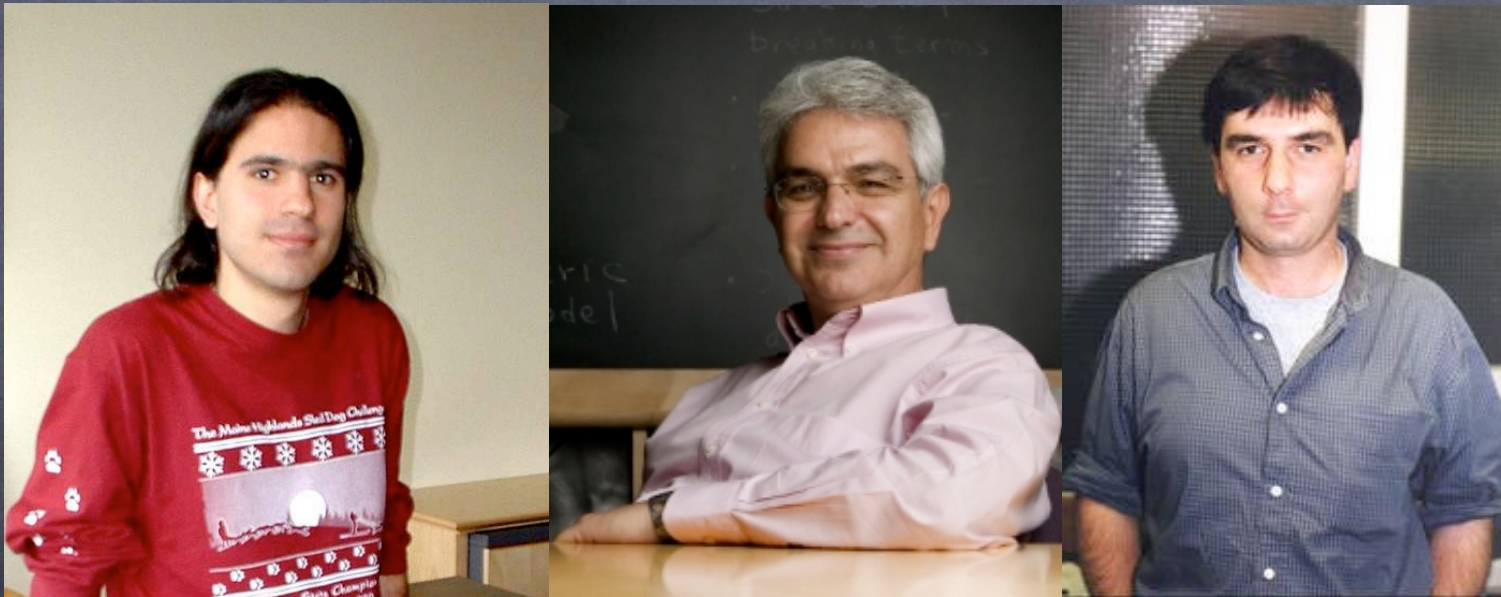


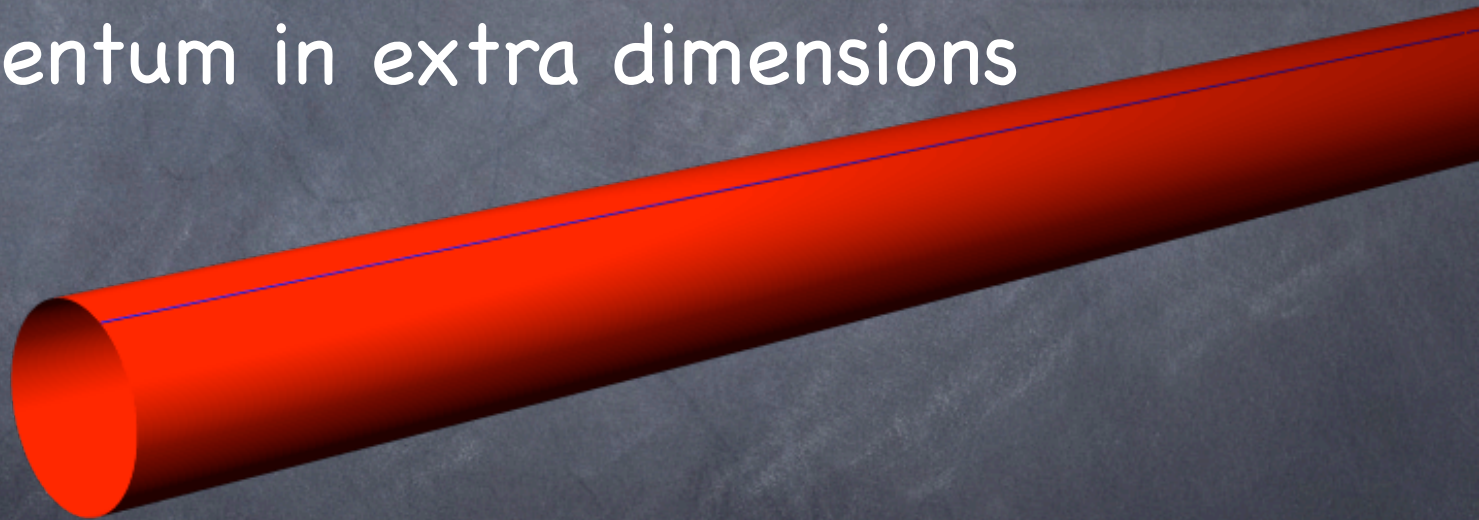
# Chapter 19: Large Extra Dimensions

# Arkani-Hamed, Dimopoulos, Dvali

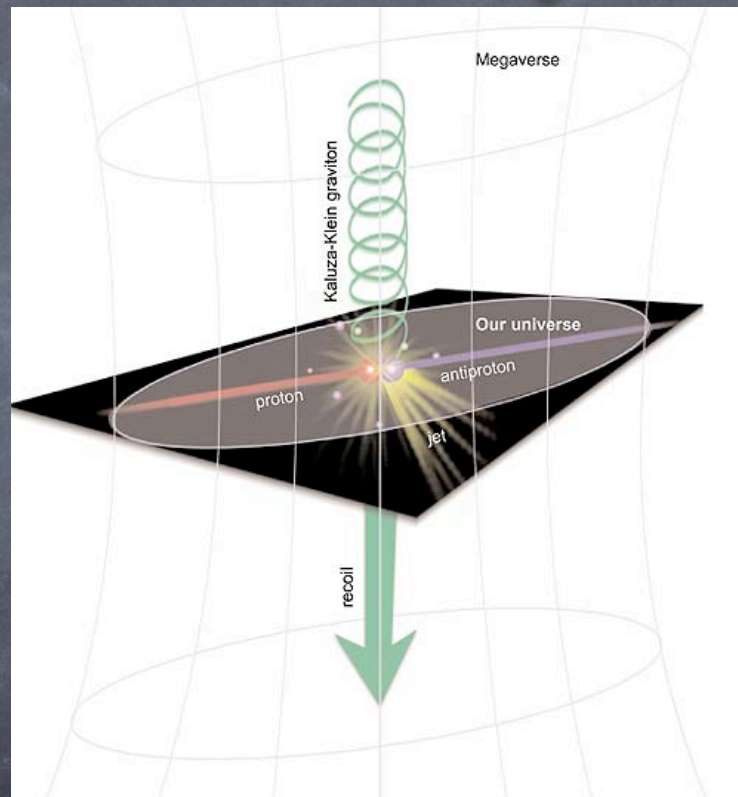


# ADD: Stuck on a Brane

quarks and leptons have no  
momentum in extra dimensions



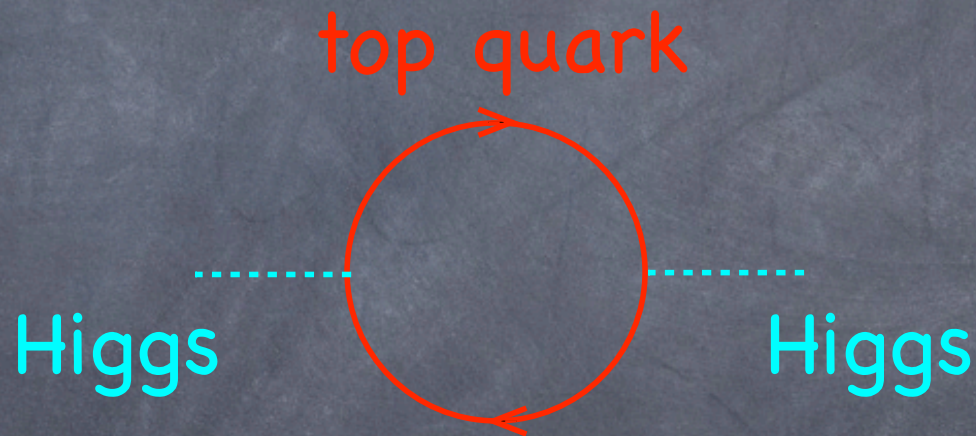
# ADD: Gravity Leaks



$$M_{string} \sim M_{weak} = 1\text{TeV}$$

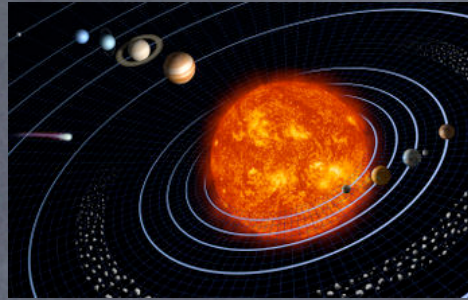
$$G_N = \frac{1}{M_{Planck}^2} \ll \frac{1}{M_{string}^2}$$

# Hierarchy Rephrased



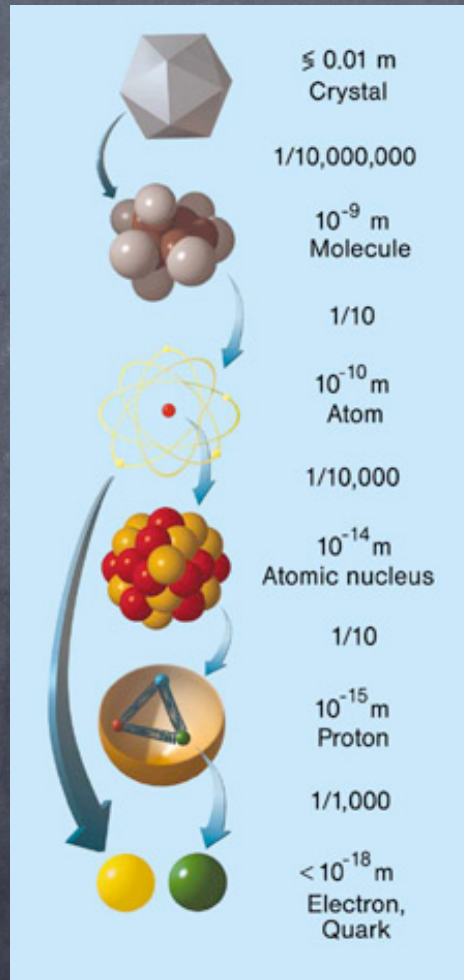
$$M_{Higgs} \sim M_{string}$$

# Sizes of $n$ Extra Dimensions



$$n = 1, R = 10^{11} \text{ m}$$

Gravity is  $3+n$   
dimensional  
for distances  
smaller than  $R$



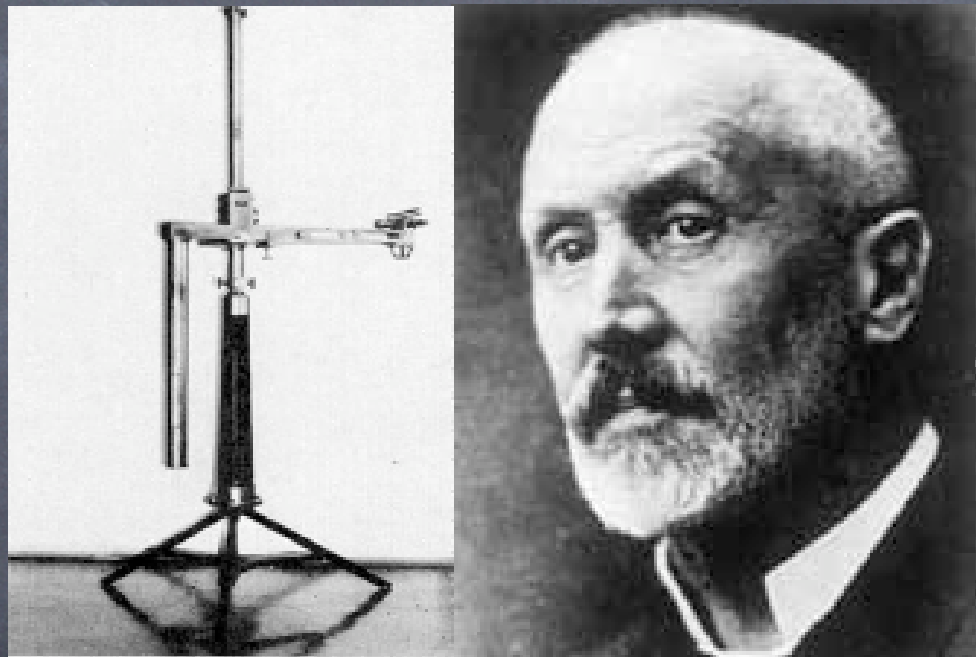
$$n = 2, R = 0.1 \text{ mm}$$

$$n = 3, R = 10^{-9} \text{ m}$$

$$n = 4, R = 10^{-12} \text{ m}$$

$$n = 6, R = 10^{-14} \text{ m}$$

# Baron von Eotvos



tested Equivalence Principle  
with torsion balance to  
5 parts in a billion

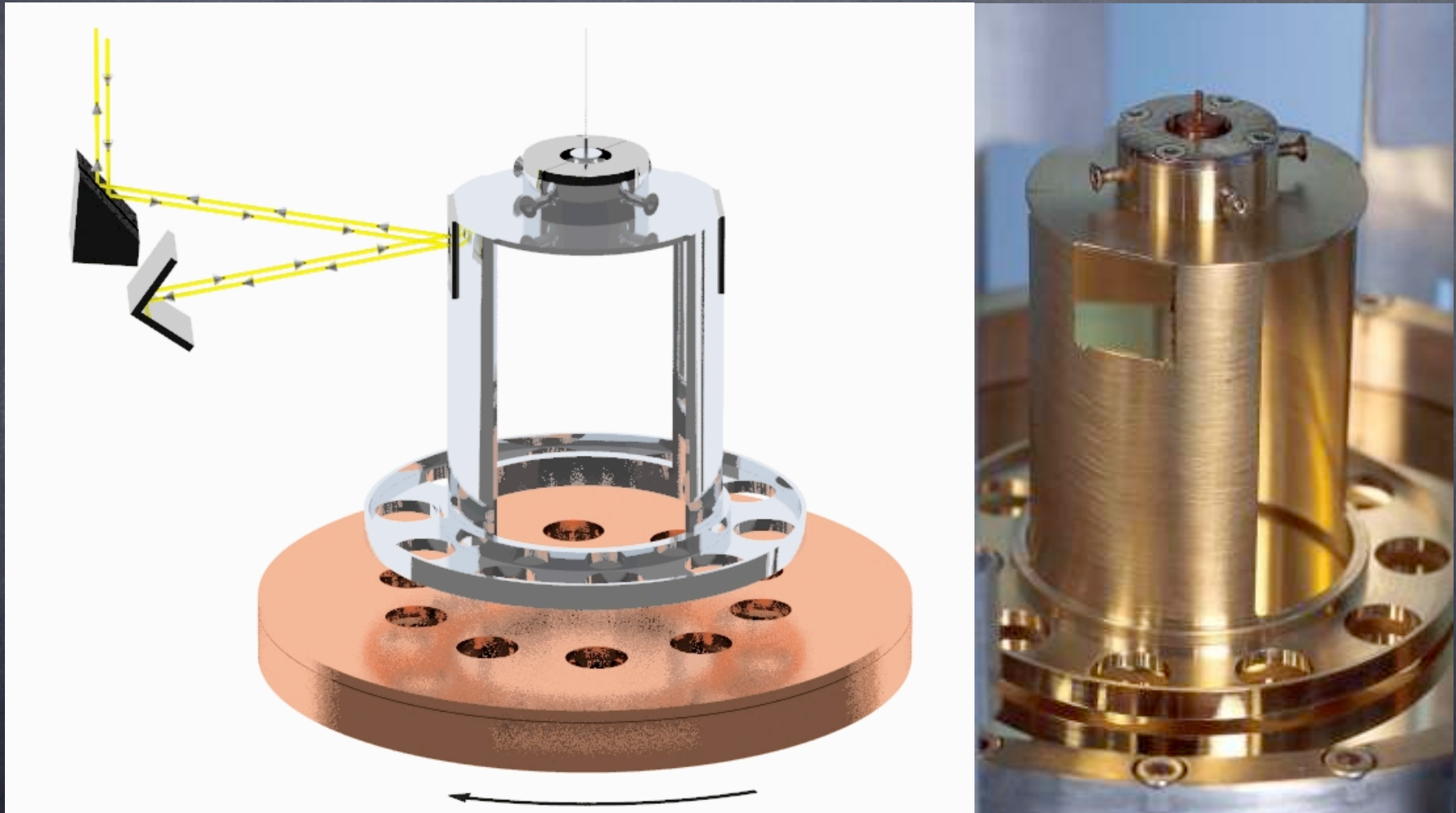
# Adelberger, Heckel



tested gravity  
with torsion balance to  
a fraction of a millimeter

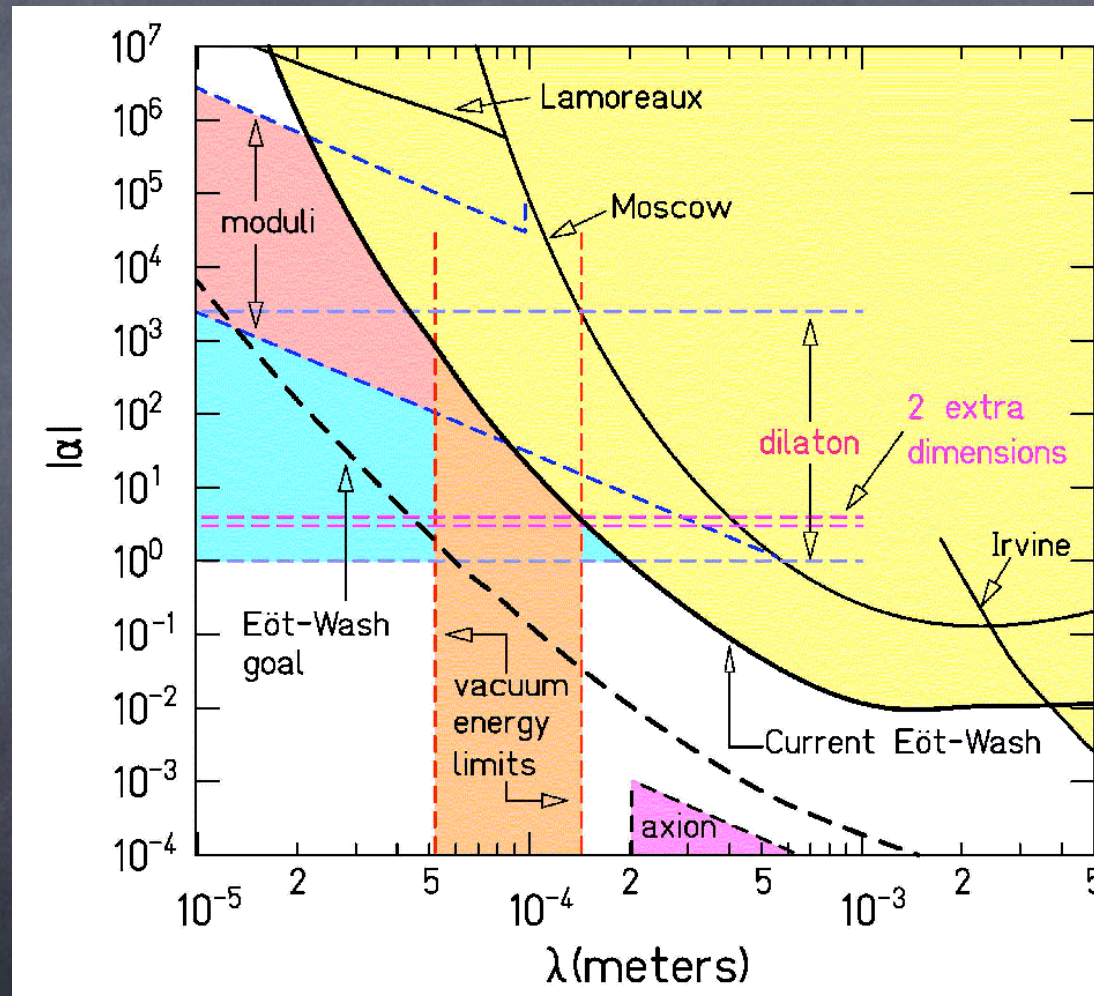


# Torsion Pendulum

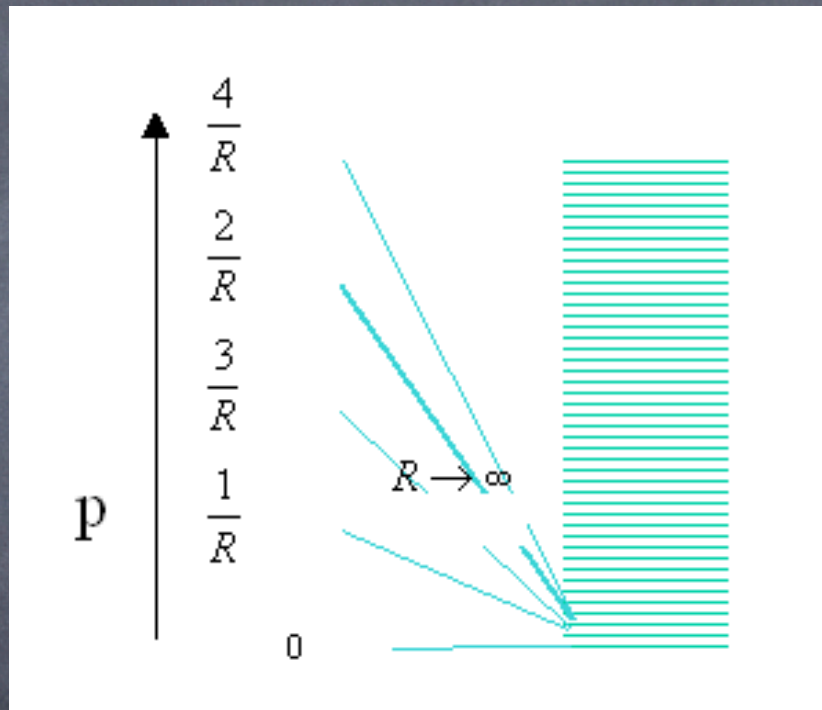


Eot-Wash

# Torsion Pendulum Limits



# ADD: KK Gravitons



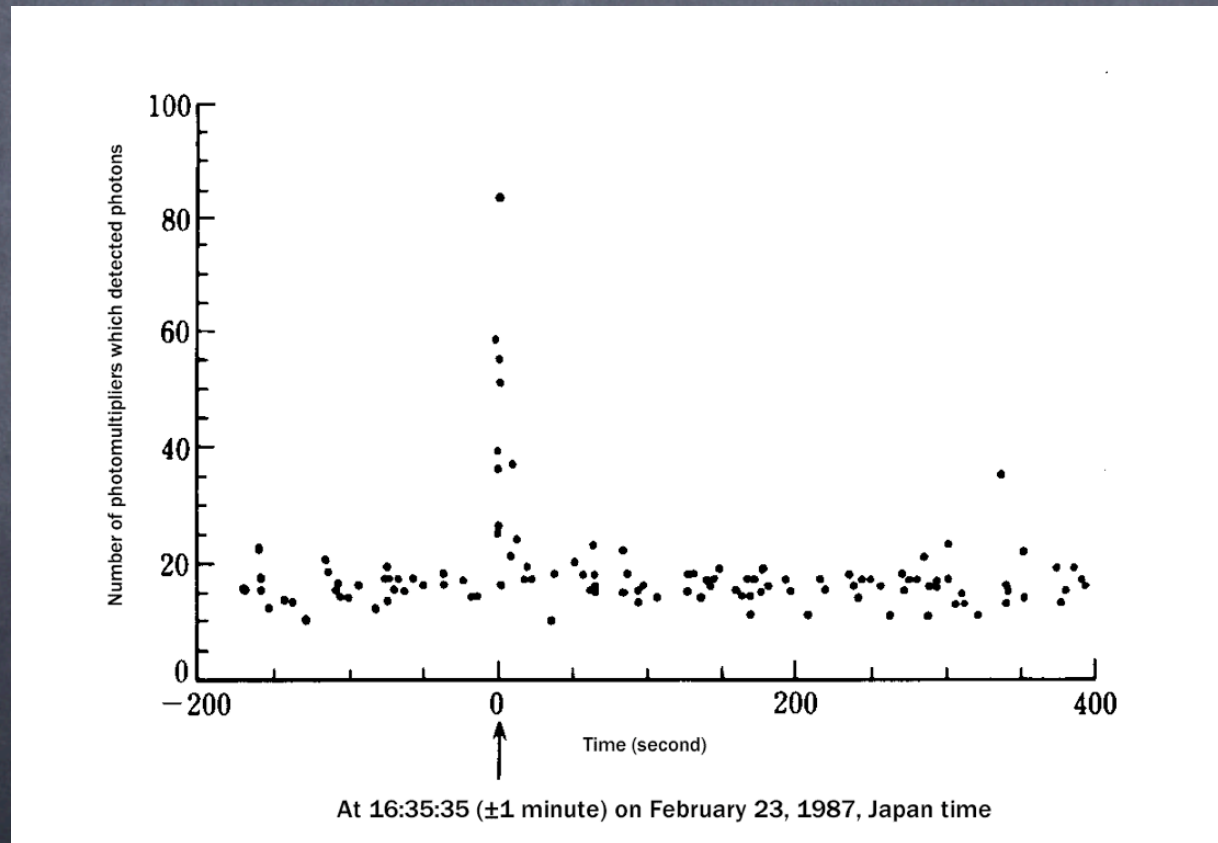
KK gravitons extremely light  
lots of them  
change Supernova cooling

# Supernovae Emit Neutrinos



(except Type IA)

# Supernova Neutrinos



# Supernova Neutrino

LVD (Italy) 1kton  
Liquid scint ~300  $\nu_e$



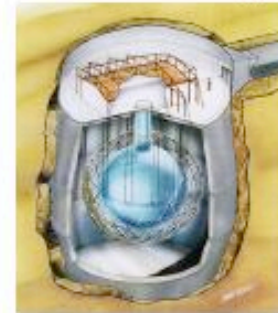
Super-Kamiokande (Japan) 50kton

7000 inv.  $\beta$  decay, 410 on  $^{16}\text{O}$ ,  
300 elast. scattering, 4° pointing



Sudbury Neutrino Observatory  
(Canada) 1.7kton  $\text{H}_2\text{O}$ , 1kton  $\text{D}_2\text{O}$

710 inv.  $\beta$  decay, 160  $^2\text{H}$  breakup,  
45 elast. scattering, 17° pointing



SSL sockets

Server  
10s coincidence  
window

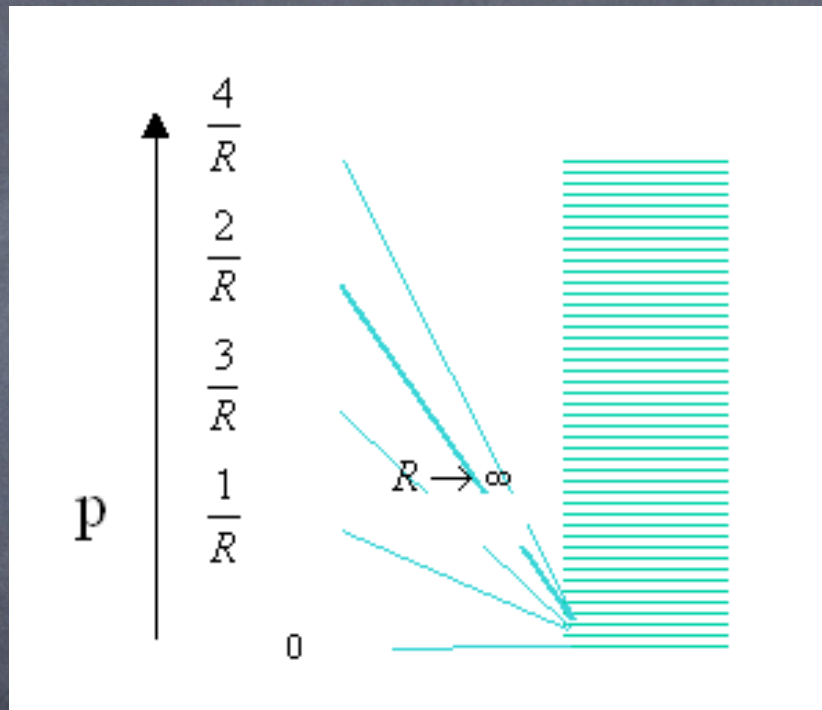
Coincidence server  
securely hosted by  
Brookhaven National Lab

PGP signed email

Email alarms  
to astronomers

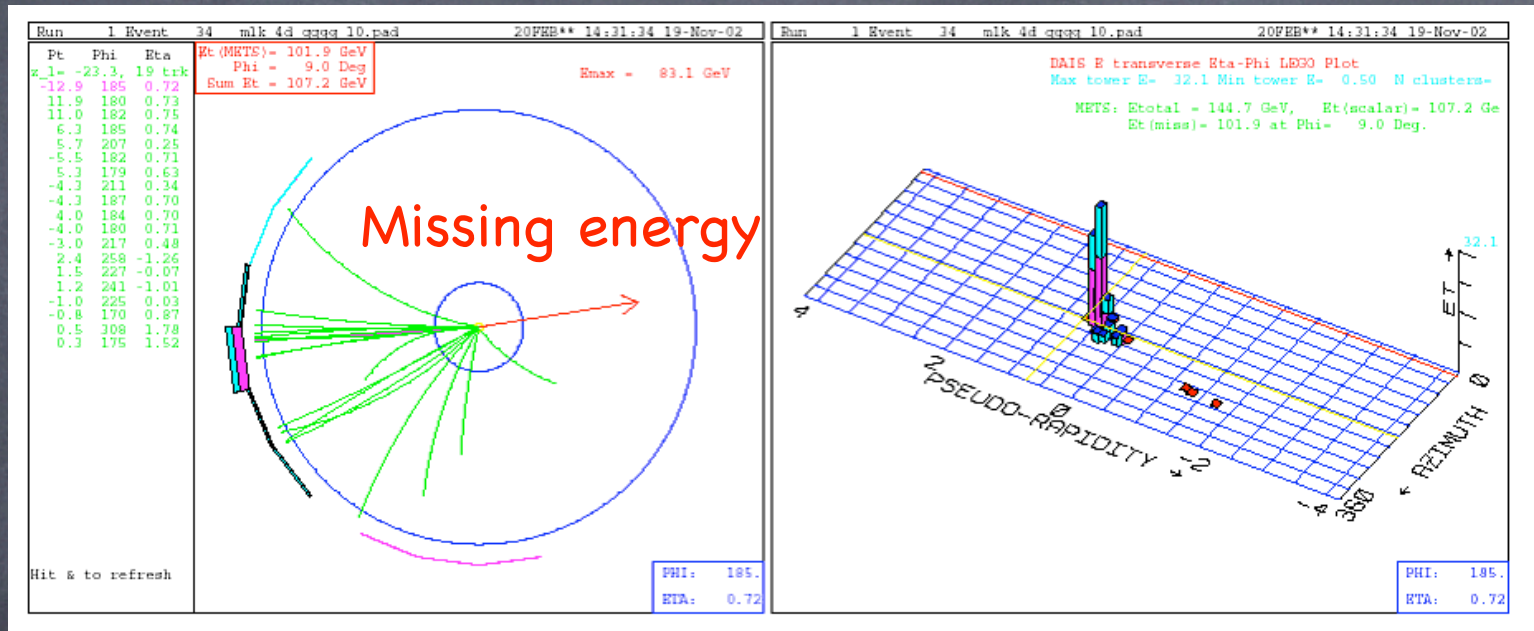
Sign up yourself to receive an  
alert at: <http://cyclo.mit.edu/snnet/>

# KK Gravitons at LHC



at TeV KK gravitons  
add up to strong  
extra dimensional gravity

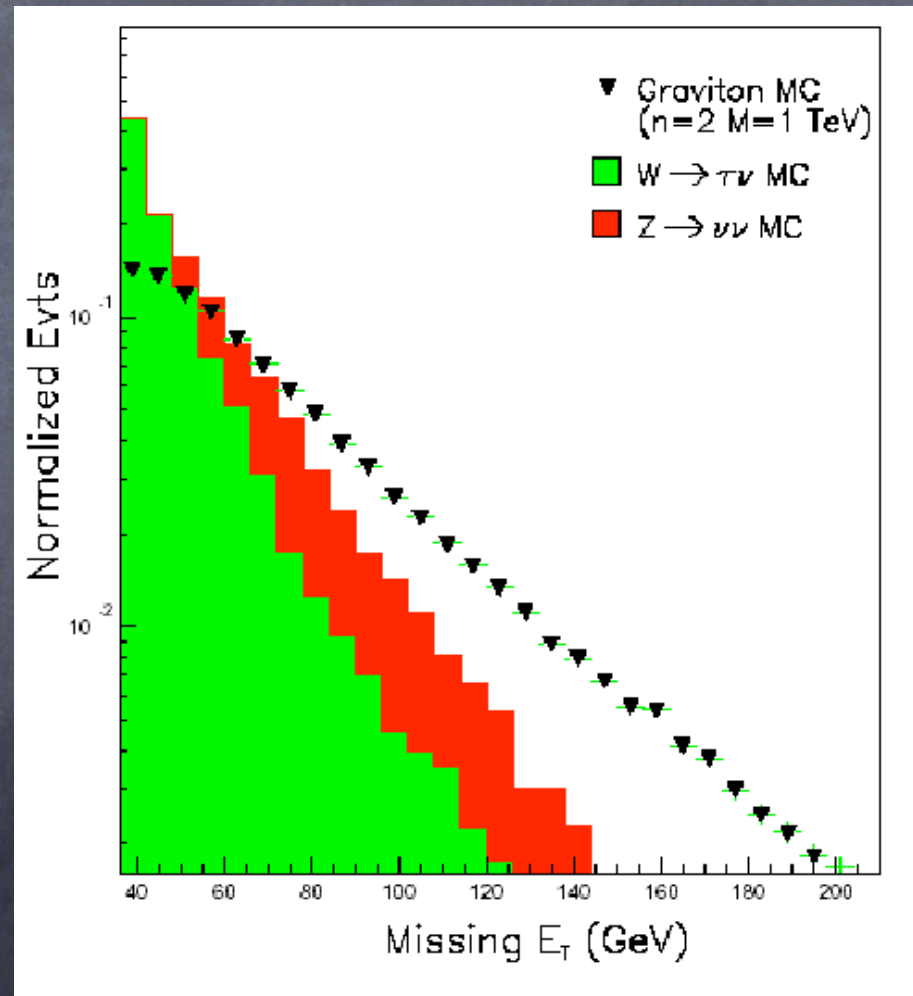
# KK Gravitons at LHC



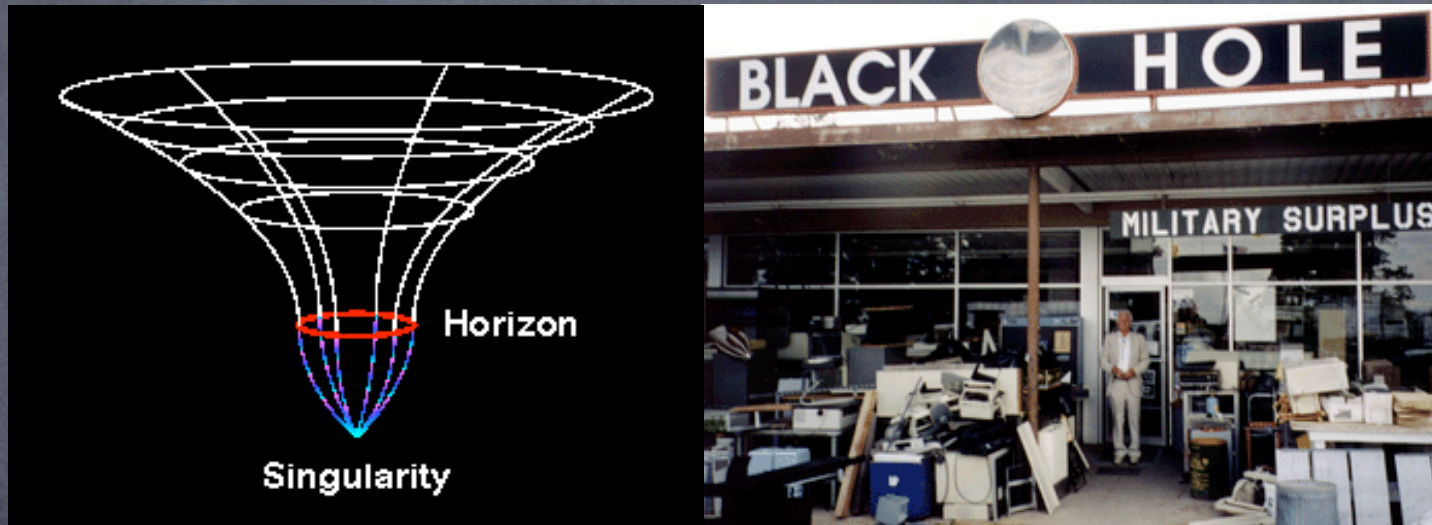
KK gravitons extremely light  
lots of them  
produced at colliders



# KK Gravitons at LHC

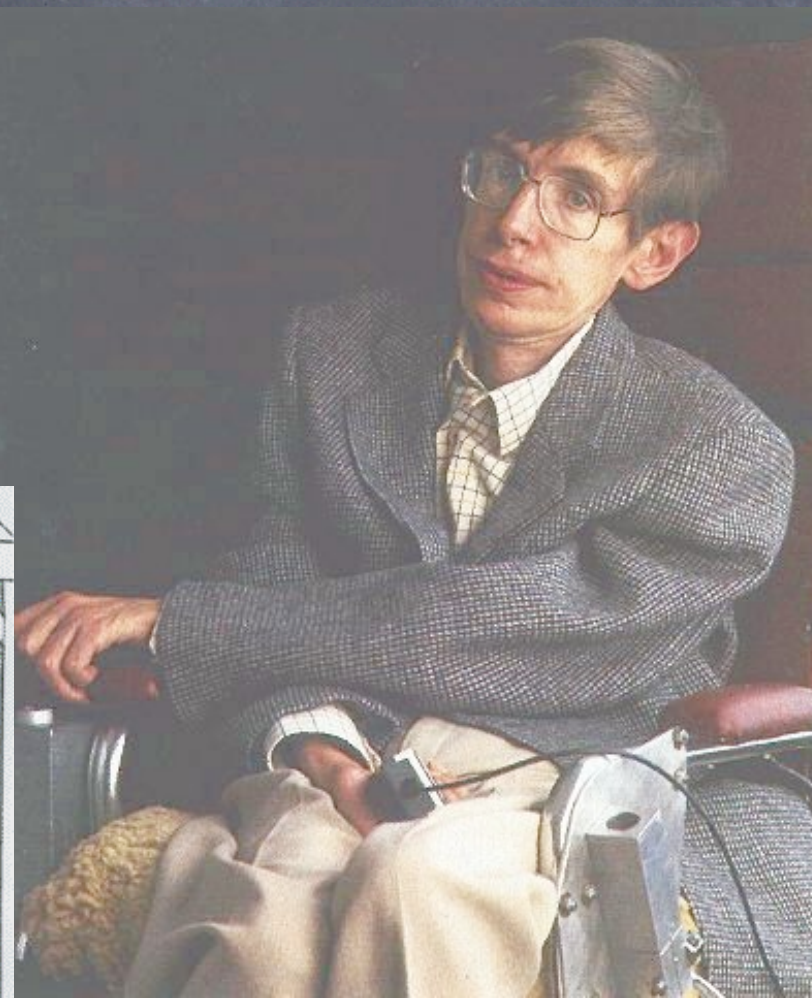
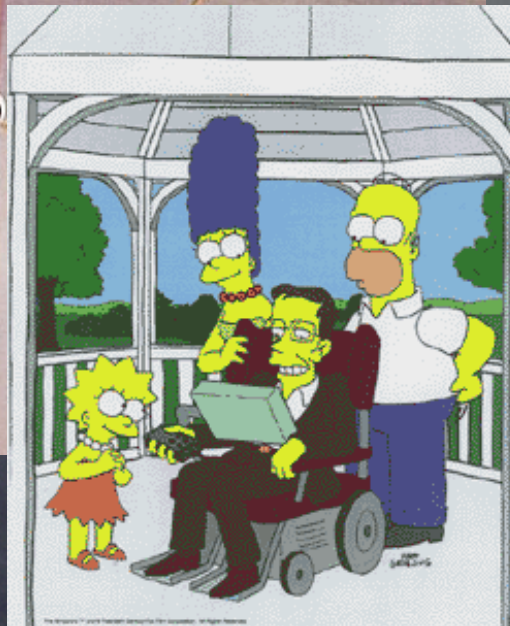
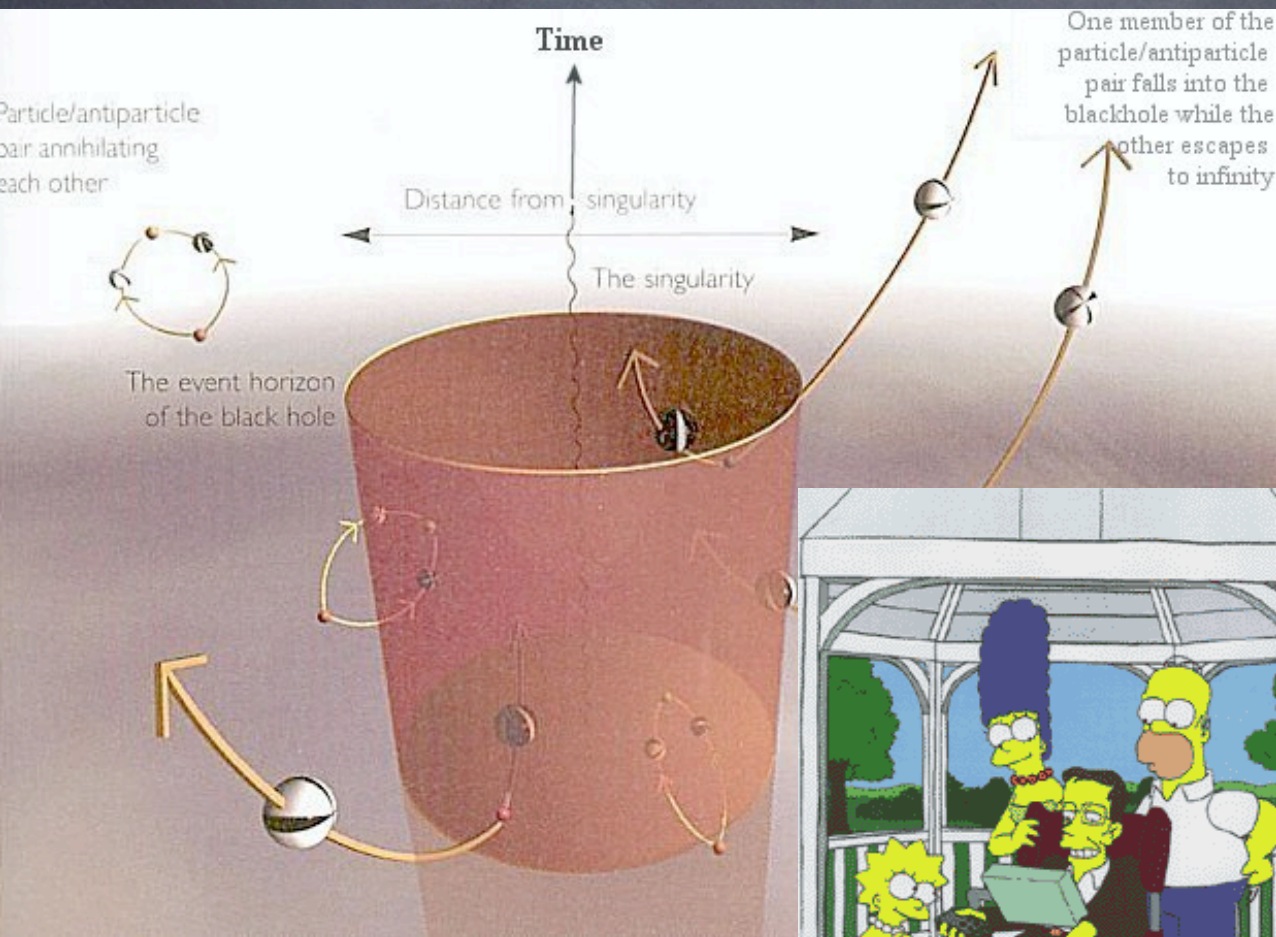


# Black Holes at LHC



at TeV KK gravitons  
add up to strong  
extra dimensional gravity

# Hawking Radiation



# Black Holes at LHC

