Photosensor plans for the UK for Hyper-Kamiokande

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CERN, Geneva

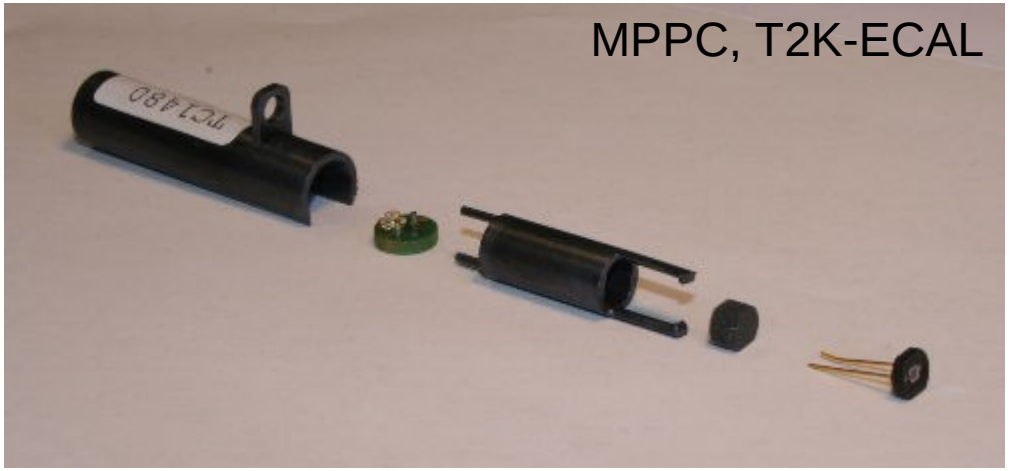
THE UNIVERSITY OF EDINBURGH

Queen Mary University of London

Status

- This is just a summary of the plans for working on the photonsensors for Hyper-K in the UK

- The work will be provided mainly at the University of Edinburgh, and at QMUL
  - Benefitting from the expertise from LHCb, T2K
  - Benefitting from collaboration with the ANNIE experiment.


MPPC, T2K-ECAL

Edinburgh Experience

Group has track record in photodetector development from Babar/LHCb

For LHCb:

- Edinburgh group responsible for HPD testing during construction (600 HPDs tested during construction phase).

- Now responsible for maintaining and monitoring performance of HPDs

For LHCb upgrade:

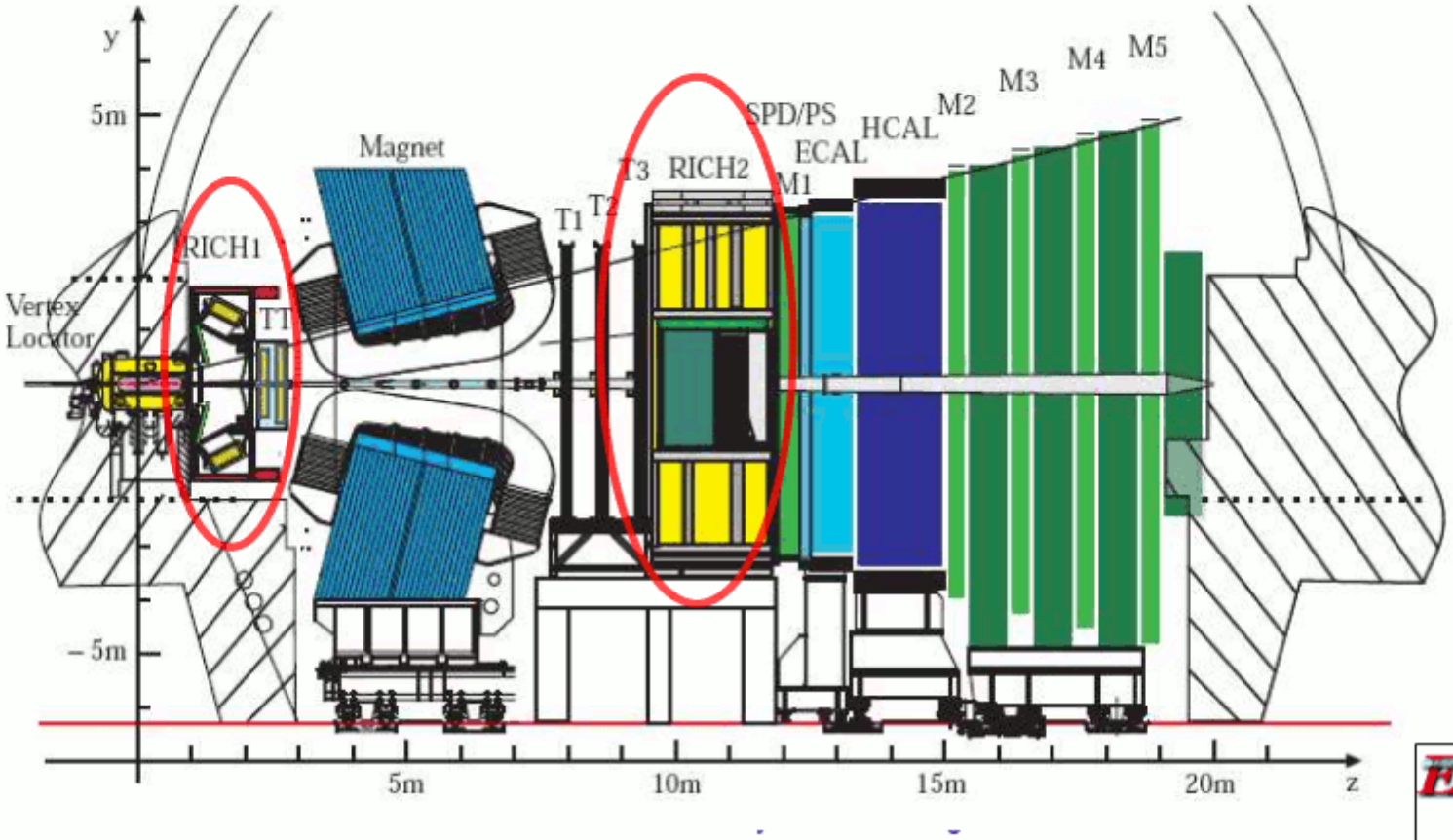
- Testing performance of multianod photomultipliers MaPMTs:
  - general performance and behaviour in magnetic fields

Edinburgh will become photodetector test centre for the LHCb upgrade (~ 3000 MaPMTs to be tested in total)

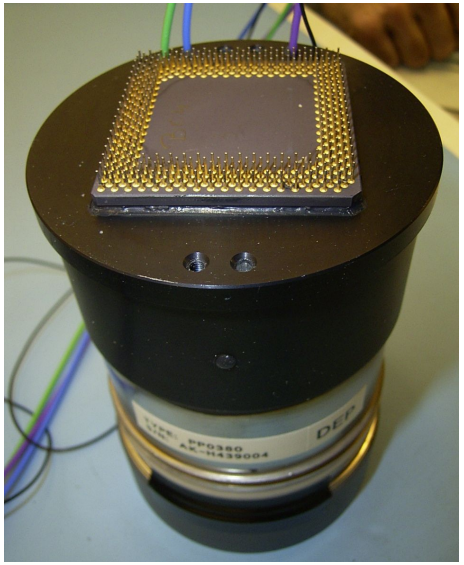
Test setup in recently equiped Advanced Detector Development Centre

The LHCb Experiment

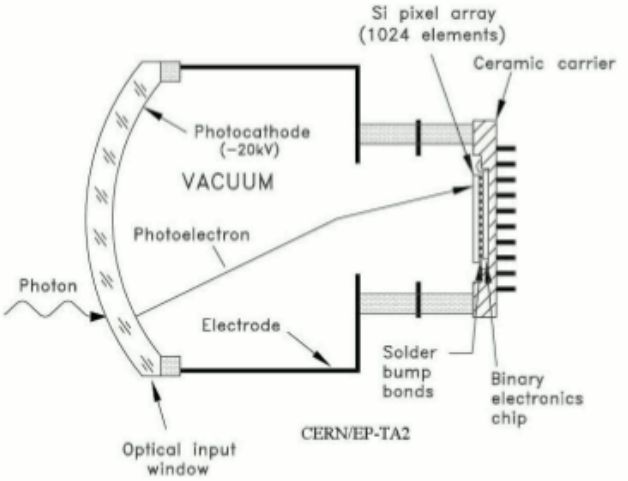
- One of the four experiments at the LHC
- p-p collisions at 14TeV centre-of-mass energy
- Single-arm spectrometer
- Aims to study Charge-Parity Violation ($\not{CP}$) in B-mesons



•Photonis HPDs used in LHCb RICH detectors

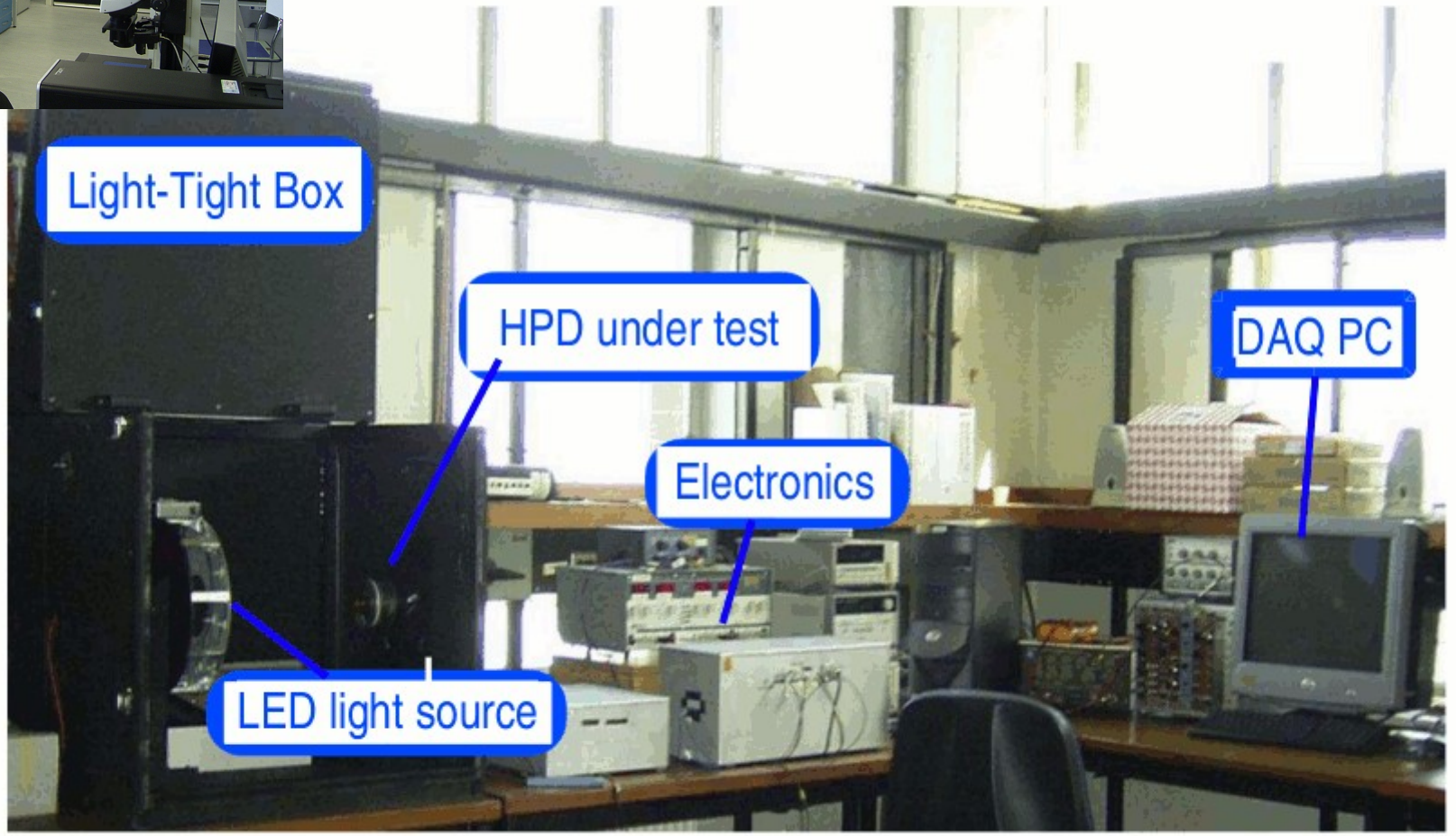


- Quartz window with multi-alkali photocathode
- Cherenkov light hitting photocathode releases photoelectrons.
- Accelerated by high voltages (~20kV) and focussed.
- Photoelectrons hit reverse biased silicon diode
- ~5000 e^- - hole pairs formed
- Anode separated into 8192 pixels
- Position of hits digitised by bump-bonded sensor chip



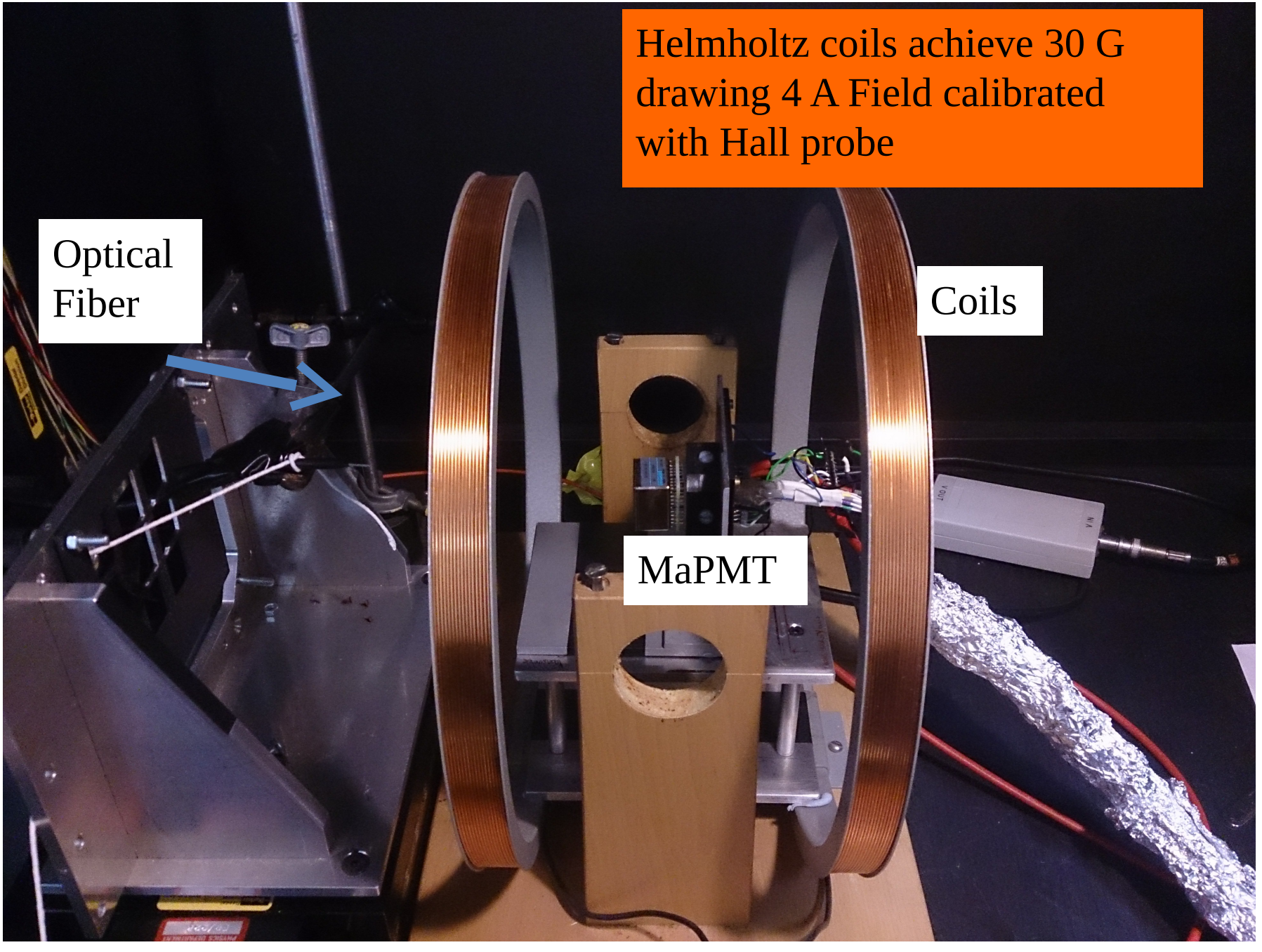
Recent photo

HPD Testing in Scotland:



Test station at Edinburgh, showing dark box and electronics

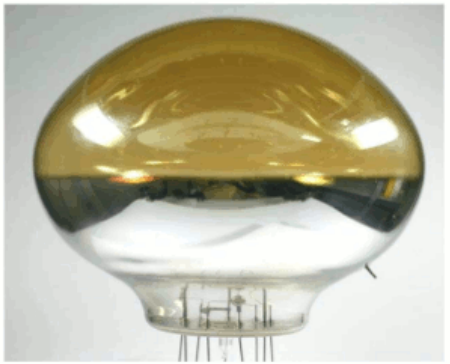
Test setup in magnetic field



Short Term Timescale

- Bough 8" HPD (~3month lead time) by Matt Needham, after discussion with Nishimura/Nakayama
- Will work on the preamp and on property tests in Edinburgh.

Photo-sensor HPD R12112 (A-type): General Specification



Parameter		Description/Value	Unit
Spectral Response		300 ～ 650	nm
Typical Maximum Photocathode Sensitivity (Quantum Efficiency)@380nm		20	%
Photocathode Material		Bialkali	-
Minimum Effective Photocathode Area		180	mm dia.
Window Material		Borosilicate glass	-
Electron Multiplication Method		Semiconductor Electron Bombardment Multiplying System	-
Target Semiconductor		5mmφ Backside Illumination Avalanche Diode	-
Absolute Maximum Ratings	Photocathode – Target Semiconductor	10	kV
	Target Bias Voltage	350	V

Intro on LAPPDs Usage

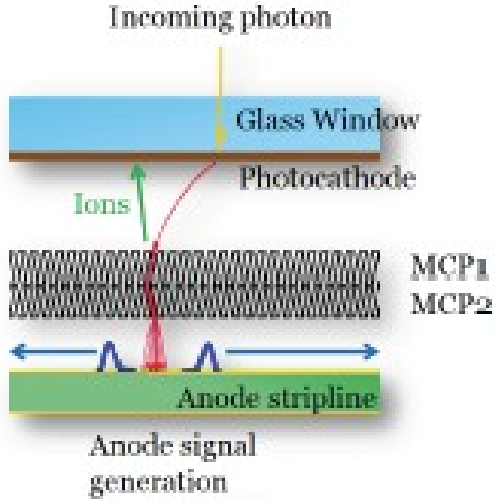
- Potential candidate especially for near detector.
- LAPPDs (Large Area Picosecond Photo-Detector) not commercially available yet. Expected timescale <3y
- Currently:
  - Investigate physics improvements with new technology (see Matthew's talk)
  - Participate in ANNIE (see next slides). Technical report for the Fermilab PAC expected in the Fall.
  - Contribute to LAPPD reconstruction and R&D (R.Sacco, new QMUL electronic engineer*)
  - QMUL experience in MCCPs for T2K
- Longer term future:
  - Tests in the UK
  - Assess feasibility for near detector

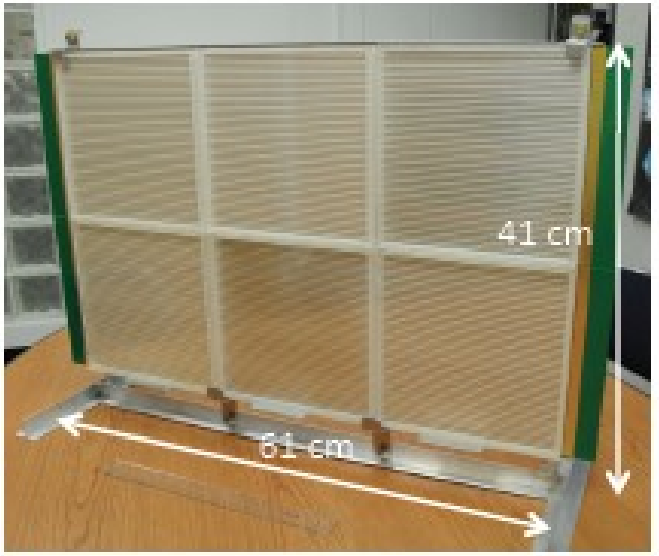
*Job advert (just advertised): http://www.jobs.qmul.ac.uk/4872

LAPPD

LAPPD: Approach

- Base on Existing Technology: Micro Channel Plate (MCP) photo-multiplier
  - Picosecond-level time resolution
  - Micron-level spatial resolution
  - Excellent photon-counting capabilities
  - Expensive
- New Aspect: Fully Integrated Approach
  - Exploit advances in material science and electronics to produce large-area MCP-PMTs:
    - Preserve time and space resolutions of conventional micro-channel plate detectors
    - At low enough cost per unit area

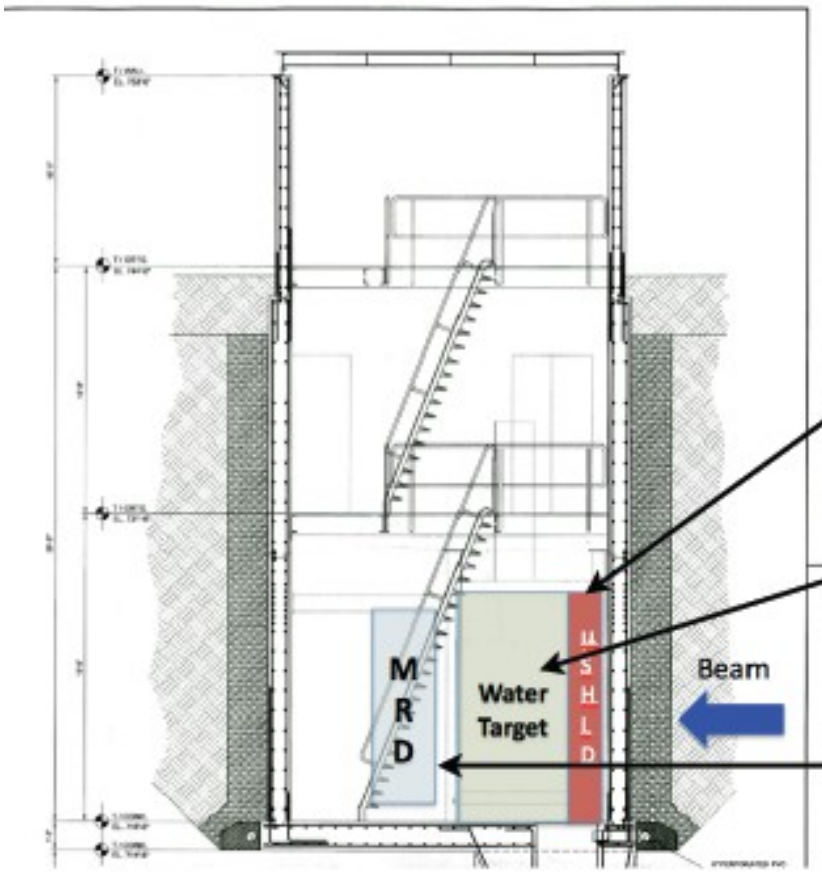




Annie

- Both for R&D (LAPPDs studies) and for Physics (neutron yield from ν interactions → background for proton decay)
- SciBooNE hall in the FNAL booster beam.

ANNIE – basic concept



"ANNIE Hall"

veto on muons produced upstream of the detector

3m x 3m x 1.9 m tank of Gd enhanced water (w/ wbLS? oil?)

Muon Range Detector: steel with scintillating bars in between. Stop the muons, measure their energy.

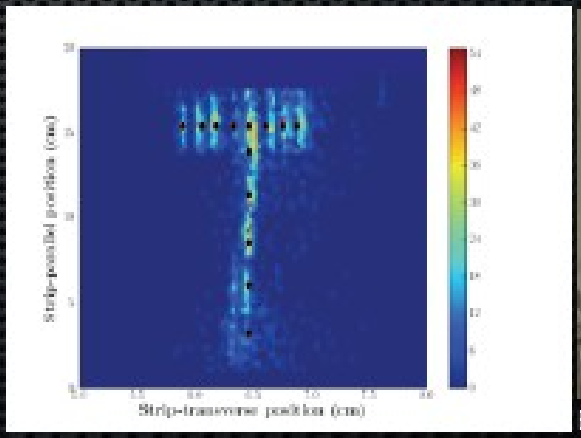
LAPPDs

LAPPD Status

- Testing end-to-end detector system:
  - complete “demountable” glass-body 8” MCP-detector.
  - full readout and front-end electronics, 80 cm anode line.
- Producing and testing separate 8” x 8” tile, bialkalai photocathodes with QE > 20%
- There is also 8” Sealed-Tube processing tank at Berkeley SSL built and being tested.
- Psec4 chip benchmarked at:
  - 1.6 GHz analog bandwidth,17 Gsamples/second, ~ 1mV noise
- Psec electronics system is capable of shape-fitting the LAPPD pulses for time, position, and charge at the front-end.

ANL “demountable” detector system - glass body LAPPD
Reconstruct of a “T” below

Berkeley SSL detector system - ceramic body LAPPD

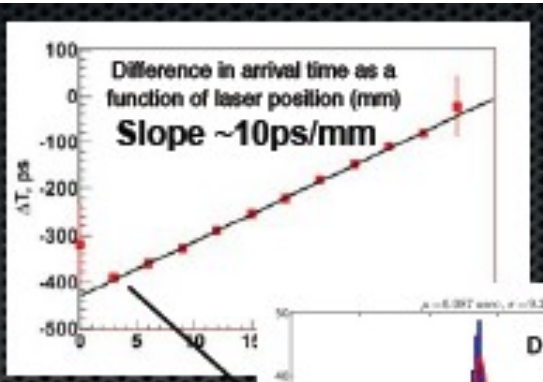


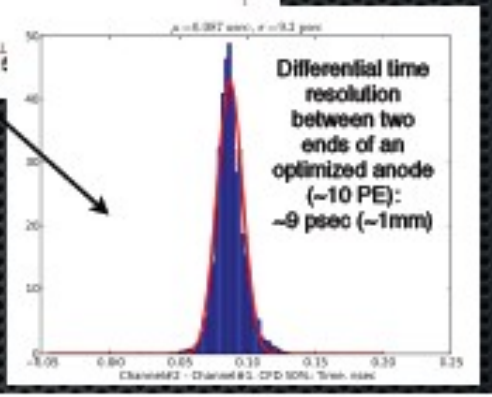
Berkeley SSL Sealed-Tube Processing Tank

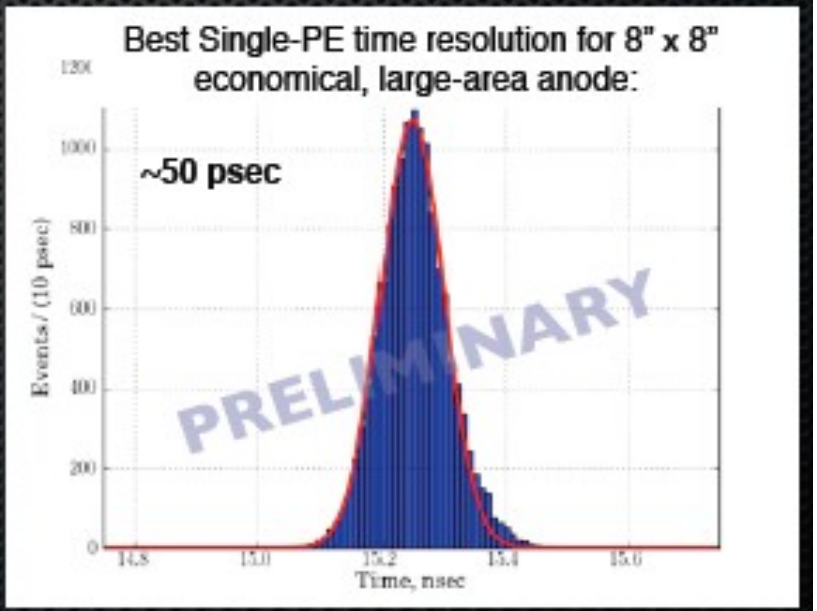
LAPPDs

LAPPD Status

- Testing 8" x 8" (Argonne-made) MCPs:
  - Pulse height peaked at **10^7 gain**.
  - Differential time resolution between two ends of delay-line anode <10 psec.
  - **2 mm spatial resolution** parallel to the strip direction, <1 mm in transverse.
  - **Time resolution of ~50 psec** using economical anode design.
- Commercialization progress: **$3 M awarded** in SBIR funding to US company to commercially develop LAPPDs.







M. Sanchez - ISU/ANL

M. Wetstein/A. Elagin (UChicago/ANL)

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Summary

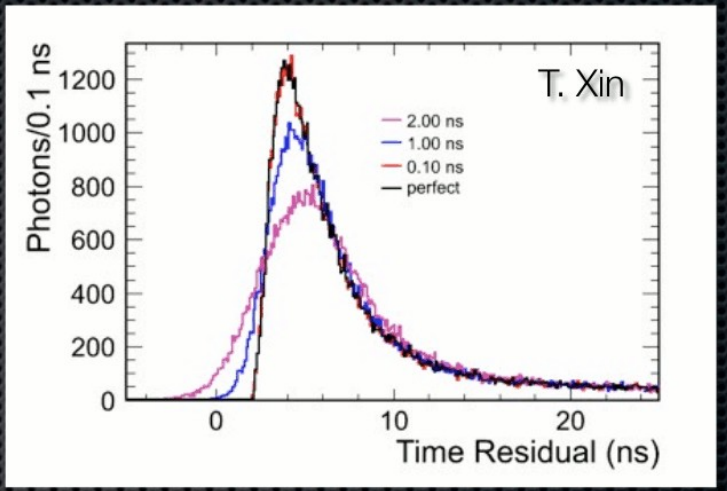
- Effort just started in the UK to join the global effort to develop the best photosensors for the Hyper-K experiment.

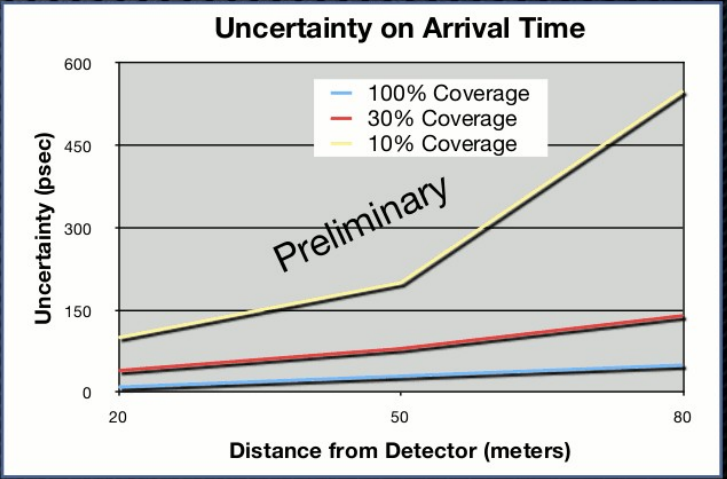
Intro on LAPPDs Usage

- Exploiting better timing/spatial resolution and coverage in WC detectors:

Using LAPPDs for Neutrinos

- The application of this new technology could enhance background rejection and vertex resolution by **improving spatial and timing information**.
- Our studies show that beyond 100 psec there are no further gains when using time residual distributions in a 200kton detector.
- We have also found that for a given detector size, the uncertainties in the position of the leading edge become smaller if better photodetector coverage is considered.



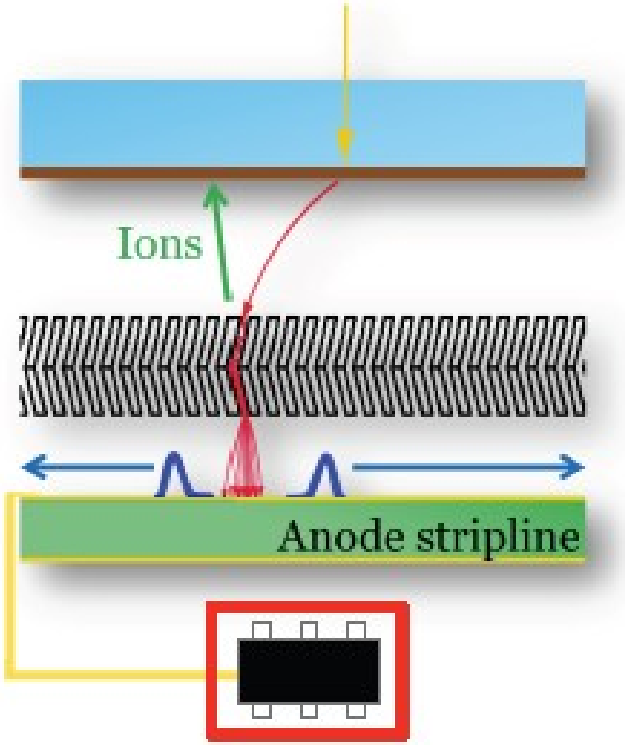


M. Sanchez (ISU/ANL), M. Wetstein (U Chicago/ANL),
I. Anghel (ISU), G. Davies (ISU), T. Xin (ISU)

Project funded under NSF CAREER award

LAPPD

LAPPD Deconstructed



1. Photo-Cathode (PC)
   - Conversion of photons to electrons
   - Engineer III-V materials to develop robust high QE photo-cathodes
2. Micro-Channel Plates
   - Amplification of signal: two plates with tiny pores, held at high potential difference. Use Atomic Layer Deposition for emissive material on inert substrates to create avalanche
3. Transmission line, high speed readout
   - Anodes is a 50Ω scalable strip line silk-screen printing on glass ground plane (Borofloat 33)
4. Hermetic Packaging
   - Maintain vacuum and provide support. No internal connections; no penetrations
5. Electronics
   - Readout at both ends with fast custom CMOS SCA chip with 18 GHz waveform digitization; optimized design yields pico-second timing resolution