

# 暗黒の歴史

by 関谷

2017.1.26 大阪暗黒懇談会



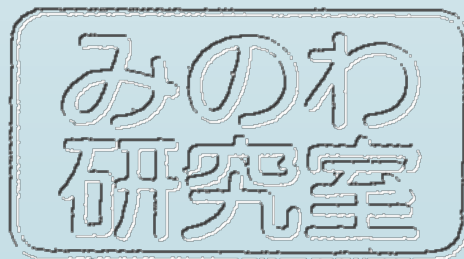
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# 前史

- みのわ研
  - 1997 森山 D論 (solar axion)
  - 1998 大谷 D論 (LiF@鋸山)
  - 2002 身内 D論 (LiF@神岡)
  - 2002 難波 D論 (天体 axion)
  - 2003 竹田 D論 (NaF@神岡)
  - 2004 関谷 D論 (スチルベン)
  - 2005 清水 D論 (CaF<sub>2</sub>)
  - 2007 秋本 D論 (solar axion)
  - 20?? 太田D論 (solar axion)
  - 20?? 水本D論 (hidden photon)
  - 2016 井上 D論 (solar axion)
  - 2017 富田 D論 (hidden photon)

# 蓑輪研神岡地下暗黒物質実験

- ▶ 1999-2003
  - ▶ LiF/NaF bolometerを用いたスピんに依存した相互作用に特化した暗黒物質探索
- ▶ 2003
  - ▶ Stilbene単結晶を用いた方向に感度を持った暗黒物質探索
- ▶ 2004-2005
  - ▶  $\text{CaF}_2(\text{Eu})$ を用いたスピんに依存した相互作用に特化した暗黒物質探索



# 貧者の<sup>19</sup>F

## Neutralino-nucleus cross section

$$\sigma_{\chi-N} = 4G_F^2 \mu_{\chi-N}^2 C_N$$

$$\mu_{\chi-N} = \frac{M_\chi M_N}{M_\chi + M_N} \quad \text{Reduced mass}$$

Enhancement factor

$G_F$  Fermi coupling constant

$$C_N = C_N^{SD} + C_N^{SI} \quad (C_N^{SI} \propto A^2)$$

$\langle S_p \rangle_N$  nucleon spin  
 $\langle S_n \rangle_N$  in the nucleus

$$C_N^{SD} \propto (a_p \langle S_p \rangle_N + a_n \langle S_n \rangle_N)^2 \frac{J+1}{J}$$

$a_p, a_n$  :  $\chi$ -nucleon coupling

F has opposite sign of  $\langle S_p \rangle_N / \langle S_n \rangle_N$  compared to Na, I, Ge, Xe.

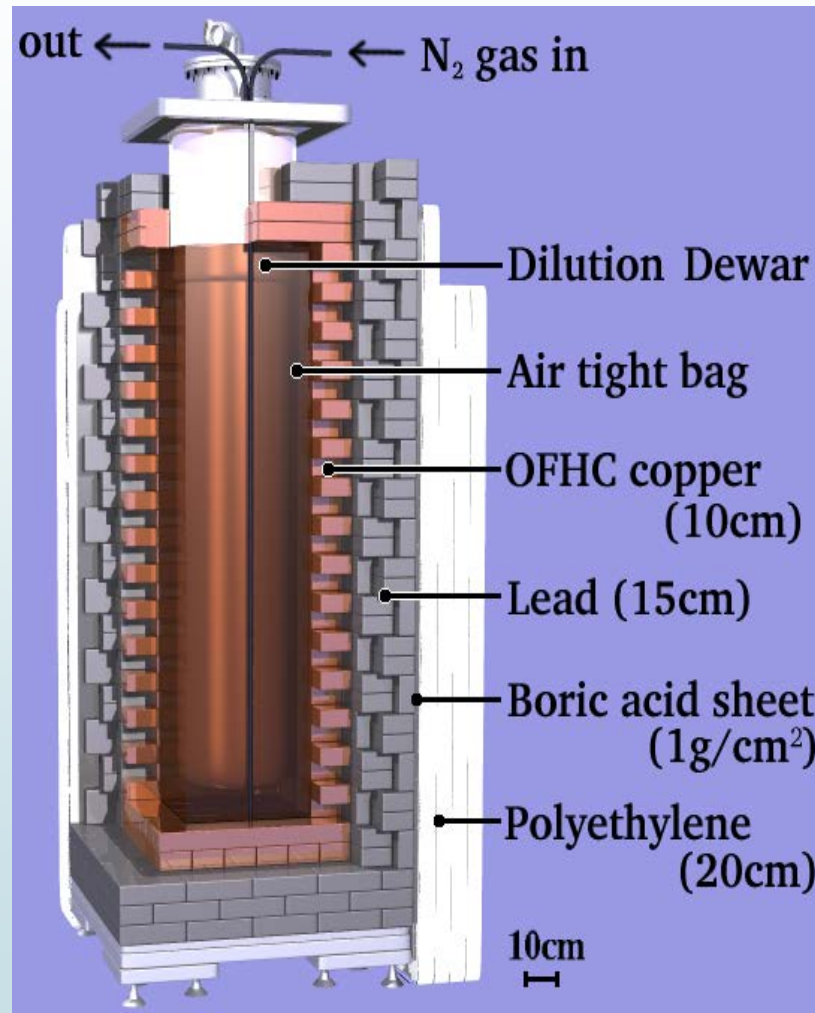
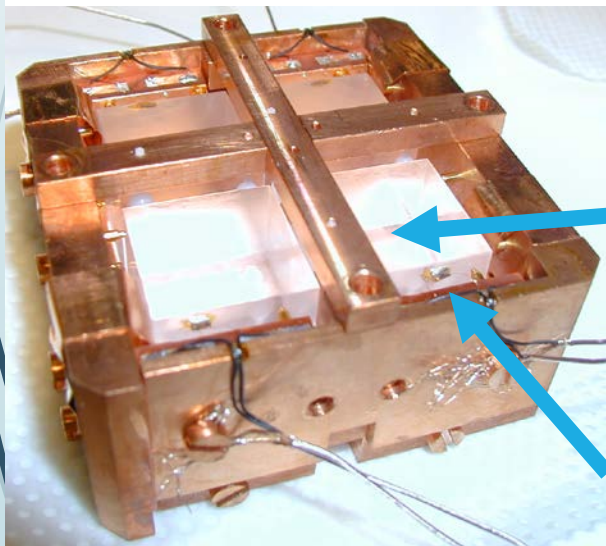
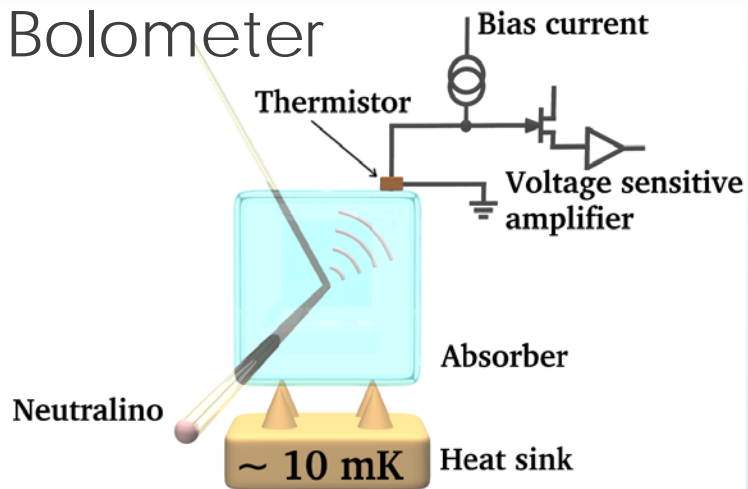


$a_p, a_n$  へユニークな制限を付けられる

Isotope	J	$\langle S_p \rangle_N$	$\langle S_n \rangle_N$
<sup>19</sup> F	1/2	0.441	-0.109
<sup>7</sup> Li	3/2	0.497	0.004
<sup>23</sup> Na	3/2	0.248	0.020
<sup>73</sup> Ge	9/2	0.009	0.372
<sup>127</sup> I	5/2	0.309	0.075
<sup>129</sup> Xe	1/2	0.028	0.359
<sup>131</sup> Xe	3/2	-0.009	-0.227

# Fを検出器に

## Bolometer

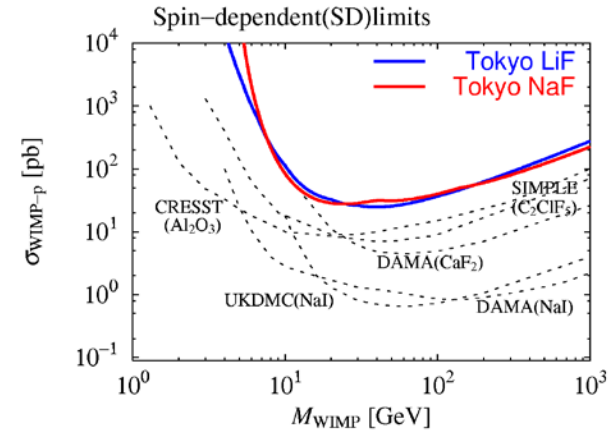
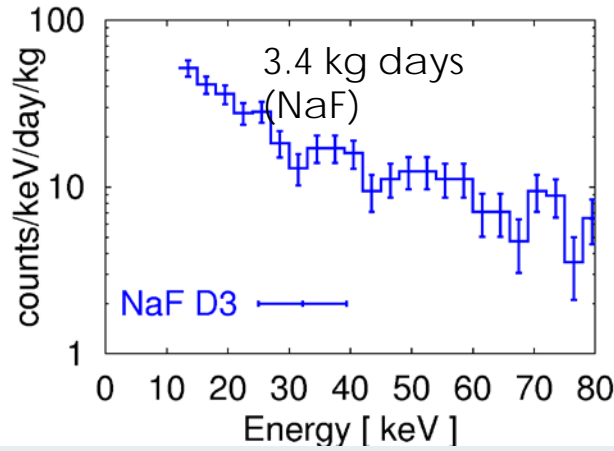
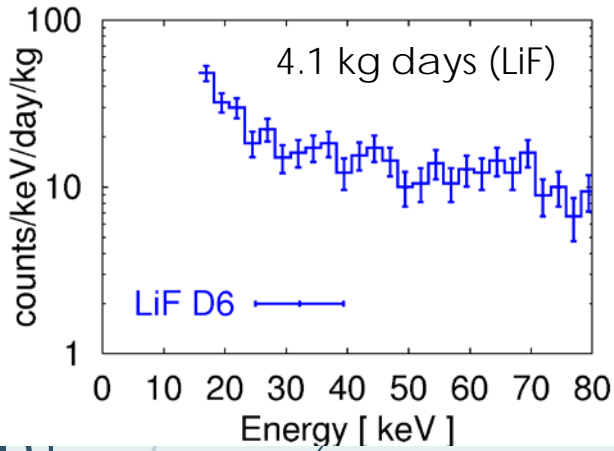


# 駐車場の片隅で

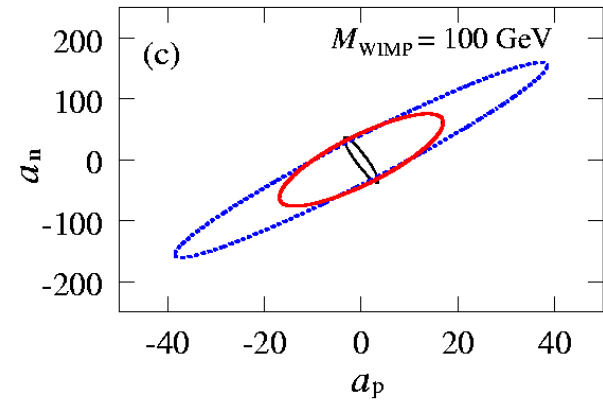
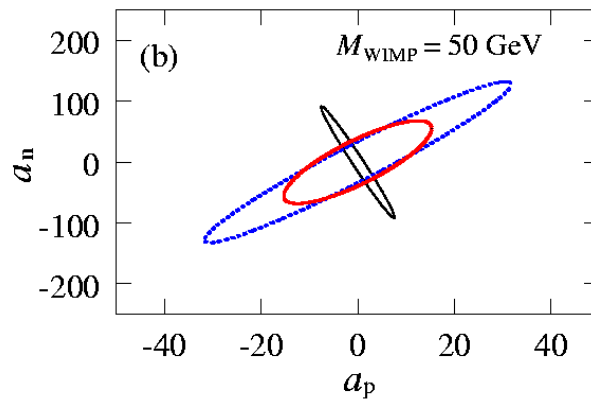
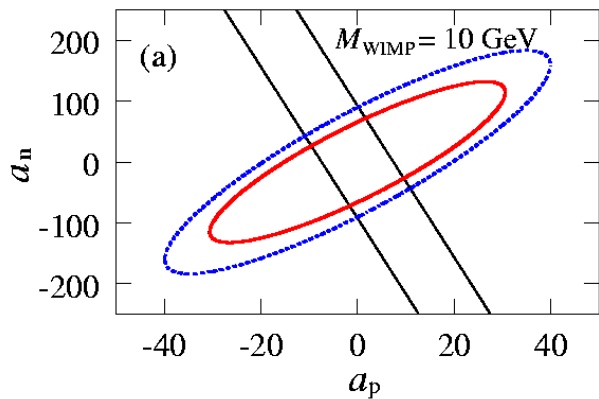
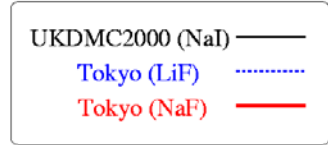


- Installation started in Nov. 1999
- LiF run: 22 Nov. 2001- 12 Jan. 2002
- NaF run: 23 Dec. 2002 – 24 Jan. 2003

# LiF/NaF bolometer結果

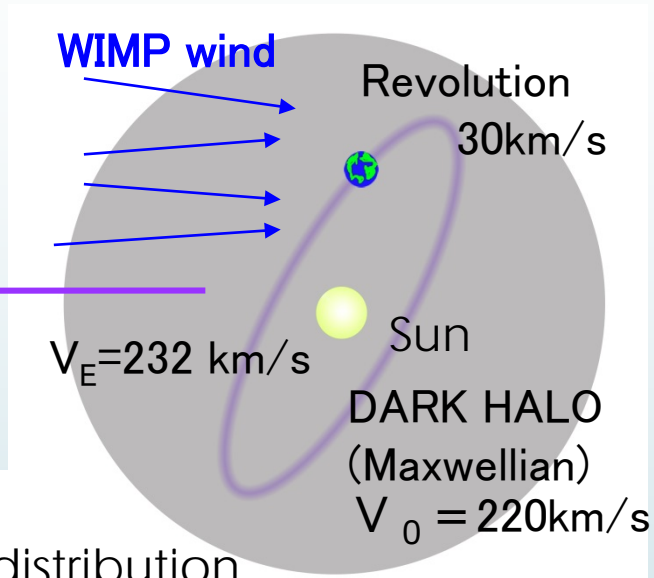
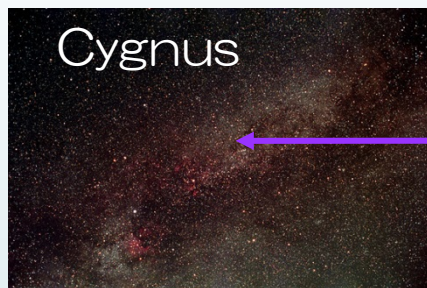


➡ BGが高いものの。。。 (Background is high...)

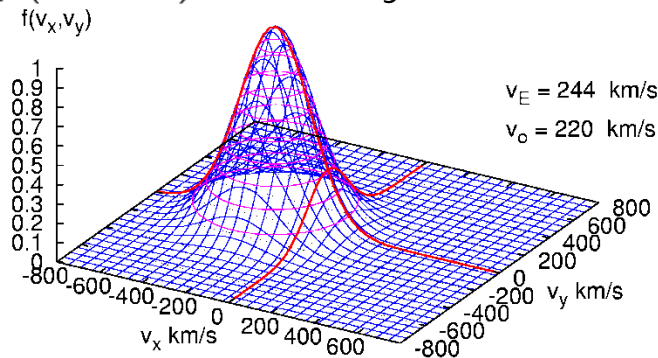


# Direction Sensitive Scintillator

- 暗黒物質の風を捕える



$f(\vec{v} + \vec{v}_E)$  Velocity distribution

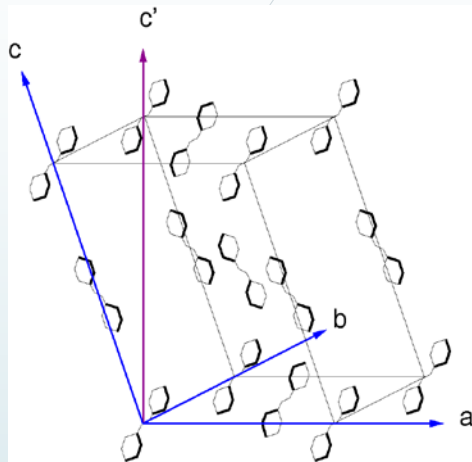


- 最初は、磁場中でのNaIなどに異方性が生じないか調べていた。

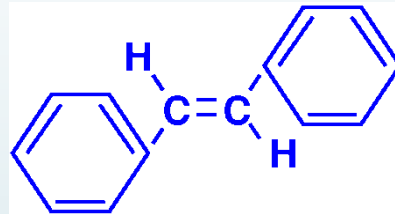


# Stilbene scintillator

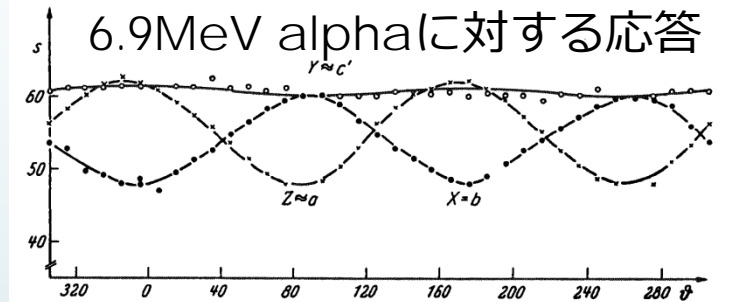
重荷電粒子の入射方向によってクエンチングファクターが異なる



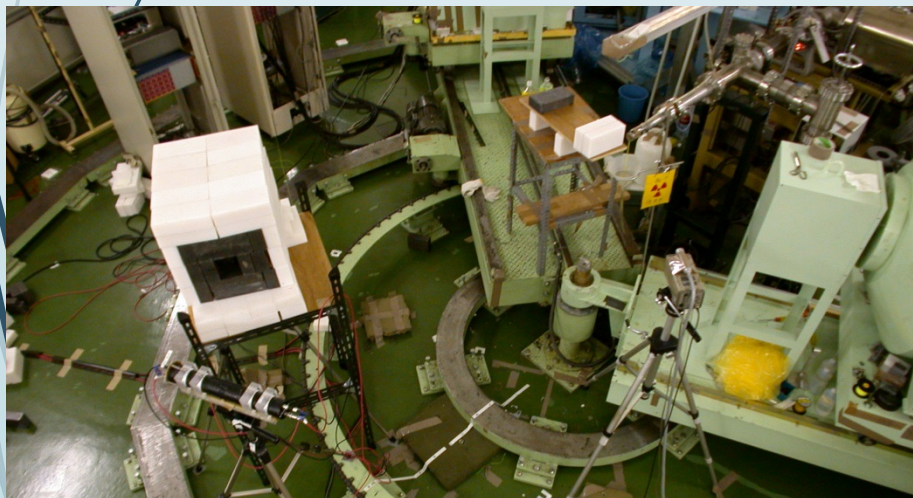
trans-stilbene



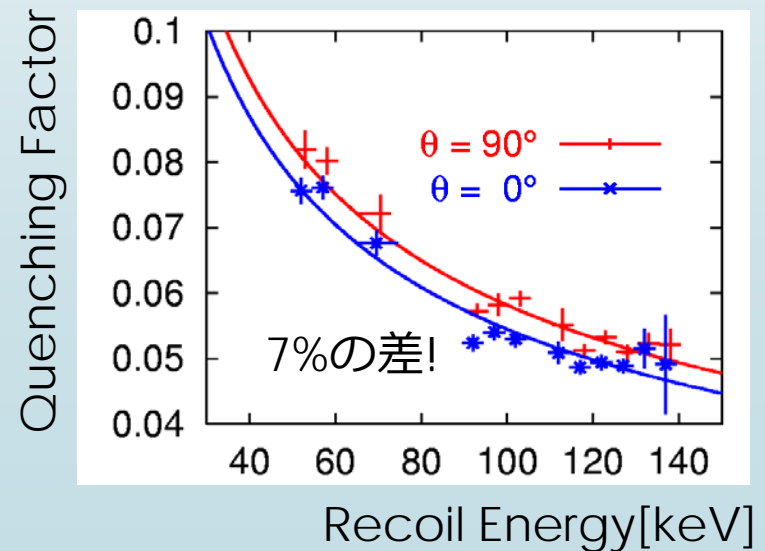
Z. Phys. 162 (1961) 122



低エネルギー中性子で実際に測定した@東工大

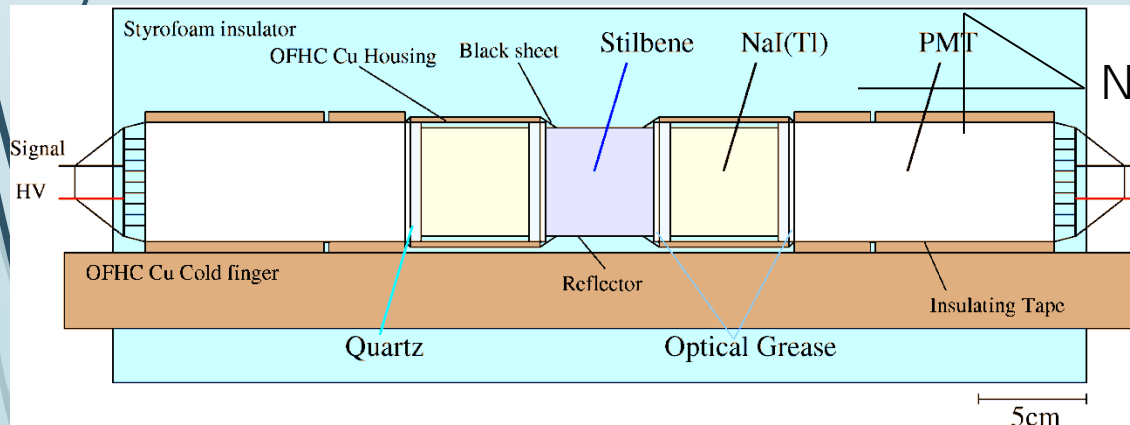
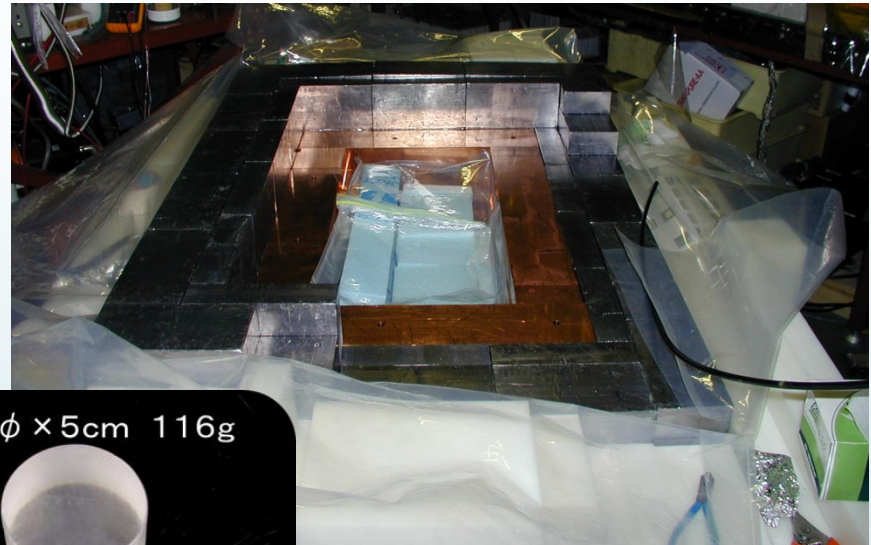
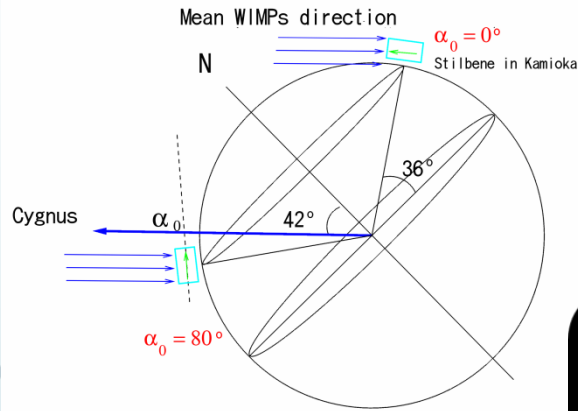


加速器実験！！



# Bolometer破却後の測定

神岡では軸に対して80度変化する

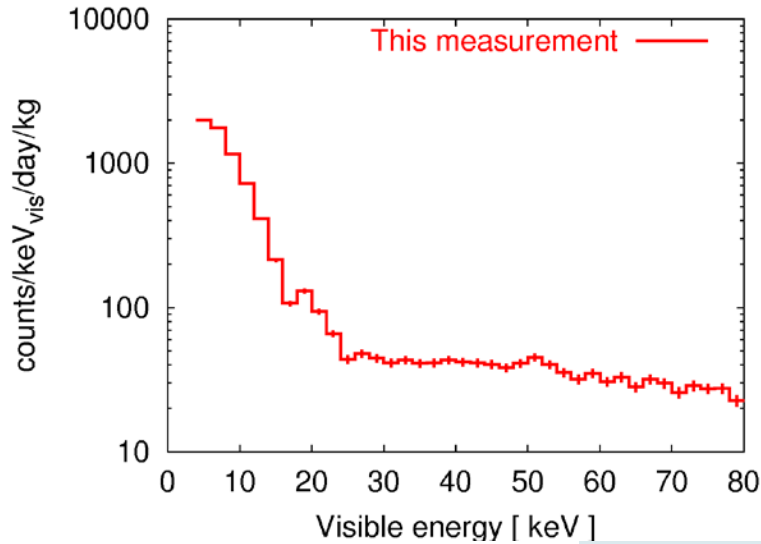


Bolometerのシールド  
XMASSのPMT

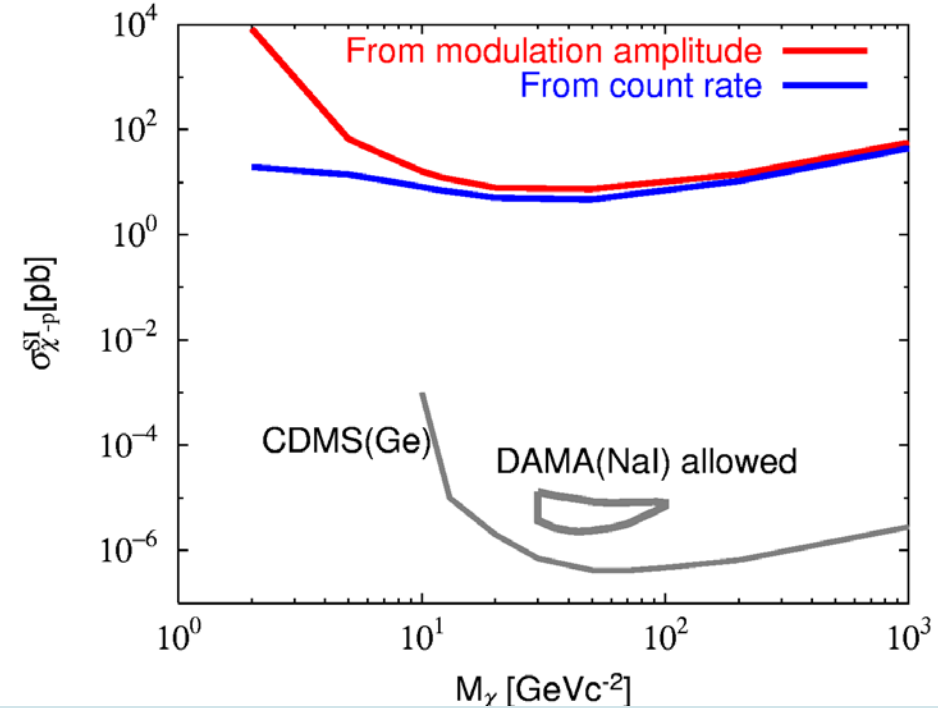
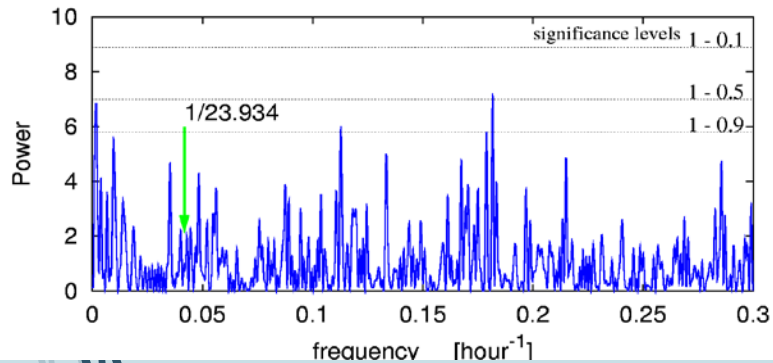
(R8778)

阪大(伏見さん)のNaI  
(堀場製作所)

# Stilbeneの結果



4-6keVeeのpower spectrum



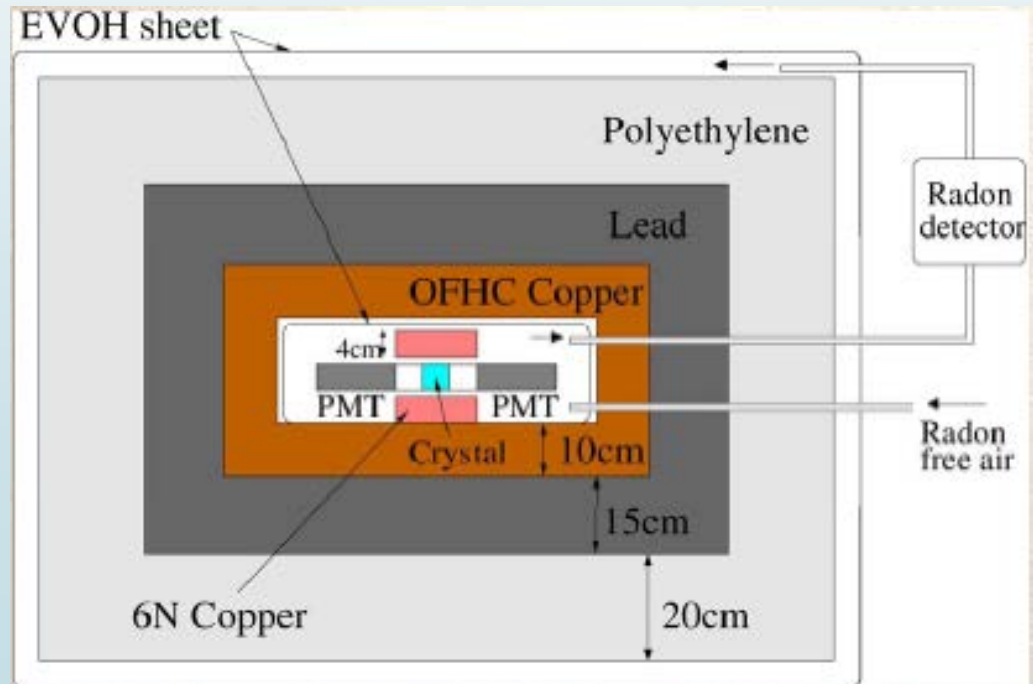
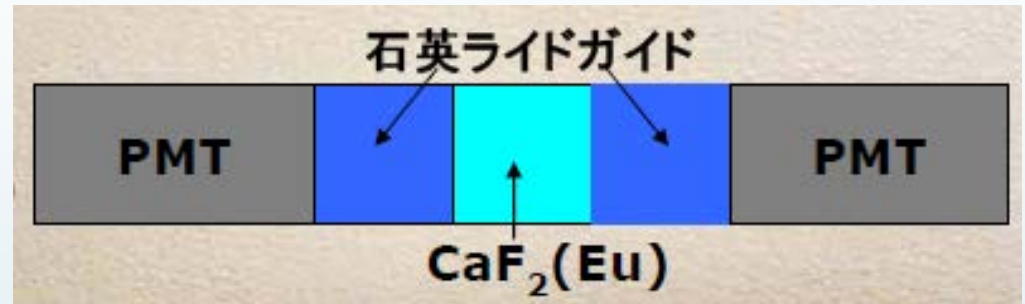
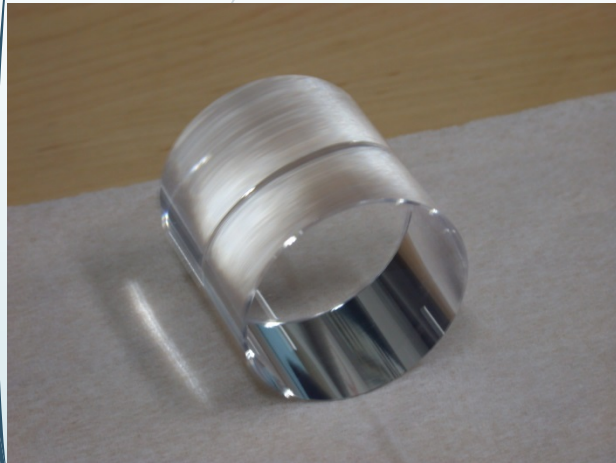
- 世界初の方向感度による制限！

▶ 実はNaIでリミット出した方が良く→CaF<sub>2</sub>(Eu)実験へ

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# CaF<sub>2</sub>(Eu)

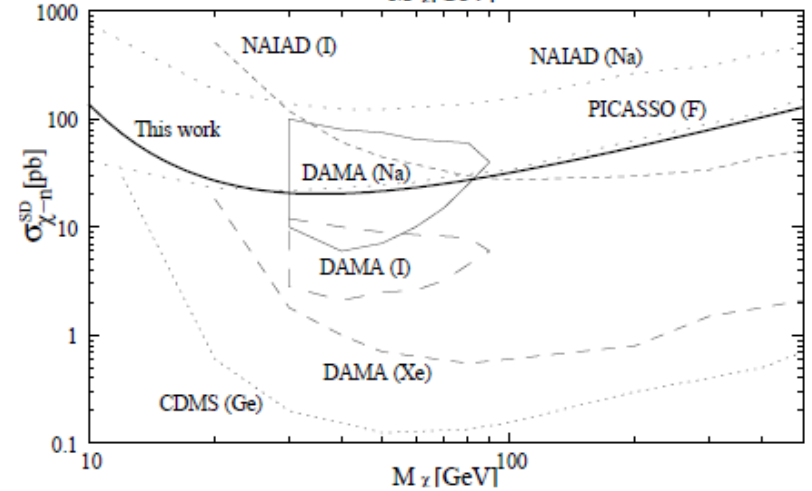
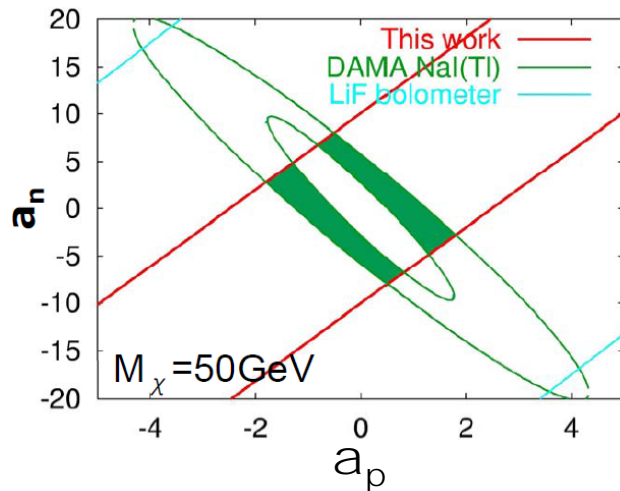
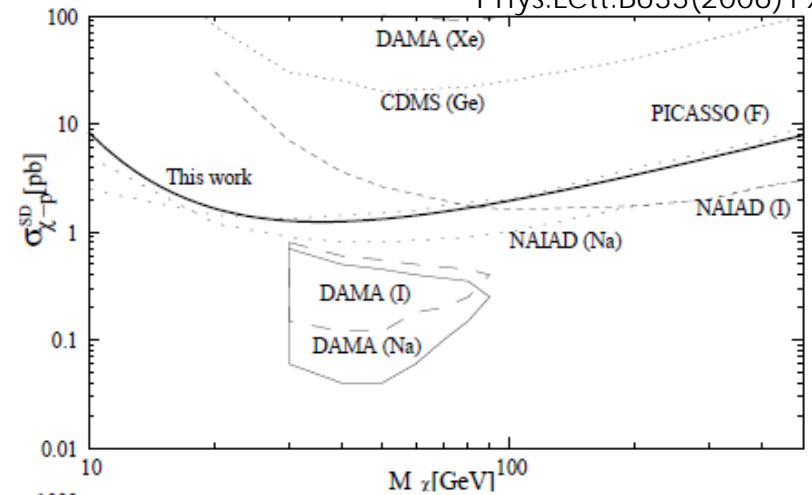
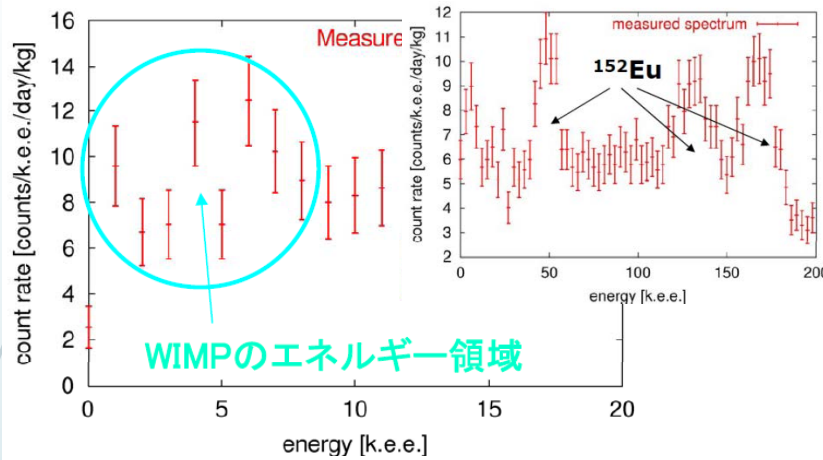
- ▶ CANDLESのpure CaF<sub>2</sub>にEuF<sub>3</sub>をドーブ



# CaF<sub>2</sub>(Eu)の結果

■ 明らかにEuがBG源だけど、みのわ研としての最終到達点

Phys.Lett.B633(2006)19



- DAMAの切り具合としてはXMASS-CMと同等の結果！NEWAGEは足元にも及ばん！
- みのわさんは、ここでやめる決断をした

# 神岡歴代実験リスト (Kamiokandeで時期分け)

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- ▶ KAMIOKANDE(1983-)
  - ▶ ELEGANT(DM, double beta)
- ▶ Super-Kamiokande-I(1996-)
  - ▶ LISM(重力波 20m干渉計)
  - ▶ みのわ研(bolometer/stilbene/CaF<sub>2</sub>),
  - ▶ K2K
- ▶ Super-Kamiokande-II(2002-)
  - ▶ XMASS 100kg, XMASS-II(鈴木聡さん)
  - ▶ KamLAND
- Super-Kamiokande-III/IV(2006-)
  - CLIO(重力波 100m干渉計)
  - XMASS
  - NEWAGE
  - CANDLES
  - KamLAND-Zen
  - T2K
  - EGADS
  - KAGRA(重力波 3km干渉計)
- Hyper-Kamiokande(202?-)

