SFB 1258 Neutrinos Dark Matter Messengers

First Liquid Scintillator Purification Tests in Daya Bay

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Requirements for the Juno Scintillator

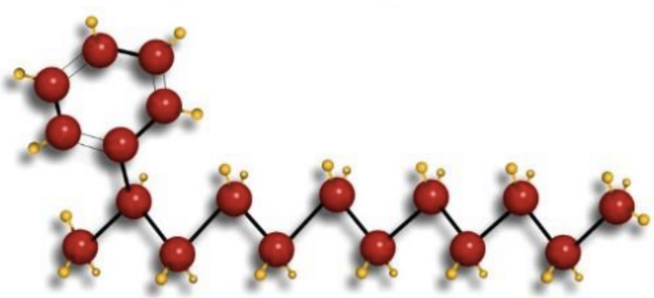
- <u>Optical properties:</u>
  - High light output: 1200 p.e. / MeV
  - High attenuation length: > 20 m @ 430 nm

- <u>Radiopurity:</u>
  - Reactor neutrinos: ^{238}U / $^{232}Th < 10^{-15}$ g/g , $^{40}K < 10^{-16}$ g/g
  - Solar neutrinos: ^{238}U / $^{232}Th < 10^{-17}$ g/g , $^{40}K < 10^{-18}$ g/g , $^{14}C < 10^{-18}$ g/g

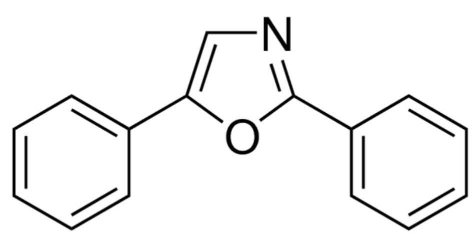
Preliminary Recipe (based on DYB experience)

LAB + 3g/L PPO + 15 mg/L bis-MSB

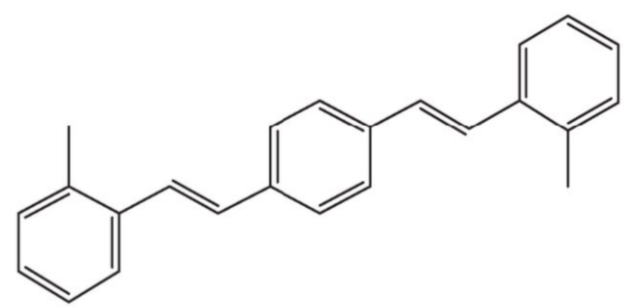
LAB
linear alkylbenzene



PPO
2,5-diphenyloxazole



bis-MSB
p-bis-(o-methylstyryl)-benzene

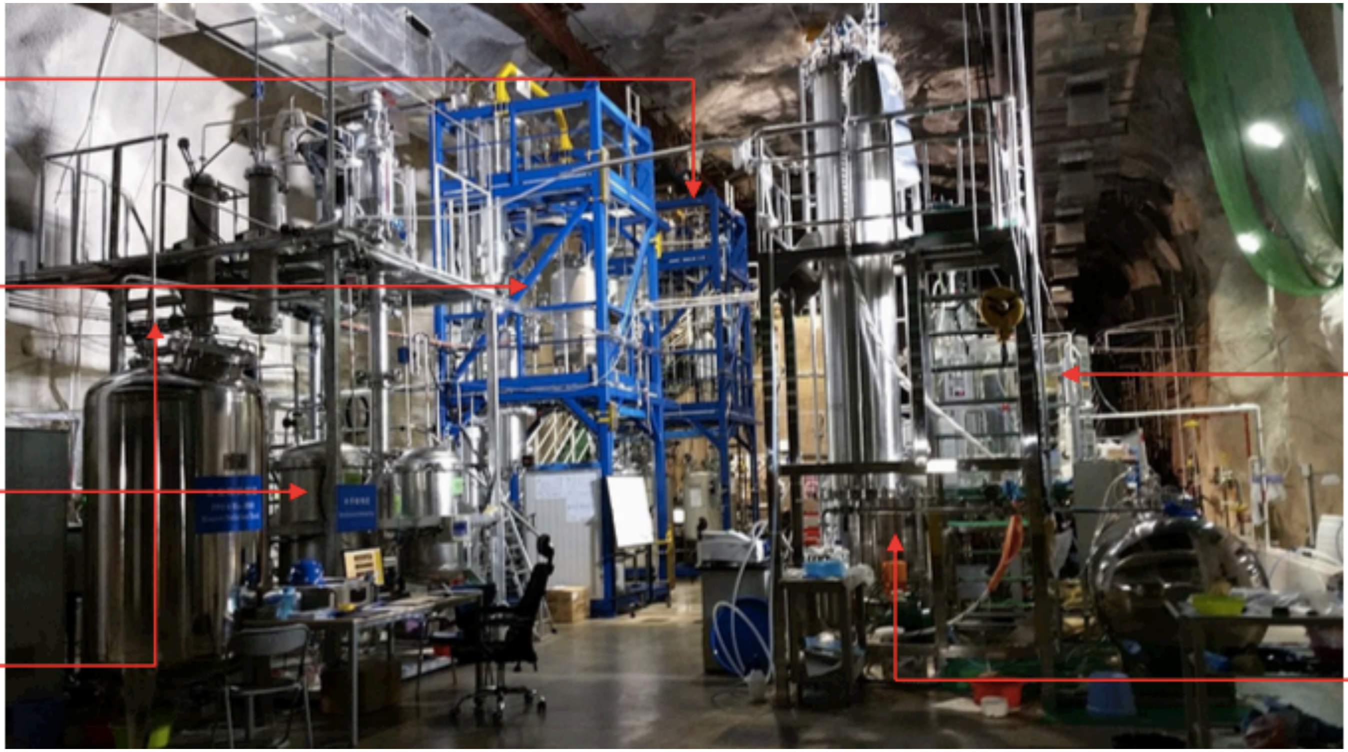


e^- → Solvent → First Fluorescence → Second Fluorescence

Initial energy deposit ***non – radiative energy transfer*** ***radiative energy transfer***

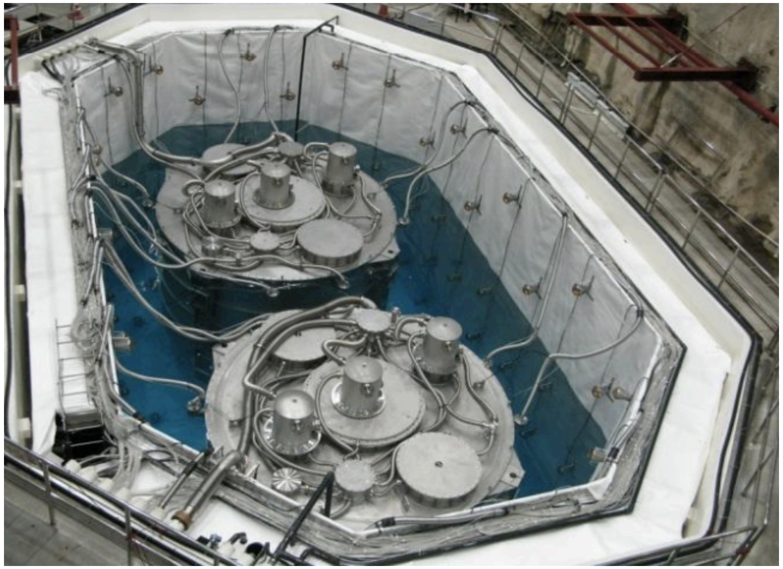
Purification Methods and Pilot Plants in Daya Bay

- Al_2O_3 filtration column: improvement of optical properties (China)
- Distillation: removement of heavy metals, improvement of transparence (INFN, Polaris, TUM, Mainz, …)
- Water Extraction: removement of radio isotopes from uranium and thorium chain and furthermore of ^{40}K (China)
- Steam / Nitrogen Stripping: removement of gaseous impurities like Ar, Kr and Rn (INFN, Polaris, TUM, Mainz, …)

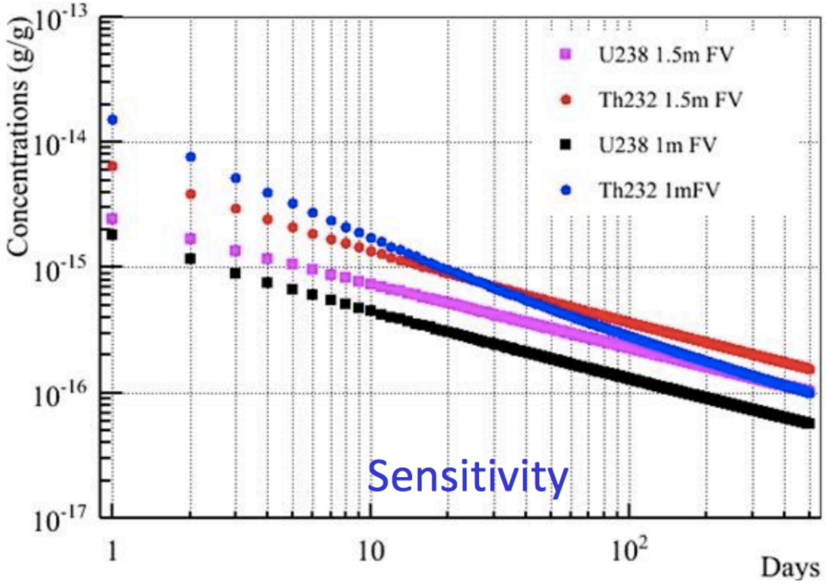


Measurement of the LS radiopurity and light yield in AD-1

- Measurement of radio impurities of the scintillator requires a sensitive detector
    - 20t Daya Bay AD-1 detector can reach the needed sensitivity (fiducial volume cut)

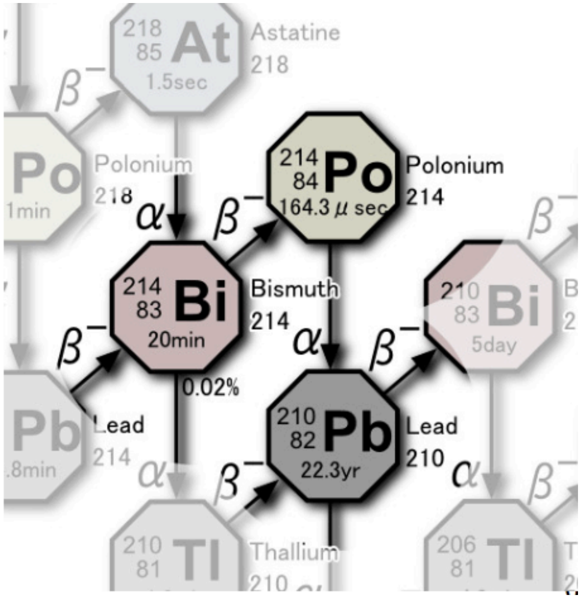


Xilei Sun, Daya Bay Collaboration, 2017



- 24 m^3 of LS were produced and filled into AD-1 within three weeks in February/March 2017
- Pilot Plants were operated in three eight hours shift by three shifters 24h a day
- Production speed of the plants 85 - 100 liters / hour
- Continous data taking with AD-1 during the filling and in the weeks after the tests

^{238}U / ^{222}Rn Analysis



^{214}Bi:
$T_{1/2}$ = 20min
Radiation: β / γ (end point: 3270keV)

^{214}Po:
$T_{1/2}$ = 164.3μs,
Radiation: α (Energy: 7689.82keV → quenched)

This allows cutting on this coincidence to subpress backgrounds.

Search for events with a time difference of less than 500 μs!

<u>Further cuts:</u>

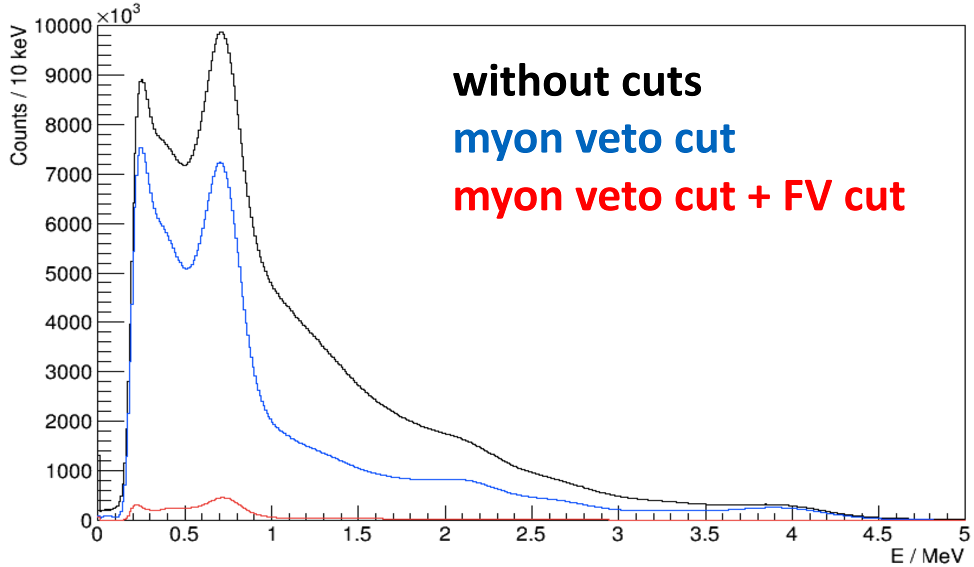
Myon Veto: All events in the LS within a 1 ms time window after a myon veto trigger are removed!

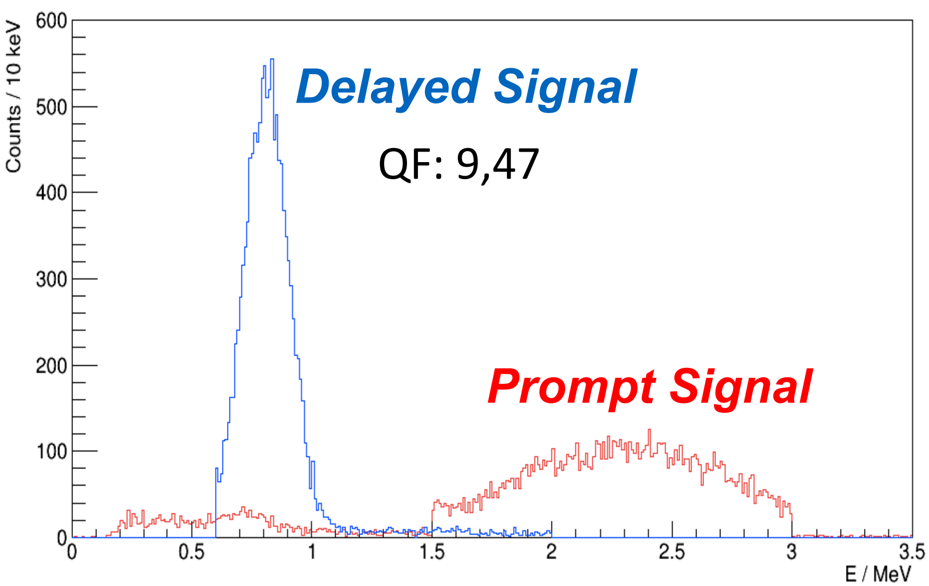
Fiducial volume: r < 1 m , − 1 m < z < 1 m

Spacial distance of coincidence events: d < 1 m

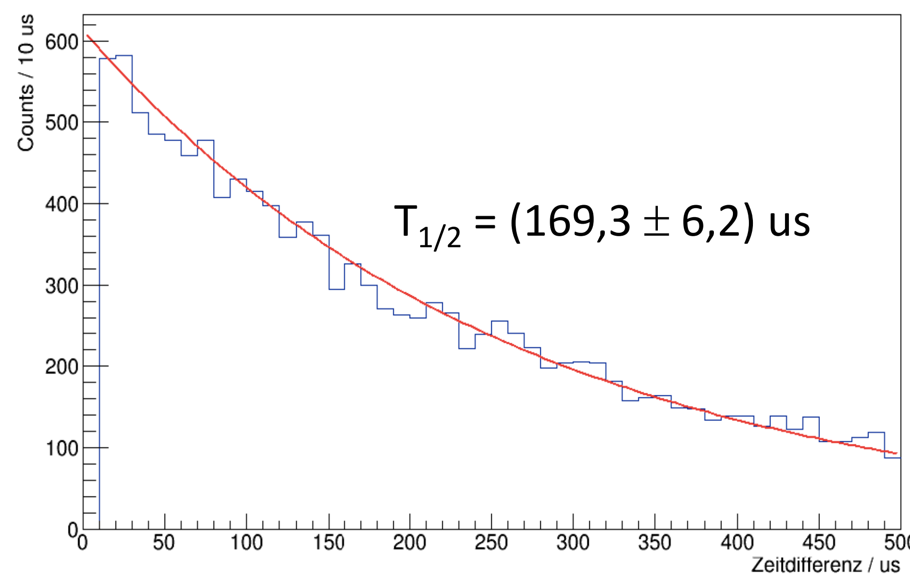
Energy cut: prompt signal 1.5 MeV to 3 MeV
delayed signal 0.7 to 1.1 MeV (due to α quenching),

Energy Spectra and Cuts

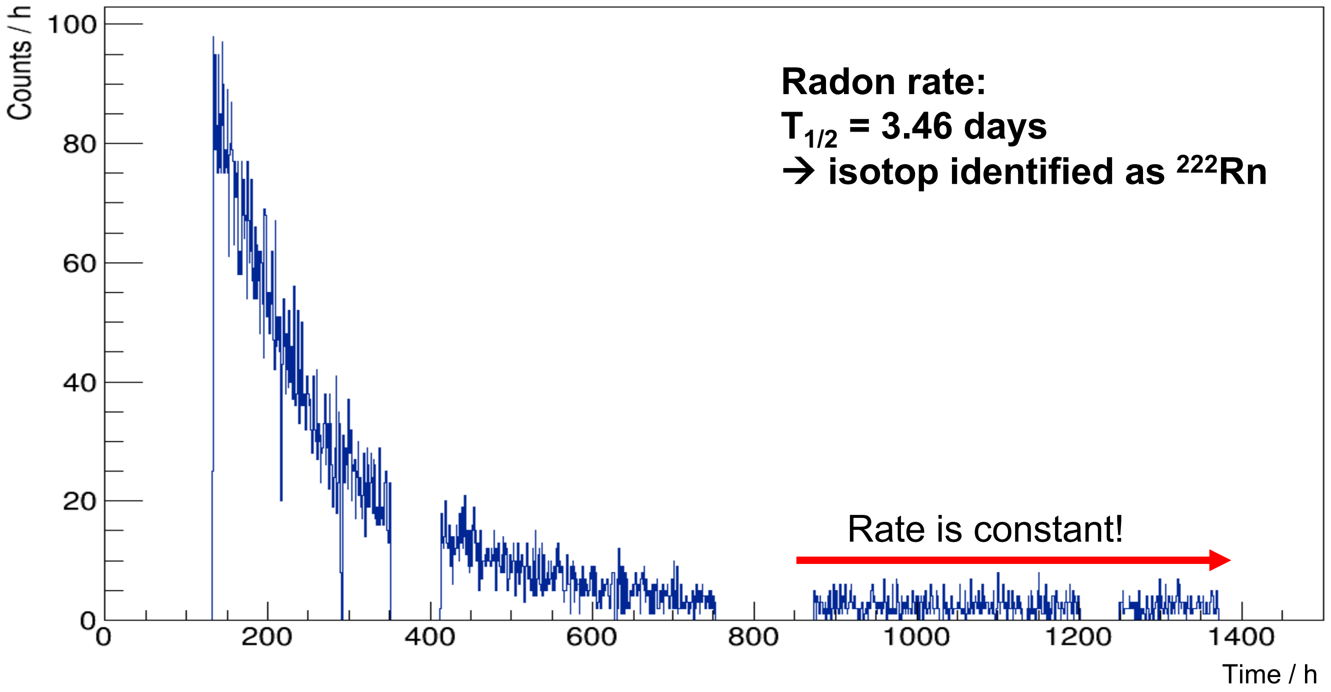




Time Difference (delayed – prompt)



^{222}Rn Count Rate and ^{238}U Concentration in LS

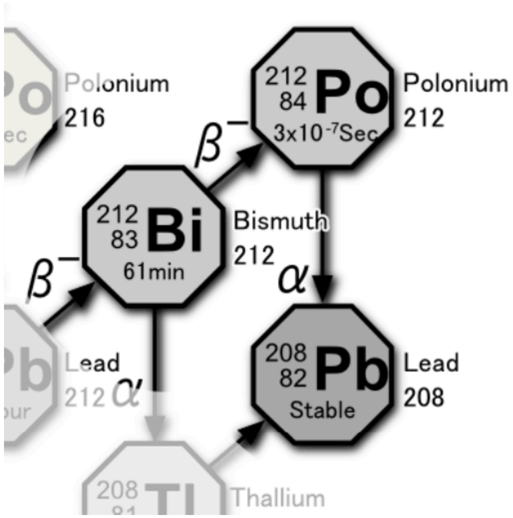


Constant count rate: 2,6 coincidences per hour → acticity: 10^{-4} Bq / m^3

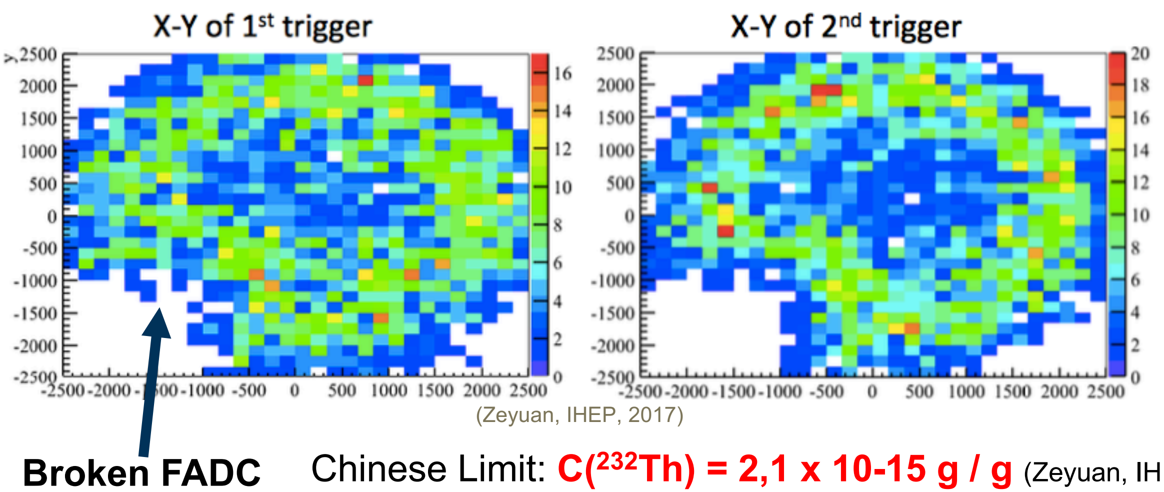
Calculated ^{238}U contamination of the LS:

$C(^{238}U) = 10^{-14}$ g/g (no background events extraction)

232Th Analysis – Quick Overview



- **299 ns half life time of ^{212}Po allows usage of coincidence method!**
- **Coincidence cut applied on data from 30. March to 20. April**
- **Fiducial volume: R < 1.2 m |Z| = 1.5 m (cut efficiency has to be simulated!)**
- **Coincidences in 93 events were observed.**
- **Problems:**
  - **Efficiency of the Daya Bay Setup was very low due to the short half life of 299 ns.**
  - **One FADC failed → loss of numerous PMT channels**



(Zeyuan, IHEP, 2017)

Analysis in Munich is still ongoing!

Detailed analysis with Monte Carlo studies for efficiencies and backgrounds are available from chinese and intalian groups.

Chinese Limit: **C(^{232}Th) = 2,1 x 10-15 g / g** (Zeyuan, IHEP, 2017)

INFN Analysis: **C(^{232}Th) < 2.8 x 10-15 g / g (90 % C.L.)** (A. Formozov, INFN, 2017)

Further Removement of ^{222}Rn by Nitrogen Stripping

- A leak was observed in AD-1! → Detector is due to the leak contaminated with ^{222}Rn.
- Currently the leak is beeing searchel and fixed by the Chinese colleagues.
- In a second test of the steam / nitrogen stripping system the 222Rn should be removed.
- The stripping plant will be operated with the detector in a loop mode.

Conclusions

- Requirements for the radiopurity of the LS are currently not reached.
- Huge radon rate was observed at the beginning from the data taking. → Source is under discussion! (ultra pure water, gas blankets in the tanks, emmanation?)
- Radon content in the water system and of the nitrogen blankets in the filling tanks and the detector has to be monitred carefully.
- A huge detector volume is necessary for monitoring the LS quality during the production or before the filling of the Juno CD.
- A pre detector like OSIRIS planned by the Mainz Group would be of great advantage for Juno.

Thank you for your attention!

Questions?