2024 年终考核

探测器二组
胡 涛

2024,11,21

岗位职责

- ✓ JUNO液闪研制 (L2)

JUNO液闪研制

长衰减长度，低放射性本底

液闪质量直接决定实验的成败

Requirements for LS:

High light yield: ～1200 p.e./MeV

Long attenuation length: >20m

Low radio-impurity: $^{238}U/\ ^{232}Th<10^{-15}g/g$, $10^{-17}g/g$ $^{40}K<10^{-16}g/g$

LAB + 2.5 g/L PPO + 3 mg/L BisMSB

The most important thing is the purification of LAB/LS

	KamLAND	Borexino	Daya Bay	JUNO
LS mass	~1000 t	~300 t	~170t	20000t
Energy Resolution	6%/√E	5%/√E	7.5%/√E	3%/√E
Light yield	250 p.e./MeV	500p.e./MeV	200p.e./MeV	1200 p.e./MeV

JUNO研制了5+2套纯化设备

- ✓ Al_2O_3 column plant is based on the "absorption" technique to remove optical impurities and increase the A.L. of LAB
- ● Distillation plant is to remove heavy metal of LAB
- ✓ PPO master solution acid/water wash
- ✓ Water Extraction is to remove ^{238}U, ^{232}Th and ^{40}K .
- ● Gas Stripping plant remove the impurities : Ar, Kr and Rn.

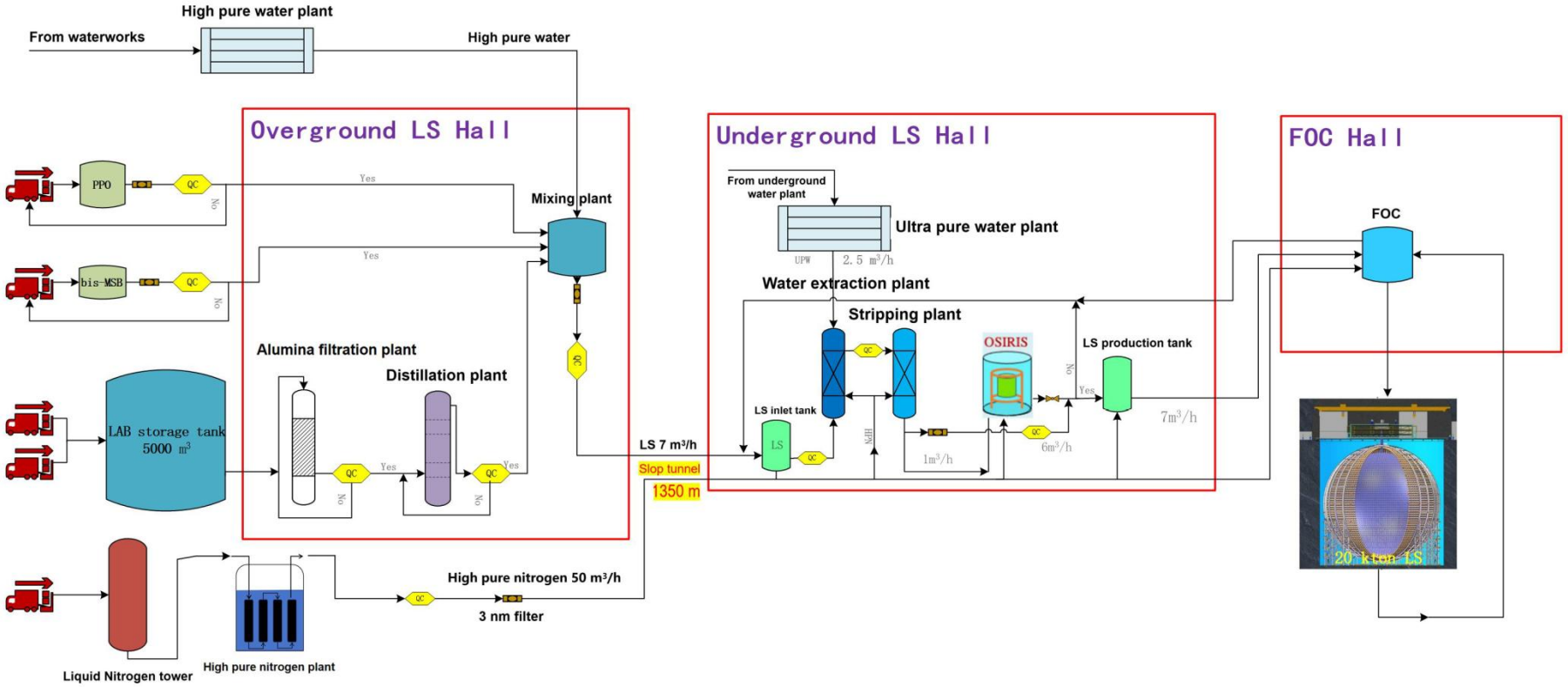
Optical and radioactive purification

- ✓ Ultra Purity Water (U/Th, Rn)
- ✓ High purity N2 (Rn)

其中 标注✓ 的5套设备由中方液闪组负责

LS Mass Production flow chart

- 20kton LS will be purified by purification plants
- Filling time ~6months @ flow rate 7000 l/h



✓ 所有设备均完成了在JUNO现场安装及调试运行

QA/QC method

- Optical transparency
  - ✓ absorption spectrum (UV-Vis)
  - ✓ attenuation length measurement

- Radon
  - ✓ Si detector
  - ✓ Enrichment system
  - ➢ Rn/O_2 in LS

研制了多套设备
用于质量检测

- U/Th
  - ✓ HPGe
  - ✓ Particle counting
  - ✓ ICP-MS （NAA by Italia）
  - ➢ OSIRIS　已开始运行取数，调试中……

原料准备

- ✓ 20000吨LAB合同已签订，保证高质量的LAB的定制生产、灌装
  - ➢ 5000立方的LAB存储罐已建成
  - ➢ 运输合同已签（200个定制全新的20吨iso tank）
  - ➢ 已全流程用 5 iso tank 运输200吨LAB到现场
- ✓ 所有PPO已完成生产，U/Th<0.1ppt
- ✓ 所有bisMSB已完成生产，U/Th<3ppt
- ✓ 为保证液闪30年以上寿命，新增 50ppm BHT
  合同在走程序，样品已达标

Successful Joint Commissioning

✓ 提前一年多开始了联合调试运行

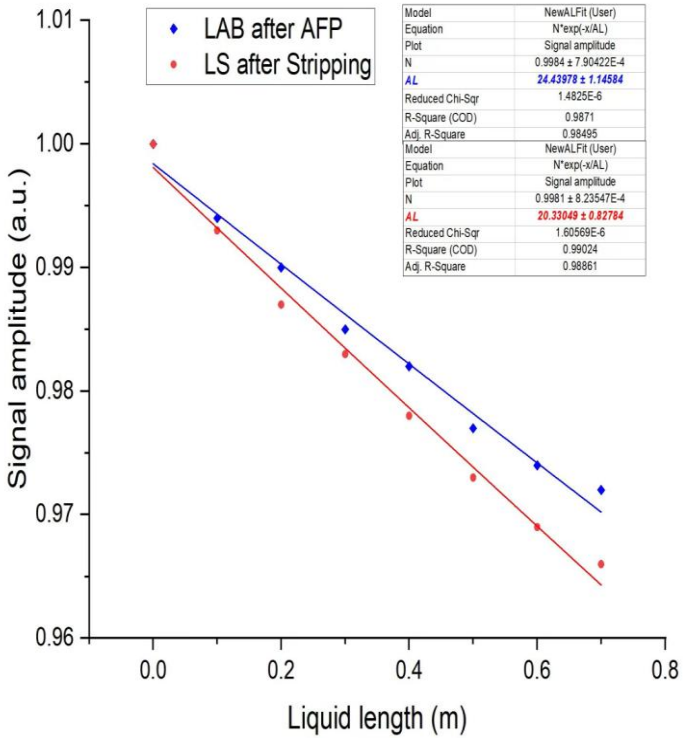
- 1st : 2023, 3-5月
  AFP+Distillation+Mixing(LAB+PPO)+Stripping
- 2nd : 2023, 10-11
  AFP+Distillation+Mixing(LAB+PPO+BisMSB)+Water Extraction+Stripping

✓ @7m³/h

✓ 成品液闪质量

✓ 衰减长度　20.3米

➢ 蒸汽剥离 → 氮气剥离



3rd Joint Commissioning

March , 2024

1. W.E. can running at high temperature
   - Water Extraction plant
   - Stripping plant

   + Ultra Pure Water plant

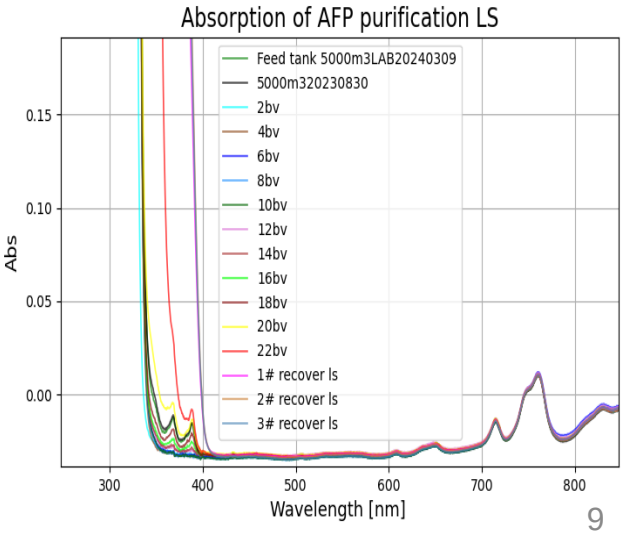
   water can be controlled at 20ppm level

2. waste LS can be reused
   - Alumina Filtration plant (AFP)
   - Distillation plant

AFP can remove PPO until 20 BV

Distillation can remove some PPO though not all

W.E. Temp.	after W.E.	After Stripping
18° C	112ppm	18ppm
30° C	123ppm	20ppm, 90° C
40° C	155ppm	89ppm, 70° C
50° C	140ppm	26ppm, 70° C more N_2
60° C	154ppm	21ppm, 70° C more N_2



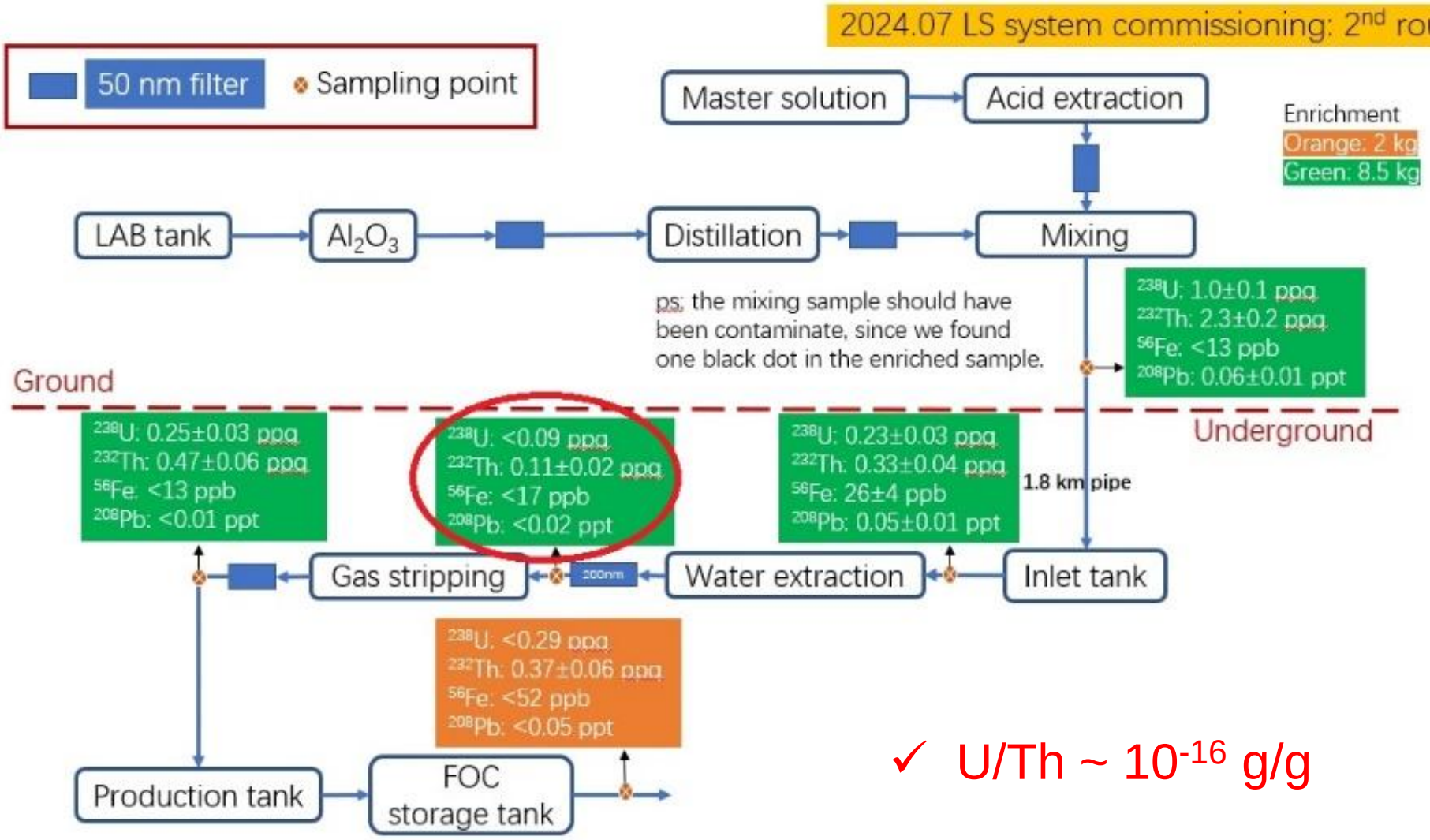
4th Joint Commissioning

July , 2024 all LS purification plants

- Alumina Filtration plant
- Distillation plant
- LS mixing with acid/water wash
- Water Extraction plant
- Stripping plant
- Ultra Purity Water plant
- High purity N2 plant

- 1^{st} batch LS ($26m^3$) was filled into OSIRIS
- 2^{nd} batch LS ($45m^3$) was filled into FOC

LS screened by ICPMS

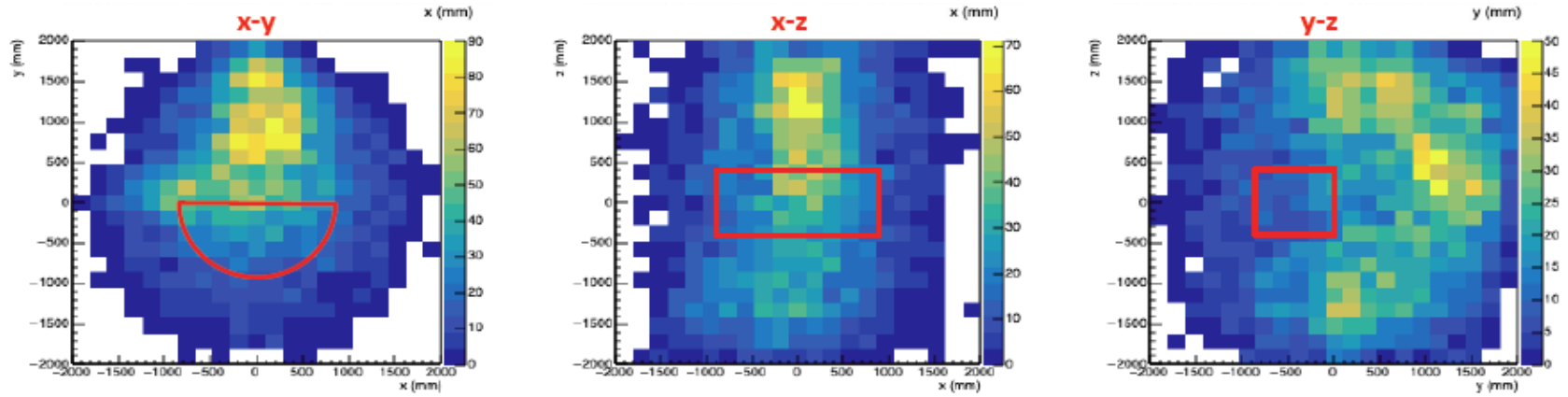


✓ U/Th ~ 10^{-16} g/g

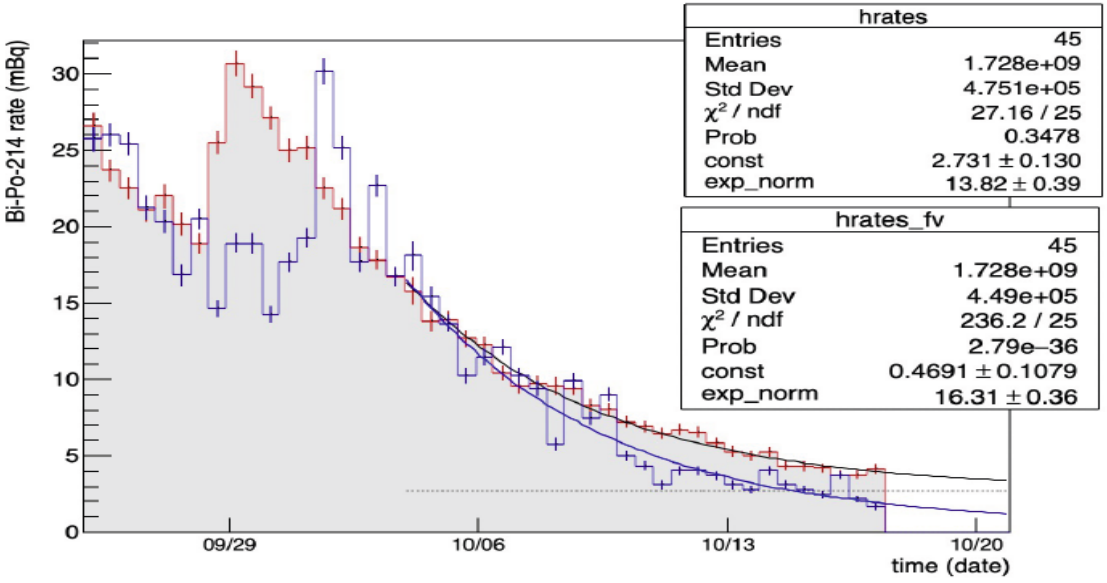
Results by OSIRIS

- Rn < 1 mBq/m^3 , U/Th < 1.5 x10-15 g/g

Bi-214 (2nd plateau)



Current Data: BiPo-214 rates total/inside FV



hrates	
Entries	45
Mean	1.728e+09
Std Dev	4.751e+05
χ^2 / ndf	27.16 / 25
Prob	0.3478
const	2.731 ± 0.130
exp_norm	13.82 ± 0.39

hrates_fv	
Entries	45
Mean	1.728e+09
Std Dev	4.49e+05
χ^2 / ndf	236.2 / 25
Prob	2.79e−36
const	0.4691 ± 0.1079
exp_norm	16.31 ± 0.36

- **overall** rate of 2.7 mBq in 20m^3 roughly corresponds to 10^{-14} g/g U
- **Fiducial Volume** definition:
  - rho < 100cm → no AV walls
  - |z| < 50 cm → center layer
  - y < 0 → no thermorod
- Total volume: 1.6m^3
- Based on rad source calibration, volume under-estimated: 2.4m^3
- constant term ca. 1.5x10^{-15} g/g U!

5th Joint Commissioning

Nov, 2024 all LS purification plants

- Alumina Filtration plant
- Distillation plant
- LS mixing with acid/water wash
- Water Extraction plant
- Stripping plant
- Ultra Purity Water plant
- High purity N2 plant

- 1^{st} batch LS ($30m^3$) was filled into repaired OSIRIS
- 2^{nd} batch LS ($25m^3$) is stored for later test

文章及经费

- 液闪组文章（4+1） （不含JUNO、BES合作组文章）

1、Detector upgrade for 222Rn concentration in high purity nitrogen measurement
JINST 19 (2024) 10, P10004

2、 Determination of Henry's law coefficient of oxygen in LAB for JUNO，
JINST 19 (2024) 03, P03011

3 、 JUNO high purity nitrogen plant
Appl.Radiat.Isot. 208 (2024) 111305

4 、 Study of the concentrations of Kr and Ar in high-purity nitrogen of JUNO
Radiat.Detect.Technol.Methods 8 (2024) 3, 1359-1365

5 、 A practical approach of measuring 238U and 232Th in liquid scintillator to sub-ppq level using ICP-MS
Submitted to NIMA

- 经费

JUNO液闪研制（L2） 3.2亿

学术交流

- 组织每周一下午的液闪组会
- 组织JUNO合作组会液闪分会

其它/公共服务

- 作为LIM（现场安装经理）协调JUNO现场安装

  4(5) 人轮流值班：本人3个月

- 学生培养

  ✓ 中国科学院大学核心课程 “粒子探测技术”首席

- 参加了所里组织的研究生中期考核（博士组）

- 参加了实验员、科研助理招聘的面试

存在问题（困难与挑战）

- 在江门现场建一个小化工厂
- 化工的规模/半导体级的要求
- 密封/焊接/洁净 （设计、制造、运行）

- 要求（灵敏度）极高，实验室质量监测难

- 任务重，既包含纯化设备，还包括质检设备

- 液闪灌装期间，长时间高质量稳定运行的保证

总结及下一步计划

- ✓ 液闪生产及纯化各系统都已完成在现场安装，并提前进行了五轮联合调试
  - ➢ 氧化铝、液闪混制、水萃取 （蒸馏、气体剥离）
    ＋ 高纯氮、高纯水/超纯水、导热油炉、冷却系统
  - ➢ 系统运行稳定，达到预期指标

- ➢ 在联调基础上各系统优化改进
- ➢ 明年2月开始正式液闪灌装，预计6个月完成JUNO探测器的建造，开始物理取数

谢谢！