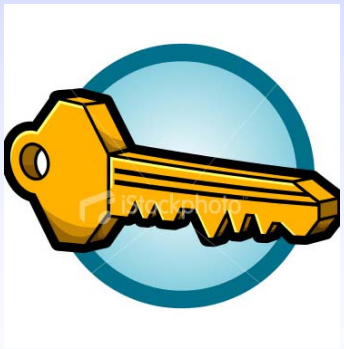
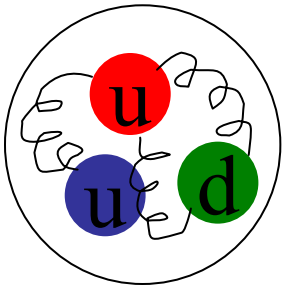
Hunting for the Higgs at LHC

Konstantin Goulianos
RU HOL FORUM
October 6, 2011



The key to mass?

About the Higgs



The Standard Model (SM)
(Glashow, Salam and Weinberg – 1979 Nobel prize)

Elementary Particles

Quarks	*u* up	*c* charm	*t* top	*g* gluon	Force Carriers
	d down	*s* strange	*b* bottom	*γ* photon	
Leptons	ν_e *e* neutrino	ν_μ *μ* neutrino	ν_τ *τ* neutrino	*W* *W* boson	
	e electron	*μ* muon	*τ* tau	*Z* *Z* boson	
3 →	I	II	III	← Generations	

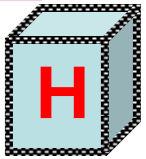
Symmetry:

SU3XSU2XU1

WS

SM

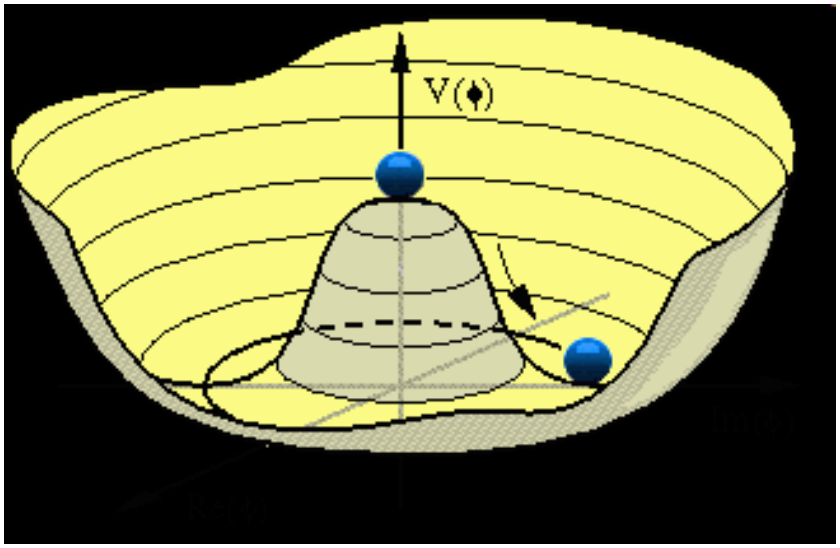
M_w and M_Z



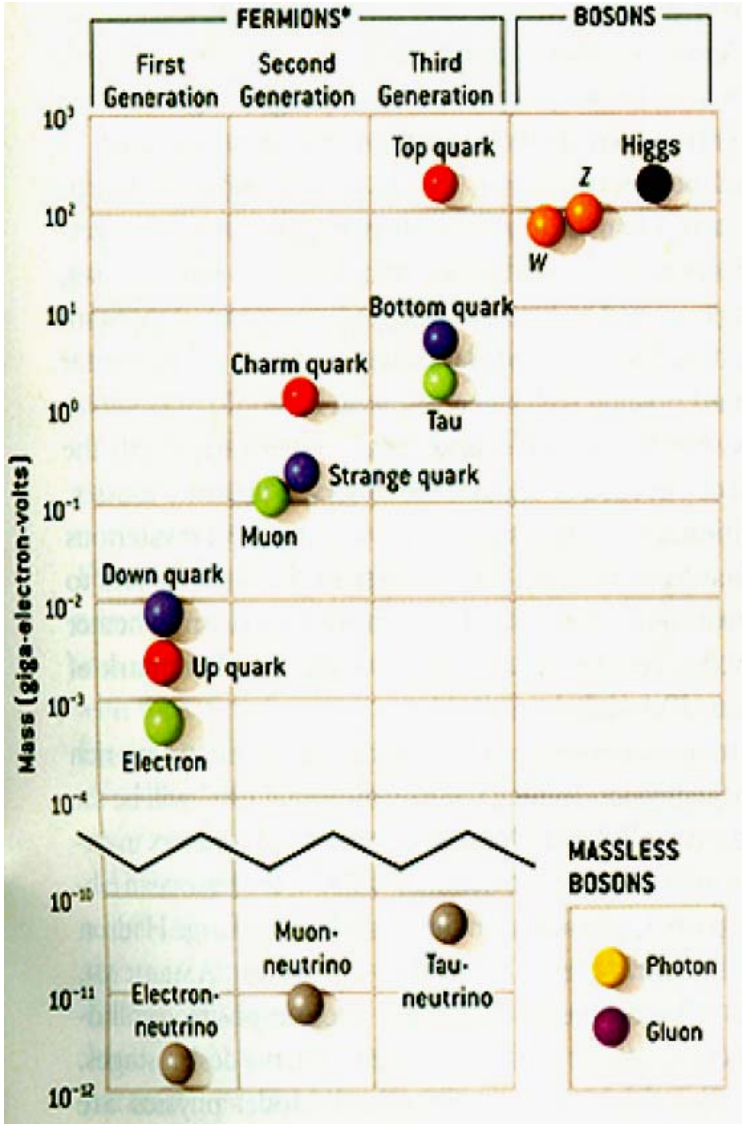
$M\gamma, g = 0$ $M_{W,Z} \sim 100\ m_p$ $M_{top} \sim M_{gold}$

In the SM all particles have zero mass
The Higgs field is needed to renormalize the theory
➔ "generates" mass – but not its own mass

Higgs mechanism



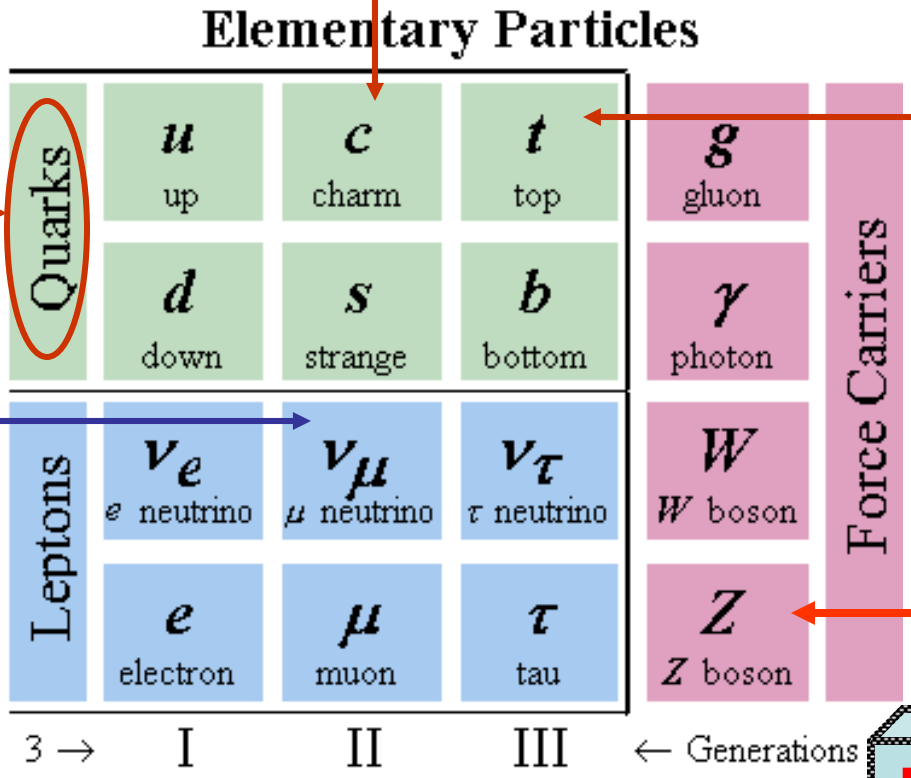
solves mass hierarchy problem ➔



- **Higgs:renormalizes the theory (removes infinities)**
- **one neutral Higgs boson**
- **“generates” the quark masses by coupling to quarks ~ mass.**

The SM & RU

predict *charm* in 1979 – Glashaw, Iliopoulos (RU) , Miani



CERN 1970s Evidence for quarks

BNL 1962 (my PhD thesis at Columbia)

Fermilab 1995

BNL 1981 $\nu_\mu p \rightarrow \nu_\mu p$ evidence for Z

(Z discovered at CERN in 1983)

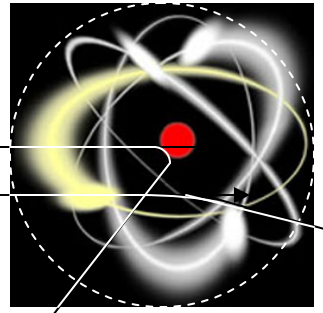
What are we doing now in the search for the Higgs?

Particle accelerators

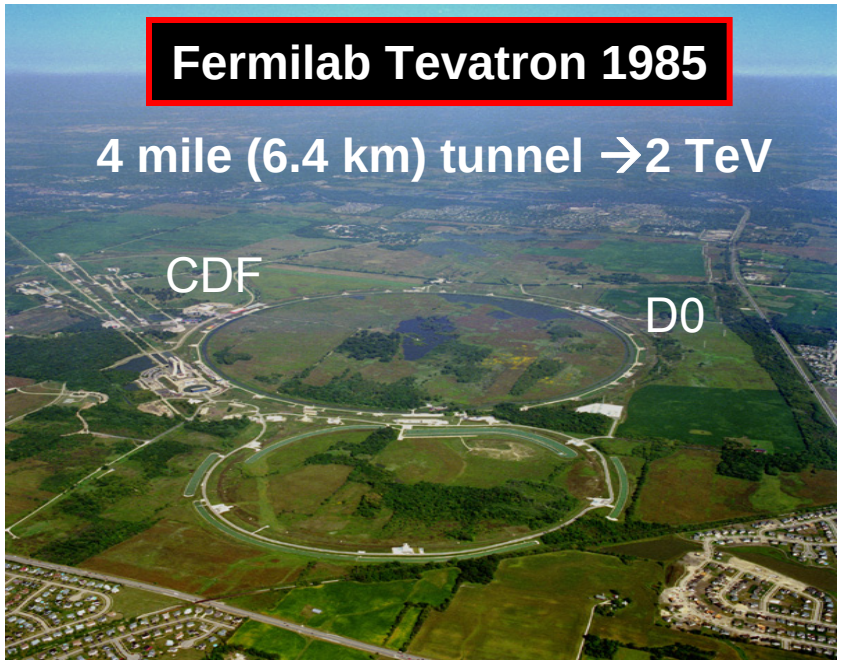
Rutherford Experiment

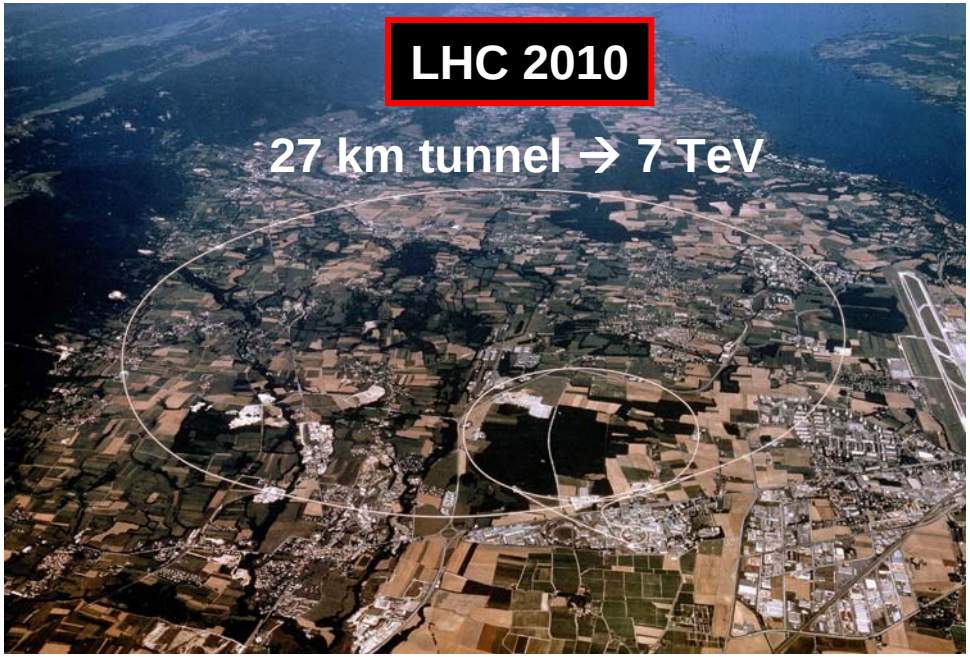
1910

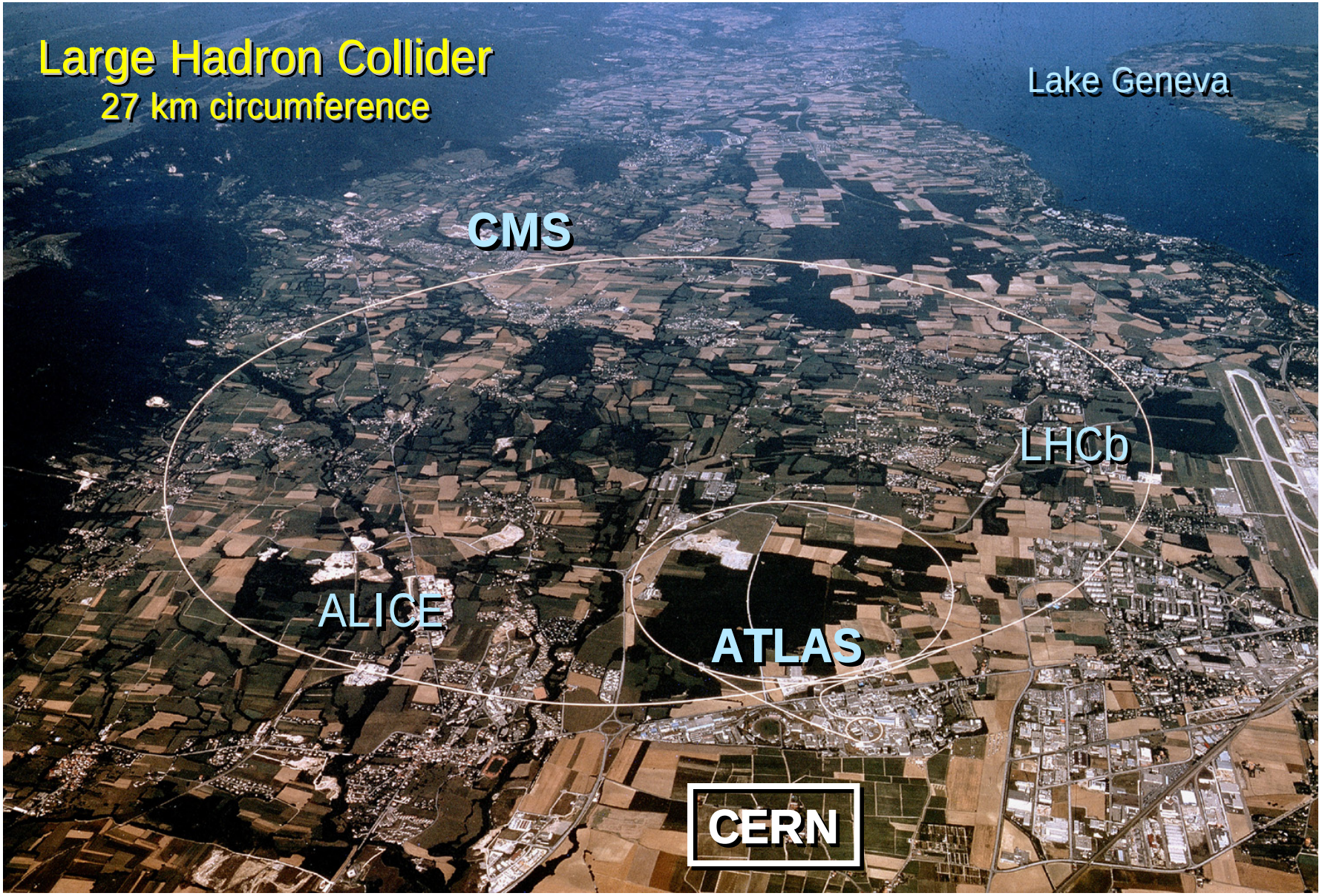
Source → α-particles



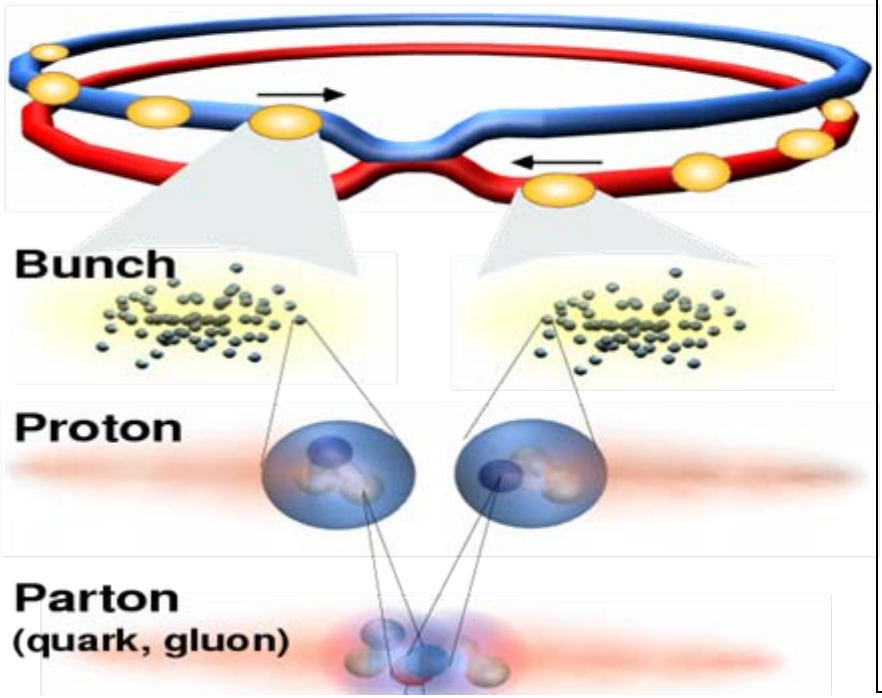
Large angle scattering → atoms have nuclei





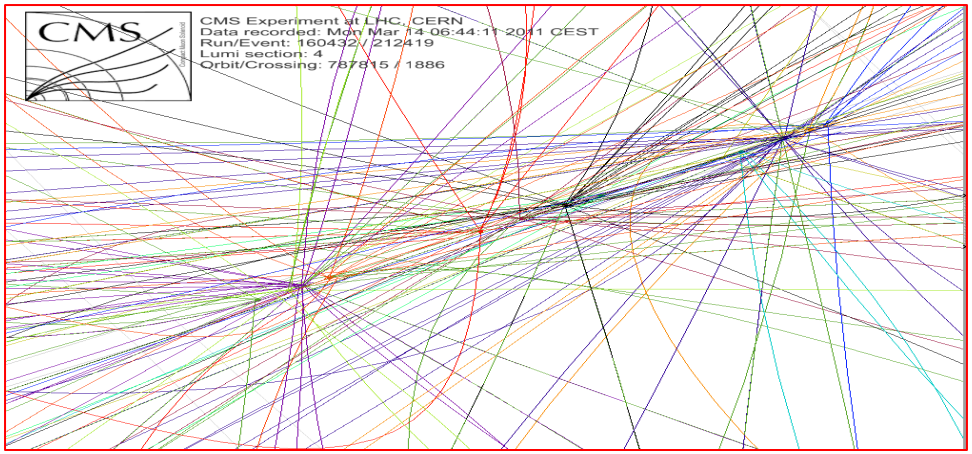

Large Hadron Collider
27 km circumference
Lake Geneva
CMS
LHCb
ALICE
ATLAS
CERN

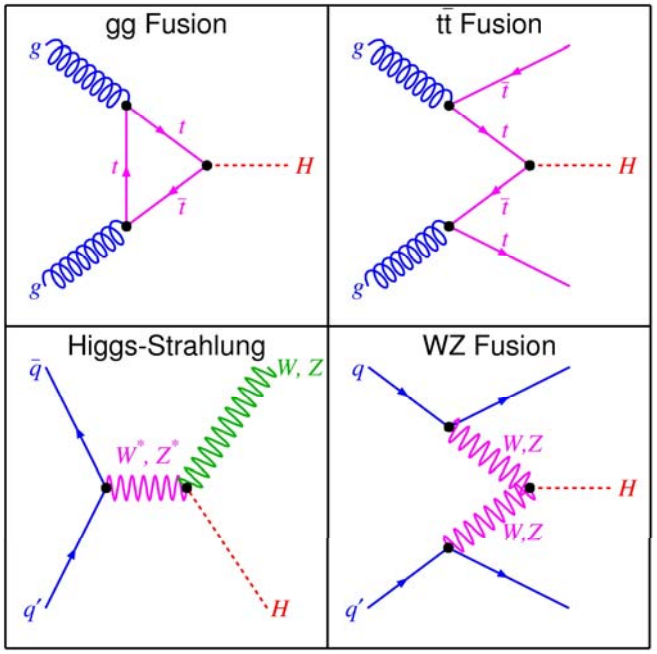
Collisions at LHC



Proton-Proton	(2835 x 2835 bunches)
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

search down to 1 part in 10^{13}





Higgs searches at CMS - I

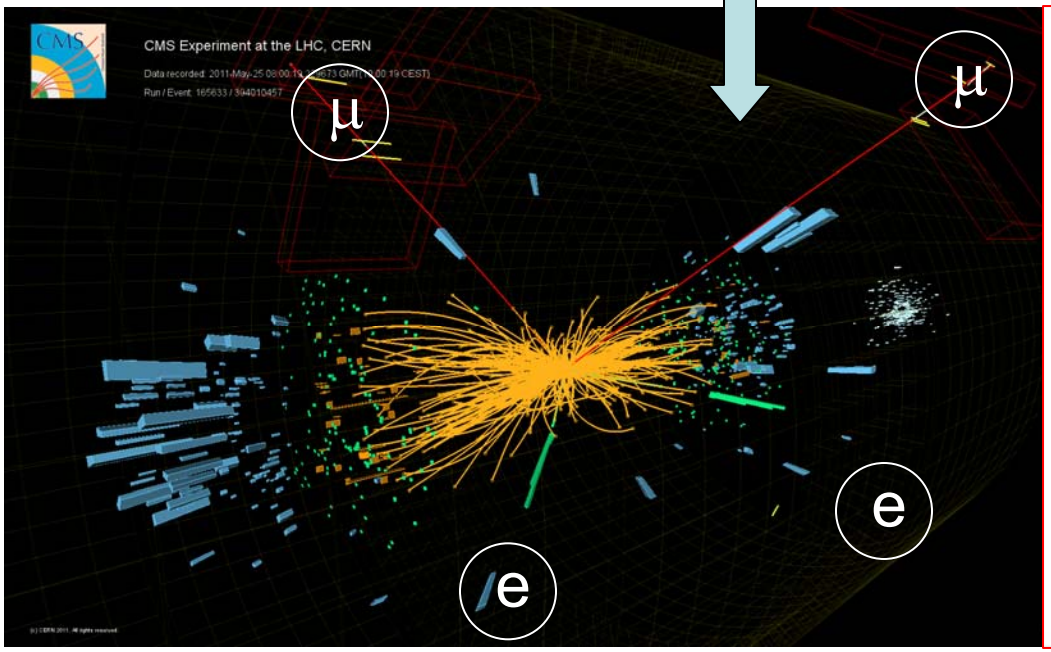
H→γγ

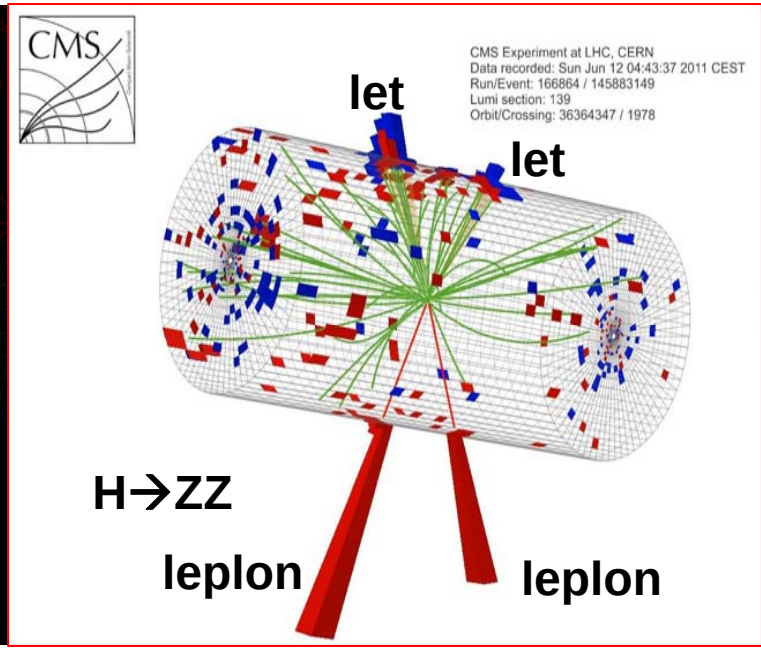
H→$\tau^+\tau^-$

H→$b\bar{b}$ (displaced vertex)

H→W^+W^-

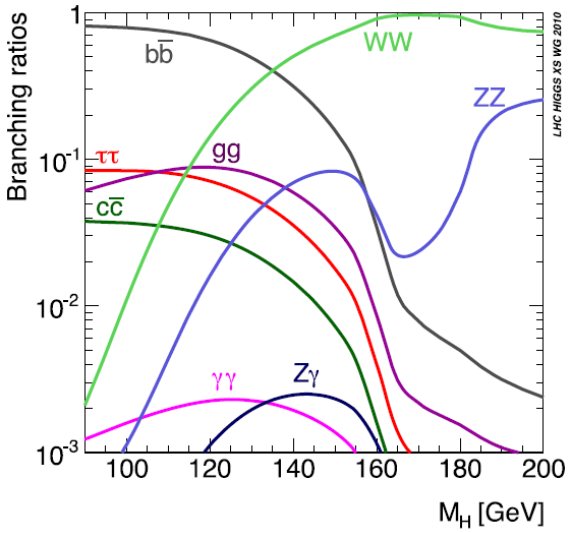
H→Z^0Z^0 (Z^0→e+e- /$\mu^+\mu-$)



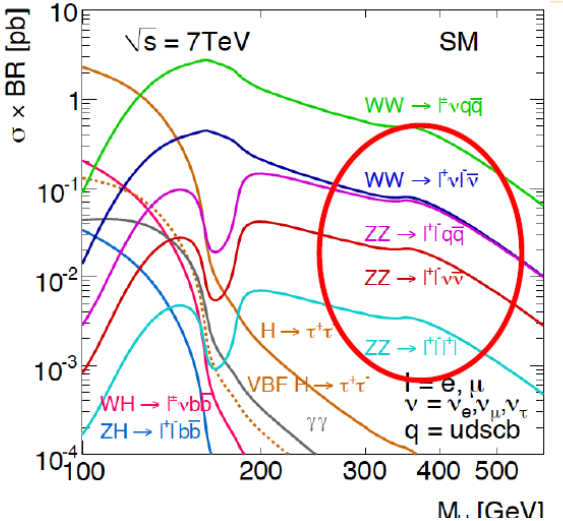


Higgs searches at CMS -II

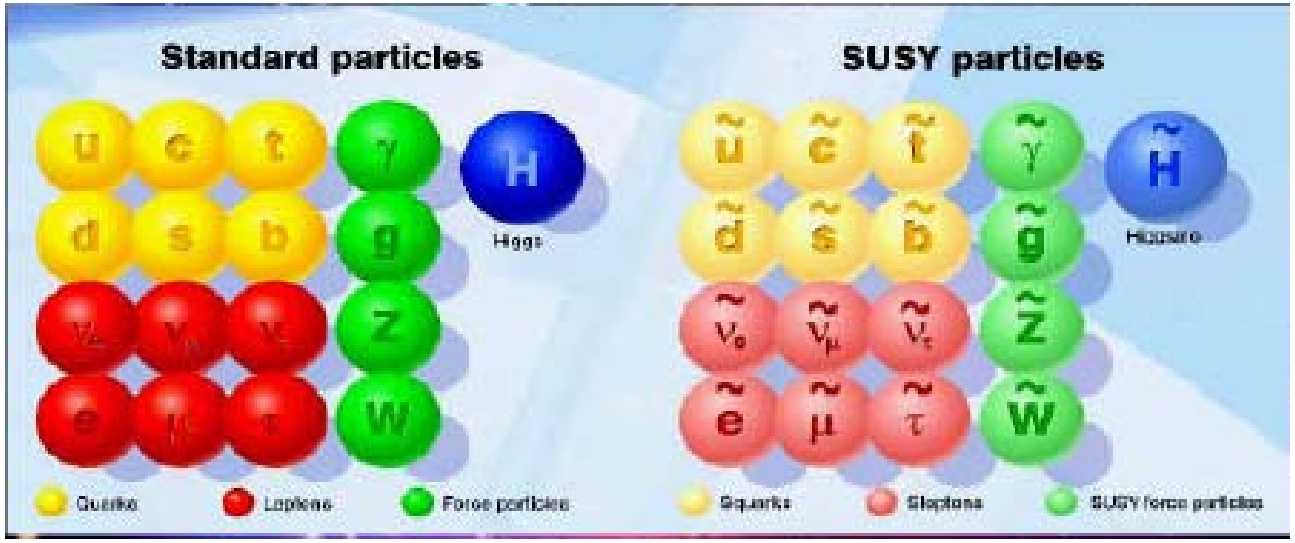
- Light Higgs
  - H→bb
  - H→ττ
  - H→γγ
  - H→WW
  - H→ZZ→4l



- Medium to Heavy Higgs
  - H→WW→2l2ν (+jets)
  - H→ZZ→ (2l2j, 2l2ν, 4l, 2l2τ)



Super-symmetry (SUSY)

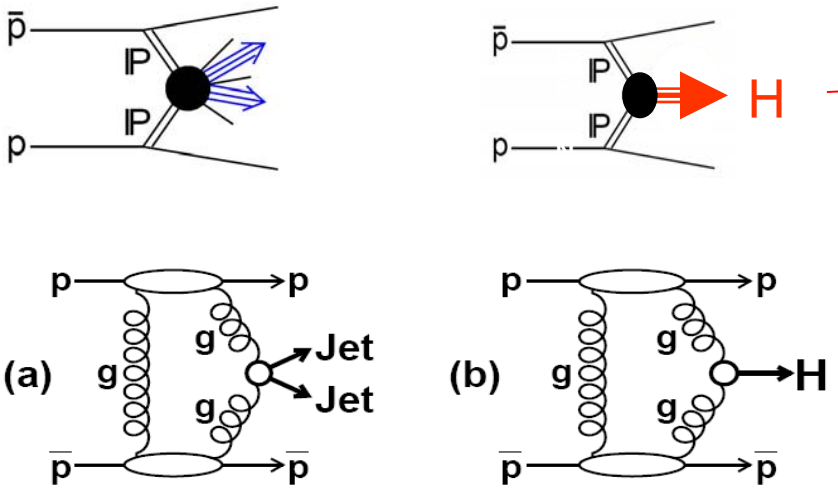


- The SM is not stable at high energies because of loop corrections
- SUSY → renormalizes the SM by introducing opposite sign contributions
- The lightest SUSY particle (LSP) escapes detection

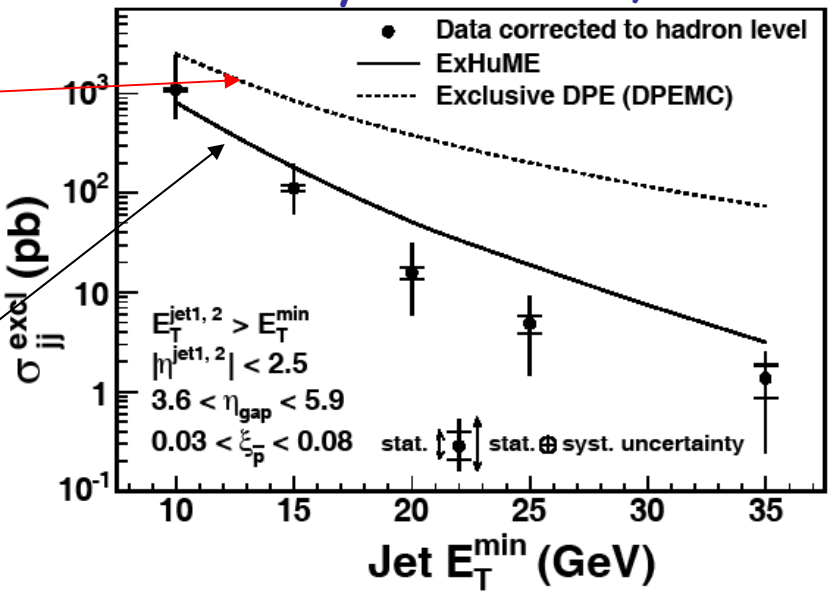
  → candidate for dark matter

  …but what about dark energy???

Exclusive Higgs Production



Phys. Rev. D 77, 052004



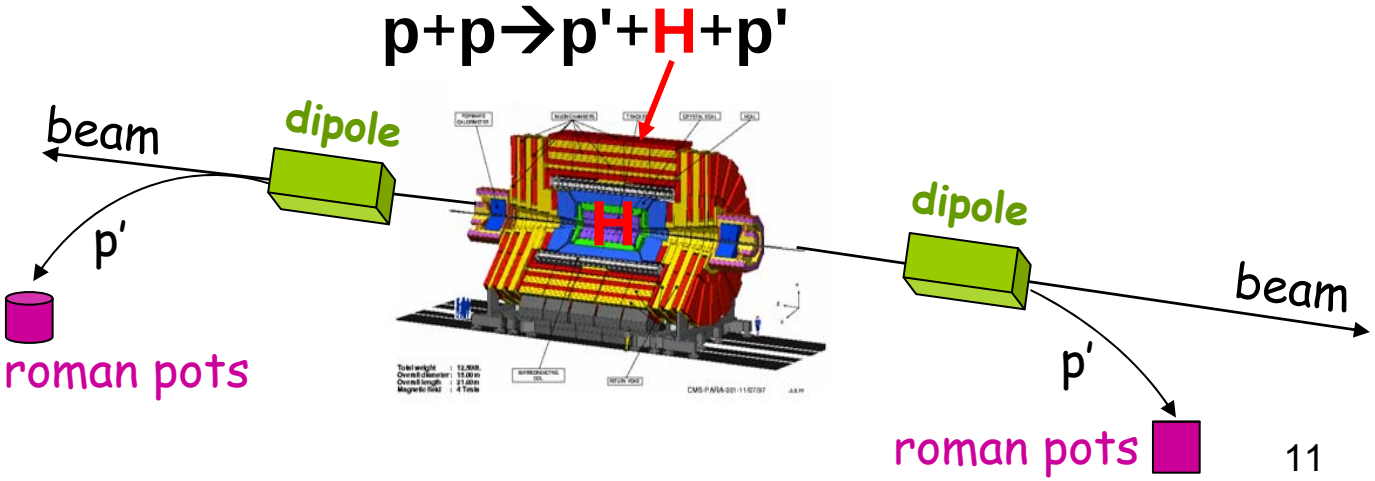
$J_z = 0$

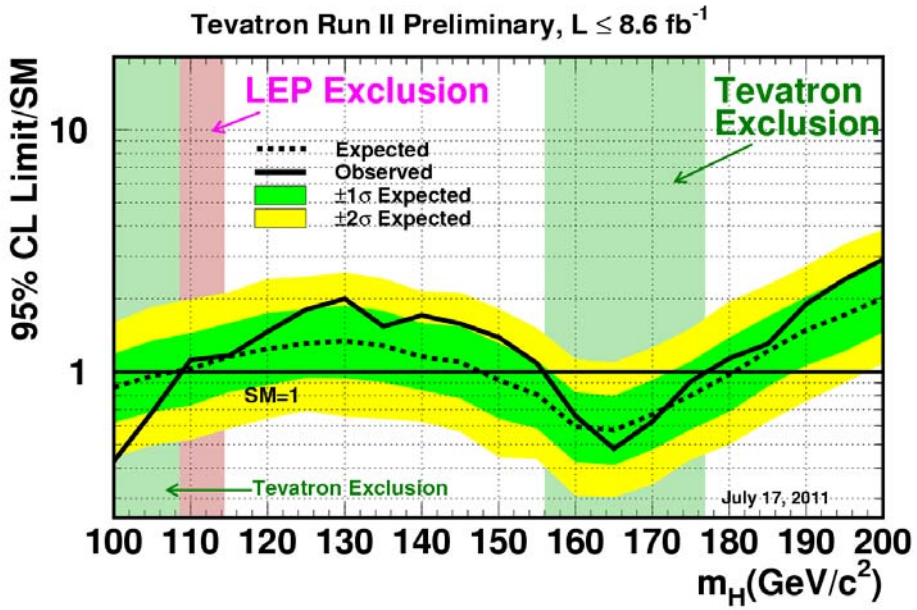
0^{++} state $\Rightarrow$ identifies Higgs

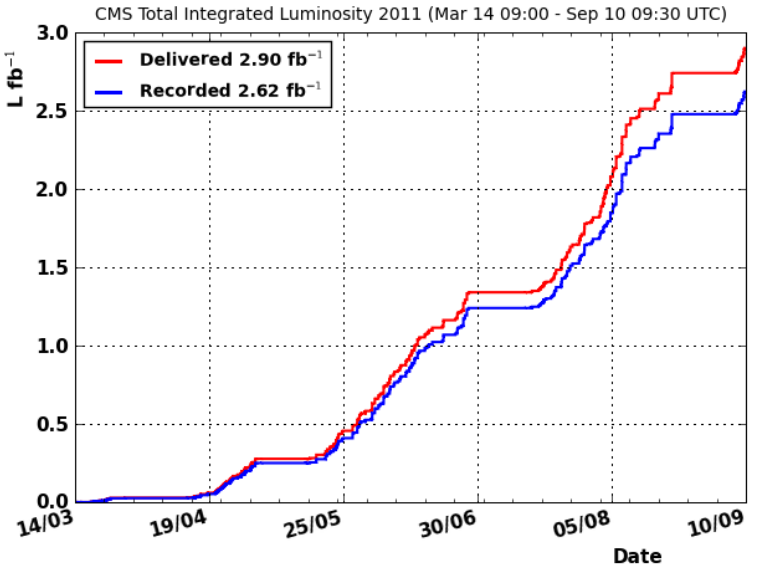
$\text{Rate}(q\bar{q}/gg) \sim \frac{m_q^2}{M^2} \sim 10^{-7}$

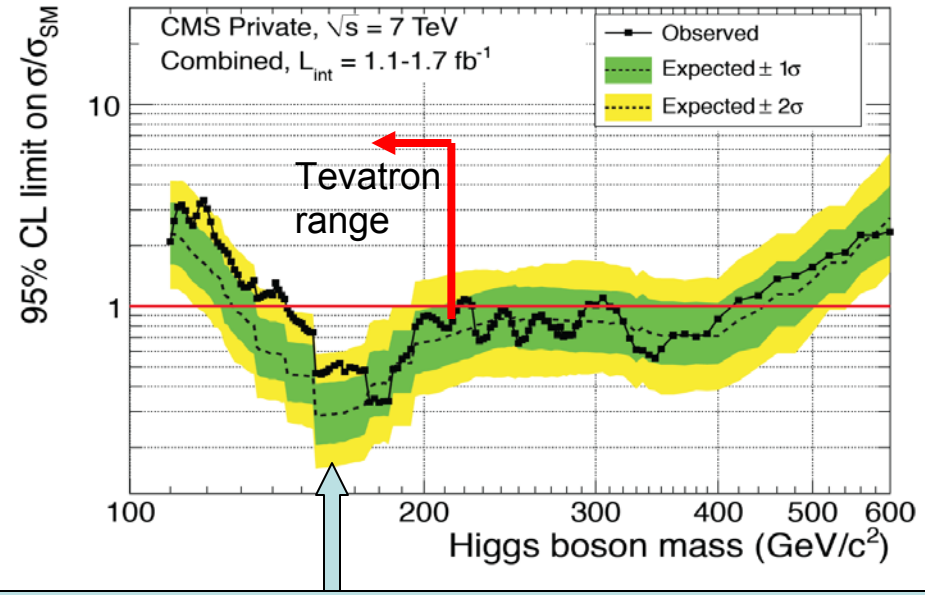
$M \sim 2 \bullet \delta p$

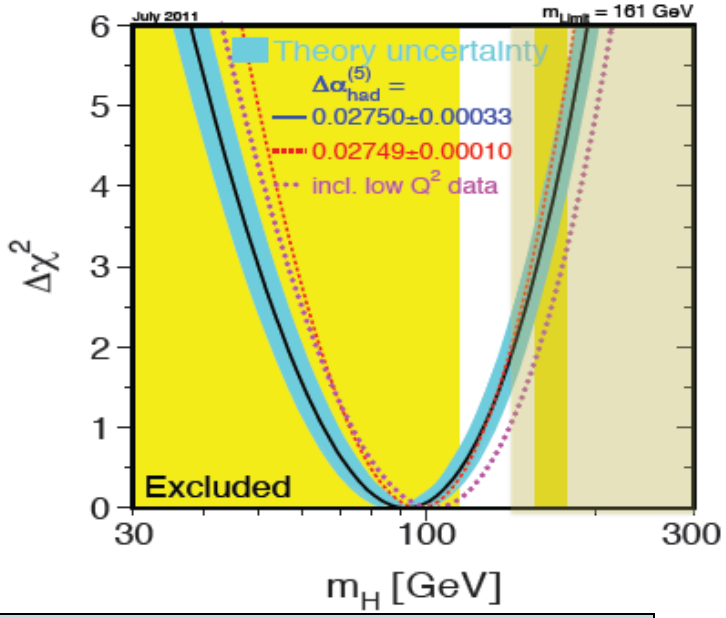
$\text{TOF} \Rightarrow \delta M \sim 1-2\,\text{MeV}$







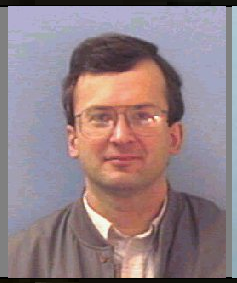




With 5fb-1 & combination of CMS+ATLAS data the SM Higgs exclusion reach is in the range140<M_H<600GeV
➔The non-discovery of the SM Higgs will be an even bigger discovery!

HOL talk in 2004


Anwar


Luc


Stefano


Michele


Mary


Koji


Christina


Andrea (student)


Ken

2011






Robert


Jim




Sarah



http://physics.rockefeller.edu

← Vadim and Joe →
(machine shop)

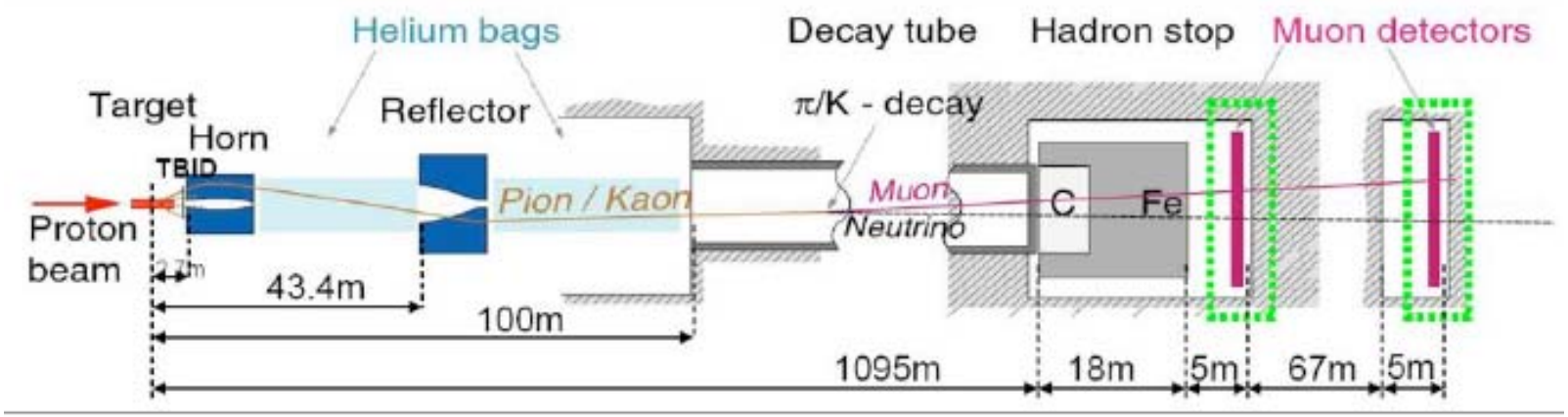


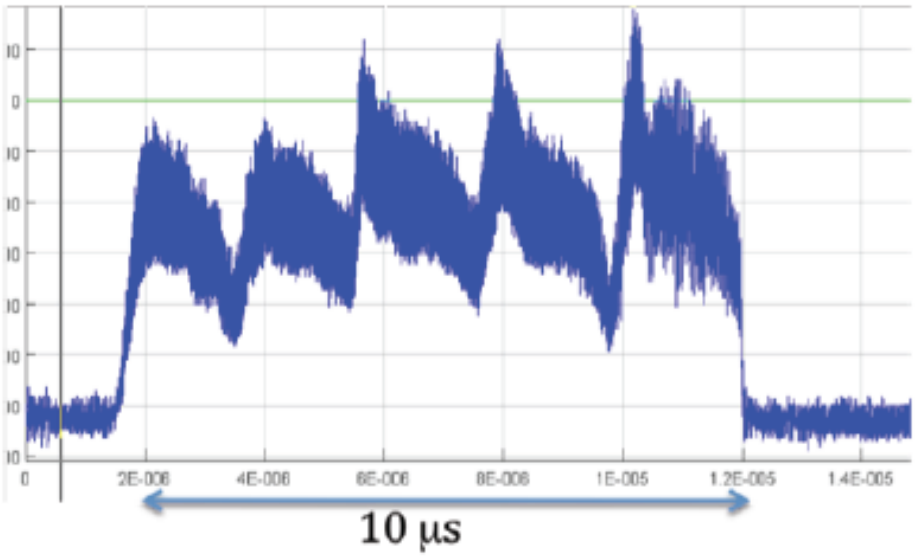
Backup

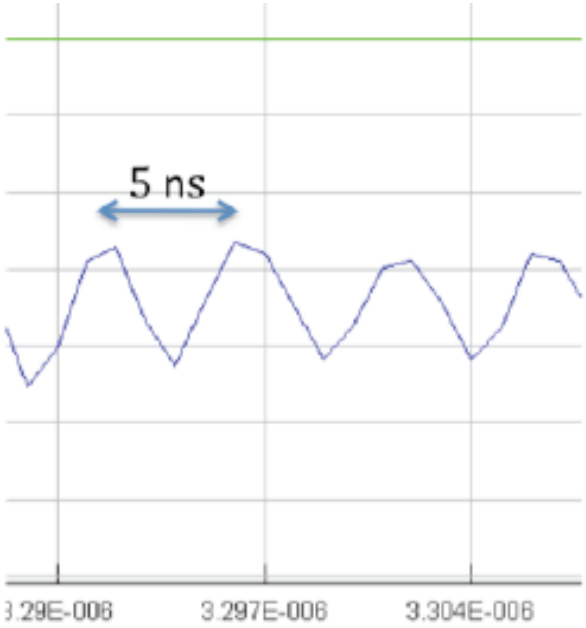
Neutrino mass hierarchy problem

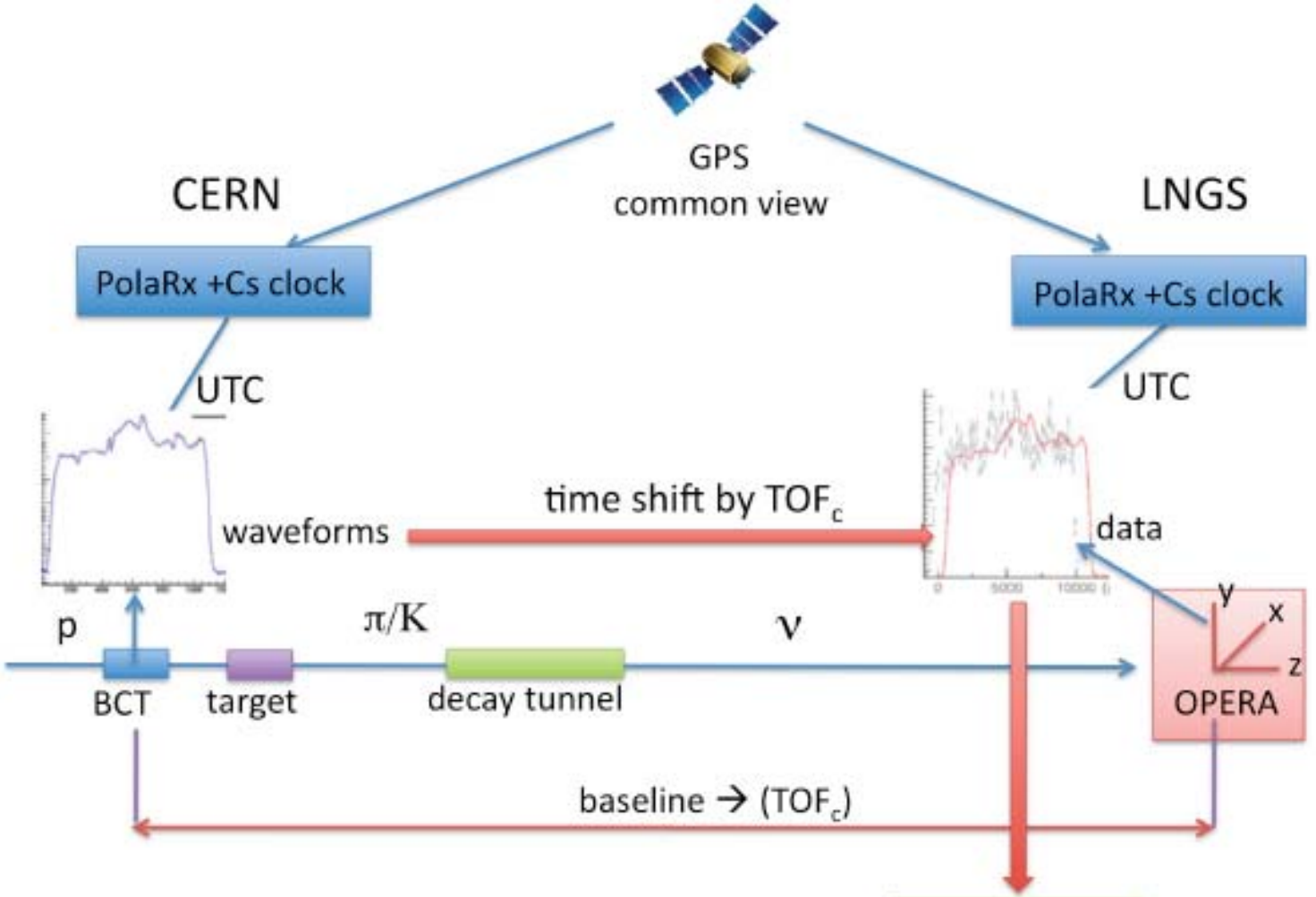
Accelerator and CR experiments→ $M^2_{12} \sim 7.9 \times 10^{-5}$ eV^2.

From cosmology:
CMB and large scale structure experiments → $\Sigma = 0.03 < m1+m2+m3. < 0.05eV$


Helium bags
Decay tube
Hadron stop
Muon detectors
Target
Horn
Reflector
π/K - decay
TBID
Pion / Kaon
Muon
Neutrino
C
Fe
Proton beam
43.4m
100m
1095m
18m
5m
67m
5m


2E-006
4E-006
6E-006
8E-006
1E-005
1.2E-005
1.4E-005
10 μs


5 ns
3.29E-006
3.297E-006
3.304E-006



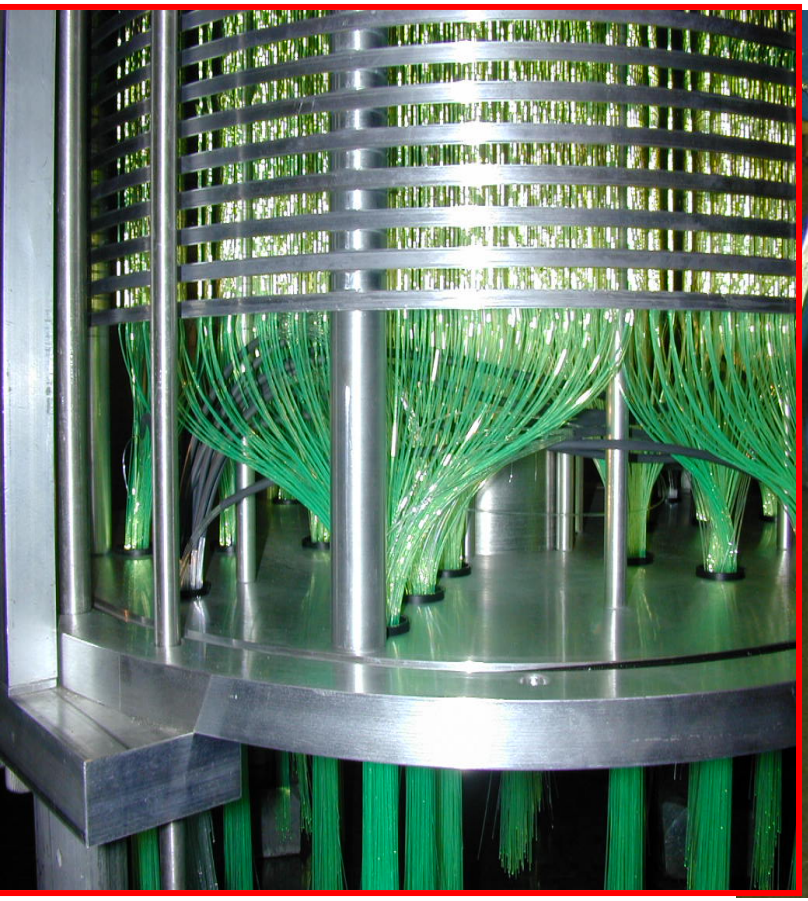
$\delta t = (60.7 \pm 6.9\ (\text{stat.}) \pm 7.4\ (\text{sys.}))\ \text{ns}$

$(v\text{-}c)/c = \delta t\ /(TOF'_c - \delta t) = (2.48 \pm 0.28\ (\text{stat.}) \pm 0.30\ (\text{sys.})) \times 10^{-5}$

significance of 6.0 σ

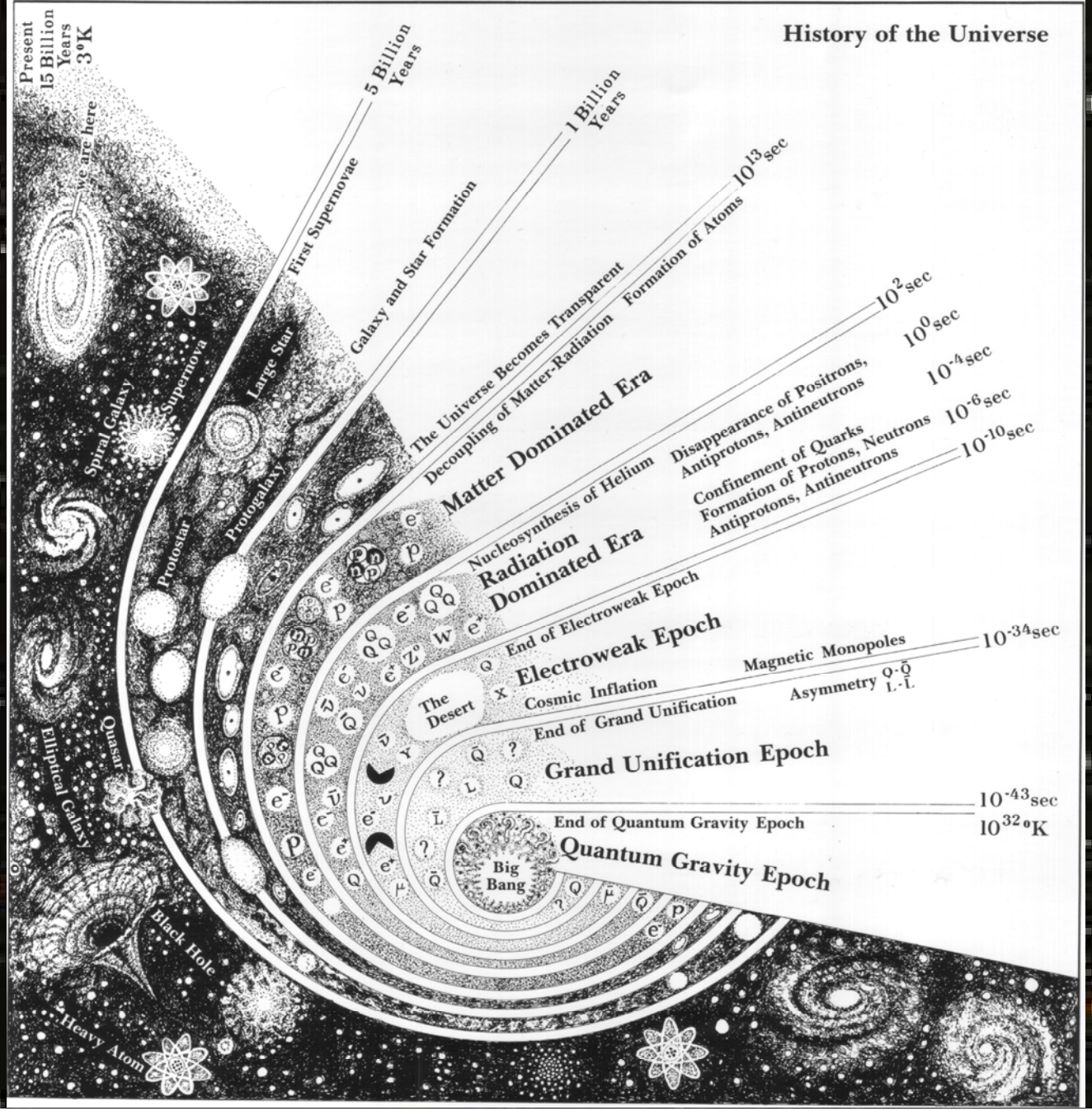
The MiniPlugs @ CDF

Threading the MiniPlug fibers

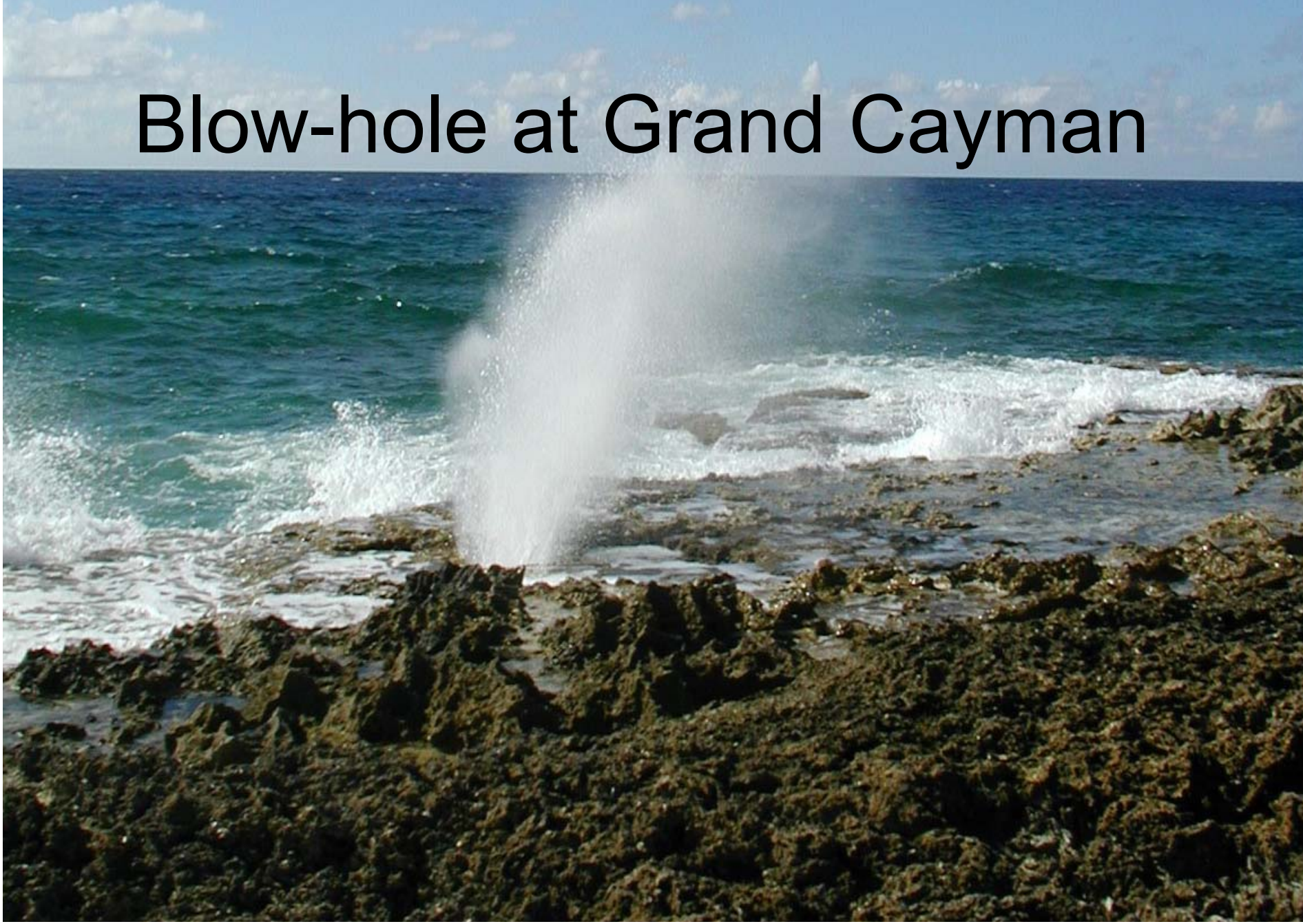




About 1500 wavelength shifting fibers of 1 mm dia. are 'strung' through holes drilled in 36x$\frac{1}{4}$" lead plates sandwiched between reflective Al sheets and guided into bunches to be viewed individually by multi-channel photomultipliers.


History of the Universe
Present
15 Billion
Years
3°K
we are here
5 Billion
Years
1 Billion
Years
First Supernovae
Galaxy and Star Formation
The Universe Becomes Transparent
Decoupling of Matter-Radiation
Formation of Atoms
10^{13}sec
Spiral Galaxy
Supernova
Large Star
Protostar
Protogalaxy
Matter Dominated Era
Nucleosynthesis of Helium
Disappearance of Positrons, Antiprotons, Antineutrons
10^{2}sec
10^{0}sec
Confinement of Quarks
Formation of Protons, Neutrons
Antiprotons, Antineutrons
10^{-4}sec
10^{-6}sec
10^{-10}sec
Radiation Dominated Era
End of Electroweak Epoch
Electroweak Epoch
The Desert
Cosmic Inflation
Magnetic Monopoles
10^{-34}sec
End of Grand Unification
Asymmetry $Q\text{-}\bar{Q}$ $L\text{-}\bar{L}$
Grand Unification Epoch
10^{-43}sec
End of Quantum Gravity Epoch
10^{32}°K
Big Bang
Quantum Gravity Epoch
Quasar
Elliptical Galaxy
Black Hole
Heavy Atom

Blow-hole at Grand Cayman



p-p Interactions

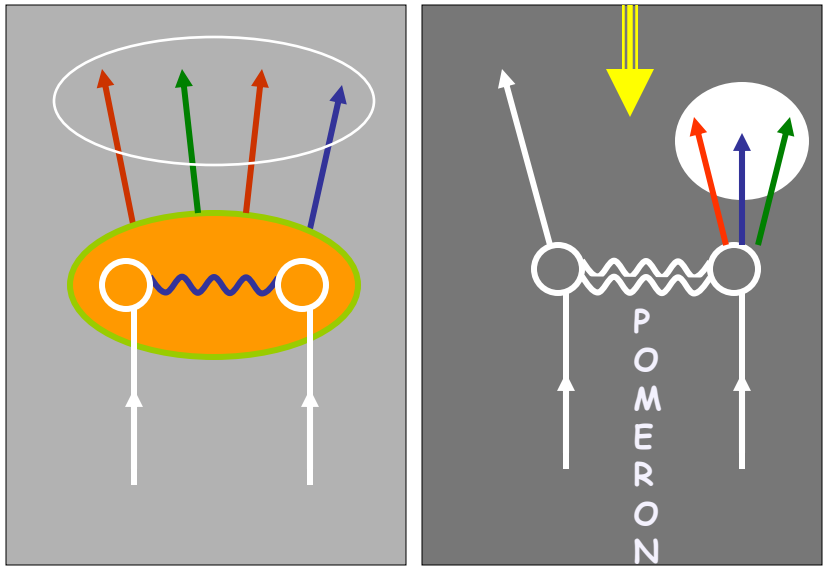
Non-diffractive:

Color-exchange

Diffractive:

Colorless exchange with vacuum quantum numbers

rapidity gap



Incident hadrons acquire color and break apart

CONFINEMENT

Incident hadrons retain their quantum numbers remaining colorless

pseudo-DECONFINEMENT

Goal: understand the QCD nature of the diffractive exchange

Dark Energy

Non-diffractive interactions

Rapidity gaps are formed by multiplicity fluctuations:

$$P(\Delta y) = e^{-\rho \Delta y}; \quad \rho = \frac{dN_{particles}}{dy}$$

P(Δy) is exponentially suppressed

Diffractive interactions

Rapidity gaps at t=0 grow with Δy:

$$\Delta y \approx -\ln \xi = \ln s - \ln M^2$$

$$P(\Delta y)\big|_{t=0} \sim e^{2\varepsilon \Delta y}$$

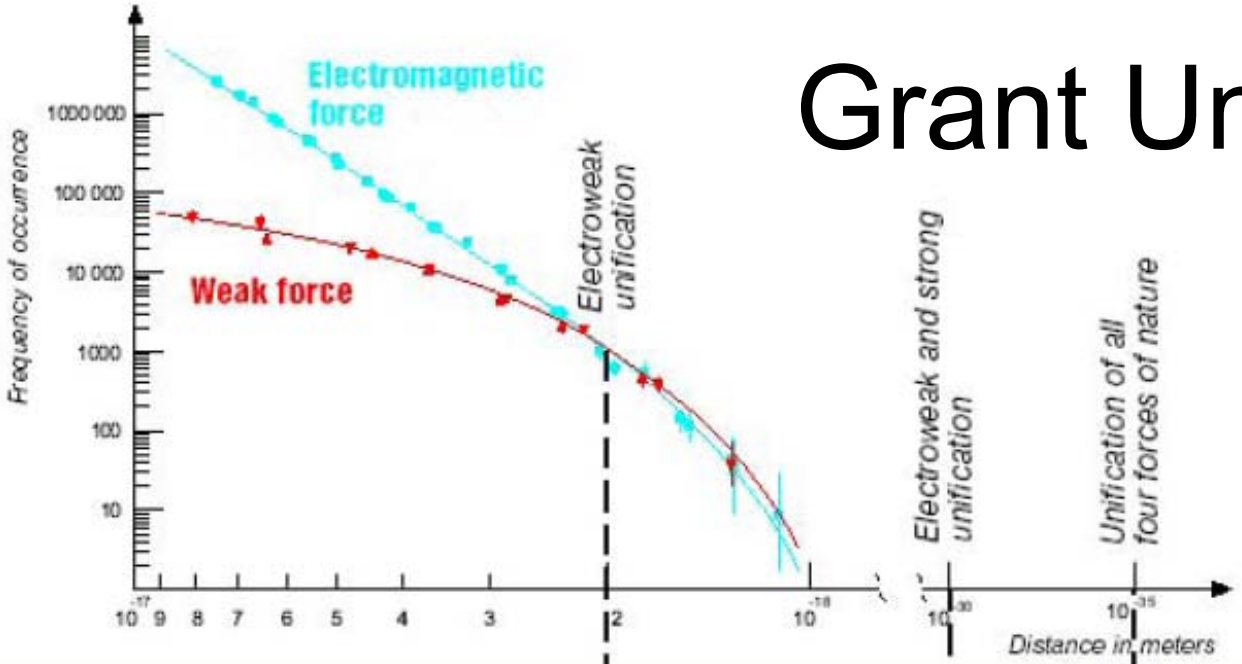
2ε: negative particle density!

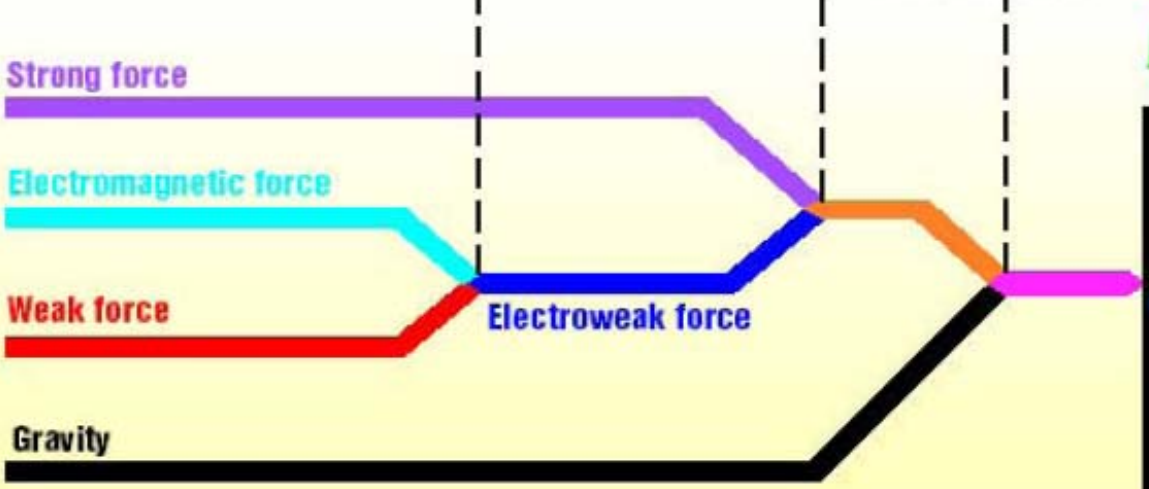
Gravitational repulsion?

http://physics.rockefeller.edu/dino/myhtml/talks/goulianos_konstantin_eds09_discussion.pdf

http://physics.rockefeller.edu/dino/myhtml/conference.html

Grant Unification





Big Bang

