Status of the WCTE Proposal and Review

M. Hartz

2020/07/30

Background on WCTE Proposal

- Proposals for experiments in the CERN East Area beam lines are reviewed by the CERN SPSC
- The WCTE collaboration submitted an Letter of Intent to the SPSC in October 2019: CERN-SPSC-2019-042 ; SPSC-I-254
- At this time, two reviewers were assigned to the WCTE: Giulliana Fiorillo, Roberto Santorelli
  - In SPSC system, reviewers review the material and make reports to the SPSC
- The WCTE collaboration submitted a proposal to the SPSC in March 2020: CERN-SPSC-2020-005 ; SPSC-P-365
  - Over 110 authors
  - Thanks to all collaborators who contributed to the proposal
- Reviewers sent questions/comments around beginning of July 2020
- We met with reviewers in late July to answer many of their questions

WCTE Proposal Content

WCTE Proposal, Next Steps

- Responses to the reviewer questions at July meeting can be found in the backup slides
- There were still a few questions from before July meeting that needed additional work to address
- Some more questions were raised at July meeting
- The reviewers will next report to the SPSC at the January 19 SPSC meeting
- We have a meeting with the reviewers on December 15 (15:00 CET)
  - We aim to have addressed all of their questions and update the proposal by this meeting
- Today, I would like to go through:
  - Open questions from the SPSC reviewers and plans to address them
  - Suggested updates to the proposal based on material shown at this meeting

Open Question - Event Rates

Chapter III

A) Beam setting and expected rates

—> provide a table detailing the expected signal and background rates for each secondary beam configuration assumed in chapter IV (detail 3 beam configurations)

- Matej provided rates for the tertiary beam configuration at the July meeting with reviewers
  - Need to be updated for configuration with compensating magnet
- We still haven't received particle rates for secondary beam configuration from CERN beam experts
  - Should aim to have some preliminary numbers, even if based on old beam line configuration by December meeting

Open Questions - mPMT Plan/Schedule

B) mPMT & Electronics

—> please provide a reference to more details on the mPMT design and characterization tests.

What are the differences with respect to the technology developed in KM3NET?

How is the scintillator layer used to discriminate backgrounds? Do you have any experimental test of this new design?

Is this the design that has been selected for the HyperK far detector?

Where is the actual construction going on? Provide a detailed schedule for construction and test of the 128 mPMT units

- Most of the questions related to the mPMT and electronics were answered at the July meeting
- The mPMT construction plan and schedule are being developed by T. Lindner and M. Ziembicki
- T. Lindner showed schedule for production in Canada
    - Need to update based on production lines in Poland and Canada

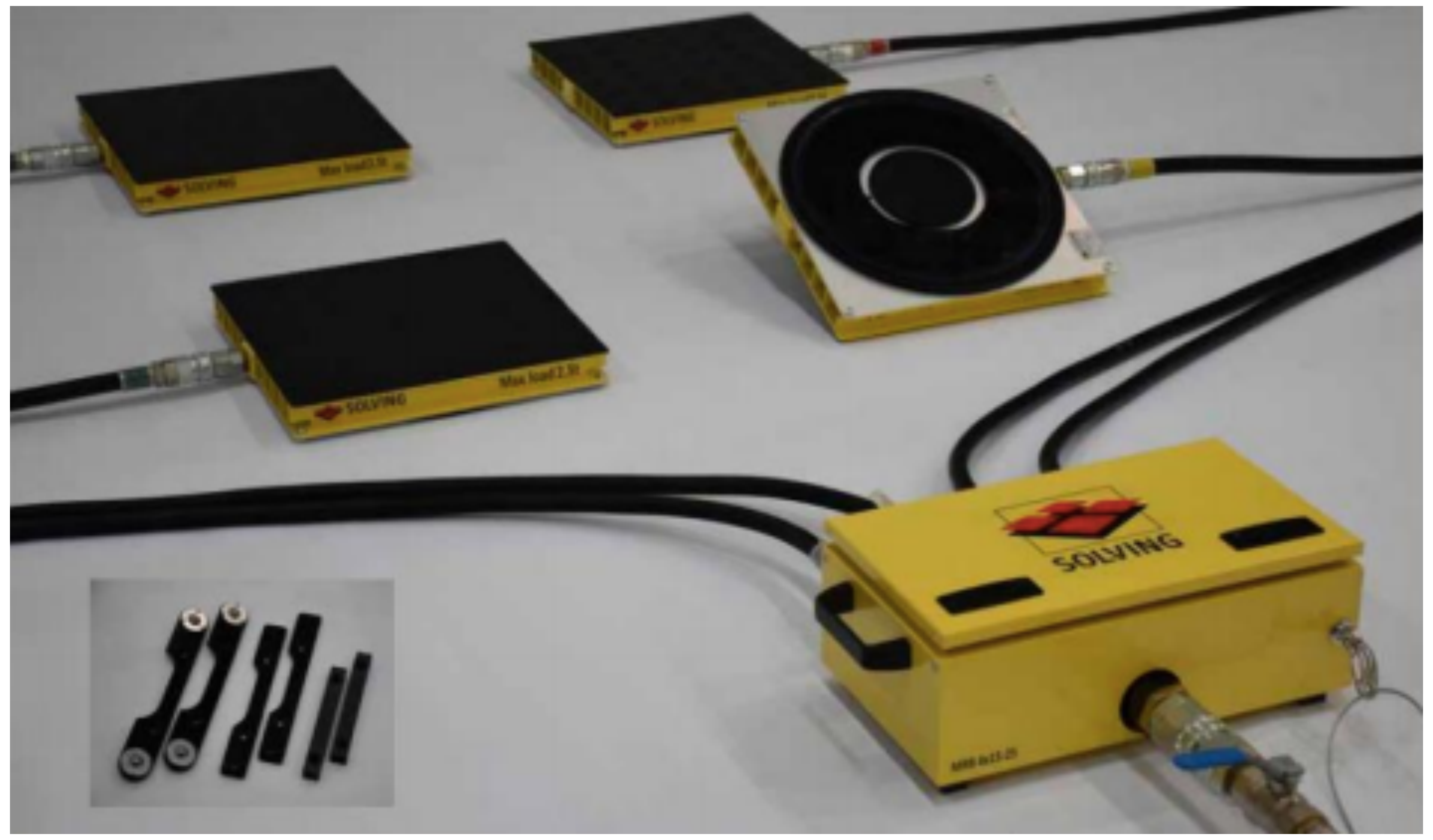
Open Questions - Detector Moving

I) Experimental layout

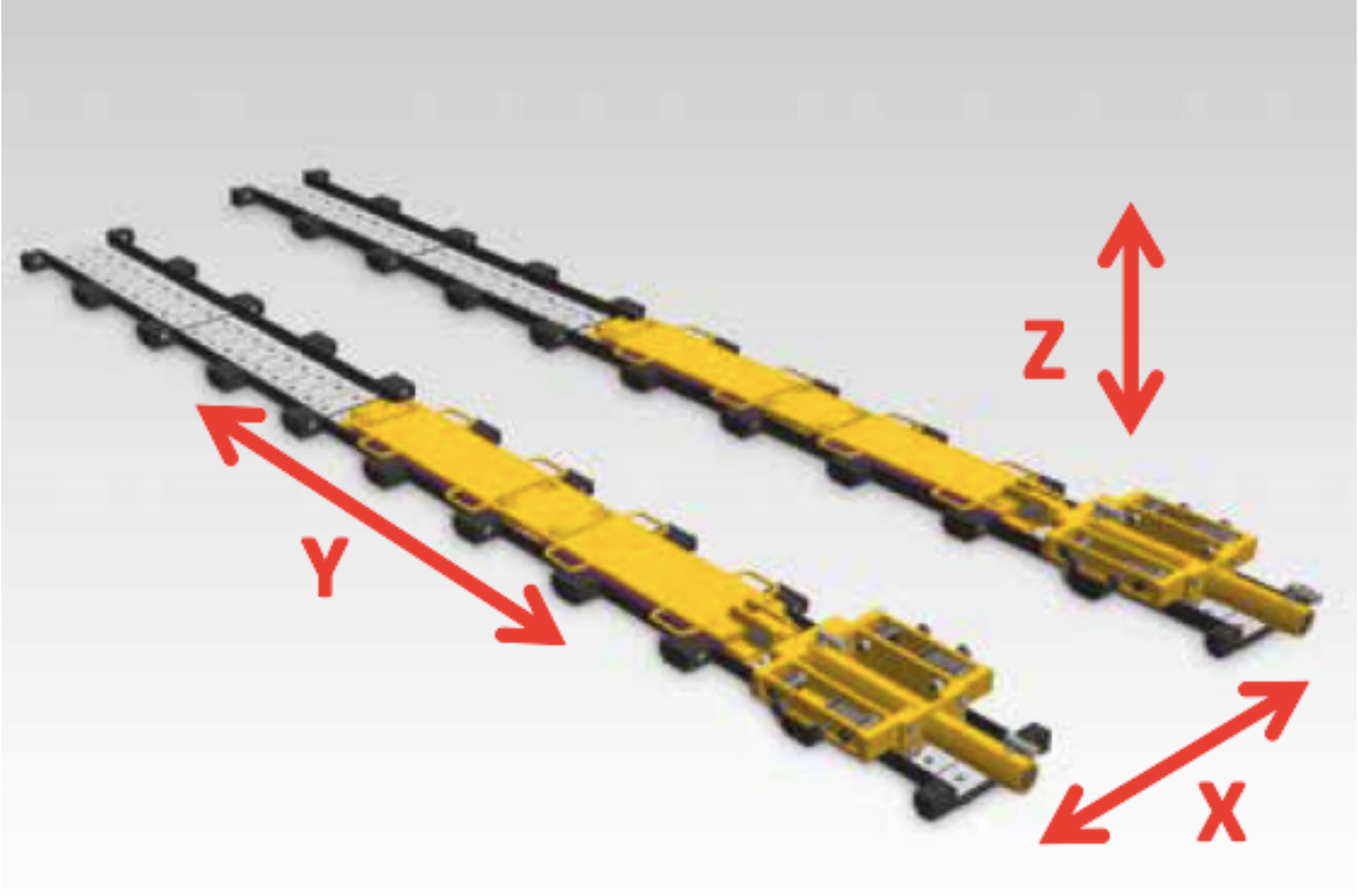
—> procedures to partially drain and lift the WCTE tank to be checked with CERN

- O. Jeremy is investigating detector moving methods
  - Engagement with CERN transportation group
- Can we include an initial plan in the proposal by Dec. 15?
  - Ideally endorsed by CERN group
- Would hydrodynamic simulation of moving be ready by Dec 15?

Air Skate



Hydraulic Rail



Questions from the WCTE Reviewers

—> Total request for beam time is 11 weeks in 2022.
What contingency do you assume in the schedule?

In proposal:

- 1 week: Move detector into beam line, fill with water, purify water.
- 1 week: Initial commissioning of the detector.
- 0.5 weeks: Calibration of the detector.
- 1 week: Operation of the detector in the tertiary pion configuration.
- 0.5 weeks: Move detector into the secondary beam for muon operation.
- 1 week: Re-commissioning and calibration of the detector.
- 1 week: Operation of the detector in the secondary muon configuration.
- 0.5 weeks: Addition of Gd to the detector.
- 0.5 weeks: Calibration of the detector with Gd.
- 1 week: Operation of the detector in the secondary muon configuration with Gd.
- 0.5 weeks: Move detector into the tertiary pion configuration.
- 1 week: Re-commissioning and calibration of the detector.
- 1 week: Operation of the detector in the tertiary pion configuration with Gd.

- We should update the operation schedule in the proposal
- Calibration group should estimate time necessary for calibration
- For commissioning:
  - Expect initial commissioning in assembly area without water
  - Once moved to beam area, need to repeat some commissioning steps
    - Experts on systems, please provide estimates of commissioning time
  - Need to set up and commission beam line equipment
    - Add 1-2 weeks to schedule
- We need to make an estimate of how long it takes to move the detector between secondary and tertiary beam configurations
- We need to make an estimate of how long Gd loading takes

Requests from Reviewers at July Meeting

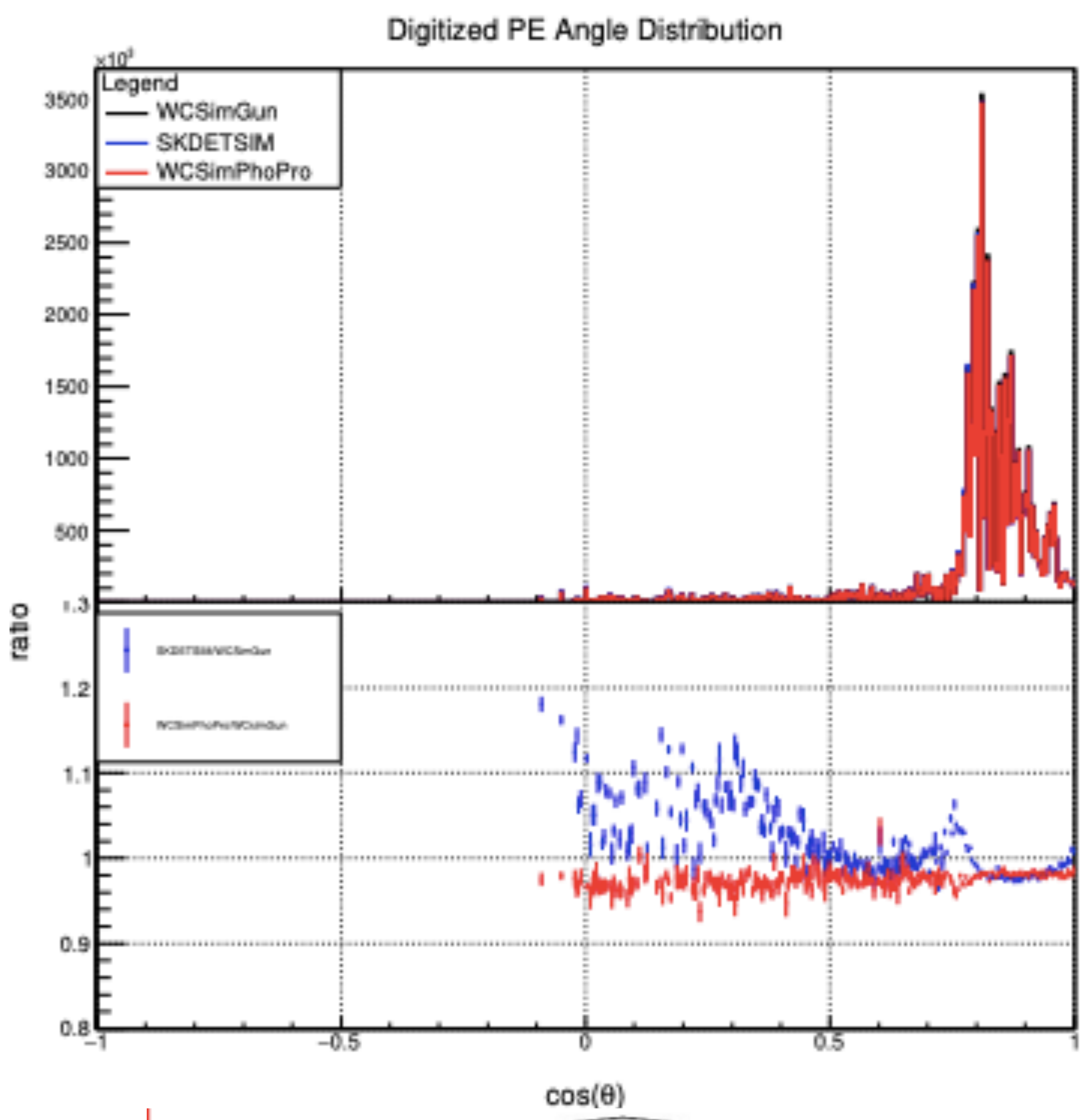
- Emphasize connections to Hyper-K more in proposal
  - Will add more discussion of Hyper-K connection in introduction and motivation section
  - Will discuss more the potential use of any mPMT, calibration or other systems in Hyper-K detector (not just IWCD)
  - Add connections to T2K and Super-K programs as discussed on Monday
- Add section on consideration of other beam lines
  - Discussion of why we need secondary beam line of ~10-20 GeV/c to produce tertiary flux
  - Discussion of why we want secondary beam that can go down to ~400 MeV/c
  - Why CERN T9 beam line is preferred over test beams at Fermilab
    - Beam properties
    - Experimental area

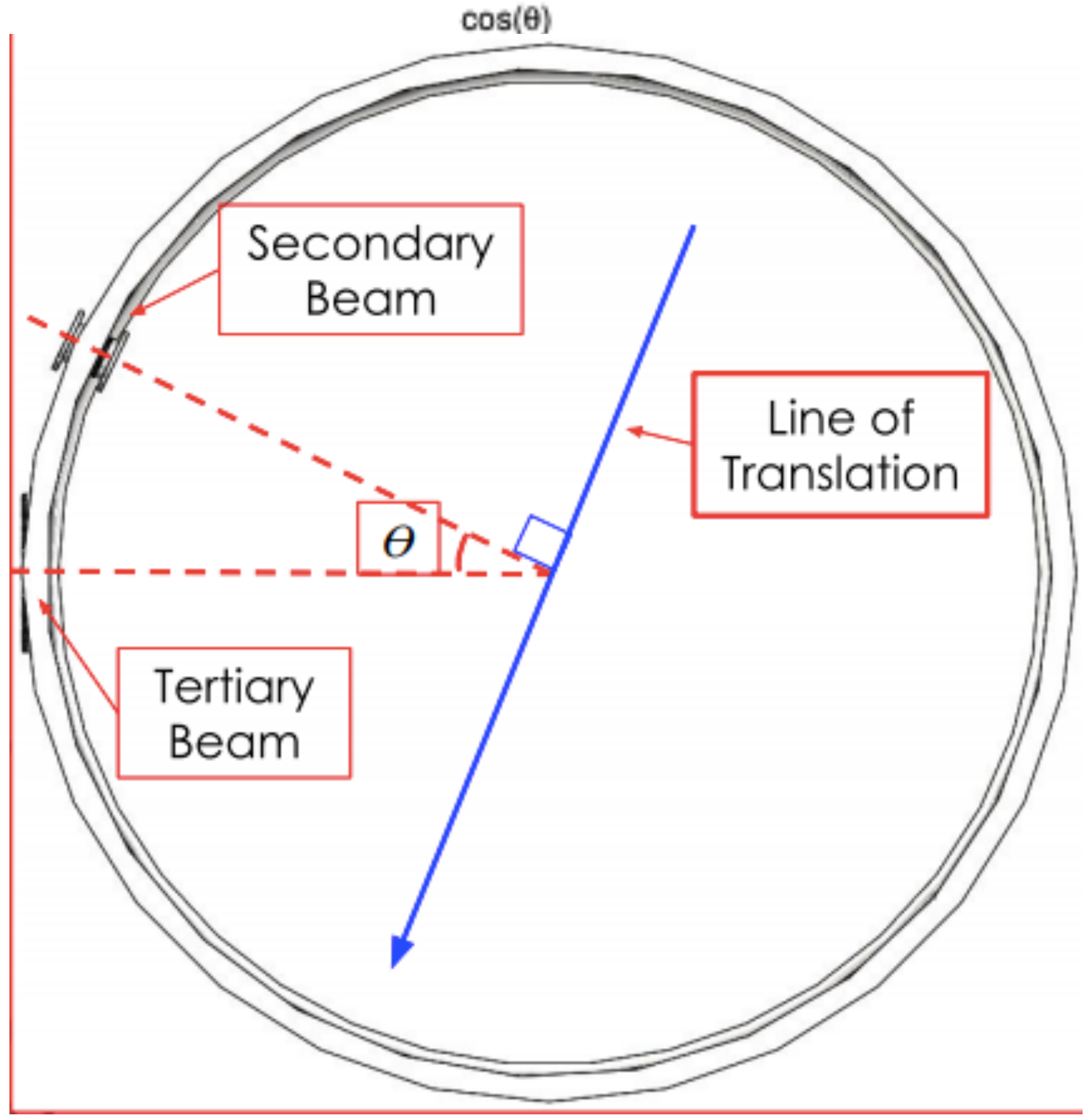
Requests from Reviewers at July Meeting - Schedule

- Reviewers would like us to provide a more clear and detailed schedule for WCTE
- In proposal, we had planned operation of the WCTE in 2022
- Based on COVID-19 pandemic impact and more realistic understanding of schedules, we have moved our goal to start detector assembly at CERN in 2022 and operation in 2023
- WCTE steering group is now working with collaborators on critical path components of WCTE to develop a detailed schedule

Additional Updates to Proposal

- Physics measurements and analysis
  - Will add discussion of motivations for T2K and SK
  - Can M. Jia's studies of Cherenkov light profile converge and be include?
- Tertiary beam and spectrometer design:
  - Description of updated design with compensating magnet
  - Description of available RPC detectors for TOF
  - Description of options for silicon trackers?
- Beam window and beam pipe descriptions should be added





Additional Updates to Proposal

- Updates to tank and support structure design should be added
  - Do we mention option for curved tank bottom?
- We should give a more detailed description of the plan to assemble the detector and then move it to the experimental area
- Various mechanical simulation results should be summarized
- Some more detail may be given for the water system description (but not much has changed since proposal)
- Should check that mPMT/electronics/DAQ descriptions are up-to-date

Proposal Update Logistics

- Proposal can be edited from Overleaf: https://www.overleaf.com/3362267282kkqjfntgmrft
  - Please inform M. Hartz and M. Scott if you will make significant edits
- For updates where content is available now, request for proposal to be updated by Dec. 4
- For updates where content is still being produced, please share when updates are expected to be ready
- Would like to circulate an updated draft by December 8

Extra Slides

Hyper-K/IWCD Approval

HyperK was approved in Japan in January 2020.

—> What is the status of IWCD approval?

Is the group of proponents also involved in the design and construction of the far HyperK detector?

- The IWCD is part of the Hyper-K proposal that was approved in 2020
- Funding for design studies of the IWCD has been started in 2020
  - It is expected that funding for the construction of the IWCD will be requested after design studies are complete
- Yes, there are WCTE collaborators working on the Hyper-K detector components. These include:
  - UK and Canada collaborators will work on the calibration systems for HK
  - Poland, Canada and Italy collaborators are interested to install mPMTs in the Hyper-K detector
  - UK collaborators are working on the DAQ system for Hyper-K

Performance Requirements

Understanding the reconstruction of pions and evaluating calibration methods to control energy scale and vertex bias errors are goals of the WCTE.

Requirements: Energy scale uncertainty of 0.5% or less; vertex reconstruction biased by less than 1 cm

—> compile a list of requirements/specifications for the detector performance

- Requirements can be broken into a few categories
- Reconstruction level calibration requirements:
  - 0.5% energy scale uncertainty
  - 1 cm vertex reconstruction bias
  - 1% uncertainty on efficiency for various event selections
- Hardware requirements:
  - Spatial resolution (for reconstruction near wall): ~8 cm diameter PMTs
  - Timing resolution (for vertex resolution): 1.5 ns FWHM
  - Dark rate (for low energy reconstruction): <1kHz

Performance Requirements

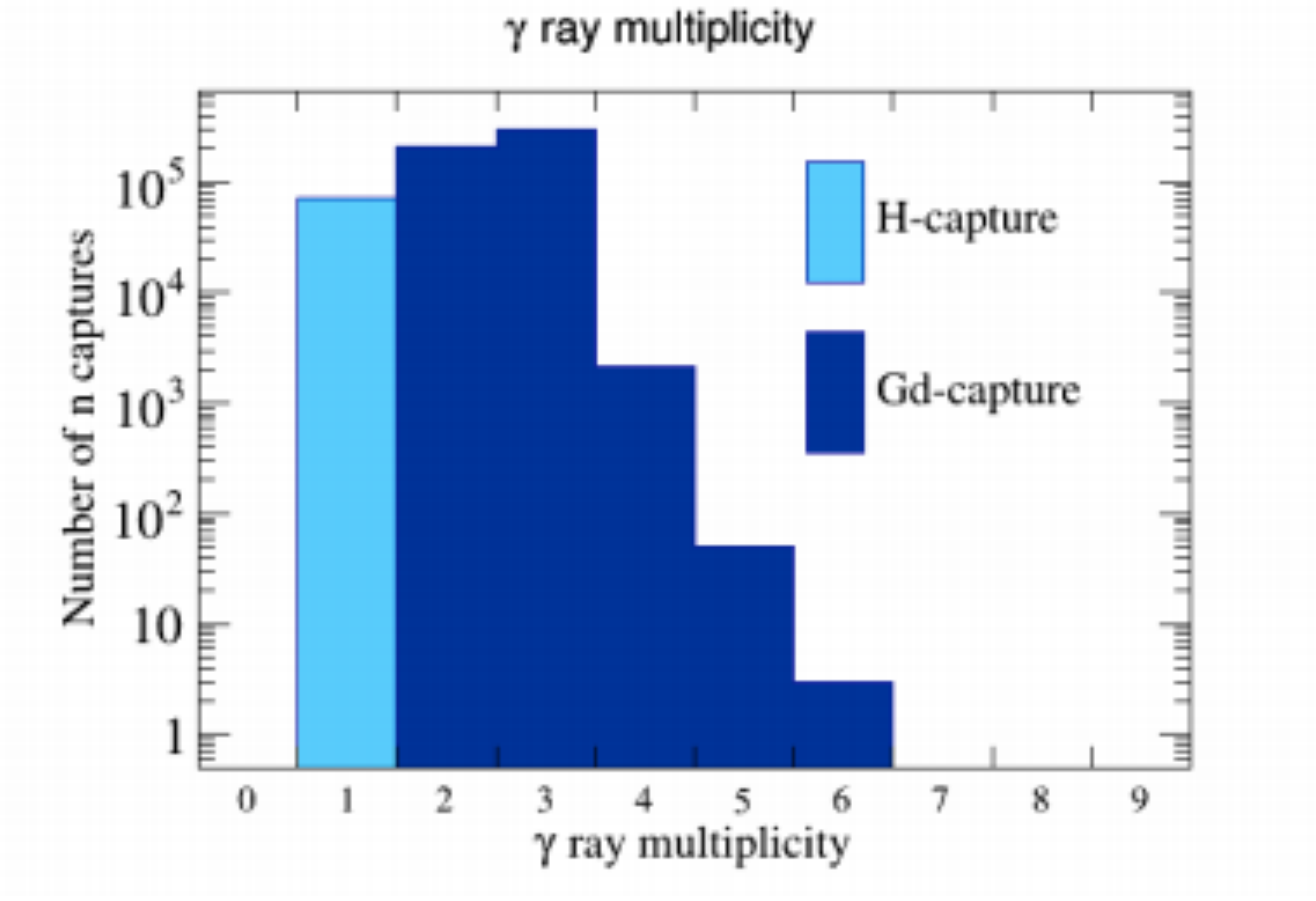
- Hardware requirements:
  - Afterpulsing: low enough to allow neutron reconstruction (later slides)
  - Electronics: Maintain PMT timing resolution, deadtimeless readout, separate reconstruction of photons arriving >10 ns apart
  - mPMT vessel: compatibility with ultra-pure and Gd-loaded water. Acrylic transparent to UV light over sensitive range of PMT
  - Water system: 2 ton/hr flow rate
- Reconstruction performance requirements:
  - Muon misidentification as electrons below 0.5%
  - π^0 misidentification as electrons below 5-10%
  - Vertex resolution for electrons of 12 cm
  - Maintain >90% efficiency for reconstruction of events with >30 MeV of visible energy in the ficucial region
- Will add table to proposal

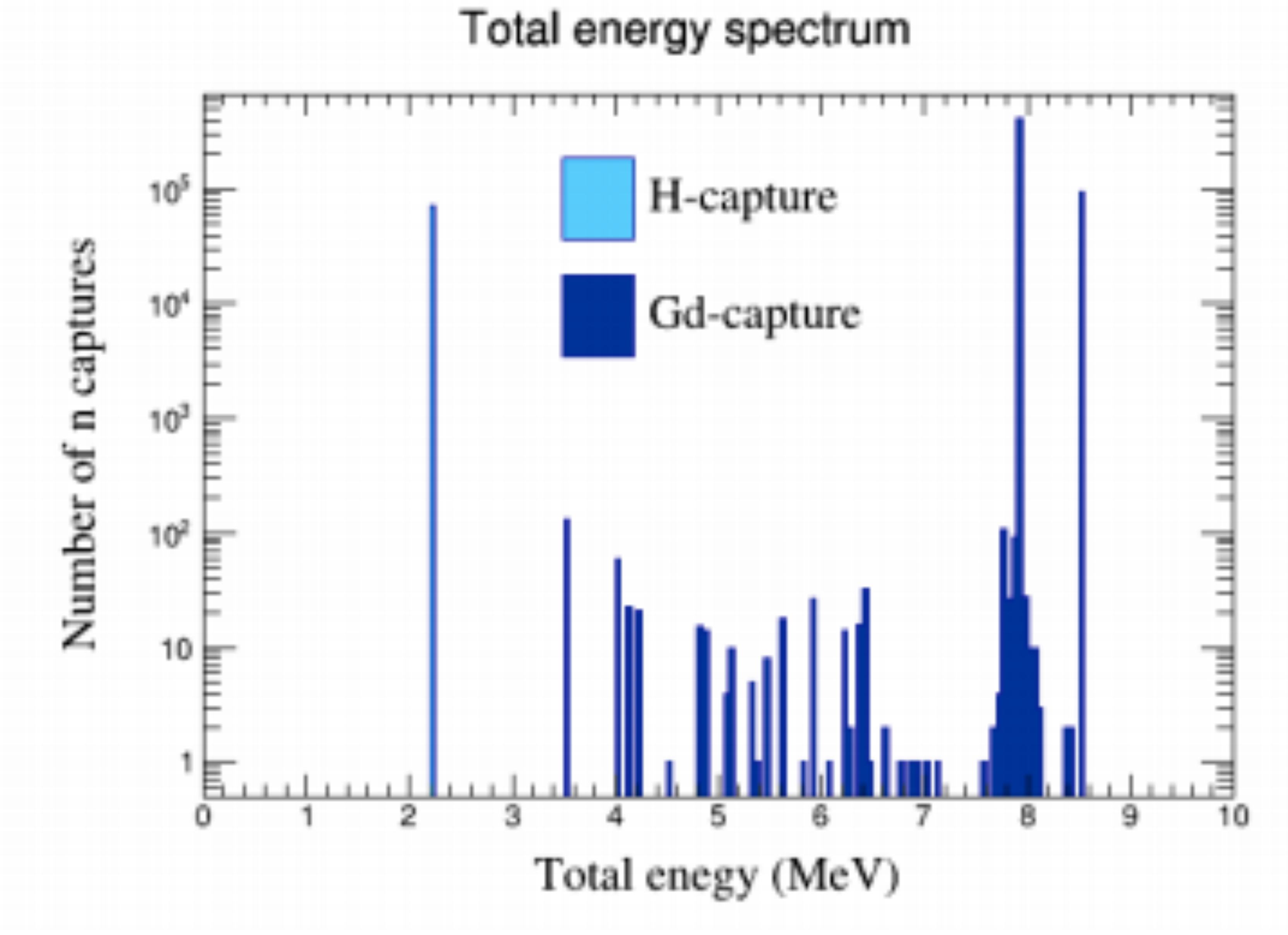
Neutron Detection

The interpretation of the IWCD neutron multiplicity data will require an understanding of the secondary neutrons produced when various final state particles traverse the detector medium. This secondary neutron production can be measured in the WCTE.

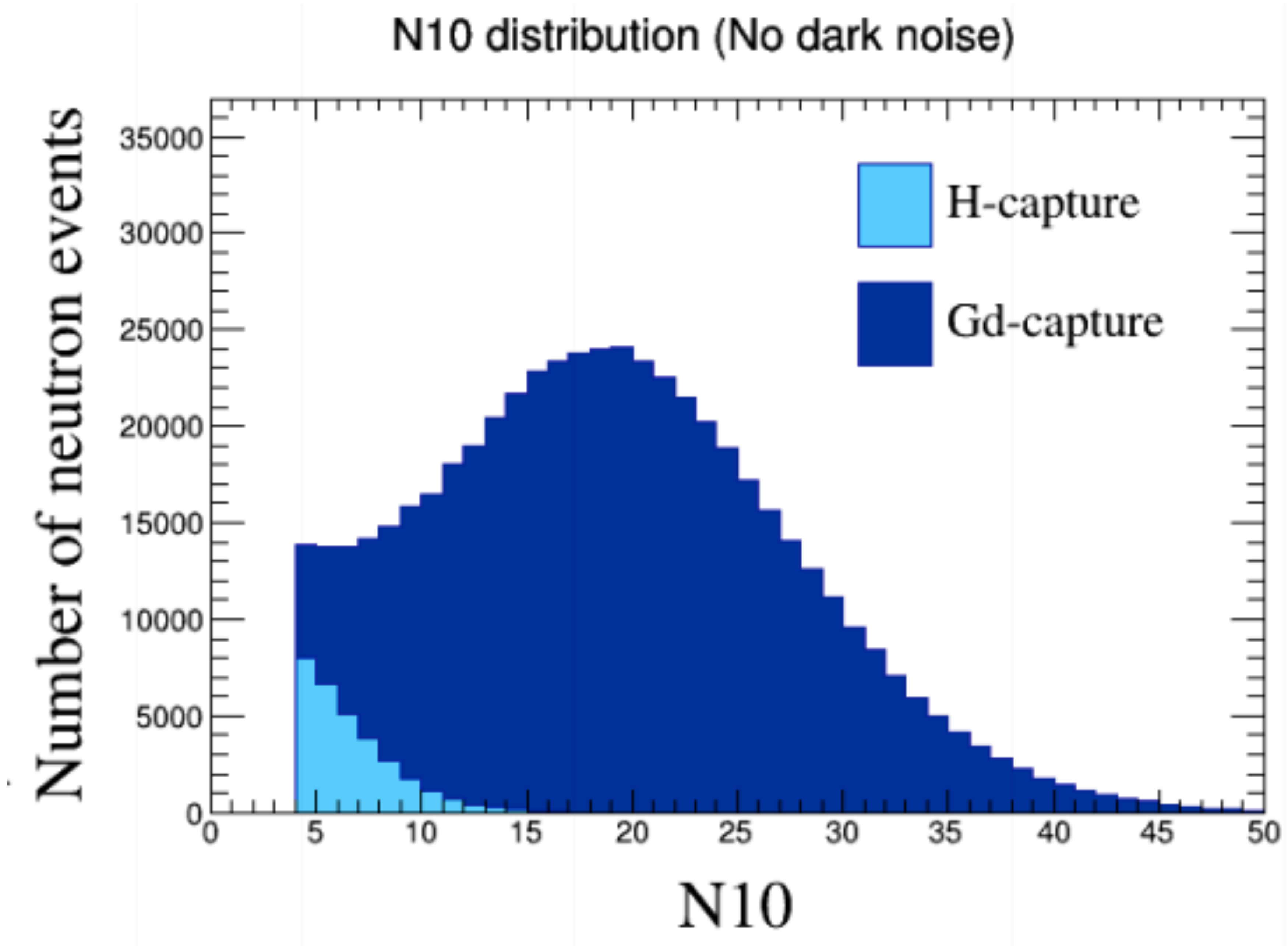
—> list requirements for detector performance

- The neutron captures on Gd are relatively low energy, but still have significantly more energy than neutron captures on H or radioactivity in the detector



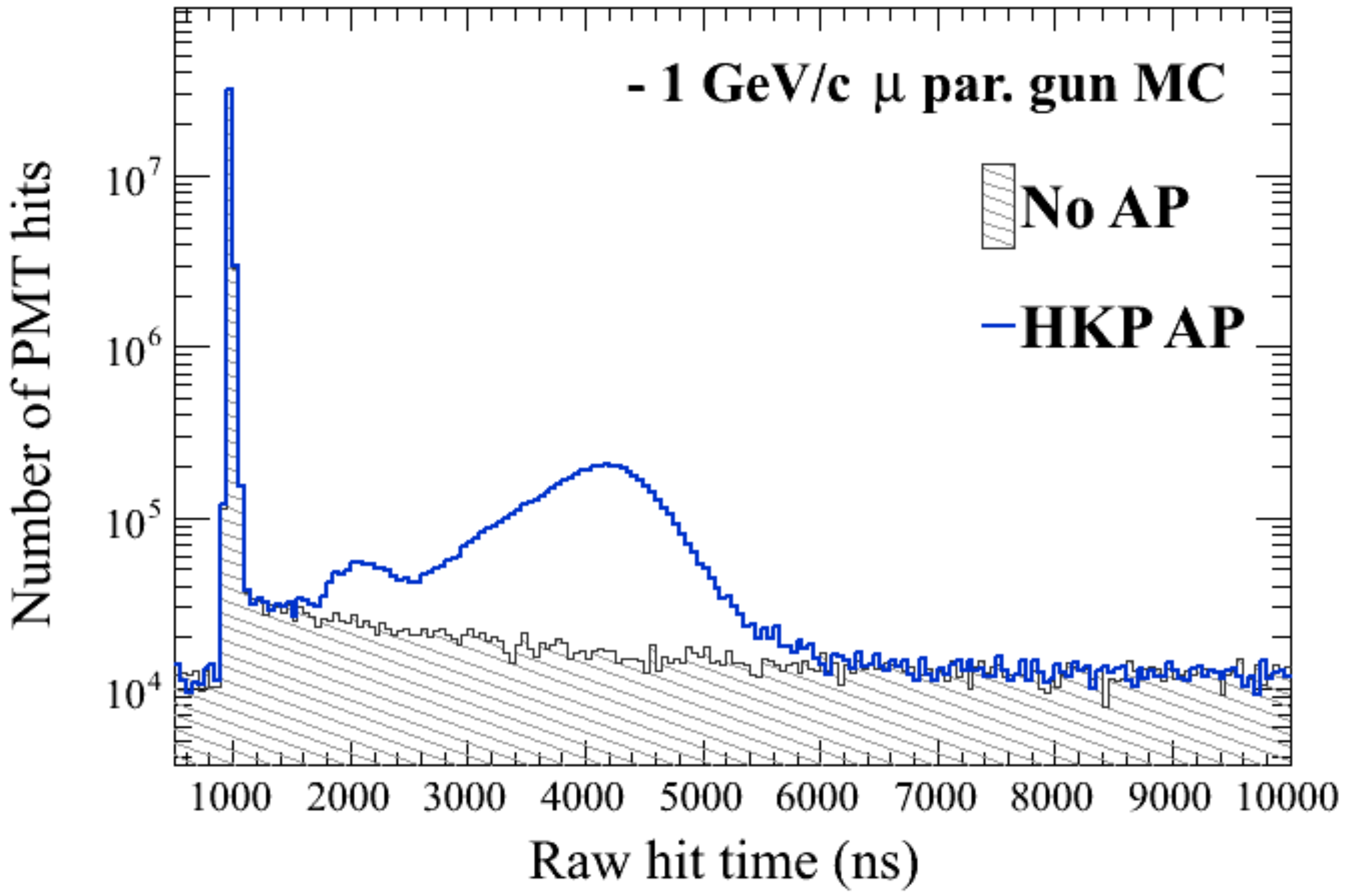


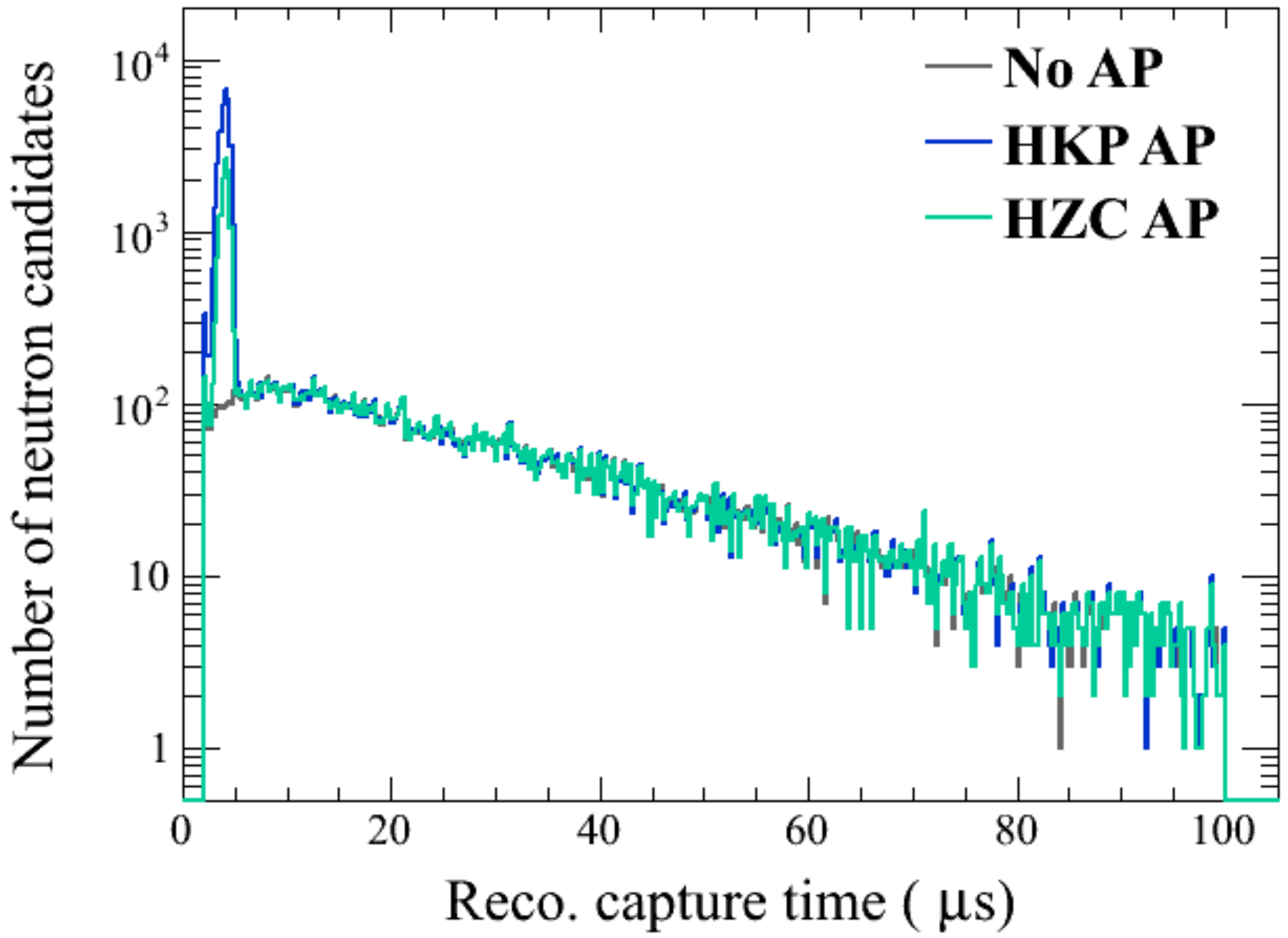
Neutron Detection - Dark Rate, Photocoverage



- A simple search of # of hits in a rolling 10 ns window can be used to find neutron captures
  - >4 hits used in current analysis
  - If photocoverage was significantly reduced, impact on efficiency at low side of N10 distribution
- The PMTs have a dark rate of 500 Hz or less, so for 2508 PMTs in the detector, there is a dark hit every ~800 ns
- Coincidence of 4 dark hits is rare enough, even with trials factor that comes with 100 us search window
- **500 Hz dark rate is ok**

Neutron Detection - Afterpulse





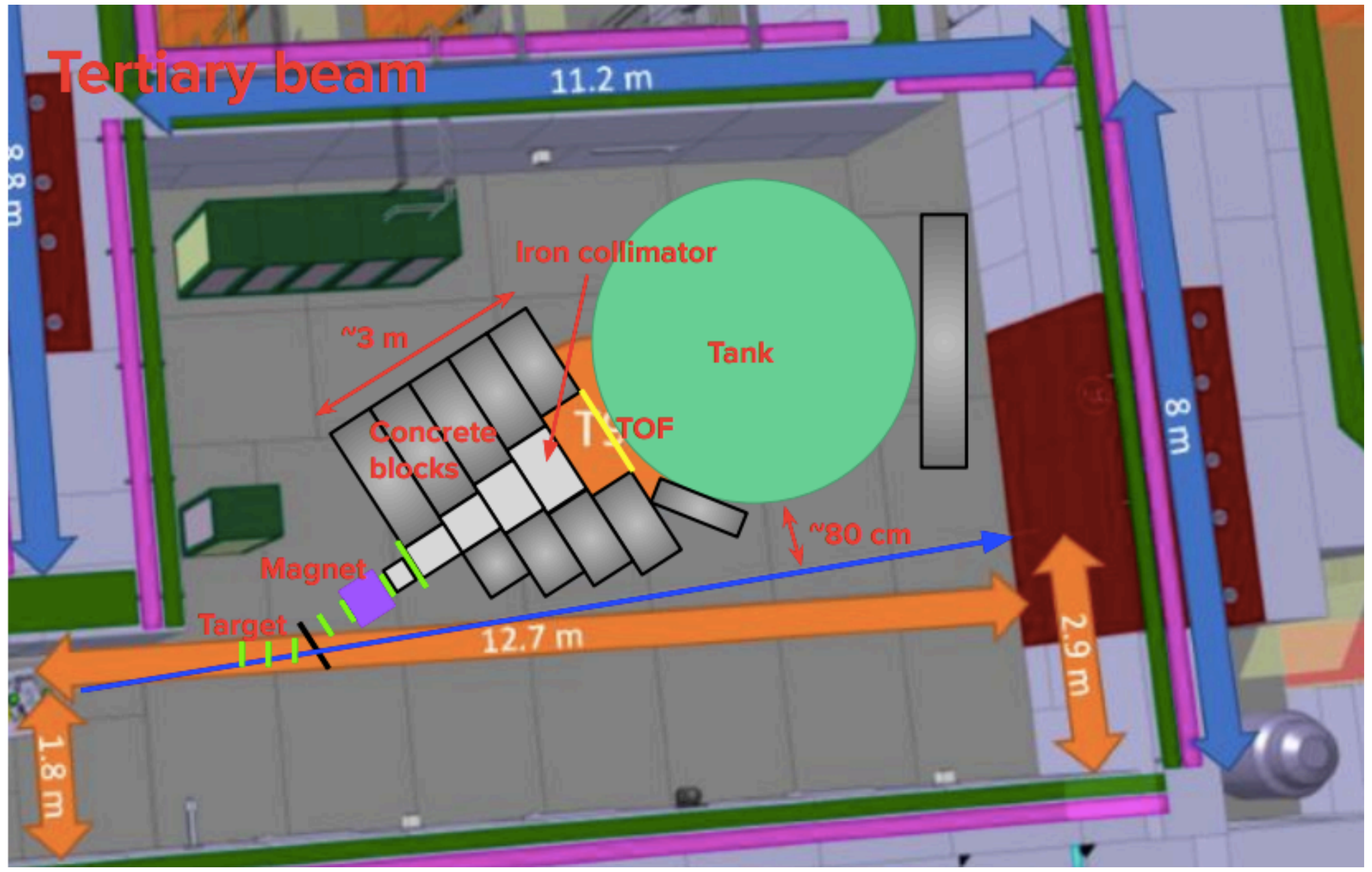
- Our most significant concern for neutrons is the affect of PMT afterpulsing
- Afterpulsing adds a significant number of hits 1-4 μs after the prompt event (left)
- This leads to the reconstruction of fake neutrons in the first 5 μs after prompt event (right)
- We can remove these with a timing cut, but we also consider other mitigation:
  - Work with Hamamatsu to reduce afterpulsing
  - Use masking of PMTs with a large amount of charge in the prompt event

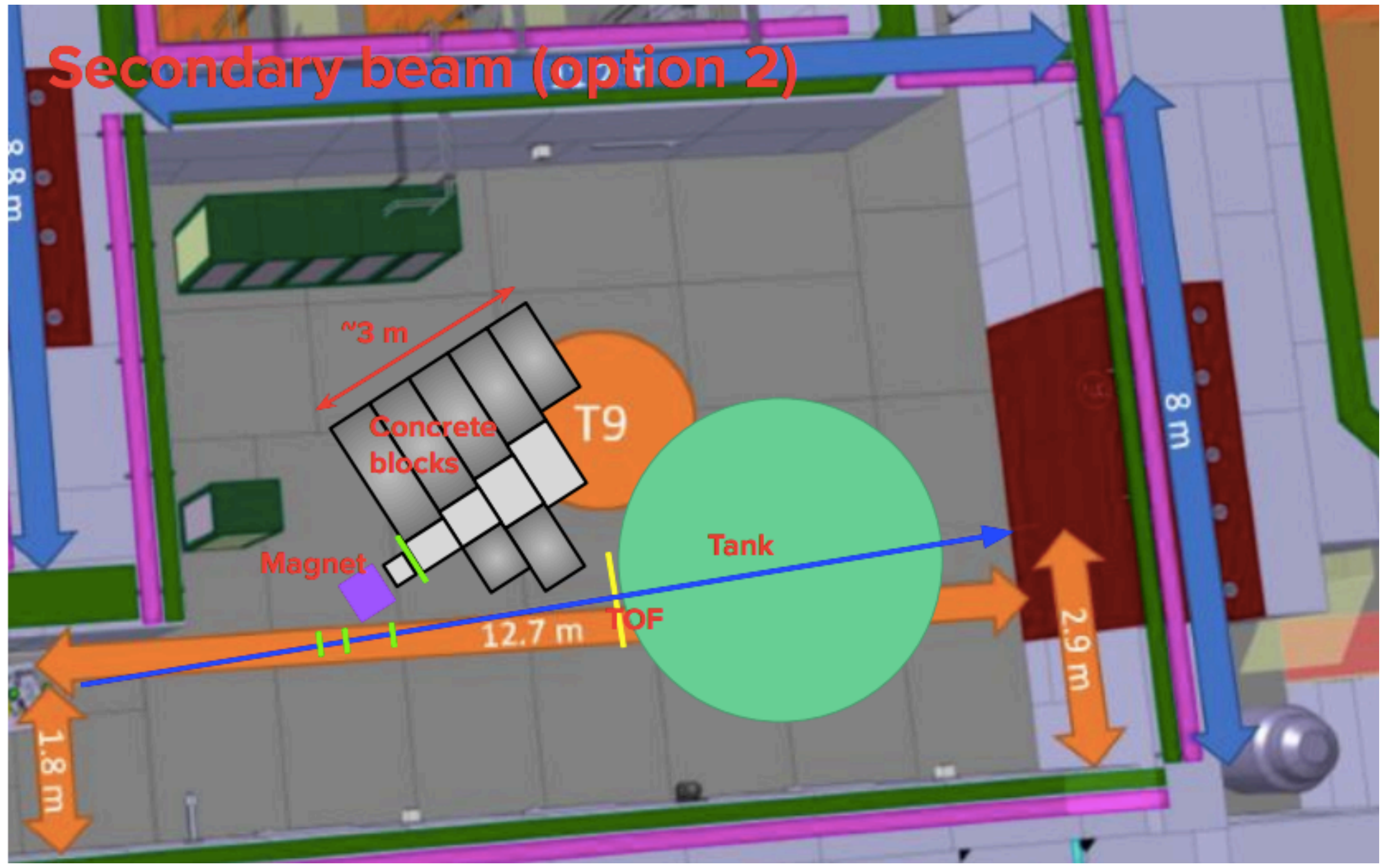
Beam Configurations

Chapter III

A) Beam setting and expected rates

—> provide a table detailing the expected signal and background rates for each secondary beam configuration assumed in chapter IV (detail 3 beam configurations)

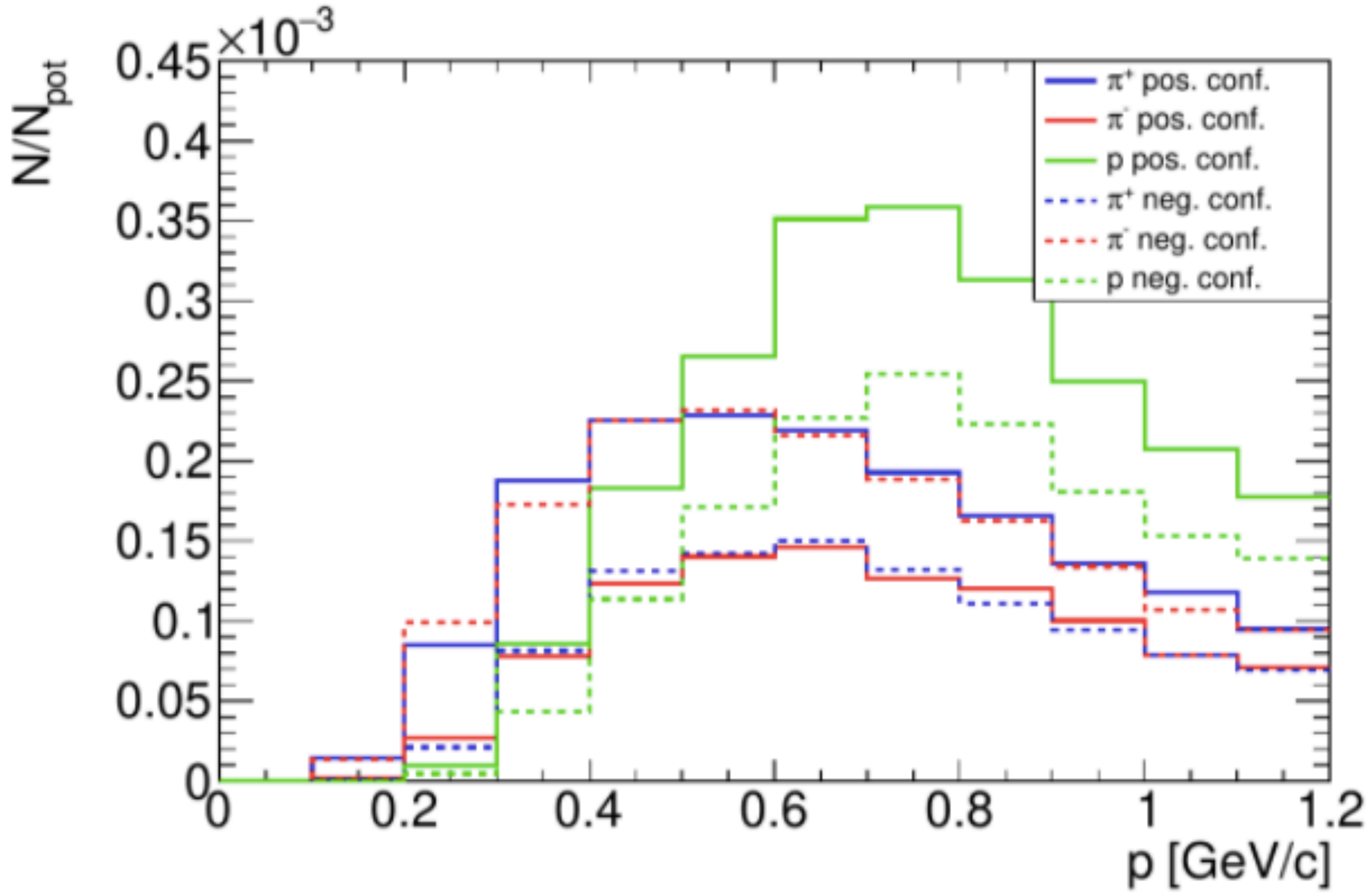




- We will operate in two primary configurations
  - Tertiary particle production with target and spectrometer (pion/proton flux)
  - Direct secondary beam at low momentum setting (muon/electron flux)
    - We haven't yet received the particle fluxes for the secondary beam configuration

Tertiary Particle Spectra

Tertiary beam rates



Tertiary beam rates per 10^6 secondary protons

Positive configuration

p [GeV/c]	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	1.0-1.1	1.1-1.2
π^+	85.00	187.80	225.60	228.20	219.00	192.80	165.40	136.20	117.80	94.80
π^-	26.60	77.60	123.60	140.20	146.00	126.60	120.20	100.20	79.00	71.00
p	9.40	85.40	182.80	265.00	351.20	358.60	313.20	249.80	207.00	177.20

Negative configuration

p [GeV/c]	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	1.0-1.1	1.1-1.2
π^+	21.00	81.40	131.40	142.40	150.00	132.20	111.00	94.60	78.60	69.40
π^-	99.20	172.60	225.60	231.40	216.20	188.80	162.60	134.00	107.00	94.60
p	4.60	43.20	113.60	171.00	226.60	254.20	223.00	180.40	153.40	139.00

Background Rates

Background rates per selected tertiary beam particle

Created in hadronic interactions in the target, magnet and shielding

Positive configuration

p [MeV/c]	0-5	5-25	25-200	>200
γ	0.32	0.15	0.03	0.01
e^-	0.02	0.01	0.00	0.00

p [MeV/c]	0-25	25-50	50-200	>200
n	0.21	0.09	0.10	0.11

Negative configuration

p [MeV/c]	0-5	5-25	25-200	>200
γ	0.32	0.13	0.03	0.00
e^-	0.02	0.00	0.00	0.00

p [MeV/c]	0-25	25-50	50-200	>200
n	0.23	0.08	0.10	0.10

Muon background rates per selected tertiary beam pion

Positive configuration

Muons in the first bin are not really a background → we can remove pion events with momentum < 200 MeV

p [GeV/c]	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2
$\mu^{\pm}$	0.46	0.13	0.06	0.03	0.01	0.00

Negative configuration

p [GeV/c]	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2
$\mu^{\pm}$	0.47	0.12	0.06	0.02	0.01	0.00

mPMTs & Electronics

B) mPMT

—> please provide a reference to more details on the mPMT design and characterization tests.

What are the differences with respect to the technology developed in KM3NET?

How is the scintillator layer used to discriminate backgrounds? Do you have any experimental test of this new design?

Is this the design that has been selected for the HyperK far detector?

Where is the actual construction going on? Provide a detailed schedule for construction and test of the 128 mPMT units

C) mPMT Electronics

—> same questions: provide a reference to more details on the mPMT electronics design and characterization tests.

What are the differences with respect to the technology developed in KM3NET?

Is this the design that has been selected for the HyperK far detector?

Where is the actual construction going on? Provide a detailed schedule for construction and test of the 128 mPMT units

mPMT & Electronics

- We have a detailed description of the mPMTs and electronics development in our internal Hyper-K documentation of the IWCD
  - You can read it here: https://drive.google.com/file/d/1bca3OwULxNixo9SZphJDUeOSnOUxQS8I/view
  - If you think it is helpful, we can add more detail to the proposal (as appendix?) when updating the proposal
- **What are the differences with respect to the technology developed in KM3NET?**
  - IWCD geometry is focused inwards, whereas KM3NET PMTs look in all directions
  - Less pressure resistant design, since water depths not as deep for IWCD or Hyper-K
  - More focus on low dark rate PMTs and improved timing resolution, since these matter more for IWCD than they do for KM3NET

mPMT

- **How is the scintillator layer used to discriminate backgrounds? Do you have any experimental test of this new design?**
  - The scintillator will be used to tag some entering backgrounds that produce gamma conversions in inner detector of the IWCD.
  - So far, we have carried at simulation studies, which are in the process of being improved to be more realistic in modeling dead material in the IWCD
  - Tests at TRIUMF test beam line may be done before WCTE on single modules
- **Is this the design that has been selected for the HyperK far detector?**
  - The plan is that a fraction of Hyper-K photosensors be mPMTs; somewhere in the 3000-5000 mPMTs. These will complement the larger number of 20” PMTs that Hyper-K will have.
  - IWCD and Hyper-K mPMTs will be largely the same mechanical design; but the electronics will be quite different for the Hyper-K and IWCD mPMTs, because of different requirements.
  - WCTE will mostly test IWCD mPMTs, but also plan to test fraction of Hyper-K mPMTs.

Electronics

- **What are the differences with respect to the technology developed in KM3NET?**
  - It is a totally different design for IWCD electronics compared to KM3NET; IWCD electronics will use FADC digitization. The key requirements for IWCD electronics are
    - Deadtime-less readout, since we need to deal with high hit rates during 5us neutrino beam spill
    - Excellent timing resolution so that digitization does not contribute to the intrinsic timing resolution of the PMTs (0.6ns RMS for 1PE pulse)
- **Is this the design that has been selected for the HyperK far detector?**
  - No, the Hyper-K mPMT will use different electronics:
    - IWCD mPMT electronics optimized to deal with high hit rate
    - HyperK mPMT electronics optimized for low power and cost; provides time and charge measurements using a sample/hold scheme with discrete components.
- **Where is the actual construction going on? Are production sites ready?**
  - We plan to have production sites at TRIUMF, Warsaw and perhaps Japan.
  - The production sites are not ready yet, though we have produced several prototypes already and are actively optimizing the production procedure.

mPMT Production Schedule

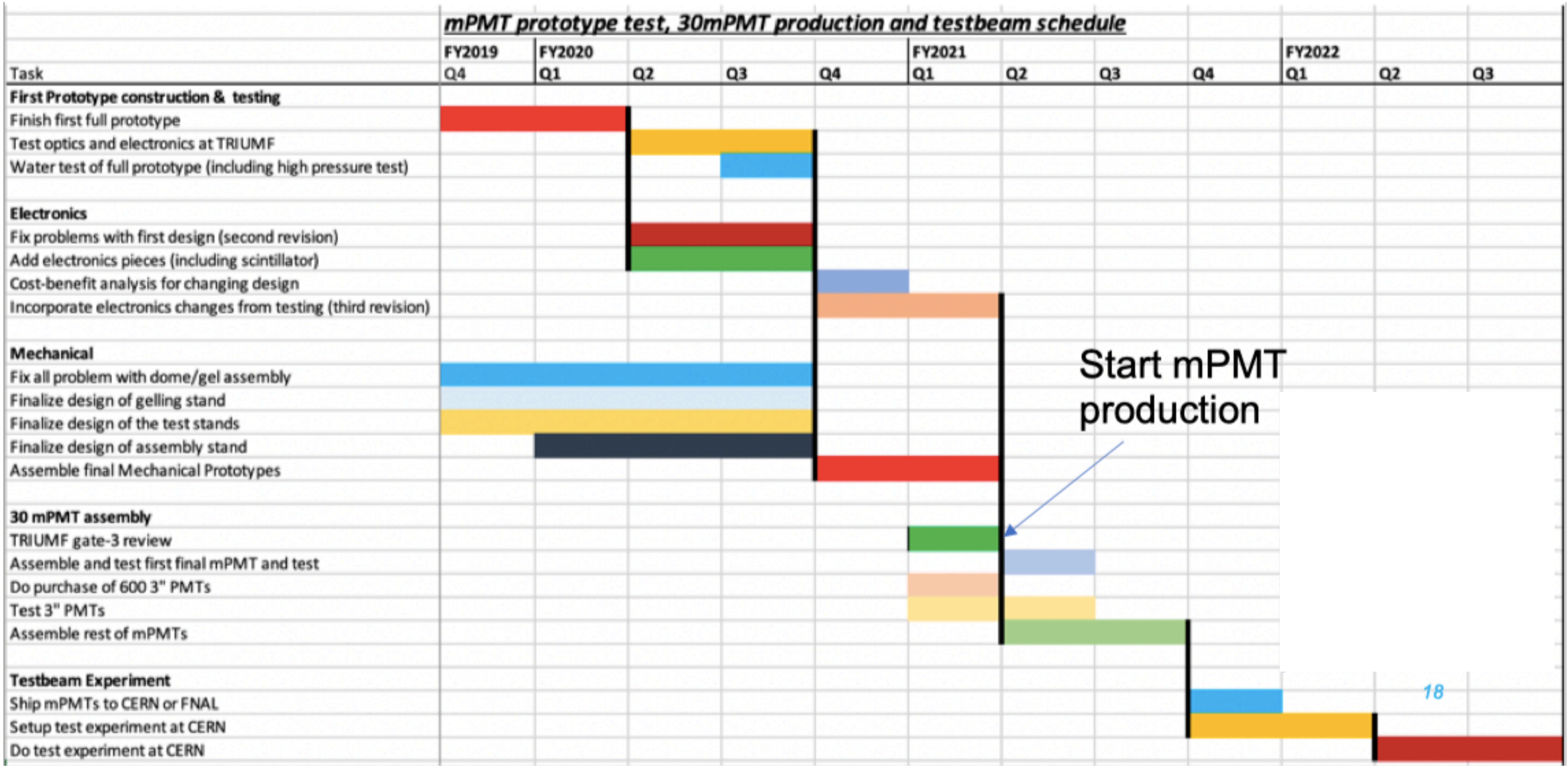
mPMT production assumed to start in 2021 and be concluded in 6 months

—> please provide a more refined schedule for production

Are production sites ready? If not please provide details for preparation activities as well

- The mPMT production schedule will be impacted by COVID-19 and we are now evaluating the impact on the mPMT an WCTE in general
- Schedule under discussion on next slide

mPMT Production Schedule



Calibration

F) Calibration Systems

—> please provide a list and short description of the SuperK calibration systems that will also be implemented in WCTE.

- We have added the following table to our updated proposal draft:

TABLE IV. List of calibration sources and experiments they have been/will be deployed at. This table only includes sources deployed at the experiment, and only those sources that will be used at WCTE. Parentheses indicate differences between sources at experiments. The Super-Kamiokande and Hyper-Kamiokande diffuser balls can only be deployed down fixed vertical lines. The neutron source will only be deployed for WCTE and IWCD provided the detector contains Gadolinium.

Calibration System	Super-Kamiokande	WCTE and IWCD	Hyper-Kamiokande
Light Injectors	✓	✓	✓
Diffuser Ball	(✓)	✓	(✓)
Nickel Source	✓	✓	✓
Neutron Source	✓	(✓)	✓
Photogrammetry	✓	(✓)	✓
mPMT LEDs		✓	✓
Muon tracker		✓	

- Proposal is being updated with a short description of each one of these calibration sources
- More details of calibration sources can be found at: https://www.dropbox.com/s/3zgfbscjq74fcm4/MScott_WCTECalibration_300720.pdf?dl=0

Water System

G) Water system: need for a deionized water source at CERN

—> actual availability or possibility to install commercial unit to be checked with CERN

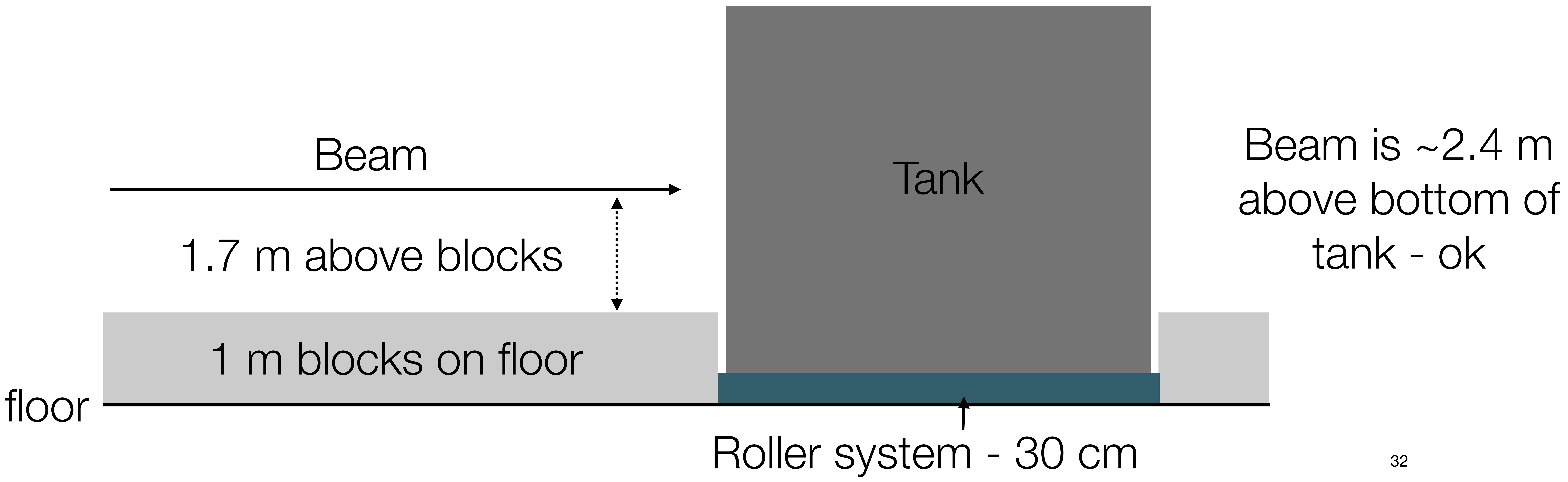
- We had a meeting with CERN personnel in late April and this was one of the topics mentioned
- At that time we were told that 50 ton of deionized water is at the limit of the CERN source (used primarily for magnets)
- We have asked to follow up on this topic with experts at a dedicated meeting
- If we cannot use the CERN source, we will aim to bring the deionized water system that will eventually be used for IWCD, or a prototype of the system for IWCD

Moving of WCTE

I) Experimental layout

—> procedures to partially drain and lift the WCTE tank to be checked with CERN

- We have had a couple of meetings with CERN experts and decided that the best way to move the detector is by placing it on a roller system
- The roller system has been used for detectors that are much more massive than the 60 tons of the fully filled WCTE



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- For the initial schedule, we have not assumed any contingency
- We will discuss areas where contingency should be added
  - Delays in initial commissioning
  - Longer than expected calibration time
  - Beam availability considerations
  - Detector downtime

Extra Slides

Hyper-K/IWCD Approval

HyperK was approved in Japan in January 2020.

—> What is the status of IWCD approval?

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- Yes, there are WCTE collaborators working on the Hyper-K detector components. These include:
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  - 1% uncertainty on efficiency for various event selections
- Hardware requirements:
  - Spatial resolution (for reconstruction near wall): ~8 cm diameter PMTs
  - Timing resolution (for vertex resolution): 1.5 ns FWHM
  - Dark rate (for low energy reconstruction): <1kHz

Performance Requirements

- Hardware requirements:
  - Afterpulsing: low enough to allow neutron reconstruction (later slides)
  - Electronics: Maintain PMT timing resolution, deadtimeless readout, separate reconstruction of photons arriving >10 ns apart
  - mPMT vessel: compatibility with ultra-pure and Gd-loaded water. Acrylic transparent to UV light over sensitive range of PMT
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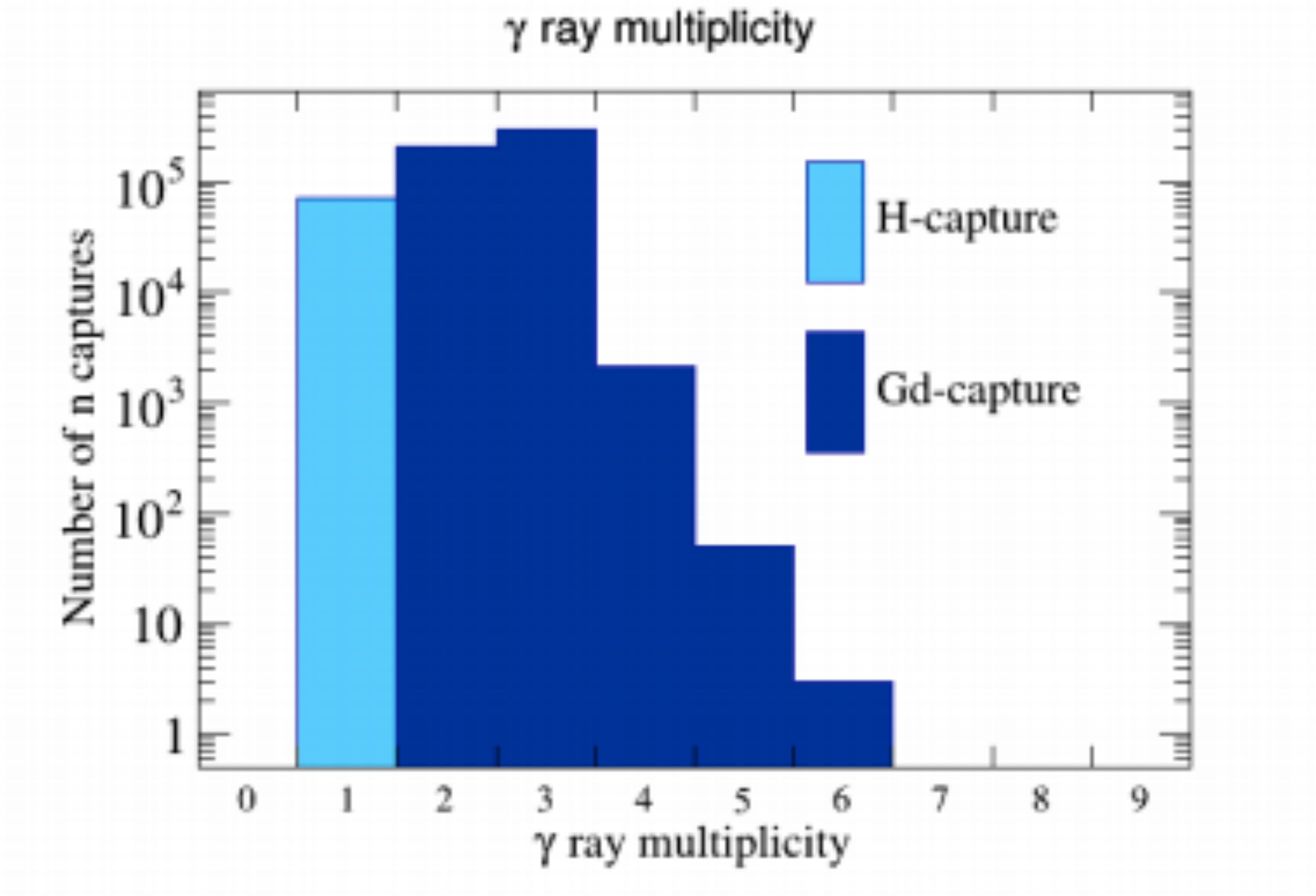
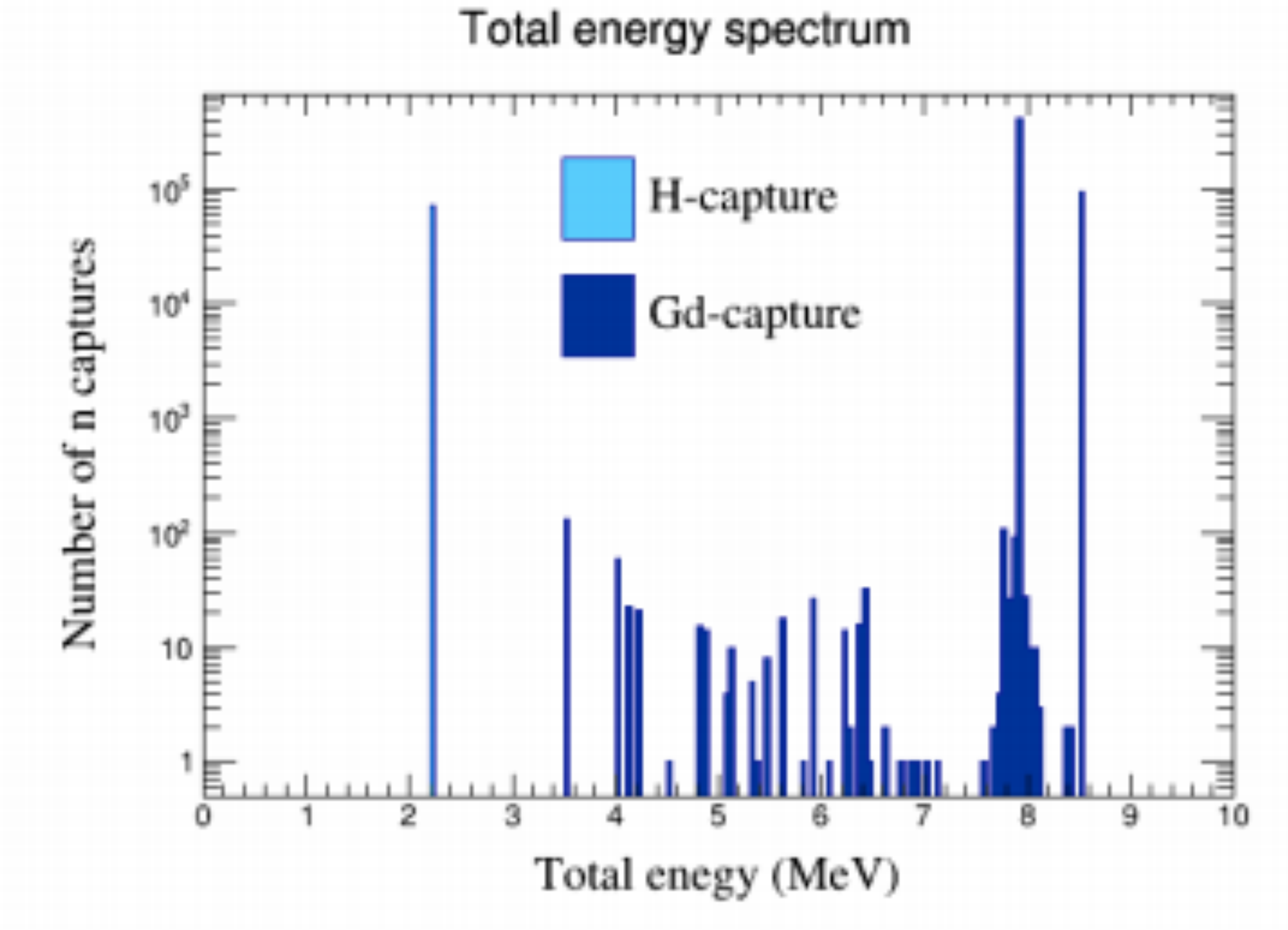
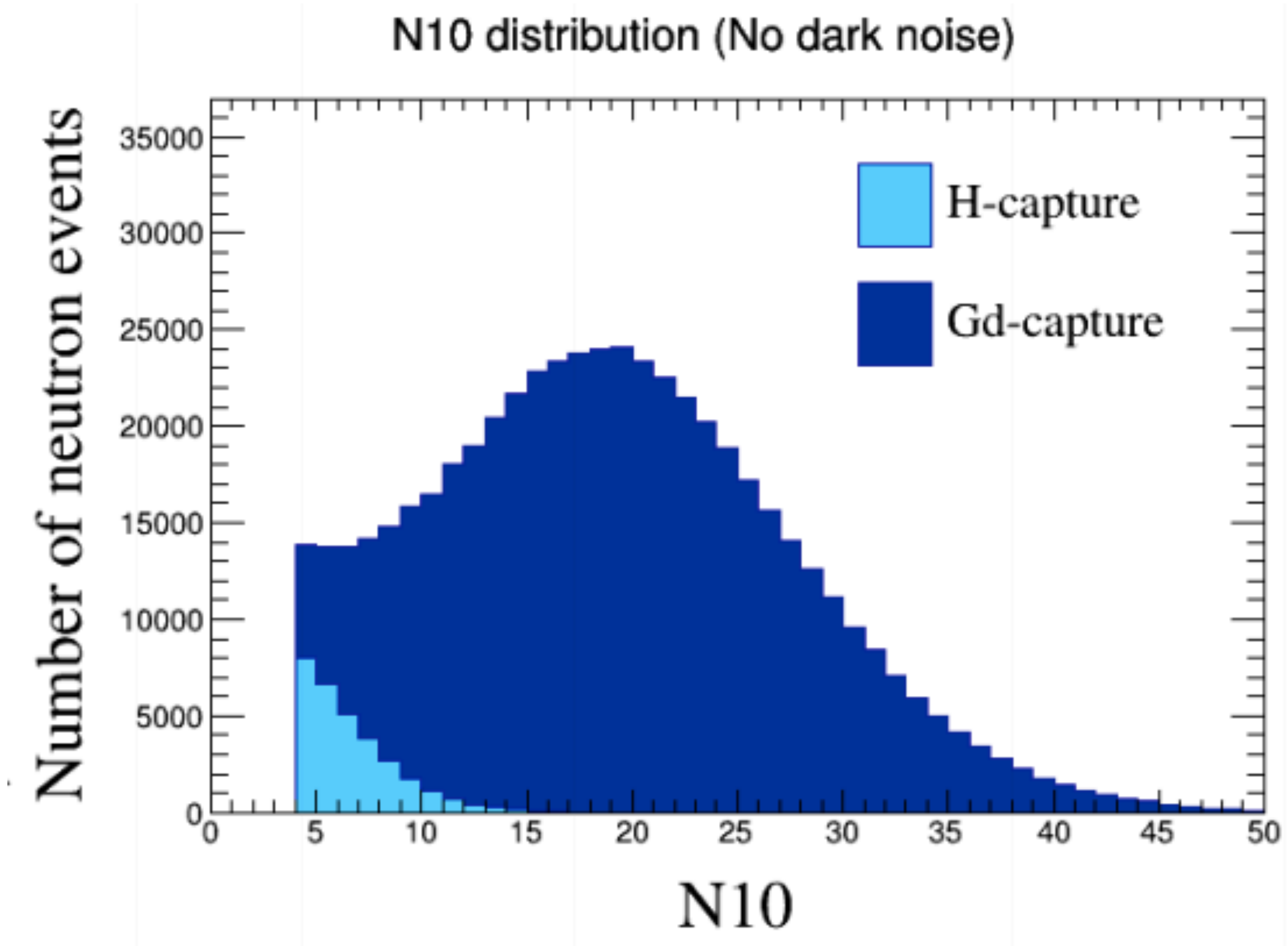
- The neutron captures on Gd are relatively low energy, but still have significantly more energy than neutron captures on H or radioactivity in the detector



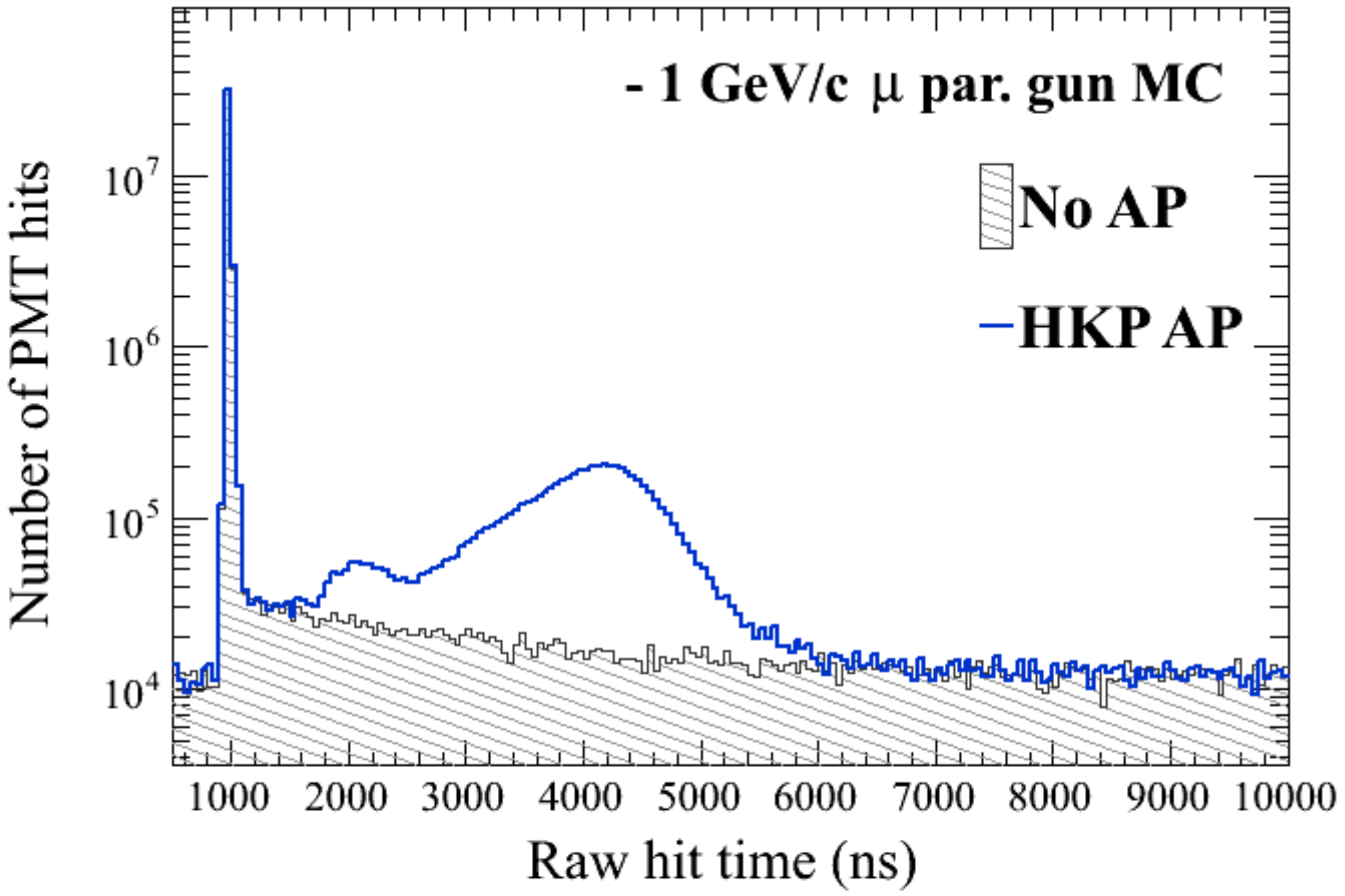


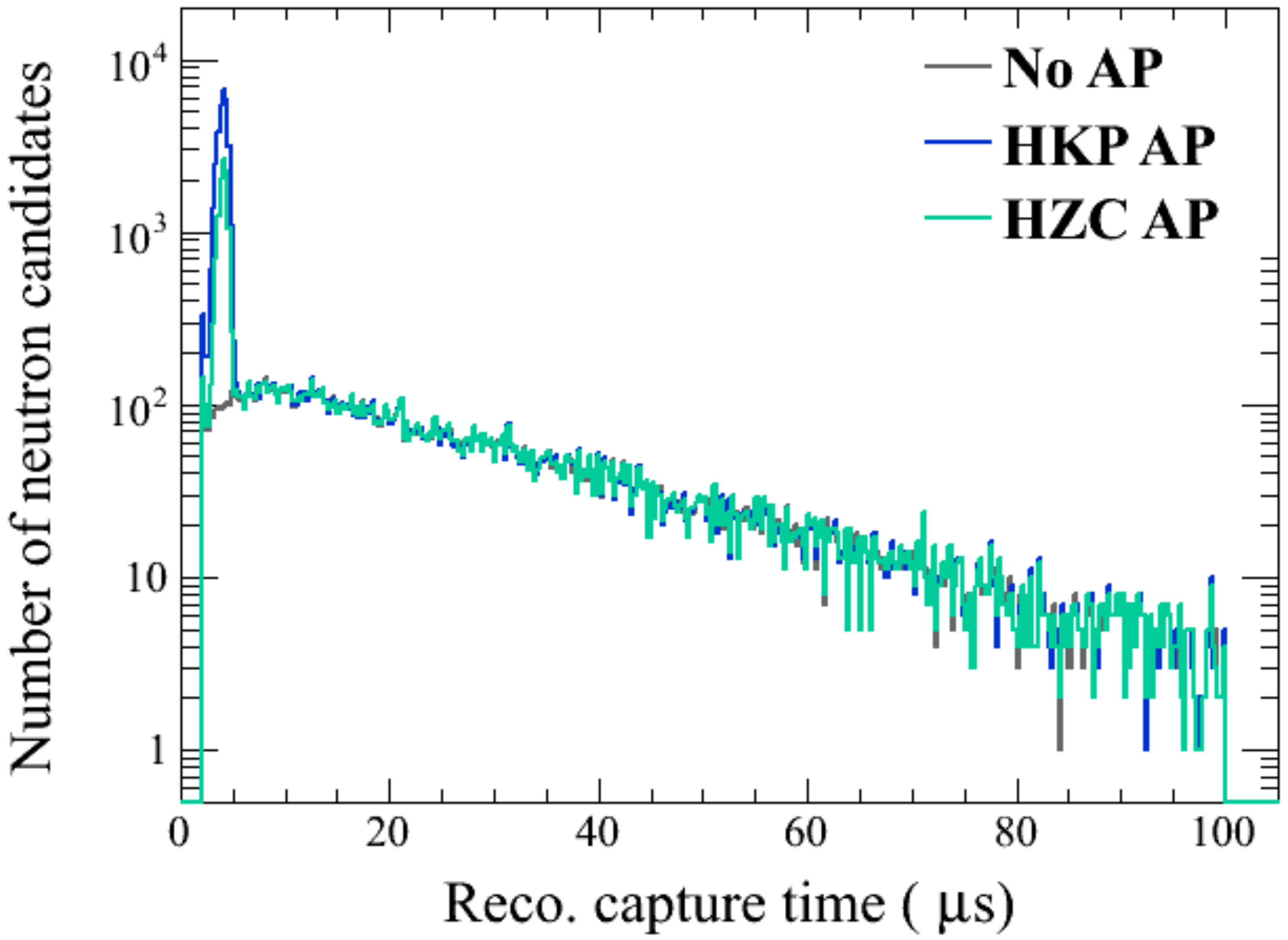
Neutron Detection - Dark Rate, Photocoverage



- A simple search of # of hits in a rolling 10 ns window can be used to find neutron captures
  - >4 hits used in current analysis
  - If photocoverage was significantly reduced, impact on efficiency at low side of N10 distribution
- The PMTs have a dark rate of 500 Hz or less, so for 2508 PMTs in the detector, there is a dark hit every ~800 ns
- Coincidence of 4 dark hits is rare enough, even with trials factor that comes with 100 us search window
- **500 Hz dark rate is ok**

Neutron Detection - Afterpulse





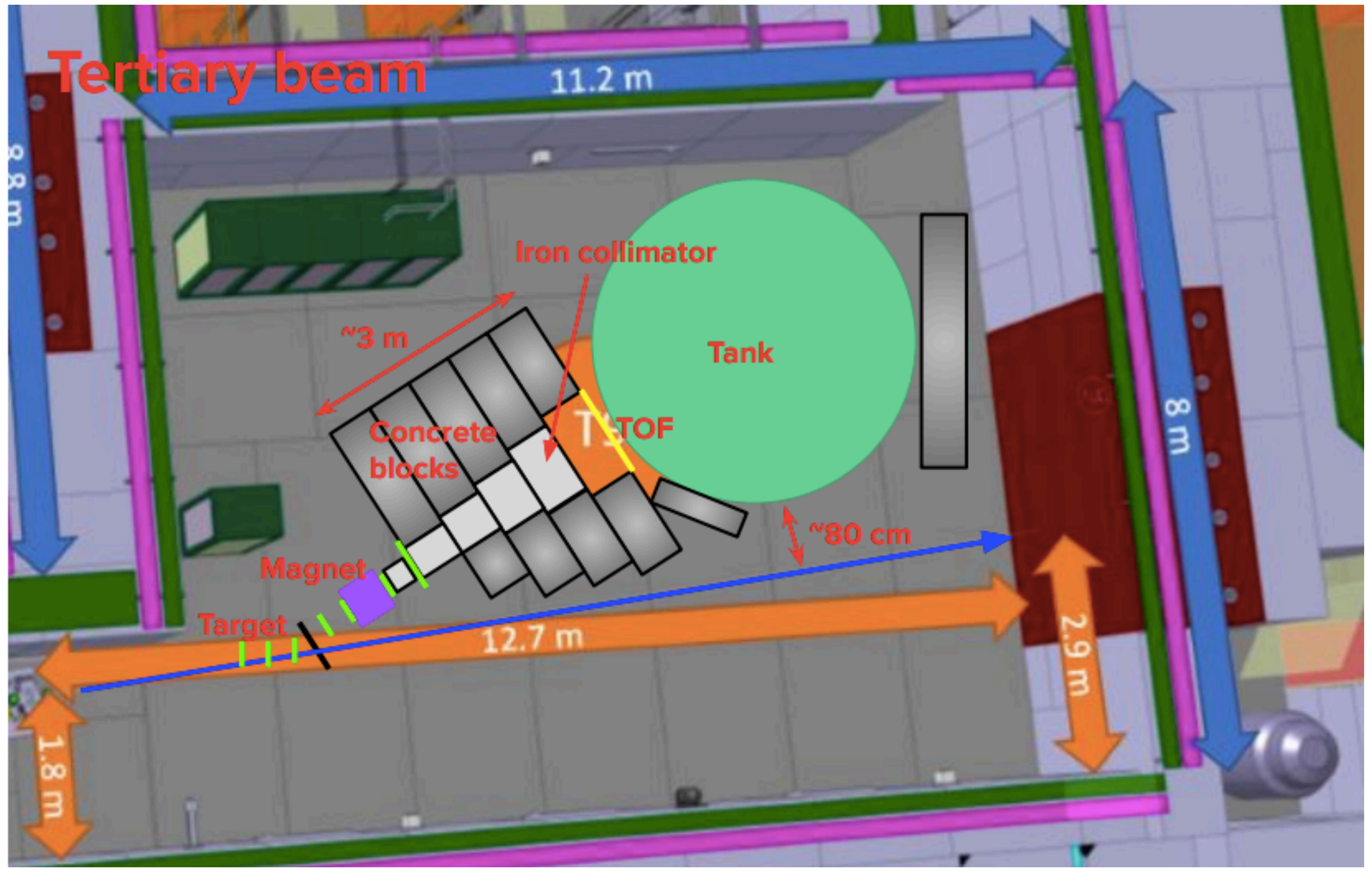
- Our most significant concern for neutrons is the affect of PMT afterpulsing
- Afterpulsing adds a significant number of hits 1-4 μs after the prompt event (left)
- This leads to the reconstruction of fake neutrons in the first 5 μs after prompt event (right)
- We can remove these with a timing cut, but we also consider other mitigation:
  - Work with Hamamatsu to reduce afterpulsing
  - Use masking of PMTs with a large amount of charge in the prompt event

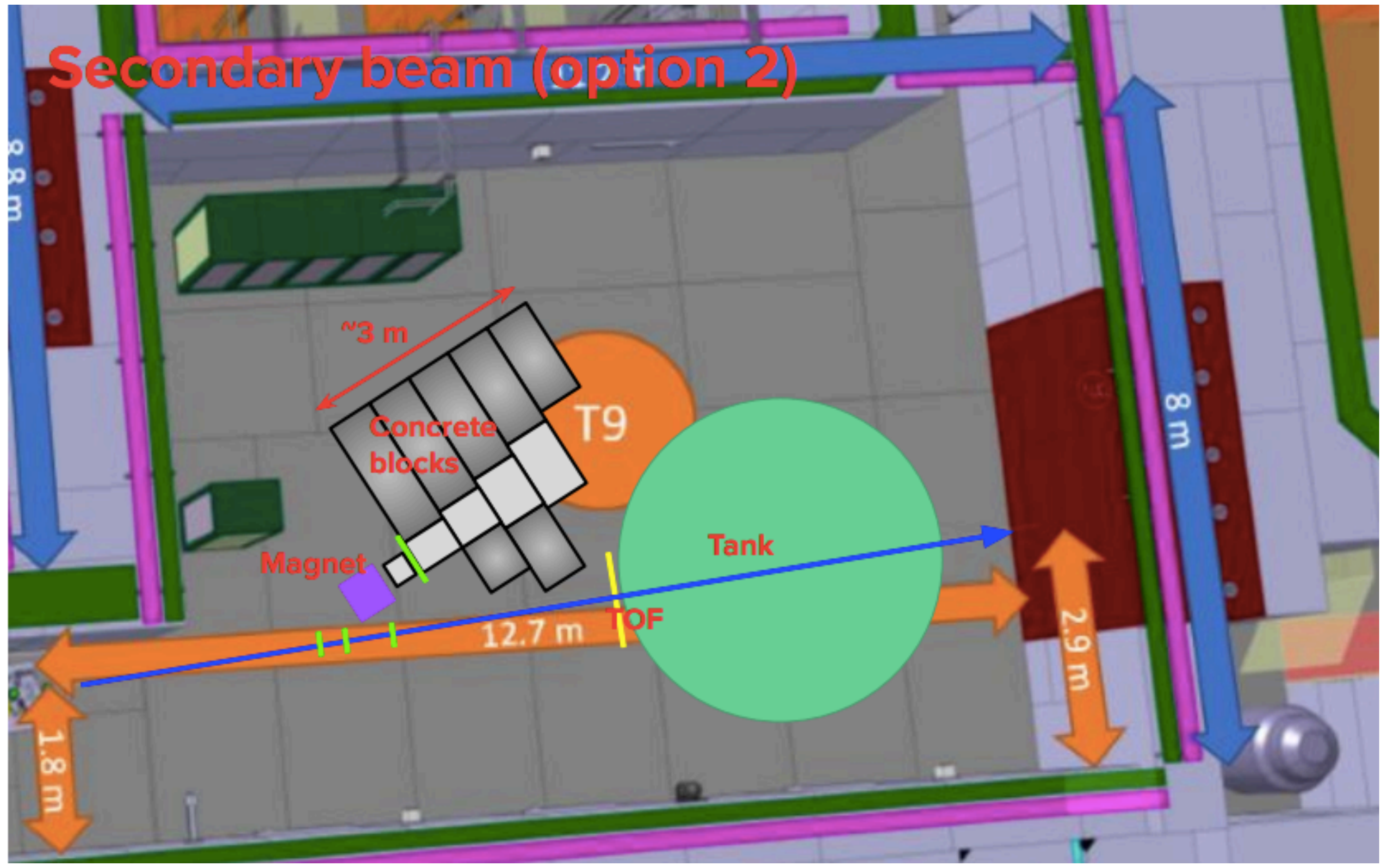
Beam Configurations

Chapter III

A) Beam setting and expected rates

—> provide a table detailing the expected signal and background rates for each secondary beam configuration assumed in chapter IV (detail 3 beam configurations)

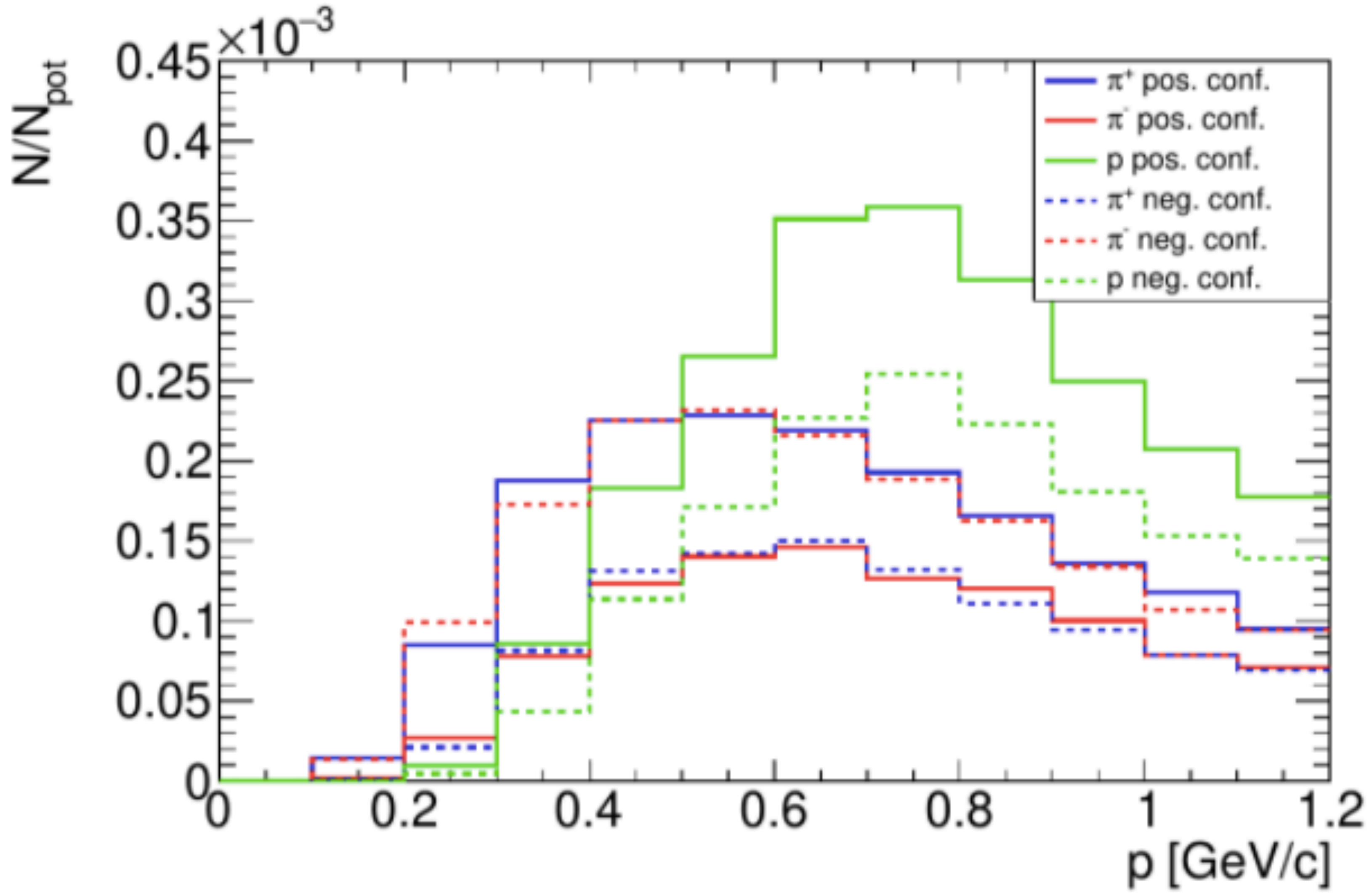




- We will operate in two primary configurations
  - Tertiary particle production with target and spectrometer (pion/proton flux)
  - Direct secondary beam at low momentum setting (muon/electron flux)
    - We haven't yet received the particle fluxes for the secondary beam configuration

Tertiary Particle Spectra

Tertiary beam rates



Tertiary beam rates per 10^6 secondary protons

Positive configuration

p [GeV/c]	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	1.0-1.1	1.1-1.2
π^+	85.00	187.80	225.60	228.20	219.00	192.80	165.40	136.20	117.80	94.80
π^-	26.60	77.60	123.60	140.20	146.00	126.60	120.20	100.20	79.00	71.00
p	9.40	85.40	182.80	265.00	351.20	358.60	313.20	249.80	207.00	177.20

Negative configuration

p [GeV/c]	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	1.0-1.1	1.1-1.2
π^+	21.00	81.40	131.40	142.40	150.00	132.20	111.00	94.60	78.60	69.40
π^-	99.20	172.60	225.60	231.40	216.20	188.80	162.60	134.00	107.00	94.60
p	4.60	43.20	113.60	171.00	226.60	254.20	223.00	180.40	153.40	139.00

Background Rates

Background rates per selected tertiary beam particle

Created in hadronic interactions in the target, magnet and shielding

Positive configuration

p [MeV/c]	0-5	5-25	25-200	>200
γ	0.32	0.15	0.03	0.01
e^-	0.02	0.01	0.00	0.00

p [MeV/c]	0-25	25-50	50-200	>200
n	0.21	0.09	0.10	0.11

Negative configuration

p [MeV/c]	0-5	5-25	25-200	>200
γ	0.32	0.13	0.03	0.00
e^-	0.02	0.00	0.00	0.00

p [MeV/c]	0-25	25-50	50-200	>200
n	0.23	0.08	0.10	0.10

Muon background rates per selected tertiary beam pion

Positive configuration

Muons in the first bin are not really a background → we can remove pion events with momentum < 200 MeV

p [GeV/c]	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2
$\mu^\pm$	0.46	0.13	0.06	0.03	0.01	0.00

Negative configuration

p [GeV/c]	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2
$\mu^\pm$	0.47	0.12	0.06	0.02	0.01	0.00

mPMTs & Electronics

B) mPMT

—> please provide a reference to more details on the mPMT design and characterization tests.

What are the differences with respect to the technology developed in KM3NET?

How is the scintillator layer used to discriminate backgrounds? Do you have any experimental test of this new design?

Is this the design that has been selected for the HyperK far detector?

Where is the actual construction going on? Provide a detailed schedule for construction and test of the 128 mPMT units

C) mPMT Electronics

—> same questions: provide a reference to more details on the mPMT electronics design and characterization tests.

What are the differences with respect to the technology developed in KM3NET?

Is this the design that has been selected for the HyperK far detector?

Where is the actual construction going on? Provide a detailed schedule for construction and test of the 128 mPMT units

mPMT & Electronics

- We have a detailed description of the mPMTs and electronics development in our internal Hyper-K documentation of the IWCD
  - You can read it here: https://drive.google.com/file/d/1bca3OwULxNixo9SZphJDUeOSnOUxQS8I/view
  - If you think it is helpful, we can add more detail to the proposal (as appendix?) when updating the proposal
- **What are the differences with respect to the technology developed in KM3NET?**
  - IWCD geometry is focused inwards, whereas KM3NET PMTs look in all directions
  - Less pressure resistant design, since water depths not as deep for IWCD or Hyper-K
  - More focus on low dark rate PMTs and improved timing resolution, since these matter more for IWCD than they do for KM3NET

mPMT

- **How is the scintillator layer used to discriminate backgrounds? Do you have any experimental test of this new design?**
  - The scintillator will be used to tag some entering backgrounds that produce gamma conversions in inner detector of the IWCD.
  - So far, we have carried at simulation studies, which are in the process of being improved to be more realistic in modeling dead material in the IWCD
  - Tests at TRIUMF test beam line may be done before WCTE on single modules
- **Is this the design that has been selected for the HyperK far detector?**
  - The plan is that a fraction of Hyper-K photosensors be mPMTs; somewhere in the 3000-5000 mPMTs. These will complement the larger number of 20” PMTs that Hyper-K will have.
  - IWCD and Hyper-K mPMTs will be largely the same mechanical design; but the electronics will be quite different for the Hyper-K and IWCD mPMTs, because of different requirements.
  - WCTE will mostly test IWCD mPMTs, but also plan to test fraction of Hyper-K mPMTs.

Electronics

- **What are the differences with respect to the technology developed in KM3NET?**
  - It is a totally different design for IWCD electronics compared to KM3NET; IWCD electronics will use FADC digitization. The key requirements for IWCD electronics are
    - Deadtime-less readout, since we need to deal with high hit rates during 5us neutrino beam spill
    - Excellent timing resolution so that digitization does not contribute to the intrinsic timing resolution of the PMTs (0.6ns RMS for 1PE pulse)
- **Is this the design that has been selected for the HyperK far detector?**
  - No, the Hyper-K mPMT will use different electronics:
    - IWCD mPMT electronics optimized to deal with high hit rate
    - HyperK mPMT electronics optimized for low power and cost; provides time and charge measurements using a sample/hold scheme with discrete components.
- **Where is the actual construction going on? Are production sites ready?**
  - We plan to have production sites at TRIUMF, Warsaw and perhaps Japan.
  - The production sites are not ready yet, though we have produced several prototypes already and are actively optimizing the production procedure.

mPMT Production Schedule

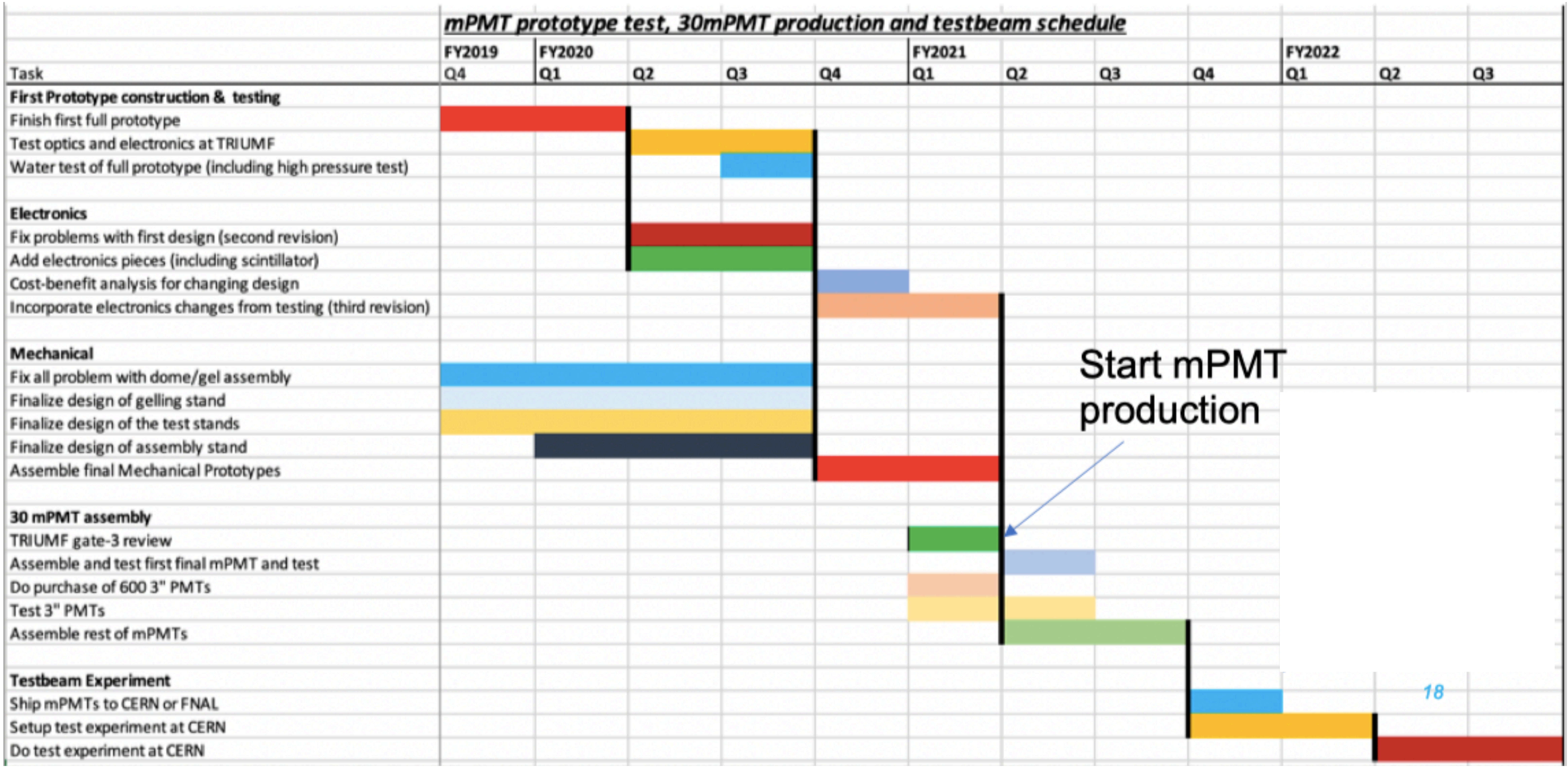
mPMT production assumed to start in 2021 and be concluded in 6 months

—> please provide a more refined schedule for production

Are production sites ready? If not please provide details for preparation activities as well

- The mPMT production schedule will be impacted by COVID-19 and we are now evaluating the impact on the mPMT an WCTE in general
- Schedule under discussion on next slide

mPMT Production Schedule



Calibration

F) Calibration Systems

—> please provide a list and short description of the SuperK calibration systems that will also be implemented in WCTE.

- We have added the following table to our updated proposal draft:

TABLE IV. List of calibration sources and experiments they have been/will be deployed at. This table only includes sources deployed at the experiment, and only those sources that will be used at WCTE. Parentheses indicate differences between sources at experiments. The Super-Kamiokande and Hyper-Kamiokande diffuser balls can only be deployed down fixed vertical lines. The neutron source will only be deployed for WCTE and IWCD provided the detector contains Gadolinium.

Calibration System	Super-Kamiokande	WCTE and IWCD	Hyper-Kamiokande
Light Injectors	✓	✓	✓
Diffuser Ball	(✓)	✓	(✓)
Nickel Source	✓	✓	✓
Neutron Source	✓	(✓)	✓
Photogrammetry	✓	(✓)	✓
mPMT LEDs		✓	✓
Muon tracker		✓	

- Proposal is being updated with a short description of each one of these calibration sources

- More details of calibration sources can be found at: https://www.dropbox.com/s/3zgfbscjq74fcm4/MScott_WCTECalibration_300720.pdf?dl=0

Water System

G) Water system: need for a deionized water source at CERN
—> actual availability or possibility to install commercial unit to be checked with CERN

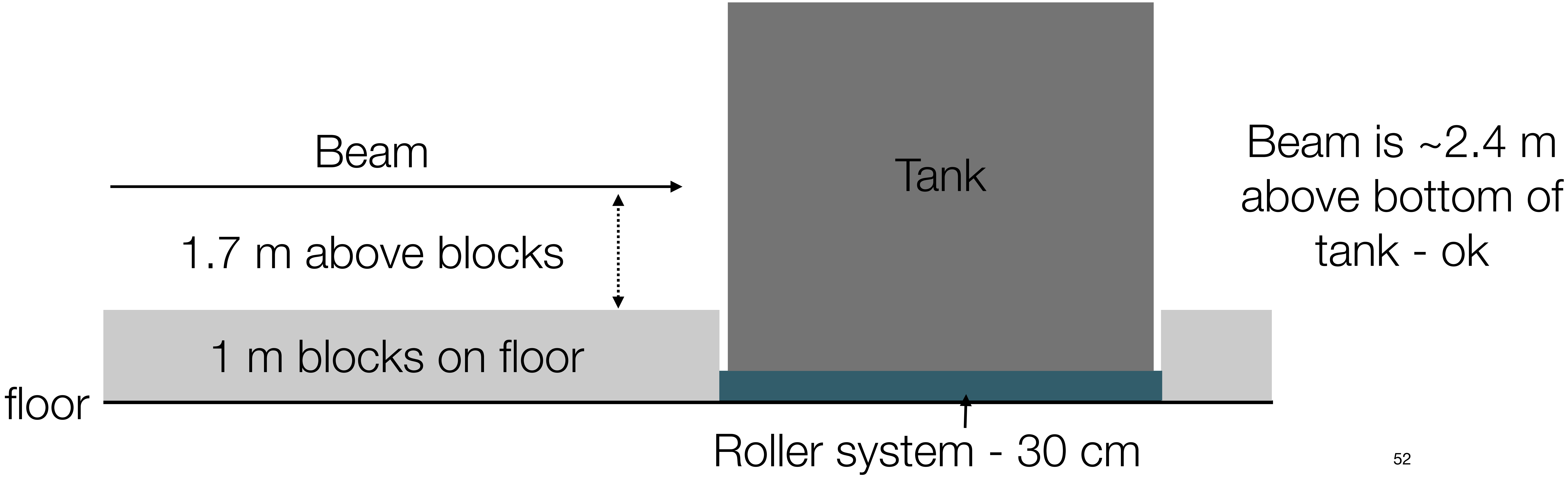
- We had a meeting with CERN personnel in late April and this was one of the topics mentioned
- At that time we were told that 50 ton of deionized water is at the limit of the CERN source (used primarily for magnets)
- We have asked to follow up on this topic with experts at a dedicated meeting
- If we cannot use the CERN source, we will aim to bring the deionized water system that will eventually be used for IWCD, or a prototype of the system for IWCD

Moving of WCTE

I) Experimental layout

—> procedures to partially drain and lift the WCTE tank to be checked with CERN

- We have had a couple of meetings with CERN experts and decided that the best way to move the detector is by placing it on a roller system
- The roller system has been used for detectors that are much more massive than the 60 tons of the fully filled WCTE



Operation Schedule

—> Total request for beam time is 11 weeks in 2022.
What contingency do you assume in the schedule?

- 1 week: Move detector into beam line, fill with water, purify water.
- 1 week: Initial commissioning of the detector.
- 0.5 weeks: Calibration of the detector.
- 1 week: Operation of the detector in the tertiary pion configuration.
- 0.5 weeks: Move detector into the secondary beam for muon operation.
- 1 week: Re-commissioning and calibration of the detector.
- 1 week: Operation of the detector in the secondary muon configuration.
- 0.5 weeks: Addition of Gd to the detector.
- 0.5 weeks: Calibration of the detector with Gd.
- 1 week: Operation of the detector in the secondary muon configuration with Gd.
- 0.5 weeks: Move detector into the tertiary pion configuration.
- 1 week: Re-commissioning and calibration of the detector.
- 1 week: Operation of the detector in the tertiary pion configuration with Gd.

- For the initial schedule, we have not assumed any contingency
- We will discuss areas where contingency should be added
  - Delays in initial commissioning
  - Longer than expected calibration time
  - Beam availability considerations
  - Detector downtime