

# Physics Beyond the Standard Model with Muons g-2/EDM, COMET Muon Physics Programmes at J-PARC Mu\_01

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LPNHE(CNRS/IN2P3/UPMC) Paris



2014 Joint Workshop  
of the  
France-Japan (TYL/FJPPL) and France-Korea (FKPPL)  
Particle Physics Laboratories,  
Bordeaux, 26-28 may 2014

# Outline

- Introduction

→ Physics Motivation

→ COMET and  $g-2$ /EDM at J-PARC

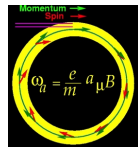
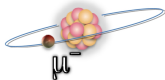
- France-Japan collaboration in COMET

- France-Japan collaboration in  $g-2$ /EDM

- Summary

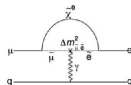
# Physics Motivation : muon physics in the search for new physics

- ▶ Direct search (Energy Frontier) LHC, ILC : higher energy for heavier new particle(s).
- ▶ Indirect search (Intensity Frontier): "slight" difference from SM prediction.



## Charged LFV

- ▶  $\mu \rightarrow e\gamma$  search from MEG@PSI  
 $Br(\mu \rightarrow e\gamma) < 5.410^{-13}$  (90%CL)
- ▶  $\mu - e$  conversion search  
SINDRUMII@PSI  $7.10^{-13}$   
COMET@J-PARC  $10^{-14}$  ( PHASE I) &  
 $10^{-16}$  ( PHASE II)  
Mu2e@FNAL  $10^{-16}$



## Muon g-2/EDM

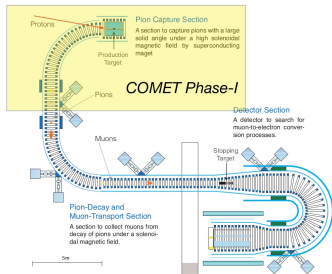
- ▶ g-2 measurement E821@BNL  
 $a_\mu[exp] - a_\mu[SM] = 3.3\sigma$  and  
 $d_\mu < 2.710^{-19}$  e cm (90%CL)
- ▶ New measurements
  - ▶ J-PARC  
0.1 ppm for g-2 /  $O(10^{-21})$  for EDM
  - ▶ FNAL



# COMET and g-2/EDM

$\mu \rightarrow e$  conversion

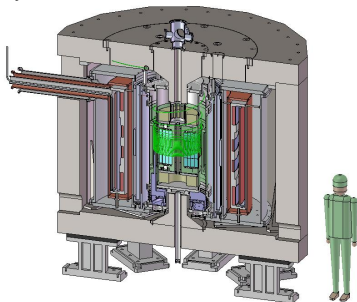
- ▶ Staging approach
- ▶ Phase I to achieve  $10^{-14}$  sensitivity and then Phase II



- ▶ Funding approved in JFY 2012 supplementary budget
- ▶ Annex of the current existing hall
- ▶ 8GeV, pulsed proton beam to produce high-intensity muon beam
- ▶ J-PARC Hadron Experimental Hall completed by end of JFY2015

Muon g-2/EDM measurements

- ▶ High-intensity muon beam produced by 3GeV proton beam from RCS
- ▶ Muon acceleration through muonium
- ▶ Systematics different from BNL or Fermilab



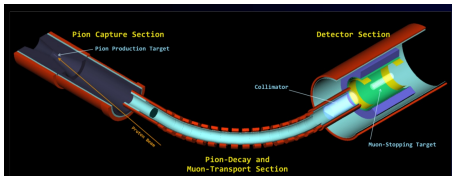
- ▶  $R = 33\text{cm}$ ,  $B = 3\text{T}$  and  $\vec{E} = \vec{0}$



## COMET (E21)

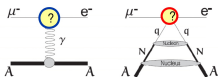
COMET Phase I (2016)

- ▶ Beam background study and achieve S.E.S.  $\simeq 3.10^{-15}$  with 8 GeV - 3.2 kW proton beam,  $\sim 3$  months DAQ



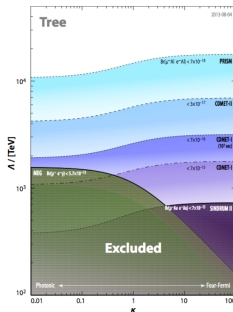
COMET Phase II (2020)

- ▶ 8GeV - 56kW proton beam ,  $\sim 1$  year DAQ to achieve the COMET final goal of S.E.S  $\simeq 3.10^{-17}$



For searches at colliders

- ▶  $|A_{SM} + \epsilon_{NP}|^2 \simeq |A_{SM}|^2 + 2Re(A_{SM}\epsilon_{NP})$
- CLFV sensitive to NP at high energy scale  $\Lambda$
- ▶  $|A_{SM} + \epsilon_{NP}|^2 \simeq |\epsilon_{NP}|^2 \Rightarrow \text{Rate} \simeq \frac{1}{\Lambda^4}$

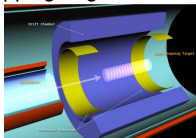


$\mu^- N \rightarrow e^- N$  low energy effective lagrangian

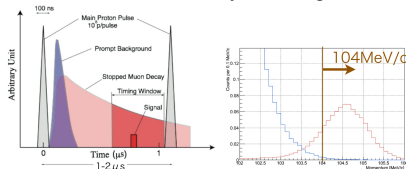
$$\mathcal{L} = \frac{1}{1+\kappa} \frac{m_\mu}{\Lambda^2} \bar{\mu}_R \sigma^{\mu\nu} e_L \mathcal{F}_{\mu\nu} + \frac{\kappa}{1+\kappa} \frac{1}{\Lambda^2} (\bar{\mu}_L \gamma^\mu e_L) (\bar{q}_L \gamma_\mu q_L) + h.c.$$

# France-Japan collaboration in COMET

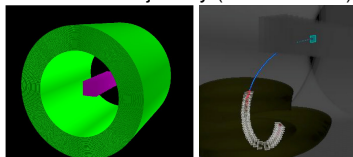
- ▶ COMET Phase I  
Construction of the muon transport solenoid down to the 1<sup>st</sup> 90<sup>o</sup> bend
- ▶ CDC and Triggering counter surrounding a muon stopping target



$\mu \rightarrow e$  conversion signal identified with an energetic electron of 105MeV emitted from a muonic atom with delayed timing.



- ▶ LPNHE R&D for an active muon stopping target in order to get an additional point for the electron trajectory (CM11 - 2013)

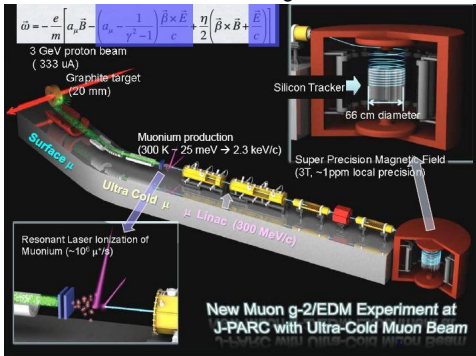


- ▶ Simulation and reconstruction with GENFIT within ICEDUST(Integrated Comet Experiment Data User Software Toolkit), the new COMET Software Framework
- ▶ Discussion on the possibility of a beam test of ATLAS pixels at J-PARC with Kyushu University.
- ▶ MARS and ICEDUST installed at CCIN2P3 available on the VO France Asia using iRODS, thanks to Yonny Cardenas from CCIN2P3, including discussion on the data model.



# g-2/EDM (E34)

"Null" electric field, no "magic momentum"



On the use of low energy  $e^+e^-$  data :  
 M. Benayoun vs M. Davier at Photon 2013.



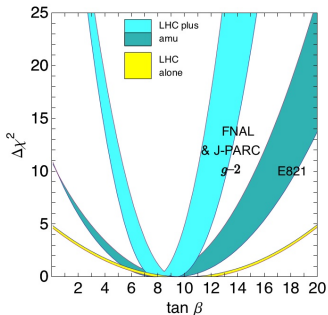
Observed Difference with BNL using  $e^+e^-$  :

$a_\mu [\text{exp}] - a_\mu [\text{SM}] = (27.5 \pm 8.4) \times 10^{-10}$   
 $\rightarrow$  3.3 „standard deviations“

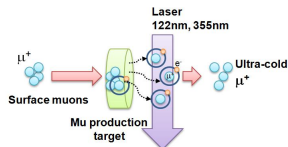
More precise computations using real data.



Improved precision to constrain SUSY



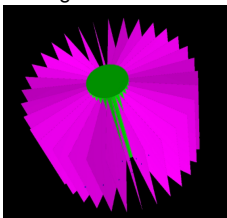
# France-Japan collaboration in g-2/EDM



Recent breakthrough in  $\mu$  production yield.

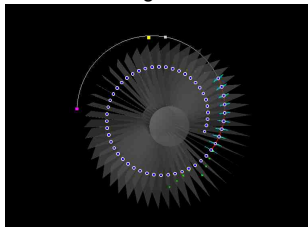
Muon beam intensity can be large enough to test the BNL g-2 anomaly better than 0.5ppm precision.

- ▶ Muon acceleration test
- ▶ Beam transport design
- ▶ Error on B-field and correction scheme
- ▶ Detector design



- ▶ Detector characterization including beam tests of silicon-strip vanes at DESY/J-PARC
- ▶ Software framework

- ▶  $e^+$  reconstruction using GENFIT



- ▶ Simulation software and computing resources at CCIN2P3, thanks to Yonny Cardenas.
- ▶ VO France Asia intensive use for silicon vanes alignment. (Master thesis of Soishiro Nishimura)



# Members and funding request

- ▶ **French Group**

(LPNHE-Paris CNRS/IN2P3/UPMC)

Frédéric KAPUSTA

Wilfrid da SILVA

Jacques DAVID

Jean-François GENAT

Giovanni CALDERINI

- ▶ **Funding request**

4 travels + 40 days stay

€4000 + €6000

- ▶ **Japanese Group**

(KEK & Osaka U)

Tsutomu MIBE

Naohito SAITO

Satoshi MIHARA

Kazuki UENO

Hajime NISHIGUCHI

Yoshitaka KUNO

Akira SATO

Yoshinori FUKAO

Masashi OTANI

- ▶ **Funding request**

3 travels + 45 days stay

¥450k + ¥900k

- ▶ Common COMET g-2/EDM FJPPL Workshop (Paris, 20-21 february 2014)



Workshop on silicon detectors for  
g-2/EDM/COMET experiments

20-21 février 2014  
L'INiE Paris  
D'Orsay/Paris

**Overview**  
Agenda  
Timetable  
Registration  
1. Registration Form  
List of registrants  
Access to L'INiE

The g-2/EDM and COMET experiments will detect positrons and electrons with silicon microstrips and pixels detectors.  
The current status and the future needs will be reviewed and discussed.

Début: 20 fév. 2014 09:00  
Fin: 21 fév. 2014 19:00  
Europe/Paris

L'INiE Paris  
1215-PC08-11

- ▶ COMET

- ▶ CDC tracker design and prototype R&D (JP)
- ▶ Development of tracking algorithm design optimization using simulation (FR)
- ▶ Active muon stopping target and Beam monitor planning (FR)

- ▶ g-2/EDM

- ▶ Silicon tracker R&D (JP)
- ▶ Simulation and tracking software framework (FR)
- ▶ TDR planned for release in Jan 2015.

# Summary

- ▶ Role of muon physics in LHC era
- ▶ Charged LFV search & measurements of muon magnetic and electric dipole moments
- ▶ J-PARC projects :  
COMET and muon  $g-2$ /EDM  
Efficient and intensive R&D in the FJPPL framework