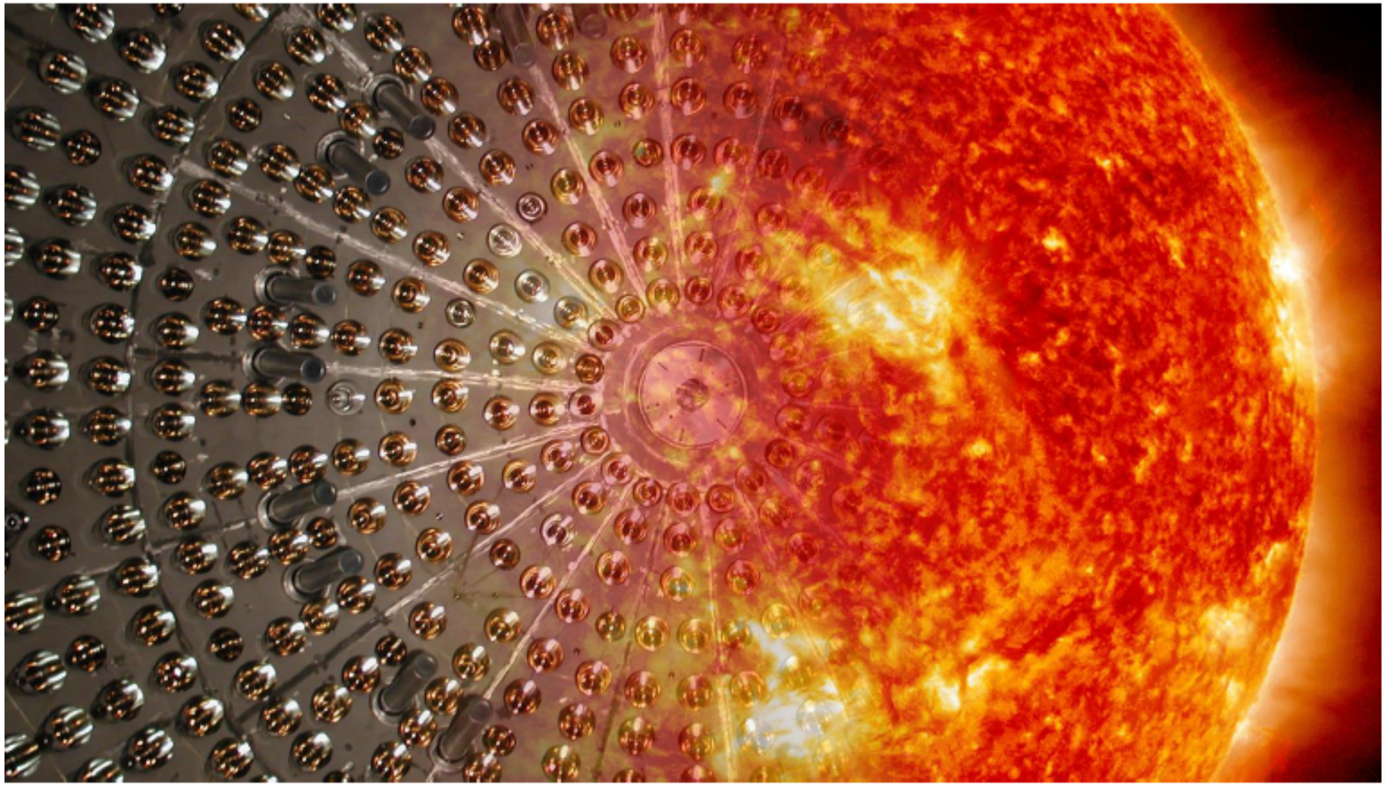
A short scientific history of Borexino



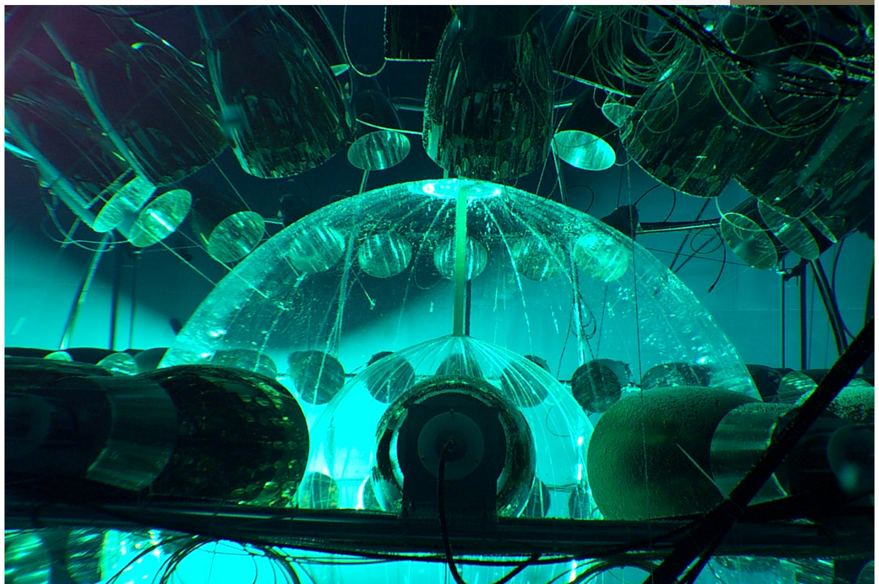
1990 Start up of the design

1991 Start up of the R&D for the scintillator radio-purification-goal : 10^{-16} g/g; problem:

no instruments sensitive enough to measure the low activities achieved:

Counting Test Facility –sensitivity $5 \cdot 10^{-16}$ g/g

(now part of it is used by DarkSide)



1995 CTF showed that we were able to reach the needed radiopurity

1996-1997 Approval of the Borexino funding by INFN, NSF, German agencies

may 2007 Start up of the data taking

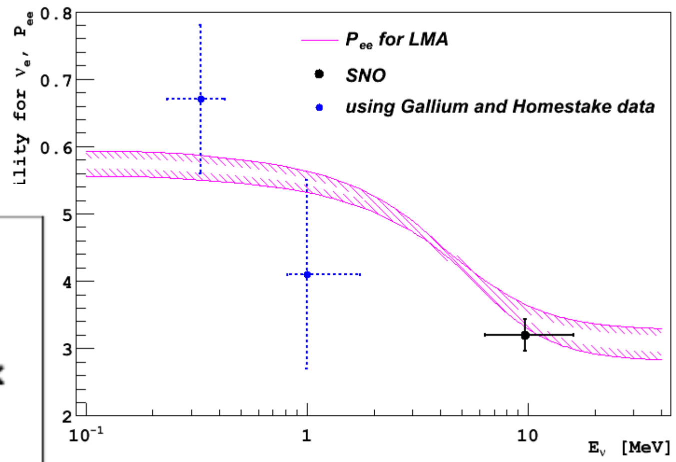
main performances: scintillator properties (500 p.e./MeV; efficient α/β discrimination) ; unprecedented radio-purity: (scintillator, stripping N_2, vessel Nylon, shielding water)

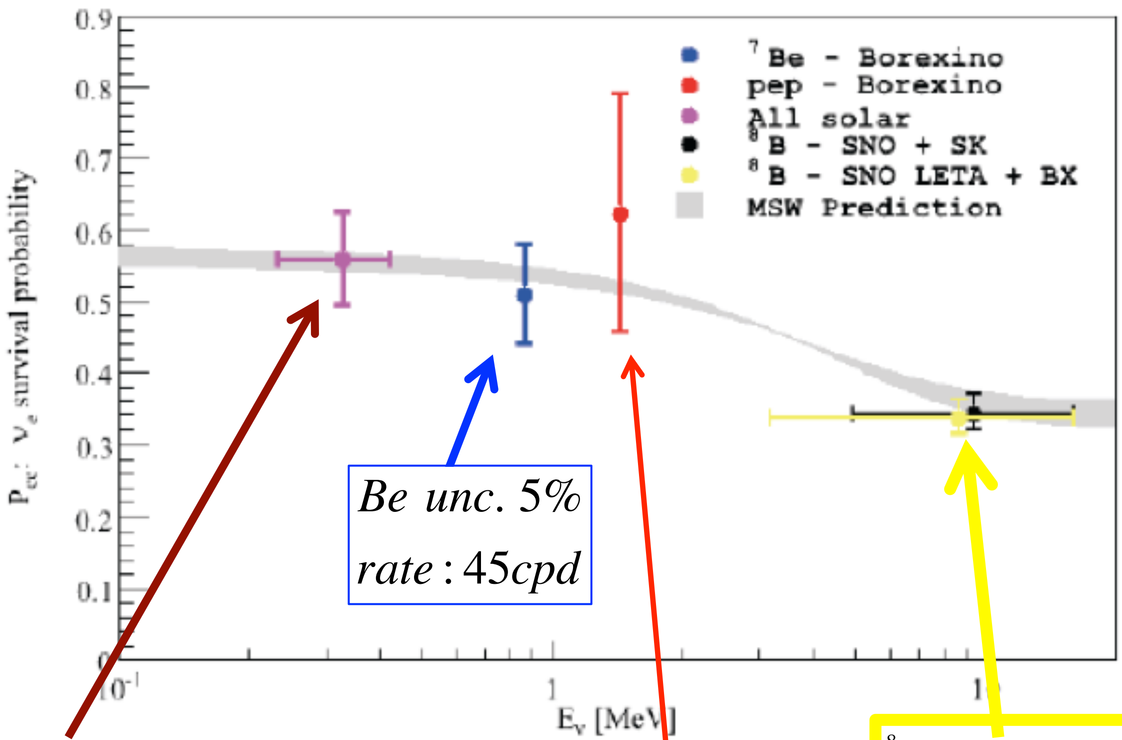
Gianpaol

LEVELS OF RADIOACTIVITY CONTAMINANTS

Radio isotope		Concentration or flux		Final
Name	Source	Typical	Required	Achieved
^{14}C	intrinsic PC	$\sim 10^{-12}$ g/g	$\sim 10^{-18}$ g/g	$\sim 2 \times 10^{-18}$ g/g
^{238}U	dust, metallic	10^{-5}–10^{-6} g/g	$< 10^{-16}$ g/g	$(5.0 \pm 0.9) \times 10^{-18}$ g/g
^{232}Th				$(3.0 \pm 1.0) \times 10^{-18}$ g/g
^{7}Be	cosmogenic	$\sim 3 \times 10^{-2}$ Bq/t	$< 10^{-6}$ Bq/t	not observed
^{40}K	dust, PPO	$\sim 2 \times 10^{-6}$ g/g (dust)	$< 10^{-18}$ g/g	not observed
^{210}Po	surface cont. from ^{222}Rn		< 7 c/d/t	May ’07: 70 c/d/t May ’09: 5 c/d/t
^{222}Rn	emanation from materials, rock	10 Bq/l air, water 100–1000 Bq/kg rock	< 10 cpd/100 t	< 1 cpd/100 t
^{39}Ar	air, cosmogenic	17 mBq/m^3 (air)	< 1 cpd/100 t	$\ll$ ^{85}Kr

Impact on the Neutrino Oscillation Model.





$Be\ unc.\ 5\%$

$rate: 45cpd$

$pep: uncert.\ 19\%$

$systematic$

$rate: 3.13cpd$

$^8B:\ uncert.\ 13\%$

$statistical$

$rate: 0.22\ cpd$

all solar + solar luminosity

- first observation of the oscillation in vacuum
- validation of the MSW - LMA model in the vacuum regime
- first determination of

$$\frac{P_{ee}^{VAC}}{P_{ee}^{Matter}} = 1.63 \pm 0.26$$

phase 1- may 2007- may 2010 (4 months of calibration included}

ACHIEVEMENTS:

measurement for the first time of the solar neutrino fluxes from **^{7}Be, pep, ^{8}B** with the threshold down to **3. MeV**;

best limit on the **CNO flux.**

Day/night effect found to be null in the ^{7}Be energy region

Annual modulation of solar neutrinos flux (±3.5%)

Evidence of **geoneutrinos** has been reached with C.L. at **4.2 σ** (previously Kamland at 2.5 σ).

#Limit on the neutrino Mag. Moment – see phase 2

study of rare phenomena reaching the best limits: on Pauli principle violation, antineutrino presence in the solar flux, existence of 5.5 MeV solar axions, etc.

Impact on the Sun physics

ν flux	GS98	AGS09	$cm^{-2}\ s^{-1}$	Experim. results
pep	1.44 (1±0.012)	1.47 (1±0.012)	x 10^8	1.6±0.3 Borexino
^{7}Be	5.00 (1±0.07)	4.56 (1±0.07)	x 10^9	4.87±0.24 Borexino
^{8}B	5.58 (1±0.14)	4.59 (1±0.14)	x 10^6	5.2±0.3 SNO+SK+Borex+Kamland 5.14 SNO-LETA N.C. 5.05 LETA ^{8}B total
^{13} N **^{15}O** **^{17}F**	2.96 (1±0.14) 2.23 (1±0.15) 5.52 (1±0.17)	2.17 (1±0.14) 1.56 (1±0.15) 3.40 (1±0.16	x 10^8 x 10^8 X 10^6	<7.4 Borexino

may 2010-october 1011 **further purification**

^{85}Kr (^{7}Be region)	< 7. cpd/100 tons 95% C.L.
^{210}Bi (pep and CNO region)	25.5±1.8 cpd/100 tons
^{238}U	< 8. 10^{-20} g/g
^{232}Th	< 9. 10^{-19} g/g

phase 2 october 2011- april 2015 (4 months of calibration included)

goals:

- § **neutrino flux from pp**- already achieved **(see Smirnov's talk)**
- § **improvement ^{7}Be flux- from 5% to 3%**
- § **measurement of ^{8}B flux in the range 3.-5. MeV- 13% uncertainty expected** (transition region)
- § **possibly improvement of pep flux uncertainty**
- § **better measurement of the seasonal variation of the solar neutrino flux (±3.5%)**
- § **NMM: 5.4 10^{-11} μ_B in phase 1- phase 2:** expected **3-4 $10^{-11}\mu_B$**- Gemma 2.8 **$10^{-11}\mu_B$** but in Borexino effective NMM

(see Testera's talk)

§ **geoneutrinos** –already achieved- statistics ~2.4 higher than the first paper
With respect to Kamland: less statistics and lower background

Cosmochemical and geochemical BSE models slightly favored
model; that means a radiogenetic heat of 11±2-20±4 TW

Indication at ~ 1σ of presence of radioactive elements in the mantle

Indication at ~ 1σ of an agreement of Th/U ratio with the chondritic ratio (3.9).

More statistics needed

§ **CNO-** problems with ^{210}Bi; energy spectra: similar shape, close each other, rate 2-3 time higher- solutions: knowledge of the Bi exact rate or reduce drastically the Bi rate- **strategy in Phase 2:** extract the ^{210}Bi rate from the ^{210}Po decay shape vs time- analysis in progress, but very difficult. Problems with the temperature changes and following convective movements- probable presence of particulate on the internal vessel walls

(see Testera's talk)

Phase 3 - april 2014-……….. ; goals: CNO and sterile neutrino

1- important debate within the collaboration if to proceed with a further purification to reduce ^{210}Bi-
2-study in progress for a thermal isolation of the detector

§ we will proceed with 2 if feasible. For 1 it has been not decided yet .
In any case 1 makes no sense without 2

§ **What is sure is that we will proceed with SOX**
Claims for the *reactor and Gallex source anomalies.* But also the results of *LNSD and MiniBooNE*- if a $\Delta m^2 \cong 1\ eV^2$ exists a fourth neutrino is needed
A ^{144}Ce-^{144}Pr source, activated at 2-4 PBq, placed in a tunnel below Borexino at ~ 7.5 m from the center of the detector; $\bar{\nu}_e$ emitter with an end energy point (^{144}Pr) of ~3MeV (inverse beta decay threshold 1.8 MeV).
Similar procedure with a ^{51}Cr source activated at 200-400 PBq; ν_e emitter at two energies: 750 (90%) and 430 (10%) keV. E/L similar to MiniBooNE and LNSD, but different flavor of neutrinos.

Acknowledgments to the present co-spokesmen: Cristiano Galbiati, Marco Pallavicini (who now left for another commitment), Gioacchino Ranucci, the analysis groups (see Smirnov's and Testera's talks), and all collaboration members

In the mean time life goes on

Cristina Arpesella
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Emma
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Ascanio
Adelfi
Michela
Matilde
Anna
Riccardo
Chiara
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Leonardo
Amelie
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Verena
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Alice
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