Physics Requirements and Goals for the Photon Detector System

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(with input from Chris Backhouse)

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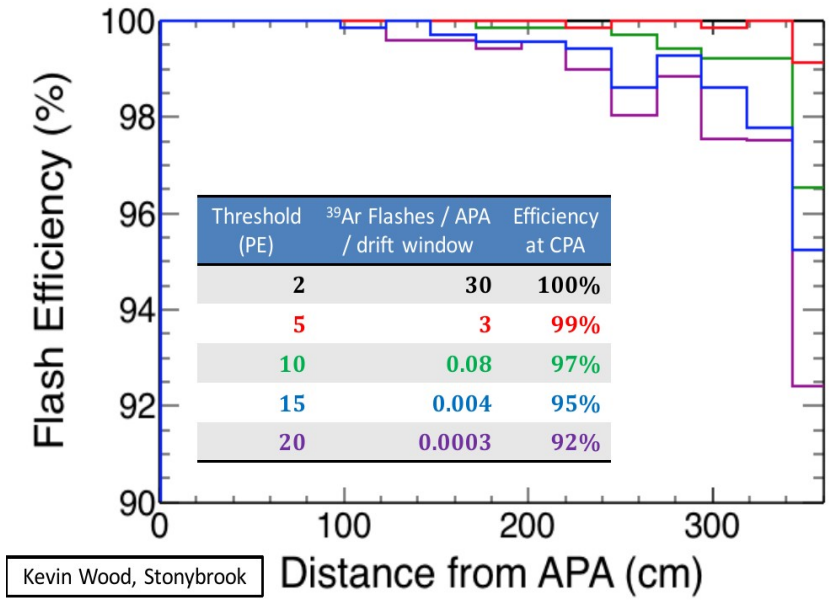
Introduction

- These slides are intended as an introduction of the Physics and Software group **and** the Physics Requirements as currently defined, in order to begin the discussion about their (re?)definition.
- The general requirements and goals presented in this talk, are the ones we have been considering for some time.
- Results presented here are based on the work summarized in the Far Detector Task Force report, dune-doc-3384.
- They present the current status of our understanding of requirements and goals, based on simulations with the IU design, and simple scalings of its efficiency.
  - This design is used because we have the best measurements of its expected performance.
  - These studies take no position on the relative merits of the various designs.
- Requirements/goals presented in order of increasing difficulty (IMHO).

Requirement: T0 finding for NDK

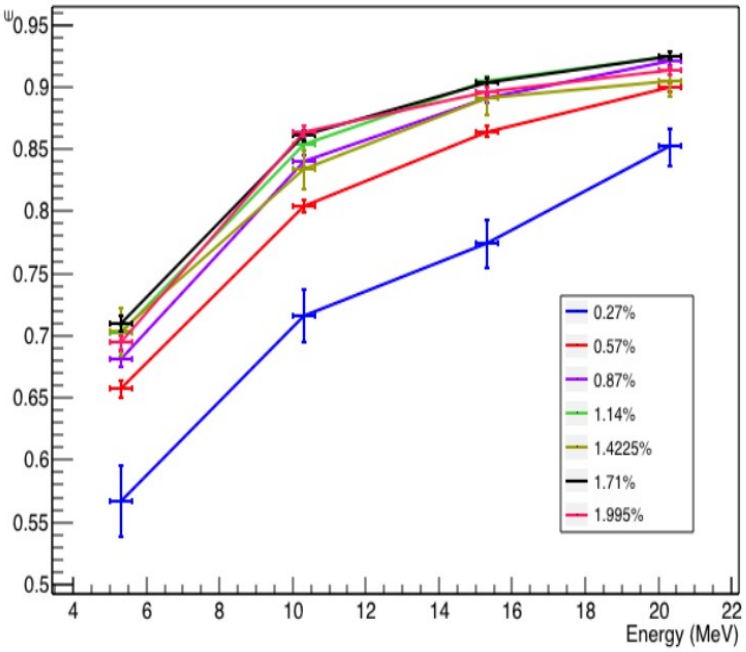
- Needed to localize events in TPC (exclude cosmic backgrounds + energy reconstruction).
- We meet this requirement, with >99% efficiency achievable all the way to the CPA for NDK-scale events. Timing resolution better than the TPC tick length (500 ns) doesn't further improve position resolution. See PDTF p. 107-8
- Could be affected if LY lower than expected of 39Ar background higher than expected.



Threshold (PE)	^{39}Ar Flashes / APA / drift window	Efficiency at CPA
2	30	100%
5	3	99%
10	0.08	97%
15	0.004	95%
20	0.0003	92%

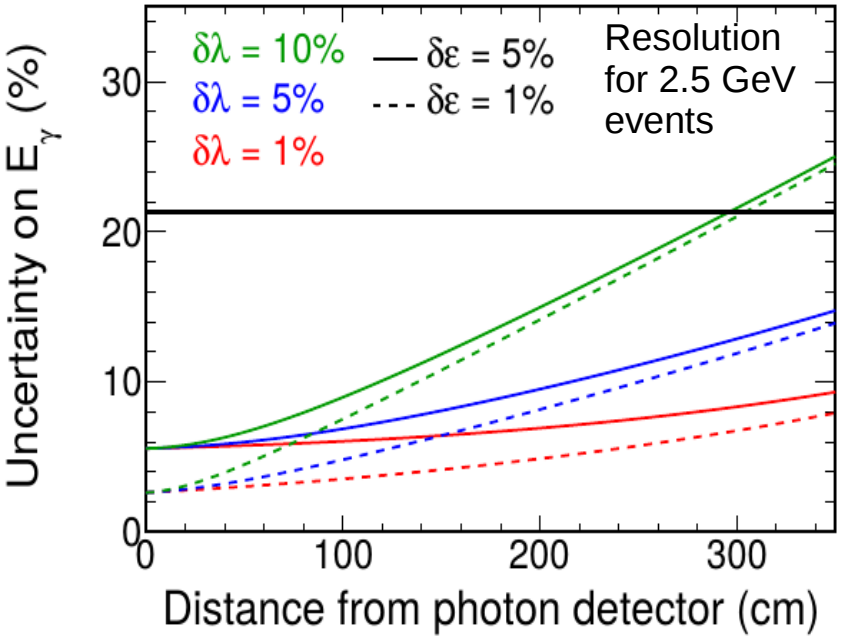
Goal: T0 finding for SNB

- We know we can get T0 for some SN events. At the current stage not all events.
- How well can we tell multiple events in the same TPC?
- These are conservative estimates: increasing light yield can help, as can improvements in algorithms. (current estimates are extremely conservative about potential reconstruction performance.)
- For low energy events, such as SN neutrinos understanding DAQ and electronics will be crucial (difference between seeing and not seeing an event).
- This can be influenced by the actual Rayleigh scattering length (studies in progress by L. Mendes - Santos)



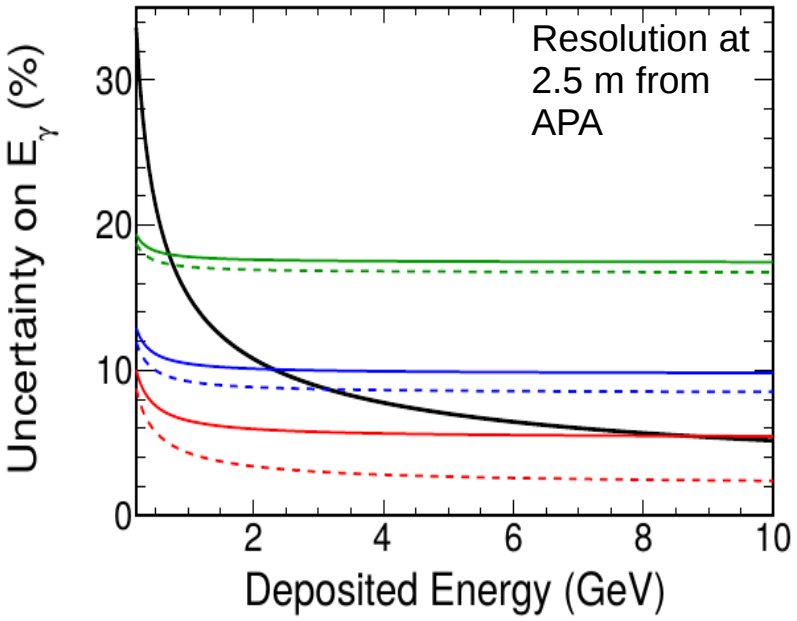
Goal: Calorimetry for Beam, Atm, NDK events

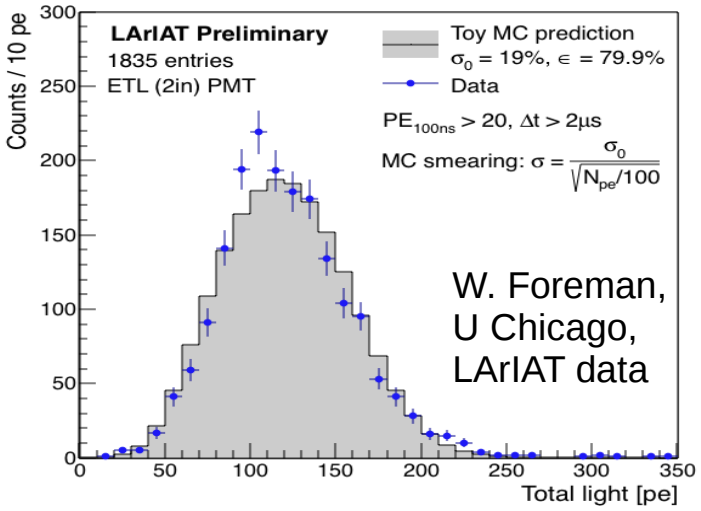
- At high energies the photon detector system can provide a reasonable cross check or additional input to the TPC measurements.
- In the current setup photon counting statistics start to become important around 1 GeV of deposited energy.
  - With a higher LY, we can extend this to lower energies, e.g. NDK regime (or lower? See next slide)
- Need electronics to collect all of the early and late light. Not necessarily needed to distinguish between the two.
- Potential effects from non-uniformity of light collection?
- See PDTF p. 108-112



Goal: Calorimetry for SN events

- This is where study is needed.
- Might be possible for a subset(?) of SN events. Possibly need to increase LY.
- How good would it need to be?





Goal: PID with pulse shape discrimination

- Pulse shape discrimination seems achievable with the current light yields
  - Assuming the electronics are designed to do acquire full waveform.
- However, the physics case that we can use this for PID has not been made (yet?).
  - LArTPCs are good at PID with charge: what do we gain with light?
  - Perhaps helps at lower energies?
- See PDTF p. 112

Timing and position resolution?

- How good of a position resolution do we need?
- An overlap of flashes from signal and background is unlikely in one frame.
- What about close - by supernova event?

- Timing – ~500 ns should be enough for t0 resolution. Do we need to do better? What are the constraints from transport effects and detectors?

Goals of the Sim/Physics Group

- Continue the studies mentioned before and explore the potential physics benefits of design choices mentioned in TF report but not fully simulated, e.g.:
  - Reflector foils for more uniform light yield.
  - ARAPUCAs with finer segmentation along the Z-axis.
  - Full electronics simulation for all options.
  - Explore the effects of radioactive backgrounds.
  - We are open to new ideas to explore.
- Develop the software infrastructure for PD detectors: calibration, DAQ etc...

The Sim/Physics Group

- Meetings on Mondays at 12:00 pm FNAL, 6pm UK, 7pm CERN time.
- First meeting on the 9th of October.
- Use consortium mailing list with [physics+simulation] before subject.

- Extremely challenging programme in the next months.
- We have a list of projects that newcomers can take over: email us to get involved:
  ahimmel@fnal.gov
  schol@phy.duke.edu
  andrzej.szelc@manchester.ac.uk
- Join the SLACK channels at: dunescience.slack.com
  #pd-sim-reco #pd-tutorials #photon-detectors