



**Borexino/DarkSide:
recent results and project
proposal for the next 3 years
(2019-2021)**

O. Smirnov (DLNP)

, January 31, 2018

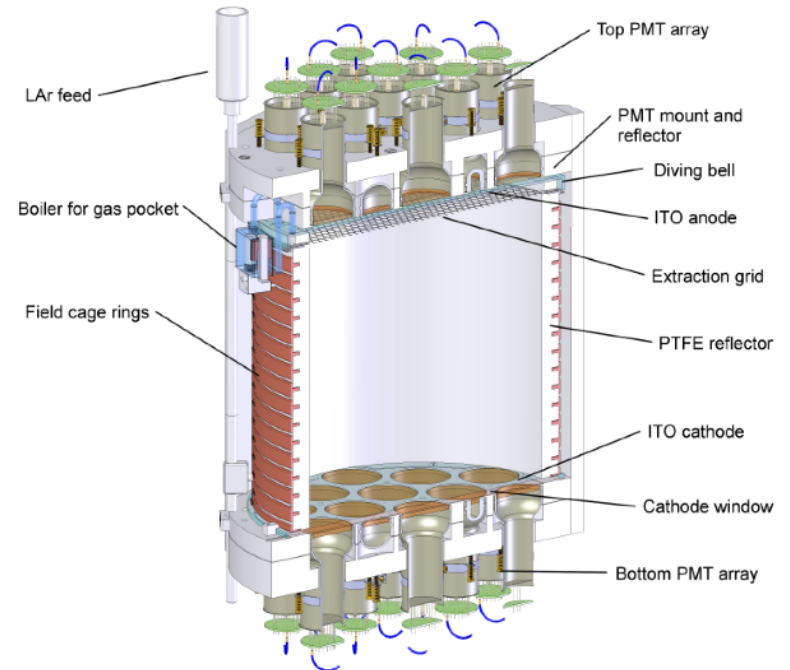
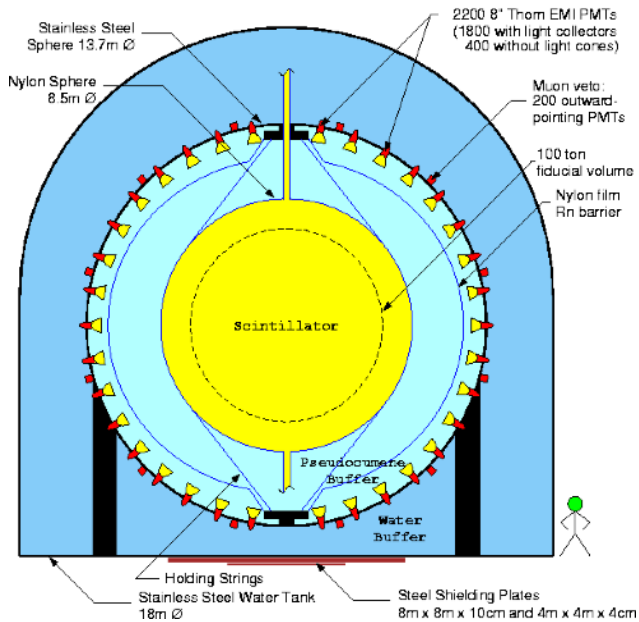
BOREXINO/DARKSIDE



LOW-RADIOACTIVITY
UNDERGROUND
ARGON

Large volume LS detector

2-Phase Argon TPC



Borexino Phase-II physics program

- Improvement of the ${}^7\text{Be}$ -neutrino flux (3%) and its seasonal variations (5σ)
- Measurement of *pep*-neutrino flux with better than 3σ accuracy $\rightarrow 5\sigma$
- ${}^8\text{B}$ -neutrino flux measurement with 10% accuracy (x4 higher statistics) $\rightarrow 8\%$
- Limits on effective solar neutrino magnetic moment $\rightarrow \times 2$
- Improvement of geo-neutrino flux measurement \rightarrow planned for 2018
- Study of non-standard neutrino interactions (NSI) \rightarrow planned for 2018
- Measurement (or limits on) of the CNO-neutrino flux $\rightarrow 2019-2021$
- Measurements with artificial neutrino sources – search for sterile neutrinos and neutrino magnetic moment: SOX project (Short distance Oscillations with BoreXino) $\rightarrow 2019-2021$
- Dark Matter search with the updated Borexino's prototype detector (CTF): DarkSide project. DarkSide-50 (50 kg of liquid Underground Ar (UAr), sensitivity at $2 \cdot 10^{-44} \text{ cm}^2$ for 100 GeV WIMP over 3 year statistics), first results are obtained. DarkSide-G2 (the second generation, 3.3 t of UAr). Expected sensitivity is $2 \cdot 10^{-47} \text{ cm}^2$ for WIMP-nuclei scattering over 5 year statistics, that is 400 times better than the current level.

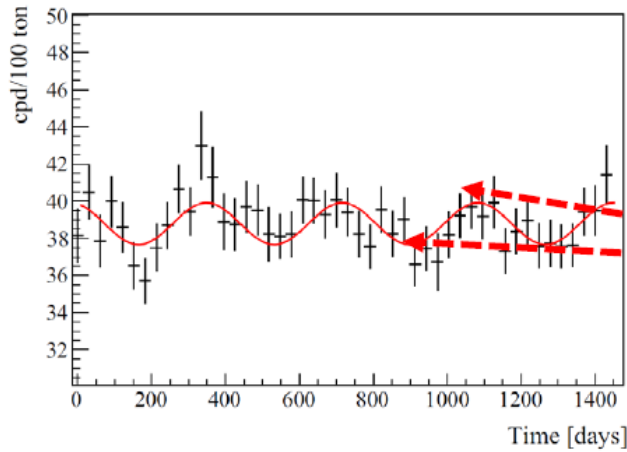
Dubna group contribution

- Analytical procedure for spectral analysis (Vishneva+Smirnov)
- Pile-up modeling (Korablev+Vishneva)
- ${}^7\text{Be}+pp$ (Vishneva+Smirnov)
- Magnetic moment (Vishneva+Smirnov)
- NSI (Formozov)
- geo-neutrino (Smirnov)

- Participation in the SN group of DS (Sheshukov)
- Analysis of the ${}^{39}\text{Ar}$ data (Samoylov+Sheshukov+Smirnov)
- MC tuning of the DS20k configuration (Gorchakov+Fomenko)
- SiPM modeling (Gorchakov)
- PMT tests (Sotnikov+Korablev)

Seasonal modulations of ${}^7\text{Be}$ neutrino flux

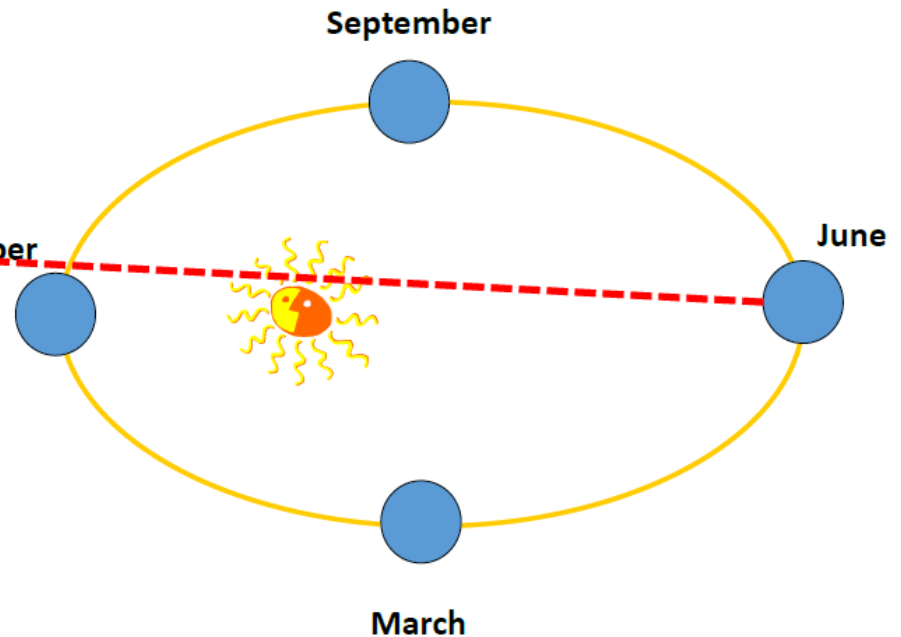
M. Agostini et al. / Astroparticle Physics 92 (2017) 21–29



Fit to the evolution
of the rate in time
(bin of 30 days)

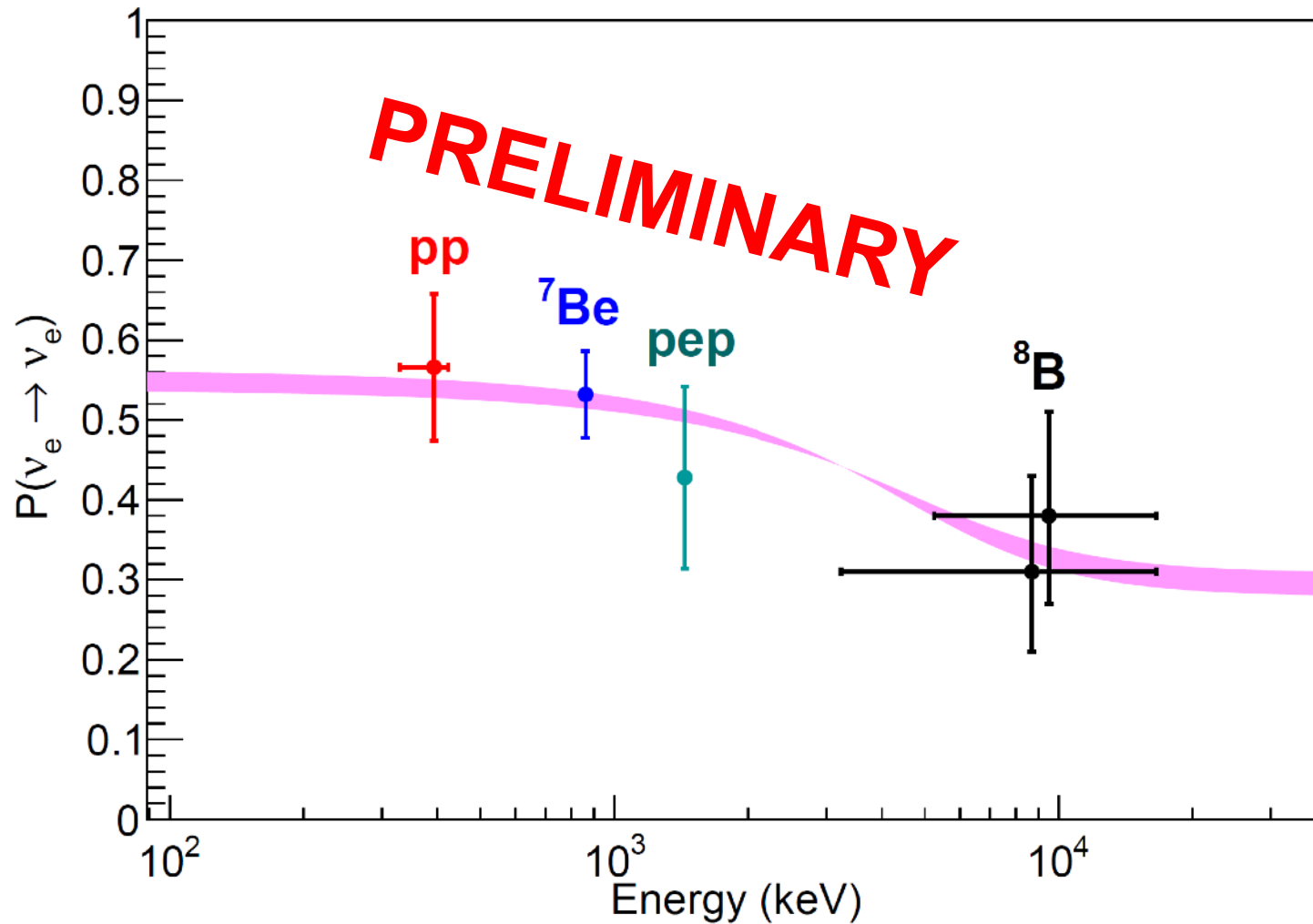


$$\begin{aligned}\epsilon &= (1.74 \pm 0.45)\% \\ T &= (367 \pm 10) \text{ days} \\ \Phi &= (-18 \pm 24) \text{ days}\end{aligned}$$



The duration of the astronomical year is measured from underground using neutrino!

Borexino results on solar neutrinos (to be published in 2018)



...and more beyond the original proposal

- **M. Agostini et al. (The Borexino collaboration), “Borexino’s search for low-energy neutrino and antineutrino signals correlated with gamma-ray bursts”, *Astroparticle Physics* 86, p.11, 2017.**
- **M. Agostini et al. (The Borexino collaboration), “A Search for Low-energy Neutrinos Correlated with Gravitational Wave Events GW 150914, GW 151226, and GW 170104 with the Borexino Detector”, *The Astrophysical Journal*, 850:21 (2017).**

DarkSide:

- **P. Agnes et al. (DarkSide Collaboration), “Results from the first use of low radioactivity argon in a dark matter search.” *Physical Review D*, 93 (2016).**
- **DS20k yellow book : arXiv:1707.08145v1 : 2017 (JINST) – project of G2 LAr detector**

Dubna group in 2017

- **7 publications (collaboration), 3 publications in proceedings, 6 talks at the conferences, 8 poster presentations, 1 lecture, 6 seminars.**

DarkSide

^{39}Ar abundance in underground argon has been studied (factor 1500 lower than in atmospheric).

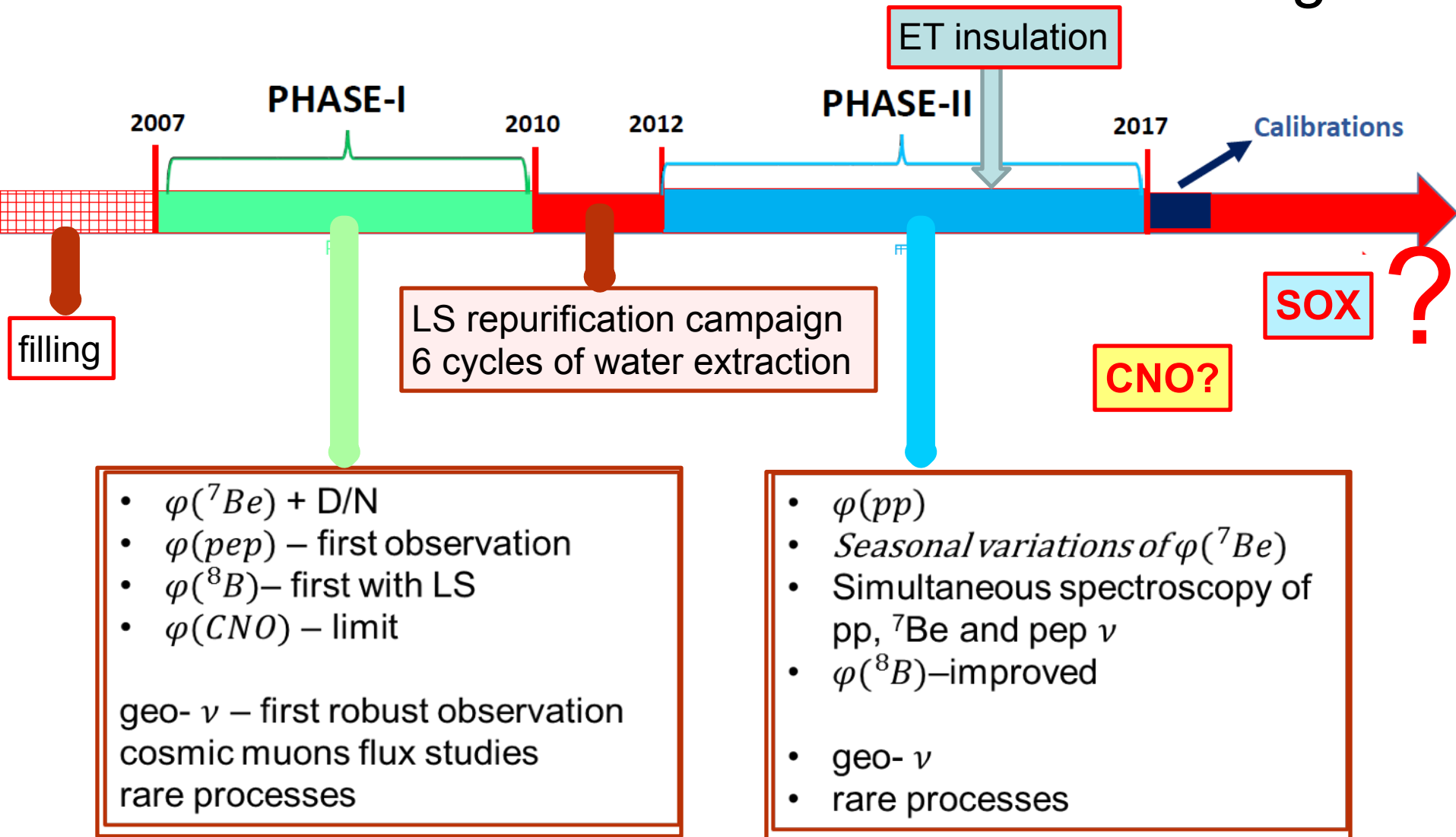
Demonstrated discrimination coefficient for ER/NR at the level of 3×10^9

In “search for the DM” mode (exposition 2616 ± 43 kg days) limit has been obtained on spin-independent WIMP-nucleon cross section of 2.0×10^{-44} cm² for WIMP with mass 100 GeV.

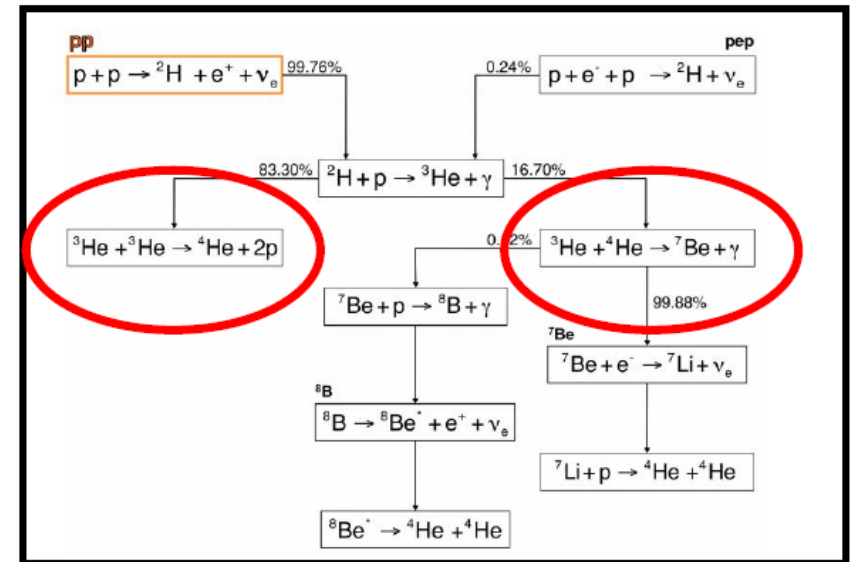
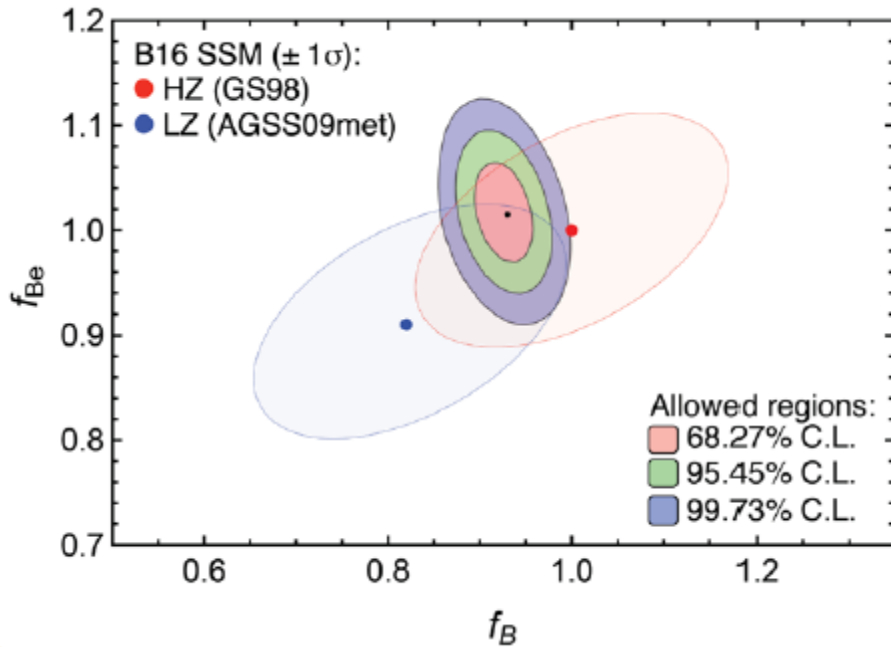
P. Agnes et al. (DarkSide Collaboration), “Results from the first use of low radioactivity argon in a dark matter search.” *Physical Review D*, 93 (2016)

DS-50 continues to take data, total exposition corresponds to 650 days of live time, data are being prepared for blind analysis.

Borexino since the start of the data taking



Solar metallicity problem



$$R \equiv \frac{\langle {}^3\text{He} + {}^4\text{He} \rangle}{\langle {}^3\text{He} + {}^3\text{He} \rangle} = \frac{2\phi({}^7\text{Be})}{\phi(\text{pp}) - \phi({}^7\text{Be})}$$

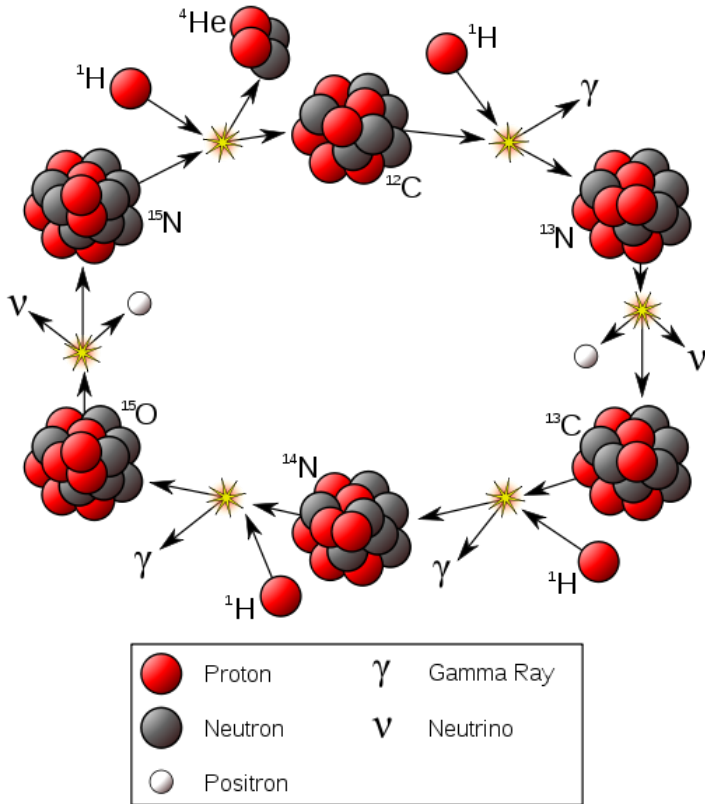
$$R(\text{HZ}) = 0.18 \pm 0.01$$

$$R(\text{LZ}) = 0.16 \pm 0.01$$

From the pp and ${}^7\text{Be}$ flux new measurement

$$R = 0.18 \pm 0.02$$

CNO



Prediction for HZ ~ 5 cpd/100 t

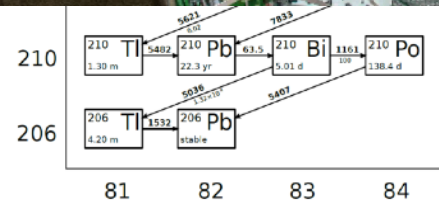
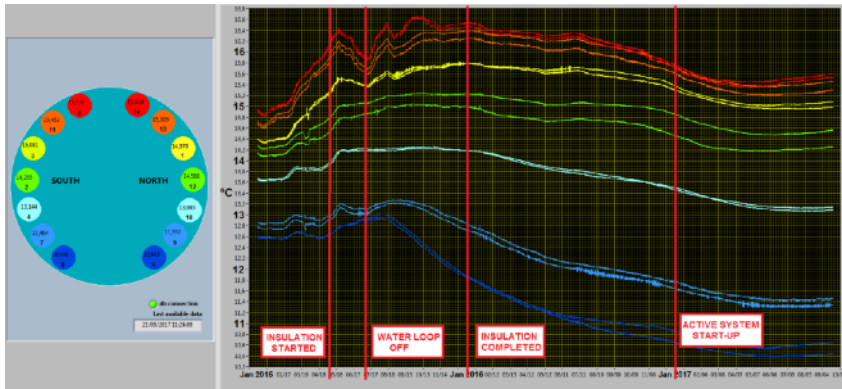
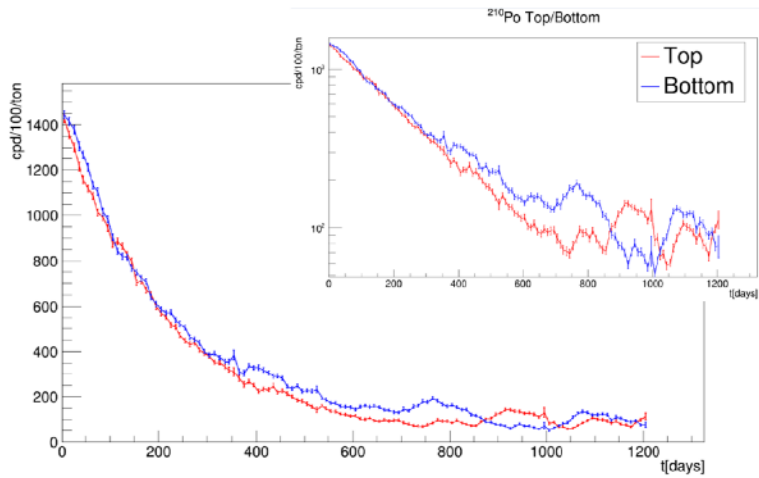
LZ ~ 3 cpd/100 t

Main background from ^{210}Bi :

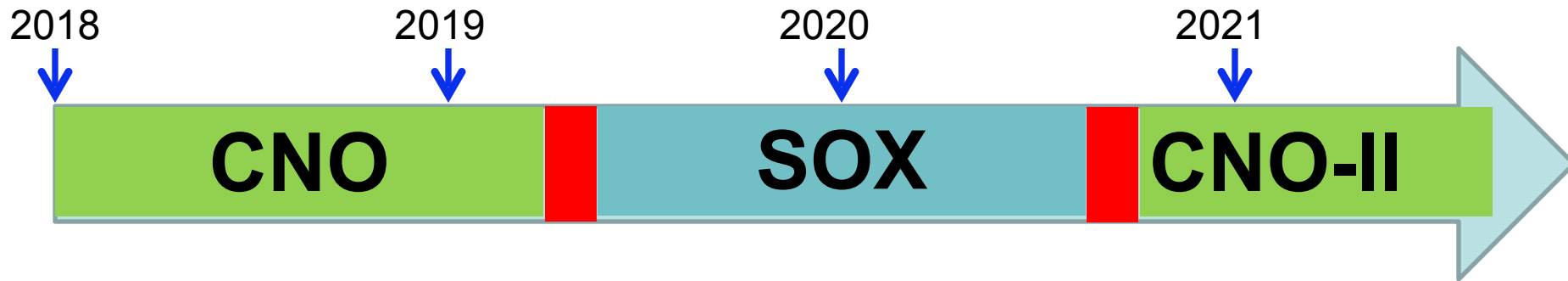
~ 20 cpd/100 t

If we will be able to extract ^{210}Bi with few counts precision, we will be able to constraint it in the spectral fit and extract the CNO flux at $1-2\sigma$ level.

Thermoinsulation of the external tank



Borexino in 2018-2021



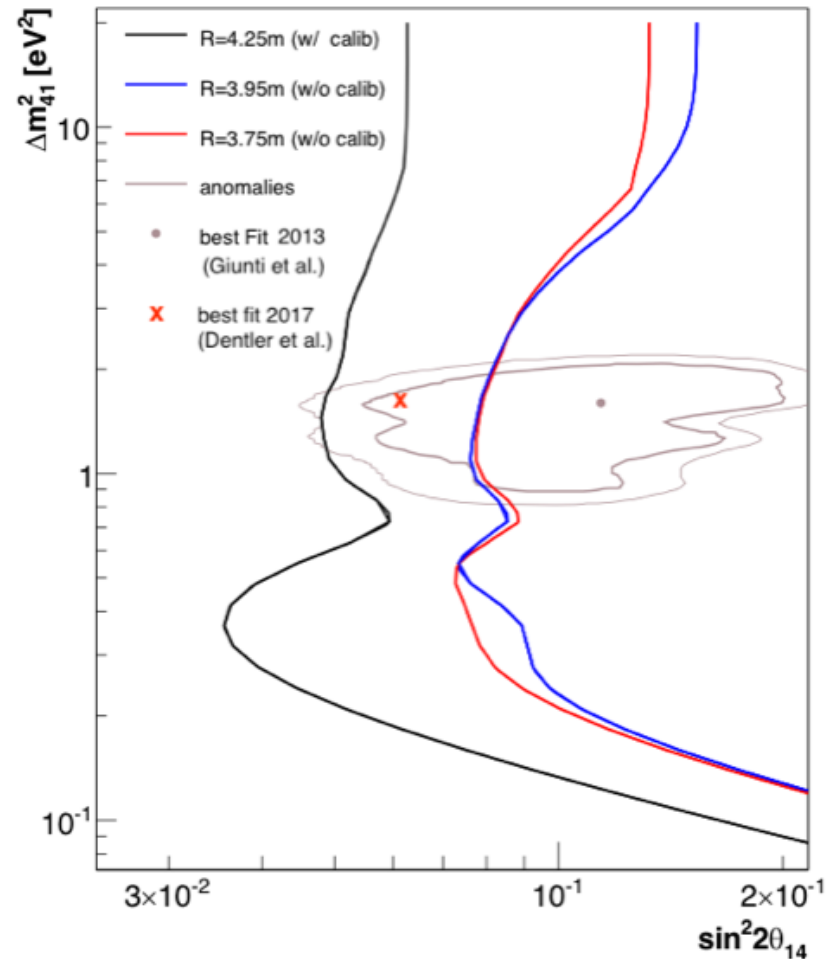
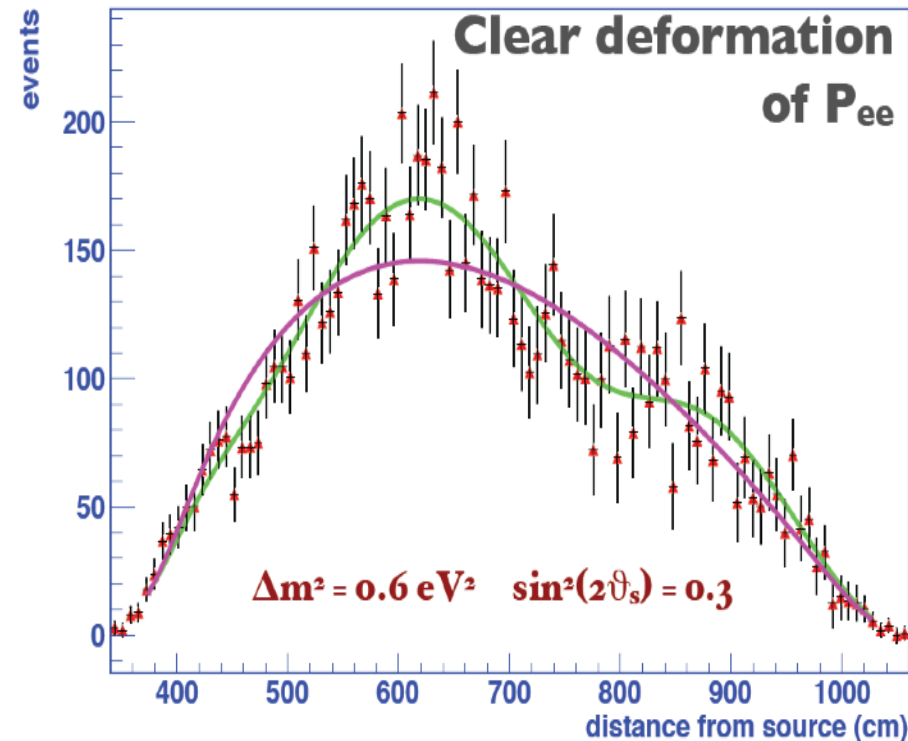
 Calibration campaigns

CNO-II – possible project of LS purification from ^{210}Bi (under discussion in collaboration)

- CNO
- geoneutrino (x2 on statistics)
- pp-neutrinos (+Phase I)
- NSI

Short distance Oscillations with Borexino: SOX

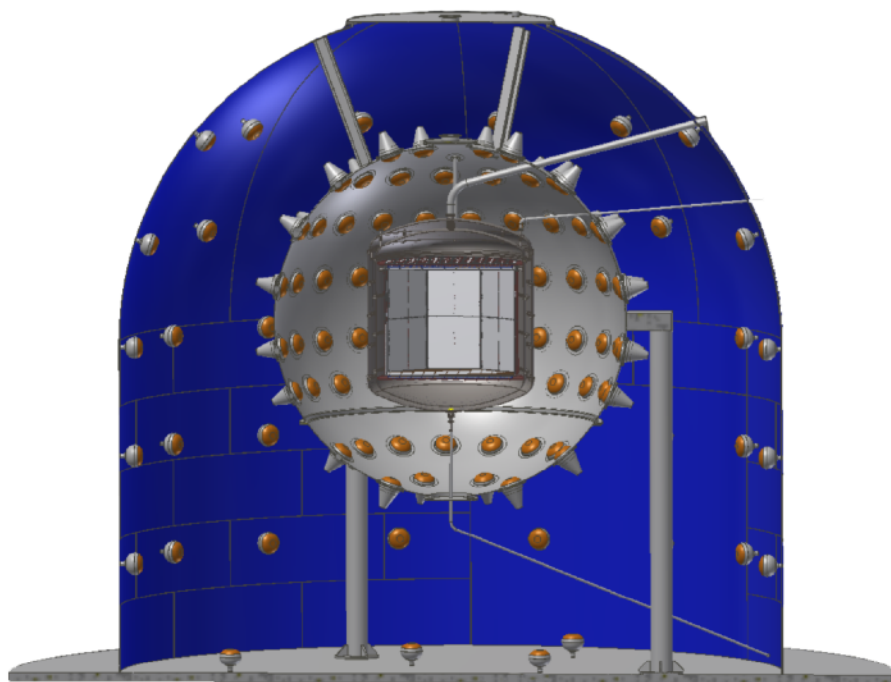
- external source of anti-neutrinos ^{144}Ce : 150 kCi.



JINR group involvement

| Name | Position | Responsibilities | FTE |
|----------------|-------------------|---|-----|
| Smirnov O.Yu. | Senior Researcher | Administrative tasks, R&D, data analysis (Borexino/DS) | 0.7 |
| Gorchakov O.E. | Senior Researcher | MC/Geant4, data analysis (DS) | 0.5 |
| Fomenko K.A. | Researcher | MC/Geant4 (Borexino/DS) | 0.5 |
| Formozov A.A. | PhD student | R&D, data analysis (Borexino) | 0.5 |
| Korablev D.E. | Researcher | PMT tests, electronics (DS) | 0.4 |
| Samoylov O.B. | Head of sector | software, data handling (DS) | 0.3 |
| Sheshukov A.S. | Researcher | software, data analysis, SN group representative (DS) | 0.3 |
| Sotnikov A.P. | Engineer | hardware, electronics, PMT tests (Borexino/DS) | 0.4 |
| Vishneva A.V. | Engineer | data analysis (Borexino) | 1.0 |

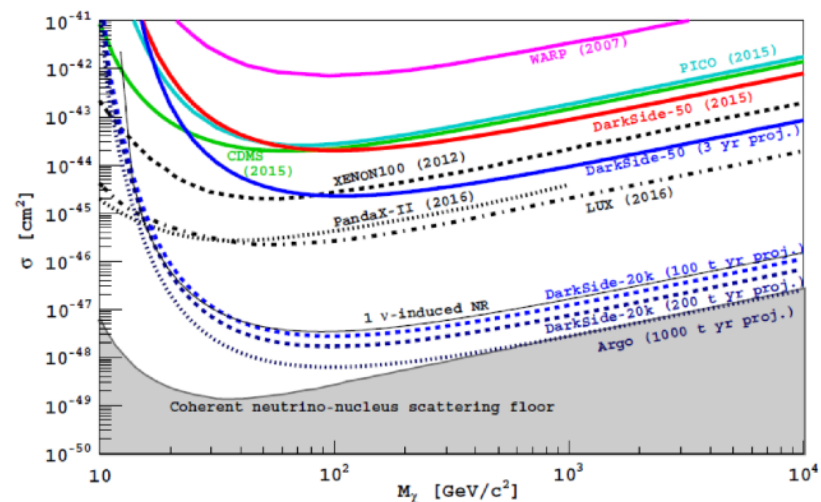
DS20k



Subprojects:

ARIA : underground radon

URANIA : isotope separation

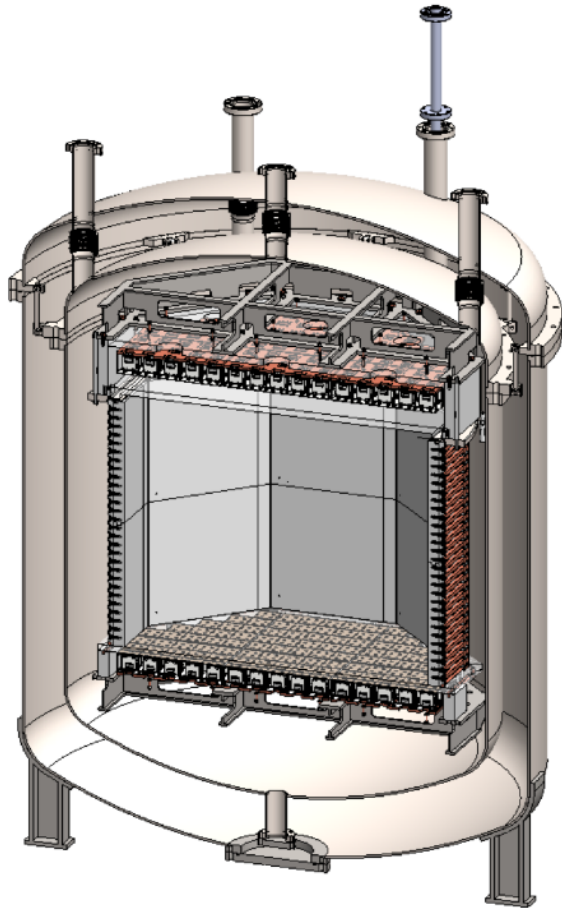


**04/2017: Funded by INFN to be hosted at LNGS
+Italian government, regione Abruzzo and
Regione Autonoma della Sardegna**

**ArDM(LSC),DS50(LNGS),DEAP3600 and MiniCLEAN
(SNOlab) agreed to join forces to carry out DS20k as
a single G2 experiment : Global Argon Dark Matter
Collaboration (GADMC)**

**08/2017 : officially supported by LNGS+LSC+SNOlab
10/2017 : NSF approved DS20k construction proposal
+ approval obtained for existing Canadian funding
from CFI for extraction of underground Ar.**

DarkSide Proto (~1 t prototype)



Construction in 2018 at CERN

Tests till 2019

Test of photodetector modules (PDMs)

Our plans in brief

- Borexino data analysis :
 - further improvements of pp-neutrino flux measurement (10%→6-7%)
 - geo-neutrino with full statistics and better selection cuts (x2 in exposition)
 - attempt to solve solar metallicity puzzle (CNO+Be/B+R)
- SOX
- development, tests and production of the magnetic shielding of the large volume PMTs
- MC studies of the DS20k configuration
- Geant4 based MC of SiPM
- Analysis of DS50 data (^{39}Ar shape)
- Estimates for possible solar neutrino program/rare physics with G2 and G3 LAr detector

| № | TASKS | Total costs (kUSD) | 2019 | 2020 | 2021 |
|-----------------------------|---------------------------------|-----------------------|-------------|-------------|-------------|
| Direct costs of the Project | | | | | |
| 1. | Materials and equipment | 15.0 | 5.0 | 5.0 | 5.0 |
| 2. | Travel resources | 57.0 | 19.0 | 19.0 | 19.0 |
| | Total direct cost (kUSD) | 72.0 | 24.0 | 24.0 | 24.0 |

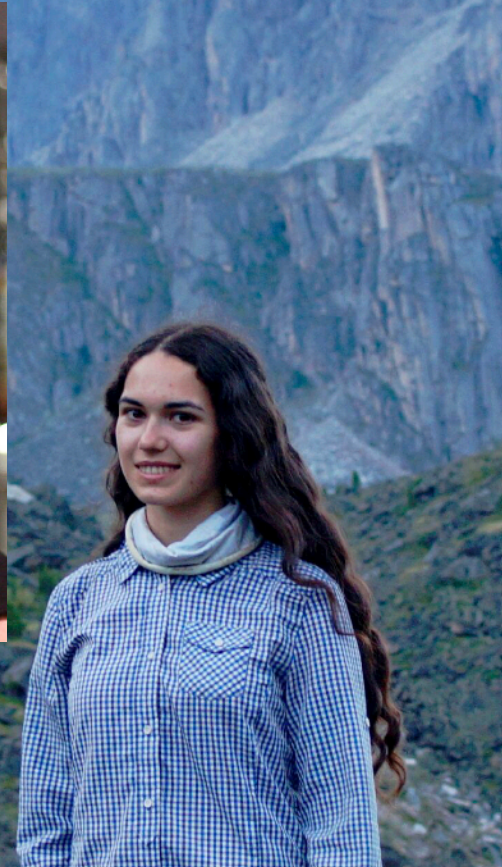
Response to referee

As also mentioned in the SWAT analysis the referee sees serious risks for the SOX activities, mostly in relation to the availability of the intense source and to the related authorizations.

SOX is delayed by 1 yr. More time for CNO program

Moreover, the referee is concerned by the consistence of the group: 9 people with 4.5 FTs, no one at 100% and only one student, who regrettably is working only at 50%.

Vishneva is a PhD student



This issue should be better developed in the open presentation, making the specific JINR group contributions in the last period more evident, with emphasis on young researchers and leadership positions.

Dubna group contribution

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- **Pile-up modeling (Korablev+Vishneva)**
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