

TPC Readout Using the Gas Electron Multiplier

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The TPC readout endcap usually consists of proportional wires with cathode pads. Track angle effects, the $E \times B$ field near the anodes and space-charge effects limit the $r-\phi$ resolution. The Z -resolution limit ultimately comes from positive ion tail effects. With a GEM readout, these systematic effects will be largely absent. With the right electronics, the spatial resolution and the two track resolving power, both in $r-\phi$ and in Z , can be significantly better than the wire/pad TPC. Preliminary results from a GEM test cell at Carleton appear to confirm the viability of a GEM readout for the TPC.

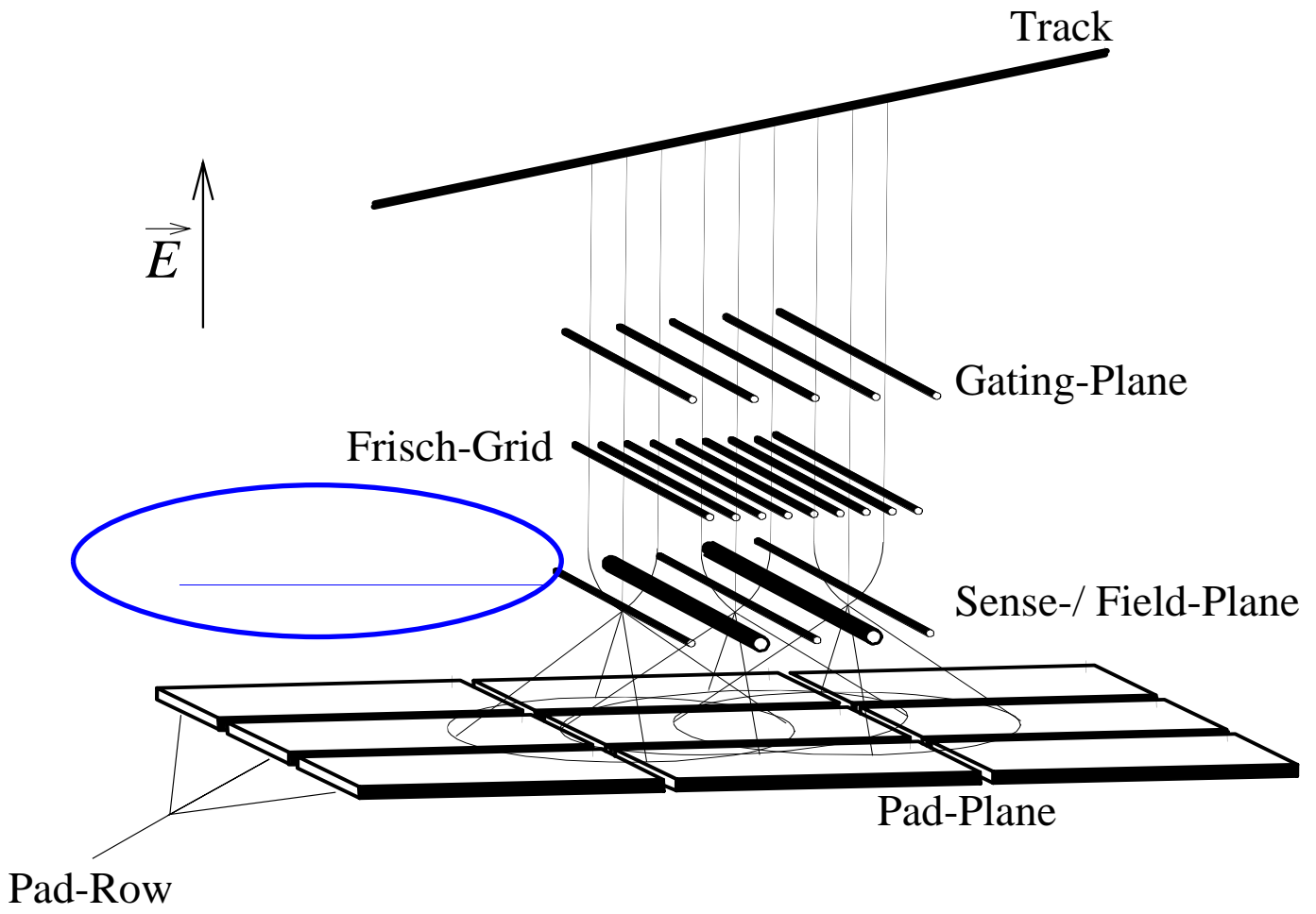
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Talk Outline

- **Introduction – proportional wire/pad TPC readout**
- **Why use GEM for the TPC readout?**
- **How to process the GEM signal for best resolution?**
- **Preliminary results from double GEM test cell with anode strips**
- **R & D plans**

Introduction - Proportional Wire/Pad Readout for the TPC

- **$r - \phi$ resolution dominated by $E \times B$ and track crossing angle effects**
- **Positive ion space-charge effects require gating**
- **The Z resolution ultimately limited by positive ion tails (slow rise time for the anode pulse)**
- **Large endcap mass limits forward calorimetry**

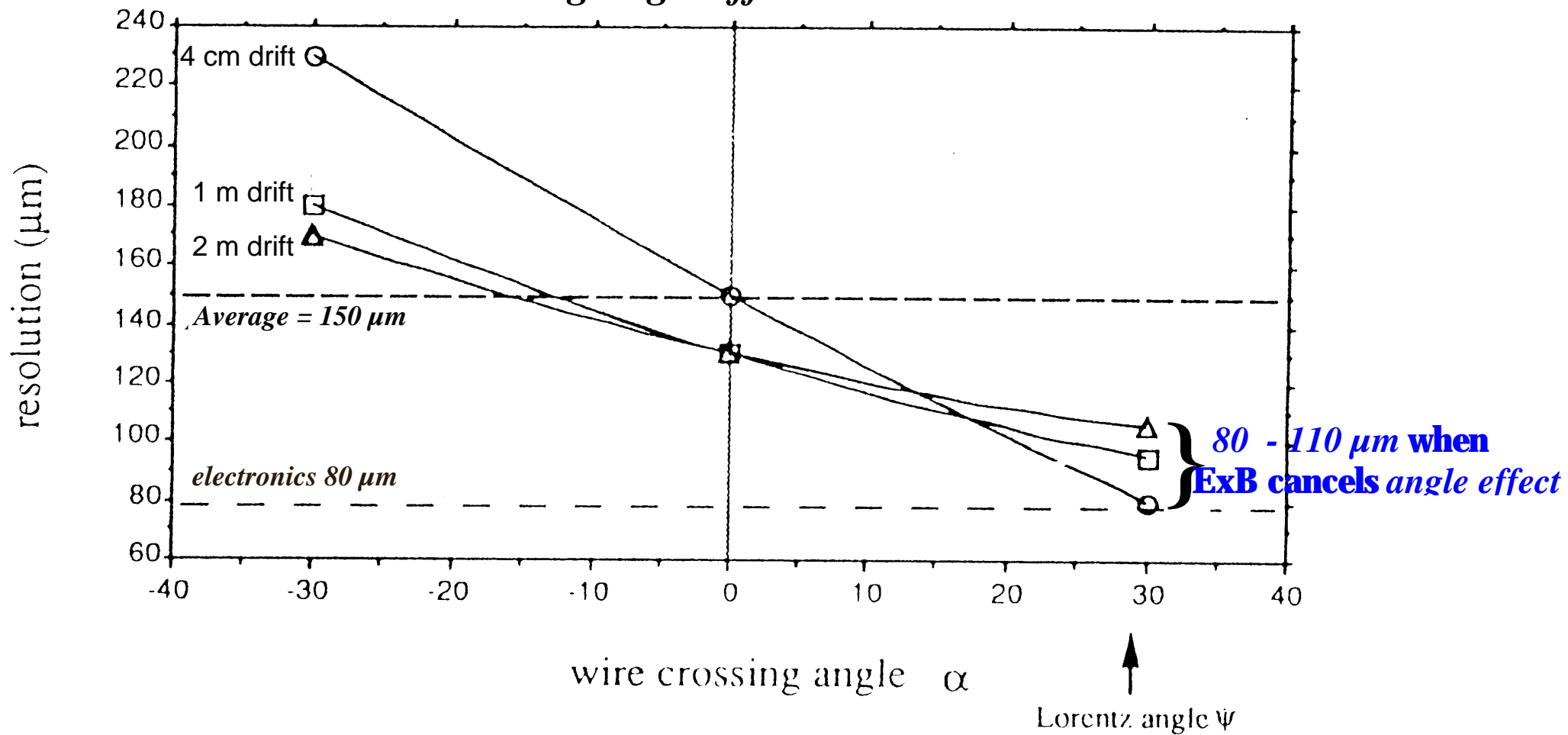


S.R. Amendolia et al. / The spatial resolution of the ALEPH TPC

Nuclear Instruments and Methods in Physics Research A283 (1989) 573–577

North-Holland, Amsterdam

ExB and wire crossing angle effects dominate TPC resolution

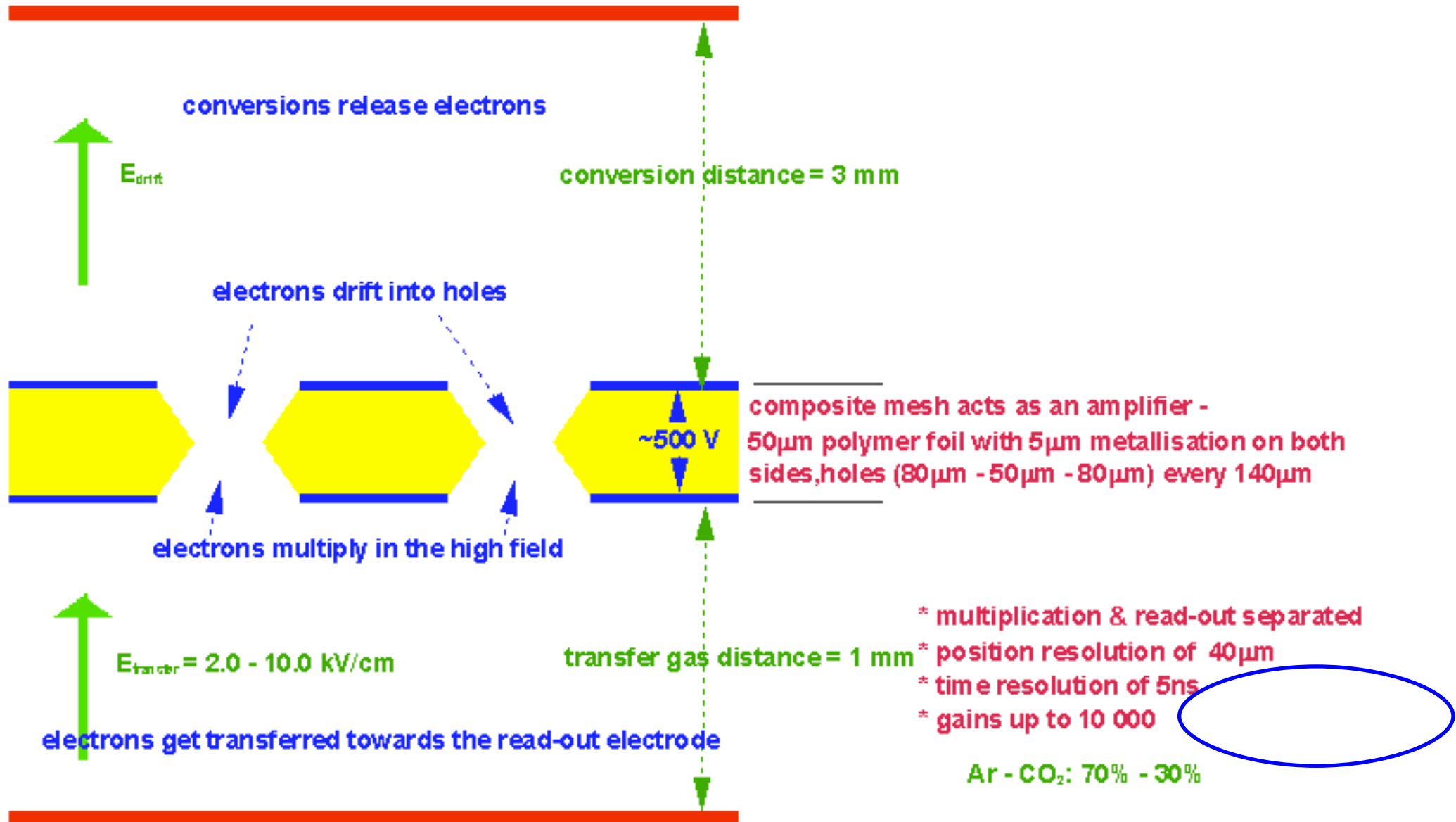


Why Use GEM for the TPC Readout?

- **Significantly better $r - \phi$ resolution & 2 track resolving power in absence of ExB and track angle effects**
- **Ion feedback suppression to 1% or lower level**
(S. Bachmann et al, CERN-EP/ 99-48, 1999)
Simple ungated operation may be feasible
- **Fast charge pulse – better Z resolution and 2 track resolving power**
- **Mechanically simpler and lower mass endcap for better downstream calorimetry**

Gas Electron Multiplier - GEM

(F. Sauli, NIM A386(1997)531)

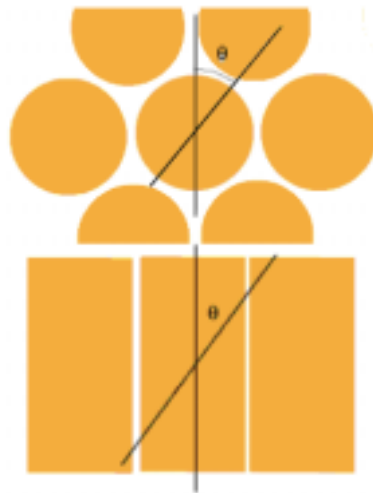


How to Process the GEM Pad Signal for Best Resolution?

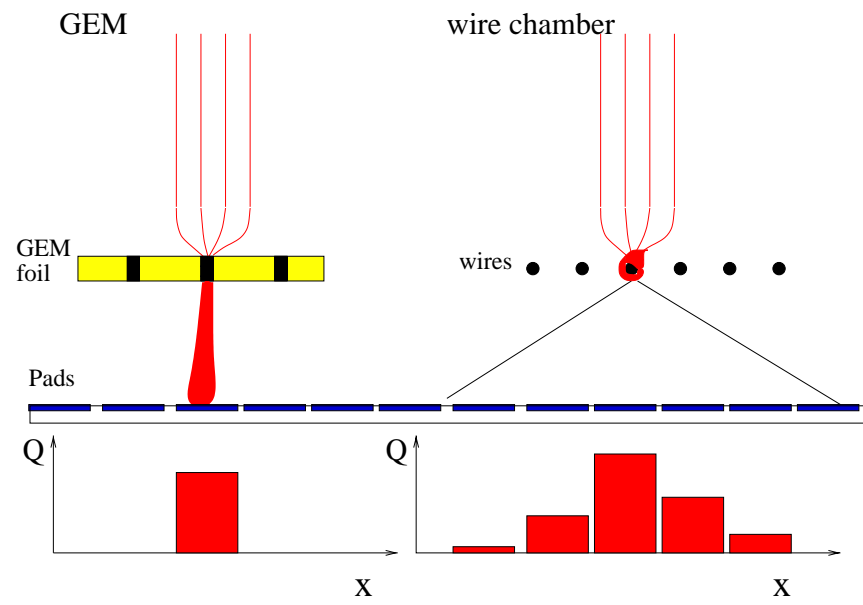
- **For ~ 1 mm wide pads, all charge may go to a single pad due to the suppression of transverse diffusion in high 3-4 T field. Resolution ~ $1/\sqrt{12}$ with charge integration**
- **Track crossing angle with respect to the pad further degrades resolution (R. Hawkings – DESY report)**
- **Measure transient induction charge pulses in adjacent pads for centroid determination?**
- **Promising simulation results for space point resolution with circular pads for TESLA TPC in a 3 T magnetic field.**

How to Process the GEM Pad Signal for Best Resolution?

- For ~ 1 mm wide pads, all charge may go to a single pad due to the suppression of transverse diffusion in high 3-4 T field. Resolution $\sim 1/\sqrt{12}$ with charge integration
- Track crossing angle with respect to rectangular pads further degrades resolution (R. Hawkings – DESY report)

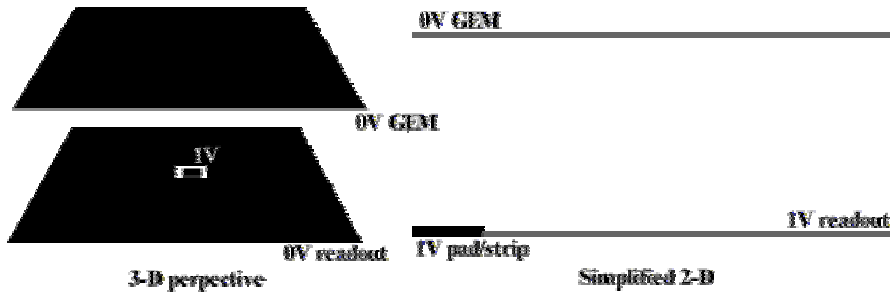


- Measure transient induction charge pulses in hexagonal (circular) pads for position determination?
- Promising simulation results for space point resolution with circular pads for TESLA TPC in a 3 T magnetic field.



Simulation

- **Weighting field potentials for the readout geometry (Ramo's theorem)**



- **3 D => 2 D reduction:**

Hex (\approx Circular) pads, $V = V(r, z)$ [$V \neq V(\theta)$]

Rectangular pads (length \gg width), $V = V(x, z)$

- **Laplace solution ($r \rightarrow x$ for rect. pads):**

$$V(r, z) = \sum_p \frac{4 \sin \alpha b \cos \alpha r \sinh \alpha z}{(2p+1)\pi \sinh \alpha H} \quad \text{Here, } \alpha = (2p+1)\pi/a,$$

$a =$ GEM width, $b =$ pad radius (half-width)

and $H =$ GEM induction gap height.

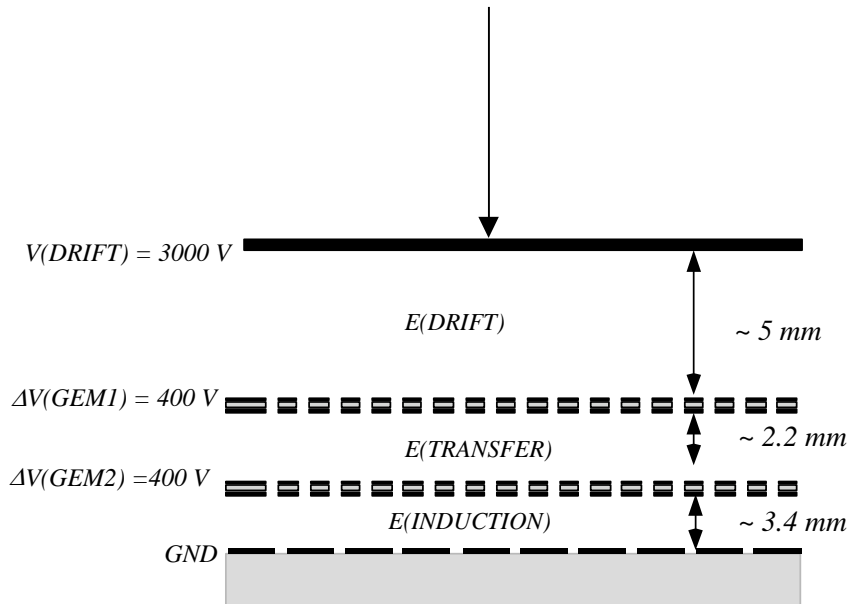
- **Tracks parallel to GEM plane & (rectangular) pad length**
- **Diffusion, primary and secondary ionization**
- **Gas gain = 16 (for computing efficiency)**
- **Compute induction signal sums for pads**
- **Space point resolution with added noise**

Preliminary Results from Double GEM Test Cell with Anode Strip Readout

- **8 channel LeCroy HQV 810 & Aleph TPC anode charge sensitive preamps**
- **6 keV x ray from ^{55}Fe , 4.5 - 6 kVp x rays from a Cu anode x-ray tube and ^{90}Sr betas**
- **Ar/CO₂ 70/30 and P10 gas mixtures**
- **500 MHz Tektronix digitizing scope for data acquisition**

DOUBLE GEM SETUP FOR TESTING WITH X RAYS

**0.85 mm wide anode strips (1 mm pitch), LeCroy HQV810 &
Aleph TPC ChargePreamps, P10 and Ar/CO₂ gas mixtures**



*Tests with Fe-55 (6 keV) source, 4.5 kVp
collimated x rays & Sr-90 betas (~ MIP)*

Use Aleph TPC Readout Front End

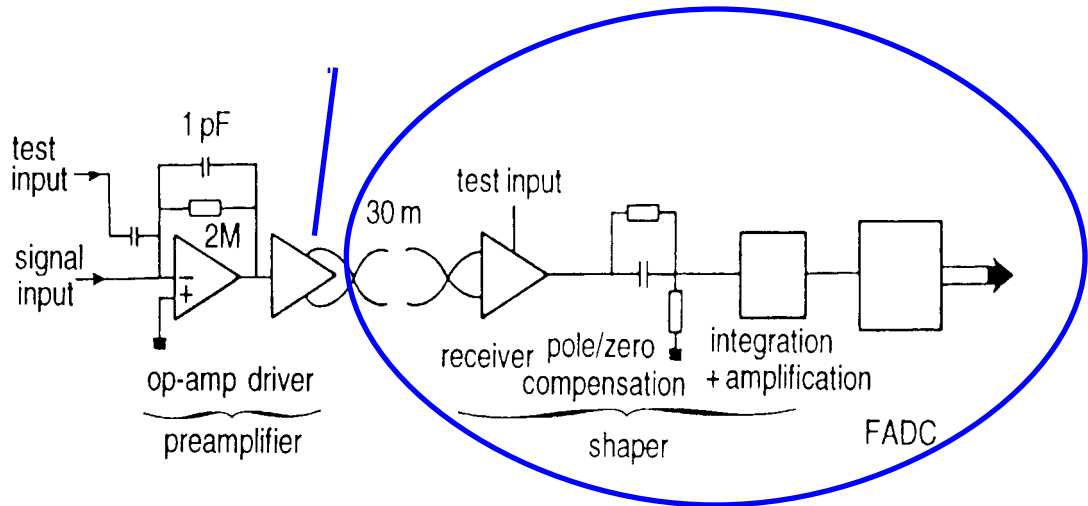


Fig. V.22 Functional diagram of the analog electronics chain.

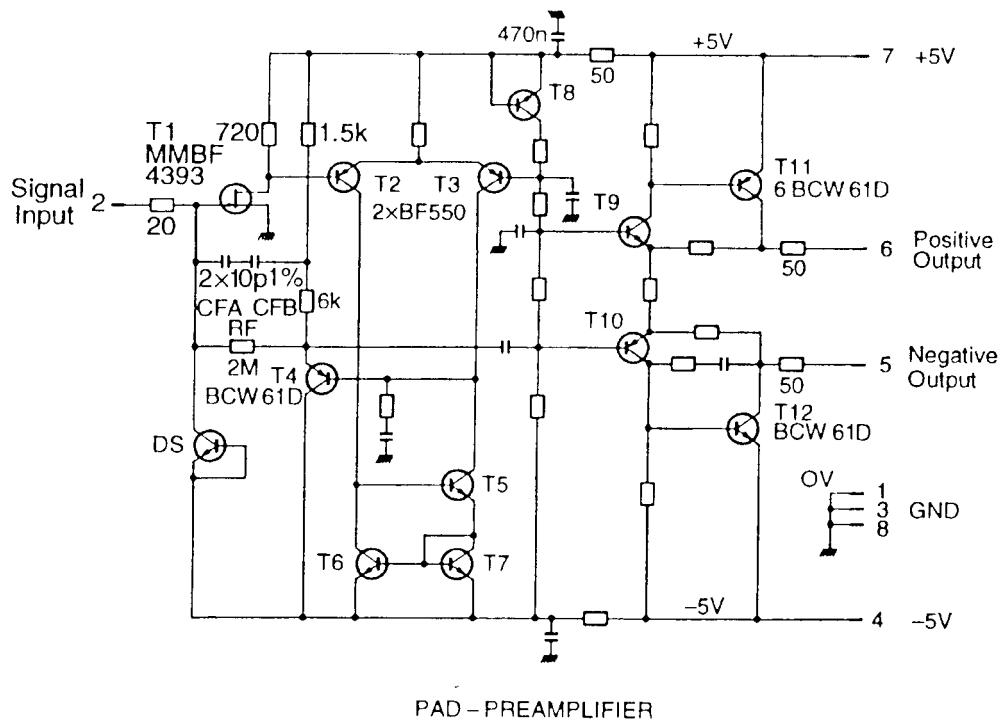
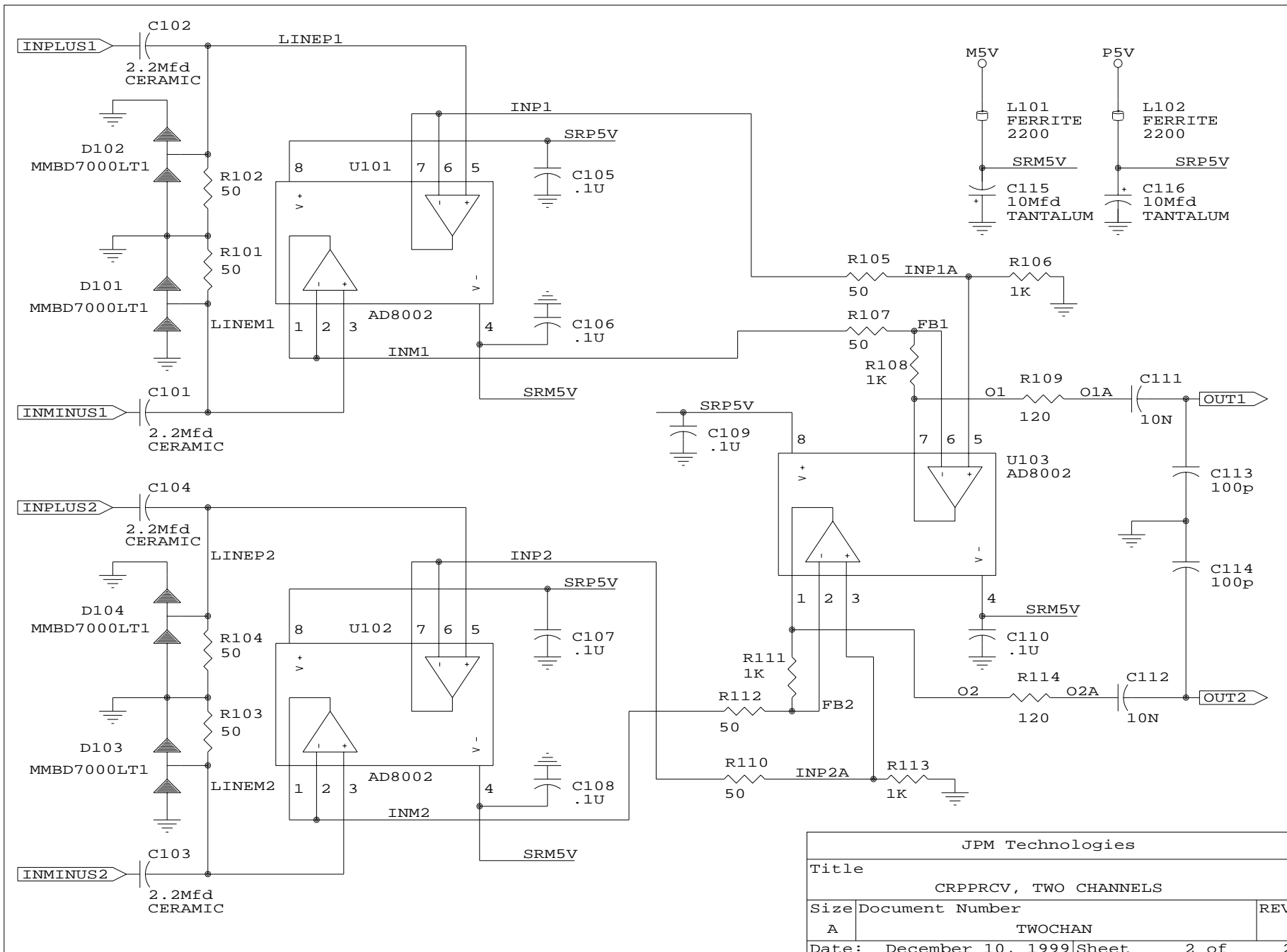
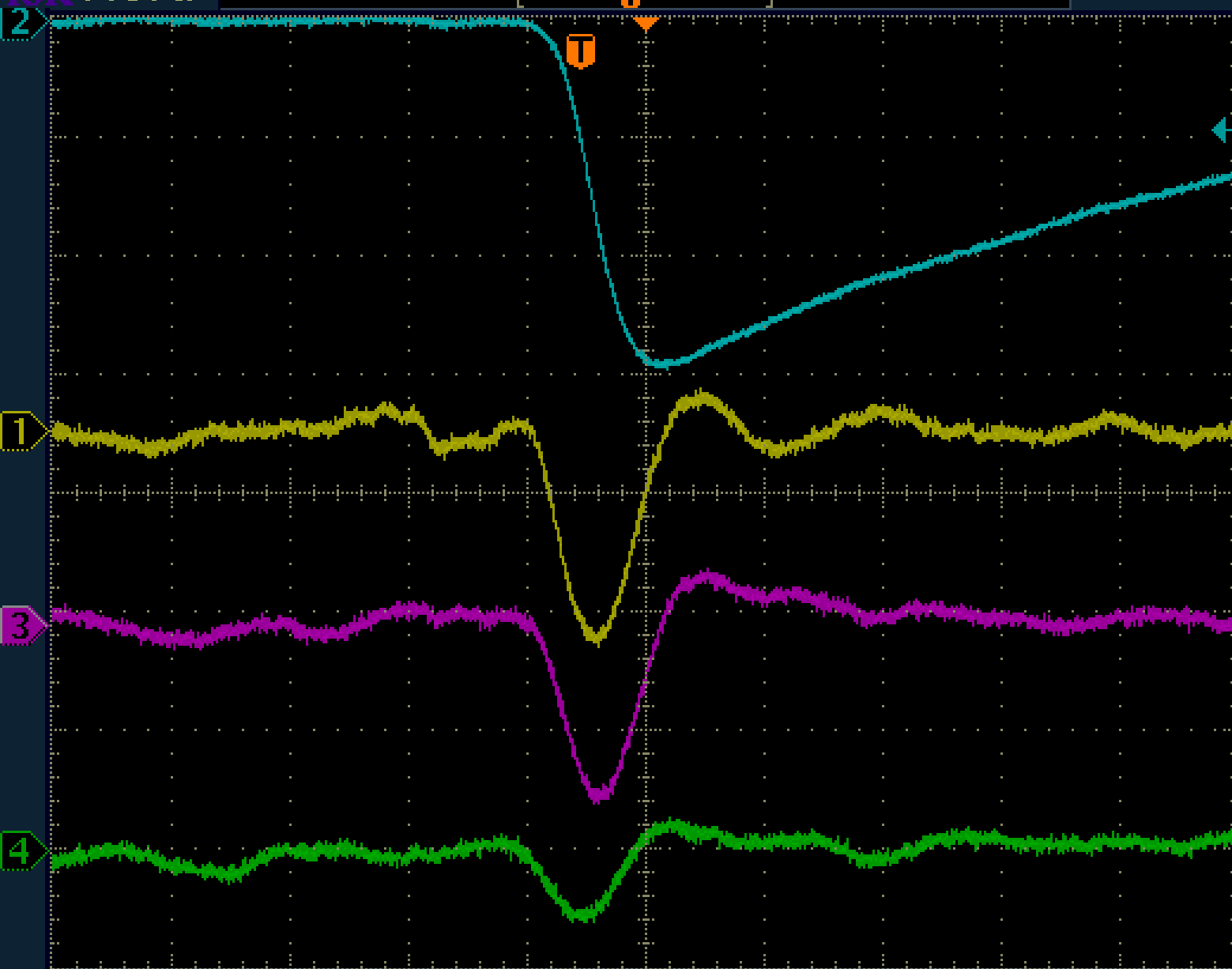


Fig. V.23 Circuit diagram of the pad amplifier.

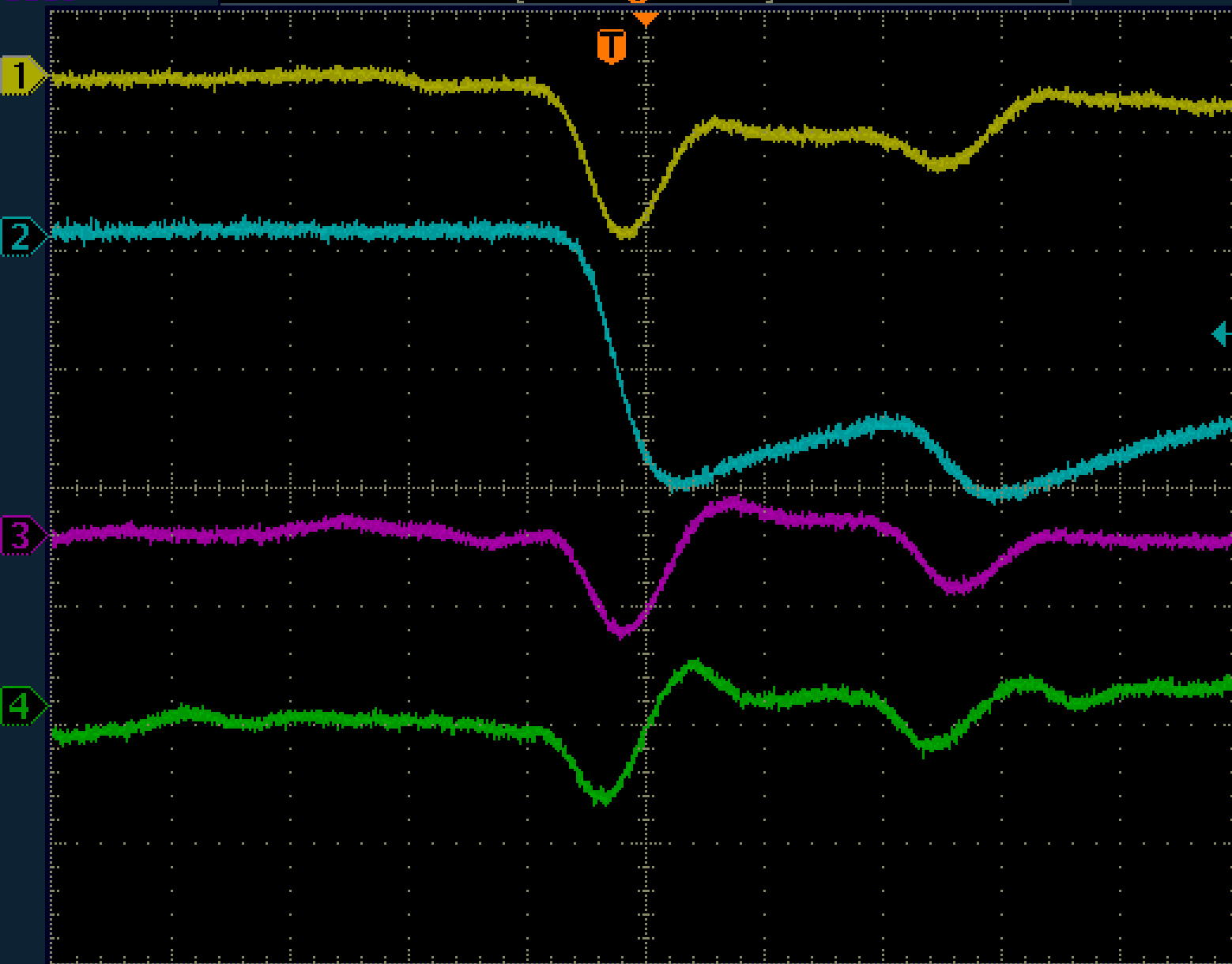


JPM Technologies		
Title		
CRPPRCV, TWO CHANNELS		
Size	Document Number	REV
A	TWOCHAN	
Date:	December 10, 1999	Sheet 2 of 2



Ch1 20.0mVΩ Ch2 100mVΩ M 100ns A Ch2 \approx -92.0mV
Ch3 20.0mVΩ Ch4 20.0mVΩ

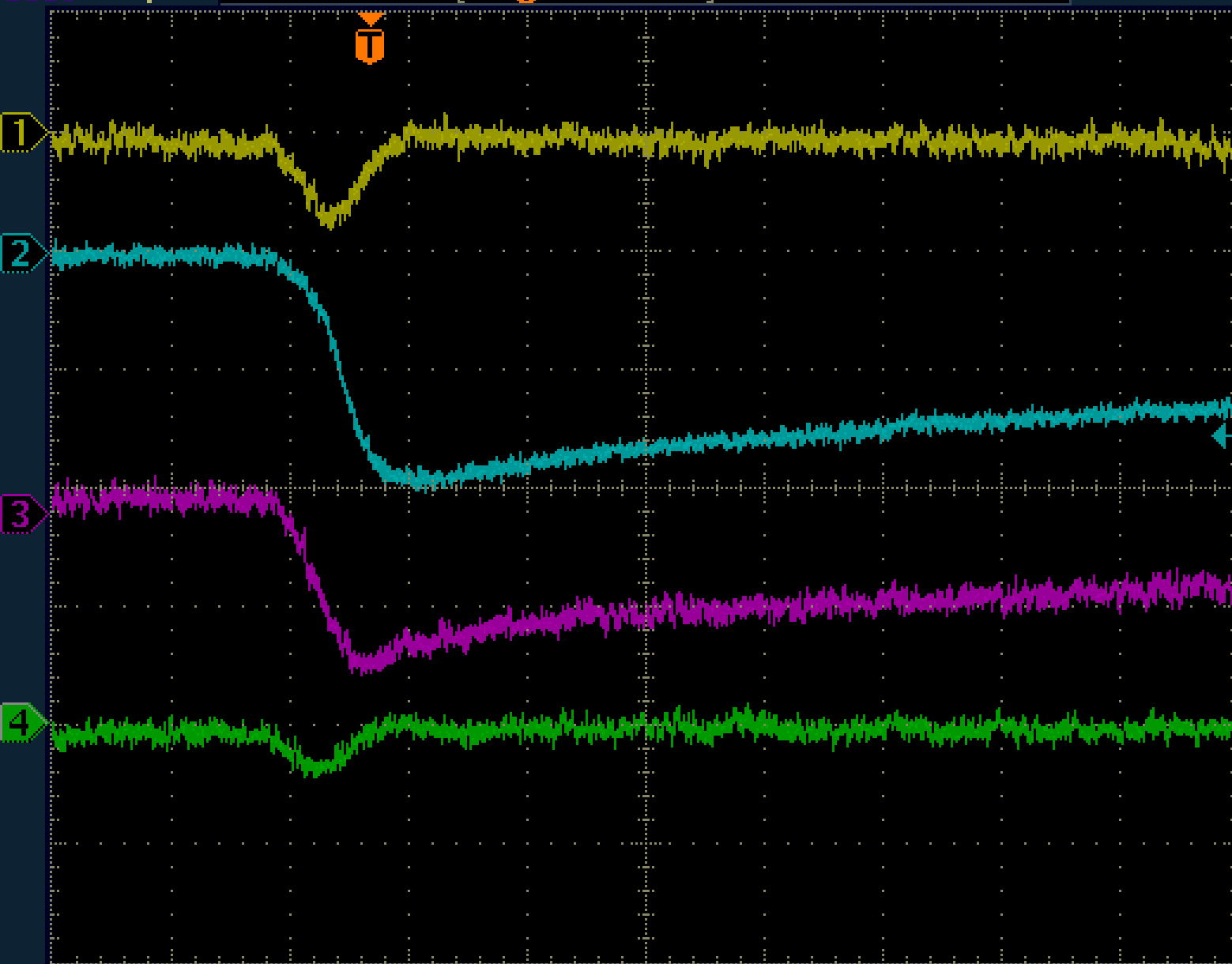
54.0000ns



Ch1 50.0mVΩ Ch2 200mVΩ M 100ns A Ch2 ↖ -164mV
 Ch3 50.0mVΩ Ch4 20.0mVΩ

↕→ 28.0000ns

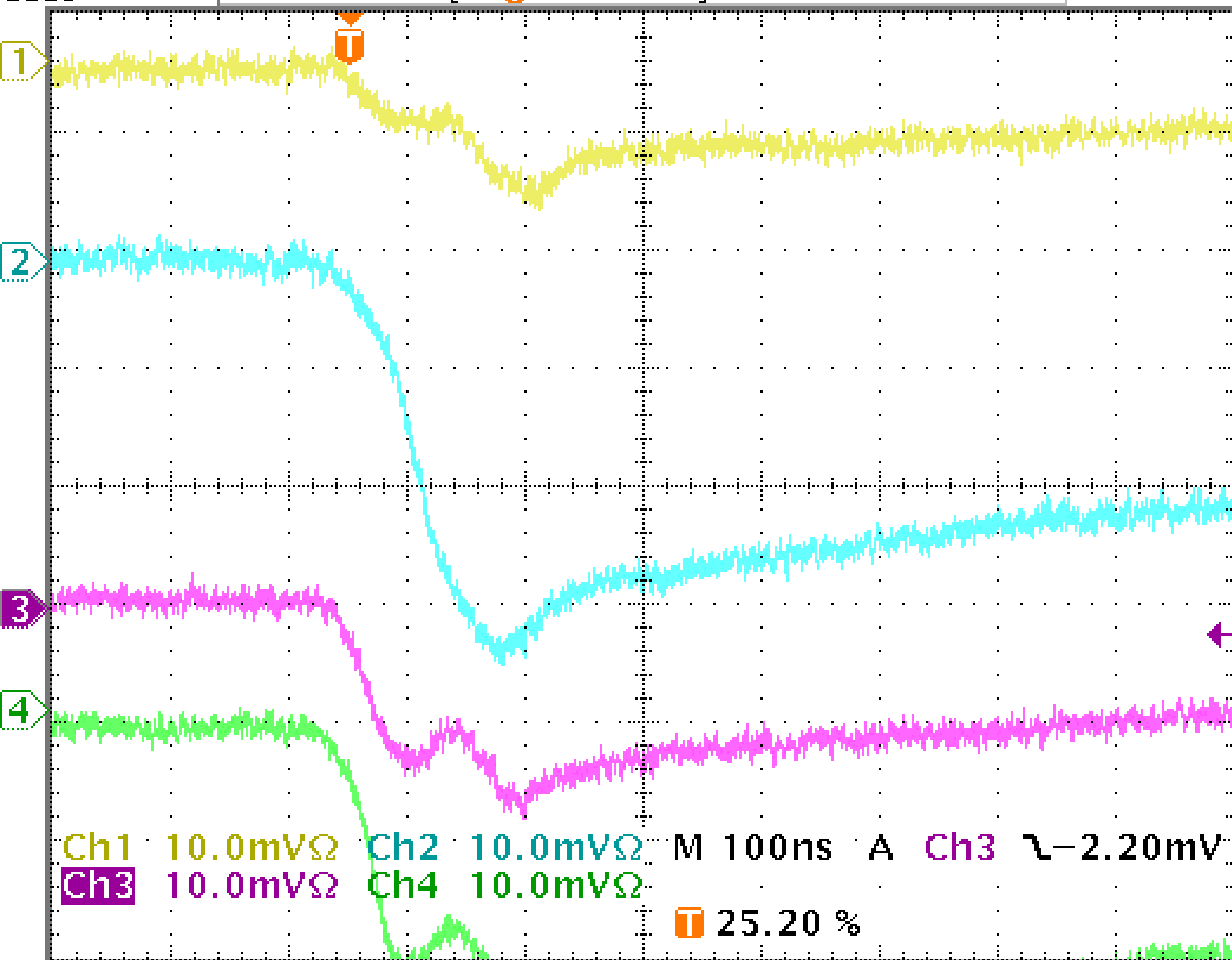
Tek Stop



Ch1	10.0mVΩ	Ch2	20.0mVΩ	M	100ns	A	Ch2	↖-30.8mV
Ch3	10.0mVΩ	Ch4	10.0mVΩ					

26.80 %

20 Jan 2000
12:31:54



TRIGGER

A Trig Type
Edge
Video

Mode
Auto
Normal

Source
Ch: 1 2 3 4
AC Line

Coupling
DC Noise
HF Reject
LF Reject

Slope
↗ ↘

VERTICAL (CH3)

Coupling	Impedance	Bandwidth
DC AC \mathcal{H}	1MΩ 50Ω	↓ Full

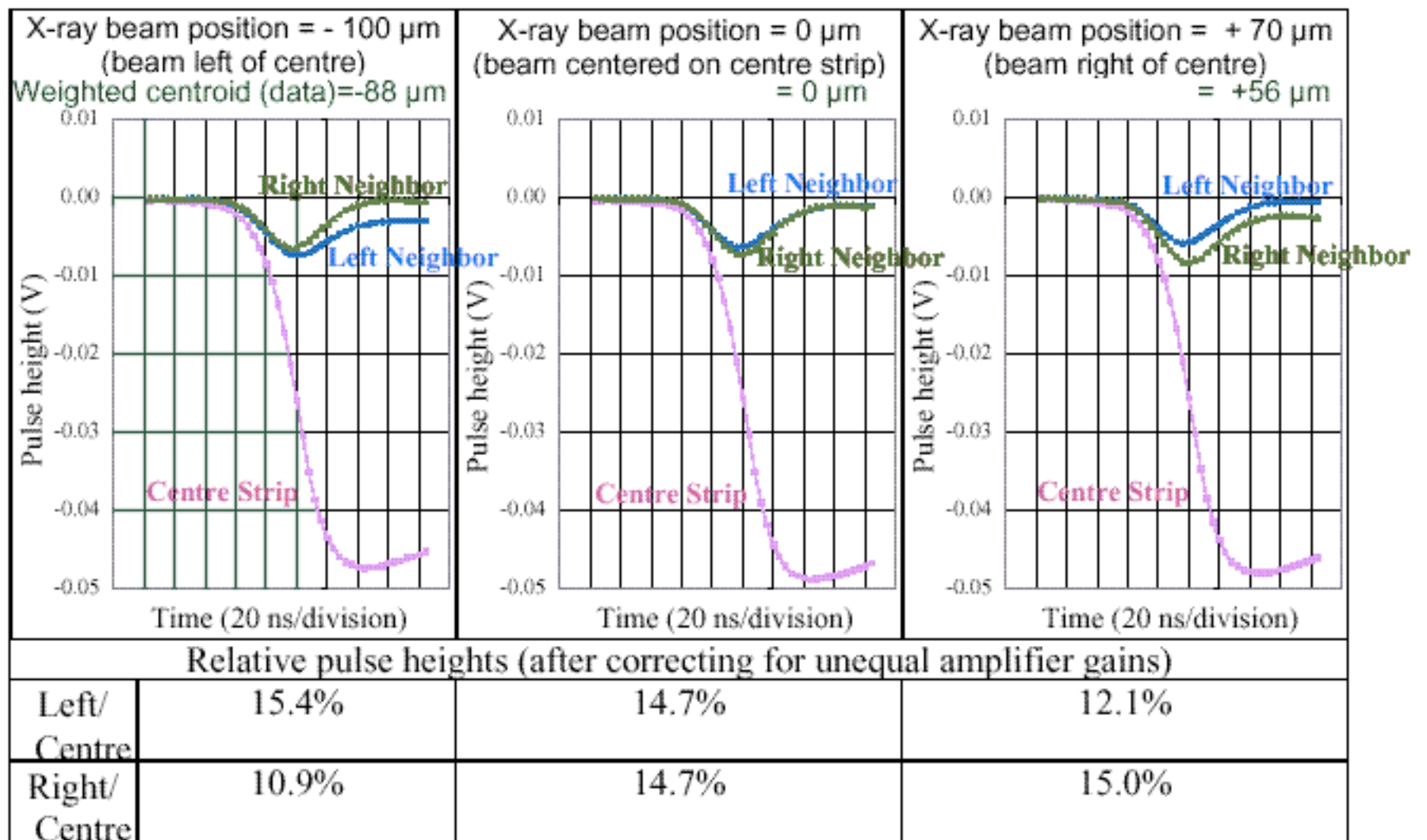
ACQUIRE

Fast Trig	Mode
Normal ↓	Sample

CURSOR

Off
HBar VBar

Anode Strip Response to Collimated 4.5 kVp X Rays (500 MHz Tektronix - 500 pulse averages)



GEM induction gap ~ 3.4 mm, 0.85 mm wide anode strips at 1 mm pitch.
 ~ 100 μm collimated x ray beam incident normally on centre anode strip

Conclusions & Future Plans

- **Induction charge pulse height centroids can be determined with adequate accuracy with ~ mm dimension anodes**
- **Measure anode strip and hexagonal pad response functions with collimated x-rays**
- **Simulation and comparison with measurement**
- **Development of needed high density low cost front-end charge sensitive preamplifiers and FADC system**
- **Cosmic ray tests of a mini TPC with pad readout**
- **1 m drift TPC tests in a 2-3 T field with the DESY group (longer term)**