A STAGED PATHWAY TO THE ENERGY FRONTIER

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INTRODUCTION

- The following presents an illustrative long-term multi-stage vision for the future of the national high energy physics program that takes the U.S. back to the energy frontier.

- The vision maintains a flexible diverse world-class domestic accelerator-based program at every stage.

- The vision is not bound by any "budget guidance" … the rough budget required for a healthy future is an output not an input.

- The details presented (for example, the particular list of experiments, or exact budget numbers or timescales) are for illustration only. The purpose is to illustrate scope and direction, rather than promote a specific set of experiments.

WORKING ASSUMPTIONS

(1) The long-term vision for Fermilab should lead us back to the energy frontier.

(2) New technologies and approaches are required that will span many years in development, but must be embraced.

(3) A healthy experimental program must exist along the way to attract students into the field and maintain a diverse population of scientific users.

(4) We must be willing to shoulder large costs, but ones that are reasonably distributed over time and matched to the discovery potential of the overall program.

ILC & LHC ASSUMPTIONS

(1) SCRF R&D for ILC will proceed

(2) We will not know the fate of the ILC until 2010-2012 or later, contingent upon LHC physics results.

(3) There is at least a 10 year gap between the end of the Tevatron Collider running and the beginning of the ILC running.

(4) The U.S. will be fully participating in the LHC and its upgrades.

ENERGY FRONTIER POSSIBILITIES

- There are three plausible beyond-the-LHC ENERGY FRONTIER machines that are/have been considered:

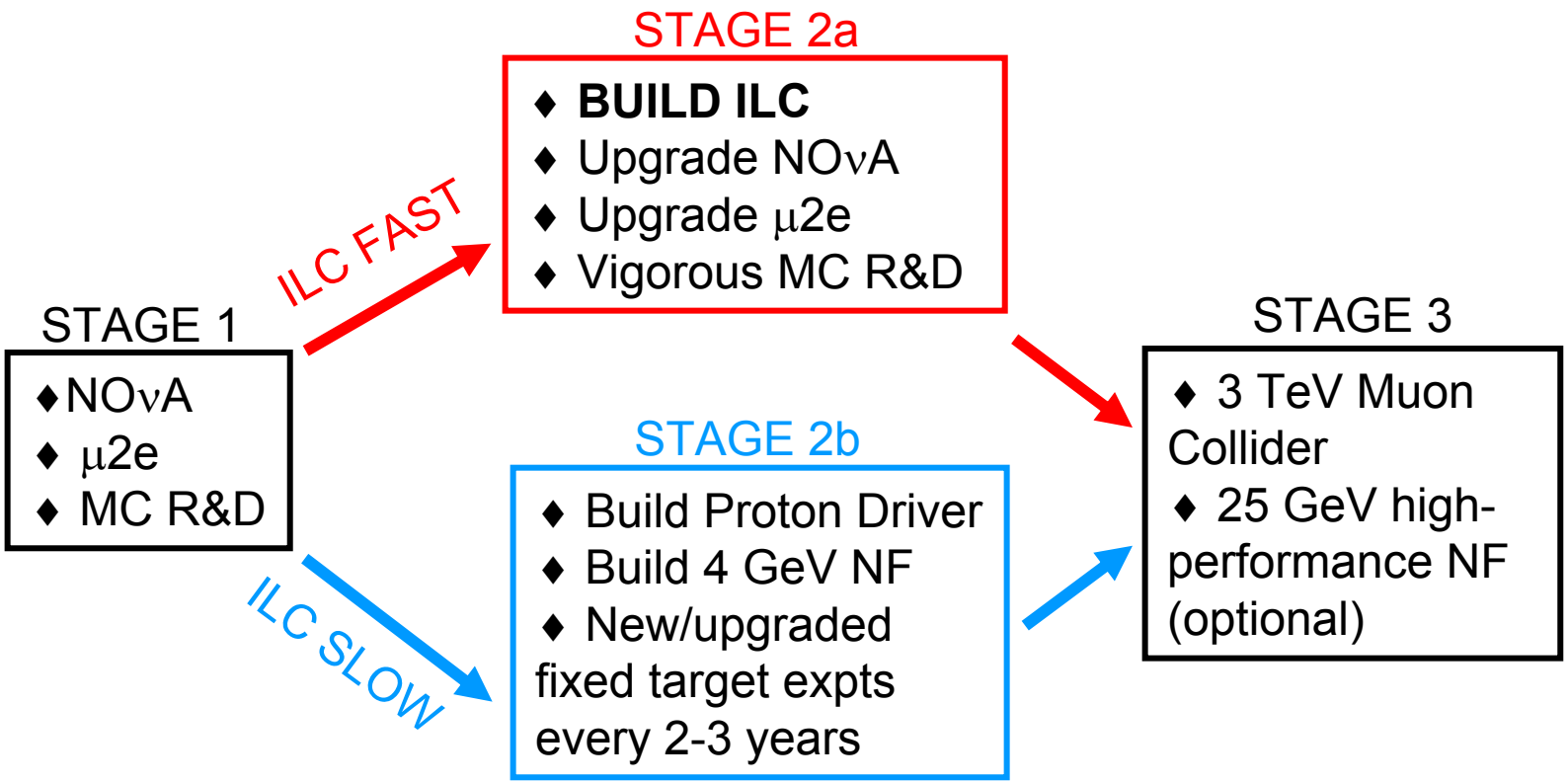
  - VLHC
  - Multi-TeV Linear Collider
  - Muon Collider

- In the following we show an illustrative vision for a staged pathway to a multi-TeV Muon Collider.

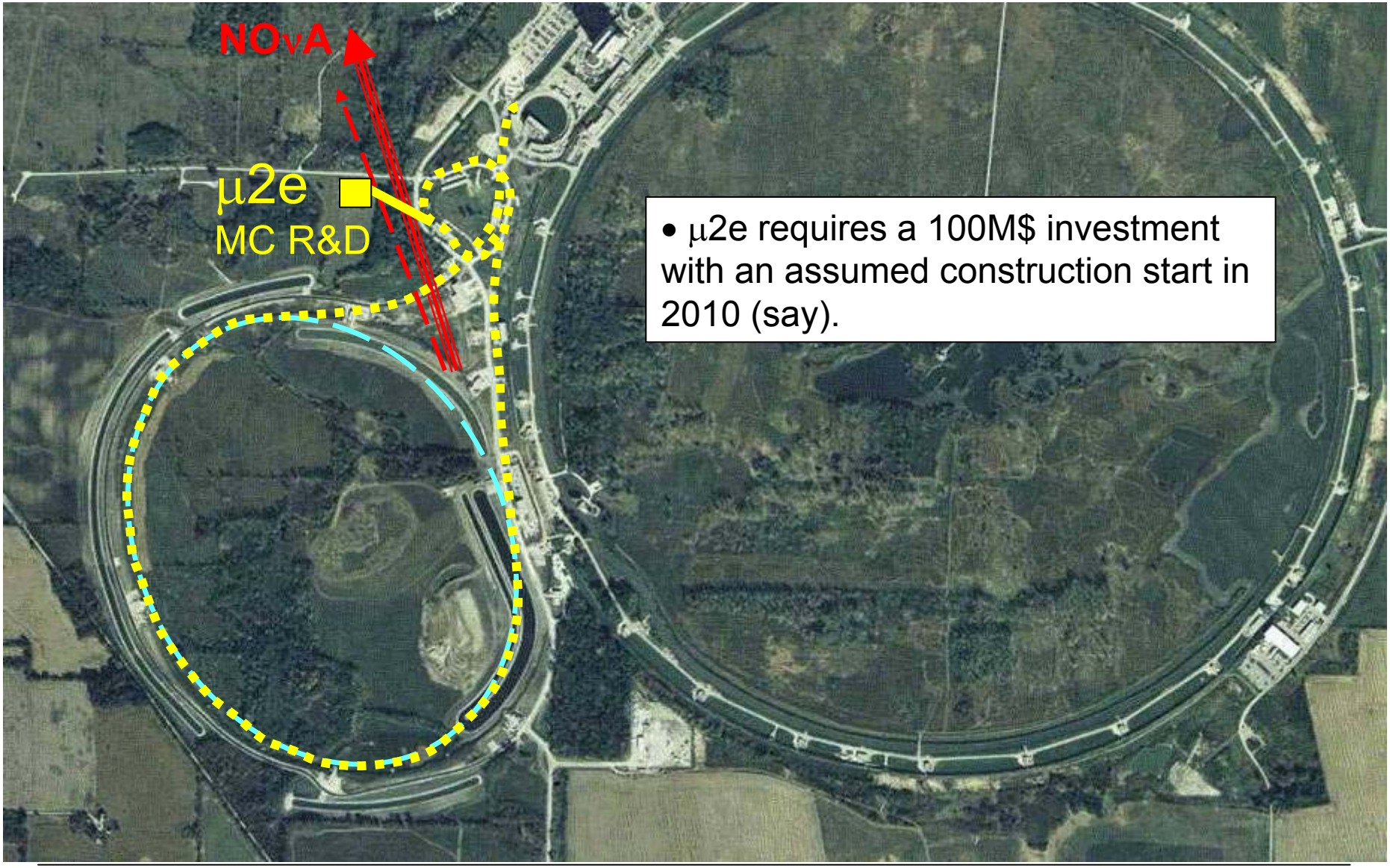
- The vision depends upon whether the ILC is under construction in a few years time:

  - fast track scenario
  - slow track scenario

A MUON-BASED FUTURE IN THREE STAGES

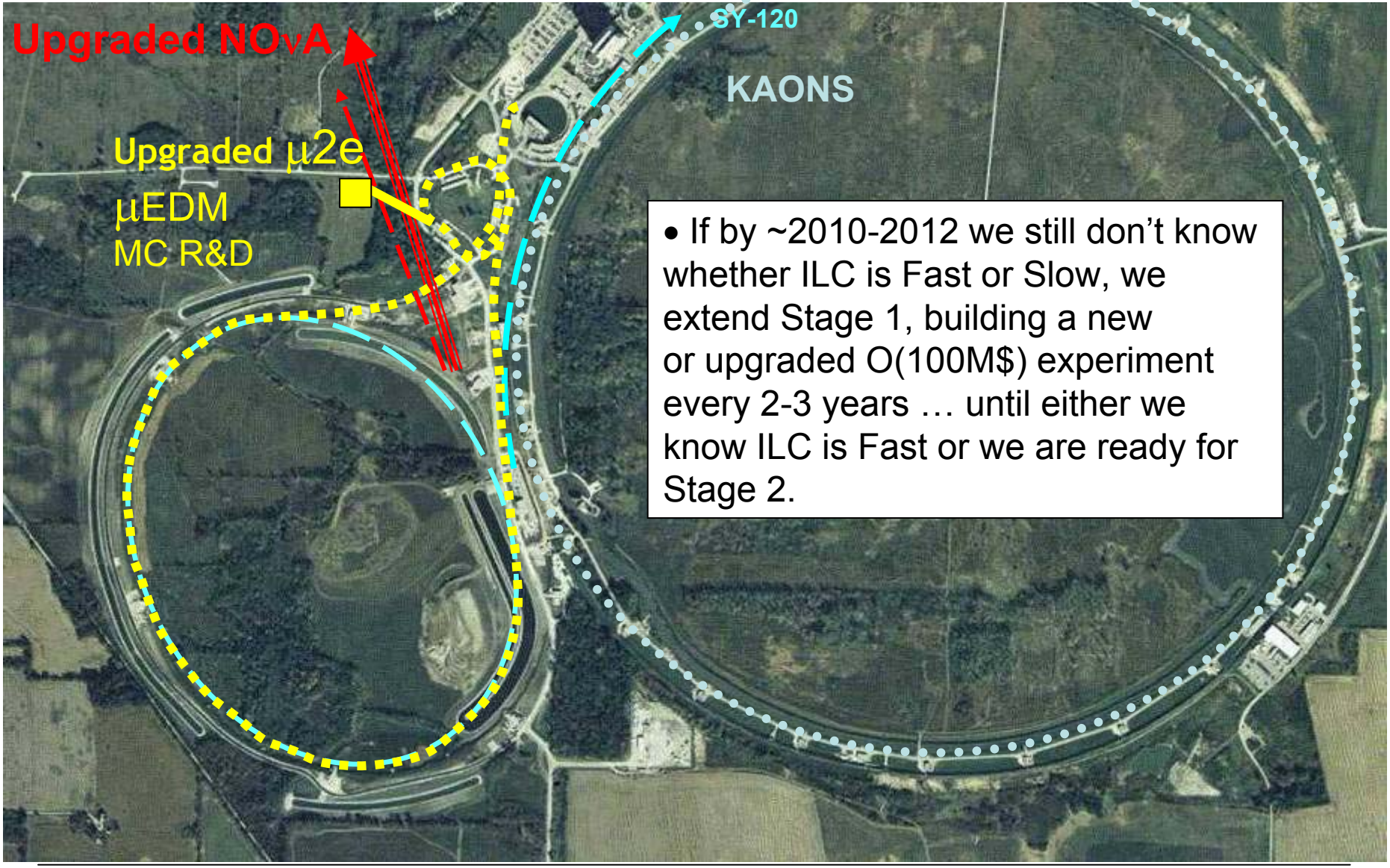


Stage 1: Independent of ILC Fast/Slow



- μ2e requires a 100M$ investment with an assumed construction start in 2010 (say).

Stage 1 Extended: Neutrinos, Muons & Kaons



- If by ~2010-2012 we still don't know whether ILC is Fast or Slow, we extend Stage 1, building a new or upgraded O(100M$) experiment every 2-3 years … until either we know ILC is Fast or we are ready for Stage 2.

STAGE 1 Extended: Construction Funds

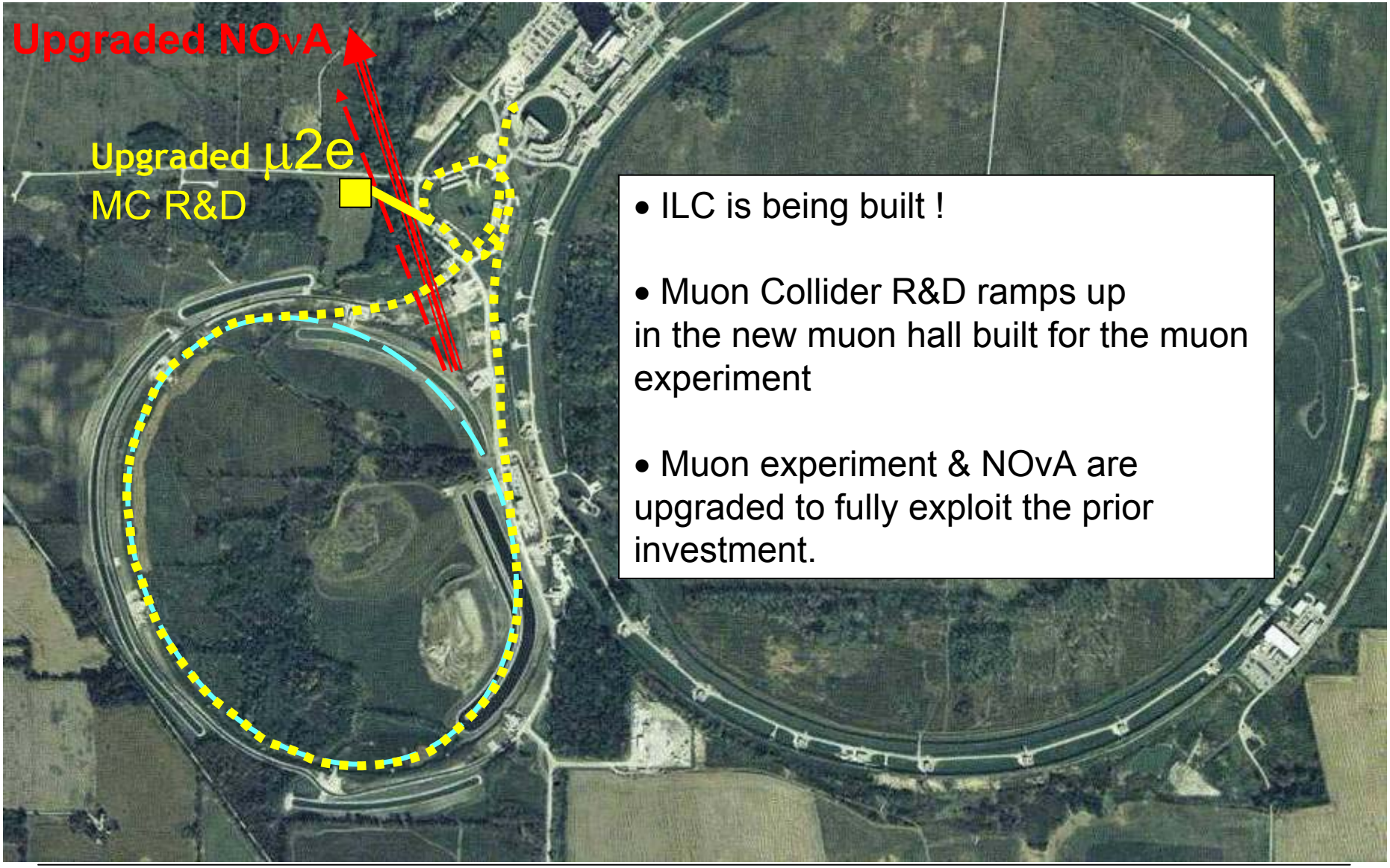
Putting in place a strong DOMESTIC PROGRAM at the present complex, that ultimately leads to an energy frontier Muon Collider (Stages 2 & 3).

		MC R&D	Expt 1	Expt 2	Expt 3	Expt 4
Candidate Expt ?			μ2e	Kaon	μEDM	NoVA Upgr
YEAR	**Sub Tot**		**100**	**100**	**100**	**200**
1	**20**	10	10			
2	**50**	10	40			
3	**60**	10	40	10		
4	**70**	10	10	40	10	
5	**80**	10	Running	30	40	
6	**90**	10	Running	20	30	30
7	**100**	10	Running	Running	20	70
8	**110**	10	Running	Running	Running	100

EXTENDED PROGRAM

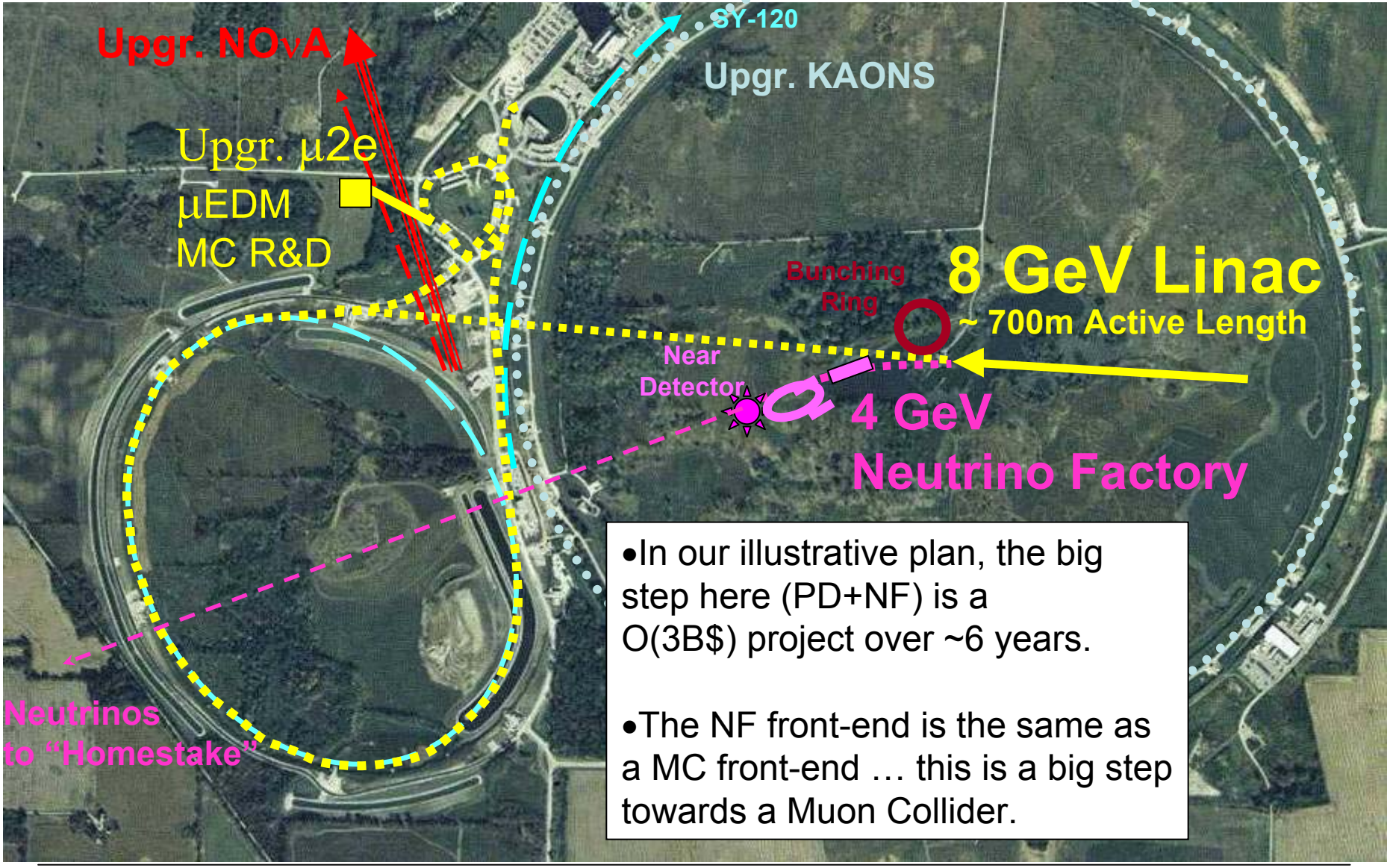
Note: NOνA assumed to be already funded

Stage 2a: ILC Fast



- ILC is being built !
- Muon Collider R&D ramps up in the new muon hall built for the muon experiment
- Muon experiment & NOvA are upgraded to fully exploit the prior investment.

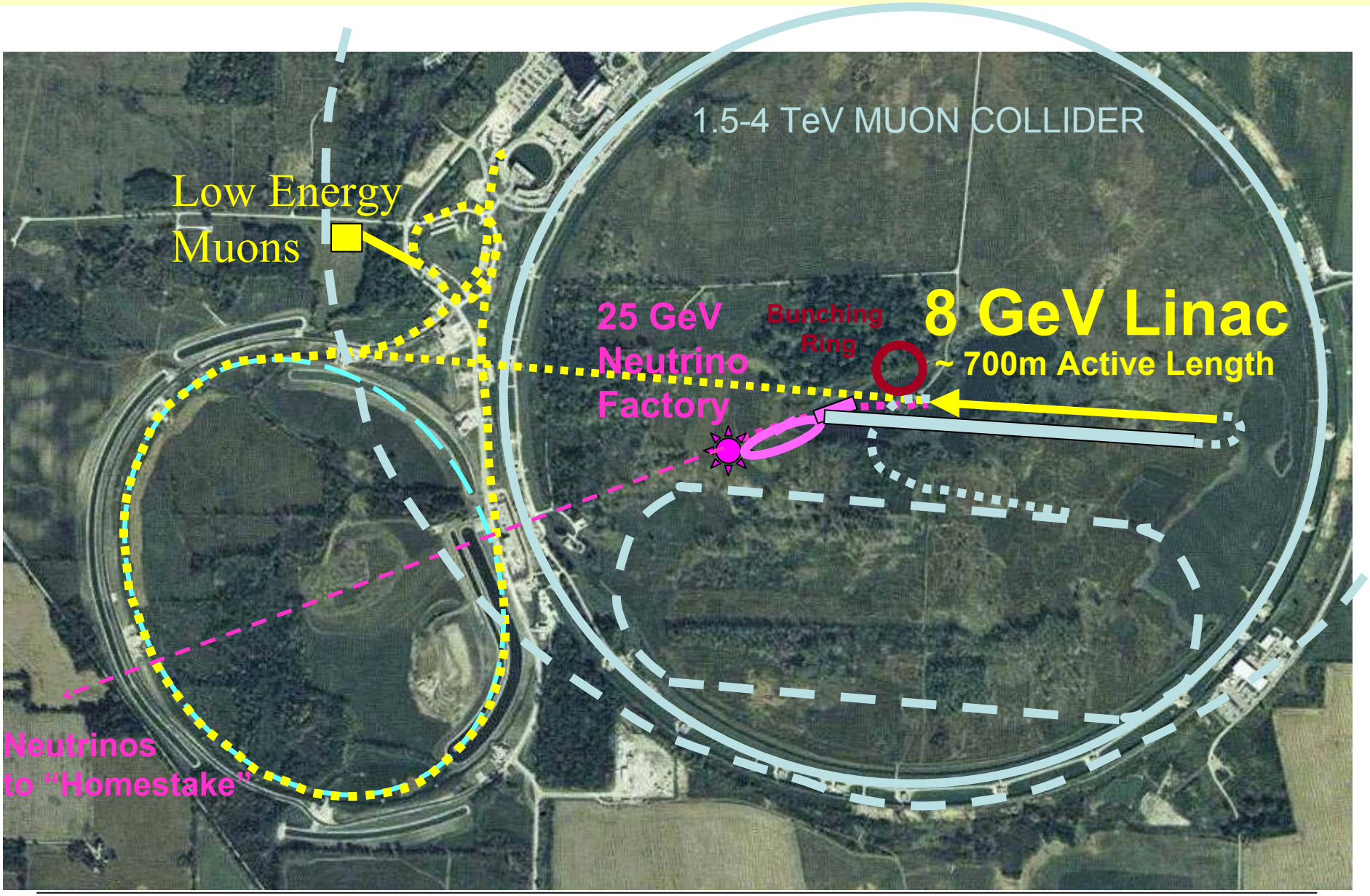
Stage 2b (ILC Slow): Proton Driver & 4 GeV Neutrino Factory



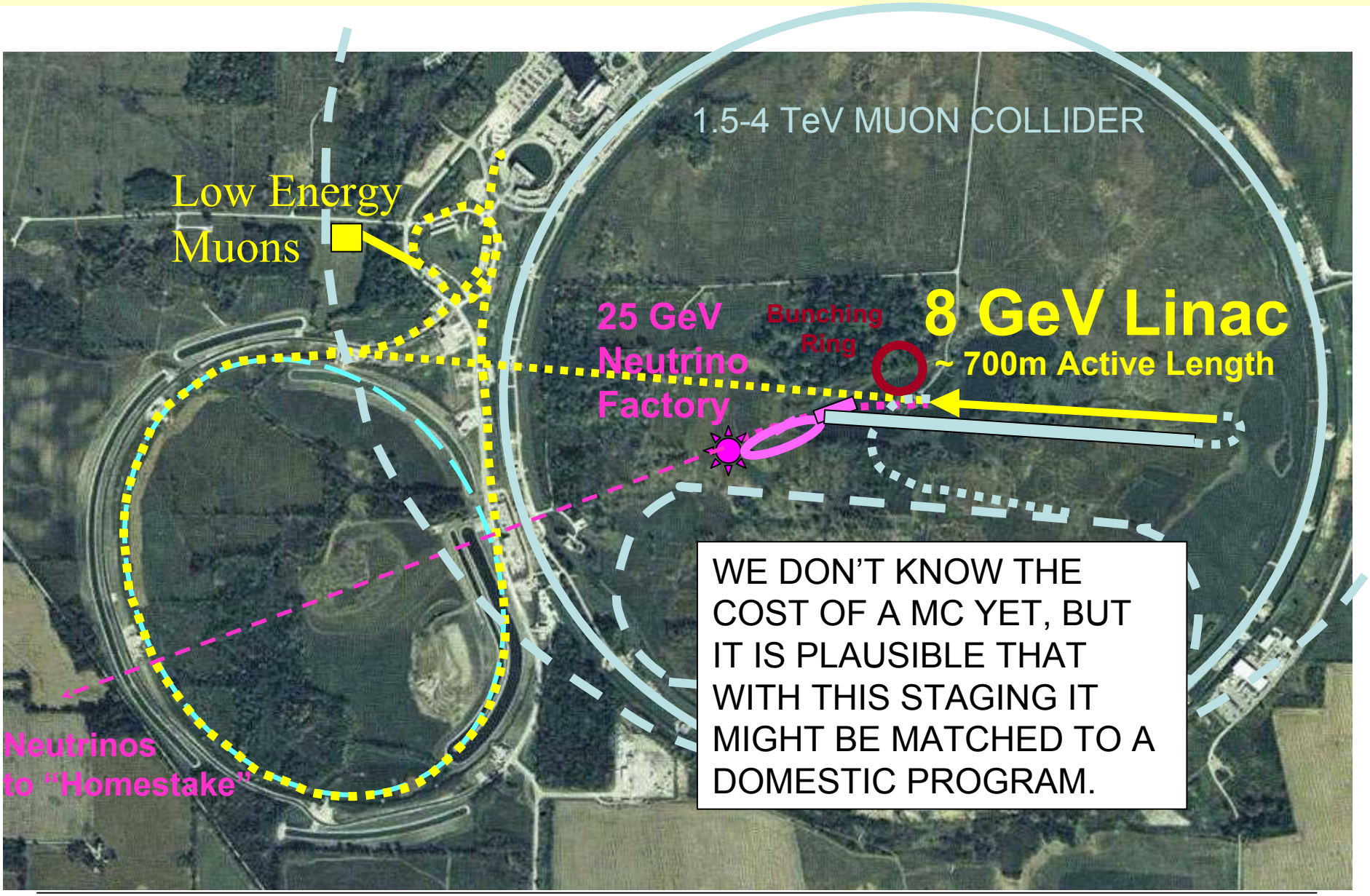
- In our illustrative plan, the big step here (PD+NF) is a O(3B$) project over ~6 years.

- The NF front-end is the same as a MC front-end … this is a big step towards a Muon Collider.

Stage 3b: Muon Collider & 25 GeV Neutrino Factory



Stage 3b: Muon Collider & 25 GeV Neutrino Factory



WE DON'T KNOW THE COST OF A MC YET, BUT IT IS PLAUSIBLE THAT WITH THIS STAGING IT MIGHT BE MATCHED TO A DOMESTIC PROGRAM.

STAGES 2b and 3b

Peak annual construction funding = 800M$ → DOMESTIC PROGRAM ?

		PROJECT 1: 3000 M$			BASE PROGRAM EXPERIMENTS			PROJECT 2: 4600 M$		
		PD+NF	PD Det 1	NF Det 1	PD Det 2	PD Det 3	MC R&D	NF Det 2 + Upgrade	MC	MC Det
YEAR	**Sub Tot**	**2300**	**200**	**500**	**200**	**200**	**380**	**600**	**3000 (?)**	**1000**
9	**210**	150	40	0			20			
10	**380**	300	60	0			20			
11	**770**	580	70	100			20			
12	**800**	600	30	150			20			
13	**700**	460	PD 1	150	40		50			
14	**420**	210	PD 1	100	60		50			
15	**300**		PD 1	NF 1	50	50	100	100	0	0
16	**350**		PD 1	NF 1	50	50	100	150	0	0
17	**570**			NF 1	PD 2	70		150	300	50
18	**800**			NF 1	PD 2	30		150	520	100
19	**800**			NF 1	PD 2	PD 3		50	600	150
20	**800**				PD 2	PD 3		NF 2	500	300
21	**800**					PD 3		NF 2	600	200
22	**680**					PD 3		NF 2	480	200
23						PD 3		NF 2		MC 1

Note: colored cells denote running experiments

SUMMARY

- We have presented an illustrative long-term vision for Fermilab that:

- Leads back to the energy frontier

-Respects the number 1 priority: Getting ILC onto a fast track

-Is robust against the uncertainty of when we will know that the ILC is on the fast track? (Stage 1 → Extended Stage 1)

-Is robust against uncertiainties in the fate of the ILC (Extended Stage 1 evolves into ILC fast track or into an alternative path)

-Is staged, & preserves a diverse world class accelerator-based program at each stage (new experiment every 2-3 years)

- If the path leads us through Stages 2b and 3b, there would be a large pre-MC project (PD+NF) followed by a large upgrade to a MC … these projects might be in the 3B$ - 5B$ range (fully loaded) although we are not far enough along with the MC R&D to provide a defensible cost estimate for Stage 3b.

APPENDIX: Neutrino Factory Cost

- Assume a 4 GeV Initial Neutrino Factory … requires detector ideas to work out. The upgraded (25 GeV) NF would be in the MC era, and use (part of) the MC cooling channel & acceleration.

- NF Study 2 cost (20 GeV) = 1538 M$ (unloaded, not including PD+Targetry)
  NF Study 2a design reduced cost by a factor of 0.6 → 923 M$

- Low Energy NF (hep-ph-xxxx) reduces cost by a factor 0.59 (guesstimate)
  → 544 M$ (unloaded, not including PD+Targetry)

- Assume loading factor = 2.4 → 1300 M$ (Loaded, not including PD+Targetry)

- Guess 500 M$ for fully active magnetized low energy NF Detector (consistent with ISS preliminary studies)

- Guess 1000 M$ for 2MW PD + Targetry

- NF upgrade to a 25 GeV (using the cooling + acceleration systems constructed for a MC) … guess 600 M$ for new detector + NF ring.