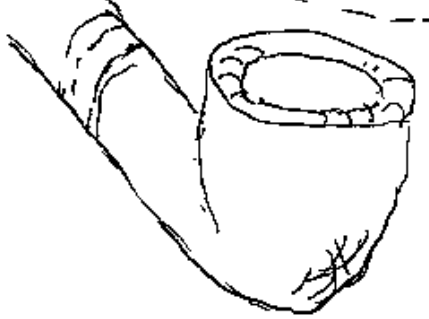
Birmingham IOP

$\mu^+\mu^-$ Collider Physics



W. Murray
RAL

Advantages of a muon collider

1. Pointlike colourless objects - calculable!
2. Large mass suppresses bremstrahllung - so higher energies or smaller rings possible than in an electron collider
3. Very low beam energy spread available for narrow resonances
4. Energy can be measured extremely precisely using precession and decay
5. Mass enhances s-channel Higgs production by a factor 40,000 over electrons
6. Neutrino beams from muon decay clean and very well understood

We can do precision measurements with this machine!

Disadvantages of a muon collider

1.Lifetime of only 2.197us restricts fill live-time and hence luminosity
2.Muon decay gives huge electron background
3.Beam preparation difficult, e.g muon collection and cooling

Luminosity (per amp) vital!

$\mu^+\mu^-$ Collider Parameters

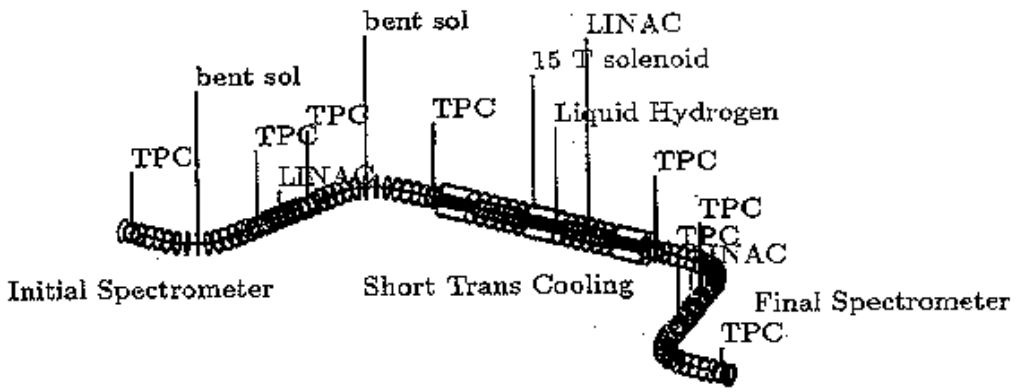
	Higgs factory		Top	4 TeV
$\sqrt{s}$	100 GeV/c^2		400	4000
$\mathcal{L}$	10^{31}	10^{32}	10^{33}	10^{35}
Pulse Rate	15 Hz		15 Hz	15 Hz
Radius	50 m		150 m	1200 m
Norm. Emittance	0.025	0.010	0.010	0.005
I.R. Beam Size	270 μm	90 μm	23 μm	2.1 μm
$\delta E/E$	0.003 %	0.12 %	0.12 %	0.12 %

Cooling Proposals

- Ionization cooling – Default
- Optical Stochastic
- Low-energy frictional
- Zero-energy

COOLING EXP

(Proposed to FNAL)



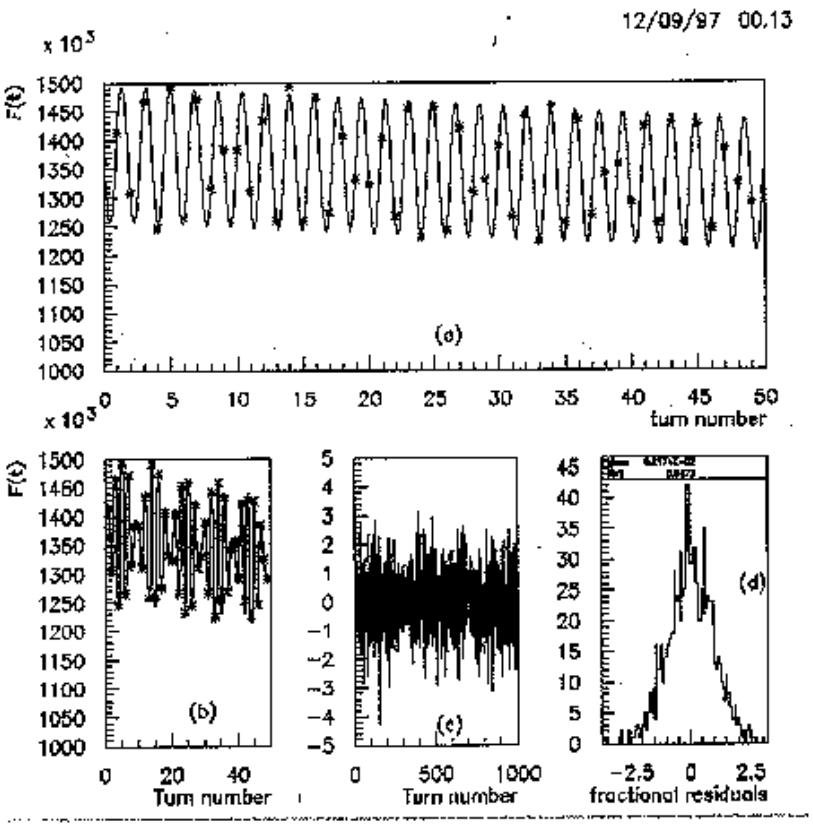
In 2 Years

1. Low Power RF Cavity Test (LBL)
2. High Power RF Cavity Test (FNAL)
3. Add Solenoidal Field

In $\approx$ 3 Years

4. Build 10 m of channel
5. Measure 6D Cooling
6. Build Bent Sol ϵ exch.
7. Measure dp/p reduction
8. Develop liquid Li Lenses
9. Measure Cooling in Li Lenses

In-situ energy calibration

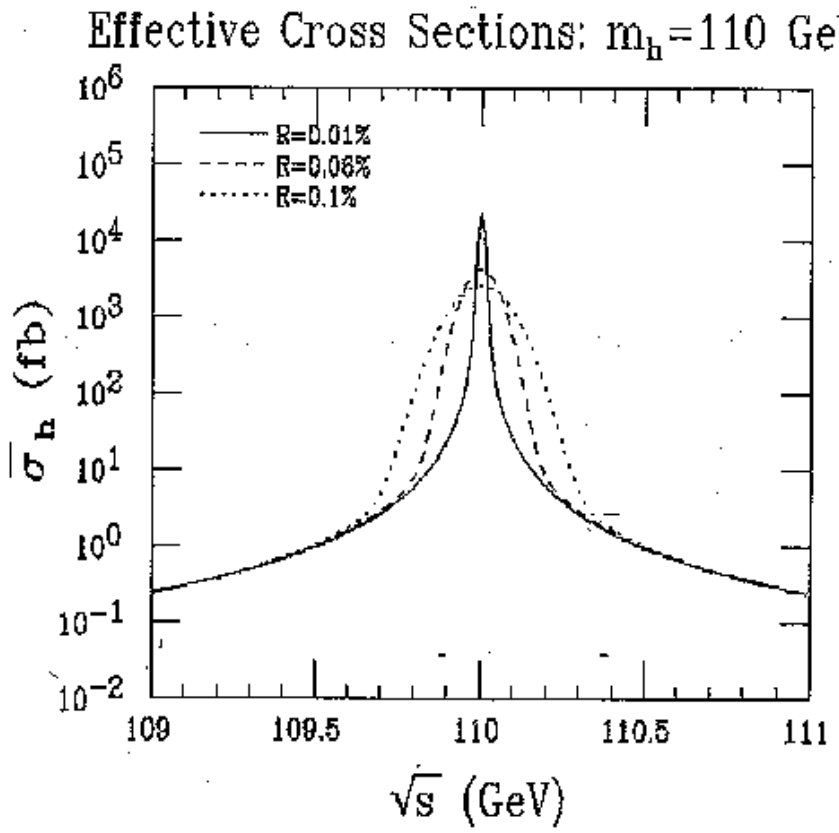


- Muons are polarized
- The polarisation precesses at

$$\vartheta_s = \frac{E}{m} \cdot \frac{g-2}{2}$$

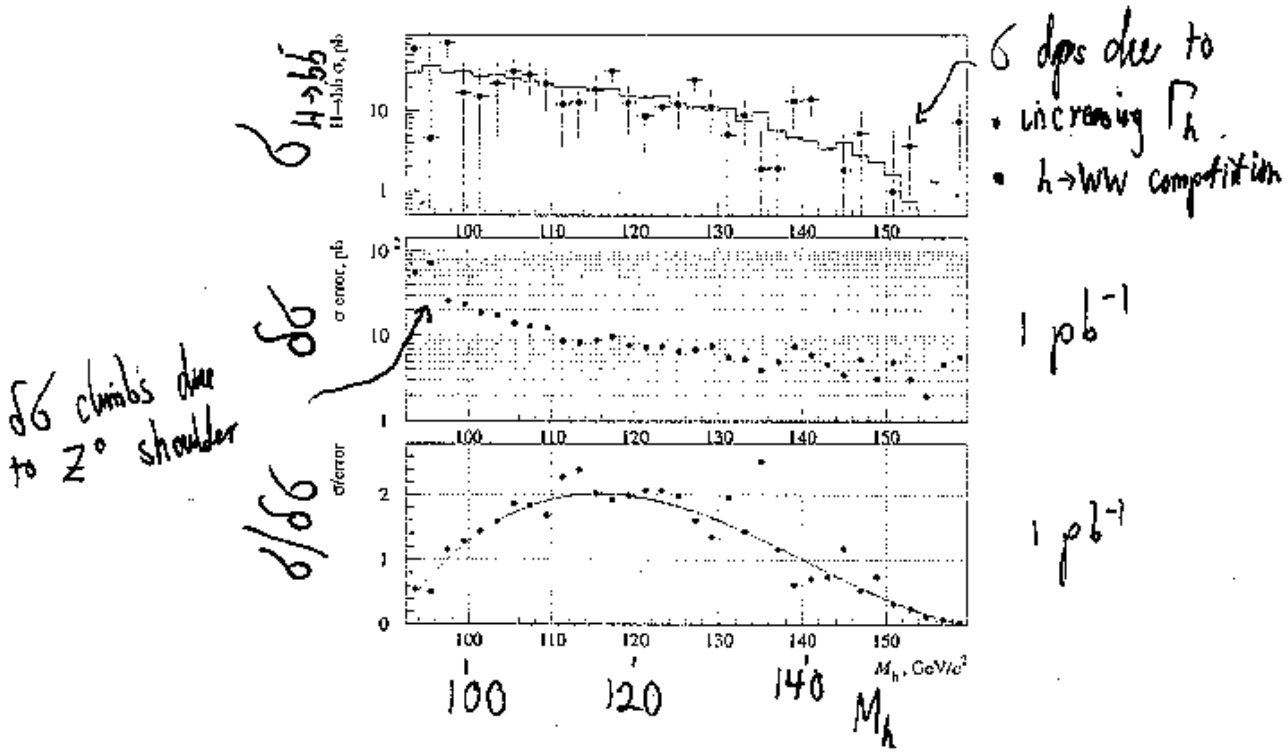
- This alters the Lab electron energy spectrum
- Extract energy to precision of g-2, 10^{-6}

Dependence on beam energy spread



- The Higgs width measurement depends upon better than 0.06% momentum spread at 110GeV
- This costs luminosity, but can be relaxed as width grows.

Performance of S.M. Higgs Scan

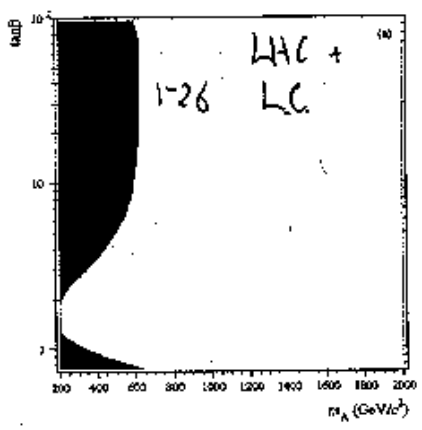


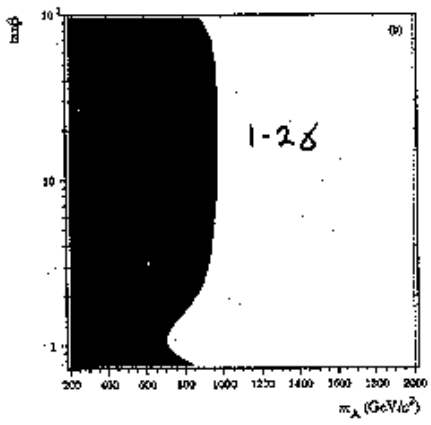
Optimal region 100- 140 GeV/c²

⇒ SUSY favoured region!

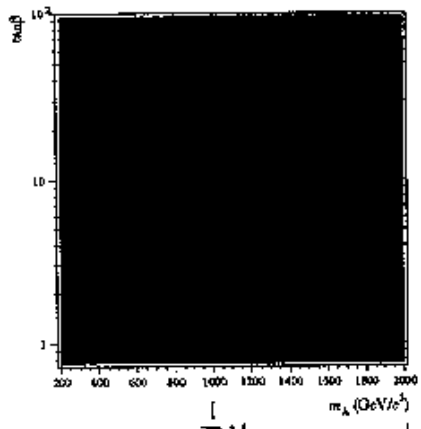
Value of Precise Higgs Measurement

χ^2 to S.M. of lightest Higgs





0.2 fb^{-1} μC



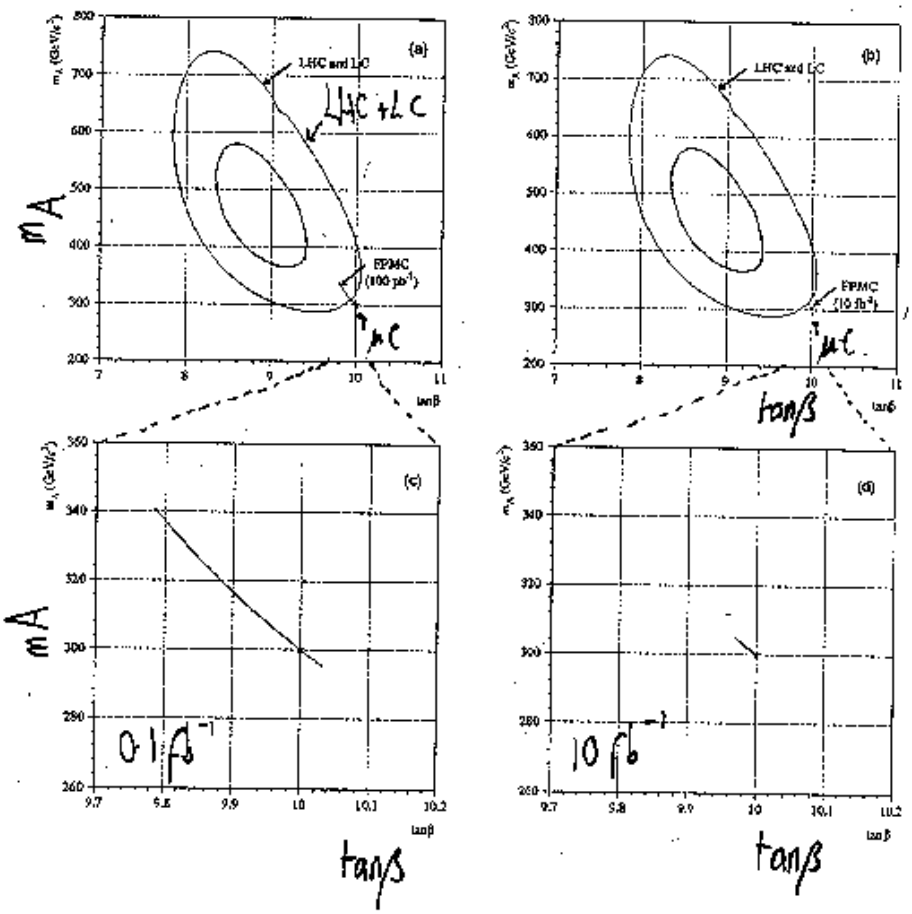
10 fb^{-1} μC

1 TeV

2 TeV

Can exclude A up to ~2 TeV !

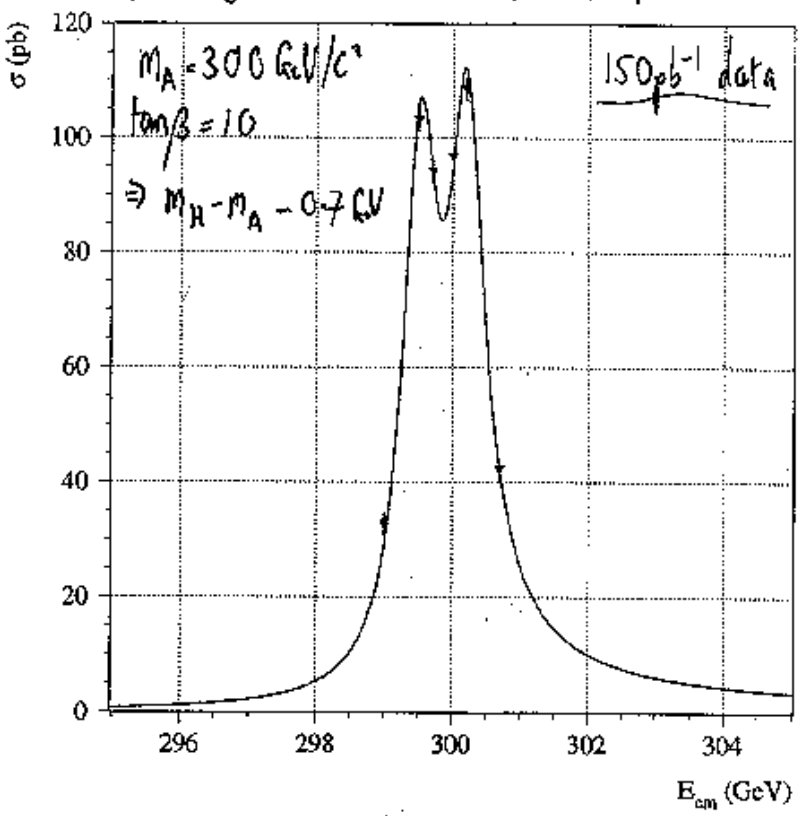
Measurement of m_A, $\tan\beta$ from lightest h only



All other SUSY parameters fixed.

Scan over H, A

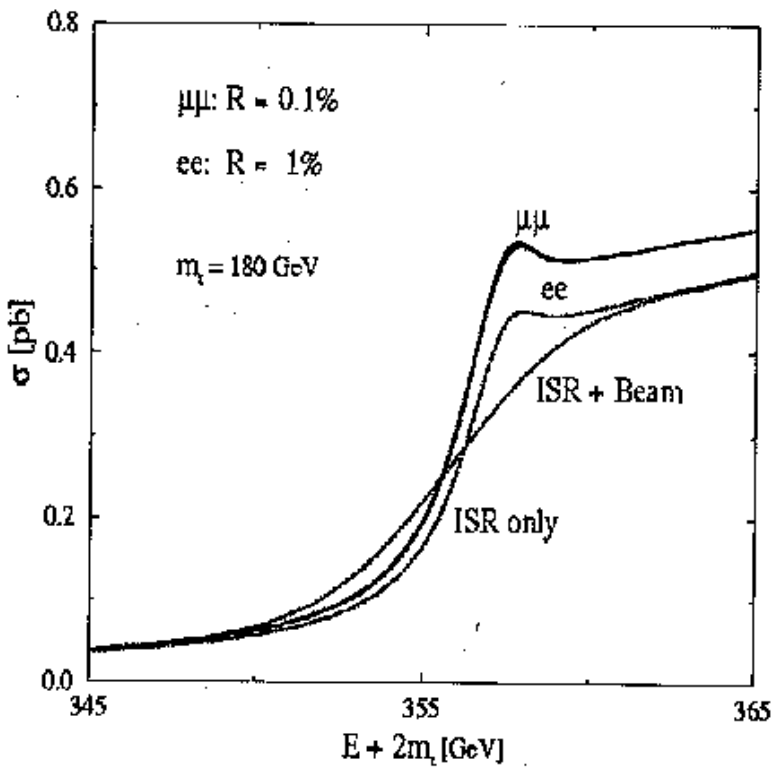
Only way to see two separate particles?



2 B.W. ⇒ 6 point scan

- If tanβ low, different H, A, br's can be seen
- Rather like K^0 system; can we observe CP?

Top Threshold studies

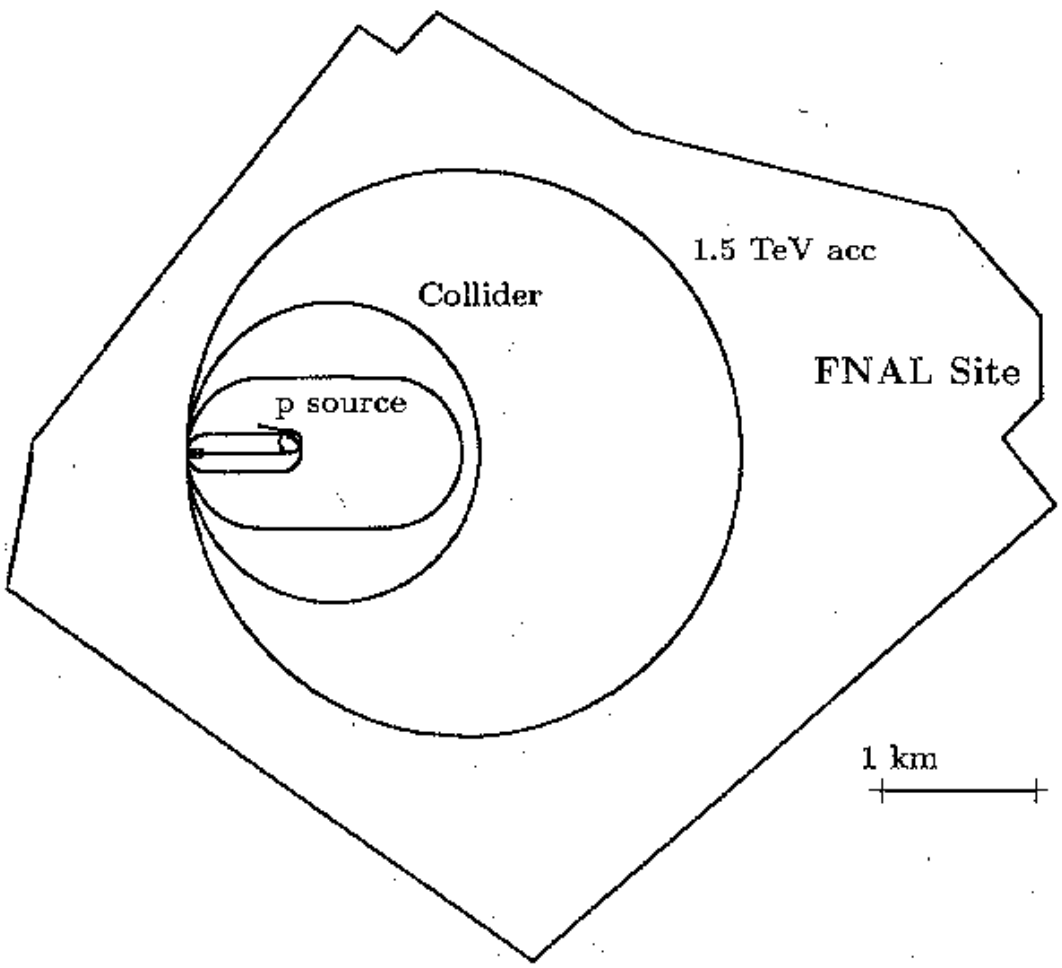


- The effect of Beasmstrahlung on the NLC and Muon collider top thresholds.
- Beamstrahllung lowers the NLC energy by a few GeV, and will be difficult to know to a MeV precision.

It could be reduced - at a price in luminosity.

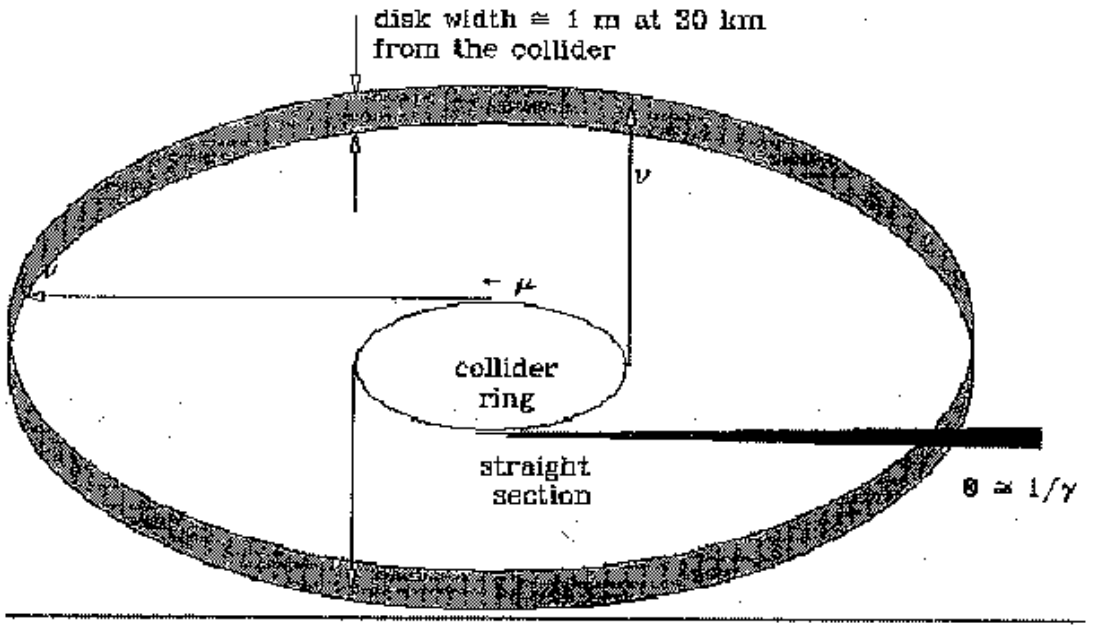
- Observation of the 'peak' in a muon collider would take a dedicated run.

3 TeV COLIDER



Does a small ring mean cheap?

Radiation hazard from Neutrinos

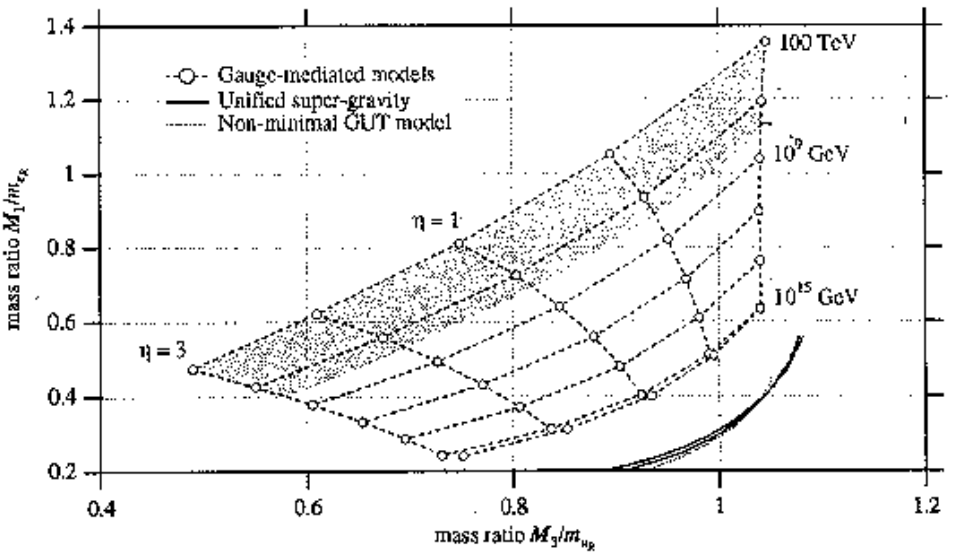


Provided straight sections are short, radiation is uniform disk.

Radiation rises as E^3 k.

Gives limit of 3TeV on muon collider energy (using ionisation cooling)

Study of SUSY breaking



Direct measurements of MSSM particle masses reveal breaking structure

The use (or otherwise!) of a precise mass determination depends upon the theory in which the mass is derived.

Conclusions

- Muon rings offer great possibilities in neutrino physics - without needing all the pieces of a muon collider
- The 's' channel Higgs production is a unique MC feature
- Retains precision nature to 3TeV, limited by radiation concerns.
- Cooling and targetry are critical concerns.
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- We should get involved now - this needs PEOPLE!

More than just a pipe-dream!