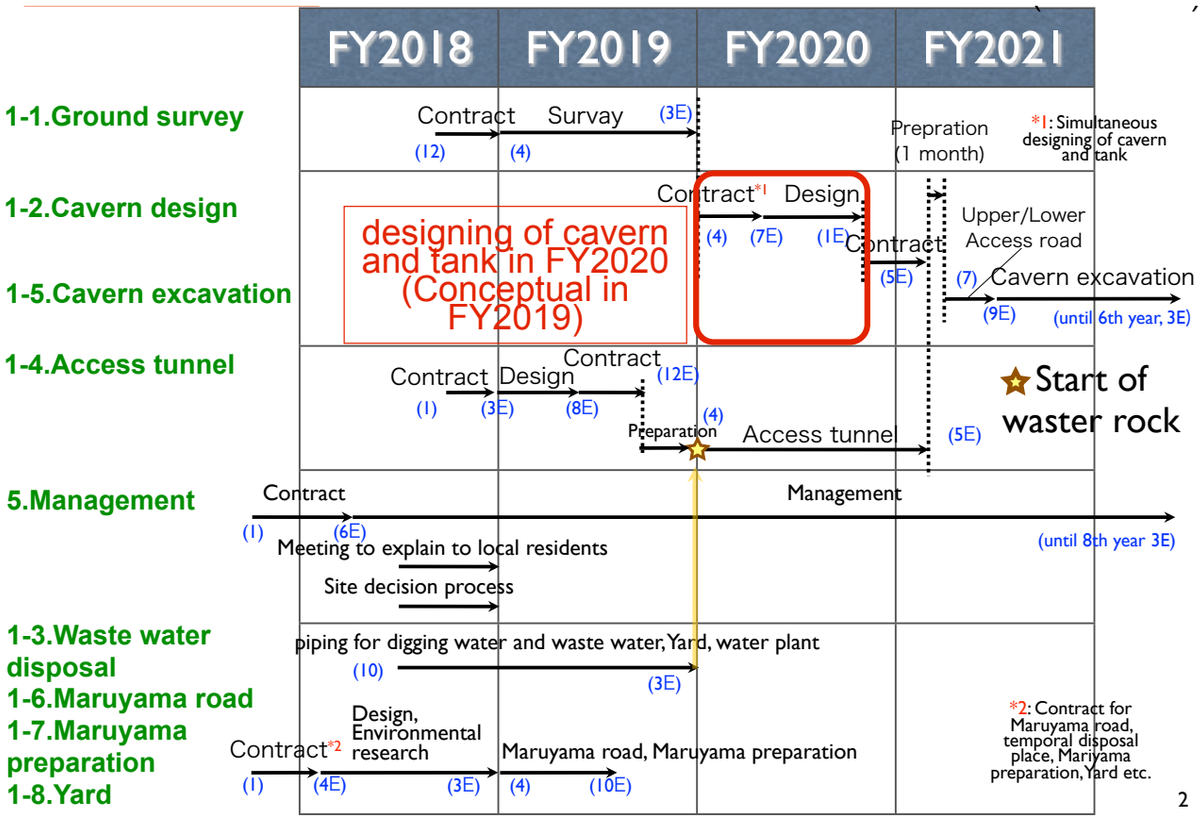
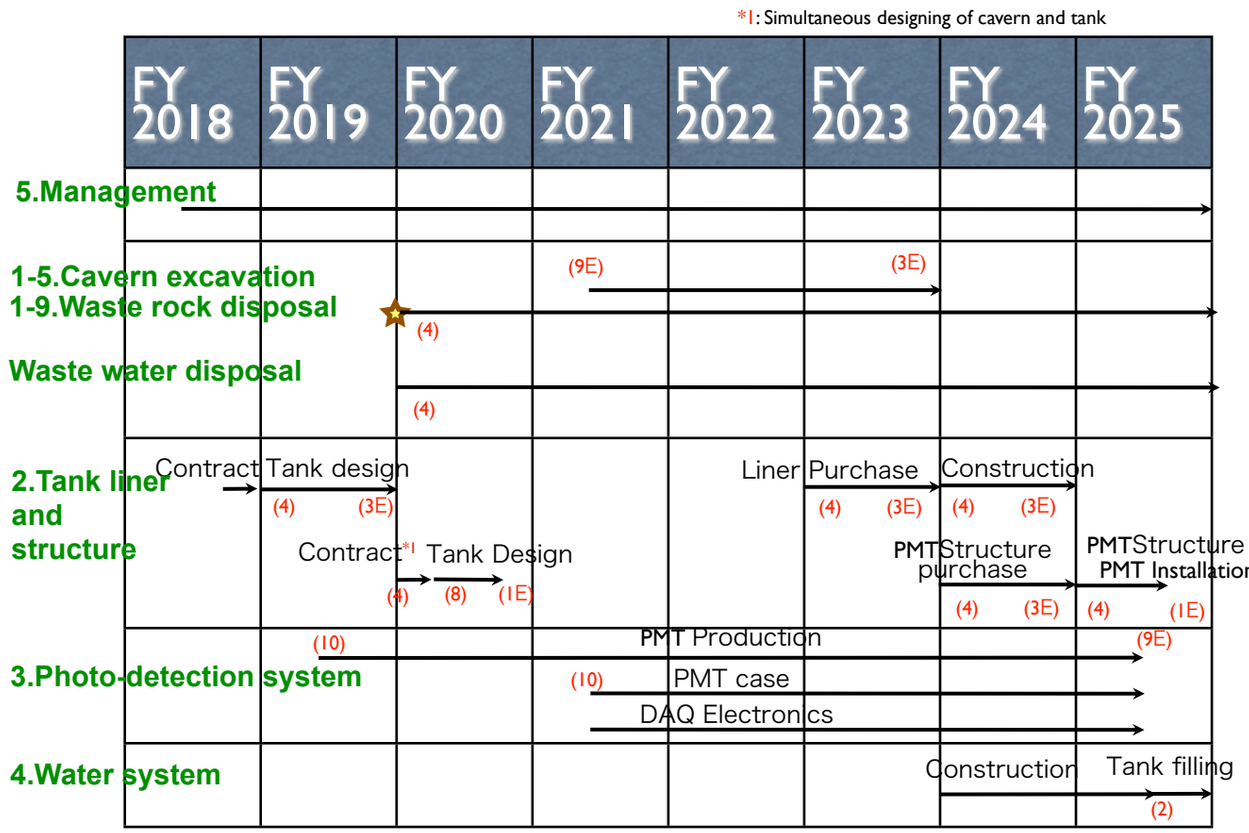
THOUGHTS ON MPMT AND PMTS

HK SCHEDULE





- From conveners+ meeting
- Tank and support structure
  - Design of tank occurs in FY2018-2019, contract in FY
  - PMT structure purchase occurs in FY2024, installation in FY2025. When is design fixed?
- 20″ PMT
  - production to start in FY2019
  - installation start late FY 2025? after PMT structure is installed?

NuPRISM SCHEDULE

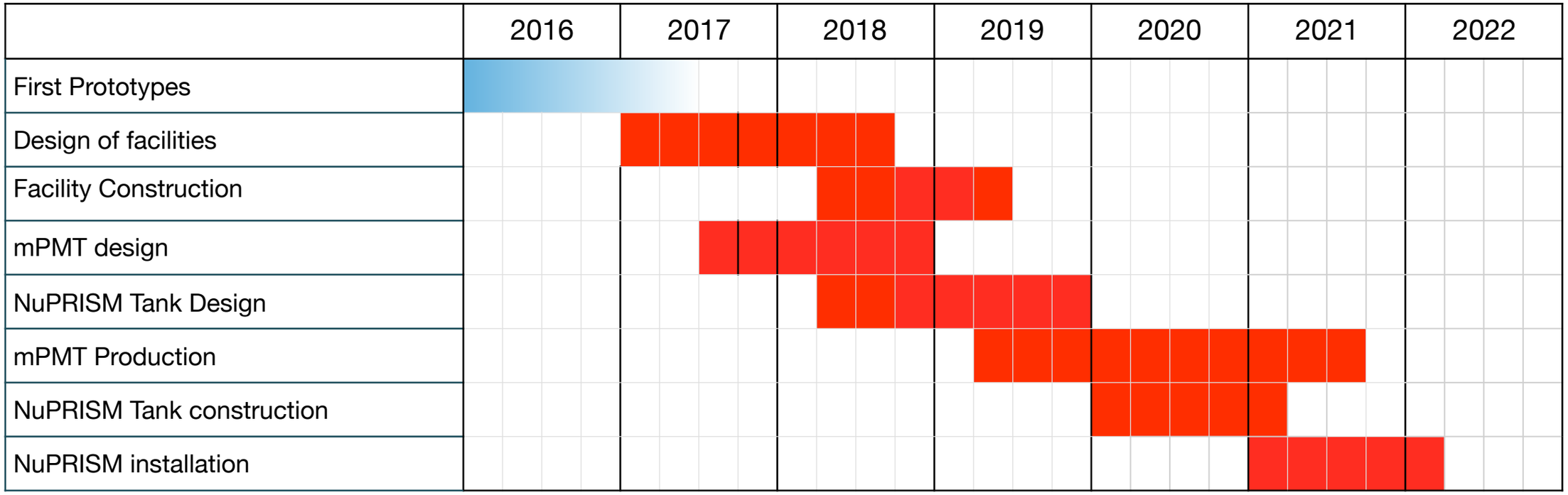


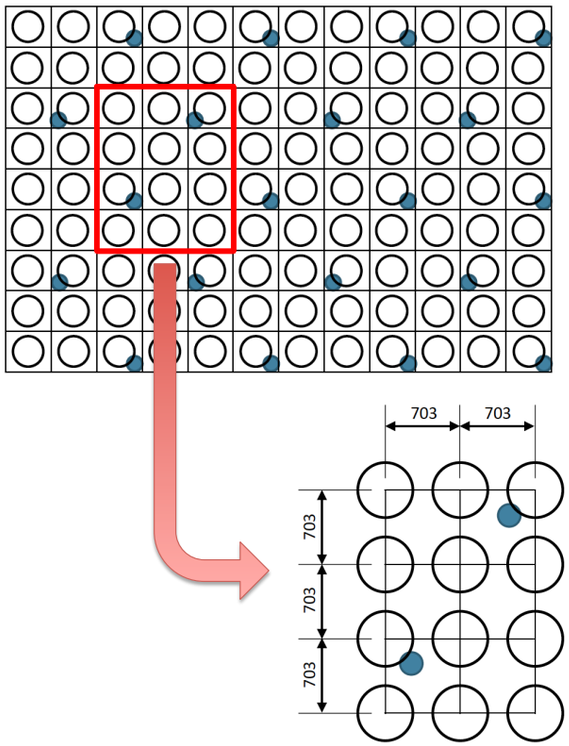
Figure 1: Overall Timetable

- mPMT design moving rapidly now with TRIUMF support
  - hopefully we may have a mechanical design by end of this calendar year?
  - electronics development cannot start yet (funding, resources, needed).
  - Hopefully completed by 2019.
- Budget for ~500 mPMTs for NuPRISM
  - production capacity may be 10-20/week
  - ~1 year production time
  - depends on production of other modules (PINGU, KM3NET) in same facilities
  - we may expect to finish in 2020

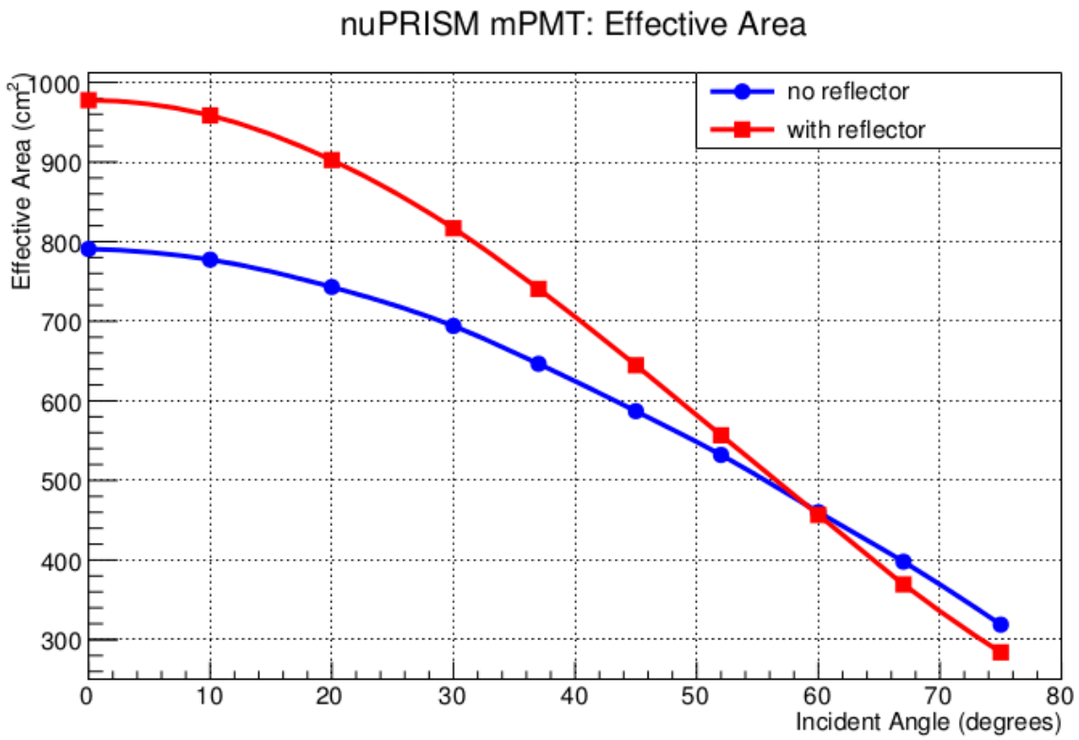
MERGING HK +NUPRISM mPMT R&D

- mPMT is well-motivated for NuPRISM
  - Situation is not so clear for HK, more study is needed
  - can design effort go in parallel?
- NuPRISM maximum depth is 50 m
  - already challenging for “standard” acrylic manufacturers
  - new, more specialized means may be needed for HK (80 m)
- Support structure is certainly different
  - for NuPRISM, structure is dedicated to mPMT
  - for HK, starting point is 20”ID, 8” ID system
    - need to design a hybrid support structure
- Other differences:
  - electronics? cabling? power requirements?
  - failure tolerance . . .

CONSIDERATIONS



- With 40% coverage, 20” PMTs are nearly maximally packed on the wall
- Naively, each have πx(25 cm)^2 ~ 2000 cm^2 effective area



- 50 cm diameter mPMT with 19 ID 3” PMTs
  - Effective area is ~1000 cm^2
- Geometrically, replacing one 20” PMT with a mPMT of the same diameter reduces photo coverage by 1/2.

- Motivation for mPMTs in HK should be something other than photocathode coverage
  - even if cost/area is less, geometry may not allow equivalent photocathode coverage
  - (unless more detailed geometrical packing study is done).

HK mPMT STUDIES

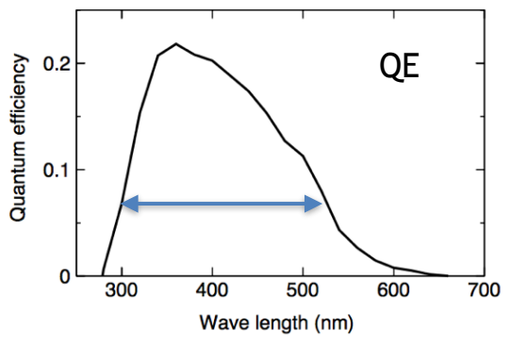
- Main potential advantages of mPMT
- Time resolution of 3” PMTs
  - vertex resolution for low energy events may be improved
- Granularity
  - ring identification may be improved (counting and particle ID)
- Directionality:
  - new frontier . . . .
  - effective dark noise reduction in conjunction with vertex?
  - background suppression by considering only forward PMTs ?
- mPMT software model hopefully finished now (?)
  - detailed study will still take time (and probably still some debugging)
  - can simpler studies be done?

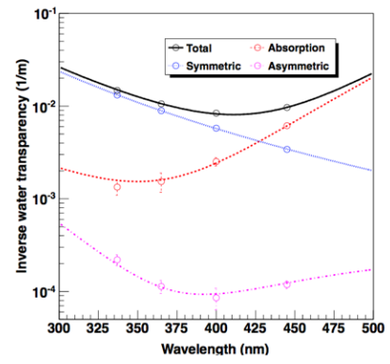
TIMING RESOLUTION

- Can we consider simulating improved timing resolution directly?
  - i.e. simulate 20” B&L PMT with 1.3 TTS of 3” PMT as a starting point
  - are we limited by chromatic dispersion?
  - If promising:
    - reduce PMT coverage by 75%? 50%?
    - simulate half PMTs with 2.7 ns TTS, half with 1.3 ns TTS?
- Perform physics studies:
  - vertex resolution for low E?
    - solar, relic neutrino, etc.
  - p→K+ν?

Timing limitation due to chromaticity?

- 300nm (n=1.349) — 525nm (n=1.334):
  - Δn/n=1.1% => Δt=0.05 nsec/m (full width)
  - Δt=1.3 nsec (TTS of the new 3” PMT) for 26m path
    - TTS dominates up to ~20m of light path for the new 3” PMT
    - UV side of light are absorbed for longer light path, shrinking Δt
  - TTS dominates for 20” box-and-line PMT’s

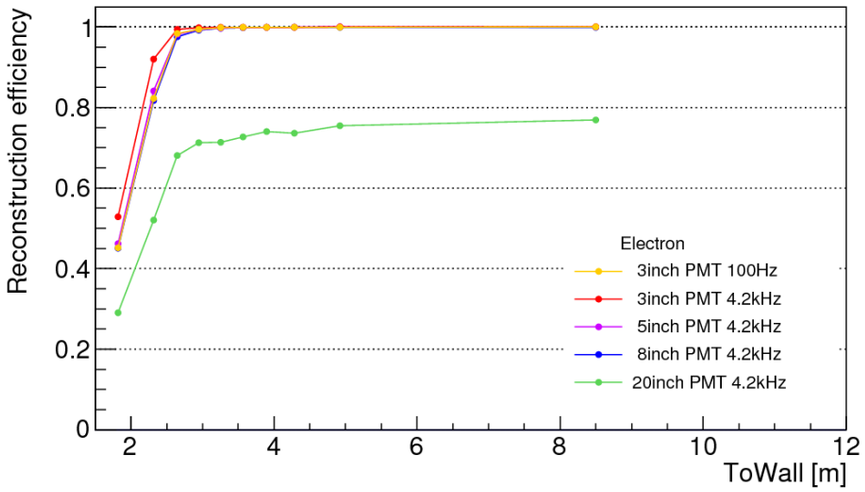


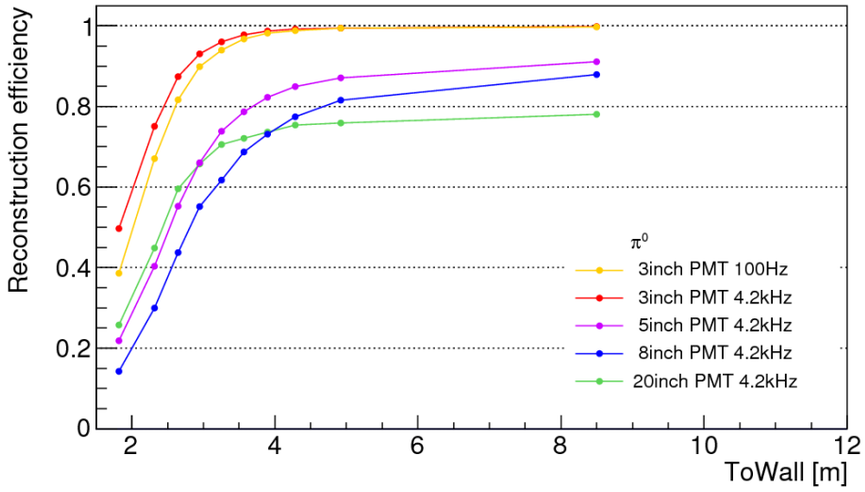


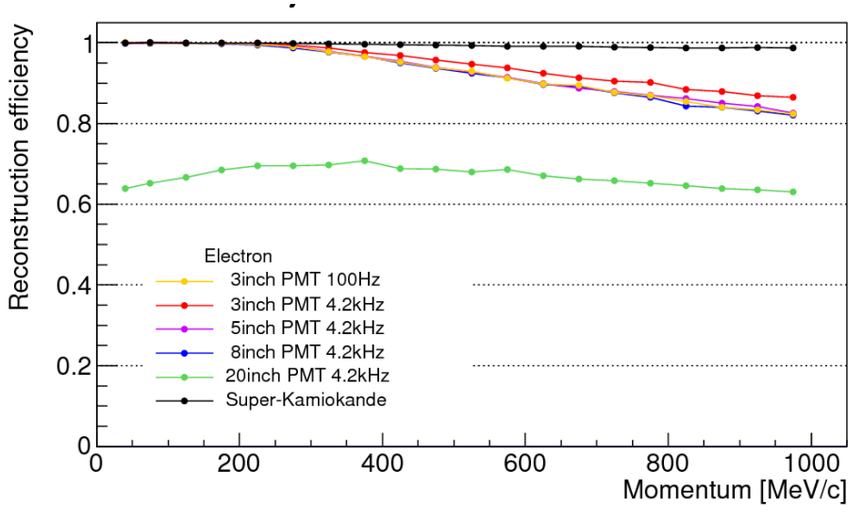
λ(μm)	n
0.300	1.349
0.325	1.346
0.350	1.343
0.375	1.341
0.400	1.339
0.425	1.338
0.450	1.337
0.475	1.336
0.500	1.335
0.525	1.334
0.550	1.333
0.575	1.333
0.600	1.332

GRANLUARITY

- NuPRISM studies show clear gain in performance vs. towel for 3” PMT
  - uniform array, not in mPMT
- Can we extrapolate to HK?
  - Need to match performance of 20” B&L in NuPRISM with 20” B&L in HK
    - “ToWall” for sample of particles with different
    - this probably means a study as a function of momentum and ToWall
- Gain in performance near wall in NuPRISM can be translated to HK
  - background reduction
  - vertex resolution (fiducial volume, etc.)







DIRECTIONALITY:

- Probably needs actual mPMT implementation in MC
- For high energy, incorporation into a reconstruction algorithm is probably needed
  - qualitatively new information that may be difficult to incorporate into fiTQun
    - this is probably the most challenging aspect
- For low energy:
  - rejection of light produced from PMT-related backgrounds (e.g. photon emission, etc.)
    - produce low energy tracks from PMT surface
    - see if light can be rejected by PMT directionality or if aperture occludes light

COMBINING mPMT R&D

- My guess is that NuPRISM and HK mPMTs would end up being quite similar (maybe mechanically identical)
  - Can we quickly determine:
    - do we need thicker wall, thicker cover?
    - are materials compatible with low energy physics?
    - electronics? requirements for triggering?
    - are power consumption requirements ?
      - HK mPMTs will need more extensive testing for deep underwater deployment and implosion
- Can we also quickly come up with a support structure concept for both mPMTs and 20” B&L PMTs?
  - each position can accommodate either an mPMT or 20” PMT with a common mounting mechanism?
  - details of where PMTs/mPMTs go can then be decided later.
- The physics studies are where we may diverge, since NuPRISM has a much more focussed program.

IN CANADA:

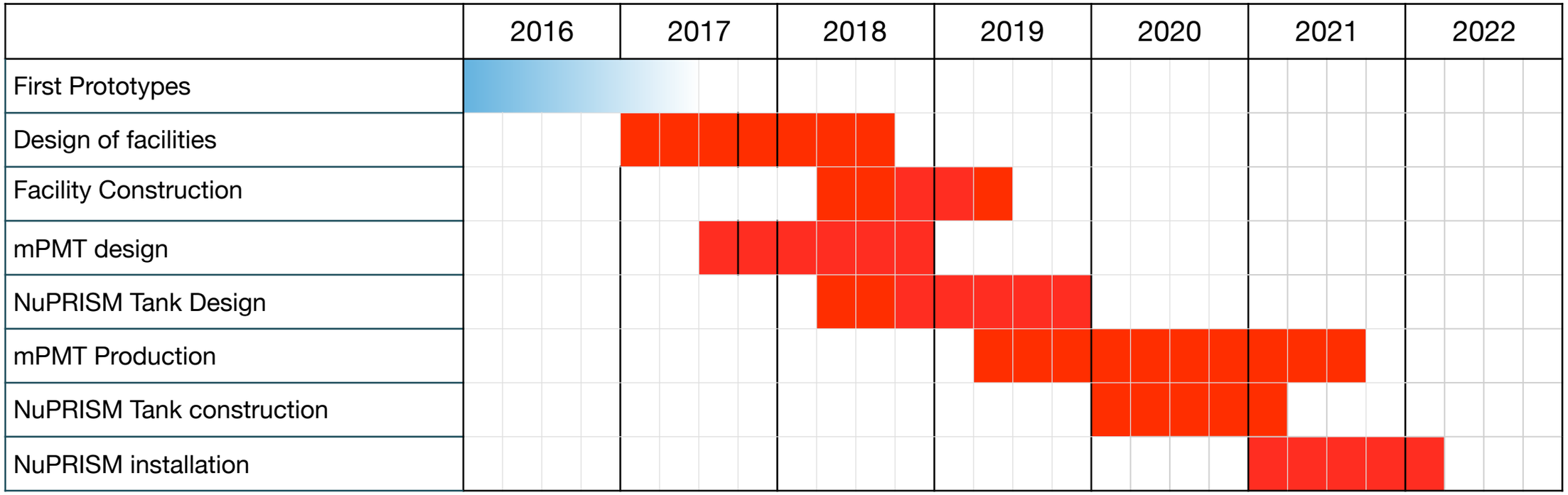


Figure 1: Overall Timetable

- We have ongoing request for ~500 mPMT modules to be produced ~2020 for NuPRISM
- If this is successful (outcome in May) we can:
  - adapt design for HK. Engage in testing in 2019 alongside NuPRISM?
  - make another request in 2019 (outcome in May 2021)
  - O(1k) modules may be possible in a “reasonable” request
  - if second request is unsuccessful, move NuPRISM mPMTs to HK?

GENERAL ISSUE:

- Clearly, more countries need to participate if we want a substantial contribution (O(10k) modules)
- Can other countries contribute mPMT if design is effectively done by Canada?
    - After conceptual design and initial requirements, can we break up the design into work packages to allow more definite and concrete design contributions from other countries?
- Can we parallelize component sourcing
    - locally produce as many components as possible (vessel, cover, internal structure, etc.)
    - can even PMTs come from different vendors?
    - start from common design
        - make specification and qualify vendors and sources.