10 Psec Workshop April 28 at UTA

Andrew Brandt (UT-Arlington)

- **Follow up on visit to SLAC to meet Jerry Va'vra and very successful Pico-Second Timing Hardware Workshop at University of Chicago Nov. 18 2005 : sponsored by ANL (Karen Byrum) and University of Chicago (Henry Frisch) with topics including:**
  1) **What has been done to date?**
  2) **What can be done by industry (Burle and Hamamatsu) to improve the Transit Time Spread (TTS) and lower costs?**
  3) **The specs and design for readout electronics for large systems of ultra-fast TOF detectors**

- **This UTA workshop is dedicated to issues in fast TOF detectors O(10 psec), with a focus on near beam detectors at the LHC. Special attention will be paid to Burle MCP-PMT performance and readout electronics.**

- Of specific interest to FP420 is electronics and other issues involved in achieving 10-15 psec resolution, status of tube development, and fostering collaboration; hope to have significant discussion

Some Details

- http://heppc12.uta.edu/~brandta/uta-pico/uta-pico.html
- Wireless user: gstpico10 passwd: mcppmt
- outgoing smtp: mail.uta.edu
- Upload slides
- Ask questions
- VRVS Twister Room (I hope)

Agenda

- **1. Jim Horwitz (UTA)** (10') Welcome
- **2. Andrew Brandt (UTA)** (30') Workshop goals. QUARTIC.
- **3. Luc Bonnet (Louvain)** (30') GASTOF
- **4. Henry Frisch (Univ. Chicago)** (20') Large Area ps TOF systems
- **5. Jerry Va'vra (SLAC)** (40') MCP-PMT studies
-
- **11:10**coffee break

- **6. Paul Hink (Burle)** (30') Burle Update
- **7. All** (20') Discussion
- **8. Mike Albrow (Fermilab)** (10') Timing references

- **12:30**Lunch

- **9. Jim Pinfold (Univ. Alberta)** (20') QUARTIC timing circuit
- **10. All** (30') Discussion of fast timing circuits, amplis, Burle tubes, Collaboration UTA/UC/SLAC/UA etc.
- **14:20**coffee break
- **11. All** (xh00') More discussion, open ended

FP420/QUARTIC

Andrew Brandt (UT-Arlington), Mike Albrow (FNAL),
Jim Pinfold (Alberta)

FP420 LOI to LHCC signed by 29 institutes from 11 countries - more joining

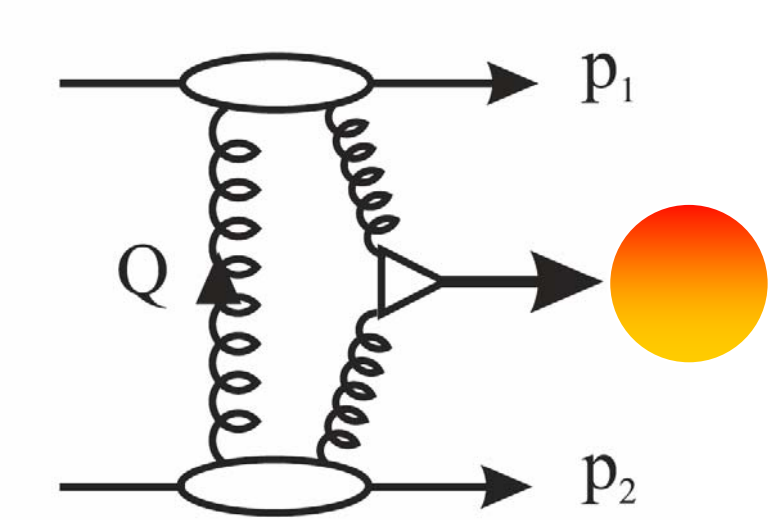
The aim of FP420 is to install high precision silicon tracking and fast timing detectors close to the beams at 420m from ATLAS and / or CMS

"The LHCC acknowledges the scientific merit of the FP420 physics program and the interest in its exploring its feasibility." - LHCC

"The panel believed that this offers a unique opportunity to extend the potential of the LHC and has the potential to give a high scientific return." - UK PPRP (PPARC) {500,000 Λ ! }

FP420 Overview

FP420: Double proton tagging at 420m as a means to discover new physics



- Tagging the protons means excellent mass resolution (~ 1 to few GeV) independent of decay channel
- Selection rules mean that central system is dominantly 0^{++} (CP even)
- If you see a new particle in any decay channel with proton tags, you know its quantum numbers
- Proton tagging may be ***THE*** discovery channel in certain regions of the MSSM

Used to be called Double Pomeron Exchange

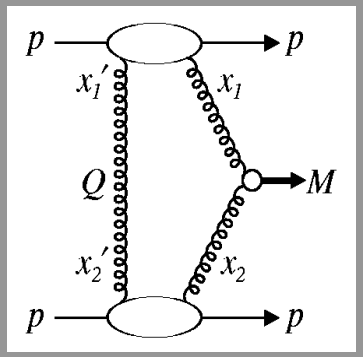
now Central Exclusive Diffraction

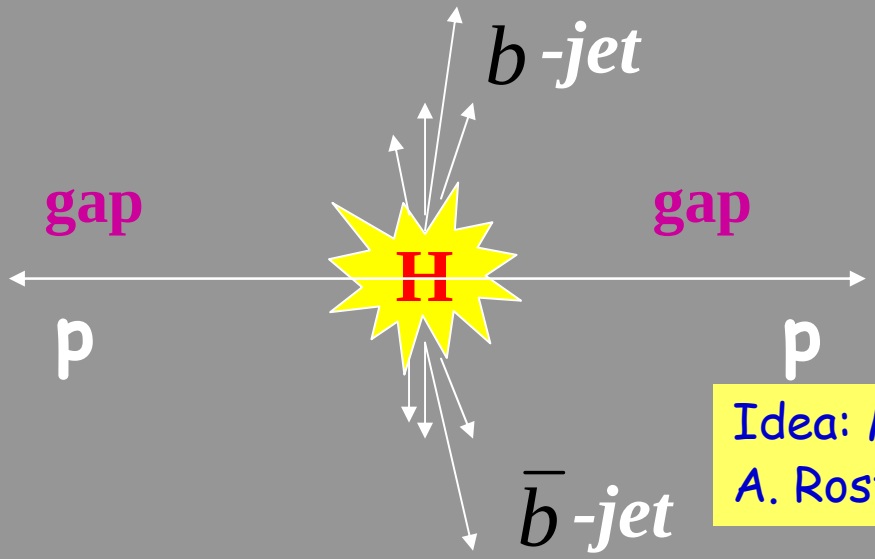
0^{++} Selection rule

$$\frac{m_b^2}{E_T^2}\frac{\alpha_S^2}{M_{b\bar{b}}^2 E_T^2}$$

Central Exclusive Higgs Production

$pp \rightarrow p\,H\,p$: 3-10 fb



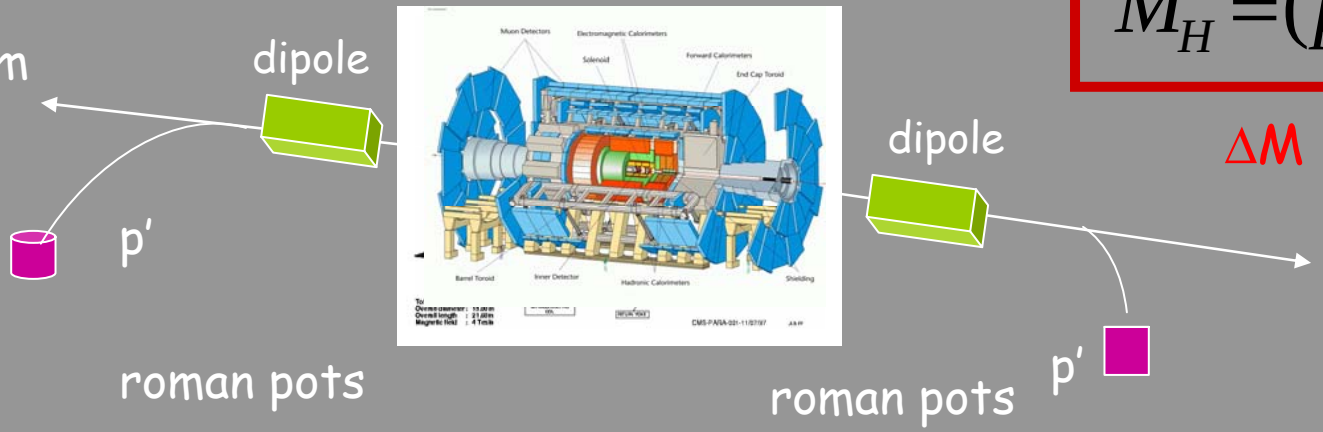


E.g. V. Khoze et al
M. Boonekamp et al.
B. Cox et al.
V. Petrov et al...
Levin et al...
η

Idea: M. Albrow & A. Rostovtsev forTevatron

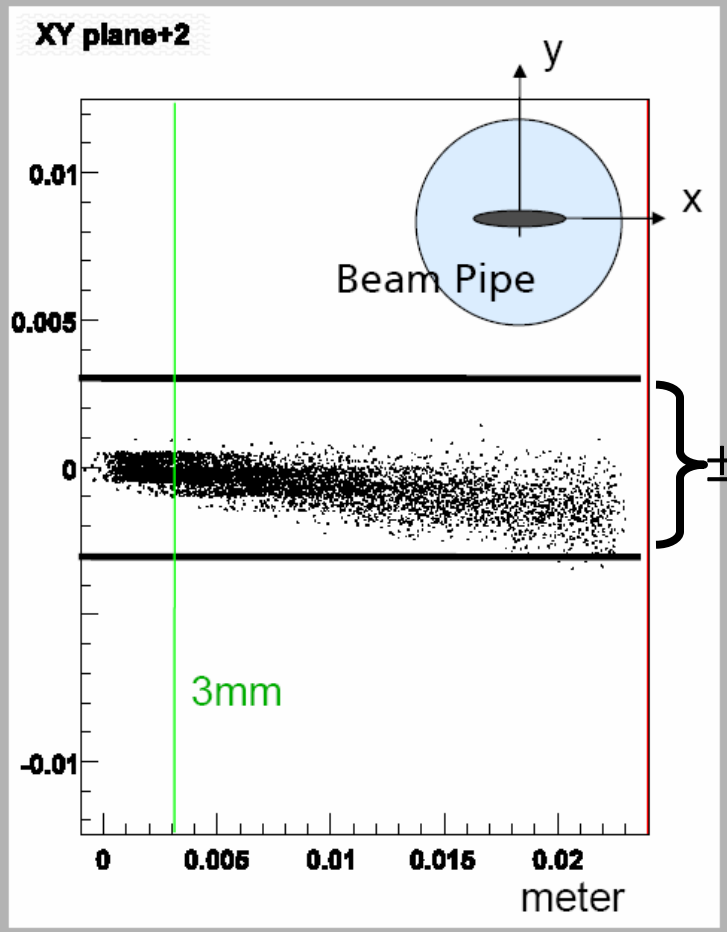
$$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$$

ΔM = O(1.0 - 2.0) GeV

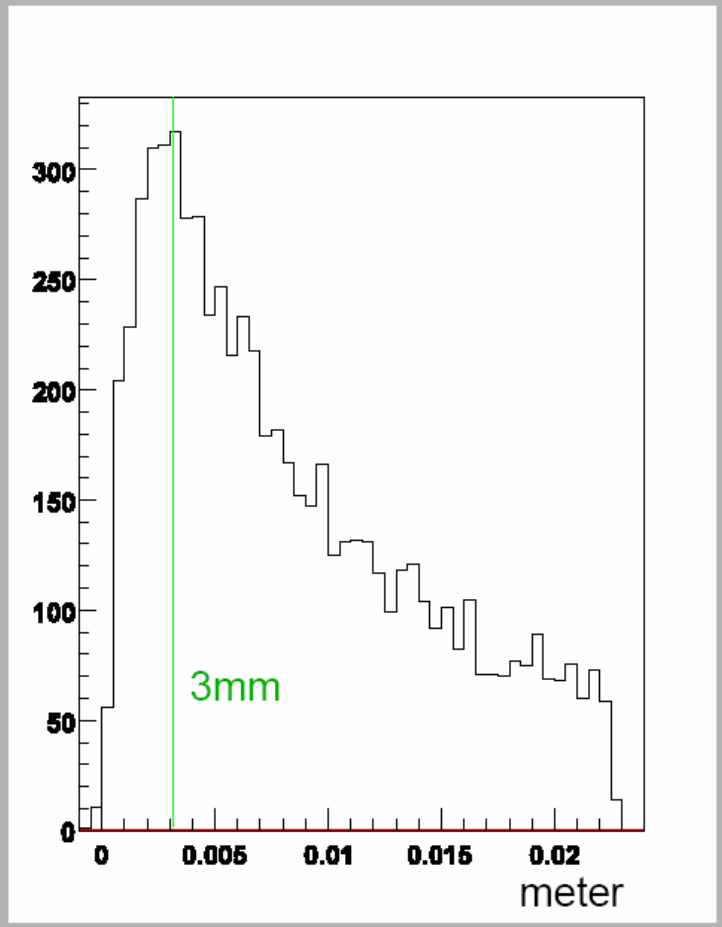


Where do Protons go at 420m?

120 GeV Higgs courtesy Peter Bussey, Manchester.

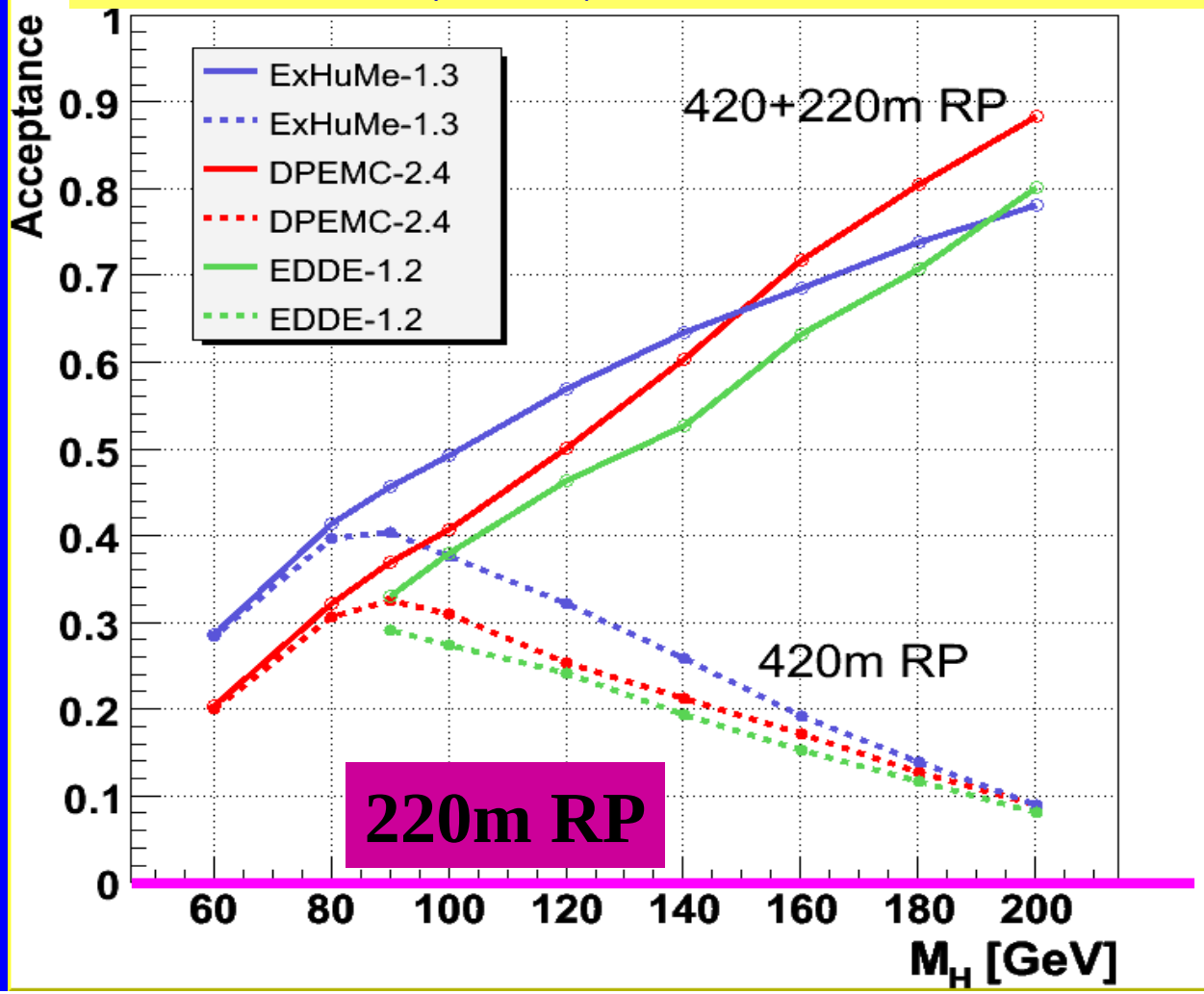


±3 mm



Higgs Acceptance vs. Mass (M_H)

Helsinki Group study for TOTEM and FP420



Low β^*: (0.5m): Lumi 10^{33}-10^{34}cm^{-2}s^{-1}

220m: $0.02 < \xi < 0.2$

400m: $0.002 < \xi < 0.02$

RPs in the cold region/FP420 are needed to access the low ξ values

Physics of FP420

- At low luminosity (~ 30 fb-1) we can :

  Establish the quantum numbers of SM Higgs

  Be the discovery channel in certain regions of the MSSM

  Make high precision measurements of $\gamma\gamma \rightarrow WW$ / ZZ couplings

  Perform interesting QCD measurements ($0.002 < xIP < 0.015$)

- In addition, at higher luminosity (~ 100 fb-1) we can :

  Discover exotic bound states such as gluinoballs

  Make direct observation of CP violation in some SUSY Higgs scenarios

  Disentangle wide range of SUSY scenarios, including ~degenerate Higgs

- FP420 turns the LHC into a energy tunable glue-glue (and $\gamma\gamma$) collider

FP420 Challenges

- VACUUM MECHANICS

  Integration of detectors into accelerator.
  Modification of existing cryostat.
  Development of roman pot mechanics.

- TRACKER,

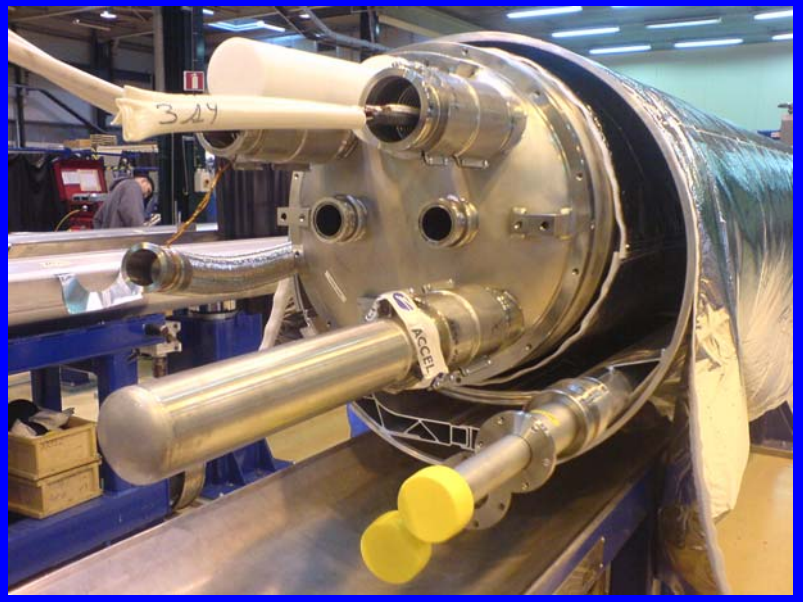
  3D silicon. For momentum measurement.
  10 um precision
  Acceptance to the edge of the detector.

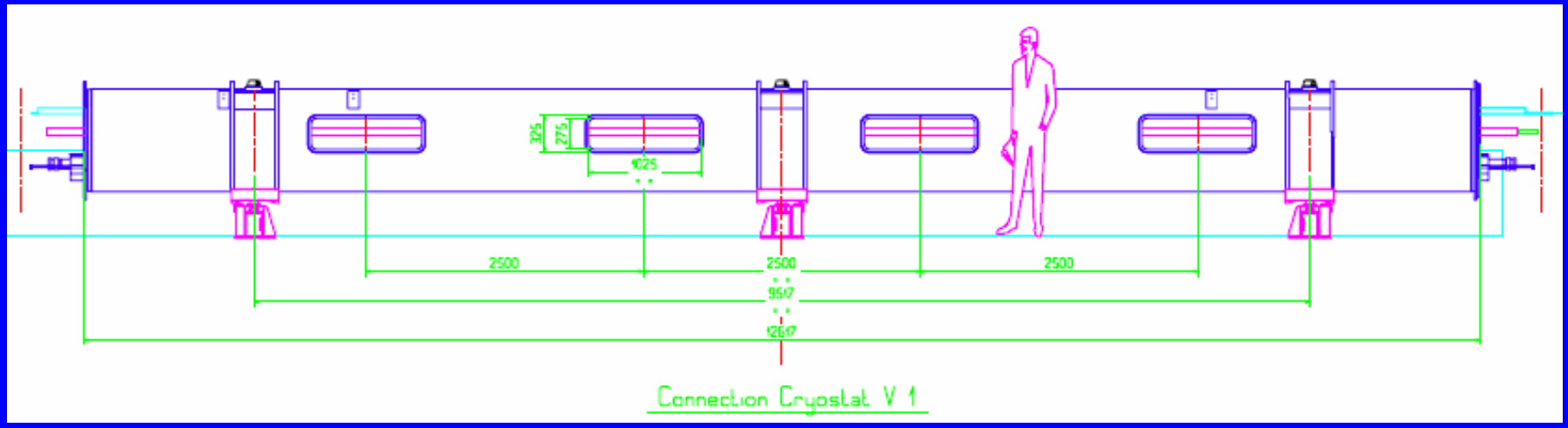
UK
500k£ R&D grant
+
Helsinki
+
Louvain

- TIME OF FLIGHT COUNTER

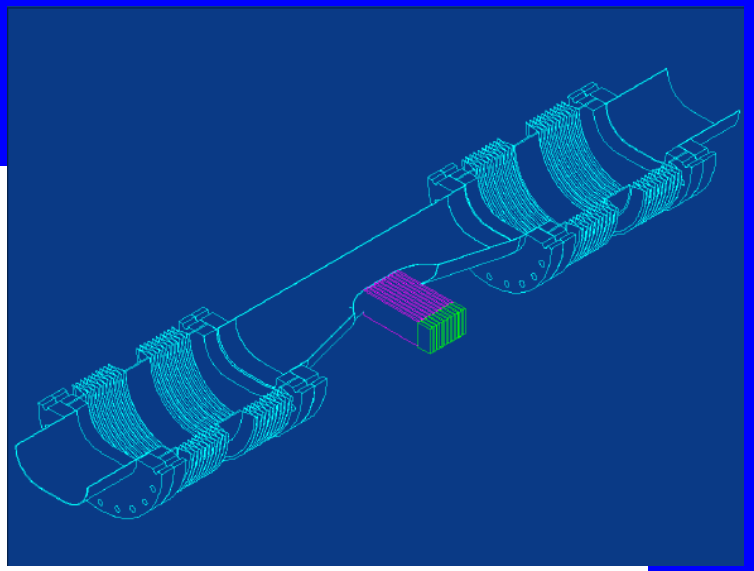
  UTA / Alberta / FNAL

The 420m region at the LHC





Movement Mechanism Designs



UTA News

- Formed group with 2 undergrads and grad student
- Calculated background rejection as f(resolution)
- Calculated light output
- Calculated time distributions for different configurations
- Poster session at UTA leads to EE contacts
- Pico-sec workshop in November (short but valuable)
- SLAC trip in March to visit Jerry Va'vra
- Ordered quartz
- Submitted DOE ADR 12/15/05
  $100k/2 years; June notification, elec+students
- Submitted internal pre-proposal for Texas ARP;
  11/30/05 approved for ARP submission (12/79!)
  2/14/05 full proposal; 4/20/05 decision;

FUNDED!

5/15/05 funds $100k/2 years
mechanics+pulser+students

Fast TOF

Available online at www.sciencedirect.com
SCIENCE DIRECT®
Nuclear Instruments and Methods in Physics Research A 528 (2004) 763–775
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

MCP-PMT timing property for single photons

M. Akatsu, Y. Enari, K. Hayasaka, T. Hokuue, T. Iijima, K. Inami*, K. Itoh, Y. Kawakami, N. Kishimoto, T. Kubota, M. Kojima, Y. Kozakai, Y. Kuriyama, T. Matsuishi, Y. Miyabayashi, T. Ohshima, N. Sato, K. Senyo, A. Sugi, S. Tokuda, M. Tomita, H. Yanase, S. Yoshino

Department of Physics, High Energy Physics Laboratory, Nagoya University, Furo-Cho, Chikusa, Nagoya 464-8602, Japan

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Abstract

We have measured the performance, especially the timing properties, of micro-channel plate photo-multiplier tubes (MCP-PMTs) by irradiating with single photons with/without a magnetic field. A time resolution of $\sigma \sim 30$–35 ps was obtained for single photons under 1.5 T. With an MCP-PMT, a small time-of-flight counter by means of Cherenkov light radiation instead of scintillation light has been prepared, and a time resolution $\sigma \sim 10$ ps was attained for a high-energy π-beam by multiple photons.

It's been done!

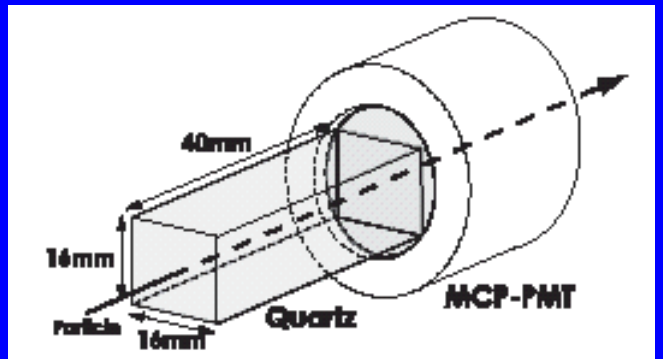


Fig. 12. Schematic drawing of the test TOF counter. HPK10 is used as the MCP-PMT.

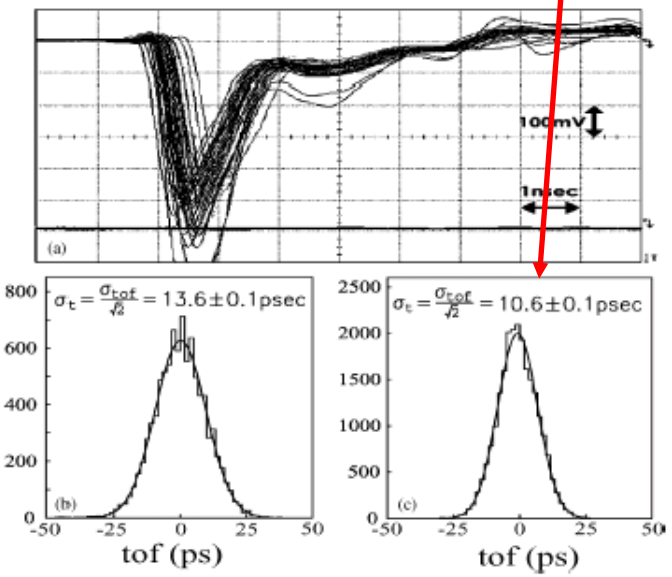


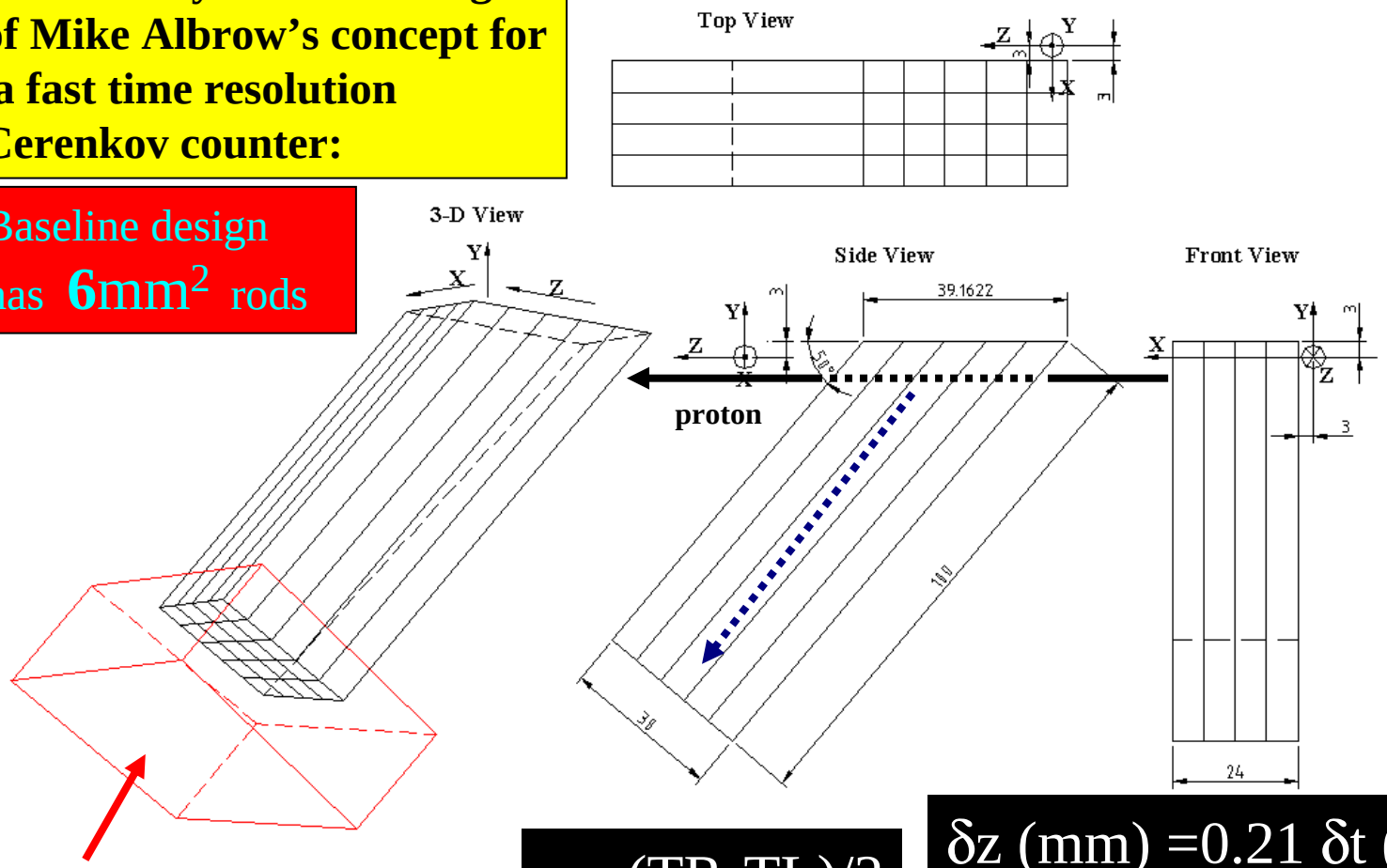
Fig. 13. (a) shows HPK 10s output signal for 3 GeV/c pion beam; (b) and (c) are the distributions of the time difference between two counters without and with a quartz radiator, respectively. Their resulting time resolutions of the single counter are obtained as $\sigma_t/\sqrt{2} = 13.6 \pm 0.1$ ps and 10.6 ± 0.1 ps.

Can't put our PMT in 7 TeV beam!

QUARTIC Update

Preliminary UTA drawing of Mike Albrow's concept for a fast time resolution Cerenkov counter:

Baseline design has $6mm^2$ rods

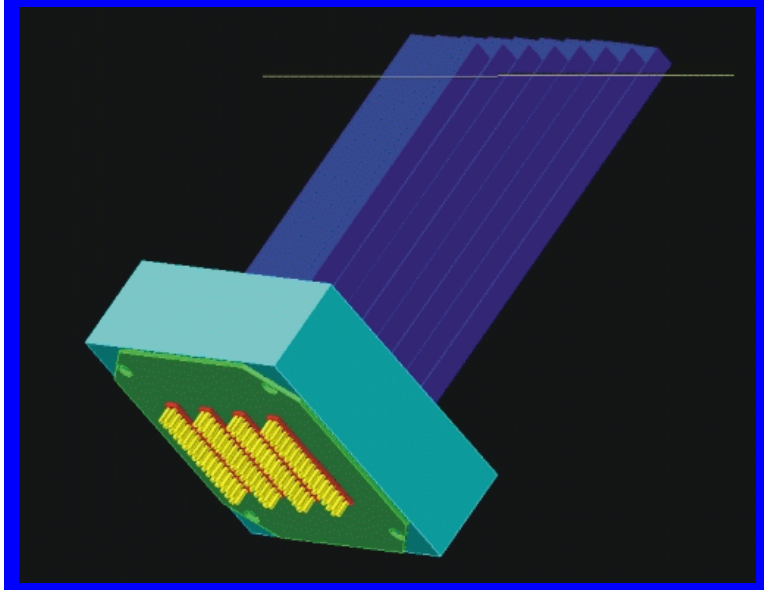


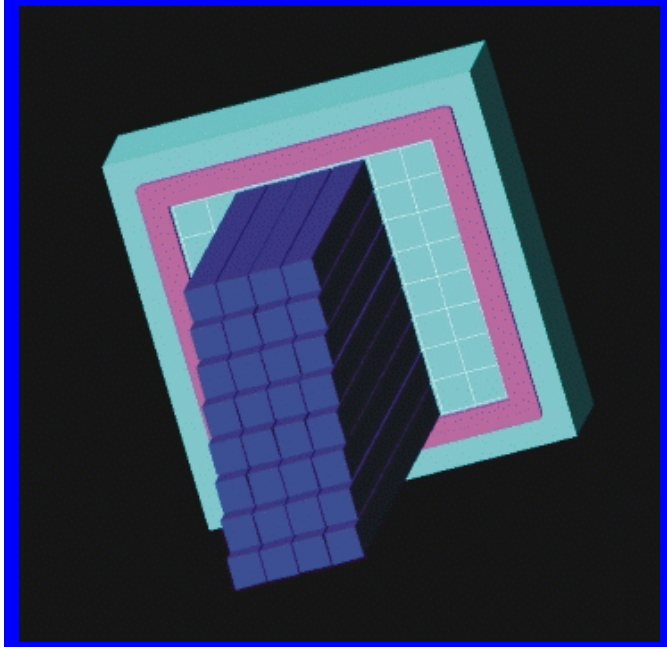
Microchannel plate PMT

$z=c(TR-TL)/2$

δz (mm) $=0.21\ \delta t$ (psec)
(2.1 mm for $\delta t=10$ psec)

New Drawings



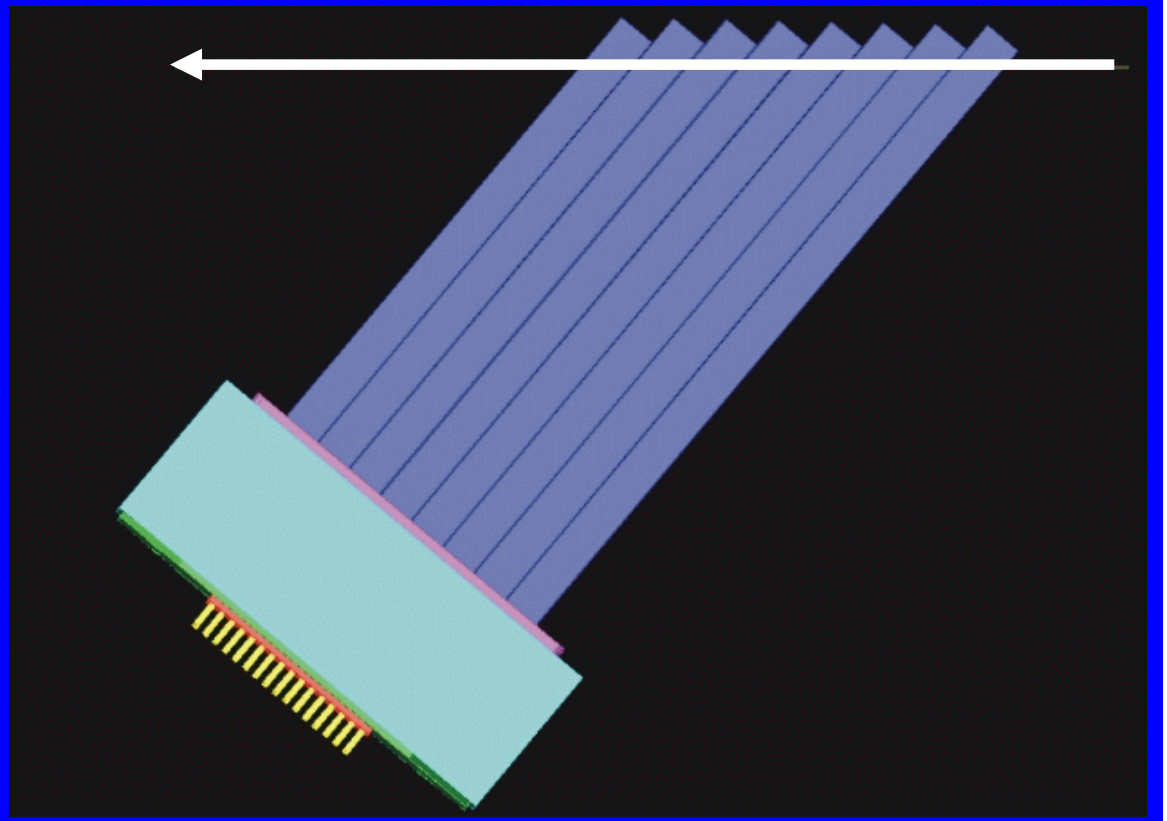


courtesy of:

Jaak Lippma

Helsinki

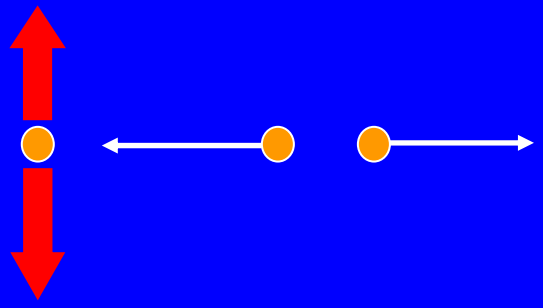
- Sawtooth easier to fabricate
- 8 rods in z



QUARTIC Background Rejection

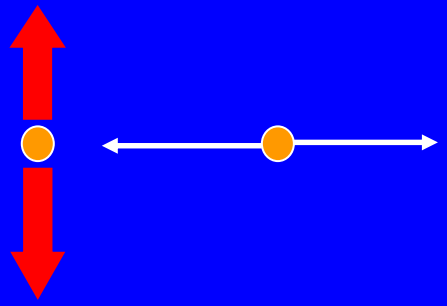
Pedro Duarte

1) 2 single diffractive protons overlayed with a hard scatter (1% of interactions have a proton at 420m)



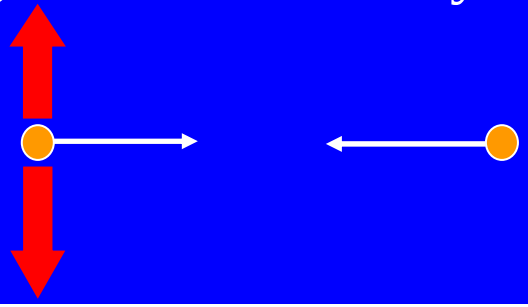
97.4% of events primary vertex and fake vertex from combining proton times more than 2.1mm (1σ) apart ; 94.8% if 20 psec

2) double pomeron overlayed with a hard scatter



97.8% of time vertices more than 2.1mm apart; 95.6% if 20 psec

3) hard SD overlayed with a soft SD



95.5% of time primary vertex and fake vertex more than 2.1mm apart; 91.0% if 20 psec

Background Rejection

- Big issue is fake background, not multiple proton background, we do not know absolute magnitudes
- What I think is needed: generate inclusive SD +DPE (Phojet, other), Hard SD (Pomwig/other), inclusive Higgs (no protons Herwig/Pythia), SD Higgs (Pomwig/other)
- Track protons to 420m
- Apply kinematic constraints, comparison of missing mass to central mass, apply additional constraints from timing and see to what luminosity FP420 is feasible
- Some of this work has been done by TOTEM, I am organizing WG to follow up on this

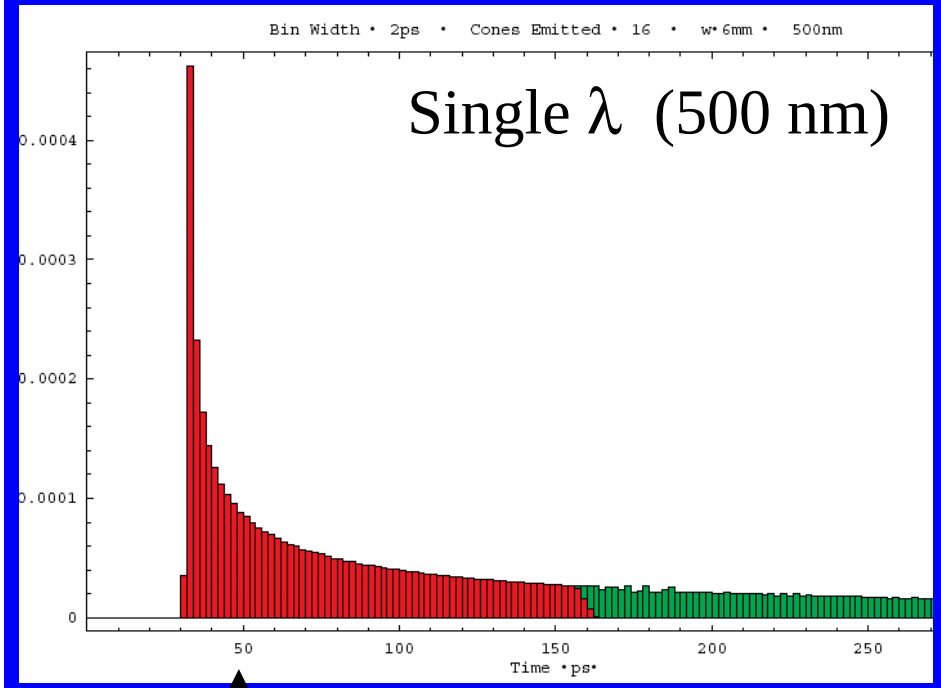
QUARTIC Design

- Baseline detector: 4x8 6mm square rods of fused silica
- In z consider 4@12 mm instead of 8@6 mm
- In x consider 16 x 1.5 mm (needs 1032 tube)
- Consider limiting wavelength range
- Larger n to get more light
- Gallium arsenide to improve QE for visible
- Surfaces aluminized or spaced

Continuing studies while awaiting definitive answer from simulations (GEANT) and/or test beam:

Time resolution for the full detector system:
1. Intrinsec detector time resolution
2. Jitter in PMT's
3. Electronics (TDC)

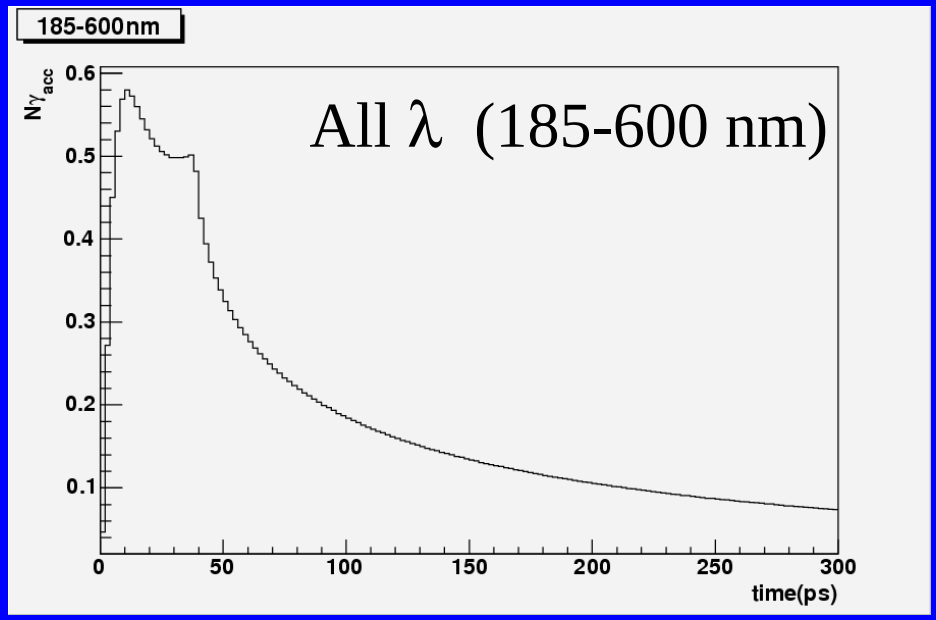
Preliminary Time Distributions (UTA):



50 psec

red = totally internally reflected light

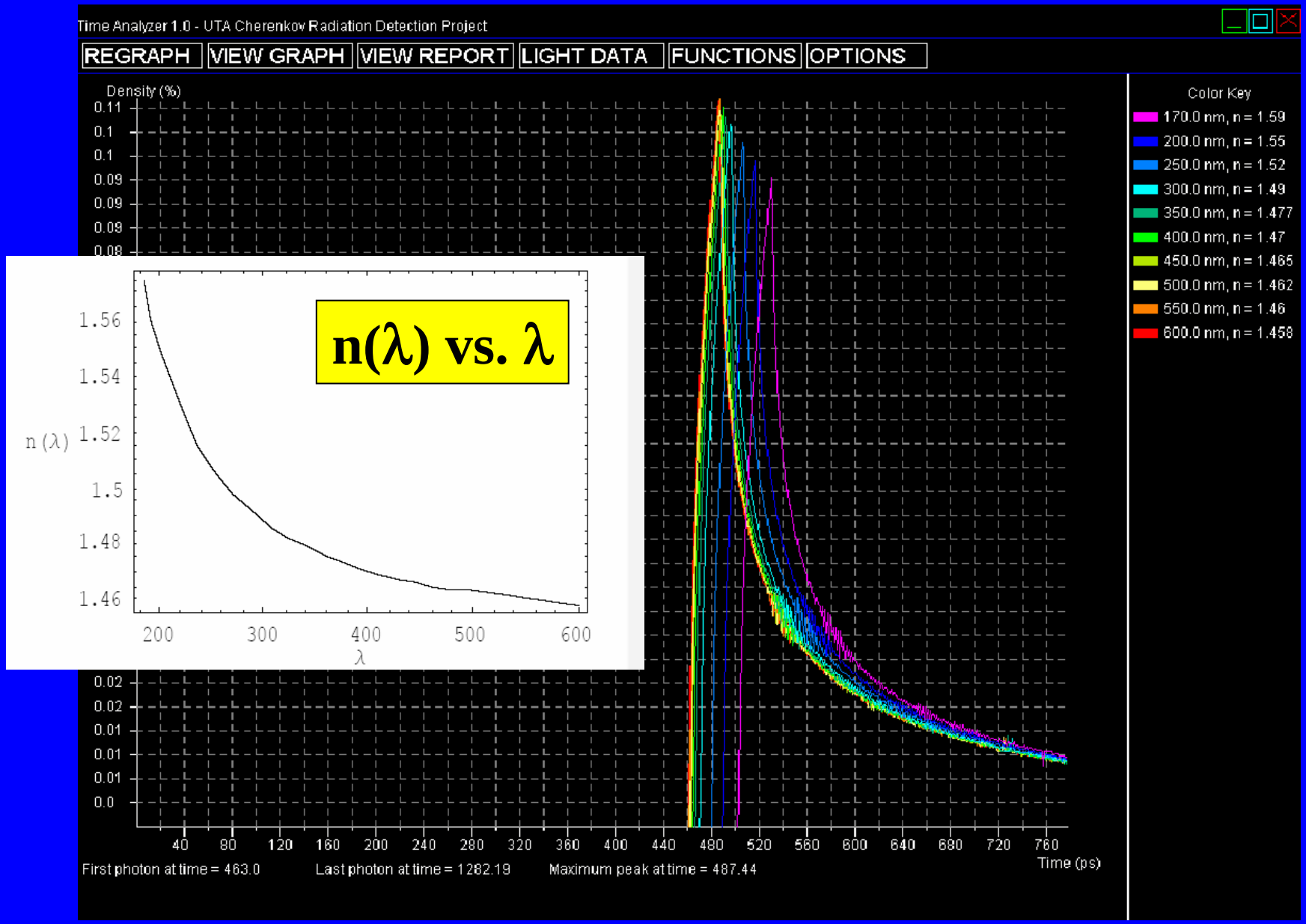
green = extra light if aluminized



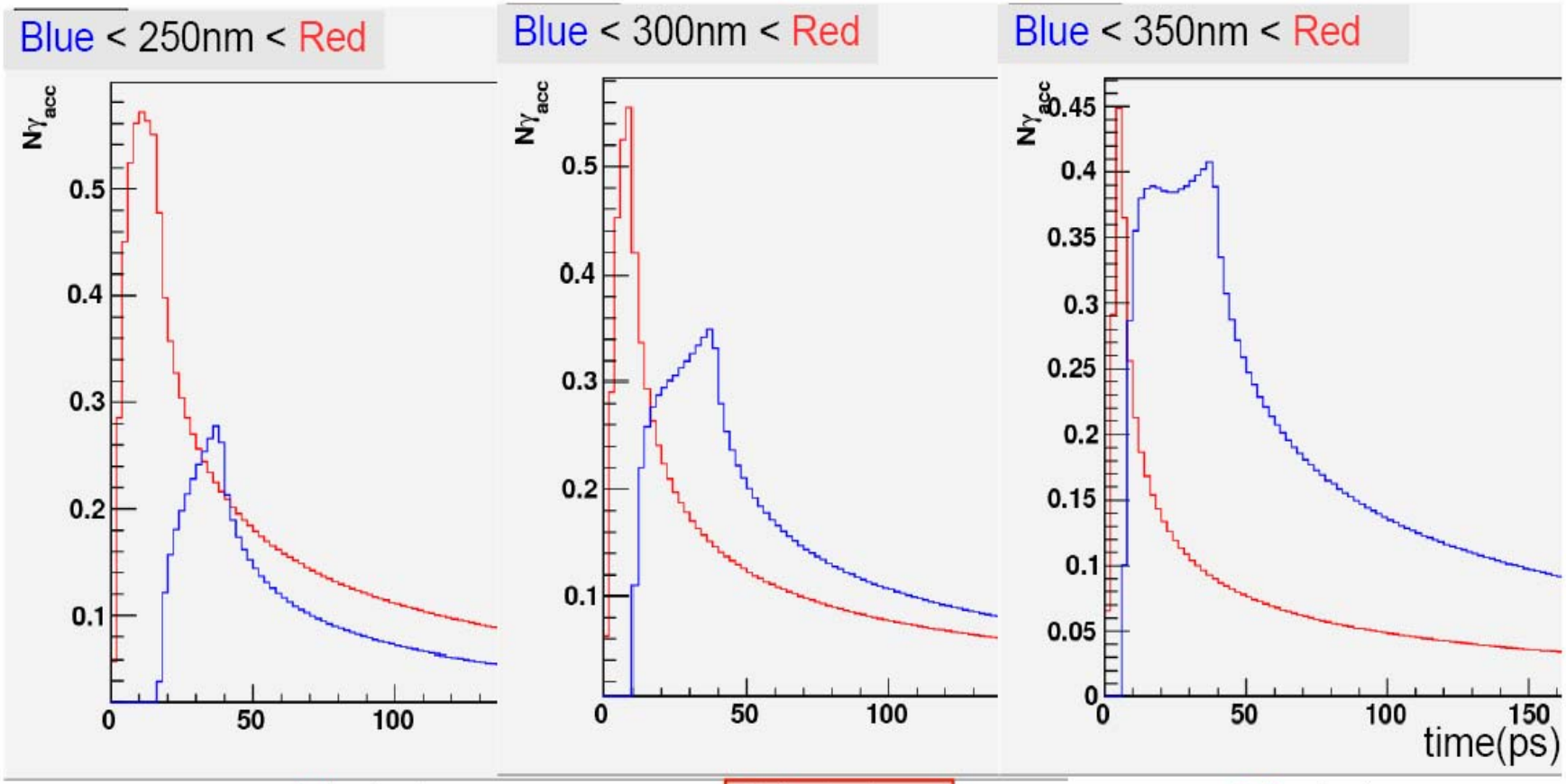
Not enough light in leading edge; peak to wide!

Time Distributions by Wavelength

Joaquin Noyola

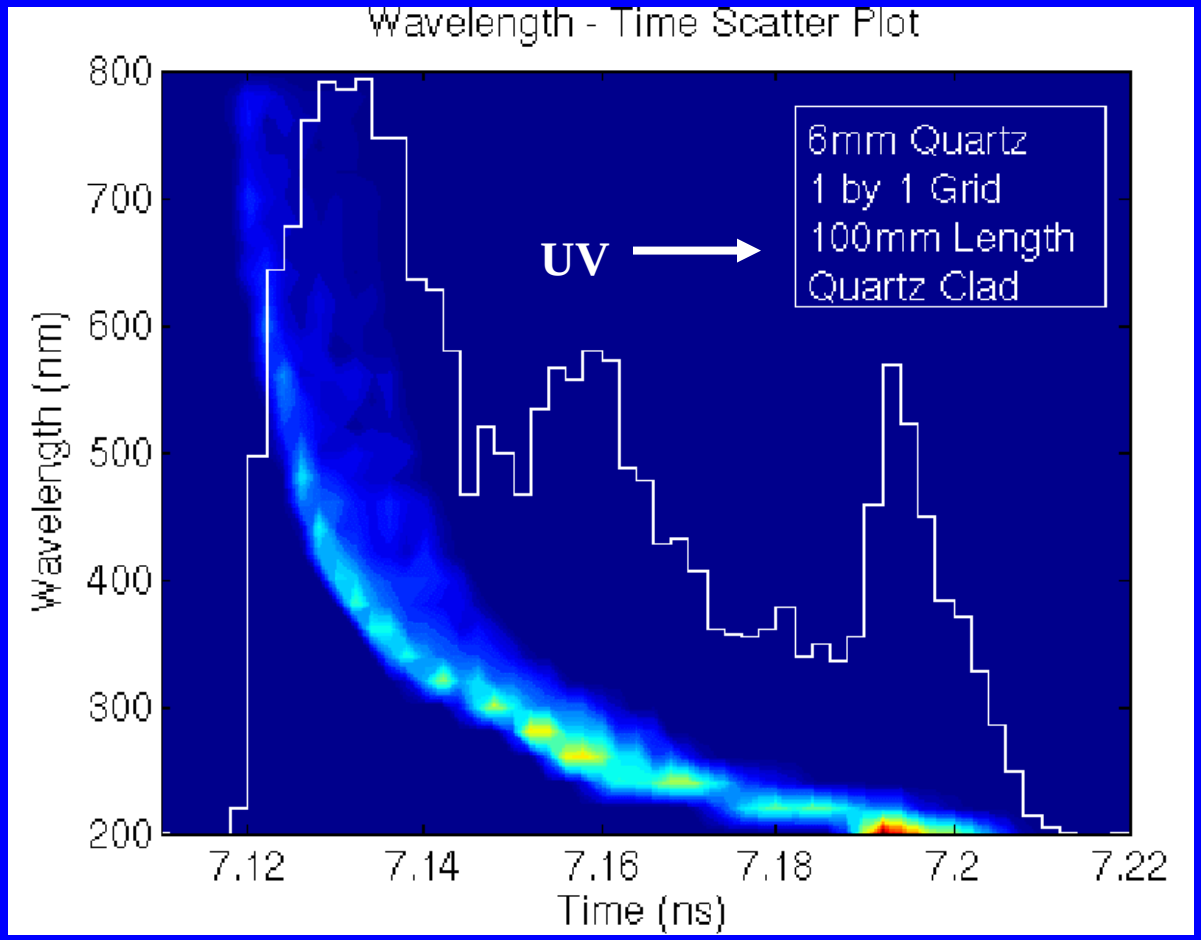


Cerenkov Light in Fused Silica with Filtering



	Blue < 250nm < Red	Blue < 300nm < Red	Blue < 350nm < Red
FIRST 20ps	4.4 photons 1.9 photon	3.4 photons 2.7 photons	2.3 photons 3.4 photons
WIDTH	30 ps 34 ps	18 ps 48 ps	12 ps 56 ps

Geant Simulation (Alberta)

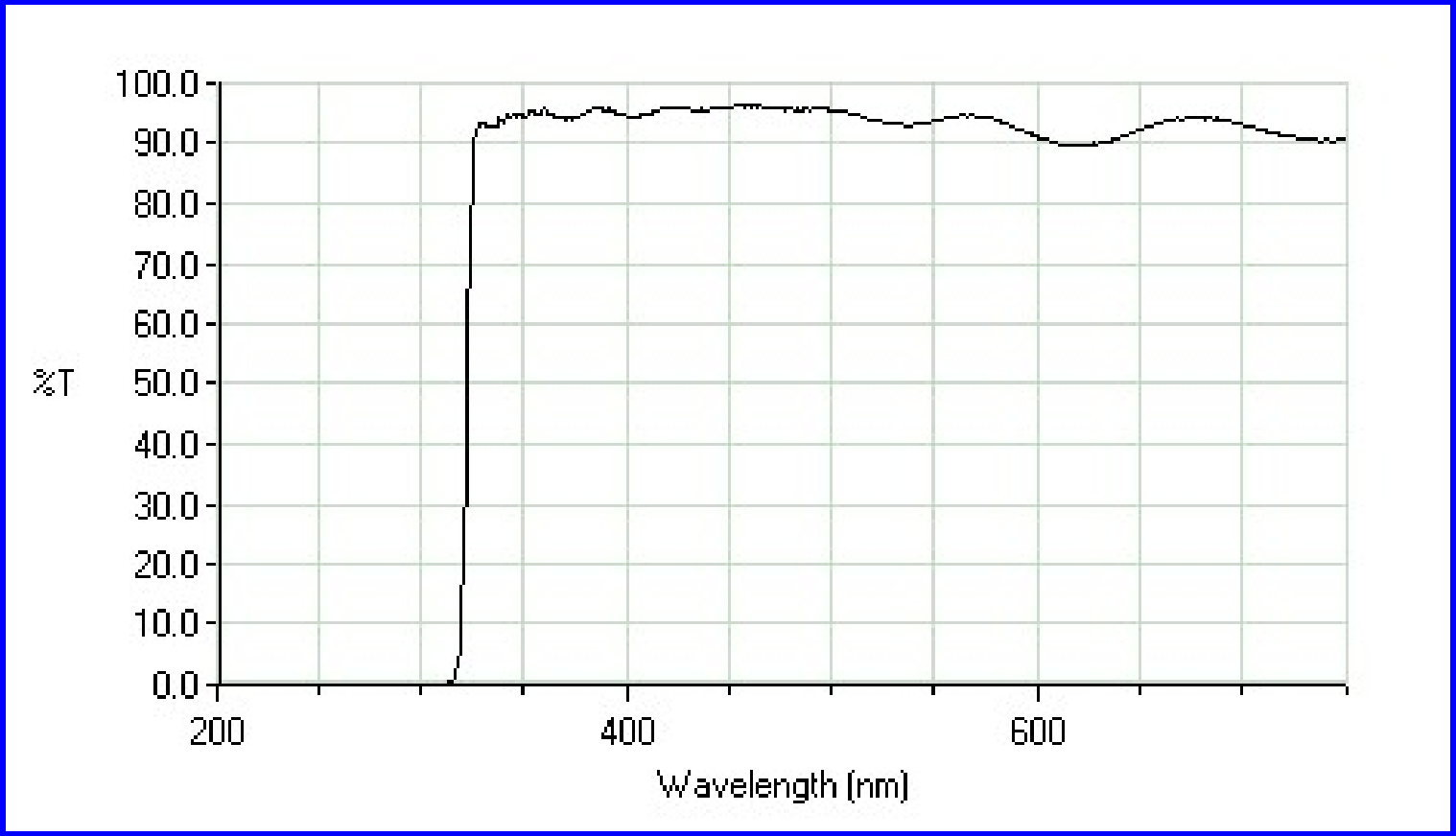


(Yushu Yao)

Longer wavelengths arrive first, UV light does not help timing much

Lumpiness under study—geometric affect?

Filter Solution?



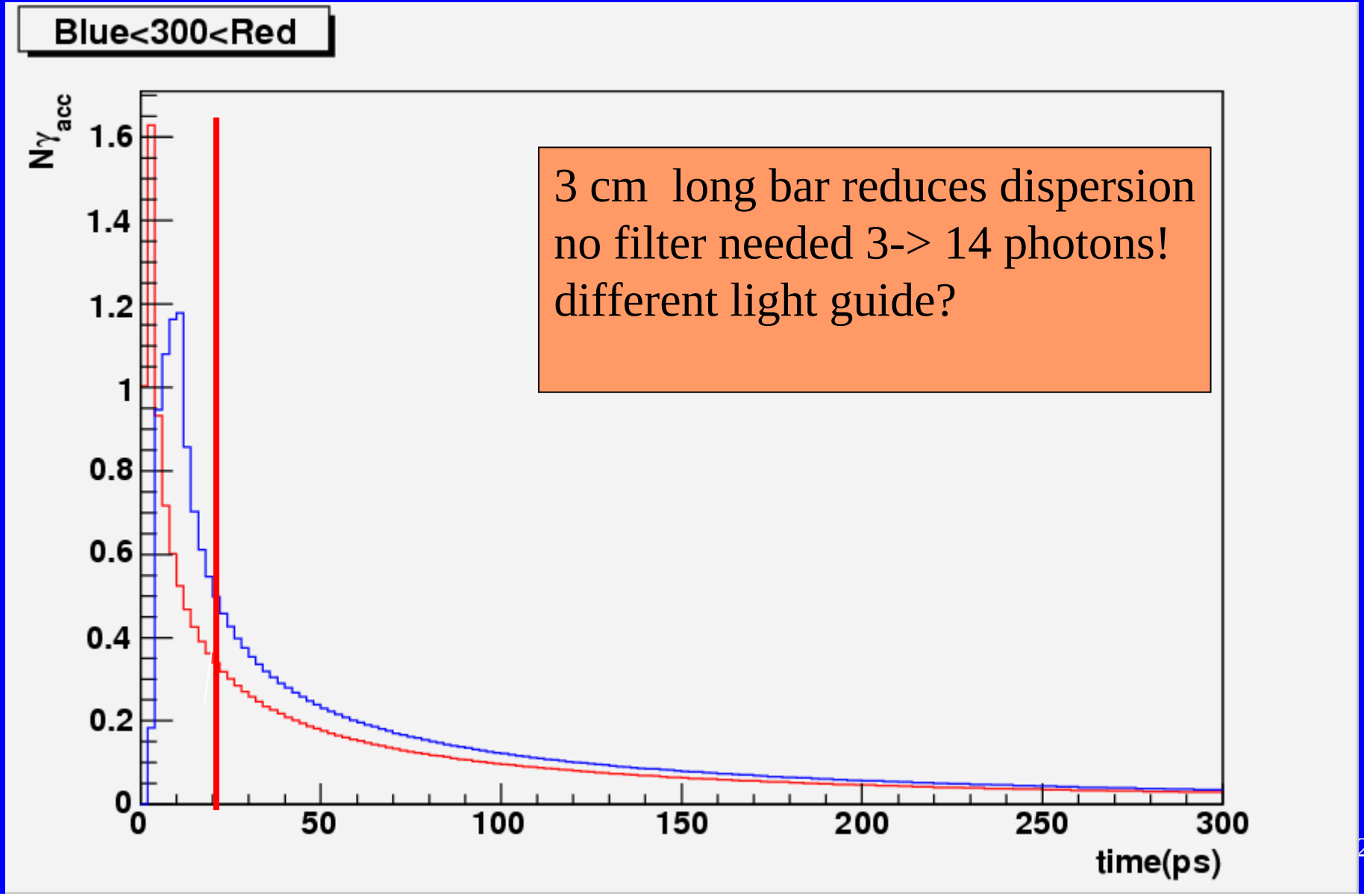
$?

- Chroma Technology Corp
- http://www.chroma.com

Some Variations

- Larger n (1.8) does not give more timely light, larger angle so less effective width, a little more light but later
- 12 mm bars give a little more than twice the fast light (about 7 photons for >300nm case)

Short Bars?



3 cm long bar reduces dispersion
no filter needed 3-> 14 photons!
different light guide?

Fused Silica Purchase

Specialty Glass Products, Inc:

5. Fused Silica Rod; 6mm+-.051mm square; 9cm+-.0254cm long; 6mm x 9cm sides mechanically polished finish, within 1° parallelism and perpendicularity and less than or equal to 1 wave/inch flat; one end mechanically polished finish.

Quantity 8 pieces

Price $39.00 each

6. Fused Silica Rod; 6mm+-.051mm square; 9cm+-.0254cm long; 6mm x 9cm sides mechanically polished finish, within 1° parallelism and perpendicularity and less than or equal to 1 wave/inch flat; both ends mechanically polished finish.

Quantity 24 pieces

Price $36.00 each

Technical Glass Products, Inc:

I) Fused silica n~1.5

lengths for a set are 90,95,100,105,110,115 mm

a) high transmission over range 180-700 nm

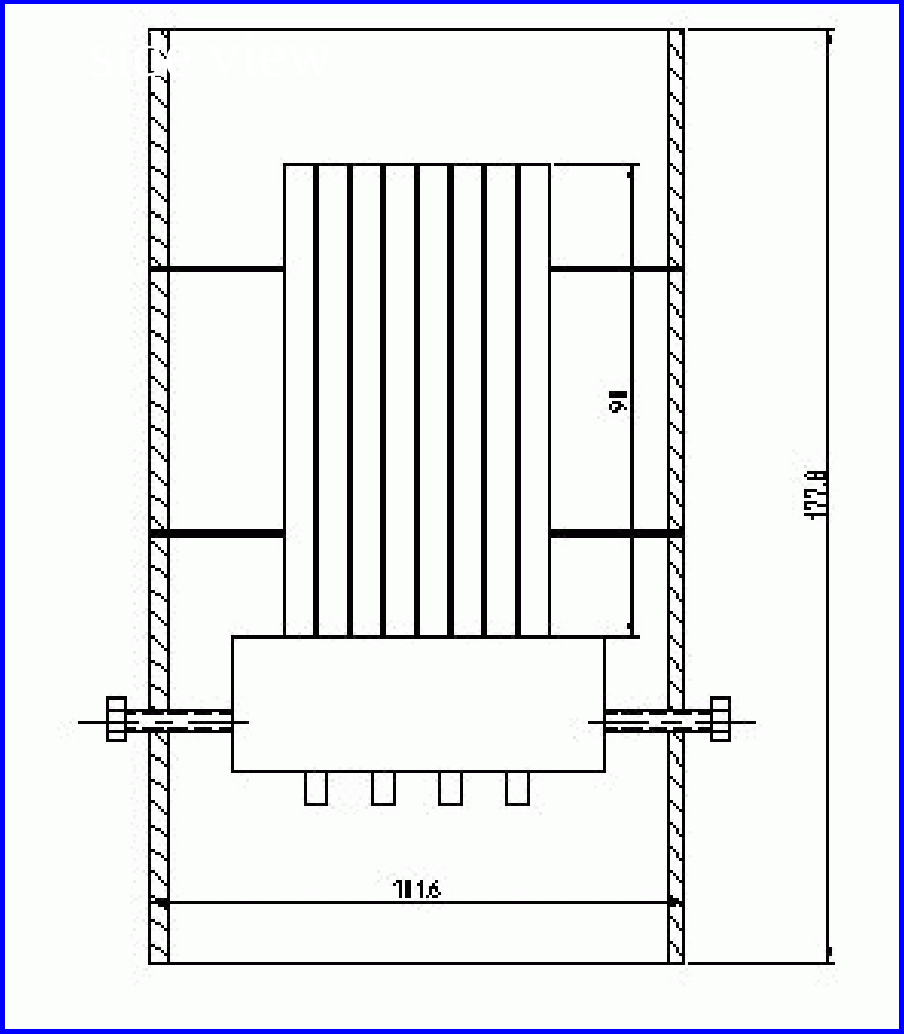
i) 4 sets polished on all faces ***$2,565.00 per set* (GASP)**

QUARTIC Timeline

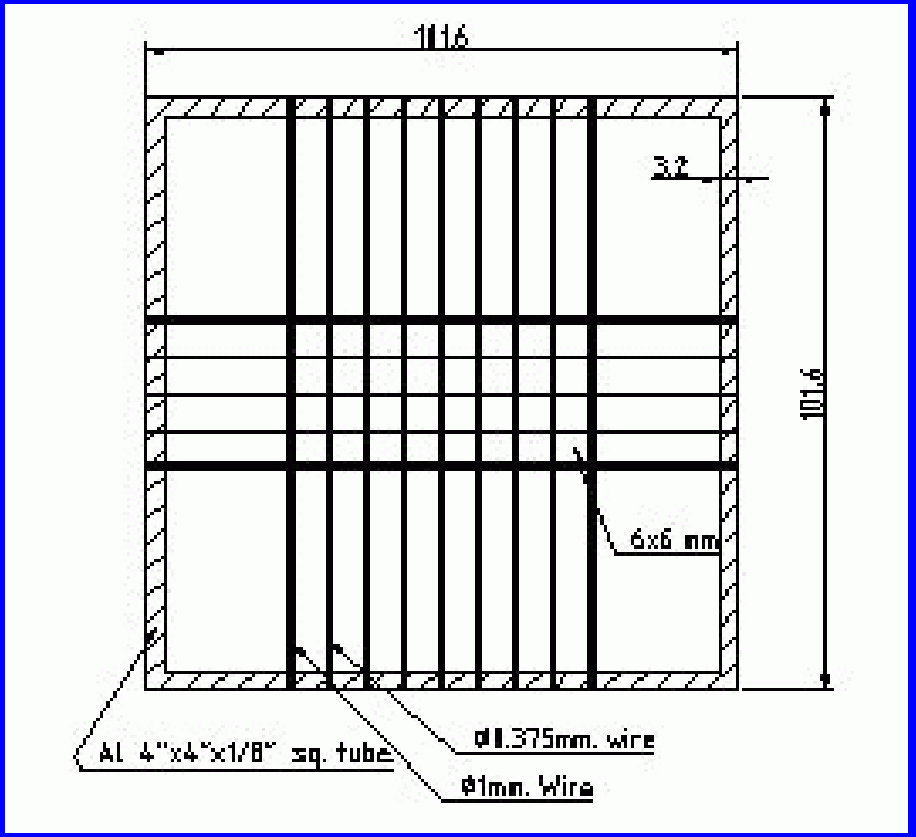
1) buy "quartz" (UTA), ship May 5
2) simple frame, plan to be ready when quartz arrives w/cosmic test stand (UTA)
3) electronics circuit (Alberta)
   April 28 UTA meeting will be a focal point
   given that circuit likely to take 3+ months (1 month design, 2 months fab) and testing, a 2 phase approach seems desirable
   i) off shelf nim-type cfd and tdc for early test beam (Louvain?), July 10-24
   ii) new improved circuit for Aug.?
4) Test beam preparation (FNAL, UTA, Alberta)
   manpower June-August, pedro+? Louvain (3)
   Helsinki?, Saclay? other?
   need to integrate Quartic into test beam readout (Pedro/Alberta?)
   (discuss Saturday, except #3)

Test Beam Frame

side view



cross section



wires to hold bars allows reconfig

Conclusions

Fast TOF is a critical part of FP420

So how do we achieve a resolution of 10-20ps for the full detector system?
1. 20 ps actual detector seems feasible.
2. 30 ps in the MCP-PMT for a single photon seems feasible.
3. 15 ps electronics seems feasible.

Therefore need multiple photon statistics (for each fused silica bar) as well as multiple measurements along the track. (have several bars).

Plan to test baseline detector in Fermi test beam this summer

Electronics schedule tight

Test beam manpower is an issue

Funding is less of an issue then it used to be!

Some Discussion Issues

Need reasonably fast timing circuit for July

Need 40 MHz solution eventually (PMT mods?)

Availability of 10 μ pore tubes, 1032 pixels

Gallium arsenide

Light guide ideas

Amplifiers, Discruminators, TDC's (128 channels)

Fast scopes

Collaboration