Beam Instrumentation Abort Gap Monitor/Longitudinal Density Monitor

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Diagnostics for measuring longitudinal parameters of the LHC beams

LHC SPECIFICATIONS
C. Fischer, LHC-B-ES-0005

- **Abort Gap Monitor**

- **Debunched Beam**
- **Bunch Tails**
- **Ghost Bunches**

- **Bunch Core ("real time")**

MODE		SENSITIVITY Ultra-high	High	Standard
Observation period (ns)		100	0.05	0.05
Integration time (s / rev)		0.1 / 1100	10 / 10^5	10^{-3} / 10
UPD (p/ps)	0.45TeV		0.9×10^8	
	7TeV		2×10^8	
Sensitivity (p/ps)	0.45TeV	Š4×10^4	10^4	10^6
	7TeV	Š60		
Sensitivity/UPD	0.45TeV	4.4×10^{-4}	5×10^{-5}	5×10^{-3}
	7TeV	3×10^{-7}		
Dynamic range (p/ps)	0.45TeV	4×10^5	10^4 - 3×10^8	10^6 - 5×10^8
	7TeV	6×10^4		
Accuracy (p/ps)	0.45TeV	Š$\pm 2 \times 10^3$	$\pm 4 \times 10^3$	$\pm 10^4$
	7TeV	Š±30		
Transmission rate (s)		Š1	60	0.1

APPLICATIONS			
Abort Gap monitoring	X		
Tails		X	
Ghost bunches		X	
De-bunched beam		X	
Calibration		X	
Core parameters			X

Diagnostics for machine protection and accelerator physics

- Abort Gap Monitor (AGM) to be included in the **LHC interlock chain**.
  - Monitoring the 3.3 μs long gap in the LHC fill pattern (abort kicker raise time.

- Other applications (LDM) are for accelerator physics studies.

- Even though a single device/technique could do the job, the above strongly points towards **two independent instruments**.

AGM: deliverables for CY04

- Engineering feasibility study white paper.
  - Investigation of viable techniques based on:

Synchrotron Radiation

- Gated PMT
- APDs
- Streak camera

Wake Fields

- BPMs
- Wall current monitor

MCP-PMT for the AGM

Gate min. raise time: 1 ns

<2.5 ns RF bucket spacing

Gate voltage: 10 V

Low voltage switching required

Gain at –3.4 kV: 10^6

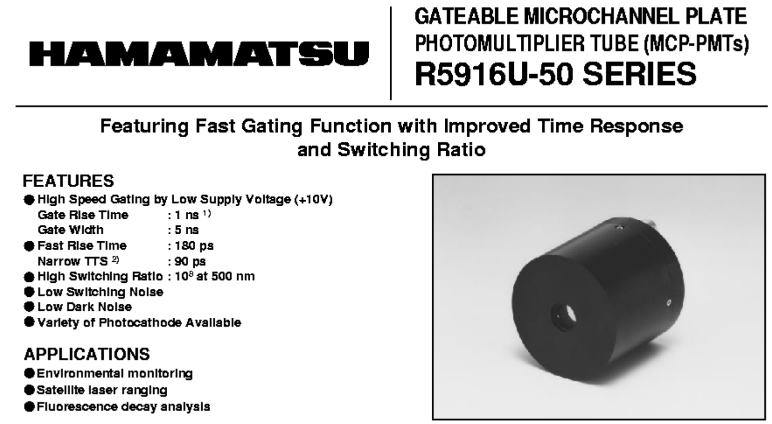
High gain

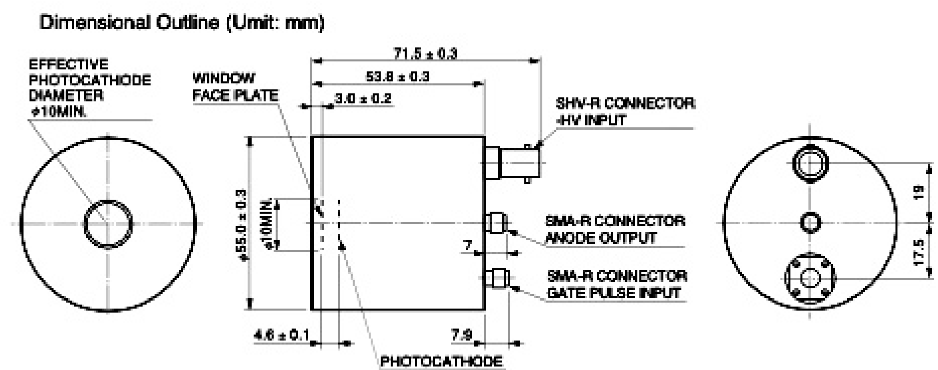
< 10 dark counts/sec

Low noise

Max duty cycle: 1%

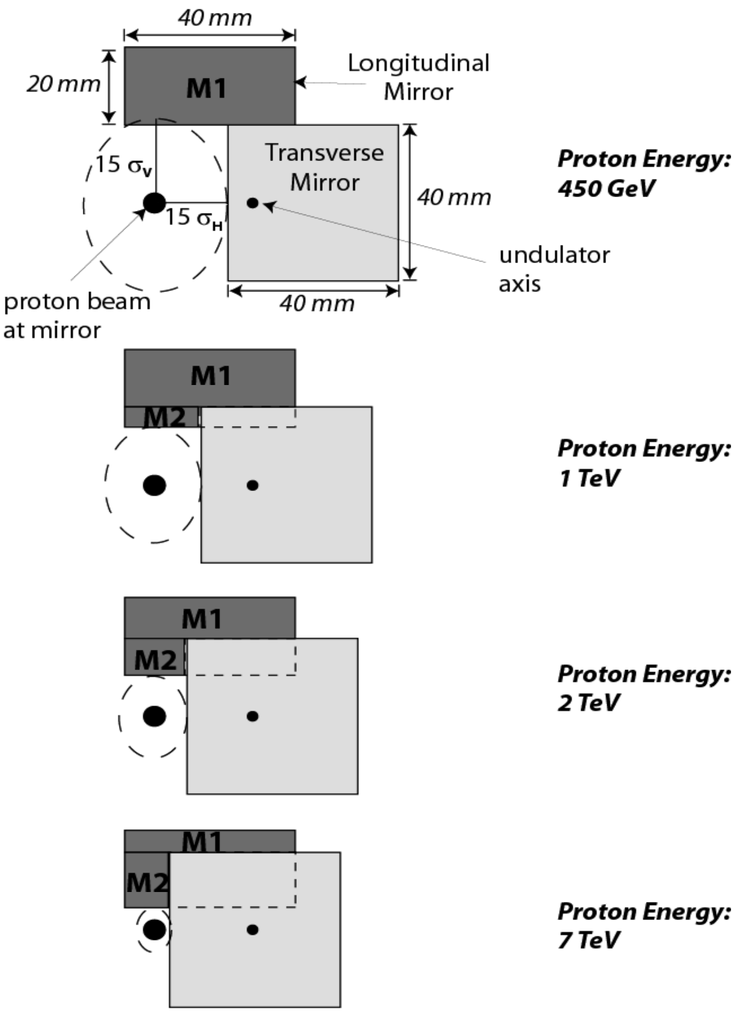
100 ns -> 100 kHz max sampling rate -> 3 ms to measure entire abort gap (w/o integration)





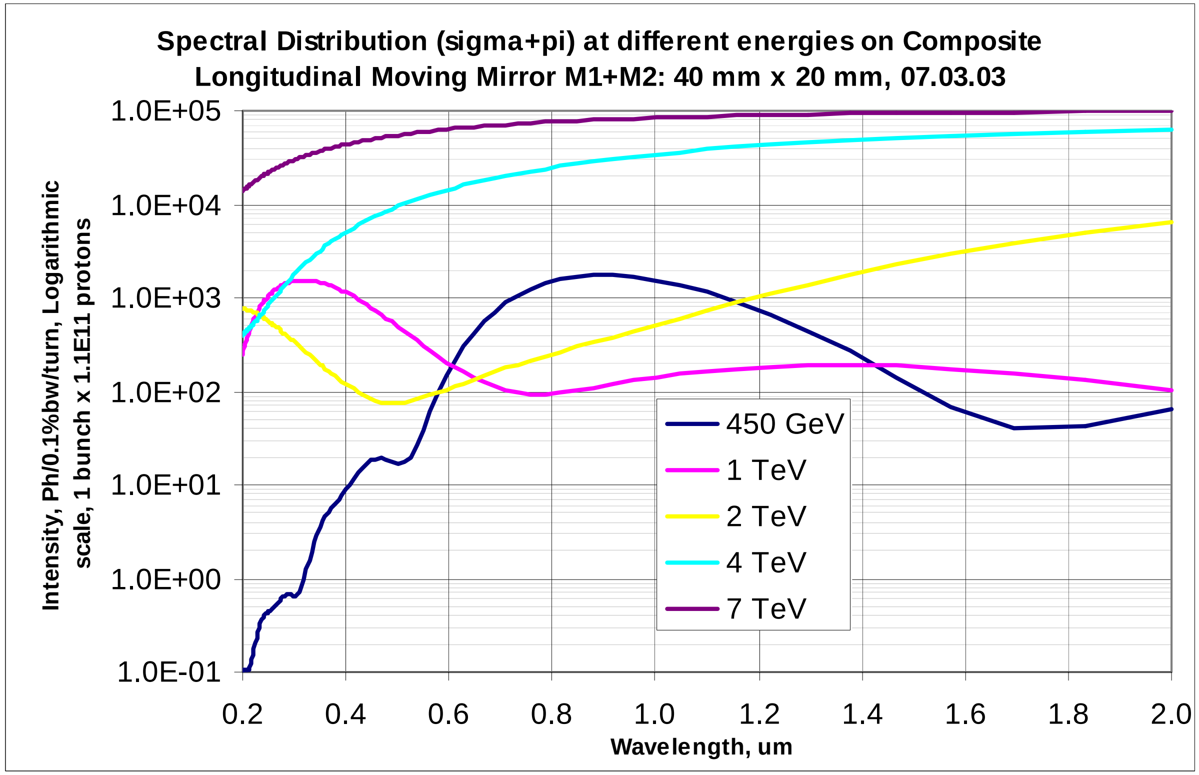
Synchrotron light source for longitudinal diagnostics

Extraction mirror



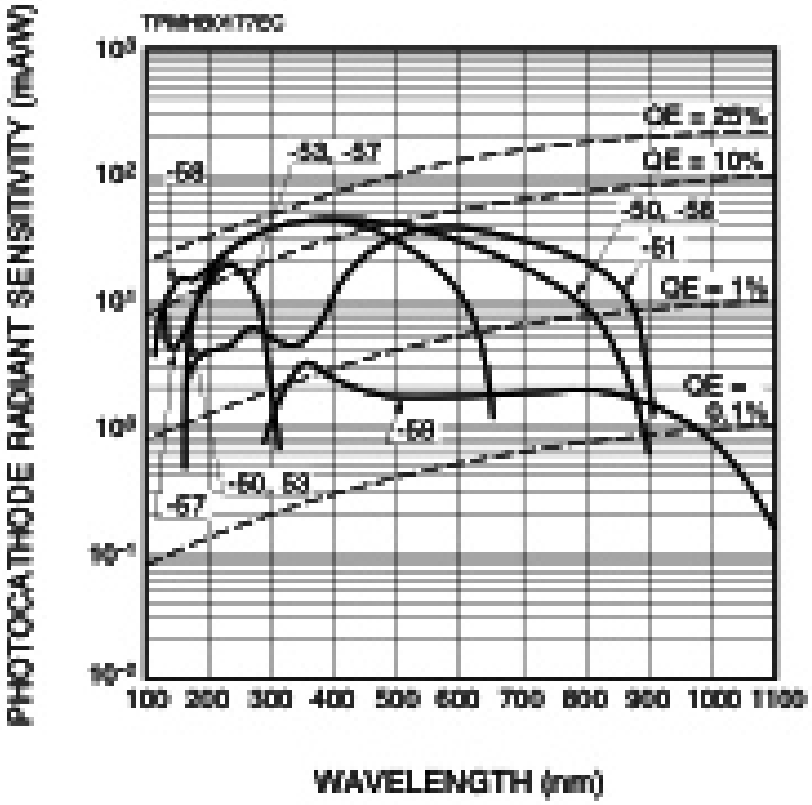
- 5T SC undulator in IR4 (low energy)
- Exit edge of D3 magnet (high energy)

Available photon flux



MCP-PMT has the required sensitivity and accuracy

Conservative estimates (1% QE, 10% BW, etc.) point out that a MCP-PMT based AGM can easily detect the required charge densities at both injection and collision energy.



The MCP-PMT could map the rest of the ring at the same time and measure the unbunched beam. Unbunched beam at injection generates “radiation flashes” during the ramp. This should be part of the protection system as well

AGM hardware tests

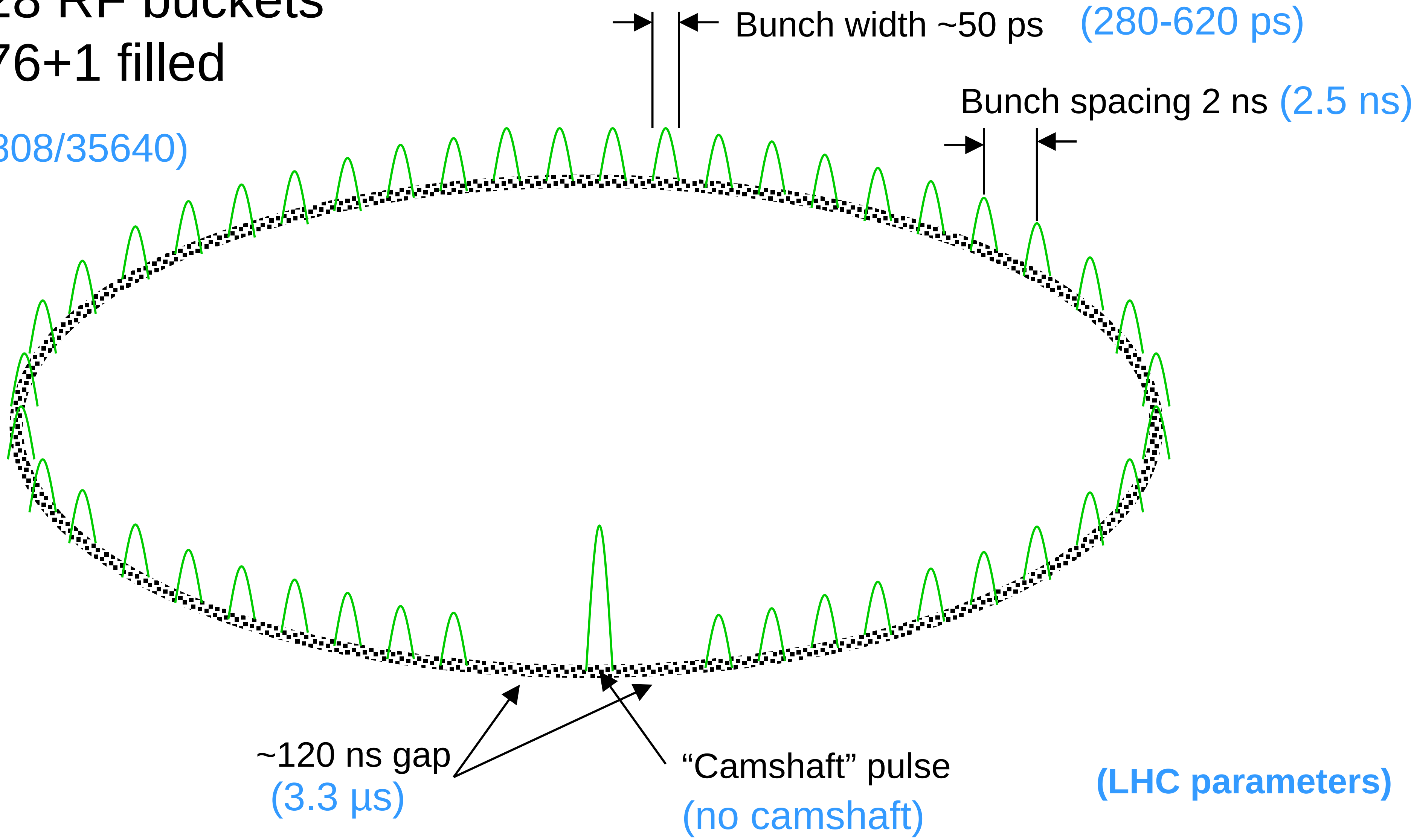
- An MCP-PMT has been tested at the ALS (*dynamic range*, *photocatode saturation*, *noise properties*) and will be tested on the Tevatron (*unbunched beam*).

- The MCP-PMT will also be tested as a possible device for accelerator physics applications (LDM).

Tests at the ALS

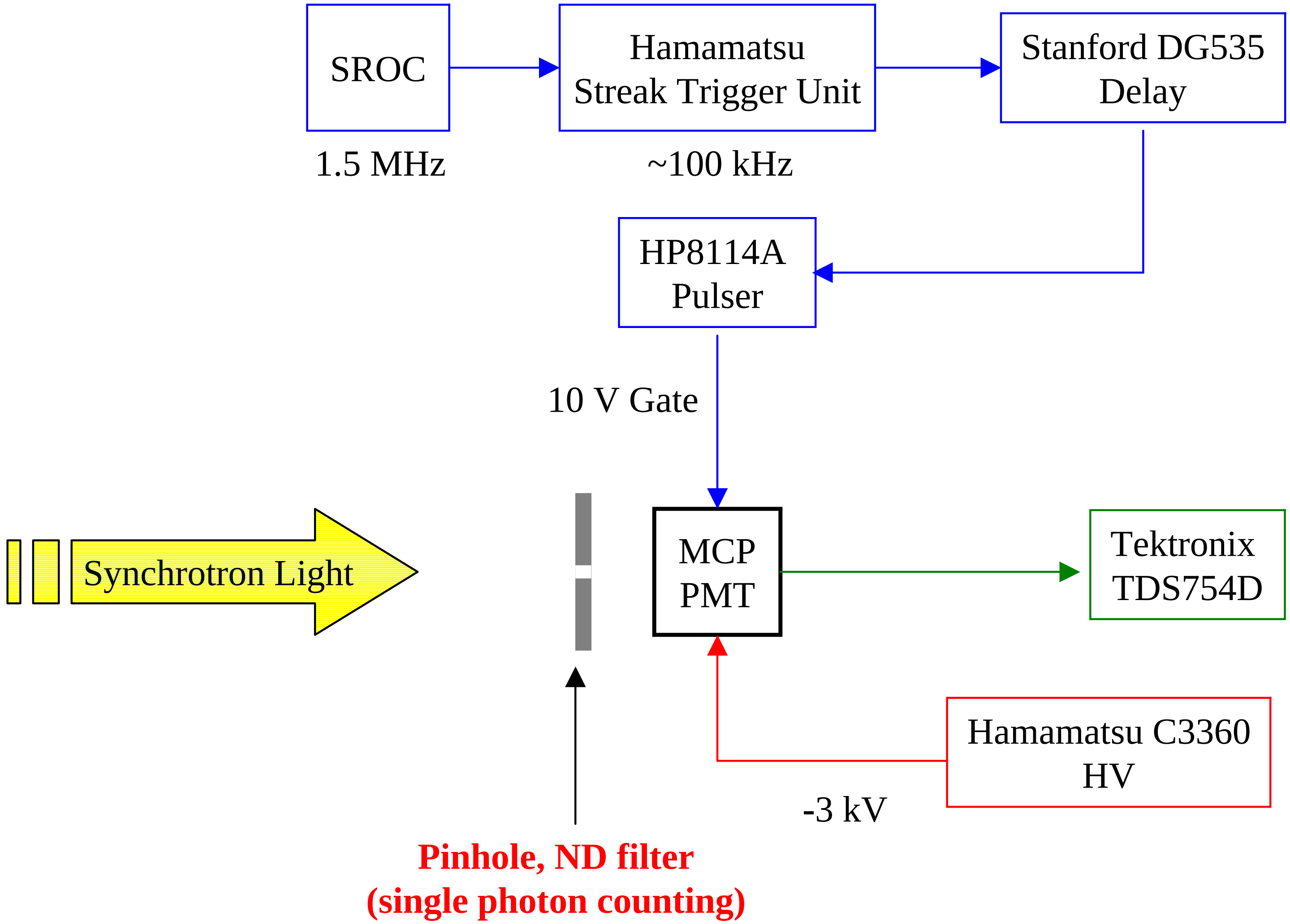
328 RF buckets
276+1 filled

(2808/35640)

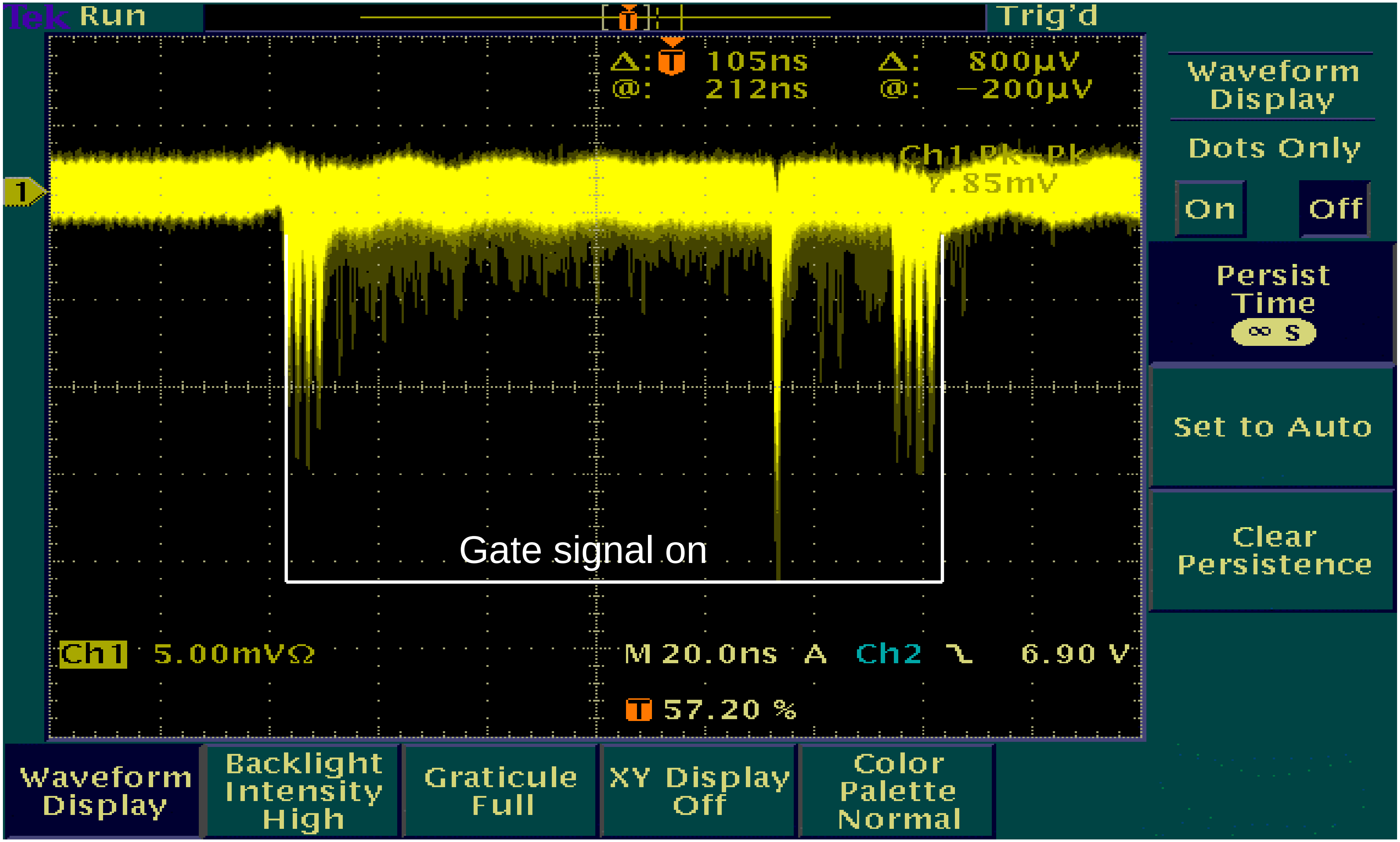


(LHC parameters)

Experimental setup

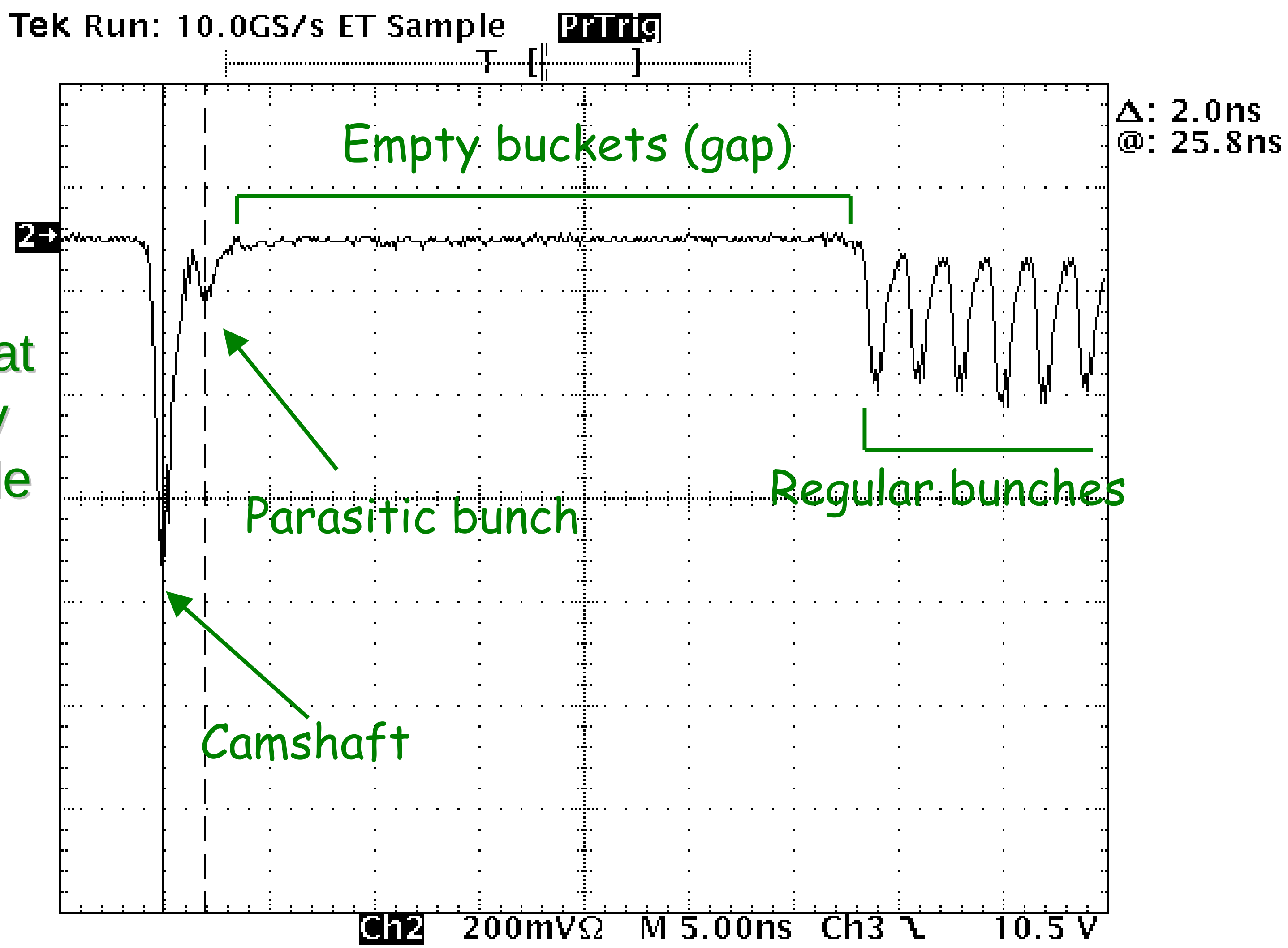


First experimental data



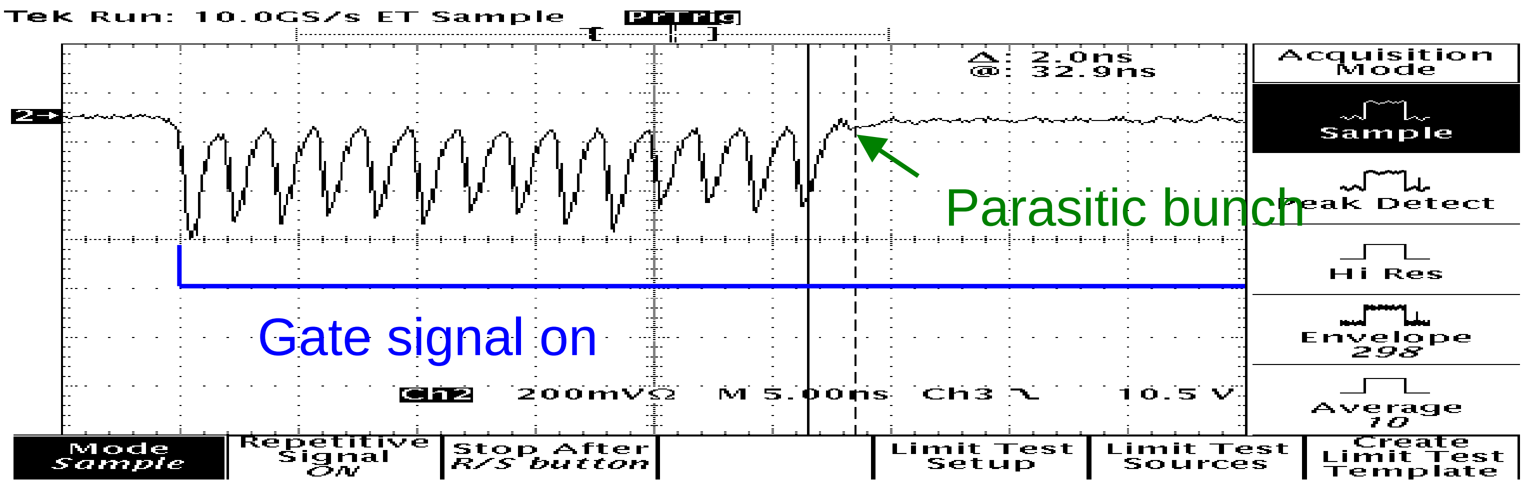
…and more recent data

No need to average data, at least at the ALS.
Future experiments at the ALS will carefully evaluate the available photon flux and simulate the LHC parameters, if possible.

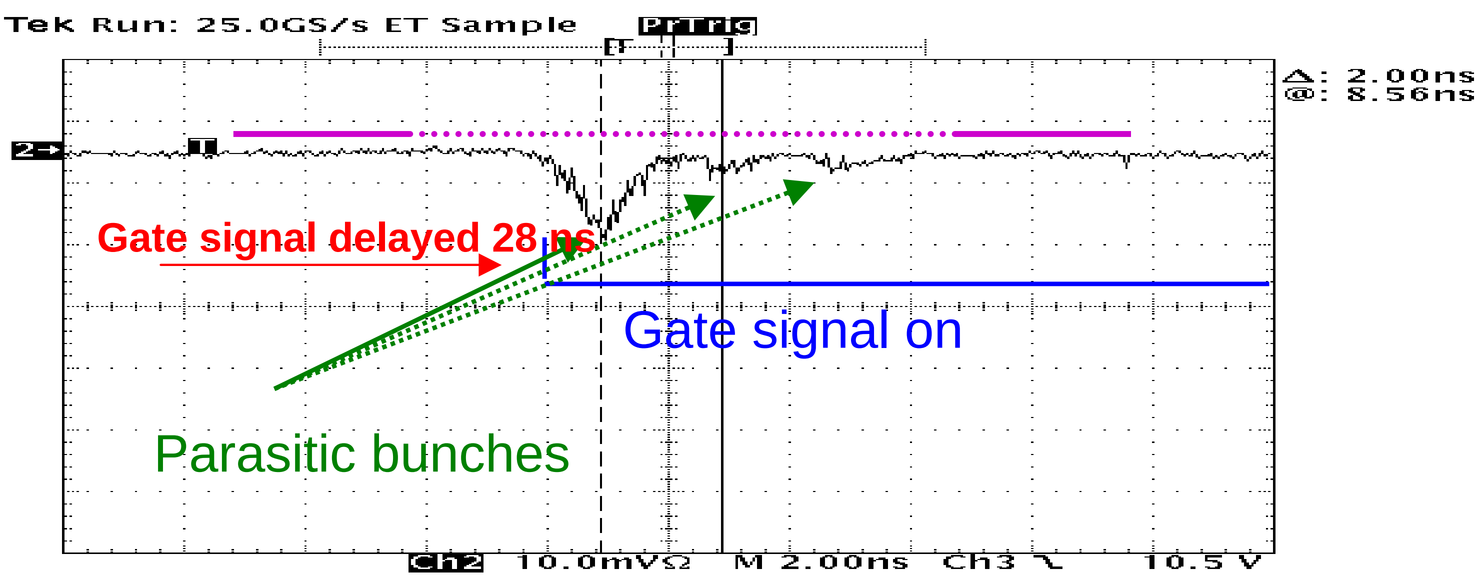


Some more interesting data

Photocatode recovery is not an issue



Compare zero level with gate on and off



AGM Summary

MCP-PMT looks promising

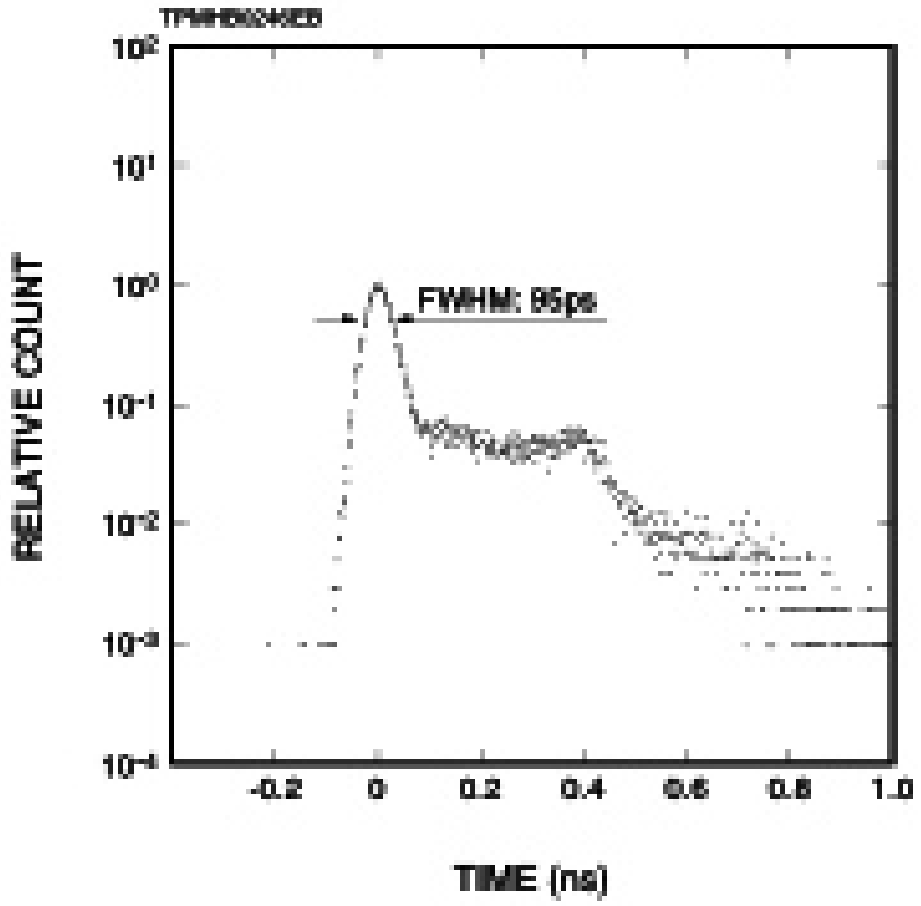
- Can be easily switched at the required speed
- S/N ratio seems adequate
- Fast photocatode recovery (~100's ps)
- Can we simulate the expected LHC photon flux at the ALS (10^{-5} ph/p) ?
- MCP-PMT available in different bands. Which is the most suitable for LHC ?
- 100 ns integrating circuit ? Numerology of data.
- Future test on the Tevatron (particularly for unbunched beam)

Longitudinal Density Monitor

Why not use a MCP-PMT for LDM too ?

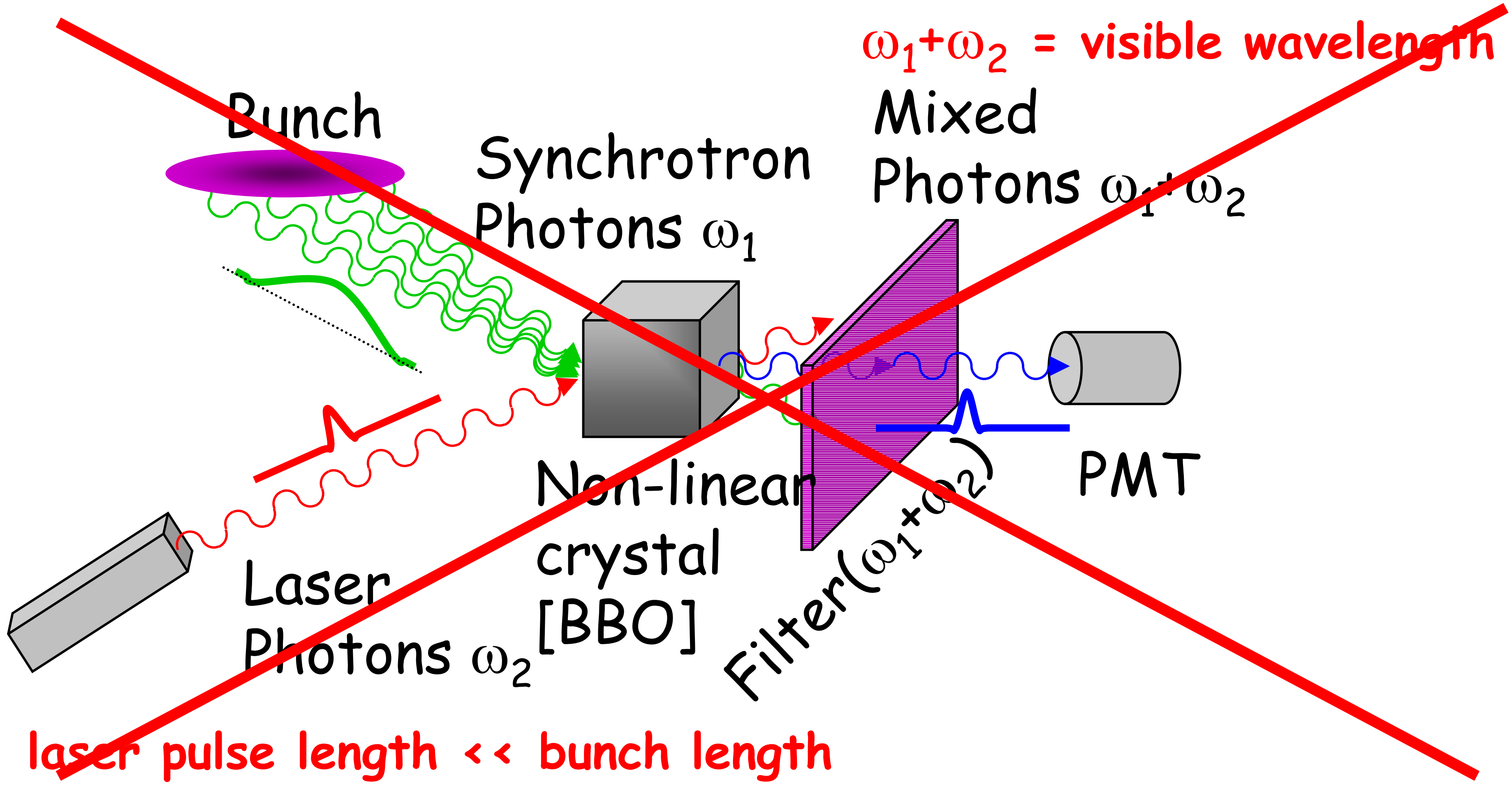
The MCP-PMT could be conceivably used for LDM too.

The 50 ps time resolution required, could be achieved by inverse filtering, due to the 95 ps FWHM Instrument Response Function.



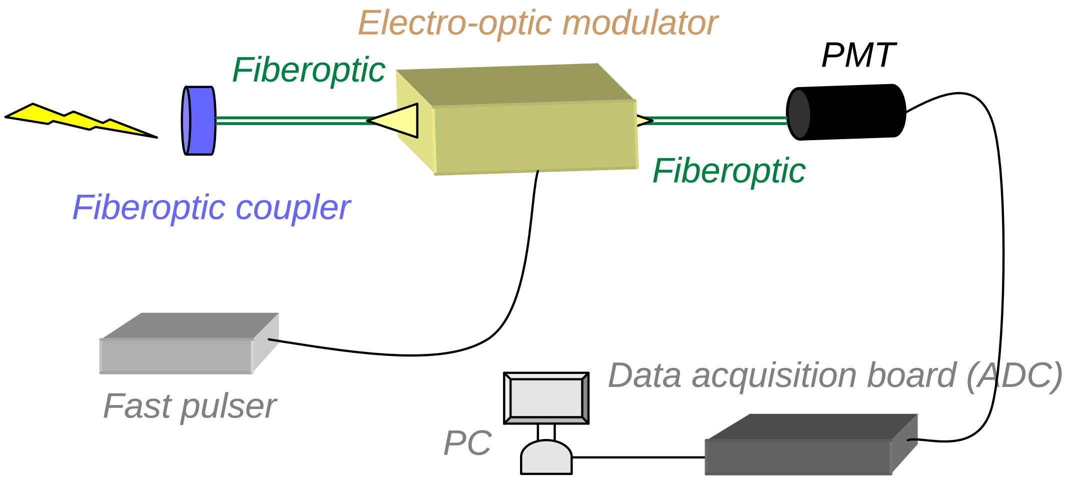
LDM: laser-mixing technique

- an optical sampling scope -

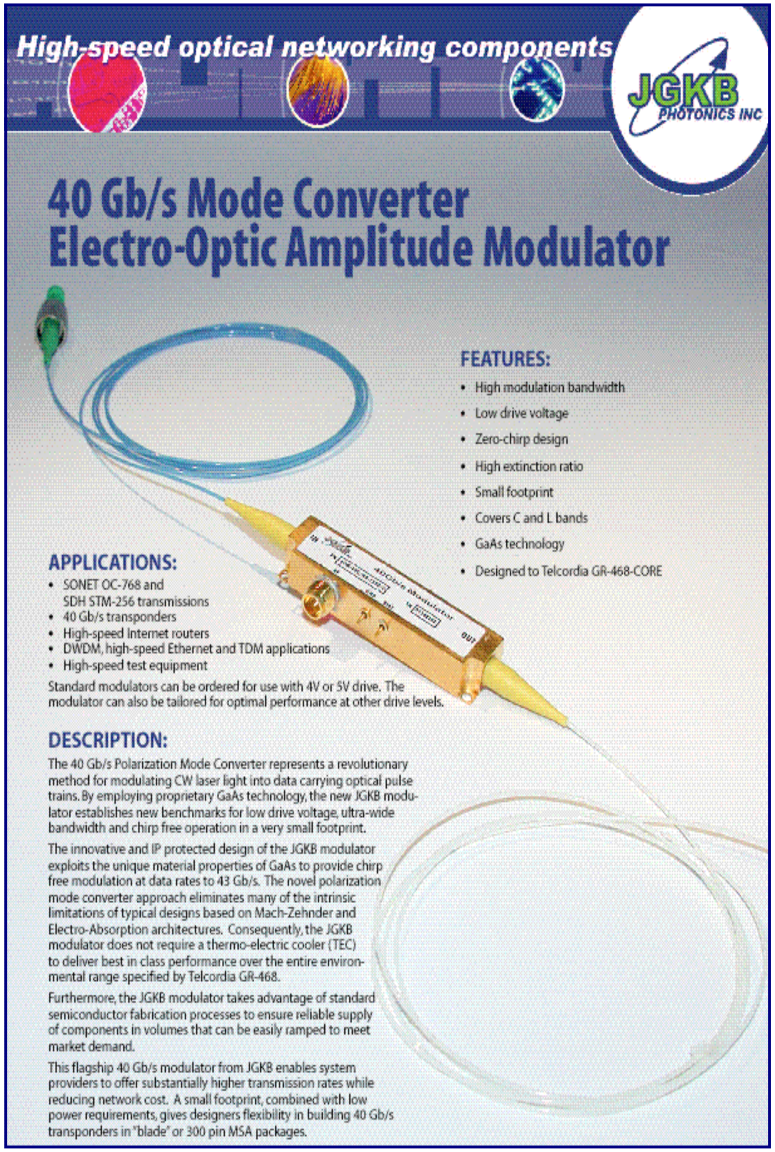


Too good for the LHC: ~fs resolution !

Optical sampling by electro-optic modulation



- ***Highly reliable technology (commonly used in large bandwith data networks).***
- ***Synchrotron light transmitted on fiber optics allows for the instrument to be easily placed away from high-radiation areas (ground level ?).***
- ***Needs an RF pulser capable of generating 50 ps long pulses at 40 MHz repetition rate.***
- ***Coupling of synchrotron light into fiber optics needs to be investigated.***



High-speed optical networking components — JGKB PHOTONICS INC

40 Gb/s Mode Converter Electro-Optic Amplitude Modulator

FEATURES:
- High modulation bandwidth
- Low drive voltage
- Zero-chirp design
- High extinction ratio
- Small footprint
- Covers C and L bands
- GaAs technology
- Designed to Telcordia GR-468-CORE

APPLICATIONS:
- SONET OC-768 and SDH STM-256 transmissions
- 40 Gb/s transponders
- High-speed Internet routers
- DWDM, high-speed Ethernet and TDM applications
- High-speed test equipment

Standard modulators can be ordered for use with 4V or 5V drive. The modulator can also be tailored for optimal performance at other drive levels.

DESCRIPTION:

The 40 Gb/s Polarization Mode Converter represents a revolutionary method for modulating CW laser light into data carrying optical pulse trains. By employing proprietary GaAs technology, the new JGKB modulator establishes new benchmarks for low drive voltage, ultra-wide bandwidth and chirp free operation in a very small footprint.

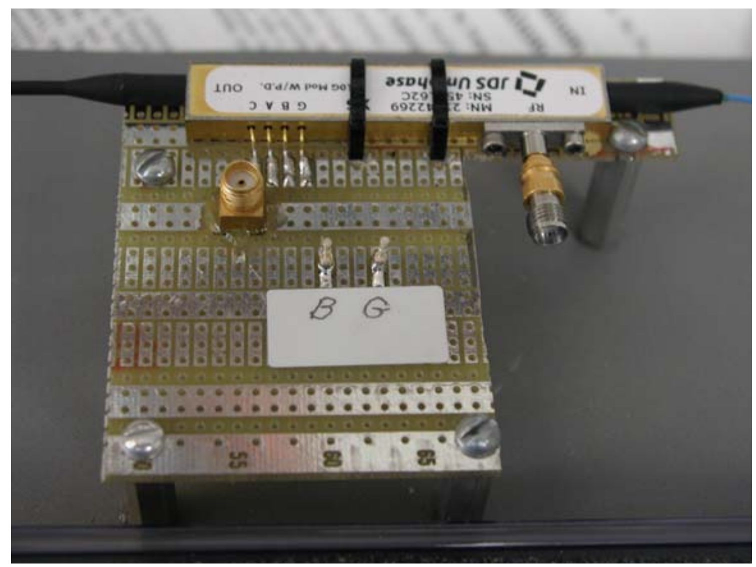
The innovative and IP protected design of the JGKB modulator exploits the unique material properties of GaAs to provide chirp free modulation at data rates to 43 Gb/s. The novel polarization mode converter approach eliminates many of the intrinsic limitations of typical designs based on Mach-Zehnder and Electro-Absorption architectures. Consequently, the JGKB modulator does not require a thermo-electric cooler (TEC) to deliver best in class performance over the entire environmental range specified by Telcordia GR-468.

Furthermore, the JGKB modulator takes advantage of standard semiconductor fabrication processes to ensure reliable supply of components in volumes that can be easily ramped to meet market demand.

This flagship 40 Gb/s modulator from JGKB enables system providers to offer substantially higher transmission rates while reducing network cost. A small footprint, combined with low power requirements, gives designers flexibility in building 40 Gb/s transponders in "blade" or 300 pin MSA packages.

Present status of the optical sampling technology

- An LBNL private venture, up to now.
- Though much slower than the laser-mixing scheme, it is still adequate for satisfying the LHC specifications.
- We are presently running bench tests with a 10 Gb/s modulator. Test at the ALS are also planned, devoted mainly to study the coupling of synchrotron radiation into an optical fiber.



LDM Summary

No LARP financial support

- Great interest from the accelerator physics point of view.
- Optical sampling technique makes for a very flexible instrument.
- Depending on the particular technology used (laser-mixing, electro-optical modulation, MCP-PMT) can be adapted to very wide range of synchrotron rings (damping rings, storage rings, electron and hadron machines)