

Photomultiplier development at ET Enterprises and ADIT Electron Tubes

Andy Cormack

Sensor Development Director, ETEL

Richard Leclercq

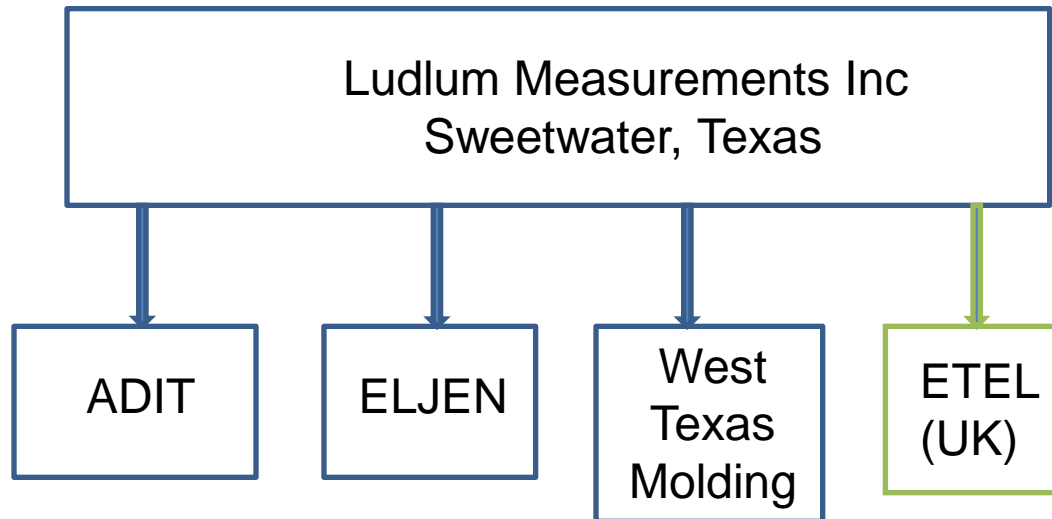
PMT Design Engineer, ADIT

Graham Sperrin

European Sales Manager, ETEL



- Introduction to the ETEL and ADIT Companies
- Development progress on 3" pmts for KM3NeT
- Technical requirements for 1.5" pmts for CTA
- Large area pmts for Cherenkov detection



Ludlum Measurements

Radiation Detection & Measurement



Sweetwater, Texas



Product Lines

- Portable Survey Meters & Radiation Detectors
- Contamination Monitors
- Sample Counting Systems
- Gateway Systems
- Area Monitors

Markets Served

- Nuclear Power
- National Labs
- National Security & Emergency Response
- Metals Industry
- Solid Waste
- Medicine
- Mining

Distribution Network

- Representatives in 78 countries

www.ludlums.com

Back



ADIT

Photomultiplier Tubes for Radiation Detection



Sweetwater, Texas



Product Lines

- Photomultiplier Tubes
- Sockets
- Bases
- Voltage Dividers

Markets Served

- Industry
- Scientific Community

www.aditpmt.com

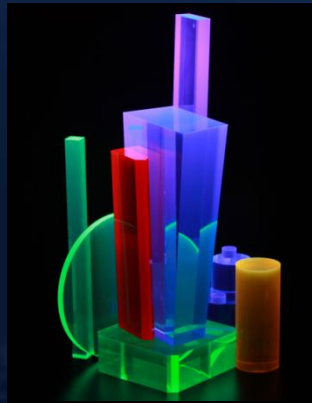
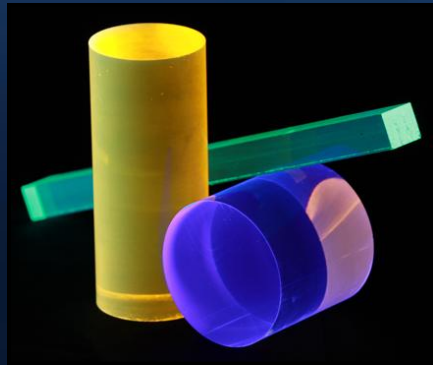


Eljen Technology

Organic Scintillators



Sweetwater, Texas



Product Lines

- Plastic Scintillators
- Liquid Scintillators
- PMMA & UVT Material
- Loaded Scintillators
- Paints
- Neutron Detectors
- Wave Shifting Plastics
- Zinc Sulfide Shifting Plastics
- Optical Cement, Greases, Adhesives etc.

Markets Served

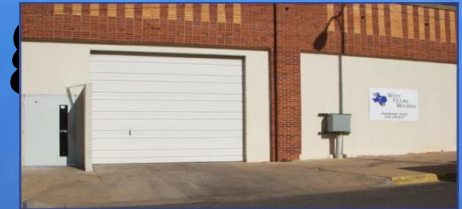
- Industry
- Research



www.eljentechnology.com

West Texas Molding

Plastic Injection Molding & Assembly



Sweetwater, Texas



Specialty

- Short Run Production
- Insert Molding
- Prototype Molding
- Hot Stamping
- Custom Coloring

In-House Services

- Tooling & Design
- Mold Fabrication
- Product Assembly
- Product Packaging
- Product Warehousing
- Shipping to End User



www.wtmolding.com



ET Enterprises Limited

45 Riverside Way

Uxbridge

UB8 2YF

United Kingdom

phone: +44 (0)1895 200880

fax: +44 (0)1895 270873

web: <http://www.et-enterprises.com>

e-mail: info@et-enterprises.com



ADIT

300 Crane St.

Sweetwater, TX

79556

Phone: (325) 235-1418

Toll-free: (800) 399-4557

FAX: (325) 235-2872

E-mail: adit@aditpmt.com

URL: www.aditpmt.com



Photomultiplier manufacturing (3)



Additional manufacturing facility being prepared



Burle Photonis
equipment ready
for installation



Specific requirements for the KM3NeT PMT design

- 3" (76 mm) diameter
- Very short length of 103.5 mm
- Low transit time jitter ($\sigma < 2$ ns)
- $> 20\%$ QE at 470 nm
- High collection efficiency
- Good cathode uniformity ($\pm 10\%$ across active diameter)
- High gain capability (single photoelectron detection)
- High gain for low operating voltage
- Low dark noise

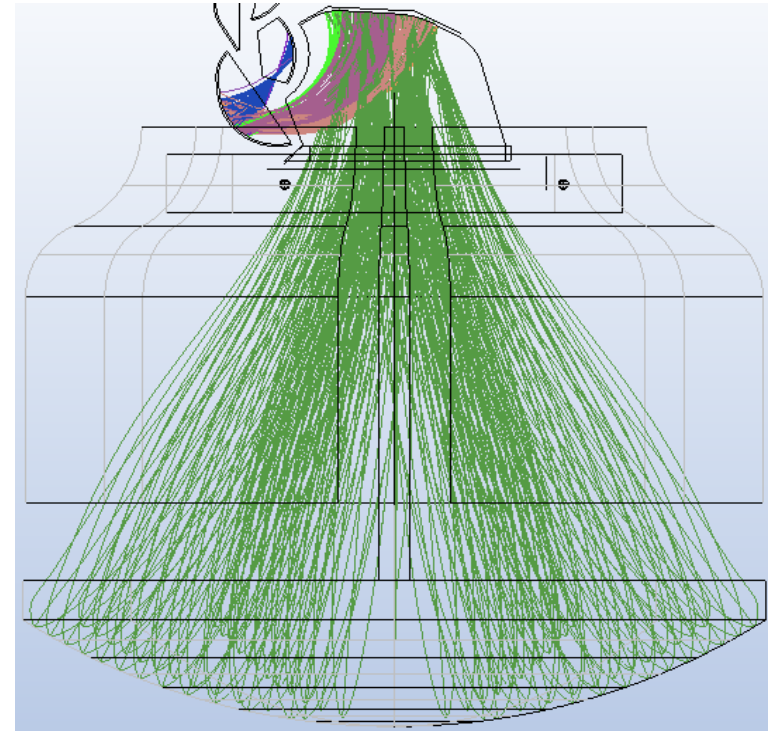
Developed under NDA and part funded by KM3NeT



Simulated time response

Full 3D simulation

	Overall	Sigma
k-d1	23.4	0.8
k-d2	29.5	1.6
k-d3	31.6	1.8

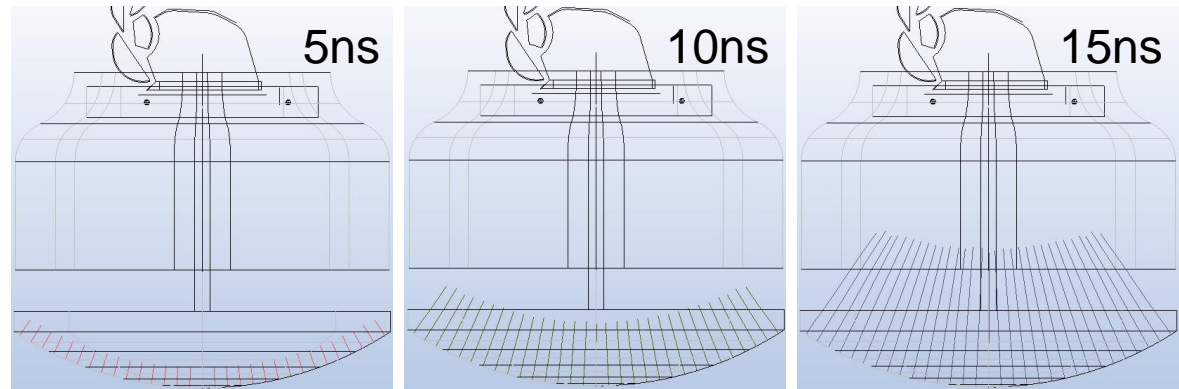




Preliminary E-O design

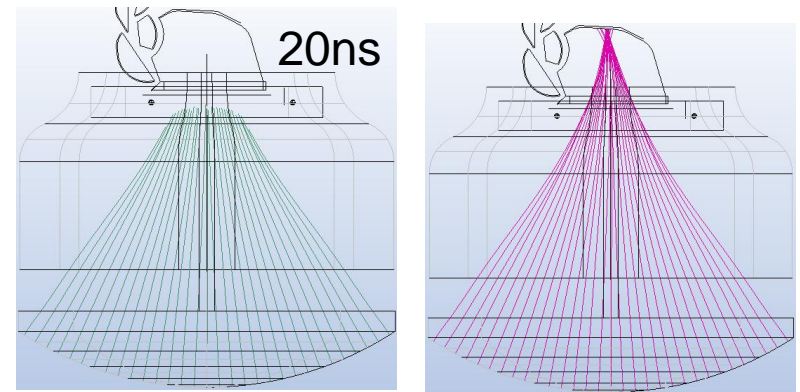
Time slice images of Preliminary E-O

5ns time segments

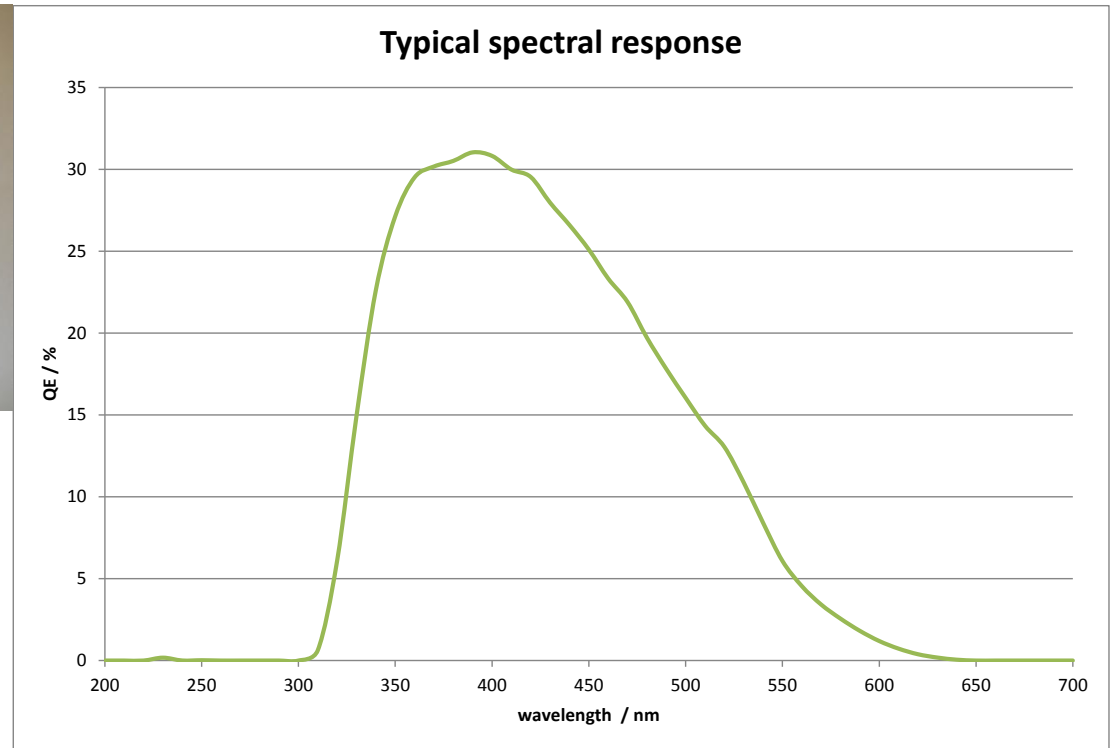
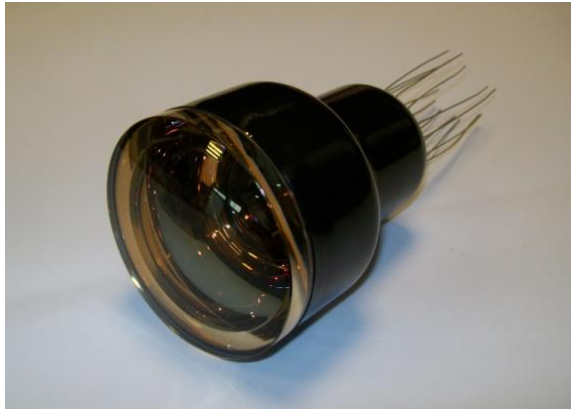


Electrons launched perpendicular to surface

Centre to edge difference 1ns

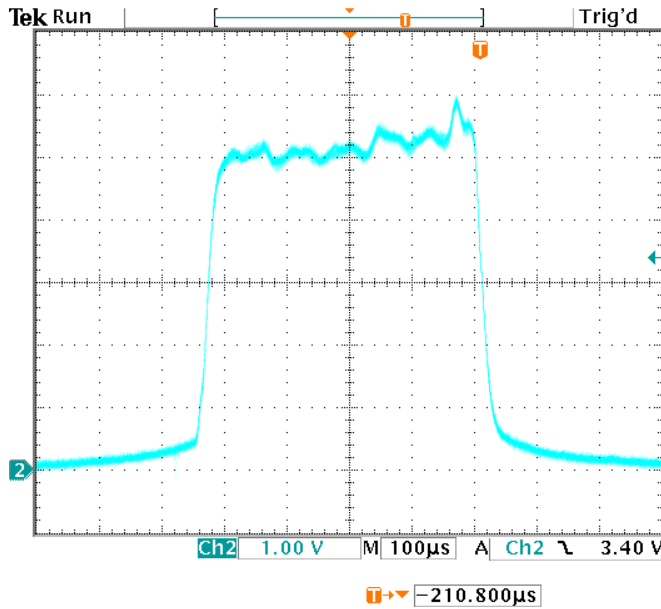


D783FL typical performance

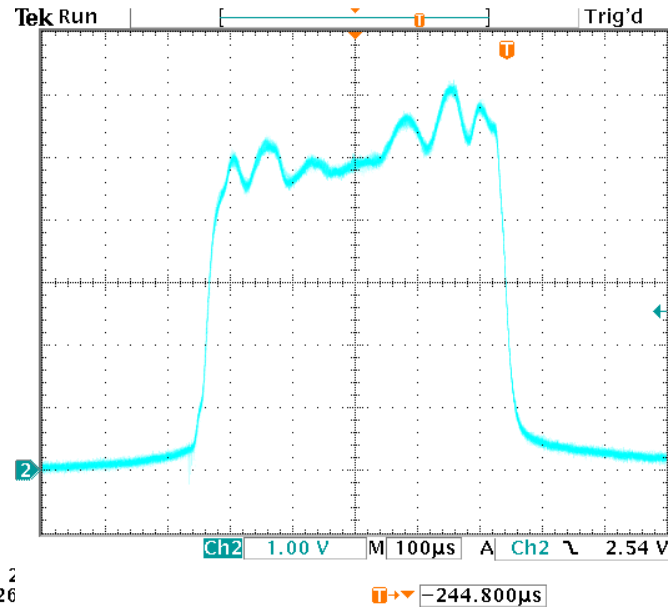


Typical QE at 470 nm 22%

D783FL typical performance



Anode uniformity Along d1

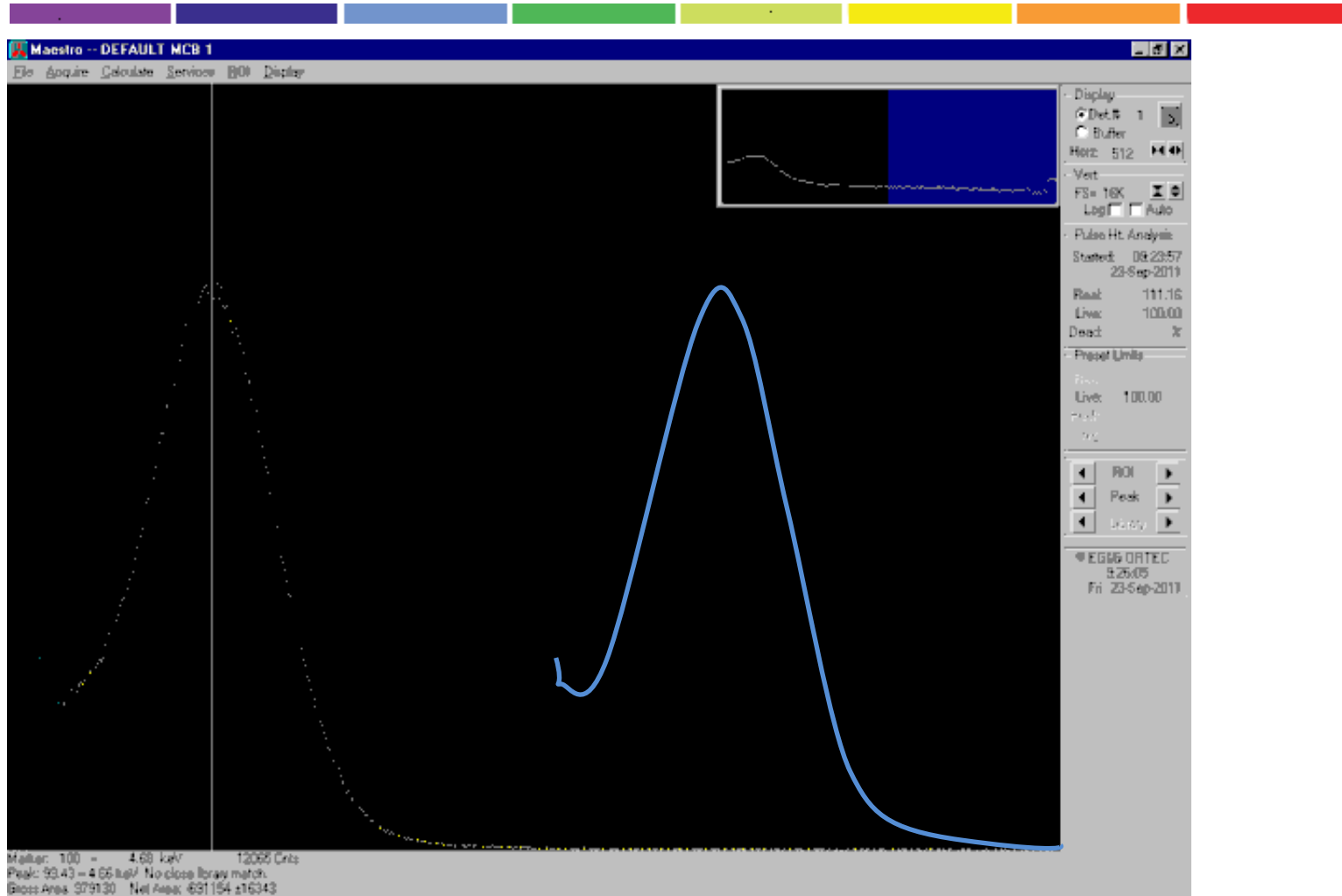


Anode uniformity Across d1

Active diameter 72-73 mm

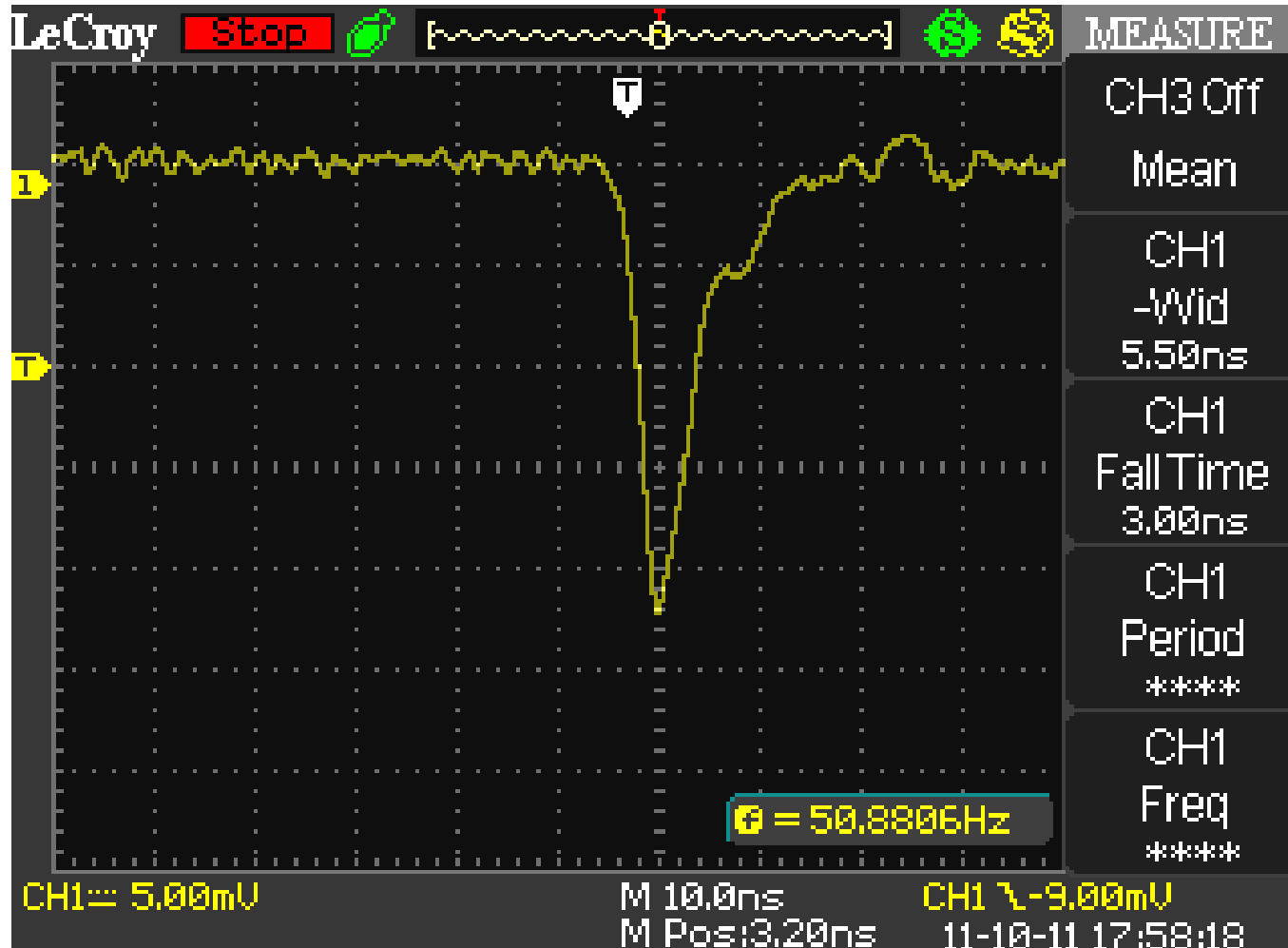
D783FL typical performance

Single photoelectron response



D783FL typical performance

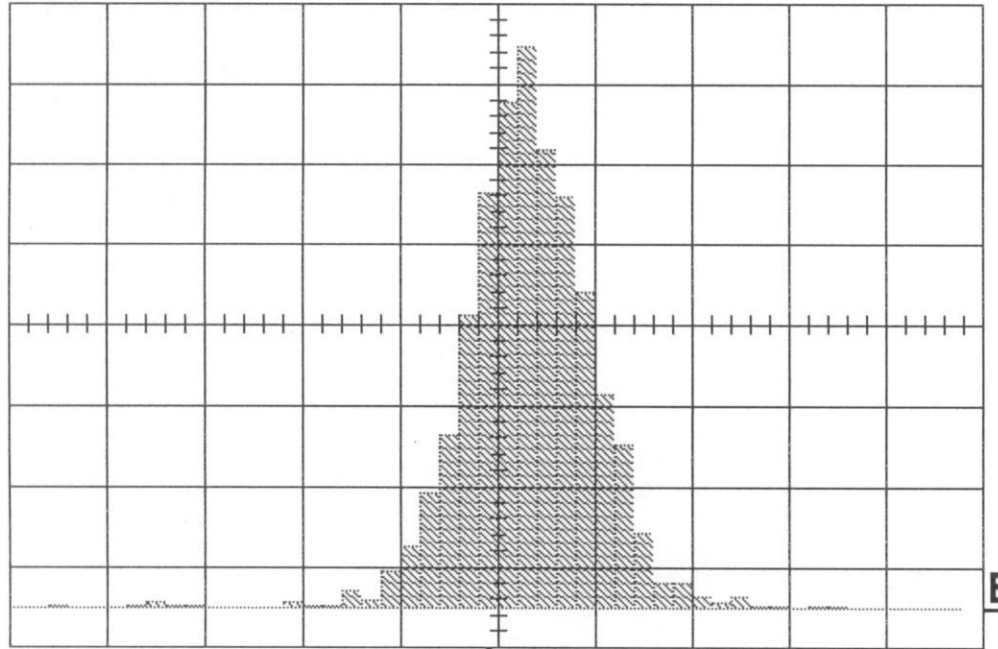
Single photoelectron timing



D783FL typical performance

13:55:21

B: HΔdly(1,2)
2 ns
31.6 #
←1%/→0%
inside 1542



	1564 sweeps:	average	low	high	sigma
$\Delta dly(1,2)$		79.4 ns	40.5	85.9	3.5
$fwhm(B)$		2.46 ns	0.40	2.86	0.40
$\sigma(B)$		1.37 ns	0.98	1.76	0.06
$hmedian(B)$		79.63 ns	79.30	79.74	0.07

50 ns

Single photoelectron jitter less than 2 ns sigma (typ. 1.5 ns)

Performance requirements for PMTs for CTA

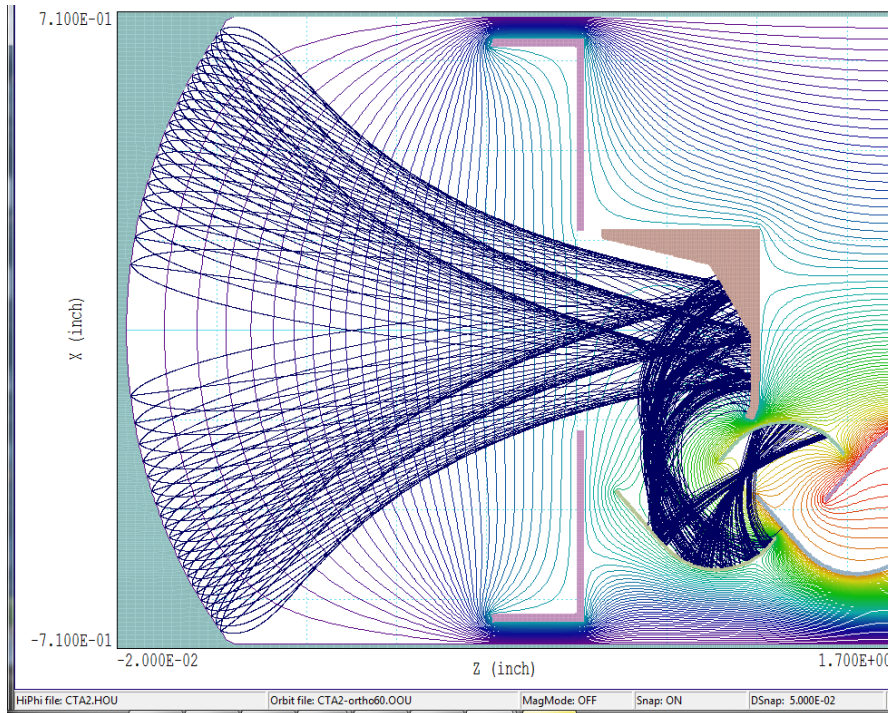
- 1.5in (38mm) diameter
- Working diameter > 30 mm
- Peak QE of 35%
- Uniformity of response +/- 10%
- Collection efficiency > 90%
- Single photoelectron jitter <1.5 ns
- Single photoelectron FWHM <2.5 ns
- Gain 5×10^4
- Linear response to 5,000 pe in 5 ns
- A/P rate > 4pe equivalent < 0.02%
- SER p/v ratio > 1.5

Currently no pmts in ETEL or ADIT range that meet this requirement

New pmt design needed

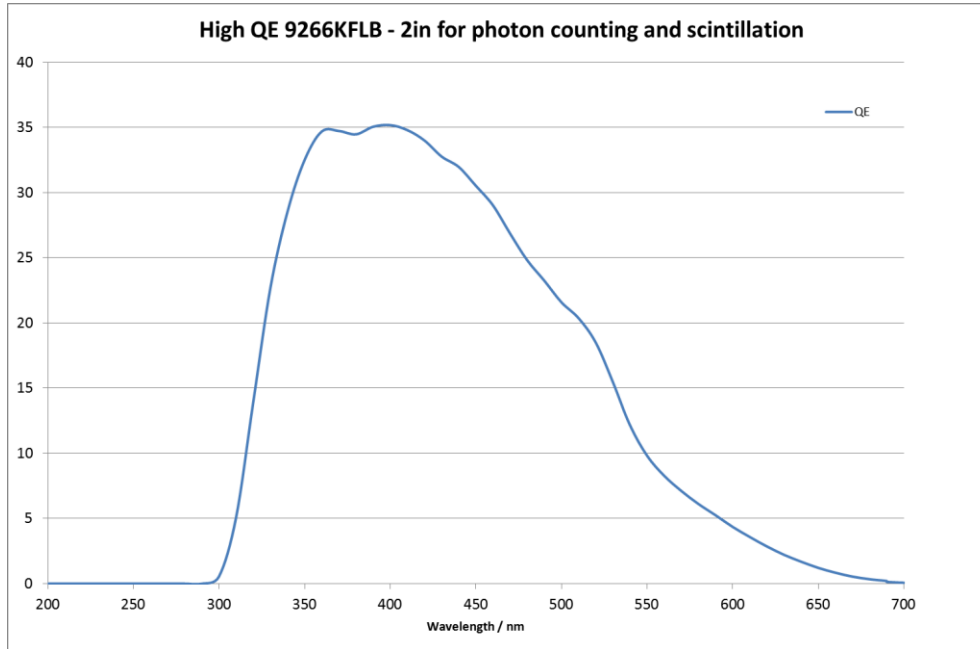


PMTs for CTA



DESIGN1			
Y=0	K->D1	K->D2	K->D3
AVG(ns)	7.48	11.55	12.93
Stdev(ns)	0.34	1.53	0.91
FWHM(ns)	0.80	3.62	2.15

Anticipate first samples towards end of 2012



Best example 35% at 400nm

Glass, $n = 1.5$
Photocathode, $n=2.5-3.0$
Reflected light 10-20%



Intermediate layers to

- Provide anti-reflective property
- Provide compatible substrate with photocathode growth
- Compatibility with photomultiplier manufacture

Modelling to maximise light absorption in the photocathode
Manufacturing samples to test the models

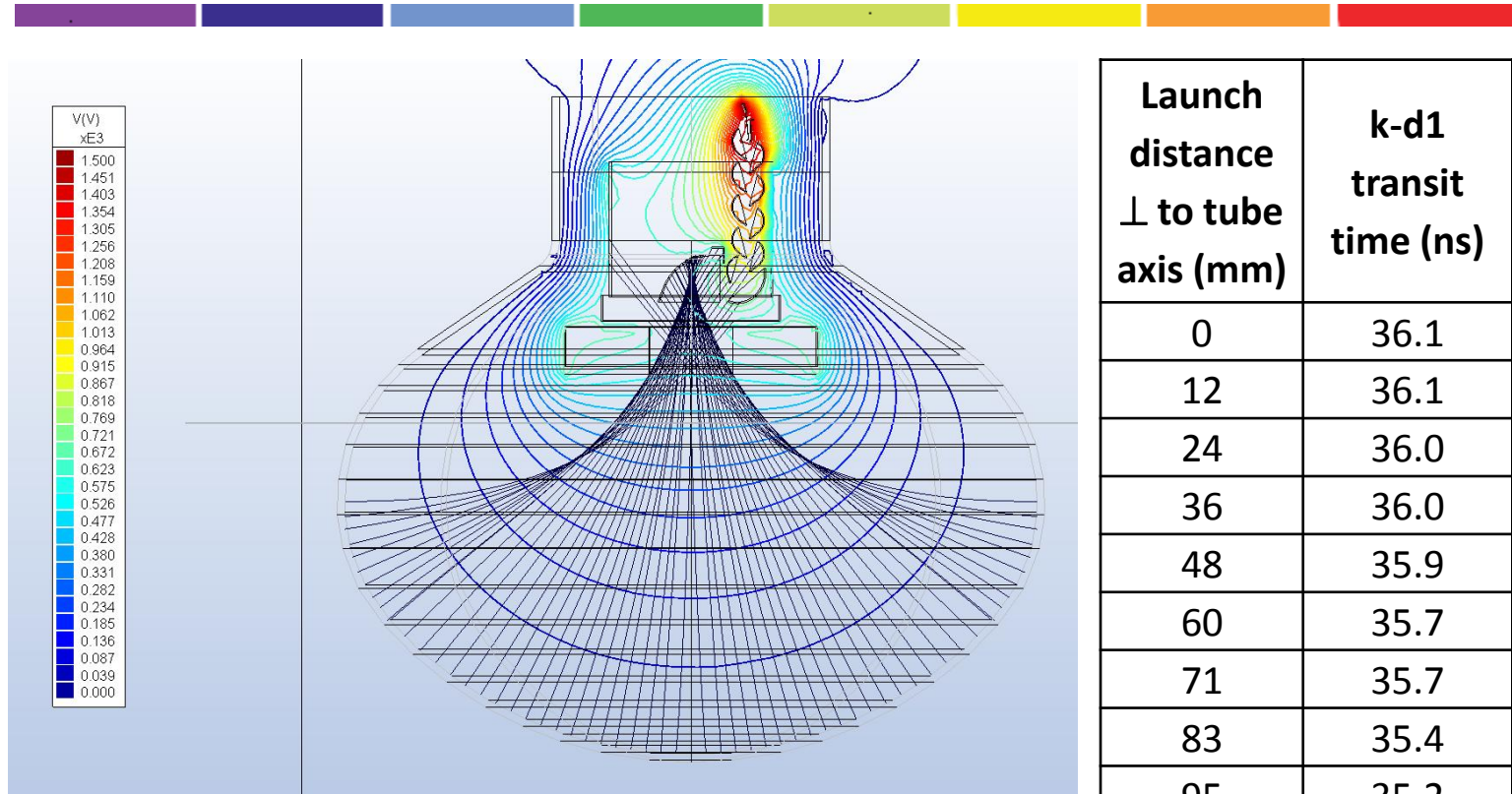
Another iterative design process

Large diameter pmt range

Parameter	9372	9350	9352	9354	9357	D784
Diameter (in)	5	8	8	8	8	11
No. of stages	6	14	6	12	12	12
Typical operating gain	10 ⁷	10 ⁸	10 ⁴	10 ⁷	10 ⁷	10 ⁷
Typical QE% at peak	28	30	30	30	18	30
Surface area (cm ²)	160	425	425	425	425	800
Typical dark cps at 20C	1500	4000	-	4000	4000	8000
Typical SER ratio	1.5	1.5	-	2	2	2
Typical 1e TTJ fwhm(ns)	2.7	8	-	2.7	2.7	3
Minimum Temperature	-30C	-30C	-30C	-30C	-196C	-30C
Weight (grams)	380	700	700	700	700	2000

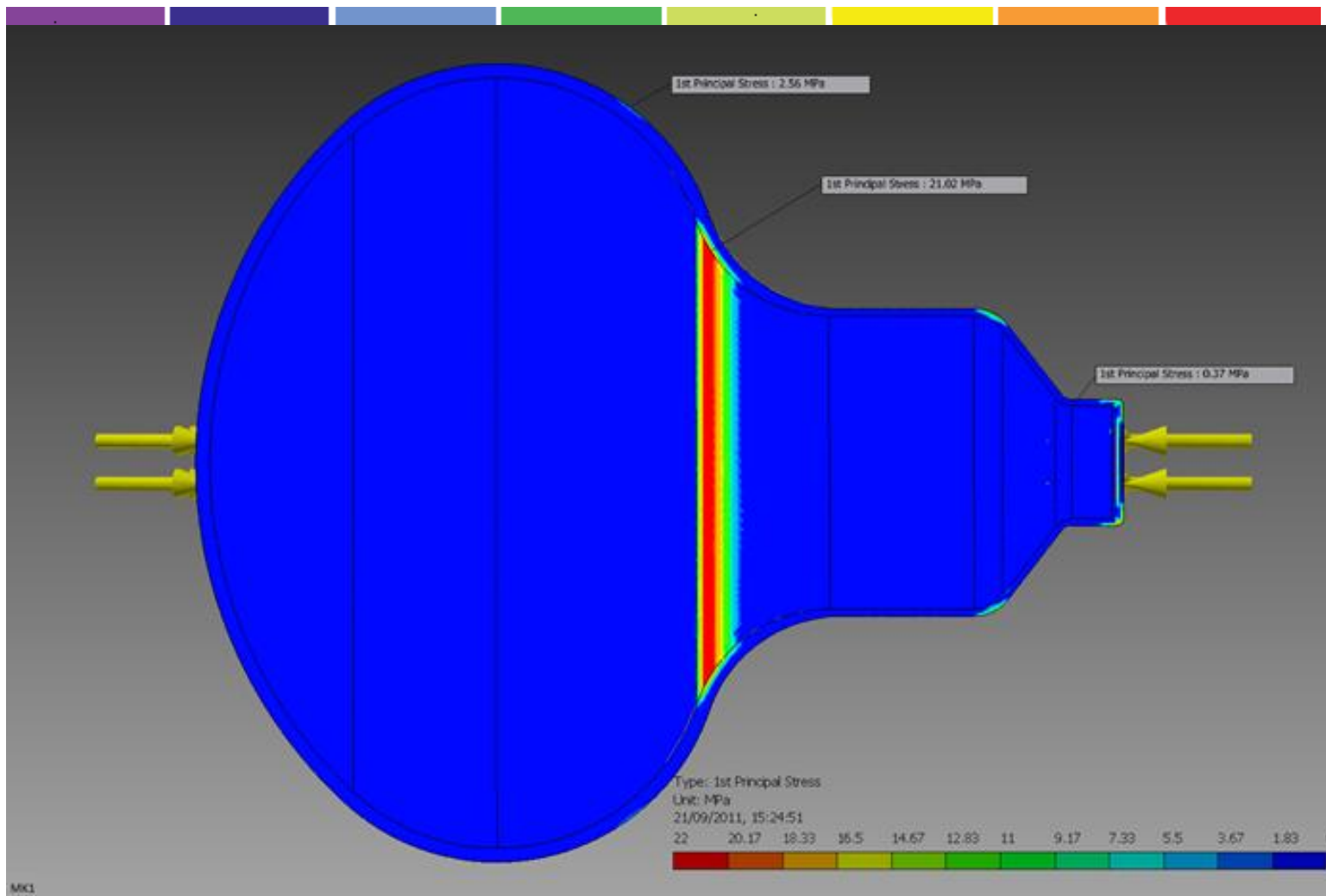
Design specifications:

- External water pressure of 11 bar
- Long life in pure water
- Glass with low content of radioactive isotopes
- Design for good photoelectron collection
- Design for good timing (TTJ)

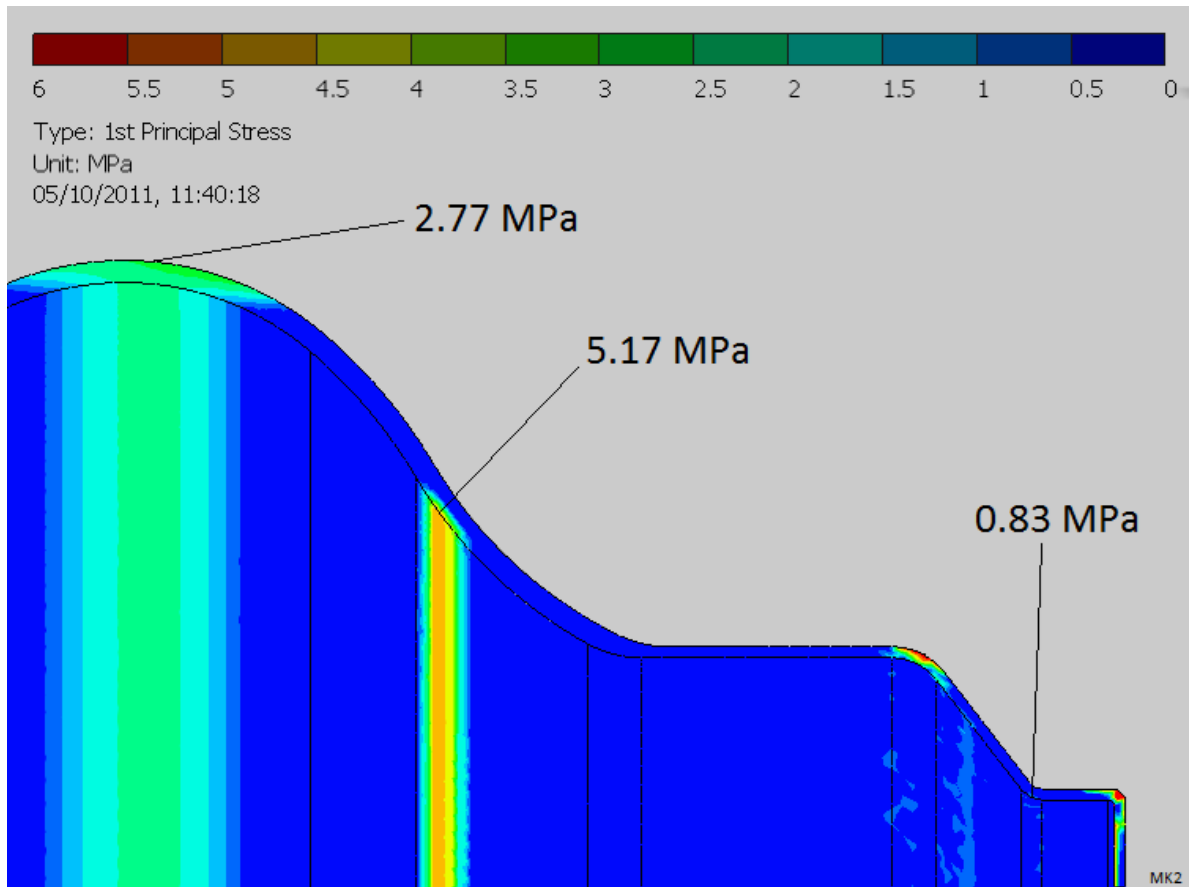


Launch distance ⊥ to tube axis (mm)	k-d1 transit time (ns)
0	36.1
12	36.1
24	36.0
36	36.0
48	35.9
60	35.7
71	35.7
83	35.4
95	35.2
107	35.2
119	35.6
137	34.9

Mechanical stress analysis – Mk1 design



Mechanical stress analysis – Mk2 design



Expected gamma decay rate – Mk4



UL BGD glass	Concentration
Natural potassium	60 ppm
Thorium	30 ppb
Uranium	30 ppb

Glass Activity

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

*Estimated Gamma emission > 0.1 MeV



- Introduction to the ETEL and ADIT Companies
- Development progress on 3" pmts for KM3NeT
- Requirements for CTA
- Large area pmts for Cherenkov detection



ET Enterprises Limited
45 Riverside Way
Uxbridge
UB8 2YF
United Kingdom
Tel: +44 (0)1895 200880
Fax: +44 (0)1895 270873
web: <http://www.et-enterprises.com>
e-mail: info@et-enterprises.com

ADIT Electron Tubes
300 Crane Street
Sweetwater Texas 79556
USA
Tel: (+1) 325 235 1418
Toll Free: (+1) 800 521 8382
Fax: (+1) 325 235 2872
e-mail: sales@electrontubes.com