BOREXINO achievements and prospects

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On behalf of the BOREXINO Collaboration

Astroparticle Physics in Poland , 20-22.09.2017 Krakow, Poland

Outline

- BOREXINO detector
- Achievements
- Prospects
- Summary

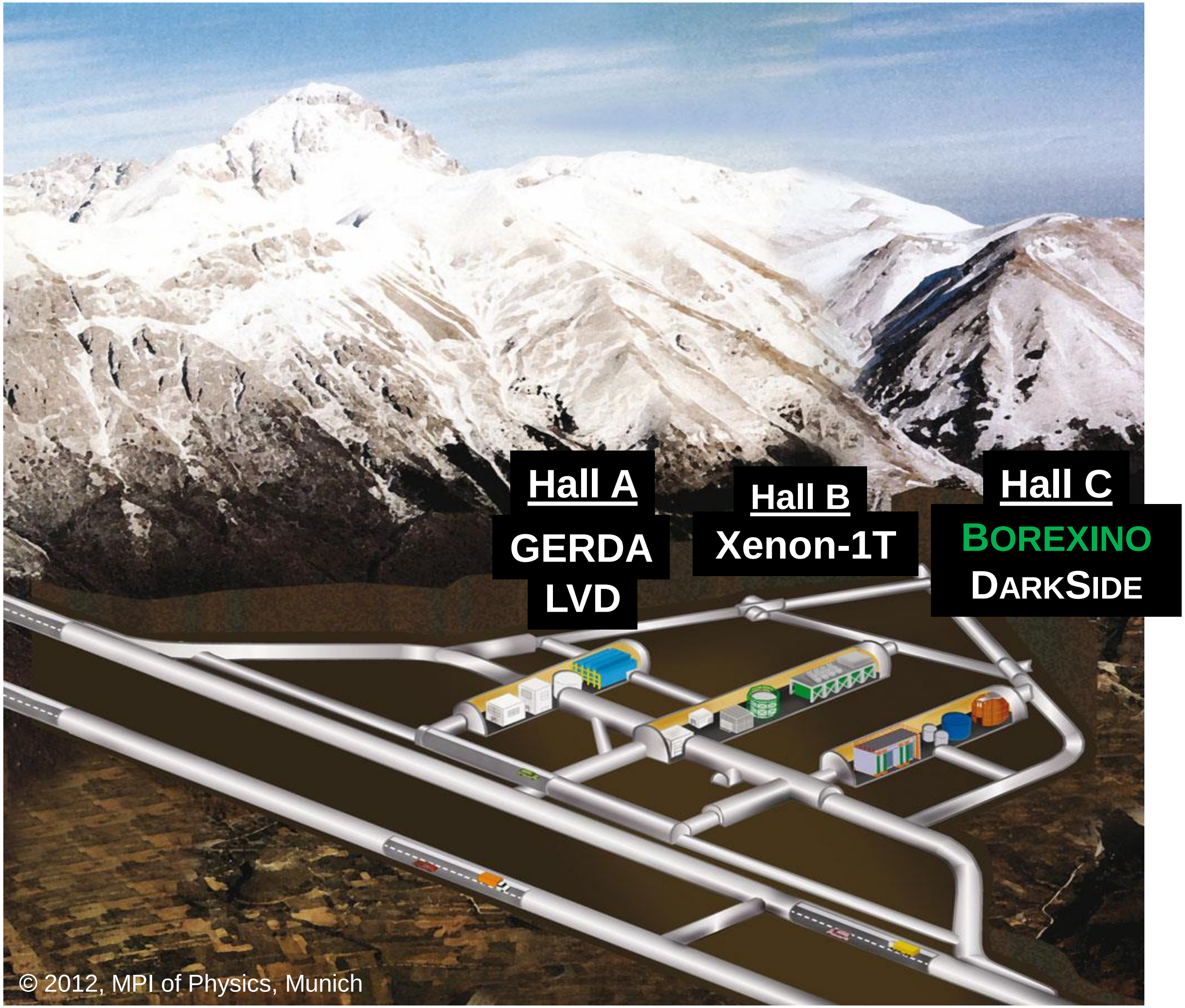
BOREXINO at LNGS

BOREXINO

Achievements

Prospects

Summary



BOREXINO Collaboration

UNIVERSITÀ DEGLI STUDI DI MILANO

INFN

LNGS

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UNIVERSITÀ DEGLI STUDI DI GENOVA

NATIONAL RESEARCH CENTER "KURCHATOV INSTITUTE"

St. Petersburg Nuclear Physics Inst.

TUM Technische Universität München

University of Houston

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THE UNIVERSITY OF CALIFORNIA UCLA

TECHNISCHE UNIVERSITÄT DRESDEN

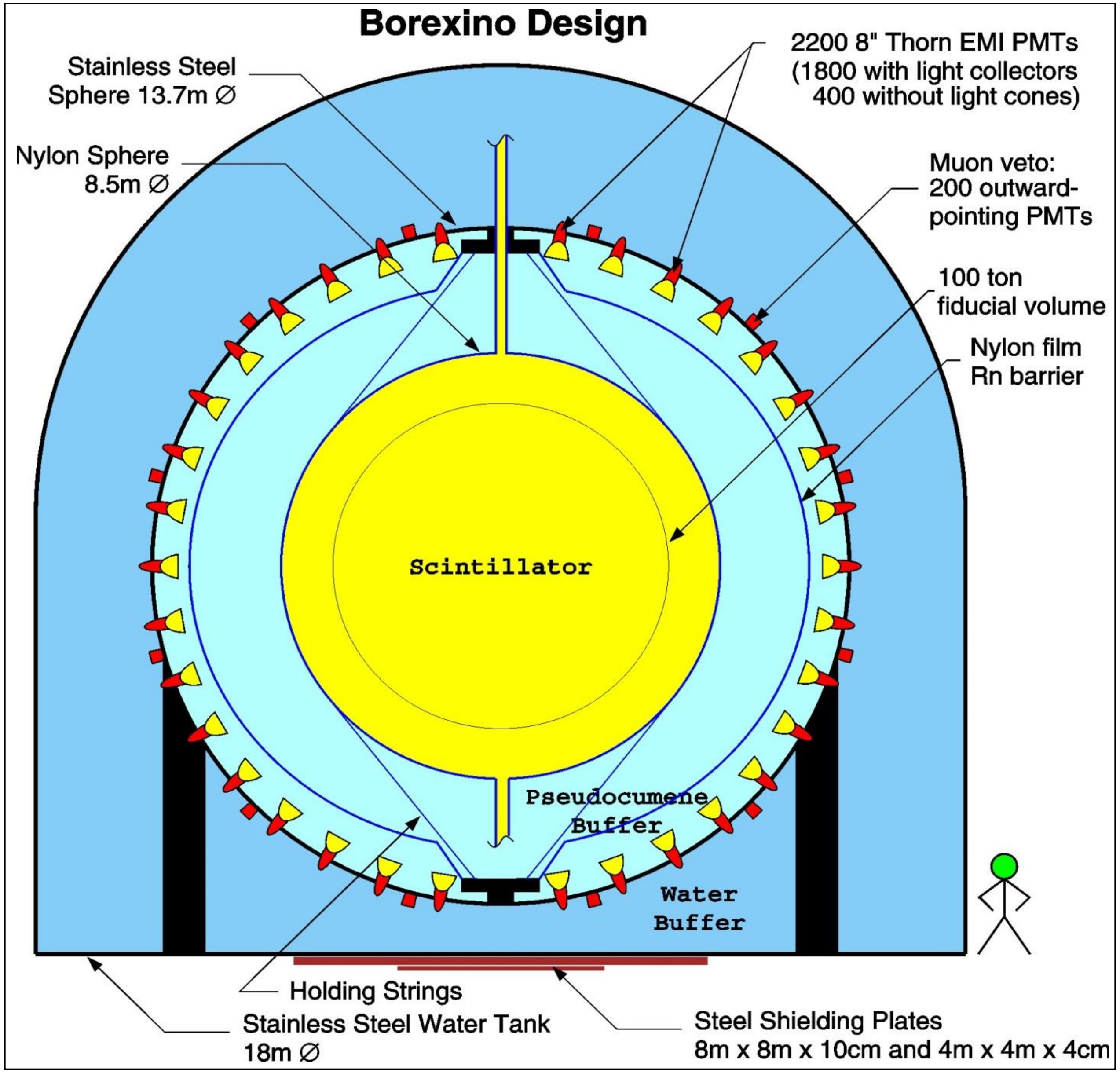
APC

STUDIUM GENERALE CIVITATIS PERUSII

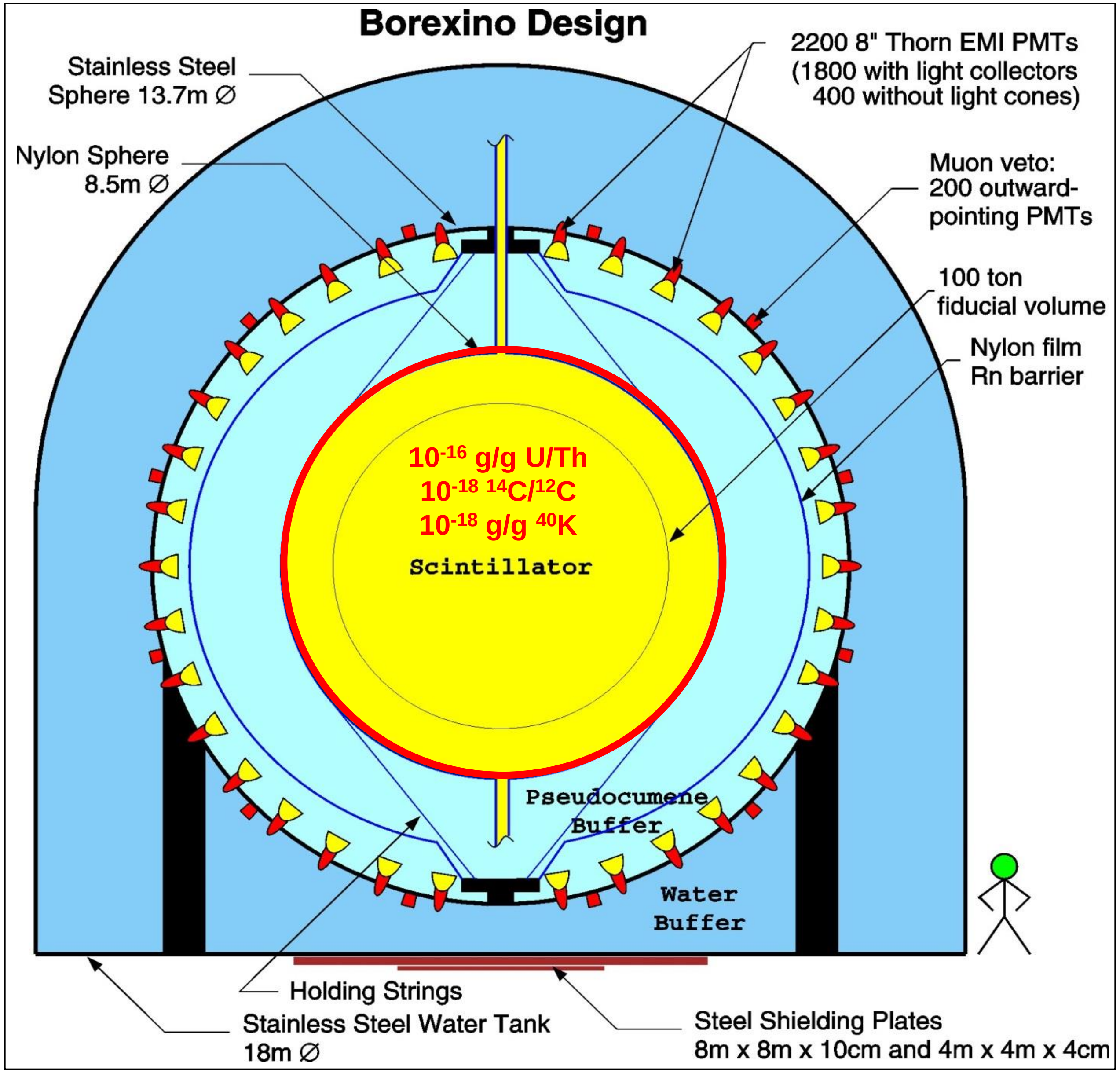
POLITECNICO MILANO 1863

24 institutions, 6 countries (Europe/USA), ~100 physicists

BOREXINO design



BOREXINO design



CTF – testing the scintillator

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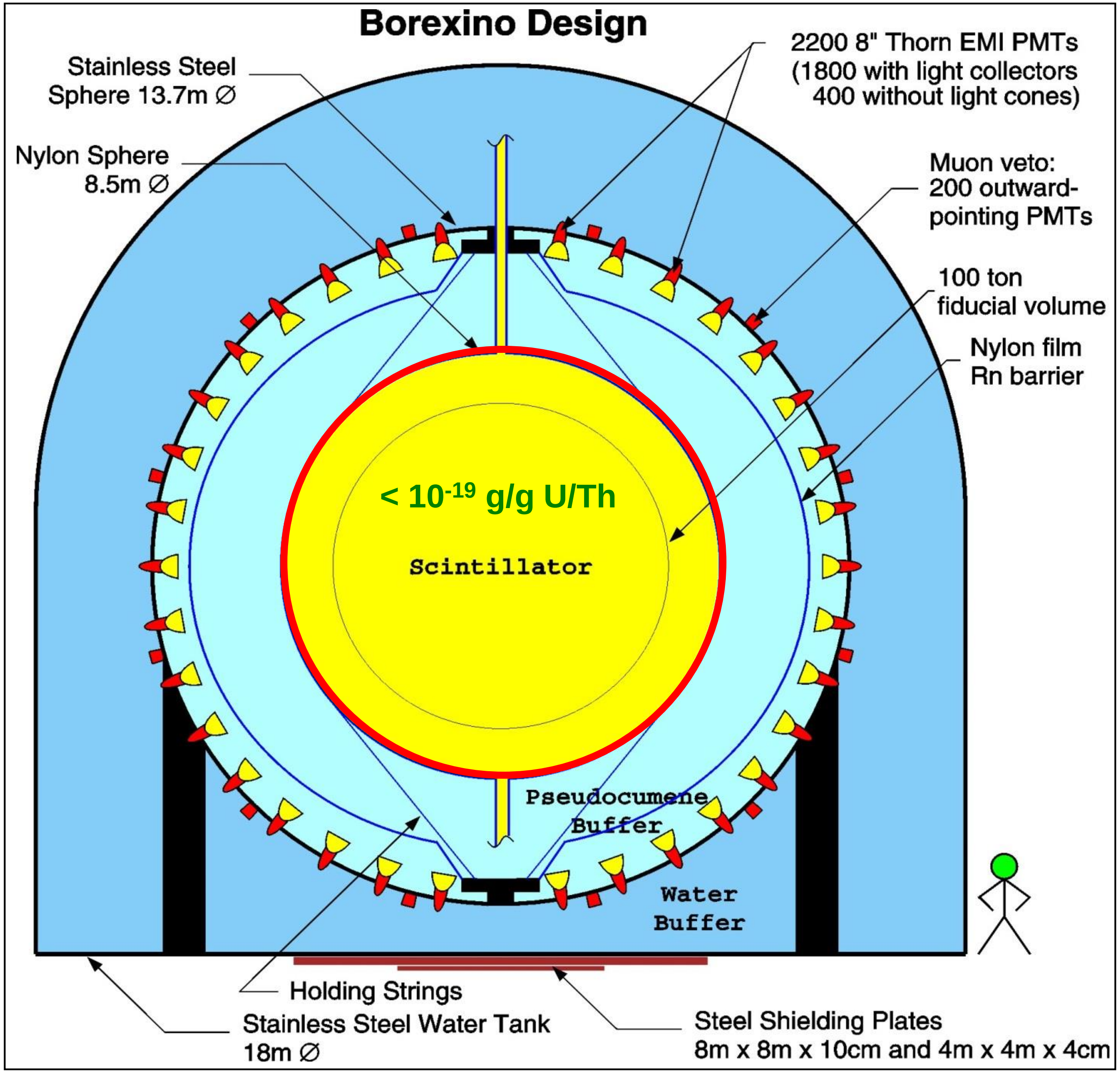
CFT – 1: 1995
CTF – 2: 2000
CTF – 3: 2001-2003

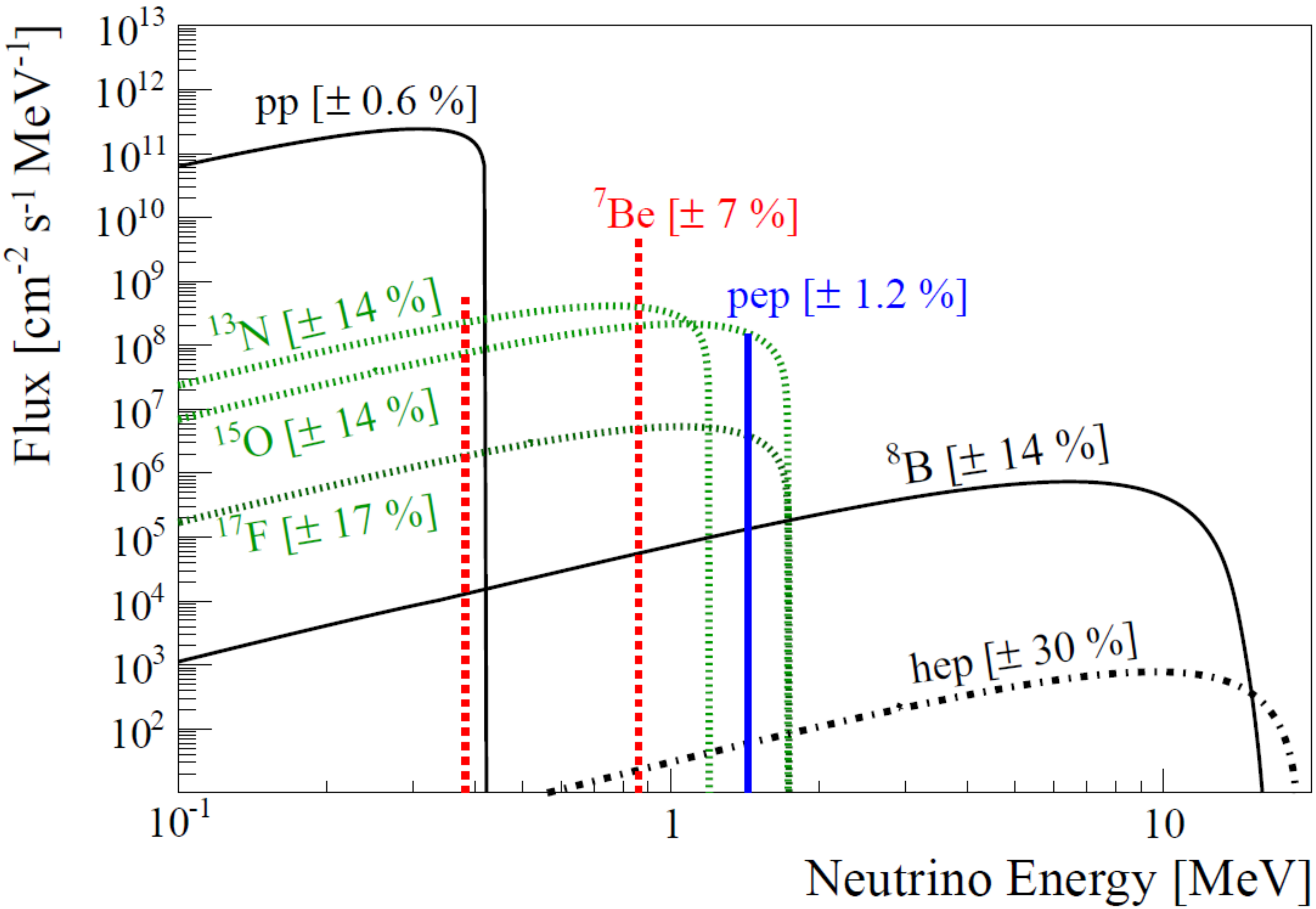
- Phys. Lett. B, 422, 349 (1998)
- Astrop. Phys. 8(3), 141 (1998)
- NIM A406, 411 (1998)
- Physics Letters B 525, 29 (2002)
- Physics Letters B 563, 23 (2003)
- Physics Letters B 563, 37 (2003)
- JETP Lett. 78 No 5, 261 (2003)
- Eur. Phys. J. C 37, 421 (2004)
- Eur. Phys. J. C 47, 21 (2006)
- Phys. Rev. C 74, 045805 (2006)

$$\frac{^{14}C}{^{12}C} \sim 10^{-18} \qquad C_{U/Th} \sim 4 \times 10^{-16}\ g/g$$

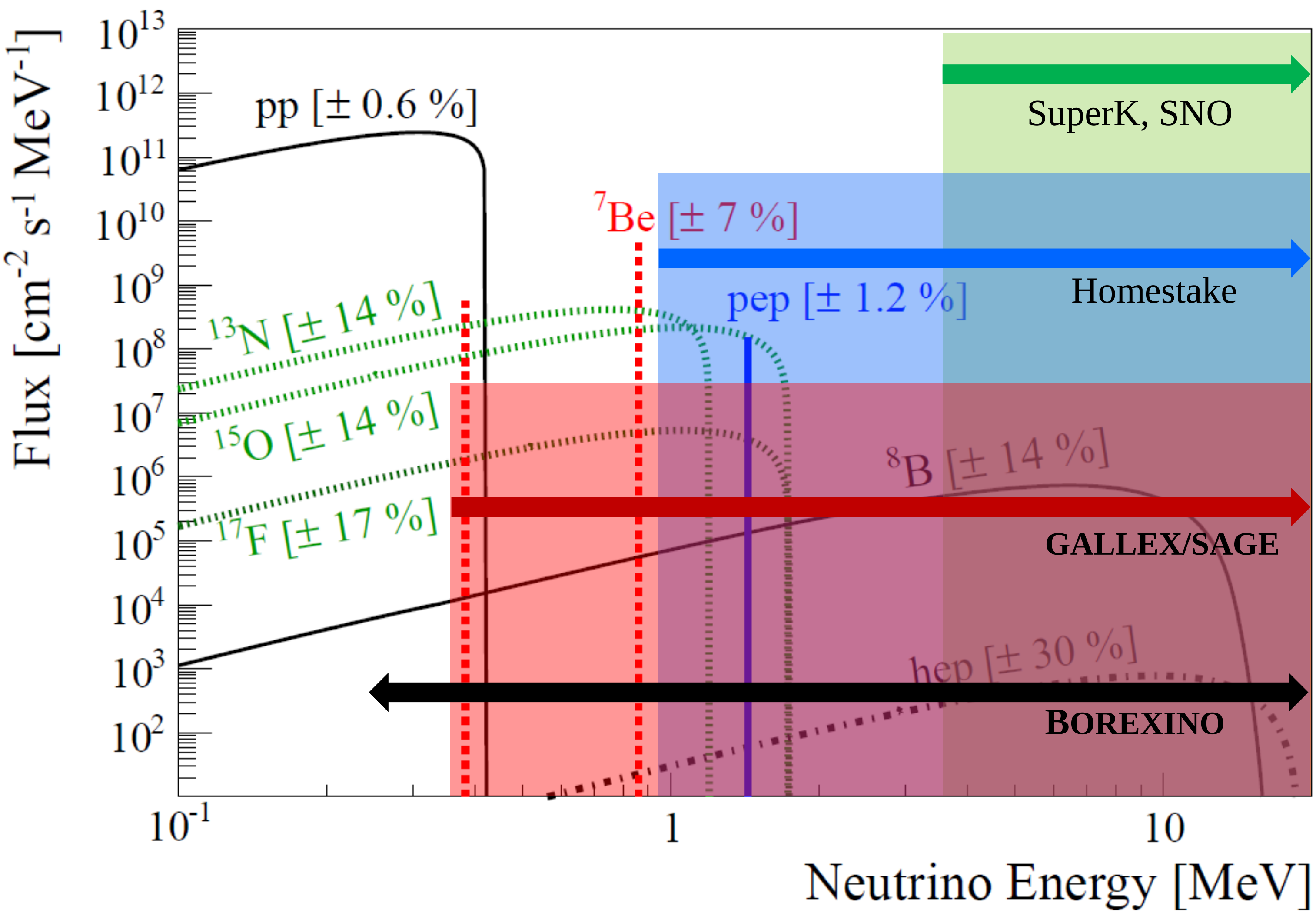
BOREXINO design



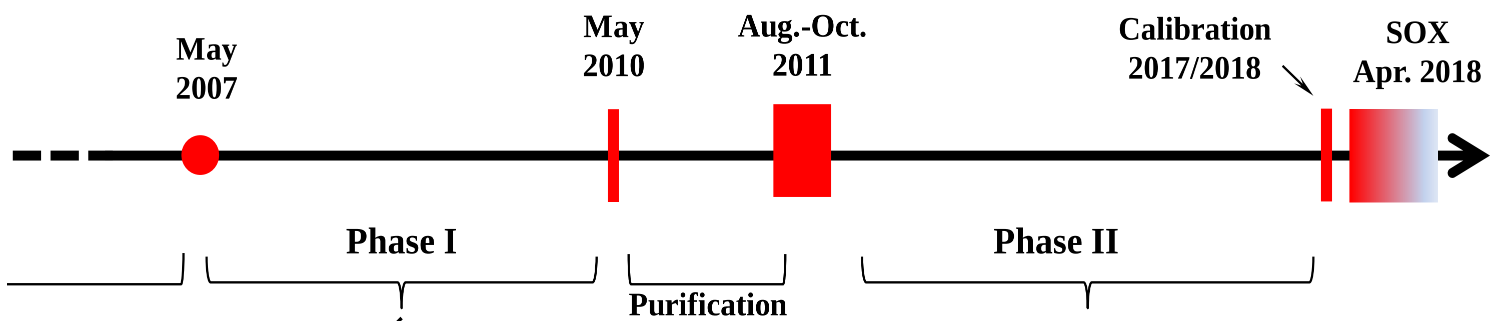
BOREXINO and solar neutrinos



BOREXINO and solar neutrinos



BOREXINO time-line



- (First) solar ^{7}Be-ν measurement
- Low-threshold ^{8}B-ν
- First pep-ν detection
- Best upper limit on CNO-ν
- ^{7}Be-ν day-night asymmetry
- First geo-ν observation at > 4σ
- Muon seasonal variations
- Limits on rare processes

- Measurement of pep-ν flux
- Measurement of pp-ν flux
- Improved ^{7}Be-ν (5%)
- Improved ^{8}B-ν
- ^{7}Be-ν seasonal modulation
- Updated geo-ν flux
- Limit on μ_B

SOX – see next talk by M. Misiaszek

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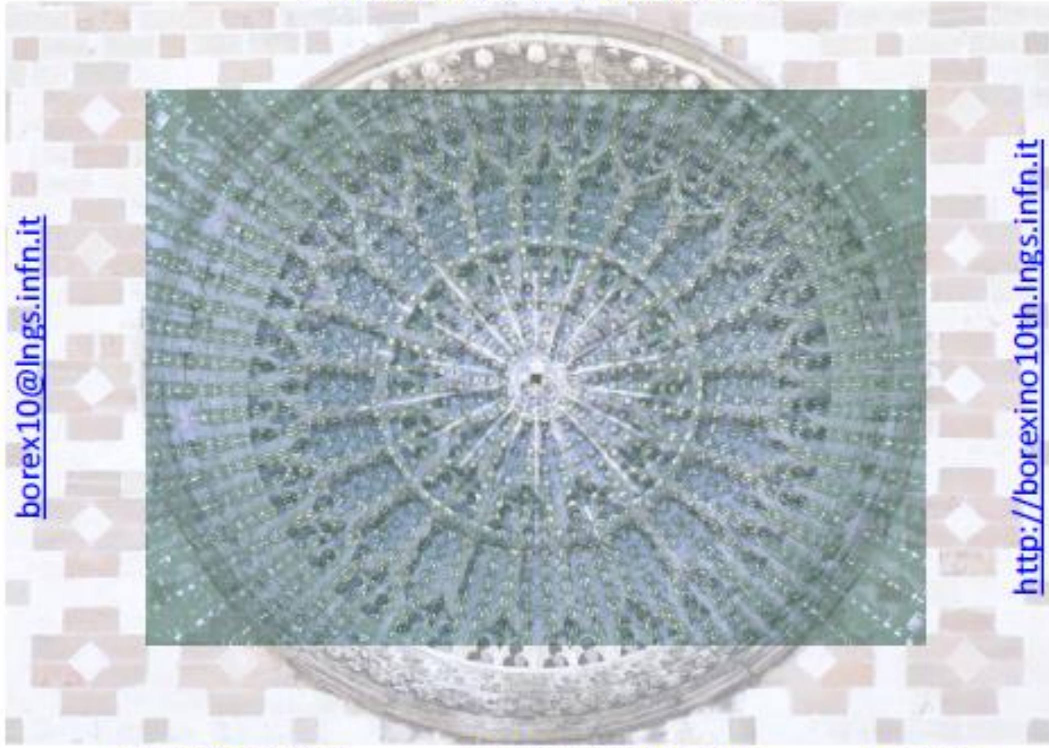
RECENT DEVELOPMENTS IN NEUTRINO PHYSICS AND ASTROPHYSICS

The Borexino Collaboration celebrates in L'Aquila (Italy) the 10° anniversary of data-taking

SEPTEMBER 4-7, 2017 @ LNGS and GSSI

borex10@lngs.infn.it



http://borexino10th.lngs.infn.it

Scientific Committee

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Gianpaolo Bellini
Olga Botner
Frank Calaprice
Mark Chen
Eugenio Coccia
Fernando Ferroni
Fabio Finelli
Cristiano Galbiati
Luigi Guzzo
Kunio Inoue
Takaaki Kajita
Art MacDonald
Antonio Masiero
Victor Matveev
Marco Pallavicini
Georg Raffelt
Stefano Ragazzi
Gioacchino Ranucci
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Tiina Suomijarvi
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Yoichiro Suzuki
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Expected vs measured fluxes

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Rates in cpd/100 t

Solar ν	BOREXINO	B16(GS98)-HZ	B16(AGSS09)-LZ
pp	$134 \pm 10^{+6}_{-10}$	131.0 ± 2.4	132.1 ± 2.3
^{7}Be	$48.3 \pm 1.1^{+0.4}_{-0.7}$	47.8 ± 2.9	43.7 ± 2.6
pep (HZ)	$2.43 \pm 0.36^{+0.15}_{-0.22}$	2.74 ± 0.05	2.78 ± 0.05
pep (LZ)	$2.43 \pm 0.36^{+0.15}_{-0.22}$	2.74 ± 0.05	2.78 ± 0.05
^{8}B	$0.22 \pm 0.04 \pm 0.01$	0.211 ± 0.025	0.173 ± 0.021
CNO	< 8.1 (95% C.L.)	4.91 ± 0.56	3.52 ± 0.37

- High precision of the ^{7}Be flux measurement
- Φ(Be/B) – hint for HZ
- CNO-ν flux a good proxy for Z/H scenario

Survival probability

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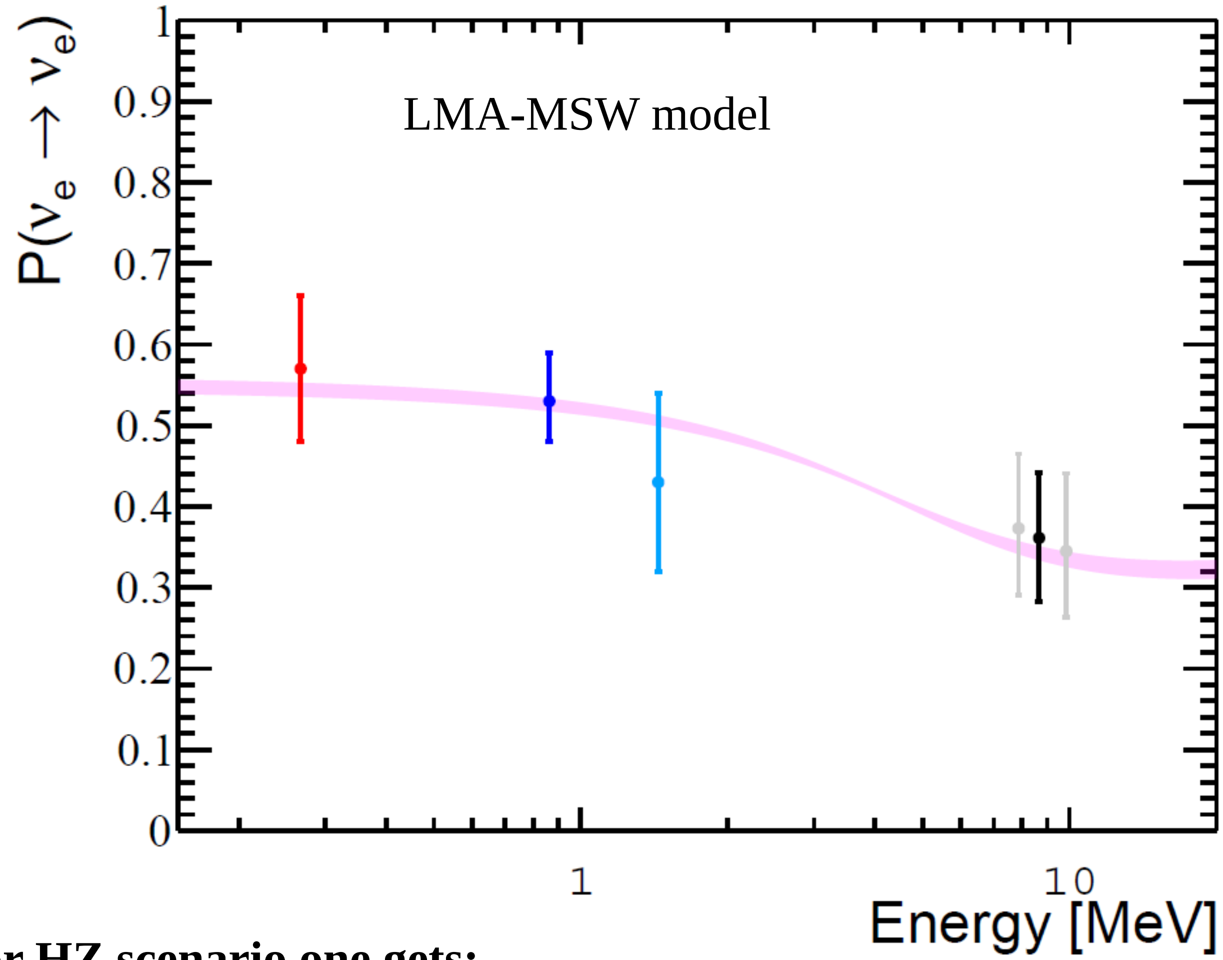

For HZ scenario one gets:

$P_{ee}(pp) = 0.57 \pm 0.10$ $P_{ee}(^{7}Be) = 0.43 \pm 0.11$

$P_{ee}(pep) = 0.53 \pm 0.05$ $P_{ee}(^{8}B) = 0.36 \pm 0.08$

Future of BOREXINO

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- Towards measurement of CNO-ν
  - ➢ Lower ^{210}Bi background is required
    - CNO high metallicity rate is ~5 cpd/100 t
    - ^{210}Bi is still too high at ~20 cpd/100 t: reduction to 2 cpd/100 t is needed (measurement via ^{210}Po)
  - ➢ Knowledge of energy spectrum of ^{210}Bi
  - ➢ Improved energy calibration (±1 %)
  - ➢ Control of detector temperature (ΔT < 0.1 C/month) – thermal insulation of the detector
- ^{7}Be, ^{8}B and pep fluxes measured with better precision
- SOX (next talk)

Summary

- BOREXINO has achieved an unprecedented background level in the liquid scintillator
- +10 years of R&D, many people/institutions involved
- *Particle physics*: test the LMA-MSW model vs. alternatives (e.g. NSI)
- *Astrophysics*: hunt for CNO neutrinos and try to solve the Solar metallicity puzzle
- *Geophysics*: use antineutrinos to investigate the Earth
- Neutrino astronomy – after solving the oscillation problem

Participation of the Cracow group in BOREXINO supported by National Science Centre (NCN)

Summary

Solar physics results:

- First measurement of the interaction rate of the ^{7}Be (862 keV) neutrinos (5 % accuracy) [Phys. Rev. Lett. 107 (2011) 141302]
- Exclusion of any significant day-night asymmetry of the ^{7}Be solar neutrino flux [Phys. Lett. B 707 (2012) 22-26]
- Annual modulation observation of the ^{7}Be neutrino flux (recently updated) [Astropart. Phys. 92 (2017) 21-29]
- First direct observation of the mono-energetic 1440 keV pep solar neutrinos **[Phys. Rev. Lett. 108 (2012) 051302]**
- Set of the strongest upper limit of the CNO solar neutrinos flux
- Measure of the ^{8}B solar neutrinos with an energy threshold of 3 MeV [Phys. Rev. D82 (2010) 033006]
- First spectroscopical observation of pp neutrinos **[Nature 512 (2014) 383-386]**
- First Simultaneous Precision Spectroscopy of pp, ^{7}Be, and pep Solar Neutrinos with Borexino Phase-II [arXiv:1707.09279]

Other results:

- 5σ geo-netrinos detection [Phys. Rev. D 92 (2015) 031101(R)]
- Charge conservation [Phys. Rev. Lett. 115 (2015) 231802]
- Low-energy neutrinos with GRB [Astropart. Phys. 86 (2017) 11-17]
- GW [arXiv:1706.10176]
- μ_{ν} [arXiv:1707.09355]