MEG実験用液体Xeプロトタイプ検出器の中性子に対するレスポンス

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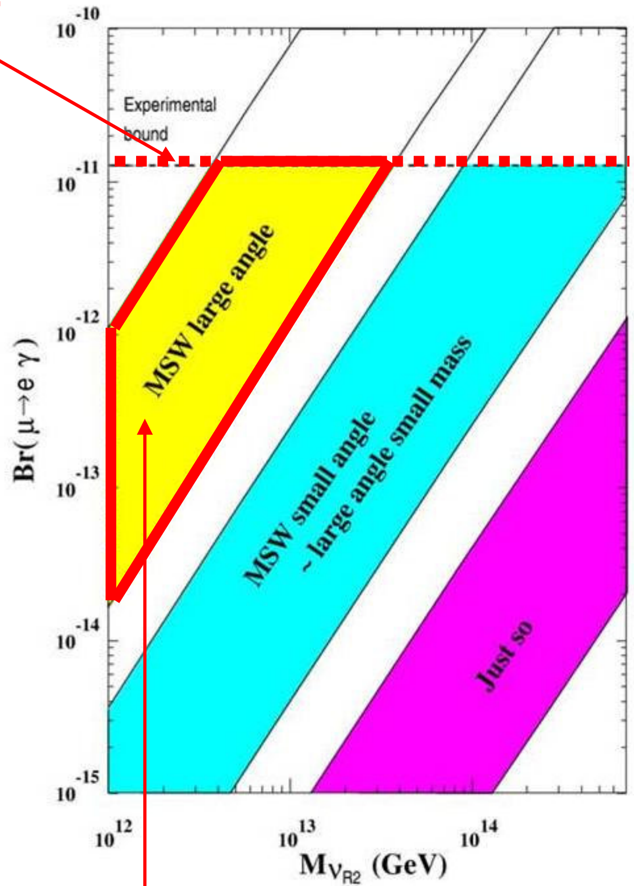
Motivation & Event Signature

- LFV process
- Forbidden in the SM
- Sensitive to SUSY-GUT, SUSY-seesaw etc.
- Our goal : $Br(\mu\to e\gamma) > 10^{-13} \sim 10^{-14}$

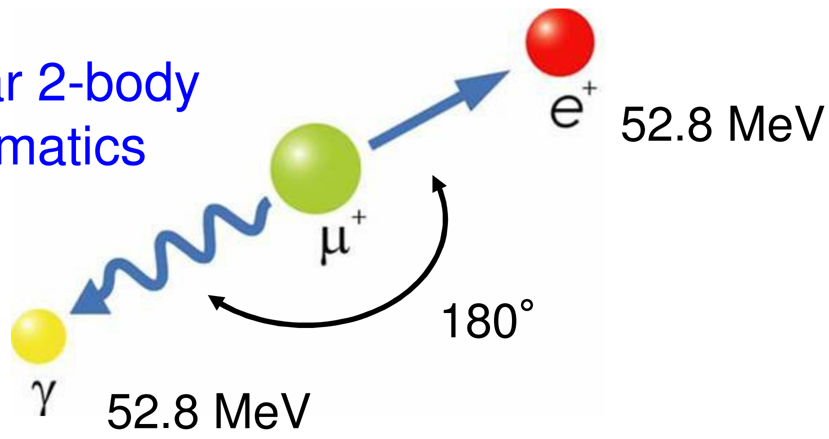
Present limit: 1.2×10^{-11}

$\mu\to e\gamma$ branching ratio



Only allowed after KamLAND

Clear 2-body kinematics



Michel decay ($\mu^+\to e^+\nu_e\nu_\mu$) + random γ

Background Rate ~ 10^{-14}

Radiative muon decay ($\mu^+\to e^+\nu_e\nu_\mu\gamma$)

Background Rate < 10^{-14}

MEG Experiment & Detector

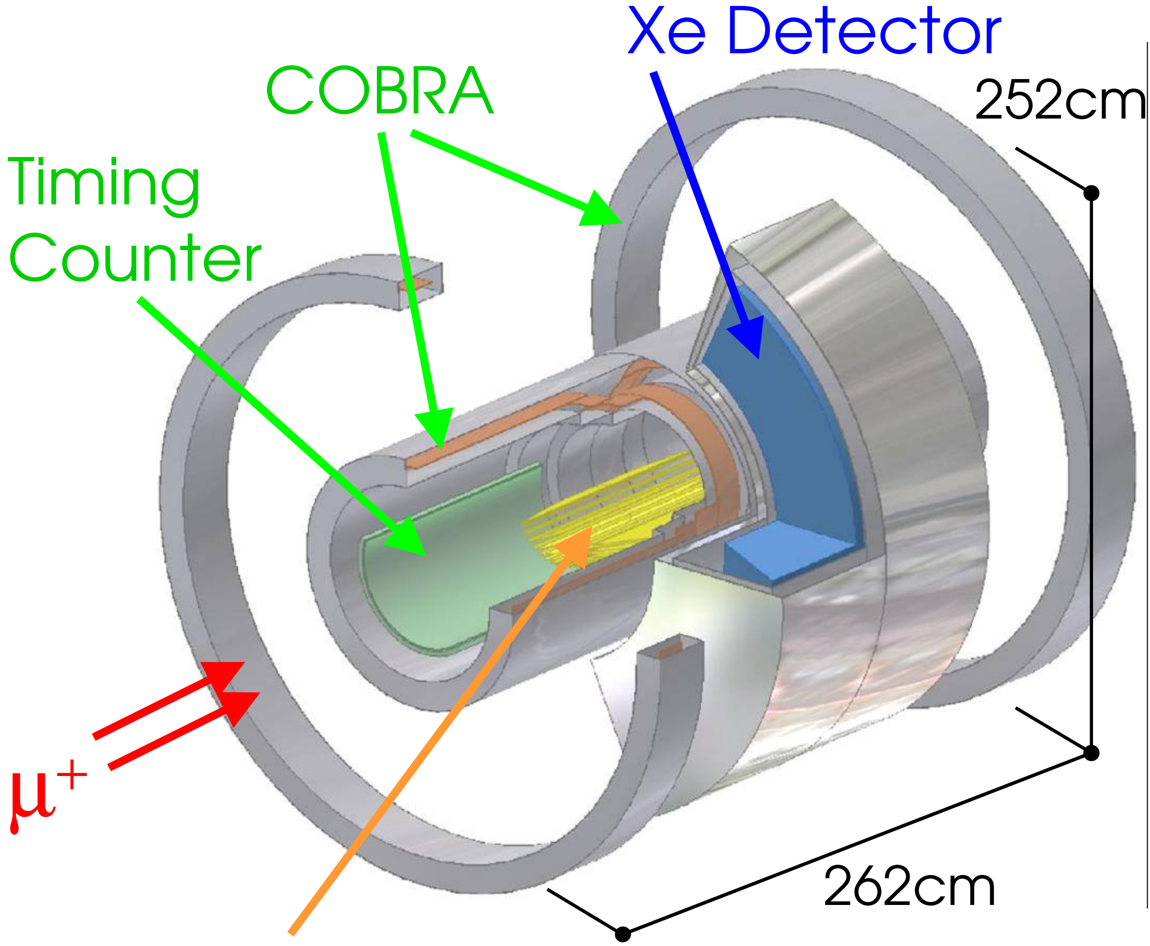
Approved in 1999,
at Paul Scherrer Institut

Physics run in 2006
Initial goal at 10^{-13},
finally to 10^{-14}

μ^+ beam :
World's most Intense
DC Beam $10^8\ \mu^+$ /s

γ detector :
800liter liquid xenon
scintillation detector
with 830 PMTs

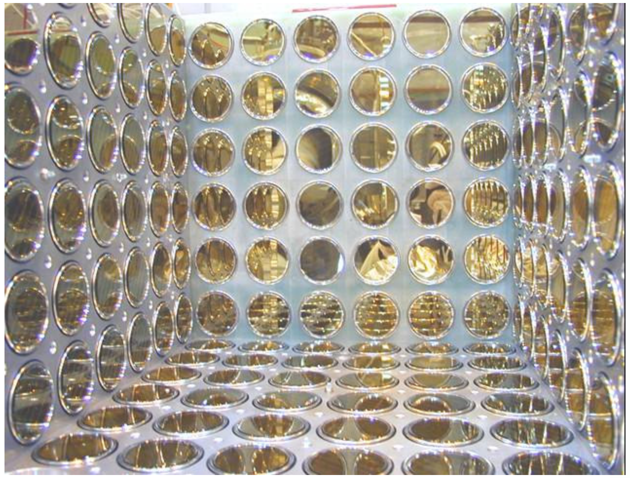
e^+ detector :
solenoidal magnetic
spectrometer with a gradient
magnetic field (COBRA)



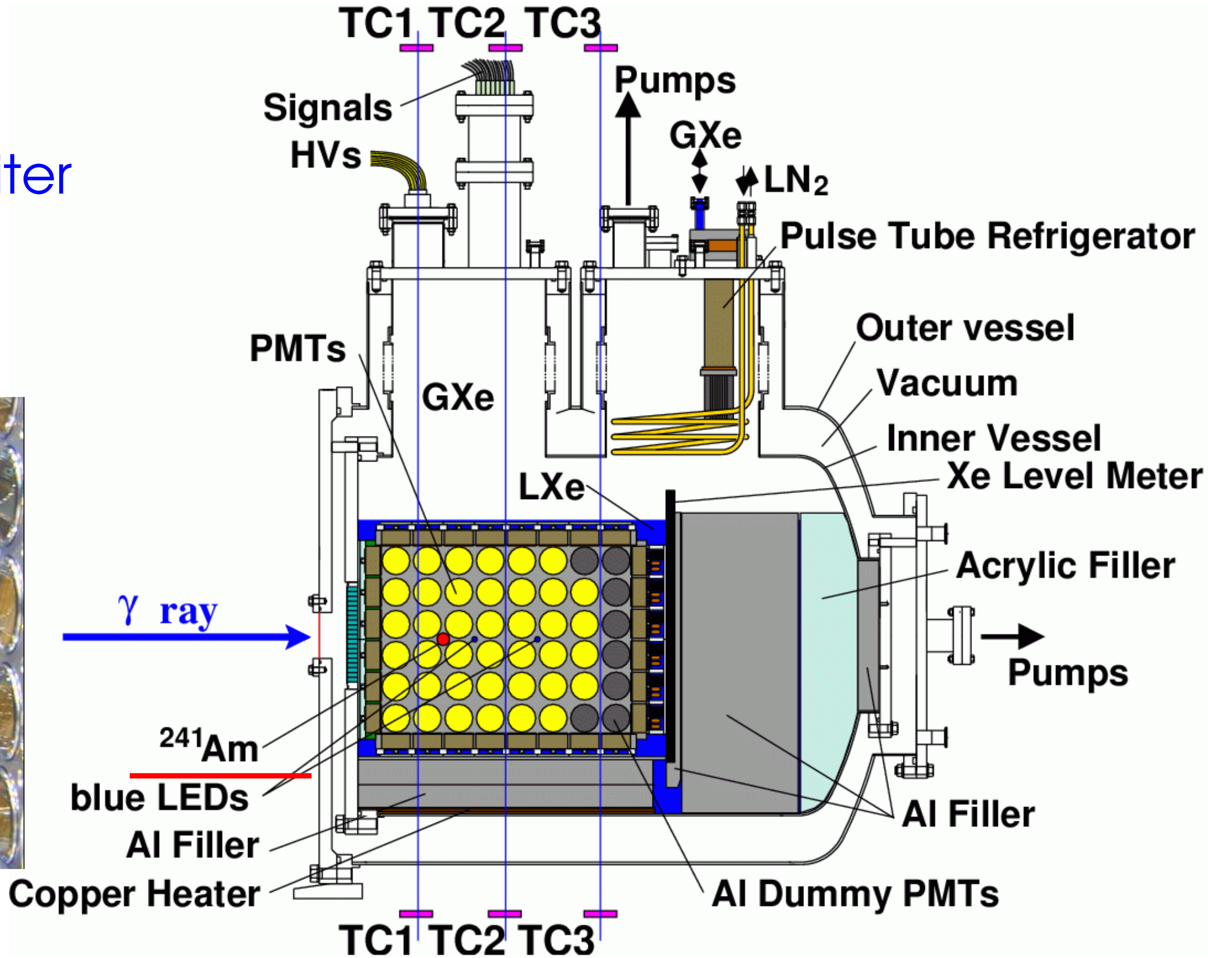
(**29pSB-9** H. Nishiguchi)

Large Prototype Detector

Smaller acceptance
Xe detector
Active Volume : 68.6 liter
228 2" PMTs (R6041Q)



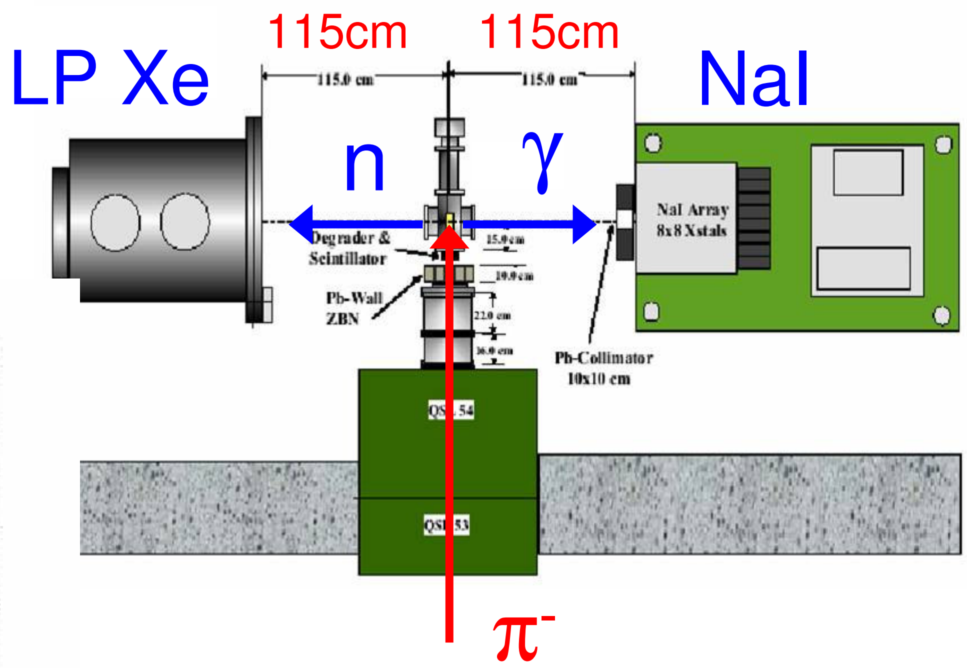
Inside View

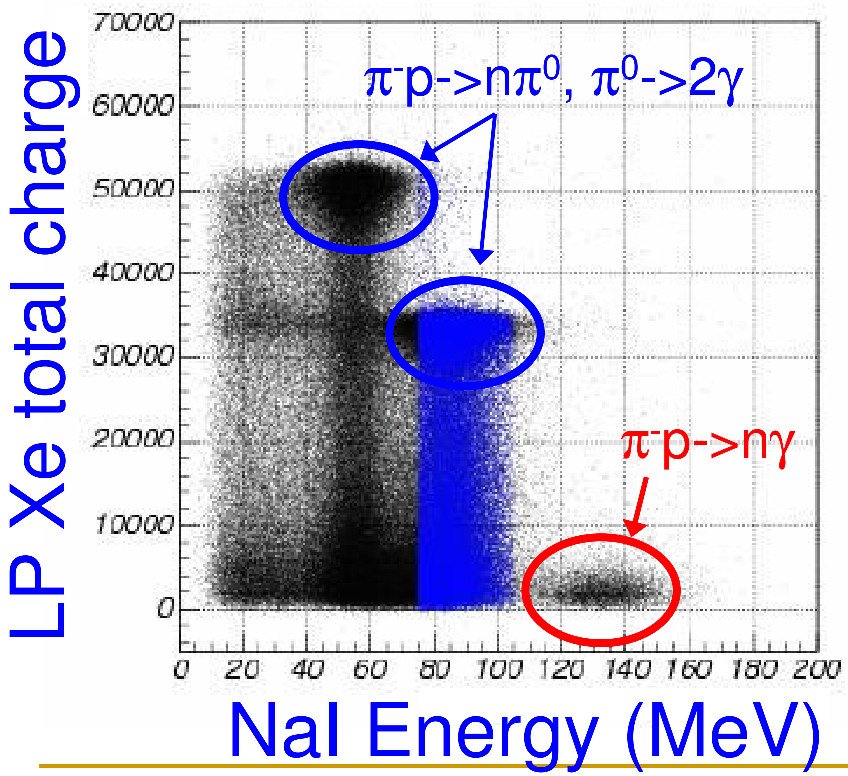


π^0 Beam Test at PSI

For neutron measurement

- $\pi^- + p \to n(8.9\text{MeV}) + \gamma\ (129\text{MeV})$
- Beam induced thermal neutron

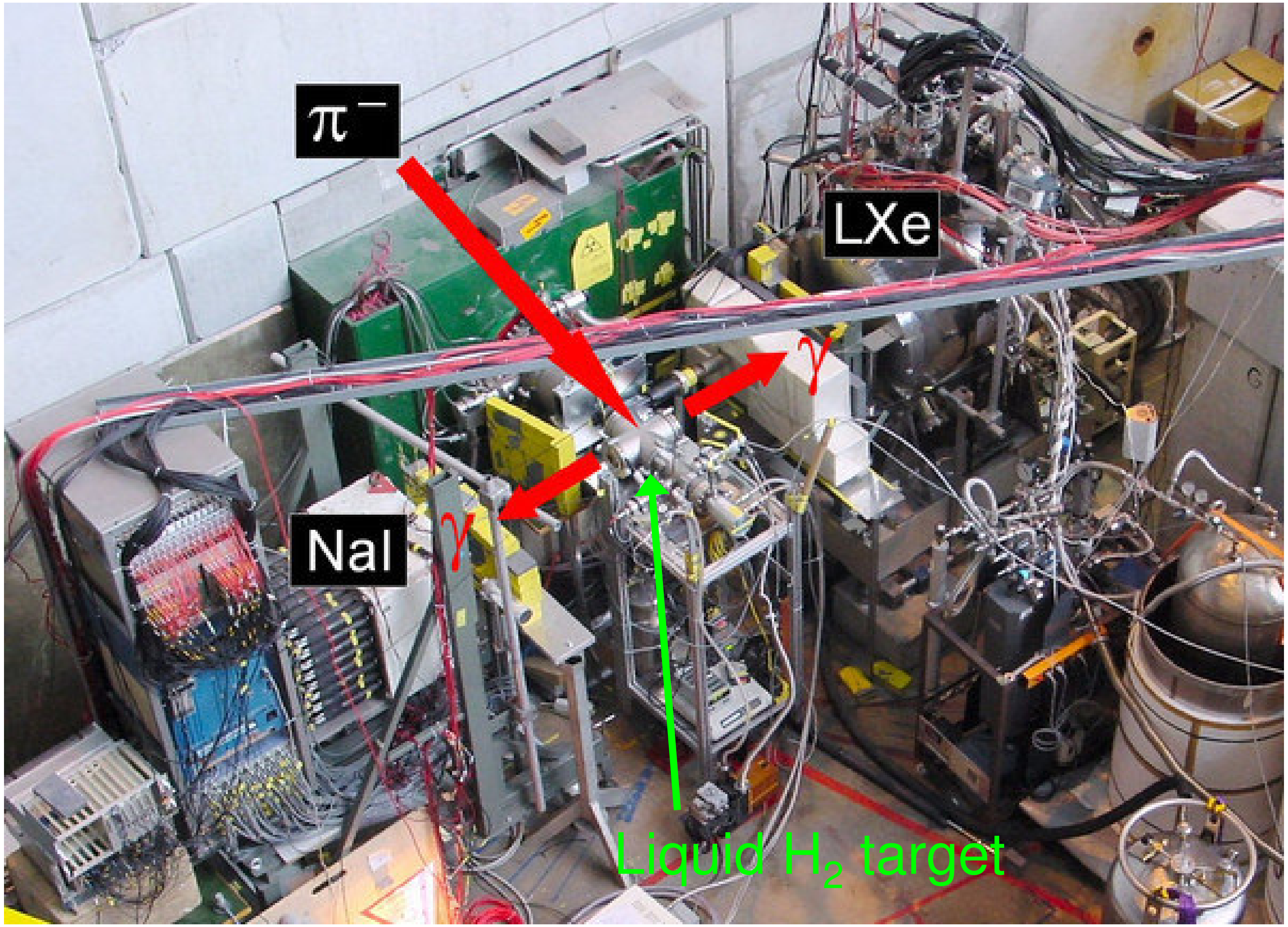




Main purpose of this beam test

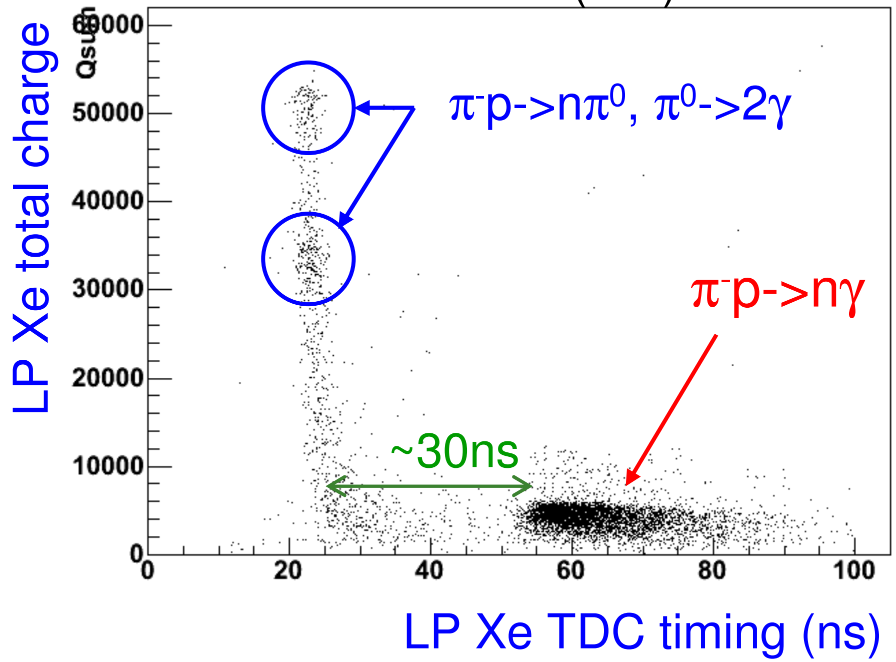
- π^- (at rest) $+ p \to \pi^0 + n$,
  $\pi^0(28\text{MeV/c}) \to \gamma + \gamma$
  $(54.9\text{MeV} < E_\gamma < 82.9\text{MeV})$
  Almost monochromatic γ calibration of around 52.8MeV

π^0 Beam Test at PSI

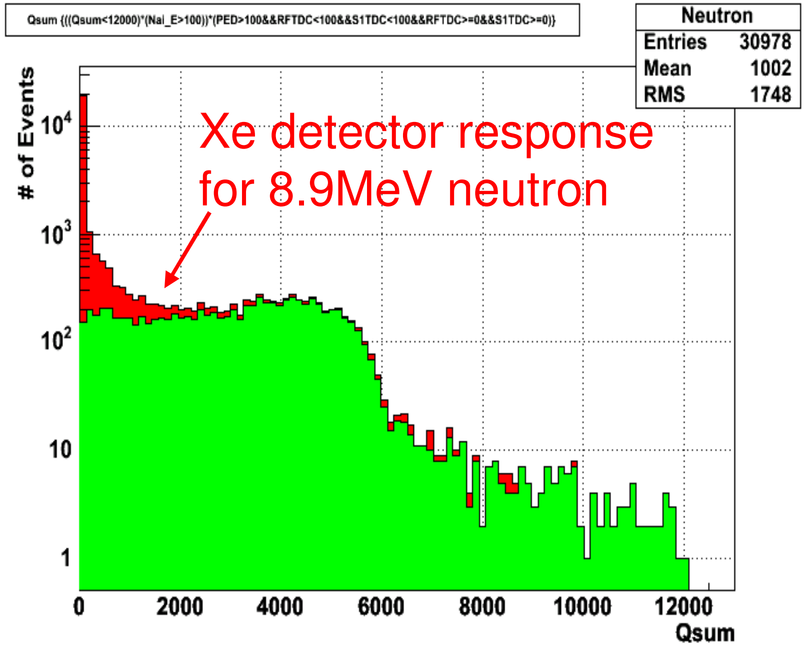


Neutron Response in Large Prototype

E(NaI)>100MeV



E(NaI)>100MeV, Qsum<20000

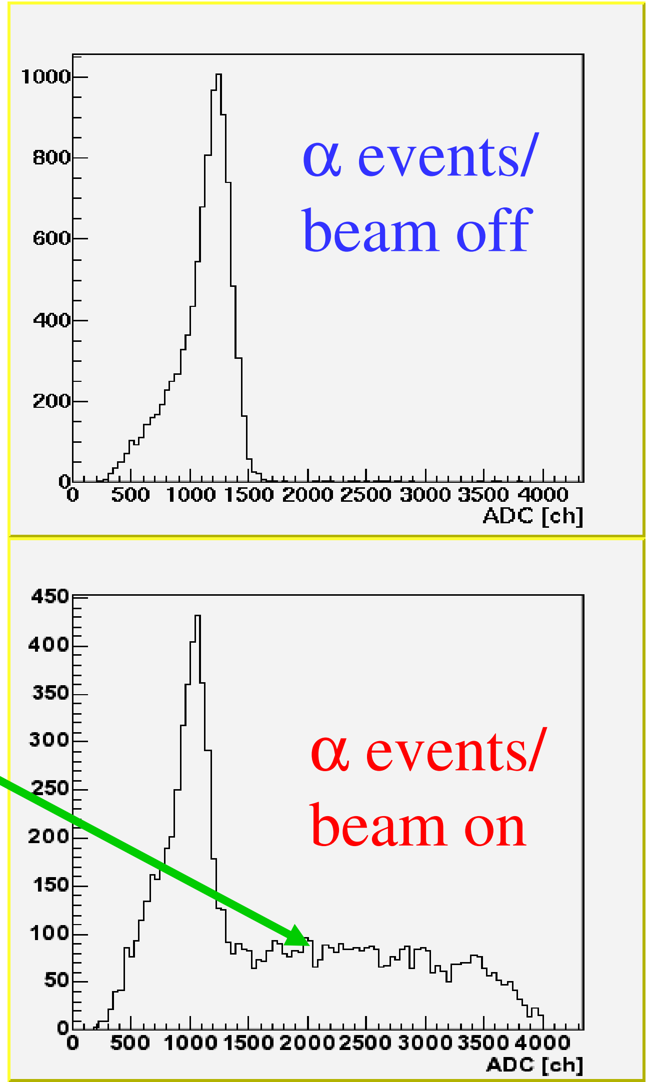


Neutron TOF ~ 30ns (115cm/0.14c)
Neutron Kenergy=8.9 MeV
No bias data for Xe
Require the beam correlation

It might be the first time to detect the fast neutron like 8.9MeV in such a large scale Xe detector.
45% detection efficiency @0MeV th.
30% @1MeV th.

Thermal Neutron Response in LP

- π^- beam test for LP energy calibration
- Alpha data taken w/wo beam



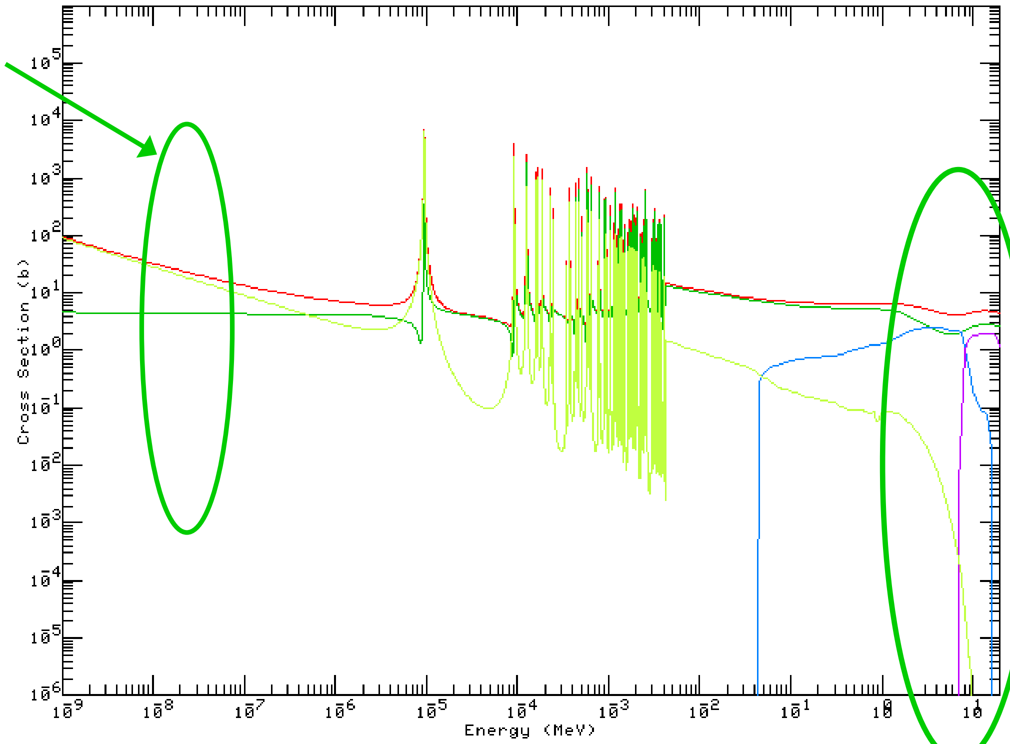
- most probably caused by beam-related neutrons, (thermal neutron capture?)
- Energy deposit up to 9-10 MeV

What was occurred in Xe?

For example, (^{129}Xe + n) cross section (from ENDF-VI Library)

Thermal neutron Region

Capture process is dominant
length ~ 3cm



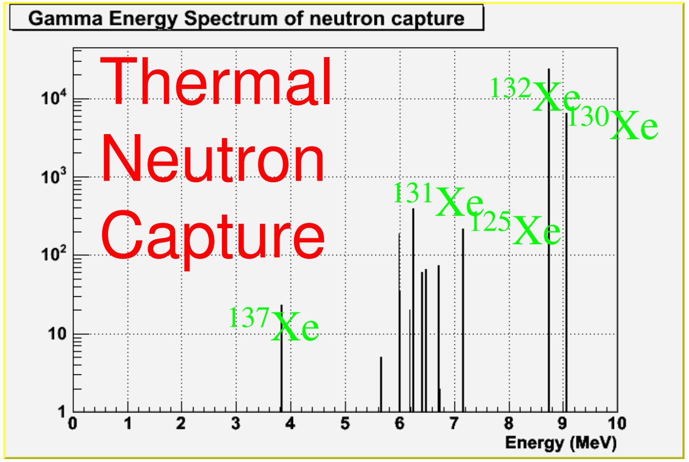
10^{-9} 10MeV

8.9MeV Region

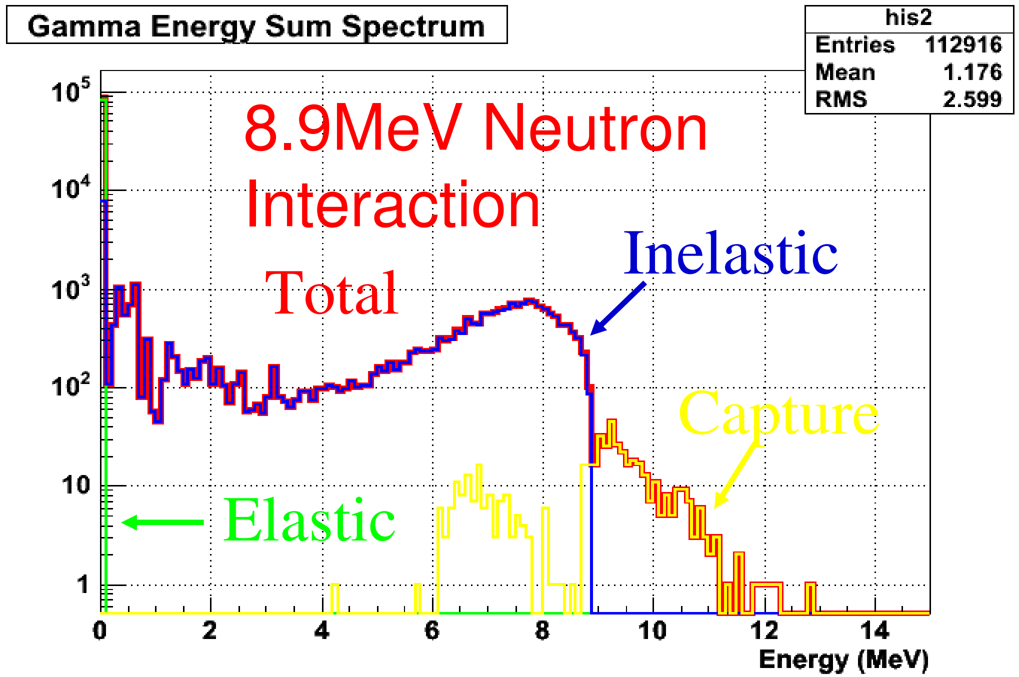
Elastic, (z,n), and (z,2n) is occurred.
~3 barn
~ 24cm

Data
- Total
- Elastic
- (z,n)
- (z,2n)
- capture

Simple Calculation



many γ's sum
125Xe : 7.15MeV
127Xe : 6.73MeV
129Xe : 6.71MeV
130Xe : 9.06MeV
131Xe : 6.24, 6.41MeV
132Xe : 8.74MeV
133Xe : 6.01, 6.24MeV
135Xe : 6.18, 5.66MeV
137Xe : 3.83MeV



Dominant process : Xe + n -> Xe + n + γ
No γ from Xe + n -> Xe + n + n
Small difference between the data and MC

Target : Only Liquid Xe 37.2x37.2x49.6cm3
Base : Geant4 + low energy neutron data formats of ENDF/B-VI (from thermal energies to 20 MeV)

Neutron Background Concern

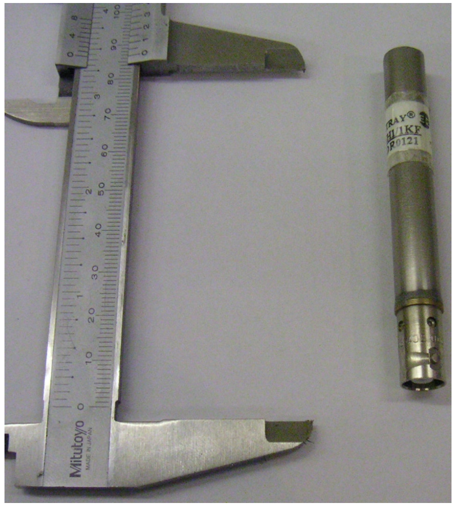
- Thermal neutron capture signal can affect PMT outputs from the continuous energy deposit (up to 10MeV).
  - If $20n/cm^2/s$, ~2μA @10^6Gain in a PMT in final detector.
  - γ from radiative muon decay, μ -> eννγ, ~0.4μA
- Non thermal neutron component is also important.
- New PMT(R9288) development for the environment such as higher rate and for high Q.E.

（**29aSB-3** Y. Hisamatsu, **29aSB-4** A. Yamaguchi）

- Succeeded to develop the PMT available up to 2μA current
- The flux of the neutron in a experimental hall should be less than $20n/cm^2/s$ for the MEG Experiment.

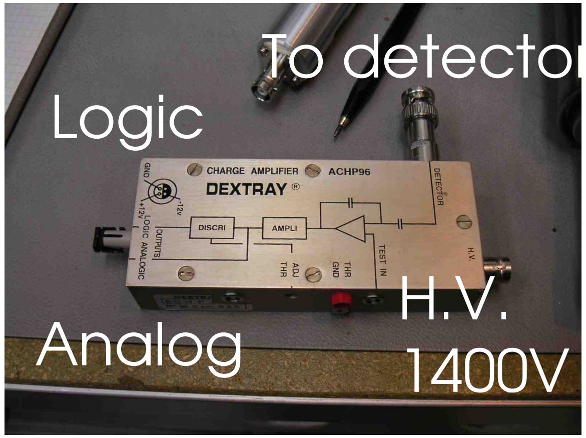
Thermal neutron detection by ^{3}He

$n + {}^3He \rightarrow p + {}^3T$, Q=765keV, σ=5400barns

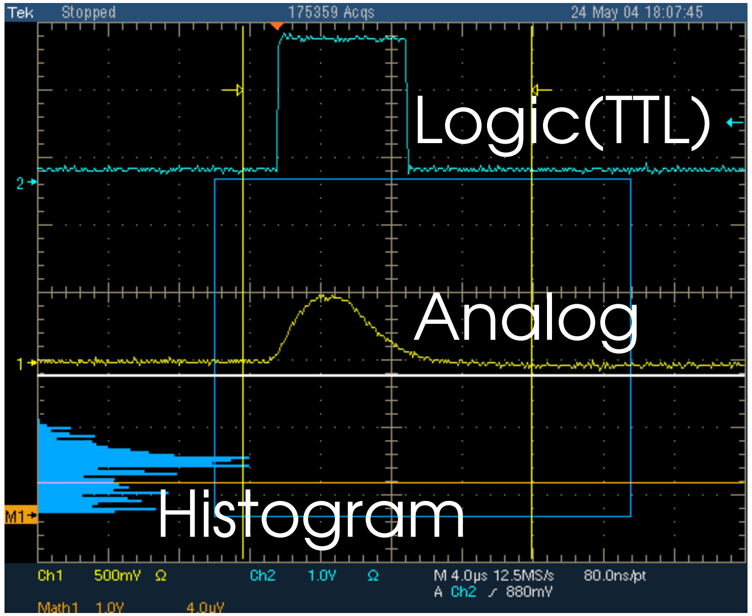


^{3}He propotional counter

Model : 0.5NH1/1KF (DEXTRAY)
Sensitivity (c/s per n/cm^2/s) : 0.5
Active length/diam. : 10mm/10mm
Inside gas : ^{3}He 8bars + Kr 2bars



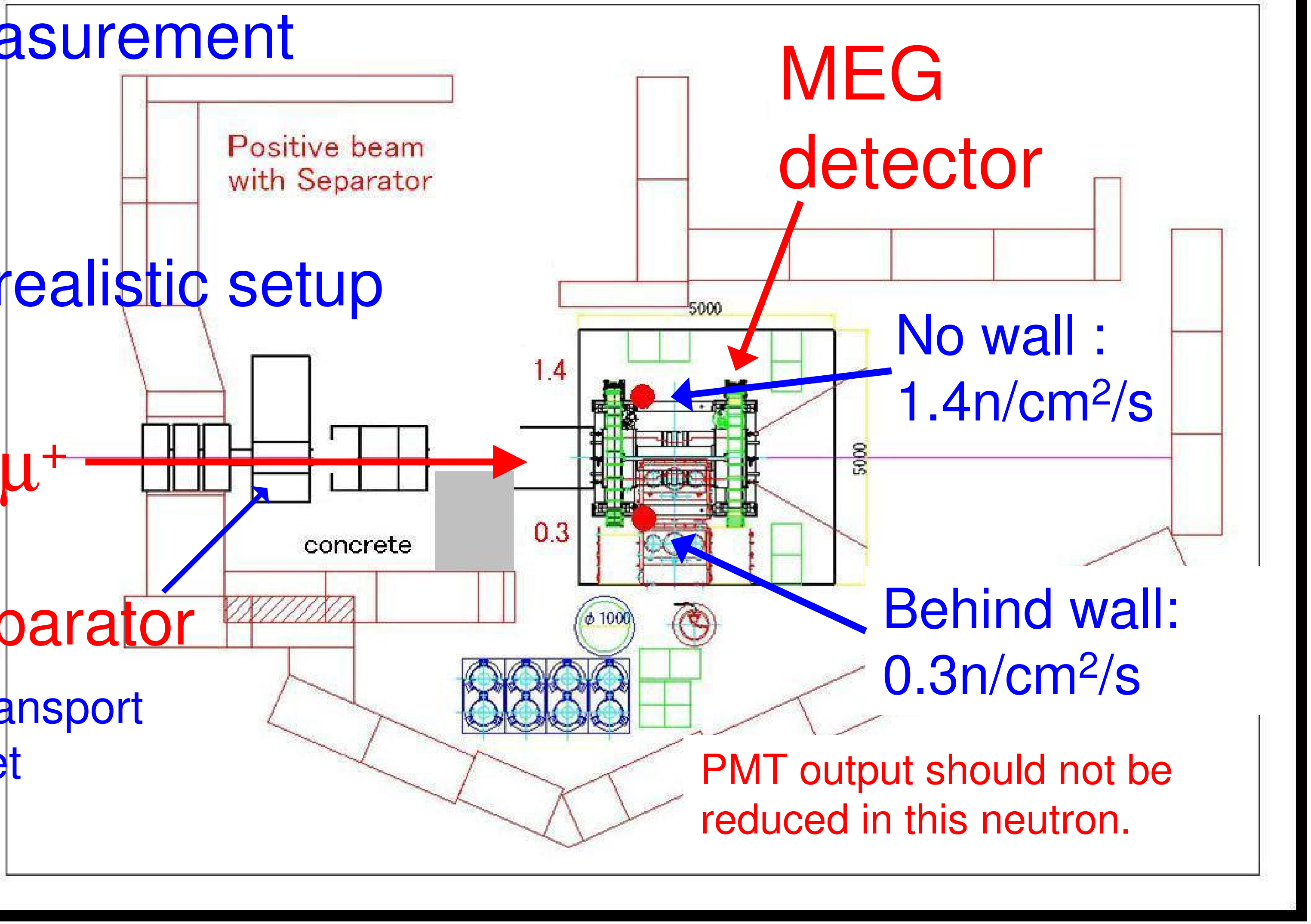
Raw data (4μs/1div.)



Thermal neutron in PSI (μ^+)

^{3}He measurement

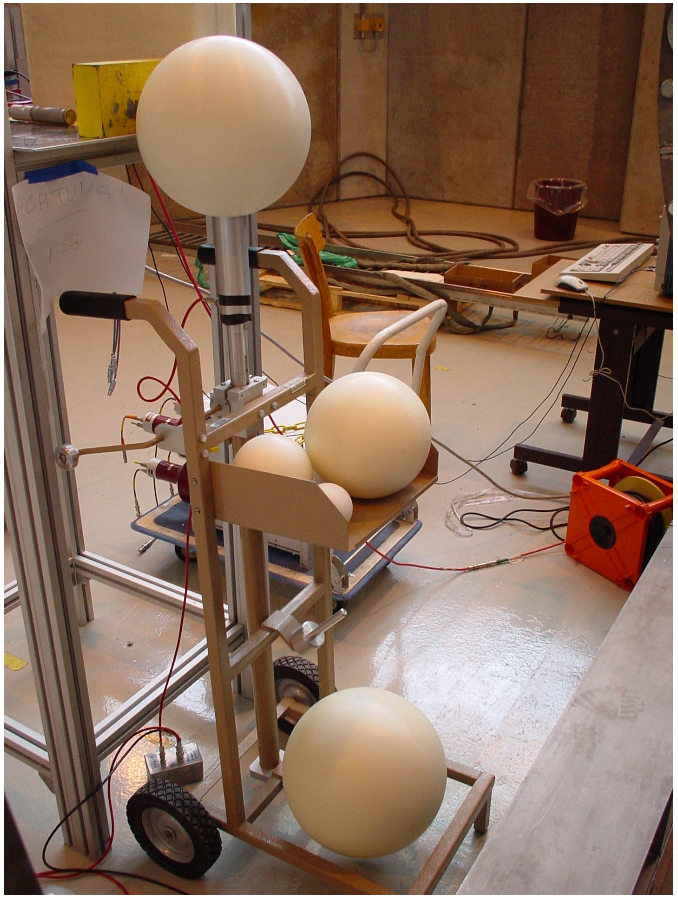
Almost realistic setup



No beam transport solenoid yet

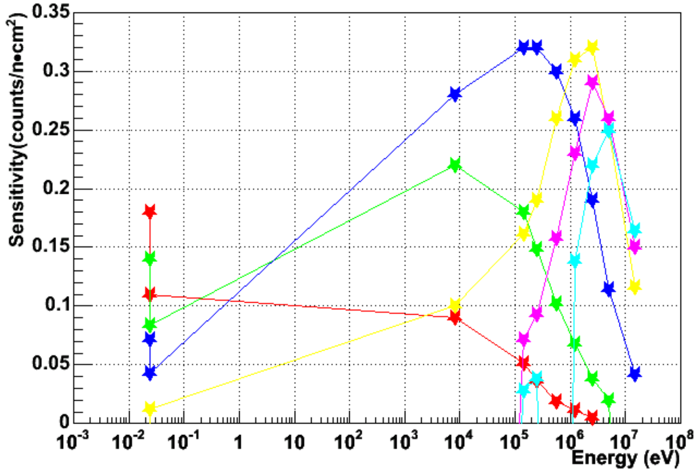
PMT output should not be reduced in this neutron.

Bonner Sphere (for Non-thermal)



Using ^{3}He and polyethylene spheres,
fast neutron can be thermalized and captured.
5 different sizes (2,3,5,8,10,12 inches)
-> can measure neutron energy spectrum

Sensitivity plot
of different bonner sphere



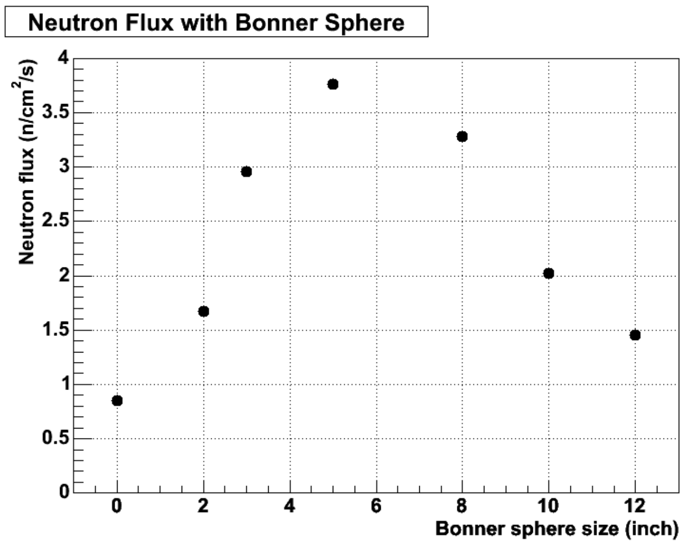
2”
3”
5”
8”
10”
12”

What spectrum of fast neutron?

Unfolded Neutron Energy Spectrum

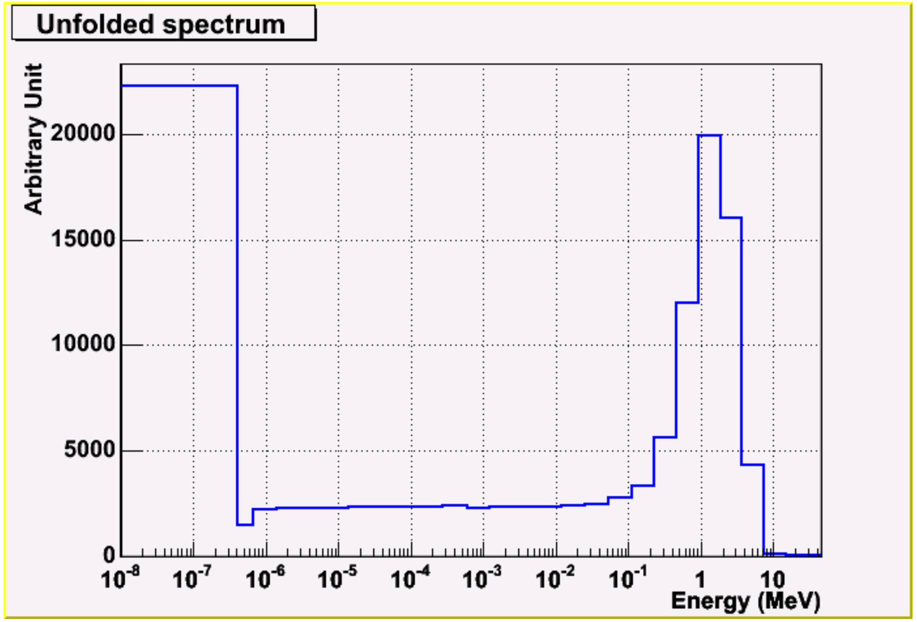
Measurement results

Neutron flux ($n/cm^2/s$)



Size of Bonner Sphere (inch)

Neutron spectrum calculated by BON-3.



Reconstructed neutron flux ~ 12 $n/cm^2/s$

Thermal component ~ 2 $n/cm^2/s$

In total, at most 10 $n/cm^2/s$ into Xe, corresponds to < 1μA

No problem for PMT performance

Summary

- We observed the 8.9MeV neutrons from the reaction of $\pi^- p \rightarrow n\gamma$ by the large prototype Xe detector in 70 liter scale.
- The effect from the thermal neutrons was also seen in our LP detector.
- The neutron background will not affect PMT outputs for the PMTs of the MEG experiment because the thermal neutron flux is less than 2n/cm^2/s and the total flux is less than 10n/cm^2/s.