MEG Experiment
A New Experiment to Search for $\mu \rightarrow e\,\gamma$ at PSI

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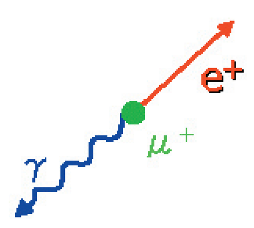
Abstract

A new experiment to search for the lepton flavor violating decay, $\mu \rightarrow e\,\gamma$ is planned at the Paul Scherrer Institute(PSI). The experiment is designed to search for the decay with a sensitivity down to 10^{-14} -10^{-13} branching ratio. The gamma-ray and positron from the decay can be detected by a liquid xenon scintillation detector and thin-wall superconducting spectrometer with gradient magnetic field, respectively. Current status of the preparation for the experiment will be presented focusing on the results from the beam test of the 100-liter prototype of the liquid xenon detector using laser Compton backscattering photon and the excitation test of the superconducting magnet.

$\mu \rightarrow e\,\gamma$



- Lepton flavor violating process
- Event signature
  - Back to back
  - Time coincident
  - $E_e=E_\gamma=52.8$MeV
- Extremely small branching ratio in the SM with finite neutrino mass.
  ex.) BR($\mu \rightarrow e\,\gamma$)<$10^{-48}(m_\nu/1eV)^4$
- Sensitive to the physics beyond the SM
  BR($\mu \rightarrow e\,\gamma$)~$10^{-15}$ -10^{-12} in SU(5)-GUT
  ~10^{-13} -10^{-11} in SO(10)-GUT
  >10^{-14} in SUSY+ν_R(Seesaw model) (See Fig.1)

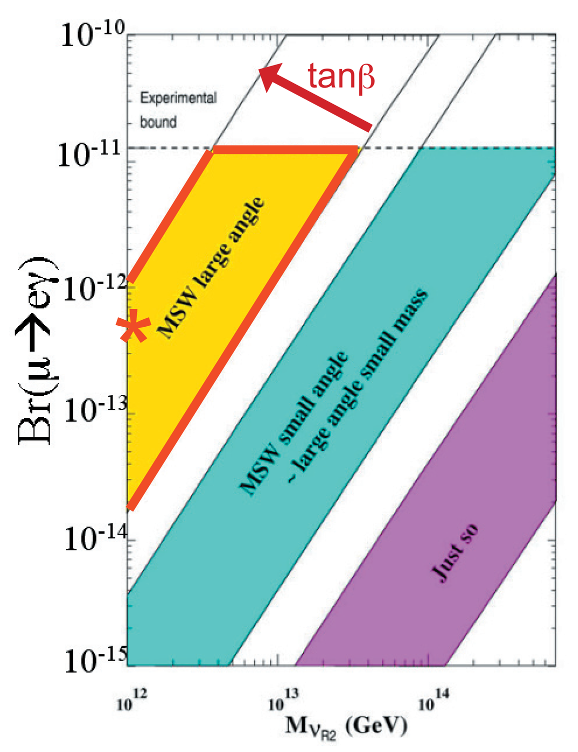


Fig.1 Branching ratio of $\mu \rightarrow e\,\gamma$ in SUSY+Seesaw model(J.Hisano et al. 1999)

*only solution after KamLAND

MEG Experiment

- A new experiment with a sensitivity down to BR~ 10^{-14} -10^{-13} planned at PSI in Switzerland
- Liquid xenon scintillation photon detector(800liter LXe viewed by 800 PMTs)
- Positron spectrometer with graded magnetic field(COBRA spectrometer)
- World's most intense DC muon beam at PSI $\rightarrow 10^8\mu$/sec with 100% duty factor
- Main background: accidental overlap of Michel positron and random gamma.

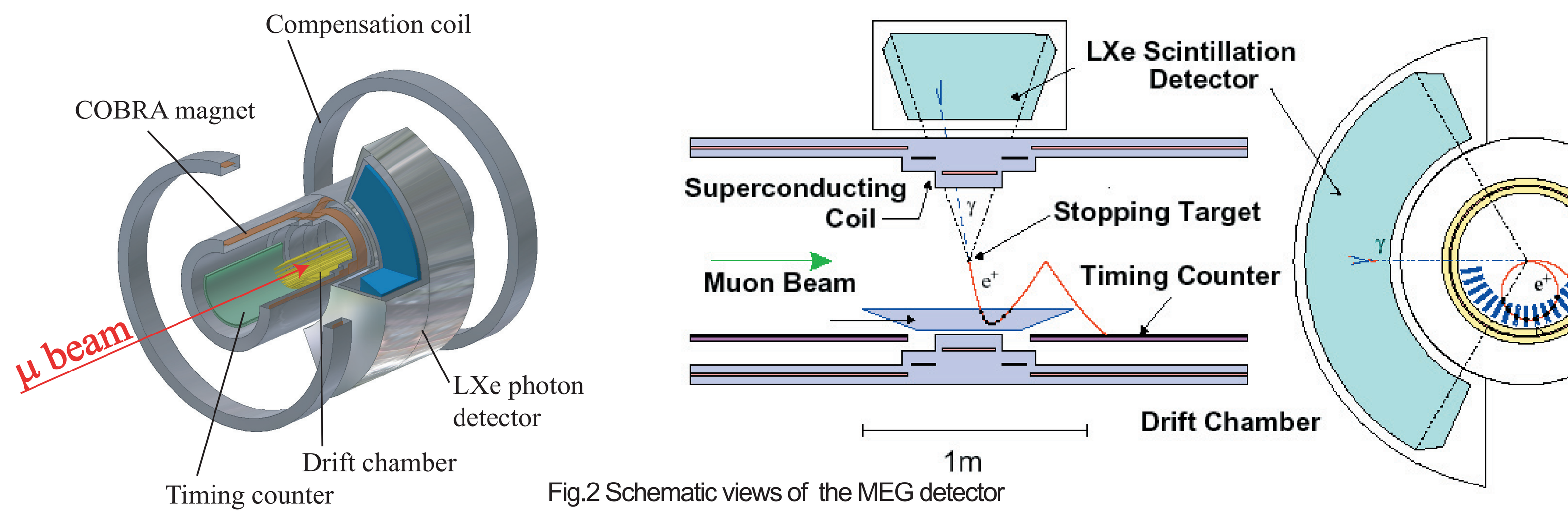


Fig.2 Schematic views of the MEG detector

LXe Scintillation Photon Detector

- High light yield (W_{ph}(LXe)=24eV, W_{ph}(NaI)=17eV)
- Good energy resolutions(energy, position, time) $\rightarrow$ Design goal: σ_E~1%, σ_x~2mm, σ_t~50ps
- Fast decay $\rightarrow$ usefull for pile-up rejection
- Spatially uniform response

Prototype Detector

- Constructed to demonstrate the performance of the proposed full-scale detector
- 69 liter active volume of LXe(120 liter in total)
- Viewed by 238 x PMTs
- Large enough to test with ~50MeV photon
- Xenon purification system was developed in this prototype detector.
  $\rightarrow$ Long absorption length over 100cm achieved! (~10cm without xenon purification)

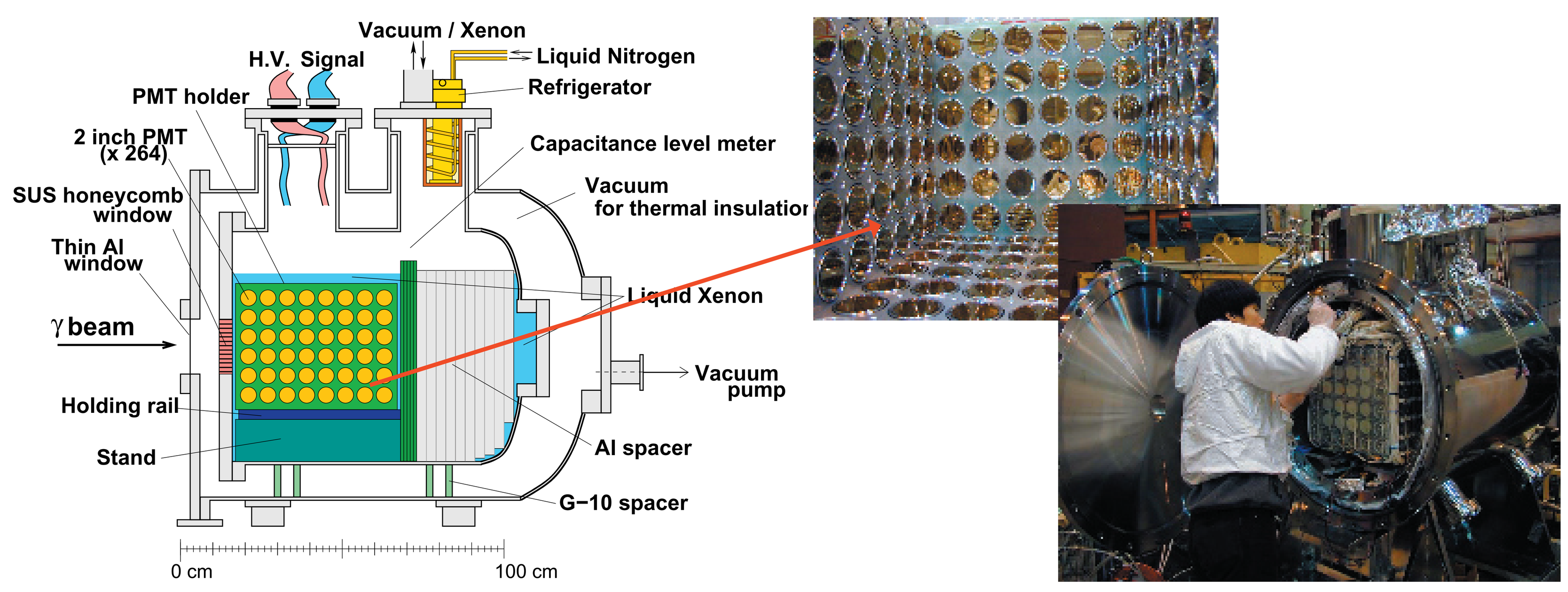


Fig.3 Schematic view of prototype of LXe photon detector.

Beam Tests at Laser Compton Backscattering Facility

- Laser Compton backscattering facility at TERAS in the AIST, Tsukuba, Japan(Fig.4)
- Response to 40, 20, 10MeV LCS photons was studied
- Spread of the Compton edge is used to evaluate the energy resolution
- Data taken in Feb. 2002(without purification, λ_{abs}~10cm) and Apr. 2003(with purification, λ_{abs}>100cm)

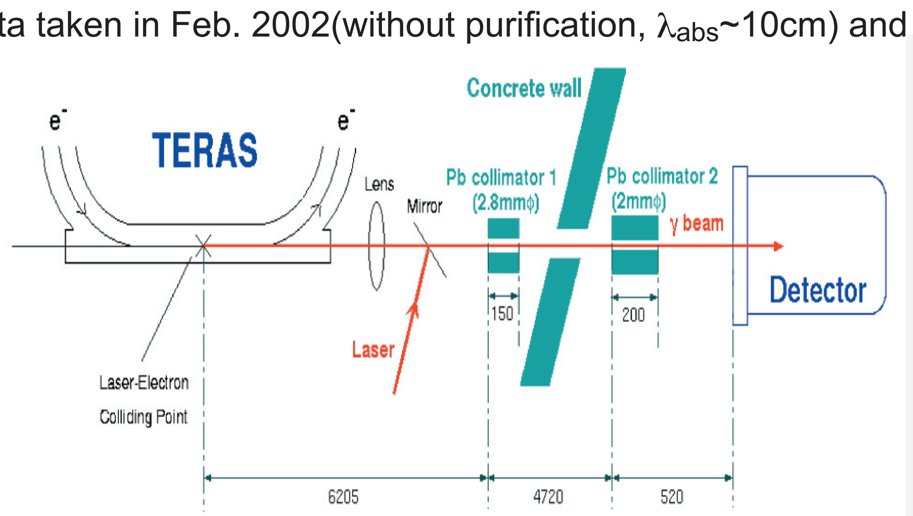


Fig.4 Layout of the beam tests at the laser Compton backscattering facility at TERAS electron storage ring in the AIST, Tsukuba, Japan

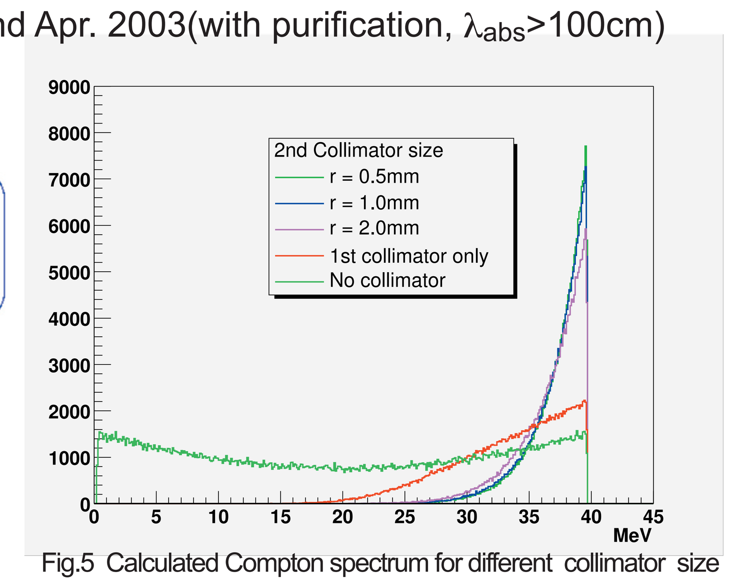


Fig.5 Calculated Compton spectrum for different collimator size

Preliminary Results from the Beam Tests

- Strong correlation between the observed N_{pe} and depth parameter due to the light absorption disappeared after the xenon purification.
- For evaluating energy resolution, shallow events(depth parameter < 45) with large leakage of the light is discarded(30%).
- Energy resolution σ_E<2% (No correction for first conversion depth) for 40MeV photons $\leftarrow$ very preliminary

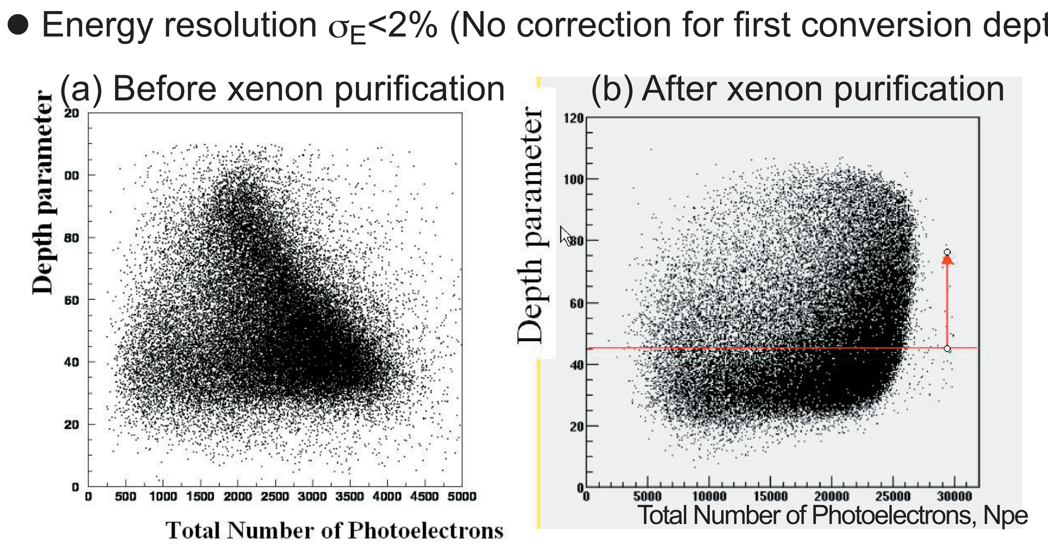


Fig.6 Total number of observed photoelectrons vs. depth parameter.
(a) before xenon purification (b) after xenon purification

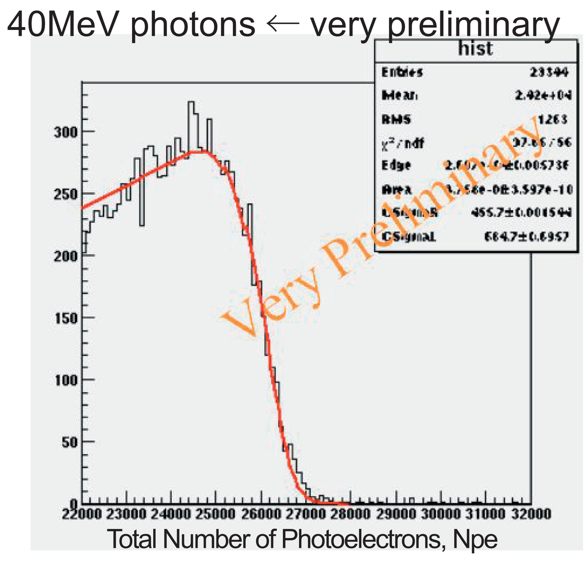


Fig.7 Spectrum of total number of photoelectrons with xenon purification.

- Detailed analysis is in progress.(Energy, position, timing resolutions, etc.)

COBRA(COnstant Bending RAdius) Spectrometer

Concept of COBRA Spectrometer

- The magnet is designed to form graded magnetic field in the positron tracking region.
  - Constant bending radius of the positron independent of emission angle
    $\rightarrow$ definitive momentum window(Fig.8 (a))
  - Michel positrons are quickly swept out. $\rightarrow$ reduce the hit rate of the tracking chamber(Fig.8 (b))

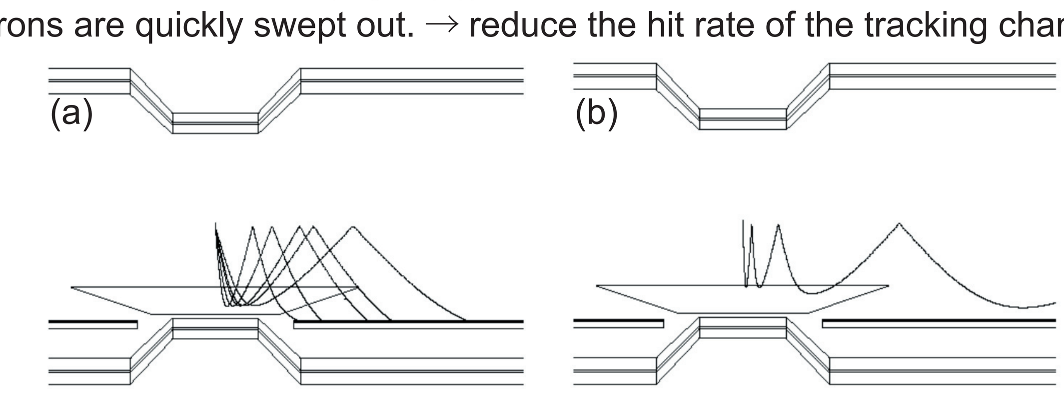


Fig.8 Concept of COBRA spectrometer.

Magnet

- Five superconducting coils with three different radii to form graded magnetic field.
- B_c = 1.26T, $B_{z=1.25m}$=0.49T@ operating current = 360A
- Compensation coils to suppress the residual field around the photon detector down to ~50Gauss for proper operation of the photon detector.
- Transparent for the photons from $\mu \rightarrow e\,\gamma$ (52.8MeV)
  - High-strength aluminum stabilized superconducting cable
  - Thickness of the magnet ~ $0.2X_0$
- Construction was finished! (Fig.9)

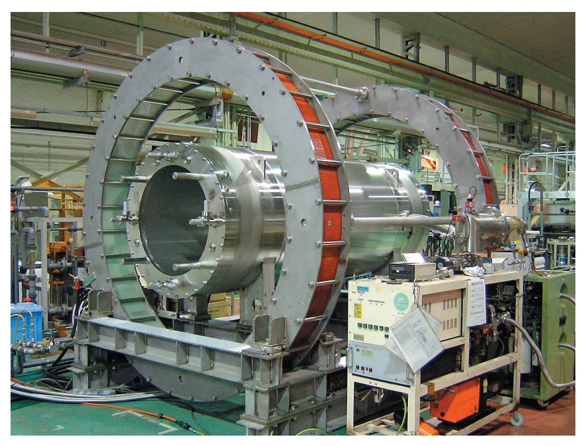


Fig.9 COBRA magnet.

Excitation Test of the Magnet

- Excitation test wad done to study the performance of the magnet.
- Excitation up to 83% of full operating current was done due to the problem of the quench protection heaters.
- Mechanical strength was checked by measuring the strain of the superconducting magnet(Fig.10).
  $\rightarrow$ Good behavior in strain distribution.
- Magnetic field in the tracking region was measured by 3-D mapping machine which was developed for the magnet(Fig.11). $\rightarrow$ Good agreement with calculation!
- Stray field around the photon detector region was measured(Fig.12)
  $\rightarrow$ Good suppression of stray field! (<50Gauss)

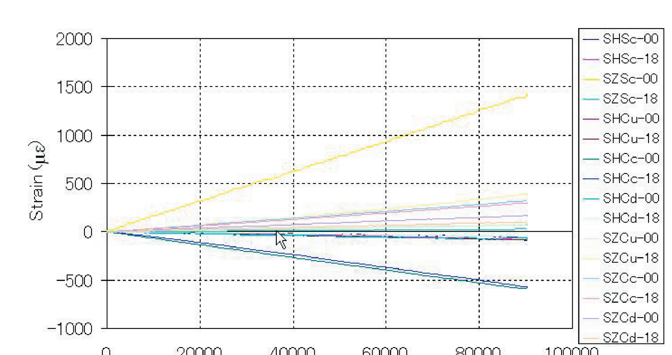


Fig.10 Measured strain of the superconducting coils as a function of square of coil current.

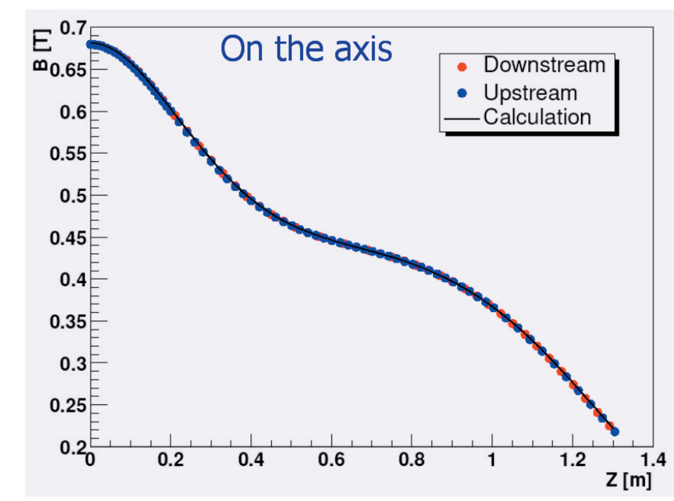


Fig.11 Measured magnetic field along magnet axis. Calculated magnetic field is also shown with a solid line.

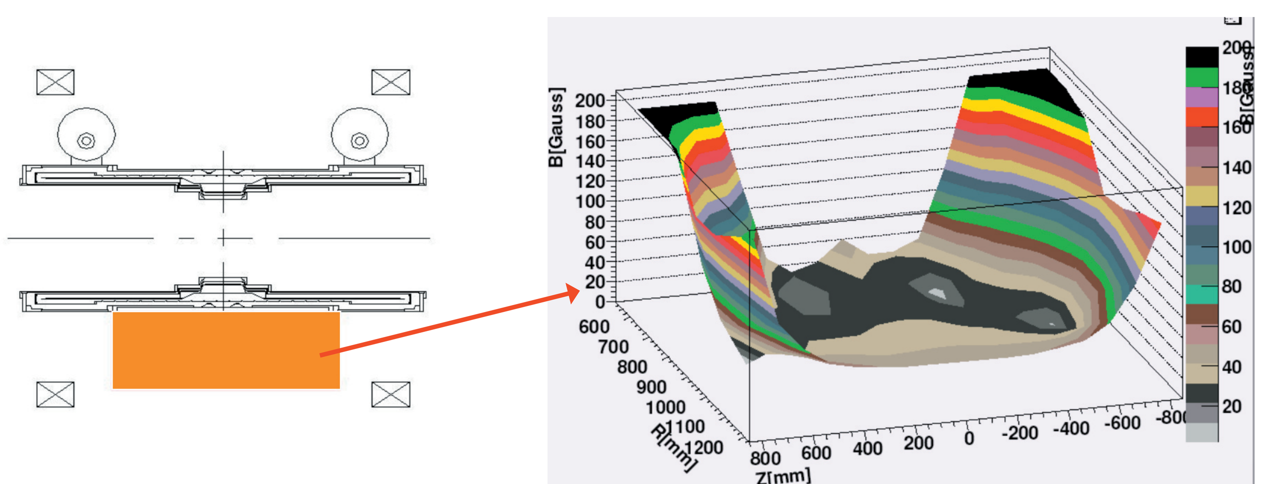


Fig.12 Measured stray field around the photon detector region.

Summary

- A new experiment with a sensitivity down to BR~10^{-14} -10^{-13} is planned at PSI
- R&D works on the sub-detectors are going well.
- Liquid xenon scintillation photon detector
  - Prototype detector with 120liter LXe was constructed
  - Purification system was developed and long absorption length over 100cm achieved.
  - Performance was measured by using high-energy photons up to 40MeV
  - Energy resolution σ_E<2.0% (no correction, very preliminary)
  - Detailed analysis is in progress.
- COBRA spectrometer
  - Construction of the magnet was finished.
  - Good performance of the magnet was confirmed in the excitation test.