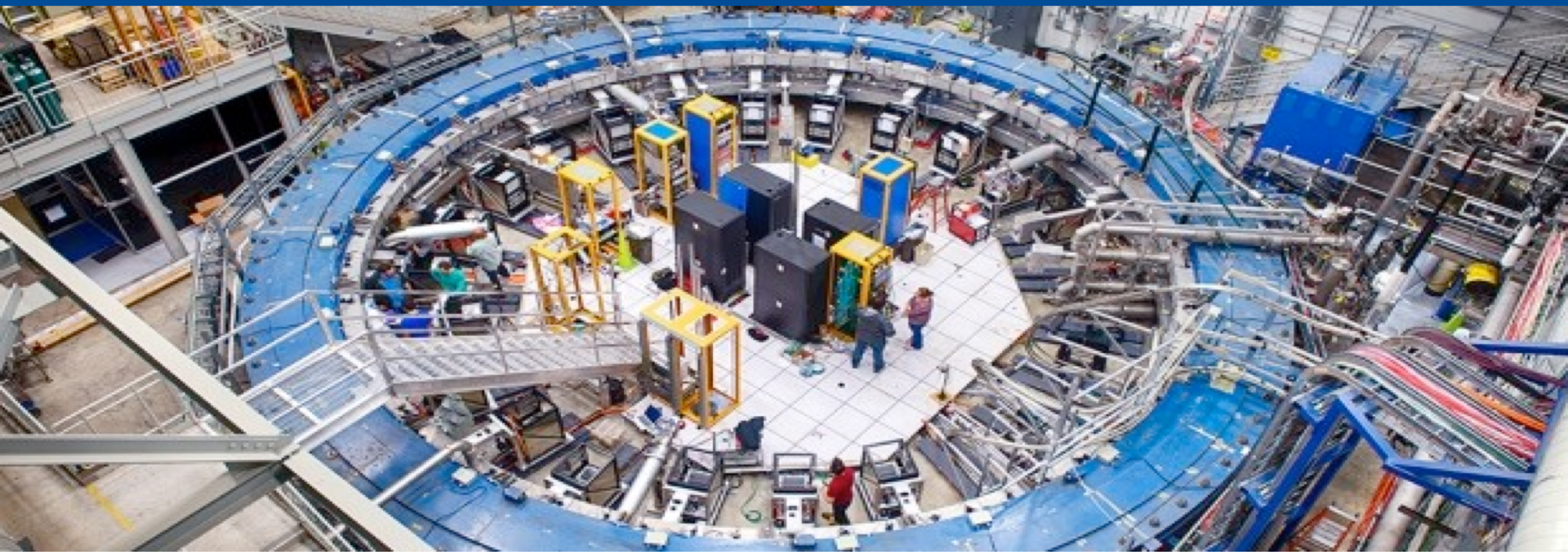


Il coinvolgimento italiano nell'esperimento Muon g-2

Graziano Venanzoni– INFN Pisa

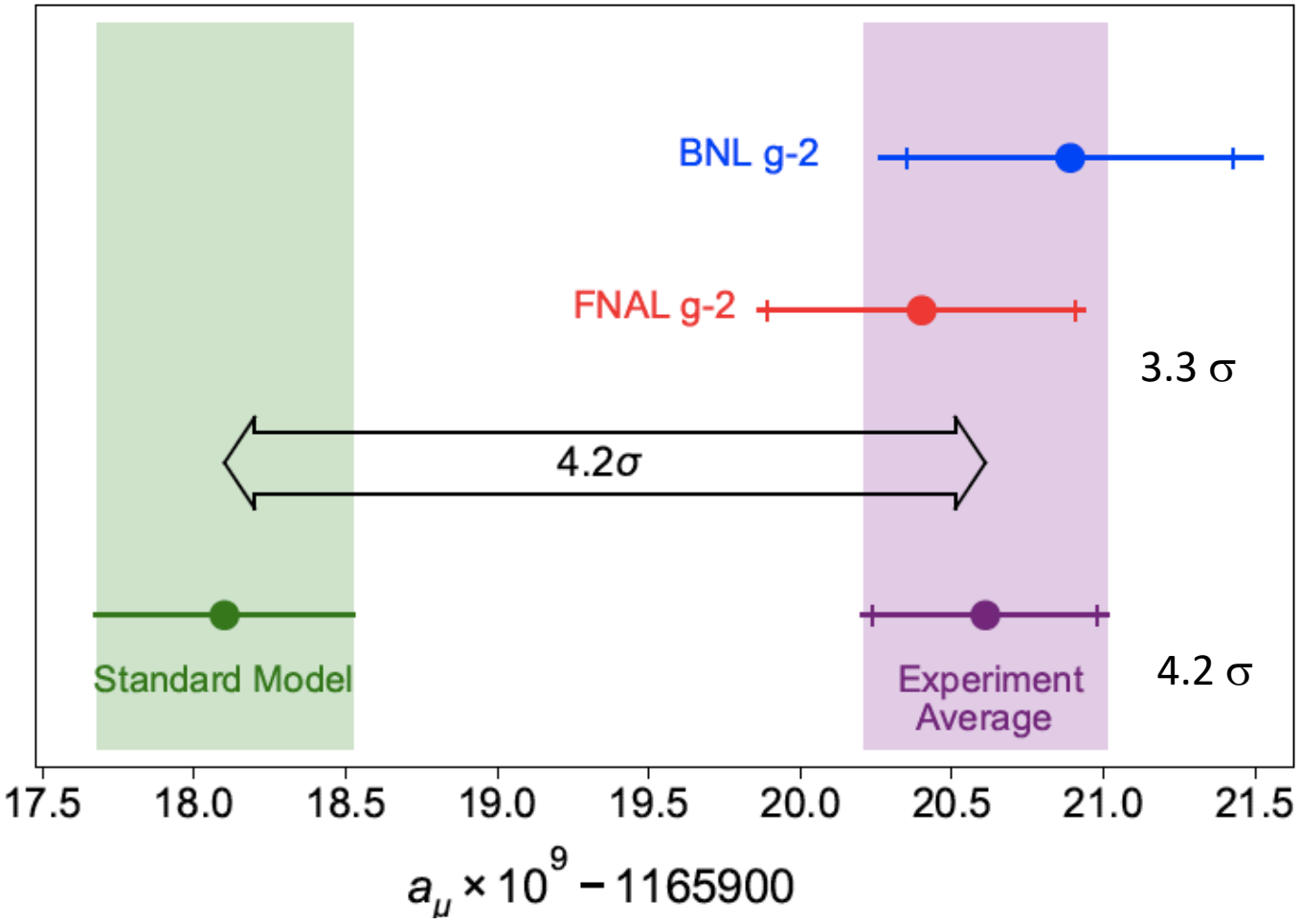
Pisa 14 Aprile 2021

SEMINARIO A PISA, 31 Maggio 2017 (ultima slide)

Se sarà o no nuova fisica ve lo diremo tra qualche anno!!

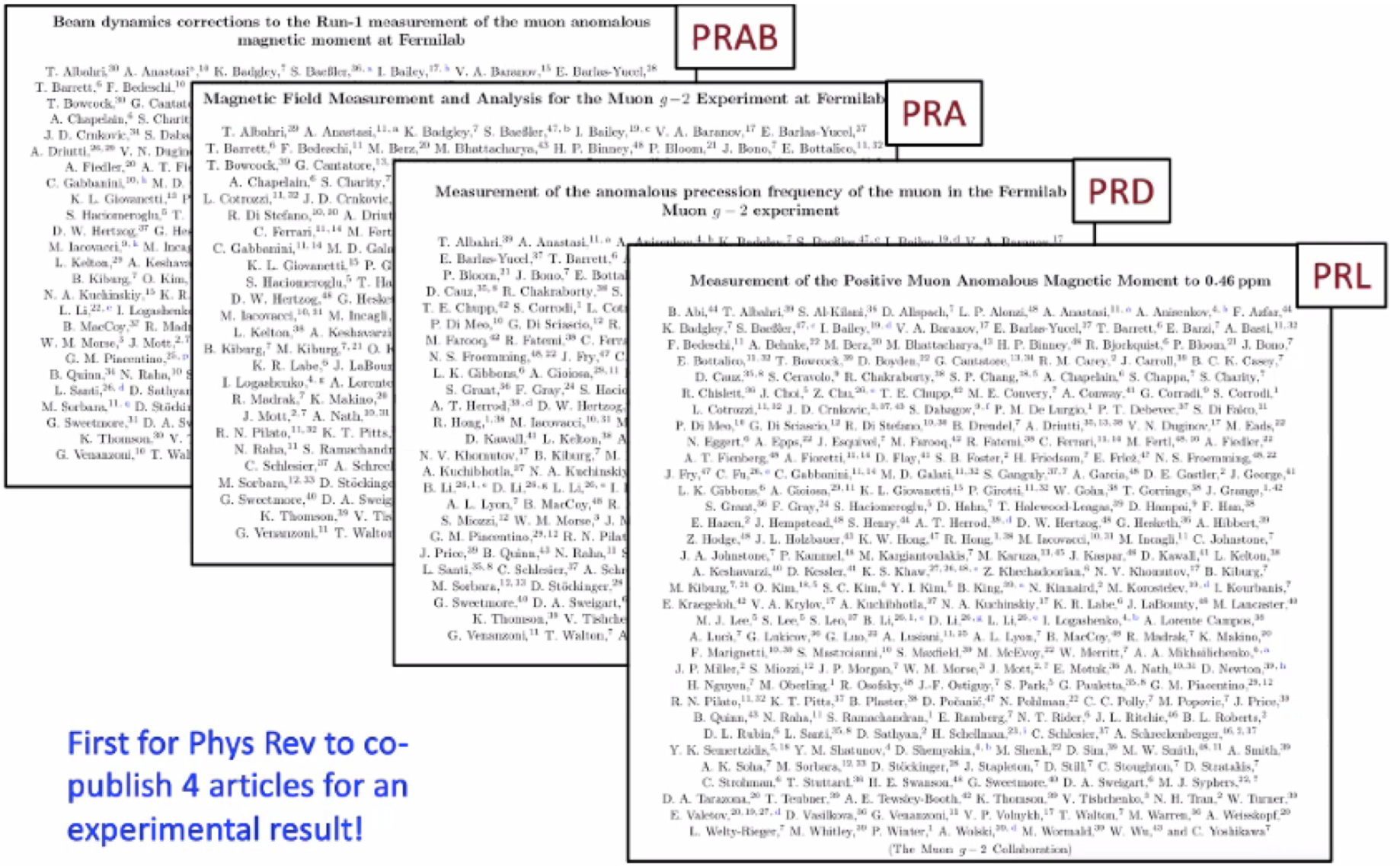
7 Aprile 2021

a_μ



$$a_\mu(\mathrm{FNAL}) = 116\,592\,040(54) \times 10^{-11} \quad (0.46\,\mathrm{ppm})$$

>100 pagine di documentazione sottomessa il 7 Aprile



First for Phys Rev to co-publish 4 articles for an experimental result!

Risonanza enorme:

- +8500 partecipanti alla release di Fermilab (7/4)
- 1300 partecipanti al seminario CERN (8/4)
- >30 theoretical papers il giorno dopo l'annuncio (8/4)
- Notizia ripresa su tutti i giornali, socials
- **2.7 miliardi** di persone hanno letto la notizia della misura dall'annuncio mercoledi' 7 aprile alle 12:00 del 9 aprile (ufficio stampa di fermilab)
- Milioni di visualizzazioni youtube etc…

Prima pagina NYT

8 Aprile 2021

"All the News That's Fit to Print"

The New York Times

Late Edition

Today, mostly sunny, remaining quite mild for early April, high 67. Tonight, partly cloudy, low 48. Tomorrow, variably cloudy, a bit cooler, high 62. Weather map, Page B10.

VOL. CLXX . . . No. 59,022 © 2021 The New York Times Company NEW YORK, THURSDAY, APRIL 8, 2021 $3.00

Biden Tax Plan Aims to Curtail Use of Havens

Loophole Has Enriched Global Corporations

By JIM TANKERSLEY and ALAN RAPPEPORT

WASHINGTON — Large companies like Apple and Bristol Myers Squibb have long employed complicated maneuvers to reduce or eliminate their tax bills by shifting income on paper between countries. The strategy has enriched accountants and shareholders, while driving down corporate tax receipts for the federal government.

President Biden sees ending that practice as central to his $2 trillion infrastructure package, pushing changes to the tax code that his administration says will ensure American companies are contributing tax dollars to help invest in the country's roads, bridges, water pipes and in other parts of his economic agenda.

On Wednesday, the Treasury Department released the details of Mr. Biden's tax plan, which aims to raise as much as $2.5 trillion over 15 years to help finance the infrastructure proposal. That includes bumping the corporate tax rate to 28 percent from 21 percent, imposing a strict new minimum tax on global profits and cracking down on companies that try to move profits offshore.

The plan also aims to stop big companies that are profitable but have no federal income tax liability from paying no taxes to the Treasury Department by imposing a 15 percent tax on the profits they report to investors. Such a change would affect about 45 corporations, according to the Biden administration's estimates, because it would be limited to companies earning $2 billion or more per year.

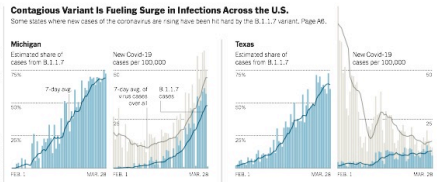
"Companies aren't going to be able to hide their income in places like the Cayman Islands and Bermuda in tax havens," Mr. Biden said on Wednesday during remarks at the White House. He defended the tax increases as necessary to pay for infrastructure investments that America needs and to help reduce the federal deficit over the long term.

Still, his 15 percent tax is a narrower version of the one he proposed in the 2020 campaign that would have applied to companies with $100 million or more in profits per year.

Continued on Page A18

Contagious Variant Is Fueling Surge in Infections Across the U.S.

Some states where new cases of the coronavirus are rising have been hit hard by the B.1.1.7 variant. Page A6.



PAIR OF SETBACKS FOR ASTRAZENECA OVER ITS VACCINE

BLOOD CLOT CONCERNS

U.K. Curbs Use by Adults Under 30 as the E.U. Outlines Risks

By BENJAMIN MUELLER

LONDON — Britain said on Wednesday that it would curb the use of AstraZeneca's vaccine in adults under 30 because of the risk of rare blood clots, a blow to the efforts of scores of countries reliant on the vaccine to stamp out the coronavirus pandemic amid a global surge in cases.

Adding to the unease, the European Medicines Agency outlined a "possible link" between the vaccine and rare clots, even as it said that Covid-19 remained the far greater threat, leaving decisions about how to use the vaccine in the hands of the 27 member states of the European Union.

Taken together, the decisions represented a considerable setback for the AstraZeneca shot, which has been seen as the principal weapon in the battle to reduce deaths in the vaccine-starved global south.

The world's most widely administered coronavirus vaccine, it is far less expensive and easier to store than some of the alternatives, spurring its use in at least 111 countries, rich and poor. AstraZeneca, based in Britain, has promised to deliver three billion doses this year, enough to inoculate nearly one in five people worldwide.

Britons under 30 will receive another vaccine if one is available, with limited exceptions, officials said. Until Wednesday, Britain had not wavered in its use of the homegrown vaccine, holding out even as many European neighbors paused injections over the unusual, though sometimes fatal clots.

But cases began to appear in Britain as well, and a consensus has since emerged among global regulators that the evidence points to a plausible link, as yet unexplained, between the vaccine and rare clots.

Amid a vicious wave of Covid-19 in Europe, the safety concerns have delayed inoculations, sank confidence in the shot and created

Continued on Page A9

ISIS and African Militants Join In a Marriage of Convenience

Terrorist Group Using Attacks on Continent to Raise Its Profile

By CHRISTINA GOLDBAUM and ERIC SCHMITT

JOHANNESBURG — The Islamic State's self-declared caliphate has fallen, its fighters have dispersed and its leader, Abu Bakr al-Baghdadi, has been killed.

But two years after it suffered stinging defeats in Syria and Iraq, the terrorist group has found a new lifeline in Africa, where analysts say it has forged alliances with local militant groups in symbiotic relationships that have pumped up their profiles, fund-raising and recruitment.

Many of those homegrown insurgencies are only loosely connected to the Islamic State, also known as ISIS. Still, over the past year, as violence from Islamist extremists on the African continent reached a record high, the Islamic State has trumpeted these battlefield wins to project an image of strength and inspire its supporters worldwide.

Most recently, the Islamic State claimed credit last week for a days-long rampage in war-afflicted northern Mozambique, where militants with distant ties to the terrorist organization ambushed a key port town. The attack left dozens of people dead, including at least one South African and one British citizen, and set off talk on the Islamic State's online forums of the establishment of a new caliphate there, according to researchers.

"As an organization more broadly, ISIS is hurting," said Col-

Continued on Page A11

New York to Provide $2.1 Billion For Undocumented Immigrants

Covid Relief Plan Rifles G.O.P. and Worries Some Democrats

By ANNIE CORREAL and LUIS FERRÉ-SADURNÍ

When the coronavirus arrived in New York City a year ago, it hit enclaves of undocumented immigrants with a fury, killing thousands and wiping out the service and construction jobs that kept many families afloat.

Lifelines like unemployment insurance and federal stimulus checks were out of reach because undocumented people are ineligible for most government aid. Instead, they have relied on food pantries, lenient landlords and loans from friends.

But after a sweeping move by lawmakers this week, New York will now offer one-time payments of up to $15,000 to undocumented immigrants who lost work during the pandemic. The effort — a $2.1 billion fund in the state budget — is by far the biggest of its kind in the country and a sign of the state's shift toward policies championed by progressive Democrats.

"I've met neighbors who have not been able to pay rent, or put food on the table, or been able to provide their children with a laptop when a public school has not been able to provide one," said State Senator Jessica Ramos, a Democrat from Queens and lead proponent of the fund.

The excluded workers fund, part of the state's new $212 billion budget deal that was reached on Tuesday, was one of the most contentious points of debate during

Continued on Page A16

A Particle's Tiny Wobble Could Upend the Known Laws of Physics

By DENNIS OVERBYE

Evidence is mounting that a tiny subatomic particle seems to be disobeying the known laws of physics, scientists announced on Wednesday, a finding that would open a vast and tantalizing hole in our understanding of the universe.

The result, physicists say, suggests that there are forms of matter and energy vital to the nature and evolution of the cosmos that are not yet known to science.

"This is our Mars rover landing moment," said Chris Polly, a physicist at the Fermi National Accelerator Laboratory, or Fermilab, in Batavia, Ill., who has been working toward this finding for most of his career.

The particle under scrutiny is the muon, which is akin to an electron but far heavier, and is an integral element of the cosmos. Dr. Polly and his colleagues — an international team of 200 physicists from seven countries — found that muons did not behave as predicted when shot through an intense magnetic field at Fermilab.

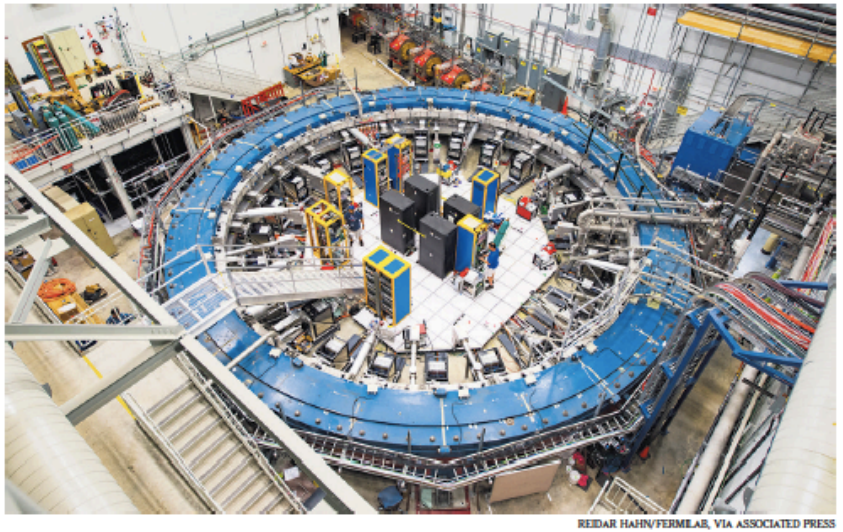
The aberrant behavior poses a firm challenge to the bedrock theory of physics known as the Standard Model, a suite of equations that enumerates the fundamental particles in the universe (17, at last count) and how they interact.

"This is strong evidence that the muon is sensitive to something that is not in our best theory," said Renee Fatemi, a physicist at the University of Kentucky.

The results, the first from an experiment called Muon g-2, agreed with similar experiments at the Brookhaven National Laboratory in 2001 that have teased physicists ever since.

At a virtual seminar and news conference on Wednesday, Dr. Polly pointed to a graph displaying white space where the Fermilab findings deviated from the theoretical prediction. "We can say with fairly high confidence, there

Continued on Page A19



REIDAR HAHN/FERMILAB, VIA ASSOCIATED PRESS

A ring at the Fermi National Accelerator Laboratory in Illinois is used to study the wobble of muons.

A Particle's Tiny Wobble Could Upend the Known Laws of Physics

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Continued on Page A19

REIDAR HAHN/FERMILAB, VIA ASSOCIATED PRESS

A ring at the Fermi National Accelerator Laboratory in Illinois is used to study the wobble of muons.

Adventurers Fleeing Pandemic Strain the West's Rescue Teams

By ALI WATKINS

PINEDALE, Wyo. — Kenna Tanner and her team can list the cases from memory. There was the woman who got tired and did not feel like finishing her hike; the campers, in shorts during a blizzard; the base jumper, misjudging a leap from a treacherous granite cliff face; the ill-equipped snowmobiler, buried up to his neck in an avalanche.

All of them were pulled by Ms. Tanner and the Tip Top Search and Rescue crew from the rugged Wind River mountain range in the last year, in this sprawling, remote pocket of western Wyoming. And all of them, their rescuers said, were wildly unprepared for the brutal backcountry in which they were traveling.

"It is super frustrating," said Ms. Tanner, Tip Top's director. "We just wish that people respected the risk."

In the throes of a pandemic that has made the indoors inherently dangerous, tens of thousands more Americans than usual have looked outdoors, fleeing crowded cities for national parks and the public lands around them. But as these hordes of inexperienced adventurers explore the treacherous terrain of the backcountry, many inevitably call for help. It has strained the patchwork, volunteer-based search-and-rescue

Continued on Page A17

A trail in the Wind River Range in western Wyoming.

Riviste Nazionali

Corriere

FERMILAB

Muone, la reazione «inattesa» della particella che può cambiare le leggi della fisica

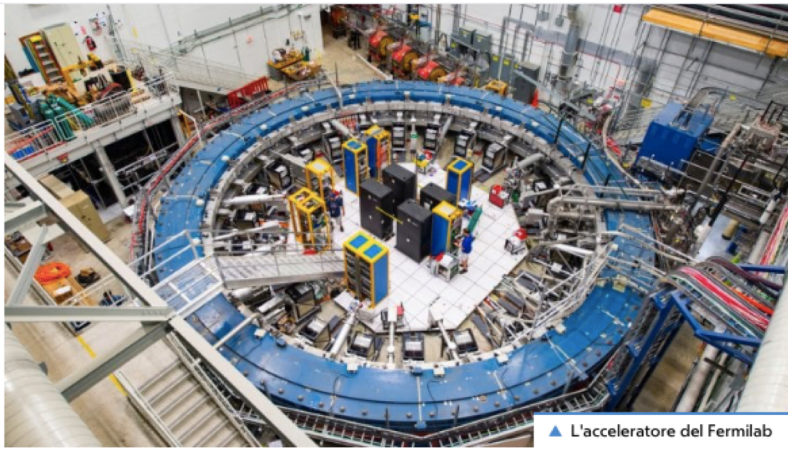
I dati dell'esperimento Muon g-2, con l'importante contributo italiano dell'Istituto nazionale di fisica nucleare, indicherebbero fenomeni non descritti dalle attuali teorie. Venanzoni (Infn): «Un successo in buona parte merito dei giovani ricercatori». Ma Nature frena

di Paolo Virtuani

Notizia riportata dale principali (>30) testate giornalistiche. Grande enfasi sul contributo Italiano (INFN)

Repubblica

L'anomalia del muone: l'esperimento che suggerisce l'esistenza di nuove forze della natura



▲ L'acceleratore del Fermilab

di Matteo Marini

L'acceleratore di particelle del Fermilab, a Chicago, ha misurato un'anomalia nel valore del momento magnetico del muone. Sembrerebbe un dettaglio riservato agli appassionati di fisica. Invece è una notizia che apre la porta alla presenza di nuove particelle. Perfino di un secondo bosone di Higgs

Contributo Italiano g-2: Un po' di storia

- Siamo partiti (in maniera esplorativa) nel 2009
- 2012 Consolidamento della collaborazione e contributo CNR INO
- Nel 2013 apertura sigla INFN (~6 FTE)
- Nel 2021 raggiunti ~18 FTE >30 collaboratori

Submitted to FNAL

February 9, 2009

The New $(g-2)$ Experiment:

A Proposal to Measure the Muon Anomalous Magnetic Moment to ± 0.14 ppm Precision

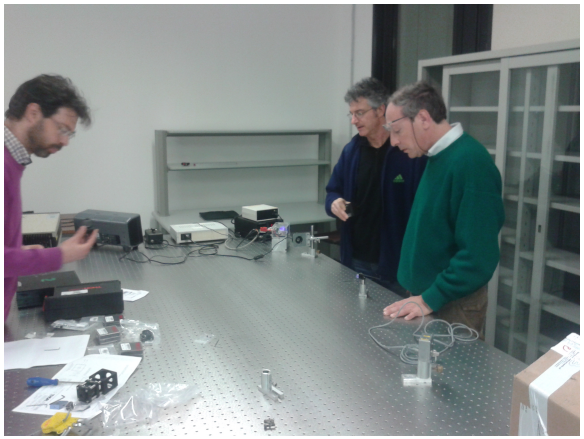
New $(g-2)$ Collaboration: R.M. Carey[1], K.R. Lynch[1], J.P. Miller[1], B.L. Roberts[1], W.M. Morse[2], Y.K. Semertzidis[2], V.P. Druzhinin[3], B.I. Khazin[3], I.A. Koop[3], I. Logashenko[3], S.I. Redin[3], Y.M. Shatunov[3], Y. Orlov[4], R.M. Talman[4], B. Casey[5], J. Johnstone[5], D. Harding[5], A. Klebaner[5], A. Leveling[5], J-F. Ostiguy[5], N. Mokhov[5], D. Neuffer[5], M. Popovic[5], S. Strigonov[5], M. Syphers[5], G. Velev[5], S. Werkema[5], F. Happacher[6], G. Venanzoni[6], P. Debevec[7], M. Grosse-Perdekamp[7], D.W. Hertzog[7], P. Kammel[7], C. Polly[7], K.L. Giovanetti[8], K. Jungmann[9], C.J.G. Onderwater[9], N. Saito[10], C. Crawford[11], R. Fatemi[11], T.P. Gorringe[11], W. Korsch[11], B. Plaster[11], V. Tishchenko[11], D. Kawall[12], T. Chupp[13], C. Ankenbrandt[14], M.A Cummings[14], R.P. Johnson[14], C. Yoshikawa[14], André de Gouvêa[15], T. Itahashi[16], Y. Kuno[16], G.D. Alkhazov[17], V.L. Golovtsov[17], P.V. Neustroev[17], L.N. Uvarov[17], A.A. Vasilyev[17], A.A. Vorobyov[17], M.B. Zhalov[17], F. Gray[18], D. Stöckinger[19], S. Baeßler[20], M. Bychkov[20], E. Frlež[20], and D. Počanić[20]

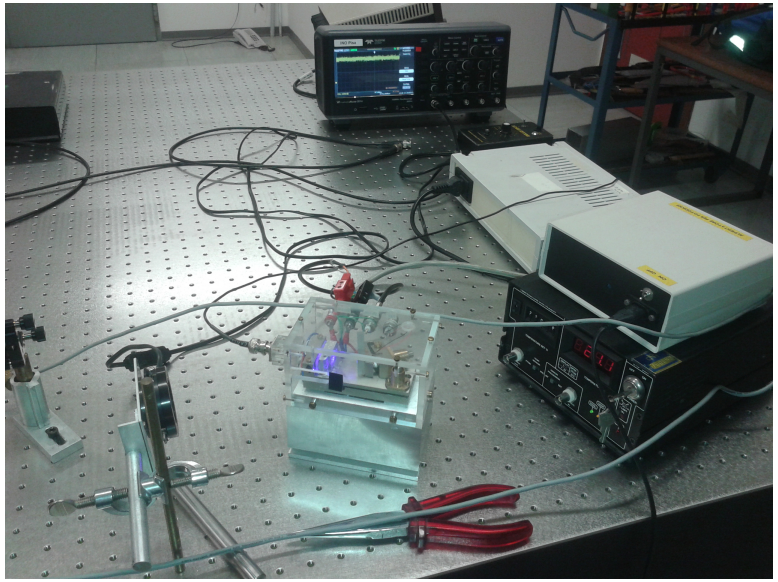
Da dove siamo partiti

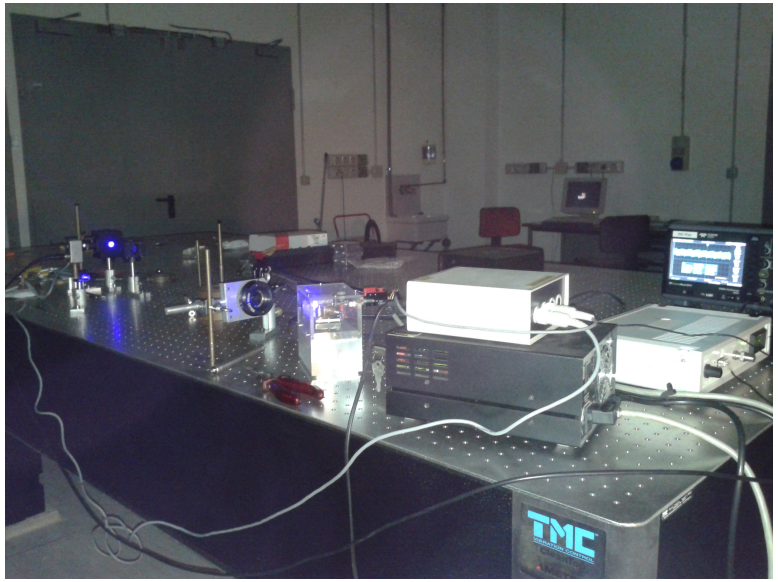
Category	E821 [ppb]	E989 Improvement Plans	Goal [ppb]
Gain changes	120	Better laser calibration	
		low-energy threshold	20
Pileup	80	Low-energy samples recorded	
		calorimeter segmentation	40
Lost muons	90	Better collimation in ring	20
CBO	70	Higher n value (frequency)	
		Better match of beamline to ring	< 30
E and pitch	50	Improved tracker	
		Precise storage ring simulations	30
Total	180	Quadrature sum	70

→ Un laser con controllo delle fluttuazioni di guadagno al di sotto del per mille. Sistematico dominante in BNL!

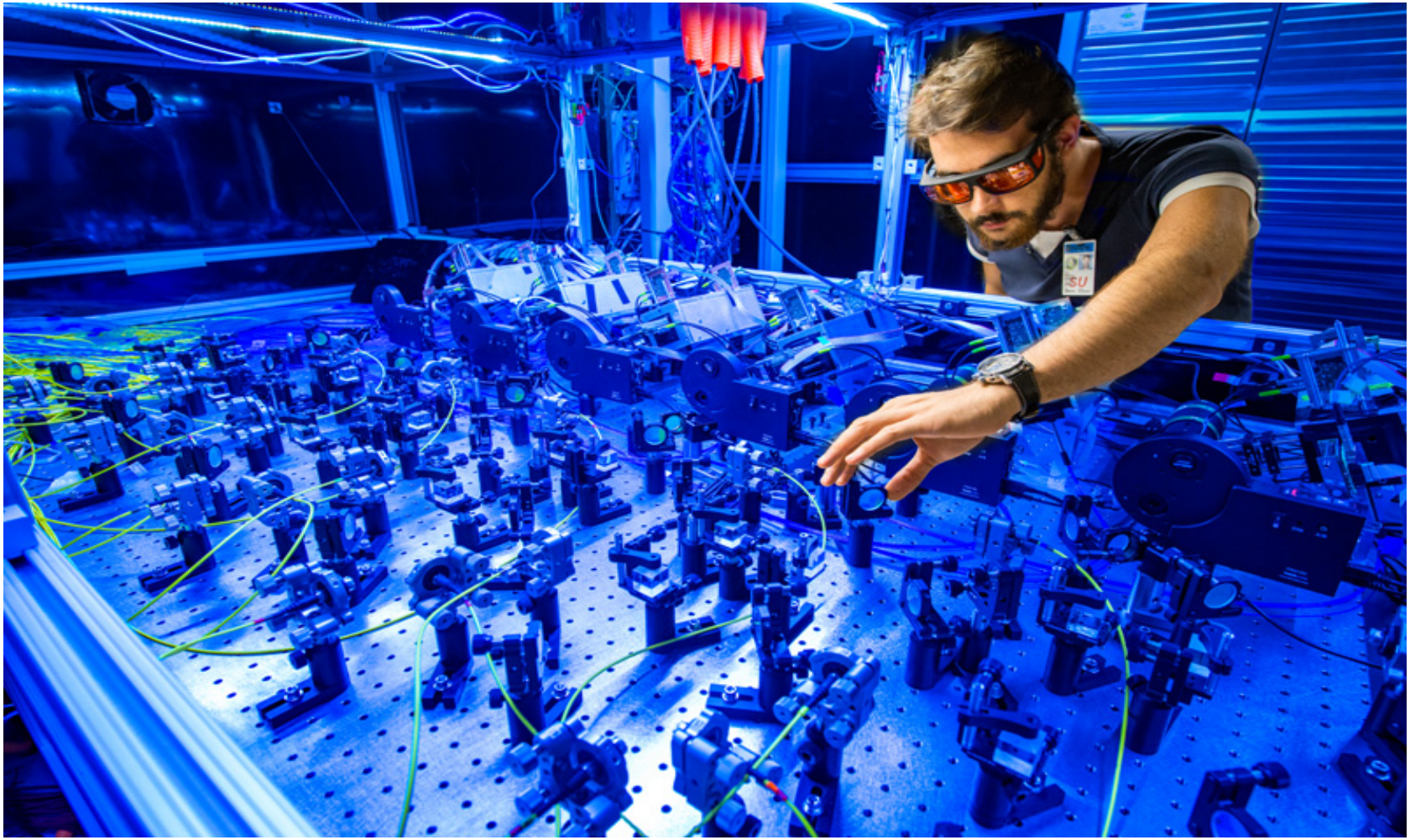
Primi test all'INO 2013







Sistema laser (~2018)



JINST 14 (2019) P11025 (1906.08432)

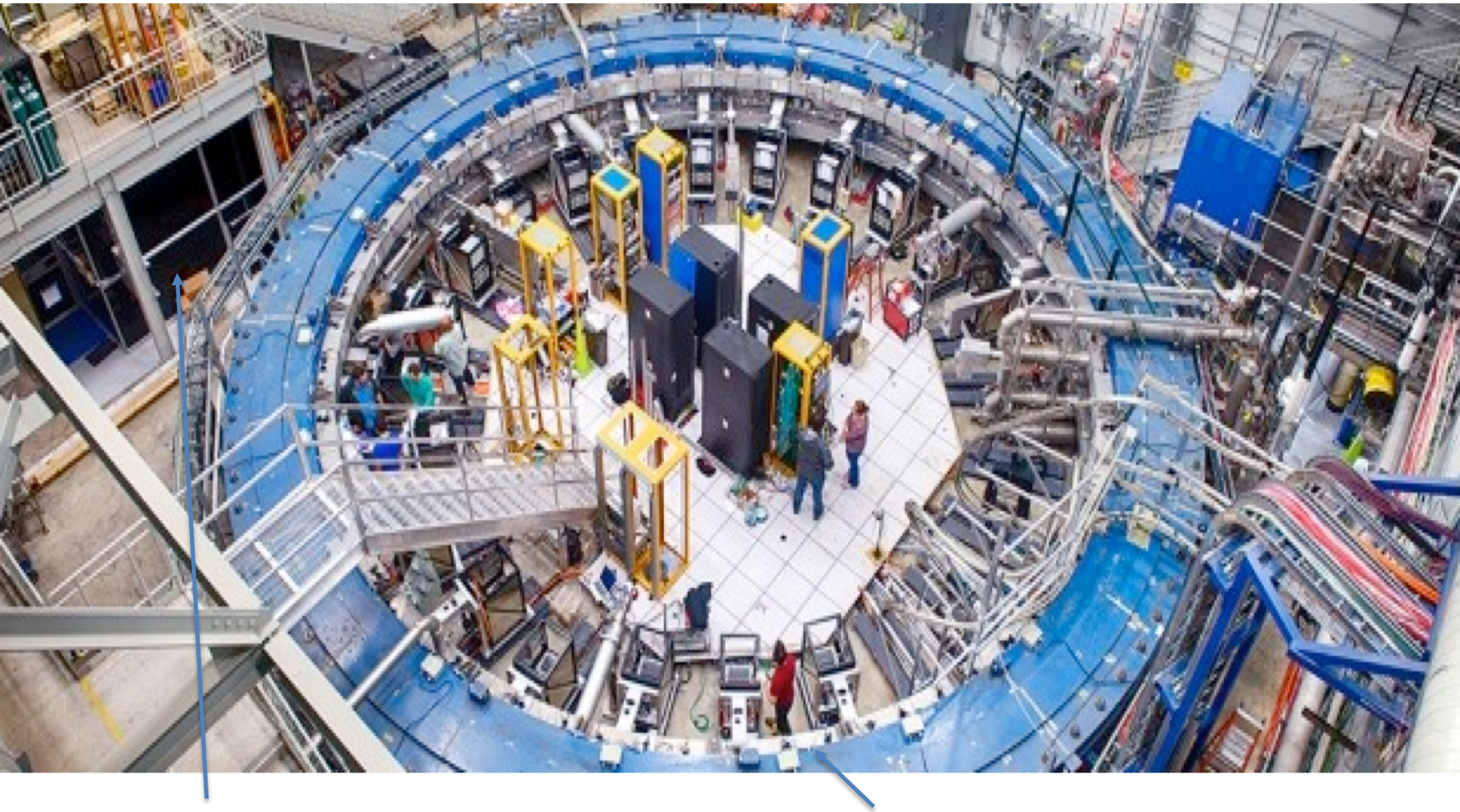
The laser-based gain monitoring system of the calorimeters in the Muon $g-2$ experiment at Fermilab

A. Anastasi,[a] A. Basti,[a,c] F. Bedeschi,[a] A. Boiano,[b] E. Bottalico,[a,c] G. Cantatore,[d,e] D. Cauz,[d,f] A.T. Chapelain,[g] G. Corradi,[h] S. Dabagov,[h,i,j] S. Di Falco,[a] P. Di Meo,[b] G. Di Sciascio,[k] R. Di Stefano,[b,l] S. Donati,[a,c] A. Driutti,[d,f] C. Ferrari,[a,m] A.T. Fienberg,[n] A. Floretti,[a,m,1] C. Gabbanini,[a,m] L.K. Gibbons,[g] A. Gioiosa,[k,o] P. Girotti,[a,c] D. Hampai,[h] J.B. Hempstead,[n] D.W. Hertzog,[n] M. Iacovacci,[b,p] M. Incagli,[a] M. Karuza,[d,q] J. Kaspar,[n] K.S. Khaw,[n] A. Lusiani,[a,r] F. Marignetti,[b,l] S. Mastroianni,[b] S. Miozzi,[k] A. Nath,[b] G. Pauletta,[d,f] G.M. Piacentino,[k,o] N. Raha,[a] L. Santi,[d,f] M. Smith,[a,n] M. Sorbara,[k,s] D.A. Sweigart[g] and G. Venanzoni[a,1]

Abstract: The Muon $g-2$ experiment, E989, is currently taking data at Fermilab with the aim of reducing the experimental error on the muon anomaly by a factor of four and possibly clarifying the current discrepancy with the theoretical prediction. A central component of this four-fold improvement in precision is the laser calibration system of the calorimeters, which has to monitor the gain variations of the photo-sensors with a 0.04% precision on the short-term (~ 1 ms). This is about one order of magnitude better than what has ever been achieved for the calibration of a particle physics calorimeter. The system is designed to monitor also long-term gain variations, mostly due to temperature effects, with a precision below the per mille level. This article reviews the design, the implementation and the performance of the Muon $g-2$ laser calibration system, showing how the experimental requirements have been met.

Errore su ω_a <20 ppb
(*Phys.Rev.D* 103 (2021) 7, 072002)

Storage Ring 2018



Laser Hut

C. Ferrari

Muon g-2 Physics Week a L'Elba (2019)


Fermilab Nov 2019
a_μ=...

Gruppo INFN g-2 (2021)

6 INFN Sections:

- LNF (Frascati)
- Napoli
- PISA
- Roma2
- Trieste
- Lecce

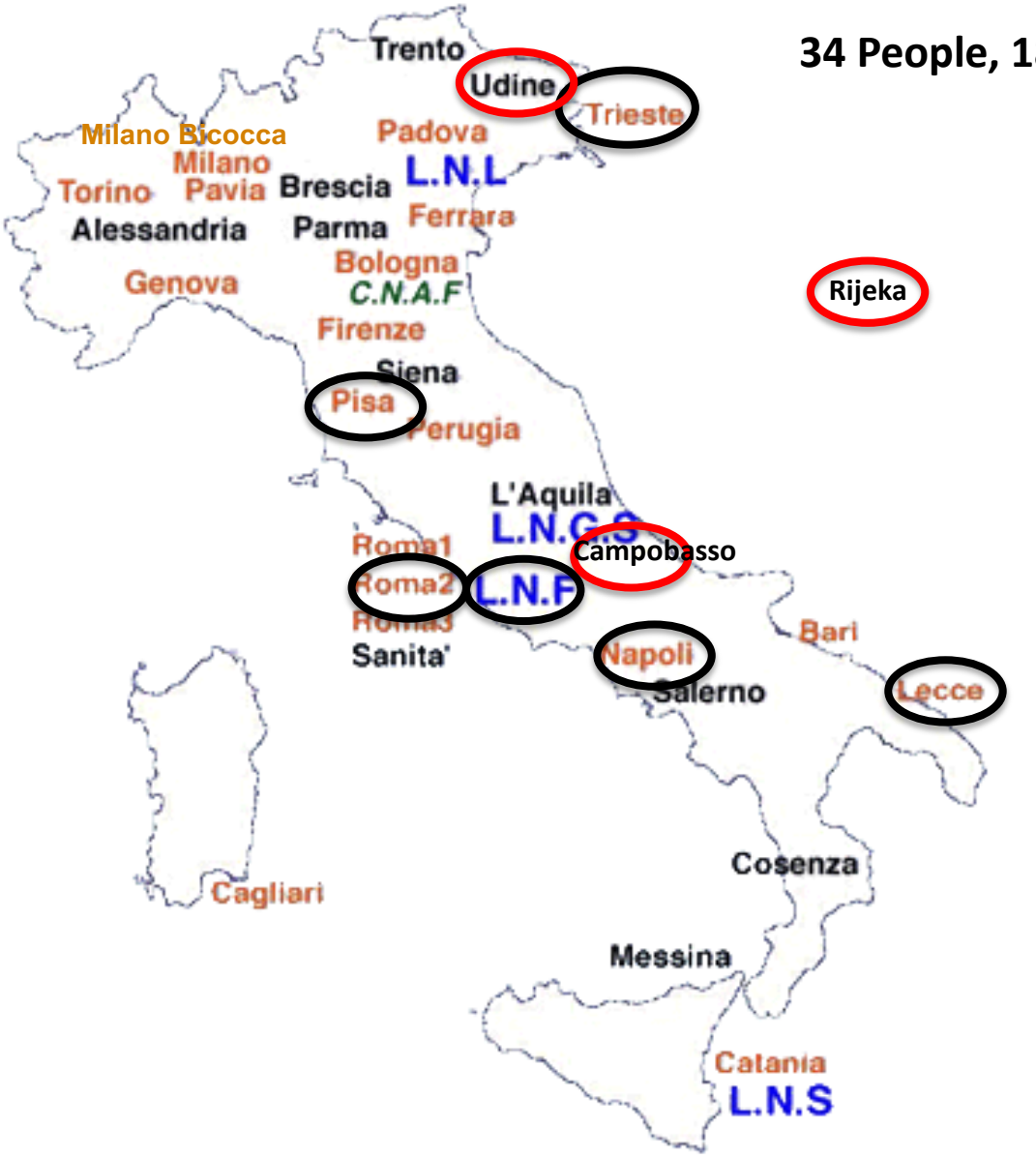
6 Universities:

- Udine
- Naples
- Trieste
- Rjeka
- Molise (Campobasso)
- Scuola Normale Superiore (Pisa)

CNR INO:

- Pisa

34 People, 18 FTE



Ruoli Gruppo Italiano

Ruoli del Gruppo Italiano in g-2:

- G. Venanzoni : **co-spokesperson**; chair del Publication committee
- F. Bedeschi: **membro** del talk committee
- M. Incagli: detector coordinator; **chair Institution Board**
- A. Lusiani: responsabile computing Italia; **chair combinazione a_μ**
- M. Sorbara: **responsabile** Gruppo Analisi omega_a Europa
- E. Bottalico/P. Girotti: **responsabili** Sistema laser
- A. Gioiosa: **responsabile** slow control
- S. Mastroianni: DAQ **expert**
- N. Piacentino e E. Bottalico **membri** D&I committee

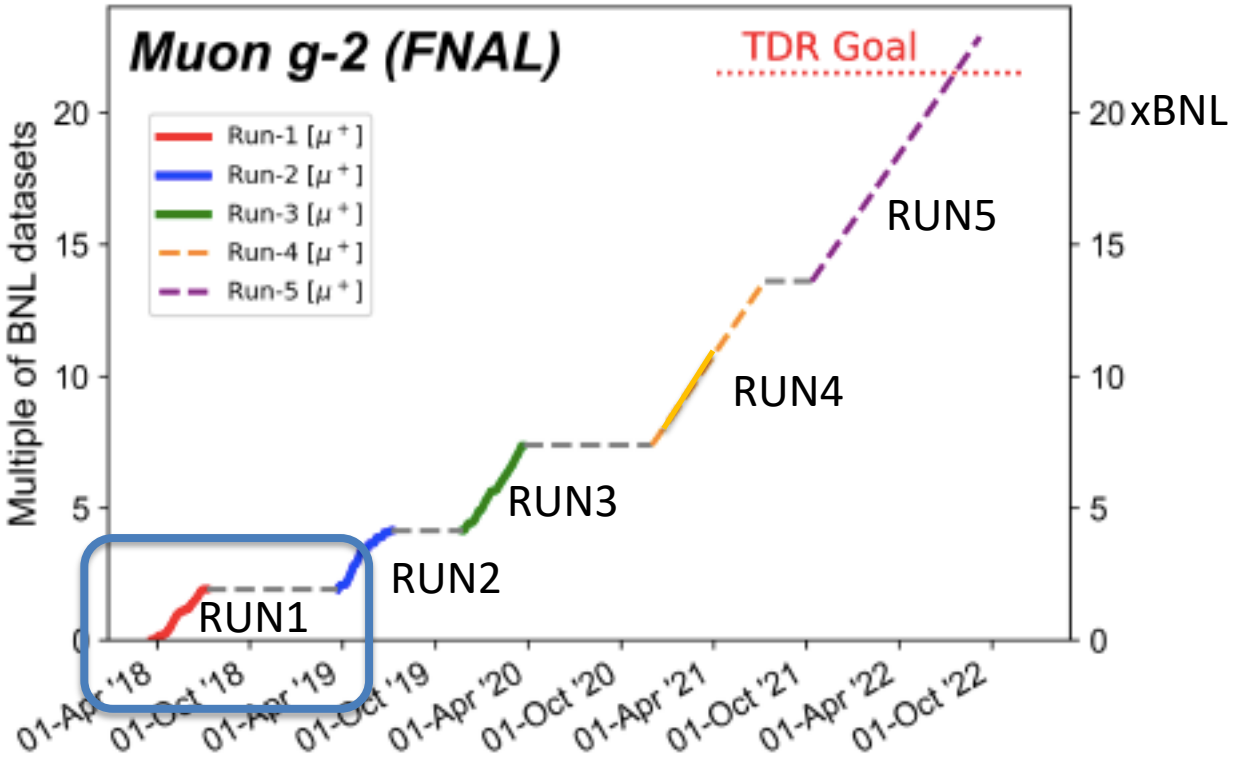
g-2 Young

- M. D. Galati (MSc. at UniPi): Magnetometer, Run2 analysis, lost muons and pileup studies;
- P. Leo (Msc. At UniPi): Run2 analysis, ReconIta;
- E. Bottalico (PhD. at UniPi): Phase acceptance systematics, Laser studies and beam dynamics;
- L. Cotrozzi (PhD at UniPi): Run2/3 analysis;
- P. Girotti (PhD. at UniPi): Gain corrections, Run 1 residual gain analysis, pileup studies;
- M. Sorbara (PhD. at UniRoma2): Run 1/2 analysis, result combination and calorimeter simulation.

4 dottorandi 2 studenti di laurea magistrale

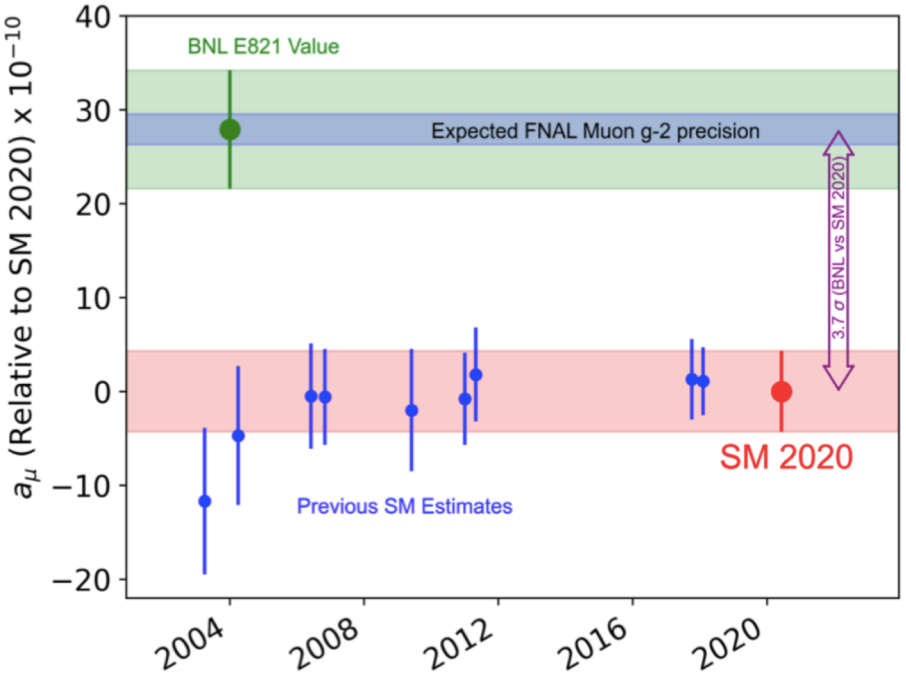
Cosa ci aspetta

- RUN1 is only 6% of the final dataset
- Analysis of RUN2/3 (expect an improvement of a factor ~2 in precision)
- RUN4 (November 2020-July 2021) is expected to bring the statistics to ~13 BNL
- RUN5 in 2021-2022 should allow to achieve the x20 BNL project goal



Nel frattempo dalla teoria: Giugno 2020

- T. Aoyama «The anomalous magnetic moment of the muon in the Standard Model», June 8, 2020, 194 pages, e-print: 2006.04822 [hep-ph] *Phys.Rept.* 887 (2020) 1-166 (>180 citations)



Contribution	Value $\times 10^{11}$
Experiment (E821)	116 592 089(63)
HVP LO (e^+e^-)	6931(40)
HVP NLO (e^+e^-)	−98.3(7)
HVP NNLO (e^+e^-)	12.4(1)
HVP LO (lattice, *udsc*)	7116(184)
HLbL (phenomenology)	92(19)
HLbL NLO (phenomenology)	2(1)
HLbL (lattice, *uds*)	79(35)
HLbL (phenomenology + lattice)	90(17)
QED	116 584 718.931(104)
Electroweak	153.6(1.0)
HVP (e^+e^-, LO + NLO + NNLO)	6845(40)
HLbL (phenomenology + lattice + NLO)	92(18)
Total SM Value	116 591 810(43)
Difference: $\Delta a_\mu := a_\mu^{\rm exp} - a_\mu^{\rm SM}$	279(76)

- Results of 4 years efforts of Theory Initiative (>170 people)
- No surprise (although one single number)
- HVP LO largest contribution (→MUoNE)

$\Delta a_\mu = (279 \pm 76) \times 10^{-11} = 3.7\sigma$

$(\Delta a_\mu \sim 2300 \text{ppb})$

Teoria: Aprile 2021

Article | Published: 07 April 2021

Leading hadronic contribution to the muon magnetic moment from lattice QCD

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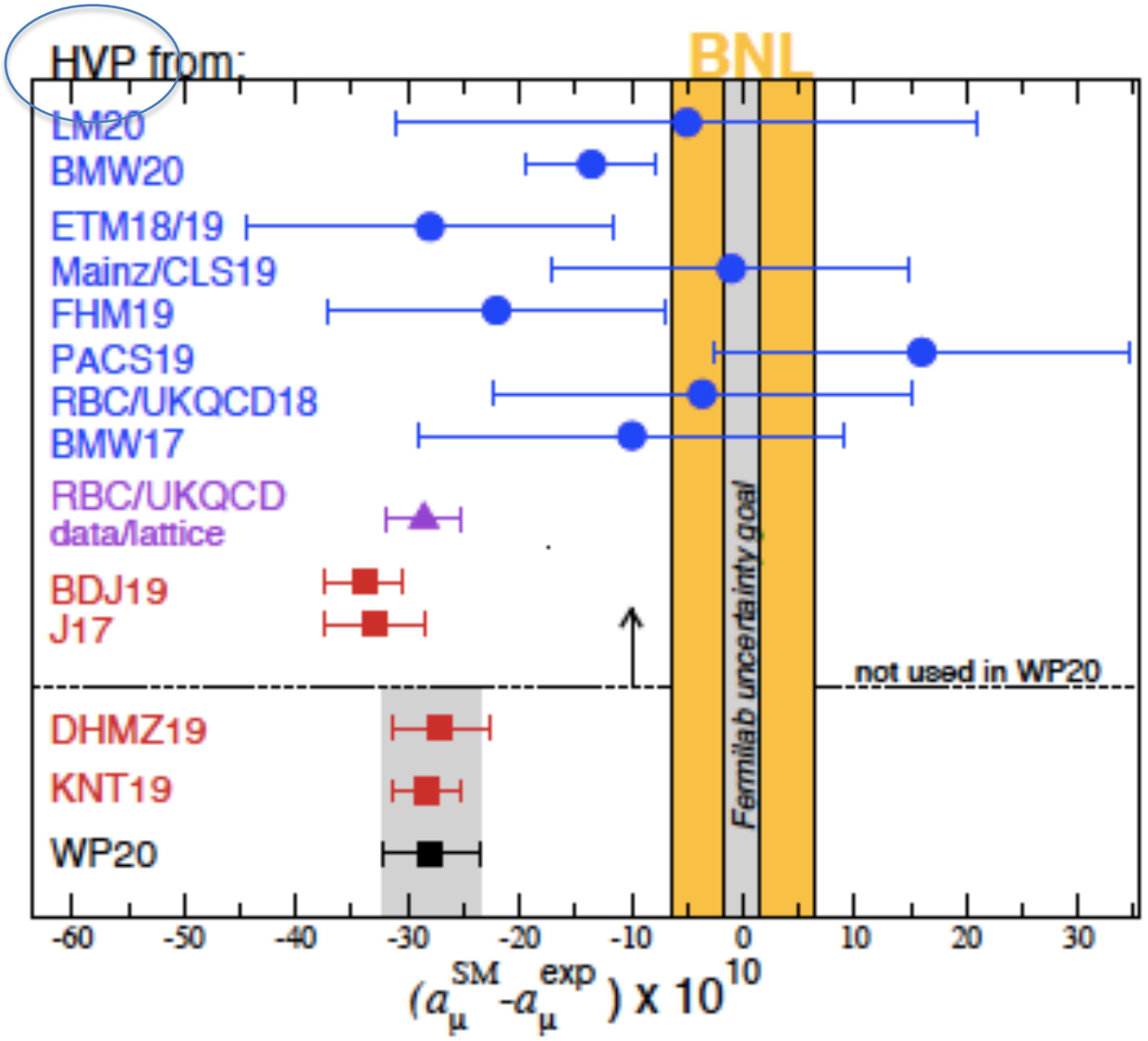
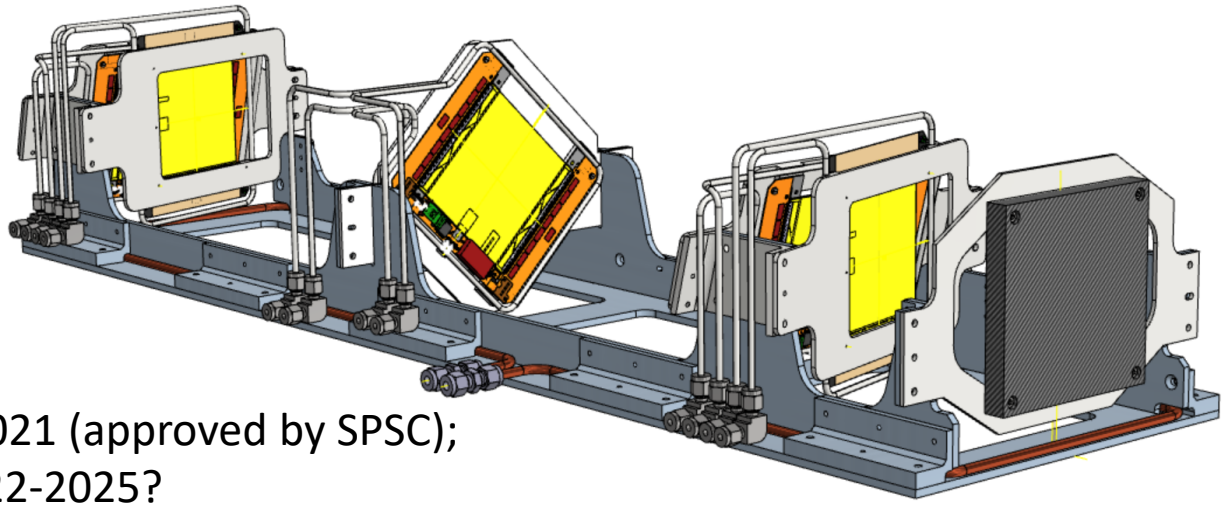
to reduce its uncertainties. The most precise, model-independent determinations so far rely on dispersive techniques, combined with measurements of the cross-section of electron–positron annihilation into hadrons[3,4,5,6]. To eliminate our reliance on these experiments, here we use ab initio quantum chromodynamics (QCD) and quantum electrodynamics simulations to compute the LO-HVP contribution. We reach sufficient precision to discriminate between the measurement of the anomalous magnetic moment of the muon and the predictions of dispersive methods. Our result favours the experimentally measured value over those obtained using the dispersion relation. Moreover, the methods used and developed in this work will enable further increased precision as more powerful computers become available.

Cosa ci riservera' il futuro?

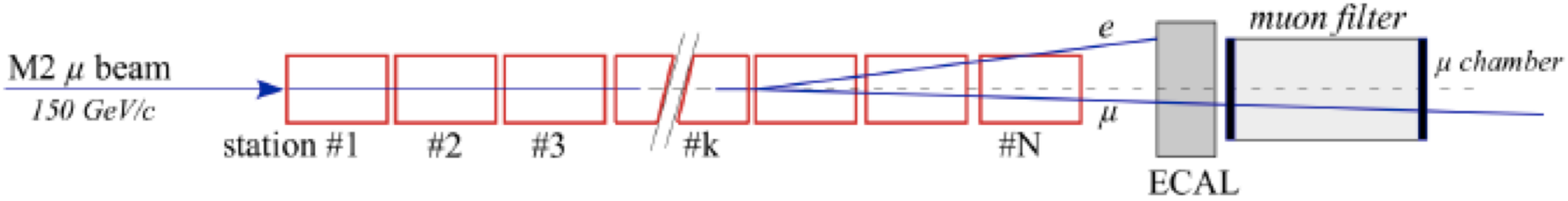
- Misura RUN2/3 @300ppb
- Theory?
- Nei prossimi due anni sapremo…



MUONE al CERN



Test RUN 2021 (approved by SPSC);
Full run 2022-2025?



Misura indipendente del contributo HVP di a_μ

-*A. Abbiendi et al Eur.Phys.J.C* 77 (2017) 3, 139
-LoI https://cds.cern.ch/record/2677471/files/SPSC-I-252.pdf

(contributo importante di M. Massa, A. Moggi)

Conclusioni: Pisa e l'esperimento g-2: una lunga storia con un finale ancora da scrivere

- 1960-1980:
  - E. Picasso (Muon g-2 experiment @ CERN → 7ppm)
- 1990-2010:
  - KLOE (Cervelli, Di Falco, Incagli Venanzoni) → Misura della sezione d'urto adronica, sviluppo tecnica ISR per contributo HVP
- 2010-202..:
  - Muon g-2 (Bedeschi, Incagli, Lusiani, Di Falco, Donati, Venanzoni, Bottalico, Girotti, Cotrozzi): →Sistema laser (+CNR INO: Ferrari Fioretti, Gabbanini); Analisi ω_a
- 2020-202…
  - MUonE (Incagli, Ligabue, Venanzoni, Pilato, Massa, Moggi) →Misura diretta HVP attraverso scattering mu su e-
  - ….

The SIGHAD03 workshop in Pisa considered the challenges presented by different sources of low-energy hadronic cross-section data.

Pisa 2003

In summary, this was a short but very intensive workshop. However, there were also two moments of relaxation, with a visit to the Piazza dei Miracoli, where the leaning tower is located, and a delicious dinner in the lovely ancient Villa Toscana. During the dinner, Simon Eidelman proposed organizing the next workshop in Novosibirsk two years from now. By then, new theoretical and experimental results, expected in particular from the g-2 experiment at Brookhaven, as anticipated by Lee Roberts (and now released, see *CERN Courier* January/February 2004 p6) will clarify whether the discrepancy observed in a_μ will vanish, or whether it will remain, so requiring new physics.

Antonio Anastasi (18/9/1989-23/3/2020)

- Summer student at Fermilab 2013
- Master Thesis on the Laser Calibration system in 2013 (first Italian master student in g-2)
- PhD Thesis on the Laser Calibration system in 2017 (**first PhD in E989**, see https://gm2-docdb.fnal.gov/cgi-bin/private/RetrieveFile?docid=4911&filename=Thesis_anastasi.pdf&version=1)
- TB at SLAC in 2014 and at Frascati in 2016 (leading the efforts)
- Many helps and contributions on the finalization of the laser system.
- Author of "calorimeter/laser" Technical papers (NIM/JINST)

Antonio was an exceptional person in his freshness and with his enthusiasm and talent. His positive being was contagious. He was full of life and love for what he did and he was a person of great faith and very sunny. The strength with which he has faced the last years of his life during the illness will remain an indelible teaching. No words can express how we miss him.

(Antonio in Seattle in 2015)

DOTTORATO DI RICERCA IN FISICA *XXIX* CICLO

The Calibration System of the E989 Experiment at Fermilab
PhD Thesis
Antonio ANASTASI

SSD:FIS04

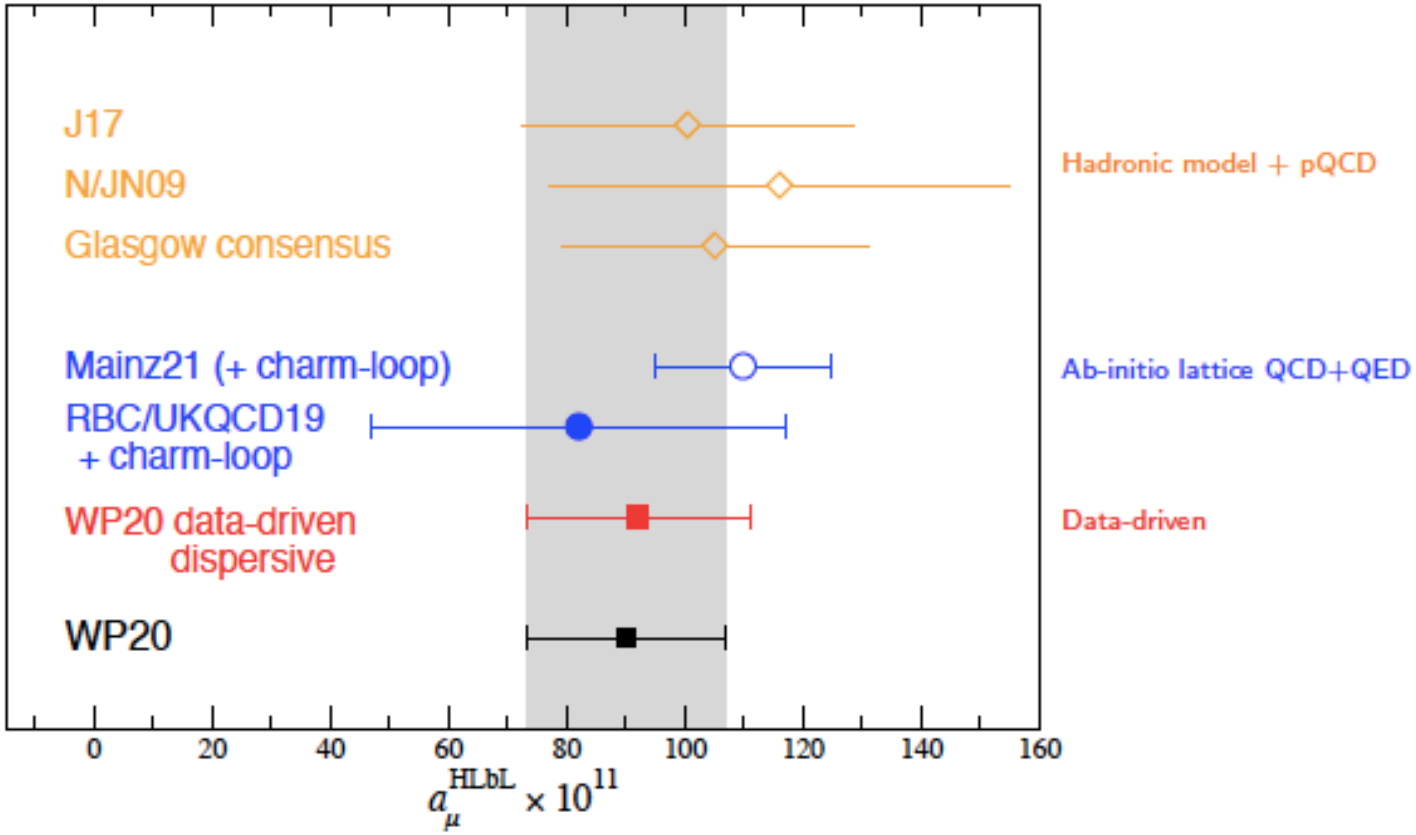
PhD Coordinator:
Prof. Lorenzo TORRISI

Tutor:
Dr. Giuseppe MANDAGLIO
Co-Tutor:
Dr. Graziano VENANZONI
Co-Tutor:
Prof. David HERTZOG

Triennio 2014/2016

END

Status of hadronic light-by-light contribution



Systematically improvable methods are maturing; uncertainty to a_μ controlled at 0.15ppm; cross-checks facilitated by Theory Initiative

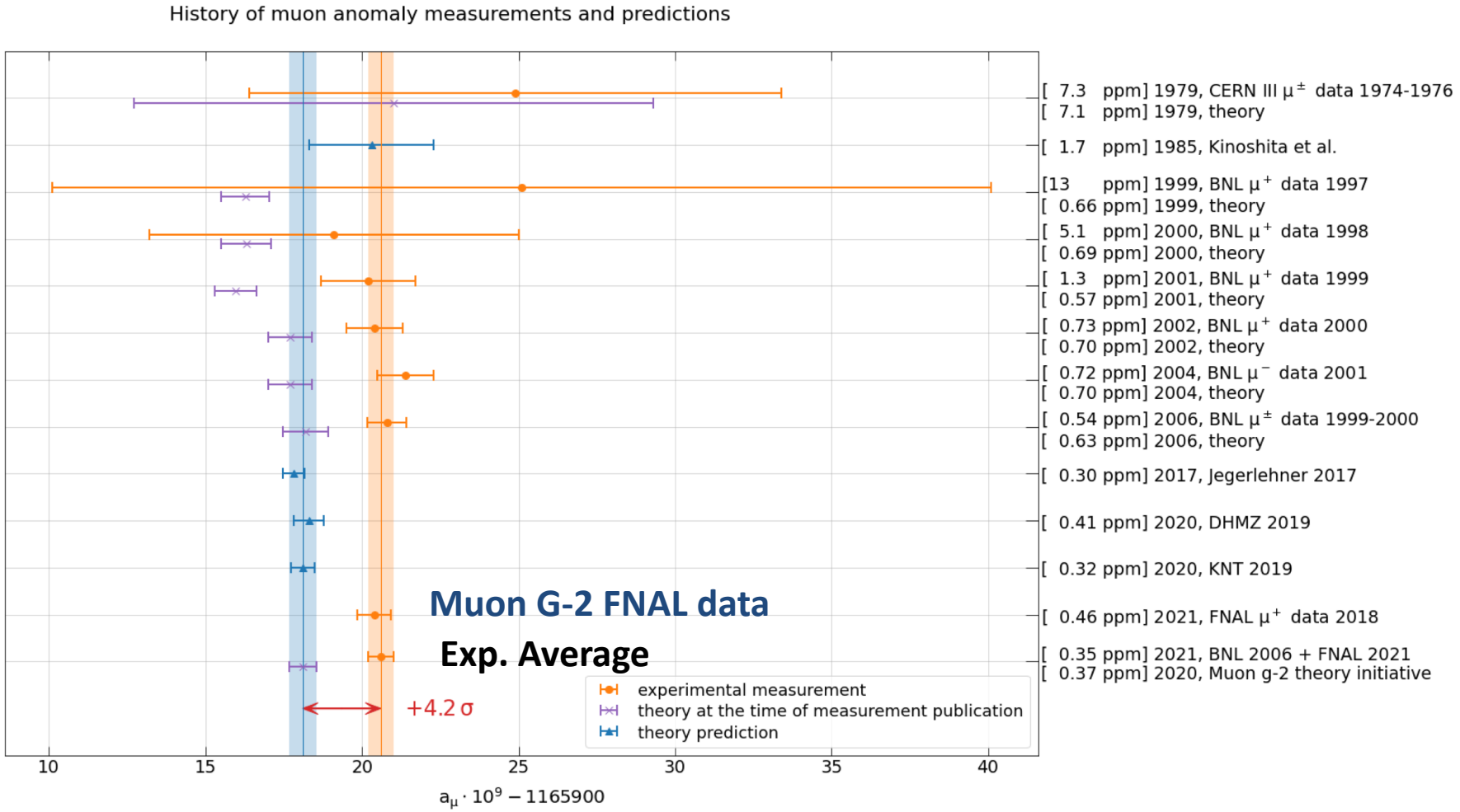
a_μ: Unblinding

Quantity	Correction Terms (ppb)	Uncertainty (ppb)
ω_a (statistical)	–	434
ω_a (systematic)	–	56
C_e	489	53
C_p	180	13
C_{ml}	-11	5
C_{pa}	-158	75
$f_{calib}\langle\omega_p'(x,y,\phi)\times M(x,y,\phi)\rangle$	–	56
B_q	-17	92
B_k	-27	37
$\mu_p'(34.7^\circ)/\mu_e$	–	10
m_μ/m_e	–	22
$g_e/2$	–	0
Total	–	462

434 ppb stat ⊕ 157 ppb syst error

$$a_\mu(\mathrm{FNAL}) = 116\,592\,040(54)\times 10^{-11} \quad (0.46\,\mathrm{ppm})$$

Updated g-2 history (April 8 2021)



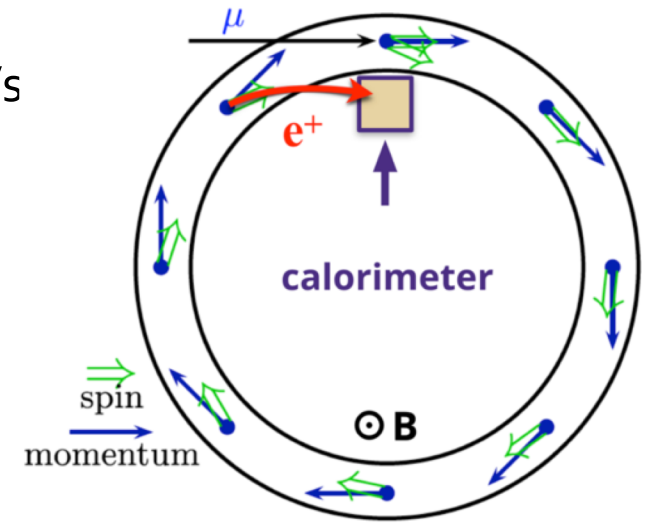
$$a_\mu(\text{AVG}) = 116\,592\,061(41) \times 10^{-11} \quad (0.35\,\text{ppm}).$$

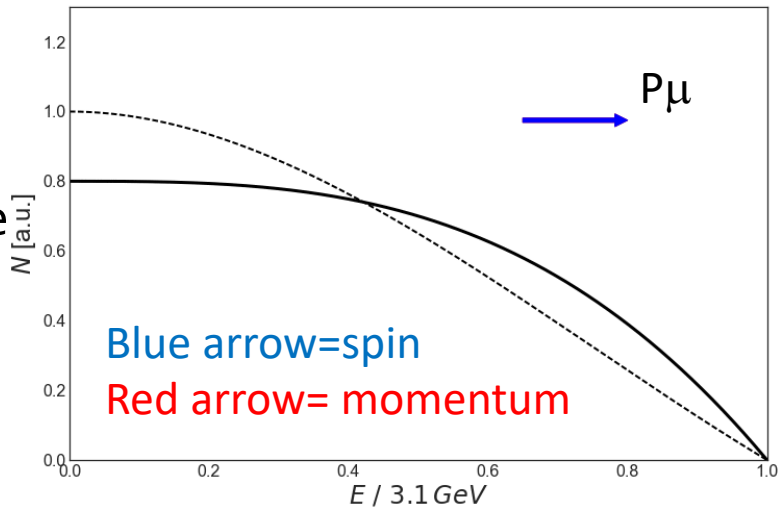
ω_a Measurement

- Muon's spin is correlated to high energy positron's momentum
- The number of positrons is modulated by the anomalous precession frequency

$$N_0 e^{-t/\tau}[1 - A\,cos(\omega_a t + \phi)]$$

- 4 different analysis methods:
  - T: integrate all positrons above 1.7 GeV
  - A: weight the positrons with A(E) function and integrate above 1.1 GeV
  - R: randomly split dataset in 2 subsets shifted by ±half a g-2 period, build combinations of the 2 subsets to remove slow terms (exponential, gain…)
  - Q: No clustering: just integrate energy above threshold (in theory no threshold should be applied) for each crystal





E and t are the measured observables.