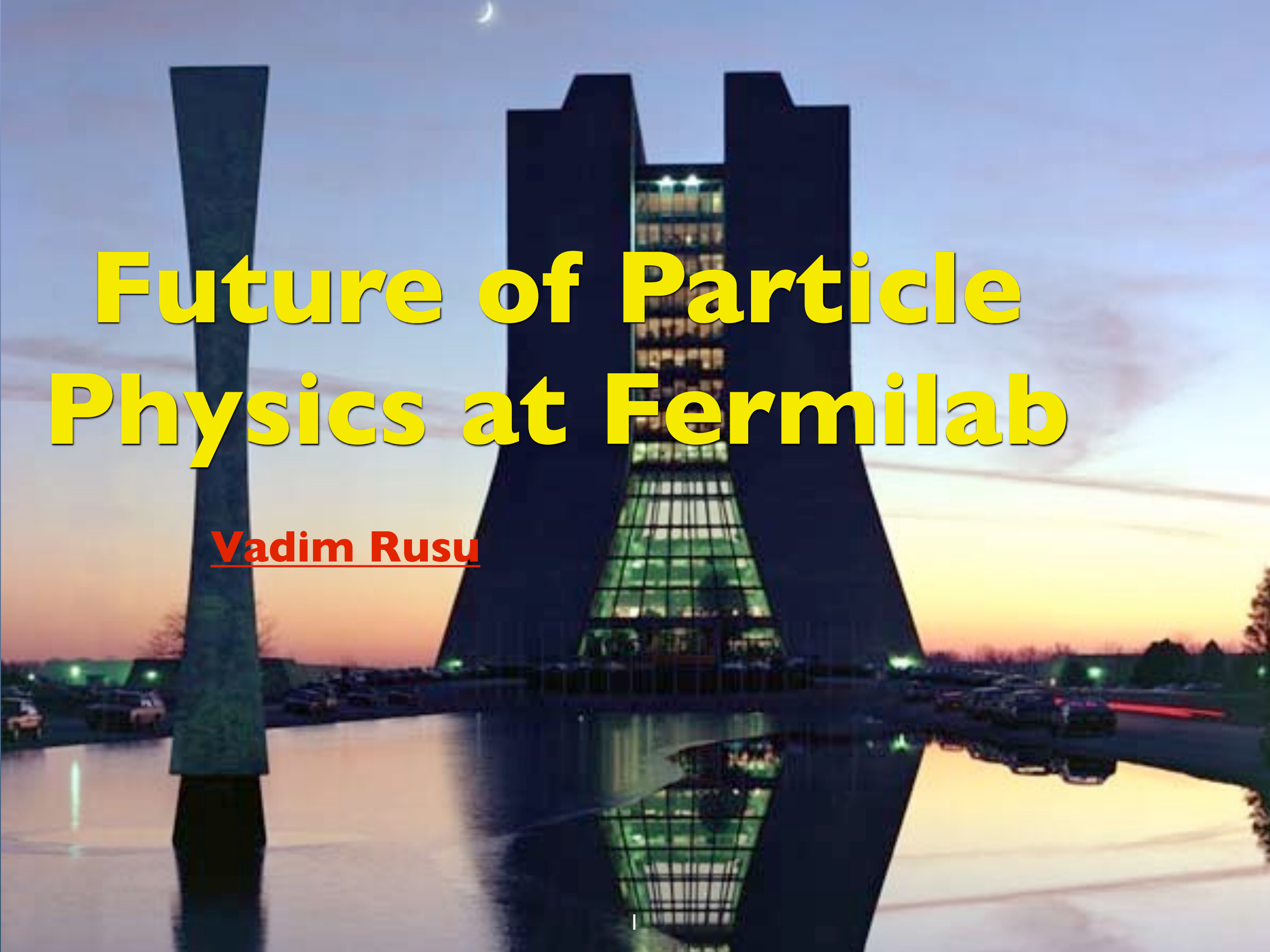
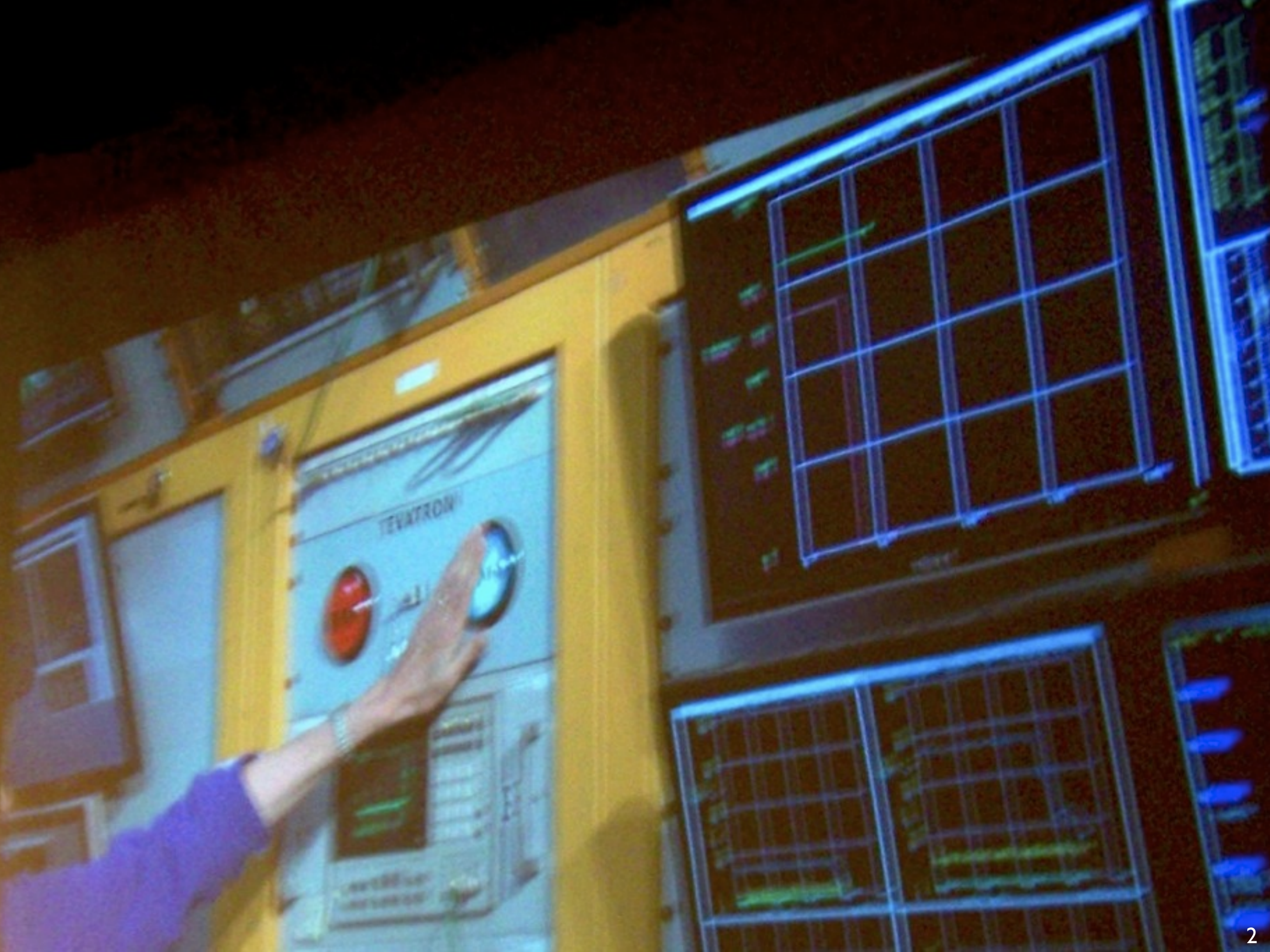


The background image shows the Fermilab Main Building at dusk. The building is a tall, dark structure with a central glass-enclosed section that is brightly lit from within, showing multiple floors. It is flanked by two large, dark, tapering pylons. The building is situated on a grassy area with a parking lot in the foreground. The sky is a mix of blue and orange, indicating sunset or sunrise. A small crescent moon is visible in the upper left part of the sky. The entire scene is reflected in a body of water in the foreground.

Future of Particle Physics at Fermilab

Vadim Rusu





CORRIERE DELLA SERA

Fisica: chiude negli Usa il Tevatron

30 Settembre 2011 14:16 | [SCIENZE E TECNOLOGIE](#) |

Tevatron
than 25 years

News | Sport | Weather | Travel
ENVIRONMENT
shuts after more

The Washington Post

NATIONAL

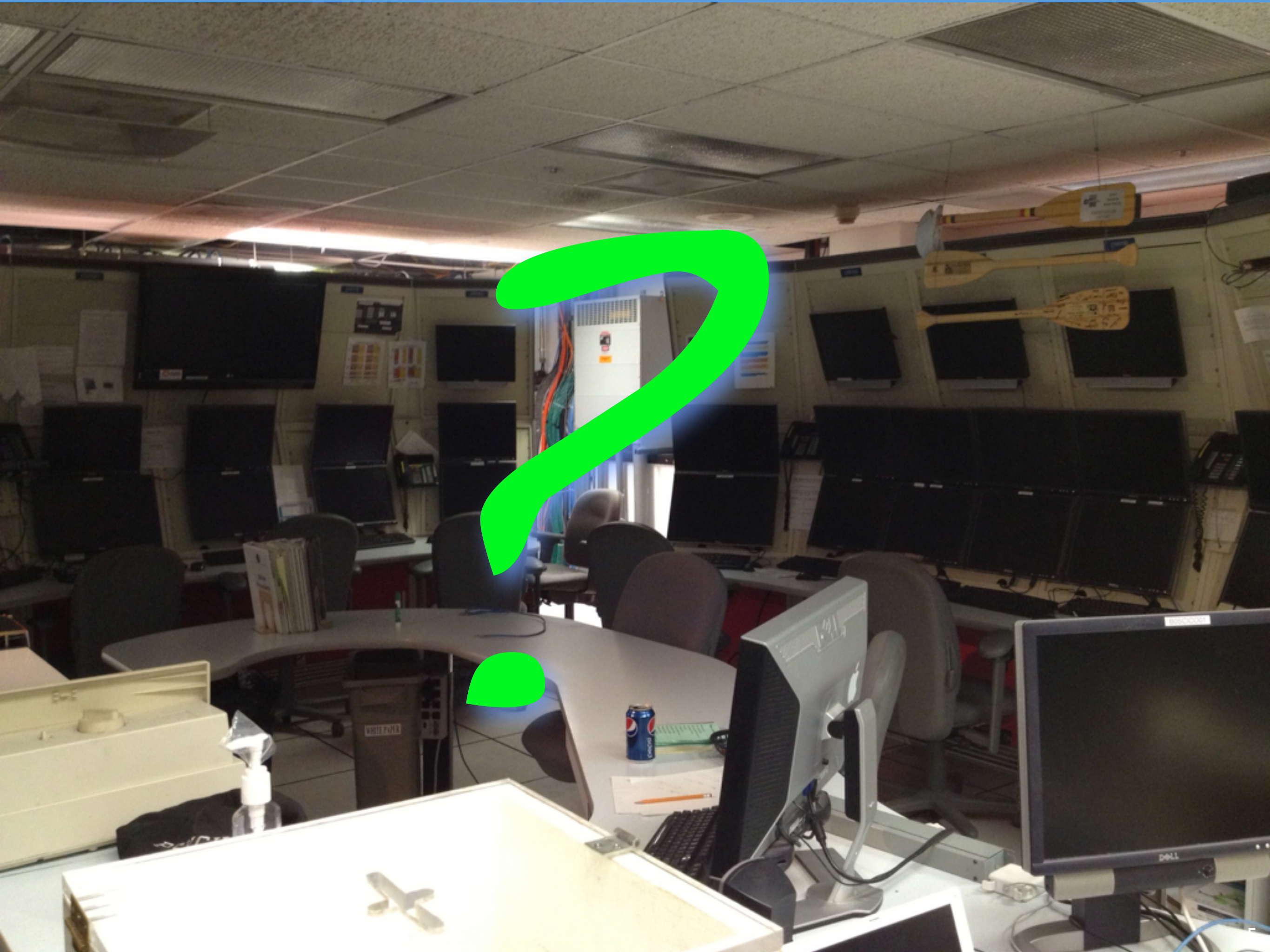
Tevatron atom smasher's close ends era of big science

nature

International weekly journal of science

Fermilab faces life after the Tevatron





Particle Physics 21'st Century

1. Multiple generations

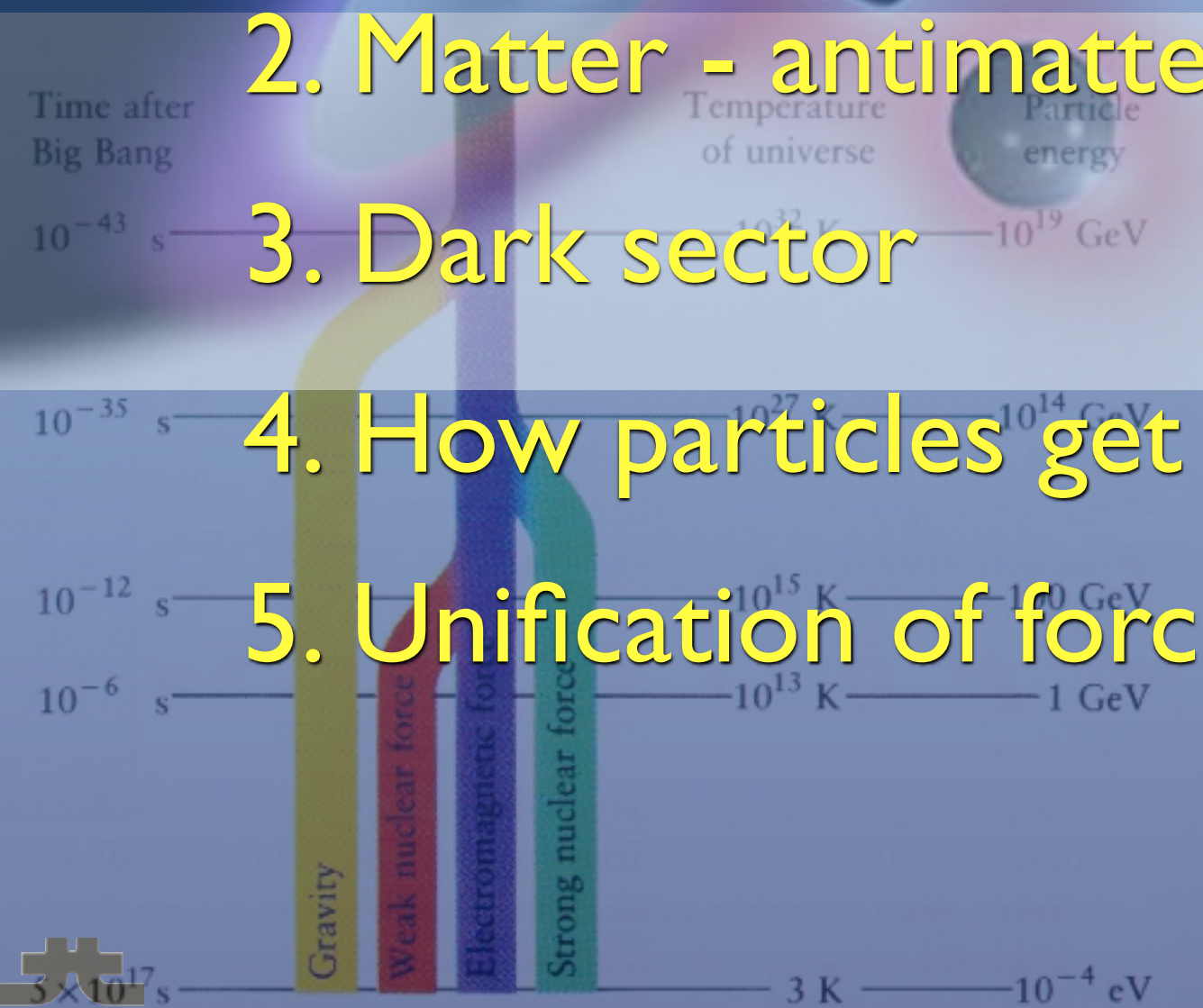
2. Matter - antimatter

3. Dark sector

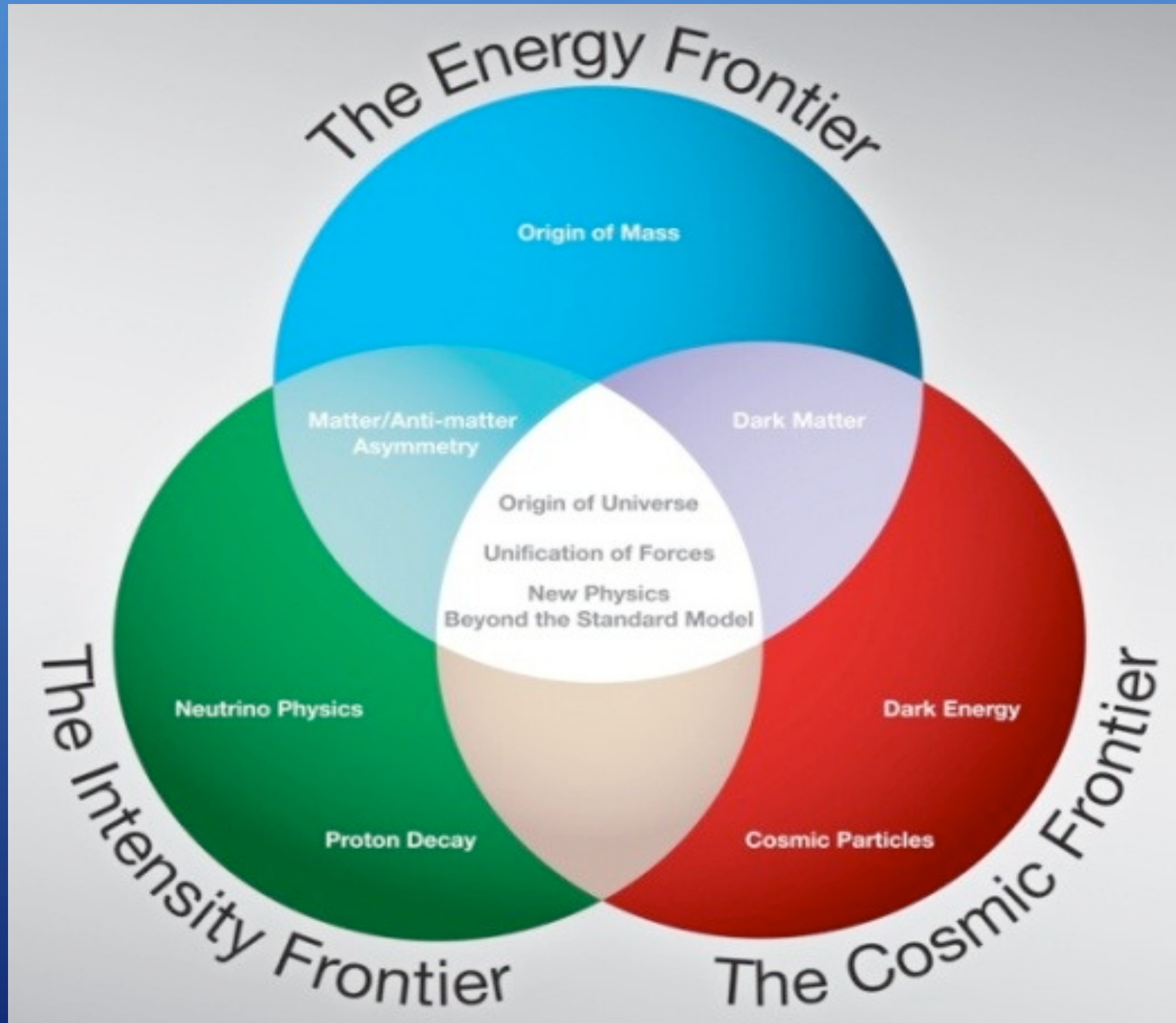
4. How particles get mass

5. Unification of forces

Experimentalist's
ranking



The three frontiers



Energy Frontier



Tevatron



LHC

??Future Collider??

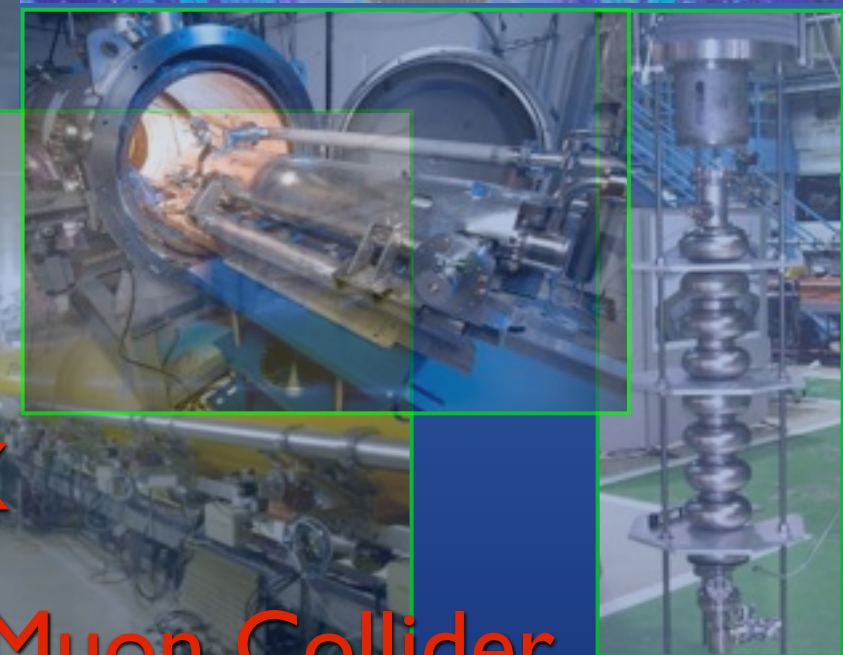
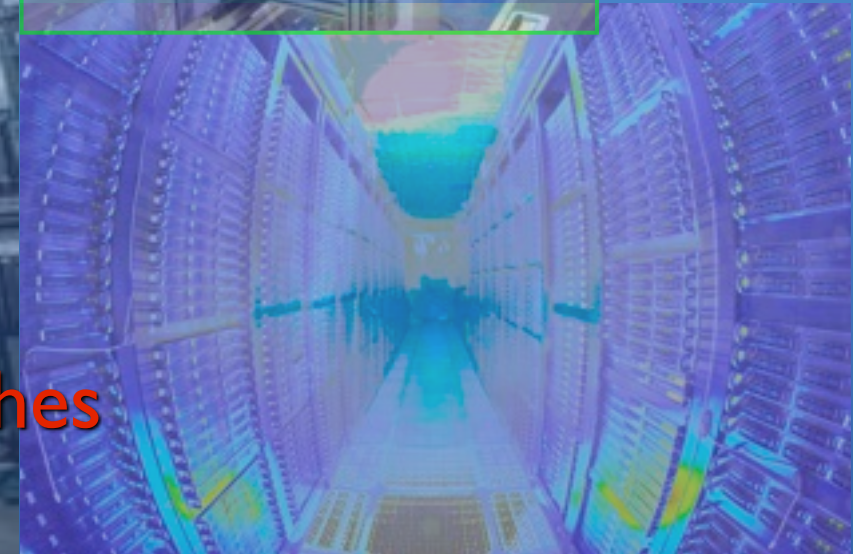
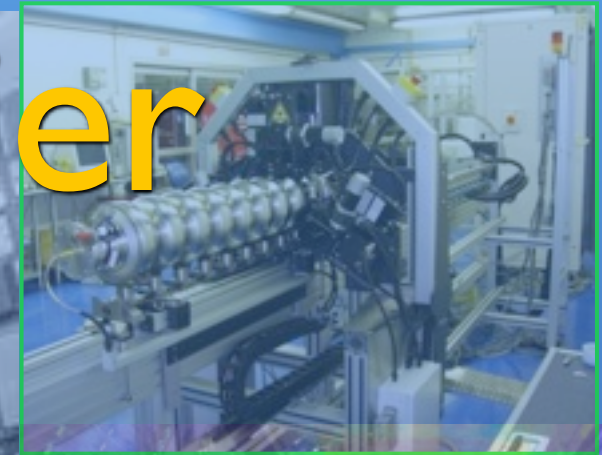


Energy Frontier

- Tevatron: 10fb^{-1} data to analyze
 - ⇒ W mass, QCD, top cross section, searches
- LHC

- ⇒ Detector Upgrades
- ⇒ Analysis

- SCRF: ILC, Muon Collider, Project X
- High field magnets: LHC Upgrades, Muon Collider



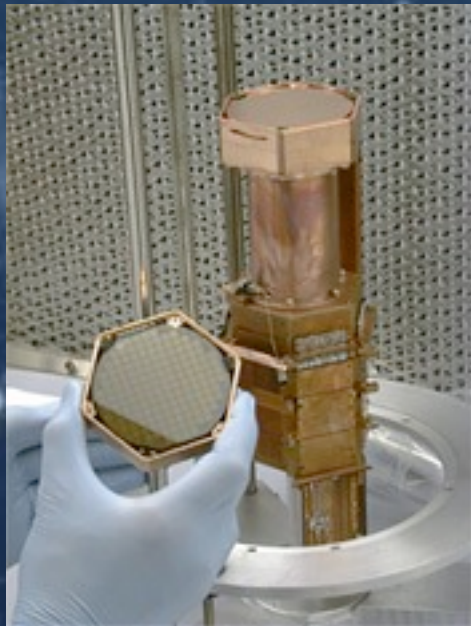
Cosmic Frontier

- Dark Matter
- Dark Energy
- UHE Cosmic rays
- Other initiatives
 - ➡ Axion searches
 - ➡ Holographic noise
 - ➡ CMB polarization



Searching for DM

CDMS



COUPP



DAMIC

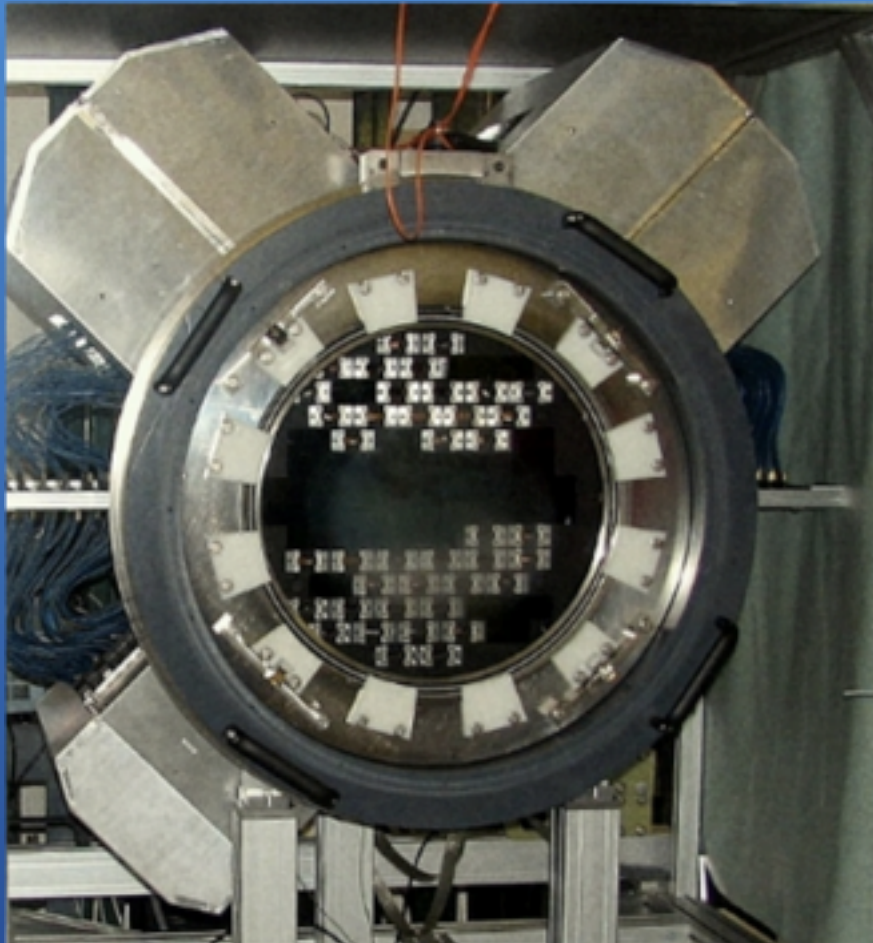


Darkside

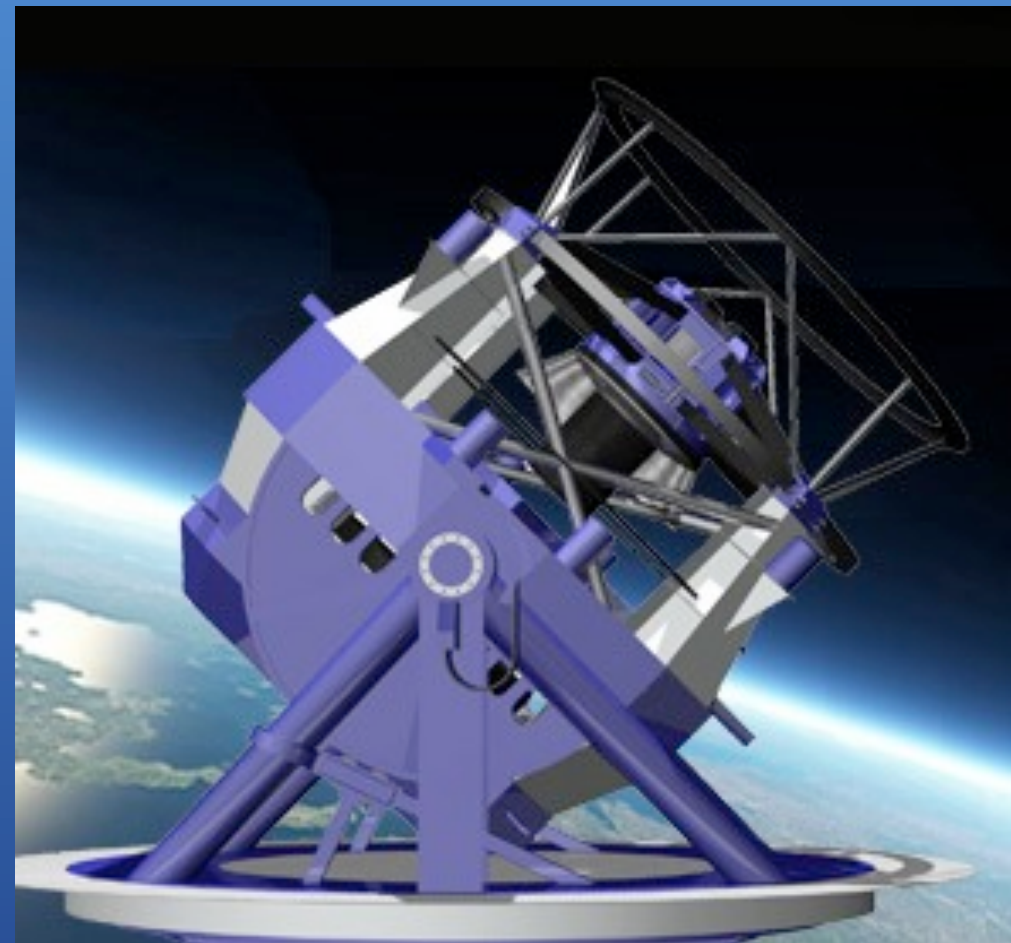


Searching for DE

DES



LSST



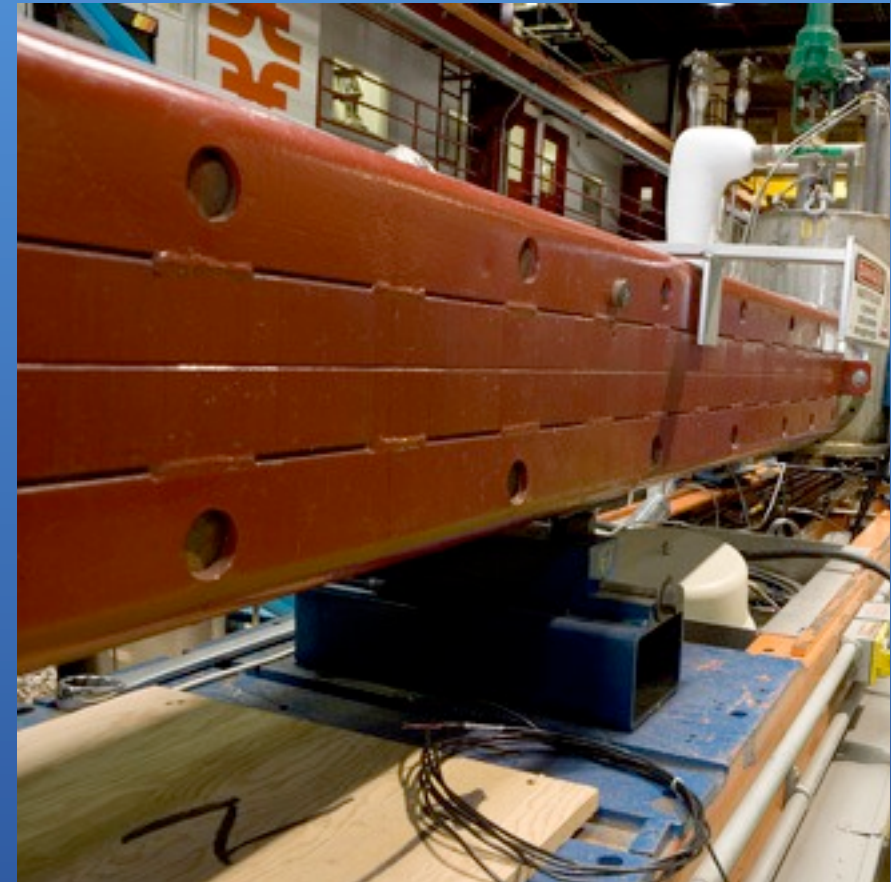
- Type Ia supernovae
- BAO
- Galaxy Cluster Count
- Weak Gravitational Lensing
- Wide sky surveys



Others



QUIET



GAMMEV



HOLOMETER



Timeline

Now

2013

2016

2019

2022



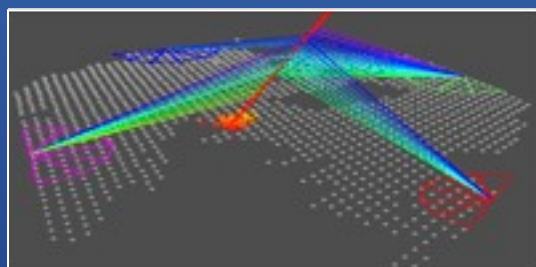
DM: $\sim 10\text{kg}$
DE: SDSS
Auger

DM: $\sim 100\text{kg}$
DE: DES
Auger

DM: 1 ton
DE: LSST

DE: LSST

holometer

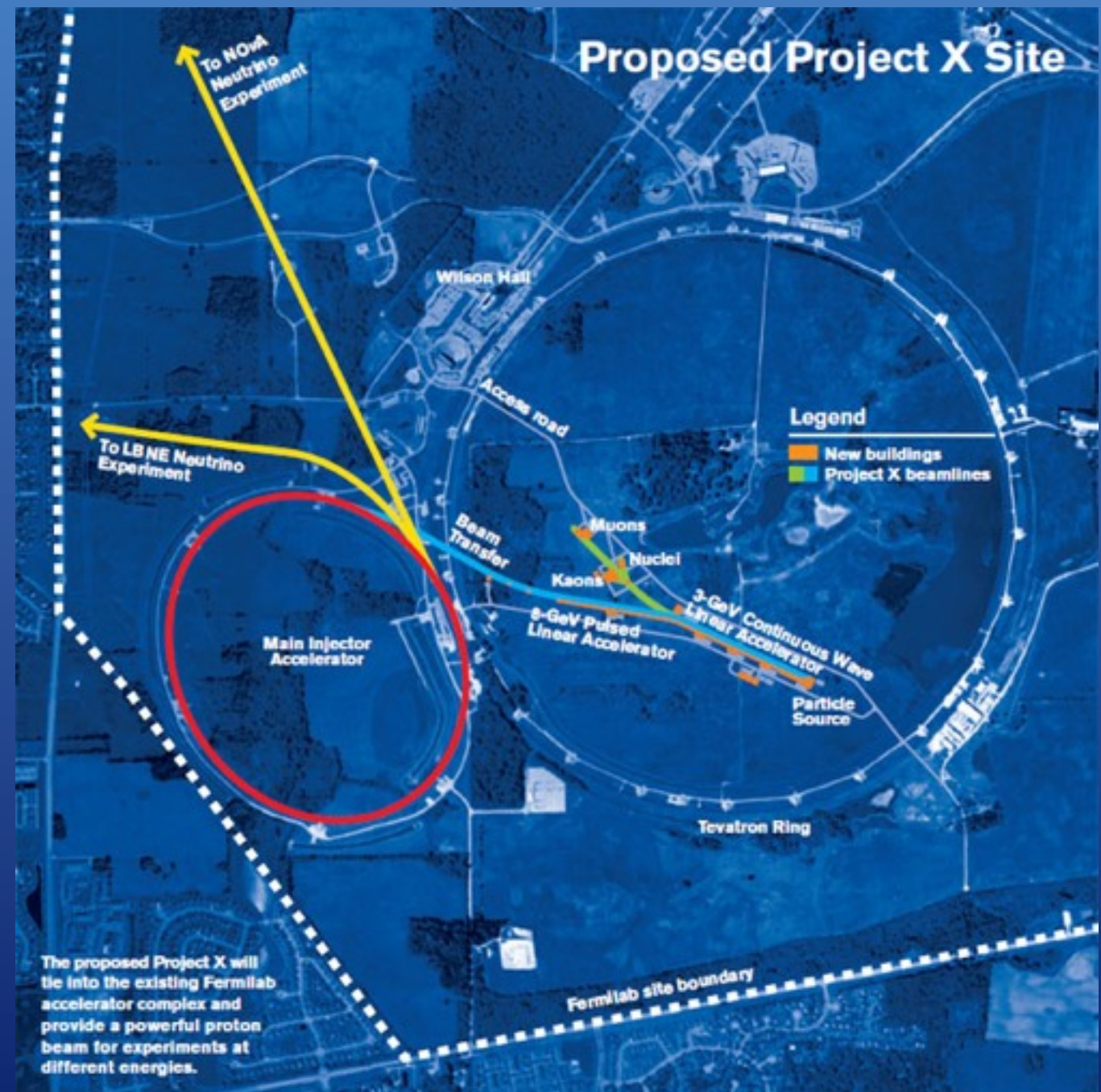


Intensity Frontier

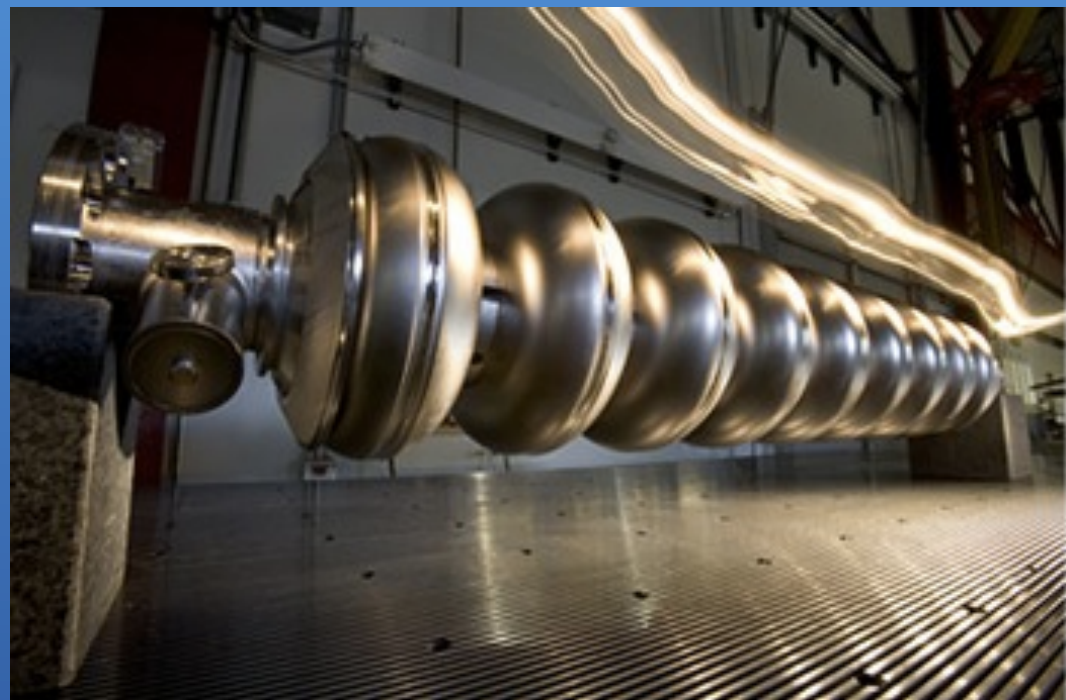
Booster “Era”

PX

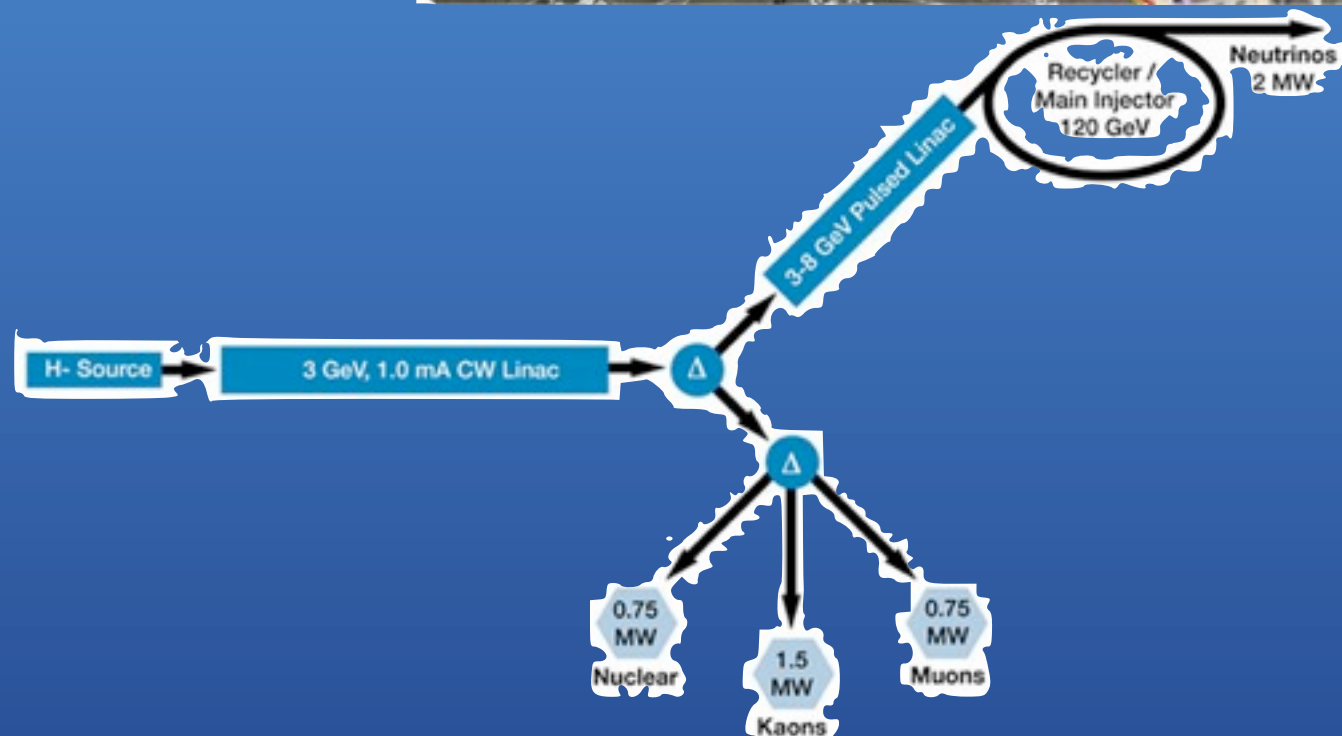
- Neutrinos
- Muons
- Kaons
- Nuclear physics
- Energy applications



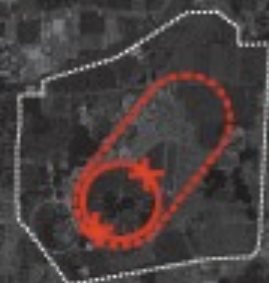
Project X



- 3GeV CW Linac (3MW)
 - ➡ muon, kaon, nuclear, energy
- 8GeV bridge to MI/R (2MW)
 - ➡ neutrinos
- SCRF technology
- Front end for future muon collider
 - ➡ back to energy frontier



Muon Collider



Muon Collider
d=2km

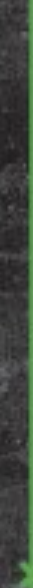
- Few TeV lepton collider
 - ➔ clean calculations
- Electrons brem
 - ➔ hence only linear feasible
 - ➔ too long
- Higgs factory
- Neutrino factory
- Requires a high power multiGeV proton source (PX)



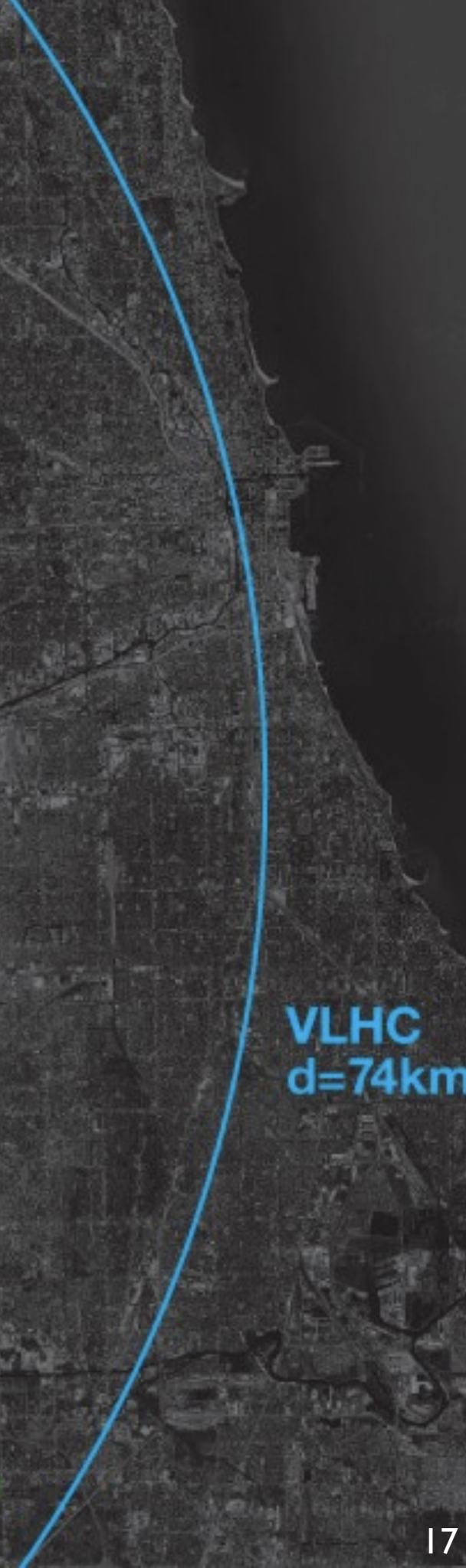
LHC
d=8.4km



ILC
l=30km



CLIC
l=50km



VLHC
d=74km

Muon Collider Conceptual Design

- **Project X**

- ➔ Accelerate H ions to 8GeV using SRF technology

- **Compressor ring**

- ➔ reduce size of beam

- **Target**

- ➔ Collisions lead to muons of ~200MeV

- **Muon capture and cooling**

- ➔ Capture, bunch and cool muons to create a tight beam

- **Initial acceleration**

- ➔ In a dozen turns, accelerate muons to 20GeV

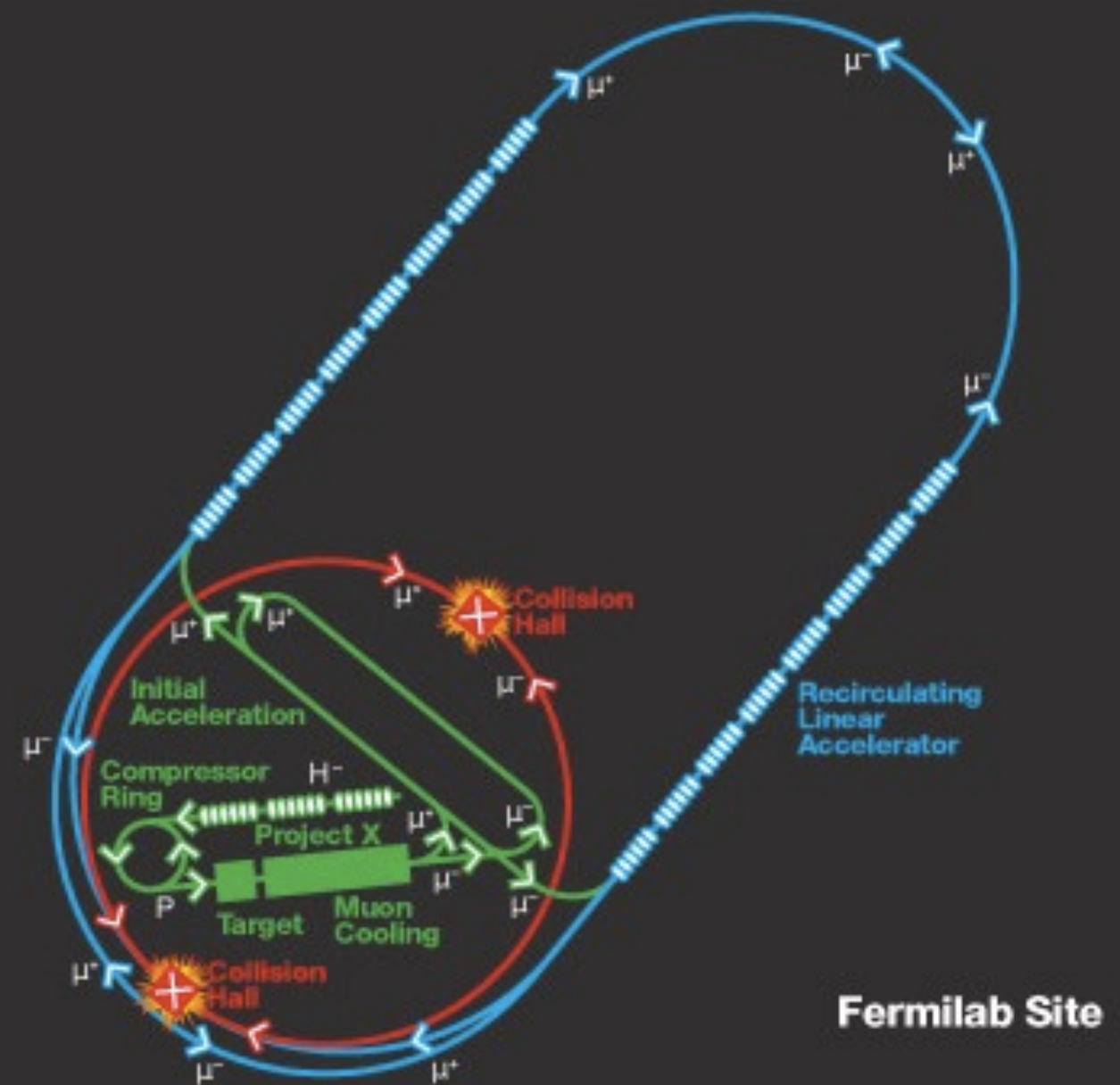
- **Recirculating linear accelerator**

- ➔ In a number of turns accelerate muons to 2TeV using SRF technology

- **Collider ring**

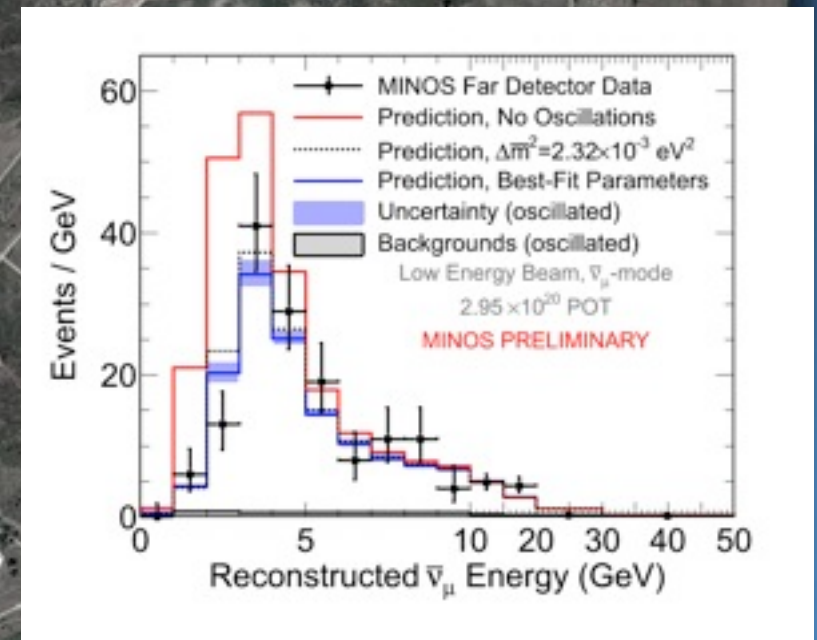
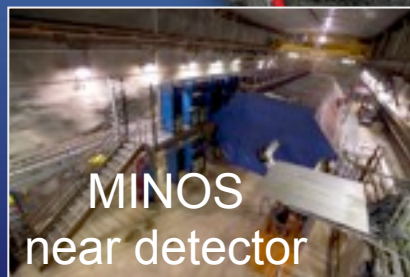
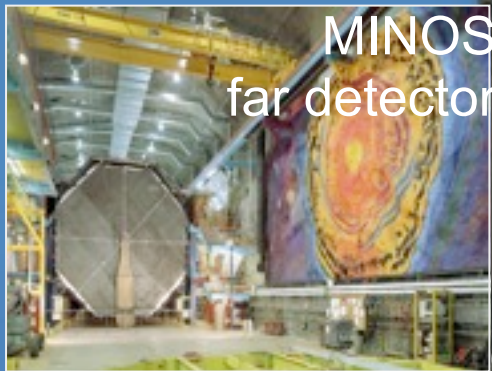
- ➔ Bring positive and negative muons into collisions at two locations 100m underground

North



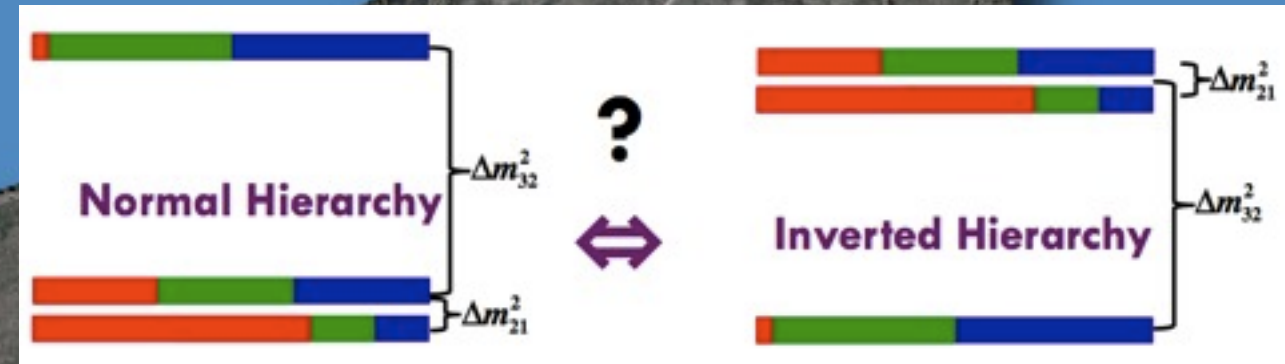
Long baseline neutrinos

Minos on axis 735km
(2006-present)



Long baseline neutrinos

NOvA: off-axis (2013 –) – 810 km
 MINOS: on-axis (2006 – 2014?) – 735 km

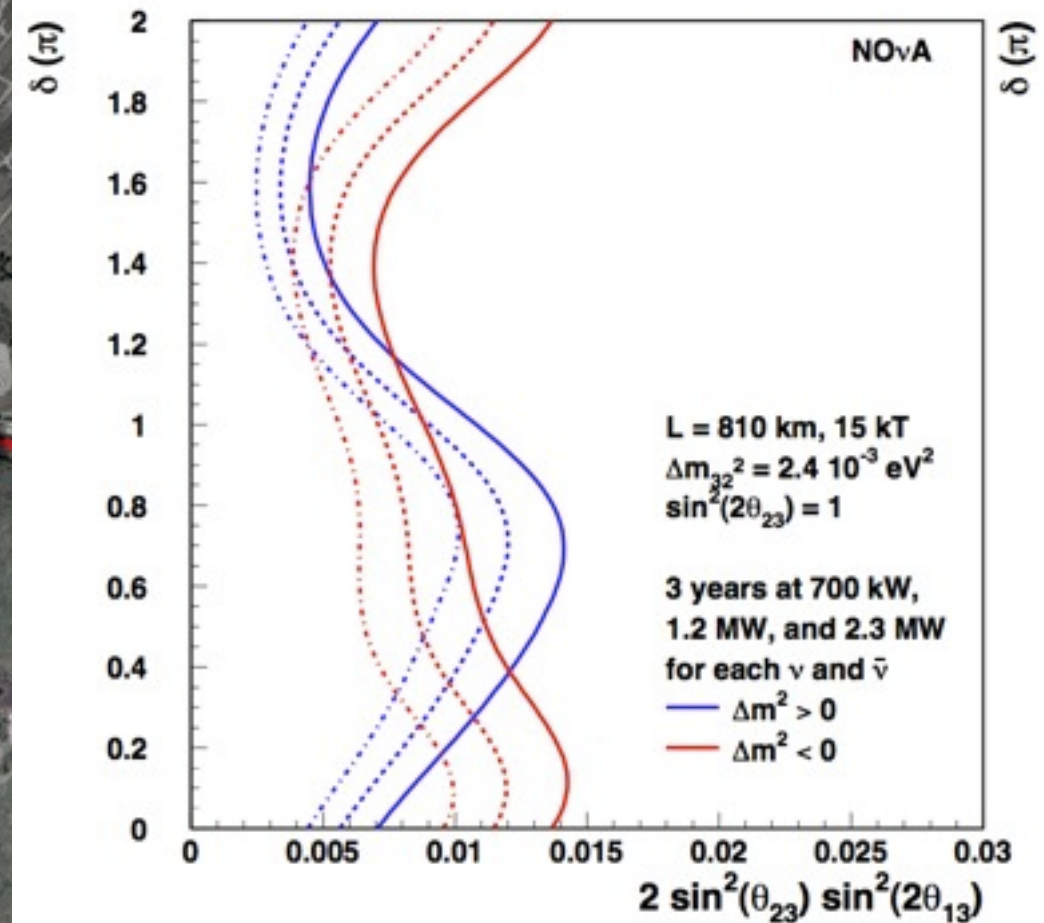


far detector under const.



near det. on surface
 (taking data)

90% CL Sensitivity to $\sin^2(2\theta_{13}) \neq 0$

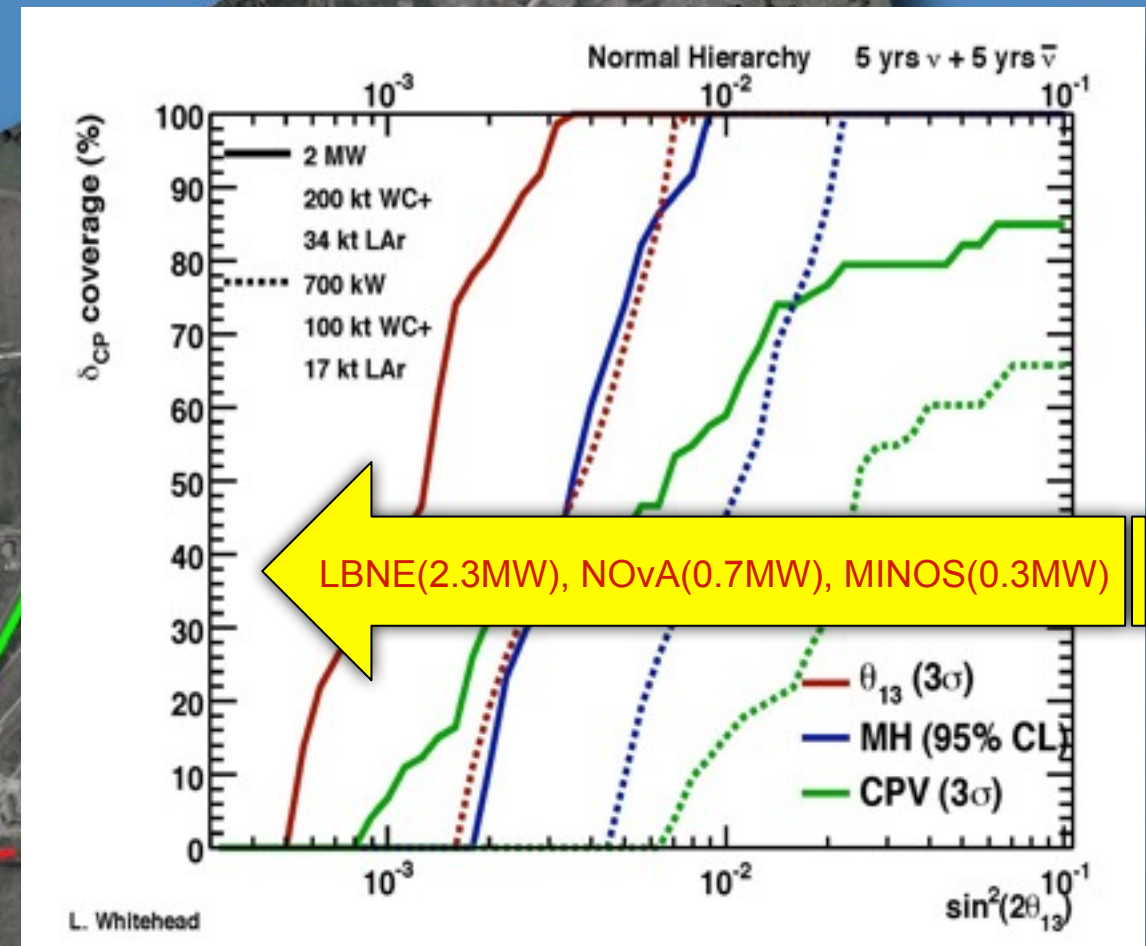
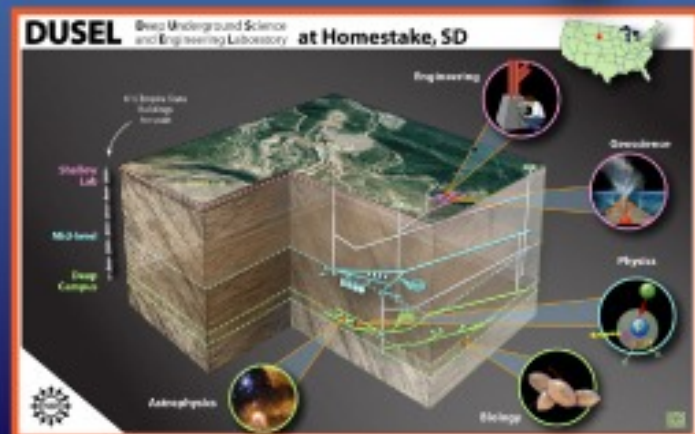


Long baseline neutrinos

Long Baseline Neutrinos (beyond NOvA)

LBNE (DOE Stage 1 Approval, Jan. 2010):
Neutrinos, Proton decay, Supernova, ...

296 members, 58 institutions,
5 countries (India, Italy, Japan, UK, US)
Continue to grow!



Short baseline neutrinos

Short Baseline Neutrinos (Now)

MiniBooNE (2002 – present)

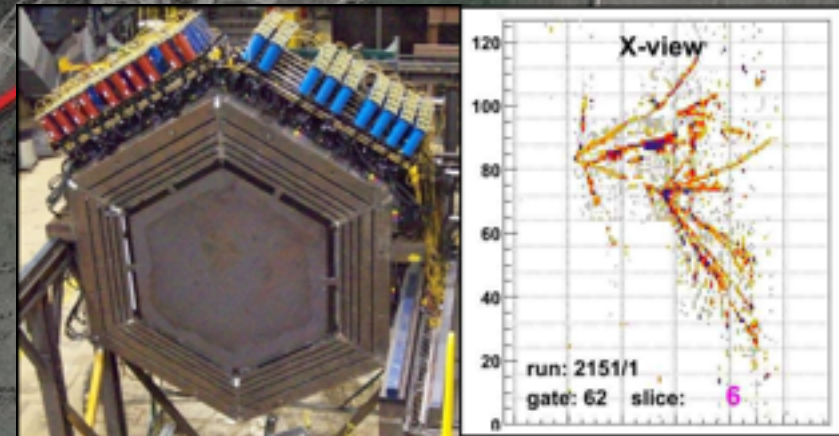
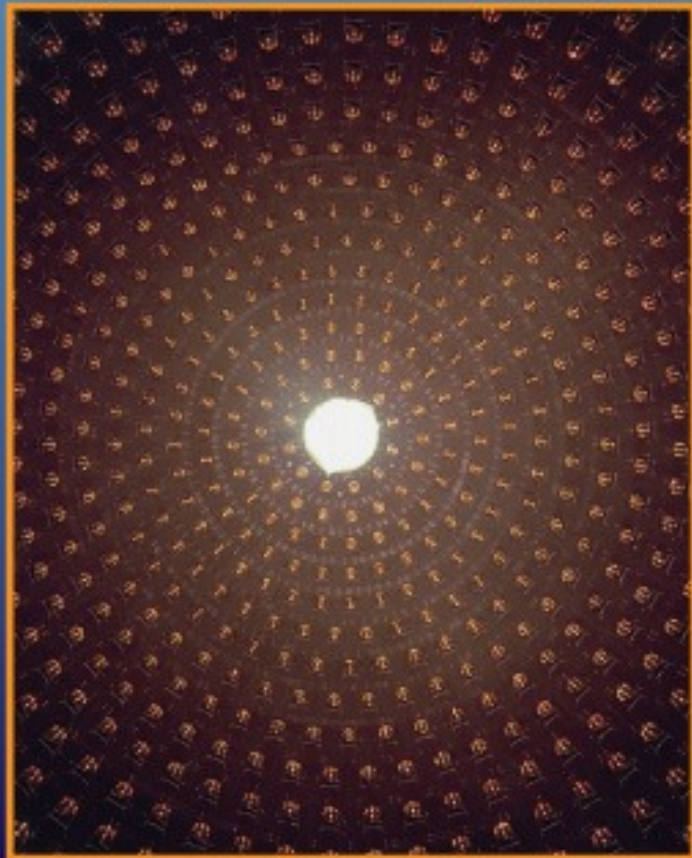
SciBooNE (2007 – 2008)

MINERvA (2010 – present)

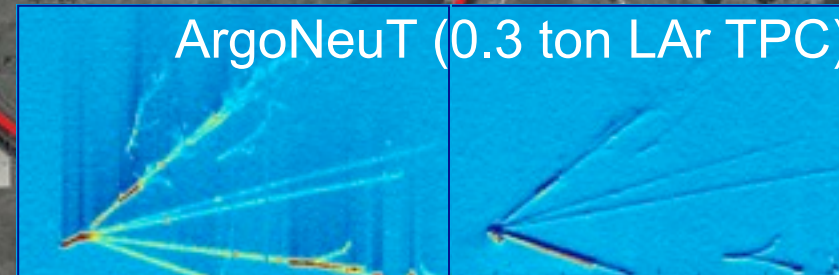
ArgoNeuT (2009 – 2010)

8 GeV protons

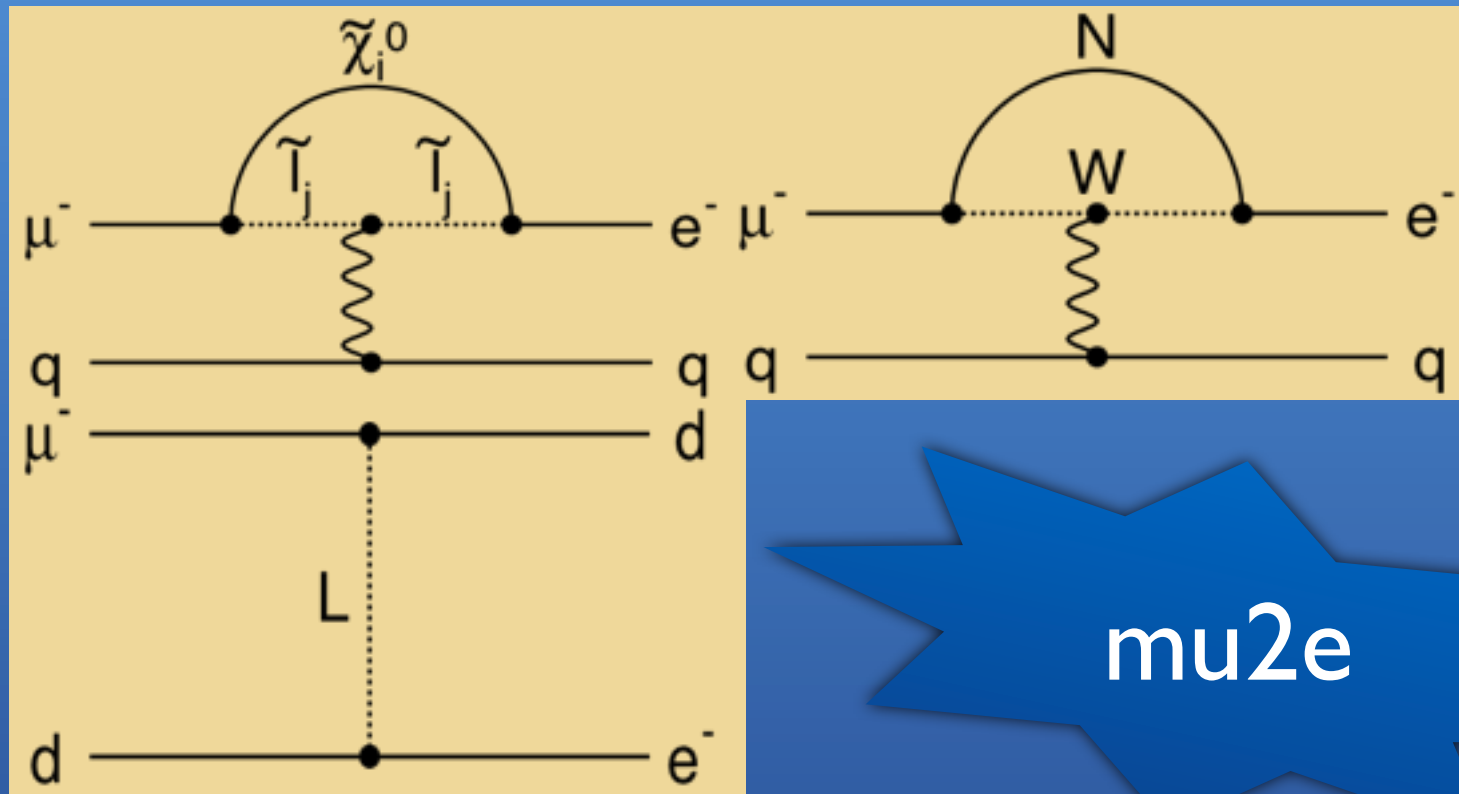
120 GeV protons (MINOS near det hall)



ArgoNeuT (0.3 ton LAr TPC)

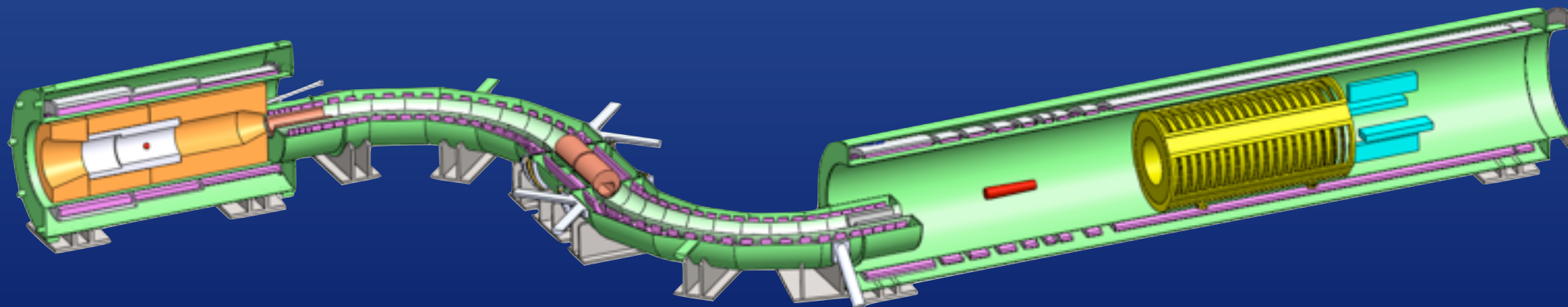
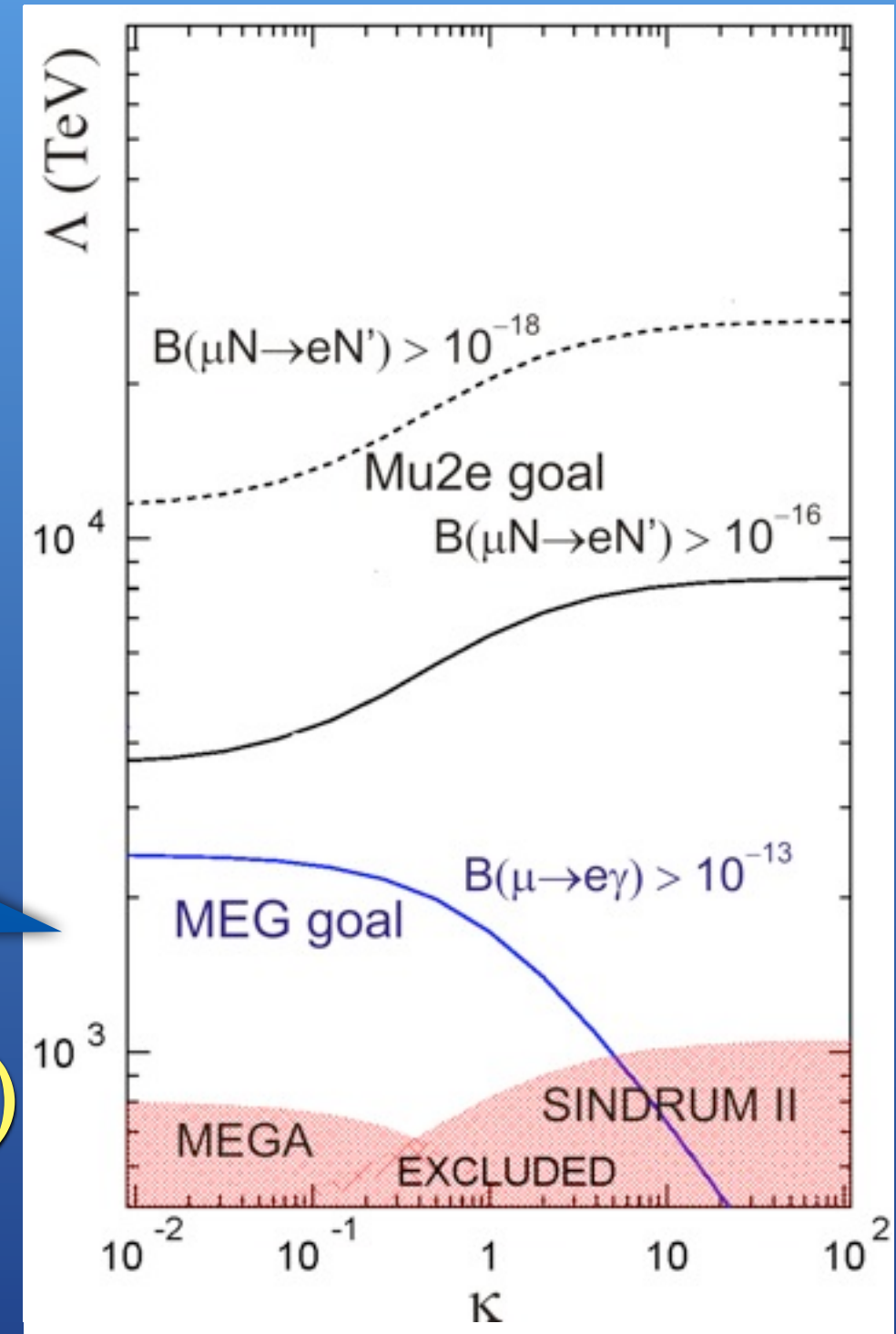


Muon program

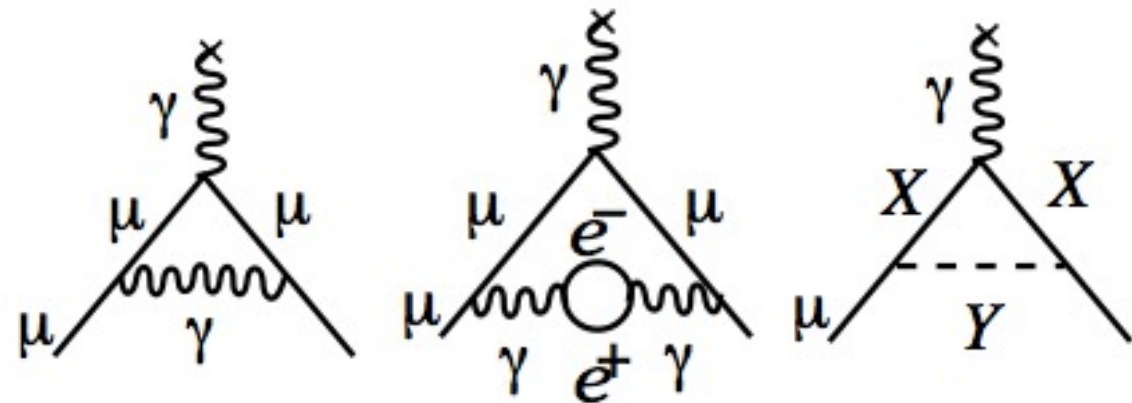


mu2e

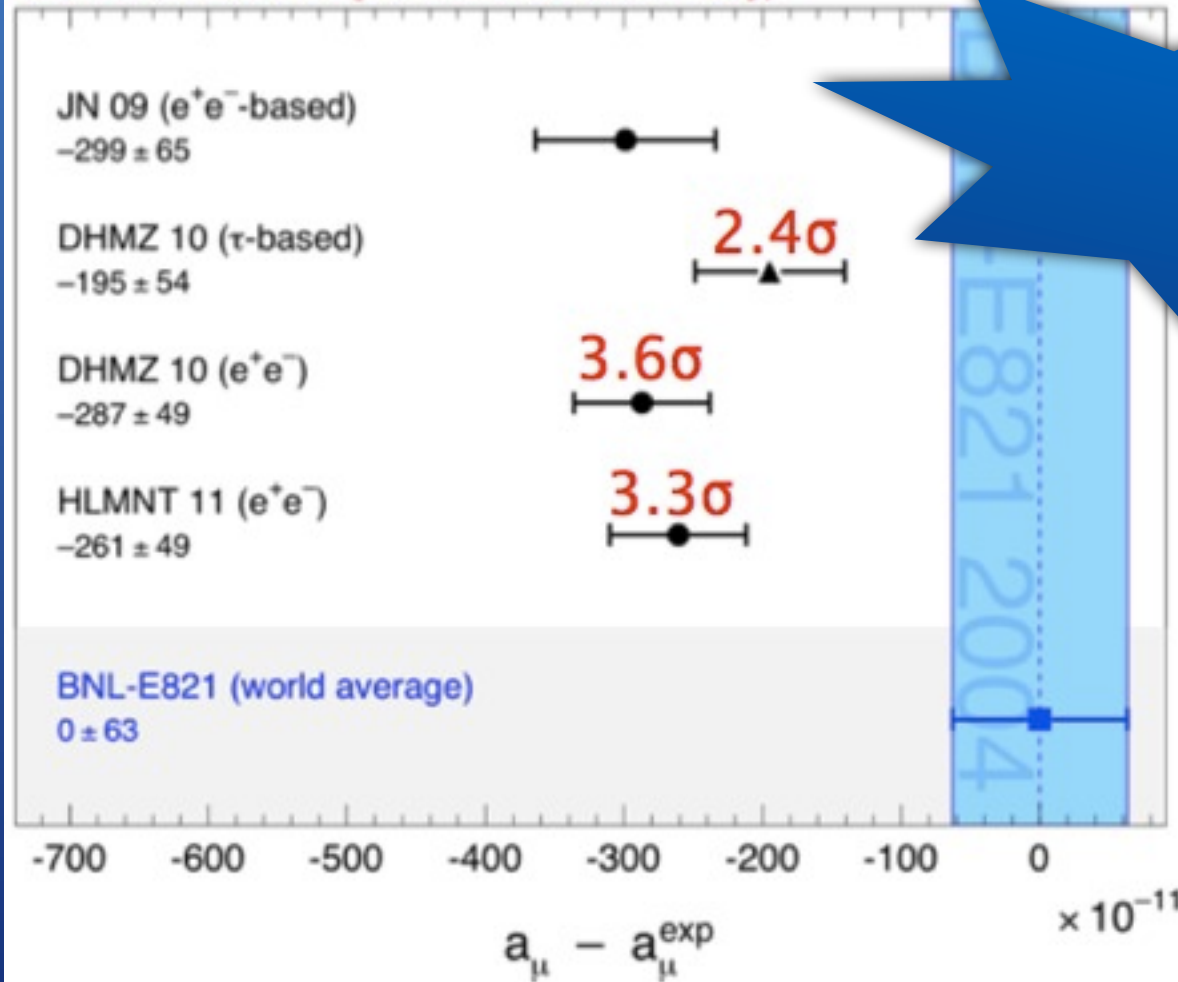
- pulsed beam (low backgrounds)
- high intensity (high stats)



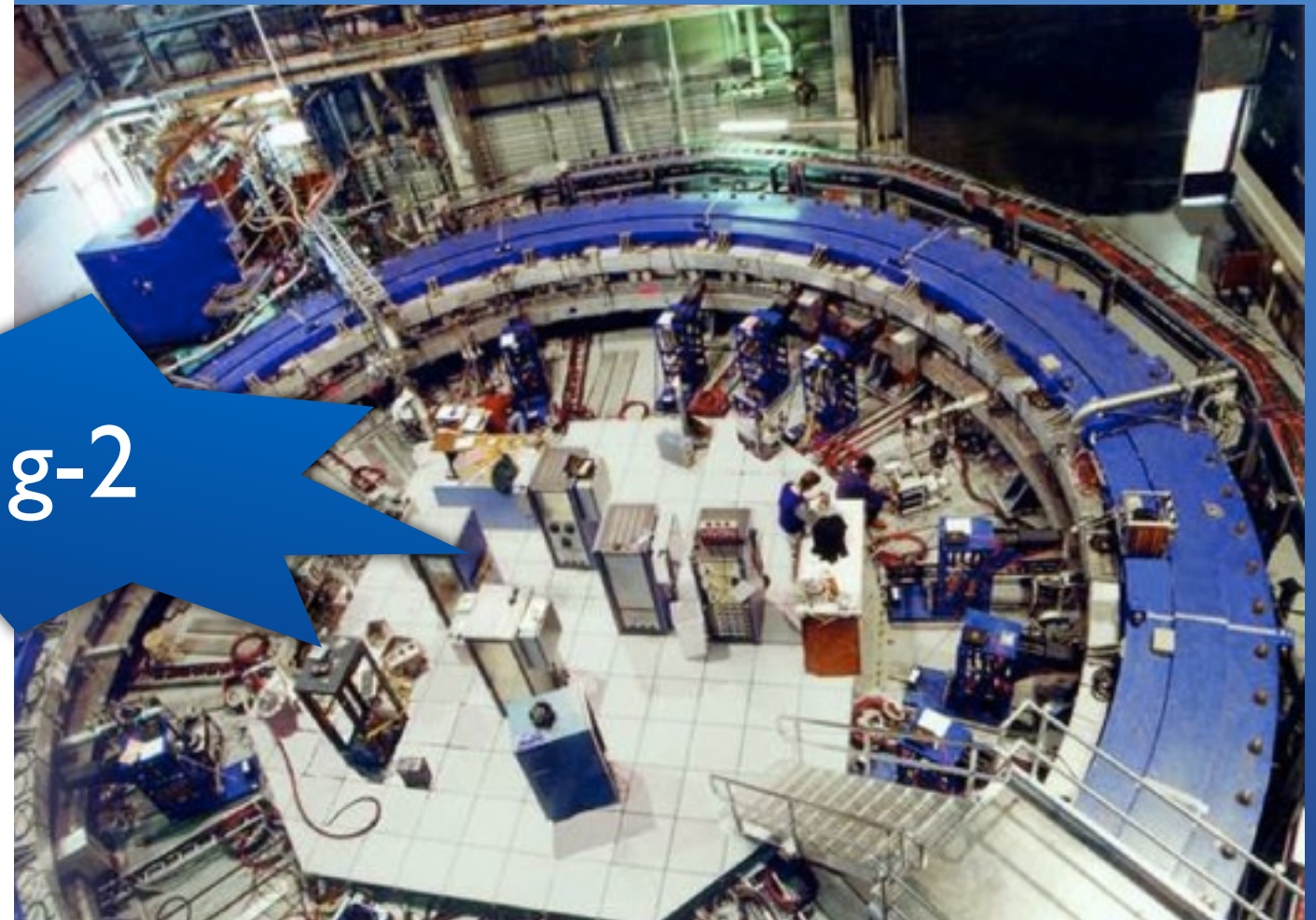
Muon program



Status: summer 2011 (published results shown only)



$g-2$



- BNL experiment ended stats limited
- More flux $\rightarrow 5\sigma$



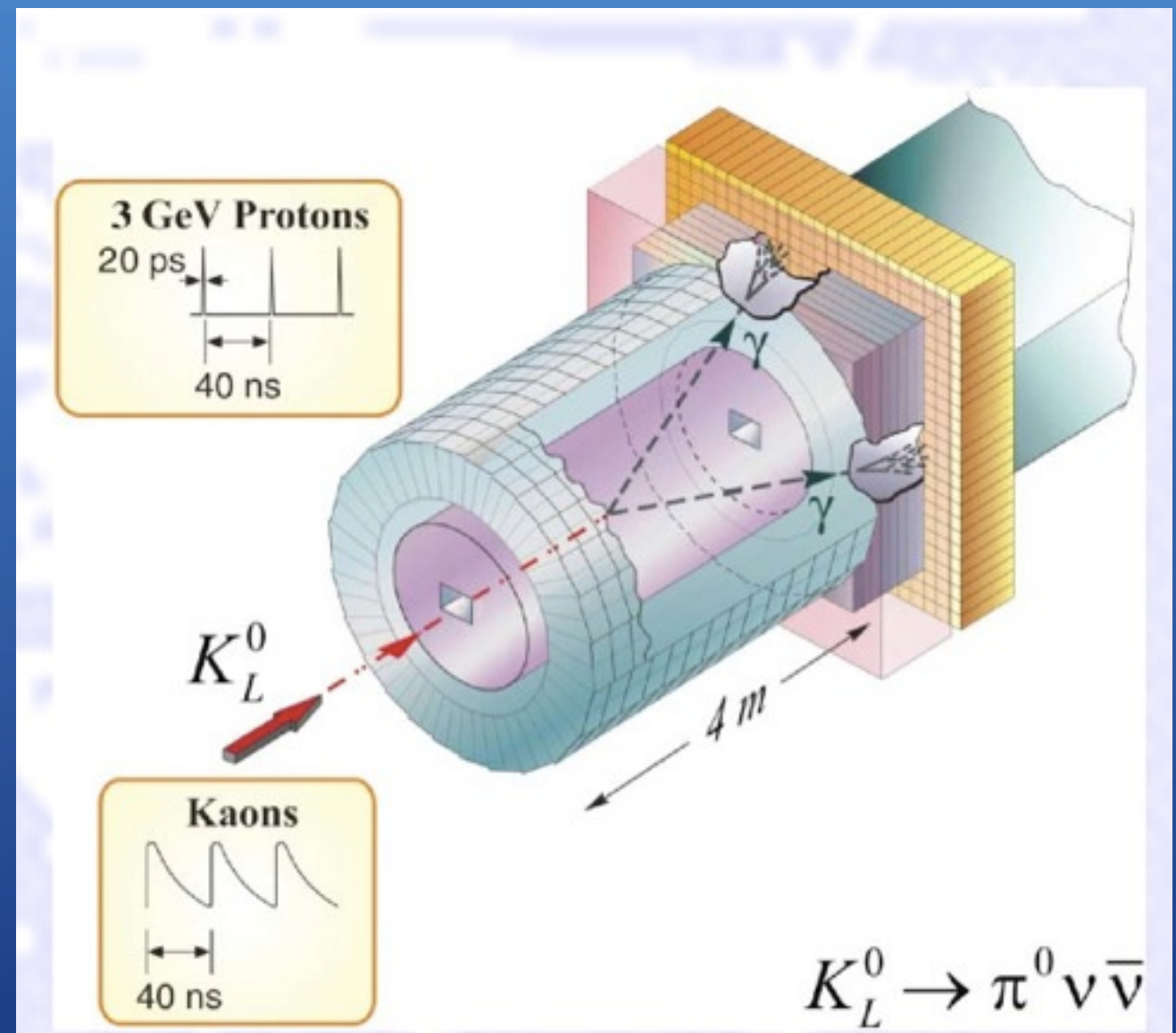
Muon physics at PX

- muon to electron conversion
- $g-2$
- μ edm
- $\mu \rightarrow eee$
- $\mu^+ e^- \rightarrow \mu^- e^+$
- $\mu^+ A \rightarrow \mu^- A; \mu^- A \rightarrow \mu^+ A; \mu^- A \rightarrow e^+ A$
- ...the list can go on and on...



Kaons

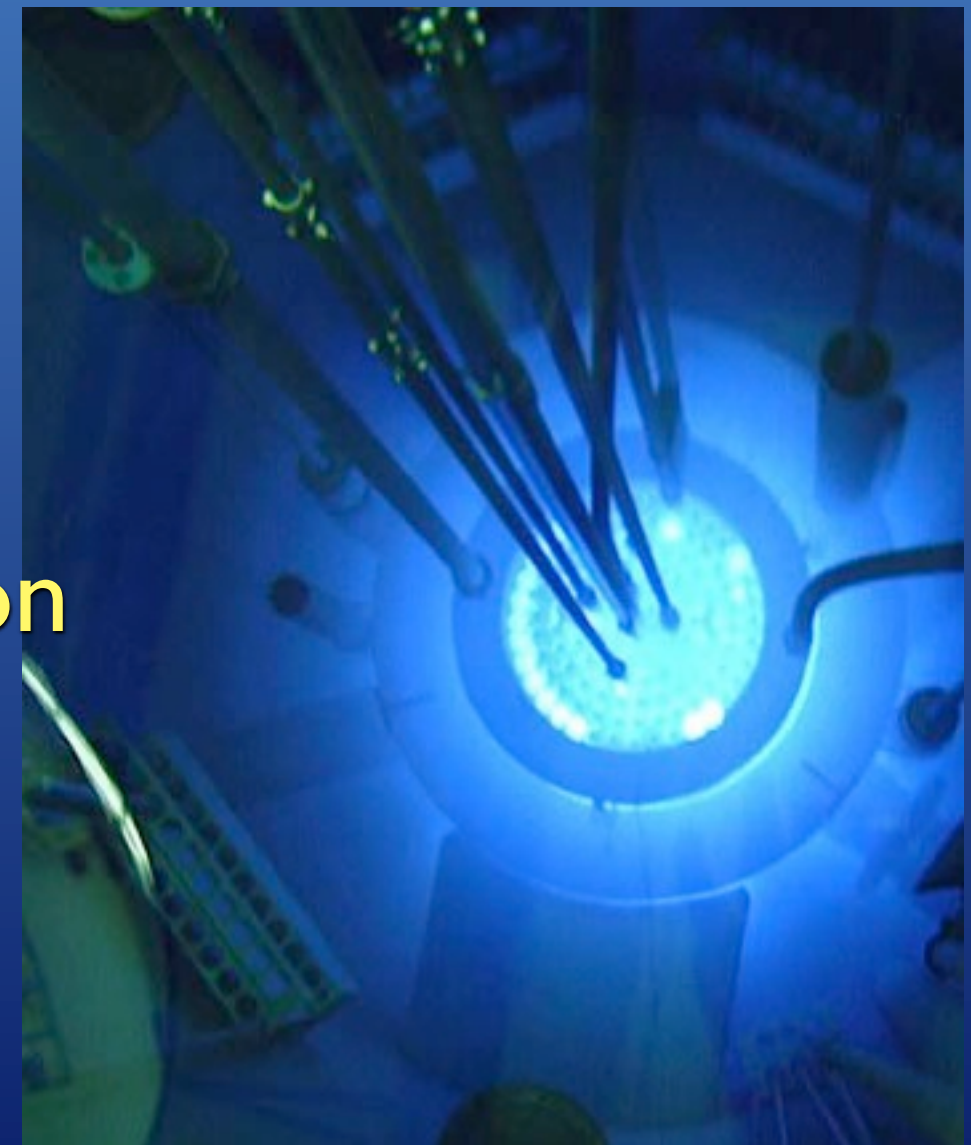
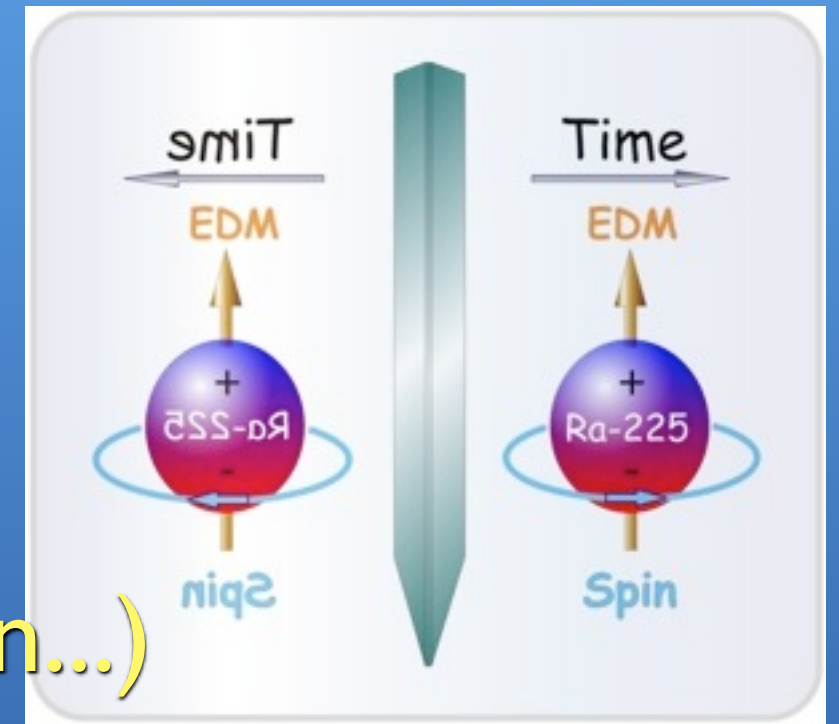
- $K^+ \rightarrow \pi^+ \nu \bar{\nu}$: > 1000 events, precision rate and form factor
- $K_L \rightarrow \pi^0 \nu \bar{\nu}$: 1000 events, high flux and precision TOF
- $K^+ \rightarrow \pi^0 \mu^+ \nu$: Measurement of T-violating μ polarization
- $K^+ \rightarrow (\pi \mu) + \nu \chi$: search for heavy ν
- $K^0 \rightarrow \pi^0 \Pi$: < 10% CP violation measurement
- $K^0, K^+ \rightarrow \text{LFV}$: next generation LFV experiments



....

Nuclear physics

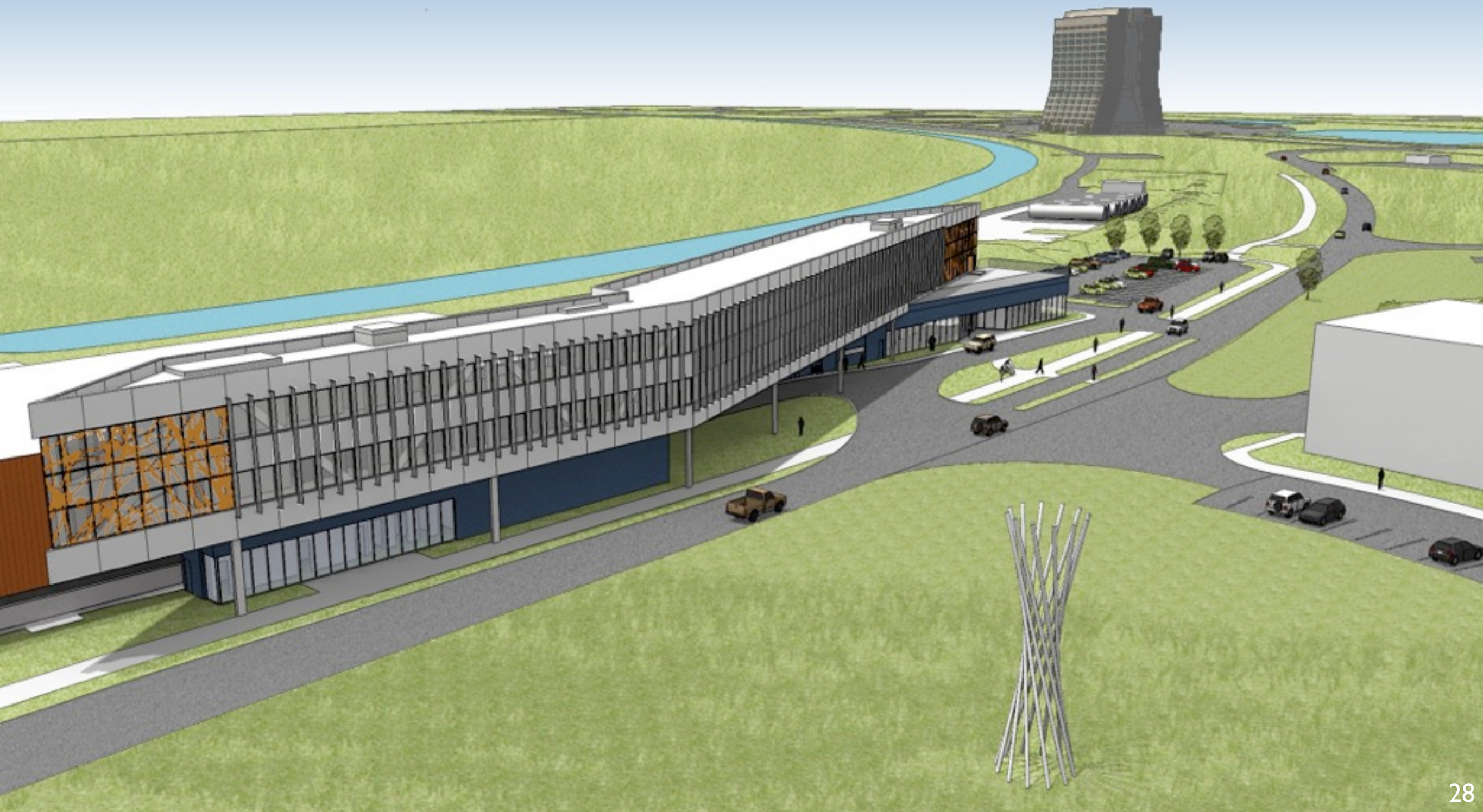
- EDMs in neutral systems (Fr, Ra, Rn...)
 - ➔ CP violation
- Processing nuclear waste
 - ➔ technology
- Material tests under high radiation
- ADS



Accelerator R&D

ground breaking last week!

IARC



Fermilab plan



Now	2013	2016	2019	2025
	Tevatron LHC	LHC	LHC Upgrades ILC??	LHC ILC, CLIC or Muon Collider
	MINOS MiniBooNE MINERvA SeaQuest	NOvA / MINOS(?) MicroBooNE MINERvA Muon g-2 SeaQuest	NOvA / LBNE MicroBooNE MINERvA Mu2e	Project X: (LBNE & other ν 's) (μ , K programs) (nuclei, engy prog.s) ν Factory ??
	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??



Summary

- Fermilab has a strong program on particle physics for next decades
- Focus will shift towards intensity frontier
 - ➡ Project X
- Neutrino+muon experiments this decade
- Whatever the new physics at LHC by now is clear that is neither the simplest nor the most accessible
 - ➡ a diversified world particle physics program is the only way to disentangle and come up with the next steps



Fermilab complex

Fermilab Accelerator Complex
Operating Simultaneously
(Now)

