MRPC Detectors for Ultra High Rate Applications

CECILIA URIBE ESTRADA
INSTITUTO DE CIENCIAS
BENEMÉRITA UNIVERSIDAD AUTÓNOMA DE PUEBLA

XXXIV Annual Meeting of the DPyC2020, Virtual Conference, 9–10 Jul 2020

Introduction

The excellent timing performance of Multigap Resistive Plate Chambers (MRPCs) makes them widely used in HEP and nuclear physics experiments

- The detectors for future experiments require higher rate capabilities as well as timing precision
- As an example the Compressed Baryonic Matter (CBM) experiment is planned to operate at the Facility for Antiproton and Ion Research (FAIR) to study nucleus-nucleus collisions
- For the CBM's Time of Flight (TOF) system: MRPCs will work at particle fluxes ~ 1-10 kHz/cm^2 for outer region & ~10-25 kHz/cm^2 for the central region

Introduction

Thus the rate capability is a key factor for the MRPCs

- Better time resolution under high flux will also allow particle identification with TOF techniques to be performed at higher momenta
- Thus there is an urgent need for MRPCs which can work at a higher incident flux of particles and operate reliable with a time resolution ~ 20 ps for through-going particles

Introduction

MRPCs' fundamental parameter is the rate capability

- Lower resistivity materials improve the rate capability of MRPCs
- However low-resistivity material is often thicker (>0.7mm) than commercial soda-lime float glass (down to 0.28mm)
- Thicker material ➔increases material budget➔ imposes a limit to the # of gaps ➔time precision more challenging

Introduction

MRPCs' fundamental parameter is the rate capability

- Additionally we want to maintain the feasibility of building a large area detector, together with low cost, ease of construction, with a minimum material budget.

Introduction

A new low-resistivity float-glass (Picotech S.A.S.) is under consideration for high rate MRPC purposes

- Glass panes with an area of more than 1 m^2 and a thickness of 400 μm are available
- The surface quality of the rough material is excellent and it does not need additional polishing
- The mechanical strength of the pane allows a robust detector assembling procedure

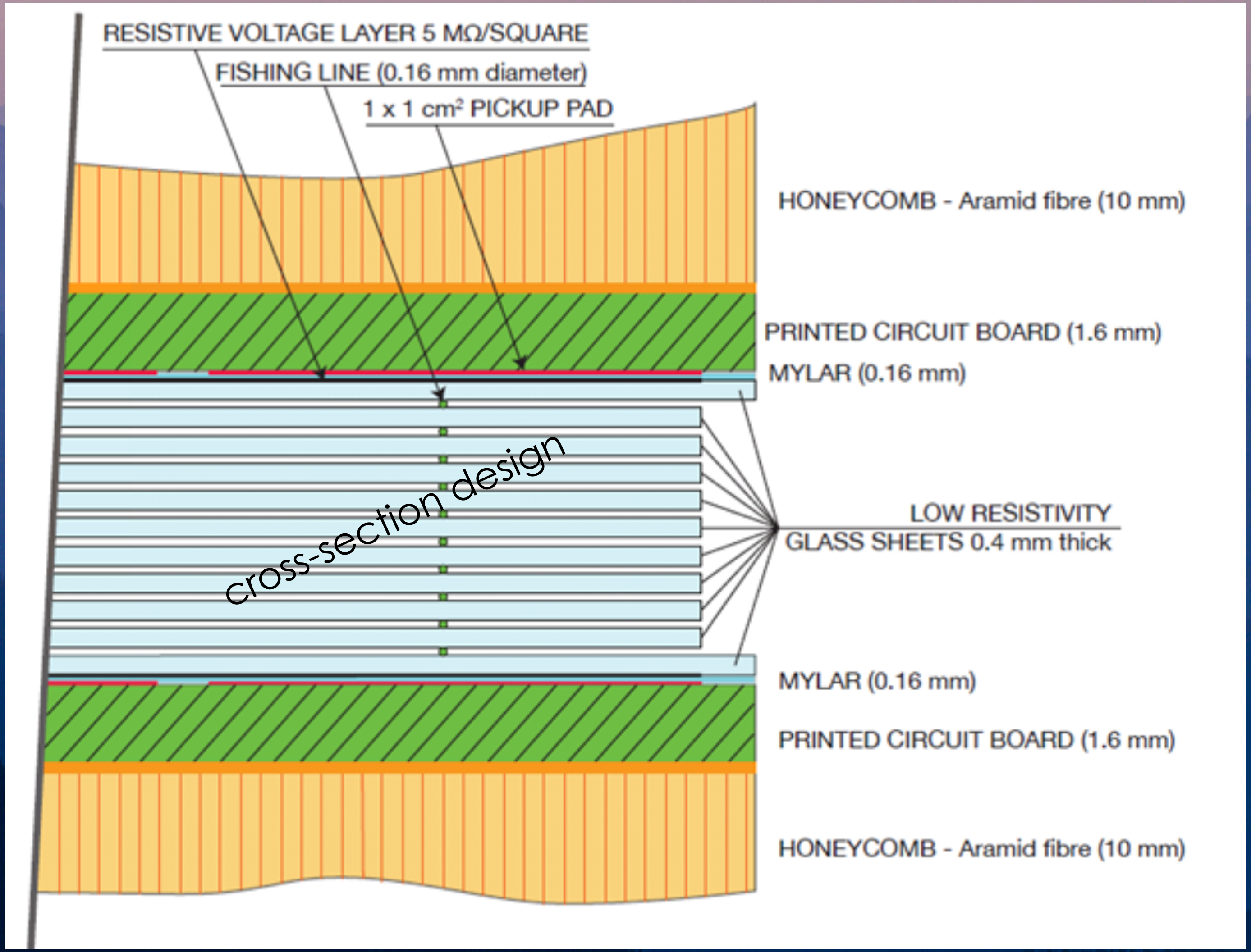
Introduction

MRPC prototypes with this low-resistive float-glass are assembled at CERN and a test of a 6-gap MRPC at the PS T10 shows an efficiency of 90 % at 90 kHz/cm²

- *To consolidate the results a 10-gap MRPC has been built at CERN and tested at the high-rate electron accelerator ELBE@HZDR for fluxes up to 200 kHz/cm²*

- *A dedicated bulk resistivity measurement system at HZDR has been used to characterize the long term behavior of the new low-resistive float-glass*

MRPC construction

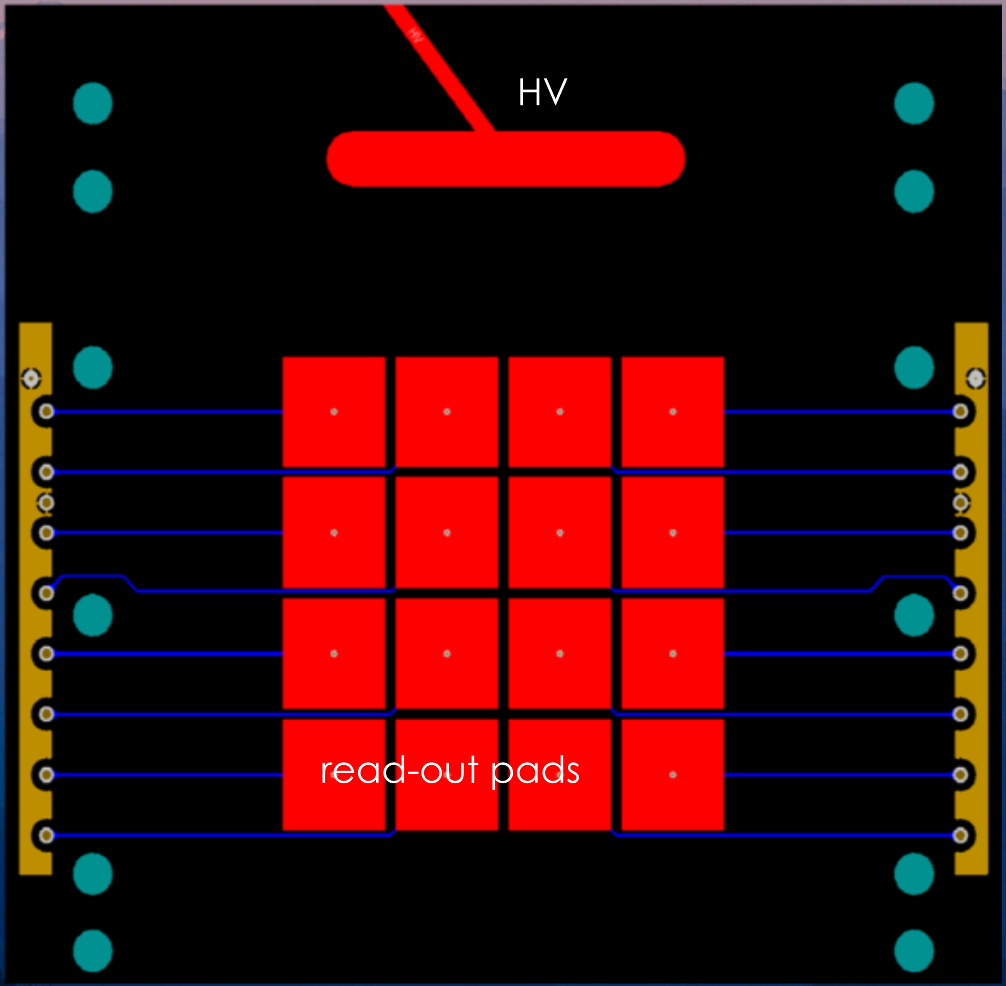


MRPC read out

The induced signal from MRPC is read out by 4x4 array of pads. Each pad is 1cm x 1cm. The gap between pads is 0.1cm. The differential signal from top and bottom paired pad is sent to NINO ASIC.
The active area of the MRPC is 5 cm x 6 cm which is covered by the beam spot.

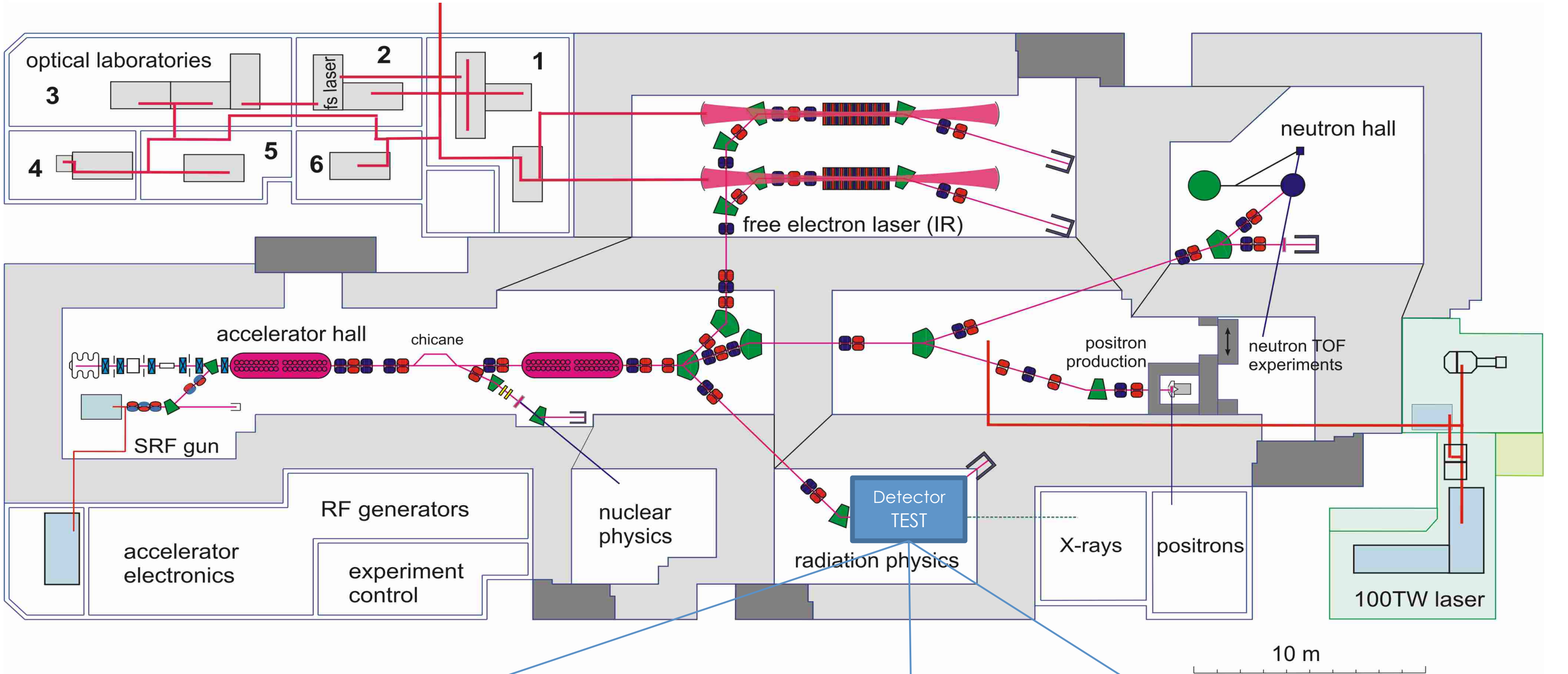
MRPC:

Gas-gaps:	10 per 160 μm
Floating electrodes:	9 per 400 μm
Read-out pads:	2x (4x4) per 1x1 cm²
HV-electrode area:	5x6 cm²
Gas-mixture:	C2H2F4(95%), SF6 (5%)
Gas-flow:	30 ml/min



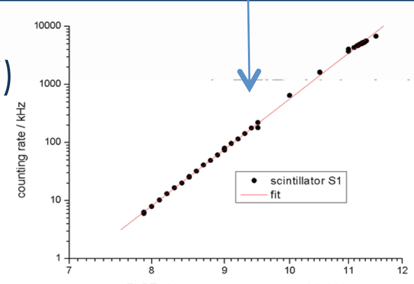
Detector test-facility @ ELBE

The radiation source **ELBE** (**E**lectron **L**inac for beams with high **B**rilliance and low **E**mittance) delivers multiple secondary beams, both electromagnetic radiation and particles.

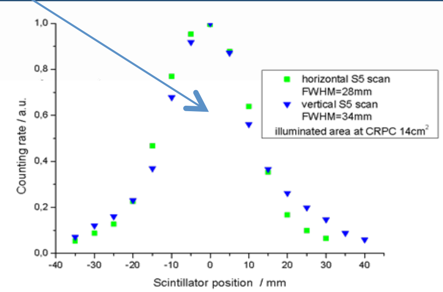


single electrons

electron energy	**30MeV** (12 - 40 MeV)
pulse repetition freq.	13.7 MHz/2^n
pulse duration	**5** ps
aver. beam current	$\mathbf{10^{-17}}$ -10^{-3} A
RF-reference time jitter	35 ps

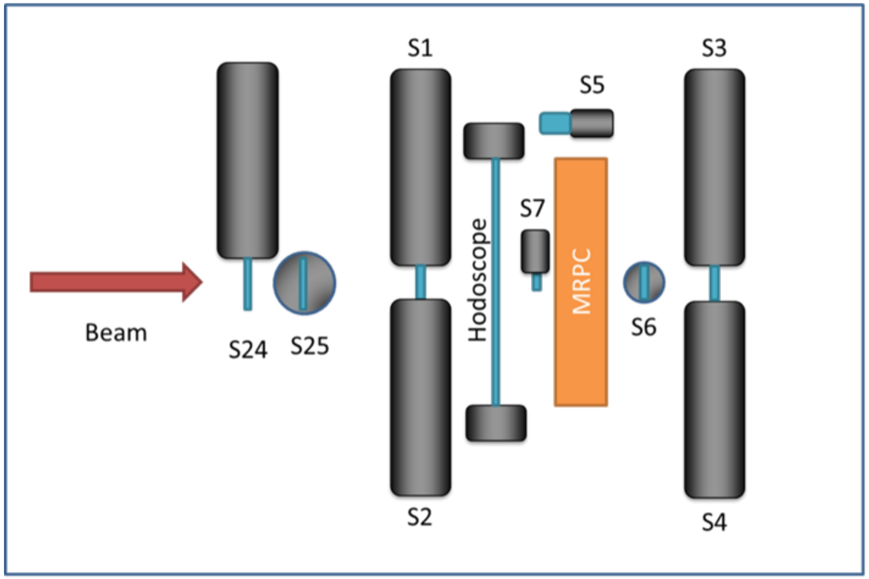


rep. rate 1Hz - 1MHz

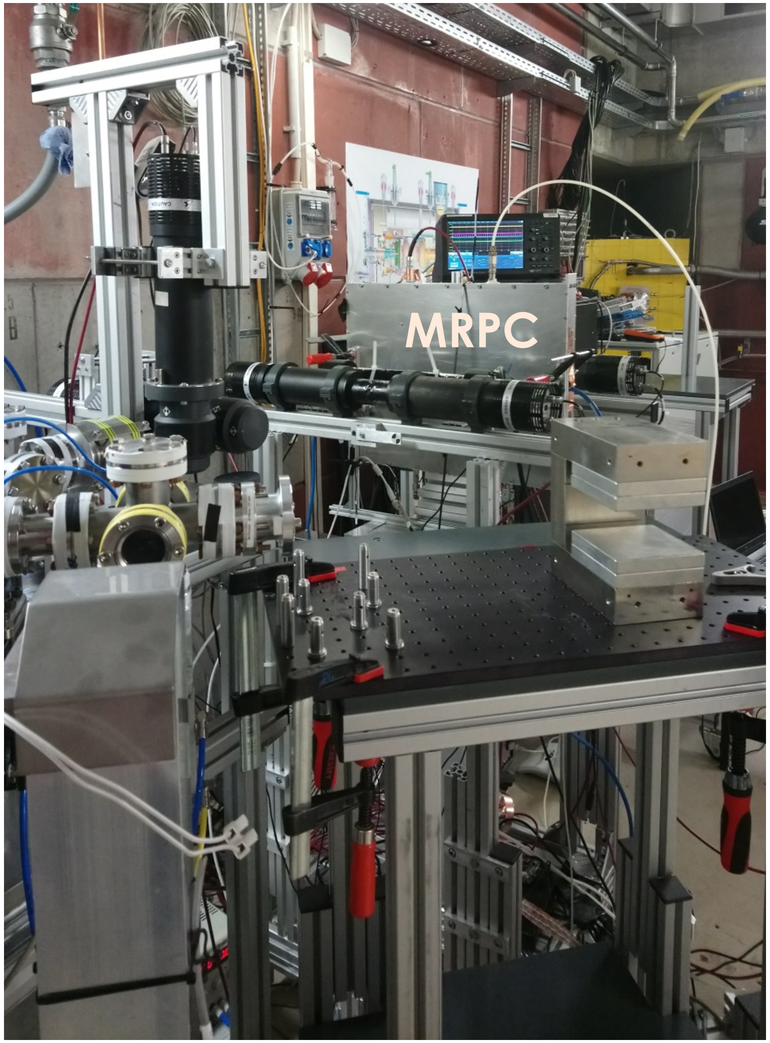


spot size ≥10 cm²

Experimental setup @ ELBE



Detector Setup Top View

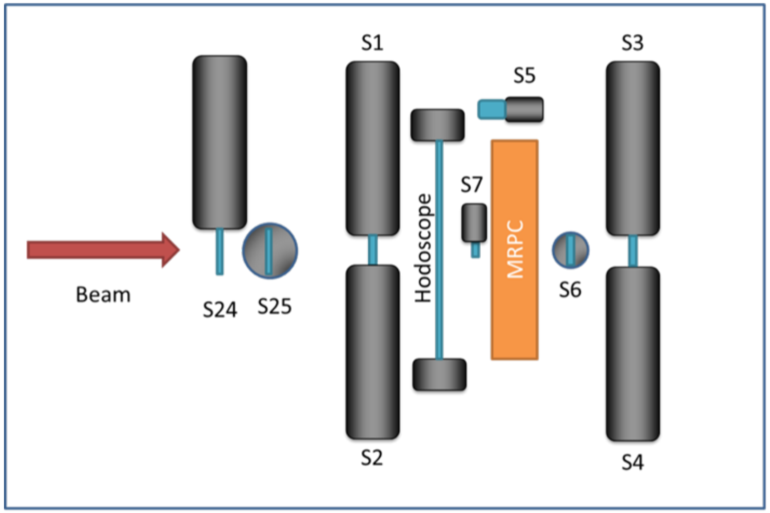


The MRPC is placed in a set of scintillators. The singals from the MRPC and PMTs are fed to the DAQ system.

Scintillation-counters:

Beam-spot:	S5 (Ø 9 mm)
Beam-rate:	S25 and S24 (4x4 cm²)
Trigger:	S1S2 and S3S4 (2x2 cm²)
Trigger:	S6 (4x4 cm²)
Pad definition:	S7 (1x1 cm²)
Hodoscope:	16 fibers (2x2 mm²)

Efficiency and time resolution



Detector Setup Top View

MRPC *differential signals* →
→ NINO ASIC *discriminator* →
→ LVDS-to-NIM *converter* →

→ **WaveCatcher** T_{MRPC}, ToT, N_{MRPC}

→ **RF&S1S2&S3S4** $N_{Trigger}$, T_{Ref}

Efficiency

ε = *Total MRPC hits/Total Valid Events*

Efficiency

$\varepsilon = N_{MRPC}/N_{trigger}$

Time resolution

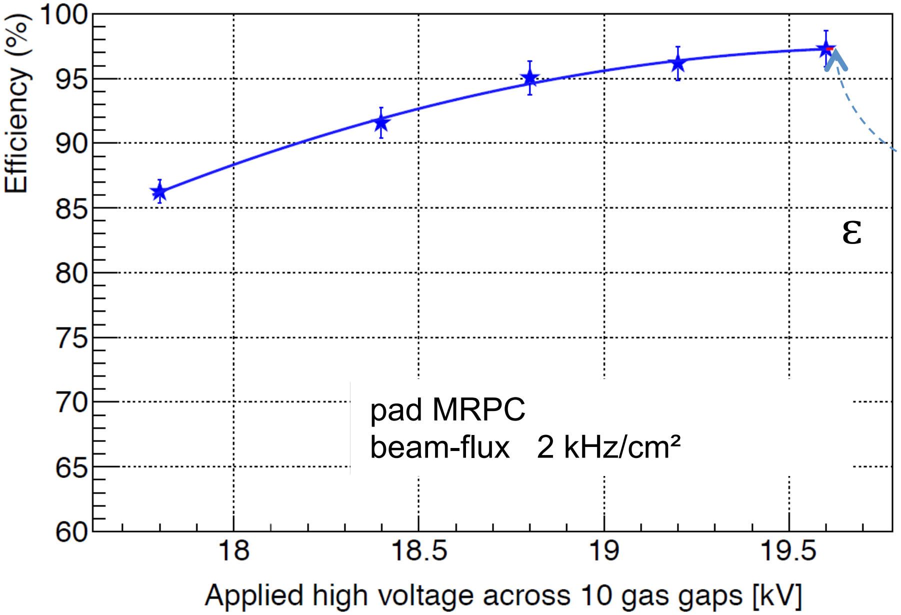
FWHM(Full Width at Half Maximum)=
2 sqrt(2 ln 2) $\sigma \approx 2.3548\ \sigma$

Time resolution

$\sigma(t) = FWHM\ (T_{MRPC} - T_{Ref})\ /\ 2.3548$

MRPC characteristics and rate capability

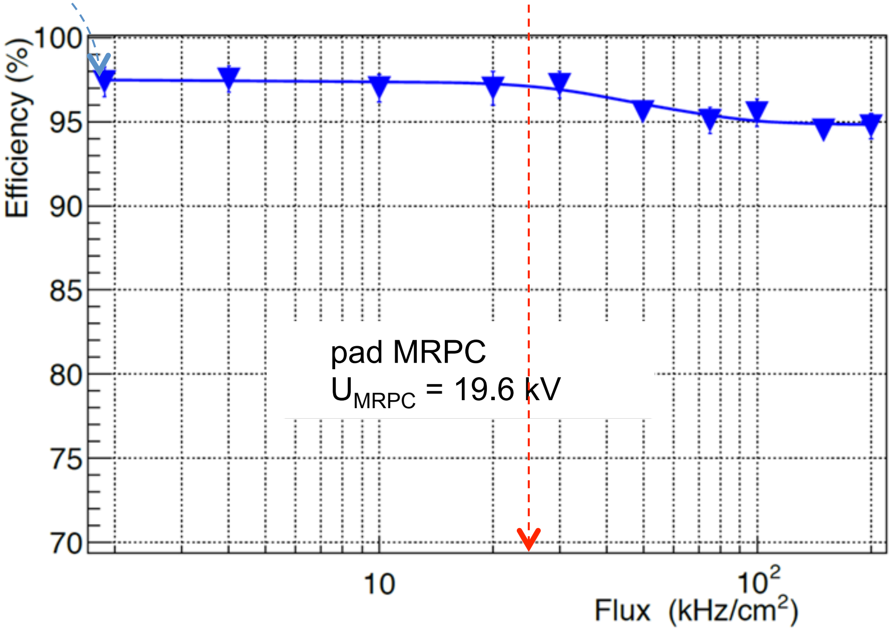
Efficiency vs. HV



At 19.6 kV, the efficiency of MRPC reaches the plateau

Efficiency vs. flux

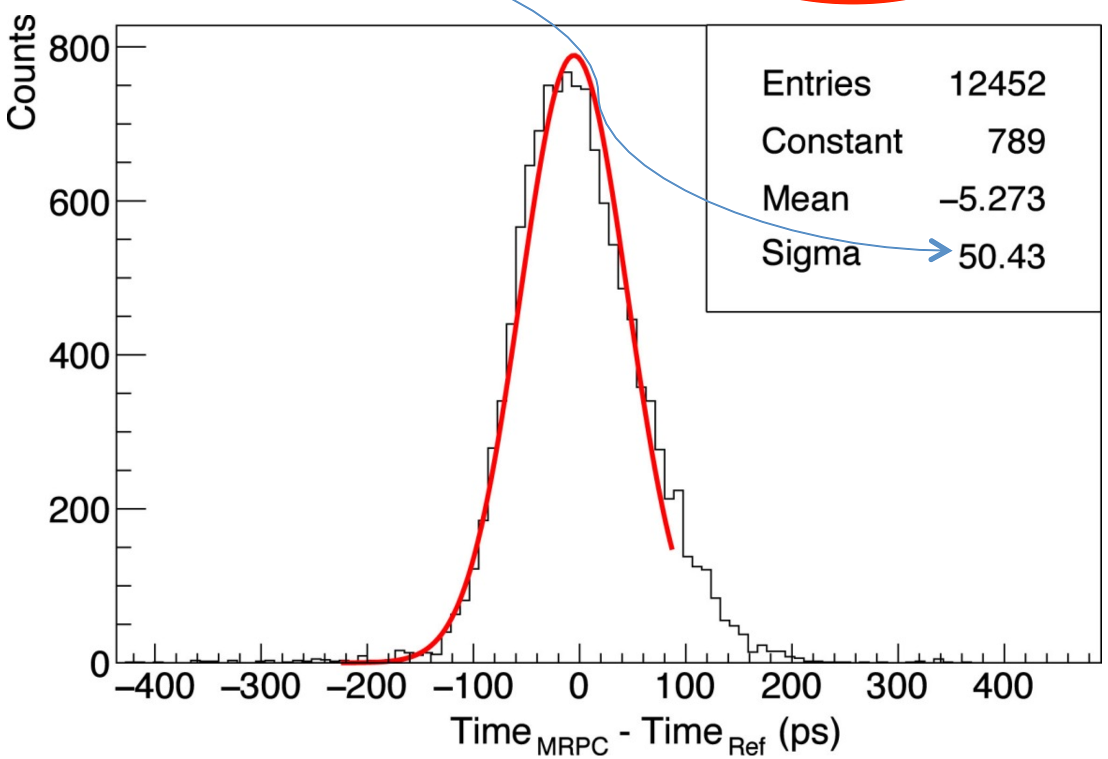
$\varepsilon \geq 97$ %@25 kHz/cm²



Detector test: MRPC time resolution

U_{MRPC} = 19.2 kV; beam-flux 2kH/cm²
RF reference time jitter

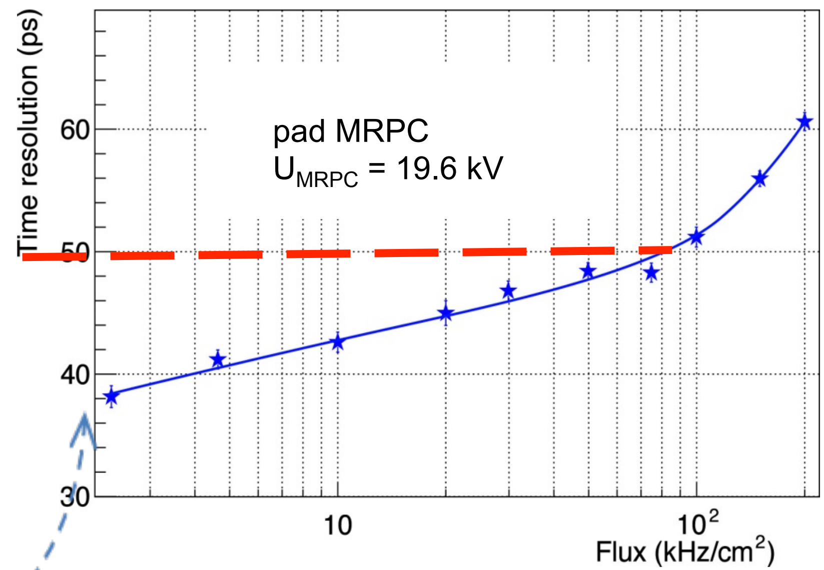
$$\sqrt{(50.4ps)^2-(35ps)^2} = (36\pm0.8)\,ps$$



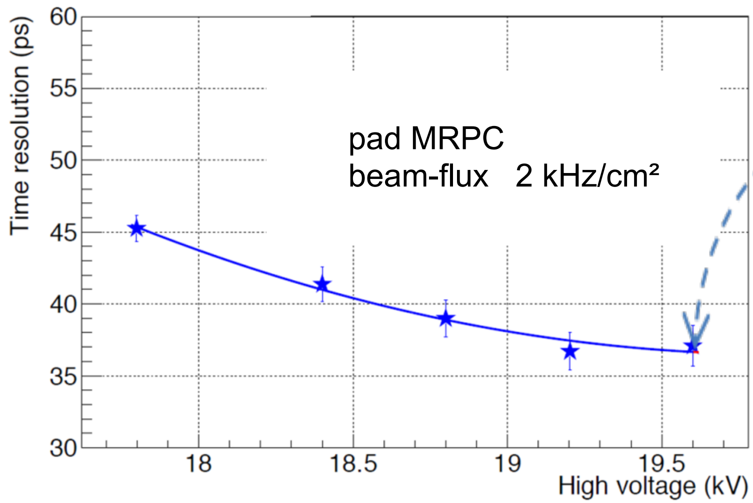
Detector test: MRPC time resolution

50 ps @ ≤ 100 kHz/cm²

Time resolution vs. Flux



Time resolution vs. HV



Summary: Detector test @ ELBE

- Single electron cw beam 30 MeV
- RF time-jitter 35 ps
- Beam-spot size ≥ 10 cm² → Read-out pad size ≈ 16 cm²

10-gap MRPC

Beam-flux	2 kHz/cm²	100 kHz/cm²	200 kHz/cm²
Efficiency (ε)	97%	97%	95%
Time resolution (σ)	36ps	50ps	60ps

- No long-term MRPC exposure during this beam-time → accumulated charge in the glass electrodes ≤ 10 mC
- The resistivity studies of this MRPC are included in the related article: Nuclear Inst. And Methods in Physics Research, A 959 (2020) 163483

Team and the most recent publication

European Centre for Nuclear Research (CERN), Geneva, Switzerland:

Z. Liu, M.C.S. Williams, A. Zichichi

Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany:

R. Beyer, J. Dreyer, X. Fan, A. Laso Garcia,
R. Greifenhagen, R. Kotte, L. Naumann, K. Römer, D. Stach

Benemerita Universidad Autonoma de Puebla, Mexico:

C. Uribe Estrada

Gangneung-Wonju National University, Gangneung, South Korea:

D.W. Kim

Nuclear Inst. and Methods in Physics Research, A 959 (2020) 163483

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Novel low resistivity glass: MRPC detectors for ultra high rate applications

Z. Liu [a,b,*], R. Beyer [c], J. Dreyer [c], X. Fan [c], R. Greifenhagen [c], D.W. Kim [e], R. Kotte [c], A. Laso Garcia [c], L. Naumann [c], K. Römer [c], D. Stach [c], C. Uribe Estrada [d], M.C.S. Williams [a,e,f], A. Zichichi [a,f,g]

[a] *European Centre for Nuclear Research (CERN), Geneva, Switzerland*
[b] *ICSC World Laboratory, Geneva, Switzerland*
[c] *Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany*
[d] *Benemerita Universidad Autonoma de Puebla, Mexico*
[e] *Gangneung-Wonju National University, Gangneung, South Korea*
[f] *INFN and Dipartimento di Fisica e Astronomia, Universita di Bologna, Italy*
[g] *Museo Storico della Fisica e Centro Studi e Ricerche E.Fermi, Roma, Italy*

ARTICLE INFO

Keywords:
Multigap resistive plate chamber
Low resistivity glass
Rate capability
Efficiency
Time resolution

ABSTRACT

Multigap Resistive Plate Chambers (MRPCs) are often used as time-of-flight (TOF) detectors for high-energy physics and nuclear experiments thanks to their excellent time accuracy. For the Compressed Baryonic Matter (CBM) TOF system, MRPCs are required to work at particle fluxes on the order of 1–10 kHz/cm^2 for the outer region and 10–25 kHz/cm^2 for the central region. Better time resolution will allow particle identification with TOF techniques to be performed at higher momenta. From our previous studies, a time resolution of 25ps has been obtained with a 20-gap MRPC of 140 μm gap size with enhanced rate capability. By using a new type of commercially available thin low-resistivity glass, further improvement MRPC rate capability is possible. In order to study the rate capability of the 10-gap MRPC built with this new low-resistivity glass, we have performed tests using the continuous electron beam at ELBE. This 10-gap MRPC, with 160 μm gaps, reaches 97% efficiency at 19.2 kV and a time resolution of 36ps at particle fluxes near 2 kHz/cm^2. At a flux of 100kHz/cm^2, the efficiency is still above 95% and a time resolution of 50ps is obtained, which would fulfil the requirement of CBM TOF system.

1. Introduction

The excellent timing performance of Multigap Resistive Plate Chambers (MRPCs) makes them widely used in high energy and nuclear physics experiments [1–3]. The detectors for future experiments require higher rate capabilities as well as timing precision. As an example, the Compressed Baryonic Matter (CBM) experiment is planned to operate at the Facility for Antiproton and Ion Research (FAIR) to study nucleus–nucleus collisions [4]. For the Time of flight (TOF) system of CBM experiment, MRPCs will be required to work at particle fluxes on the order of 1–10 kHz/cm^2 for the outer region and 10–25 kHz/cm^2 for the central region [5]. Thus the rate capability is a key factor for the MRPCs used at the CBM experiment. Better time resolution under high flux will also allow particle identification with TOF techniques to be performed at higher momenta. Thus there is an urgent need for MRPCs which can work at a higher incident flux of particles and operate reliably with a time resolution approaching 20 ps for through-going particles.

Building an MRPC with a time resolution better than 20 ps while maintaining high efficiency is possible, as reported in [6]. Our R&D goal is to design and build an MRPC with similar performance, while operated with a high flux of particles. Additionally we want to maintain the feasibility of building a large area detector, together with low cost, ease of construction, with a minimum material budget. Starting from the design presented in [7], a time resolution of 25 ps has been obtained with 20-gap MRPC with a 140 μm gap size [8].

A fundamental parameter for MRPCs is the rate capability. Lower resistivity materials have been shown to improve the rate capability of MRPCs [9,10]. However, low-resistivity material is often thicker (more than 0.7 mm) than commercial soda-lime float glass (with values down to 0.28 mm). Using thicker plates increases the material budget and thus imposes a practical limit to the number of gas gaps; reducing the number of gas gaps (with increased gap size) makes precise timing more of a challenge. We have obtained new low-resistivity glass samples[1] with 0.4 mm thickness, which are commercially available. It should be noted that this glass is manufactured by industry using standard high

* Corresponding author at: European Centre for Nuclear Research (CERN), Geneva, Switzerland.
E-mail address: zheng.liu@cern.ch (Z. Liu).

[1] The samples were received from Picotech SAS.

https://doi.org/10.1016/j.nima.2020.163483
Received 3 December 2019; Received in revised form 18 January 2020; Accepted 20 January 2020
Available online 21 January 2020

Team @ ELBE

Thank you for your attention!