LHC Accelerator Research Program
Progress on a luminosity monitor

LAPAC

17-18 June, 2004

John Byrd

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

LBL LARP Instrumentation Group

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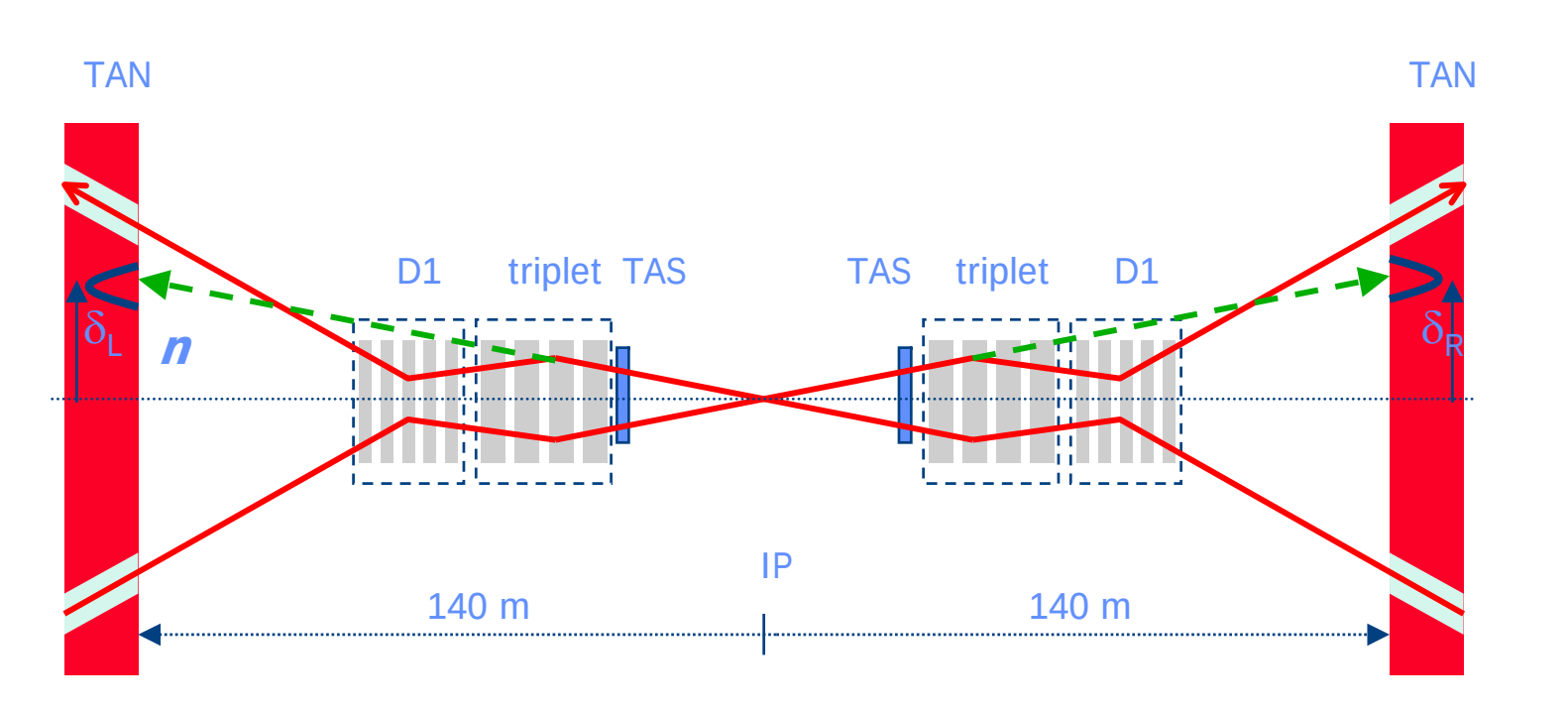
High Bandwidth Luminosity Monitor

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



- Luminosity $\propto N_{MIP}$ from ***n*** shower
- Crossing Angle $\propto \delta_L + \delta_R$

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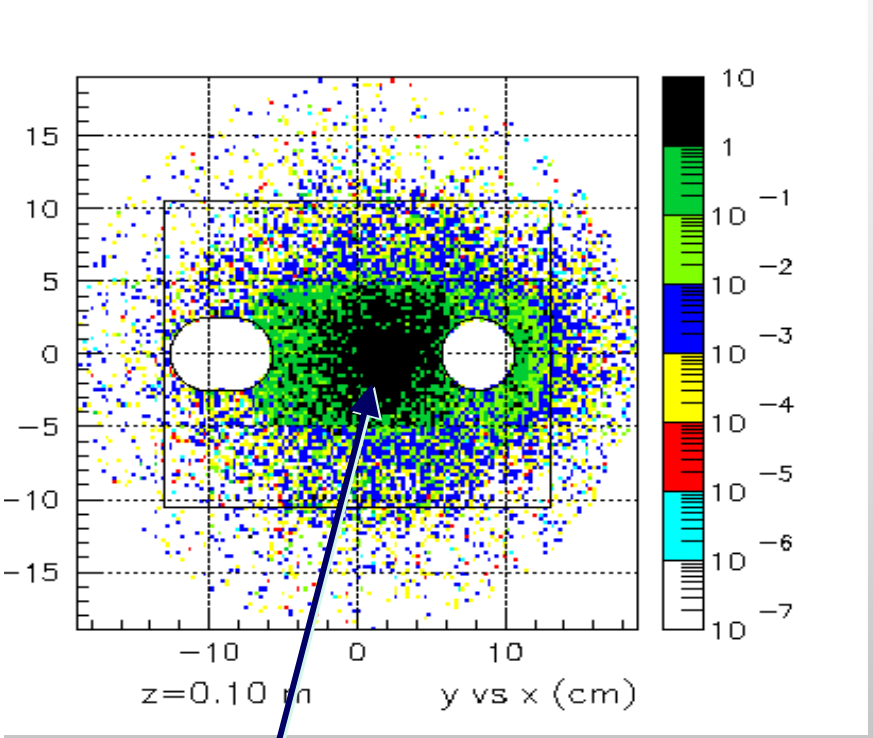
neutron signal in the TAN



Offset due to ±150 µrad crossing angle

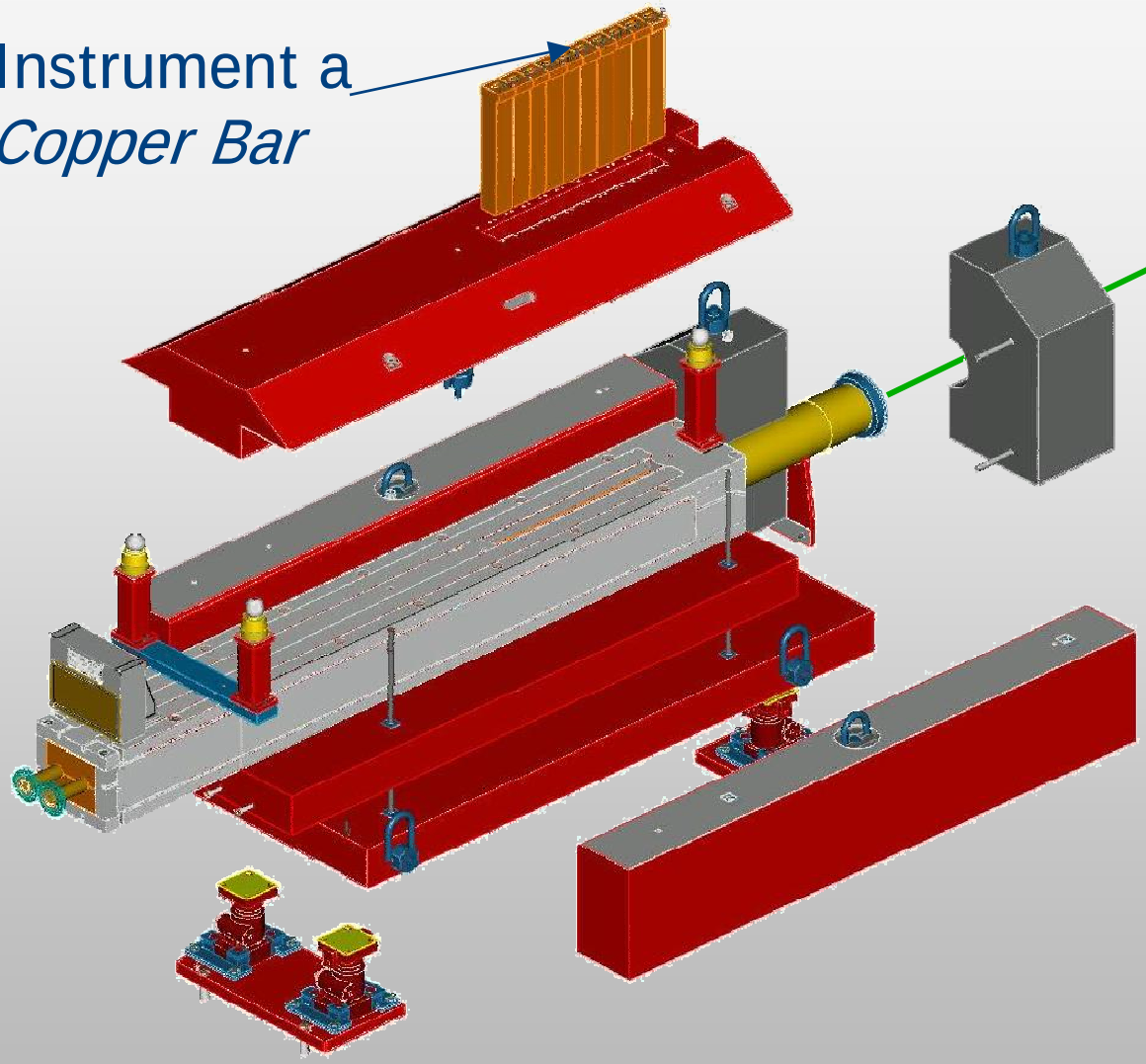
Charged particles swept away (Gas) Detector placed after several λ_{INT} (few γ)
m ~1 *n* per 3 *pp* interactions (in the acceptance)

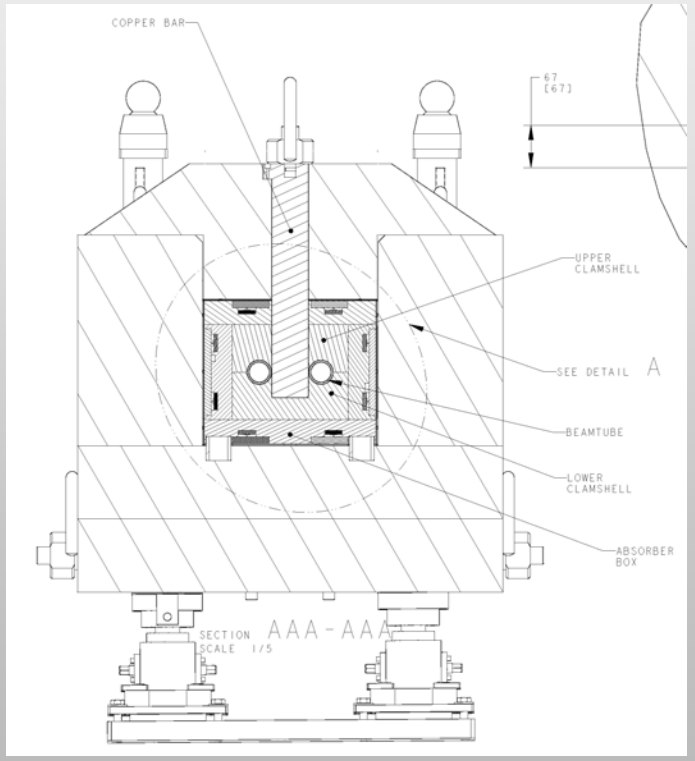
- Horizontal, vertical or 45° crossing
- ~ 80 x 80 mm^2 for detector
- Segment (for position)

Instrumented TAN absorber

Instrument a
Copper Bar

IP





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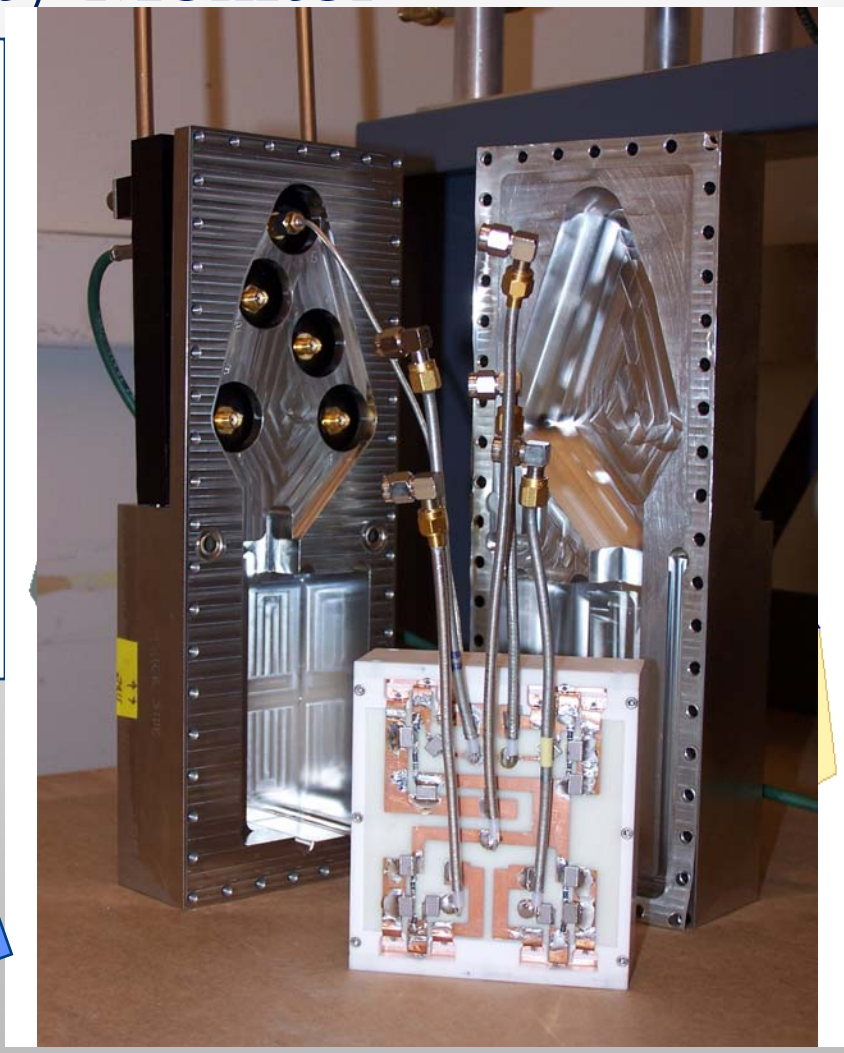
LHC Luminosity Monitor

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



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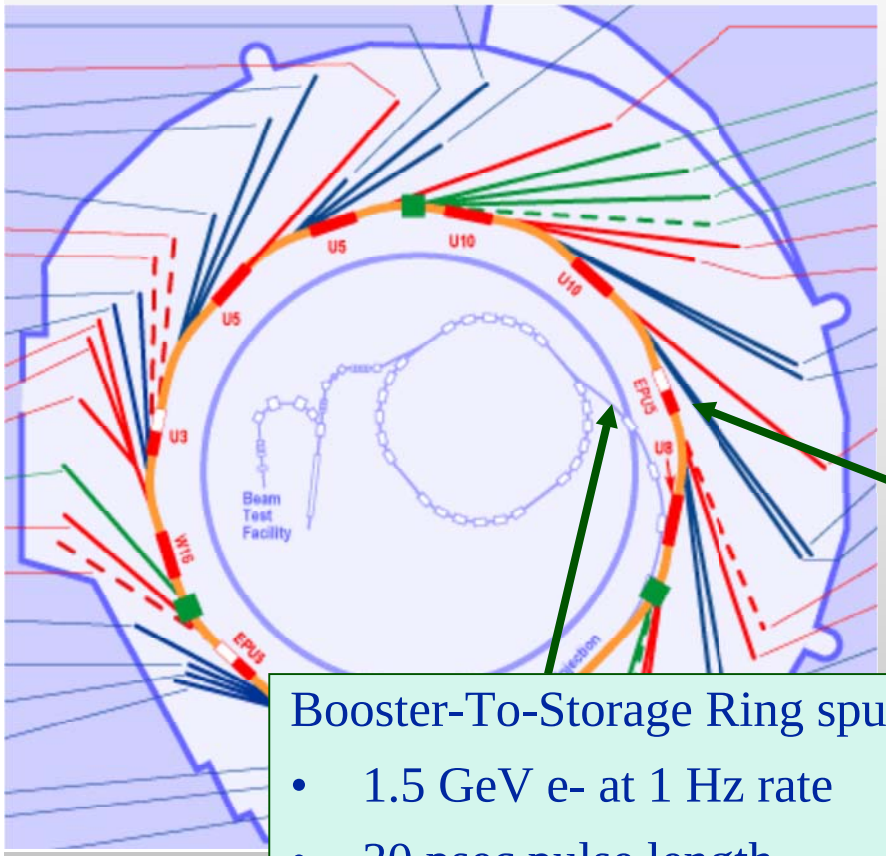
Luminometer Beam Tests



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:

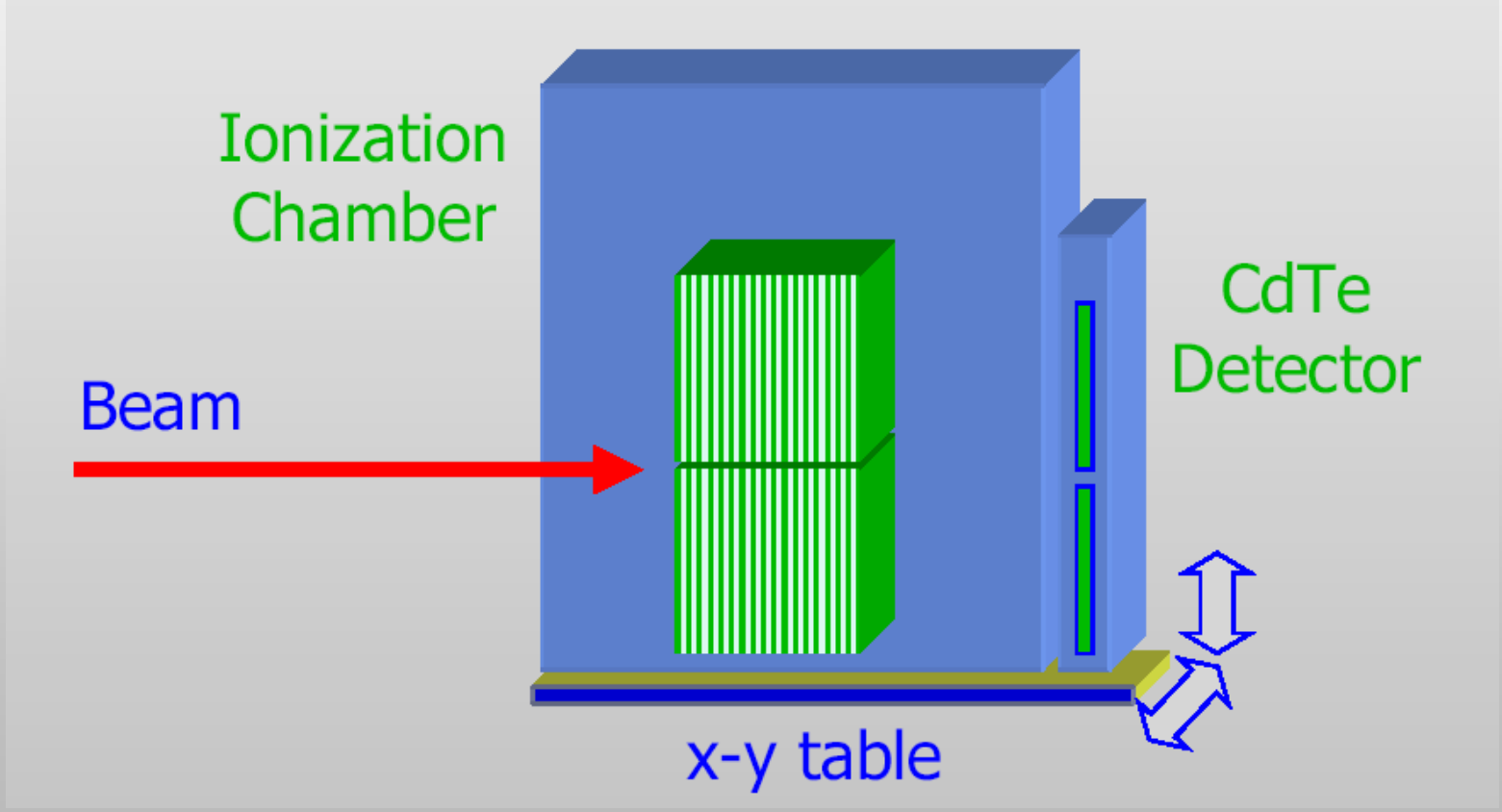
- 1.5 GeV e- with variable spacing
- 30 psec pulse length
- intensity of a few e-
- weekly access

Taking data

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

BTS Tests

- "delta-function" e- beam (50 ps); 1.5 GeV; 1 Hz
- Adjustable intensity (typically ran at 20 pp±50%)



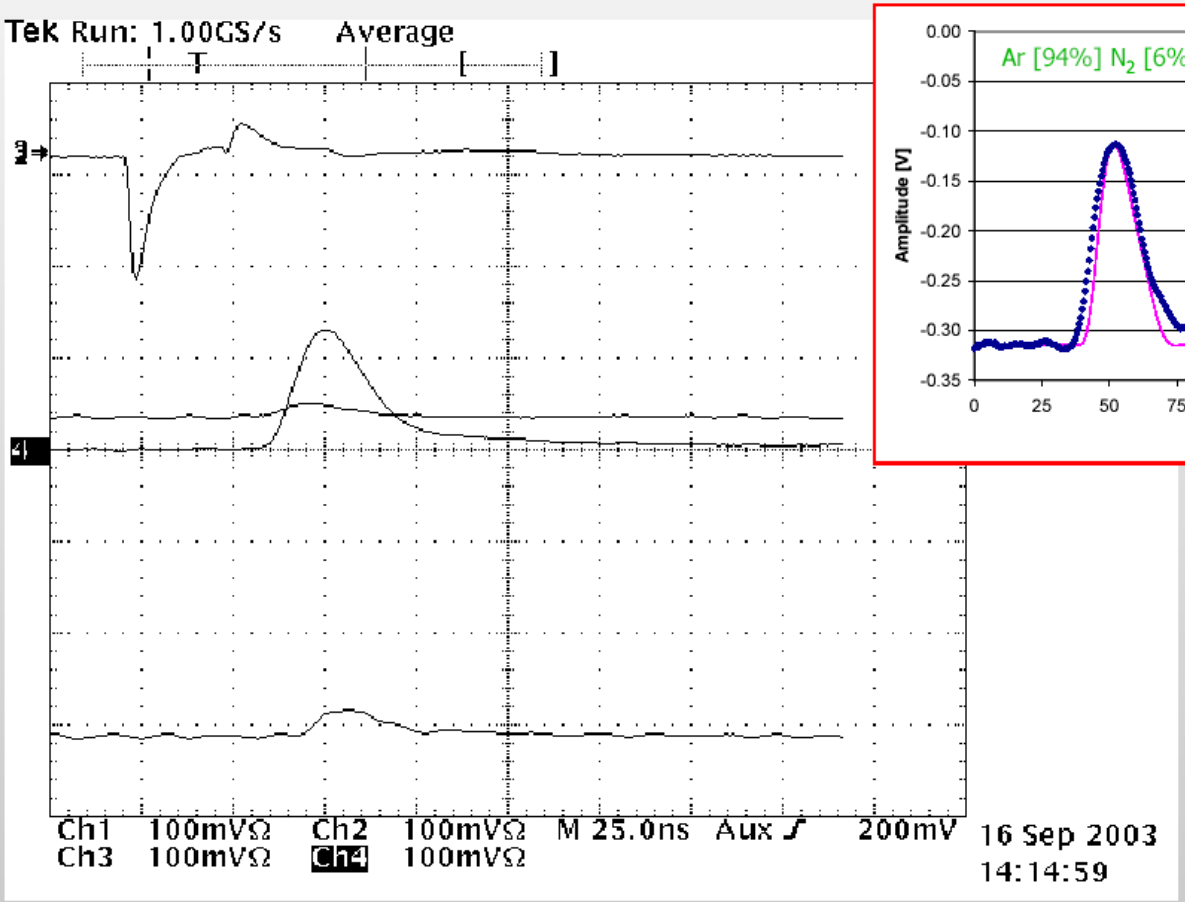
BTS Setup

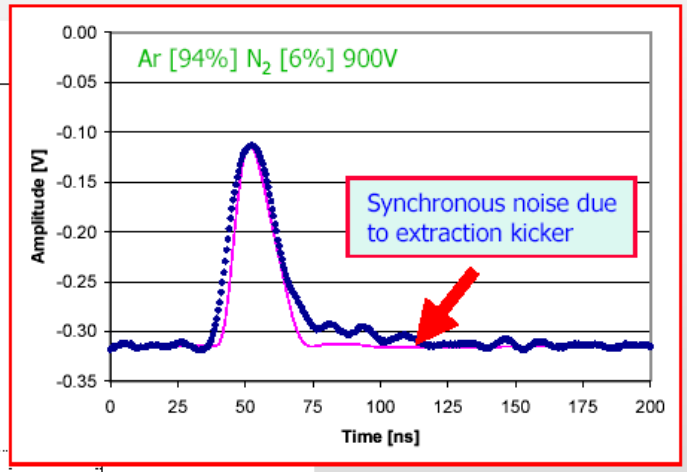
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

BTS Waveforms

CdTe

Gas Quadrants





◆ Measured

— Simulation

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Position Sensitivity

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

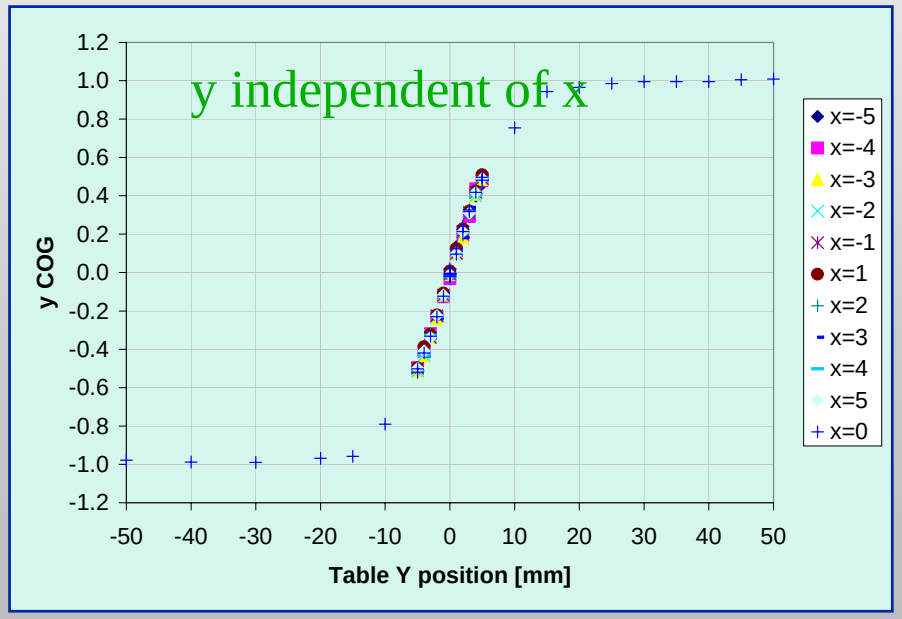
x=(left-right)/sum

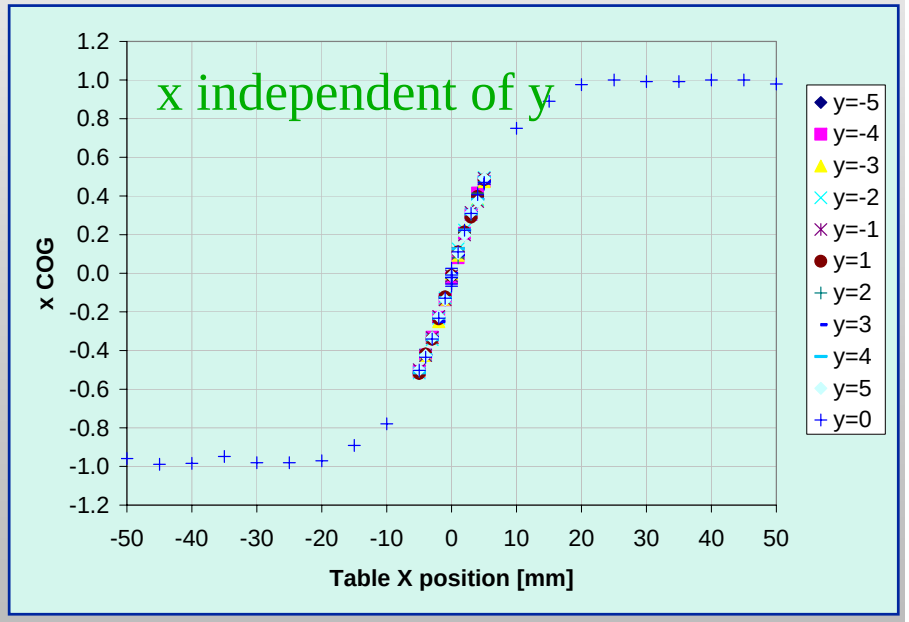
y=(top-bottom)/sum

•Ionization chamber works as a true 4-quadrant detector

•x and y are independent (no crosstalk)

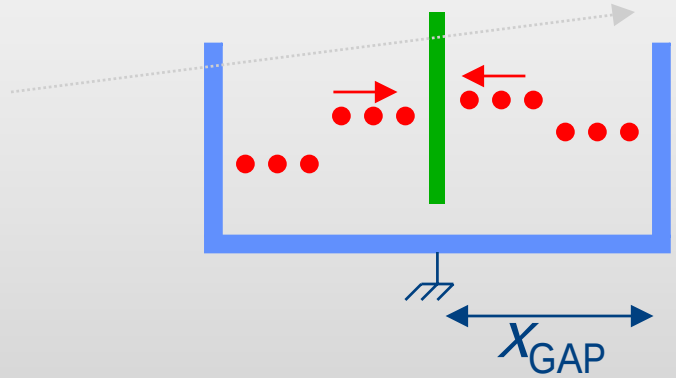
•Position resolution < 110 µm

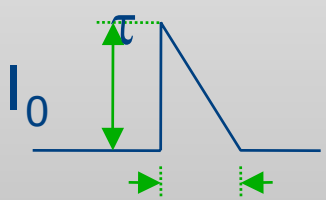




Gas Tests

- Chamber uses Ar (100-x %) + N2 (x%)
- Design was based on Monte Carlo calculations of gas properties
- Drift velocity is key parameter (determines speed)





$$\tau = x_{GAP} / v_D \quad Q = \int_0^{\tau} I(t)dt = \frac{1}{2} I_0 \tau$$

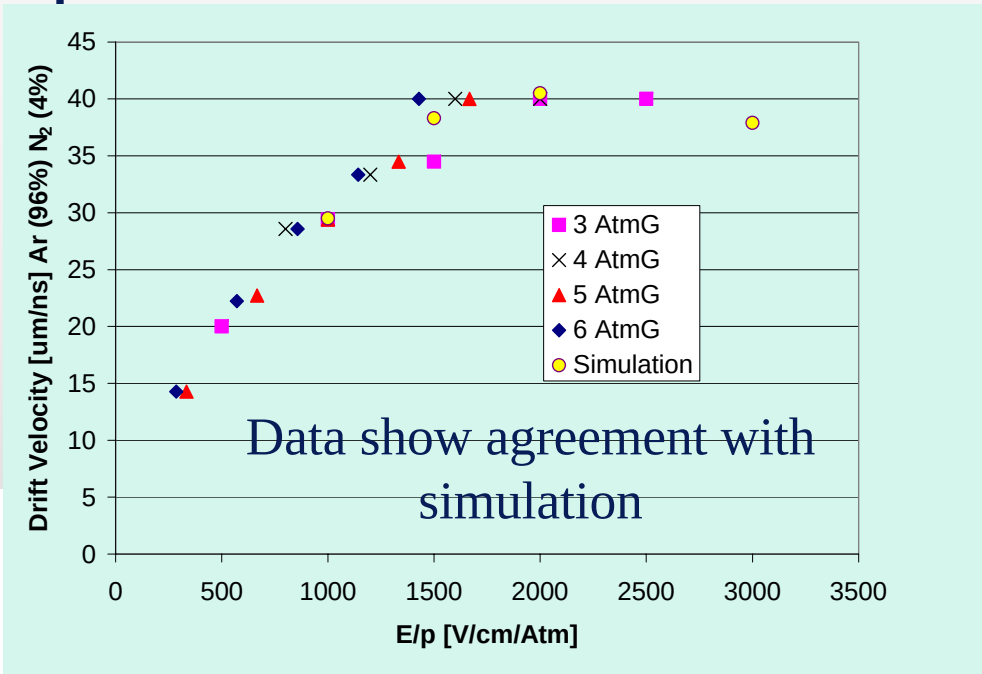
$$= 9.7\ e^{-}/MIP/\text{mm} \times 231\ MIP/\text{h} \times x_{GAP} \times P \times N_{GAP}$$

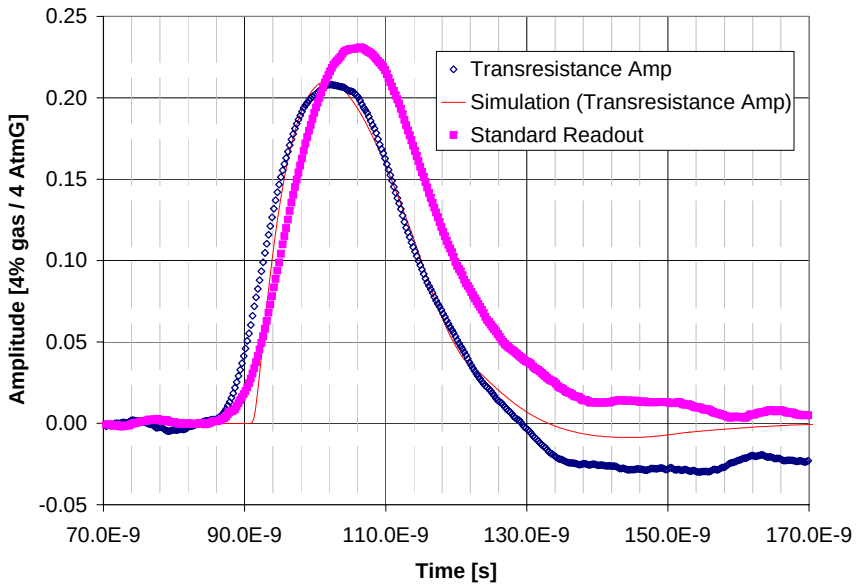
$$I_0 = 2\ Q_0 v_D P N_{GAP}$$

$$= 0.72\ \text{nA} \times v_D\ [\mu\text{m/ns}] \times P\ [\text{Atm}] \times N_{GAP}$$

Detector response time

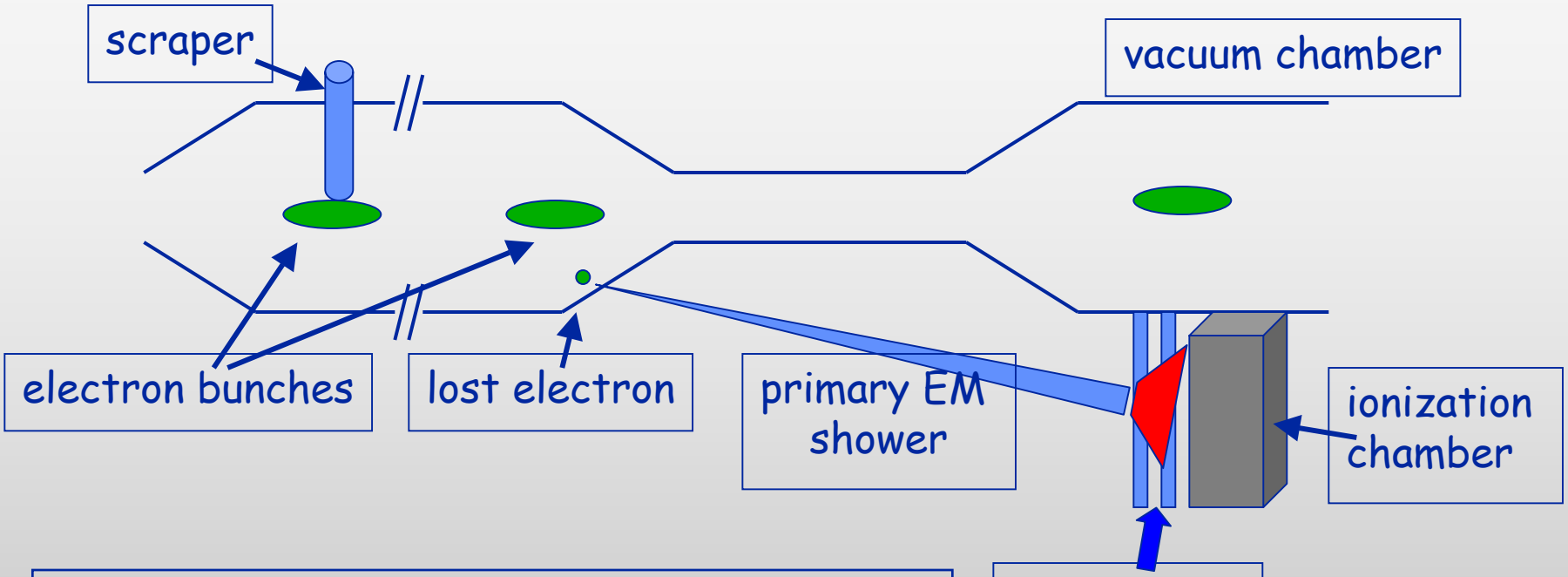
Measure pulse response for varying pressure, gas mixture, and voltage. Derive drift velocity from fit using electronics response.





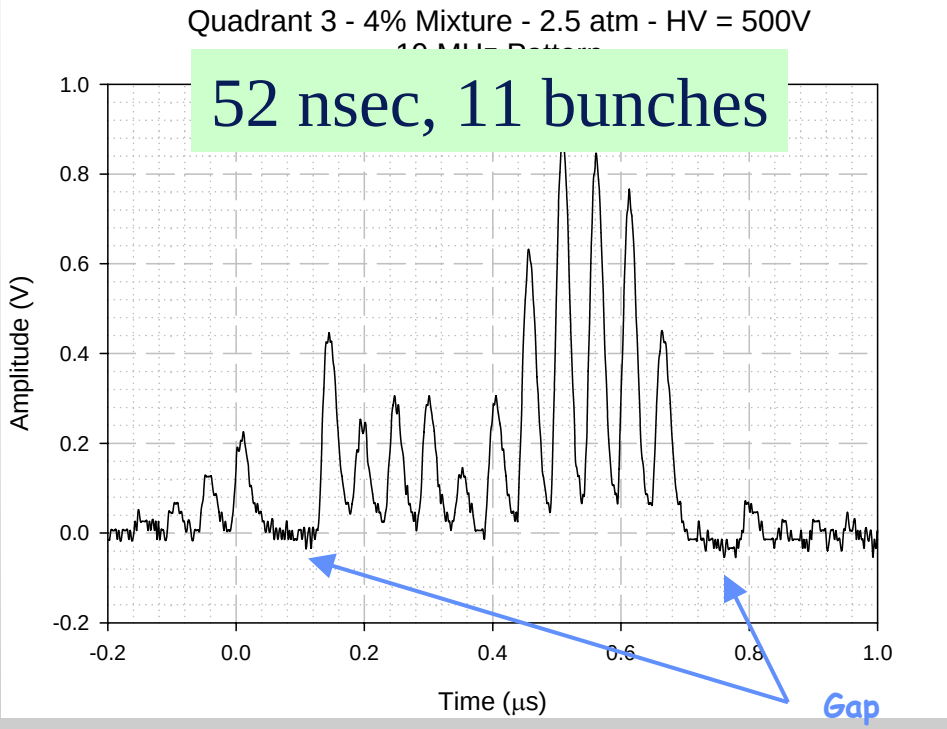
Pulses a bit longer than expected due to additional capacitance of detector/cable but still suitable for 25 nsec operation.

Simulate LHC Pulse Rate in the ALS

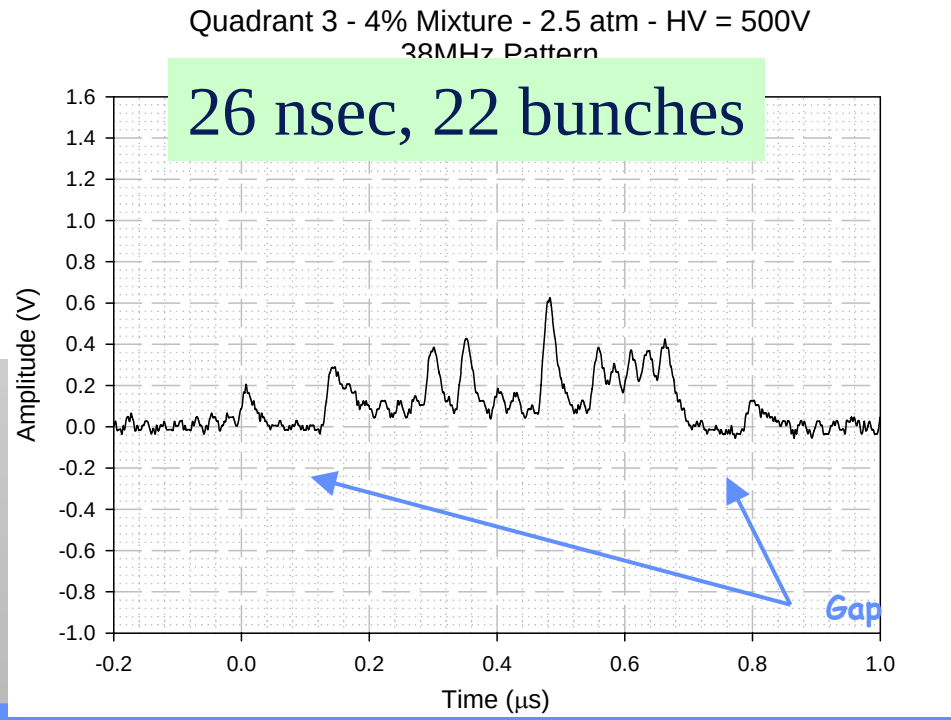


Fill pattern adjustable with 2 nsec spacing into 328 buckets. Test up to 24 nsec spacing.

Fast Pulse Beam Test Results

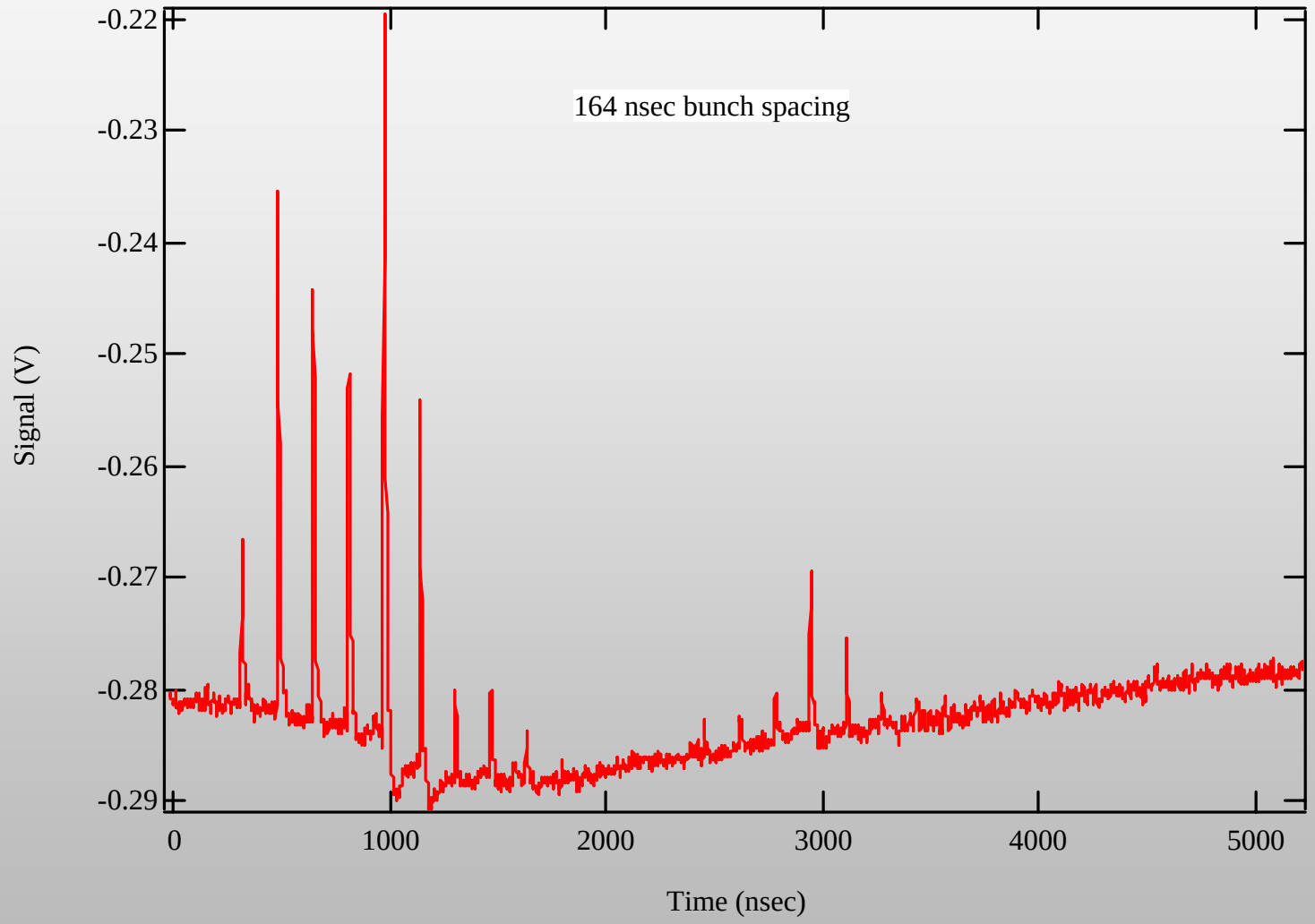


Spilled ALS beam provides a test of LHC conditions.



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

Latest results (last Saturday)



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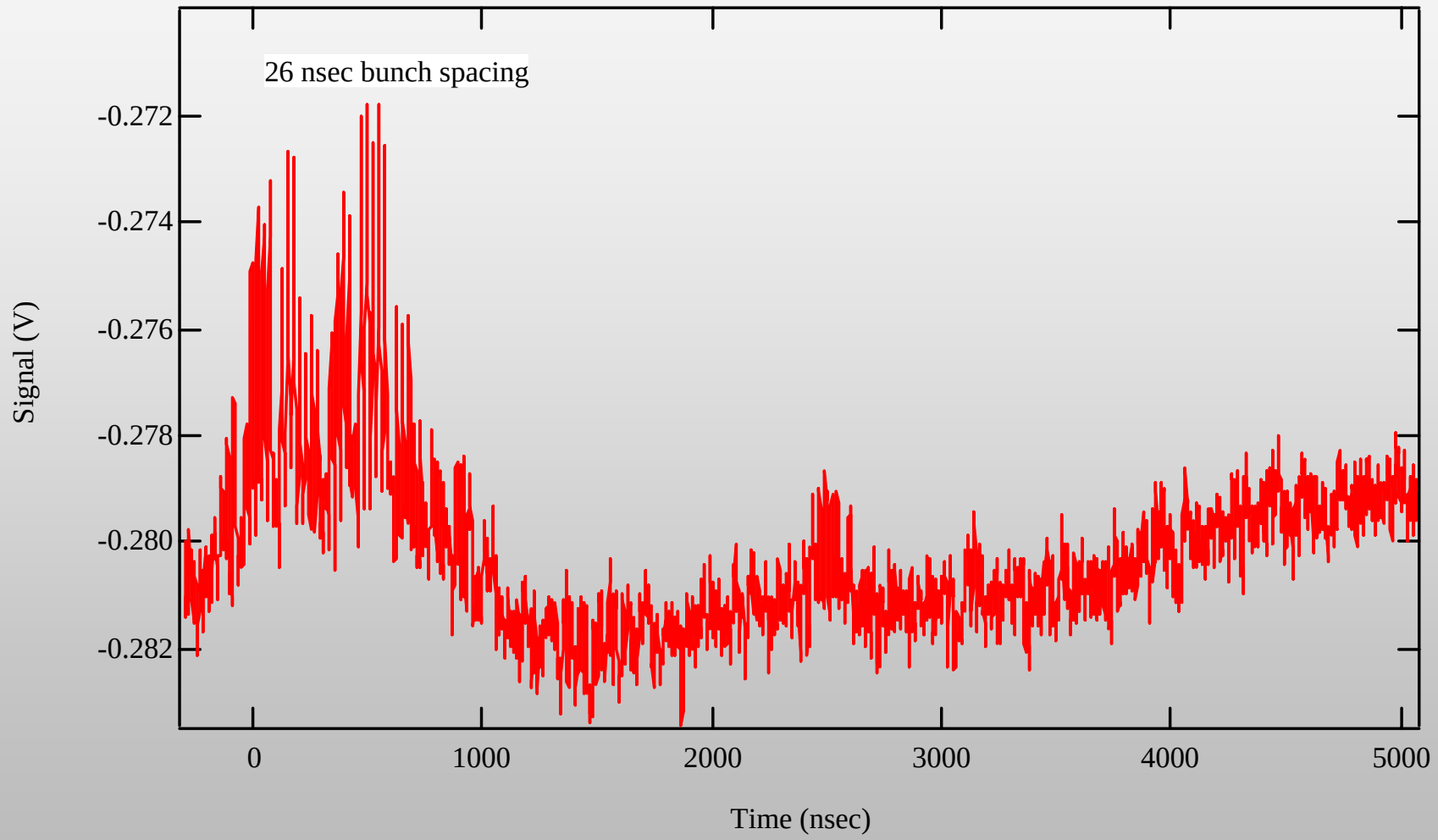
Recent results 26 nsec spacing



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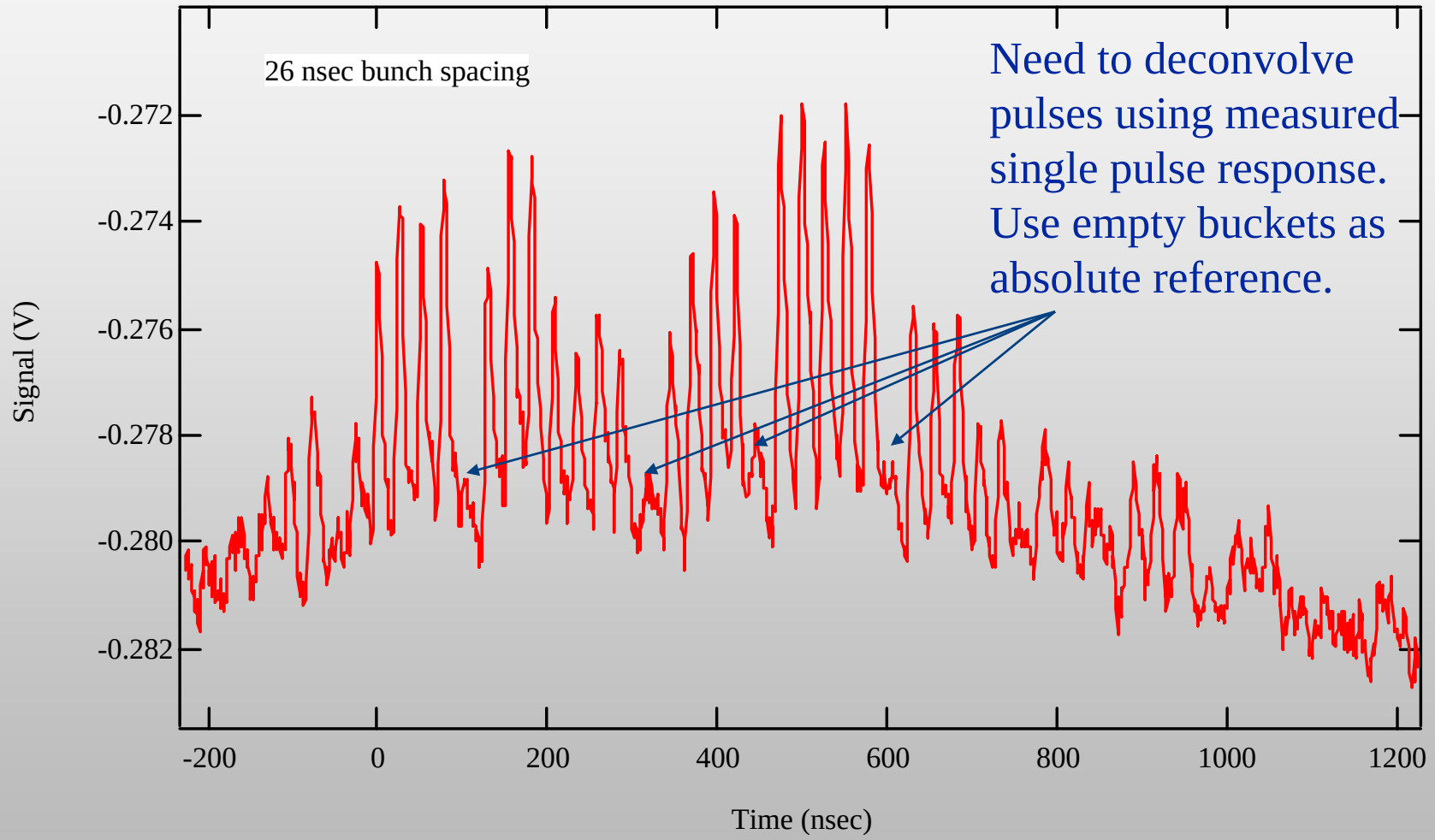
26 nsec bunches zoom



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Front End Electronics modeling

single pulse response

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

- model of existing electronics including chamber capacitance explains undershoot.

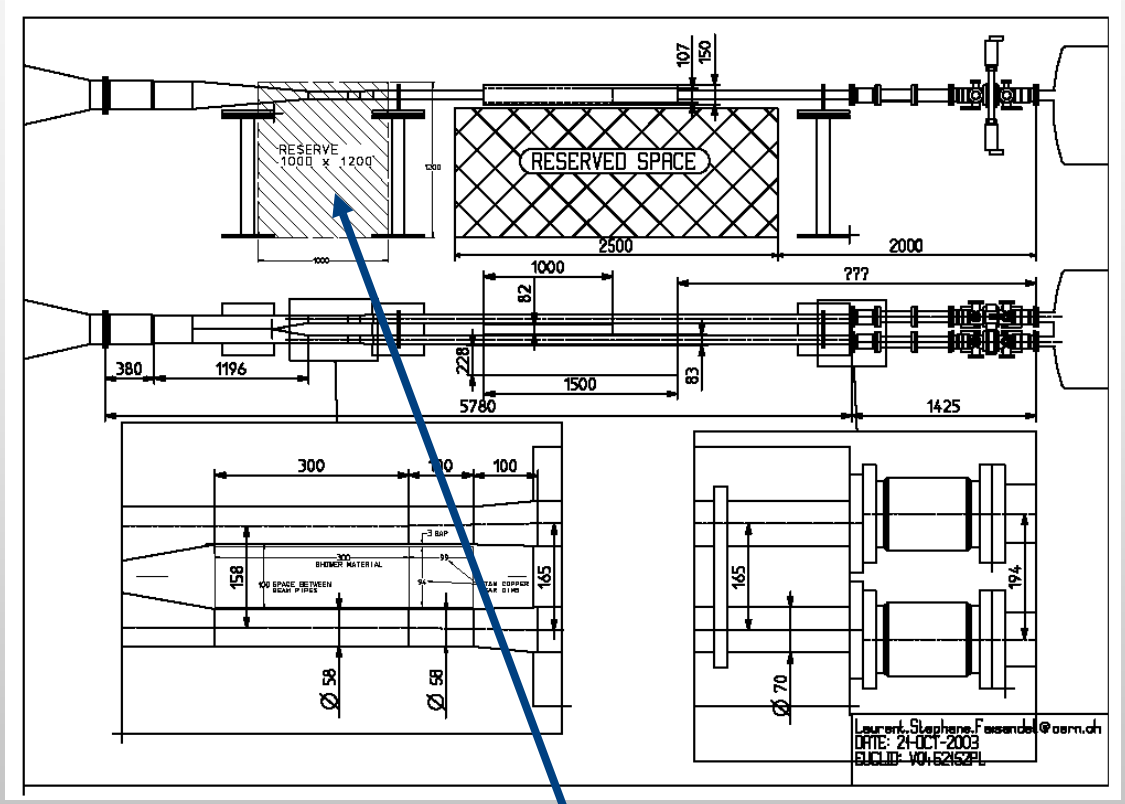
25 nsec pulse response

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Possible installation in IP2 and 8

- Effort to define envelope for installation at “low” luminosity IPs for use in p-p operations
- No TANs-IC detectors require supports and must be moved for Pb-Pb operations.



sufficient space for IC Lumi

Summary

Luminosity monitor

- Tremendous progress with limited budget
- on track to meet LHC specs
  - prototype chamber/electronics designed and built
  - 25 nsec test in progress;
  - work beginning on deconvolution process
- ready to begin engineering of production prototype
  - improved mechanical design
  - optimised front-end electronics
- preliminary work for installation in IP2+8

LARP beam instrumentation will provide a firm basis for participation in LHC commissioning and operation