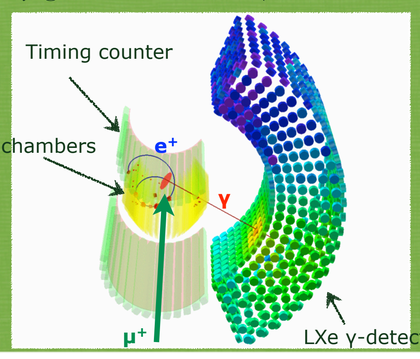
Development of Pixelated Scintillation Detector for Highly Precise Timing Measurement in MEG Upgrade

W. Ootani, *ICEPP University of Tokyo*, on behalf of MEG collaboration

Abstract: A pixelated scintillation detector with an ultimate timing resolution is under development for the upgrade of the MEG experiment. Design of the new detector and R&D status are described.

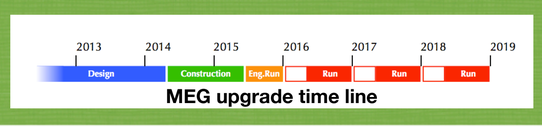
1. MEG Experiment

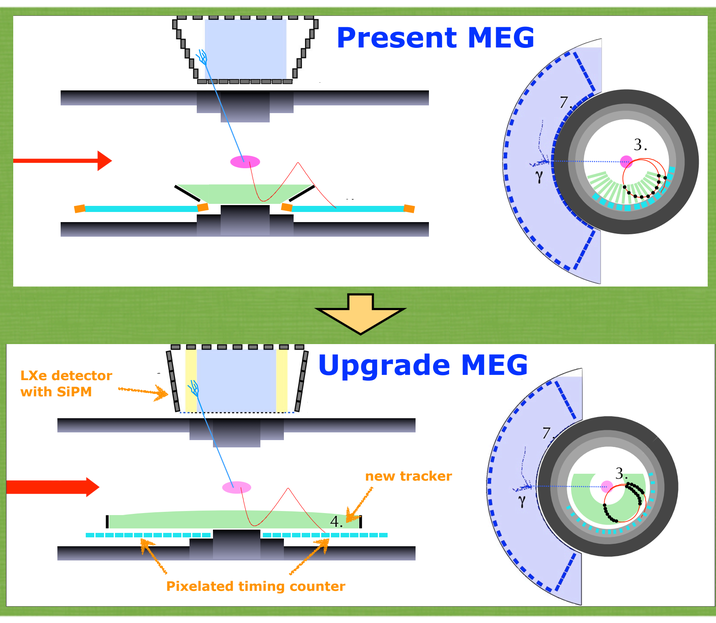
- MEG experiment at Paul Scherrer Institute searches for lepton flavor violating decay **μ→eγ** as a **clear evidence of BSM physics** with an unprecedented sensitivity.
- BR sensitivity goal: **~6×10^{-13}** (to be achieved in 2013)



2. MEG Upgrade

- Major upgrade planned aiming at **improving sensitivity by one order of magnitude** (**~6×10^{-14}**)
- Key items in MEG upgrade
  - Higher μ intensity
  - High performance new positron tracker
  - **Pixelated timing counter with SiPM readout**
  - LXe with SiPM readout (poster by D.Kaneko, board #88)
  - Thinner target
- **MEG upgrade proposal to PSI is approved in Jan. 2013** [1].



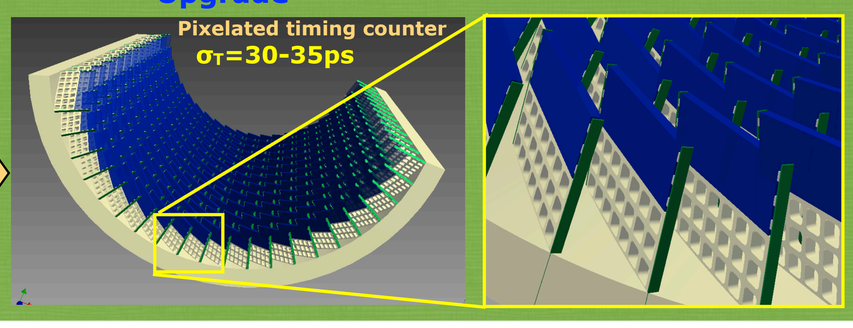


3. Design of New Positron Timing Counter

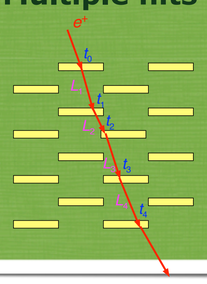
- **Design overview**
  - Composed of several hundred of **small fast scintillator plates with SiPM readout**
  - Ultimate time resolution by **averaging positron impact time over multiple pixel hits** (**<N_{hit}>~5**)
    - **~×2 improvement: 75ps (present) → 30-35ps (new)**
  - **Highly segmented** → small prob. of pileup and double hit at higher beam intensity
  - Flexible detector layout
  - Operational in B-field and He-gas inside spectrometer volume

Present

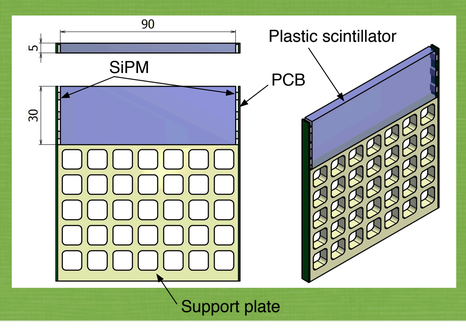
Upgrade



Multiple hits

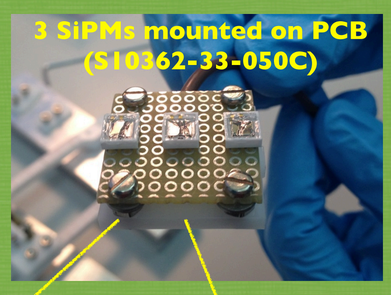


- **Single pixel counter**
  - **Fast scintillator plate** (typ. 30×90×5mm^3)
    - Scintillator candidates: ultra-fast scintillator from Saint-Gobain (BC422, 418, 420), p-Terphenyl
  - Readout at each end by **3-4 SiPMs connected in series**
    - **Passive adjustment of over-voltage (=gain)** over SiPMs connected in series
    - SiPM candidate (sensor area: 3×3mm^2): HPK S10931-050P, AdvanSiD ASD-SiPM3S-P-50, KTEK PM3350
  - Similar counter working at PSI μSR facility [2].

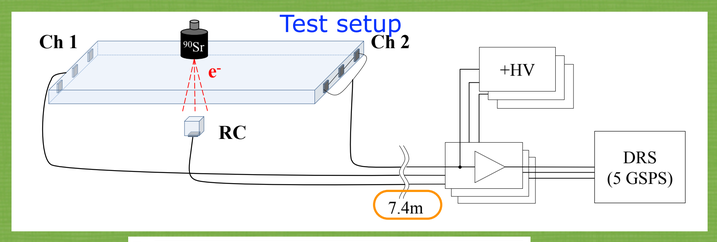


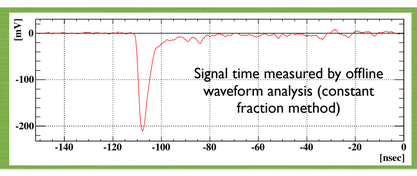
4. Prototype Test of Single Pixel Counter

- **Prototype study to optimize single pixel counter configuration**
  - Scintillator material
  - Scintillator size (↔ hit multiplicity, cost)
  - # of SiPMs
  - SiPM manufacturer
  - Reflector

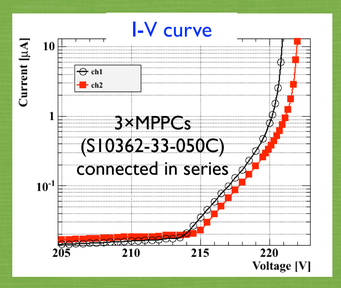


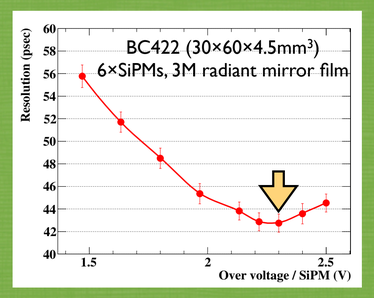
- **Test Setup**
  - Irradiated by β-rays from Sr-90 (E<2.28MeV)
  - Small reference counter for triggering/ collimation (5×5×5mm^3 BC422 with SiPM readout, σ=28ps)
  - **7.4m-long coaxial cable bw/ SiPM and amplifier** to simulate realistic condition in final detector
  - SiPM chain is readout by waveform digitizer (DRS4@5Gs/s).
  - Time resolution estimated from $(t_1+t_2)/2-t_{ref}$



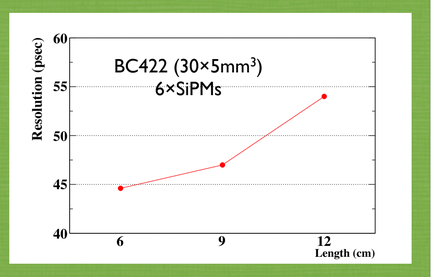


- **Single pixel time resolution**
  Best time resolution 42ps obtained at optimum over-voltage of 2.3V/MPPC

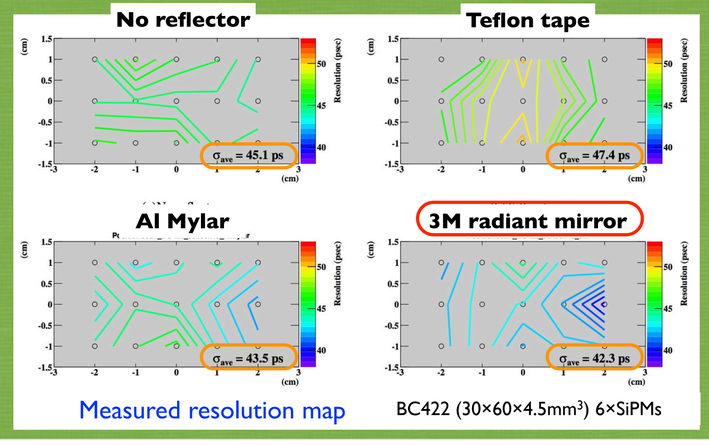




- **Scintillator size dependence**
  Reasonably good resolution ~50ps obtained even with long scintillator



- **Reflector type dependence**
  Best time resolution obtained with **3M radiant mirror film**



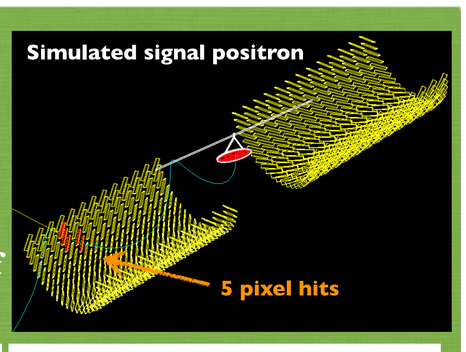
5. Expected Performance

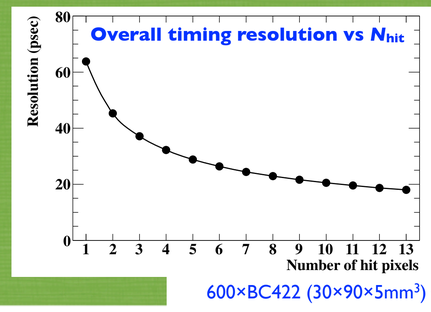
- **Ultimate time resolution can be obtained by averaging over multiple hits**
  - Contributions from single pixel time resolution (~50ps) and inter-pixel time jitter (~40ps) are diluted with a proper averaging.
  - Correction for inter-pixel positron flight time with positron track extrapolated from tracker
  - Effect of multiple scattering is negligibly small (<10ps).

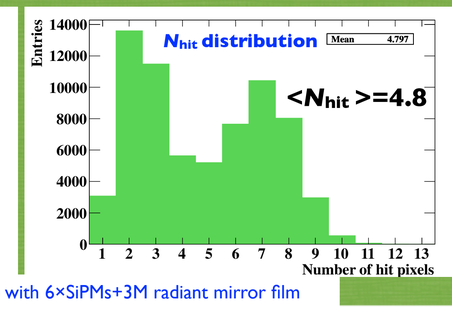
$$\sigma^2_{overall}(N_{hit}) = \frac{\sigma^2_{single}}{N_{hit}} + \frac{\sigma^2_{inter\text{-}pixel}}{N_{hit}} + \sigma^2_{MS}(N_{hit})$$

Sigle pixel time resolution | inter-pixel time jitter | Multiple scattering

- **Expected time resolution studied by MC simulation**
  - Measured single pixel time resolution taken into account
  - **Overall time resolution of 30-35ps is achievable.**







600×BC422 (30×90×5mm^3) with 6×SiPMs+3M radiant mirror film

6. Summary

- A pixelated timing counter with an ultimate time resolution is under development for MEG upgrade.
- **Very good single pixel timing resolution (~50ps)** is achieved in prototype tests.
- **Excellent overall time resolution (30-35ps)** is found to be achievable in the final detector.
- Beam tests with prototype detector with multiple pixel counters will be performed soon to demonstrate improved time resolution with multiple hit scheme.

References

[1] MEG upgrade proposal, arXiv:1301.7225
[2] A.Stoykov et al., *Nucl. Instrum. Meth.* A695(2012)202