WG4 – Muon Physics: setting the scene

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Muon physics

- A Neutrino Factory is also a Muon Factory

$$p + \text{target} \rightarrow \begin{matrix} \pi \rightarrow \mu\nu \\ K \rightarrow \mu\nu \end{matrix}$$

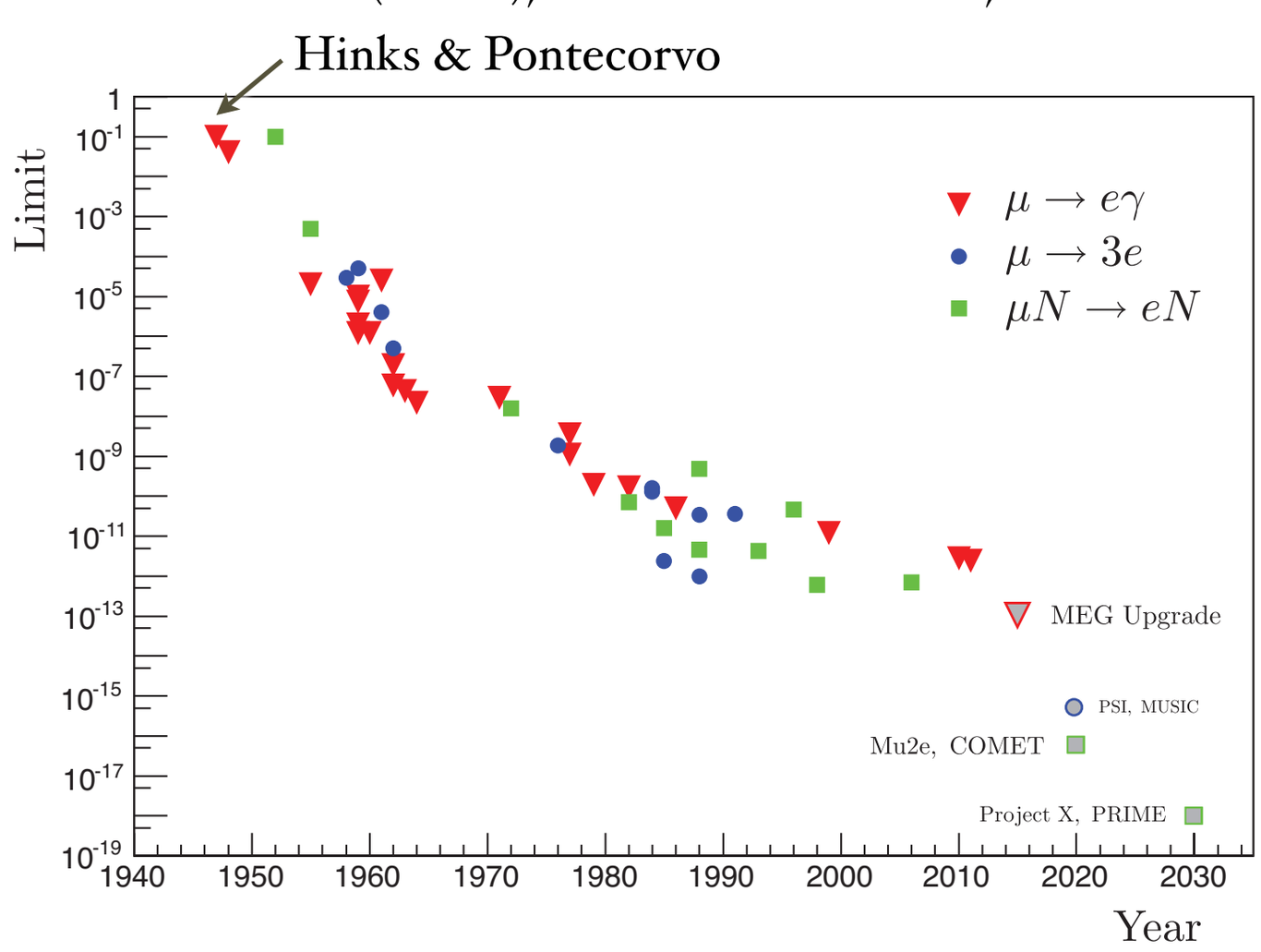
- The number of produced muons exceeds what it is presently available.

- Is there any fundamental connection between muon physics and neutrino physics?
- The question dates back to the 40s

Bruno Pontecorvo: 100 years

- Centenary of the birth of Bruno Pontecorvo
  - Bruno Pontecorvo was born in Pisa on 22 August 1913
  - Completed his studies in Rome under E. Fermi
  - Went to Paris and then to Canada during WW2

- Muon: discovered 1936 (N&A), Lattes et al. 1947, Conversi et al. 1947



BP's legacy

- Inverse β-process (1946)
  - neutrino detection
- Nuclear capture of mesons (1947)
  - universality of Fermi interaction
- Absence of μ→eγ (1948-1950)
  - neutrino and muons are connected
- Electron and muon neutrinos (1959)
  - neutrino beams
- Neutrino oscillations (1967→)
- Lepton mixing and the solar neutrino puzzle (1977)

"[...] one may say that experiments planned to test the identity of ν_e and ν_μ, though very difficult, must be seriously thought over when new intense accelerators are being designed. In particular, the problem of radiation shielding in such experiments must be considered at a very early stage of the accelerator's design." (B. Pontecorvo, Zh. Eksp. Teor. Fiz. 1959, vol. 37, p. 1751)

"Is there any connection between, say, the μ→eγ process and the phenomenon of neutrino oscillations? The observation of anyone of these effects would mean that there is lepton mixing. In this general sense and only in this sense the observation of the μ→eγ decay would make the existence of oscillations more likely, and conversely." (B. Pontecorvo, Comments Nucl. Part. Phys. 1977, vol.7 n.5 149-152)

Back to our days

- S.L.Glashow, "Particle physics in the USA, a personal view", May 23, 2013, arXiv:1305.5482 [hep-ph]

> • *Testing Flavor Symmetries with Muons:* I focus on these three flavor-changing muon decay modes: radiative decay ($\mu \to e + \gamma$), 3-e decay ($\mu \to e + e + \bar{e}$) and orbital conversion ($\mu + \mathcal{N} \to e + \mathcal{N}$) where $\mathcal{N}$ denotes an atomic nucleus to which the muon is bound. These decay modes conserve $\mathcal{L}$ and are technically allowed via the flavor-violation responsible for neutrino oscillations. Because their standard-model branching ratios are far too tiny for possible detection, observation of any mode would be certain evidence of new physics. That's what makes such sensitive searches potentially transformative.
>
> Whatever enables one muon mode enables the others as well, but often with considerable suppression. If new physics primarily generates flavor-changing lepton magnetic moments, $\mu \to e + \gamma$ would dominate the other modes by factors exceeding 200. Likewise, doubly-charged dileptons could strongly favor the 3-e mode while leptoquarks could strongly favor orbital conversion. Thus an improved search for one mode does not obviate the need to search for the others. Current bounds on all three modes should be improved as much as possible. (Flavor-violating decays of tau leptons, such as $\tau \to \mu +$ hadrons or $\tau \to \mu + \mu + \bar{e}$, may be worth further constraining, but these experiments cannot approach the sensitivity accessible to the three golden muon modes.)

Plenary talks

- It is not my role to summarize the physics
- We will have plenary talks on Wed, Aug 21

11:30 **Theory overview on muon physics** *30'*
Lorenzo Calibbi (University of Brussels (ULB))

12:00 **Lepton flavor physics with muon beam** *30'*
Prof. Satoshi Mihara (KEK, IPNS)

- Large ϑ_{13}
- Higgs at 125 GeV
  - ν masses different from lepton's
  - is ν mixing different from lepton mixing?
- No SUSY, yet

Muon physics

- charged Lepton Flavour Violation (cLFV)
  - μ→eγ, μ→eee
  - μ2e, τ→cLFV

7 talks

- Precision experiments
  - μHFS
  - g–2
  - “proton radius puzzle”
  - μ-capture on different targets

6 talks

- Muon Facilities
  - present & future

13 talks

total of 26 talks

Including WG1+4 (1 session 3 talks)
& WG3+4 (3 sessions 10 talks)

Tue 20

- The MEG experiment status and upgrade (L. Galli)
- Muegamma search with converted photon (C. Cheng)
- The Mu3e experiment at PSI (A. Bravar)

CLFV

- g–2 at FNAL
- Muon g–2 and EDM at J-PARC (T. Mibe)
- Present status of J-PARC MUSE (K. Shimomura)

precision + facility

- Measurement of muonium hyper-fine splitting
- The MUSE experiment: simultaneous μ-p and e-p elastic scattering (W. Briscoe)

precision

Wed 21

J34

- Results from Step I of MICE and the Physics Plan for Step IV (D. Adey)
- Progress towards completion of the MICE demonstration of ionisation cooling of muons (D. Kaplan)
- Studies of New, High Performance, 6D Ionization Cooling Lattices for the Muon Accelerators (D. Stratakis)

facility

- The Mu2e experiment (Z. You)
- The Mu2e extinction system (P. Kasper)
- COMET (Ye Yuan)

CLFV

- Experimental Search for μ-e Conversion in Nuclear Field at J-PARC MLF H-Line – DEEME (Y. Nakatsugawa)
- Study of muon capture on Al target (Y. Kuno)

CLFV

Thu 22

- Vacuum RF 6D cooling lattices (R. Palmer)
- Development of Six-Dimensional Helical Muon Beam Ionization Cooling Channel for Muon Colliders (K. Yonehara)
- A Staged Approach for Muon-based Facilities (D. Neuffer)

J34

facility

Fri 23

J34

- A New DC Muon Beam Line at MuSIC (A. Sato)
- PRISM system - status and challenges (J. Pasternak) (Imperial College London/ RAL-STFC)
- CW muon beam acceleration with FFAG (Y. Mori)
- Low Energy Muon Beams from the AP0 Target (M. Popovic)

facility

J14

- Neutrino and muon connections (F. Joachim)
- Last results on τ-CLFV and perspectives (C. Shen)
- Muon analysis in the peripheral region of INO-CAL (Kanishka, Meghna)

CLFV
and
ν-μ connections

Conclusion

- ...of the introduction
- Muon experiments can address some of the most interesting questions in our field
- We need intense muon sources, that could be provided by neutrino factories
- Much overlap in the development of technology for high intensity muon beams with neutrino beams
- Worldwide, the muon program is getting faster and faster
- so.... follow us and stay tuned!