The Time-of-Flight Detector for the ALICE experiment

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Subject of this talk:

"A quick review of 2 years' R&D of the multigap RPC"

Question: What is needed for the ALICE TOF detector?

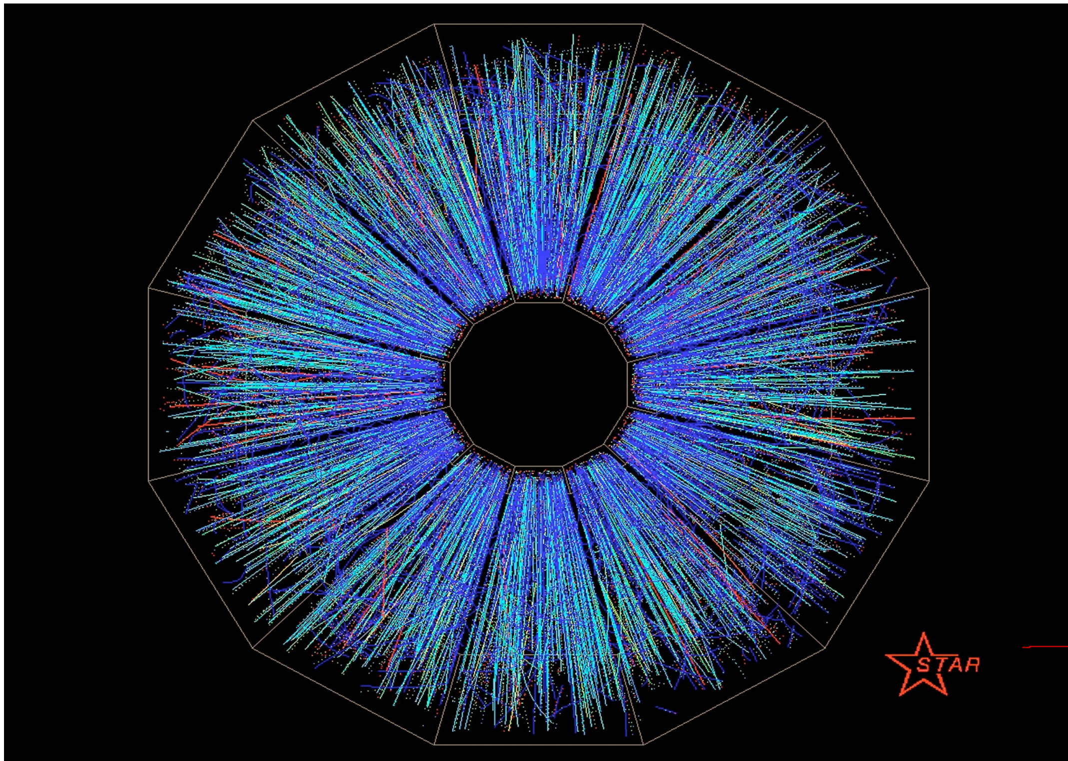
Answer:

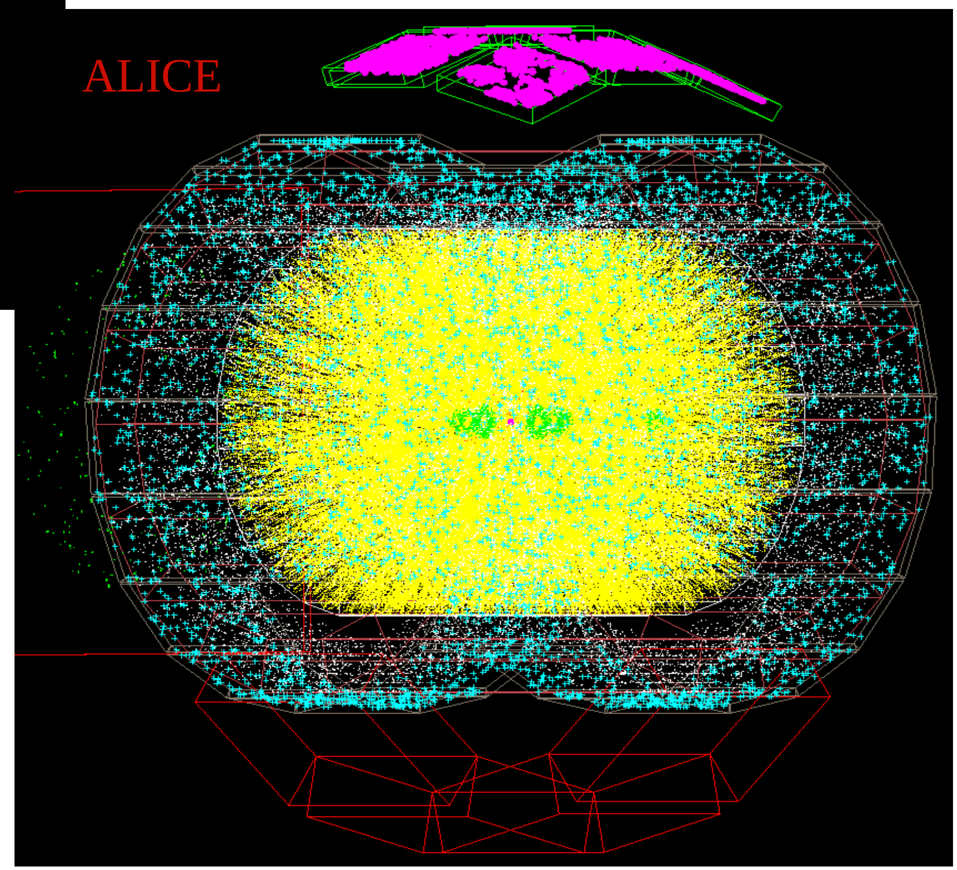
(1) Highly segmented detector (160,000 channels)

(2) Large area 150 m^2 (i.e. low cost)

(3) Time resolution ~100 ps

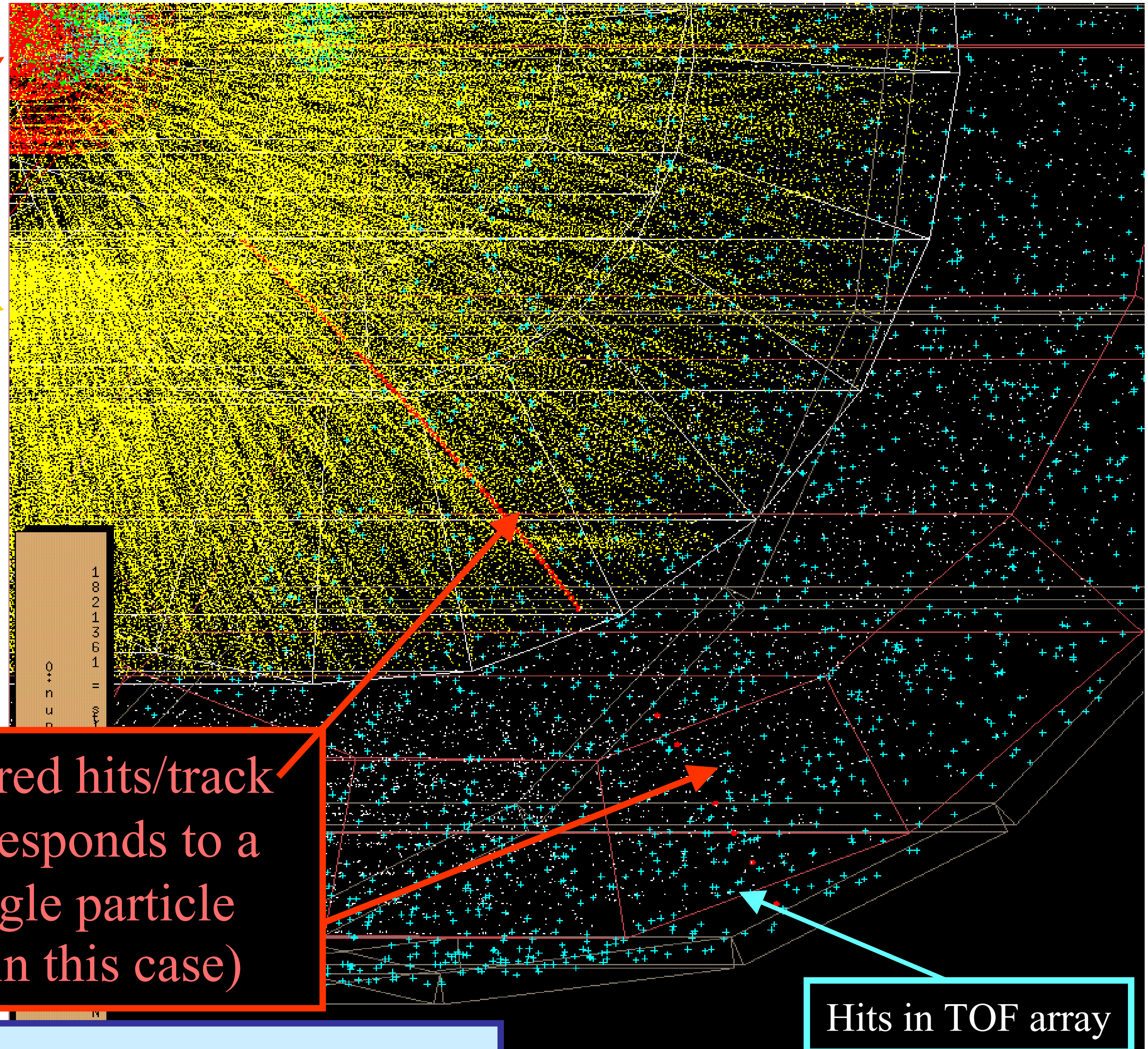
The Multigap Resistive Plate Chamber





Question: How do we make sense of this?

Answer: Identify each particle - or at least as many as possible.



TOF with very high granularity needed!

ALICE TOF

covers 150 m^2
consists of 160,000 readout channels.
Each pad is 2.5 x 3.5 cm^2.
Occupancy ~ 12% (if 8,000 particles produced per unit of rapidity)

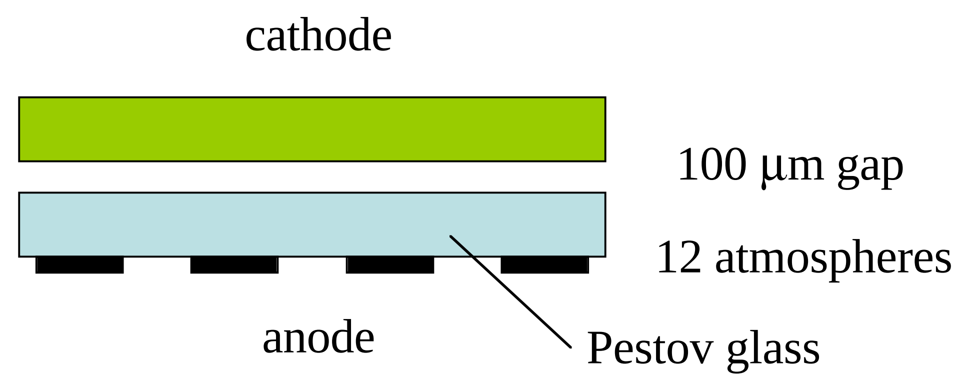
‘Standard’ TOF system built of scintillators plus phototubes would cost ~ 80 MCHF

Gaseous detectors route to large area detectors at affordable price.

Two gaseous detectors considered for ALICE

Pestov counters

Glass electrode and metal electrode

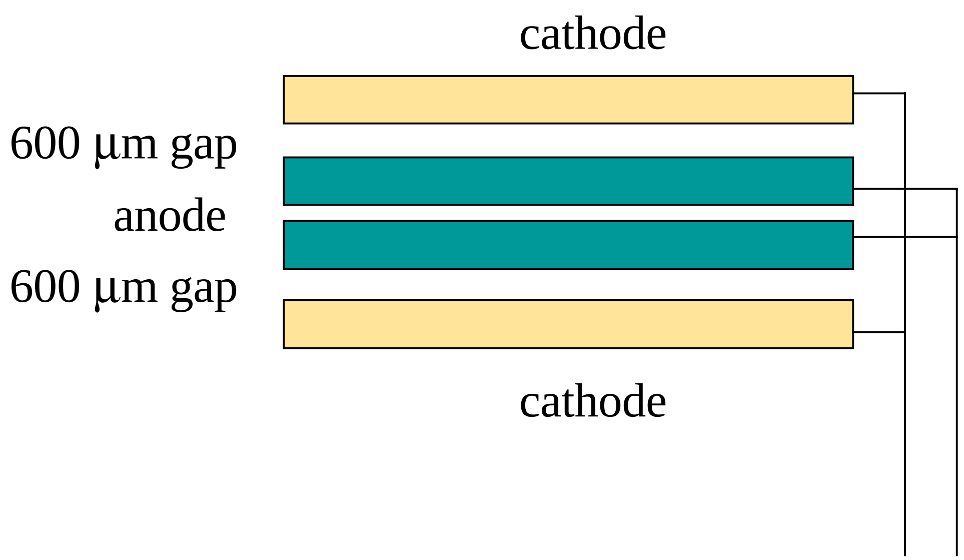


Excellent time resolution ~ 50 ps

But long tail of late events
Mechanical constraints (due to high pressure)
Non-commercial glass

Double gap PPC

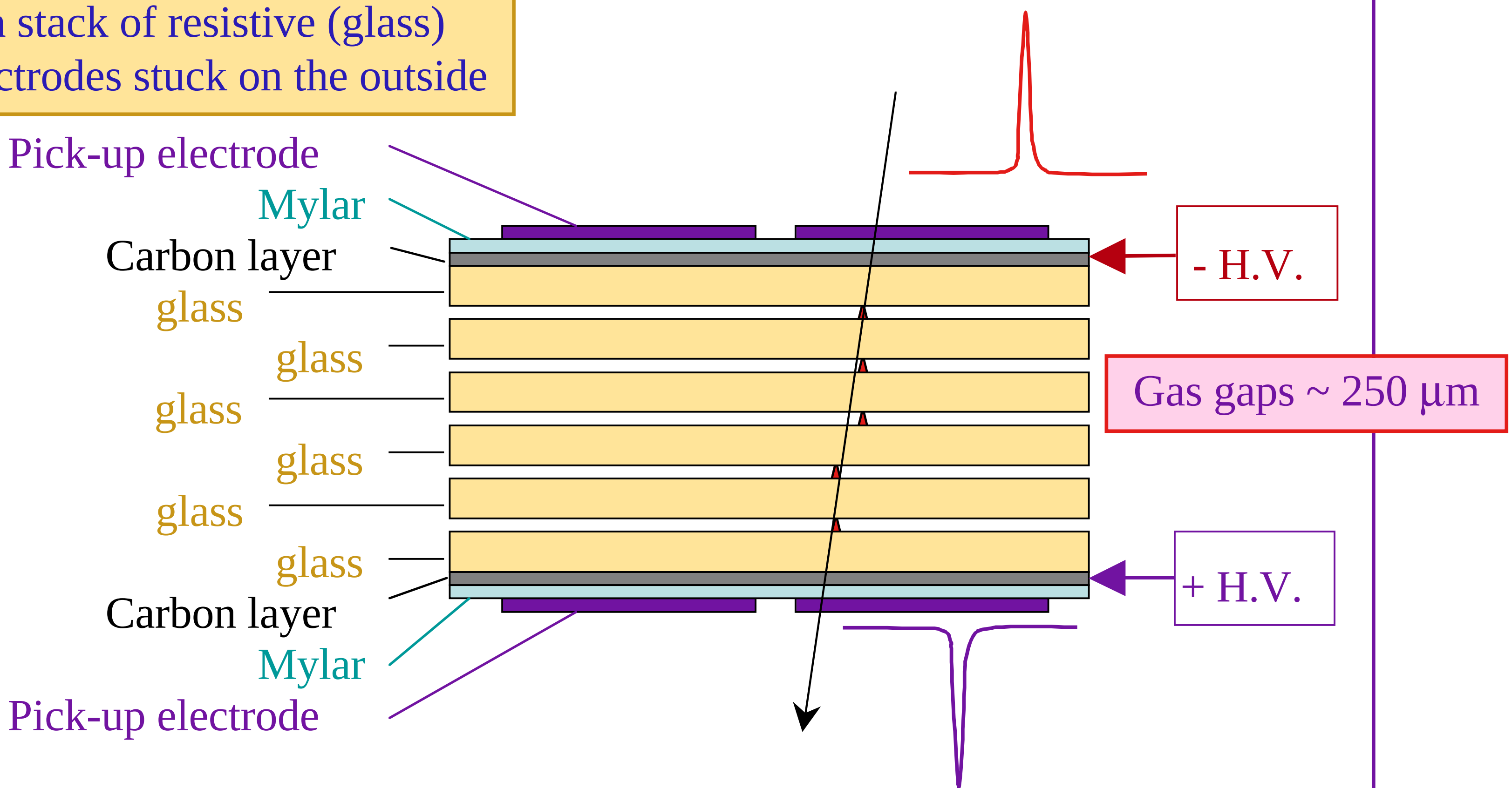
Both electrodes metallic



Marginal time resolution ~ 250 ps
Small signal (to keep sparks at low probability)
Difficult to build

The MULTIGAP Resistive Plate Chamber

Essentially a stack of resistive (glass) plates with electrodes stuck on the outside



Note 1: internal glass plates electrically floating - take and keep correct voltage by electrostatics and flow of electrons and ions produced in gas avalanches

Note 2: resistive plates transparent to fast signals - induced signals on external electrodes is sum of signals from all gaps

History

November 1998 — First tests of MRPCs for ALICE TOF

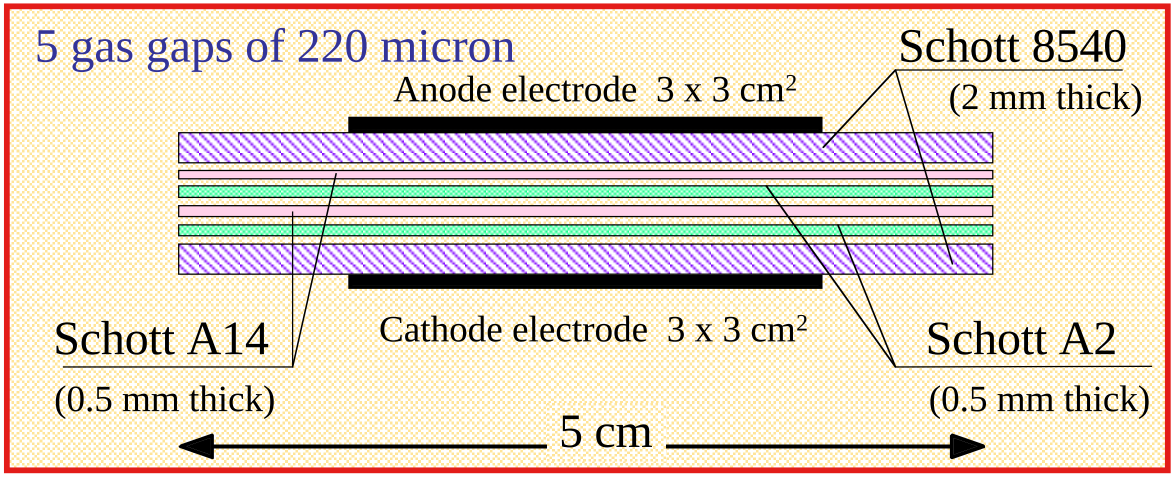
April 1999 — INFN Bologna joins ALICE
lead group for TOF based on MRPCs

January 2000 — ALICE TOF TDR submitted

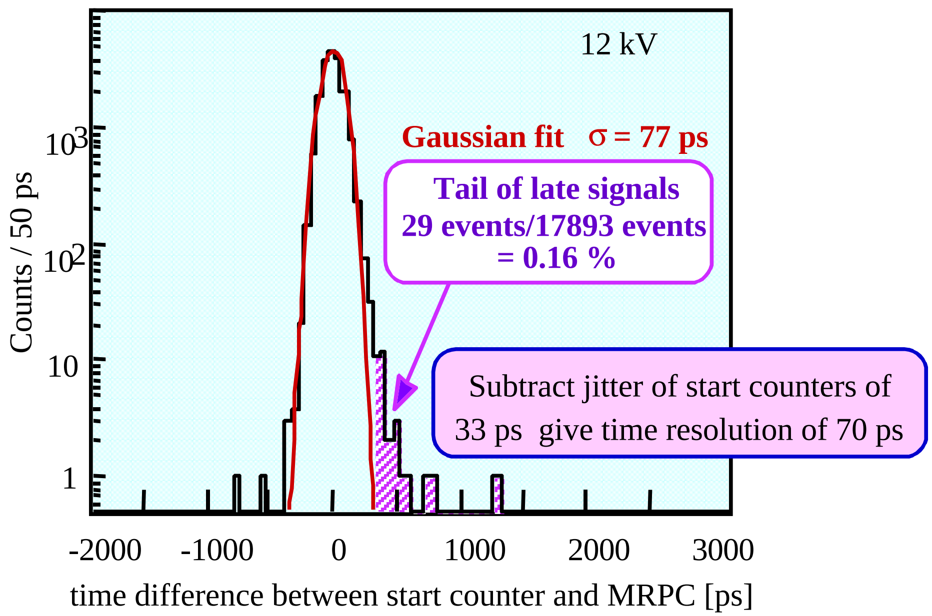
Period of intense R&D - what problems - what solutions?

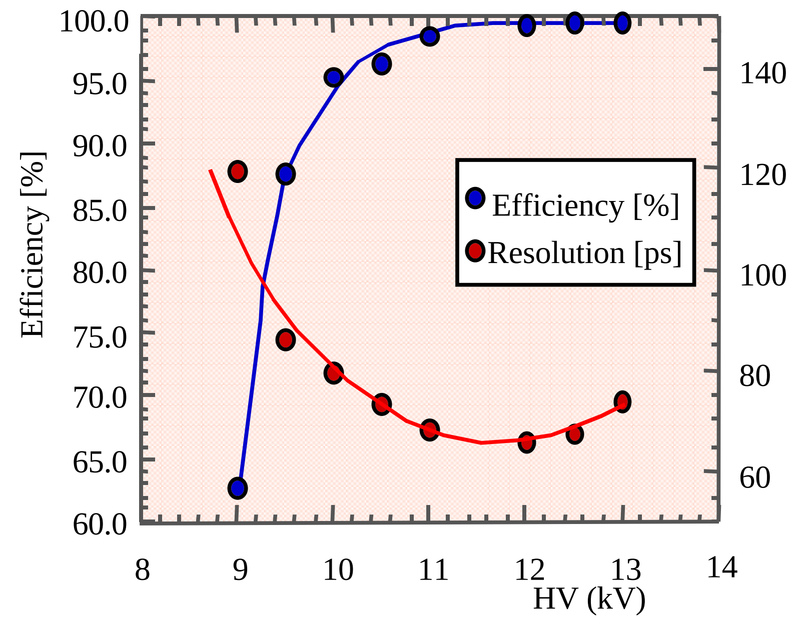
Starting point
Spring 1999

Single cell 3 x 3 cm^2 active area



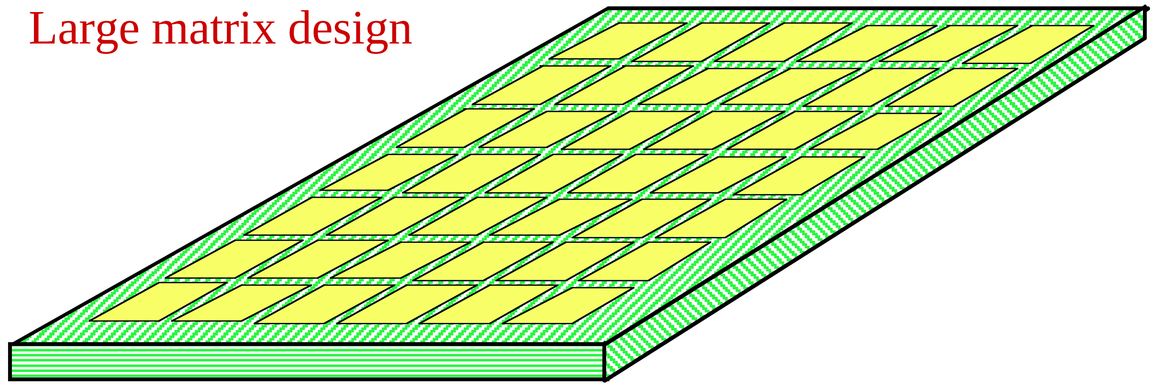
Question:
Can we build big device with similar performance to small single cells?





1999 tests: Two ‘large’ designs tested - large matrix and strip

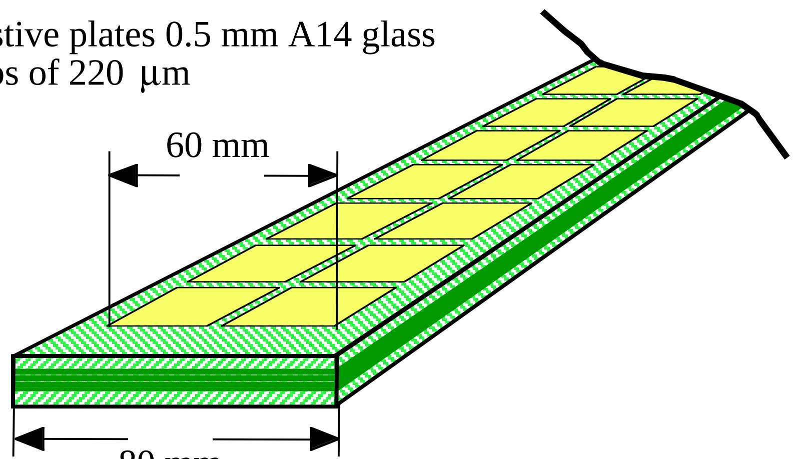
Large matrix design



Various sizes with various materials tested

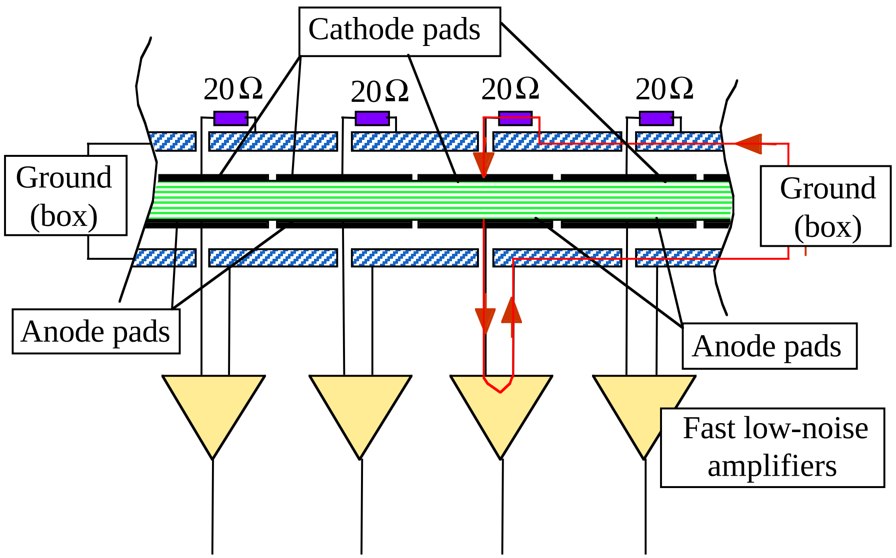
Strip design of MRPC

Resistive plates 0.5 mm A14 glass
5 gaps of 220 µm



Allows tilting of strips so detector normal to incoming particles - this suits ALICE geometry better and also allows differential read-out of detector

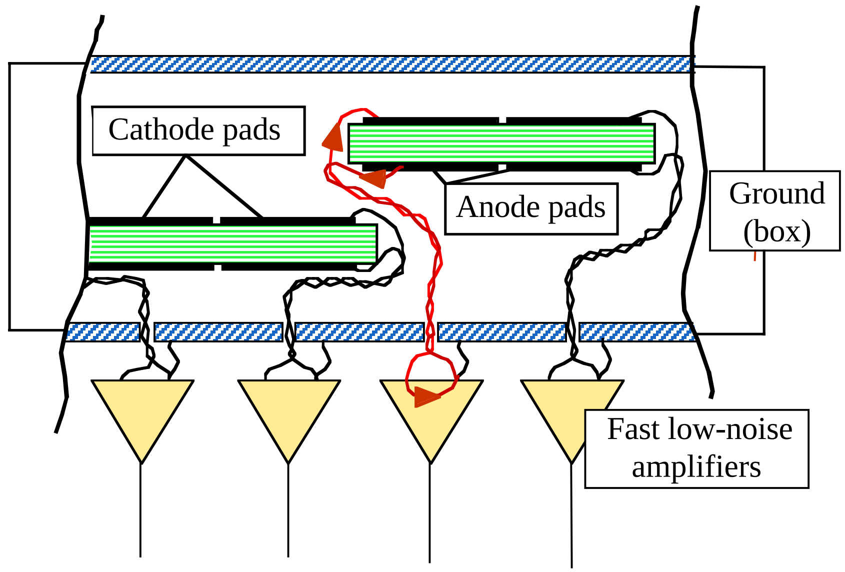
See next transparency



Large matrix: signal return via shielding box (i.e. extra noise)

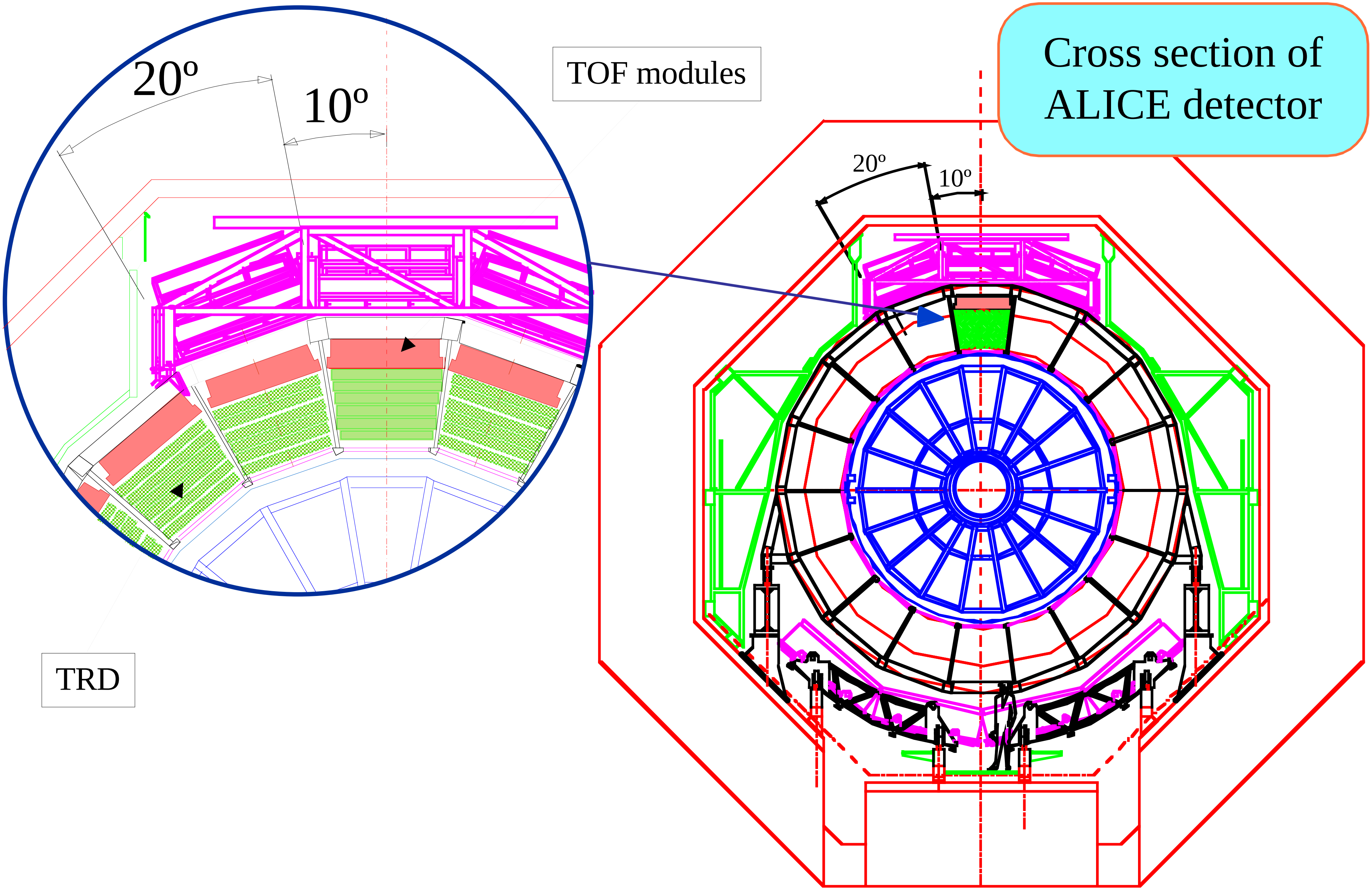
Signal created between anode and cathode - but amplifiers measure anode signal w.r.t. ground

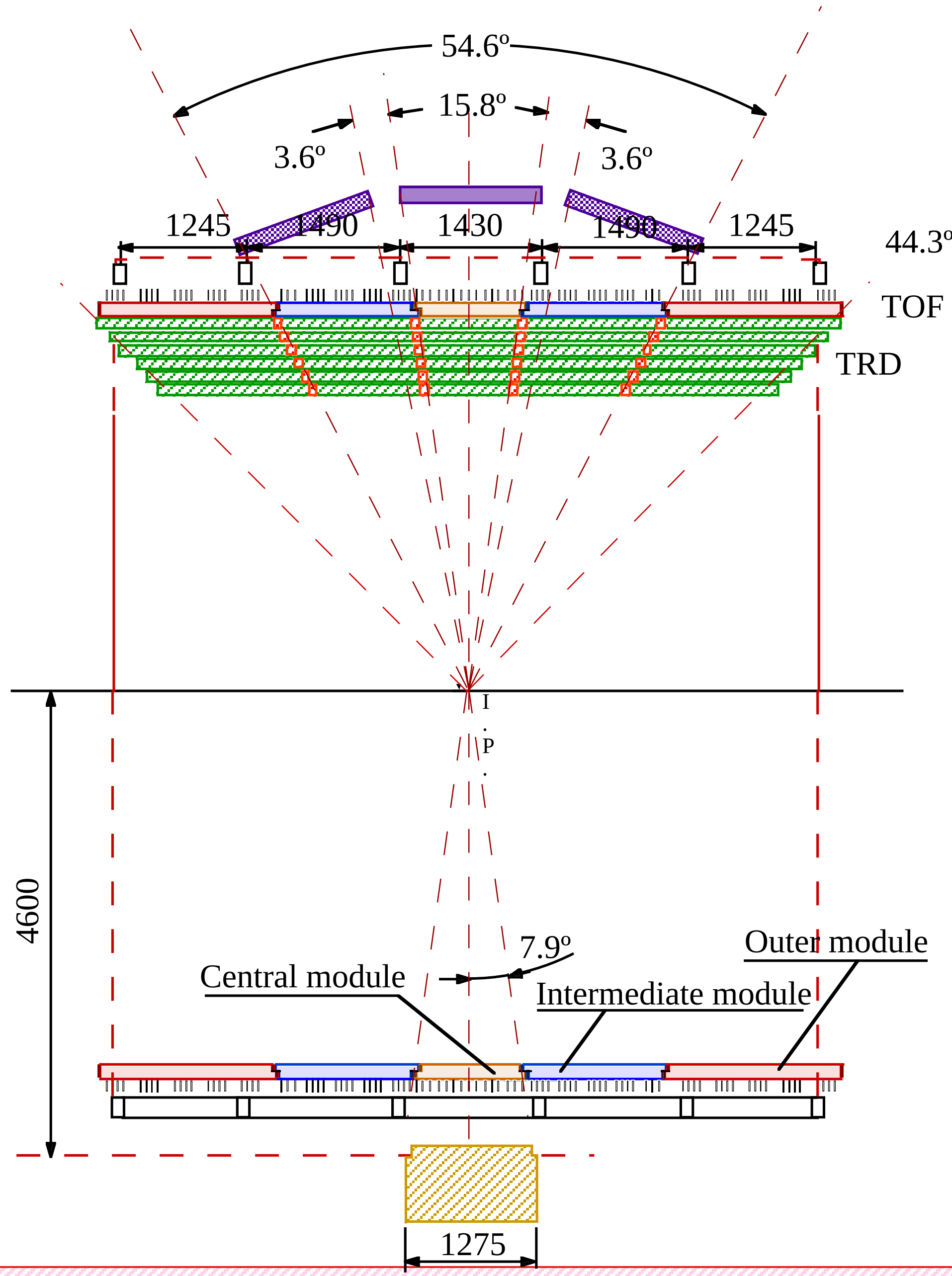
Problems related to noise and stability disappeared with this implementation



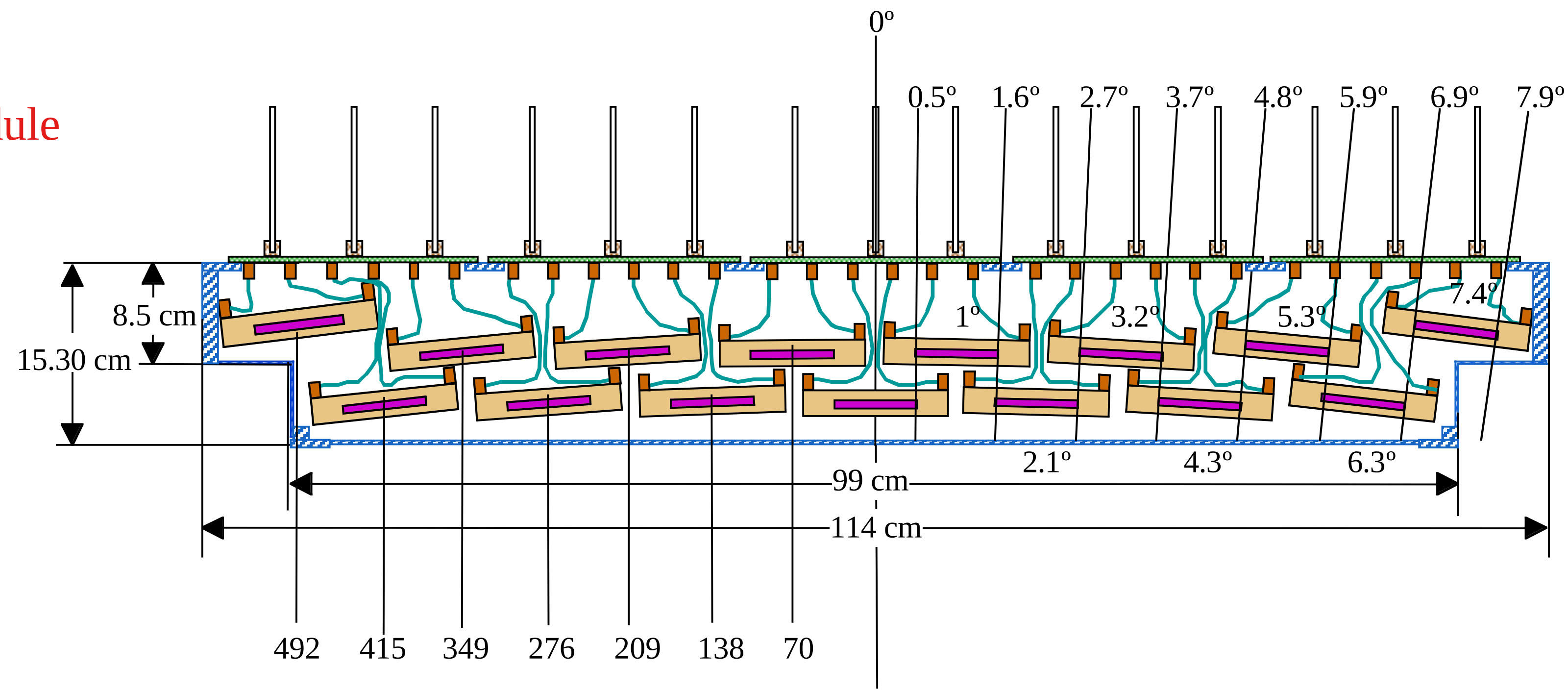
Strip MRPC : signal + signal return with twisted pair (i.e.low noise) - crucially important for time resolution

Cross section of ALICE detector

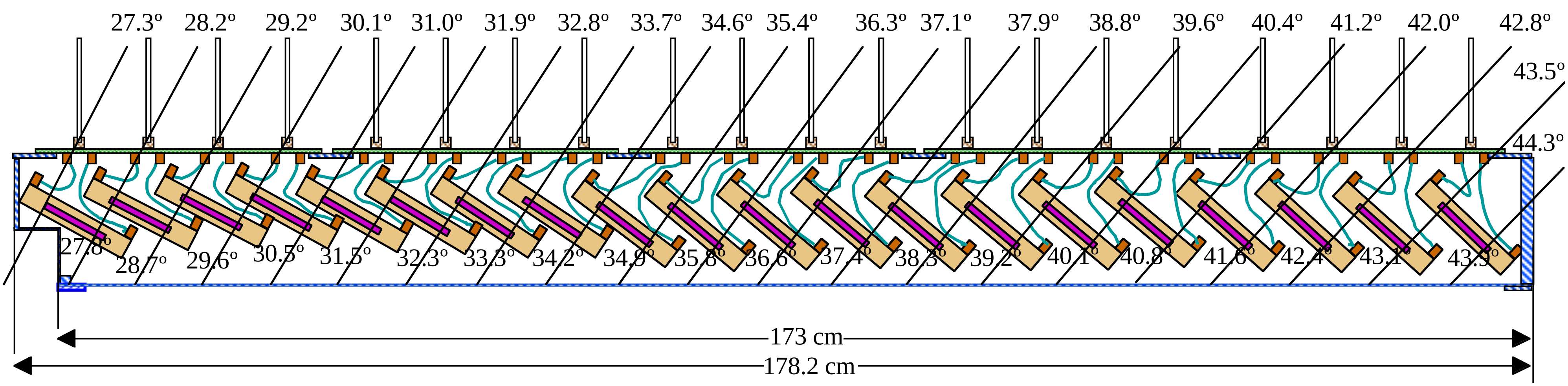



54.6º
15.8º
3.6º
3.6º
1245
1490
1430
1490
1245
44.3º
TOF
TRD
I.P.
4600
7.9º
Outer module
Central module
Intermediate module
1275

Central module

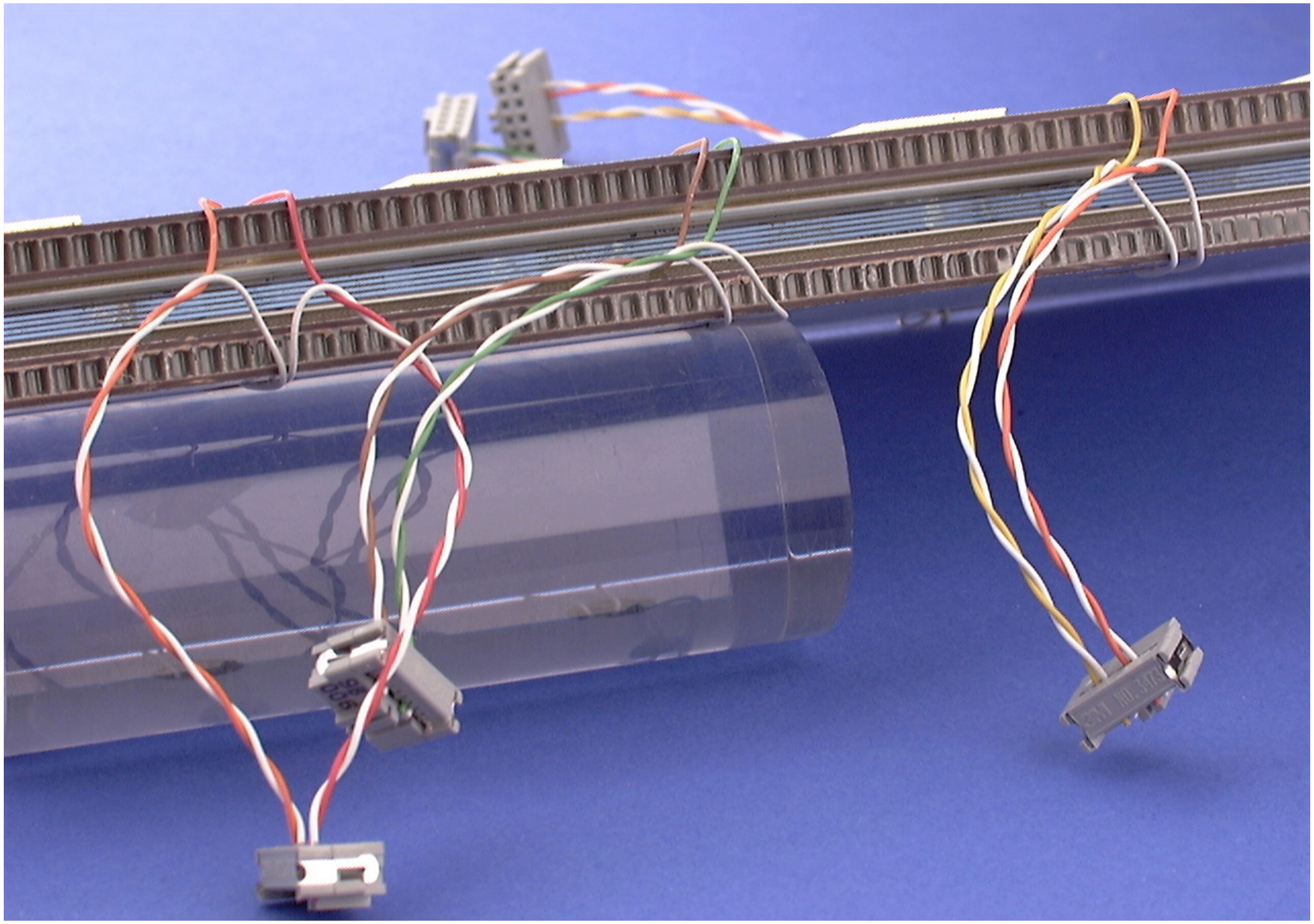


Outer module



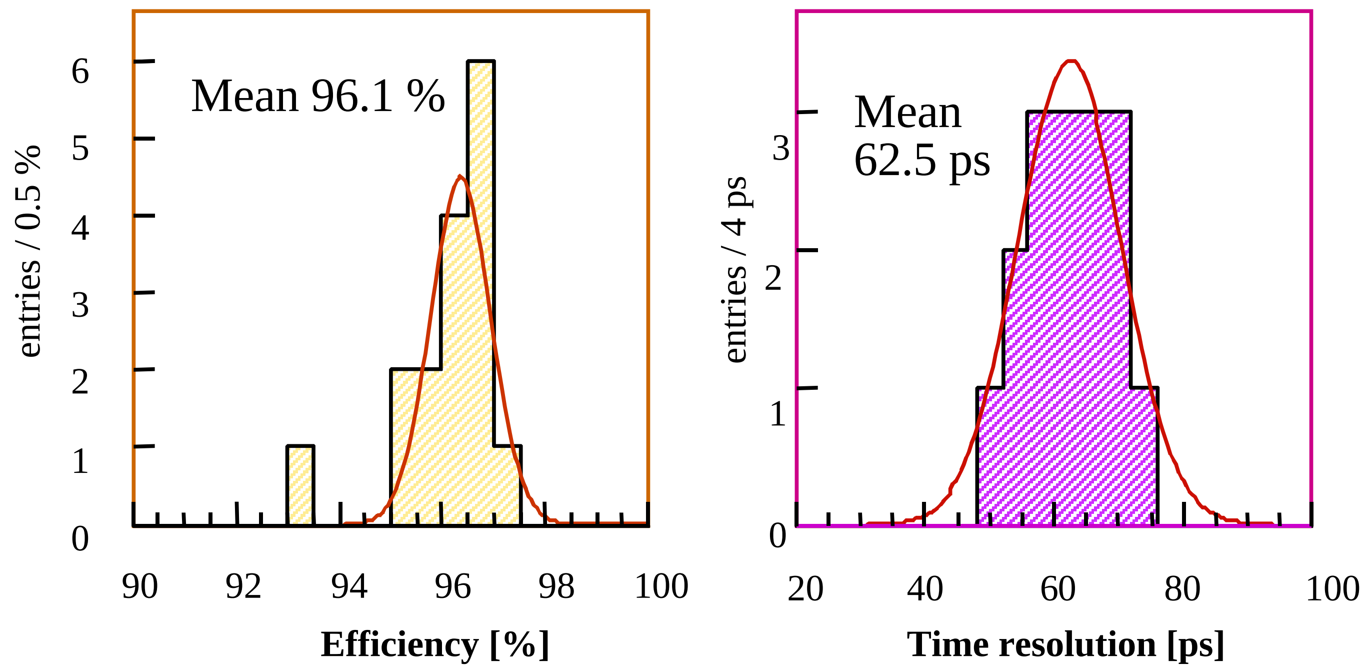
November 1999

Built and tested 16 pad strip active area 24 x 6 cm^2



16 pad strip works just fine!

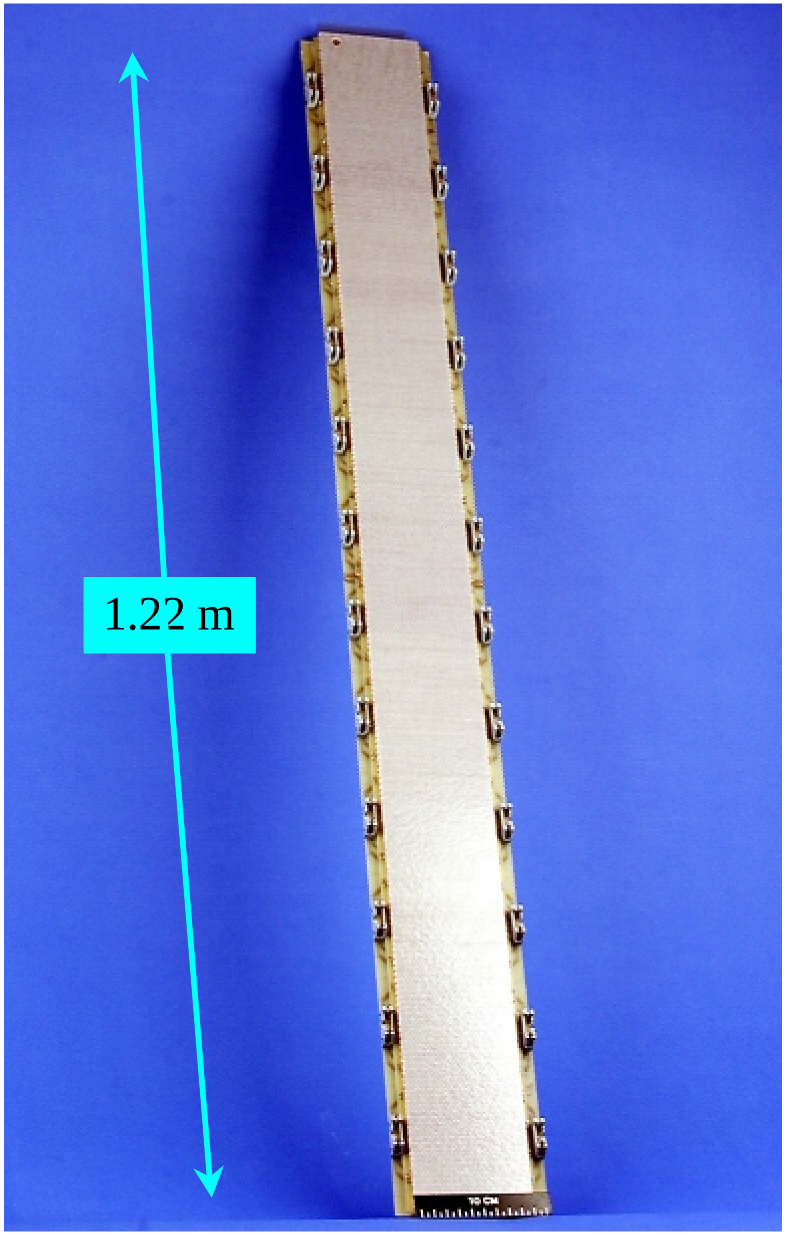
8x2 cell strip detector 12.5 kV

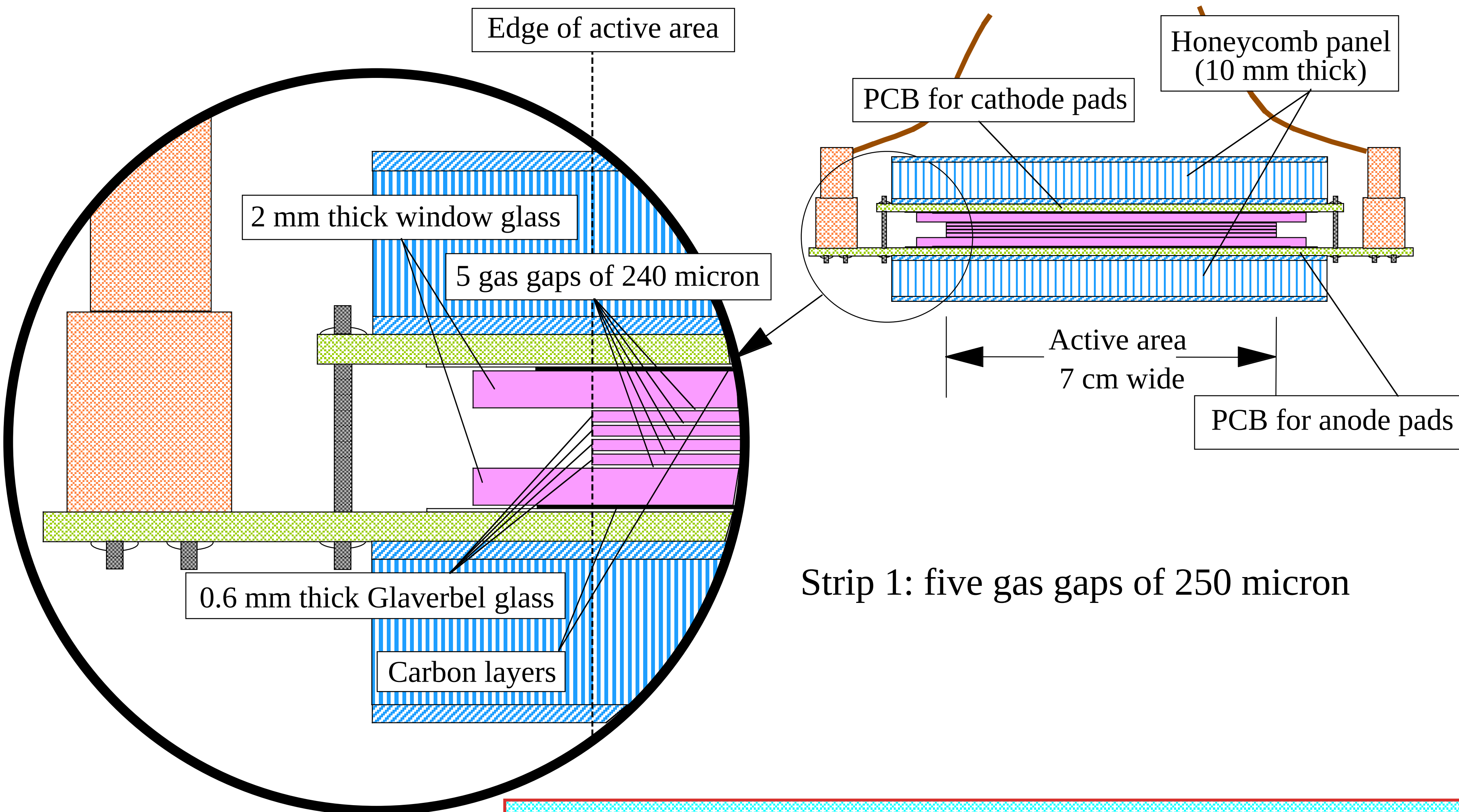


Spring 2000

1.2 m length strips
2 x 48 pads

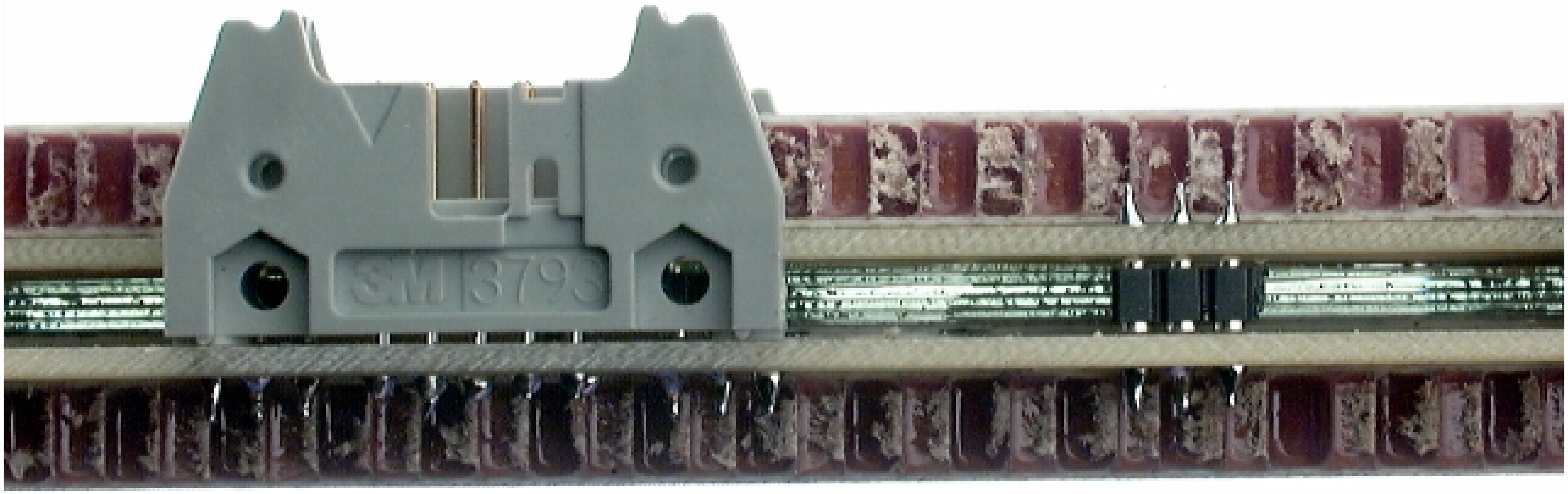
Standard unit detector for ALICE detector
(ALICE TOF will be constructed with
~ 16,000 such strips)



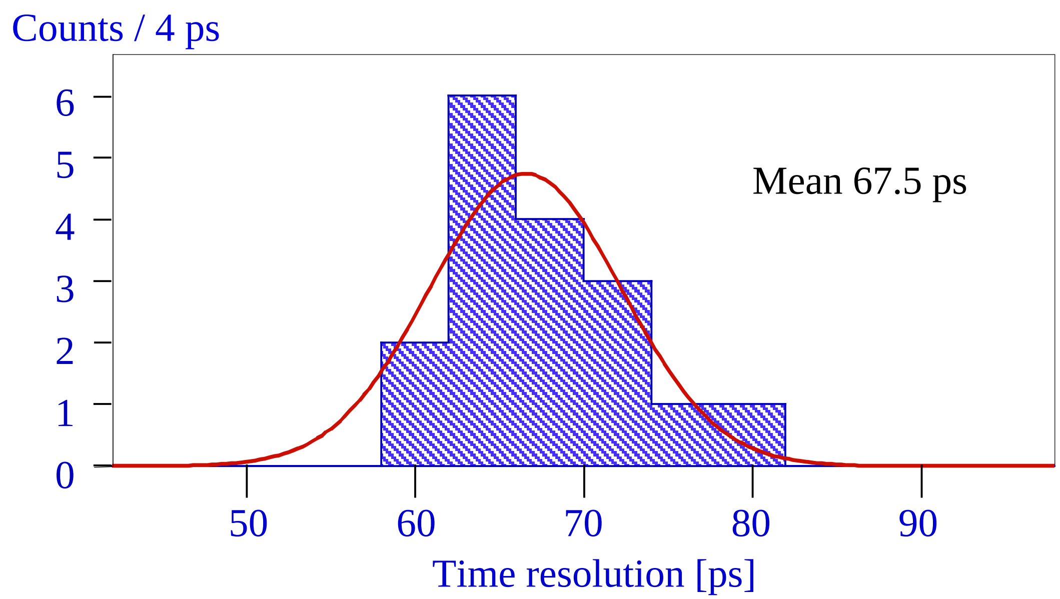


Strip 1: five gas gaps of 250 micron

Spacers: fibre across width of strip every 2.5 cm
Edge: defined by edge of cut glass


3M 3793

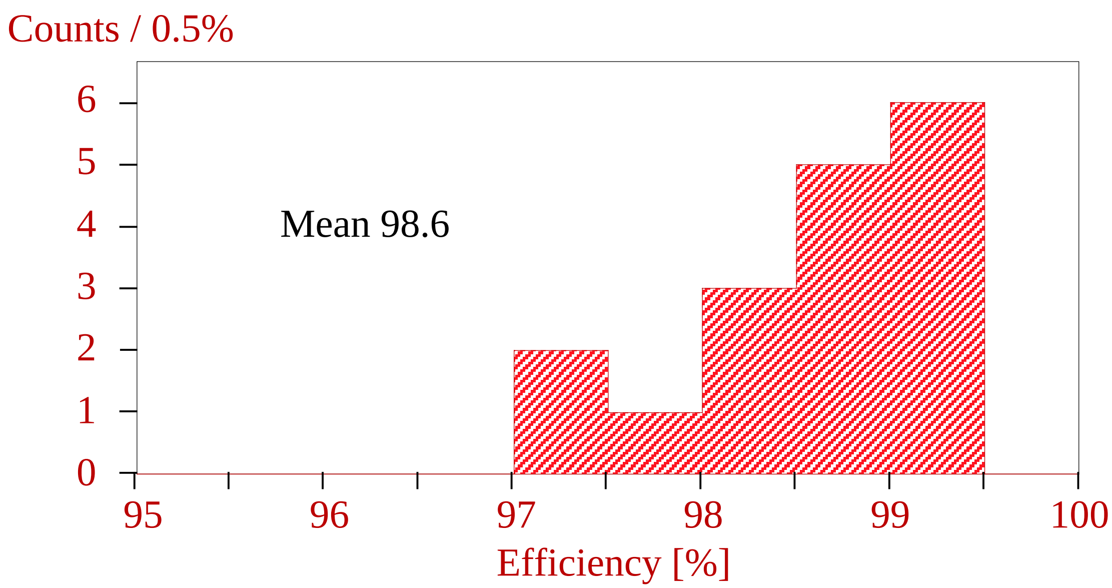
1.2 m length
ALICE TOF strip



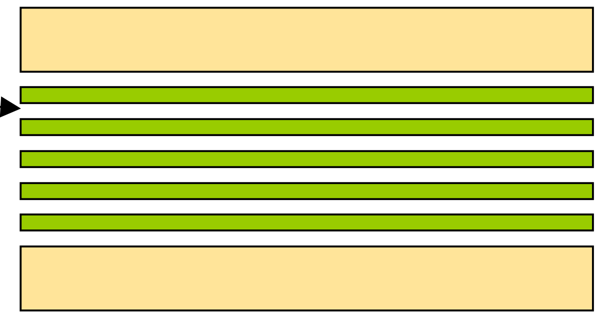
No problem to build long strips

Why not?

Question - how precise does the gas gap of 250 μm need to be?



Question: What happens if the size of the gap is varied??



STRIP 6

550 micron internal glass sheets
2.5 mm external glass (Schott black welding glass)
6 gas gaps of 250 micron
fish line spacers across width of strip
Edge defined by edge of glass
guard rings

STRIP 7

550 micron internal glass sheets
2.5 mm external glass (Schott black welding glass)
6 gas gaps of 220 micron
Fish line spacers across width of strip
Edge defined by edge of glass
guard rings

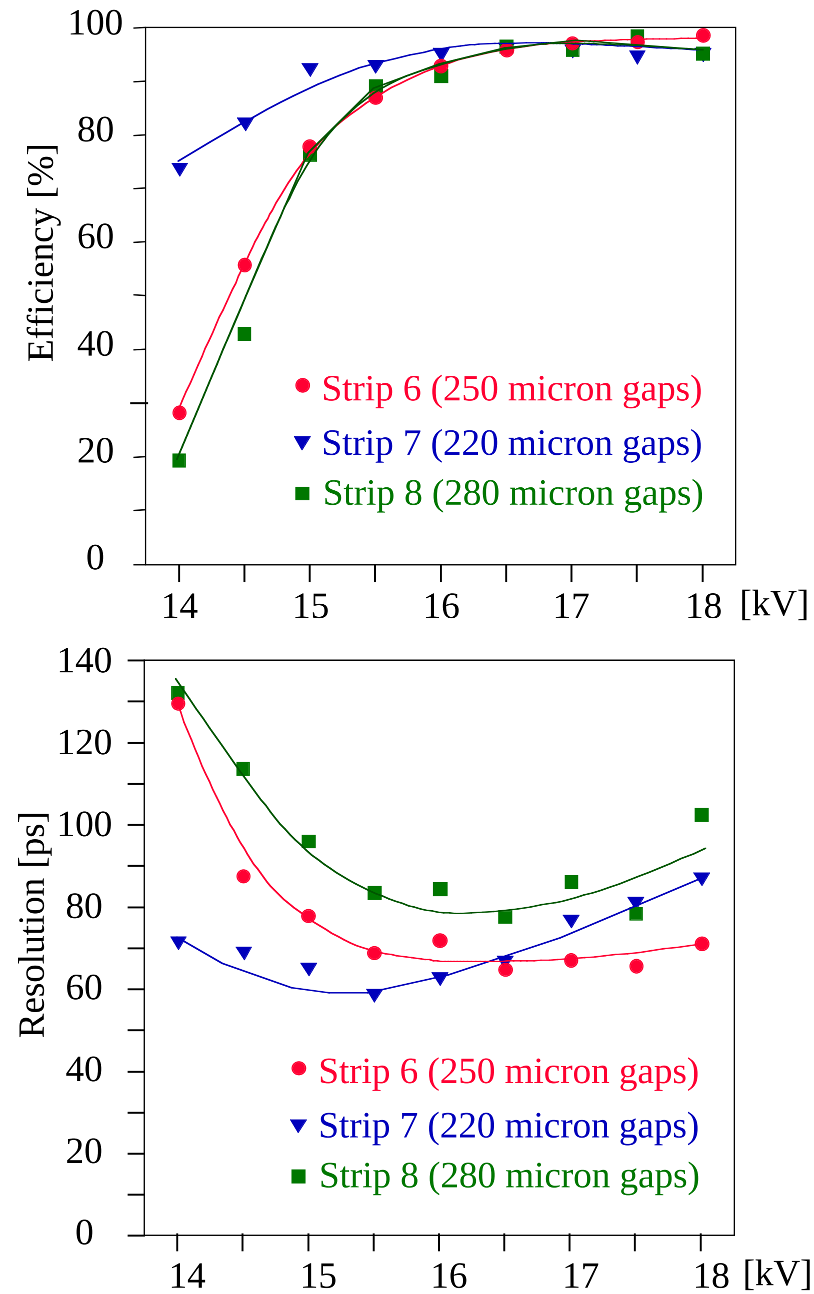
Increase gap by 60 micron
i.e. 27 %
Total gap 1.32 mm
increased to 1.68 mm

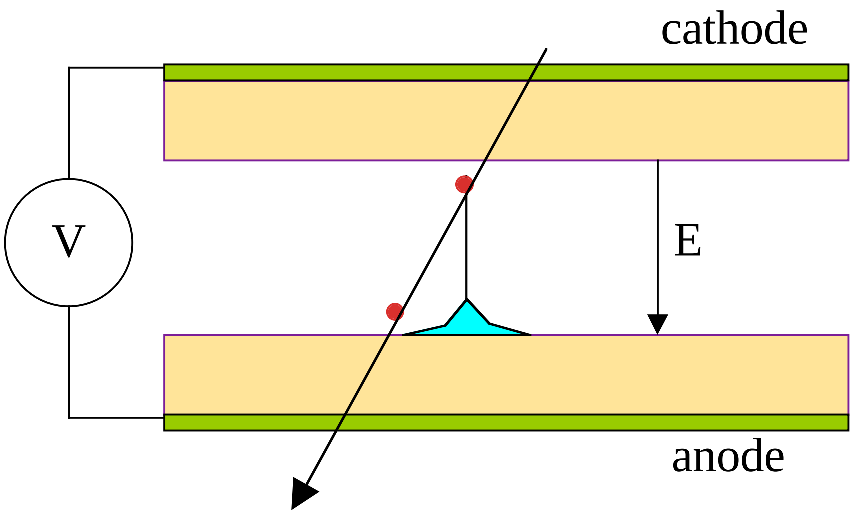
STRIP 8

550 micron internal glass sheets
2.5 mm external glass (Schott black welding glass)
6 gas gaps of 280 micron
fish line spacers across width of strip
Edge defined by edge of glass
guard rings

Big change in gap size ⟶ small change in operating voltage. Large ‘plateau’ region where efficiency high, time resolution excellent and gap can vary by ± 30 μm

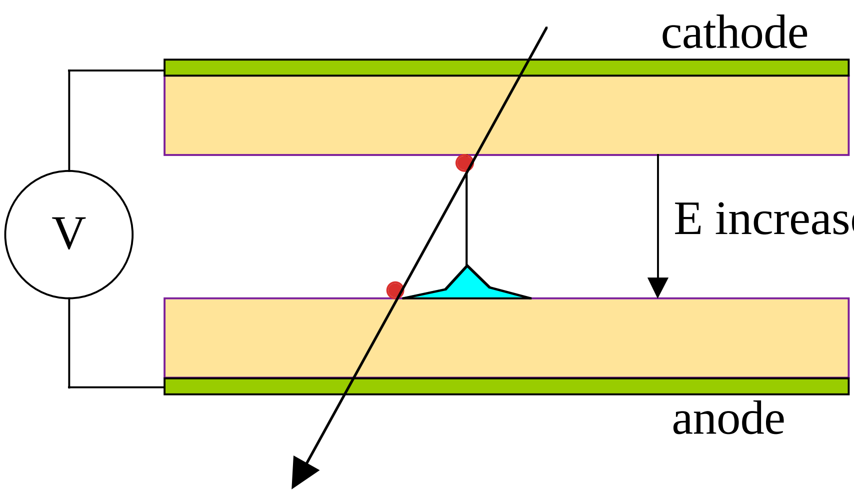
Thus device with this excellent time resolution can be built with very ‘relaxed’ mechanical tolerances





Charged particle passes through gas gap and creates clusters of electrons and positive ions electrons avalanche towards anode →fast signal on external electrodes - etc

Now consider smaller gap



E increased (same V - smaller gap)

Thus Townsend coefficient higher - bigger avalanche (i.e. higher gain)

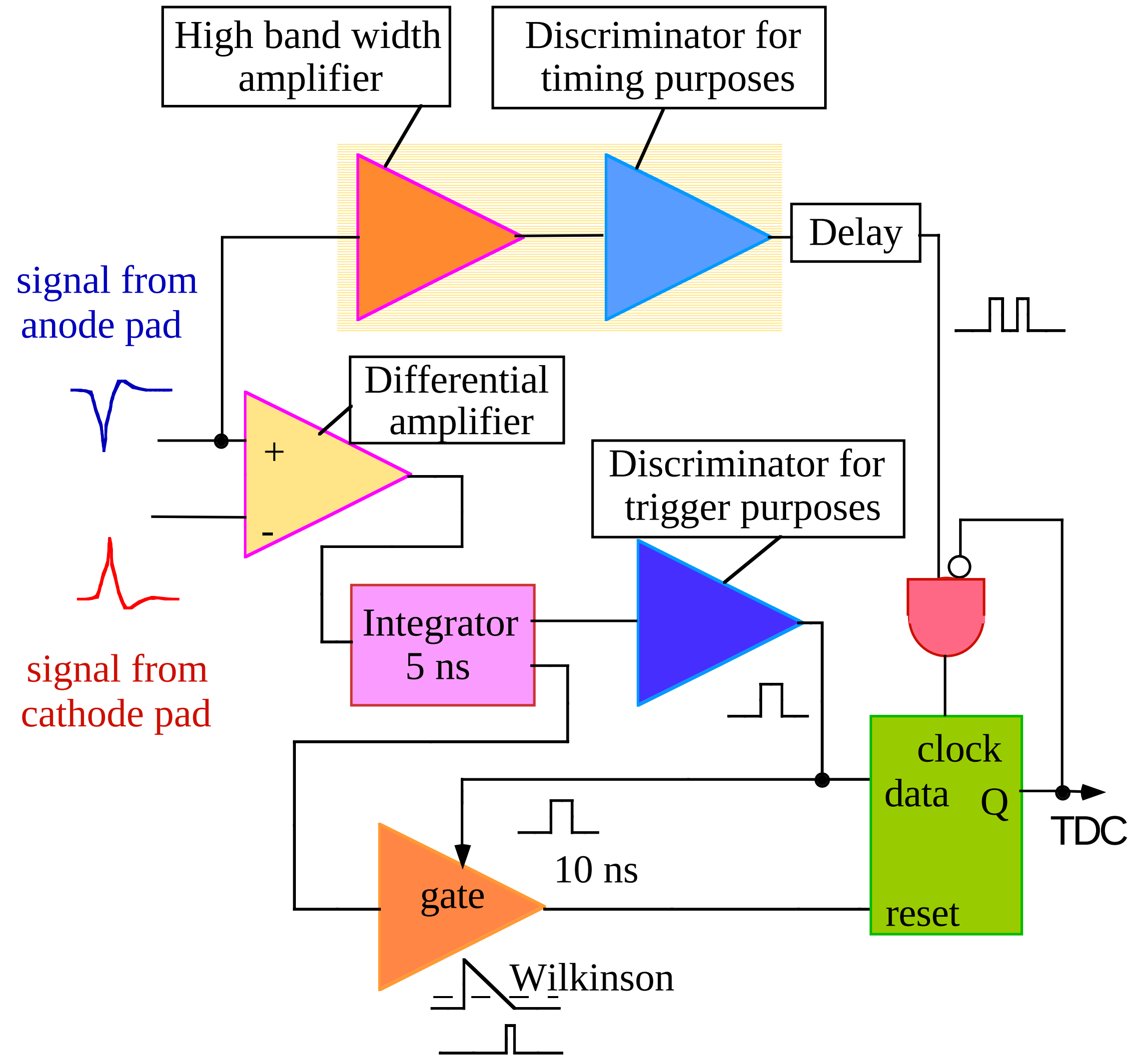
however gap smaller therefore less distance for avalanche to grow (i.e. lower gain)

Apparently we are working in region where both effects cancel (by 'magic' it is rather an exact cancellation)

Proposed electronic scheme presented in TDR

Problem: to get 'best' time resolution need to make timing correction according to pulse height (T(A) corrections).

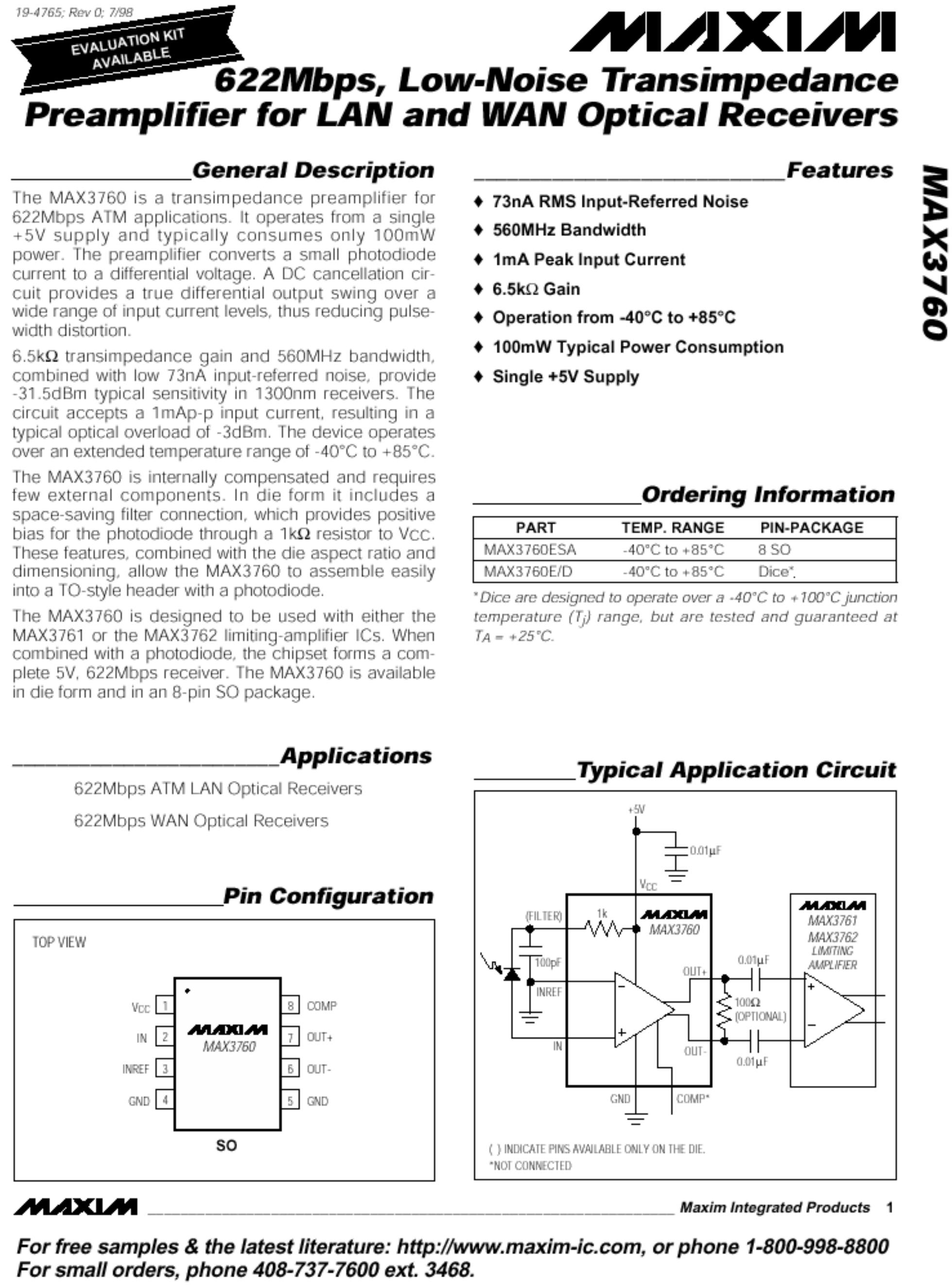
We need high quality TDC for timing - proposal: convert charge of input signal to Time-over-Threshold and use TDC to measure time of both edges (no ADC required). However need to develop front-end ASIC to keep costs/size/power reasonable.



Key point: 560 MHz Bandwidth

Key question: can it be made to work?

No problem with noise or oscillation (maybe differential output from chamber helps)



19-4765; Rev 0; 7/98

EVALUATION KIT AVAILABLE

MAXIM

622Mbps, Low-Noise Transimpedance Preamplifier for LAN and WAN Optical Receivers

MAX3760

General Description

The MAX3760 is a transimpedance preamplifier for 622Mbps ATM applications. It operates from a single +5V supply and typically consumes only 100mW power. The preamplifier converts a small photodiode current to a differential voltage. A DC cancellation circuit provides a true differential output swing over a wide range of input current levels, thus reducing pulse-width distortion.

6.5kΩ transimpedance gain and 560MHz bandwidth, combined with low 73nA input-referred noise, provide -31.5dBm typical sensitivity in 1300nm receivers. The circuit accepts a 1mAp-p input current, resulting in a typical optical overload of -3dBm. The device operates over an extended temperature range of -40°C to +85°C.

The MAX3760 is internally compensated and requires few external components. In die form it includes a space-saving filter connection, which provides positive bias for the photodiode through a 1kΩ resistor to VCC. These features, combined with the die aspect ratio and dimensioning, allow the MAX3760 to assemble easily into a TO-style header with a photodiode.

The MAX3760 is designed to be used with either the MAX3761 or the MAX3762 limiting-amplifier ICs. When combined with a photodiode, the chipset forms a complete 5V, 622Mbps receiver. The MAX3760 is available in die form and in an 8-pin SO package.

Features

- 73nA RMS Input-Referred Noise
- 560MHz Bandwidth
- 1mA Peak Input Current
- 6.5kΩ Gain
- Operation from -40°C to +85°C
- 100mW Typical Power Consumption
- Single +5V Supply

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX3760ESA	-40°C to +85°C	8 SO
MAX3760E/D	-40°C to +85°C	Dice*

*Dice are designed to operate over a -40°C to +100°C junction temperature (T_J) range, but are tested and guaranteed at T_A = +25°C.

Applications

622Mbps ATM LAN Optical Receivers

622Mbps WAN Optical Receivers

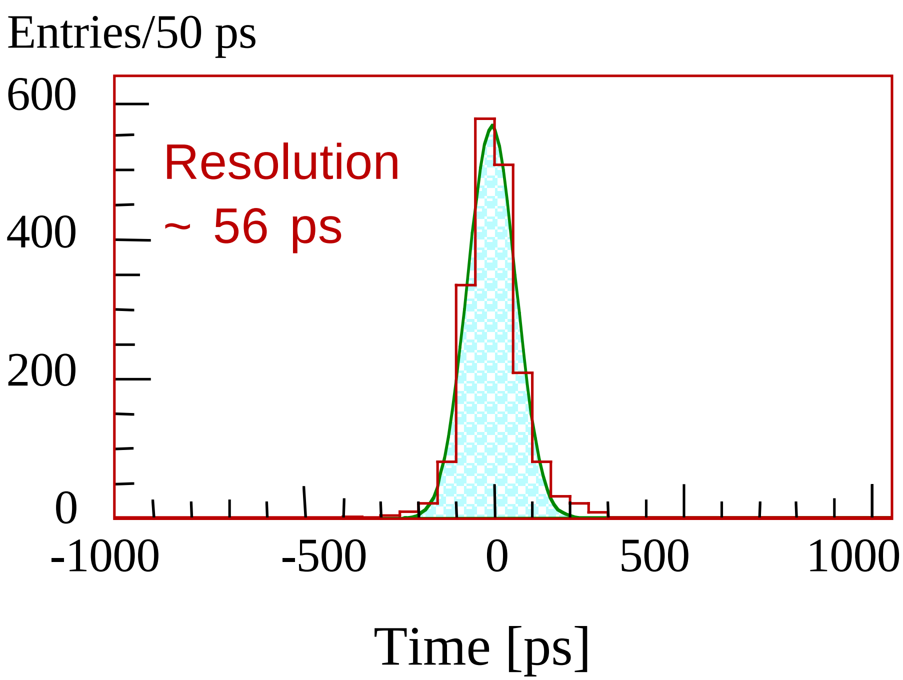
Pin Configuration

Typical Application Circuit

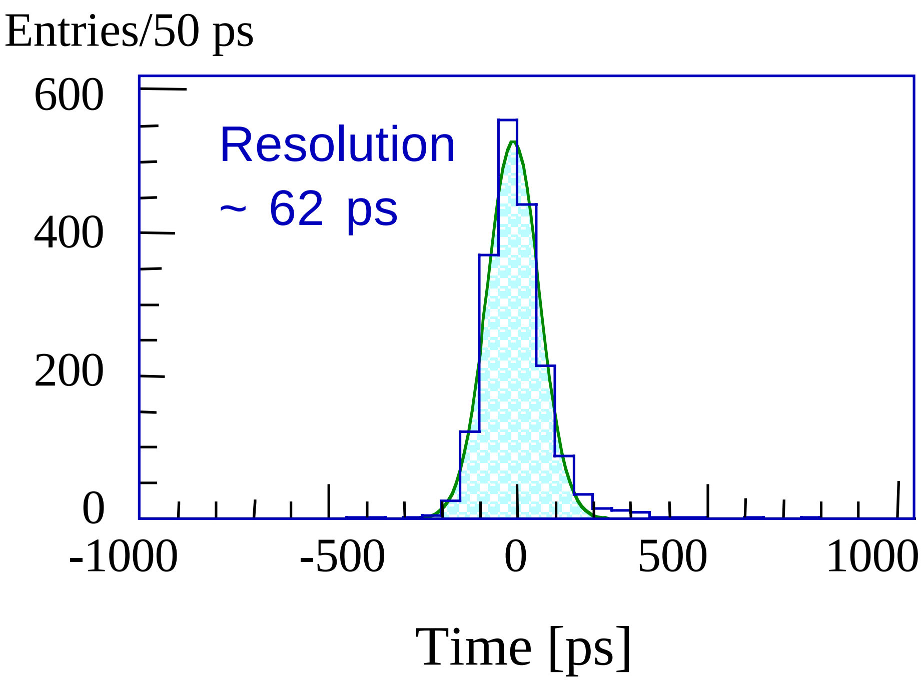
MAXIM Maxim Integrated Products 1

For free samples & the latest literature: http://www.maxim-ic.com, or phone 1-800-998-8800
For small orders, phone 408-737-7600 ext. 3468.

Using ADC for T(A) corrections



Using Time-over-Threshold for T(A) corrections



Summary

2 years investigation of multigap resistive plate chamber as a TOF detector

Detector that is easy to build - just make a stack of glass plates
Gap tolerances very relaxed ± 30 μm for 250 μm gap

Excellent time resolution ~ 70 ps with insignificant tails
small “time-walk” ($\Delta T/\Delta V$ ~ between 0 - 100 ps / 1000V)

Large detectors arrays easy to realise
(a) differential readout - low noise for electronics
(b) Loose gap tolerance

Commercial amplifiers ideally suited to detector requirements
and have reasonable cost (however ASIC
amplifier-discriminator still under investigation)

ALICE TOF project is in good shape