COMET and g-2/EDM experiments at J-PARC : an overview

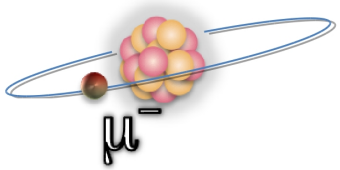
W. da Silva and F. Kapusta
LPNHE Paris

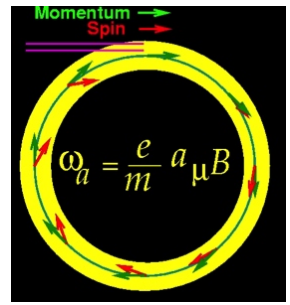
FJPPL Computing Workshop
10-11 march 2015

In memory of Jacques Ganouna

Physics Motivation : Beyond the Standard Model with muons

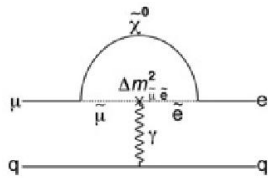
- Direct search (Energy Frontier) LHC, ILC : higher energy for heavier new particle(s).
- Indirect search (Intensity Frontier): "slight" difference from SM prediction.





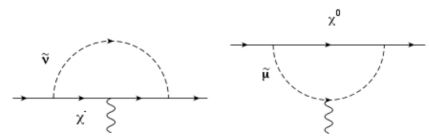
Charged LFV

- $\mu \to e\gamma$ search from MEG@PSI
  $Br(\mu \to e\gamma) < 5.4\ 10^{-13}(90\%CL)$
- $\mu - e$ conversion search
  SINDRUMII@PSI 7.10^{-13}
  COMET@J-PARC $3\ 10^{-15}$(PHASE I) &
  $2.6\ 10^{-17}$(PHASE II)
  Mu2e@FNAL $2.4\ 10^{-17}$



Muon g-2/EDM

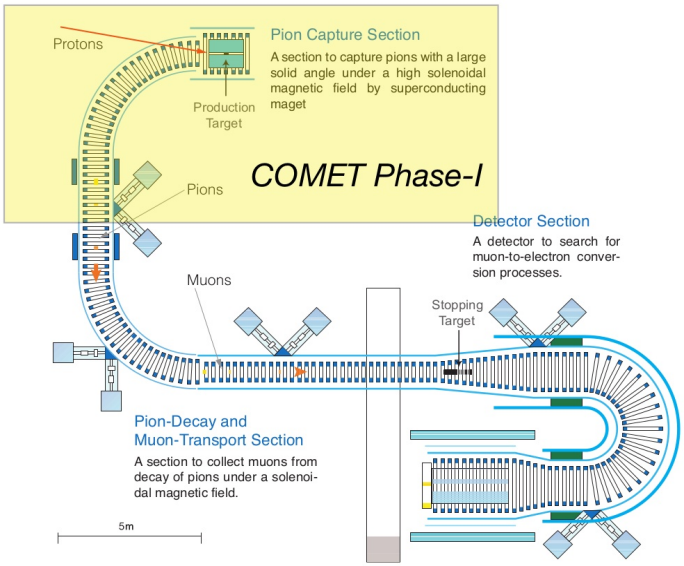
- g-2 measurement E821@BNL
  $a_\mu[exp] - a_\mu[SM] = 3.3\ \sigma$ and
  $d_\mu < 2.7\ 10^{-19}$ e cm (90% CL)
- New measurements
  - J-PARC
    0.1 ppm for g-2 / $O(10^{-21})$ for EDM
  - FNAL



COMET and g-2/EDM

$\mu \rightarrow e$ conversion

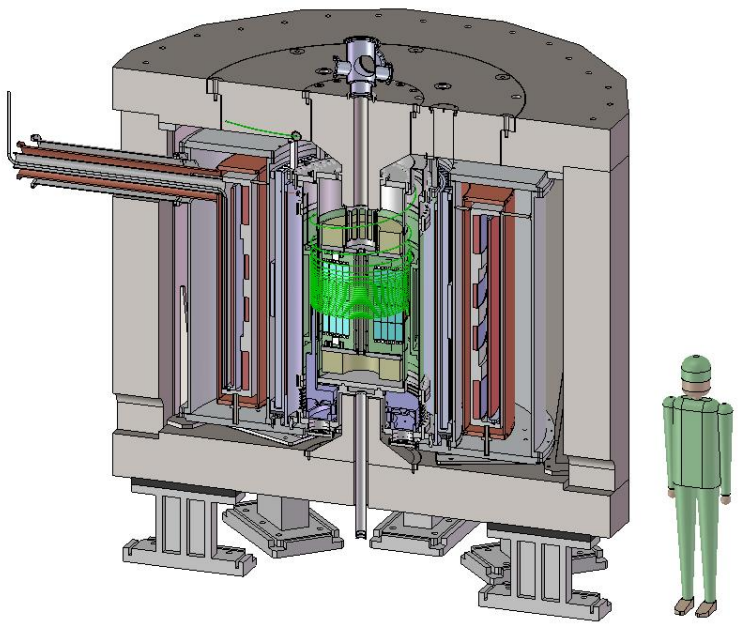
- Staging approach
- Phase I to achieve 10^{-14} sensitivity and then Phase II



- Funding approved in JFY 2012 supplementary budget
- Annex of the current existing hall
- 8 GeV, 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 3 GeV proton beam from RCS
- Muon acceleration through muonium
- Systematics different from BNL or Fermilab



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

From Yoshitaka Kuno @CM15

COMET Collaboration

Osaka University

164 collaborators
37 institutes, 12 countries

The COMET Collaboration

R. Akhmetshin[6,28], V. Anishchik[4], M. Aoki[29], R. B. Appleby[8,22], Y. Arimoto[15], Y. Bagaturia[33], Y. Ban[3], W. Bertsche[22], A. Bondar[6,28], S. Canfer[30], S. Chen[25], Y. E. Cheung[25], B. Chiladze[32], D. Clarke[30], M. Danilov[13,23], P. D. Dauncey[11], J. David[20], W. Da Silva[20], C. Densham[30], G. Devidze[32], P. Dornan[11], A. Drutskoy[13,23], V. Duginov[14], A. Edmonds[35], L. Epshteyn[6,27], P. Evtoukhovich[14], G. Fedotovich[6,28], M. Finger[7], M. Finger Jr[7], Y. Fujii[2], Y. Fukao[15], J-F. Genat[20], M. Gersabeck[22], E. Gillies[11], D. Grigoriev[6,27,28], K. Gritsay[14], R. Han[1], K. Hasegawa[15], I. H. Hasim[29], O. Hayashi[29], M. I. Hossain[16], Z. A. Ibrahim[21], Y. Igarashi[15], F. Ignatov[6,28], M. Iio[15], M. Ikeno[15], K. Ishibashi[19], S. Ishimoto[15], T. Itahashi[29], S. Ito[29], T. Iwami[29], Y. Iwashita[17], X. S. Jiang[2], P. Jonsson[11], V. Kalinnikov[14], F. Kapusta[20], H. Katayama[29], K. Kawagoe[19], V. Kazanin[6,28], B. Khazin[§6,28], A. Khvedelidze[14], M. Koike[36], G. A. Kozlov[14], B. Krikler[11], A. Kulikov[14], E. Kulish[14], Y. Kuno[29], Y. Kuriyama[18], Y. Kurochkin[5], A. Kurup[11], B. Lagrange[11,18], M. Lancaster[35], H. B. Li[2], W. G. Li[2], A. Liparteliani[32], R. P. Litchfield[35], P. Loveridge[30], G. Macharashvili[14], Y. Makida[15], Y. Mao[3], O. Markin[13], Y. Matsumoto[29], T. Mibe[15], S. Mihara[15], F. Mohamad Idris[21], K. A. Mohamed Kamal Azmi[21], A. Moiseenko[14], Y. Mori[18], N. Mosulishvili[32], E. Motuk[35], Y. Nakai[19], T. Nakamoto[15], Y. Nakazawa[29], J. Nash[11], M. Nioradze[32], H. Nishiguchi[15], T. Numao[34], J. O'Dell[30], T. Ogitsu[15], K. Oishi[19], K. Okamoto[29], C. Omori[15], T. Ota[31], H. Owen[22], C. Parkes[22], J. Pasternak[11], C. Plostinar[30], V. Ponariadov[4], A. Popov[6,28], V. Rusinov[13,23], A. Ryzhenenkov[6,28], B. Sabirov[14], N. Saito[15], H. Sakamoto[29], P. Sarin[10], K. Sasaki[15], A. Sato[29], J. Sato[31], D. Shemyakin[6,28], N. Shigyo[19], D. Shoukavy[5], M. Slunecka[7], M. Sugano[15], Y. Takubo[15], M. Tanaka[15], C. V. Tao[26], E. Tarkovsky[13,23], Y. Tevzadze[32], N. D. Thong[29], V. Thuan[12], J. Tojo[19], M. Tomasek[9], M. Tomizawa[15], N. H. Tran[29], I. Trek[32], N. M. Truong[29], Z. Tsamalaidze[14], N. Tsverava[14], S. Tygier[22], T. Uchida[15], Y. Uchida[11], K. Ueno[15], S. Umasankar[10], E. Velicheva[14], A. Volkov[14], V. Vrba[9], W. A. T. Wan Abdullah[21], M. Warren[35], M. Wing[35], T. S. Wong[29], C. Wu[2,25], G. Xia[22], H. Yamaguchi[19], A. Yamamoto[15], M. Yamanaka[24], Y. Yang[19], H. Yoshida[29], M. Yoshida[15], Y. Yoshii[15], T. Yoshioka[19], Y. Yuan[2], Y. Yudin[6,28], J. Zhang[2], Y. Zhang[2]

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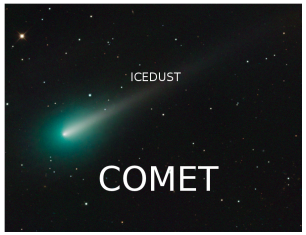
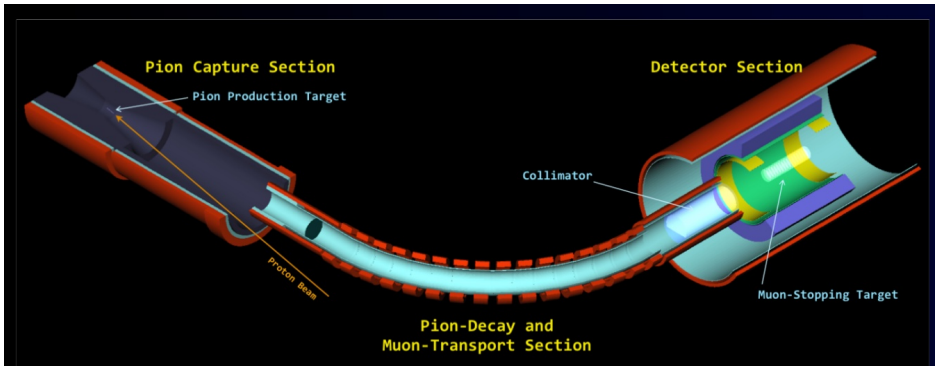
[2] *Institute of High Energy Physics (IHEP), Beijing, People's Republic of China*
[3] *Peking University, Beijing, People's Republic of China*
[4] *Belarusian State University (BSU), Minsk, Belarus*
[5] *B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus*



COMET (E21)

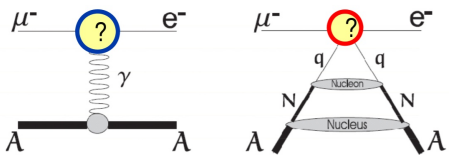
COMET Phase I (2016)

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



COMET Phase II (2020)

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

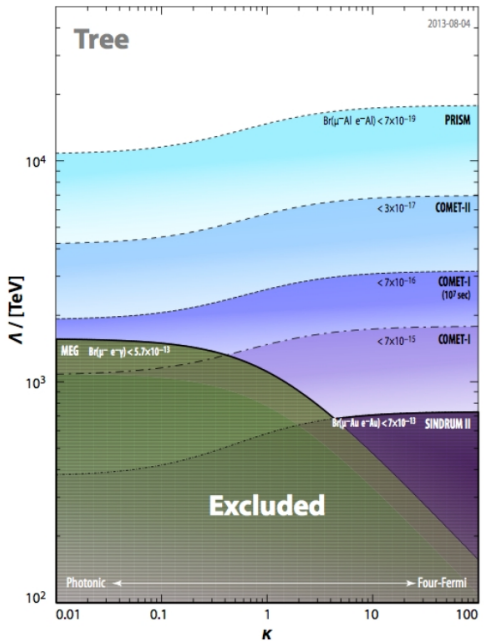


For searches at colliders

- $|A_{SM} + \varepsilon_{NP}|^2 \simeq |A_{SM}|^2 + 2Re(A_{SM}\varepsilon_{NP})$

CLFV sensitive to NP at high energy scale Λ

- $|A_{SM} + \varepsilon_{NP}|^2 \simeq |\varepsilon_{NP}|^2 \Rightarrow$ Rate $\simeq \frac{1}{\Lambda^4}$

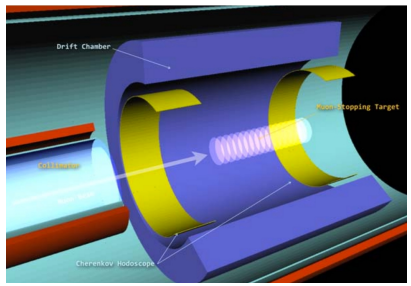


$\mu^- N \to e^- N$ low energy effective lagrangian

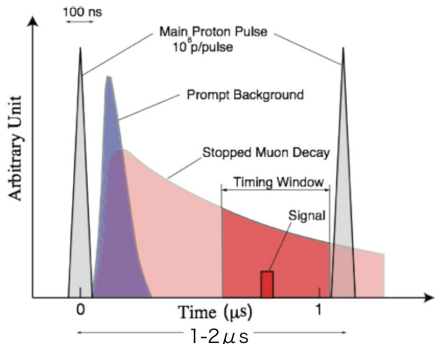
$$\mathcal{L} = \frac{1}{1+\kappa}\frac{m_\mu}{\Lambda^2}\bar{\mu}_R\sigma^{\mu\nu}e_L\mathcal{F}_{\mu\nu} + \frac{\kappa}{1+\kappa}\frac{1}{\Lambda^2}(\bar{\mu}_L\gamma^\mu e_L)(\bar{q}_L\gamma_\mu q_L) + h.c.$$

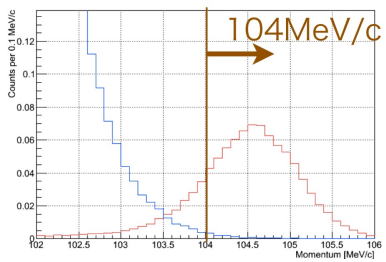
France-Japan collaboration in COMET

- COMET Phase I
  Construction of the muon transport solenoid down to the 1^{st} 90^0 bend
- CDC and Triggering counter surrounding a muon stopping target

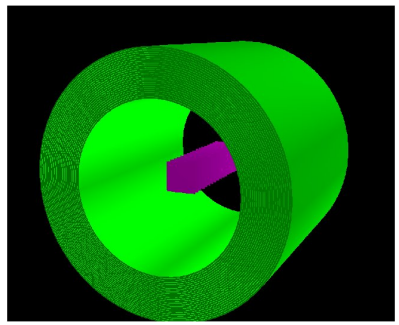


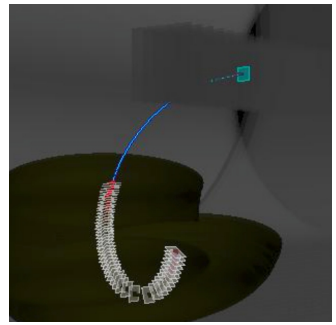
$\mu \rightarrow e$ conversion signal identified with an energetic electron of 105MeV emitted from a muonic atom with delayed timing.





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

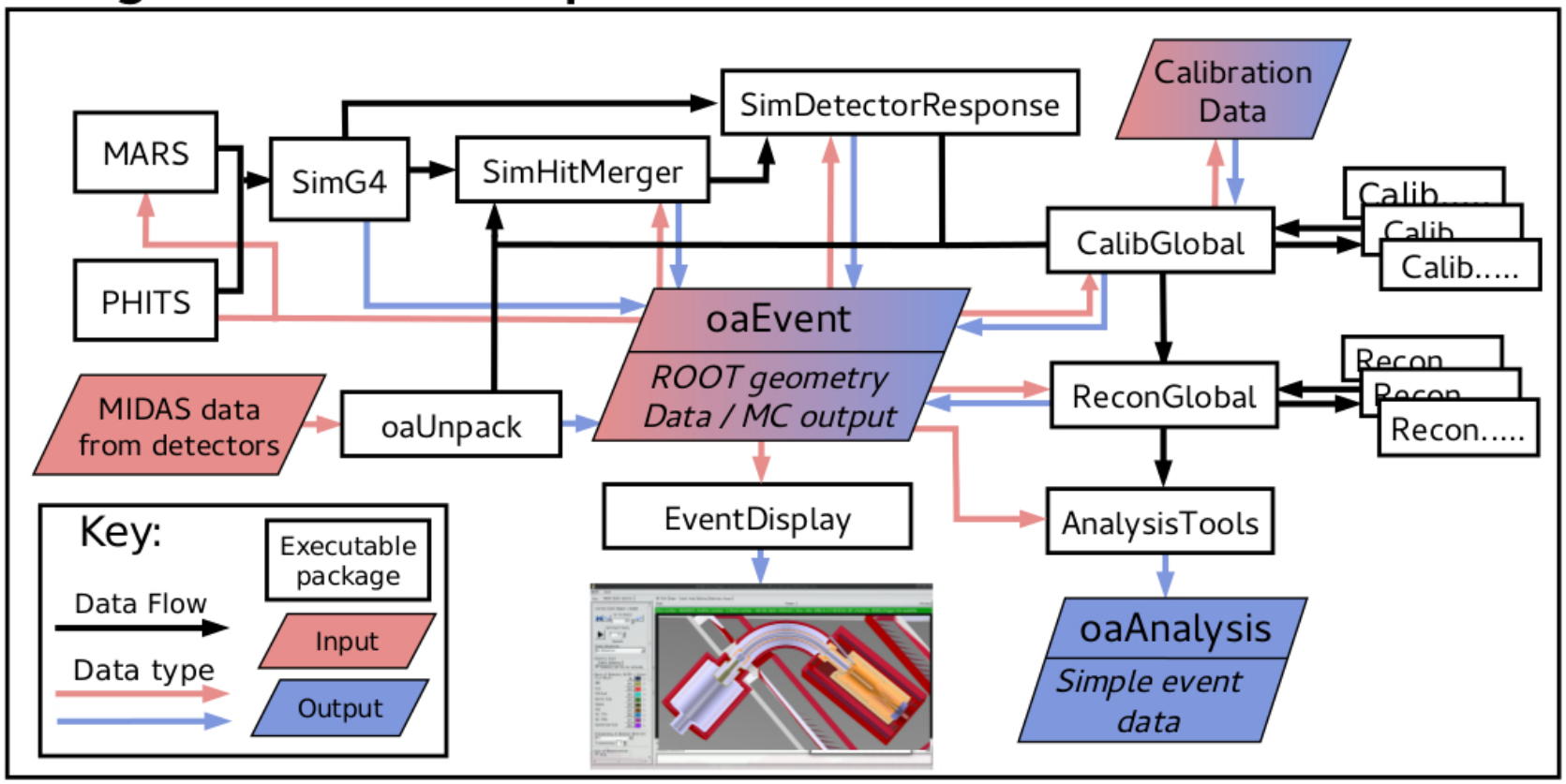




- Simulation and reconstruction with GENFIT within ICEDUST(Integrated Comet Experiment Data User Software Toolkit), the new COMET Software Framework rooted in T2K ND280.
- Discussion on the possibility of a beam test of ATLAS pixels at J-PARC with Kyushu University.
- MARS and ICEDUST installed at CCIN2P3 (thanks to Yonny Cardenas).

ICEDUST Overview

Integrated Comet Experiment Data User Software Toolkit



Collaboration

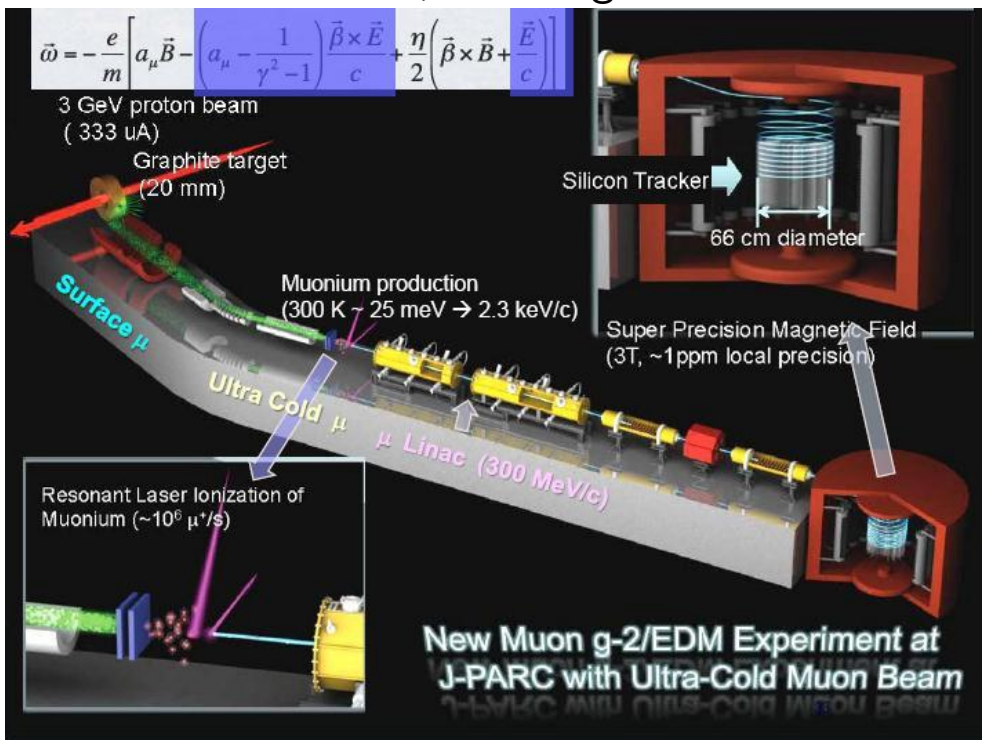
Muon g-2/EDM at J-PARC

- > 98 members (...still evolving)
- > 21 Institutions
- Academy of Science, BNL, BINP, CRNS-APC, UC Riverside, Charles U., KEK, Korea U, NIRS, UNM, Osaka U., PMCU, RCNP, STFC RAL, RIKEN, Rikkyo U., SUNYSB, CRC Tohoku, U. Tokyo, TITech, TRIUMF, U. Victoria
- 9 countries
- Canada, China, Czech, France, Japan, Korea, Russia, UK, USA (alphabetic order)

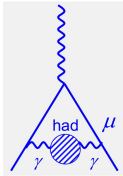
Msaharu Aoki[8], Pavel Bakule[20], Bernd Bassalleck[24], George Beer[26], Gerry Bunce[27], Abhay Deshpande[19], Simon Eidelman[4], Douglas E. Fields[24], Miloslav Finger[6], Michael Finger Jr.[6], Yuya Fujiwara[17,14], Yoshinori Fukao[10], Noriyosu Hayashizaki[16], Seiko Hirota[10,14], Hiromi Iinuma[10], Masanori Ikegami[10], Masahiro Ikeno[10], Katsuhiko Ishida[17], Masa Iwasaki[17], Ryosuke Kadono[10], Takuya Kakurai[12], Takuya Kamitani[10], Yukihide Kamiya[10], Sohtaro Kanda[12], Frédéric Kapusta[5], Naritoshi Kawamura[12], Takashi Kohriki[10], Sachio Komamiya[14], Kunio Koseki[10], Yoshitaka Kuno[8], Alfredo Luccio[12], Oleg Luchev[2], Muneyoshi Maki[12], Glen Marshall[22], Mika Masuzawa[10], Yasuyuki Matsuda[9], Teijiro Matsuzaki[17], Tsutomu Mibe[10], Katsumi Midorikawa[2], Satoshi Mihara[10], Yasuhiro Miyake[10], William M. Morse[3], Jiro Murata[17,13], Ryotaro Muto[10], Kanetada Nagamine[23,10,18], Takashi Naito[10], Hisayoshi Nakayama[10], Megumi Naruki[10], Makiko Nio[21], Hajime Nishiguchi[10], Daisuke Nomura[10], Hiroyuki Noumi[15], Tomoko Ogawa[2], Toru Ogitsu[10], Kazuki. Ohishi[17], Katsunobu Oide[10], Masahiro Okamura[3], Art Olin[22,26], Norihito F. Saito[2], Naohito Saito[10,14], Yasuhiro Sakemi[7], Ken-ichi Sasaki[10], Osamu Sasaki[10], Akira Sato[12], Aurore Savoy-Navaro[5], Yannis K. Semertzidis[3], Yuri Shatunov[12], Koichiro Shimomura[10], Boris Shwartz[4], Wilfrid da Silva[25], Patrick Strasser[10], Ryuhei Sugahara[10], Michinaka Sugano[10], Ken-ichi Tanaka[10], Manobu Tanaka[10], Nobuhiro Terunuma[10], Nobukazu Toge[10], Dai Tomono[17], Eiko Torikai[12], Toshiyuki Toshito[11], Akihisa Toyoda[10], Kyo Tsukada[12], Tomohisa Uchida[10], Kazuki Ueno[17], Vlasov Vrba[1], Satoshi Wada[2], Akira Yamamoto[10], Kaoru Yokoya[10], Koji Yokoyama[17], Makoto Yoshida[10], Mitsuhiro Yoshida[10], Koji Yoshimura[10]

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.

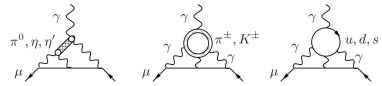


Observed Difference with BNL using e^+e^-:

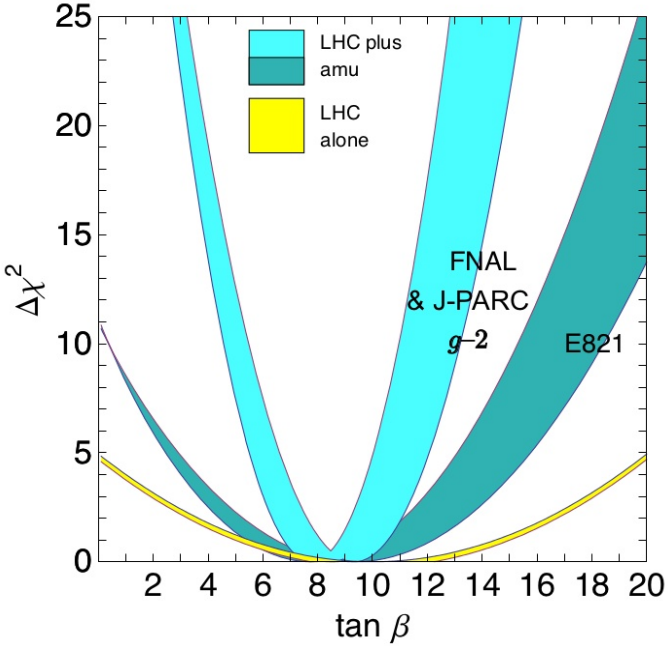
a_μ[exp] – a_μ[SM] = $(27.5 \pm 8.4) \times 10^{-10}$

➡ 3.3 „standard deviations"

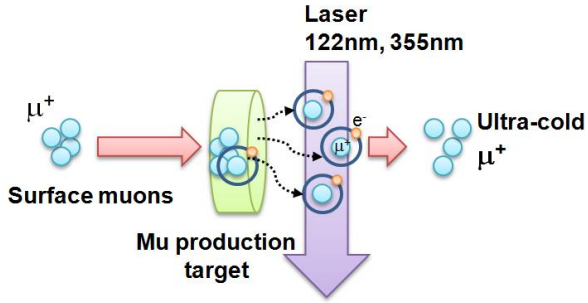
More precise computations using real data.



Improved precision to constrain SUSY

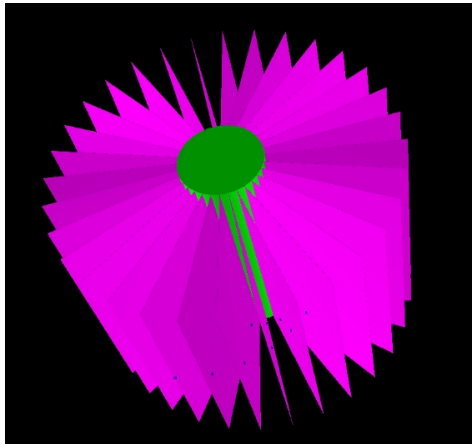


France-Japan collaboration in g-2/EDM



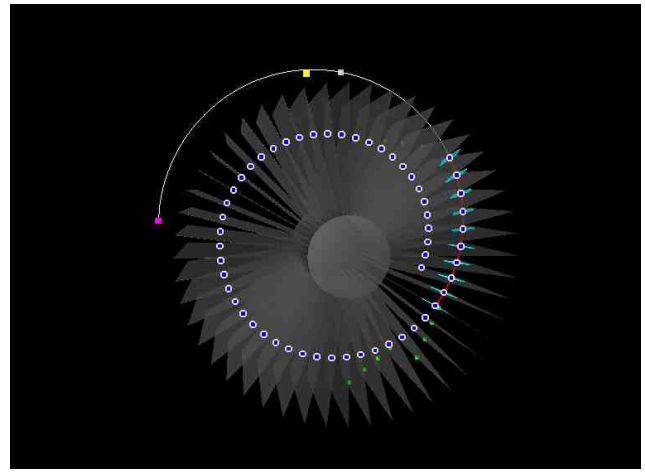
Recent breakthrough in μ production yield.
Beam intensity large enough to test the BNL g-2 anomaly better than 0.5ppm precision.

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



- Detector characterization.
- Software framework

- e^+ reconstruction using GENFIT



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

Software Activity

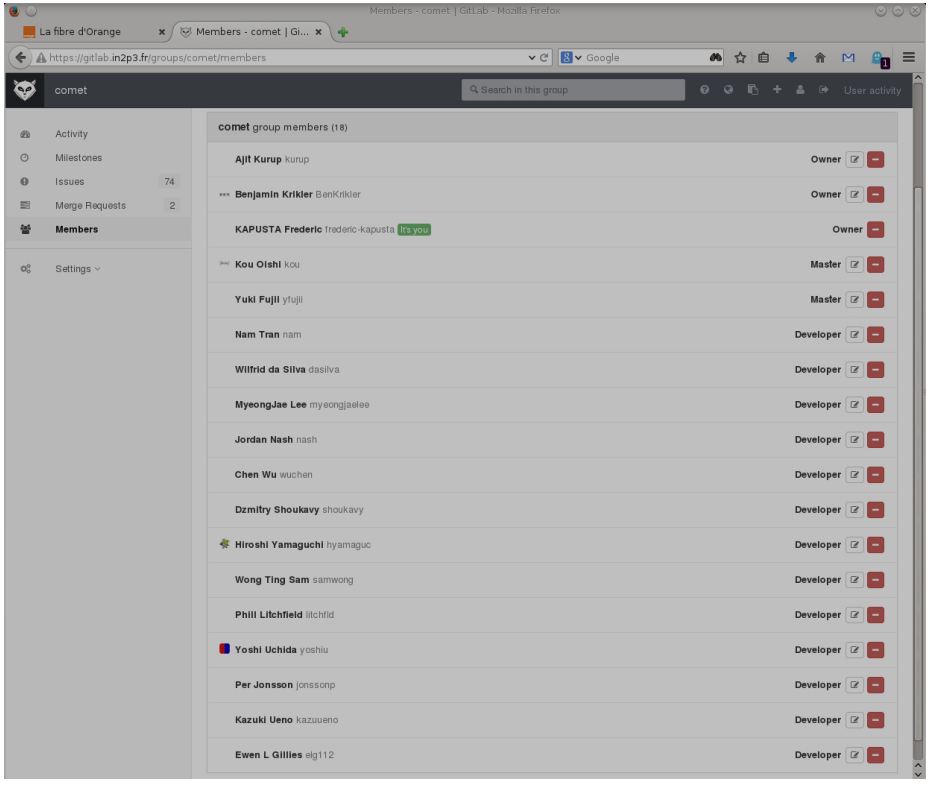
Software group structure, january 2014

- Software group involves 13+ people

Sub-group coordinator: Ajit Kurup

Sam Tygier: Fluka	**Andy Edmonds** MARS, SimG4
Ben Krikler: SimG4, overall framework	**Chen Wu** Build system, repository, CyDet
Per Johnsson: Unit tests, ND280 support	**Phill Litchfield** Offline databases, ND280 support
Kazuki Ueno: Straw tracker	**Fedor Ignatov** Reconstruction
Wilfrid da Silva, Frederic Kapusta: GENFIT, Active Target	**Vladimir Kalinnikov, Elena Velicheva** ECAL

GitLAB members, march 2015



FJPPL Members and Activities

- **French Group**
  (LPNHE-Paris CNRS/IN2P3/UPMC)
  Frédéric KAPUSTA
  Wilfrid da SILVA
  Maurice BENAYOUN
  Luigi DELBUONO
  Giovanni CALDERINI
  Jacques DAVID
  Jean-François GENAT

- **Japanese Group**
  (KEK/JPARC & Osaka U.)
  Tsutomu MIBE
  Naohito SAITO
  Satoshi MIHARA
  Kazuki UENO
  Hajime NISHIGUCHI
  Yoshitaka KUNO
  Akira SATO
  Yoshinori FUKAO
  Masashi OTANI

- 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 2015.

Recent history

- COMET Software Framework: from ND280 to ICEDUST.
  Imperial College London lead : Ajit Kurup, Ben Krikler COMET soft jpg.
- Common COMET g-2/EDM FJPPL Workshop (Paris, 20-21 february 2014)

- 3rd Workshop on Muon g-2, EDM and Flavour Violation in the LHC Era in december 2014

- It was the right time for a decision from CCIN2P3 director and IN2P3 Particle Scientific Deputy Director to create a comet group to allow "foreign collaborators" to register and use CCIN2P3 machines.

Recent events

- At COMET CM15 in january at KEK, final agreement to use the COMET Software Framework as a starting point for g-2/EDM.
- Accepted proposal from the french group to use the CCIN2P3 computing power and support in order to prepare a Grid computing at the COMET Collaboration level.
- Accepted proposal to have gitlab.in2p3.fr hosting the COMET software in order to ease the collaborative work.
- ICEDUST is running with MARS using a common 1 TB of semi-permanent space on /sps/hep/comet.
- SimMARS still under test and optimization at CCIN2P3.
- A MySQL database is available for parameters storage.
- muon.in2p3.fr is a french website under construction to unify μ^+ and μ^- experiments for BSM physics, the official COMET website being comet.kek.jp

Summary : comments, requests and questions

- VO-Asia is part of a FJPPL agreement which could be extended to FCPPL and FKPPL with the help of our chinese and korean colleagues
- Preparation of a Grid computing at the COMET Collaboration level.
- The CCIN2P3 ressources will be described in the g-2/EDM 2015 TDR.
- Back up of the developpers space : contributions have to be tested safely before being pushed to gitlab.
- CPU and storage : accurate estimates only after the first release of ICEDUST in april.
- Rough estimates : with 10^{10} proton events 150000 CPU hours $\simeq$ 1.5 10^{6} HS06 and 20 TB of storage to generate data with SimMARS. And at least the same CPU time to process with SimG4.
- GitLab Enterprise integrates git-annex, ideal to store the magnetic field maps in the same repository as ICEDUST. But git-annex written in Haskell introduces another dependency to the software and therefore makes it a bit less attractive. Nice only if other alternatives using CVMFS are not possible.
- Database file sizes might be of a similar order of magnitude as ND280, which means 7 GB for calibration and 100 GB for slow control with someone to provide support.
- Thanks in advance to FJPPL computing experts and CCIN2P3 support.