REACTOR NEUTRINO LIQUID XENON COHERENT SCATTERING EXPERIMENT (RELICS)

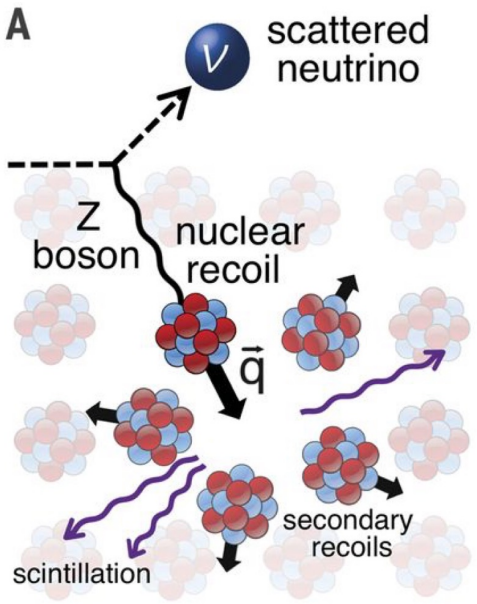
蔡畅 清华大学

On behalf of the RELICS collaboration

2024. 8. 15 青岛

RELICS 合作组

RELICS实验： LXe-TPC + CEνNS



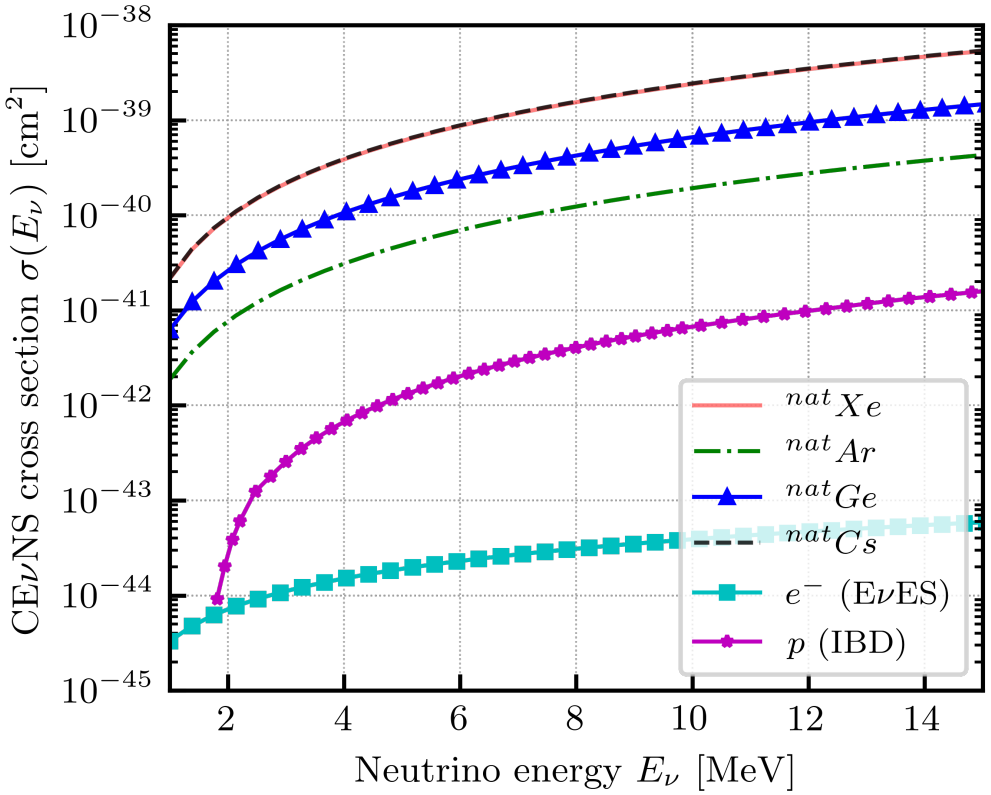
$$\frac{d\sigma}{dT} = \frac{G_F^2}{4\pi} Q_W^2 M \left(1 - \frac{MT}{2E_\nu^2}\right) F(Q^2)^2.$$

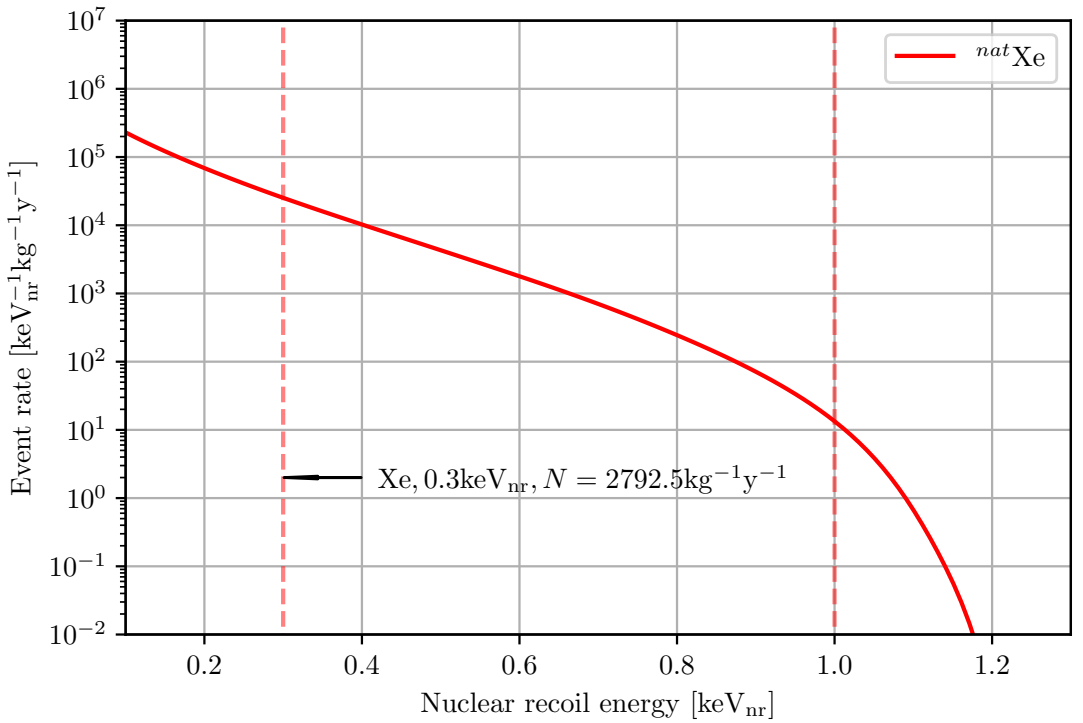
$$Q_W = N - (1 - 4\sin^2\theta_W) Z$$

$$Q_W \propto N \implies \frac{d\sigma}{dT} \propto N^2$$

- 规划实验地点：浙江三门核反应堆
- 核反应堆功率: ~3GW
- TPC-堆芯距离: ~25m
- 预期中微子流量:~$10^{13}\nu/cm^2/s$

使用LXe-TPC探测反应堆CEνNS



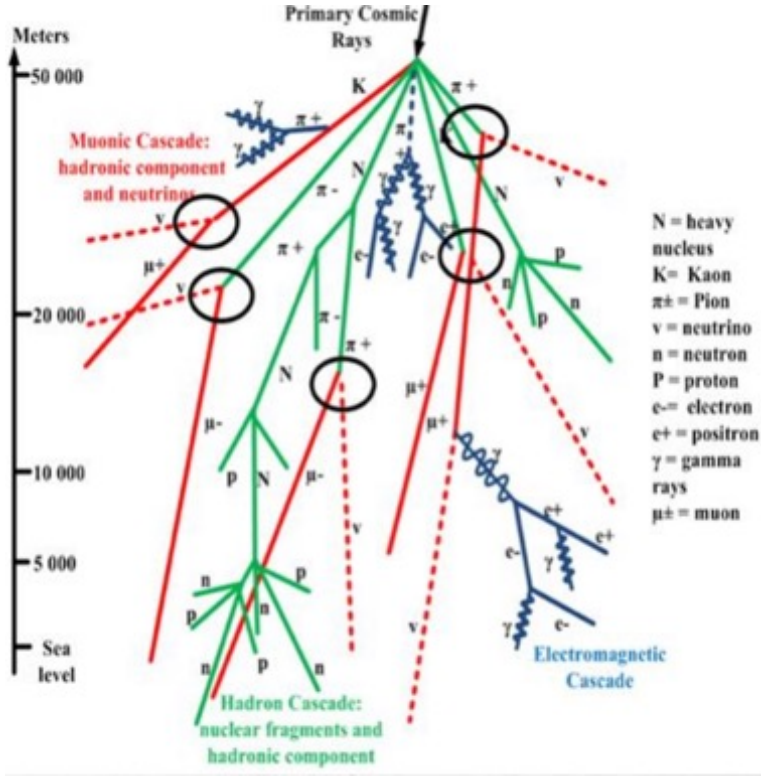


- 更大的中微子散射截面:
  - 中微子流强~$10^{13}\upsilon \cdot cm^{-2} \cdot s^{-1}$;
  - 沉积能量区间: [0.3,1]keV$_{nr}$;
  - 曝光量:32 $kg.year$;
  - 预期获得CEνNS 年事件量:~1e4;

- 更低的核反冲沉积能量:
  - 液氙中沉积能量 < 1.2keV;
  - O(1)电子产额与光产额;
  - S1 信号难以探测，S2 only分析，对信号采集和本底控制带来挑战;

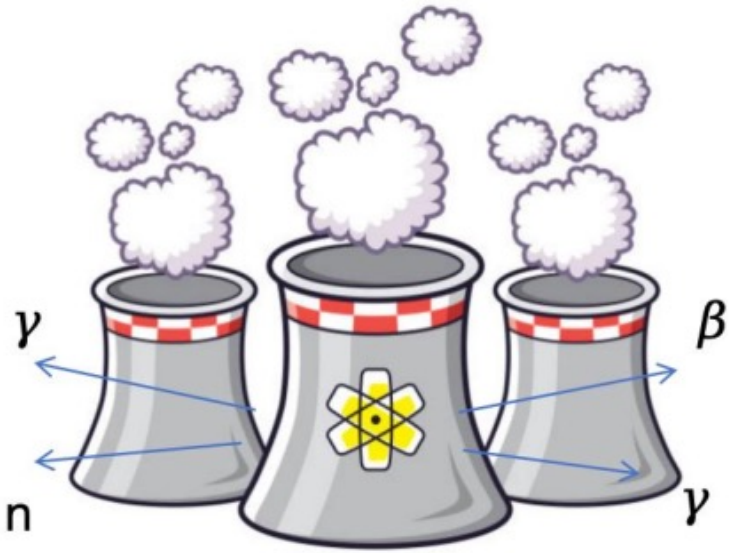
RELICS实验物理本底

宇宙线本底



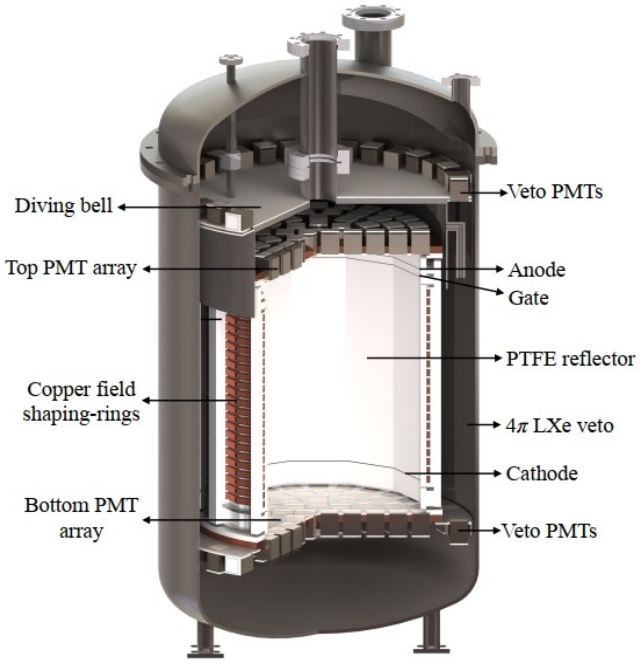
- 宇宙线μ;
- 宇宙线中子;
- Others…

反应堆本底



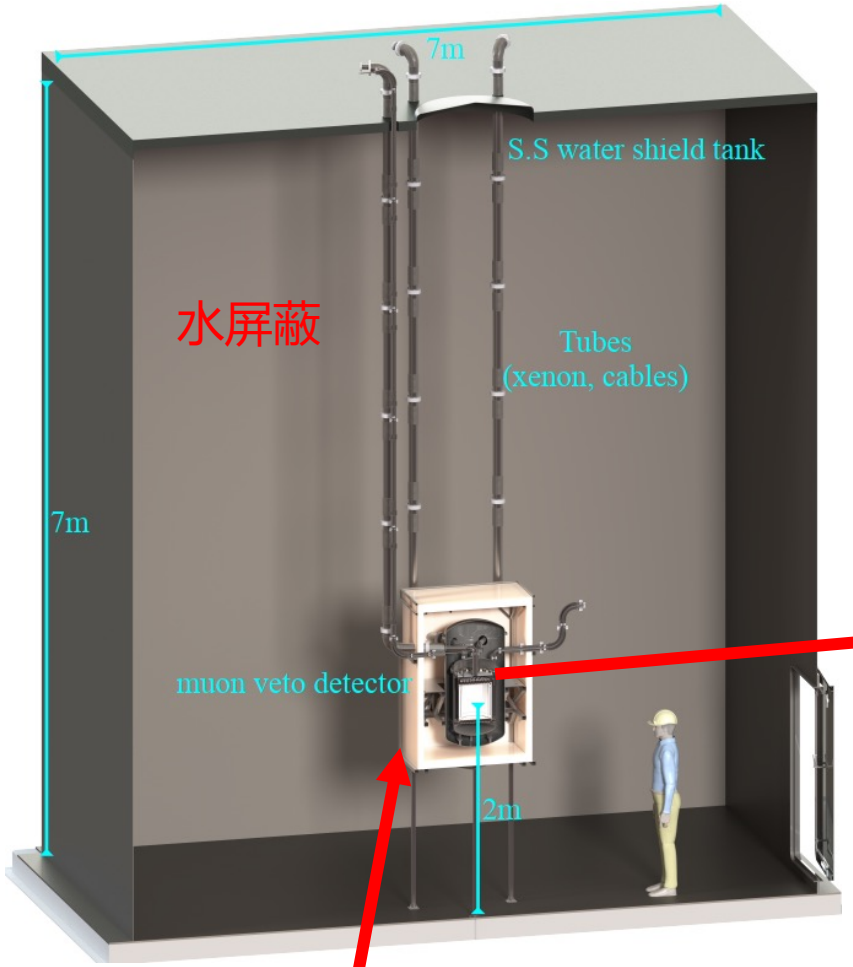
- 反应堆中子
- 反应堆γ;
- Others…

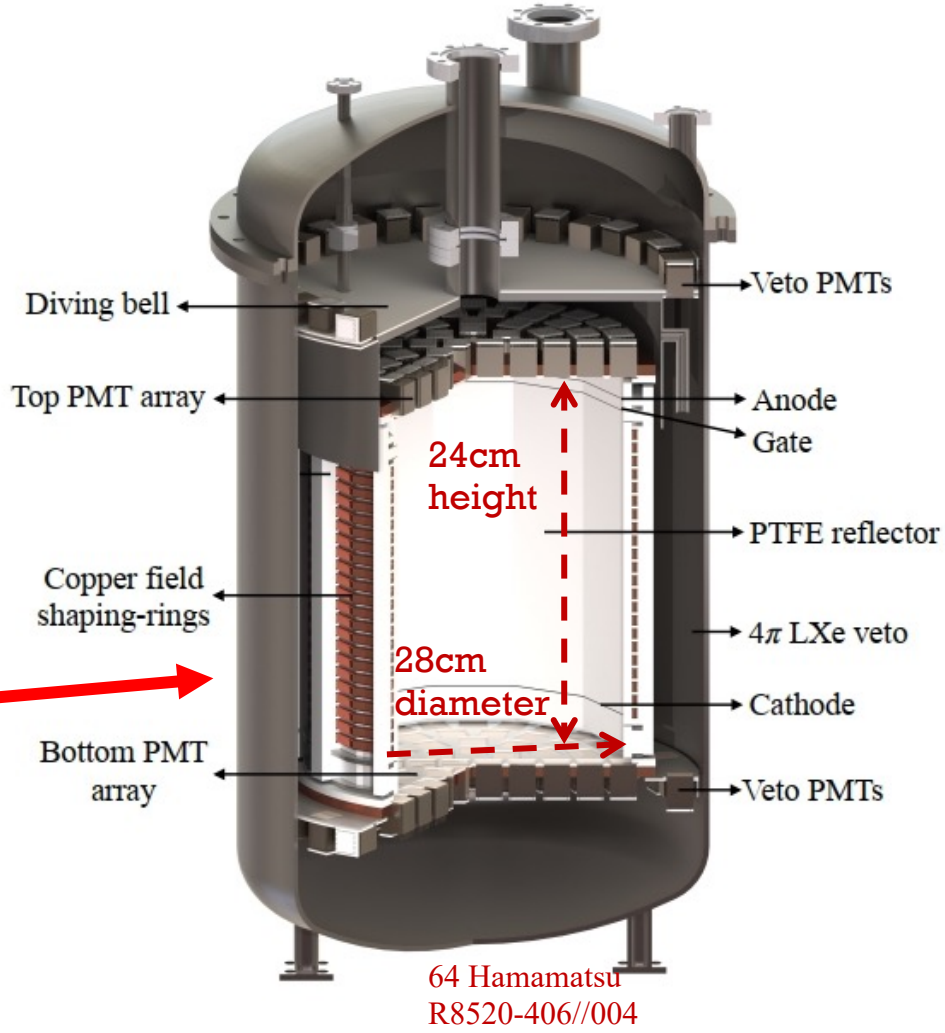
材料本底



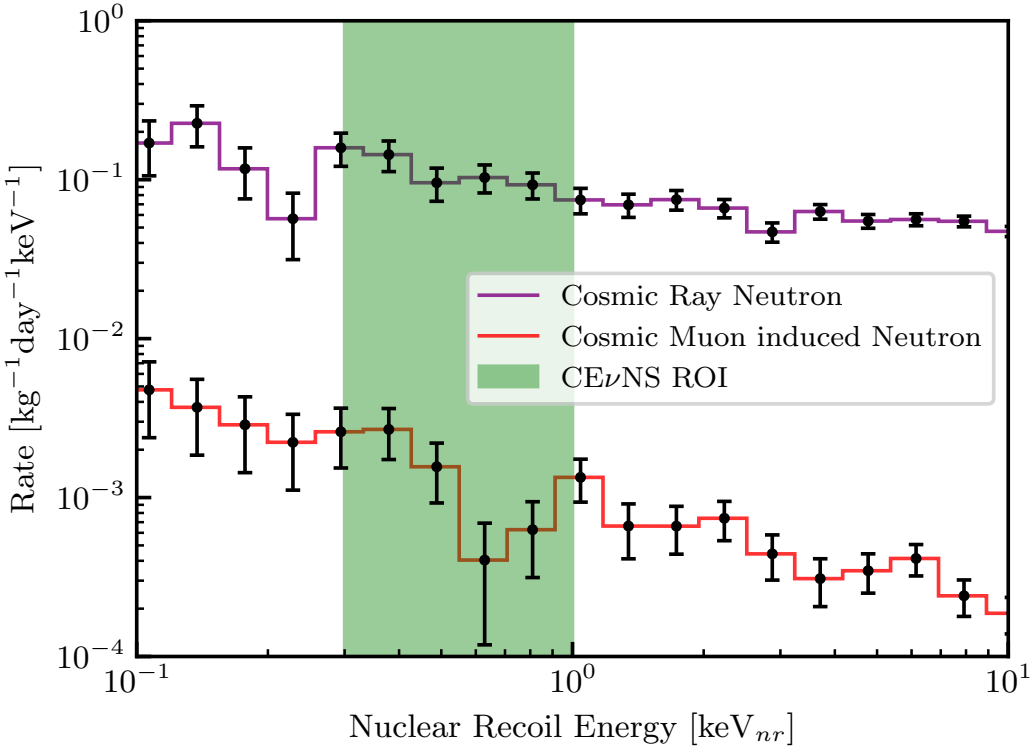
- 材料γ, beta本底;
- 宇宙线μ产生次级中子;
- Others…

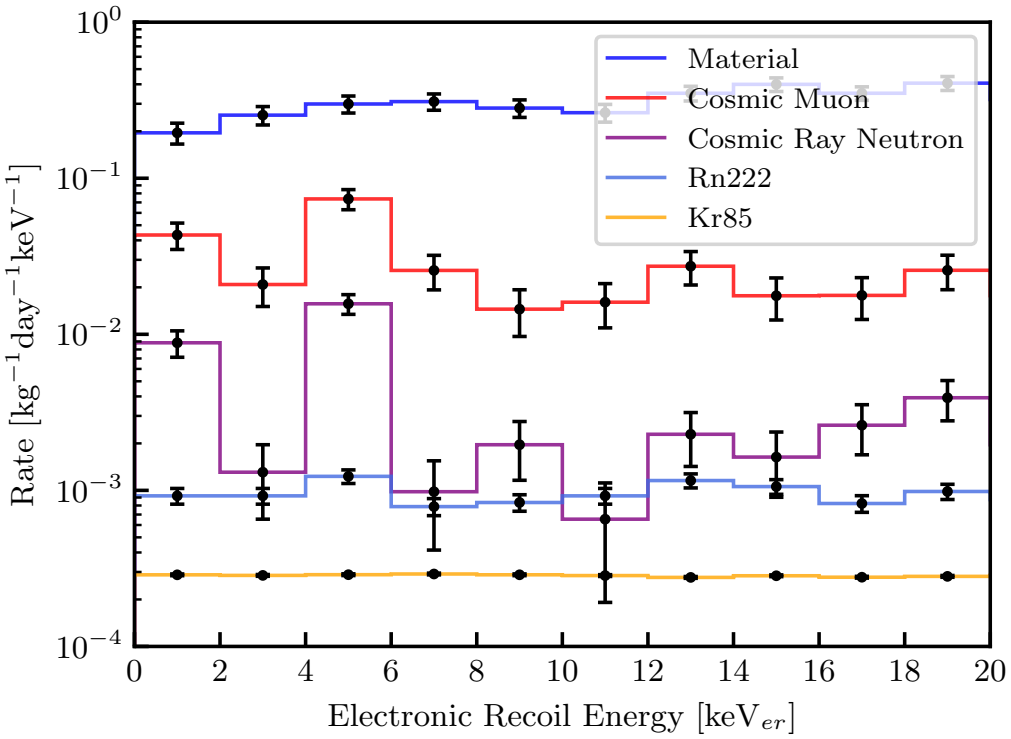
RELICS探测器设计





RELICS实验物理本底

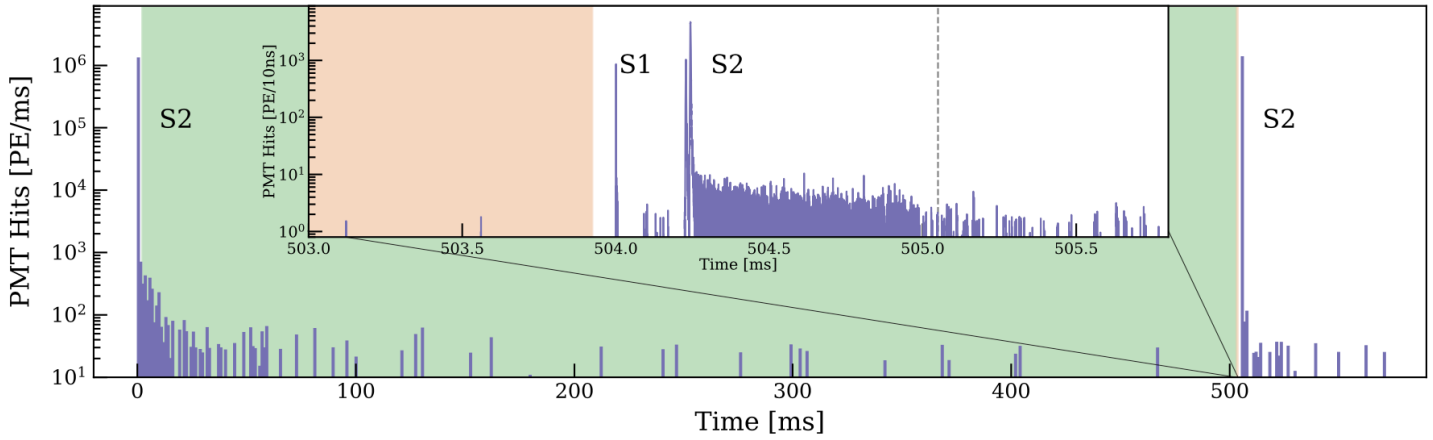


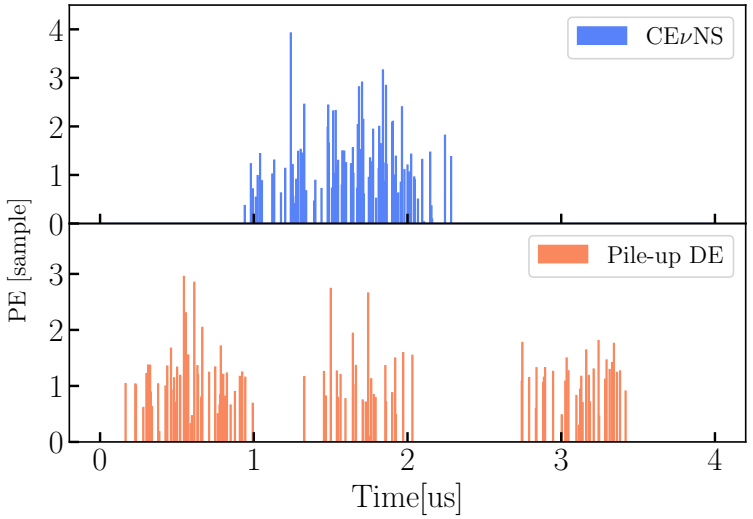


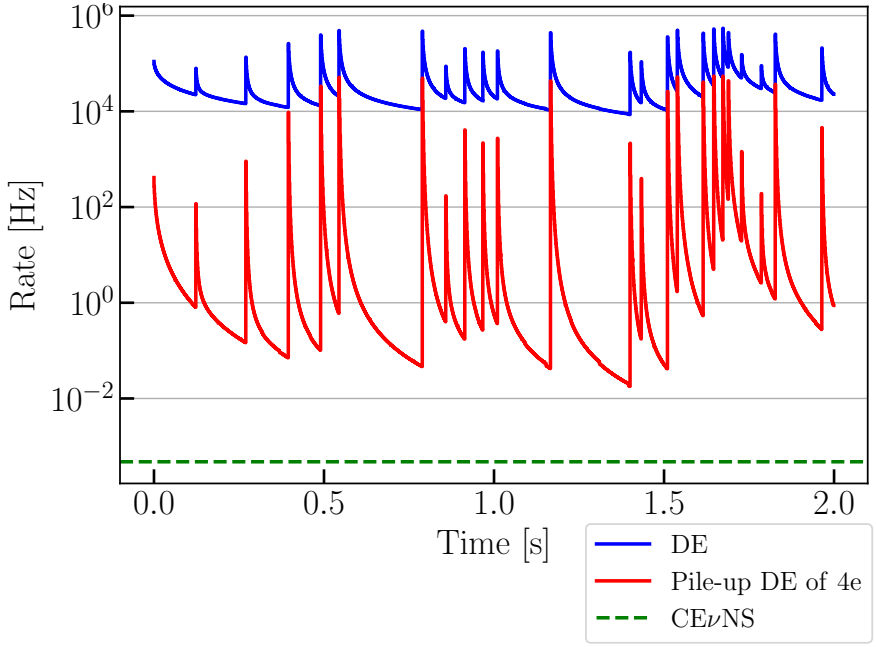
- NR本底预期事例率：$(7.7 \pm 0.7)\times10^{-2}\ kg^{-1}\cdot day^{-1}$ ([0.3,1]keV_{nr})
- ER本底预期事例率：$(310 \pm 10)\times10^{-3} kg^{-1}\cdot day^{-1}\cdot keV^{-1}$(WithoutS2 Width Cut rejection power of ~94%)

延迟电子本底 Delayed Electrons

Phys. Rev. D 106, 022001(2020)





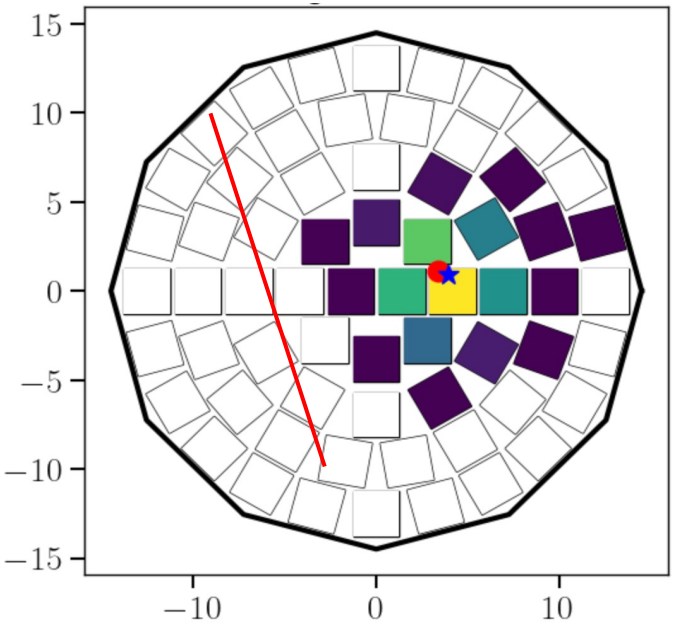


- 根据已有实验结果，延迟电子具有以下特征：
  - 位置相关，时间幂率衰减，延迟时间达到2s以上；
  - 延迟电子数量与液氙洁净度强相关，拉出点场弱相关；
  - O(10) Hz Muon 的S2后续延迟电子堆叠形成的伪多电子信号会成为RELICS主要本底；

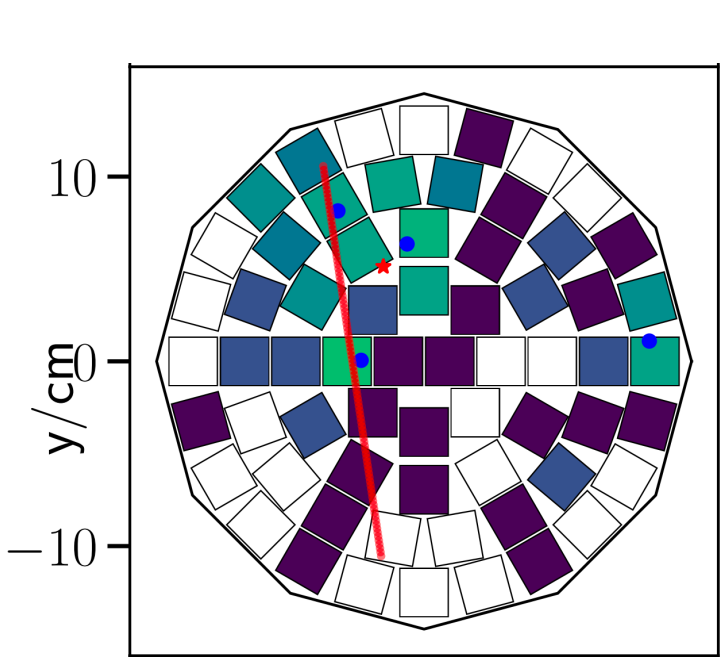
延迟电子本底

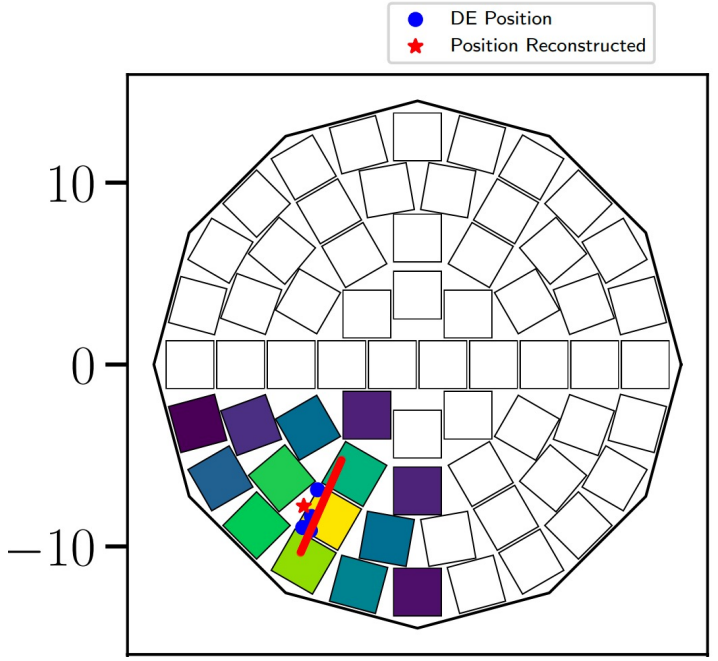
筛选：“S2光子分布”与“时空关联”

Pattern Coefficient VS Spacetime Correlation



CEvNS信号 S2光子分布





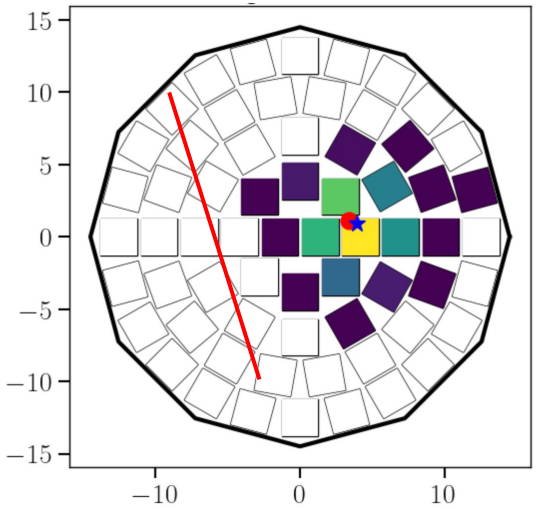
延迟电子堆叠信号S2光子分布

延迟电子本底

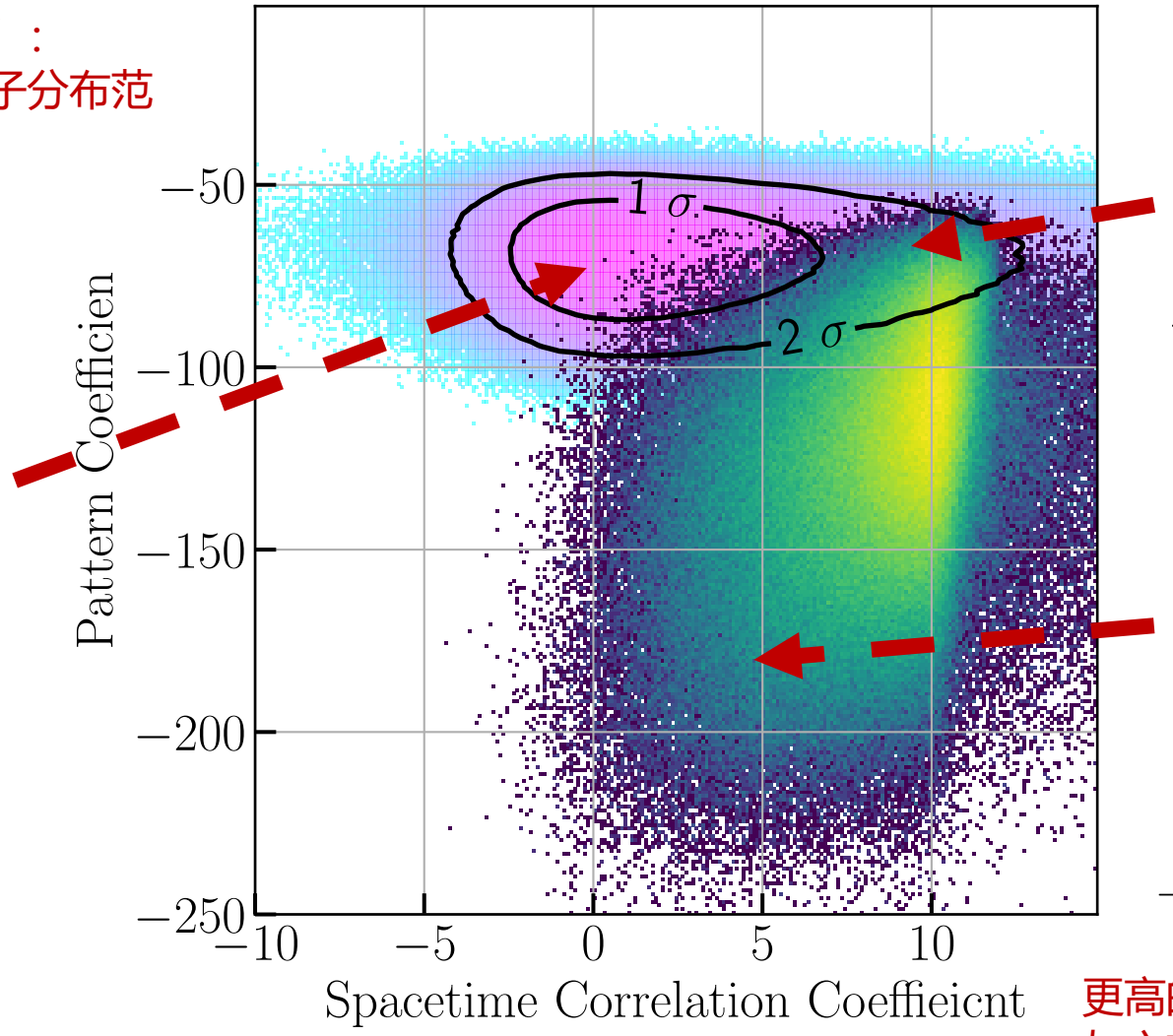
筛选：“S2光子分布”与“时空关联”

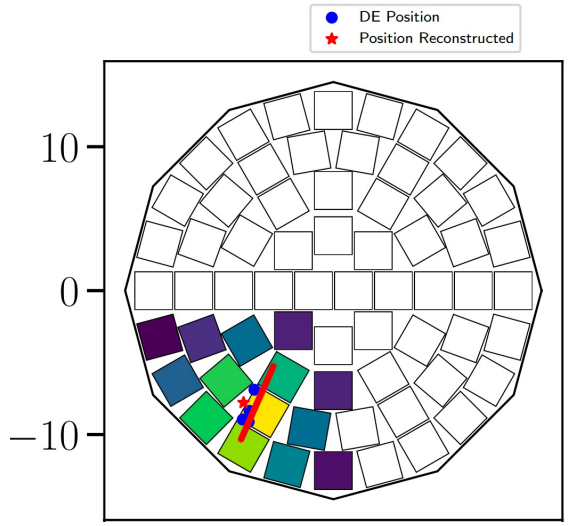
Pattern Coefficient VS Spacetime Correlation

更高的“光子分布”：
顶部PMT阵列的光子分布范式更类似单点事件

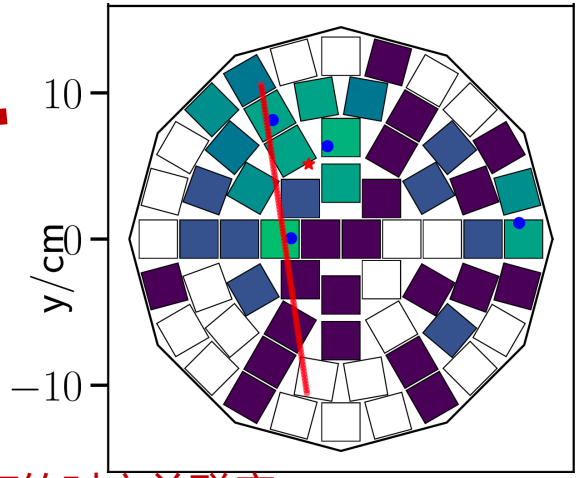


CEvNS信号 S2光子分布



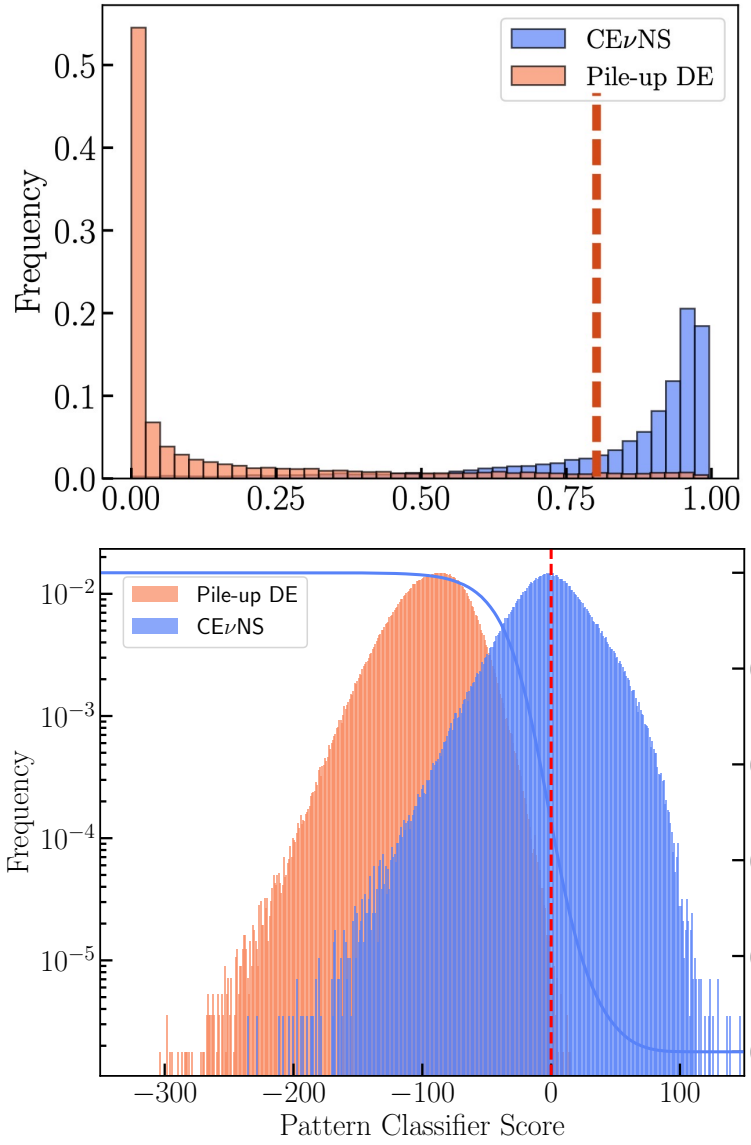


延迟电子堆叠信号S2光子分布

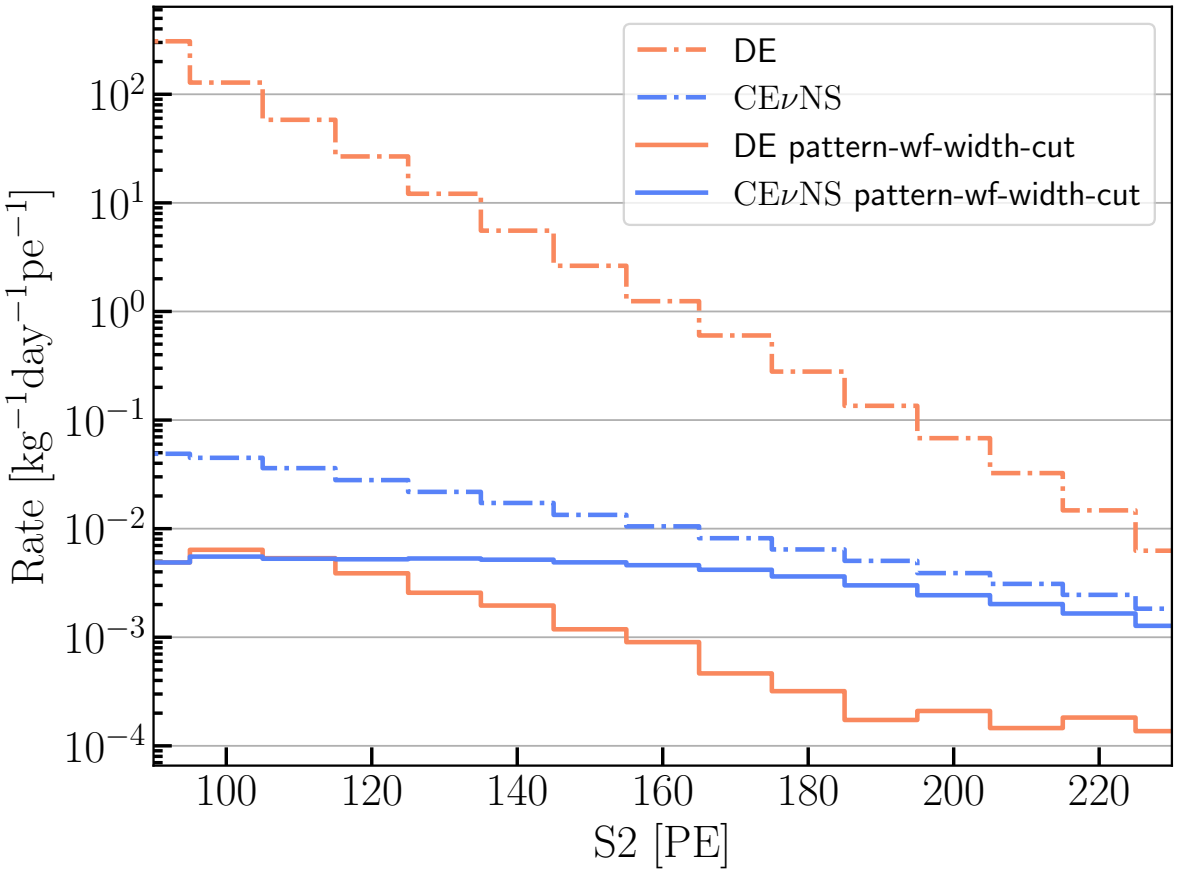


更高的时空关联度：
与之前的muon track更接近

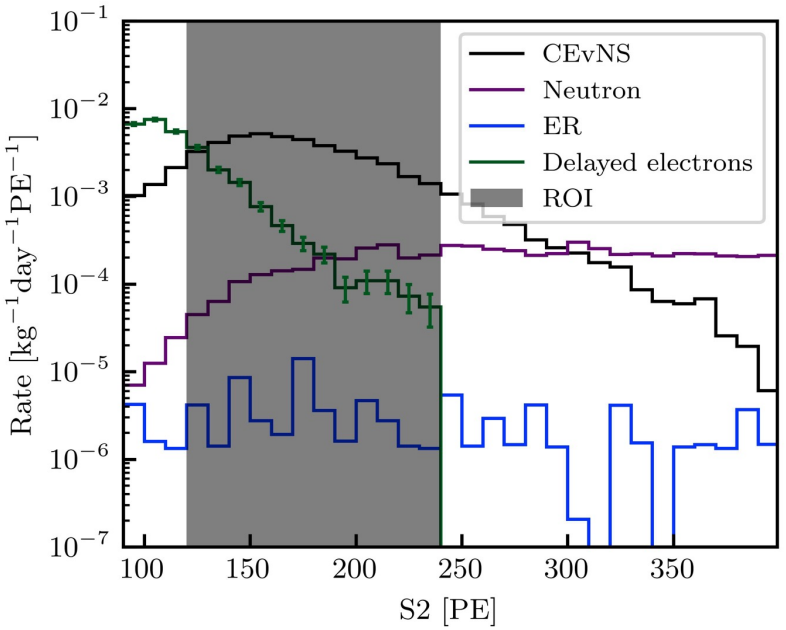
延迟电子本底

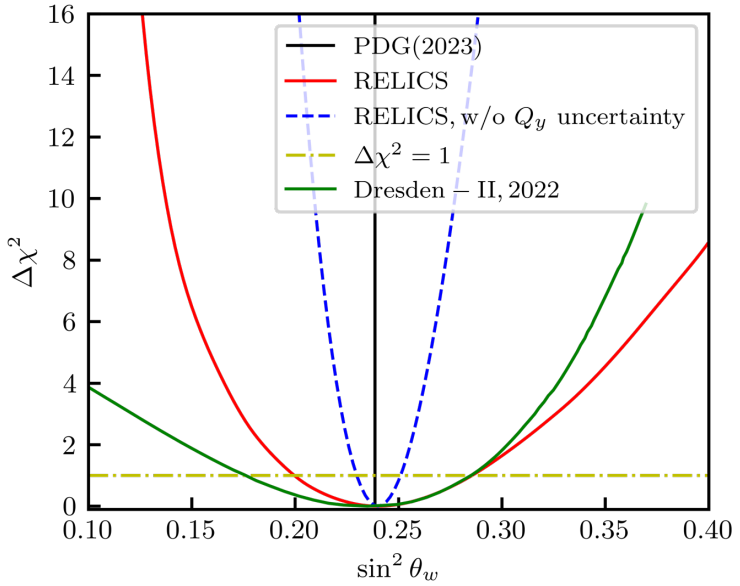


	Acceptance	Background remaining
波形鉴别Cut	~80%	~10%
“光子分布与时空关联” Cut	~52%	~ 1/1e4



实验本底与灵敏度分析





CEvNS 感兴趣能区: S2 [120, 240] PE

	Events/$(32kg \cdot year)$
CEvNS	4902.4
Cosmic Ray Neutron	229.4
Neutron Induced by Cosmic Muon	1.5
ER	5.7
DE Pile-ups	1081.9

High Energy Physics – Experiment

arXiv:2405.05554 (hep-ex)

[Submitted on 9 May 2024]

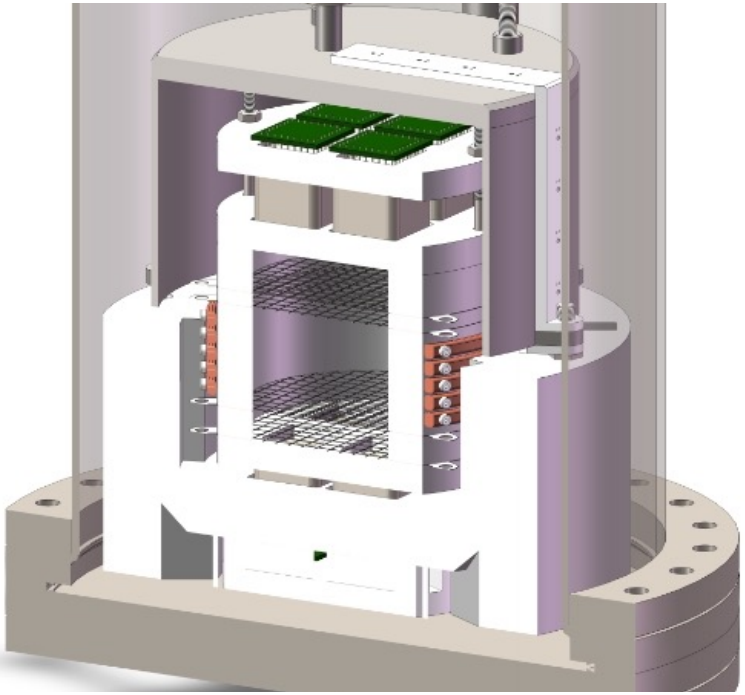
RELICS: a REactor neutrino LIquid xenon Coherent elastic Scattering experiment

Chang Cai, Guocai Chen, Jiangyu Chen, Fei Gao, Xiaoran Guo, Tingyi He, Chengjie Jia, Gaojun Jin, Yipin Jing, Gaojun Ju, Yang Lei, Jiayi Li, Kaihang Li, Meng Li, Minhua Li, Shengchao Li, Siyin Li, Tao Li, Qing Lin, Jiajun Liu, Minghao Liu, Sheng Lv, Guang Luo, Jian Ma, Chuanping Shen, Mingzhuo Song, Lijun Tong, Xiaoyu Wang, Wei Wang, Zihu Wang, Yuehuan Wei, Liming Weng, Xiang Xiao, Lingfeng Xie, Dacheng Xu, Jijun Yang, Litao Yang, Long Yang, Jingqiang Ye, Jiachen Yu, Qian Yue, Yuyong Yue, Bingwei Zhang, Shuhao Zhang, Yifei Zhao

RELICS开发进展报告

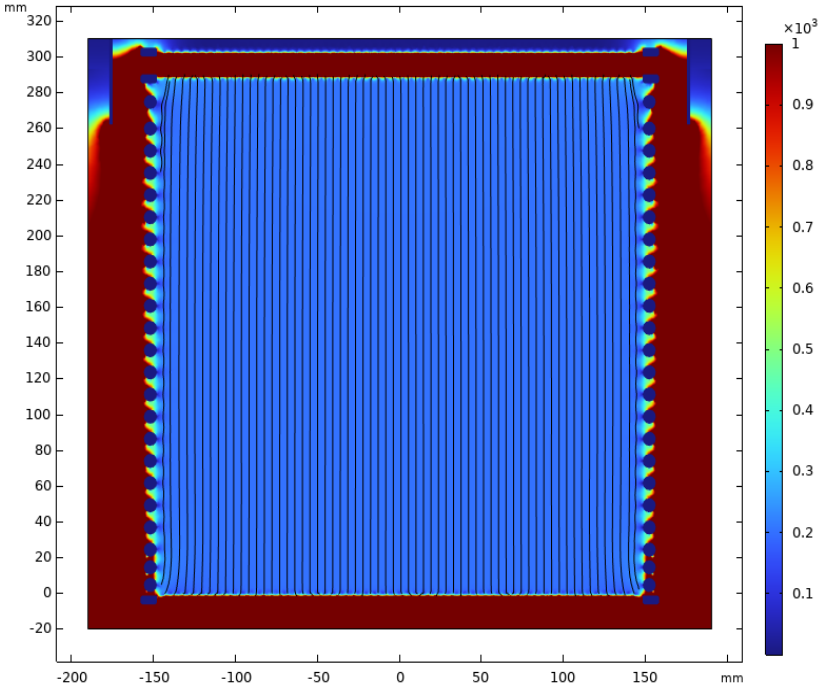
原型机建设

Poster：5-21



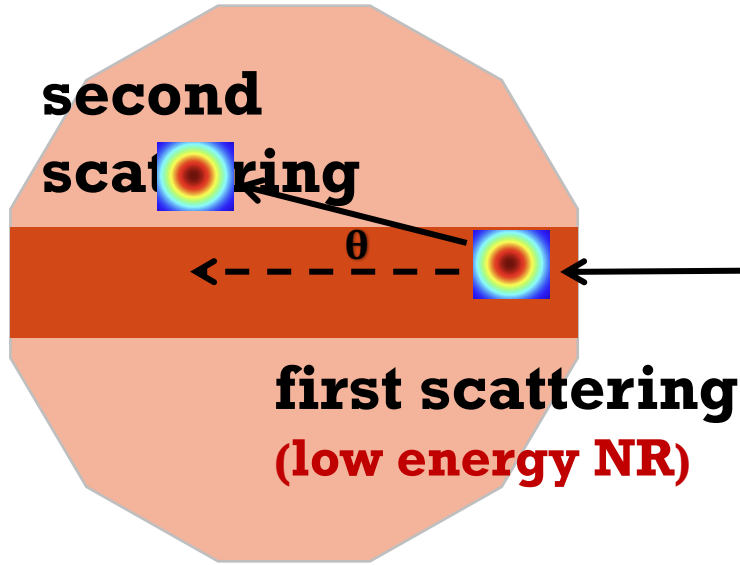
电场优化

Poster：4-06



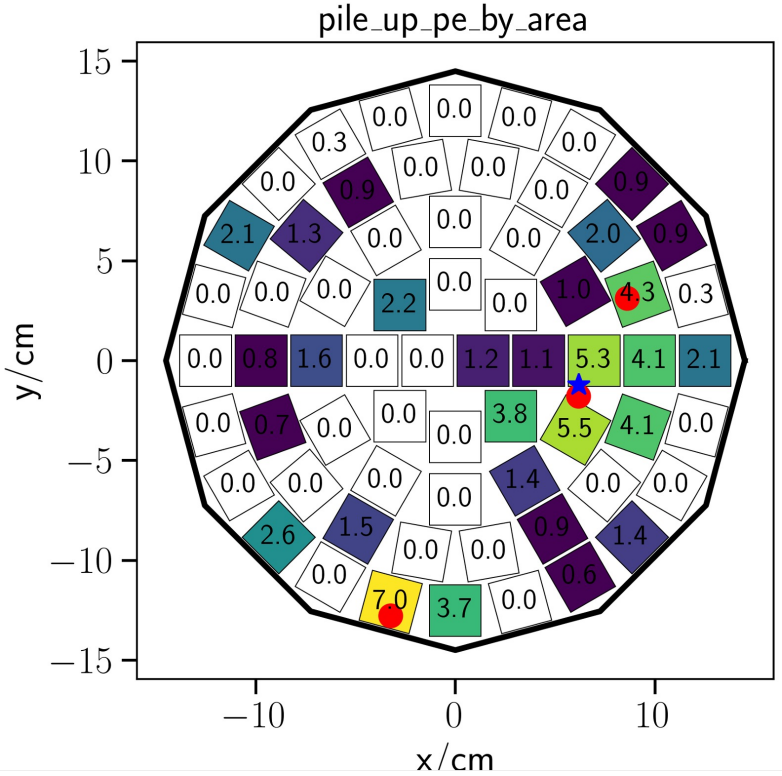
标定系统

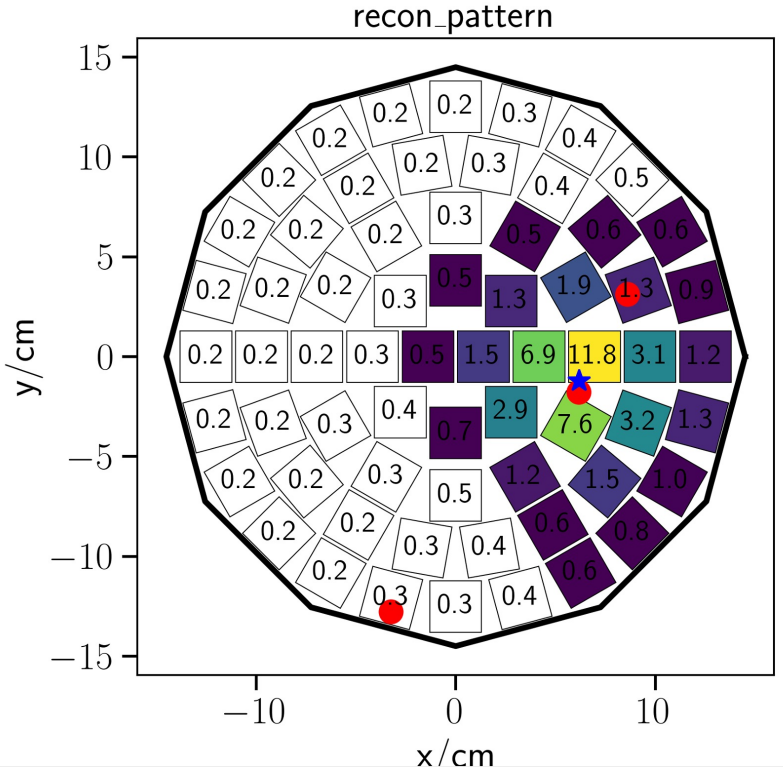
Flash Talk



Back Up

Pattern Coefficient Calculation:





$$P = \sum_{ch=0}^{63} \log\left(\frac{{\lambda_{ch}}^{N_{ch}^{pe}} \times e^{-\lambda_{ch}}}{N_{ch}^{pe}!}\right)$$

$$P_i = N_i \times (t - t_i)^{-\gamma} \times \frac{1}{2\pi \cdot \sigma^2} e^{-\frac{(x-x_i)^2+(y-y_i)^2}{2\sigma^2}}$$