The Atmospheric Neutrino Neutron Interaction Experiment (ANNIE)

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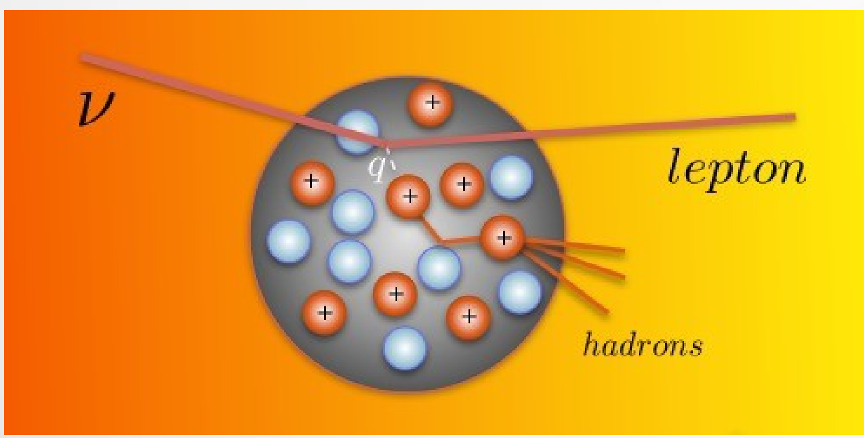
On behalf of the ANNIE collaboration

5th Open Hyper-Kamiokande Meeting
19-23 July 2014, Vancouver

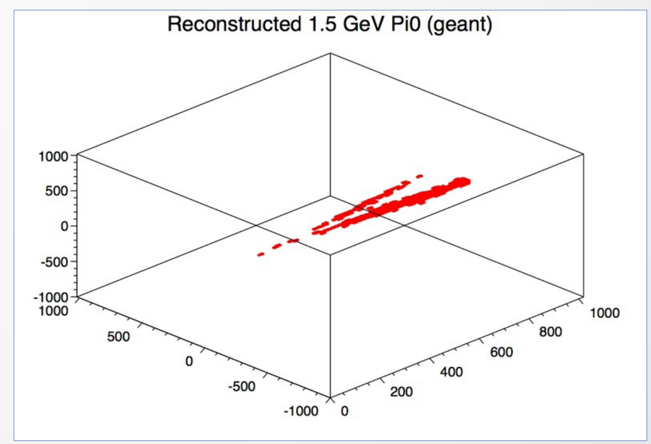
What are ANNIE's Goals?

- A measurement of the abundance of final state neutrinos from neutrino interactions in water, as a function of the energy.

A key measurement for proton decay physics, supernova neutrinos detection in water, and fundamental neutrino interaction physics

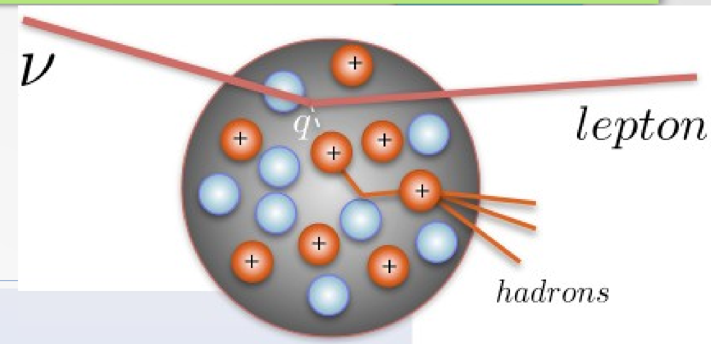


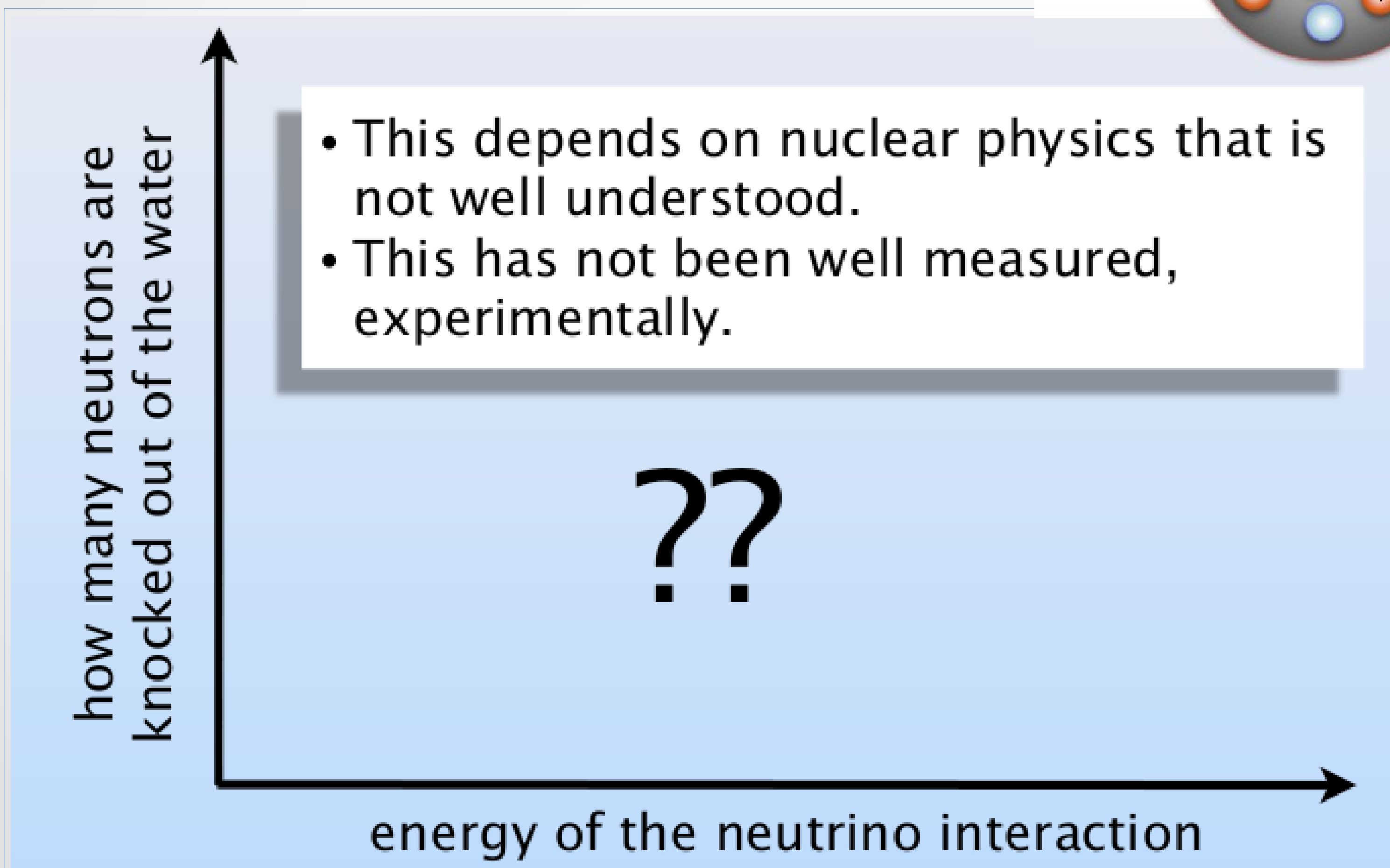
first 2 radiation lengths of a 1.5 GeV $\pi_0 \rightarrow \gamma\,\gamma$ reconstructed



- Demonstration of a new approach to neutrino detection: *Optical Time Projection Chamber* using new photosensor technology.

The ANNIE measurement (in a nutshell)



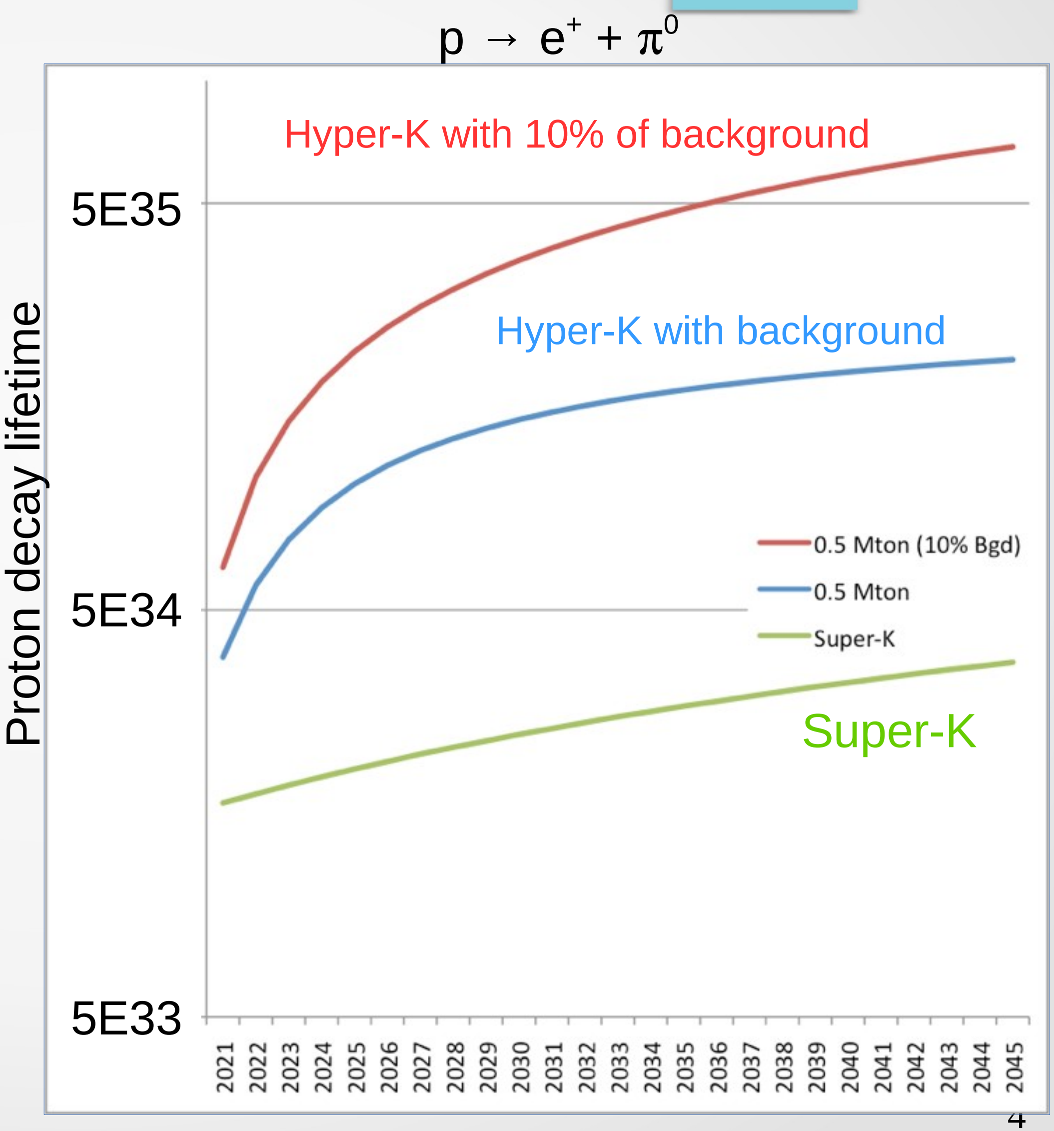


Motivation

- Proton decay searches in planned megaton-scale water Cherenkov detectors such as Hyper-K could achieve unprecedented sensitivity.

- However, at such scales, previously negligible backgrounds from atmospheric neutrinos start to limit this sensitivity.

- Techniques capables of reducing there backgrounds would have a large impact on the potential physics reach.

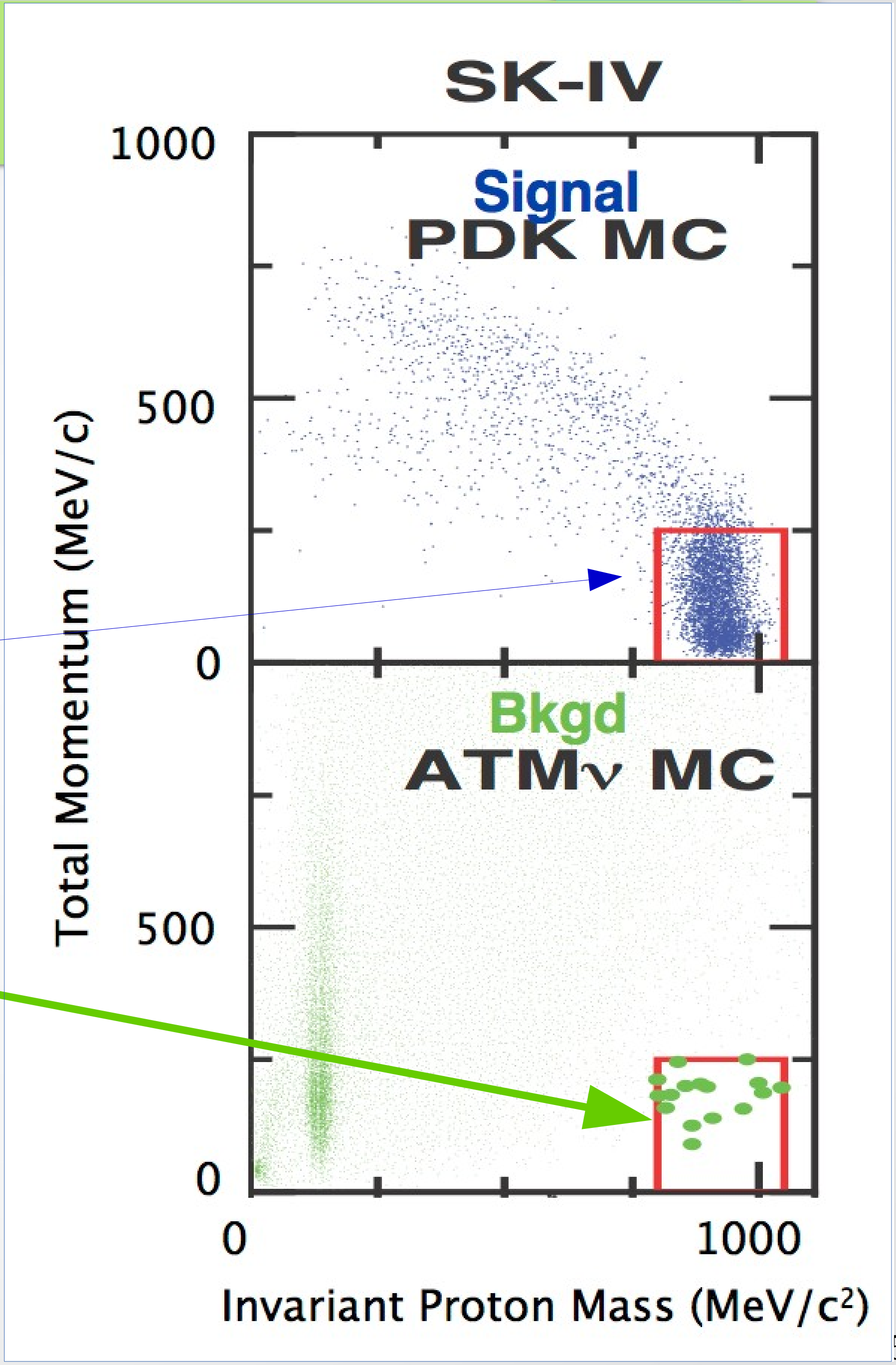


Motivation

Backgrounds come almost exclusively from atmospheric neutrino interactions

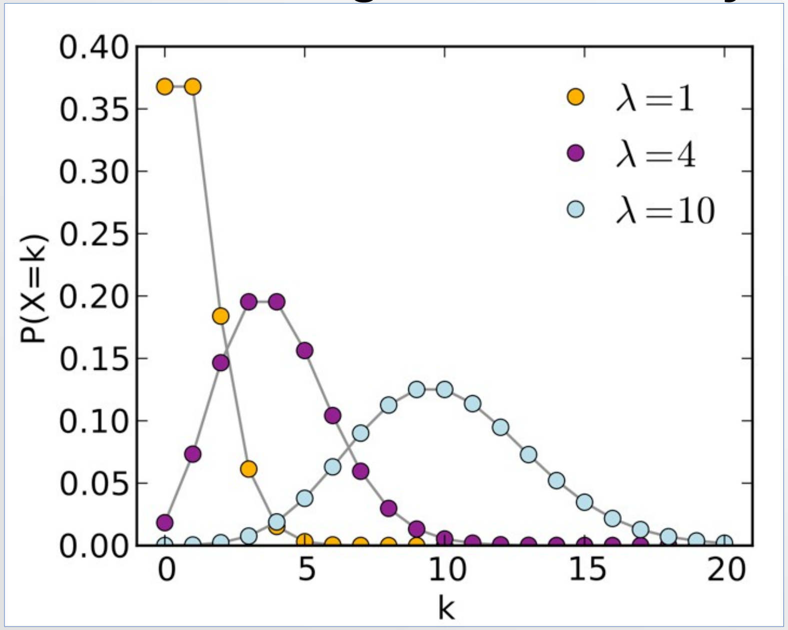
Proton decays events are expected to only rarely produce neutrons in the final state.

High energy neutrino interactions typically produce neutrons in the final state.



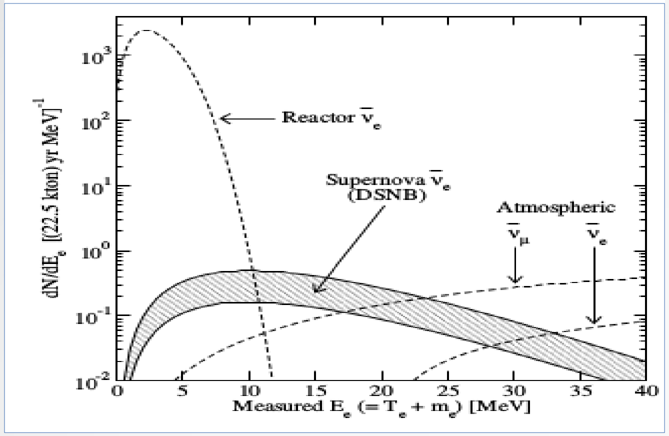
Why produced neutrons are relevant?

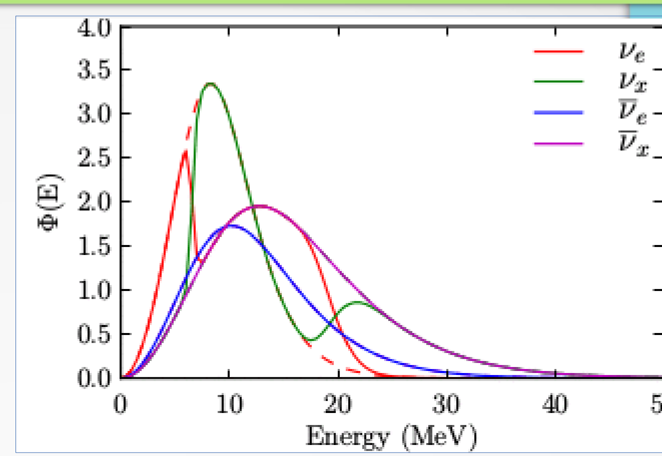
- The presence of any neutrinos can be used to confidently reject proton decay backgrounds.
- But the absence of any neutrons is not necessarily a strong indicator of a signal (could be detector inefficiency).
- Attributing confidence to proton decay candidates without neutrons requires:
  - Knowledge of the neutron tagging efficiency, and
  - **Knowledge of how many neutrons are expected per background event**



Did we see 0 neutrons given the expectaction of 1 or 10?
What is the number of expected neutrons?
The spread?

Neutron Tagging Extended Impact



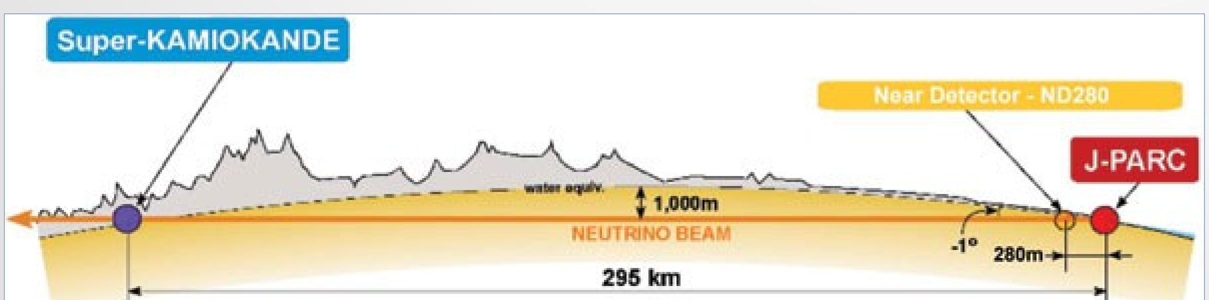


SN Neutrino Detection

- Helps to separate diffuse SN neutrinos from various backgrounds
- Helps to disentangle the various fluxes from core collapsed SN

Neutrino Interaction Physics

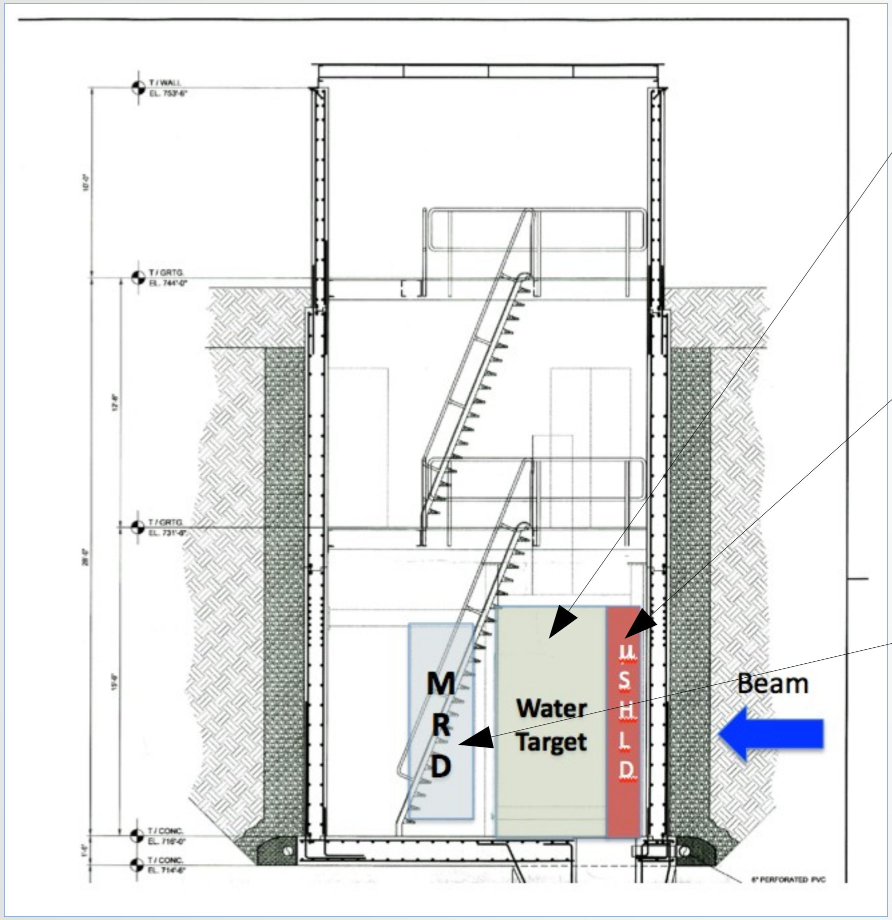
Helps to constrain and distinguish between various model of ν-nucleon interactions



Precision Neutrino Oscillation Measurement

- Helps improving background rejection

The Hall



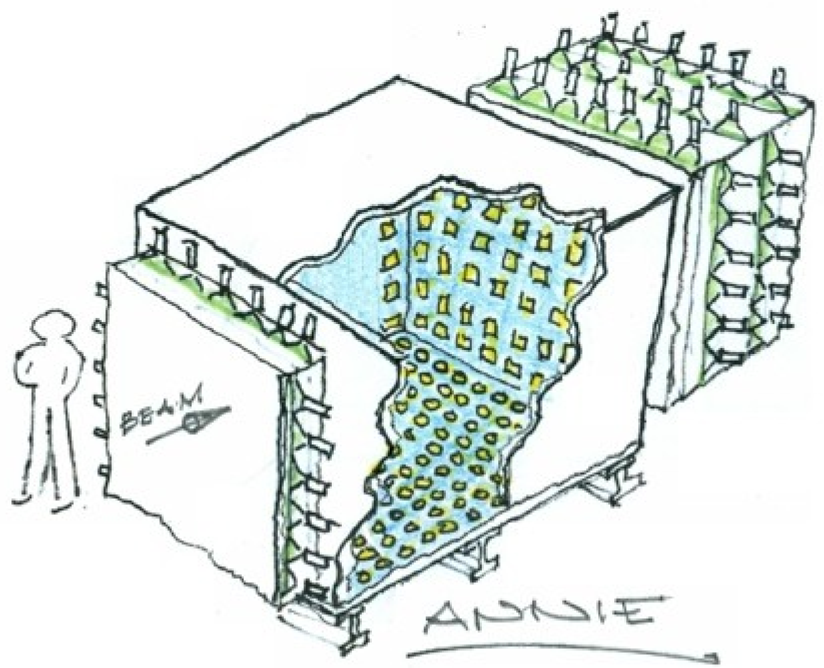
„ANNIE Hall“
Formely the SciBooNE pit

3m x 3m x 3m tank of Gd enhanced water instrumented with photosensors

Existing veto on muons produced upstream of the detector (FACC)

Existing Muon Range Detector (MRD)

The ANNIE Detector System



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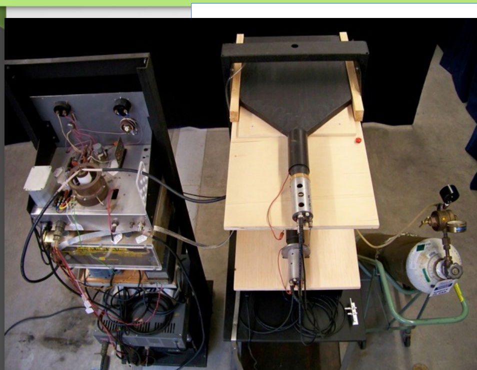
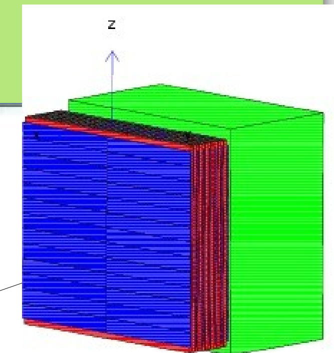
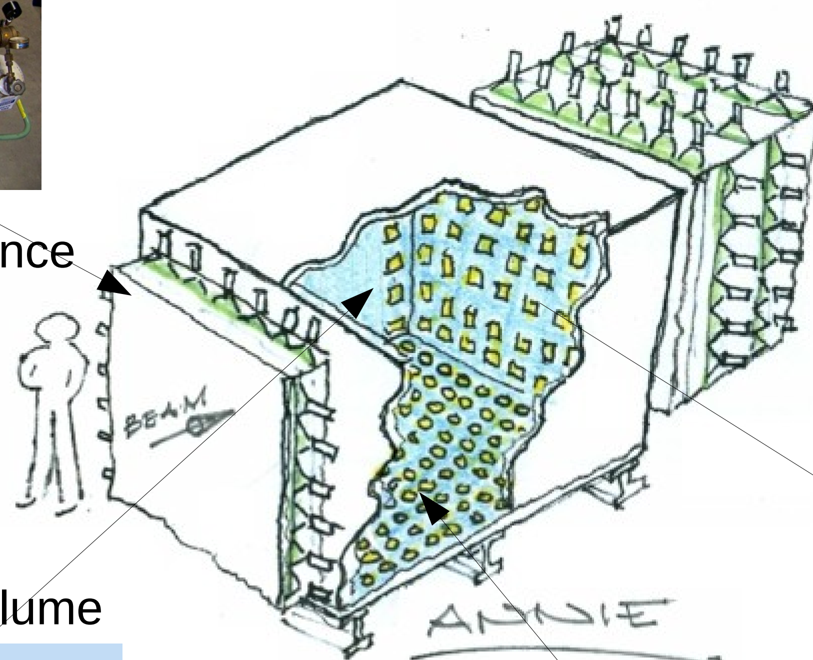


Front Anti-Coincidence Counter

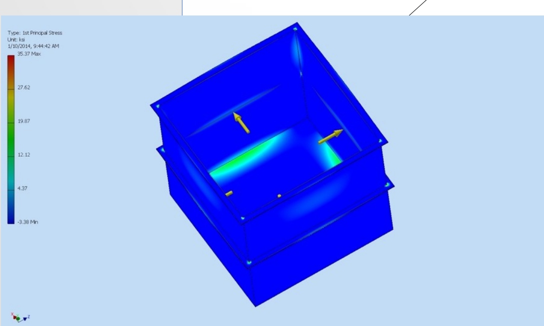


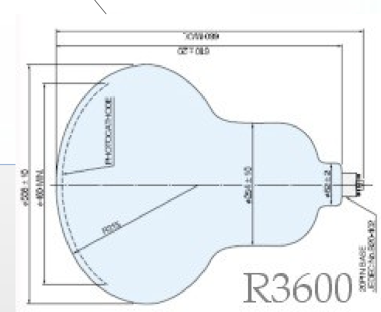
Muon Range Detector



LAPPDs

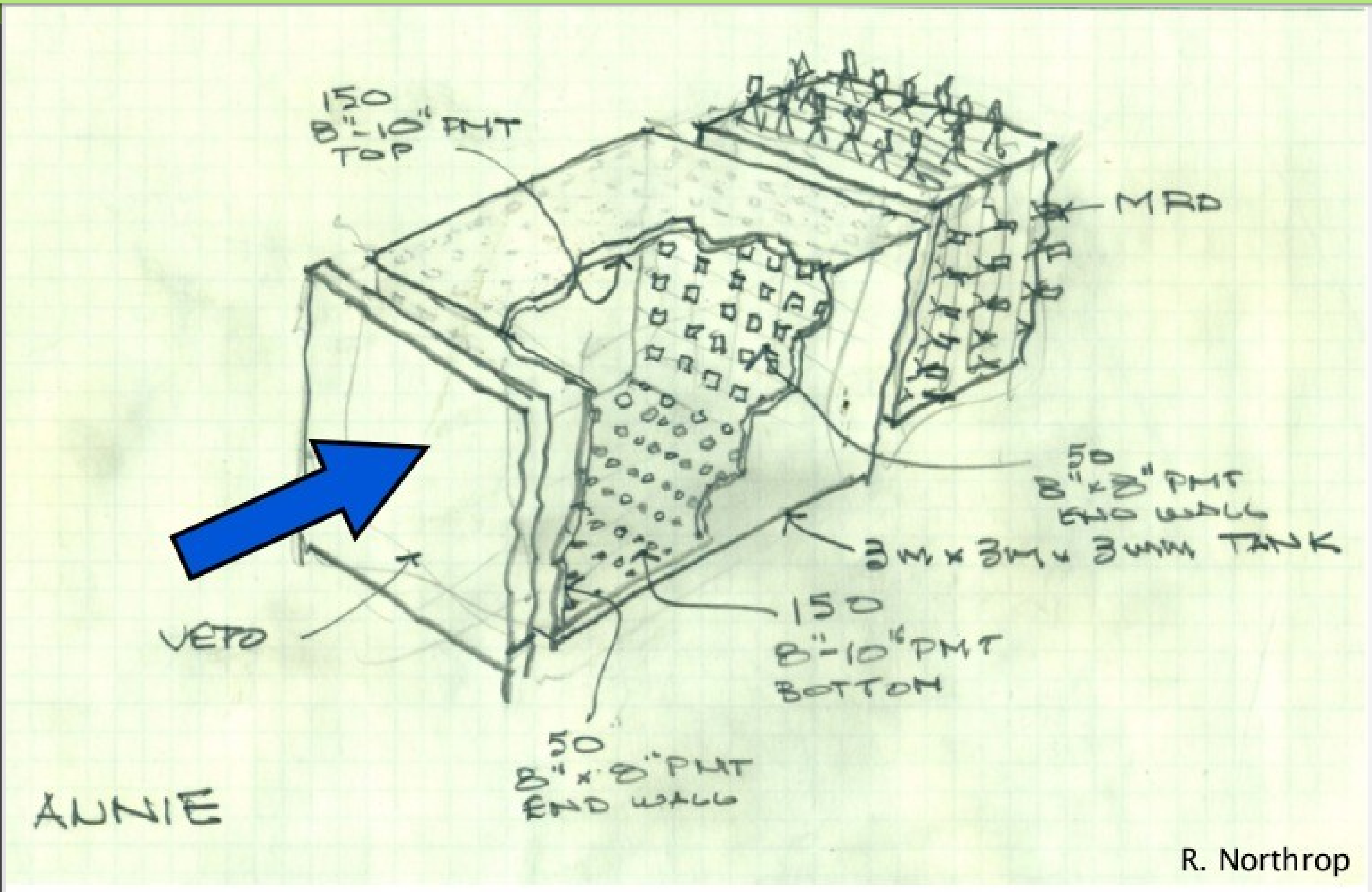
Gd-loaded water volume





Conventional PMTs

ANNIE – Basic Concept



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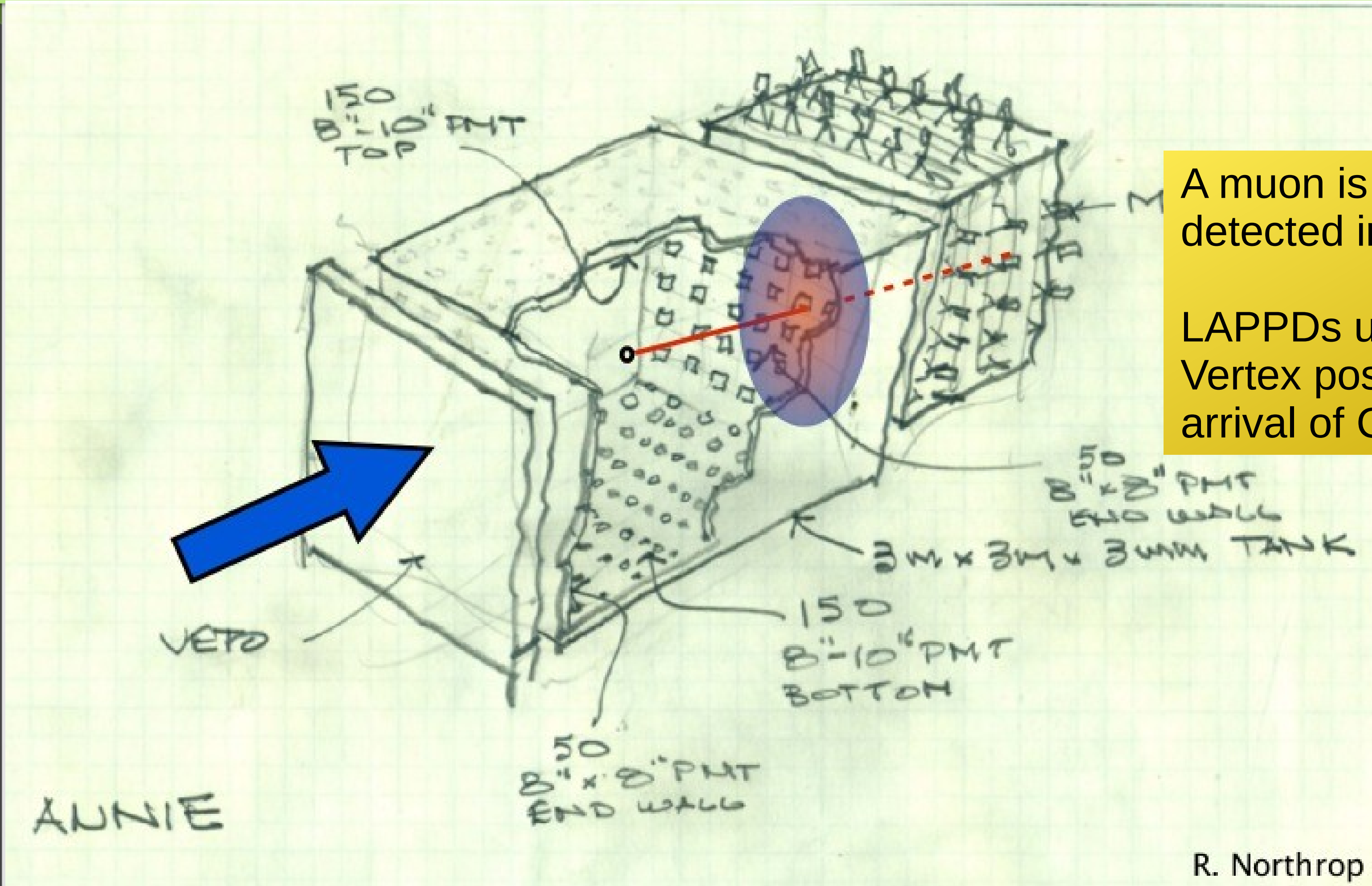

A muon is produced and detected in the MRD

LAPPDs used to reconstruct Vertex position based on arrival of Cherenkov light

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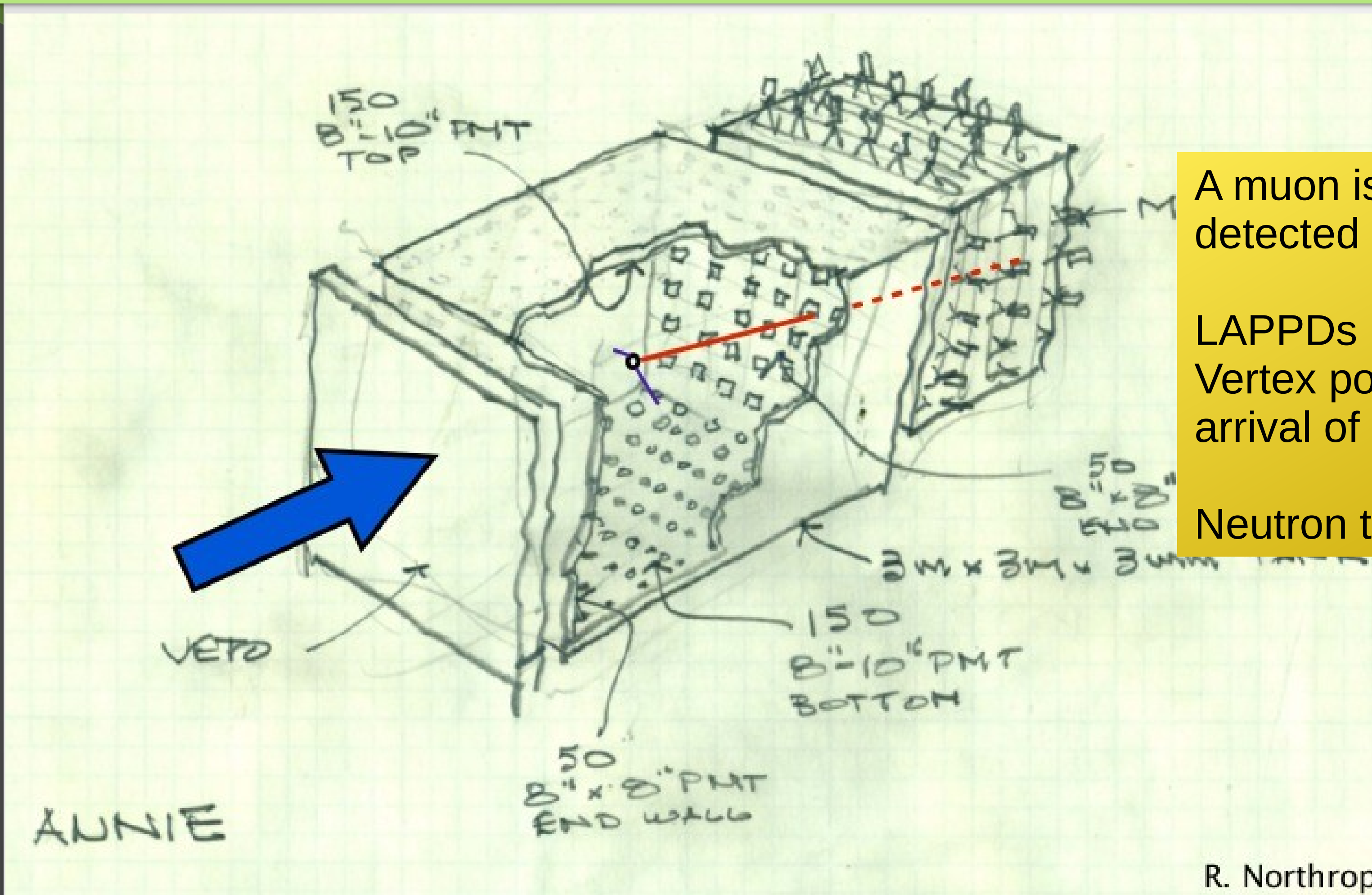

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Neutron thermalize

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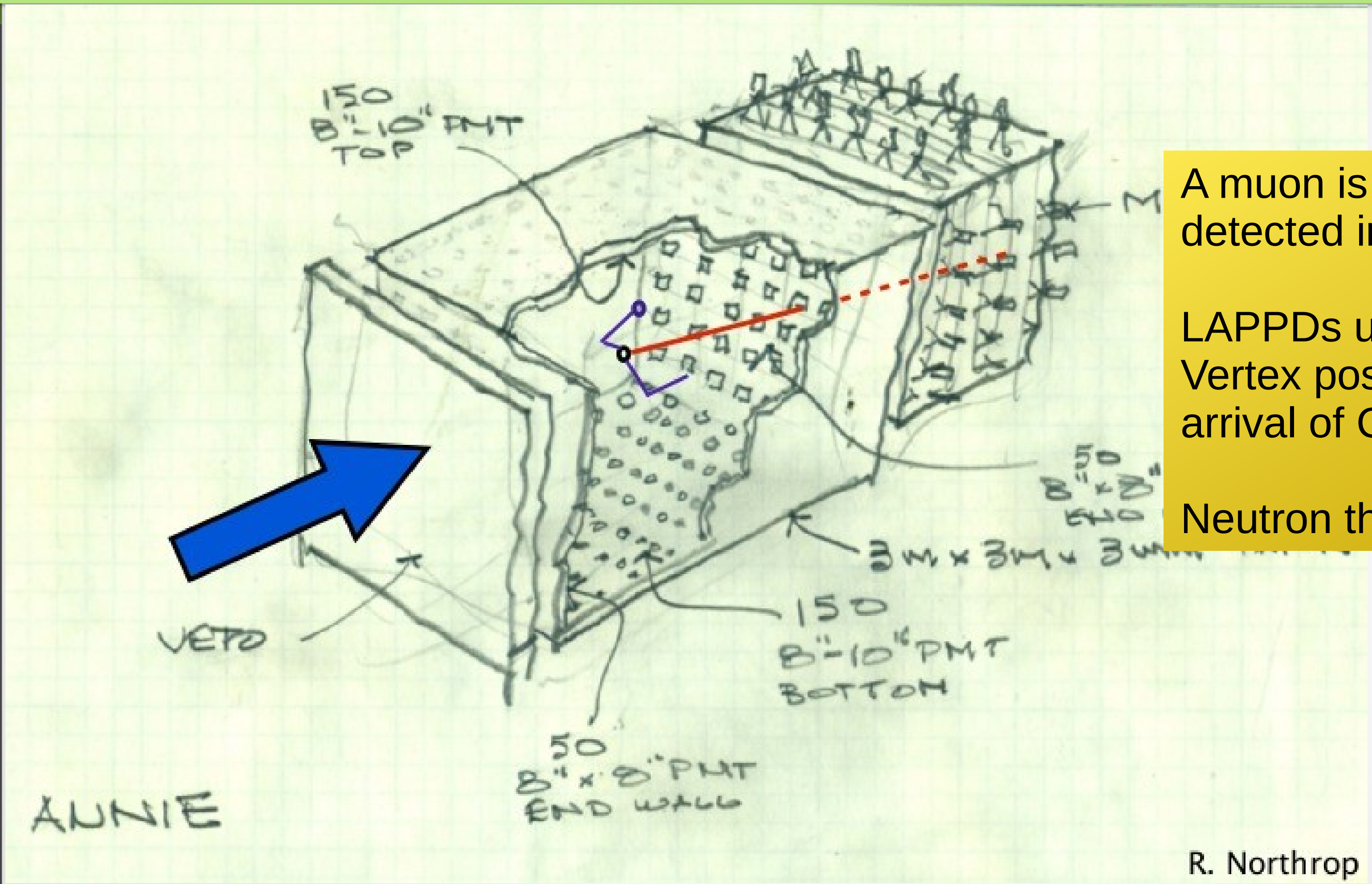

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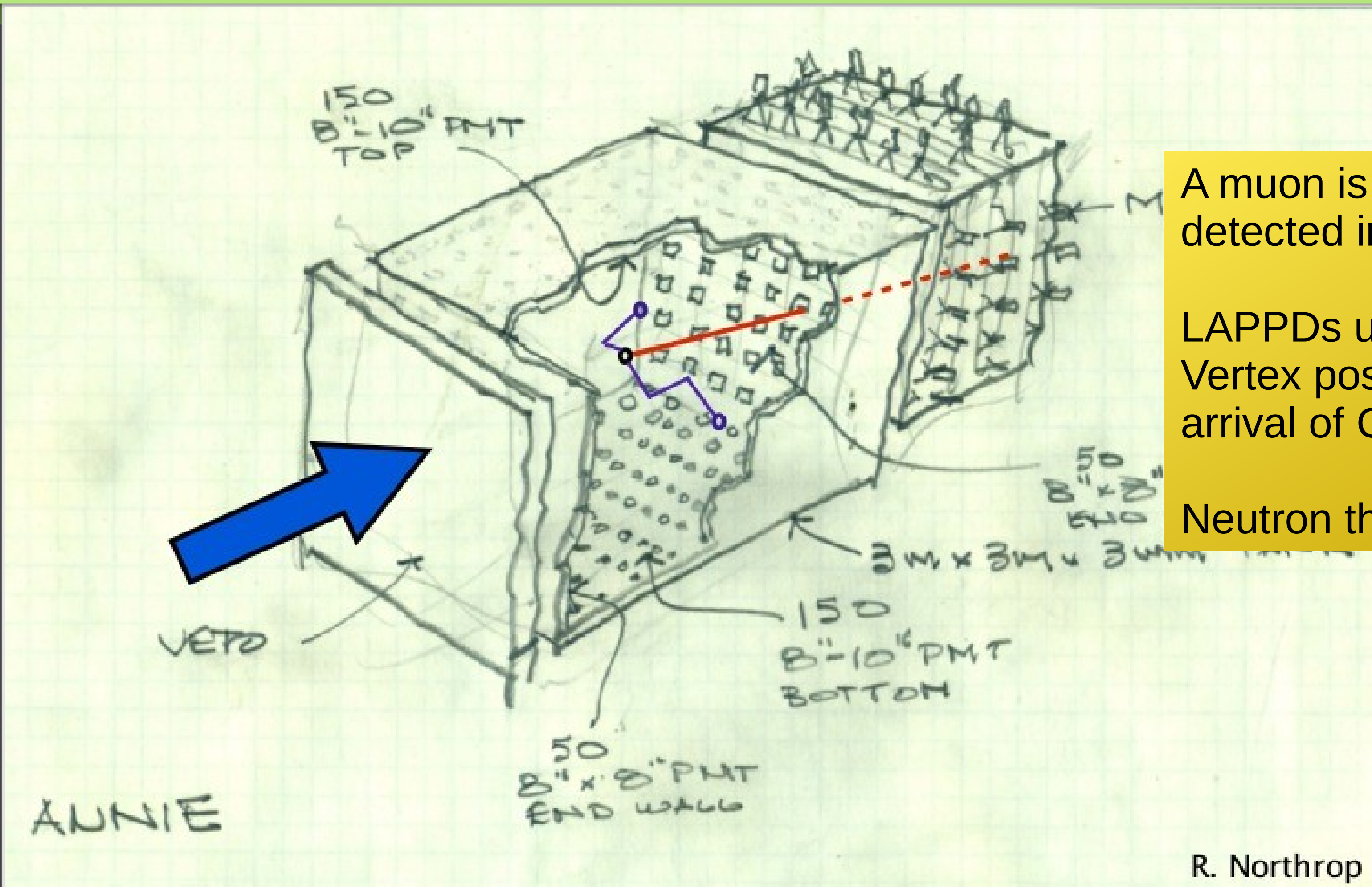

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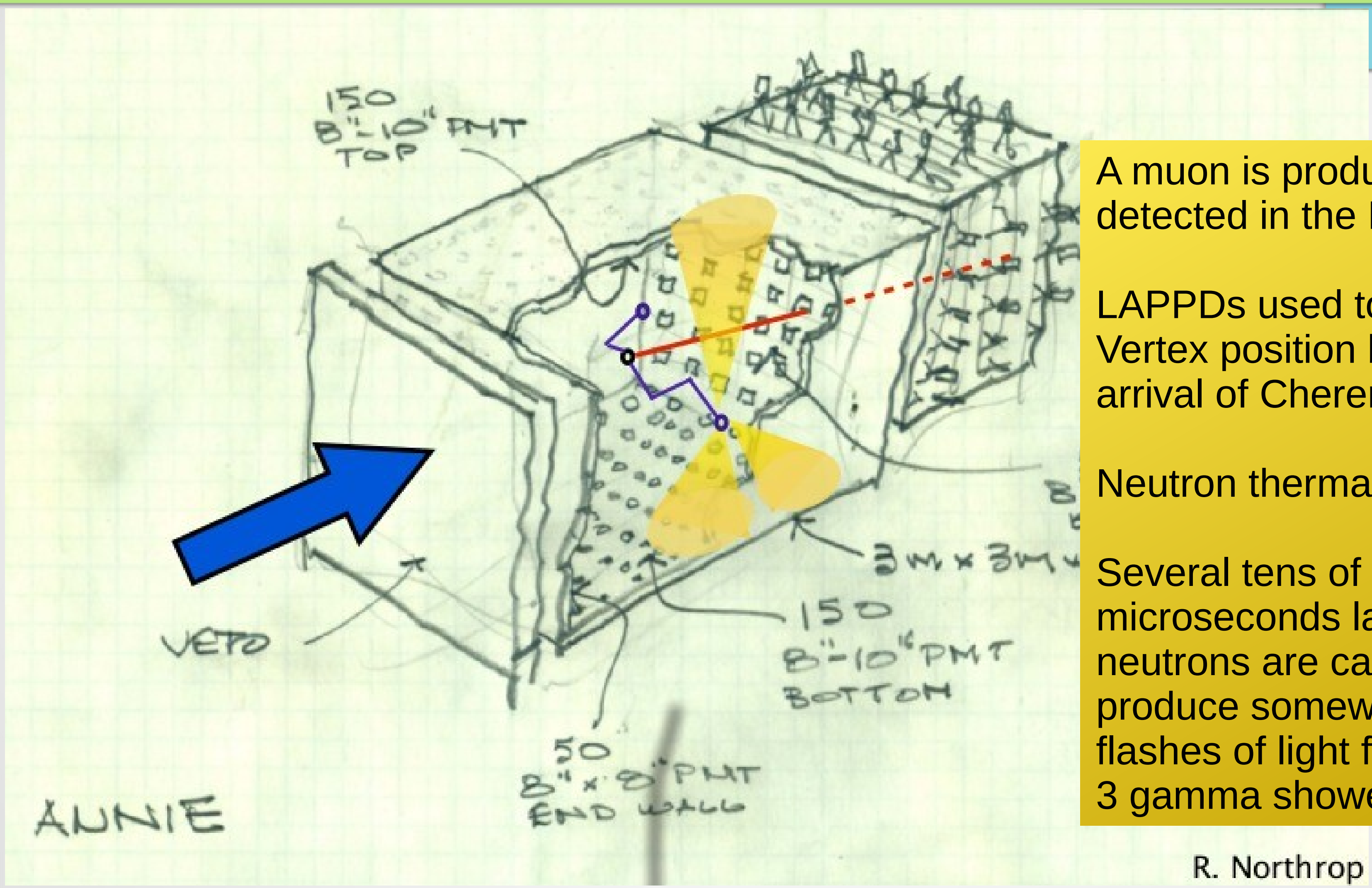

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Neutron thermalize and stop

Several tens of microseconds later, the neutrons are captured and produce somewhat isotropic flashes of light from typically 3 gamma showers (8 MeV)

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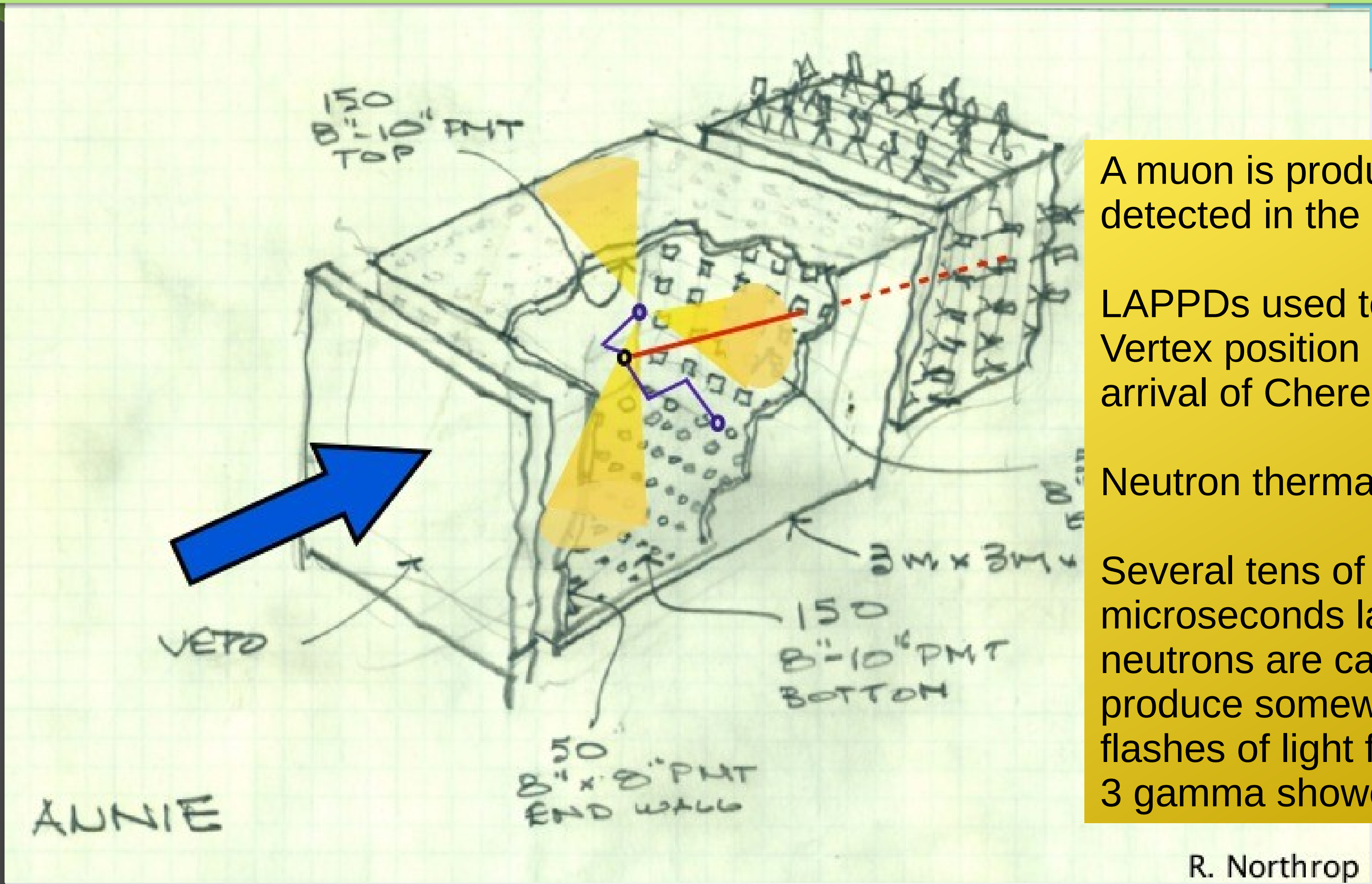

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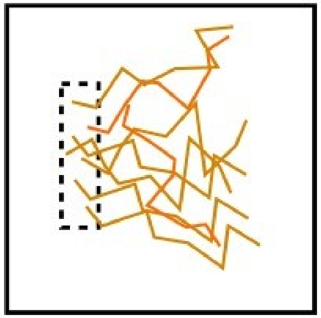
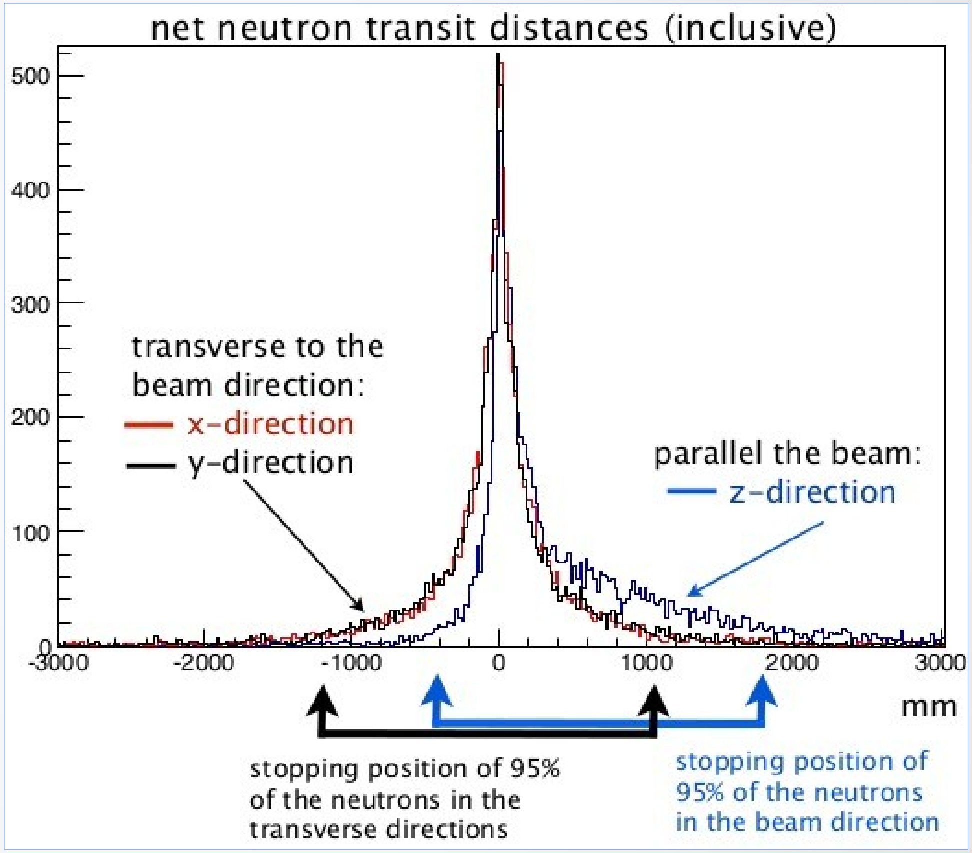
Timing-based vertex recons. essential

Neutrons in ANNIE will typically drift over 2 meter distance.

In order to get a clean sample of neutrons, this analysis must be restricted to a small fiducial volume situated sufficiently far from the walls of the tank to then stop the neutrons





In order to identify events in this fiducial volume, we need to reconstruct the interaction vertex to better than 10cm. Accurate timing based reconstruction from the Cherenkov light is essential.

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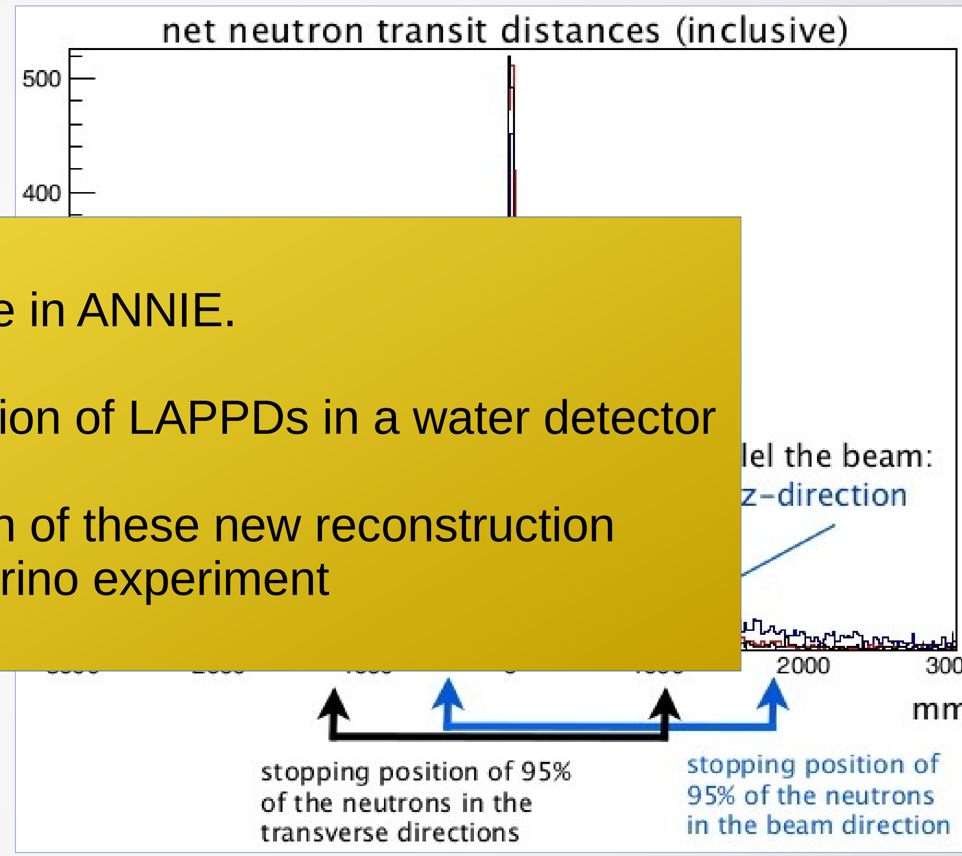
LAPPDs will play an essential role in ANNIE.

This will represent the first operation of LAPPDs in a water detector

This will be the first demonstration of these new reconstruction Capabilities in a high energy neutrino experiment



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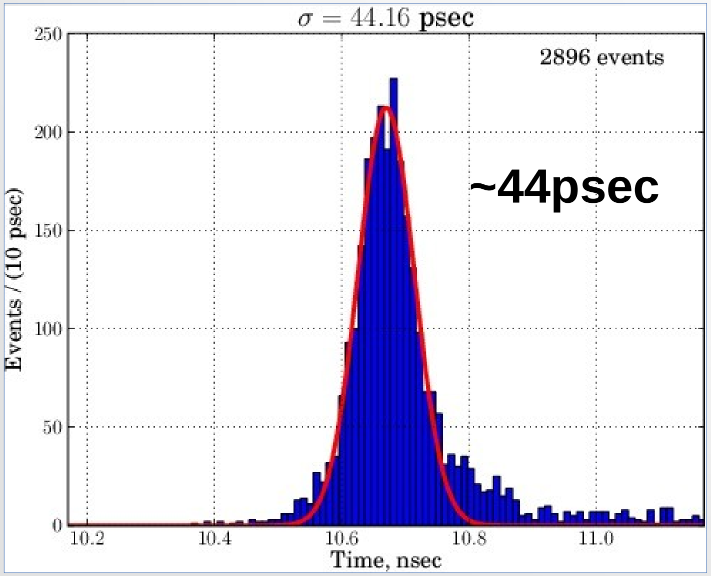
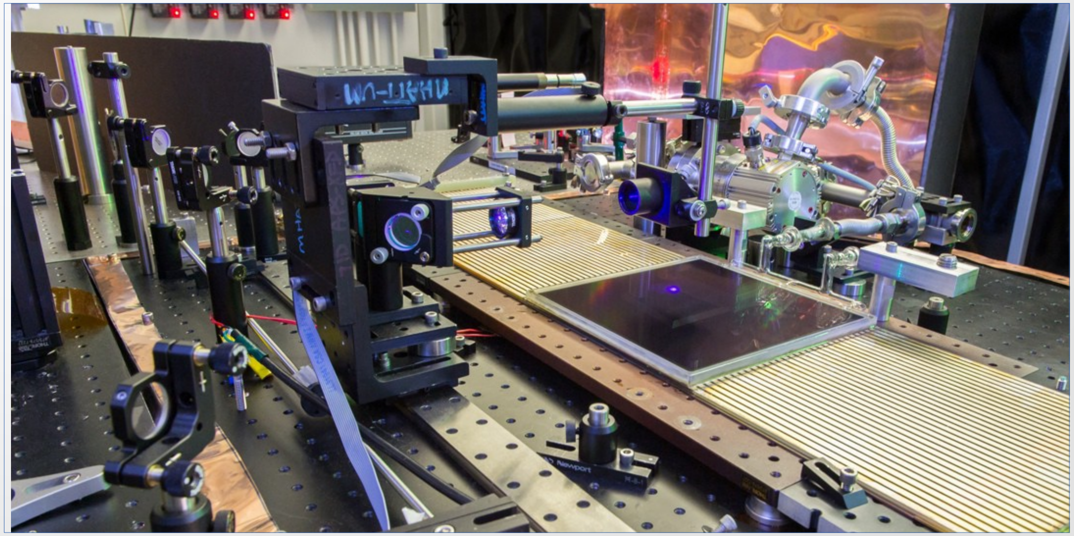
LAPPDs for photosensors capabilities

The Large Area Picosecond Photodetectors (LAPPD):

- Large, flat panel, (multi-channel plate) MCP-based photosensors. Use Atomic Layer Deposition.
- <50 psec time resolutions and < 1cm spatial resolutions
- Based on new, potentially economical industrial processes
- LAPPD design includes a working readout system
- Phase II request for $3M for commercialization by Incom, Inc approved





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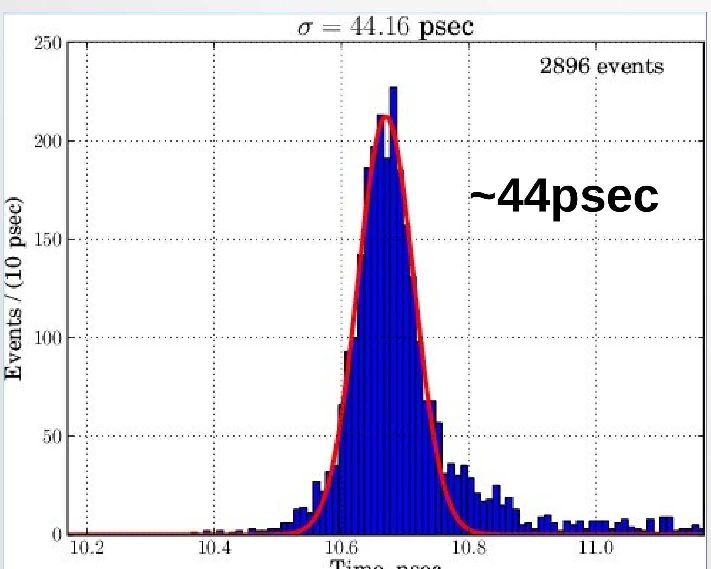
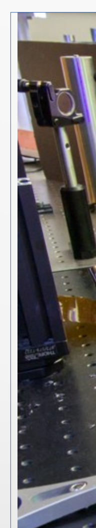




a few key LAPPD papers

H. Grabas, R. Obaid, E. Oberla, H. Frisch J.-F. Genat, R. Northrop, F. Tang, D. McGinnis, B. Adams, and M. Wetstein; *RF Strip-line Anodes for Psec Large-area MCP-based Photodetectors*, Nucl. Instr. Meth. A71, pp124-131, May 2013

B. Adams, M. Chollet, A. Elagin A. Vostrikov, M. Wetstein, R. Obaid, and P. Webster; *A Test-facility for Large-Area Microchannel Plate Detector Assemblies using a Pulse Sub-picosecond Laser;* Review of Scientific Instruments 84, 061301 (2013)

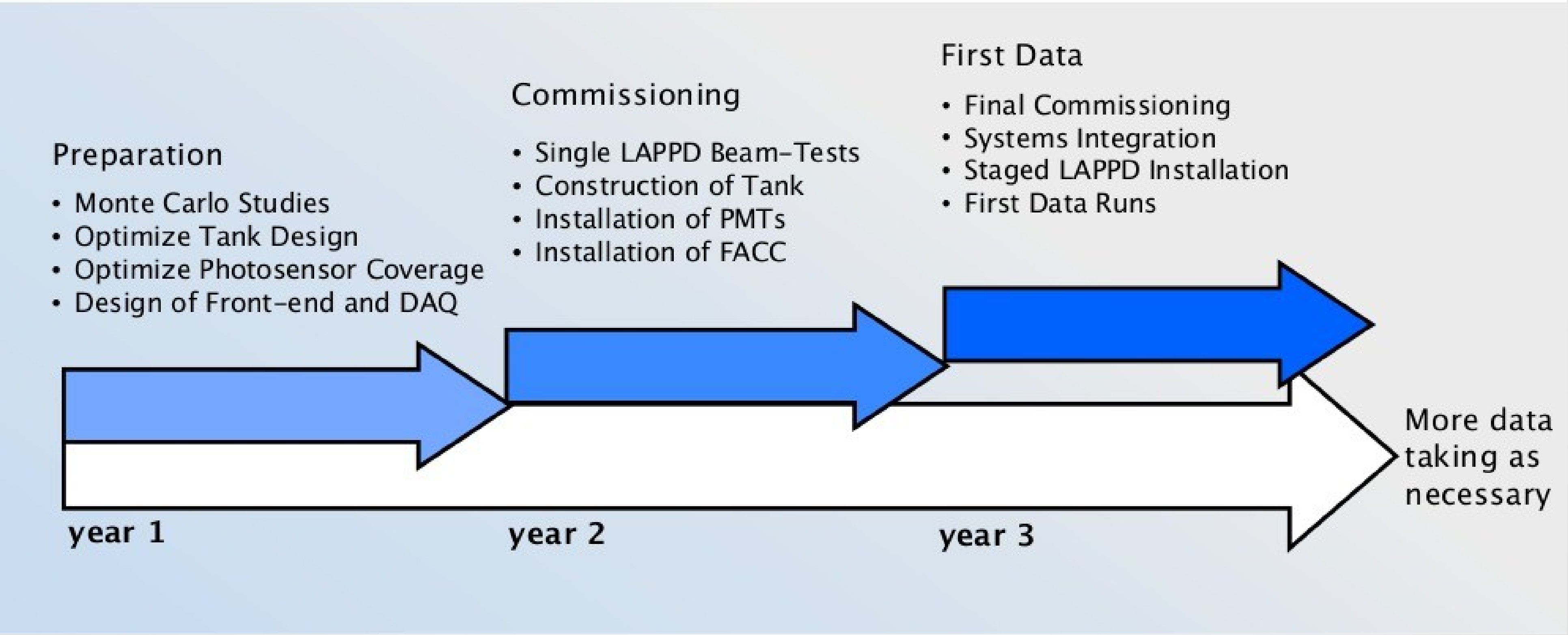
E. Oberla, J.-F. Genat, H. Grabas, H. Frisch, K. Nishimura, and G Varner; A 15 GSa/s, 1.5 GHz *Bandwidth Waveform Digitizing ASIC*; Nucl. Instr. Meth. A735, 21 Jan., 2014, 452; http://dx.doi.org/10.1016/j.nima.2013.09.042; arxiv:http://arxiv.org/abs/1309.4397

O.H.W. Siegmund,*, J.B. McPhate, J.V. Vallerga, A.S. Tremsin, H. Frisch, J. Elam, A. Mane, and R. Wagner; *Large Area Event Counting Detectors with High Spatial and Temporal Resolution;* submitted to JINST; Dec, 2013

See http://psec.uchicago.edu for more references

Timeline and Budget

We hope to keep the budget for ANNIE below $1M and we think we can do it.



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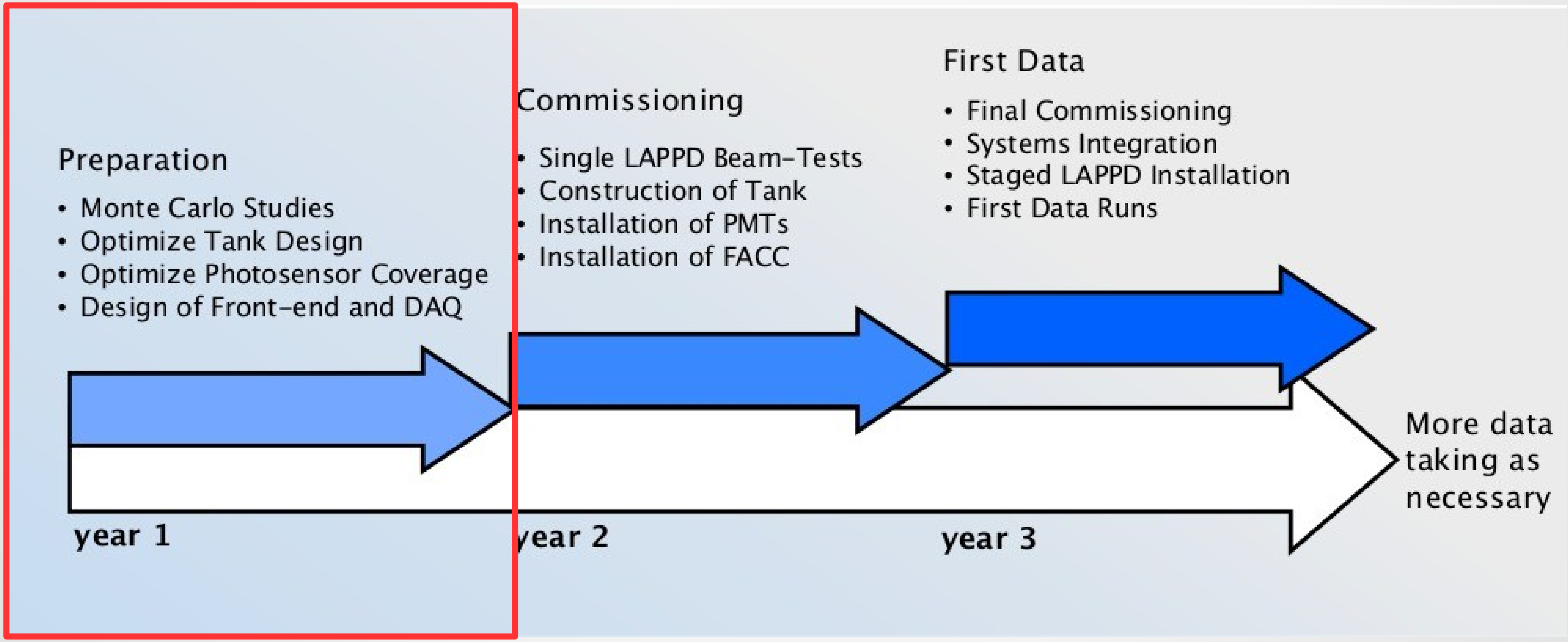

Separate R&D proposal this year

Synergie with TITUS

- Similar detector design for ANNIE and TITUS.

- A few common members so far and expanding: F. Di Lodovico, T. Katori, M. Malek, R. Sacco (recently).
- F. Di Lodovico, T. Katori signed the ANNIE preprint in February (arXiv:1402.6411 [physics.ins-det])
- Current simulation for TITUS is an application of WchSandBox (M. Wetstein). We are contributing to the SW effort, mainly F. Di Lodovico and M. Malek. Ongoing effort.
- Starting to contribute on HW (QM engineer, R. Sacco)
- ANNIE will provide a very nice test-bed for TITUS.
- Our effort can also benefit Hyper-K (if Gd-doped) and other detectors aiming to use Gd and/or LAPPDs.

Summary

- ANNIE measures an important aspect of neutrino-nuclear interactions with high impact on a variety of physics analyses. This includes a major handle on the limiting backgrounds for proton decay.
- Also represents a working demonstration of new neutrino detection methods, such as a first demonstration of LAPPDs in an optical TPC.
- Capitalizes on largely existing beams and infrastructure and fits in well with the Fermilab Intensiti Frontier Programme.
- The main technical tasks build on a large body of existing work.

For more information visit:

- annie.uchicago.edu
- arXiv:1402.6411
- psec.uchicago.edu