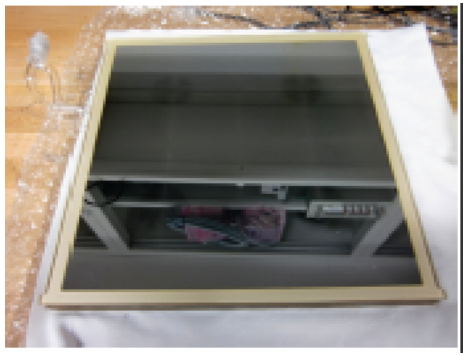
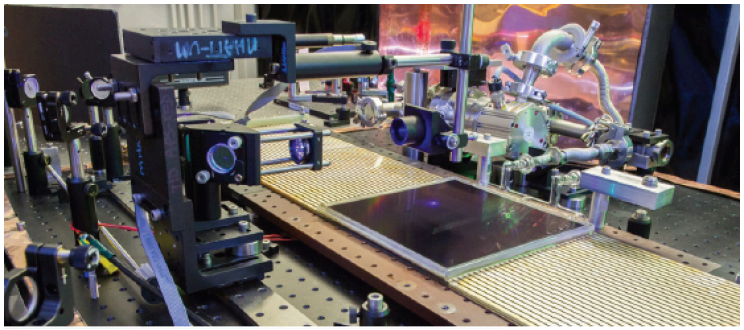
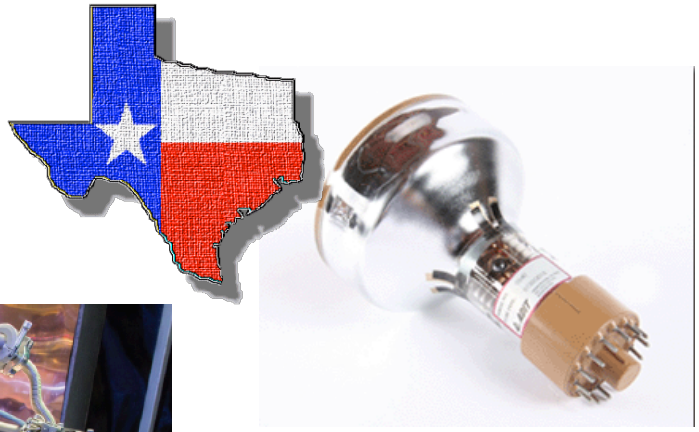
U.S. PMT Update





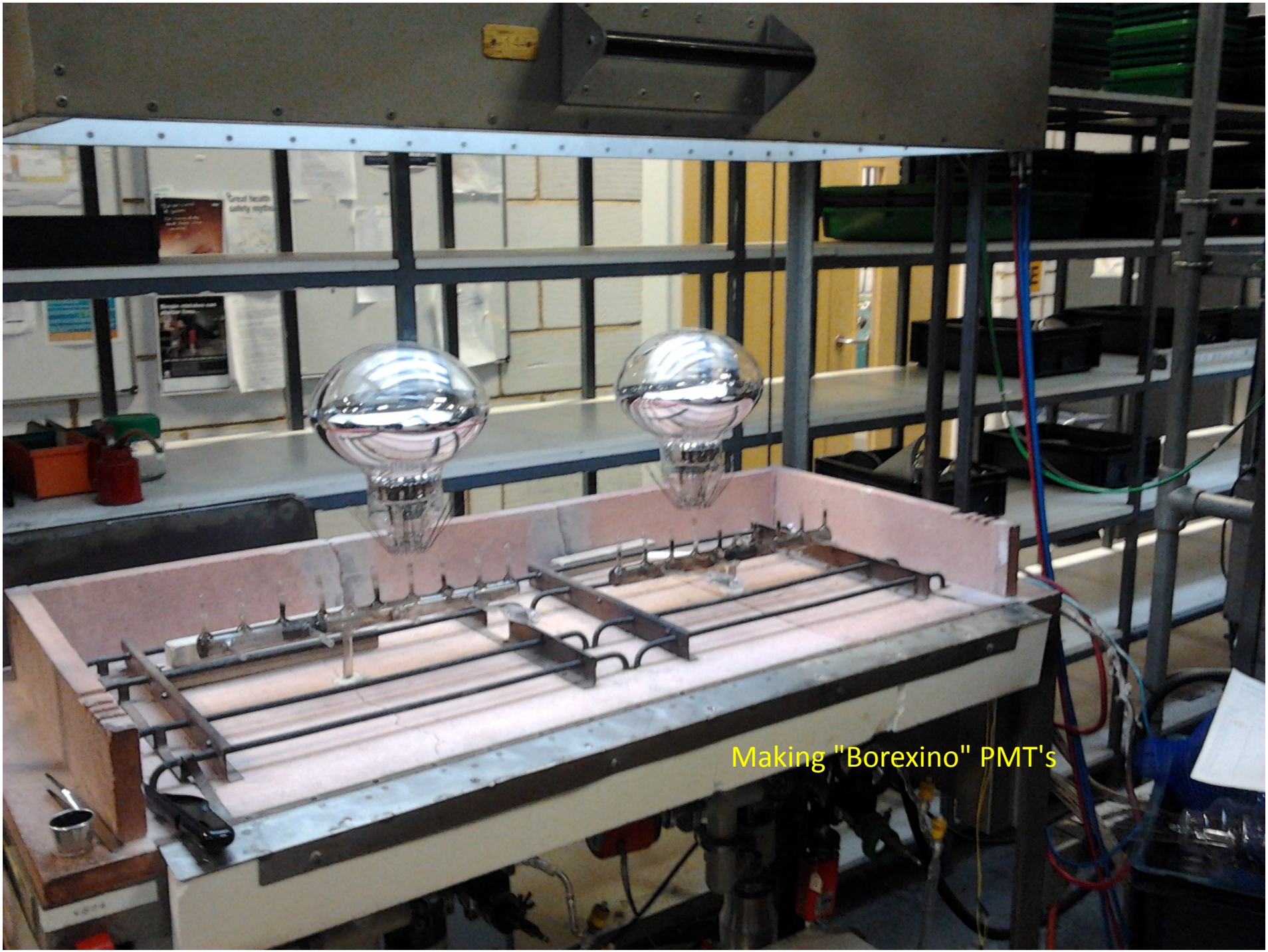


- Engineering of Prototype 11" HQE PMT's is almost done
- Visit to ETL/ADIT development facility in U.K. December 10th
- Schedule of delivery of first 20 prototypes
- Estimate of production capabilities
- New experiments in U.S. (WATCHMAN and ANNIE) relevant for Hyper-Kamiokande photosensor development.
- Mike talked about ISODAR. WATCHMAN is possible site.

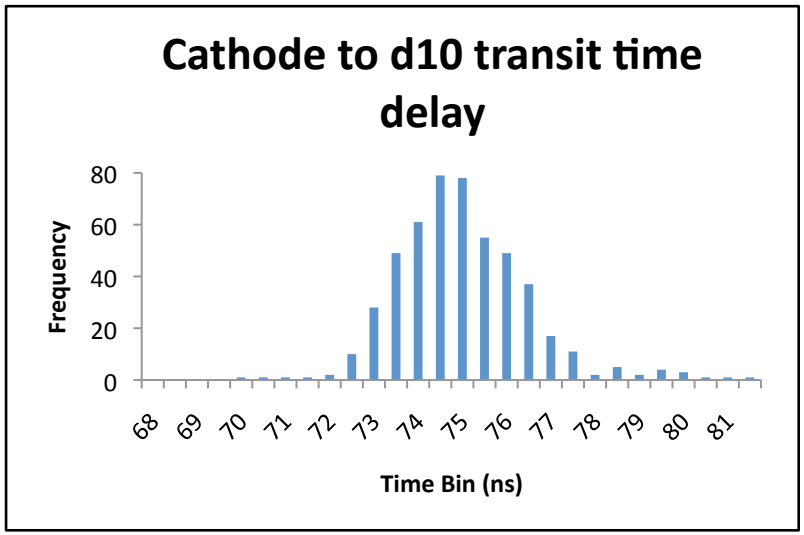
Visit to ETEL/ADIT in U.K.

On December 10th there was a visit to the ETEL/ADIT facility just outside London. This facility houses the research part of the company (which also owns Ludlum Instruments and Eljen Plastics). The new company combines the research facility and small production of ETEL with the very large production capability of ADIT in Texas.

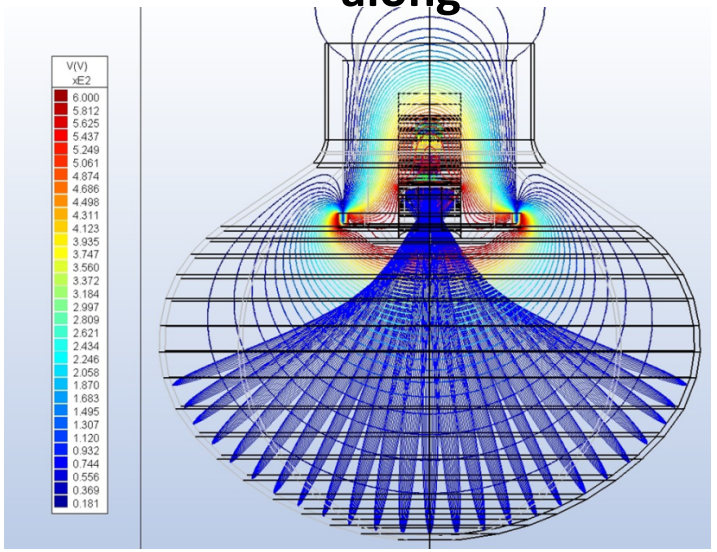
The company president who happened to be in the U.K. came to the meeting for half the time.


Making "Borexino" PMT's

1. Electron Optics: Jitter & Collection modelling



along



Jitter along d1 dynode

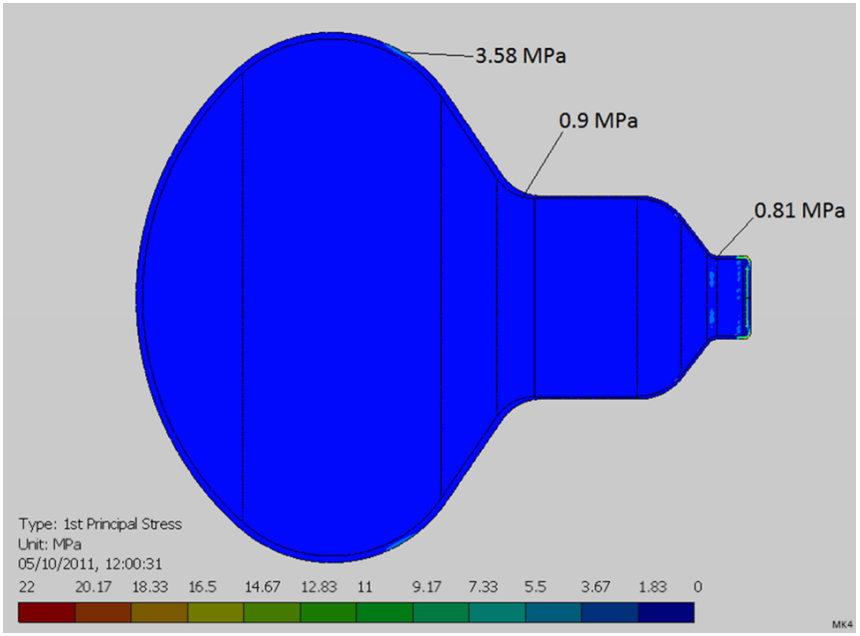
	k – d1	k – d2	k – d3
Mean	40.4	50.6	53.2
Sigma	0.85	1.2	1.5

(Simulation)

FWHM k – d3 collection Area

Description of light sensitive area	Predicted Area for Chosen Design (cm^2)
Projected photocathode area	550
Photocathode curved surface area	700
Outer bulb curved surface area	750

1. Bulb FEA: 1st Principal Stress



Bulb FEA: Input Parameters

Glass	8250 & 8246
Young's Modulus	70 GPa
Poisson's ratio	0.21
Pressure Difference Inside / Outside	11 bar

First WATCHMAN/Hyper-K
11" ETEL/ADIT PMT envelopes
prior to glass finishing

3. D784KFLB – Glass options

ET Enterprises electron tubes

ADIT

with 11 bar design pressure

Schott 8246	Concentration
Natural potassium	60 ppm
Thorium	30 ppb
Uranium	30 ppb

what is the requirement for ID and OD?

*Estimated Gamma emission > 0.1 MeV

Glass thickness	Expected mass (g)	Gamma rate (Bq)* (60ppm K, 30ppb Th, 30ppb U)
Maximum	2,218	3.2 ± 1.7
Minimum	1,482	2.2 ± 1.1

11 Bar
4 Bar

Example of range of glass mass to be used

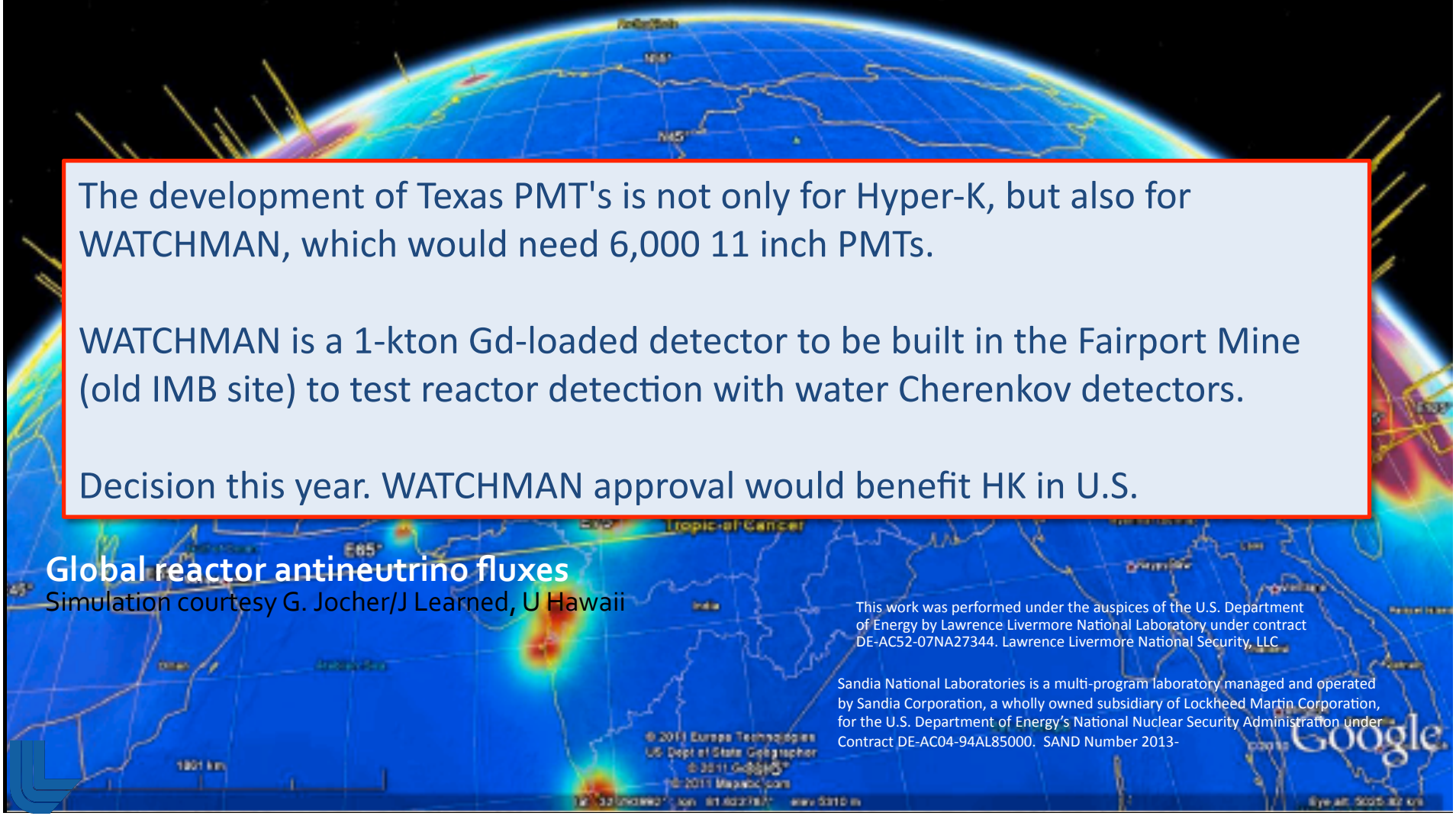
WATCHMAN

WATer CHerenkov Monitoring of Anti-Neutrinos

The development of Texas PMT's is not only for Hyper-K, but also for WATCHMAN, which would need 6,000 11 inch PMTs.

WATCHMAN is a 1-kton Gd-loaded detector to be built in the Fairport Mine (old IMB site) to test reactor detection with water Cherenkov detectors.

Decision this year. WATCHMAN approval would benefit HK in U.S.

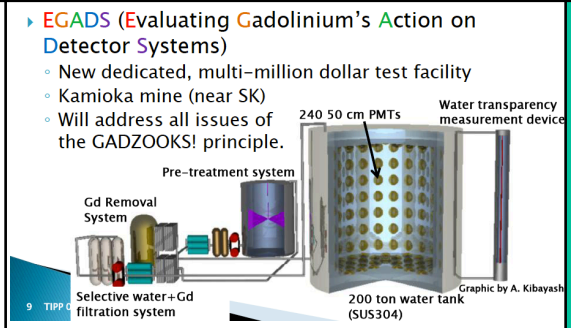
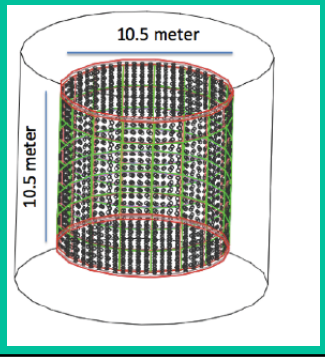
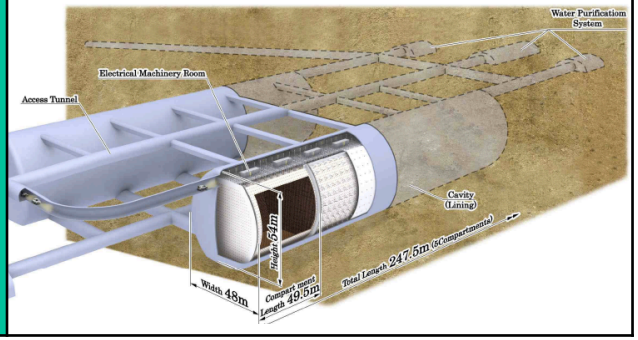


Global reactor antineutrino fluxes
Simulation courtesy G. Jocher/J Learned, U Hawaii

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000. SAND Number 2013-

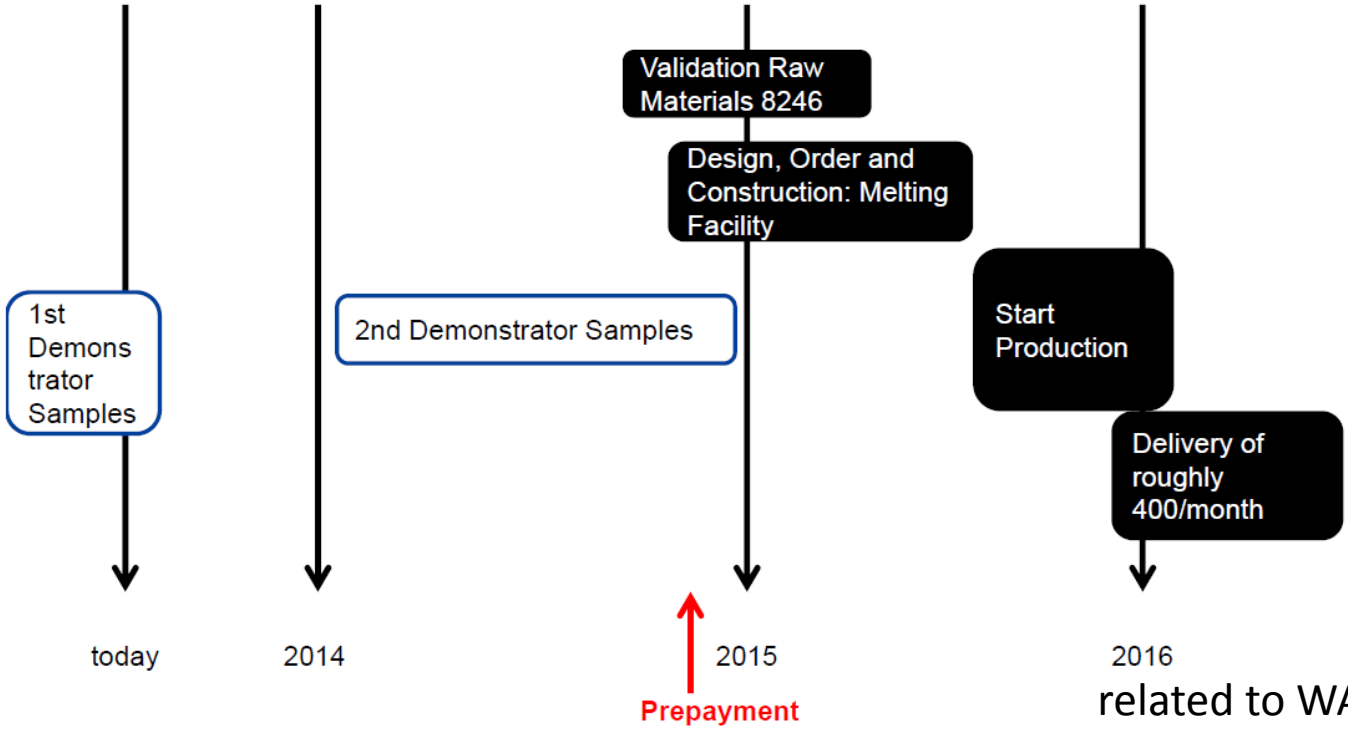
Shown at U.S. DOE HQ last October

Detector	EGADS	WATCHMAN	Hyper-K
Status	Ongoing	2016 start	2021 start (approx.)
Mass (ton)	200	1,000 - 10,000	560,000
Type	Gd-WCD	Gd-WCD	Pure H2O or Gd-WCD
Purpose	Measure background materials,energy threshold Too small to see reactor antineutrinos	Remotely detect reactor antineutrinos – some oscillation sensitivity	Neutrino oscillations, proton decay, supernovae… WATCHMAN would demonstrate Gd option for HyperK or other future big detectors
			

3. From review with Schott - Mainz, Nov 2013

Time Line Neutrino Bulbs from 8246

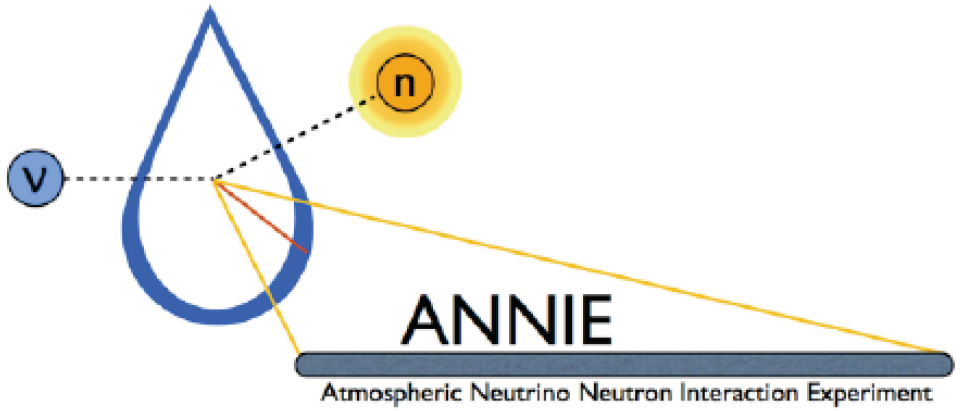
Not for Distribution



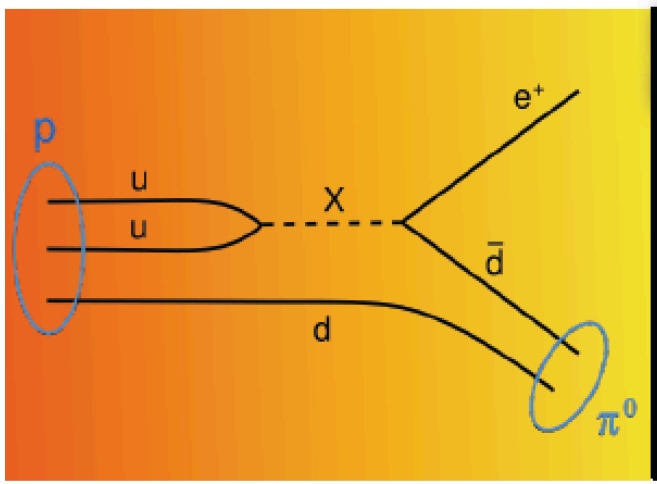
related to WATCHMAN schedule

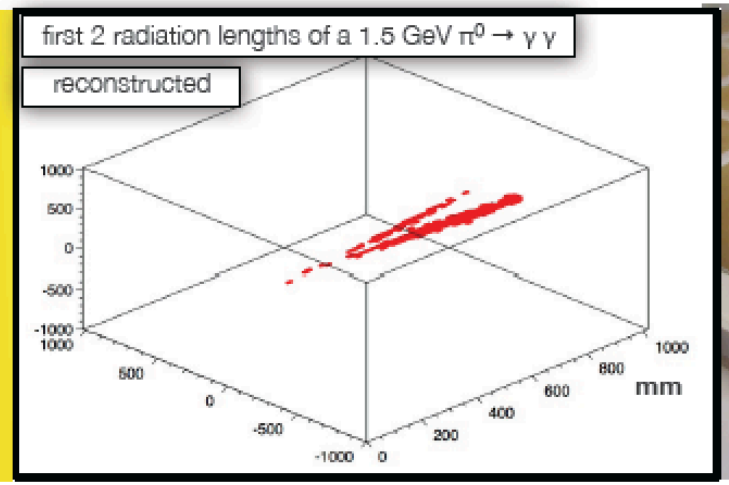
What is ANNIE?

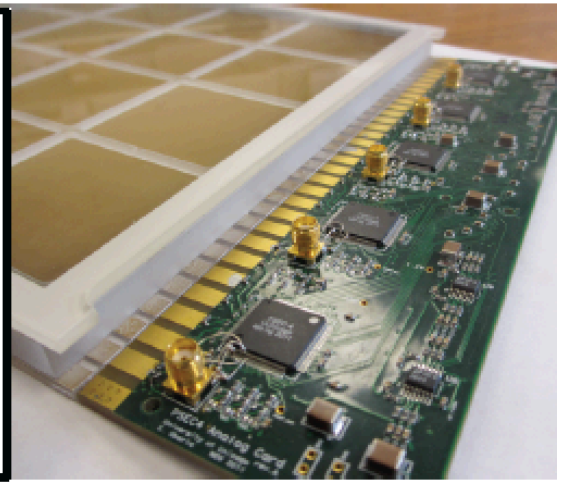
- A measurement of the abundance of final state neutrons from neutrino interactions in water, as a function of energy.



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







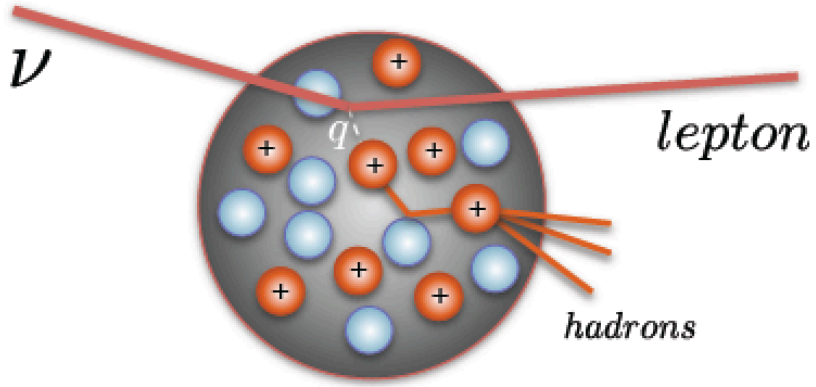
- Demonstration of a new technological approach to neutrino detection: "optical Time Projection Chambers" (using new photosensor technology)

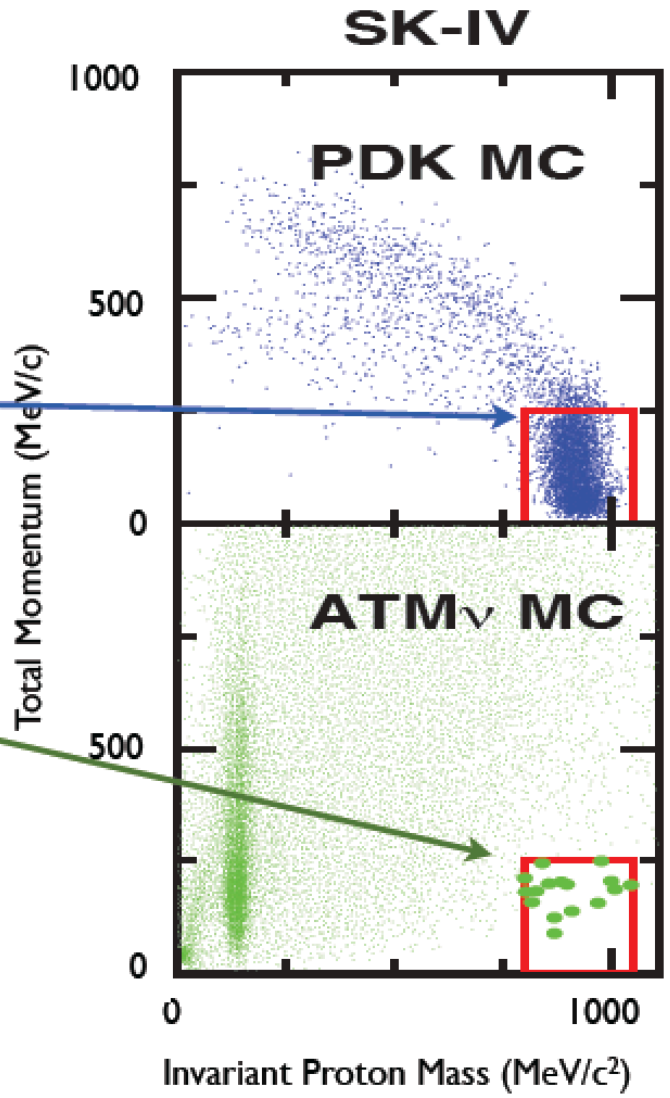
Motivation

Backgrounds come almost exclusively from atmospheric neutrino interactions

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

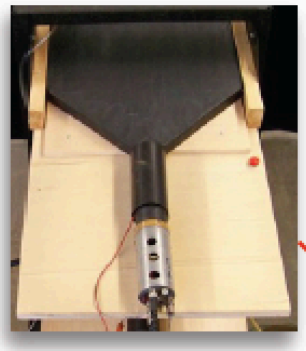
High energy neutrino interactions typically produce neutrons in the final state



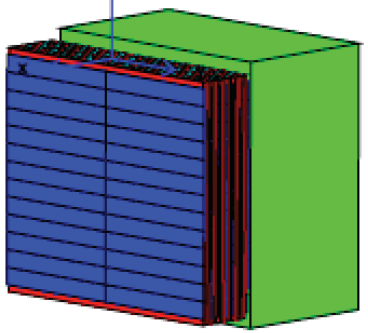


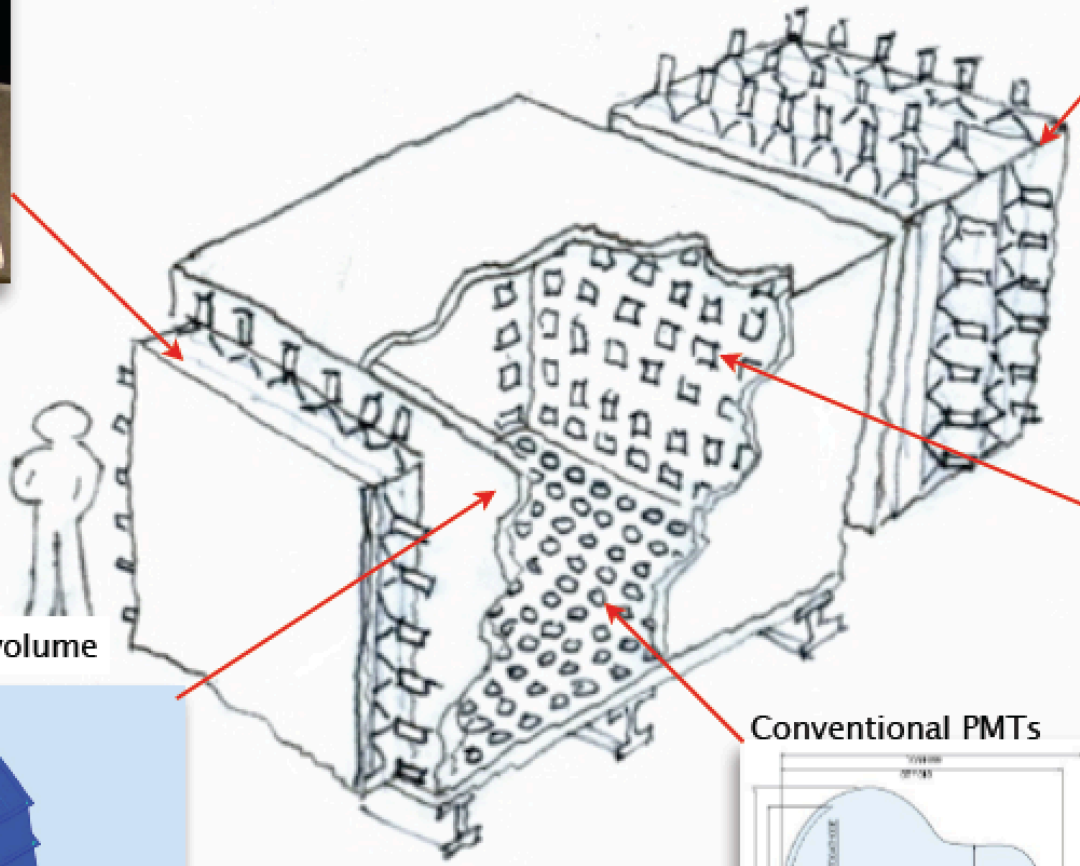
The ANNIE Detector System

Front Anti-Coincidence Counter



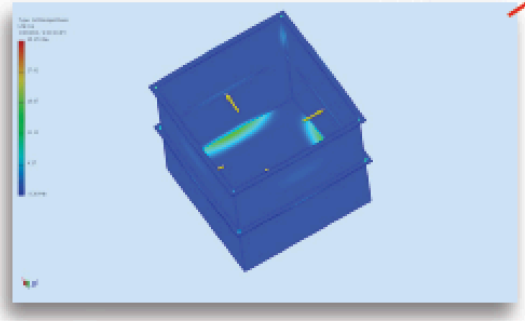
Muon Range Detector



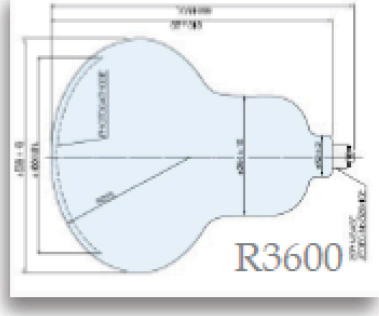


LAPPDs

Gd-loaded water volume



Conventional PMTs



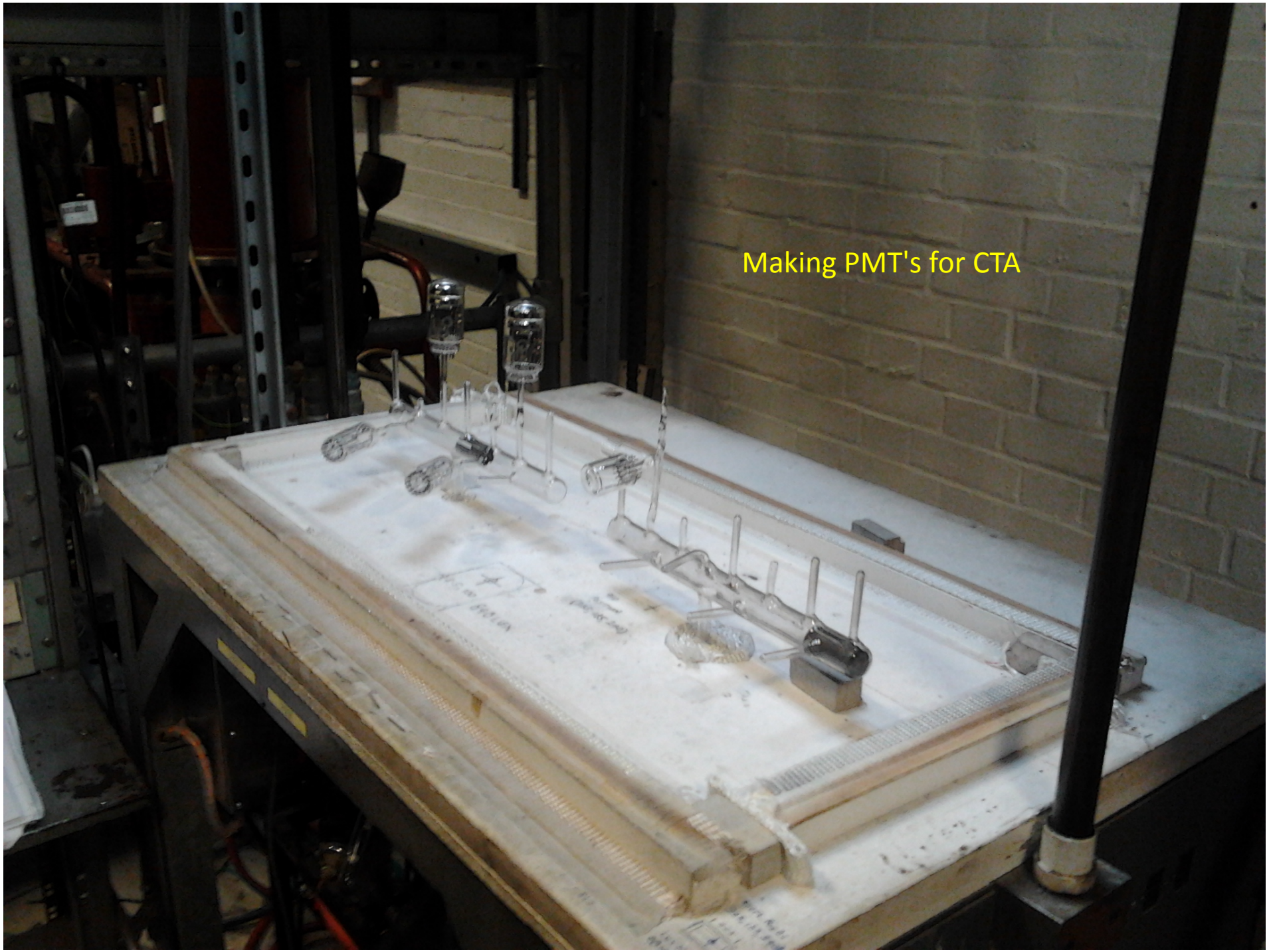
Conclusions

- 20 Prototype PMT's to be delivered to UC Davis starting in June with two, with rest to follow after quick testing of first two
- These are not "fully functional" – will have HQE cathode and electron optics but not final glass design. Requested further funding from DOE to make fully functional prototypes
- ADIT production capacity can easily handle HK OD requirements of ~12,000 11" PMT's. They also can do potting. Could they do more?
- WATCHMAN/ISODAR Meeting Virginia Tech May 1-2 – We should **include Hyper-K in this discussion and have open invitation to new U.S. groups. HK Collaborators welcome.**
- U.S./U.K ANNIE proposal to Fermilab PAC last week – meeting planned for Chicago March 2-3. HK Collaborators welcome.

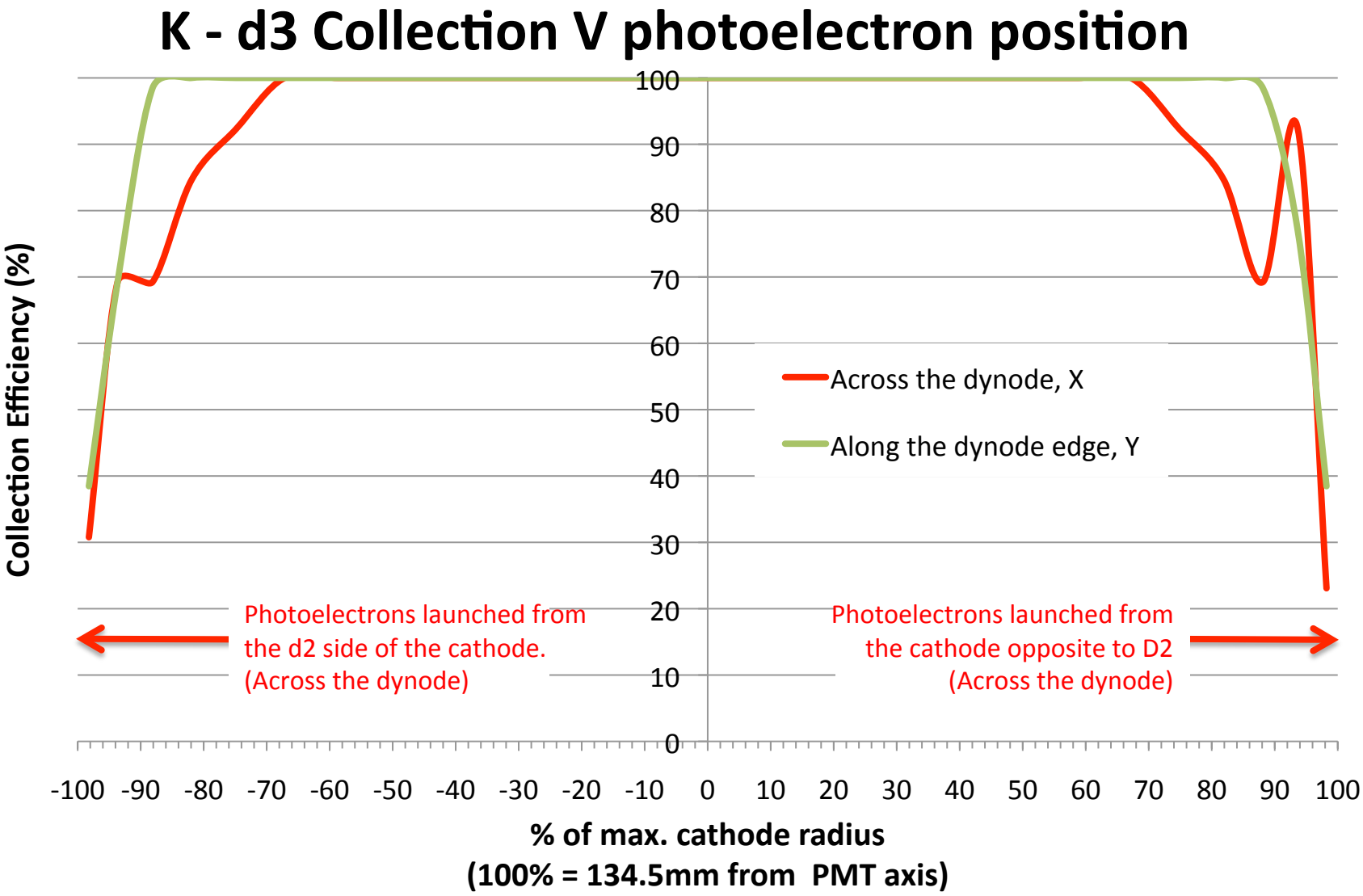
Backup

1. Electron optical modelling

- 3D modelling using 2 independent modelling packages
  - Work led by ETEL and verified at ADIT
  - Design compromise
    - Highest collection efficiency = large d1 = poorer jitter
    - Best jitter = smaller d1 = poorer k-d1 collection and increased magnetic susceptibility
  - Optimum chosen to collect from > 95% of cathode diameter


Making PMT's for CTA

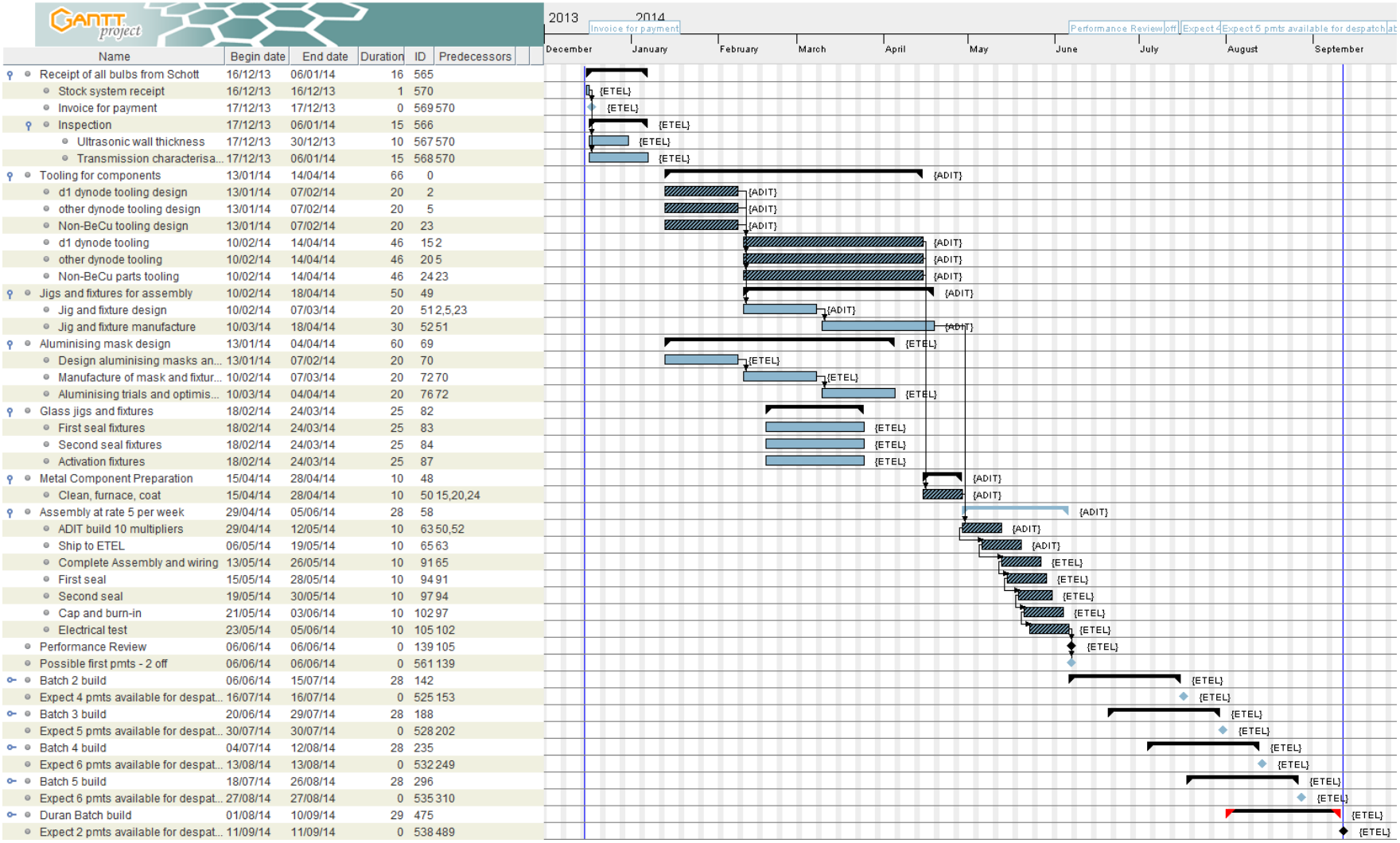
1. Electron Optics: Jitter & Collection modelling



2. D784KFLB – Project plan for delivery of 20 pmts

ET Enterprises electron tubes

ADIT



Name	Begin date	End date	Duration	ID	Predecessors
Receipt of all bulbs from Schott	16/12/13	06/01/14	16	565	
Stock system receipt	16/12/13	16/12/13	1	570	
Invoice for payment	17/12/13	17/12/13	0	569	570
Inspection	17/12/13	06/01/14	15	566	
Ultrasonic wall thickness	17/12/13	30/12/13	10	567	570
Transmission characterisa...	17/12/13	06/01/14	15	568	570
Tooling for components	13/01/14	14/04/14	66	0	
d1 dynode tooling design	13/01/14	07/02/14	20	2	
other dynode tooling design	13/01/14	07/02/14	20	5	
Non-BeCu tooling design	13/01/14	07/02/14	20	23	
d1 dynode tooling	10/02/14	14/04/14	46	15	2
other dynode tooling	10/02/14	14/04/14	46	20	5
Non-BeCu parts tooling	10/02/14	14/04/14	46	24	23
Jigs and fixtures for assembly	10/02/14	18/04/14	50	49	
Jig and fixture design	10/02/14	07/03/14	20	51	2,5,23
Jig and fixture manufacture	10/03/14	18/04/14	30	52	51
Aluminising mask design	13/01/14	04/04/14	60	69	
Design aluminising masks an...	13/01/14	07/02/14	20	70	
Manufacture of mask and fixtur...	10/02/14	07/03/14	20	72	70
Aluminising trials and optimis...	10/03/14	04/04/14	20	76	72
Glass jigs and fixtures	18/02/14	24/03/14	25	82	
First seal fixtures	18/02/14	24/03/14	25	83	
Second seal fixtures	18/02/14	24/03/14	25	84	
Activation fixtures	18/02/14	24/03/14	25	87	
Metal Component Preparation	15/04/14	28/04/14	10	48	
Clean, furnace, coat	15/04/14	28/04/14	10	50	15,20,24
Assembly at rate 5 per week	29/04/14	05/06/14	28	58	
ADIT build 10 multipliers	29/04/14	12/05/14	10	63	50,52
Ship to ETEL	06/05/14	19/05/14	10	65	63
Complete Assembly and wiring	13/05/14	26/05/14	10	91	65
First seal	15/05/14	28/05/14	10	94	91
Second seal	19/05/14	30/05/14	10	97	94
Cap and burn-in	21/05/14	03/06/14	10	102	97
Electrical test	23/05/14	05/06/14	10	105	102
Performance Review	06/06/14	06/06/14	0	139	105
Possible first pmts - 2 off	06/06/14	06/06/14	0	561	139
Batch 2 build	06/06/14	15/07/14	28	142	
Expect 4 pmts available for despat...	16/07/14	16/07/14	0	525	153
Batch 3 build	20/06/14	29/07/14	28	188	
Expect 5 pmts available for despat...	30/07/14	30/07/14	0	528	202
Batch 4 build	04/07/14	12/08/14	28	235	
Expect 6 pmts available for despat...	13/08/14	13/08/14	0	532	249
Batch 5 build	18/07/14	26/08/14	28	296	
Expect 6 pmts available for despat...	27/08/14	27/08/14	0	535	310
Duran Batch build	01/08/14	10/09/14	29	475	
Expect 2 pmts available for despat...	11/09/14	11/09/14	0	538	489