JUNO : INFN perspectives

G. Ranucci
INFN Milano

2014 **INFN-IHEP Bilateral Meeting**

Roma, May 16 - 2014

Framework of INFN involvement in JUNO

Main Motivations

Scientific continuity $\rightarrow$ Neutrino oscillation study and astroparticle program in JUNO natural evolution of the INFN activities in both fields and may represent one of the pillars of the INFN participation to the next round of "gigantic" neutrino oscillation experiments worldwide

Technological continuity $\rightarrow$ broad expertise acquired throughout the Borexino program in PMT's, scintillator, purification and low background techniques can be profitably reused within the JUNO project

Added later in the course of the on-going discussions $\rightarrow$ option to reuse the OPERA plastic scintillator tracker (**40% INFN funded for PMTs**) for the JUNO top muon tracker

Framework of INFN involvement in JUNO

First contact triggered by the President in occasion of the 2012 **INFN-IHEP Bilateral Meeting** held in Rome at the INFN headquarters on May 19th, 2012

The general features of our possible involvement were discussed during the **NPB 2012** workshop at Shenzhen on September 2012 – Antonio, Roberto and Rinaldo were part of the discussion

After that, in a series of participation to general (Beijing January 2013, Beijing July 2013, Kaiping January 2014) and restricted (LNGS September 2013) meetings, we have **initially** shaped the guidelines of our participation by identifying two major items of interest:

- ✓ Scintillator
- ✓ PMT's

Now the Opera tracker issue has emerged as the third main element of this cooperative effort

Scintillator

- Scintillator optical measurements (very wide and deep experience gained within the Borexino R&D)

- Procurement of LAB from European suppliers and check of the properties to compare with the LAB from China. A LAB supplier has been found in Italy, at Augusta $\rightarrow$ breakthrough also for the possible future of initiatives at Gran Sasso. Other two suppliers in Germany and Spain. Exchange of samples (solvents and scintillator cocktails)

- Conceptual definition, design and construction of the **distillation column** and of the associate **N_2 stripping column** for scintillator purification. Possibility to do the pre- assembly here in Italy and send the pre-assembled skid to China. Potential industrial partner, located close to Milano, already identified

The Perugia and Milano Borexino groups are those involved in the scintillator activity

Note: studies for alternative novel LS solvents initiated before the JUNO effort

Nuclear Instruments and Methods in Physics Research A 701 (2013) 133–144

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Decay time and pulse shape discrimination of liquid scintillators based on novel solvents

Paolo Lombardi [a], Fausto Ortica [b], Gioacchino Ranucci [a,*], Aldo Romani [b]

[a] Istituto Nazionale di Fisica Nucleare, via Celoria 16, 20133 Milano, Italy
[b] Dipartimento di Chimica and INFN, via Elce di Sotto 8, 06123 Perugia, Italy

A R T I C L E I N F O

Article history:
Received 3 May 2012
Received in revised form
12 October 2012
Accepted 16 October 2012
Available online 23 October 2012

Keywords:
Liquid scintillators
Scintillation light
Fluorescence decay time
Pulse shape discrimination
Linear alkylbenzene
Di-isopropylnaphthalene

A B S T R A C T

Over the past few years the liquid scintillation technique employed for particle detection applications has undergone a significant technological breakthrough with the introduction of novel solvents tailored to address the concerns about toxicity, flammability and disposal problems associated with the scintillators of traditional formulation.

The increasing popularity of the new solvents in the realization of experimental set-ups of various degrees of size and complexity implies the need of a thorough study and characterization of the features of the corresponding scintillation mixtures, with the aim to approach eventually a level of understanding similar to that, very accurate, achieved throughout many years of research for the scintillators realized with conventional solvents.

In this general context, aim of this work is to illustrate the results of the fluorescence decay time and pulse shape discrimination measurements carried out on a set of scintillation mixtures realized using two of such novel solvents, i.e., linear alkylbenzene (LAB) and di-isopropylnaphthalene (DIN). The measurements have been performed either under particle or UV excitation of the scintillating solutions, which permitted to unravel the features both of the fast component and of the long tail forming the entire scintillation pulse.

Moreover, the particle characterization via β or α excitation allows also predicting the α/β pulse shape discrimination capability of the mixtures, a property of paramount significance for applications focused on the increasingly important field of low background detectors.

1. Introduction

Liquid scintillation technology [1] is a well-established method used to realize a great variety of devices for particle detection, with size ranging from small table-top set-ups intended for laboratory measurements, to massive detectors focused on the search of very rare events. The latter application implies very often the deployment in underground caves of large experiments, employing hundreds or even thousands tons of liquid scintillator. Examples of experiments of this kind, running since several years, are the Borexino [2] solar neutrino experiment located at the Gran Sasso Laboratory, the supernova observatory LVD [3], again at Gran Sasso, and the KamLAND [4] detector in the Kamioka mine. The more recent Double Chooz [5] and Reno [6] near and far detectors, as well as the Day Bay [7] multiple detectors complex, are specific implementations of the liquid scintillation method for the detection of anti-neutrinos from reactor (the main, but not unique goal of KamLAND, too), while the imminent start-up of the SNO+ [8] experiment, the successor of SNO+ that will replace the heavy water with liquid scintillator, is expected within 2013. The largest liquid scintillator detector currently under construction is NOvA [9], which will employ 13 kt of liquid organic scintillator to catch neutrinos in an accelerator beam from Fermilab. Looking far in the future, the possibility of the gigantic detector LENA [10], based on 50–100 kt of liquid scintillator, is actively pursued with the perspective to be installed in the Pyhäsalmi mine in Finland.

Therefore this mature technique, born in the 1950s, is still an important tool in the particle physics arena, as witnessed not only by the numerous experiments under operation or installation, but also by its crucial role in the recent assessment of the neutrino oscillation phenomenon [11,4] through the measurements, among others, of Borexino and KamLAND.

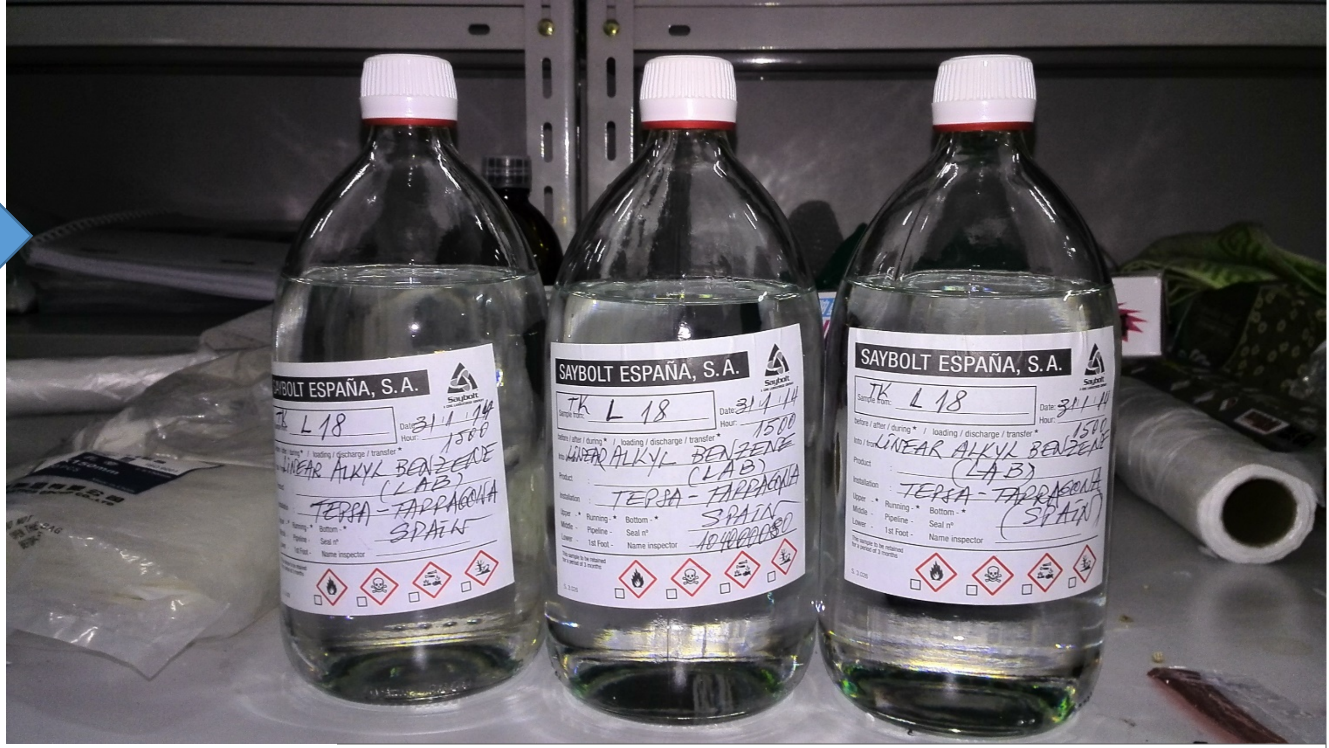
Most of the technical foundations in this field were established in the 1950s and 1960s, when the organic, aromatic compounds Xylene, Toluene and Pseudocumene were identified as the best suited choices for the solvent, i.e., the basis for any scintillator formulation.

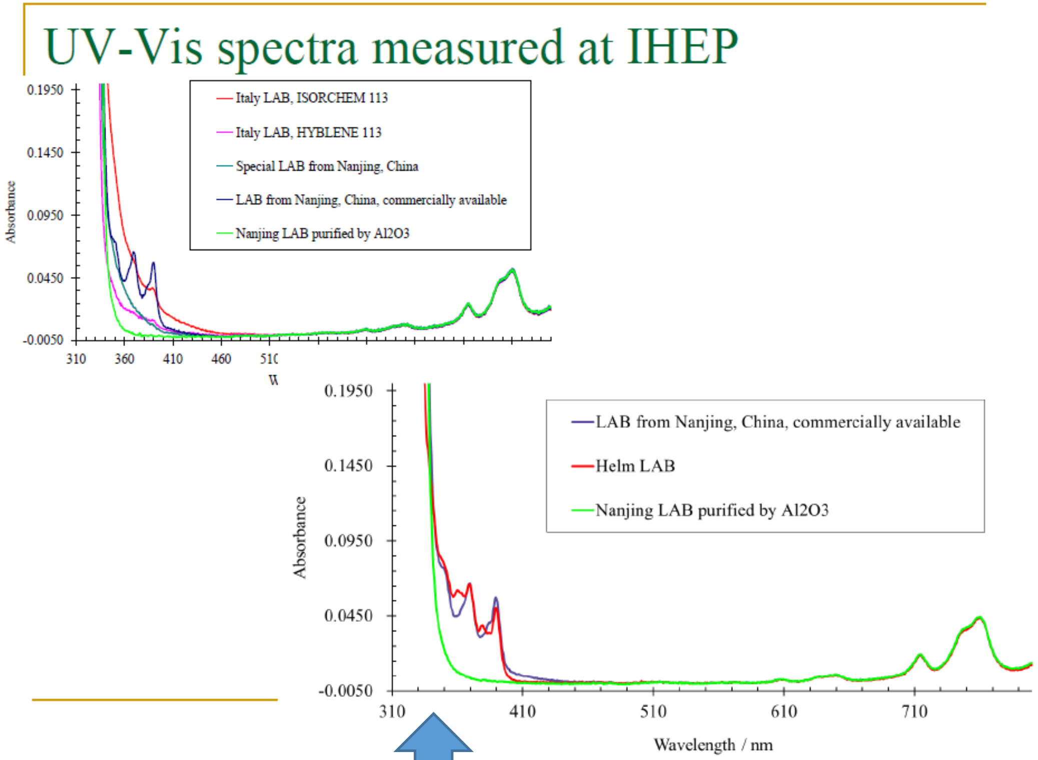
* Corresponding author. Tel.: +39 02 50317362; fax: +39 02 50317617.
E-mail address: gioacchino.ranucci@mi.infn.it (G. Ranucci).

0168-9002/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.nima.2012.10.061

Joint measurements effort well in progress

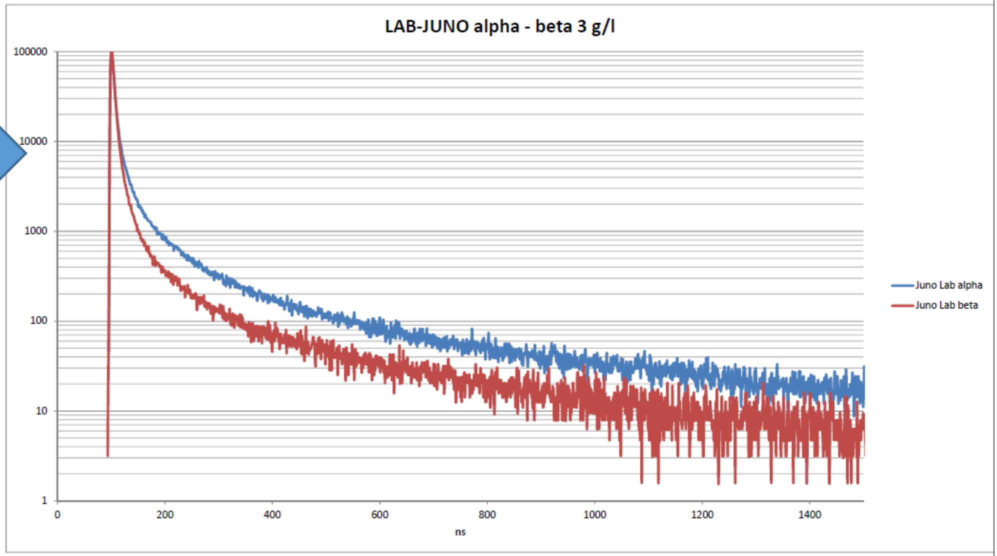
Samples from a European company to IHEP





Absorbance and attenuation length measures at IHEP of our European samples

Our own measurements on a scintillator sample from IHEP



Introduction

From the talk of Paolo Lombardi @ the last proto-collaboration meeting at Kaiping

In Milano we have started a research activity for a possible LAB scintillator purification plant starting from our past long term experience in this field.
The conceptual idea is to adopt, with a proper scaling, the successful purification technique, sequence and construction specifications developed for Borexino experiment @ Gran Sasso .

Borexino plant was designed and by a NJ company (Koch Modular Process System).

We have searched for a reliable European company and we found one in Milano

Polaris engineering   http://www.polarisengineering.com

The company already worked with us for a design upgrade of the cryogenic distillation column at Fermilab for the underground Ar gas purification of DarkSide experiment

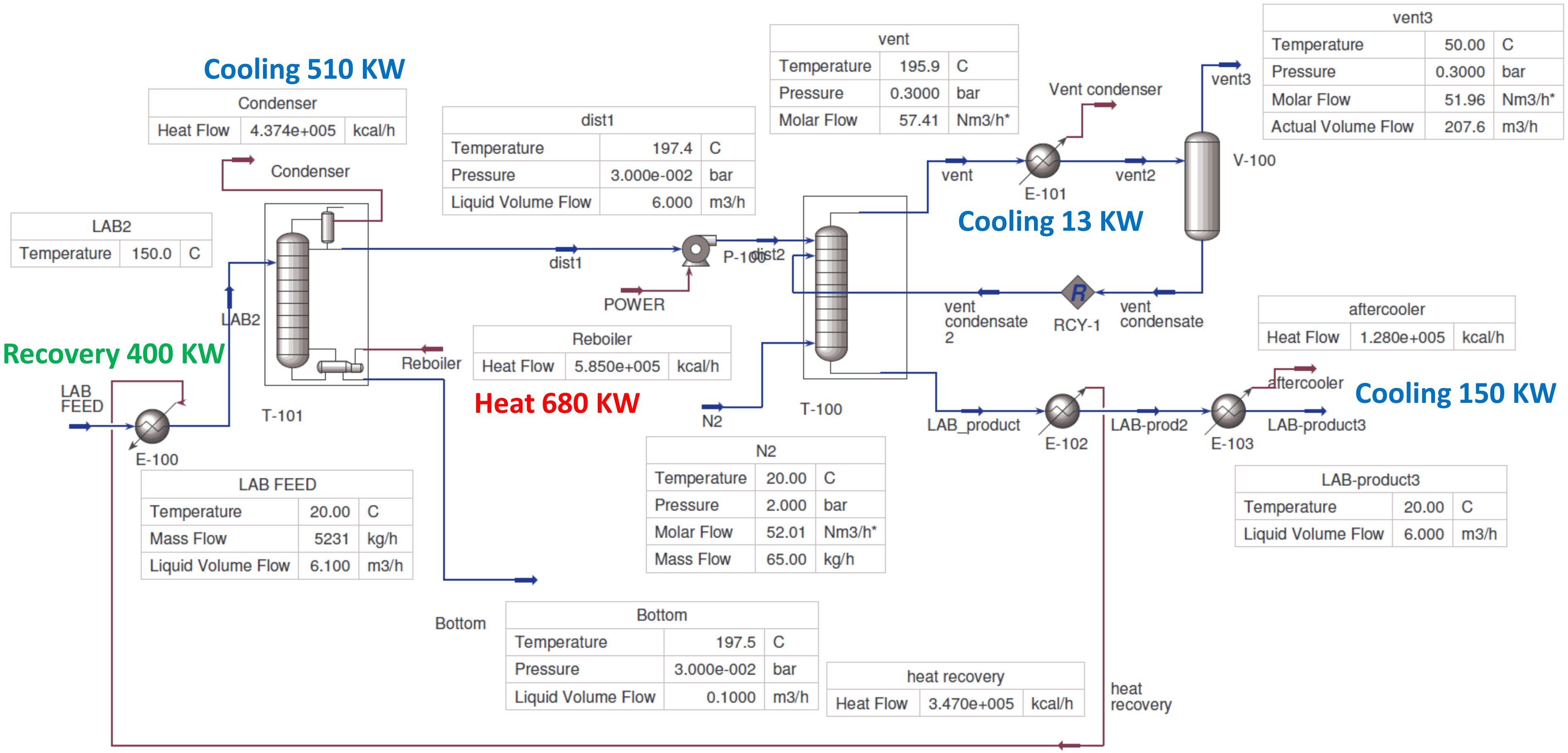
Preliminary mass and energy flow chart

From the talk of Paolo Lombardi @ the last proto-collaboration meeting at Kaiping

Reboiler Heat power: 680 KW

Condensers Cooling power: 673 KW

Inlet-Outlet Energy recovery: 400 KW



Space requirements

From the talk of Paolo Lombardi @ the last proto-collaboration meeting at Kaiping

Concept:

We have considered to divide the LAB purification plant in 3 separate skids to be prepared in Italy and shipped and installed at JUNO site

Item	Footprint	Height	Weight
Distillation skid	3,0 m x 4,0 m	12,0 m	15 tons
Stripping skid	3,0 m x 4,0 m	12,0 m	11 tons
Accessories skid (vacuum pumps, heat recovery, etc.)	3,0 m x 4,0 m	6,0 m	7 tons

To be further discussed

PMT's

Our broad experience with phototubes makes it natural for us to be involved somehow also in this area.

Test of prototypes

MCP-PMTs prototype

- The Chinese group has started since several time an effort leaded by Yifang for the development of innovative MCP-PMTs with North Night Vision Technology : we recently received two 8" spherical prototypes→ testing already started - stemmed useful suggestions for the divider to improve the shape of the signal
- Move of the Philips Photonix to China completed → **HZC Photonics**. Contacts established with the CEO Dr. Maggie Wang. Also received two 8" spherical devices XP1805, testing commenced
- Hamamatsu "path" : new 20" device based on the 3600 Super-Kamiokande type → High SBA QE . Next meeting with the Company **middle of July** . We will receive further improved prototypes as far as they will be available
- The amount of possible further works and commitments will depend on the final composition and strength of the group (realization of divider and ancillary parts, participation to installation)

Other possible areas of contribution

Linked to the joining of other groups

Very concrete plans of participation : Padova, Frascati, Ferrara ……..

- ✓ Top Tracker

  → see the previous exhaustive description of Yifang concerning the solid option to re-use of the Opera tracker based on plastic scintillators **Yesterday meeting in Frascati between IHEP and Opera groups (Frascati, Padova, Strasbourg, Dubna)**

- ✓ Electronics & DAQ

  → contacts being taken with the Chinese colleagues and in coordination with the other European groups

- ✓ General simulation of the detector

  → Other potential groups could join in this Marco Grassi from Roma-La Sapienza, co-funded by INFN and IHEP post-doc

- ✓ Development of analysis tools

Scenario for a broad European participation

Stemming from previous joint efforts

- Strasbourg, Dubna, Hamburg : Opera

- Paris APC , Munich, Tubingen&Mainz, Dubna, Hamburg : Borexino (Paris and Munich cooperating in Double Chooz)

But not only

- Aachen

- Prague (already in Daya Bay)

Perspectives for a strong European Collaboration, in sizable fraction coming from Borexino and Opera, suitable to put in a broader context our role in the experiment

Meetings in Milano before the next Collaboration meeting:

Italian component $\rightarrow$ May 22
European meeting $\rightarrow$ JUNE/JULY to be finalized

Conclusion

The vast potential physics reach of JUNO - MH determination and beyond - makes the experiment very attractive for Italian as well as European groups

The perspectives for an INFN participation of significant impact are very promising, solidly grounded on previous expertise and well positioned in a larger European framework