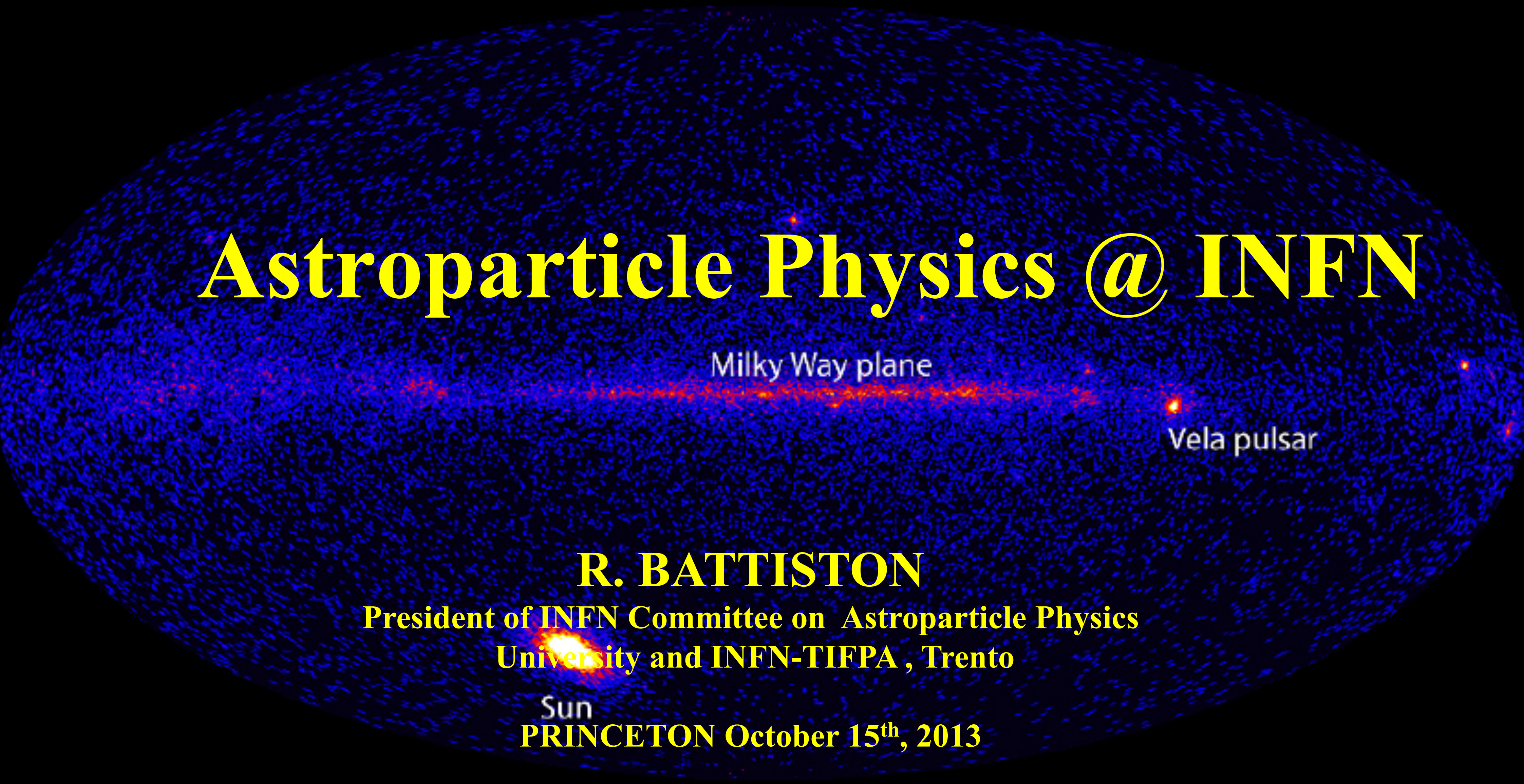
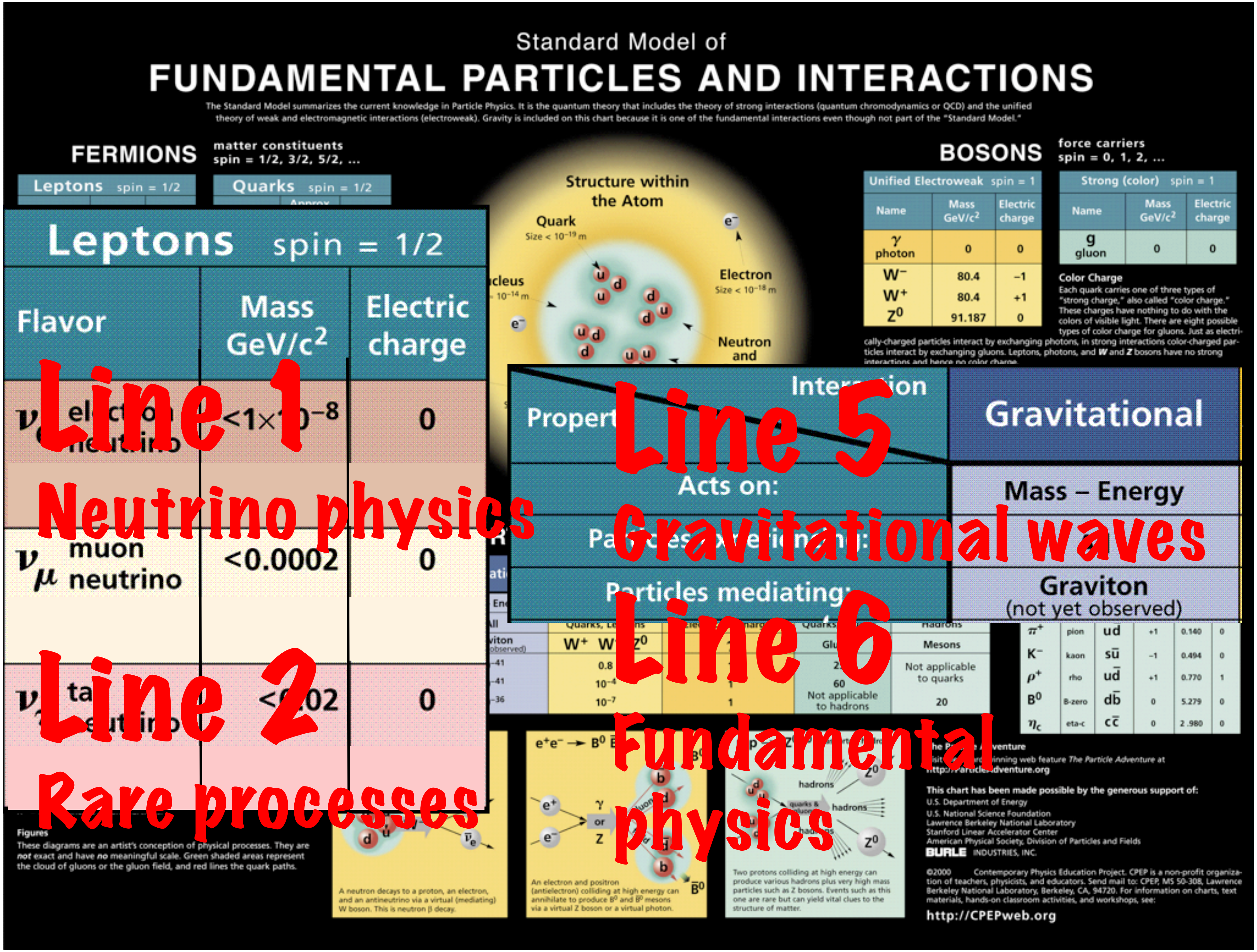
Astroparticle Physics @ INFN



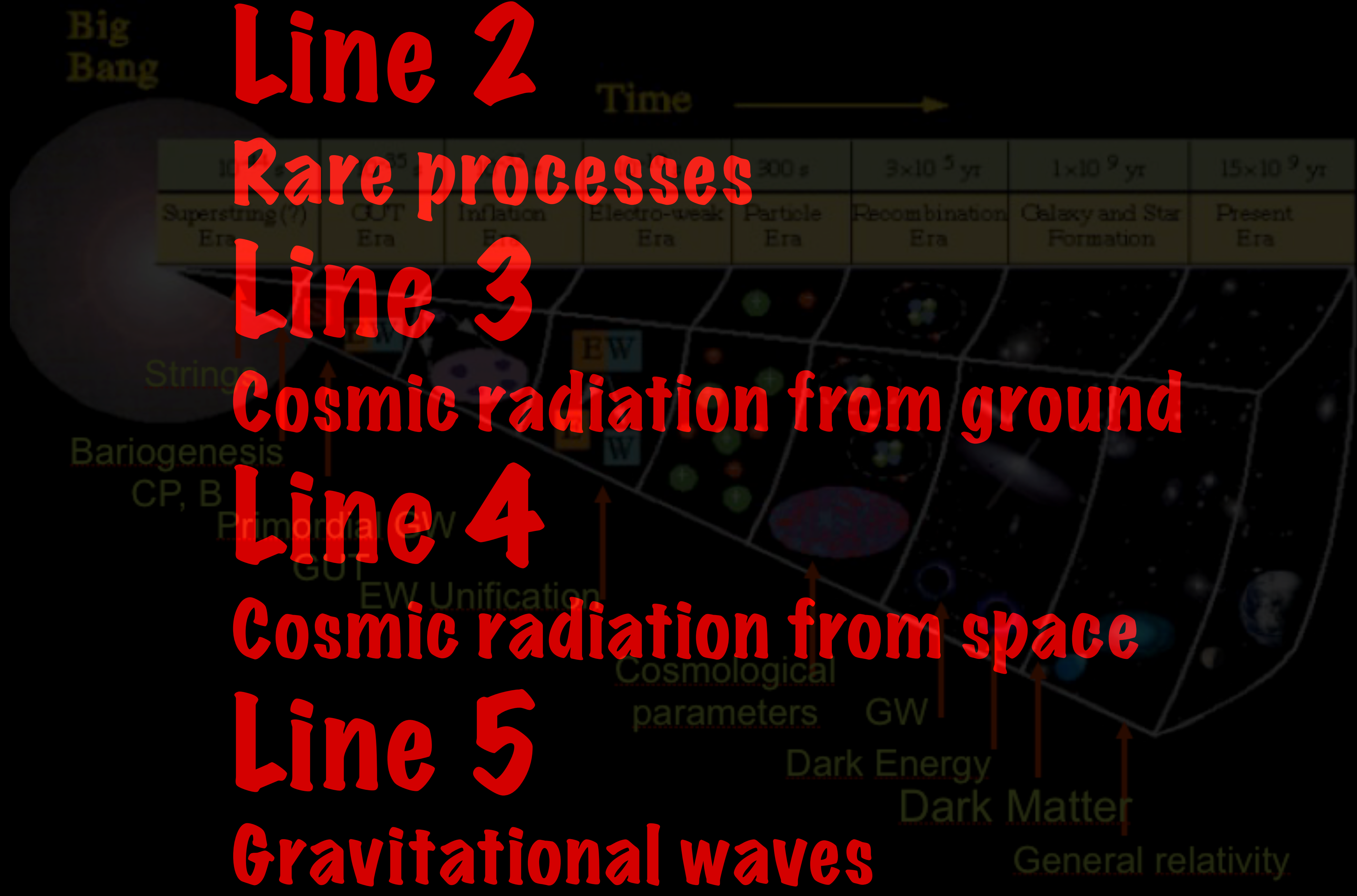
R. BATTISTON
President of INFN Committee on Astroparticle Physics
University and INFN-TIFPA , Trento

PRINCETON October 15th, 2013

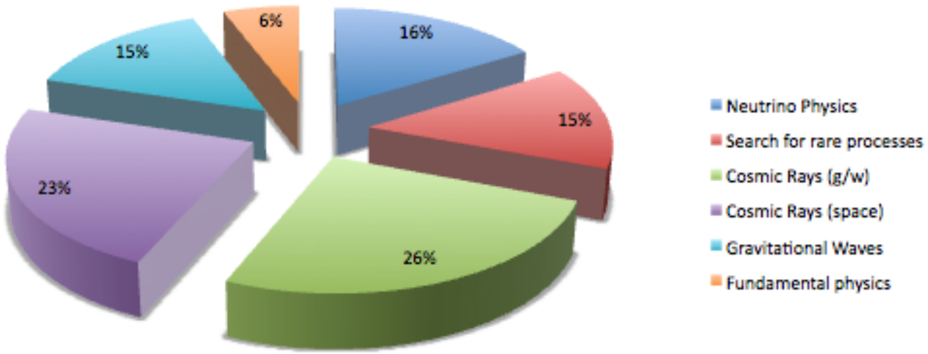


Standard Model of
FUNDAMENTAL PARTICLES AND INTERACTIONS
FERMIONS
matter constituents
spin = 1/2, 3/2, 5/2, ...
BOSONS
force carriers
spin = 0, 1, 2, ...
Structure within the Atom
Leptons spin = 1/2
Flavor
Mass GeV/c²
Electric charge
muon neutrino
<0.0002
0
Line 1
Neutrino physics
Line 2
Rare processes
Unified Electroweak spin = 1
Strong (color) spin = 1
Interaction
Gravitational
Acts on:
Mass – Energy
Particles mediating:
Graviton
(not yet observed)
Line 5
Gravitational waves
Line 6
Fundamental physics
http://CPEPweb.org

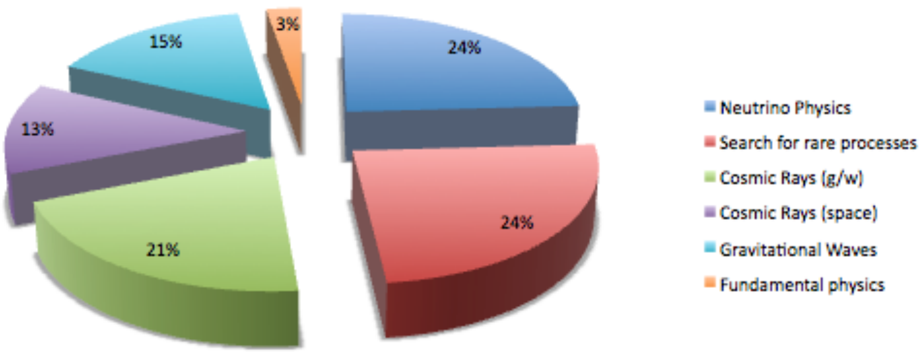
Comos is the "ultimate" laboratory to study fundamental physics, up to energy scales unreachable with the most powerful accelerators……



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	595
PEOPLE	800

2012 Funding 12.2 M€

External funds: **~ 1 M€ /year ASI**
~ 2 M€ /year ERC, EU
22 M€/3 years PON KM3

External funding

Non-INFN sources of funding:

- **ASI →** AMS-02, Pamela, FERMI **(~ 1 M€/y)**
- **Premium projects →** HUMOR(QP-CNR), MICRA (GW-CNR), LIMADOU(Space-ASI),Retroreflectors(Space-ASI), RingLaser(FP-INRIM) **(~ 2 M€/y)**
- **ERC →** RareNoise, Lucifer, Sox-Ge, Holmes **(~ 2 M€/y)**
- **FP7 →** SR2S **(0,5 M€/y) (CSN5)**
- **PON →** KM3 **(7,5 M€/y for three years)**

TOTAL ~ 13 M€ / y : exceeds the internal funding

– CSN2 –
2012 Scientific Production

Participants (People & FTE)

Year	2007			2008			2009			2010			2011			2012		
	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F
FTE	676			674			644			650			607			595		
People	919			903			860			873			828			847		

Note: the decrease in FTE 2010-2012 is mainly due to change in counting rules

ISI publication rate keep increasing for the 6th 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**

–CSN2 –
2012 Scientific production

Year	2007	2008	2009	2010	2011	2012
ISI Pub	190	220	233	258	286	300
no ISI Pub	8	4	6	9	11	16
IF/article	2.9	2.8	4.4	4.1	3.8	3.6
Pub/FTE	0.28	0.33	0.38	0.40	0.48	0.57
INFN authors (%) (ISI Pub)	64	62	54	51	50	44
Milestone Completion (%)	73	73	82	74	80	88

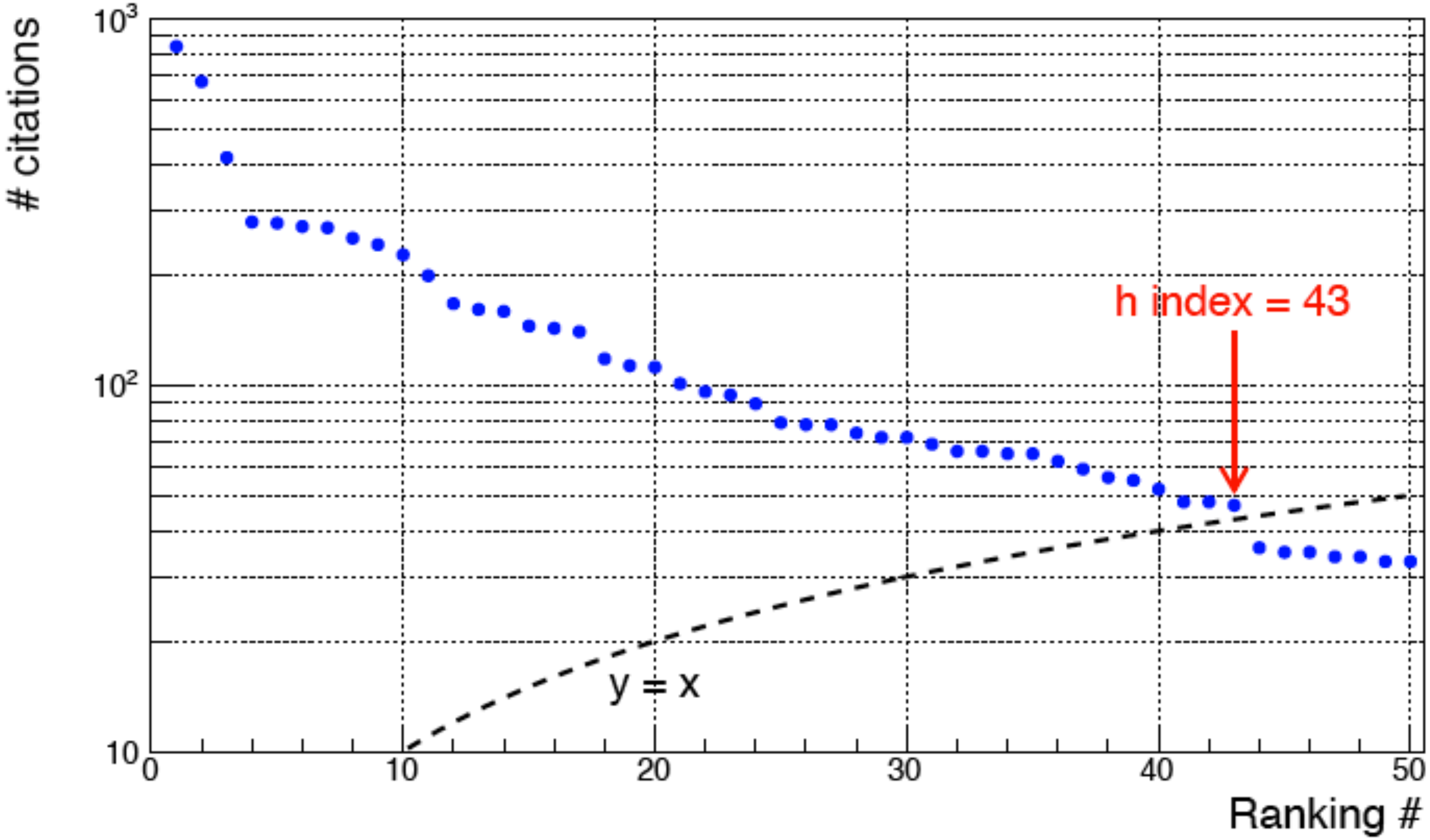
Impact Factor

	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

Collaboration publications

aka Fermi's h-index, from inSPIRE

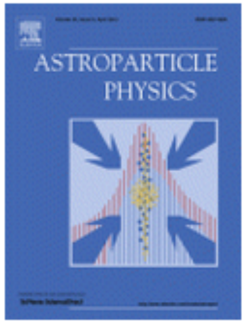


Top 25 Hottest Articles

Physics and Astronomy > Astroparticle Physics

January to December 2012 full year

RSS Blog This! Print **Show condensed**



1. **The XENON100 dark matter experiment**
   Astroparticle Physics, Volume 35, Issue 9, April 2012, Pages 573-590
   XENON100 Collaboration; Aprile, E.; Arisaka, K.; Arneodo, F.; Askin, A.; Baudis, L.; Behrens, A.; Brown, E.; Cardoso, J.M.R.; Choi, B.; Cline, D.; Fattori, S.; Ferella, A.D.; Giboni, K.L.; Kish, A.; Lam, C.W.; Lang, R.F.; Lim, K.E.; Lopes, J.A.M.; Marroda
   Cited by Scopus (42)
2. **Analysis of gamma radiation from a radon source: Indications of a solar influence**
   Astroparticle Physics, Volume 36, Issue 1, August 2012, Pages 18-25
   Sturrock, P.A.; Steinitz, G.; Fischbach, E.; Javorsek, D.; Jenkins, J.H.
   Cited by Scopus (3)
3. **Additional experimental evidence for a solar influence on nuclear decay rates**
   Astroparticle Physics, Volume 37, September 2012, Pages 81-88
   Jenkins, J.H.; Herminghuysen, K.R.; Blue, T.E.; Fischbach, E.; Javorsek, D.; Kauffman, A.C.; Mundy, D.W.; Sturrock, P.A.; Talnagi, J.W.
4. **TeV gamma-ray astronomy: A summary**
   Astroparticle Physics, Volume 39-40, December 2012, Pages 61-75
   Holder, J.
5. **Description of atmospheric conditions at the Pierre Auger Observatory using the Global Data Assimilation System (GDAS)**
   Astroparticle Physics, Volume 35, Issue 9, April 2012, Pages 591-607
   The Pierre Auger Collaboration; Abreu, P.; Aglietta, M.; Ahlers, M.; Ahn, E.J.; Albuquerque, I.F.M.; Allard, D.; Allekotte, I.; Allen, J.; Allison, P.; Almela, A.; Alvarez Castillo, J.; Alvarez-Muniz, J.; Ambrosio, M.; Aminaei, A.; Anchordoqui, L.; Andrin
   Cited by Scopus (15)
6. **A Heitler model of extensive air showers**
   Astroparticle Physics, Volume 22, Issue 5-6, January 2005, Pages 387-397
   Matthews, J.
   Cited by Scopus (58)
7. **On the sensitivity of the HAWC observatory to gamma-ray bursts**
   Astroparticle Physics, Volume 35, Issue 10, May 2012, Pages 641-650
   Abeysekara, A.U.; Aguilar, J.A.; Aguilar, S.; Alfaro, R.; Almaraz, E.; Alvarez, C.; Alvarez-Romero, J.d.D.; Alvarez, M.; Arceo, R.; Arteaga-Velazquez, J.C.; Badillo, C.; Barber, A.; Baughman, B.M.;

AUGER	5
ANTARES	2
XENON100	1
FERMI	1
CUORE	1
MAGIC	1

–CSN2 –
in International Collaborations

	2007	2008	2009	2010	2011	2012
%FTE in Int. Coll.	77	78	81	81	85	86
% Fundig in Int. Coll.	81	84	86	86	86	85
% Papers in Int. Coll.	64	68	64	73	69	71
Leadership roles (%)	39	43	57	55	56	56

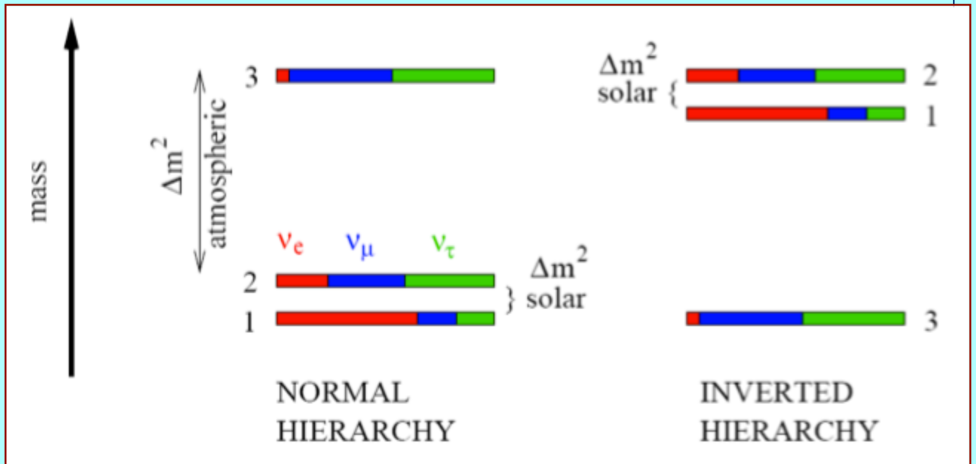
Neutrino oscillation: what we don't know

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

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

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**

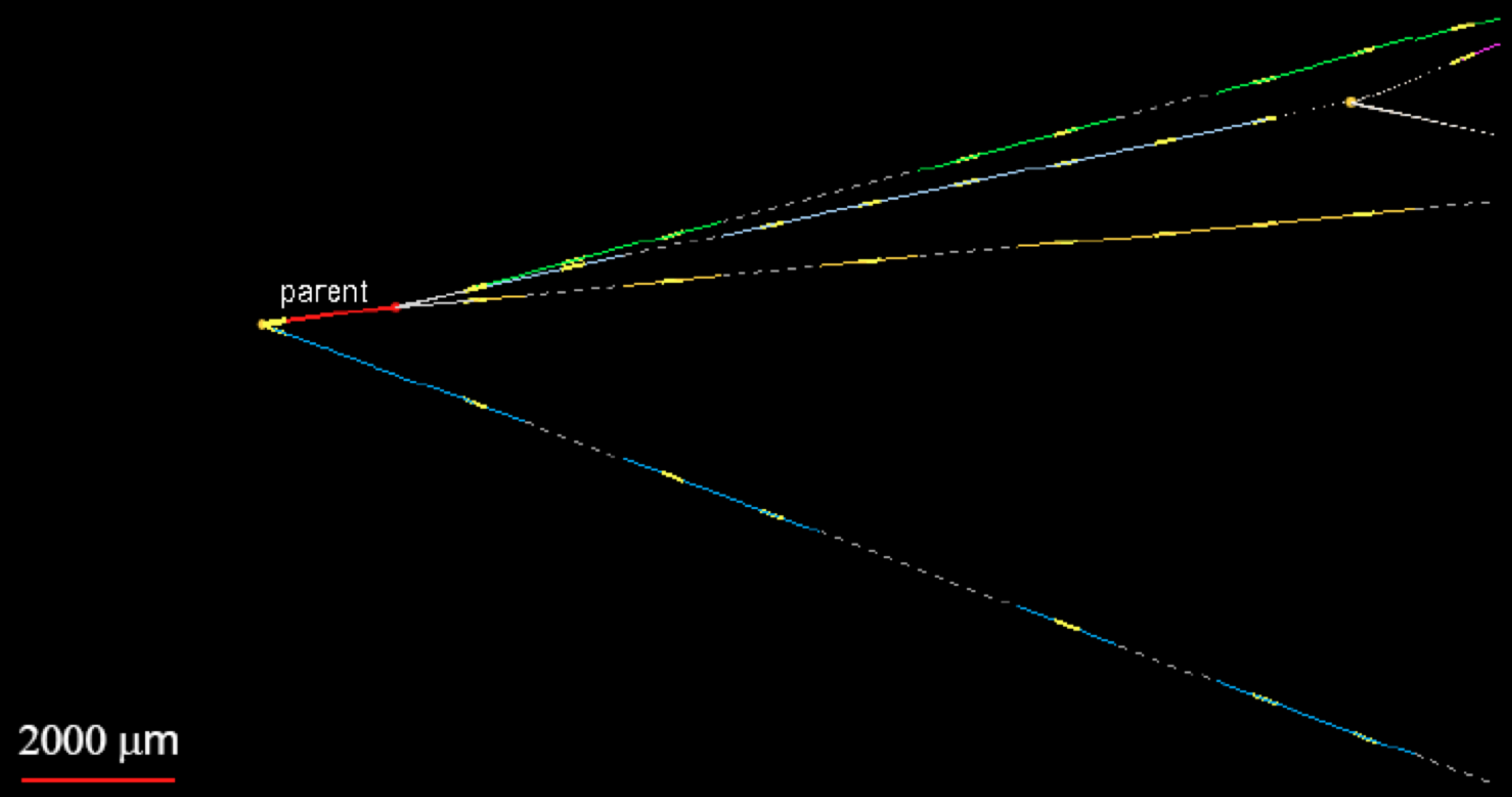
Neutrino oscillations & sterile neutrinos

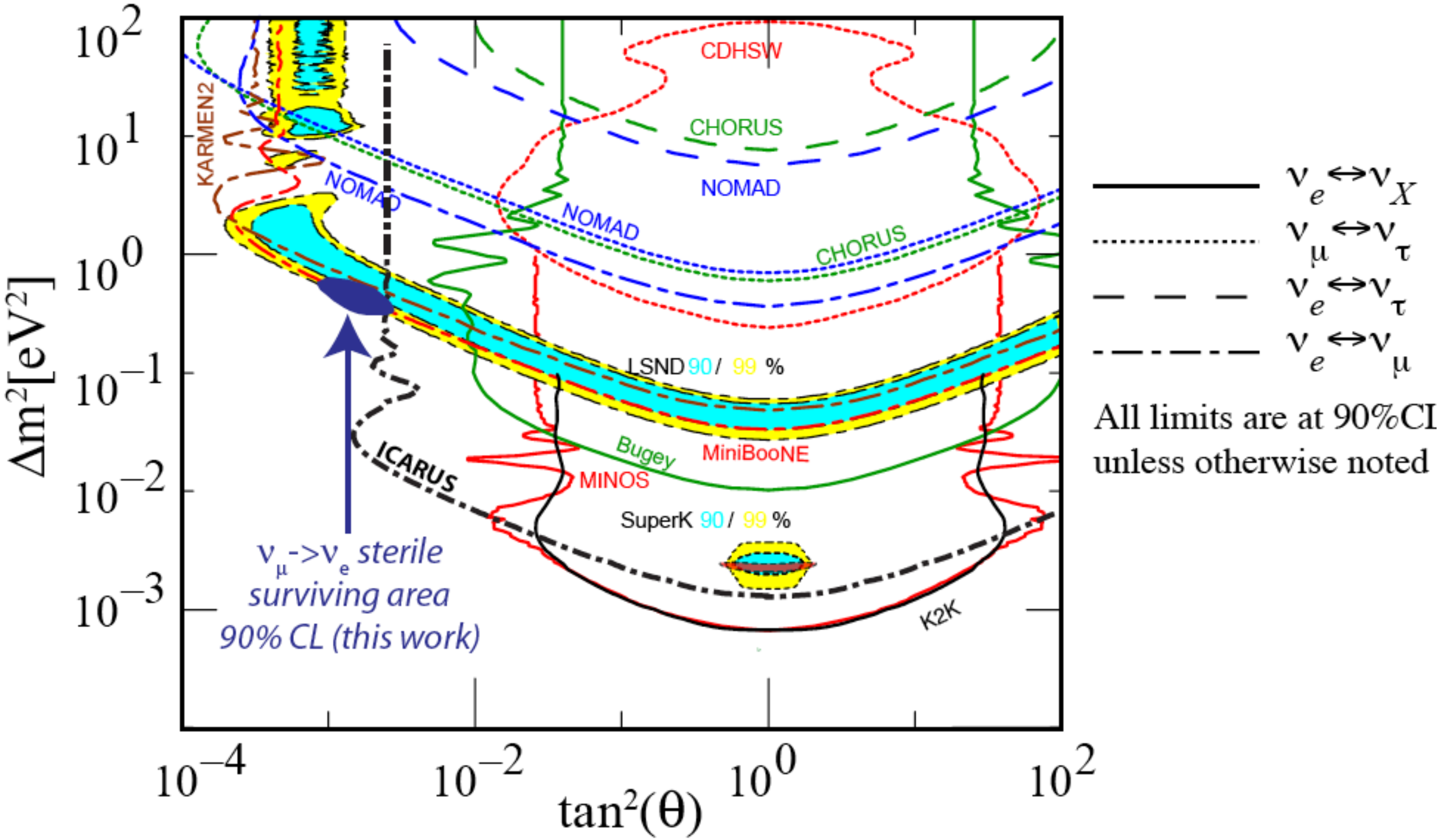
- **Atmospheric neutrinos(θ_{23})**
  - SuperK， HyperK/UNO， INO， TITAND,…
- **Solar neutrinos(θ_{12}):**
  - GALLEX/SAGE, SuperK, SNO, Borexino, XMASS, …
- **Reactor neutrinos(θ_{12},θ_{13} → mass hierarchy):**
  - KamLAND, Daya Bay→ JUNO, Double CHOOZ, Reno,…
- **Accelerator neutrinos(θ_{23},θ_{13}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

Line 1: neutrino physics SUMMARY

- **PAST YEAR(S)** : BOREXINO, OPERA 3 ν_τ, ICARUS-CNGS, T2K θ_{13}
- **NEXT YEAR(S)** : **BOREXINO (sterile-ERC)**, **CNGS COMPLETED**, **T2K CONTINUES**, *ICARUS (+NESSIE ?) @ CERN/LBNE,* **Holmes (nu-mass-ERC)**
- **LONG TERM STRATEGY**: **LONG BASELINE (US, JP), JUNO (Cina)**

New ν_τ Candidate Event





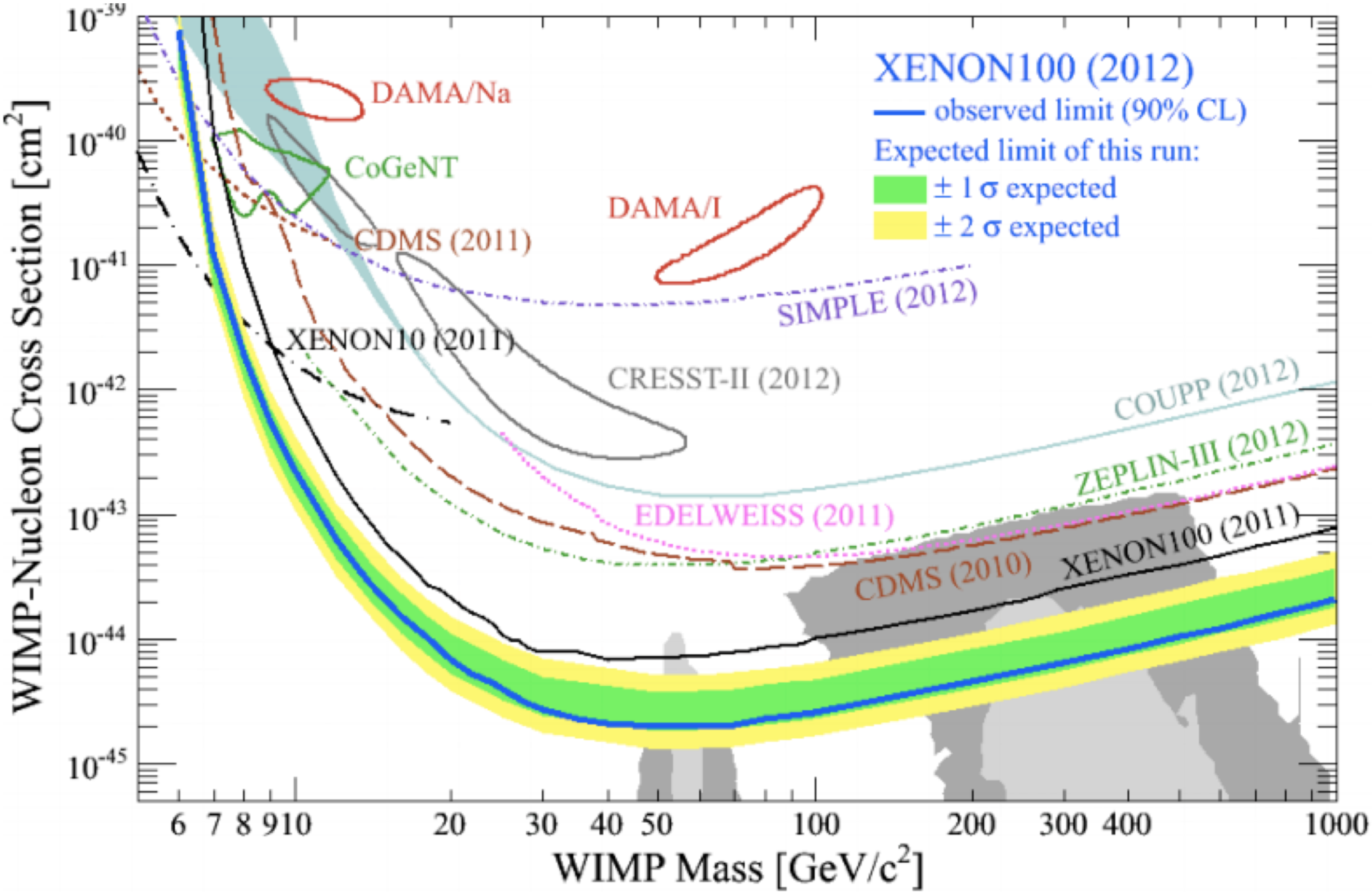
CDHSW
CHORUS
NOMAD
KARMEN2
NOMAD
NOMAD
CHORUS
LSND 90 / 99 %
Bugey
MiniBooNE
MINOS
ICARUS
SuperK 90 / 99 %
K2K
ν_μ->ν_e sterile
surviving area
90% CL (this work)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
$\Delta m^2[eV^2]$
10^{-4}
10^{-2}
10^0
10^2
$\tan^2(\theta)$
$\nu_e \leftrightarrow \nu_X$
$\nu_\mu \leftrightarrow \nu_\tau$
$\nu_e \leftrightarrow \nu_\tau$
$\nu_e \leftrightarrow \nu_\mu$
All limits are at 90%CI
unless otherwise noted

Line 2: rare processes
SUMMARY

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

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

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

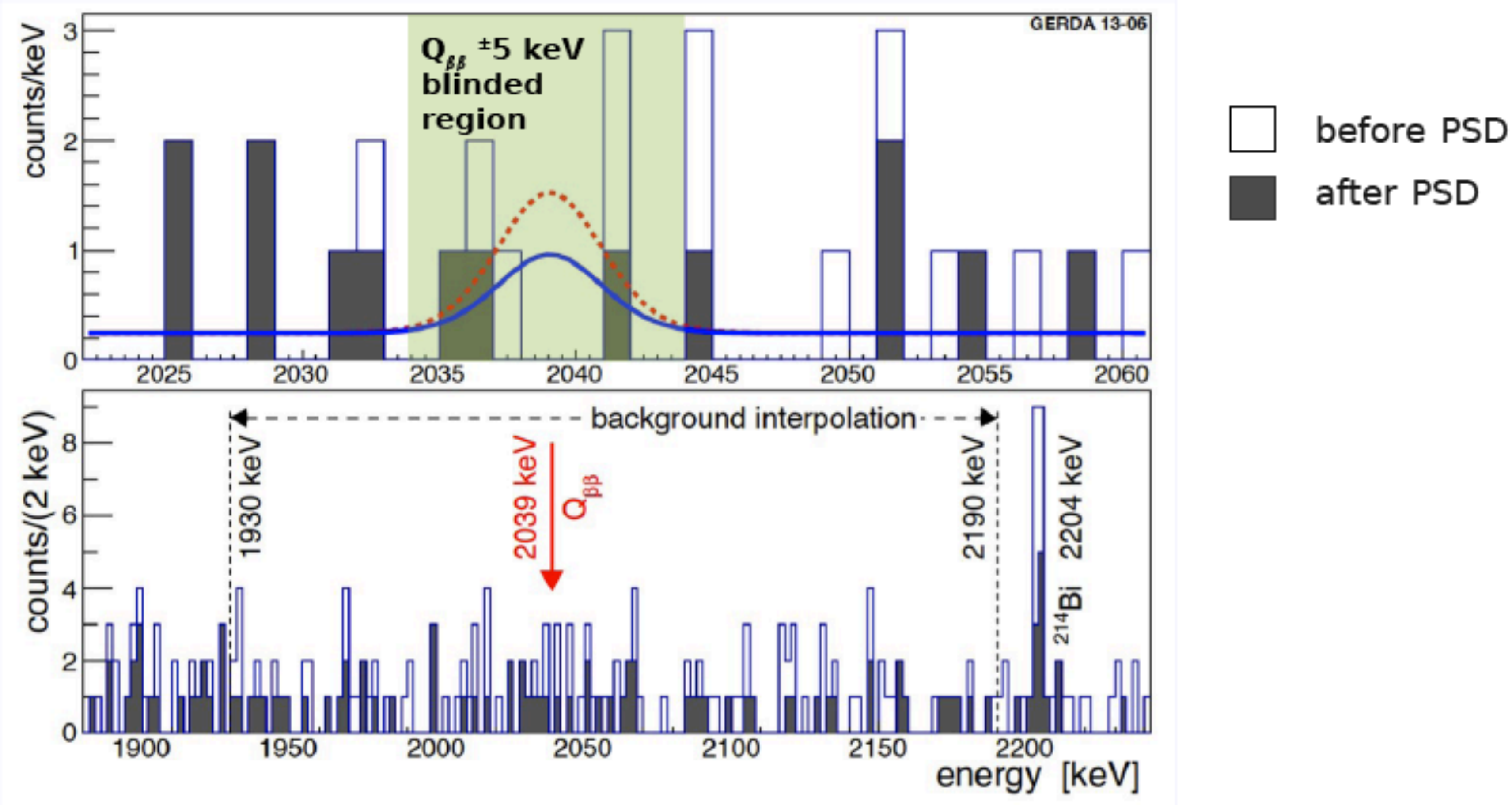


Upper Limit (90% C.L.) is 2×10^{-45} cm^2 for 55 GeV/c^2 WIMP

New spin independent DM limit by XENON


DARK SIDE

Unblinding : Full data set (21.6 kg · yr)



Full data set: **7** eventi nella blinded window (± 5 keV attorno al $Q_{\beta\beta}$) → **5.1** aspettati (bkg only)

3 eventi dopo la PSD → **2.5** aspettati (bkg only)

0 eventi in $Q_{\beta\beta} \pm \sigma_E$

Line 3: cosmic rays from ground SUMMARY

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

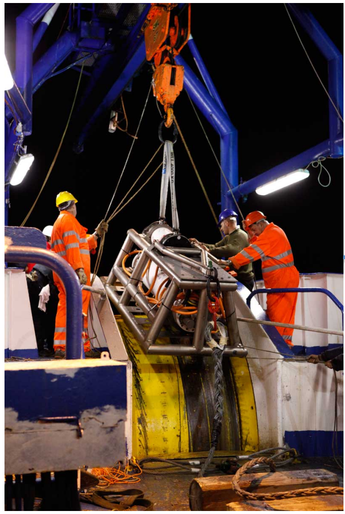
- **NEXT YEAR(S)** : **AUGER**, MAGIC, **CTA**
  KM3

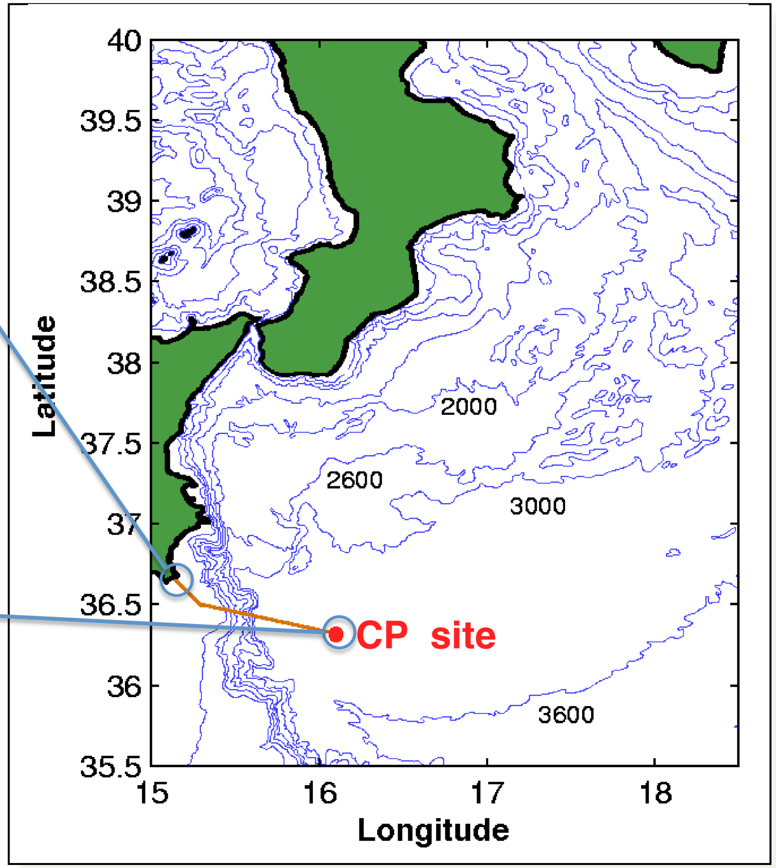
- **LONG TERM STRATEGY**: **CTA**
  KM3-NET

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)



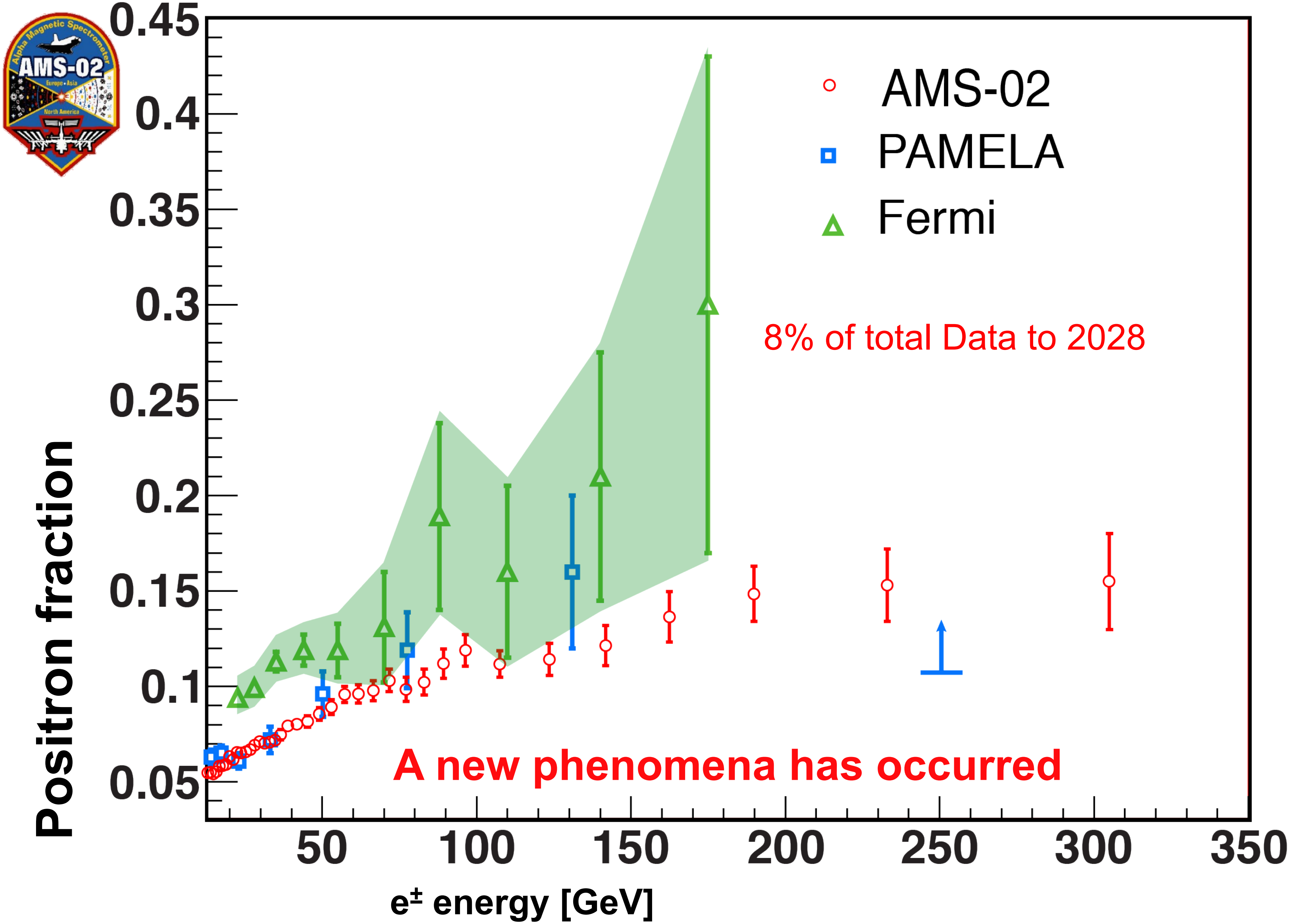


Line 4: cosmic rays from space SUMMARY

- **PAST YEAR(S)** : PAMELA, AGILE, FERMI, AMS-02

- **NEXT YEAR(S)** : **FERMI, AMS-02, DAMPE, CSES**

- **LONG TERM STRATEGY**: **AMS-02,** JEM-EUSO, **GAMMA-400 ,** HERD



AMS-02
PAMELA
Fermi
8% of total Data to 2028
A new phenomena has occurred
Positron fraction
e± energy [GeV]
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
50
100
150
200
250
300
350

Line 5: gravitational waves SUMMARY

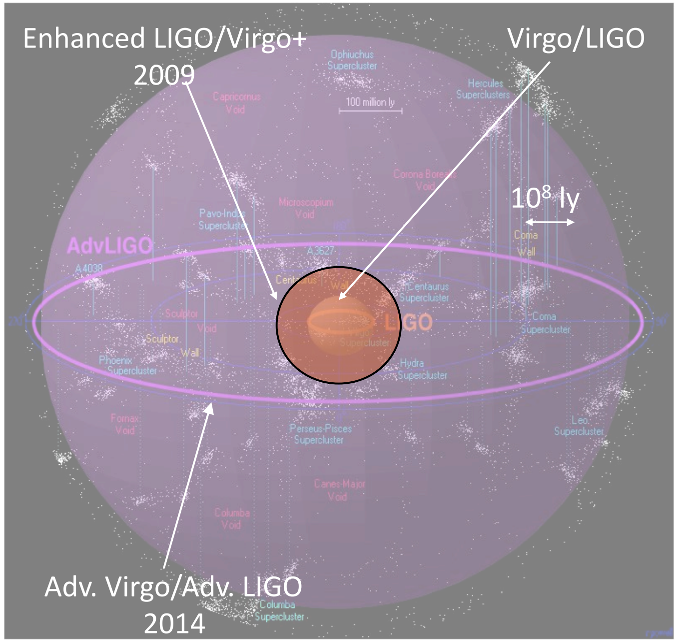
- **PAST YEAR(S)** : 3 BARS (Explorer, Auriga, Nautilus), VIRGO, VIRGO+, LISA-PATHFINDER

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

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

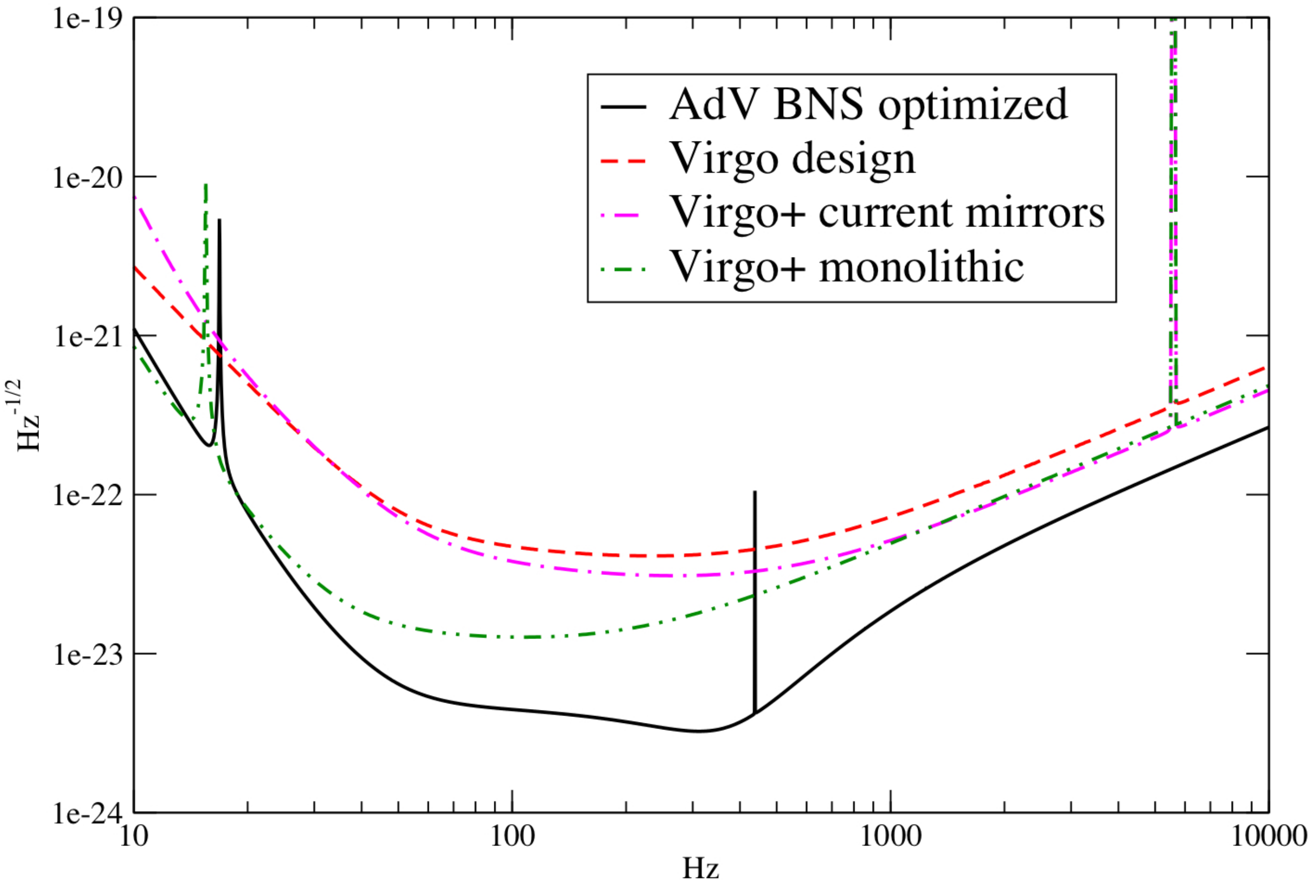
ADVANCED VIRGO (AdV) 2009-2014

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

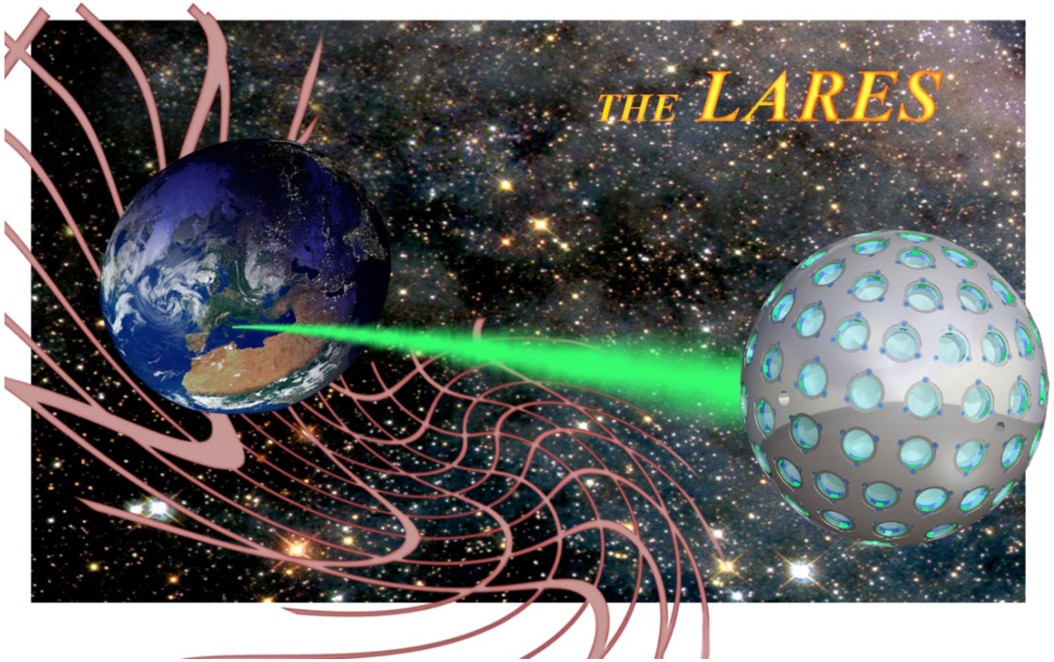


- **GOALS**:
- ❑ Sensitivity: about 10x better than Virgo
- ❑ Timeline: be back online with Adv LIGO

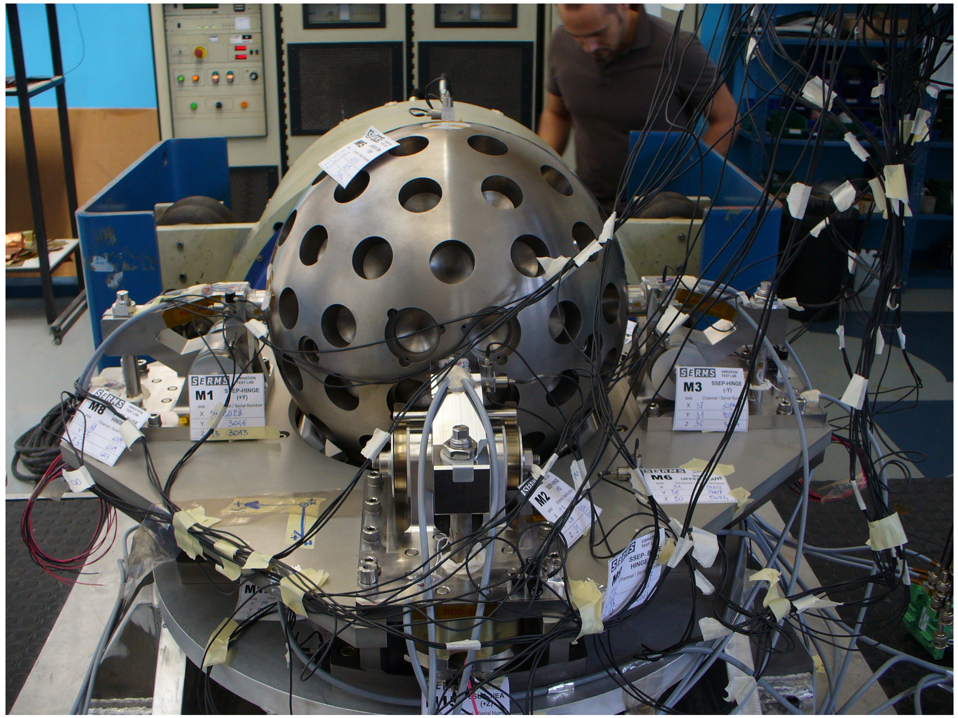
Line 6: fundamental physics SUMMARY

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

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]

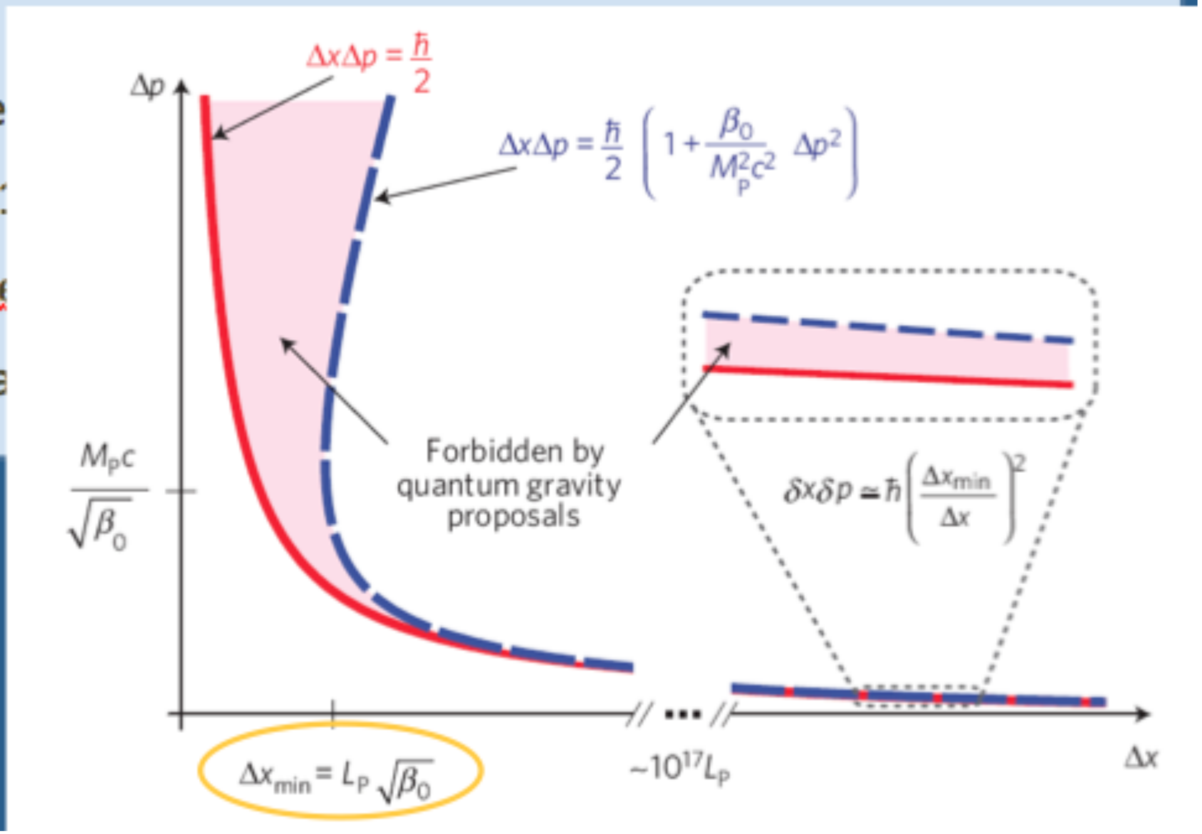
'Phenomenological quantum gravity'

- 'osservazione': non si può dete

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

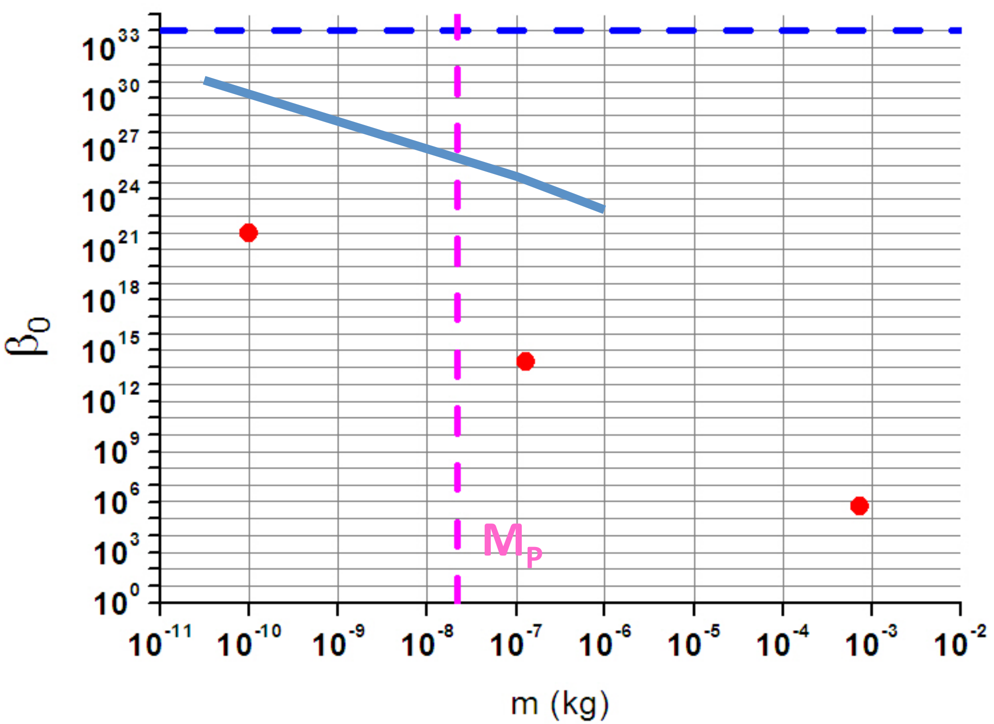
- Si introducono relazioni di Heis
- Si ricavano commutatori genera

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



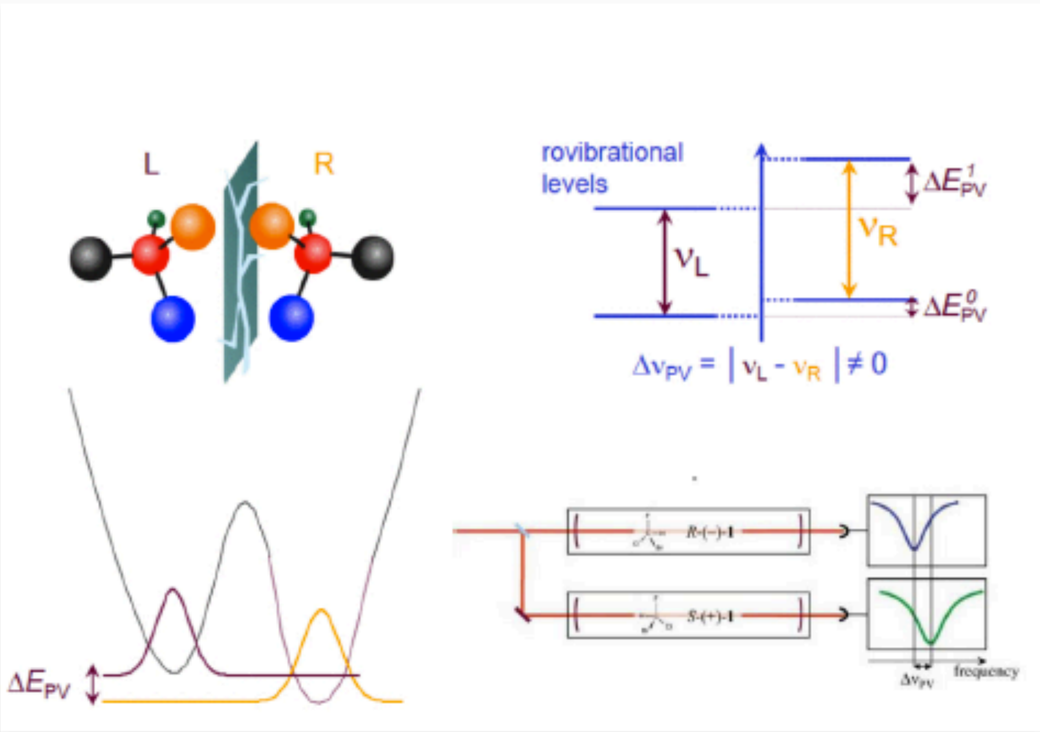
HUMOR
Preliminar results

	FI	CAM	exp. evoluto
$\mathcal{F}$	4×10^4	10^4	4×10^4
m (kg)	10^{-7}	3×10^{-11}	10^{-6}
$\omega_m/2\pi$ (Hz)	10^5	10^5	10^5
λ_L (nm)	1064	1064	1064
N_p	5×10^{10}	5×10^8	10^{14}
τ (ns)	300	300	10
L_{cav} (mm)	0.6	1	10^{-3}
Φ	4	8	800
$(\beta_0)_{max}$	10^{25}	10^{31}	10^{23}



SUPREMO

Other Tests of Fundamental Symmetries - 1

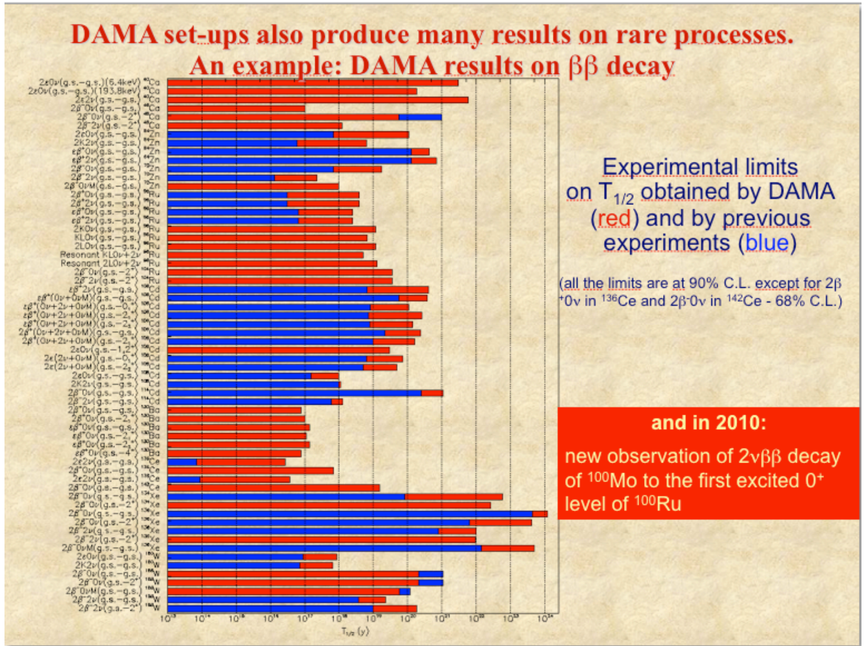


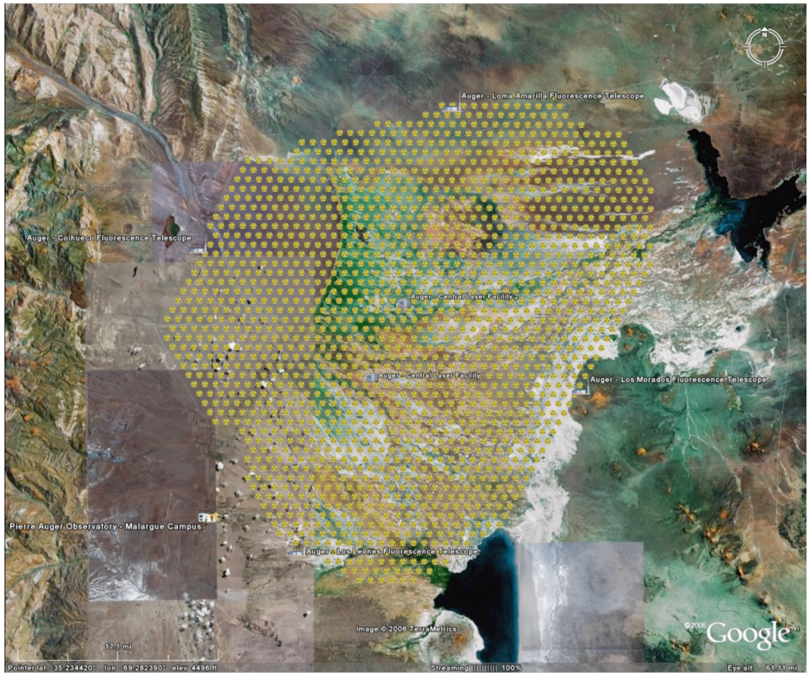
B. Darquie et al., Chirality **22**, 870 (2010)

Parity violation in chiral molecules

Weak nuclear coupling between atomic nucleons and electrons in molecular systems is responsible for molecular parity-violation energy, *i.e.*, that the energy of a chiral molecule is different from that of its specular image

CHFClBr @ 9.3 μm ⇒ 4×10^{-13}





Astroparticle physics unique facilities