Fermilab Program: Today and Tomorrow

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IWLC2010
19 October 2010

U.S. DEPARTMENT OF ENERGY

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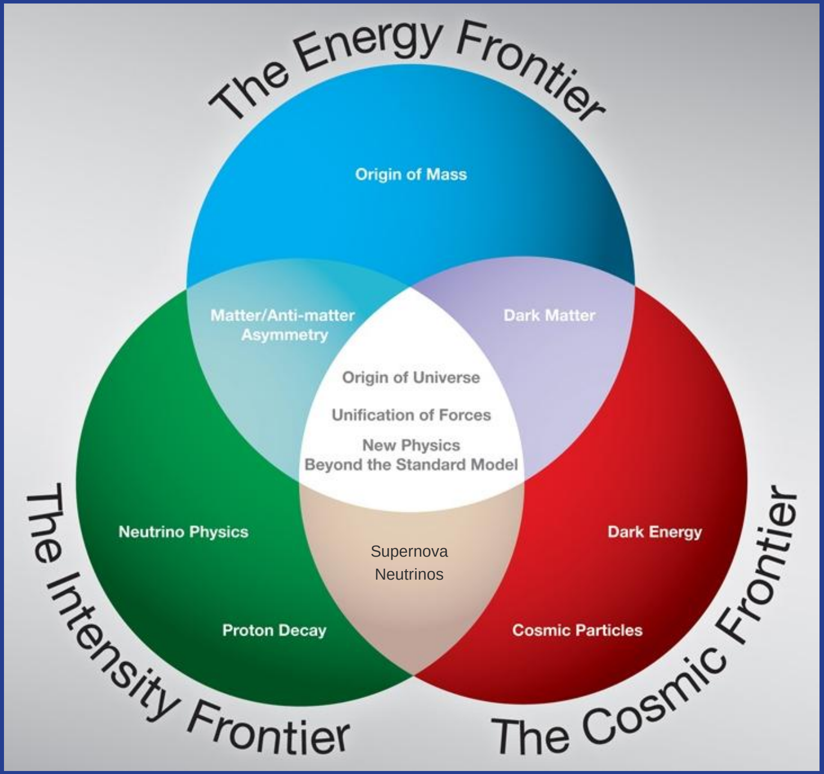
Outline

- 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

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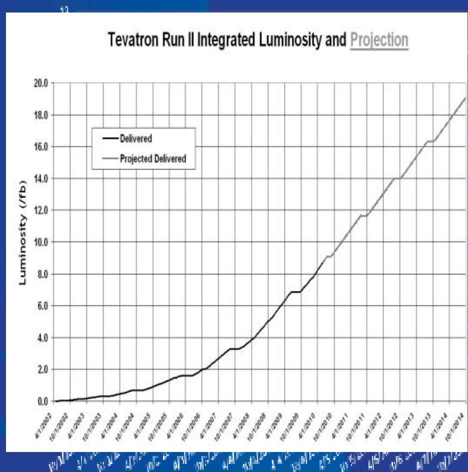
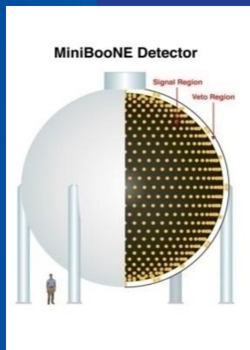
Present plan: energy frontier

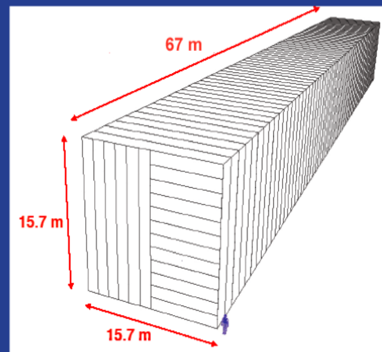
Now – 2013	2013 – 2016	2016 – 2019	2019 – 2022
Tevatron LHC	LHC	LHC Upgrades ILC?	LHC ILC, CLIC or Muon Collider

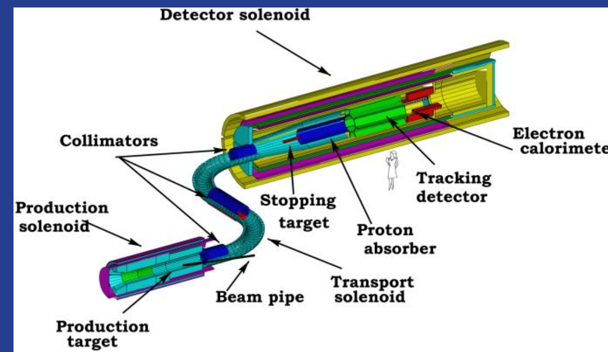
Now 2013 2016 2019 2022

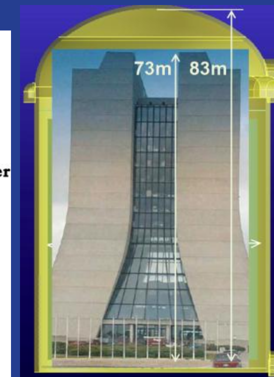


Present plan: intensity frontier



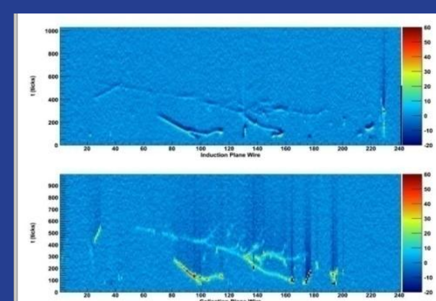


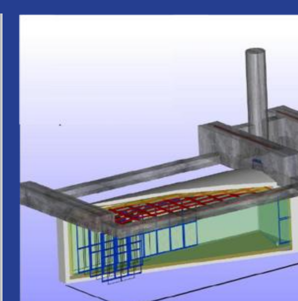




MINOS MiniBooNE MINERvA SeaQuest	NOvA MicroBooNE g-2?? SeaQuest	LBNE Mu2e	Project X+LBNE μ, K, nuclear, … ν Factory ??

Now 2013 2016 2019 2022





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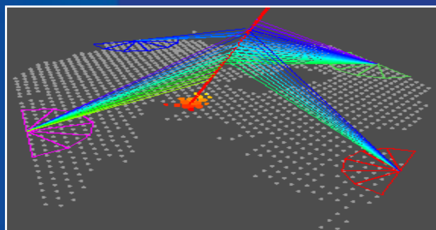
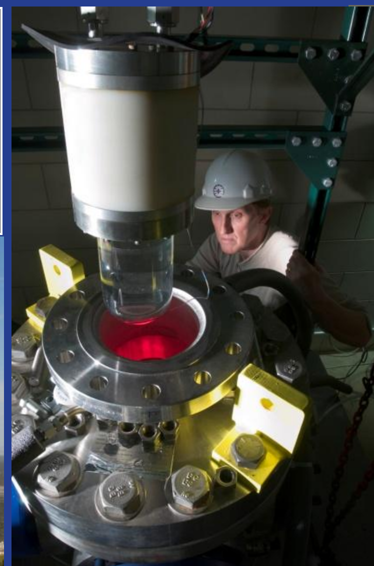
Present plan: cosmic frontier






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

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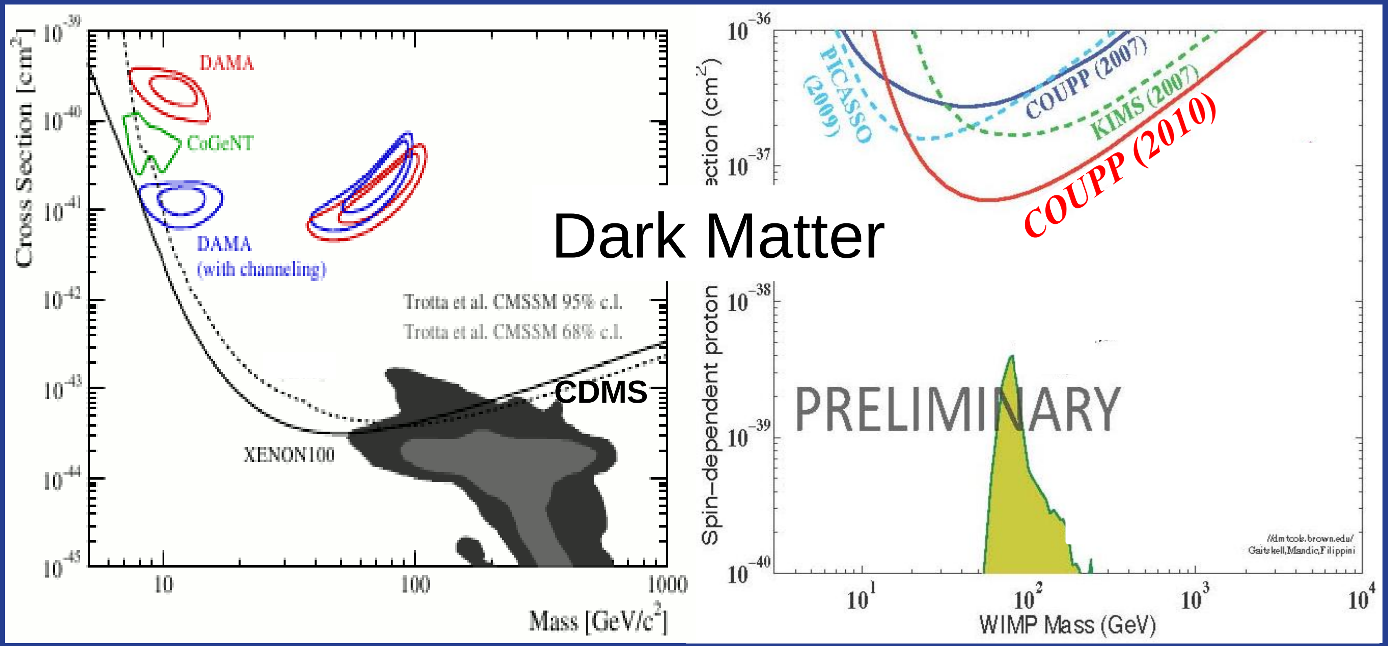
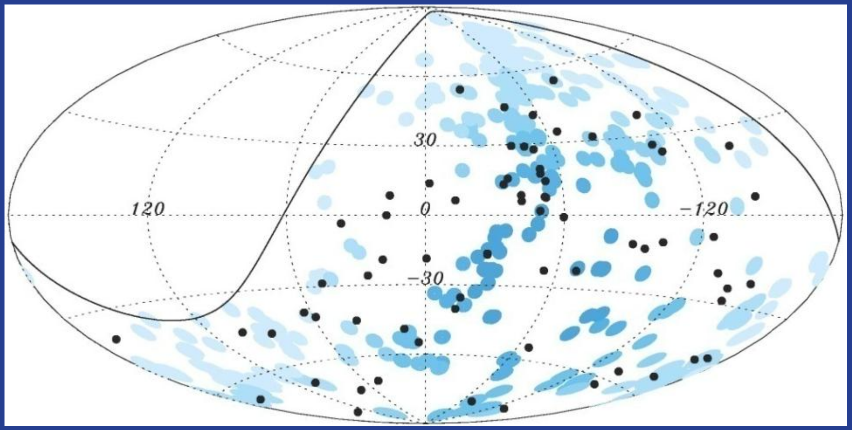
Cosmic Frontier: Recent Results



Dark Matter

Ultra high energy cosmic rays (Auger)



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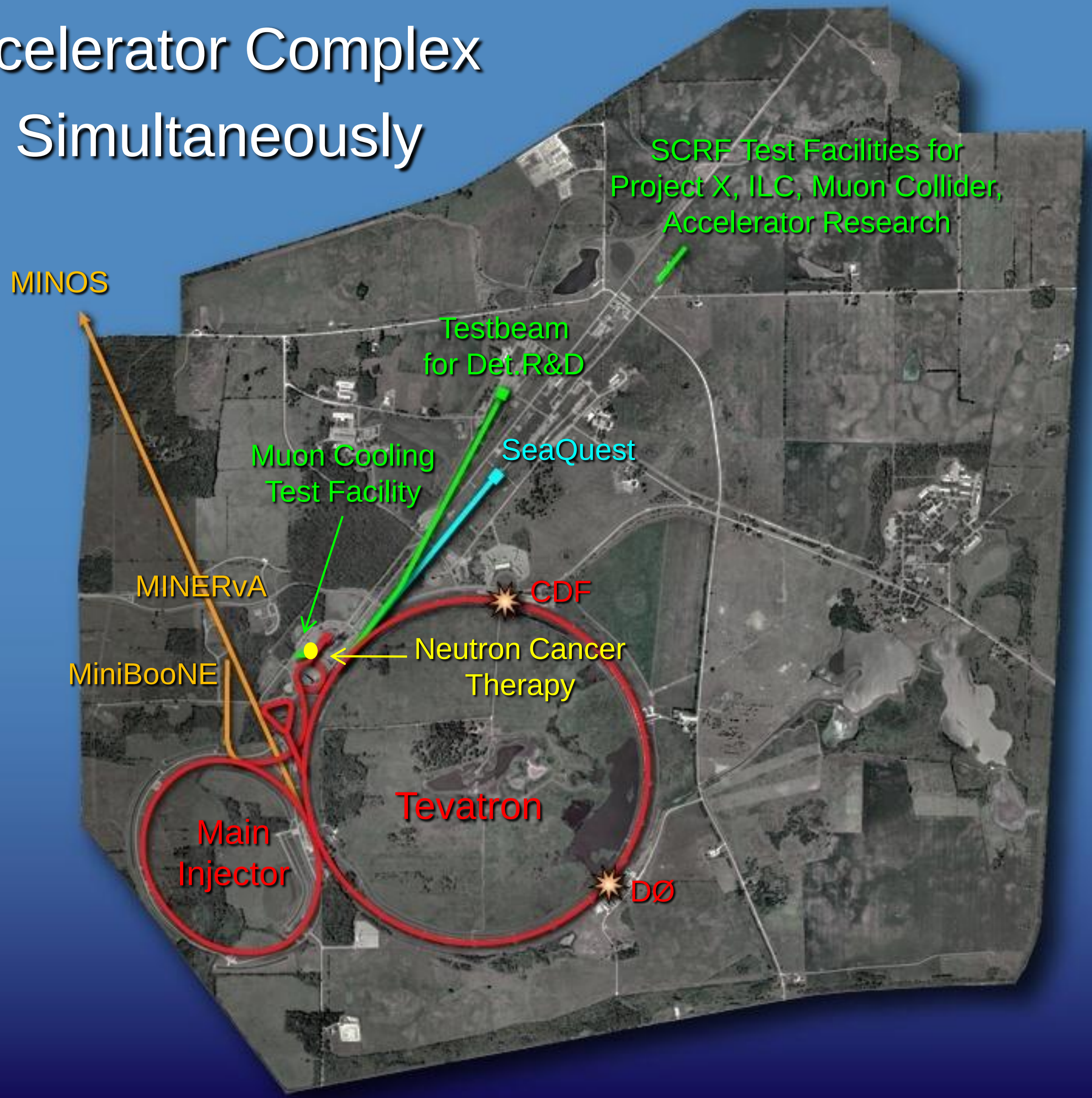
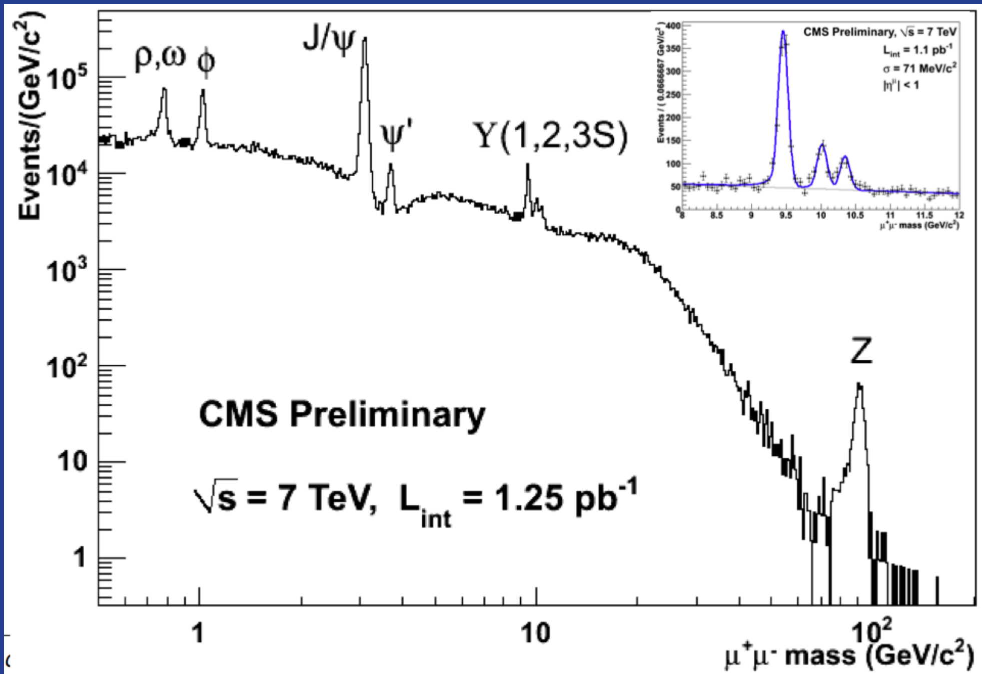
Fermilab Accelerator Complex Operating Simultaneously



Start of CMS Physics!!

LHC Instantaneous luminosity already > 1.5 x 10^{32} cm^{-2} 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

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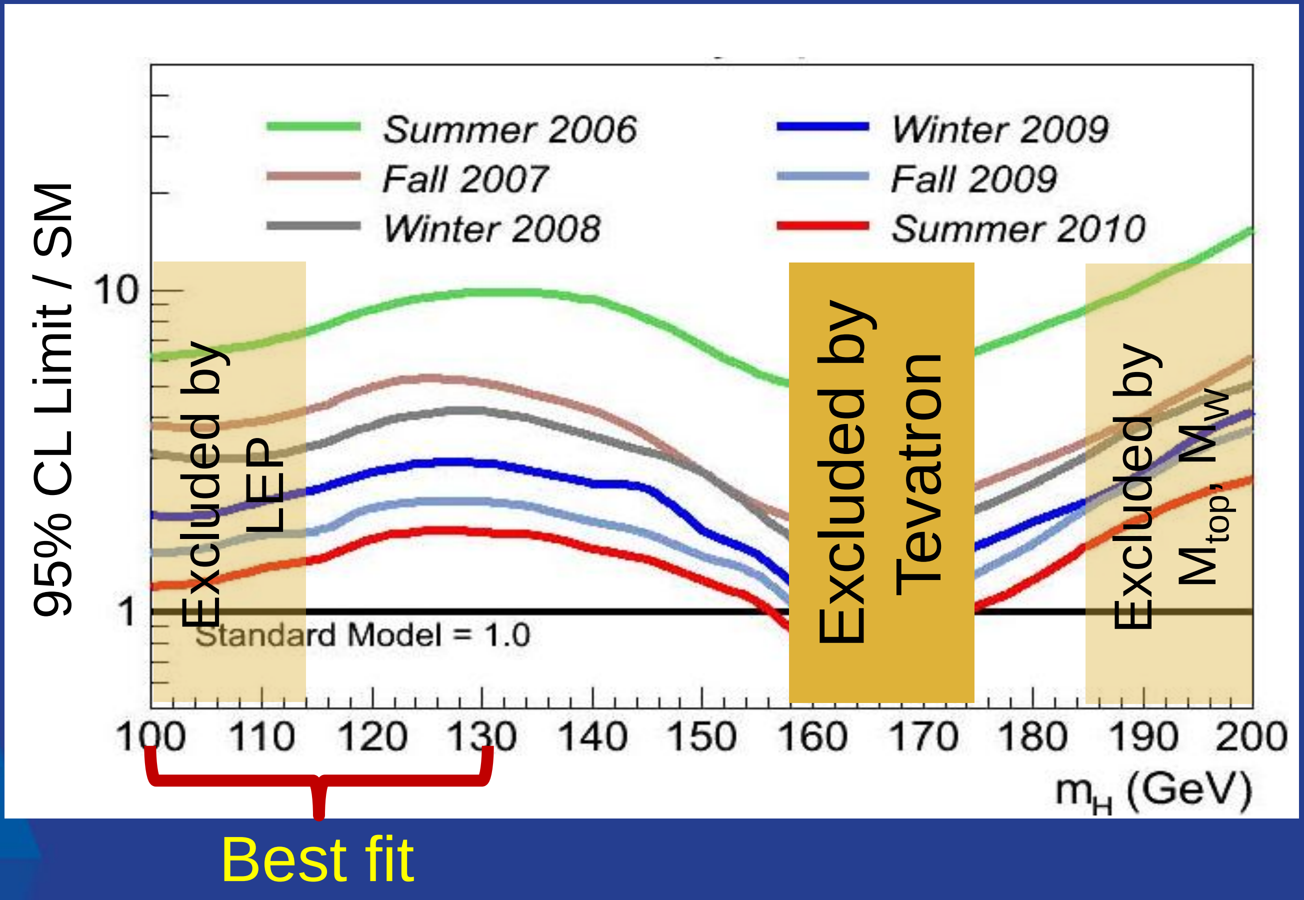
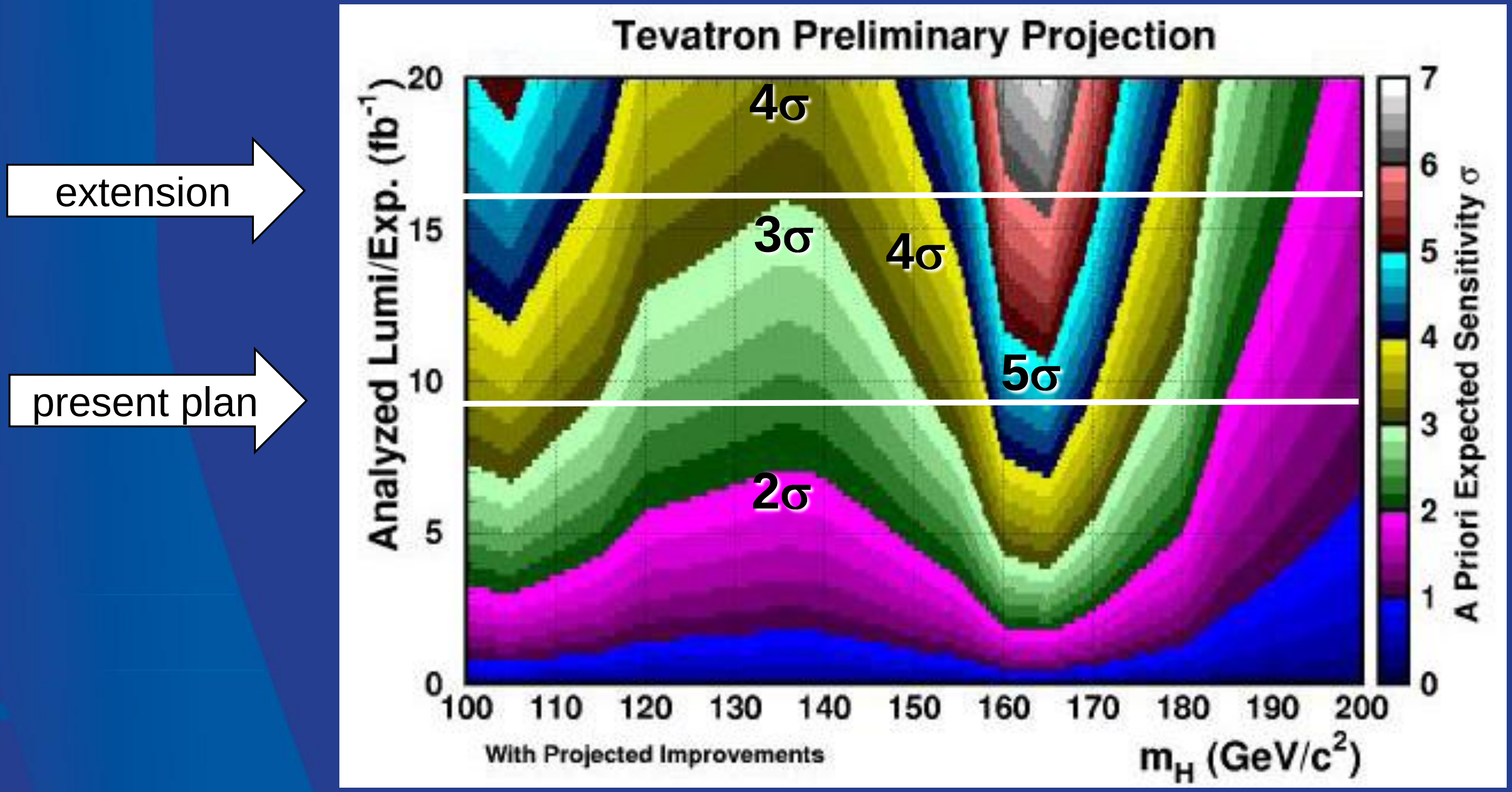
Energy Frontier: Recent Tevatron Results

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



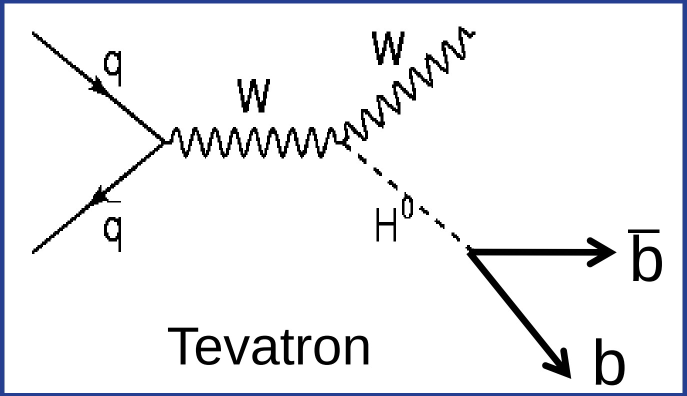
Tevatron extension (FY12 – FY14)

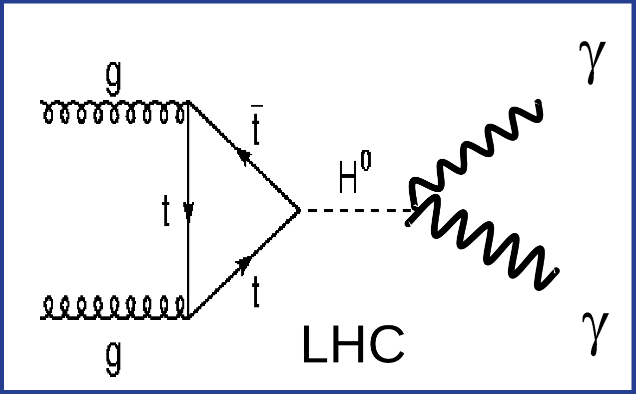
- A great short term opportunity for the Tevatron to get clearly into electroweak symmetry breaking territory



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 → $b\bar{b}$, Tevatron is competitive through 2014 and in general will have higher signal to background than LHC

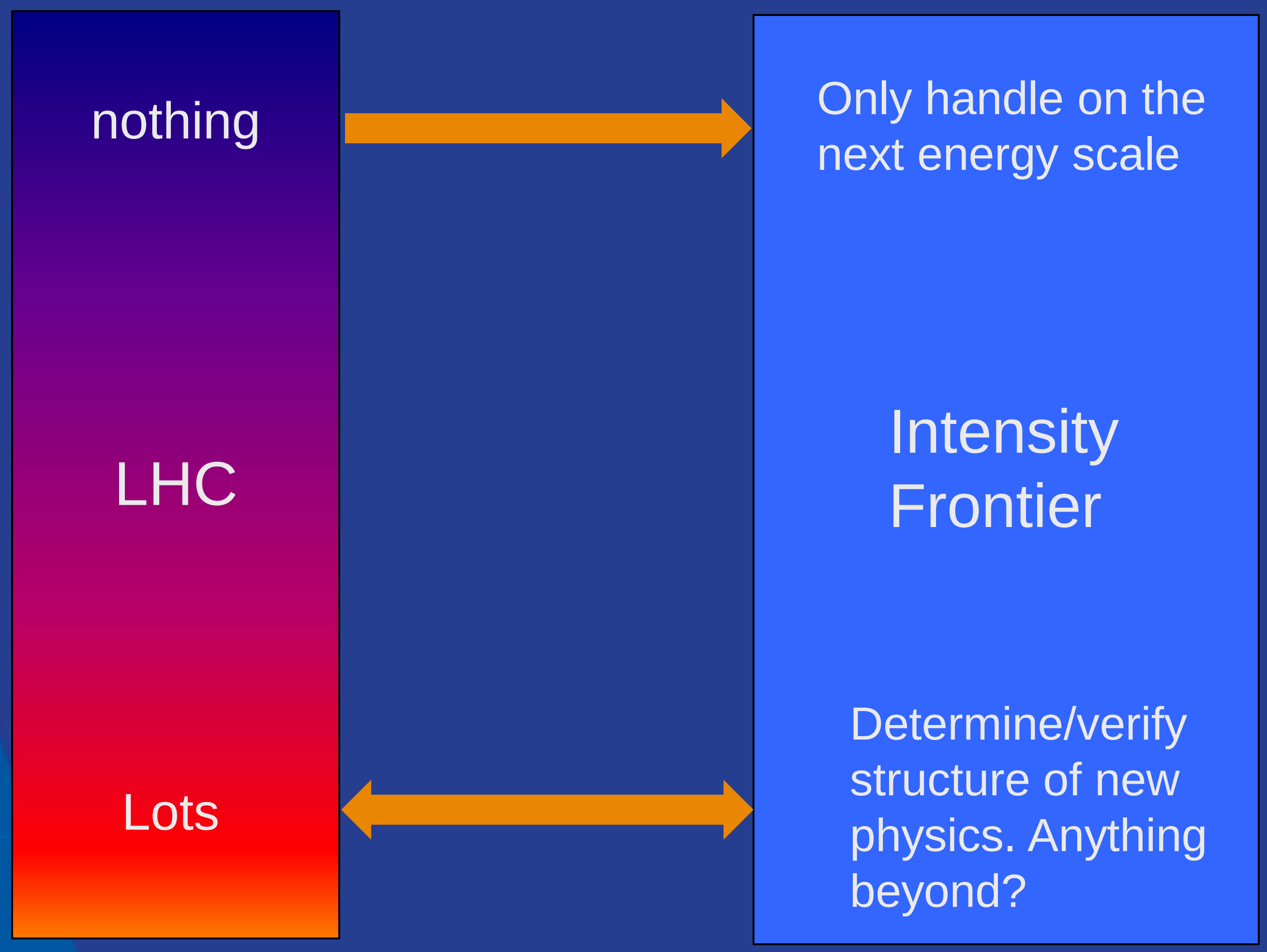
Tevatron extension: process

- 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

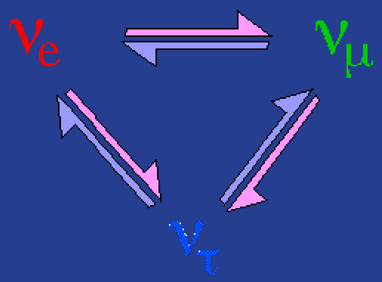
Laboratory’s position on Tevatron extension

- 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 braking territory if we get $35M/year in FY12-14.

Interplay: LHC ⟷ Intensity Frontier



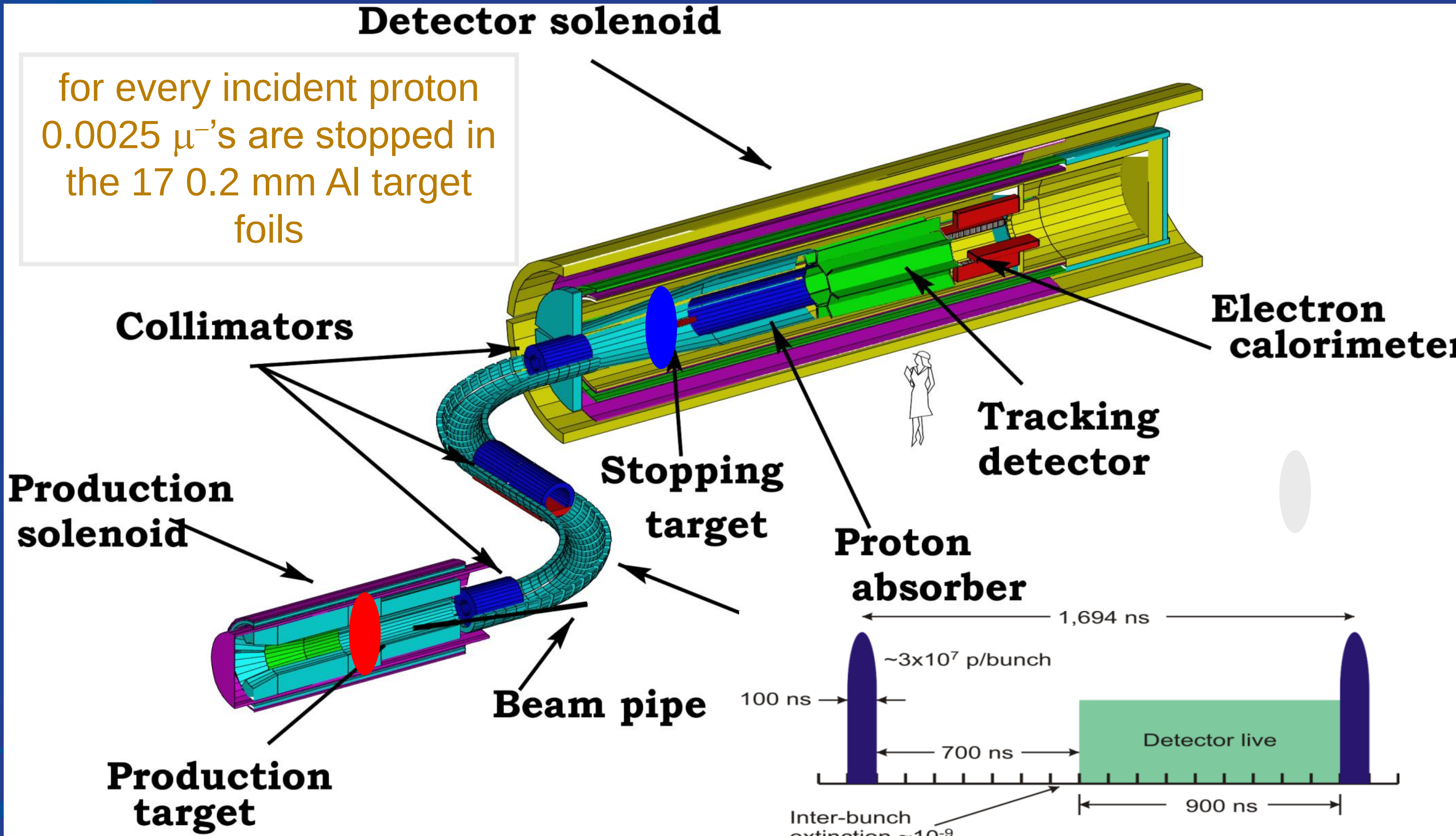
Intensity is key for neutrinos



- 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 ($\mu N \rightarrow eN$)

for every incident proton 0.0025 μ^-'s are stopped in the 17 0.2 mm Al target foils



Mu2E Project

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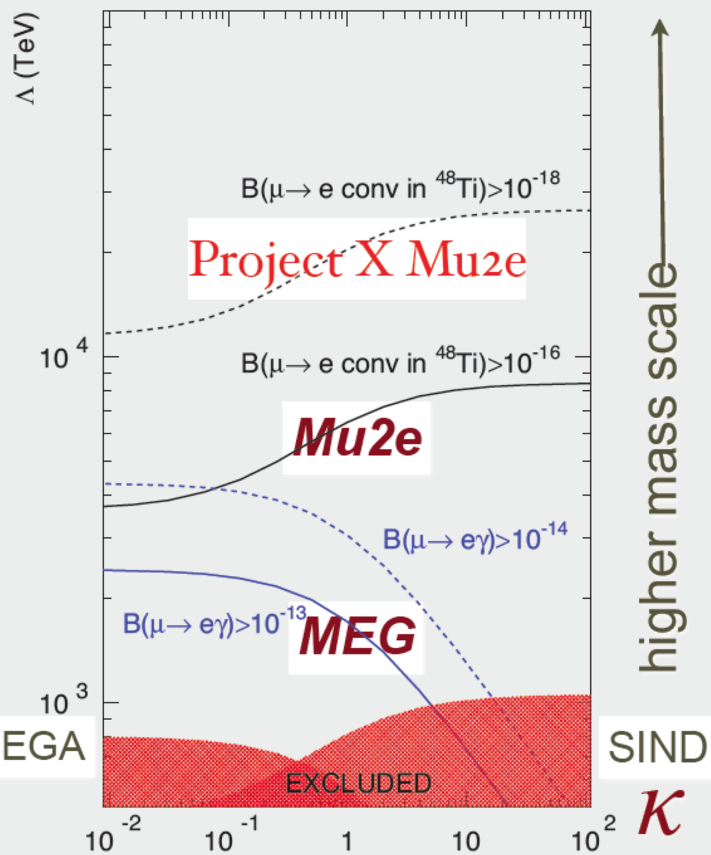
Mu2e can probe mass scales up to 10^4 TeV

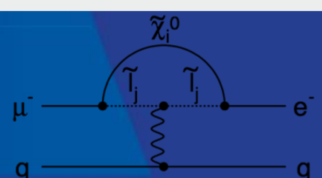
1) *Mass Reach to ~10^4 TeV*

2) *about x2 beyond MEG in loop-dominated physics*



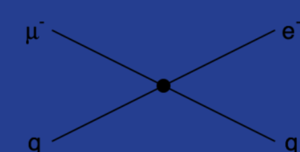
André de Gouvêa, Project X Workshop Golden Book

SUSY



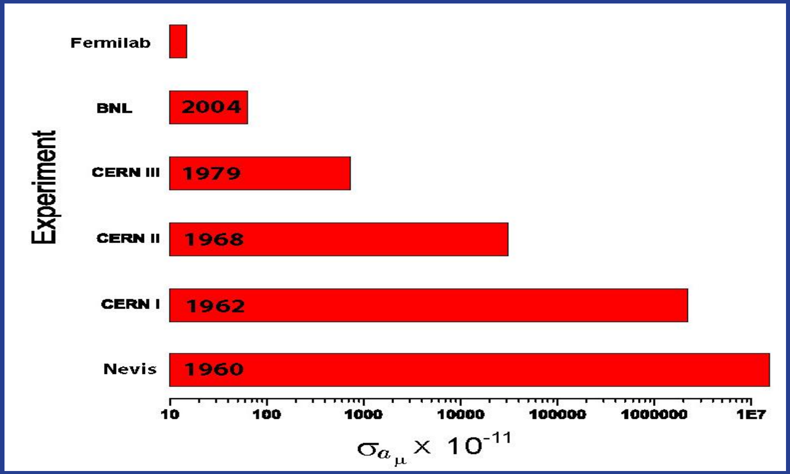
Loops

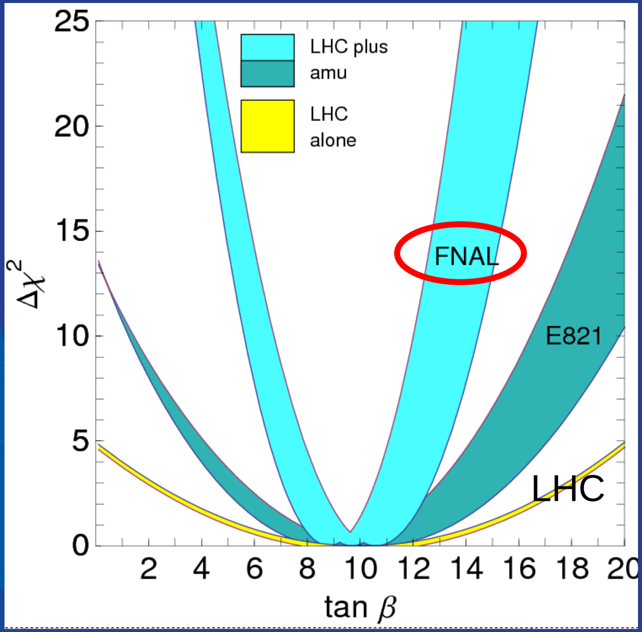
Contact Terms

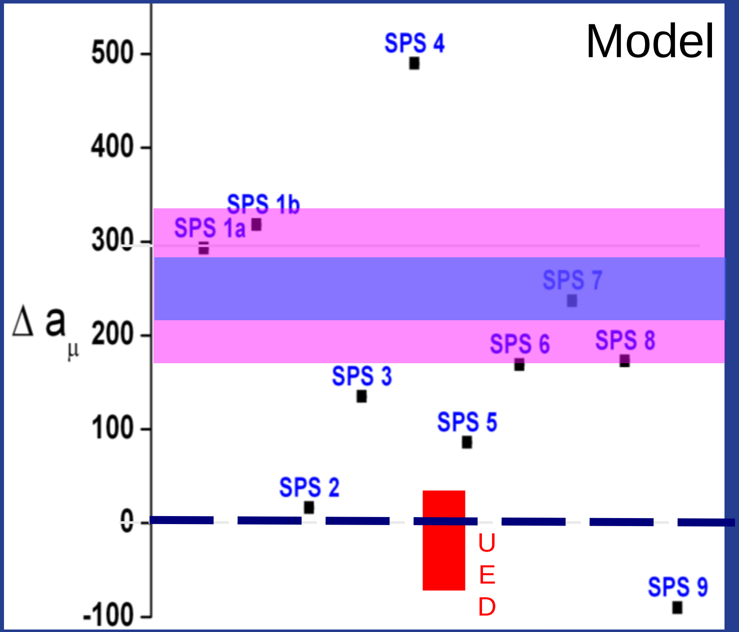


Target Mu2e sensitivity best in all scenarios

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







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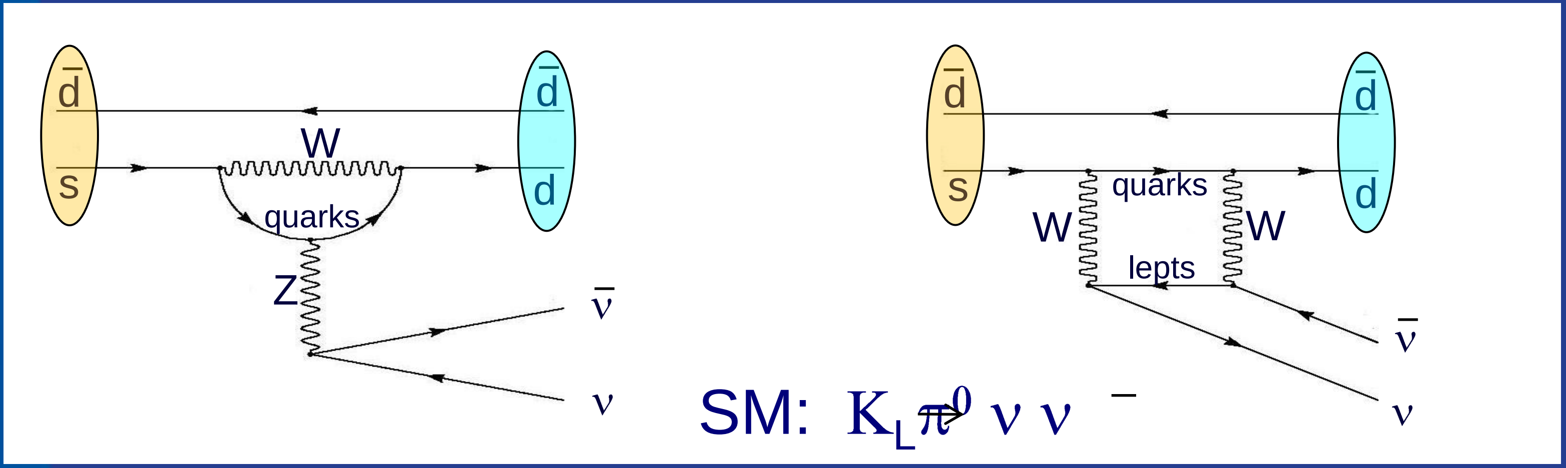
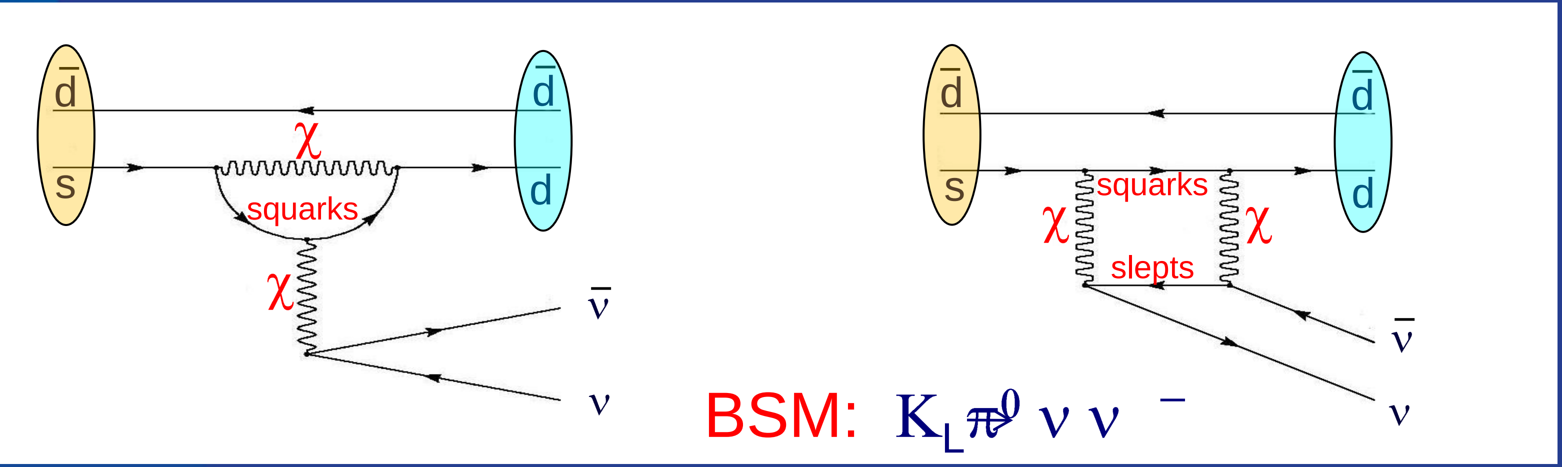
Large effects in kaon decay rates





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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; Neutron → Quark Chromo-EDM

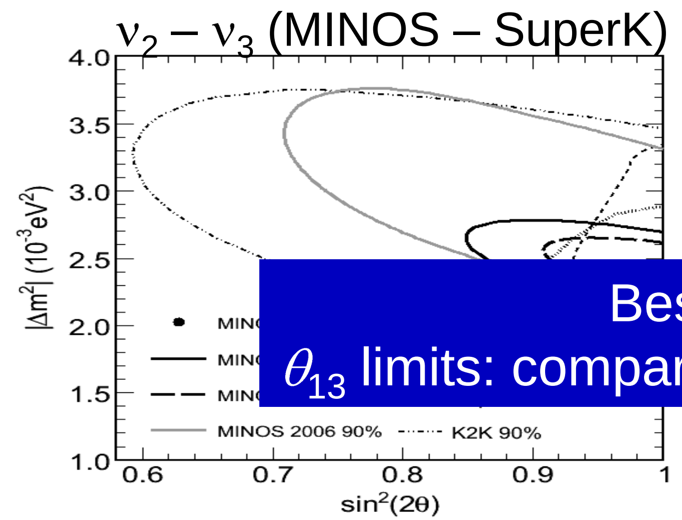
Diamagnetic Atoms (Hg, Xe, Ra, Rn) → Quark Chromo-EDM

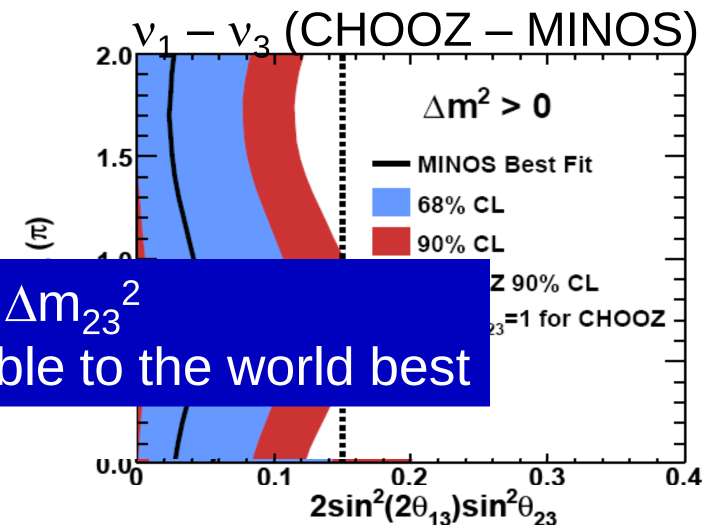
Paramagnetic Atoms (Tl, Fr)
Molecules (PbO) → Electron EDM

Quark EDM, Quark Chromo-EDM, Electron EDM → Physics beyond the Standard Model: SUSY, Strings …

Guy Savard, ANL

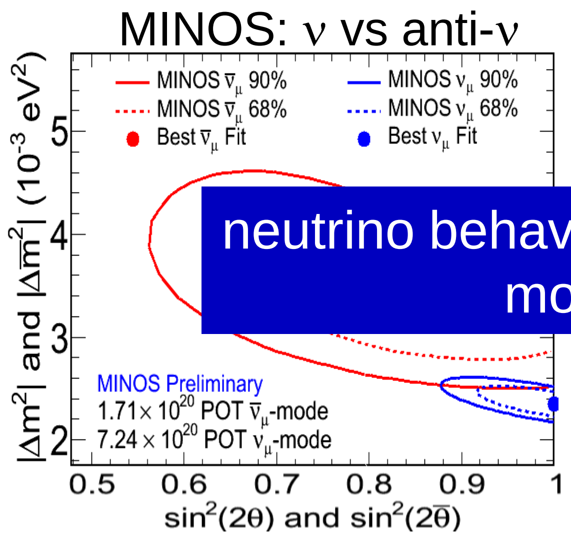
Intensity Frontier: Recent Results

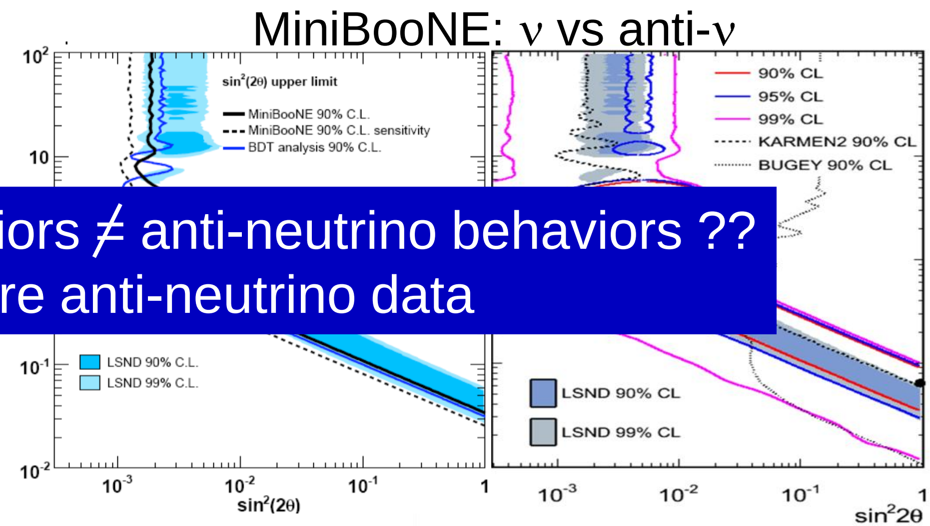




Best $\Delta m_{23}{}^2$

θ_{13} limits: comparable to the world best





neutrino behaviors ≠ anti-neutrino behaviors ??

more anti-neutrino data

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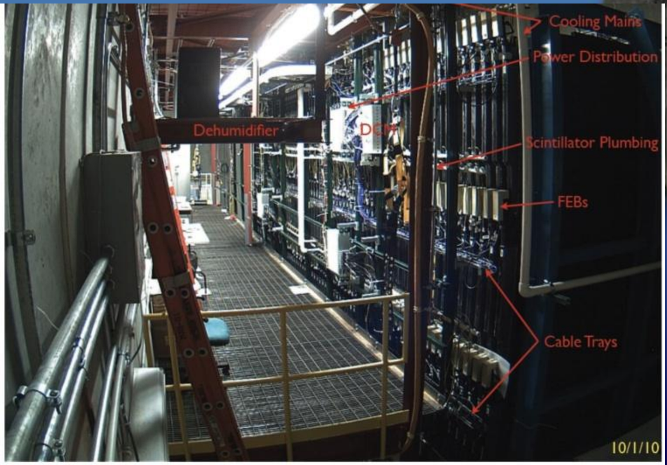
Intermediate Steps

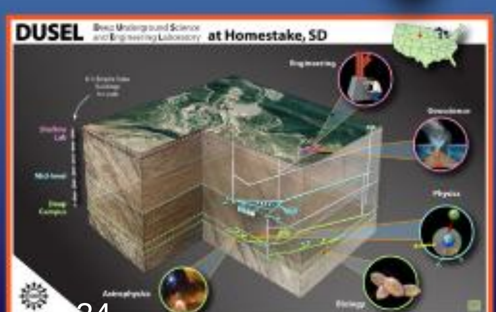
NOvA (off-axis)
MINERvA
SeaQuest
MicroBooNE (LAr TPC)



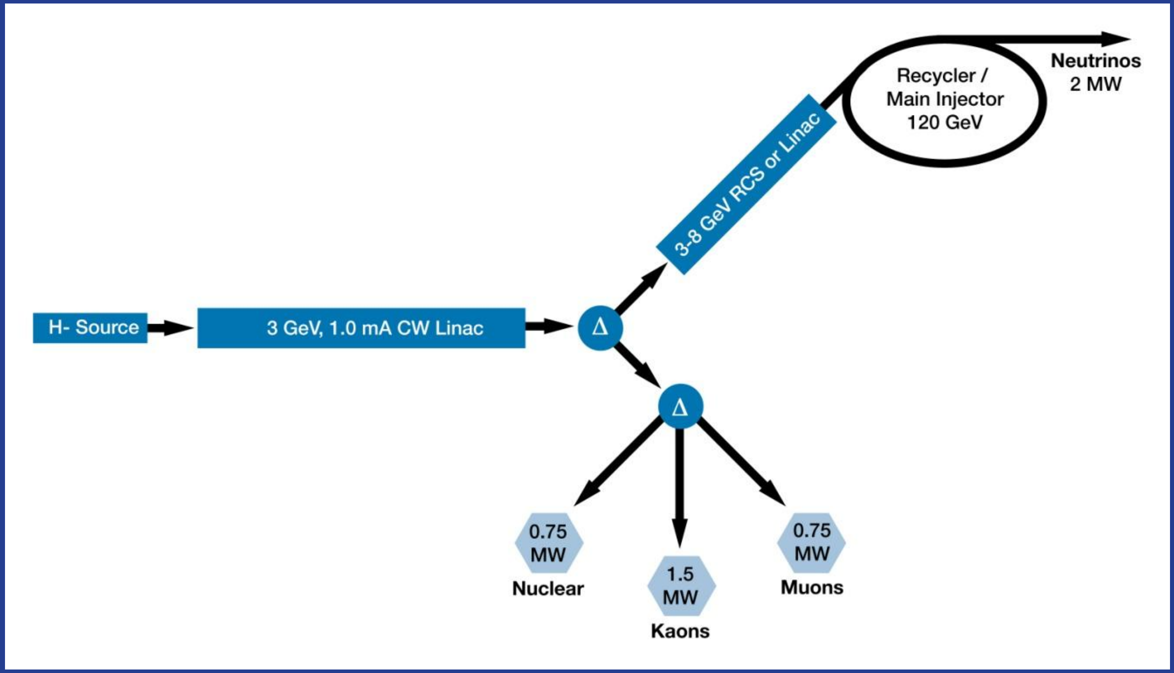
“Ultimate Goal”

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

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.**

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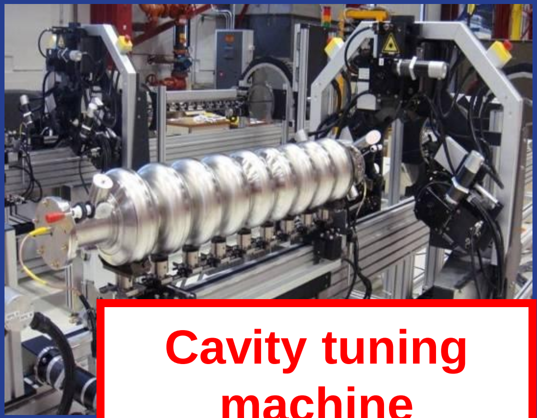
New FNAL SRF infrastructure

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

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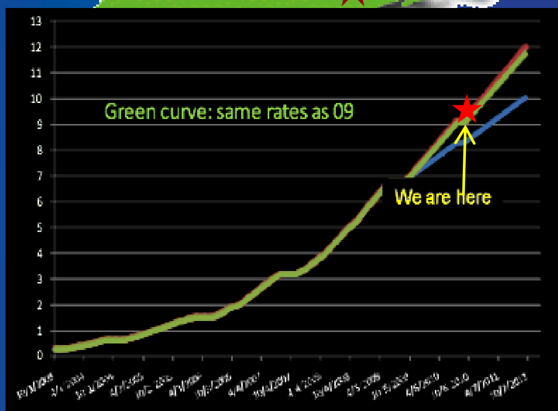
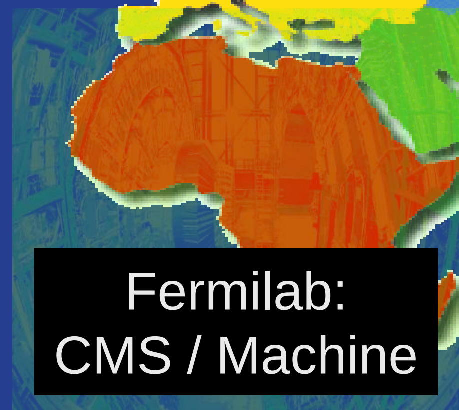




Tevatron

LHC

Lepton Collider
(ILC, CLIC, Muon Collider)

(energy decision)

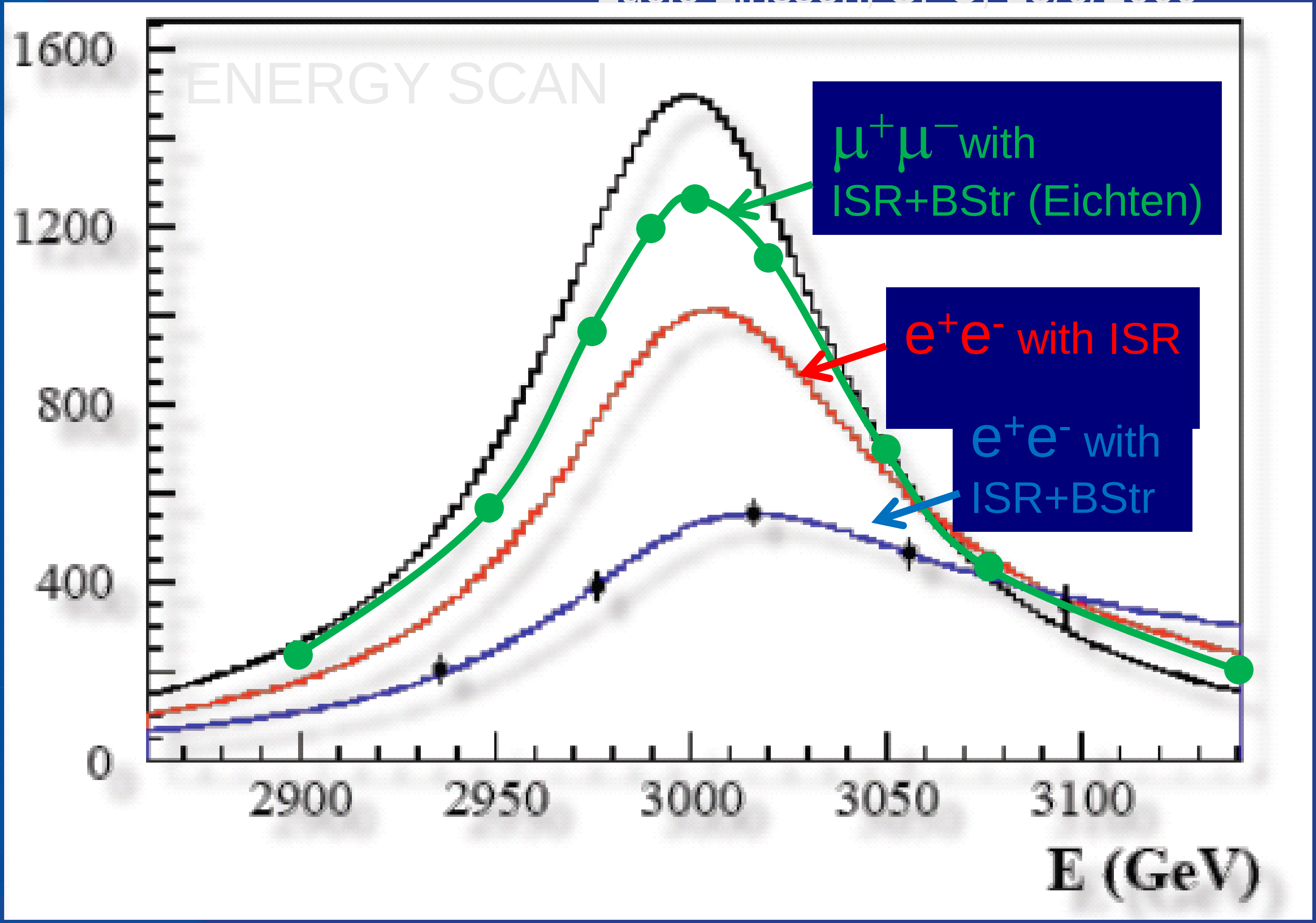
SCRF: ILC R&D, Muon Collider, Project X
High field magnets: LHC upgrades, Muon Collider

Muon Collider

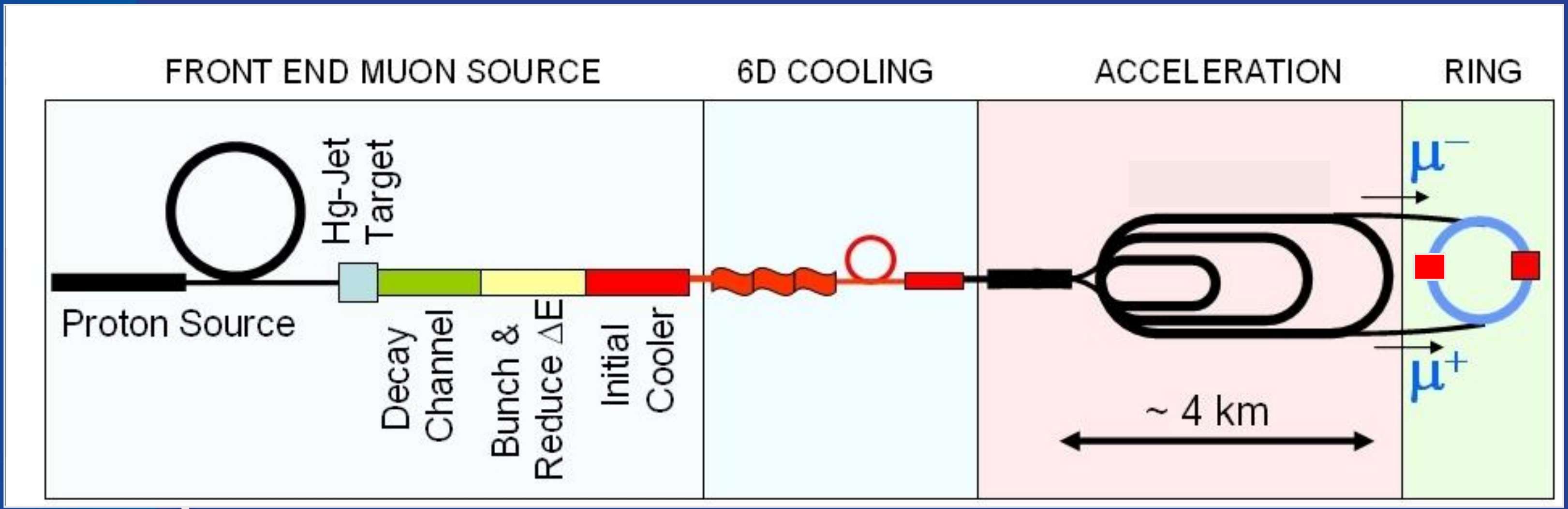
- Collider based on a secondary beam: we have experience basing colliders on antiprotons. For muons we must do it in 20 msec. The biggest advantages are: narrow energy spread (no beamstrahlung) and small physical footprint (no synchrotron radiation
- After a decade of steady progress on Muon Collider 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



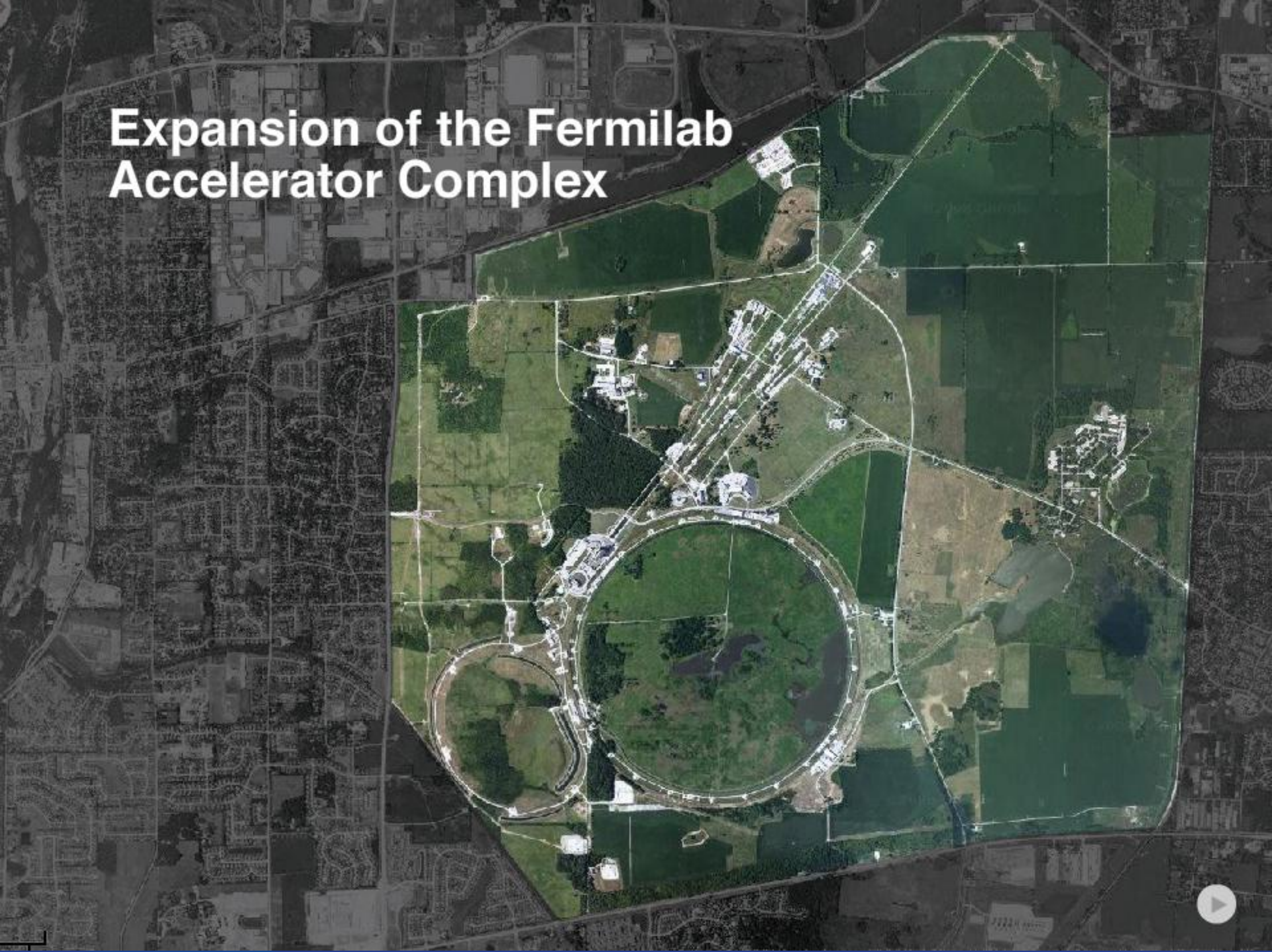
Proton source: Example: upgraded PROJECT X (4 MW, 2±1 ns long bunches)

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

$\varepsilon_{\perp N}$=6000 μm
$\varepsilon_{//N}$=25 mm

$\sqrt{s}$ = 3 TeV
Circumference = 4.5km
$\mathcal{L} = 3\times10^{34}\ cm^{-2}s^{-1}$
μ/bunch = 2×10^{12}
$\sigma(p)/p$ = 0.1%
$\varepsilon_{\perp N}$ = 25 μm, $\varepsilon_{//N}$=70 mm
β^* = 5mm
Rep Rate = 12Hz

Expansion of the Fermilab Accelerator Complex



Muon Collider

The first collider of this kind