卓越中心方向一

年度报告

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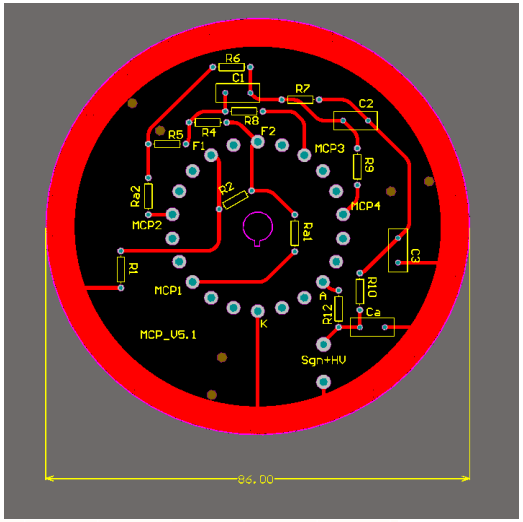
2017-12-02

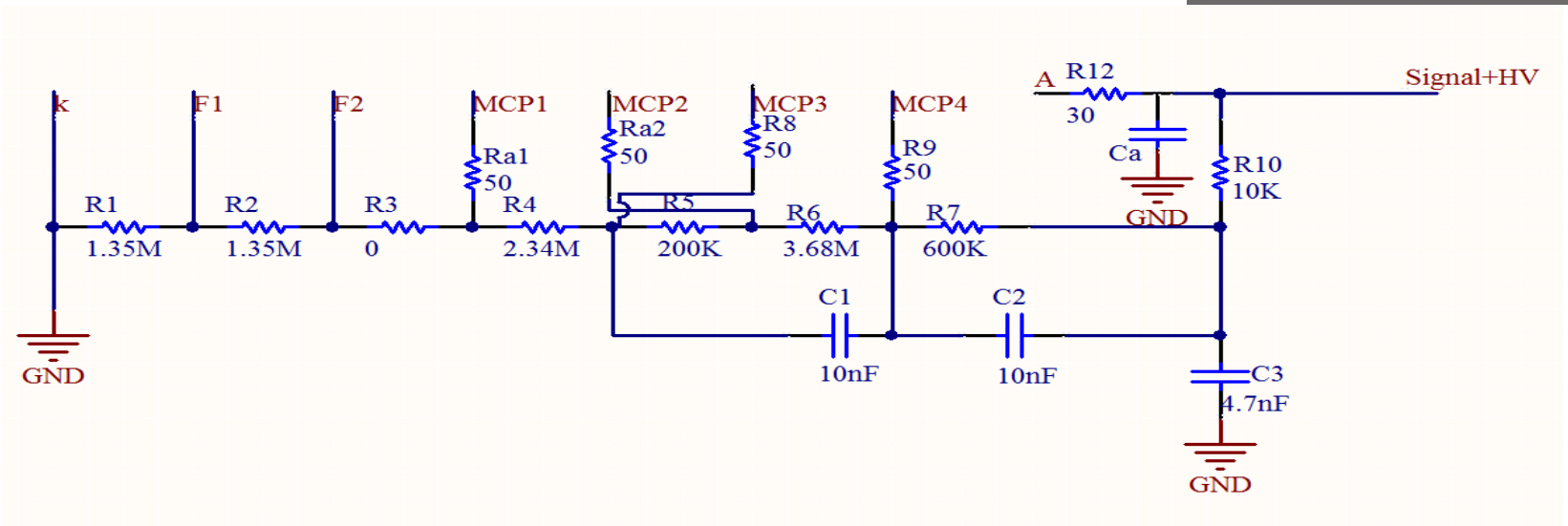
主要工作

- 江门中微子实验（JUNO）
  - 具体负责光电倍增管读出信号特征优化
  - 具体负责建设江门中微子实验中山泛亚20寸PMT测试与封装工作站 （JUNO L3）
  - 具体负责江门中微子实验20寸PMT验收测试工作（JUNO L3）

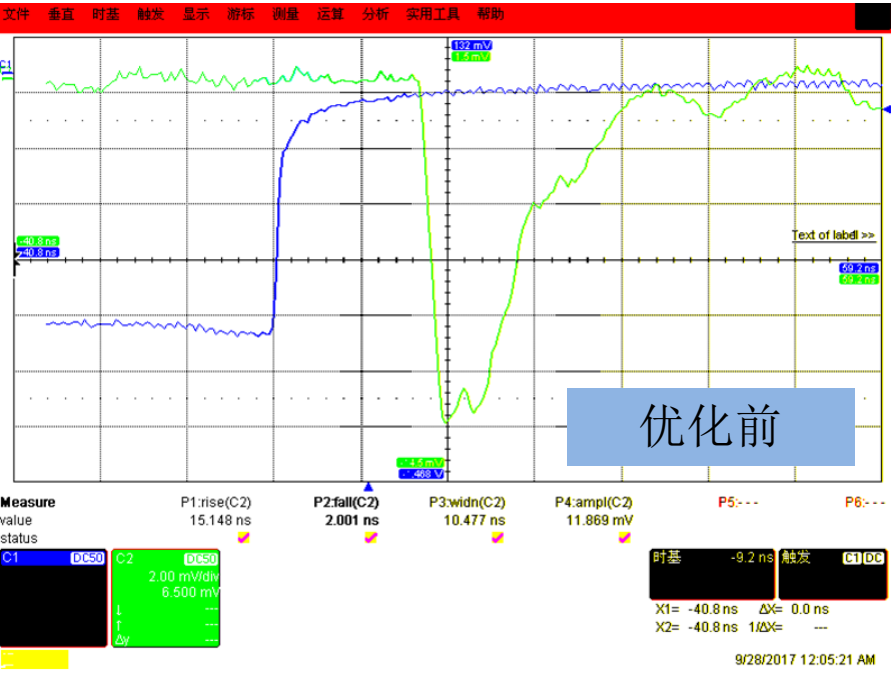
20” MCP PMT读出信号特征优化

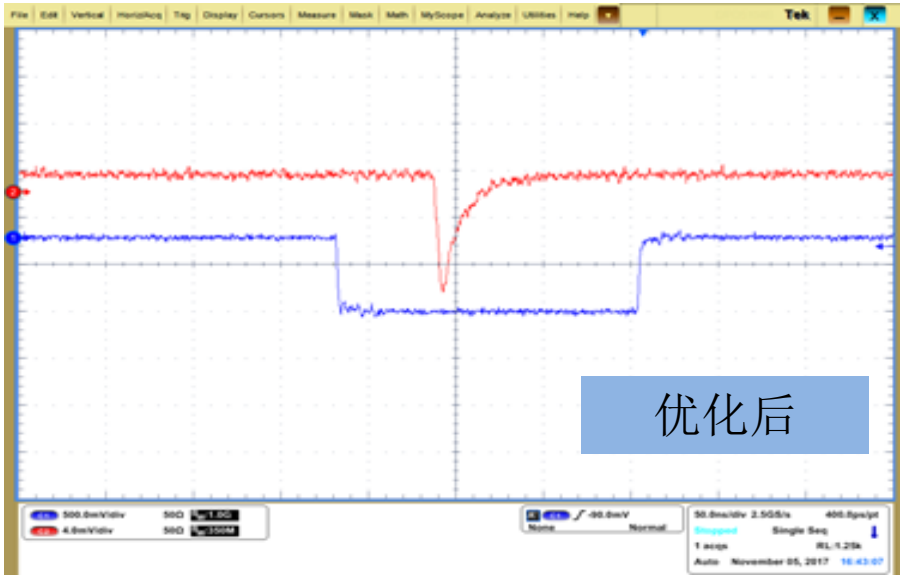
- JUNO 采用15000只 国产20英寸 MCP PMT， 5000只日本滨松PMT；
- 通过JUNO 合作组、MCP PMT合作组，NNVT厂家联合攻关测试，优化确定20” MCP PMT输出信号特征：信号前沿、后沿、信号幅度、振荡特性等；
- 理解、调整分压器各部分功能及PMT特性，完成多角度测试、验证；
- 最终实现20英寸MCP PMT信号平滑输出，达到预期目标，取得阶段性、关键性进展。





- 明确阻尼电阻作用
- 明确阳极阻、容作用
- 明确稳压电容与PMT信号特征关系
- 明确工作电流影响
- 明确信号特征要求
- 实现, SPE 信号特征优化
  - 信号前沿：~3ns
  - 信号后沿：~15ns
  - 幅度：7~8 mV
  - 信号平滑输出





- 这项工组涉及到JUNO项目组内不同的测试组、MCP PMT合作组、MCP PMT生产厂家等多方面的关系
- 涉及到不同测试方法、不同测试系统的差别，需要验证不同测试结果的差别，统一结果；

- 协调困难，历经波折

- 最终，通过协同攻关理解了20英寸MCP PMT的特性，优化了输出信号波形、完成了对信号特征及要求的全面理解，
  - 通过适当增大信号前沿上升时间、减小信号后沿下降时间，在保证信号信息不丢失的前提下，平滑输出信号波形，消除大、小信号过冲与振铃，达到电子学测量和物理分析对输出信号的要求；
  - 为MCP PMT使用及实现未来JUNO探测器的测量目标及最终物理目标打下良好基础。

Zhongshan Pan-Asia Station for PMT Test

用于20000只20英寸PMT存储、测试、封装

厂房设计要求
厂房存储空间布局、设计
厂房测试电学设计
厂房装修落实
厂房设备安装
厂房运行、安全管理规范

Internal videos

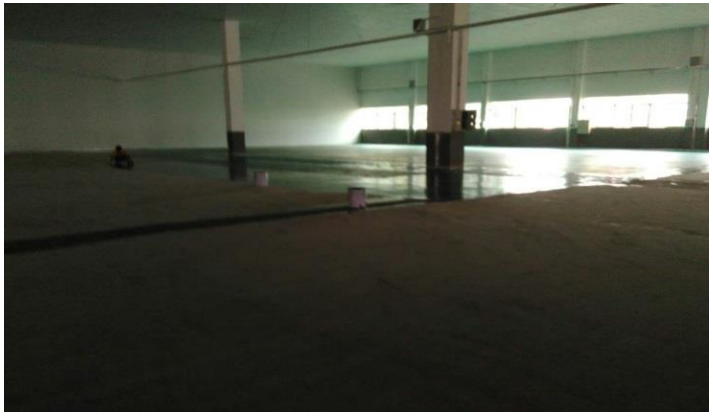


2017年3，4，5月





2017年3，4，5月




~4500平米厂房，温度23~26摄氏度，相对湿度40%~60%

1st PMT Receiving/storage

MCP-PMT



Hamamatsu




May 17th: 1st NNVT 20” MCP-PMT arriving at Pan-Asia, total 336 tubes in 28 packages

May 20th: 1st Hamamatsu 20” PMT arriving at Pan-Asia, total 160 tubes in 40 packages

JUNO Received tubes

@Pan-Asia station

- Totally 5936 tubes
  - MCP: 11 batches (3696tubes)
    - 1st: 336 tubes
    - 2nd:312 tubes
    - 3rd: 360 tubes
    - 4th: 336 tubes
    - 5th: 336 tubes
    - 6th: 336 tubes
    - 7th: 336 tubes
    - 8th: 336 tubes
    - 9th: 336 tubes
    - 10th,336 tubes: 2017-11-08
    - 11th,336 tubes: 2017-11-23
  - Hamamatsu: 10 batches (2240 tubes)
    - 1st: 160 tubes (batch #5)
    - 2nd: 320 tubes (batch #6)
    - 3rd: 800 tubes (batch #1~#4)
    - 4th: 160 tubes (batch #7)
    - 5th: 320 tubes (batch #8)
    - 6th: 320 tubes (batch #9)
    - 7th: 160 tubes (batch #10): 2017-11-29

Updated to 2017 Nov. 29th

具体组织2017年6月份测试现场厂房评估、国内合作单位测试值班讨论会

- 这项工作涉及到JUNO合作组国内、外多家合作单位的进度、人员的沟通与协调、包括生产厂家，在之前已有基础上
  - 需要尽快落实测试与存储厂房的准备，以保证20英寸PMT顺利接收、安全存储，
  - 实现测试设备尽快进场调试，建立测量和分析方法，尽快开始验收测试。
- 异地建设，长期出差；
- 常驻人员的管理、安全等多方面因素。

- 最终，在大家的配合与支持下，
  - 及时完成仓储厂房建设，
  - 测试设备到场，
  - 基本完成第一台套设备调试，实现8月~9月份试运行，9月开始正常测试；
  - 分析及改进工作同步进行，迎接合作组、PMT生产厂家的验收review, 确保作为JUNO探测器探测核心的PMT测试性能的真实、准确、可靠；

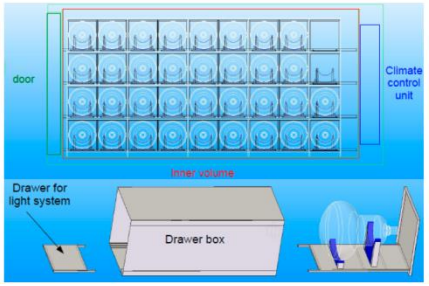
Parameters on Contract

Characteristics at 25 ℃

Serial No.	Item	Symbol	Tube Type	Min.	Typical	Max.	Unit
1	Gain	-			10^7	-	-
2	HV@10^7	Ebb	Hamamatsu	-	2000	2300	V
			MCP		2500	2800	
3	Detection Efficiency	DE	Hamamatsu	24.0	27.0	-	%
			MCP	24.4	27.1		
4	Quantum Efficiency	QE	Hamamatsu	27.0	30.3		%
			MCP	26. 5	28. 5		
5	Collection Efficiency	CE	Hamamatsu		95.6		%
			MCP	96	98		
6	Effective Area	-	Hamamatsu	(93)	490 (93)	-	mm (%)
			MCP	96	97		%
7	SPE P/V	P/V	Hamamatsu	2.5	3.0	-	-
			MCP	2. 8	3. 5		
8	Pre Pulse	PP	Hamamatsu	-	0.8	1.5	%
			MCP		0. 5	1	
9	After Pulse	AP	Hamamatsu	-	10	15	%
			MCP		1	2	
10	T.T.S. (FWHM)	TTS	Hamamatsu		2.7	3.5	ns
			MCP		12	15	
11	Rise Time	RT	Hamamatsu		5	7	ns
			MCP	-	1. 7	1. 7± 0. 2	
12	Fall Time	FT	Hamamatsu		9	12	ns
			MCP		12	12±2	
13	Dark Counts @ 0.25 PE 10^7 Gain，22 degree C	DC	Hamamatsu	-	10	50	k *s^{-1}
			MCP		20	30	
14	QE Uniformity (from tube axis)	in 70 degree	Hamamatsu	-	5	15	%
		in 80 degree	Hamamatsu	-	20	30	
			MCP		8	10	

JUNO 20” PMT Testing systems

- Using 1 GHz Waveform Sampling electronics
- Container System: 100% tubes
  - Gain, PDE, S/N, P/V, resolution, pre/after pulse, TTS, dark count….
- Scan station: ~5% of the tubes
  - Uniformity
  - Cross check



- ✓ Detection efficiency @ 420nm (av. 27%, > 24%)
- ✓ TTS of Single Photon Events (< 12ns)
- ✓ Rise time / fall time (< 8ns / < 16 ns)
- ✓ HV applied to reach gain of 10^7
- ✓ Dark Rate (< 50 kHz)
- ✓ P/V ratio (> 2.5)
- ✓ Pre- and after-pulse ratio (< 5% / < 10%)

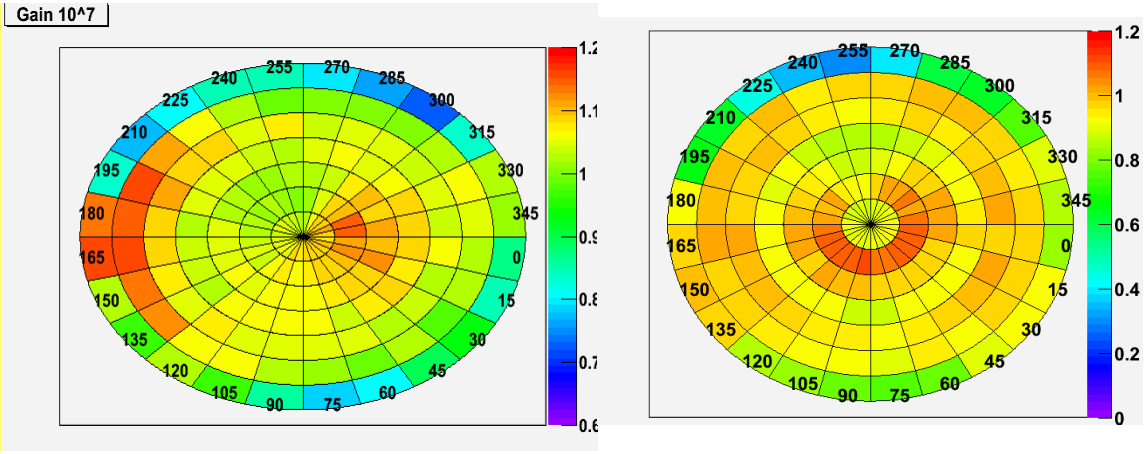
FADC with waveform sampling
w/o amplifier; 36 tubes per test

List of the Parameters	Min (max) requirements
Detection efficiency @420nm	27% in average, all >24% (???)
TTS of SPE (FWHM)	<15 ns
Rise time and fall time	<5ns, < 12ns
Gain	10^7 (???)
Non-linearity @10^7 gain	<10% (0 - 1000 ph.e)
Dark rate @ 0.25 SPE, 10^7 gain	<50kHz
Non-uniformity of PDE	<15% (???)
Pre-pulse ratio (80ns time windows) and after-pulse ratio (20μs time windows)	<1%, <10%
Geomagnetic field sensitivity	>1/10 EMF (???)

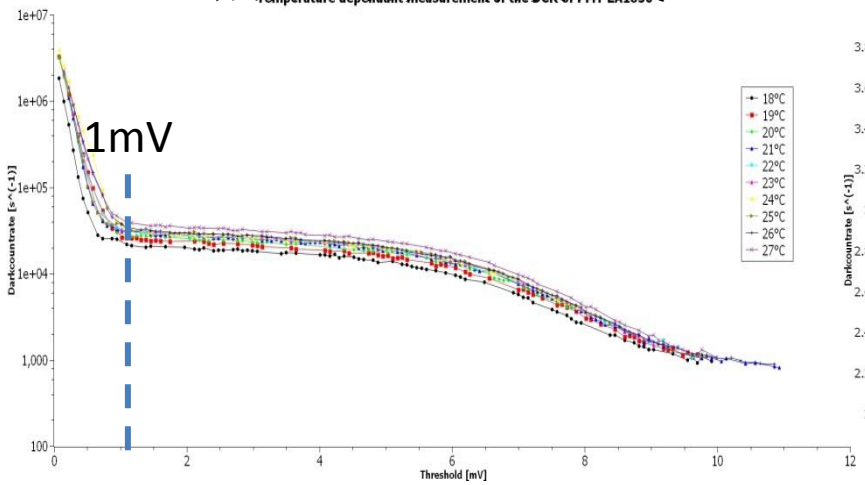
FADC with waveform sampling
w/ amplifier, 1 tube per test

Test facilities' commissioning

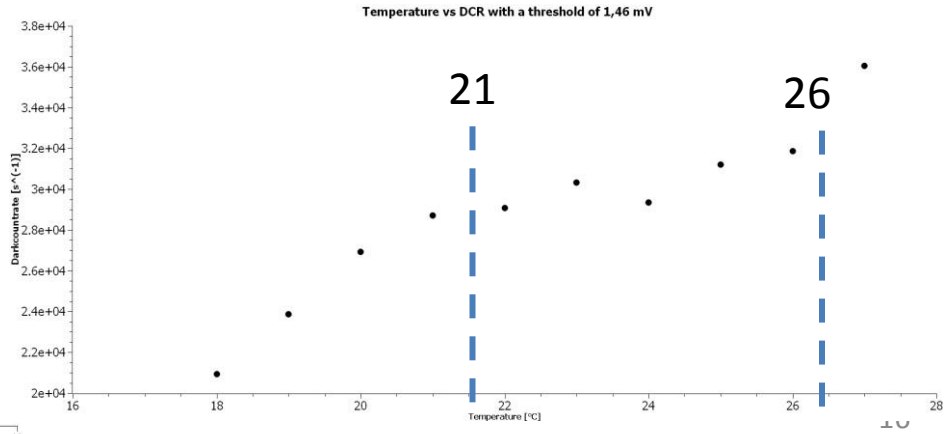
20" PMT 全面积增益及探测效率均匀性



暗噪声计数vs幅度曲线



暗噪声计数vs温度曲线



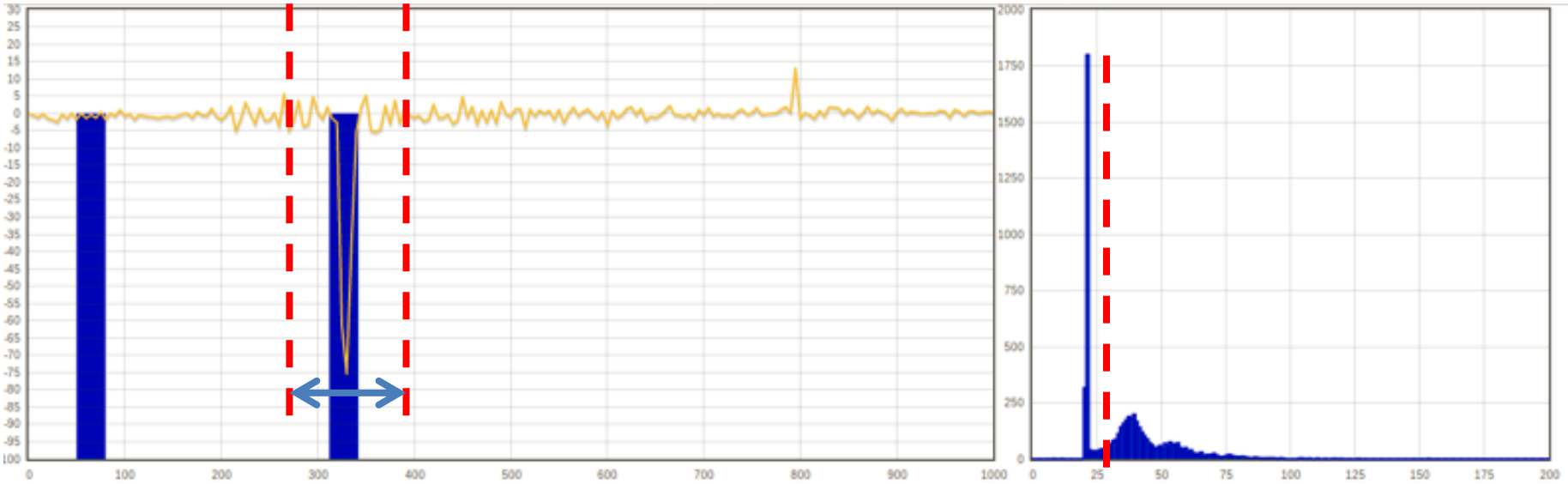
统一参数定义，明确分析过程

Waveform

Integration/baseline Window

Charge spectrum

Threshold/dark count/gain



- Stability/Repeat ability
- Consistency
- Uncertainty

Charge Integration window for both Hamamatsu & NNVT
Threshold in Charge for PDE
Threshold in amplitude for dark count (discriminator)
Threshold in amplitude for Pre/after pulse (data)

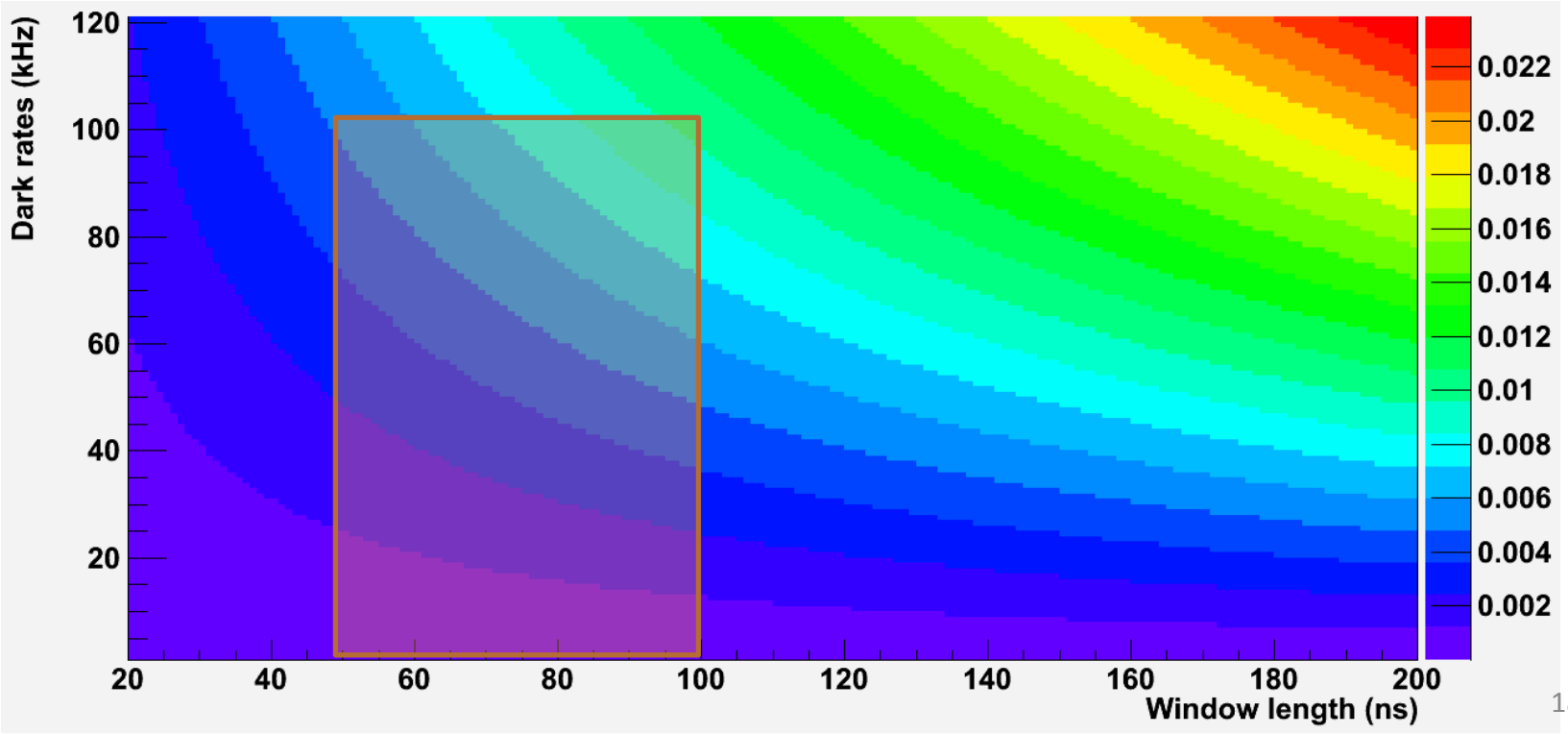
Hope to finalize all the things in this month, reach the agreement with both companies.

Training for the future JUNO analysis, understanding real detector performance further.

测试误差分析及验证

- Random coincidence Ratio of dark rates
  - Factor=1+ (darkCount*windowLength)*1/mu
  - If mu~0.7p.e.,
    - the effect range is +0.3%@20kHz@75ns

关键：实现相对效率测量误差~3% 的目标要求



探测效率验收

- One of the key parameter of JUNO 20” PMT acceptance test is the detection efficiency (DE), normally defined as QE X CE;
  - Absolute calibration/understanding for still working in process to reach the required uncertainty ~1%
  - Relative to reference tube and known detector performance and trying to understand this further
    - The current tubes in hands or used
      - 1。滨松2英寸： R7725-100 ➔ HZC used
      - 2。滨松3英寸： R12199 ➔ absolute DE calibration
      - 3。滨松1英寸： R1355 ➔ JUNO scan station used
      - 4。南京NNVT： 20寸
      - 5。展创3英寸； XP72B22 ➔ DE study
      - 6。滨松8英寸： R5912-100， R5912 ➔ Dayabay used
      - 7。滨松20英寸：R12860-50 ➔ Hamamatsu/NNVT used
- 该工作是JUNO 20英寸PMT验收的关键指标之一，预期2周内完成相关工作；
- 该问题的准确理解，对预期未来JUNO物理测量具有关键意义。

文章与国际会议报告情况

- ***The Detector System of The Daya Bay Reactor Neutrino Experiment***, Daya Bay Collaboration (F P. An et al.), Nucl. Instrum .Meth. A811, (2016) 133–161 DOI:10.1016/j.nima.2015.11.144
- ***Measurement of the Reactor Antineutrino Flux and Spectrum at Daya Bay***, Daya Bay Collaboration (F P. An et al.), Phys. Rev. Lett. 116, (2016) 061801 DOI:10.1103/PhysRevLett.116.061801
- ***New measurement of ϑ13 via neutron capture on hydrogen at Daya Bay***, Daya Bay Collaboration (F. P. An et al.), Phys.Rev. D93 (2016) 072011 DOI
- ***Improved Search for a Light Sterile Neutrino with the Full Configuration of the Daya Bay Experiment***, Daya Bay Collaboration (F. P. An et al.), arXiv:1607.01174 ,Phys. Rev. Lett. 117, 151802)
- ***Limits on Active to Sterile Neutrino Oscillations from Disappearance Searches in the MINOS, Daya Bay, and Bugey-3 Experiments***, Daya Bay and MINOS Collaborations (P. Adamson et al.), arXiv:1607.01177 , Phys. Rev. Lett. 117, 151801
- ***Improved Measurement of the Reactor Antineutrino Flux and Spectrum at Daya Bay***, Daya Bay Collaboration (F.P. An et al.), arXiv:1607.05378 , submitted to Chinese Physics C
- ***Study of the wave packet treatment of neutrino oscillation at Daya Bay***, Daya Bay Collaboration (F.P. An et al.), arXiv:1608.01661 , submitted to Physics Letters B
- ***Measurement of electron antineutrino oscillation based on 1230 days of operation of the Daya Bay experiment***, Daya Bay Collaboration (F.P. An et al.)arXiv:1610.04802 , submitted to Physical Review D
- JUNO collaboration 1 paper
- Conference paper 2

Thanks