PID pixel rates

J. Va'vra, SLAC

Rate scaling from BaBar

(J. Va'vra and B. Ratcliff)

- **<u>BaBar empirical scaling law:</u>**

  Sector 3: PMT rate/kHz ~ 5.3 I_{LER} / A + 19.2 I_{HER} / A + 22.2 LUMI / 10^{33}

  => PMT Rate (LUMI contribution) ~200 kHz at L ~ 10^{34}, which agrees what we observe <u>when things are good</u> !!!

  => If we blindly use this formula we get a PMT Rate >20 MHz at L ~ 10^{36}.

- **We know that our Belle friends do not have a LUMI term.**

- **We will assume that Super-B LUMI term is 10% of the BaBar LUMI term.**

- **<u>Simple method to estimate the pixel rate for the option 3 (H8500 MaPMT)</u>:**

  a. BaBar DIRC 1" dia. PMT rate at L ~ 10^{34}: Measured rate ~200 kHz/PMT

  b. Scale 1" dia. PMT -> H8500 pixel is 6mm x 6mm => Factor ~ π $1.27^2/0.6^2$ ~ 14

  c. Non-focusing DIRC SOB is smaller for at Super-B => Factor ~ 7

  => Expected pixel rate ~ 200 kHz * 100 / (10 * 7 * 14) ~ 20 kHz / pixel

BaBar PMT · Scaling to 10^{36} · LUMI term · SOB volume · Pixel size

DIRC options

Favored ?

	BaBar DIRC	Option 1	Option 2	Option 3	Option 4
PMT type	ETL 9125B	equivalent	upgraded	MaPMT 8500	MaPMT 9500
No of pixels/PMT	1	1	1	8x8 = 64	16x16 = 256
PMT rise time	~1.5 ns	~1.5 ns	0.5 - 1.0 ns	~ 0.5 ns	~ 0.7 ns
PMT σ_{TTS}	1.6 ns	~1.5 ns	0.25 - 0.5 ns	~150 ps	~220 ps
Expected PMT gain	~3×10^6	similar	similar	~10^6	~10^6
Amplifier voltage gain	~10	~10	~10	40-60x	40-60x
Typ. pulse height	~40 mV	equivalent	equivalent	A few hundred mV	A few hundred mV
Typ. expected rate/PMT	~200 kHz	1 MHz	1 MHz	**~20 kHz/pixel**	~5 kHz/pixel
TDC/ADC equiv. resol.	500 ps/count	500 ps/count	~100 ps/count	~50 ps/count	~50 ps/count
Waveform analysis	no	no	no	possibly	possibly
Integration	Custom front end	similar	similar	ASIC for 64 ch.	ASIC for 256 ch.
Latency	12 µs	12 µs	12 µs	12 µs	12 µs
Max. DAQ rate	10 kHz	100 kHz	100 kHz	100 kHz	100kHz
Data link	1.2 Gbit fiber	upgrade	upgrade	upgrade	upgrade
No of channels	12,000	12,000	12,000	64,000	256,000
No of detectors	12,000	12,000	12,000	1000	1000

Options:

1. **DIRC detector as it is now, but replace PMTs to types with similar specs (σ_{TTS} ~ 1.5 ns)**
2. **DIRC detector as it is now, but upgrade PMTs to types with faster transit time spread (σ_{TTS} ~ 250 - 500 ps)**
3. **"Non-focusing DIRC" with a new SOB - Use flat panel H-8500 MaPMT (Gary Varner's waveform digitizer)**
4. **"Focusing DIRC" with a new SOB - Use flat panel H-9500 MaPMT (Gary Varner's waveform digitizer)**

FDIRC photon detector candidates - options 3

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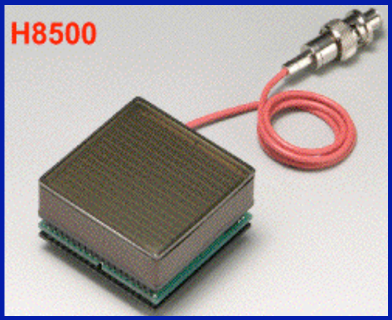
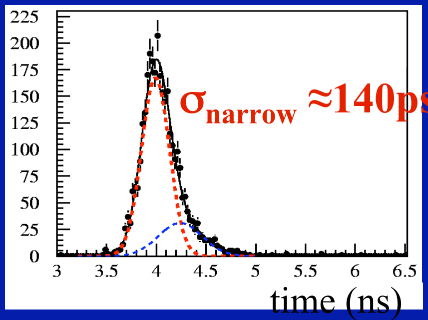
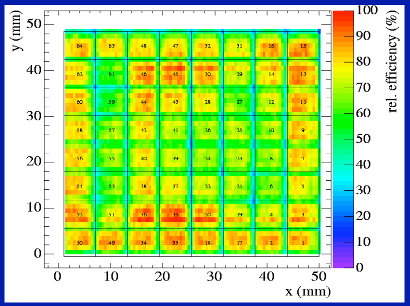
Hamamatsu H-8500 MaPMT (64 pixels, 6x6mm pad, σ_{TTS} ~140ps)







Cost:
Detectors: $1.6M/1000
Electronics: $1.1M/1000

- **64-pixel nominally, however, we may short 2 pads together.**
- **Total overall MaPMT rate: ~ 1.3 MHz**
- **At what rate it gives up a useful measurement ? 10 MHz ?**

TOF options

Favored ?

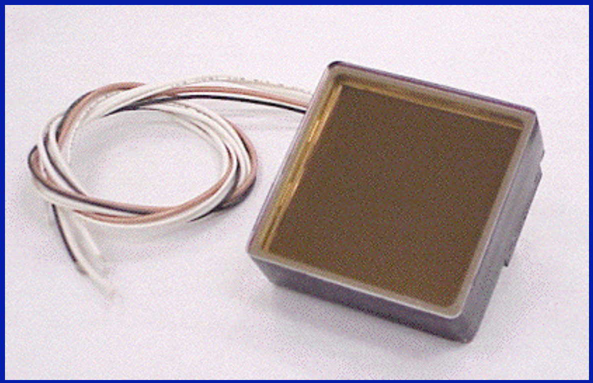
	Option 1	Option 2	Option 3
PMT type	Burle MCP-PMT, 10 μm	Burle MCP-PMT, 10 μm	Burle MCP-PMT, 10 μm
No of pixels/PMT	8x8 = 64	8x8 = 64	4x4 = 16
Input capacitance/pix	~ 5 pF	~5 pF	~20 pF
PMT rise time	~ 200-400 ps	~ 200-400 ps	~ 300-500 ps
Expected PMT gain	~$8x10^4$ @0kG, ~$4x10^5$ @16kG	~$8x10^4$ @0kG, ~$4x10^5$ @16kG	~$8x10^4$ @0kG, ~$4x10^5$ @16kG
PMT σ_{TTS}	~30 ps	~30 ps	~30 ps
No of photoelectrons	~ 50 / 1 cm of radiator	~ 50 / 1 cm of radiator	~ 50 / 1 cm of radiator
Raw pulse height/50pe^-	~ 50 mV	~ 50 mV	~ 40 mV
Particle track rate/PMT	A few kHz	A few kHz	A few kHz
Pixel rate	~ 500 Hz	~ 500 Hz	~ 125 Hz
TDC/ADC equiv. resol.	5-10 ps/count	5-10 ps/count	5-10 ps/count
Amplifier gain	~10x	~10x	~10x
Effective front end BW	0.7-1 GHz	0.7-1 GHz	0.7-1 GHz
Timing scheme	CFD + ADC correction	Waveform digitization (~10 GSa/s)	Waveform digitization (~10 GSa/s)
Latency	12 μs	12 μs	12 μs
Total number of pixels	64,000	64,000	16,000
No. of detectors	1000	1000	1000

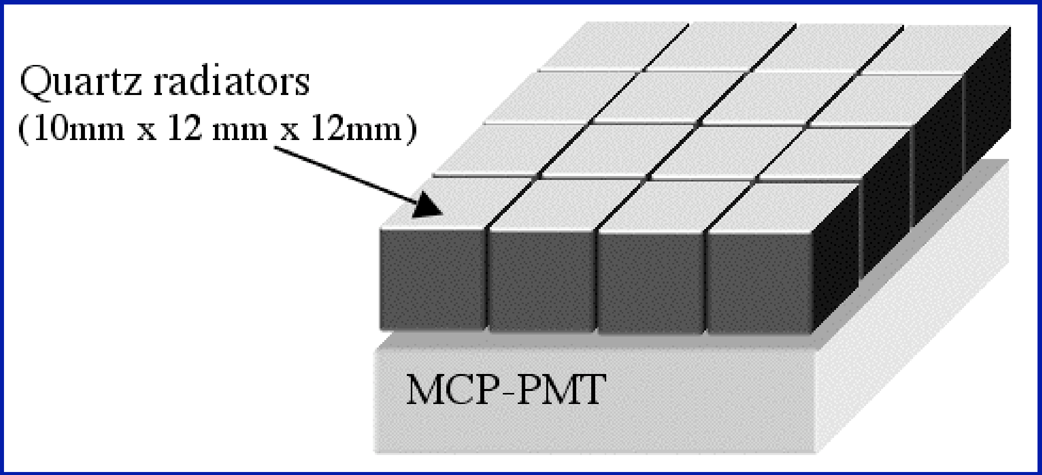
Options:

1. **TOF with CFD & Time-over-threshold ADC correction (a'la Jeff Peck, retired ORTEC engineer)**
2. **TOF with waveform digitization (a'la Gary Varner)**
3. **The same as option 2, but short 4 pixels together (live with a larger capacitance)**

Possible radiator for a TOF counter

Burle/Photonis MCP-PMT (10µm, 64 pixels, 6x6mm pad, σ_{TTS} ~30ps)





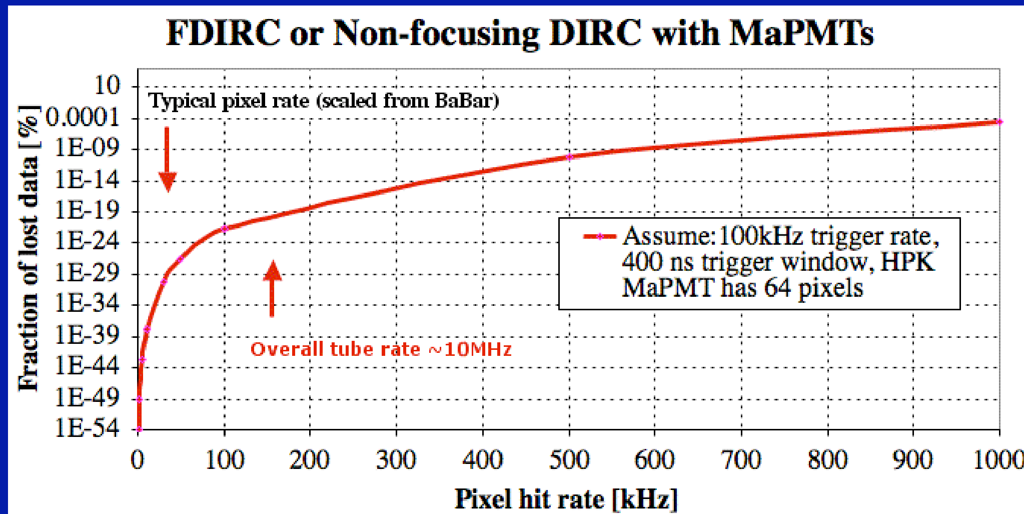
- **Short 4 pixels together**
- **Quartz radiator cubes 10mm x 12 mm x 12 mm.**
- **Al coating from sides**
- **Glued together with RTV to protect the Al coating.**

Apendix

(to be shown if Gary will not make it)

Expected DAQ performance for DIRC

(G. Varner & J. Va'vra)



We will reach a maximum possible rate on the PMT a way before we hit troubles with the dead time.

Note: 1) BLAB2 chip performance comes from Gary Varner
2) Pixel rates from scaling of BaBar PMTs (J. Vavra & B. Ratcliff)
FDIRC or Non-focusing DIRC with MaPMT detectors:
(assume that we use 64 pixel HPK MaPMT tubes)

Hit Rate/pixel [Hz]	Hit Rate/pixel [kHz]	Trigger window [ns]	Occupancy Singels/pixel [fraction]	Occupancy Doubles/pixel [fraction]	Total Occupancy per pixel [fraction]	Ave. number of BLAB2 chip reads/trigger {16 pixels/chip} [pixels]	Ave. dead time per BLAB2 chip [1us/16 pixels] {16 pixels/chip} [us]	Ave. dead time per tigger [1us/16 pixels] {16 pixels/chip} [fraction]	Max Super-B trigger rate [Hz]	Fraction of time that data start to be "delayed" (Not yet lost !!) [Fraction]	Fraction of time that data start to be "delayed" (Not yet lost !!) [%]	Fraction of time data is lost due to overflowing the buffer (assuming 16x deep analog bufering) [%]
1000	1	200	0.0002	0.00000004	0.00020004	0.00320064	0.00320064	3.20064E-09	100000	0.000320064	0.0320064	1.2128E-54
2000	2	200	0.0004	0.00000016	0.00040016	0.00640256	0.00640256	6.40256E-09	100000	0.000640256	0.0640256	7.97367E-50
5000	5	200	0.001	0.000001	0.001001	0.016016	0.016016	1.6016E-08	100000	0.0016016	0.16016	1.87441E-43
10000	10	200	0.002	0.000004	0.002004	0.032064	0.032064	3.2064E-08	100000	0.0032064	0.32064	1.2482E-38
30000	30	200	0.006	0.000036	0.006036	0.096576	0.096576	9.6576E-08	100000	0.0096576	0.96576	5.72674E-31
50000	50	200	0.01	0.0001	0.0101	0.1616	0.1616	1.616E-07	100000	0.01616	1.616	2.16303E-27
100000	100	200	0.02	0.0004	0.0204	0.3264	0.3264	3.264E-07	100000	0.03264	3.264	1.6596E-22
500000	500	200	0.1	0.01	0.11	1.76	1.76	0.00000176	100000	0.176	17.6	8.47623E-11
1000000	1000	200	0.2	0.04	0.24	3.84	3.84	0.00000384	100000	0.384	38.4	2.23511E-05

Trigger window*Hit rate

(Trigger window*Hit rate)^2

Total occupancy*16

Convert to μs

Convert to fraction

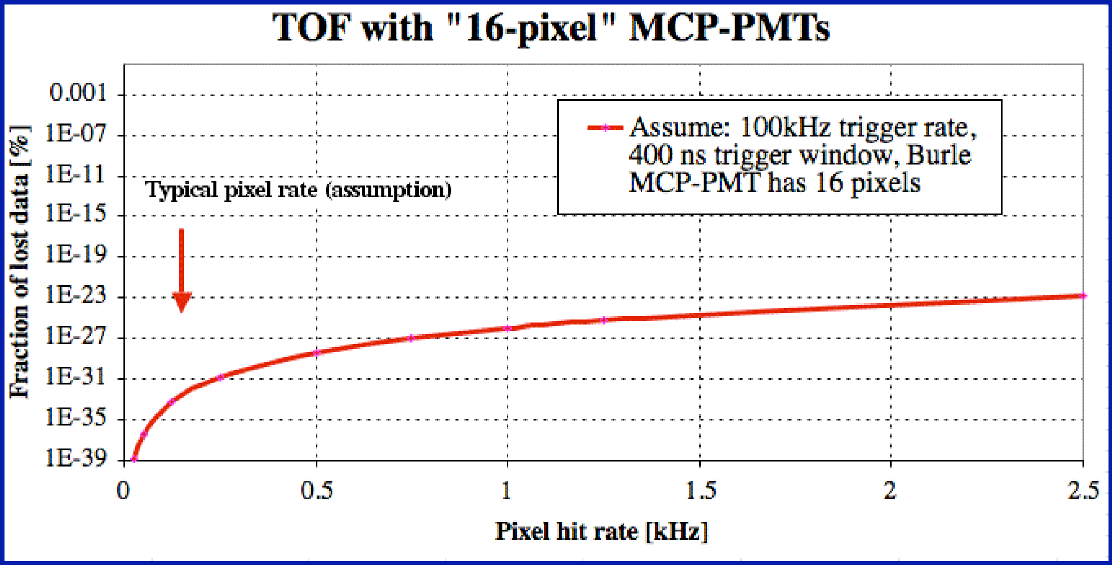
Max.trigger rate*Ave.dead time

Convert to %

(100*Max.trigger rate*Ave.dead time)^{16}

Expected DAQ performance for TOF

(G. Varner & J. Va'vra)



TOF - option 2

Assume: 1. Short 4 pads together

2. Run with a threshold of 5-10 pe- => DAQ does not see the Cherenkov photons

3. Typical expected track rate per PMT is ~2kHz. => 125 Hz/pixel

Track Rate/PMT [Hz]	Track Rate/PMT [kHz]	Hit Rate/pixel {assume: 16 pixels/track} [Hz]	Hit Rate/pixel {assume: 16 pixels/track} [kHz]	Trigger window [ns]	Occupancy Singels/pixel [fraction]	Occupancy Doubles/pixel [fraction]	Total Occupancy per pixel [fraction]	Ave. number of BLAB2 chip reads/trigger {16 pixels/chip} [pixels]	Ave. dead time per BLAB2 chip [1us/16 pixels] {16 pixels/chip} [us]	Ave. dead time per tigger [1us/16 pixels] {16 pixels/chip} [fraction]	Max. Super-B trigger rate [Hz]	Fraction of tim that data start to be "delayed (Not yet lost !! [Fraction]	Fraction of time that data start to be "delayed" (Not yet lost !!) [%]	Fraction of time data is lost due to overflowing the buffer (assuming 8x deep analog bufering) [%]
100	0.1	6.25	0.00625	200	0.00000125	1.5625E-12	1.25E-06	2E-05	2E-05	2E-11	100000	2E-06	0.0002	2.56003E-44
200	0.2	12.5	0.0125	200	0.0000025	6.25E-12	2.50001E-06	4.00001E-05	4.00001E-05	4.00001E-11	100000	4.00001E-06	0.000400001	6.55373E-42
500	0.5	31.25	0.03125	200	0.00000625	3.90625E-11	6.25004E-06	0.000100001	0.000100001	1.00001E-10	100000	1.00001E-05	0.001000006	1.00005E-38
1000	1	62.5	0.0625	200	0.0000125	1.5625E-10	1.25002E-05	0.000200003	0.000200003	2.00003E-10	100000	2.00003E-05	0.002000025	2.56026E-36
2000	2	125	0.125	200	0.000025	6.25E-10	2.50006E-05	0.00040001	0.00040001	4.0001E-10	100000	0.000040001	0.0040001	6.55491E-34
3000	3	187.5	0.1875	200	0.0000375	1.40625E-09	3.75014E-05	0.000600023	0.000600023	6.00023E-10	100000	6.00023E-05	0.006000225	1.68012E-32
4000	4	250	0.25	200	0.00005	2.5E-09	5.00025E-05	0.00080004	0.00080004	8.0004E-10	100000	0.000080004	0.0080004	1.67839E-31
5000	5	312.5	0.3125	200	0.0000625	3.90625E-09	6.25039E-05	0.001000063	0.001000063	1.00006E-09	100000	0.000100006	0.010000625	1.0005E-30
10000	10	625	0.625	200	0.000125	1.5625E-08	0.000125016	0.00200025	0.00200025	2.00025E-09	100000	0.000200025	0.0200025	2.56256E-28

Trigger window*Hit rate

(Trigger window*Hit rate)^2

Total occupancy*16

Convert to µs

Convert to fraction

Max.trigger rate*Ave.dead time

Convert to %

(100*Max.trigger rate*Ave.dead time)^8