



Conceptual Design of the Muonium-to-Antimuonium Conversion Experiment (MACE)

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(MACE working group)

Contents

- Motivations
- Conceptual design of MACE
- Proposal of MACE Phase-I
- Summary



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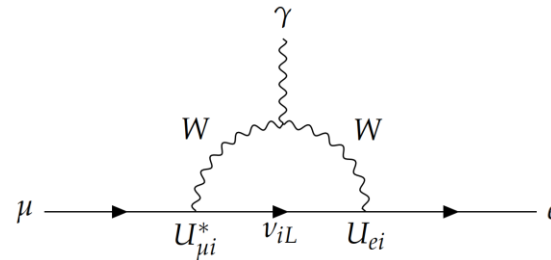


Motivations for cLFV searches

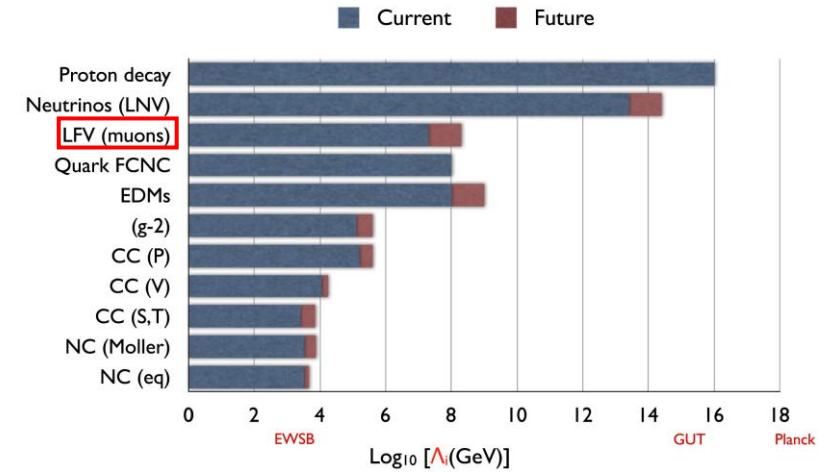
- Quark flavor mixing: **CKM matrix** (2008 Nobel Prize)
- Neutral lepton flavor mixing: **Neutrino oscillation** (2015 Nobel Prize)
- **Charged lepton:** _____

Consider tiny neutrino masses in the Standard Model

$$\text{Br}(\mu \rightarrow e\gamma) = \frac{3\alpha}{32\pi m_W^4} \left| U_{\mu 2} U_{2e}^\dagger \Delta m_{21}^2 + U_{\mu 3} U_{3e}^\dagger \Delta m_{31}^2 \right|^2 \sim 10^{-54}$$



- ✓ **Forbidden in SM, free of SM background.**
- ✓ Many BSM models predict scalable cLFV
- ✓ **“Smoking gun” evidence of BSM, if observed!**
- ✓ Complementary with the high-energy frontiers.

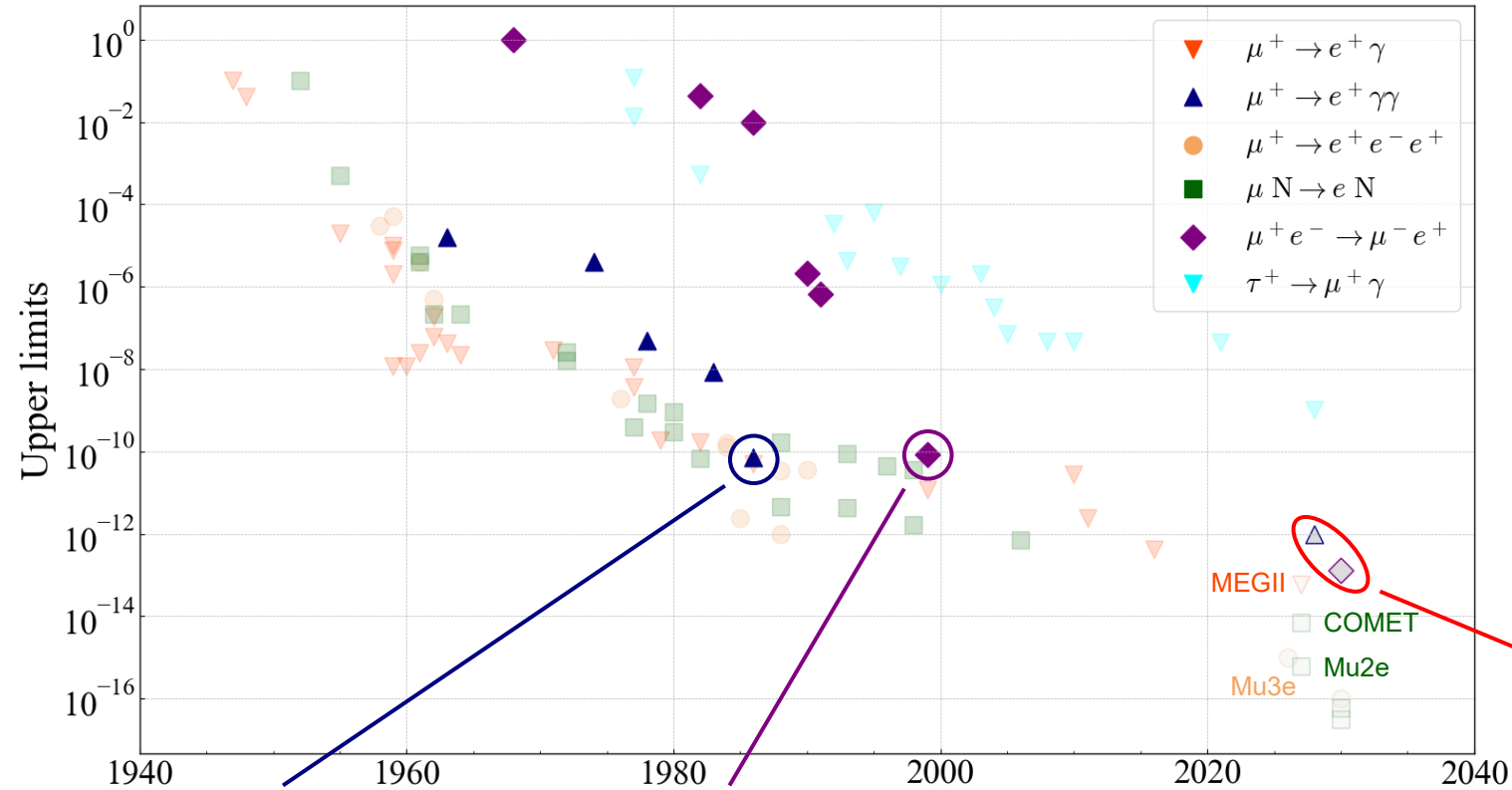


Prog.Part.Nucl.Phys. 71 (2013) 2-20

Why muon?

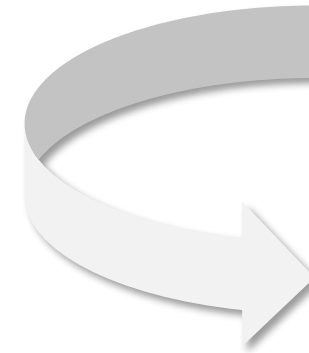
- Lightest massive unstable charged lepton.
- Reasonably long 2.2-μs lifetime.
- Almost free from QCD corrections.

1940s till now: a cLFV odyssey



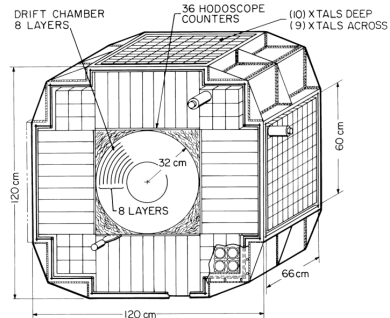
Towards new muon cLFV experiments

- Construction of intense muon beamlines in China
- Development of particle detection technology

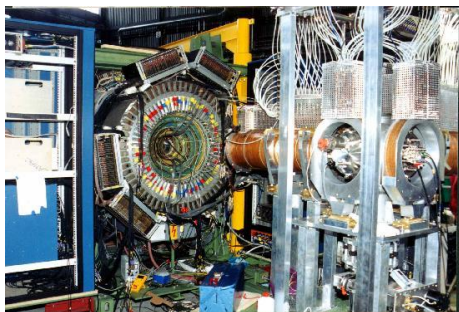


$\mathcal{O}(10^{-13})$ sensitivity!

Crystal Box, 1986
 $BR < 7.2 \times 10^{-11}$



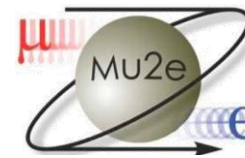
MACS, 1999
 $P_{M \rightarrow \bar{M}} < 8.3 \times 10^{-11}$



MEG II
 (PSI)
 $\mu^+ \rightarrow e^+ \gamma$



Mu3e
 (PSI)
 $\mu^+ \rightarrow e^+ e^- e^+$



Mu2e
 (Fermilab)
 $\mu^- N \rightarrow e^- N$



COMET
 (J-PARC)
 $\mu^- N \rightarrow e^- N$



MACE (China)
 $M \rightarrow \bar{M} (\mu^+ e^- \rightarrow \mu^- e^+)$

Muonium conversion

Muonium ($M = \mu^+ e^-$): a leptonic isotope of hydrogen

- 1957, *B. Pontecorvo* first suggested $M \rightarrow \bar{M}$ process.
- 1960, *V.W. Hughes* et al. first observed the muonium directly.
- 1961, *G. Feinberg* and *S. Weinberg* published a research on $M \rightarrow \bar{M}$.

$M \rightarrow \bar{M}$: an $\Delta L_\ell = 2$ process

✓ In SMEFT: operators different from $\Delta L_\ell = 1$ processes

($\mu \rightarrow e\gamma, \mu \rightarrow eee, \mu N \rightarrow eN$)

✓ $\Delta L_\mu = -\Delta L_e = 2$ can be possible even if $\Delta L_\ell = 1$ is suppressed.

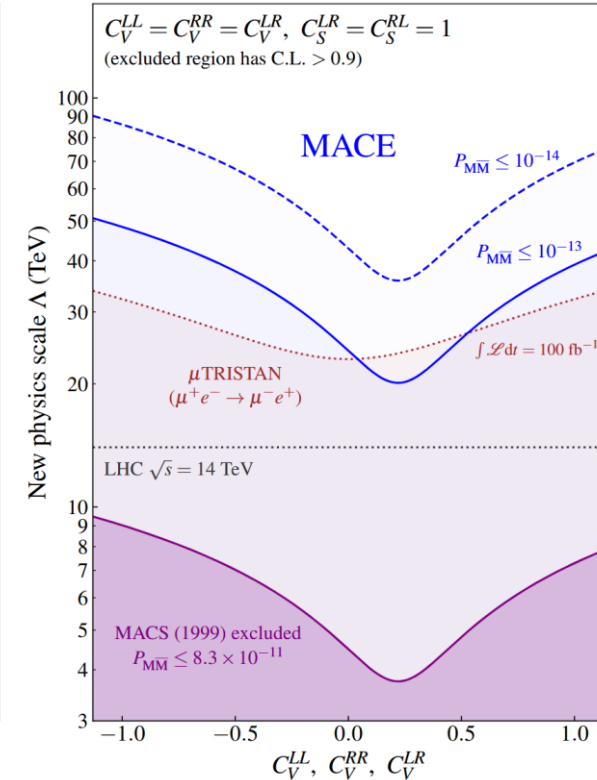
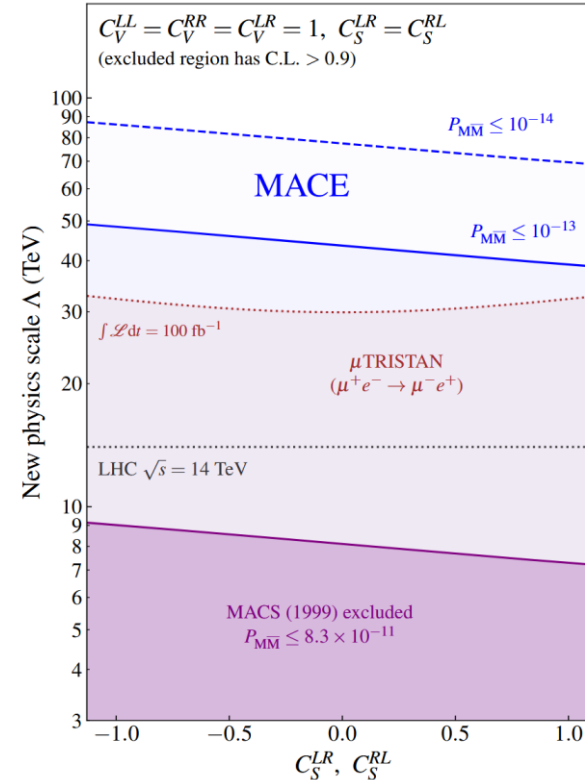
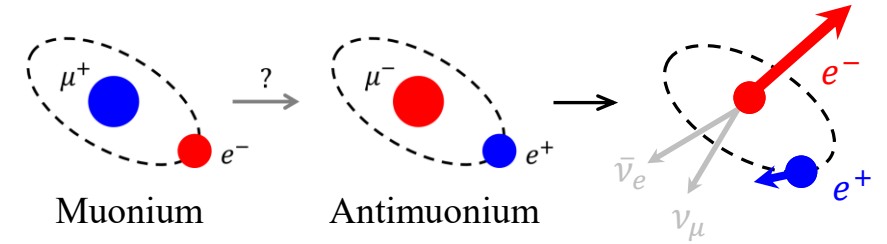
✓ Complementary to $\Delta L_\ell = 1$ process searches.

Phys.Lett.B 852 (2024) 138621
Phys.Rev.D 105 (2022) 1, 015026

Current bound:

$P_{M \rightarrow \bar{M}} < 8.3 \times 10^{-11}$
in 0.1T field, 90% C.L.

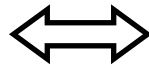
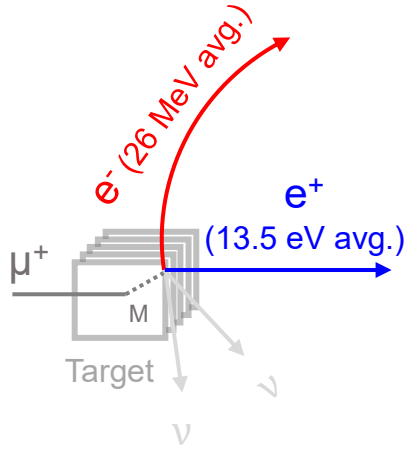
Phys. Rev. Lett. 82 (1999), 49-52.



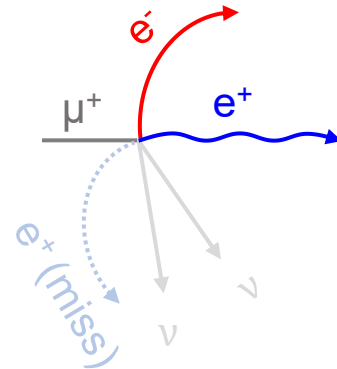
Signal and backgrounds

Signal:

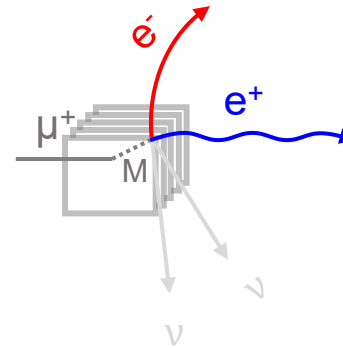
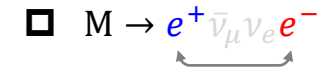
fast e^- + slow e^+



1. Internal conv. (IC) decay

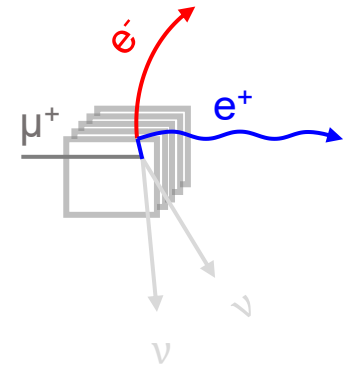


2. Final state scattering



3. Accidental bkg.

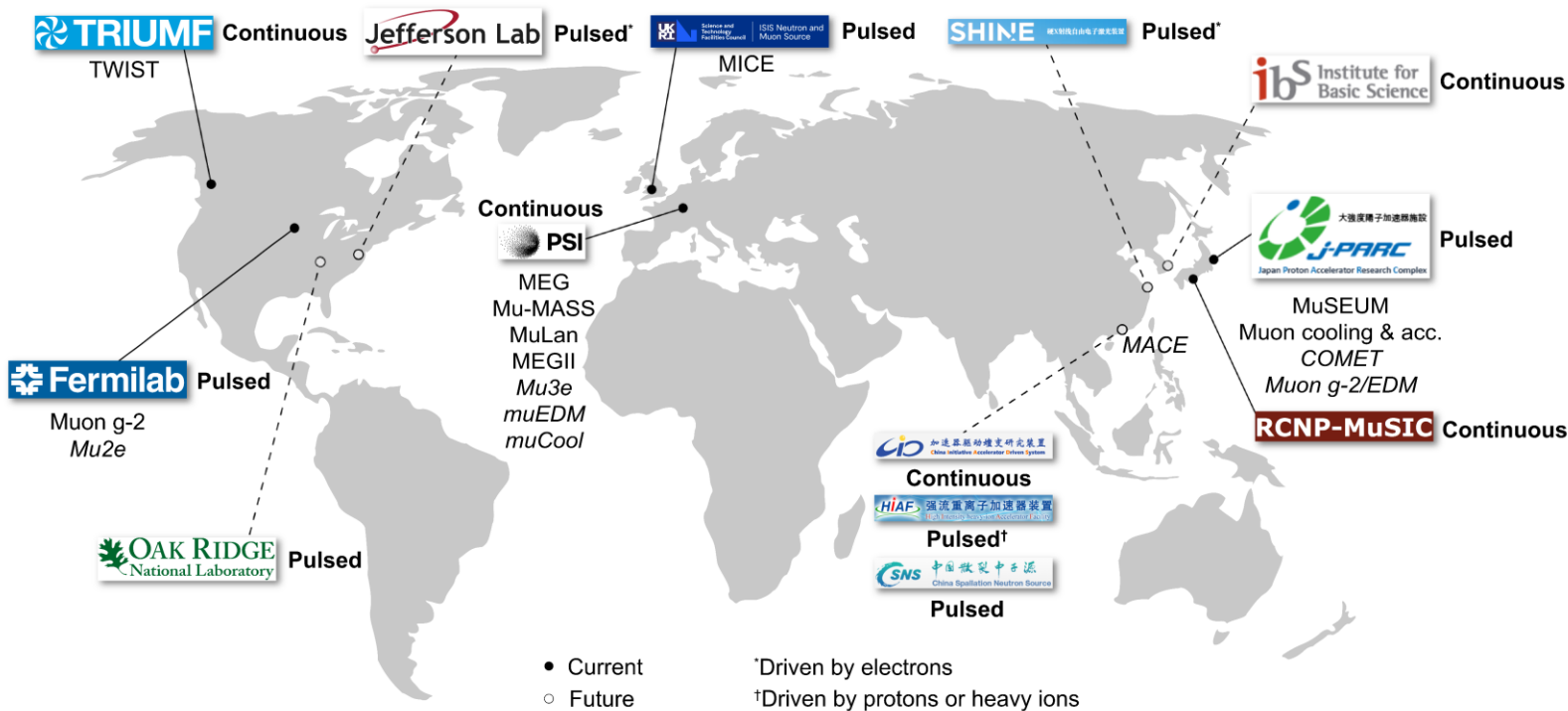
- Scattering/conv. e^-
- Mis-reconstruction
- Cosmic ray, etc.



- Coincidence of a fast e^- and a slow e^+
- Common vertex (by selecting e^+/e^- track DCA)
 - ✓ Select p_{xy} of e^+
 - ✓ Reject accidental e^-
- Time coincidence (by selecting e^+ TOF)
 - ✓ Select p_z of e^+
 - ✓ Reject e^+ from IC decay or Bhabha scattering
- Charge identification (by e^- track & e^+ annihilation)

- A "clean" data taking duration
 - Pulsed muon beam
- Excellent vertex resolution
 - e^+/e^- spatial resolution
 - Precise e^+ transport in EM field
- Excellent time resolution
 - e^+/e^- time resolution

Status of muon sources

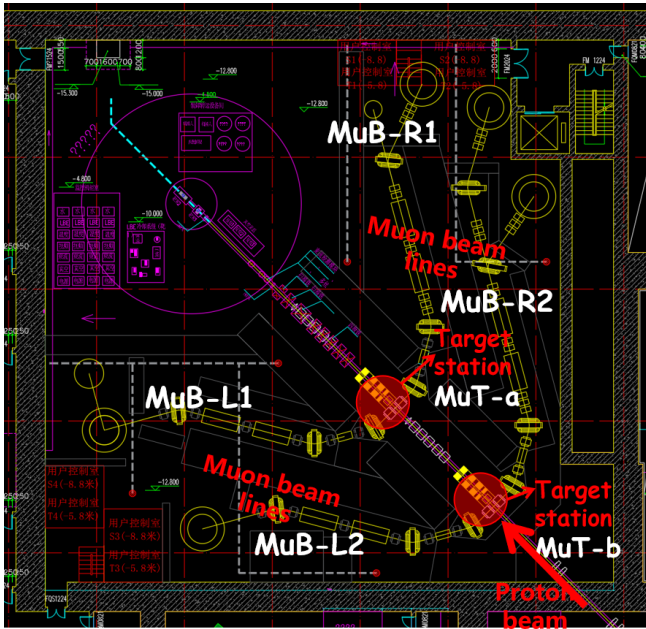


- Global facilities: PSI (Switzerland), J-PARC (Japan), ISIS (UK), TRIUMF (Canada), FNAL (USA).
- First high-intensity muon source in **China**, to be built in the Greater Bay Area: **CiADS/CSNS/HIAF/SHINE**.

Muon beamline of CiADS

- A surface muon beamline is under way at **China Initiative Accelerator Driven System (CiADS)**
- Exploring cutting-edge research with high muon flux?

Credit: Han-Jie Cai



Beam power	Target	Target	Intensity (s^{-1})	Spin pol.	background
300 kW	Graphite	Full-solenoid	$> 5 \times 10^8$	~94%	<0.1%
		Mixing	$> 5 \times 10^7$	>99%	
3 MW	Lithium jet	Full-solenoid	$> 1 \times 10^{10}$	~94%	
		Mixing	$> 1 \times 10^9$	>99%	

H. -J Cai et al. PRAB 27 (2024) 2, 023403

2025 ~ 2026

25 kW: 500MeV & 50 μ A

- Accelerator construction
- Proton beam commissioning

2026 ~ 2027

250 kW: 500MeV & 500 μ A

- Beam stability test
- Muon beam commissioning
- One target station, two beamlines

2027~2030

3 MW: 600MeV & 5mA

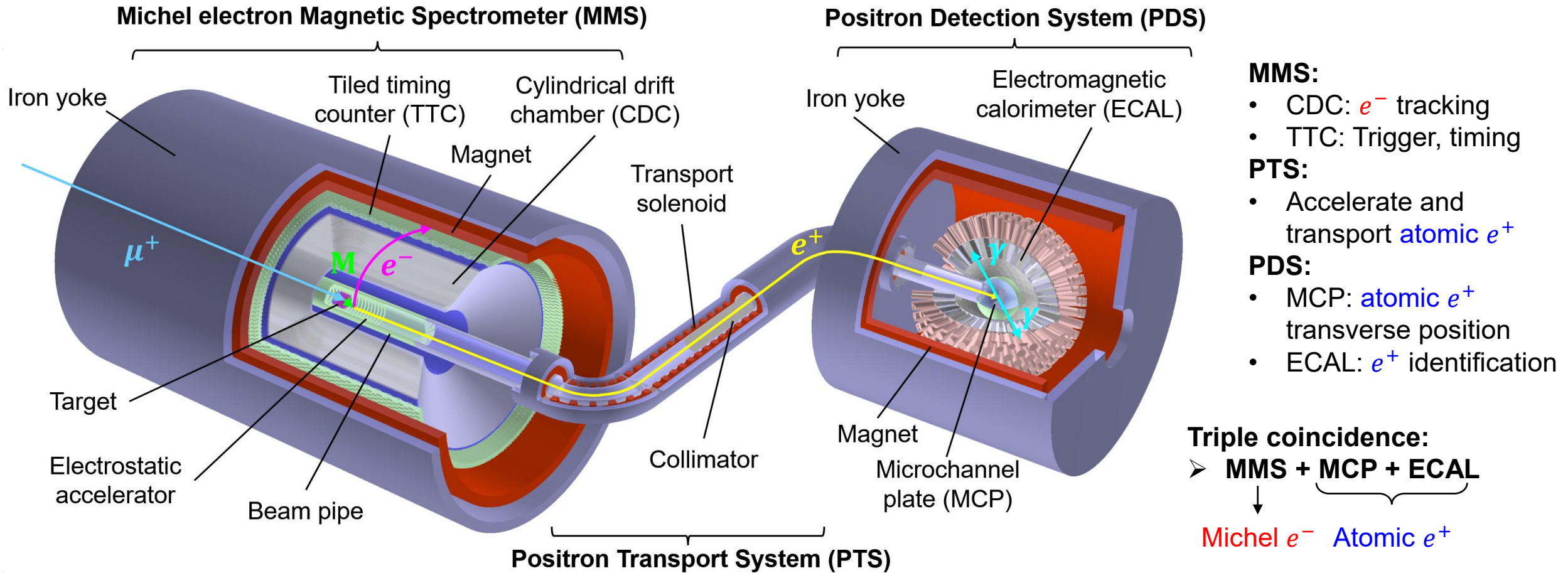
- 2.5 MW commissioning
- 2.5 MW long-term run
- Two target station, four beamlines
- Muon physics and applications

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Conceptual design of MACE detector system



- MMS:**
- CDC: e^- tracking
 - TTC: Trigger, timing
- PTS:**
- Accelerate and transport **atomic e^+**
- PDS:**
- MCP: **atomic e^+** transverse position
 - ECAL: e^+ identification

Triple coincidence:
 ➤ **MMS + MCP + ECAL**
 ↓
 Michel e^- Atomic e^+

- I. Surface muons stop in target → muonium
- II. M diffuses into vacuum & converts to \bar{M}
- III. Decay in a vacuum: $\bar{M} \rightarrow e^+ e^- \nu_\mu \bar{\nu}_e$
- IV. CDC detects **Michel e^-** track

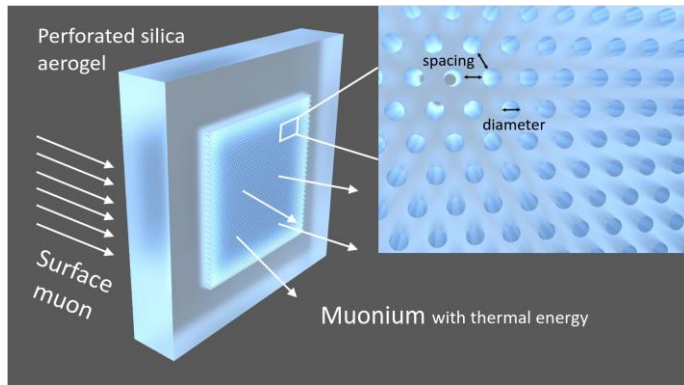
- I. Transport **atomic e^+** to MCP (conserving transverse position)
- II. MCP detects e^+ position
- III. e^+ annihilates on MCP
- IV. ECAL detects 2 back-to-back annihilation γ

Muonium production target

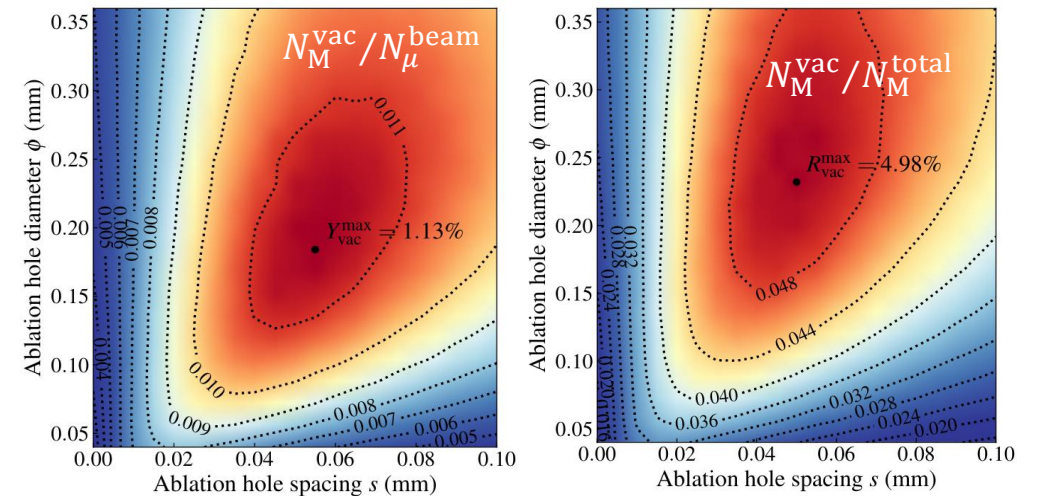
- Intensity of in-vacuum muonium source: $I_M^{\text{vac}} = I_{\text{beam}} Y_{\mu \rightarrow M}$
- $Y_{\mu \rightarrow M}$ can be improved by utilizing porous materials, ideally perforated silica aerogel.
- A simulation method is developed to accurately simulate muonium production and diffusion.

- The simulation is validated by muonium yield data measured in TRIUMF. J. Beare et al., PTEP. 2020, 123C01 (2020)
- Optimize $Y_{\mu \rightarrow M}$ in perforated bulk target by scanning parameters, it can achieve
 - ✓ Max $Y_{\mu \rightarrow M} = N_M^{\text{vac}} / N_{\mu}^{\text{total}} = 1.134\%$, with 2mm hole depth, $p_{\text{beam}} = 28 \text{ MeV}/c$ and $\frac{\sigma p_{\text{beam}}}{p_{\text{beam}}} = 2.5\%$.

2 times larger than the yield in 1999



Zhao, Shihan, and Jian Tang. "Optimization of muonium yield in perforated silica aerogel." *Physical Review D* 109.7 (2024): 072012.



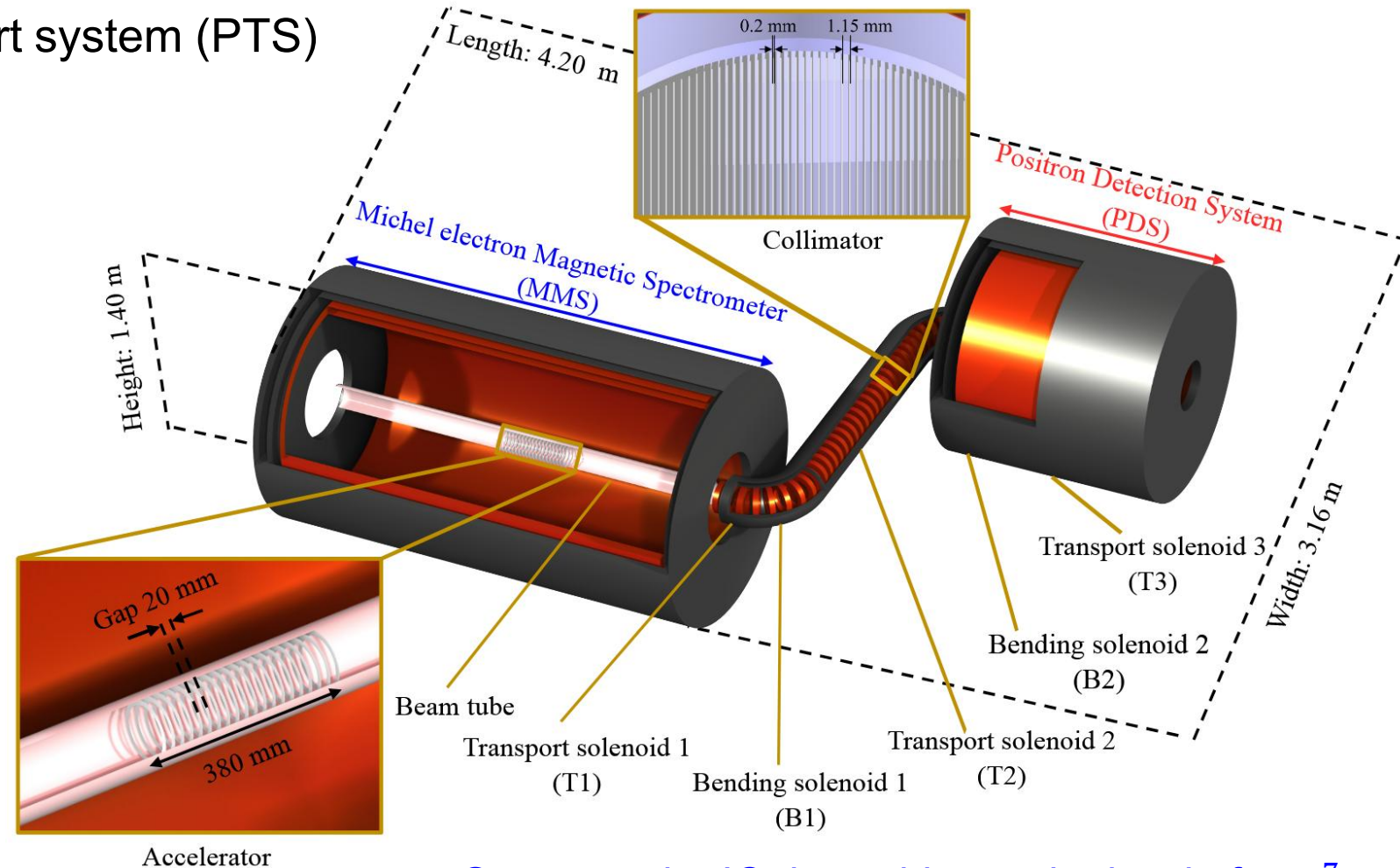
Positron transport system

- The component of positron transport system (PTS)

- I. Electrostatic accelerator
- II. Solenoid system
 1. MMS solenoid
 2. TS solenoid
 3. ECAL solenoid

- PTS performance

- I. Transmission efficiency: 65.8%.
- II. Flight time: 322 ns.
- III. Flight time FWHM: 6.9 ns.
- IV. Spatial resolution: $0.088 \text{ mm} \times 0.102 \text{ mm}$



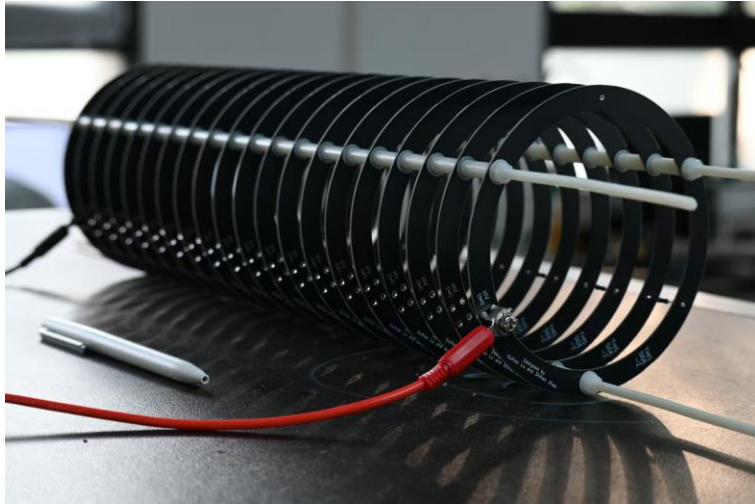
Suppress the IC decay bkg. to the level of 10^{-7}

Lu, Guihao, et al. "Positron Transport System for Muonium-to-Antimuonium Conversion Experiment." *arXiv preprint arXiv:2508.07922* (2025).

PTS prototyping progress

- **PTS validation**

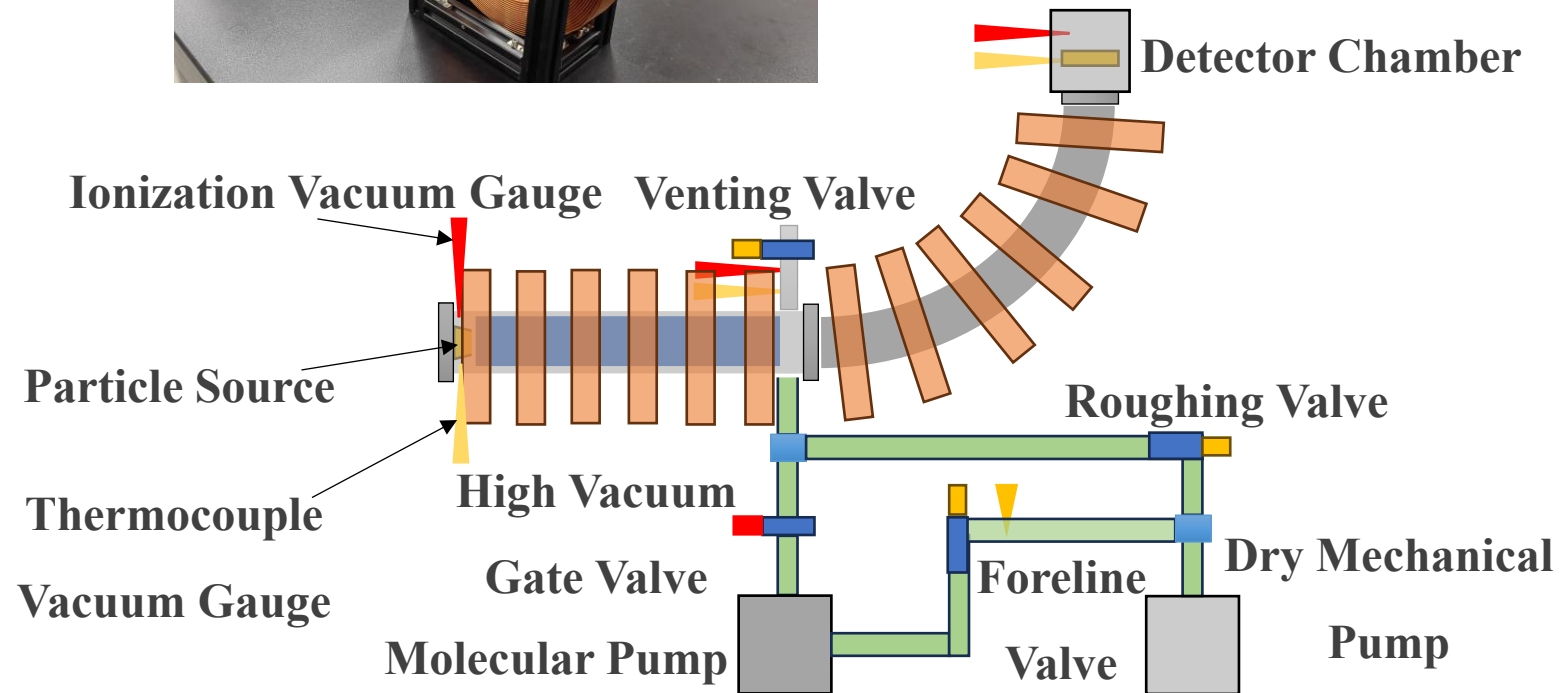
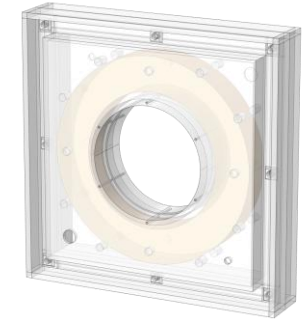
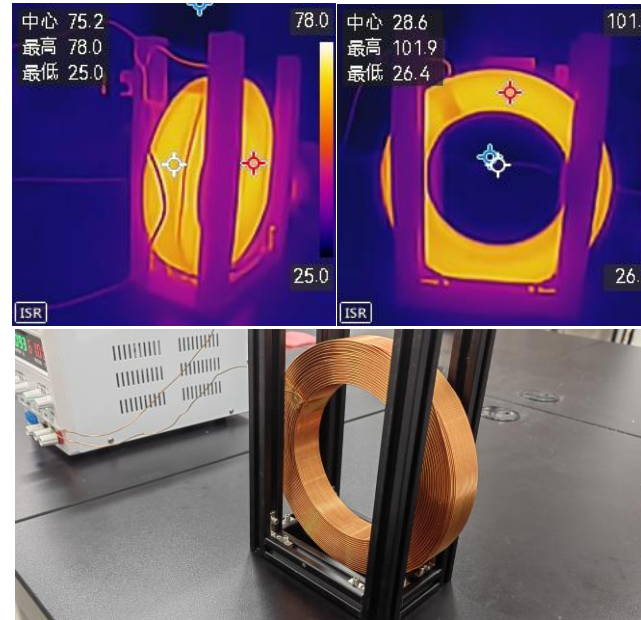
Testing with TS solenoids and accelerator module



- **Accelerator module prototype**

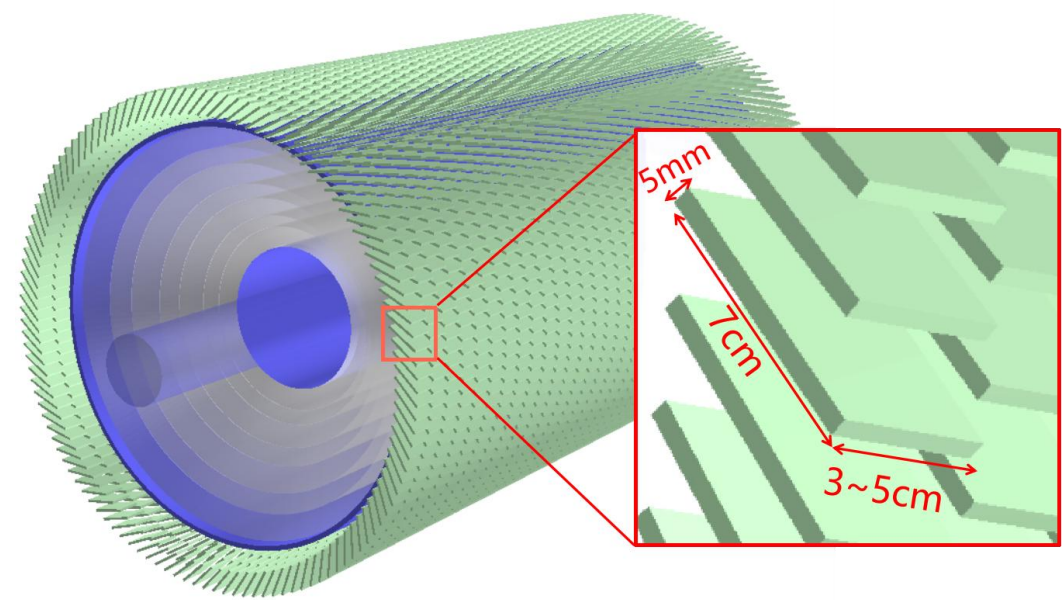
Multi-layer PCB

High voltage > 2 kV



Tiled timing counter

- Tilt design, signal track hits 2-3 scintillator tiles.
- Azimuth spacing $\varphi = 2.951^\circ$, tilt angle $\alpha = 46^\circ$.
- Full simulation result:
 - Geometry efficiency: $\varepsilon_{\text{geom}} = 83.7\%$
 - Detection efficiency (amp. > 3 p.e.): $\varepsilon_{\text{thr}} = 99.6\%$

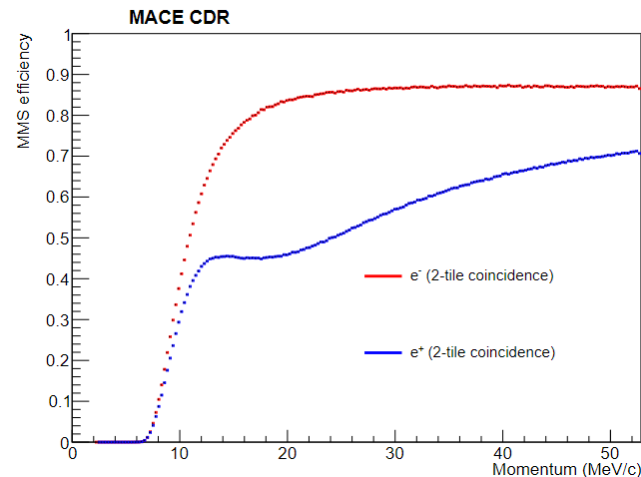
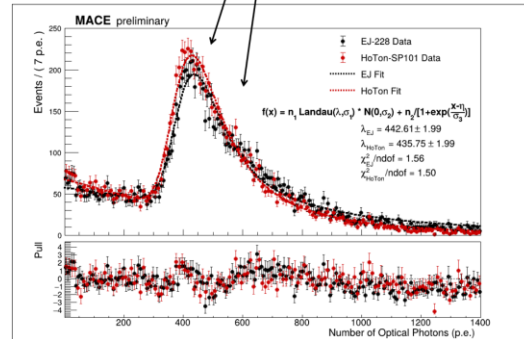
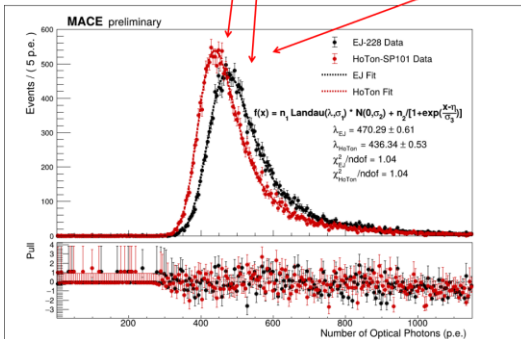
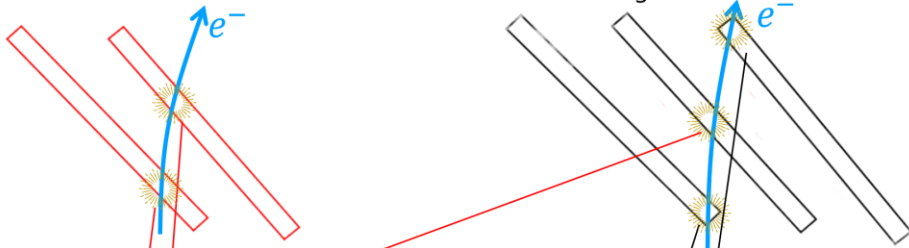


Test with cosmic-ray muons:

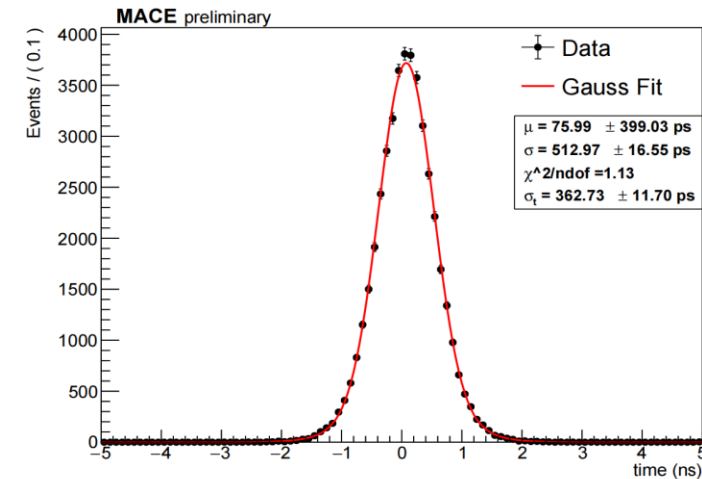
- Fitted time resolution:
 - Double-tile: $\sigma_t = (513 \pm 17) \text{ ps}$
 - Single-tile: $\sigma_t = (362 \pm 12) \text{ ps}$

Double hits: track will not cross the angle

Triple hits: the first and third tiles may be crossed the angles



MMS efficiency vs. Momentum

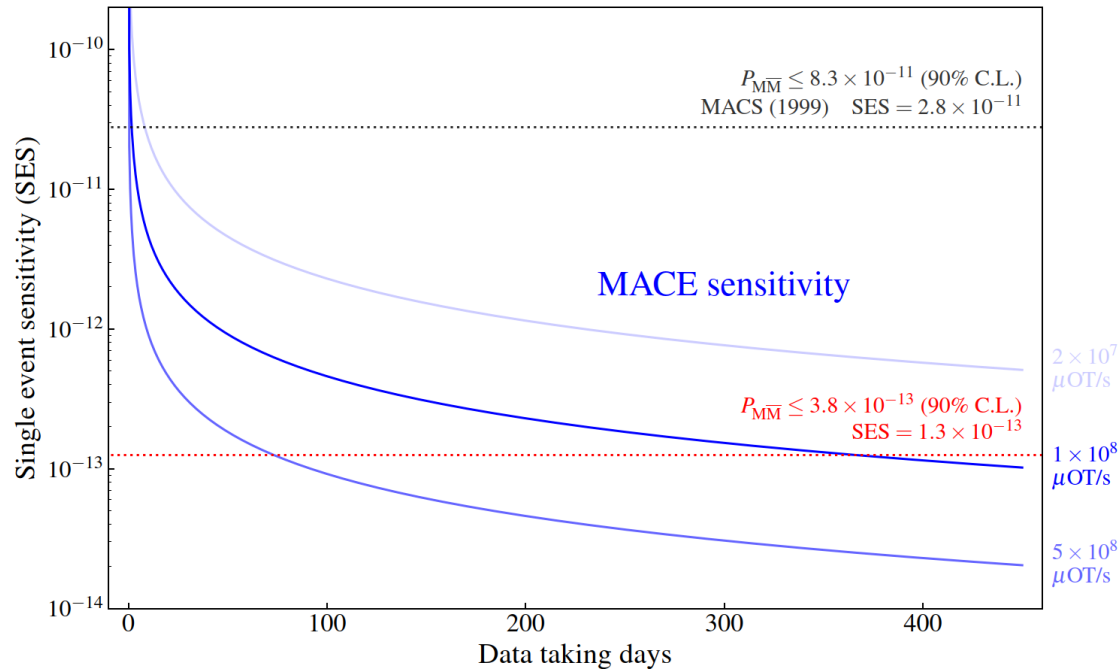


Timing resolution

Sensitivity estimation

- Summary of current simulation results:

Background type		Counts/($10^8 \mu^+ / s \cdot 1 \text{ yr}$)
Physical background	$\mu^+ \rightarrow e^+ e^- e^+ \nu_e \bar{\nu}_\mu$	0.287 ± 0.020
Accidental background	Beam positron	< 0.07
	Cosmic ray (with veto)	< 0.1
Total		< 1



Detector, component or analysis	Efficiency type	Efficiency value
Magnetic spectrometer (MMS)	Geometric efficiency ($\varepsilon_{\text{MMS}}^{\text{geom}}$)	84.6%
	Reconstruction efficiency ($\varepsilon_{\text{MMS}}^{\text{recon}}$)	$\sim 80\%$
Positron transport system (PTS)	Transmission efficiency (ε_{PTS})	65.8%
Microchannel plate (MCP)	Detection efficiency (ε_{MCP})	32.6%
	Incident efficiency $\varepsilon_{\text{ECAL}}^{\text{In}}$	63.4%
	Geometric efficiency $\varepsilon_{\text{ECAL}}^{\text{Geom}}$	95.3%
Electromagnetic calorimeter (ECAL)	Reconstruction efficiency $\varepsilon_{\text{ECAL}}^{\text{Recon}}$	94.0%
	Total detection efficiency	
Analysis	Signal efficiency (ε_{Cut})	$\sim 80\%$
Total signal efficiency		6.6%

$\mathcal{O}(10^{-13})$ single event sensitivity is expected:

$$\text{SES} = \frac{1}{\varepsilon_{\text{MMS}}^{\text{geom}} \varepsilon_{\text{MMS}}^{\text{recon}} \varepsilon_{\text{PTS}} \varepsilon_{\text{MCP}} \varepsilon_{\text{ECAL}}^{\text{In}} \varepsilon_{\text{ECAL}}^{\text{Geom}} \varepsilon_{\text{ECAL}}^{\text{Recon}} \varepsilon_{\text{Cut}} N_{\text{M}}^{\text{vac}}} = 1.3 \times 10^{-13}$$

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Proposal of MACE Phase-I

□ Muon cLFV decay modes

- ✓ $\mu^+ e^-$ annihilation: $\mu^+ e^- \rightarrow \gamma\gamma$ $\mathcal{O}(10^{-5})$, 1959
- ✓ Neutrinoless decay: $\mu^+ \rightarrow e^+ \gamma\gamma$ $\mathcal{O}(10^{-11})$, 1988
- ✓ New particles: DM, ALP, Familon, ... Crystal Box, MEG

PRL, 1959, 3: 288-291

PRD, 38 (1988) 2077

EPJC, 80 (2020) 9, 858

□ Test of the Standard Model

- ✓ $\mathcal{BR}(\mu^+ \rightarrow e^+ \gamma \nu \nu)$ $\mathcal{O}(10^{-8})$, $E_e > 45$, $E_\gamma > 40$ MeV, 2016
 - ✓ $\mathcal{BR}(\pi^+ \rightarrow \pi^0 e^+ \nu_e)$ $\mathcal{O}(10^{-8})$, 2004
 - ✓ $\mathcal{BR}(\pi^+ \rightarrow e^+ \nu_e) / \mathcal{BR}(\pi^+ \rightarrow \mu^+ \nu_\mu)$ $\mathcal{O}(10^{-4})$, 2015
- PIONEER CDR, 2022*

EPJC, 76 (2016) 3, 108

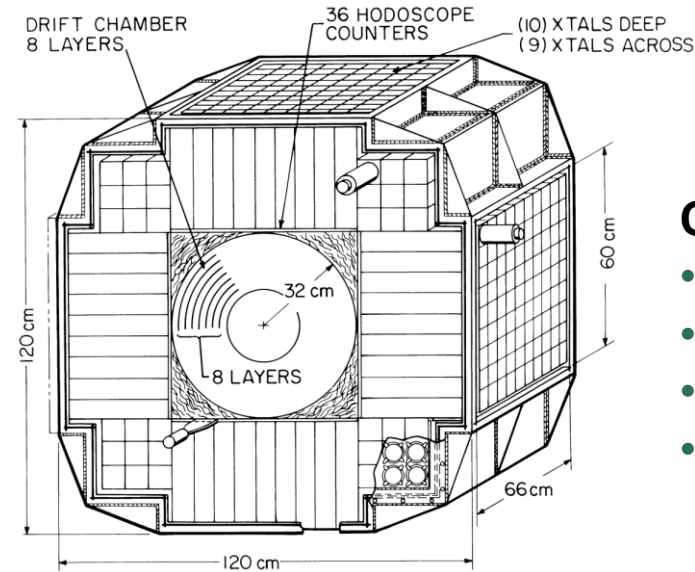
Int.J.Mod.Phys.A, 20 (2005) 472-481

PRL, 115 (2015) 7, 071801

arXiv: 2203.01981

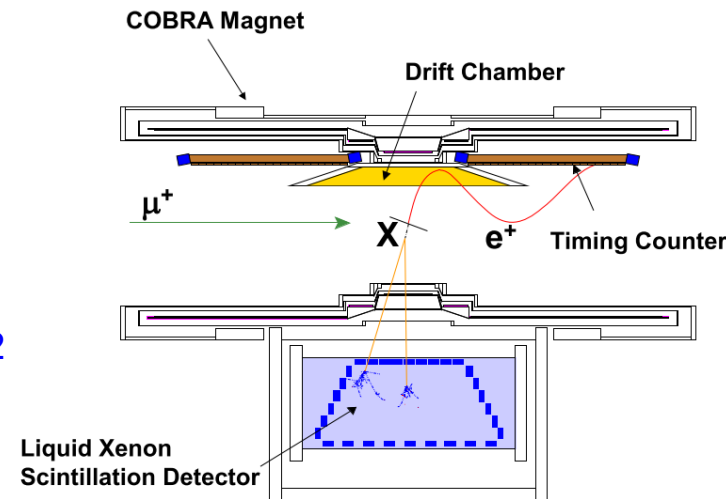
□ Perhaps: X17 anomaly ...

PRL, 2016, 116, 042501



Crystal Box:

- $\mu^+ \rightarrow e^+ \gamma\gamma$
- $\mu^+ \rightarrow e^+ X, X \rightarrow \gamma\gamma$
- $\mu^+ \rightarrow e^+ \gamma f$
- ...

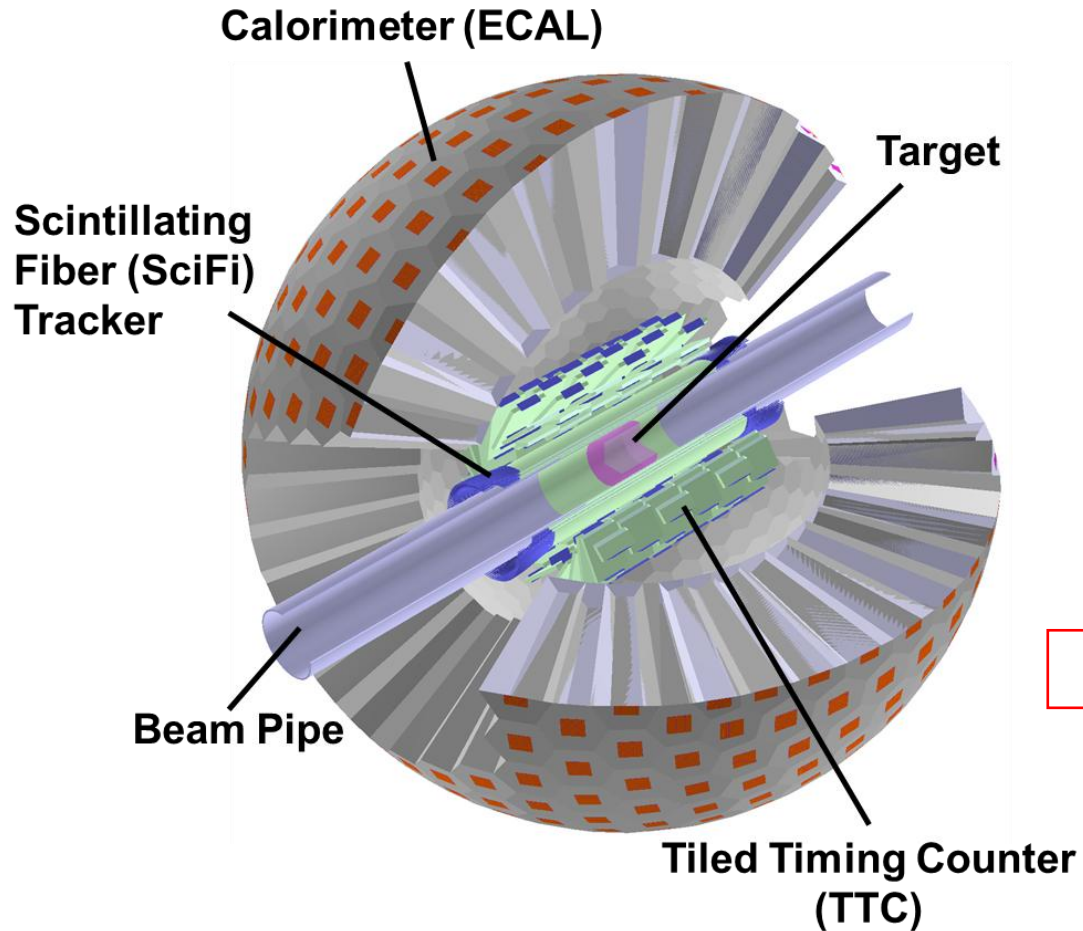


MEG:

- $\mu^+ \rightarrow e^+ \gamma$
- $\mu^+ \rightarrow e^+ \gamma \nu \nu$
- $\mu^+ \rightarrow e^+ X, X \rightarrow \gamma\gamma$

How to improve the sensitivities?

MACE Phase-I detector



Phase-I requirements:

- High-intensity muon beam — improvement of statistics
- Detectors with fast response — “pileup” rejection
- e^+ tracking and timing, e^+/γ discrimination
- High acceptance and granularity, good resolution

Challenges: No applied magnetic field, high background rate.

Detailed simulations and calibrations are undergoing!

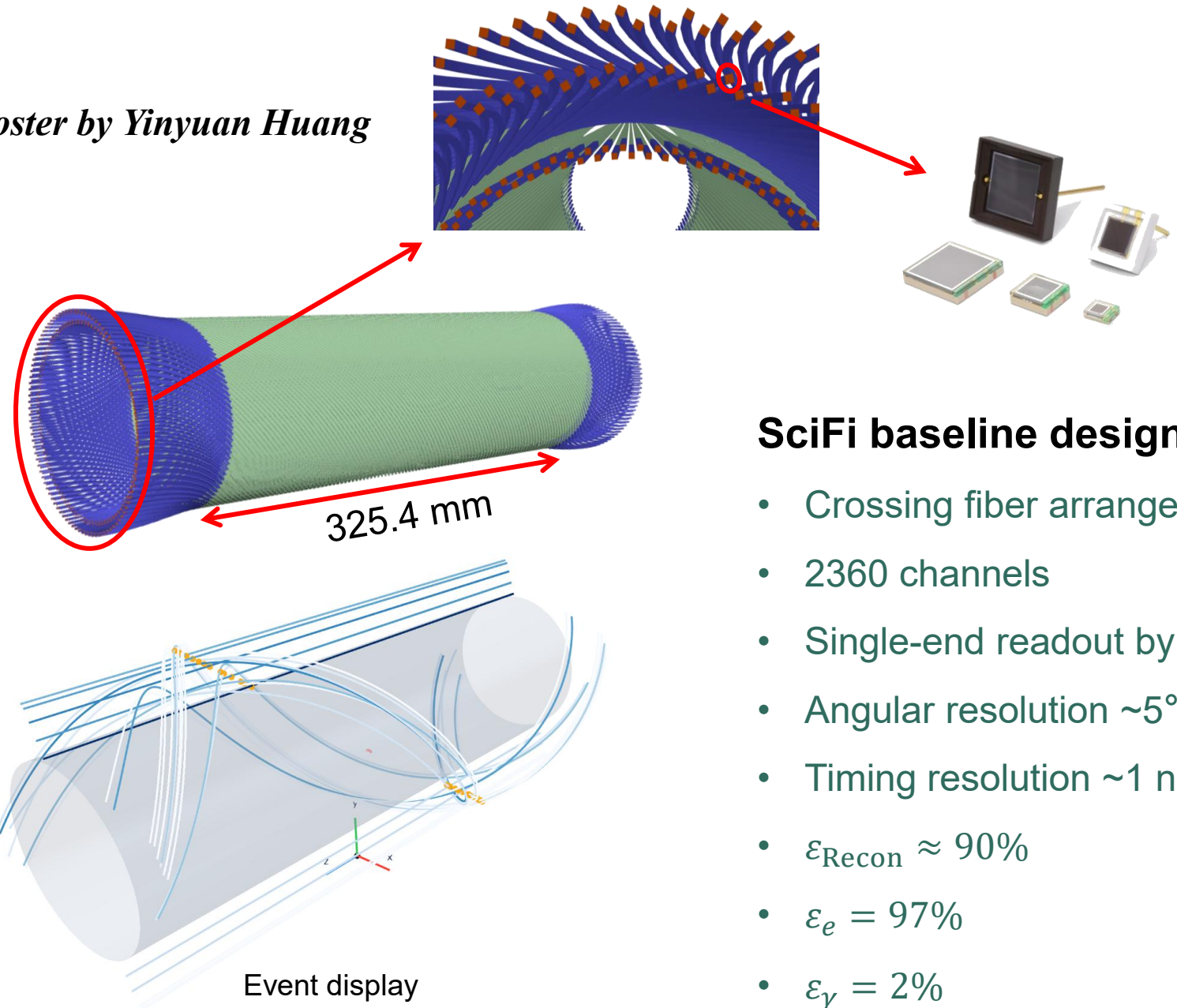
Tracking System

- Precise timing ability
- Low material budget
- Low cost
- e^+/γ discrimination
 - High active area
 - High e^+ detection efficiency
 - Low γ detection efficiency



Plastic scintillators!

See poster by Yinyuan Huang



SciFi baseline design:

- Crossing fiber arrangement
- 2360 channels
- Single-end readout by SiPM
- Angular resolution $\sim 5^\circ$
- Timing resolution ~ 1 ns
- $\epsilon_{\text{Recon}} \approx 90\%$
- $\epsilon_e = 97\%$
- $\epsilon_\gamma = 2\%$

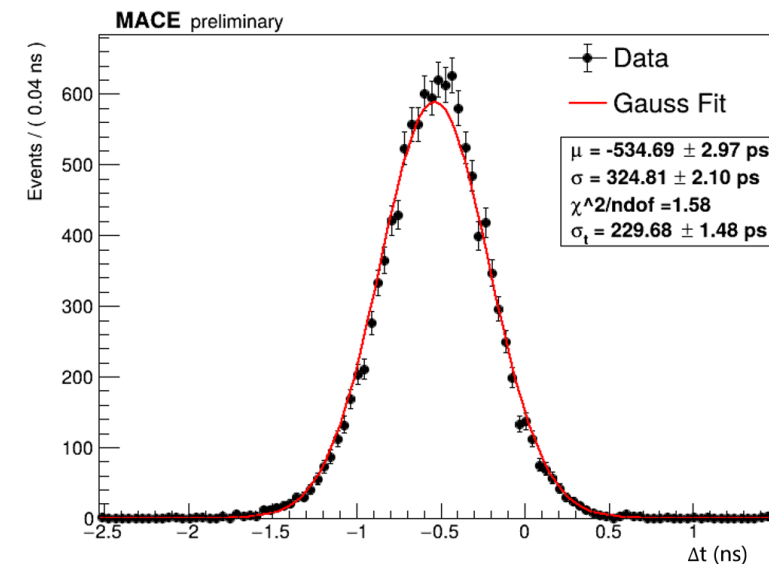
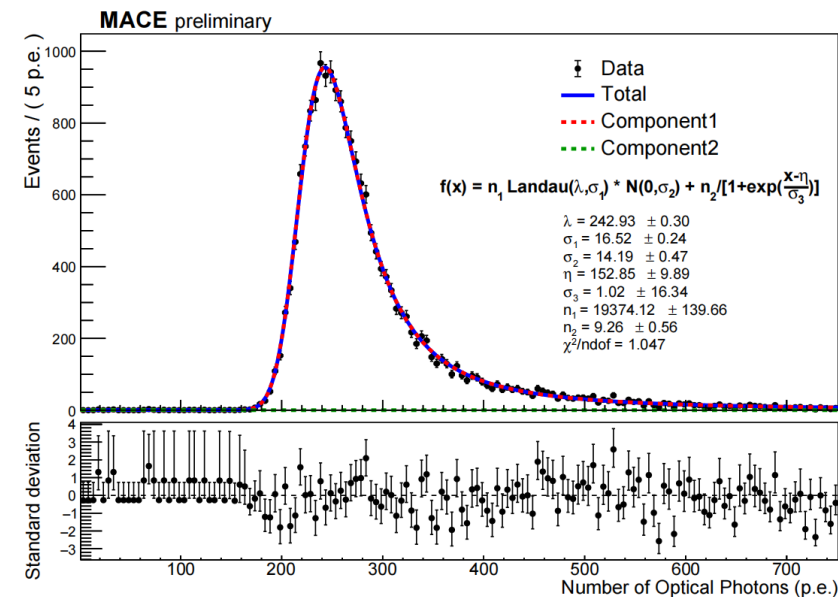
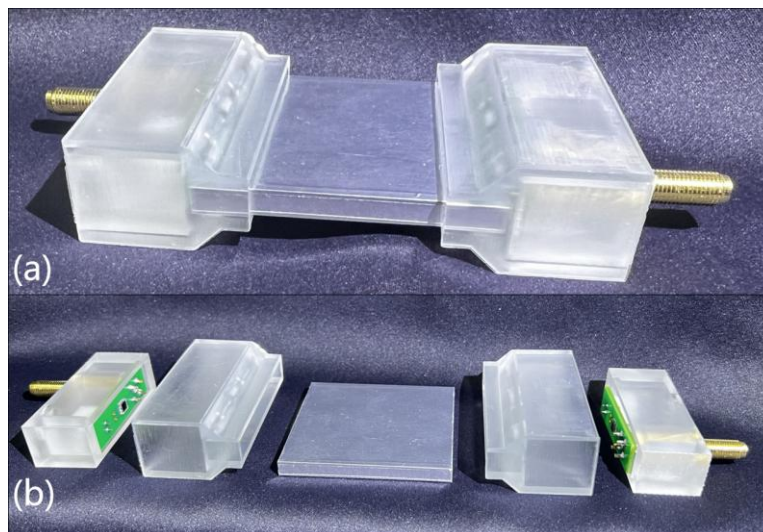
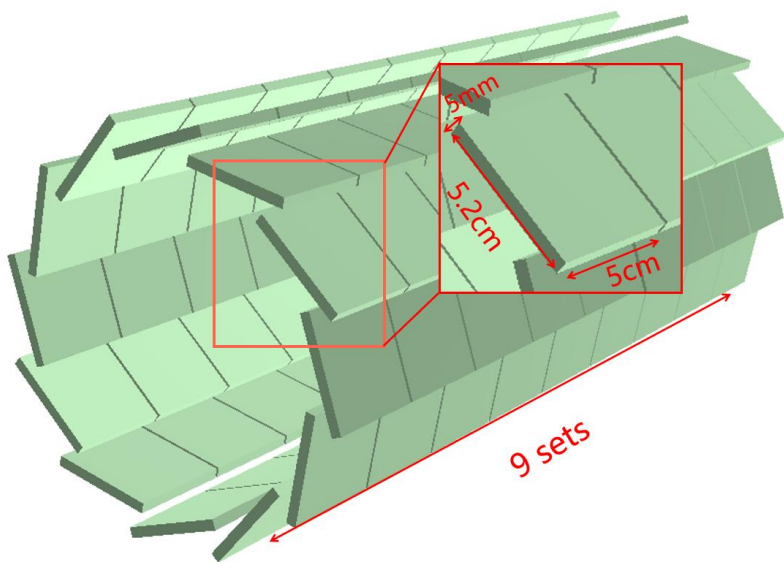
Tracking System

• Tiled timing counter (TTC)

- 108 tiles of plastic scintillator in total
- Double-end readout by SiPM arrays
- Good timing resolution, $\sim \mathcal{O}(100)$ ps
- Providing timing information to ECAL, e/γ discrimination

See poster by Hao Jiang

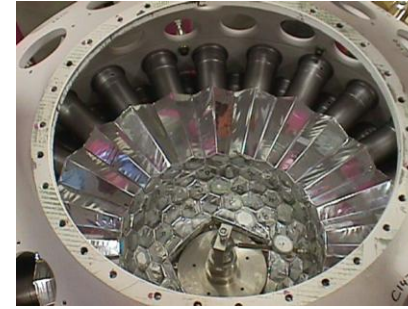
Prototype readout by **single SiPM** each end reaches **230 ps**.



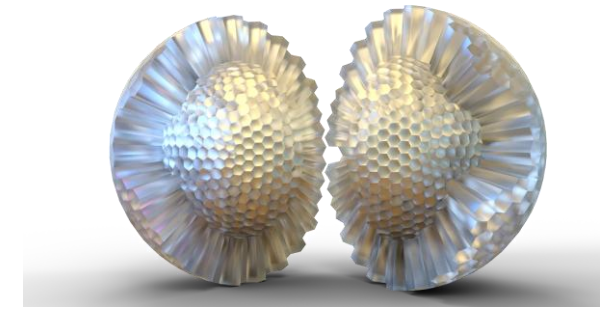
Electromagnetic Calorimeter

Design scheme:

- High acceptance and granularity
- Symmetrical structure
- Class-I GP(8,0) Goldberg polyhedron
- Crystal scintillators coupled with SiPM arrays



PEN detector
pCsl + PMT



MACE ECAL
pCsl + SiPM

LYSO

- 30000 ph/MeV
- **40 ns**
- Radiation hard
- Not hygroscopic
- Emits at 420 nm
- CNY ¥ 300/cm³

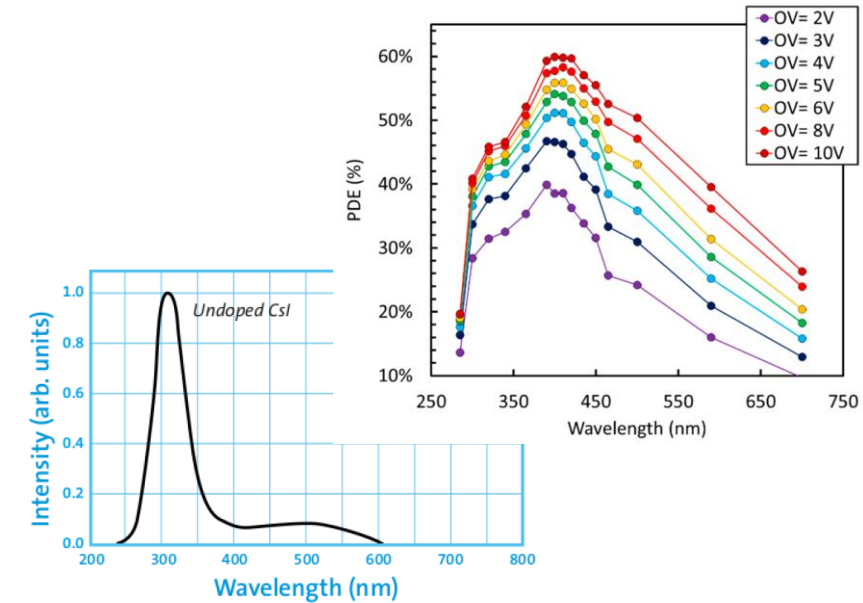
BGO

- 8000 ph/MeV
- 300 ns
- Not hygroscopic
- Emits at 480 nm
- CNY ¥ 100/cm³

Pure Csl

✓ Baseline design

- 3500 ph/MeV
- **40 ns**
- Slight hygroscopic
- Emits at 310 nm
- Adopted by **Mu2e** and **PIBETA**
- **CNY ¥ 30/cm³**

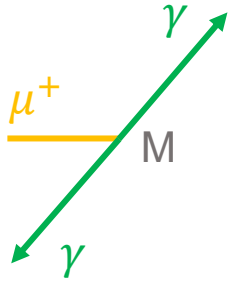


NUV SiPM readout

Sensors 19 (2019) 2, 308

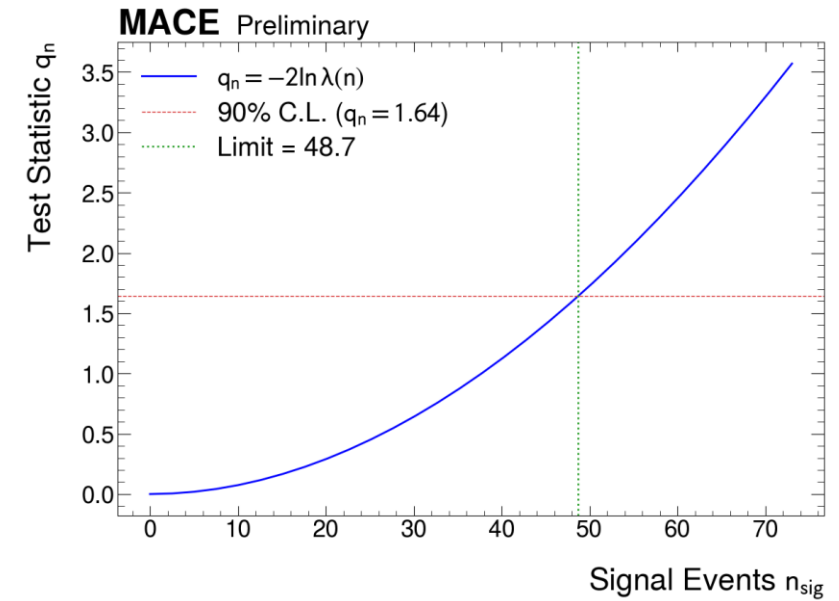
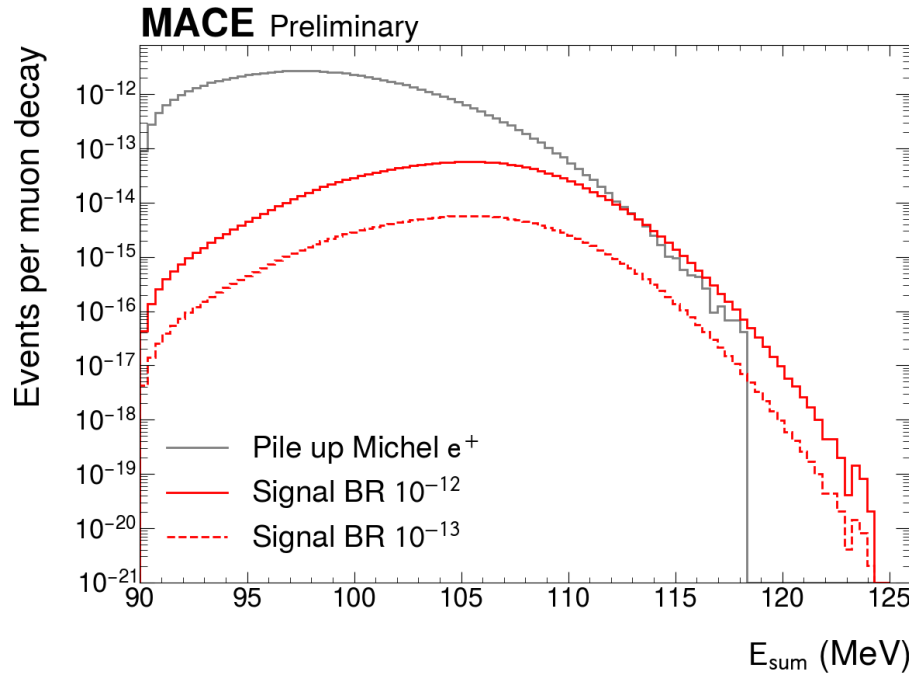
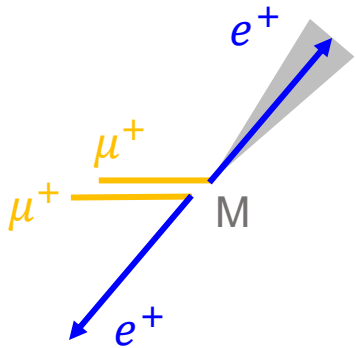
Sensitivity estimation of $M \rightarrow \gamma\gamma$

Signal: Double collinear 53 MeV gamma-rays.



- Non-response in Tracker
- Double tracks reconstructed by ECAL

Background: Accidental coincidence of “pileup” positrons.



- Asimov dataset (signal & bkg)
- Profile likelihood ratio test
- 5% systematics error included

Upper limit of BR: 5.2×10^{-13} (90% C.L.)

$O(10^{-5})$ in 1959 PRL, 1959, 3: 288-291

See also **Backup slides**
for estimation methodology

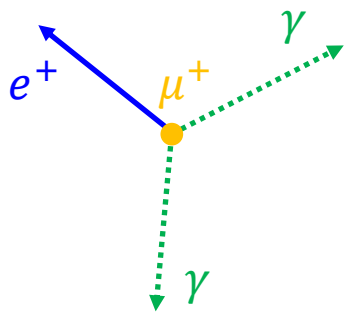
Sensitivity estimation of $\mu^+ \rightarrow e^+ \gamma \gamma$

Event selection criteria:

- Time coincidence
- **Single track** in Tracker, **Triple tracks** in ECAL
- Energy-momentum conserved

Signal:

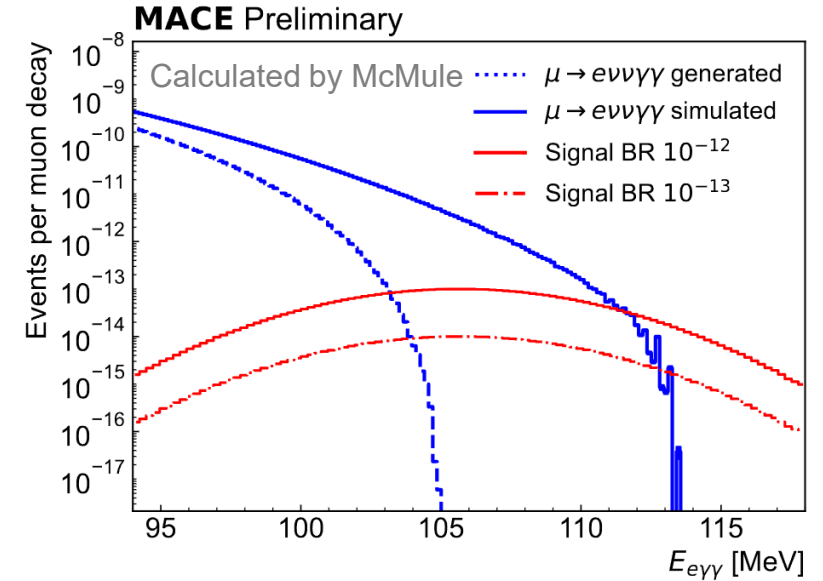
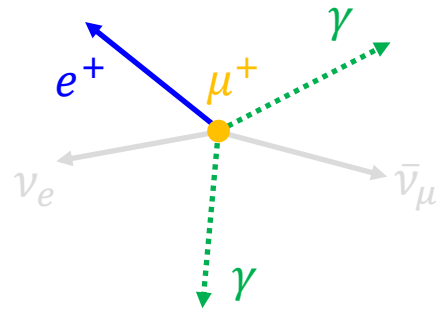
Triple coplanar tracks
 e^+ and two γ s



Background:

Double radiative muon decay

SciPost Phys. 9, 027 (2020)



$$S_{up} = \frac{1}{2} F_{\chi^2}^{-1}[1 - \alpha, 2(n_{obs} + 1)] - b$$

$$n_{obs} = b$$

$$BR(\mu^+ \rightarrow e\gamma\gamma) = \frac{S_{up}}{\epsilon_{signal} \Phi_\mu T}$$

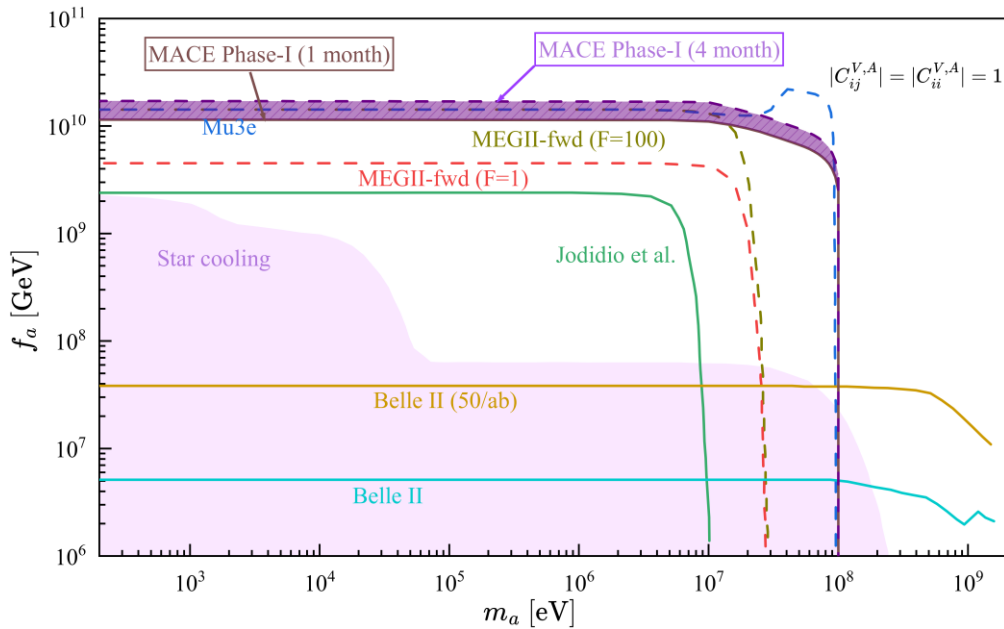
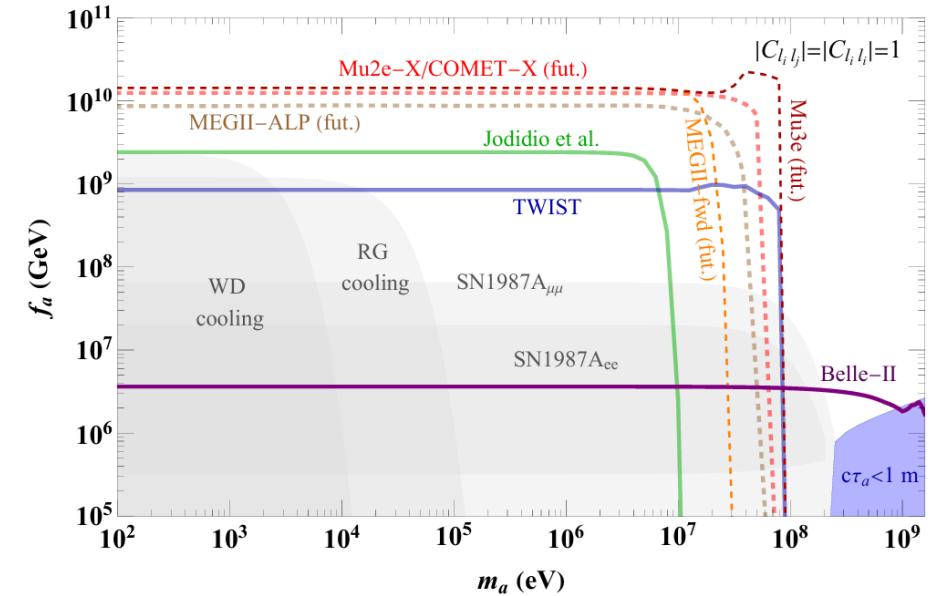
Upper limit of BR: 3.5×10^{-13} (90% C.L.)

$O(10^{-11})$ in 1988 PRD 38 (1988) 2077

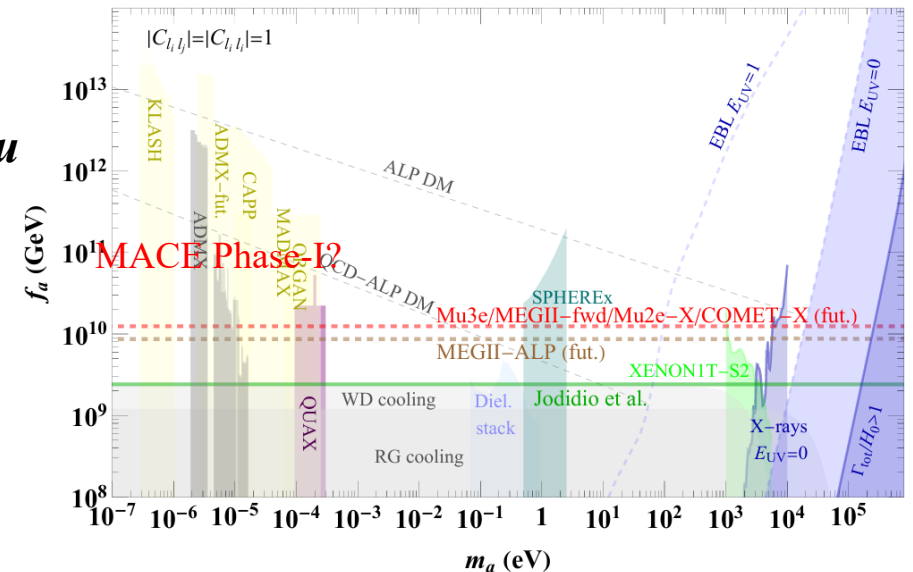
More solid simulations and refined data analyses to be updated!

Sensitivity estimation of $\mu^+ \rightarrow e^+ + a$

- Background: normal muon decays
- Beam time of approximately 28 days
- Comparable to that of Mu3e and MEGII-fwd
- Extending the running time to 120 days would provide a clear sensitivity advantage $\sim \mathcal{O}(10^{-8})$
- **It is possible to search for ALPs in MACE Phase-I!**



See poster by Guihao Lu



PRD 109, 035025 (2024)

Contents

- Motivations
- Conceptual design of MACE
- Proposal of MACE Phase-I
- Summary



Summary

- Next-generation muon cLFV experiment — MACE aims at **two orders of magnitude improvement** in $M\text{-to-}\bar{M}$ conversion probability.
- MACE Phase-I: Forerunner of MACE. A search for batches of **muon(ium) cLFV decay modes** could be forthcoming, also aiming at **broader physics programs**.
- $\mathcal{O}(10^{-13})$ sensitivities are expected.
- **Welcome to joining the high-intensity muon physics experiment MACE!**



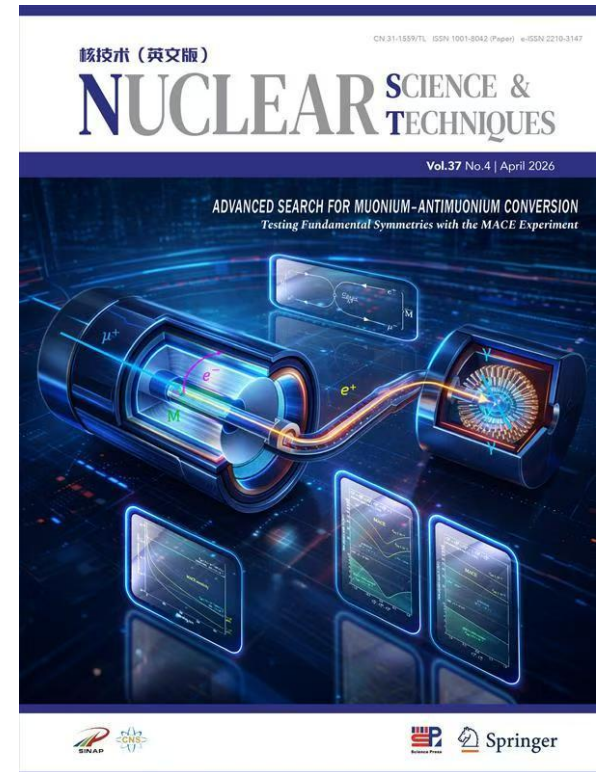
Muonium-to-Antimuonium Conversion Experiment

Conceptual Design of the Muonium-to-Antimuonium Conversion Experiment (MACE)

Ai-Yu Bai,^{1,2} Hanjie Cai,^{3,4} Chang-Lin Chen,⁵ Siyuan Chen,^{1,2} Xurong Chen,^{3,4,6} Yu Chen,^{1,2} Weibin Cheng,⁷ Ling-Yun Dai,^{5,8} Rui-Rui Fan,^{9,10,11} Li Gong,⁷ Zihao Guo,¹² Yuan He,^{3,4} Zhilong Hou,⁹ Yinyuan Huang,^{1,2} Huan Jia,^{3,4} Hao Jiang,^{1,2} Han-Tao Jing,⁹ Xiaoshen Kang,⁷ Hai-Bo Li,^{9,4} Jincheng Li,^{3,4} Yang Li,⁹ Daming Liu,¹³ Shulin Liu,^{9,4,14} Guihao Lu,^{1,2} Han Miao,^{9,4} Yunsong Ning,^{1,2} Jianwei Niu,^{3,15} Huaxing Peng,^{9,4,14} Alexey A. Petrov,¹⁶ Yuanshuai Qin,³ Mingchen Sun,^{1,2} Jian Tang,^{1,2,*} Jing-Yu Tang,¹⁷ Ye Tian,³ Rong Wang,^{3,4} Xiaodong Wang,^{18,19} Yi Wang,¹³ Zhichao Wang,^{1,2} Chen Wu,^{9,10} Tian-Yu Xing,^{20,21} Weizhi Xiong,²² Yu Xu,²³ Baojun Yan,^{9,14} De-Liang Yao,^{5,8} Tao Yu,^{1,2} Ye Yuan,^{9,4} Yi Yuan,^{1,2} Yao Zhang,⁹ Yongchao Zhang,¹² Zhilv Zhang,³ Guang Zhao,⁹ and Shihan Zhao^{1,2}

¹School of Physics, Sun Yat-sen University, Guangzhou 510275, China
²Platform for Muon Science and Technology, Sun Yat-sen University, Guangzhou 510275, China
³Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
⁴University of Chinese Academy of Sciences, Beijing 100049, China
⁵School of Physics and Electronics, Hunan University, Changsha 410082, China
⁶Southern Center for Nuclear Science Theory (SCNT), Institute of Modern Physics, Chinese Academy of Sciences, Huizhou 516000, Guangdong Province, China
⁷School of Physics, Liaoning University, Shenyang 110036, China
⁸Hunan Provincial Key Laboratory of High-Energy Scale Physics and Applications, Hunan University, Changsha 410082, China
⁹Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China
¹⁰China Spallation Neutron Source, Dongguan 523803, China
¹¹State Key Laboratory of Particle Detection and Electronics, Beijing, 100049, China
¹²School of Physics, Southeast University, Nanjing 211189, China
¹³Key Laboratory of Particle and Radiation Imaging, Department of Engineering Physics, Tsinghua University, Beijing 100084, China
¹⁴State Key Laboratory of Particle Detection and Electronics, Beijing 100049, China
¹⁵School of Nuclear Science and Technology, Lanzhou University, Lanzhou 730000, China
¹⁶Department of Physics and Astronomy, University of South Carolina, Columbia, South Carolina 29208, USA
¹⁷School of Nuclear Science and Technology, University of Science and Technology of China, Hefei 230026, China
¹⁸School of Nuclear Science and Technology, University of South China, Hengyang 421001, China
¹⁹Key Laboratory of Advanced Nuclear Energy Design and Safety (MOE), University of South China, Hengyang 421001, China
²⁰INFN Sezione di Milano, Milano 20133, Italy
²¹Università degli Studi di Milano, Milano 20122, Italy
²²Key Laboratory of Particle Physics and Particle Irradiation (MOE), Institute of Frontier and Interdisciplinary Science, Shandong University, Qingdao 266237, China
²³Advanced energy science and technology Guangdong laboratory, Huizhou 516007, China

Contact person:
Prof. Jian Tang (tangjian5@mail.sysu.edu.cn)



Thank you!

A recent review article

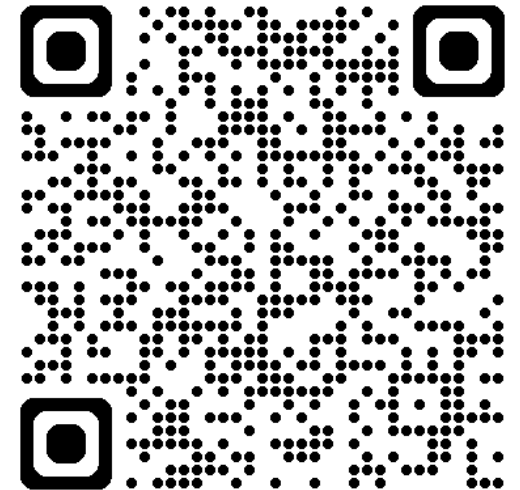
Muon beams towards muonium physics: progress and prospects

Siyuan Chen, Mingchen Sun, Jian Tang*

[arXiv:2601.15818](https://arxiv.org/abs/2601.15818)

- Existing reviews are nearly fragmented or outdated.
- Covers a complete set of **muon beams** and **muonium physics** studies to date.
 - Muon beamline development and future prospects
 - Precise muonium physics: from **cLFV** to atomic spectroscopy
 - Applications: μ SR and MIXE
- Received high praise from the international muon community
- ***Comments are welcome!***

Scan me!

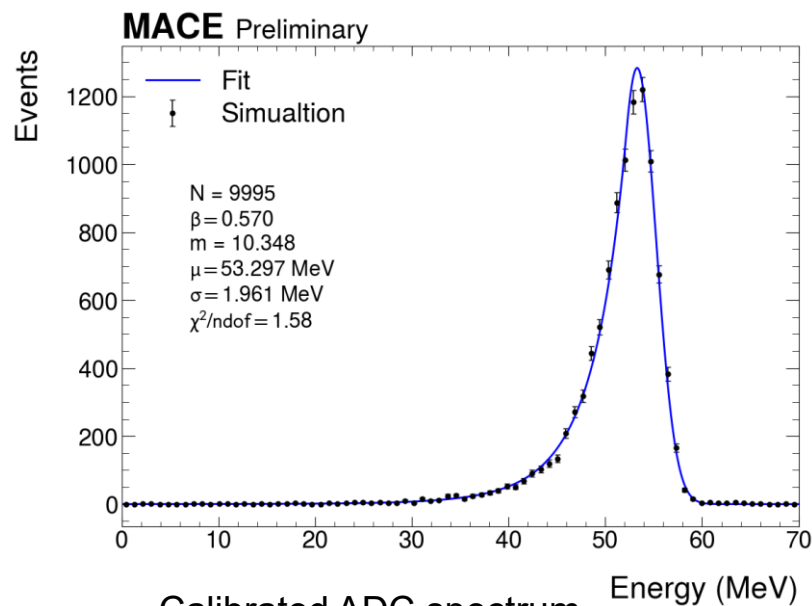
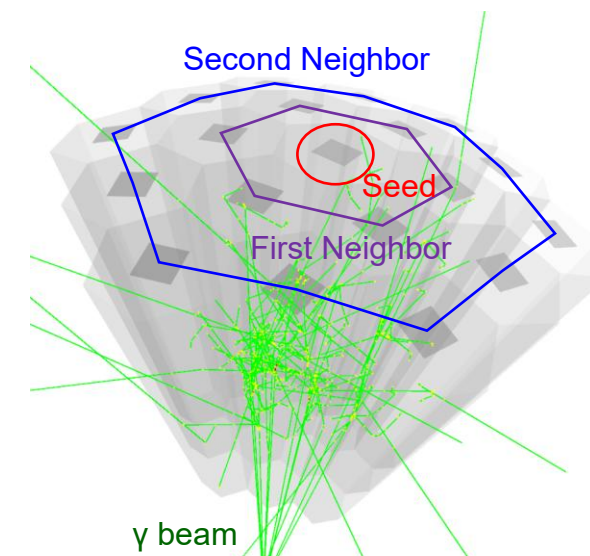


Backup slides

Phase-I ECAL performance

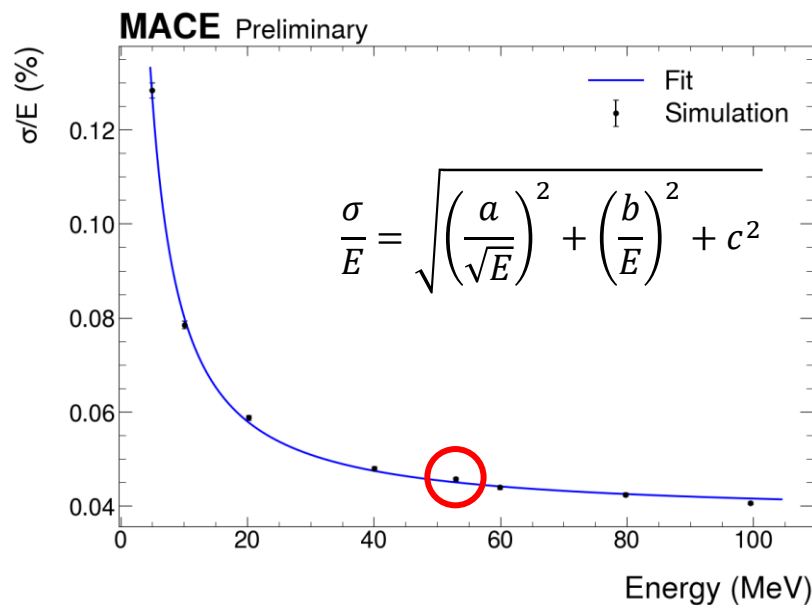
- Baseline requirement based on full simulation:
 - Full optical physics: scintillation, transportation, collection
 - Coincidence timing resolution better than **200 ps**
 - Energy resolution better than **5% @ 53 MeV**
 - Angular resolution better than **5°**

Energy-weighted clustering



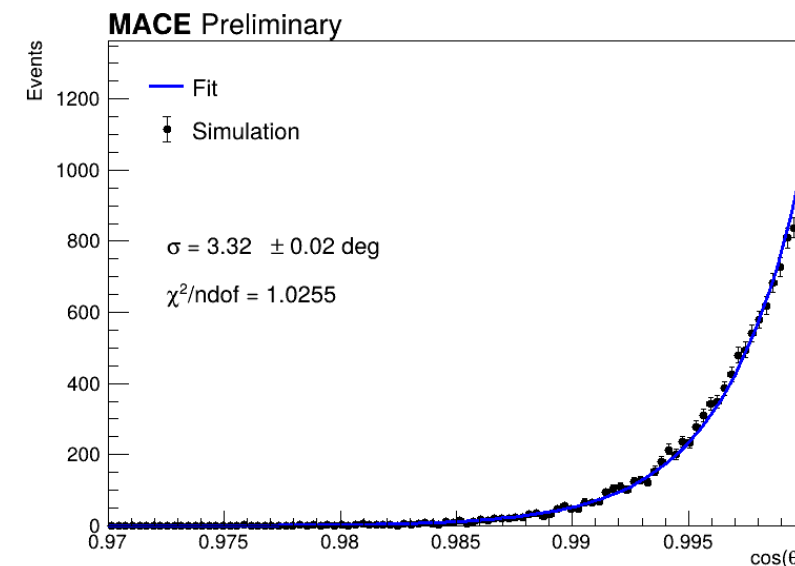
Calibrated ADC spectrum
fitted by Crystal Ball function

0(50) p.e. **electronic noise** considered



Energy resolution

1.5% nonlinear correction considered



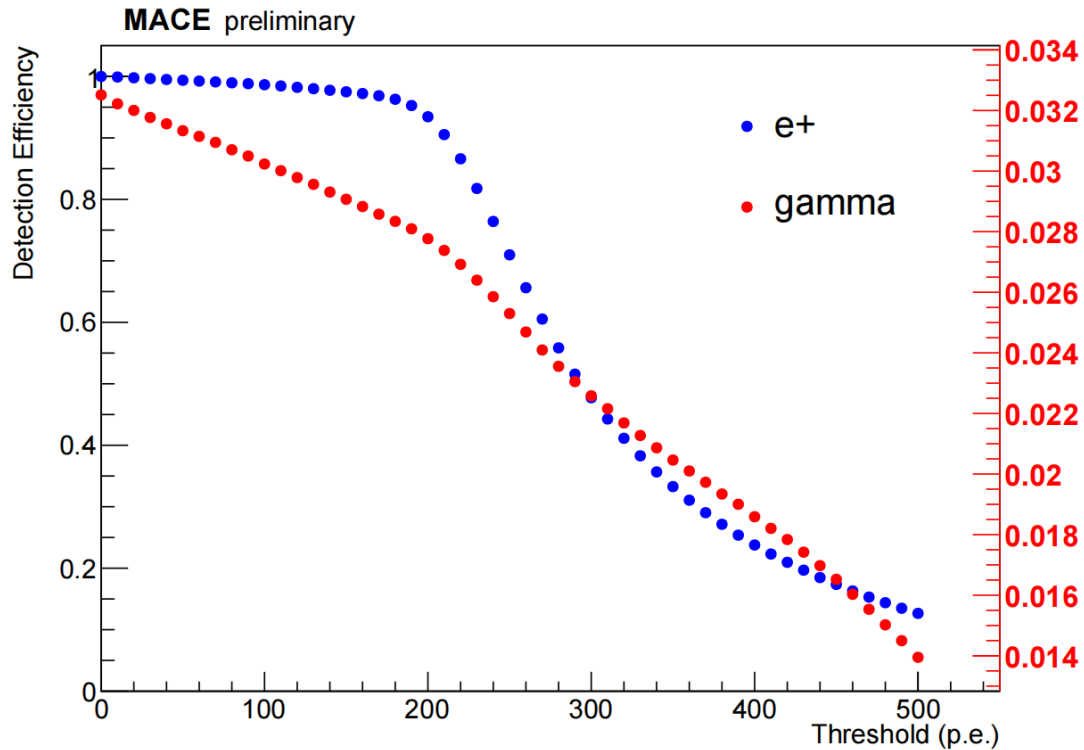
Angular resolution

Events isotopically emitted from the target

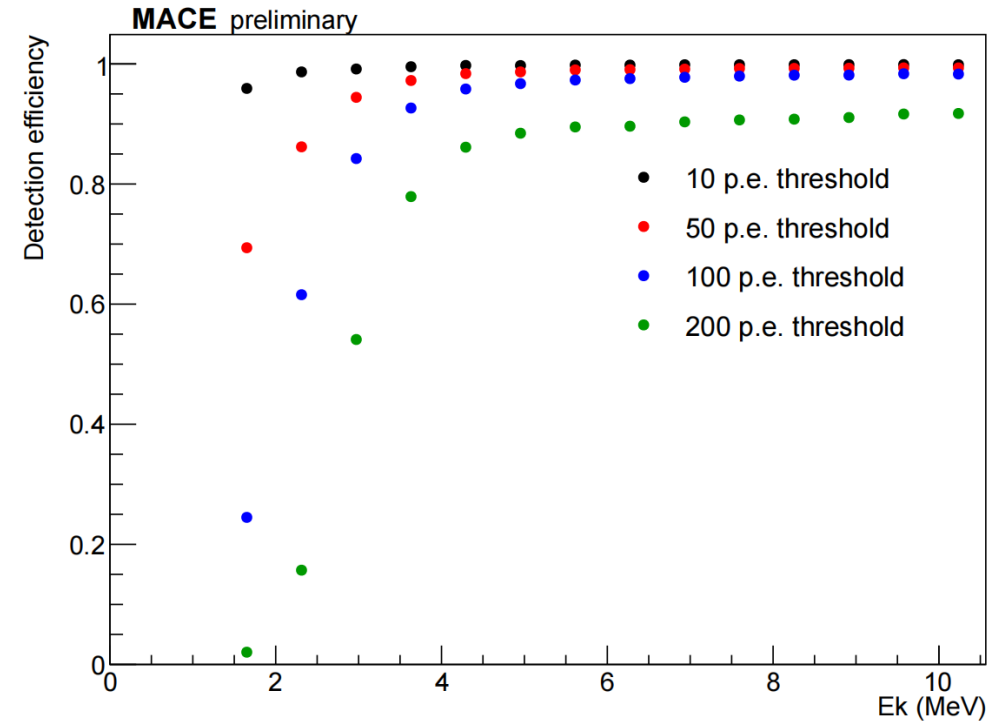
Phase-I TTC performance

- Full simulation result to investigate TTC efficiency curve and QDC threshold

✓ $\varepsilon_e = 99\%$ $\varepsilon_\gamma = 5\%$



53 MeV, Threshold vs. Efficiency

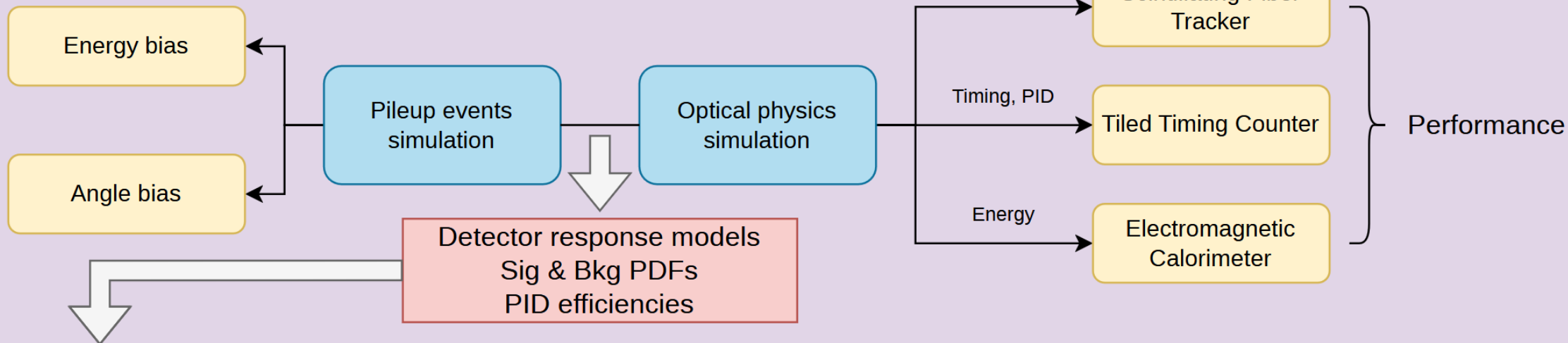


e^+ , Energy vs. Efficiency

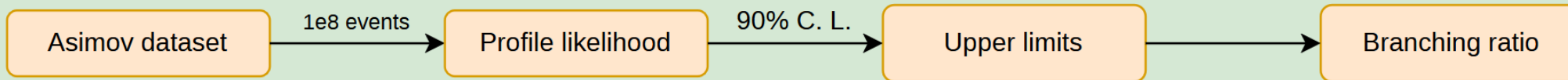
Profile likelihood based test of $M \rightarrow \gamma\gamma$

Sensitivity estimation

Data preparation



Statistical tests



See also
arXiv:1007.1727