# Study of Beam Effects for Muon Entrance Detector for the muEDM Experiment at PSI

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## Search For Muon EDM

### EDM violate T&P Symmetries (CPV)

Small SM CPV: $d_\mu^{SM} = 1.4 \times 10^{-38}\ e \cdot \mathrm{cm}$ (had. long dist.) [1]

Observed EDM → extra CPV from BSM

### Direct BSM/UV physics probe with muon EDM

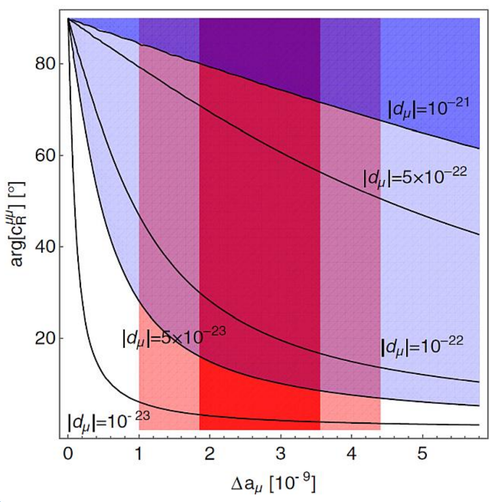
BSM models predict large $d_\mu$ (one loop contribution)

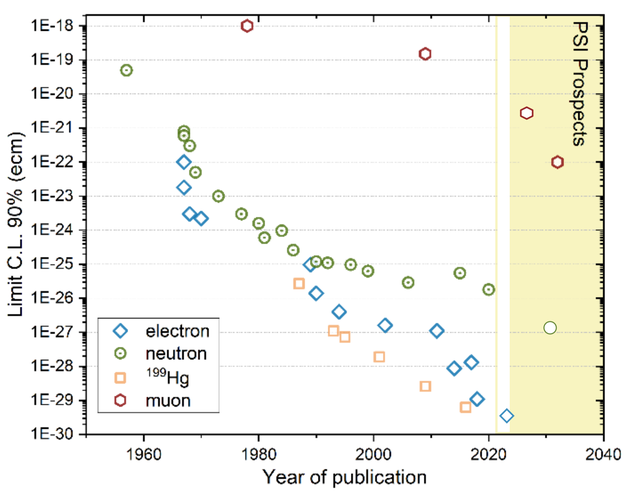
EFT analysis: Sizeable $d_\mu$ accommodating $\Delta a_\mu$ [2]

### Current status for muon EDM searches

Best direct limit: $1.8 \times 10^{-19}\ e \cdot \mathrm{cm}$ (95 % C.L.) [3]

Planned: $\mathcal{O}(10^{-21})\ e \cdot \mathrm{cm}$ (Fermilab [4] & J-PARC [5] )




## Experiment Principle

### Entrance Detector:

fast trigger for kicker

EDM

$$-\frac{e}{m}\left\{\cancel{a\vec{B} + \left(\frac{1}{\gamma^2-1} - a\right)\frac{\vec{\beta}\times\vec{E}}{c}} + \frac{\eta}{2}\left(\frac{\vec{E}}{c} + \vec{\beta}\times\vec{B}\right)\right\}$$

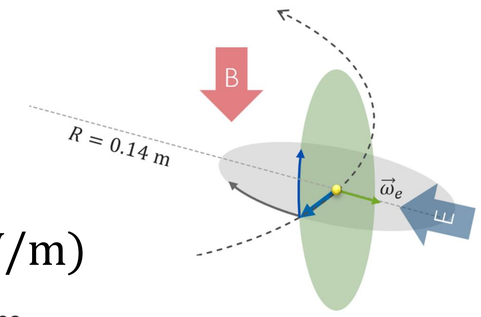
### Kicker B:

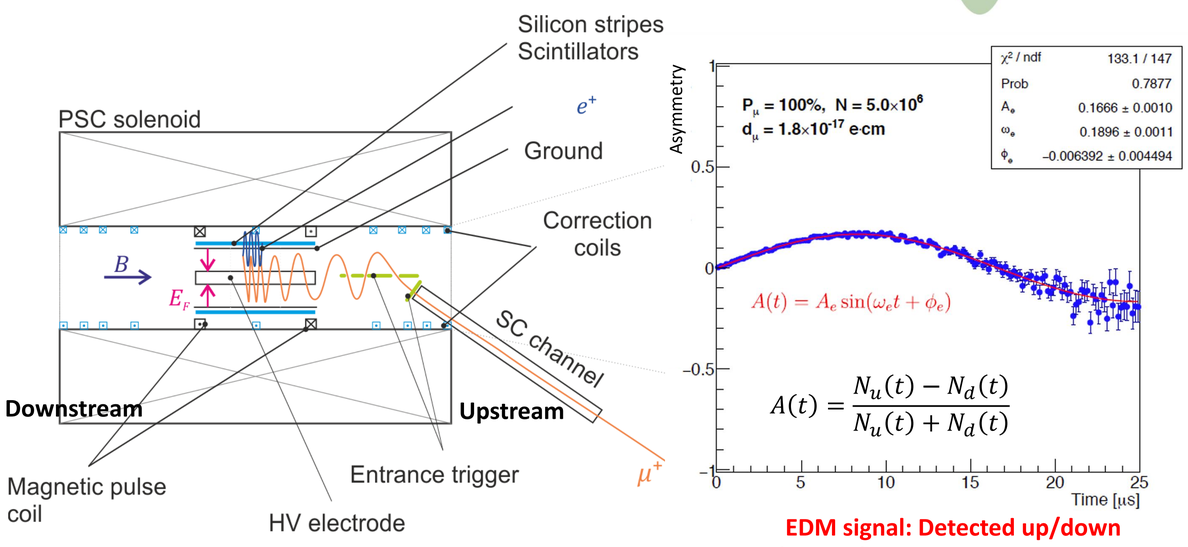
stop $p_{\parallel}$ of 3D injected muons

### Improve sensitivity with

Frozen-spin: $\boldsymbol{E_r = aBc\beta\gamma^2}$

Large $\vec{E} = \gamma c\vec{\beta} \times \vec{B} = \mathcal{O}(\mathrm{GV/m})$

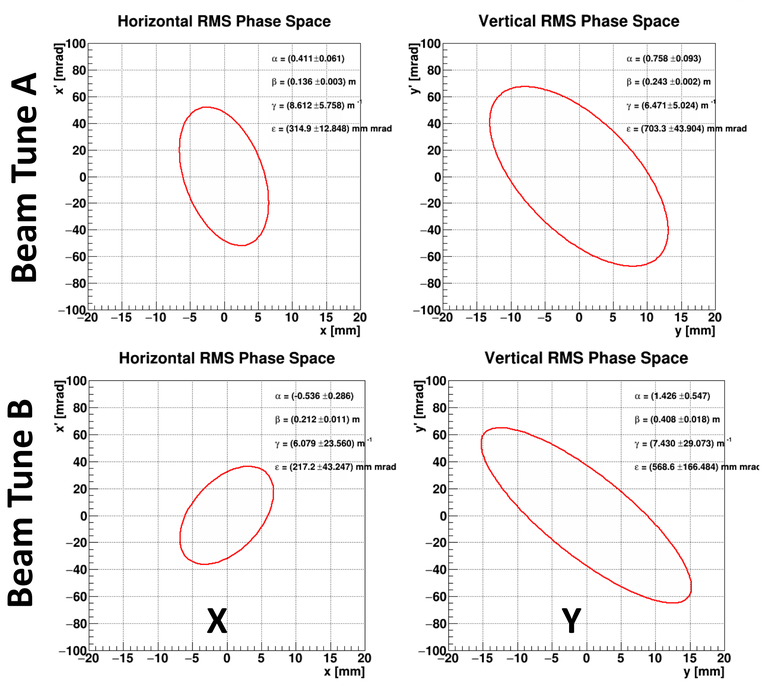


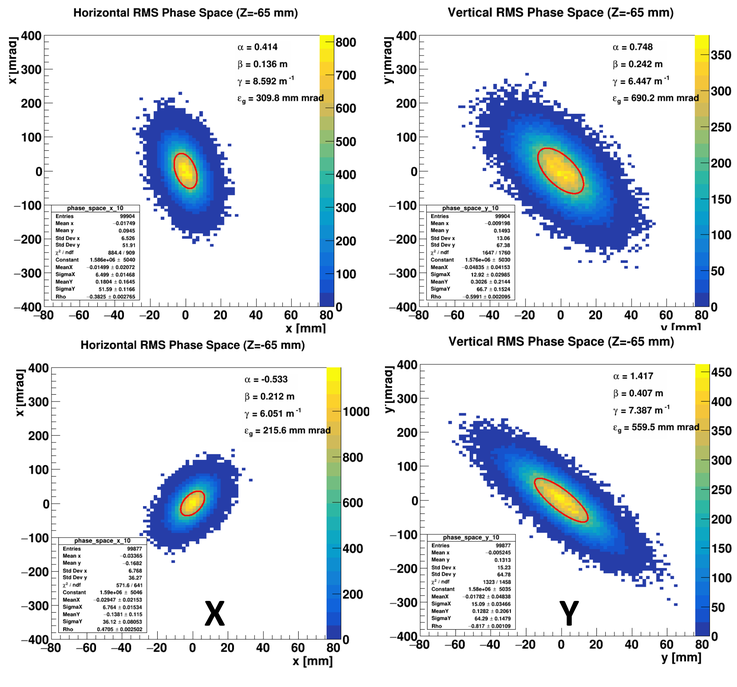

**EDM signal: Detected up/down (stream) asymmetry in e+ counts**

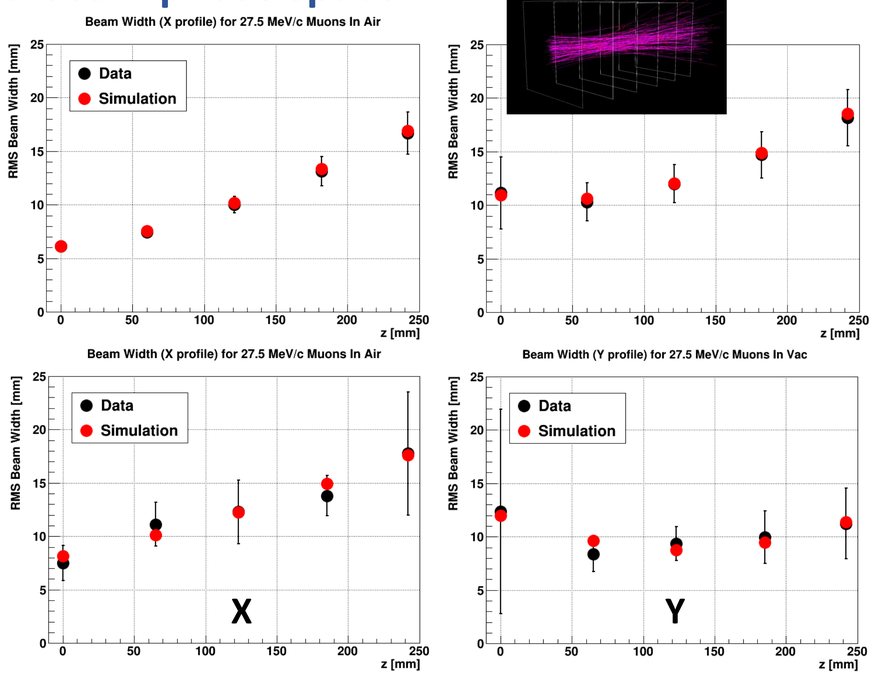
## Muon Beam Tunes at PSI's PiE1 beam line @ 27.5 Mev/c

### Beam width measurement to Phase Space




### MC simulation from the extracted beam phase space

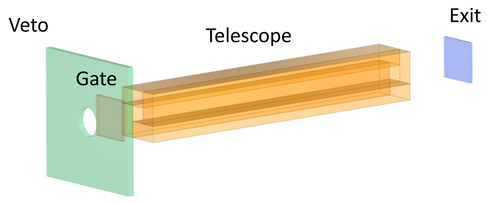


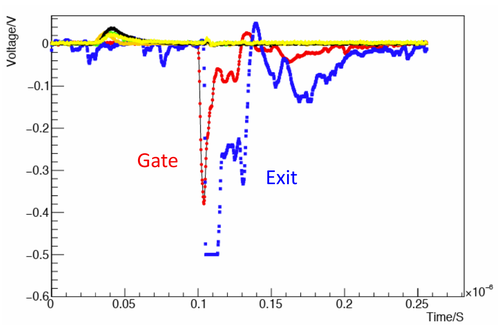




## Performance of the Entrance Detector

### Plastic scintillator + SiPM

- Online trigger by gate-telescope anti-coincidence
- SiPM waveform digitized for analysis



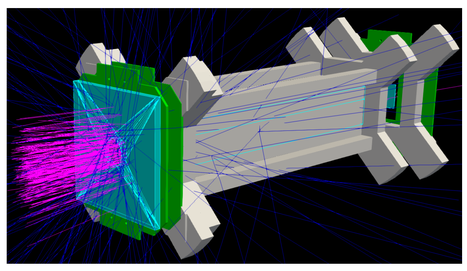

### Study event selection efficiencies under different

- Trigger patterns
- Beam tunes

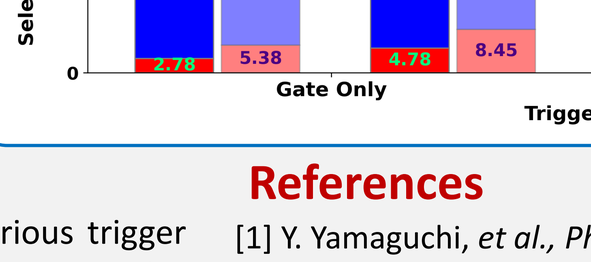
**Is the extra Exit coincidence helps in terms of selection efficiency ?**

### MC simulation incorporating

- Beam model
- Detector geometry



## Results




- ✓ **Gate-exit coincidence leads to > 70% accepted events**
- ✓ **No significant difference between beam tunes**




## Conclusion

We studied the event selection efficiency of the muon entrance detector across various trigger patterns and beam tunes. By employing a Monte Carlo simulation that integrated beam properties and detector geometry, we reproduced the results based on SiPM waveform analysis. Utilizing gate and exit coincidences in conjunction with telescope anti-coincidence, an event selection efficiency >70% was achieved. Remarkably, alterations in the beam tune exhibited minimal impact on this efficiency.

## References

[1] Y. Yamaguchi, *et al., Phys. Rev. L* **125** (2020), 241802

[2] A. Crivellin, *et al., Phys. Rev. D* **98**(2018) no.11, 113002

[3] G. W. Bennett, *et al*., *Phys. Rev. D* **80** (2009), 052008

[4] J. Ryan,*et al., Phys. Rev. D* **102** (2020), 115018

[5] M. Abe, *et al*., *Prog. Theor. Exp. Phys.* (2019), 053C02

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