# DISCHARGES IN MICROMEGAS
# &
# EFFECT OF GEM

*NB: studies performed from 2009 to 2011…*

Sébastien Procureur
CEA-Saclay

# INTRODUCTION TO DISCHARGES

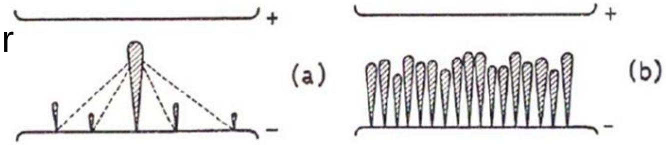
**Study of discharges in gases is a looong story**

*Von Guericke, (Picard priest,) Hauksbee, …, Paschen, Townsend, …, Raether, …*

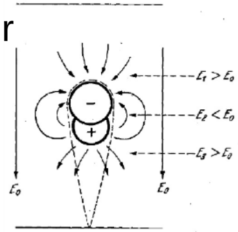
**2 different mechanisms**

- Townsend mechanism: slow, related to $2^{ndary}$ avalanches ($\gamma$ coefficient, see HDR)
- Streamer mechanism: much faster, single avalanche, related to « Raether limit » (idem)

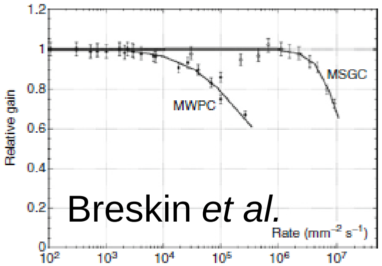
Raether



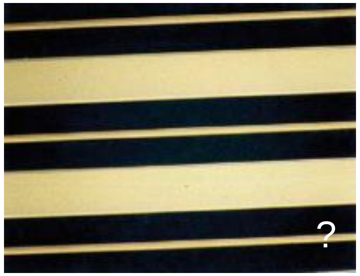
Raether

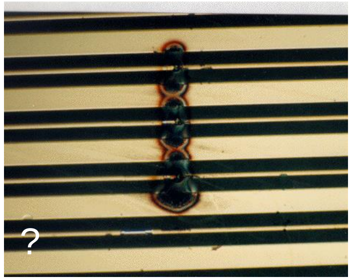


**Serious issue for Micro Pattern Detectors since MSGC…**



Breskin *et al.*





**… and well known problem in beams for Micromegas starting with Compass exp.**

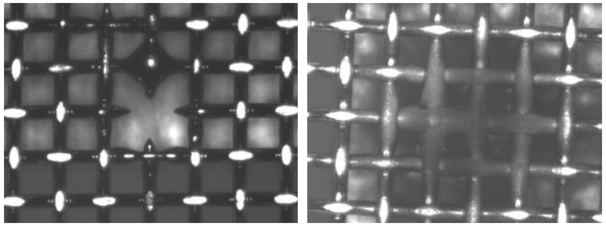
# DISCHARGES IN MM: HISTORIC MEASUREMENTS

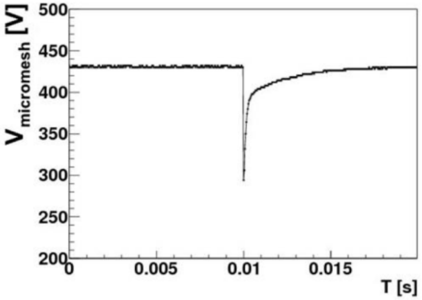
## First systematic study by Thers et al. in 2001

- *Usually no ageing of the Micromegas due to discharges*

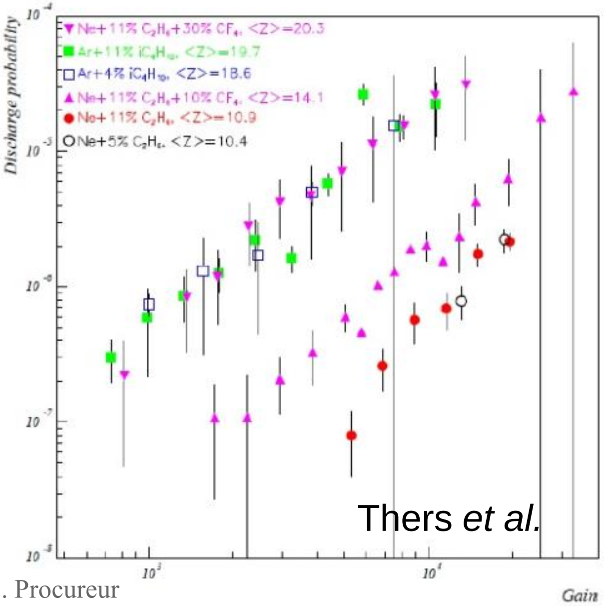
- *But dead time associated to the HV drop (charge loss)*

counter-examples…





## Precise measurements in CERN/PS beam line



Thers *et al.*

- Rate proportional to beam intensity
  - ⇒ Can use discharge probability per particle P
- P exhibits a power law dependence with gain G
- P is gas dependent (Z)
  - ⇒ Neon instead of Argon
- Much higher in hadrons wrt muons
- Independent on beam energy in 3-15 GeV range

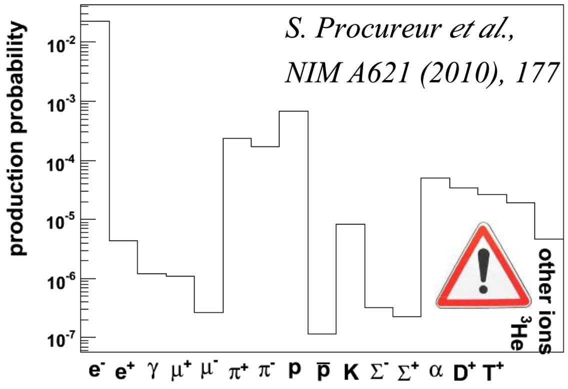
**Origin?**

# ORIGIN OF DISCHARGES

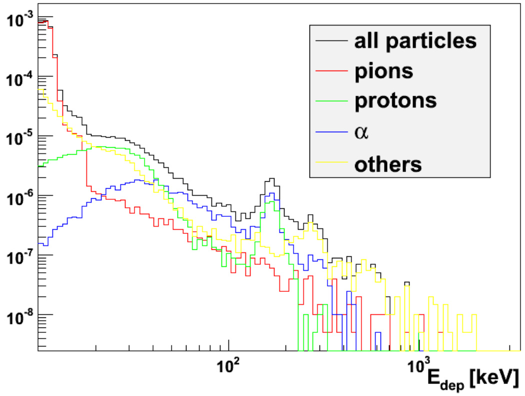
**Cannot originate from ionization/avalanche fluctuations**

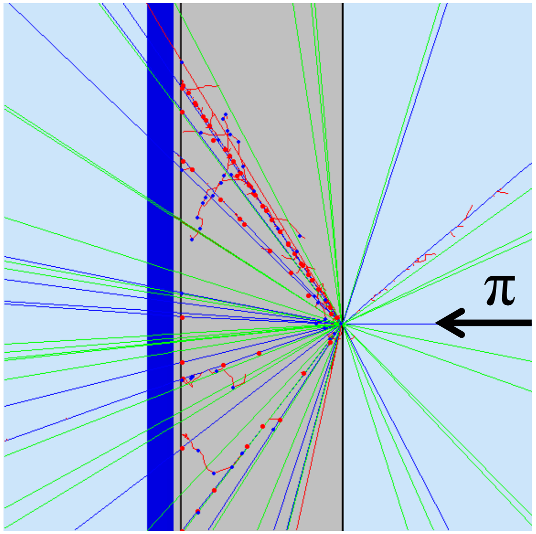
**Investigate secondary particle production with a Geant4 model of the MM**

⟶ (rare) occurrence of « catastrophic » events with HIPs production in nuclear collisions with MM material (required large simulations)



*S. Procureur et al., NIM A621 (2010), 177*





⇒ Energy above 1 MeV (2,000 MIPs) can be released!

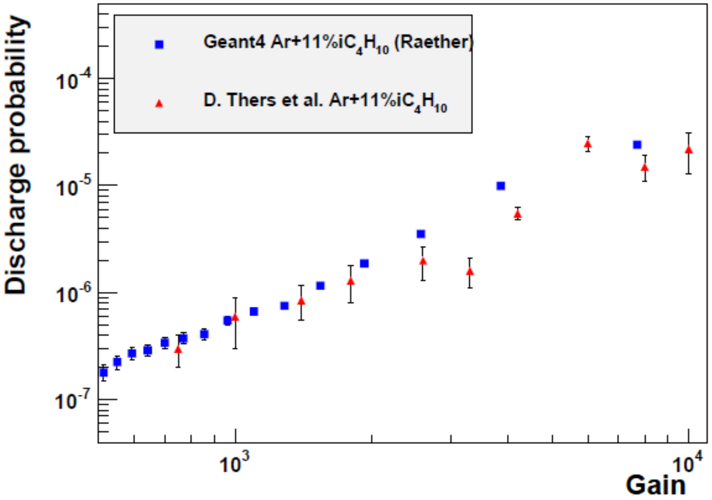
⟶ rough estimate of the discharge probability by integrating $E_{dep}$ on small volumes, and compare it with the Raether limit

$$P(G) = \int_{E_{dep}=N_R\times w_i/G}^{\infty} f(X)dX$$

- No precise treatment of transverse diff.
- Threshold effect at the Raether limit

# ORIGIN OF DISCHARGES

## Interesting results:



- Power law dependence with the same slope
- Quantitative agreement with reasonable Raether limit
- (Partly) reproduces the gas effect

## Many questions/mysteries to solve

⟶ dependence on the material (e.g. with thicker meshes of bulk)?

⟶ dependence on the beam energy and type (e.g. CLAS12 vs COMPASS…)

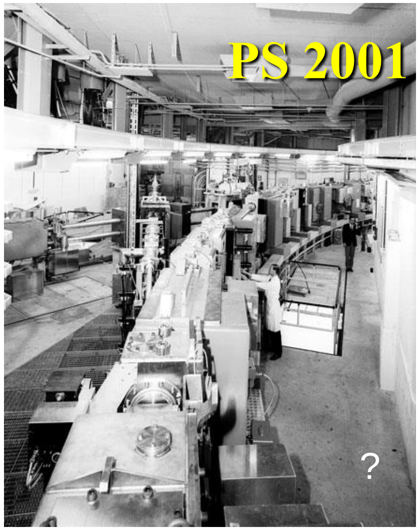
⟶ dependence on magnetic field, and more generally transverse diffusion?

⟶ effect of a GEM foil in the reduction of the discharge probability?

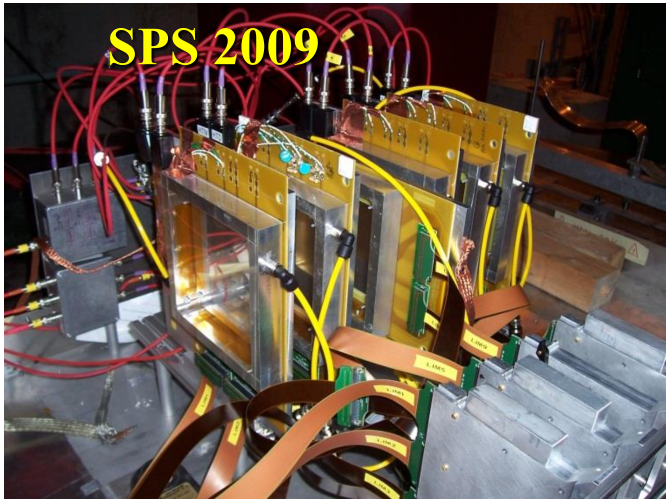
⇒ **Organization of a series of beam tests in different conditions**

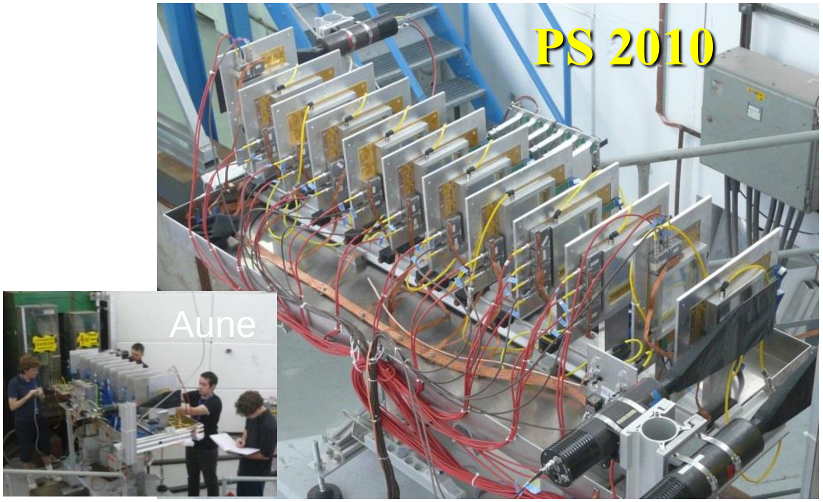
# DISCHARGES AND BEAM TYPE

15 GeV $\pi$ (Thers)



150 GeV $\pi$



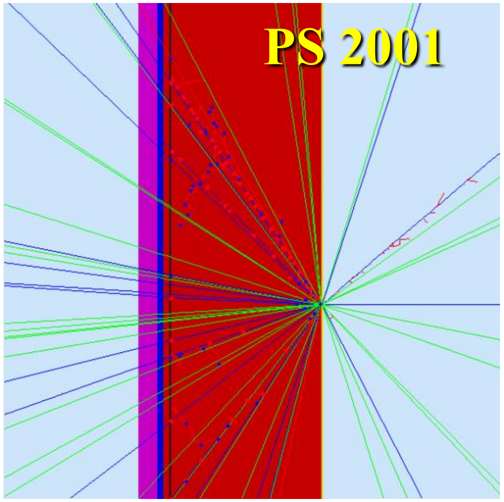


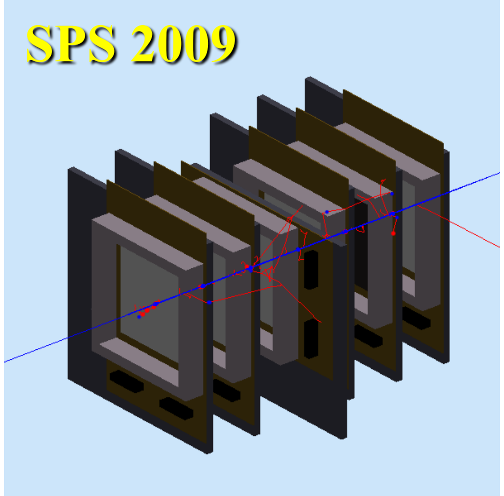
0.2 to 3 GeV/c $\pi^+$, $\pi^-$, p

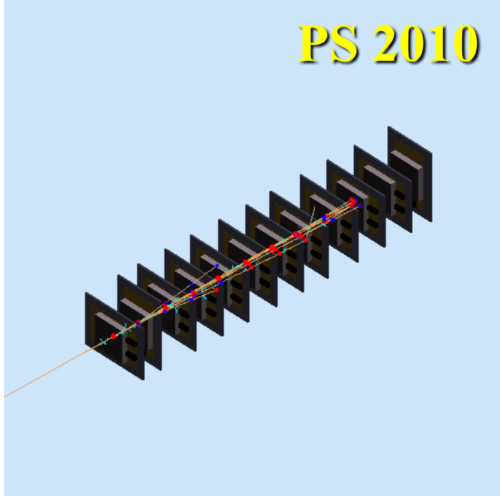
Photon beam on $CH_2$, B field

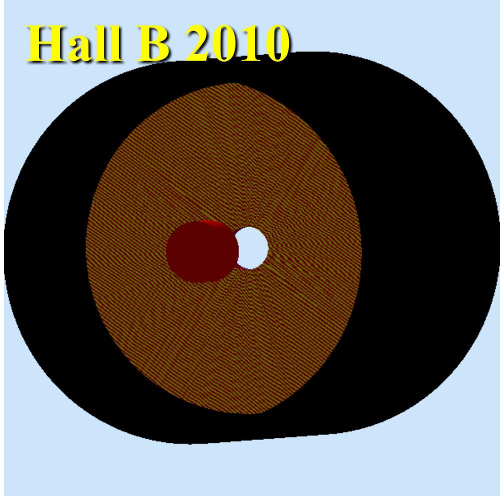
# DISCHARGES AND BEAM TYPE

## Detailed Geant4 simulation of the setups

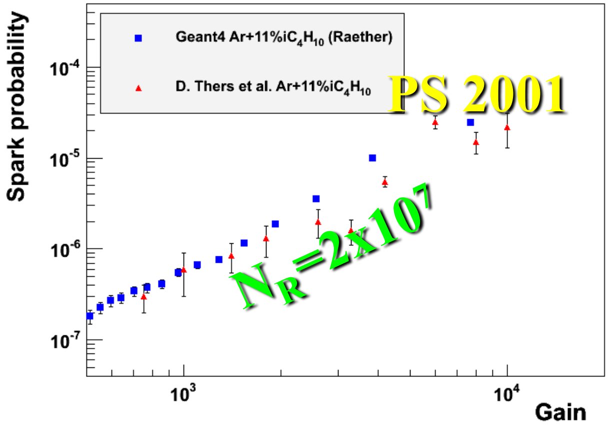






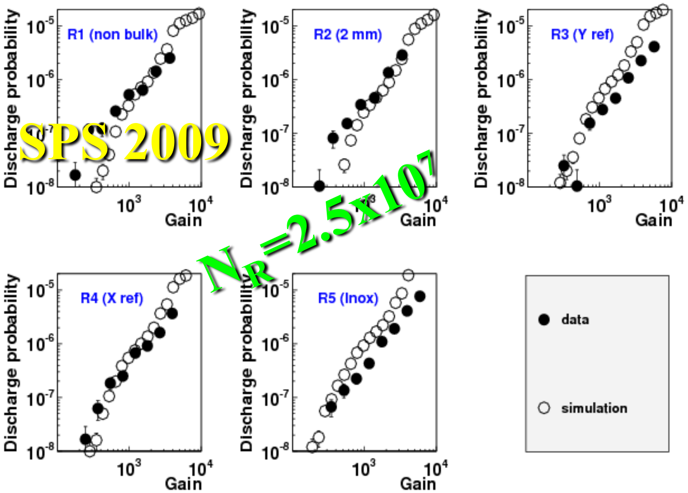


# DISCHARGES AND BEAM TYPE



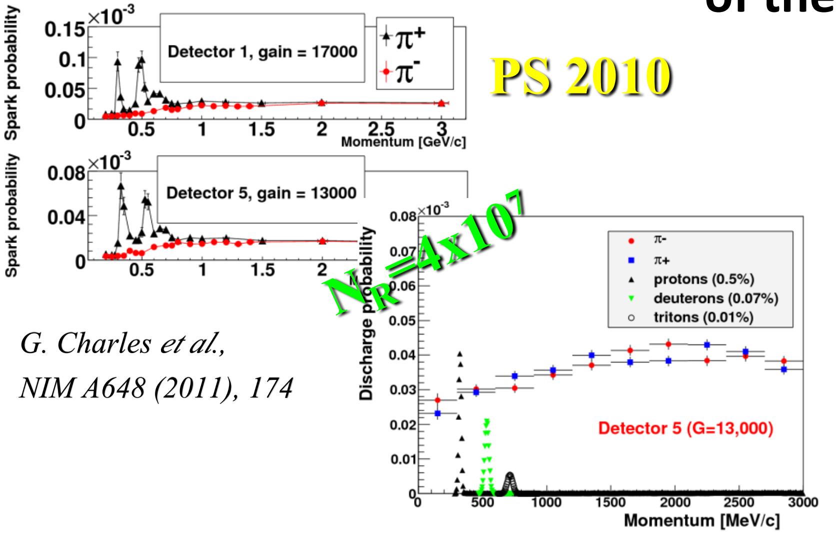
*S. Procureur et al.,*
*NIM A621 (2010), 177*

*S. Procureur et al.,*
*NIM A659 (2011), 91*

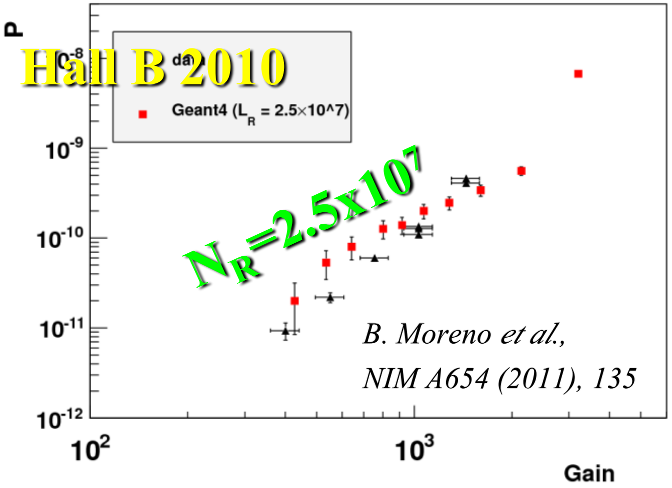


**Strong validation of the model**

(+ no difference with thicker meshes)



*G. Charles et al.,*
*NIM A648 (2011), 174*

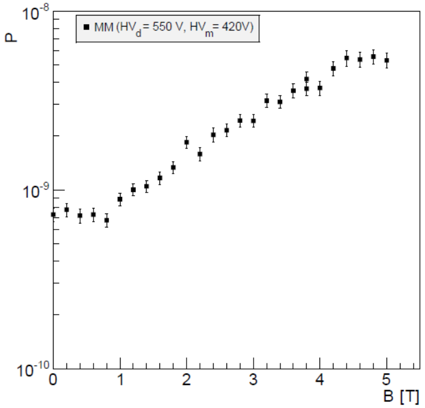


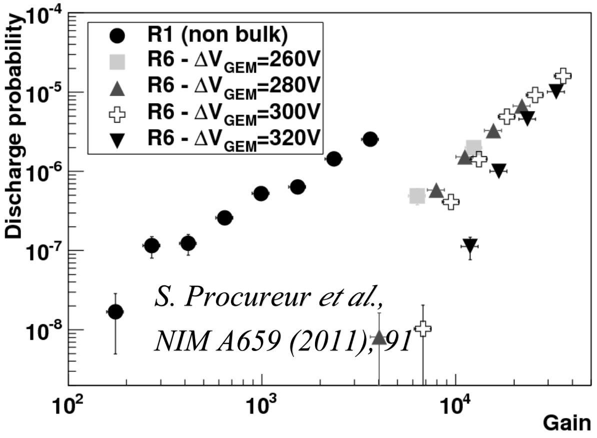
*B. Moreno et al.,*
*NIM A654 (2011), 135*

(+ explanation of bumps with $\pi^+$ from beam contamination)

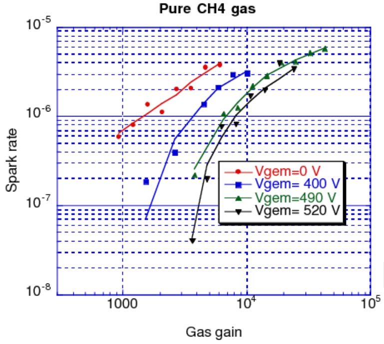
# DISCHARGES AND TRANSVERSE DIFFUSION

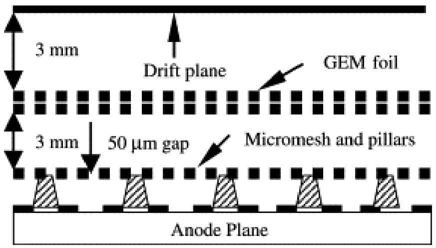
## Additional measurements with B field and hybrid MM-GEM detectors





*S. Procureur et al.,*
*NIM A659 (2011), 91*

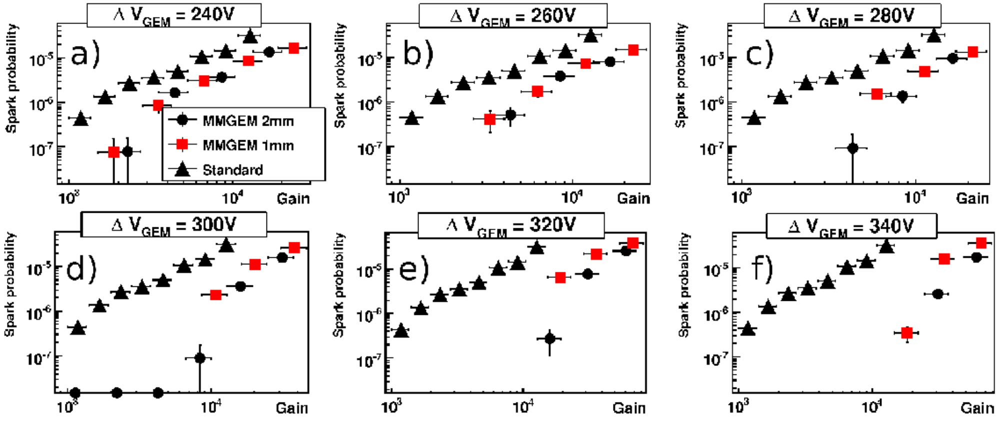




Kane *et al.* (2001)

⇒ Strong effect of transverse diffusion

## Systematic measurements during PS tests, with ≠ transfer gaps h (1 and 2 mm)



1) P reduction already at small $G_{GEM}$
2) No effect of h at moderate $G_{GEM}$
3) Effect of h at larger $G_{GEM}$
4) Saturation of the reduction at large $G_{GEM}$
5) Change of slope at large $G_{GEM}$

*G. Charles et al.,*
*NIM A648 (2011), 174*

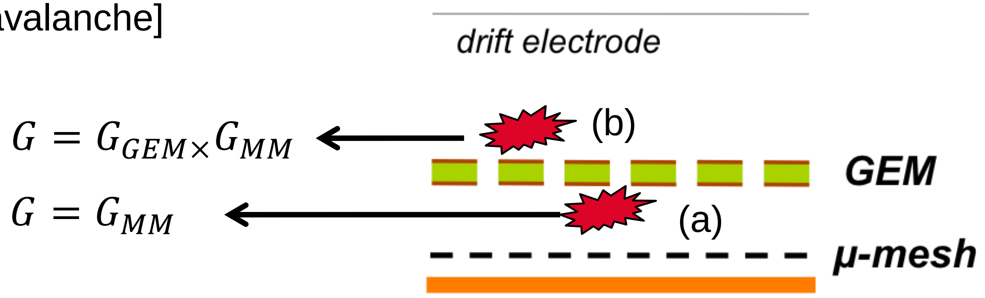
# DISCHARGES AND TRANSVERSE DIFFUSION

## Modification of the model to take into account the transverse diffusion

⟶ discharge criterion on the charge density

$$d_S = \frac{4 \times G \times E_{dep}}{\pi w_i (a(E,B) \times \sqrt{z})^2}$$

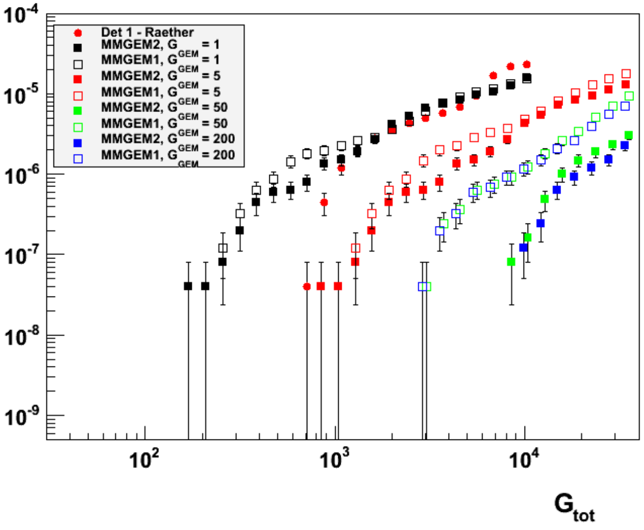
[NB: Raether limit derived for (and in) a <u>single</u> avalanche]



$$G = G_{GEM} \times G_{MM}$$

$$G = G_{MM}$$

## Results of the simulation:

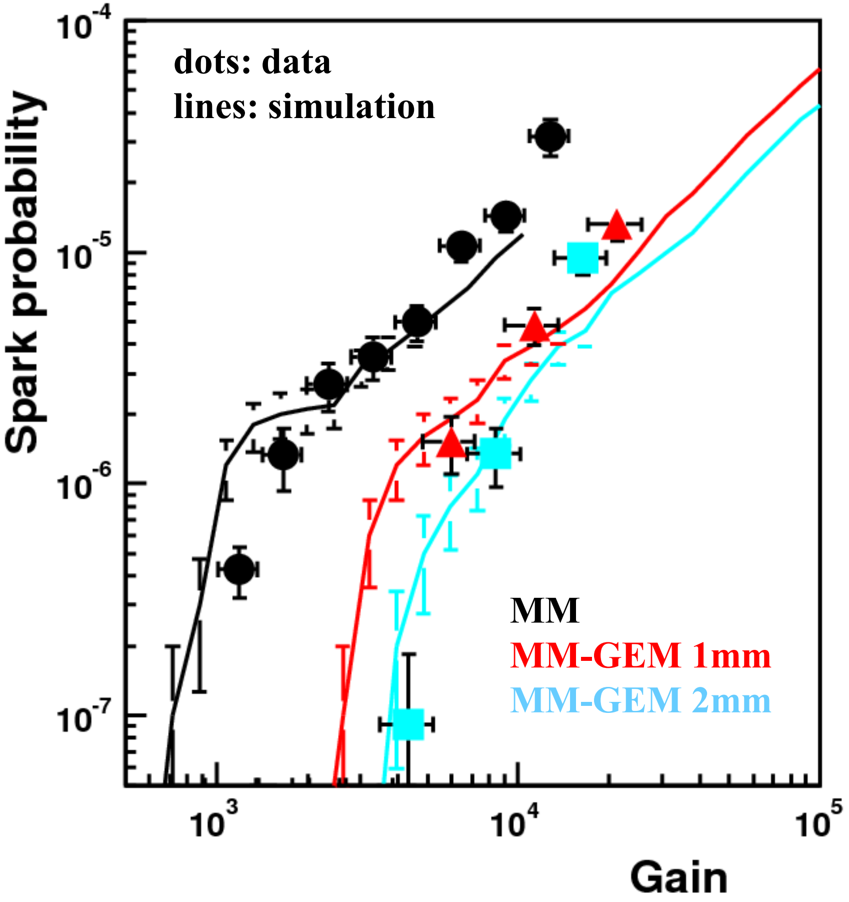


⇒ **The 5 effects observed are reproduced, in particular:**

- Low $G_{GEM}$: discharges from (a) are favoured
  ⇒ No effect of transfer gap size
- Increasing $G_{GEM}$ at fixed gain suppresses discharges (a)
  ⇒ Progressive reduction of spark rate
- At large enough $G_{GEM}$, discharges from (b) are dominant
  ⇒ Larger transfer gap further reduces P

# DISCHARGES AND TRANSVERSE DIFFUSION

## Comparison with the data @ intermediate $G_{GEM}$ (x30)



$$d_s^{\,lim} = 2 \times 10^9 \; el/mm^2$$

*S. Procureur et al.,*
*JINST 7 C06009 (2012)*

[NB: change of slope due to $E_{dep}$ distribution, enhances the discharge reduction in GEM]

⇒ **Quantitative explanation of the strong discharge reduction with GEM**

# CONCLUSION

→ **Origin of sparks with hadrons quantitatively understood in Micromegas**

⇒ Related to large energy deposits in the detector, often from secondaries

⇒ Well compatible with Raether limit in cases where transverse diffusion effect can be neglected

→ **Validity of the model has been checked from 0.3 to 150 GeV/c**

⇒ Can use Geant4 to make predictions in a given configuration

→ **Measurements of the B effect (up to 1.5 T for $B_{\perp}$, 5 T for $B_{//}$)**

→ **Validity of the simulation extended to GEM foils by taking into account trans. diff.**

⇒ Spark data interpreted in terms of (surface) charge density instead of « naive » Raether limit

⇒ Quantitative description of the effect of a GEM in the spark rate reduction

# BACKUP


Gaseous radiation detectors
F. Sauli
Particle Detectors
Grupen
&
Shwartz
W. R. Leo