A high rate fast precision tracking trigger with RPCs

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Fast precision trigger with (RPC) for high rate

- Fast precision trigger for high rate requirements :

  - Precision spatial information from the front-end electronics of RPC (few mm strip pitch and sub-millimeter spatial resolution)

  - Fast trigger decision (50 – 200 ns)

  - High noise rejection

  - High performance front-end electronics

RPC for high rate

- The rate capability of a RPC is limited by the voltage drop (V_d) in the resistive electrode
- The voltage drop in the resistive electrode is :

$V_d = I * R$ with :

I = counting rate * average charge

and

R = resistivity * thickness of electrode

Strategy to increase the RPC rate capability

- Decrease the **resistivity** and the **thickness** of the electrode
- Decrease the **average charge** per count

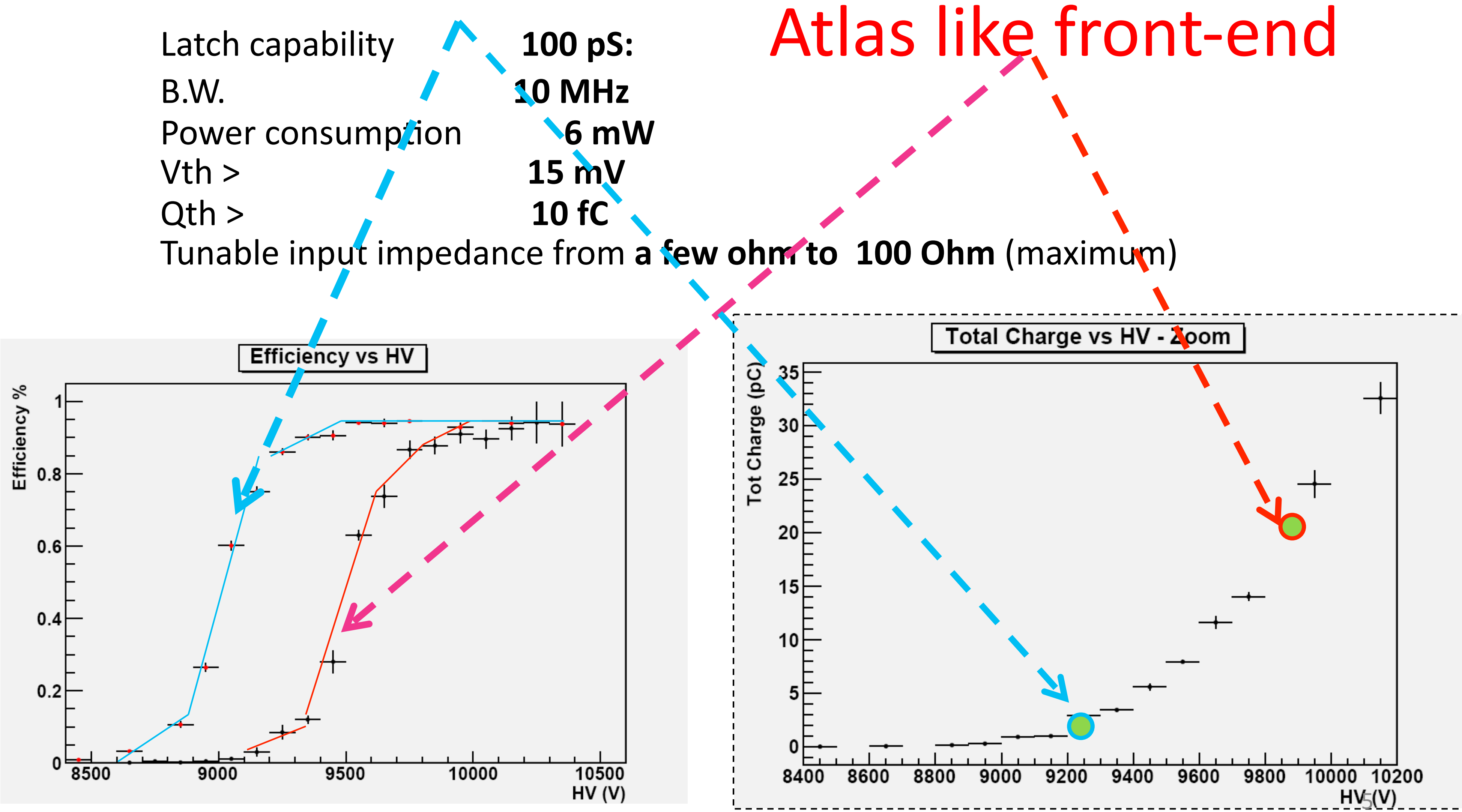
The **ageing** of the RPC is proportional to the current.

The **power** consumption is also a function of the current.

For this reasons we choose to decrease the **average charge** with a high performance **front-end electronics**

Efficiency and charge studies with cosmic ray
New vs present front-end for 2mm gap RPC

- New electronics tested by Roma at GIF
  - Sensitivity **1.5 mV/fC**
  - Noise **2 fC RMS**
  - Latch capability **100 pS:**
  - B.W. **10 MHz**
  - Power consumption **6 mW**
  - Vth > **15 mV**
  - Qth > **10 fC**
  - Tunable input impedance from **a few ohm to 100 Ohm** (maximum)



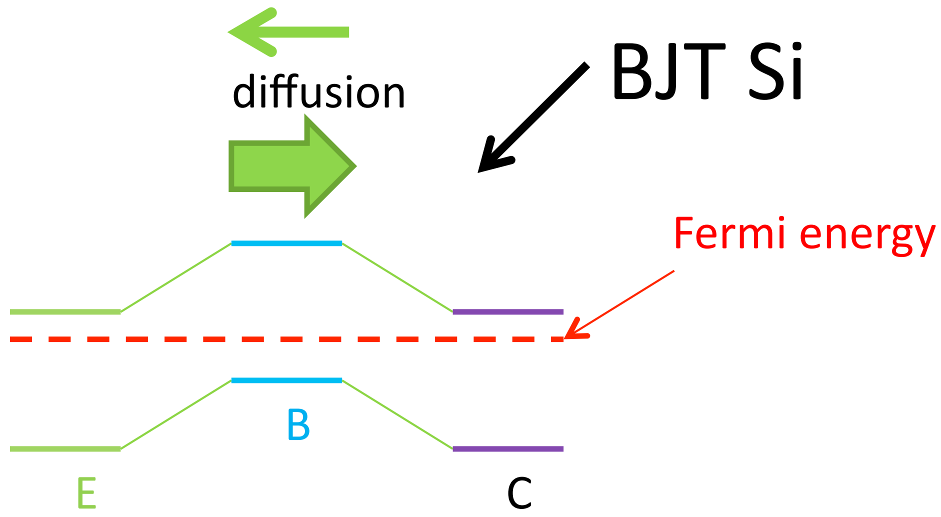
BJT Si v.s. SiGe

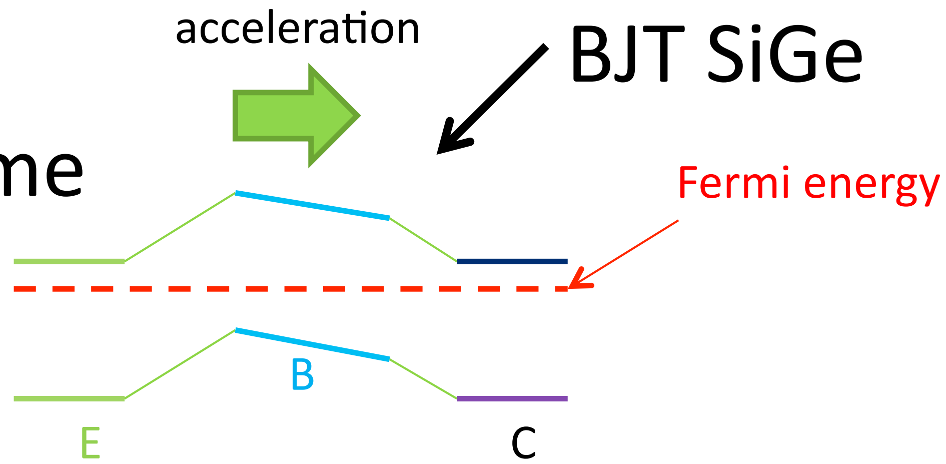
- B JT performances
- $\beta = \tau_c / \tau_t$
- $f_t = 1/\tau_t$
- $N = K^* \tau_t$

τ_c = base life time

τ_t = base transient time

τ_t (Si) >> τ_t (SiGe)





Strategy new front-end(SiGe)

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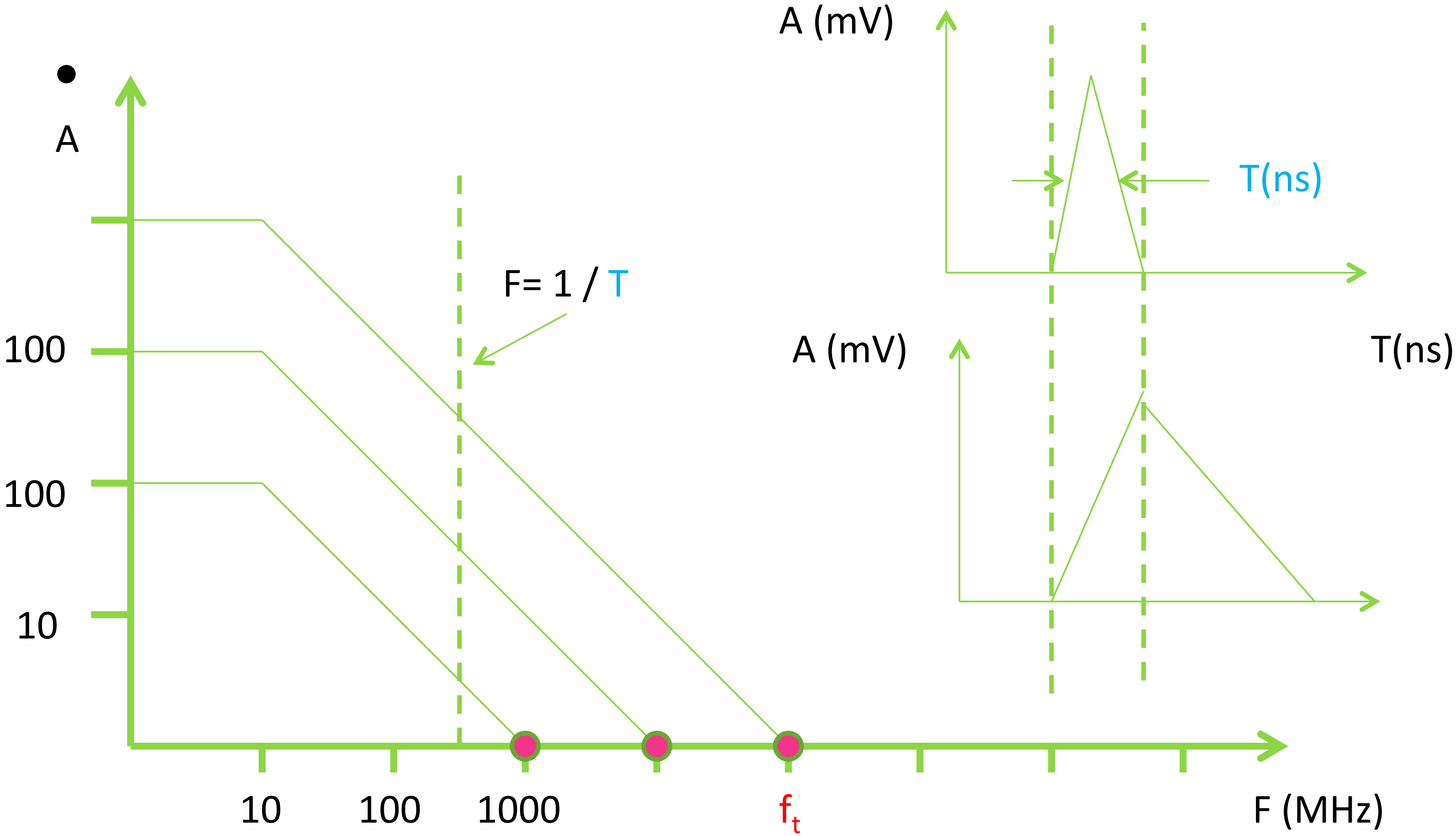
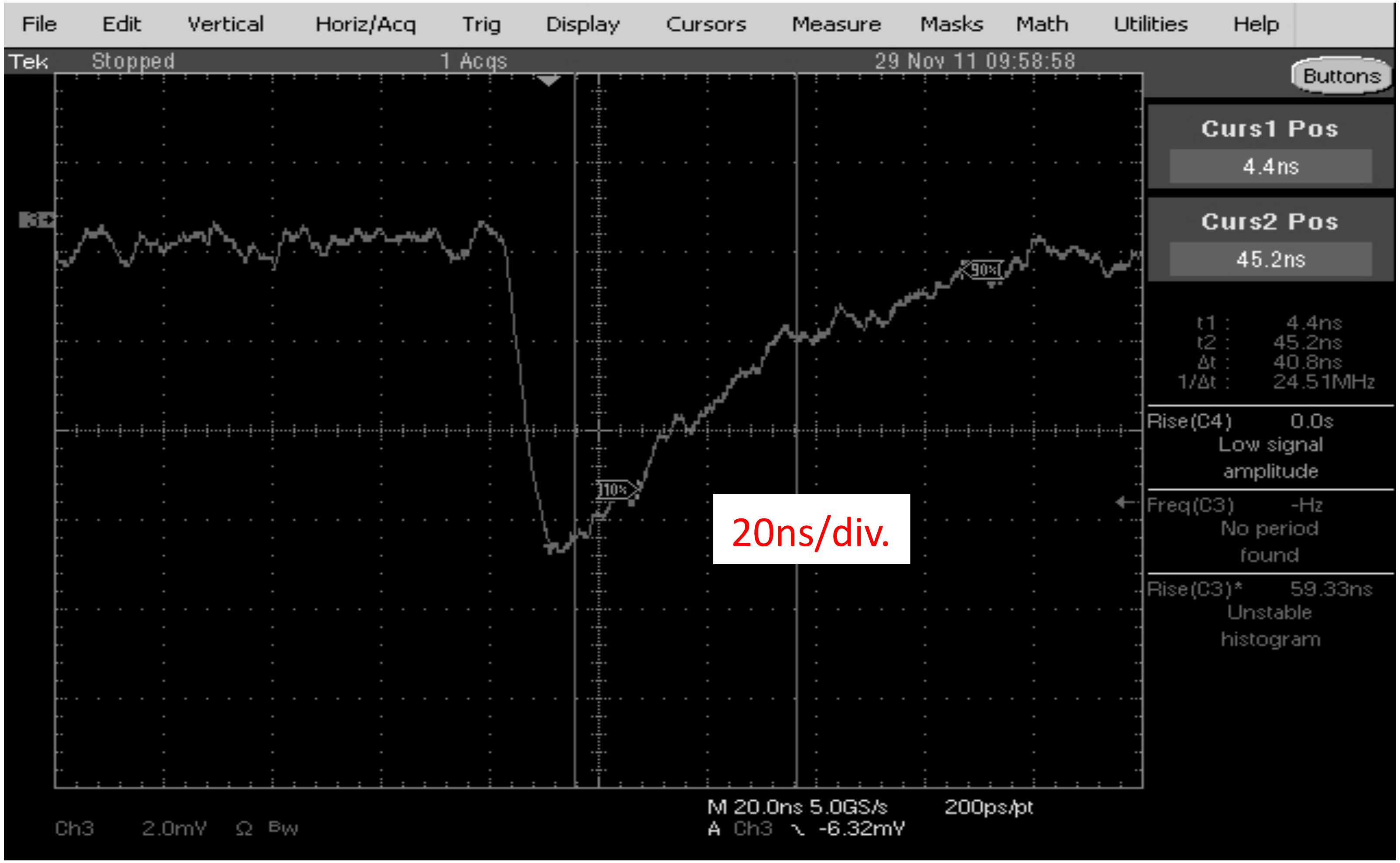


Amplifier, AC, (BJT SiGe, BFP740)

Voltage supply	3 Volt
• Sensitivity	6 mV/fC
• noise	500 e^{-} RMS
• Input impedance	10 - 100 Ohm
• B.W.	30 - 100 MHz
• Power consumption	10 mW/ch
• Low cost	2 – 3 eur./ch
• Rise time δ(t) input	100 - 300 ps
• Radiation hardness	50 Mrad, 10^{15} n cm^{-2}

1 fC signal with SiGe aplifier

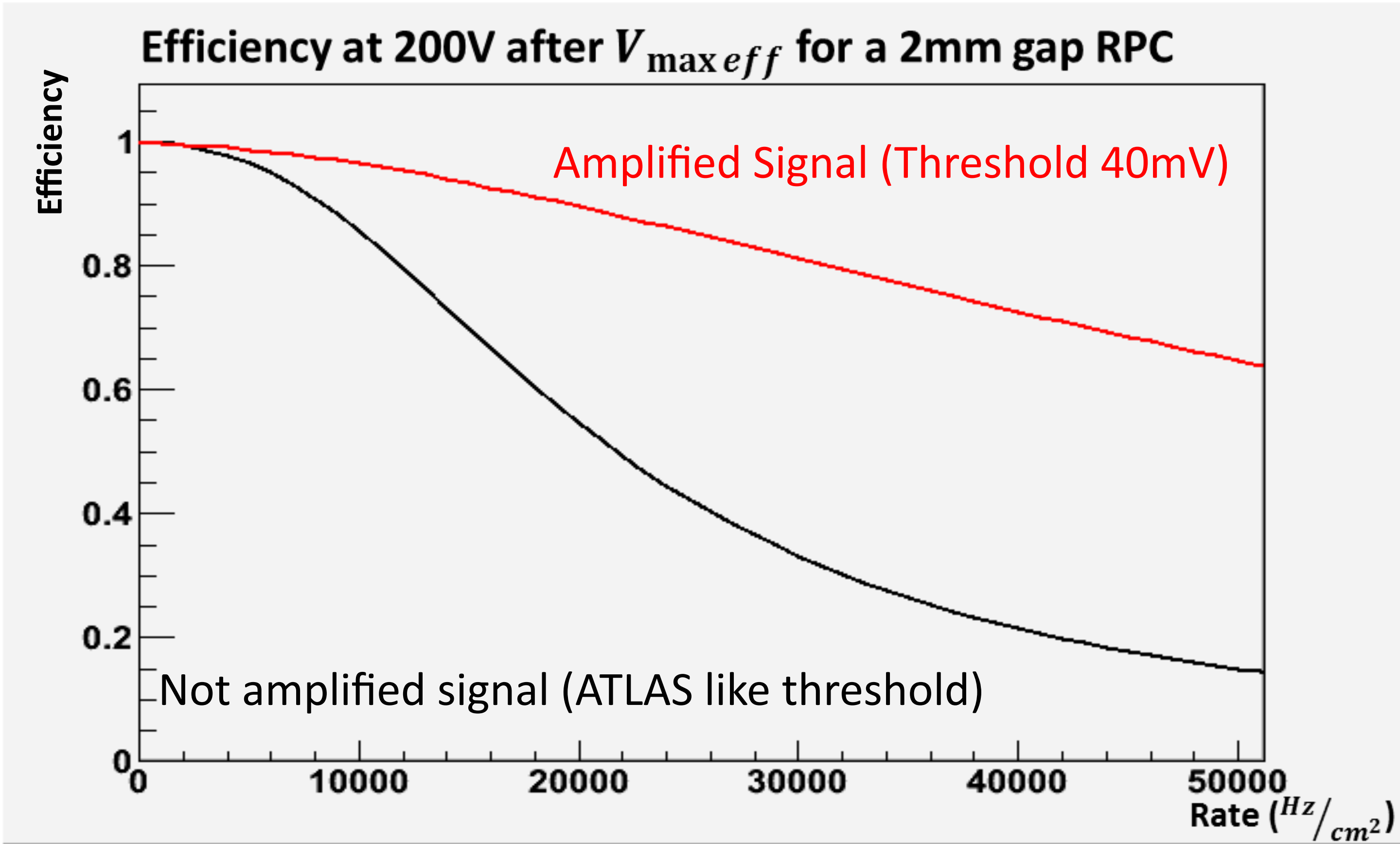


Simulation of the efficiency at different rates as a function of resistivity and front end electronics [1]

Extracting from experimental data the efficiency and the charge as a function of V_{gas} and using the relation

$$V_{gas} = V_A - R \cdot I = V_A - \rho \cdot d \cdot \Phi \cdot Q(V_{gas})$$

It is possible to simulate the behavior of the RPC at different rates



Resistivity:
$1 \cdot 10^{10} \Omega \cdot cm$

[1] Simulation done by L. Paolozzi using experimental data from a cosmic ray test.

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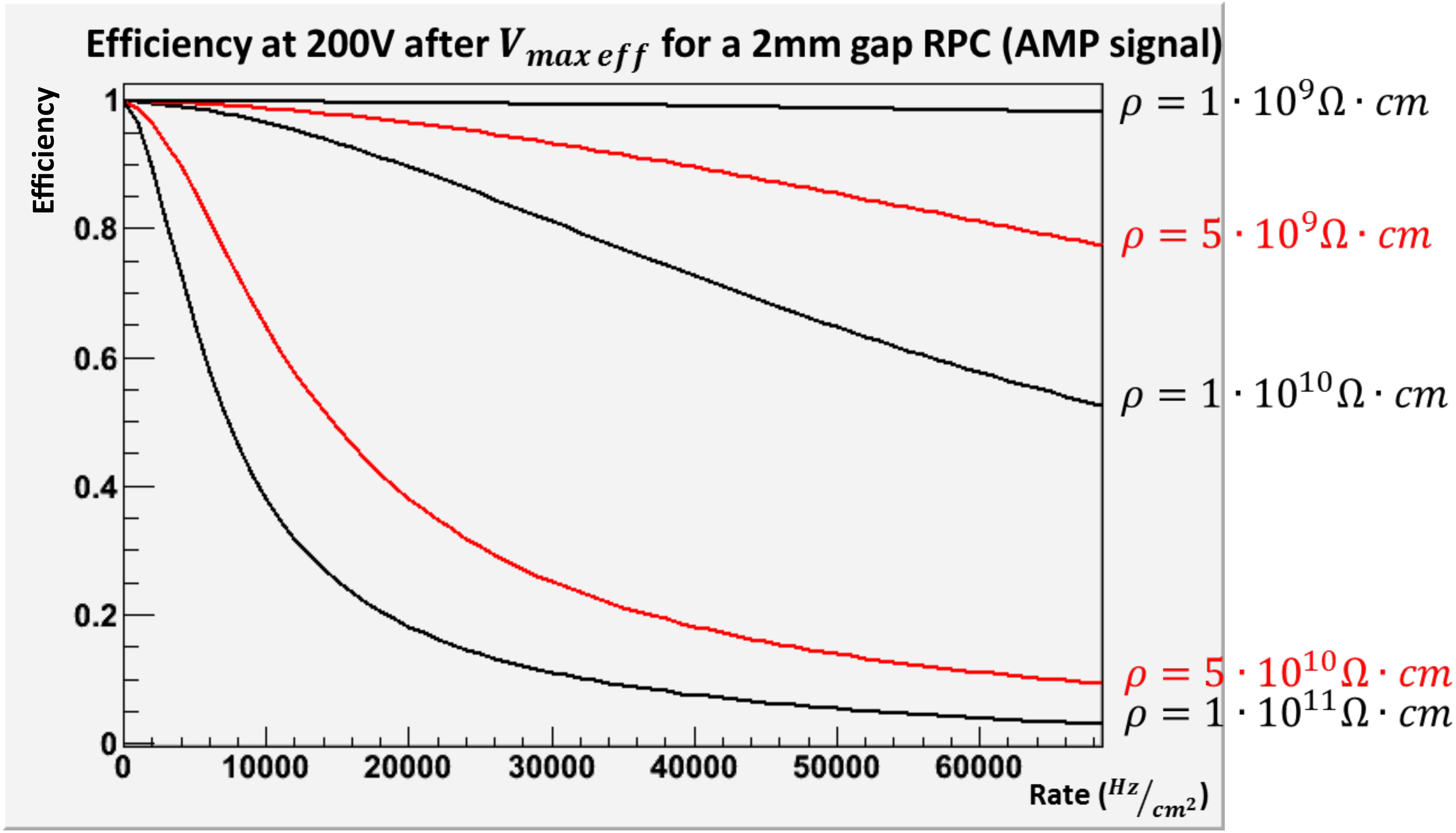


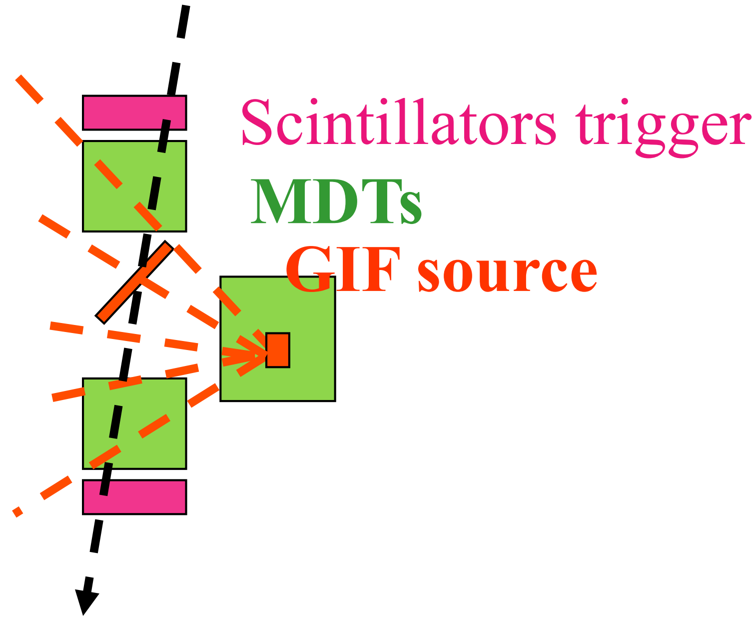
[1] Simulation done by L. Paolozzi using experimental data from a cosmic ray test.

Rate capability GIF test of RPCs equipped with the new front-end electronics

- MDT-RPC integrated set up
- RPC of 18x18 cm^2 sensitive area with strips of 13 mm pitch
- 2 mm gap, Atlas standard
- New front end electronics
- Atlas gas mixture
- Rate capability increased above 7 kHz/cm^2 (limited by the GIF intensity) with very modest voltage shift
- Further improvements foreseen

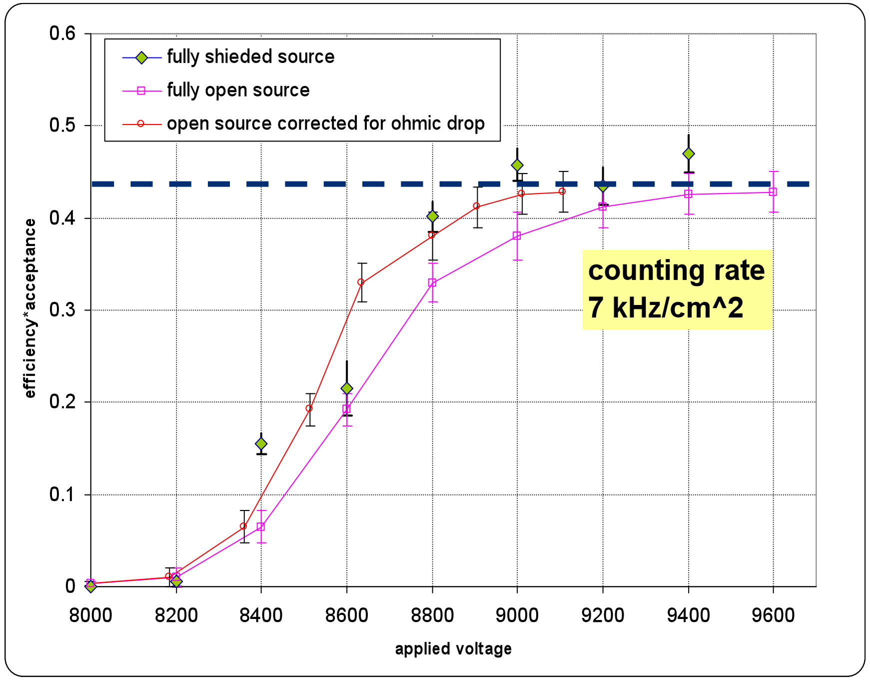
RPC rate = 7 kHz/cm^2

from about 1.4 x 10^6 gamma cm^{-2} s^{-1}

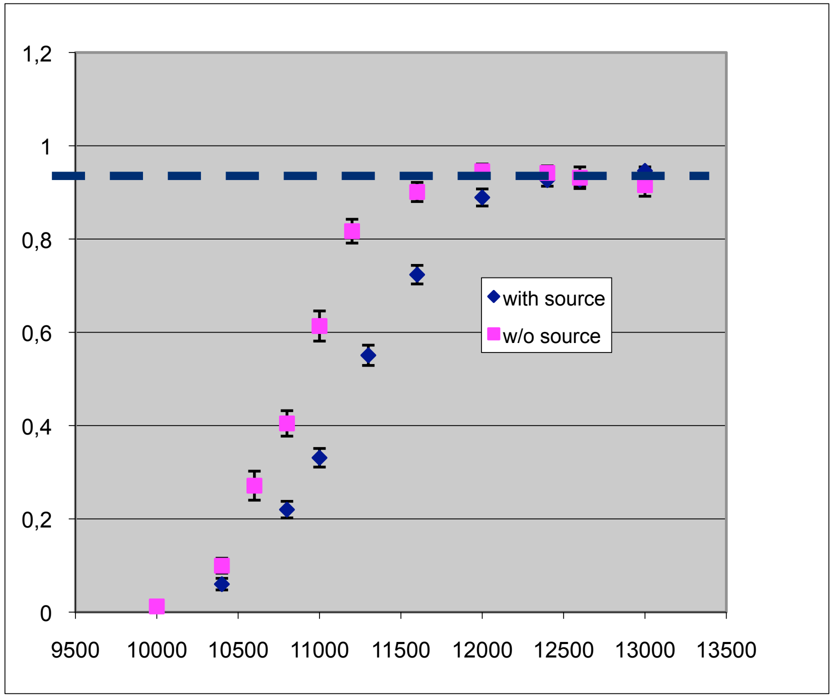


Efficiency * acceptance at closed and full source with new front-end

mono gap 2 mm



Bigap 1+1 mm



Strategy for fast spatial information

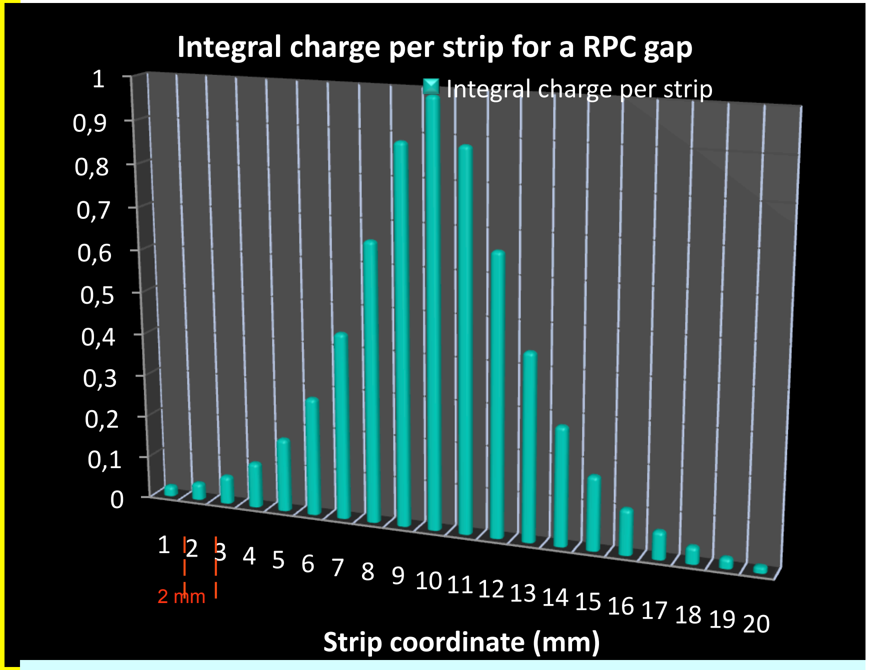
- Decrease the pitch of the strips
- Minimize the distance from strip and gas gap

For a strip pitch as small as 2mm the physical cluster size tends to increase and a very fast way to find the cluster center is needed at the trigger level

- This task is accomplished by a purposely developed **Maximum Selector** circuit

RPC based fast trigger scheme

- The RPC charge distribution among contiguous strips is given by well known relationships which in principle allows a spatial resolution of the order of 100 micron based on the classical chare centroide
- However the required calculation time would be incompatible with the requirement of a very fast trigger
- An alternative method is to select the maximum of the distribution with an appropriate circuit
- A general satisfactory solution of this problem requires to focus the following points
  - If two (or more) strips are near to the maximum the second maximum ha s also to be selected
  - **The large amplitude variability requires to normalize the charge distribution**
- cc



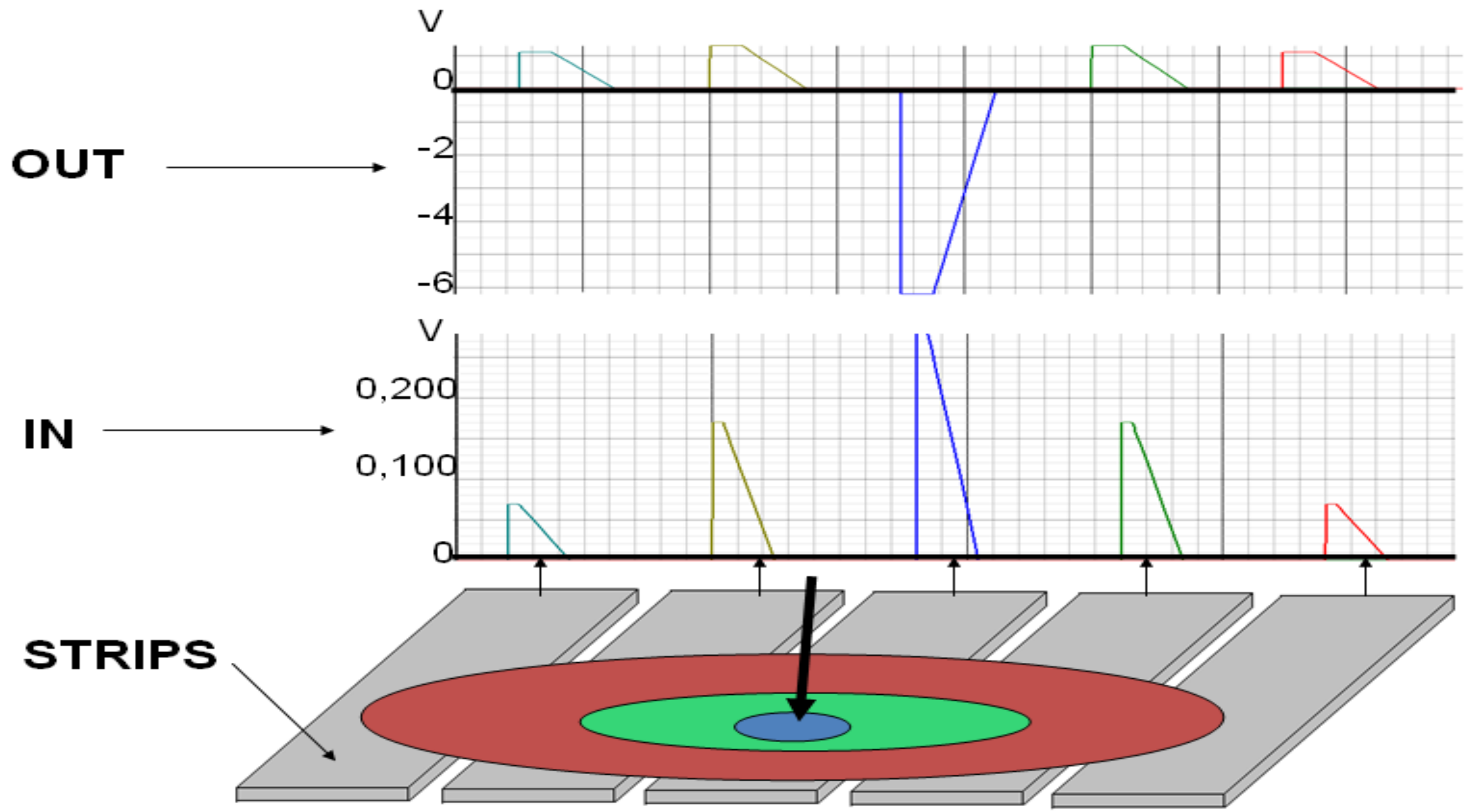
$$\sigma(x,\bar{x}) = \frac{A}{\cosh\left[(x-\bar{x})/\delta\right]}$$

$\Rightarrow$ integrating over each strip

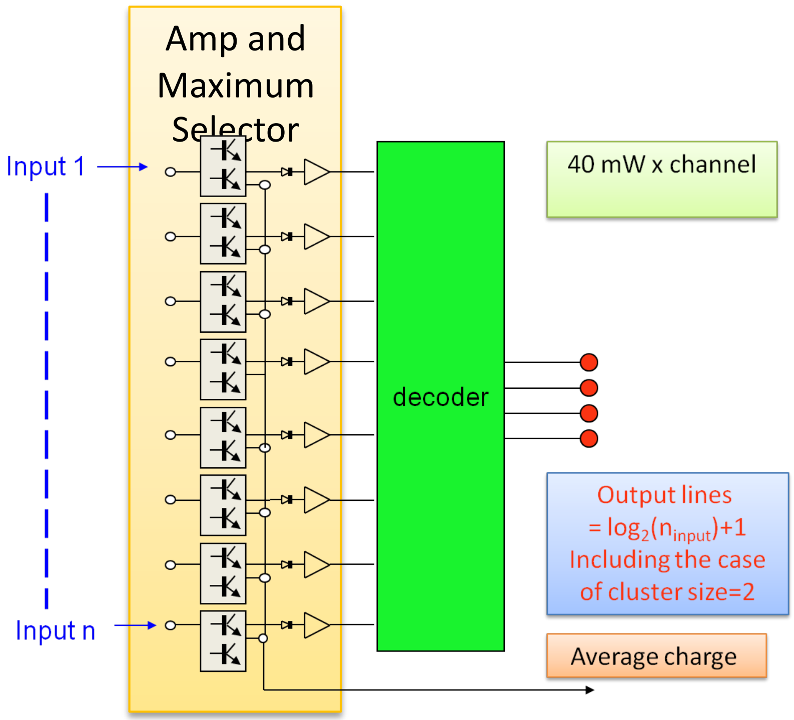
$$Q_i = \int_{x1}^{x2} \frac{A}{\cosh\left[(x-\bar{x})/\delta\right]} =$$

$$= A\delta \cdot arctg\left[\left(e^{(x-\bar{x})/\delta)}\right)\right]_{x1}^{x2}$$

Charge spot on the pick up plane

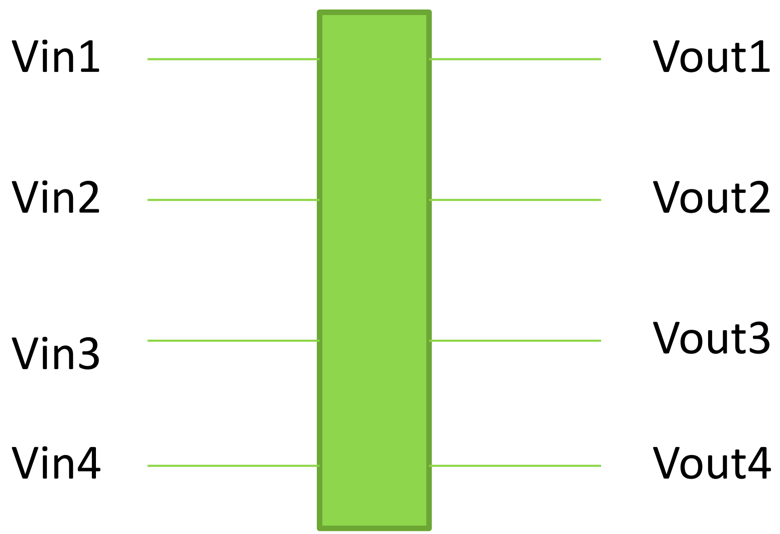


Maximum Selector



- N strips are processed at the same time (N can vary reasonably in the range of ~10)
- The threshold is chosen to have one or two strips firing (cluster size 1 or 2)
- The decoder transforms the simple digital pattern into a number representing the hit coordinate on the chamber
- The processing time of **(7-10 ns)** is highlighted in figure

MS working principle
(4 ch as an example)



$$Vout1=(((Vin1+Vin2+Vin3+Vin4)/4) *K - Vin1)*G$$

$$Vout2=(((Vin1+Vin2+Vin3+Vin4)/4) *K - Vin2)*G$$

$$Vout3=(((Vin1+Vin2+Vin3+Vin4)/4) *K - Vin3)*G$$

$$Vout4=(((Vin1+Vin2+Vin3+Vin4)/4)*K - Vin4)*G$$

IF $Vin > ((Vin1+Vin2+Vin3+Vin4)/4)*K$
$Vout < 0$

IF $Vin < ((Vin1+Vin2+Vin3+Vin4)/4)*K$
$Vout > 0$

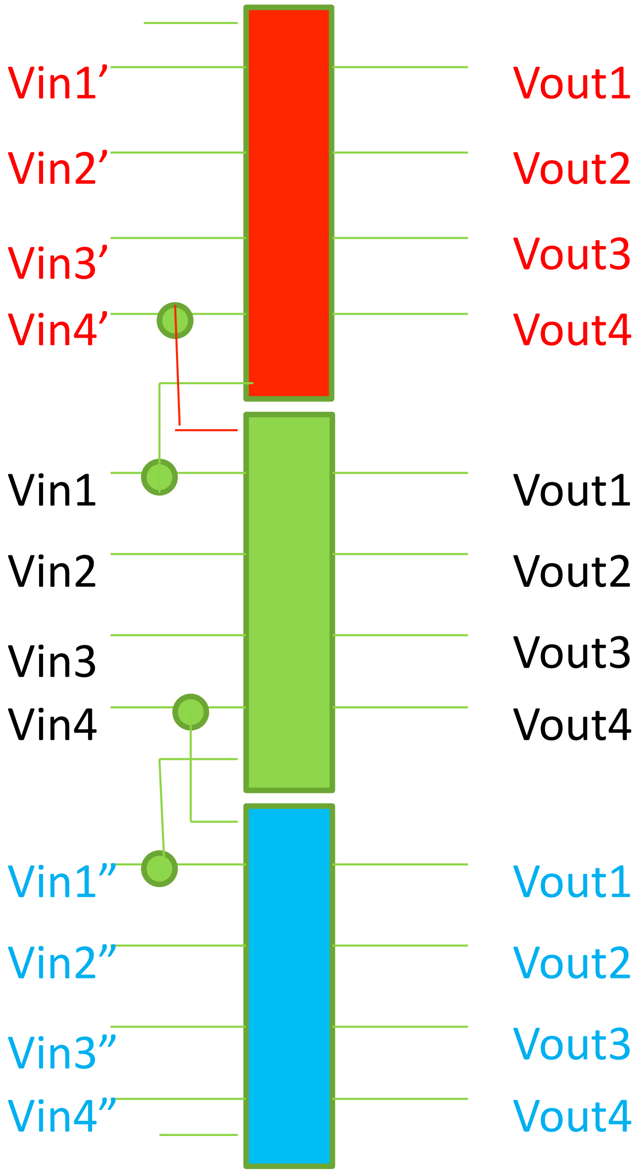
$0 < K < 2$

$G > 1$

K = relative threshold (cluster size tuning)

G = Amplifier gain

solution of the MS contiguity problem



Vout1=(((Vin4’+Vin1+Vin2+Vin3+Vin4+Vin1”)/6) *K– Vin1)*G

Vout2=(((Vin4’+Vin1+Vin2+Vin3+Vin4+Vin1”)/6) *K– Vin2)*G

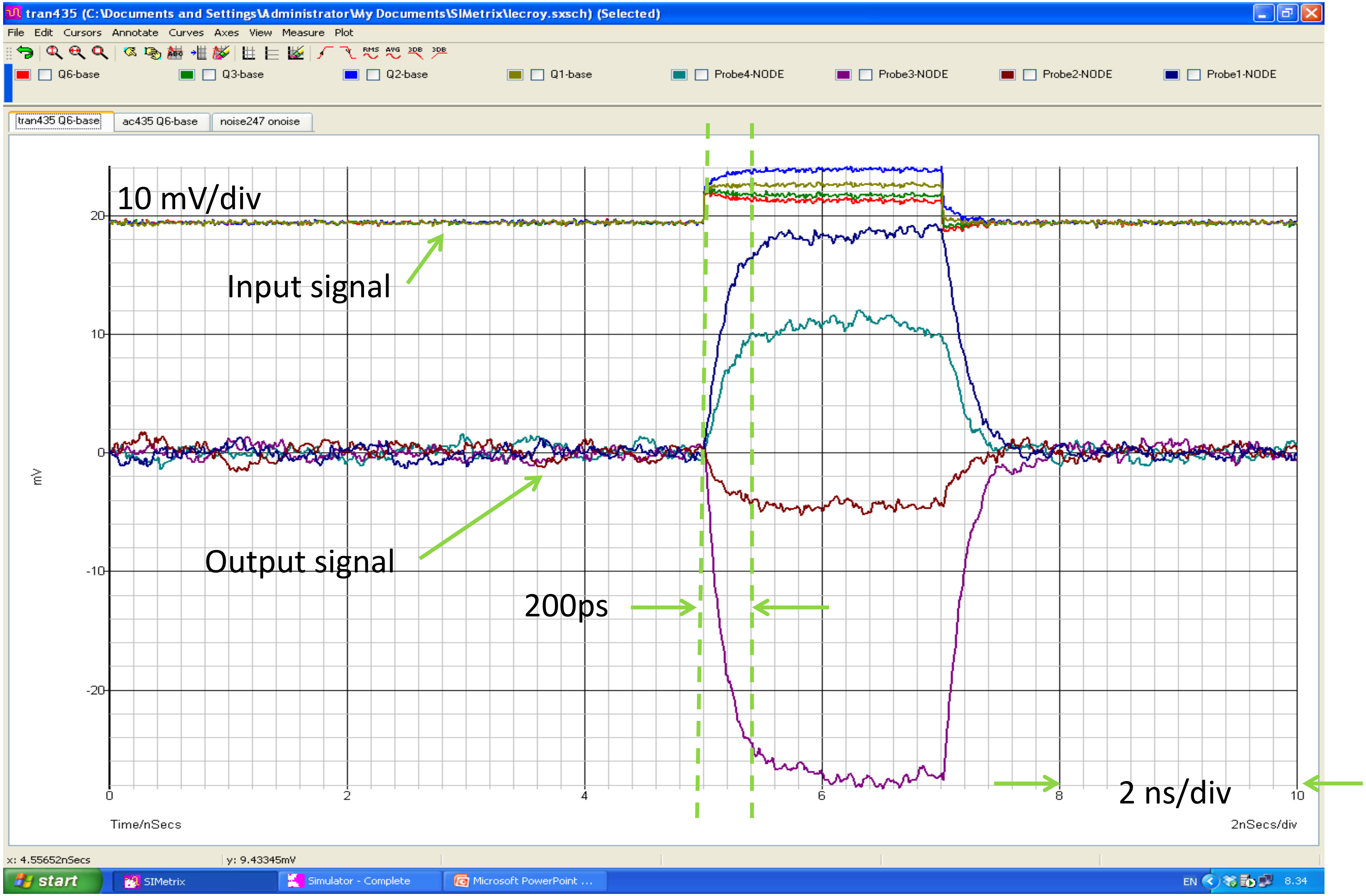
Vout3=(((Vin4’+Vin1+Vin2+Vin3+Vin4+Vin1”)/6) *K – Vin3)*G

Vout4=(((Vin4’+Vin1+Vin2+Vin3+Vin4+Vin1”)/6)*K – Vin4)*G

$0 < K < 2$

$G > 1$

Analog simulation of Maximum Selector
Vcc=3V Vee=-3V Power Consumption=9mW/ch



Maximum Selector features

- **0.1-500 mV** input
- **0.4 mV** output noise RMS; G = 8; BW = 2 GHz
- 6 inputs – 4 outputs
- **50 ohm** input impedance
- **200 ps** computing time
- **10 mW/ch** power consumption
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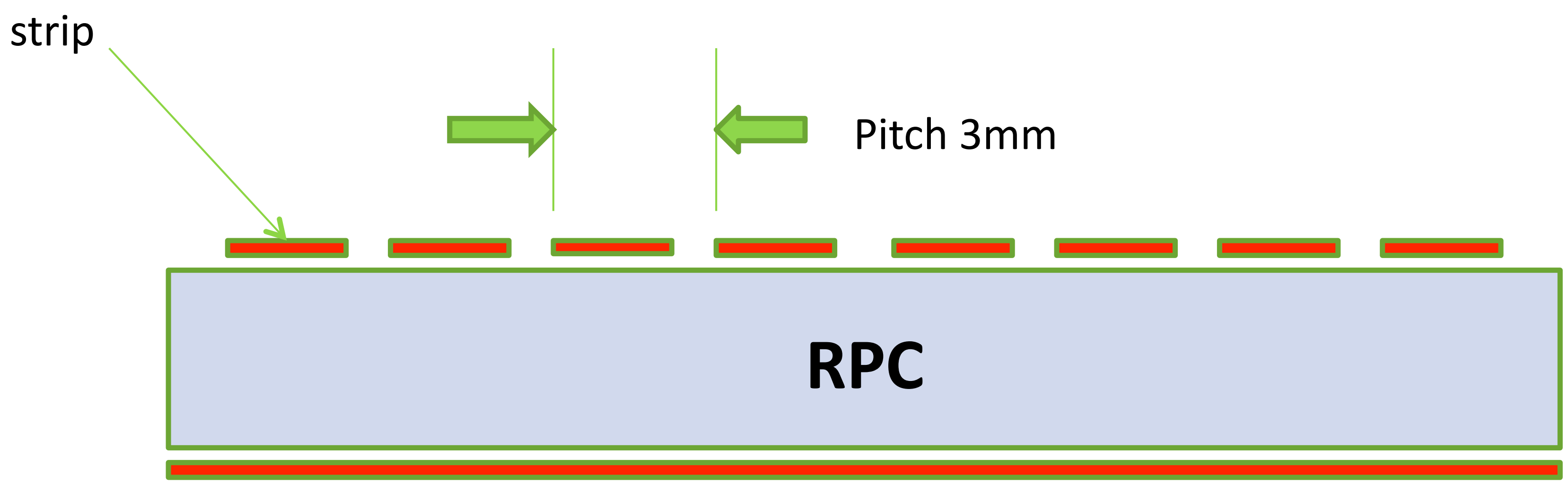
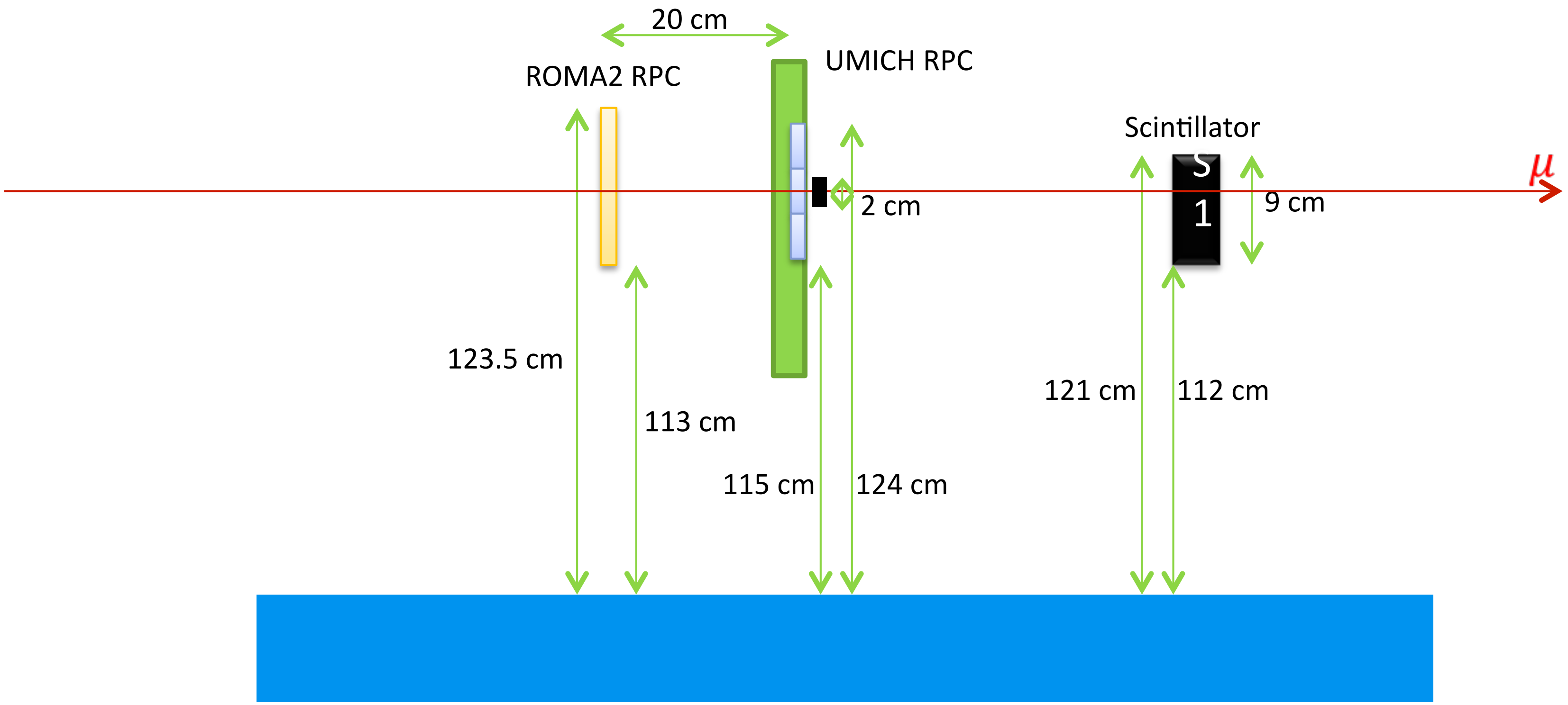
- Radiation hardness **50 Mrad, 10^{15} n cm $^{-2}$**

Test of a precision spatial information from the front-end electronic of RPC (3mm pitch)



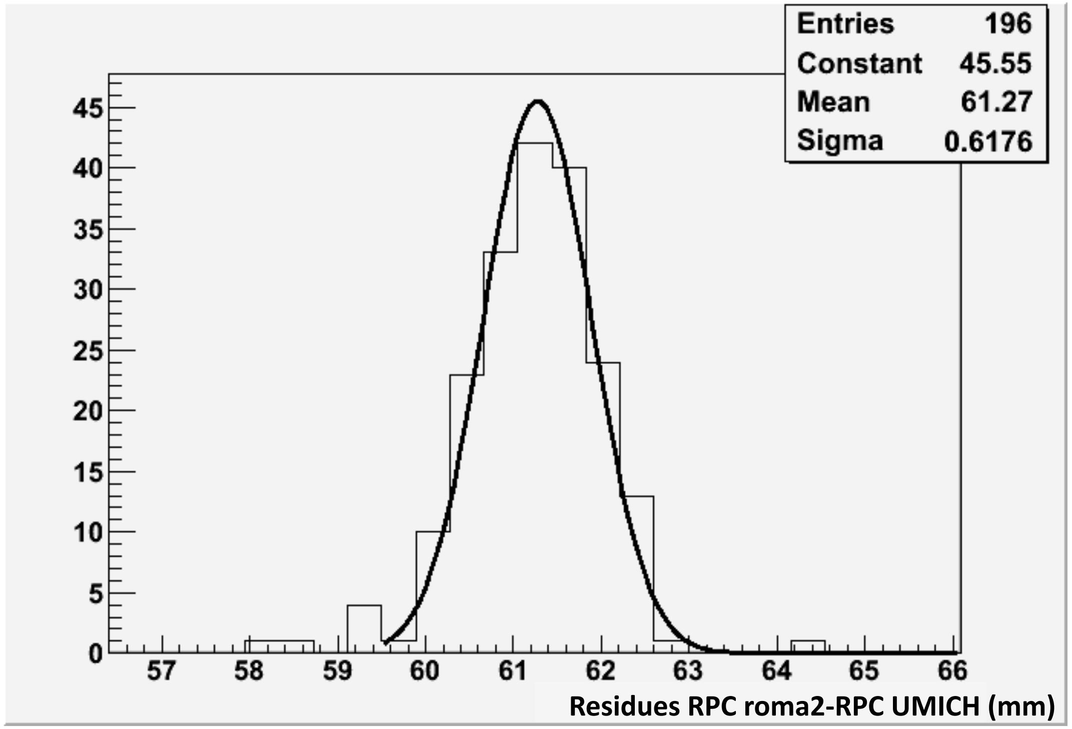
H8 10/2011: Test Beam layout (RPC only)



Track average angular spread was measured in a previous run using sMDT.

Test Beam results: spatial resolution with Maximum Selector (Preliminary)

Residues between Roma 2 RPC and UMICH RPC using maximum selector with cluster size information



Strip pitch: 3mm

Expected resolution achievable using cluster size information:

$$\sigma_s \geq \frac{3mm}{2\sqrt{12}} = 0.43mm$$

UMICH RPC (pitch 1.27mm) position vs ROMA 2 RPC position (assuming zero beam divergence)

Resolution achieved (preliminary):

$\sigma_s = 0.62mm$

Raw data, to be corrected for:

. UMICH RPC resolution:

$$\sigma_{UMICH} \leq 0.37mm$$

. Beam divergence:

2 gaussian distributions

$70\%\ events, \sigma_1 = 0.14mm$

$30\%\ events, \sigma_2 = 0.60mm$

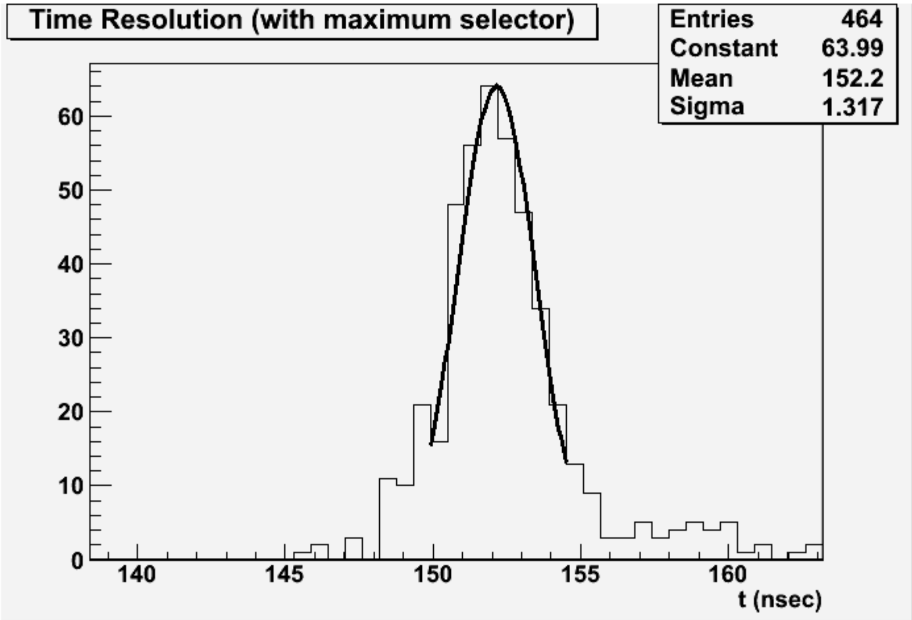
Strategy for high rejection of both correlated and in correlated background

- decrease **the width of the coincides**
- Increase the **time resolution**
- Increase the **spatial resolution**

For those reasons the need to **decrease the gas gap** as much as possible and **rise time of the front-end** as short as possible.

RPC time resolution with Maximum Selector

Time resolution no cuts



. Hit position extrapolated by charge centroid on UMICH RPC (tracks are considered as parallel)

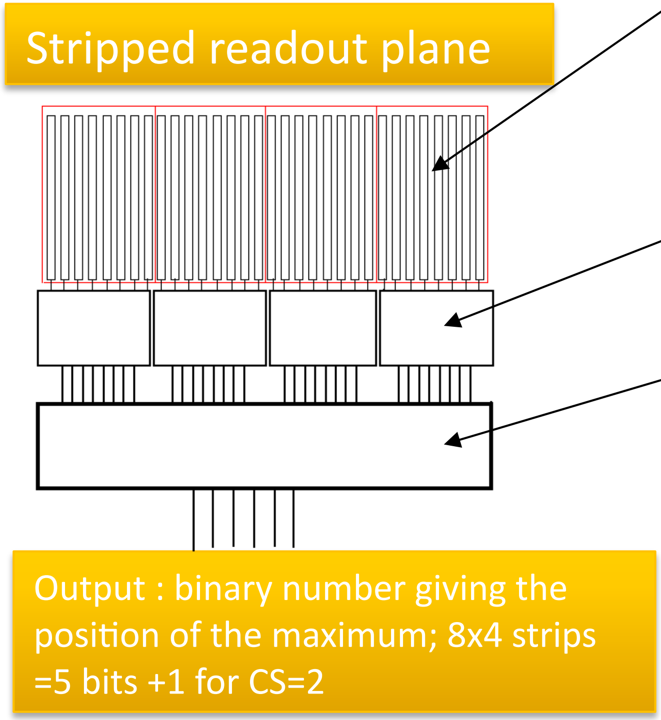
Time Resolution: **1.3 nsec**

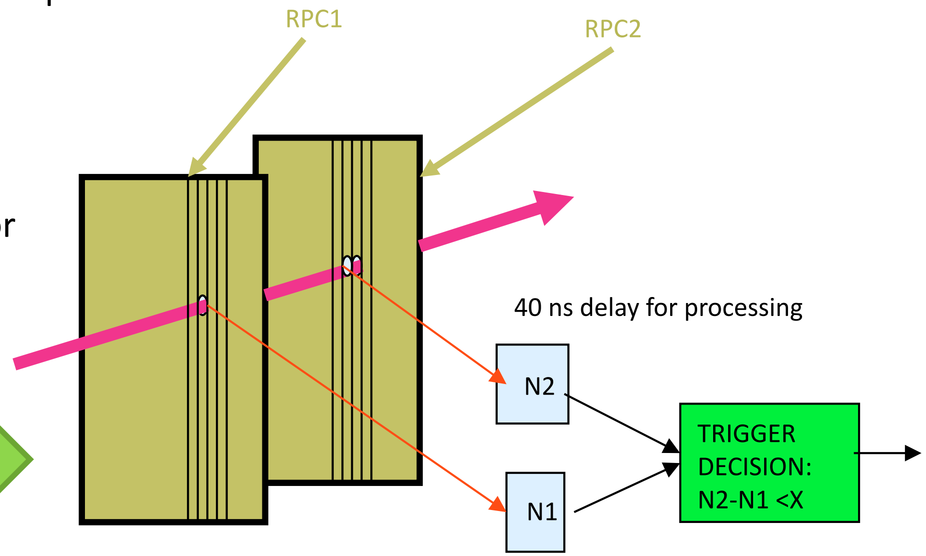
Raw data to be corrected for:

- Mezzanine rise time correction

-Deconvolution of the scintillator jitter

Readout and trigger scheme example





Single RPC plane spatial resolution

Strip pitch **2 mm**

$\boldsymbol{\sigma}$ = 2 mm / √12 = **580 µm (only CS=1)**

$\boldsymbol{\sigma}$ = 2/2 mm / √12 = **289 µm (CS=1 or 2)**

Conclusions

- We have realized the front-end electronic for RPC working at **high rate** (up to **10 kHz/cm^2**)
- The prompt (few nanosecond) spatial resolution of **0.5 mm** is achieved with **Maximum Selector**
- We have shown the scheme of a very fast and high precision trigger at high rate with RPC