# *Welcome to Fermilab!*

# Extremes Accelerators

(*Thank you for visiting us. Please feel free to interrupt for questions,...*

*Speedy Neutrinos, Higgs, what to do with a 6.28 km circumference Tunnel* )

Large, Man-Made Accelerators

Versus

Very large Cosmic Accelerators.

# Particle beams to meet national challenges

*From about 110  years, electrons accelerators are used widely... For instance..*

Sterilizations,

Bandages fabrication

*Courtesy: AEB*

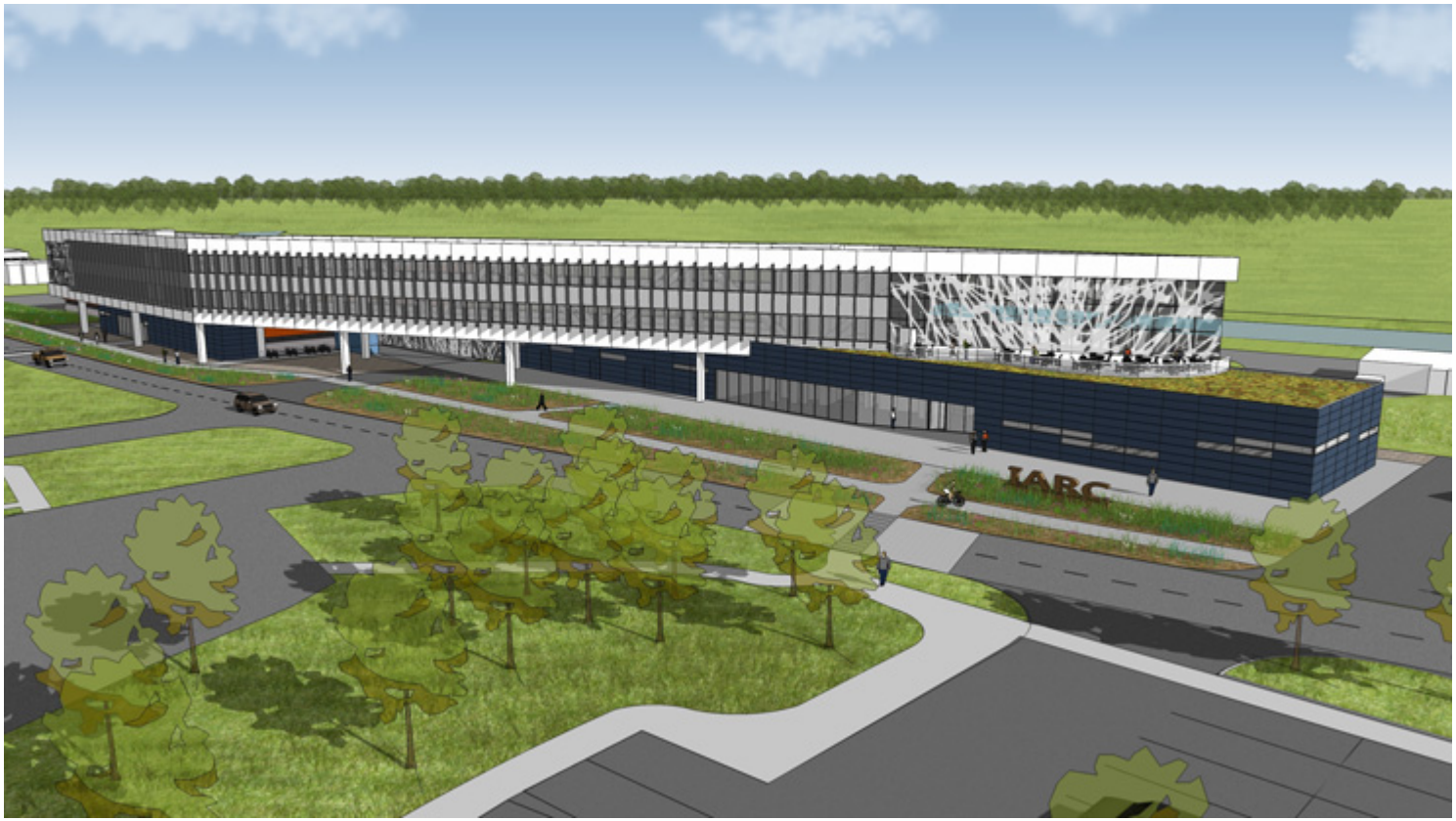
Photo: Reidar Hahn, Fermilab

A beam of the right particles with the right energy at the right intensity can shrink a tumor, produce cleaner energy, spot suspicious cargo, make a better radial tire, clean up dirty drinking water, map a protein, study a nuclear explosion, design a new drug, make a heat-resistant automotive cable, diagnose a disease, reduce nuclear waste, detect an art forgery, implant ions in a semiconductor, prospect for oil, date an archaeological find, package a Thanksgiving turkey,

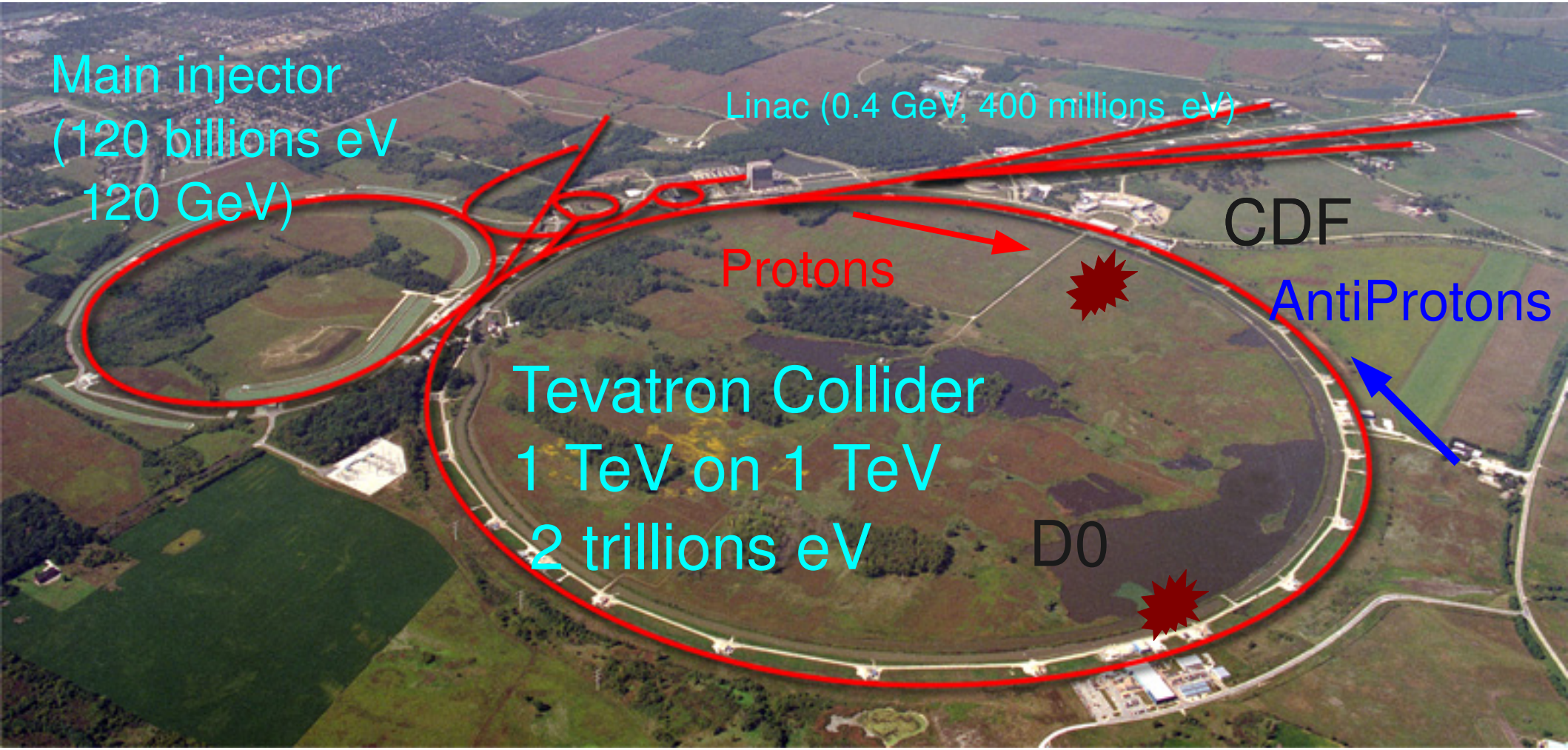
Or ... discover the secrets of the universe.

(Symmetry Magazine, “ Accelerators for America's Futures..”, August, 2010)

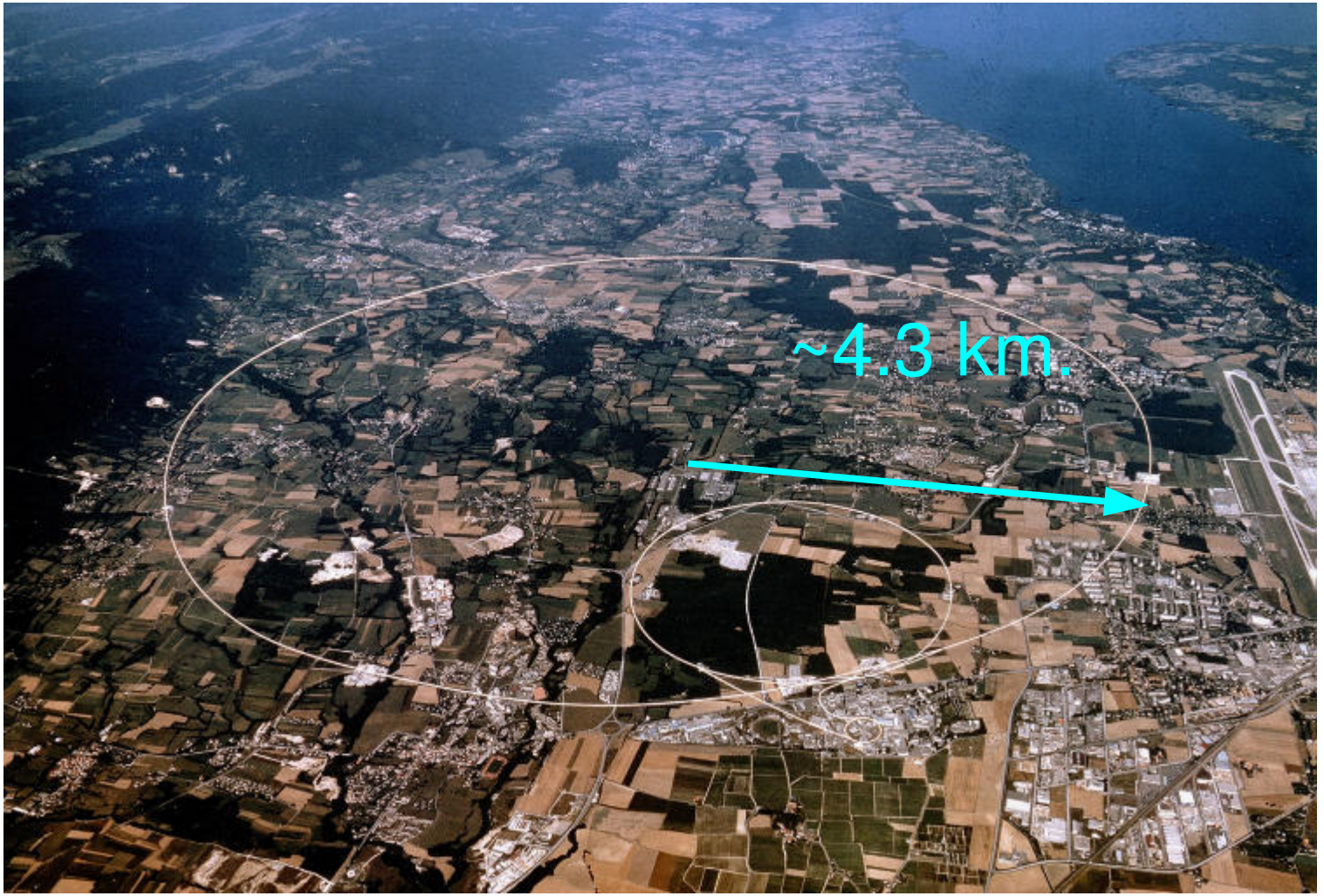
*Designing, building and commissioning  new type of accelerators is a big part of our mission*



# Our Accelerator.. (Size matter)

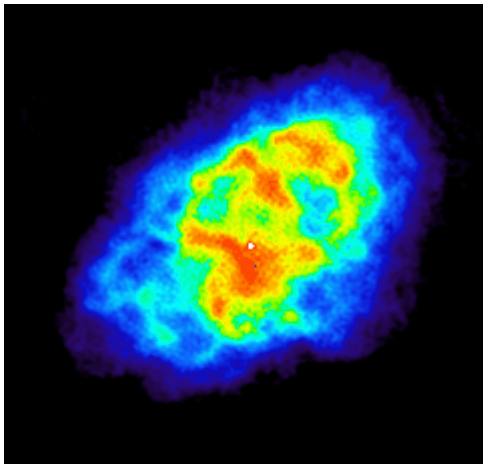


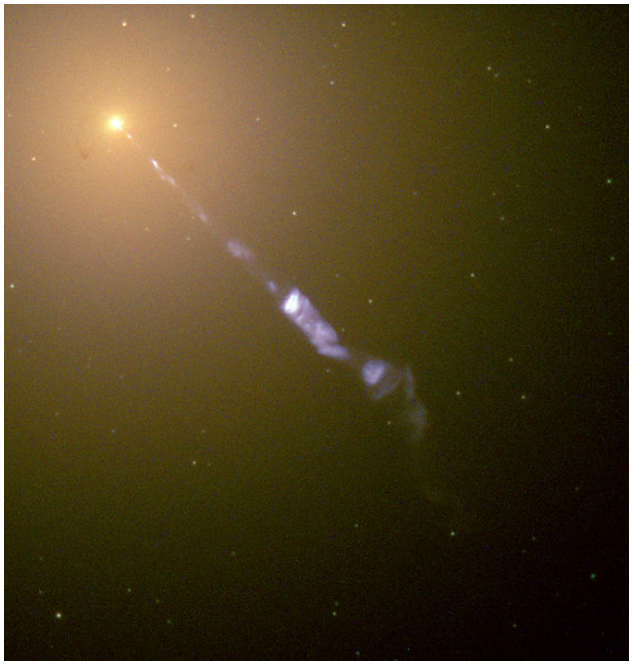
# At CERN, Europe.

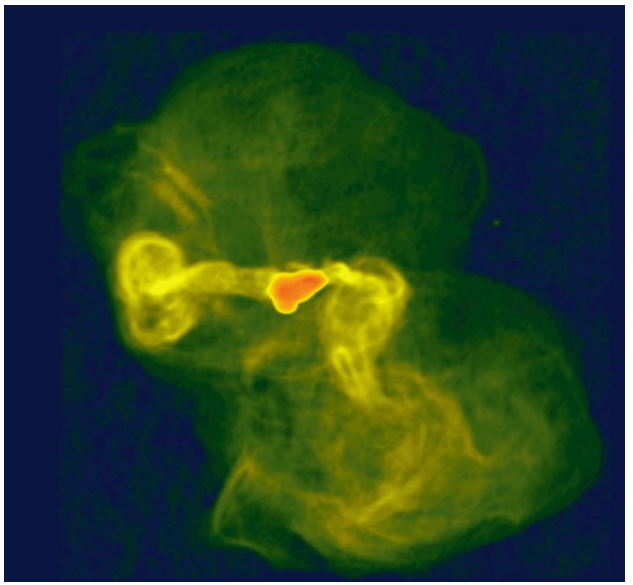



3.5 trillions eV on 3.5 trillions eV... in a a year or two, 7 on 7

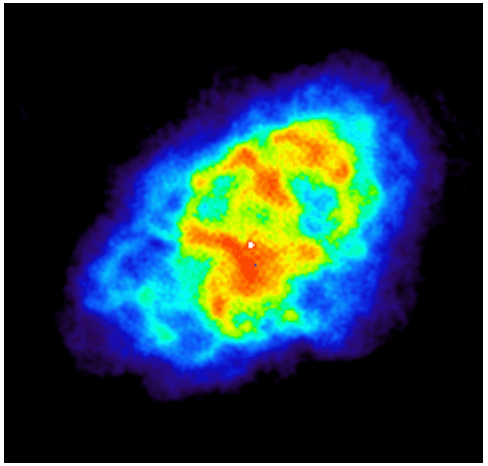
Any idea of what these could be ?





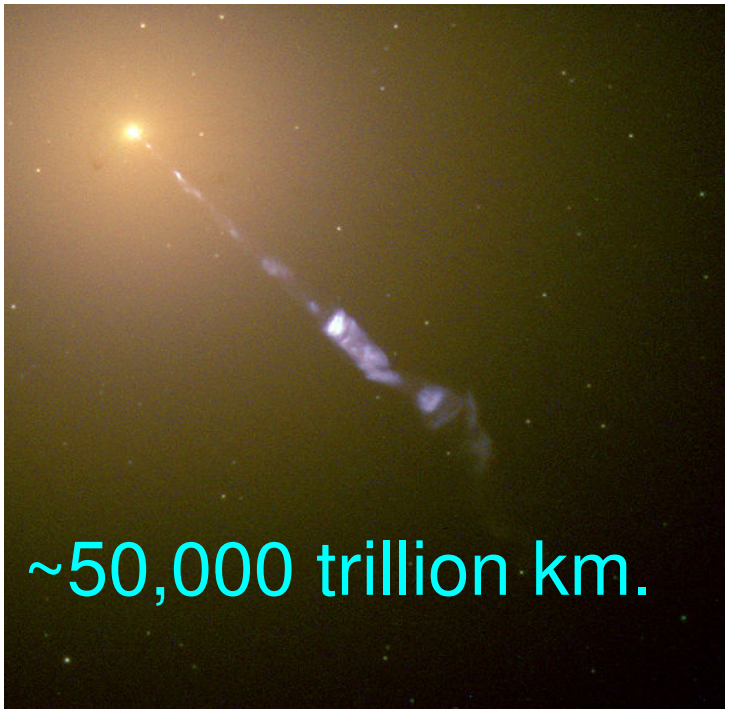


# Star remnants .....to galaxies

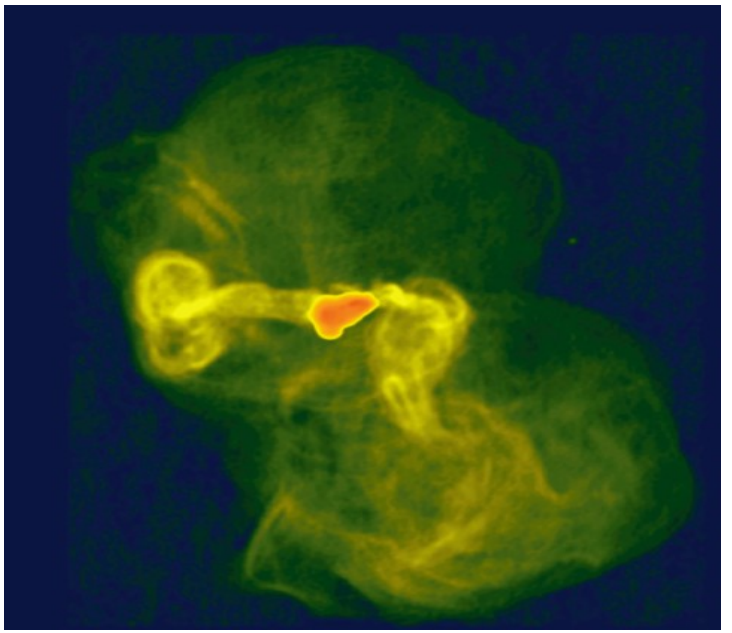


Radio image of the Crab Nebulae

~ 50 trillion km in size




Messier 87, Radio..



Seen also in gamma ray band!.

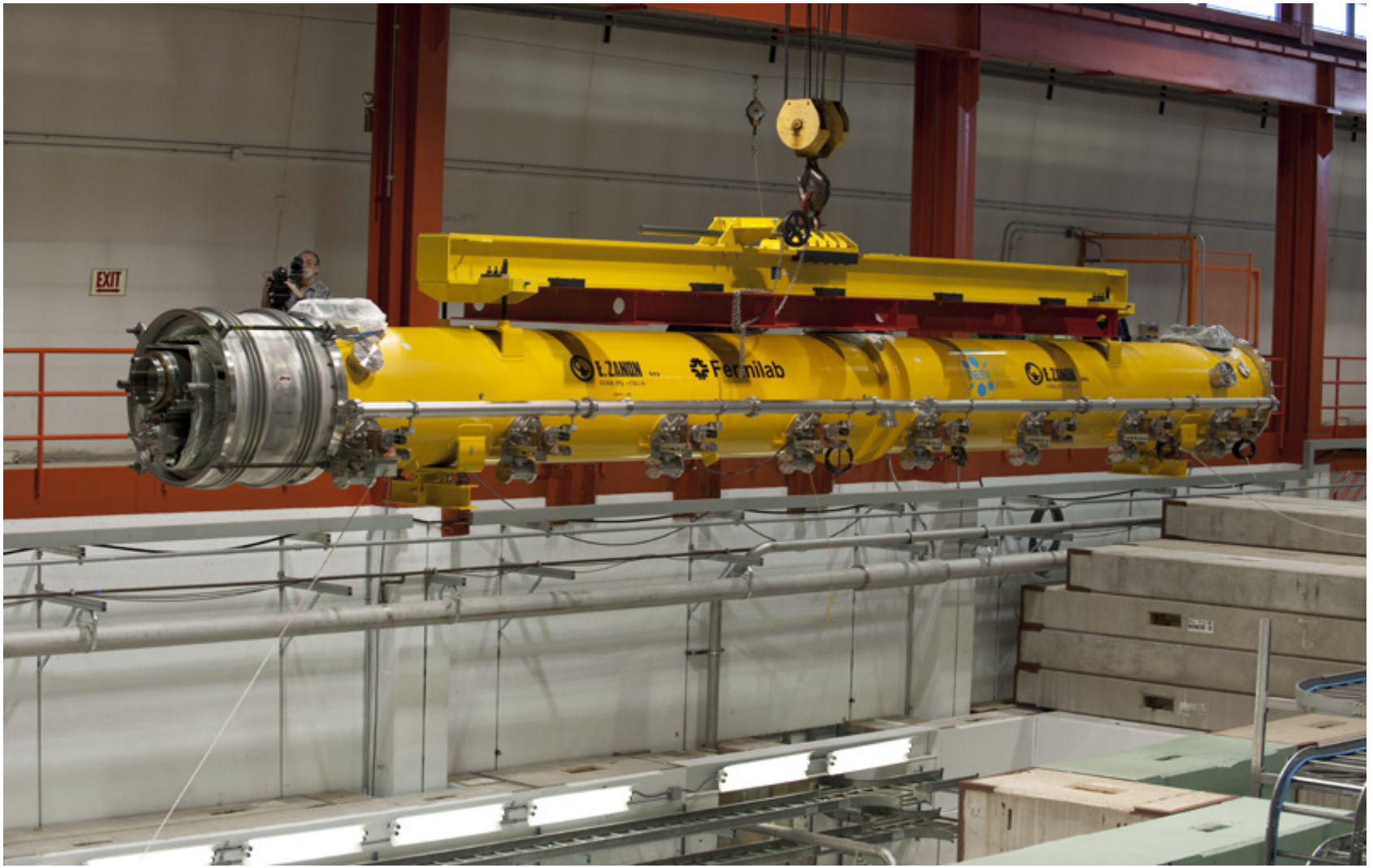
They must be the site where particles are accelerated.

What's the maximum energy? Where does the power comes from?  What type of accelerators? Are they circular? Linear?

# Types of Accelerators

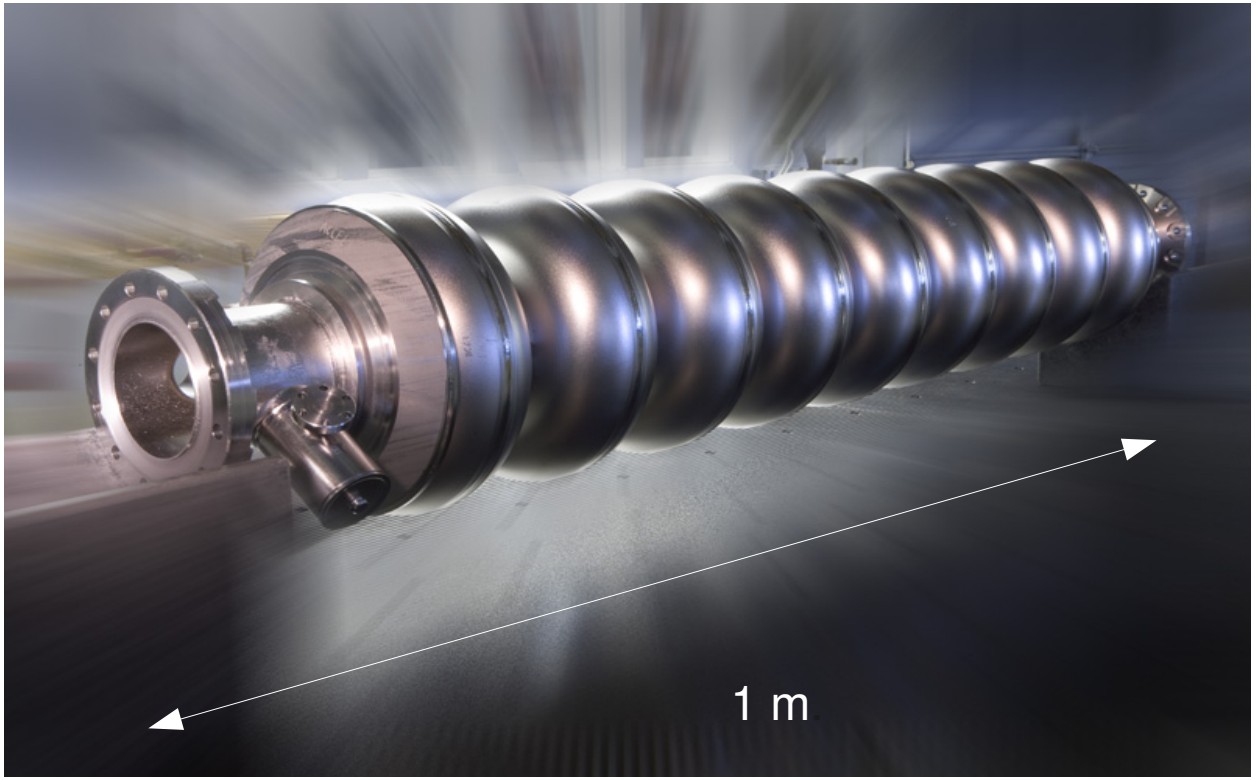
- LINAC: Linear Accelerators. “Single pass”: a given proton goes through a given section only one time. Beam is accelerated, focused, accelerated,.. Example: Project-X 3 GeV Linac.
- Synchrotrons: Beam is contained in confined in a ring, strong magnetic bend proton trajectories. As they get accelerate, this magnetic field get stronger.

# A Test Linac under construction...



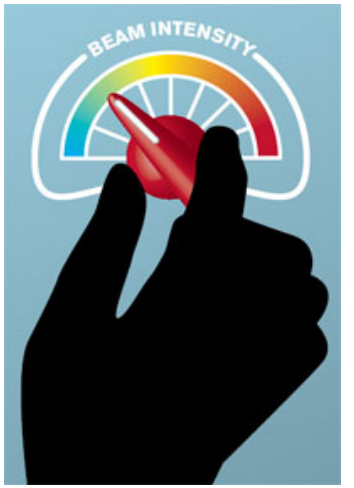
Inside such a module..

Complex cryogenics (< 2 K$^{o}$ )




9 cell, 1.3 GHz cavity.
Superconducting

# Accelerator Power




- Power

  = Energy X Number of particles / second

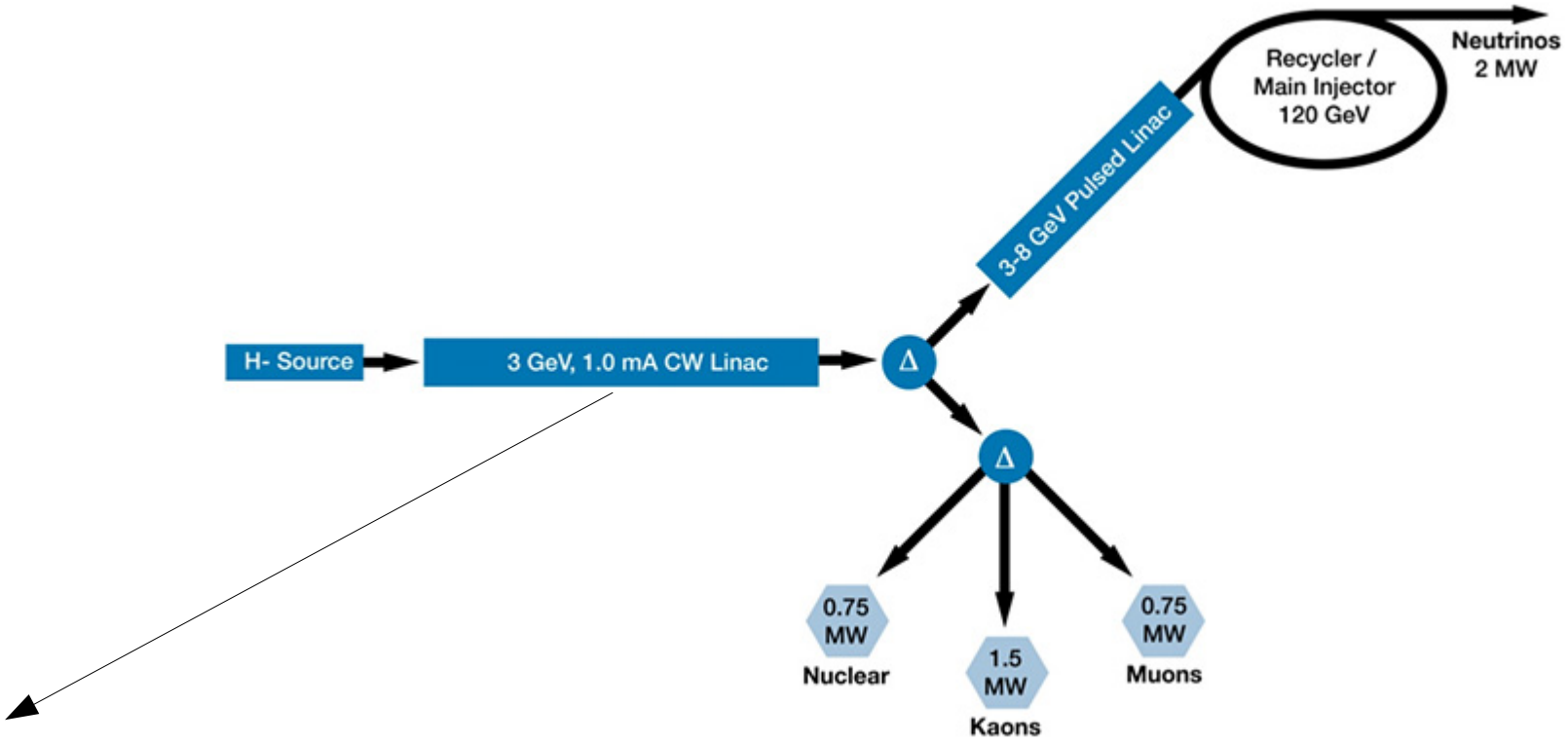
Energy Frontier

Direct discovery of new particles

Intensity Frontier

Precision measurement
Rare processes
Small deviations from known laws of physics.
Detection of the same – albeit virtual - particles

# Project-X Reference Design




3 GeV = 3 billion electron volt

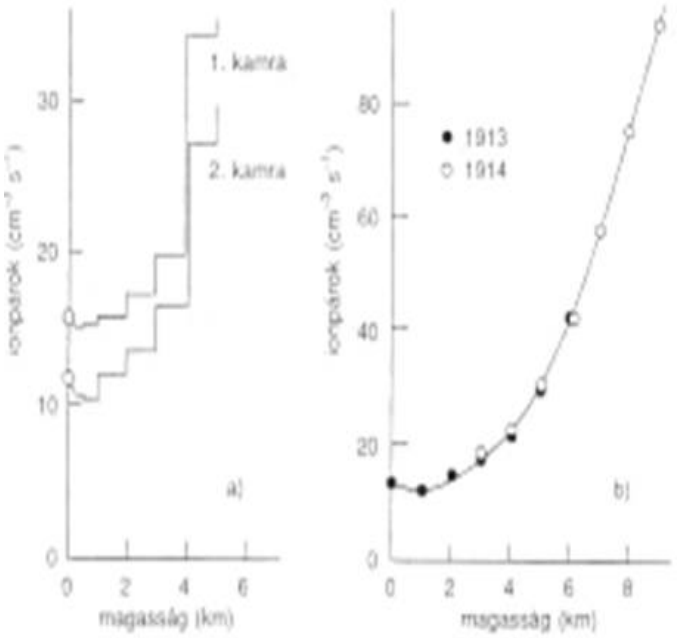
1 mA ( or ~6 thousand trillion particles/sec)

3 MW of beam power

(requires ~ 5 to 10 x more wall-plug power... ~ 15 to 30 MW

Cosmic Accelerators do exists as well:

Observation of Cosmic Rays (1912)

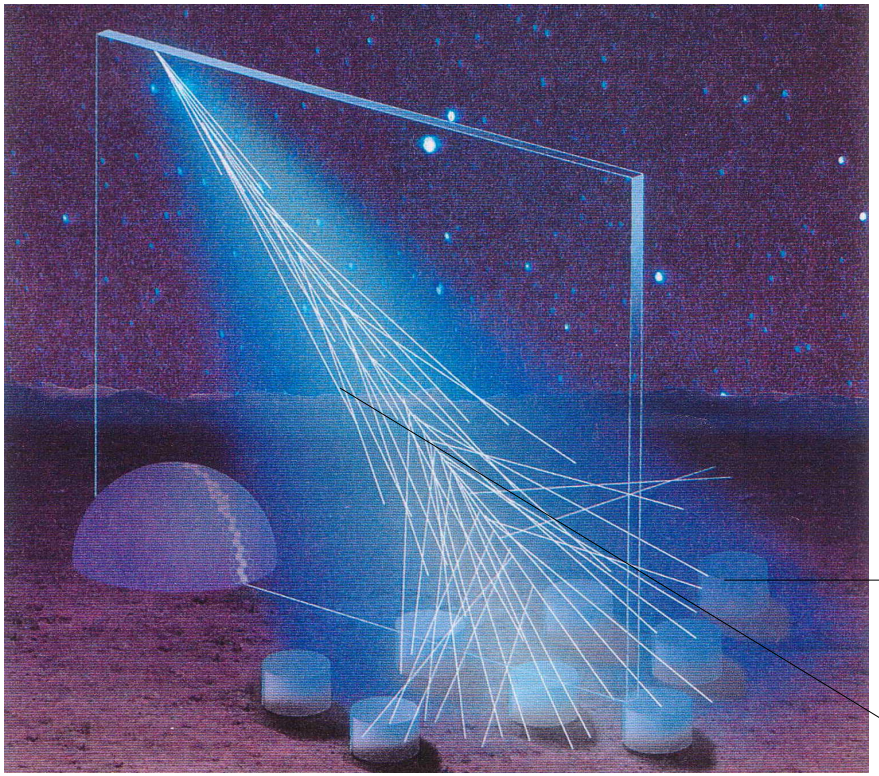
# Cosmic Accelerators..

Related to the existence of disastrous collisions...

We observed cosmic ray (particles from the sky...) with energies of ~ $10^{20}$ eV, 20 millions times bigger than produced at the LHC.. tens of Joules (not that many kcalories!) but...

***per particle !***

***Remember the Avogadro number (6 $10^{23}$)***

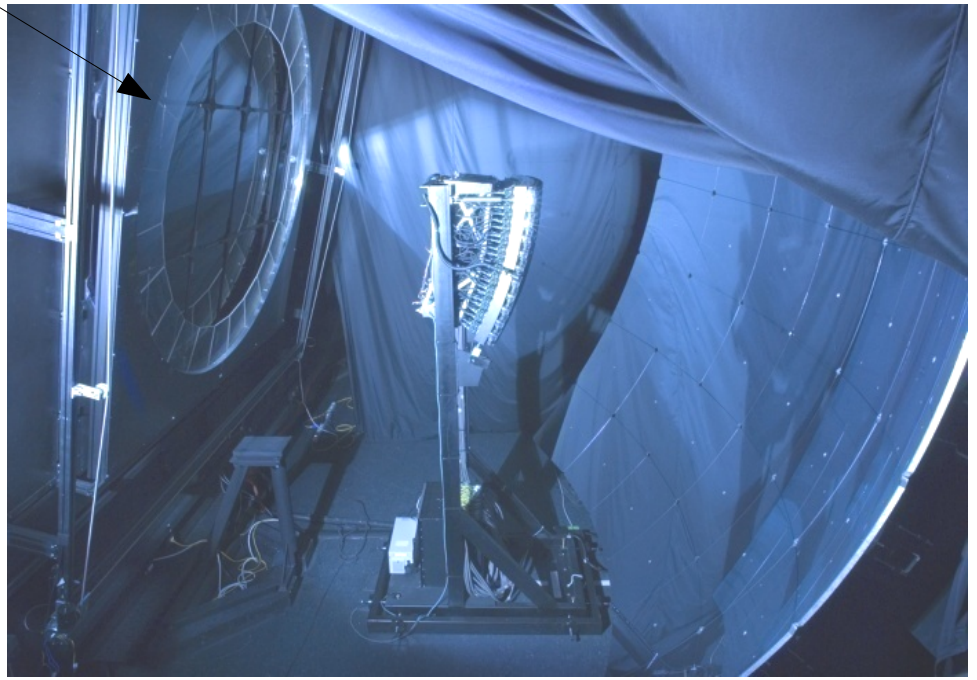



At the Pierre Auger Observatory,
(Argentina)

We detect ultra high energy cosmic rays

… 50 to 100 billion billion electron volt

… *2 events per month!* ..



http://www.auger.org/index.html

# Real Cosmic Accelerators!

- At low energy (MeV -> TeV ($10^{12}$ eV)), we identified a few of them, but a detailed understanding is difficult!.
- At the Highest energy ($10^{20}$ eV), while Auger has found an interesting correlation of arrival of direction with Active Galactic Nuclei, but not yet confirmed individual sources in the sky...
- And no consistent models for such large (very large) accelerators.

# How big a Project-X type linear accelerator do we need to reach 50 billion billions eV ?

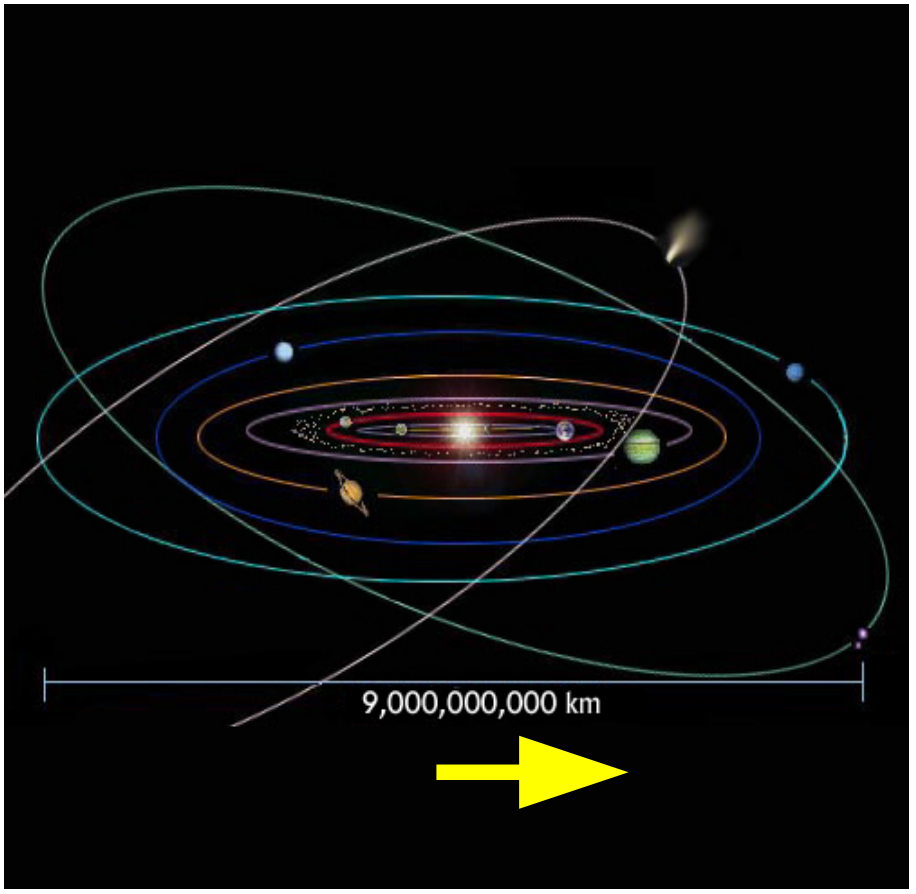
## Solar System Scale!

Simple arithmetic!

35 MeV/m

→ 1.4 billion km.

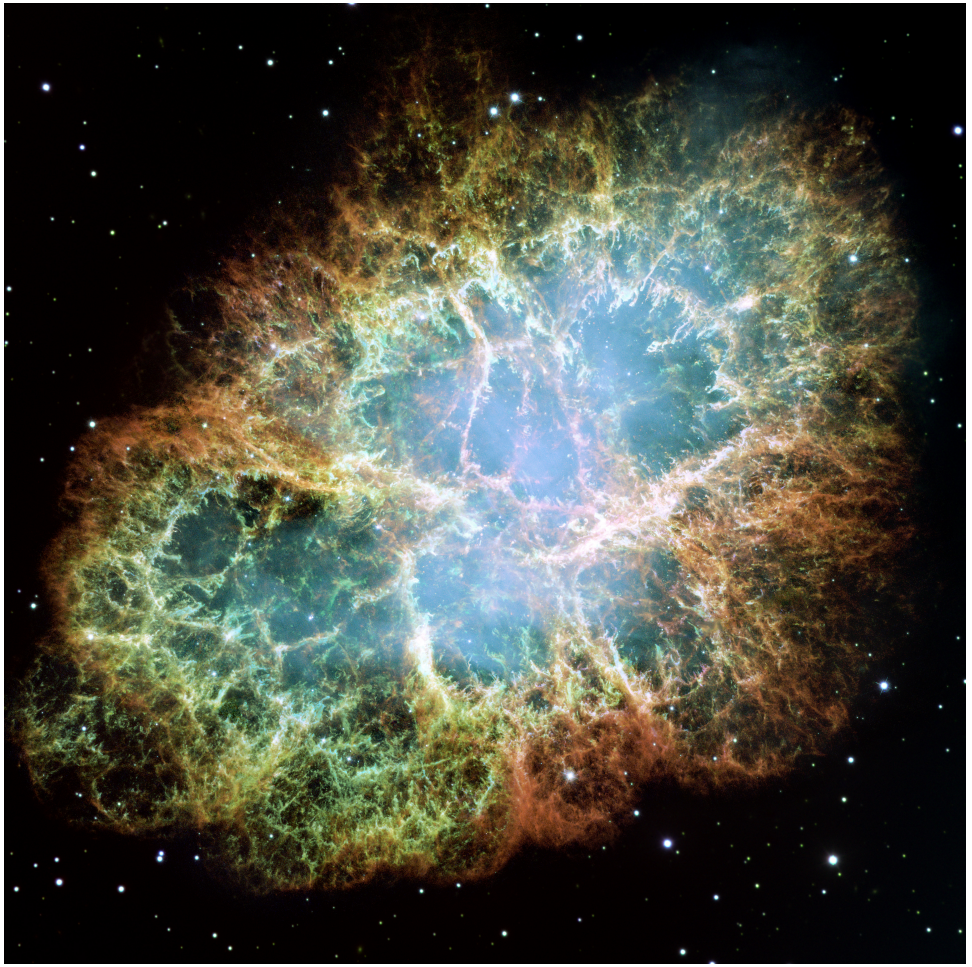
Or 180 billion cryomodules



In all fairness, our accelerator based colliders can almost reach such very high energy: Cosmic Rays interact with a stationary target (an atom in the atmosphere, which is “at rest”), while we can collide particles “head on”.

100 million billions eV Cosmic Ray is ~
14 Terra (100 billions) eV, the design energy of the Large Hadron Collider at CERN.

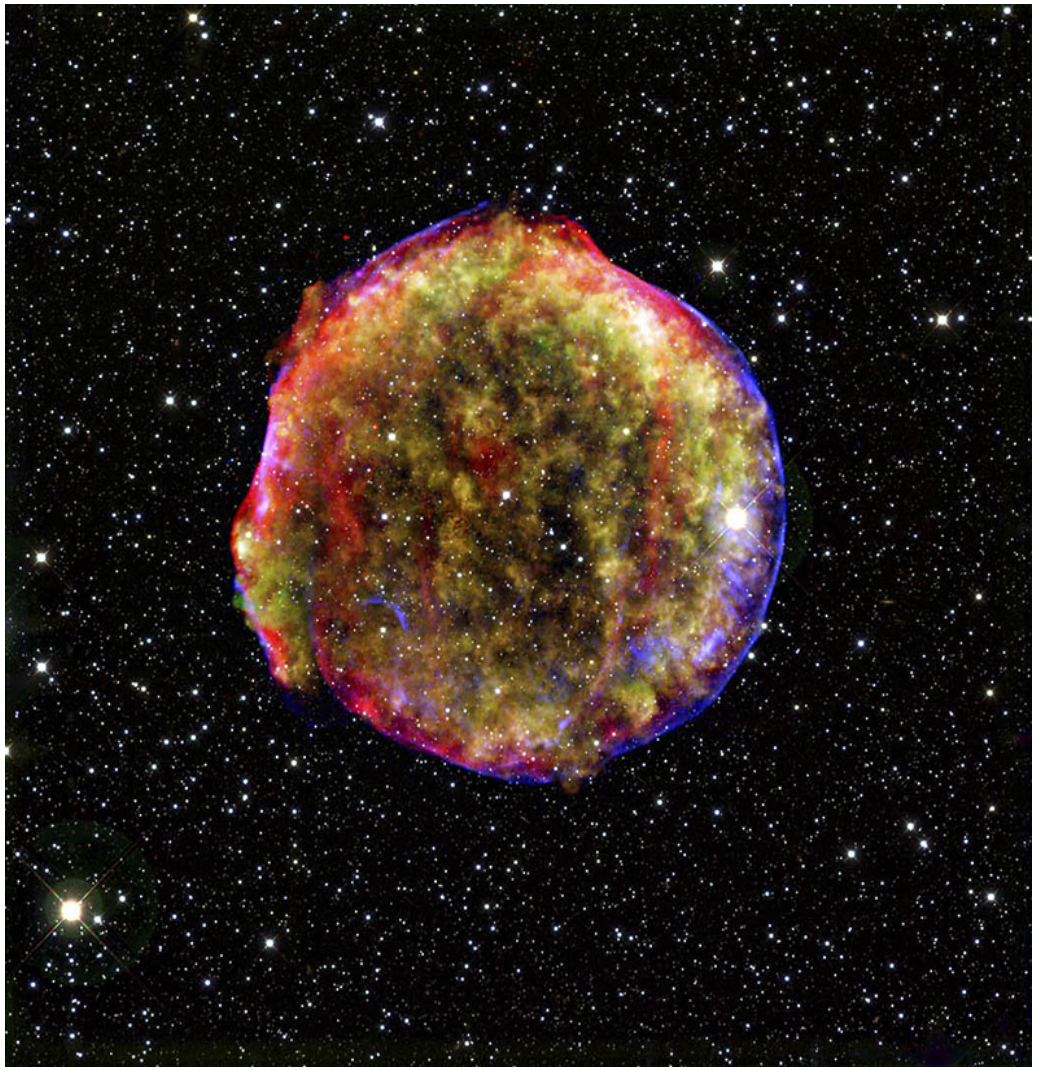
# Crab Nebula



Optical + IR (Hubble!)
size: ~ 4 pc

At the center, the Pulsar
X-Ray + optical, TeV emitter.

# Tycho's Supernova Remnant (SN_1572)



- Explosion of white dwarf star that became unstable due accretion from a companion star.
- Acceleration mechanism: plasma “shocks”... some ~400 years ago.

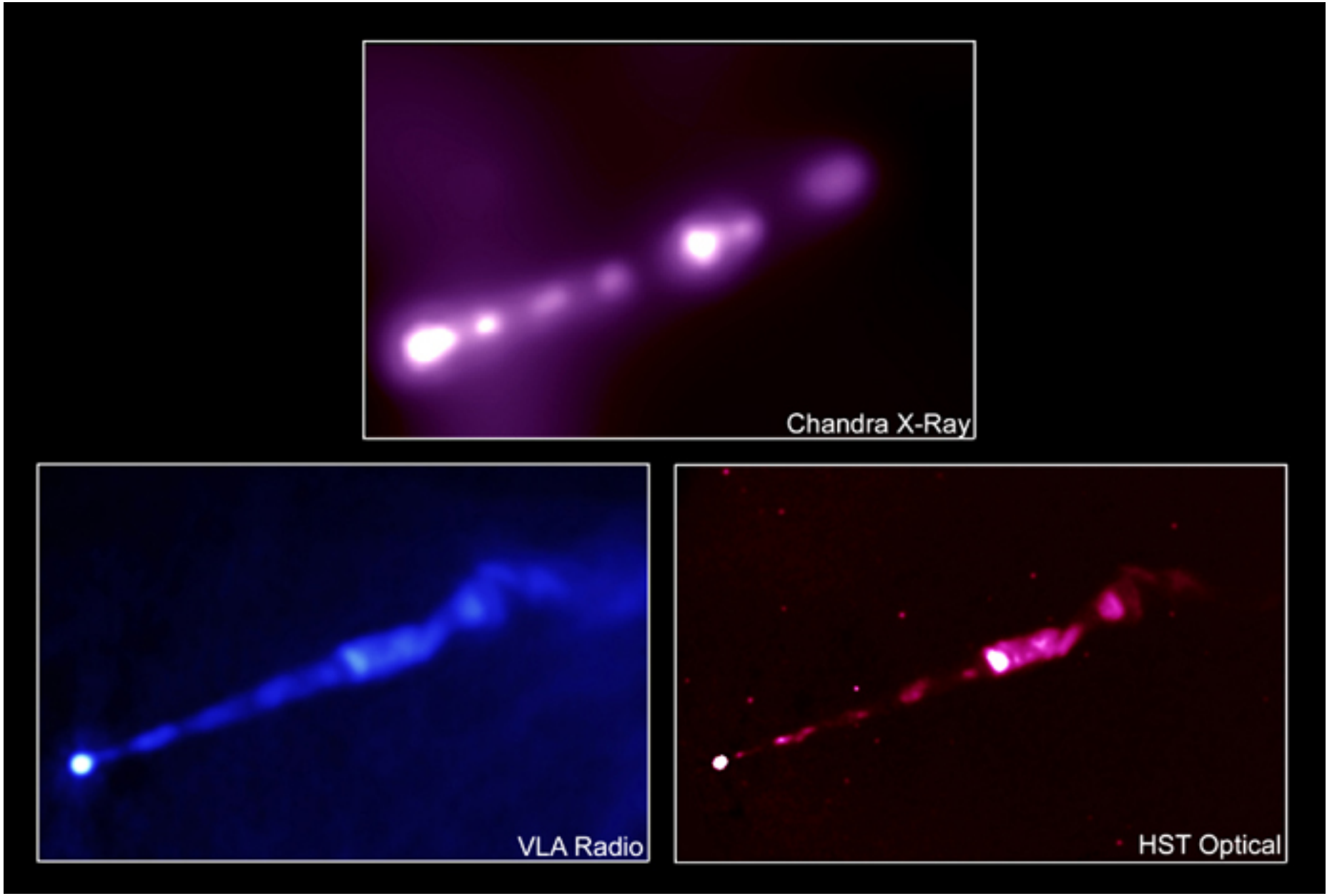
# Active Galactical Nuclei

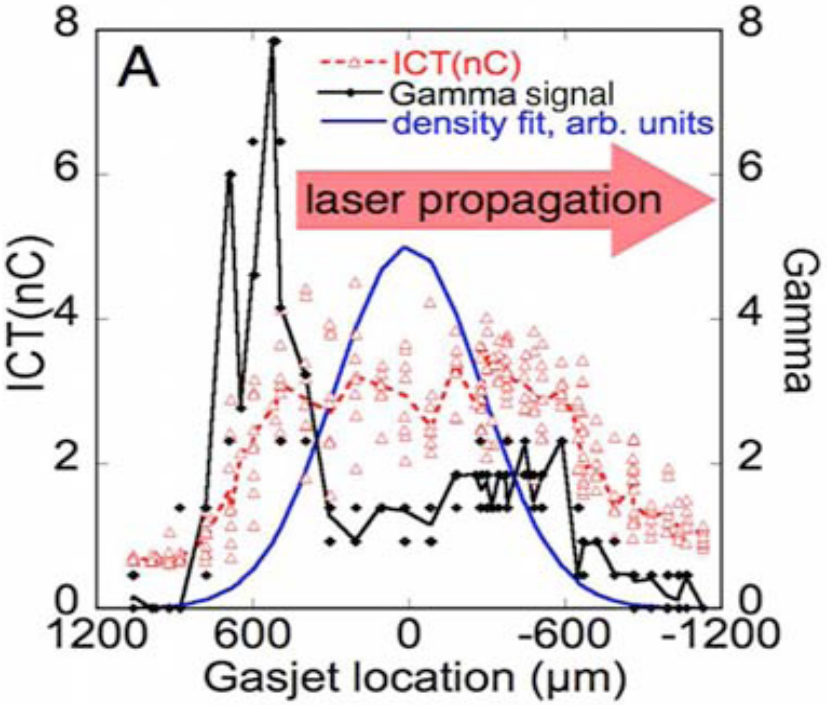
Centaurus A  (10 millions light years)

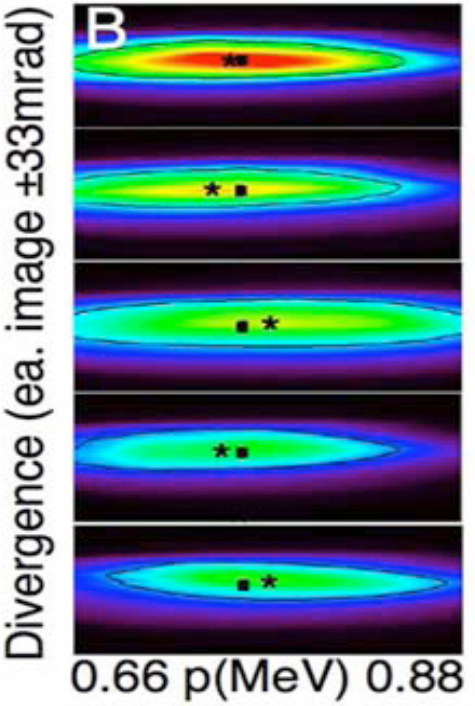
M87 (Virgo Cluster ), 53 Mly

Inside these big galaxies...

# Active Galaxy Nuclei (M87)

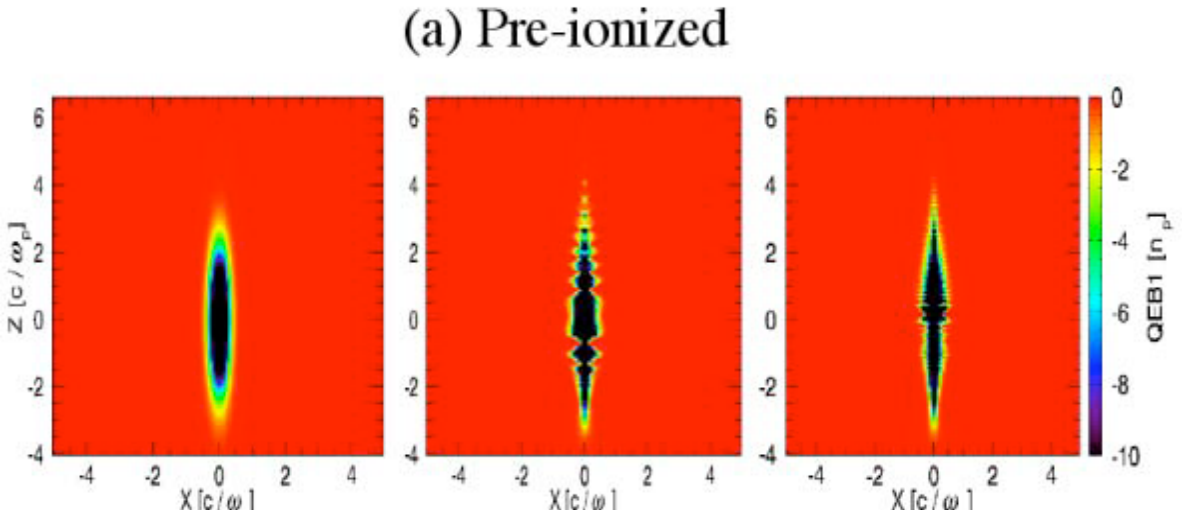



Pac07, Geddes et al...

# *Plasma Wake Field Accelerator!*

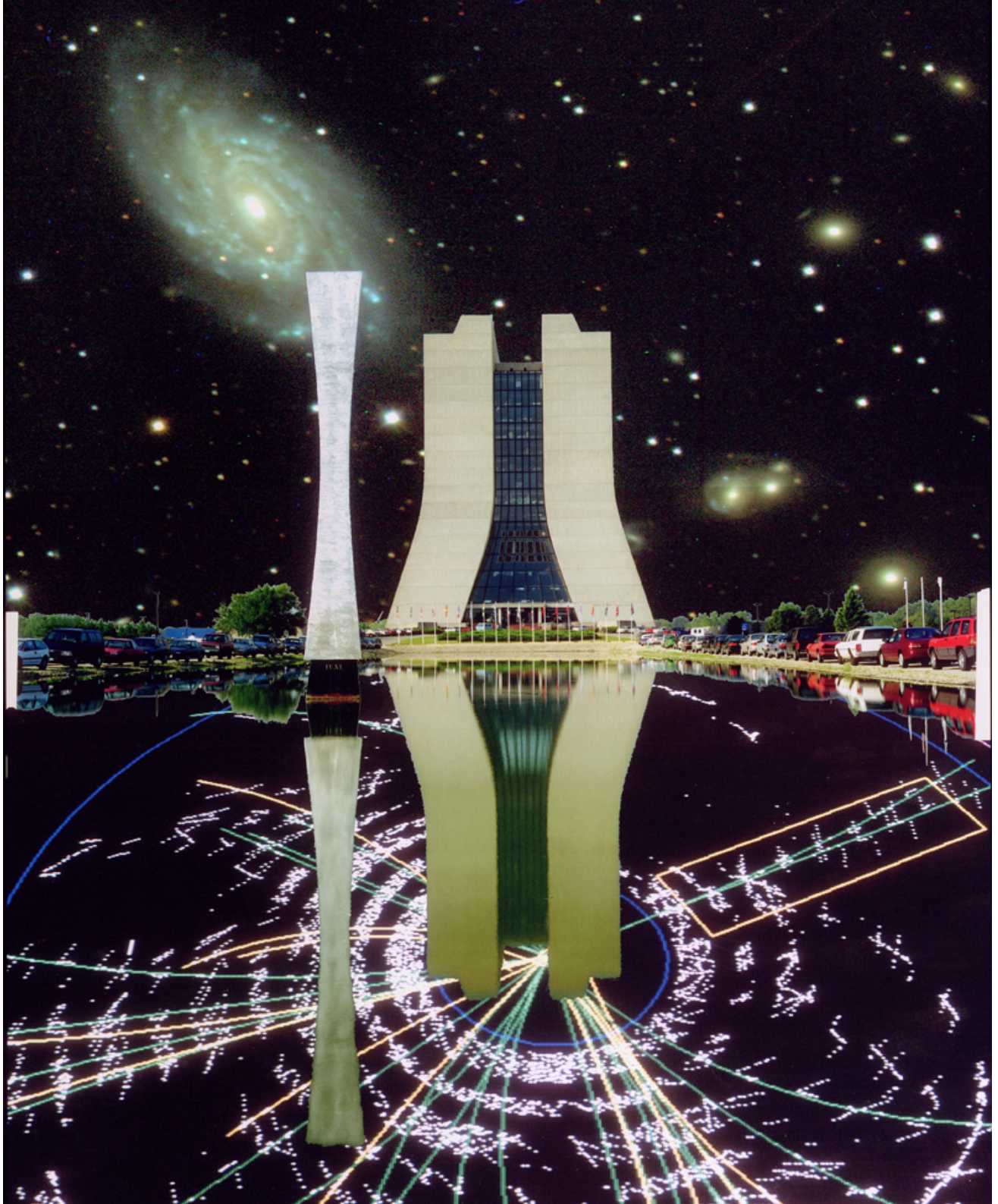



***Tricky!..***

***(very) complicated..***

Computer Simulation do help

Credits : Estelle Cormier et al, TechX corp.



# Acknowledgment


- Fermilab Visual Media Services
- Wikipedia!.
- *NASA...*