LHC Accelerator Research Program
Beam Instrumentation and Diagnostics

LARP Collaboration Meeting
Fermilab

26-27 February, 2004

John Byrd

LBL LARP Instrumentation Group

LBNL

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- Bill Turner
- Peter Denes
- Massimo Placidi
- Alex Ratti
- Stefano De Santis
- Jean-Francois Beche
- Jim Greer
- Max Zolotorev

- CERN
  - Hermann Schmickler
  - Enrico Bravin
  - Steve Hutchins
- University of Pavia
  - Franco Manfredi
  - Gianluca Traversi
  - Lodovico Ratti
  - Massimo Manghisoni

LARP Beam Instrumentation and Diagnostic Techniques

LARP will help the LHC in 3 key areas:

- *Bring LHC to full energy*

  Betatron tune, coupling, and chromaticity control during ramp

- *Bring LHC to design luminosity*

  Real-time luminosity monitor

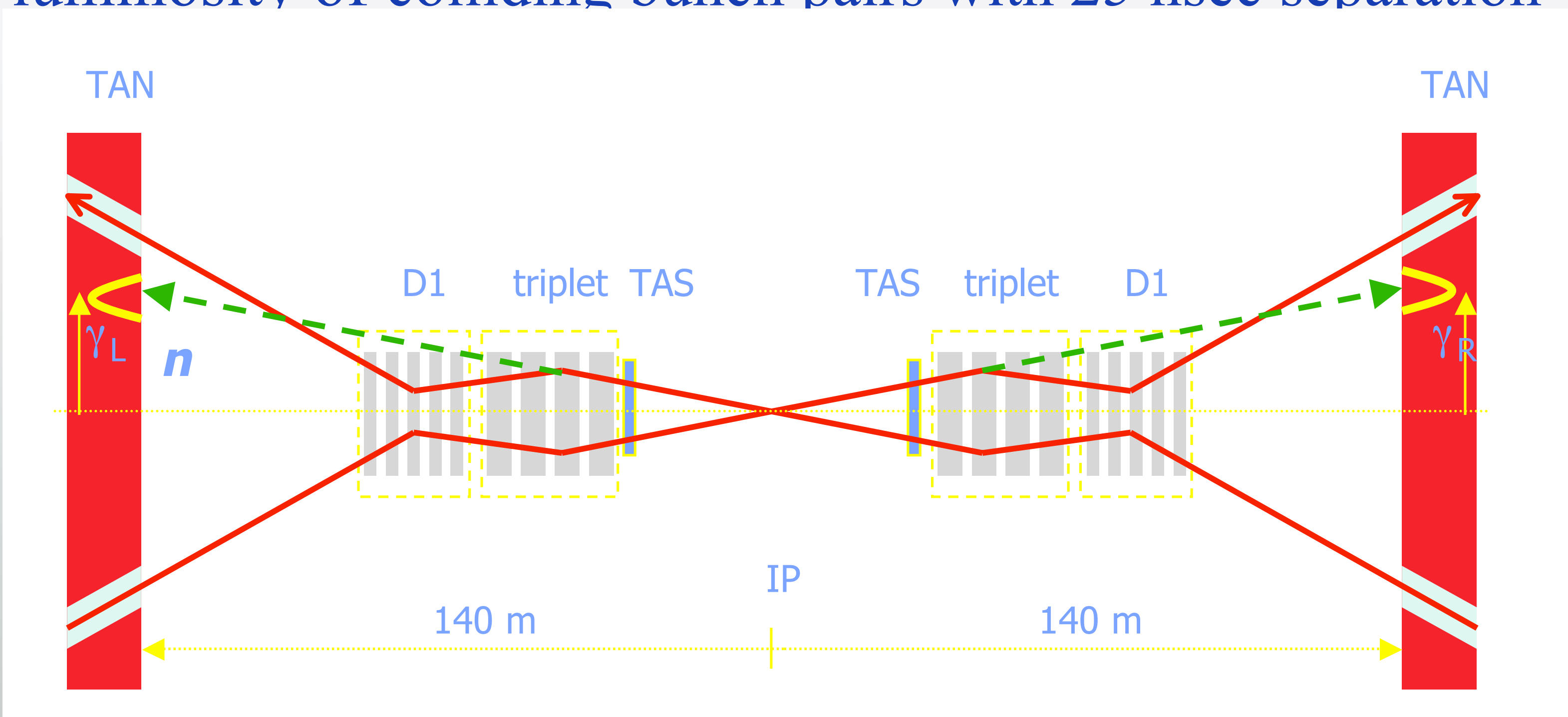
- *LHC machine protection*

  Longitudinal density monitors

These contributions advance the state-of-the-art in beam instru-mentation and have direct contributions to present and future US accelerator projects.

High Bandwidth Luminosity Monitor

Instrument US-built TAN absorbers to measure and optimize the luminosity of colliding bunch pairs with 25 nsec separation



- Luminosity γ $\mathcal{N}_{MIP}$ from ***n*** shower
- Crossing Angle γ $\gamma_L+\gamma_R$

Lumi: a year in review

- Lumi hardware design and construction
  - prototype chamber designed and built
  - improved electronics built
  - backup electronics built
  - CdTe detector received and installed for tests
- Beam and bench tests
  - electronics optimized for 25 nsec lumi pulses
  - extensive study of test at FNAL RTF (booster)
  - lumi beam tests at ALS booster (1 Hz pulses)
    - verify IC drift velocity modeling vs voltage, pressure, mix
    - demonstrated position detection<100 micron sensitivity
  - lumi beam tests in ALS ring (~25 nsec pulses)
    - demonstrated feasibility of slow beam spill at 40 MHz

Almost 100% turnover in group (since Oct. 2002)

•still going strong

•institutional commitment has kept us alive

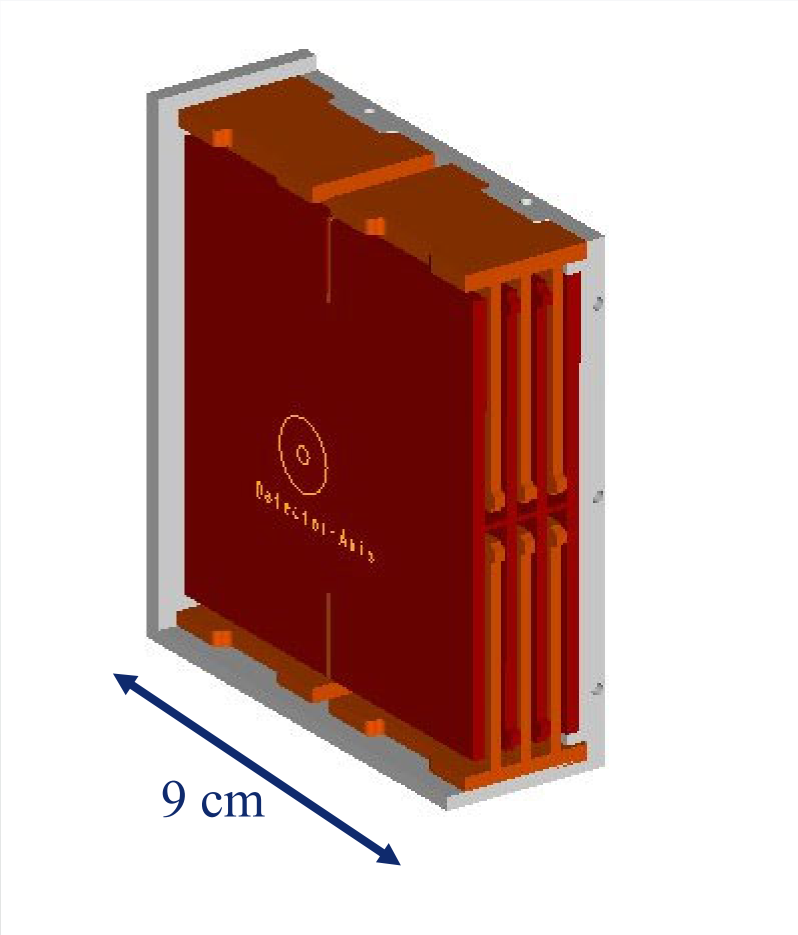
LHC Luminosity Monitor

The challenge:

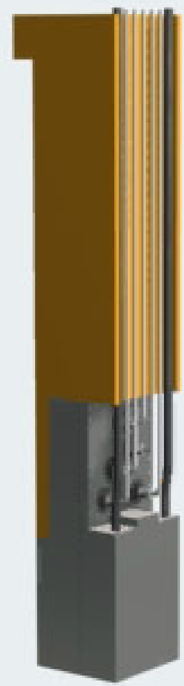
- High radiation environment (100 MGy/year)
- Bunch-by-bunch capability (25 nsec separation)

The solution:

- Segmented, multi-gap, pressurized ArN_2 gas ionization chamber constructed of rad hard materials



Lumi Engineering Design

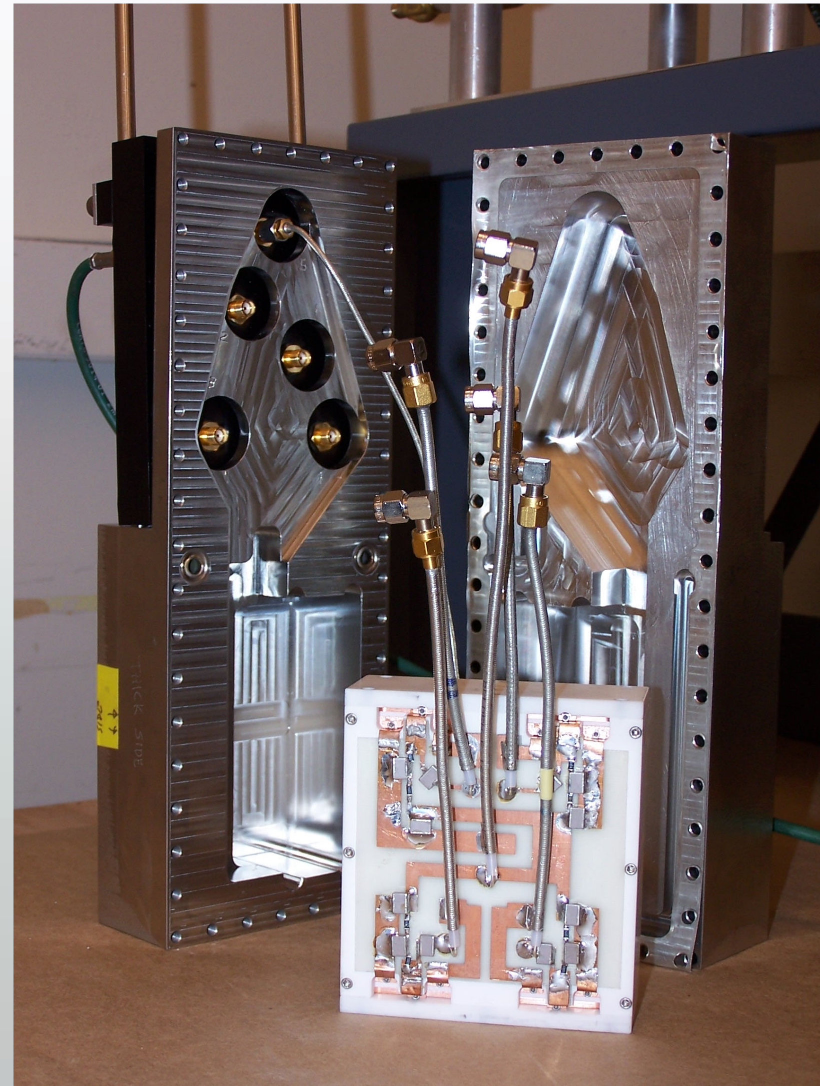


Chamber built

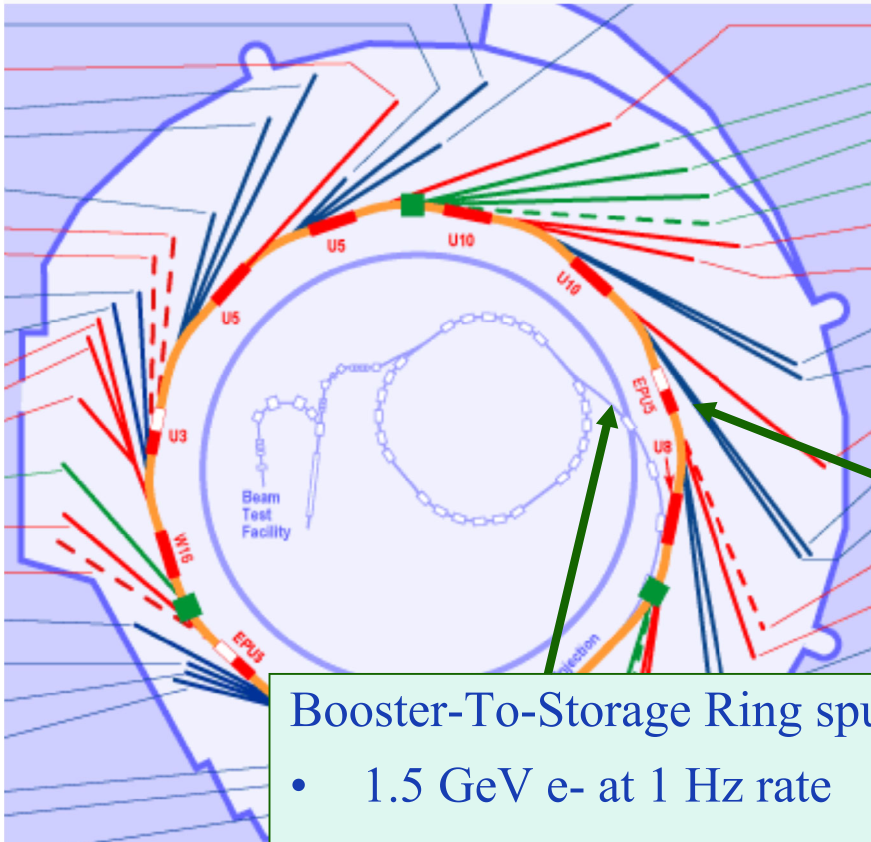
- High pressure vessel

  Six-layer chamber with ceramic insulation

  Rad-hard signal and HV cables



Luminometer Beam Tests



Use beam test facilities at the ALS to provide MIPs for the detector to test

- position sensitivity
- time response and gain
- accuracy
- operating experience over long time periods

Booster-To-Storage Ring spur:

- 1.5 GeV e- at 1 Hz rate
- 30 psec pulse length
- intensity from 1 to 1e9 e- (1e3 typical)
- daily access and availability

Storage Ring spill:

- 1.5 GeV e- with variable spacing
- 30 psec pulse length
- intensity of a few e-
- weekly access


EXIT
B0309
B0310


ACU-RITE

Position Sensitivity

- Raster scan detector through pencil beam
- Record 4 quadrants:

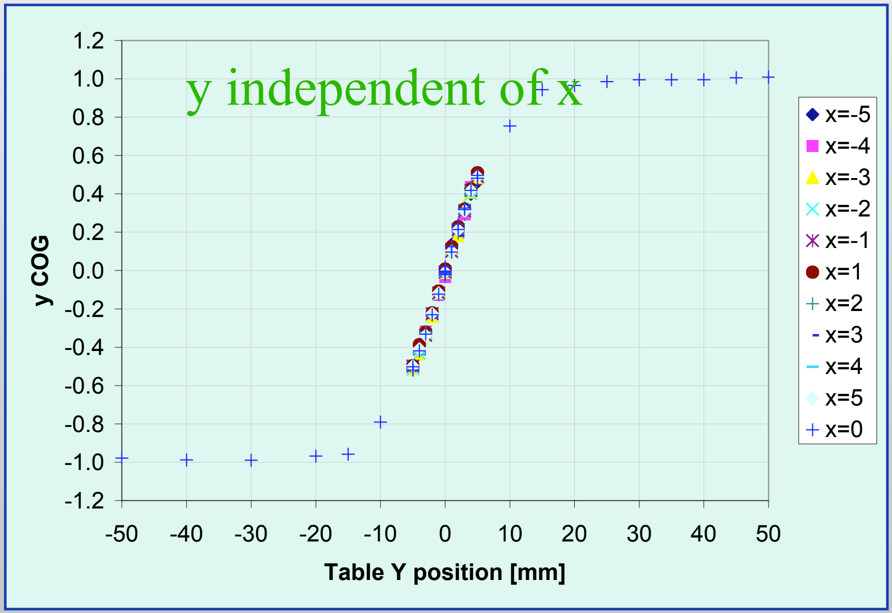
x=(left-right)/sum

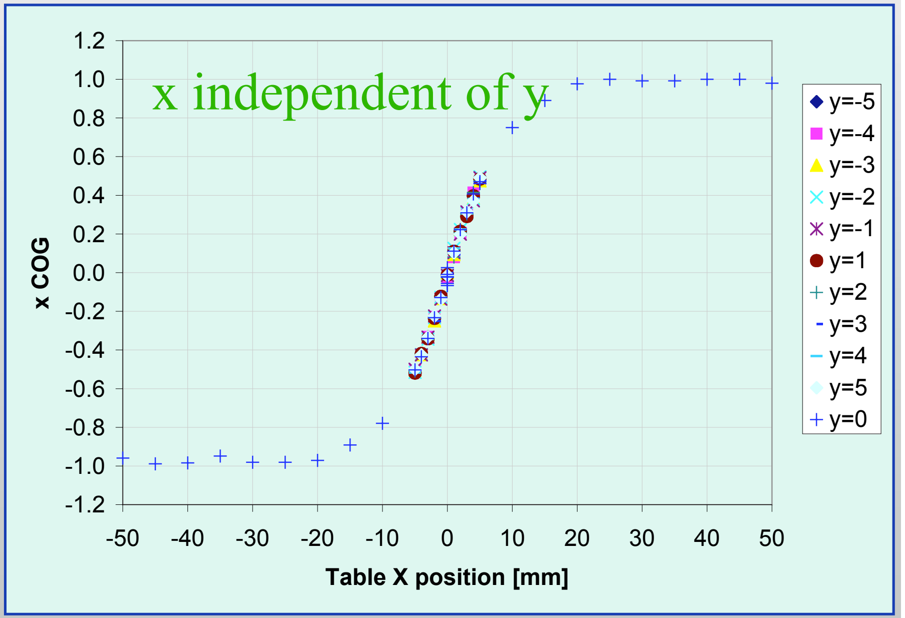
y=(top-bottom)/sum

•Ionization chamber works as a true 4-quadrant detector

•x and y are independent (no crosstalk)

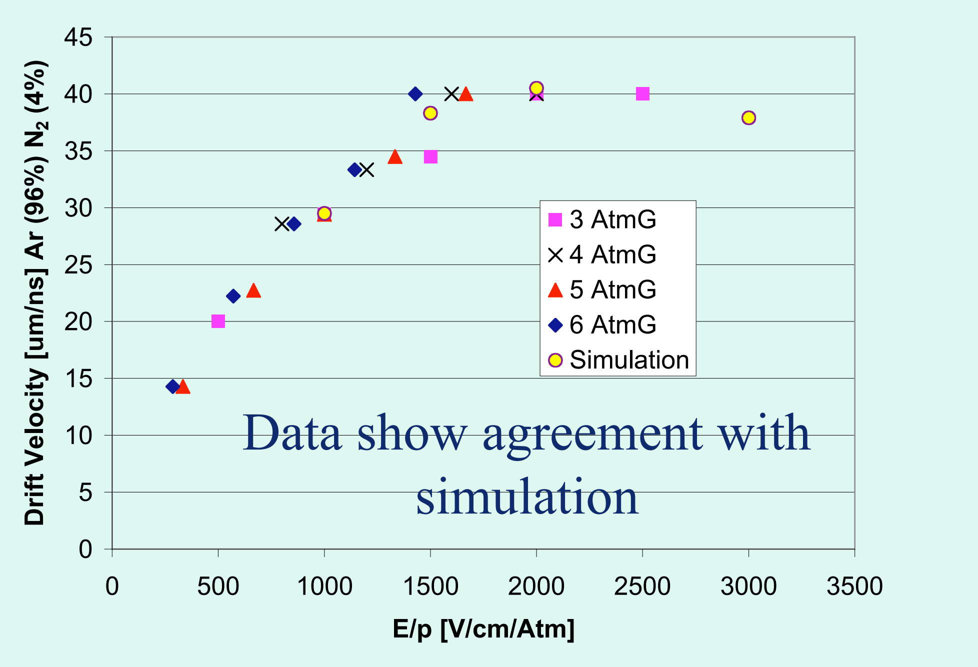
•Position resolution < 110 μm



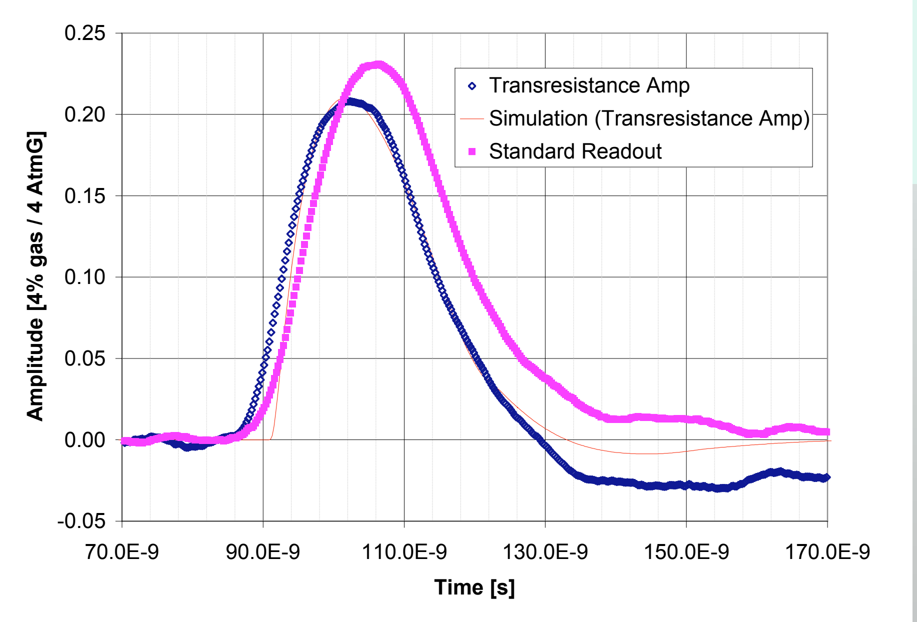


Detector response time

Measure pulse response for varying pressure, gas mixture, and voltage. Derive drift velocity from fit using electronics response.



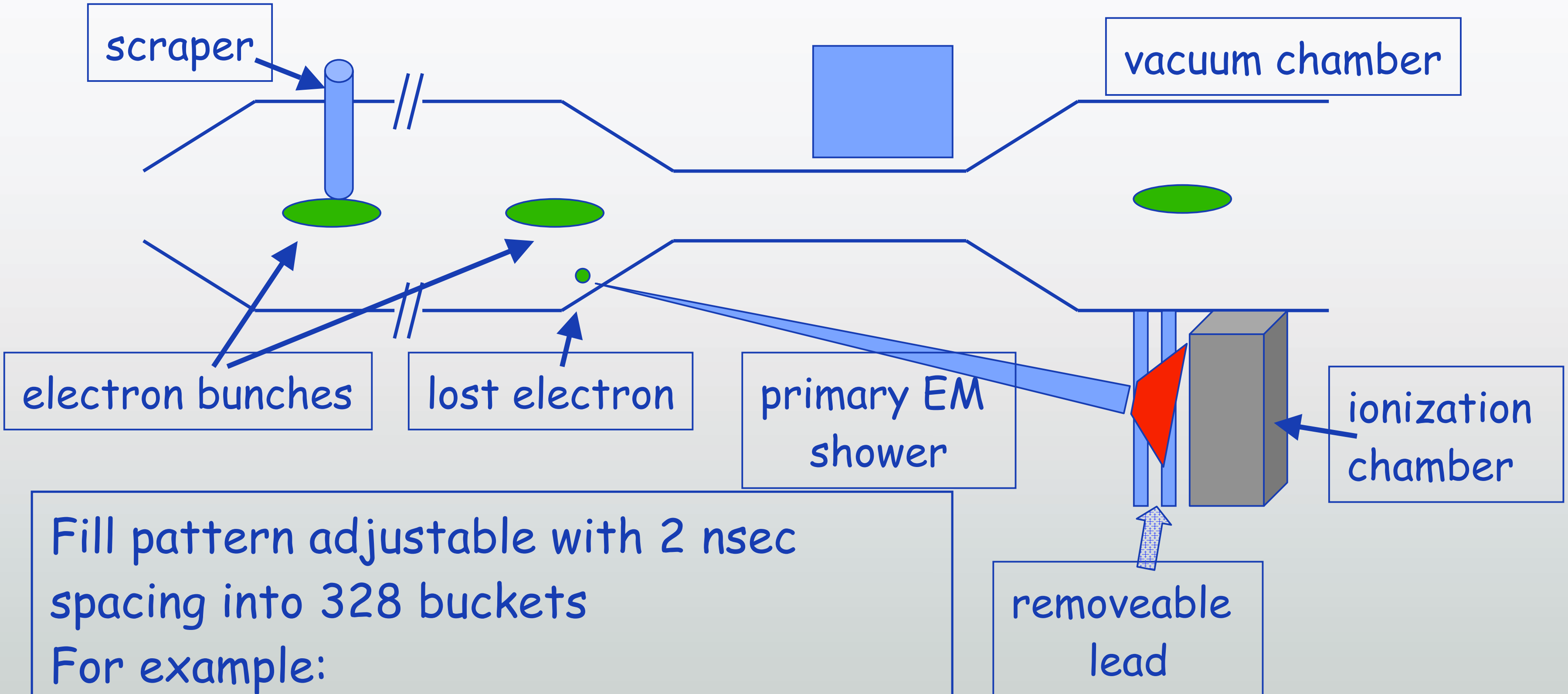
Data show agreement with simulation



Pulses a bit longer than expected due to additional capacitance of detector/cable but still suitable for 25 nsec operation.

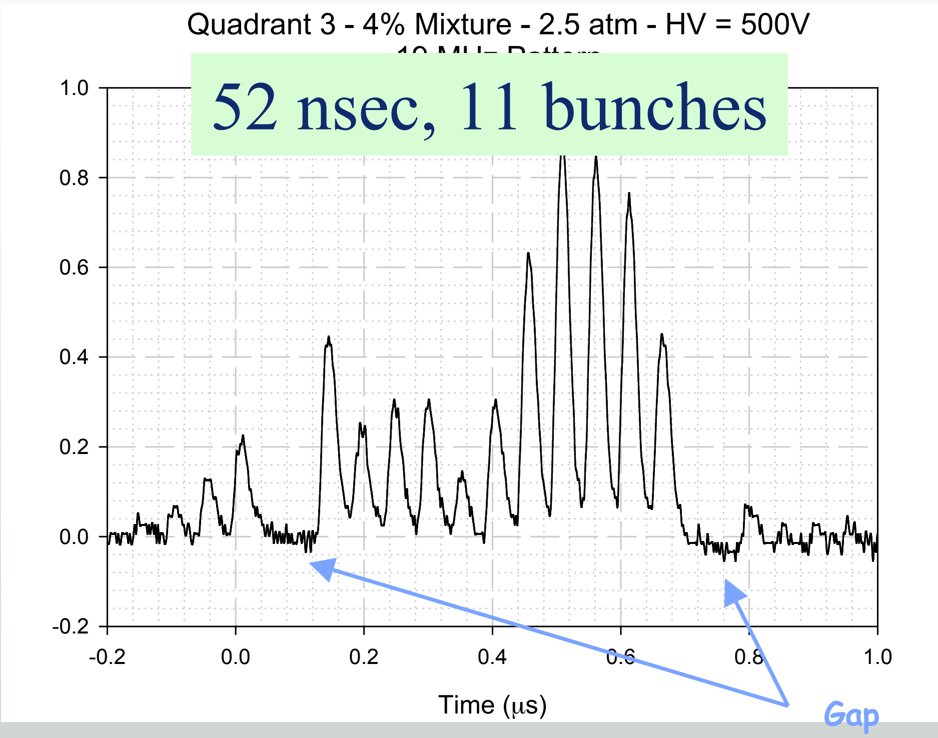
John Byrd

Simulate LHC Conditions in the ALS

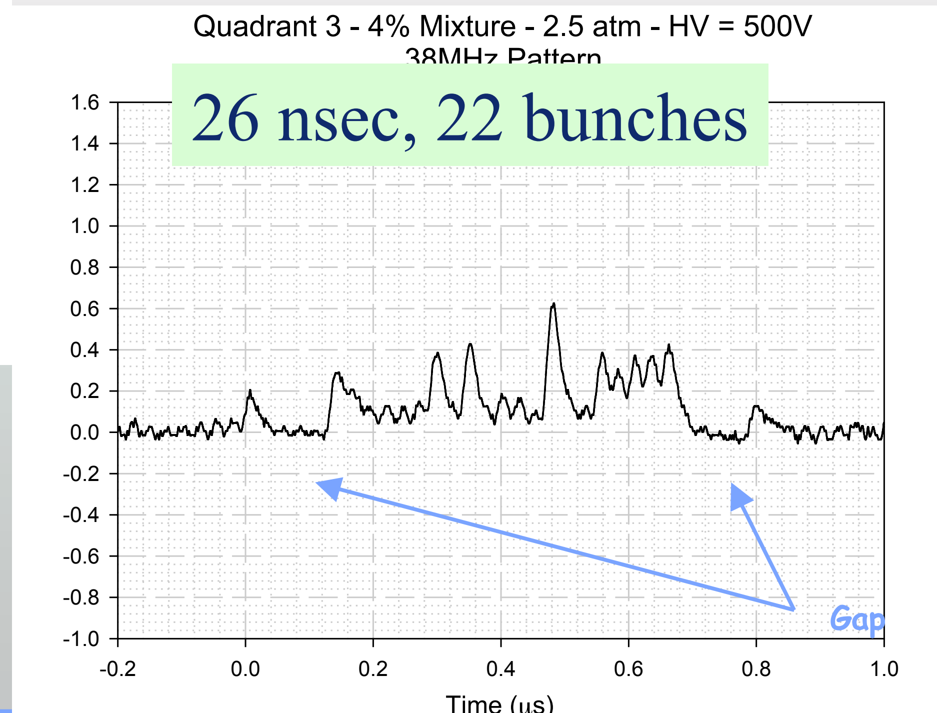


Fill pattern adjustable with 2 nsec spacing into 328 buckets
For example:
24 nsec->41.7 MHz, max 27 bunches
26 nsec->38.5 MHz, max 25 bunches
LHC conditions: 25 nsec-> 40 MHz

Fast Pulse Beam Test Results



Spilled ALS beam provides a test of LHC conditions.



Further studies to determine if pulses can be deconvolved to 1% accuracy.


12/04/2003

LHC Longitudinal Charge Density

LHC beam carries 350 MJ. Beam loss in magnets can cause severe damage.

- Machine operation/protection issues for study include:
  - Debunched beam at injection
  - Population in abort gap
  - Ghost bunches
  - Bunch core and tails
- Requirements:
  - 10^4 dynamic range
  - 20 samples/bunch giving ±2γ (1120 psec). Corresponds to 50 psec sampling resolution.
  - Do this for all buckets (h=35640!). Drives overall sampling rate.

The LDM will also be an invaluable tool for beam dynamics studies in LHC.

LHC Longitudinal Charge Density Specs

Function	Beam energy TeV	Nominal peak density*, p/ps	Resolution, p/ps	Integration time
Debunched beam	0.45	1.0×10^{8}	2×10^{4}	~10 sec
Abort gap population	7.0	2.0×10^{8}	60	~ 100 ms
Ghost bunches	7.0	2.0×10^{8}	2×10^{4}	~ 10 sec
Tails	7.0	2.0×10^{8}	$2 \pm 1 \times 10^{4}$	~ 10 sec
Bunch core	7.0	2.0×10^{8}	$2 \pm 1 \times 10^{6}$	~ 1 msec

* $N_b = 10^{11}$

Requirements (from. C. Fischer, LHC-BSRL-ES-0005.00 rev 2.0, 07 Jan 03)

Two instruments

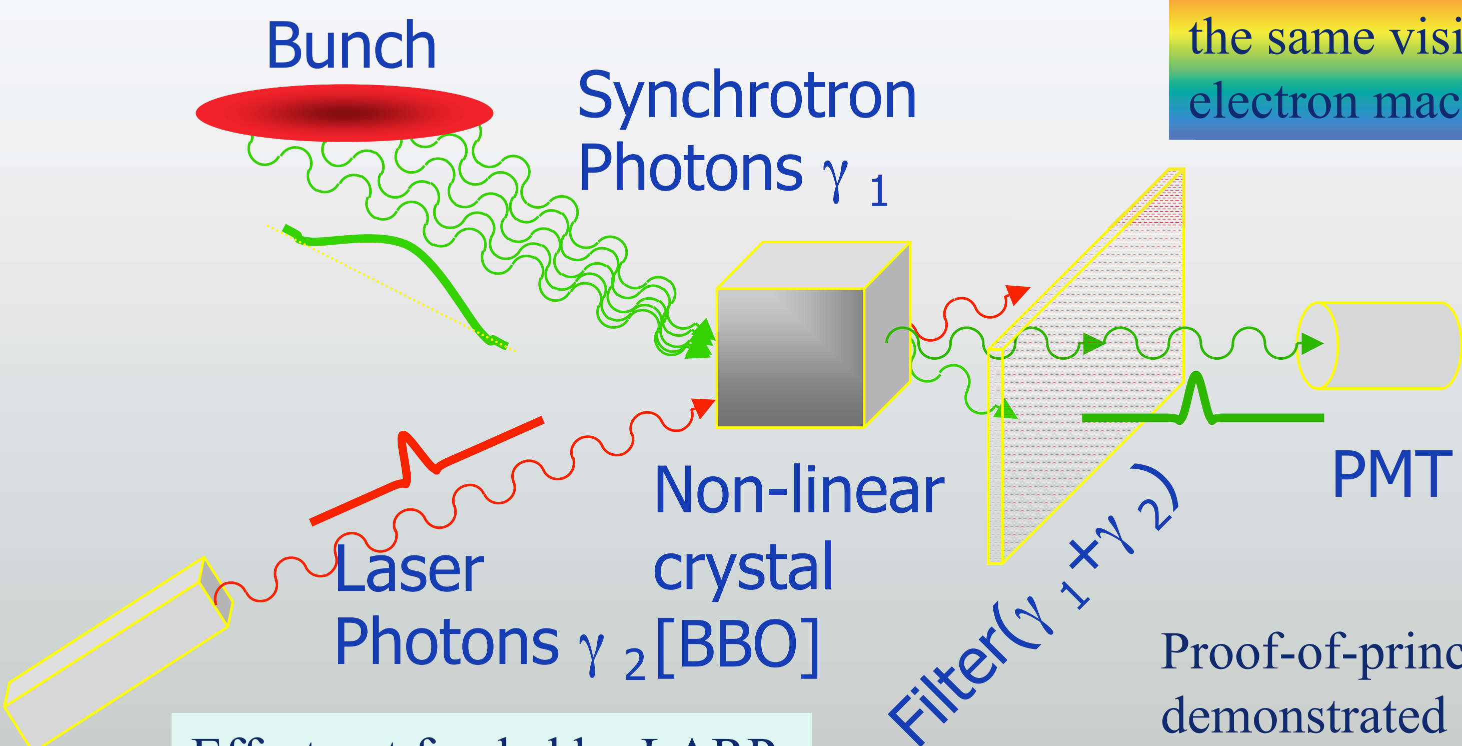
•Longitudinal density monitor (LDM)
high counting rates require sophisticated design
bunch core and tails for all 3000 bunches

•Abort gap monitor
simple design
use in machine protection

Optical Sampling Technology

- Use mixing of synchrotron radiation with a short laser pulse to sample the longitudinal bunch profile

LHC beams (γ=7000) emit the same visible light as electron machines



Effort not funded by LARP in FY04. Increase to 140k$ in FY05

Proof-of-principle demonstrated on the ALS. Developed in collaboration with femtoslicing program.

Abort Gap Monitor

Goal: detect presence of charge in gap for abort kicker rise time
LHC Spec

Possible solution: detect synch light with gated MCP/PMT.

HAMAMATSU

GATEABLE MICROCHANNEL PLATE PHOTOMULTIPLIER TUBE (MCP-PMTs)
R5916U-50 SERIES

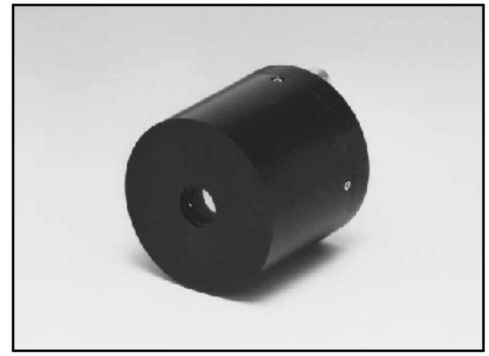
Featuring Fast Gating Function with Improved Time Response and Switching Ratio

FEATURES

- High Speed Gating by Low Supply Voltage (+10V)
  - Gate Rise Time : 1 ns [1]
  - Gate Width : 5 ns
- Fast Rise Time : 180 ps
  - Narrow TTS [2] : 90 ps
- High Switching Ratio : 10^8 at 500 nm
- Low Switching Noise
- Low Dark Noise
- Variety of Photocathode Available

APPLICATIONS

- Environmental monitoring
- Satellite laser ranging
- Fluorescence decay analysis



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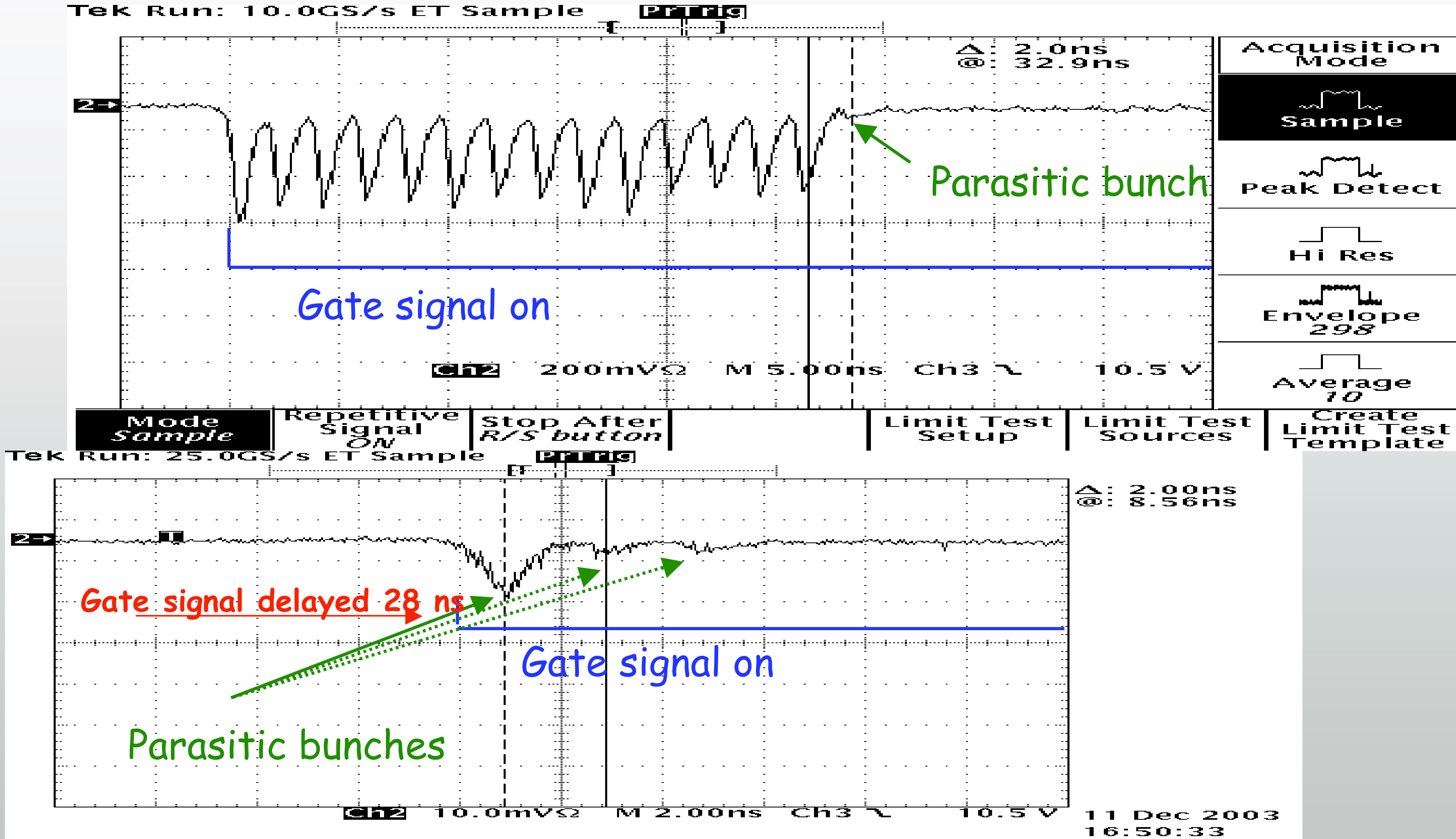
Similar approach used in light sources to measure parasite bunches.

Initial Abort Gap Monitor Tests



White Paper Study

DRAFT

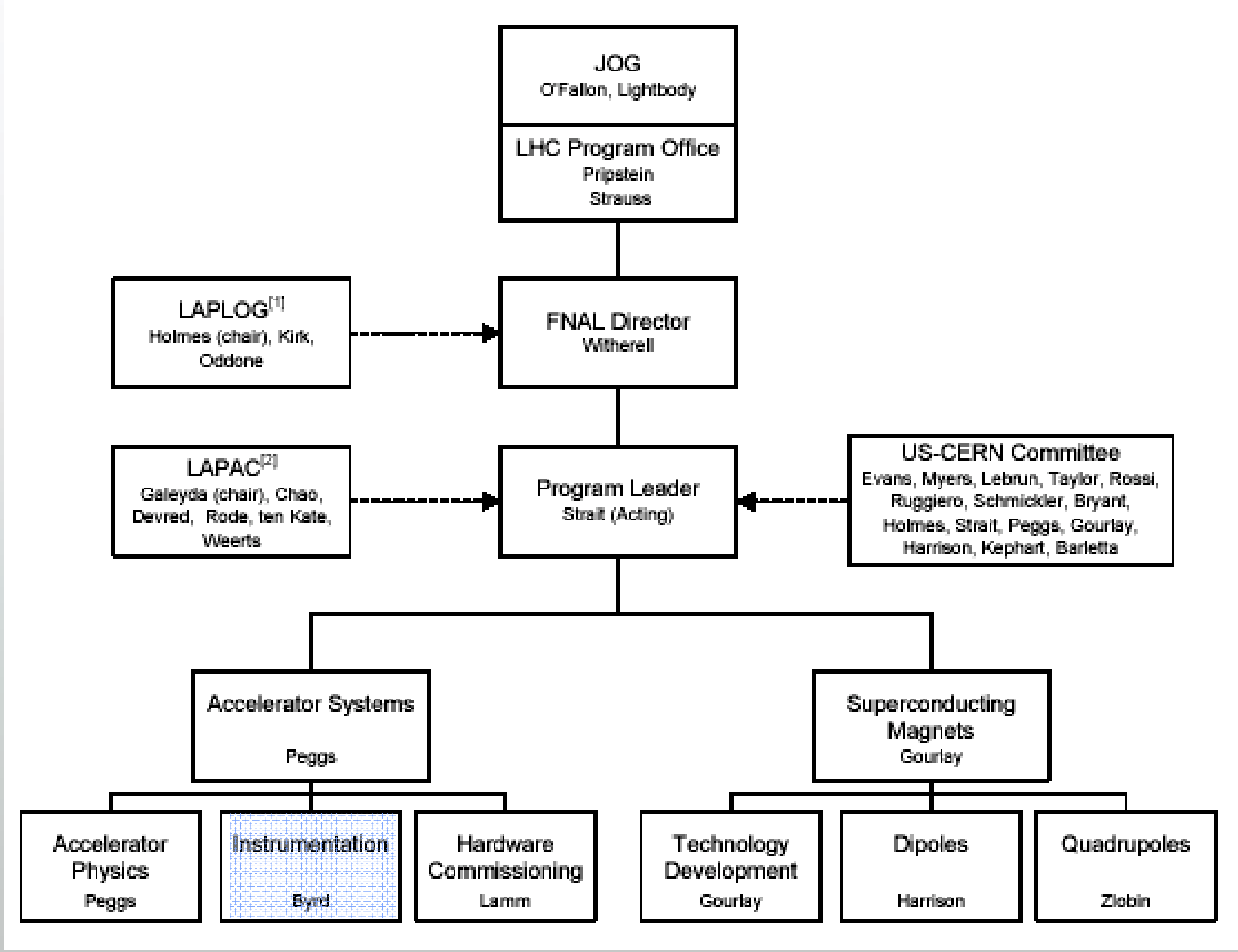
Notes on the Measurement of Longitudinal Beam Density in the LHC using Optical Methods

M. Placidi, W.C. Turner and **M. Zolotorev**
(January 2004)

1. Introduction

This note is intended to provide a numerical evaluation of the feasibility of matching the technical requirements for the longitudinal beam diagnostics at the LHC in connection with different technical approaches in the optical domain, available at the time of writing A summary of the attainable accuracies with the different approaches is presented to allow choosing the most appropriate solutions that match the criteria contained in the official LHC specifications. The diagnostic performance offered by non-optical methods will be the object of another document.

LARP Structure



Summary

Luminosity monitor

- prototype designed, built, and fully tested (almost!) to meet LHC specs
- 25 nsec test in progress; come on down!
- ready to begin of engineering prototype

Longitudinal Density Monitor(ing)

- laser mixing technique demonstrated
  - effort for FY04 not funded
  - paper in preparation to summarize results and application to LHC
- Abort Gap Monitor
  - complex funding profile (total=R+jX $)
  - white paper study in progress
  - gated MCP/PMT appears promising

We want to help commission and operate the LHC.

To this end, we will deliver, commission, maintain, and integrate these instruments into LHC operation.