FERMILAB-SLIDES-08-005-PPD

Mu2e: A Proposal to Search for $\mu N \rightarrow eN$ with A Single Event Sensitivity Below 10^{-16}

J. Miller
for the Mu2e Collaboration

3 Nov 2008

Outline

- Brief theoretical motivation
- Description of experimental approach
- Description of proposed apparatus
- Discussion of backgrounds which impact the design

Muon to Electron Conversion

Charged Lepton Flavor Violation

Mu2e proposal $$R_{\mu e} = \frac{\mu^- Al \rightarrow e^- Al}{\mu^- Al \rightarrow \text{capture}} < 6x10^{-17} \text{ (90\% c.l.)}$$

Current limits: $$R_{\mu e} = \frac{\mu^- Au \rightarrow e^- Au}{\mu^- Au \rightarrow \text{capture}} < 7x10^{-13} \text{ (SINDRUM II)}$$

$$R_{\mu e} = \frac{\mu^- Ti \rightarrow e^- Ti}{\mu^- Ti \rightarrow \text{capture}} < 4.3x10^{-12} \text{ (SINDRUM II)}$$

$$R_{\mu e} = \frac{\mu^- Ti \rightarrow e^- Ti}{\mu^- Ti \rightarrow \text{capture}} < 4.6x10^{-12} \text{ (TRIUMF)}$$

Endorsed in US Roadmap

A muon-electron conversion program: Strongly endorsed by P5

"The experiment could go forward in the next decade with a modest evolution of the Fermilab accelerator complex. Such an experiment could be the first step in a world-leading muon-decay program eventually driven by a next-generation high-intensity proton source. **The panel recommends pursuing the muon-to-electron conversion experiment... under all budget scenarios considered by the panel**"

Mu2e is a central part of the future US program

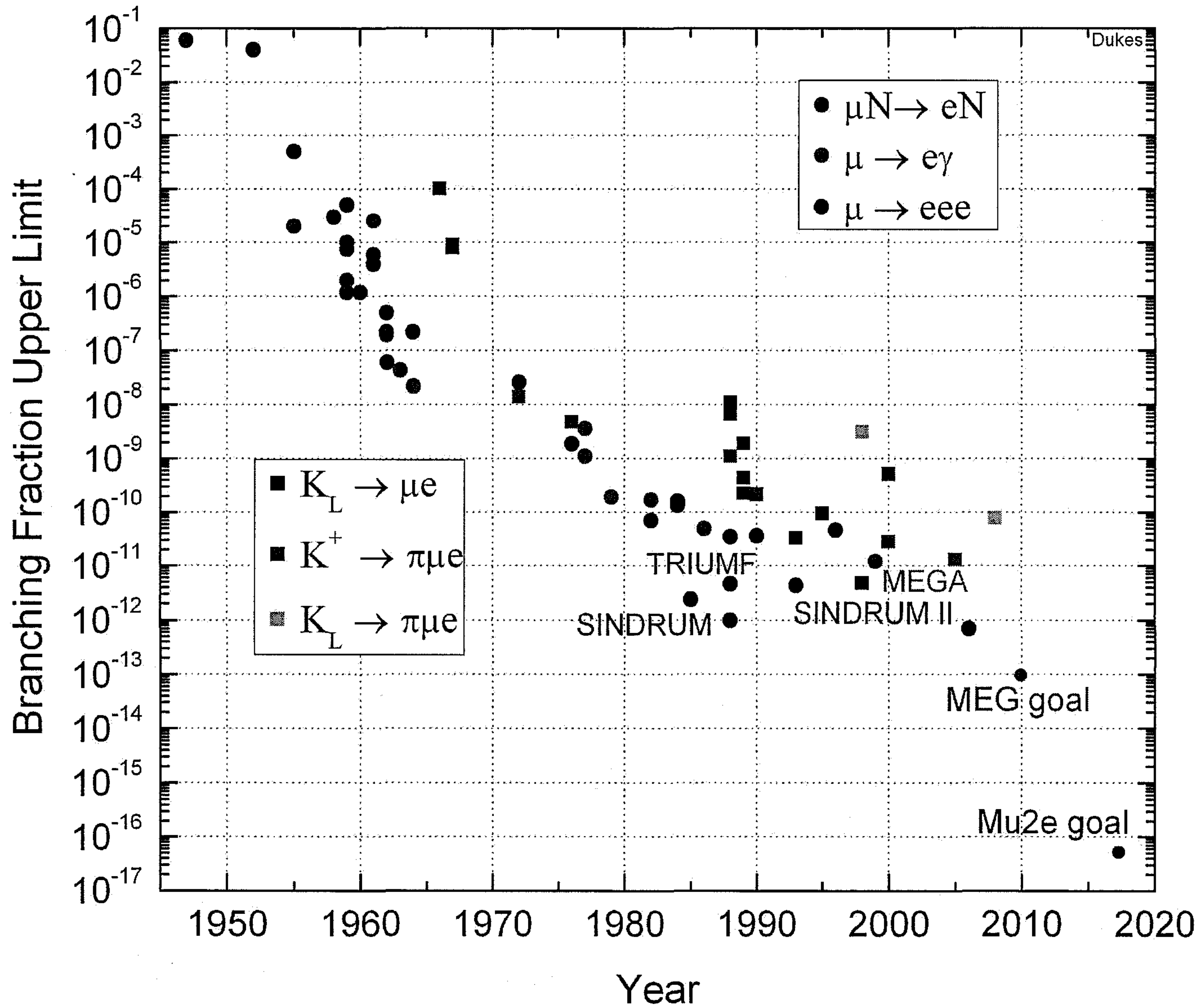
Collaboration

- Boston University: **R.M. Carey, K.R. Lynch, J.P. Miller*, B.L. Roberts**
- BNL: **W. Marciano,Y. Semertzidis, P. Yamin**
- UC Berkeley: **Yu.G. Kolomensky**
- FNAL: **C.M. Ankenbrandt , R.H. Bernstein*, D. Bogert, S.J. Brice, D.R. Broemmelsiek, R. Coleman, D.F. DeJongh, S. Geer, R. Kutschke, M. Lamm,M.A. Martens, S. Nagaitsev, D.V. Neuffer, M. Popovic, E.J. Prebys, M. Syphers, R.E. Ray, H.B. White, K. Yonehara, C.Y. Yoshikawa**
- Idaho State University: **D. Dale, K.J. Keeter, E. Tatar**
- UC Irvine: **W. Molzon**
- University of Illinois/Champaign-Urbana: **P.T. Debevec, G. Gollin,D.W. Hertzog, P. Kammel**
- INFN/Università Di Pisa: **F. Cervelli, R. Carosi, M. Incagli,T. Lomtadze, L. Ristori, F. Scuri, C. Vannini**
- INR Moscow: **V. Lobashev**
- U Mass Amherst: D. Kawall, K. Kumar
- Muons, Inc: **R.J. Abrams, M.A.C. Cummings, R.P. Johnson, S.A. Kahn,S.A. Korenev, T.J. Roberts, R.C. Sah**
- City University of New York: **J.L. Popp**
- Northwestern University: **A. DeGouvea**
- Rice University: **M. Corcoran**
- Syracuse University: **R.S. Holmes, P.A. Souder**
- University of Virginia: **M.A. Bychkov, E.C. Dukes, E. Frlez, R.J. Hirosky, A.J. Norman, K.D. Paschke, D. Pocanic**

new institution / **new collaborator**

since June 2008

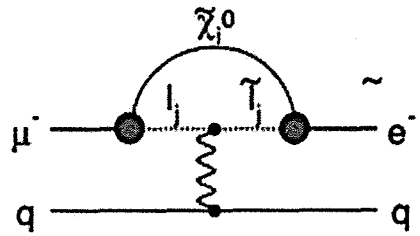
History of CLFV Searches



Contributions to μe Conversion

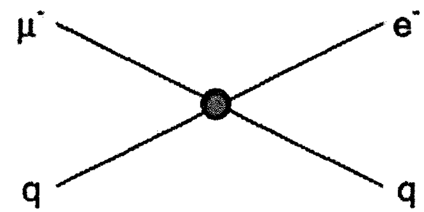
Supersymmetry

rate ~ 10^{-15}



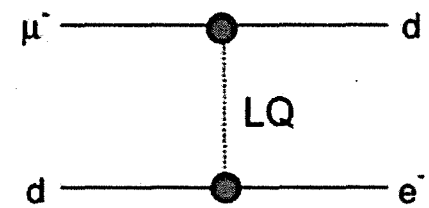
Compositeness

$\Lambda_c \sim 3000$ TeV



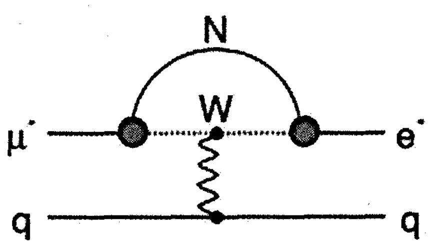
Leptoquark

$M_{LQ} =$
$3000\ (\lambda_{\mu d}\lambda_{ed})^{1/2}$ TeV/c^2



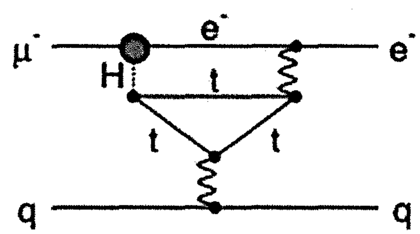
Heavy Neutrinos

$|U_{\mu N}U_{eN}|^2 \sim 8\times10^{-13}$



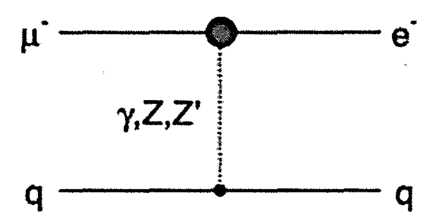
Second Higgs Doublet

$g(H_{\mu e}) \sim 10^{-4} g(H_{\mu\mu})$



Heavy Z' Anomal. Z Coupling

$M_{Z'} = 3000$ TeV/c^2



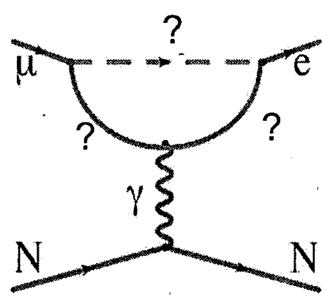
also see Flavour physics of leptons and dipole moments, arXiv:0801.1826

"Model-Independent" Picture

$$L_{CLFV} = \frac{m_\mu}{(\kappa+1)\Lambda^2}\bar{\mu}_R\sigma_{\mu\nu}e_L F^{\mu\nu} + \frac{\kappa}{(1+\kappa)\Lambda^2}\bar{\mu}_L\gamma_\mu e_L(\bar{u}_L\gamma^\mu u_L + \bar{d}_L\gamma^\mu d_L)$$

Λ sets the energy scale, κ controls relative weights of terms

"Loops"

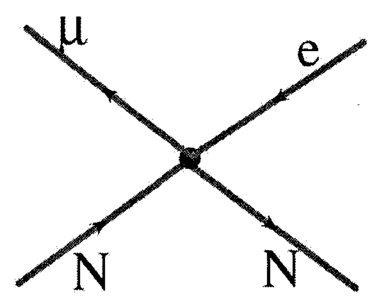


$\kappa=0$

Supersymmetry and Heavy Neutrinos

Contributes to $\mu \to e\gamma$

"Contact Terms"



$\kappa=\infty$

Exchange of a new, massive particle

Does not produce $\mu \to e\gamma$

Quantitative Comparison?

Physics Reach of μ→eγ and μ→e Conversion

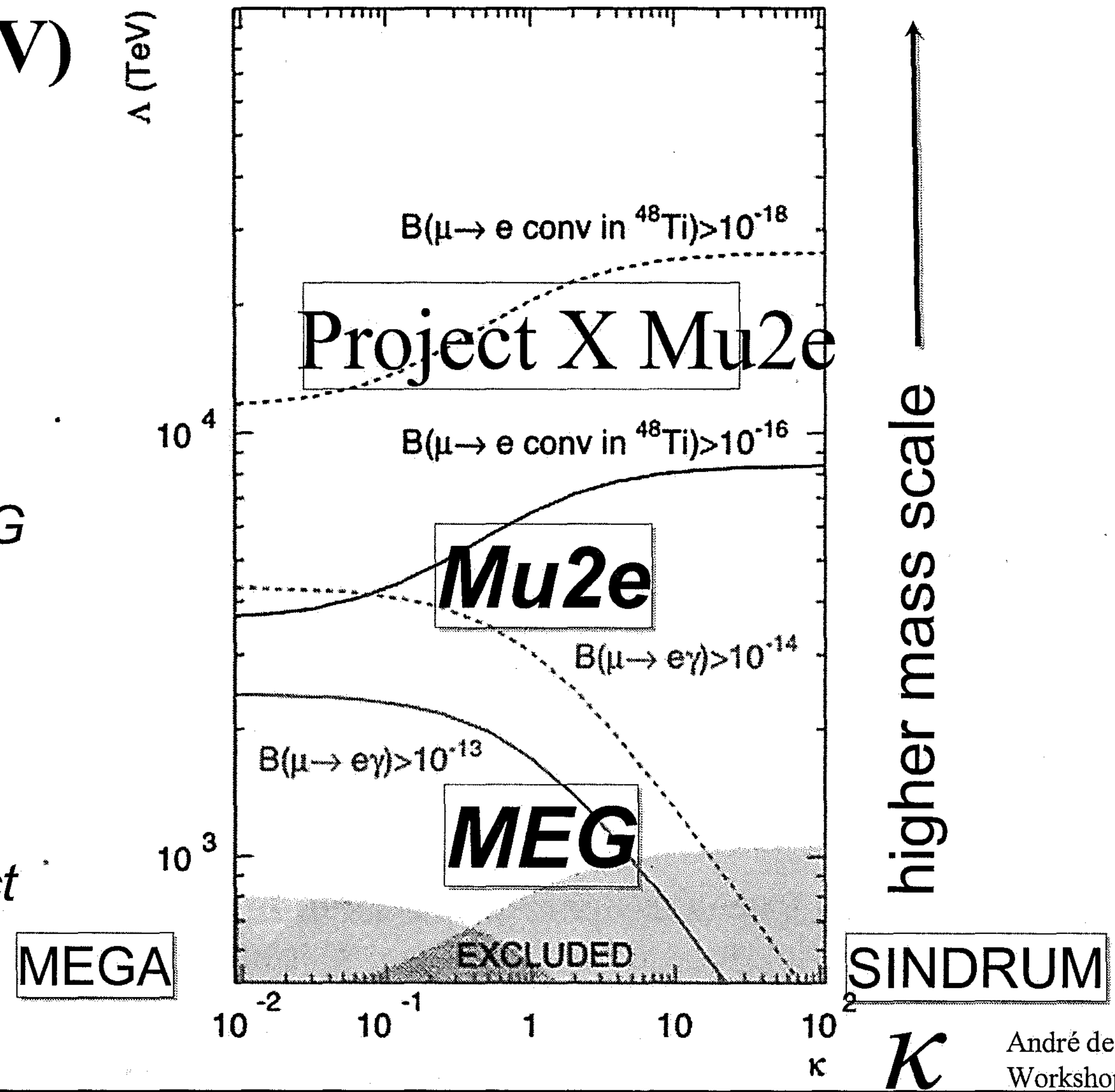
Λ (TeV)

Mu2e:

1) *Scale extends to several x 10^3 TeV*

2) *~2 times more sensitivity than MEG in loop-dominated physics*

3) *Much greater sensitivity to contact terms*



André de Gouvêa, Project X Workshop Golden Book

Power of Signal in Muon-Electron Conversion

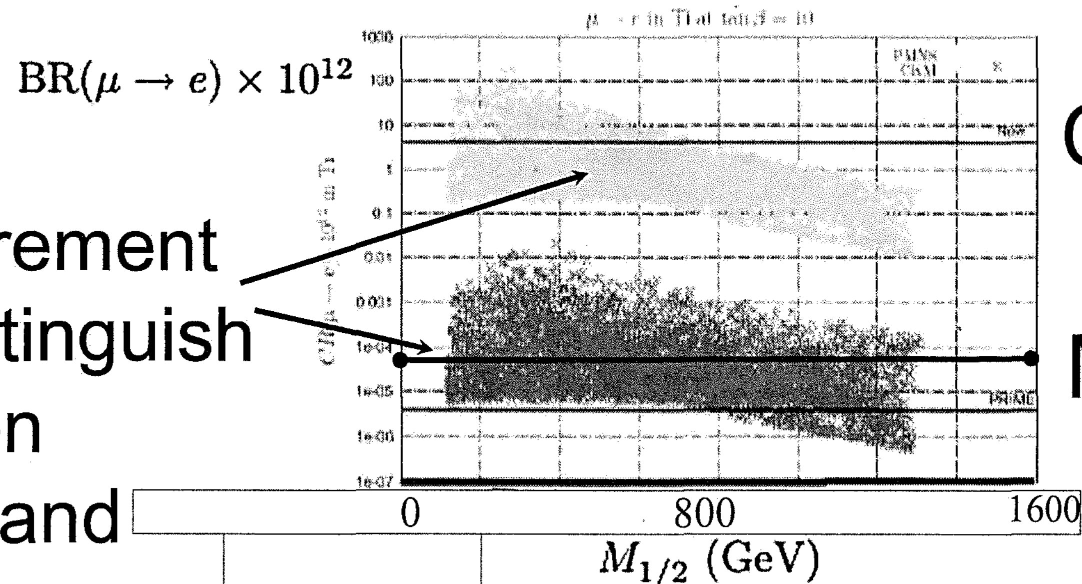
L. Calibbi, A. Faccia, A. Masiero, S. Vempati hep-ph/0605139
neutrino mass via the see--saw mechanism,analysis in SO(10) framework

Neutrino-Matrix Like (PMNS) Minimal Flavor Violation(CKM)

Tan β=10

Current

measurement can distinguish between PMNS and MFV



Mu2e

L. Calibbi, A. Faccia, A. Masiero, S. Vempati, hep-ph/0605139

Sensitivity of Mu2e

$R_{\mu e} < 6 \times 10^{-17}$ 90% CL

- For $R_{\mu e} = 10^{-15}$
  - ~40 events / 0.4 bkg (LHC SUSY?)
- For $R_{\mu e} = 10^{-16}$
- ~4 events / 0.4 bkg

Physics Case

- Mu2e is compelling with or without the discovery of new physics at the LHC
  - *Tight constraints on models in the case of observations at the LHC (e.g. PMNS or MFV)*
  - *Probes up to 10^4 TeV for new physics if no new physics at LHC (e.g. SM Higgs and nothing else)*
  - *Is a Unique Window*
- Mu2e Will Either:
  - *Reduce the limit for $R_{\mu e}$ by ~ four orders of magnitude ($R_{\mu e} < 6\times10^{-17}$ @ 90% C.L.)*
  - *Discover unambiguous proof of Beyond Standard Model physics at a scale directly relevant for the LHC*

The Measurement Method

- Stop negative muons in an aluminum target
- The stopped muons quickly form muonic atoms
  - hydrogenic 1S level around the aluminum nucleus
  - Bohr radius ~20 fm (inside all electrons), Binding E~500 keV
  - Nuclear radius ~ 4 fm → muon and nuclear wavefunctions overlap
  - Muon lifetime in 1S orbit of aluminum ~864 ns (40% decay, 60% nuclear capture), compared to 2.2 μsec in vacuum
- Look for a monoenenergetic electron from the neutrinoless conversion of a muon to an electron:

$$\mu^- + {}^{27}_{13}Al \rightarrow {}^{27}_{13}Al + e^-$$ Electron energy~105 MeV

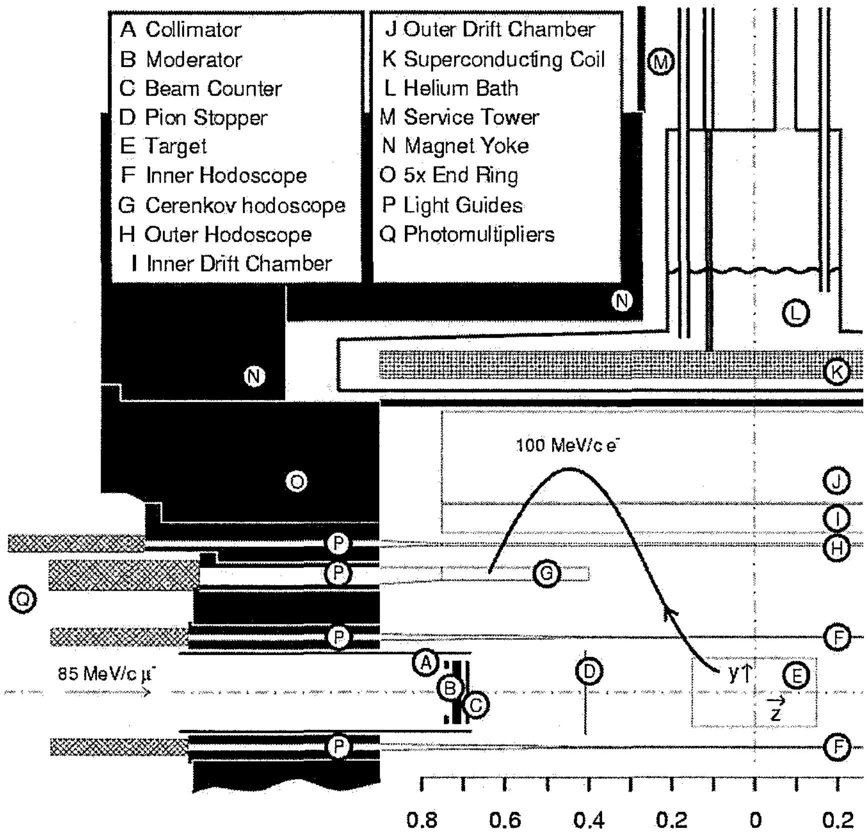
- Actually measure the ratio $R_{\mu e}$:

$$R_{\mu e} = \frac{\mu^- + {}^{27}_{13}Al \rightarrow {}^{27}_{13}Al + e^-}{\mu^- + {}^{27}_{13}Al \rightarrow X + \nu_\mu (capture)}$$, where X=A(N,Z)+neutrons, protons,...

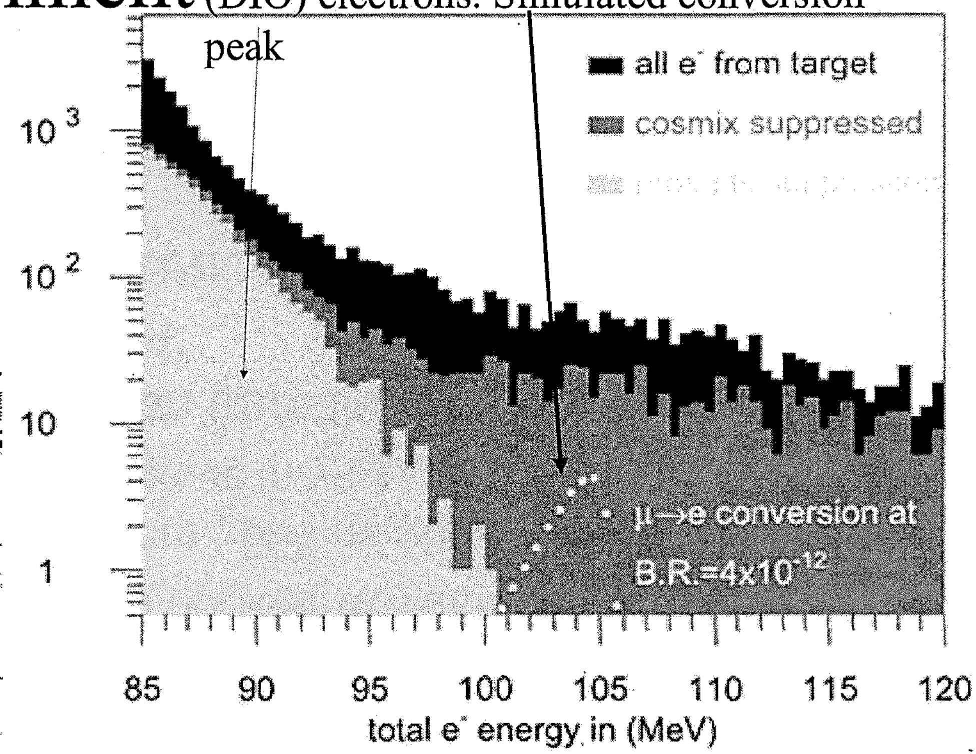
- Goal: $R_{\mu e} < 6\times10^{-17}$, 90% c.l. x10000 better than current limit

Previous Data, $\mu N \to eN$

From SINDRUM Experiment



High energy tail of Decay-in-orbit (DIO) electrons. Simulated conversion peak



$$R_{\mu e} \equiv \frac{\Gamma\left(\mu^- Ti \to e^- Ti\right)}{\Gamma\left(\mu^- Ti \to \text{capture}\right)} < 4.3\times10^{-12}$$

DC beam

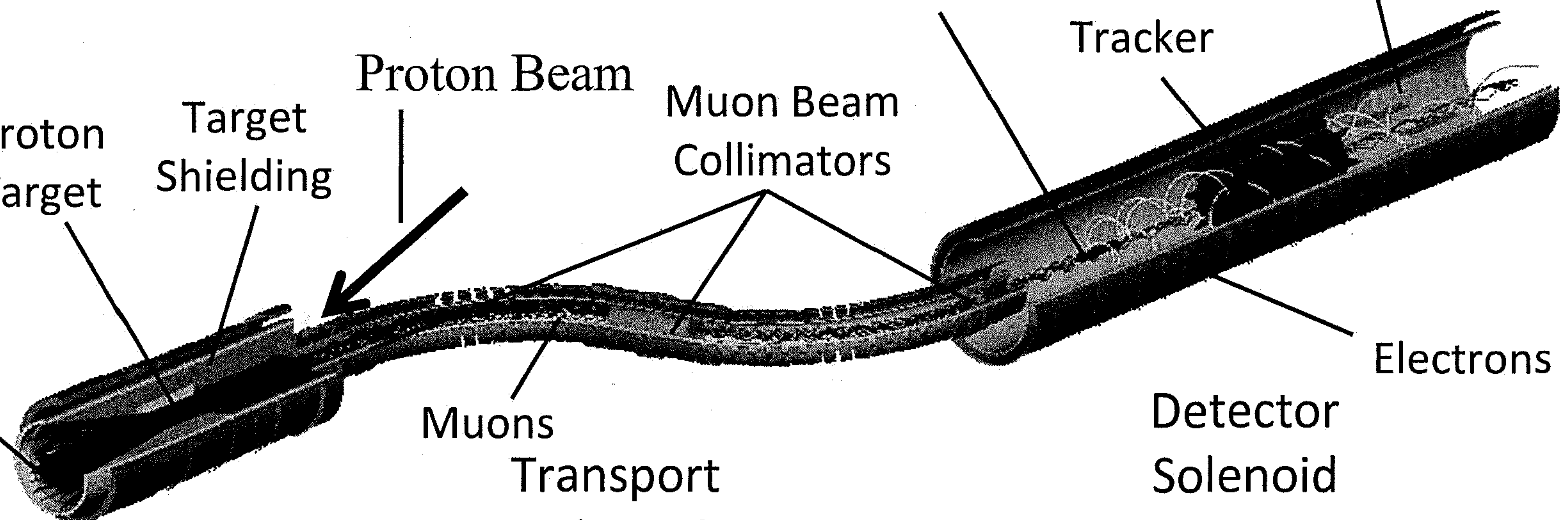
- Rate limited by need to veto prompt backgrounds! → pulsed beam

Muon Beamline Requirements

- Deliver high flux μ^- beam to stopping target
  - high proton flux ~$20x10^{12}$ Hz
  - Mu2e: use solenoidal muon collection and transfer scheme
  - muons ~5×10^{10} Hz , 10^{18} total
- Muon properties
  - low energies and narrow momentum spread
    - stop max # muons in thin target
    - avoid ~105 MeV e^- from in-flight μ^- decay (keep p_μ<75 MeV/c)
- Background particles from beam line must be minimized
  - especially ~105 MeV e^-
  - a major factor driving design of muon beamline

Mu2e Muon Beamline- follows MECO design

Muons are collected, transported, and detected in superconducting solenoidal magnets



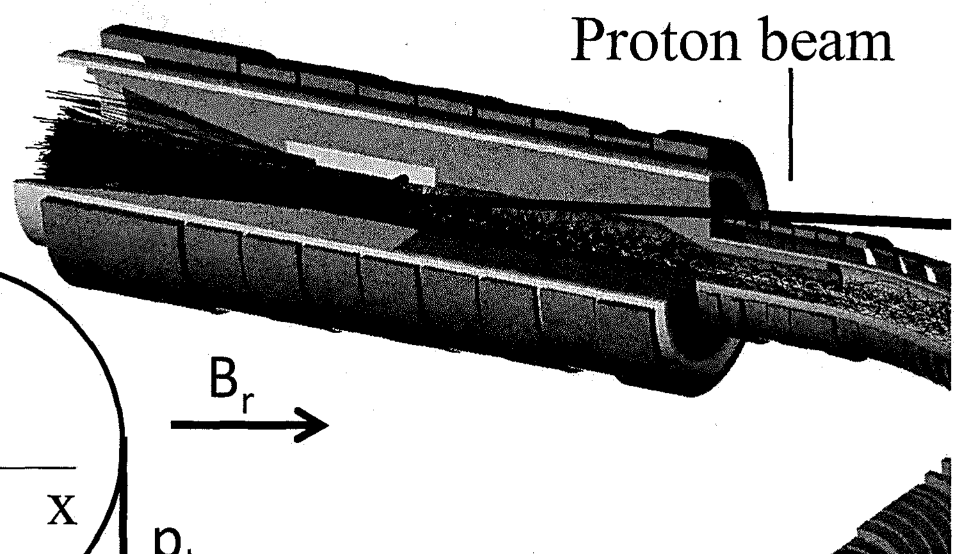
Transport Solenoid
- Selects low momentum μ^-
- Avoids straight line from production target to detectors

Delivers 0.0025 stopped muons per 8 GeV proton

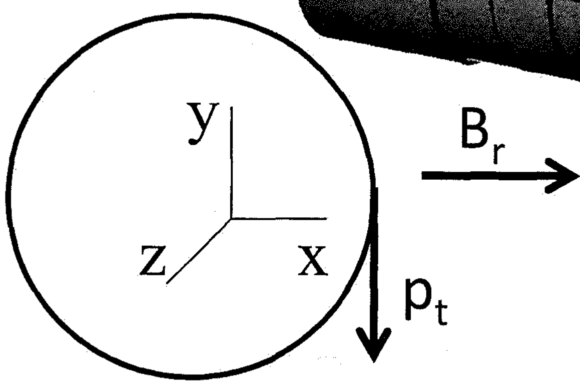
Production Solenoid

- 4m long x 0.95 m radius, 0.30 m clear bore
- Protons enter solenoid in upstream direction
- Field: 5 T upstream to 2.5 T at downstream end, target in middle
- Field holds many pions and their muon decay products in spirals
- Pions and muons are 'pushed' downstream by the field gradient
  - some upstream-going particles are reflected back downstream (mirror effect)
  - particles born with small pitches acquire larger pitches as they move downstream

$$B_z = B_0 - |G_z| z \qquad B_r = \frac{1}{2} |G_z| r$$



Case: B field decreasing out of paper, $G_z<0$. Note that net $q\mathbf{p}_t x \mathbf{B}_r$ points downstream regardless of q (if q flips sign, $\mathbf{p}_t$ reverses direction)



Transport Solenoid

Inner bore radius=25 cm
Length=13.11 m
Toroid bend radius=2.9 m

Define pitch $= \alpha = \frac{p_l}{p}$

$$D = \frac{1}{2} \times \frac{q}{0.3 \times B} \times \frac{s}{R} \times p(\frac{1}{\alpha} + \alpha).$$

Curved sections eliminate line of sight transport of n, γ.

Radial gradients in toroidal sections cause particles to drift vertically; off-center collimator signs and momentum selects beam- 1st bend disperses, 2[nd] re-centers

dB/dS < 0 in straight sections to avoid slow transiting particles

Collimation designed to greatly suppress transport of e^- greater than 100 MeV

Length decreases flux, by decay, of pions arriving at stopping target in measurement period

Goals:

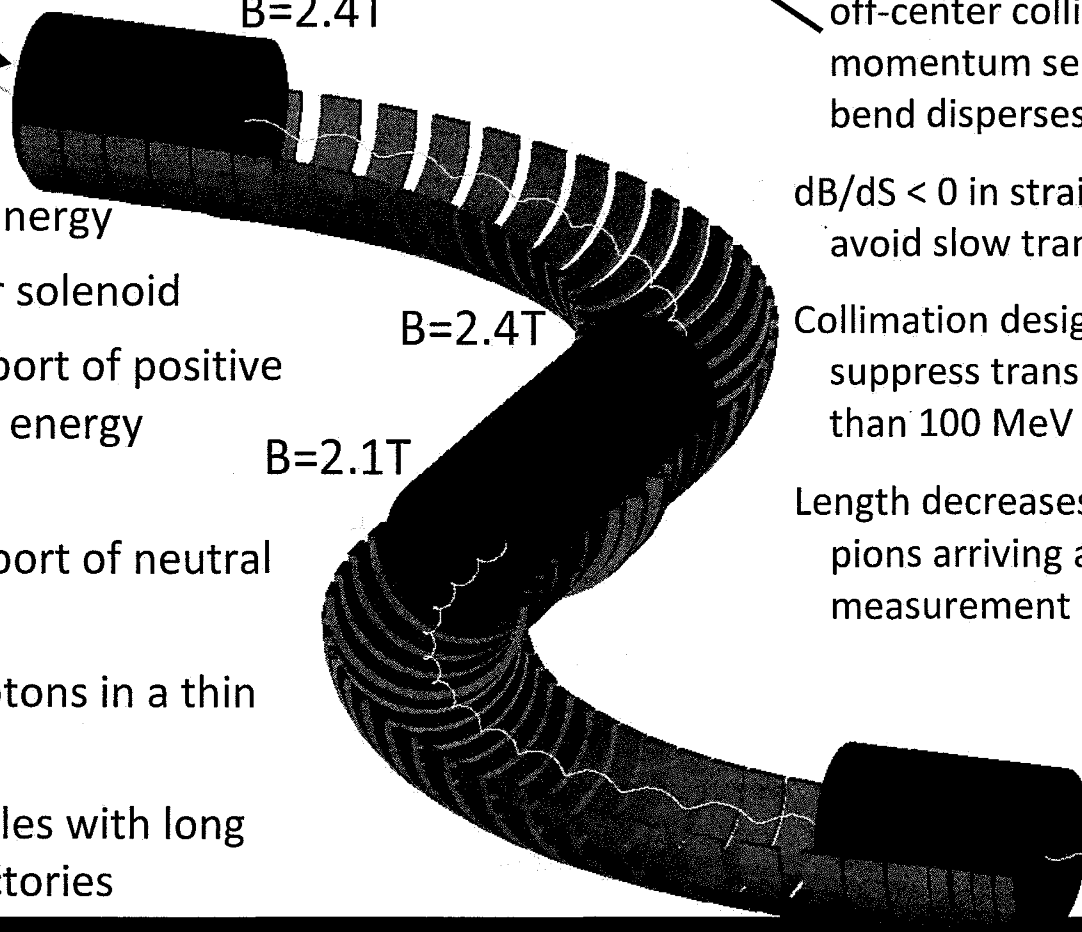
—Transport low energy μ^- to the detector solenoid

—Minimize transport of positive particles and high energy particles

—Minimize transport of neutral particles

—Absorb anti-protons in a thin window

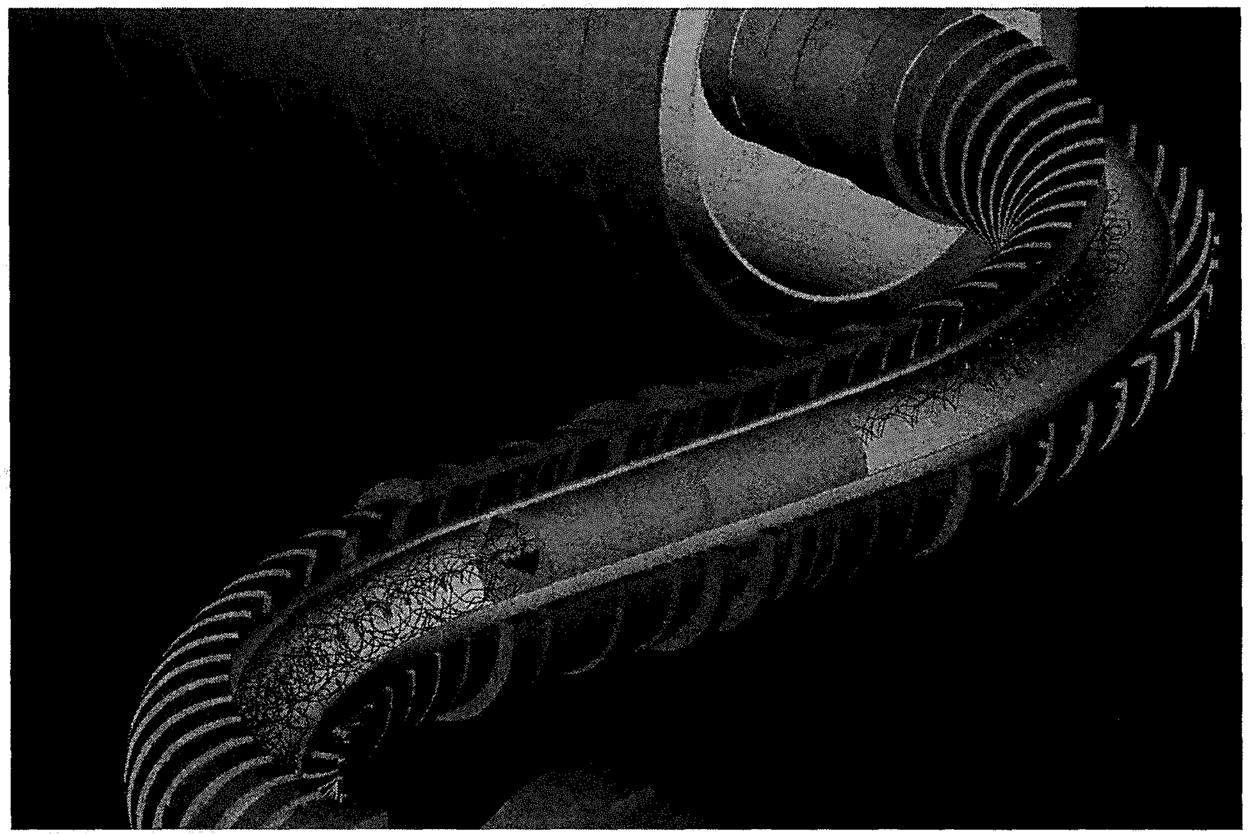
—Minimize particles with long transit time trajectories

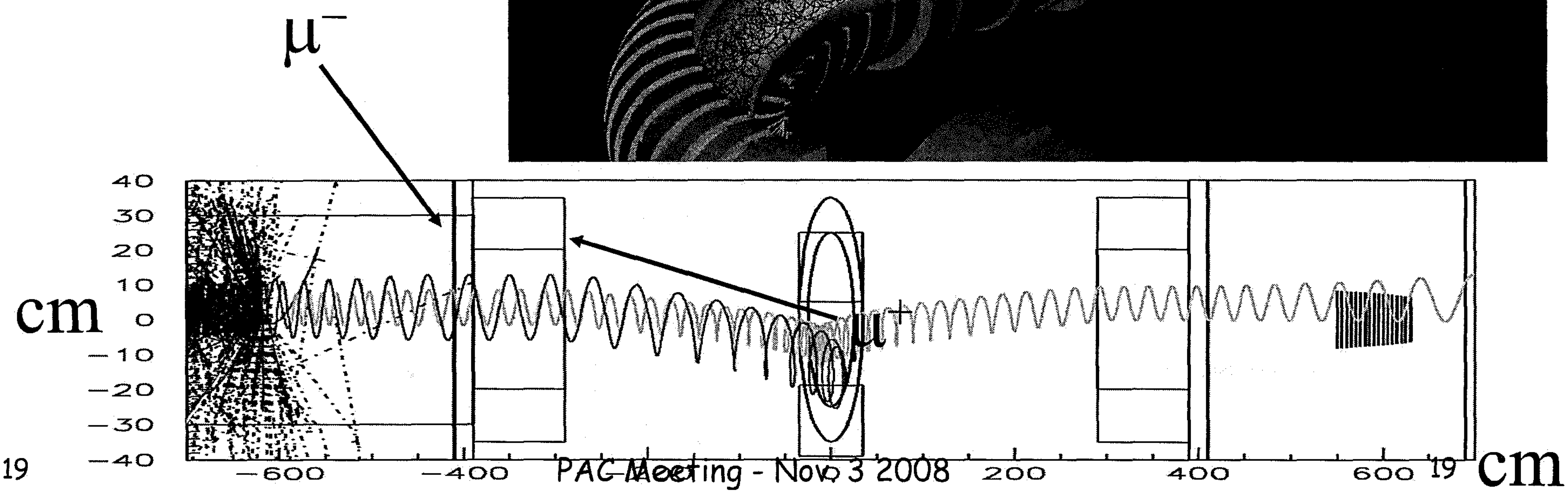


Separation of μ^- from μ^+

$$\text{pitch} = \alpha = \frac{p_l}{p}$$

$$D = \frac{1}{2} \times \frac{q}{0.3 \times B} \times \frac{s}{R} \times p\left(\frac{1}{\alpha} + \alpha\right).$$



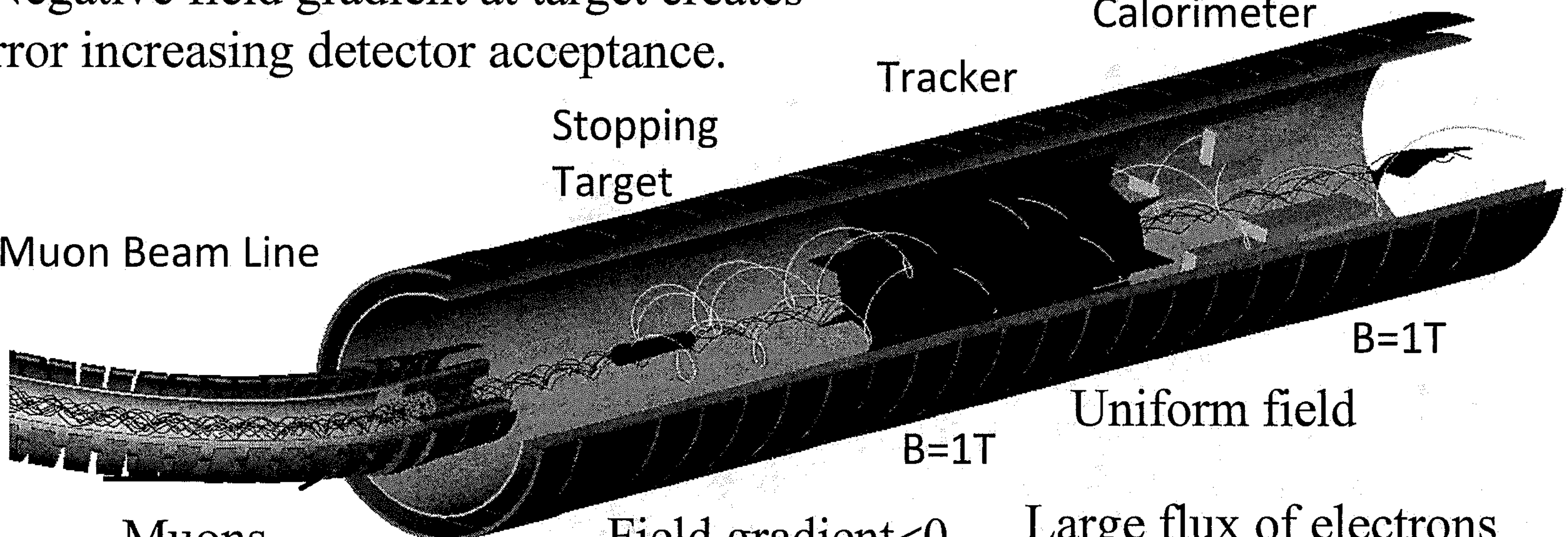


Detector Solenoid

► Solenoid, 1m radius, B=2 T→1T from 0 to 4 m, B=1 T from 4 to 10 m

► Stopping target: thin to reduce loss of energy resolution due to energy straggling

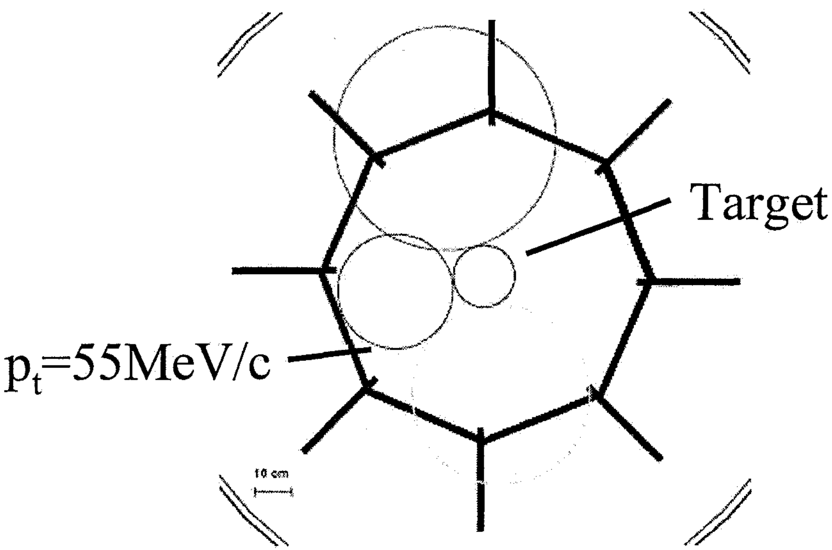
► Negative field gradient at target creates mirror increasing detector acceptance.

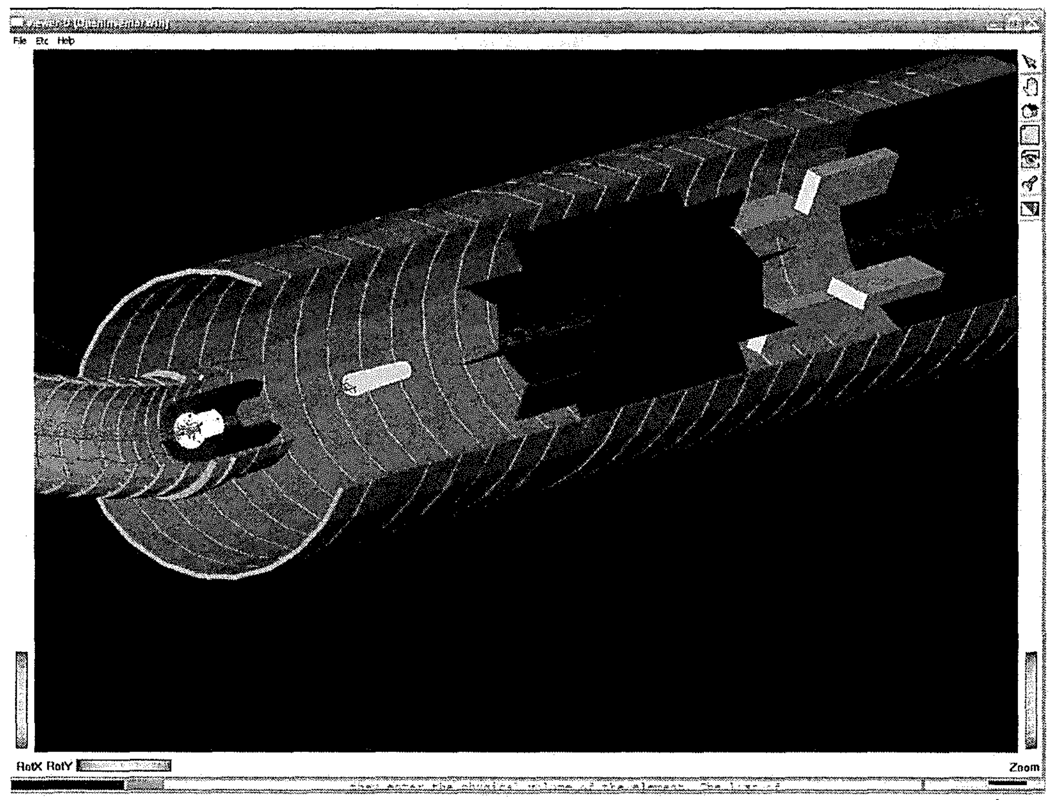


Large flux of electrons from low energy portion of muons decaying in target (DIO) spiral harmlessly through the centers of the detectors

Detector Solenoid:Stopping Target and Detectors

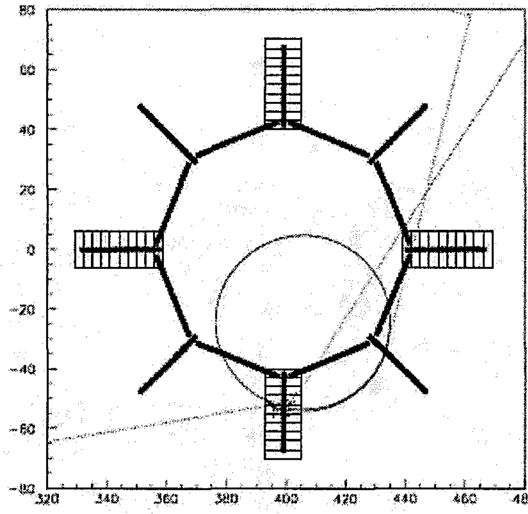
- Tracker measures energy of electrons to <1MeV FWHM, high-side tail $\sigma\sim300$ keV
- Calorimeter after the tracker: provides fast trigger, confirms energy and trajectory
- 2.4-2.9 m long, 0.5 cm diameter straws
- Specs: $\sigma_z\sim1.5$ mm, $\sigma_r\sim\sigma_\varphi\sim200$ μm



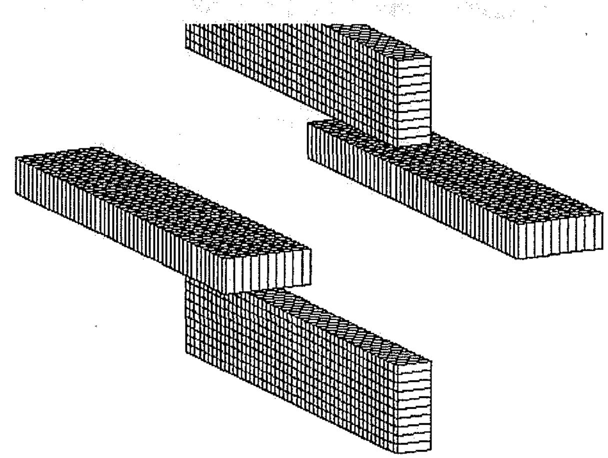


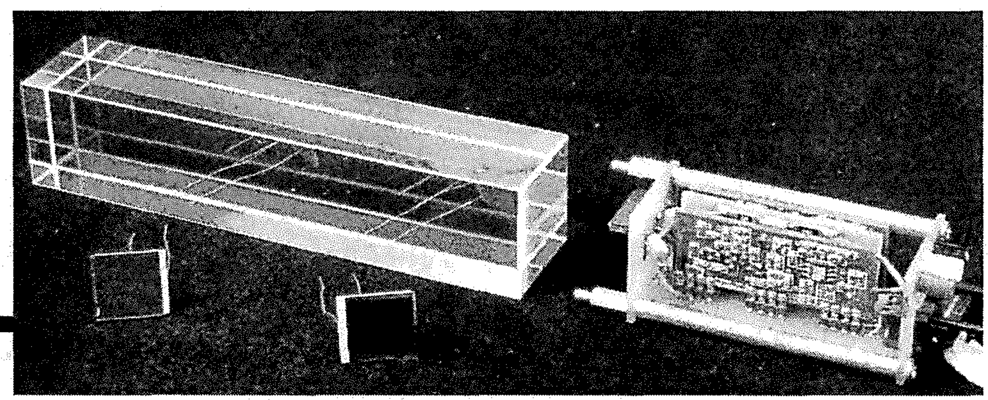
Calorimeter

➢ Function: provide initial trigger to system (E>80 MeV gives trigger rate ~1 kHz), and redundant position, timing, and energy information

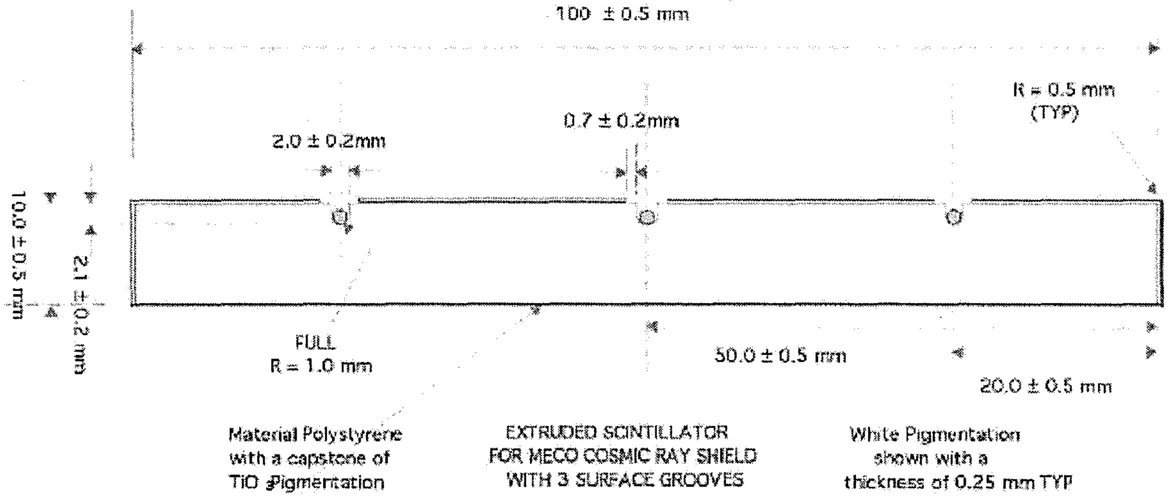


- 1800 $PbWO_4$ crystals, 3 x 3 x 12 cm^3 arranged in four vanes. Density 8.3g/cm^3, Rad. Length 0.89 cm, R(Moliere)=2.3 cm, decay time 25 ns
- Each crystal is equipped with two large area Avalanche Photo-Diodes: gives larger light yield and allows identification of events with charged particles traversing photodiode
- Both the front end electronics (amplifier/shapers) and the crystals themselves are cooled to -24^0 C to improve $PbWO_4$ light yield and reduce APD dark current.
- Single crystal performance has been demonstrated with cosmic rays: 38 p.e./MeV, electronic noise 0.7 MeV. Estimated performance with electrons, σ~5-6 MeV at 100 MeV, $\sigma_{position}$<1.5 cm





Cosmic Ray Veto and Shielding



- Active shielding goal: inefficiency $<10^{-4}$
  - Simulation study has shown that 10^{-4} inefficiency in scintillator veto → 0.016 background events / $2x10^7$s.
  - Three overlapping layers of scintillator consisting of 10 cm x 1 cm x 4.7 m strips. Veto= signals in 2 or more layers.
  - Cost-efficient MINOS approach: extruded (not cast) scintillator,1.4 mm wavelength-shifting fiber.
  - Use multi-anode PMT readout of WLS fiber
- Passive shielding: heavy concrete plus 0.5 m magnet return steel. Steel also shields CRV scintillator from neutrons coming from the stopping target.

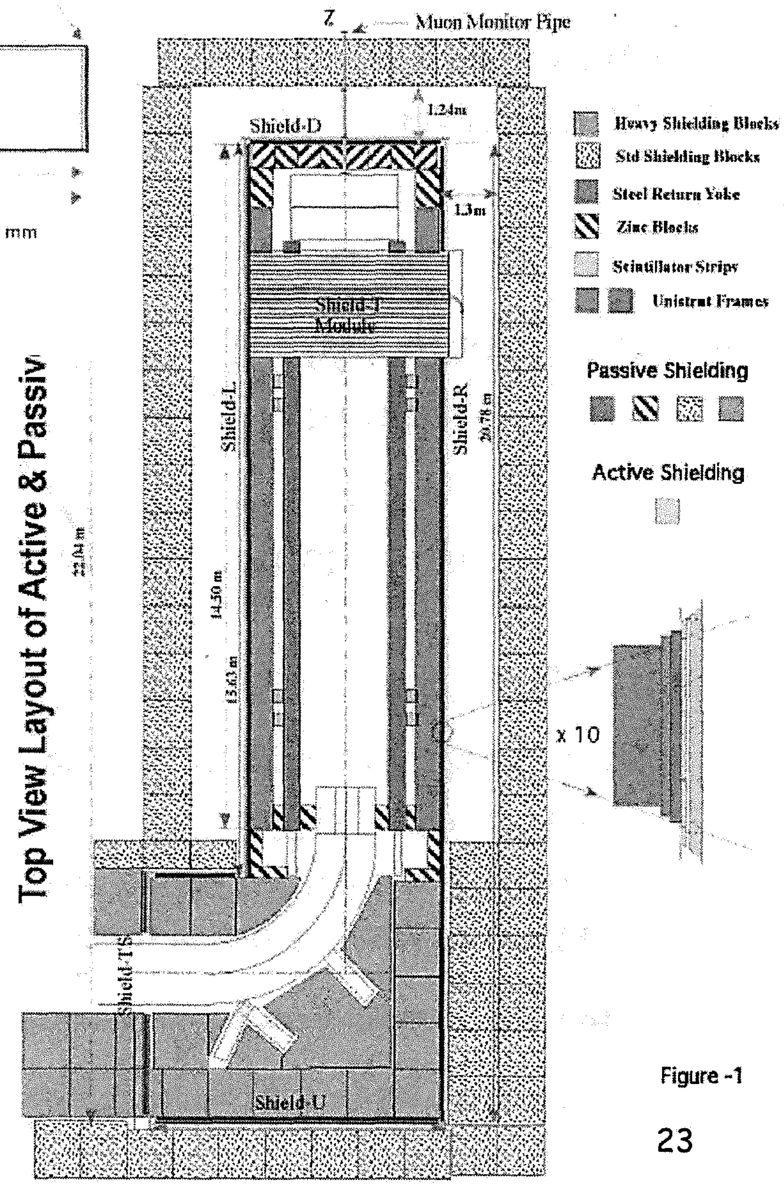
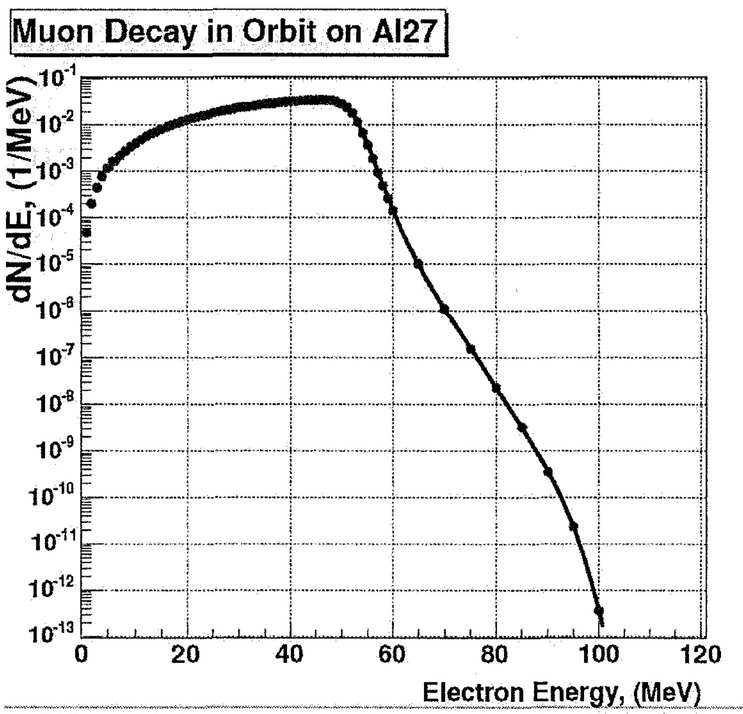
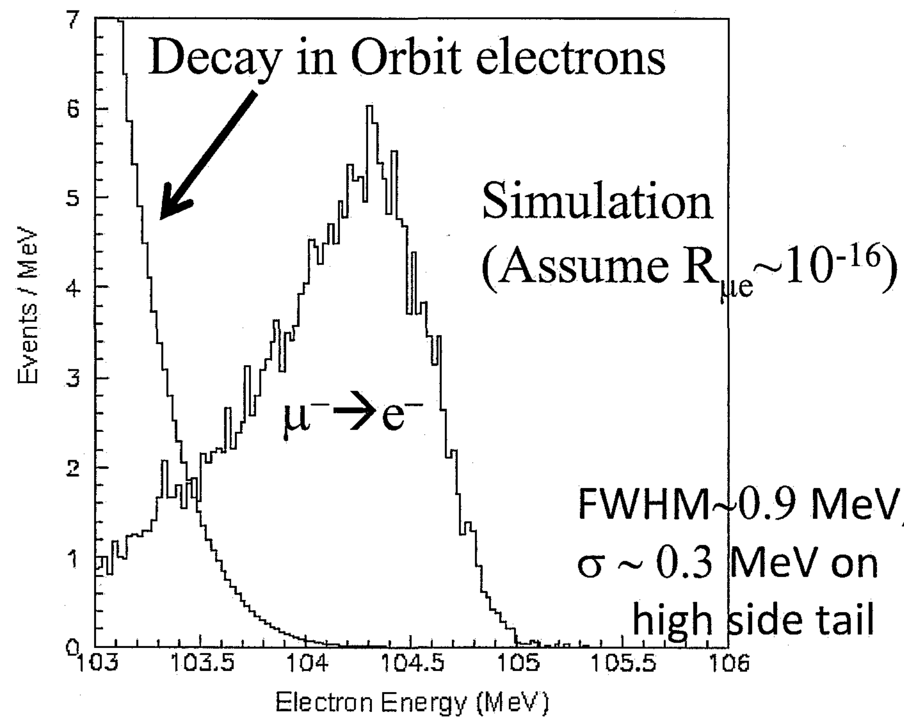


Figure -1

Backgrounds from Stopped Muons

- Essentially all muons stopped in stopping target wind up in the 1S atomic orbital of the stopping target nuclei. Then, they decay (40%) or capture (60%) on the nucleus
- Conversion electrons of interest: $[\mu^- + \text{Al}(13,27)]_{\text{bound}} \rightarrow \text{Al}(13,27) + e^-$ (105 MeV)
- Electrons from decay of bound muons (DIO) -- kinematic endpoint equals conversion electron energy: $[\mu^- + A(N,Z)]_{bound} \rightarrow A(N,Z) + e^- + \bar{\nu}_e + \nu_\mu \qquad prob \propto (E_{endpt} - E)^5$





Energy Calibration

- Mu2e resolution: σ~300 keV on high-side tail, FWHM ~ 1 MeV
  - Response function needs to be well established
- Proposed energy integration region: 103.6-105.1 MeV
- Proposed absolute energy calibration: σ~0.1-0.2 MeV
- Calibration approaches

$$\pi^+ \rightarrow e^+ + \nu_e,\ \mathrm{E}(e^+) \sim 70\ \mathrm{MeV}$$

  - Gives energy response function and energy calibration but at lower energy
  - Lower solenoid field to improve geometric overlap with detector
  - Reverse field to transport positive particles
- Use DIO spectrum to monitor calibrations
- Calibrate with a 100 MeV electron gun

Backgrounds from Stopped Muons(Cont'd)

- Ordinary muon capture on the nucleus

  $\mu^- + A(N,Z) \rightarrow A'(N',Z') + \nu_\mu + an + bp + c\gamma$, $\langle a \rangle \sim 2$, $\langle b \rangle \sim 0.1$, $\langle c \rangle \sim 2$

  - In aluminum, 40% capture, 60% decay, lifetime = 864 ns
  - n, p are low energy, γ are mostly low energy, well below conversion electron energy: create high rate background in detectors, potential track recognition errors
    - Neutral background (n, γ) is reduced by displacing detectors downstream from the stopping target
    - Protons are reduced by placing thin absorbers in their path
  - Muon radiative decay, γ near conversion energy, prob ~ few x 10^{-5}; endpoint for aluminum 102.4 MeV, 2.5 MeV below conversion electron energy. Smaller event rate but still significant compared to DIO.
- In-flight muon decay
  - p_μ>75 MeV/c can decay to >100 MeV electron

Radiative Pion Capture Background

- π^-, like μ^-, stop in stopping target and form atoms
  - reaction of π^- with nucleus is fast: occurs mid-cascade

$$\pi^- + A(N,Z) \rightarrow A'(N',Z') + X + \gamma$$

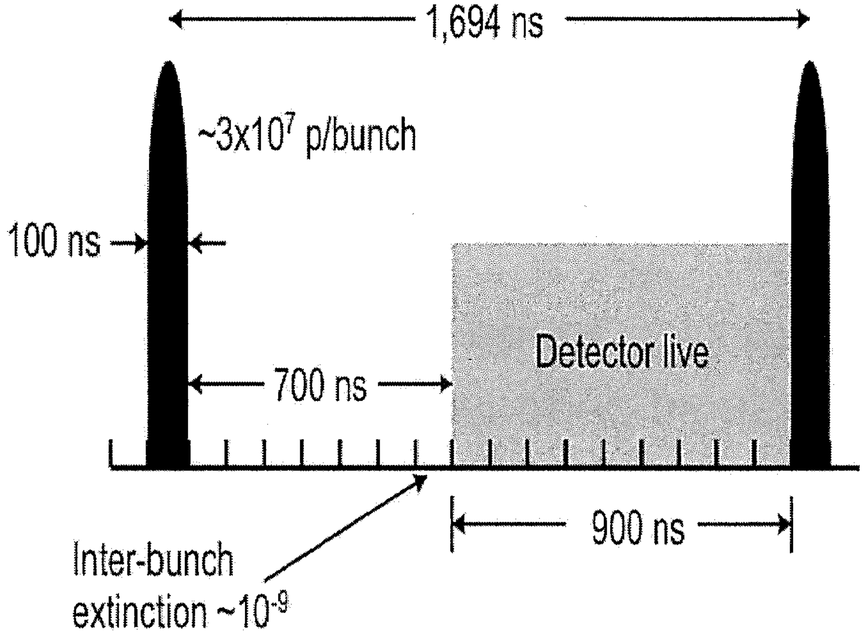
$$\pi^- + {}^{27}_{13}Al \rightarrow {}^{27}_{12}Mg + \gamma, \text{ E} \sim 137 \text{ MeV}$$

  - BR 2% for photon > 55 MeV, peak prob ~110 MeV, endpoint~137 MeV
  - γ + material (e.g. target) e^+e^-
  - There are: (stopped pions) / (proton on primary target) = $3\text{x}10^{-7}$
  - Which gives about $1.7\text{x}10^{-13}$ false conversion electrons per proton

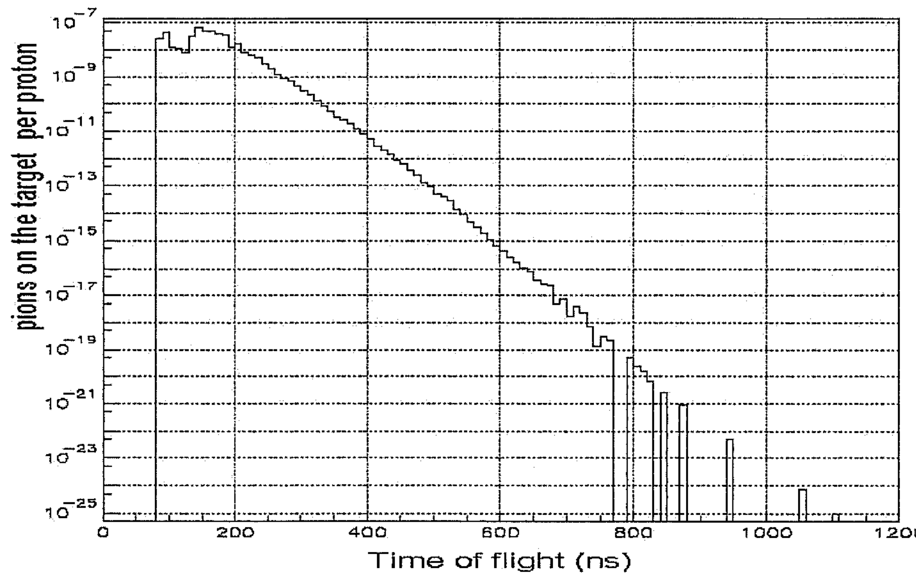
Dealing with radiative pion capture background

Use pulsed proton beam

Well-matched to 864 ns muonic Al lifetime

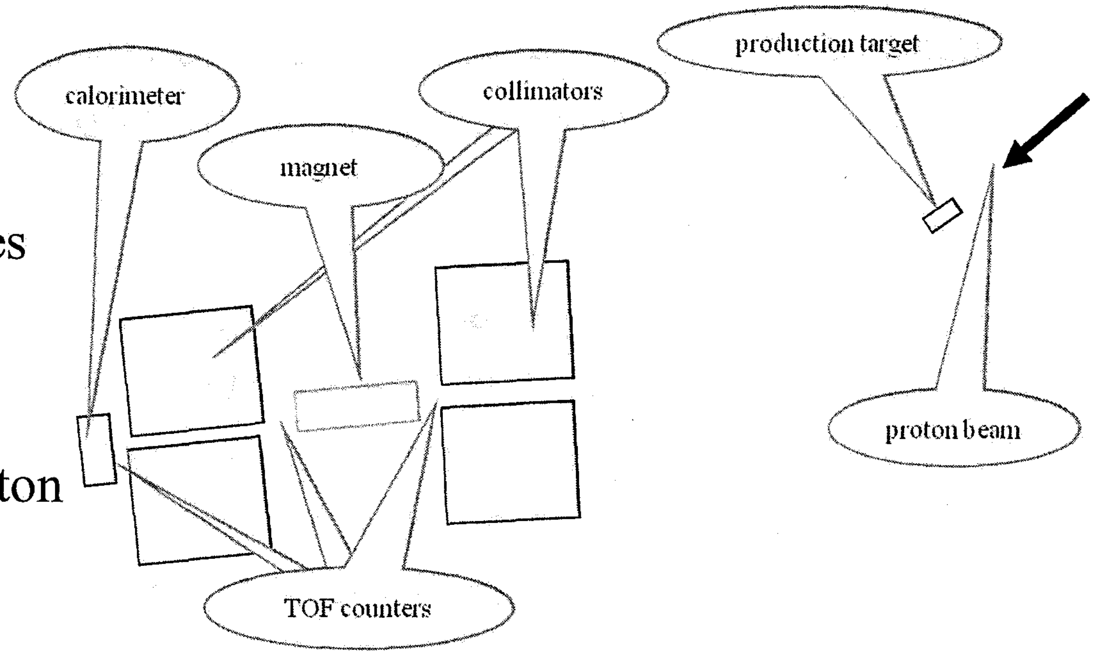


Time distribution of pions arriving at target after proton strikes the production target



- Wait ~700 ns to start measurement, pion stopping rate is reduced by $\sim 10^{11}$ → ~0.0007 events background, compared to ~4 events signal at $R_{\mu e}=10^{-16}$
- Extinction (=between-pulse proton rate) < 10^{-9} gives ~0.07 counts
- Recognized and studied by time dependence, presence of e+

Extinction Monitor



Requirement: 10^{-9} extinction of proton beam between pulses

Concept: Monitor 1-2 GeV proton production rate
- 1-2 cm diameter collimators
- 5 kG-m field
- Momentum-select 1-2 GeV protons
- Measure energy, TOF
- Good shielding to suppress background
- Run occasionally during microbunch to normalize the calorimeter
- Expect ~1 proton every few minutes for 10^{-9} extinction

Alternative being developed by COMET experiment with support of US-Japan agreement: pressurized gas Cerenkov detector placed in front of production target.

Long Transit Time Background

- Particles with low longitudinal velocity can take a long time to traverse the beam line, arriving at the stopping target during the measurement period
  - Antiprotons and radiative pion capture:
    - Antiprotons are stopped by a thin window in middle of transport
    - Adjust measure start time until most long-transit time pions decay
- Example of a potential problem
  - Pion decays into a muon early in the transport solenoid
  - Muon can have small pitch and progress very slowly downstream
  - Muon can decay after a long time into an electron
  - Decay electron can be >100 MeV if p_μ>75 MeV/c
  - Electron could scatter in collimators, arriving at the target late during the measurement period, where it could scatter into the detector acceptance
- To suppress this…
  - Straight sections of solenoids have $dB_s/ds<0.02$ T/m
    - Greatly reduces number of particles (e.g. $\pi \rightarrow \mu$) with small pitch
    - Gradient criterion not necessary in curved solenoid sections, low pitch particles are swept away vertically by dB_s/dr field gradient.

Background Summary

Source	Events	Comment
μ decay in orbit	0.225	signal/noise = 20 for $R_{\mu e} = 10^{-16}$
Pattern recognition errors	< 0.002	
Radiative μ capture	< 0.002	
Beam electrons*	0.036	
μ decay in flight*	< 0.027	without scatter in target
μ decay in flight*	0.036	with scatter in target
π decay in flight*	< 0.001	
Radiative π^- capture*	0.063	from protons during detection time
Radiative π^- capture	0.001	from late arriving π^-
Anti-proton induced	0.006	
Cosmic ray induced	0.016	assuming 10^{-4} CR veto inefficiency
Total background	0.41	

Total run time, 2×10^7 seconds

Total protons, 4×10^{20}

Total stopped muons, 1×10^{18}

Total conversion electrons (if $R_{\mu e}=10^{-16}$)=4 counts

* Depends on extinction, 10^{-9} assumed

Conclusions

- Strong physics case for muon to electron conversion:
  - A positive signal indicates new physics
  - $\mu \rightarrow e$ can be large in most extensions to the SM
  - lepton flavor conservation properties are at the core of understanding why we have three generations
  - $\mu \rightarrow e$ likely has the greatest potential experimental sensitivity for CLFV
- Addresses P5 goal of Terascale (and often well beyond) sensitivity to new physics complementary to LHC, and has strong P5 endorsement
- Mu2e experiment is based on MECO design
  - Innovative design to obtain the muon beam
  - Many successful MECO reviews
    - Physics
    - Experimental design
    - Costing
  - Exceptional fit at FNAL
    - Desired beam can be had with modest modifications to existing facilities
    - Operation with minimal impact on NoVA program

END

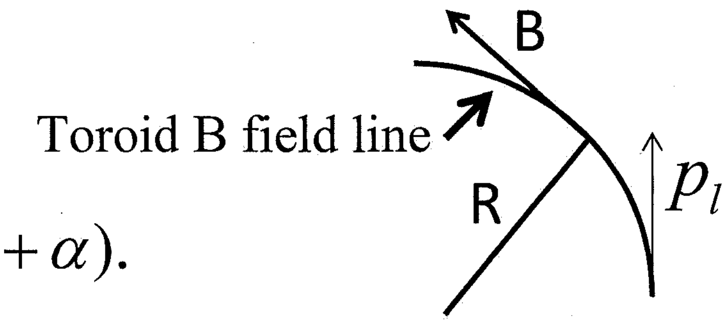
Vertical Drift Motion in a Toroid

Toroidal Field: Axial field B_s=constant x 1/r. This gives a large dB_s/dr
Particle spiral drifts vertically (perpendicular to the plane of the toroid bend):

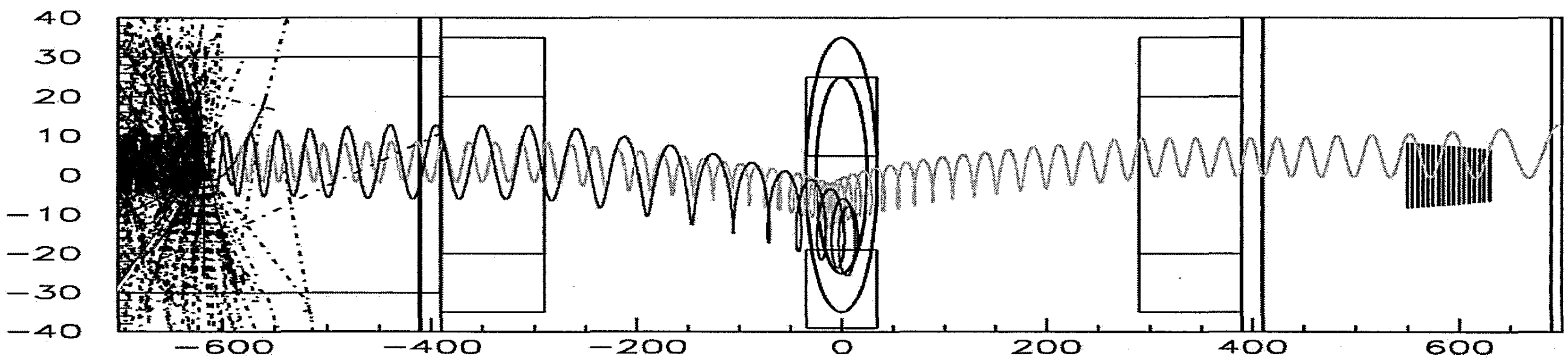
D= vertical drift distance
p_l=longitudinal momentum
p_t=transverse momentum

R=major toroid radius=2.9 m,
s/R = total toroid bend angle=90^0
D[m]=distance, B[T], p[GeV/c]

$$\text{Define pitch } = \alpha = \frac{p_l}{p}$$



$$D = \frac{1}{2} \times \frac{q}{0.3 \times B} \times \frac{s}{R} \times p(\frac{1}{\alpha} + \alpha).$$



Cosmic Ray Background

- Well-studied and controlled by previous muon conversion experiments
- Reactions which could produce a fake conversion electron:
  - Scattered electrons from cosmic ray muons in target or detectors
  - Muons decaying in-flight in the Detector Solenoid
  - Muon scattering from the target, then mistaken for an electron
  - Muons interacting in shielding, producing hadrons or photons which may not register in a veto counter.
- MECO design
  - 0.5 m steel, 2 m concrete shielding
  - Active 4π scintillator veto, 2 out of three layers report, 10^{-4} inefficiency
  - From simulations with ~70x cosmic flux, expect 0.021 events in 2×10^{7} seconds running at FNAL

Antiproton-induced background

- Cross section for production by 8 GeV protons is small
- Only very low energy antiprotons are transported.
  - Can move very slowly through beam line.
- When material is encountered, forms atom, annihilates producing energetic pions, gammas, etc.
- Potentially dangerous background source.
- Eliminated by stopping all antiprotons in a very thin window in the middle of the Transport Solenoid
- Simulation: Secondary particles from antiproton annihilation tracked.
- Estimate: 0.006 counts
- Background is fairly continuous in time, unlike muons and pions

Sensitivity of Mu2e

- For $R_{\mu e} = 10^{-15}$
  - ~40 events / 0.4 bkg (LHC SUSY?)
- For $R_{\mu e} = 10^{-16}$
- ~4 events / 0.4 bkg ***$R_{\mu e} < 6 \times 10^{-17}$ 90% CL***

Source	Number/3.6 x 10^{20} POT
Decay-In-Orbit	0.225
Radiative π capture	0.063
Muon Decay-In-Flight	0.063
Scattered e^-	0.036
π Decay-In-Flight	< 0.004

Radiative Pion Capture Background

- π^-, like μ^-, stop in stopping target and form atoms
  - reaction of π^- with nucleus is fast: occurs mid-cascade

$$\pi^- + A(N,Z) \rightarrow A'(N',Z') + X + \gamma$$

$$\pi^- + {}^{27}_{13}Al \rightarrow {}^{27}_{12}Mg + \gamma,\ \mathrm{E} \sim 137\ \mathrm{MeV}$$

  - BR 2% for photon > 55 MeV, peak prob ~110 MeV, endpoint~137 MeV
  - γ + material (e.g. target) e^+e^-

Calculation:

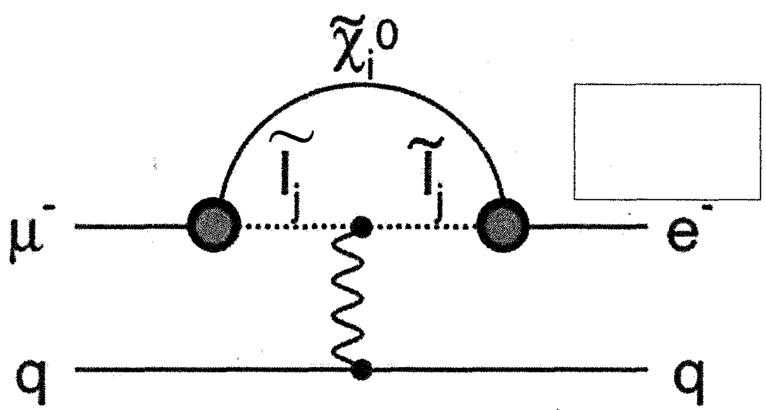
- BR~0.02
- (stopped pions) / (proton on primary target) = $3\mathrm{x}10^{-7}$
- Probability: e^- (101.5<E<105.5) produced in target = $3.5\mathrm{x}10^{-5}$
- Detector acceptance ~0.8
- This gives $(0.02)(3\mathrm{x}10^{-7})(3.5\mathrm{x}10^{-5})(0.8) = 1.7\mathrm{x}10^{-13}$/proton
- For $4\mathrm{x}10^{20}$ protons, there would be $7\mathrm{x}10^{7}$ potential false conversion e's over the entire measurement.

LFV, SUSY and the LHC

Supersymmetry

In some models,

rate ~ 10^{-15}



Access SUSY through loops:

signal at Terascale seen by LHC implies ~40 event signal in this experiment

Experimental Advantage of $\mu \rightarrow e$

- Electron energy, 105 MeV, is far above the bulk of low energy decay electron background. Considerable improvement in the ultimate sensitivity is quite likely.
- Contrast with $\mu \rightarrow e\gamma$:
  - e and γ each have energies of 53 MeV, right at the maximum flux of electron energies from ordinary muon decay. This background is believed to limit future improvements in achievable limits on the branching ratio.

Electrons from Production Target

- Electrons present largest flux of particles during the proton injection
  - Most traverse the beam line quickly compared to muons, pions, etc.
  - Suppression depends on extinction + suppression in the beam line.
- Beamline and collimators are designed to strongly suppress electrons > 100 MeV from arriving at stopping target
- Simulation: With 10^7 electrons starting at the production target, none made it to the stopping target.
- Electrons >100 MeV entering the Detector Solenoid from the Transport Solenoid will have the wrong (too large) pitch when arriving at the detector compared to a conversion electron, due to gradient field in the stopping target region, except for target scatter.
  - $45<\Theta_{max}<$ 60 degrees for electrons from stopping target
  - $\Theta_{max}<$ 45 degrees for electrons from entrance of Detector Solenoid
- Estimate: 0.04 background events

MECO Simulations

- Full GEANT simulations of all particles traversing muon beam line: e,π,μ,γ,n,K…
- Full GEANT tracking of particles in detector region
- Separate studies of long transit time particles
  - pions,K0, K+,K-,pbars
  - K_L live a long time, ~52 ns
    - Separate simulation, following decays of low energy K_L from production region; number of background electrons at the stopping target was found to be tiny.
  - neutrons: can energetic neutrons survive many bounces down the beam line and be delayed enough in time to arrive in the measurement period? Study needed
- As part of the process of absorbing the MECO knowledge, Mu2e is seting up a general simulation apparatus and will repeat the MECO calculations