# Report CSN2, Catania 18-22 Sett 2017

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UniPD/INFN-PD

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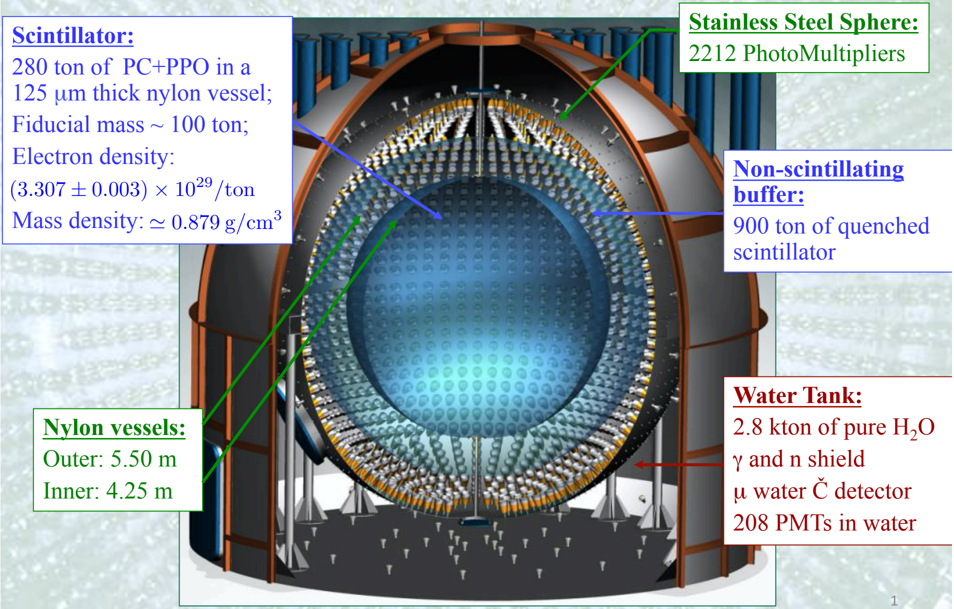
Padova, Consiglio di Sezione INFN

# Il Rivelatore BOREXINO



# La storia di BOREXINO

Purification

**Phase I (2007-2010)** | **Phase II (2012-2017)**

2007 — 2010 — 2012 — now

- $^{7}$Be flux;
- Absence of day/night asymmetry for $^{7}$Be signal;
- $^{8}$B flux;
- pep flux;
- CNO upper limit.

Further radiopurity improvement

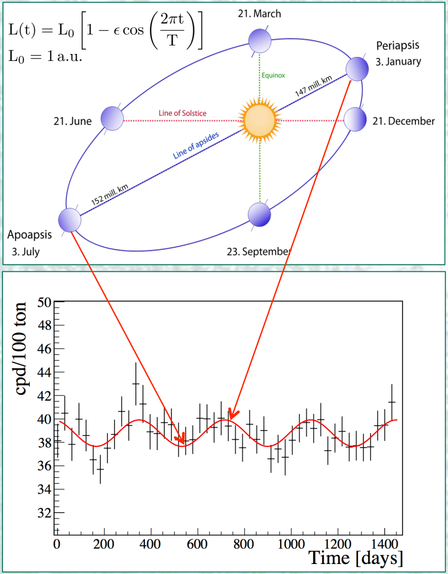
- pp flux: 1$^{st}$ direct measurement ;
- Geoneutrinos (> 5$\sigma$);
- Electric charge conservation (best limit to date);
- Gamma-ray burst corr.

**Latest results released during this summer:**

✓ $^{7}$Be flux seasonal modulation;
✓ Simultaneous precision low-energy solar neutrino spectroscopy;
✓ New limit on neutrino magnetic moments;
✓ $^{8}$B improved measurement.

# $^7$Be-$\nu$ Flux Seasonal Modulation

"Seasonal modulation of the $^7$Be solar neutrino rate in Borexino" - *Astr. Phys. 92 (2017) 21*




We searched for the seasonal variations of the neutrino interaction rate due to the varying distance L(t) between Sun and Earth during the year.

Astronomical observations:

- T = 365.256 d
- ε = 0.0167

**Borexino results**:

- T = 367 ± 10 d
- ε = 0.0174 ± 0.0045

The absence of seasonal modulation is ruled out at 99.99% C.L. (3.91σ).

➡ **All approaches show consistency with the solar origin of $^7$Be neutrinos.**

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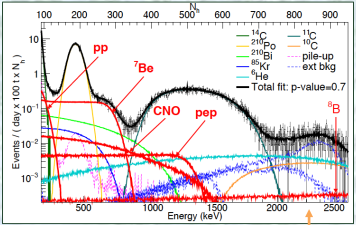
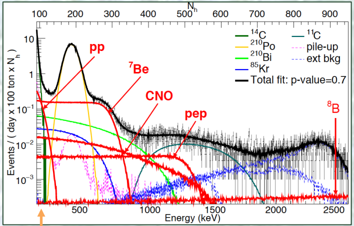
# Simultaneous Solar Neutrino Spectroscopy

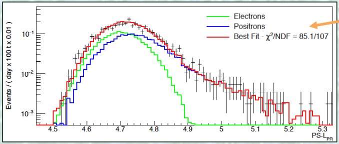
"First simultaneous precision spectroscopy of *pp*, $^7$Be, and *pep* solar neutrinos with Borexino Phase-II"
*arXiv: 1707.09279 [hep-ex] (2017)*

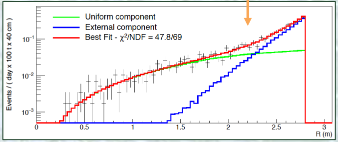
**Multivariate fit**: neutrino interaction rates obtained by maximazing a binned likelihood function




$$\mathcal{L}_{\rm MV} = \mathcal{L}_{^{11}{\rm C-tag}} \cdot \mathcal{L}_{^{11}{\rm C-sub}} \cdot \mathcal{L}_{\rm PS} \cdot \mathcal{L}_{\rm rad}$$



# Simultaneous Solar Neutrino Spectroscopy

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*arXiv: 1707.09279 [hep-ex] (2017)*

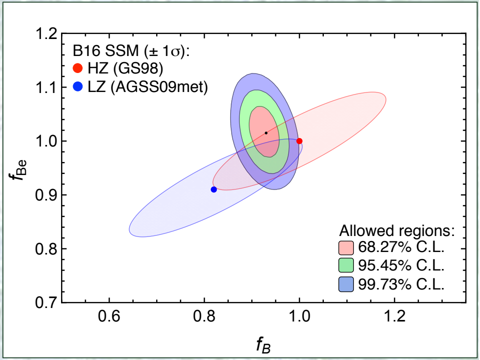
## Implications of the new results: the metallicity issue

The new Borexino results on $^7$Be neutrino rate seem to give an hint towards the High Metallicity hypothesis:

p-value (HZ) = 0.87
p-value (LZ) = 0.11

We are now largely dominated by the theoretical SSM errors.

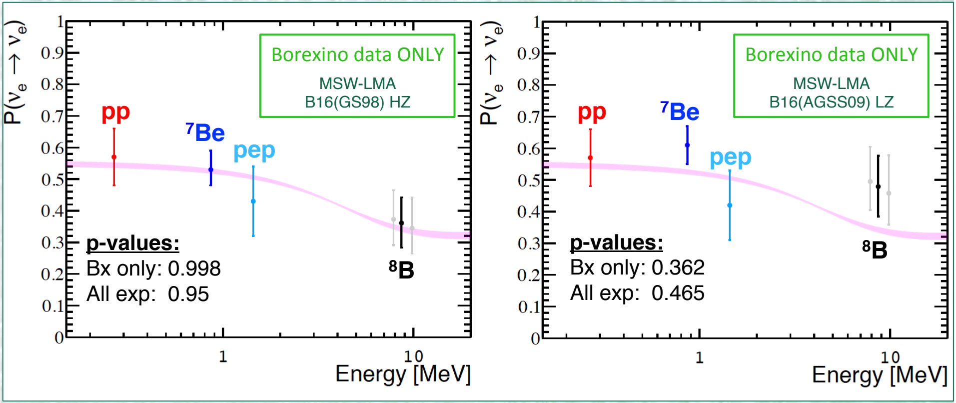
$$f_{\mathrm{Be}} = \frac{\Phi(^7\mathrm{Be})}{\Phi^{\mathrm{HZ}}_{\mathrm{SSM}}(^7\mathrm{Be})} \qquad f_{\mathrm{B}} = \frac{\Phi(^8\mathrm{B})}{\Phi^{\mathrm{HZ}}_{\mathrm{SSM}}(^8\mathrm{B})}$$




Global analysis performed over BX+SNO+SK+KL data, assuming SSM solar-ν fluxes from *N. Vinyoles et al., Astrophys. Journal 835:202 (2017)* and neutrino oscillation parameters from *I. Esteban et al., JHEP 01 (2017).*

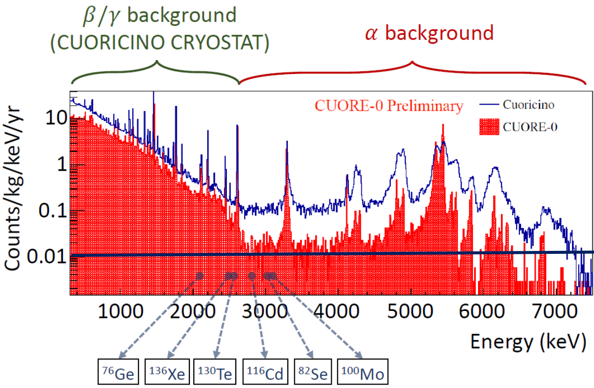
# Studying the Sun with neutrinos (and viceversa)

**All latest Borexino results combined**




SSM solar-ν fluxes (both HZ and LZ) from *N. Vinyoles et al., Astrophys. Journal 835:202 (2017)*
Neutrino oscillation parameters from *I. Esteban et al., JHEP 01 (2017).*

# Il fondo di misura nel $\beta\beta$




Per ridurre il fondo

Necessaria discriminazione α/β

**Fondo da alfa degradate**

Un'attenta selezione degli isotopi ββ da utilizzare

Permette di ridurre il fondo β/γ se l'energia di transizione >2615 keV
Ma per molti di questi nuclei l'arricchimento isotopico e' necessario

# Il programma di R&D CUPID

Sulla base delle richieste della CSN2 e del programma presentato nel Maggio 2016
Per il completo sviluppo dell'attivita' di CUPID sono state individuate due linee

**Bolometri Scintillanti**

Cristalli scintillanti a bassa T
Elevata resa in luce
Vari meccanismi di reiezione (….., PSD)
Rivelatore di luce criogenico semplice

Fondo dei cristalli da ottimizzare
E' pressocche' necessario l'arricchimento
Riproducibilta' cristalli da dimostrare

⇩

**CUPID-0**

**Bolometri Cerenkov ($TeO_2$)**

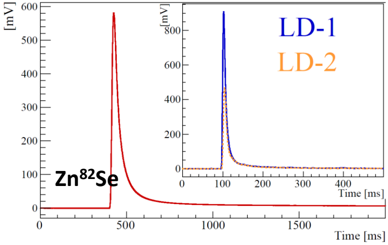
Cristalli che non scintillano a bassa T
Pochi fotoni Cerencov emesis per MeV
Reiezione Cerenkov (on/off)
Rivelatori di luce criogenici molto sensibili

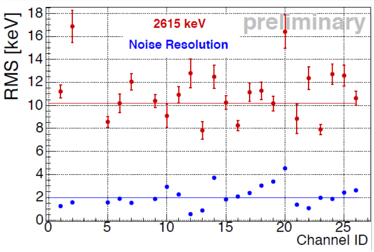
Cristalli di $TeO_2$ hanno basso fondo
E' possibile non arricchire il Te
Filiera dei cristalli di $TeO_2$ solida (CUORE)

⇩

**Rivelatori criogenici di luce Cerenkov**

# CUPID-0 con i cristalli di ZnSe




All ZnSe and light detectors work correctly

Excellent scintillating performances

Very low noise for light and heat channels

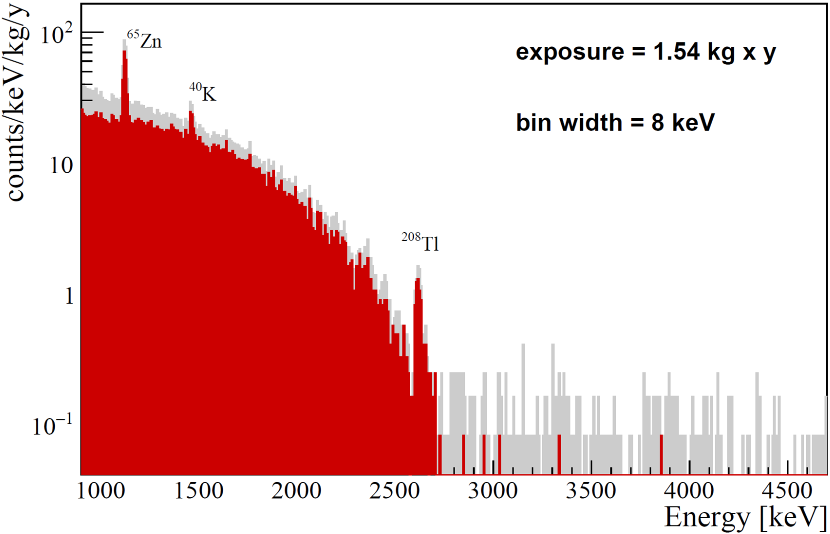
**But**

Energy resolution **on heat channels** not optimal
Average **FWHM @ 2.6** MeV around **25 keV**
Main contribution comes **from crystal quality**

There are room for improvements

# Il primo fondo di CUPID-0

**Background spectrum obtained with (DS1000 + DS1001)**



# Il programma di R&D con i bolometri Cherenkov

Al fine di sfruttare l'esperienza accumulata in CUORE

**Utilizzare anche in CUPID cristalli di $TeO_2$**

La tecnologia dei cristalli $TeO_2$ e' nota
I cristalli sono molto puri (<$10^{-14}$ g/g)
Il $^{130}$Te ha un'abbondanza naturale del 34%
L'arricchimento e' poco costoso e veloce
Tutta l'esperienza fatta in CUORE aiuta
……..
Avremmo gia' una tonnellata di cristalli

**Reiezione delle alfa misurando fotoni Cerenkov**

e- di qualche MeV fanno pochi fotoni
La raccolta di luce non e' ottimale
E' necessario avere soglie alla decina di eV
I rivelatori di luce sono complicati
Non sembrano esserci effetti di Pulse Shape

E' necessario sviluppare rivelatori criogenici di fotoni molto performanti
**ERC- CALDER** → Rivelatori basati su KIDs (fino a febbraio 2018)
**SINGLE-CSN5 Grant** → Rivelatori Neganov Luke su Silicio (fino a aprile 2018)
Rivelatori Neganov Luke su Germanio

VIRGO

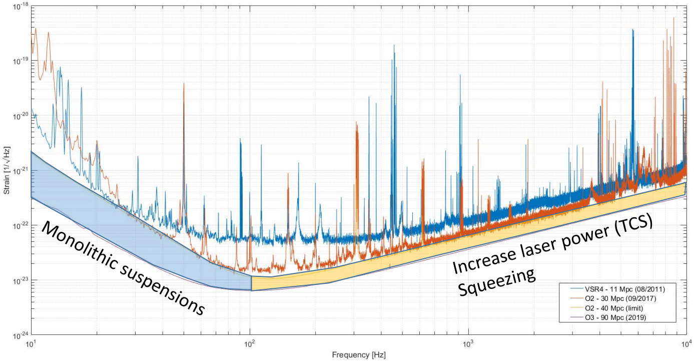
## Upgrades during the O2-O3 break

- At least 12 months break between O2 and O3 (likely 15-18 months)
- Planned major upgrades
  - **Monolithic suspensions** / vacuum upgrade for dust protection (A. Rocchi)
  - High power laser (A. Rocchi)
  - **Frequency independent squeezing** (J.-P. Zendri)
  - Newtonian noise test installation
  - *Power recycling mirror exchange only if problems with CITF stability*
  - *Signal recycling → after O3*

- Three months post-O2 commissioning for studying recycling cavity and debugging the interferometer
- Three months (or more) pre-O3 noise hunting and optimization

# VIRGO : sensibilità prevista

From O2 to O3



# VIRGO : Beyond O3

VIRGO

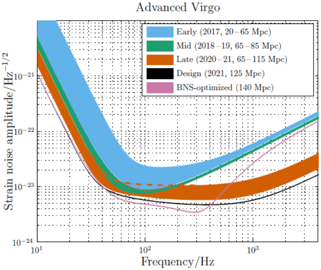
## Beyond O3

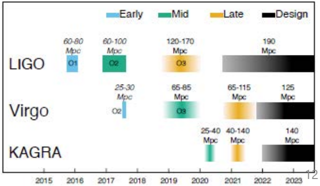
- Phased approach:
  - Phase I: achieve design sensitivity (2017 – 2021)
  - Phase II: achieve maximum sensitivity within infrastructure limits (2021 – 2025)
  - Phase III: optimize AdV in view of a new infrastructure (> 2025)

**A Vision Beyond the Advanced Virgo Project**

**VIR-0136A-16**

- **Attract new groups**, with different and complementary expertise, to fully exploit the science that the detector **is going to deliver**
(instrument, data analysis, EM follow-up, theory)

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# VIRGO : Time Schedule

Time schedule

**2018**

- Preparation of OMC, ellipse rotation cavity, and optical setup for conditional detection
- Non-degenerate OPO pumping
- Scattered light reduction
- Design of the compact optical bench

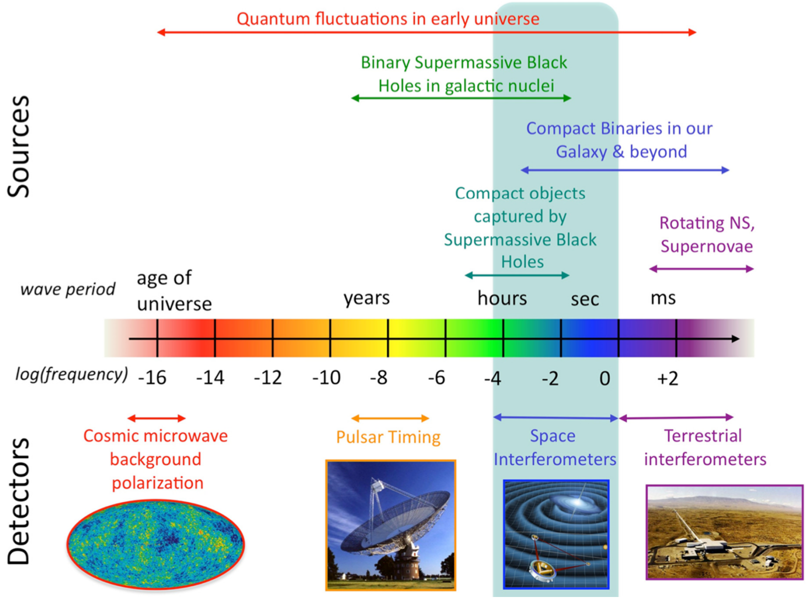
**2019**

- Implementation of the EPR scheme using a Fabry-Perot with rigid spacer
- Prepare the integration of SIPS
- Mitigation of optical losses, development of in-vacuum components

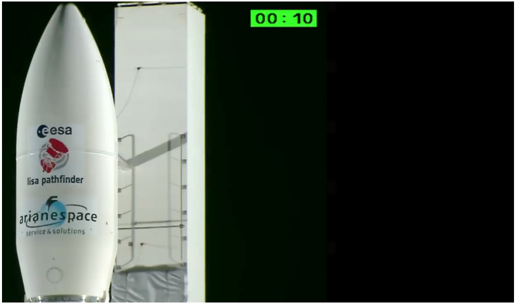
**2020**

- Demonstration of frequency-dependent squeezing and optimisation of noise reduction
- Prepare the compact optical bench for injection in Virgo

# Gravitational Waves Spectrum



# Lisa Pathfinder





- LISA Pathfinder was launched on 3 December 2015 at 04:04UTC
  - Transfer to Lagrange Point 1 (L1) took ∼50 days
- 11 January Switch-on of LISA Technology Package
- 15 & 16 February Test Mass release → free floating test masses
- 1 March Start of Science Operations
- NASA DRS joint operations July–December 2016
- ⋄ 7 December 2016 mission extension began
- ⋄ Switched off in July 2017

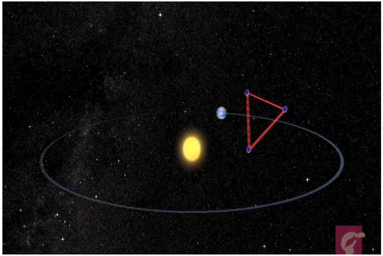
# LISA Mission Profile and Orbit

Defined LISA Science Objectives

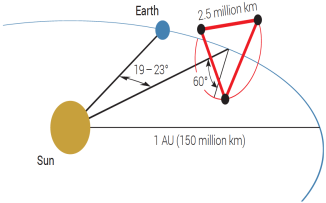
Identified Observational Requirements necessary to reach those objectives

Definedt he Mission Requirements for the noise performance, mission duration, etc

- 3 identical spacecraft
- 3 arms of 2.5 Million km
- 1 AU , 20-degree trailing Earth orbit
- Triangle rotates and changes
  by ±1.5°, ±20 000 km,±10 m/s

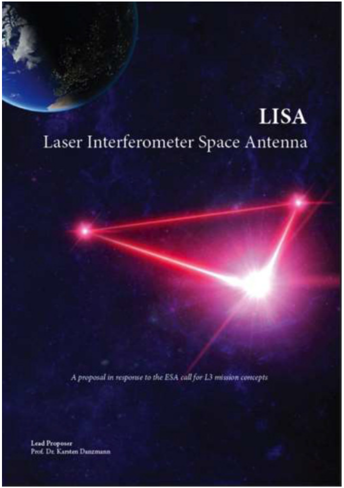


- 30 cm telescopes
- 2W lasers, 100 pW at receiver
- Heterodyne laser interferometry in transponder mode
- Test masses in sub-femto-g free fall
  (10e-15 m/s2/√Hz) of LISA PF



# LISA Mission Concept Proposal

- At the end of 2016: Call for mission project addressing the science of the "Gravitational Universe" was issued by ESA
- An international collaboration of scientists called " LISA Consortium" submitted a proposal in January 2017
- Beginning 2017 ESA started CDF study
- Mission selection in June 2017
- Mission Definition Review in Nov 2017
- Phase A , industrial implementation studies 2018-2020
- Mission adoption 2020-2022
- Launch 2030-2034

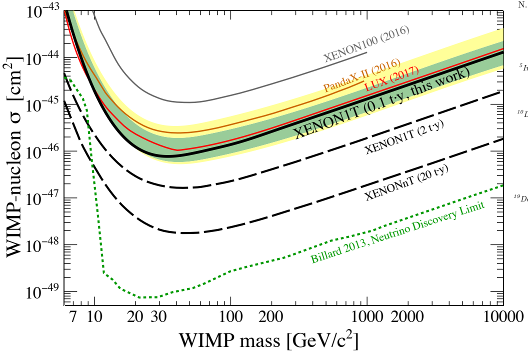



The LISA Consortium:
12 EU Member States +US

www.lisamission.org/proposal/LISA.pdf

# XENON1T results summary

- Lowest background ever achieved in a DM experiment
- First result paper submitted to PRL. arXiv:1705.06655
- World's best sensitivity and more data is on the way




**First Dark Matter Search Results from the XENON1T Experiment**


E. Aprile,[1] J. Aalbers,[2,*] F. Agostini,[3,4] M. Alfonsi,[5] F. D. Amaro,[6] M. Anthony,[1] F. Arneodo,[7] P. Barrow,[8] L. Baudis,[8] B. Bauermeister,[9] M. L. Benabderrahmane,[7] T. Berger,[10] P. A. Breur,[2] A. Brown,[2] A. Brown,[8] E. Brown,[10] S. Bruenner,[11] G. Bruno,[3] R. Budnik,[12] L. Bütikofer,[13,†] J. Calvén,[9] J. M. R. Cardoso,[6] M. Cervantes,[14] D. Cichon,[11] D. Coderre,[13] A. P. Colijn,[2] J. Conrad,[9,‡] J. P. Cussonneau,[15] M. P. Decowski,[2] P. de Perio,[1] P. Di Gangi,[4] A. Di Giovanni,[7] S. Diglio,[15] G. Eurin,[11] J. Fei,[16] A. D. Ferella,[9] A. Fieguth,[17] W. Fulgione,[3,18] A. Gallo Rosso,[3] M. Galloway,[8] F. Gao,[1] M. Garbini,[4] R. Gardner,[19] C. Geis,[5] L. W. Goetzke,[1] L. Grandi,[19] Z. Greene,[1] C. Grignon,[5] C. Hasterok,[11] E. Hogenbirk,[2] J. Howlett,[1] R. Itay,[12] B. Kaminsky,[13,†] S. Kazama,[8] G. Kessler,[8] A. Kish,[8] H. Landsman,[12] R. F. Lang,[14] D. Lellouch,[12] L. Levinson,[12] Q. Lin,[1] S. Lindemann,[11,13] M. Lindner,[11] F. Lombardi,[16] J. A. M. Lopes,[6,§] A. Manfredini,[12] I. Mariş,[7] T. Marrodán Undagoitia,[11] J. Masbou,[15] F. V. Massoli,[4] D. Masson,[14] D. Mayani,[8] M. Messina,[1] K. Micheneau,[15] A. Molinario,[3] K. Morå,[9] M. Murra,[17] J. Naganoma,[20] K. Ni,[16] U. Oberlack,[5] P. Pakarha,[8] B. Pelssers,[9] R. Persiani,[15] F. Piastra,[8] J. Pienaar,[14] V. Pizzella,[11] M.-C. Piro,[10] G. Plante,[1,¶] N. Priel,[12] L. Rauch,[11] S. Reichard,[8,14] C. Reuter,[14] B. Riedel,[19] A. Rizzo,[1] S. Rosendahl,[17] N. Rupp,[11] R. Saldanha,[19] J. M. F. dos Santos,[6] G. Sartorelli,[4] M. Scheibelhut,[5] S. Schindler,[5] J. Schreiner,[11] M. Schumann,[13] L. Scotto Lavina,[21] M. Selvi,[4] P. Shagin,[20] E. Shockley,[19] M. Silva,[6] H. Simgen,[11] M. v. Sivers,[13,†] A. Stein,[22] S. Thapa,[19] D. Thers,[15] A. Tiseni,[2] G. Trinchero,[18] C. Tunnell,[19,**] M. Vargas,[17] N. Upole,[19] H. Wang,[22] Z. Wang,[3] Y. Wei,[8] C. Weinheimer,[17] J. Wulf,[8] J. Ye,[16] Y. Zhang,[1] and T. Zhu[1]
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[21]LPNHE, Université Pierre et Marie Curie, Université Paris Diderot, CNRS/IN2P3, Paris 75252, France
[22]Physics & Astronomy Department, University of California, Los Angeles, CA 90095, USA



(Dated: May 17, 2017)

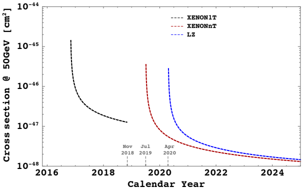

Approved by PRL


We report the first dark matter search results from XENON1T, a ~2000-kg-target-mass dual-phase (liquid-gas) xenon time projection chamber in operation at the Laboratori Nazionali del Gran Sasso in Italy and the first ton-scale detector of this kind. The blinded search used 34.2 live days of data acquired between November 2016 and January 2017. Inside the (1042±12) kg fiducial mass and in the [5, 40] $keV_{nr}$ energy range of interest for WIMP dark matter searches, the electronic recoil background was $(1.93 \pm 0.25) \times 10^{-4}$ events/(kg × day × $keV_{ee}$), the lowest ever achieved in a dark matter detector. A profile likelihood analysis shows that the data is consistent with the background-only hypothesis. We derive the most stringent exclusion limits on the spin-independent WIMP-nucleon interaction cross section for WIMP masses above 10 GeV/$c^2$, with a minimum of $7.7 \times 10^{-47}$ $cm^2$ for 35-GeV/$c^2$ WIMPs at 90% confidence level.

# From XENON1T to XENONnT

➜ new XENONnT proposal submitted to INFN

- all ancillary systems designed to work up to 10 t target mass
  - larger inner cryostat vessel
  - more LXe target mass (3× XENON1T)
  - new TPC structure with increased diameter and more PMTs
  - improve the purification system and reduce Rn by factor 10
  - tag neutrons around the TPC ➜ new neutron VETO detector



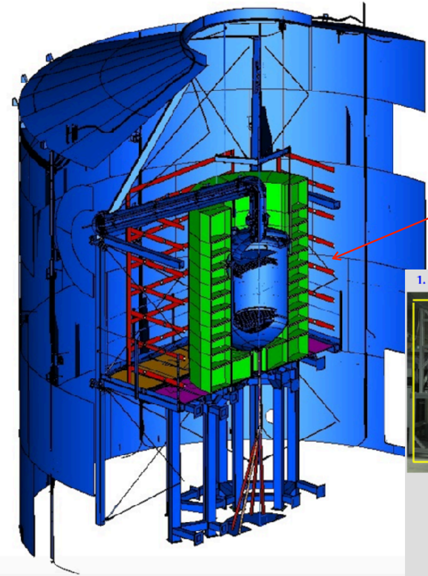

## INFN contributions (wish list)

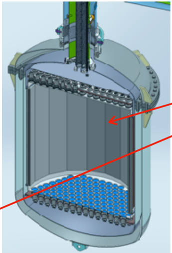
- LXe (500 kg)
- purification system (Rn removal, w/ cryogenic distillation)
- neutron VETO detector system (PMTs, mechanics, electronics/DAQ)
- TPC electronics

➜ construction/commissioning End 2018, science run Mid 2019

➜ one year before LZ will start taking data

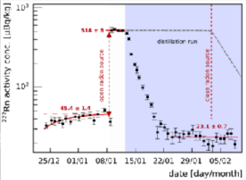
# XENONnT





**Basic ingredients:**
- **Larger TPC**
- **Active n veto**
- **Rn removal via distillation**

**1. Demonstration of online $^{222}$Rn-removal by cryogenic distillation**


- Integration of XENON1T distillation column into XENON100 system
- $^{222}$Rn activity inside XENON100 monitored by α-tagging
- $^{222}$Rn concentration artificially increased
- measured **reduction factor of >27** (@ 95% CL)

9

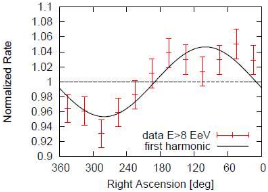
## Anisotropy

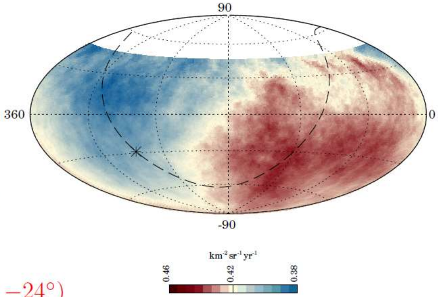
Science 22 settembre

Harmonic analysis in right ascension $\alpha$

| $E$ [EeV] | events | amplitude $r$ | phase [deg.] | $P(\geq r)$ |
|---|---|---|---|---|
| 4-8 | 81701 | $0.005^{+0.006}_{-0.002}$ | $80 \pm 60$ | 0.60 |
| $> 8$ | 32187 | $0.047^{+0.008}_{-0.007}$ | $100 \pm 10$ | $2.6 \times 10^{-8}$ |

significant modulation at $5.2\sigma$ ($5.6\sigma$ before penalization for energy bins explored)

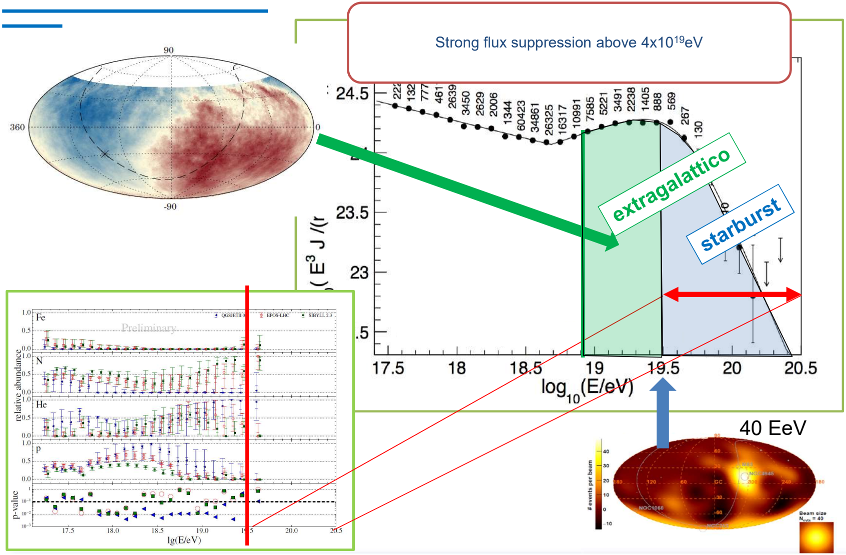



3-d dipole above 8 EeV:

$(6.5^{+1.3}_{-0.9})\%$ at $(\alpha, \delta) = (100°, -24°)$

# Anosotropy and composition



Measure with the Pierre Auger Observatory until 2025.
*(MOUs have been signed in Nov 2015)*

## The AugerPrime upgrade:

1. Add a Surface Scintillator Detector (SSD) to measure the mass composition in combination with the Water Cherenkov Detectors (WCD).
2. Add a small PMT to increase the dynamic range of the WCD.
3. Upgrade the Surface Detector Electronics (SDE) to improve the performance of the WCD, acquire the SSD and the small PMT.
4. Add an Underground Muon Detector (AMIGA) to have a direct muon measurement and cross-check the SSD-WCD combined analysis.
5. Extended the Fluorescence Detector (FD) duty cycle to increase the statistics of the more energetic hybrid showers.

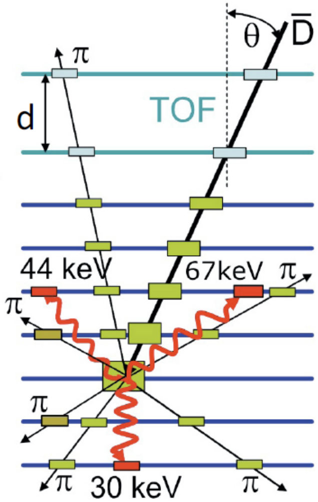
# GAPS: General AntiParticle Spectrometers

- ***Antideuterons* as DM signatures**
  - **no astrophysical background** at low energy
  - **complementary** to direct/indirect searches and collider experiments
  - search for: **light DM**, heavy DM, gravitino DM,
    LZP in extra-dimensions theories, (evaporating PBH)
- ***Antiprotons* as DM and PBH signatures**
  - precision flux measurement at ultra-low energy (E < 0.25 GeV)
  - **complimentary** to direct/indirect searches and collider experiments
  - **~ 10 times more statistics** @ 0.2 GeV, compared to BESS/PAMELA
  - search for: **light DM** gravitino DM,
    LZP in extra-dimensions theories, evaporating PBH
- *Expected to launch from Antarctica in 2020/2021*

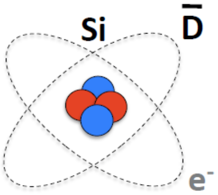
> - **1 LDB flight (~35 days) -> precision antiproton flux measurement**
>
>   ~1500 antiprotons in GAPS *E* < 0.25 GeV, while 30 for BESS, 7 for PAMELA at *E* ~ 0.25 GeV
> - **2 LDB flights (~70 days) -> improved antideuteron statistics**
>
>   Antideuteron sensitivity: ~3.0 x $10^{-6}$ [$m^{-2}$ $s^{-1}$ $sr^{-1}$ $(GeV/n)^{-1}$] *at E* < 0.25 GeV
> - **3 LDB flights (~105 days) -> Antideuteron sensitivity: <2.0 x $10^{-6}$ [$m^{-2}$ $s^{-1}$ $sr^{-1}$ $(GeV/n)^{-1}$] *at E* < 0.25 GeV**

# GAPS: General AntiParticle Spectrometers

GAPS uses ***novel detection technique*** based on exotic atom capture and decay



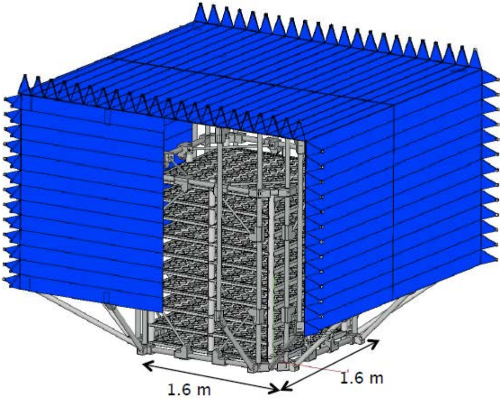

- **Time-of-flight** system measures velocity
- Loses energy in layers of semiconducting **Silicon targets/detectors**
- Stops, forming **exotic excited atom**
- Atom de-excites, emitting **x-rays**
- Remaining nucleus annihilates, emitting **pions and protons**

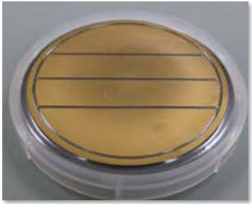



T. Aramaki et al. (2013) 1303.3871

# GAPS: General AntiParticle Spectrometers

**Plastic scintillator TOF**
- high–speed trigger and veto
- 160–180 cm long, 0.5 cm thick
- read out both ends
- ~500 ps timing resolution



**Si(Li) targets/detectors**
- X–ray identification, dE/dx, stopping depth, and shower particle multiplicity
- 2.5 mm thick, 4” diameter
- 4 keV resolution for X–rays

# GAPS: Stato del Progetto e Constributi INFN

- Sviluppo e prototipazione degli ASIC: INFN TS e Università Bergamo/INFN PV.
- Sviluppo del software di simulazione e di analisi dei dati così pure interpretazione degli stessi: INFN TS e INFN FI, Università/INFN Tor Vergata.

- The near term milestones are scheduled to allow an initial mission level design review, to be held at UCLA in February of 2018. For some subsystems, this will gate the procurement of flight hardware. Where schedule allows, other subsystems will begin work on engineering models in advance of a critical design review in the final quarter of 2018. **The project is still tracking to a first flight in late 2020**.

  - NASA/CSBF infrastruttura e logistica per lancio dell'apparato dalla base di McMurdo, Antartide.

  - NASA/Istituti statunitensi: ~7.6 M$, più possibili ulteriori finanziamenti derivanti da proposal che sono stati sottomessi ad NSF e fondazioni private.

  - JAXA/ISAS: progetto approvato fino al 2022 (ovvero più voli). Finanziamento garantito per hardware, quindi non inclusivo di personale, infrastrutture, ecc., di 2.3 M$.

# Il bilancio della CSNII

- Budget totale: 13.5 M€ di cui 4.25 M€ per missioni
- taglio del 5% sulle missioni di tutte le CSN per accantonamento stipendi (4.25 M€contro i 4.5 M€dell'anno prima)
- richieste :

| | Fisica Del Neutrino | Radiazione dall'Universo | L'Universo Oscuro | Onde Gravitazionali Fis. Gen + Quant. |
|---|---|---|---|---|
| Richieste | 9369.5 | 7027 | 4602 | 3114 |
| Rich. Tot. | 26301.5 | | | |
| Assegnazioni | 4581.5 | 4555.5 | 2356.5 | 1741 |

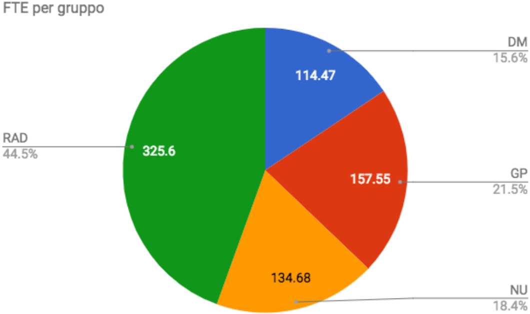
# Il processo decisionale per le assegnazioni

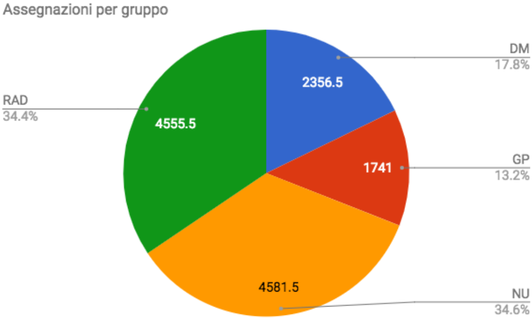
1) analisi dei referee e prima proposta con riduzione da 26.5 M€ a 18 M€

2) analisi collegiale per le richieste sopra una certa soglia (grandi esperimenti)
   - riduzione dello spread k€ /FTE sulle missioni
   - anticipi nel 2017 sulle restituzioni di settembre

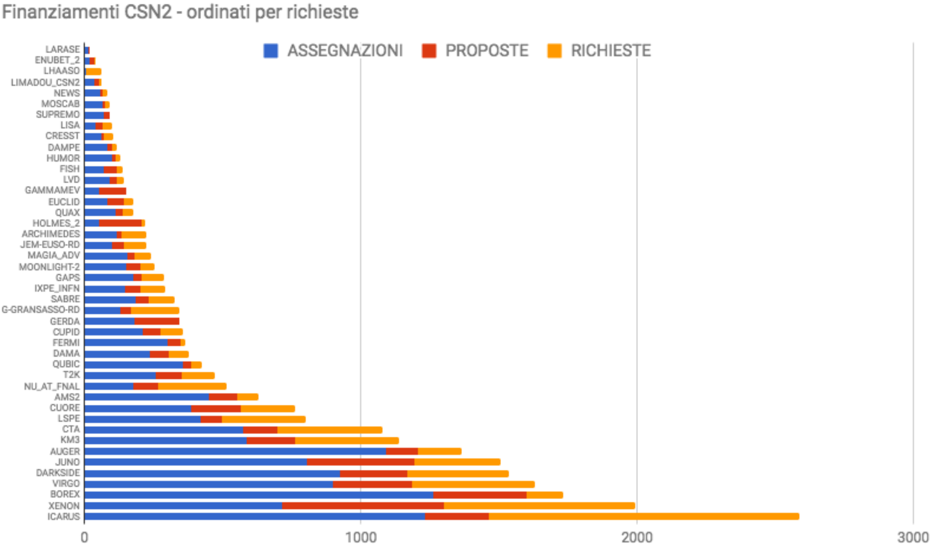
3) taglio piatto del 20% sulle missioni e del 10% sugli altri capitoli
   - accantonamento di un fondo indiviso (167.5 k€ Missioni e 536.5 k€ su apparati)
   - spostamento 30% delle Missioni in SJ

# La CNS2 e le Assegnazioni



# Le Assegnazioni 2018



# Le Assegnazioni 2018