Beyond the Standard Model with muons : improving COMET and g-2/EDM simulation and tracking

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LPNHE Paris

Tentative logo

**Joint TYL-FJPPL FKPPL Meeting**
Strasbourg
11 mai 2017

Motivations

- The Standard Model is incomplete.
- Neutrino oscillations already imply a tiny Leptonic Flavor Violation in the charged sector.
- Direct search at high energy of new particles (Energy Frontier):
$$|A_{SM} + \varepsilon_{NP}|^2 \simeq |A_{SM}|^2 + 2Re(A_{SM}\varepsilon_{NP})$$
- Indirect search (Intensity Frontier): rare processes $|A_{SM} + \varepsilon_{NP}|^2 \simeq |\varepsilon_{NP}|^2$ and measurement of fundamental quantities such as $a_\mu = (\frac{g-2}{2})_\mu$
- Two middle size first class experiments at J-PARC
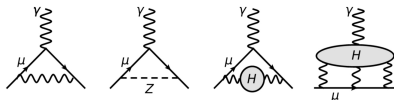
COMET (E21)

$\mu^- + A(N, Z) \rightarrow e^- + A(N, Z)$
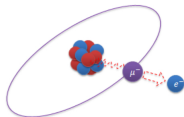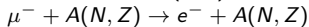
André de Gouvêa (2008):
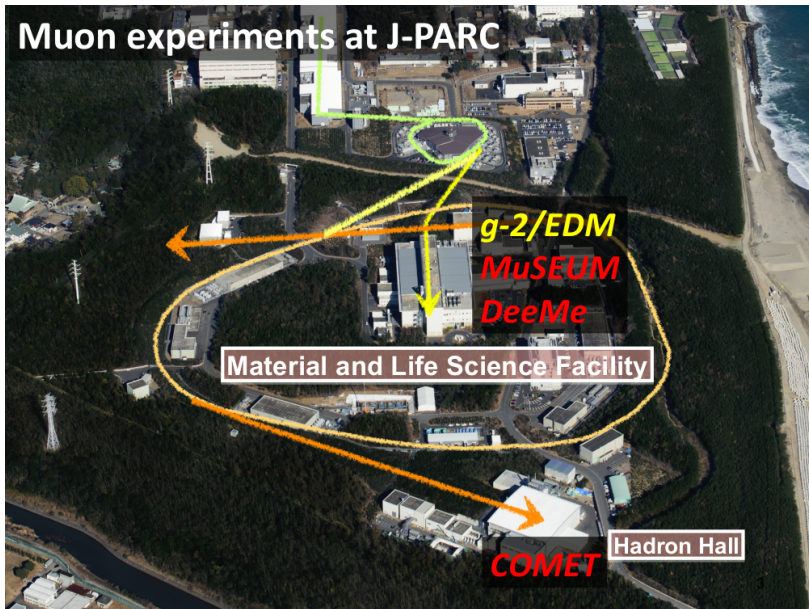"If the LHC does not discover new states
$\mu \rightarrow e$ conversion can access
1000+ TeV new physics scale"

g-2/EDM (E34)

$(a_\mu^{exp} - a_\mu^{th}) \pm \delta(a_\mu^{exp} - a_\mu^{th}) = (270 \pm 76).10^{-11}$
Discrepancy at 3.6σ

Muon experiments at J-PARC

g-2/EDM
MuSEUM
DeeMe
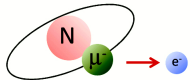
Material and Life Science Facility

Hadron Hall

COMET

COMET overview

- Selection of low momentum μ.
- Phase I in 2018 : 150 days with a 3.2 kW proton beam.
- Phase II in 2021 : 1 year with a 56 kW proton beam.
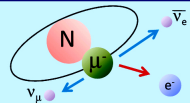- COMET Single-Event-Sensitivity Phase-I $\leq 3\ 10^{-15}$ and Phase-II $\leq 3\ 10^{-17}$
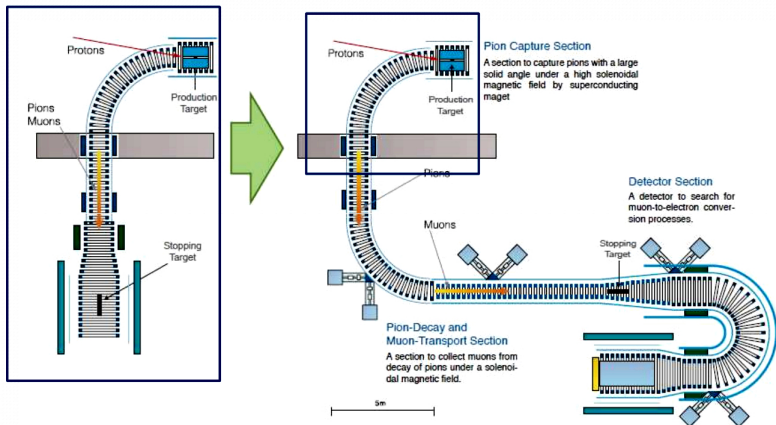
Made possible with intense and pulsed beams : 6.10^9 stopped μ/s for Phase I.

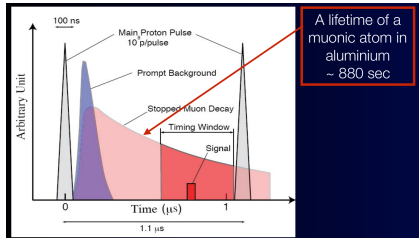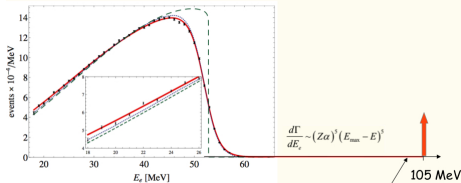# COMET overview

- **Signal : Mono-energetic electron**
  $E_e = m_\mu - B_\mu \sim 105$ MeV
- Coherent Process

A lifetime of a muonic atom in aluminium ~ 880 sec

- **BGs**
  - Prompt (Beam-related)
  - Decay in Orbit (DIO)
  - Radiative π/μ-capture
  - Decay in Flight (DIF)
  - Cosmic-rays

Spectrum of the bound muon decay

$$\frac{d\Gamma}{dE_e} \sim (Z\alpha)^5 (E_{max} - E)^5$$

105 MeV

It is the main background for the expected conversion signal

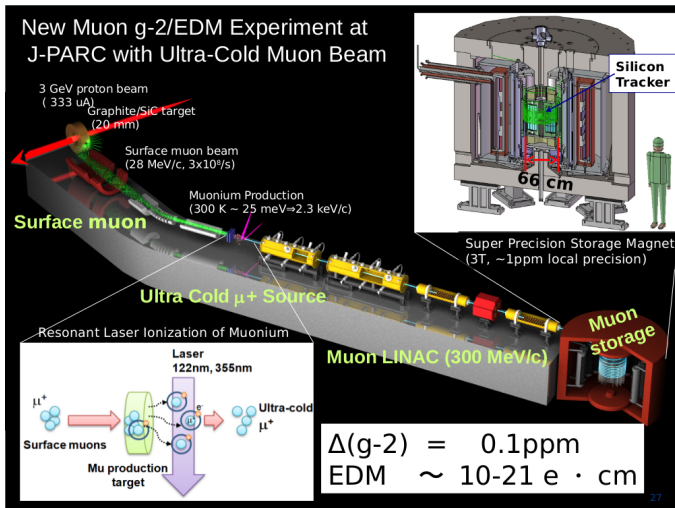Signal and DIO (BR=3 × 10⁻¹⁵)

Background   **Signal**
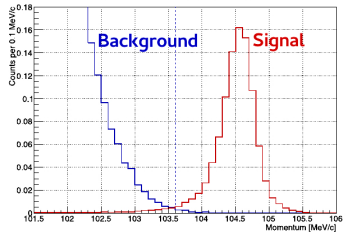
Andrzej Czarnecki and Robert Szafron

Need very good resolution detectors for background rejection and the best simulation and tracking available.

- Ultra-cold muon beam, compact storage ring and spin flip aerogel.

g-2/EDM overview
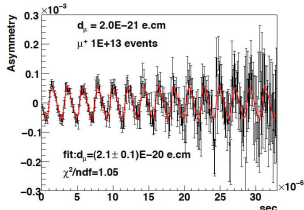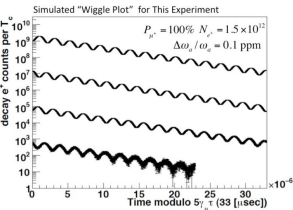
Independent measurement of muon g-2.

$$\vec{\omega} = -\frac{e}{m}[a_\mu\vec{B} - (a_\mu - \frac{1}{\gamma^2-1})\frac{\vec{\beta}\times\vec{E}}{c} + \frac{\eta}{2}(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c})]$$
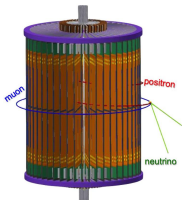
No magic momentum, but $\vec{E} = \vec{0}$.

Breakthrough in muonium production
in laser-ablated silica aerogel.

Stored muons : $3.10^5\mu$/s
Running time 2.10^7s

Silicon vanes
support

Positron tracker

Silicon strip sensor

Front End ASIC

Ongoing study of systematics and spin manipulation.
Goal of 90% track reconstruction efficiency.

People (J=Japan, K=Korea, F=France)

|				
COMET	Yoshitaka KUNO	Osaka University	FJPPL	
	Naohito SAITO	KEK/J-PARC	FJPPL	
	Satoshi MIHARA	KEK/J-PARC	FJPPL	
	Akira SATO	KEK/J-PARC	FJPPL	
	Hajime NISHIGUCHI	KEK/J-PARC	FJPPL	
	Yoshinori FUKAO	KEK/J-PARC	FJPPL	
	Mark WONG	Osaka University	FJPPL	
	MyeongJae LEE	CAPP/IBS		FKPPL
	Frederic KAPUSTA	LPNHE/IN2P3	FJPPL	FKPPL
	Wilfrid da SILVA	LPNHE/UPMC	FJPPL	FKPPL
	Giovanni CALDERINI	LPNHE/IN2P3	FJPPL	
	"Consultant for sensors"			
g-2/EDM	Tsutomu MIBE	KEK/J-PARC	FJPPL	
	Masashi OTANI	KEK/J-PARC	FJPPL	
	Eunil WON	Korea University		FKPPL
	Soohyung Lee	CAPP/IBS		FKPPL
	Maurice BENAYOUN	LPNHE/IN2P3		FKPPL
	Luigi DEL BUONO	LPNHE/IN2P3		FKPPL

COMET Phase I activities

- Setting up the Beamline in the Hall.
- Construction and tests of the detectors.

All geometry implemented in the full simulation: ICEDUST
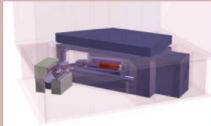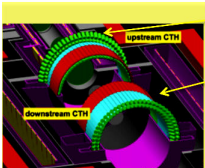
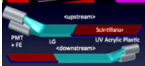**Detector for physics measurement in Phase I**
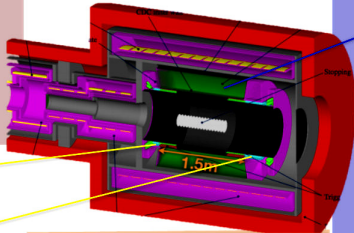
CDC : the main detector of COMET Phase-I Physics

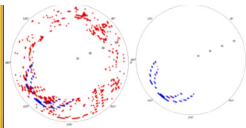Total ~20,000 wire stringing completed in Nov. 2015 at KEK

upstream CTH

downstream CTH

Analysis algorithm development in progress using simulation data. ex) track finding in CyDET

PMT + FE   LG   Scintillator   UV Acrylic Plastic   <downstream>   <upstream>
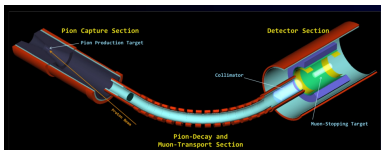
Beam test @ PSI 2015

Trigger Hodoscope Counter Scintillator + Cerenkov

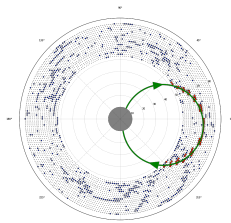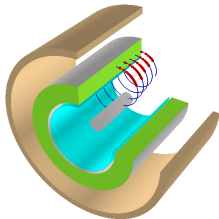CDC Read Out Electronics RECBE production at IHEP

COMET Phase I activities: J K F

- ▶ J : Developing the Software Framework.
- ▶ K : Trigger system.
- ▶ F :
  - ▶ Managing CC-IN2P3 computing and storage facilities for the collaboration high statistics (2.10^{19} protons) Monte Carlo productions.
  - ▶ Testing the software.
  - ▶ Improving the tracking.
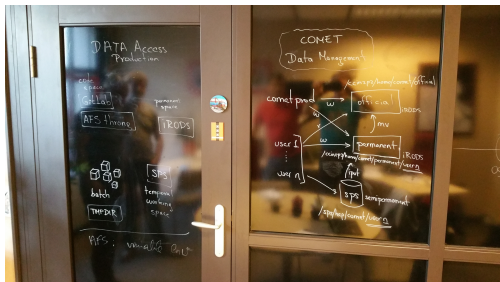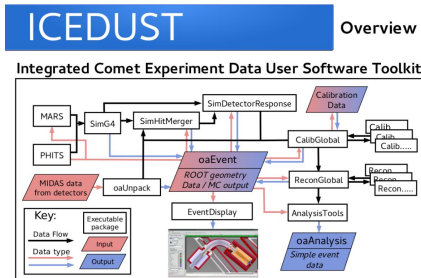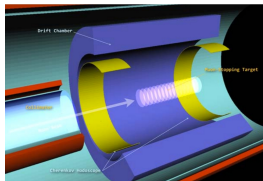
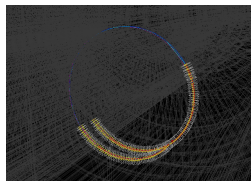# COMET Phase I activities: J K F

Track finding

- ▶ FJ : Mark Wong spent june 2016 in Paris, after presenting "Track fitting with GENFIT2 in the ICEDUST framework" in Marseilles.
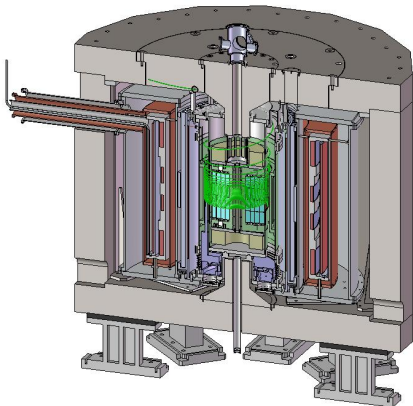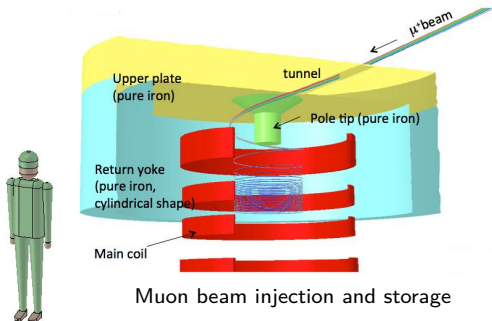

Marseilles workshop

Double turn

- ▶ FJ : Yoshitaka Kuno mid-september to mid-november. Starting the study of a "Phase III detector": a Muon Cylindric Converter with Si Vanes Detector.
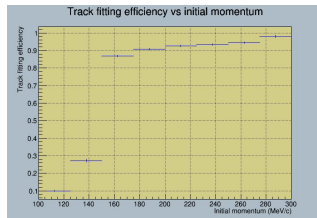
Muon storage magnet and detector
Uniform $\vec{B}$ and $\vec{E} = \vec{0}$

Muon beam injection and storage

g-2/EDM activities : J K F

- JF : "Track fitting for the muon g-2/EDM Experiment" by Shobhit Gupta supervised by Wilfrid da Silva and Tsutomu Mibe.
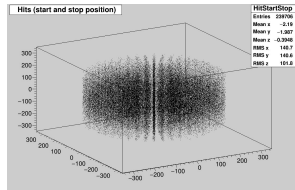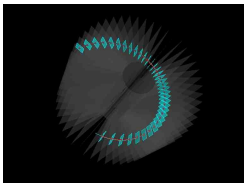
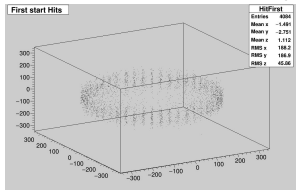

- K : DC-DC converter for readout electronics
- KF : KAIST summer student Paschalis Tsilias supervised by MyeongJae Lee

"Examining the Simulation
and Track Reconstruction techniques
for the J-PARC muon g-2 experiment"
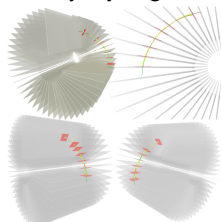
g-2/EDM activities : J K F

► F : CC-IN2P3 computing facilities proposed to the g-2/EDM collaboration.

► F : "g-2/EDM detector simulation using ICEDUST and track fitting using GENFIT at CC-IN2P3" presented to the g-2/EDM Collaboration in december 2016 during the Detector Group session at CM13@J-PARC.

The 13th collaboration meeting on muon g-2/EDM at J-PARC
Nov. 30 – Dec. 2, 2016
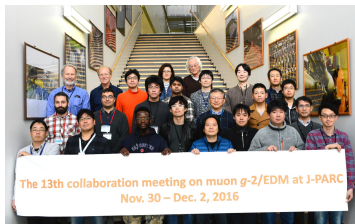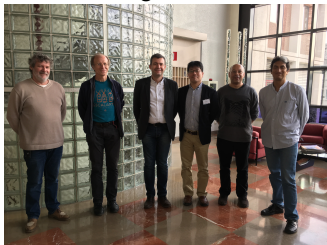
► F : CC-IN2P3 g-2 group created thanks to IN2P3 Scientific Deputy Director Patrice Verdier.

► FJ : Tsutomu Mibe visited CC-IN2P3 in february 2017. MoU in preparation.

FJPPL and FKPPL specific projects

FJPPL centered on simulation and tracking	FKPPL centered on simulation and tracking

- improving the Kalman Filter.
- optimizing the muon stopping target.
- studying a new geometry muon stopping target and detector.
- pursuing the study of an active pixel muon stopping target.

- g-2 detector simulated within ICEDUST
- implementing track finding and track fitting
- optimizing the geometry
- systematics studies

Budget request needed for specific meetings and mini-workshops.

Visit g-2/EDM and the COMET Hall
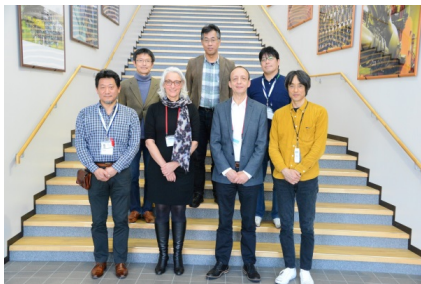
Welcome to COMET and g-2/EDM
looking for physics Beyond the Standard Model with muons