Saturday Morning Physics - Accelerators

- Accelerators
- What's Up Now?
- What's Up Next? <<<< We Are Here ...
- http://tdserver1.fnal.gov/Finley/030329_SMP_TWO.pdf

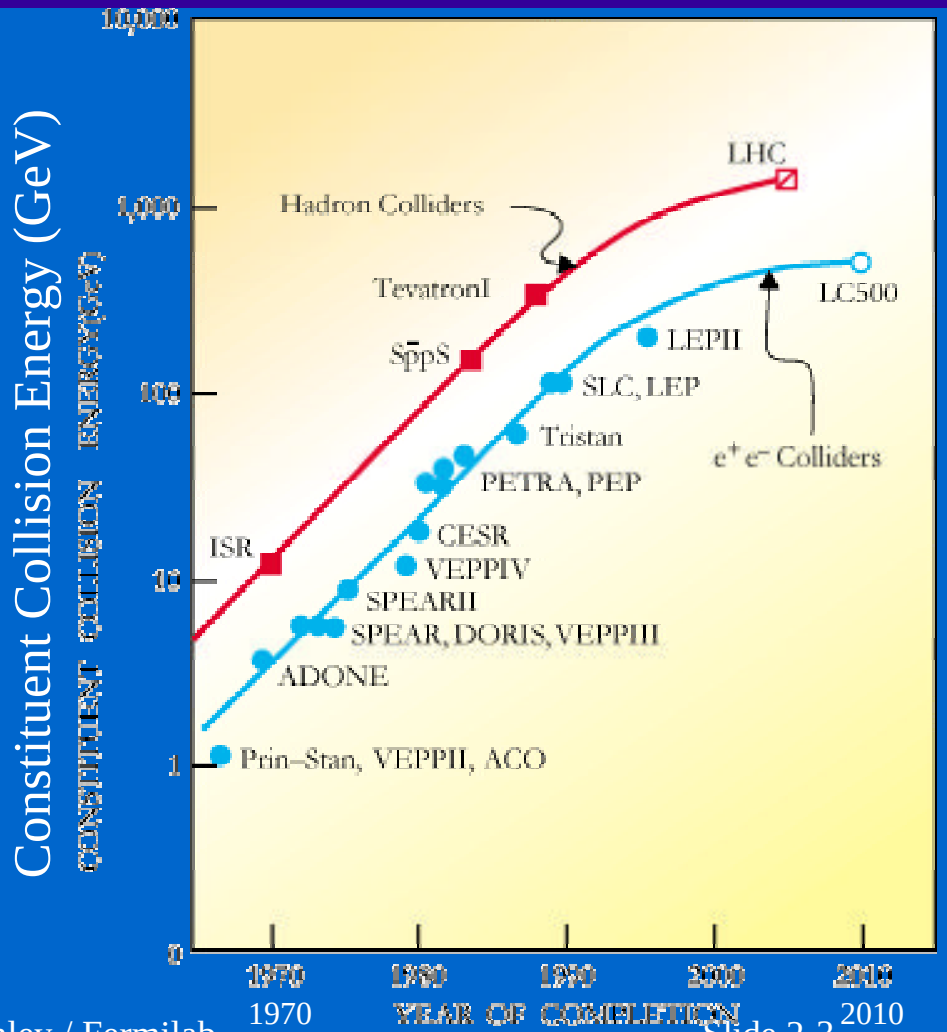
Accelerators - What's Up Next?

- What Up Next?
  - electrons and positrons : e^+e^- Colliding Beams
  - protons and protons : pp Colliding Beams
  - muons and muons : $\mu^+ \mu^-$ Colliding Beams
  - neutrino beam : From decaying muons

- But first, a word about recent times ...

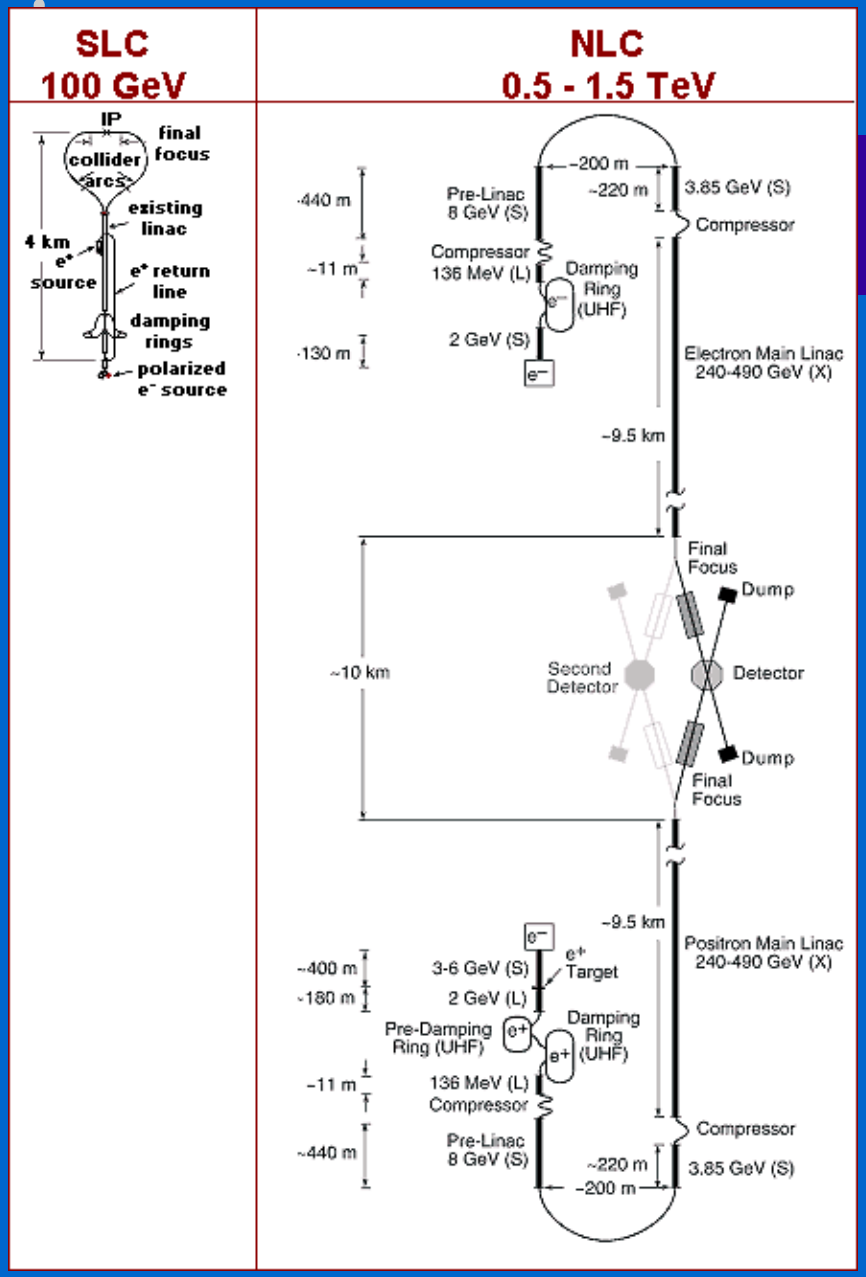
Recent Times ...

- **Physics Today** January 2001
  - Maury Tigner (Cornell University)
- Comparing hadrons and leptons
  - Constituent hadron collision energy is about 1/10 of total hadron beam energies
  - Constituent lepton collision energy is all of total lepton beam energies
- Leveling off? … yes … why?
  - It's a fact of life if you keep using the same concepts and evolve with the same basic technology



e^+e^- Linear Colliders

- The good new is:
  - The electron is a lepton
    - A point (so far as we can see)
    - Simple particles give simpler interactions
  - Precision tool (if you know where to look)
    - Q4: How is it that we see more matter than antimatter?
    - Q2: How does it all behave?
- The bad new is:
  - Not much mass …
    - radiates photons like crazy when you deflect them
    - (This is a good thing at Argonne … but a bad thing for e^+ e^-)



- The NLC is an e+e- Option.

(NLC = Next Linear Collider)

Two straight accelerators about 10 km long each providing 250 GeV beams.

- Several smaller (and rather complicated) accelerators and devices to feed them … 2 GeV, 3-6 GeV, positron target, 3.85 GeV, damping rings, compressors

- A pair of final focus lines, a detector, and a beam dump.

- Total Length = about 30 km.

(SLC = SLAC Linear Collider)

(SLAC = Stanford Linear Accelerator Center)

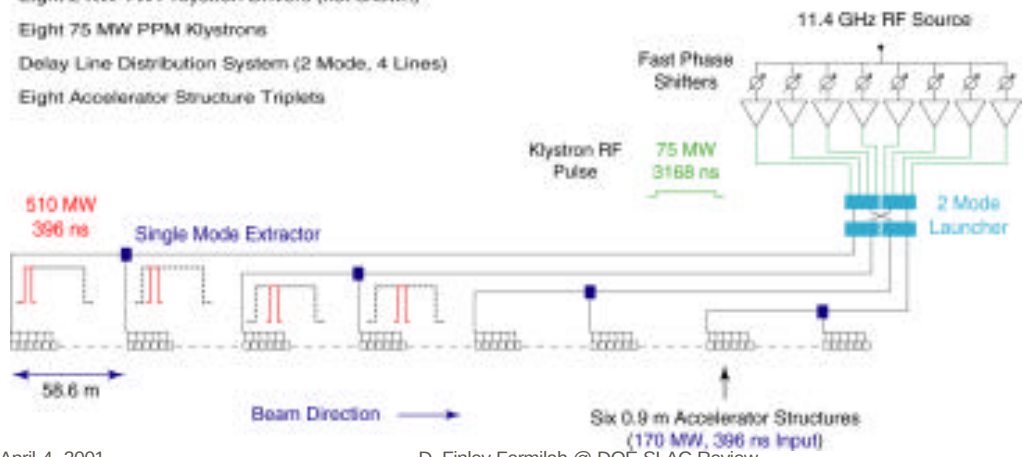
Schematic of NLC RF Test

ETF (Engineering Test Facility)

- March 2001 Version shown
- About 400 meters long
- 6 RDDS 0.9 m structures per girder shown
- Tests Power Sources. DLDS. Structures

NLC Linac RF Unit

Low Level RF System
One 490 kV 3-Turn Induction Modulator (not shown)
Eight 2 KW TWT Klystron Drivers (not shown)
Eight 75 MW PPM Klystrons
Delay Line Distribution System (2 Mode, 4 Lines)
Eight Accelerator Structure Triplets



April 4, 2001 D. Finley Fermilab @ DOE SLAC Review 3

Fermilab is developing a long term plan for performing this test in a refurbished fixed target beam enclosure …

see next slides

A Tunnel for an NLC RF Test

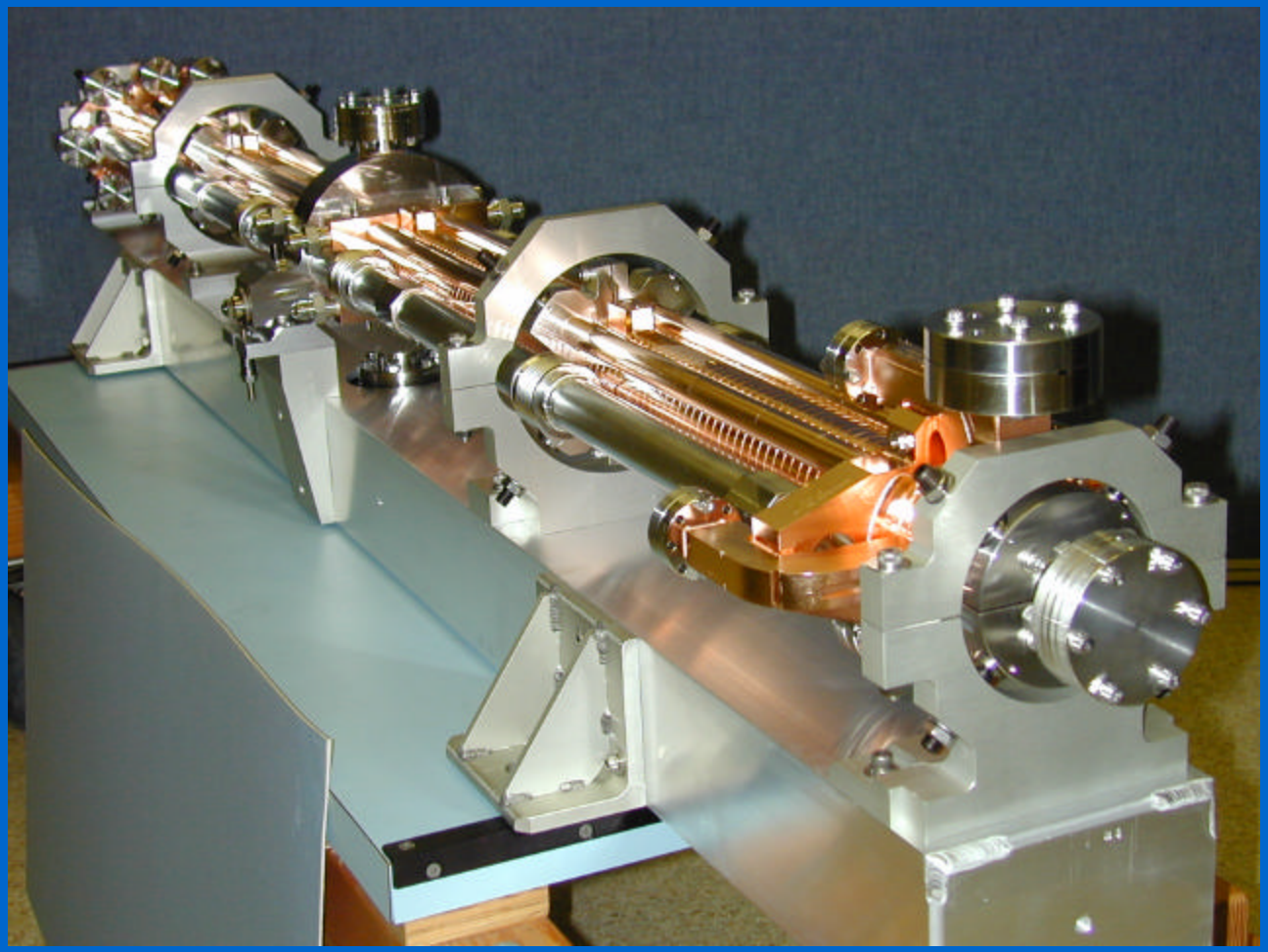
The ETF enclosure is mostly empty now … and that is good!

And Building for an NLC RF Test

The MP9 building is now being used to make parts of the CMS detector for the LHC …

but it can be reused for the ETF.

1.8 meter long NLC RF structure

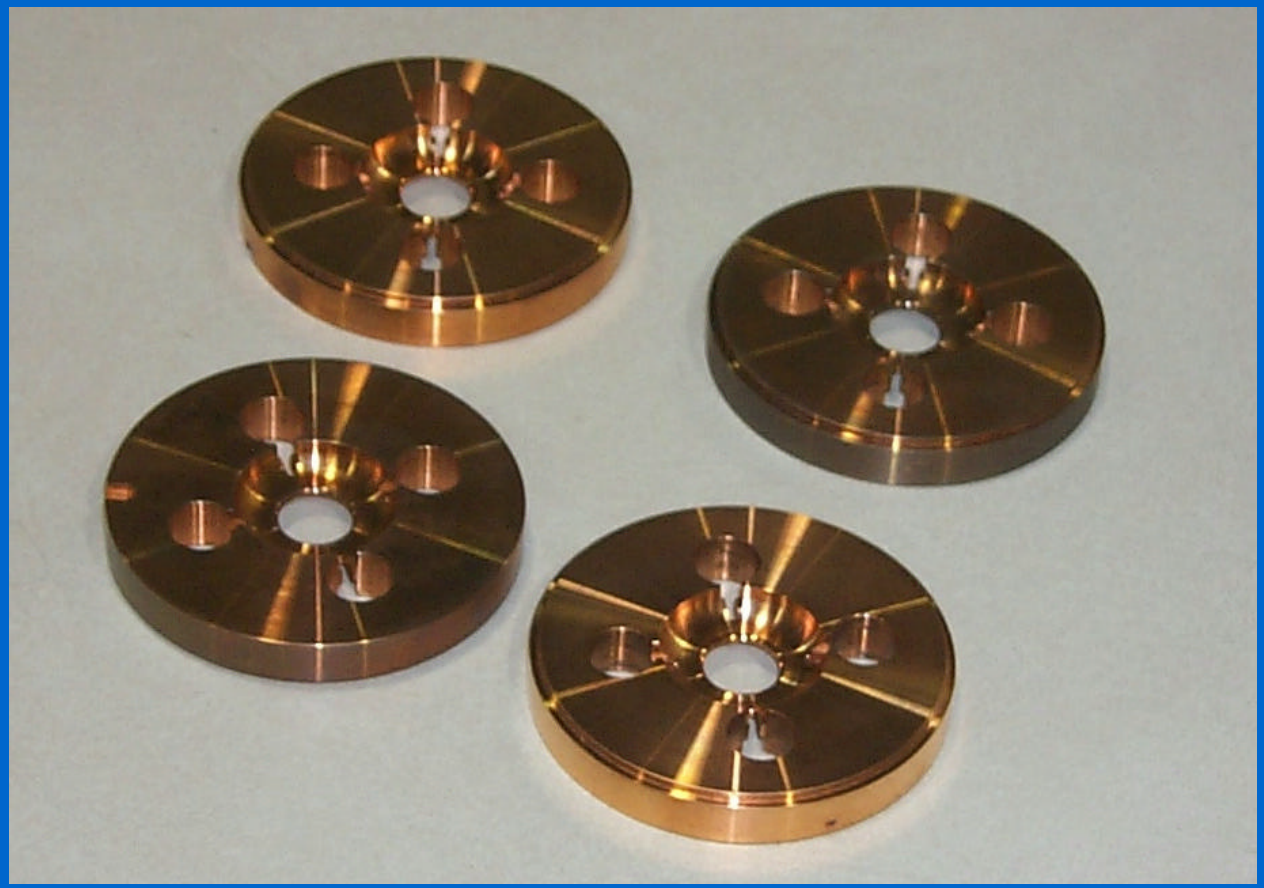


Made by the KEK lab in Japan and tested at the SLAC lab in California

Each structure has 206 disks … see next slide

NLC RF copper disks

Each disk has a 61 mm outer diameter and 8 mm thickness.

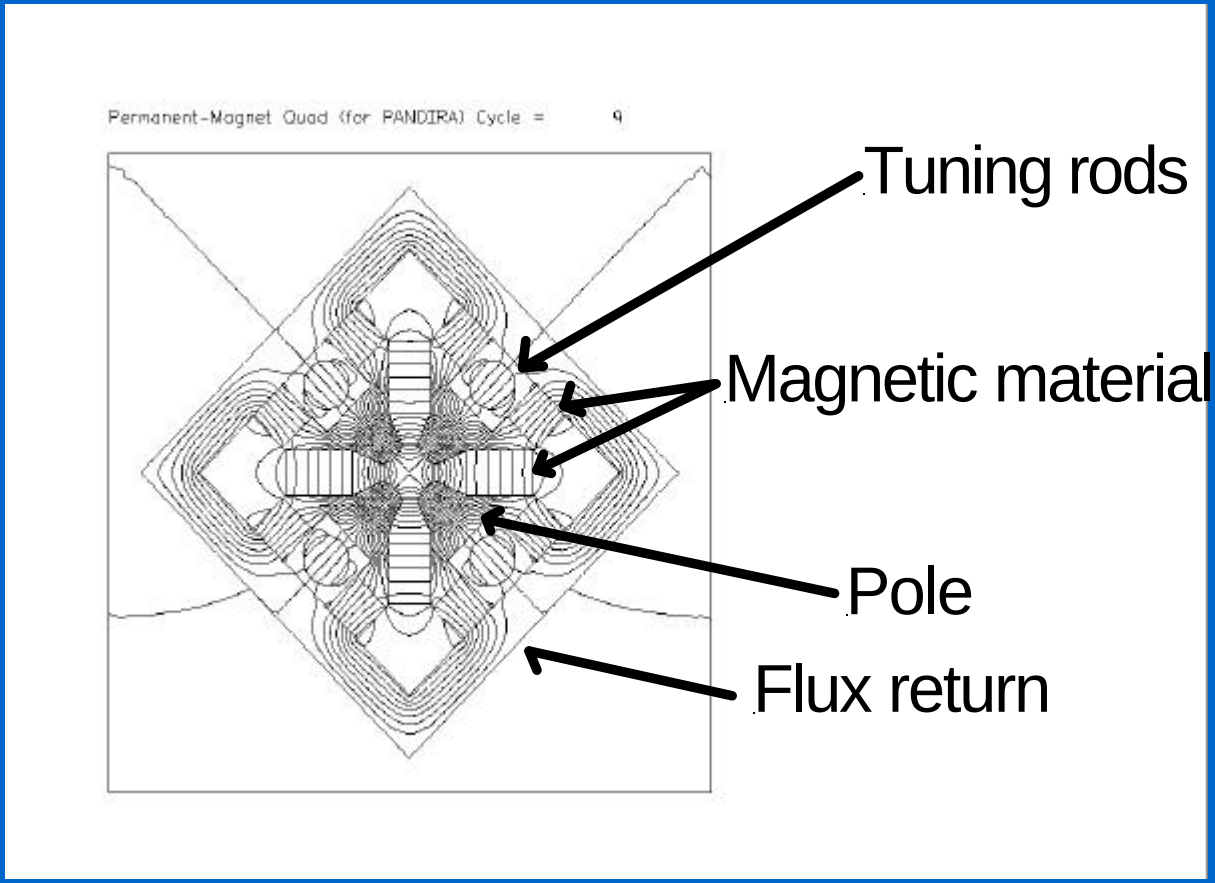


The electron or positron beam goes through the center hole and unwanted energy is taken away in the four side channels.

Need 2,000,000

NLC Permanent Magnet Research

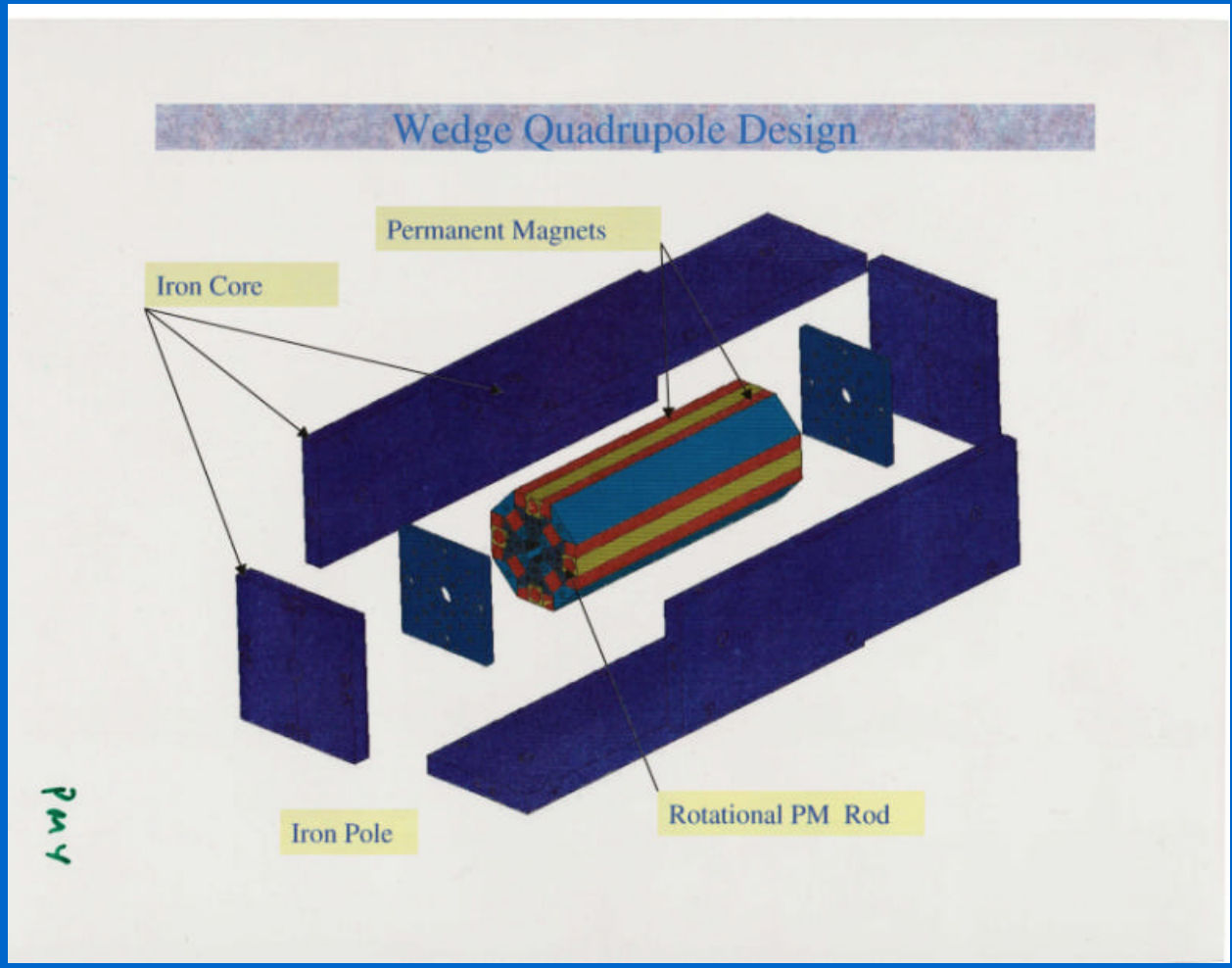
Concept



Courtesy J. Volk et al, PAC01 Chicago

NLC Permanent Magnet Research

Design



Courtesy J. Volk

NLC Permanent Magnet Research

Reality

Courtesy J. Volk

NLC Permanent Magnet Research

Measure the fields

Courtesy J. Volk

Think.

Realize temperature control is important.

NLC Permanent Magnet Research

Control the Temperature …

Courtesy J. Volk

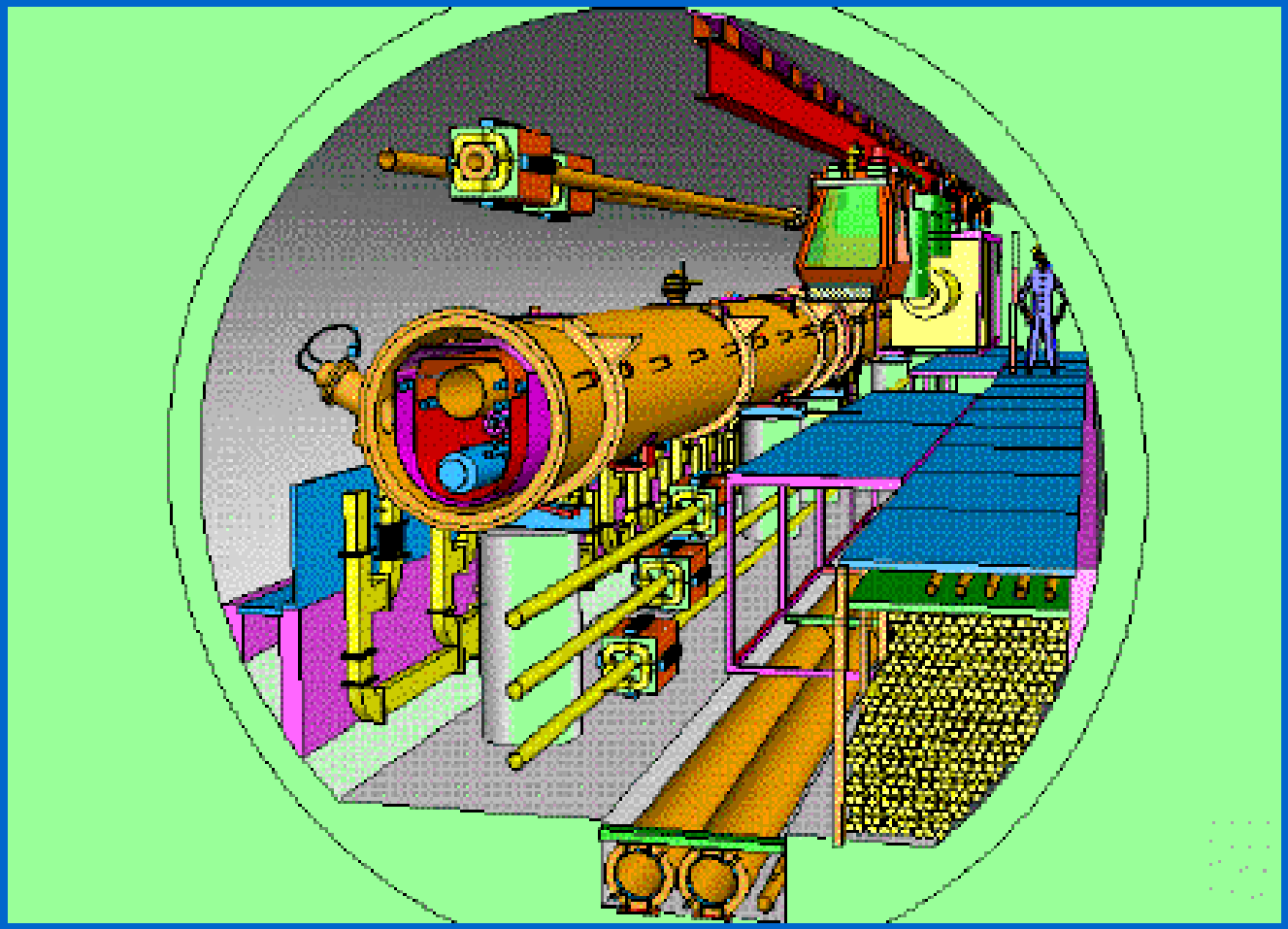
Measure the fields while controlling the temperature …

Think.

Modify the design … etc etc

TESLA at DESY is also an e^+e^- Option

(TESLA = TEv Superconcucting Linear Accelerator)



The DESY lab has proposed an e+e- collider.

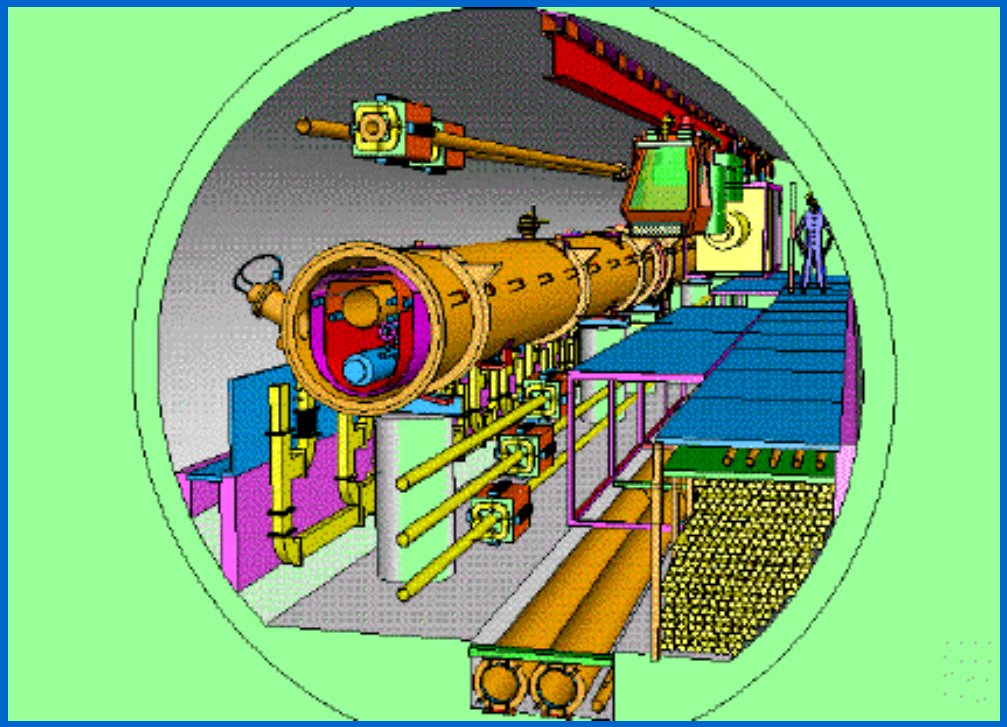
The accelerator is made of superconducting rf cavities.

The tunnel is about 5 meters in diameter.

TESLA & NLC Tunnel Sketches

TESLA Main Linac Beam Enclosure.

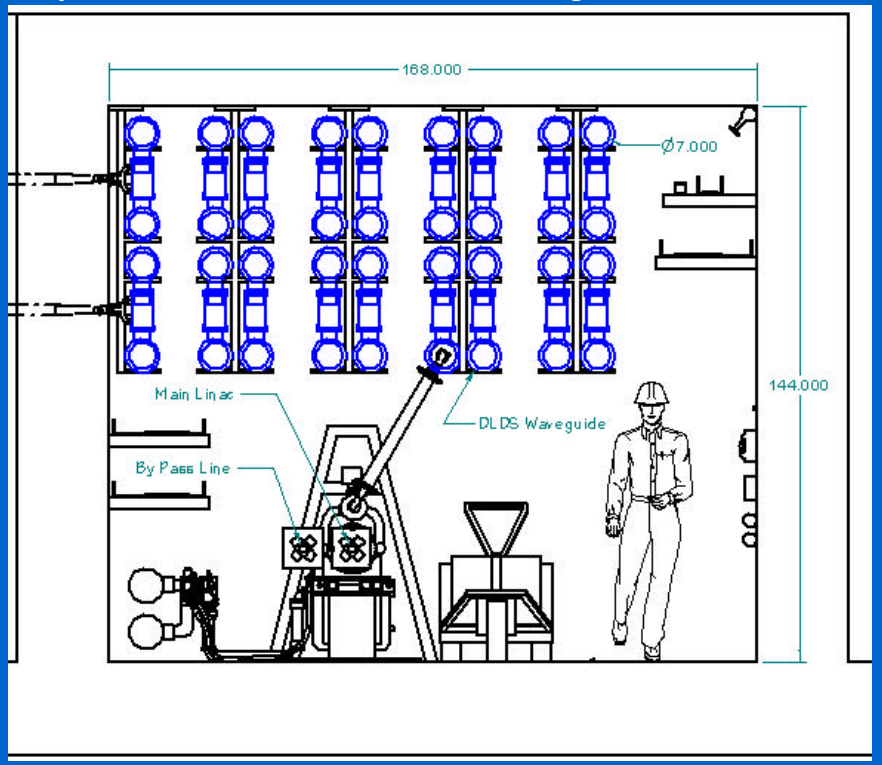
Modulator & refrigerator enclosures / buildings not shown.



Tunnel is 5.2 meter diameter

NLC Main Linac Beam Enclosure.

Klystron & modulator enclosures / buildings not shown.



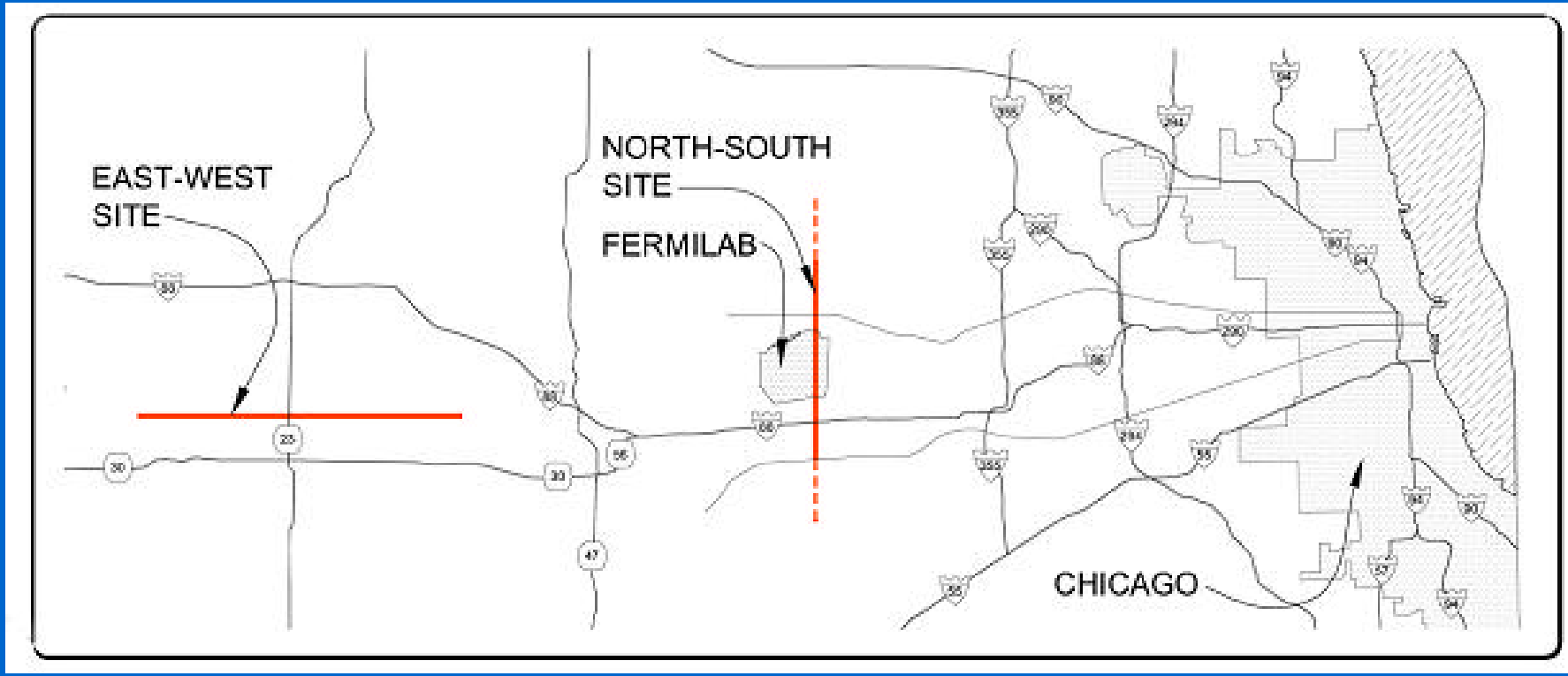
Tunnel is 12’ high and 14 ft wide (3.66 m x 4.27 m)

The Size of a Linear Collider

In California …

The Size of a Linear Collider

In Illinois …

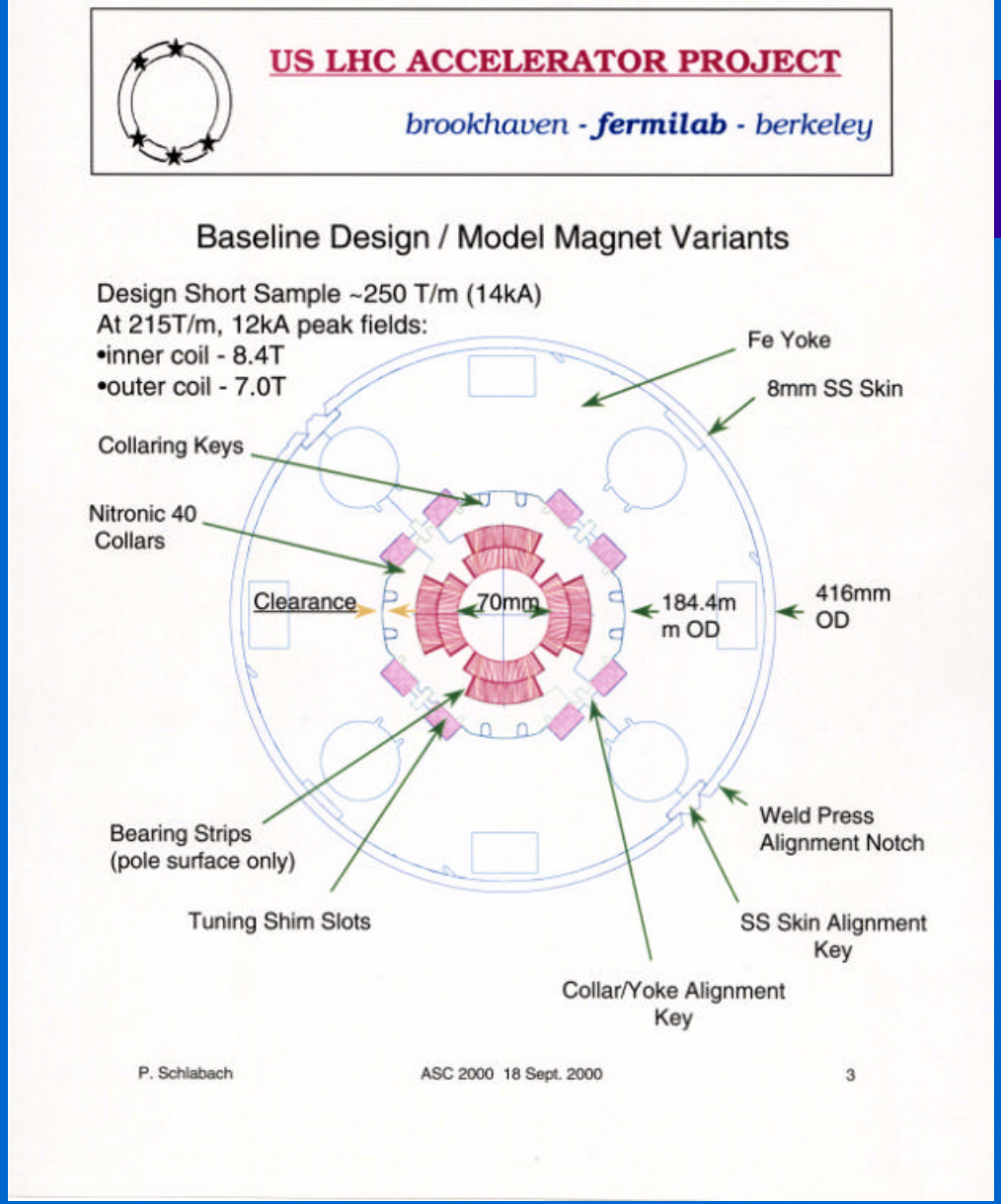


Protons on protons

- The good news is:
  - We know how to do this … standard techniques
  - This gives us the energy frontier
  - This is the path to discovery
    - Q1: What's it all made of?
    - Q2: How does it all behave?

- The bad news (if any) is:
  - It gets to be very large …(see later slides)
  - And some* say wait for LHC results.

* "Some" include Directors of the world's HEP labs.

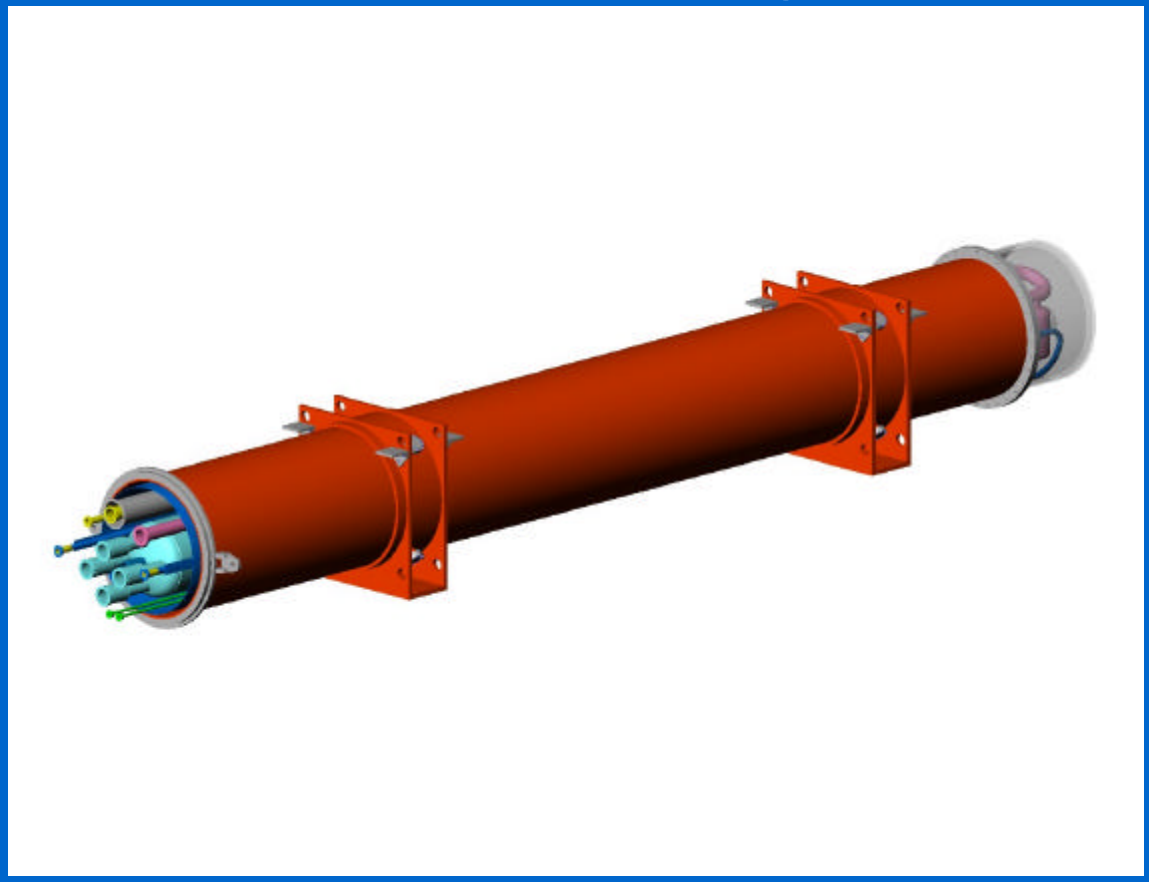


LHC IR Quadrupole Magnet (Cold Mass Only)

Courtesy Phil Schlabach

LHC IR Quadrupole Magnet

This quadrupole magnet is 36 inches in diameter and about 7 meters long

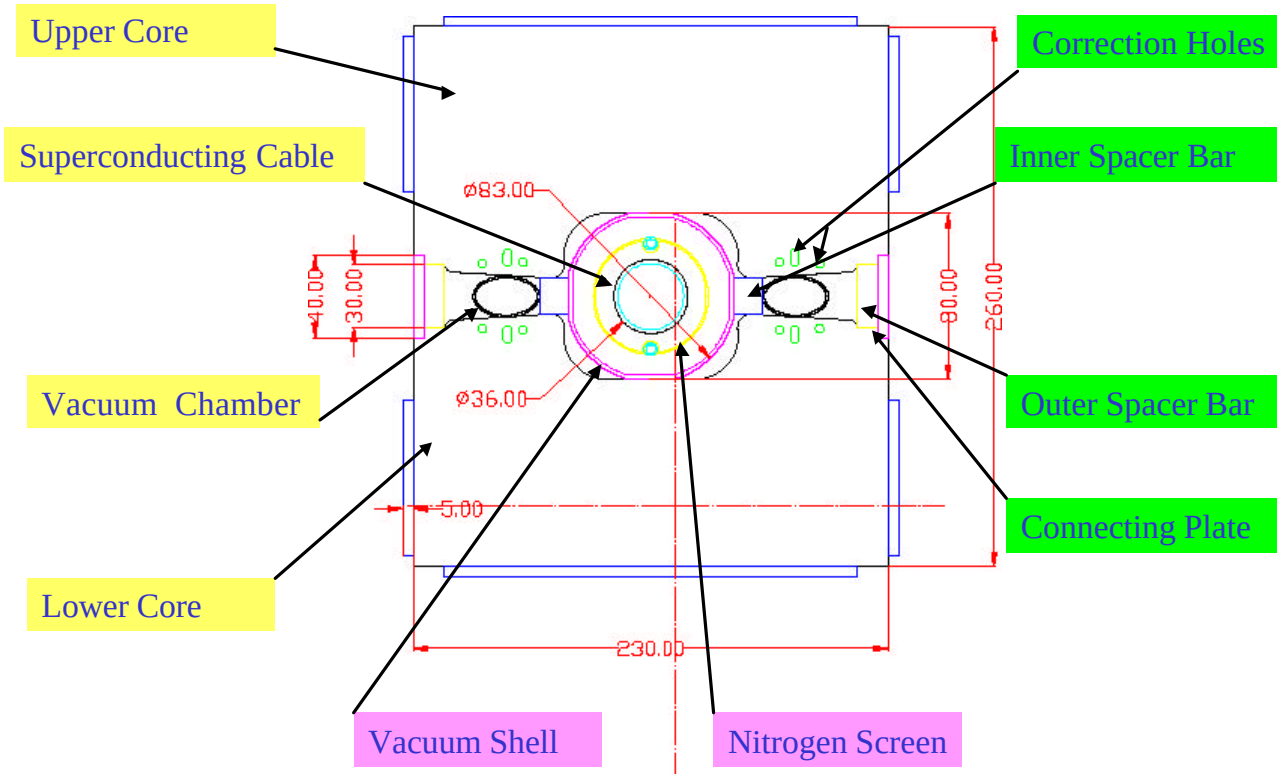


Fermilab is making several high gradient quadrupole magnets for the Interaction Regions at the LHC

VLHC - Low Field Option

(Very Large Hadron Collider)

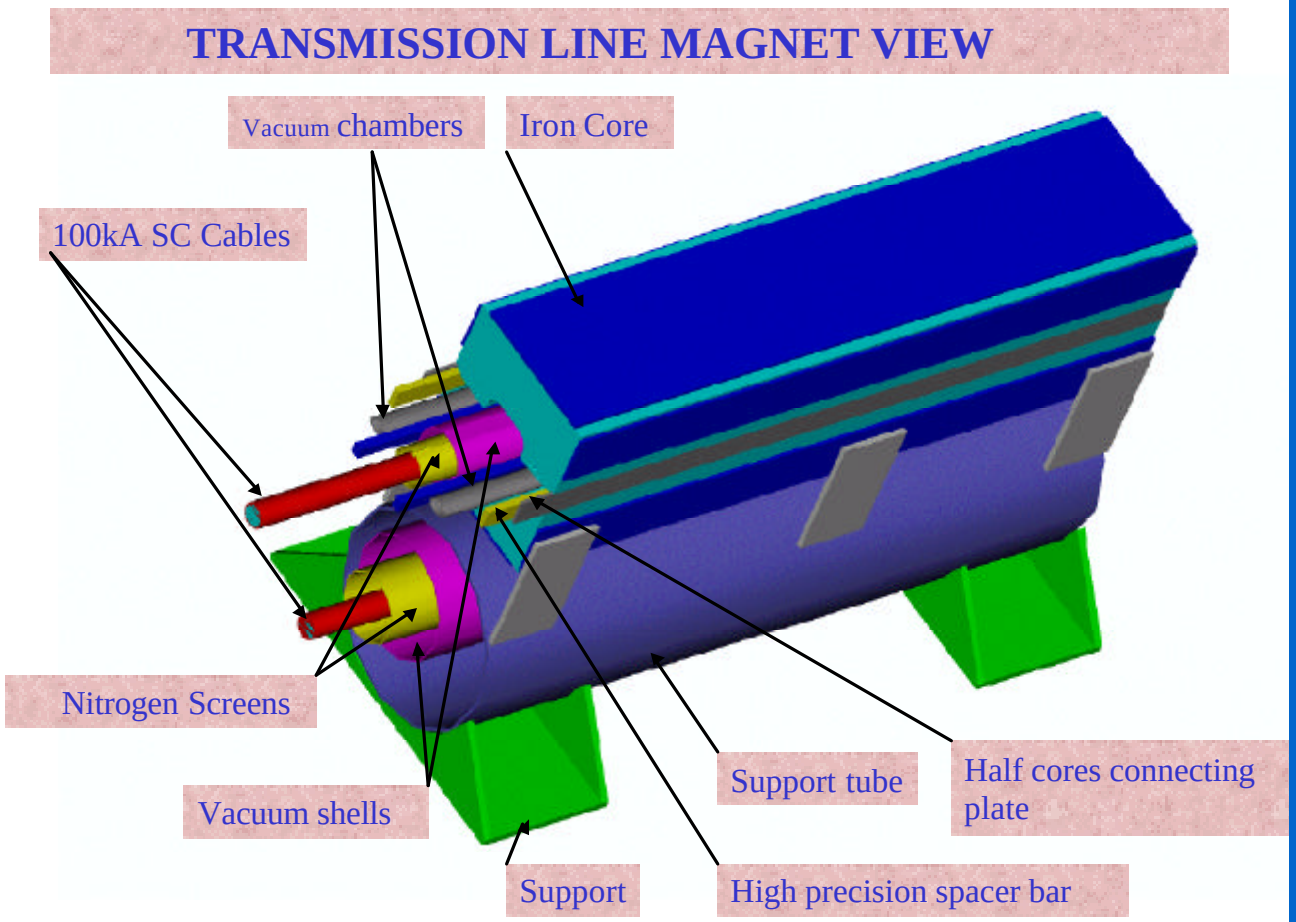
Magnet Cross-section



G.W. Foster and V. Kashikhin

May 2000

VLHC - Low Field Option



G.W. Foster and
V. Kashikhin

May 2000

VLHC - Low Field Option

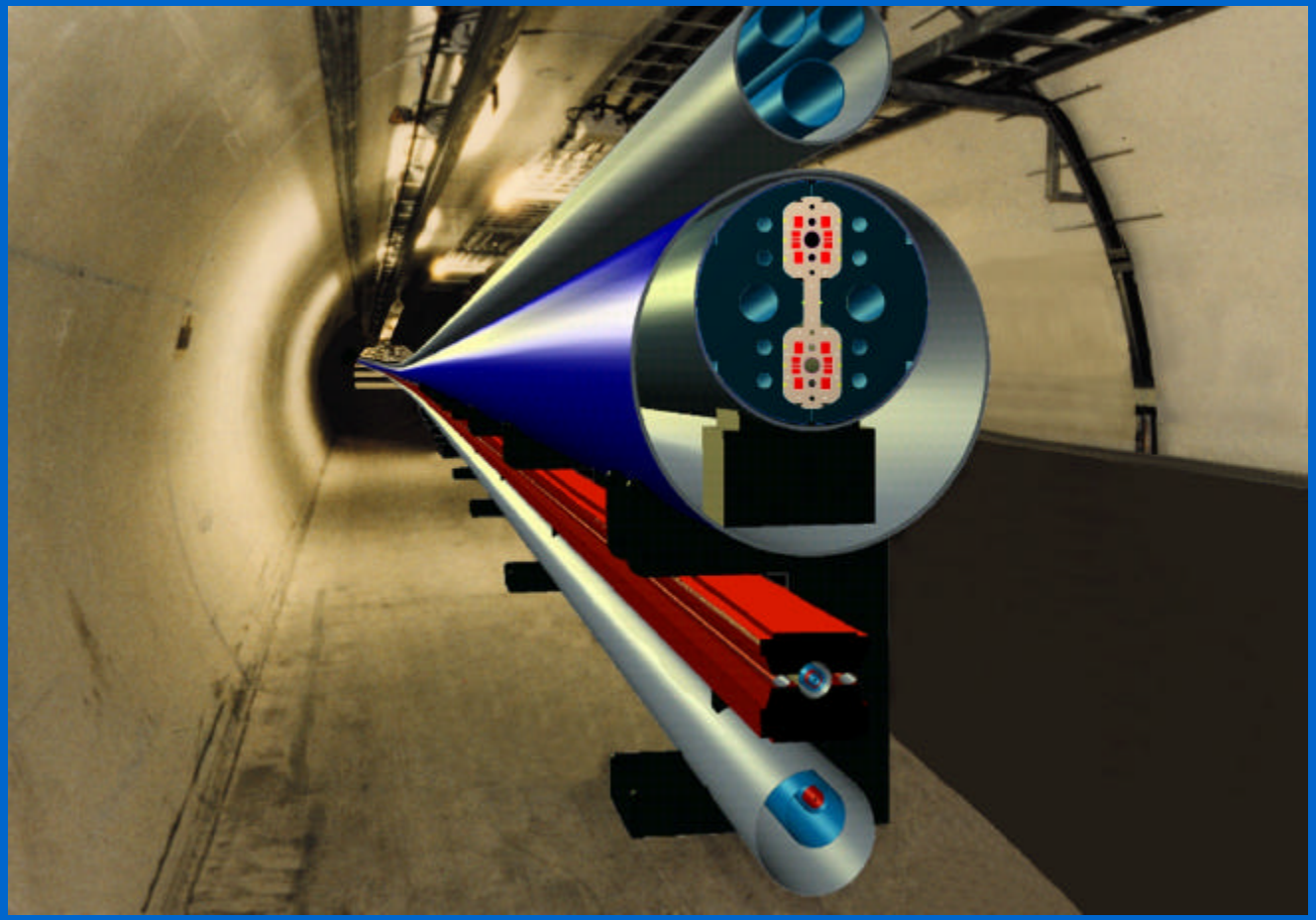
Test Stand for the Field Measurement

G.W. Foster and
V. Kashikhin

May 2000

A Tunnel Vision for the VLHC

Both high and low field options are shown in the LEP tunnel as an example.



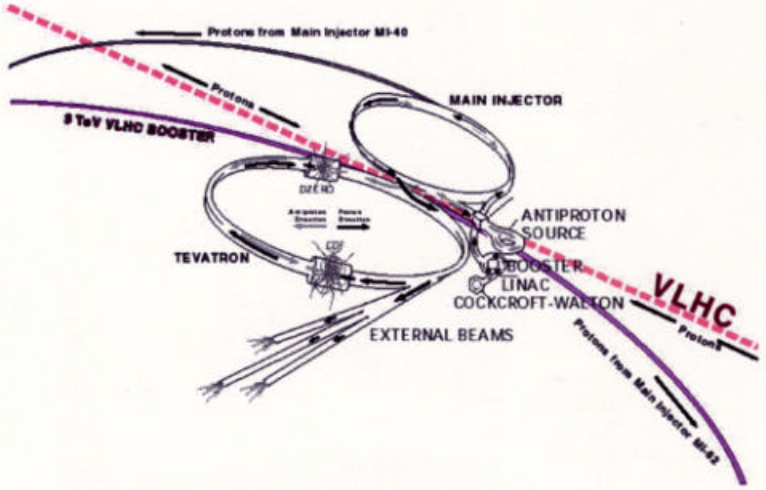
The low field is on the bottom, the high field is on the top.

The tunnel is real and is about 12 feet in diameter.

Comments on a U.S. site at Fermilab:
Geology and Tunneling

The U.S. site of the vlhc is assumed to be Fermilab.

- Existence of the injector chain
- Excellent Geology

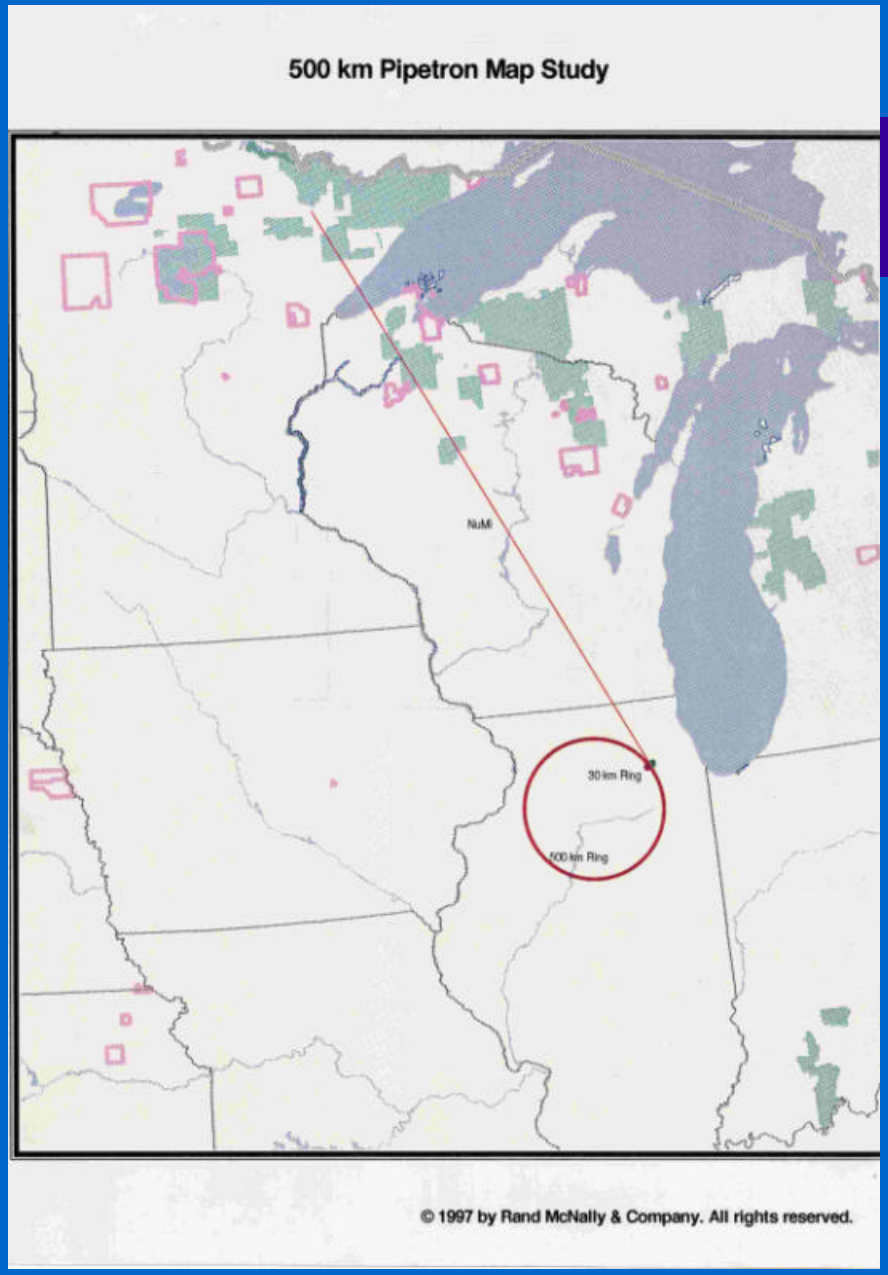


VLHC

Why put the VLHC at Fermilab?

Courtesy E. Malamud

malamud@fnal.gov



VLHC

Recall it is named “very large” for a good reason.

It would not really be “at Fermilab”.

Rather it would be under “Northern Illinois”

But the NuMI neutrino beam already will go from Fermilab to northern Minnesota.

(Yes, under Wisconsin!).

Courtesy E. Malamud
malamud@fnal.gov

Muons on Muons … Good News

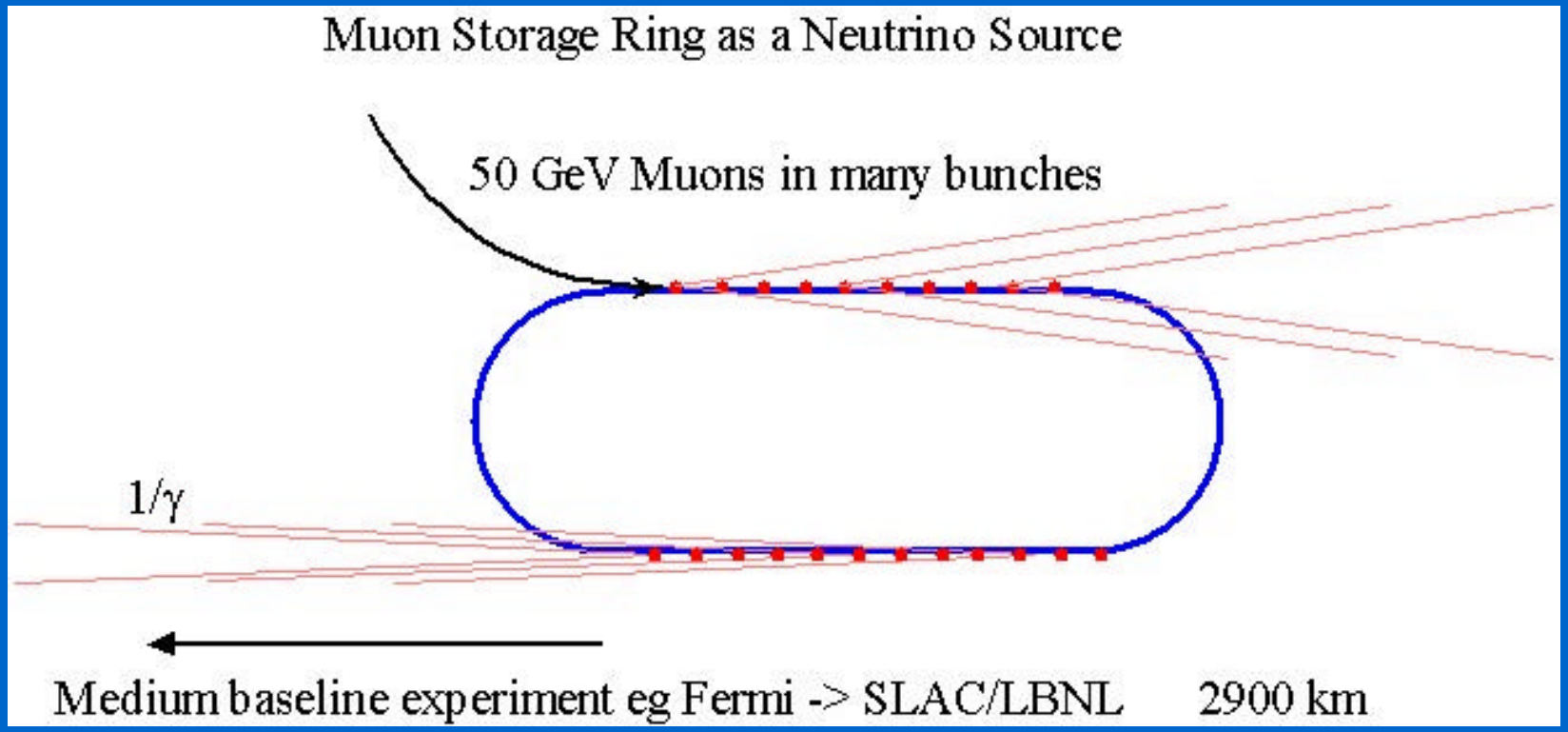
- The good news is:
  - Just another simple lepton … just like the electron
  - But heavier than the electron
    - They don’t radiate photons like crazy
    - They interact better (40,000 times better) with Higgs
      - Q3: How do particles come by their mass?

Muons on Muons … Bad News

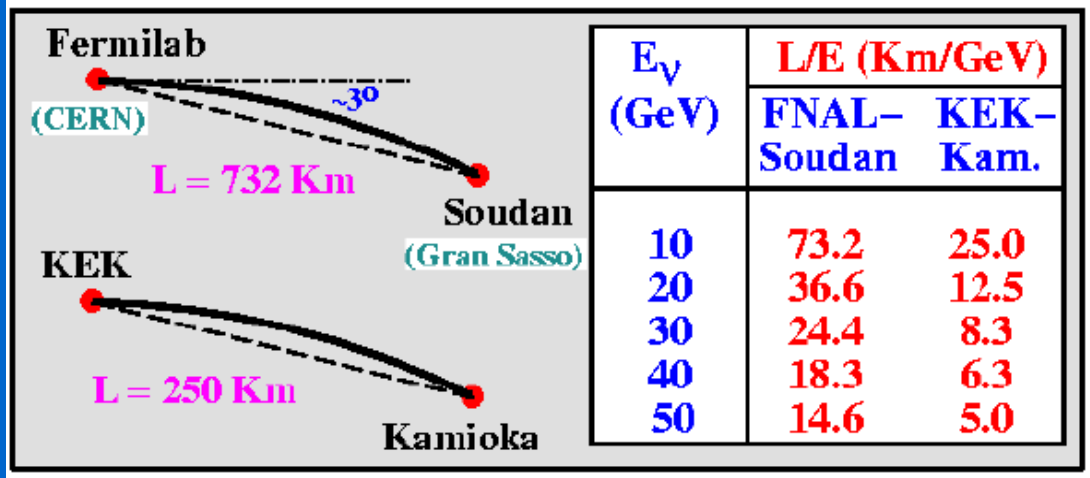
- The bad new is:
  - They only stay around for 0.000 002 seconds (or so)
  - They spit out electrons … which then radiate like crazy
  - And they spit out neutrinos … hmmm …
  - Is this short lifetime so bad?
  - Can it be used to our advantage? >>> See next slides

Neutrino Factory

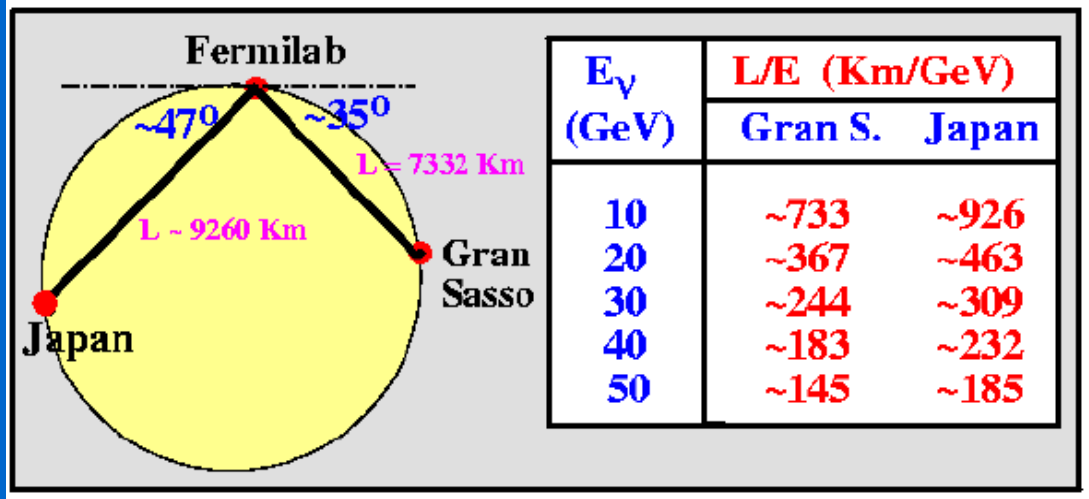
Concept (from Steve Geer / Fermilab)



	L (km)	Dip (Deg.)	Heading (Deg.)
FNAL –> Soudan	732	3	336
FNAL –> Gran Sasso	7332	35	50
FNAL –> Kamioka	9263	47	325



E_ν (GeV)	L/E (Km/GeV) FNAL–Soudan	L/E (Km/GeV) KEK–Kam.
10	73.2	25.0
20	36.6	12.5
30	24.4	8.3
40	18.3	6.3
50	14.6	5.0



E_ν (GeV)	L/E (Km/GeV) Gran S.	L/E (Km/GeV) Japan
10	~733	~926
20	~367	~463
30	~244	~309
40	~183	~232
50	~145	~185

Neutrino Factory

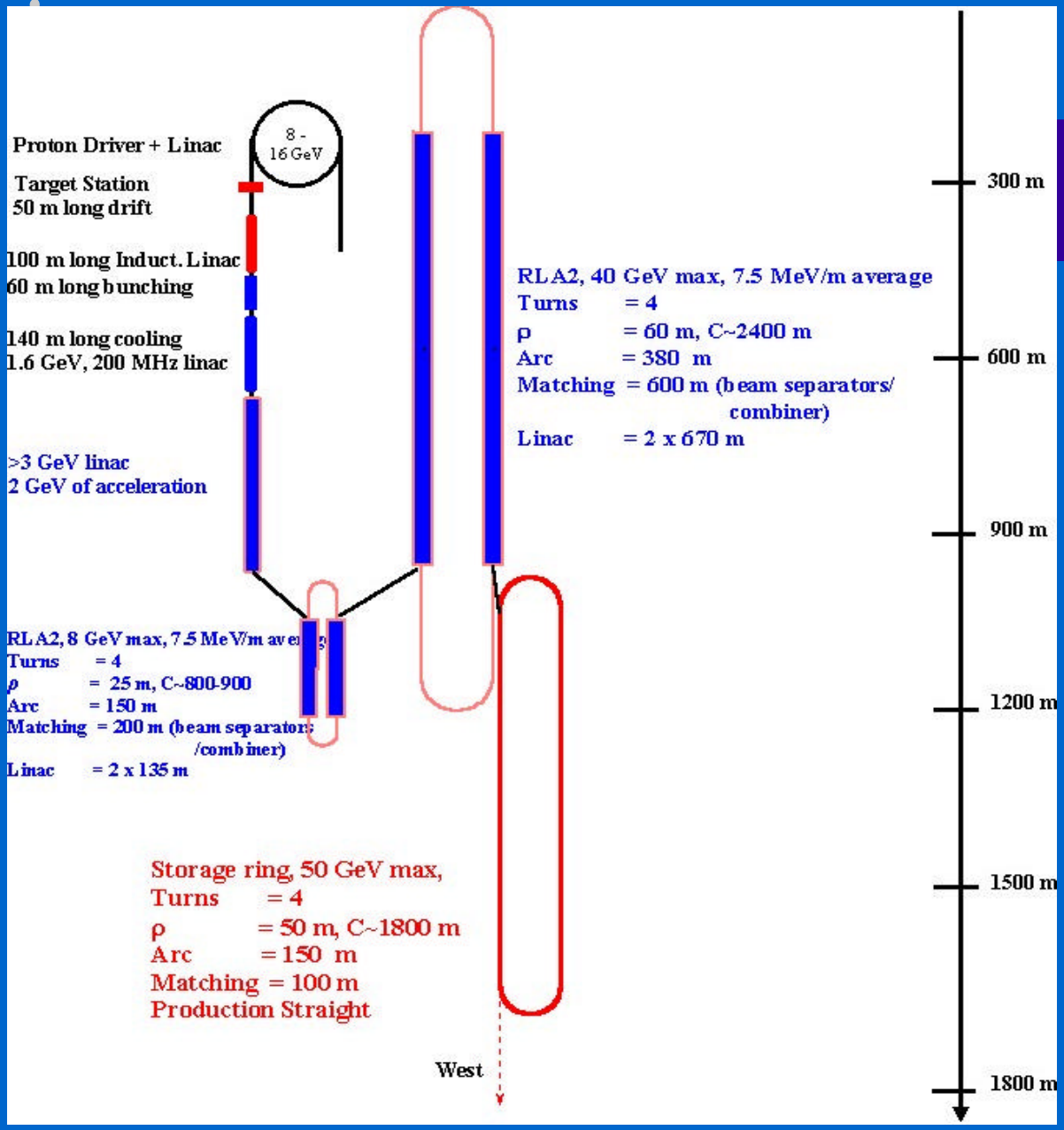
Physics Guidance.

The Distance L between the Neutrino Source and Neutrino Detector is important.

And so is the ratio of L to the Energy E of the neutrino beam.

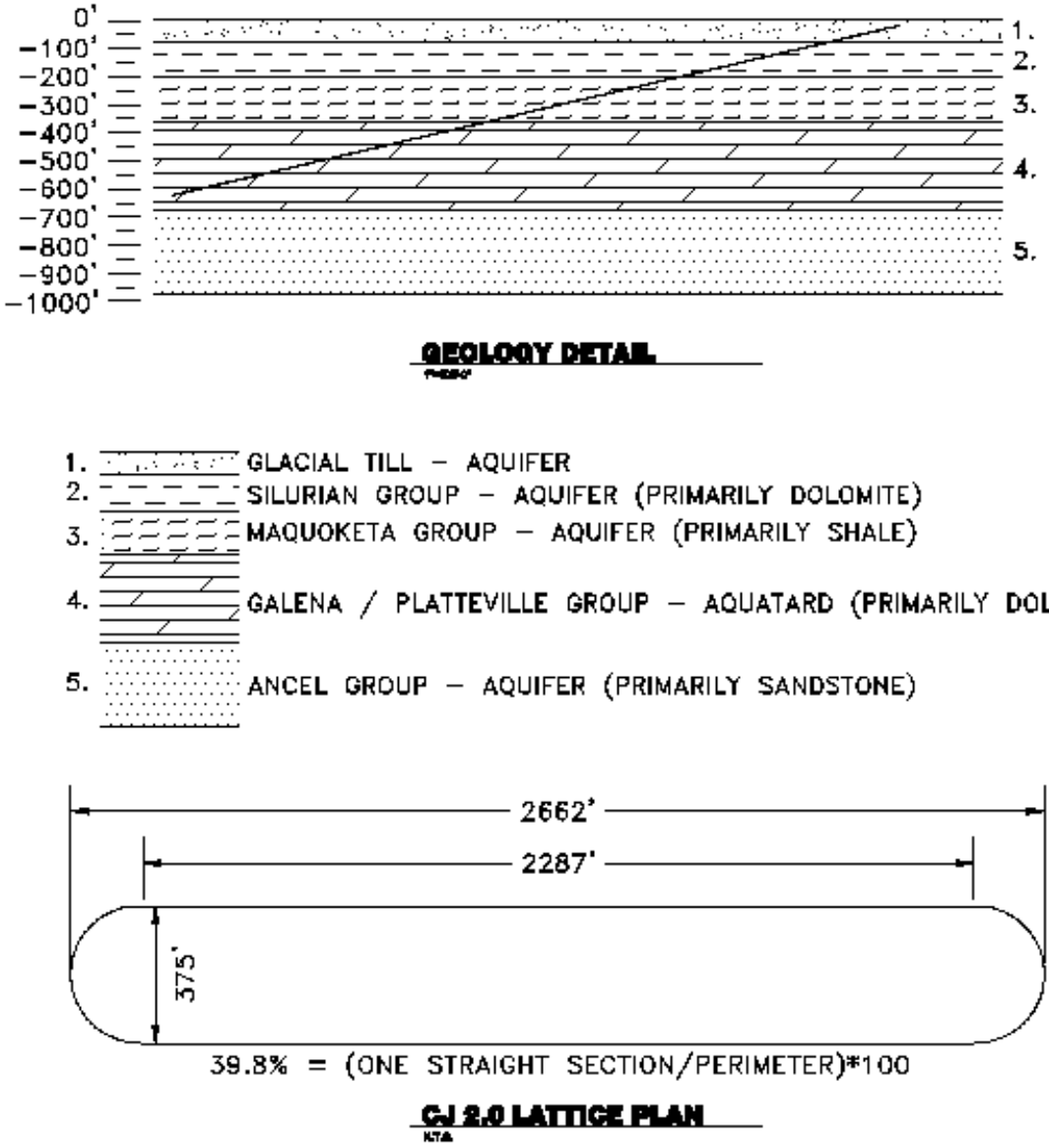
Courtesy S. Geer

Neutrino Factory



Layout.

It takes a lot of things to feed it, but all together it is not so very large.



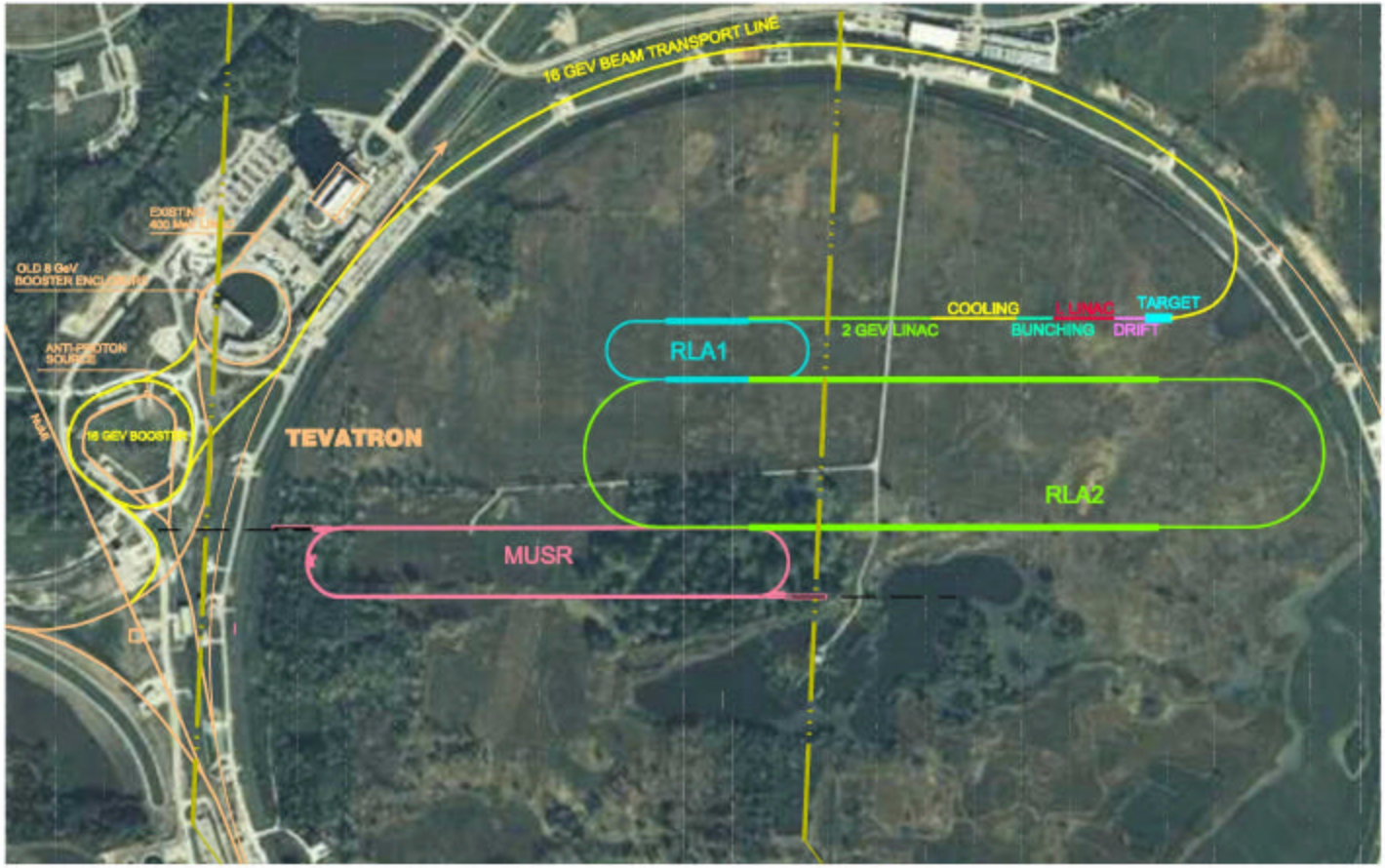
Neutrino Factory

Design.

We need to aim DOWN … so …

What's under Fermilab?

A Neutrino Factory at Fermilab



Neutrino Beam

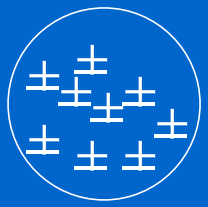
- The good new is:
  - All the muons decay to electrons and neutrinos
  - Never been done … surprises probably in store
    - Q1, Q2, Q3, Q4, Q4++
- The bad news is:
  - Not discovery, not simple … So, maybe not “interesting”?
- Aside: Really global-sized experiments

And Into the Beyond ...

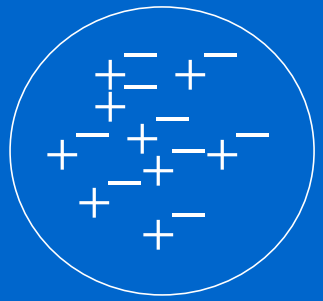
- The good news AND the bad news is:
  - Hasn't been done before …
  - For good reasons, usually ...
- One example is Plasma acceleration
  - 100 TeV center of mass … and ...
  - All the equipment fits on the Fermilab site
  - But is costs too much to operate …
  - At least … using today's ideas and technology

Plasma

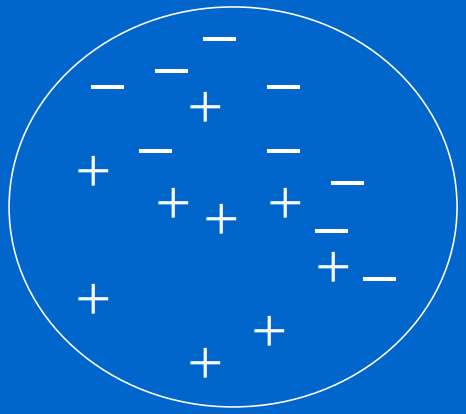
- How is it made?



Start with Atoms

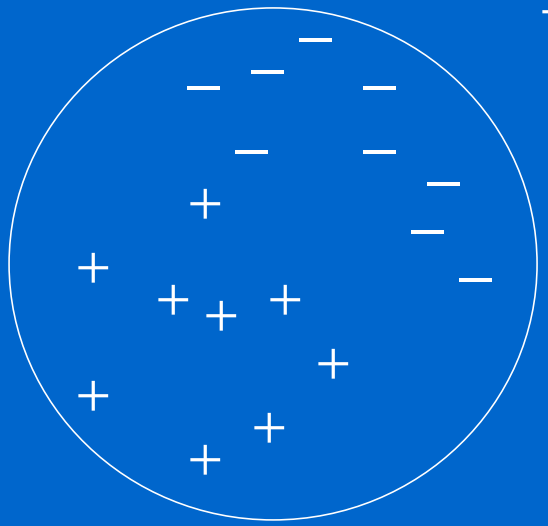


Pull Them …



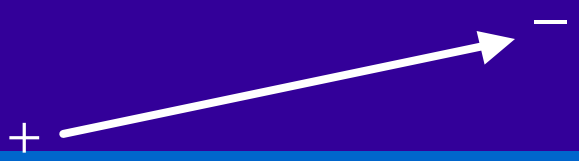
Pull Them …

Ideal (but highly unstable)



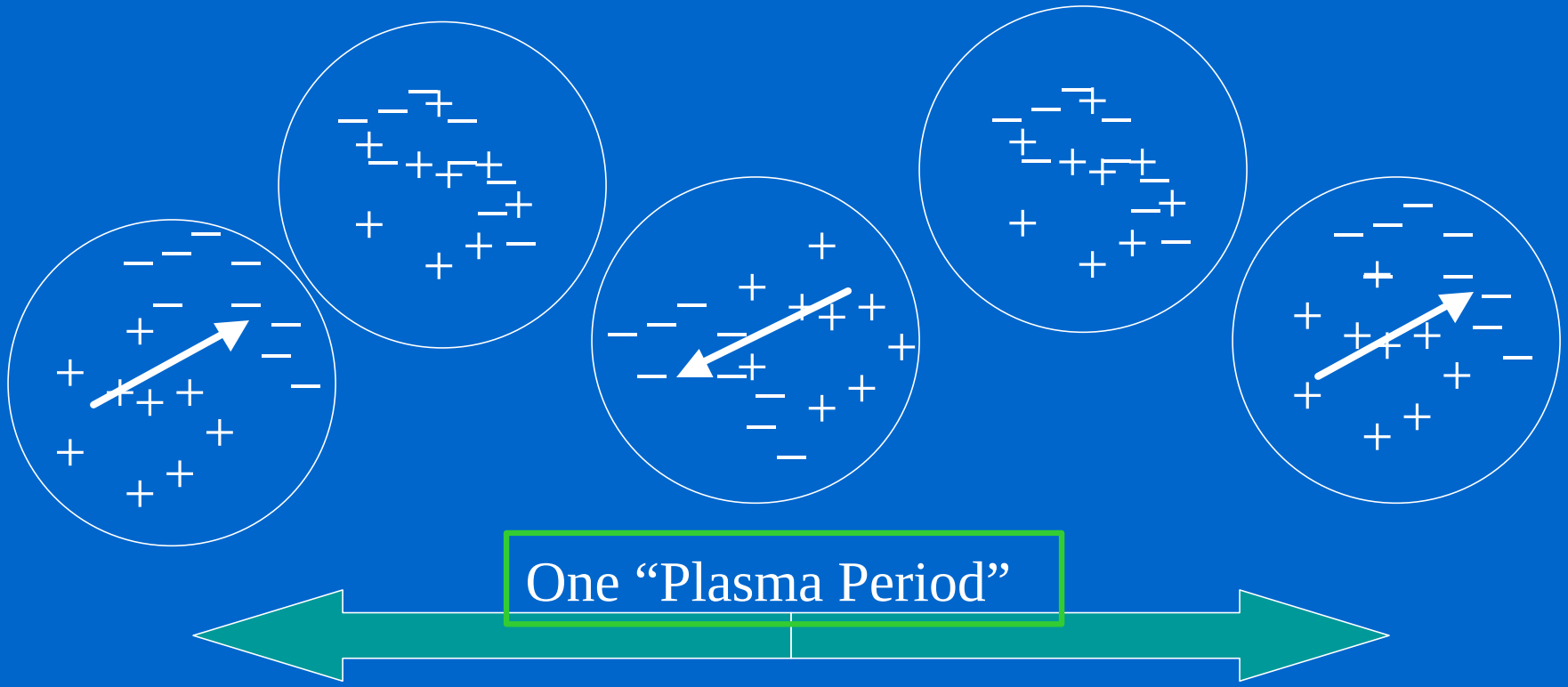
Pull Them Apart!

Plasma

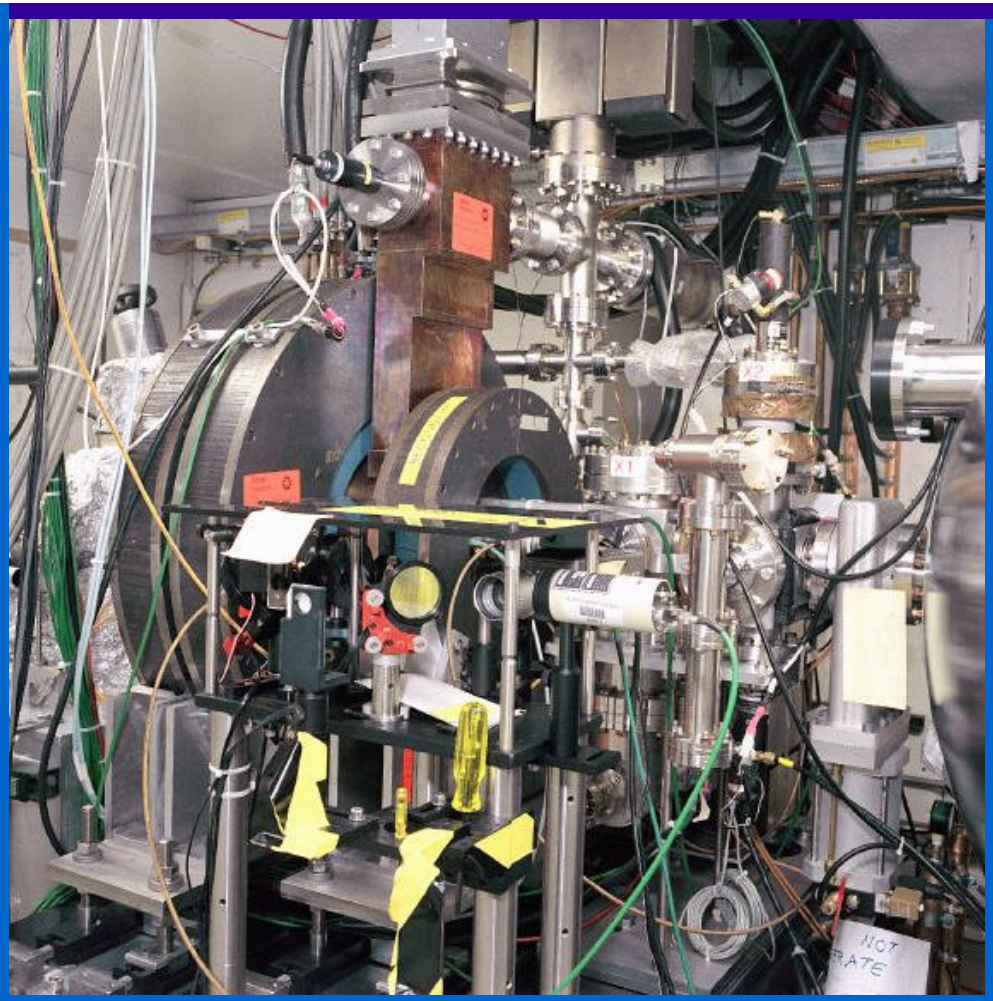


Electric Field

- How does it act?



A0 Photoinjector at Fermilab

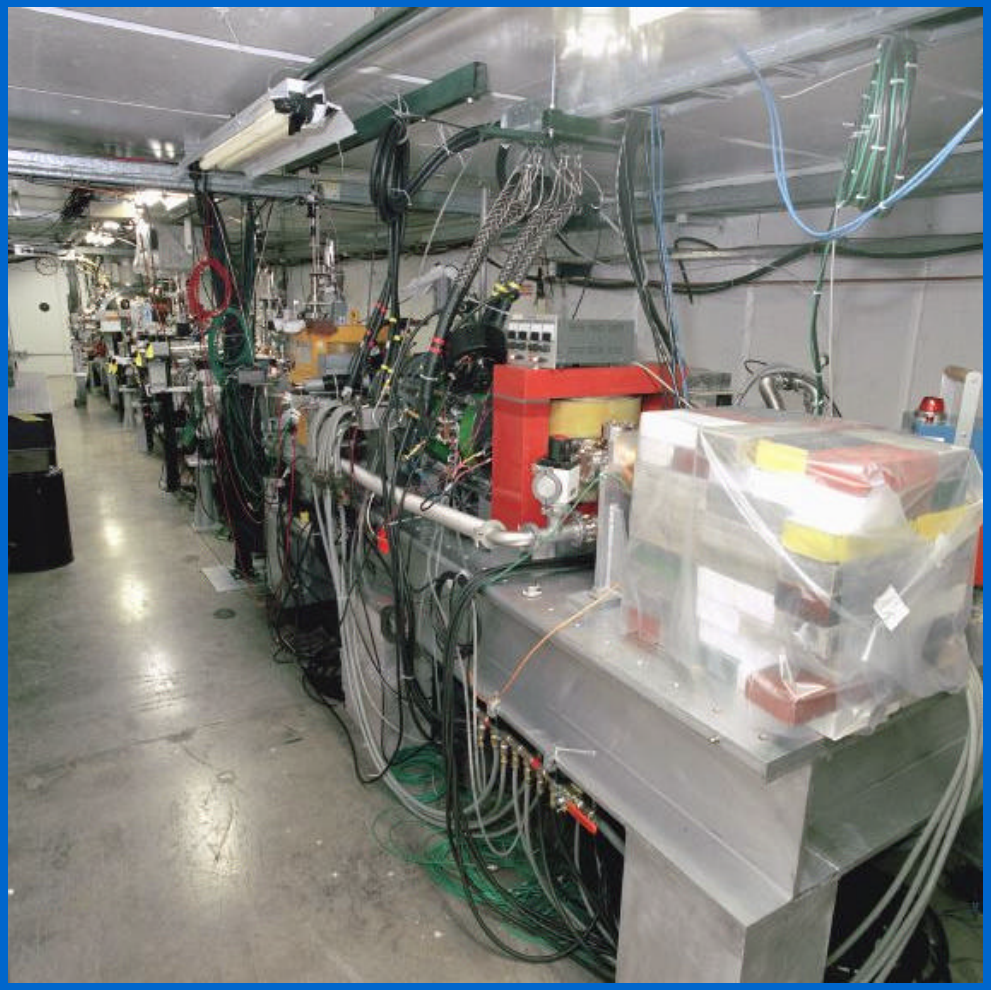


RF Gun and focussing solenoids

NIU (Northern Illinios University) is now heavily involved with this project.

http://www-ap.fnal.gov/A0PI/a0pics.html

A0 Photoinjector at Fermilab



Spectrometer magnets, plasma chamber, and beam dump

http://www-ap.fnal.gov/A0PI/a0pics.html

Summary

- This is still fun.
  - Q1: So what IS it all made of? and
  - Q2: How DOES it all behave? etc etc
- There is still lots to do.
  - Decades (in performance and on calendars)
  - The best ideas are yet to come ...

That's It From Me ...
And Now For Today's Tour

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BEHIND THE SCIENCE

SHOW AIRS: SAT 3/29 at 9am CT

Your Host: David Finley
finley@fnal.gov