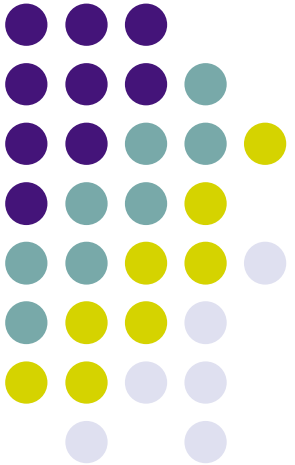
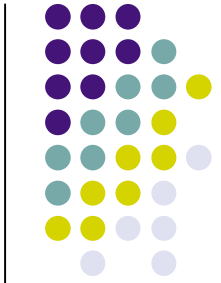
Search for a monochromatic component of solar axions using Fe-57

Toshio Namba

ICEPP, University of Tokyo



Axion



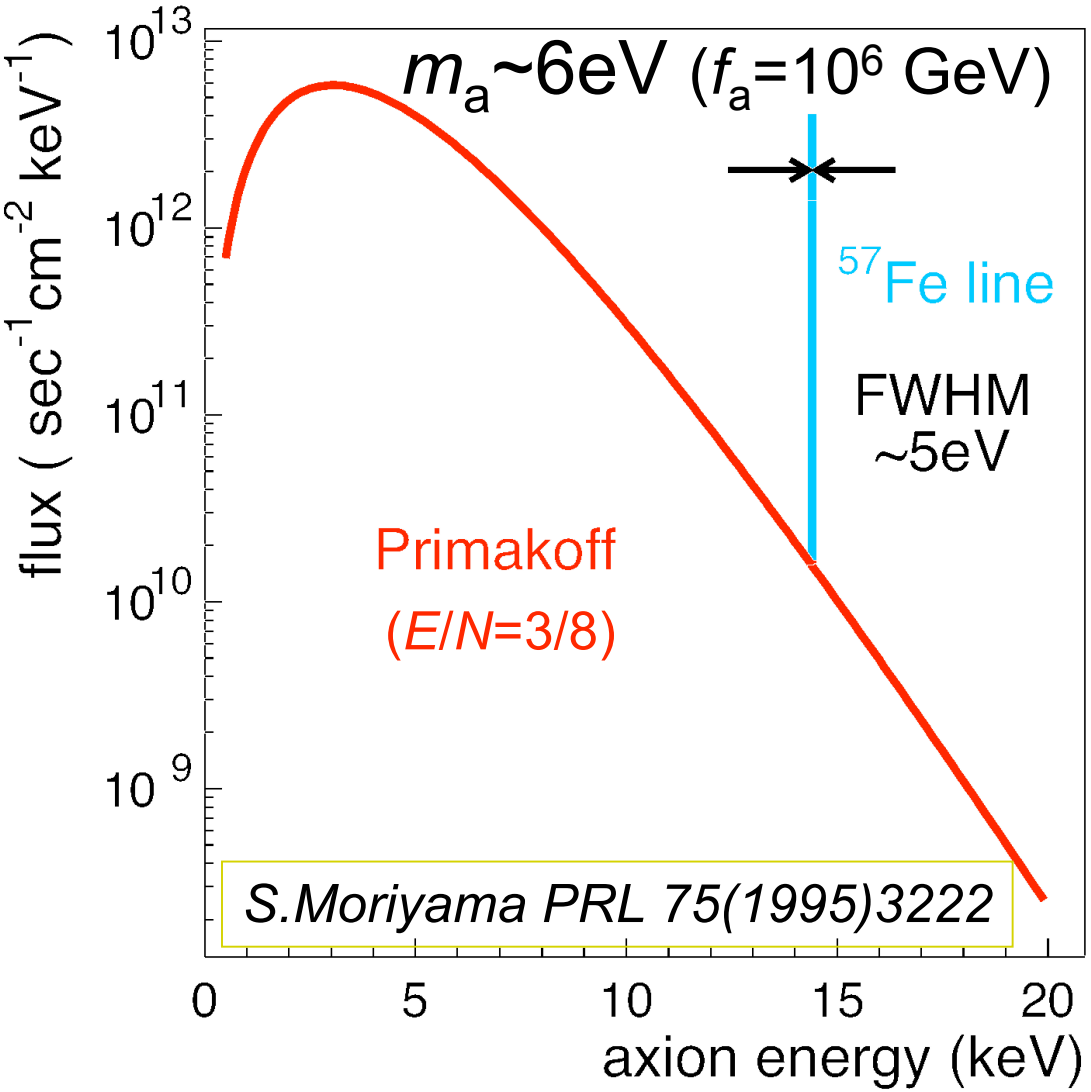
- Undiscovered pseudoscalar particle predicted to solve the ``strong CP'' problem
- m_a??, g_a?? no prediction,

  but $m_a \propto g_a$
- One candidate of cold dark matter,

  if $m_a = 10^{-3} \sim 10^{-6}$ eV $\Rightarrow$ Cavity experiments
- If m_a (g_a) is reasonably large, it is unlikely as CDM, but

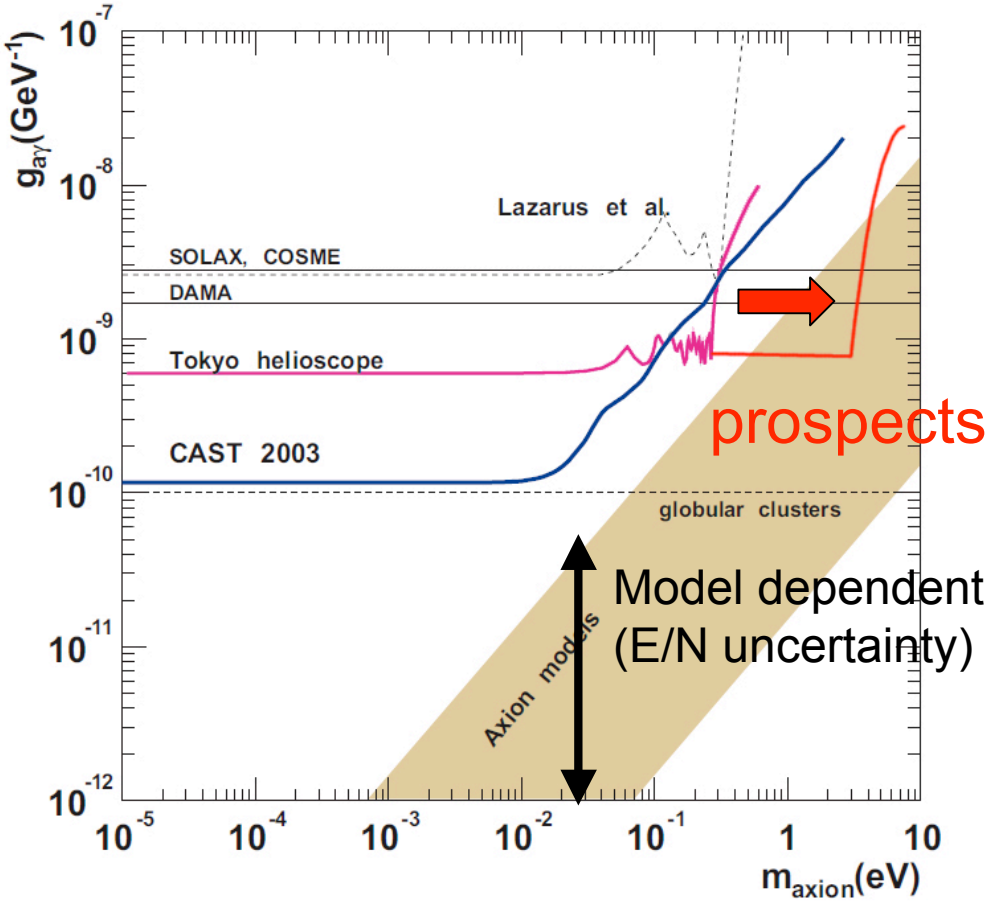
  $\Rightarrow$ <u>the sun can be a bright axion source</u>

Solar axion



- Blackbody component ($g_{a\gamma\gamma}$)
  ⇒Magnet experiments
- Monochromatic component (g_{aNN})
  ⇒Topics of this talk

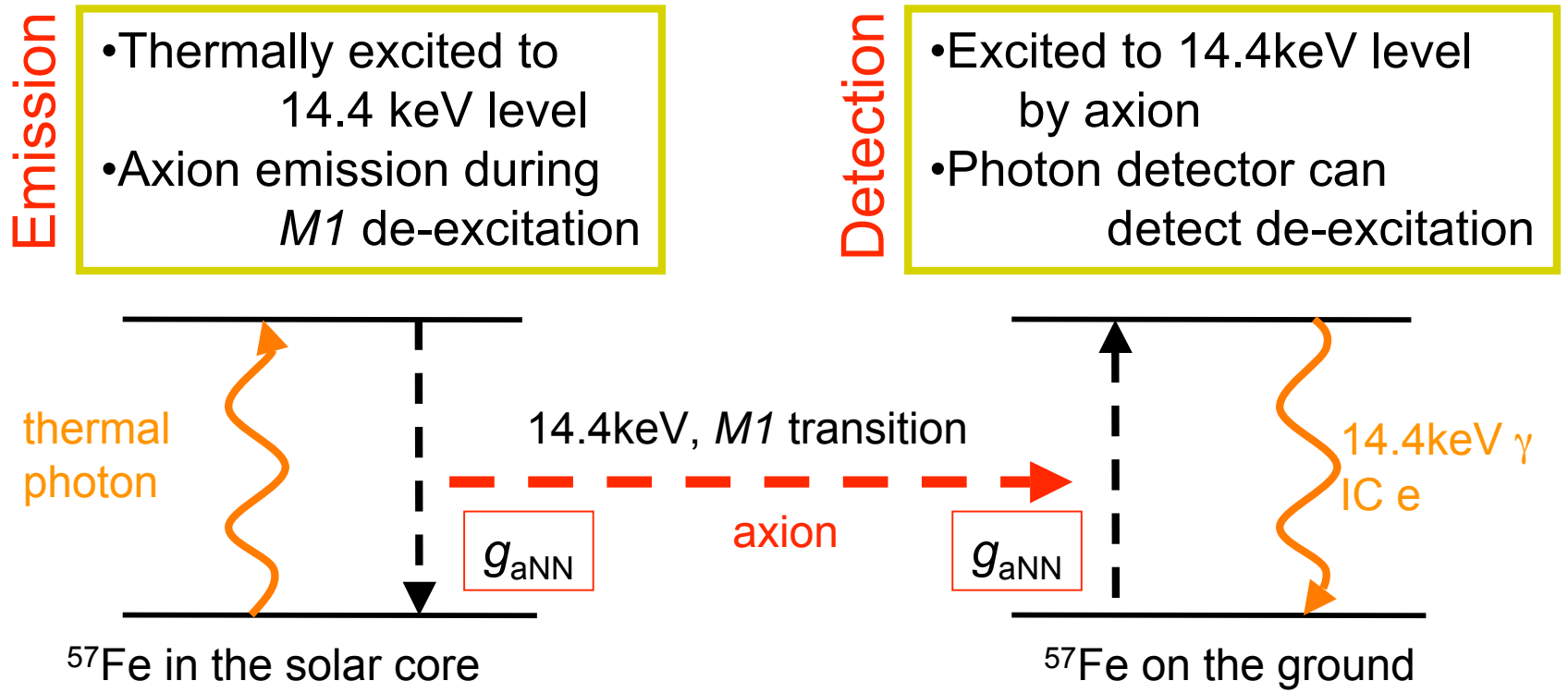
(off-topic) Search with $g_{a\gamma\gamma}$ Tokyo axion helioscope



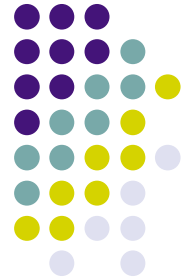
- *BL*=4T×2m
- Improvements will be done in ~one year to explore m_a~ eV region

Monochromatic solar axion and its detection

- Like Mössbauer effect
- No need to move detector (~5eV width due to thermal motion)
- Not affected by the theoretical uncertainty of $g_{a\gamma\gamma}$



Target region and other experimental constraints based on g_{aNN}



- Not so many experimental constraints
  - From J/ψ decay: m_a<~6 keV
  - Similar solar ^{57}Fe axion search: m_a<745 eV

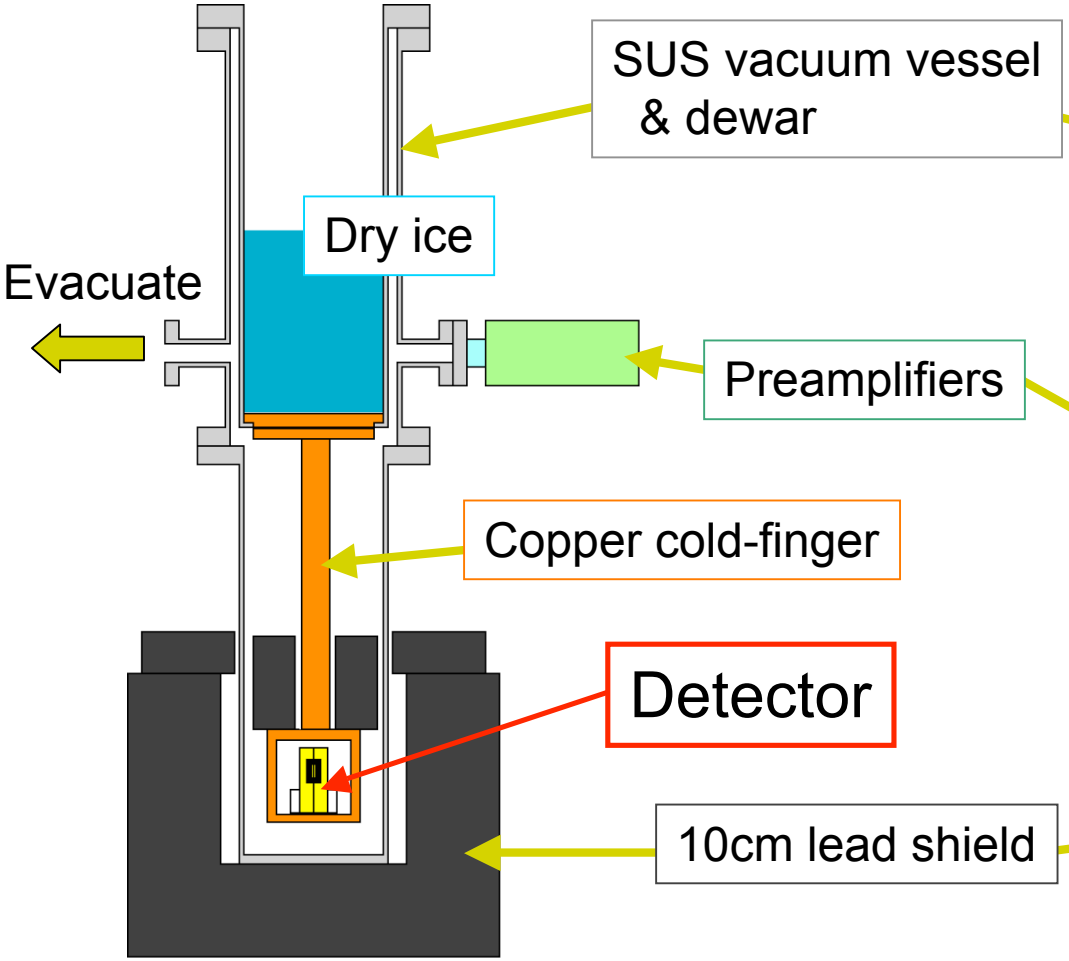
    (M. Krčmar *et al.*, PLB 442(1998)38)
  - SN1987A??? What is it?

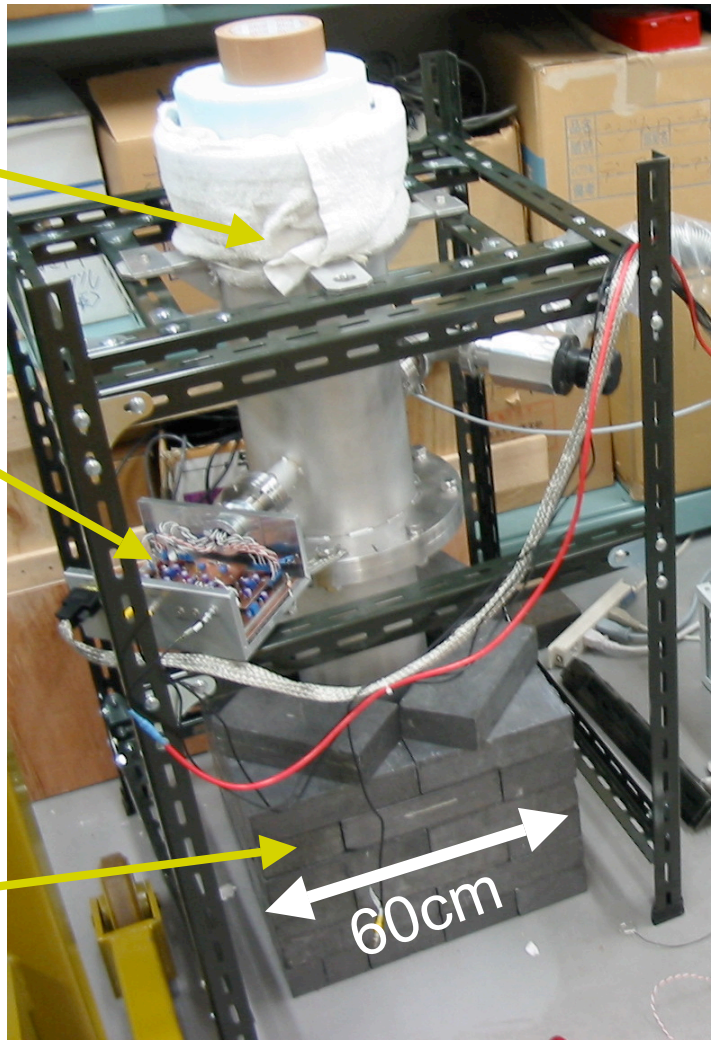
    Even if so, the hadronic axion window still exists arond m_a ~ a few tens eV!!

- If m_a~100 eV,
  - ^{57}Fe axion flux on the earth: ϕ~10^{12} cm^{-2} s^{-1}
  - ^{57}Fe excitation rate: R~10^{2} day^{-1} g^{-1}

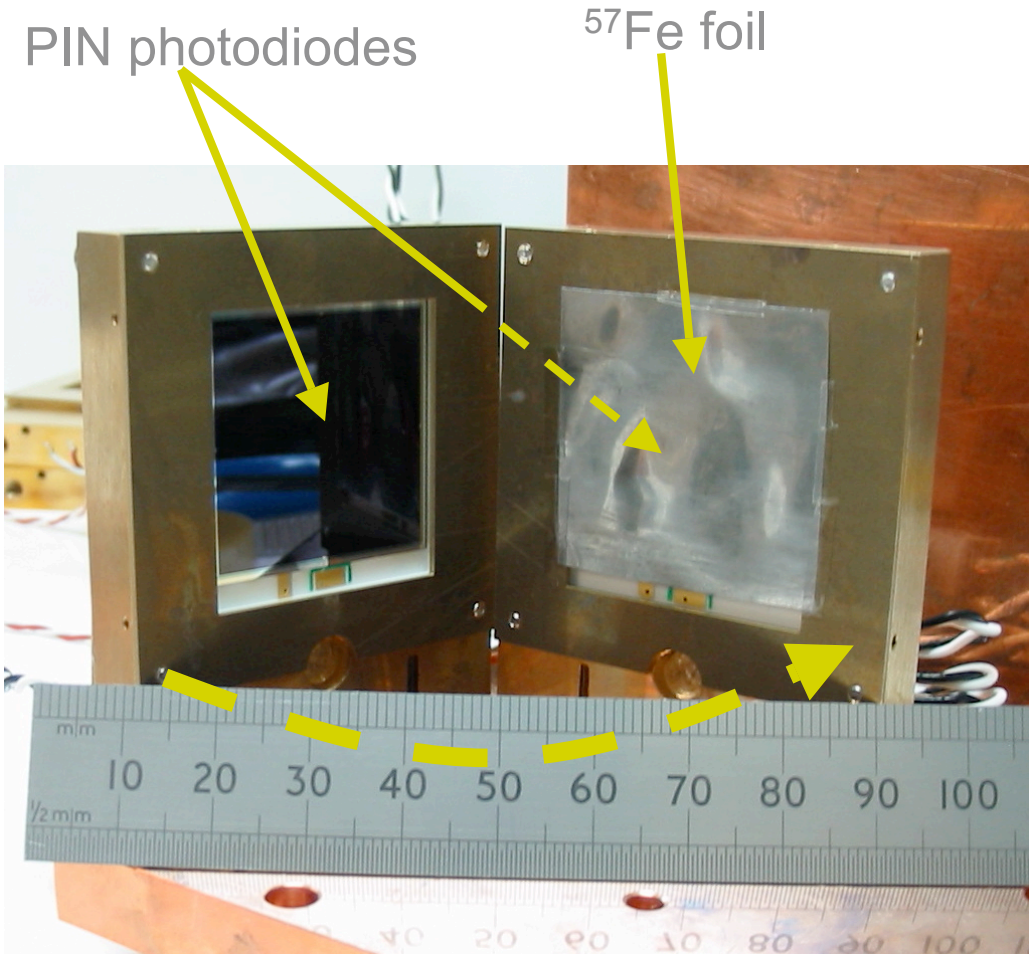
Detector setup I

- ^{57}Fe foil and large area Si PIN photodiodes
- Cooled with dry ice (195 K)



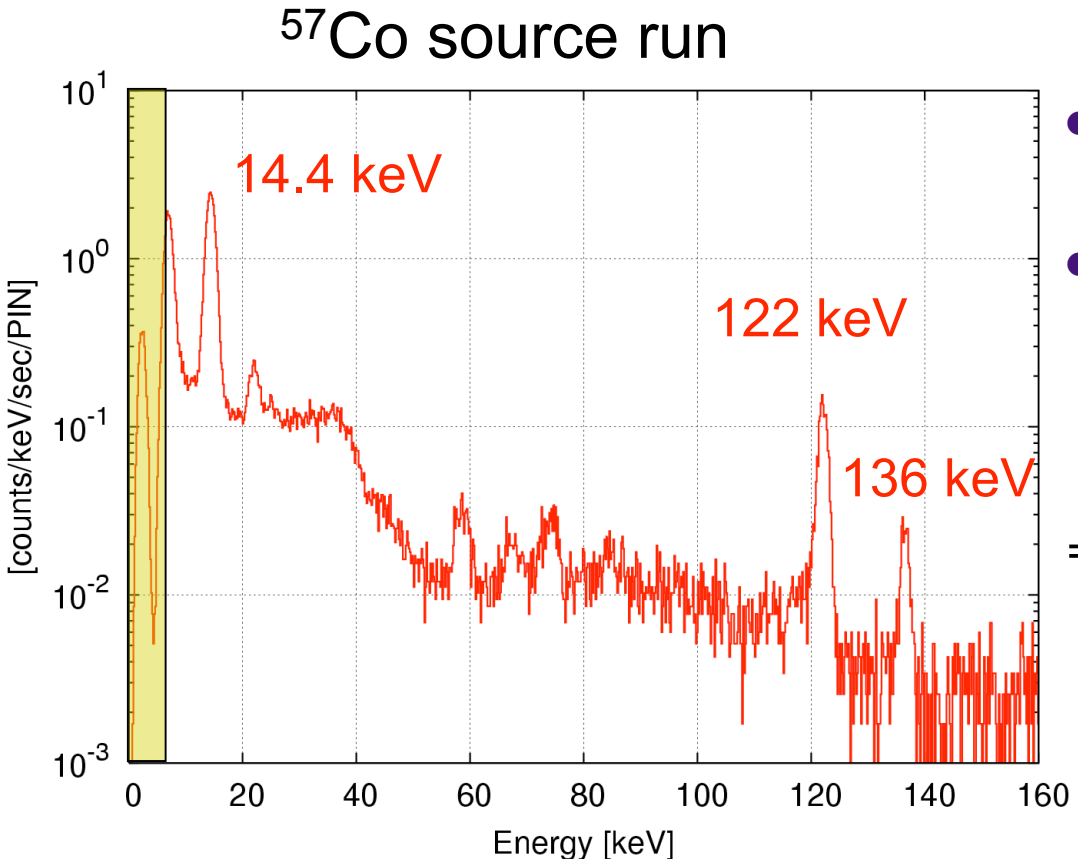


Detector setup II



- 2 × Si PIN photodiodes:
  - Hamamatsu S3584-06
  - Active area: 28mm×28mm
  - Thickness: 500μm
  - Specially packaged with low-BG ceramic
- ^{57}Fe foil
  - Enriched: 95.85%
    (natural abundance: 2.2%)
  - 32mm × 32mm
  - Thickness: (40±5)μm
    (att. length=20μm @14.4keV)
  - Mass: 320mg

Detector performance



- Efficiency & Linearity checked by ^{57}Co source
- (70.6±5.5)% for perpendicular incidence
- Overall efficiency
  - Absorption in iron
  - Acceptance
  - Incident angle

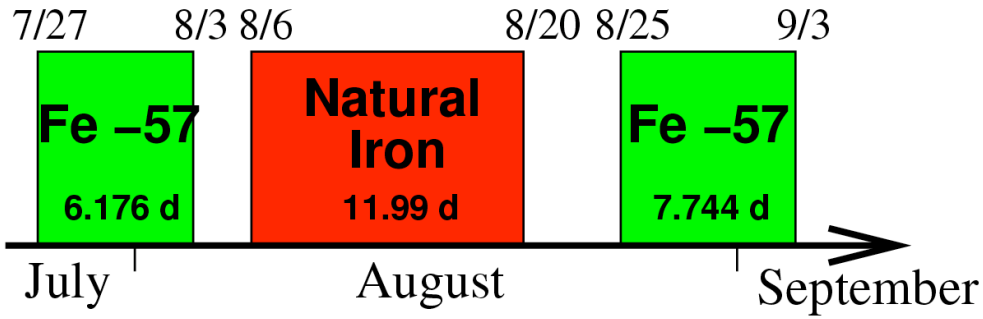
⇒Estimated by Geant4 based MC

>14.8%

for 14.4keV from the foil

Measurement

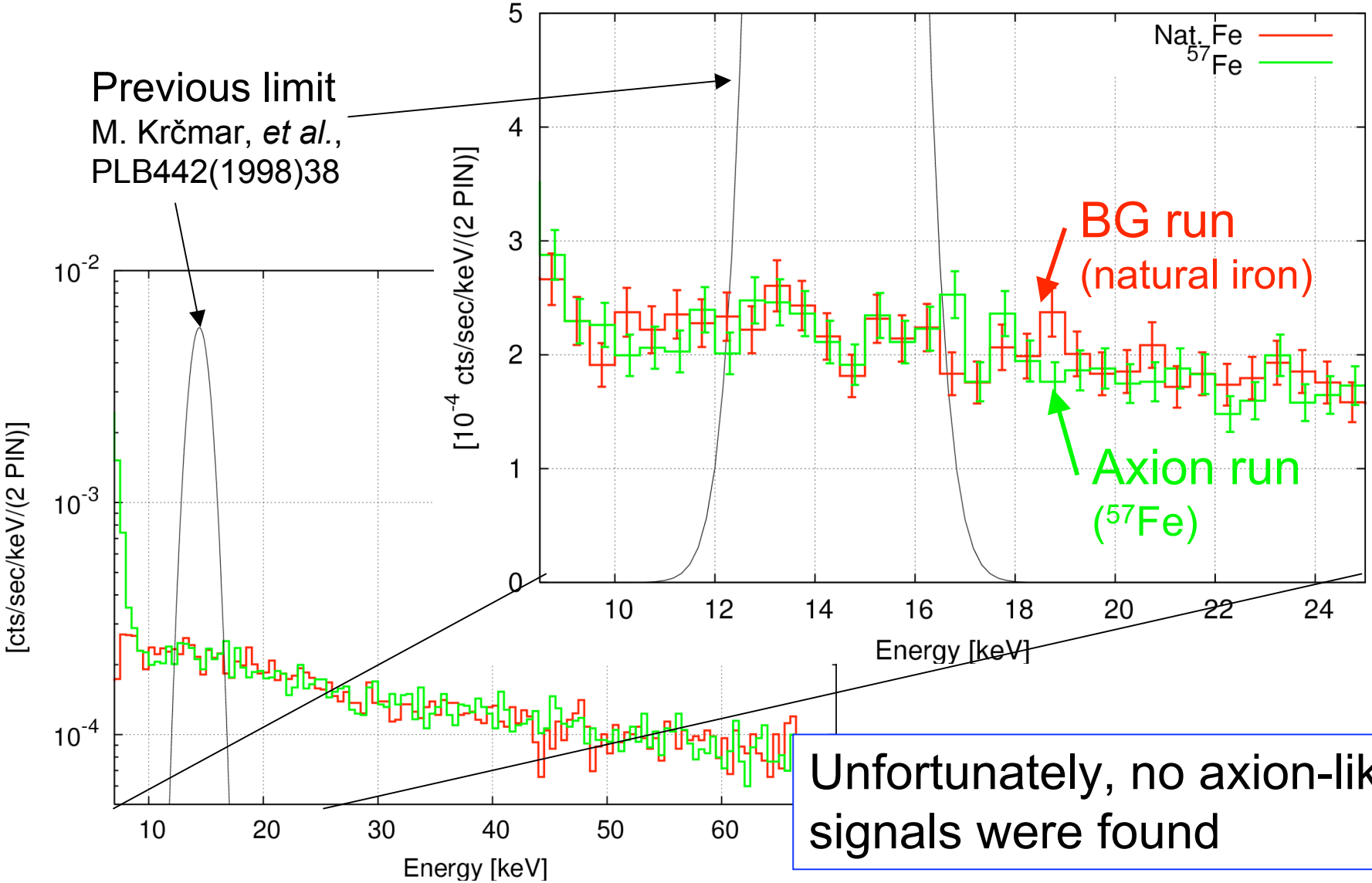
- From July 26th, 2005 to September 3rd, 2005
  - Two types of foils were attached



- ^{57}Fe foil (95.85%):
  - Axion run
- Natural Iron foil (2.2%)
  - Background run

  - Background subtraction corresponds to signals from 93.6% ^{57}Fe
- During all measurements,
  - Same apparatus were used except for the foil
  - Stable operation
    - Temperature of Holder (198±1) K
    - Temperature of 1st stage FET (212±1) K
    - Gain fluctuation < ±0.3% (Checked by 59.5keV from ^{241}Am)

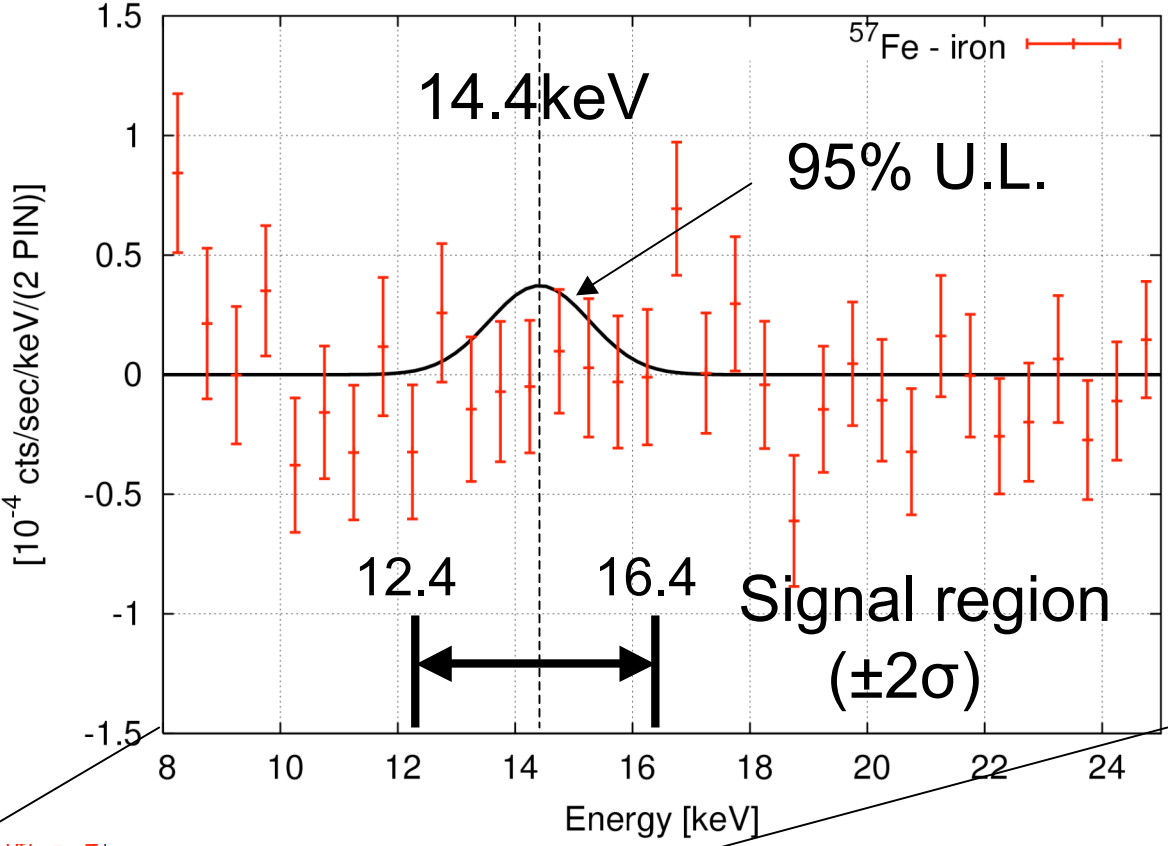
Obtained spectrum

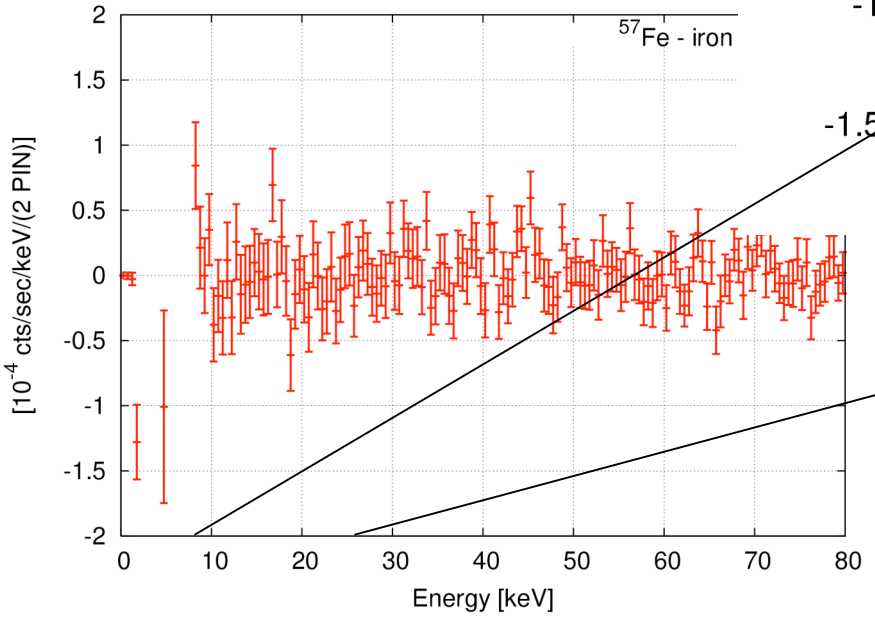


Unfortunately, no axion-like signals were found

Background subtraction

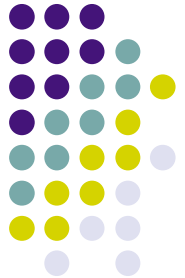
- Subtracted spectrum
- (Axion run)−(BG run)





From total counts in signal region
Signal: $(1.37 \pm 3.99) \times 10^{-5}$ cps

Results



- From the obtained 95% limit: < 7.93×10^{-5} cps

  ±2σ region: 95.45%

  ^{57}Fe mass difference: 197mg

  Detection efficiency: 14.8%

  Branch of γ-ray emission: 10.5%

  ⇒ Excitation rate of ^{57}Fe: $R < 2.35\times10^{3}$ /day/g (95% C.L.)

  (Factor 144 improvement)

- This corresponds to:
  - $f_a > 2.89\times10^{4}$ GeV, $m_a < 216$ eV (if z=0.56, S=0.5)

    (Factor 3.5 improvement)

Future prospects

- Towards the hadronic axion window

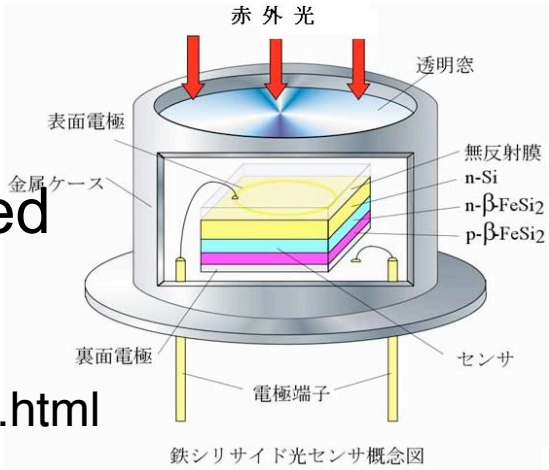
  (m_a ~ a few tens eV)

  - Development of a new detector made of iron is necessary
  - If iron detector is possible,

    ⇒ 2 order improvements of S/N, even if the same BG level
  - One candidate:

    New generation semiconductor: β-$FeSi_2$ (iron silicide)
  - Possibility for the application as a particle detector is under investigating (e.g. growth of bulk)

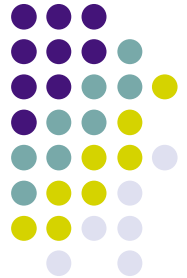
IR sensor developed by a company



鉄シリサイド光センサ概念図

http://www.jst.go.jp/pr/report/report308/02.html

Summary



- A new search for solar axion was performed
- This search is based on g_{aNN}
- ^{57}Fe foil and silicon PIN photodiodes were used
- From the absence of ^{57}Fe related signals, a new experimental constraint was obtained

$m_a < 216$ eV, $f_a > 2.89 \times 10^4$ GeV

(z=0.56, S=0.5)