

Fermilab Program: Today and Tomorrow

*Greg Bock
IWLC2010
19 October 2010*

Outline

- Fermilab research program near and long term
- Emphasis on accelerator program and its evolution
- Further Emphasis
 - Tevatron extension
 - Project X
 - Muon Collider feasibility study

Fermilab Program at Three Frontiers Today

Hadron Colliders:

Tevatron

LHC

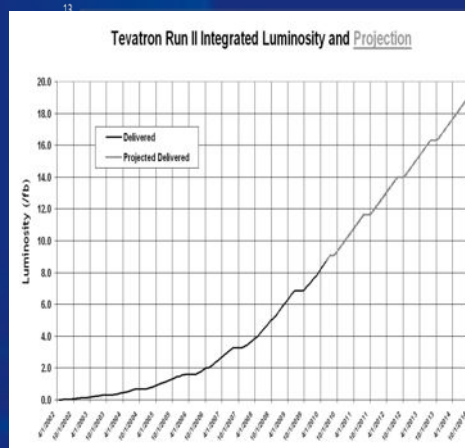
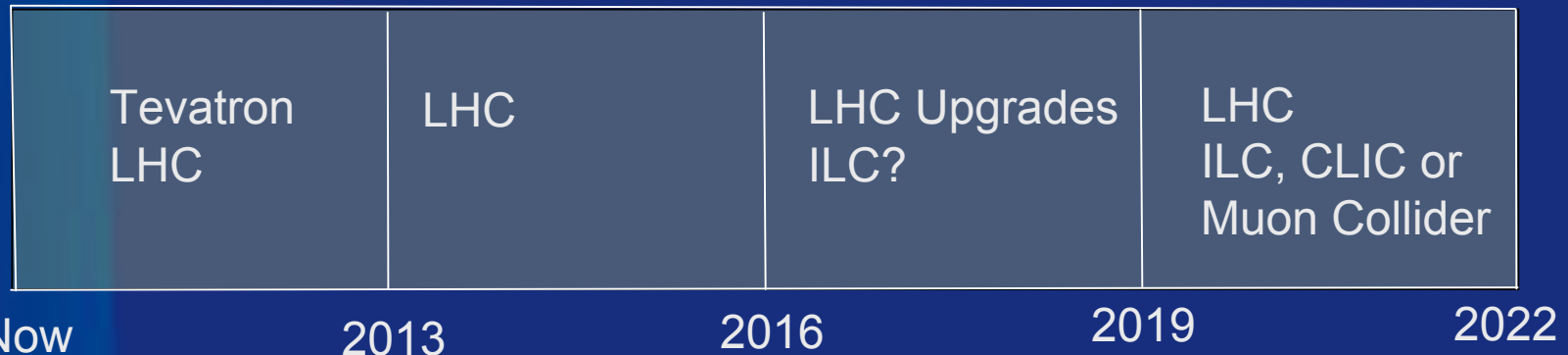
Neutrinos



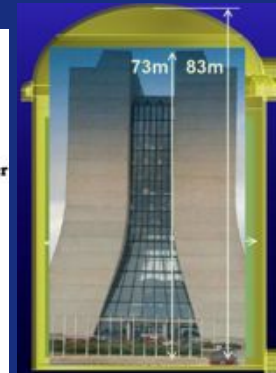
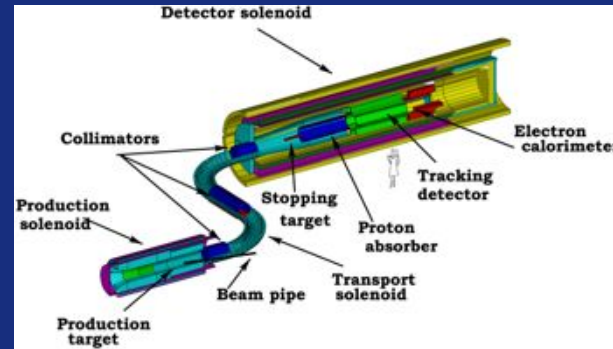
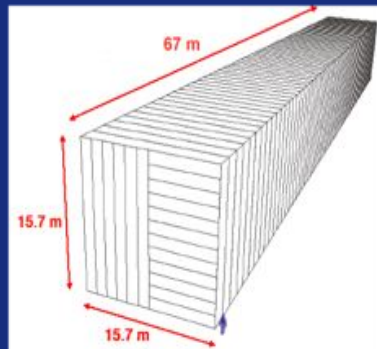
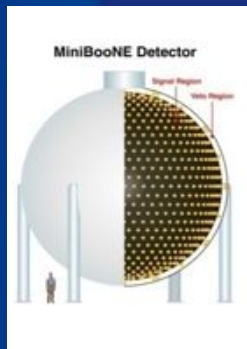
Dark Matter,
Dark Energy,
UHE Cosmic Rays

Accelerator and detector research and development at the 3 frontiers

Present plan: energy frontier



Present plan: intensity frontier



MINOS
MiniBooNE
MINERvA
SeaQuest

NOvA
MicroBooNE
g-2?
SeaQuest

LBNE
Mu2e

Project X+LBNE
 μ , K, nuclear, ...
 ν Factory ??

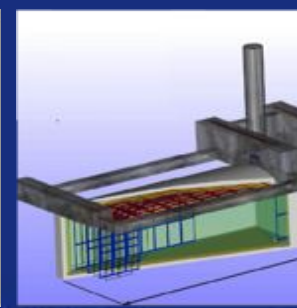
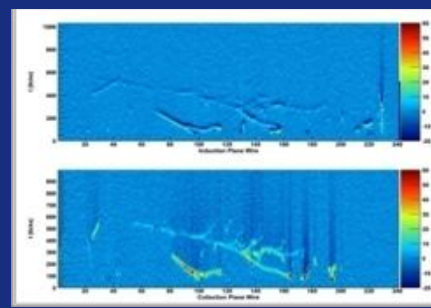
Now

2013

2016

2019

2022



Present plan: cosmic frontier



DM: ~10 kg
DE: SDSS
P. Auger

DM: ~100 kg
DE: DES
P. Auger
Holometer?

DM: ~1 ton
DE: LSST
WFIRST??
BigBOSS??

DE: LSST
WFIRST??

Now

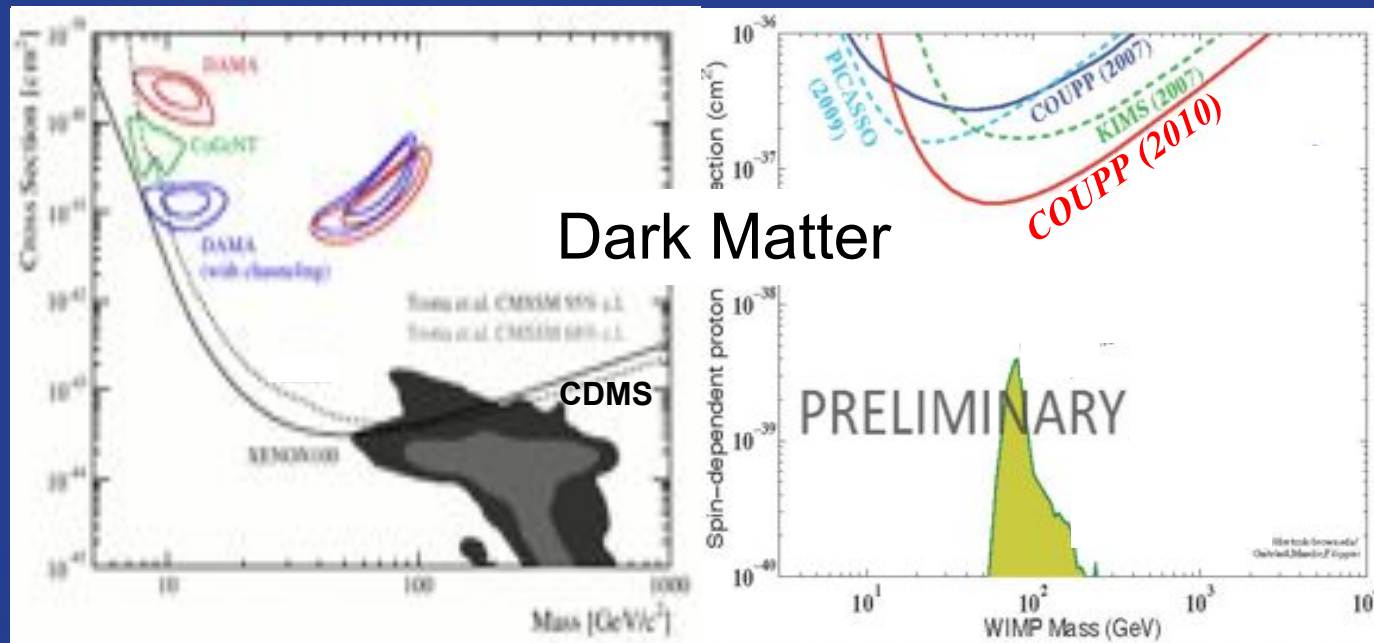
2013

2016

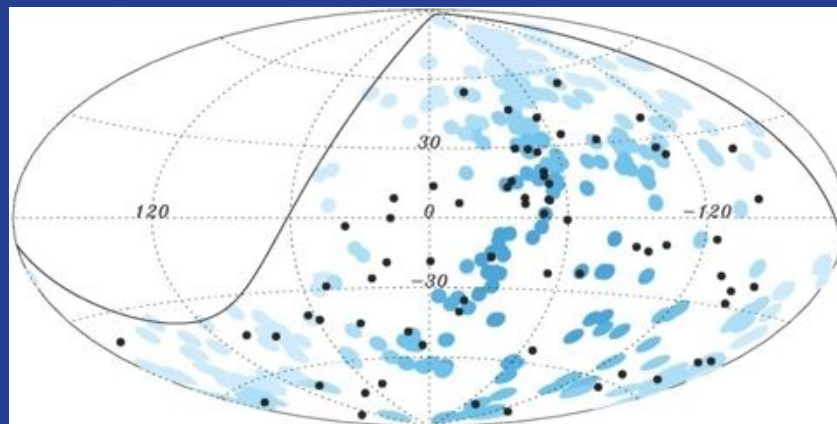
2019

2022

Cosmic Frontier: Recent Results



Ultra high energy
cosmic rays
(Auger)



Fermilab Accelerator Complex Operating Simultaneously



Start of CMS Physics!!

LHC Instantaneous
luminosity already $> 1.5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$

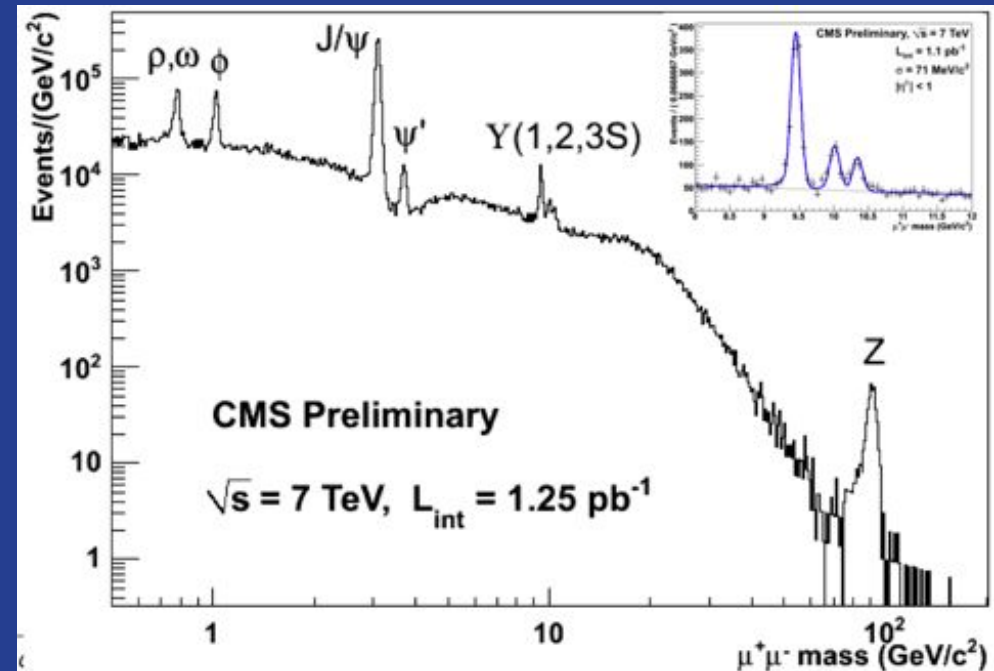
CMS producing physics quickly
Fermilab serves as the U.S. hub
for data analysis and operations

LHC Physics Center

Computing facilities provide large resources to CMS and
access to data

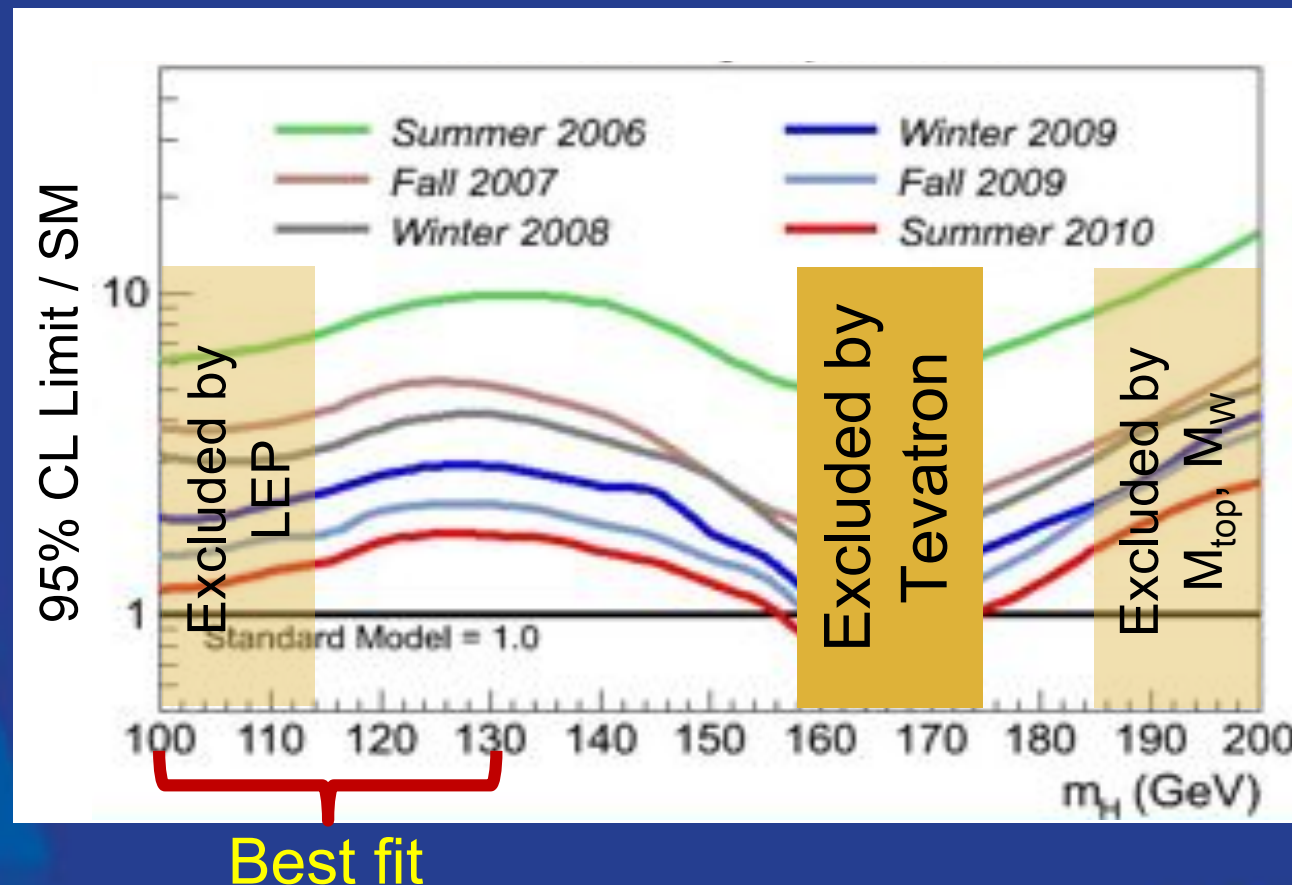
Remote Operations Center allows U.S. to engage in
operations, shifts etc

Participate in Upgrades of both Accelerator and
CMS



Energy Frontier: Recent Tevatron Results

- Tevatron continues to operate very well: ~25% of the favored region (114 – 185 GeV) now excluded

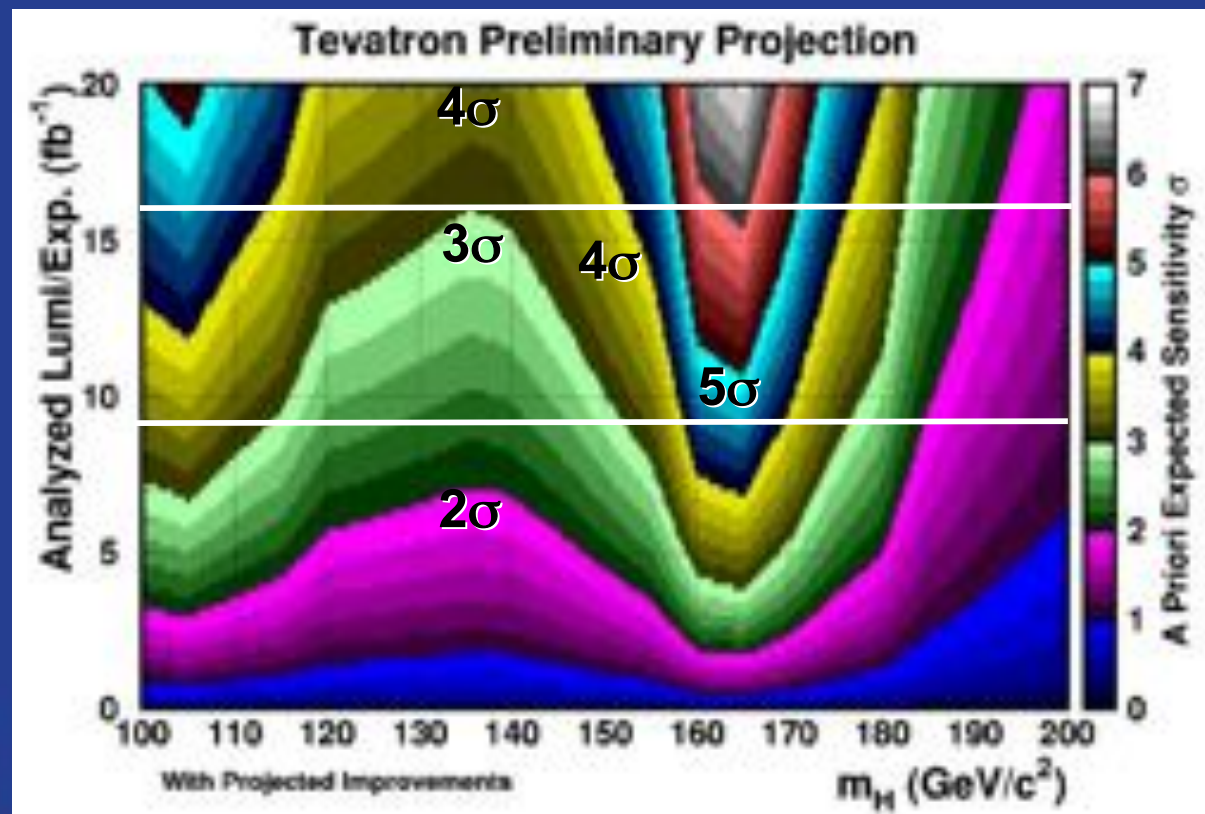


Tevatron extension (FY12 – FY14)

- A great short term opportunity for the Tevatron to get clearly into electroweak symmetry breaking territory

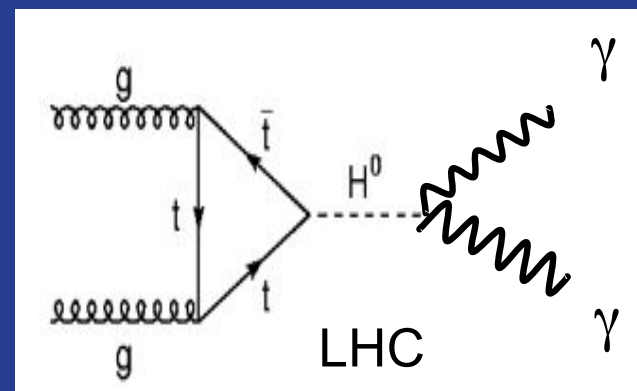
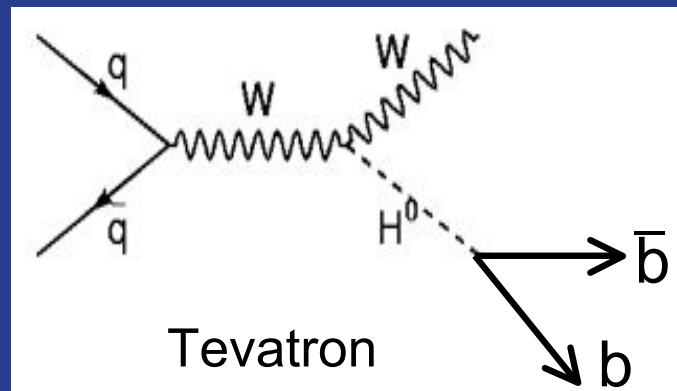
extension →

present plan →



Tevatron-LHC: complementary

- All indirect measurements point to a light Higgs. It couples mostly to $b\bar{b}$ and the rate is robust in all models that are not highly contrived. If the Higgs is light we must measure the rate to $b\bar{b}$.



- For the $H \rightarrow b\bar{b}$, Tevatron is competitive through 2014 and in general will have higher signal to background than LHC

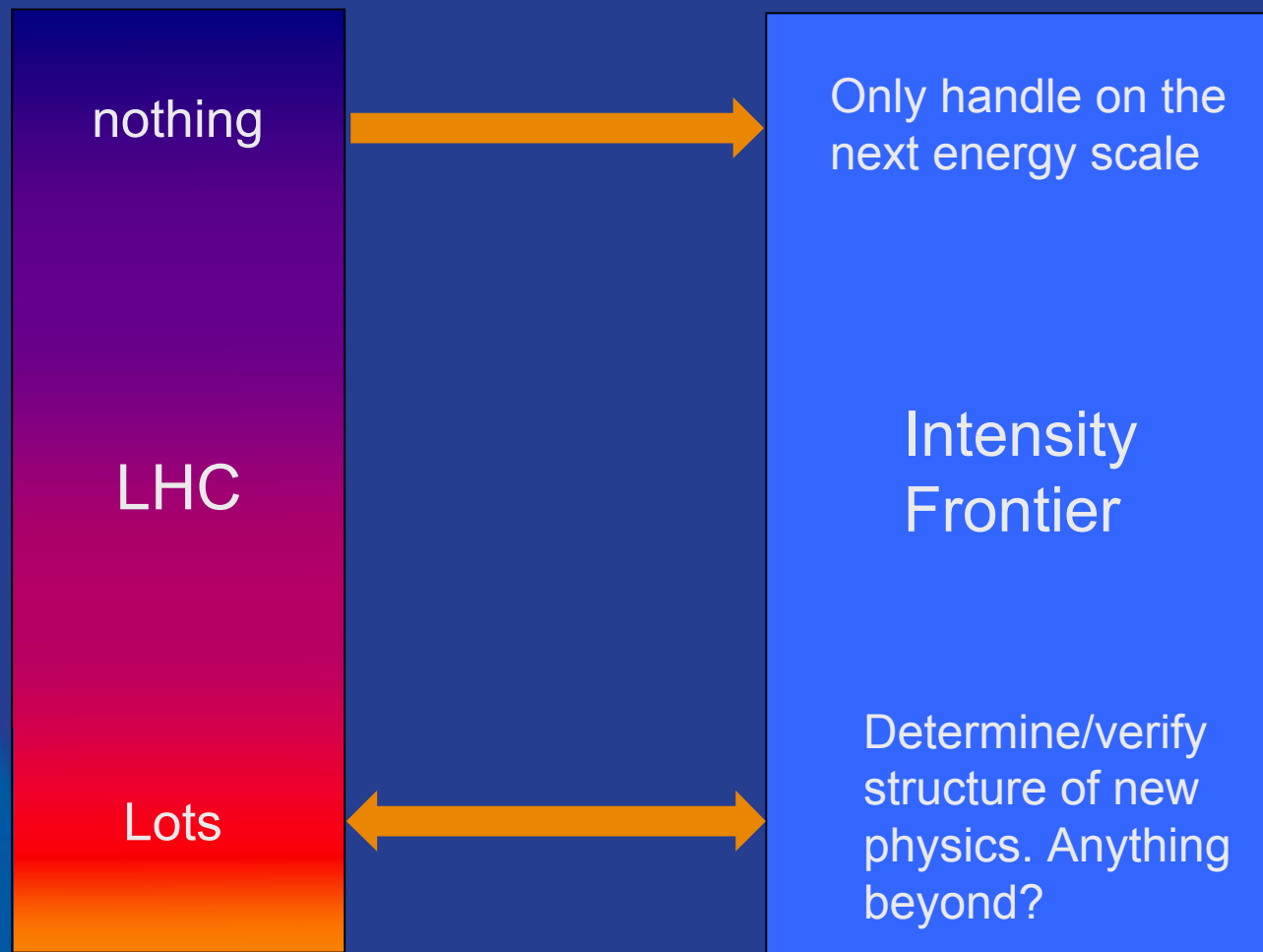
Tevatron extension: process

- Request from the community
 - Tevatron experiments
 - Letters to Steve Chu
 - ~40 theorists
 - 220 young scientists
- Very strong recommendations by Fermilab PAC
 - PAC meeting in June
 - Special PAC meeting in August
- DOE/NSF reconvened P5 on October 15-16
- Special HEPAP meeting on October 26

Laboratory's position on Tevatron extension

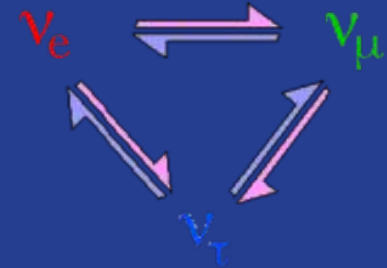
- A great short term opportunity for the Tevatron to get clearly into electroweak symmetry breaking territory.
- However, we should not endanger the future. Additional resources (~\$35M/year) into HEP in FY12-14 could mitigate. Even with additional funding, impact on NOvA cannot be mitigated. Most severe in 2015-2017 when the experiment would have ~50% of presently planned
- Weighing the pros and cons, we should try to extend Tevatron run and get solidly into electroweak symmetry breaking territory if we get \$35M/year in FY12-14.

Interplay: LHC \longleftrightarrow Intensity Frontier

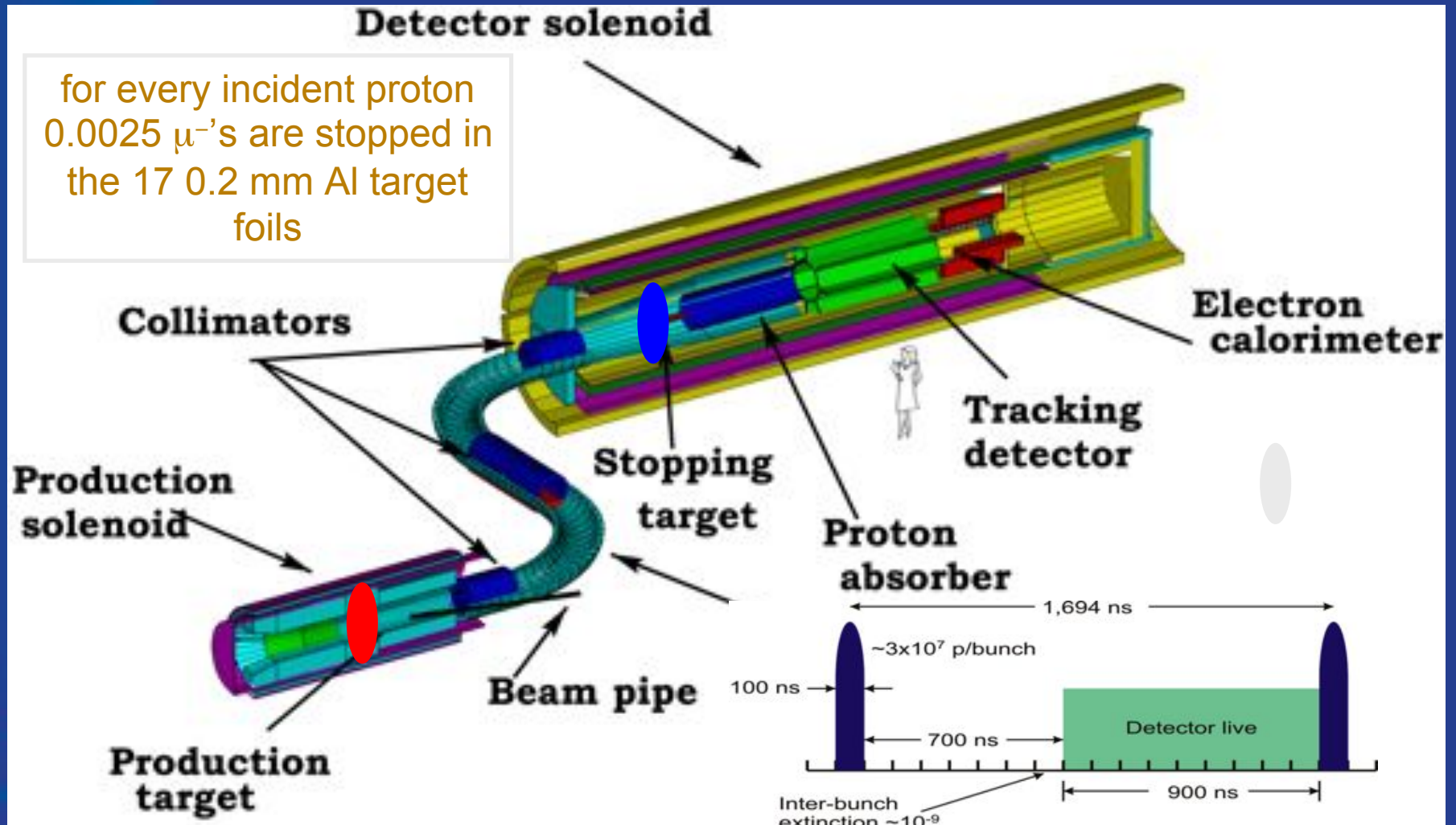


Intensity is key for neutrinos

- Recent Discoveries
 - produced much excitement.
- Behave so different from other particles
- Possibly key to understand the matter-dominate Universe
- Unification
- Cosmic Connection
- This route like the energy path depends of what we find in the current generation of experiments

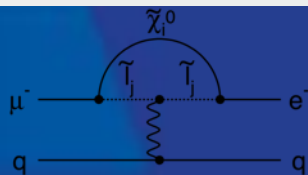
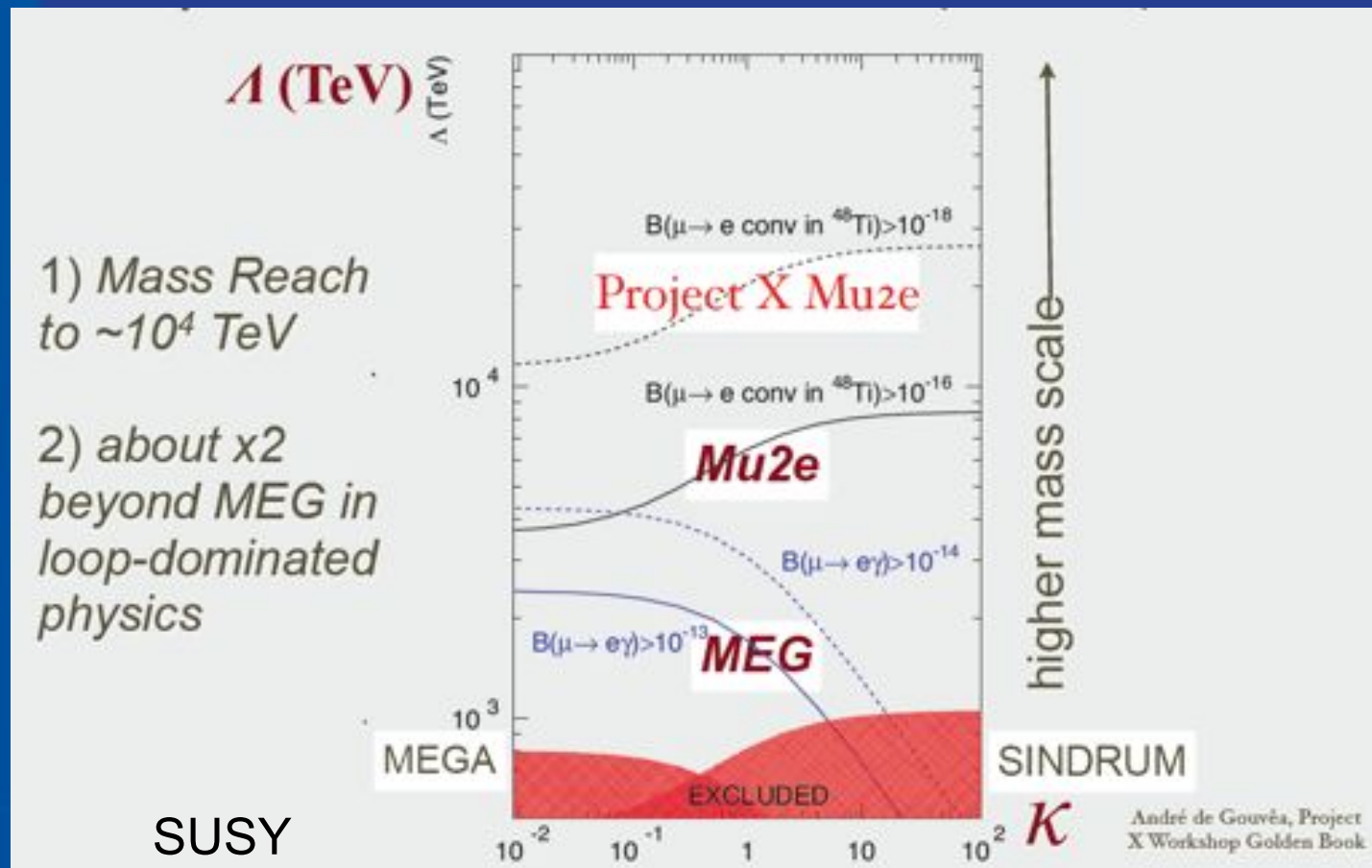


μ to e Conversion ($\mu N \rightarrow eN$)



Mu2E Project

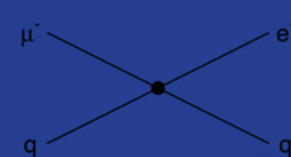
Mu2e can probe mass scales up to 10^4 TeV



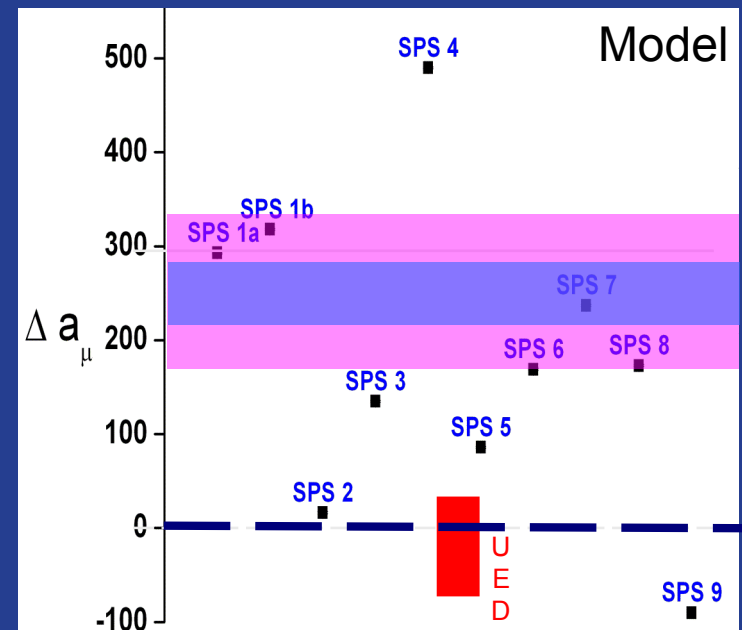
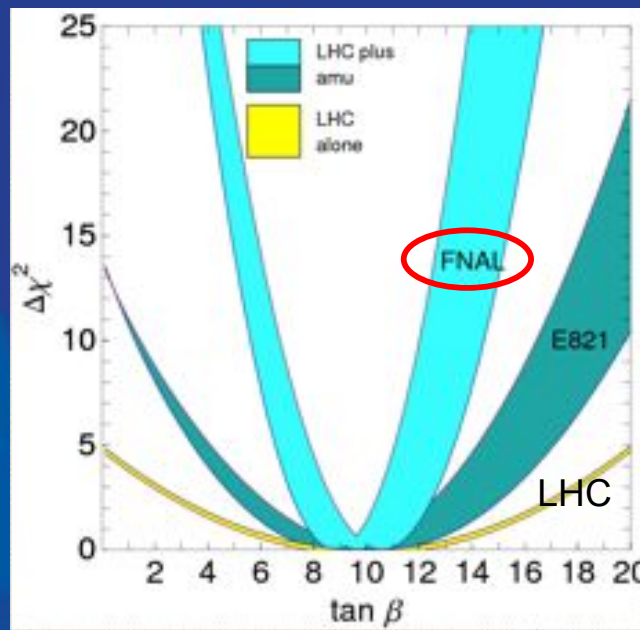
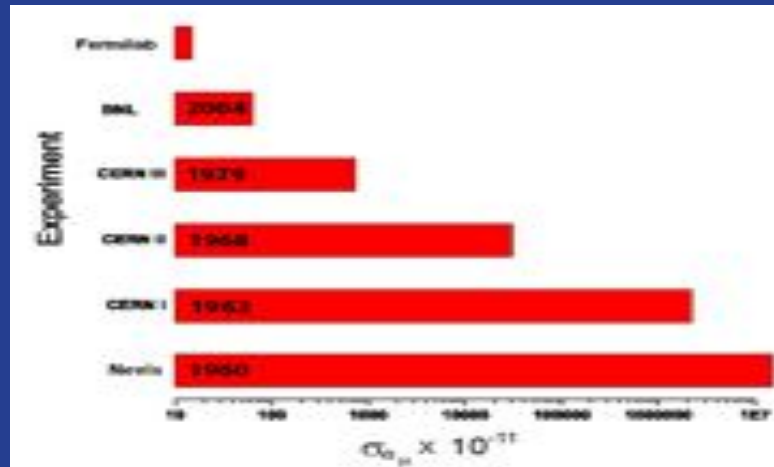
Loops



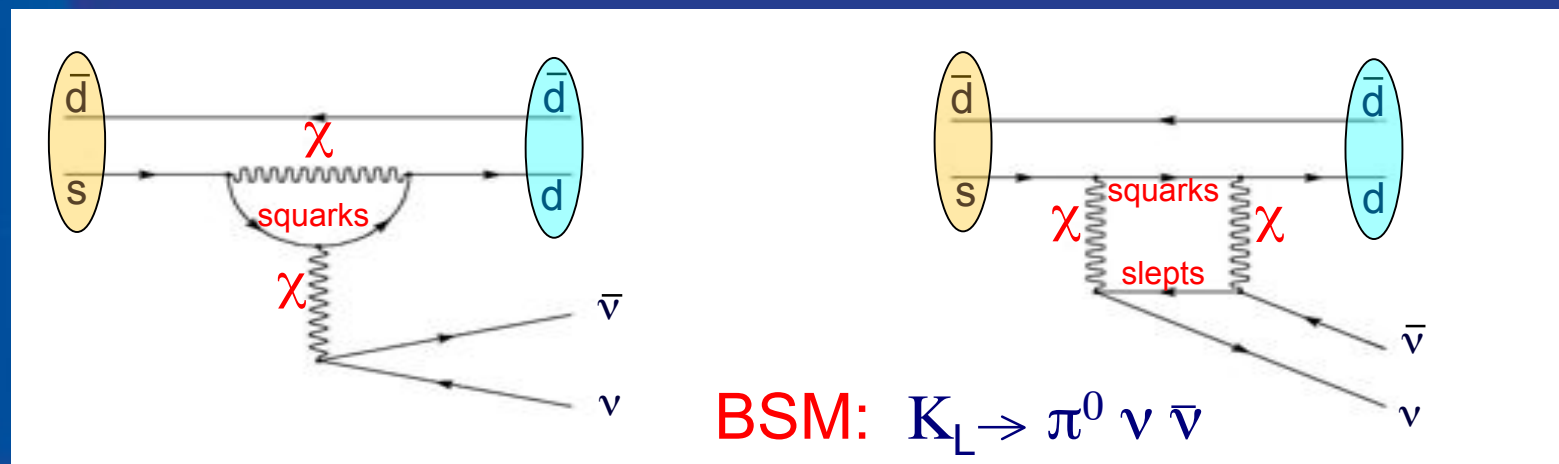
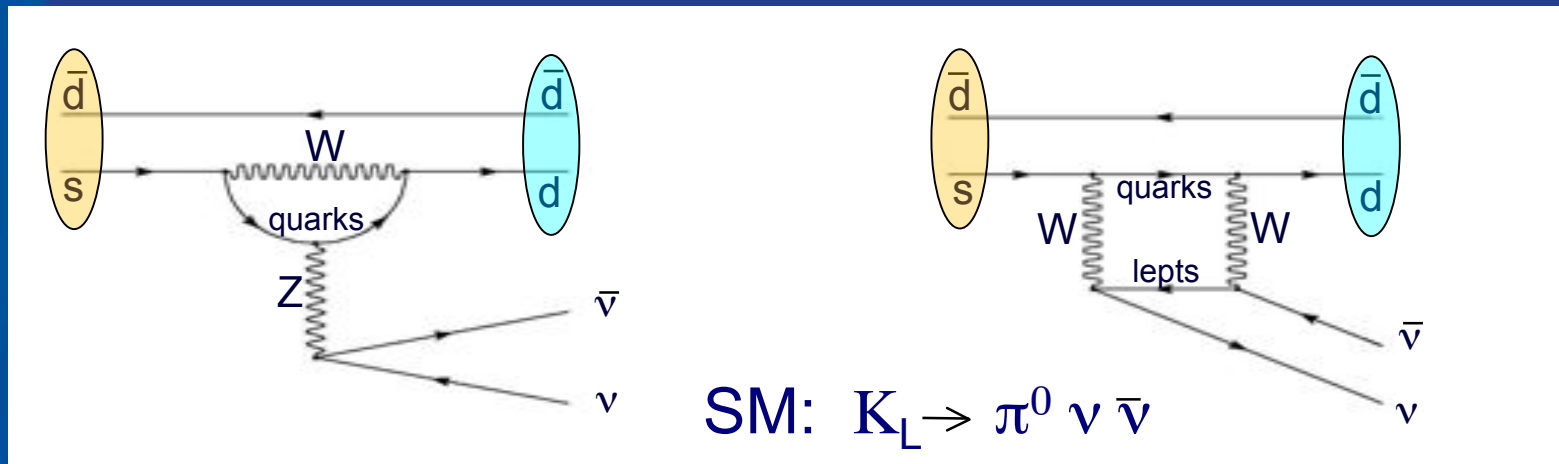
Contact Terms



A new (g-2) to uncertainty $0.14 \cdot 10^{-11}$

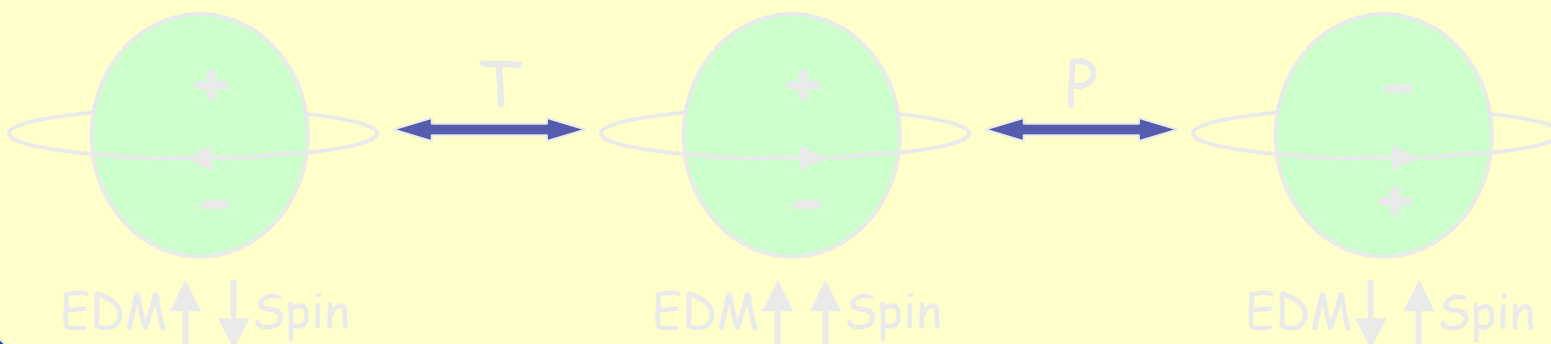


Large effects in kaon decay rates



The Quest for Electric Dipole Moments

A permanent EDM violates both time-reversal symmetry and parity



To understand the origin of the symmetry violations, you need many experiments!

Neutron

Quark EDM

Diamagnetic Atoms
(Hg, Xe, Ra, Rn)

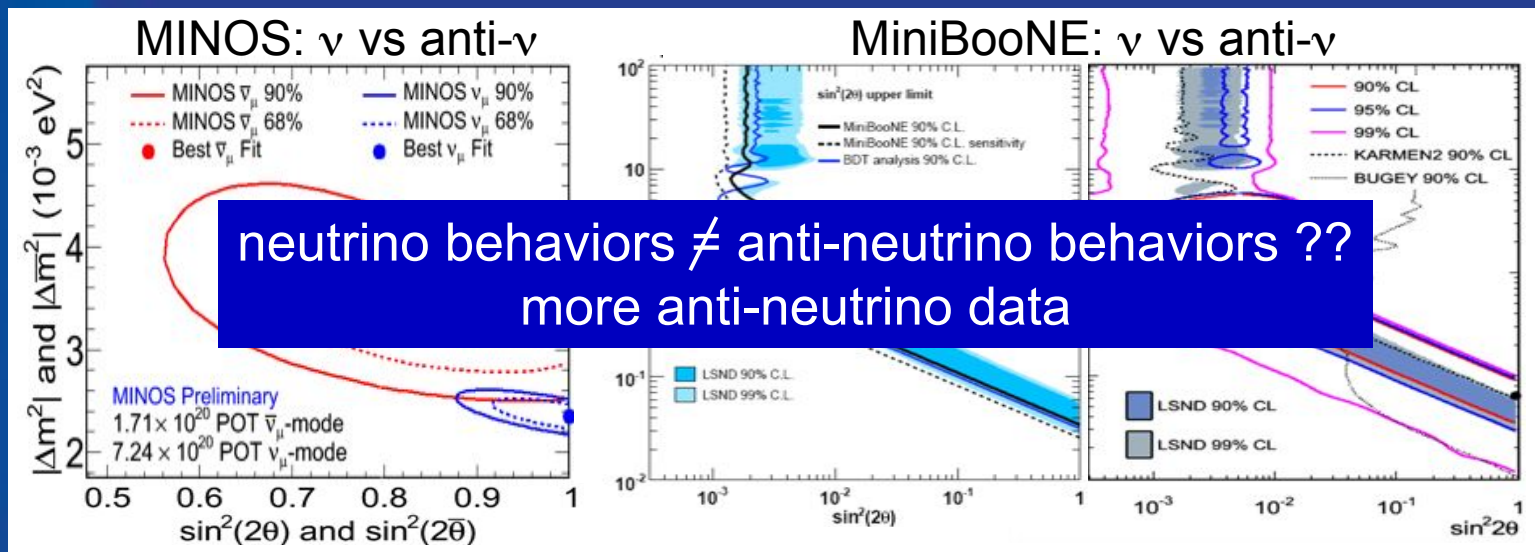
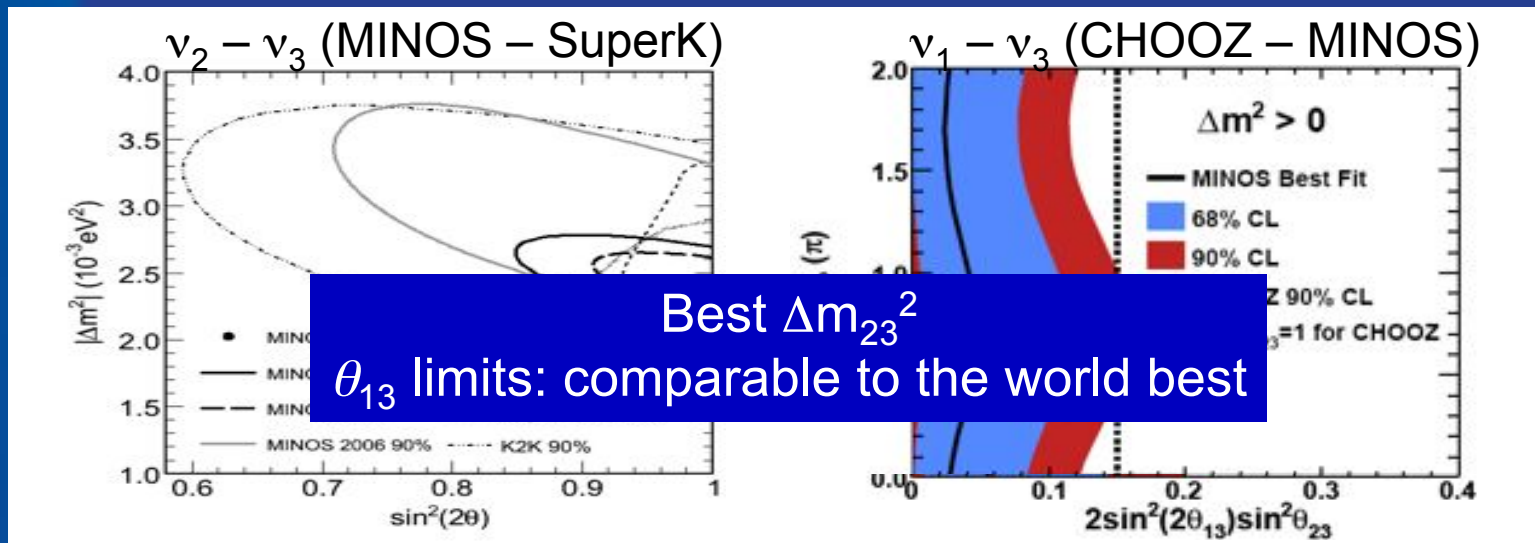
Quark Chromo-EDM

Paramagnetic Atoms (Tl, Fr)
Molecules (PbO)

Electron EDM

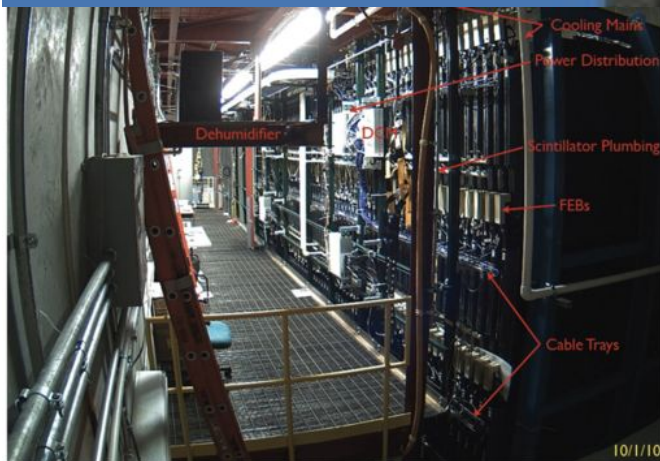
Physics beyond
the Standard
Model:
SUSY, Strings ...

Intensity Frontier: Recent Results



Intermediate Steps

NOvA (off-axis)
MINERvA
SeaQuest
MicroBooNE (LAr TPC)

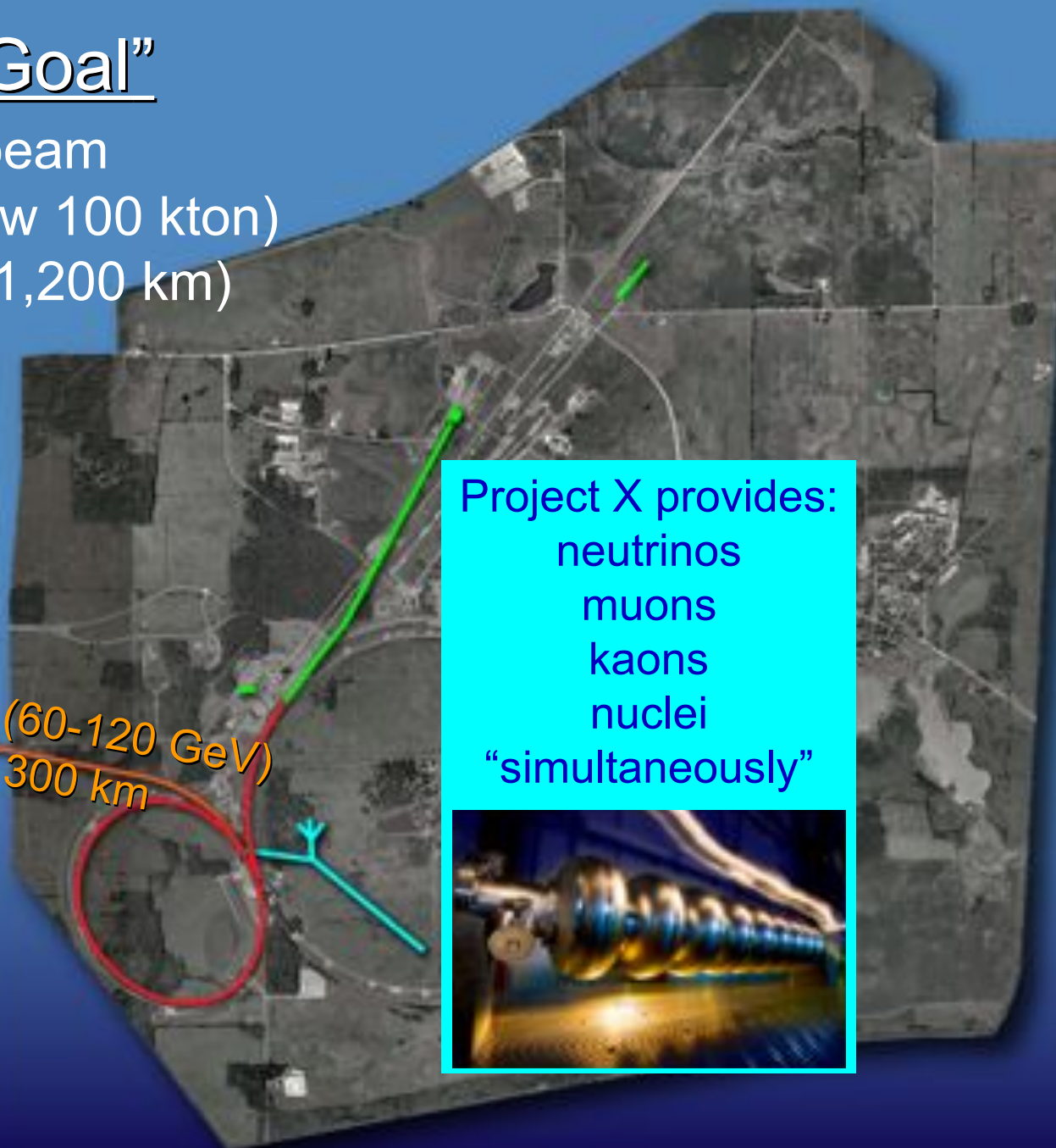


“Ultimate Goal”

multi MW beam
large detector (a few 100 kton)
long distance ($> 1,200$ km)



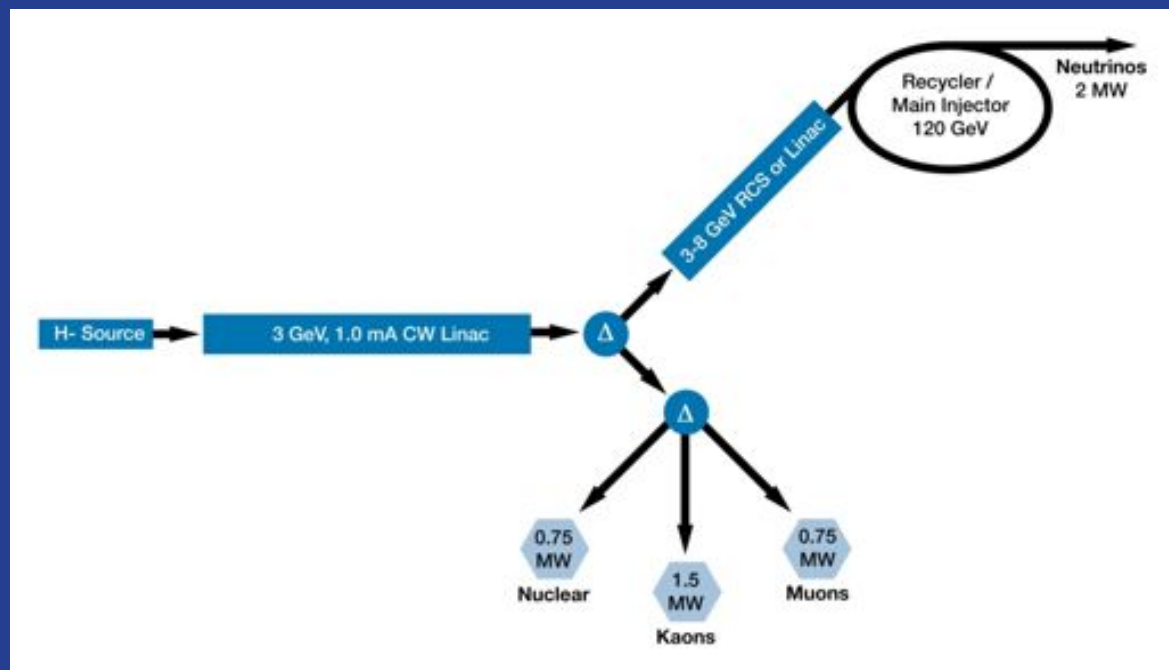
2 MW (60-120 GeV)
1300 km



Project X provides:
neutrinos
muons
kaons
nuclei
“simultaneously”



Project X



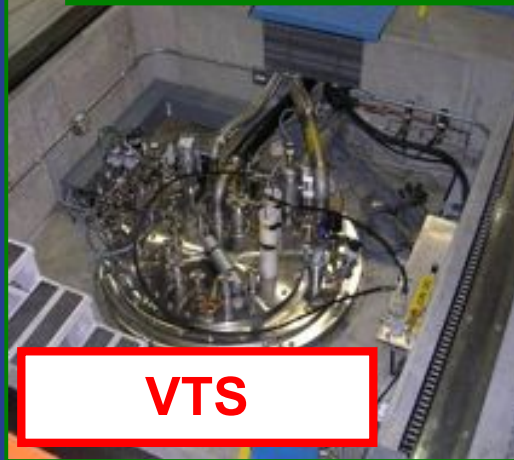
Beam Power to 3 GeV program	2870	kW
Beam Power to 8 GeV program	200	kW
Beam Power at 120 GeV	2200	kW

Design based on three families of 325 MHz Spoke resonators, two families of 650 MHz elliptical cavities, then 1300 MHz ILC cavities. Earliest construction start of 2015, operations in 2020. **3-8 GeV Linac is very similar to ILC. Same cavities, similar cryomodules.**

New FNAL SRF infrastructure



VTS



VTS



Cavity tuning machine



HTS



String Assembly



MP9 Clean Room



Final Assembly



1st U.S. built ILC/PX Cryomodule



1st Dressed Cavity

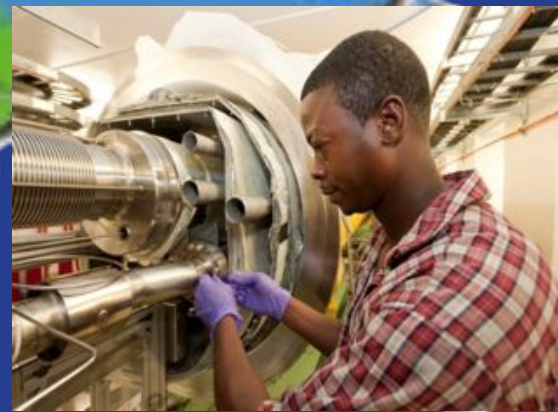
Energy Frontier: Plan

Fermilab ★

★CERN



Fermilab:
CMS / Machine



Tevatron

LHC

Lepton Collider

(energy decision)

(ILC, CLIC, Muon Collider)

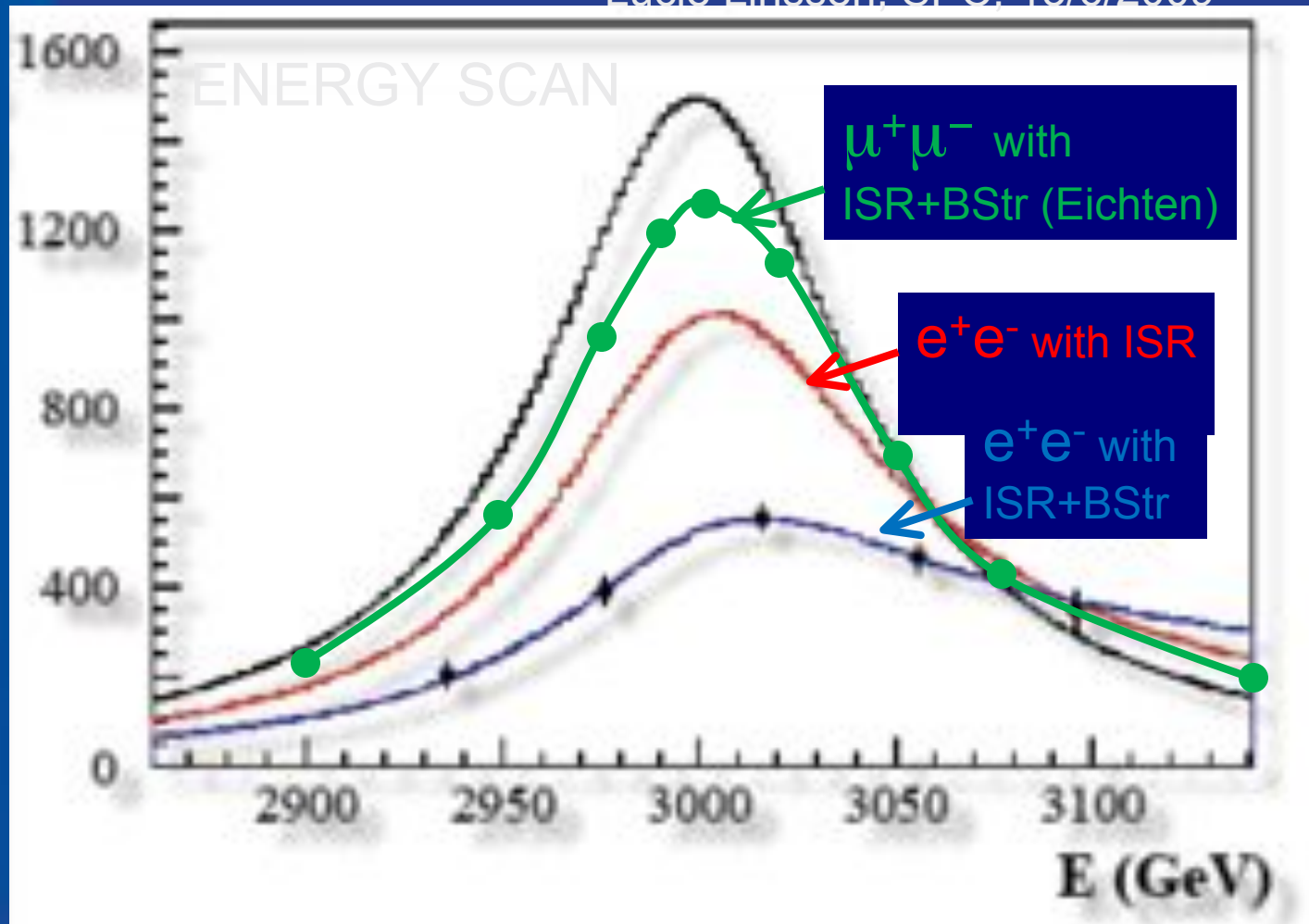
SCRF: ILC R&D, Muon Collider, Project X
High field magnets: LHC upgrades, Muon Collider

Muon Collider

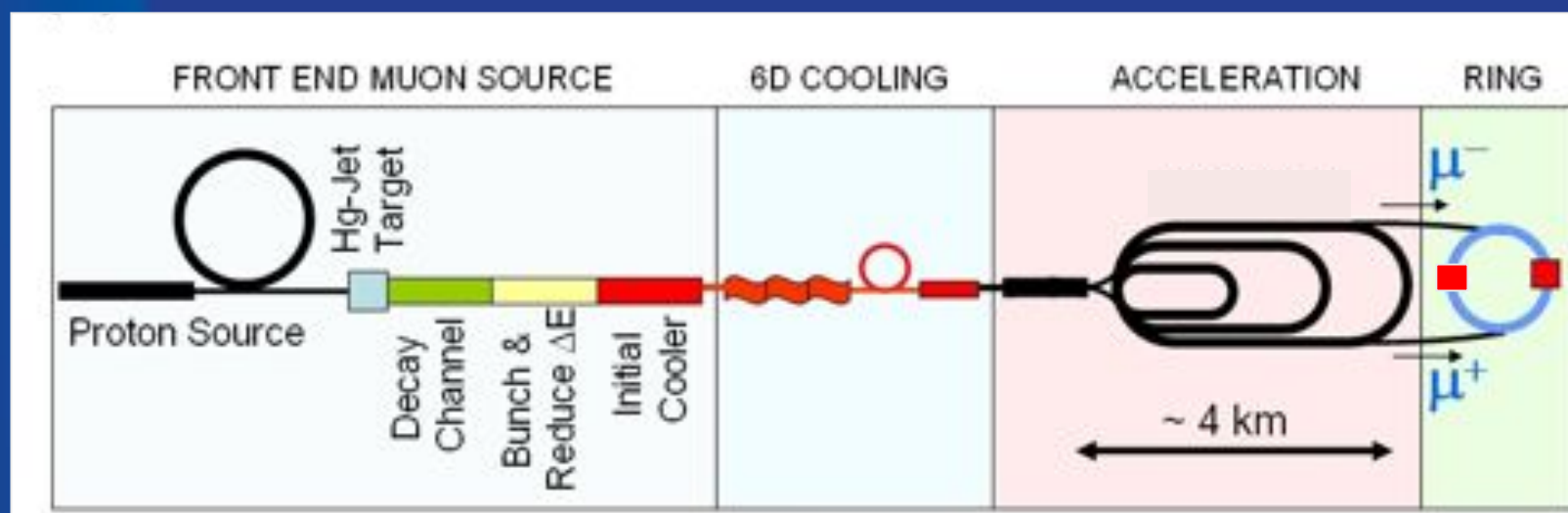
- Collider based on a secondary beam: we have experience basing colliders on antiprotons. For muons we must do it in 20 msec. The biggest advantages are: narrow energy spread (no beamstrahlung) and small physical footprint (no synchrotron radiation)
- After a decade of steady progress on Muon Collider design and technology development, a new national U.S. organization (Muon Accelerator Program) has been put in place, led and hosted by Fermilab. MAP aims to deliver a Muon Collider Design feasibility Study within ~6 years.
- A parallel Physics and Detector study is also being launched. There appears to be very significant synergies with other lepton collider detector needs and challenges.
- There will be a Muon Collider meeting 27 June – 1st July 2011 (place to be determined) to build community awareness of the progress and R&D opportunities.

$$l^+l^- \rightarrow Z' \rightarrow \mu^+\mu^-$$

Lucie Linssen, SPC, 15/6/2009



Muon Collider Schematic



Proton source:
Example:
upgraded
PROJECT X
(4 MW, 2 ± 1 ns
long bunches)

10^{21} muons per
year that fit
within the
acceptance of
an accelerator:

$$\epsilon_{\perp N} = 6000 \mu\text{m}$$

$$\epsilon_{//N} = 25 \text{ mm}$$

$\sqrt{s} = 3 \text{ TeV}$
Circumference = 4.5km
 $L = 3 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \mu$
/bunch = 2×10^{12}
 $\sigma(p)/p = 0.1\%$
 $\epsilon_{\perp N} = 25 \mu\text{m}$, $\epsilon_{//N} = 70 \text{ mm}$
 $\beta^* = 5 \text{ mm}$
Rep Rate = 12Hz

Expansion of the Fermilab Accelerator Complex



Muon Collider

The first collider of this kind

