An other look at Neutrino Properties

1) Magnetic moments
2) $\mu \rightarrow e+\gamma$

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Magnetic Moments

Magnetic Moment Matrix μ_{jk}, $k=1,2,3$ with $\begin{cases} \mu_{jj}=0 \text{ Majorana} \\ \mu_{jj}\neq 0 \text{ Dirac} \end{cases}$

Astrophysics: strong constraints on Dirac moments
less strong on Majorana moments ($\lesssim 10^{-12}\mu_B$ stellar cooling)

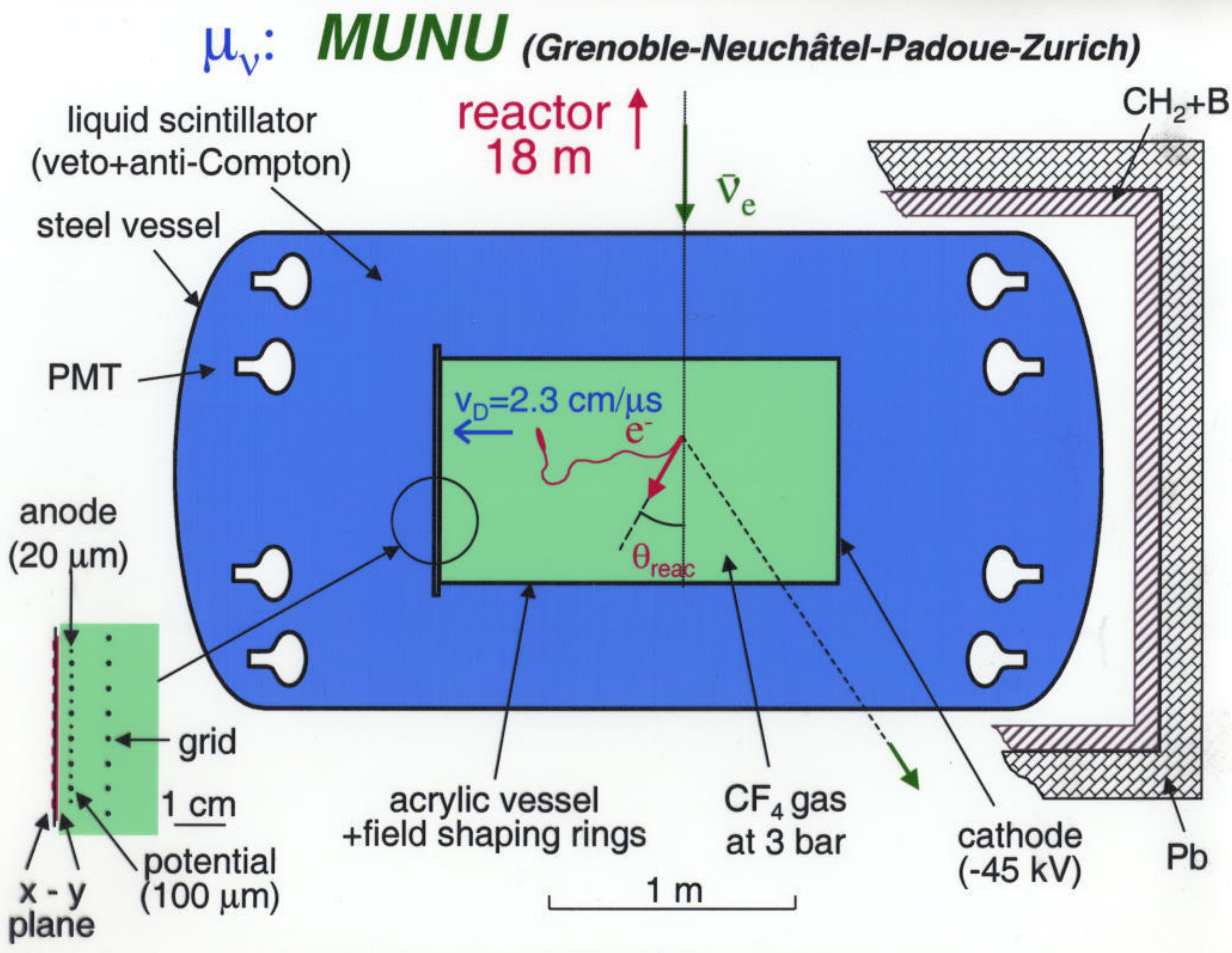
$\overset{(-)}{\nu}_e e^-$ scattering:

sun: $(\mu_e^{sol})^2 = \sum_j |\sum_k U_{ek} e^{ip_k L} \mu_{jk}|^2 \quad p_i = \sqrt{E^2 - m_i^2}$

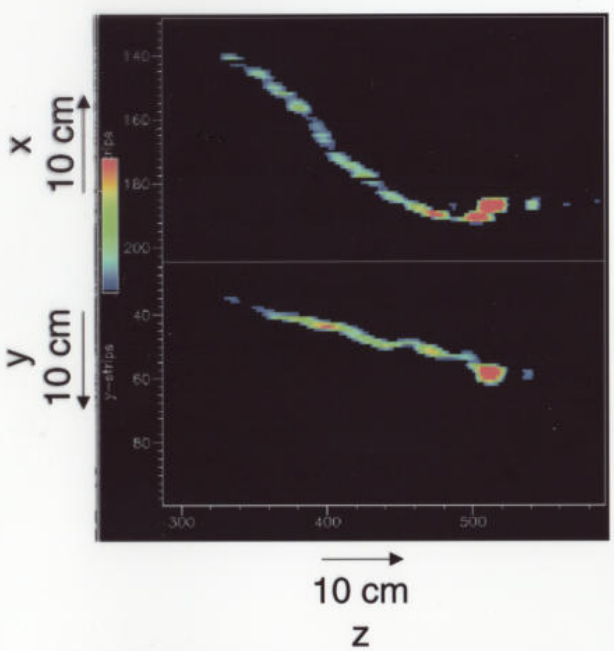
SK, Beacom + Vogel : $\mu_e^{sol} < 1.5 \cdot 10^{-10} \mu_B$ 90 % CL

reactor: $(\mu_e^{reac})^2 = \sum_j |\sum_k U_{ek} \mu_{jk}|^2$

Rovno (SB ~ 1:100) : $\mu_e^{reac} < 1.9 \cdot 10^{-10} \mu_B$ 95 % CL


μ_ν: MUNU (Grenoble-Neuchâtel-Padoue-Zurich)
reactor 18 m
$\bar{\nu}_e$
CH_2+B
liquid scintillator (veto+anti-Compton)
steel vessel
PMT
v_D=2.3 cm/μs
e^-
θ_{reac}
anode (20 μm)
grid
1 cm
x - y plane
potential (100 μm)
acrylic vessel +field shaping rings
CF_4 gas at 3 bar
cathode (-45 kV)
Pb
1 m

MUNU



TPC ⊥ reactor–detector axis, absolutely symmetric

Energy resolution: 13 % (1σ) at 1 MeV

Angular resolution: $\simeq 20^0$
(~angle dependent)

Anti–Compton threshold: 100 keV

Live time: 60% (cosmics...)

Threshold: 300 keV (but...)

Reactor: power 2750 MWth
distance 18 m

Neutrino spectrum:

E_ν<1.7 MeV: calculations (Vogel et al.)

E_ν>1.7 MeV: from measurement of beta decay of fission fragments (ILL), tested in $\bar{\nu}_e + p \Rightarrow e^+ + n$ ($\simeq$5%)

MUNU: 65 days effective reactor on (40 analyzed)
25 days effective reactor off (10.7 analyzed)

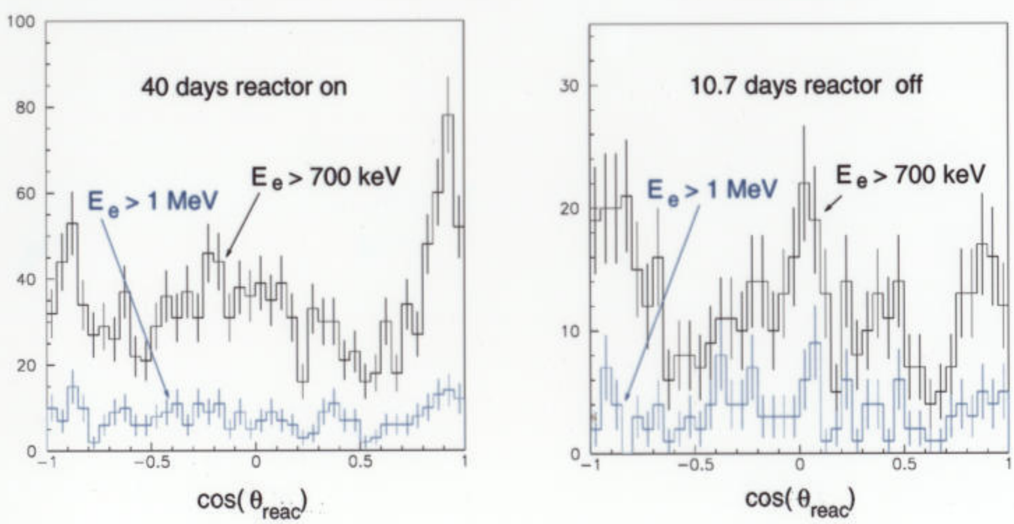
1) **Automatic filtering** eliminates:

α's, Compton, cosmics, uncontained (r>42 cm), discharges...

2) **Visual scan**:

selects **contained single electrons** (E>700 keV)

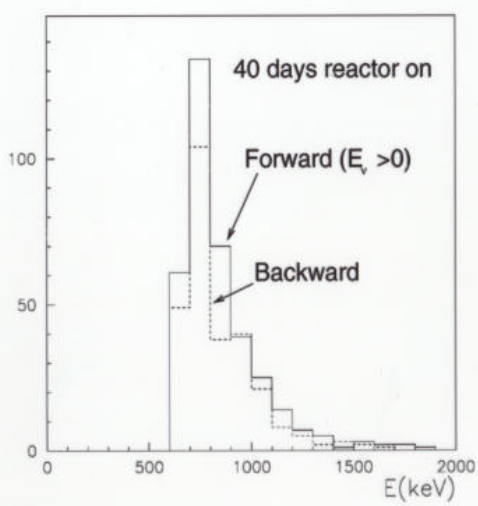
determines: $\vartheta_{det}, \varphi_{det}, \vartheta_{reac}, \varphi_{reac}$, selects: $\vartheta_{det} < 90^0$

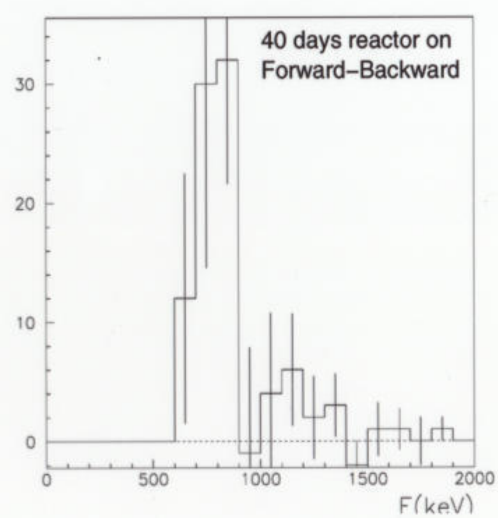


MUNU

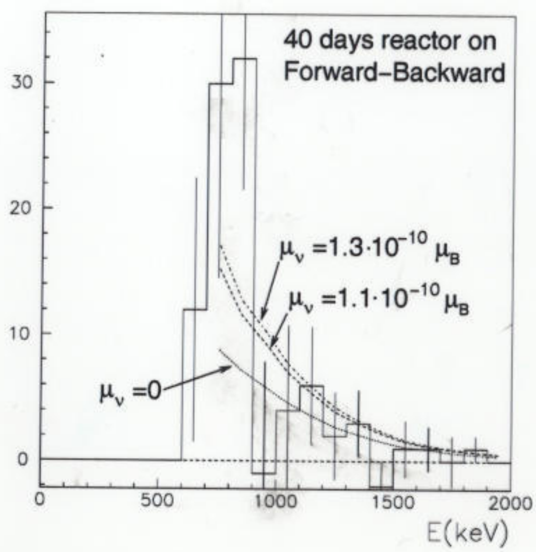
Apply kinematical cut $E_\nu(E_e, \vartheta_{reac}) > 0 (\simeq \cos(\vartheta_{reac}) > 0.7)$ (**forward**)

or $E_\nu(E_e, \pi - \vartheta_{reac}) > 0 (\simeq \cos(\vartheta_{reac}) < -0.7)$ (**backward**)





MUNU



$E_e > 700$ keV: $2.05 \pm 0.57\ \text{day}^{-1}$

calculated $\mu_\nu = 0$: $1.03\ \text{day}^{-1}$

$\mu_\nu = 0$: $\chi^2 = 10.6/6$ dof

$\mu_\nu = 1.1\cdot10^{-10}\ \mu_B$: $\chi^2 = 9.0/6$ dof (min.)

$\mu_\nu = 1.7\cdot10^{-10}\ \mu_B$: $\chi^2 = 11.6/6$ dof

→ $\mu_\nu < 1.7\cdot10^{-10}\ \mu_B$ (90% CL)

$E_e > 1$ MeV: $0.37 \pm 0.25\ \text{day}^{-1}$

calculated $\mu_\nu = 0$: $0.45\ \text{day}^{-1}$

$\mu_\nu = 0$: $\chi^2 = 0.54/3$ dof

$\mu_\nu = 1.3\cdot10^{-10}\ \mu_B$: $\chi^2 = 3.01/3$ dof

→ $\mu_\nu < 1.3\cdot10^{-10}\ \mu_B$ (90% CL)

TEXONO* Collaboration

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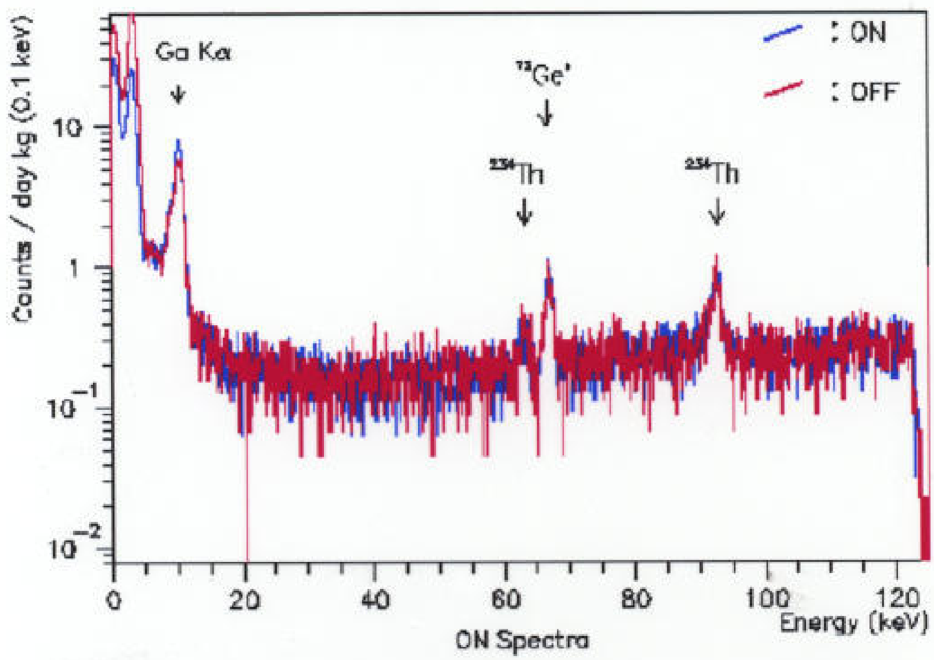
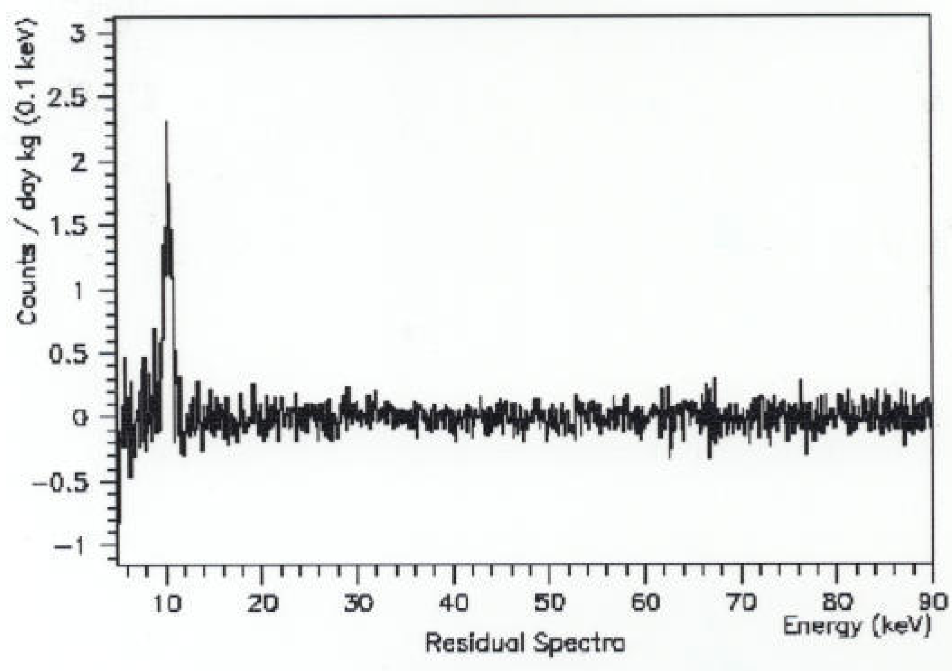
HISTORY

- Initiate : Chang Chung-Yung 1996
- First ICollaboration Meeting/Official Start : October 1997
- First Paper : October 1998
- KS Reactor Experiment Installation : June 2000
- First Ph.D. : Liu Yan , July 2000
- First Physics Data Taking : June 2001.

*Taiwan EXperiement On NeutrinO
Home Page @ http://hepmail.phys.sinica.edu.tw/~texono/

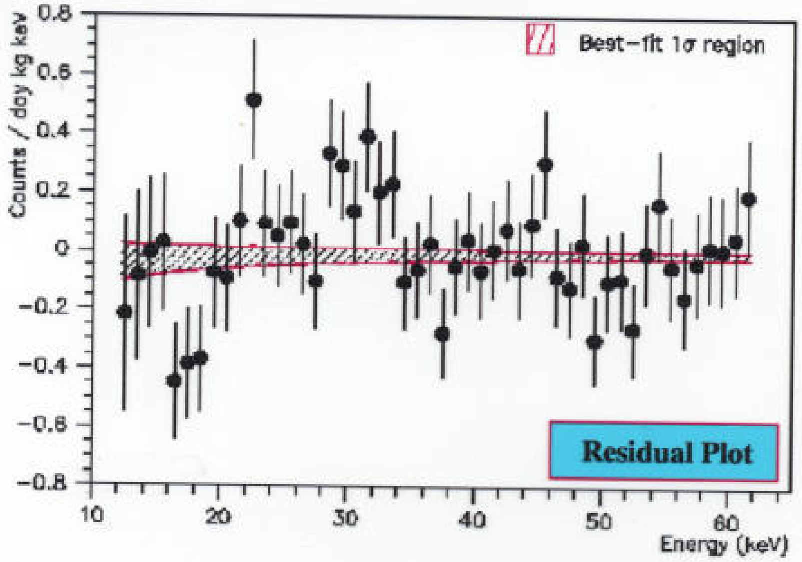
KS/P1/Ge : Spectra & Residual





Based on 62/46 days of Reactor ON/OFF data

KS/P1/Ge : First Results



- **Fit OFF spectra to ϕ_{OFF}**

E/keV	ϕ_{OFF}	χ^2/dof
12-61	$\alpha_1 e^{-\alpha_2 E} + \alpha_3 + \alpha_4 E$	39/46

- **Fit ON spectra to**

$$\phi_{OFF} + \phi_{SM} + \mu_\nu^2 \, \phi_{MM} \; [10^{-10} \mu_B]$$

Best Fit :

$\mu_\nu^2 = -1.7 \pm 2.5$ @ $\chi^2/\text{dof} = 55/49$

[Comparable sensitivities to direct-search world limits]

- **Improvements Expected :**
  - ↳ more data [$\times 3^+$ ON]
  - ↳ complete & improved analysis
  - ↳ treatment of threshold region [e.g. timing]

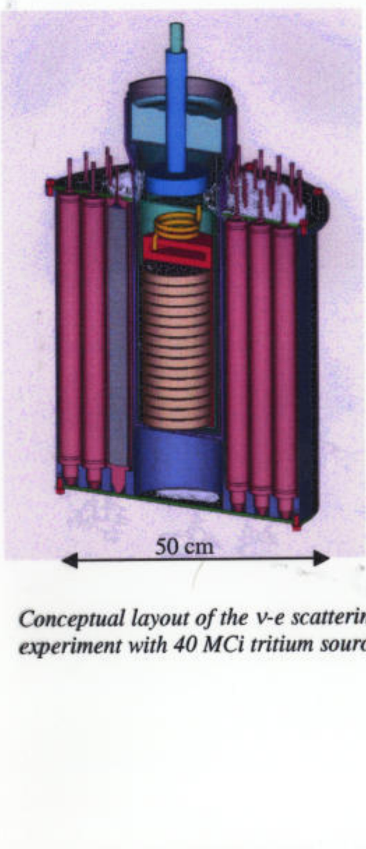
    [Aim : ~ 5 keV]

New Experiment

SEARCH FOR THE NEUTRINO MAGNETIC MOMENT

Emerging new Collaboration between:

Stanford + CWR University +… in USA and VNIIEF (Sarov) + ITEP (Moscow) +JINR (Dubna) in Russia



Conceptual layout of the ν-e scattering experiment with 40 MCi tritium source

$\tilde{\nu}_e$ - e scattering

- *New* $\tilde{\nu}_e$ **TRITIUM SOURCE of 40 MCi activity (4 kg ^3H)** **with flux density of 6×10^{14} $cm^{-2}s^{-1}$** ***(RFNC VNIIEF)***
- *New* **ULTRA-LOW-THRESHOLD DETECTORS E_{th}~10 eV:**

•**SILICON CRYODETECTOR (T=10mK) 15×100cm^3, M=3kg,** ***ionization-into-heat conversion effect (JINR-CWRU-Stanford)***

•**HIGH-PURITY-GERMANIUM DETECTOR 6×150cm^3, M=4.8kg,** ***internal proportional signal amplification by avalanche multiplication in the electric field (ITEP)***

SENSITIVITY (95% C.L.): **$\mu_\nu \leq 2.5\times10^{-12}\mu_B$**

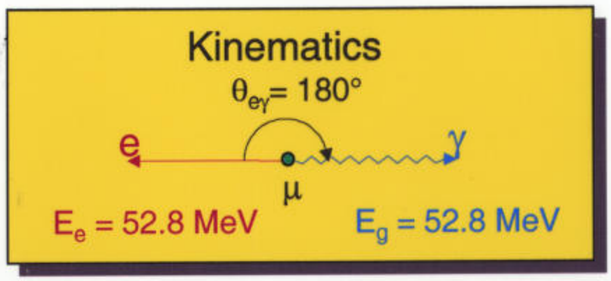
GOALS

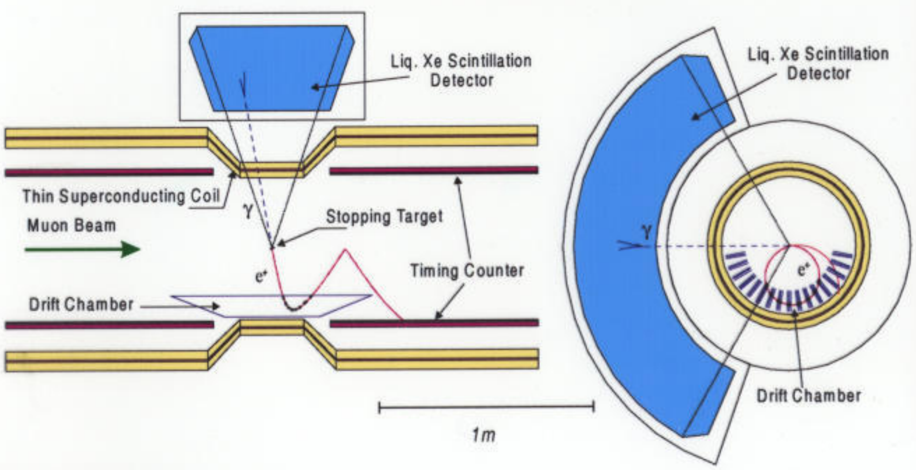
- **Search for phenomena beyond the Standard Model $\mu_\nu \cong 3(m_\nu/1eV)\times10^{-19}\ \mu_B$**
- **Increase the sensitivity compared to previous experiments by ~100 times**
- **Reach the sensitivity of astrophysical/cosmological limits $\mu_\nu \leq (1\div3)\times10^{-12}\ \mu_B$**
- **Probe the solution to the Solar neutrino problem (flux time-dependency) $\mu_\nu \geq 3\times10^{-12}\ \mu_B$**

MEG Collaboration

Institute	Country	Main Resp.	Head	Scientists	Students
ICEPP, Univ. of Tokyo	Japan	LXe Calorimeter	T. Mori	12	2
Waseda University	Japan	Cryogenics	T. Doke	5	2
INFN, Pisa	Italy	e^+ counter, trigger, M.C.	C. Bemporad	4	3
IPNS, KEK, Tsukuba	Japan	Supercoducting Solenoid	A. Maki	5	-
PSI	Switzerland	Drift Chamber, Beamline, DAQ	S. Ritt	4	-
BINP, Novosibirsk	Russia	LXe Tests and Purification	B. Khazin	4	-
Nagoya University	Japan	Cryogenics	K. Masuda	1	-
				35	7

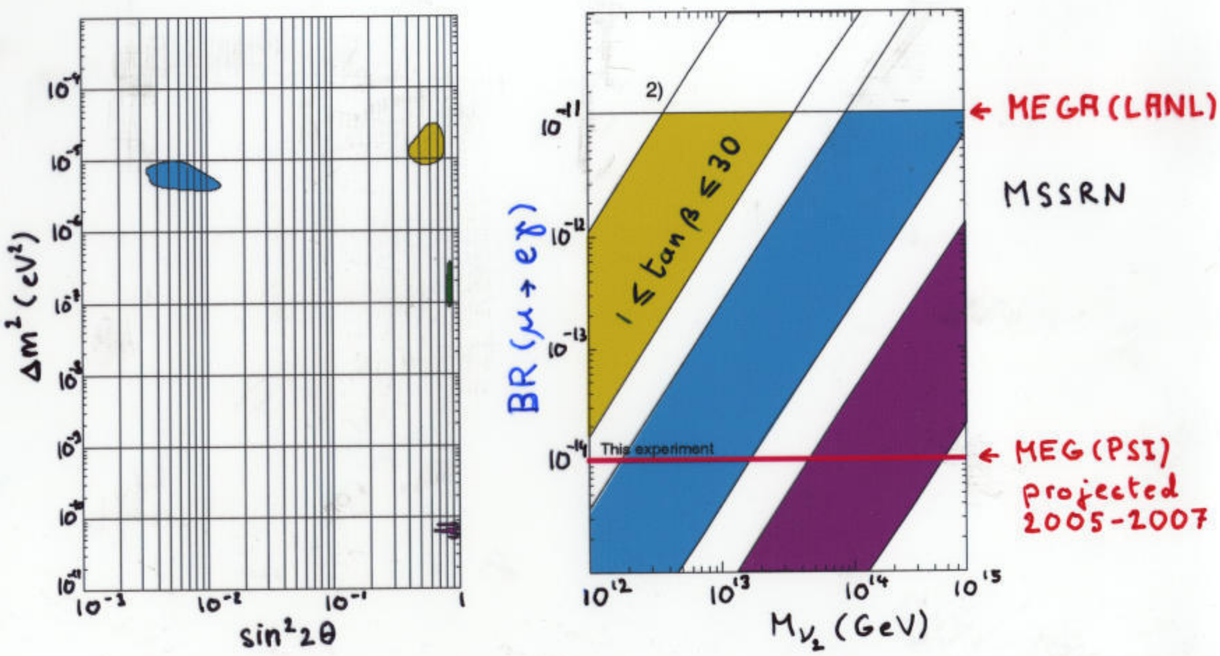
Experimental Method





- Stopped μ beam of $10^8\ s^{-1}$, 100% duty factor
- Liquid Xe calorimeter for γ detection
- Solenoidal magnetic spectrometer with gradient field
- Radial drift chambers for e^+ momentum determination
- Timing counter for e^+

$\mu \to e\gamma$: Connection with ν oscillations[1)]



1) J. Hisano and D. Nomura, Phys. Rev. D59 (1999) 116005

2) MEGA collaboration, hep-ex/9905013

Sensitivity and Background Rate

N_μ	1×10^8
T	2.2×10^7 s (~50 weeks)
$\Omega/4\pi$	0.09
ε_e	0.95
ε_γ	0.7
ε_{sel}	0.8

	FWHM
ΔE_e	0.7%
ΔE_γ	1.4%
$\Delta\theta_{e\gamma}$	12 mrad
$\Delta t_{e\gamma}$	150 ps

$BR(\mu\rightarrow e\gamma) = (N_\mu \bullet T \bullet \Omega/4\pi \bullet \varepsilon_e \bullet \varepsilon_\gamma \bullet \varepsilon_{sel})^{-1} = 0.94 \times 10^{-14}$

Prompt Background $B_{pr} \cong 10^{-17}$

Accidental Background $B_{acc} \propto \Delta E_e \bullet \Delta t_{e\gamma} \bullet (\Delta E_\gamma)^2 \bullet (\Delta\theta_{e\gamma})^2 \rightarrow 5 \times 10^{-15}$

Conclusion

Constraints on magnetic moments from laboratory experiments are getting stronger.

MUNU (60 % analyzed): $\mu_e^{reac} < 1.3 \cdot 10^{-10}\ \mu_B$ (90% CL)

Texono (Kuo–Sheng) , ^3He coming,...

$\mu \rightarrow \gamma$ may provide relevant information on neutrino properties (SUSY)