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 m² (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.
The red hits/track corresponds to a single particle ($\pi$ in this case)

TOF with very high granularity needed!
ALICE TOF

covers 150 m²
consists of 160,000 readout channels.
Each pad is 2.5 x 3.5 cm².
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
  - Cathode
  - Anode
  - 100 µm gap
  - 12 atmospheres
  - Pestov glass
- 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
- 600 µm gap
- 600 µm gap
- Marginal time resolution ~ 250 ps
- Small signal (to keep sparks at low probability)
- Difficult to build
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?
Question:
Can we build big device with similar performance to small single cells?

Starting point
Spring 1999

5 gas gaps of 220 micron
Anode electrode  3 x 3 cm²
Cathode electrode  3 x 3 cm²

Schott A2
(0.5 mm thick)

Schott A14
(0.5 mm thick)

Schott 8540
(2 mm thick)

5 cm

Efficiency [%]

Resolution [ps]

Efficiency [%]

8 9 10 11 12 13 14

HV (kV)

80 90 100 110 120 130 140

60 70 80 90 100 110 120

Counts / 50 ps

-1000 -2000 0 1000 2000 3000

time difference between start counter and MRPC [ps]

Gaussian fit $\sigma = 77$ ps

Tail of late signals
29 events/17893 events = 0.16%

Subtract jitter of start counters of 33 ps give time resolution of 70 ps

Quark-Matter 2001
ALICE TOF project
Crispin Williams 9
1999 tests: Two ‘large’ designs tested - large matrix and strip

Large matrix design

Strip design of MRPC

Resistive plates 0.5 mm A14 glass
5 gaps of 220 \( \mu \)m

60 mm

80 mm

Various sizes with various materials tested

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

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

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

TRD

TOF modules

20° 10°

20° 10°
November 1999
Built and tested 16 pad strip  active area 24 x 6 cm²
16 pad strip works just fine!

8x2 cell strip detector 12.5 kV

Mean 96.1 %

Mean 62.5 ps
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)
*2 mm thick window glass*

*0.6 mm thick Glaverbel glass*

*Edge of active area*

*5 gas gaps of 240 micron*

*Carbon layers*

*Strip 1: five gas gaps of 250 micron*

*Honeycomb panel (10 mm thick)*

*Active area 7 cm wide*

*PCB for cathode pads*

*PCB for anode pads*

*Spacers: fibre across width of strip every 2.5 cm*

*Edge: defined by edge of cut glass*
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

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

Increase gap by 60 micron
i.e. 27%
Total gap increased to 1.68 mm
Big change in gap size $\rightarrow$ small change in operating voltage. Large ‘plateau’ region where efficiency high, time resolution excellent and gap can vary by $\pm$ 30 $\mu$m

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)
Using ADC for T(A) corrections

Resolution ~ 56 ps

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

Resolution ~ 62 ps
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” (ΔT/ΔV ~ 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