

Развитие идей Лобашева В.М.



Р.М. Джилкибаев
ИЯИ Троицк 23.10.2014

НОВЫЕ ВОЗМОЖНОСТИ ИНТЕНСИВНОСТИ

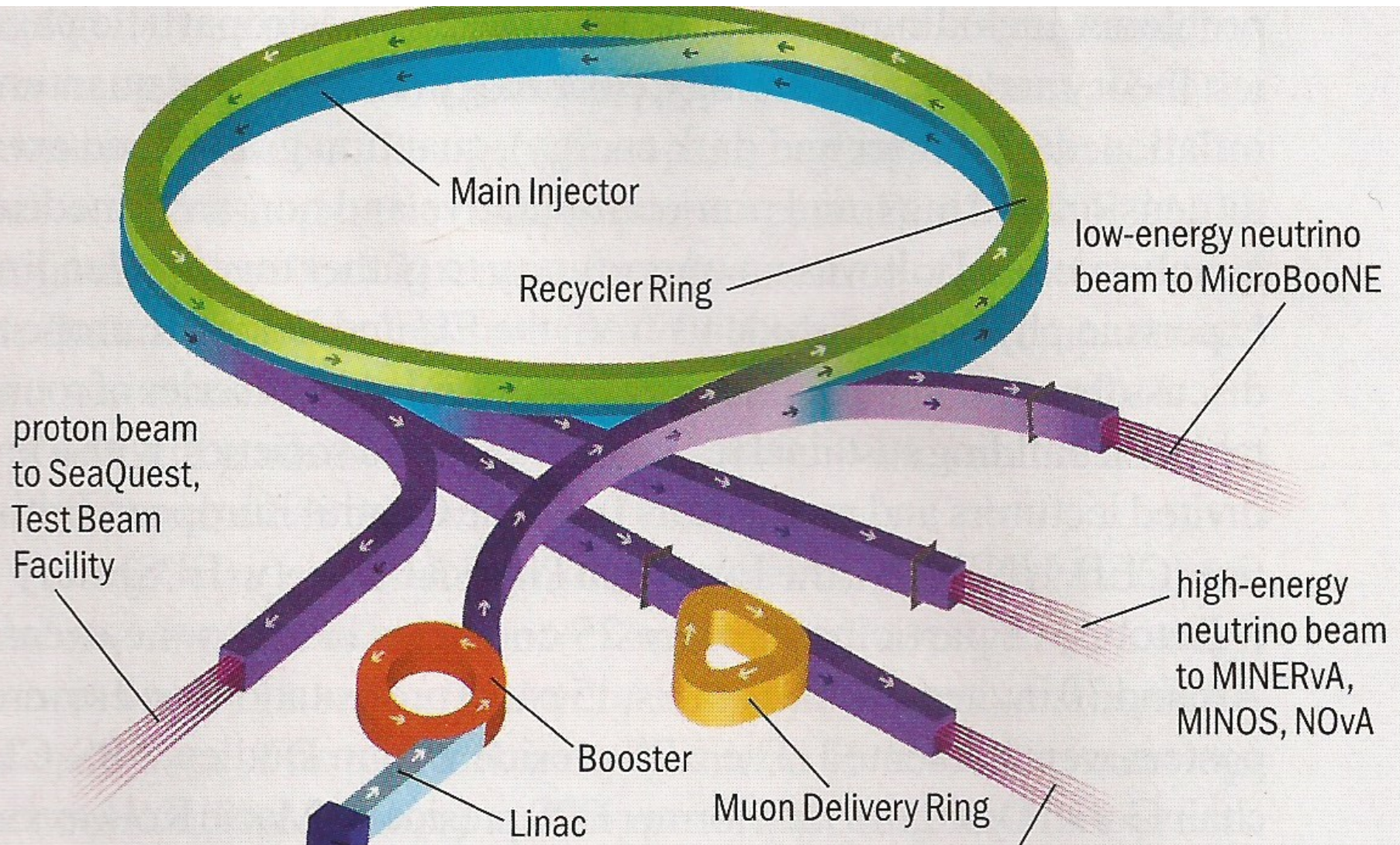
В.М. Лобашев, ИЯИ 1972 – 2011

- Нейтринные исследования Troitsk ν -mass → (KATRIN, Karlsruhe)
- Поиск редких мюонных процессов MELC → (Mu2e FNAL, COMET J-PARC)
- Intensity Frontier, FNAL USA, 2000

Building for Discovery

- **Strategic plan for U.S. particle physics in the Global Context**
- **Report of the particle physics project prioritization panel, May 2014**
- **Intensity Frontier**
- **Muons and Kaons**
- **Recommendation 22: Complete the Mu2e and muon g-2 projects.**

Intensity Frontier, FNAL

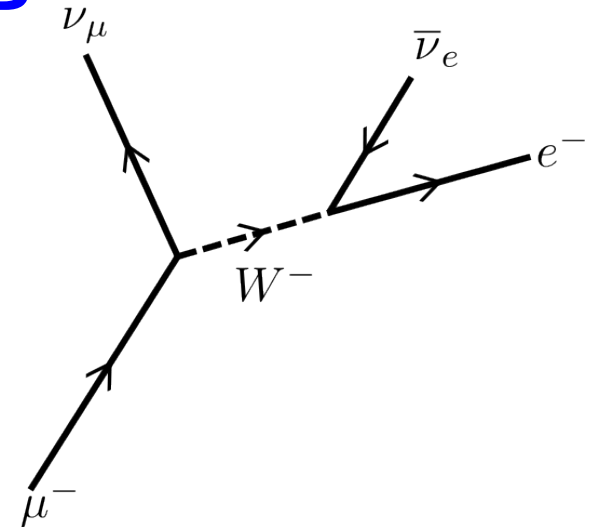


Поиск редких мюонных процессов

Основной распад мюона

$$\mu^- \rightarrow e^- \nu_e \nu_\mu$$

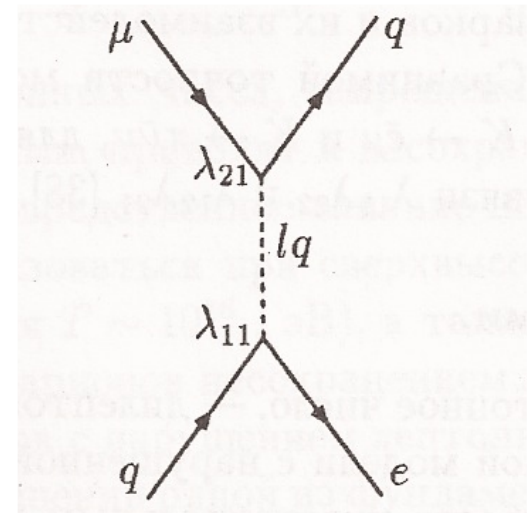
$$M_W = 80 \text{ GeV}$$



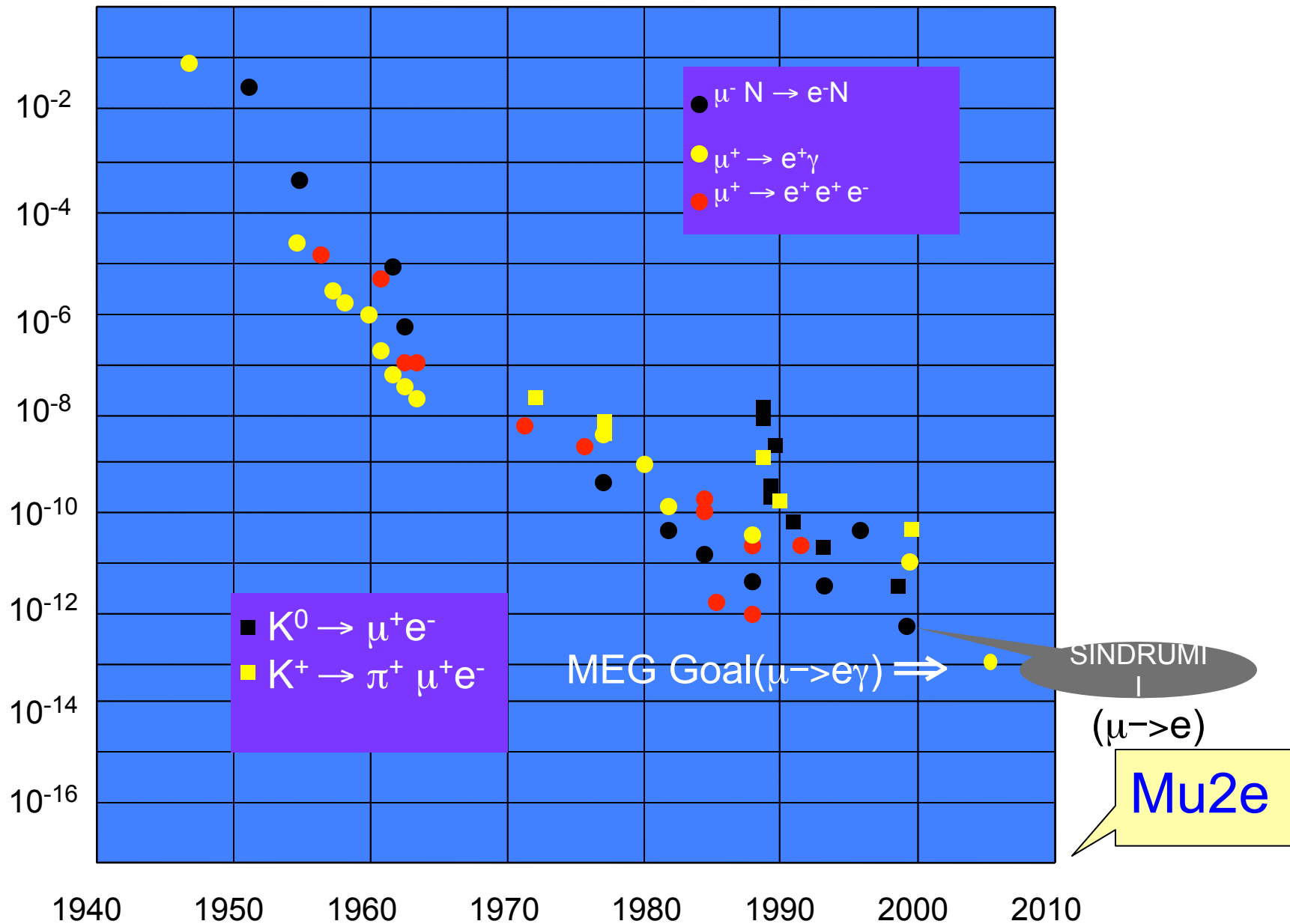
$$\text{Br}(\mu^- \rightarrow e^- / \mu^- \rightarrow e^- \nu \nu) = 10^{-16}$$

$$\text{Br}(\mu^- \rightarrow e^-) \sim (M_W/M_{lq})^4$$

$$M_{lq} \approx 1000 \text{ TeV}$$



History of Lepton Flavor Violation Searches



Theory Motivation

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

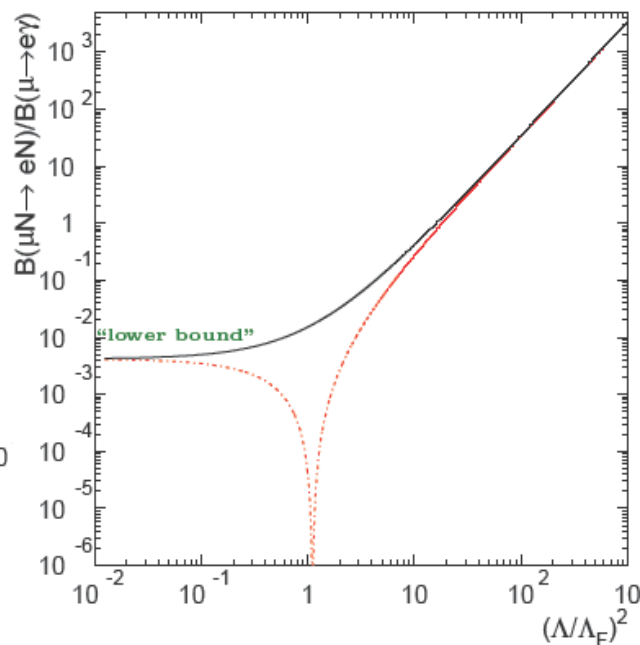
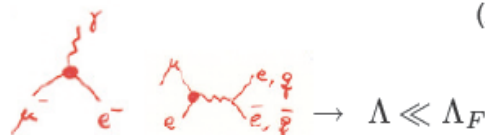
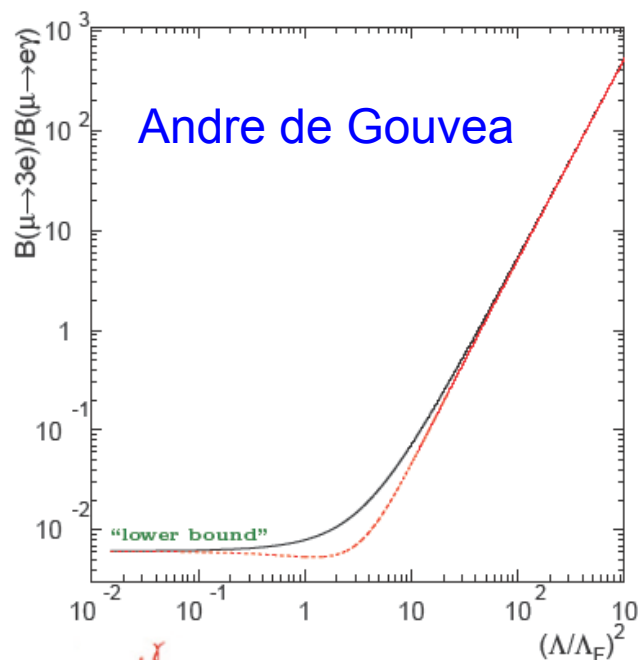
First term: mediates $\mu \rightarrow e\gamma$ and, at order α , $\mu \rightarrow eee$ and $\mu + Z \rightarrow e + Z$

Second term: mediates $\mu \rightarrow eee$ and, at one-loop, $\mu \rightarrow e\gamma$

Third term: mediates $\mu + Z \rightarrow e + Z$ and, at one-loop, $\mu \rightarrow e\gamma$

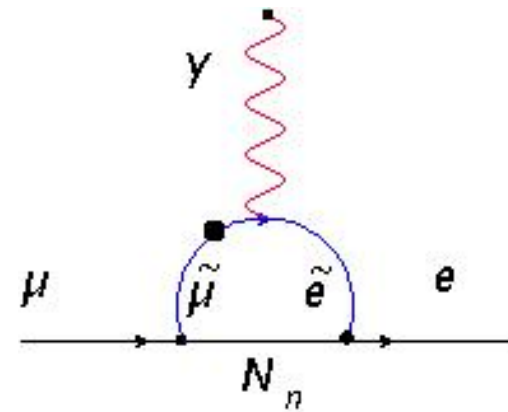
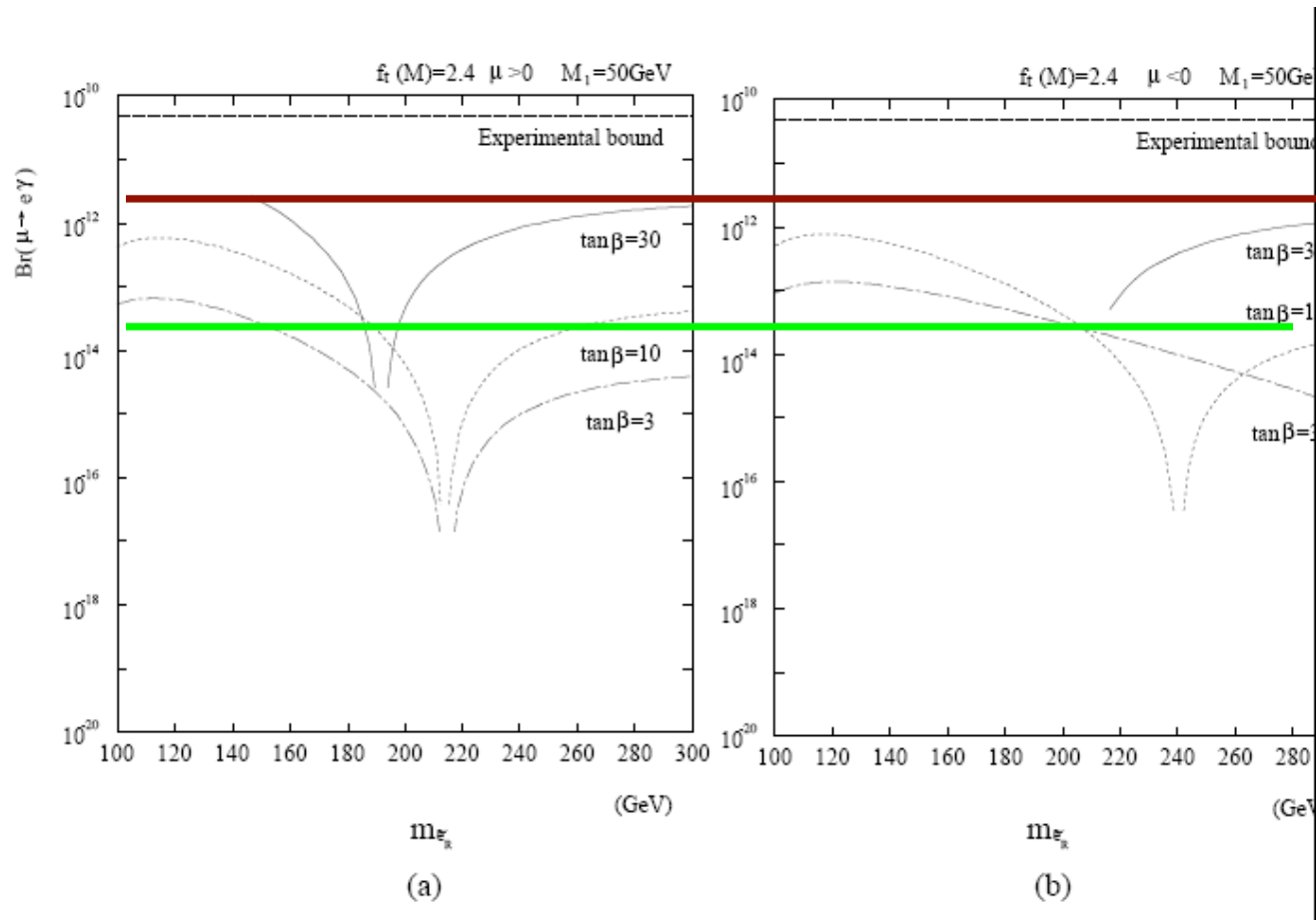
André de Gouvêa

Northwestern



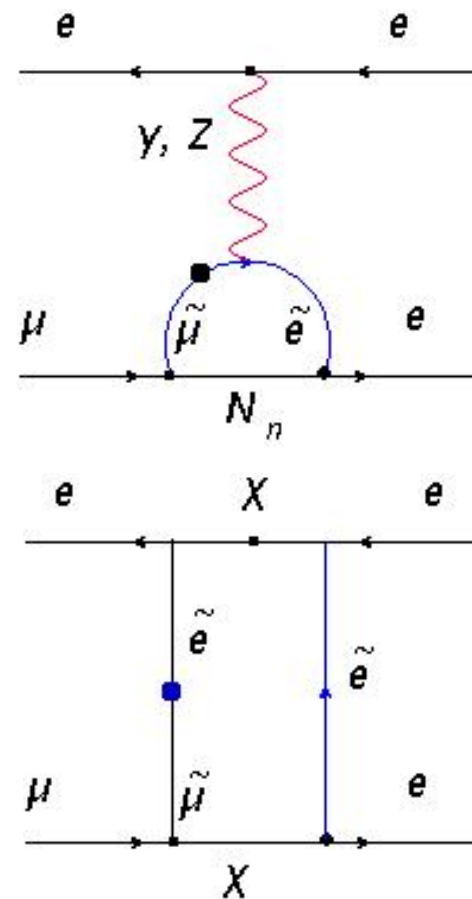
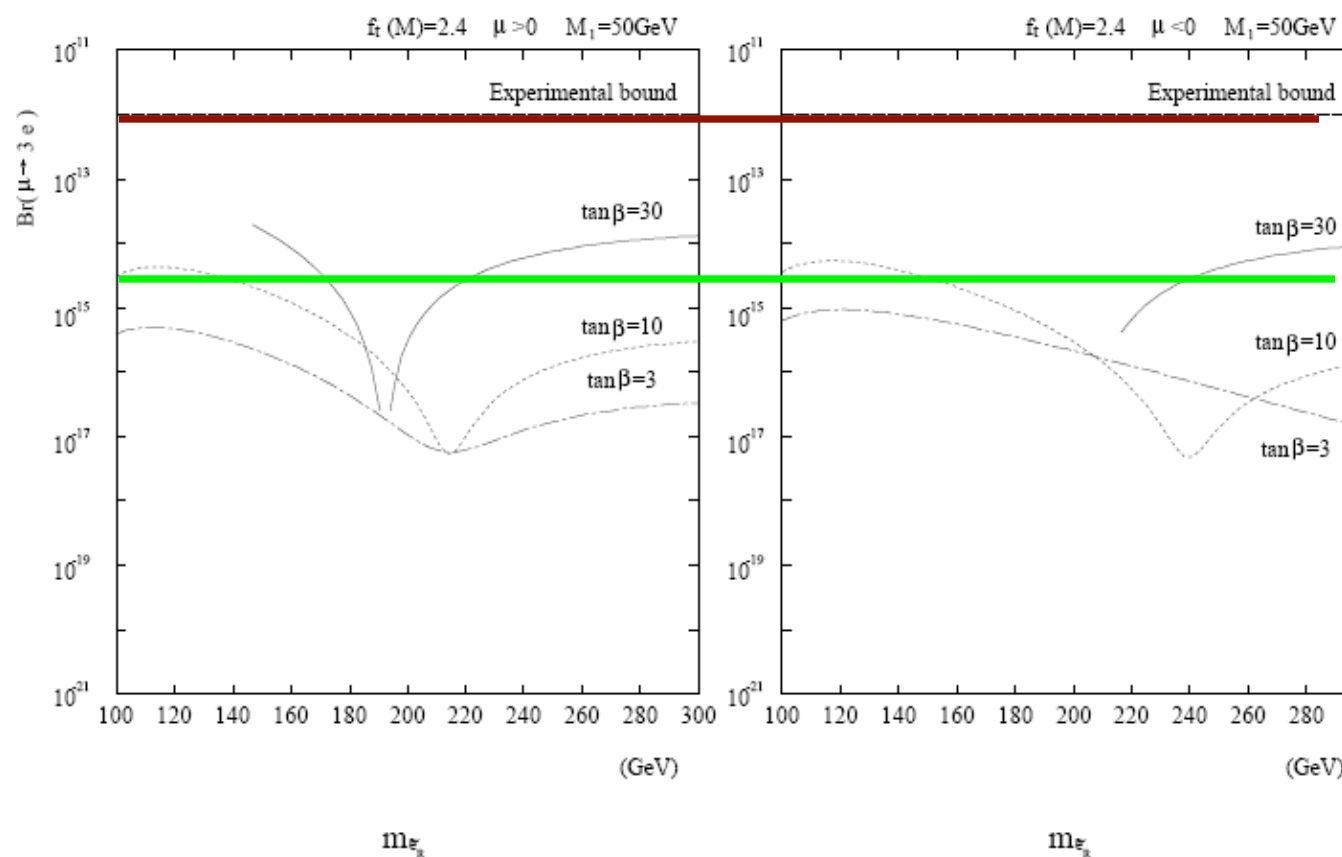
SUSY prediction for $\mu \rightarrow e + \gamma$

J.Hisano, T.Moroi, K.Tobi 1996



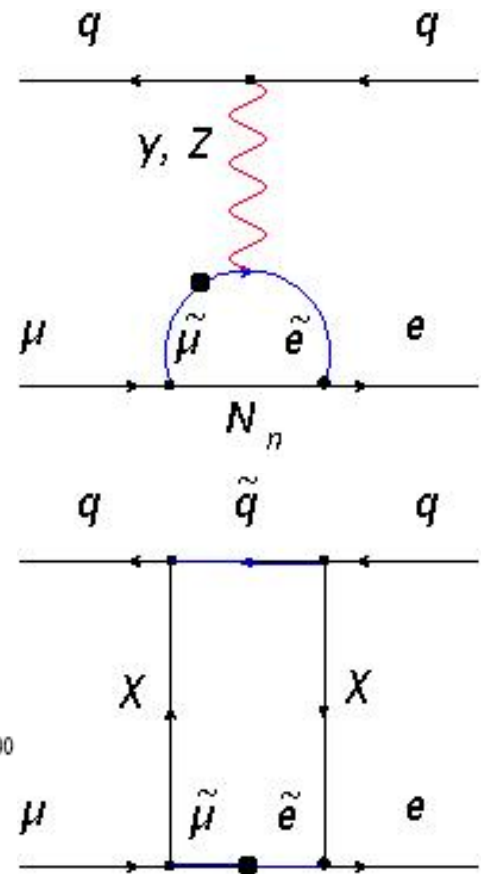
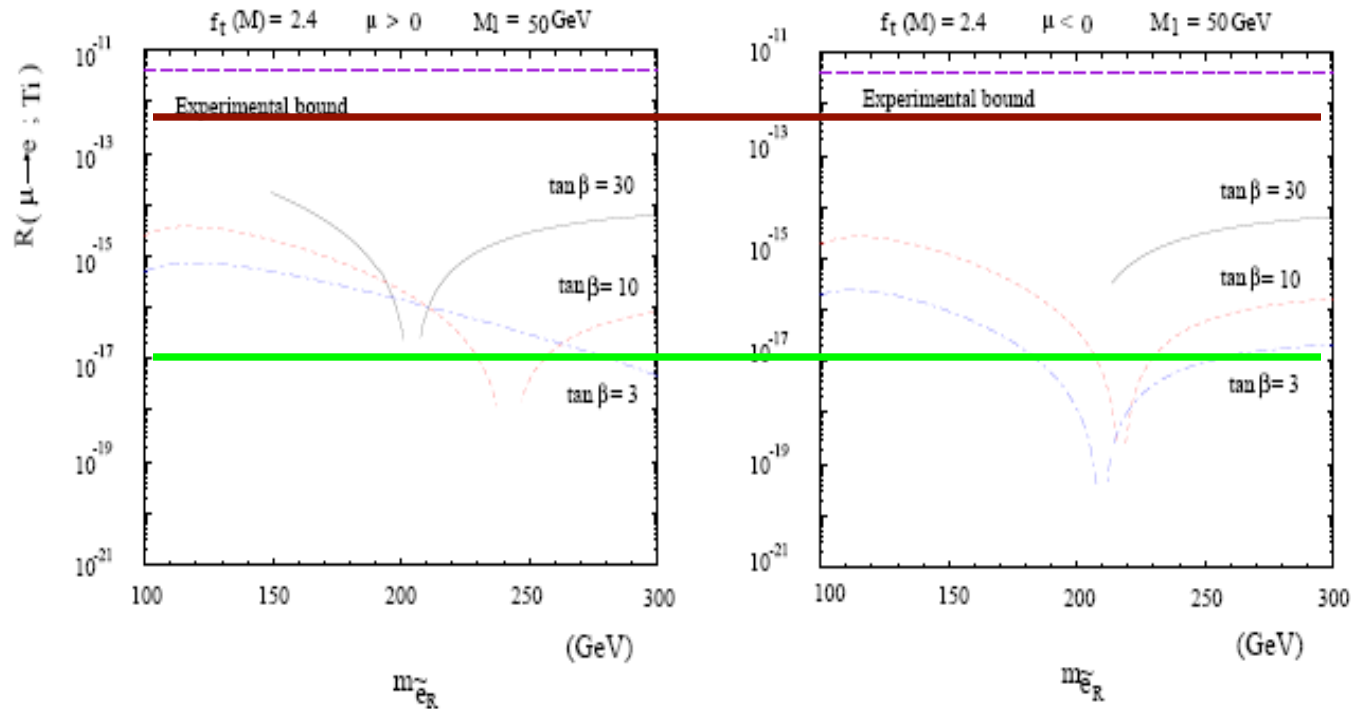
SUSY prediction for $\mu \rightarrow 3e$

J.Hisano, T.Moroi, K.Tobi 1996



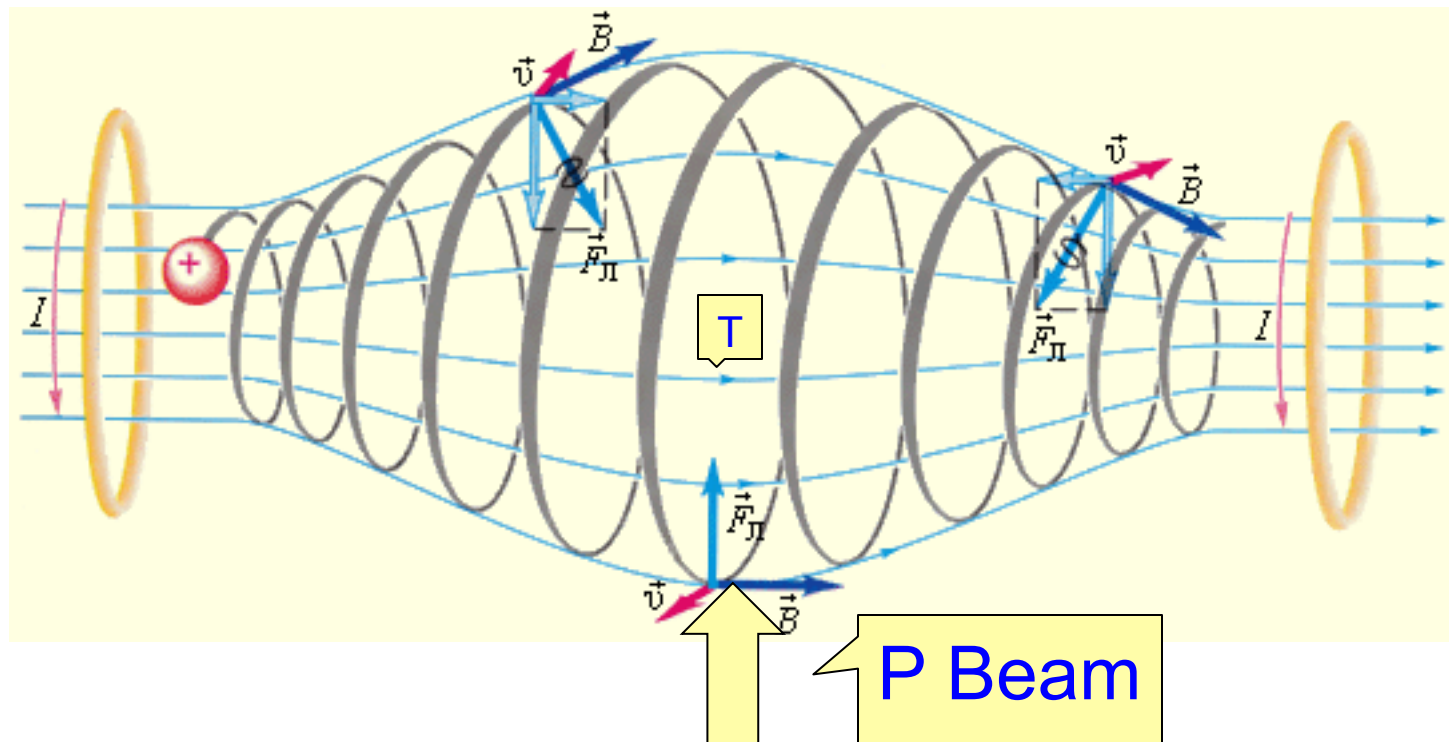
SUSY prediction for $\mu \rightarrow e$ conversion

J.Hisano, T.Moroi, K.Tobi 1996



Магнитная ловушка

- Ловушка Будкера Г.И.
- В.М. Лобашев, О.В. Сердюк 1973- 1976
Neutrino source



MELC

Pulsed proton beam 0.1 - 2 μ s

Proton beam extinction 10^{-9}

P beam 600 MeV – 9×10^{14} p/s, 90 kW

P beam 8 GeV – 4×10^{13} p/s, 50 kW

MELC (INR) - 1989

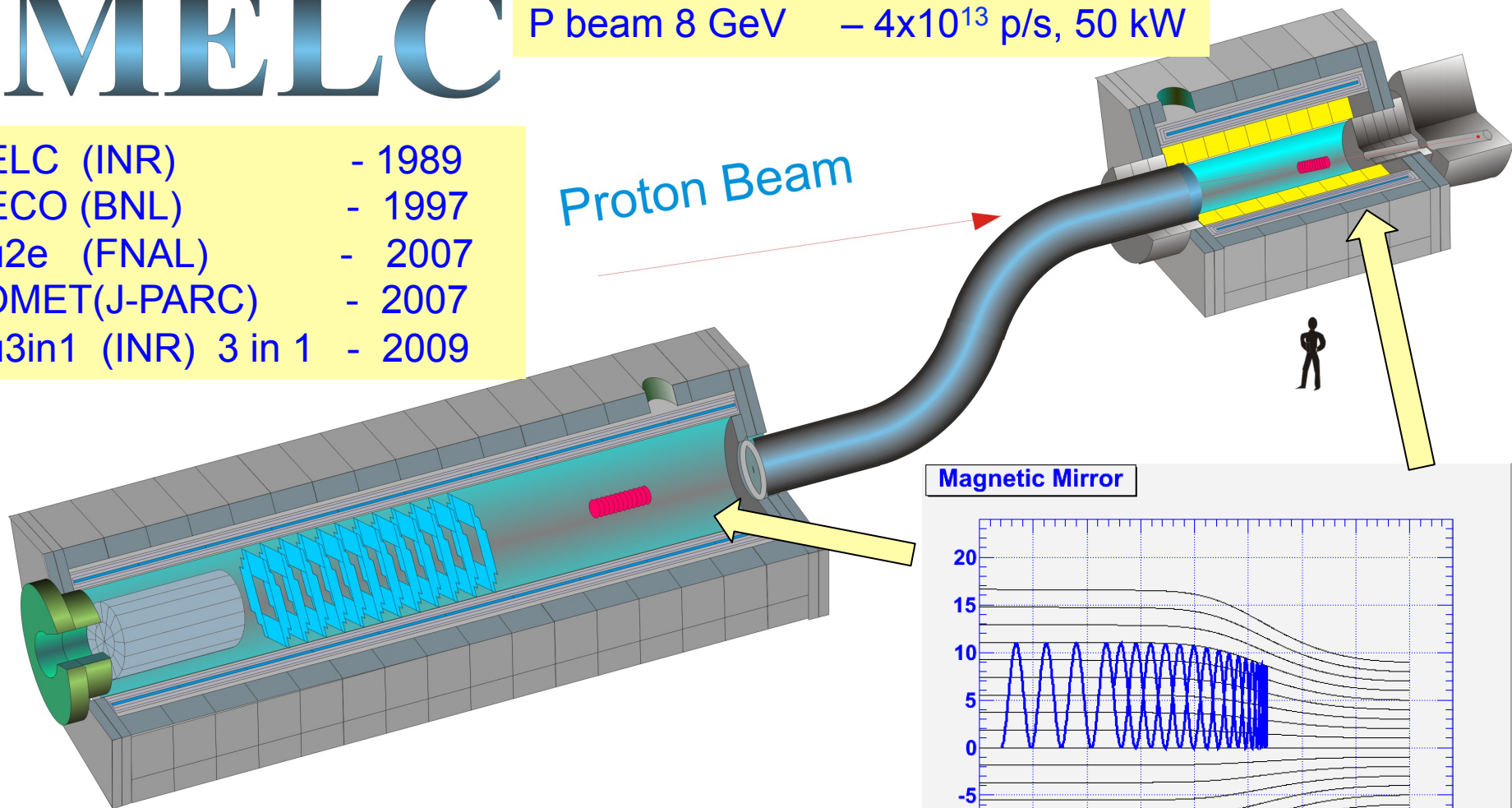
MECO (BNL) - 1997

Mu2e (FNAL) - 2007

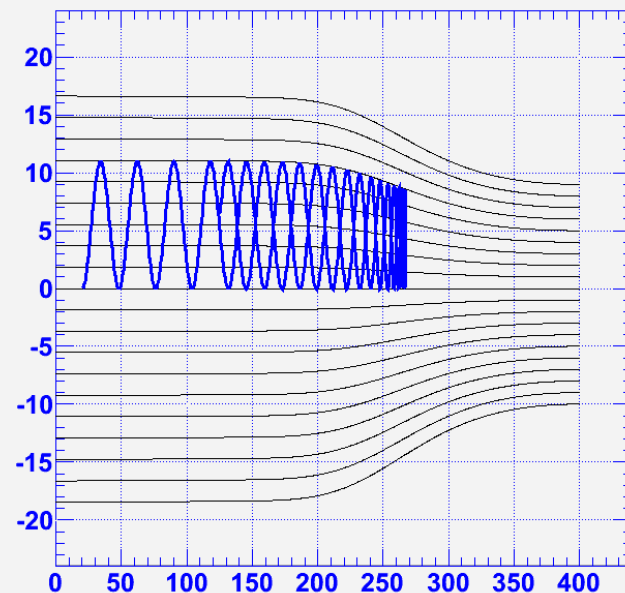
COMET(J-PARC) - 2007

Mu3in1 (INR) 3 in 1 - 2009

Proton Beam



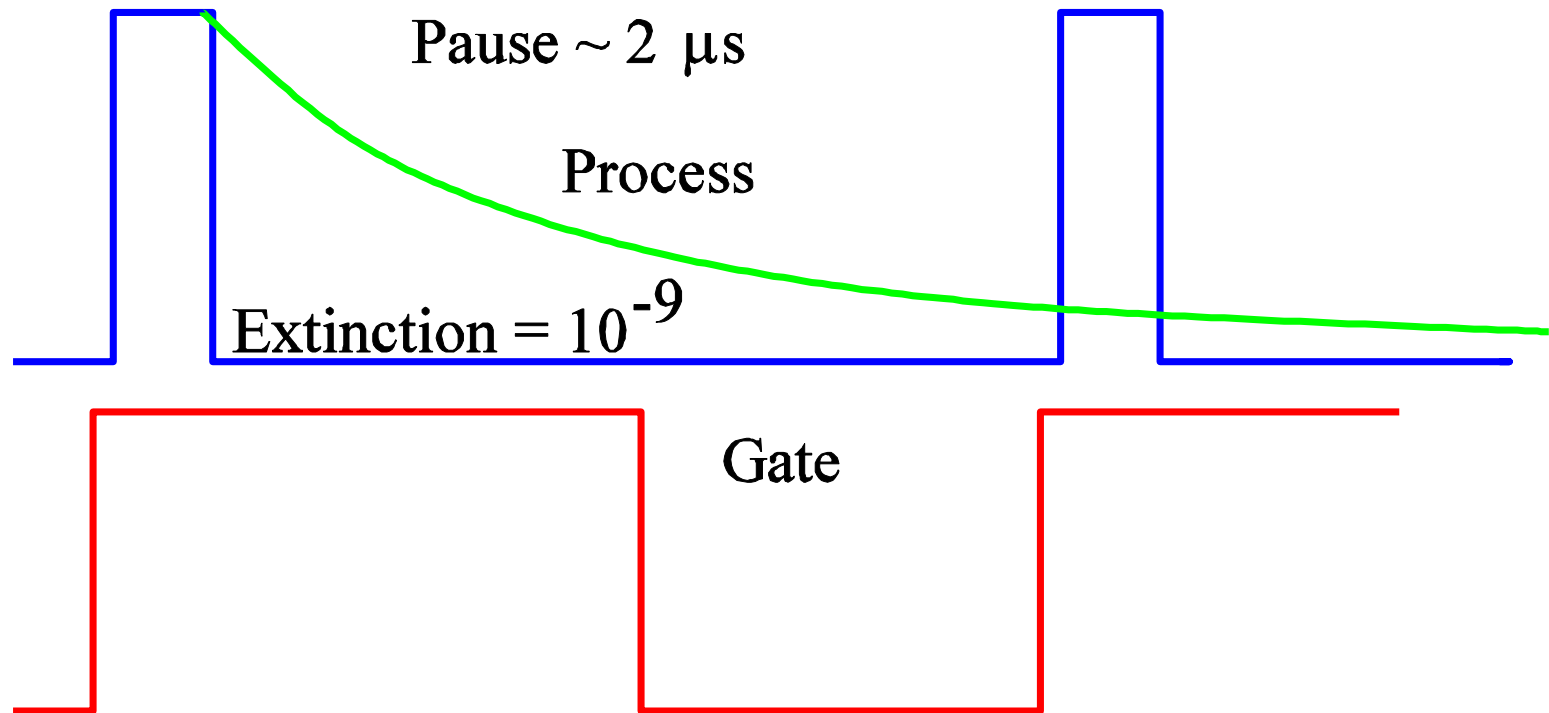
Magnetic Mirror

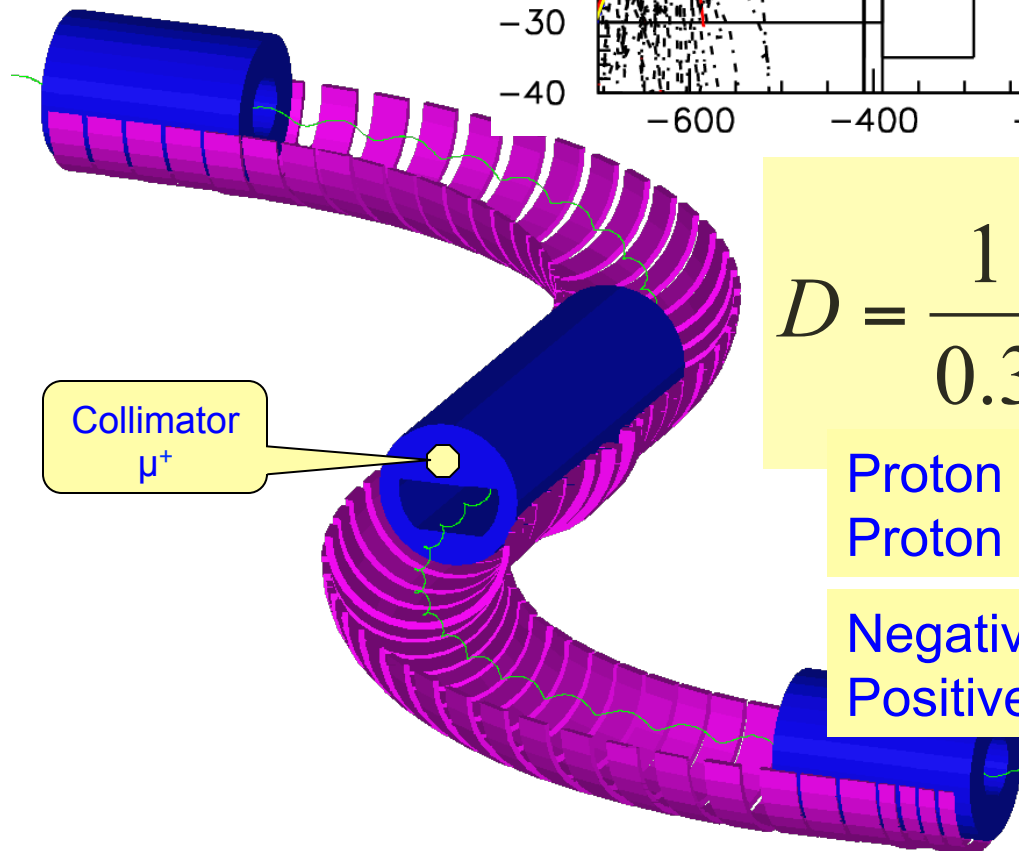
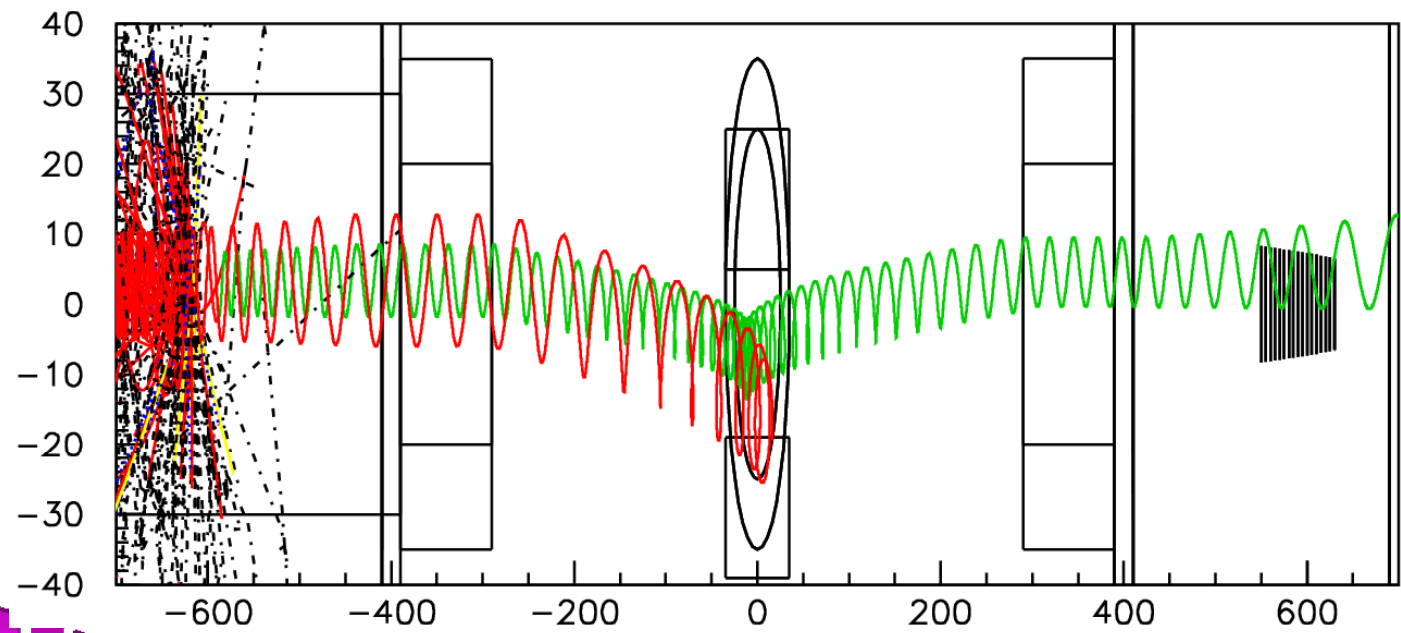


Negative Muon Stopping Rate – 10^{11} /sec
Positive Muon Stopping Rate – 5×10^8 /sec

Pulsed Proton Beam

Pulse - (50 -100) ns





$$D = \frac{1}{0.3} \frac{L}{R} \frac{p_L}{B} \left(1 + \frac{1}{2} \left(\frac{p_T}{p_L} \right)^2 \right)$$

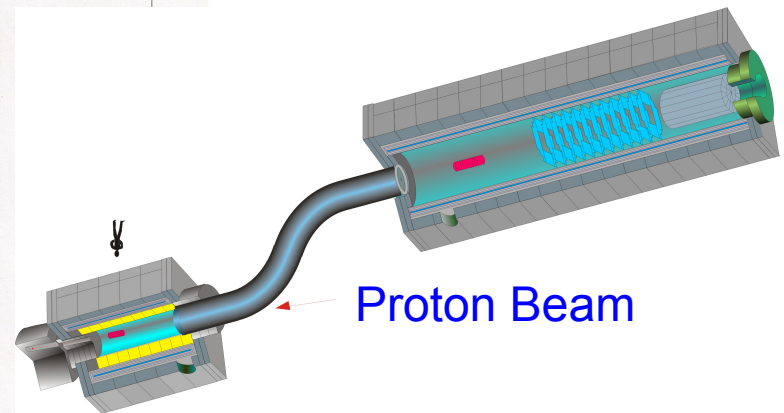
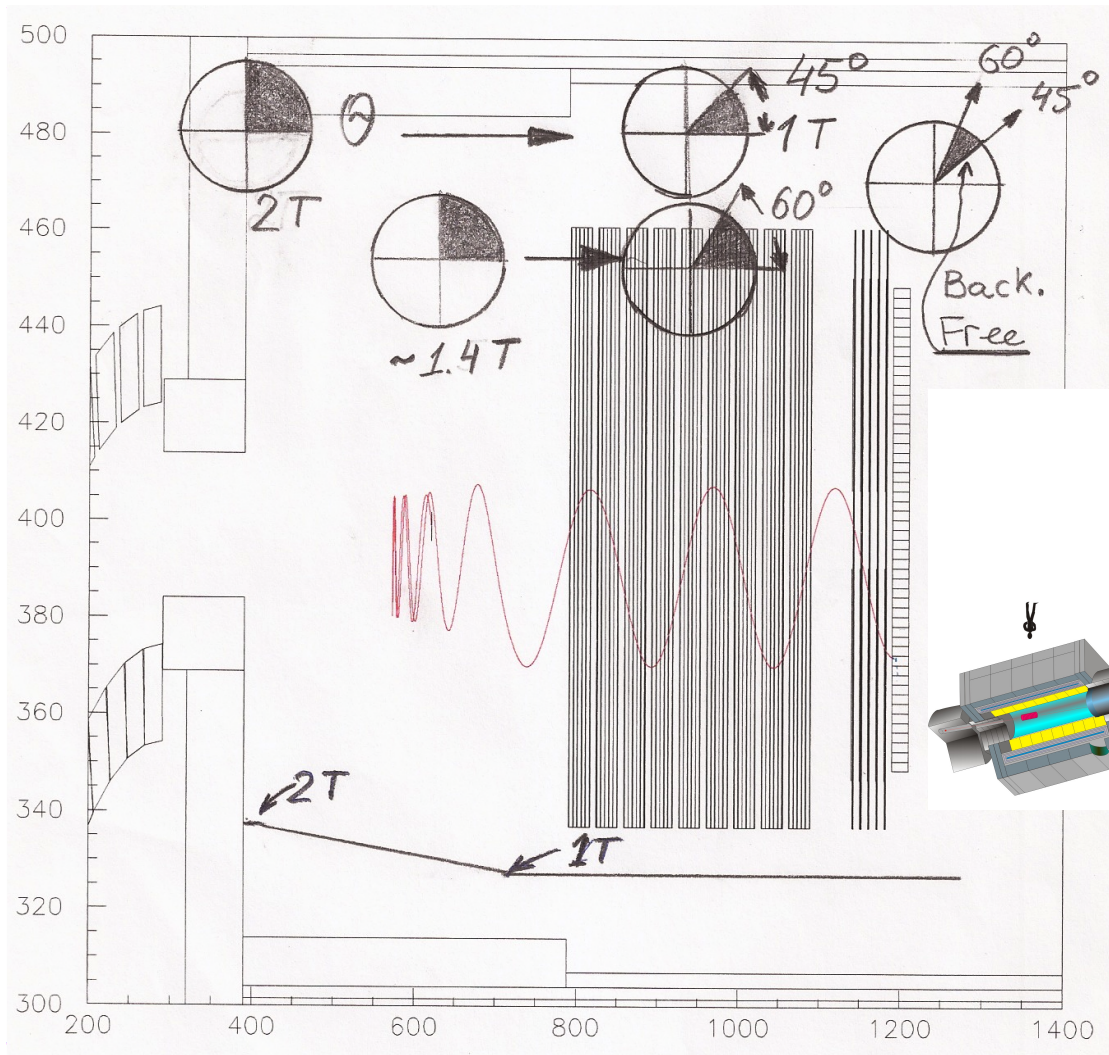
Proton beam 8 GeV – 4×10^{13} p/sec

Proton beam 600 MeV – 9×10^{14} p/sec

Negative Muon Stopping Rate – 10^{11} /sec

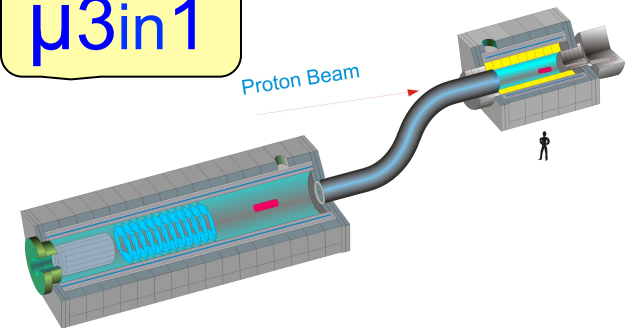
Positive Muon Stopping Rate – 5×10^8 /sec

Background Suppression

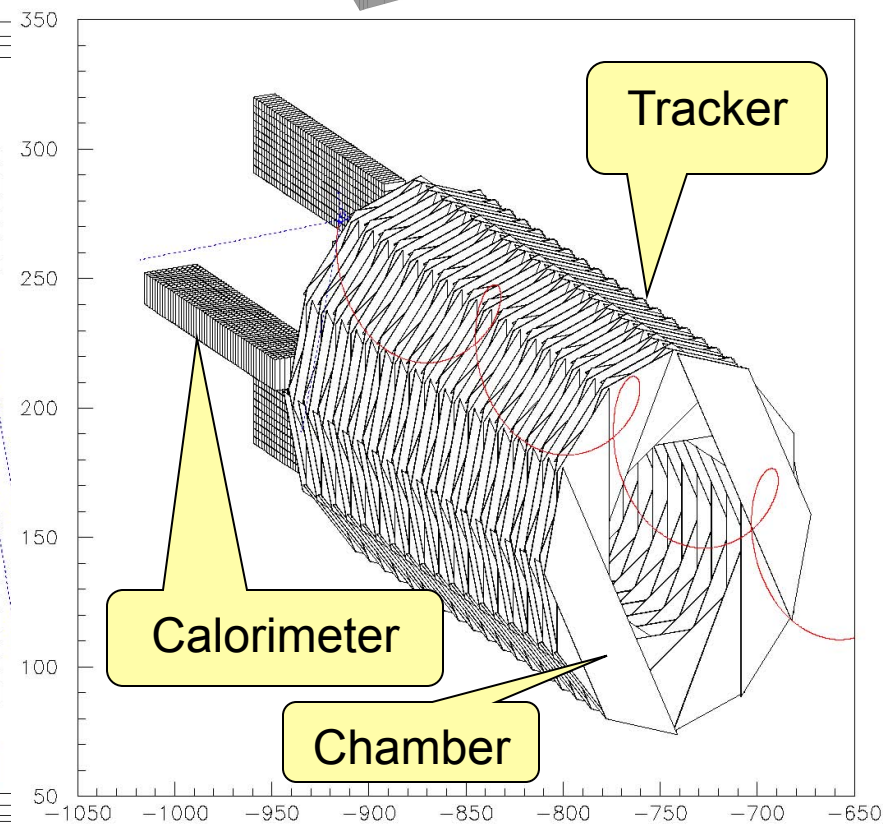
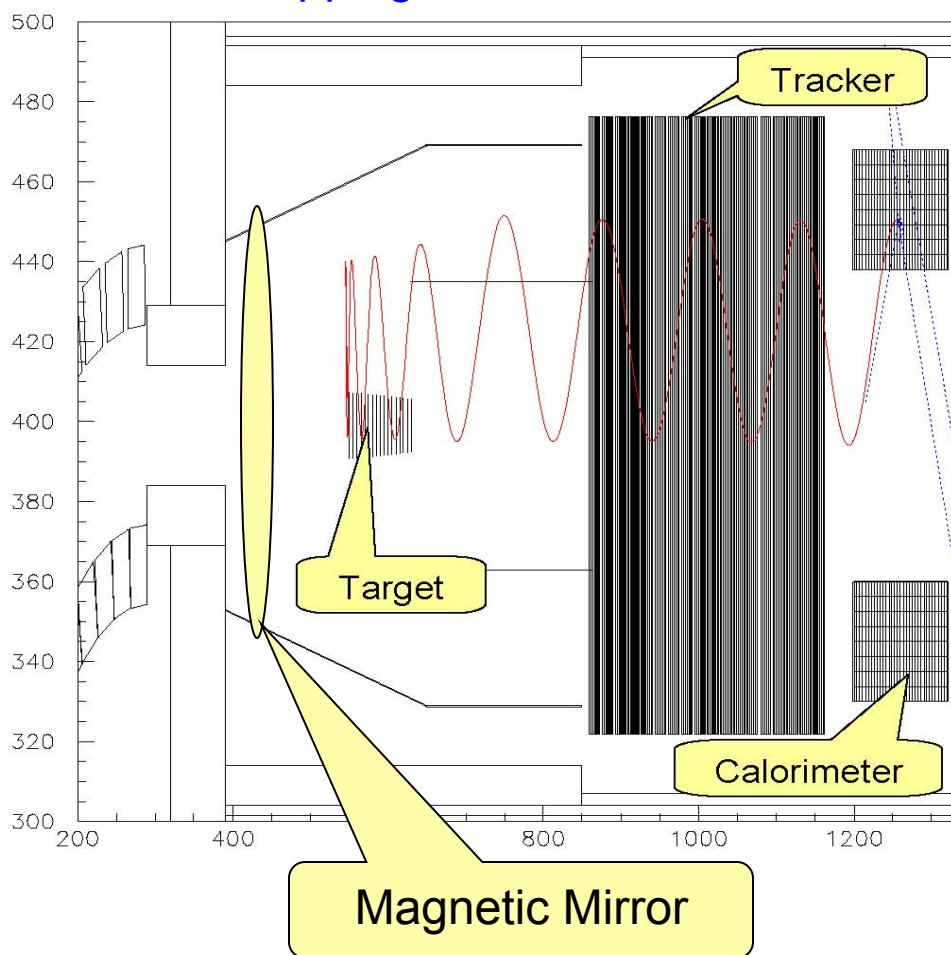


Detector Setup for $\mu \rightarrow e$ conversion

$\mu 3in1$

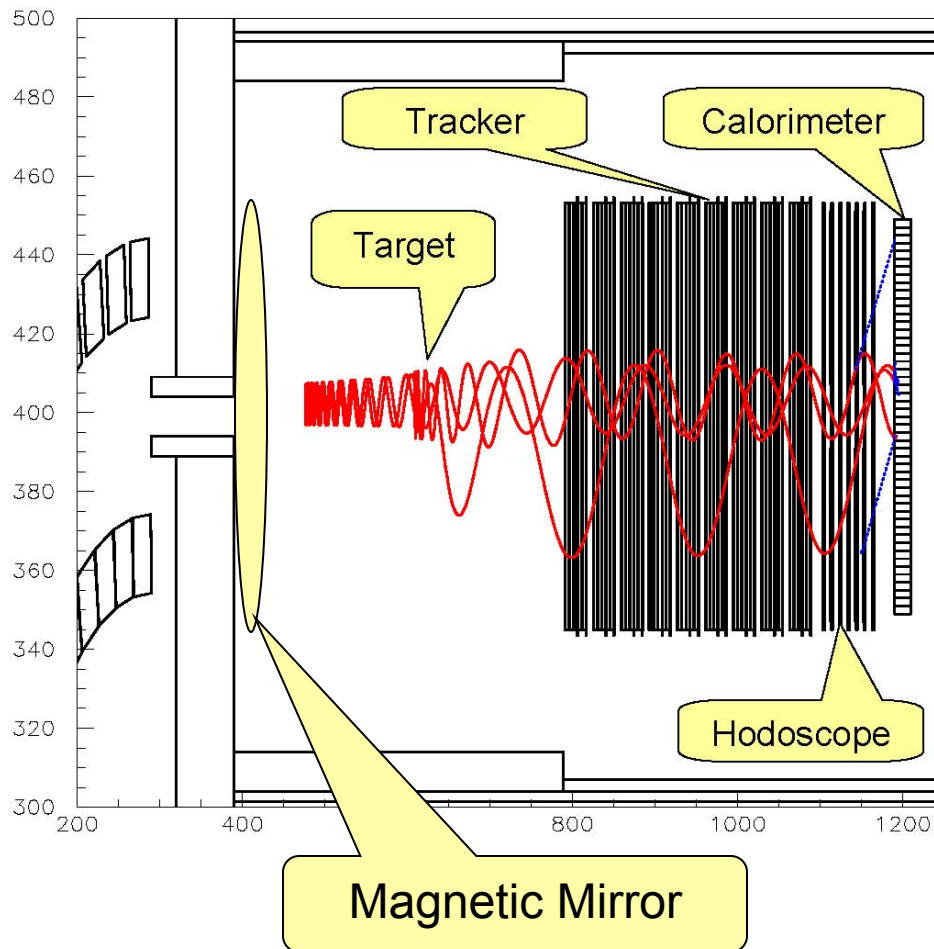


Muon stopping rate – 10^{11} /sec

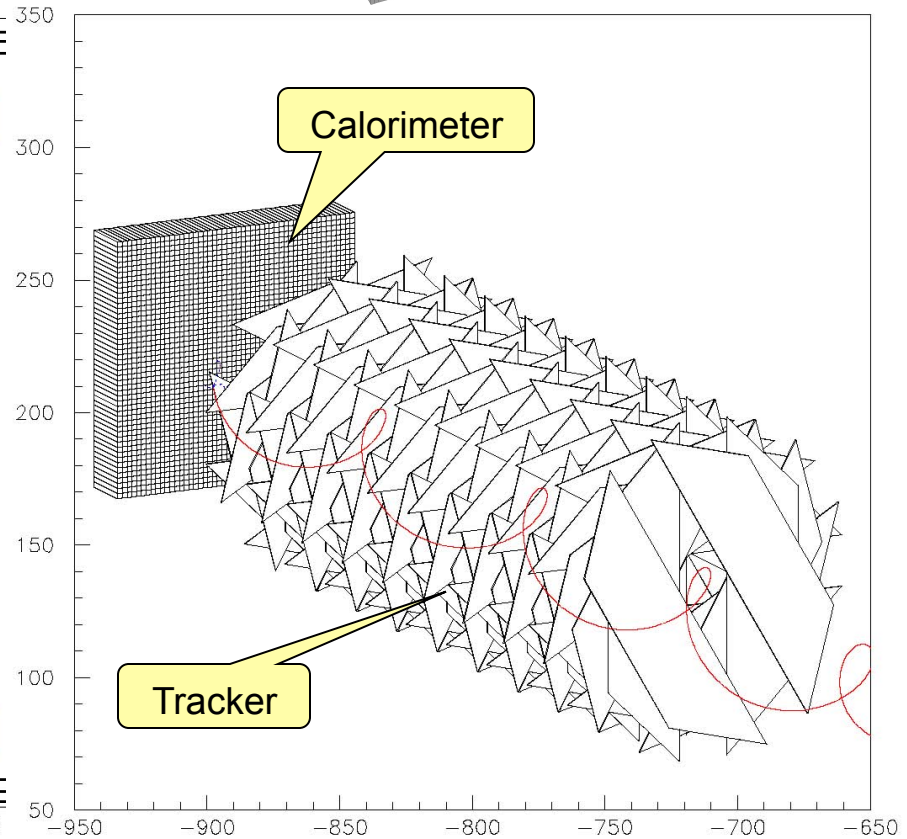
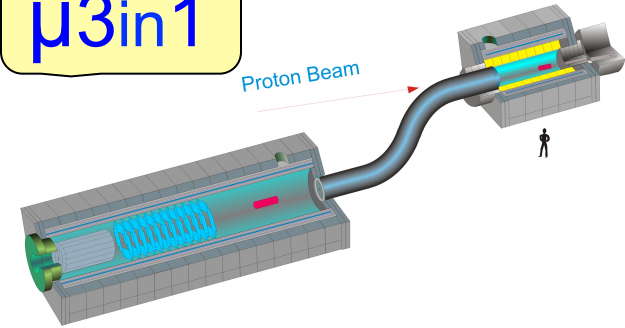


Detector Setup for $\mu \rightarrow 3e$

Muon stopping rate – 5×10^8 /sec



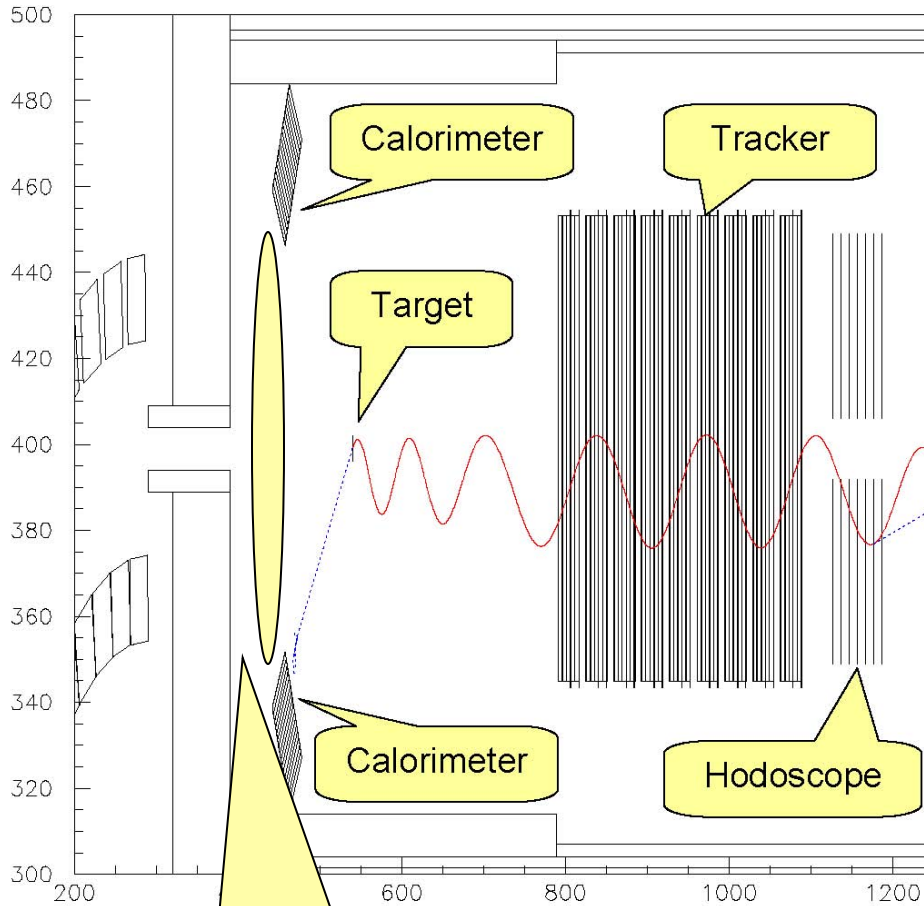
$\mu 3in1$



Detector Setup

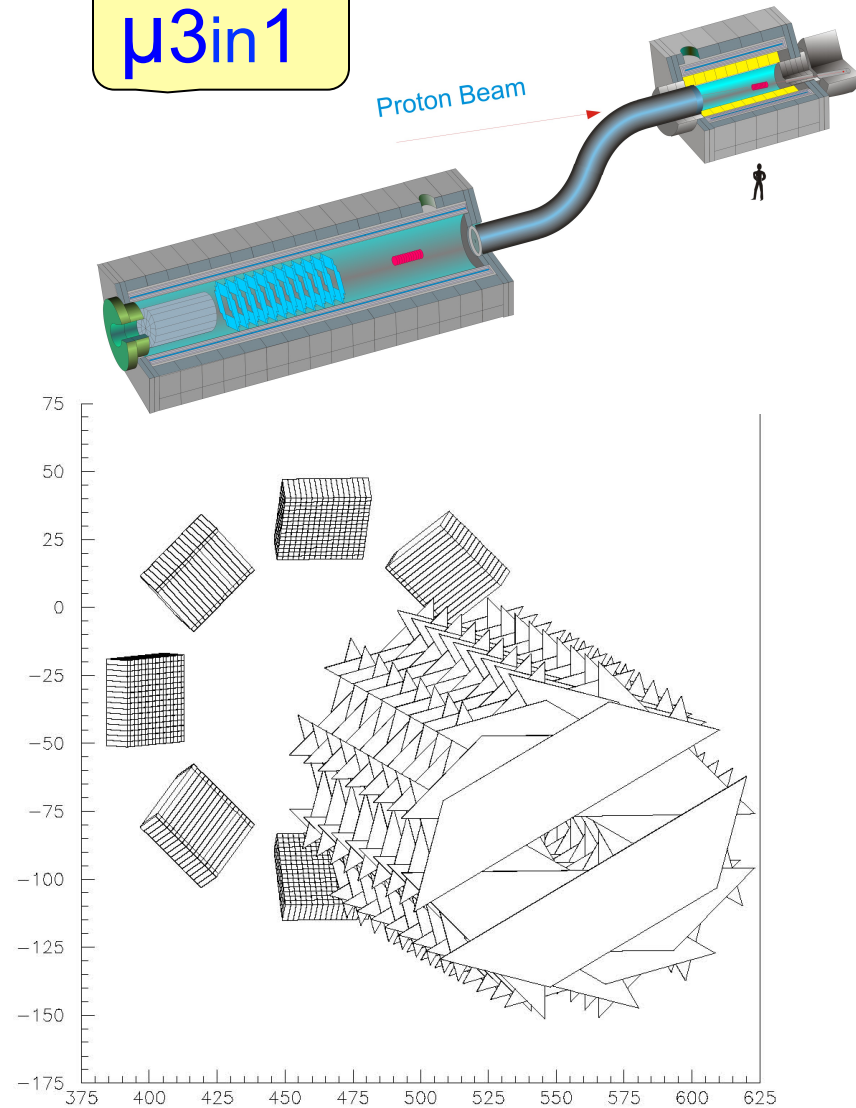
for $\mu^- \rightarrow e + \gamma$

Muon stopping rate – 5×10^8 /sec



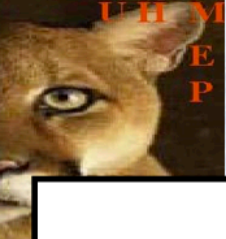
Magnetic Mirror

$\mu 3in1$



Experimental limits

Process	Current Limit	Mu3in1 level
$\mu^- N \rightarrow e^- N$	7×10^{-13}	3×10^{-17}
$\mu^+ \rightarrow e^- + e^+ + e^+$	10^{-12}	3×10^{-15}
$\mu^+ \rightarrow e^+ + \gamma$	2.4×10^{-12}	2×10^{-14}

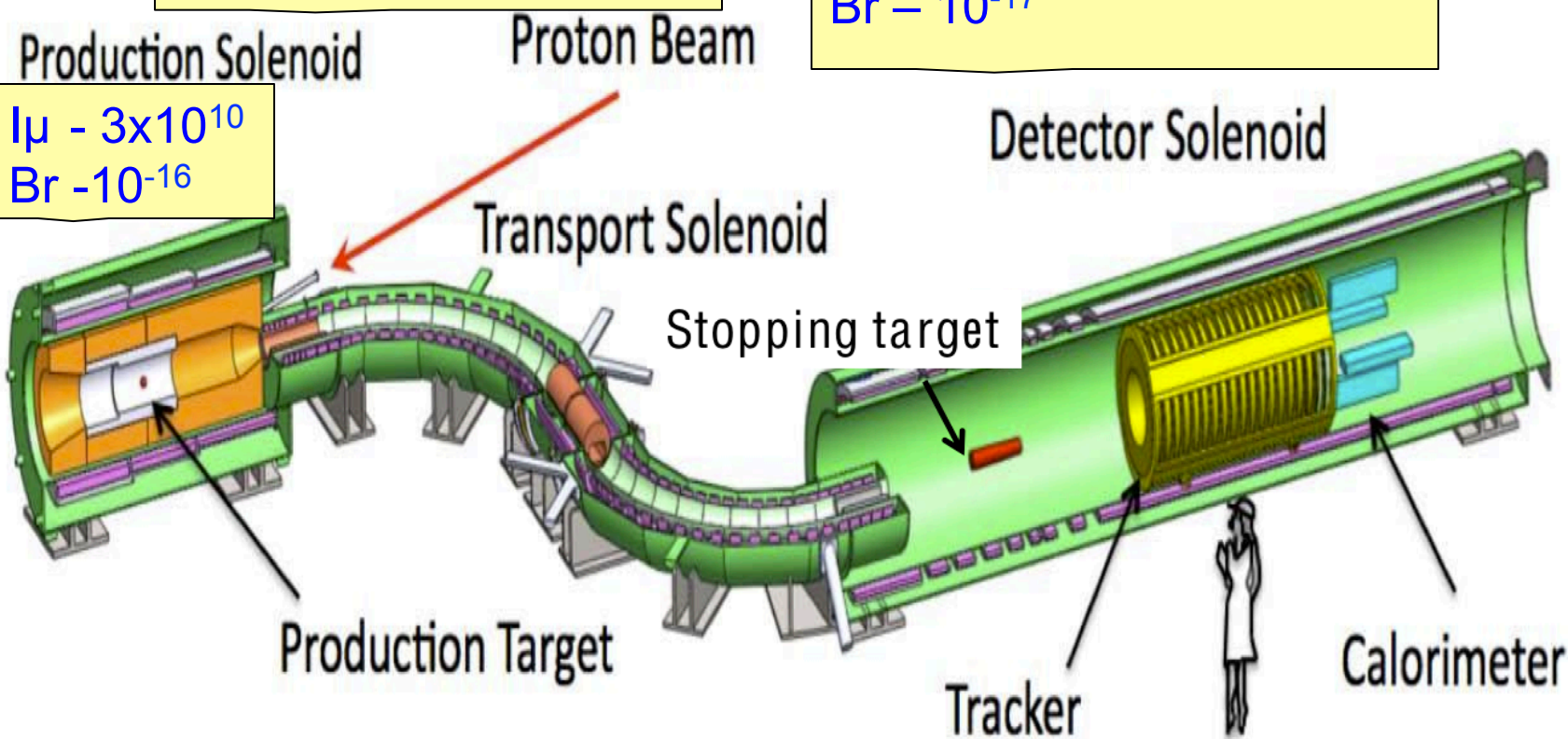


Mu2e Apparatus at FNAL



$\mu \rightarrow e$ conversion

X-Project $I_\mu \approx 10^{11} - 10^{12}$
 $Br - 10^{-17}$



Beam related background reduced by beam pulsing using delayed measurements (MELC; MECO).

Continuous Solenoids capture muons, transport them, and analyze decay electrons

COMET JHP 50 GeV

$\mu \rightarrow e$ conversion

$I_\mu = 10^{11} - 10^{12} / \text{sec}$

$\text{Br}(\mu \rightarrow e) \approx 10^{-17}$

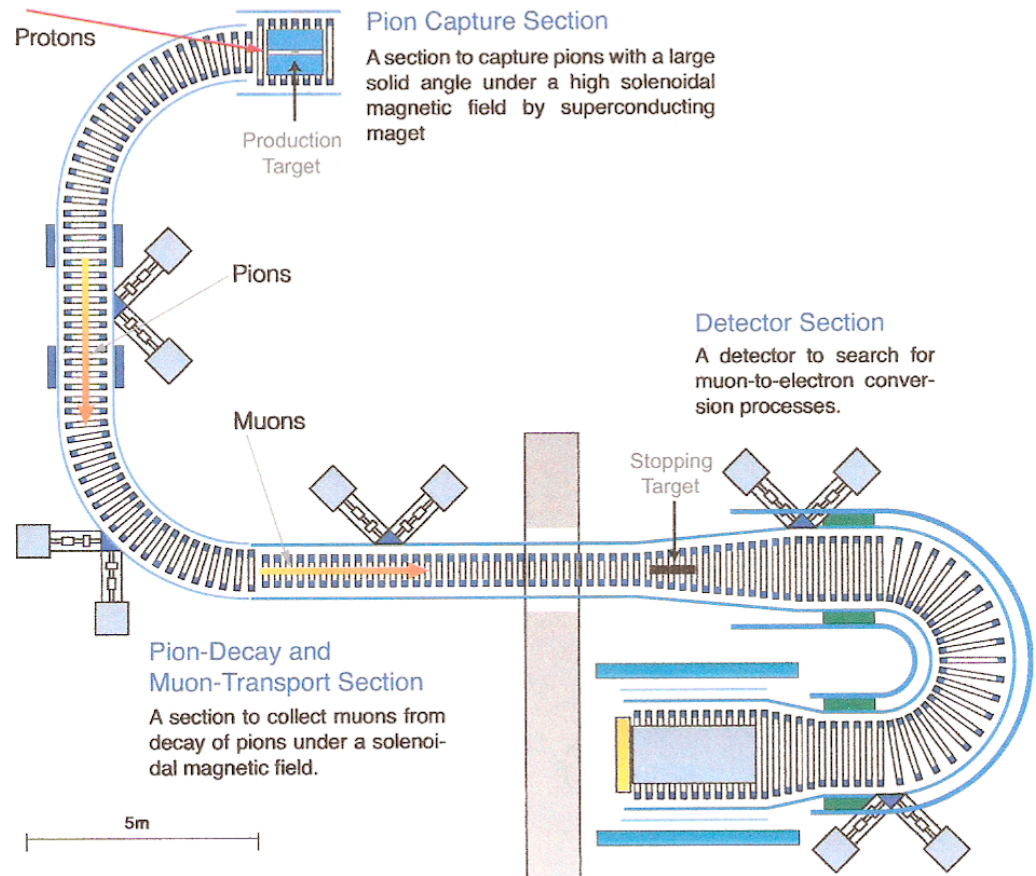


Figure 3.1: Schematic layout of the muon beamline and detector for the proposed search for $\mu^- - e^-$ conversion, the COMET experiment.