Other Physics with an Intense p/π/K/μ/ν Source

$\times 10^6$ more!

proposed new working group (+Gian Giudice)

(FNAL workshop: AIP 435)

- Outline possible physics topics

	p	π	K	μ	ν
Beyond SM					
SM					
non-particle physics					

fill in the blanks!

- Organization of studies

volunteers needed!

- Framework for presenting results?

Could this be an important supplement to the physics case?

- Interaction with accelerator group

pulsed vs continuous, ...

1 - Beyond the Standard Model

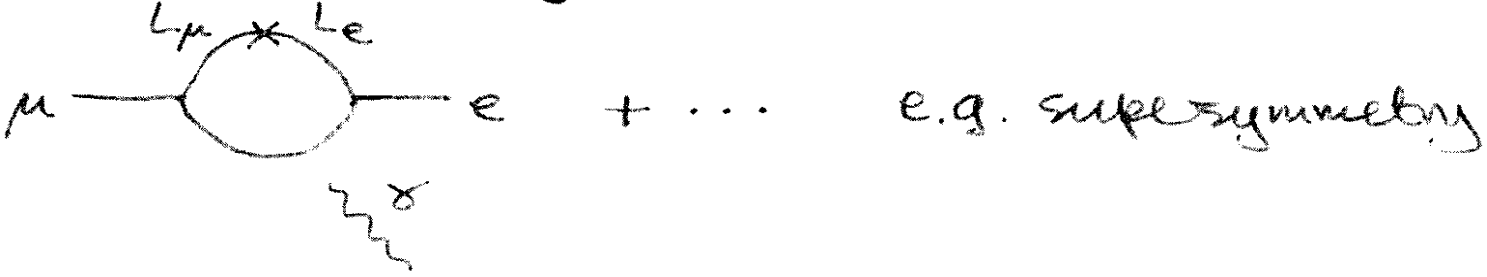
most important physics argument

μ

- <u>lepton flavour violation</u>

$\mu \to e\gamma$, $\mu \to 3e$, $\mu Z \to eZ$

put back on agenda by ν oscillations:



+ ... e.g. supersymmetry

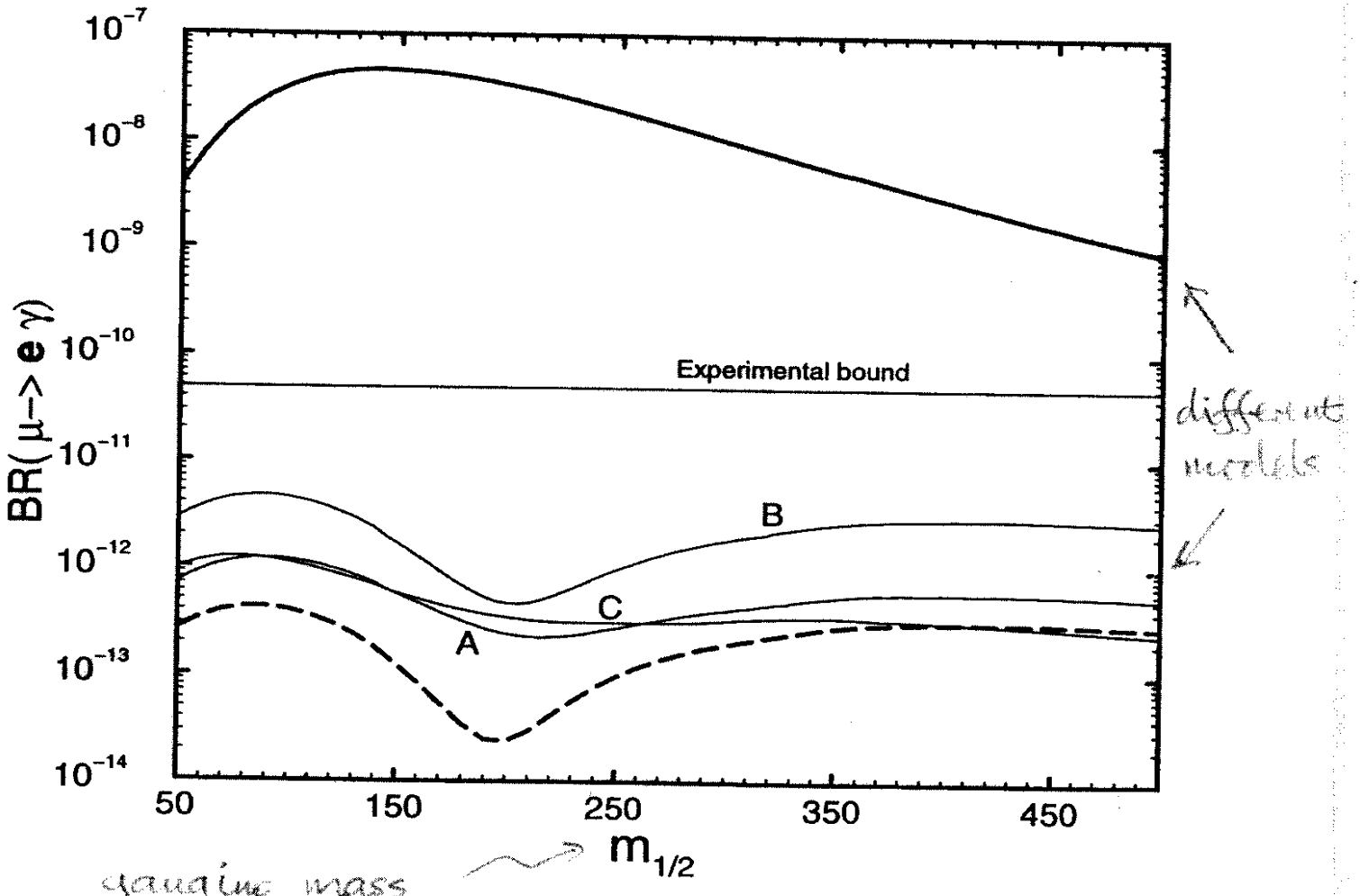
could be close to present experimental limits

limits	Now	Planned	Possible	Pulsed / Continuous
$\mu \to e\gamma$	$< 1.2 \times 10^{-11}$	10^{-14}		C
$\mu \to 3e$	$< 1.0 \times 10^{-12}$			C
$\mu Z \to eZ$	$< 6.1 \times 10^{-13}$	$< 10^{-16}$	10^{-18} ?	P

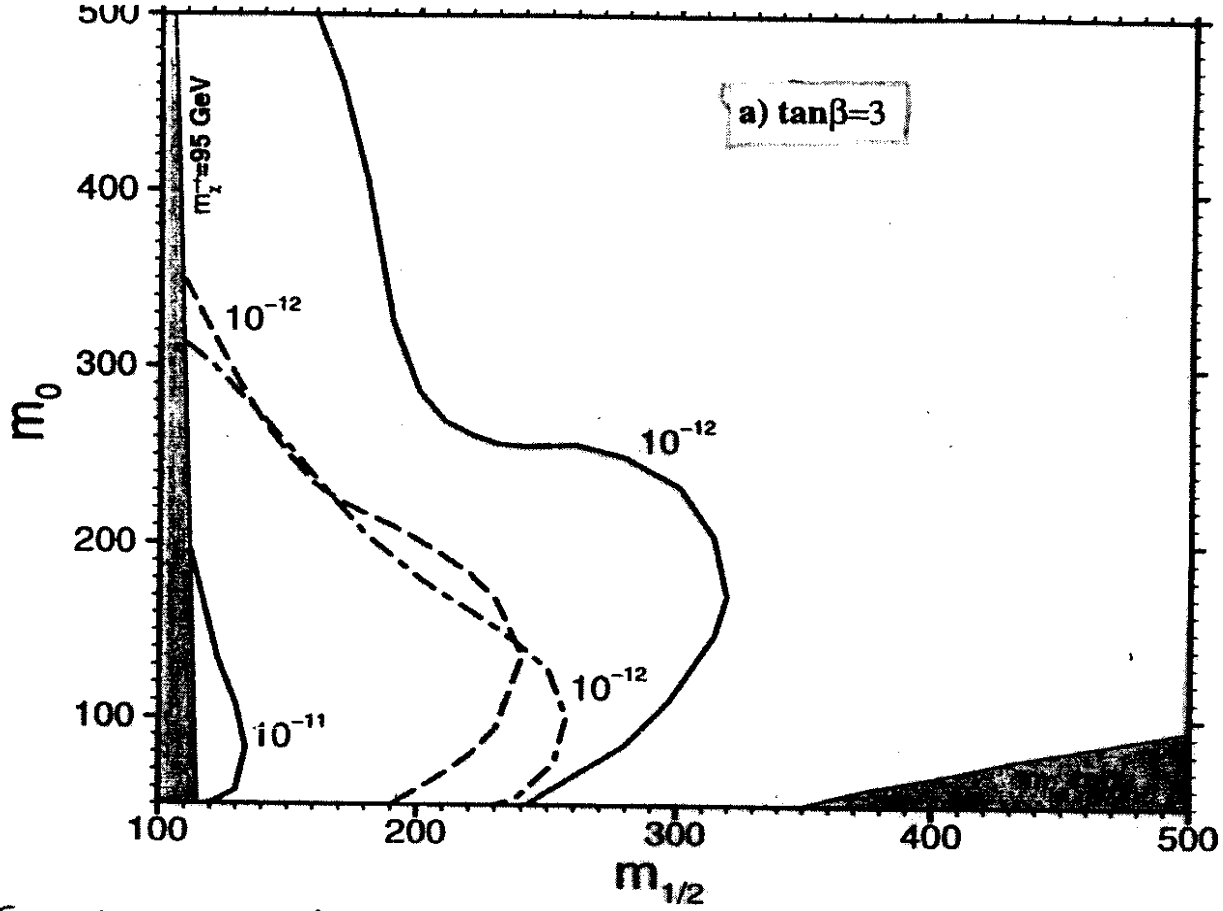
also $\mu^- Z \to e^+ (Z-2)$, $\mu^- e^+ \to \mu^+ e^-$

$B(\mu \to \gamma e)$ Calculations

in some supersymmetric GUTs
consistent with ν oscillation data

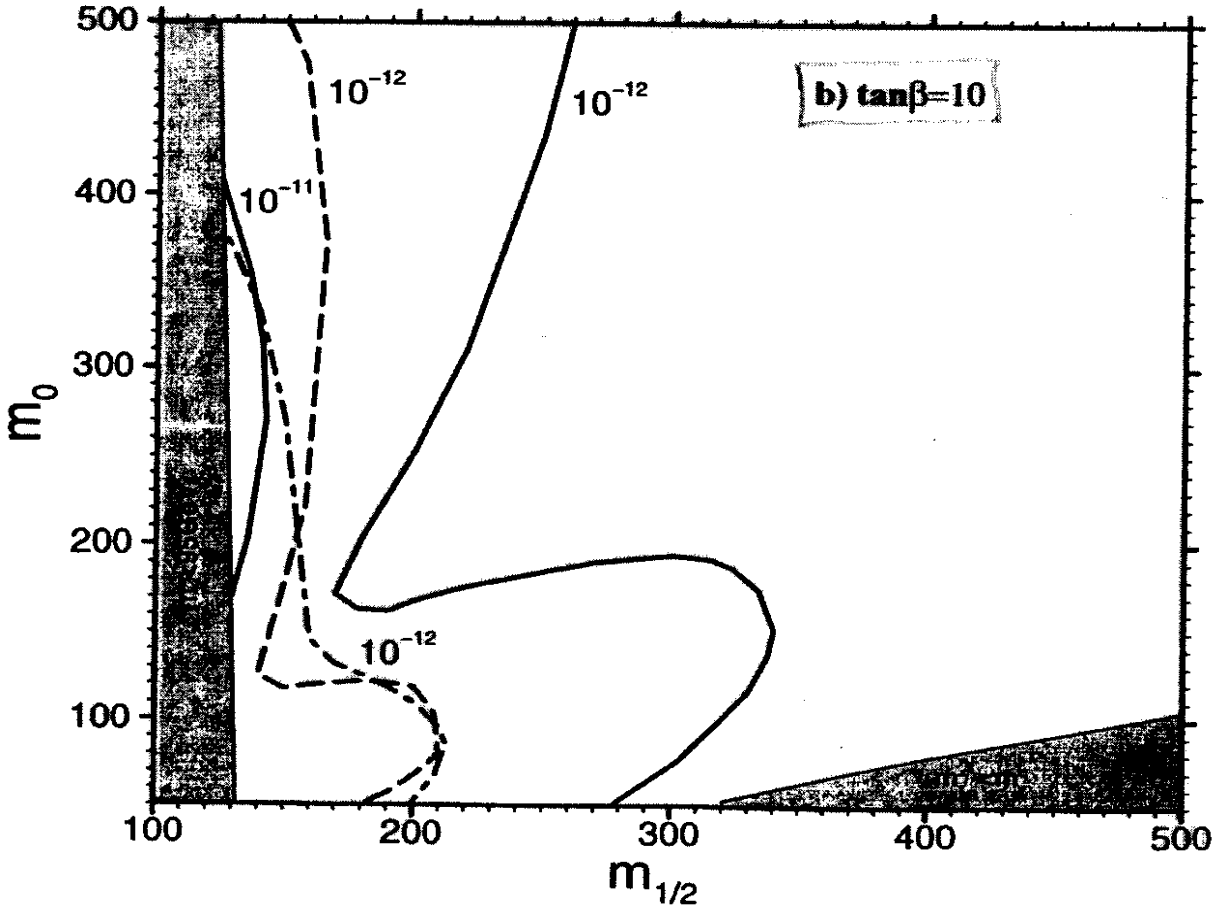


(J.E. + Gomez + Leontaris + Lola + Nanopoulos)



Contours of $\mu \to e\gamma$ branching ratio

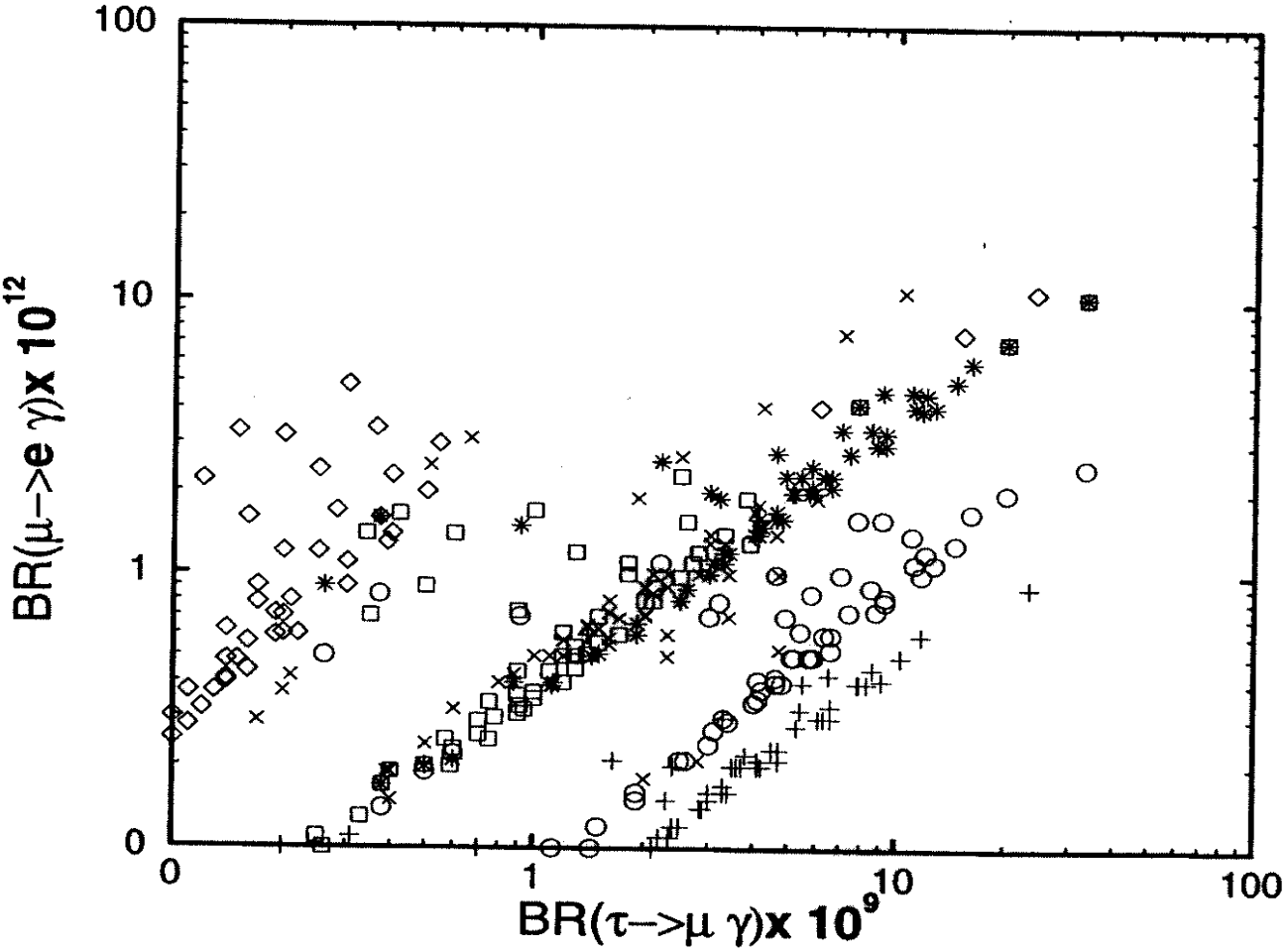
in representative GUT



(J.E.+ Gomez + Leontaris + Lola + Nanopoulos)

$B(\mu \to e\gamma)$ compared with $B(\tau \to \mu\gamma)$

in various supersymmetric models



(J.E. + Gomez + Leontaris + Lola + Nanopoulos)

$(g-2)_\mu$

current error $\delta a_\mu = 840 \times 10^{-11}$

BNL experiment $\rightarrow 40 \times 10^{-11}$

cf supersymmetry $\sim 140 \times 10^{-11} \tan\beta \left(\frac{100\,GeV}{m_{susy}}\right)^2$

But hadronic uncertainty

$\delta a_\mu \sim 40 \times 10^{-11} \longrightarrow 20 \times 10^{-11}$?

could one interpret a more accurate result?

d_μ

electric dipole moment

cf electron: expect $d_e/d_\mu \simeq m_e/m_\mu \simeq \frac{1}{200}$

present limit: $|d_e| < 4 \times 10^{-27}$ e.cm

BNL proposal: $|d_\mu| \rightarrow \sim 10^{-24}$ e.cm

useful constraint on CPX in supersymmetry

μ atoms

parity violation in μB test of

Z', LQ, contact terms : cf Cs

m_{ν_μ}

K

"all the usual suspects"

$K_L^0 \to \mu^{\pm} e^{\mp}$ currently $< 3.3 \times 10^{-11}$

$K^+ \to \pi^+ \mu^{\pm} e^{\mp}$ $< \begin{cases} 2.1 \times 10^{-10} \\ 7 \times 10^{-9} \end{cases}$

$K_L \to \pi^0 \mu e$?

2- Standard Model

[μ] τ_μ

precision measurement of G_μ

currently $\pm 1 \times 10^{-5}$

fundamental constant of Natwe

how could one interpret a measurement?

cf $\delta M_Z \sim 2.2 \times 10^{-5} M_Z$

Michel parameters

search for right-handed currents?

Muonium

spectroscopy to test QED

[ν]

deep-inelastic scattering

measwe $\sin^2\theta_W$ error $\rightarrow$ < 0.0010

V_{CKM}

polarized target charm production

Physics of Muonic Atoms

TABLE 1. Some possibilities for laser spectroscopy of muonic atoms. The potential is given for line centers determined to 1 part in 10^3. (From [10]).

System & Transition	Laser System & Frequency	Physics Interest and Potential
Muonium $1S-2S$	CW dye/diode laser with an enhancement cavity 2×1228.5 THz	Measures Lamb shift (without nuclear structure effects), QED recoil, μ^+ mass. Improve current 0.8 % Lamb shift and 5 ppm μ^+ mass determinations by several orders of magnitude.
Muonic ^{4}He ion $2S-2P$	Dye or Ti:Sapphire 369.6, 334.2 THz	Test QED vacuum polarization. Improve current 0.2% α-particle charge radius measurement by two orders of magnitude.
Muonic ^{4}He ion $3D-3P$	Carbon dioxide 30.4 THz	Probes QED vacuum polarization (insensitive to nuclear structure). Sensitivity of 1/5 of linewidth would provide new test of vacuum polarization. Potential for factor 200 more.
Muonic Hydrogen $2S-2P$	Carbon monoxide or nonlinear mixing 48.4 THz	Measures proton charge radius, polarizability, QED vacuum polarization. PSI aims at a 500 MHz measurement, giving $\langle r_p^2\rangle^{1/2}$ to a few parts in 10^4.
Muonic Hydrogen $1S, F=0, F=1$	Difference frequency generation 43.9 THz	Measures proton charge radius and polarizability. A 10 GHz uncertainty determines $\langle r_p^2\rangle^{1/2}$ to about 2%. Potential for five more orders of magnitude.
Muonic Hydrogen $3D-3P$	Free electron laser 1.6 THz	Probes QED vacuum polarization (insensitive to nuclear structure). Potential for 6 ppm test of vacuum polarization, an improvement of 1000 over current tests.

(Kawall et al.: AIP 435)

Measurement of $\sin^2\theta_W$ in $\nu N \to X$

TABLE 1. $\sin^2\theta_W$ **uncertainties (not all the errors from NuTeV are available).**

SOURCE OF UNCERTAINTY	CCFR	NuTeV	μ-Col (20M)
data statistics	0.0019	0.0019	0.0004
Monte Carlo statistics	0.0004		
TOTAL STATISTICS	0.0019	0.0019	0.0004
ν_e flux	0.0015	0.0006	$<<$ 0.0004
Cosmic Ray Background	$<$0.0001	$<$ 0.0001	
Transverse Vertex	0.0004	0.0004	$\sim$ 0
Energy Measurement			
Hadron Energy Scale (1%)	0.0004	0.0004	0.0004
Muon Energy Loss in Shower	0.0003	0.0002	$\sim$ 0.0001
Muon Energy Scale (1%)	0.0002	0.0002	$\sim$ 0.0002
Hadron Energy Resolution	0.0001		$<$ 0.0001
NC/CC E_{had} Difference	0.0001		$<$ 0.0001
e/π ratio	$<$0.0001		
Event Length			Irrelevant
Hadron Shower Length	0.0007	0.0001	
Counter Fiducial Size	0.0005	0.0004	
Counter Efficiency	0.0004	0.0001	
Counter Noise	0.0001	0.0002	
Vertex Determination	0.0003	0.0007	
TOTAL EXP. SYST.	0.0019	0.0012	$<$ 0.0004
Charm Production, $\bar{s}$			
($m_c = 1.31 \pm 0.24$ GeV)	0.0027	$\sim$ 0	$\sim$ 0?
Higher Twist	0.0010	0.0006	Need to be controlled
Longitudinal Cross-Section	0.0008	N/A	Need to be measured
Charm Sea, ($\pm$100%)	0.0006	0.0004	Need to be measured
Non-Isoscalar Target	0.0004	0.0004	$\sim$ 0 for D_2
Structure Functions	0.0002	0.0001	0.0001
Rad. Corrections	0.0001		
$\sigma^{\bar{\nu}}/\sigma^{\nu}$	$<$0.0001	N/A	
TOTAL PHYSICS MODEL	0.0030	$\sim$0.0008	$<<$ 0.0008?
TOTAL UNCERTAINTY	0.0041	0.0024	$<$ 0.0010
ΔM_W	0.21 GeV/c^2	0.11GeV/c^2	$<$ 0.050GeV/c^2 0.030GeV/c^2 (EXP)

(Yu + Kotwal: AIP 439)

K

$K^+ \to \pi^+ \bar{\nu}\nu$, $K_L^0 \to \pi^0 \bar{\nu}\nu$

CP violation

alternative way to measure unitarity Δ

CP, CPT

next generation of experiments beyond

CPLEAR, KTeV, NA48, KLOE

more precise determinations of

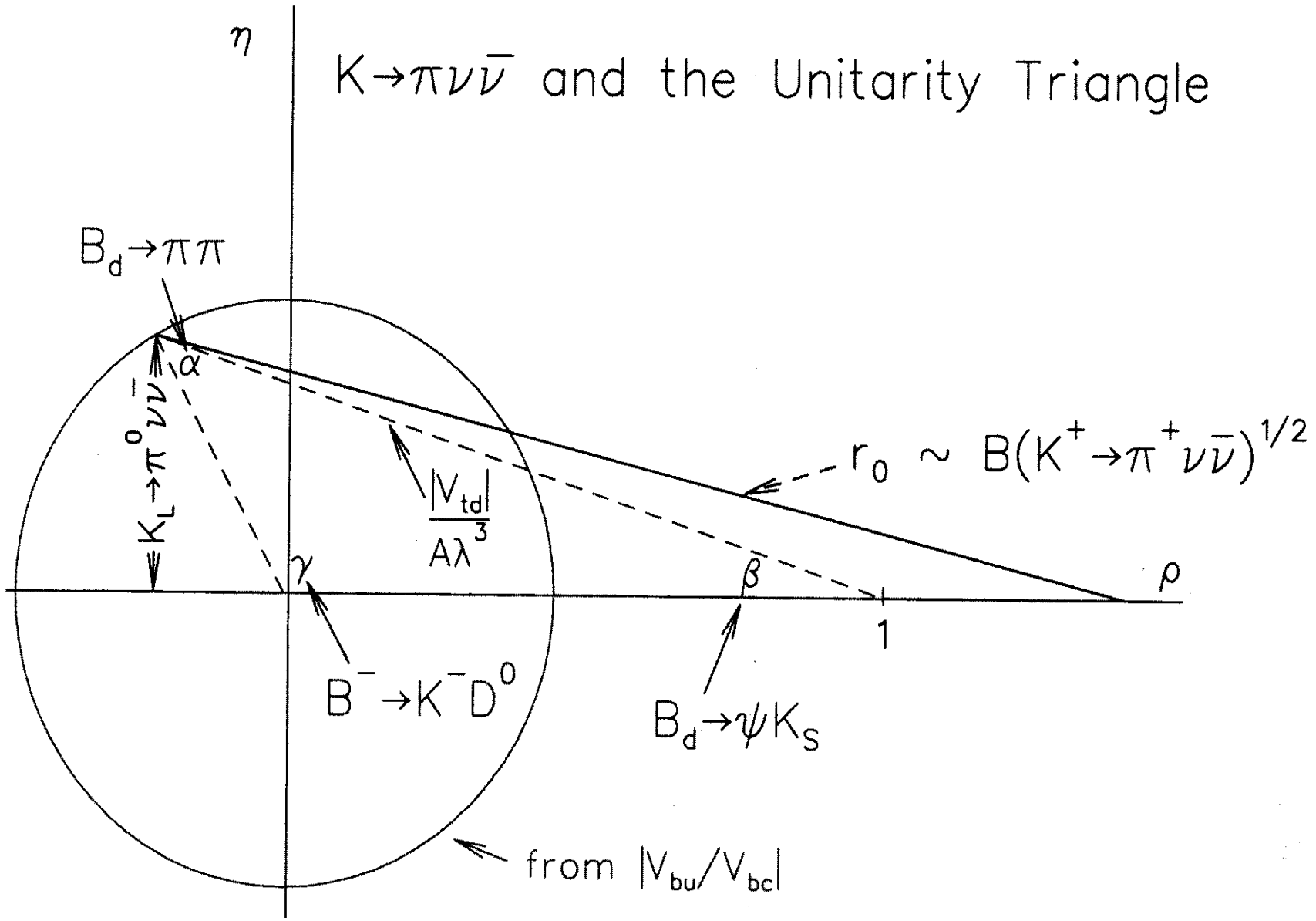
ϕ_{+-}, $\mathrm{Im}\, x$, $\mathrm{Im}\, \eta_{+-0}$, $\mathrm{Im}\, \eta_{000}$, $|\eta_{+-l}|$, $|\eta_{+-\gamma}|$, ...

rare K decays

many orders of magnitude improvement in sensitivity possible

p

any interest in hadronic physics?



(Littenberg: AIP 435)

3 - Non-particle Physics

μ capture

what does one learn?

μ-catalyzed fusion

processes in solid hydrogen

μSR

useful for condensed-matter physics

Spallation Neutron Source

Radioactive waste disposal

comparable beam power required

Energy amplifier

[Tritium production]

could other scientific communities be allies?

if FEL ← biologists
ELFE ← nuclear physicists
} @ TESLA