

Αναζήτηση σωματιδίων σκοτεινής ύλης - ενέργειας από τον ήλιο με το CERN Axion Solar Telescope. 1999-

Φυσική πέρα από το καθιερωμένο Μοντέλο
→ Φως στο σκοτεινό Σύμπαν (!;)

K. Ζιούτας

Πανεπιστήμιο Πατρών

- CAST ΑΠΘ, ΕΜΠ, ΔΗΜΟΚΡΙΤΟΣ, ΠΑΝ/ΜΙΟ ΠΑΤΡΩΝ
- Σε συνεργασία με: O. Baker /Yale, M. Betz /CERN, P. Brax /Saclay, F. Caspers /CERN, J. Jaeckel /Duhram, A. Lindner /DESY, Y. Semertzidis /BNL, S. Troitsky /Moscow
- Παν/μιο Πατρών: Δ. Αναστασόπουλος, Β. Αναστασόπουλος, Α. Βραδής, Α. Γαρδικιώτης, Ε. Γεωργιοπούλου, Ν. Σπυλιόπουλος, Μ. Τσαγρή, Θ. Χονδρός.

Σεμινάριο,
Τμήμα Φυσικής / ΑΠΘ



SC00001091

CERN 99-21

SPSC/P312

August 9, 1999

SW 199948

Proposal to the SPSC

A solar axion search using a decommissioned LHC test magnet



The Solar Axion Telescopic ANtenna

1999

C.E. Aalseth ¹, D. Abriola ², F.T. Avignone III ¹, R.L. Brodzinski ³, J.I. Collar ^{4*},
 R. Creswick ¹, D.E. Di Gregorio ², H. Farach ¹, A.O. Gattone ², Y. Giomataris ⁵,
 S.N. Gnenenko ⁶, N.A. Golubev ⁶, C.K. Guérard ², F. Hasenbalg ², M. Hasinoff ⁷,
 H. Huck ², A.V. Kovzelev ⁶, A. Liolios ⁸, V.A. Matveev ⁶, H.S. Miley ³, A. Morales ⁹,
 J. Morales ⁹, D. Nikas ⁸, S. Nussinov ¹⁰, A. Ortiz ⁹, G. Polymeris ⁸, G. Raffelt ¹¹,
I. Savvidis ⁸, S. Scopel ⁹, I.N. Semeniouk ⁶, J.A. Villar ⁹, K. Zioutas ^{8,12#}.

¹) Department of Physics and Astronomy, University of South Carolina, Columbia SC, USA.

²) Department of Physics, TANDAR Laboratory, C.N.E.A., Buenos Aires, Argentina.

³) Pacific Northwest National Laboratory, Richland WA, USA.

⁴) Groupe de Physique des Solides, UMR CNRS 75-88, Université Paris 7, France.

⁵) CEA/DSM/DAPNIA-C.E.-Saclay, Gif/Yvette, France.

⁶) Institute for Nuclear Research, Moscow, Russia.

⁷) Department of Physics and Astronomy, University of British Columbia, Vancouver, Canada.

⁸) Physics Department, University of Thessaloniki, Thessaloniki, Greece.

⁹) Laboratorio de Física Nuclear y Atlas Energias, Universidad de Zaragoza, Zaragoza, Spain.

¹⁰) Department of Physics, Tel Aviv University, Tel Aviv, Israel.

¹¹) Max-Planck-Institut für Physik München, Germany.

¹²) CERN, Geneva, Switzerland

#) spokesperson

*) present contactperson

+

Δ. Δαμιανόγλου,

Θ. Δάφνη,

Χ. Ελευθεριάδης,

Α. Μανούσος,

Κ. Οικονόμου,

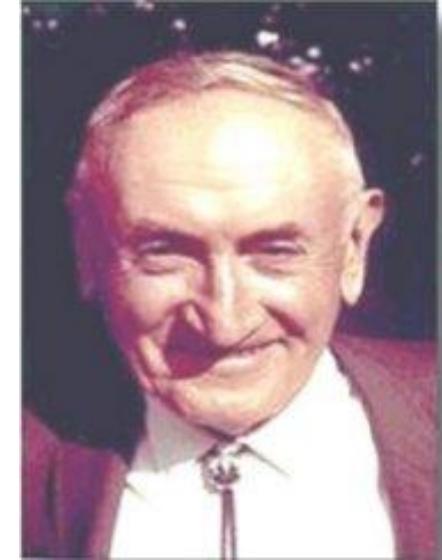
Θ. Παπαευαγγέλου,

Α. Πιλαφτσής,

Ι. Σεμερτζίδης ,

The open question since Fritz Zwicky (**1933**) is:

What is “dunkle Materie” made of?

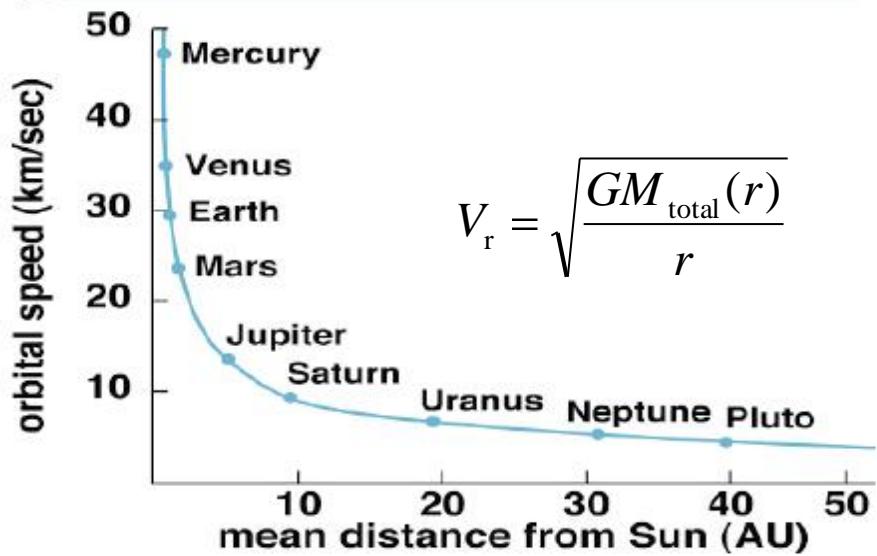
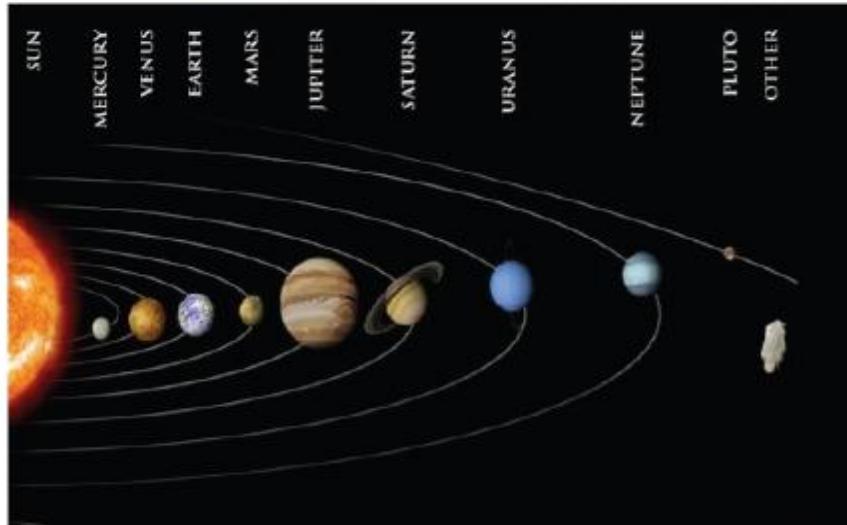


Fritz Zwicky
1898 – 1974

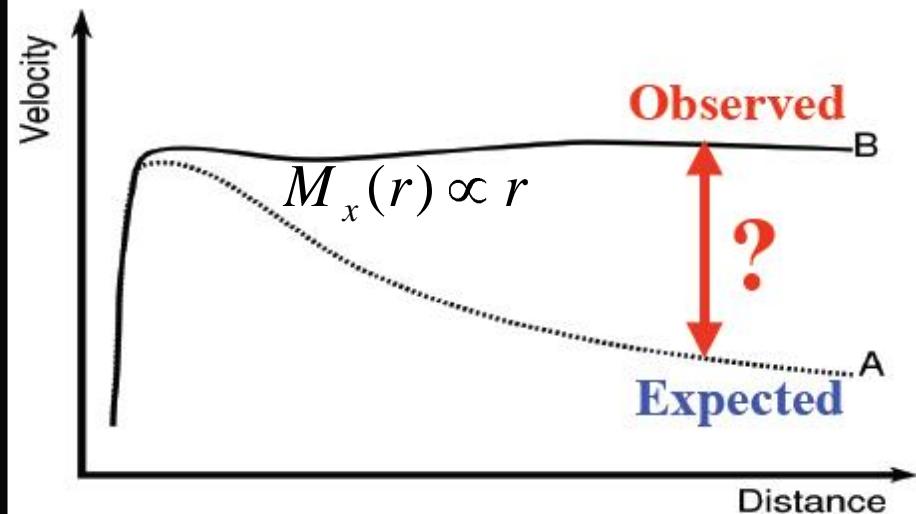
axions and WIMPs ... WISPs → ... more ?

Dark Matter: something invisible?

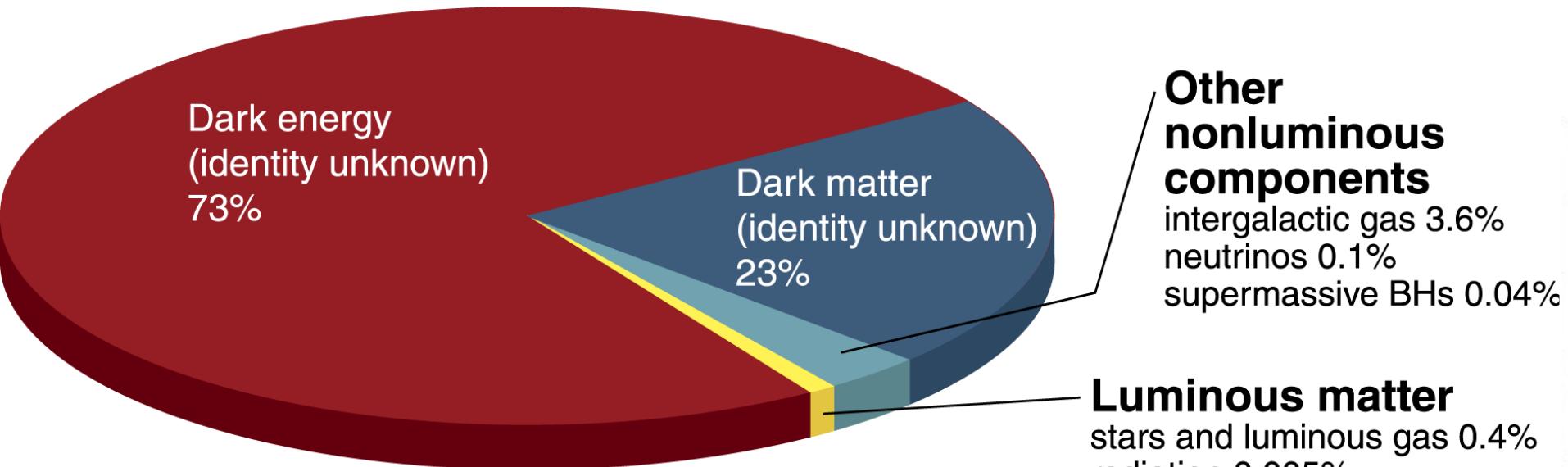
Solar System



Spiral Galaxy

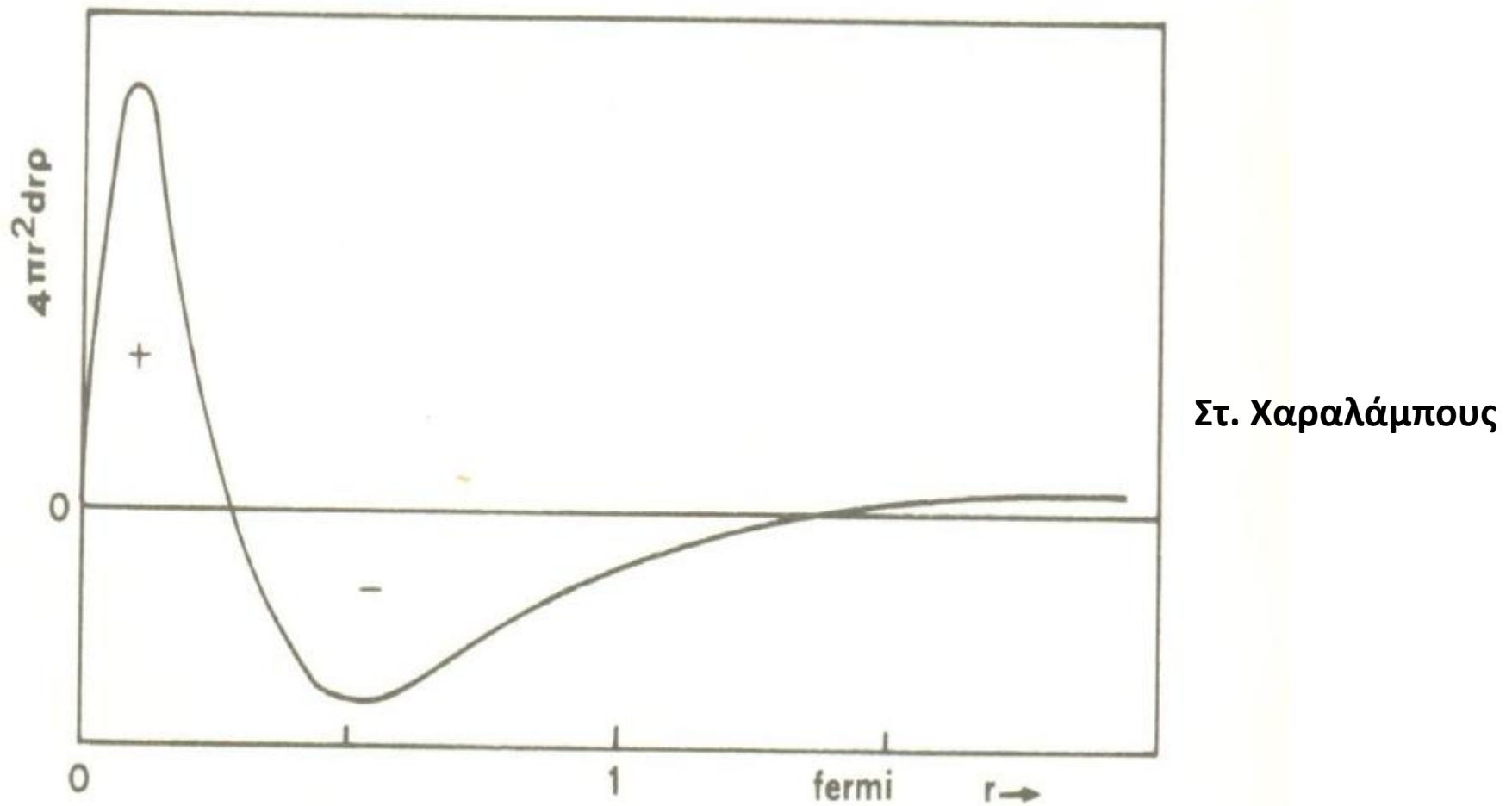


The cosmological inventory:



- But, what is dark energy or dark matter ?
- A particle relic from the Big Bang is strongly implied for DM / DE
 - WIMPs ?
 - Axions ?
 -??..

→ Beyond Standard Model physics!



Σχήμα 12.1. Άκτινική κατανομή πυκνότητας φορτίου τοῦ νετρονίου. Ο κατακόρυφος ἔξονας εἶναι μέτρο τοῦ ὀλικοῦ φορτίου στὸν σφαιρικό φλοιό r καὶ $r+dr$.

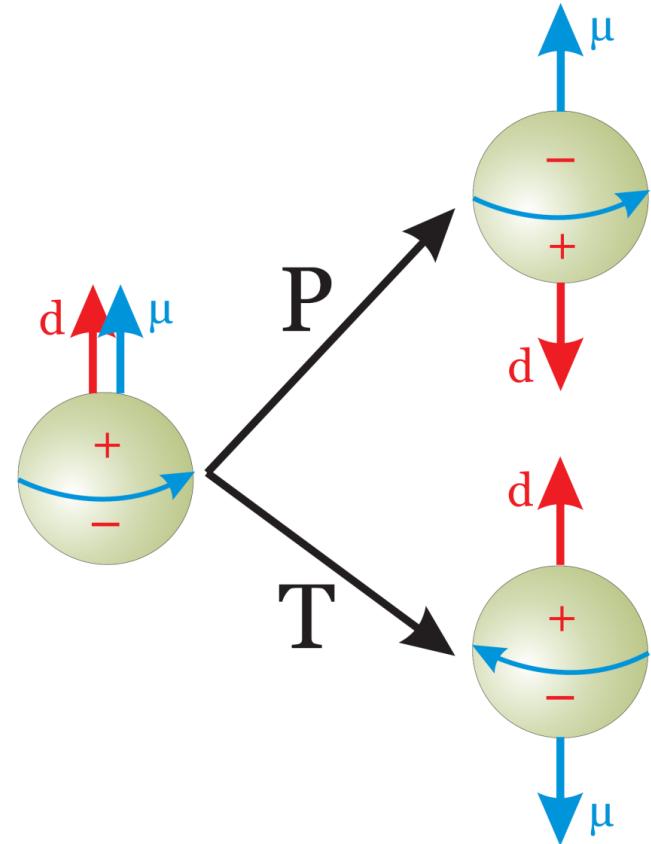
nEDM?

- Parity (**P**) and time reversal (**T**) violation, if the neutron has an **EDM** **d** in addition to the measured **magnetic dipole moment** **μ**

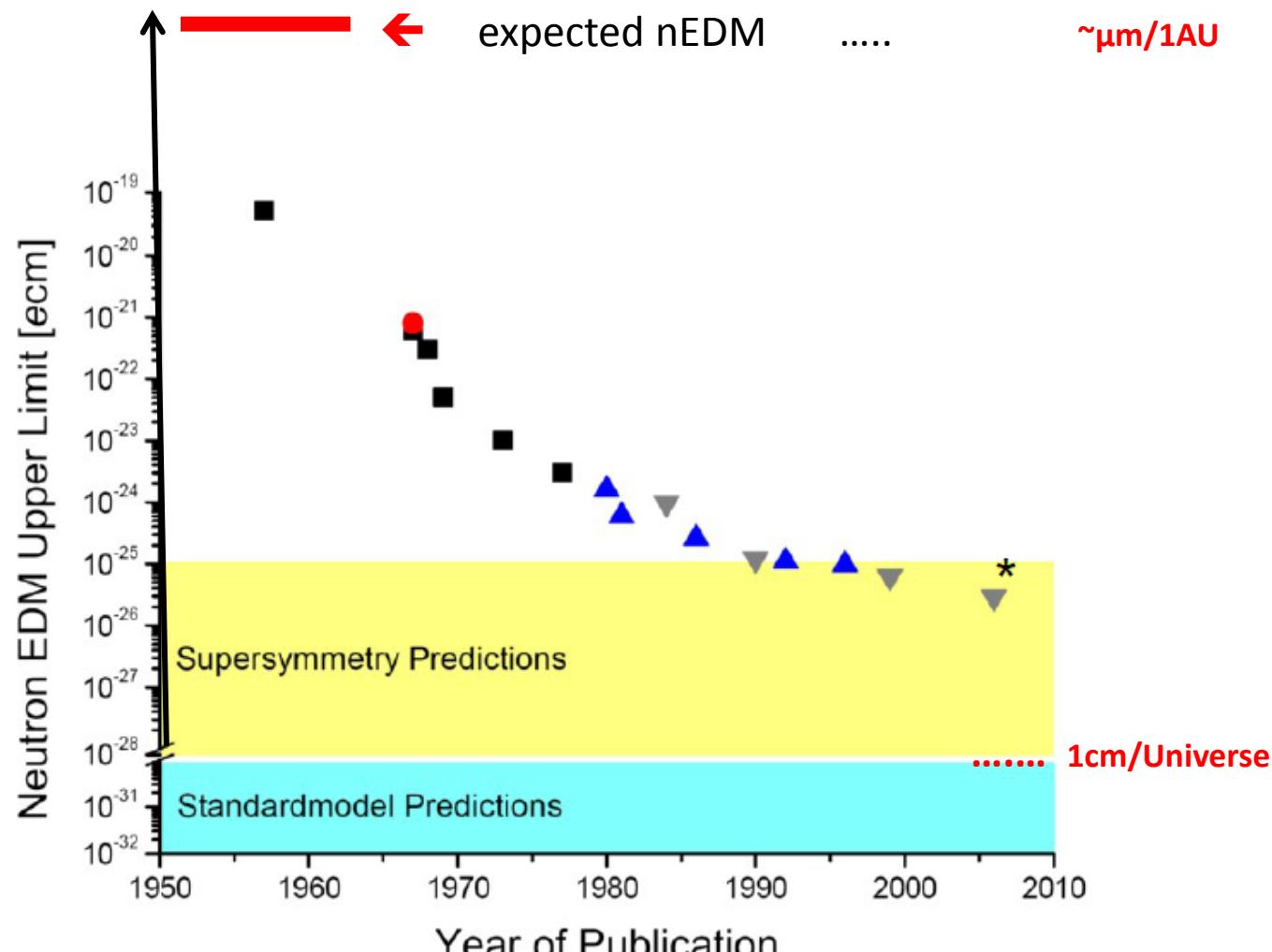
→ CP is not conserved

Both moments would change from parallelism to anti-parallelism: not allowed

The strong interaction conserves CP => no nEDM



History



Why doesn't the neutron have an EDM?

The neutron's strange property:

It consists of three charged quarks, but does not show an EDM.

Why do the wave functions of the three quarks exactly cancel out any observable static charge distribution in the neutron?

→ the “**Strong CP Problem**”: Where did QCD CP violation go?

Physics motivation for **axions**:

solve the strong CP problem:

why $nEDM \rightarrow 0$

spin-parity $\Rightarrow 0^- \Rightarrow \approx \pi^0, \gamma$ (M1) ~ stable!

Axions \rightarrow cosmology \leftarrow dark matter
+ Sun, ...

\rightarrow solve solar problems?!

\rightarrow The new ~axion fingerprints?

Roberto Peccei



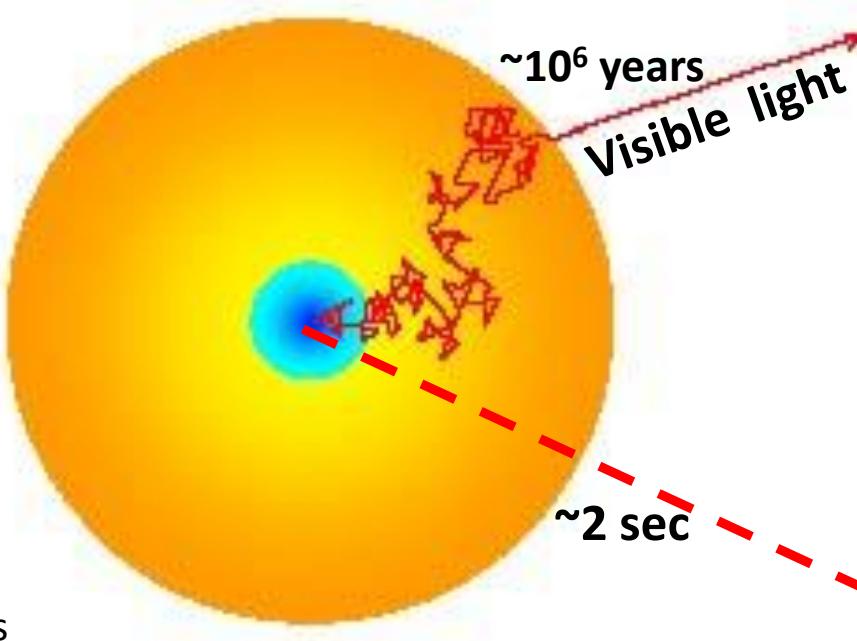
Helen Quinn



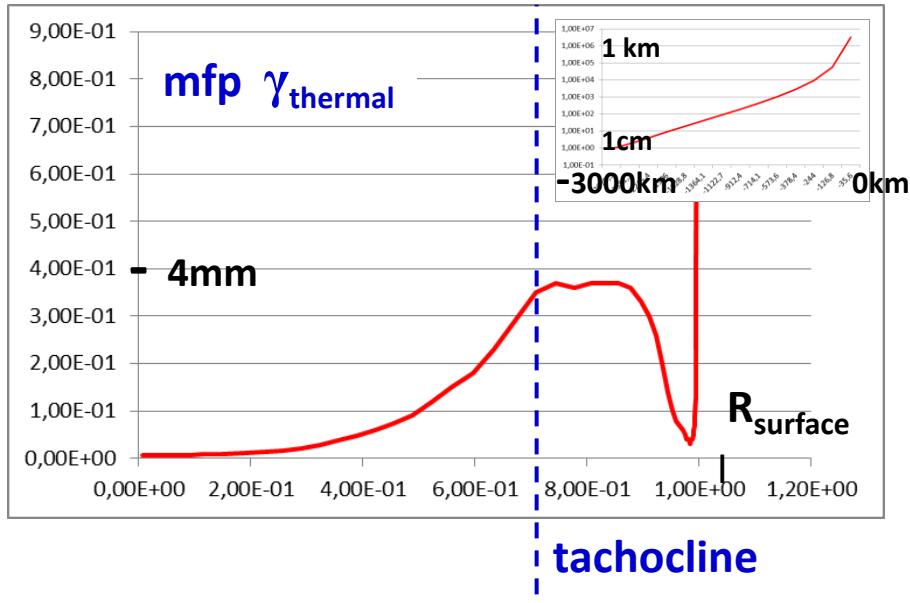
With (solar) axions:

- New elementary particle
 - Solves the strong CP problem
 - *Dark matter problem* → next #
-
- New solar physics → solar mysteries
 - e.g.: Solar corona heating problem, the unexpected solar X-rays, ...
 - other candidates: chameleons, ...

Sun: A perfectly shielded “radioactive” source of exotica



E. Georgiopoulou / UoPatras



ν' 's
Axions
Chameleons
Paraphotons
...
WISPs

more?

Solar Axions: $\phi_{tot} \approx 3.9 \cdot 10^{13} \text{ cm}^{-2} \text{ s}^{-1}$

SUN → the lab for new physics

Allowed emission of exotica < 10% L_{solar} ≈ 300 ktons/s » $L_{\text{flare}} / L_{\text{corona}}$

- + gravitational self-trapping, e.g., KK-axions ($\sim 10^{-7}$)

L.DiLella, K.Z., Astropart. Phys.(2003)

→ accumulation over 4.5Gyears!!

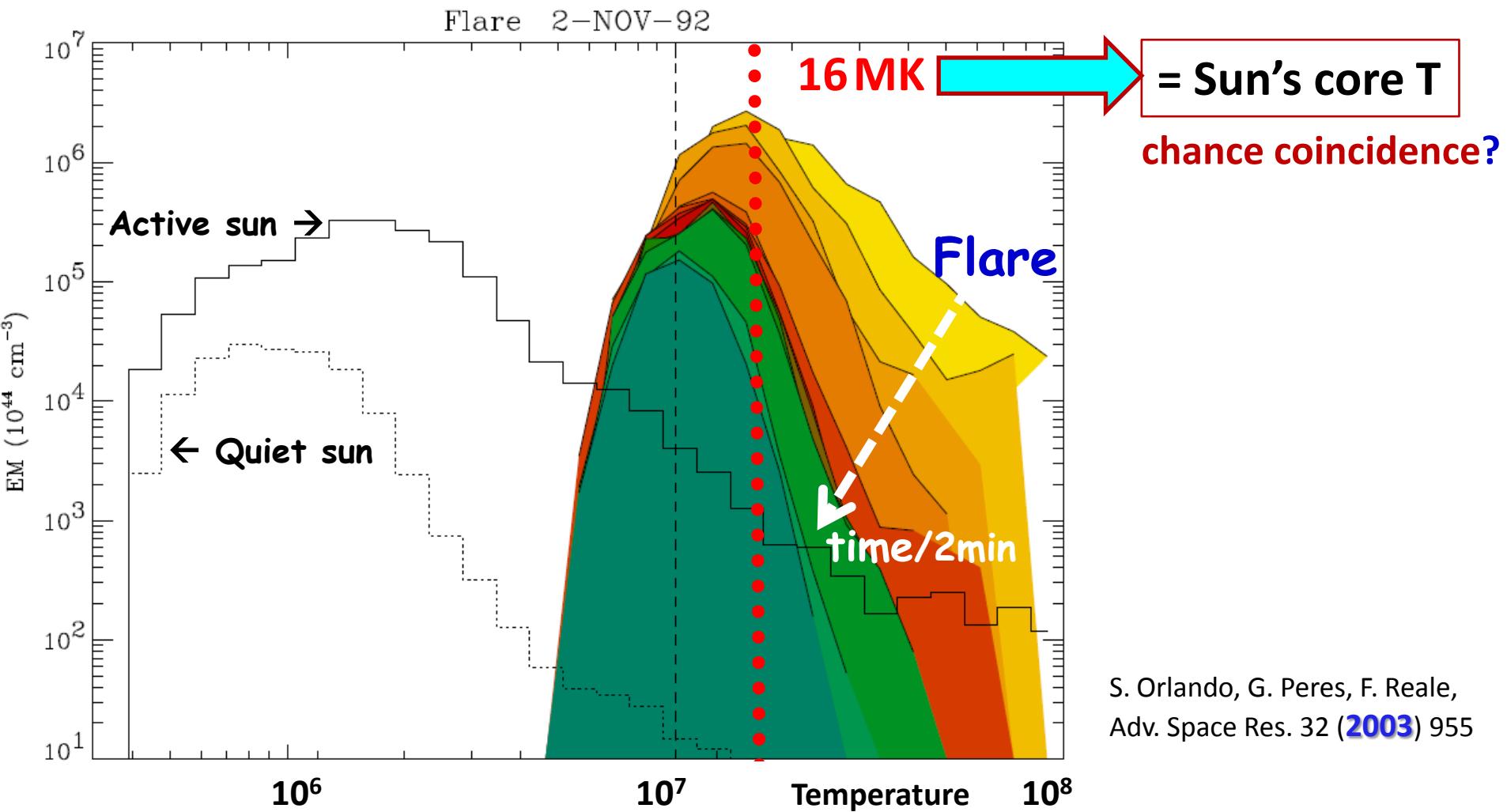
... without visible ageing effects.

But, unexpected surface photon excess/deficit,

OR, some other anomalous behaviour?

Flare 'trigger': biggest mystery

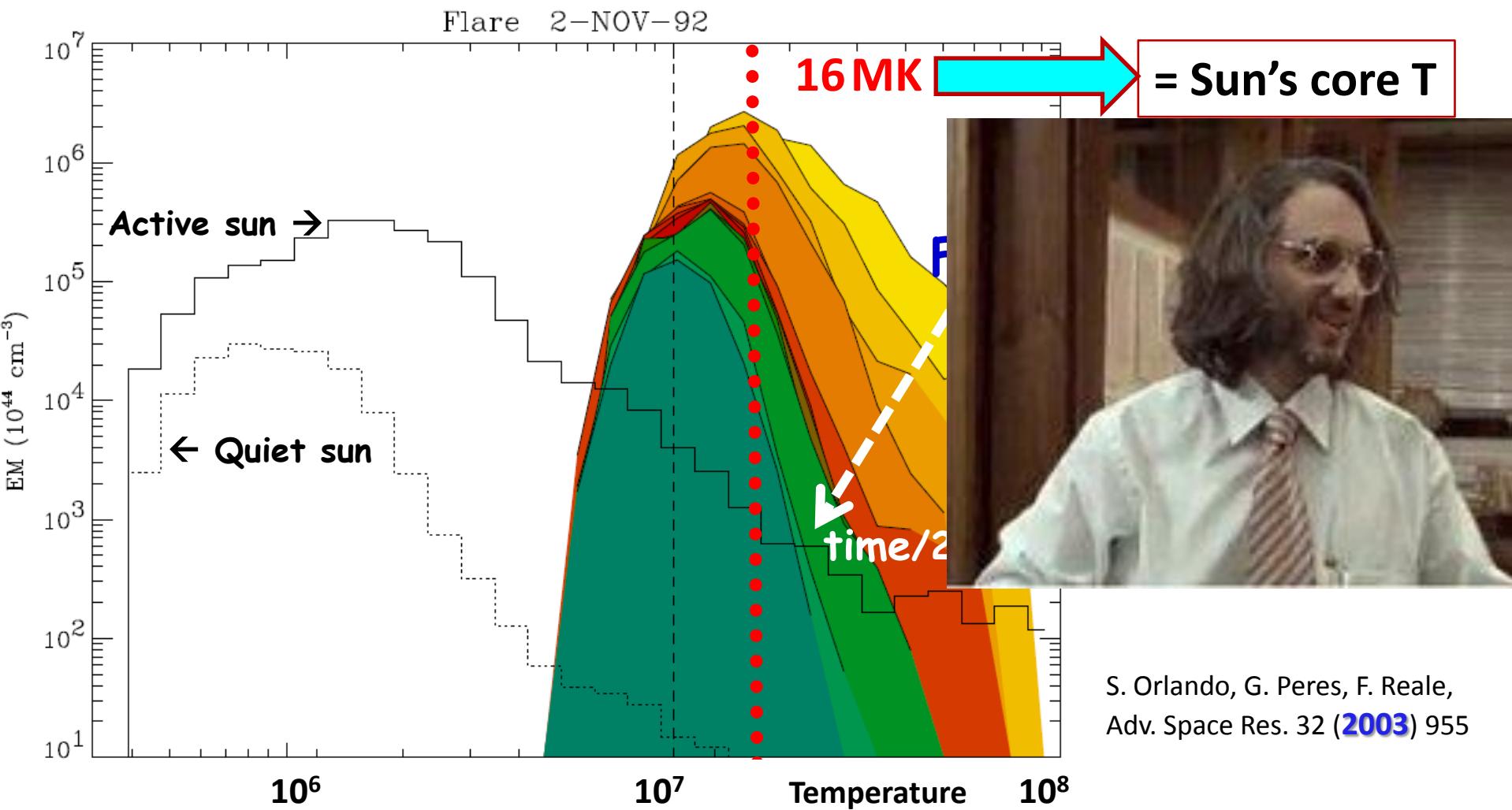
$L_x < 10^{29}$ erg/s



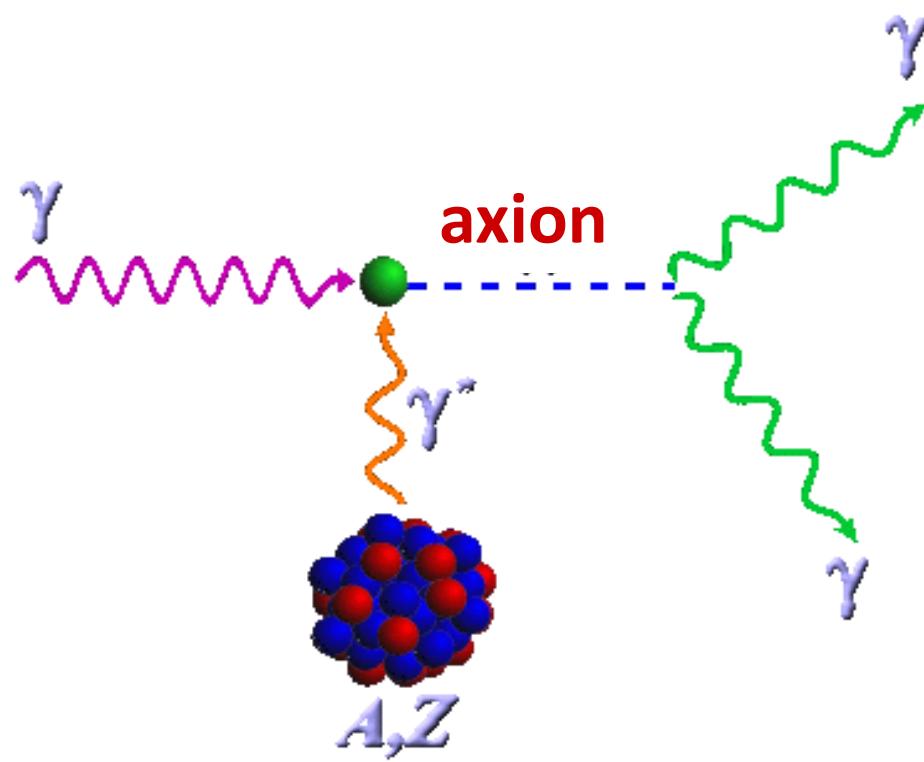
S. Orlando, G. Peres, F. Reale,
Adv. Space Res. 32 (2003) 955

Flare 'trigger': biggest mystery

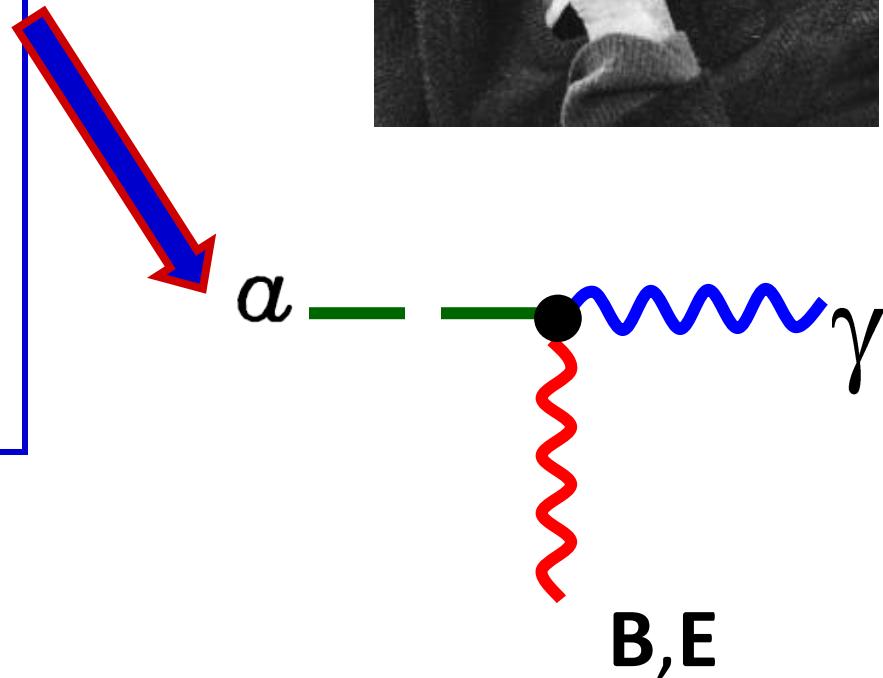
$L_x < 10^{29}$ erg/s



a-helioscope →

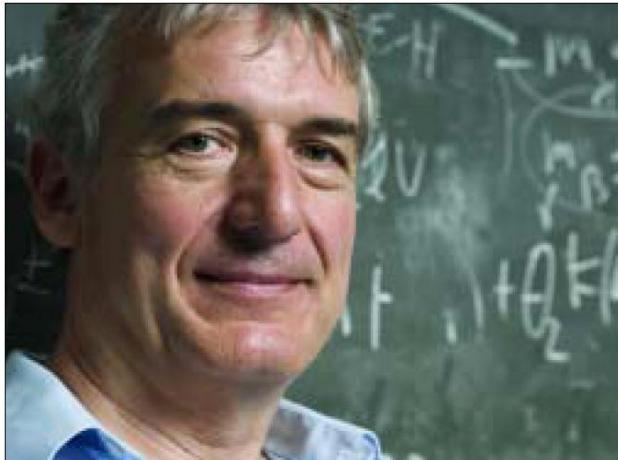


Behind all present axion work!



Idea #1

...the principle



Pierre Sikivie 1983

VOLUME 51, NUMBER 16

PHYSICAL REVIEW LETTERS

17 OCTOBER 1983

Experimental Tests of the “Invisible” Axion

P. Sikivie

Physics Department, University of Florida, Gainesville, Florida 32611

(Received 13 July 1983)

Experiments are proposed which address the question of the existence of the “invisible” axion for the whole allowed range of the axion decay constant. These experiments exploit the coupling of the axion to the electromagnetic field, axion emission by the sun, and/or the cosmological abundance and presumed clustering of axions in the halo of our galaxy.

http://prl.aps.org/pdf/PRL/v51/i16/p1415_1



PHYSICAL REVIEW D

PARTICLES AND FIELDS

THIRD SERIES, VOLUME 39, NUMBER 8

15 APRIL 1989

Design for a practical laboratory detector for solar axions

K. van Bibber

Physics Department, Lawrence Livermore National Laboratory, University of California, Livermore, California 94550

P. M. McIntyre

Physics Department, Texas A&M University, College Station, Texas 77843

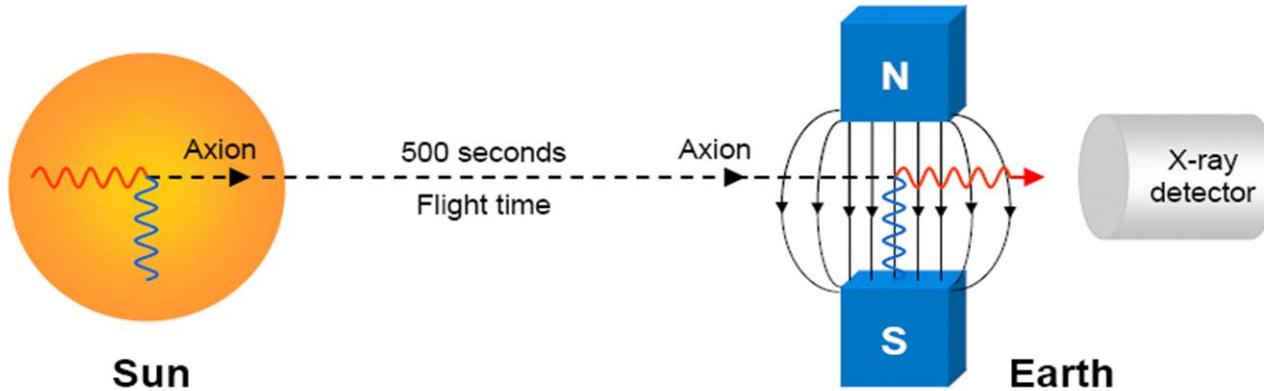
D. E. Morris

Physics Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

G. G. Raffelt

Institute for Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, University of California, Livermore, California 94550

and Astronomy Department, University of California, Berkeley, California 94720



Signal: **excess** of X-rays during alignment over background

Production: Primakoff effect
Thermal photons interacting with solar nuclei produce Axions.

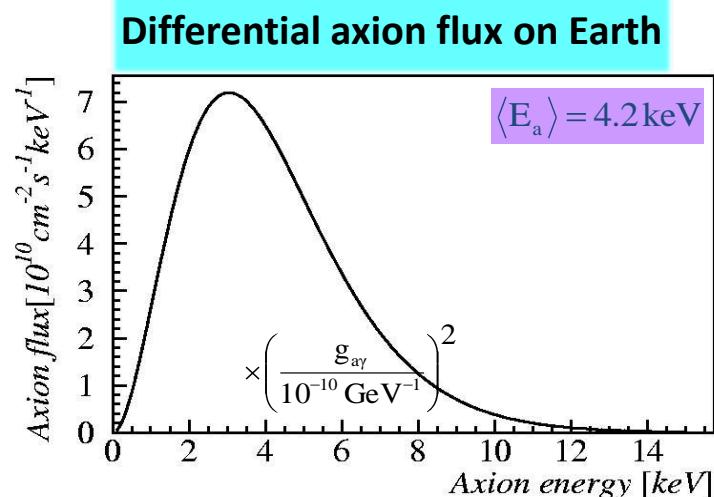
Detection Inverse Primakoff:
axion interacting coherently with a strong magnetic field ($\sim \mathbf{B}^2$) converts to a photon

Expected number of Photons:

$$N_\gamma = \int \frac{d\Phi_a}{dE_a} \cdot P_{a \rightarrow \gamma} \cdot S \cdot t \cdot dE_a$$

$$P_{a \rightarrow \gamma} \approx 1.7 \times 10^{-17}$$

$$\Phi_\gamma = 0.51 \text{ cm}^{-2} \text{ d}^{-1} g_{10}^4 \left(\frac{L}{9.26 \text{ m}} \right)^2 \left(\frac{B}{9.0 \text{ T}} \right)^2$$



Birth of solar axion astrophysics in BNL 1990

E 69, NUMBER 16

PHYSICAL REVIEW LETTERS

19 OCTOBER 1992

Search for Solar Axions

D. M. Lazarus and G. C. Smith

Brookhaven National Laboratory, Upton, New York 11973

R. Cameron,^(a) A. C. Melissinos, G. Ruoso,^(b) and Y. K. Semertzidis^(c)

Department of Physics and Astronomy, University of Rochester, Rochester, New York 14627

F. A. Nezrick

Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510

(Received 22 May 1992)

We have searched for a flux of axions produced in the Sun by exploiting their conversion to x rays in a static magnetic field. The signature of a solar axion flux would be an increase in the rate of x rays detected in a magnetic telescope when the Sun passes within its acceptance. From the absence of such a signal we set a 3σ limit on the axion coupling to two photons $g_{\alpha\gamma\gamma} \equiv 1/M < 3.6 \times 10^{-9} \text{ GeV}^{-1}$, provided the axion mass $m_a < 0.03 \text{ eV}$, and $< 7.7 \times 10^{-9} \text{ GeV}^{-1}$ for $0.03 < m_a < 0.11 \text{ eV}$.

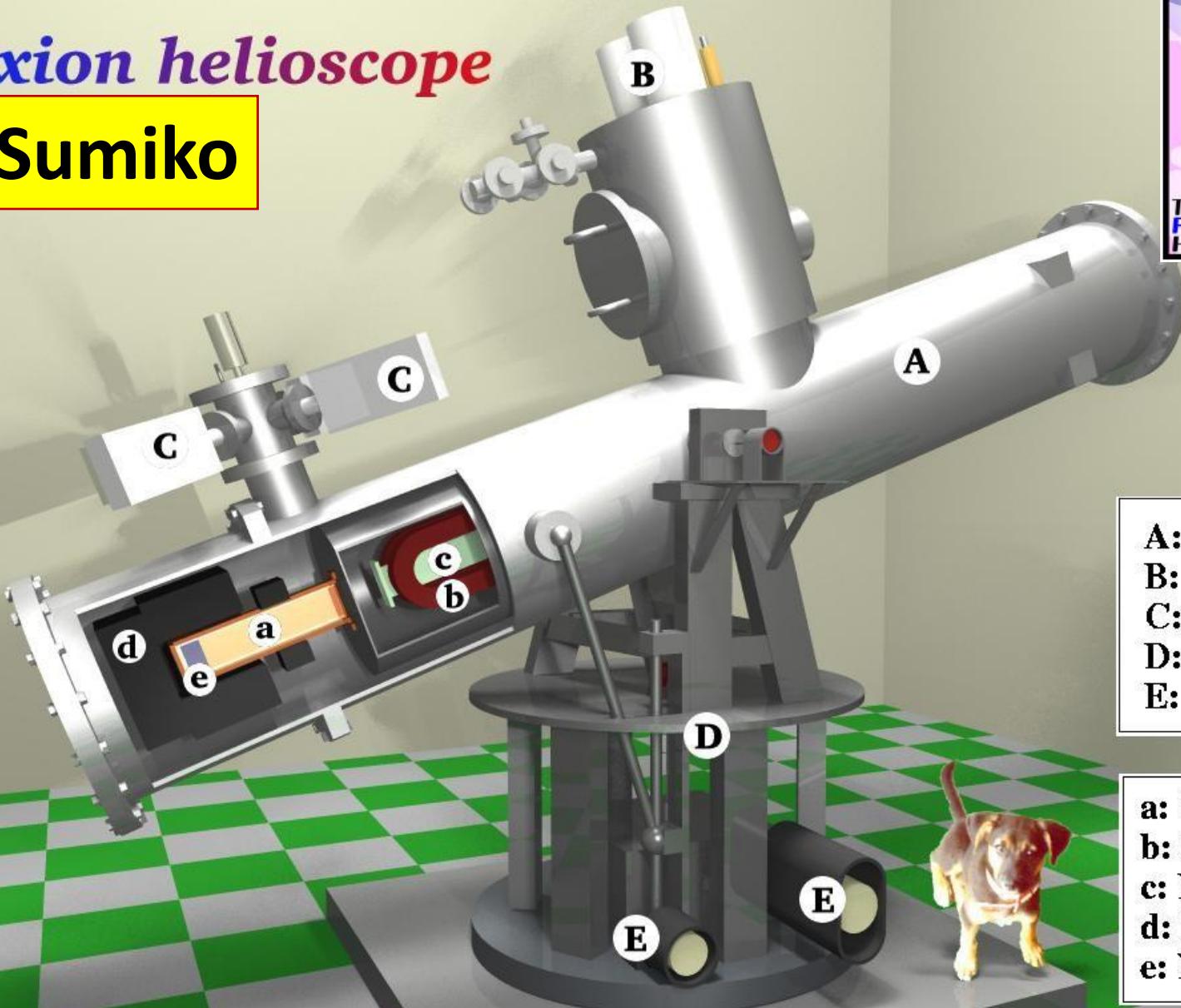
PACS numbers: 14.80.Gt, 95.85.Qx, 96.60.Vg

ent theories of elementary particles predict the ex-
of low mass scalar or pseudoscalar particles.
arise naturally when a global symmetry is spon-
ly broken, and are referred to as Nambu-

Axions that couple directly to electrons through an $e\bar{e}a$ vertex provide a very efficient energy-loss mechanism and their relative coupling is excluded by many orders of magnitude by the cooling rates of the Sun, the red giant

Axion helioscope

Sumiko



A: Main cylinder
B: Refrigerators
C: Preamplifiers
D: Turn table
E: Motors

a: Cu cold finger
b: SC coils
c: He gas tube
d: Pb shield
e: X-ray detectors

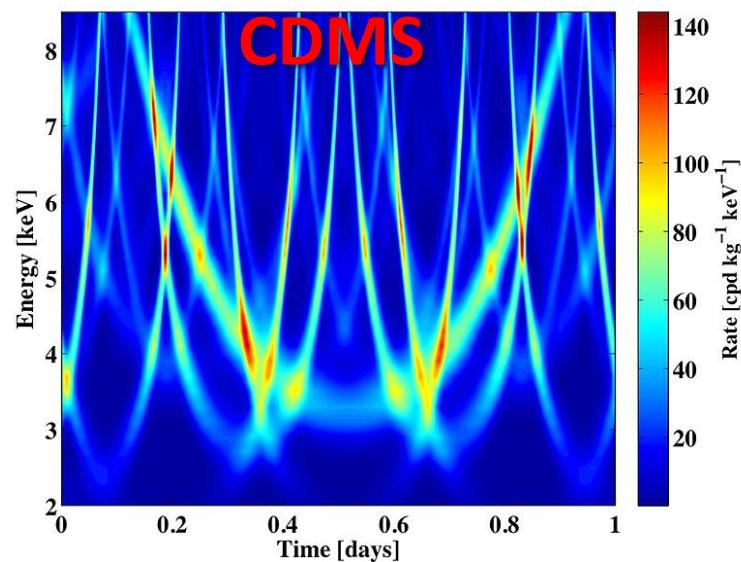
before CAST:

→ BNL & Tokyo (Sumico)

→ solar axion-Bragg scattering

E.A. Paschos, K. Z. PLB (1994)

- all underground DM exp's
- TL G. Kitis et al.
.....

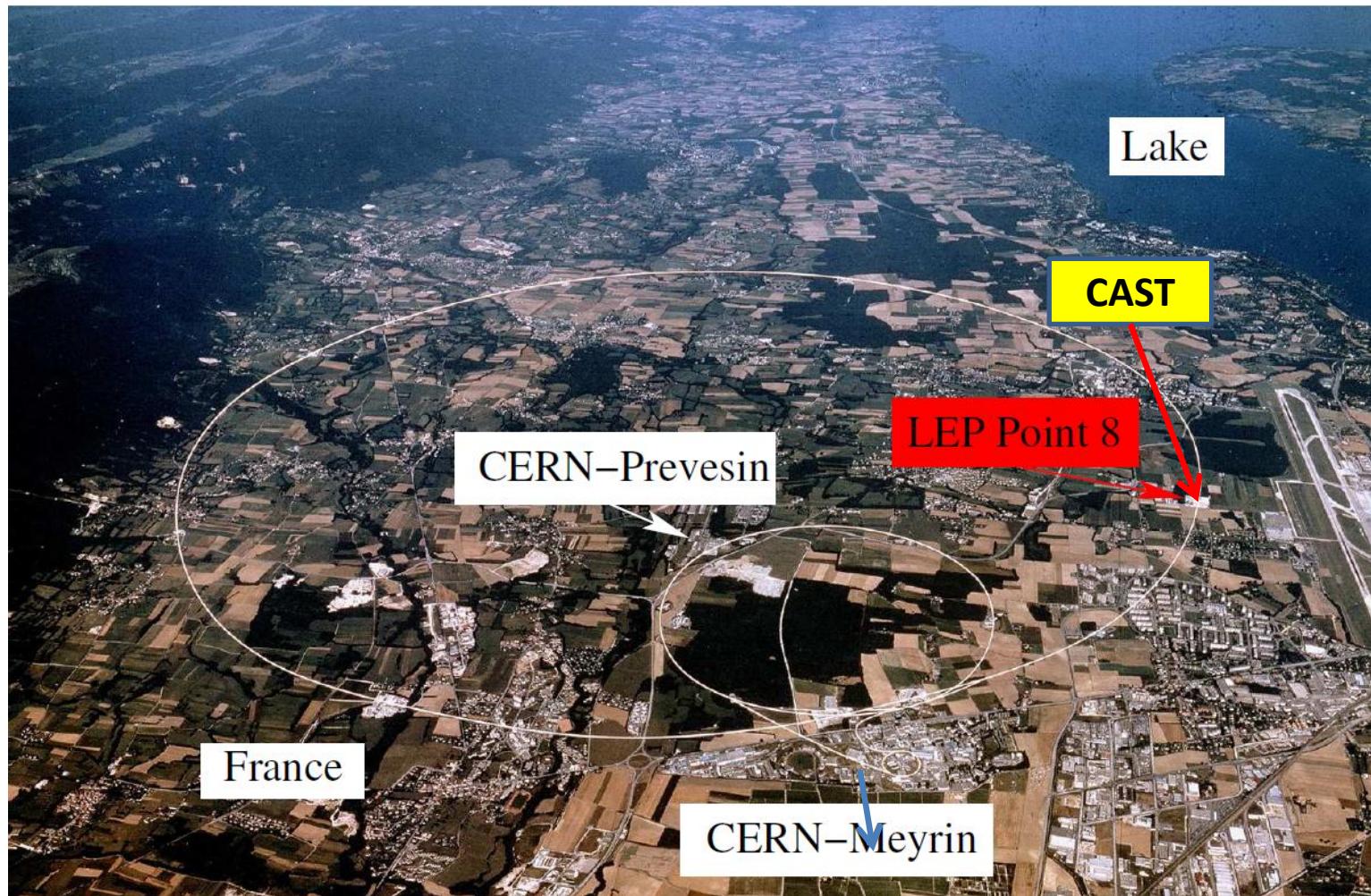


Time-energy plot of the expected converted solar axions with a germanium detector.

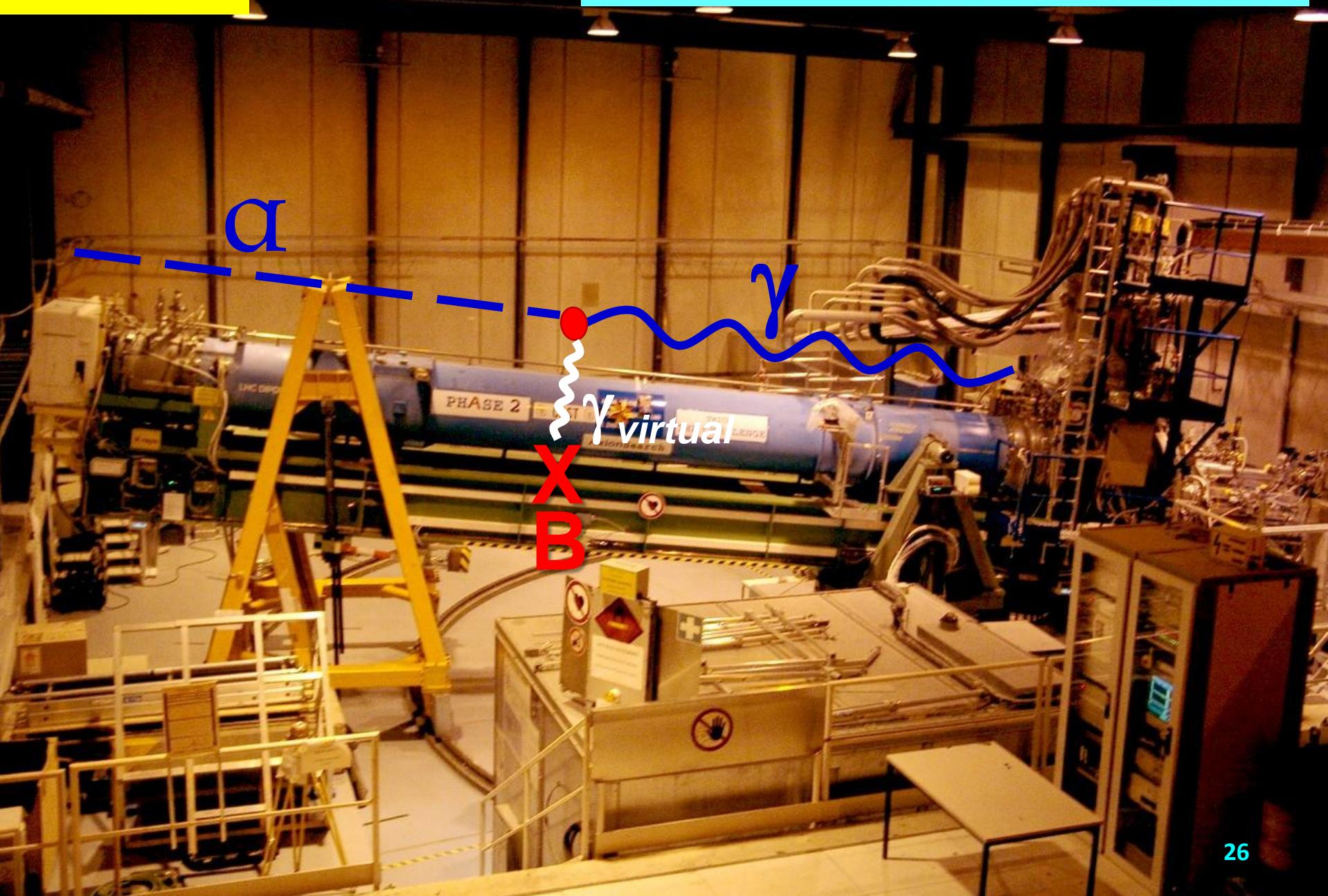
CDMS Collaboration, PRL 103, 141802 (2009)

The CAST experiment

Location





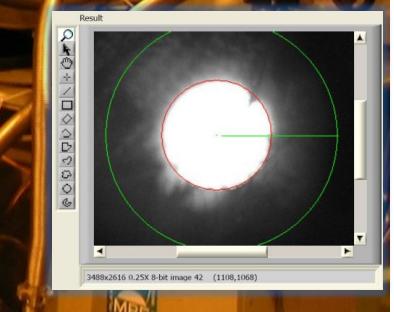
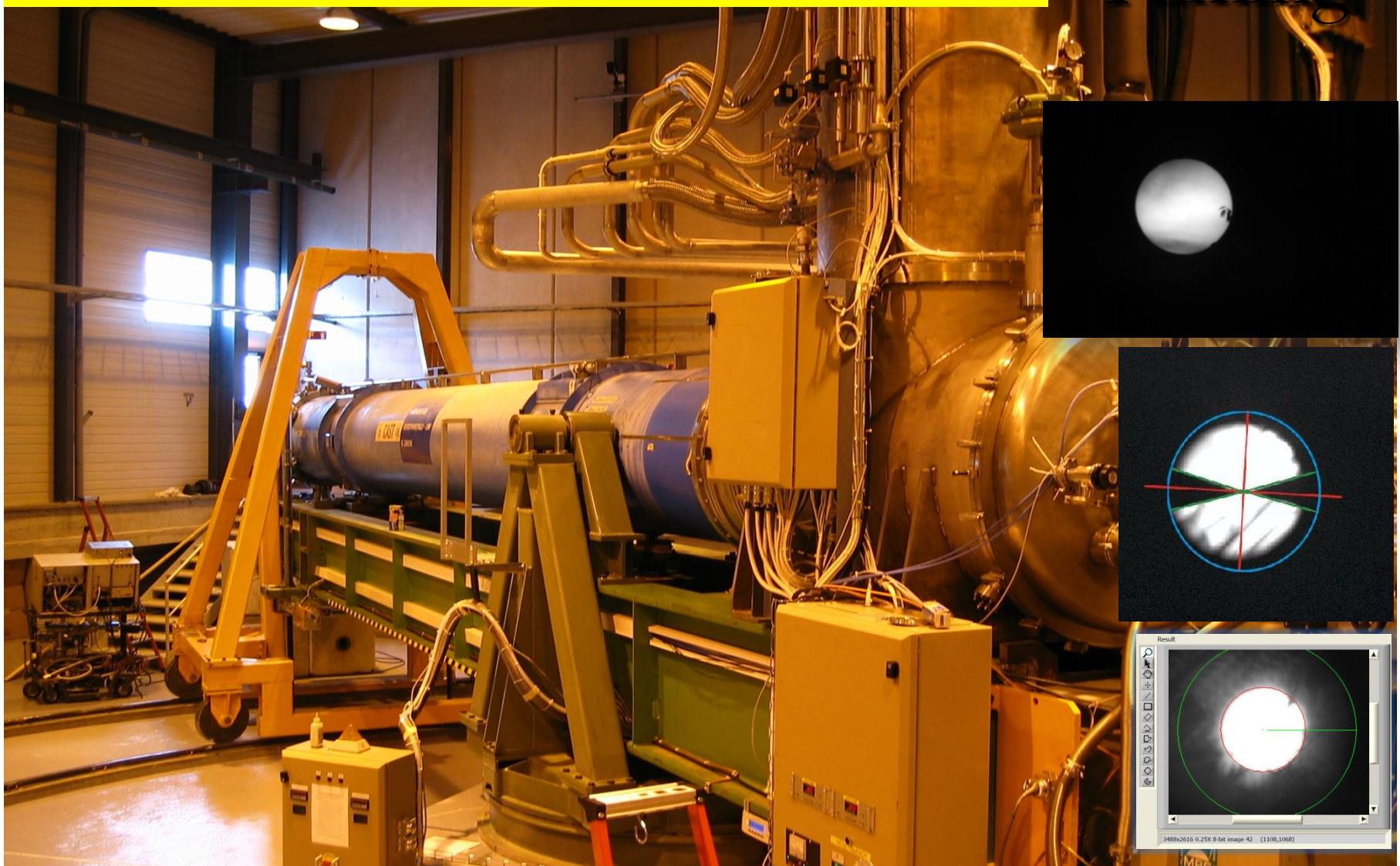


CAST = *a difficult experiment*:

- 1.8K
- superconducting (\rightarrow quenches!)
- moving / alignment
- Cryo Fluid Dynamics of buffer gas
 - \rightarrow tracking
- low background X-ray detectors

\rightarrow **the only(?) telescope at 1.8K**

Twice per year (March/September) direct optical check
A camera on top of the magnet aligned with the bore axis
Corrections for visible light refraction are taken into account



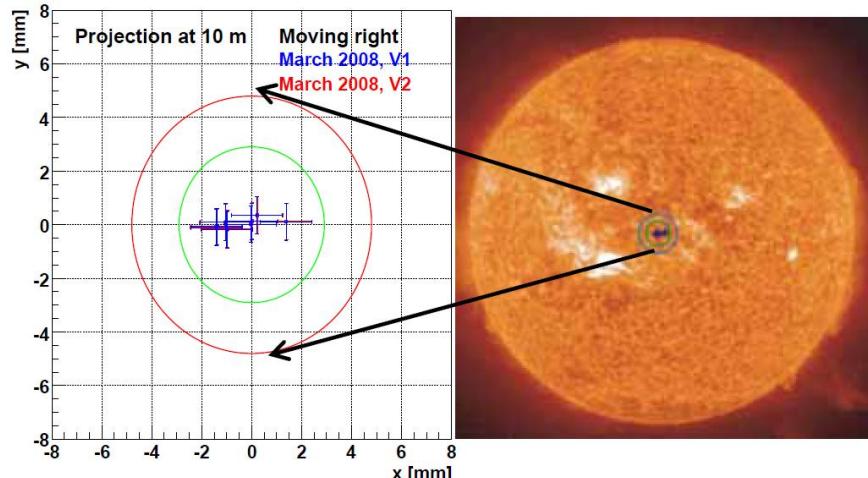
The Magnet Pointing precision is well within our requirements (0.5 mrad)

Tracking system precision

Several yearly checks cross-check that the magnet is following the Sun with the required precision

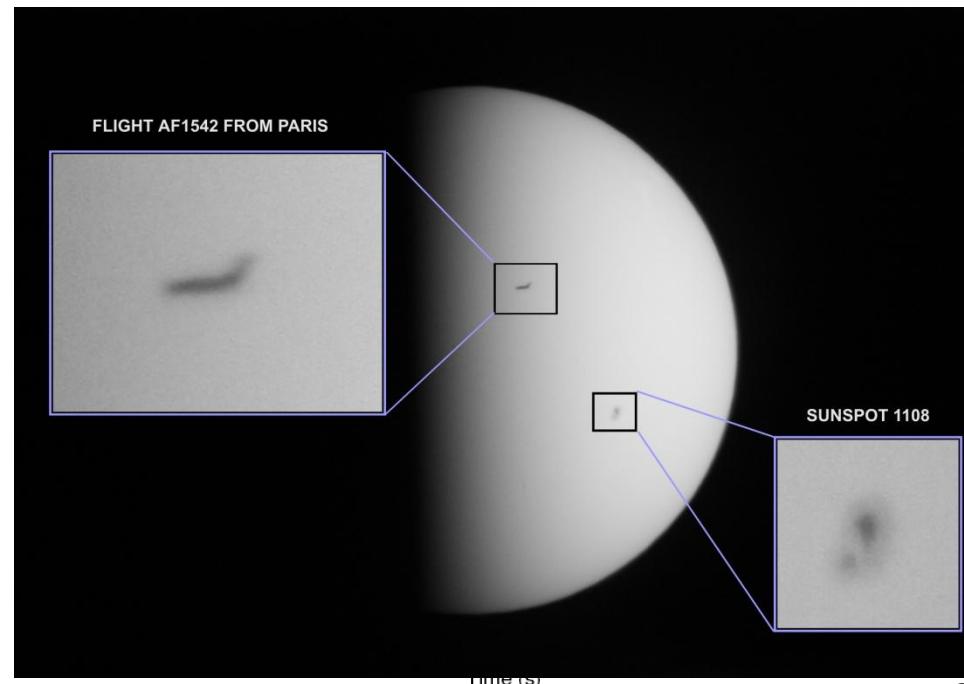
GRID Measurements

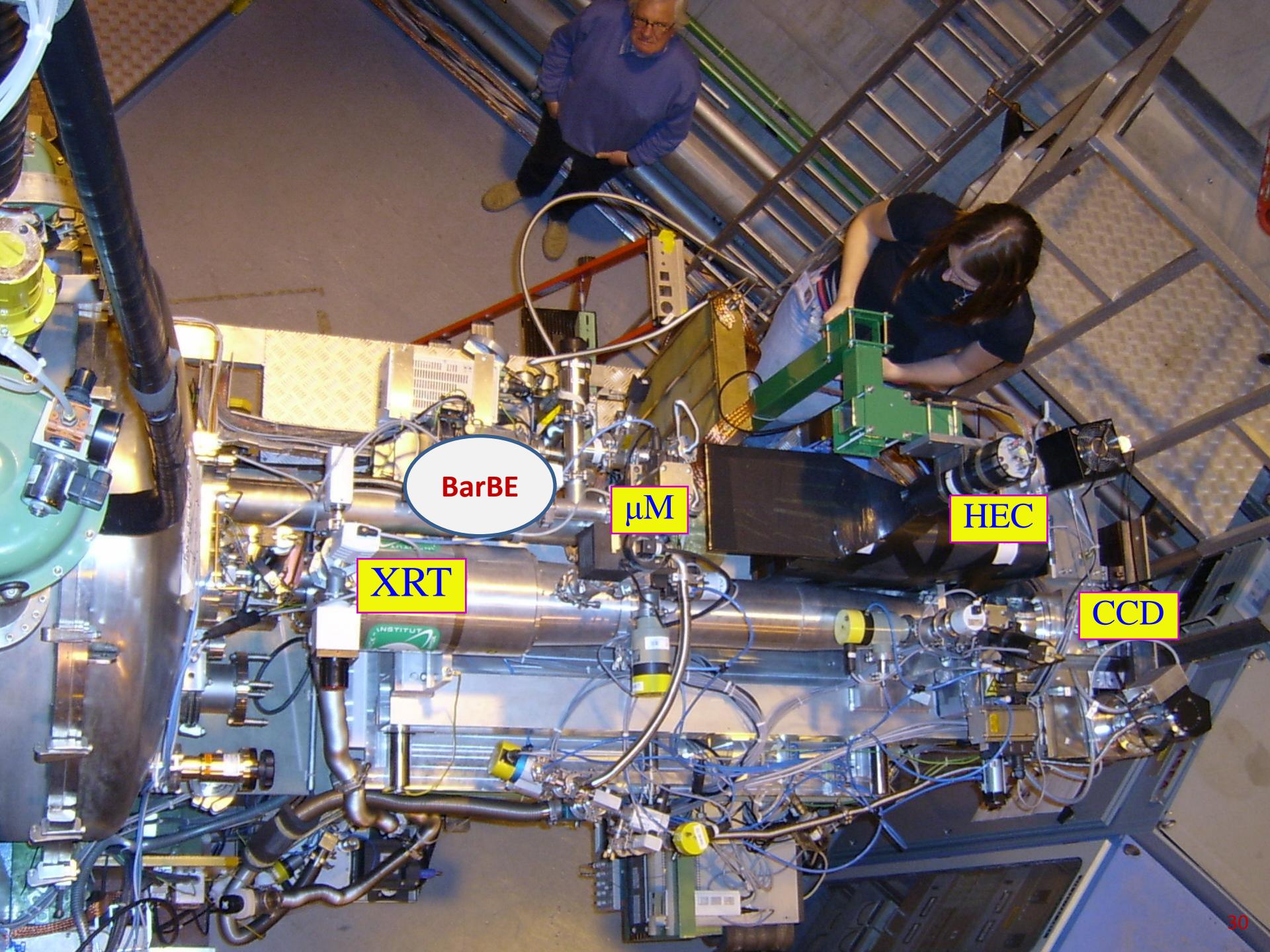
- Horizontal and Vertical encoders define the magnet orientation
- Correlation between H/V encoders has been established for a number of points (GRID points)
- Periodically checked with geometer measurements



Sun Filming

- Twice a year (March – September)
Direct optical check. Corrected for optical refraction
- Verify that the dynamic Magnet Pointing precision (~ 1 arcmin) is within our acceptance

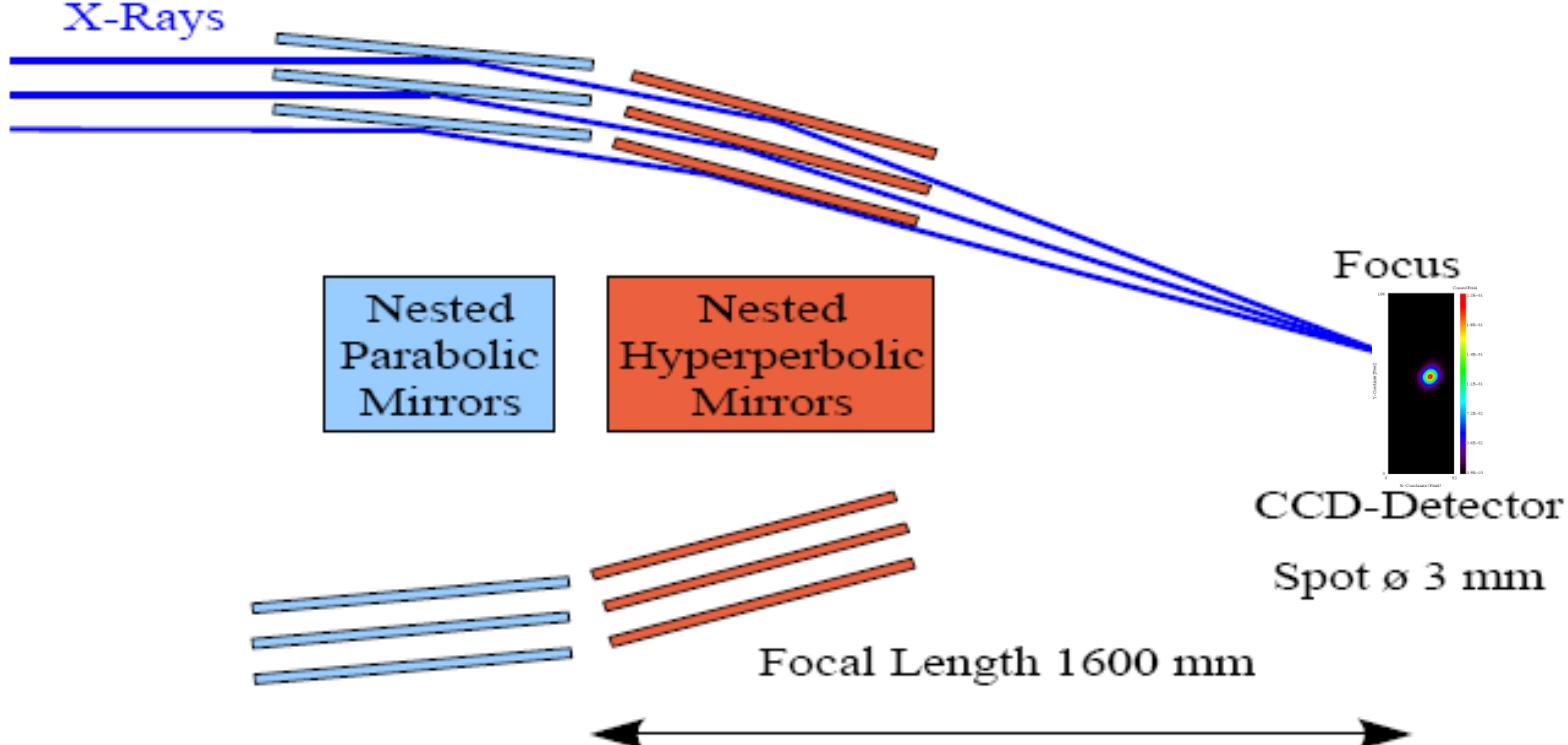




CAST X-ray telescope: MPE



$\varnothing 43$ mm

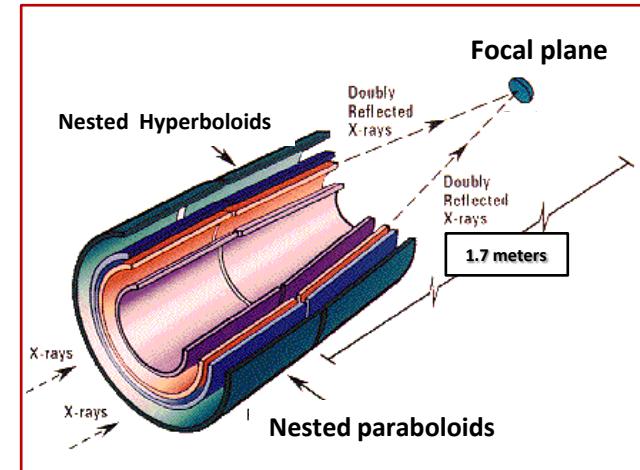
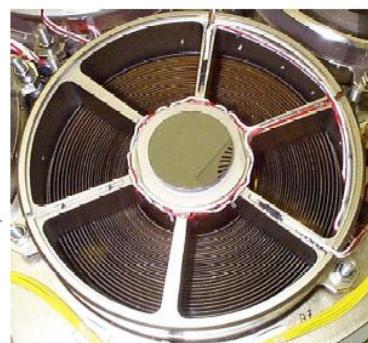


← Spare # from german space program

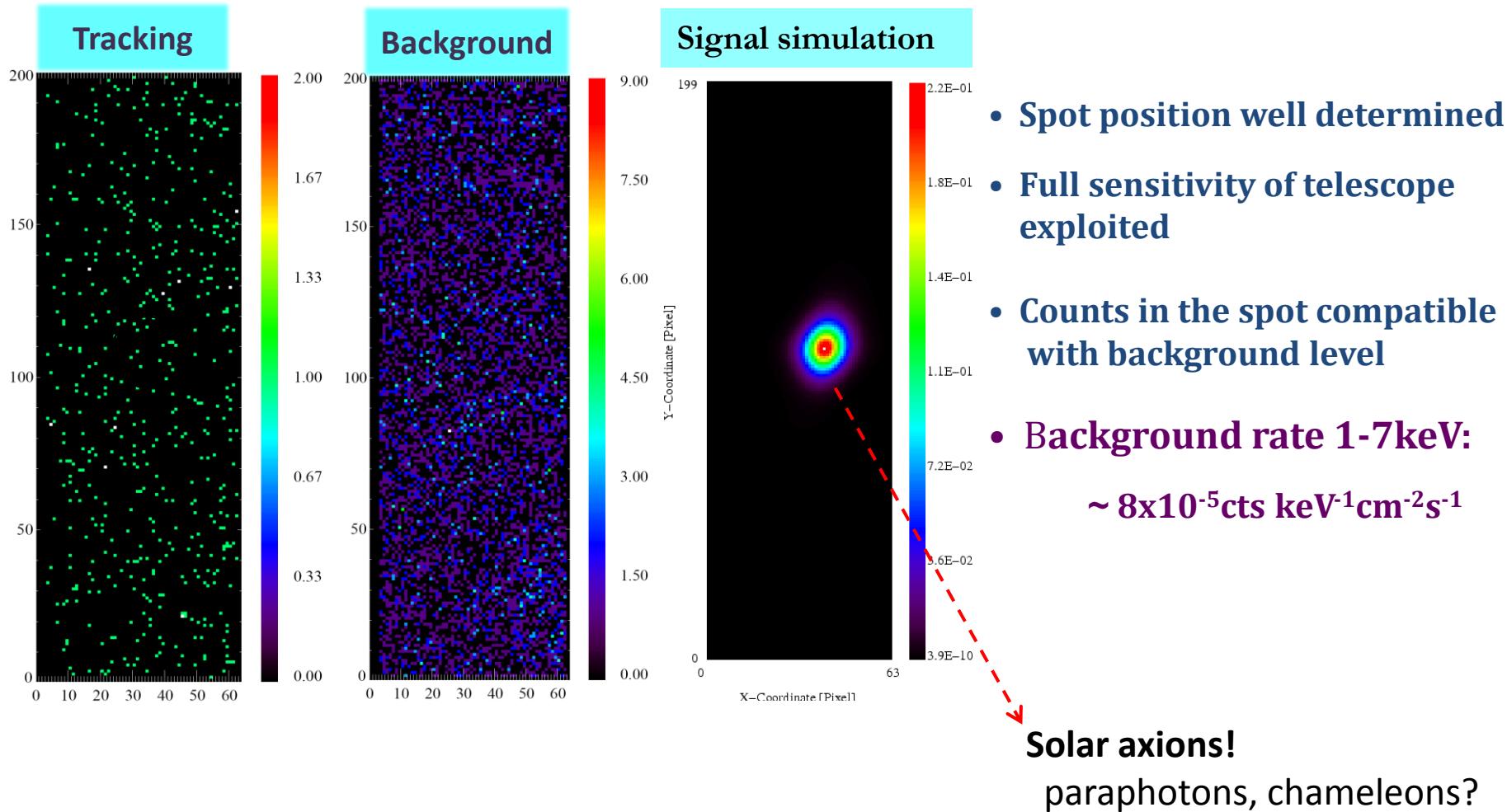
... not in the original proposal!

→ unique

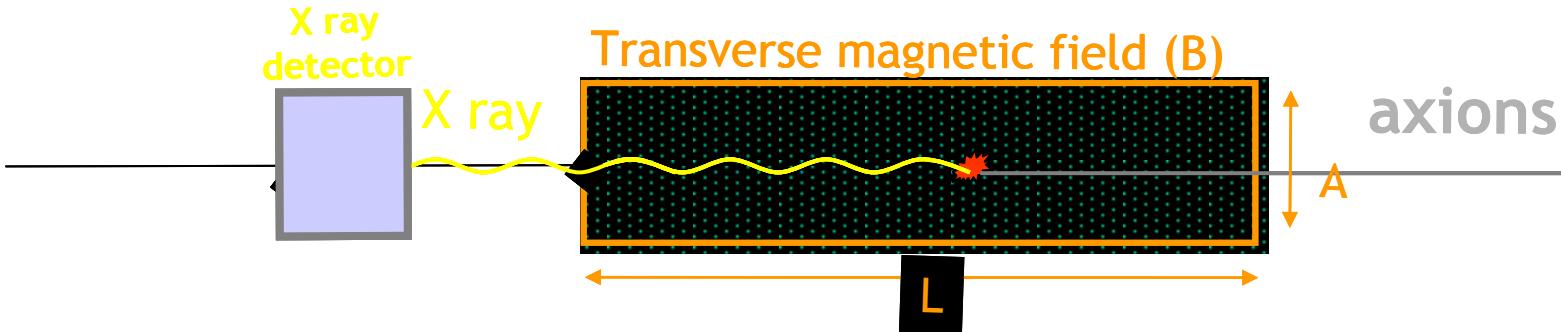
→ ID + signal-to-noise improvement



X-ray Telescope / CCD



CAST phase II – principle of detection $m_a > 0.02$ eV

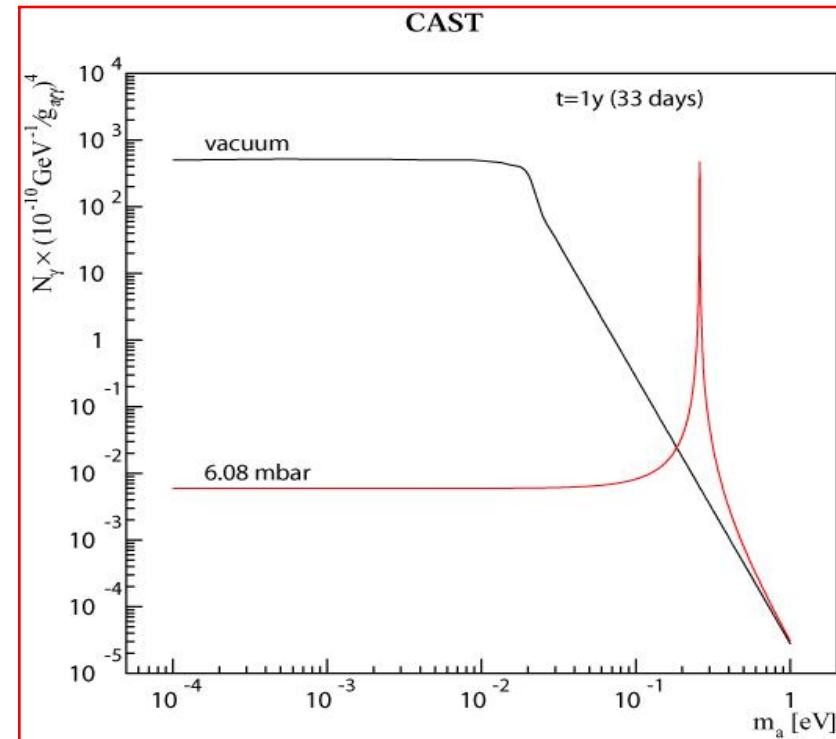


- Extending the coherence to higher axion masses...
- Coherence condition ($qL \ll 1$) is recovered for a narrow mass range around m_γ

$$|q| = \frac{m_a^2 - m_\gamma^2}{2E}$$

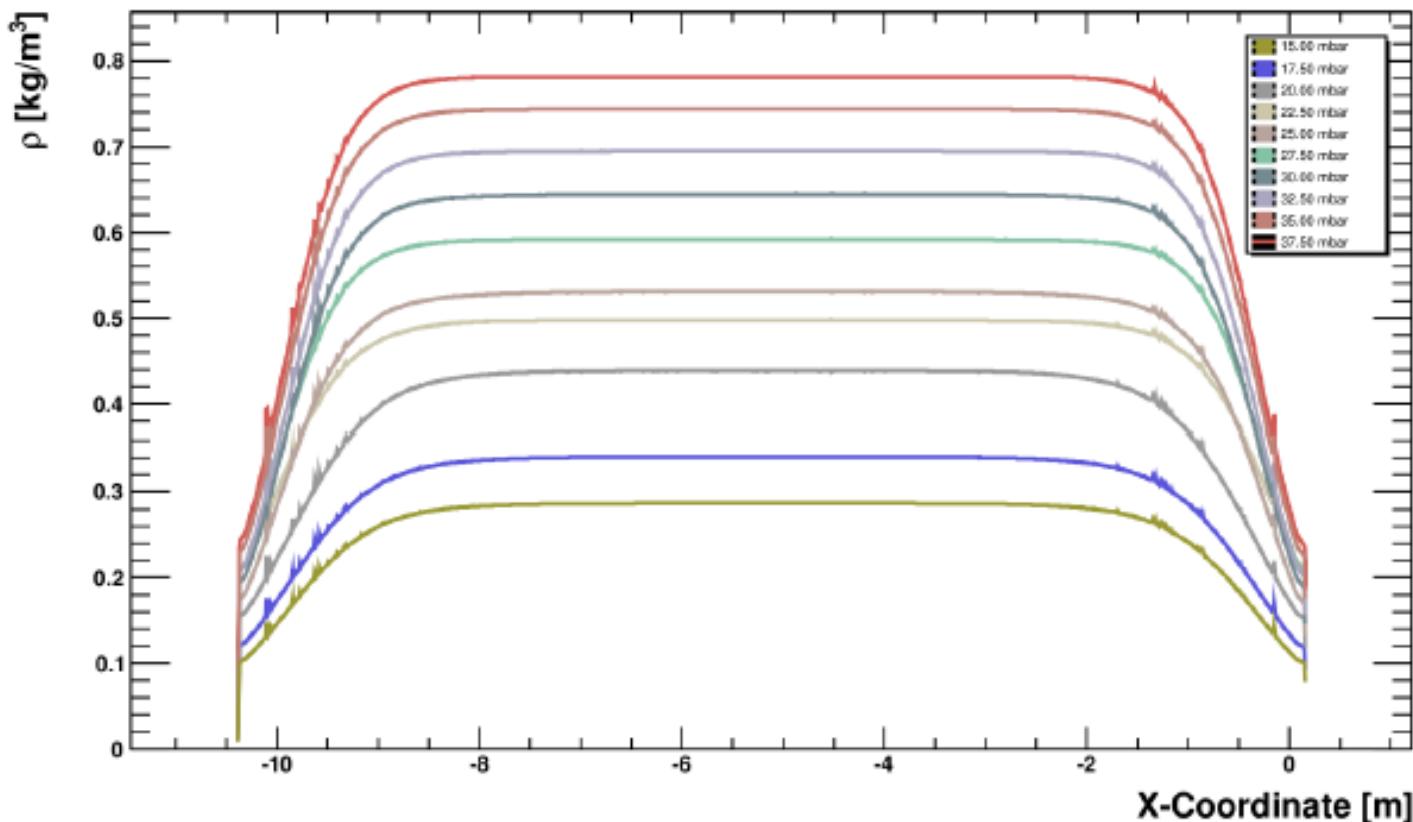
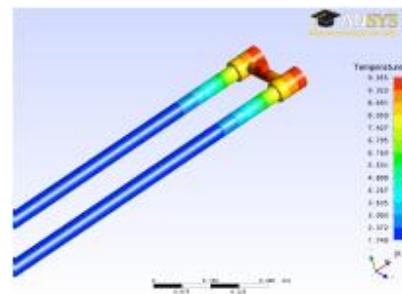
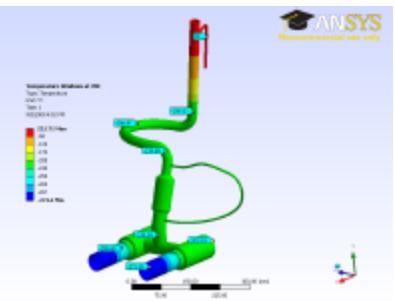
$$m_\gamma \approx \sqrt{\frac{4\pi\alpha N_e}{m_e}} = 28.9 \sqrt{\frac{Z}{A}\rho} \text{ eV}$$

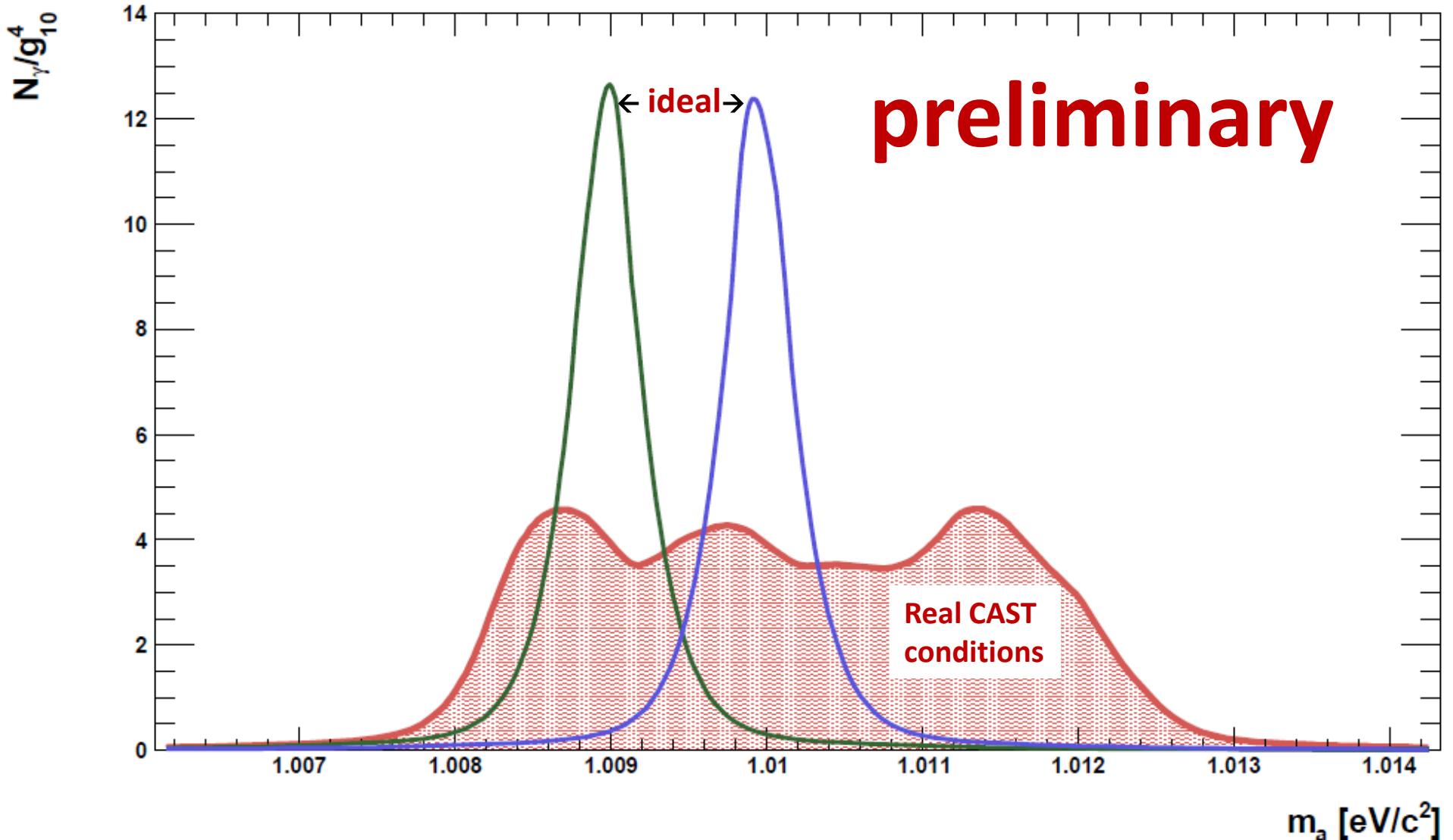
N_e : number of electrons/cm³
 ρ : gas density (g/cm³)



Coherence length?

→ Gas behaviour simulation (CFD)

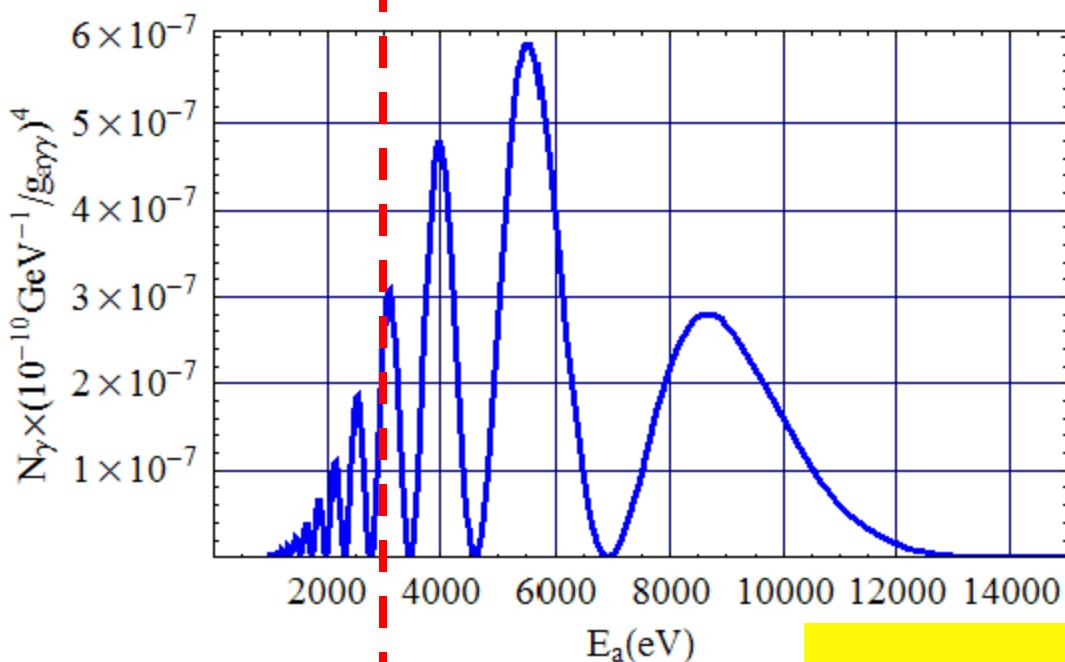




Converted axion spectrum

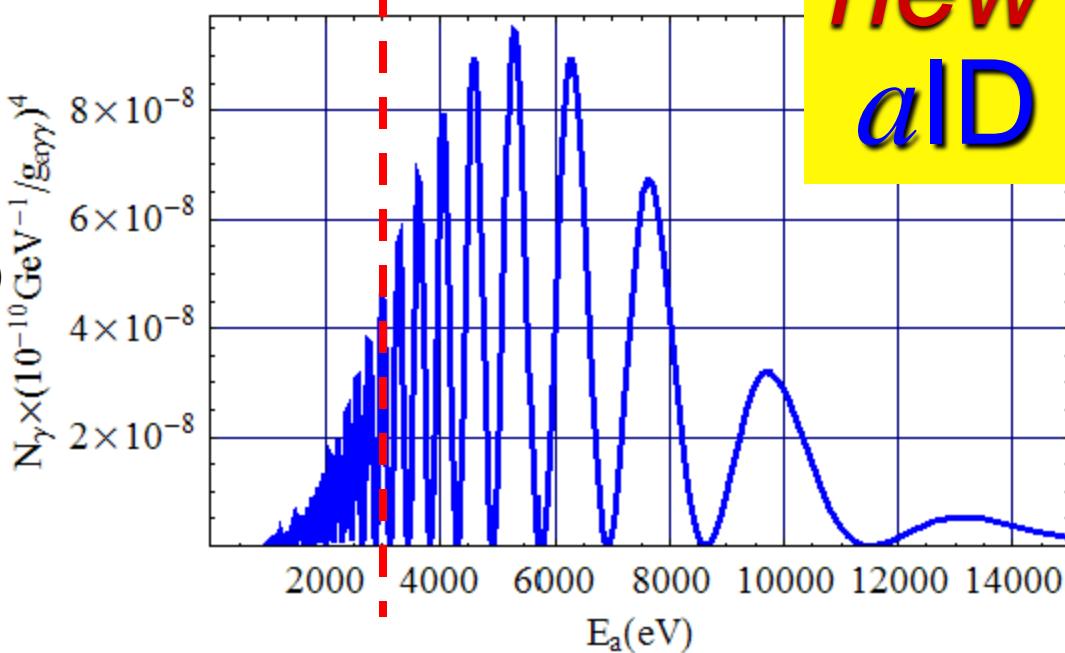
$\Delta m = 0.0088$, $\Delta P = 0.33 \text{ mbar}$ (*4 steps*)

$\langle E \rangle = 6.48 \text{ keV}$ → off-resonance

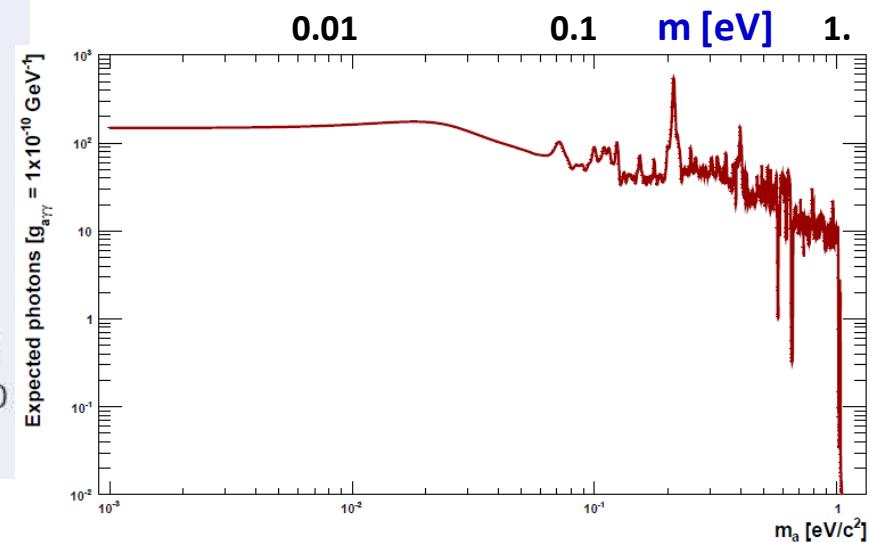
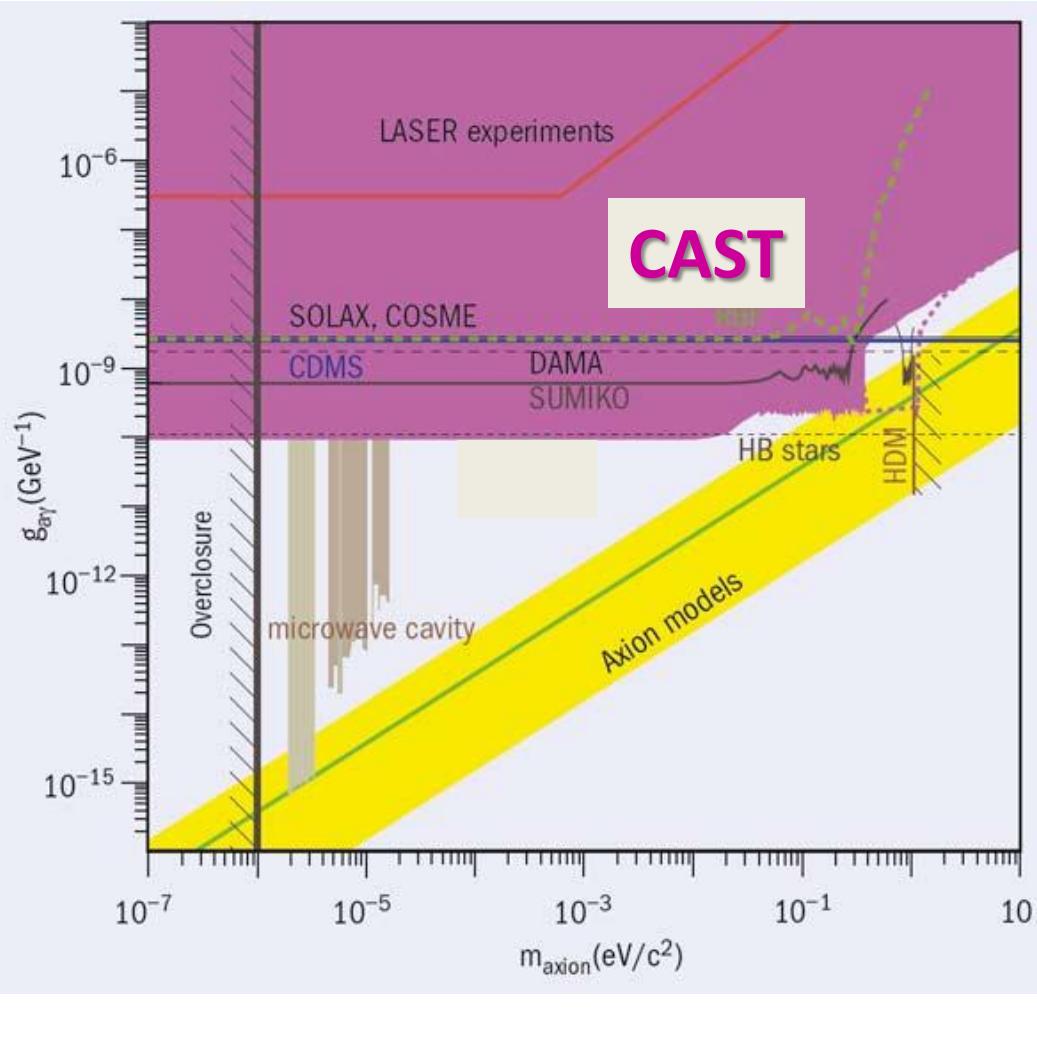


$\Delta m = 0.0214$, $\Delta P = 0.83 \text{ mbar}$ (*10 steps*)

$\langle E \rangle = 6.46 \text{ keV}$ → off-resonance



*new
alD*



... sCAST: 1999 → 2020

101st Meeting of the CERN / SPSC

CAST Physics Proposal to SPSC

K. Zioutas *on behalf of CAST*

*and
in collaboration with*

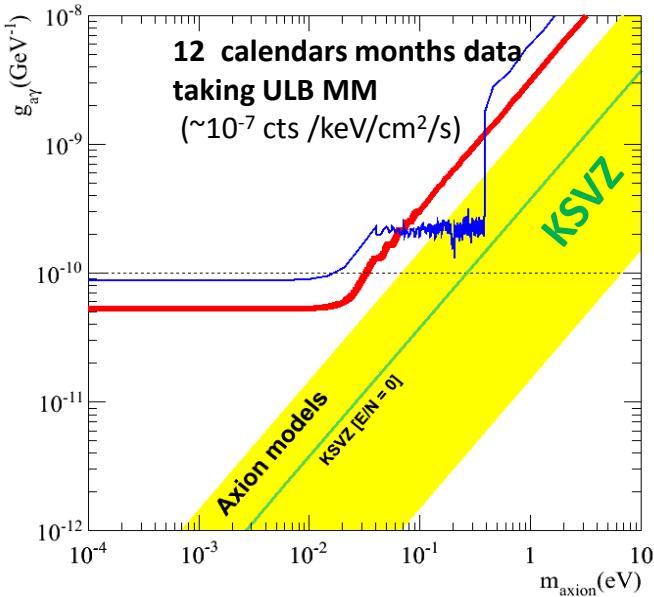
D. Anastassopoulos, O. Baker, M. Betz, P. Brax, F. Caspers, J. Jaeckel,
A. Lindner, Y. Semertzidis, N. Spiliopoulos, S. Troitsky, A. Vradis.

CERN,

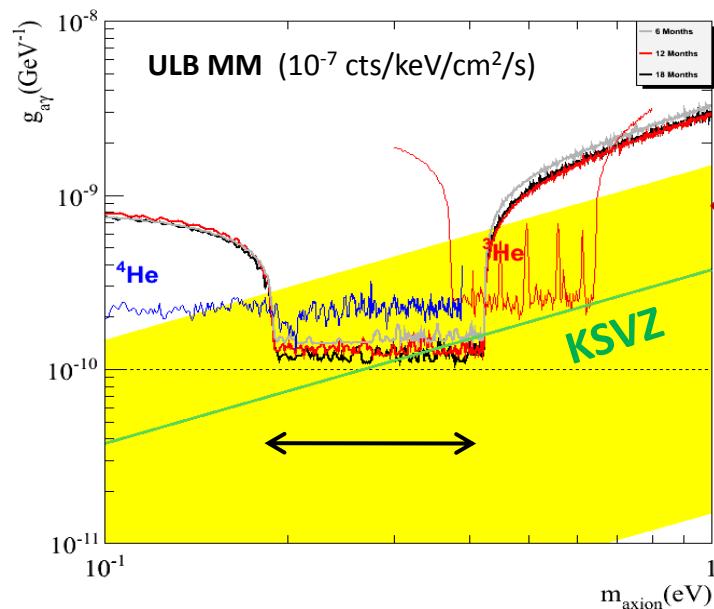
5th April 2011

$a, \gamma', \text{CH}, \dots$

Future: repeat vacuum runs and more ...



→ parallel with paraphoton & chameleon runs



3.2 - 16 mbar: 6, 12 & 18
calendar months
(1.5, 3 and 4.5 trackings/step)

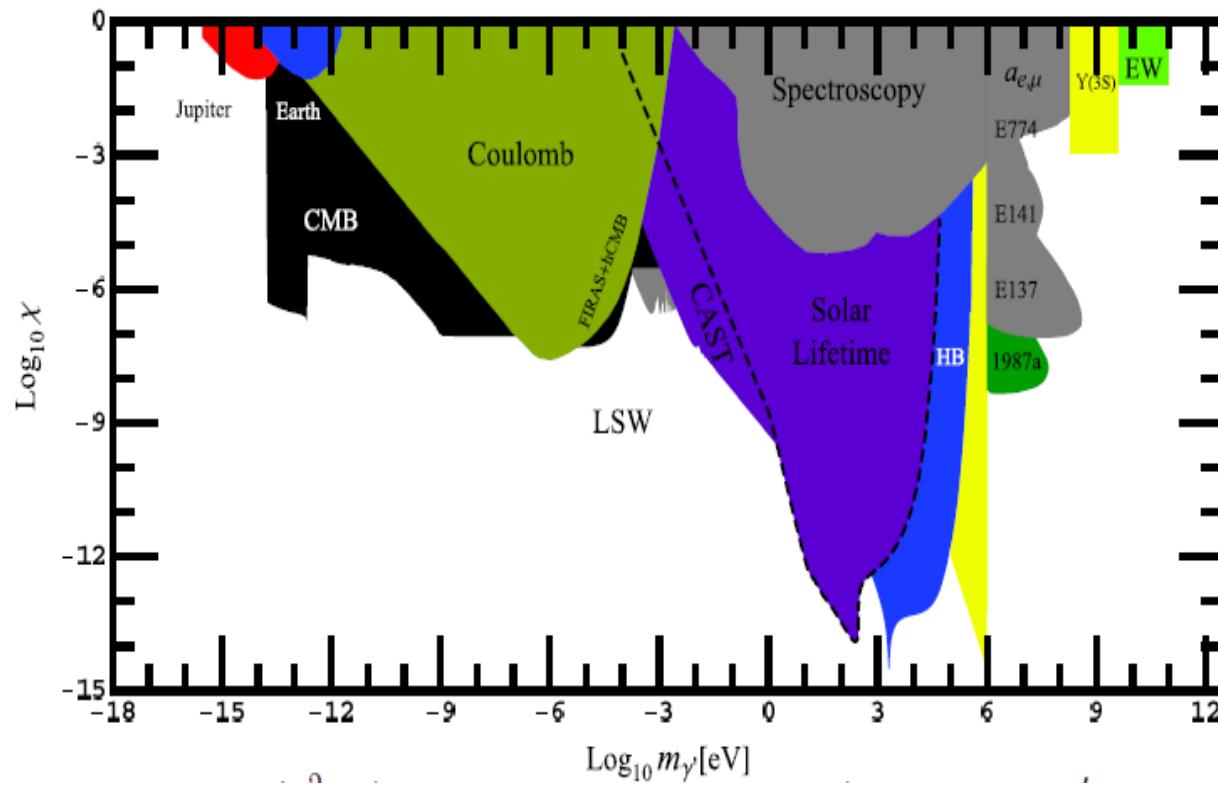
- significant improvement in background wrt. 2006
- crossing axion KSVZ model
- could start in autumn 2011

→ no competition in sight

Hidden Sector particles → Theoretically motivated

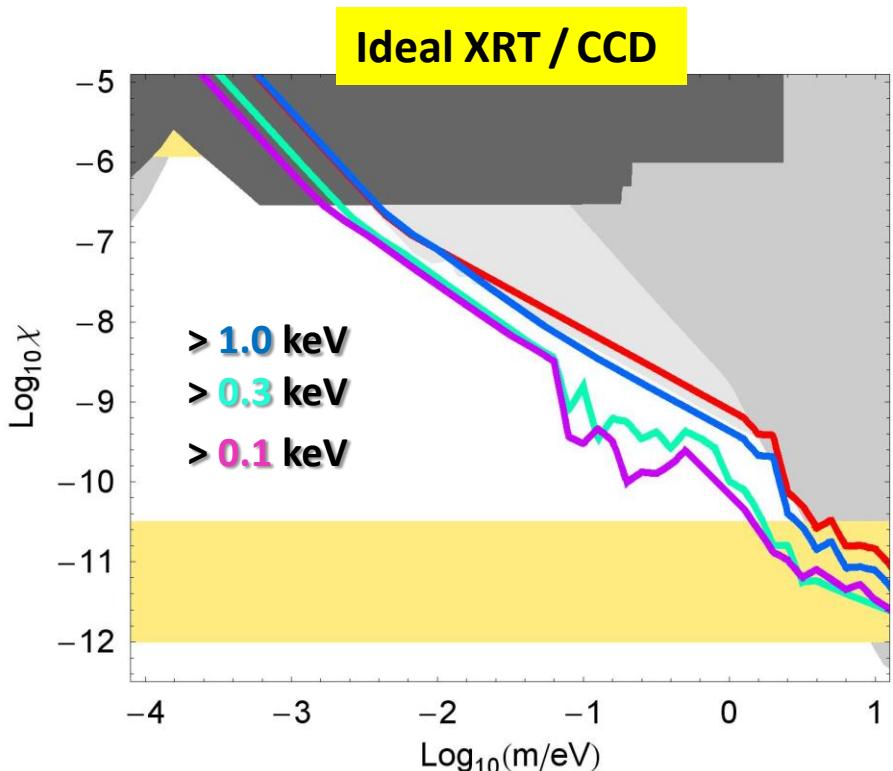
- kinetic mixing: $\gamma \leftrightarrow \gamma'$ oscillations
 - NO magnetic field! → NO cold bores needed
 - Vacuum path length relevant for oscillations
 - > upstream in front of the detector
 - a good sensitivity requires: 3 **ULB MMs & FS pnCCD**
 - also for chameleons!

Solar paraphotons – CAST already provided strong limit



Paraphoton detection sensitivity → Off-pointing

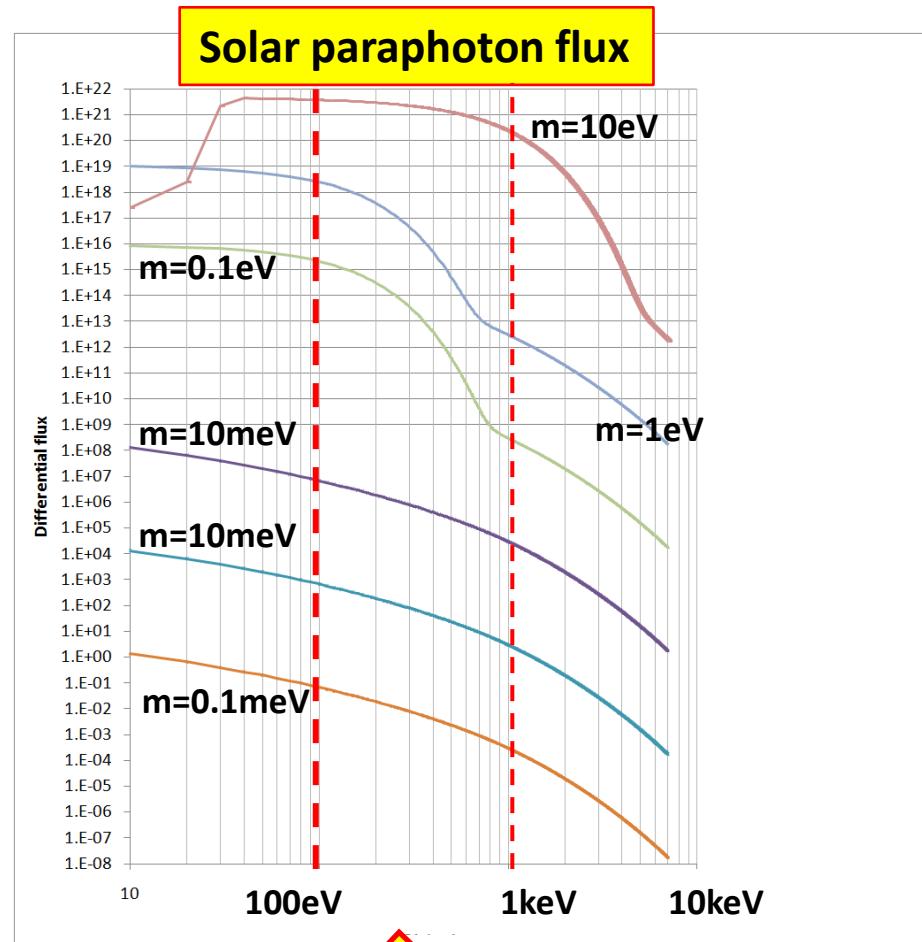
Low energy threshold: MM + CCD!



1st off-pointing measurements:

$0.7 R_o$ & $+30^\circ$

4x100min, 24-27/4/2011 To be evaluated!



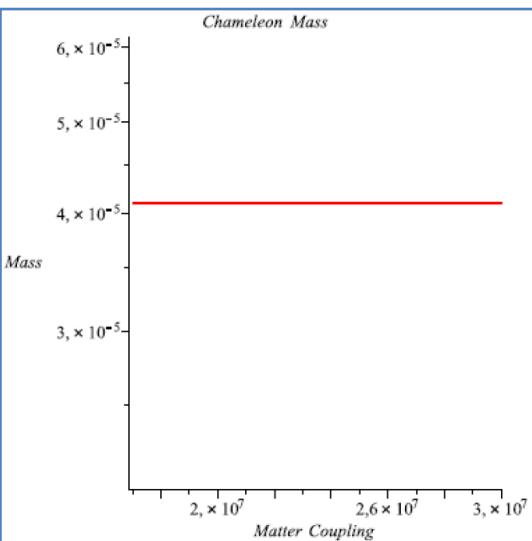
Lowering energy threshold – increases the sensitivity → more flux

- Chameleons are **DE** candidates to explain the acceleration of the Universe
- Chameleon particles can be created by the **Primakoff effect** in a strong magnetic field. This can happen in the Sun.
- The chameleons created inside the sun eventually reach earth where they are energetic enough to penetrate the CAST experiment. **Like axions**, they can then be back-converted to X-ray photons.
- In vacuum, CAST observations lead to stronger constraints on the chameleon coupling to photons than previous exp's.
- When gas is present in the CAST pipe, the analogue spectrum of regenerated photons shows characteristic oscillations: **ID**

→ **axion helioscope = chameleon helioscope**, but @ LE!!

Solar Chameleons - CAST

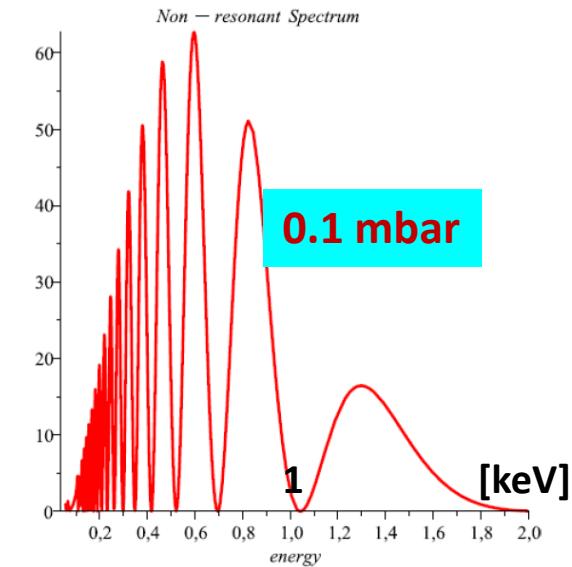
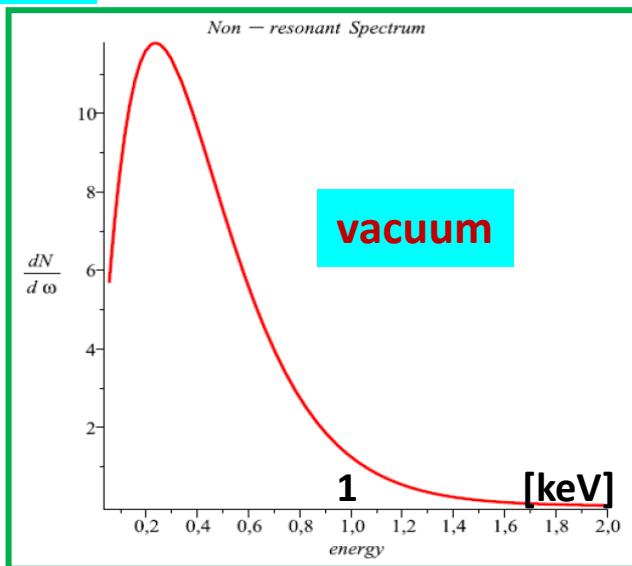
P. Brax, A. Lindner, K.Z. (2011)



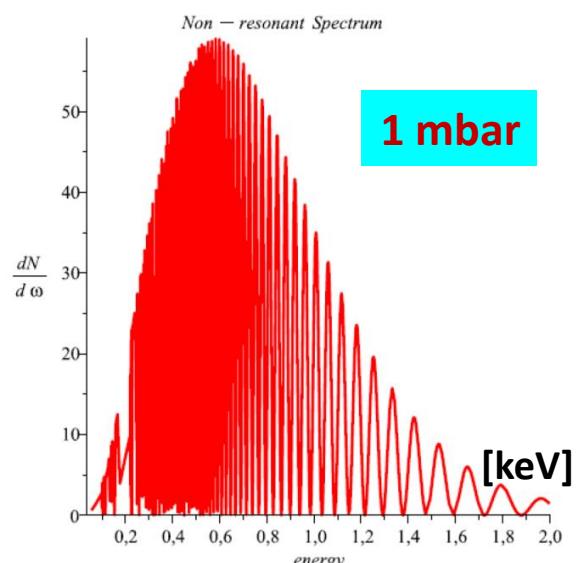
The mass of the chameleon in eV in the CAST pipe with vacuum is:

$$m_{\text{CH}} = 40 \mu\text{eV}/c^2$$

→ Low energy threshold: MM + CCD!
+ vacuum



The analogue spectrum [/hour/keV] of regenerated photons as predicted to be seen by CAST: matter coupling = 10^6 , B=30T in a shell of width $0.1R_{\text{solar}}$ around the tachocline ($\sim 0.7R_{\text{solar}}$).



Solar Axions / Paraphotons / Chameleons

- Detector requirements: → *simulation for all detectors' FOV*
→ XRT performance!
 - XRT/CCD
 - FS-CCD with ~100 eV threshold exists
 - MM
 - LET → transparent windows
 - ULB
 - Operational energy range 200eV – 7 keV
(paraphotons/axions/chameleons)

TES

- feasible!!
- Theoretical estimates in progress

Towards a new generation axion helioscope

>> 50 – 100 MEUROs project

I. G. Irastorza¹, F. T. Avignone², S. Caspi³, J. M. Carmona¹,
T. Dafni¹, M. Davenport⁴, A. Dudarev⁴, G. Fanourakis⁵,
E. Ferrer-Ribas⁶, J. Galán^{1,6}, J. A. García¹, T. Geralis⁵,
I. Giomataris⁶, H. Gómez¹, D. H. H. Hoffmann⁷, F. J. Iguaz⁶,
K. Jakovčić⁸, M. Krčmar⁸, B. Lakić⁸, G. Luzón¹, M. Pivovaroff⁹,
T. Papaevangelou⁶, G. Raffelt¹⁰, J. Redondo¹⁰, A. Rodríguez¹,
S. Russenschuck⁴, J. Ruz⁴, I. Shilon^{4,11}, H. Ten Kate⁴, A. Tomás¹,
S. Troitsky¹², K. van Bibber¹³, J. A. Villar¹, J. Vogel⁹,
L. Walckiers⁴, K. Zioutas¹⁴

¹Laboratorio de Física Nuclear y Astropartículas, Universidad de Zaragoza, Zaragoza, Spain

²Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA

³Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

⁴CERN, Geneva, Switzerland

⁵National Center for Scientific Research Demokritos, Athens, Greece

⁶IRFU, Centre d'Études Nucléaires de Saclay (CEA-Saclay), Gif-sur-Yvette, France

⁷Technische Universität Darmstadt, IKP, Darmstadt, Germany

⁸Rudjer Bošković Institute, Zagreb, Croatia

⁹Lawrence Livermore National Laboratory, Livermore, CA, USA

¹⁰Max-Planck-Institut für Physik, Munich, Germany

¹¹Physics Department, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

¹²Institute for Nuclear Research (INR), Russian Academy of Sciences, Moscow, Russia

¹³Naval Postgraduate School, Monterey, CA, USA

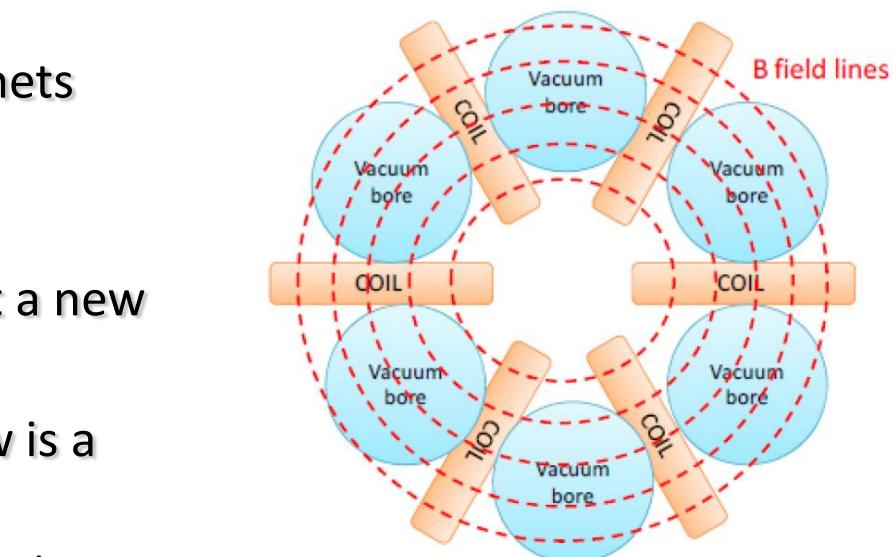
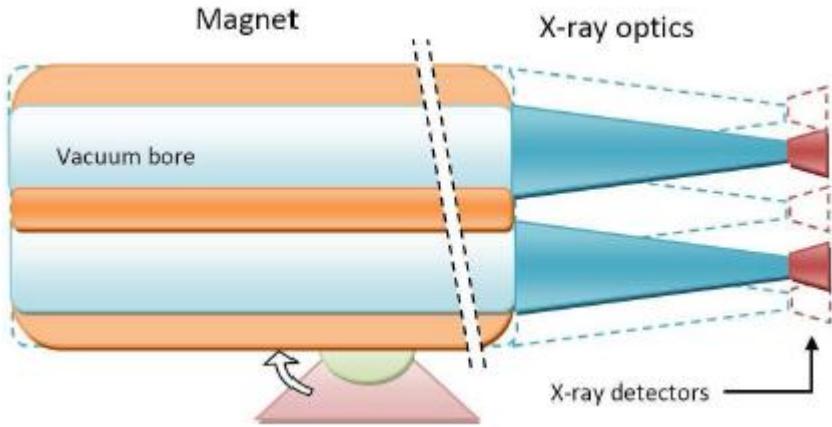
¹⁴University of Patras, Patras, Greece

New “magnet” à la ATLAS

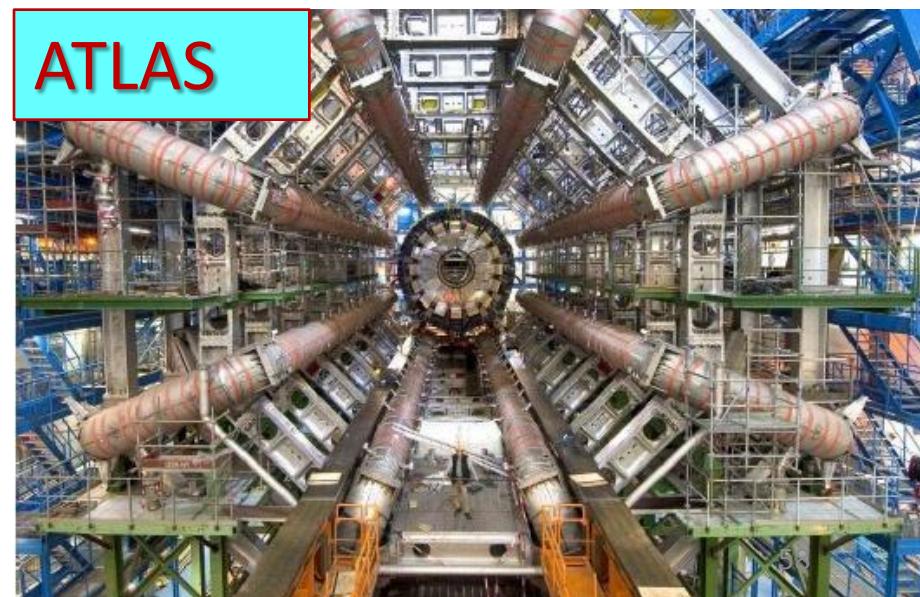


L. Walckiers'/CERN
suggestion

- CAST enjoys one of the best existing magnets than one can “recycle” for axion physics
 - LHC test magnet
- Only way to make a step further is to built a new magnet, specially conceived for this.
- Work ongoing, but best option up to know is a **toroidal configuration**:
 - Much bigger aperture than CAST: ~0.5-1 m / bore
 - Lighter than a dipole (no iron yoke)
 - Bores at room temperature



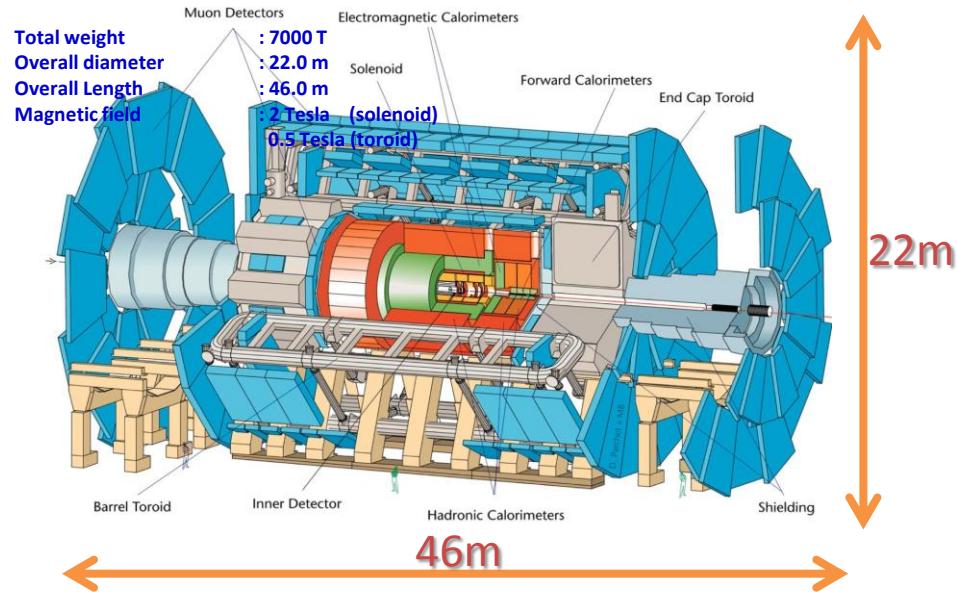
Cross section of the magnet



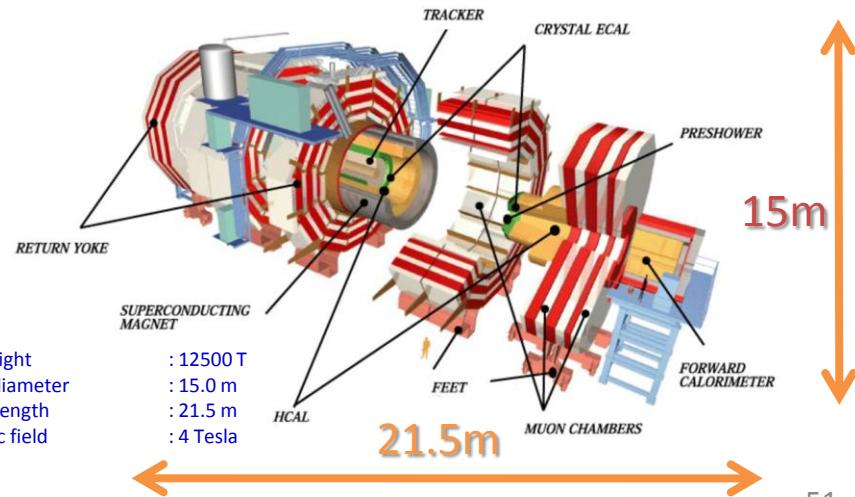
LHC experiments as “Axionscopes”?

A. Manousos, A. Liolios, C. Eleftheriadis, PoS(IDM2010)034 arXiv:1104.1572v1

ATLAS: In case of axion to photon conversion, the photon will probably escape to the Electromagnetic Calorimeter and it will be recorded as a Minimum Bias event.

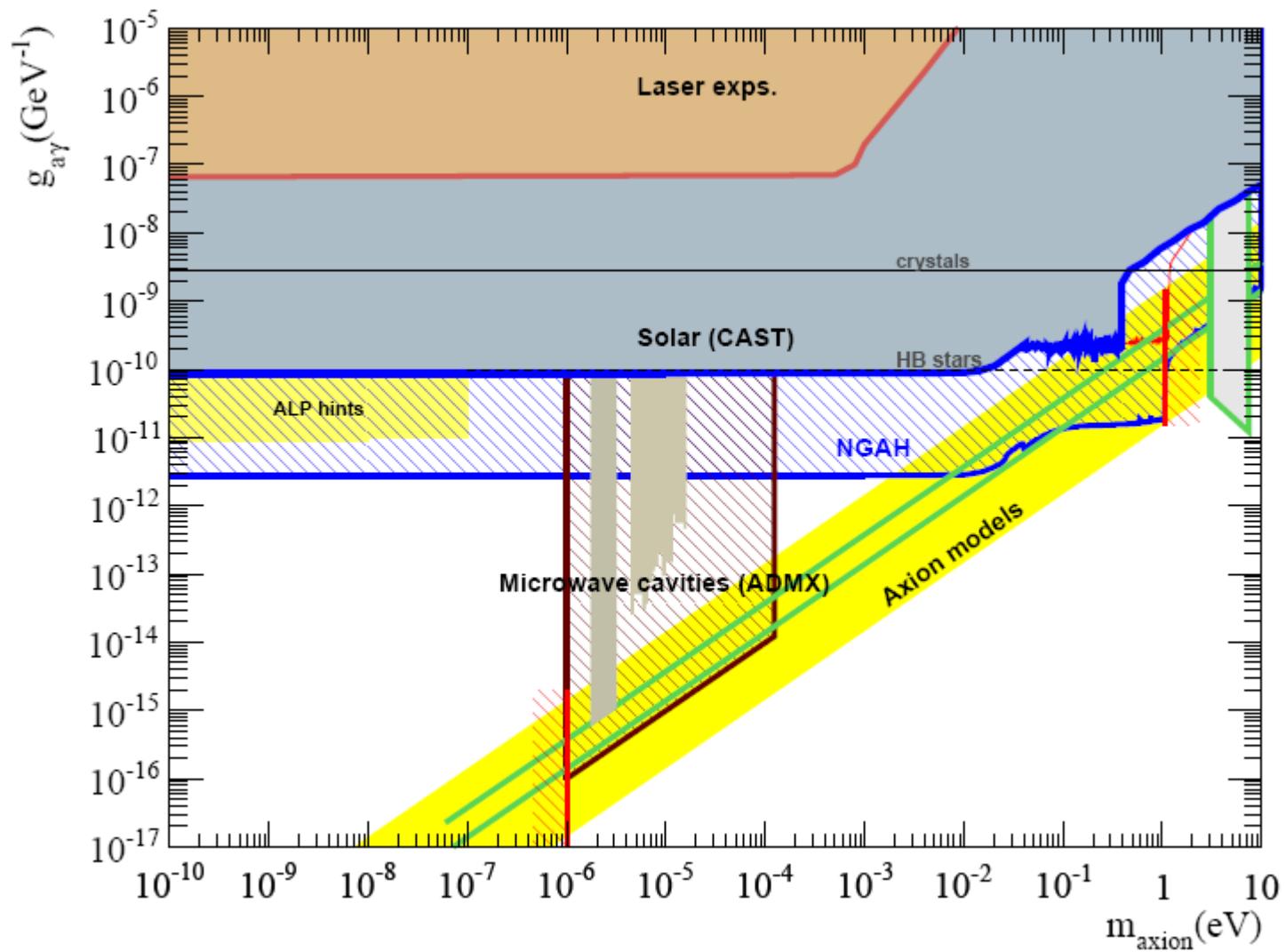


CMS: In case of axion-photon conversion → the photon will be recorded in the EM Calorimeter, as a Minimum Bias event (single photon).



How much beyond CAST?

CAST (1999) → NGAH (~2020)



ADMX



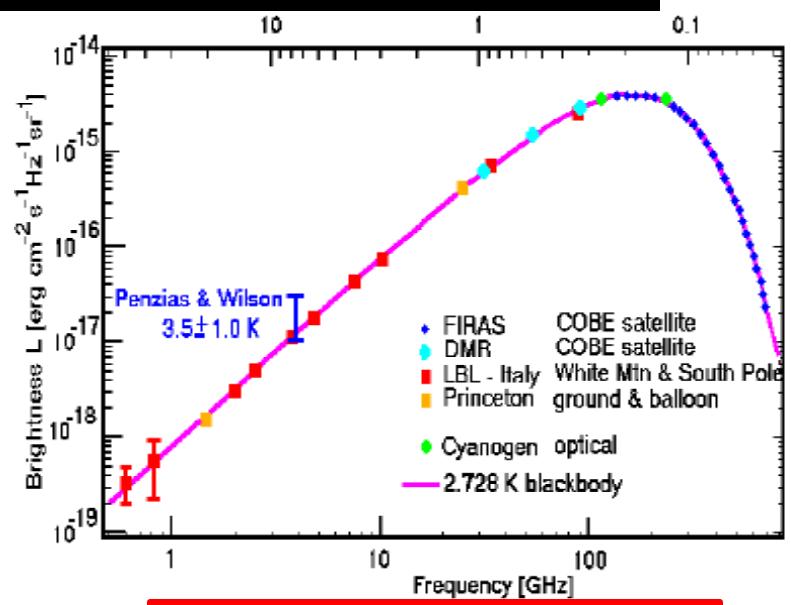
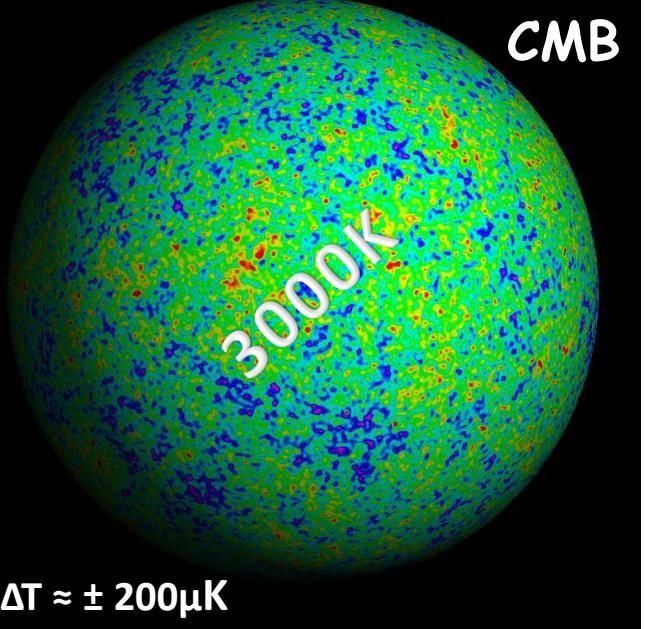
Towards a new relic axion antenna with CAST?

Dielectric waveguide inside the **CAST** magnet may perform as a new kind of “*macroscopic fiber*”, being a sensitive detector for relic axions:

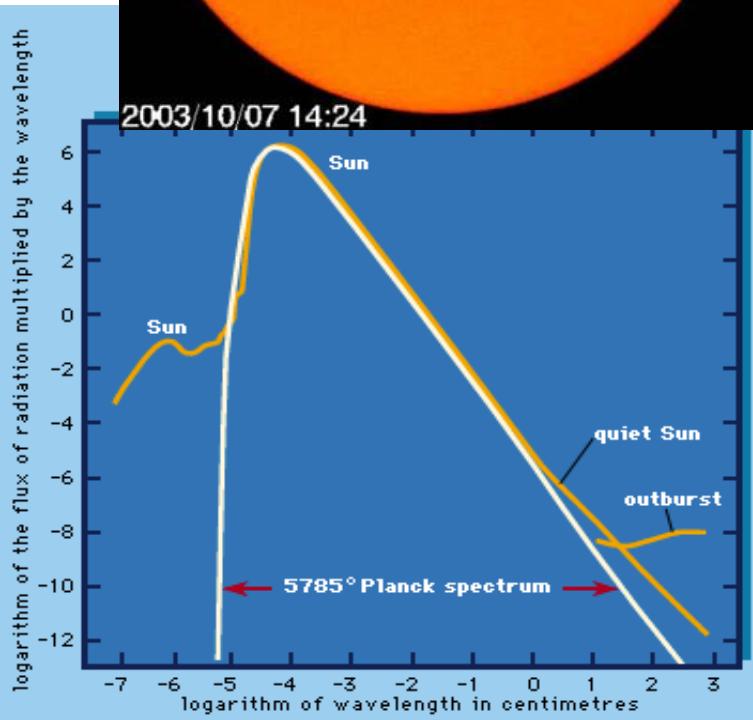
→ ~ 0.1 - 1 meV rest mass range (experimentally inaccessible)

(in)direct astrophysical signatures for...

... Solar axions / paraphotons / chameleons /



$\Delta T/T \sim \text{a few} \times 10^{-5}$



$\Delta T/T \sim 10^3$

New physics!

>> new physics?!

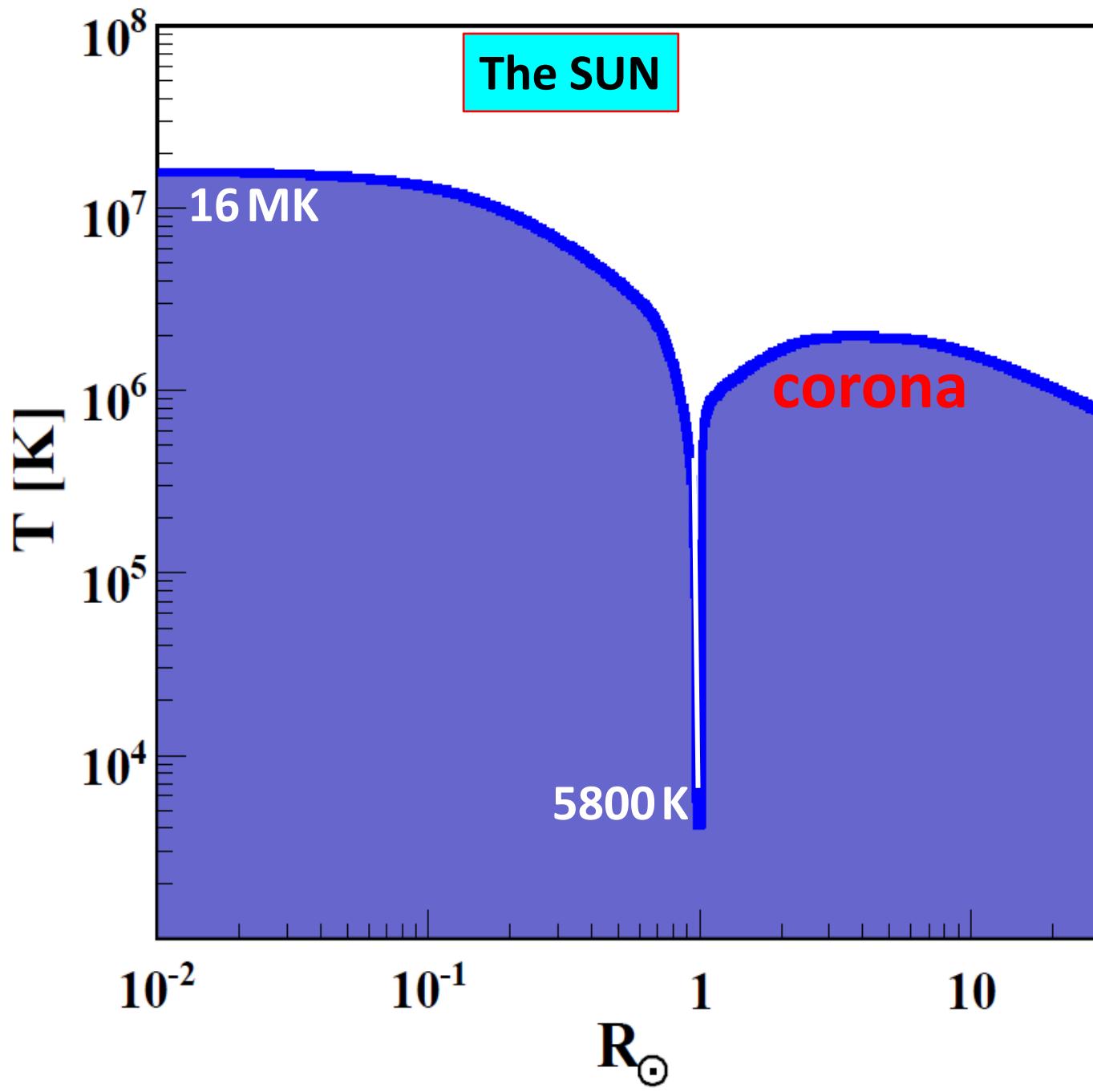
CAST @ the Sun?

B_{solar} → ignored

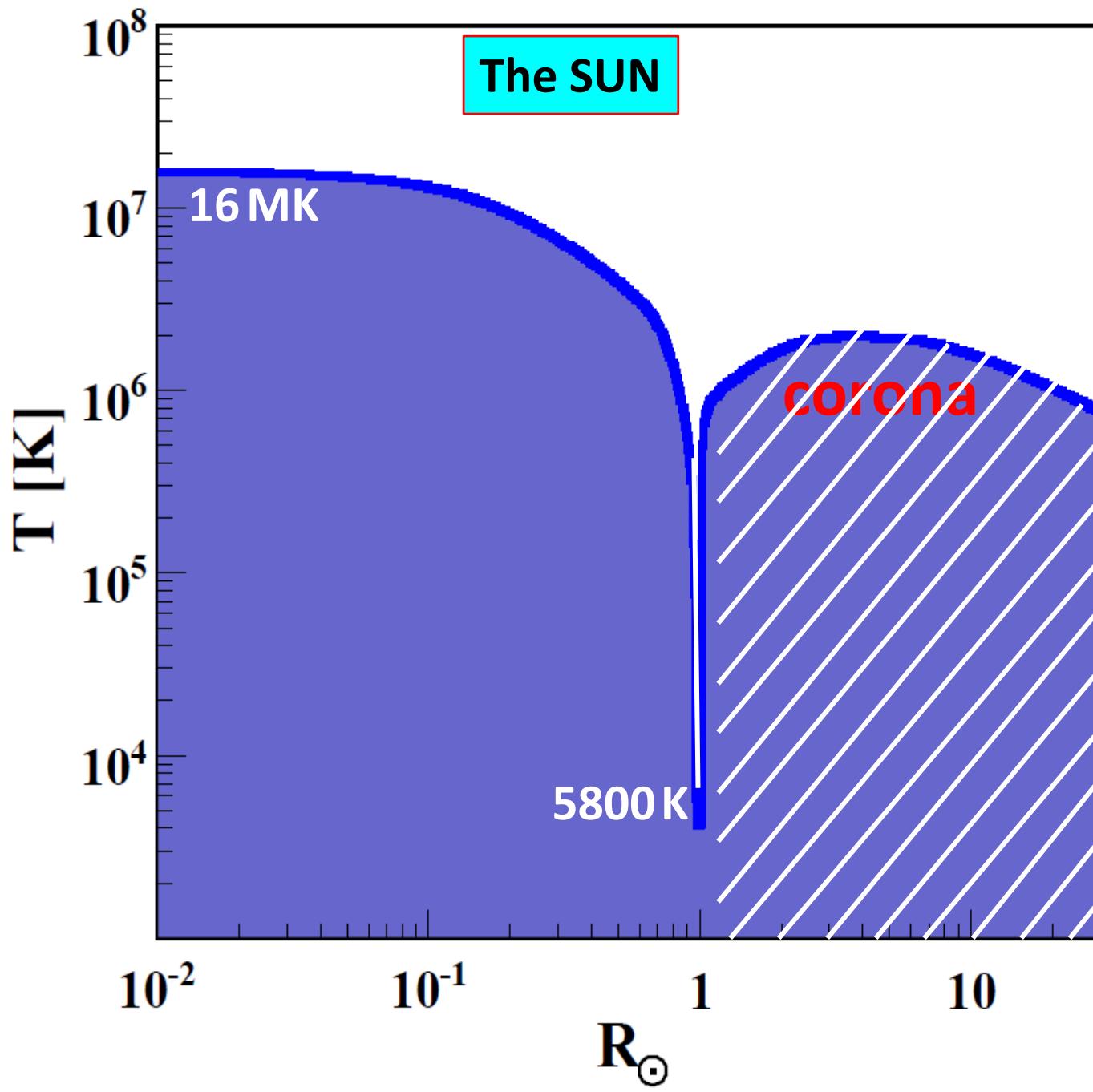
**It is remarkable + fascinating that the Sun emits intense X-rays...
→ mystery**

S. Tsuneta, APPS Bulletin, 19(#3) (**June 2009**) 11
<http://www.cospa.ntu.edu.tw/aappsbulletin/data/19-3/11Hinode.pdf>

Mystery or harbinger of exciting new physics?



W. GROTRIAN, 1939



W. GROTRIAN, 1939

Corona ... enigma....

2011

the coronal heating mechanism remains unknown!

.... but with ~axions?

B. De Pontieu, et al., Science, 331 (January **2011**) 55-58

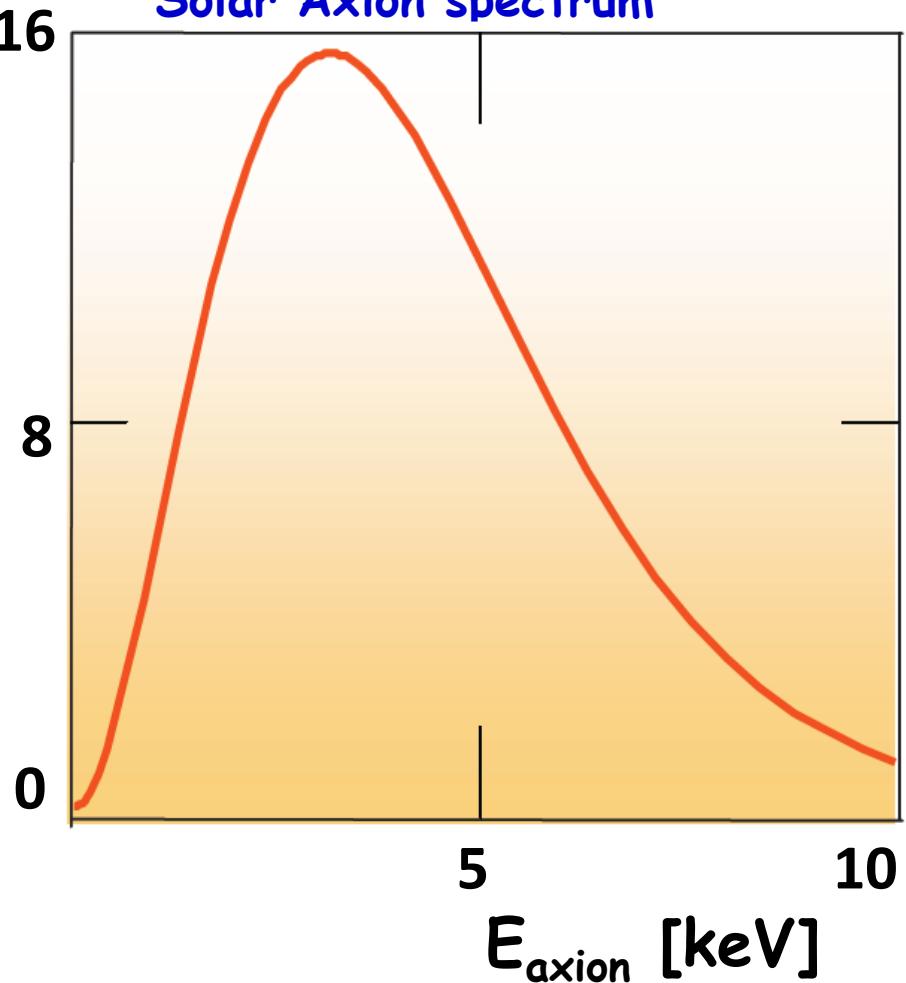
<http://www.sciencemag.org/content/331/6013/55.abstract>

See also <http://www.sciencemag.org/content/suppl/2011/01/05/331.6013.55.DC1/De-Pontieu.SOM.pdf>

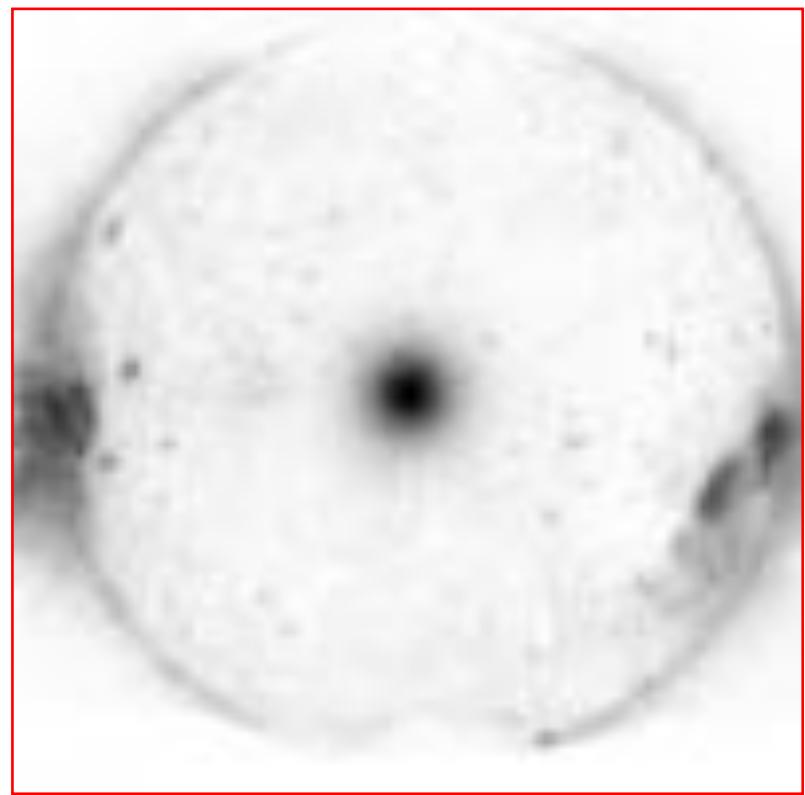
Expected ...

-> CAST phase I

Solar Axion spectrum



2D simulation



RHESSI science nugget
H. Hudson, 30.4.2007

$$m_a \ll 10^{-4} \text{ eV}/c^2$$

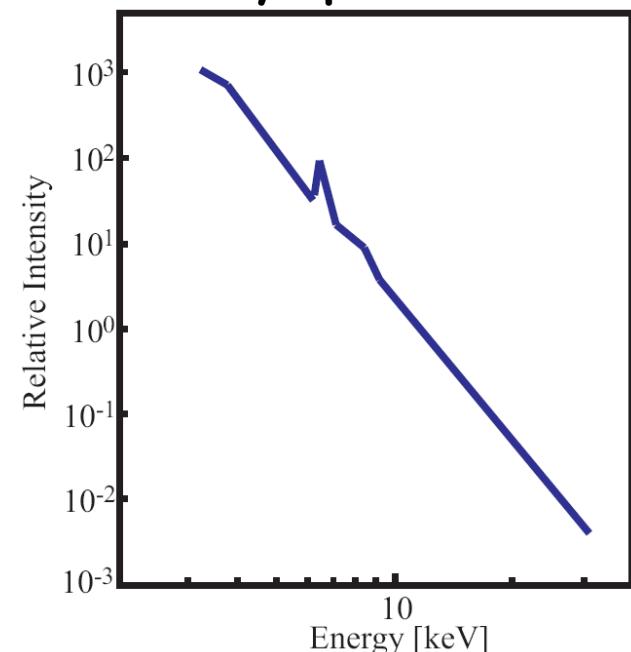
<http://www-astro-theory.fnal.gov/events/080201presentation.pdf>

...observed!

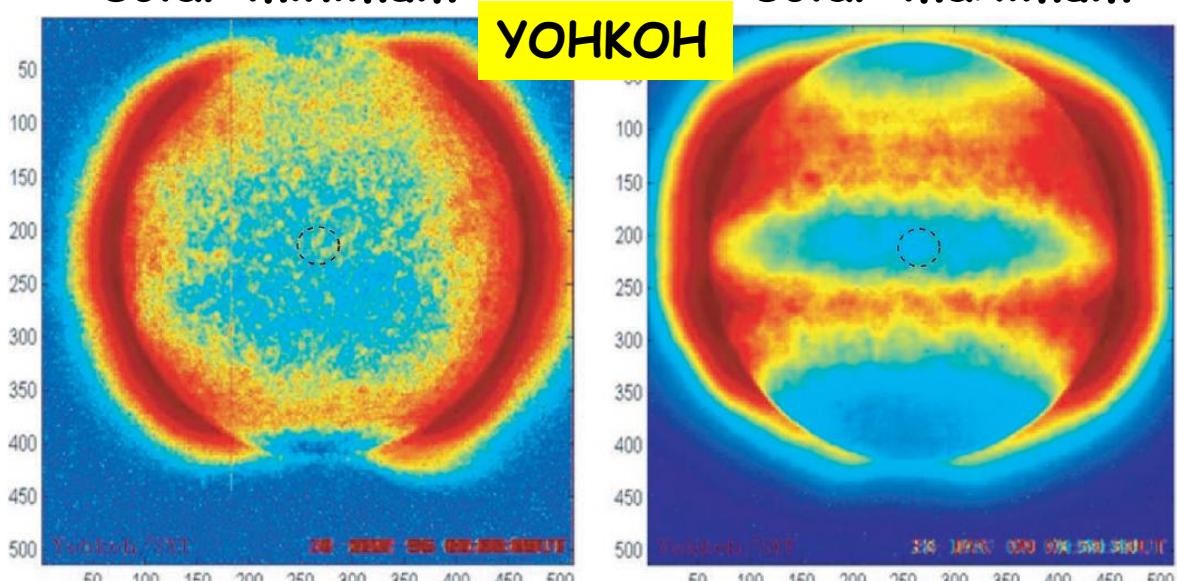
→ $m_a > 10^{-2} \text{ eV}/c^2$

-> CAST phase II

Typical analog solar
X-ray spectrum



$E_\gamma \approx 0.3 - 4 \text{ keV}$
solar minimum solar maximum



M. Tsagri, Diploma Thesis, UoPatras

From 3 independent results:

- WDs cooling rate (g_{ae})
- SN1987A neutrino-signal (g_{aN}) \leftarrow limit
- Sun's X-rays power law ($g_{a\gamma\gamma}$)

$$\rightarrow m_{ax} \approx 10 - 20 \text{ [meV/c}^2\text{]}$$

\rightarrow sCAST!?

What axions-WISPs can do? ...

... inspire novel terrestrial / celestial experiments!

Collaboration work with Axel Lindner / DESY

- anomalous nuclear decays
- Experiments must be observationally driven → beyond conventional thinking.

PATRAS WORKSOPS: ... “*crazy-ideas*”



"Thank you Konstantin,
And continue to do
'crazy' things. They are the
only thing interesting in life."

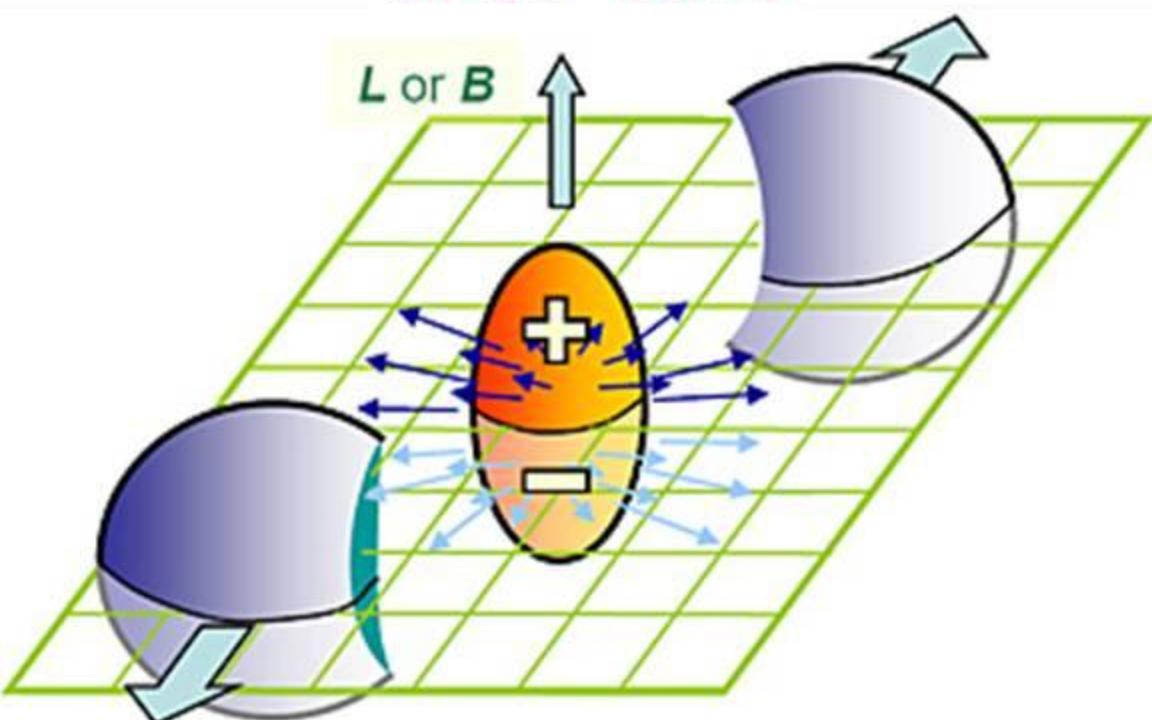
G. Charpak, 1992

Thank you Konstantin
And continue to do
"crazy" things - They are the only things interesting in life

Cheney

I would like to sincerely thank you for your warm message of congratulations
which gave me great pleasure.
Please accept, with the expression of my gratitude,
my very best wishes.

GEORGES CHARPAK

$B \approx 10^{17}$ Gauss

Particles carrying charges of opposite sign will be emitted into different hemispheres. Fluctuations of the charge symmetry with respect to the collision plane, which have been observed by STAR, may therefore be a signature of **local parity violation**.

Schematic view of the charge separation along the system's orbital angular momentum.

Y. Semertzidis / BNL

DEKharzeev, Phys. Lett. B633 (2006) 260

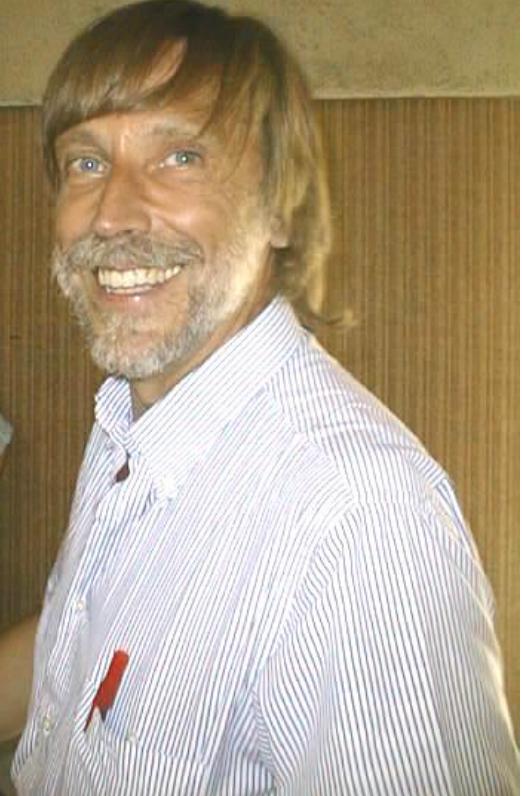
<http://physics.aps.org/view/image/3187/large/1><http://physics.aps.org/viewpoint-for/10.1103/PhysRevLett.103.251601>http://www.bnl.gov/today/story.asp?ITEM_NO=1588<http://www.pa.msu.edu/conf/wwnd2010/talks/kharzeev.pdf>

Back-up slides

Φως στο σκοτεινό Σύμπαν

Με αυτές τις νέες δυνατότητες που διαφαίνονται μπορεί να δοθεί φως στο σκοτεινό τμήμα του Σύμπαντος. Παράλληλα θα συντελέσει ως καταλύτης στην λύση μεγάλων και άλιτων προβλημάτων της Σύγχρονης Φυσικής, όπως:

- A) Σκοτεινή ύλη:** μέσω της ανίχνευσης ηλιακών axions (ή άλλων σωματιδίων με παρόμοιες ιδιότητες), που συσχετίζονται με το πρόβλημα διατήρησης της Συμμετρίας Ομοτιμίας-Φορτίου στις Ισχυρές Αλληλεπιδράσεις. Αυτό πειραματικά εκφράζεται με την (ουσιαστικά) έλλειψη ηλεκτρικής διπολικής ροπής του νετρονίου,
- B) Κρυφός τομέας:** μέσα από την ανίχνευση ηλιακών παραφωτονίων, με την κατασκευή νέων πρωτοποριακών τηλεσκοπίων ηλιακών παραφωτονίων, ή, την αξιοποίηση δεδομένων του τηλεσκοπίου HUBBLE σε τροχιά. Αυτό ίσως προχωρήσει σύντομα μέσω της επεξεργασίας εικόνων υποστρώματος που γίνονται καθημερινά για λόγους βαθμολόγησης.
- Γ) Σκοτεινή ενέργεια:** την ανάδειξη ηλιακών χαμαιλεόντων με το CASTκαι μέσα από ανάλυση – επεξεργασία ηλιακών δεδομένων.
- Δ) Το μυστήριο της ηλιακής κορώνας:** Το πρόβλημα της θέρμανσης του Ηλιακού στέμματος είναι ένα από τα μεγαλύτερα προβλήματα της αστροφυσικής γενικότερα. Η πρόταση μας είναι πως σωματίδια όπως π.χ. τα axions με μάζα ηρεμίας $\sim 17\text{meV}/c^2$ ή άλλα σωματίδια με παρόμοιες ιδιότητες είναι τα κατά πλείστον υπεύθυνα σωματίδια για το φαινόμενο αυτό. Η συνέχιση σχετικών μελετών σκοπό έχει να βελτιώσει και να ισχυροποιήσει αυτό το αποτέλεσμα κάτι που συμβαίνει εδώ και ~ 10 χρόνια. Προφανώς διαγράφεται και η προοπτική κατανόησης της εσωτερικής δομής και λειτουργίας του μη προβλέψιμου ζωοδότη Ήλιου, και κατ' επέκταση όλων των άλλων αστέρων στο Σύμπαν.



< 1998

AXION SEARCHES

are

- MANDATORY
- FUN, CREATIVE
- PROCEEDING

On axion as dark matter candidate

Wilczek conclusion (“Physics Today”):

I'm much more optimistic about the dark matter problem.
Here we have the unusual situation that two good ideas
exist... wimps and axions.



Witten conclusion (“Axions in String Theory”):

Axions are ubiquitous in string theory; as necessary as gravitons. Couplings and masses of dark matter QCD axions are tightly constrained: Allowed couplings are within a range of $\times 7$ and the mass is constrained to the two decades $10^{-6} - 10^{-4}$ eV.



The axion remains a very attractive dark-matter candidate.

→ Axion experiments are relatively inexpensive!!