

# Recent DHCAL Developments

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# Rate capability of RPCs

## Measurements of efficiency

With 120 GeV protons  
In Fermilab test beam

## Rate limitation

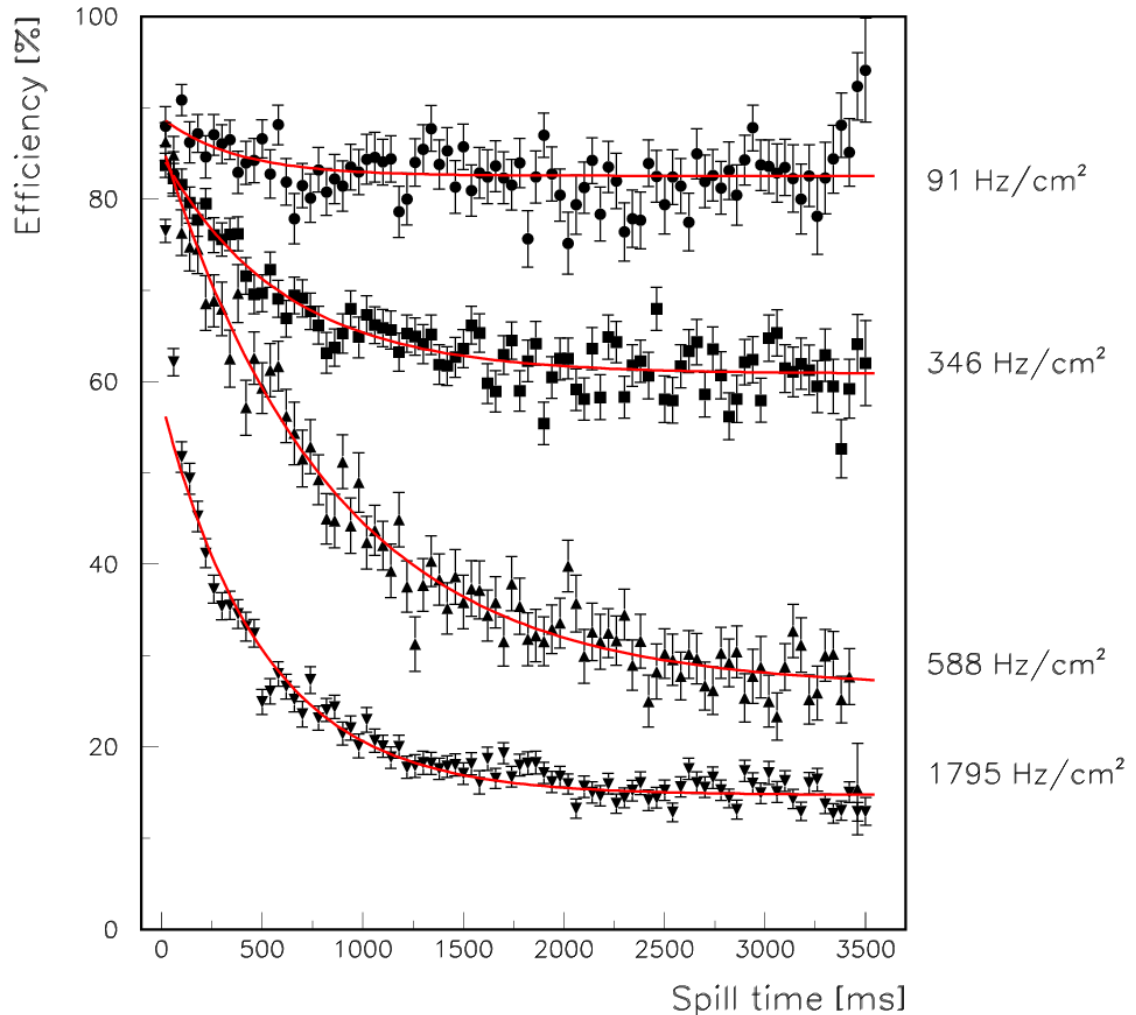
**NOT** a dead time  
But a loss of efficiency

## Theoretical curves

Excellent description of effect

## Rate capability depends

Bulk resistivity  $R_{\text{bulk}}$  of resistive plate  
(Resistivity of resistive coat)

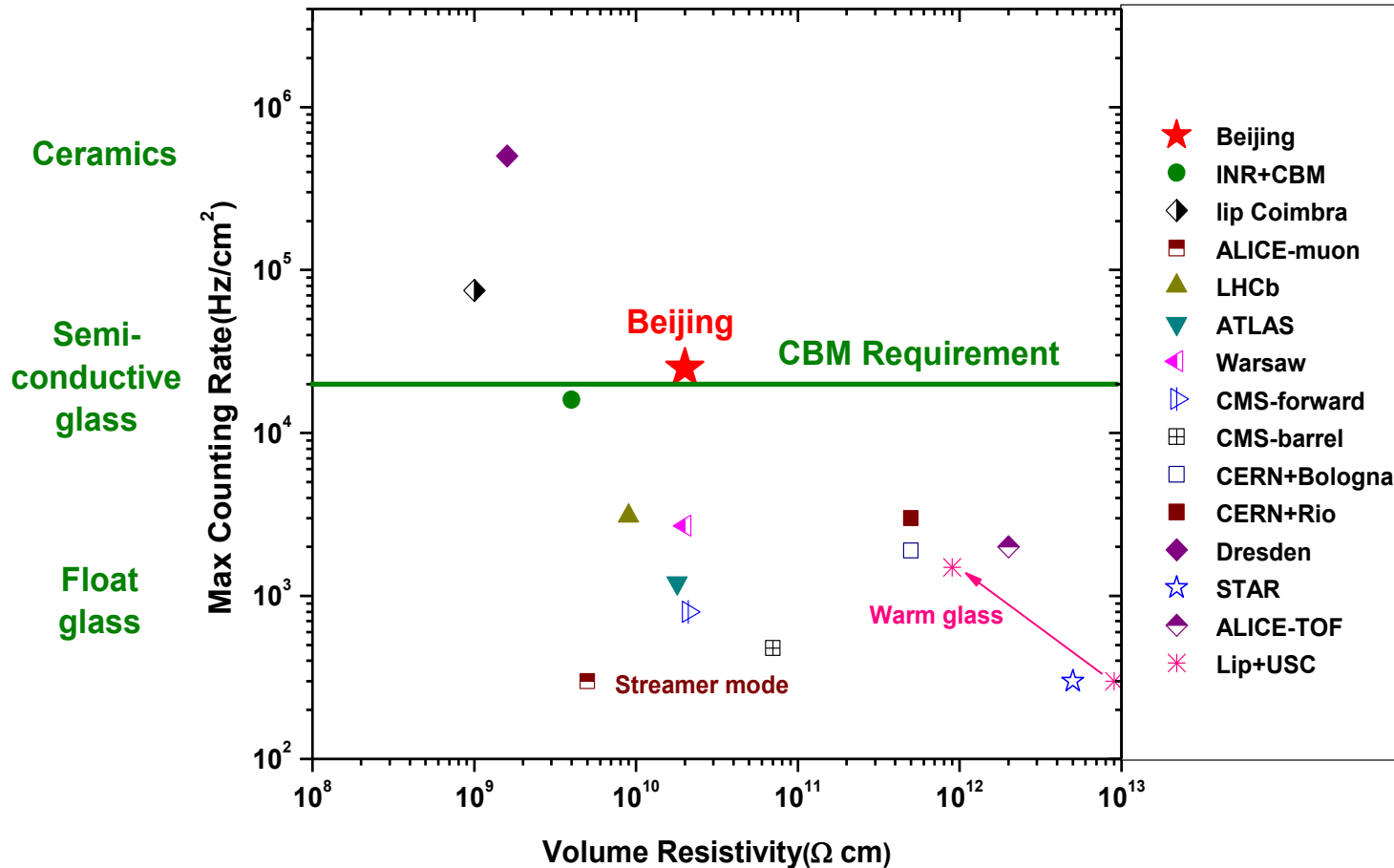


Not a problem for an HCAL at the ILC

B.Bilki et al., JINST 4 P06003(2009)



# Available resistive plates



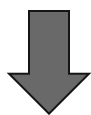
# Where to use high-rate RPCs

**ILC** – Hadron calorimeter (close to beam pipe)

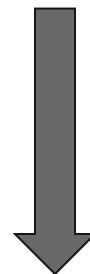
**CLIC** – Hadron calorimeter (forward direction –  $2\gamma$  background)

**CMS** – Hadron calorimeter (forward direction)

Current forward calorimeters inadequate for high-luminosity running

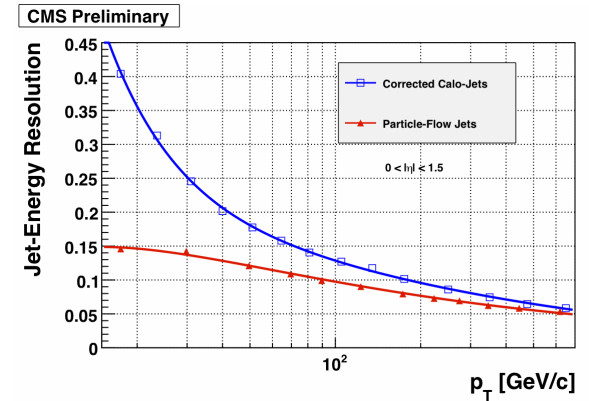


PbWO<sub>4</sub> Crystals  
Scintillator/Brass + Quartz fibers/Steel



To start in year ~2023  
Luminosity of  $5 \times 10^{34} \text{ cm}^{-2}$   
(> x10 higher than now)

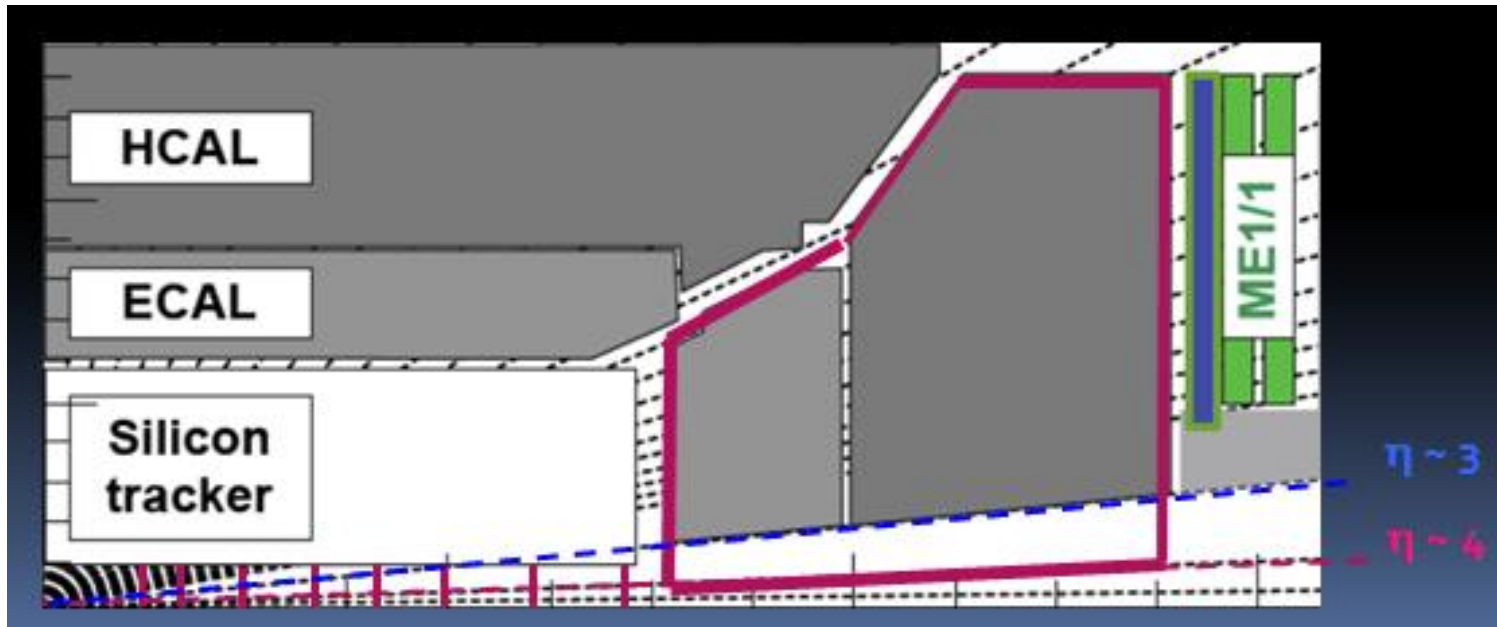
# CMS forward calorimeter



Driven by successful application of PFAs to CMS analysis

Proposal to replace forward calorimeters with an **IMAGING CALORIMETER**

Several members of CALICE have been contacted by CMS



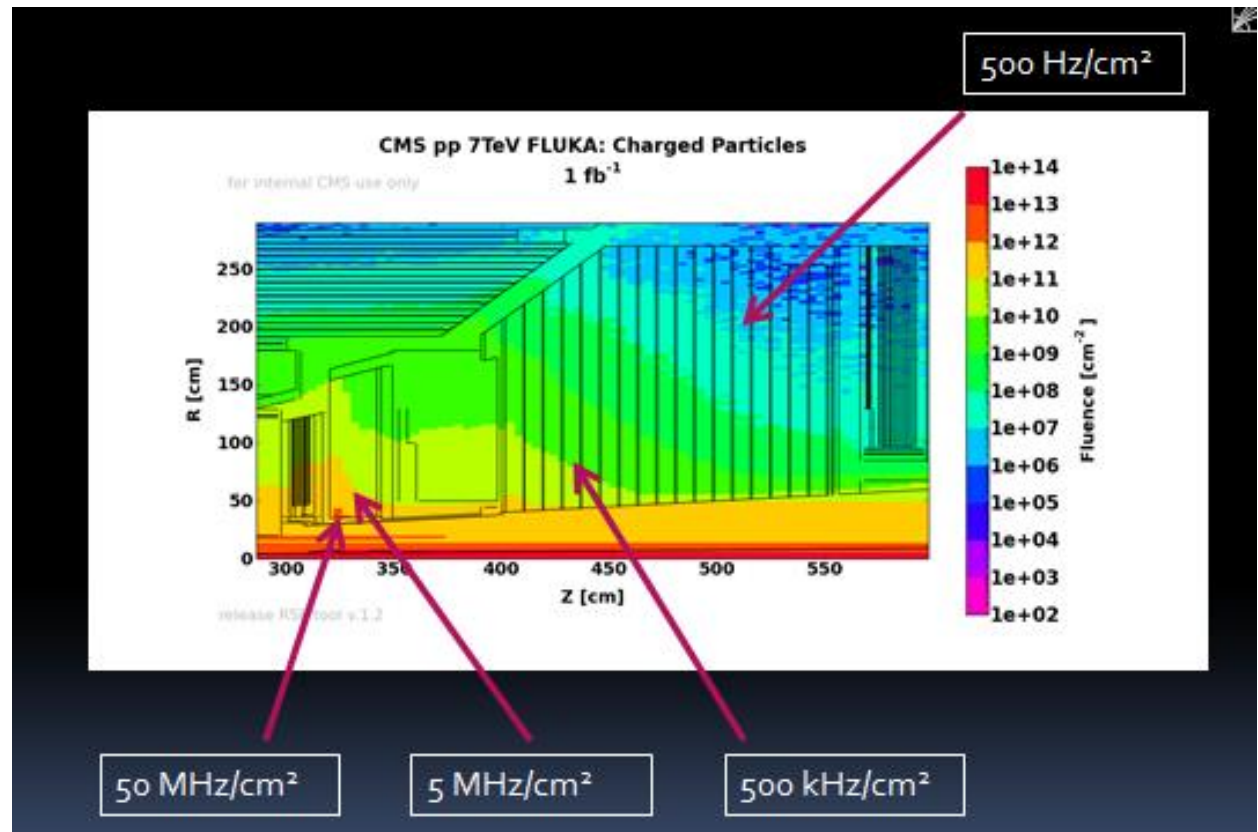
# Formidable challenge

## Charged particle flux

In calorimeter volume  
up to 50 MHz/cm<sup>2</sup> at  
shower maximum

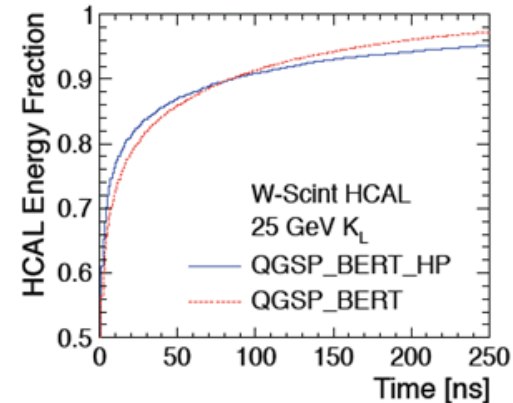
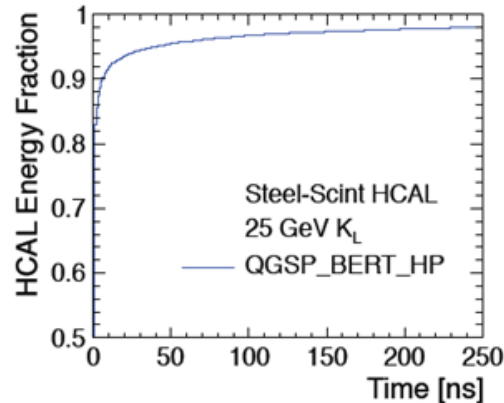
## Total dose

Fluences of 10<sup>16</sup> neutrons



# What absorber?

Tungsten? Some studies say W creates too many secondary neutrons, too slow  
Steel/Brass?



## What active element in the HCAL?

GEMs, Micromegas, (high-rate) RPCs, Micro-channel plates...

## What active element in the ECAL?

Silicon will be fried? GEMs/Micromegas? Secondary emission calorimetry (SECs)?

## Tests with GEMs planned

Linearity for em showers, performance as function of flux (FNAL, GIF++)...

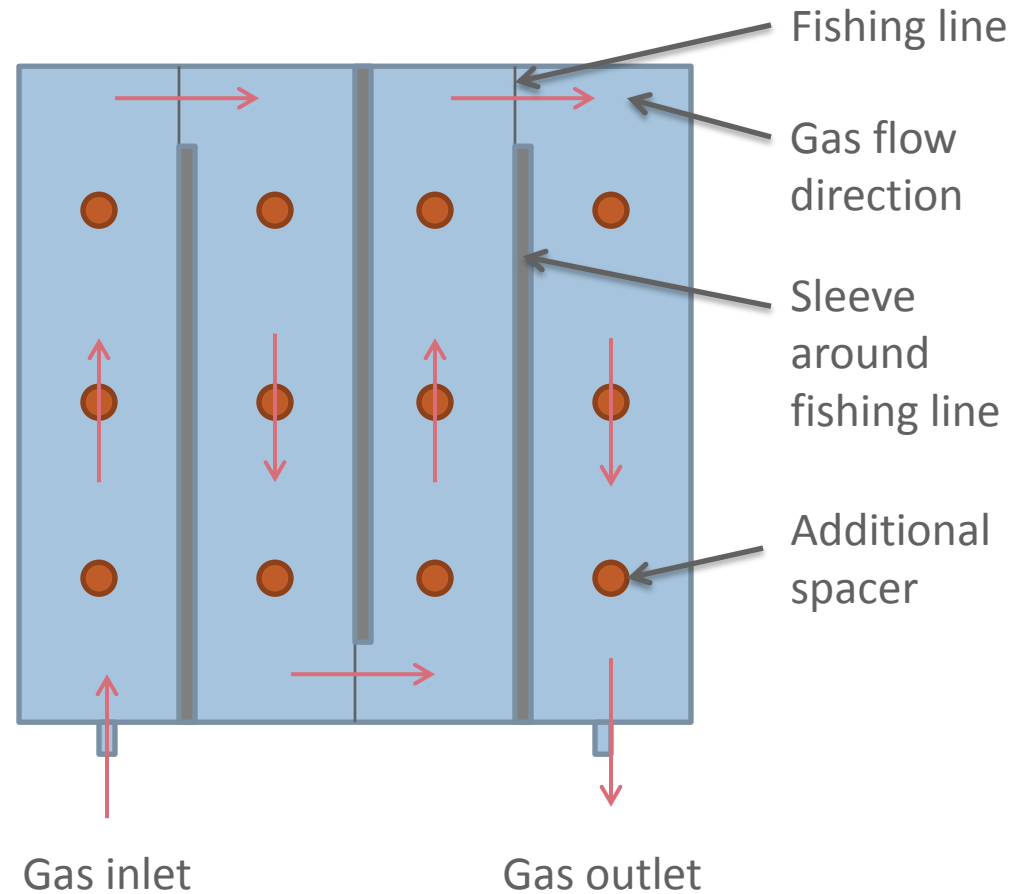
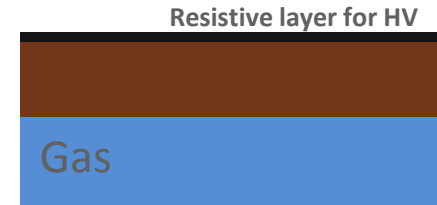
# High-rate Bakelite RPCs

Bakelite does not break like glass,  
is laminated

**but** changes  $R_{\text{bulk}}$  with depending on humidity  
**but** needs to be coated with linseed oil

Use of low  $R_{\text{bulk}}$  Bakelite with  
 $R_{\text{bulk}} \sim 10^8 - 10^{10}$  and/or Bakelite  
with resistive layer close to gas gap

Several chambers built at ANL

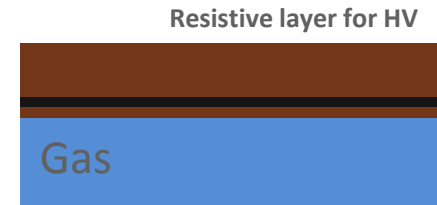




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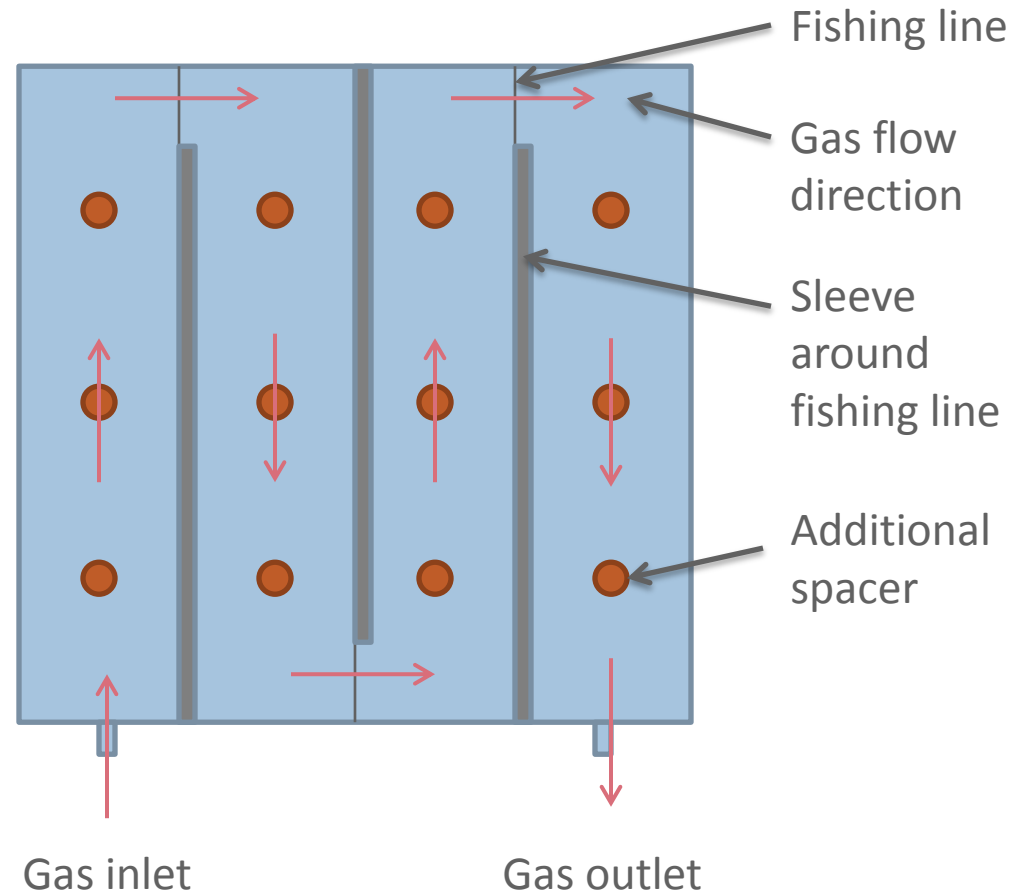
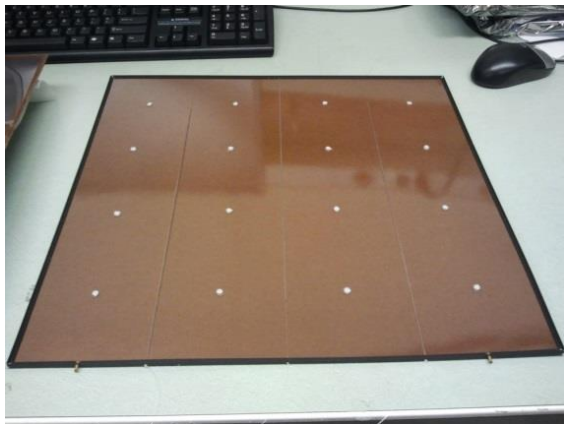
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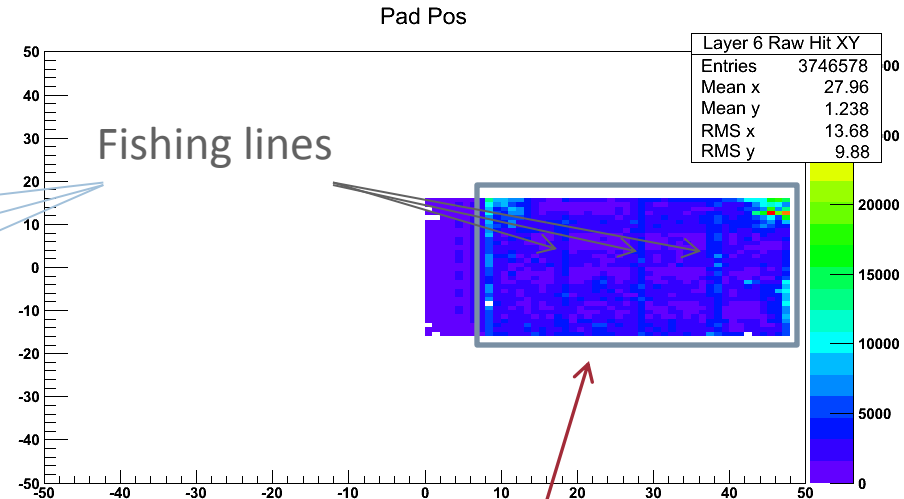
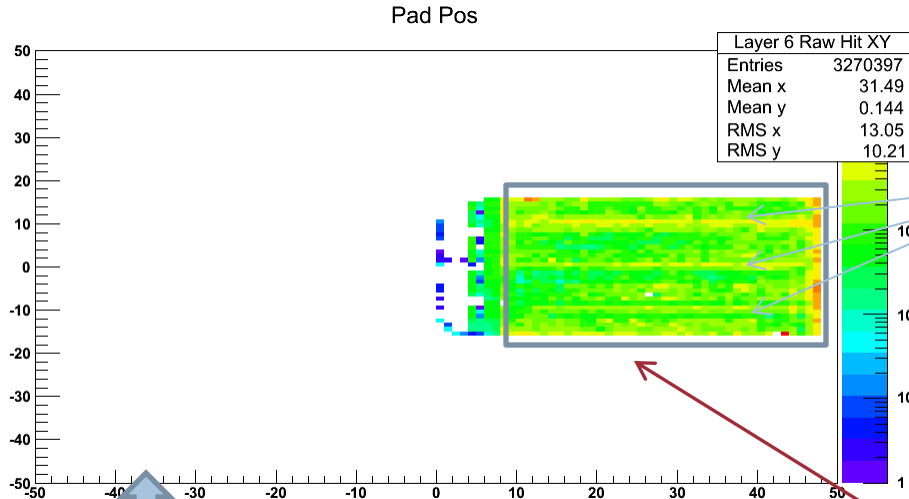
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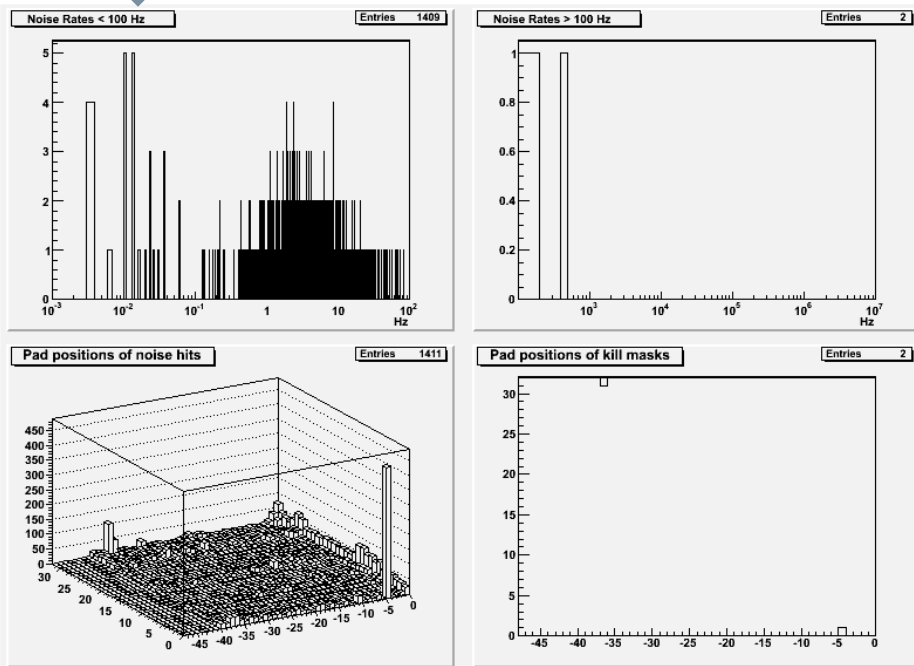
# Noise measurement: B01

(incorporated resistive layers)

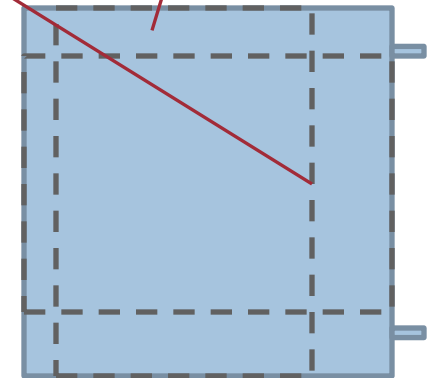


1<sup>st</sup> run at 6.4 kV

Last run, also 6.4kV, RPC rotated 90<sup>o</sup>



Readout area



# Noise measurements

Applied additional insulation

Rate 1 – 10 Hz/cm<sup>2</sup> (acceptable)

Fishing lines clearly visible

Some hot channels (probably on readout board)

No hot regions



B02

B01

1-glass RPC

Regular 2-glass

DHCAL RPCs

Dead RPC

(not used)

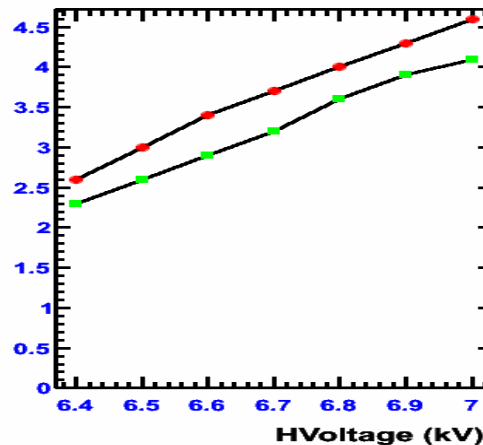
## Cosmic ray tests

Stack including DHCAL chambers for tracking

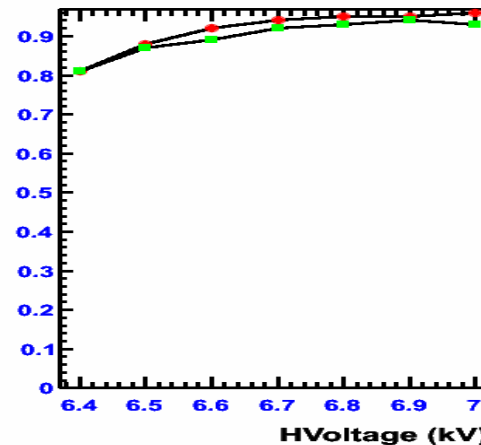
Efficiency, multiplicity measured as function of HV

High multiplicity due to Bakelite thickness (2 mm)

Multiplicity

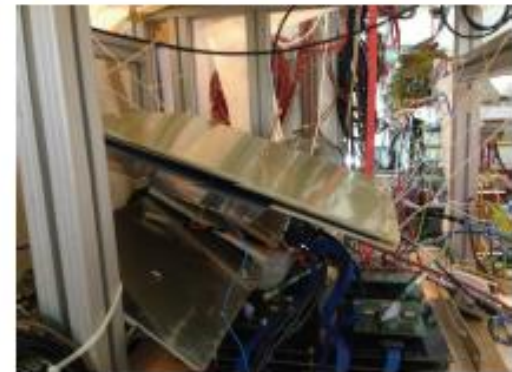
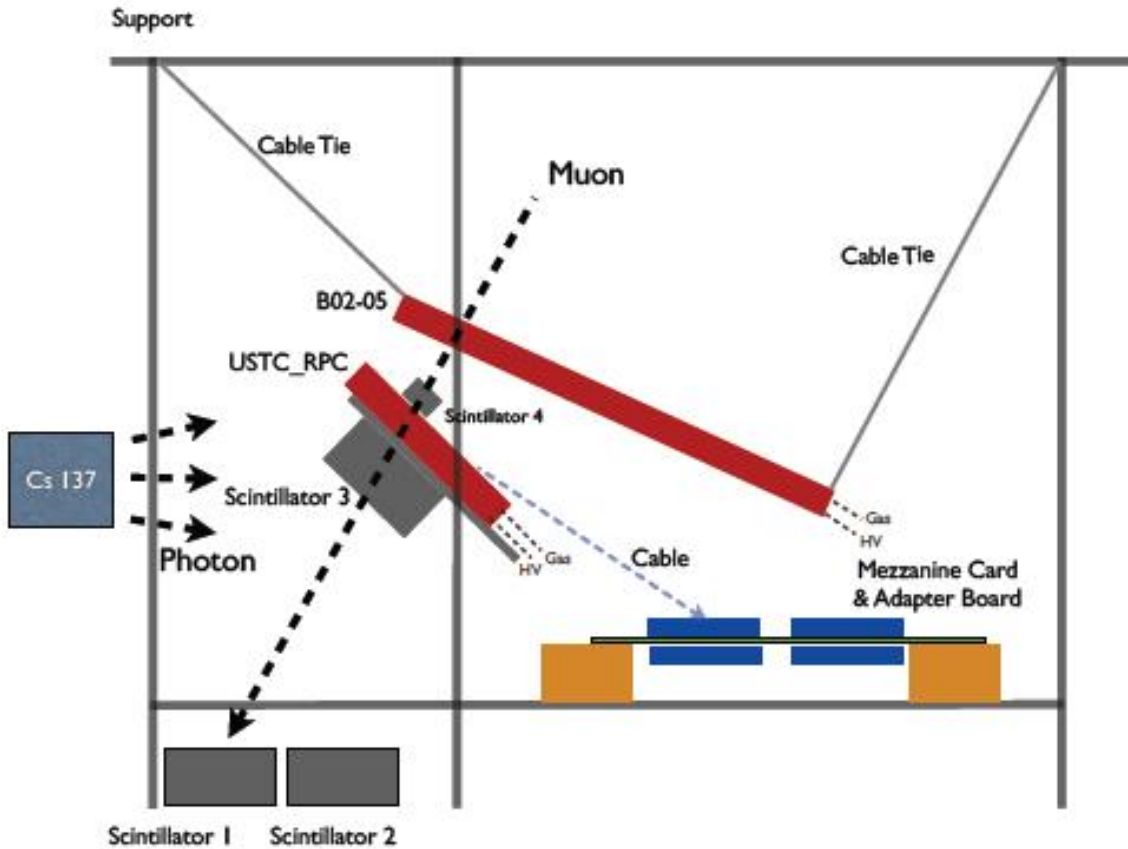


Efficiency

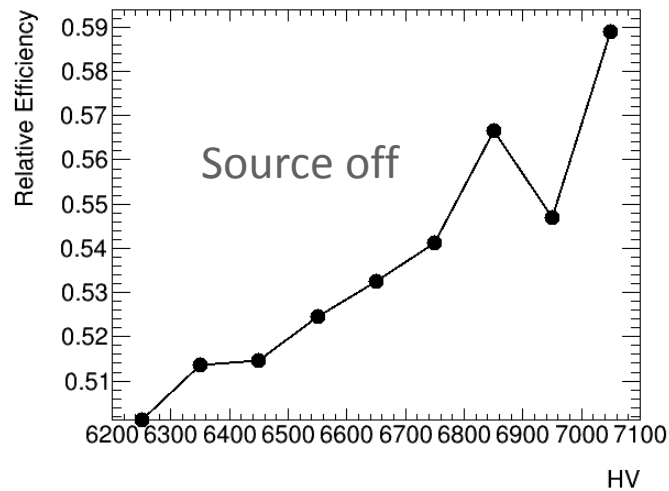
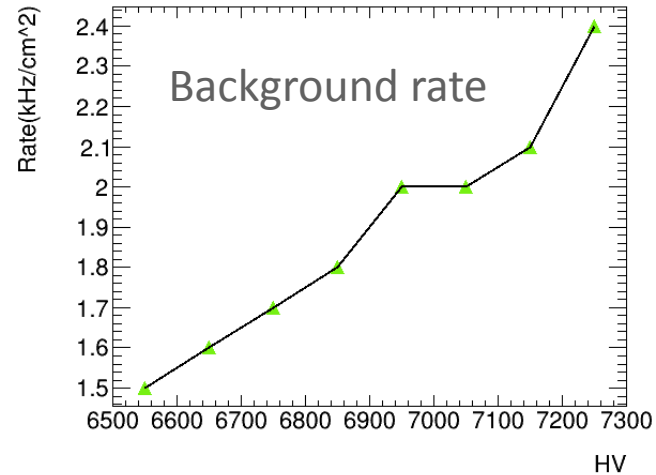
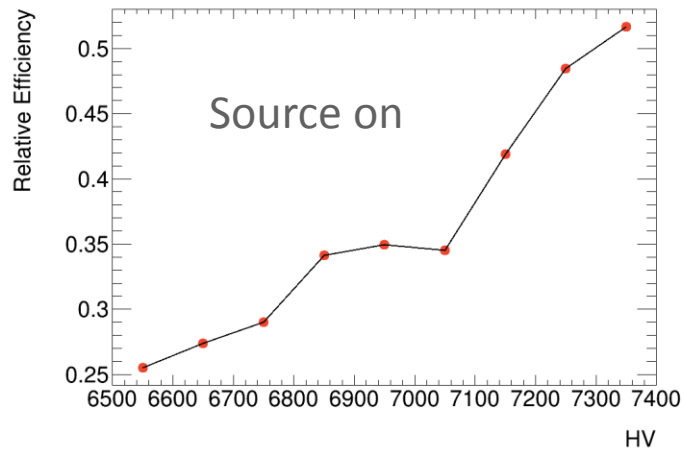


# GIF Setup at CERN

Trigger = (Sci1 or Sci2) and Sci3



# First results from GIF



Absolute efficiency not yet determined

Clear drop seen with source on

Background rates not corrected for efficiency drop

Irradiation levels still to be determined (calculated)

# Development of semi-conductive glass

Co-operation with COE college (Iowa) and University of Iowa



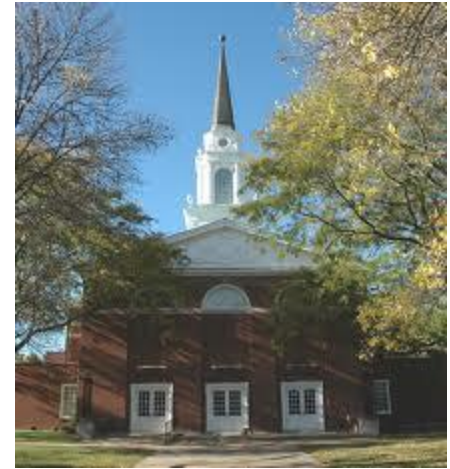
World leaders in glass studies and development

Development of Vanadium based glass (resistivity tunable)

First samples produced with very low resistivity  $R_{\text{bulk}} \sim 10^8 \Omega\text{cm}$

New glass plates with  $R_{\text{bulk}} \sim 10^{10} \Omega\text{cm}$  in production

Glass to be manufactured industrially (not expensive)



# Conclusions

**Imaging** (forwards) calorimeters being considered for LHC upgrades

Various **technologies** being considered

Viable technology **not yet established**

**Rate capability** of RPCs depends on  $R_{\text{bulk}}$

DHCAL group explores low-resistivity **Bakelite** and semi-conductive **glass**

