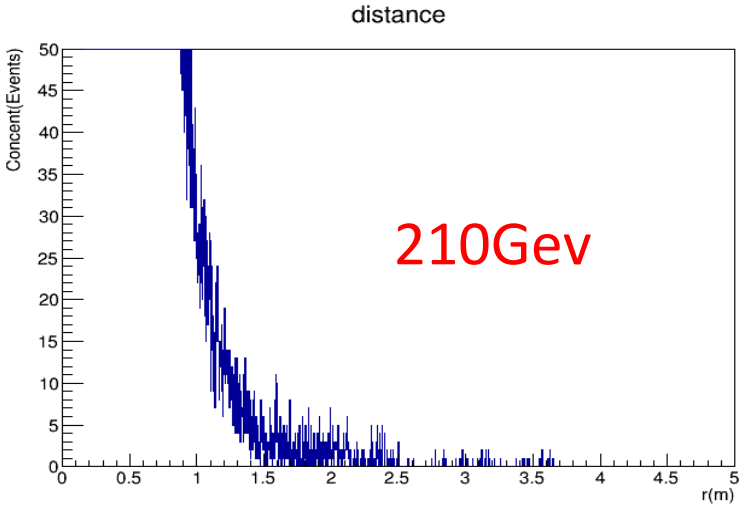
不同能量的μ产生的次级粒子的沉积能量横向分布

μ子垂直向下沿z轴方向过(0,0,0)点



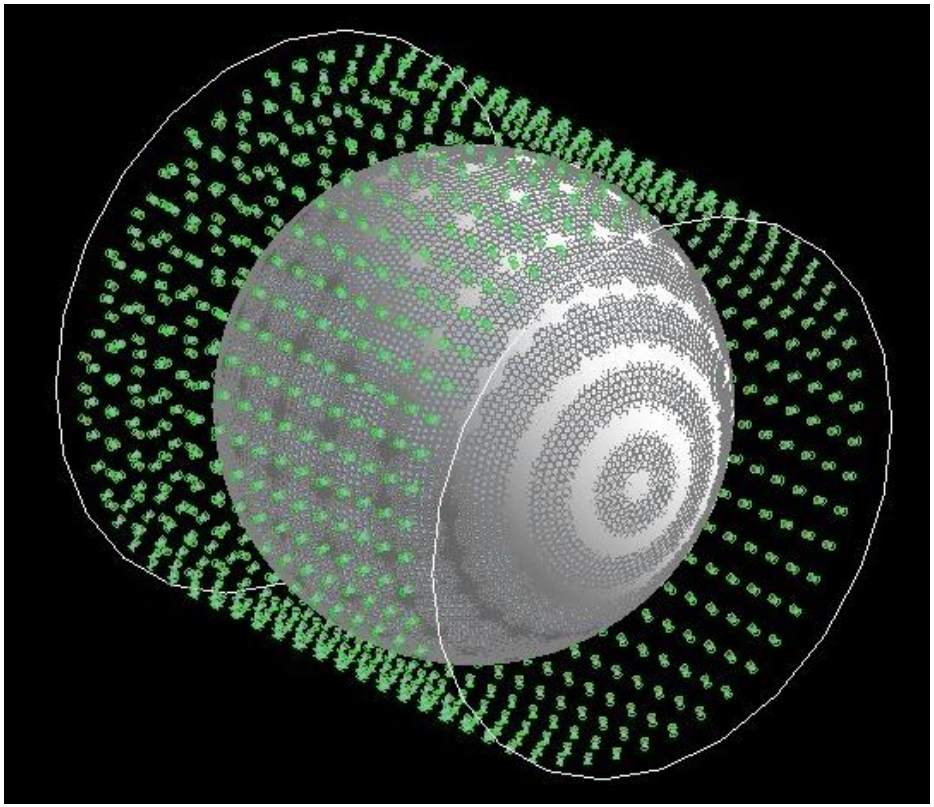




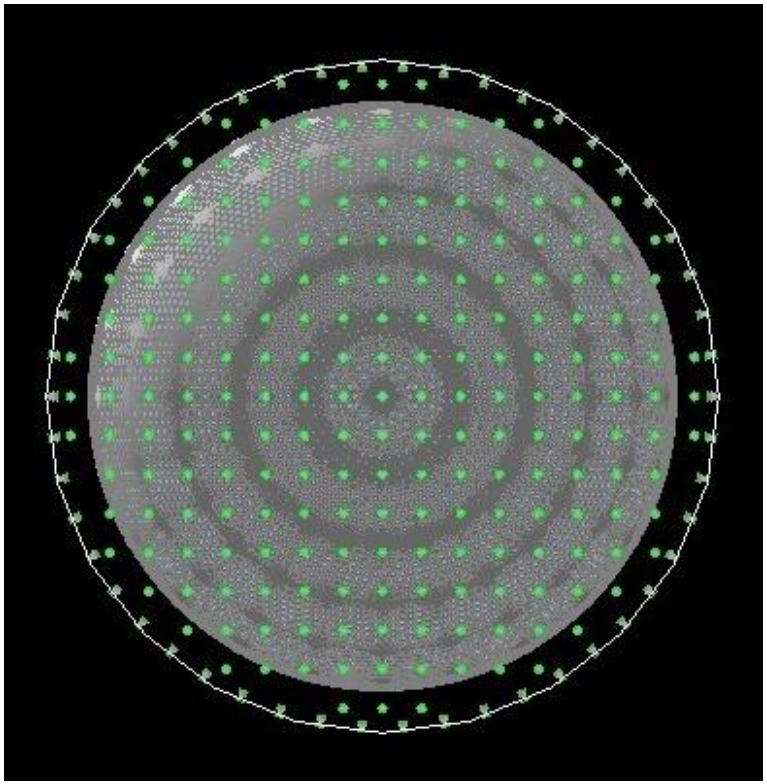


结论：反符合掉R<5m内的信号是合理的

下一步工作：球外反符合系统研究



桶侧：800PMT



桶底：213PMT

总结

- 尼龙袋方案与直接钢罐方案相比在允许5个（含）本底光子的假设下可将本底影响压低到1/3；对分辨影响不大。
- 对发生在边缘的事件，尤其是能量比较高时(例如6.13MeV的γ在x为15m处)，因靠近的同一PMT上会收集到多个光子，模拟显示无论是积分模式还是单光子工作模式都是挑战.
- 宇宙射线μ引发的次级粒子能量沉积在沿初始径迹方向5m之内。为反符合系统提供参考。
- 下一步工作：对反符合系统进行效率研究