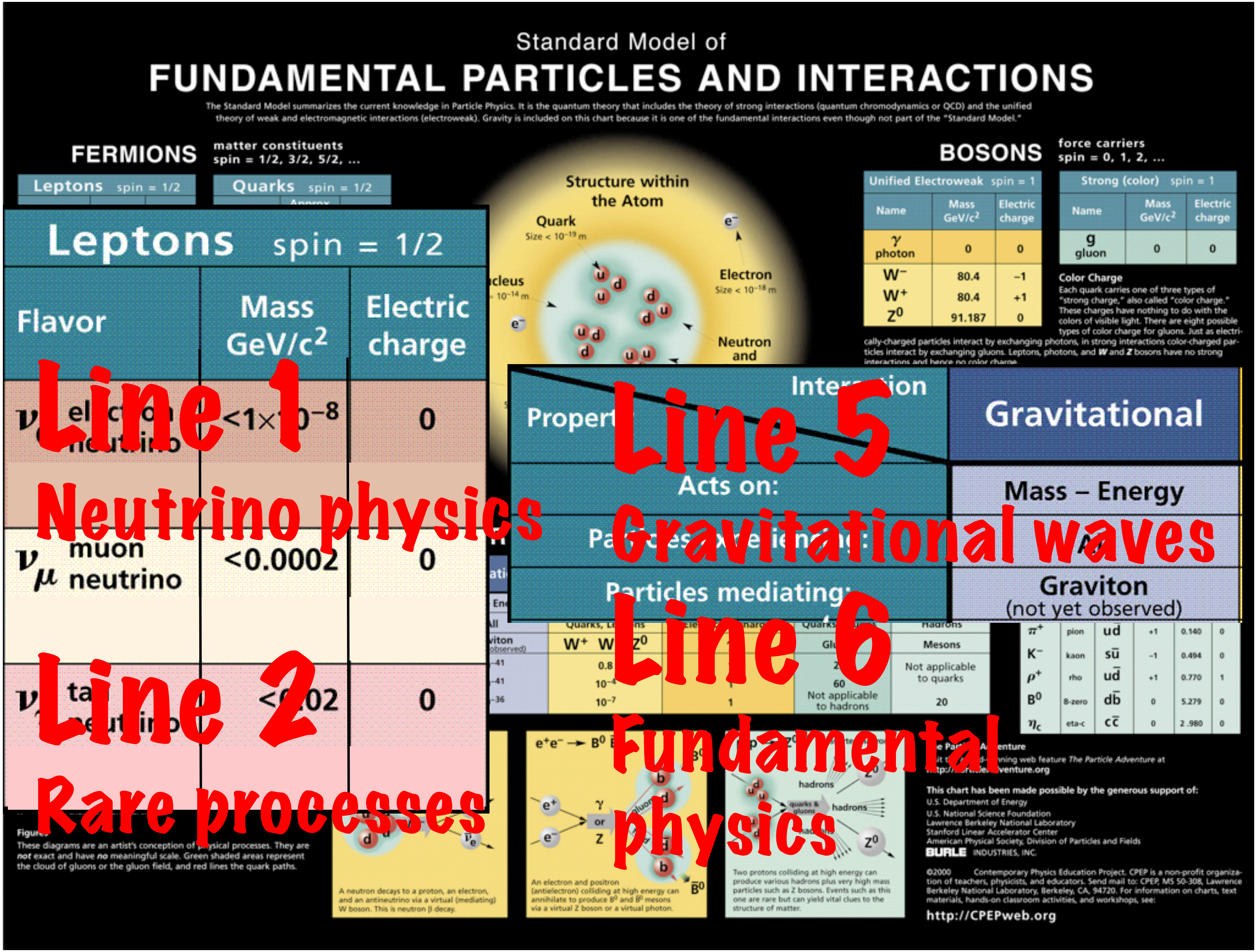
II National Scientific Commettee

ECFA 2012
LNF

R.BATTISTON


Standard Model of
FUNDAMENTAL PARTICLES AND INTERACTIONS
The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is included on this chart because it is one of the fundamental interactions even though not part of the "Standard Model."
FERMIONS
matter constituents
spin = 1/2, 3/2, 5/2, ...
Leptons spin = 1/2
Quarks spin = 1/2
BOSONS
force carriers
spin = 0, 1, 2, ...
Unified Electroweak spin = 1
Strong (color) spin = 1
Name
Mass GeV/c²
Electric charge
γ photon
0
0
W⁻
80.4
−1
W⁺
80.4
+1
Z⁰
91.187
0
g gluon
0
0
Color Charge
Structure within the Atom
Quark
Electron
Neutron
Leptons spin = 1/2
Flavor
Mass GeV/c²
Electric charge
νe electron neutrino
<1×10⁻⁸
0
νμ muon neutrino
<0.0002
0
ντ tau neutrino
<0.02
0
Line 1
Neutrino physics
Line 2
Rare processes
Interaction
Property
Gravitational
Acts on:
Mass – Energy
Particles experiencing:
Particles mediating:
Graviton
(not yet observed)
Line 5
Gravitational waves
Line 6
Fundamental physics
Mesons
This chart has been made possible by the generous support of:
U.S. Department of Energy
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Lawrence Berkeley National Laboratory
Stanford Linear Accelerator Center
American Physical Society, Division of Particles and Fields
BURLE INDUSTRIES, INC.
http://CPEPweb.org

Comos is the "ultimate" laboratory to study fundamental physics, up to energy scales unreachable with the most powerful accelerators…..

Line 2

Rare processes

Line 3

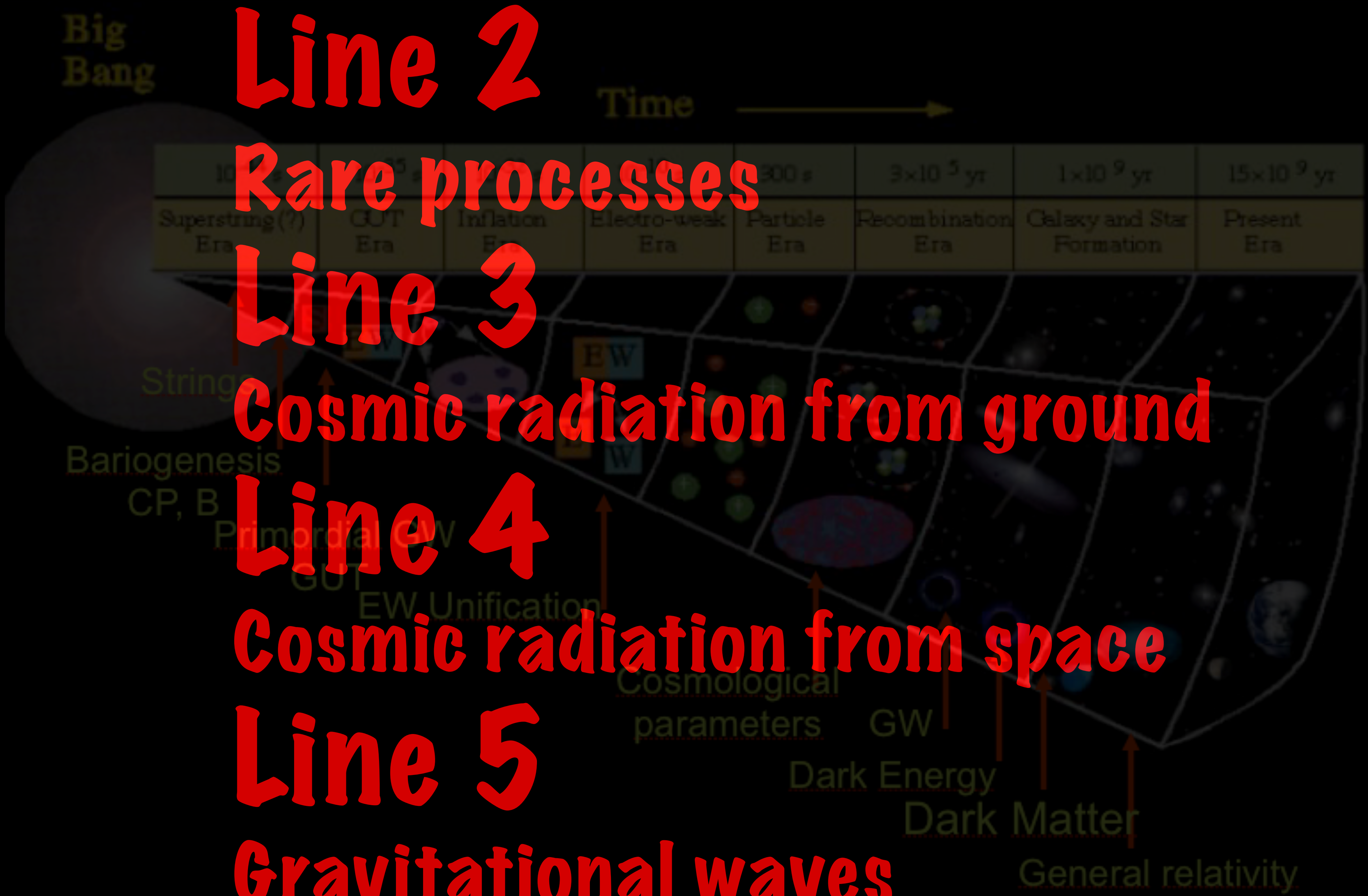
Cosmic radiation from ground

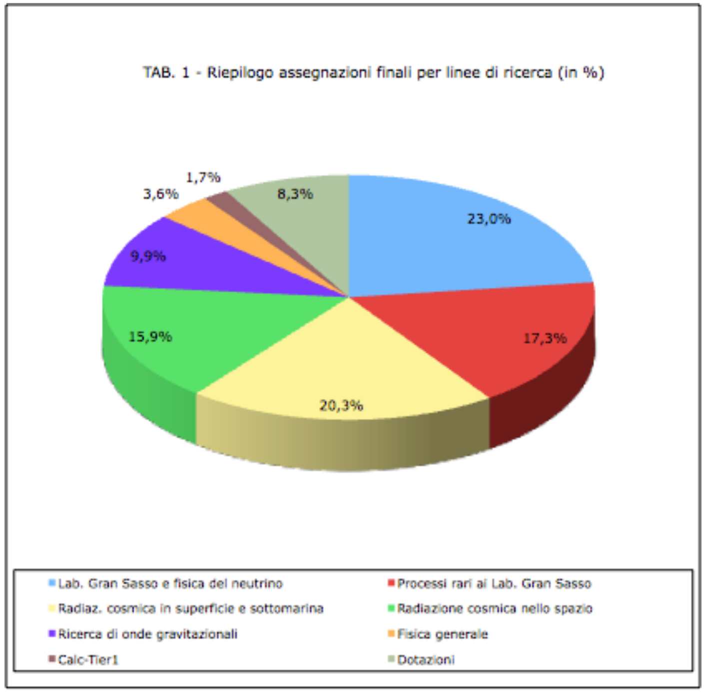
Line 4

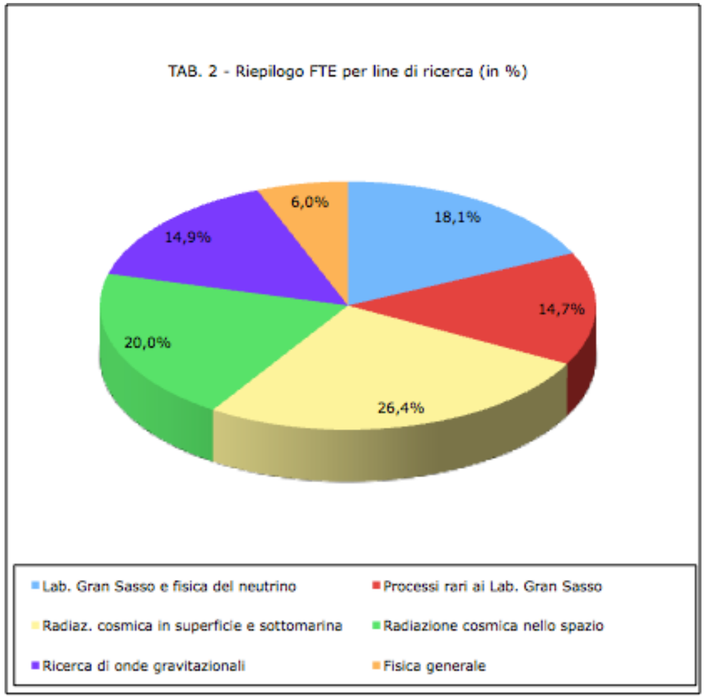
Cosmic radiation from space

Line 5

Gravitational waves







- Line 1 Neutrino Physics
- Line 2 Rare Processes (Dark matter, 0ν2β decays, SN ν)
- Line 3 Cosmic rays by ground based and underwater experiments
- Line 4 Study of the cosmic rays by experiments in the space
- *Line5 Search for gravitational waves
- Line 6 General Physics
- Others

FTE	607
PEOPLE	800

2011 Funding 12.8 M€ * (-14% vs 2010)

*Note: additional 6.2 M€ for AdV during 2009-2011

– Basic info about CSN2 for 2011 –

Number of participants (FTE)

Year	2011	2010	2009	2008	2007	2004–06 (average)	2001–03 (average)
FTE	607	650	644	674	676	646	579
People	≈800	≈820	860	≈850	≈850	742	–

Note: the decrease in FTE 2010-2011 is mainly due to change in counting rules

ISI publication rate keep increasing for the 5^{th} year in a row

		Number of ISI pubblications				
	2011	**2010**	**2009**	**2008**	**2007**	**<04-06>**
CSN1	300	277	195	256	280	296
CSN2	294	259	238	219	192	205
CSN3	276	258	223	206	266	255
CSN4	1112	1183	1099	1191	1236	1127
CSN5	361	320	326	333	325	264
Common	355	428	397	334	193	276
INFN	**2700**	**2721**	**2478**	**2539**	**2492**	**2423**
INFN/Italia	**36**	**36**	**33**	**34**	**32**	**32**

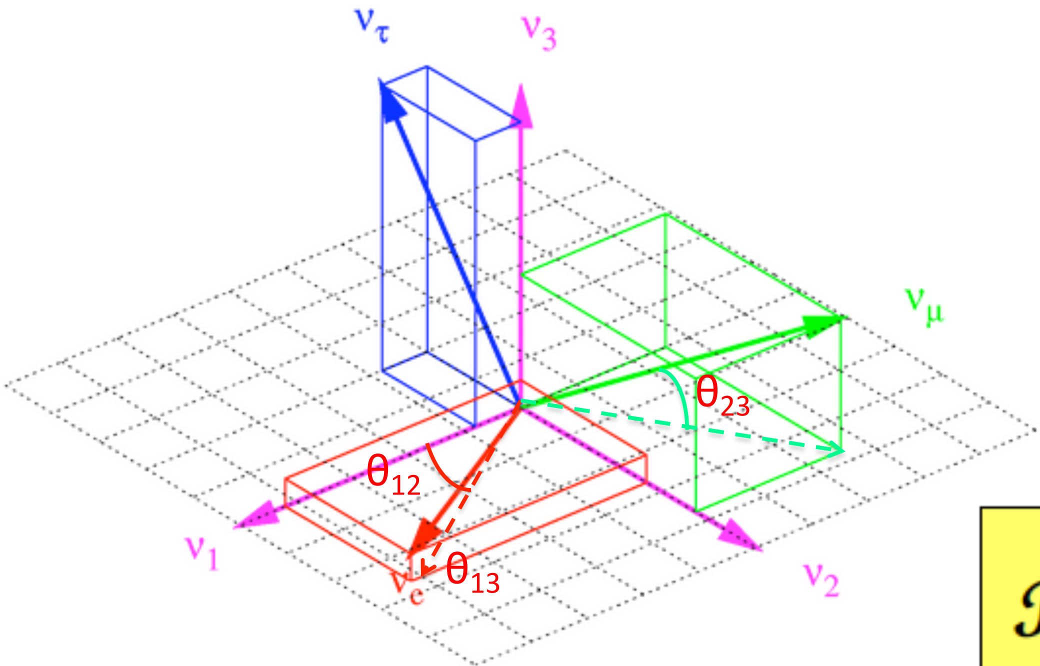
Impact Factor

	Fraction of INFN Authors(%)						Average Impact Factor					
	2011	2010	2009	2008	2007	<04-06>	2011	2010	2009	2008	2007	<04-06>
CSN1	22	38	30	42	37	36	4.77	3.80	3.90	3.10	3.65	3.78
CSN2	51	51	53	64	64	75	3.8	4.08	4.40	2.80	2.89	2.15
CSN3	43	50	44	51	53	47	3.21	2.85	2.60	2.80	2.58	2.60
CSN4	61	55	56	63	58	59	3.71	3.73	3.73	3.47	3.62	3.44
CSN5	61	66	61	67	56	66	1.72	1.97	1.96	1.70	1.54	1.46

	Number of authors (FTE)						Publications / FTE					
	2011	2010	2009	2008	2007	<04-06>	2011	2010	2009	2008	2007	<04-06>
CSN1	796	783	791	813	804	804	0.38	0.35	0.25	0.31	0.35	0.37
CSN2	607	650	644	674	676	646	0.33	0.40	0.37	0.33	0.28	0.32
CSN3	521	520	527	521	491	468	0.5	0.49	0.42	0.40	0.54	0.54
CSN4	973	949	920	977	922	859	1.14	1.25	1.19	1.22	1.34	1.31
CSN5	607	598	600	608	584	504	0.59	0.53	0.55	0.55	0.56	0.52

Line 1: neutrino physics SUMMARY

- **PAST YEAR(S)** : BOREXINO (Solar), OPERA 2 ν_τ, ICARUS-CNGS, T2K θ_{13}
- **NEXT YEAR(S)** : BOREXINO **(sterile)**, CNGS **END**, T2K **CONTINUES**, ICARUS+NESSIE@CERN
- **LONG TERM STRATEGY**: ICARUS+NESSIE@CERN, DAYA BAY 2 (?), LONG BASELINE (CERN, US, JP) (?)



Appearance

$$\mathcal{P}_{\alpha\beta}(L) = \sin^2(2\theta)\sin^2(\pi\frac{L}{\lambda})$$

$$\lambda = 2.48\frac{E}{\Delta m^2}$$

Disappearance

$$\mathcal{P}_{\alpha\alpha} = 1 - \sum_{\beta\neq\alpha}\mathcal{P}_{\alpha\beta}$$

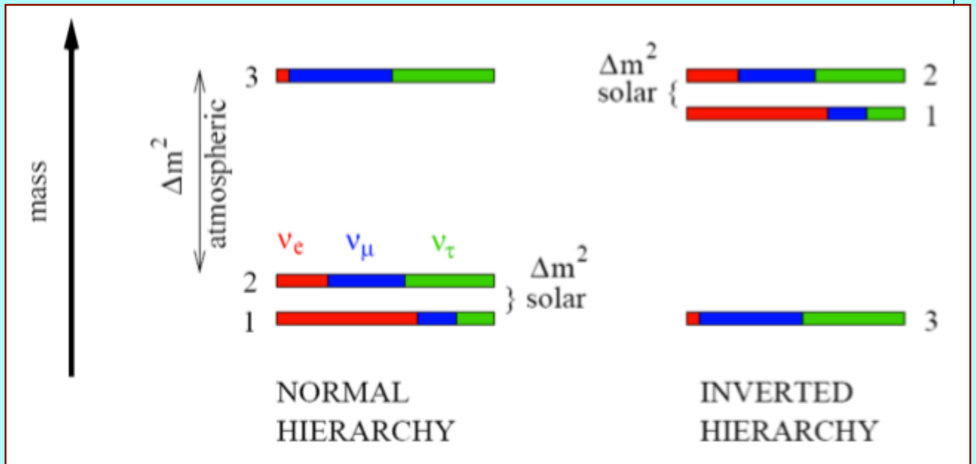
Neutrino oscillation: what we don't know

Atmospheric | CP phase & θ_{13} | Solar | Majorana phase

$$\mathbf{V} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13} \\ 0 & e^{-i\delta} & 0 \\ -s_{13} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} e^{i\rho} & 0 & 0 \\ 0 & e^{i\sigma} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Atmospheric accelerator | **reactor accelerator** | **solar reactor** | **Double beta decays**

- Unknown parameters in neutrino oscillation:
  - ~~θ_{13}~~, **mass hierarchy, CP phase** δ + Majorana phase



- **+ A number of anomalies:**
- **LSND ?**
- **Reactor neutrino flux ?**
- **Sterile neutrinos ? MiniBoone**
- ~~**V > C ?**~~

Neutrino oscillations & sterile neutrinos

- **Atmospheric neutrinos(θ_{23})**
  - **SuperK，HyperK/UNO，INO，TITAND,…**
- **Solar neutrinos(θ_{12}):**
  - **GALLEX/SAGE, SuperK, SNO, Borexino, XMASS, …**
- **Reactor neutrinos(θ_{12},θ_{13} ➔ mass hierarchy):**
  - **KamLAND, Daya Bay, Double CHOOZ, Reno,…**
- **Accelerator neutrinos(θ_{23},θ_{13} ➔ mass hierarchy, δ, …):**
  - **MINOS, OPERA, MiniBooNe, T2K, NOVA, ICARUS…**

Hall C Laboratori Nazionali Gran Sasso

OPERA @ CNGS
tau neutrino appearance

$$P(\nu_\mu \rightarrow \nu_\tau) \sim \sin^2 2\theta_{23} \cos^4\theta_{13} \sin^2(\Delta m^2_{23} L/4E)$$

Veto
(RPC's)

High Precision Tracker
- 2 x 3 planes of drift tubes

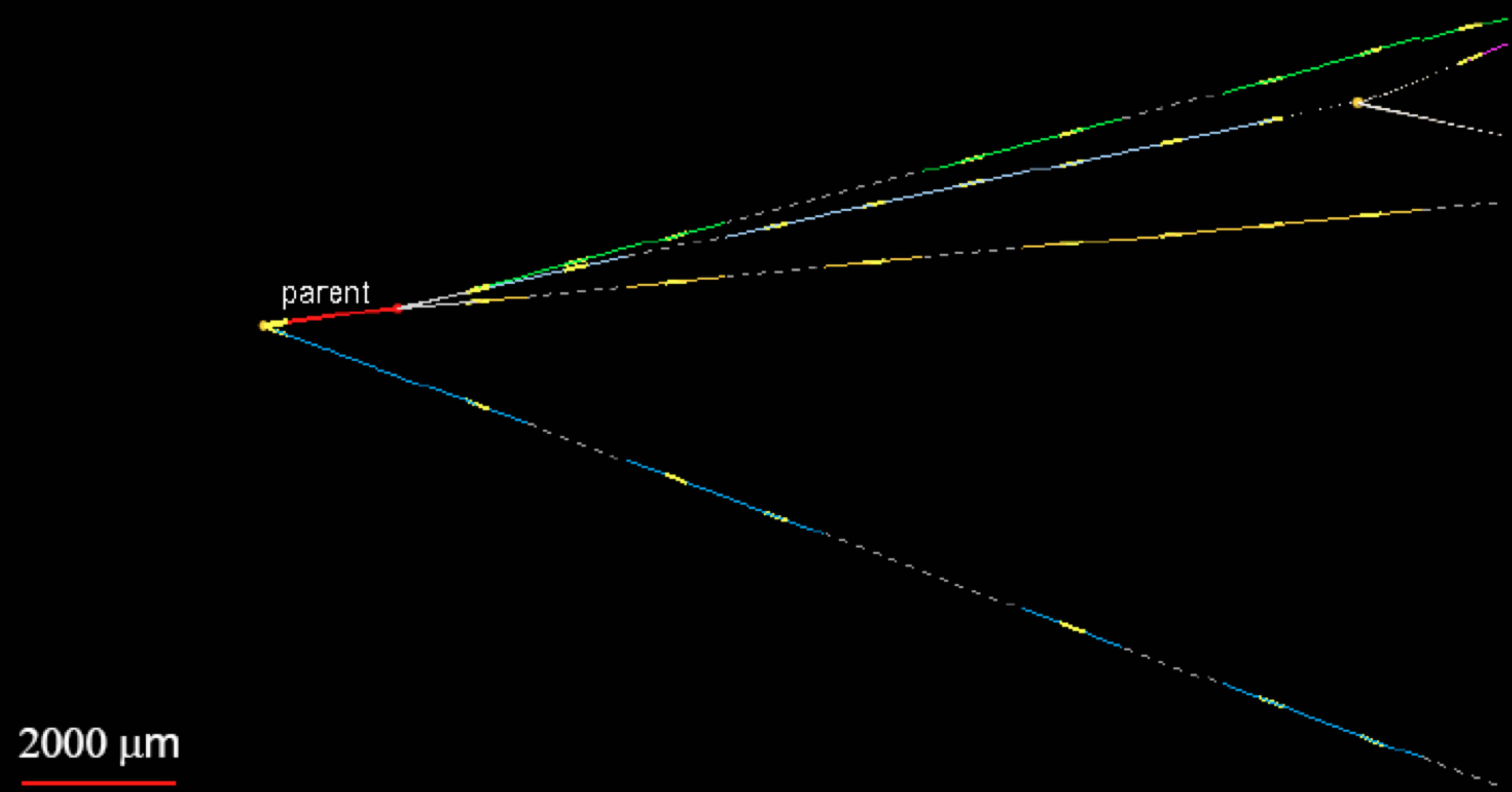
Instrumented dipolar magnet
- 1.53 *T*
- 22 x 2 XY planes of RPC's

Muon spectrometer (8×10 m^2)

Target section (6.7m)^2

- Target: 77500 *bricks* *(Pb – nuclear emulsions)* arranged into 29 *walls*
- Target tracker : XY doublets of scintillator strips + WLS fibres + multi-anodes PMT

New ν_τ Candidate Event



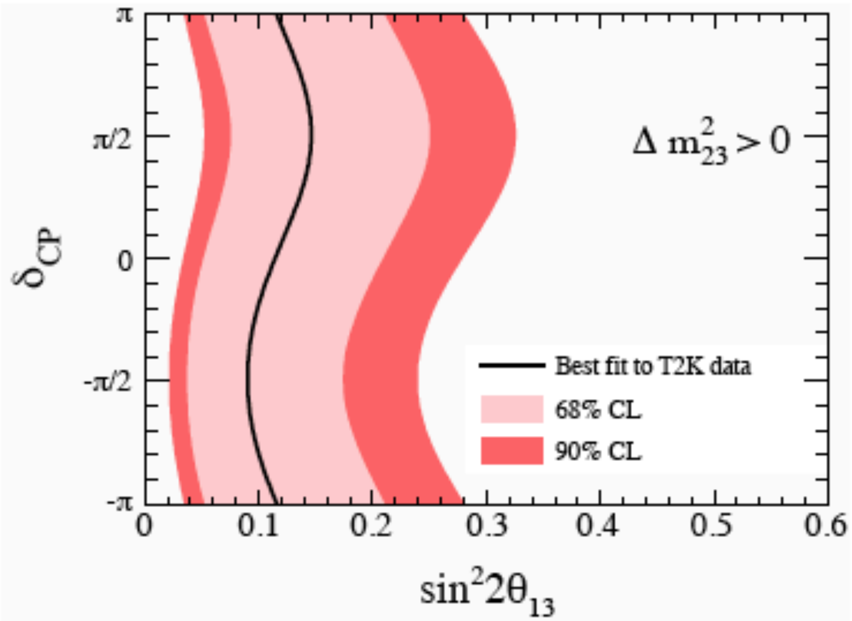
The T2K experiment

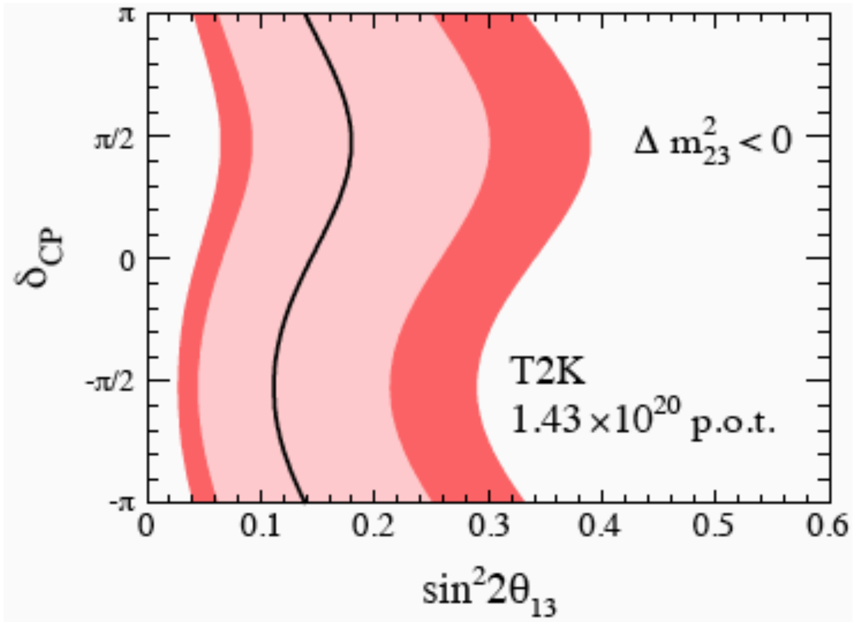
- Tokai-to-Kamioka neutrino oscillation experiment

- **to precisely measure the ν_μ disappearance, i.e. θ_{23} and Δm^2_{23} ($\sim\Delta m^2_{13}$)**
- **to intensively search for $\nu_\mu \rightarrow \nu_e$ appearance, i.e. non-zero θ_{13}**

Allowed region of $\sin^2 2\theta_{13}$ as a function of δ_{CP}

(assuming Δm^2_{23}=2.4 x 10^{-3} eV^2, $\sin^2 2\theta_{23}$=1)





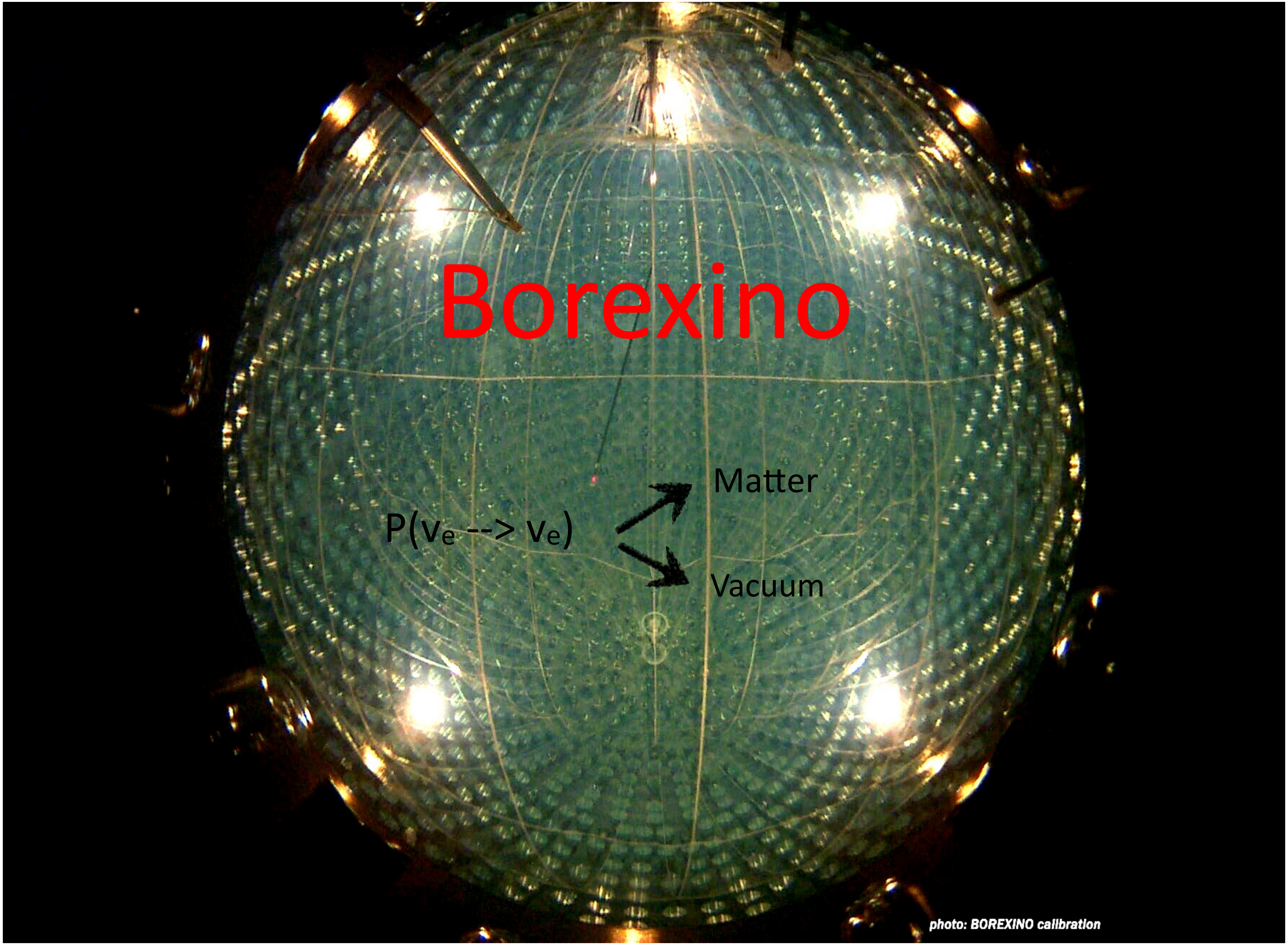
90% C.L. interval & Best fit point (assuming Δm^2_{23}=2.4 x 10^{-3} eV^2, $\sin^2 2\theta_{23}$=1, δ_{CP}=0)

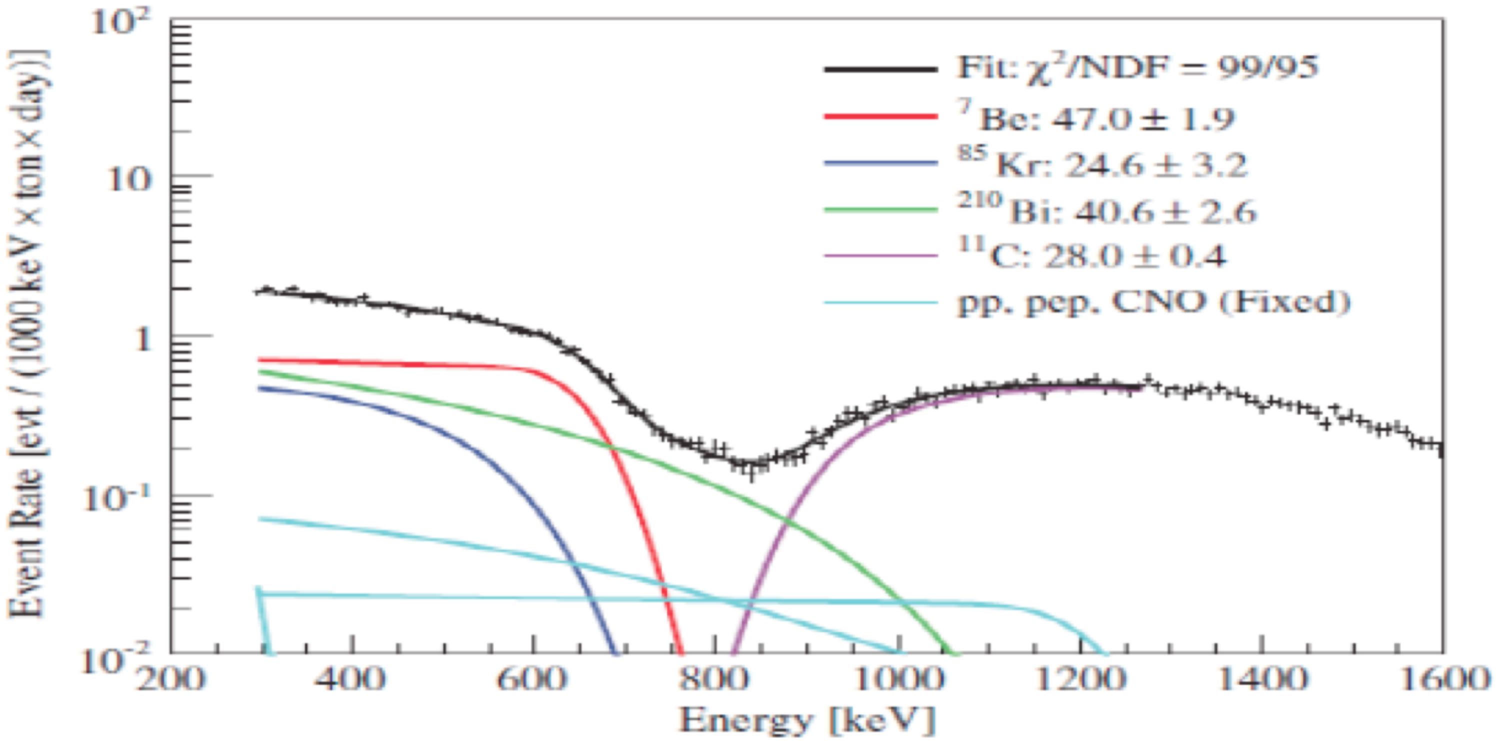
$0.03 < \sin^2 2\theta_{13} < 0.28$

$\sin^2 2\theta_{13} = 0.11$

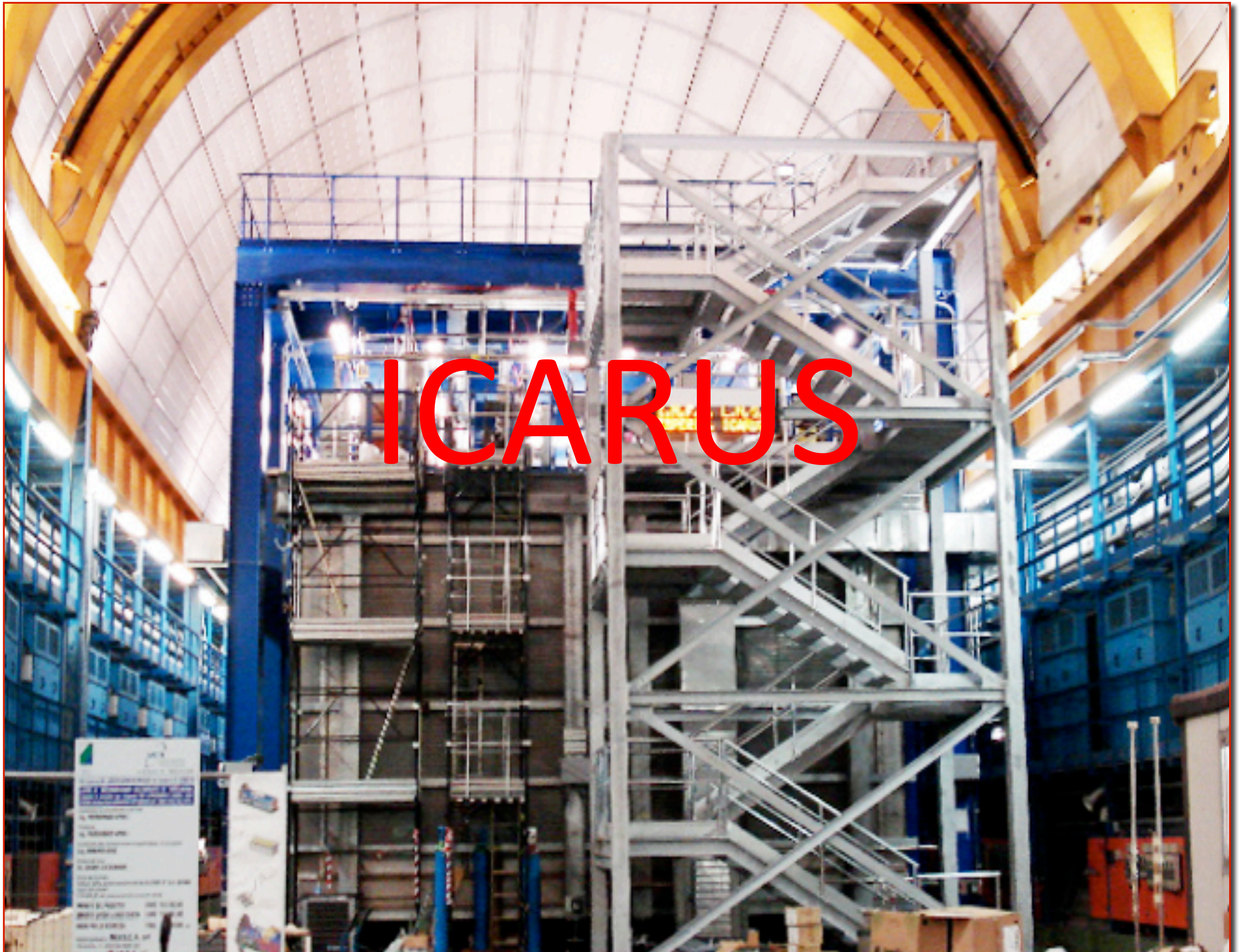
$0.04 < \sin^2 2\theta_{13} < 0.34$

$\sin^2 2\theta_{13} = 0.14$


Borexino
Matter
$P(\nu_e \dashrightarrow \nu_e)$
Vacuum
photo: BOREXINO calibration



Measurement of the ^{7}Be flux by Borexino


ICARUS

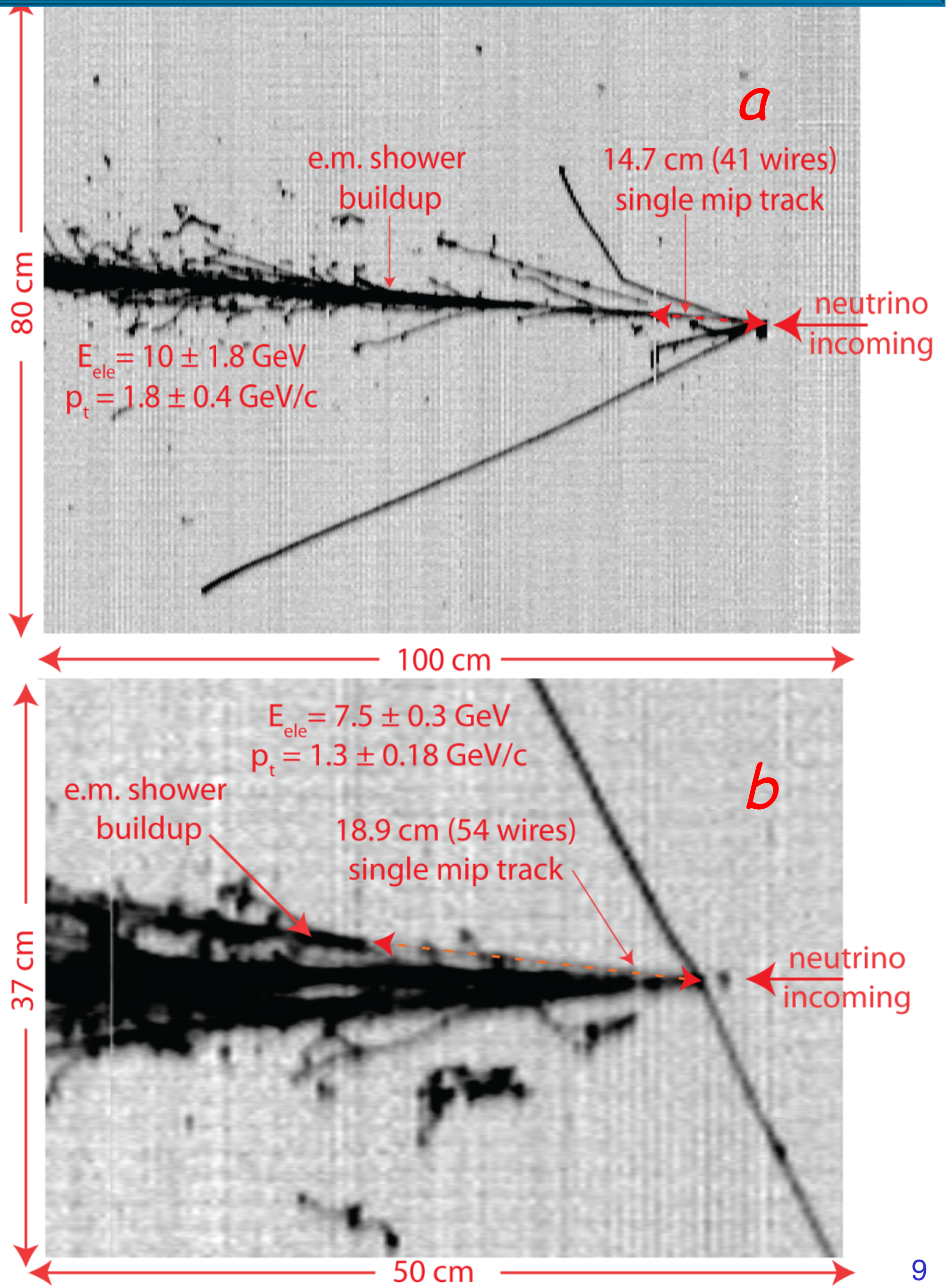
Events in the data

- Two CC events have been observed in data sample, with a clearly identified electron signature:

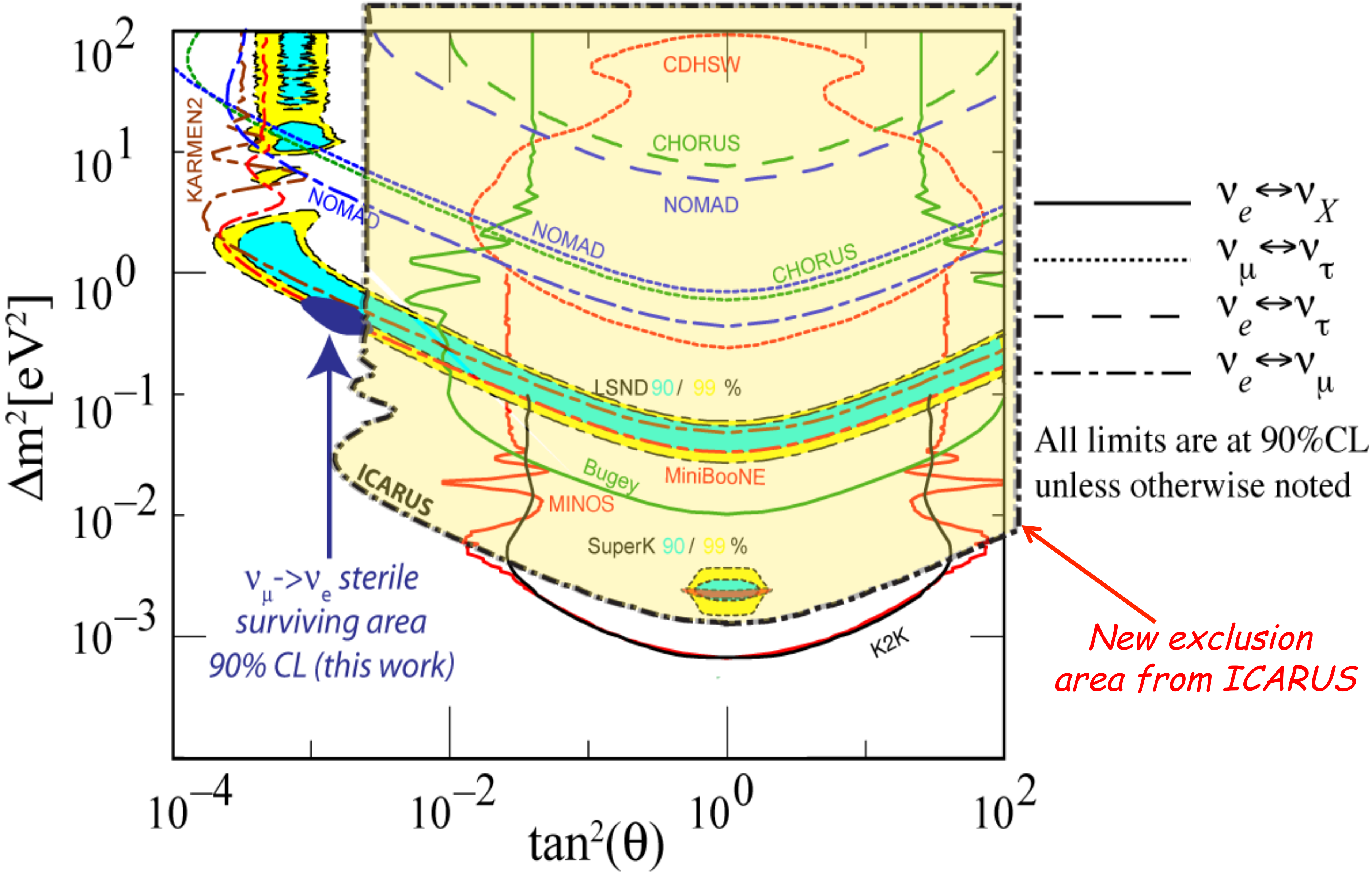
(a) total energy: 11.5 ± 1.8 GeV, P_t = 1.8 ± 0.4 GeV/c

(b) total visible energy: 17 GeV, P_t = 1.3 ±0.18 GeV/c

- In both events the single electron shower in the transverse plane is clearly opposite to the remaining of the event

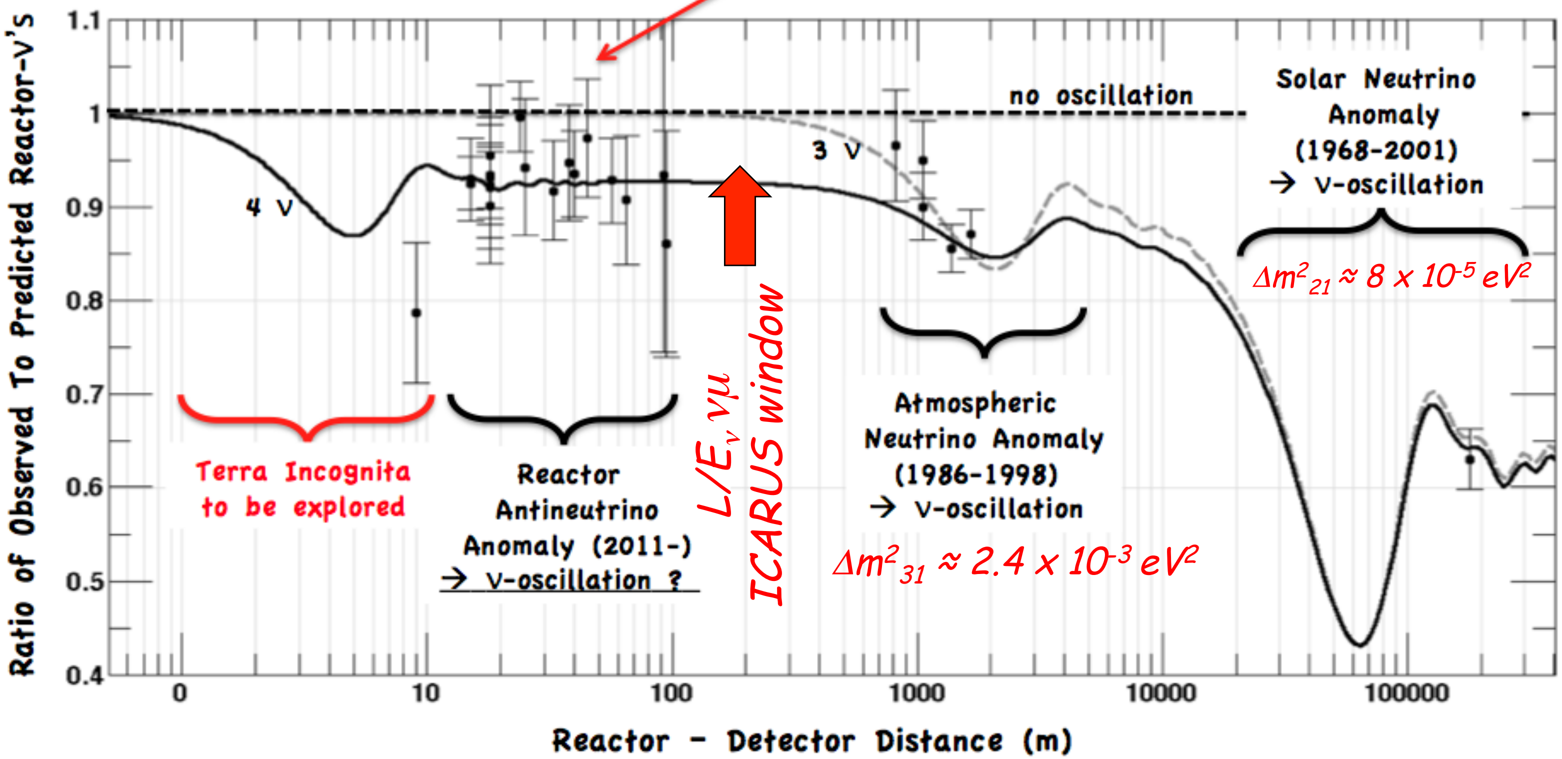


LSND-like exclusion due to the present experiment



Comparing ICARUS and reactor disappearance anomaly ?

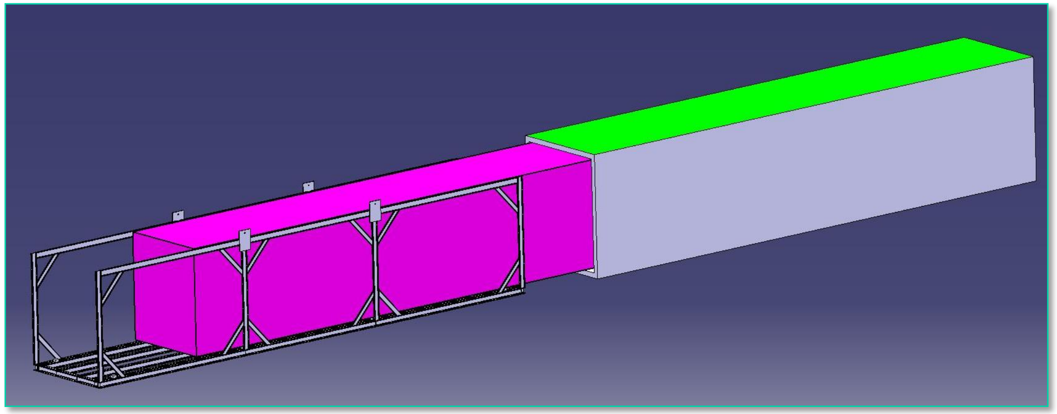
- Observed/predicted averaged event ratio: R=0.927±0.023 (3.0 σ)

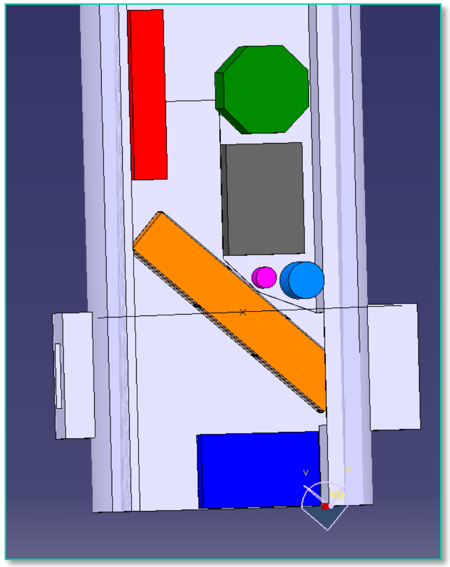


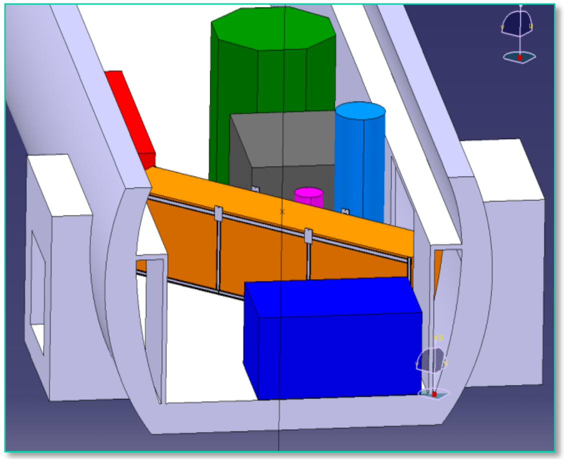
- ICARUS may offer in the future also the possibility of comparing the observed/predicted ratio R_{μ} of neutrino events to the one expected from the CERN accelerator neutrino beam.
- The ν production flux may then be compared with predictions and checked with the observed muon flux at nearby distances.

T600 TPC transport

- The TPCs will be transported inside clean and lightweight containers using the trolleys already used for the transport from Pavia to LNGS.







- Feasibility study and cost estimate for T600 transport from LNGS to CERN carried out in close collaboration with CERN Transport Group.
- No major works in LNGS underground Laboratory.

Line 1: neutrino physics SUMMARY

- **PAST YEAR(S)** : BOREXINO, OPERA 2 ν_τ, ICARUS-CNGS, T2K θ_{13}

- **NEXT YEAR(S)** : BOREXINO **(sterile)**, CNGS **ENDS**, T2K **CONTINUES**, ICARUS+NESSIE@CERN (under discussion)

- **LONG TERM STRATEGY**: ICARUS+NESSIE@CERN, DAYA BAY 2 (?), LONG BASELINE (CERN, US, JP) (?)

Line 2: rare processes SUMMARY

- **PAST YEAR(S)** :
  - DAMA-LIBRA, XENON-100
  - GERDA (operation), CUORE (construction)

- **NEXT YEAR(S)** :
  - DAMA-LIBRA, XENON-1T (constr.), DARK-SIDE (constr.)
  - GERDA, CUORE ← *Planck and CMB results*

- **LONG TERM STRATEGY**: CUORE+ (?), XENON+ (?), DARK-SIDE+ (?), CRYOGENIC CRYSTALS (?)

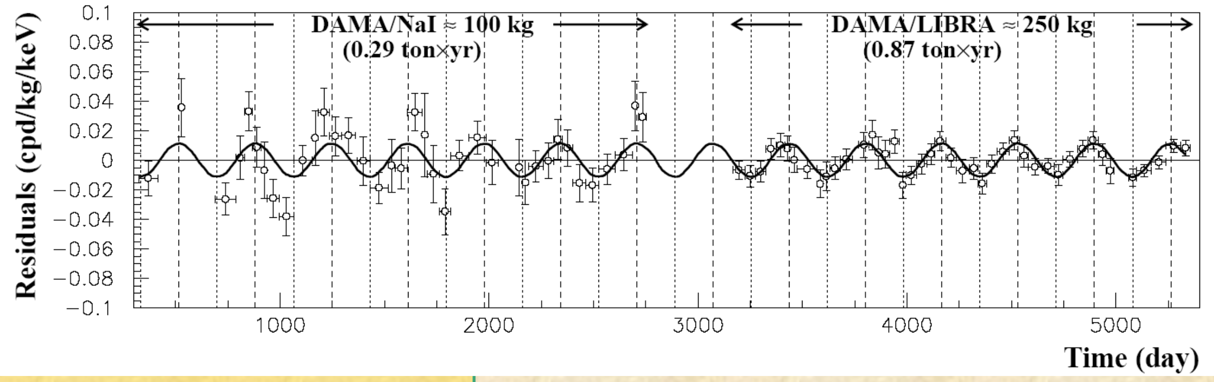
LNGS: the best laboratory in the world for the search of Dark Matter and the study of Rare Decays.

Dark Matter investigation by model-independent annual modulation signature - 1

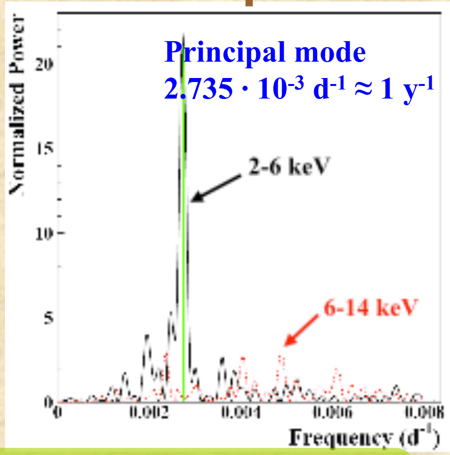
DAMA/NaI (7 years) + DAMA/LIBRA (6 years). Total exposure: **1.17 ton·yr** (the **largest** exposure ever collected in this field)

EPJC 56(2008)333, EPJC 67(2010)39

Experimental single-hit residuals rate *vs* time in 2-6 keV



Power spectrum



$A\cos[\omega(t-t_0)]$

continuous line: t_0 = 152.5 d, T = 1.00 y

A=(0.0114±0.0013) cpd/kg/keV

χ^2/dof = 64.7/79 8.8 σ C.L.

Absence of modulation? No

χ^2/dof=140/80 P(A=0) = $4.3 \cdot 10^{-5}$

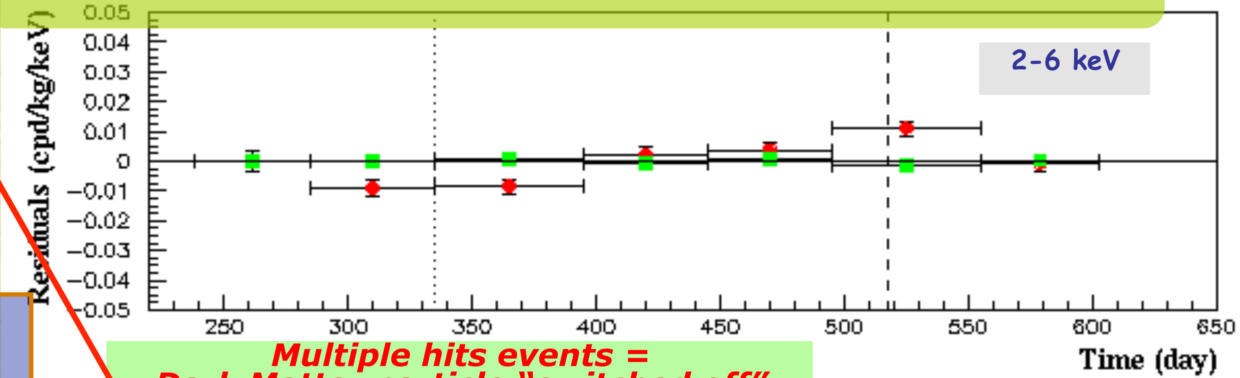
fit with all the parameters free:

A = (0.0116 ± 0.0013) cpd/kg/keV

t_0 = (146±7) d

T = (0.999±0.002) y

Comparison between **single hit residual rate (red points)** and **multiple hit residual rate (green points)** for (DAMA/LIBRA 1-6); Clear modulation in the single hit events; No modulation in the residual rate of the multiple hit events **A=-(0.0006±0.0004) cpd/kg/keV**



Multiple hits events = Dark Matter particle "switched off"

No systematics or side reaction able to account for the measured modulation amplitude and to satisfy all the peculiarities of the signature

This result offers an additional strong support for the presence of DM particles in the galactic halo further excluding any side effect either from hardware or from software procedures or from background

The data favor the presence of a modulated behaviour with all the proper features for DM particles in the galactic halo at about 9σ C.L.

The XENON Roadmap

past (2005 - 2007)	*current (2008-2010)*	*future (2011- 2015)*

XENON10

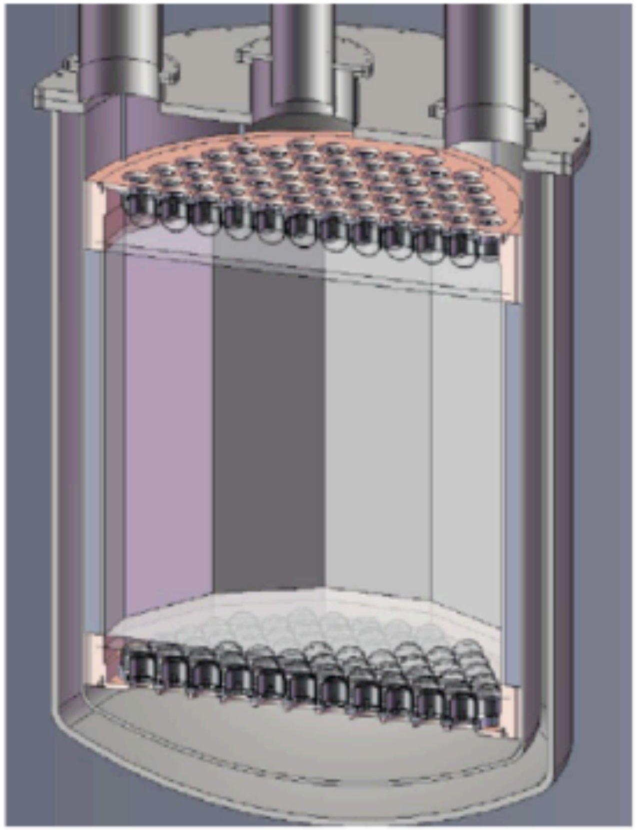
Achieved (2007) σ_{SI}=*8.8 x*10^{-44} *cm*^{2}

Phys. Rev. Lett. ***100****, 021303 (2008)*

Phys. Rev. Lett. ***101****, 091301 (2008*

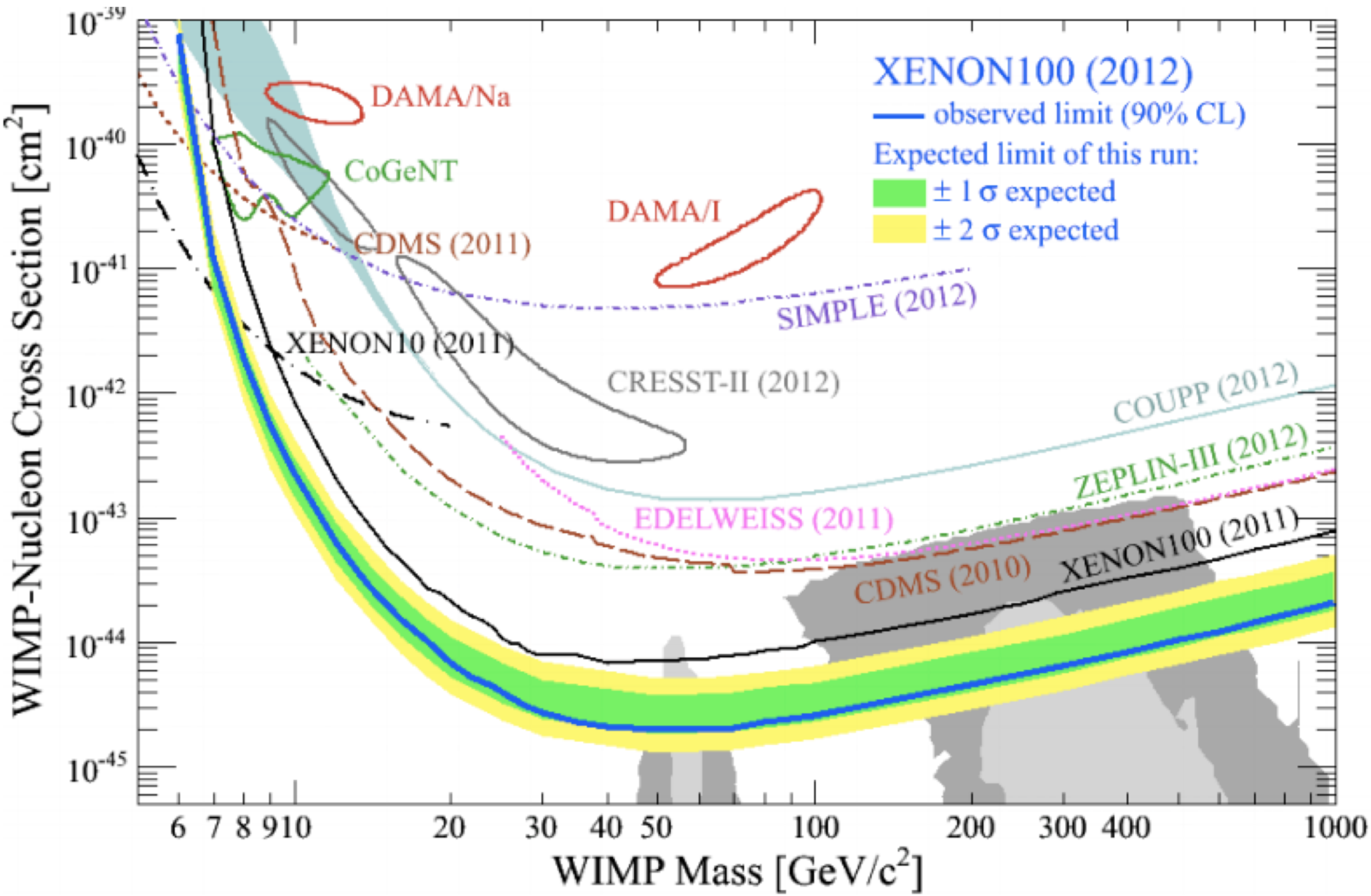
XENON100

Projected (2010) σ_{SI}~2x10^{-45} cm^2



XENON1T

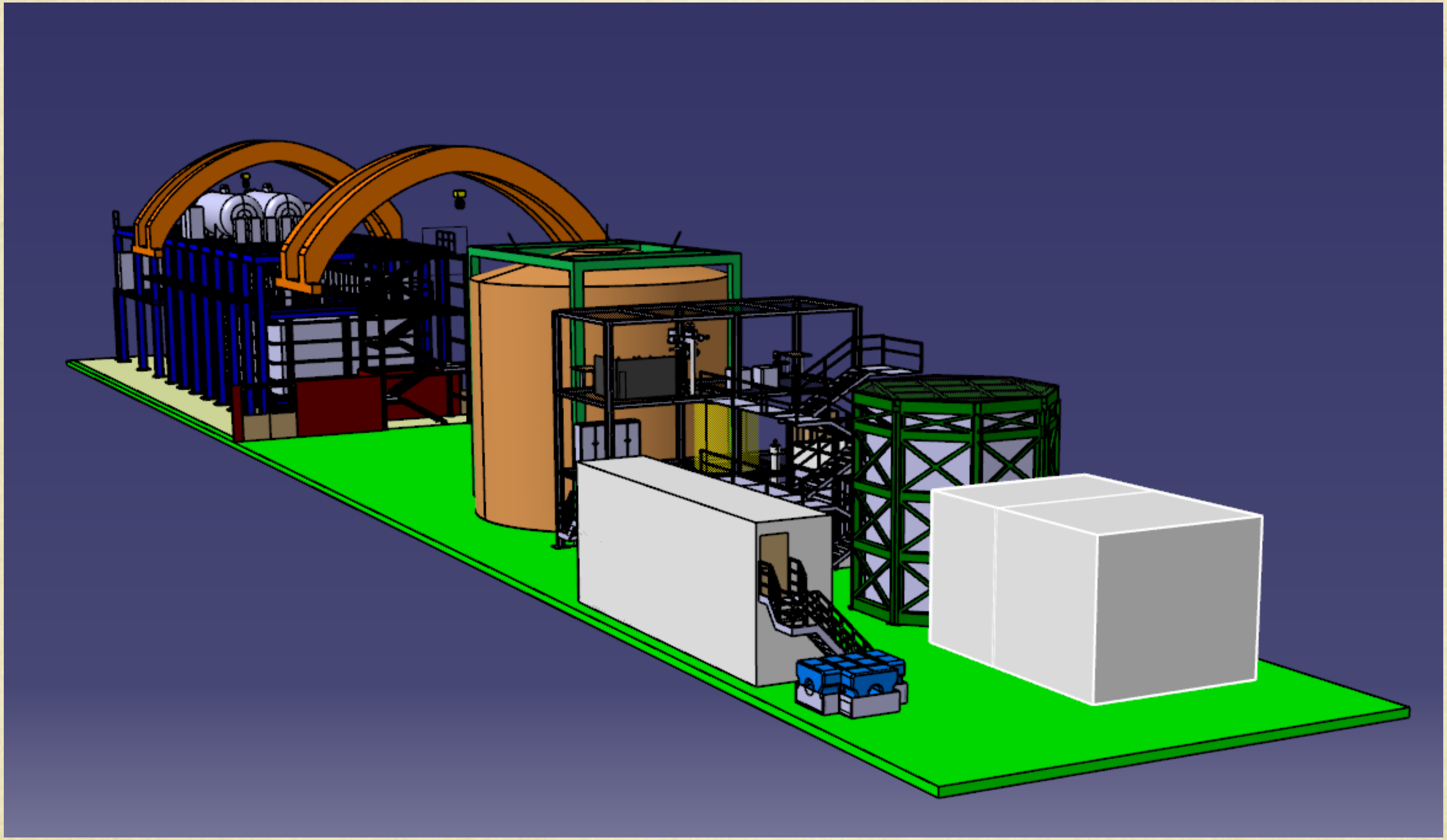
Goal: σ_{SI} <10^{-46} cm^2



Upper Limit (90% C.L.) is 2×10^{-45} cm^2 for 55 GeV/c^2 WIMP

New spin independent DM limit by XENON

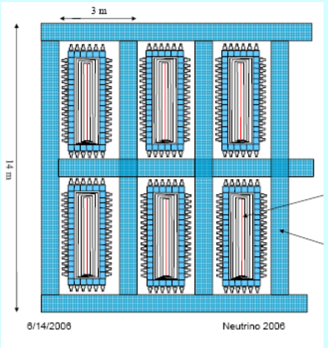
The future: Xe 1 T

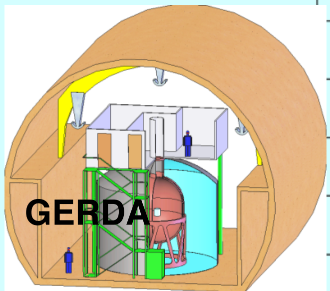


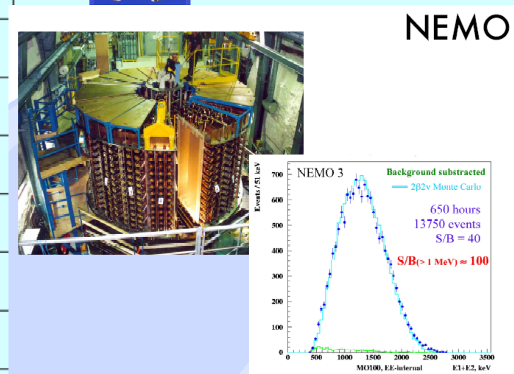
Xe
XENON
Dark Matter Project

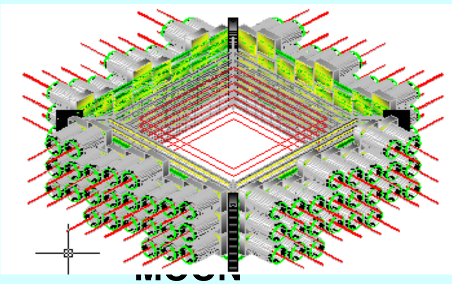
Are neutrino Maiorana particles ?
Neutrinoless double beta decay experiments

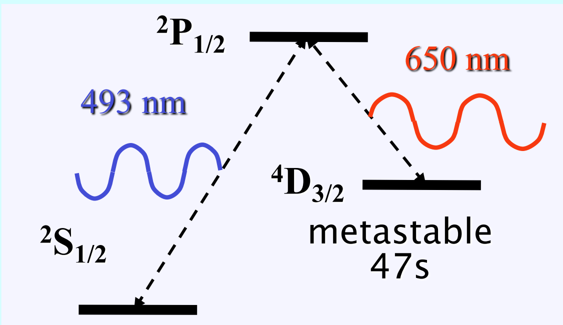
Experiment	Nucleus	Detector
NEMO III	^{100}Mo et al	10 kg of enrich. Isotopes -tracking
Cuoricino	**^{130}Te + etc.**	**40 kg of TeO_2 bolometers (nat)**
CUORE	**^{130}Te + etc.**	**750 kg of TeO_2 bolometers (nat)**
EXO	^{136}Xe	200kg - 1 t Xe TPC
GERDA	^{76}Ge	30 Ð40 kg Ð 1t Ge diodes in LN
Majorana	^{76}Ge	180 kg - 1t Ge diodes
MOON	^{100}Mo	nat.Mo sheets in plastic sc.
DCBA	^{150}Nd	20 kg Nd-tracking
CAMEO	^{116}Cd	1 t $CdWO_4$ in liquid scintillator
COBRA	^{116}Cd , ^{130}Te	10 kg of CdTe semiconductors
Candles	^{48}Ca	Tons of CaF_2 in liquid scintillators
GSO	^{116}Cd	2 t Gd_2SiO_5:Ce scintill.in liquid sc.
Xe	^{136}Xe	1.56 Xenon in liquid scintillator.
Xmass	^{136}Xe	1 t of liquid Xe

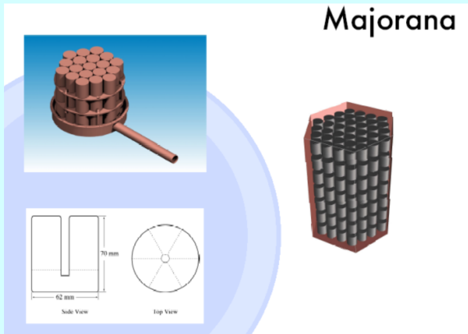


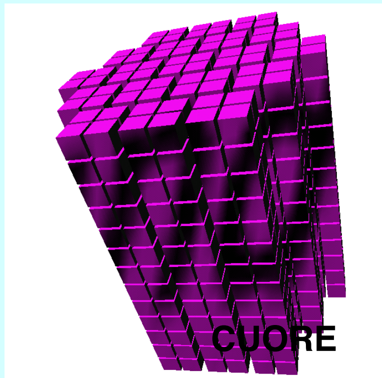










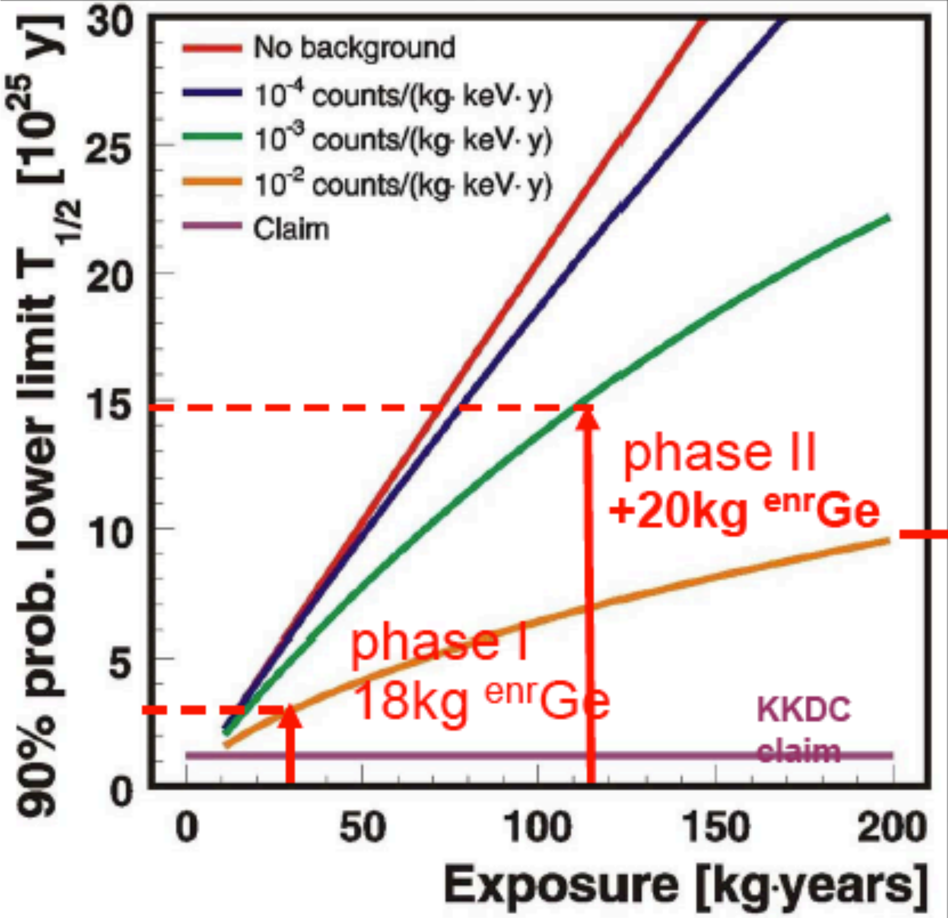


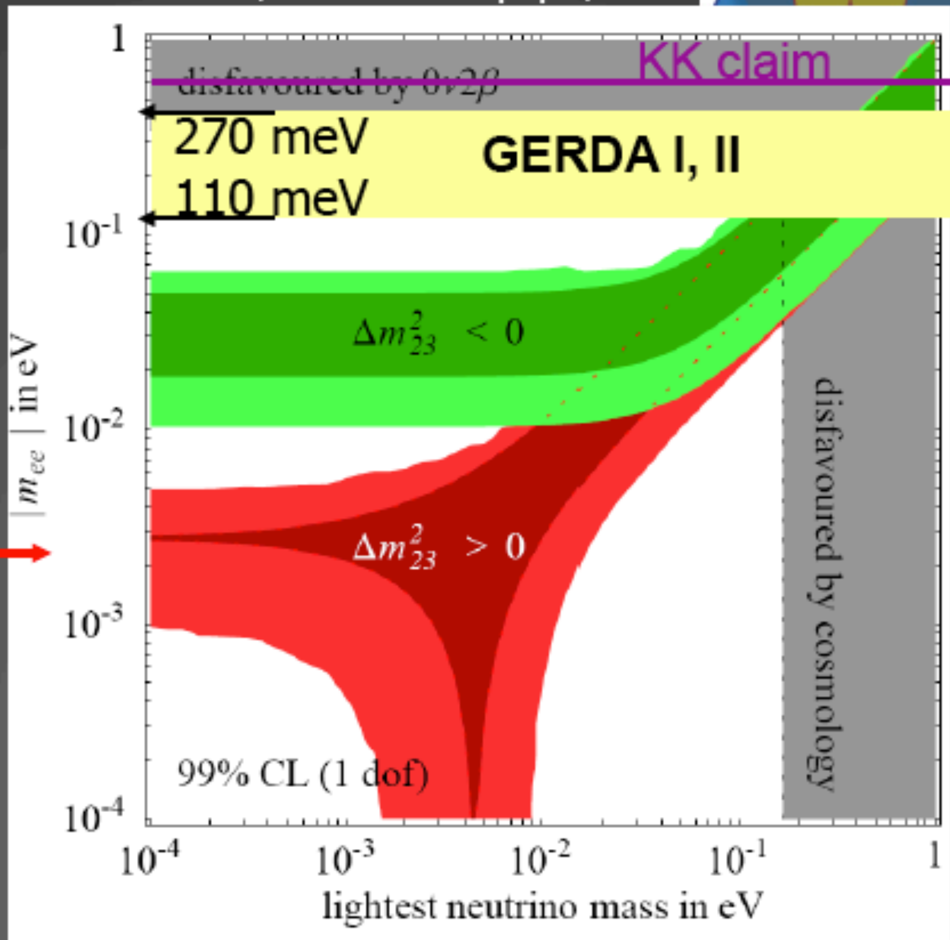

clean room – rdy
GERDA
phase I lock – under test
The GERDA setup
in Hall A of LNGS
water tank - rdy

GERDA: Sensitivity

Assumed E resolution: ΔE = 4 keV

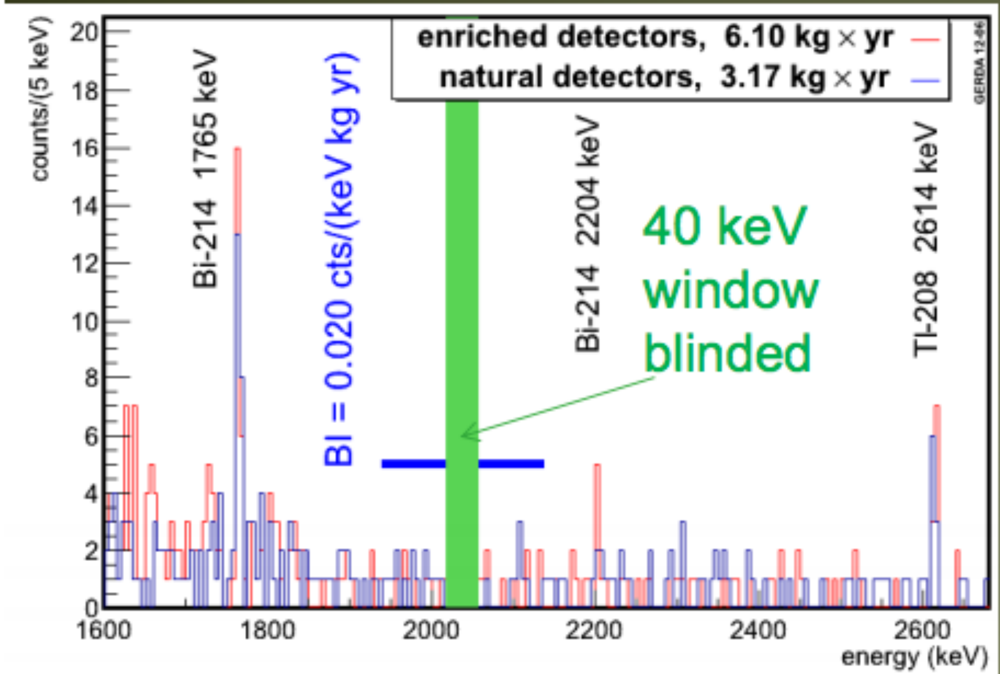
From Vissani, Strumia hep-ph/0606054v2



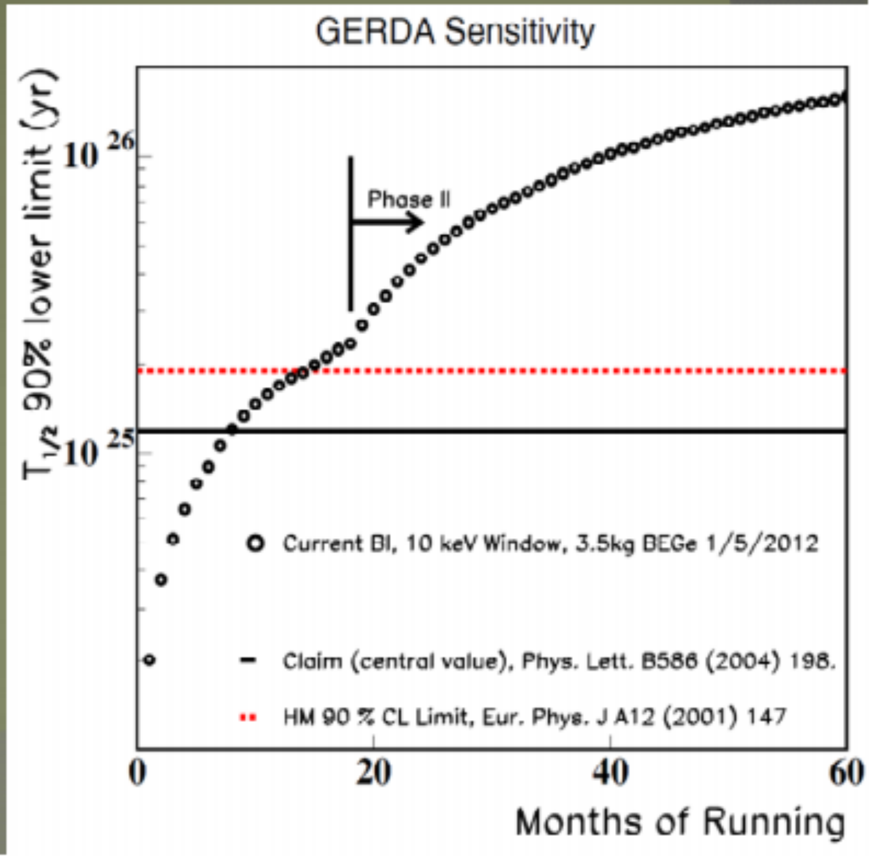


GERDA I: scrutinize in ~ 1 year data taking (assuming 18 kg y exposure) the KK claim: if true ββ decay GERDA will have 7 cts, above bckg of 1.0 cts → probability that bckg simulate signal << 10^{-3}

The spectra @ $Q_{\beta\beta}$ (± 200 keV)



Data will be unblinded in 2013



GERDA I: **with the present BI and Energy Res. scrutinize in** ~ 2 year data taking (assuming 15 kg y exposure) the KK claim: if true ββ decay GERDA will have in 1 year of data taking 7 cts, above bckg of 3 cts (in 2 FWHM).

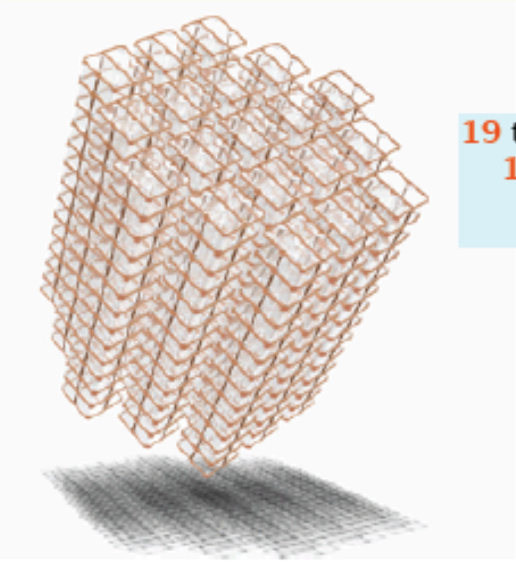
CUORE

Cryogenic Underground Observatory for Rare Events

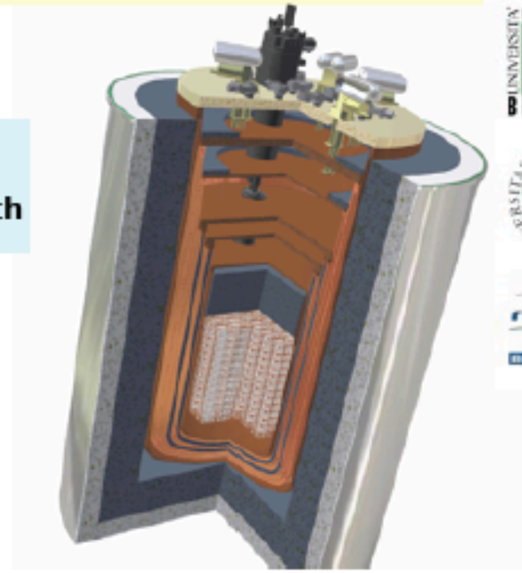
Closely packed array of 988 TeO_2 crystals 5×5×5 cm^3 (750 g)

741 kg TeO_2 granular calorimeter

600 kg Te = 203 kg ^{130}Te



19 towers
13 planes each
4 crystals each



International Collaboration

Careful design and construction of the setup

- Hut and infrastructures
- Detector
  - Crystals
  - Structure
  - Assembly
- Cryostat and shields
- Calibration system
- Electronics

Calorimetric experiment on 130Te neutrinoless DBD: sensitivity

Background	ΔE	$T_{1/2}$	$<m_{ee}>$			
c/kev/kg/y	keV	10^{26} y	R(QRPA)[1]	np(QRPA)	ISM[3]	IBM-2[4]
0.01	5	2.1	35-66	41-67	65-82	41
0.001	5	6.5	20-38	23-38	37-47	23

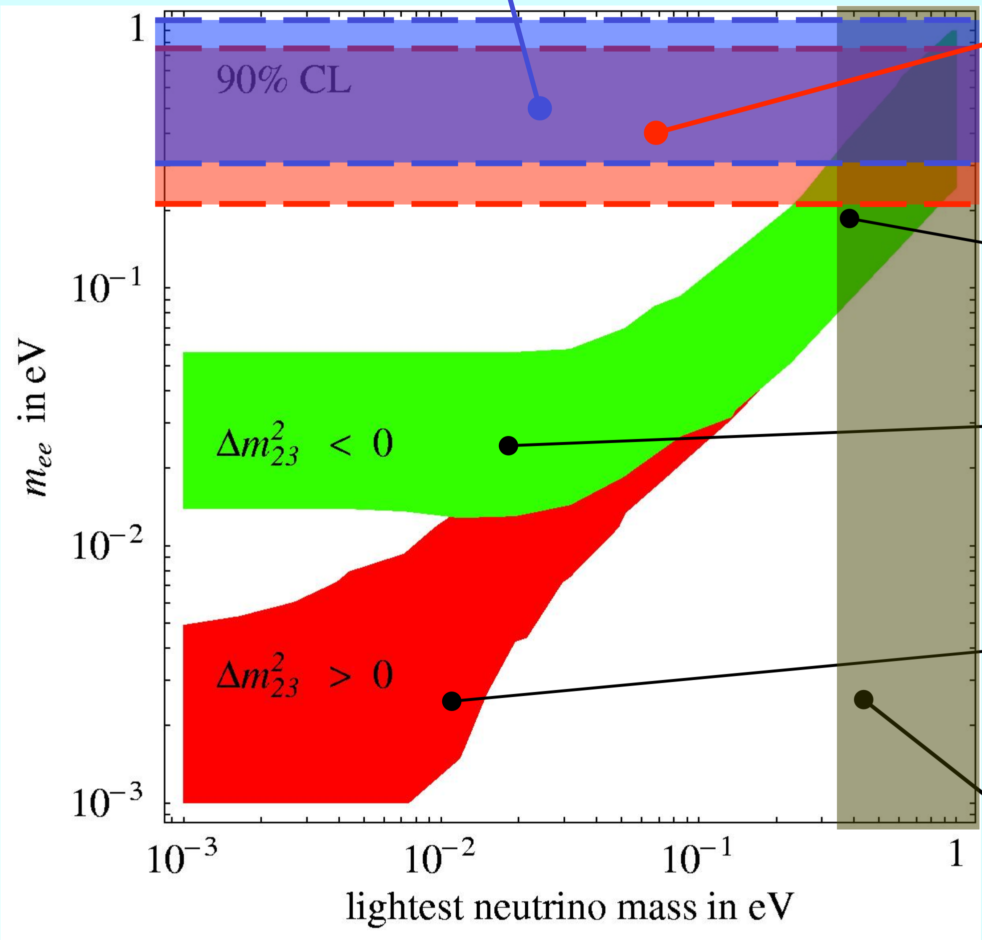
1 Šimkovic et al., PRC 77 (2008) 045503
2 Civitarese et al., JoP:Conference series 173 (2009) 012012
3 Menéndez et al., NPA 818 (2009) 139
4 Barea and Iachello, PRC 79 (2009) 044301

Limit of Cuoricino and expected sensitivity of CUORE

Present Cuoricino region

Arnaboldi et al., submitted to PRL, hep-ex/0501034 (2005).

Possible evidence (best value 0.39 eV)



With the same matrix elements the Cuoricino limit is **0.53 eV**

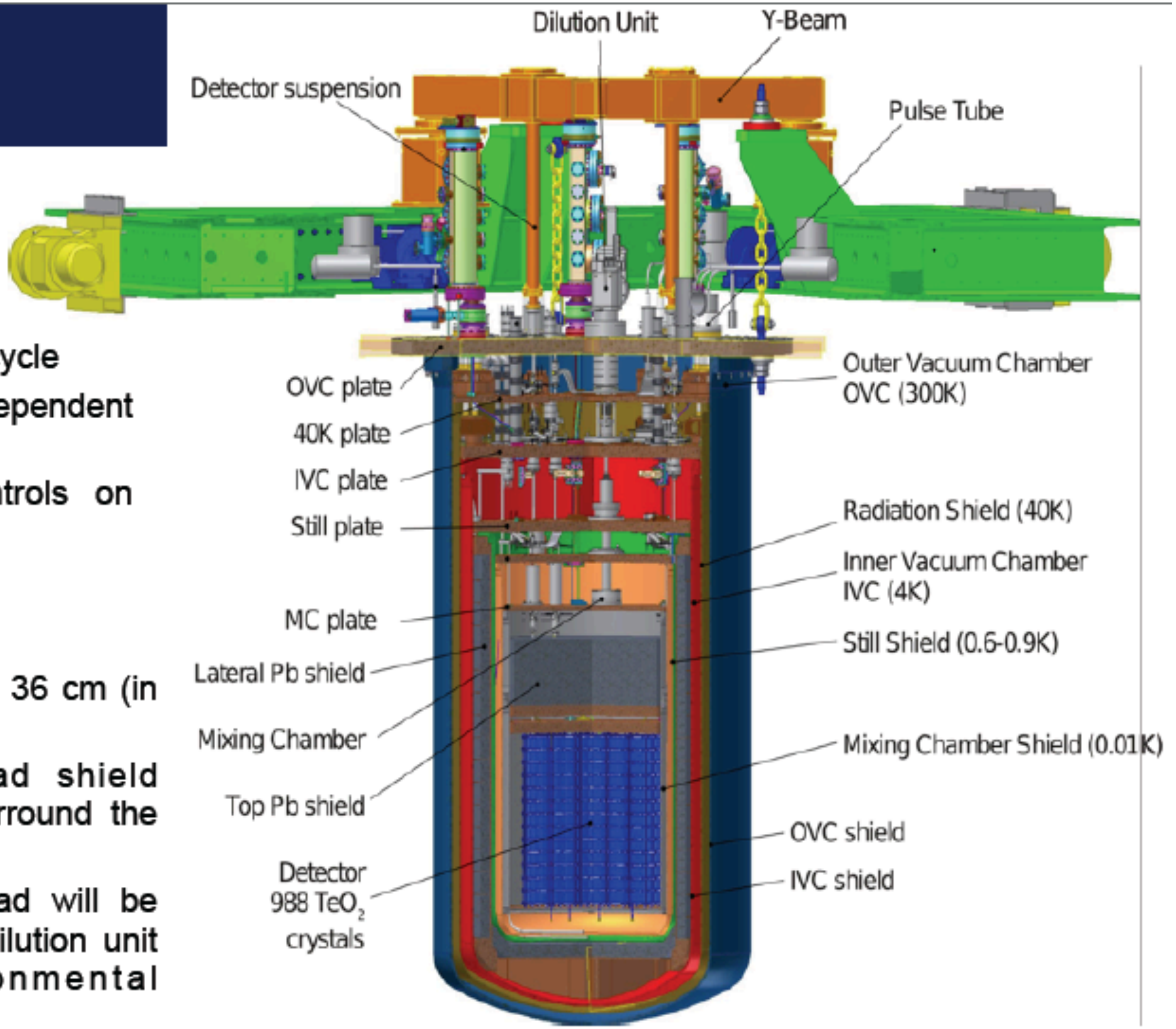
"quasi" degeneracy
$m_1 \approx m_2 \approx m_3$

$\Delta m^2_{12} = \Delta m^2_{atm}$ => *CUORE*

Direct hierarchy
$\Delta m^2_{12} = \Delta m^2_{sol}$

Cosmological disfavoured region (WMAP)

Setup

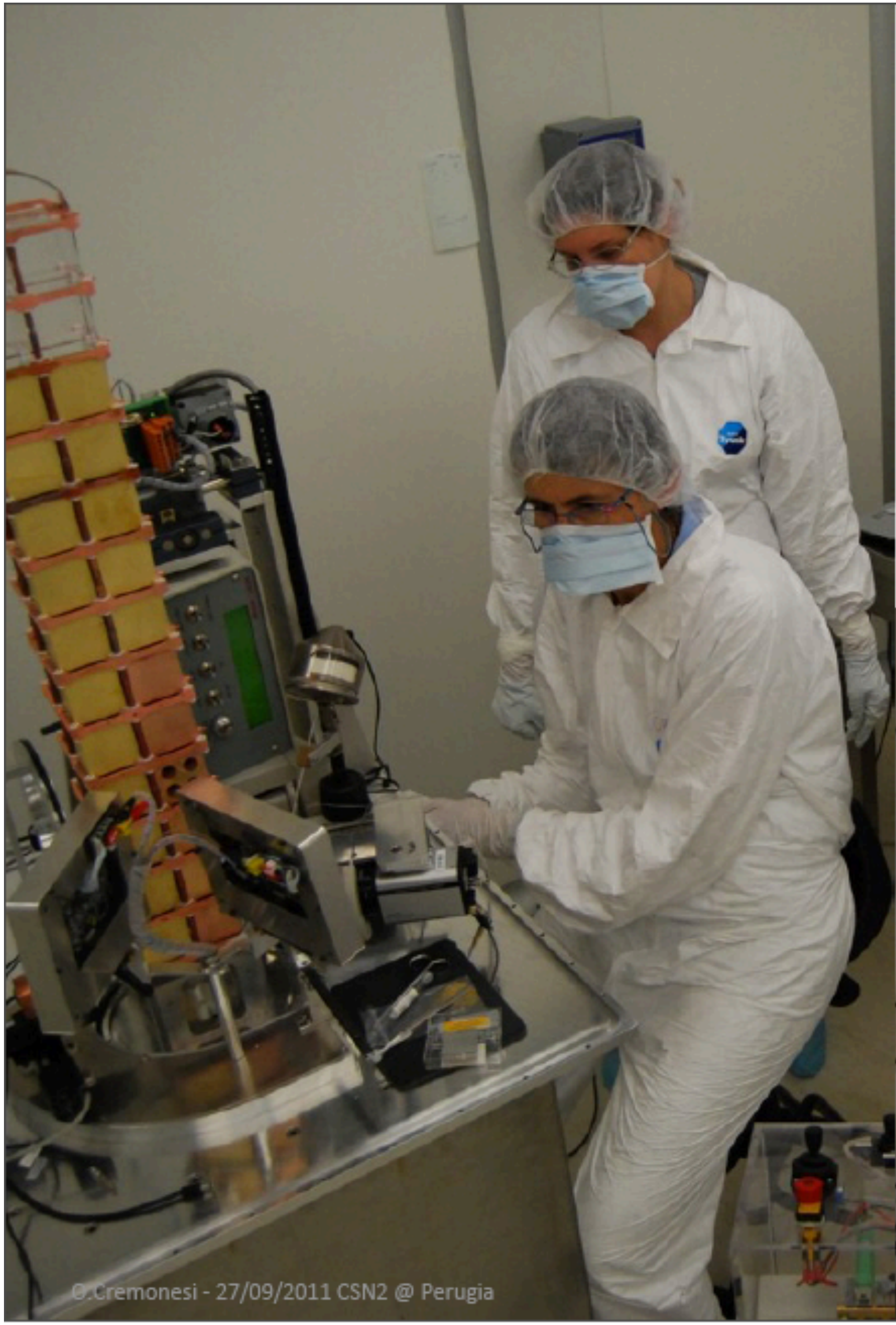


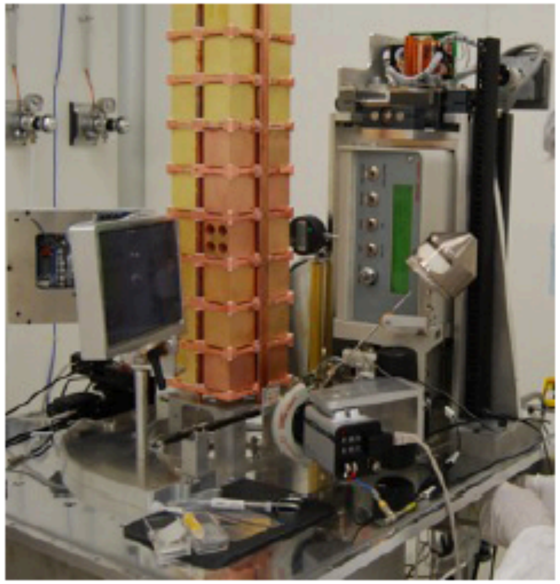
Cryostat:

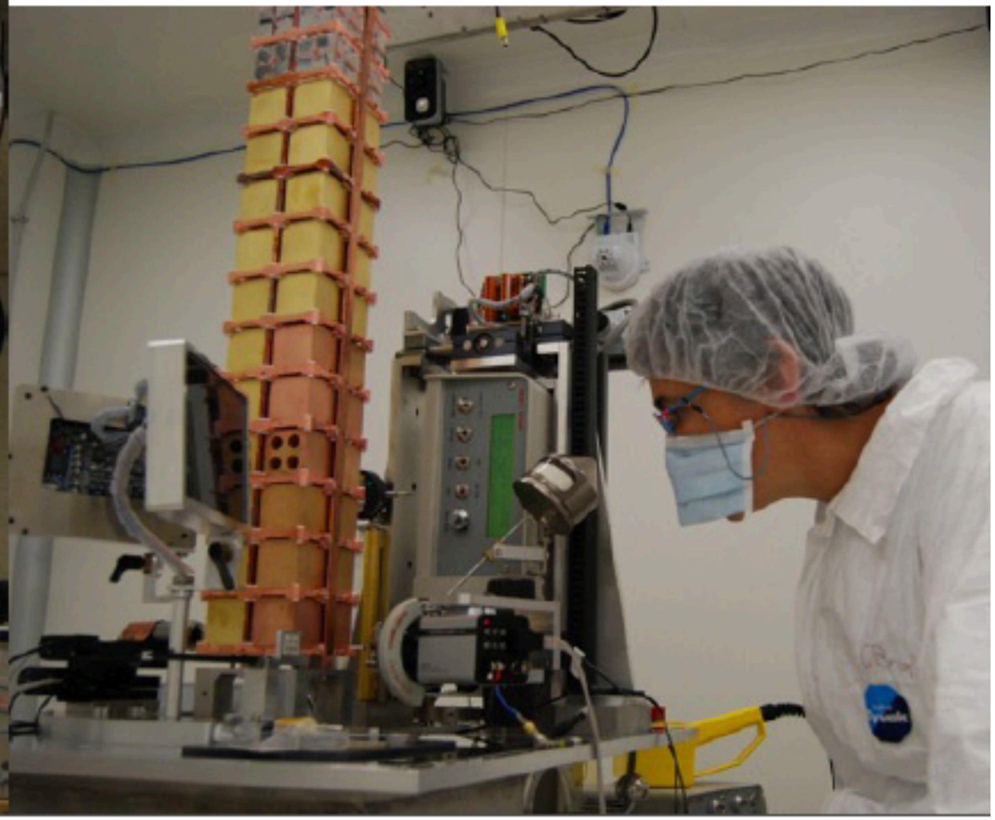
- Cryogen-free: better duty cycle
- Detector suspension independent of refrigerator apparatus
- Stringent radiopurity controls on materials and assembly

Shields:

- Minimum lead thickness ≈ 36 cm (in Cuoricino ≈ 22 cm)
- 6 cm thick roman lead shield operated at ~600 mK surround the array
- 30 cm of low activity lead will be used to shield from the dilution unit and from the environmental radioactivity
- Neutron shielding: 18 cm thick polyethylene + 2 cm of H_3BO_3 powder


O.Cremonesi - 27/09/2011 CSN2 @ Perugia





CUORE0

(second) Installation of the CUORE-0 tower (July/August)

Line 2: rare processes SUMMARY

- **PAST YEAR(S)** :
  - DAMA-LIBRA, XENON-100
  - GERDA (operation), CUORE (construction)

- **NEXT YEAR(S)** :
  - DAMA-LIBRA, XENON-1T (constr.), DARK-SIDE (constr.)
  - GERDA, CUORE ← *Planck and CMB results*

- **LONG TERM STRATEGY**: CUORE+ (?), XENON+ (?), DARK-SIDE+ (?), CRYOGENIC CRYSTALS (?)

Line 3: cosmic rays from ground
SUMMARY

- **PAST YEAR(S)** : ARGO, AUGER, MAGIC
  ANTARES, KM3-NET

- **NEXT YEAR(S)** : AUGER, MAGIC → CTA
  KM3

- **LONG TERM STRATEGY**: AUGER (?), CTA
  KM3-NET

Back to Top 25

Top 25 Hottest Articles

Physics and Astronomy > Astroparticle Physics

January to December 2011 full year

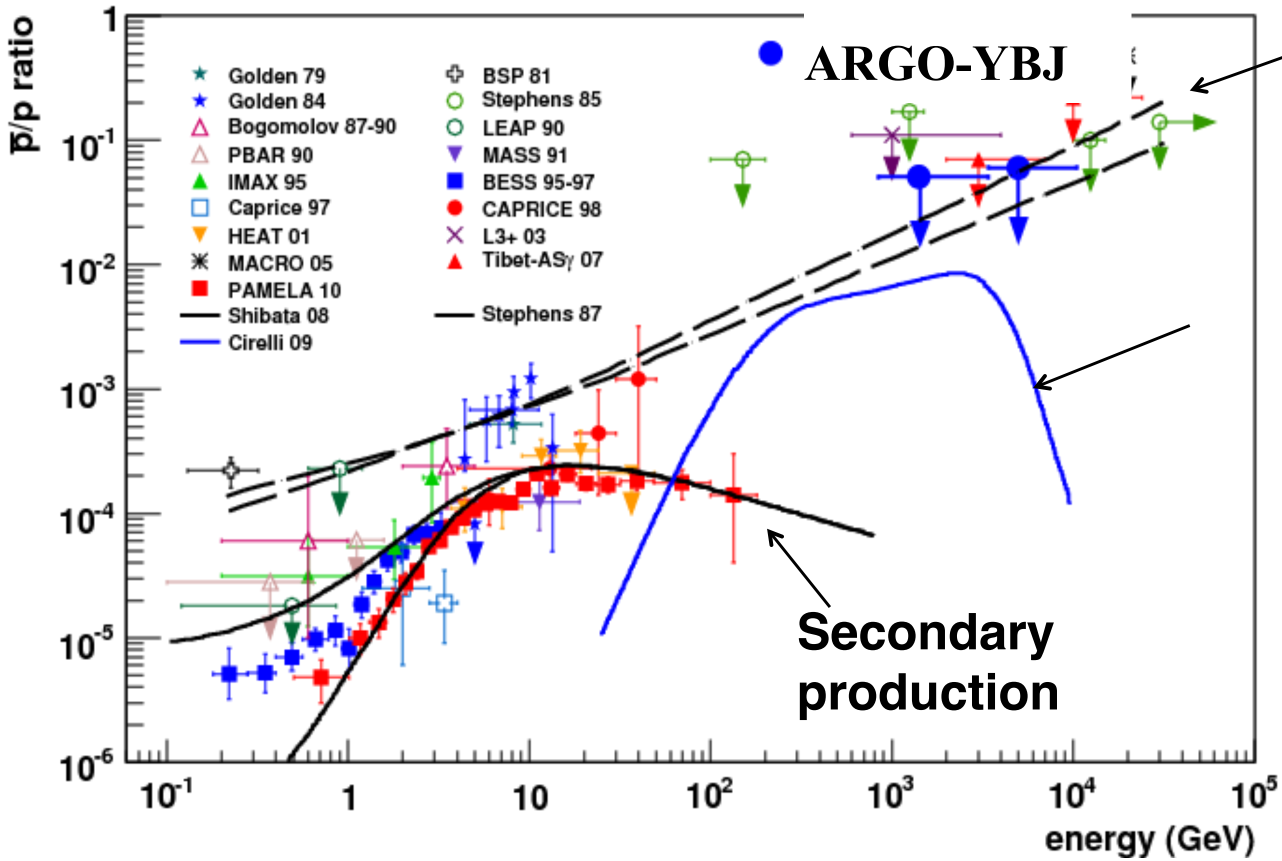
1. **Search for first harmonic modulation in the right ascension distribution of cosmic rays detected at the Pierre Auger Observatory**
   Astroparticle Physics, Volume 34, Issue 8, March 2011, Pages 627-639
   The Pierre Auger Collaboration; Abreu, P.; Aglietta, M.; Ahn, E.J.; Albuquerque, I.F.M.; Allard, D.; Allekotte, I.; Allen, J.; Allison, P.; Alvarez Castillo, J.; Alvarez-Muniz, J.; Ambrosio, M.; Aminaei, A.; Anchordoqui, L.; Andringa, S.; Anticic, T.; Ara
   Cited by SciVerse Scopus (10)

2. **Update on the correlation of the highest energy cosmic rays with nearby extragalactic matter**
   Astroparticle Physics, Volume 34, Issue 5, December 2010, Pages 314-326
   The Pierre Auger Collaboration; Abreu, P.; Aglietta, M.; Ahn, E.J.; Allard, D.; Allekotte, I.; Allen, J.; Alvarez Castillo, J.; Alvarez-Muniz, J.; Ambrosio, M.; Aminaei, A.; Anchordoqui, L.; Andringa, S.; Anticic, T.; Anzalone, A.; Aramo, C.; Arganda, E.;
   Cited by SciVerse Scopus (51)

PIERRE AUGER OBSERVATORY

6 dei 25 articoli nella top 25 di AstroParticle 2011 sono Pierre Auger tra cui il primo e il secondo.

Upper limits on $\bar{p}/p$ by ARGO-YBJ



Antimatter galaxy contribution for diffusion coefficients 0.6, 0.7

Heavy DM model (Cirelli)

In this energy range the p fraction in CR is ≈70%

5% at 1.4 TeV at 90% c.l.
6% at 5 TeV at 90% c.l.

MAGIC Telescopes

New technologies
to lower the threshold energy

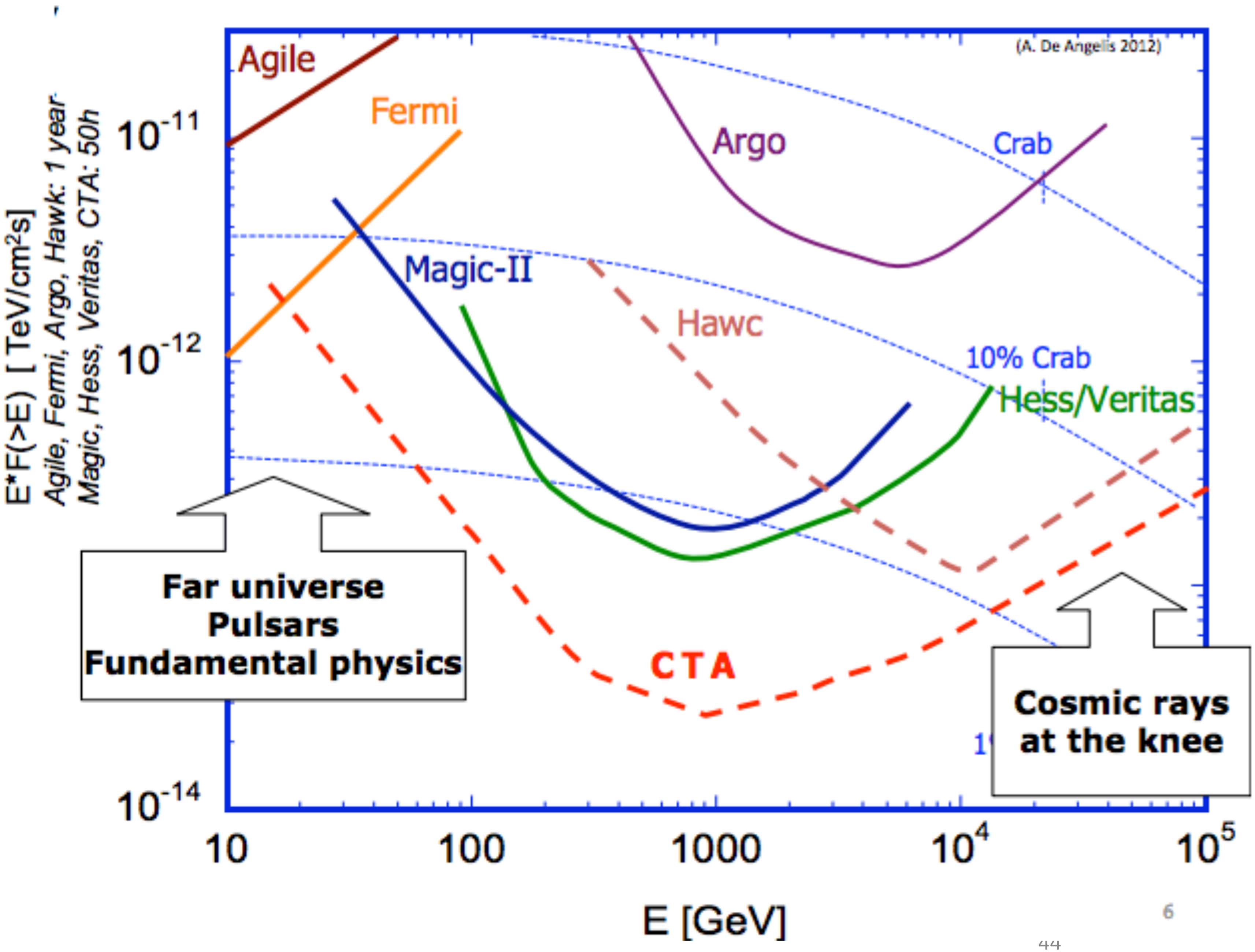
17m diameter world largest Cherenkov tel.
0.1°High resolution camera
Hemispherical High QE PMT
Optical fibre analogue signal transmission
2GS/sec Ultra Fast FADCs

Current MAGIC-I Performance

Fast rotation for GRB < 40s
Trigger threshold ~55GeV ➔ ~25GeV
Sensitivity ~1.6% of Crab (50hrs)
Angular resolution ~0.1 degrees
Energy Resolution 20-30%

MAGIC-II is completed
First Light Ceremony April 2009

Improve sensitivity by a factor of three
Effectively lower the threshold energy
(upgrade with HPD 55%QE photodetectors)



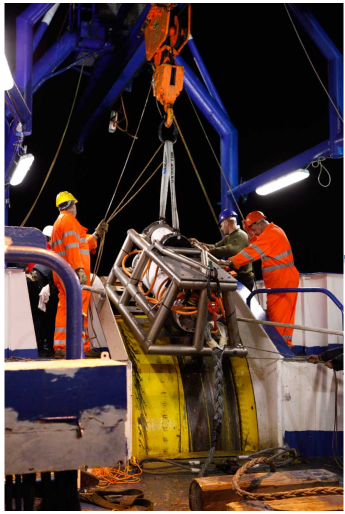
(A. De Angelis 2012)
Agile
Fermi
Argo
Crab
Magic-II
Hawc
10% Crab
Hess/Veritas
CTA
Far universe
Pulsars
Fundamental physics
Cosmic rays
at the knee
E*F(>E) [TeV/cm²s]
Agile, Fermi, Argo, Hawk: 1 year
Magic, Hess, Veritas, CTA: 50h
10^{-11}
10^{-12}
10^{-14}
10
100
1000
10^{4}
10^{5}
E [GeV]

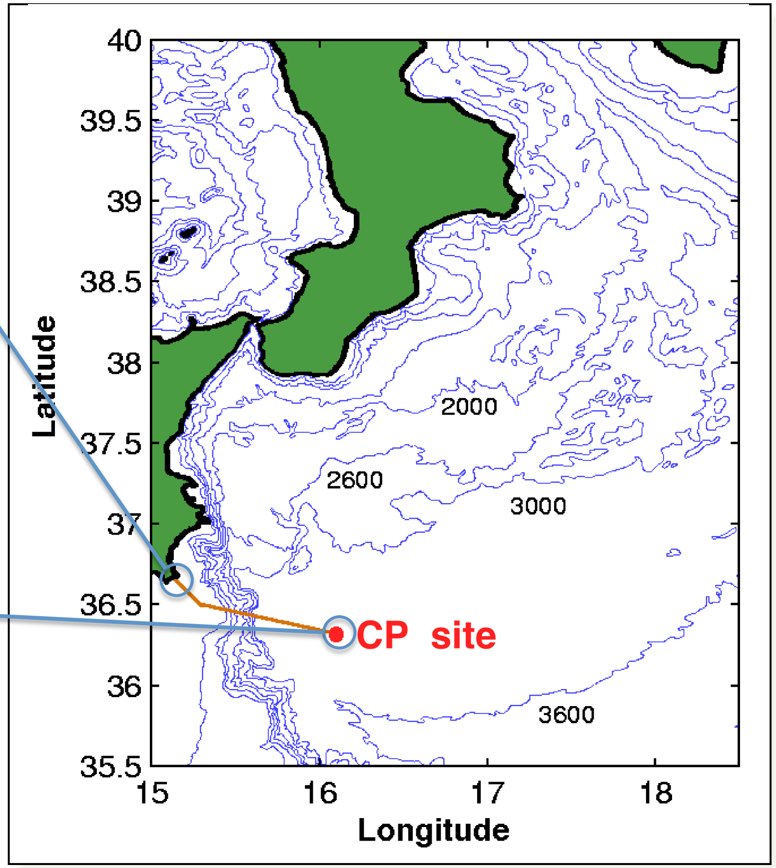
KM3 at Capo Passero

Sito studiato e caratterizzato dalla collaborazione NEMO nei passati 12 anni
Infrastruttura sottomarina e di terra già realizzata dall'INFN da upgradare con il progetto KM3NeT-Italia

Infrastrutture esistenti

- Convertitore sottomarino da 10 kW DC/DC
- Cavo elettro-ottico da 100 km
- Sistema di alimentazione
- Stazione di terra
- Connessione a larga banda (1 Gbps) con I LNS (da 16/6 operativo)





Line 3: cosmic rays from ground SUMMARY

- **PAST YEAR(S)** : ARGO, AUGER, MAGIC
  ANTARES, KM3-NET

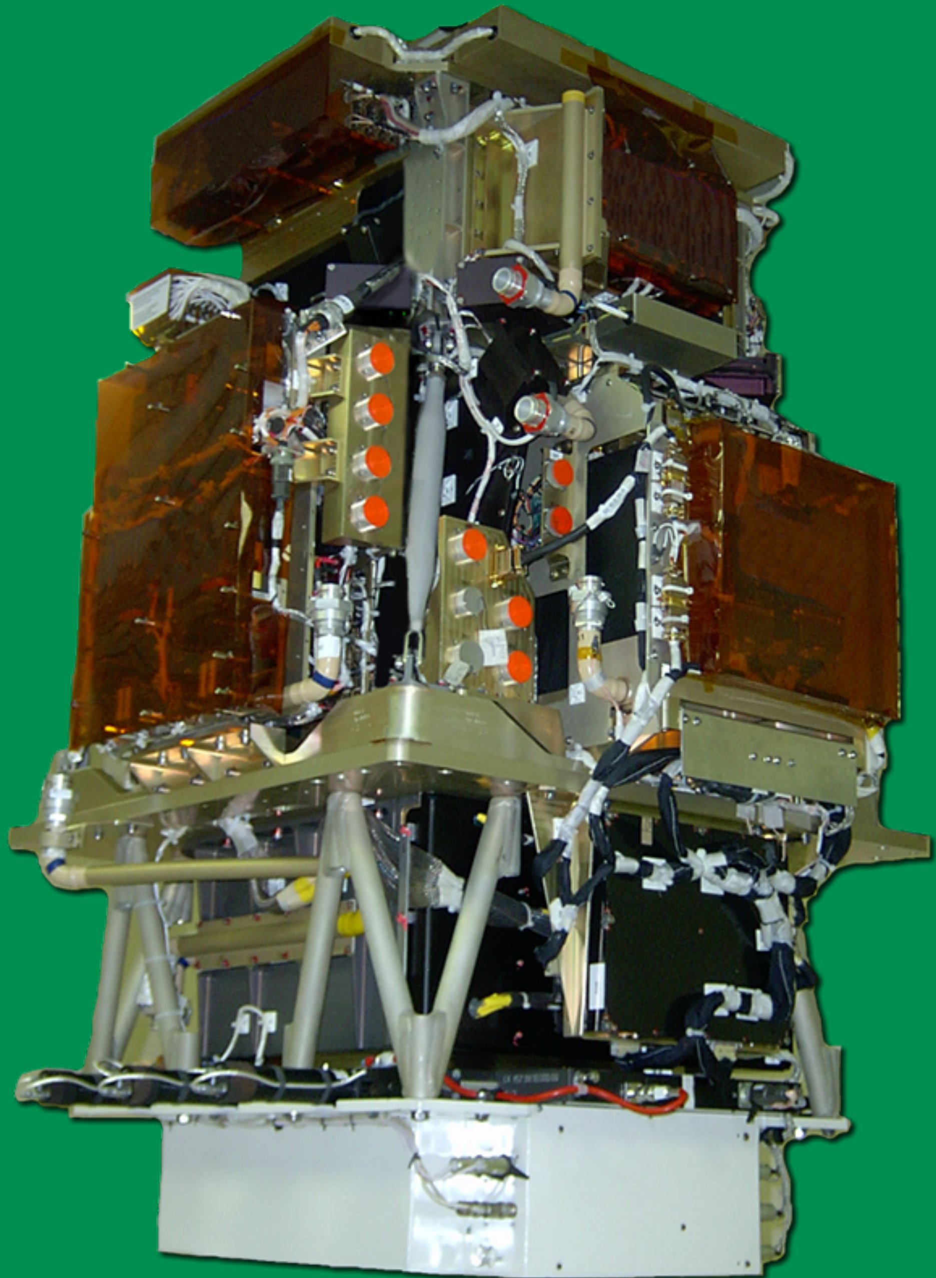
- **NEXT YEAR(S)** : AUGER, MAGIC → CTA
  KM3

- **LONG TERM STRATEGY**: AUGER (?), CTA
  KM3-NET

Line 4: cosmic rays from space SUMMARY

- **PAST YEAR(S)** : PAMELA, AGILE, FERMI, AMS-02
- **NEXT YEAR(S)** : FERMI, AMS-02
- **LONG TERM STRATEGY**: AMS-02, JEM-EUSO (?), GAMMA-400 (?), HERD (?)

PAMELA



Magnetic spectrometer

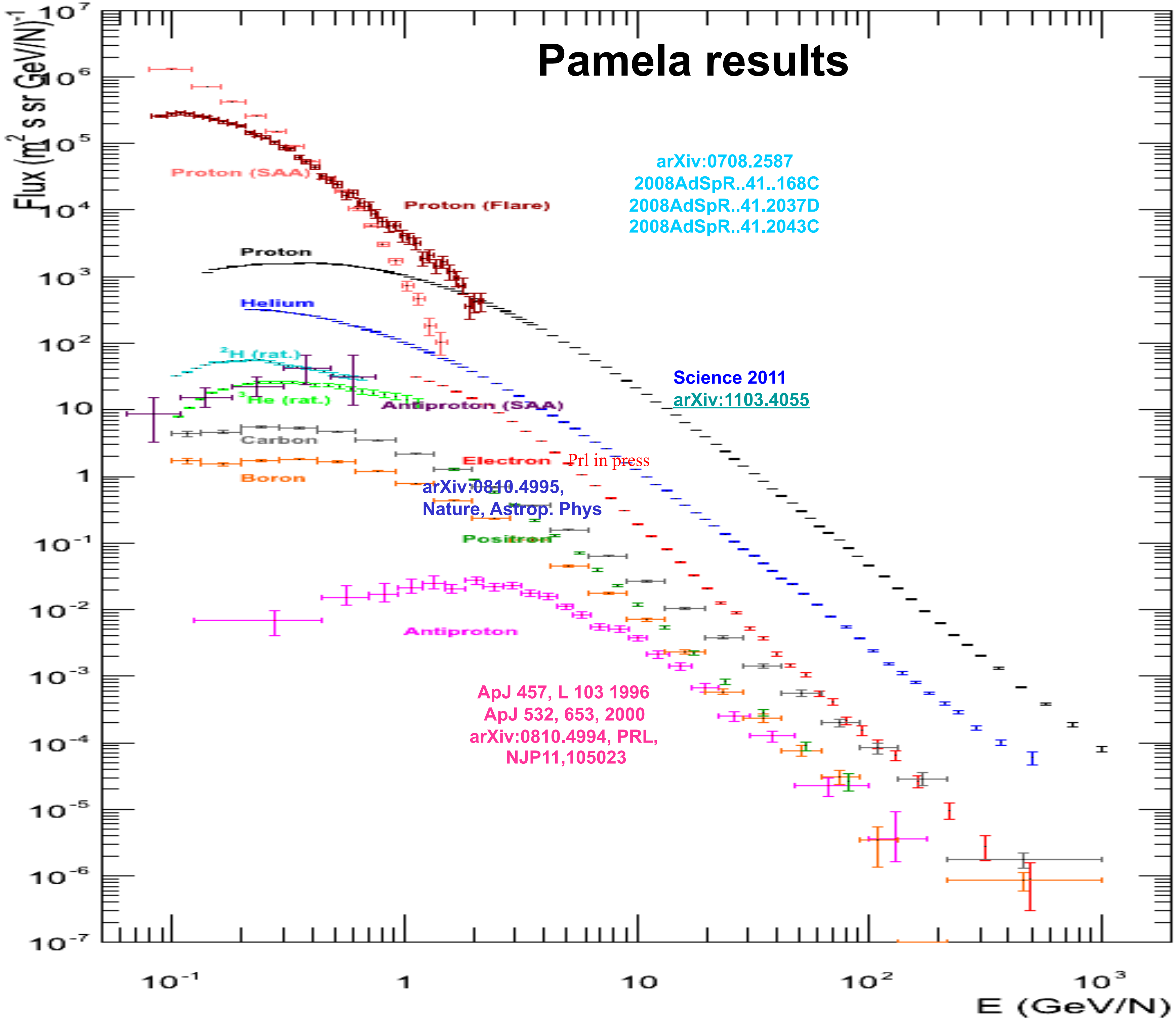
Measurement of CR composition

-> antimatter
-> dark matter
-> propagation
-> solar physics

GF ~21.5 $cm^2 sr$

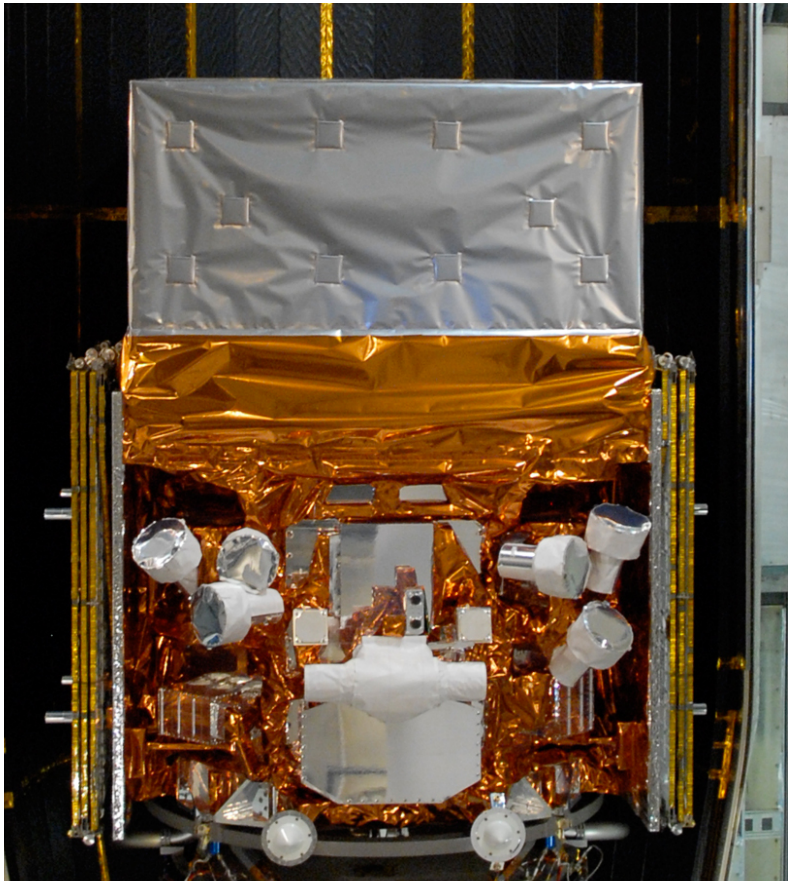
Mass: 470 kg

Size: 130x70x70 cm^3



Pamela results
arXiv:0708.2587
2008AdSpR..41..168C
2008AdSpR..41.2037D
2008AdSpR..41.2043C
Science 2011
arXiv:1103.4055
Prl in press
arXiv:0810.4995,
Nature, Astrop. Phys
ApJ 457, L 103 1996
ApJ 532, 653, 2000
arXiv:0810.4994, PRL,
NJP11,105023
Proton (SAA)
Proton (Flare)
Proton
Helium
²H (rat.)
³He (rat.)
Antiproton (SAA)
Carbon
Boron
Electron
Positron
Antiproton
Flux (m² s sr GeV/N)⁻¹
E (GeV/N)

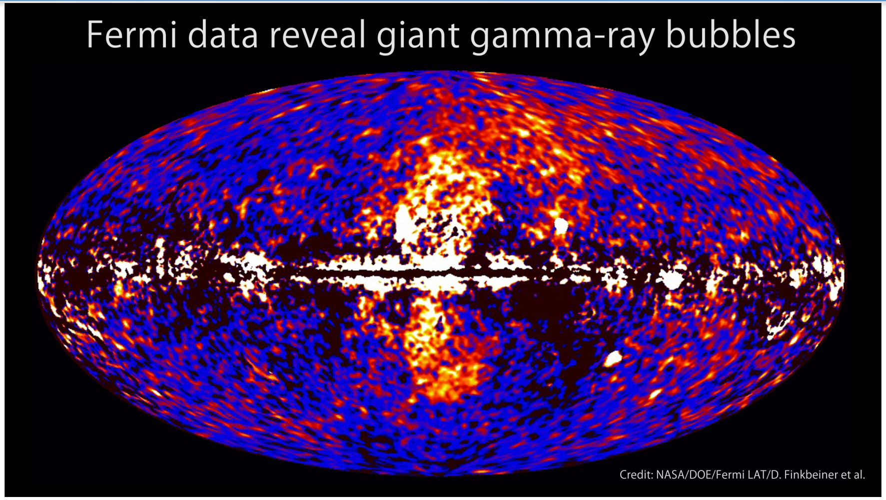
Fermi 4 years in orbit

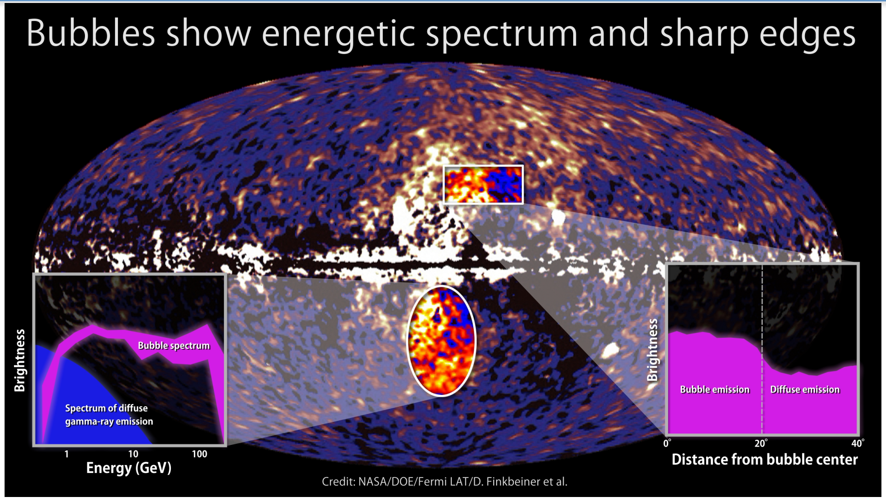


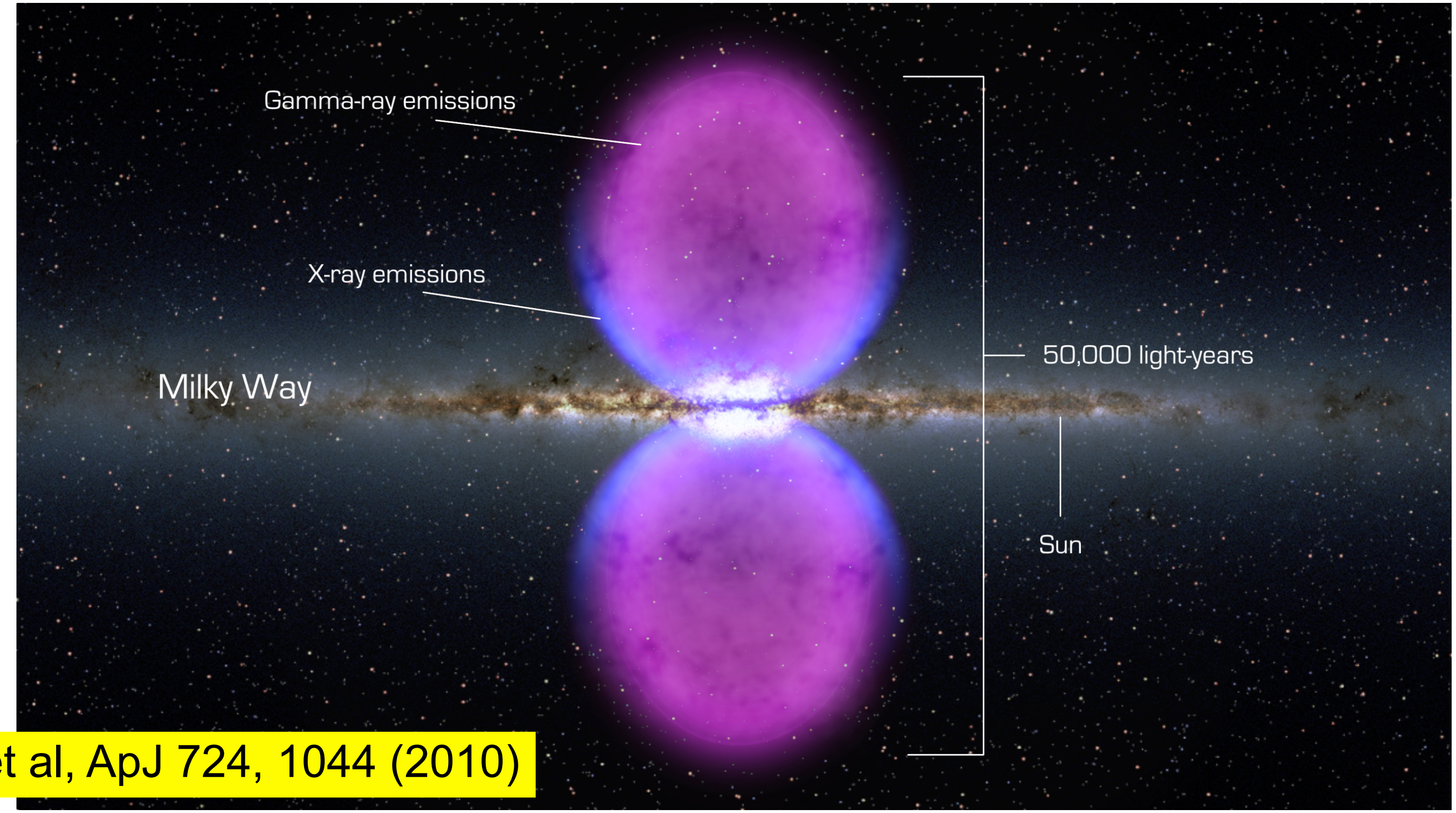
- Operations Milestones
  - 3 yrs operations last June
  - >150B triggers
    - > 35B evts to ground
    - >500M candidate photons
- Instrument
  - Remarkably stable
    - + ~ 0.01% new noisy TKR chans
    - 1/8 CAL bad chan (~ 0.5%)
  - Calibrations limited to few hours/yr (>99.99% uptime)
- Collaboration Status
  - >150 papers published
    - https://www-glast.stanford.edu/cgi-bin/pubpub
  - ~1400 talks since launch
  - > 300 citations

Fermi Gamma-ray Space Telescope

Energetic *bubbles* in our galaxy



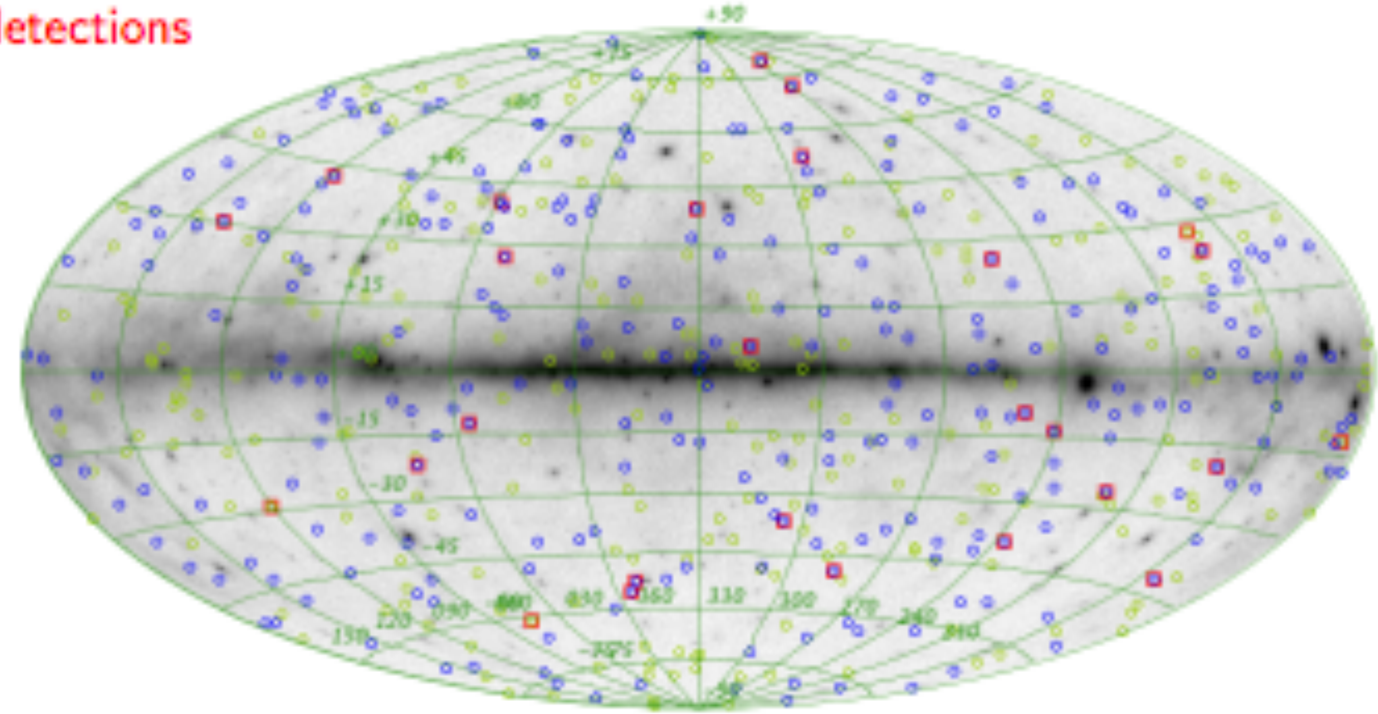




Meng Su et al, ApJ 724, 1044 (2010)

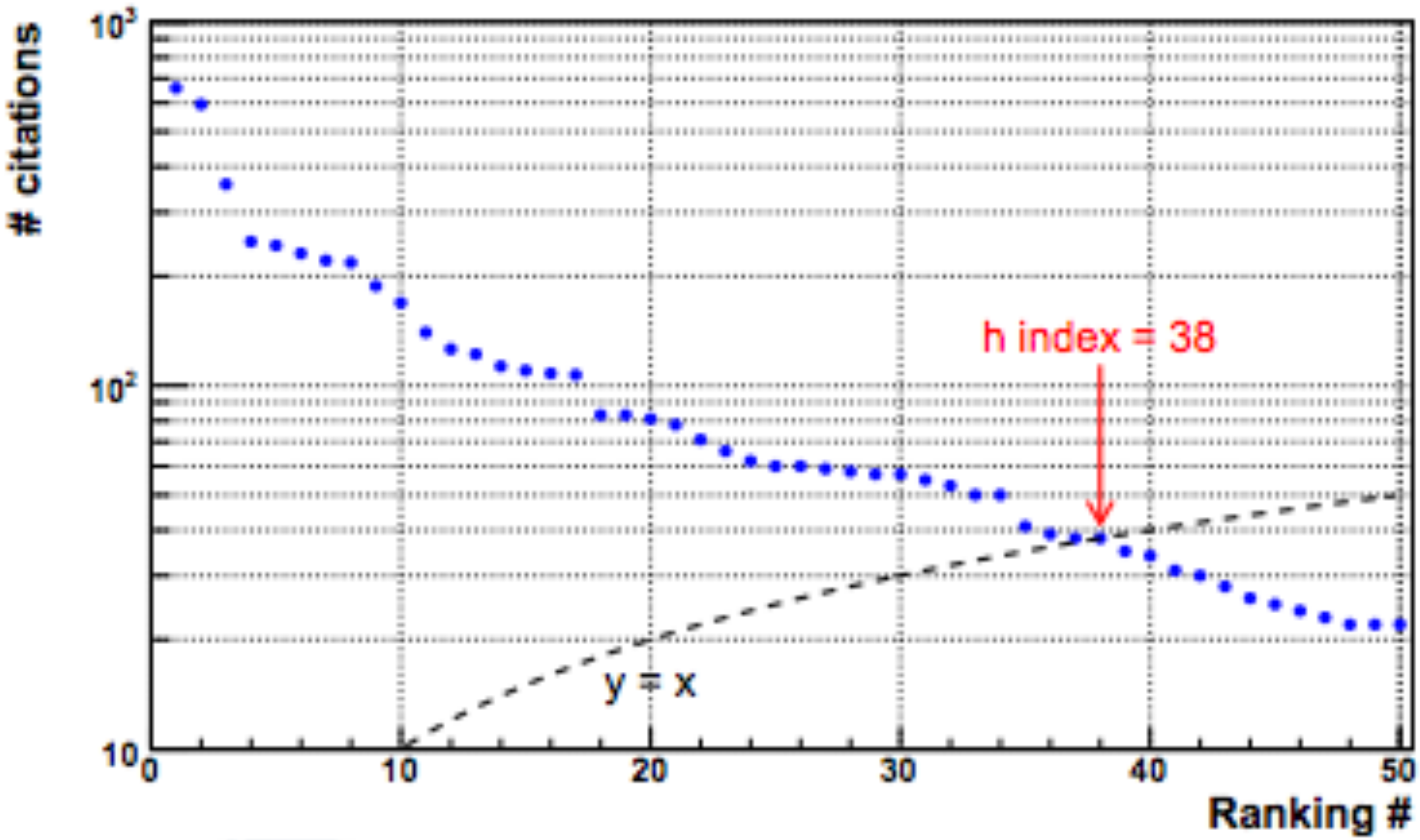
Toward the first GRB catalog

GBM bursts in the LAT FOV
GBM bursts outside the LAT FOV
LAT detections



- ~ 550 GRBs detected by the GBM, 27 LAT detections over the first three years.
  - Extended high-energy emission.
  - Delayed emission.
  - Extra spectral components.
  - LIV/quantum gravity.

Fermi LAT papers and citations
aka Fermi's h-index

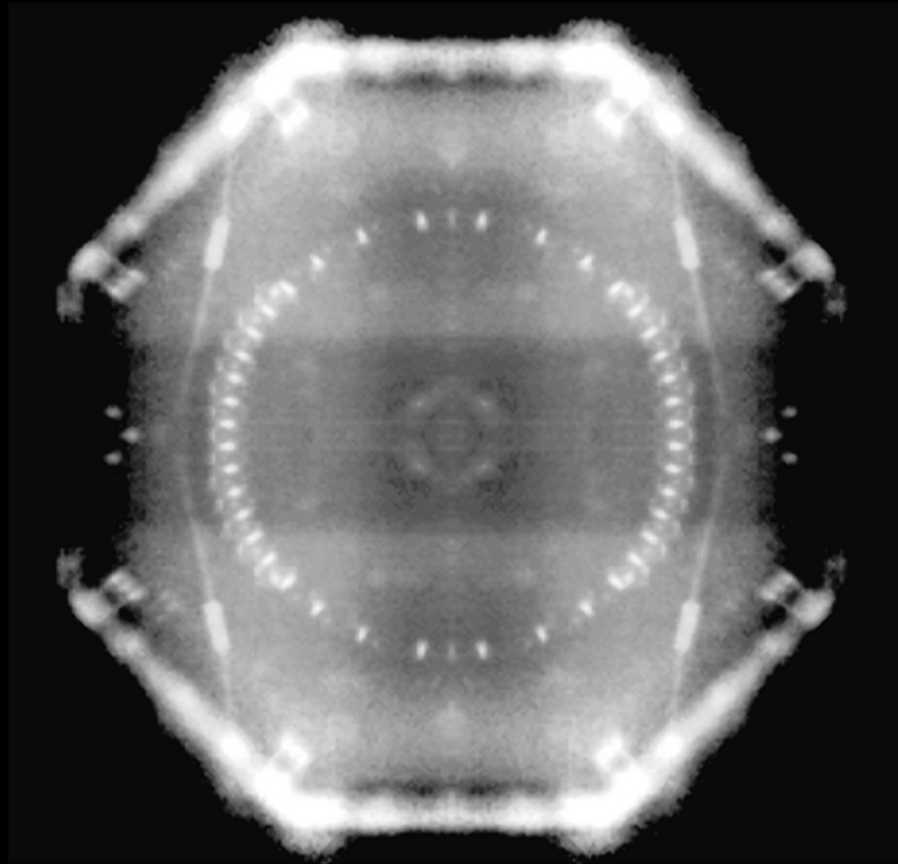



AMS
AMS

AMS Hadronic Tomography

with the cosmic-ray p/He ratio

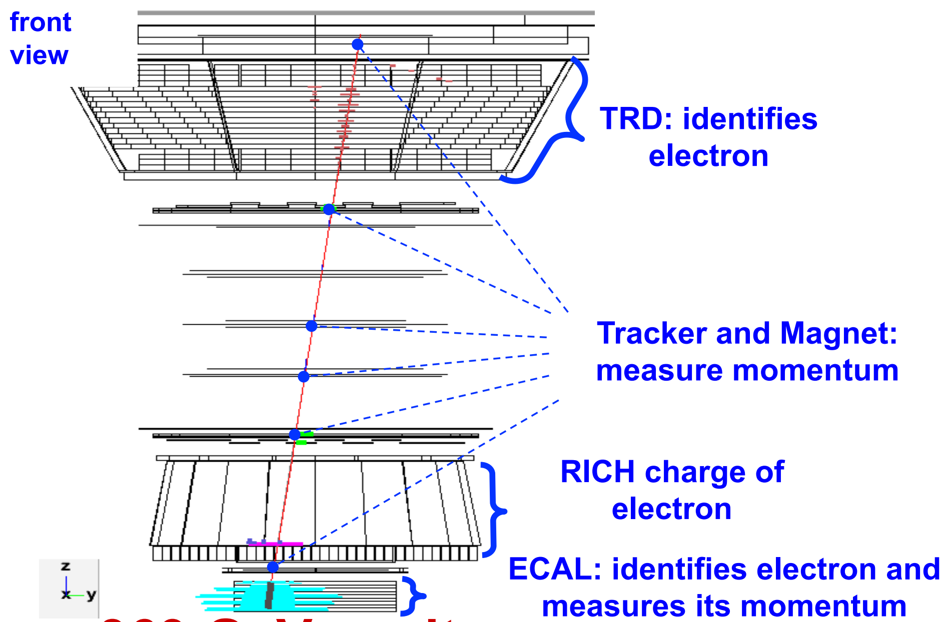
Exposure Time:	May 20 2011 – May 20 2012
Number of Protons:	3,676,863,217
Number of Helium nuclei:	620,303,906
Rigidity range:	2 GV – 2000 GV
Tomographic plane:	Z = +165 cm
XY pixel area:	1 cm^2



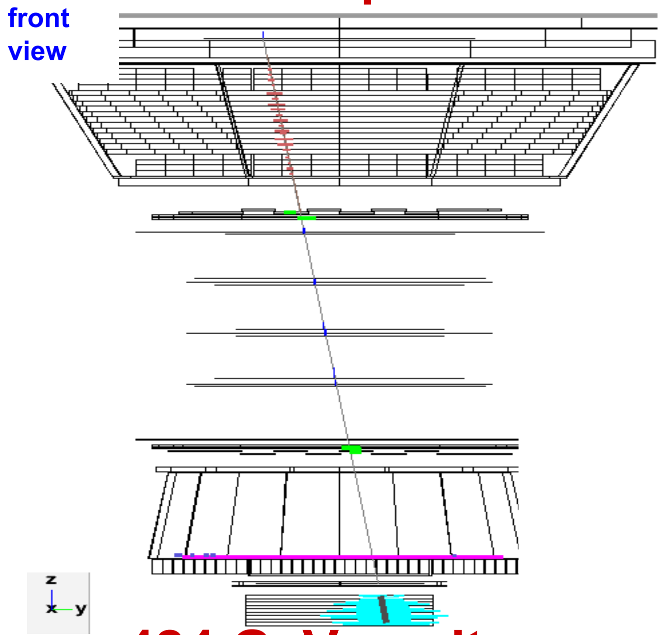
Credit: AMS Collaboration

AMS data: High energy e±

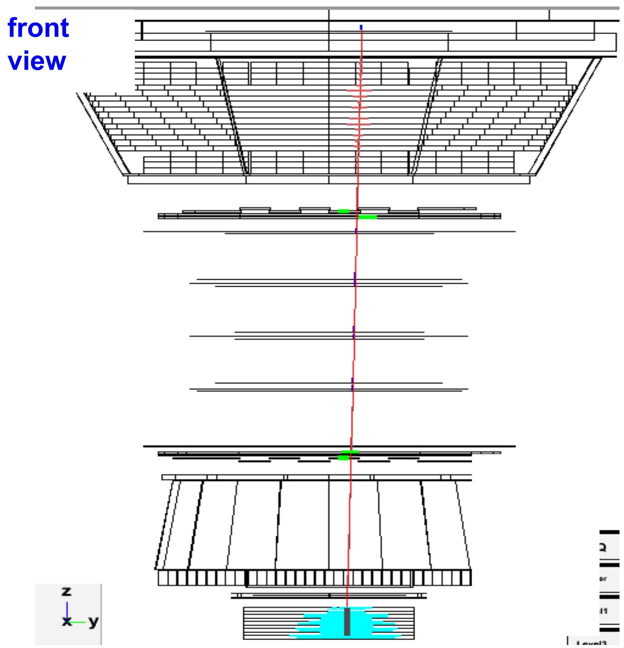
1.03 TeV electron



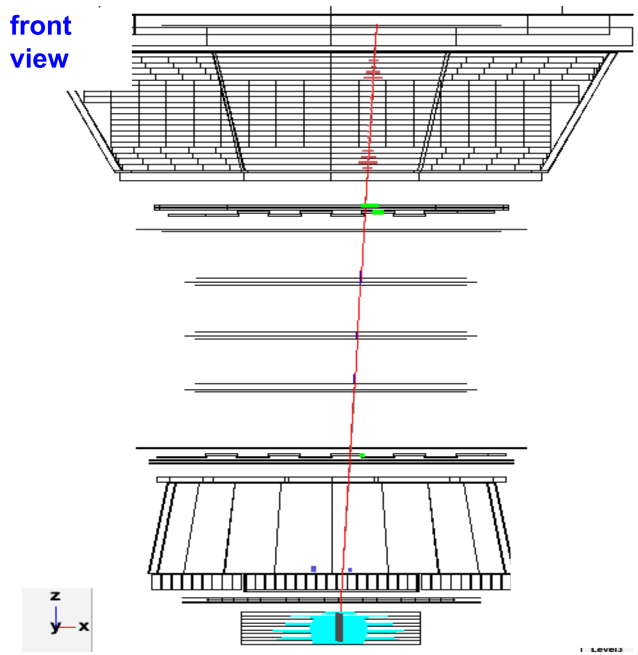
205 GeV positron



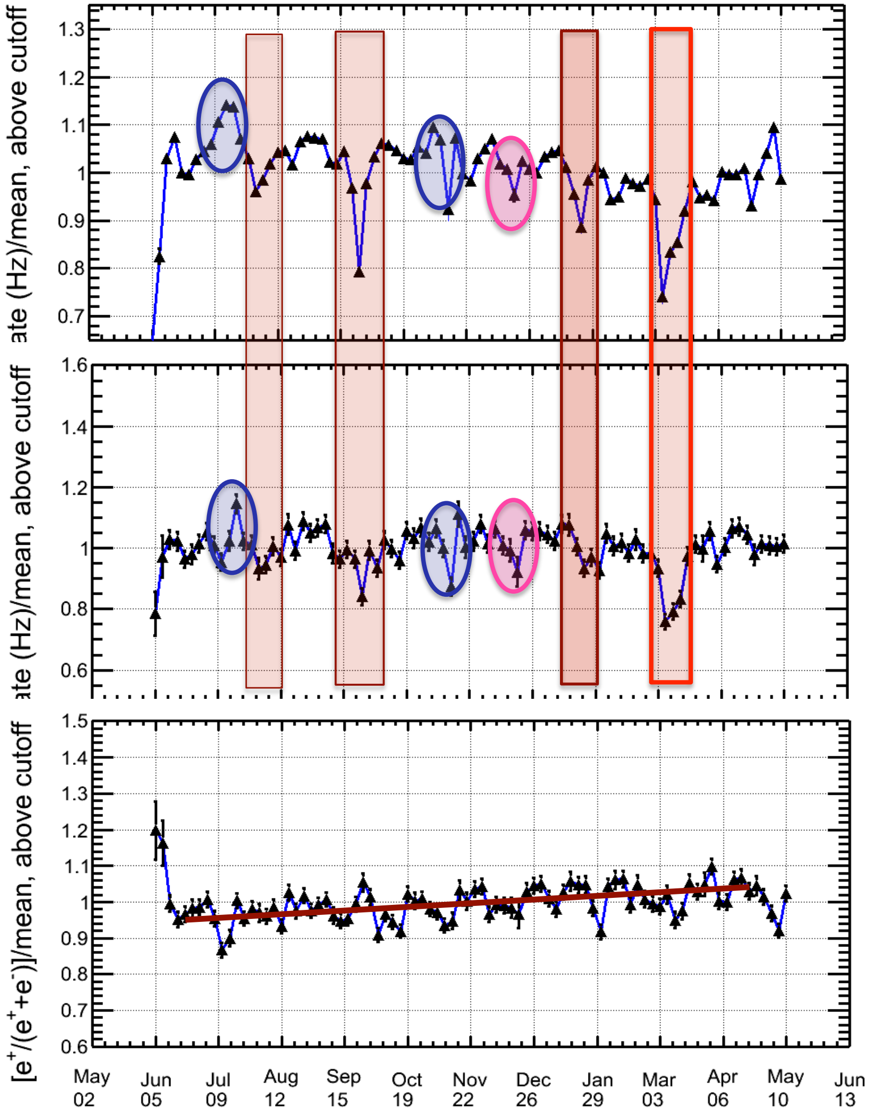
369 GeV positron



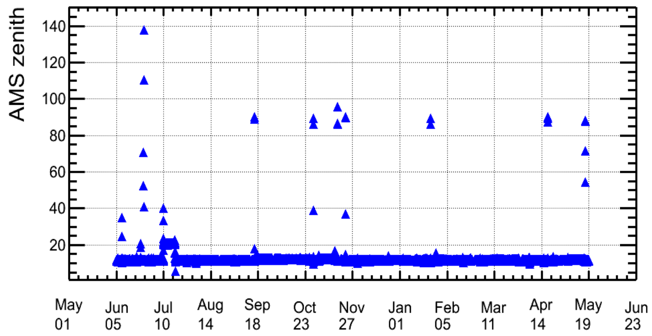
424 GeV positron



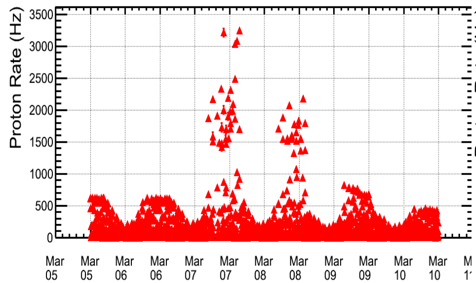
Integral e+/e- rates & ratio

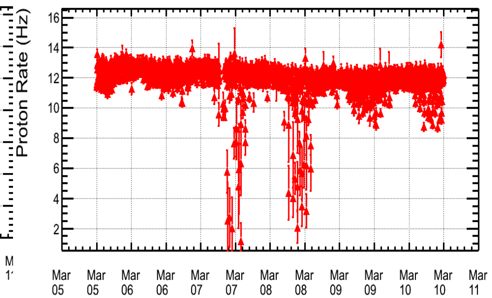


pointing



+ flares…





+ badruns…

Line 4: cosmic rays from space SUMMARY

- **PAST YEAR(S)** : PAMELA, AGILE, FERMI, AMS-02
- **NEXT YEAR(S)** : FERMI, AMS-02,
- **LONG TERM STRATEGY**: AMS-02, JEM-EUSO (?), GAMMA-400 (?), HERD (?)

Line 5: gravitational waves SUMMARY

- **PAST YEAR(S)** : 3 BARS (Explorer, Auriga, Nautilus), VIRGO, VIRGO+, LISA-PATHFINDER

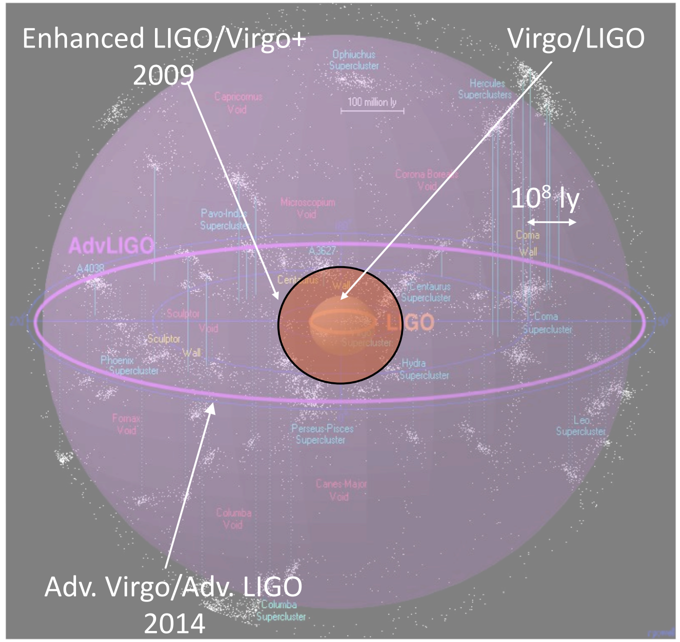
- **NEXT YEAR(S)** : 2 BARS (Auriga, Nautilus), ADVANCED VIRGO, LISA-PATHFINDER

- **LONG TERM STRATEGY**: ADVANCED VIRGO, LISA, Einstein Observatory (?)


Gravitational Wave Detectors
Interferometer
Resonant-Mass
GEO
MiniGrail
AURIGA
VIRGO
NAUTILUS
LNF INFN
gravitational wave research

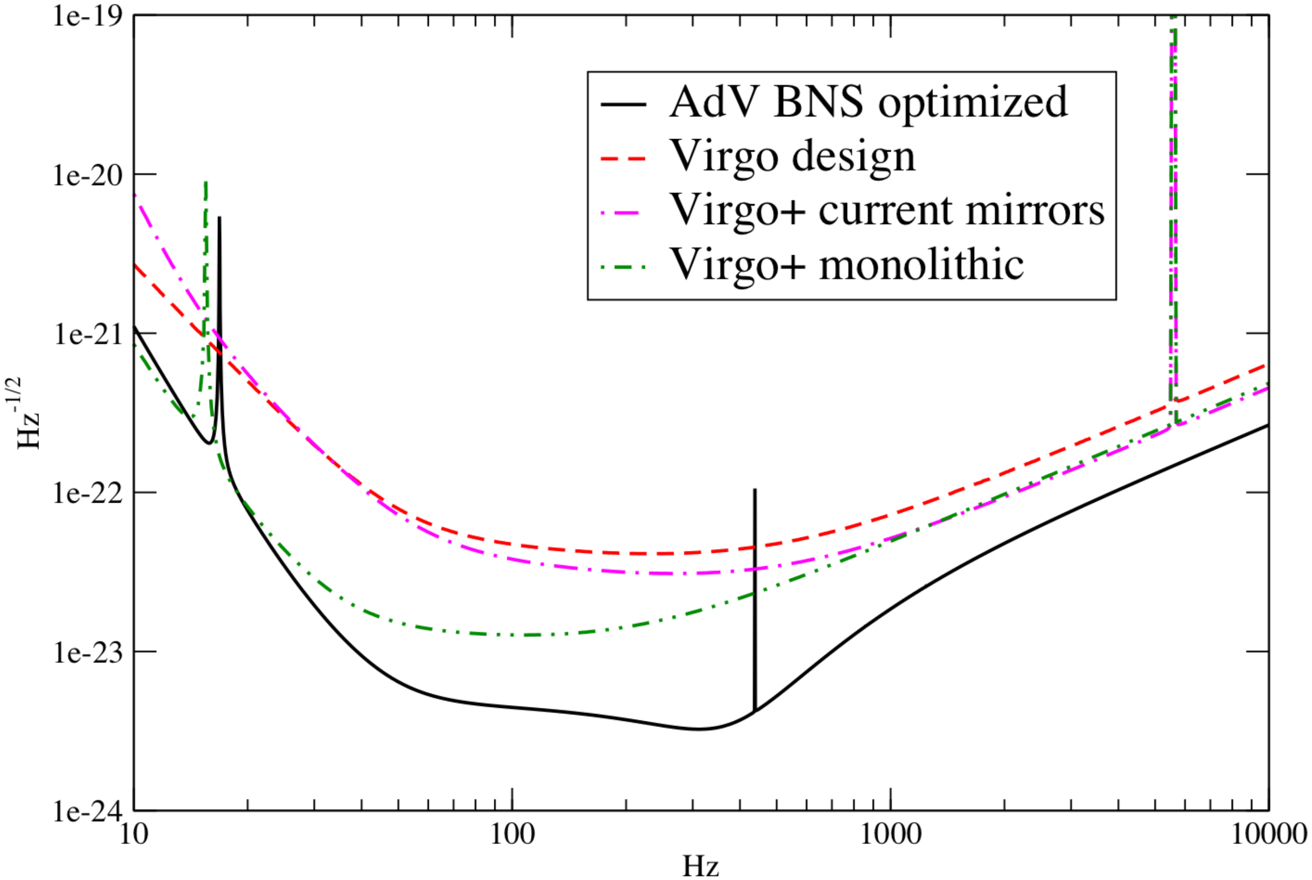
ADVANCED VIRGO (AdV) 2009-2014

Project approved by the
CSN2-INFN
Reviewed by CCS –INFN
Class Ranking A



Credit: R.Powell, B.Berger

We will explore a Universe volume 1000 times larger than VIRGO



- **GOALS**:
  - ❑ Sensitivity: about 10x better than Virgo
  - ❑ Timeline: be back online with Adv LIGO

Line 5: gravitational waves SUMMARY

- **PAST YEAR(S)** : 3 BARS (Explorer, Auriga, Nautilus), VIRGO, VIRGO+, LISA-PATHFINDER

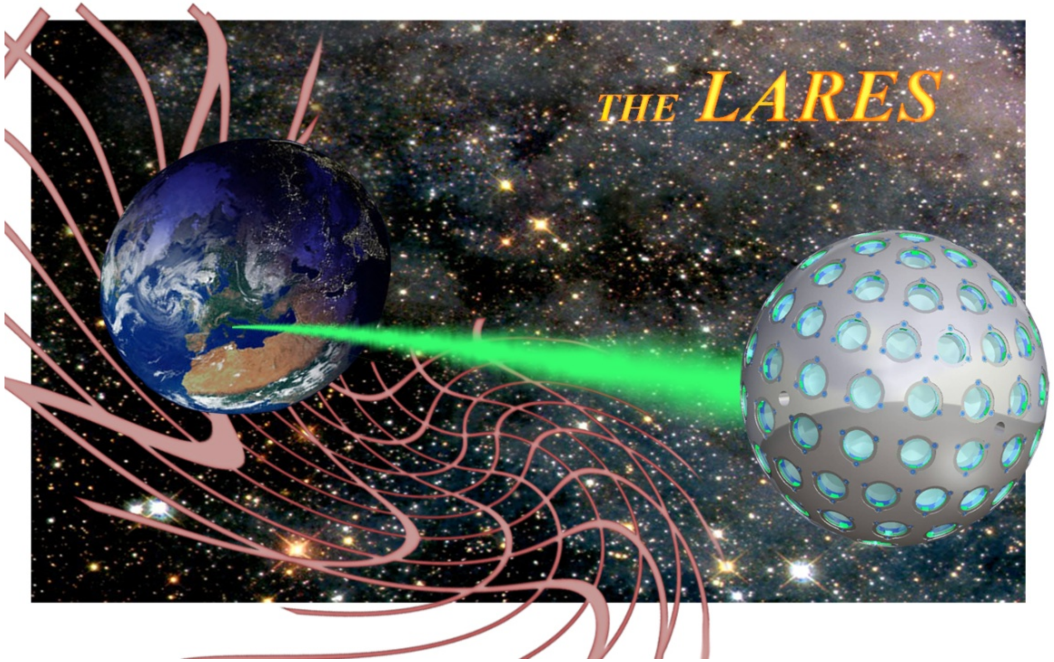
- **NEXT YEAR(S)** : 2 BARS (Auriga, Nautilus), ADVANCED VIRGO, LISA-PATHFINDER

- **LONG TERM STRATEGY**: ADVANCED VIRGO, LISA, Einstein Observatory (?)

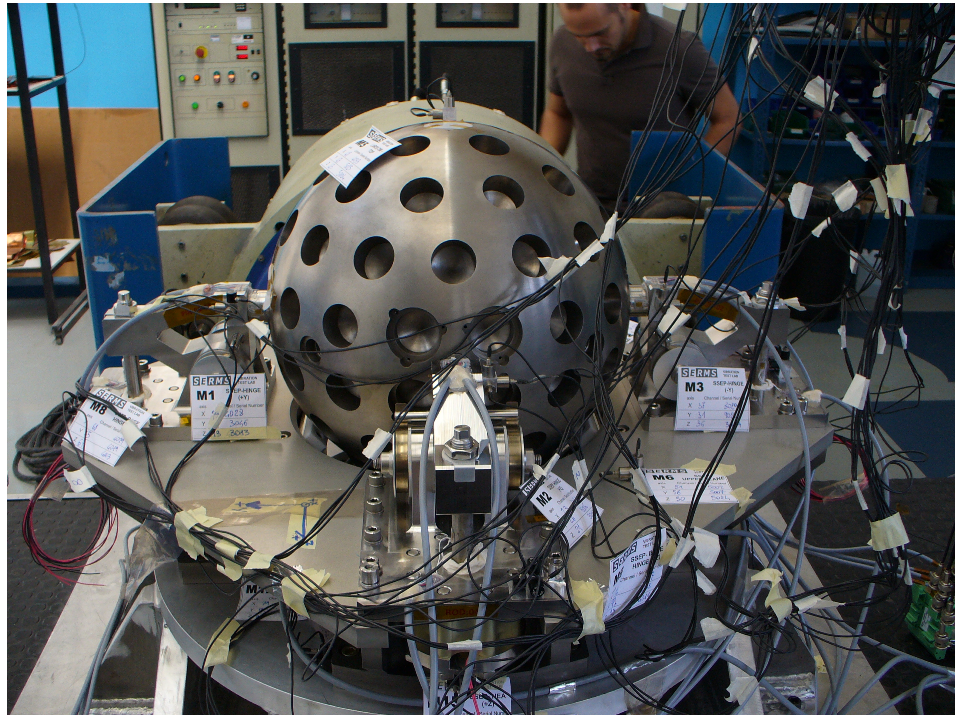
Line 6: fundamental physics SUMMARY

- **PAST YEAR(S)** : MAGIA, MIR, LARES, PVLAS
- **NEXT YEAR(S)** : MAGIA, HUMOR, LARES, G-GRANSASSO, PVLAS
- **LONG TERM STRATEGY**: G-GRANSASSO (?), MAGIA -> GW

LARES: Towards a One Percent Measurement of Frame Dragging



Launched 2012



nature physics

ARTICLES

PUBLISHED ONLINE: 18 MARCH 2012 | DOI:10.1038/NPHYS2262

Probing Planck-scale physics with quantum optics

Igor Pikovski[1,2]*, Michael R. Vanner[1,2], Markus Aspelmeyer[1,2], M. S. Kim[3]* and Časlav Brukner[2,4]

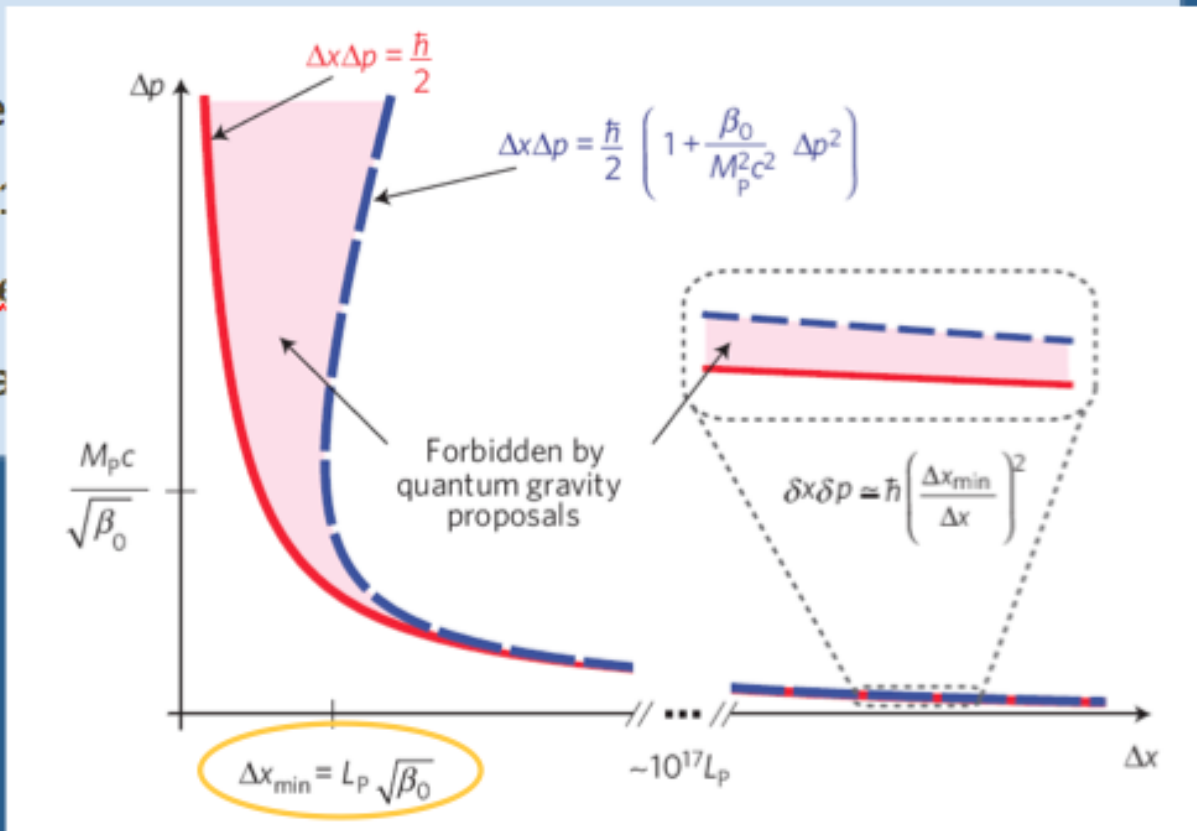
'Phenomenological quantum gravity'

- 'osservazione': non si può dete

lunghezza di Planck $L_P = \sqrt{hG/c^3} =$

- Si introducono relazioni di Heis
- Si ricavano commutatori genera

$$[x, p] = i\hbar(1 + \hat{C})$$

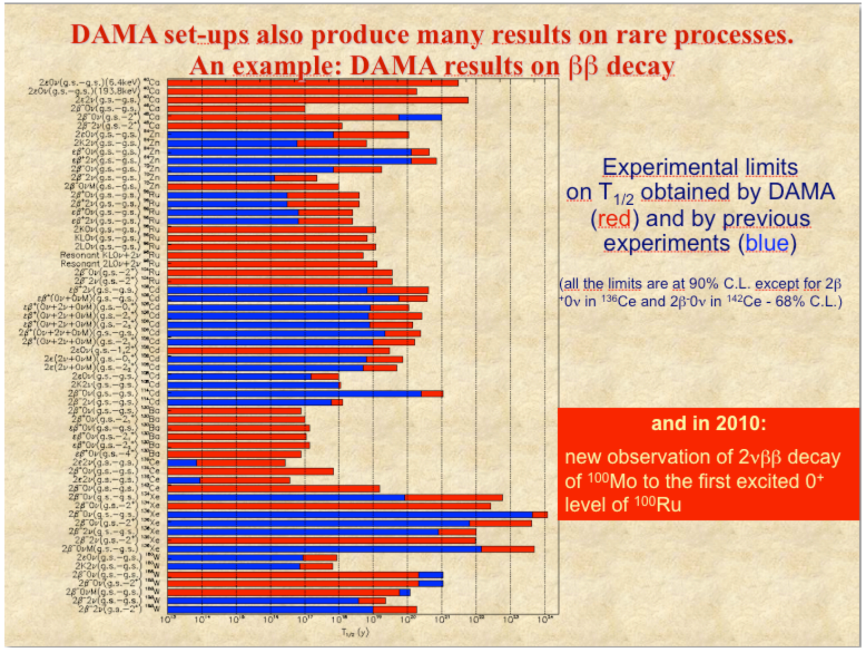


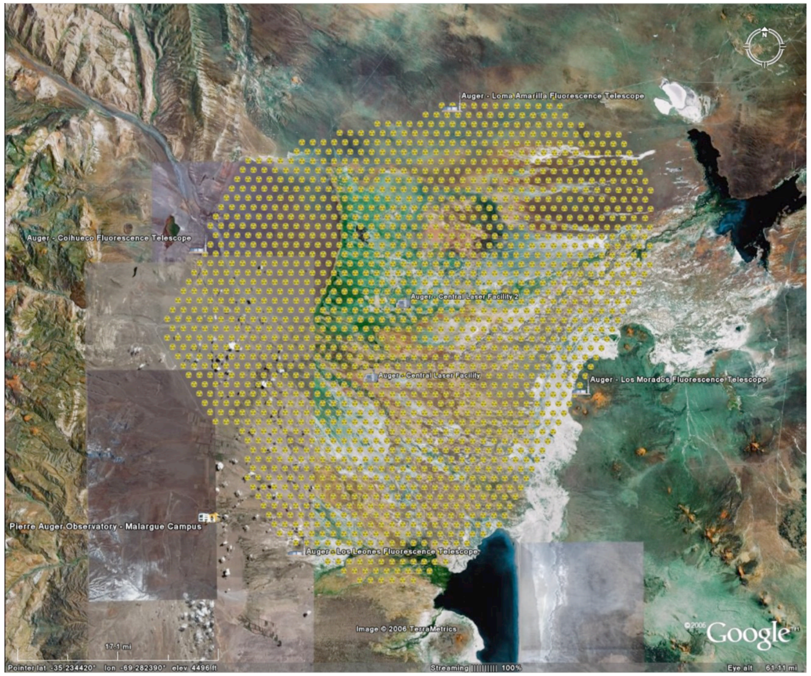
Line 6: fundamental physics SUMMARY

- **PAST YEAR(S)** : MAGIA, MIR, LARES, PVLAS

- **NEXT YEAR(S)** : MAGIA, HUMOR, LARES, G-GRANSASSO, PVLAS

- **LONG TERM STRATEGY**: G-GRANSASSO (?), MAGIA -> GW





Maintaining astroparticle physics unique facilities