Physics With the Front End of First μ Collider

Physics with Low Energy Muons

Tom Diehl + Bill Molzon
Conveners

Lepton Flavor Violation — $\mu \to e\gamma$

Results from MEGA - E. Hungerford
Ideas for Improved Expt - M. Cooper
Polarized μ Beams for $\mu \to e\gamma$ - Y. Kuno
Report on PSI Workshop - Y. Kuno

Lepton Flavor Violation — $\mu \to e$ conversion

Beam requirements for MECO - W. Molzon
Status of $\mu \to e$ Experiments - [illegible]colli
Physics Background Processes - T.C. Liu
μ Beam Simulation + Design - N. Bachman
Trigger + Rate Issues - D. Koltick
Theoretical Issues - A. Czarnecki

CP Violation + T Violation μ EDM

μ EDM in g-2 Ring - W. Morse

Other Low Energy μ Physics

μ Catalysed Fusion - G.M. Marshall
Nuclear μ Capture - P. Karvel

Accelerator Facilities, μ Beams

Japanese Hadron Facility - Y. Kuno

BNL AGS as μ Beam Source - M. Brennan

FNAL Booster as μ Beam Source - C. Moore

Ring Cooler for μ Collider - V. Balbekov / A. Van Ginneken

Pion Production Cross sections

Particle Production Models - N. Mokhov

BNL E910 Status - H. Kirk

P. Kammel

11/2/97

Low energy muon physics: Present and Future?

(in the context of muon collider frontend physics)

- Main question: Which **fundamental experiments or applications** can be dramatically improved at the mu collider frontend in 20xx ?
- Beams

existing: PSI, TRIUMF, RAL, future: BNL, JHF, FNAL
LAMPF

- Physics

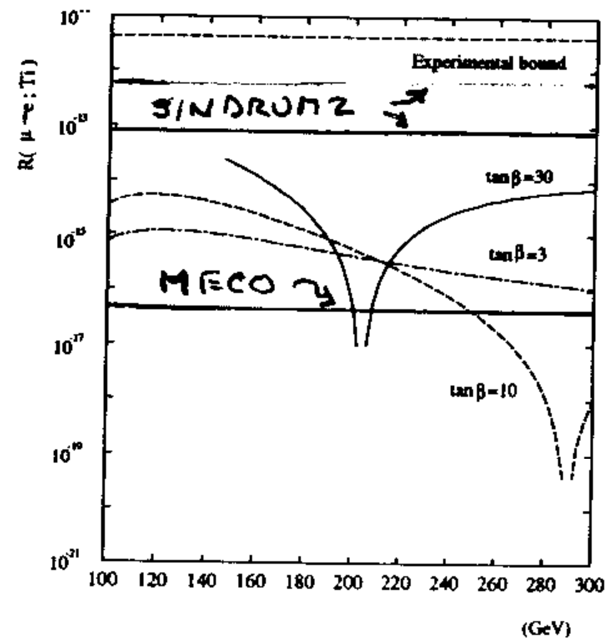
exp. program	processes	topic	>20xx
rare decays	μ+Z→e+Z μ→eγ μ→eee	Lepton Flavor violation SM test, GUT, SUSY, LRSM	YES
μ decay	lifetime spectrum	G_F, SM test SM test	possibly
ν mass	$\pi \rightarrow \mu\ \nu$ ν oscillation	SM test	?? YES
g-2 of muon	g-2	SM test	possibly YES?
simple exotic atoms	μ^+e μp $\mu\mu$?	QED test, EW interference	yes
μ capture: light nuclei	μHe3 μp OMC & RMC μd	low E QCD, χ properties SM test	possibly
μ capture	μZ	medium effects on meson properties	??
T violation	μZ, triple correlations	SM test	if feasible
μCF	mol. formation, sticking	precision atomic/molecular physics, applications	applications: keV μ^+, n source
μSR		solid state physics	YES

μ capture (margin note)

IMPROVEMENTS
- FLUX ?
- BEAM QUALITY, TIME STRUCTURE
- NEW IDEAS with FANTASTIC μ INTENSITIES

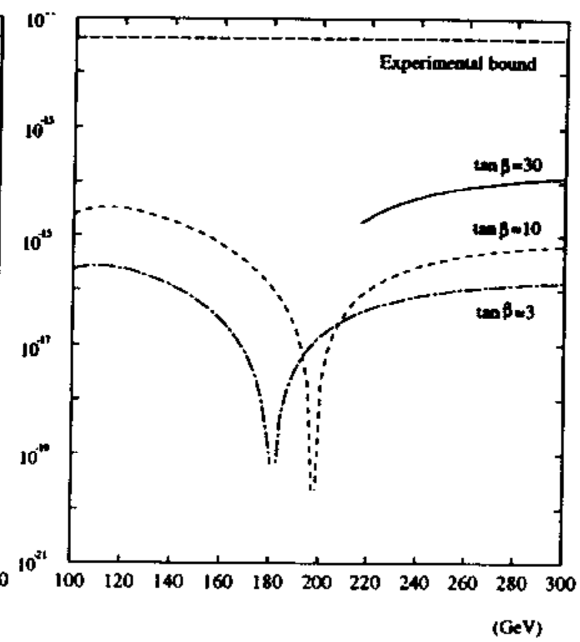
susy2 wmolson

LFV Predictions From the Model of Hisano, et al.



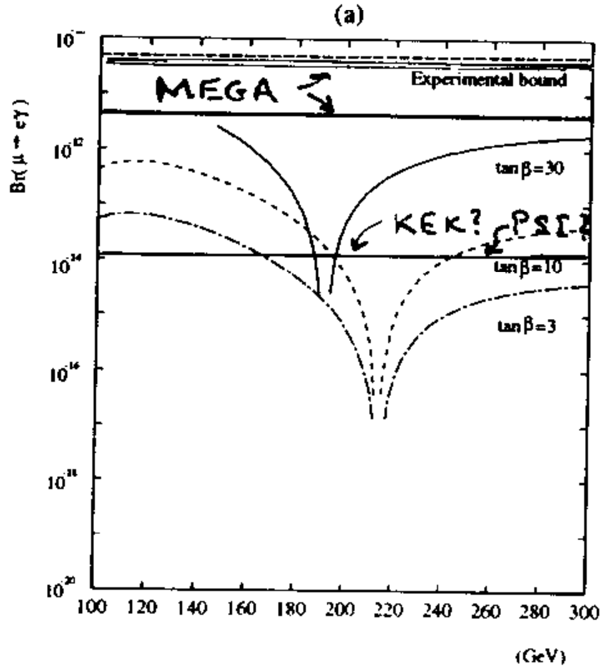
$m_{\tilde{e}_R}$

(a)



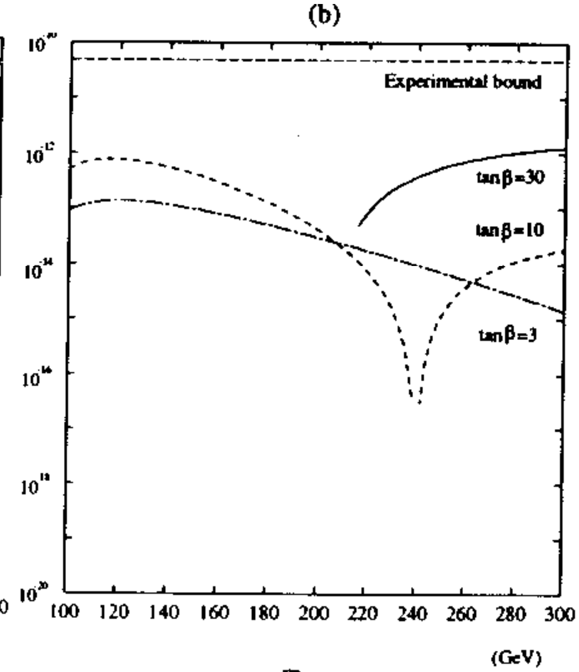
$m_{\tilde{e}_L}$

(b)



$m_{\tilde{e}_R}$

(a)



$m_{\tilde{e}_L}$

(b)

Y. KUNO

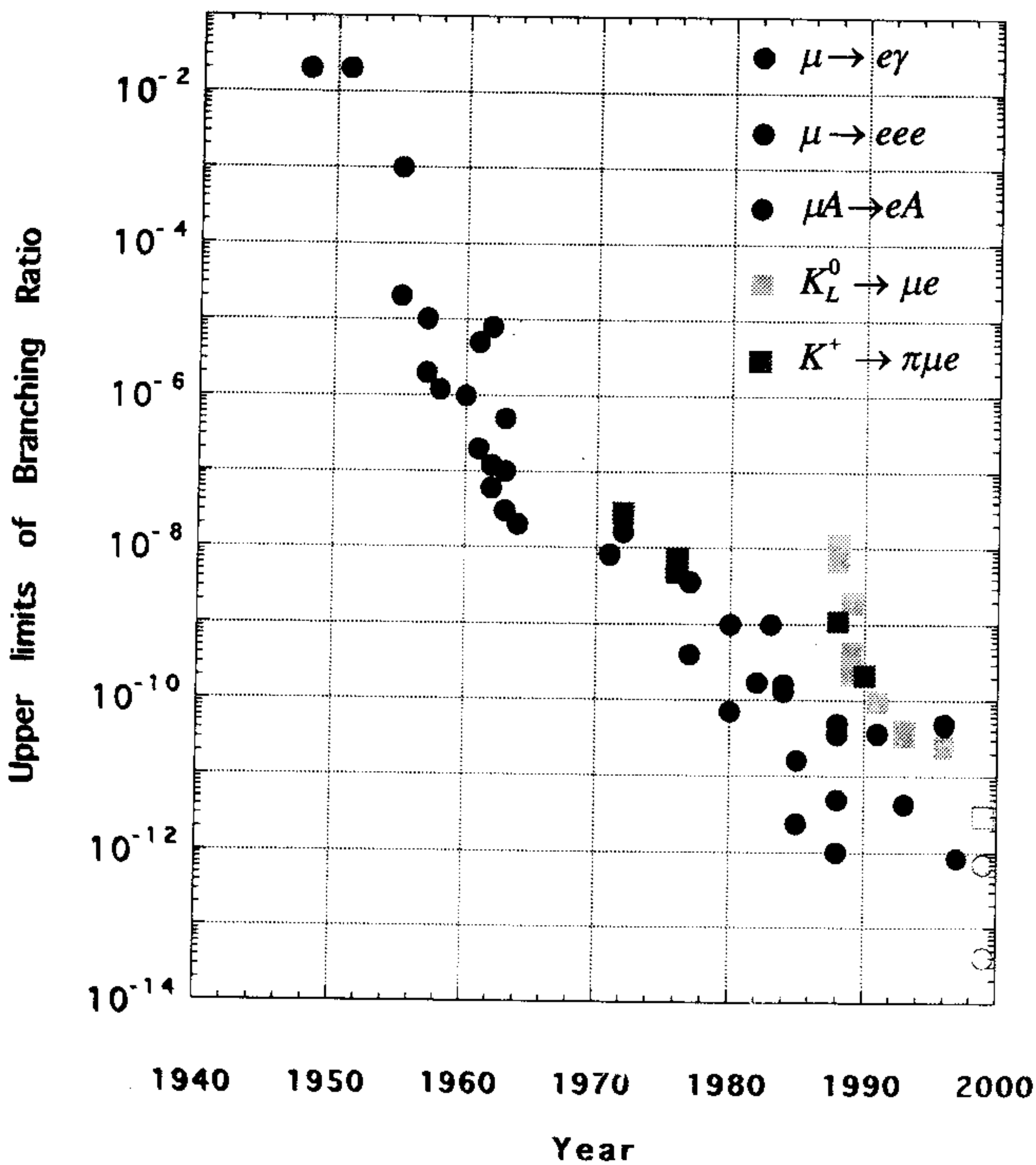
Experimental Tests of LFV

Reaction	Current bound	Ongoing efforts (goal)
$B(\mu^+ \to e^+\gamma)$	$\leq 4.9\times10^{-11}$	$\approx 6\times10^{-13}$ MEGA (LAMPF)
$B(\mu^- Ti \to e^- Ti)$	$\leq 8.4\times10^{-13}$	$\approx 4\times10^{-14}$ SINDRUM II (PSI)
$B(\mu^+ \to e^+ e^- e^+)$	$\leq 1.0\times10^{-12}$	
$B(\tau \to e\gamma)$	$\leq 1.1\times10^{-4}$	
$B(\tau \to \mu\gamma)$	$\leq 4.2\times10^{-6}$	
$B(\tau \to \mu\mu\mu)$	$\leq 1.9\times10^{-6}$	
$B(K_L^0 \to \mu^\pm e^\mp)$	$\leq 2.4\times10^{-11}$	$\approx 8\times10^{-13}$ BNL871
$B(K^+ \to \pi^+ \mu^+ e^-)$	$\leq 2.1\times10^{-10}$	$\approx 3\times10^{-12}$ BNL865
$B(B^0 \to \mu^\pm e^\mp)$	$\leq 5.9\times10^{-6}$	
$B(B \to K\mu e)$	$\leq 1.5\times10^{-5}$	
$B(Z^0 \to \mu e)$	$\leq 6\times10^{-6}$	

as of November, 1996

Y KUNO

Upper Limits for Lepton Flavor Violation

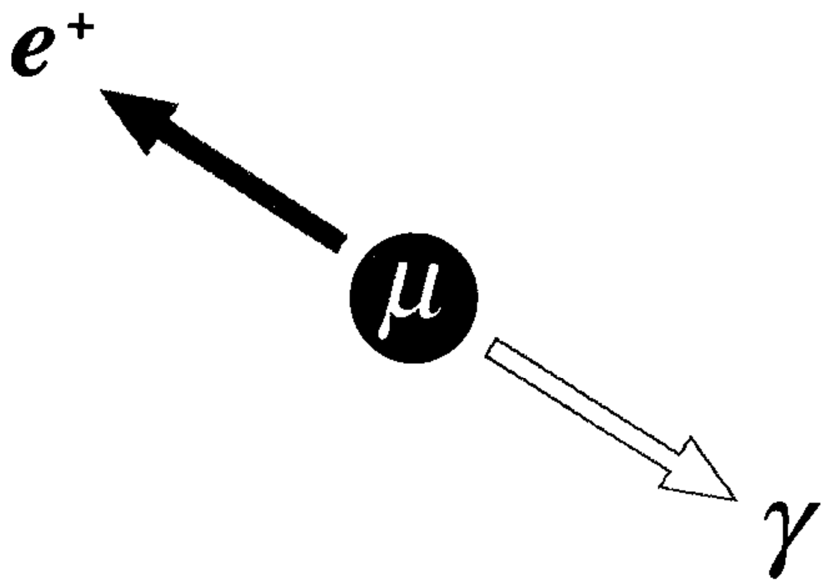


Y KUNO

$\mu^+ \rightarrow e^+\gamma$ Signature

Event Signature

- $E_e = \frac{m_\mu}{2}$, $E_\gamma = \frac{m_\mu}{2}$ (=52.8 MeV)
- $\vartheta_{e\gamma} = 180°$ back-to-back
- time coincidence



Current experimental limit

- $B < 4.9 \times 10^{-11}$ (90% C.L.)

Y KUNO

$\mu^+ \to e^+\gamma$ backgrounds

Backgrounds

- **Physics Background**

  Radiative decay $\mu^+ \to e^+\nu\bar{\nu}\gamma$

  when neutrinos carries little energy

  $B(\mu^+ \to e^+\nu\bar{\nu}\gamma) = 1.4\ \%\ (E_\gamma > 10\ \mathrm{MeV})$

- **Accidental coincidence background**

  e^+ in $\mu^+ \to e^+\nu\bar{\nu}$

  γ in $\mu^+ \to e^+\nu\bar{\nu}\gamma$

  in e^+ annihilation in flight

  in external Bremsstrahlung

Will Dominate Background

MEGA

**

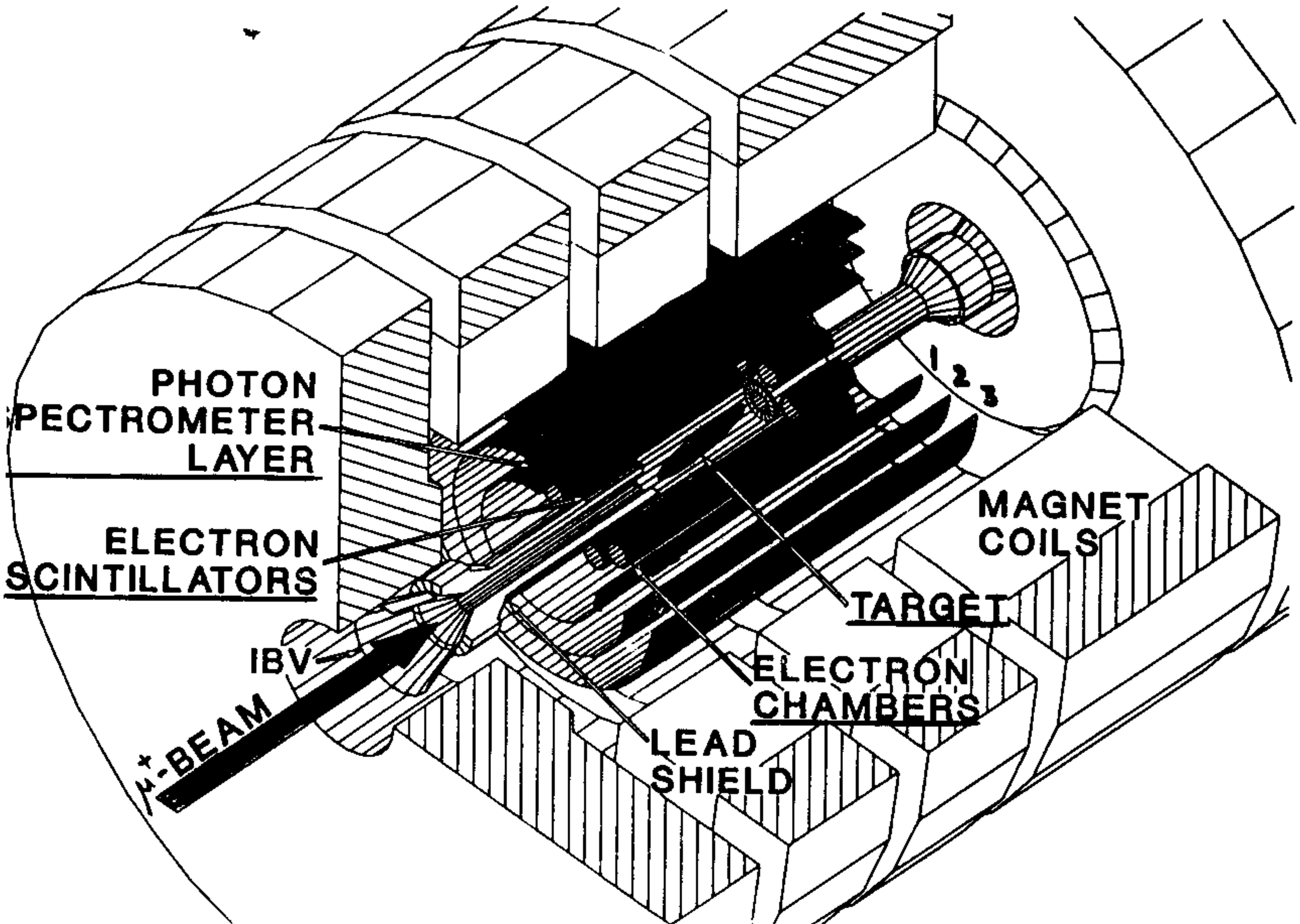
An UPDATE

Nov. 8, 1997

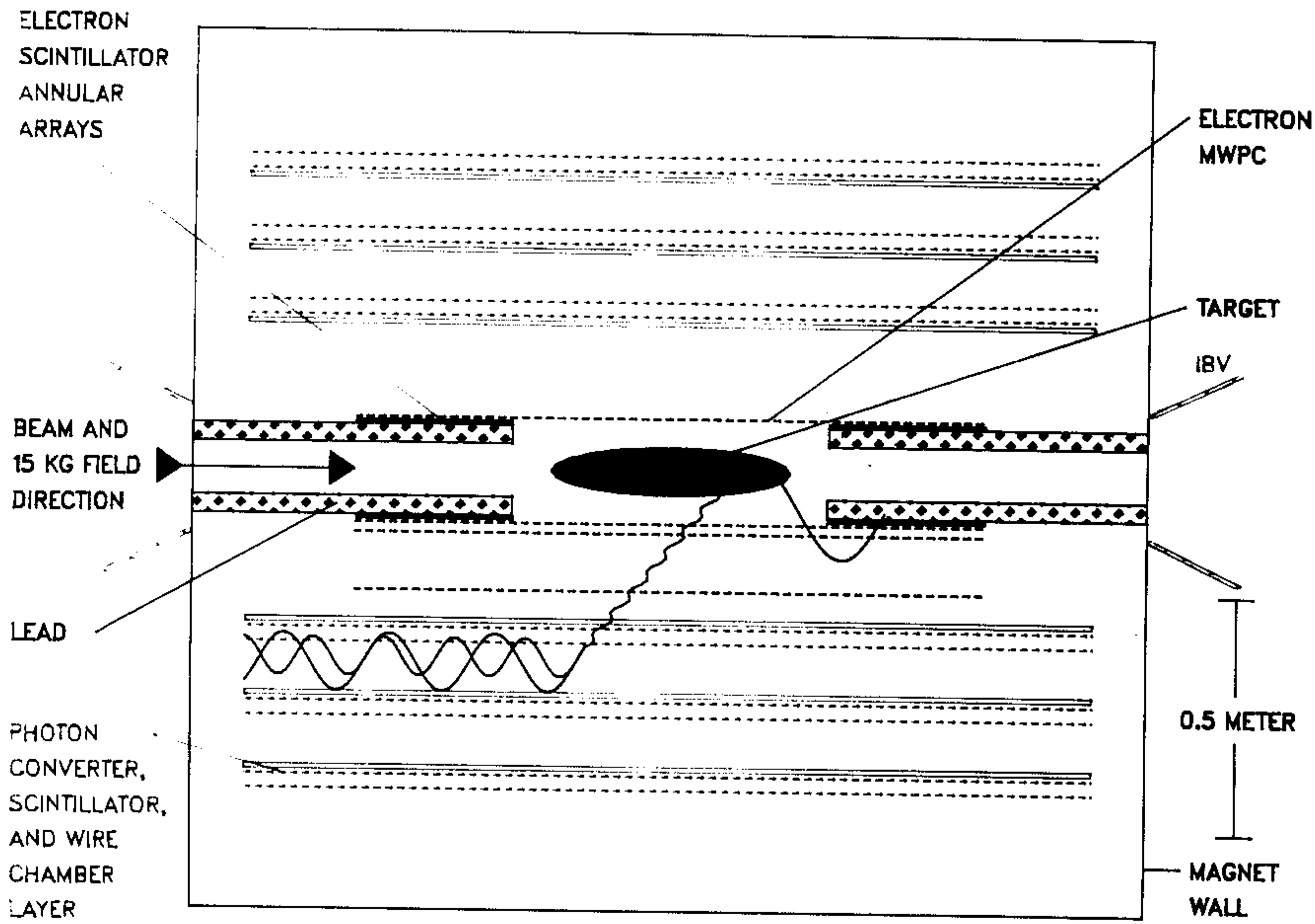
Ed V. Hungerford
University of Houston
Hunger@uh.edu

HUNGERFORD

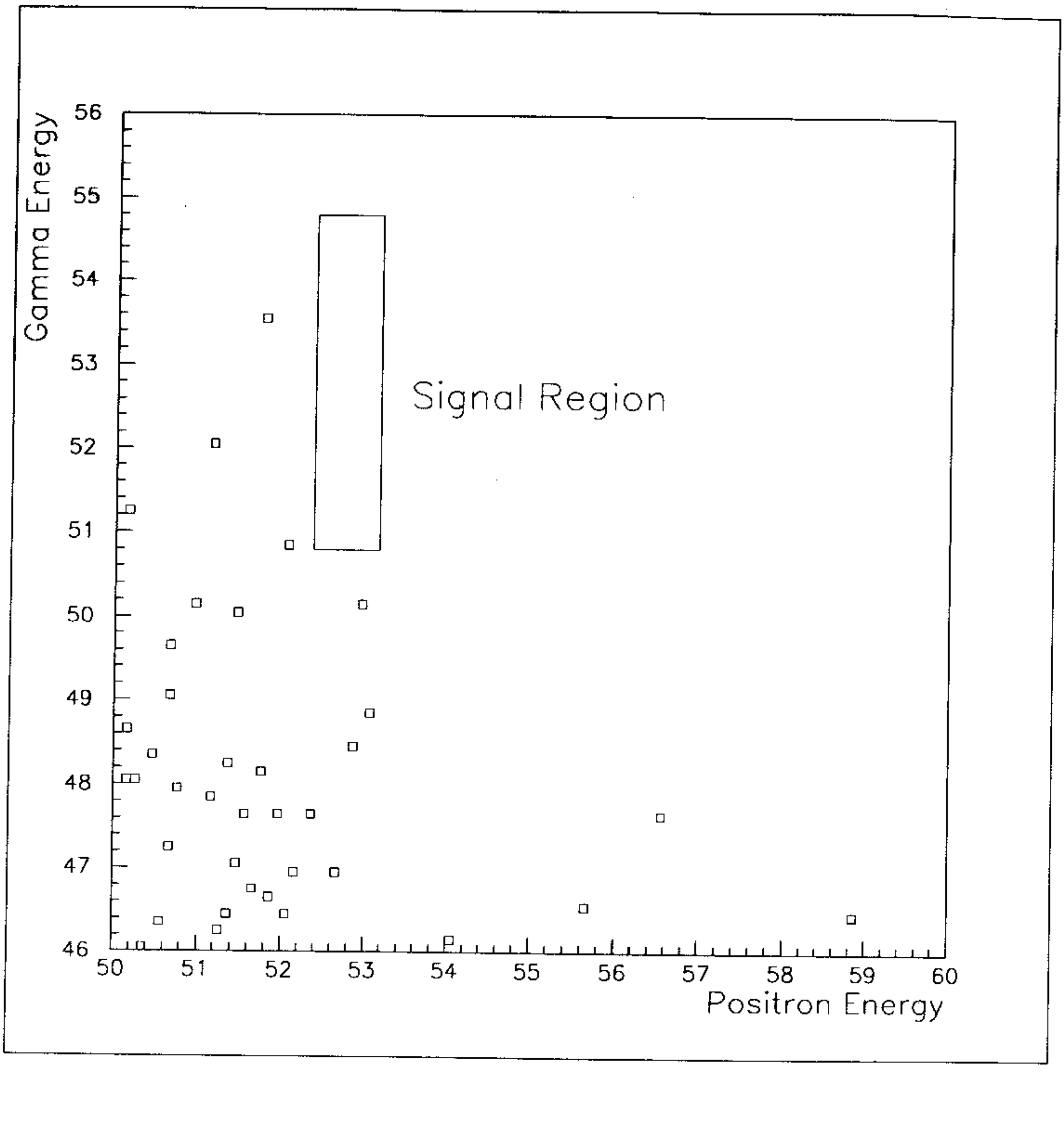
MEGA APPARATUS



HUNGERFORD



ELECTRON SCINTILLATOR ANNULAR ARRAYS
BEAM AND 15 KG FIELD DIRECTION
LEAD
PHOTON CONVERTER, SCINTILLATOR, AND WIRE CHAMBER LAYER
ELECTRON MWPC
TARGET
IBV
0.5 METER
MAGNET WALL


Gamma Energy
56
55
54
53
52
51
50
49
48
47
46
Signal Region
50
51
52
53
54
55
56
57
58
59
60
Positron Energy

Results

Result from ~16% of data

$$BR_{90\%}(\mu \rightarrow e\,\gamma) < 3.8 \times 10^{-11}$$

compare to current world limit from Crystal Box

$$BR_{90\%}(\mu \rightarrow e\,\gamma) < 4.9 \times 10^{-11}$$

Expectation from all MEGA data

$$BR_{90\%}(\mu \rightarrow e\,\gamma) < 3\text{-}6 \times 10^{-12}$$

or evidence for the decay

MARTIN COOPER

SENSITIVITY

THE NUMBER OF USEFUL μ STOPS

$$M = T \cdot R_\mu \cdot (\Omega_O/4\pi) \cdot \varepsilon_\gamma \cdot \varepsilon_p \cdot E_c$$

T	LIVE TIME
R_μ	AVERAGE STOP RATE
Ω_O	OVERLAP SOLID ANGLE
ε_γ	g-RAY DETECTION EFFICIENCY
ε_p	POSITRON DETECTION EFFICIENCY
E_c	CUT EFFICIENCY

SENSITIVITY (90% C.L.) = 2.3/M

BACKGROUND

$$B_{acc} = (R_\mu/d \cdot \Delta t) \cdot \Delta x \cdot (\Delta y/15)^2 \cdot (\Delta\theta/2)^2 \cdot f(\theta_\gamma) \cdot f(IB) \cdot f(P_\mu)$$

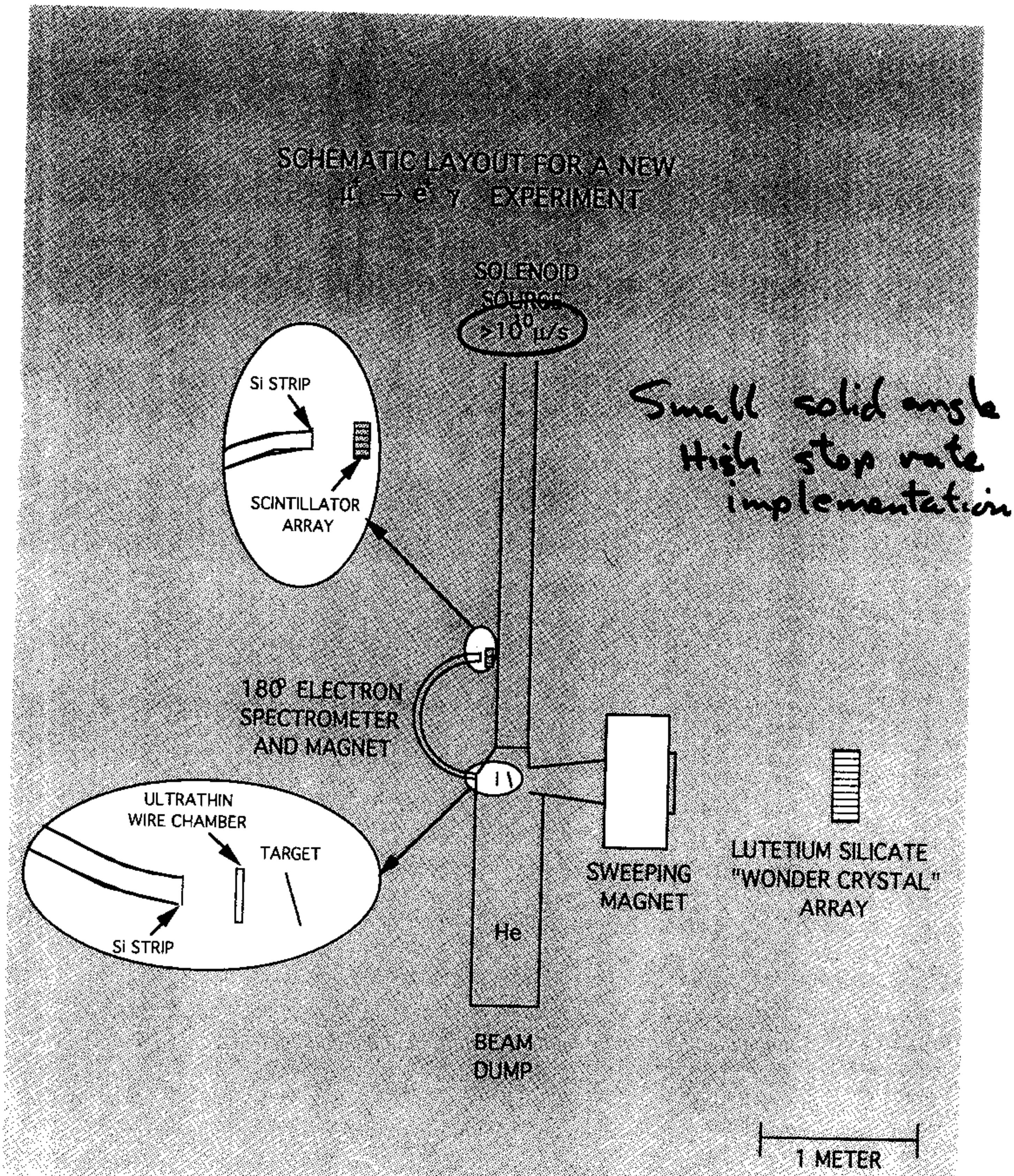
R_μ	**AVERAGE STOP RATE (/s)**
d	**DUTY FACTOR**
Δt	**ELECTRON-PHOTON RELATIVE TIME RESOLUTION (s)**
Δx	**FRACTIONAL ELECTRON RESOLUTION**
Δy	**FRACTIONAL PHOTON RESOLUTION**
$\Delta\theta$	**ELECTRON-PHOTON ANGLE RESOLUTION (rad)**
$f(\theta_\gamma)$	**FACTOR FROM PHOTON TRACEBACK**
$f(IB)$	**FACTOR FROM INTERNAL BREMSSTRAHLUNG SUPPRESSION**
$f(P_\mu)$	**FACTOR FROM MUON POLARIZATION**

RATE PARAMETERS

$R_{E\gamma>\sigma\gamma}\tau_{col-\gamma}$ $\quad$ $R_\gamma\tau_{col-\gamma}$ $\quad$ $R_e\tau_{col-e}$

$R_{trg}\tau_{readout}$

MARTIN COOPER



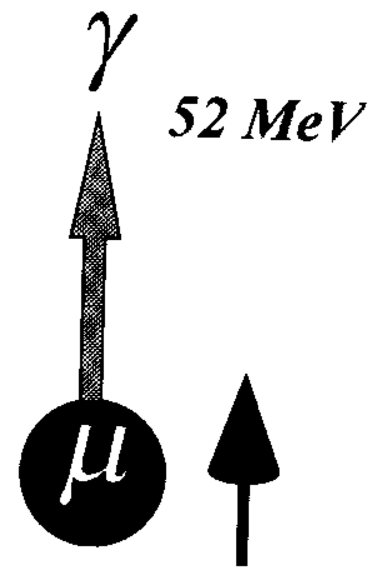
Y. Kuno

Angular Distribution of Accidental Sources

e^+ in normal muon decay

$1+\cos\vartheta$

γ in radiative muon decay

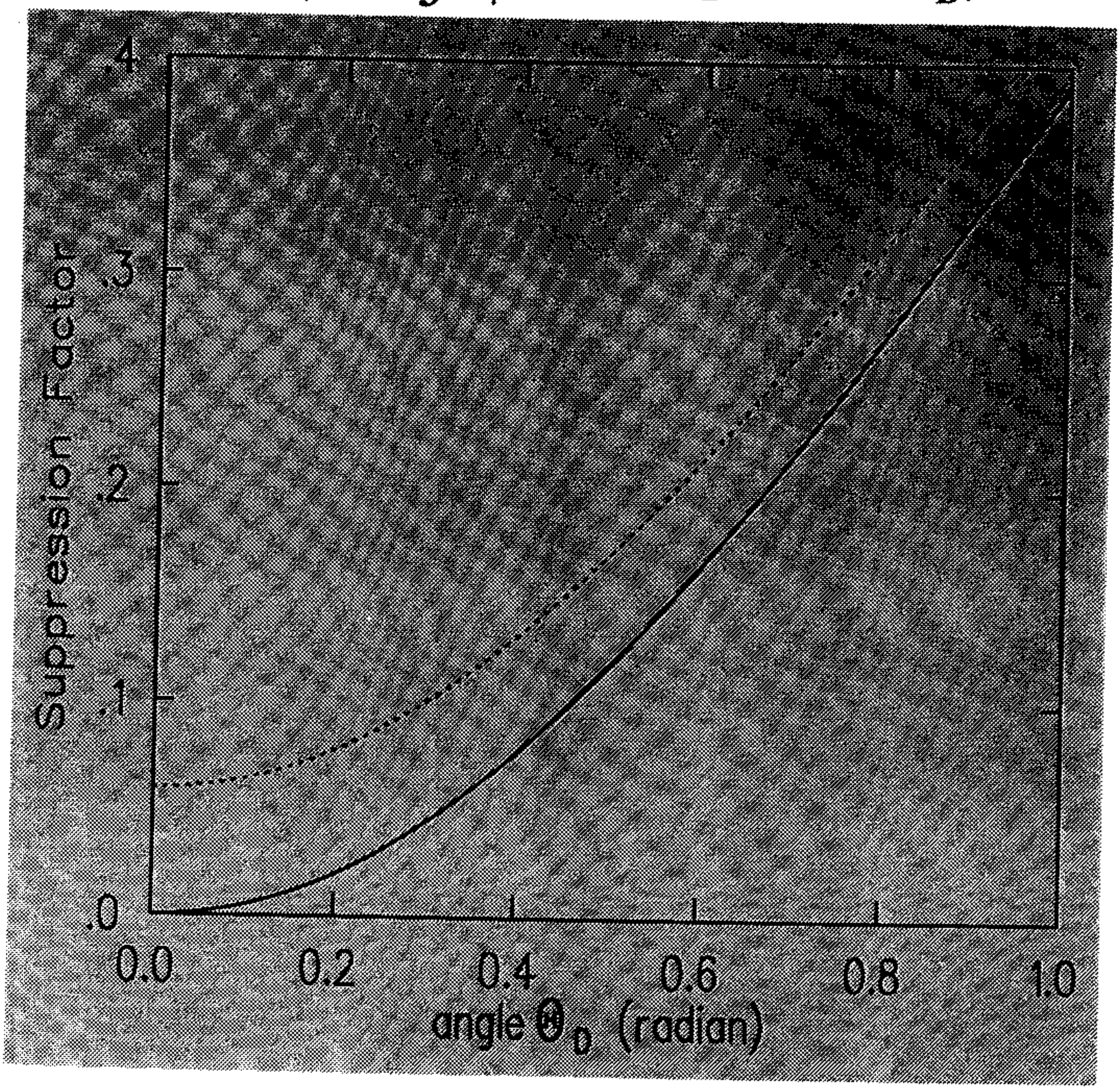


$1+\cos\vartheta$

Measurement of e^+ and photon going opposite to the muon spin will reduce accidental backgrounds.

Accidental Background Suppression

$$(1-P_\mu)^2 + \frac{1}{3}P_\mu^2(1-\cos\vartheta_D)(2+\cos\vartheta_D)$$



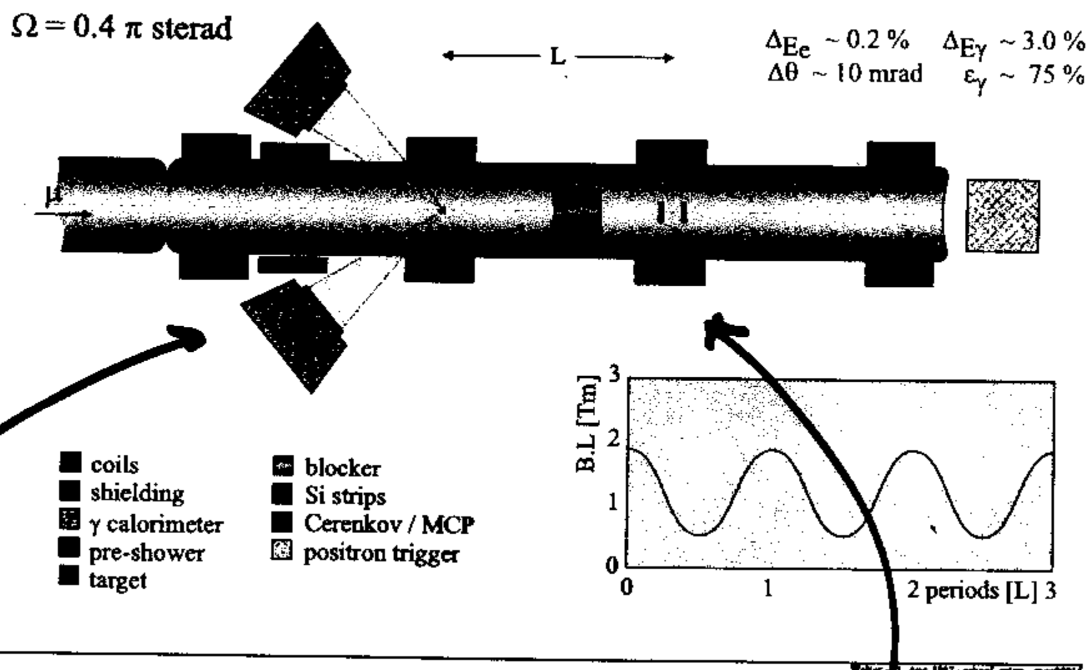
ϑ_D is a half opening angle of detection

A solid line is P_μ=100%, and a dotted line is P_μ=97%.

New ideas for $\mu \to e\gamma$

PSI workshop winter 1997

Set-up to search for $\mu \to e\gamma$ (A. v. d. Schaaf)



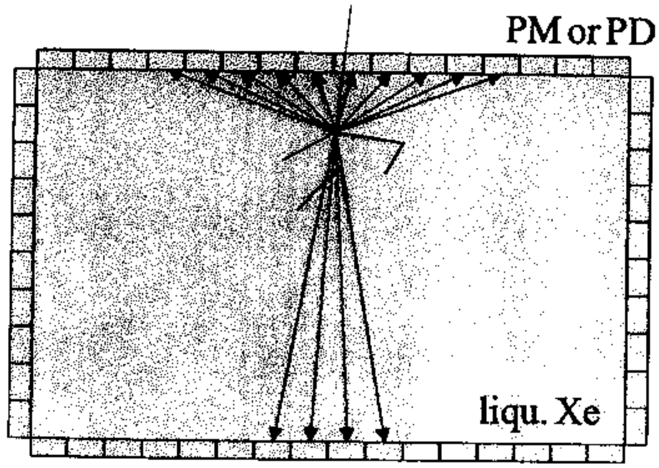
Photon detector

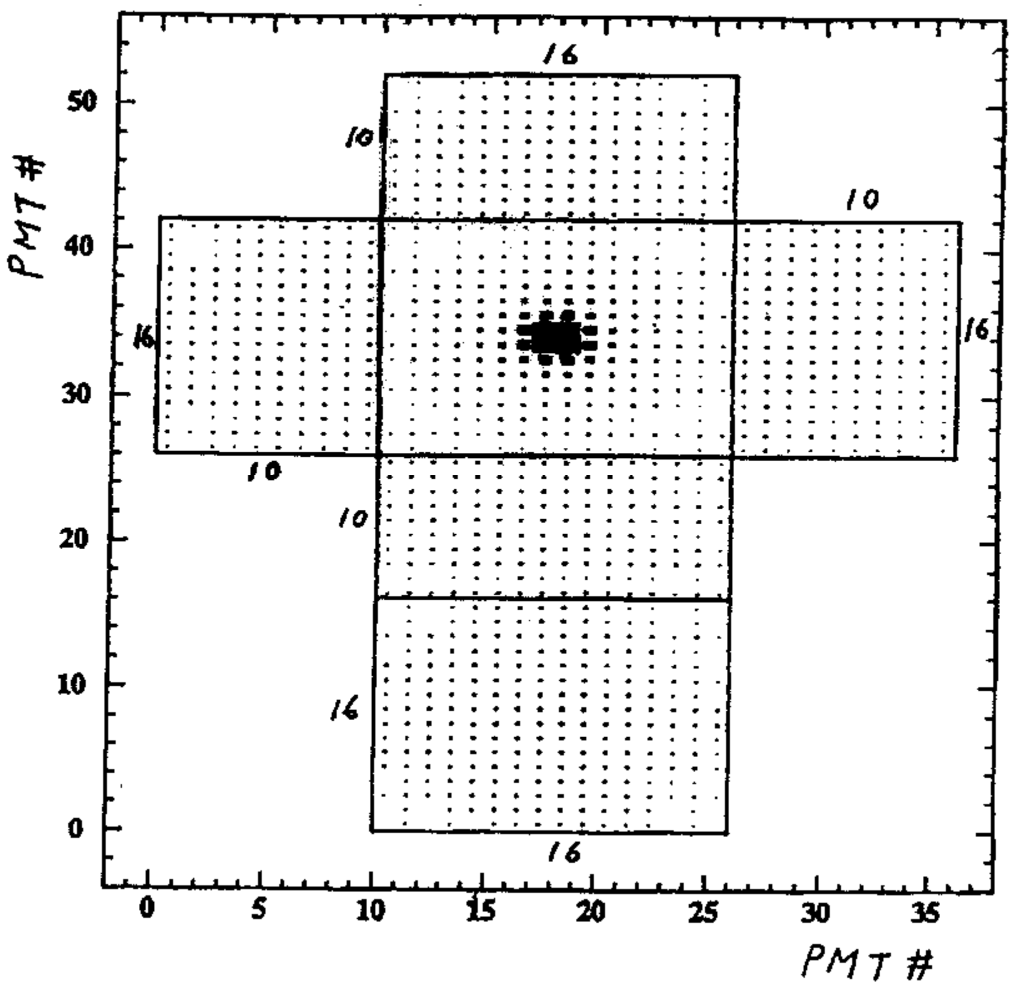
Focusing electron spectrometer

Achieves 10^{-14} sensitivity using PSI μ beam.

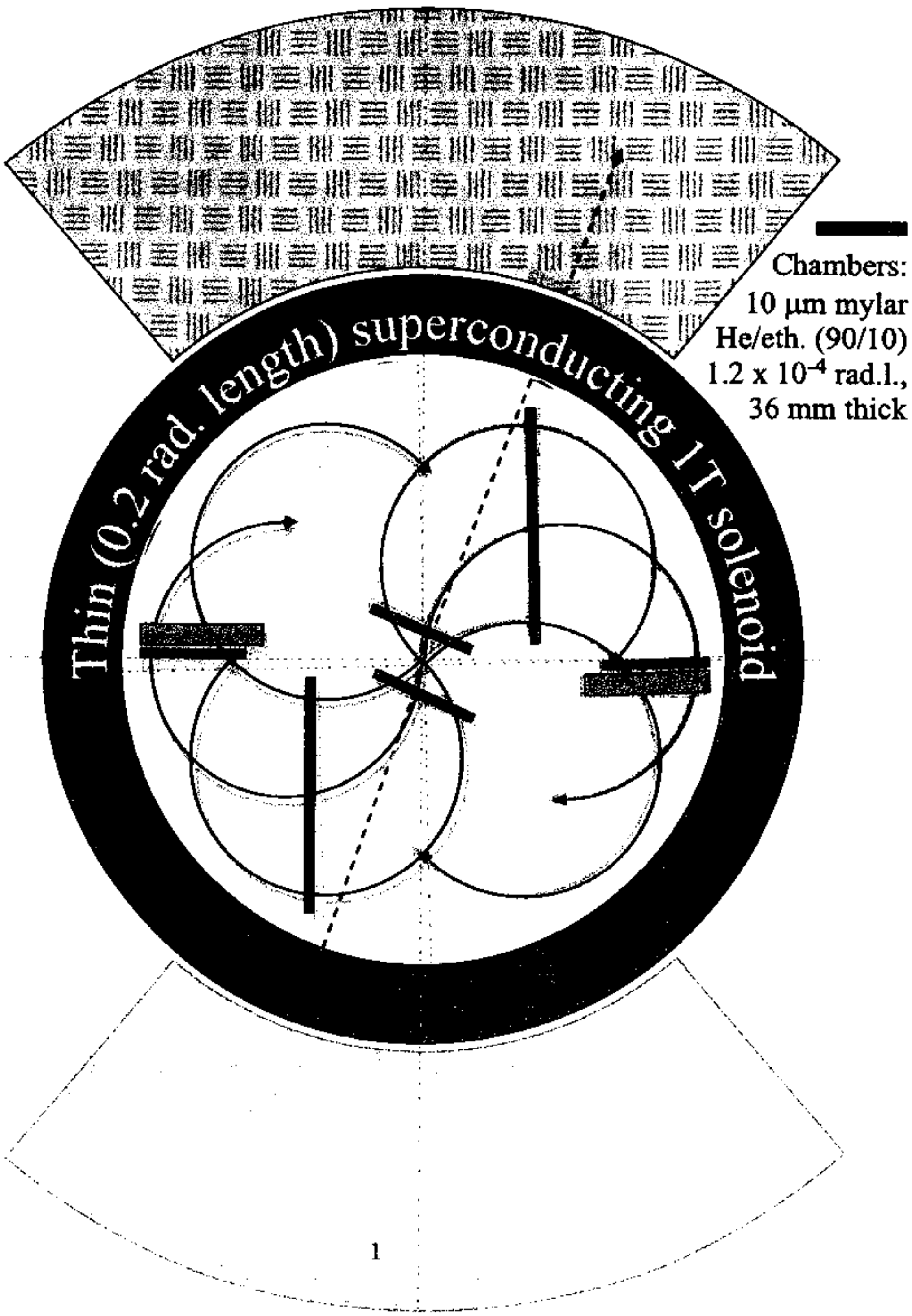
"Min - Kam" liqu. Xe cal. for $\mu \rightarrow e \gamma$ (S. Orito)

1 / 50'000 volume of Superkamiokande





Possible μ --> eγ set-up (A. Maki)



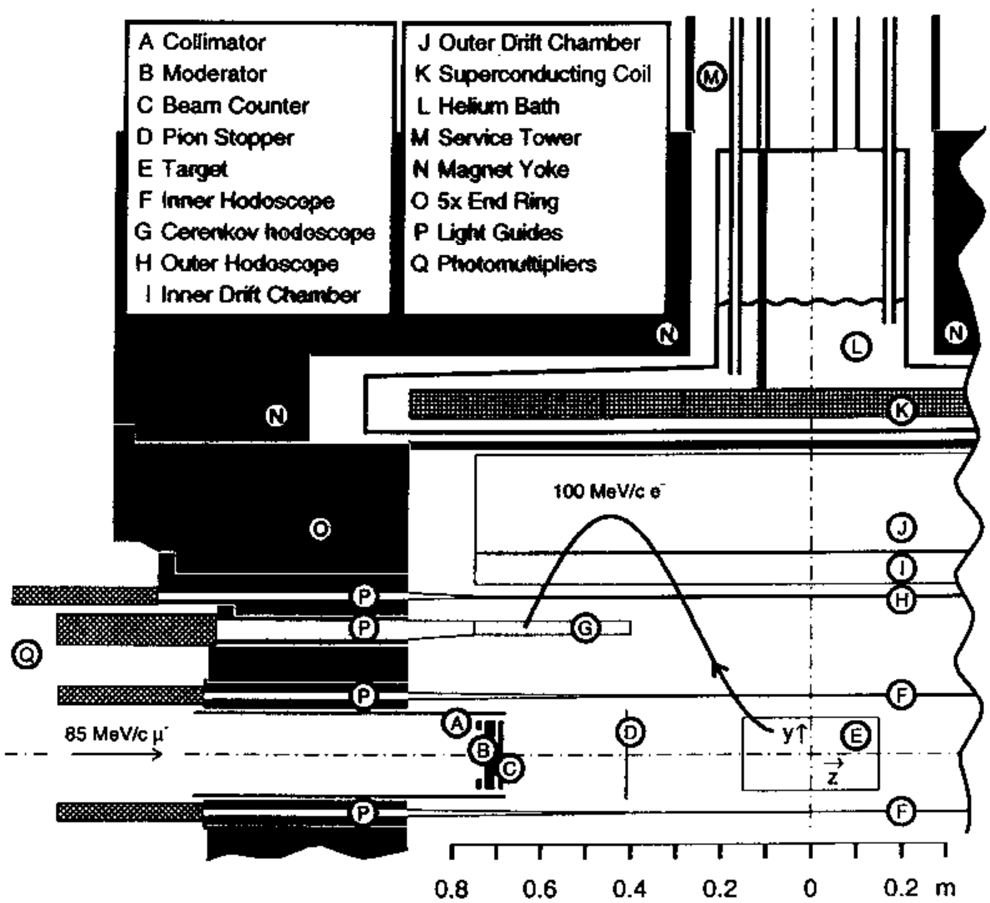
Outline of $\mu^- N \rightarrow e^- N$ Experiment

- Basic process:
  - Bring μ^- to rest in thin target
  - μ^- is captured in Coulomb orbit, cascades in
  - Can capture on the nucleus (inverse β decay)
  - Can decay in orbit
  - **May convert to electron**
- Interaction is coherent over the nucleus
  - Nucleus usually left in ground state
  - Rate for $\mu^- N \rightarrow e^- N$ enhanced for high Z nuclei
- For γ exchange, $\mathrm{B}(\mu^- N \rightarrow e^- N)$ / $\mathrm{B}(\mu^+ \rightarrow e^+ \gamma) \simeq 0.01$
- For other mechanisms, $\mu^- N \rightarrow e^- N$ can be more sensitive
- Experimental issues
  - Signature is very simple – 105 MeV electron
  - No accidental coincidence backgrounds
  - Other sources of 105 MeV electrons heavily suppressed
  - Balance higher sensitivity at high Z vs.
    less experimental difficulties at low Z

Search for $\mu^- N \rightarrow e^- N$ with SINDRUM2 at PSI

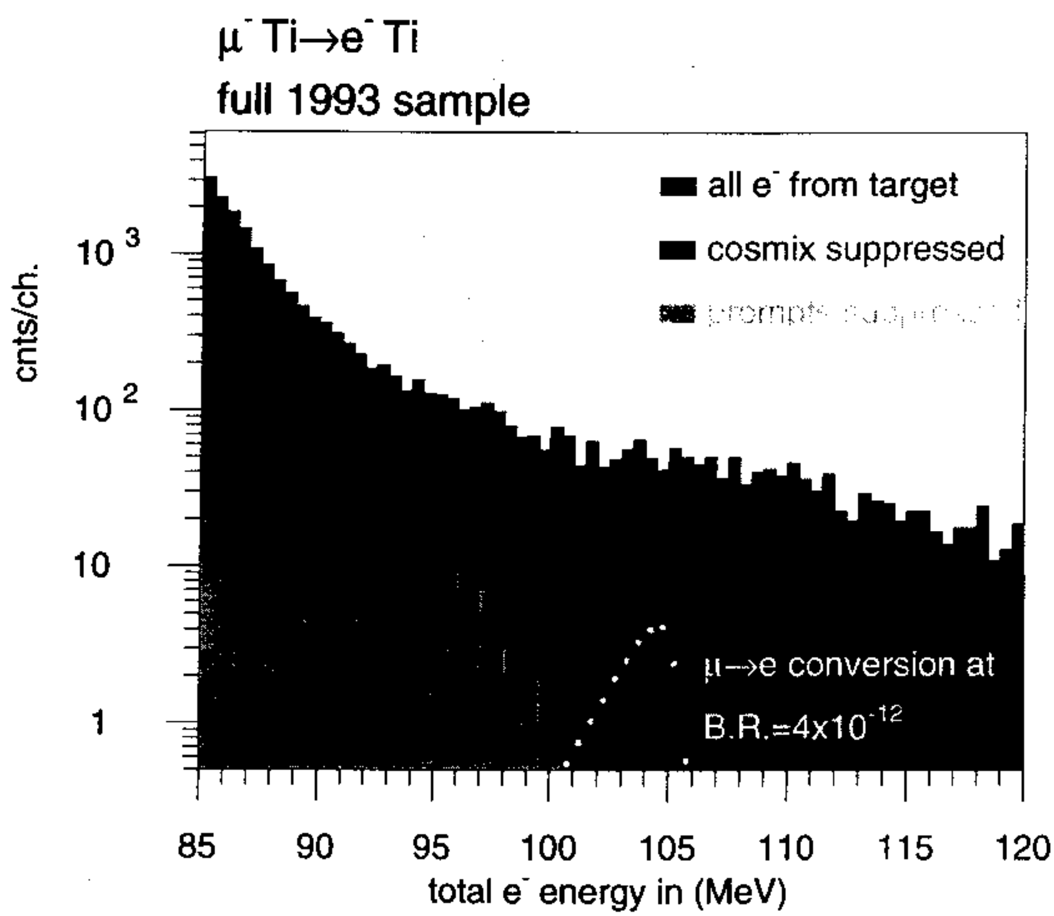
- μ^- beam derived from 1.5 mA, 590 MeV cyclotron (10^{16} protons per second at 1.2 GeV/c)
- Muon beam is a mixed 85 MeV/c π, μ, e beam with total flux $>\sim 10^7$ s^{-1}
- Data taking complete for first phase

$$\Gamma(\mu^- N \rightarrow e^- N)/\Gamma(\mu^- N \rightarrow \nu N') < 7.8 \times 10^{-13}$$



Search for $\mu^- N \to e^- N$ with SINDRUM2 ...

- Limited by "prompt" π, μ, e processes and detector rates
  - Eliminated with veto counter in beam
- Cosmic ray induced background eliminated by detecting throughgoing muon in detector
- Electron energy resolution limited by energy loss straggling and spectrometer resolution of FWHM~2.5 MeV

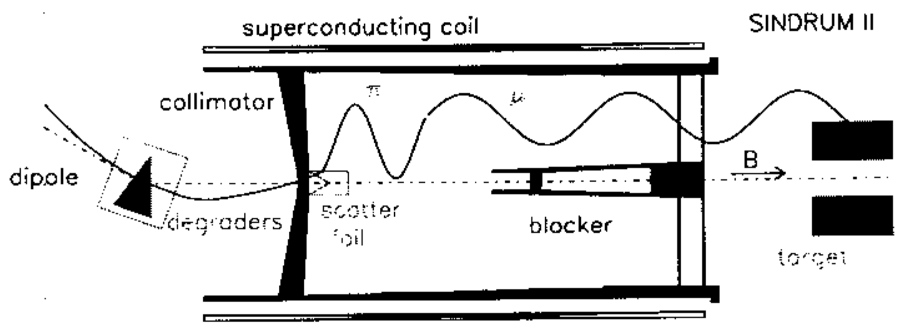


Expected Improvements from SINDRUM2

- New beam being built for SINDRUM2 at PSI
  - Reduce π beam energy below 70 MeV
    - eliminate prompt e backround
  - Absorb most pions
    - reduce prompt π background
  - Increase μ stop rate
    - no veto counter allows higher rate

Very pure μ beam
No time structure

the new muon channel



$10^9 \pi^- s^{-1}$ at 95 MeV/c

$10^8 \mu^- s^{-1}$ stops

high purity, no beam counter required

- Expected sensitivity of 4×10^{-14}
- Sensitivity then limited by available flux

P940

A Search for $\mu^- N \rightarrow e^- N$ with Sensitivity Below 10^{-16}

Muon – Electron COnversion

Proposal to Brookhaven National Laboratory AGS

M. Bachman, G. Kagel, R. Lee, T.J. Liu, W. Molzon, M. Overlin

University of California, Irvine

A. Empl, E.V. Hungerford, K. J. Lan,
B.W. Mayes, L.S. Pinsky, J. Wilson, M. Youn

University of Houston

R.M. Djilkibaev, V.M. Lobashev, A.N. Toropin

Institute for Nuclear Research, Moscow

A. Mincer, P. Nemethy, J. Sculli

New York University

W.D. Wales

University of Pennsylvania

D. Koltick, S. Carabello,

Purdue University

PRIMARY BEAM	8-20 GeV proton beam pulsed at 1.11 MHz
	4×10^{13} per spill
	2-3 second repetition rate, 50% duty cycle
PRIMARY TARGET	Radiation cooled tungsten
SECONDARY BEAM	Low energy, negative μ
	5×10^{11} per pulse
SECONDARY TARGET	Aluminum
TIME REQUESTED	4000 hours
SPOKESPERSON	W. Molzon
	Department of Physics and Astronomy
	University of California
	Irvine, CA 92697-4574
	714 824-5987
	wmolzon@uci.edu

plato.ps.uci.edu/~mec

September 1997

Essential Features of MECO Experiment

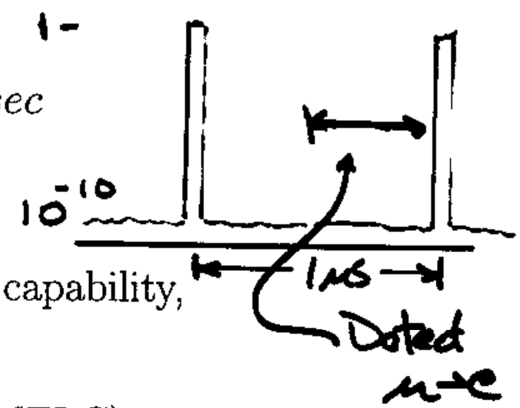
Proposal at MMF (Lobashov Djilkibaev)

- Very large muon flux
  - High Z target for enhanced pion production
  - Capture most pions in graded solenoidal field (MELC)
  - Produce $\sim 10^{-2}$ μ per proton with 8 GeV p beam (10^{-8} for SINDRUM2, 10^{-4} for MELC, 1 for μ collider)
  - Transported μ^- in curved solenoid
    Suppress high momentum negatives, all positives

- Pulsed beam to eliminate *prompt* backgrounds
  (electron detected in time with beam particle)

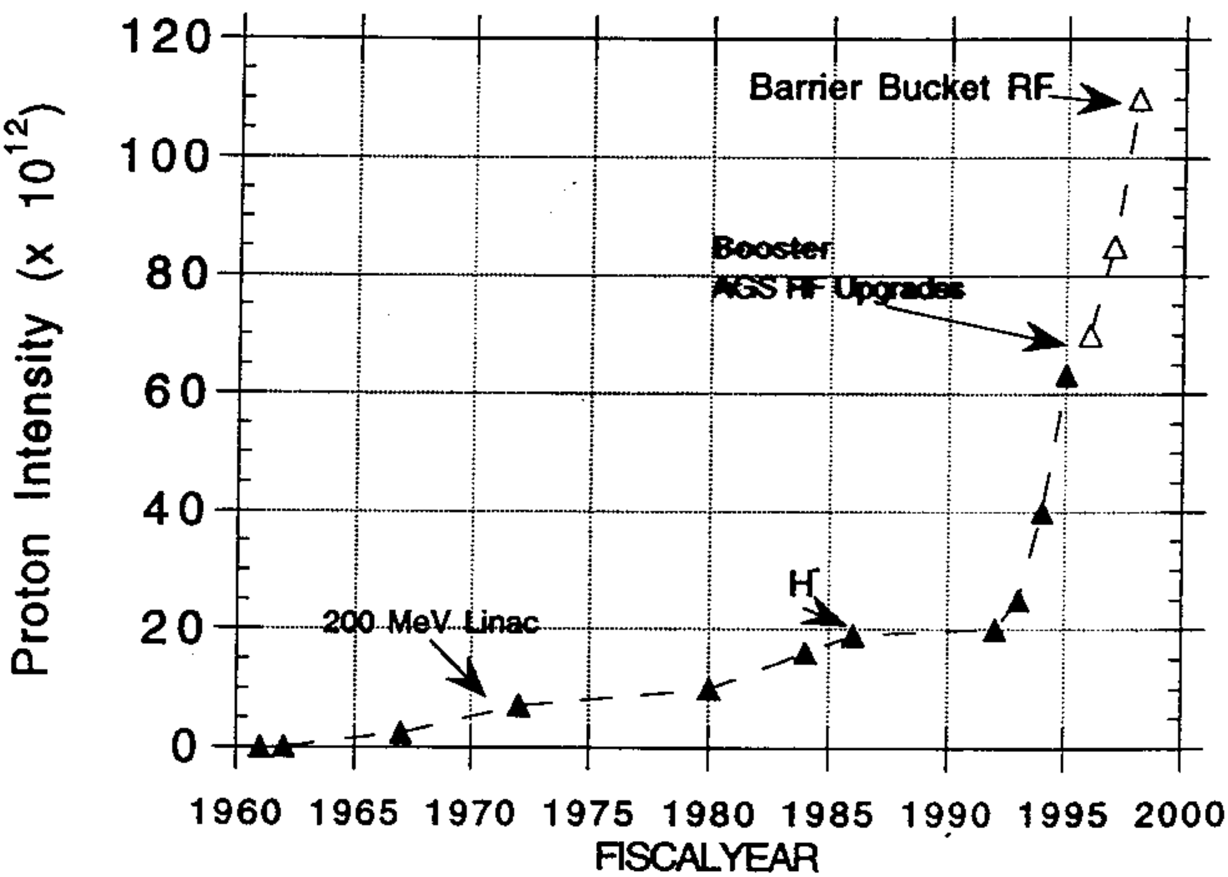
  $\tau_\mu(Al) \simeq 880ns$

  - Beam pulse length $<< \tau_\mu$
  - Time between pulses $\simeq \tau_\mu \simeq 1\ \mu sec$
  - Extinction between pulses $\simeq 10^{-10}$

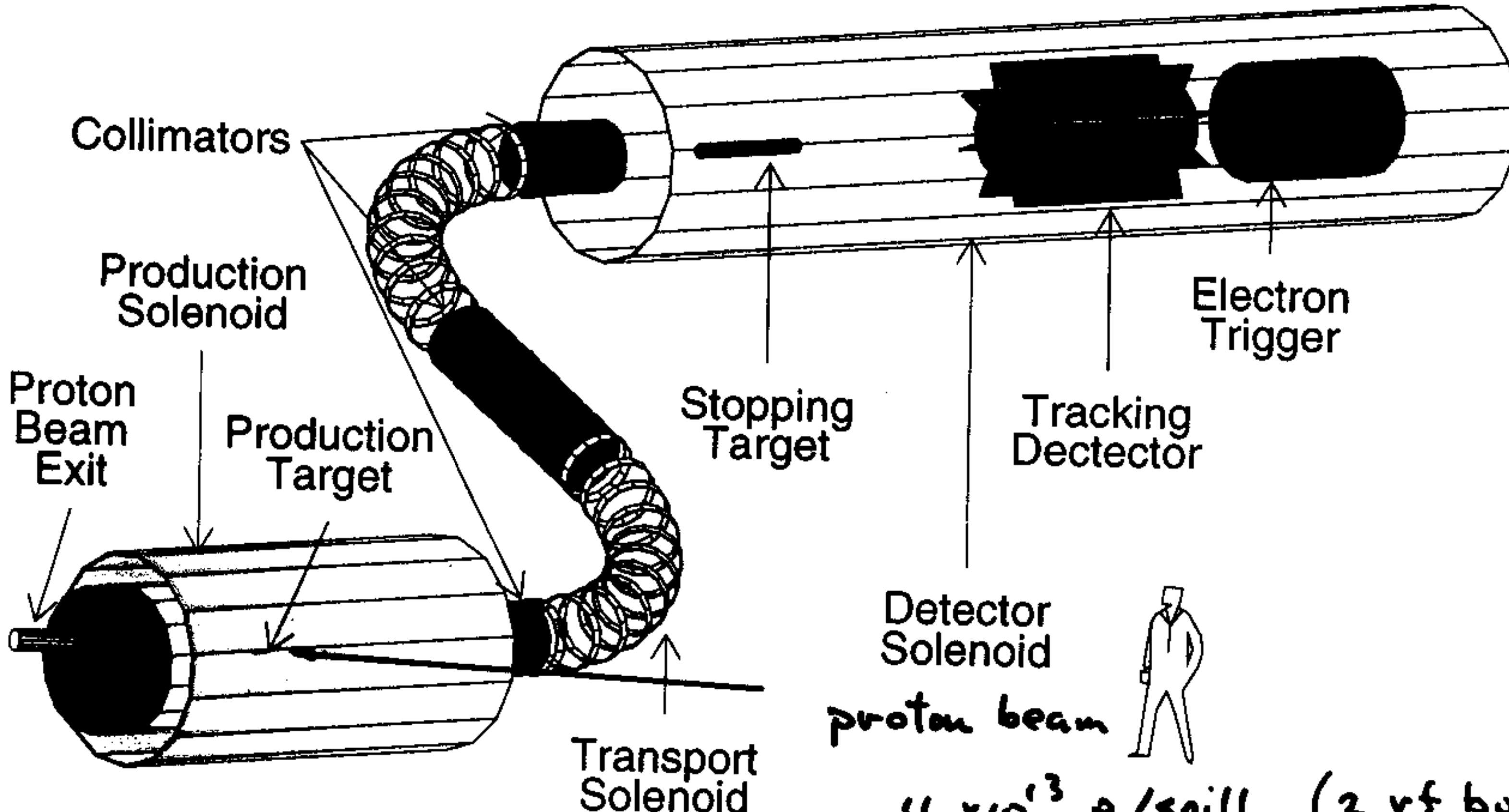


- Detector with improved resolution, rate capability, background rejection
  - Detector in graded solenoidal field (MELC)
    good acceptance and rate capabilities
  - Magnetic spectrometer with very high resolution

AGS PROTON INTENSITY HISTORY



mecoapparatusbw



4×10^{13} p/spill (2 rf bunches)

0.7 – 1.0 s cycle time

$\Rightarrow$ $4-6 \times 10^{13}$ p/s

wmolson

J. Steinberger + H. Wolfe

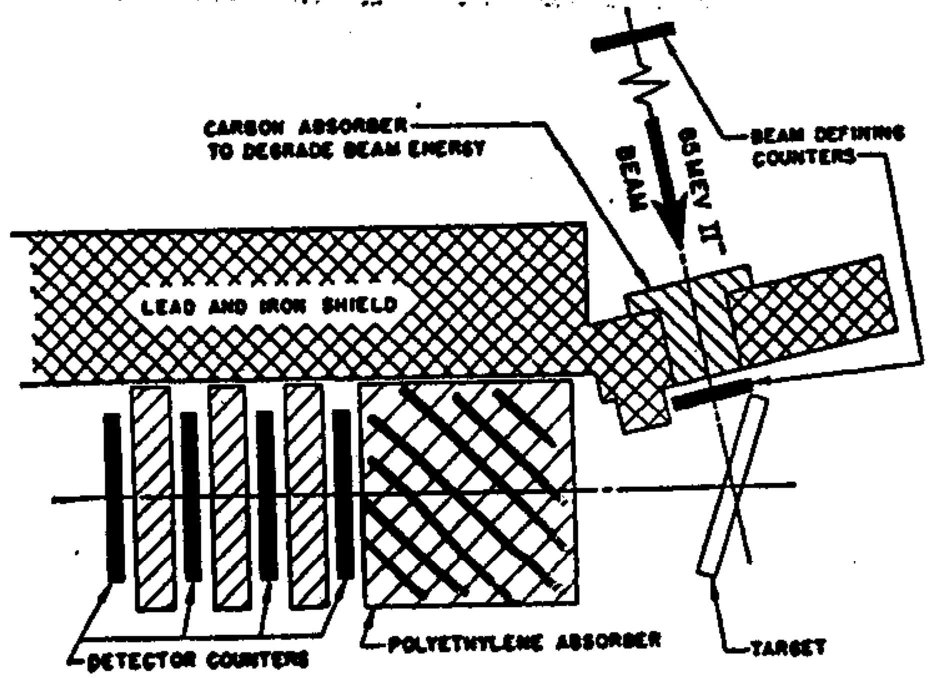


FIG. 1. Experimental arrangement.

Upper limit $\frac{\Gamma(\mu N \to e N)}{\Gamma(\mu N \to \nu N')} < 5 \times 10^{-4}$

[redacted]

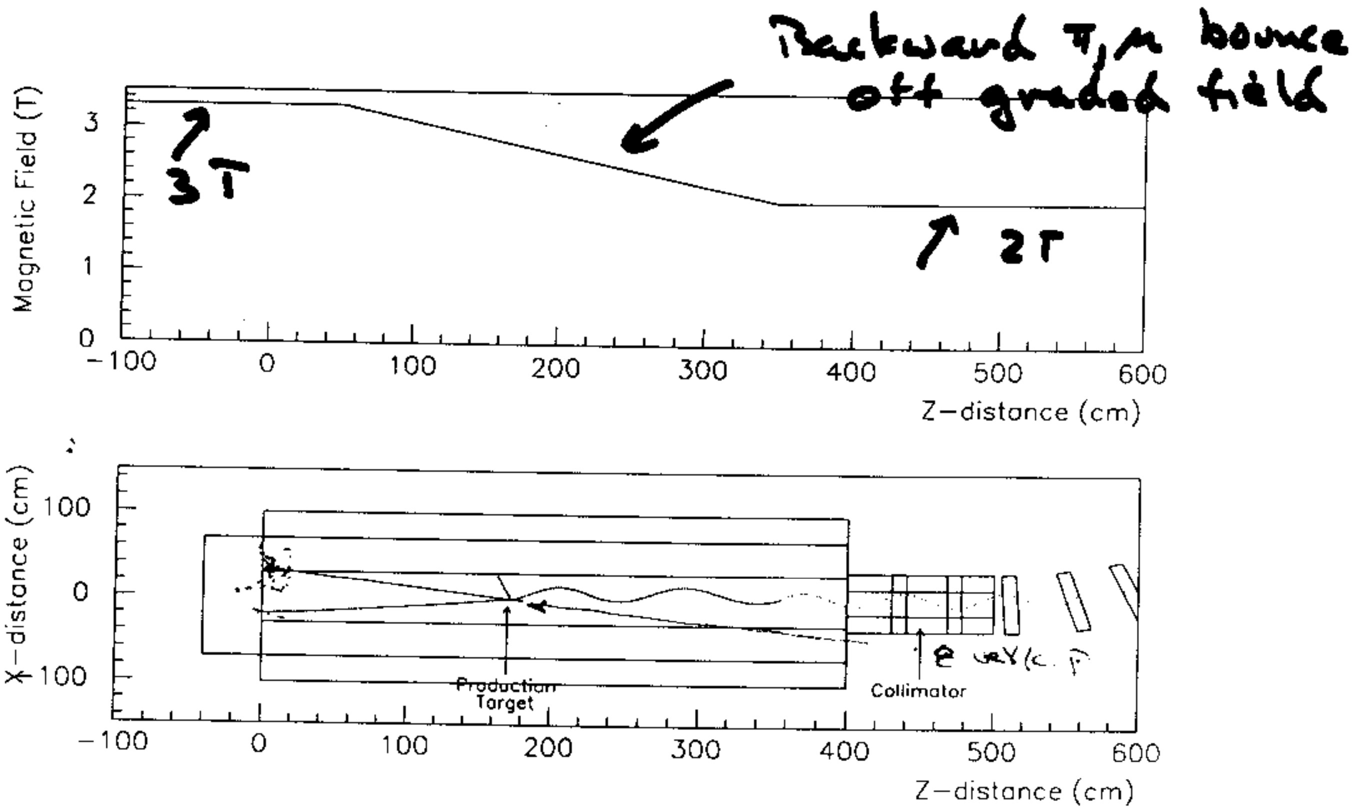
Running time 20 hrs

Poly In : 5 cts

Poly out 123 cts

Muon Production for MECO

- Target in solenoid with graded field to increase solid angle acceptance to $\sim 4\pi$
- High Z target for improved low energy muon yield
- Target backwards to minimize problems with dump



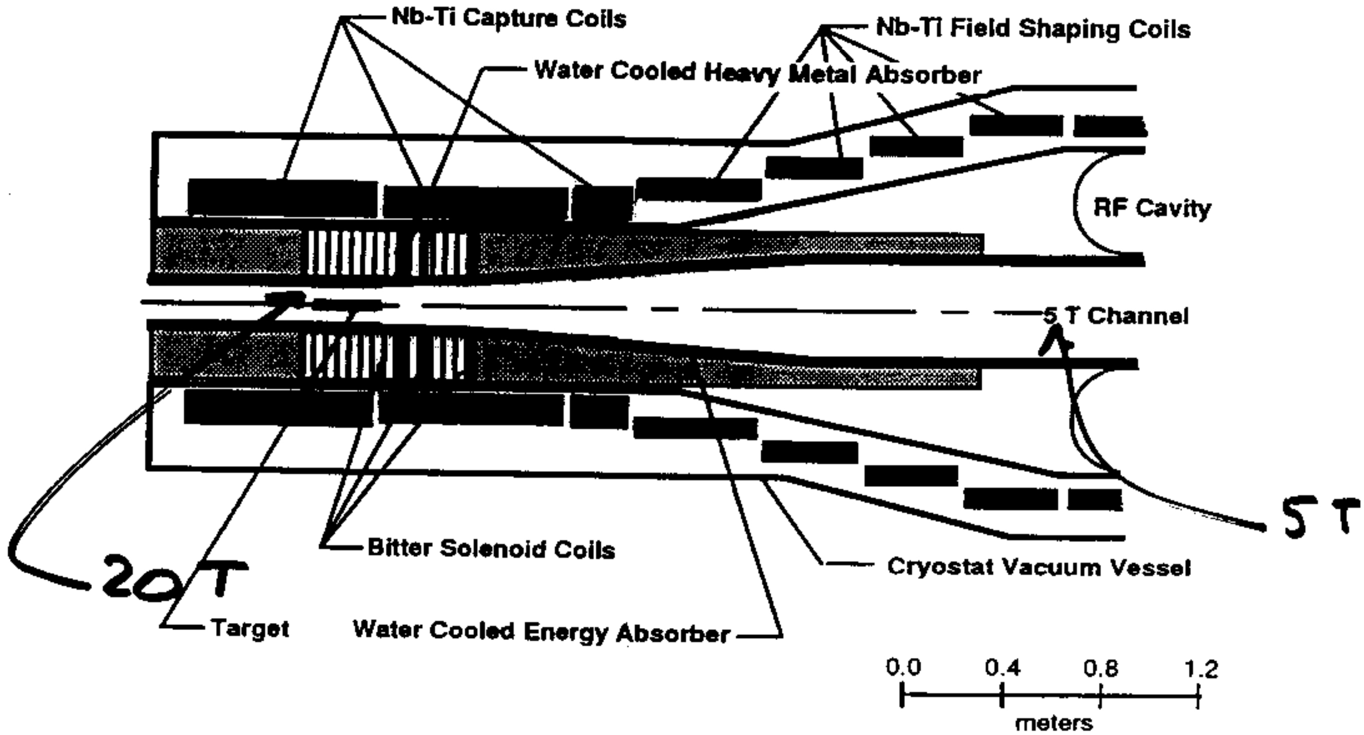


Figure 4.29: Option Two Capture and Transfer Solenoid System

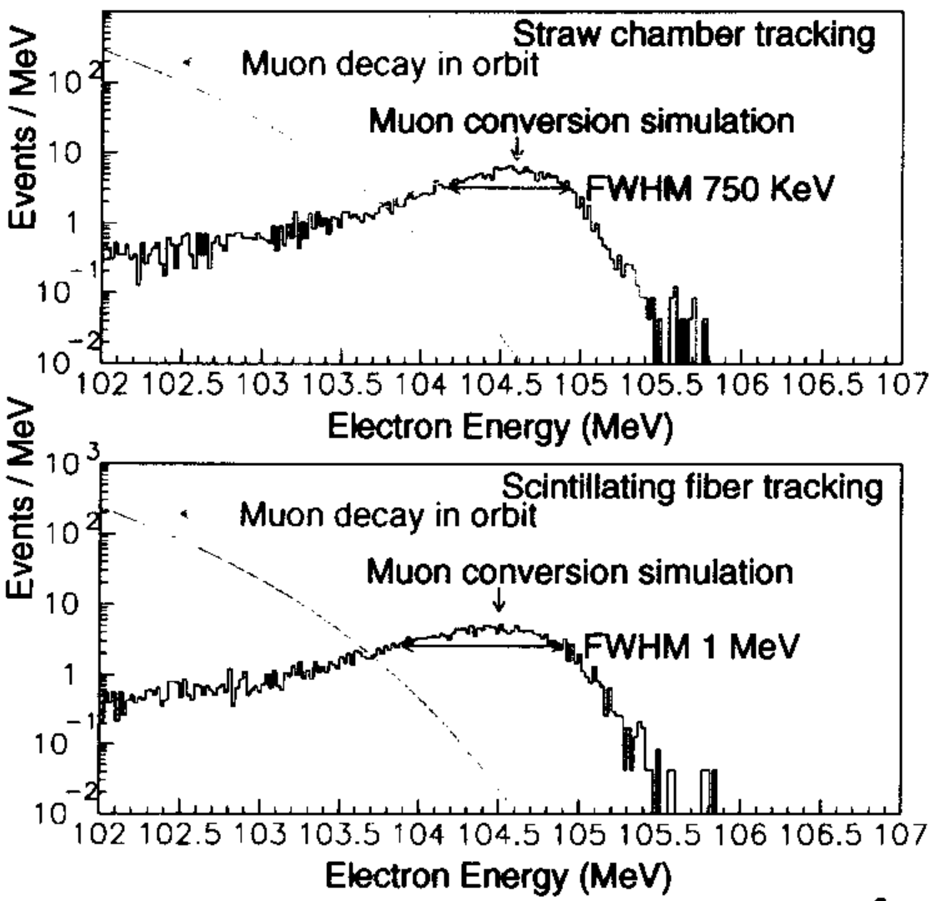
helium bath. Either approach can be used in the stored energy range shown in Table 4.4. The CICC system has the advantage of having the helium inside the conductor. The shell

Table 4.4: Parameters for the Capture and Transfer Solenoid System

Parameters	Option 1	Option 2
Magnet Section Length to x = 3 meters (m)	3.92	3.92
Cryostat Outside Diameter at x = 0 (m)	1.50	1.50
Cryostat Outside Diameter at x = 3 meters (m)	0.70	2.00
Warm Bore Diameter at x = 3 meters (m)	0.30	1.50
Capture Magnetic Induction at Target (T)	20.0	20.0
Length of the Target Region (m)	0.23	0.23
Length for Transfer to Transport Induction (m)	1.20	1.10
Nominal Transport Magnetic Induction (T)	5.0	5.0
Stored Magnetic Energy to x = 3 meters (MJ)	37.9	53.6
Stored Energy S/C Magnet to x = 3 meters (MJ)	22.4	38.1
Stored Energy for x > 3.0 meters (MJ/m)	1.58	22.1

MECO Detector Resolution Studies

- Important in eliminating μ^- decay in orbit background
- Full GEANT simulation of detector response
  - Energy loss in target (large effect, low energy tail)
  - Multiple scattering (dominates intrinsic resolution)
  - Position resolution (small contribution)
- No pattern recognition, effects of noise not yet incorporated
- Electron energy fitted by maximum likelihood method
- Signal and background plotted for $R_{\mu e} = 10^{-16}$



What is eff of high E tail?

12% of data with Gaussian response $\sigma = 1.25$ MeV
=> 1 bknd event

Principal source of backround.
- Can be reduced with improved resolution, tighten selection criteria

Expected MECO Sensitivity

- Expect ~5 $\mu^- N \rightarrow e^- N$ events for 10^7 s run, $R_{\mu e} = 10^{-16}$

Running time (s)	10^7
Proton flux (s^{-1}) now 4-6 with 0.7–1.0 s cycle time →	2×10^{13}
μ/p entering solenoid ×0.6 if 8 GeV p, pion yield uncertain } →	0.012
Stopping probability	0.37
μ capture probability	0.60
Fraction of μ which capture in time window	0.31-0.54
Electron trigger efficiency	0.90
Fitting and selection criteria	0.25
Detected events for $R_{\mu e} = 10^{-16}$	3.7-6.5

few×10^11 μ/sec

- Expect ~0.4 background events for 10^7 s run, $R_{\mu e} = 10^{-16}$

Source	Events	Comment
μ decay in orbit	0.190-0.330	S/N = 20 for $R_{\mu e} = 10^{-16}$
Radiative μ capture	<< 0.050	
μ decay in flight	< 0.003	without scatter in target
μ decay in flight	0.004	with scatter in target
Radiative π capture	0.007	from out of time protons
Radiative π capture	0.014	from late arriving π
π decay in flight	<< 0.001	
Beam electrons	< 0.020	← further suppressed by 0.1
Cosmic ray induced	0.004	10^{-4} CR veto inefficiency
Total background	0.290-0.410	

Possible MECO Timeline

Scientific Approval	October 1997
Strengthen collaboration	1997-1998
HEPAP recommendation to proceed	March 1998
Detector prototypes	1998 - 1999
Pulsed extraction tests	summer 1998
Beam emittance tests	fall 1998
Kicker prototype tests	fall 1998
Solenoid design	early 1999
Technical design	mid 1999
Detector and beam construction	1999-2001
Pulsed beam tests	early 2000
First muon beam	2001
Physics data	2002

Morse

AGS Letter of Intent-Search for an Electric Dipole Moment of Muon at the 10^{-24} e cm level.

The Muon EDM Collaboration

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University of Illinois

P. Cushman, D. Zimmerman
University of Minnesota

F. Farley
Yale University

*Spokesperson

W. MORSE

Physics

— Specific Models (e.g. Left-Right Symmetric ones) Predict:

$$d_\mu \sim 10^{-21} - 10^{-23}\ e\cdot cm$$

— **Generic SUSY Models**

$$d_e : d_n : d_\mu \simeq 1 : 5\text{-}15 : 200$$

PRD 55, (1997)
PRL 79 (1997)

Exp. Limits @ Present:

$$6\times10^{-27} : 10^{-25} : 1.1\times10^{-18}\ e\cdot cm$$

electron EDM ; neutron EDM ; μ EDM

L.O.I. ↓ $1\times10^{-24}\ e\cdot cm$

— **New Technique:**

Can take advantage of future Proposed Intense Muon Beams.

Spin Precession

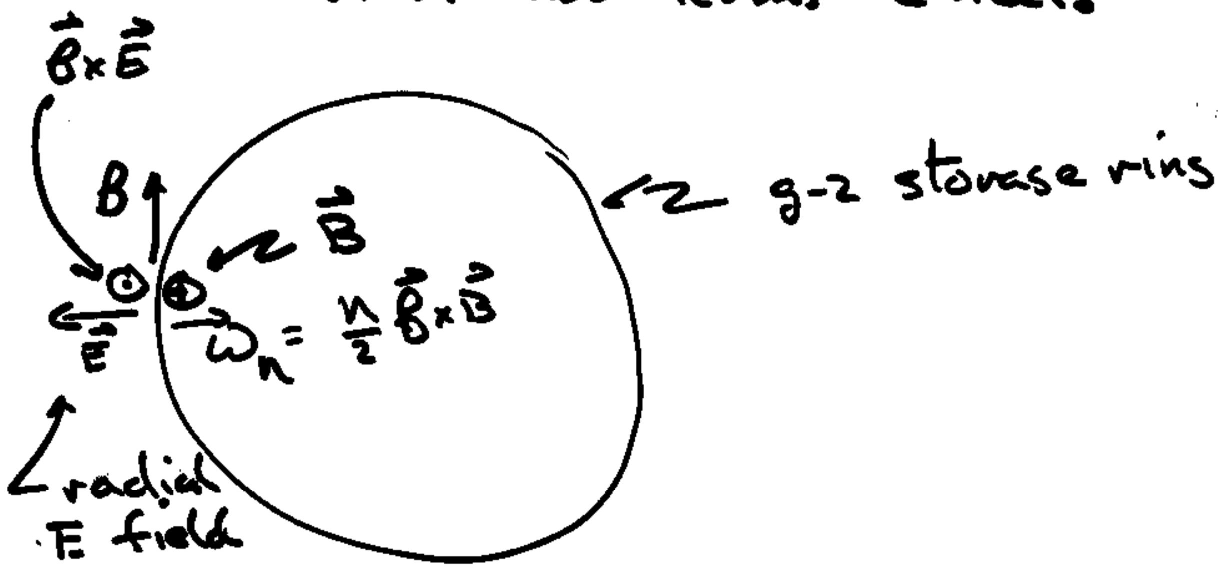
For g-2 measurement choose γ so this term = 0

$$\vec{\omega} = -\frac{e}{m}\left[a\vec{B} + \left(\frac{1}{\gamma^2-1} - a\right)\frac{\vec{\beta}\times\vec{E}}{c} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B}\right)\right]$$

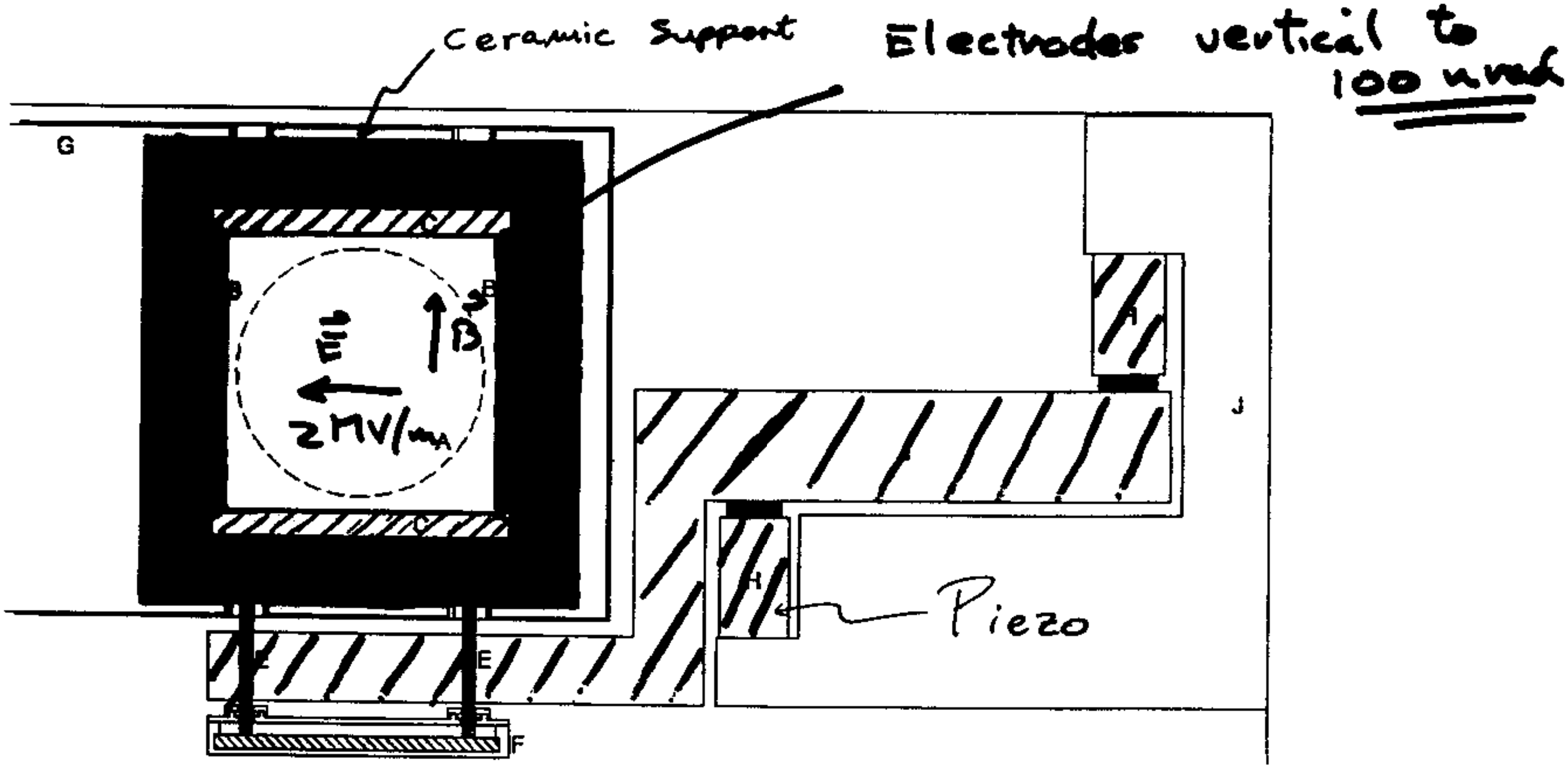
spin precession in storage ring magnetic field

EDM will cause precession

To measure EDM, choose γ so first two terms cancel!



$\langle E_v \rangle < 100$ nrad



Similar System used @ ESRF

W. MORSE

AGS Parameters:

Proton Momentum: 13.4GeV/c, Rep. Rate: 1.25s

Intensity: 100TP; Single Bunch Extraction 8 bunches each 1.2×10^{13} p

Stored μ^+ per injection: 8.6×10^7 [5×10^{12} at FMC]

Total Running Time for 10^{15} stored μ^+: 3200 hours

With 50% contingency: 4800 hours

μ Beam Requirements
polarization ≥ 50% ←
momentum 900 MeV/c ←
higher intensity could be used.

Muon Intensities for Stopping μ Expt. [and μ Collider]

- Data sparse, old
- Models don't fit all data
- Significant uncertainty in model predictions

BNL E910 will provide π production cross section measurements

Plans [preliminary] to measure yields in μ collider source configuration

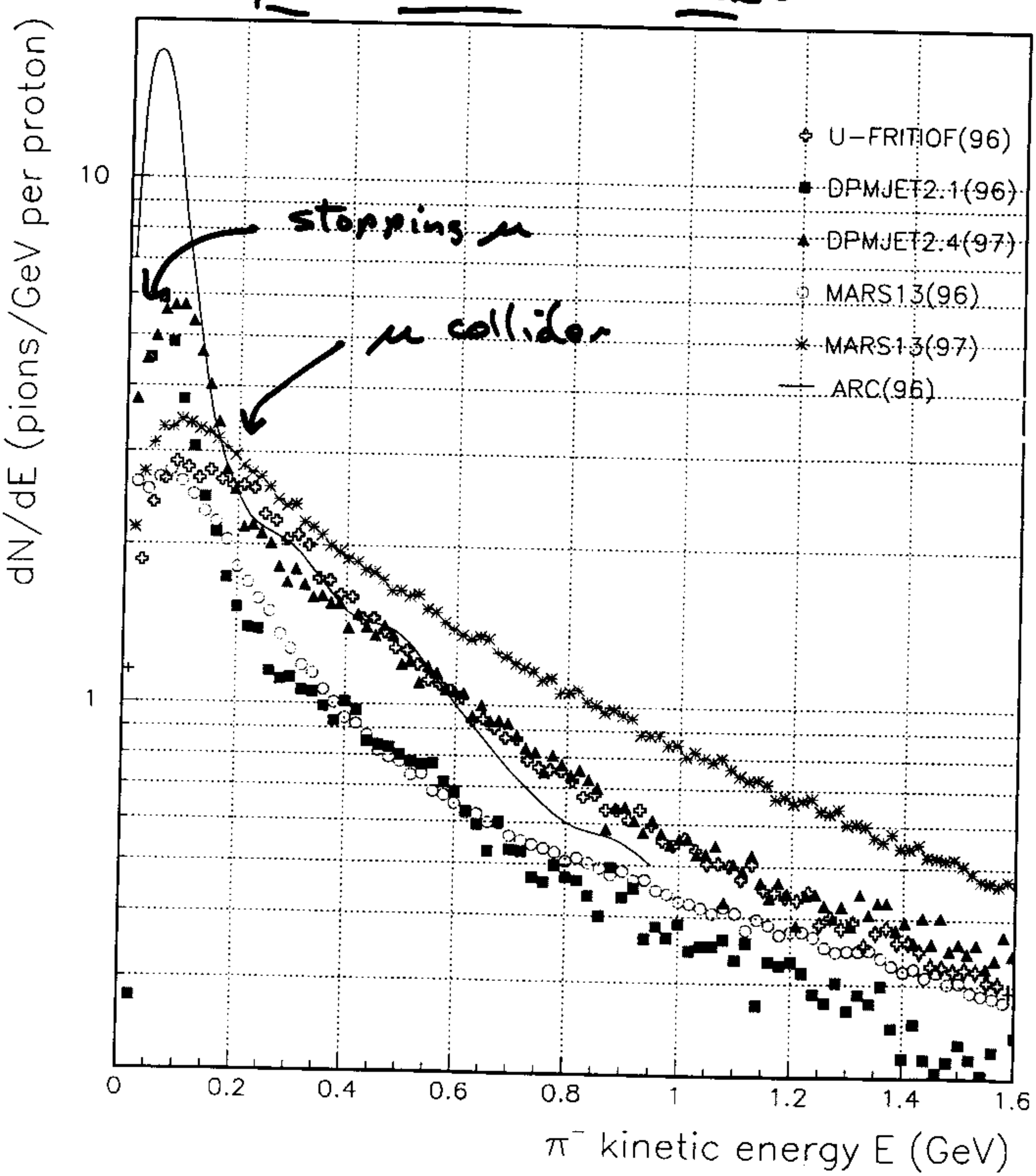
High Z target

High field solenoid capture scheme

N. Mokhov

97/11/05 11.48

pion production models



24 GeV/c protons on Hg

H. Kirk

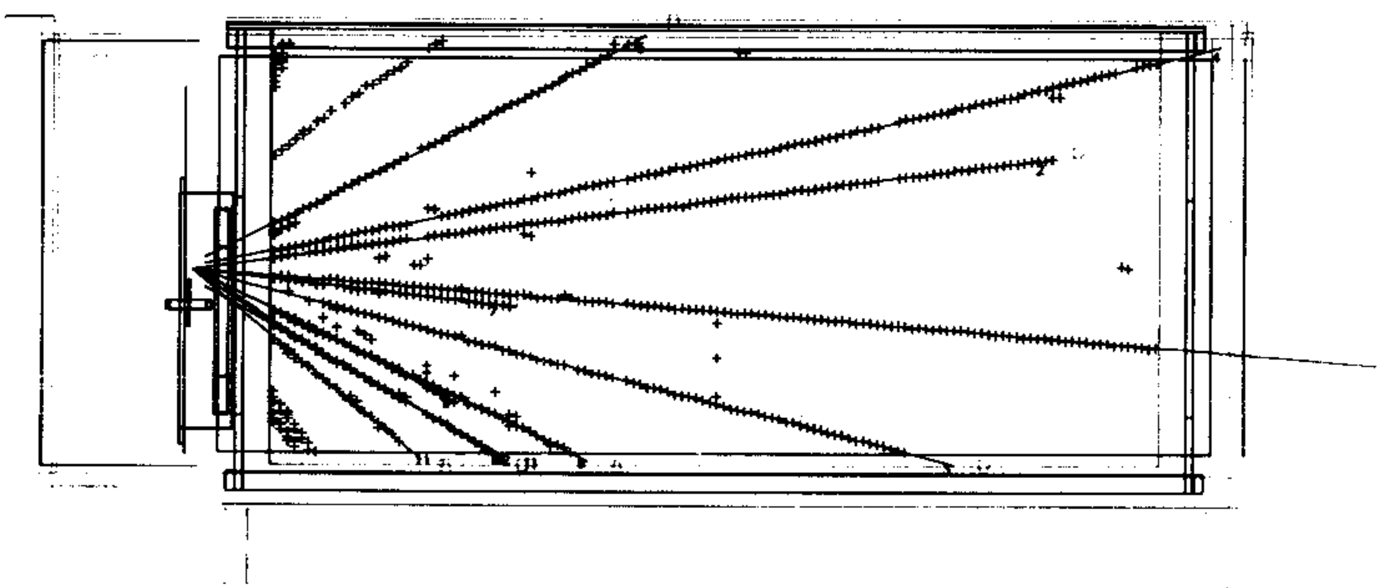
The AGS E910 experiment

Measurement of π production

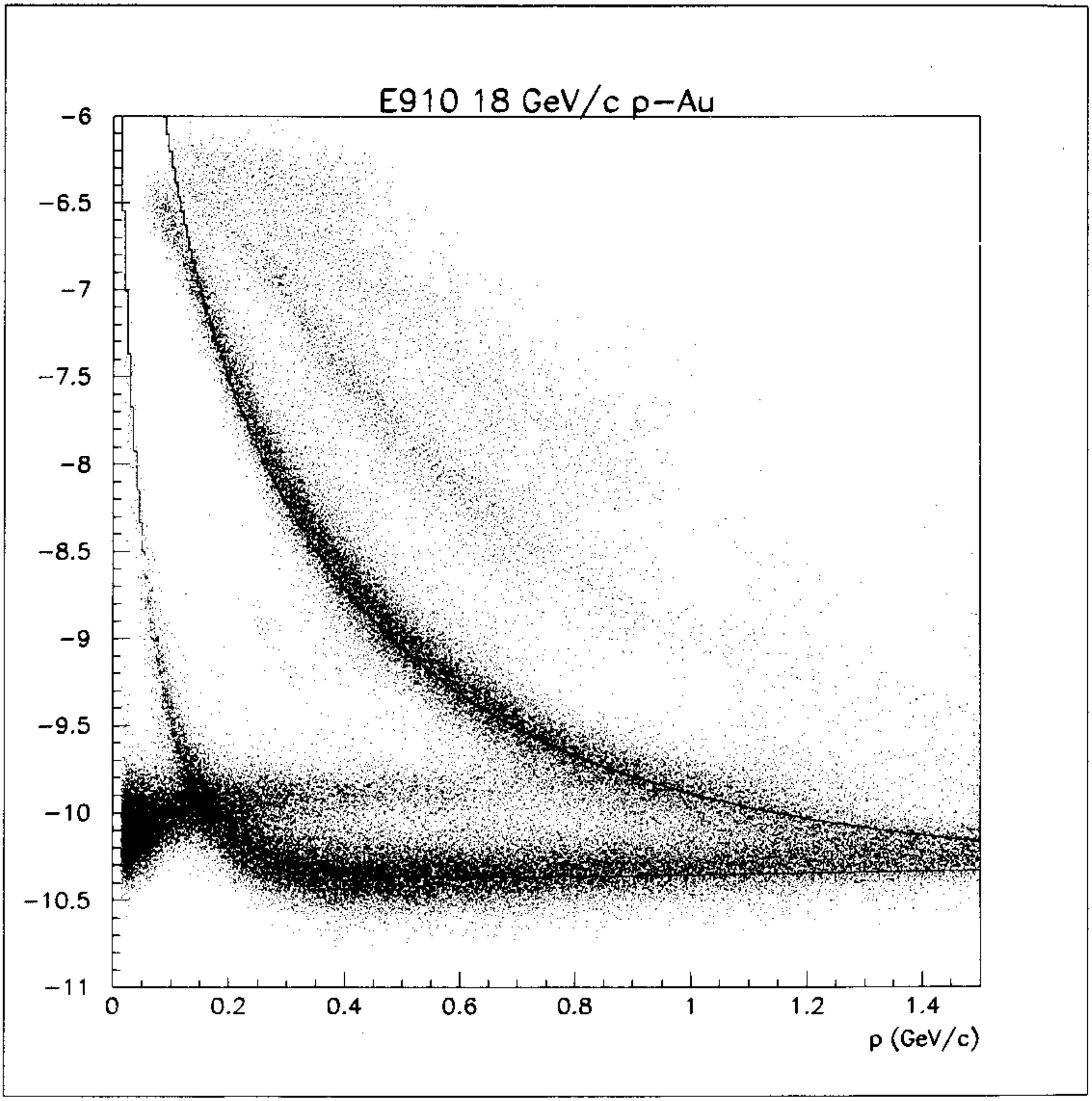
The experiment features:

- Proton beams of 6, 12.5 , and 18 GeV/c
- Various target material (Be, Cu, Au)
- High acceptance TPC for particle momenta down to 30 MeV/c
- Good particle identification in TPC by dE/dx
- Measurement of low-energy pion production cross-sections

H. Kirk

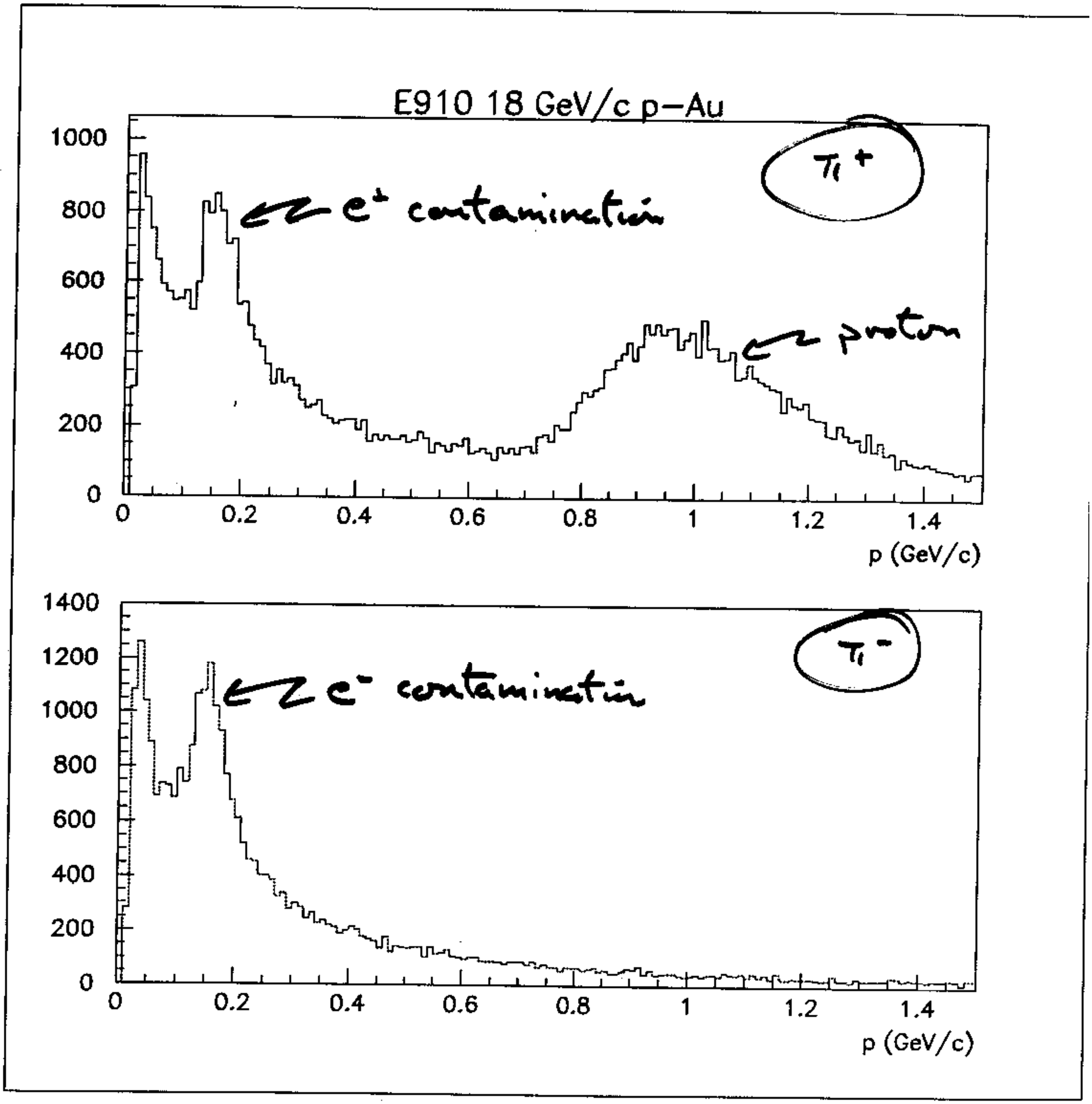


H. Kirk



E910 18 GeV/c p–Au
-6
-6.5
-7
-7.5
-8
-8.5
-9
-9.5
-10
-10.5
-11
0
0.2
0.4
0.6
0.8
1
1.2
1.4
p (GeV/c)

H. Hiro


E910 18 GeV/c p–Au
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
p (GeV/c)
π+
e+ contamination
proton
1400
1200
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
p (GeV/c)
π−
e− contamination

Muon Source Parameters for the Workshop

Parameters of muon bunches downstream of the ionization cooling channel

	Narrow σ_p	Broad σ_p
muons per bunch	5×10^{12}	5×10^{12}
μ^+ bunches per cycle	1	1
μ^- bunches per cycle	1	1
momentum (MeV/c)	200	200
σ_p/p	5%	10%
bunch length (cm)	1.5	10 ⇐ *
normalized $\varepsilon_\perp$ (mm–mr)	$200\,\pi$	$60\,\pi$
repetition rate (Hz)	15	15
μ^+ per year (10^7 secs)	7.5×10^{20}	7.5×10^{20}
μ^- per year (10^7 secs)	7.5×10^{20}	7.5×10^{20}

How does the μ physics program described use the low energy μ beam from μ collider front end?

International Comparison

Main Ring

	Energy (GeV)	Particle per pulse	Repetition (Hz)	Current (μA)
This 50GeV PS	50	~~40~~ 30 x 10^{13}	0.3	10.0
BNL AGS	30	~~6~~ 10 x 10^{13}	0.3	3.0
future pulsed	8	[illegible] x 10^{13}	1.0	—
FNAL MI	120	3 x 10^{13}	0.3	1.3
FNAL Booster	8	5 x 10^{12}	7.5	
CERN PS	26	2 x 10^{13}	0.5	1.6
KEK 12GeV PS	12	0.4 x 10^{13}	0.3	0.16
Serpukhov	70	1.7 x 10^{13}	0.1	0.27

Booster

	Energy (GeV)	Particle per pulse	Repetition (Hz)	Current (μA)
This 3GeV BS	3.0	5.0 x 10^{13}	25	200
Rutherford ISIS	0.8	2.5 x 10^{13}	20	200
LAMPF PSR	0.8			100
PSI	0.6			1500
KEK Booster	0.5	0.2 x 10^{13}	20	6

Beam requirements somewhat different

μ collider

very short p bunch - capture π, μ in *pulsed* RF cooling channel

⇒ 200 - 300 MeV/c beams
very intense cool beams

low energy μ stopping experiments

limited by instantaneous rates
- backgrounds [$\mu \to e\gamma$]
- detector issues [$\mu^- N \to e^- N$]

helped by μ polarization [$\mu \to e\gamma$]

Possible synergism

Use just μ source, without cooling - build μ beam as in MECO

Run pulsed cooling channel in CW mode - perhaps impossible [decelerate ?]

μ EDM can use very intense pulsed beam - requires significant polarization.

Conclusions

- Compelling case for "low energy" μ experiments

  LFV Searches

  - fundamental symmetry tested
  - substantial discovery potential in many SM extensions
  - $\mu^- N \rightarrow e^- N$

    BF < 10^{-13} in near future - SANDRUM 2, running at PSI

    BF < 10^{-16} in some years MECO, approved at BNL
  - $\mu^+ \rightarrow e^+ \gamma$

    BF < 10^{-11} soon from MEGA
    Plans for 10^{-14} experiment PSI, JHF

  T Violation

  - μ EDM to 10^{-24} e cm proposal at BNL in g-2 ring

- Synergism with FMC
  - People working hard to understand how to use presently available machines
  - Detailed beam requirements present challenges in using FMC beam.
    - time structure
    - polarization
- Higher intensity p driver will allow cleaner, more intense μ beams

Pattern Recognition and Pileup Issues

- Rates of order 200,000 per detector element [~ 10^{11} μ stops / sec]
- Tracking detector integration time ~30 ns
- Local information on track angle θ precision ~ 50mr
- Local timing information with precision 2-3 ns