Development of ultra-low material RPC for background identification in MEG II experiment

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Core-to-Core Program

Abstract An ultra-low material Resistive Plate Chamber (RPC) is being developed to suppress γ-ray background in MEG II experiment. It is required to detect low energy positrons associated with radiative muon decays, which is a major source of γ-ray background, under a harsh environment with a high intensity muon beam passing through it. The sensitivity of the experiment is expected to improve by 10% with this detector. R&D studies of this detector are presented.

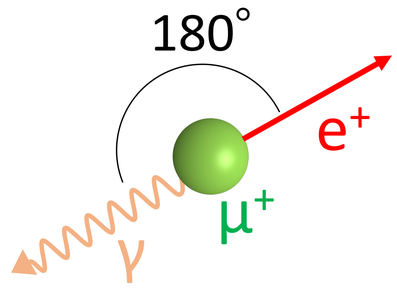
MEG II experiment

1

MEG II, an upgraded experiment from MEG will search for BSM via lepton flavor violating muon decay μ→ eγ with 6×10^{-14} branching fraction sensitivity [1], which improves the sensitivity of the MEG experiment by one order of magnitude.

MEG II signal

- 180° relative angle for e and γ
- same emission timing of e and γ
- Both of e and γ have 52.8 MeV energy

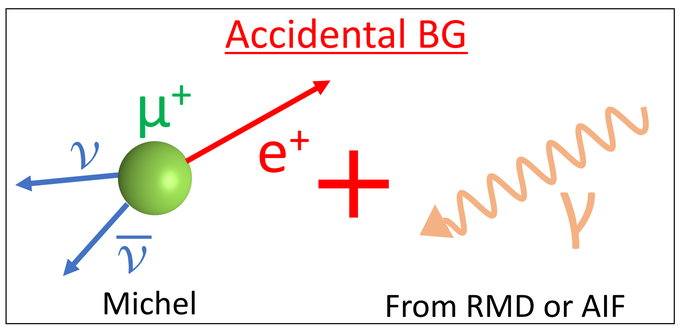


MEG II background

2

Dominant background is accidental coincidences of e and γ.

- Background e : Michel decay (μ →evν̄)
- Two sources of background γ
  1. Radiative muon decay (RMD, μ→eγνν̄)
  2. positron annihilation in flight (AIF, ee→γγ).



Background identification detectors: Detectors to suppress background γ from RMD

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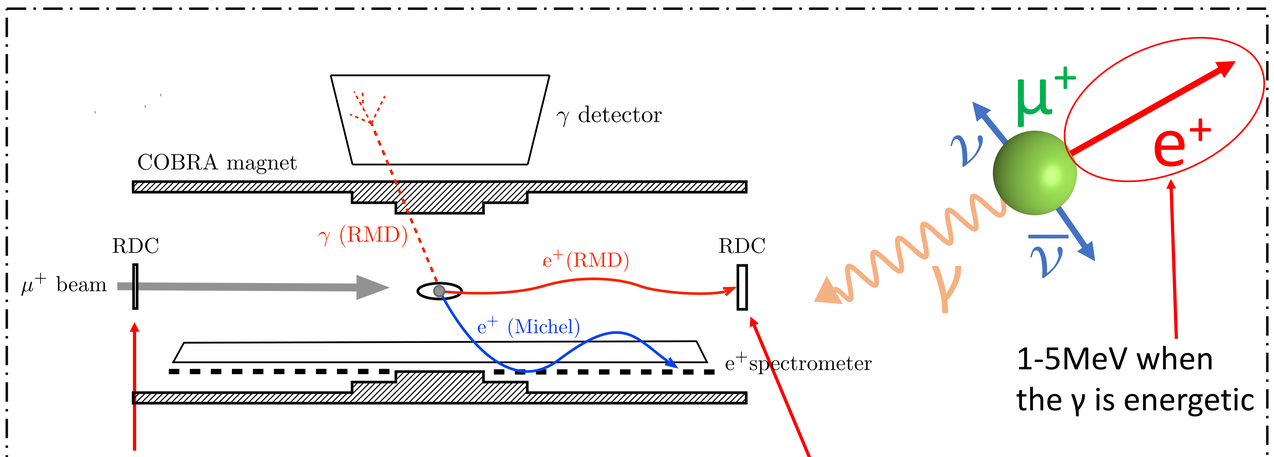
RMD events emitting ~52.8 MeV photon is accompanied by 1-5MeV positron → By detecting this positron, RMD is identified



Motivation of our study

- The aim of this study is to develop the upstream background identification detector, **improving the sensitivity by 10 %**

Difficulty of upstream detector

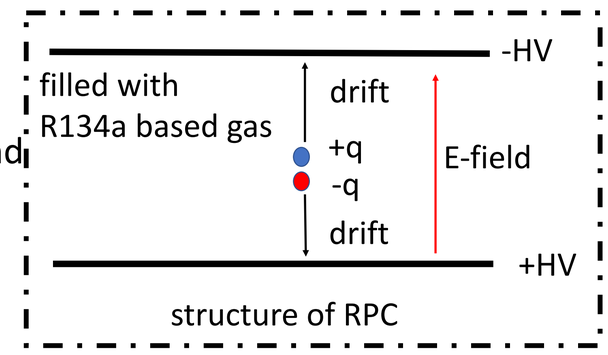
- Must be operated under high intensity muon beam (21MeV/c, 100MHz in total, 4MHz/cm^2 at the center, 60 week data taking) passing through the detector
  1. Low material budget (< 0.1% of X_0) so as not to degrade the beam
  2. Radiation hardness and rate capability

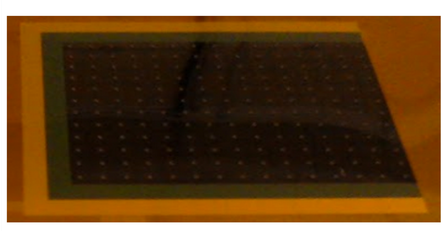
Resistive Plate Chamber(RPC)

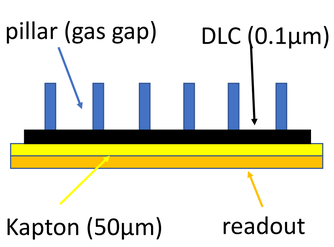
4

A hopeful candidate of the upstream detector is Resistive Plate Chamber with electrodes based on Diamond Like Carbon (DLC).

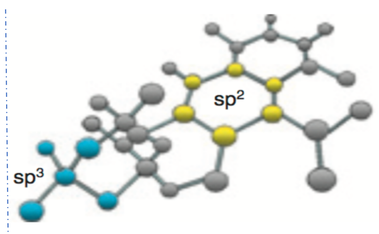
- RPC: Electric field is applied between two resistive electrodes
  - ➢ Ionizations from charged particles produce avalanches in the gas gap
- Electrodes made of DLC sputtered Kapton film
  - ✓ DLC has mixed structure of sp^2 bond and sp^3 bond of carbon
  - ✓ The advantages of DLC
    1. Low material budget
    2. Adjustable surface resistivity
  - ✓ Readout pad is implemented at the top and the bottom of the detector
  - ✓ Pillars to control gas gap distance




resistive plate made of DLC film

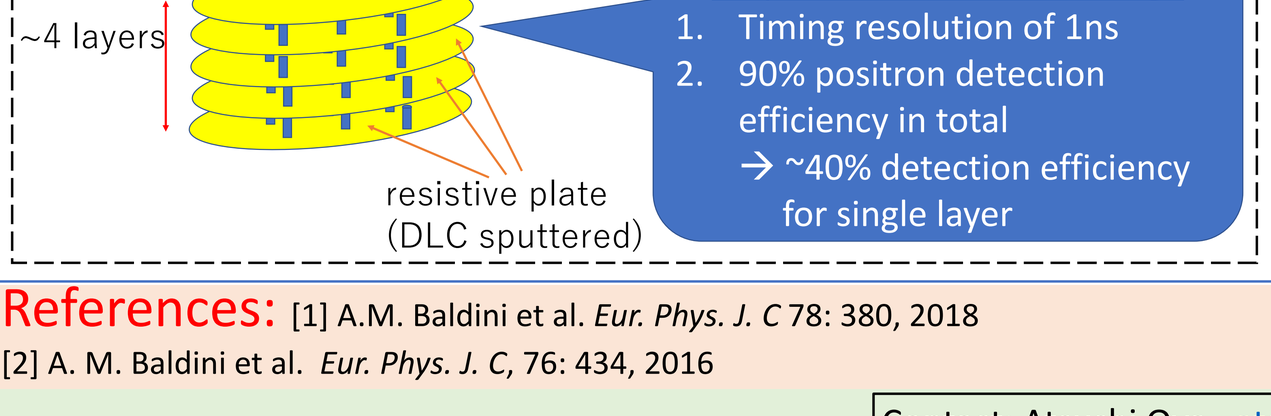


schematic view of DLC film



chemical structure of DLC

- MEG II design
  - ✓ ~4 layers (at maximum) to satisfy the requirement of low material



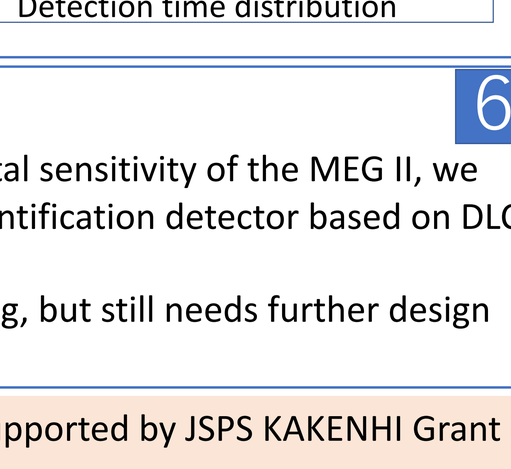
Performance evaluation of RPC

5

- Measurement setup
  - ✓ A simplified detector setup for performance evaluation (Single layer 200μm gap, 3cm × 3cm plate size, 10MΩ/sq DLC resistivity).
  - ✓ Material budget was 0.3% X_0
    → To be reduced with readout pad improvement
- Performance
  - ✓ Rate capability: At least 0.1MHz/cm^2, but not a complete result
    → To be remeasured
  - ✓ Detection efficiency: 23%
    → To be improved with larger gap distance
  - ✓ Timing resolution: better than 360ps
    → Already good enough

Rate capability

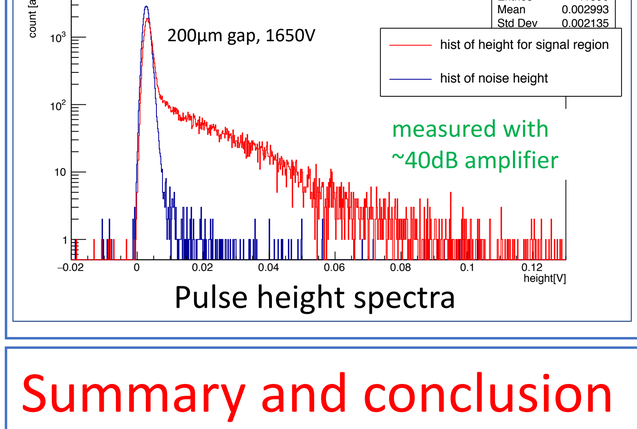
➢ Measured using intense Xray



current b/w gap vs Xray intensity

Detection efficiency

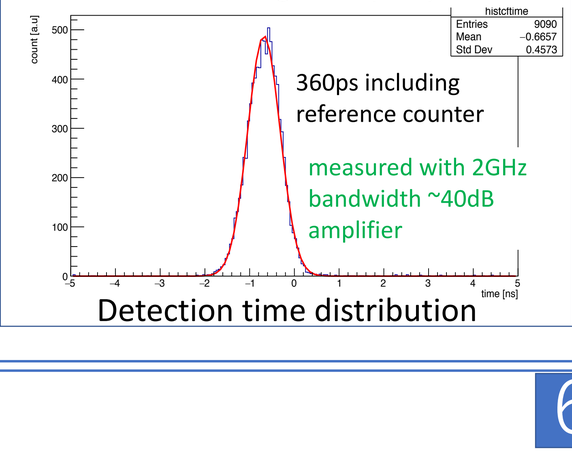
➢ Measured using Sr90 β ray



Pulse height spectra

Timing resolution

➢ Measured using Sr90 β ray



Detection time distribution

Summary and conclusion

6

- In order to further improve the experimental sensitivity of the MEG II, we are developing RPC for the background identification detector based on DLC sputtering technology.
- The measured performance looks promising, but still needs further design optimization to meet the requirements.

References: [1] A.M. Baldini et al. *Eur. Phys. J. C* 78: 380, 2018
[2] A. M. Baldini et al. *Eur. Phys. J. C*, 76: 434, 2016

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