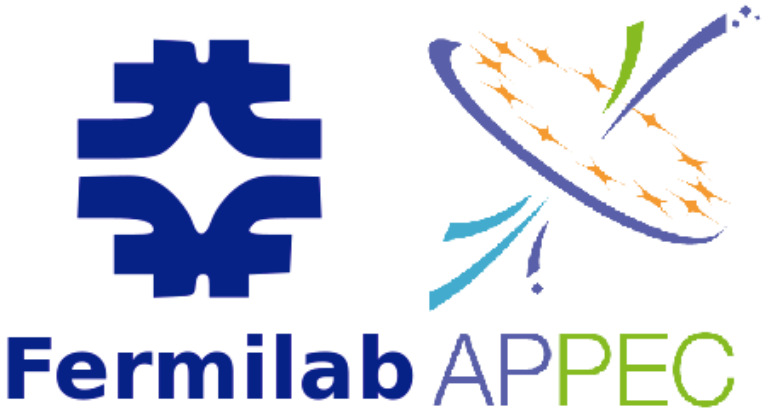


Second International Meeting for Large Neutrino Infrastructures

20-21 April 2015
Fermilab
US/Central timezone

ICFA report

Imperial College London

K. Long, 20 April, 2015

Science & Technology Facilities Council

Contents

- The ICFA Neutrino Panel
- Developing a roadmap
- Next steps

ICFA report

THE ICFA NEUTRINO PANEL

ICFA Neutrino Panel

http://www.fnal.gov/directorate/icfa/neutrino_panel.html

Mandate

To promote international cooperation in the development of the accelerator-based neutrino-oscillation program and to promote international collaboration in the development of a neutrino factory as a future intense source of neutrinos for particle physics experiments.

The ICFA Neutrino Panel

ICFA Neutrino Panel				
LONG	Kenneth	UK	Imperial	Experiment; Chair
The Americas				
TANAKA	Hirohisa	Canada	Institute of Particle Physics	Experiment
Gomes	Ricardo	Latin America	Universidade Federal de Goiás (UFG)	Experiment
GEER	Stephen	USA	FNAL	Experiment, Accelerator
de GOUVEA	Andre	USA	Northwestern	Theory
ZELLER	Sam	USA	FNAL	Experiment
Asia				
KOBAYASHI	Takashi	Japan	KEK	Experiment
SHIOZAWA	Masato	Japan	Tokyo	Experiment
KIM	Soo-Bong	Korea	Seoul National University	Experiment
MONDAL	Naba	India	TIFR	Experiment
CAO	Jun	China	IHEP	Experiment
Europe				
MEZZETTO	Mauro	Italy	Padova	Experiment
DUCHESNEAU	Dominique	France	CNRS/IN2P3	Experiment
MALTONI	Michele	Spain	Madrid	Theory
WASCKO	Morgan	UK	Imperial	Experiment
SOBCZYK	Jan	Poland	Wroclaw	Theory

20-Feb-15

History

- Panel inception summer 2013
- First year:
  - Three-region peer-group consultation;
  - Initial report …

Contents

arXiv:1405.7052v1

Initial conclusions [1]

0. The study of the neutrino is the study of new phenomena that are not described by the Standard Model;
1. Accelerator-based programme is vibrant & is international in intellectual interest, engagement and scope;
2. The optimal exploitation of the present and approved experiments will benefit from increased cooperation in the development of better s/w & analysis tools;
3. LBNE and Hyper-K offer complementary approaches to the search for CPiV;
   Dedicated programme required to manage systematics;

Initial conclusions [2]

4. Design studies are underway for LBNO, ESSnuSB & Deadalus potentially attractive alternatives to LBNE and Hyper-K;
5. The Neutrino Factory offers the best sensitivity;
   Incremental implementation of the facility is being studied;
   nuSTORM recognised as an attractive first step;
6. The anomalies in SBL measurements are being investigated energetically;
   SBL programme must also benefit the LBL programme.

Next steps

In its second year the Panel will consult with laboratory Directors, funding-agency representatives, the community and other stakeholders to:

- Develop a road-map for the future accelerator-based neutrino-oscillation programme that exploits the ambitions articulated at CERN, FNAL and J-PARC and includes the programme of measurement and test-beam exposure that will ensure the programme is able to realise its potential;
- Develop a proposal for a coordinated "Neutrino RD" programme, the accelerator and detector R&D programme required to underpin the next generation of experiments; and
- To explore the opportunities for the international collaboration necessary to realise the Neutrino Factory.

History

- Panel inception summer 2013
- First year:
  - Three-region peer-group consultation;
  - Initial report …
  - Consideration of complementarity of LBNF/DUNE and Hyper-K

Hyper-K/DUNE complementarity

- **Study of neutrino oscillation:**
  - **Optimised at same *L/E*, but, different *L* & *E* (×5)**
    - **Comparable discovery reach for CPiV**
      - **If developed on "technically limited" schedules, will compete for discovery**
      - **Independent confirmation/combined sensitivity enhances discovery potential for this important and difficult measurement**
    - **Comparable precision on mixing parameters**
      - **Matter effect**
        - **Strong at LBNF baseline (1300 km); sensitivity to matter effect**
        - **Weak at Hyper-K baseline (295 km); low sensitivity to matter effect**
      - **Technique**
        - **Hyper-K: low-energy NBB illuminating H_2O Cherenkov**
        - **LBNF: high-energy WBB illuminating Lar TPC**
      - **Added value**
        - **Exploit to resolve parameter degeneracies**
- **Non-standard neutrino physics:**
  - **Different *L* & *E* at same *L/E* gives opportunity to search for non standard effects**
- **Proton decay and supernova searches:**
  - **H_2O and LAr detectors most sensitive to different decay channels**
  - **Determination of electron (anti)neutrino flux from supernova requires both H_2O and LAr detectors**

ICFA report

DEVELOPING A ROADMAP

Overview

- Substantial progress this year:
  - Present programme pushing back the frontiers:
    - NOvA, T2K, MINOS+ accumulating data
  - MicroBOONE installed
  - International Long Baseline Neutrino Facility at FNAL serving:
    - The Deep Underground Neutrino Experiment;
    - Short-baseline Neutrino experiments
  - KEK and ICRR Directors have requested Hyper-K design report this year
- These are the foundations of the programme required to:
  - Complete the picture: MH, CPiV, θ_{23}, …;
  - Begin to test the framework:
    - Redundant set of measurements to over-constrain theSvM
  - Roadmap will identify branch points:
    - Driven by physics with the SvM … and
    - Driven by anamalies ***beyond*** the SvM
- Roadmap, goal:
  - Understand timeline of flagship measurements;
  - Identify the measurements required for the programme to fulfill its potential
  - Identify and define decision/branch points
    - Maximise discovery potential and scientific return in the near, medium and long term

Our timetable

- First full discussion of roadmap yesterday:
  - Presented here in the spirit of a workshop contribution
    - Work in progress;
      - Selection of information only in slides that follow!
- "Raw data":
  - Known, planned or projected dates for milestones
    - To be assembled in consistent form by end April 2015
  - Will engage with experiments/proponents to validate facts
- Assembled roadmap document with commentary:
  - Complete draft within Panel by end May 2015
- Goal:
  - Ready as discussion document June/July

Coherent approach

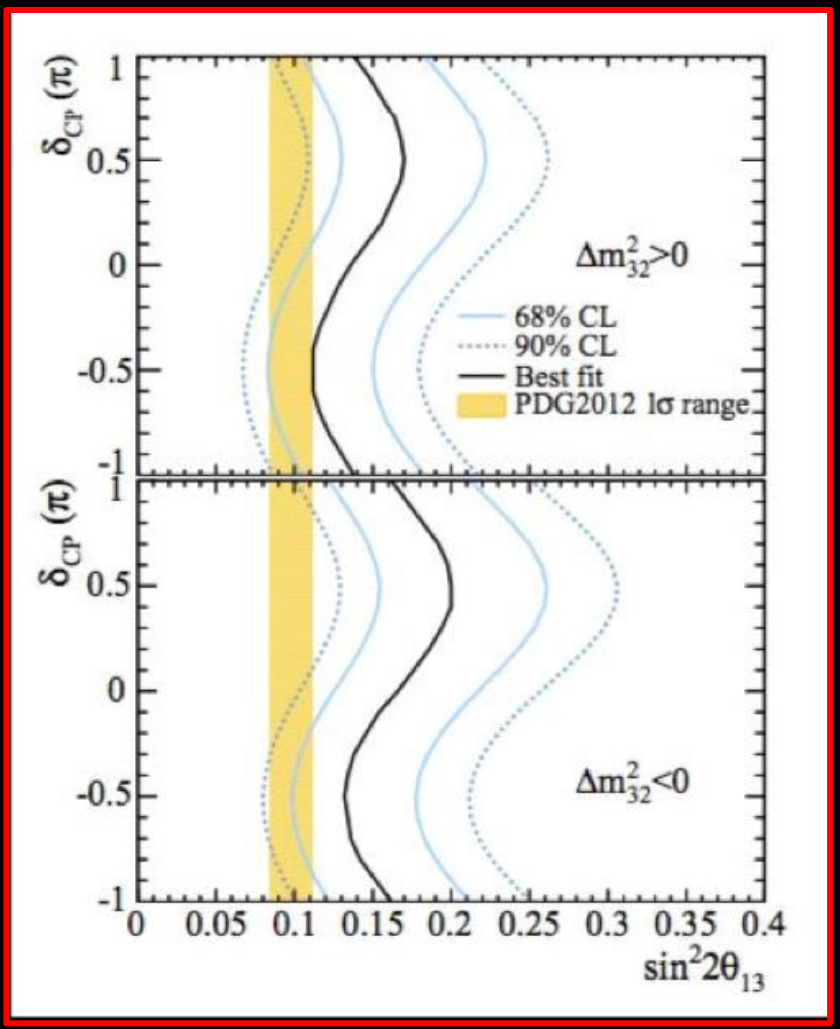
- Common interest of neutrino and astroparticle communities:
  - In large detectors (e.g. DUNE, Hyper-K, …)
  - In results of supporting programme:
    - Hadroproduction
    - Neutrino-nucleus scattering
- So, important to engage with ApPIC and ApPEC
  - Excellent start!
  - Maintain and enhance through discussion of roadmap

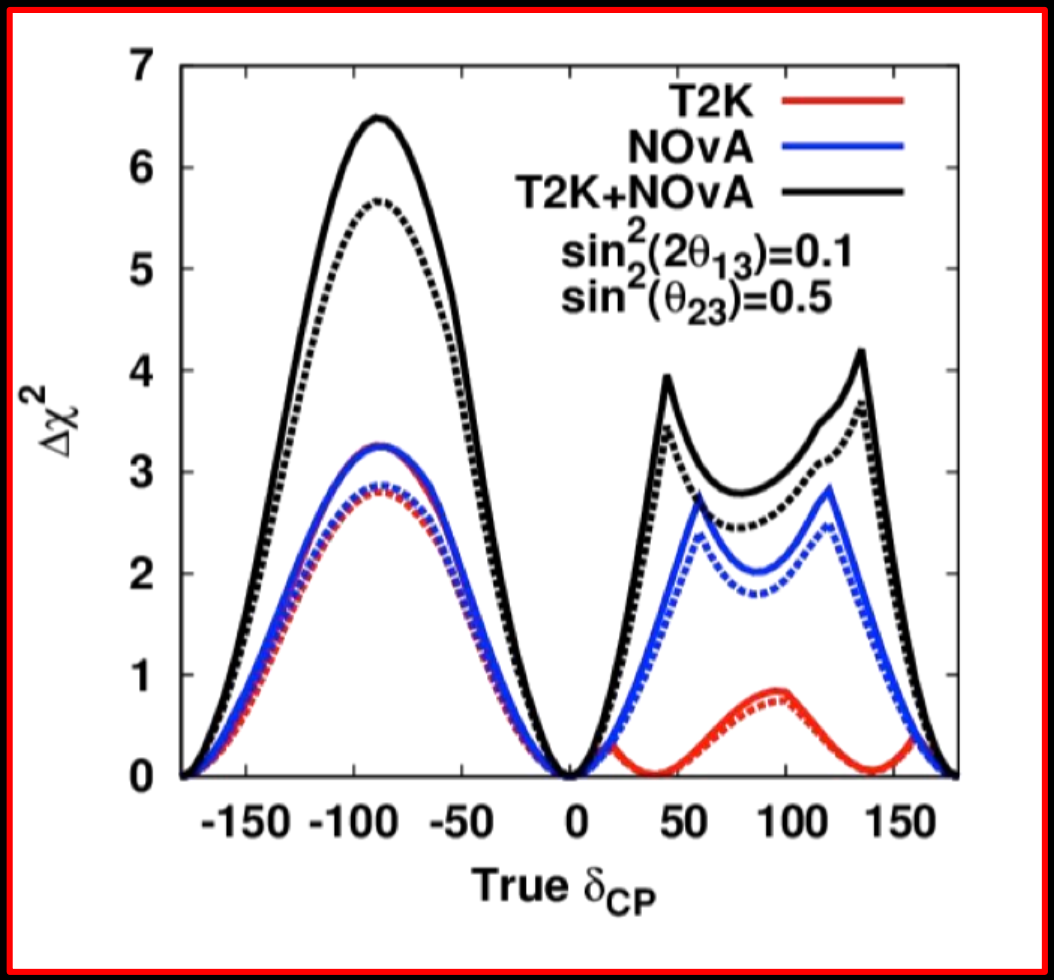
Roadmap categories

- Long-baseline oscillations:
  - NOvA, T2K, Hyper-K, LBNF/DUNE
- Short-baseline oscillations:
  - Accelerator-based sterile neutrino searches
  - Reactor oscillation measurement and sterile searches
- Neutrino fixed-target programme
- Supporting programme
- Non-terrestrial source
- Simulation, combination and code development
- Deep underground
- Non-oscillation programme

Long-baseline oscillations, now

- Seek to capture development of reach of an experiment
  - And of experiments in combination:
    - For example: T2K and combination with NOvA





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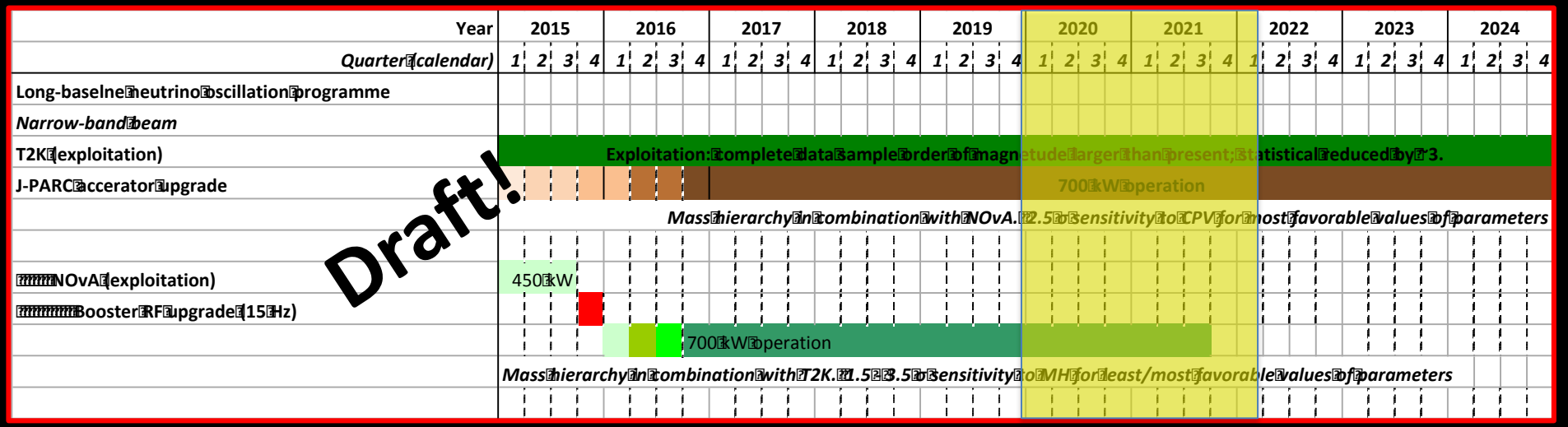
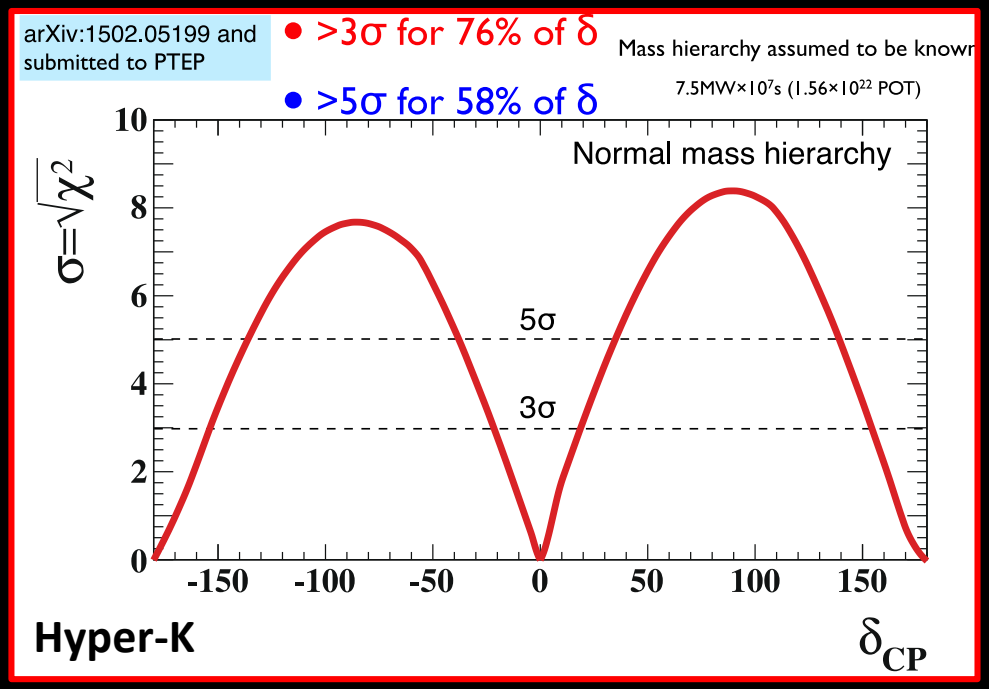
Long-baseline, short-term

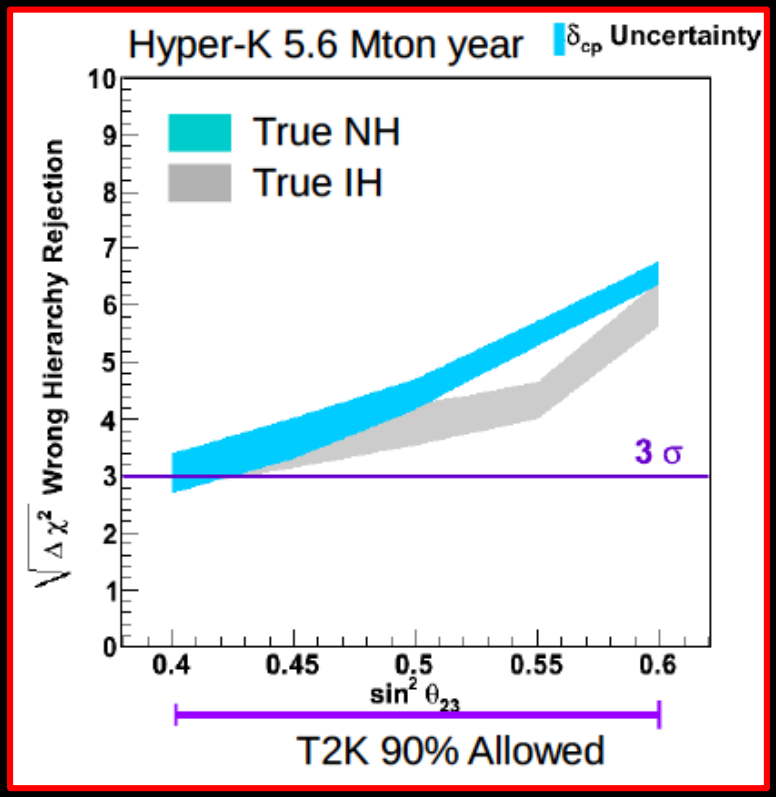


- Evolution of each experiment available:
  - Need to add to spreadsheet
- Combination may lead to exciting, early, indications on, e.g. CPiV:
  - Harder, but interesting to include

Long-baseline, medium term

- **Figures of merit to "track" development:**
  - **Examples: MH, CPiV:**
    - **Also θ_{23} …**

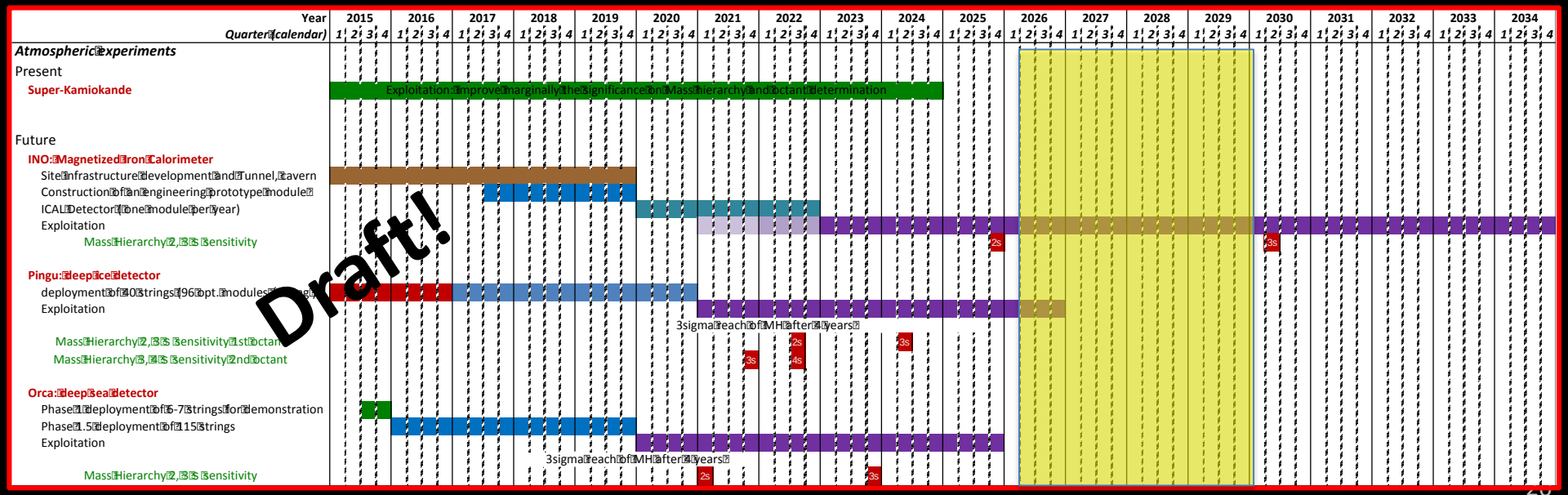




Duchesnau, Mondal

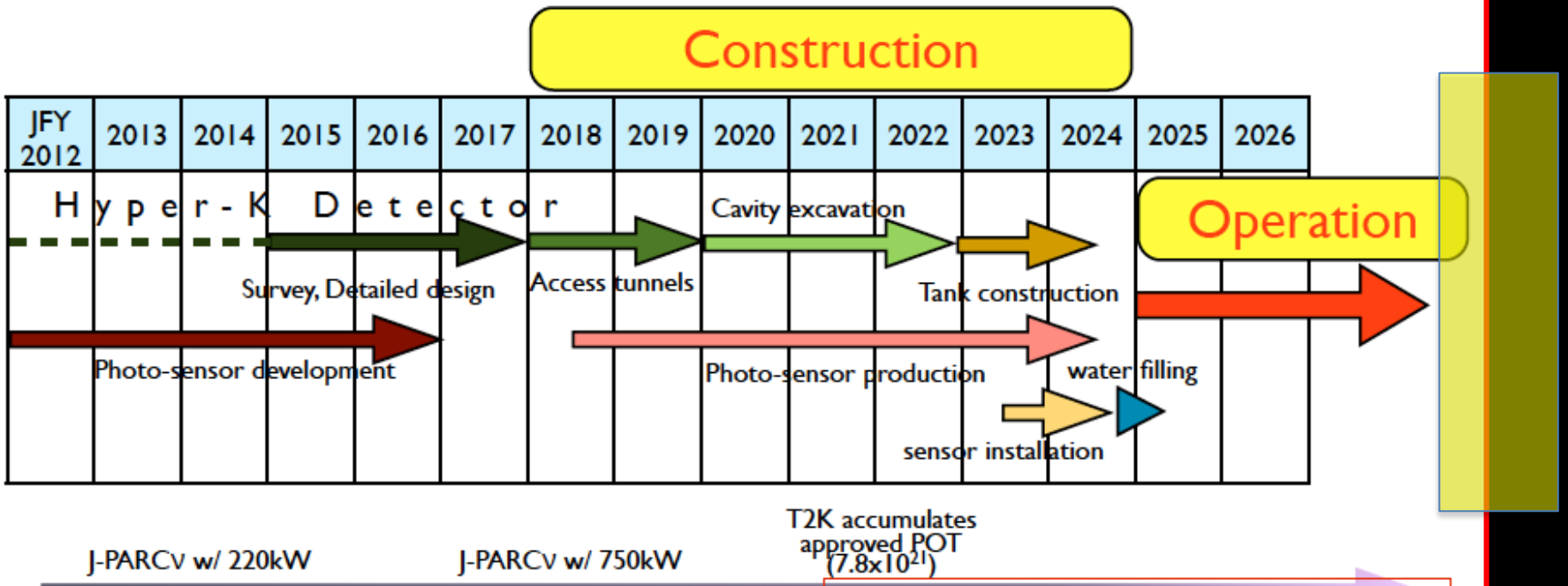
Non-terrestrial experiments

- ICECUBE and KM3NET (described tomorrow):
  - Uniquely large experiments to study astrophysical neutrinos
- Extensions, PINGU and ORCA (also tomorrow):
  - Instrumentation to reduce energy threshold;
  - Sensitivity to neutrino mass hierarchy
- India Neutrino Observatory (also tomorrow):
  - Unique: magnetised iron detector;
  - Study differences between neutrino and antineutrino
  - Anomalies may drive branch in development of accelerator based programme



Long-baseline, medium-term

Hyper-K Notional Timeline



We will assume
0.75MW 10^7sec / year

(Optimistic) Timeline for anticipated results

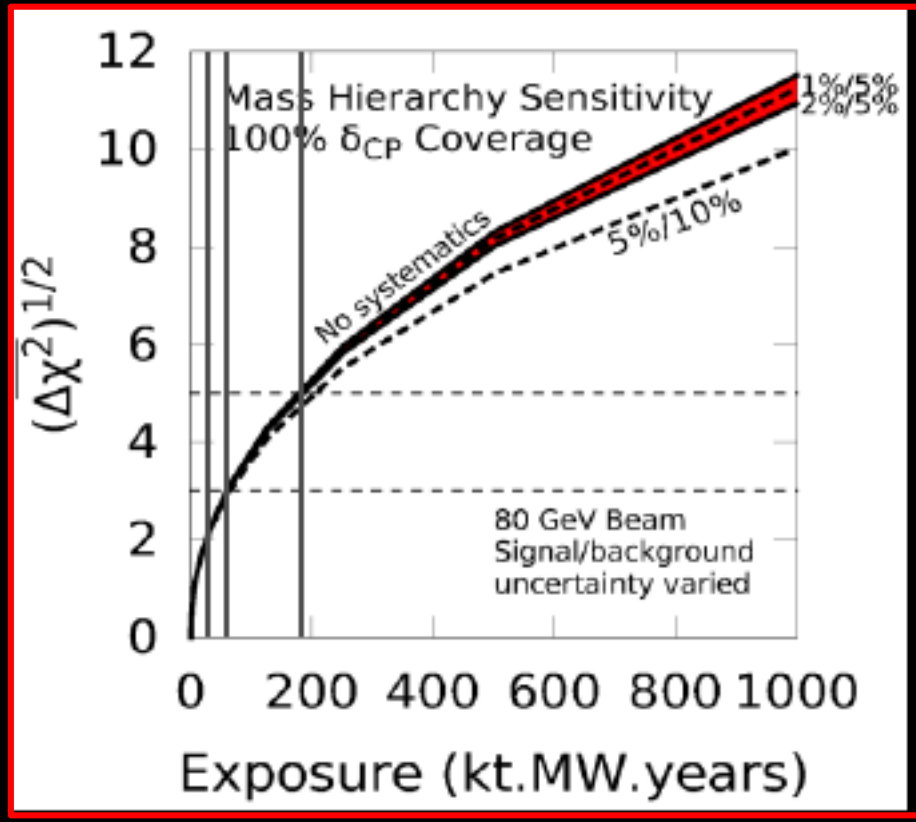
- -2022 ~2σ CPV indication (sinδ=1) by T2K+ Nova +reactors
- -2025 *Start Hyper-K data taking*
- -2028 Discovery of leptonic CPV w/ >5σ (MH at the same time or earlier)
- -2030 Discovery of proton decays
- -20XX Always ready for Supernova neutrino burst

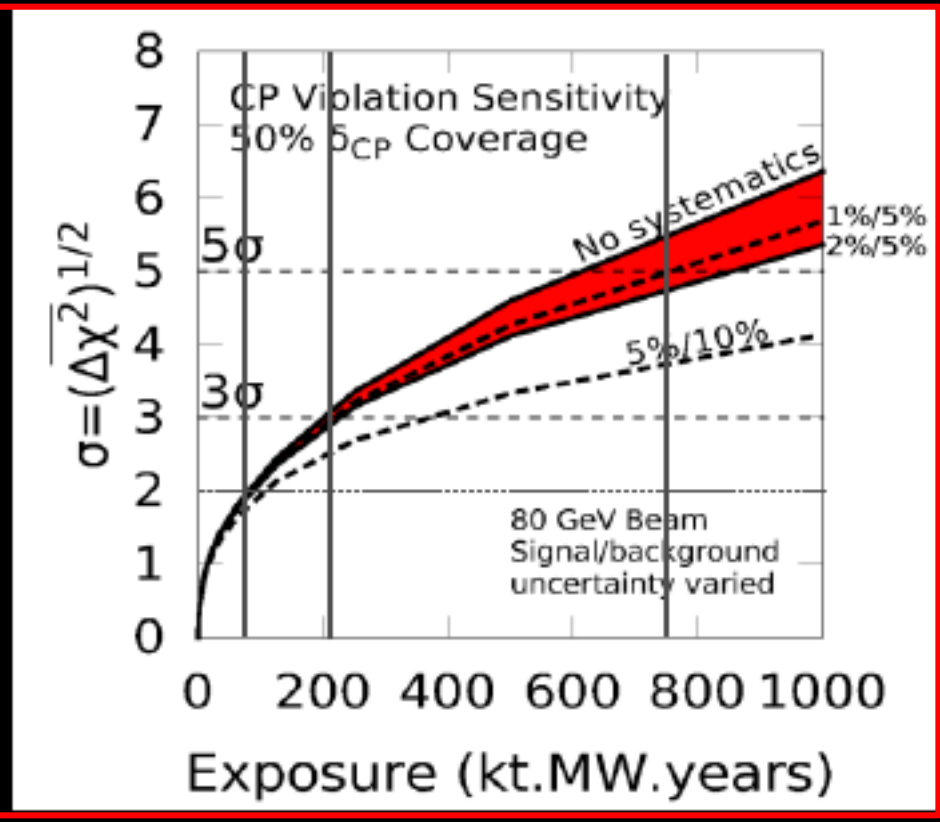
2

Long-baseline, medium term

- **Figures of merit to "track" development:**
  - **Examples: MH, CPiV:**
    - **Also θ_{23} …**

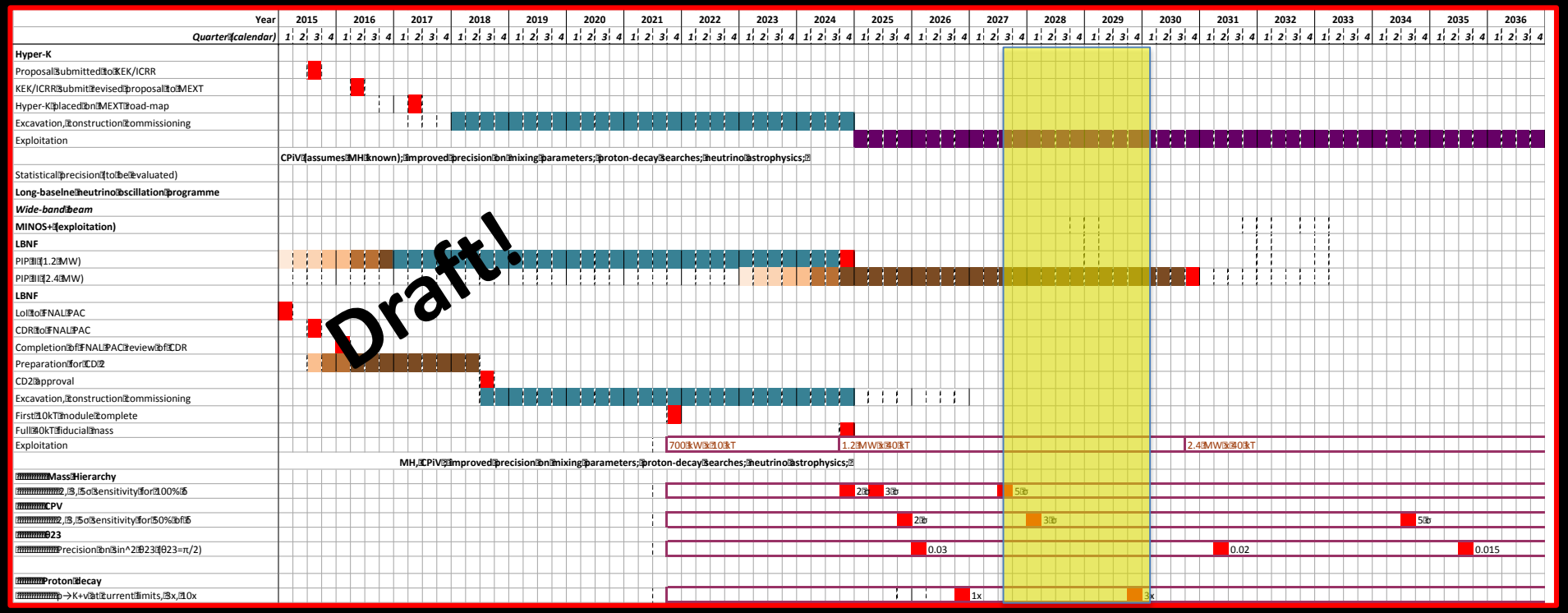
LBNE [DUNE, indicative]





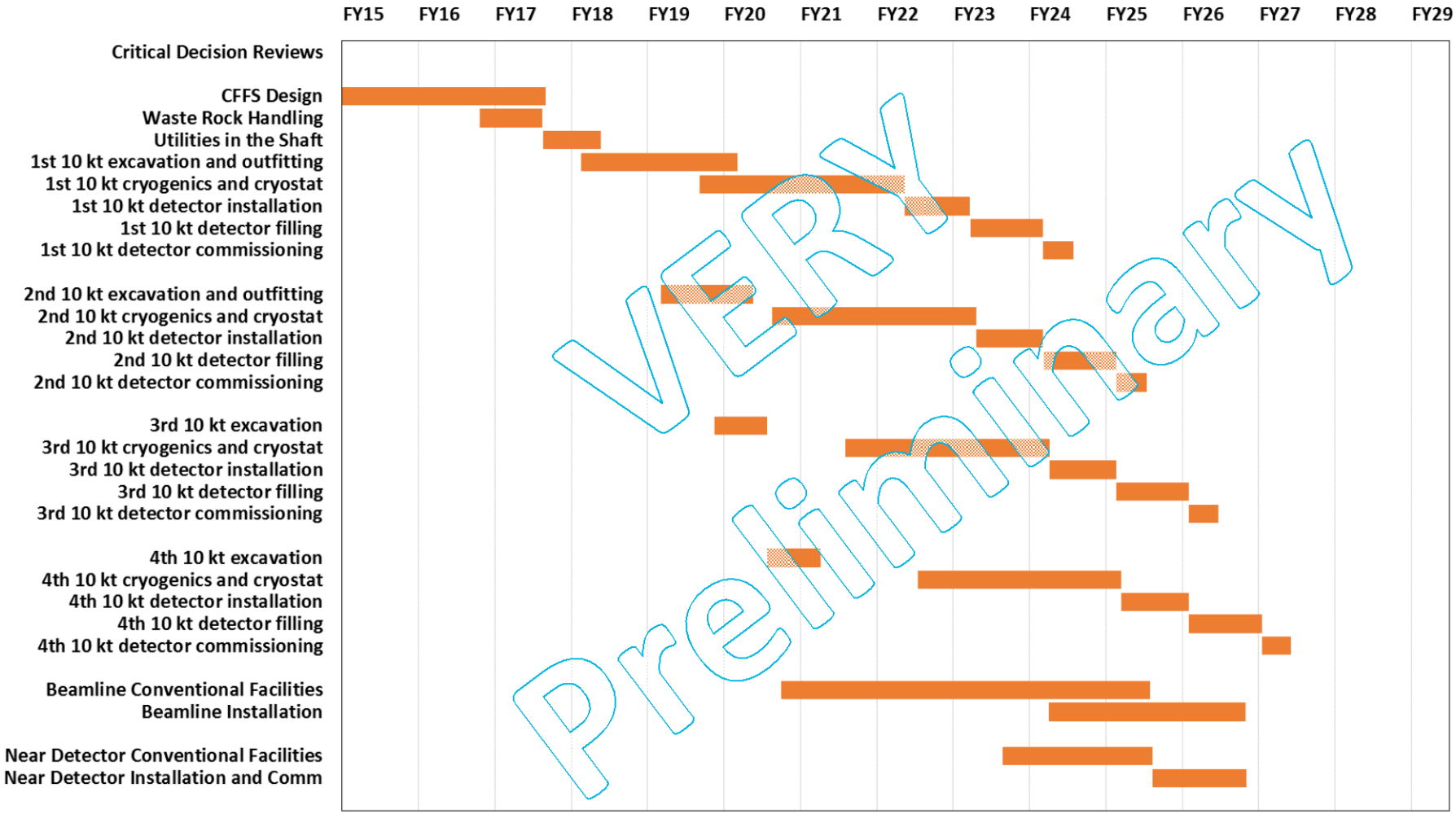
Tanaka

Long-baseline, medium term



- Evolution of experiment's sensitivity extracted from published material;
  - Engage with collaborations in completing the document
- Again, interesting to include exciting developments that may arise from combination
  - Combination DUNE/Hyper-K or other measurements offers opportunity for early discovery
  - Statistically very powerful ~2028/2029

Possible Schedule: DUNE + LBNF



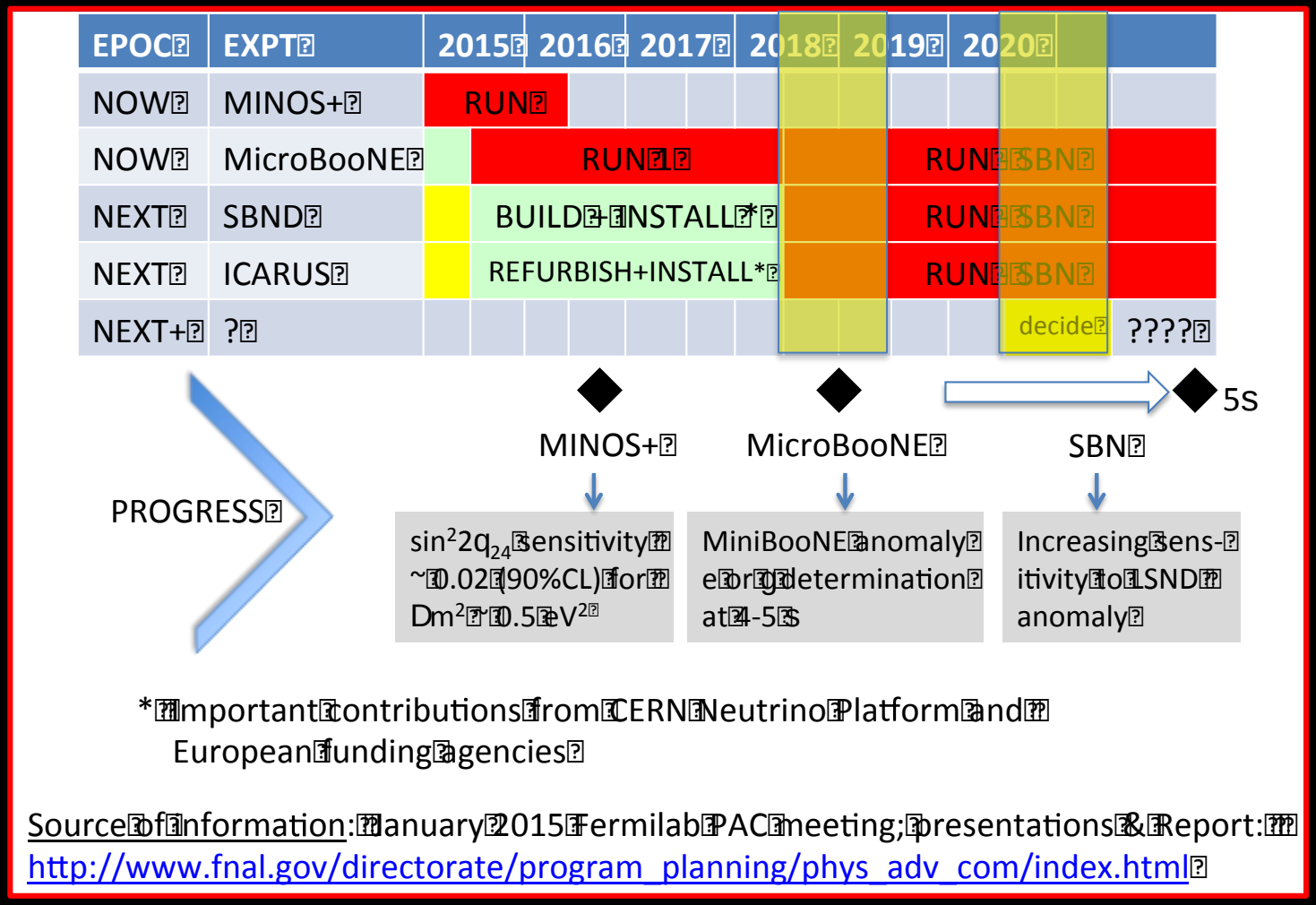
Actual schedule will depend on funding profile not yet provided by DOE and on partner agreements and their schedules to deliver their parts of the two projects.

Reactor oscillation measurement

- Reactor neutrinos offer unique precision on:
  - θ_{13} and Δm_{ee}^2
  - Anticipated precision by ~2017:
    - $\mathrm{Sin}^2(2\theta_{13})$: 10% Double Chooz; 3—4% Daya Bay; 5% RENO
    - Δm_{ee}^2 [10^{-3} eV^2]: 0.07 Daya Bay; 0.1 RENO

- Solar neutrinos extend sensitivity to:
  - θ_{12}, Δm_{21}^2 and Δm_{ee}^2
  - Anticipated precision by ~2025:
    - JUNO/RENO-50: < 1%

Short-baseline sterile neutrino search



- **Possible branch points:**
  - **2018/19: when anticipate resolution of MiniBooNE anomaly;**
  - **2020/21: when anticipate sensitivity to LSND anomaly**

Reactor and source sterile neutrino search

- **Reactor:**
  - **Detector at 5m – 20m from core:**
    - **DANSS, Hanaro, Neutrino-4, Nucifer, NuLat, Posieden, PROSPECT, SoLid, Stereo**
  - **Anticipate:**
    - **Reactor anomaly proven or rejected with 5σ significance by 2020**

- **Source:**
  - **SOX: $^{144}Ce/^{51}Cr$ source in 2016; results soon after**

Kim

Zeller, Sobczyk

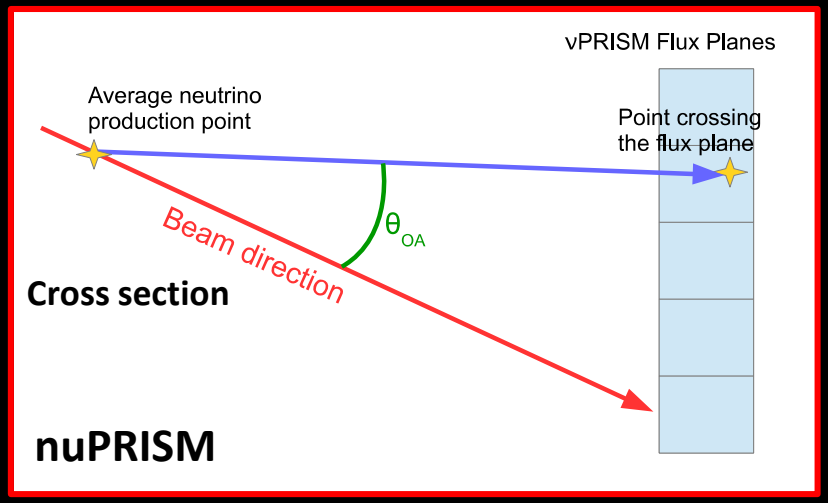
Neutrino fixed target

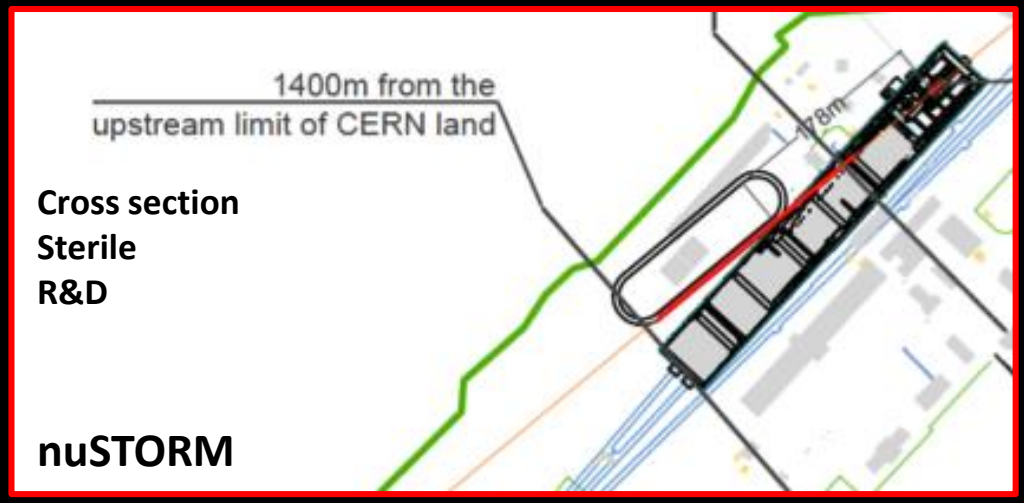
- **Motivation:**
  - Systematic uncertainties associated with neutrino-nucleus interactions will become increasingly important;
    - Already a dominant source of error in modern experiments
    - Reliable ab-initio computations can only be done for light nuclei in a restricted kinematic region;
    - Nucleon correlation effects are important and must be included;
  - What is known about electron-neutrino interactions must be extrapolated from muon neutrino scattering;
    - Is this sufficiently reliable for supporting the future neutrino programme?

- **Current (and near future) activities [~5 years]:**
  - Anticipate new results in the short term from:
    - MINERvA, T2K, MicroBooNE, and the NOvA near detector; and
    - LAR1-ND, CAPTAIN-MINERvA
  - Energy range: ~700MeV (T2K, BNB) to ~3GeV (NUMI LE & HE)
  - Variety of targets from He to Pb
  - Important measurements:
    - CC inclusive, CCQE-like, pion production, DIS
    - Very little is known about multi-pion production
  - In addition:
    - Coherent pion production, strangeness production
  - Accurate neutrino flux knowledge is paramount
  - To make continued progress, cross sections must be measured as a function of physical observables:
    - Differential and double-differential cross sections in final state particle kinematics);
    - Various energy ranges, targets, and final-state topologies to constrain uncertainties in theoretical models/simulation tools

Neutrino fixed target

- New ideas for cross-section measurement:





Also high-pressure LAr TPC …

- Is a ***new*** dedicated cross-section programme required?
- A decision point?
  - Indication that long-baseline experiments will be statistically powerful by 2028/29;
  - Most effective combination of results will require excellent understanding of systematics (including cross sections);
    - Indicates that:
      - Programme need, feasibility and cost must be established for a decision point around 2018/19

ICFA report

CONCLUSIONS/NEXT STEPS

Conclusions

- Panel has started to develop a roadmap for the accelerator-based neutrino-oscillation programme:
  - Much of the required "raw data" has been collected:
    - Panel will engage with the experiments to:
      - Make sure dates and milestones are correct;
      - To review figures of merit and to make sure they are correct

- Synthesis, identification of branch/decision points:
  - Panel plans to perform a synthesis of the "raw data";
  - Extract from the synthesis decision/branch points:
    - Example:
      - Initial discussion indicates that there is a decision point around 2018/19:
        - » Requirement to start a ***new*** dedicated cross-section programme?
        - » Requirement to start next generation sterile-search programme?

Next steps

- Complete raw-data gathering and synthesis:
  - Identify branch and decision points
- Evaluate RD and supporting programme:
  - Hadroproduction
  - Detector and accelerator R&D
- Complete roadmap and commentary:
  - Release as discussion document June/July 2015
- Revise through consultation with peers and stakeholders
  - Finalise as Panel's second report to ICFA autumn 2015