NNN 2014

International Workshop on Next generation Nucleon Decay and Neutrino Detectors

November 4-6, 2014
APC Laboratory, Paris, France

BEAMS SESSION SUMMARY

ROBERT J. WILSON
COLORADO STATE UNIVERSITY
6 NOVEMBER 2014

14:00 - 17:30	**Parallel session 4: Beams**	
	Responsable:	R. Wilson (Colorado State Univ.)
	Lieu:	Francois Arago Centre (360)

14:00 **Neutrino Beam layout from LAGUNA-LBNO** *30'*
Intervenant: I.Efthymiopoulos (CERN)
Documents: Transparents

14:30 **Fermilab future beam studies** *30'*
Intervenant: V. Papadimitriou (Fermilab)
Documents: Slides

15:00 **J-PARC future beam studies** *30'*
Intervenant: M. Tada (J-PARC)

15:30 **Coffee Break** *30'*

16:00 **Nustorm** *30'*
Intervenant: K. Long (Imperial College London)
Documents: Slides

16:30 **ESS beam studies** *30'*
Intervenant: T. Ekelof (Uppsala Univ.)
Documents: Transparents

17:00 **IsoDAR/DAEdALUS** *30'*
Intervenant: J. Spitz (MIT)
Documents: Slides

365 slides

14:00-18:20

https://indico.in2p3.fr/event/10162/

14:00 - 17:30 **Parallel session 4: Beams**

Responsable: R. Wilson (Colorado State Univ.)

Lieu: Francois Arago Centre (360)

French - detected	English
responsable	responsible

English	French
convene	convoquer

verb **convoquer**
convene, call, summon, convoke, recall, send for

15:00

15:30

16:00

09:30 - 12:00 **Summary of parallel sessions**

Responsable: J. Dawson (APC/IN2P3)

09:30	**Beams** *30'*
10:00	**LAr** *30'*
10:30	**Coffee Break** *30'*
11:00	**WCh** *30'*
11:30	**LSci** *30'*

Documents: **Slides**

https://indico.in2p3.fr/event/10162/

Neutrino beam layout for LAGUNA-LBNO

I. Efthymiopoulos - CERN

Findings of the LBNO Design Study

Design Highlights of the CERN Neutrinos to PYhäsalmi - CN2PY Neutrino Beam

High Power PS/nu beam line

Layout options at CERN

The LBNO Study - CN2PY LBL ν-beam

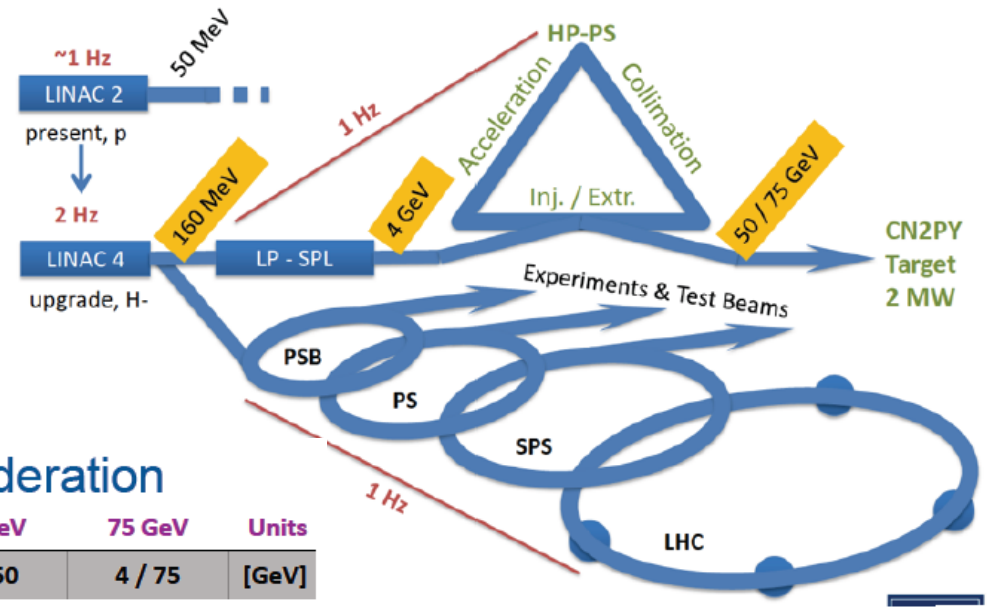
CERN Neutrinos 2 PYhäsalmi beam

- **Phase 1** : proton beam extracted beam from SPS
  - **400 GeV**, max 7.0 10^{13} protons every 6 sec, **~750 kW** nominal beam power, double extraction, 10 μs pulse
- **Phase 2** : use the proton beam from a new HP-PS
  - 50(75) GeV, 1.33 Hz, 1.9 10^{14} ppp, **2 MW** nominal beam power, 4 μs pulse
  - alternative option: upgraded SPS
  - CN2PY baseline also compatible with a NF option

Beam parameters

- 400 GeV protons from SPS (initial)
- Survey info:
  - CERN (TCC2 target station -NA) 46°15'26.27"N, 6° 3'8.19"E
  - Inmet Mine (Finland): 63°39'30.92"N, 26° 2'47.65"E
  - distance: 2296 km
  - dip angle : 10.4 deg, 181 mrad
- Neutrino beam at Pyhäsalmi ($\theta_{max} \approx$ 30 MeV/E_ν) : 14÷34 Km for E_ν 2÷5 GeV

CN2PY Phase 2: HP-PS Design



Two options for consideration

HP-PS Parameter	50 GeV	75 GeV	Units
Inj. / Extr. Kinetic Energy	4 / 50	4 / 75	[GeV]
Beam power	2		[MW]
Repetition rate	1		[Hz]
f_{rev}	0.234 / 39.31		[MHz]
RF harmonic	168		-
f_{rev}	0.238 /40.08	0.238 /40.08	[MHz]
Bunch spacing @ extr.	25		[ns]
Total beam intensity	2.5 E14	1.7 E14	-
Number of bunches	157		-
Intensity per bunch	1.6 E12	1.1 E12	-
Main dipole field inj. / extr.	0.19 / 2.1	0.19 / 3.13	[T]
Ramp time	500	500	[ms]
Dipole field rate dB/dt (acc. ramp)	3.5	5.5	[T/s]

HP-PS: Options

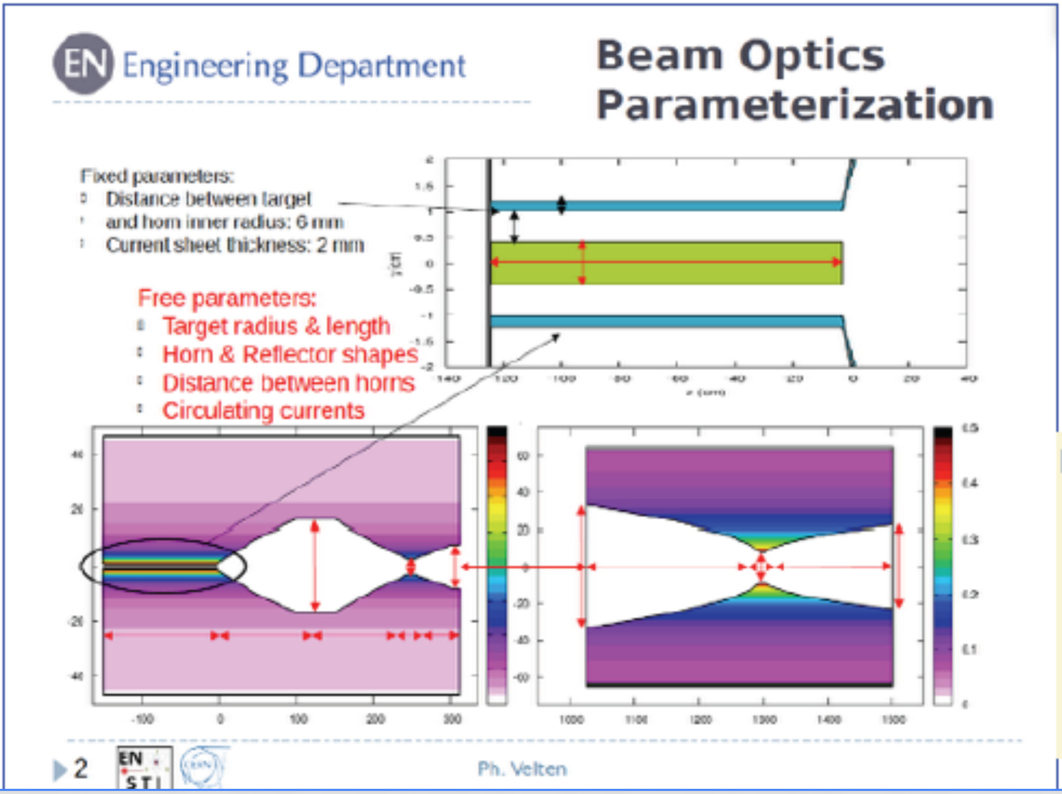
50 GeV : more convenient HW parameters but more demanding beam dynamics

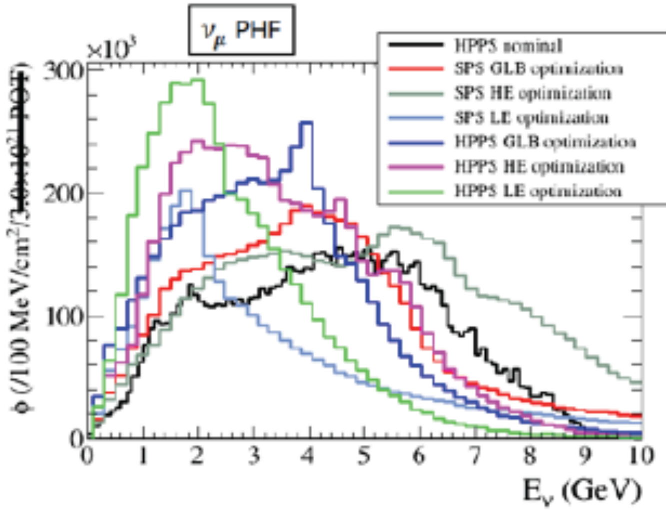
- dipole magnets ~available (FCM R&D)

75 GeV : more demanding magnet parameters but reduced beam intensity

CN2PY ν-beam optimisation

- Beam target and focusing system optimization using Genetic Algorithm
  - Multi-variable analysis of horn/reflector parameters
  - Optimization:
    - **use GLOBES** to maximize the δ_{CP} sensitivity at the FD
    - **HE-optimization**: maximum yield of ν-s in the range [1-10]GeV
    - **LE-optimization**: maximum yield of ν-s in the range [1-2] GeV





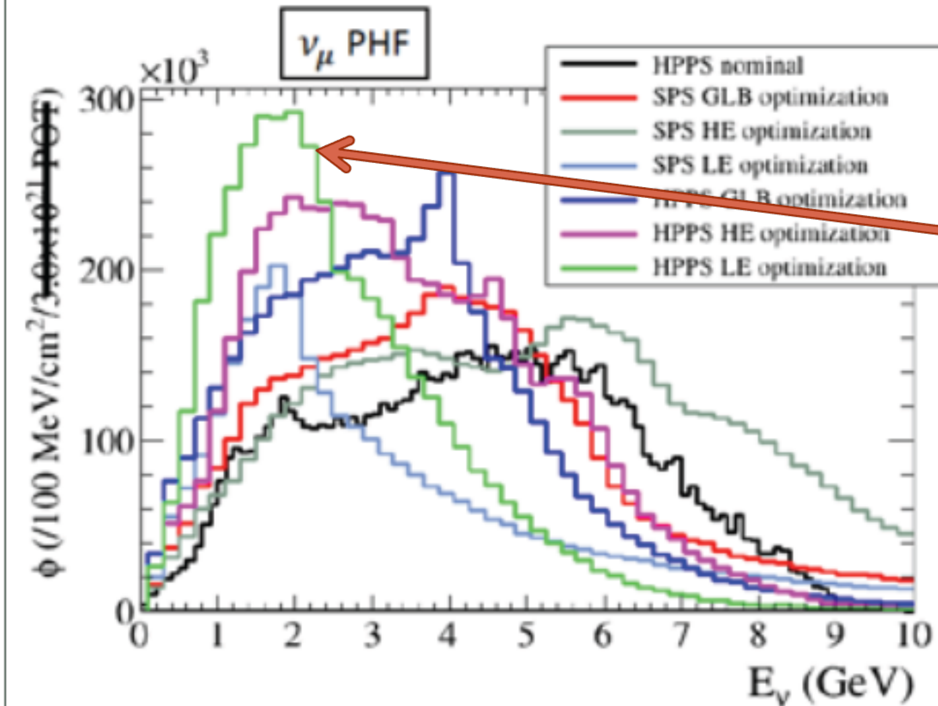
POT normalization for SPS: 3.75E+20

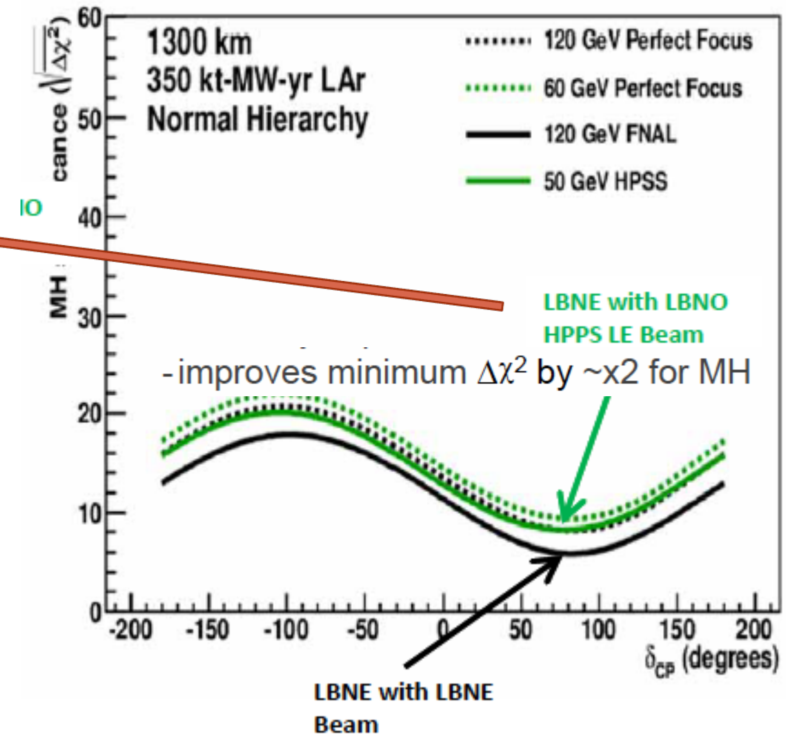
POT normalization for HPPS: 3.0E+21

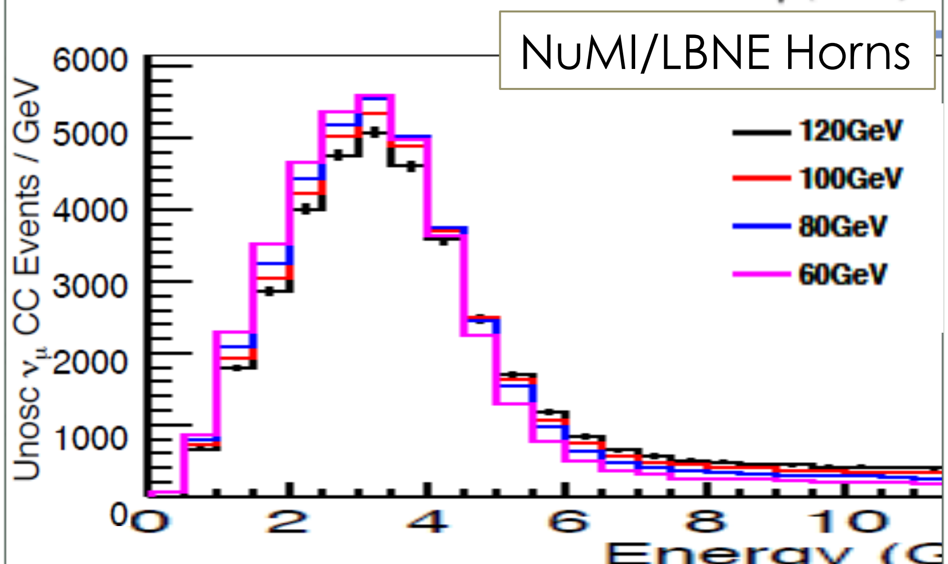
- New optimization for CDR, using additional engineering constraints:
  - R_{min} horn ~27mm
  - Same relative position horn/reflector for 400/50 GeV beams
  - Target length <1.3 m

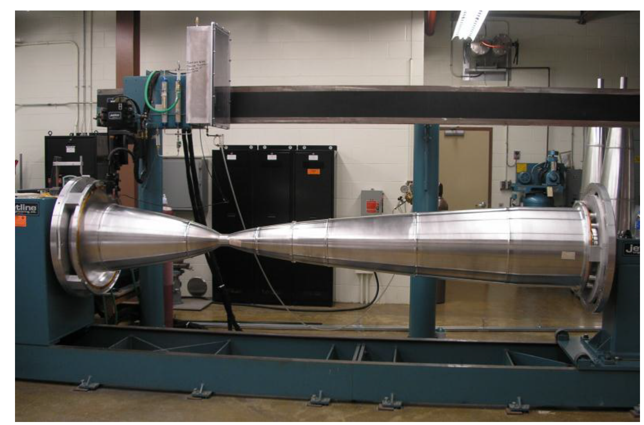
RJW Addendum

J.Strait – this meeting



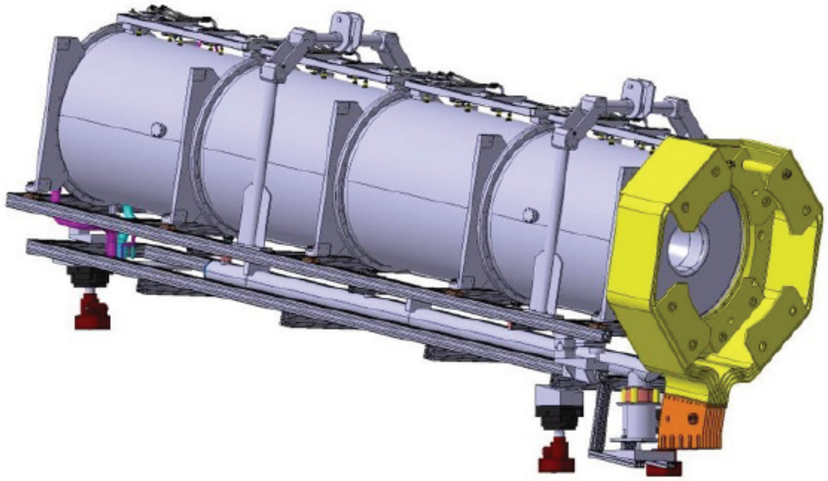


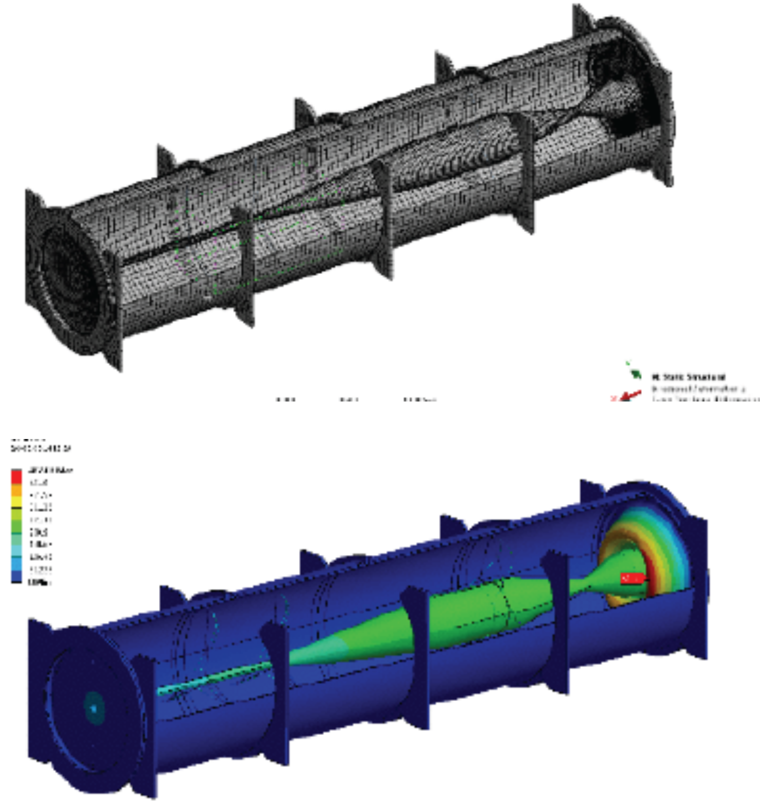




V. Papadimitriou– this meeting

CN2PY – Horn design

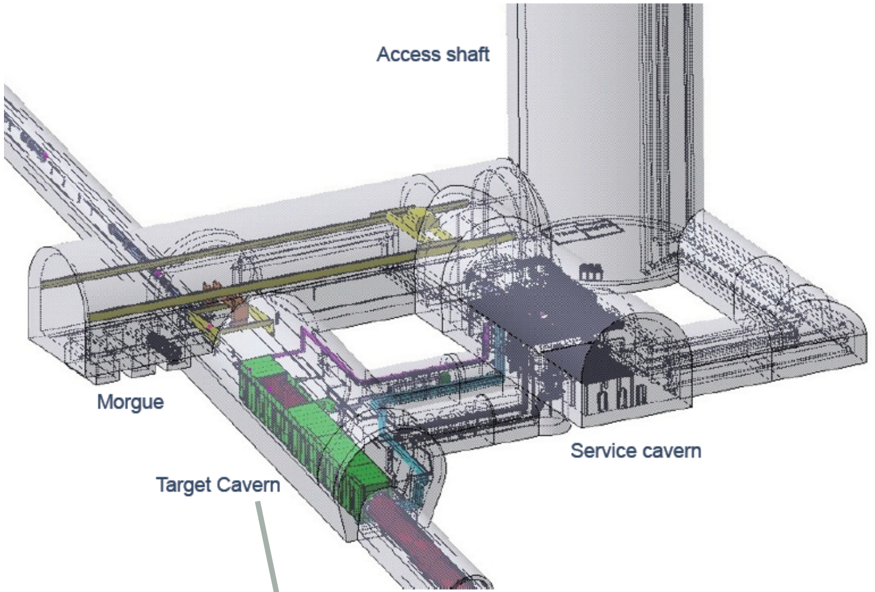


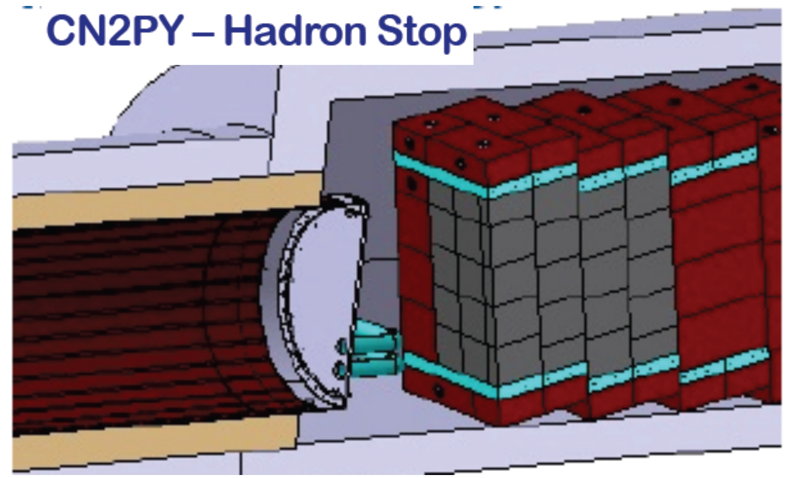


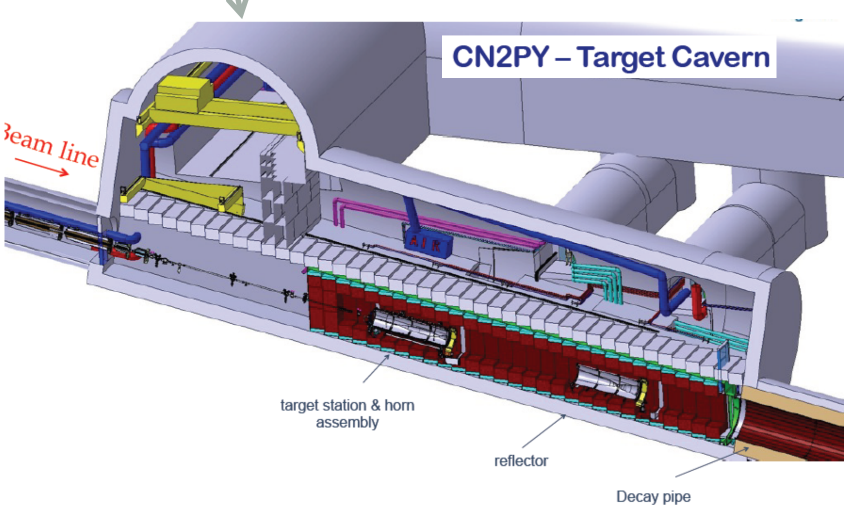
- Integrated target design - He cooled
  - 400 GeV operation: graphite rods, similar to CNGS
  - 50 Gev operation: graphite roods similar to T2K

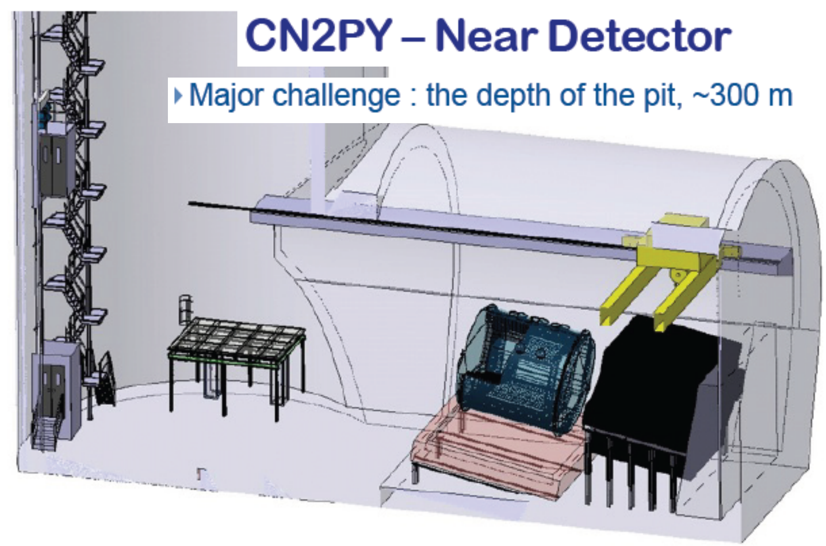
- Full structural analysis - no showstoppers identified

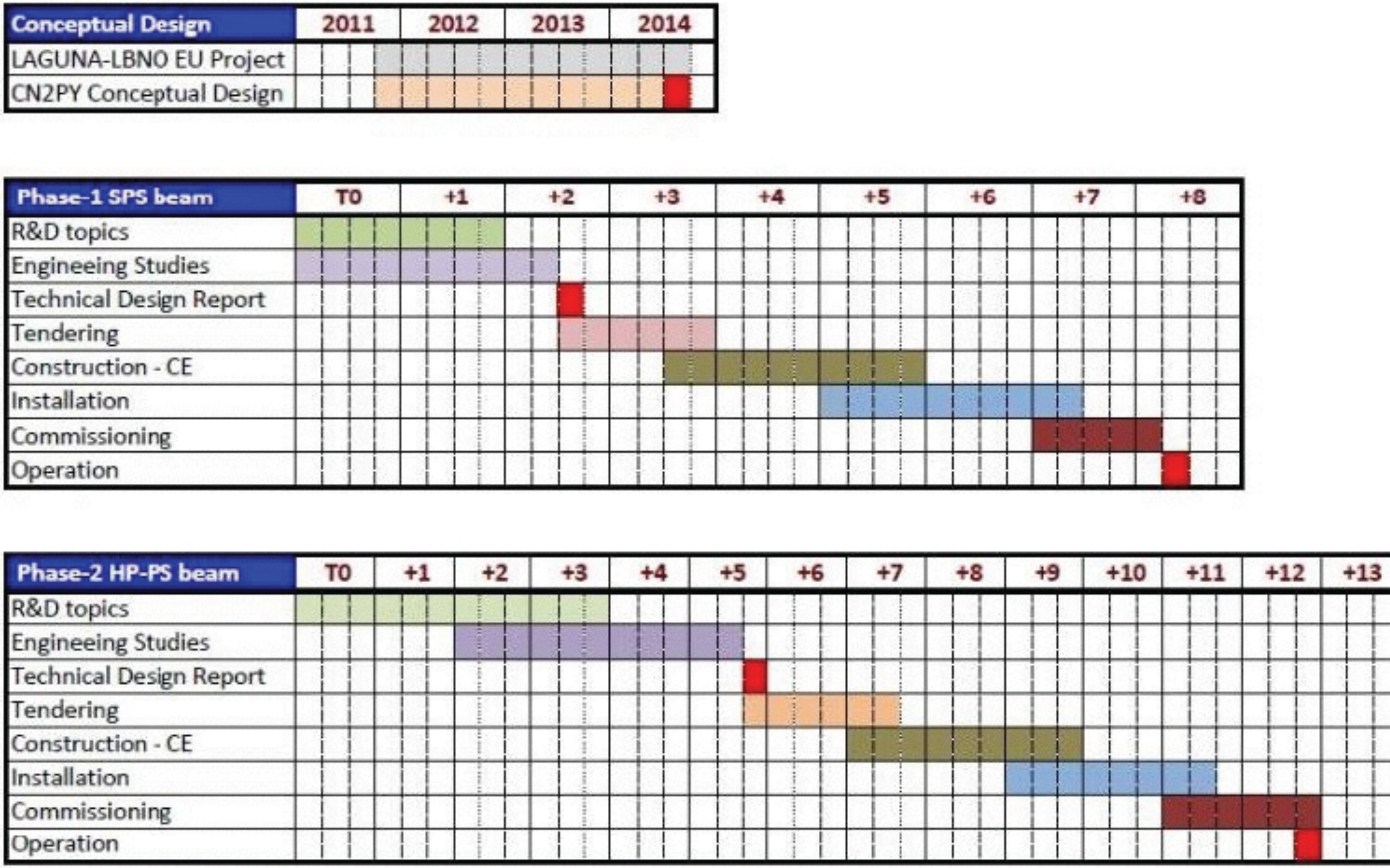
CN2PY – ν-beam underground structures







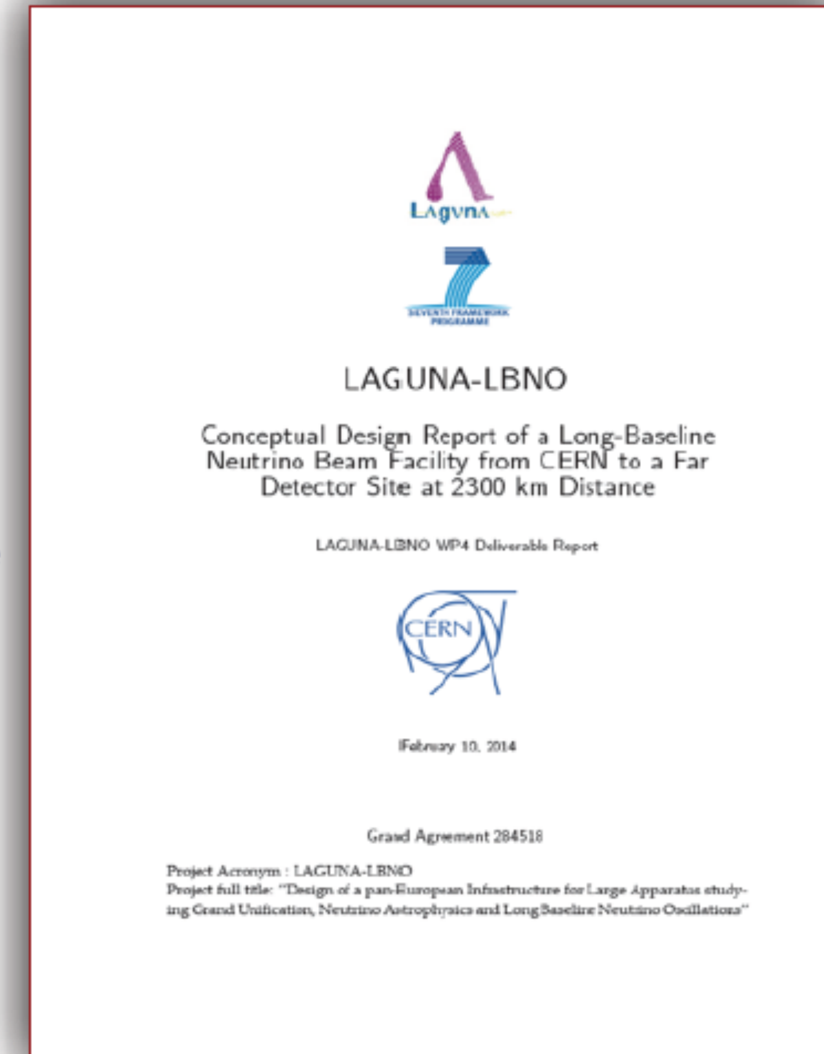




Conceptual Design
2011
2012
2013
2014
LAGUNA-LBNO EU Project
CN2PY Conceptual Design
Phase-1 SPS beam
T0
+1
+2
+3
+4
+5
+6
+7
+8
R&D topics
Engineeing Studies
Technical Design Report
Tendering
Construction - CE
Installation
Commissioning
Operation
Phase-2 HP-PS beam
T0
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
+11
+12
+13
R&D topics
Engineeing Studies
Technical Design Report
Tendering
Construction - CE
Installation
Commissioning
Operation

Summary

- The possibilities for a future long-baseline ν-beam from CERN to a far site in Europe to study the CPV and Mass Hierarchy in the Neutrino Sector were studied in the framework of the LAGUNA-LBNO EC/FP7 Design Study
- The study includes a conceptual design of a new High-Power proton synchrotron to be used as proton driver providing a 2 MW beam in the range of 50-75 GeV.
- The study builds upon the experience and available expertise at CERN from CNGS and the design of hadron machines, and is done in view of promoting solutions and technologies as well as synergies with other projects in the Lab
- The findings of this study will be documented in the CDR report of LAGUNA-LBNO, soon to be released, that could serve a basis for a technical design in a future realisation of such a facility at CERN or elsewhere


LAGUNA-LBNO

Conceptual Design Report of a Long-Baseline Neutrino Beam Facility from CERN to a Far Detector Site at 2300 km Distance

LAGUNA-LBNO WP4 Deliverable Report

February 10, 2014

Grand Agreement 284518

Project Acronym : LAGUNA-LBNO
Project full title: "Design of a pan-European Infrastructure for Large Apparatus studying Grand Unification, Neutrino Astrophysics and Long Baseline Neutrino Oscillations"

Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Fermilab Future Beam Studies

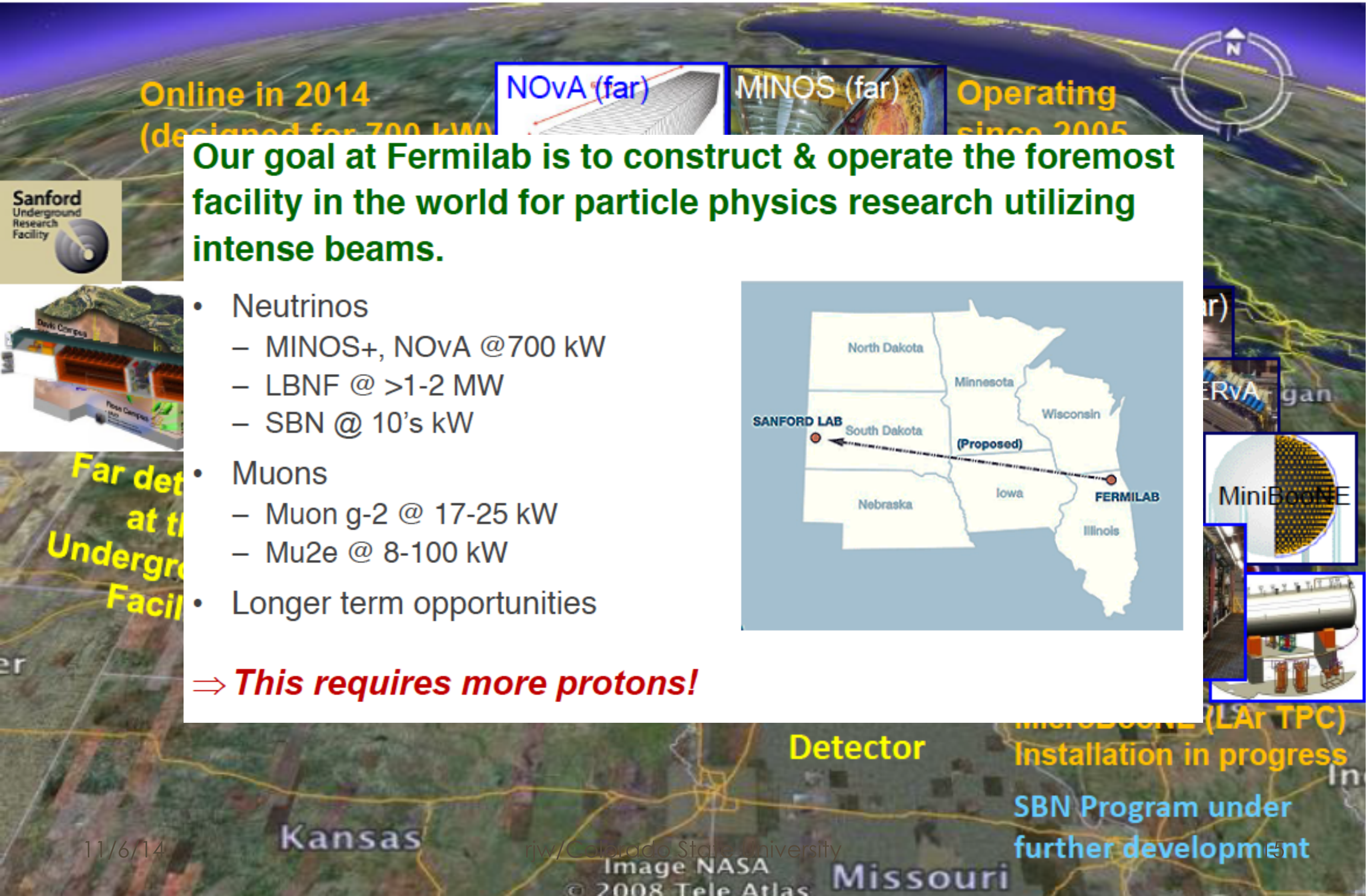
Vaia Papadimitriou
Accelerator Division Headquarters – Fermilab

NNN 2014, APC, Paris, FRANCE

4-6 November, 2014

Fermilab Accelerator Complex

Neutrino Program at Fermilab



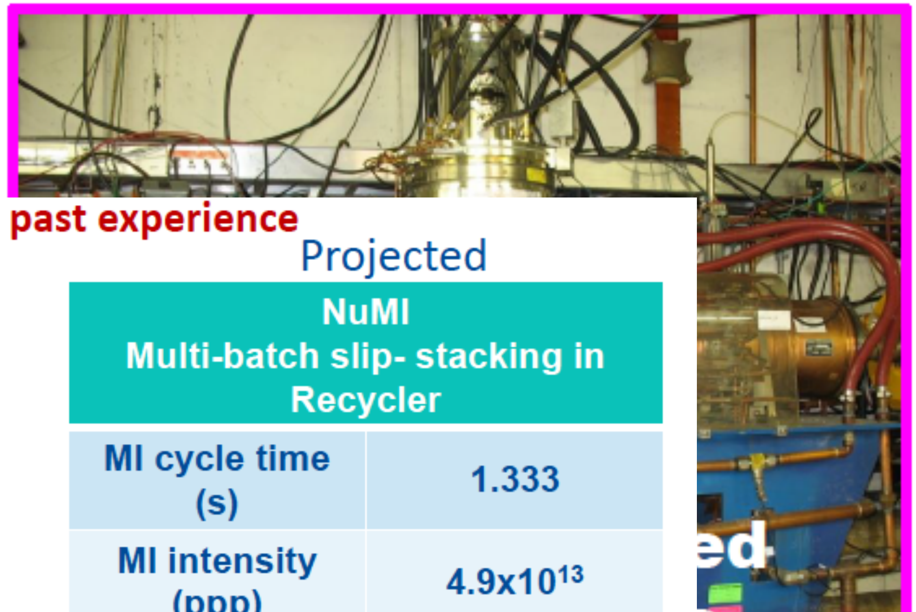
Our goal at Fermilab is to construct & operate the foremost facility in the world for particle physics research utilizing intense beams.

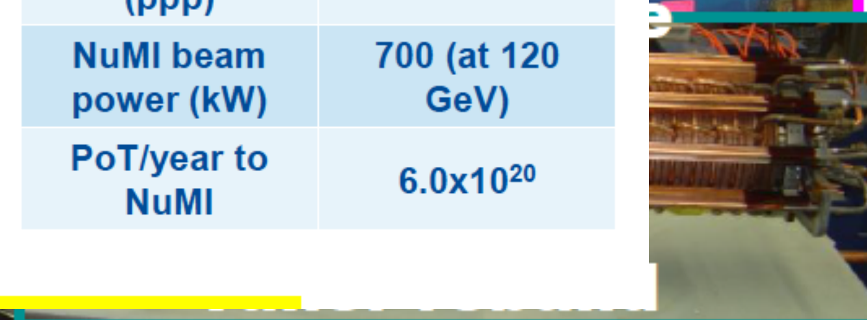
- Neutrinos
  - MINOS+, NOvA @700 kW
  - LBNF @ >1-2 MW
  - SBN @ 10's kW
- Muons
  - Muon g-2 @ 17-25 kW
  - Mu2e @ 8-100 kW
- Longer term opportunities

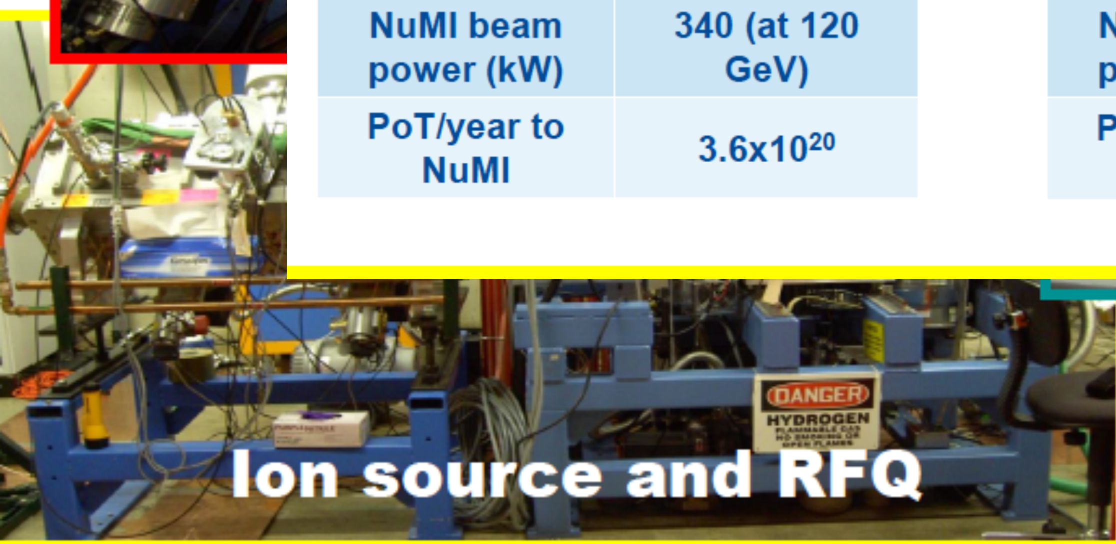
⇒ ***This requires more protons!***

Proton Improvement Plan (PIP)

- Replaced obsolete components to improve reliability
  - **40 year old Proton Source**
- Refurbishing Booster RF cavities to run at 15 Hz







Building on past experience

Past (FY2012)

NuMI Multi-batch slip- stacking in Main Inj.	
MI cycle time (s)	2.1
MI intensity (ppp)	3.7×10^{13}
NuMI beam power (kW)	340 (at 120 GeV)
PoT/year to NuMI	3.6×10^{20}

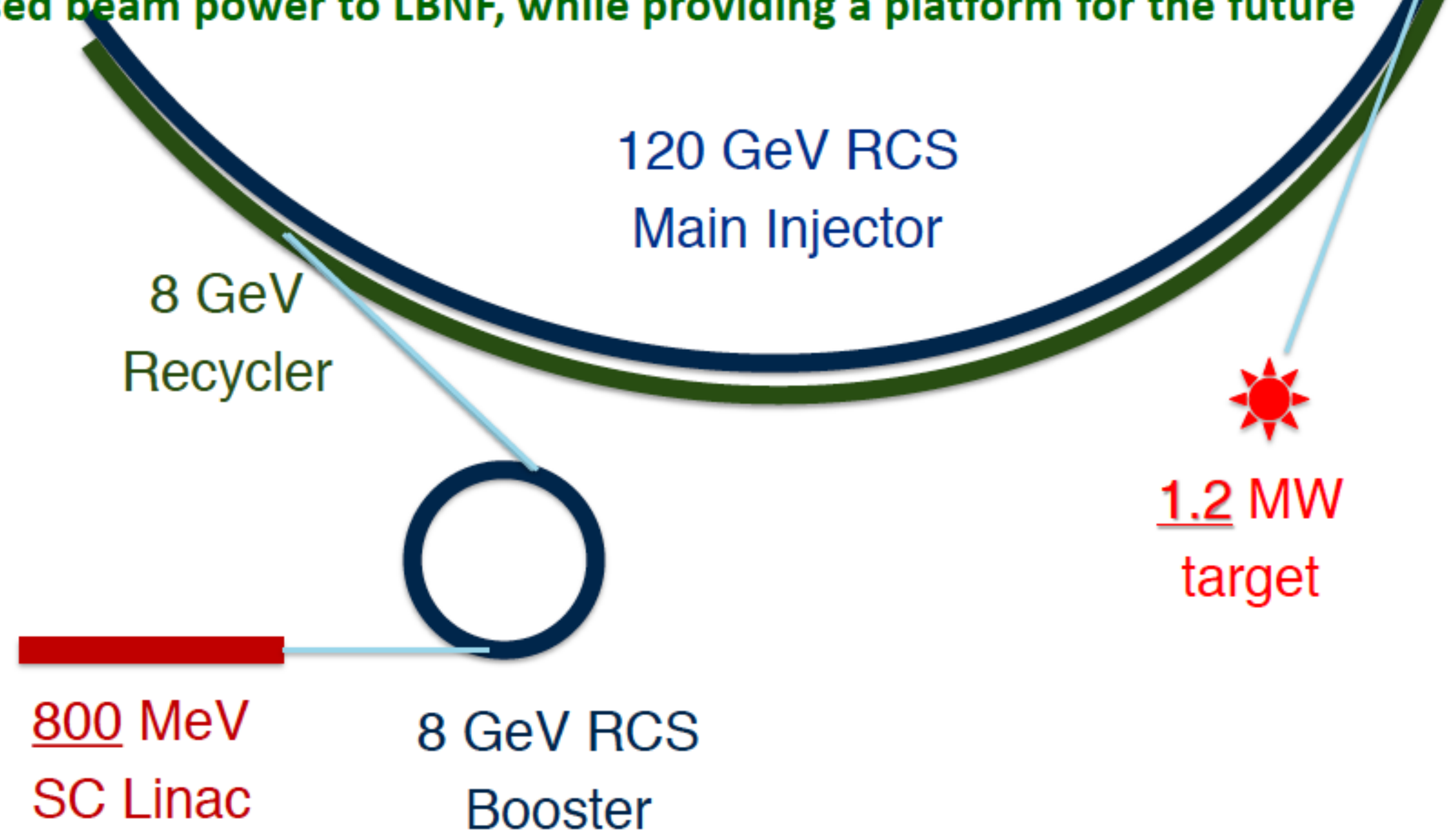
Projected

NuMI Multi-batch slip- stacking in Recycler	
MI cycle time (s)	1.333
MI intensity (ppp)	4.9×10^{13}
NuMI beam power (kW)	700 (at 120 GeV)
PoT/year to NuMI	6.0×10^{20}

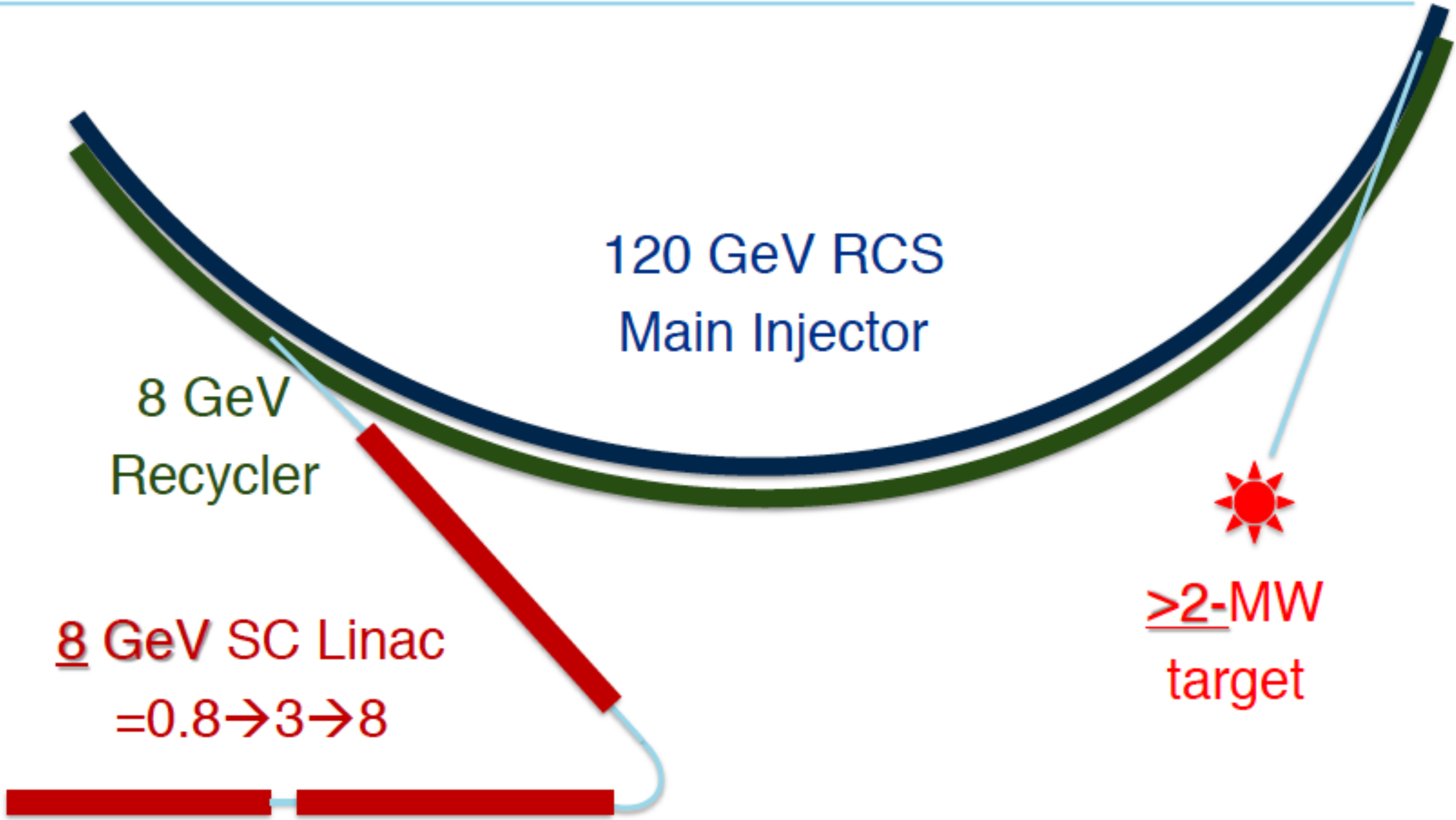
- **13 of 19 cavities have been refurbished to run at 15 Hz**

Near future, PIP-II , ca 2023-24

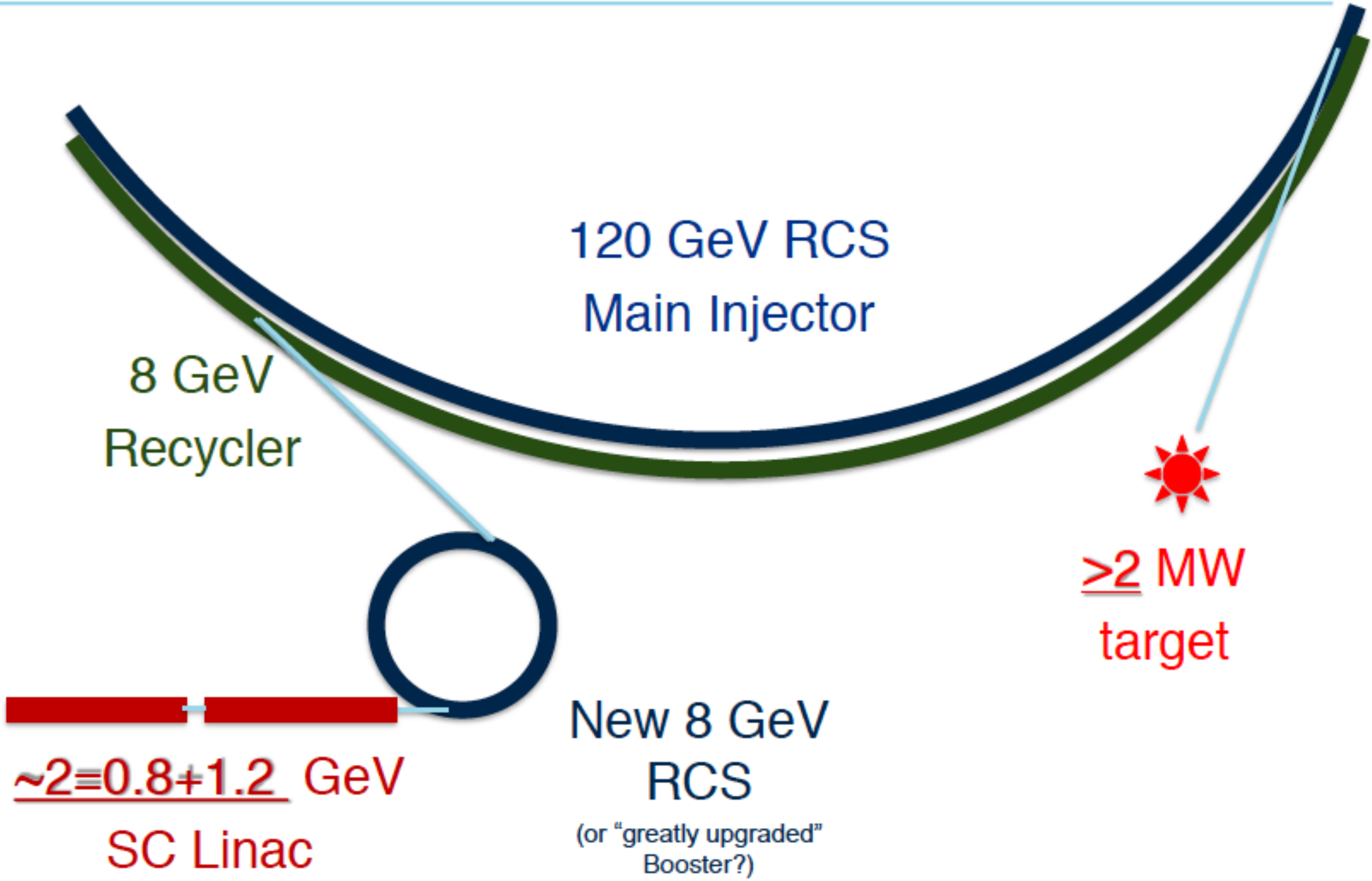
The PIP-II goal is to support long-term physics research goals by providing increased beam power to LBNF, while providing a platform for the future



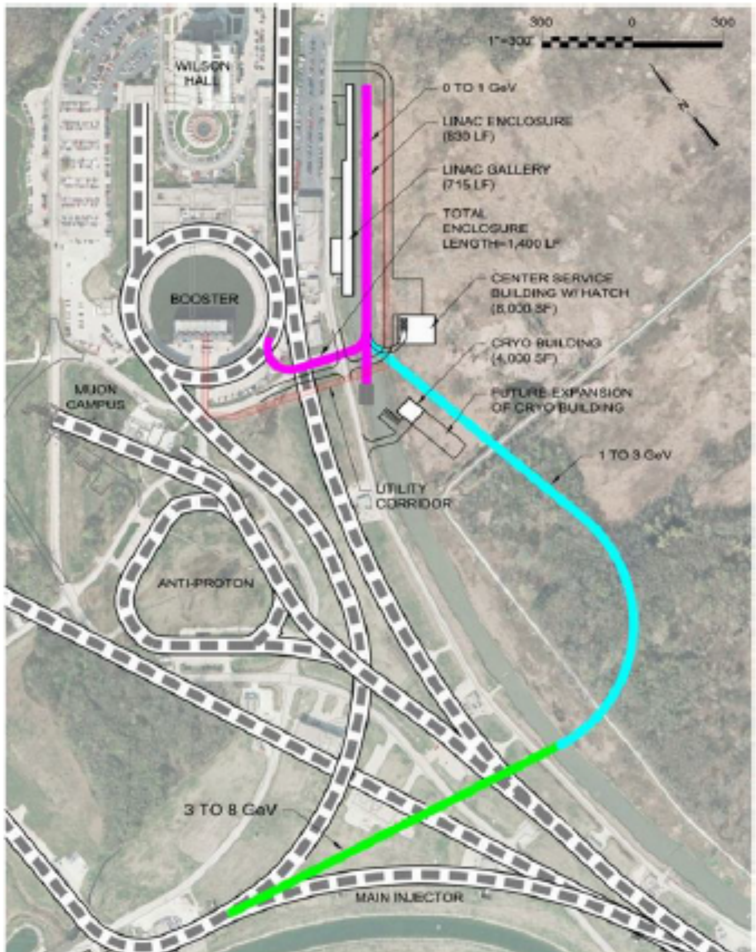
PIP-III "multi-MW" - Option A

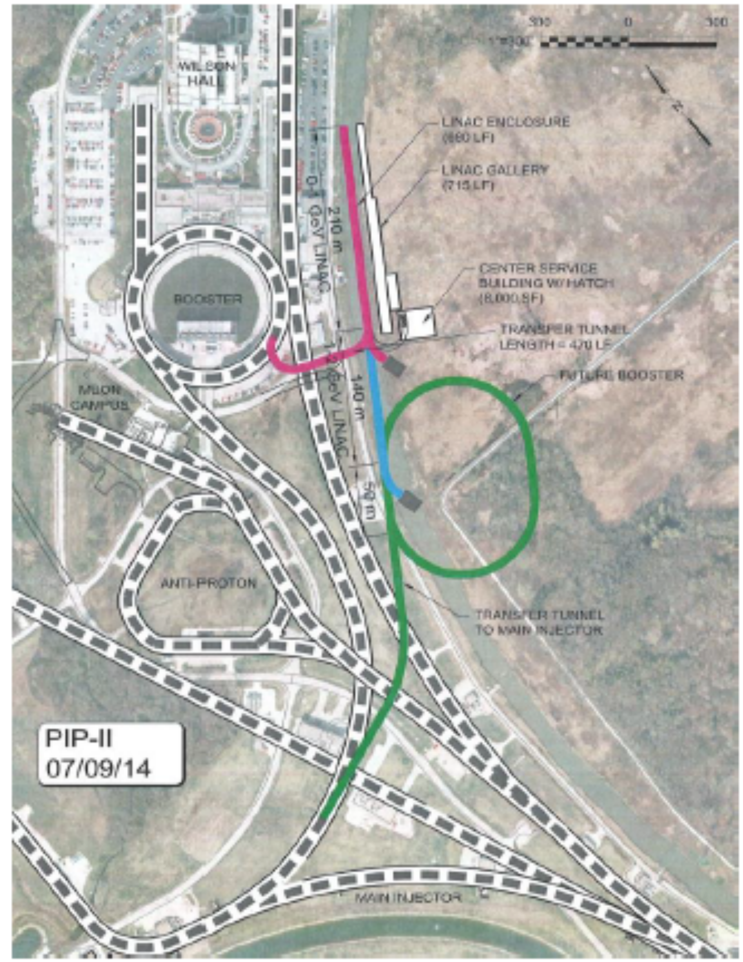


PIP-III "multi-MW" - Option B

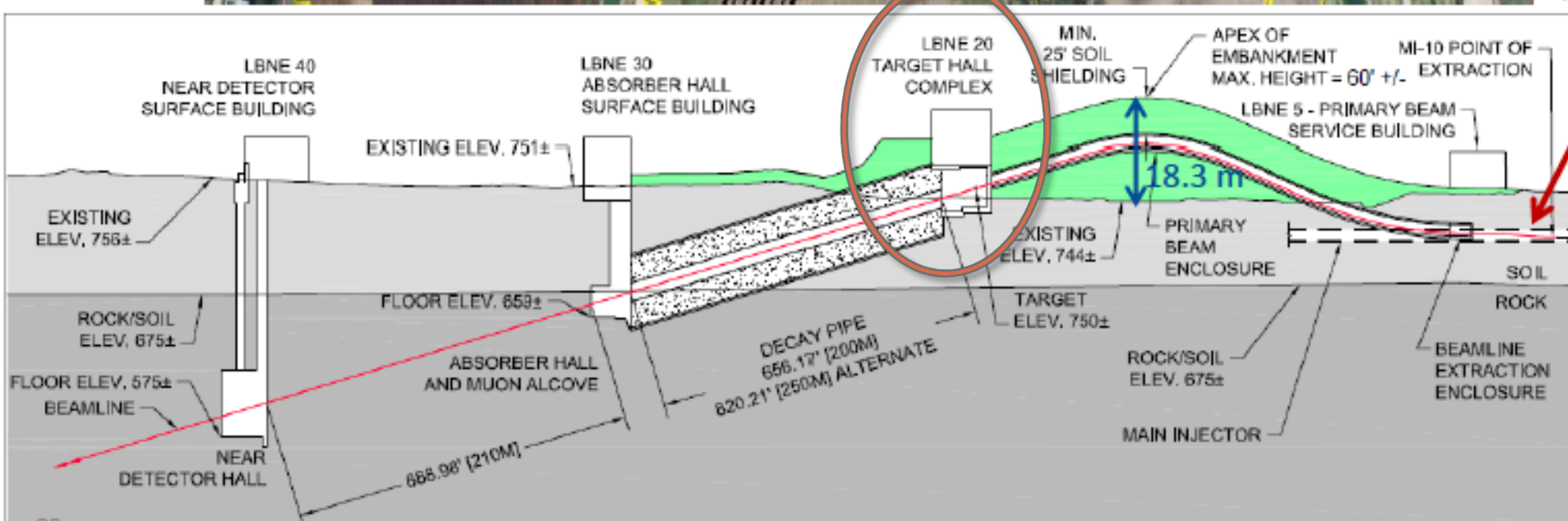


- Opportunities for expansion include full energy (8 GeV) linac or RCS



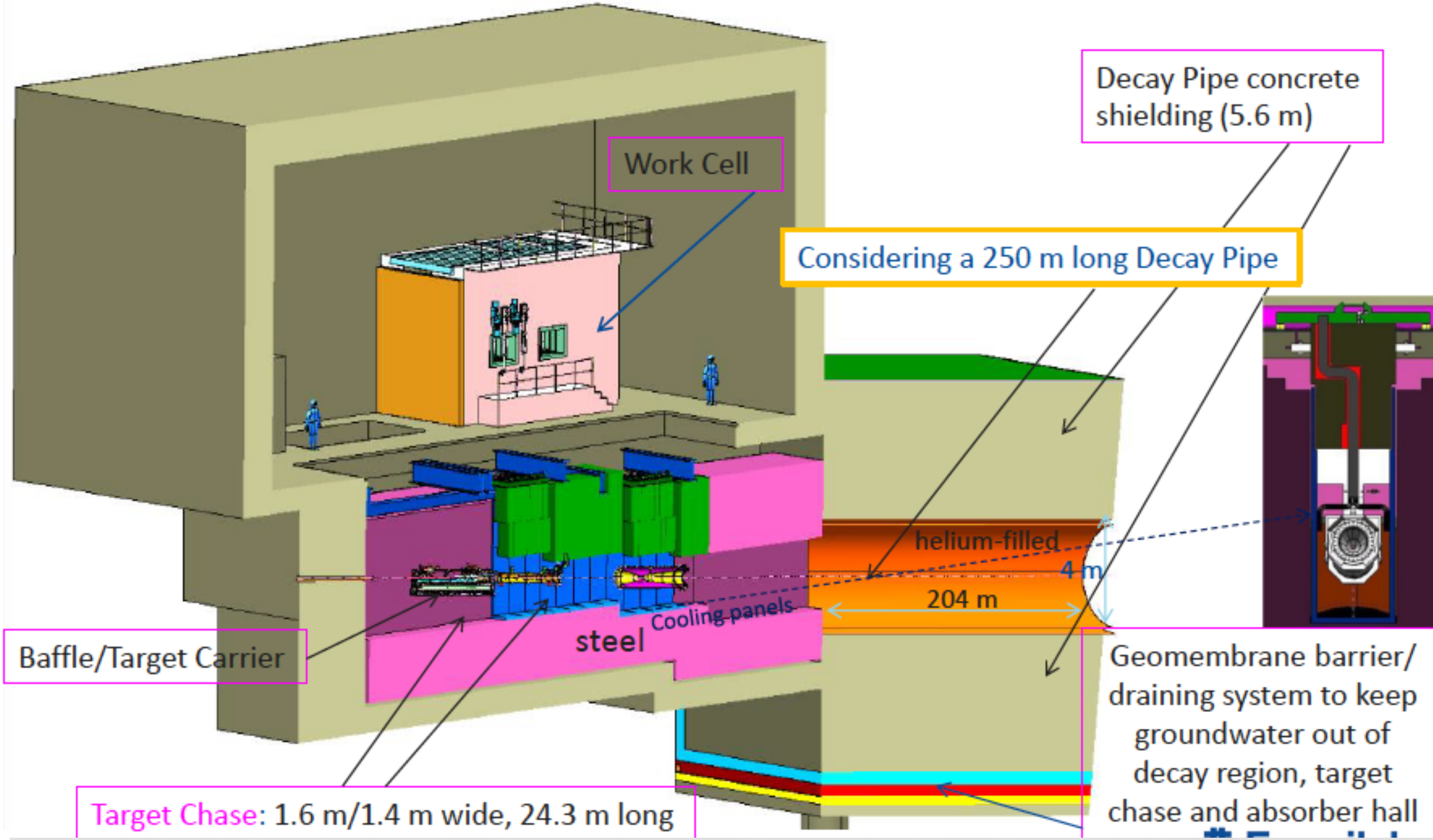


LBNE Beamline Reference Design: MI-10 Extraction, Shallow Beam



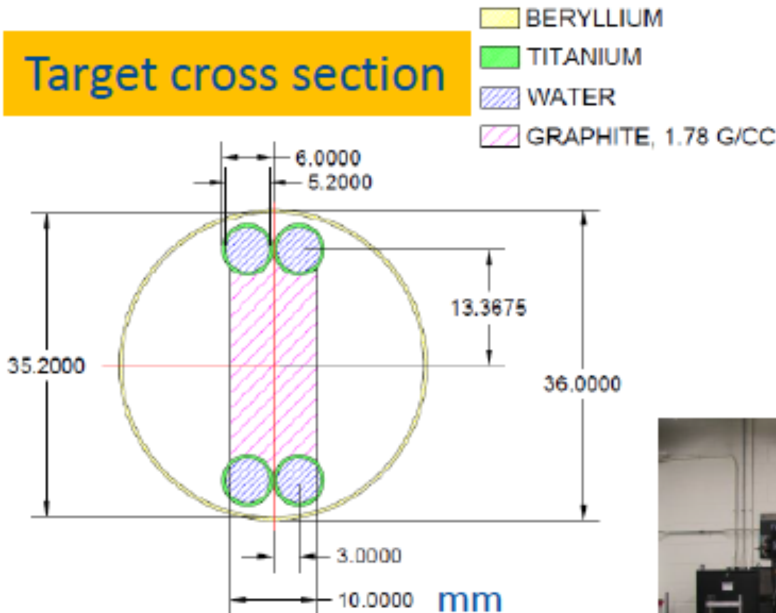
Fermilab

Target Hall/Decay Pipe Layout

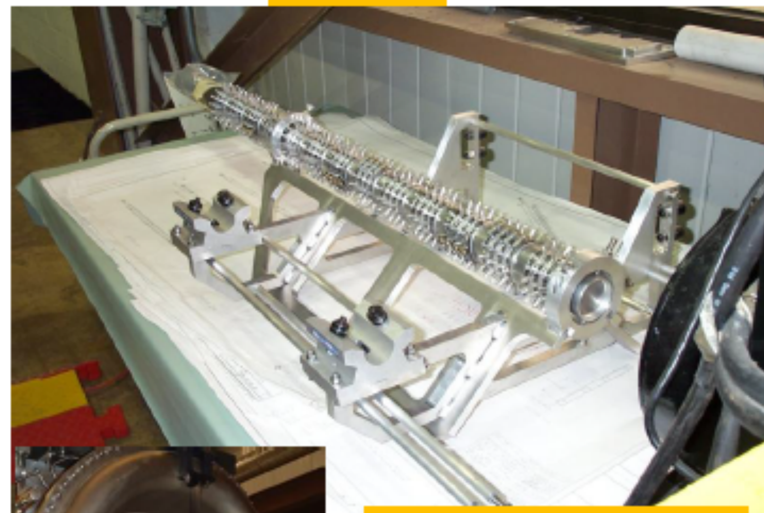


47 graphite target segments, each 2 cm long

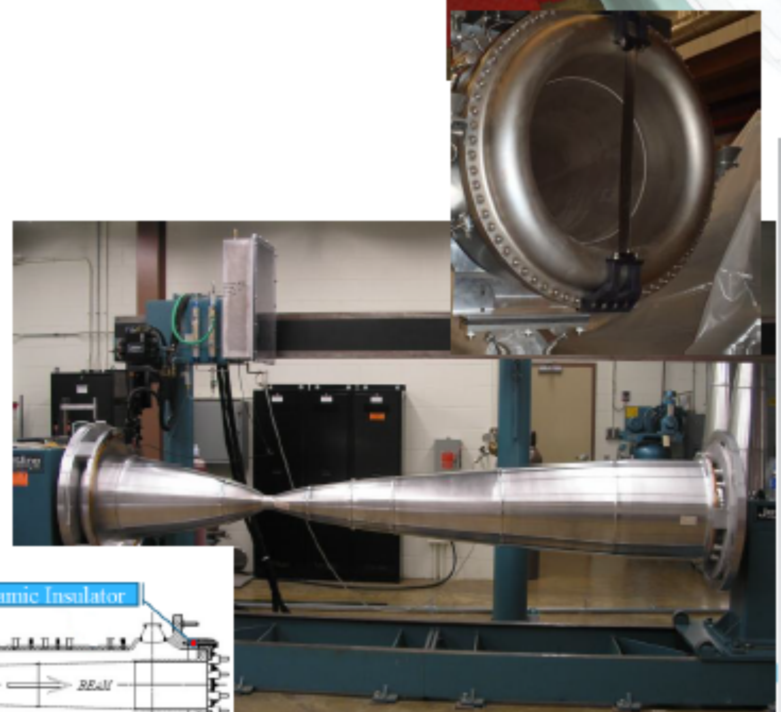
Target cross section

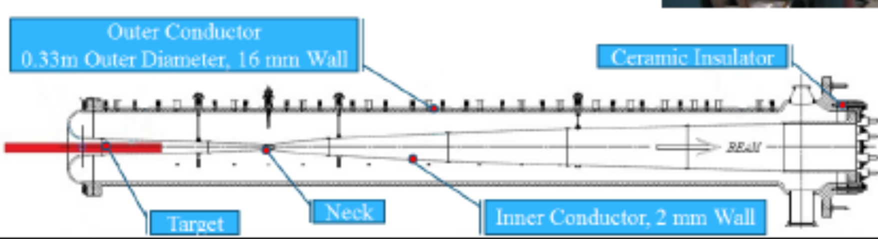


Baffle

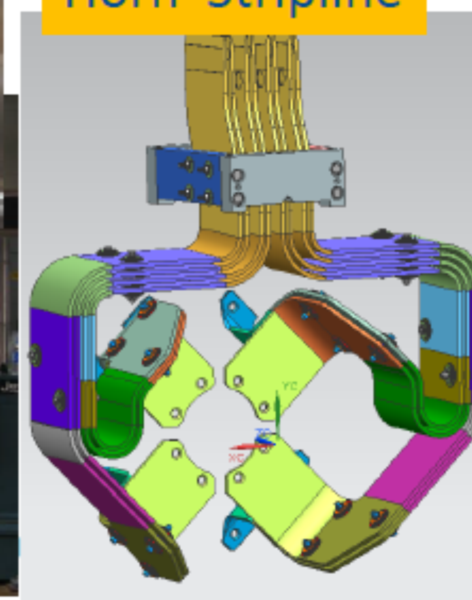


Horn





Horn Stripline



Possible improvements in the focusing system

LBNE CD-1 – NuMI like horn 1

LBNE prereconfiguration horn 1

	LBNE Sept. 2012 CD-1	LBNE March 2012
Beam Power	708 kW	708 kW
Horn 1 shape	Double Parabolic	Cylindrical/Parabolic
Horn current	200 kA	300 kA
Target	Modified MINOS (fins)	IHEP cylindrical
Target "Carrier"	NuMI-style baffle/ target carrier	New handler, target attaches to Horn 1

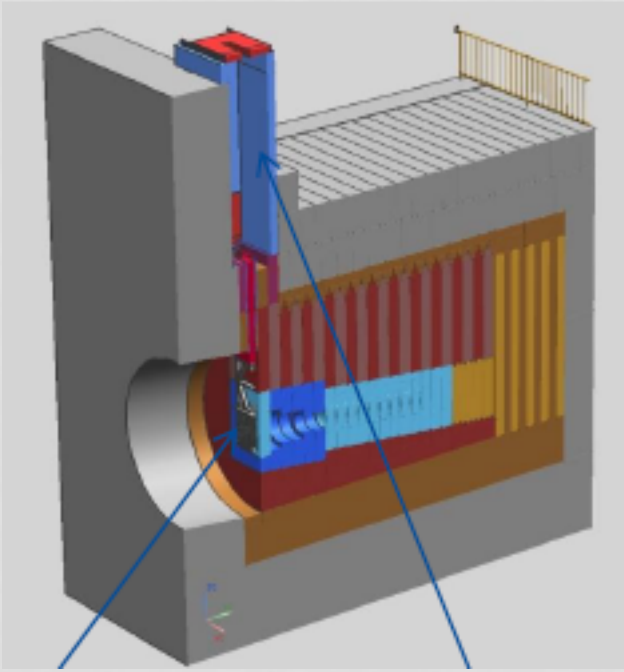
A Shift in Beamline Planning

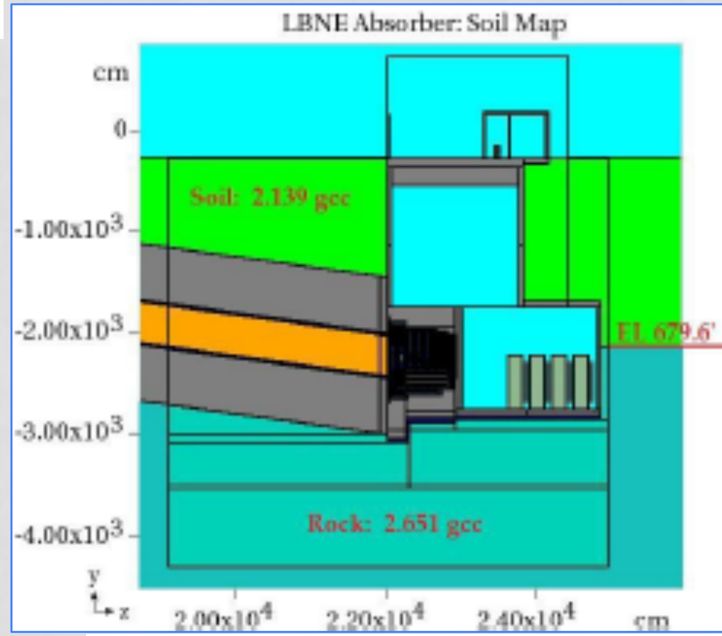
- We had been planning till ~10 months ago to start with a 700 kW beam (NuMI/NOvA at 120 GeV) and then be prepared to take significantly increased beam power (~2.4 MW) allowing for an upgradeability of the Beamline facility when more beam power becomes available.
- Fermilab is now planning to raise the beam power to 1.2 MW by the time LBNF starts operation (PIP-II).
  - We are currently assuming operation of the Beamline for the first 5 years at 1.2 MW and for 15 years at 2.4 MW.
- The lifetime of the Beamline Facility including the shielding is assumed to be 30 years.

What is being designed for 2.4 MW

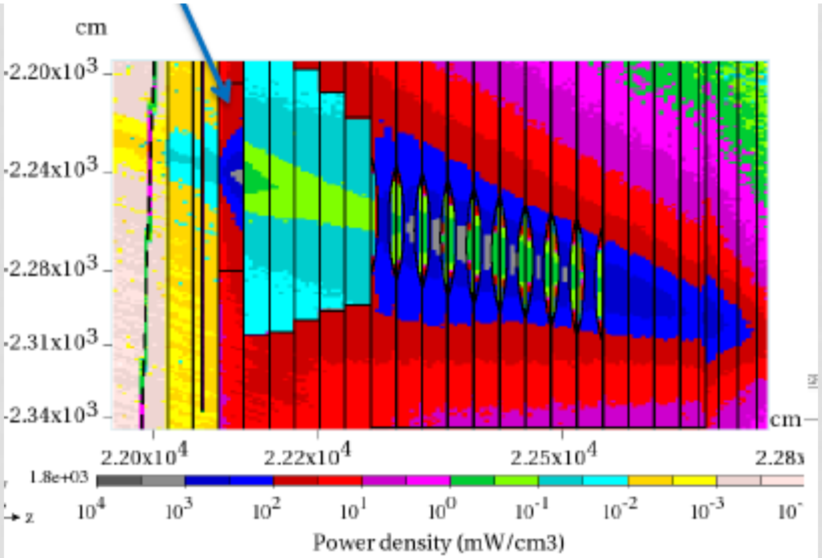
- Designed for 2.4 MW, to allow for an upgrade in a cost efficient manner:
  - Primary beamline
  - the radiological shielding of enclosures (primary beam enclosure, the target shield pile and target hall except from the roof of the target hall, the decay pipe shielding and the absorber hall) and size of enclosures
  - beam absorber
  - decay pipe cooling and decay pipe downstream window
  - remote handling
  - radioactive water system piping (in penetrations)

LBNE Absorber Complex

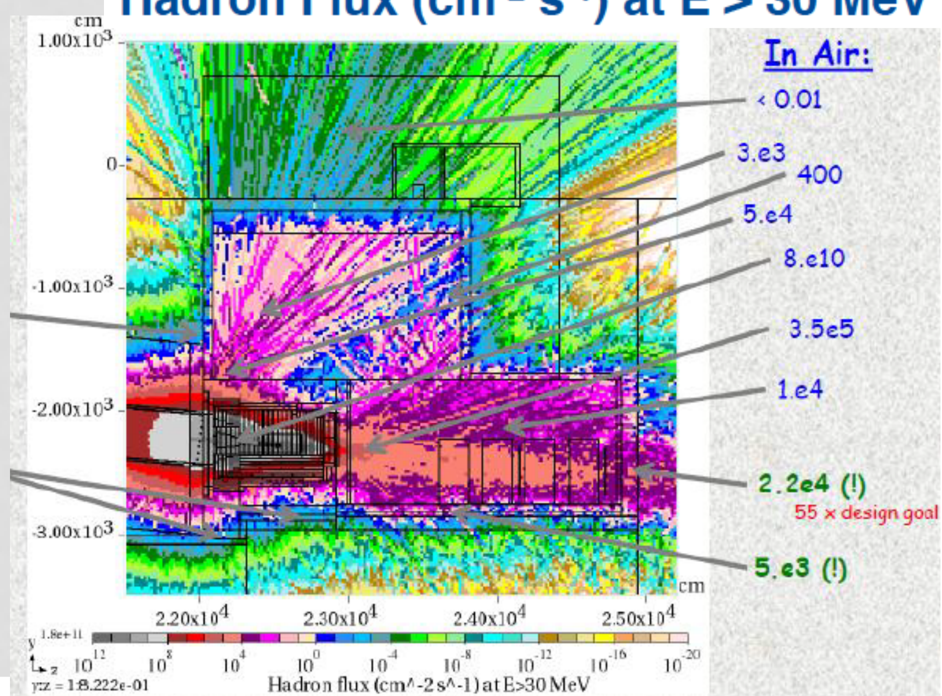




9 sculpted Al blocks and 4 solid Al blocks in the core



Hadron Flux ($cm^{-2}\ s^{-1}$) at E > 30 MeV



The Beamline Team and collaborative activities

- From Fermilab's Accelerator, Particle Physics and Technical Divisions, FESS (Facil. Eng.) and ES&H Sections.
- University of Texas at Arlington (Hadron Monitor)
- STFC/RAL (target R&D and target design)
- Bartoszek Eng. (Contract on baffle/target and horn support modules)
- RADIATE Collaboration (radiation damage for target and windows)
- CERN (target R&D, corrosion, Beamline monitoring,…)
- US-Japan Task force (radiation damage, non-interactive profile monitor, kicker magnets)
- IHEP/China (simulations, beam window, special alloys)
- Six contracts completed already with ANL, BNL, IHEP (Protvino, Russia), STFC/RAL, ORNL, Design Innovations.

Summary/Conclusions

- Upgrades to the Fermilab accelerator complex and the NuMI/ NOvA beamline recently completed, PIP in progress
  - presently at ~360 kW, Recycler operational, increasing beam power up to 450 kW in FY15, 700 kW operation expected in FY16
- PIP-II is a complete, integrated, cost effective concept, building on the accomplishments of PIP, with a goal of delivering > 1 MW by 2023-2024
- The emerging LBNF Collaboration/Project will enable a world-leading program on neutrino oscillations that will address profound questions about nature.
- A new long-baseline neutrino Beamline is needed for LBNF. A lot of progress in the Beamline design. No showstoppers seen so far for 1.2 MW operation.
- Plenty of opportunities for international collaboration

J-PARC future beam studies

2014.11.4
KEK, IPNS
J-PARC center
Tada

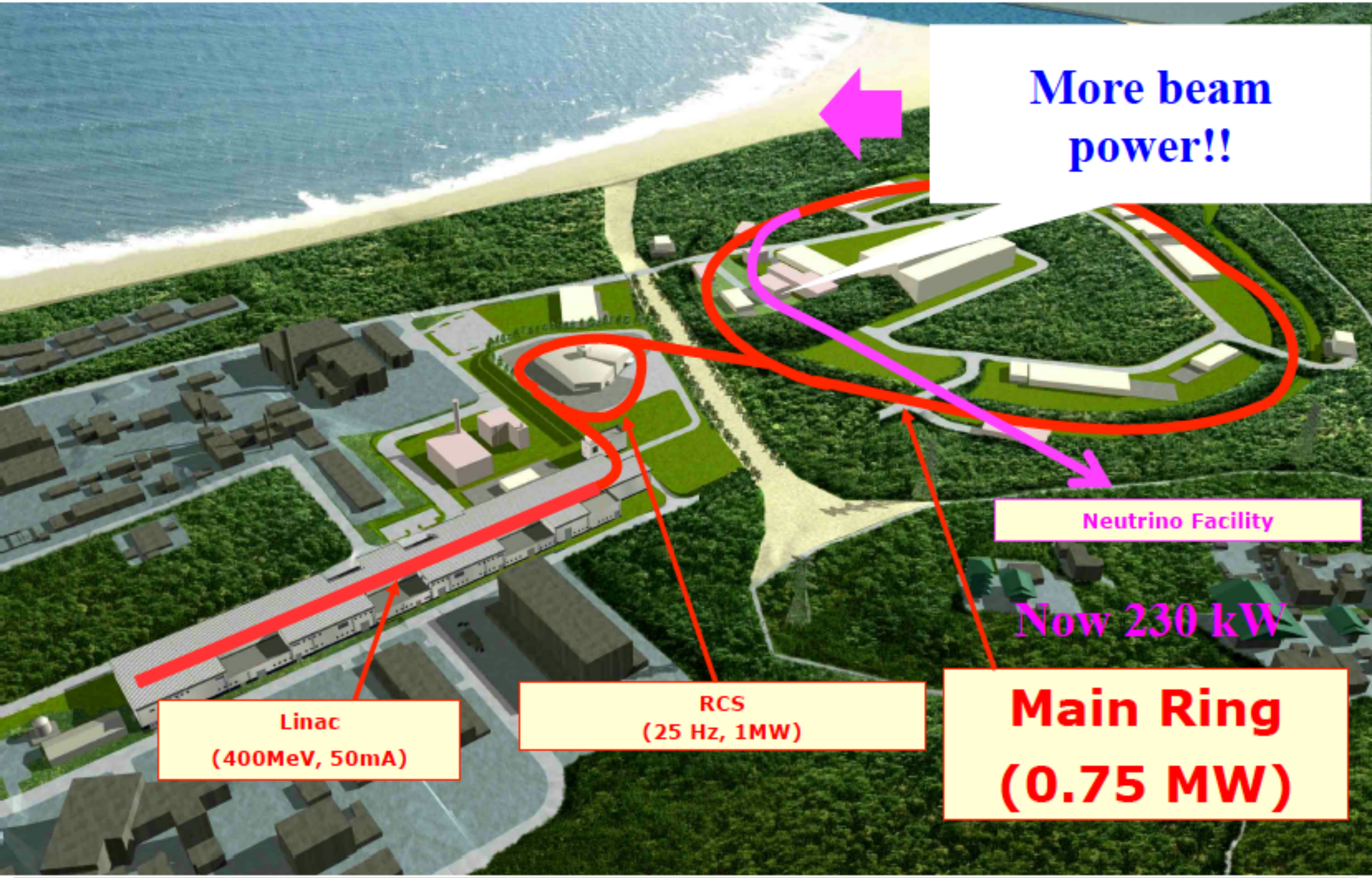
T2K Long Baseline Neutrino Experiment

Contents

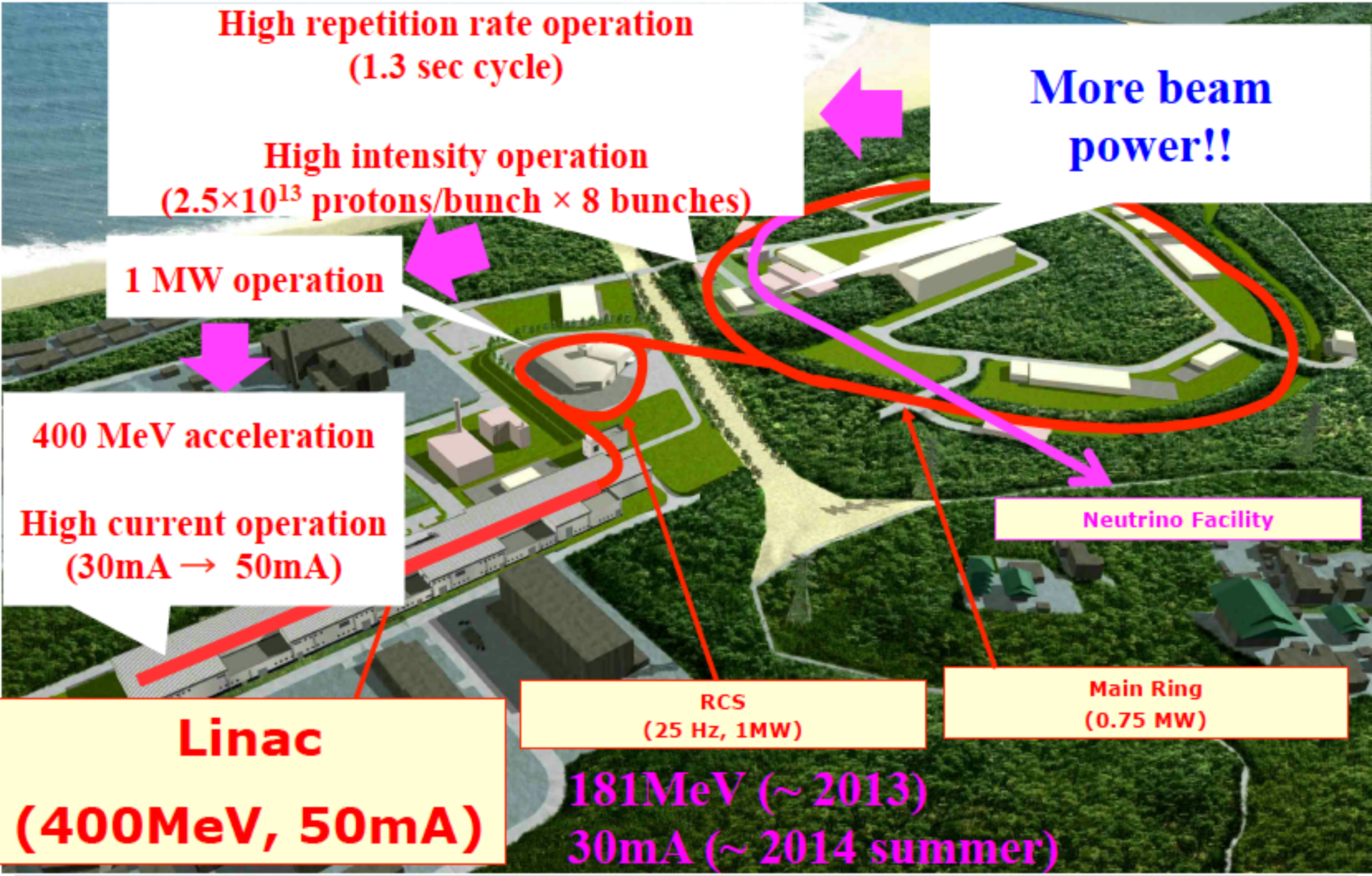
Upgrade for the high power operation in accelerator

Upgrade for the high power operation in neutrino beam line

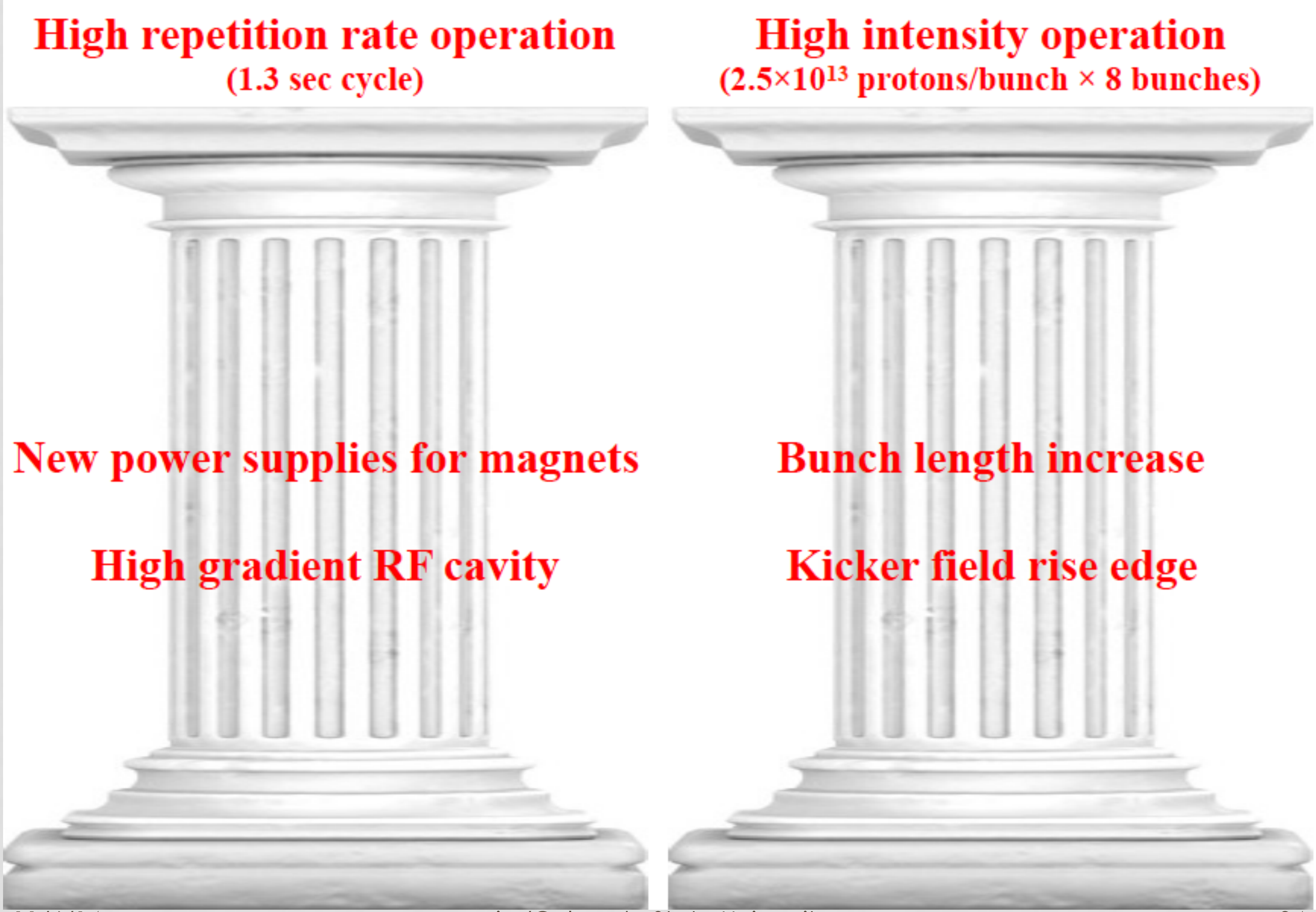
Upgrade for the high power operation in J-PARC



Upgrade for the high power operation in J-PARC



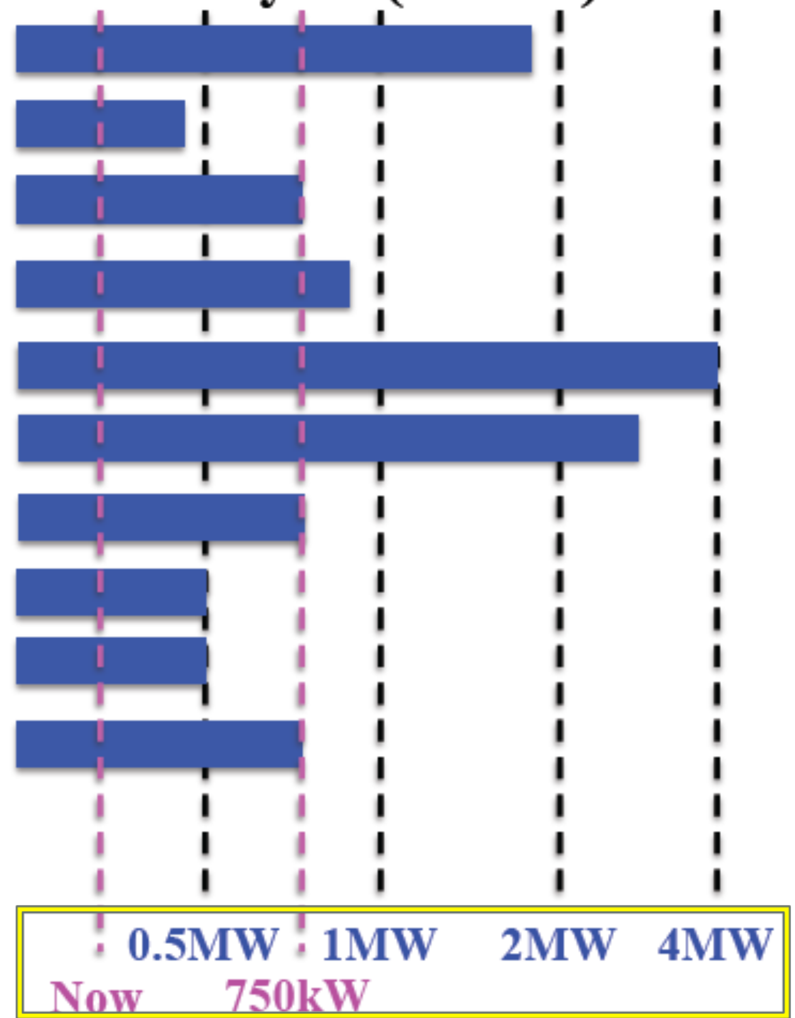
Two pillars of the upgrade plan for Main Ring accelerator



The tolerance beam power of the neutrino devices

@ 2013 summer (after achievement of the first T2K goal)

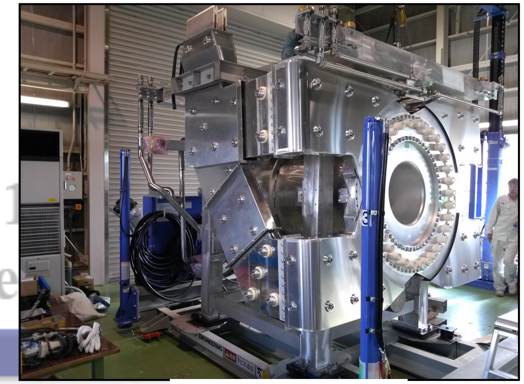
Target and window (thermal shock) : 3.3×10^{14} ppp
Horn power supply : 2.4sec cycle (250kA)
Horn cooling water system
Horn strip line cooling
Helium compressor for strip line cooling
Helium compressor for target
Helium vessel and decay volume
Beam dump
Radiation shields
Radioactivation air
Radioactvation water disposal system
Cooling water system (except horns)



We plan to upgrade sequentially from “low-limit-devices”.

The tolerance beam power of the neutrino devices

Replace to the new horns



Target and window (thermal shock) : 3.3×1

Horn power supply : 2.4se

Horn cooling water system

Horn strip line cooling

Helium compressor for strip line cooling

Helium compressor for target

Helium vessel and decay volume

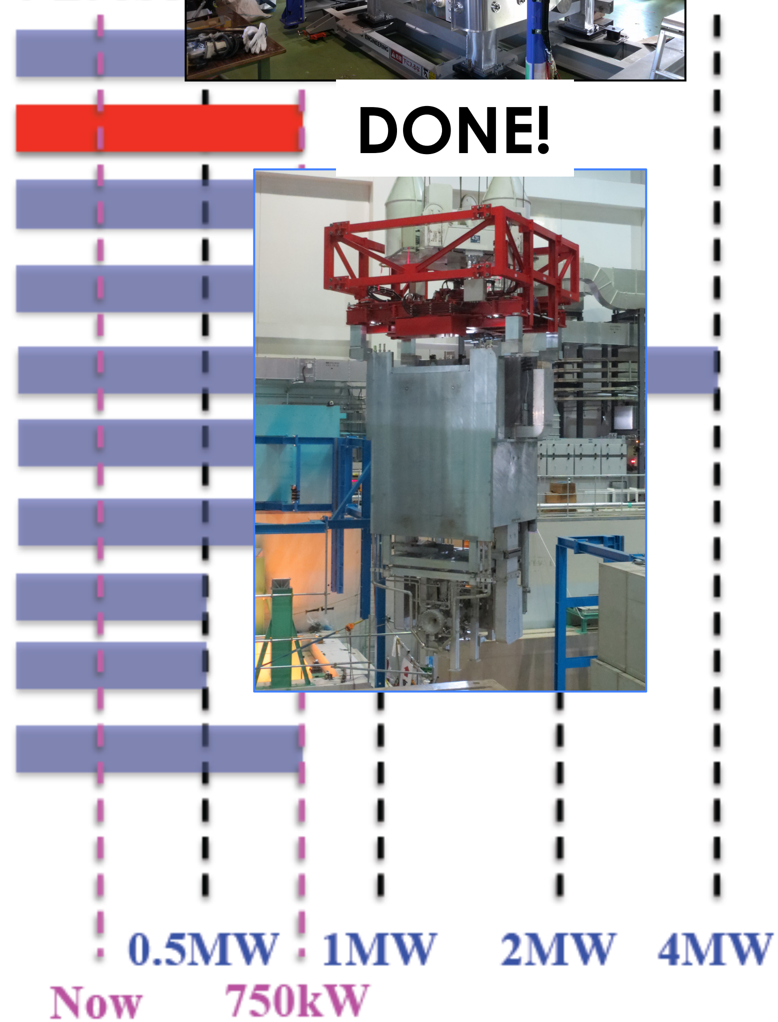
Beam dump

Radiation shields

Radioactivation air

Radioactvation water disposal system

Cooling water system (except horns)



We plan to upgrade sequentially from "low-limit-devices".

The tolerance beam power of the neutrino devices

@ 2013 summer (after achievement of the first T2K goal)

Target and window (thermal shock) : 3.3×10^{14} ppp

Horn power supply : 2.4sec cycle (250kA)

Horn cooling water system

Horn strip line cooling

Helium compressor for strip line cooling

Helium compressor for target

Helium vessel and decay volume

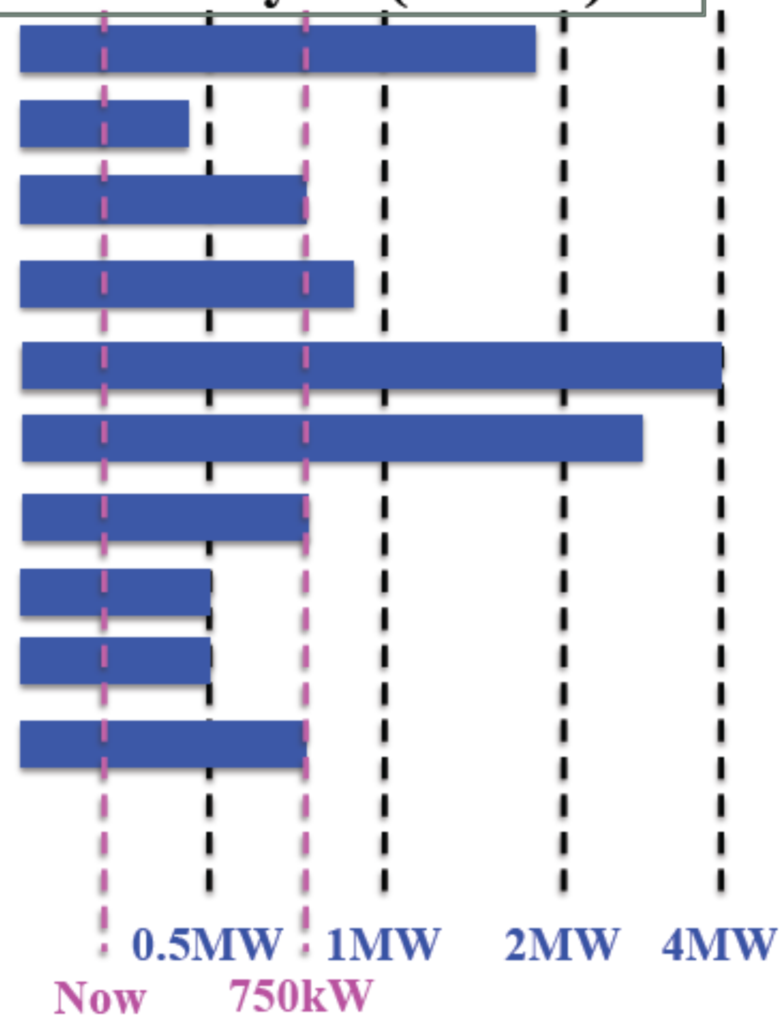
Beam dump

Radiation shields

Radioactivation air

Radioactvation water disposal system

Cooling water system (except horns)



We plan to upgrade sequentially from “low-limit-devices”.

The tolerance beam power of the neutrino devices

Introduce new-horn-power-supply system using 3 power supplies

Target and window (thermal shock) : 3.3×10^{14} ppp

Horn power supply : 1.0sec cycle (320kA)

Horn co

Horn str

Helium (

The new power supplies are secured.

The transformers are to be secured in JFY2015.

Helium compressor for target

Helium vessel and decay volume

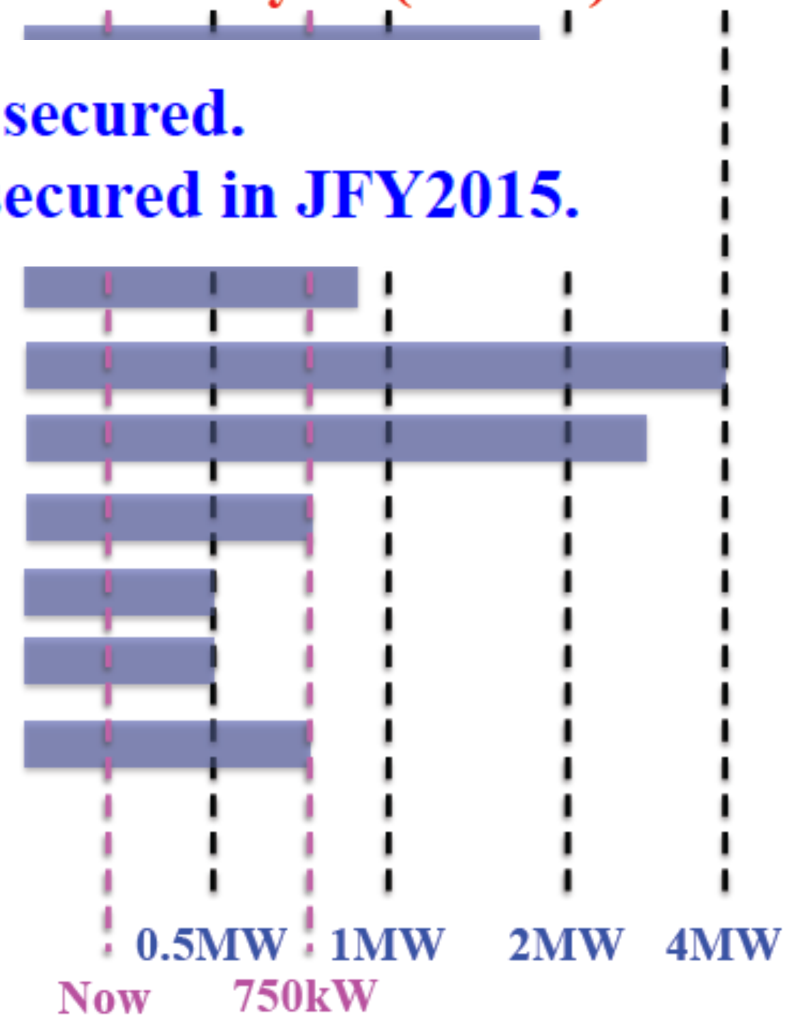
Beam dump

Radiation shields

Radioactivation air

Radioactvation water disposal system

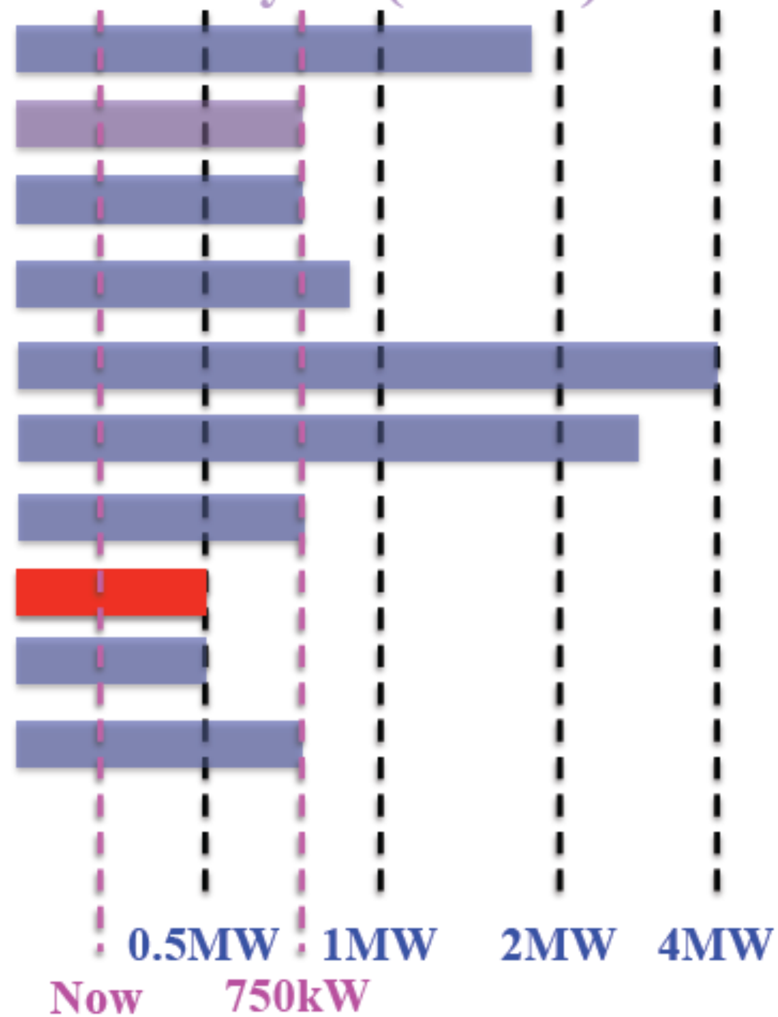
Cooling water system (except horns)



We plan to upgrade sequentially from "low-limit-devices".

The tolerance beam power of the neutrino devices

Target and window (thermal shock) : 3.3×10^{14} ppp
Horn power supply : 1.0sec cycle (320kA)
Horn cooling water system
Horn strip line cooling
Helium compressor for strip line cooling
Helium compressor for target
Helium vessel and decay volume
Beam dump
Radiation shields
Radioactivation air
Radioactvation water disposal system
Cooling water system (except horns)



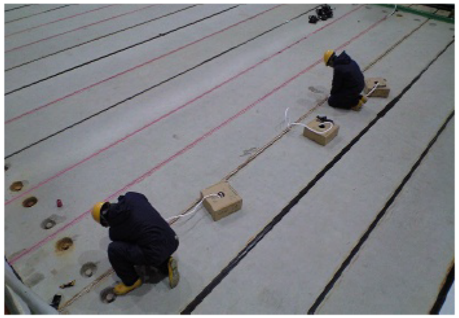
We plan to upgrade sequentially from "low-limit-devices".

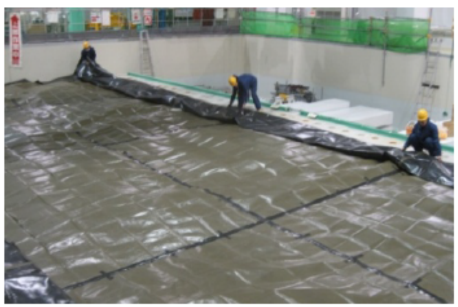
The tolerance beam power of the neutrino devices

Add air-tight lamination (made of steel and air-tight material) under concrete shields

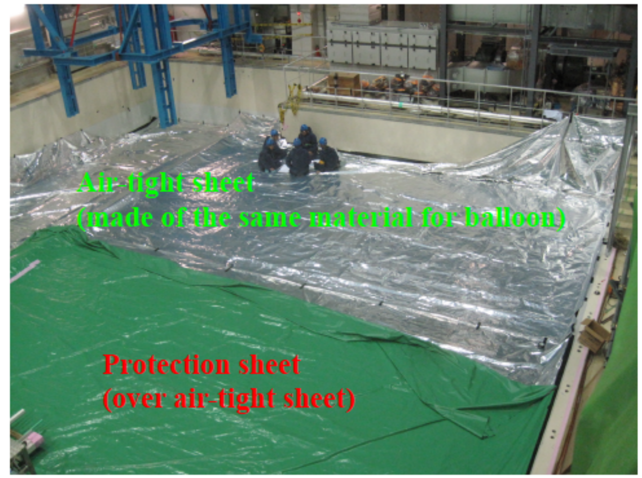
Target and w
Horn power s
Horn cooling
Horn strip li
Helium comp
Helium comp
Helium vesse
Beam dump
Radiation shi
Radioactivation air
Radioactvation water disposal system
Cooling water system (except horns)

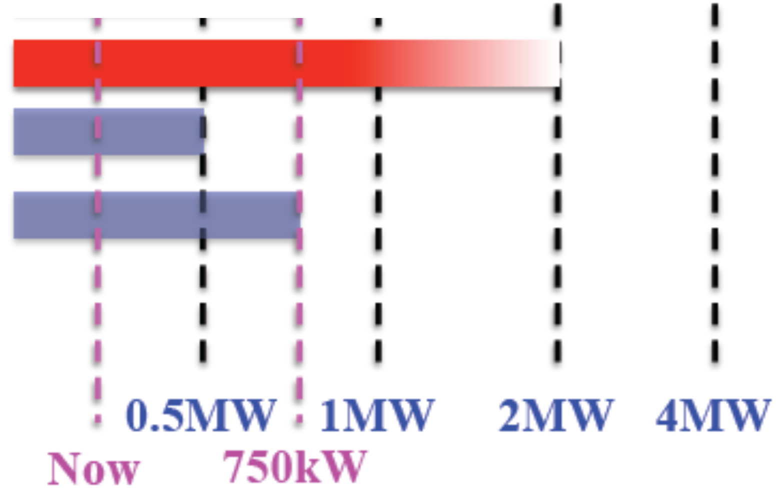
Caulking between concrete shields





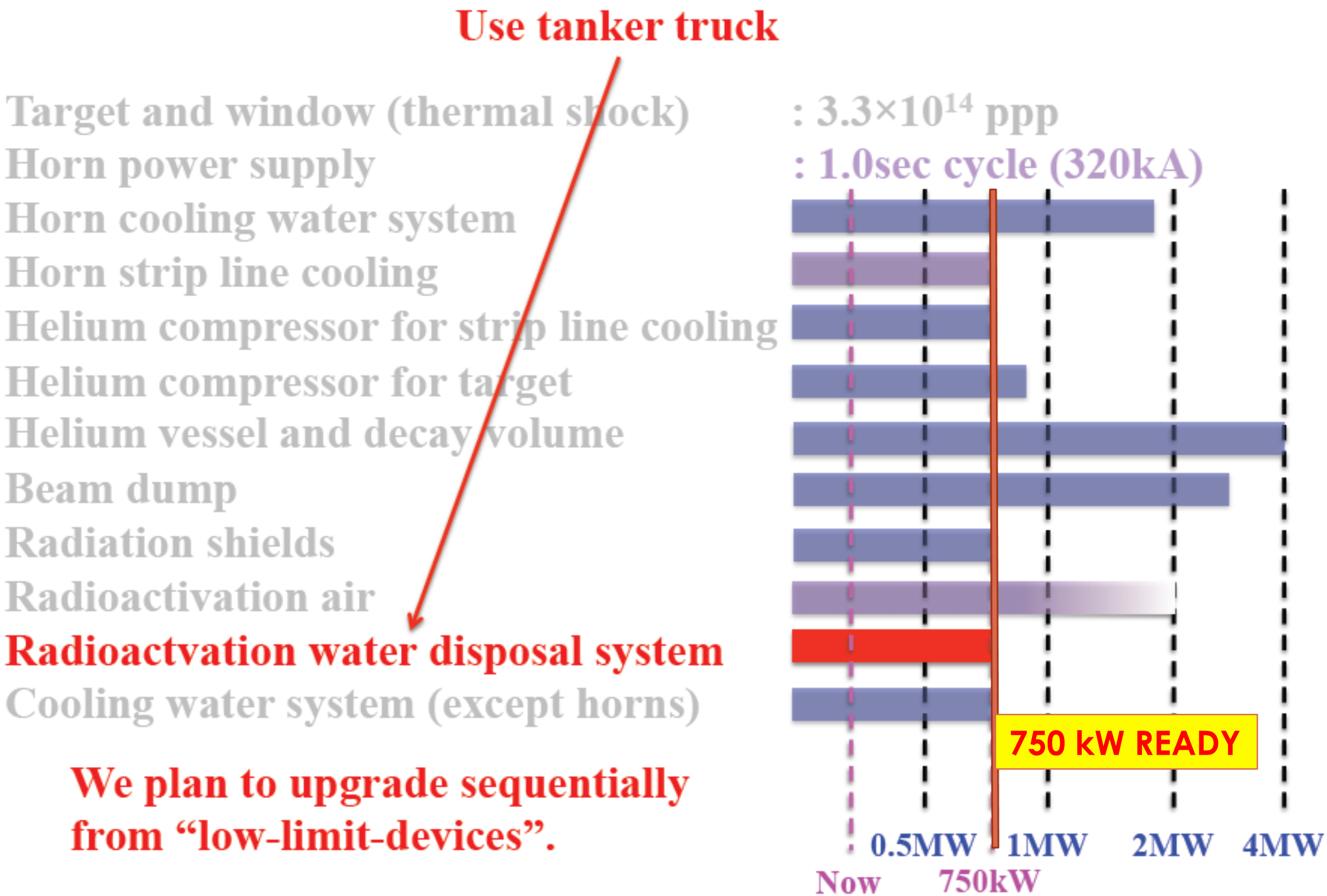
Lay the air-tight sheet





We plan to upgrade sequentially from "low-limit-devices".

The tolerance beam power of the neutrino devices

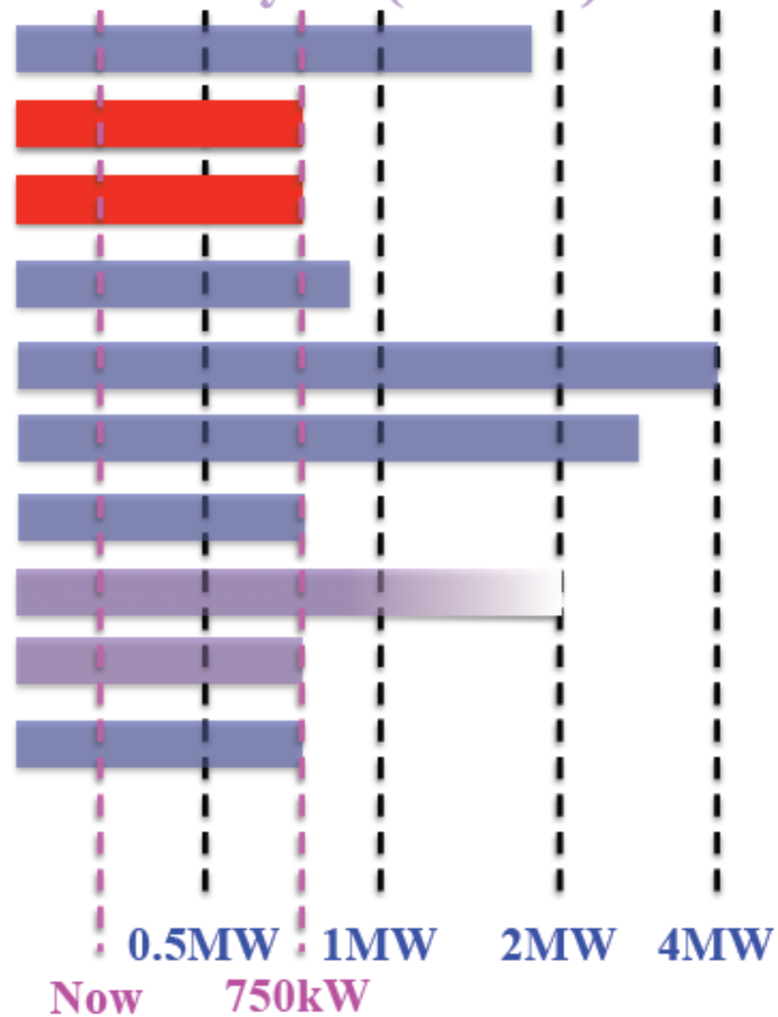


We plan to upgrade sequentially from "low-limit-devices".

The tolerance beam power of the neutrino devices

TO GO BEYOND 750 kW

Target and window (thermal shock) : 3.3×10^{14} ppp
Horn power supply : 1.0sec cycle (320kA)
Horn cooling water system
Horn strip line cooling
Helium compressor for strip line cooling
Helium compressor for target
Helium vessel and decay volume
Beam dump
Radiation shields
Radioactivation air
Radioactvation water disposal system
Cooling water system (except horns)



We plan to upgrade sequentially from "low-limit-devices".

The tolerance beam power of the neutrino devices

Target and window (thermal shock) : 3.3×10^{14} ppp
Horn power supply : 1.0sec cycle (320kA)
Horn cooling water system
Horn strip line cooling
Helium compressor for strip line cooling
Helium compressor for target
Helium vessel and decay volume
Beam dump
Radiation shields
Radioactivation air
Radioactvation water disposal system
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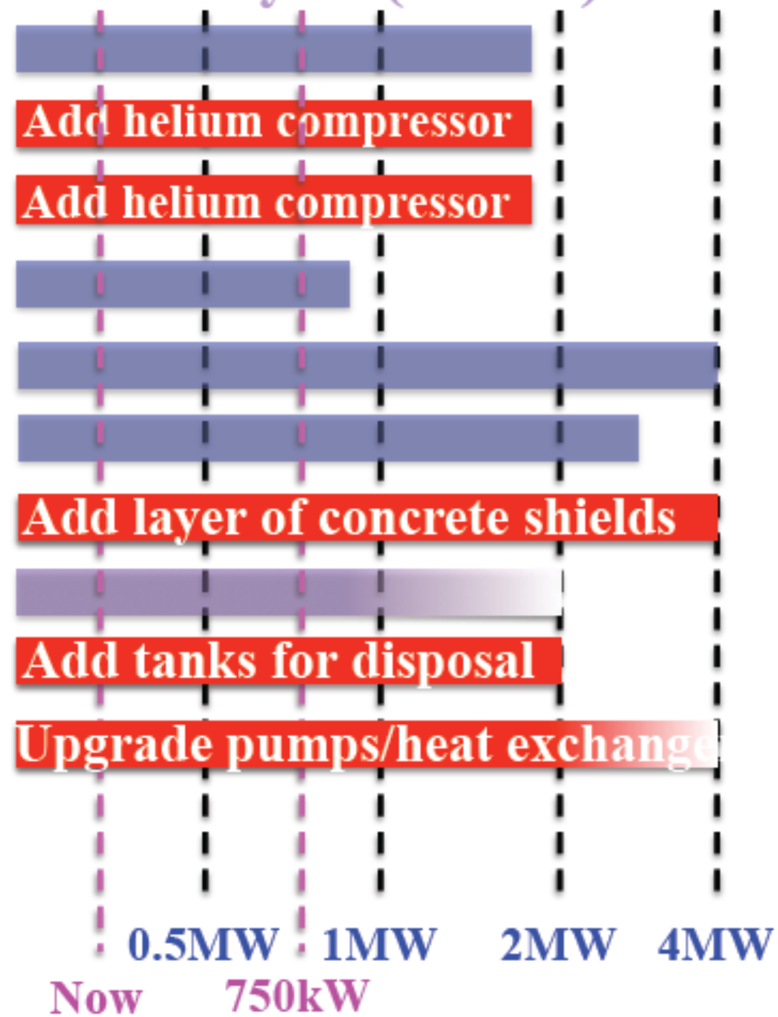

We plan to upgrade sequentially from “low-limit-devices”.

The tolerance beam power of the neutrino devices

It is relatively easy to upgrade the helium compressor system, but it is difficult to overcome the limit by thermal shock.

Target and window (thermal shock) : 3.3×10^{14} ppp
Horn power supply : 1.0sec cycle (320kA)
Horn cooling water system
Horn strip line cooling
Helium compressor for strip line cooling
Helium compressor for target
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Beam dump
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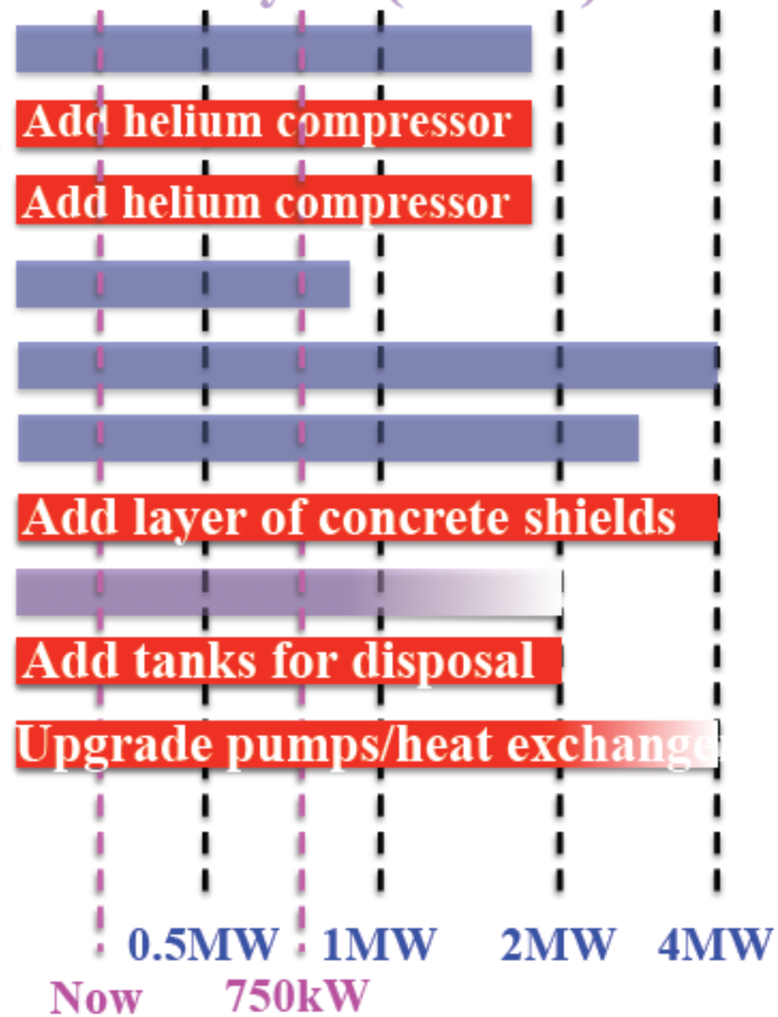
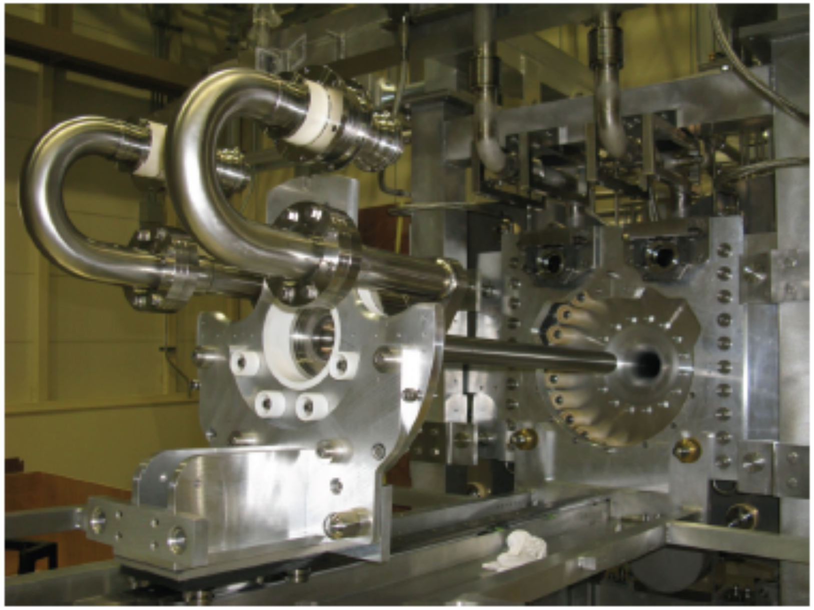
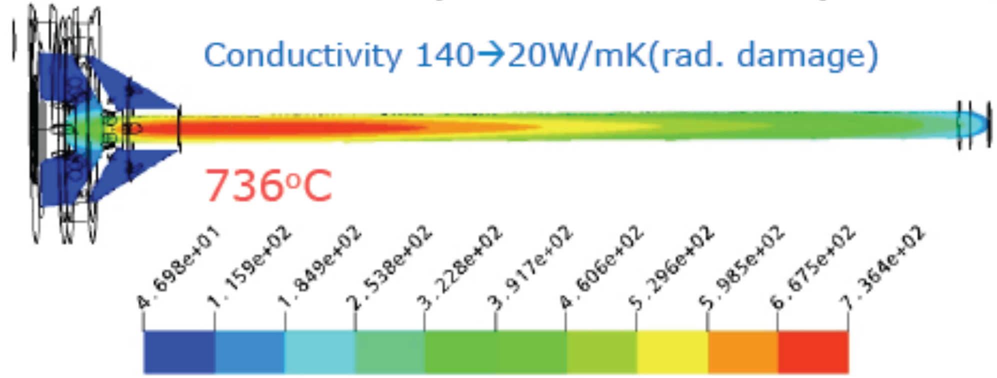


We plan to upgrade sequentially from "low-limit-devices".

Target



30GeV-750kW (~20kW heat load)

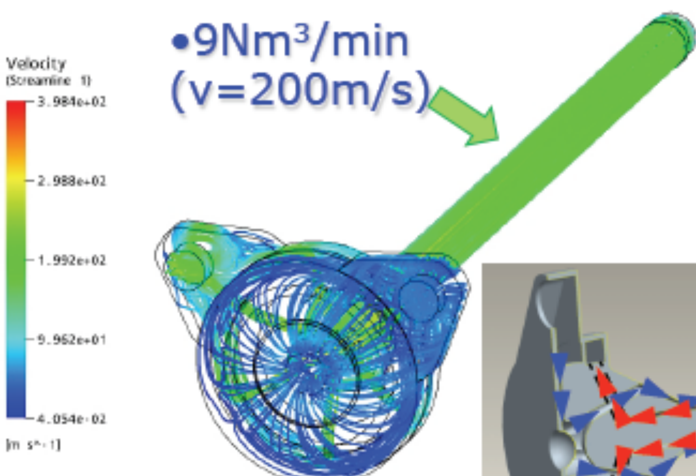


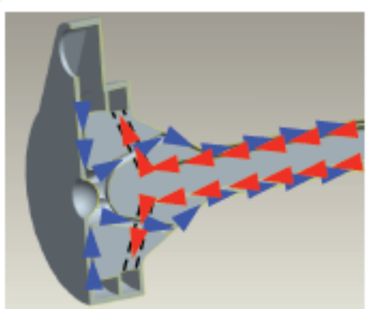
ΔT~200K ~7MPa (Tensile strength 37MPa)

Safety factor @ 750kW ~ 3.5

~ 2 ← **O_2 : 100ppm after 5 years**

CFX analyses





The limit by thermal shock

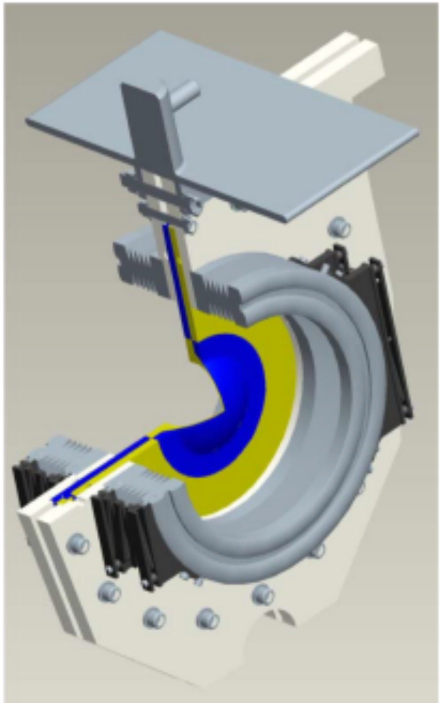
$$\textbf{750 kW} : \frac{3.3\times10^{14}\ \text{ppp}}{2.1\ \text{sec}}$$

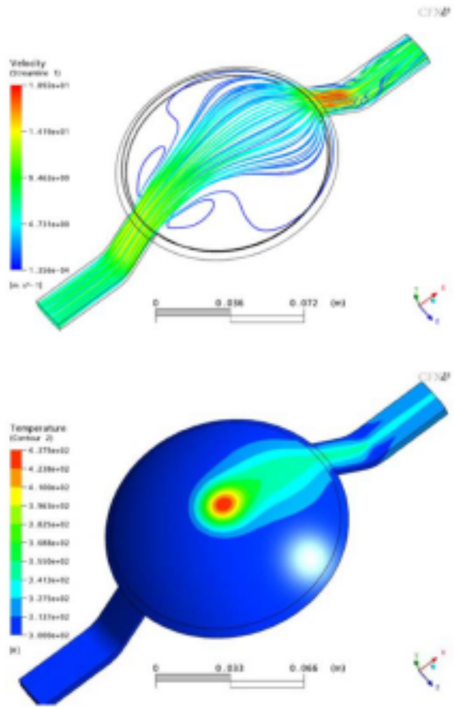
for example …

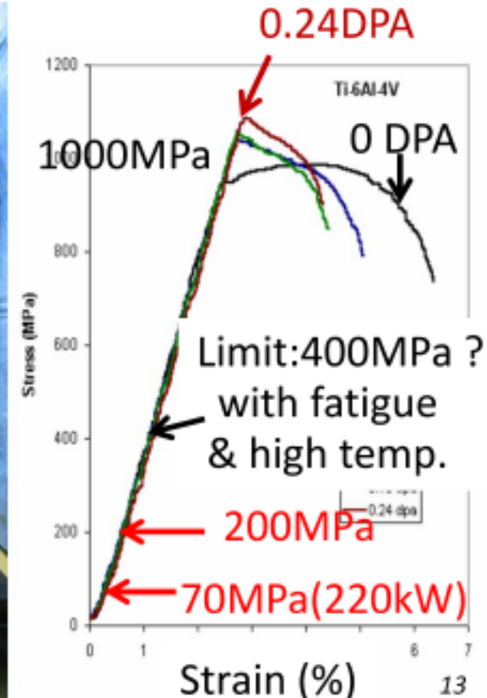
$$\textbf{1.2 MW} : \frac{3.3\times10^{14}\ \text{ppp}}{1.3\ \text{sec}}$$

It is necessary to extend the diameter for higher beam power.

Beam wondow







$$750\ \text{kW} : \frac{3.3\times10^{14}\ \text{ppp}}{2.1\ \text{sec}}$$

The limit by thermal shock

for example …

$$1.2\ \text{MW} : \frac{3.3\times10^{14}\ \text{ppp}}{1.3\ \text{sec}}$$

It is necessary to extend the diameter or to use the other material for higher beam power.

- Large θ_{13} makes discovery conceivable, *but*:
  - Places premium on the control of systematic uncertainties

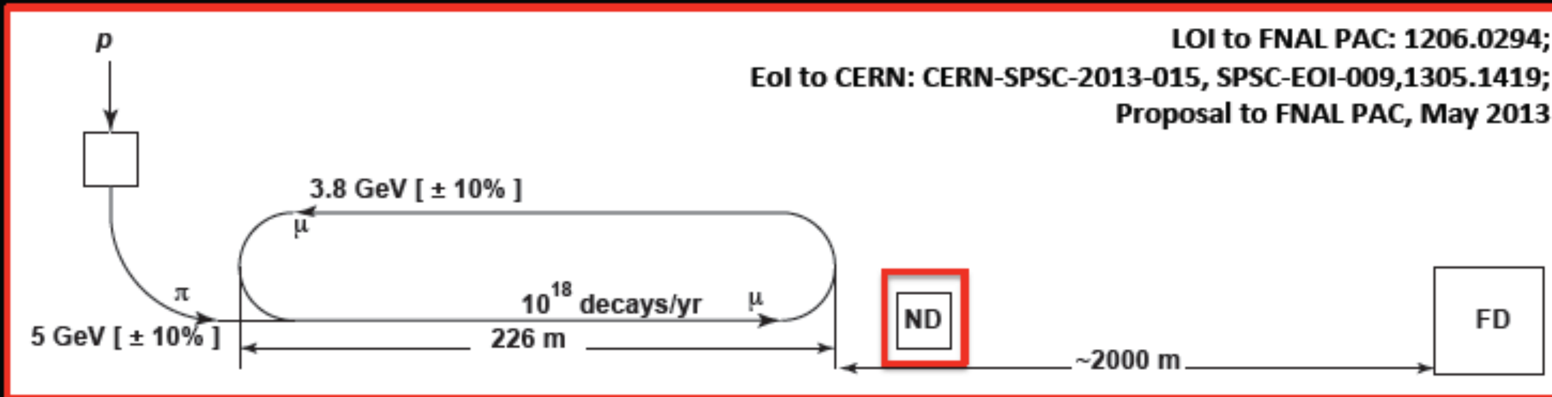
νSTORM

$\nu_e N$ and $\nu_\mu N$ scattering

Conclusions [2]:

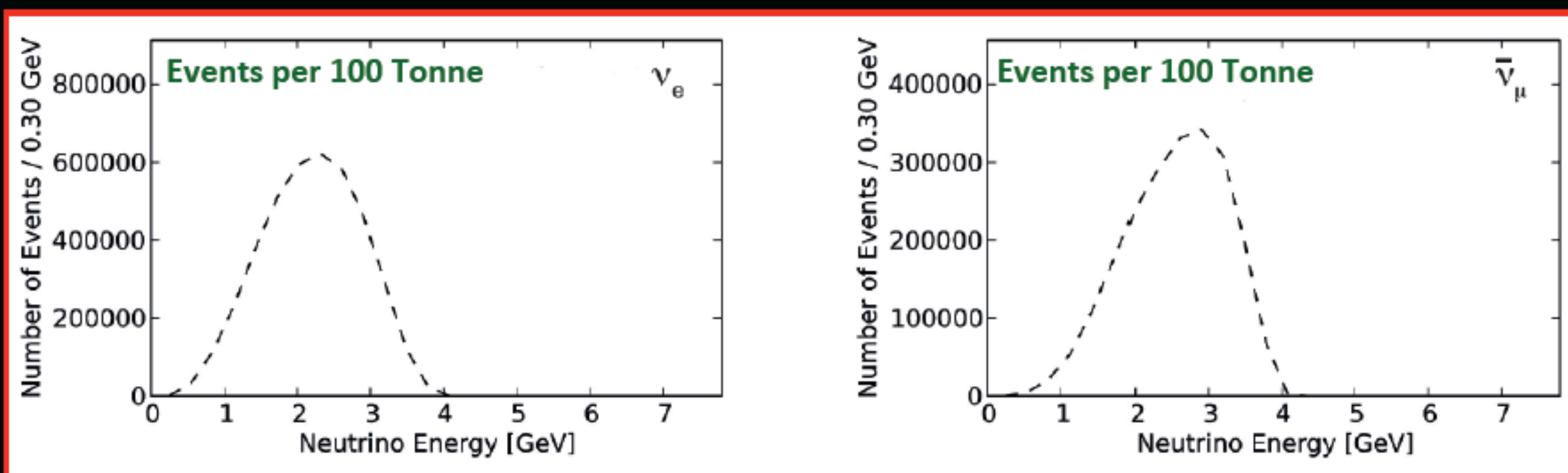
- New data, new Design Studies, new accelerator R&D allow definition of powerful incremental programme encompassing:
  - Conventional super-beam experiment(s):
    - Determination of mass hierarchy;
    - Initial scan of δ_{CP} space;
      - Critical contribution: ν_e cross section measurements from nuSTORM
- nuSTORM:
  - Control of systematic errors in long- (and short-) baseline neutrino-oscillation experiments requires precise measurements of $\nu_e N$ and $\nu_\mu N$ cross sections;
    - nuSTORM can deliver the requisite precision so allowing the LBL programme to meet its precision and sensitivity goals
  - Programme of sterile neutrino searches:
    - Development of existing sterile-neutrino search programme;
    - nuSTORM offers a qualitatively new technique that can address each of the channels of interest
  - Development of muon accelerators for particle physics:
    - nuSTORM offers the technology test bed required to develop the techniques and capabilities required to mount the Neutrino Factor and/or the Muon Collider

nuSTORM and cross section measurement:



- nuSTORM ev
  - Statistical p
    - Can mea

$$\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e \qquad \mu^- \rightarrow e^- \nu_\mu \bar{\nu}_e$$



R&D for muon accelerators

6D ionization cooling experiment:

- Reduction of 6D phase space of muon beam essential for future Muon Collider
  - MICE will provide proof of the ionization-cooling principle in 4D using a single-particle technique
- nuSTORM will provide the pulsed, high-flux muon beam required for the development of ionization cooling

nuSTORM and muon accelerators for PP:

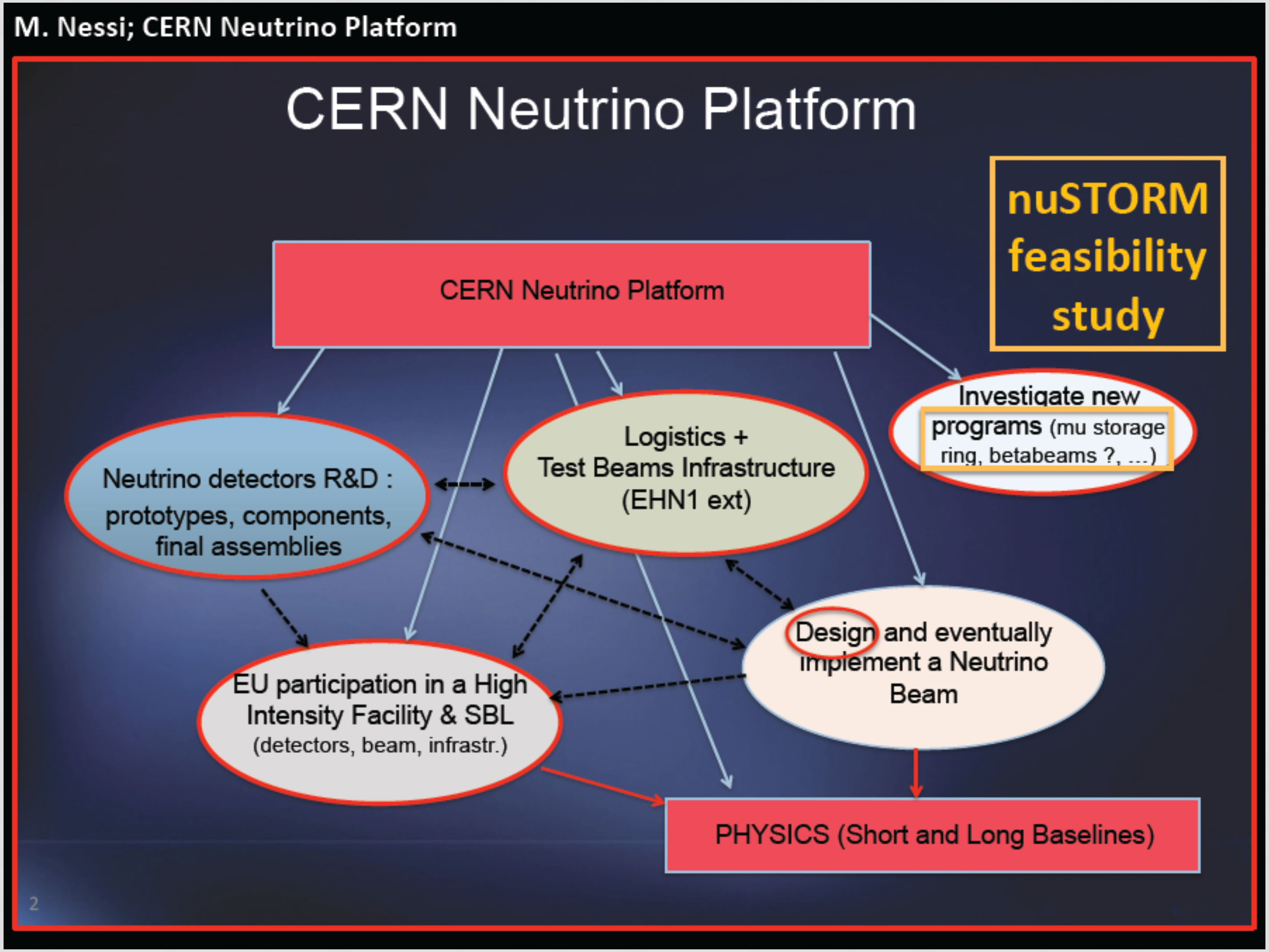
- Muon accelerators have the potential to:
  - Make definitive measurements of neutrino oscillations at the Neutrino Factory;
  - Provide multi-TeV lepton-antilepton collisions at the Muon Collider
- Incremental development of the Neutrino Factory programme offers exquisite sensitivity and precision:

Implementation, at FNAL:

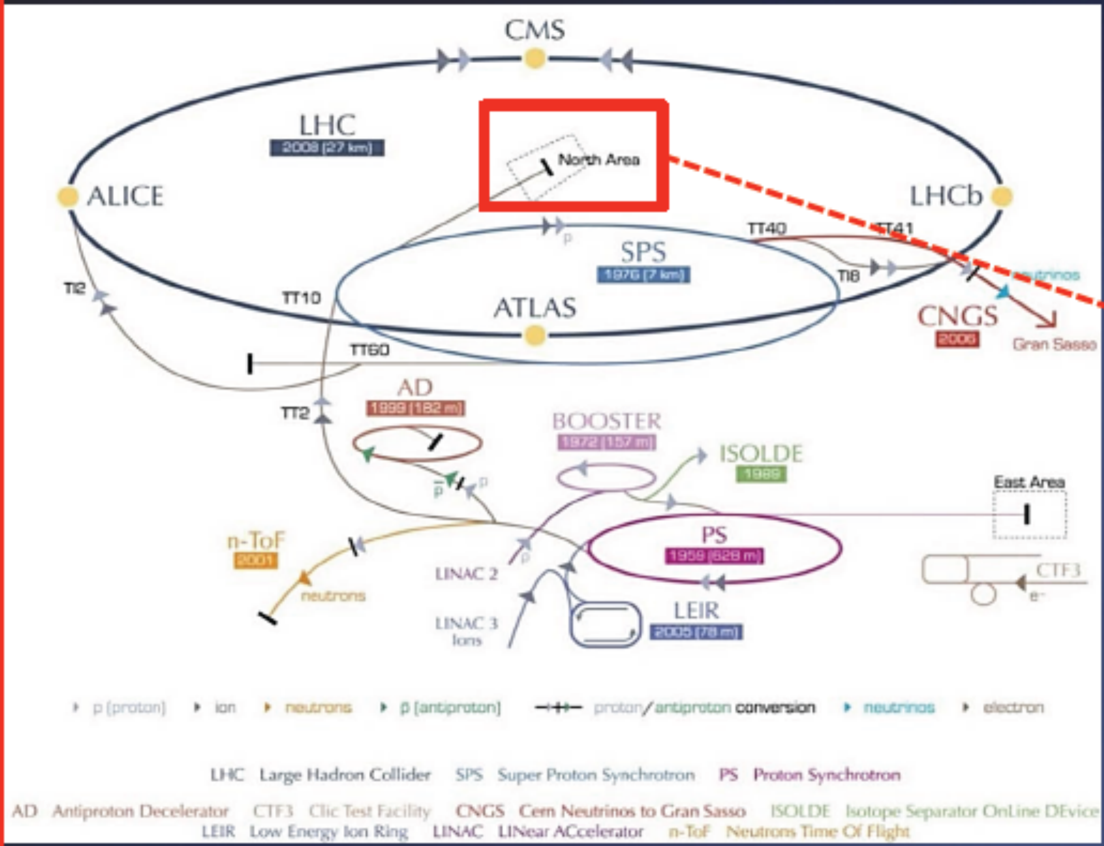
- Benefits from existing extraction tunnel;
- Ideal baseline from storage ring to D0 assembly building:
  - Space and infrastructure for SuperBIND and LAr detector;
- Space and access for near detector

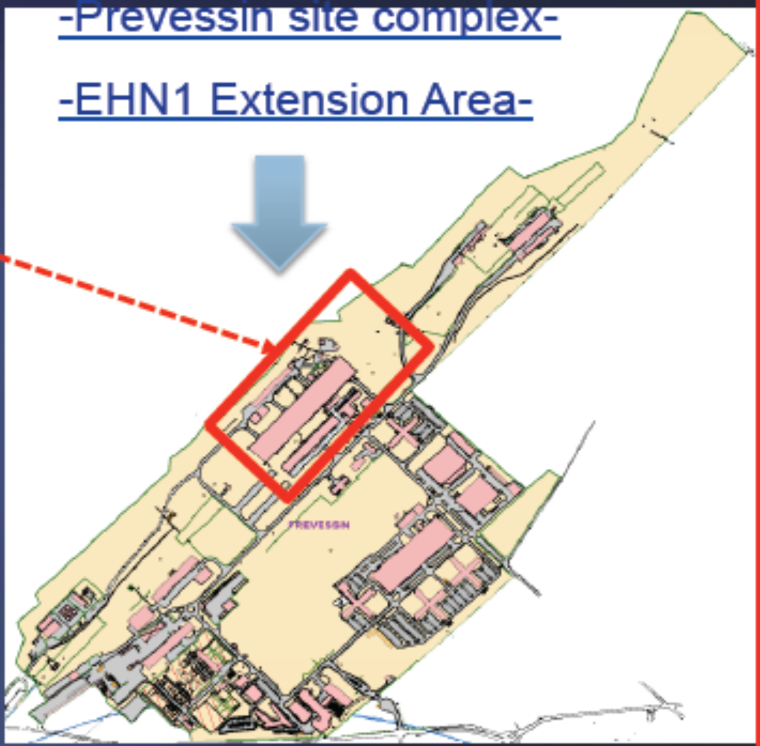
INVESTIGATE

nuSTORM at CERN



CENF – Civil Engineering Extension B887

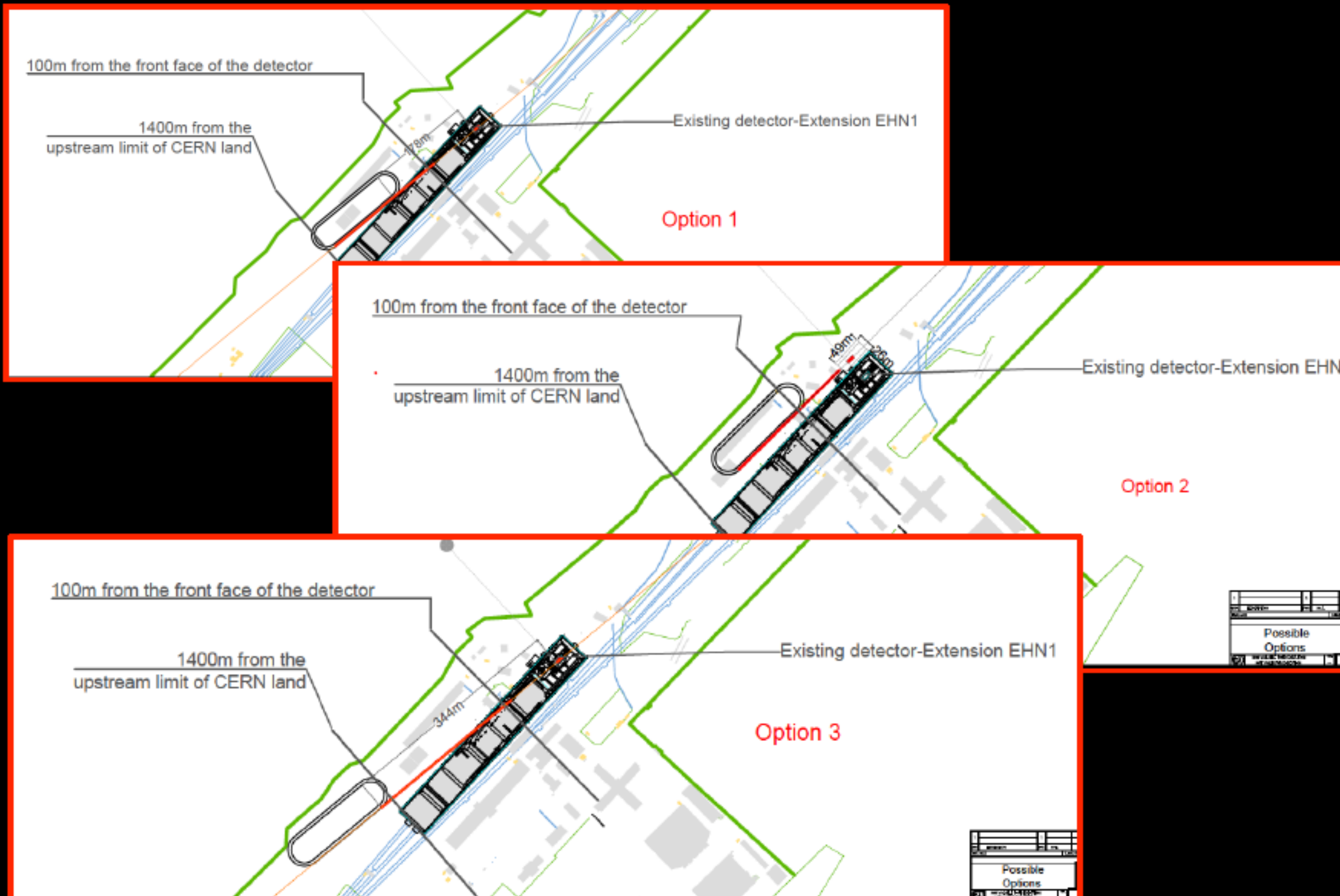




CERN Prototype Meeting – M.Nessi
N.Lopez, M.Manfredi (GS-SE)

nuSTORM serving the CERN Neutrino Platform

under study; M. Nessi et al



Opportunity?

- Is it true that *accurate measurements* of $\nu_e N$ cross sections are critical to realising the potential of the LBL programme?
  - If it is, nuSTORM seems to be the only way to achieve few-% precision

- NuSTEC, NuInt and NNN perhaps ideally placed to address the "in principal" physics question:
  - ICFA Panel:
    - Seeks to find a way to promote this discussion

rjw: KL chairs the ICFA Neutrino Panel

UPPSALA UNIVERSITET

ESSvSB

ESS v Beam Studies

European Spallation Source ESS AB
For Immediate Release

Lund, September 2, 2014

The Construction of ESS is underway

September 2 2014 a groundbreaking event

ESS groundbreaking

How to add a neutrino facility to ESS?

- Increase the linac average power from 5 MW to 10 MW by increasing the linac pulse rate from 14 Hz to 70 Hz, implying that the linac duty cycle increases from 4% to 8%.
- Inject into an accumulator ring circumference ca 400 m) to compress the 3 ms proton pulse length to 1.5 μs, which is required by the operation of the neutrino horn (fed with 350 kA current pulses). The injection in the ring requires H^- pulses to be accelerated in the linac.
- Add a neutrino target station (studied in EUROν)
- Build near and far neutrino detectors (studied in LAGUNA)
- Boundary condition: the neutron program must not be affected

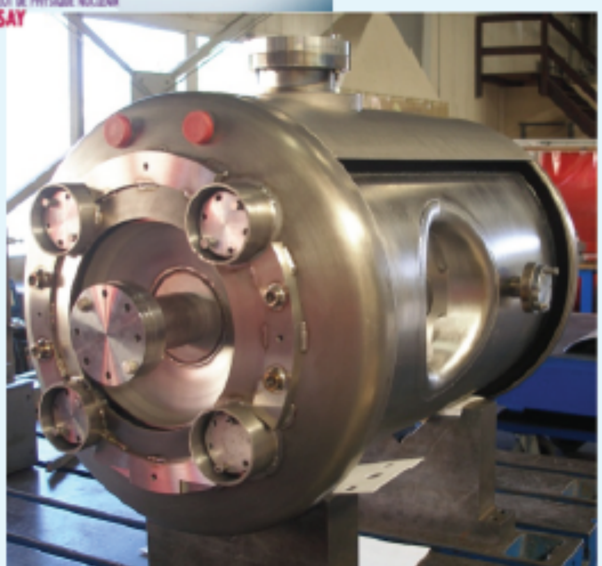
2.0 GeV protons

2.5 GeV protons

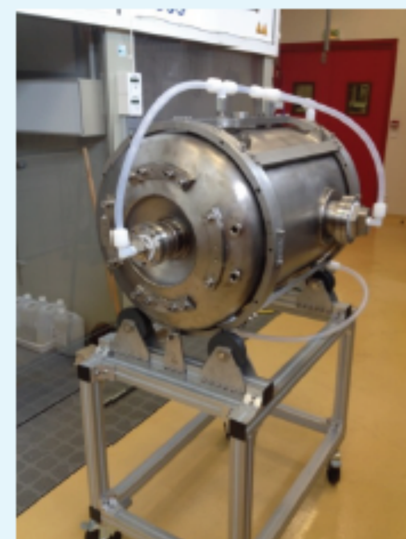
Tests of increasing the linac average power by increasing the proton pulse frequency

A prototype 352 MHz spoke cavity for the ESS linac will be tested in the **FREIA Laboratory at Uppsala University** already as from spring 2015 in a cryostat at 70 Hz pulse frequency and at the full instantaneous power

August 2014



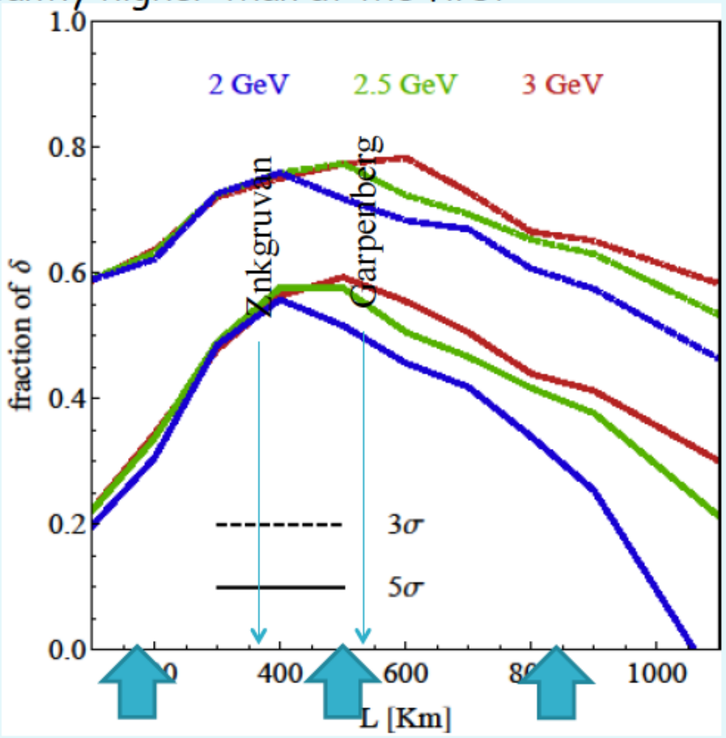
October 2014



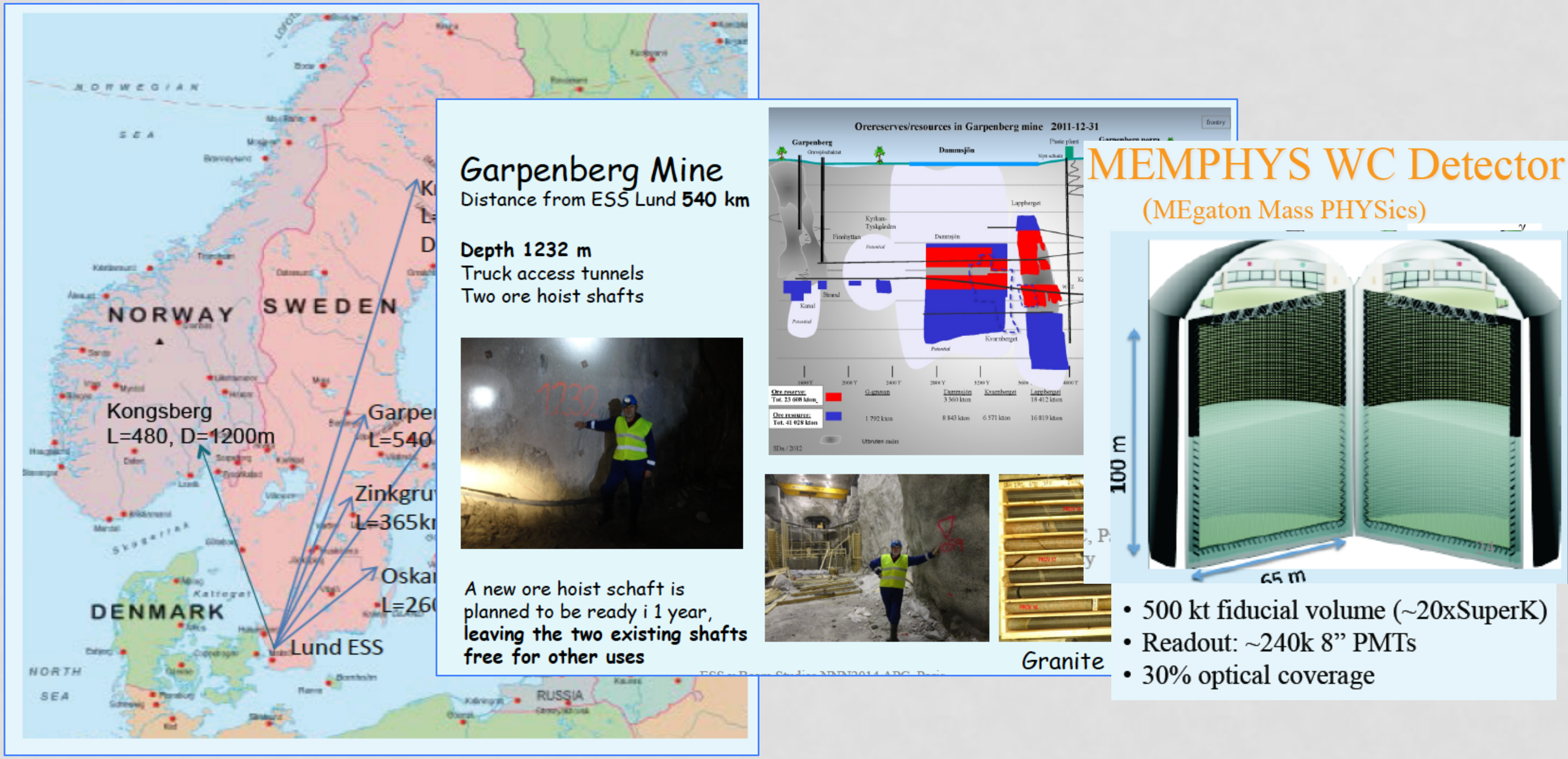
For what is this high power 5 MW needed and which is the optimal distance at which to locate the detector?

After the spring 2012, when Θ_{13} had been measured and ESSnuSB was designed, CP violation discovery probability did not increased at the first maximum – at the second maximum it however increased drastically and became significantly higher than at the first

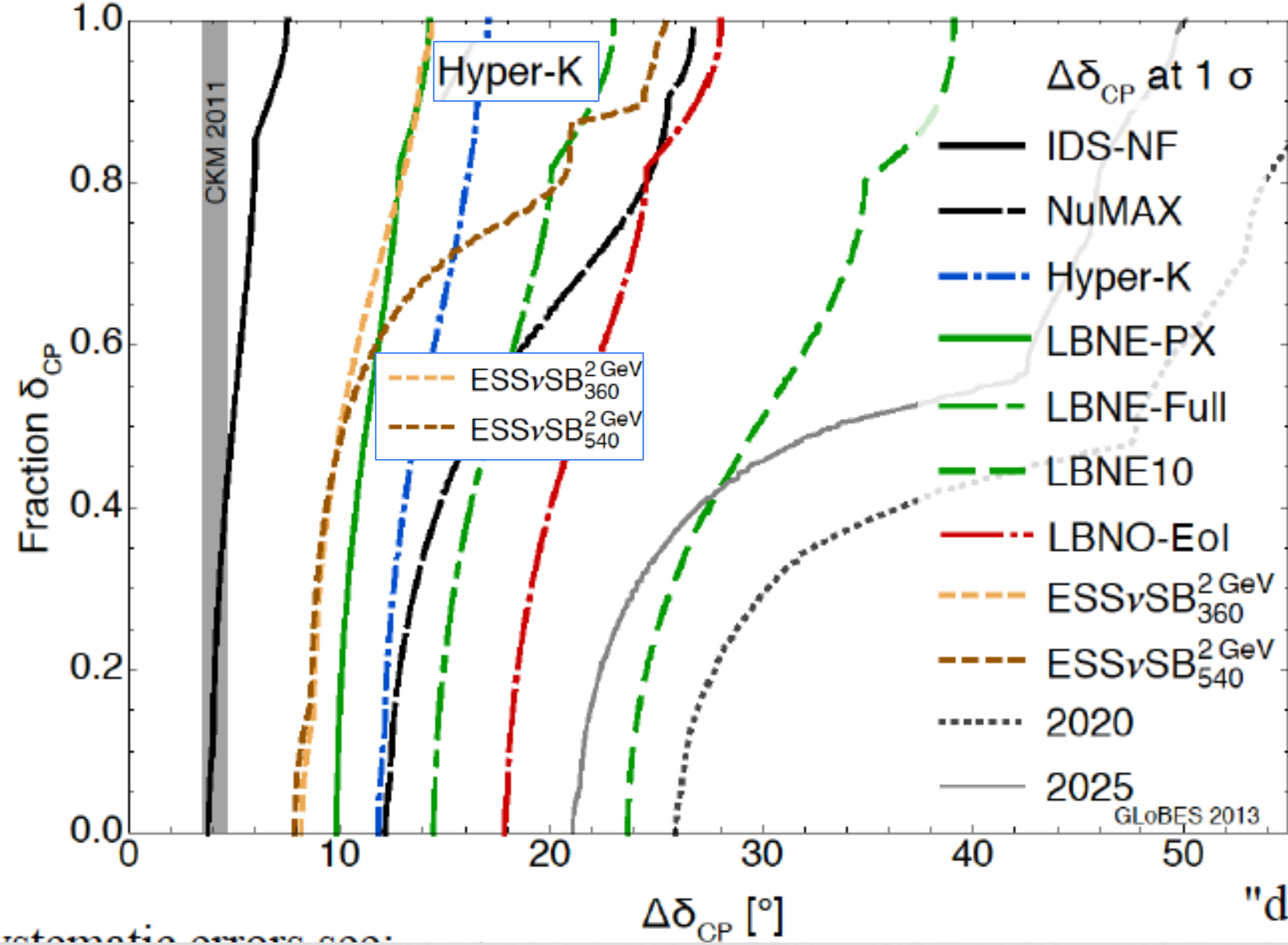
$\Theta_{13}=8.73^o$



2014-11-04 ESS ν Beam Studies NNN2014 APC, Paris
Tord Ekelof, Uppsala University 30


NORWEGIAN SEA
NORWAY
SWEDEN
DENMARK
NORTH SEA
RUSSIA
Kongsberg
L=480, D=1200m
Lund ESS
Garpenberg Mine
Distance from ESS Lund 540 km
Depth 1232 m
Truck access tunnels
Two ore hoist shafts
A new ore hoist schaft is
planned to be ready i 1 year,
leaving the two existing shafts
free for other uses
Orereserves/resources in Garpenberg mine 2011-12-31
Granite
MEMPHYS WC Detector
(MEgaton Mass PHYSics)
100 m
65 m
• 500 kt fiducial volume (~20xSuperK)
• Readout: ~240k 8" PMTs
• 30% optical coverage

(USA snowmass process, P. Coloma)



ESS Neutrino Super Beam

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Nuclear Physics B 885 (2014) 127–149
NUCLEAR PHYSICS B
www.elsevier.com/locate/nuclphysb

A very intense neutrino super beam experiment for leptonic CP violation discovery based on the European spallation source linac

E. Baussan [m], M. Blennow [l], M. Bogomilov [k], E. Bouquerel [m], O. Caretta [c], J. Cederkäll [f], P. Christiansen [f], P. Coloma [b], P. Cupial [e], H. Danared [g], T. Davenne [c], C. Densham [c], M. Dracos [m,*], T. Ekelöf [n,*], M. Eshraqi [g], E. Fernandez Martinez [h], G. Gaudiot [m], R. Hall-Wilton [g], J.-P. Koutchouk [n,d], M. Lindroos [g], P. Loveridge [c], R. Matev [k], D. McGinnis [g], M. Mezzetto [j], R. Miyamoto [g], L. Mosca [i], T. Ohlsson [l], H. Öhman [n], F. Osswald [m], S. Peggs [g], P. Poussot [m], R. Ruber [n], J.Y. Tang [a], R. Tsenov [k], G. Vankova-Kirilova [k], N. Vassilopoulos [m], D. Wilcox [c], E. Wildner [d], J. Wurtz [m]

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[b] *Center for Neutrino Physics, Virginia Tech, Blacksburg, VA 24061, USA*
[c] *STFC Rutherford Appleton Laboratory, OX11 0QX Didcot, UK*
[d] *CERN, CH-1211 Geneva 23, Switzerland*
[e] *AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Krakow, Poland*
[f] *Department of Physics, Lund University, Box 118, SE-221 00 Lund, Sweden*
[g] *European Spallation Source, ESS AB, P.O. Box 176, SE-221 00 Lund, Sweden*
[h] *Dpto. de Física Téorica and Instituto de Física Téorica UAM/CSIC, Universidad Autónoma de Madrid, Cantoblanco, E-28049 Madrid, Spain*
[i] *Laboratoire Souterrain de Modane, F-73500 Modane, France*
[j] *INFN Sezione di Padova, 35131 Padova, Italy*
[k] *Department of Atomic Physics, St. Kliment Ohridski University of Sofia, Sofia, Bulgaria*
[l] *Department of Theoretical Physics, School of Engineering Sciences, KTH Royal Institute of Technology, AlbaNova University Center, SE-106 91 Stockholm, Sweden*
[m] *IPHC, Université de Strasbourg, CNRS/IN2P3, F-67037 Strasbourg, France*
[n] *Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden*

arXiv:1212.5048
arXiv:1309.7022

14 participating institutes from 10 different countries, among them ESS and CERN

EU H2020 Design Study application to be submitted next week

IsoDAR and DAEδALUS

Joshua Spitz, MIT
NNN, 11/4/2014

DAEδALUS / IsoDAR

R&D under way on high-power cyclotrons to provide compact, high-intensity, low-energy neutrino sources:

- Stopped pion "beam"

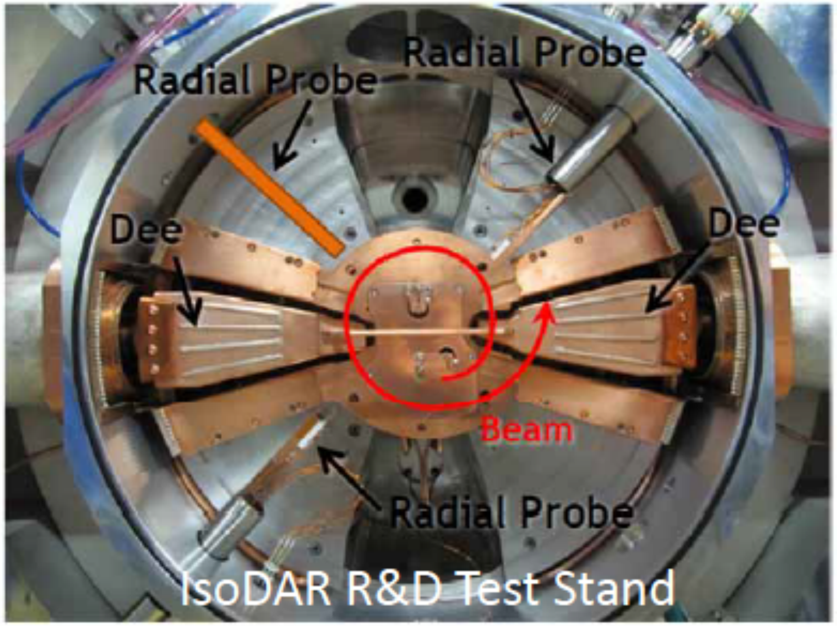
  $\pi^+ \rightarrow \mu^+ \nu_\mu;$
  $\hookrightarrow e^+ \nu_e \bar{\nu}_\mu$

  (DAEdALUS)

- Isotope decay-at-rest "beam"

  $^8\mathrm{Li} \rightarrow {}^8\mathrm{Be} + e^- + \overline{\nu}_e$

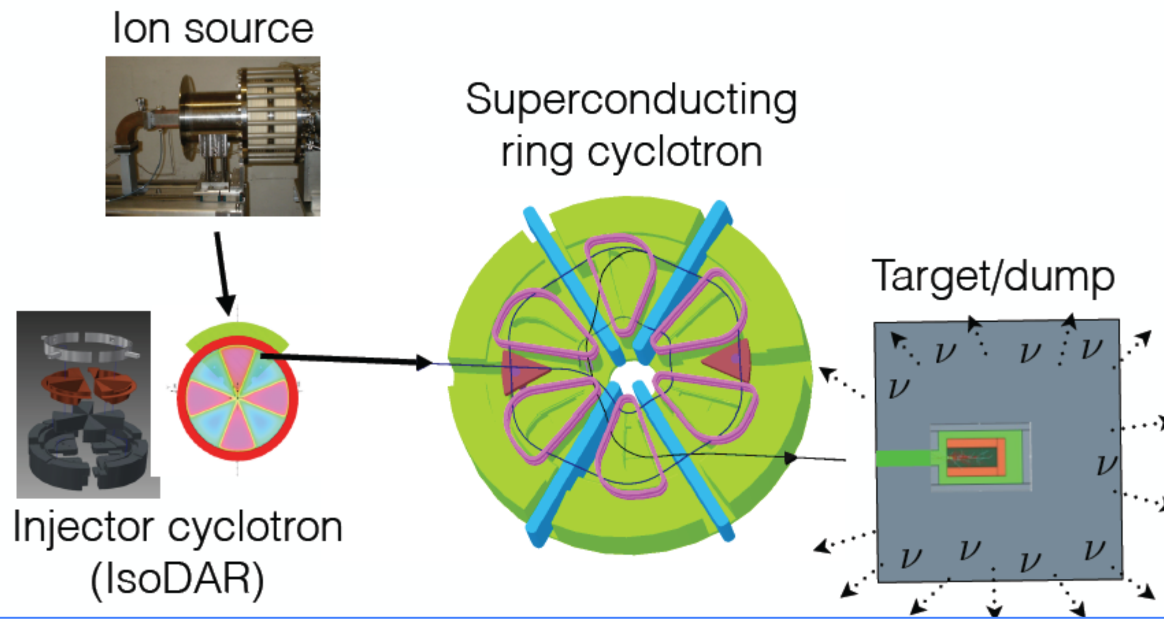
  (IsoDAR)

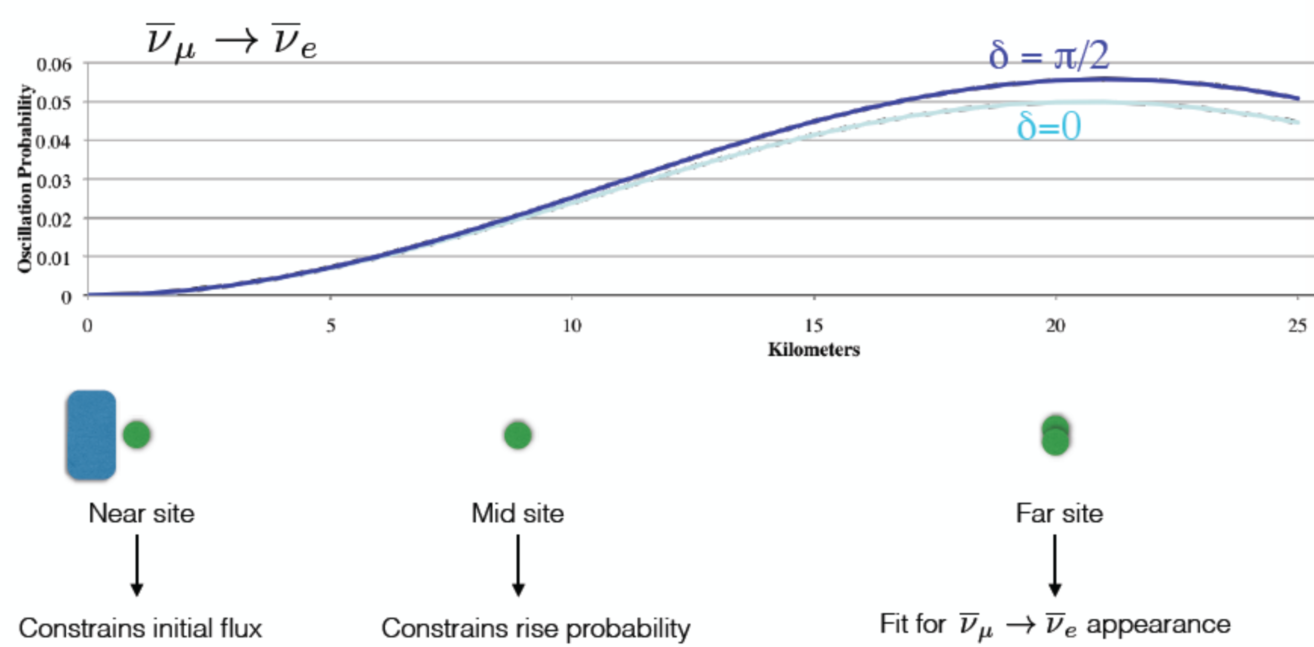


Beam has been brought from the ion source, through the low energy beam transport, through the axial inflector, and into the cyclotron where it is accelerated and make 3.5 turns (600 keV)!

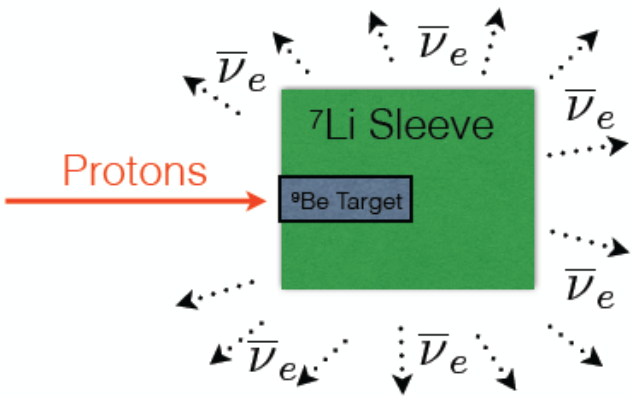
J. Spitz, NuFact 2014

The DAEδALUS program





IsoDAR updates



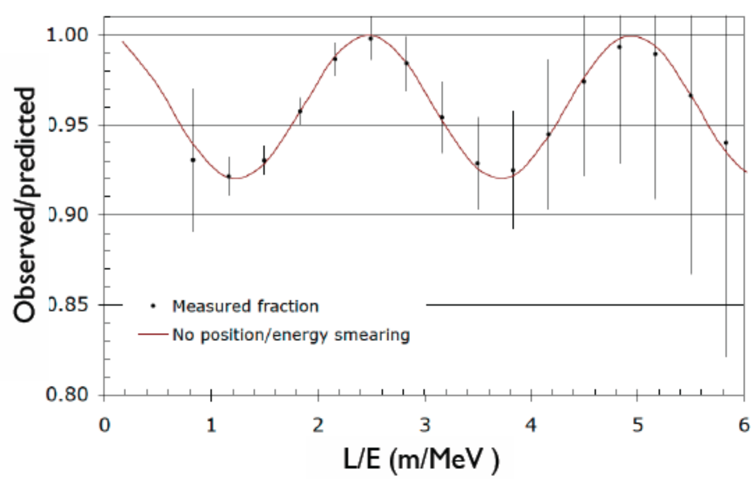
$$p + {}^9\mathrm{Be} \rightarrow {}^8\mathrm{Li} + 2p$$

$$p + {}^9\mathrm{Be} \rightarrow {}^9\mathrm{B} + n$$
$$n + {}^7\mathrm{Li} \rightarrow {}^8\mathrm{Li} + \gamma$$

$$^8\mathrm{Li} \rightarrow {}^8\mathrm{Be} + e^- + \overline{\nu}_e$$

$$\overline{\nu}_e \rightarrow \overline{\nu}_x \quad ?$$

(3+1) Model with Δm^2 = 1.0 eV^2 and $\sin^2 2\theta$=0.08



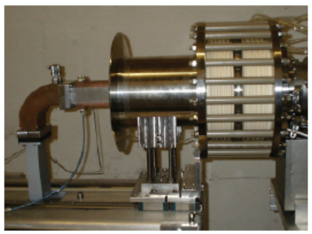
820,000 IBD events in 5 years at KamLAND
(16 m baseline to center of detector)

IsoDAR challenges

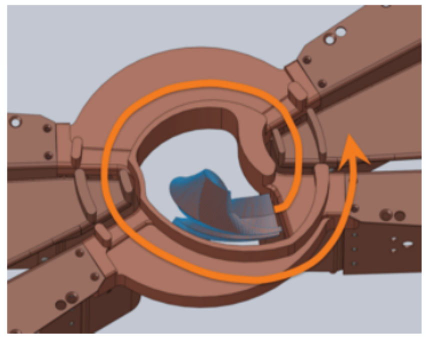
- Space charge

The beam width increases because the H_2^+ ions repel each other. This is a big problem at injection and near the outside of the cyclotron where the turn spacing is low.

- Ion source intensity

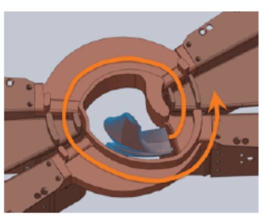


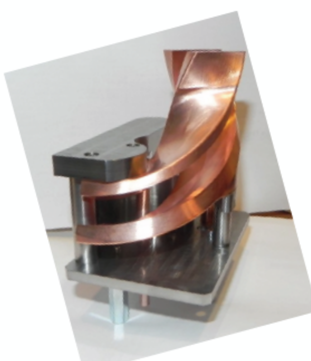
The ion source

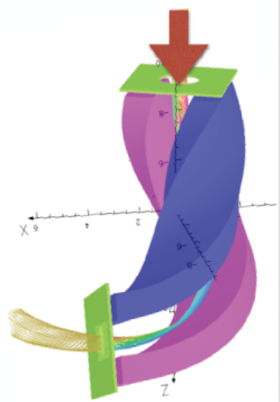


The first turn after axial inflection

- Inflection

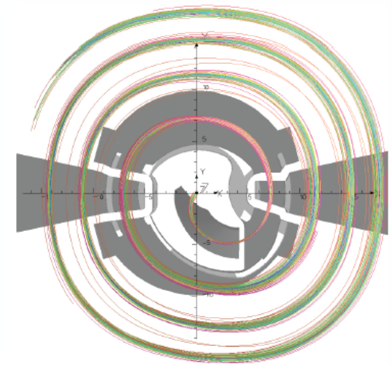




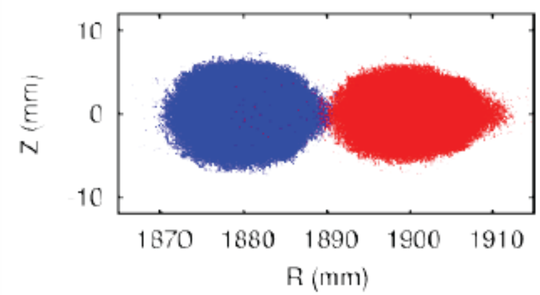


Getting the beam into the cyclotron requires taking it from the vertical to the horizontal plane. This is hard.

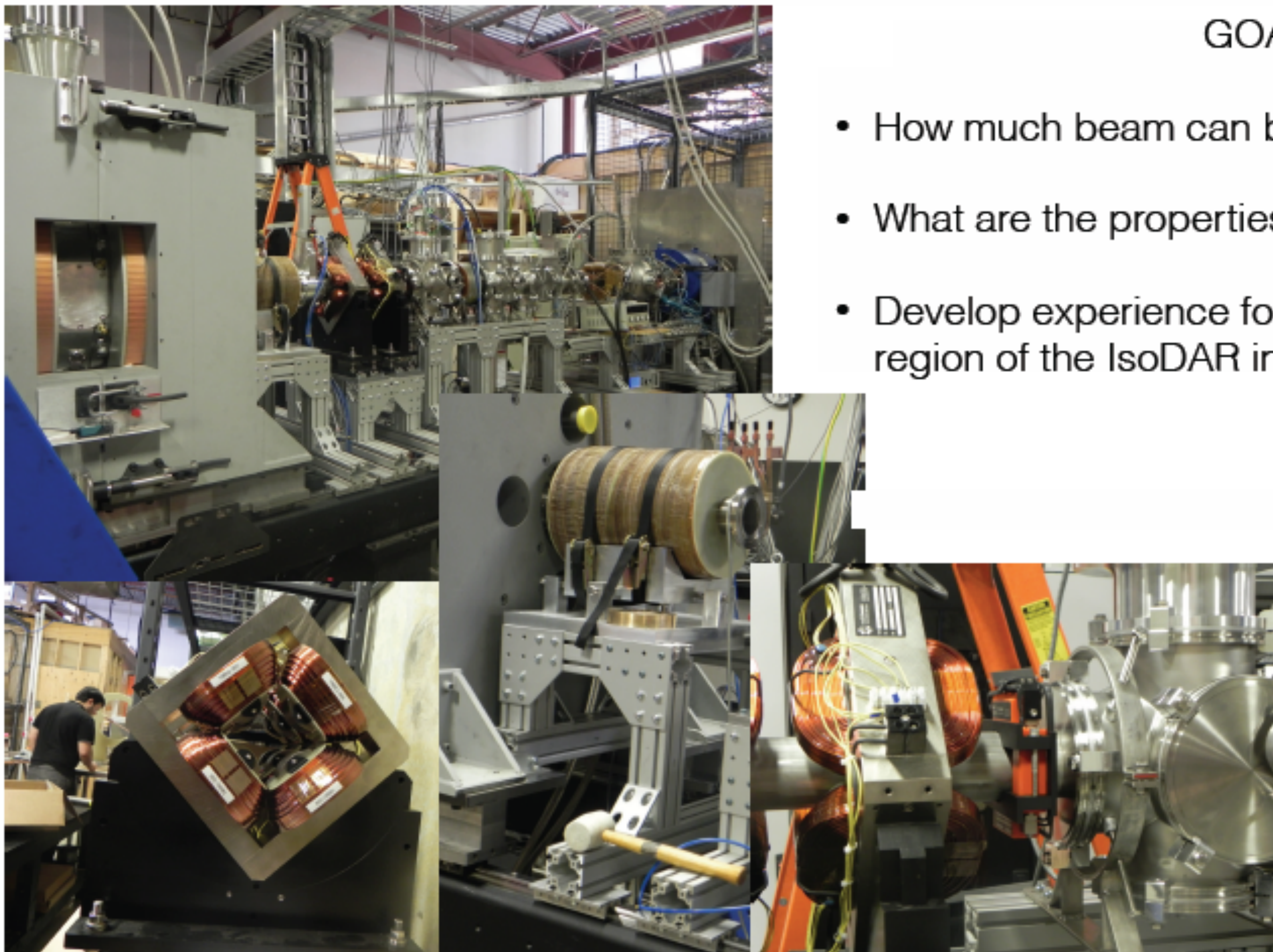
SIMULATIONS UNDERWAY



Beam dynamics sim



Beam is now being characterized at Best Cyclotrons, Inc, Vancouver (Best Cyclotron Systems, INFN-Catania, and MIT -- NSF funded)



GOALS

- How much beam can be captured?
- What are the properties of the captured beam?
- Develop experience for designing the central region of the IsoDAR injector cyclotron.

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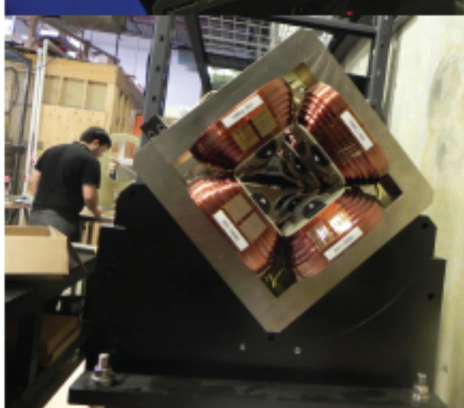
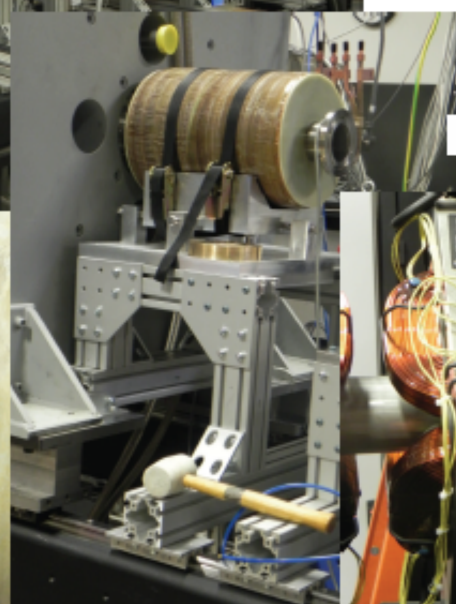
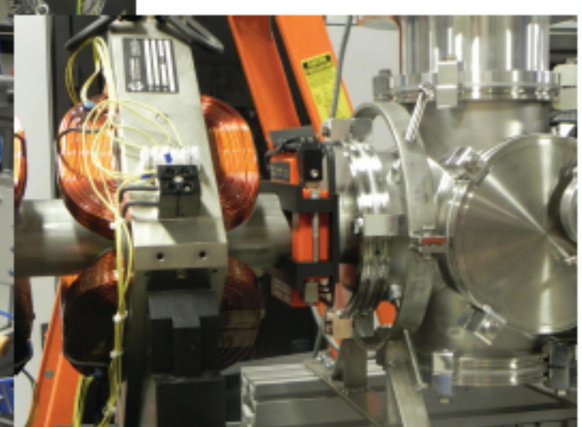
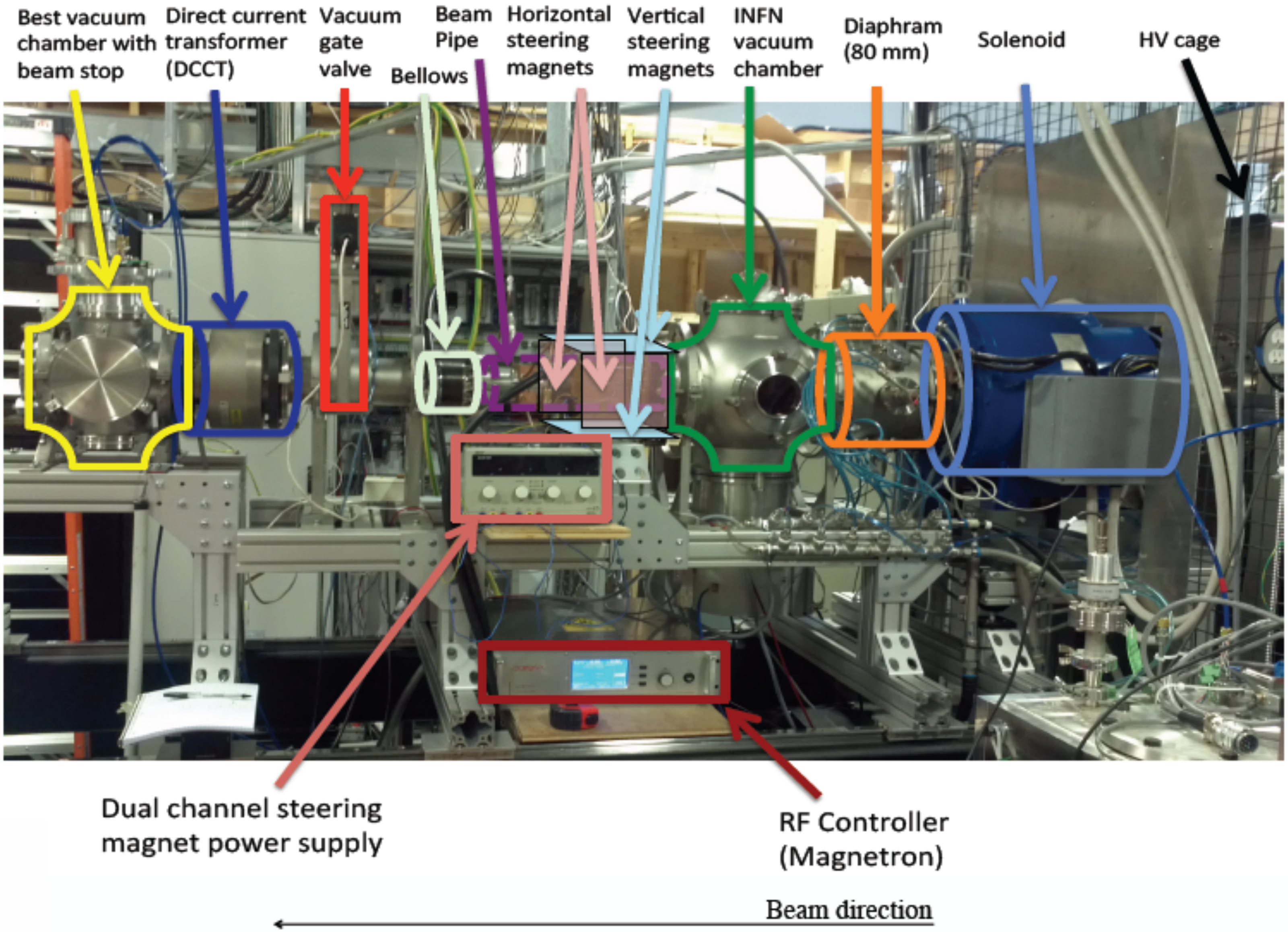
(Best Cyclotron Systems, INFN-Catania, and MIT -- NSF funded)

- Ion source from INFN-Catania installed at BEST Cyclotrons Inc. lab in Vancouver.
- 40 mA protons demonstrated (summer, 2013) and now focusing on H_2^+.
- Initial output is 12 mA (20-30 mA anticipated with new plasma chambers).

There were a number of important milestones reached this summer!



Conclusions

- The DAEδALUS collaboration is pursuing a phased approach towards a precise measurement of δ_{CP}.
- There is physics at each phase.
- IsoDAR, in combination with (e.g.) KamLAND, will provide a definitive statement on the sterile neutrino.
- These cyclotrons have applications outside of particle physics and industry is pursuing these machines by our side.

SUMMARY

- A fascinating/feature packed session – a challenge to summarize for a non-expert
- I hope I was sufficiently "responsable"