QUARTZTOF

An isochronous & achromatic Cerenkov Counter

Making Cerenkov light parallel → point focusing

Mike Albrow

New and original design/concept for fast timing Cerenkov counter

Ray-tracing calculations done:
Expect > factor 10 more photoelectrons than either GASTOF or QUARTIC
Photons arrive promptly (< few ps) at MCP-PMT

Full (wavelength dependent) simulations being done.
Needed for [x,y] position dependence over [2mm x 20mm] area.

Two being made for beam tests (in August at Fermilab).

Fast timing detectors tested in beams, in R&D report:

1) GASTOF (KP, Louvain)
2) QUARTIC (MGA Fermilab, AB UTA, JP Alberta) ++

$$\text{Cerenkov light } R \propto \left(1 - \frac{1}{n^2(\lambda)}\right) \equiv \left(\frac{n^2-1}{n^2}\right)$$

$$R(C_4F_8O) = 0.0028$$

$$R(\text{Quartz}) = 0.804$$

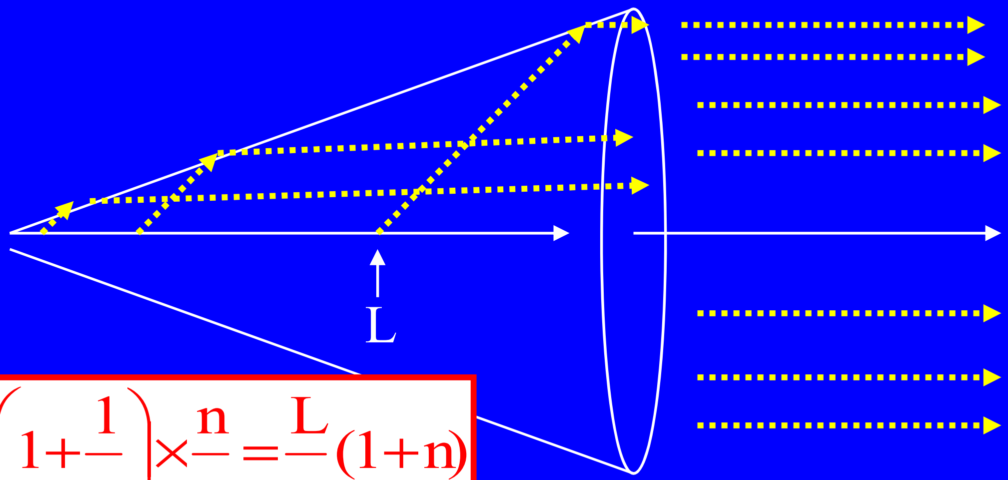
20 cm GASTOF with Atmospheric C4F8O → ~ 10 p.e.
nearly all collected, within few ps
QUARTIC bars ~ (inclined) 9 mm → ~ 130 pe,
but solid angle for direct light small, → ~ 3-4 pe/bar (in tests)

QUARTZTOF: Radiator 20-30 mm quartz,
nearly all light collected within a few ps.
(At least for 2 mm x 2mm "sweet spot")

QUARTZTOF (QT) Principle

Apex – base distance is $L\left(1+\frac{1}{n}\right)$

L is "isosceles point"



p ("needle" beam
~ 2mm x 2mm)
FP420: 2mm x 20mm

$$t(z=0)=L\left(1+\frac{1}{n}\right)\times\frac{n}{c}=\frac{L}{c}(1+n)$$

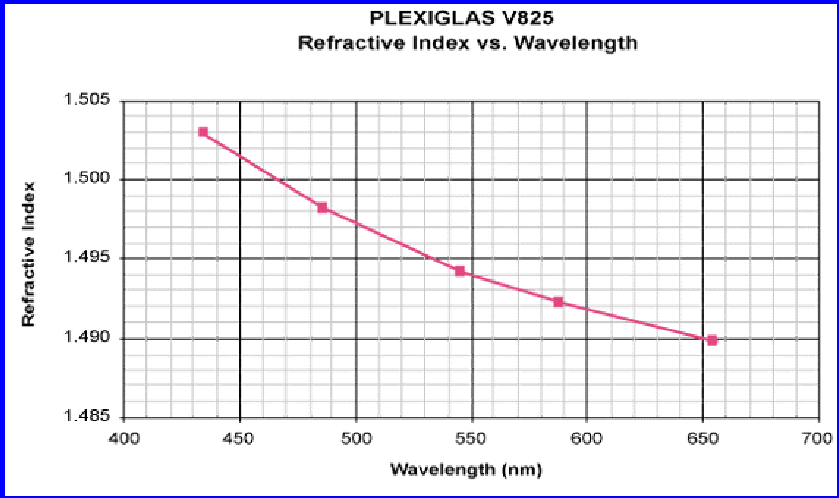
$$t(z=L)=\frac{L}{c}+\frac{Ln}{c}=\frac{L}{c}(1+n)$$

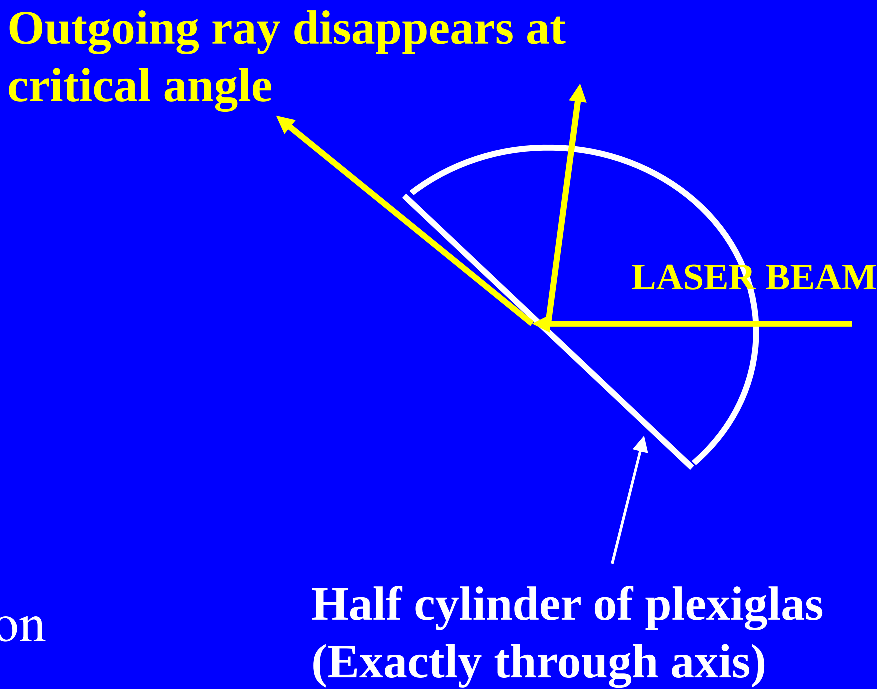
and all emission points in between

Proton along axis of cone, with half angle = half Cerenkov angle.
All Cerenkov light emitted (all ϕ) up to isosceles point L is totally internally reflected out the base and arrives simultaneously, in a parallel beam.
It can thus be focused to a point by a 90deg off-axis parabolic mirror.
→ Cannot use full cone in FP420, but cut in half (total internal reflection): QTπ
→ True for "lucky wavelength" … but can compensate for others.

Refractive Index (λ) of UVT Plexiglas.

From Altuglas literature





Not quite what we have in hand,
Actual type unknown (but UVT).
I measured sample by total internal reflection
→ Critical angle → Cerenkov angle.

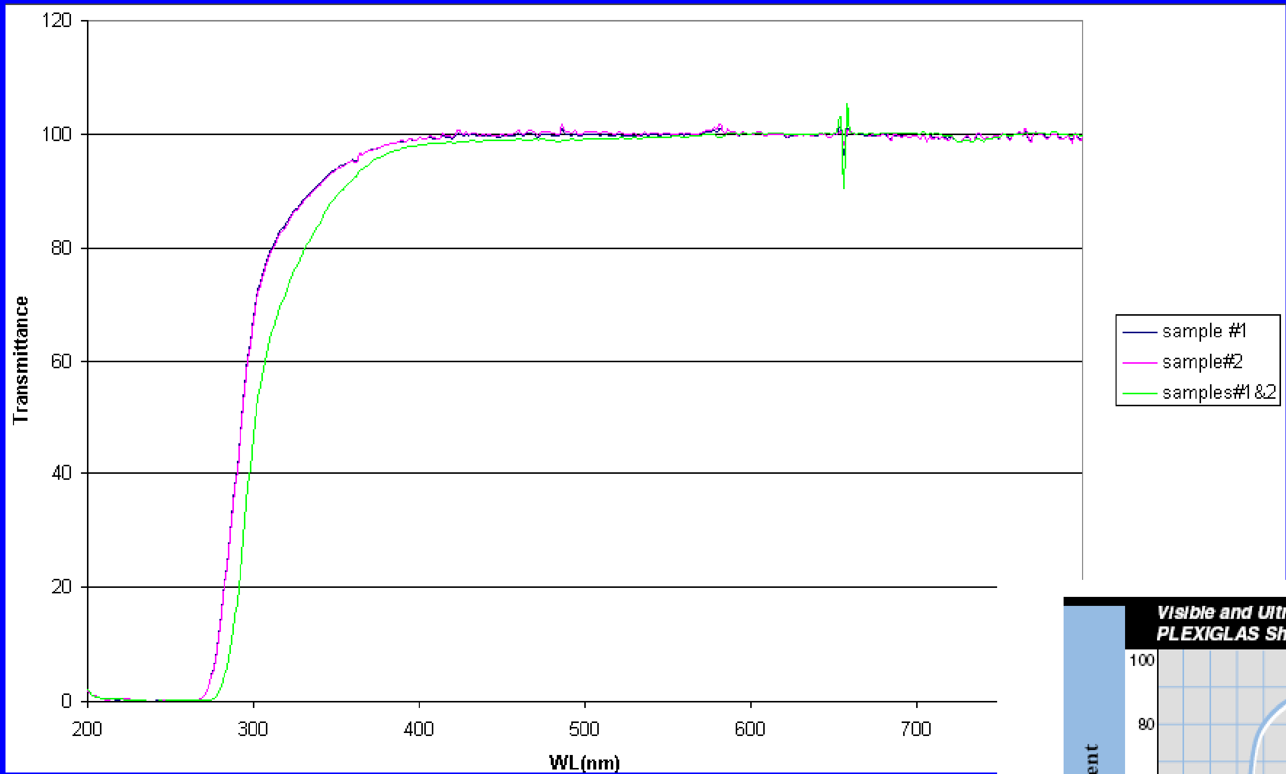
λ(nm)	n(meas)	n(AltuV825)	θ(meas)	θ(Altu)
543	1.458	1.494	46.7^0	48.0^0
612	1.473	1.491	47.2^0	47.9^0

→Cone half angle = 24deg
(23.5 my meas.)
Diff = material or my method?

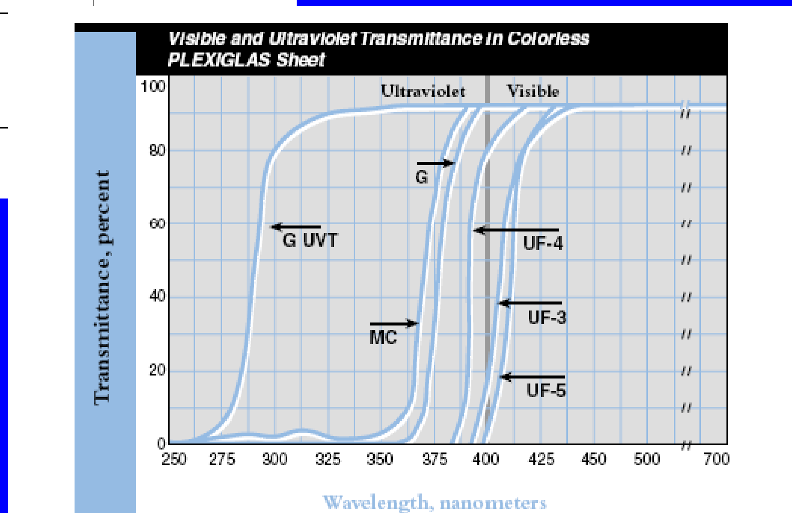
Transmission of UVT Plexi sample

We used a spectrophotometer to measure the transmittance of 200 nm – 800 nm light through 2 x 10 mm blocks, and the two together.

Irina Kubantseva



Data sheet:

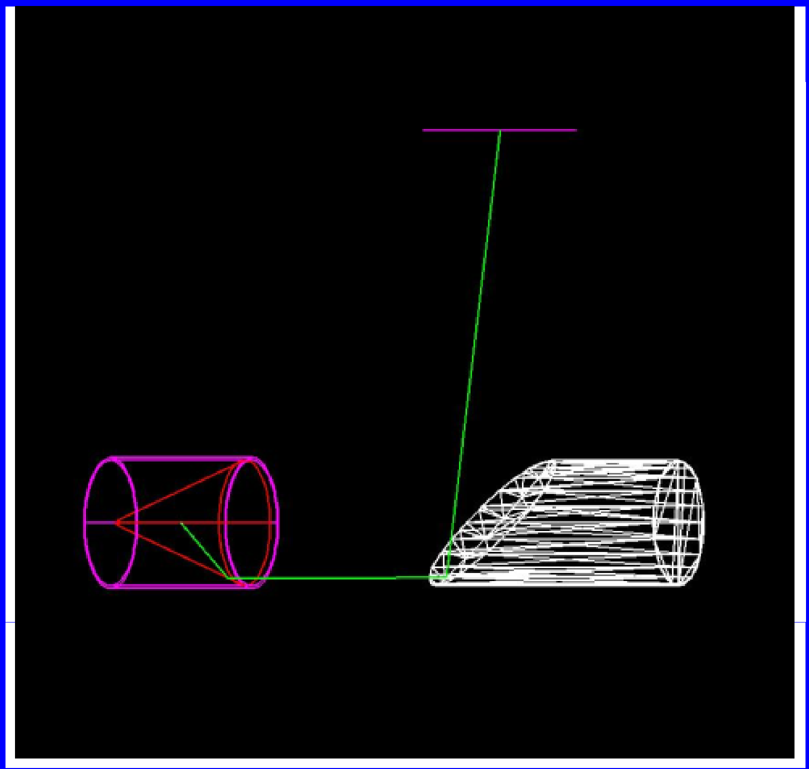


… to go into simulation.

GEANT Simulation

Will enable studies of x,y dependence
Wavelength dependence of emission, absorption, reflection, QE
Arrival time distribution vs radius at photocathode
→ Compensating "wedge" at MCP front face.

What is t(R) ?



Kristina Yancey,
Summer student
+ Hans Wenzel

Started, not there yet

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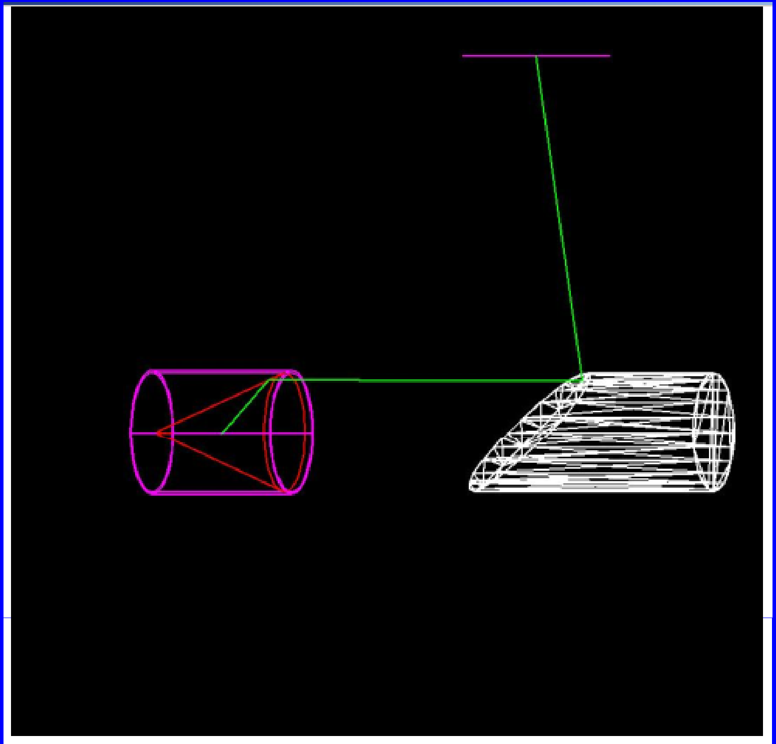

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Summer student
+ Hans Wenzel

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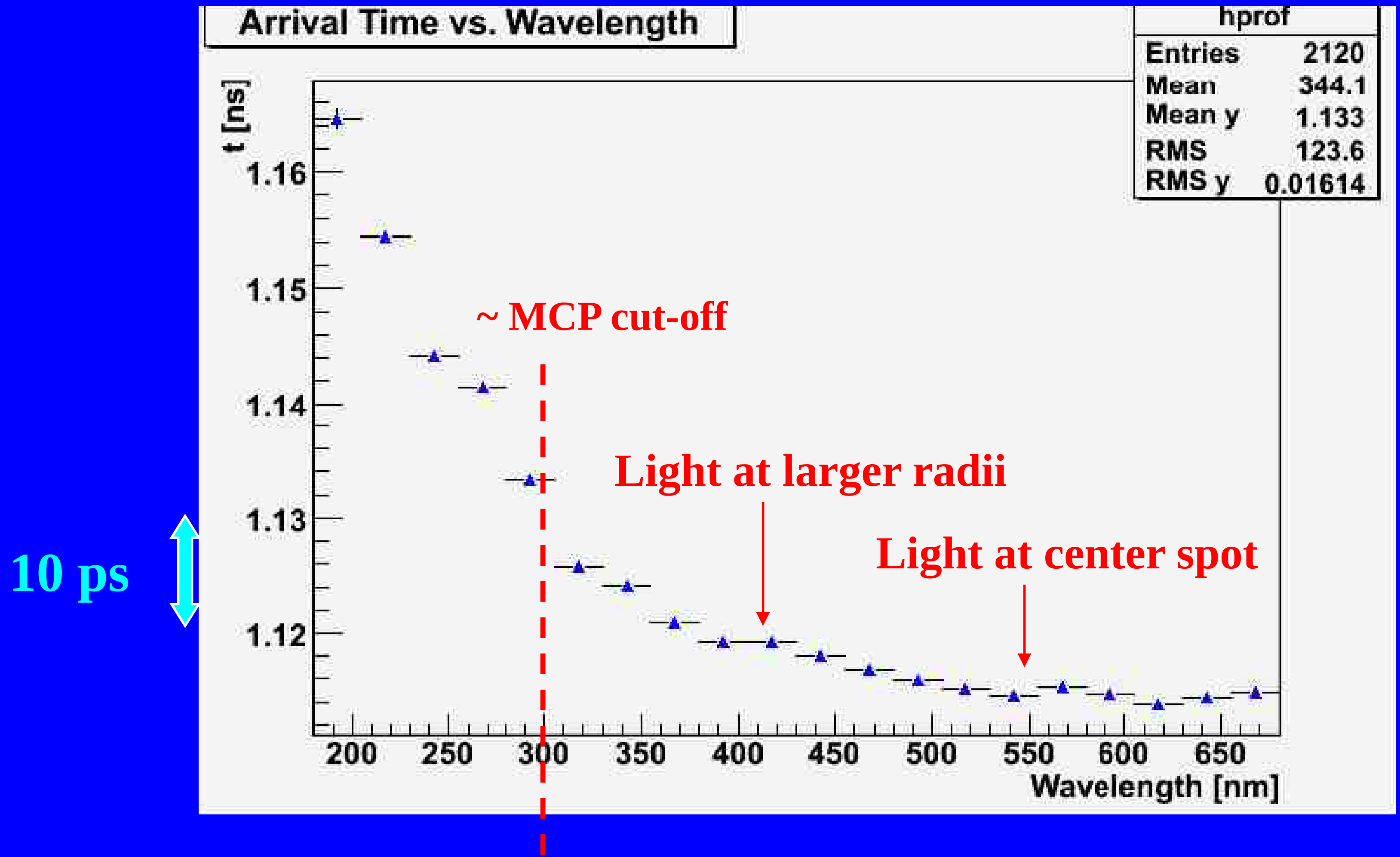
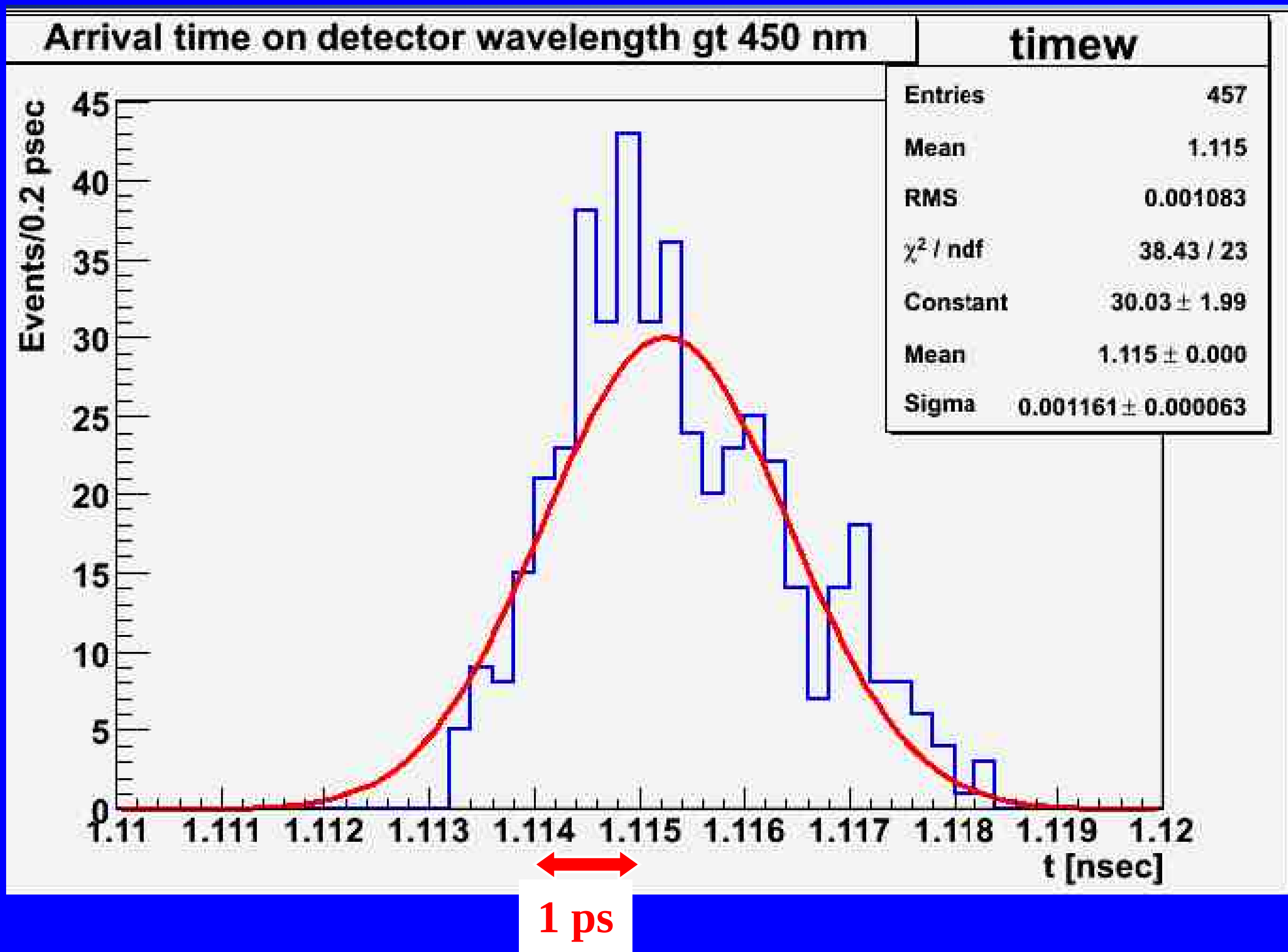
GEANT: Arrival time vs wavelength; focusing red light



Select light with λ > 450 nm:

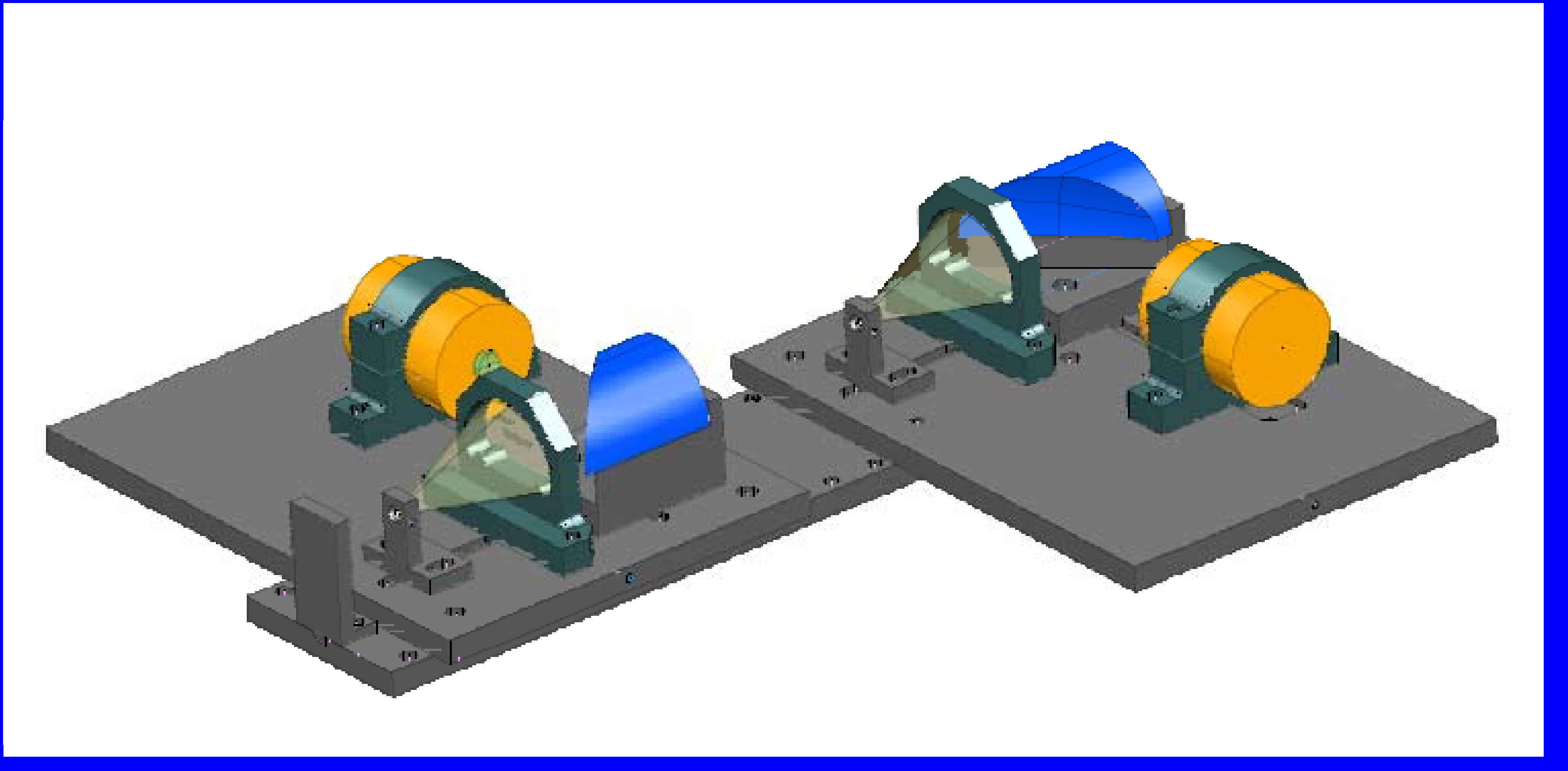


σ(t) = 1.1 ps, 457 photons (1 proton) → ~ 75 p.e.

But we can use also the light with λ < 450 nm !

Test beam Prototypes in CAD

John Rauch, FNAL



Optical Elements: Fermilab Prototypes for Test Beam Aug 08

Half-cone radiators: UVT Plexiglas. Plane surface 1mm off axis.

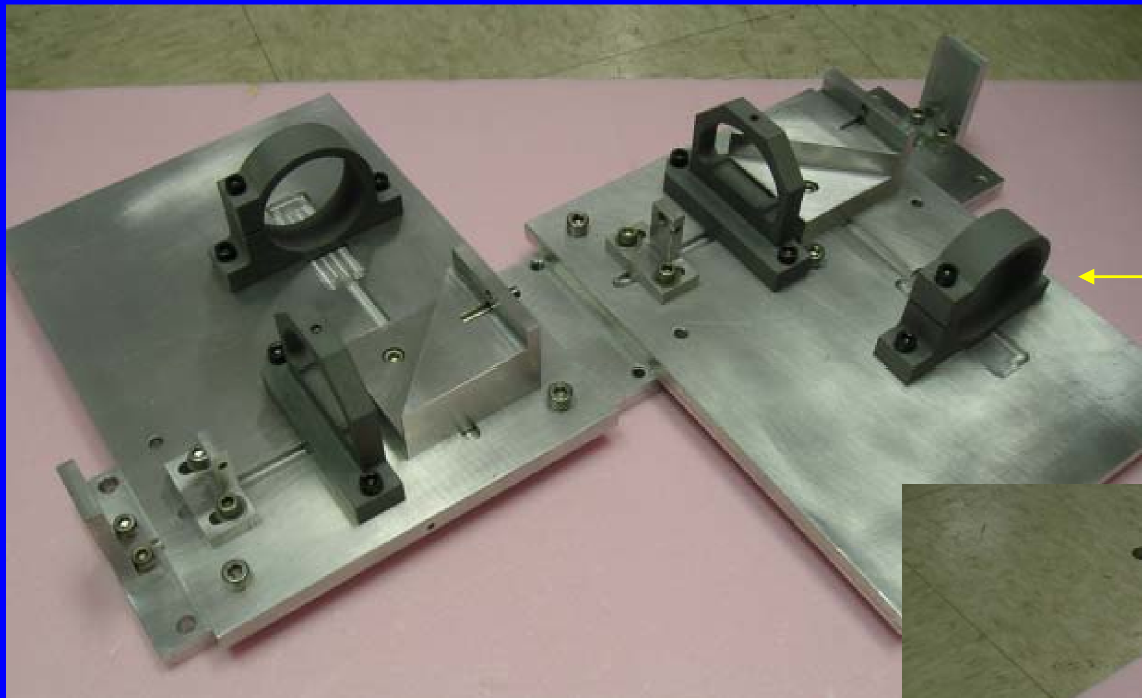
Cylindrical for mount

90deg off-axis parabolic mirror

Diamond-turned protected Al surface

Cut in two halves for "pi" detectors.

Mechanics of test beam modules, before optics mounted



Carl Lindenmeyer
John Korienek
Fermilab Technical

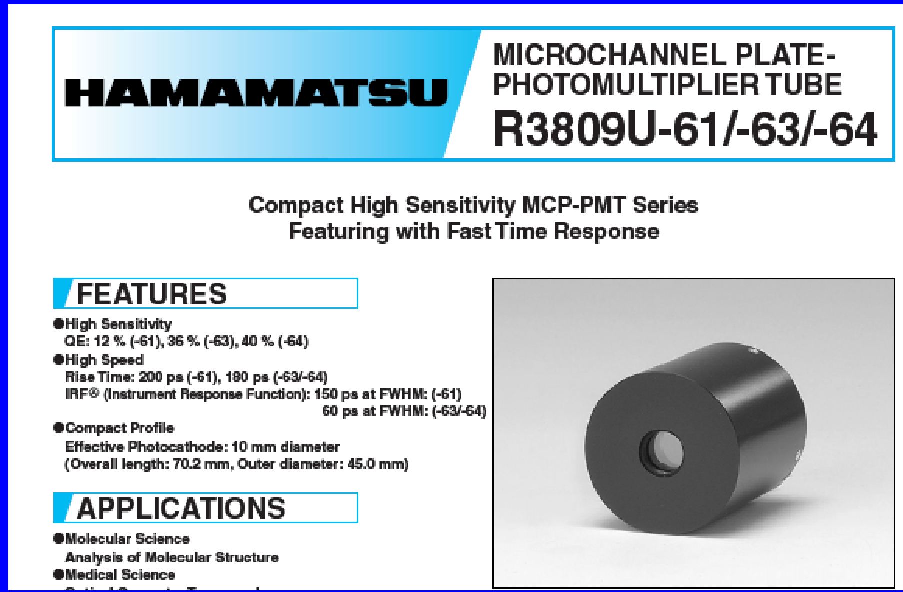
Provision for mounting:
Cylindrical Photek MCPs
Square "Burle" MCPs
4mm x 4mm SiPMs

Provision for testing "out of focus" & for varying QUARTZTOF separation:
Calibration or "speed of light over mm".

With focused light can use the best single channel MCP-PMTs
Hamamatsu or Photek.

~ 15K – 20K each!

TTS (single p.e.) < ~ 20 ps
100 prompt p.e. < ~ 2 ps


HAMAMATSU

MICROCHANNEL PLATE-
PHOTOMULTIPLIER TUBE
R3809U-61/-63/-64

Compact High Sensitivity MCP-PMT Series
Featuring with Fast Time Response

FEATURES
●High Sensitivity
QE: 12 % (-61), 36 % (-63), 40 % (-64)
●High Speed
Rise Time: 200 ps (-61), 180 ps (-63/-64)
IRF® (Instrument Response Function): 150 ps at FWHM: (-61)
60 ps at FWHM: (-63/-64)
●Compact Profile
Effective Photocathode: 10 mm diameter
(Overall length: 70.2 mm, Outer diameter: 45.0 mm)

APPLICATIONS
●Molecular Science
Analysis of Molecular Structure
●Medical Science

Photek Microchannel Plate PMT

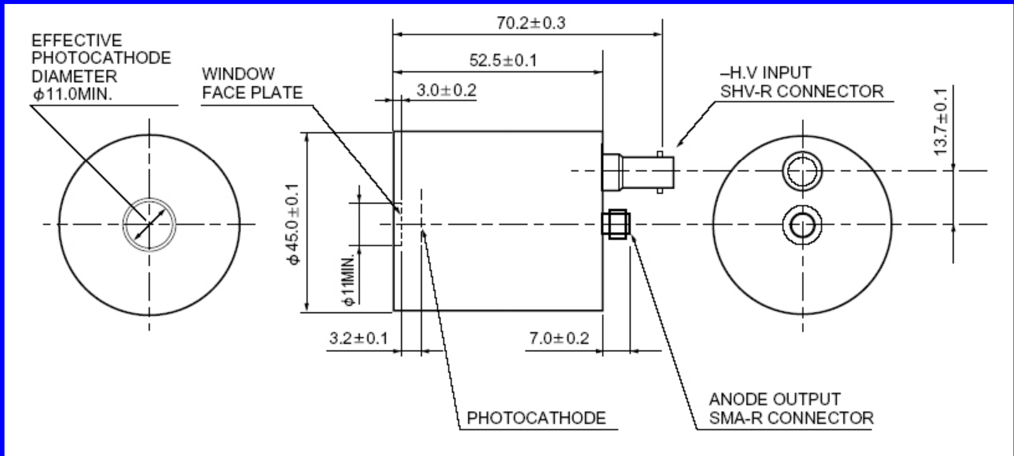
	PMT210	PMT212
Anode Size	10 mm	12 mm
Electron Gain	10^6	10^6
Peak/Valley	2:1	1.5:1
Dynamic Range cps	40,000	40,000
Pulse Rise Time	100 ps	100 ps
Pulse FWHM	170 ps	170 ps
Transit Time Jitter	30 ps	30 ps
MCP Pore Size	5/6	5/6

They are loaning us two for August

Experimental data on the reflection and transmission spectral response of photocathodes

R. J. Brooks, J. R. Howorth, K. McGarry and J. R. Powell
Photek Limited, 26 Castleham Road, St Leonards on Sea, East Sussex, TN38 9NS, United Kingdom
C.L. Joseph
Rutgers University, The State University of New Jersey, 136 Frelinghuysen Rd., Piscataway, NJ 08854, USA

Photek
www.photek.co.uk



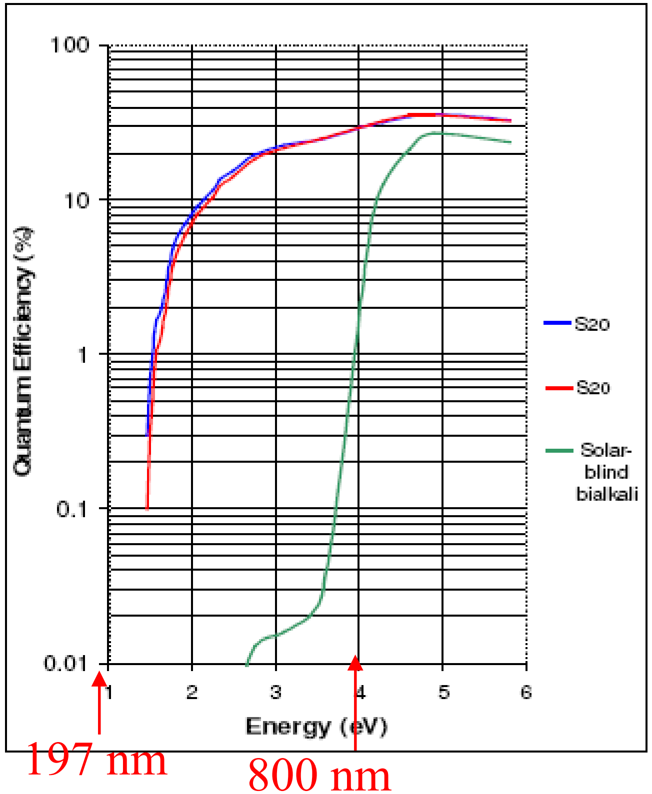
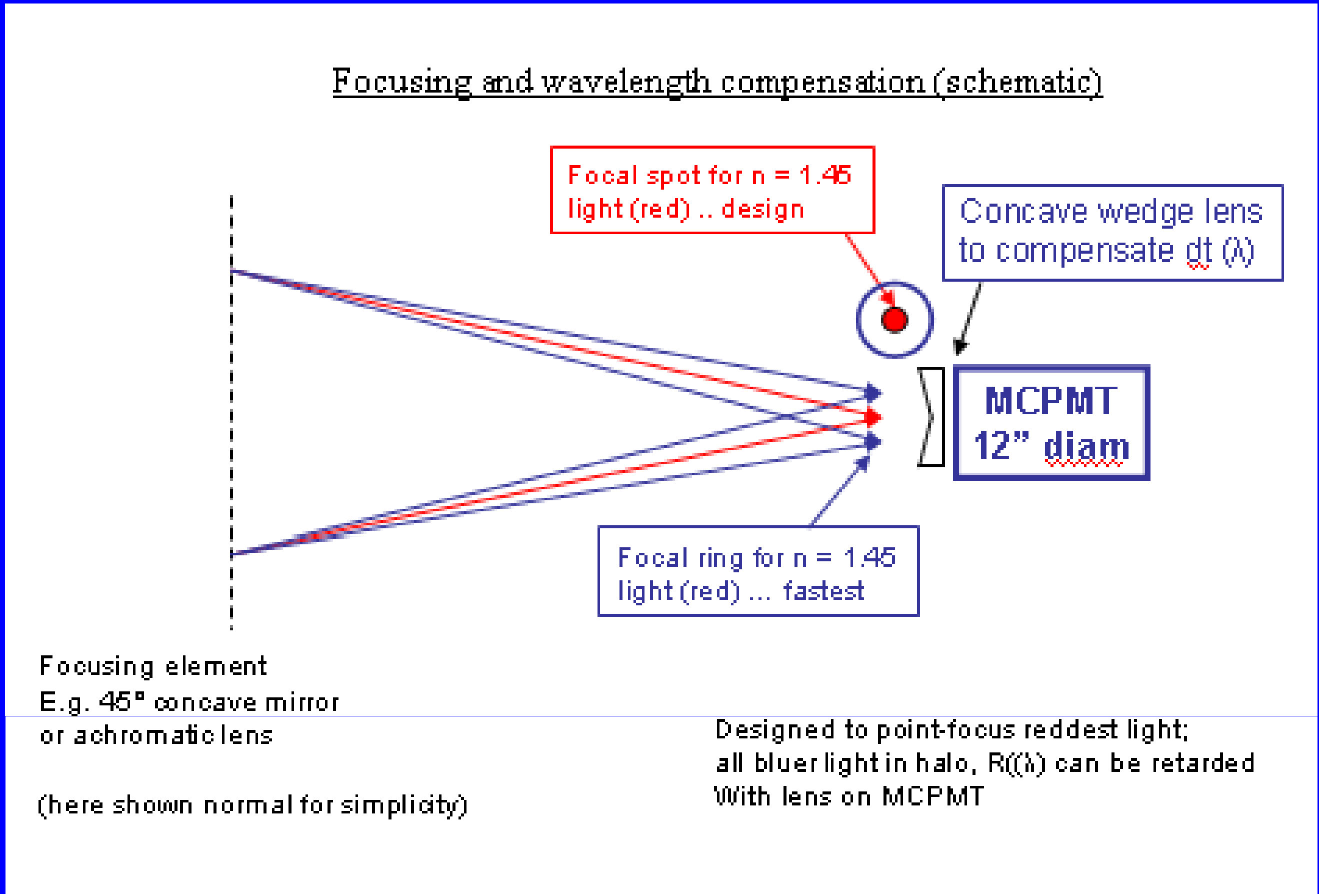


Figure G: Spectral response QE vs energy plot for S20 and solar blind tubes

10 mm, 12 mm diameter

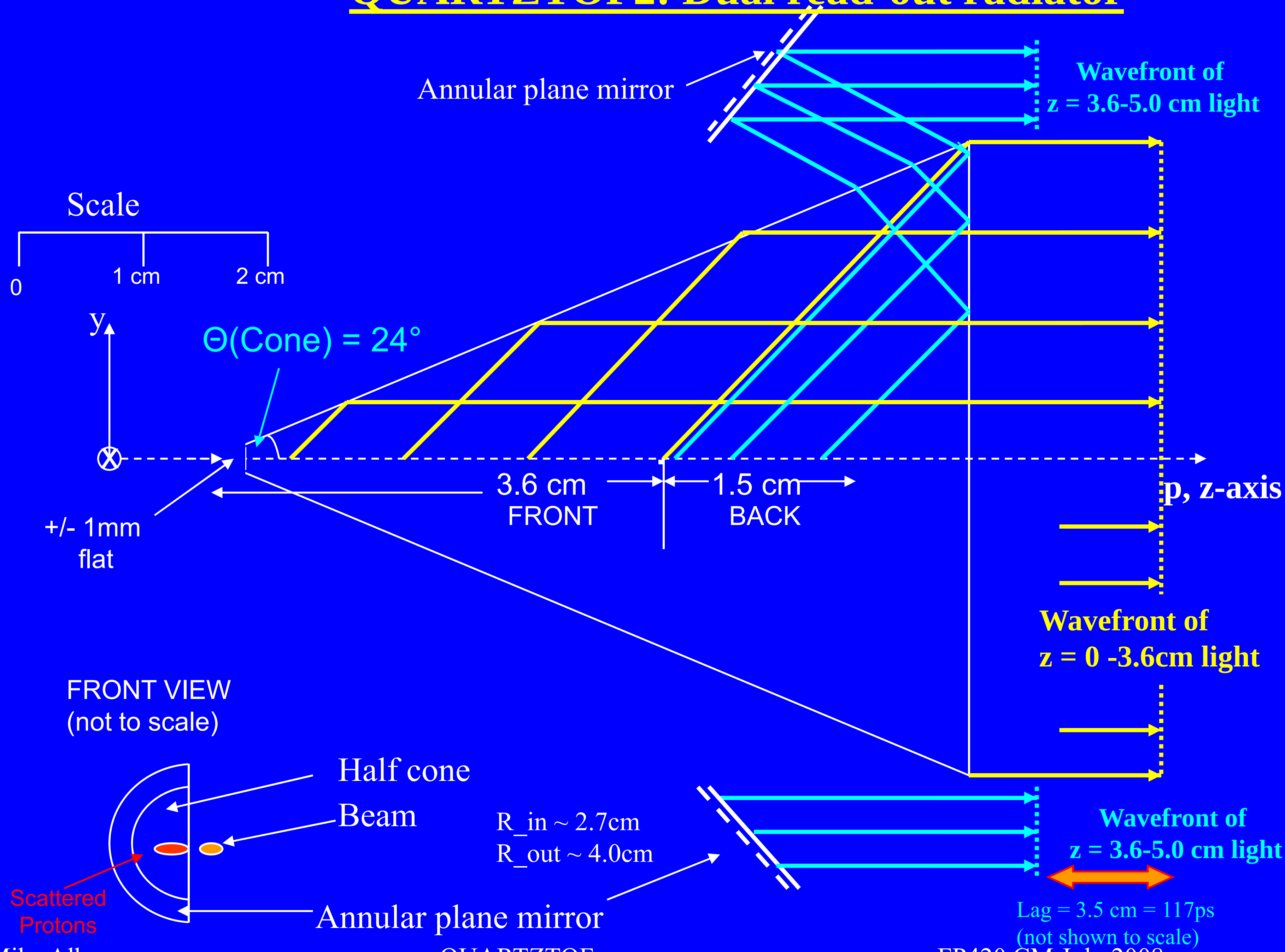
We will have two on loan for August

Light at red (blue) end of spectrum focused to a central point. Bluer (redder) light focused to concentric rings and arrives at a different time, t(r) . Spread can be compensated with a wedge lens, few mm quartz, tailored.



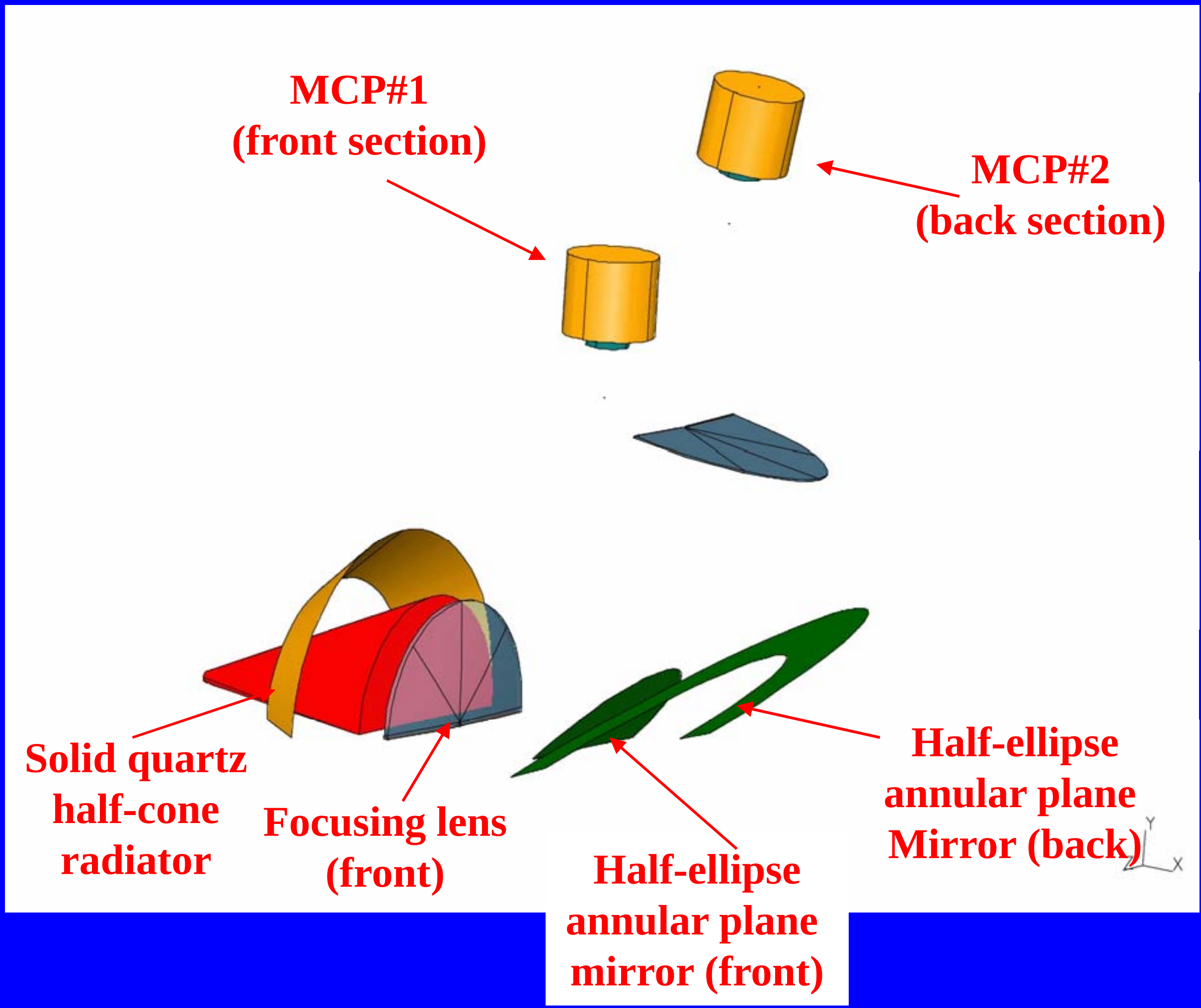
So ALL light arrives promptly at MCP! (On axis proton)

QUARTZTOF2: Dual read-out radiator



Dual readout QUARTZTOF2 (Optical Elements)

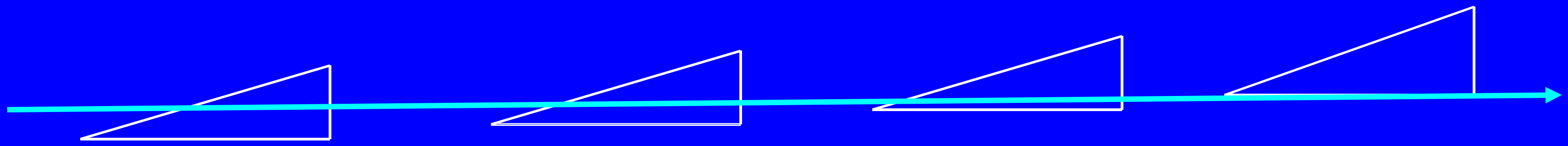
John Rauch drawings



Probably not lenses and plane mirrors, only parabolic mirrors.

Multiple QTs

Depending on performance over full x-range (~ 20 mm)
We may want a few (~ 4?) in series.
Full depth/30 mm radiator ~ 10 cm
Optimum may be 15-20 mm radiator, it scales.
Schematically:



Multiple measurements good, at least one is optimum.

Also note:
The ~ parallel beam from the parabolic mirror could be
Perhaps ~ 1 m long, so MCP's and electronics far from beam.

Plans:

Making two units, with 1 MCP-PMTs (single channel) together with state-of-art commercial electronics.
Photek and Burle MCP-PMTs and SiPMs (?)

Beam tests at Fermilab August 2008.
HV, Attenuator, Position scan, wedge lens, defocus, Delta-z…

Full simulation especially for {x,y} performance variations, with wavelength dependence of Cerenkov emission, light transmission, reflections and QE (MCP-PMT).

Perhaps < 5 ps timing is possible if electronics up to it (25ns)
Perhaps multiple protons can be measured eventually (Streaking)

Electronics for August Tests

Argonne-Chicago-Fermilab Consortium for Fast Timing studies
Karen Byrum, Henry Frisch, MA + Erik Ramberg etc.
Test beam week in June, Quartz plates on face of MCP-PMTs
Jerry Va'vra (SLAC) came.

40 GHz Tektronix scope trace recording
Two DAQ's (FERA, CAMAC)

Measured 3.8 ps TTS in MCP, 3.3 ps from Cerenkov geom,
→ better than 20 ps / detector

Same electronics for August tests.
More ideas for electronics e.g. wavelet launcher (J-Y Wu at FNAL)
John Anderson (ANL) working on ps jitter ref-time.

Remarks

Fast timing is crucial for FP420 to work.

15-20 ps may be OK for L = few x 10^33 but <~ 10 ps needed for 10^34

We have not demonstrated that yet, but we can see a way and we progress.
I am optimistic about conical QUARTZTOF, even if "sweet spot" is only a few mm^2 it should be much better than GASTOF and QUARTIC.
But we have to demonstrate it.

Longer term there could be solutions for multiple p-measurements within a bunch crossing … Streak Camera with pixel detectors. (KP idea).
Concept is there … should work in principle … some years to develop?