Status report of
~~Latest result from~~ the Tokyo axion helioscope experiment

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- Tokyo axion helioscope
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Axion

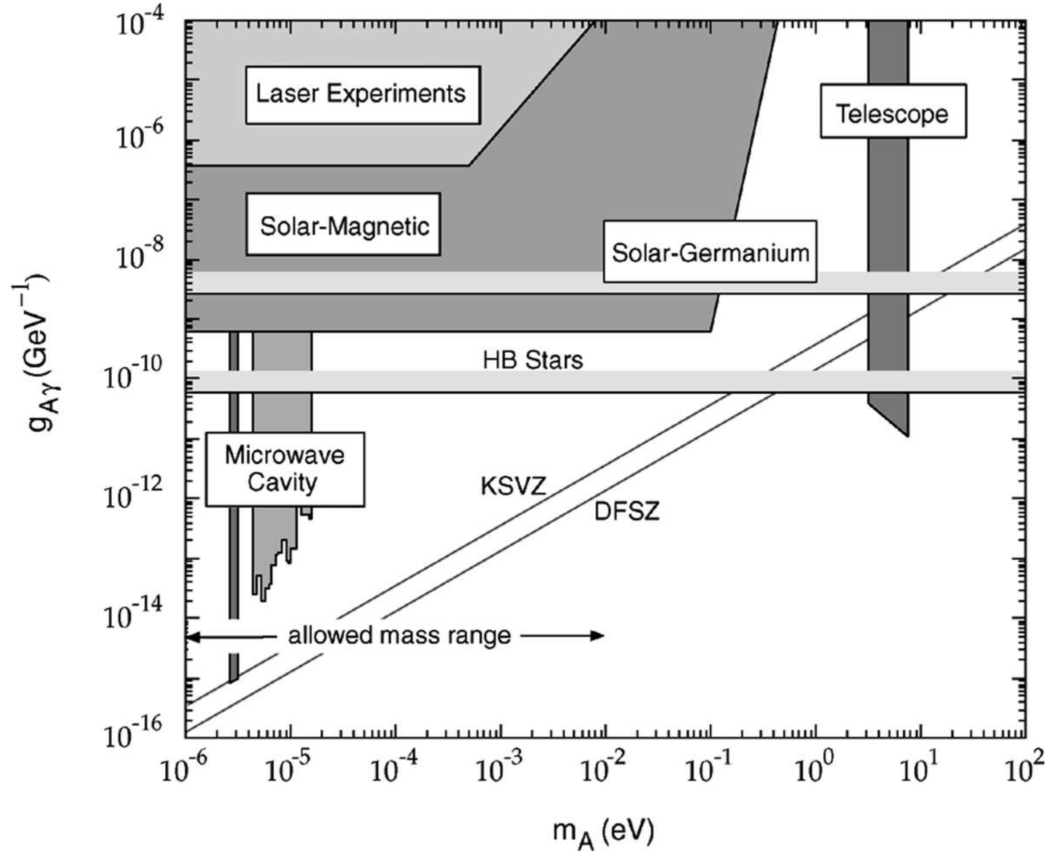
What is the Axion?

- QCD $\rightarrow \theta$ vacuum $\rightarrow$ Strong CP problem (eg. neutron EDM)
- Peccei–Quinn mechanism:
  global chiral U(1) + SSB
  $\rightarrow$ <u>NG boson</u> + $\underline{(1/32\pi^2 f_a) a F_a \tilde{F}_a}$
  $\downarrow$ axion
  $\downarrow$ resolves Strong CP

Searches/Limits:

- Experiments: Accelerator, Reactor, Nuclear transition, Telescope, <u>Solar axion</u>, Laser, Microwave cavity, …
- Astrophysics: Solar axion, Red giants, SN1987A
- Cosmology: $\Omega_a < 1$

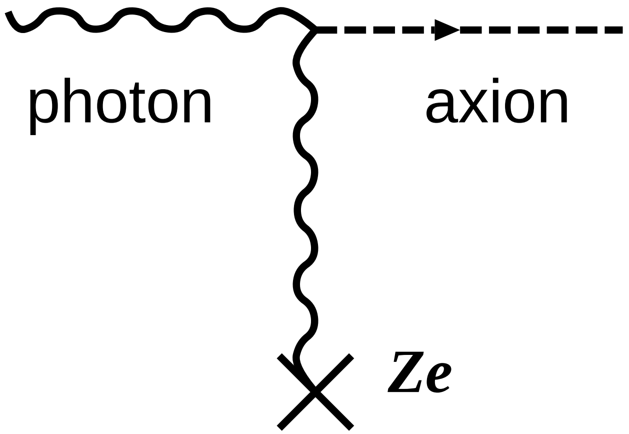
Exclusion plot ($g_{a\gamma}$ vs m_a)



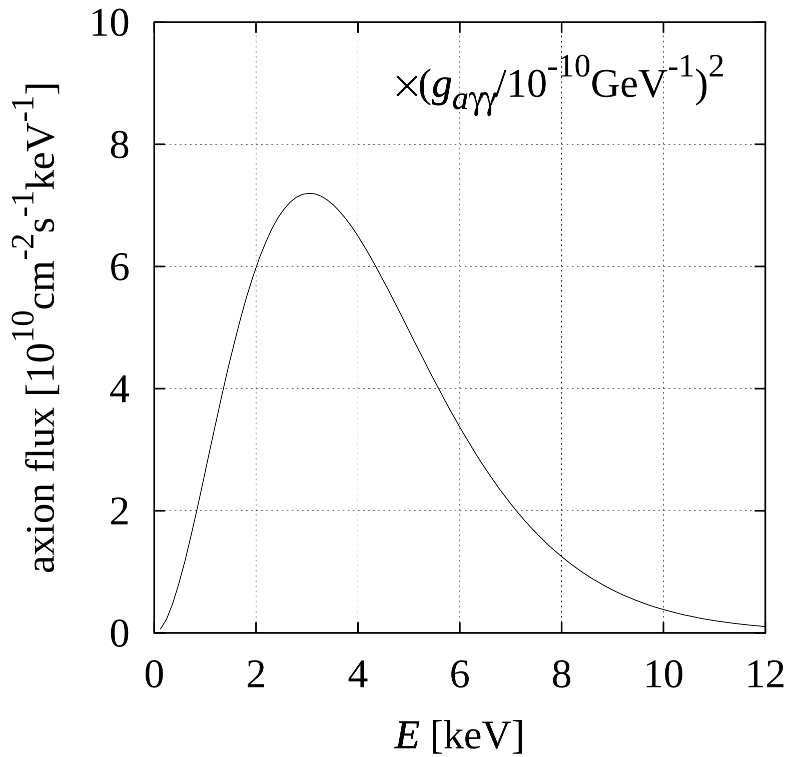
[L.J. Rosenberg, K.A. van Bibber, Phys. Rep. 325(2000)1]

Solar axion

The sun can be a powerful source of axions. In the solar core, axions can be produced from photons through the Primakoff proccess.



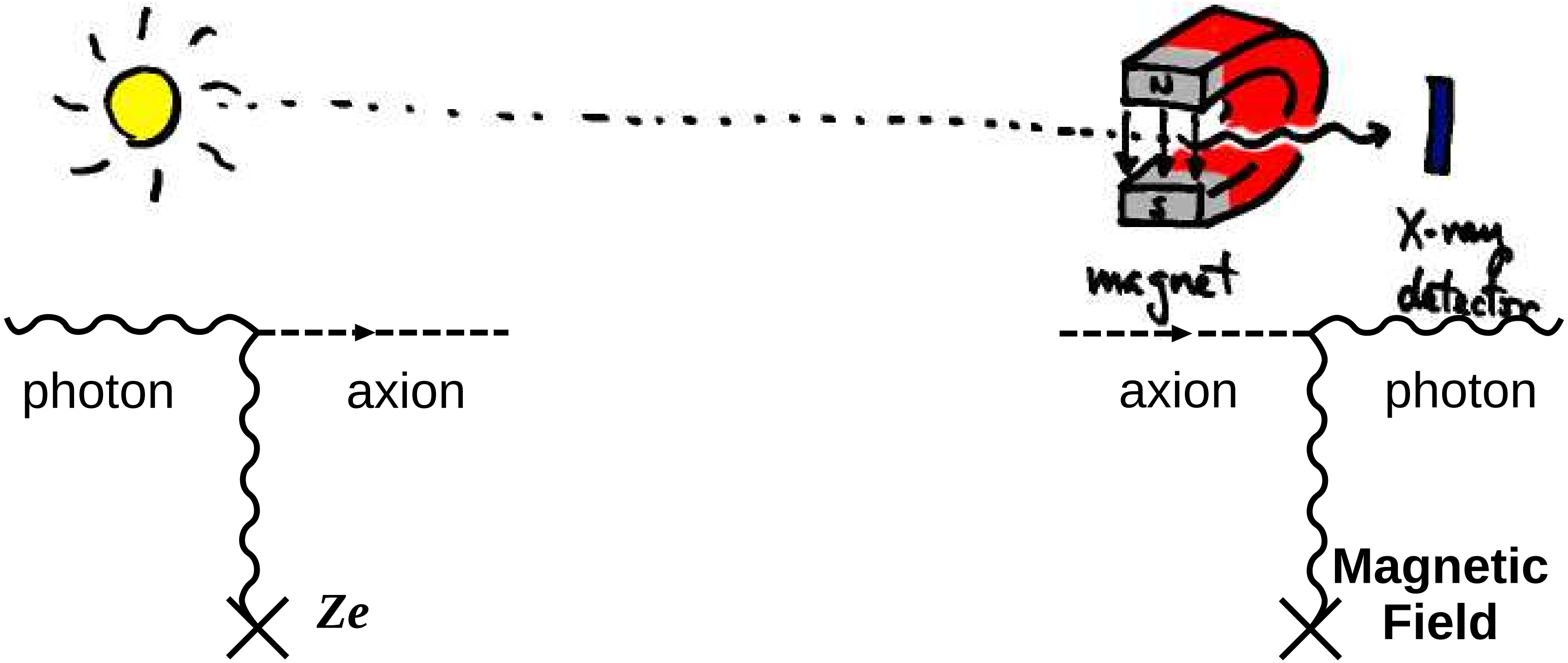
K.van Bibber *et al.*, PRD39(1989)2089



Axion telescope

[P. Sikivie, Phys. Rev. Lett. 51(1983)1415]

The solar axions can be reconverted into x-rays using a strong magnetic field in a laboratory.



Conversion rate

Conversion rate:

$$P_{a\to\gamma} = \frac{g_{a\gamma}^2}{2}\left|\int_0^L Be^{iqz}dz\right|^2 = \frac{g_{a\gamma}^2 B^2}{q^2}\sin^2\frac{qL}{2},$$

$$q = m_a^2/2E. \quad \text{(momentum transfer)}$$

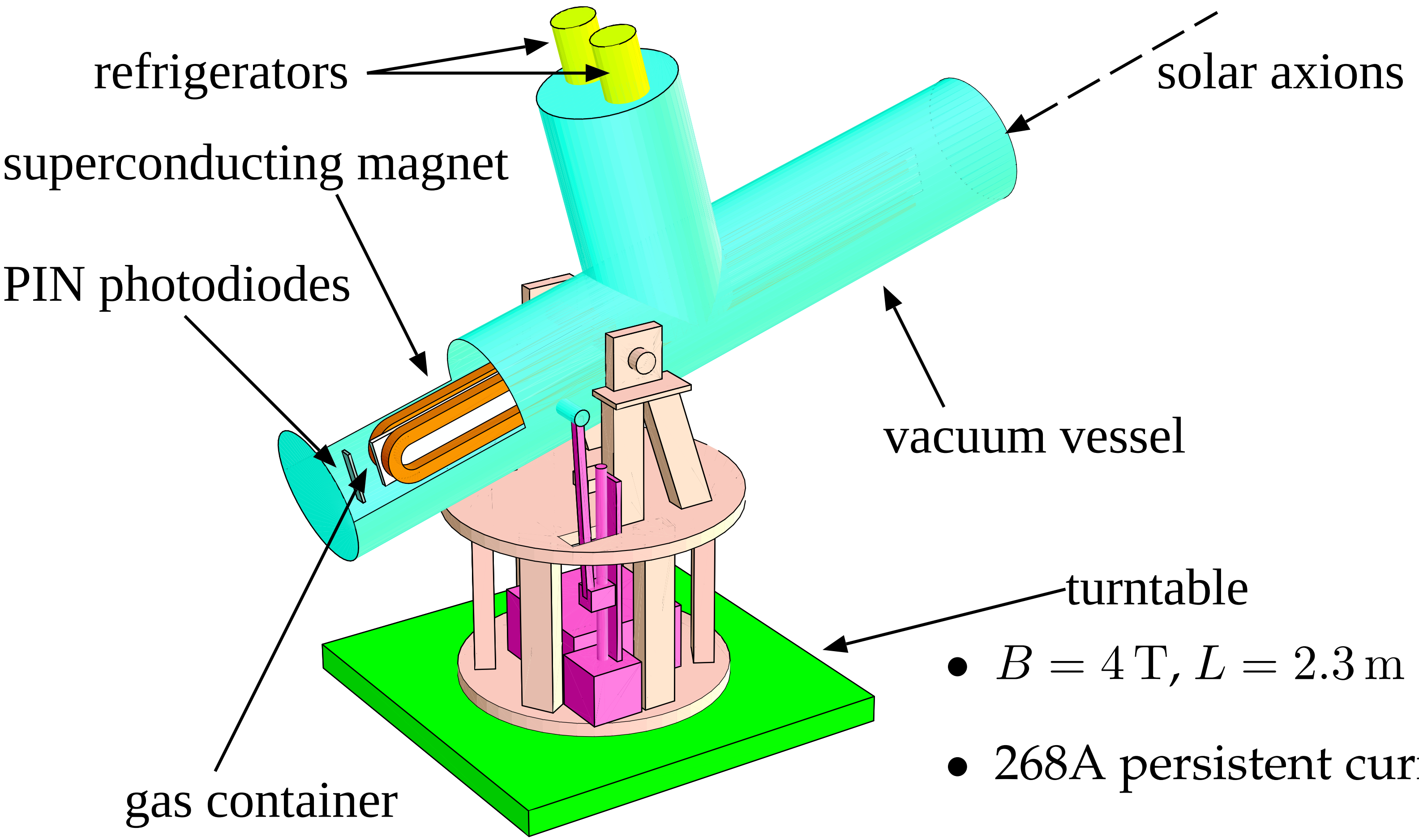
The coherence is lost for $m_a \gtrsim \sqrt{\pi E/L}\ldots$

But coherence can be restored by filling the conversion region with buffer gas. In buffer gas, the momentum transfer becomes

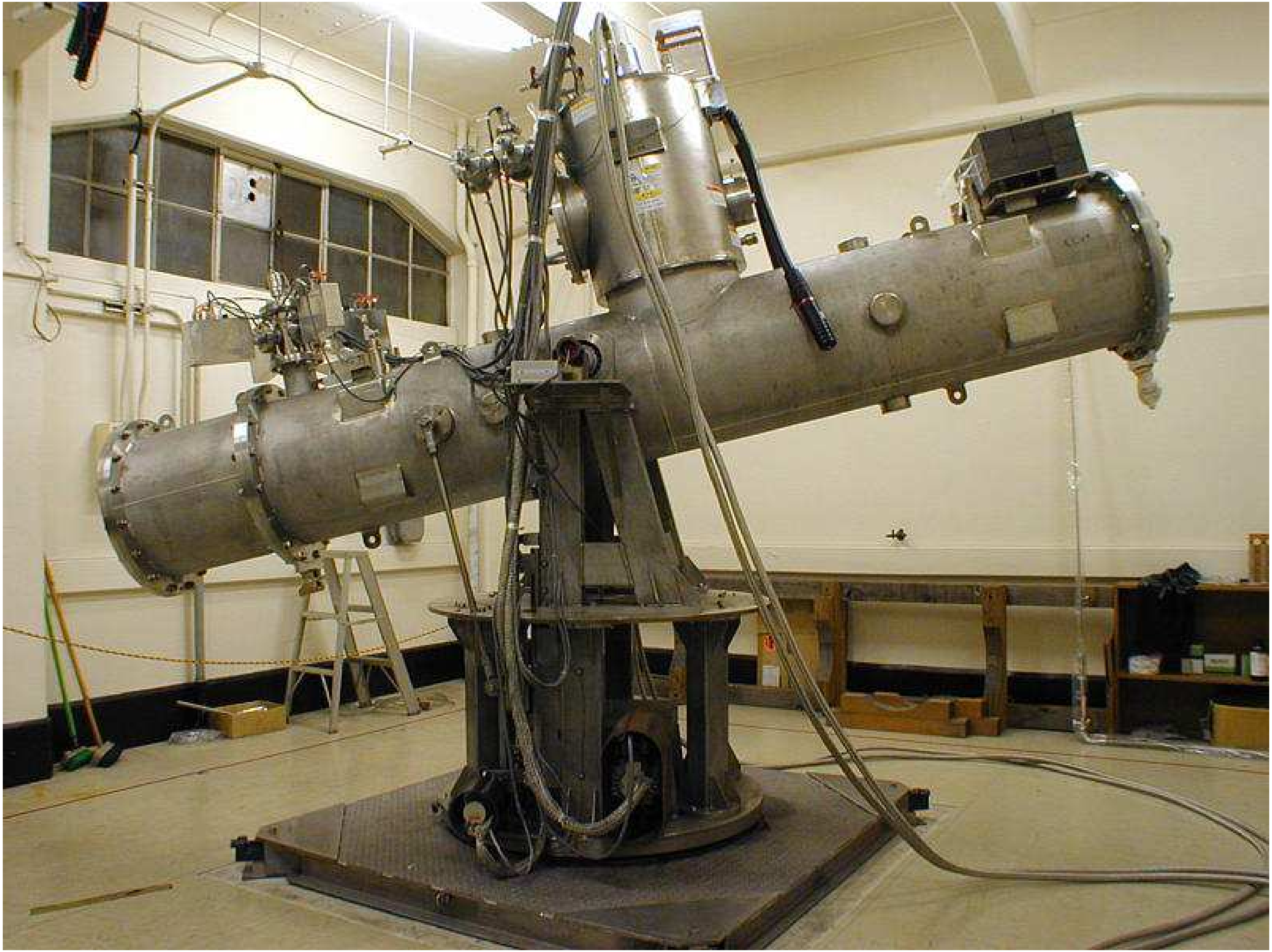
$$q = |m_\gamma^2 - m_a^2|/2E,$$

$$m_\gamma = \sqrt{\frac{4\pi\alpha N_e}{m_e}}. \quad \text{(effective photon mass)}$$

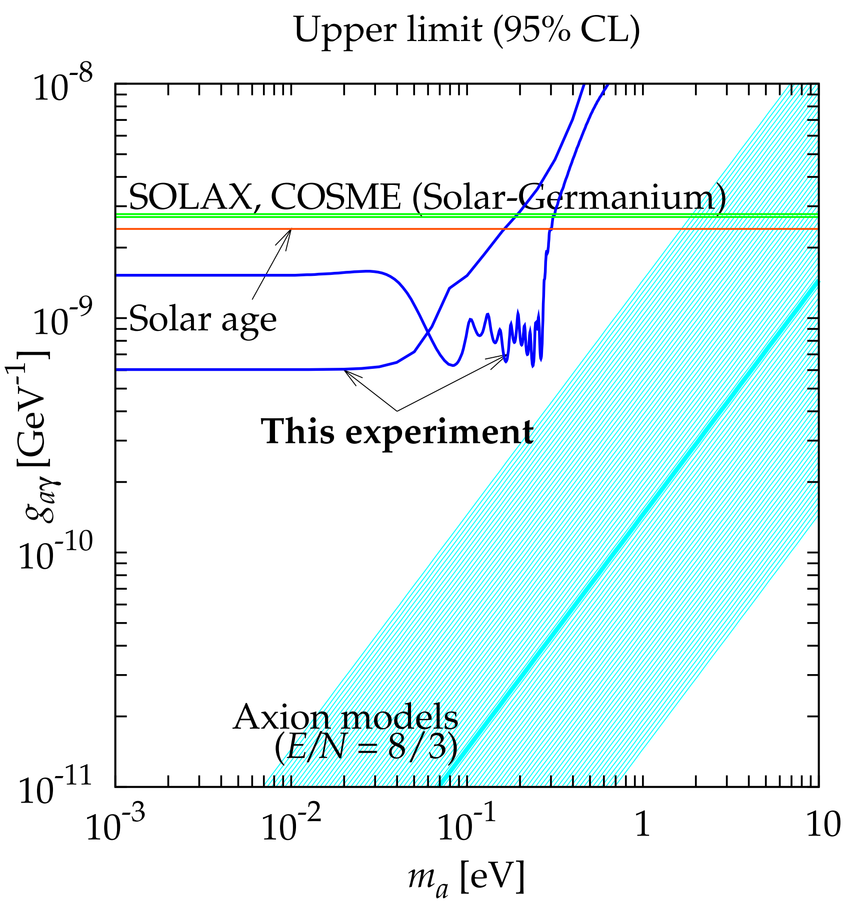
Sumico V detector



- $B = 4\,\mathrm{T}$, $L = 2.3\,\mathrm{m}$
- 268A persistent current
- 16 PIN photodiodes
- horiz. 360°, vert. $\pm 28^\circ$

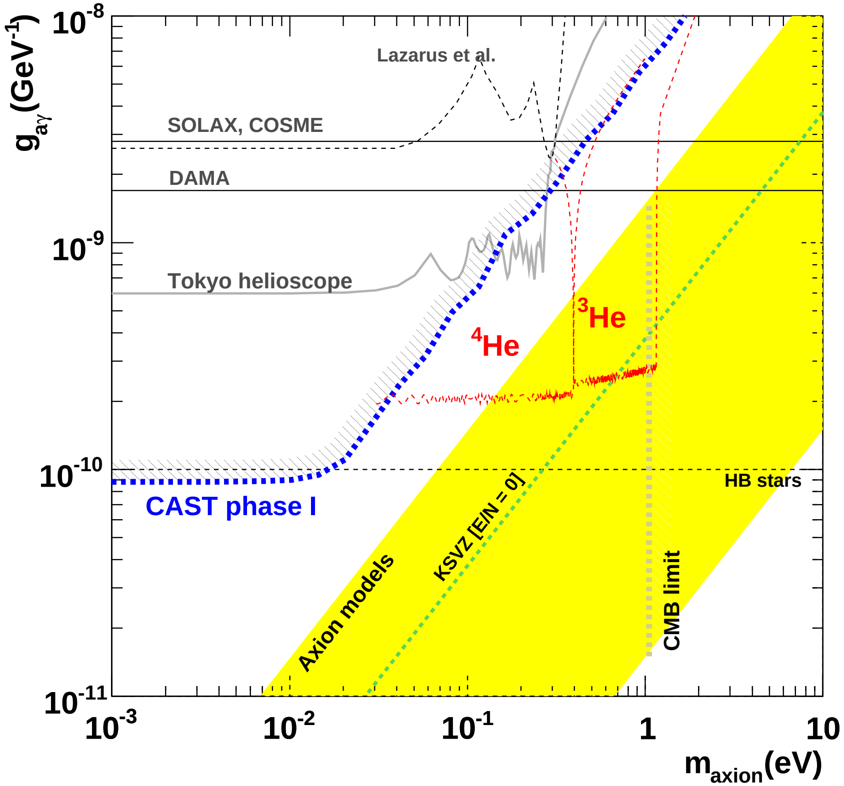


Past measurements & results



- Phase I — vacuum
  $m_a < 0.03\,\mathrm{eV}$
  1997 December
  [S. Moriyama *et al.*, Phys. Lett. B 434(1998)147]
- Phase II — low density He
  $m_a < 0.27\,\mathrm{eV}$
  ($p < 2\,\mathrm{kPa}, T = 5.2$–$5.7\,\mathrm{K}$)
  2000 July–September
  [Y. Inoue, *et al.*, Phys. Lett. B 536(2002)18]

CAST @ CERN

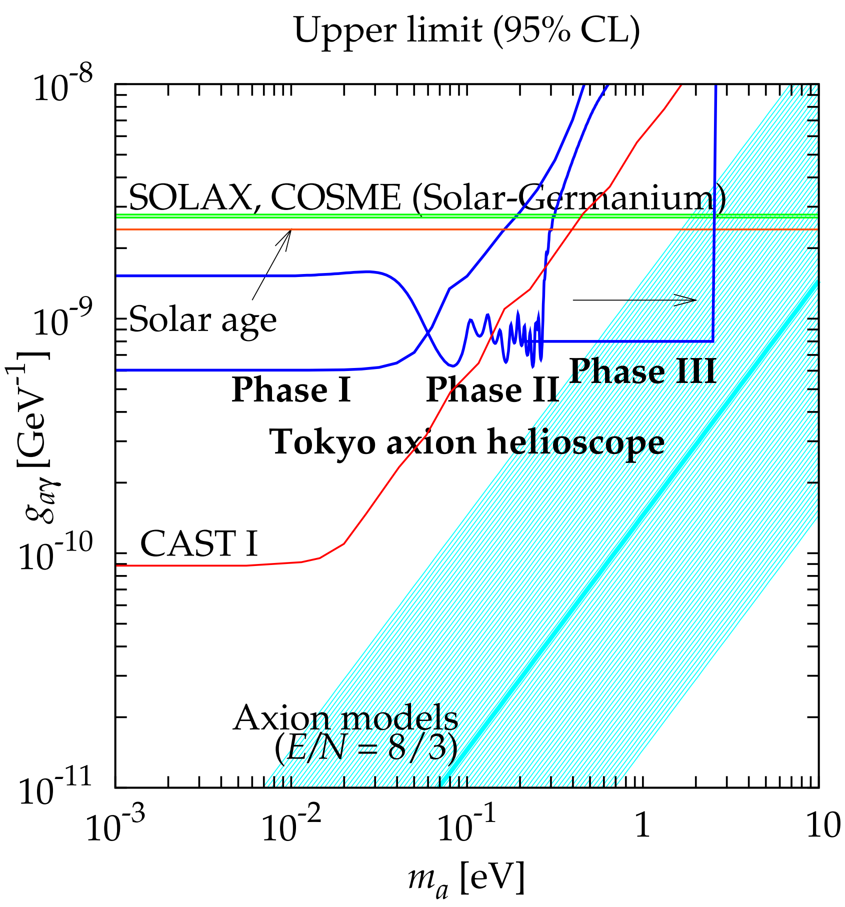


[Irastorza *et al.*,
Rencontres de Moriond EW2007]
`http://moriond.in2p3.fr/EW/2007/`

[Zioutas *et al.*,PRL94(2005)121301]

- $B = 9\,\mathrm{T}$, $L = 9.26\,\mathrm{m}$
  (LHC test magnet)
- Vertical $\pm 8°$, horizontal $\pm 40°$
- TPC, Micromegas,
  CCD+mirror

What's next? — Sumico Phase III



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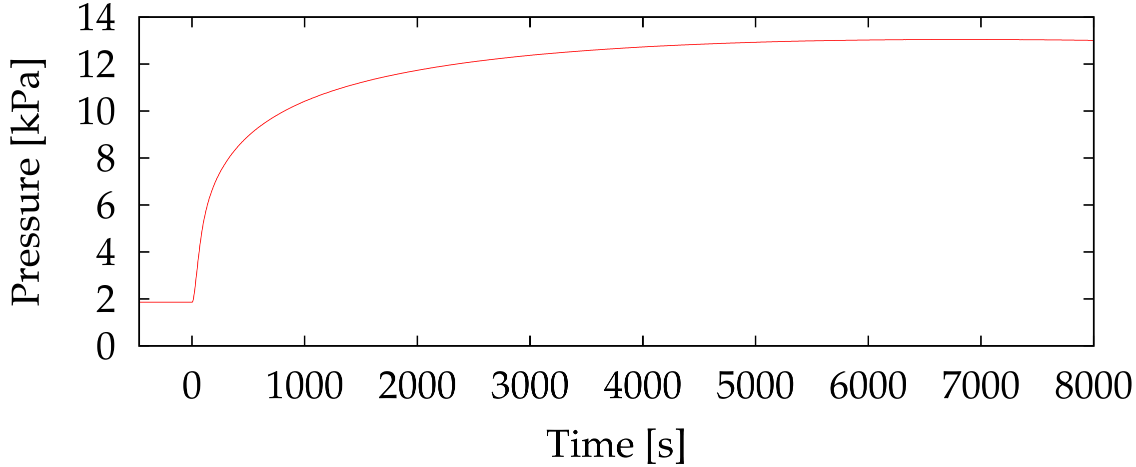
- Phase III — high density He
  $m_a \lesssim 2.2$–$2.6\,\text{eV}$
  ($p \lesssim 1$–$2\,\text{atm}$, $T = 5$–$6\,\text{K}$)

How to resist magnet quench?

When the superconducting magnet quenches, its temperature rises up to 50–60 K within a few seconds.

- No good commercial cryogenic relief valve
- Know thy enemy.
  Measured the pressure change after a forced quench.



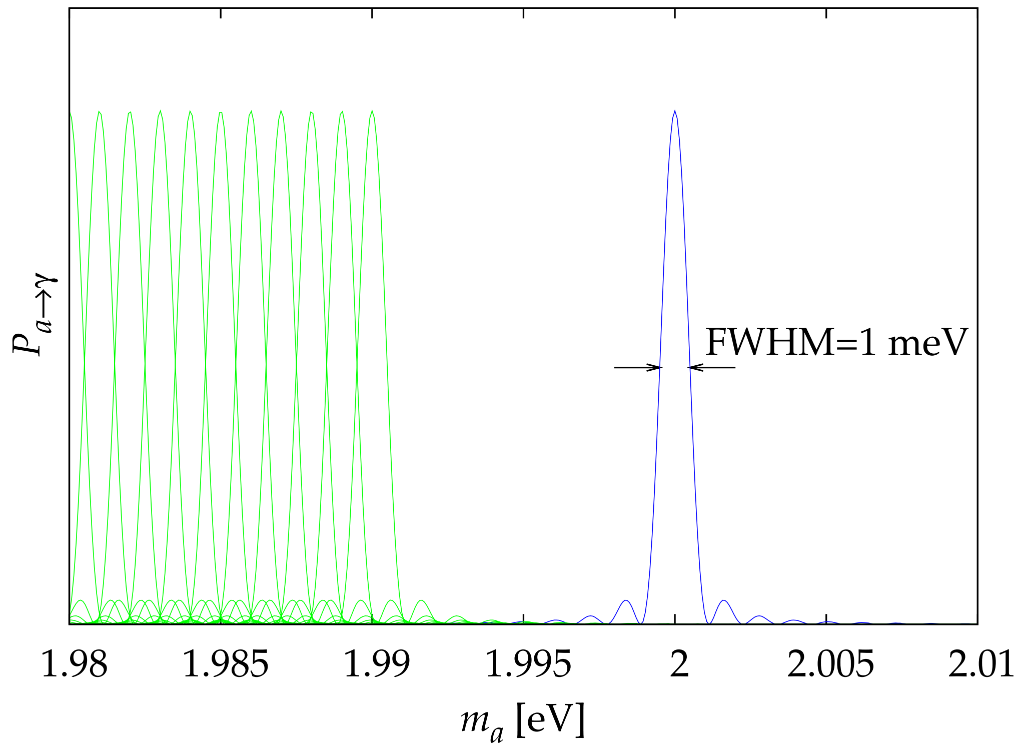
$\rightarrow$ Not as fast as the magnet: use $\phi 1/4''$ tube

And a rupture disk

- Hydrodyne
- Cryogenic precision burst disc
- 36 psi $\pm 5\%$ @ 5 K
- Exhaust through a normally evacuated 3/8″ line.

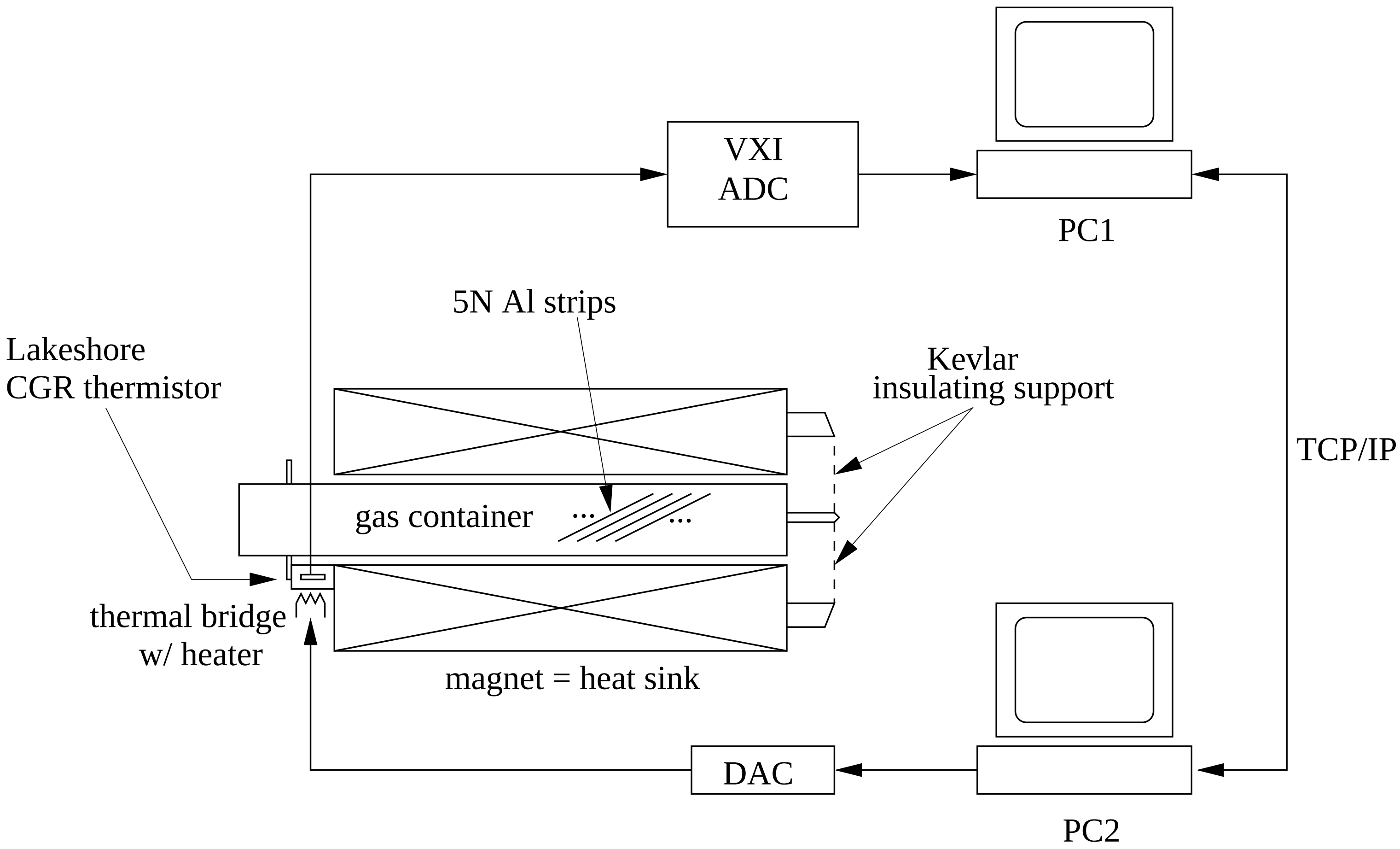
Resonance width at high m_a

$$P_{a\to\gamma} = \frac{g_{a\gamma}^2 B^2}{q^2} \sin^2 \frac{qL}{2}; \quad q = |m_\gamma^2 - m_a^2|/2E$$

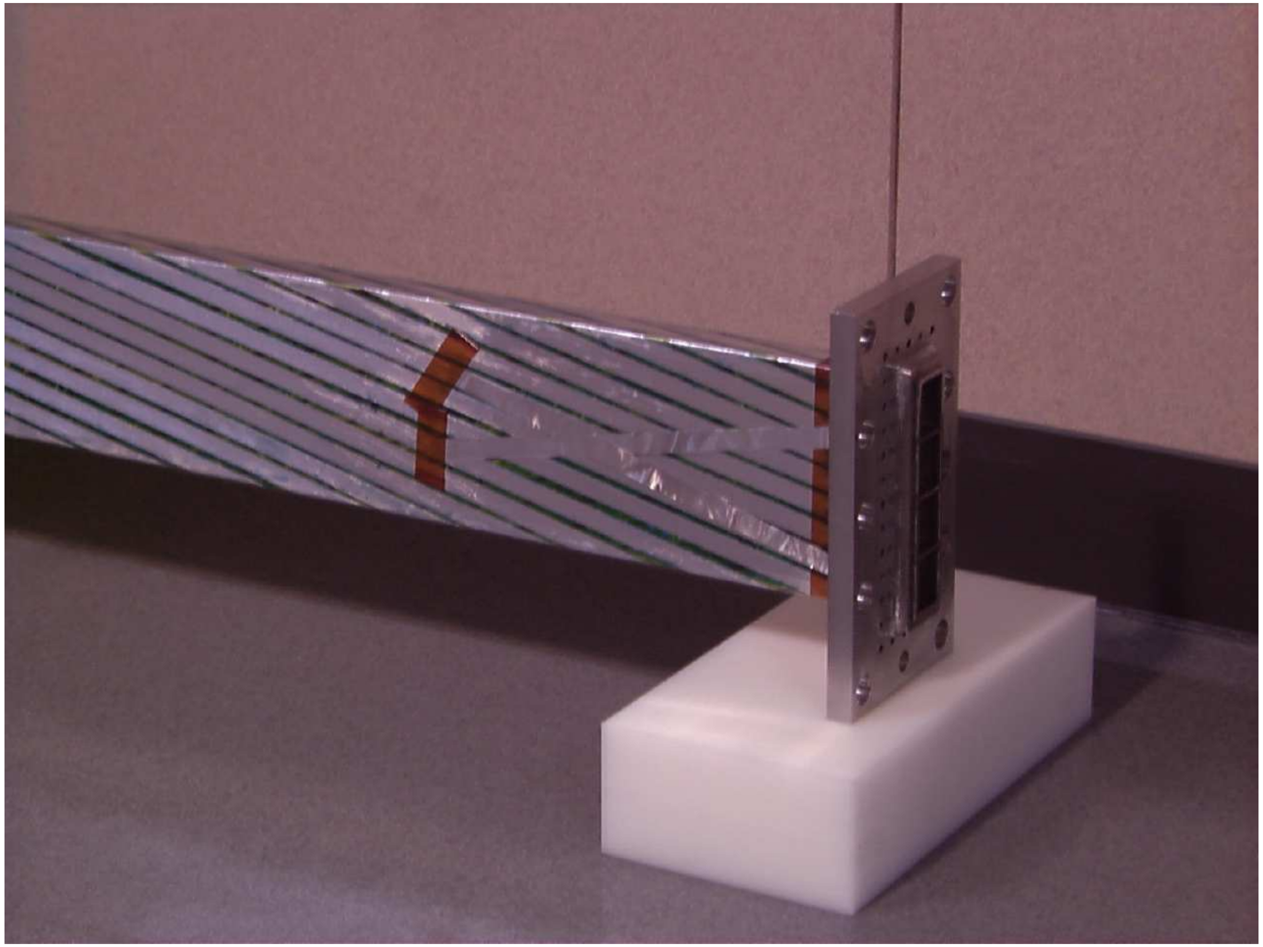


- $\delta N_{\rm He}/N_{\rm He} < 0.1\%$
  stabilize T + control p.
  $$N_{\rm He} = \frac{p}{RT}$$
- Many many data points to scan
  $\rightarrow$ computer control

Temperature stabilization

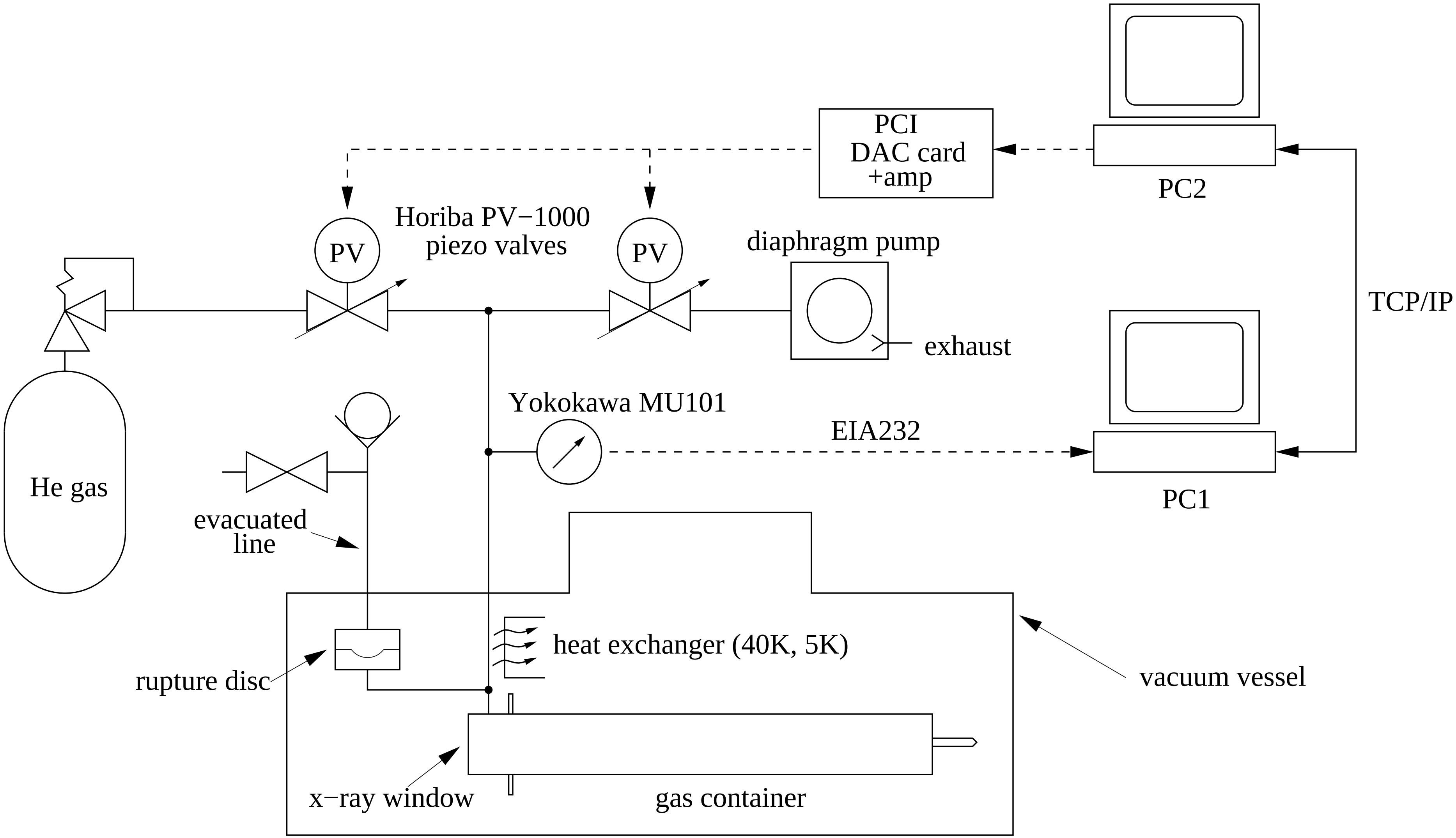


Gas container



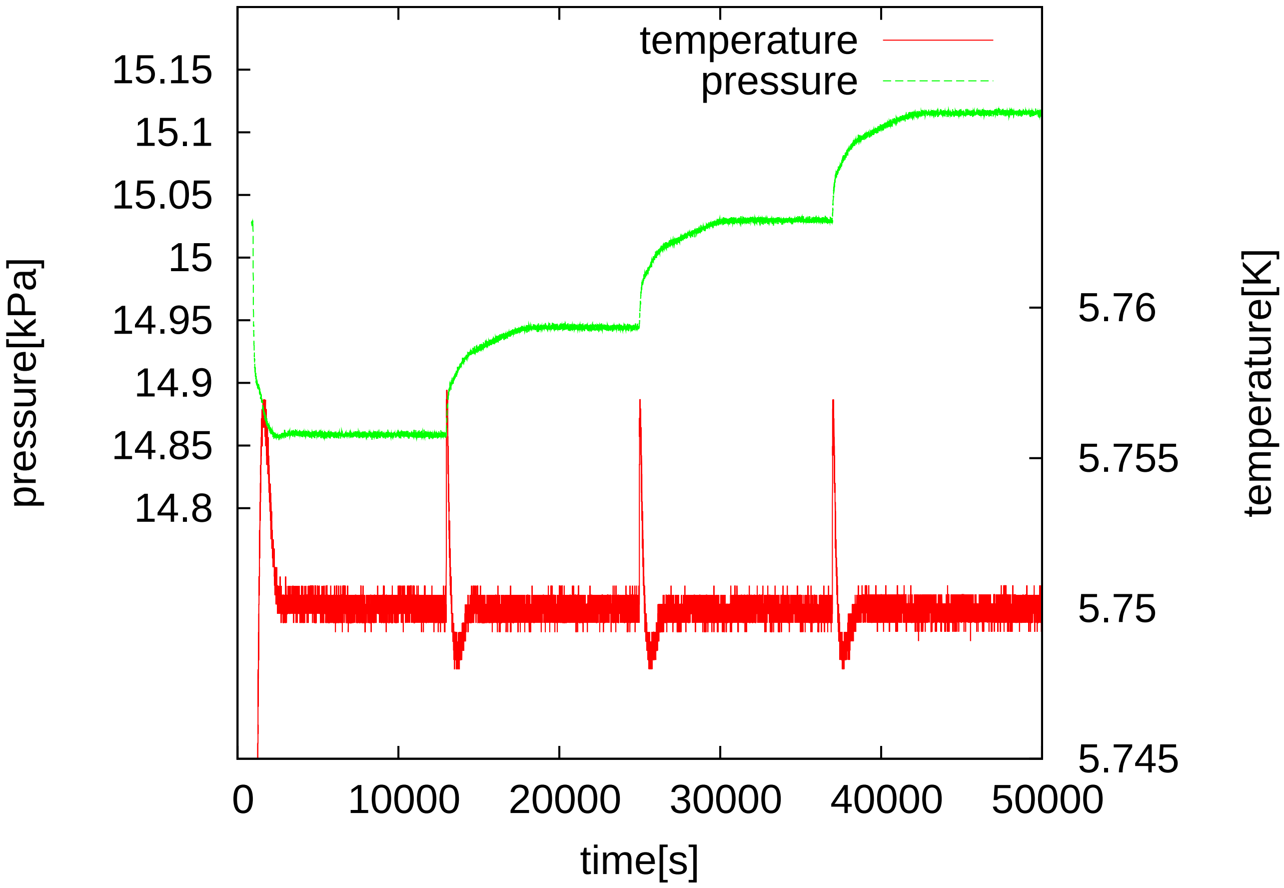
- Compact design
- Welded 4 $\times$ st. steel 304 $21.9 \times 17.9 \times 2300\,\mathrm{mm}^3$ square pipes
- Pure Al (99.999%) 0.1-mm thick, $\times$ 2 layers
- Measured thermal conductivity $\gtrsim 10^{-2}\mathrm{W/K}$ @ $5\,\mathrm{K}$, $4\,\mathrm{T}$

Gas controlling system



Test result of p, T control

$p \sim 15\,\mathrm{kPa}$, $T = 5.75\,\mathrm{K}$



Excellent!

Other progress / status

- PIN diode dead layer measurement
- Moved to a new site … again
- Recontruction — almost finished, left final precision alignment
- True north direction by gyrocompass
- Repaired and refined mechanics of altazimuth stage
- Cable handling robot — work in progress, half done
- Repairing broken cables — work in progress

Summary

- Sumico Phase III will explorer $m_a \lesssim$ 2.2–2.6 eV
- Most technical difficulties have been overcome.
- Now the magnet has been cooled.
  $T_{\mathrm{mag}} = 6\,\mathrm{K}$ as of 10 September
- Measurement will start soon.