Borexino at Gran Sasso

A real time detector for low energy solar neutrinos

Gioacchino Ranucci

Neutrino 2000

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Summary

- Description of the detector
- Physics program
- Radiopurity issues
- Status of the installation
- Conclusions

Borexino Collaboration

✓Belgium
I.R.M.M. European Joint Research Centre - Geel

✓France
College de France

✓Germany
Max-Planck-Institut Für Kernphysics Heidelberg
Technische Universität München

✓ Hungary
KFKI-RMKI Budapest

✓Italy
Dipartimento di Fisica e INFN Genova
Lab. Naz. INFN del Gran Sasso
Dipartimento di Fisica e INFN Milano
Dipartimento di Fisica e INFN Pavia
Dipartimento di Fisica e INFN Perugia

✓Poland:
Jagellonian University Krakow

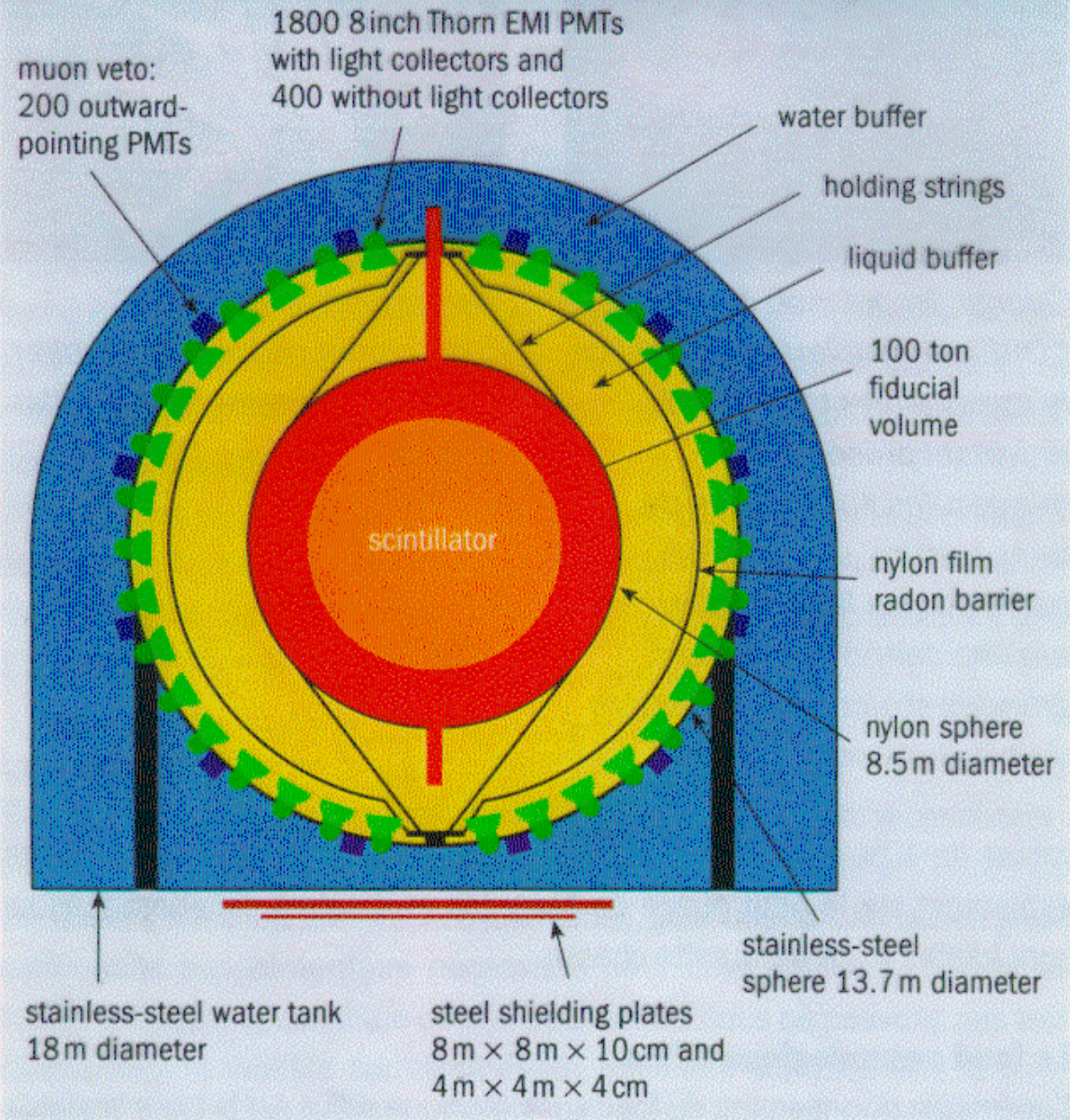
✓Russia
JINR Dubna
Kurchatov Intitue - Moscow

✓United States
Bell Laboratories, Lucent Technologies
Massachusetts Institute of Technology
Princeton University
Virginia Polytechnic Institute

Borexino

A real time, calorimetric, scintillation detector, for low energy solar neutrinos, under installation at the Gran Sasso underground Laboratory, aimed at the detection of the monoenergetic ^{7}Be neutrinos, through scattering off the electrons of the scintillator

Expérience Borexino



Main Components: Detector

Scintillator

Nylon (Inner and Outer) Vessels

Buffer Liquid

Stainless Steel Sphere

- support of PMT's
- containment of the buffer (zero buoyancy for the nylon vessels)

PMT's

Concentrators

Muon veto

Calibration equipments

Water Tank

Electronics and DAQ

Main components: Plants

Storage Vessels

Scintillator Purification systems

Water extraction

Distillation

Column purification

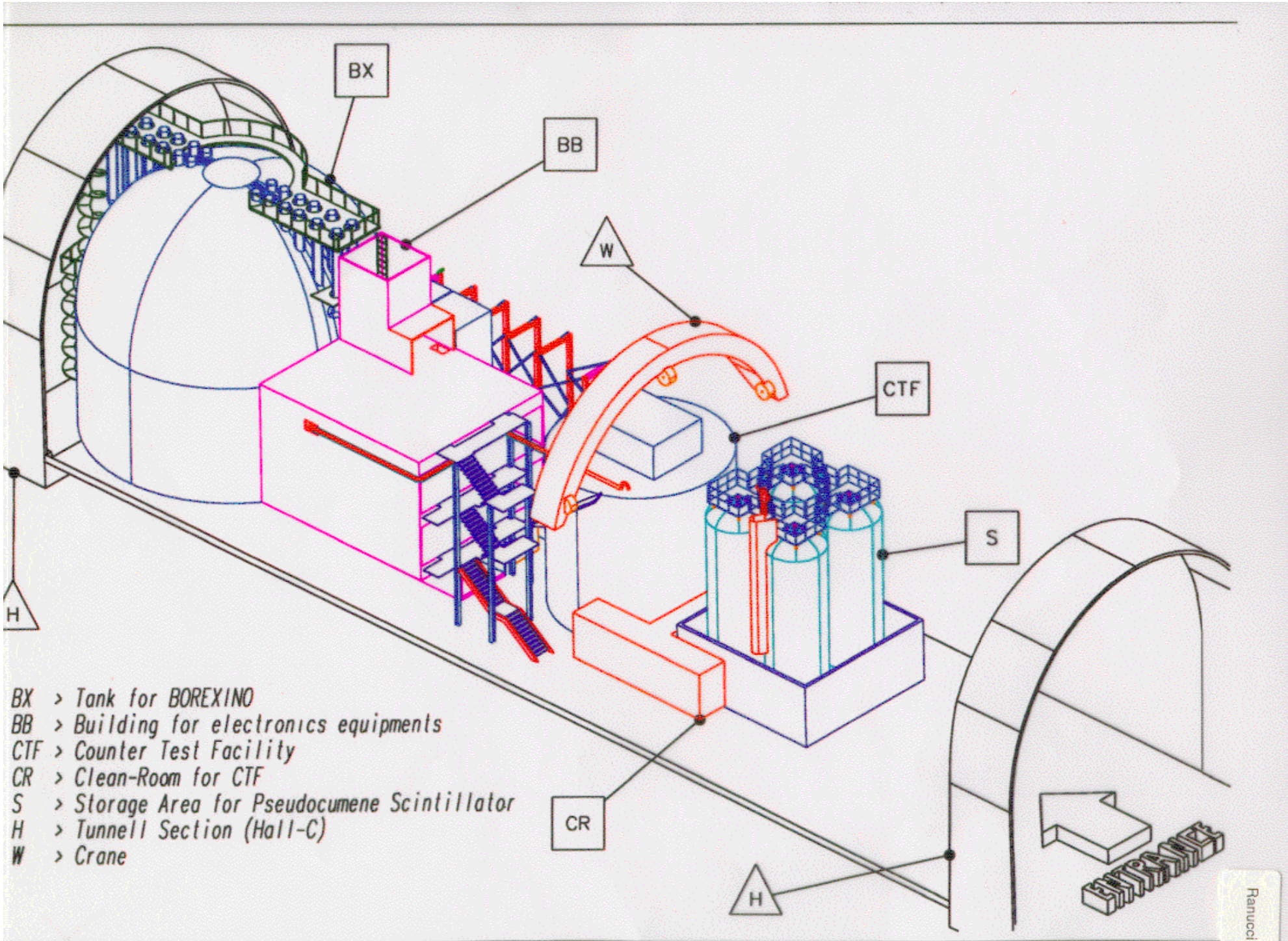
Nitrogen sparging

N_2 PLANT

Fluid Handling System

Water Purification System

Clean room



BX > Tank for BOREXINO
BB > Building for electronics equipments
CTF > Counter Test Facility
CR > Clean-Room for CTF
S > Storage Area for Pseudocumene Scintillator
H > Tunnell Section (Hall-C)
W > Crane

Scintillator

Solvent : Pseudocumene

Solute: PPO (1.5 g/l)

Light yield: 11000 ph/MeV

Att. Length (@420): 30 m

Scatt. length (@420 nm): 7 m

Decay Time (fast component) : 3.5 ns

Good α /β properties

Photomultipliers

8" Electron Tubes Limited 9351 type

P/V : 2.5

Transit Time Spread: 1 ns

Dark Count rate: 1kHz

Afterpulsing < 3%

Low radioactive glass and internal parts

Light Concentrators

Truncated string cone design

Optimized to collect the light from the inner vessel and 20 cm beyond it

Material: anodized aluminum

Mesured quantities

The electronics measures and provides for each triggered event :

- **the photomultipliers pulse height**

  ⇨ **energy measurement**

- **the photoelectrons arrival time (0.3 ns resolution)**

  ⇨ **location identification**

- **the absolute time of the event**

Expected detector performances

Effective Coverage: 30%

Photoelectron yield: 400 pe/MeV

Energy resolution (@1MeV): 5 %

Position resolution (@ 1 MeV): 10 cm

Calibrations

A variety of calibration and monitoring systems are planned:

✓Laser pulses distributed to all PMT's with a fiber optics splitting system

- timing calibration
- gain adjustment via detection of the single photoelectron peak

✓External sources (Th) located in the S.S.S close to the light cones

- check of the stability in time of the overall detector response

✓Internal sources inside the scintillator

- position calibration
- energy calibration
- α/β PSD determination

Calibrations

✓Laser beams with different wavelengths through the buffer and laser excitation of the scintillator

- stability monitoring of optical properties

✓Blue LEDs on the external tank for the outer muon veto detector

✓Active tags of trace impurities in the scintillator

- cross check of the absolute energy scale determination
- additional stability monitor

✓Calibration of the overall detector response via a sub-MeV ν-source (^{51}Cr)

Neutrino Detection in Borexino

Detection through the scattering reaction

$$\nu + e^- \rightarrow \nu + e^-$$

off the electrons of the scintillator

The high luminosity and high radiopurity

of the scintillator lead to a low detection threshold: 250 keV.

It is possible to detect the recoil electrons produced by the monoenergetic (0.861 MeV) 7Be ν.

Maximum recoil energy: 0.66 MeV

SSM prediction: 55 ev/d for 100 T F. V

The Borexino program

- First direct measurement of ^{7}Be flux

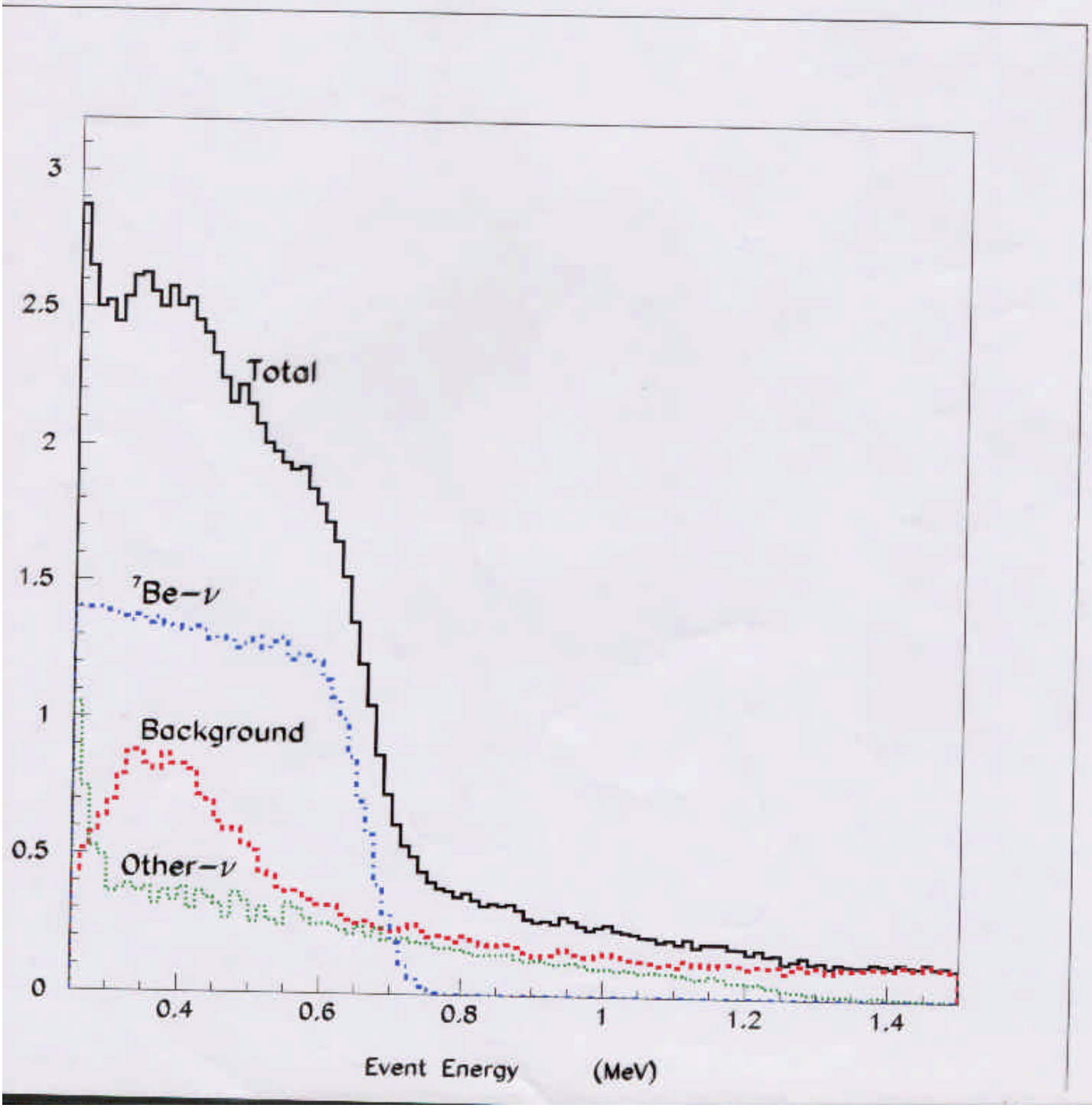
Expected rates (ev/d) in a F.V. of 100 T

Recoil Energy window MeV	SSM	LMA	SMA	LOW	VO
		$\Delta m^2=1.8 \times 10^{-5}$ eV^2 $\sin 2\theta=0.76$	$\Delta m^2=5.4\times10^{-6}$ eV^2 $\sin^2\theta=5.5\times10^{-3}$	$\Delta m^2=7.9 \times 10^{-8}$ eV^2 $\sin^2\theta=0.96$	
0.25 - 0.8	55.2	30.7	11.7	29.0	
				day/night effect	**seasonal variation**

- Probing vacuum oscillations via seasonal variation of the flux

- In absence of other time variations, demonstration of the solar origin of the signal through the 7% variation due to the Earth-Sun distance variation during the year

- Background ~ 15 ev/d


3
2.5
2
1.5
1
0.5
0
Total
^{7}Be−ν
Background
Other−ν
0.4
0.6
0.8
1
1.2
1.4
Event Energy (MeV)

Other capabilities

⇨ ^{8}B spectrum in the unique energy window 1.5-5 MeV

⇨ Antineutrino Science

$$\bar{\nu} + p \rightarrow n + e^+ \qquad \text{th=1.8 MeV}$$

$$\downarrow 200\ \mu s$$

$$n + p \rightarrow {}^2_1H + \gamma \qquad (2.2\ \text{MeV})$$

Search for solar $\bar{\nu}_e$
Geophysical $\bar{\nu}_e$ from the Earth
$\bar{\nu}_e$ from Type II Supernovae
Long-baseline $\bar{\nu}_e$ from European reactors

Radiopurity of the scintillator

Main issue for the feasibility of the experiment

Purity requirements for ^{238}U and ^{232}Th in the range of 10^{-16} g/g

Laboratory measurements on small samples: $2\text{-}3 \times 10^{-15}$ g/g
manly limited by impurities leached from the wall of the vessels

Needed a direct measurement on some tons of scintillator with a sensitivity level at least 5×10^{-16} g/g $\rightarrow$ CTF

Further high sensitivity measurements performed with Neutron Activation Analysis

Achievements of CTF

1 - Demonstration of unprecedented purity levels

$^{14}C/^{12}C = (1.94+/-0.09) \times 10^{-18}$

$^{232}Th < (4.4 +/-1.5) \times 10^{-16}$

$^{238}U < (3.5 +/-1.3) \times 10^{-16}$

2 - Demonstration of the effectiveness of the planned purification methods for Borexino

Purity levels confirmed with Neutron Activation Analysis

$^{238}U < 2 \times 10^{-16}$

CTF has been recently reinstalled for quality control of the scintillator prior to detector filling

Status of the experiment preparation

Scintillator components (PC and PPO): manufacturers identified, contracts under finalization

Nylon (Inner and Outer) Vessels: test prototypes already produced, material selection almost completed

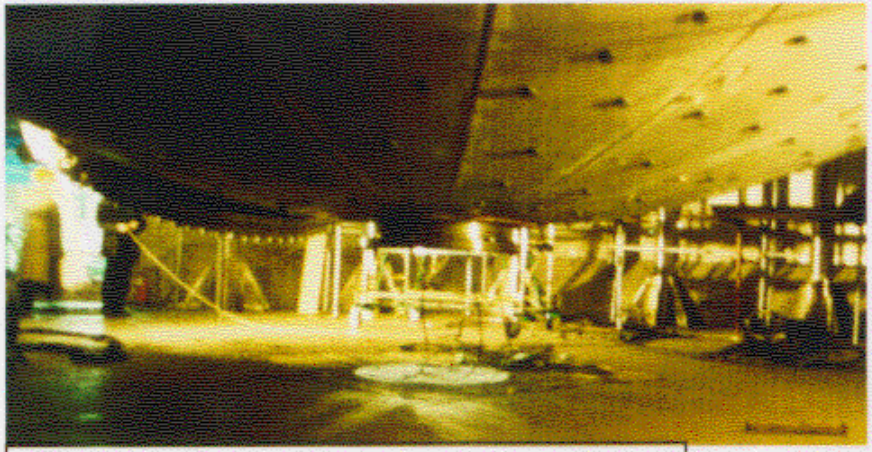
Stainless Steel Sphere: construction completed, final surface treatments in progress

PMT's:

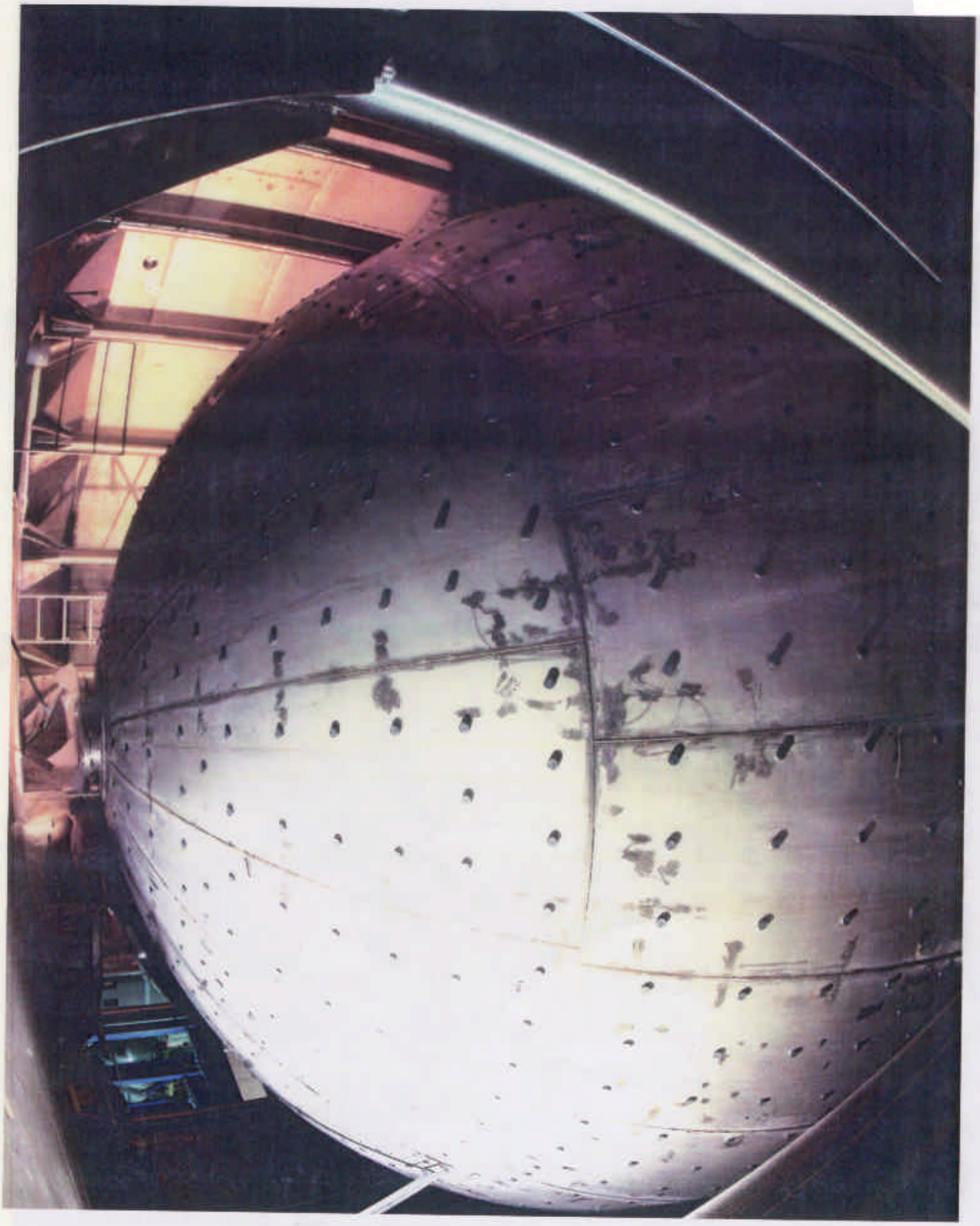
bare devices: 90% ready

PC/water proof encapsulation: designed, tested for 6 months in the "two liquid test tank"

Prototype of the Inner Nylon Vessel



Stainless Steel Sphere inside the Water Tank

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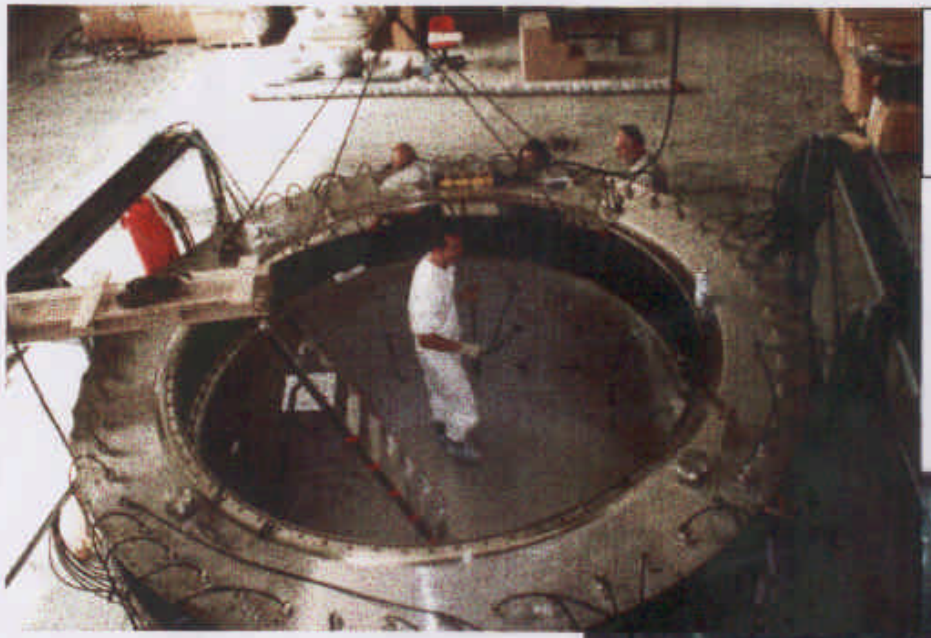
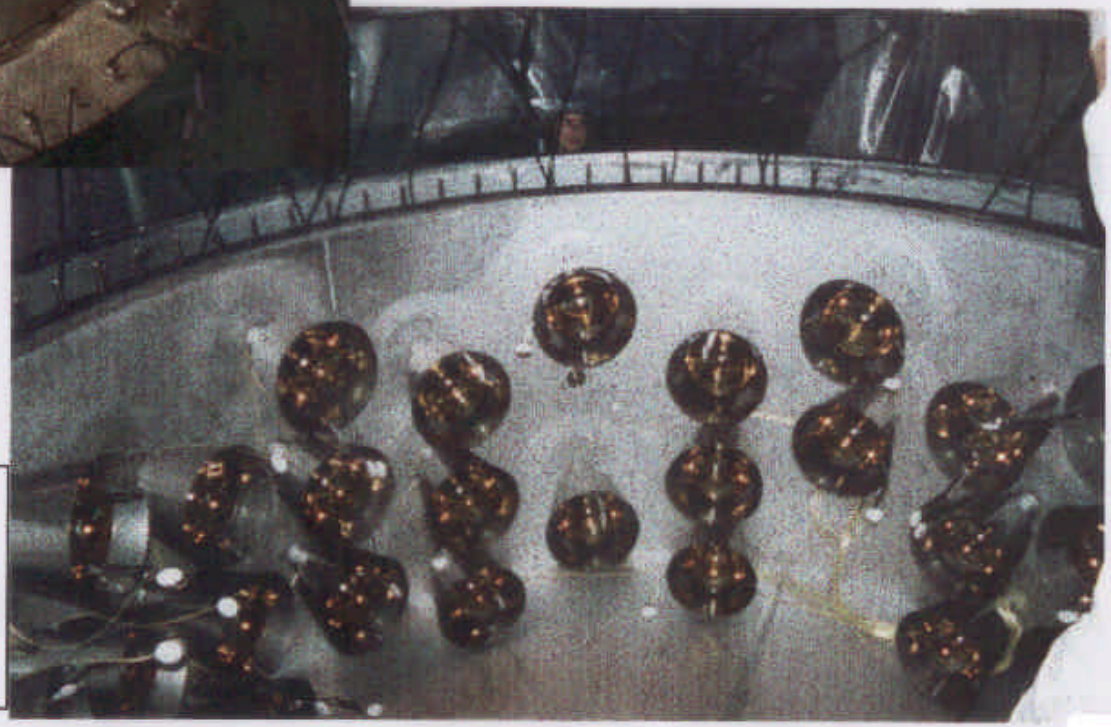
Installation of the Two-Liquid Test Tank





PMs & optical fibers mounted in the TLTT

Status of the experiment preparation

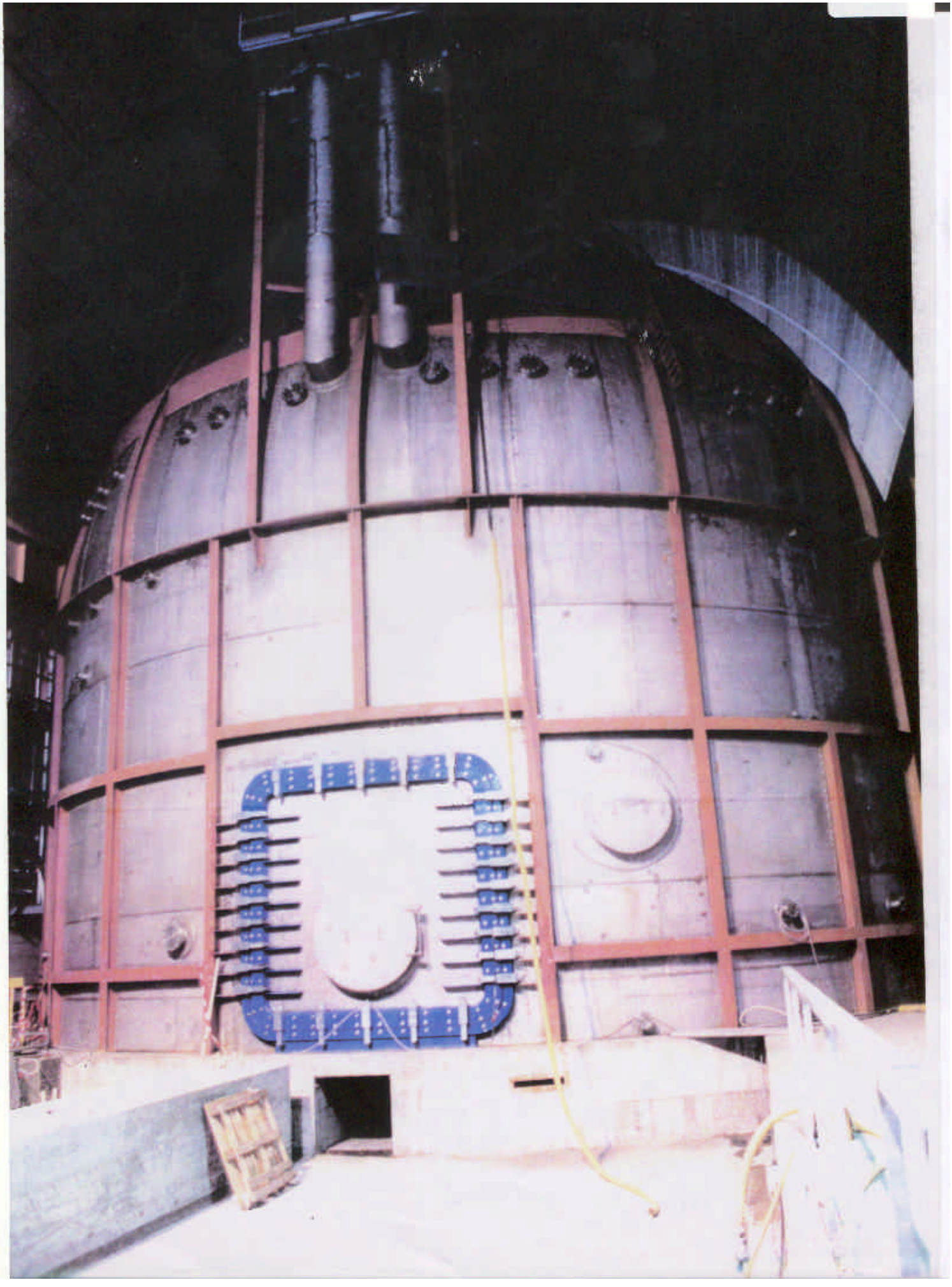
Water tank: completed

Electronics and DAQ: hardware and software ready, final integration in progress

Muon veto: dedicated PMT's and electronics in preparation

Concentrators: under production

Calibration equipments: in preparation; optical fiber system tested in the "two liquid test tank"



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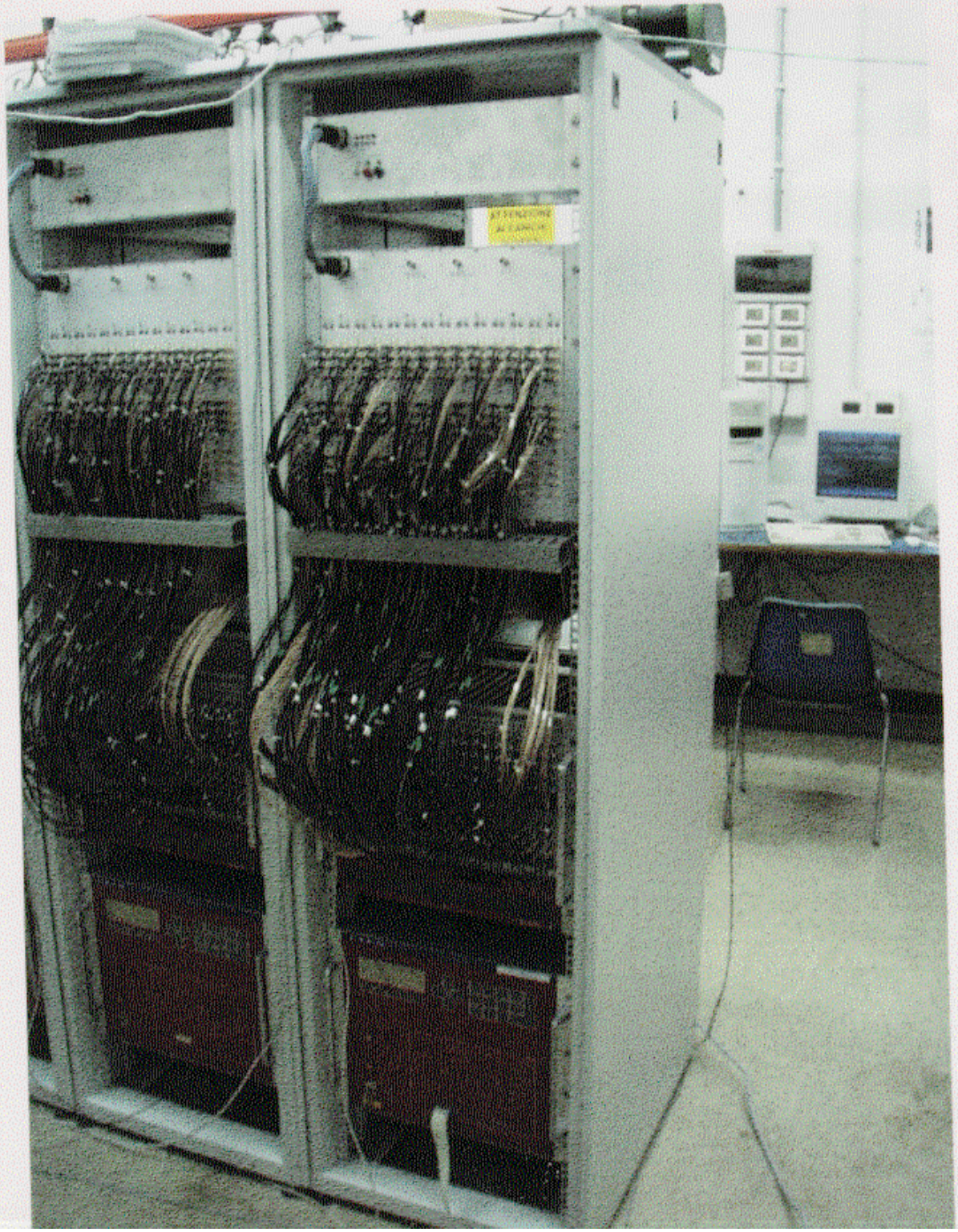


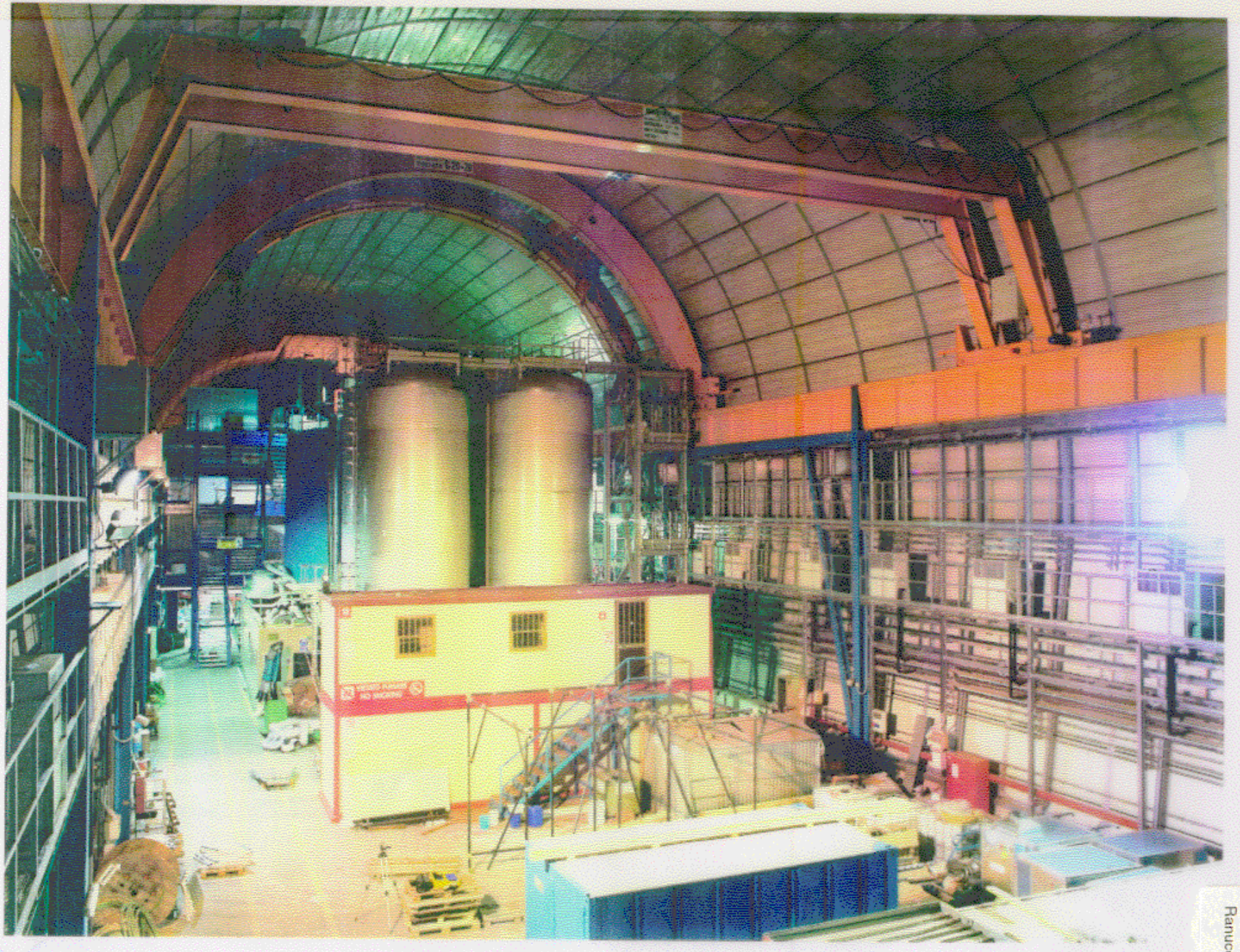
Status of the experiment construction

Storage Vessels: completed

Scintillator Purification Systems: in advanced phase of installation, test foreseen in the next fall with CTF, for column purification test already started

Fluid Handling System: ready by the Fall

Clean room: under construction, to be completed by end of August.



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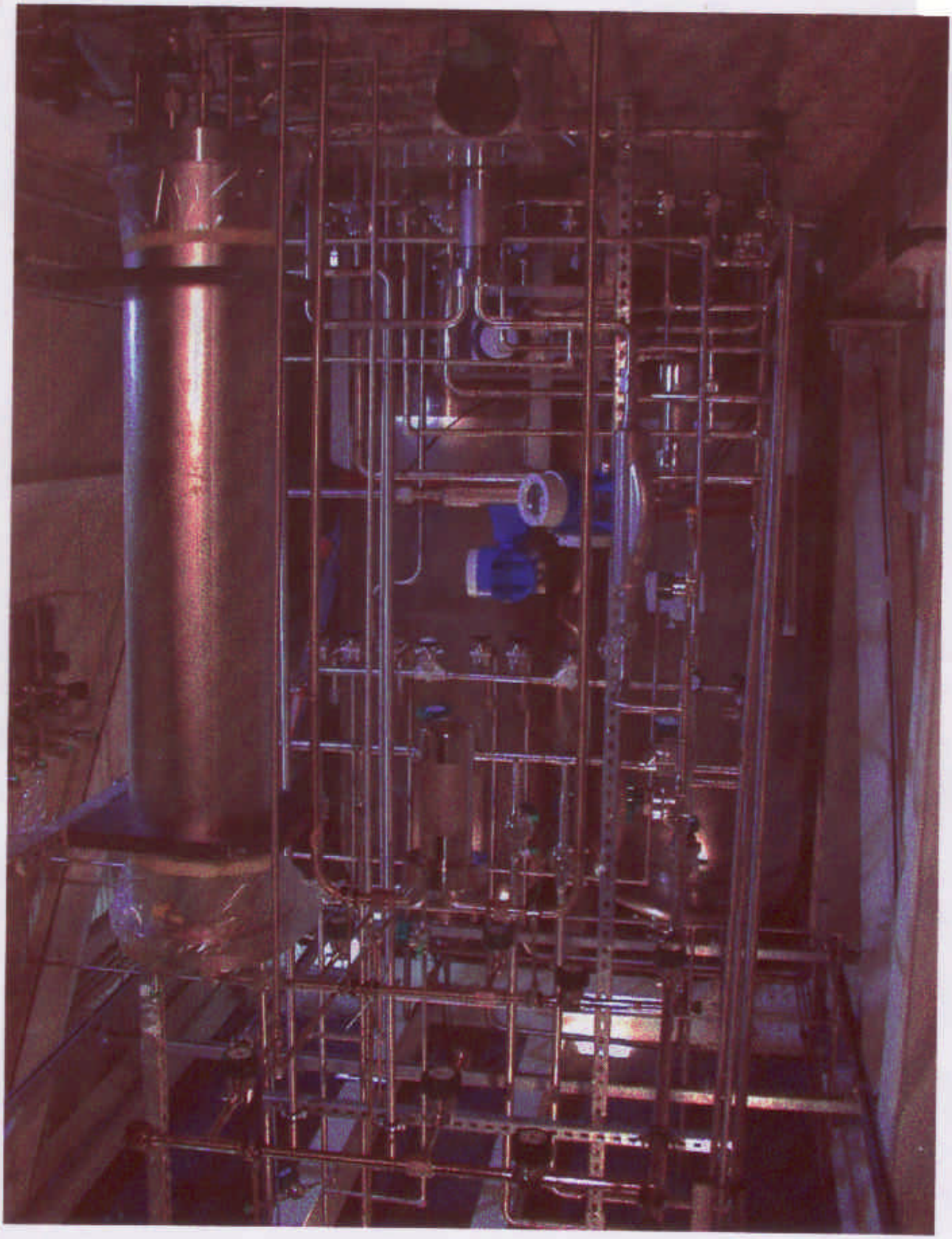

Conclusions

✓The design of all the experiment subsytems has been finalized

✓Major installations have been already completed in Hall C

✓All the other equipments to be installed are in preparation/installation phase

✓Borexino ready for filling by middle of next year

✓CTF rebuilt, ready for qualification of the scintillator and for test of the purification system