Fermilab Steering Group

develop roadmap
for accelerator-based HEP program at Fermilab

Young-Kee Kim
Fermilab and University of Chicago

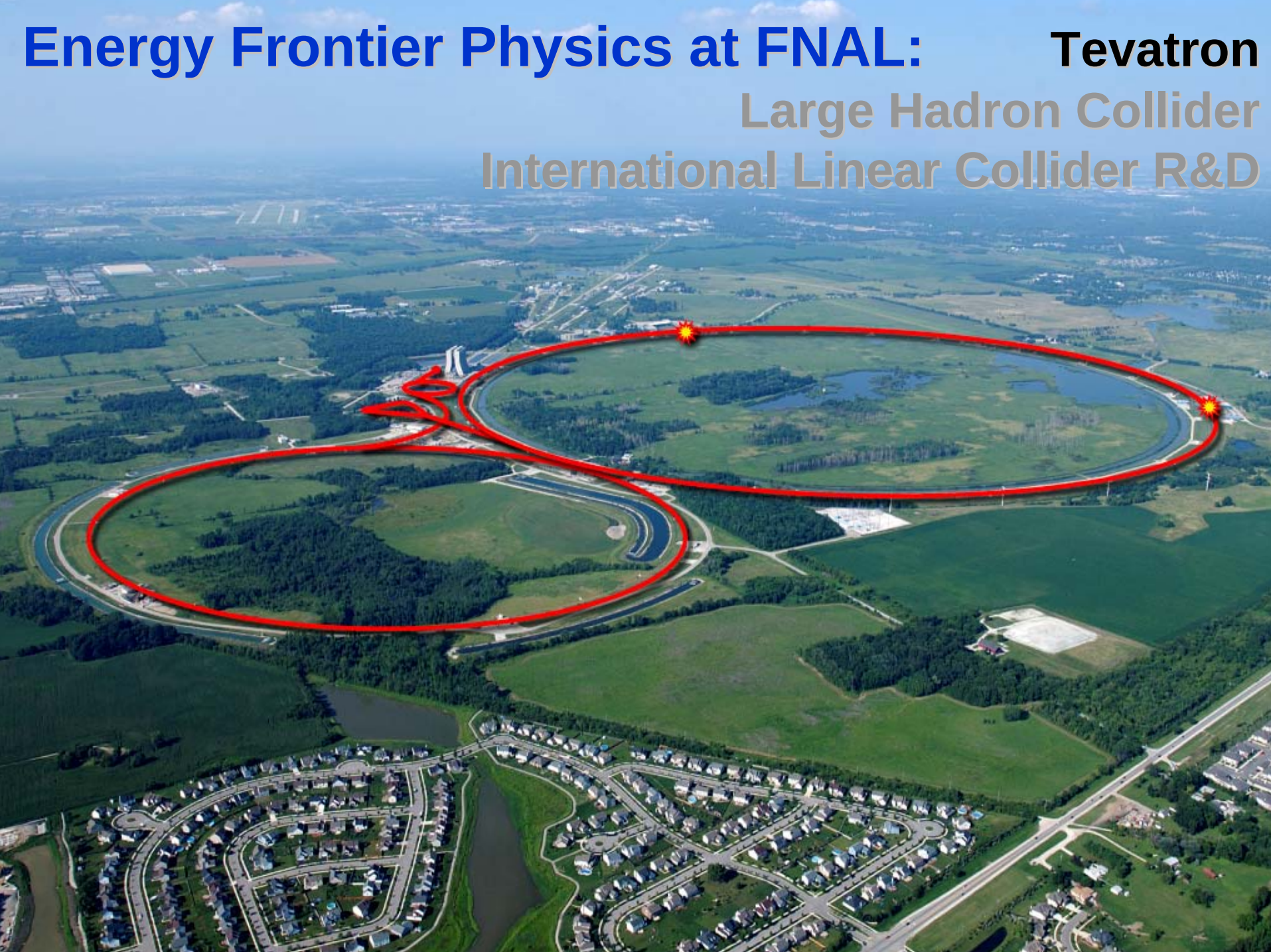
Brookhaven National Laboratory
July 5, 2007

Energy Frontier Physics at FNAL:

Tevatron

Large Hadron Collider

International Linear Collider R&D



Tevatron: close to 2 publications / week

with 0.5 – 1 fb^{-1}

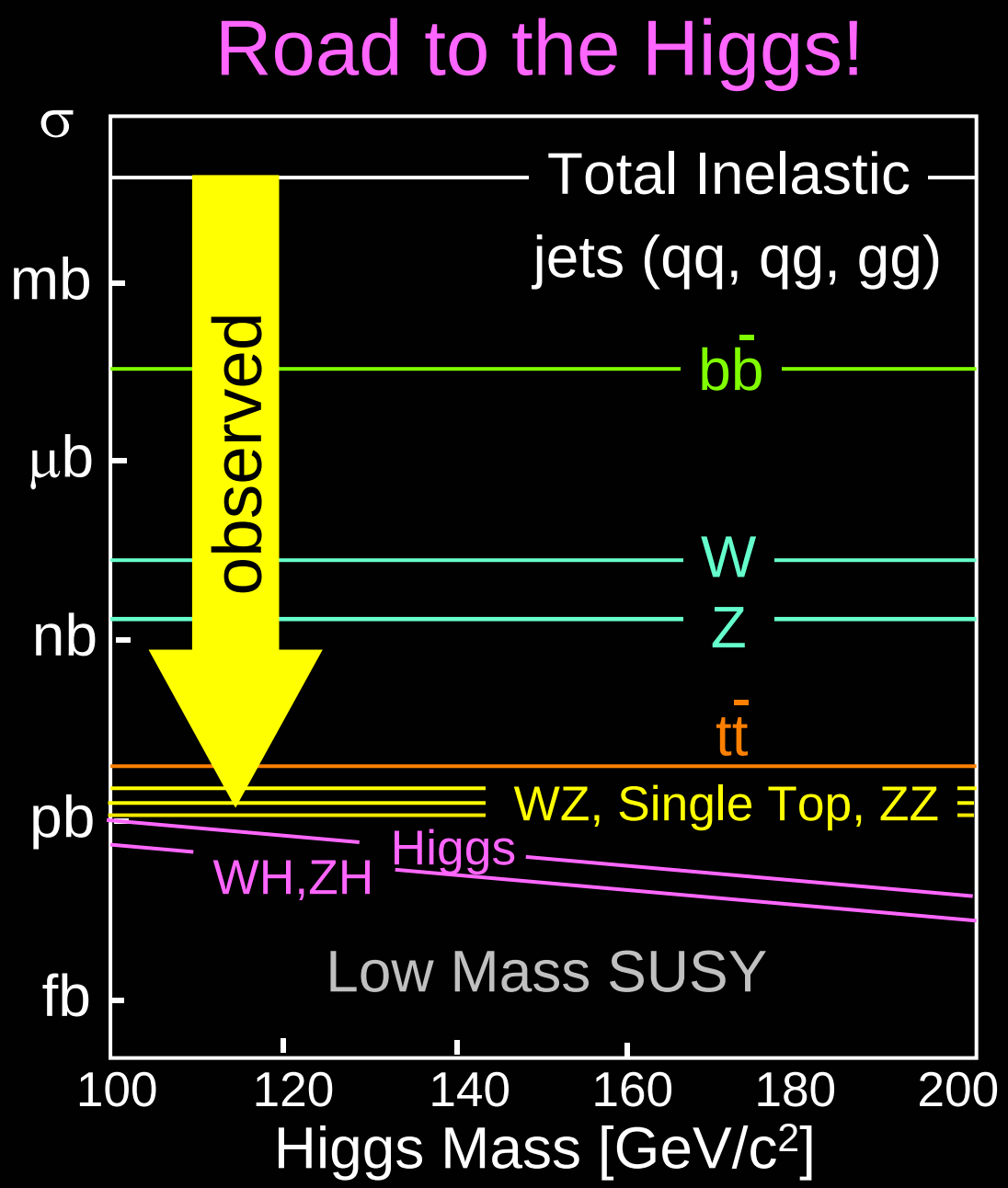
Distance Scale - 10^{-19} m

B_s–$\bar{B}_s$ Oscillation Discovery + Precision Meas.

M_W ~0.05%

M_{top} ~1%

M_{Higgs} < 144 GeV at 95% CL



Energy Frontier Physics at FNAL:

Tevatron

Large Hadron Collider (CERN)

International Linear Collider R&D

LHC Accelerator: a leading US institution

CMS: US Host Institution → Support US Community

Remote Operations Center

Tier-1 Computing Center

LHC Physics Center

(~30 University Offices in Wilson Hall)

Energy Frontier Physics at FNAL:

Tevatron

Large Hadron Collider

International Linear Collider R&D

Consensus of HEP Community: ILC is next accelerator.
Highest Priority at FNAL

Physics and Detector R&D:
Vertex Detector,
Muon, Calorimeter

Accelerator R&D:
Main Linac
Civil/Site Development

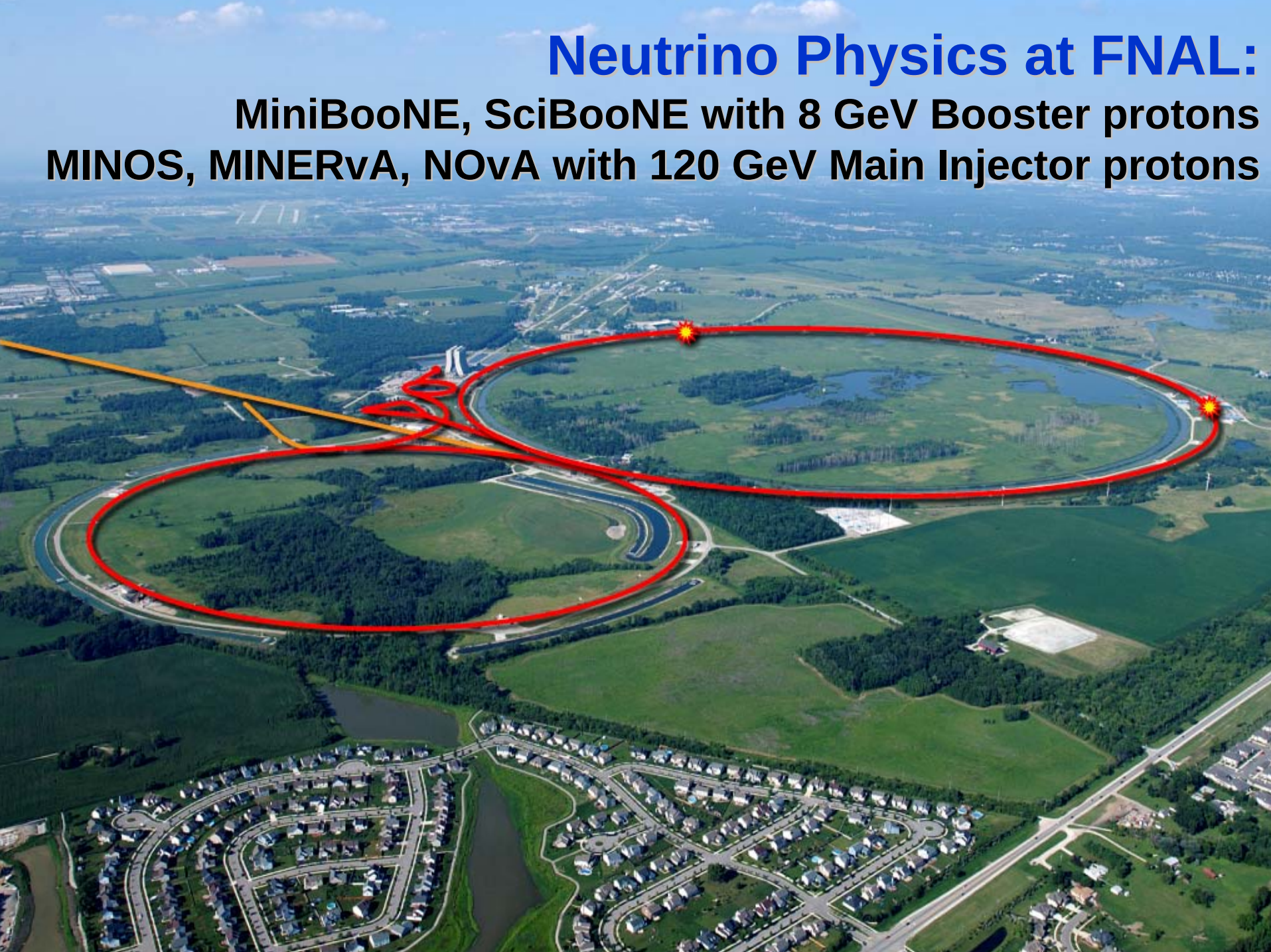
General use
for HEP Community

Collaboration with
ILC institutions

Neutrino Physics at FNAL:

MiniBooNE, SciBooNE with 8 GeV Booster protons

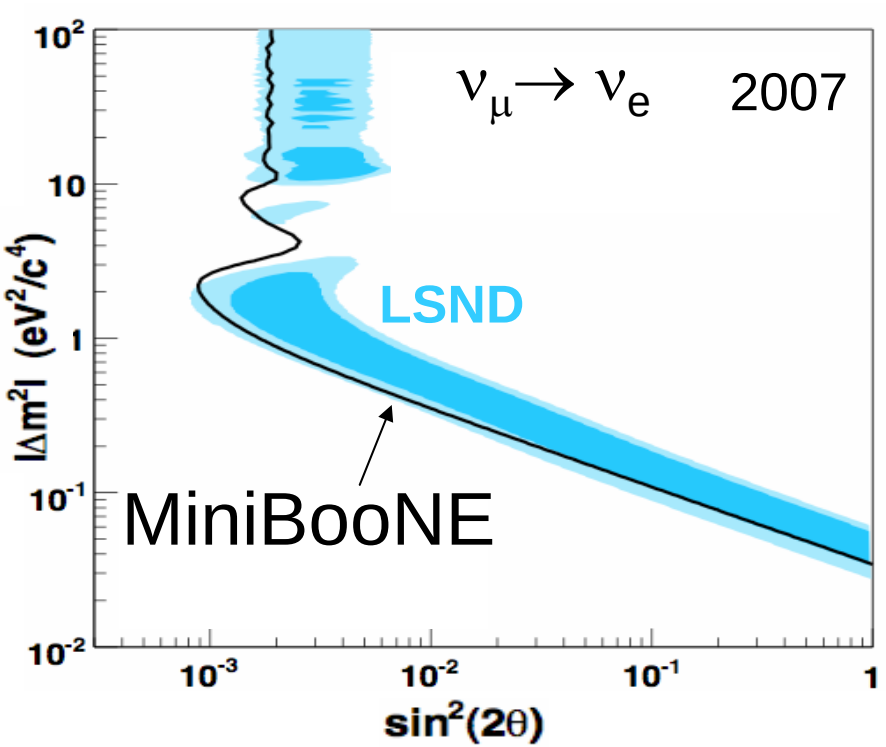
MINOS, MINERvA, NOvA with 120 GeV Main Injector protons

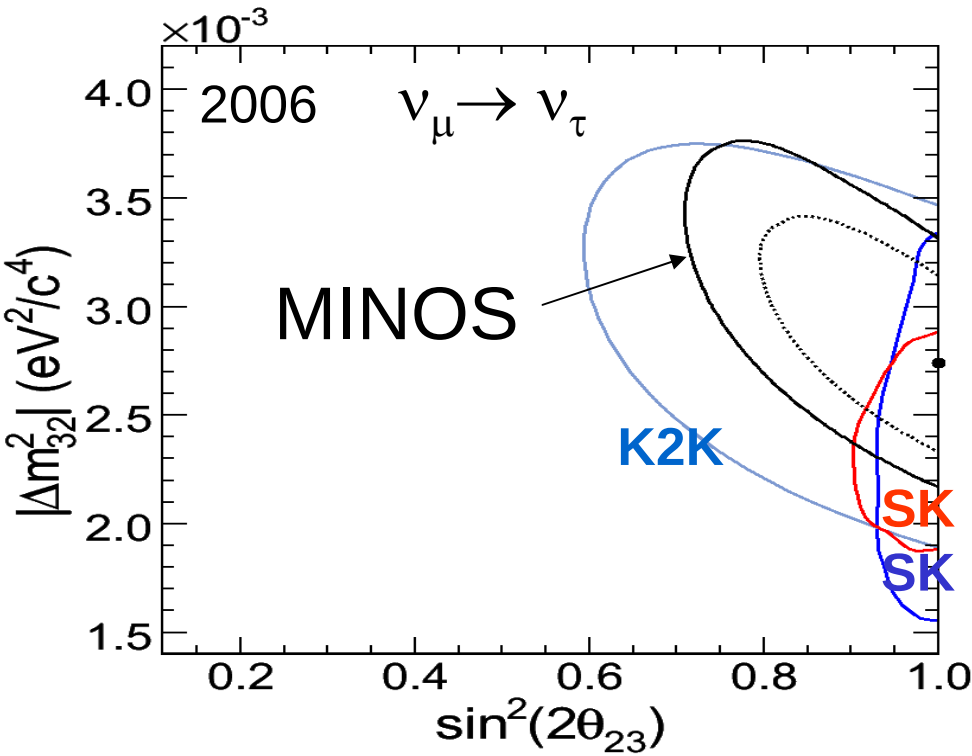


Neutrino Physics at FNAL:

MiniBooNE, SciBooNE with 8 GeV Booster protons
MINOS, MINERvA, NOvA with 120 GeV Main Injector protons

Neutrino Oscillations: MiniBooNE, MINOS, NOvA





Neutrino Cross Sections: SciBooNE, MINERvA

Accelerator Physics Center

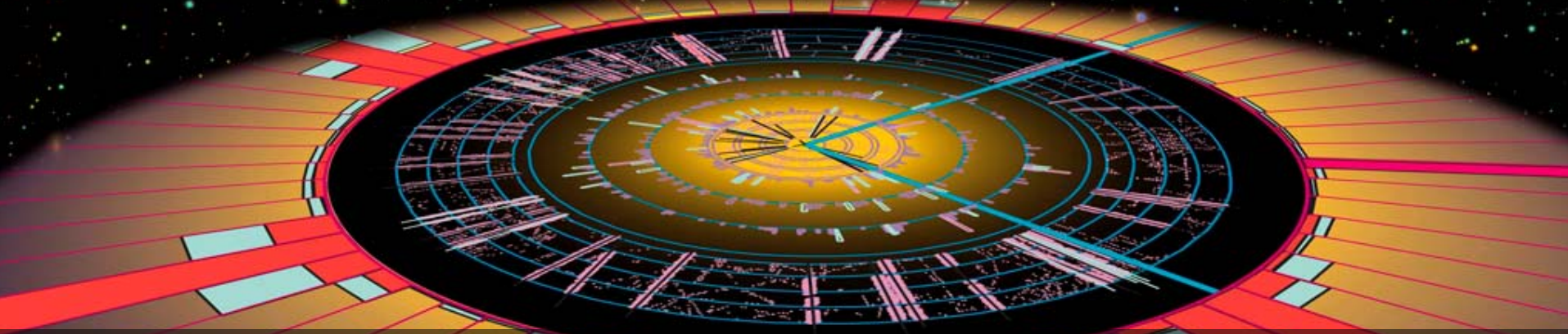
- Launched on June 1, 2007. Led by Vladimir Shiltsev
- R&D aimed at future generations of accelerators
- Educate and train next generation of accelerator scientists and engineers
  - So far, Fermilab has been supporting ~10 Ph.D. students at a given time
  - Enhance this effort
    - more Ph.D. students, undergraduate programs
- Engage university community in accelerator research

Particle Astrophysics at FNAL

Quarks to Cosmos

Center for Particle Astrophysics

Theory
Computational cosmology
Sloan Digital Sky Survey
Pierre Auger Observatory
Cold Dark Matter Search CDMS
Cold Dark Matter Search COUPP
Dark Energy Survey
Supernova Acceleration Project (SNAP) R&D



- World class limits of direct dark matter detection
- SDSS, in combination with WMAP, achieves most precise measurement of cosmological parameters

Fermilab's Scientific Program addresses:

1. Are there undiscovered principles of nature:
   New symmetries, new physical laws?
2. Are there extra dimensions of space?
3. Do all the forces become one?
4. Why are there so many kinds of particles?
5. What happened to the antimatter?
6. What is dark matter?
   How can we make it in the laboratory?
7. How can we solve the mystery of dark energy?
8. How did the universe come to be?
9. What are neutrinos telling us?

From "Quantum Universe"
and
"Discovering Quantum Universe"

Fermilab

2006-7 extraordinary years for Particle Physics at FNAL!
Much more expected in the near future.

Planning Farther Ahead:
Fermilab will be solely devoted to Particle Physics.

EPP 2010 Recommendations

1. LHC
2. ILC Global
   ILC Hosting
3. Particle Astrophysics
4. Global Neutrino Program
5. Quark Flavour Physics

P5 Recommendations

- LHC and ILC are highest priorities.
- Available resources:
  - 60% ILC R&D
  - 40%
    - Near-mid term:
      - Dark Energy Survey (DES)
      - Cold Dark Matter Search Super CDMS-25kg
      - NOvA long baseline neutrino program
      - Daya Bay reactor neutrino experiment
    - Longer term:
      - prepare SNAP and LSST

P5 Recommendations (Fermilab)

- LHC and ILC are highest priorities.
- Available resources:
  - 60% ILC R&D
  - 40%
    - Near-mid term:
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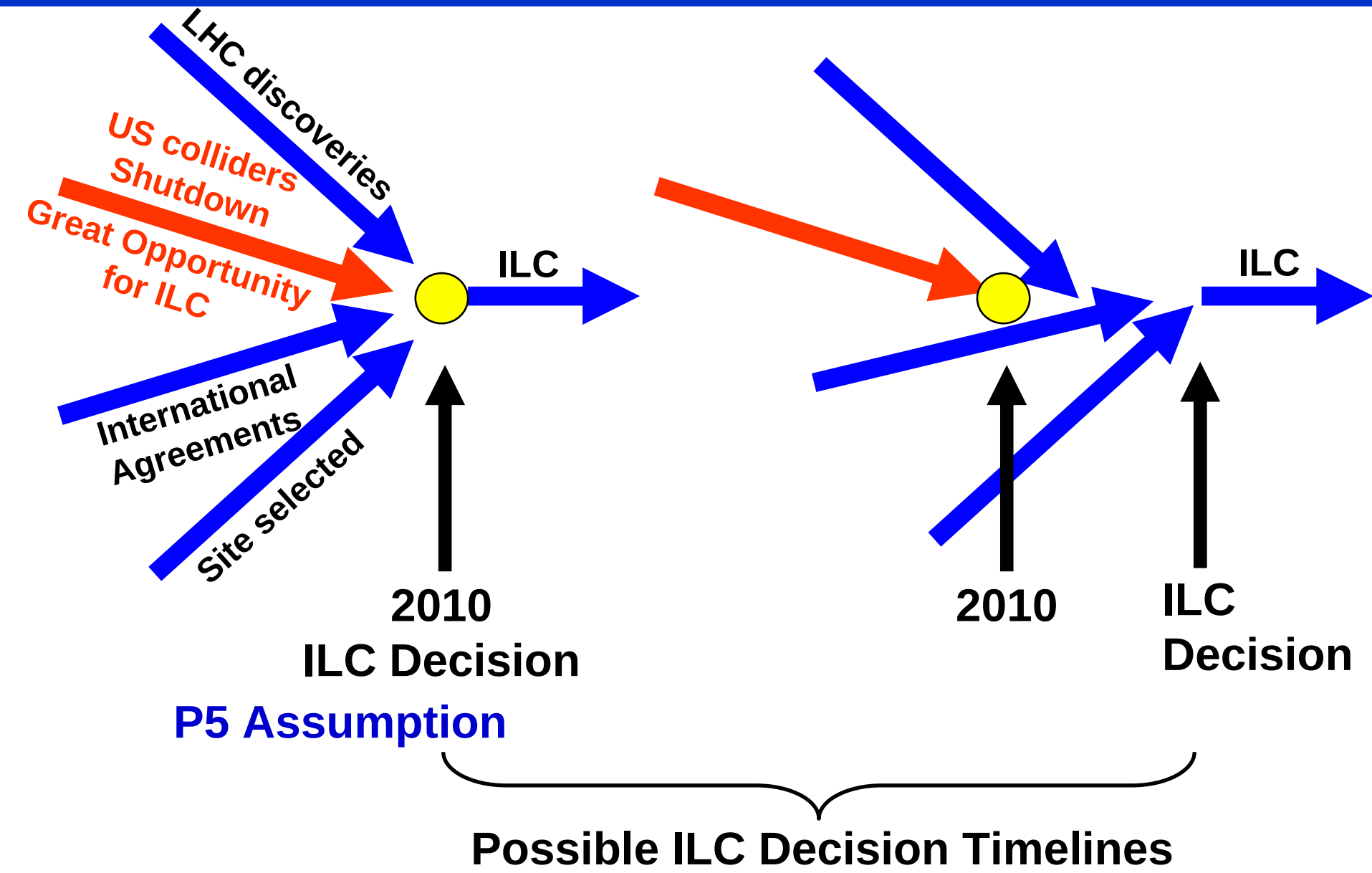
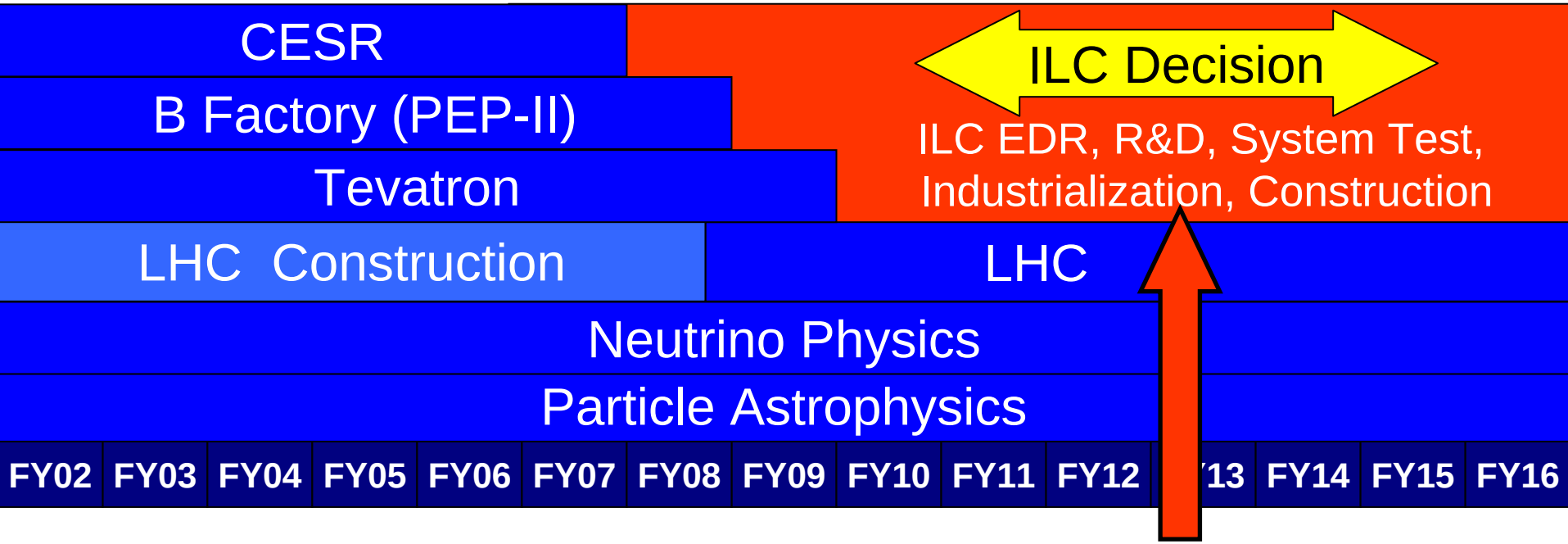
ILC assumption - early decision and start

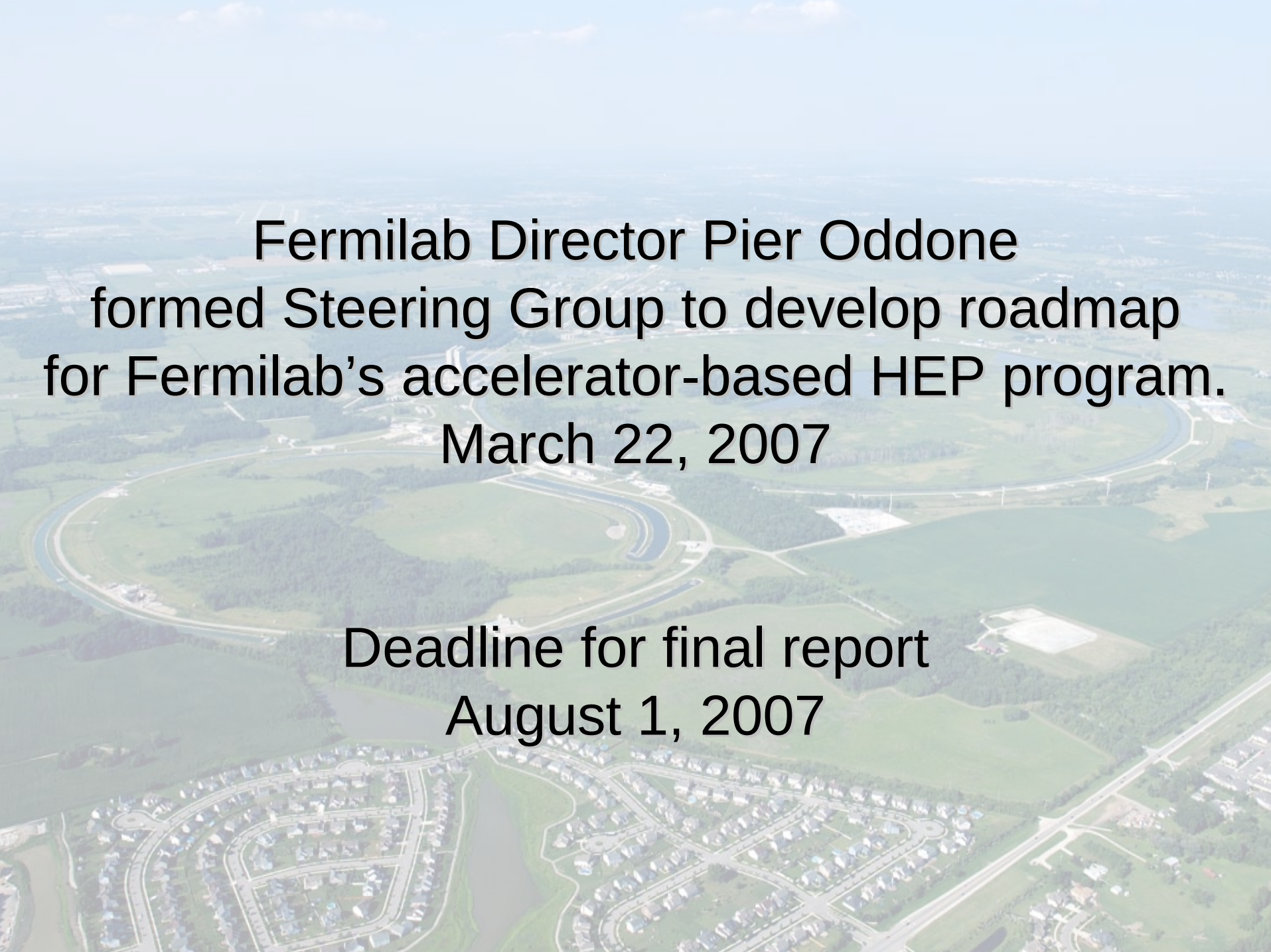
ILC Decision



Uncertainty in ILC Decision Time



- Sustain rigorous ILC R&D activities over a possibly longer period.
- Late decision:
  - System test and industrialization before decision to speed up ILC construction and commissioning time.
  - Near-mid term discovery opportunities
- Plan colliders beyond the ILC / LHC.



Fermilab Director Pier Oddone
formed Steering Group to develop roadmap
for Fermilab's accelerator-based HEP program.
March 22, 2007

Deadline for final report
August 1, 2007

Accelerator based program:

Fermilab Director Pier Oddone formed Steering Group to develop roadmap (March 22, 2007).
Deadline for final report: August 1, 2007

Non-Accelerator based program:

Particle Astrophysics

Fermilab Roadmap will be developed together with Director, Center for Particle Astrophysics
(Director search in progress)

Steering Group: Charge

The Steering Group will build the roadmap based on the recommendations of the EPP2010 National Academy report and the recommendations of the P5 subpanel of HEPAP. The Steering Group should consider the Fermilab based facilities in the context of the global particle physics program. Specifically the group should develop a strategic roadmap that:

1. supports the international R&D and engineering design for as early a start of the ILC as possible and supports the development of Fermilab as a potential host site for the ILC;

2. develops options for an accelerator-based high energy physics program in the event the start of the ILC construction is slower than the technically-limited schedule; and

3. includes the steps necessary to explore higher energy colliders that might follow the ILC or be needed should the results from LHC point toward a higher energy than that planned for the ILC.

Steering Group Membership

Eugene Beier	U. Penn
Joel Butler	Fermilab
Sally Dawson	BNL
Helen Edwards	Fermilab
Thomas Himel	SLAC
Steve Holmes	Fermilab
Young-Kee Kim (chair)	Fermilab / U.Chicago
Andrew Lankford	UC Irvine
David McGinnis	Fermilab
Sergei Nagaitsev	Fermilab
Tor Raubenheimer	SLAC
Vladimir Shiltsev	Fermilab
Maury Tigner	Cornell
Hendrick Weerts	ANL

Steering Group Activities

- **Steering group – weekly telephone meeting**
  - EPP2010 and P5 assumptions
  - ILC R&D needs, LHC Upgrades
  - Physics and Facility Opportunities: near, med, long term
    - Physics; ν, μ, K, B, C, …
    - reconfiguring existing accelerator complex, and new facilities
  - Web: http://www.fnal.gov/directorate/Longrange/Steering_Public/
    - Agendas, presentations, minutes, documents, publicly accessible

- **For all activities, we include**
  - ILC GDE leaders, HEP / ILC program managers in DOE and NSF
  - HEPAP Chair / Deputy Chair, P5 Chair
  - Chairs of Fermilab/SLAC Users Executive committees
  - Subgroup members

- **Subgroups -** ~weekly telephone meetings: detailed analysis

Subgroups

- **Oversight (additional constituents)**
  - Make sure that roadmaps being developed are consistent with EPP2010 and P5 recommendations – J. Bagger, S. Dawson, A. Seiden, M. Shochet (chair)
- **Neutrino Physics (additional constituents)**
  - Develop roadmap for neutrino physics based on NuSAG studies
- **Flavor Physics: quarks, charged leptons, ... (additional constituents)**
  - Develop 10-year plan with reconfiguring existing accelerator complex
- **Accelerator Facilities (based on technical and resources feasibilities)**
  - Develop options of a roadmap that supports ILC R&D for early start, supports Fermilab as a potential host site, and provides an accelerator-based high energy physics program in case of delayed start – H. Edward, T. Himel, S. Holmes (chair), D. McGinnis, S. Nagaitsev, T. Raubenheimer, V. Shiltsev, M. Tigner, (YKK)
- **High Energy Colliders beyond the ILC**
  - Develop steps necessary to explore higher energy colliders that might follow ILC or be needed should results from LHC point toward a higher energy than that planned for ILC – H. Edward, V. Shiltsev, M. Tigner (chair), (YKK)

Physics Groups

Neutrino Physics

NuSAG (up to ~1 MW, ν oscillation)
+ multi MW proton sources,
ν cross section measurements, …

Eugine Beier	U Penn
Deborah Harris	Fermilab
Ed Kearns	Boston Univ.
Boris Kayser	Fermilab
Sacha Kopp	UT Austin
Andy Lankford (chair)	UC Irvine
Bill Louis	Los Alamos
(Young-Kee Kim)	UChicago/FNAL

Flavor Physics

Quarks, Charged Leptons,
Physics with anti-protons, etc.

Joel Butler	Fermilab
Brendan Casey	Brown
Sally Dawson (chair)	BNL
Chris Hill	Fermilab
Dan Kaplan	IIT
Yury Kolomensky	UCBerkeley/LBNL
William Molzon	UC Irvine
Kevin Pitts	UIUC
Frank Porter	CalTech
Bob Tschirhart	Fermilab
Harry Weerts	ANL
(Young-Kee Kim)	UChicago/FNAL

Steering Group Activities (cont.)

- Reach out to HEP community for input / ideas
  - Message sent out to DPF & DPB members
  - Meetings with FNAL staff
  - Meetings with HEP collaborations
  - Presentations at Users meetings at FNAL and SLAC
  - Town Hall meetings at National Lab.s
  - Many meetings with individuals
  - Fermilab Today articles
  - ….

Letters and Proposals from the Community

- 5 letters
- 20 proposals
  - 16: one to a few pages
  - 3: EoI (Expression of Interest)
  - 1: LoI (Letter of Intent)
- http://www.fnal.gov/directorate/Longrange/Steering_Public/community_letters.html

- Many many e-mail messages

Letters and Proposals from the Community

- **Letters from the Community**
  - John Marriner (May 5, 2007)
  - Norman Gelfand (May 8, 2007)
  - Stanley Brodsky (May 31, 2007)
  - Steve Geer et al. (June 8, 2007)
  - Buck Field (June 12, 2007)
- **One Page Proposals from the community**
  - 6GeV ILC Test Linac - Giorgio Apollinari and Bob Webber (May 7, 2007)
  - LAr TPC in FNAL's Neutrino Beams - David Finley (May 29, 2007)
  - Precision Neutrino Scattering at Tevatron - Janet Conrad and Peter Fisher (May 29, 2007)
  - Very Large Cherenkov Detector - Milind Diwan et al (June 5, 2007)
  - From Tevatron to Muon Storage Ring - Terry Goldman (June 6, 2007)
  - Antimatter Gravity Experiment - Thomas Phillips (June 7, 2007)
  - Neutrino Oscillation with high energy/intensity beam - Henryk Piekarz (June 10, 2007)
  - Space-Time Ripples Study - Nikolai Andreev (June 11, 2007)
  - Fixed Targer Charm Expt - Jeff Appel and Alan Schwartz (June 11, 2007)
  - Stopped Pion Neutrino Source - Kate Scholberg (June 11, 2007)
  - UNO Experiment - Change Kee Jung (June 11, 2007)
  - n-nbar Transition Search at DUSEL - Yuri Kamyshkov (June 11, 2007)
  - 8GeV cw Superconducting Linac - Ankenbrandt et al. (June 12, 2007)
  - Neutrino Expt with 5kton LAr TPC - Fleming and Rameika (June 12, 2007)
  - MicroBooNE - Fleming and Willis (June 12, 2007)
  - delta_s - Rex Tayloe (June 14, 2007)
- **Expression of Interest (EOI)**
  - mu to e conversion - William Molzon (May, 2007)
  - me to e conversion - E.J. Prebys, J.P. Miller et al (May, 2007)
  - Klong to pi0 nu nu - D. Bryman et al (June 11, 2007)
- **Letter of Intent (LOI)**
  - Low- and Medium-Energy Anti-Proton Physics - D. Kaplan et al (June 1, 2007)

Physics Opportunities

Not Energy Frontier Physics & Accelerator Based

- Neutrino Physics
- Precision measurements involving
  charged leptons and quarks

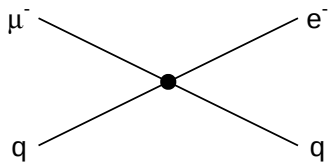
- High intensity ν, μ, K beams
- High luminosity colliders

Physics Opportunities: Criteria

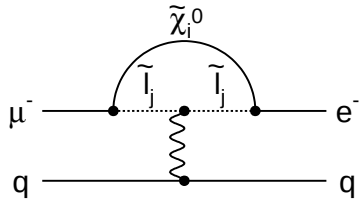
- Criteria
  - Will the physics be important in a global context when the experiment is done?
  - Can it be done *uniquely* or *substantially better* at Fermilab than at other labs?
  - Is the experiment unique in its physics reach?
- Timeline
  - Near term (2007-2012)
    - Experiments that could start construction “soon”
  - Mid term (2012-2022)

Physics Opportunities

- Neutrino: Oscillation, CP Violation, EWK Precision
- Muon: Lepton Number Violation



Compositeness to
3000 TeV scale

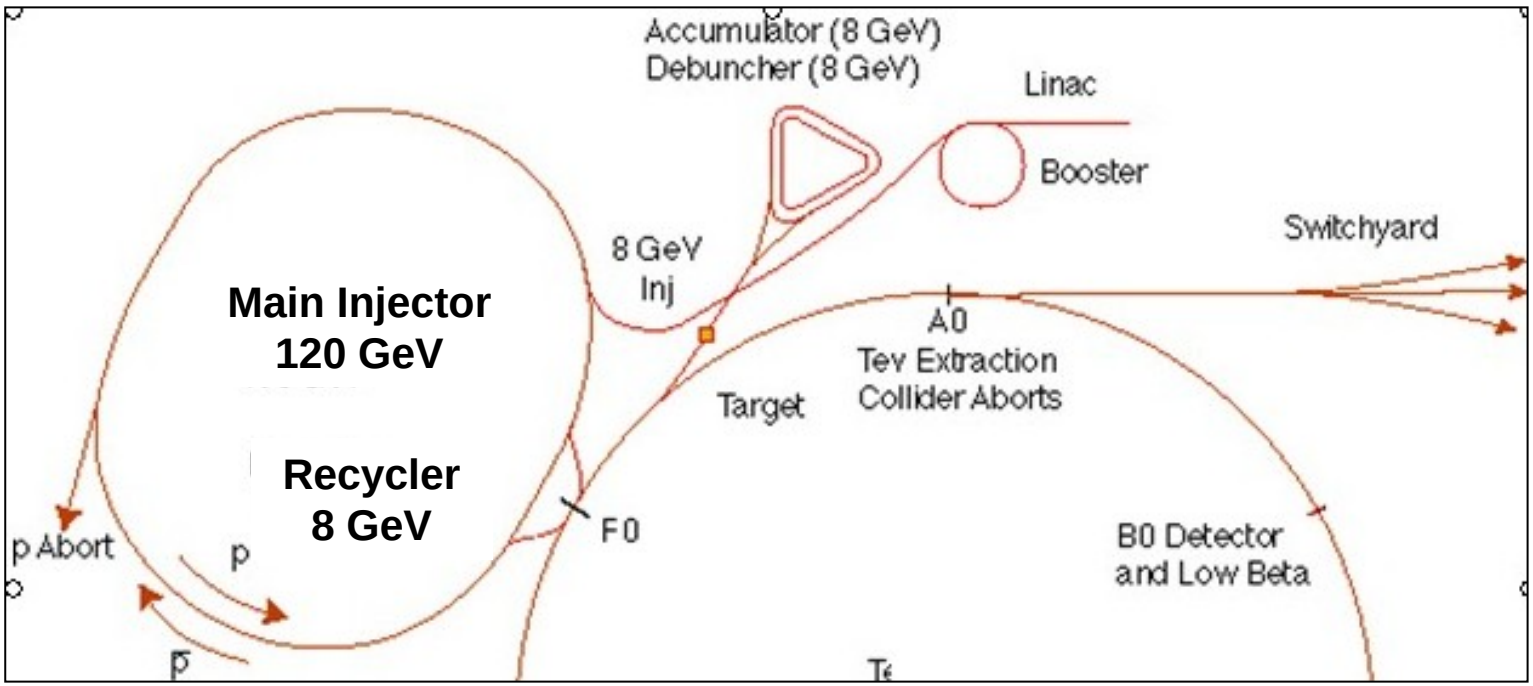


Supersymmetric models predict
$R_{\mu e} \sim 10^{-15}$ for weak scale SUSY

- Kaon: CKM Matrix, Lepton Flavor Violation
- Anti-proton: Hyperon CP Violation
- B Physics
- Electroweak Precision with Giga Z
- …

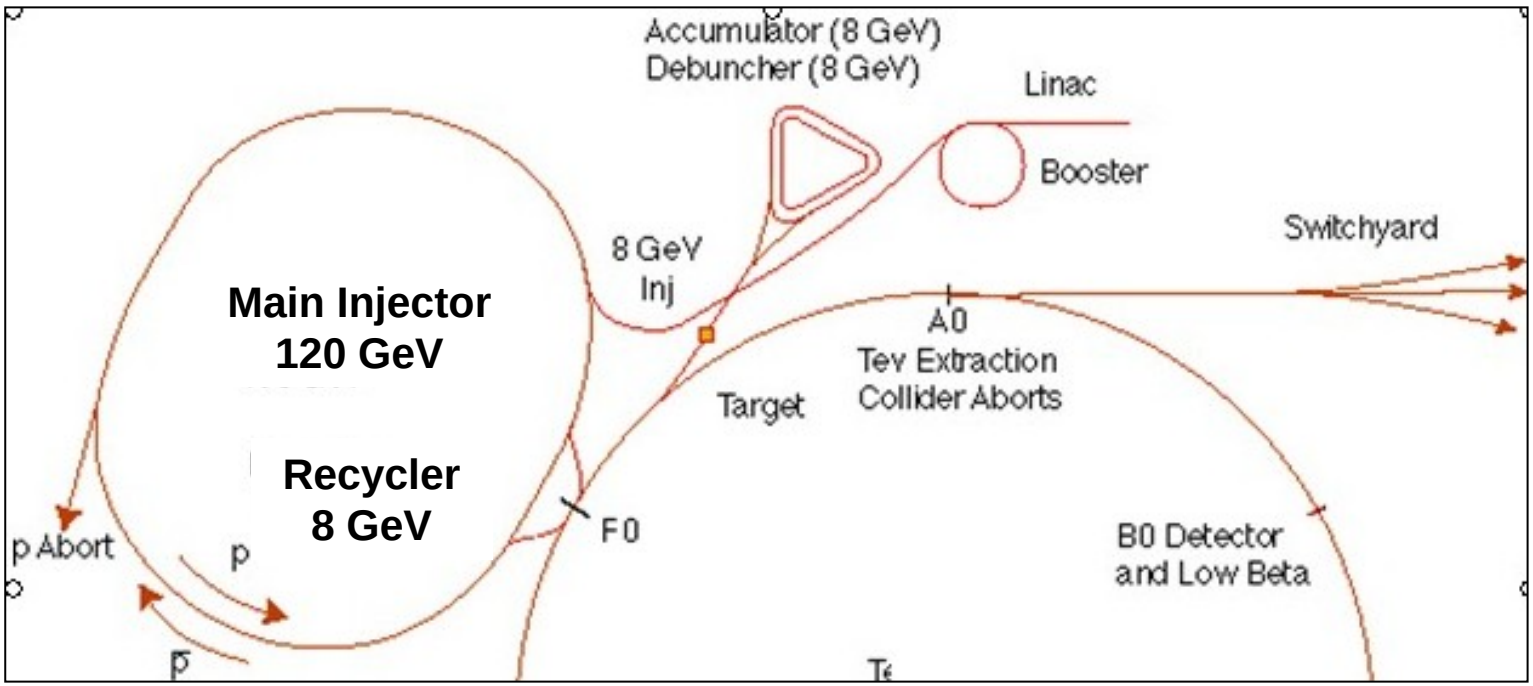
Present Fermilab Proton Source

- Linac accelerates H^- to 400 MeV
- Booster accelerates protons to 8 GeV.
- 8 GeV protons are used for MiniBooNE & to feed Main Injector.
- Main Injector accelerates protons to 120 GeV.
- MI protons are used to feed Tevatron and to make antiprotons for Collider and neutrinos for MINOS.



Present Fermilab Antiproton Source

- 3 antiproton rings for Tevatron collider - Debuncher, Accumulator, Recycler.
- Debuncher collects antiprotons from target, bunch-rotates & pre-cools them.
- Accumulator momentum-stacks antiprotons collected from Debuncher.
- Recycler Ring is a second accumulator ring that coalesces multiple Accumulator batches with electron cooling.
- At end of Run 2, Debuncher, Accumulator, Recycler, Tevatron rings become available.



NOvA Proton Plan

- Currently Fermilab produces 9 x 10^{16} protons / hr. Future plans include

1. NOvA – 0.4 MW at 120 GeV
   - Booster aperture upgrade, Modification of Main Injector

2. NOvA accelerator upgrades – 0.7 MW at 120 GeV
   - Modification of Recycler

3. sNuMI (super NuMI) – ~1.2 MW at 120 GeV
   - Modification of Accumulator and Recycler

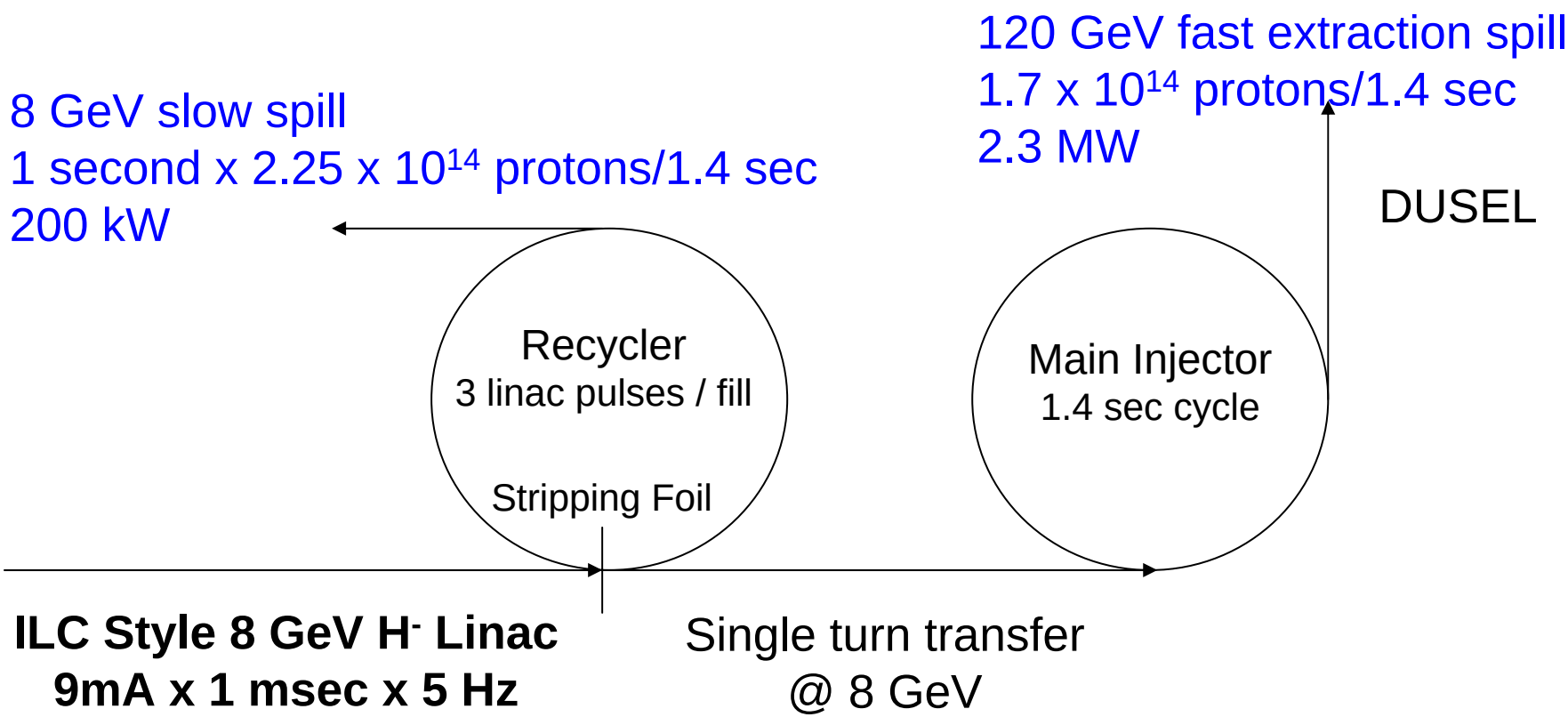
Reconfiguration of Existing Facilities

- Option 1:
  - Reconfigure existing complex
    - sNuMI
    - Debuncher as an 8 GeV Slow Spiller
    - Tevatron as a 120 GeV Slow Spill Stretcher Ring
  - Capable of producing 25 x 10^{16} protons / hr
    - 120 GeV 1 MW → 18.8 x 10^{16} protons / hr
    - 8 GeV slow & fast spill → 4.6 x 10^{16} protons / hr
      → μ, pbars, …
    - 120 GeV slow spill → 5.4 x 10^{15} protons / hr
      → 2 x 10^{14} K^+ / year

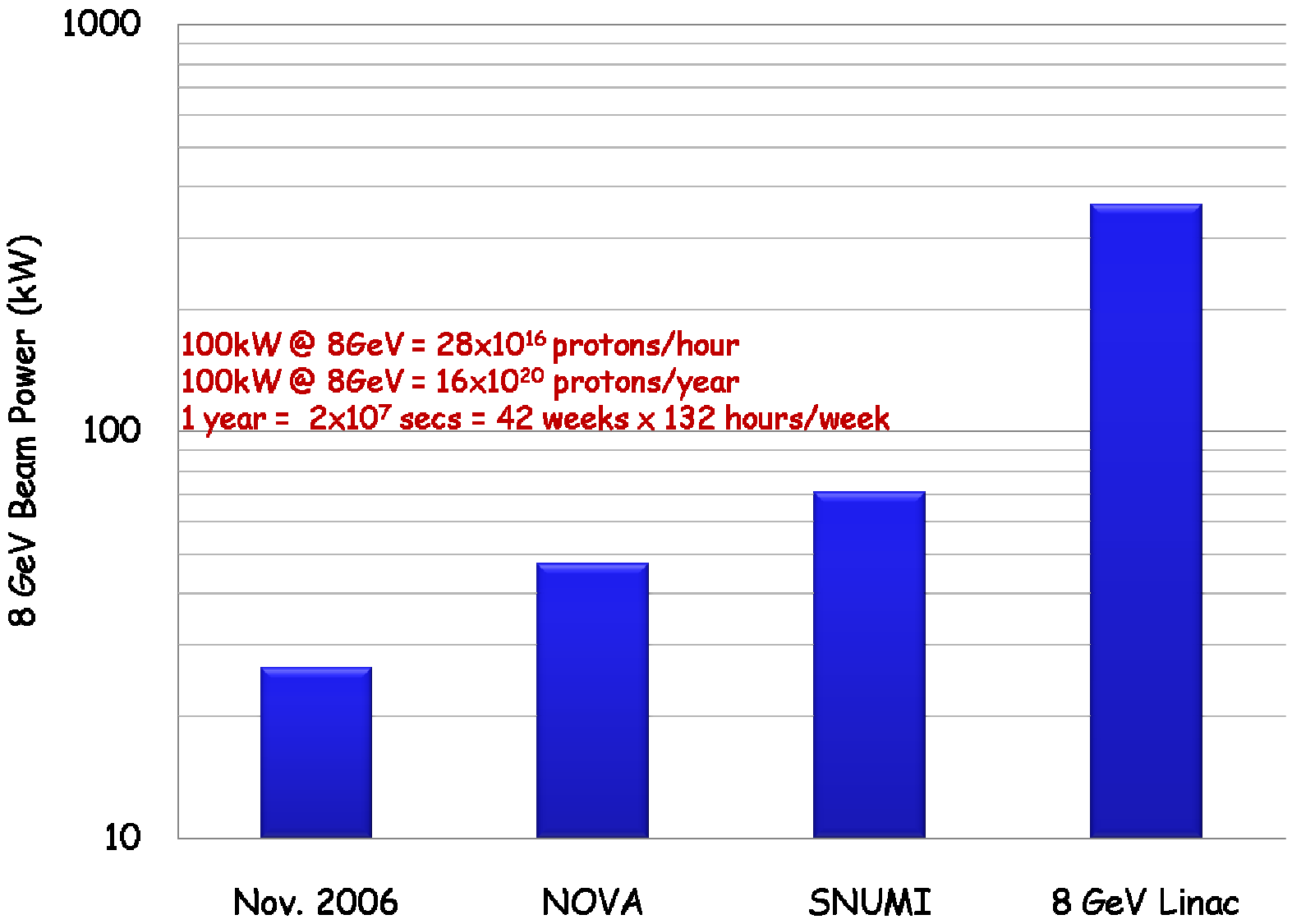
ILC-like New Facilities: Project X

- Option 2:

  (0 → 0.12 GeV) + (0.12 → 2 GeV Linac) +
  (2 → 8 GeV ILC-like Linac) + Recycler + Main Injector



Proton Flux


1000
100
10
8 GeV Beam Power (kW)
100kW @ 8GeV = 28x10^16 protons/hour
100kW @ 8GeV = 16x10^20 protons/year
1 year = 2x10^7 secs = 42 weeks x 132 hours/week
Nov. 2006
NOVA
SNUMI
8 GeV Linac

Physics Opportunities: Prelim. Conclusions

- "High intensity proton sources" offers a rich program of neutrino, kaon and muon physics in near - mid term
  - ***Physics driver is search for Beyond the Standard Model Physics***
- "Antiproton source" offers short term (and small scale) opportunity for hyperon CP violation
- Longer term (and larger scale) opportunities:
  - Flavor physics at Super B factory
  - Electroweak Precision at Giga-Z
  - Need community-wide input on priorities

Sketching Possible Roadmaps

Criteria

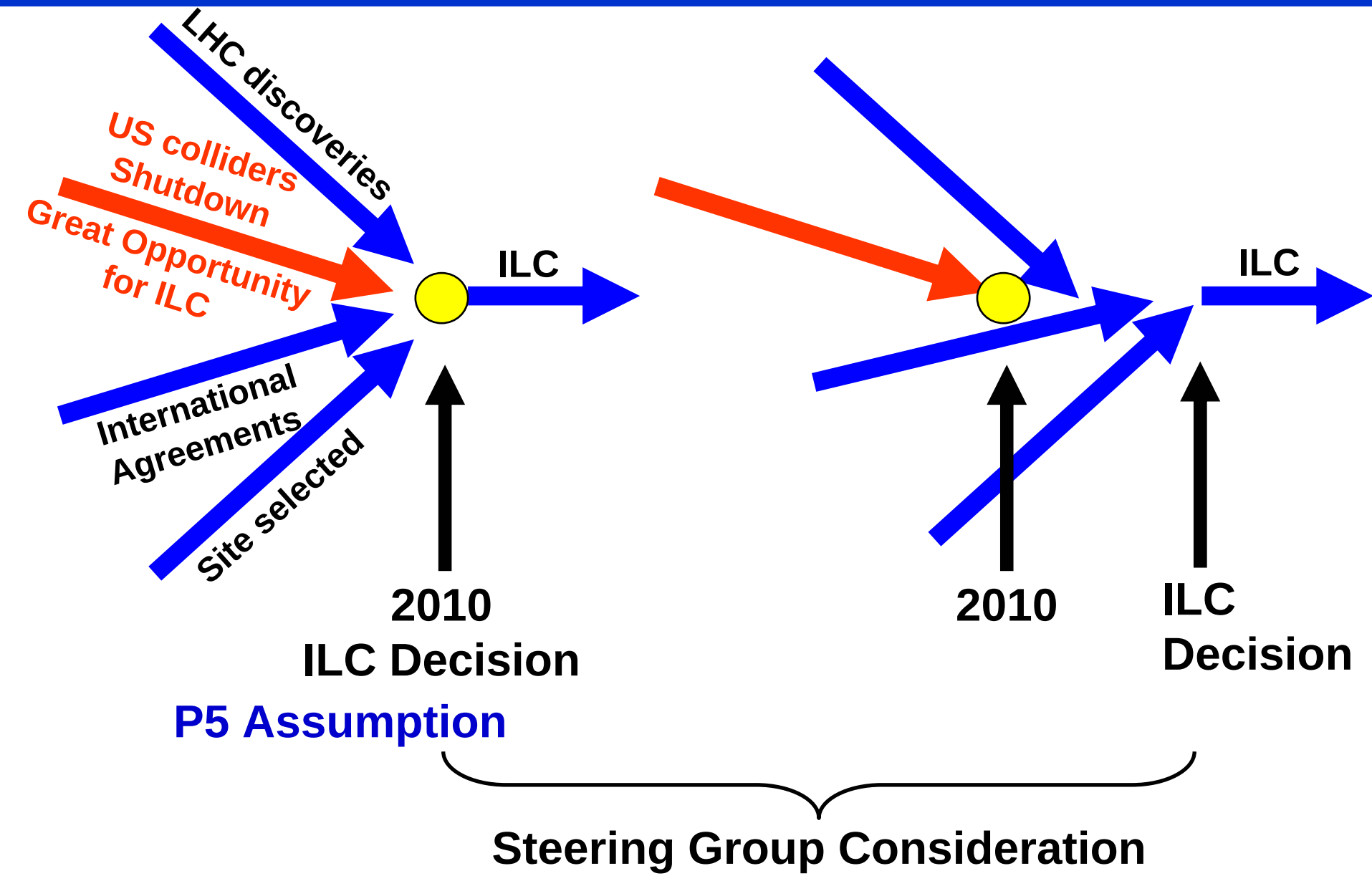
Various options considered for each ILC scenario

Choices will be made based on:

1. Science

2. How well they are aligned
   with the ILC as an ultimate goal?

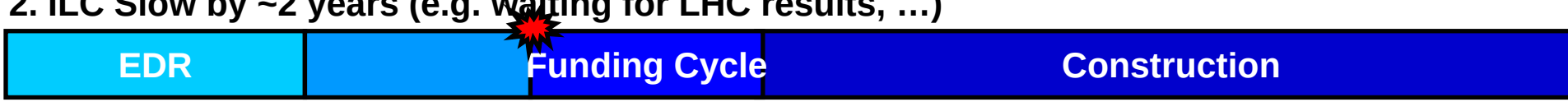
ILC Scenarios Considered (in progress)



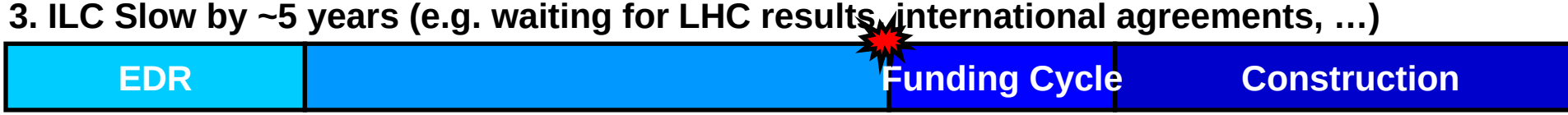
ILC Scenarios Considered (in progress)

1. Baseline (Technically Driven Schedule)

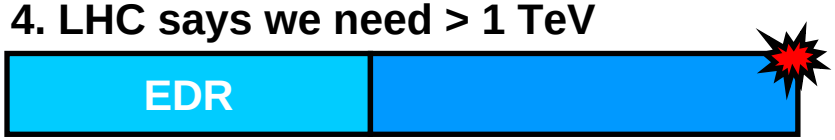
2. ILC Slow by ~2 years (e.g. waiting for LHC results, …)



3. ILC Slow by ~5 years (e.g. waiting for LHC results, international agreements, …)



4. LHC says we need > 1 TeV



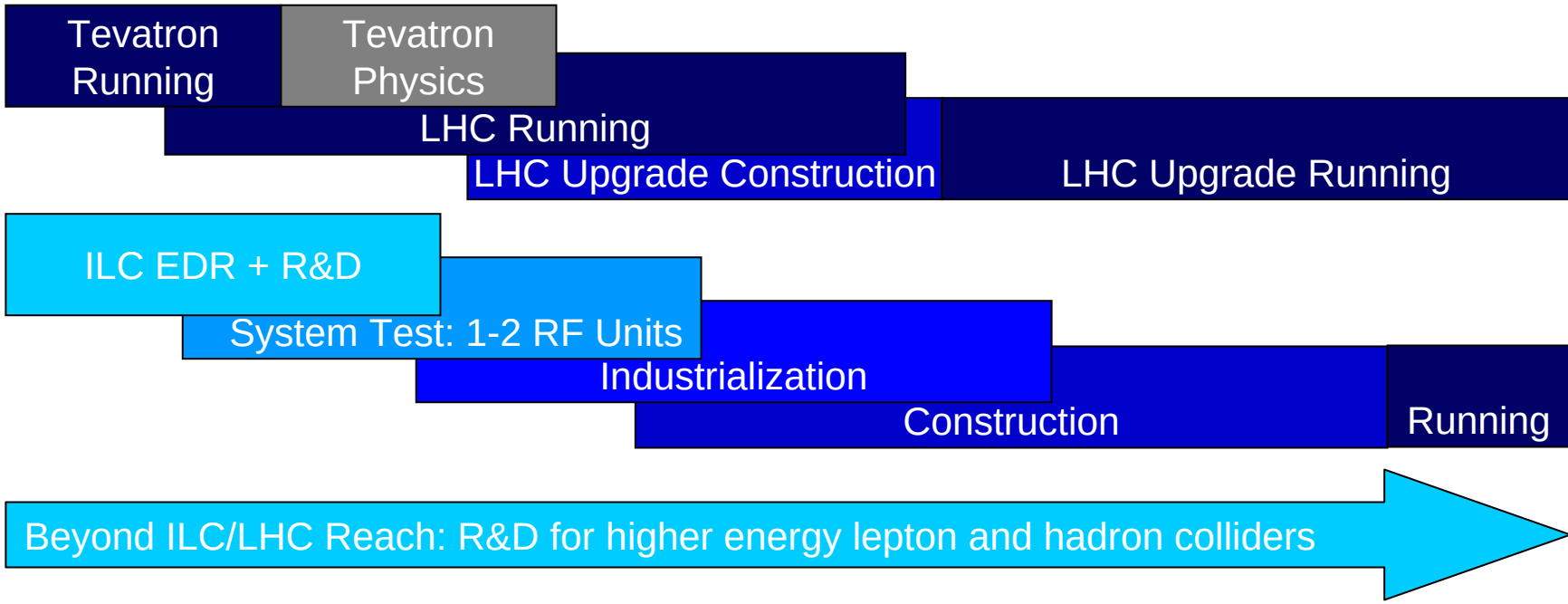
5. ILC Offshore: To be discussed

EDR Complete, LHC 1st Data
Can we see the horizon?

ILC Decision

A Possible Roadmap for ILC Scenario 1, 2

- Energy Frontier

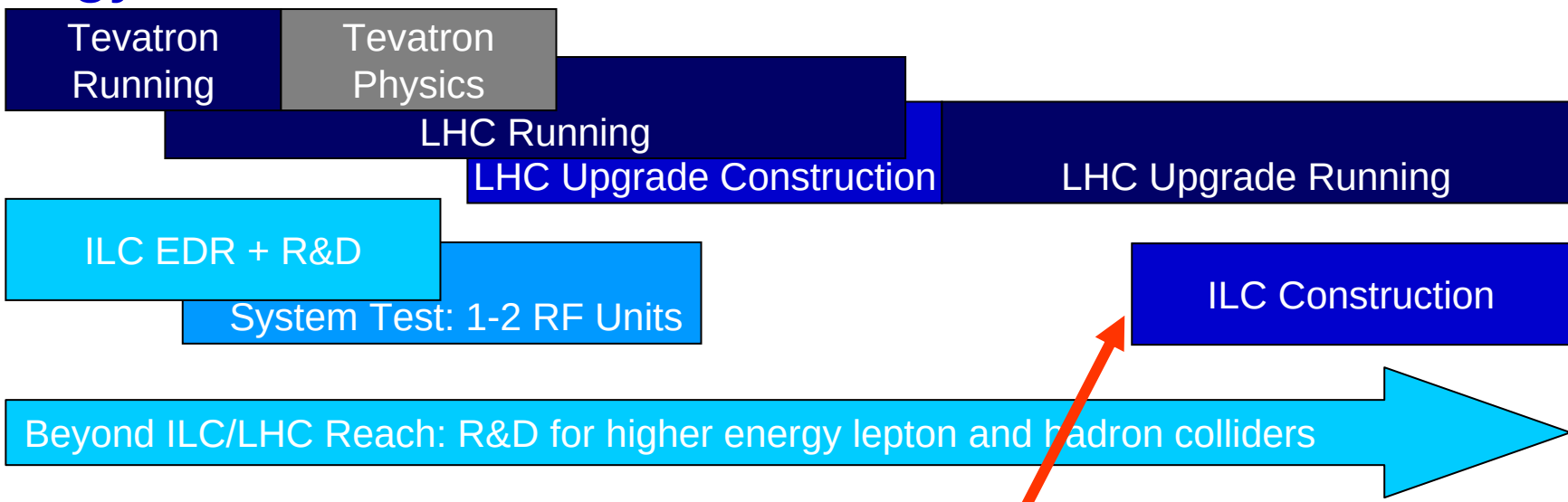


- Intensity Frontier (high intensity protons)

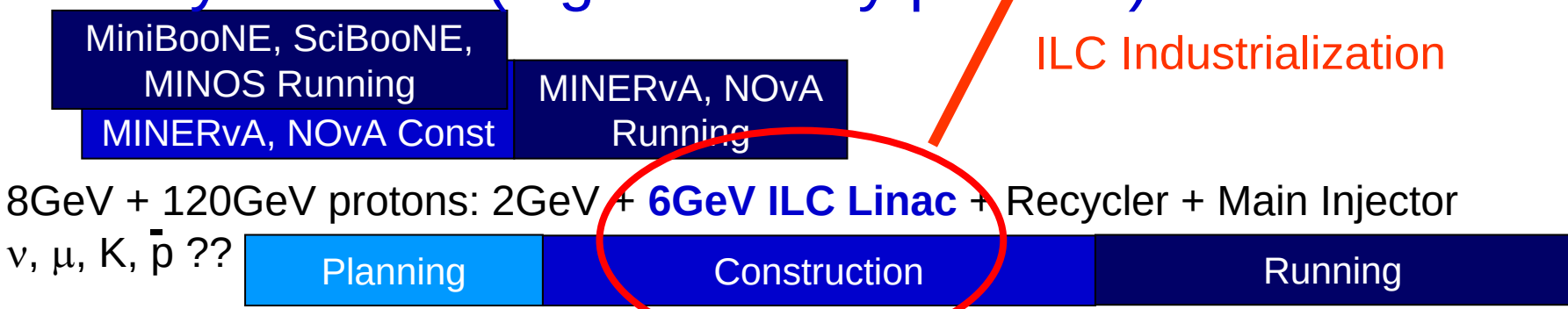
- Particle Astrophysics

A Possible Roadmap for ILC Scenario 3

- Energy Frontier

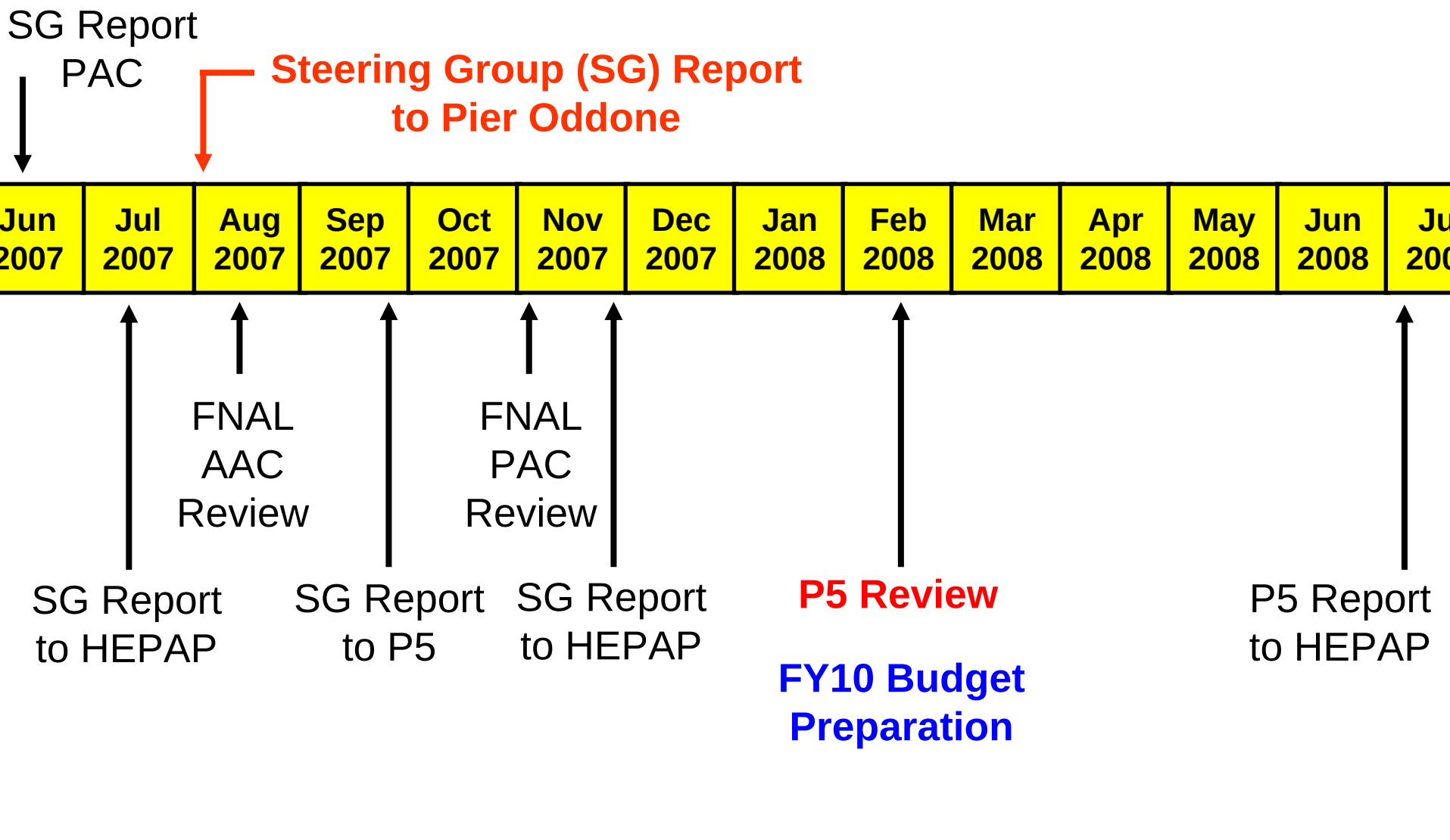


- Intensity Frontier (high intensity protons)



- Particle Astrophysics

End Game of Fermilab Roadmap



End Game of Fermilab Roadmap

- Communication with Community
  - US HEP Community
  - International HEP Community