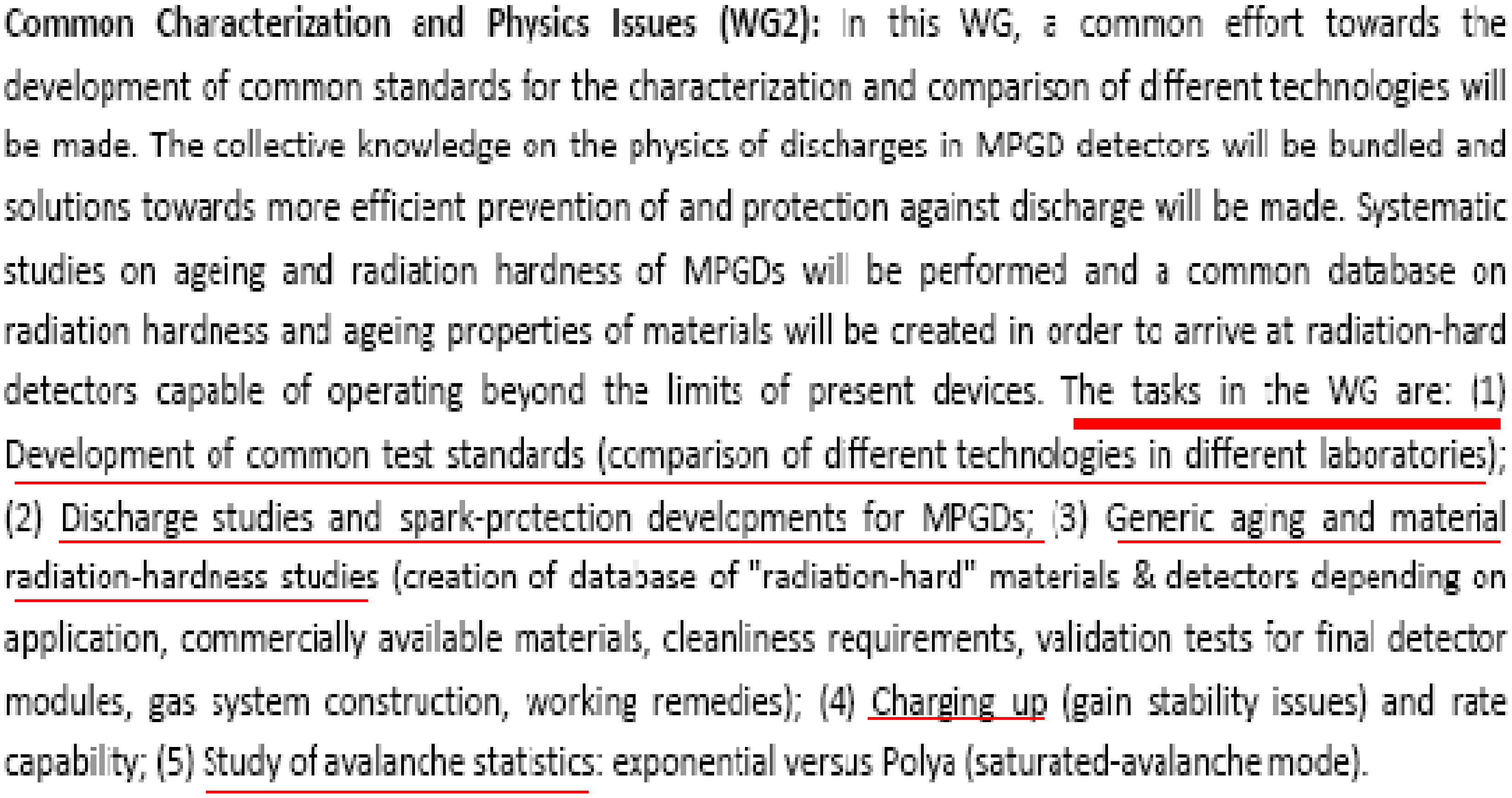
Discharge Studies in MPGD: what could be done in the frame of WG-2 collaboration

P. Fonte, V. Peskov

WG-2 tasks



Common Characterization and Physics Issues (WG2): In this WG, a common effort towards the development of common standards for the characterization and comparison of different technologies will be made. The collective knowledge on the physics of discharges in MPGD detectors will be bundled and solutions towards more efficient prevention of and protection against discharge will be made. Systematic studies on ageing and radiation hardness of MPGDs will be performed and a common database on radiation hardness and ageing properties of materials will be created in order to arrive at radiation-hard detectors capable of operating beyond the limits of present devices. The tasks in the WG are: (1) Development of common test standards (comparison of different technologies in different laboratories); (2) Discharge studies and spark-protection developments for MPGDs; (3) Generic aging and material radiation-hardness studies (creation of database of "radiation-hard" materials & detectors depending on application, commercially available materials, cleanliness requirements, validation tests for final detector modules, gas system construction, working remedies); (4) Charging up (gain stability issues) and rate capability; (5) Study of avalanche statistics: exponential versus Polya (saturated-avalanche mode).

(from the RD-51 proposal)

Discharges in MPGDs

Want cause the breakdowns?

I) In bad quality detectors – imperfections

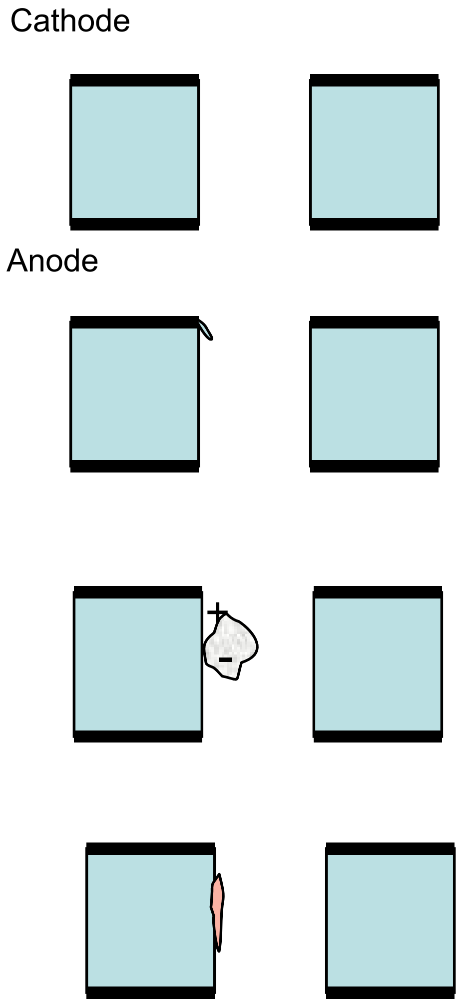
II) In good quality detectors - there are several fundamental reasons:

1) Raether limit
2) Rate effect
3) Jets
4) Feedbacks
5) Surface streamers

Imperfections:

Usually cause persisting discharges at the fixed place in the detector

Examples for hole-type gas amplifiers:



a) Ideal holes

b) Holes with sharp edges

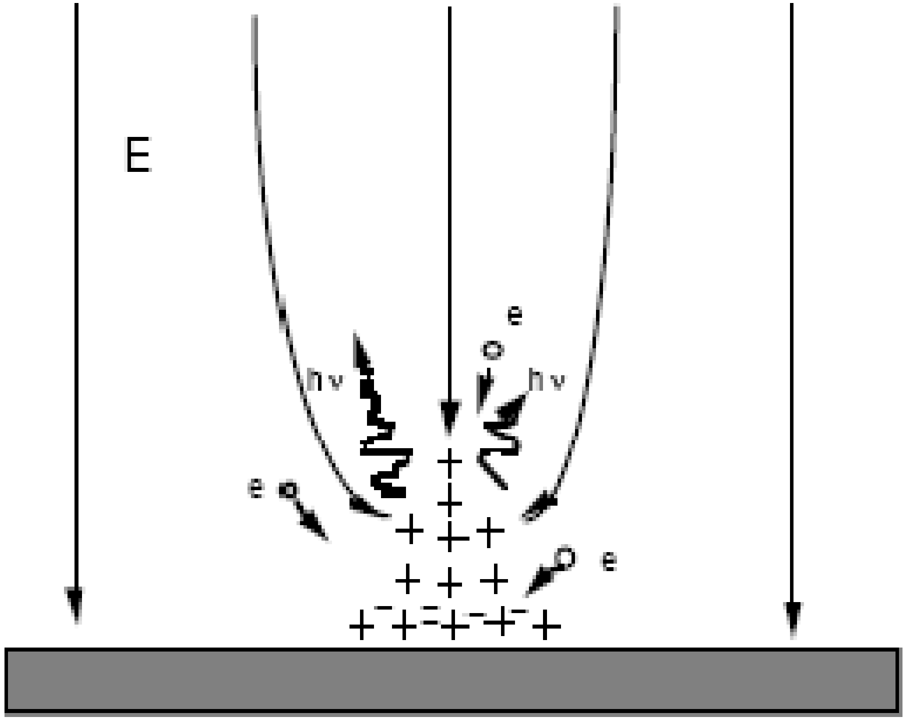
c) Holes with debris or dust particles

d) Holes with areas of slightly conductive surfaces (dirt)

Common « standards »: before comparing maximum achievable gains one have to verify that the discharges are randomly distributed over the detector surface

1)Raether limit

Discharges in parallel-plate geometry



At $A_{max}n_0 \geq \mathbf{Q_{max}}=10^8$ electrons an avalanche transits to a spark.

$A_{max}n_0=10^8$ is called a Raether limit.

Raether limit fro MPGDs:

It was recently discovered* that a similar limit applies for every micropattern detectors: GEMs, MICROMEGAS and others:

$A_{max}n_0=Q_{max}=10^6$-10^7 electrons,

where n_0 is the number of primary electrons created in the drift region of the detector

(Q_{max} depends on the detector geometry and the gas composition)

*(*see Y. Ivanchenkov et al., NIM A422,1999,300 and*
V. Peskov et al., IEEE Nucl. Sci. 48, 2001, 1070)

Conclusions:

With single primary electrons gains up to 10^6-10^7 in principle are possible

With ^{55}Fe (n_0~230 electrons) the maximum achievable gain is $<10^5$

With alphas (n_0=105) the maximum achievable gain <100

This was well observed in the case of MPGDs

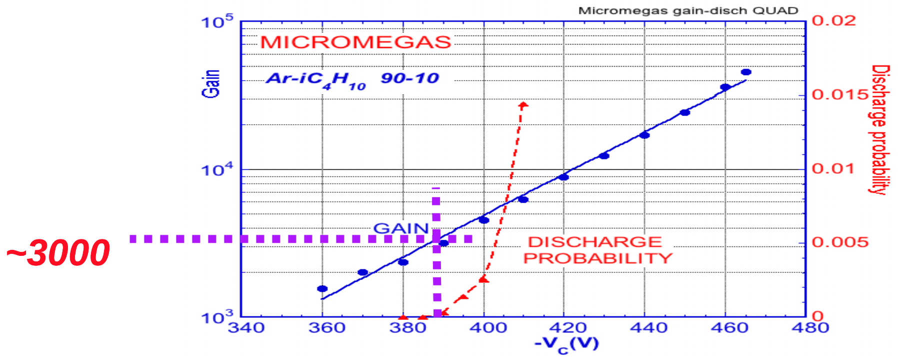
MEASURE GAIN WITH ^{55}Fe X-RAYS AND DISCHARGE PROBABILITY WITH INTERNAL ALPHA SOURCE FROM ^{220}Rn

MPGD CERTIFICATION

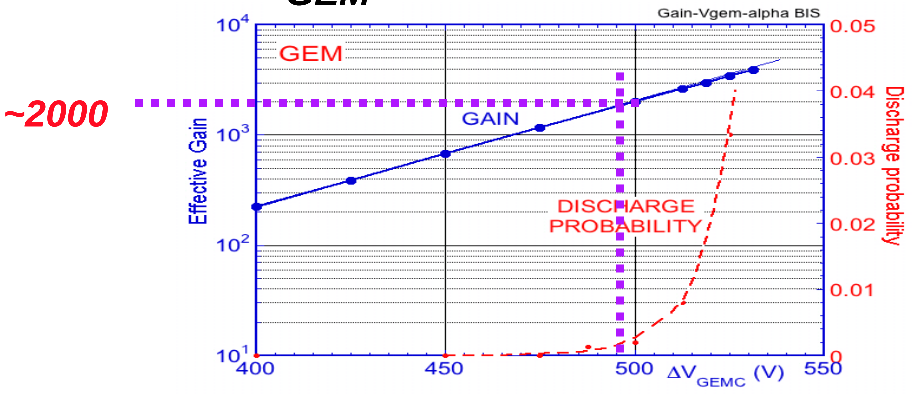
The maximum gain before discharge is almost the same for all MPGD tested:

DETECTOR	MAX GAIN	MAX CHARGE
MSGC	**2000**	**$4\ 10^7$**
ADV PASS MSGC	**1000**	**$2\ 10^7$**
MICROWELL	**2200**	**$4.4\ 10^7$**
MICROMEGAS	**3000**	**$6\ 10^7$**
GEM	**2000**	**$4\ 10^7$**

MICROMEGAS



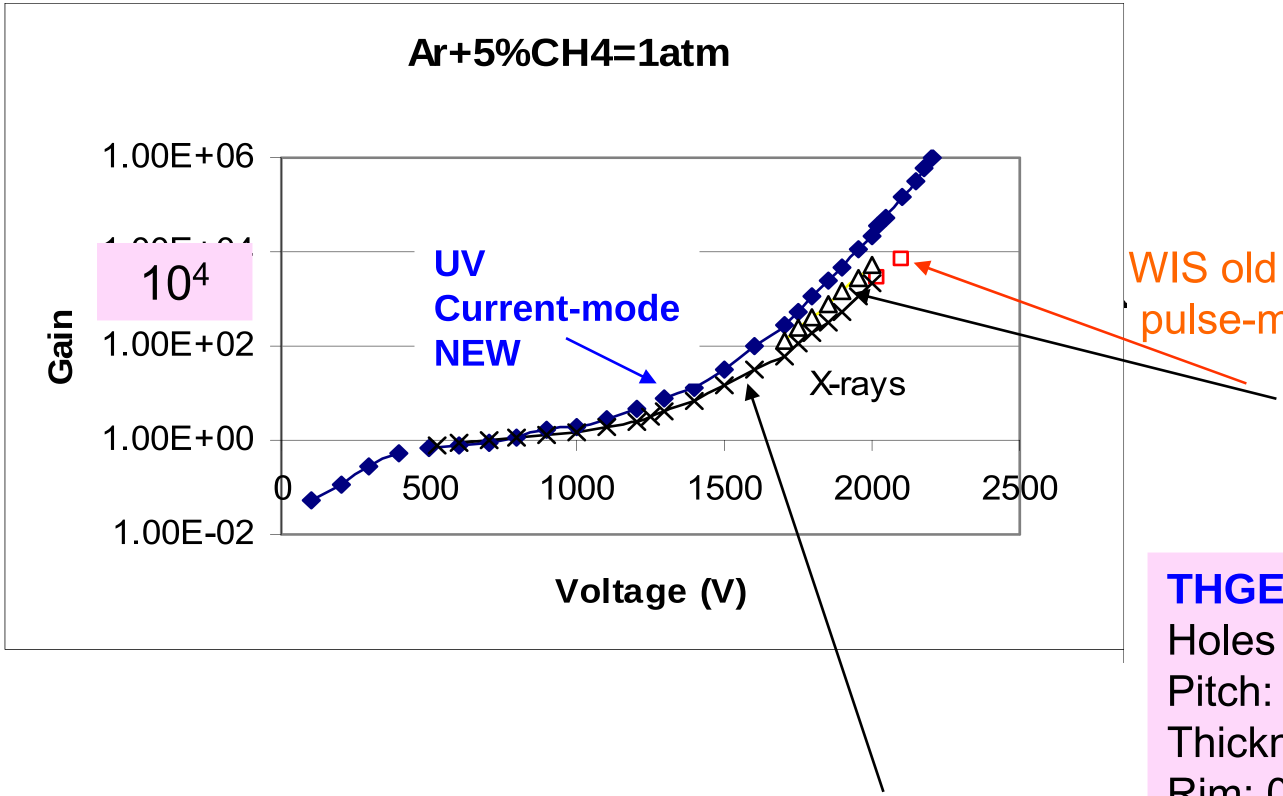
GEM



S. Bachmann et al, Nucl. Instr. and Meth. A479(2002)294

F. Sauli, Report at the RD51 collaboration meeting in Amsterdam, 2008

Single-THGEM : Ar+5%CH_4



THGEM geometry:
Holes dia: 0.5 mm
Pitch: 1 mm
Thickness: 0.8 mm
Rim: 0.1mm

Maximal gains with UV are 100 times higher than with X-rays.
For UV and x-ray gun:
The current in the plateau region (500-750V) was the same: 0.1nA.
The maximum current in gain measurements was always kept below 0.5nA

A. Breskin, V. Peskov et al, Report at the RD51 meeting in Paris, 2008

What was established up to now is just a general picture

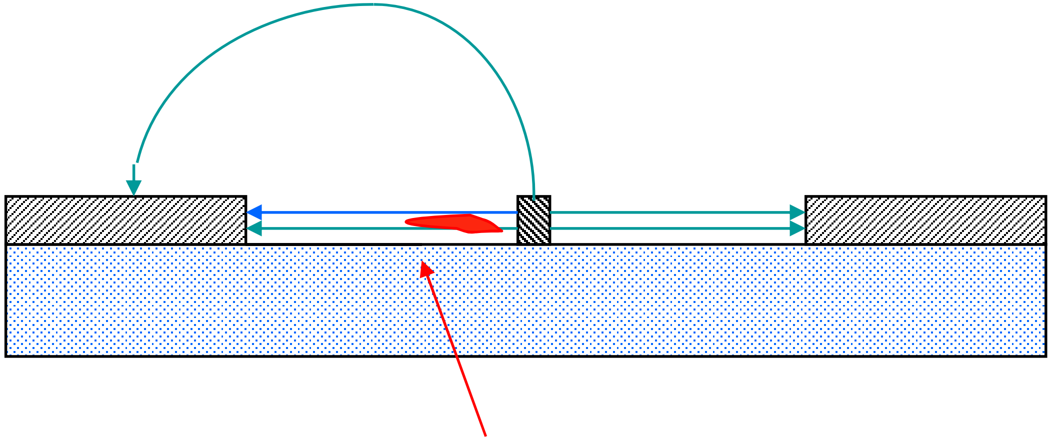
Detailed studies are still needed:

a) Simulations

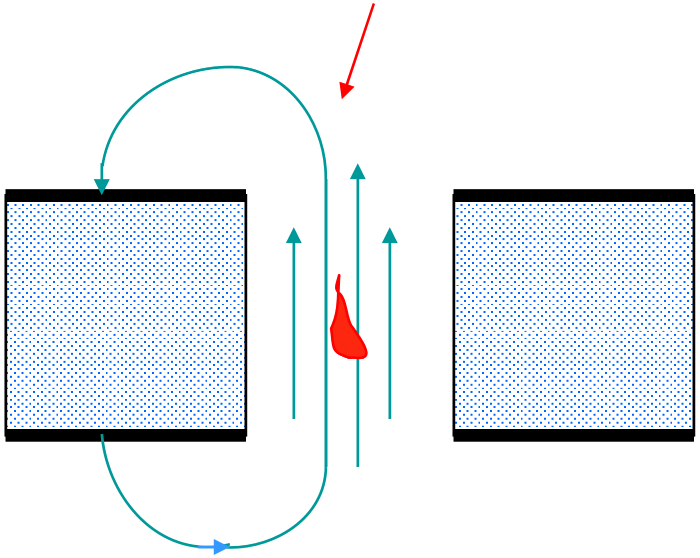
b) Geometry and gas optimization

Geometrical optimization?

Why there are sparks in micropattern gaseous detectors?

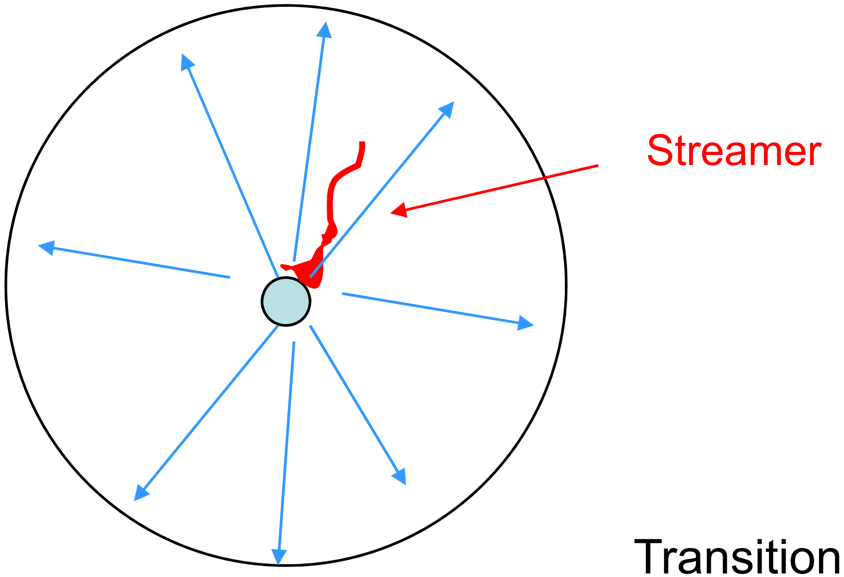


Regions with parallel fields lines where any streamer,
if appear, is unquenched and may reach the cathode



Because there are regions with parallel field lines, so streamers develop there by the same mechanism as in PPAC

Self-quenched streamer

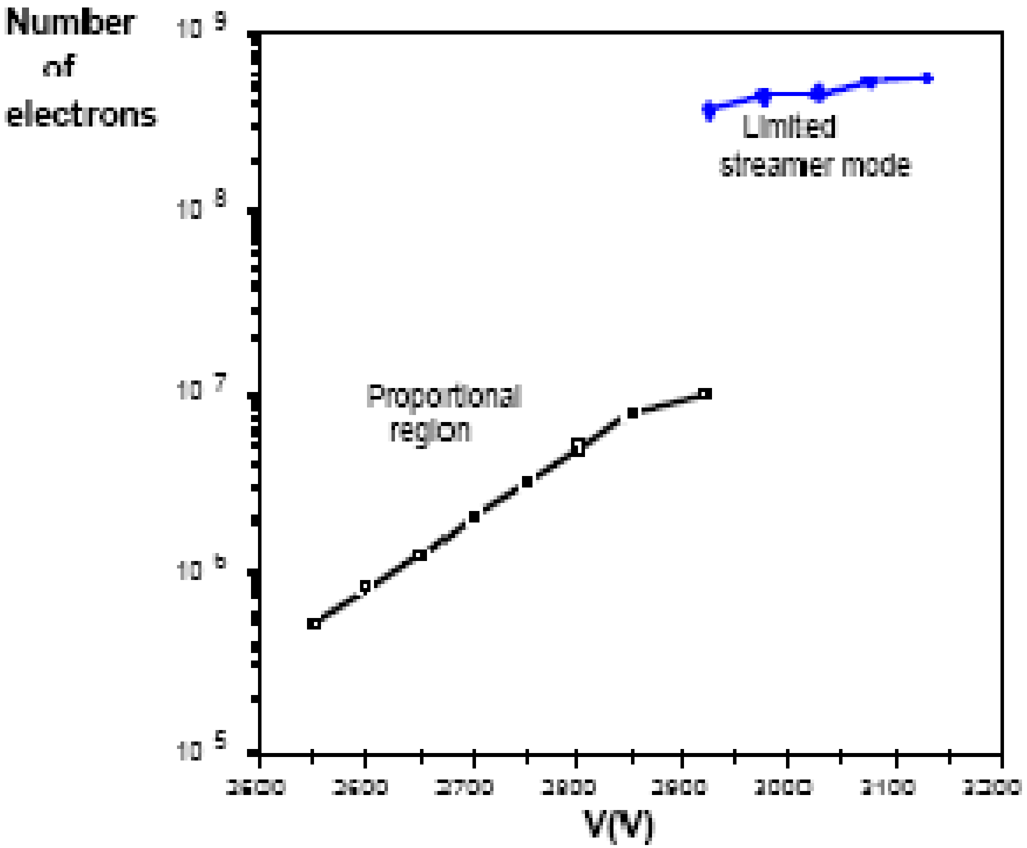


Streamers <u>cannot propagate</u> to the cathode because the electric field drops as 1/r

Transition to streamer occurs when $An_0 \geq Q_{max}$=10^8electros

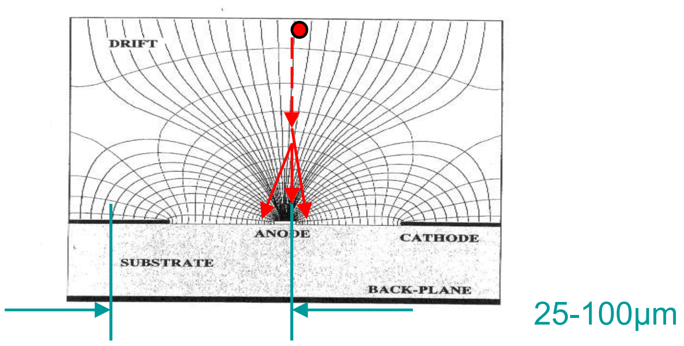
Strimers give huge amplitudes but the are not harmful as well

Signal’s amplitude in proportional and streamer modes

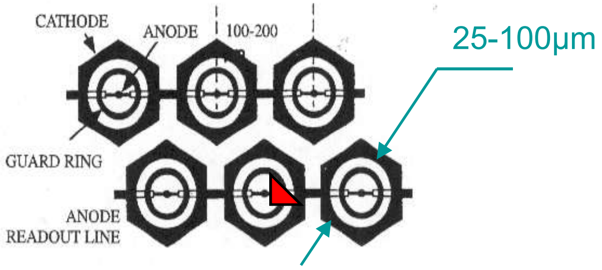


For details see: P. Fonte et al., INFN Insrum. Bull, SLAC-Journal ICFA-15-1, 1997

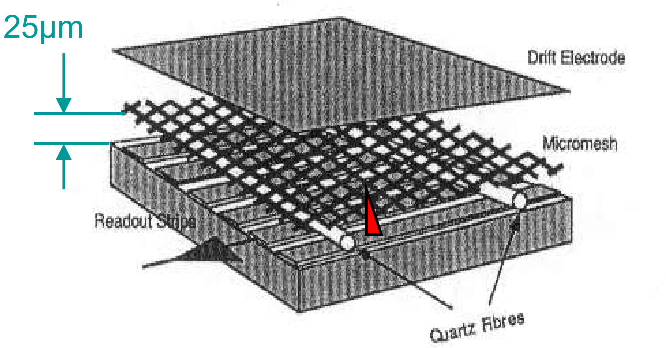
The main designs of micropattern gaseous detectors



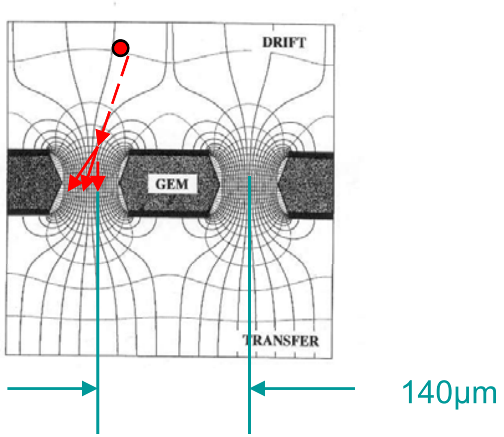
Microstrip gaseous detectors



Microdot gaseous detectors

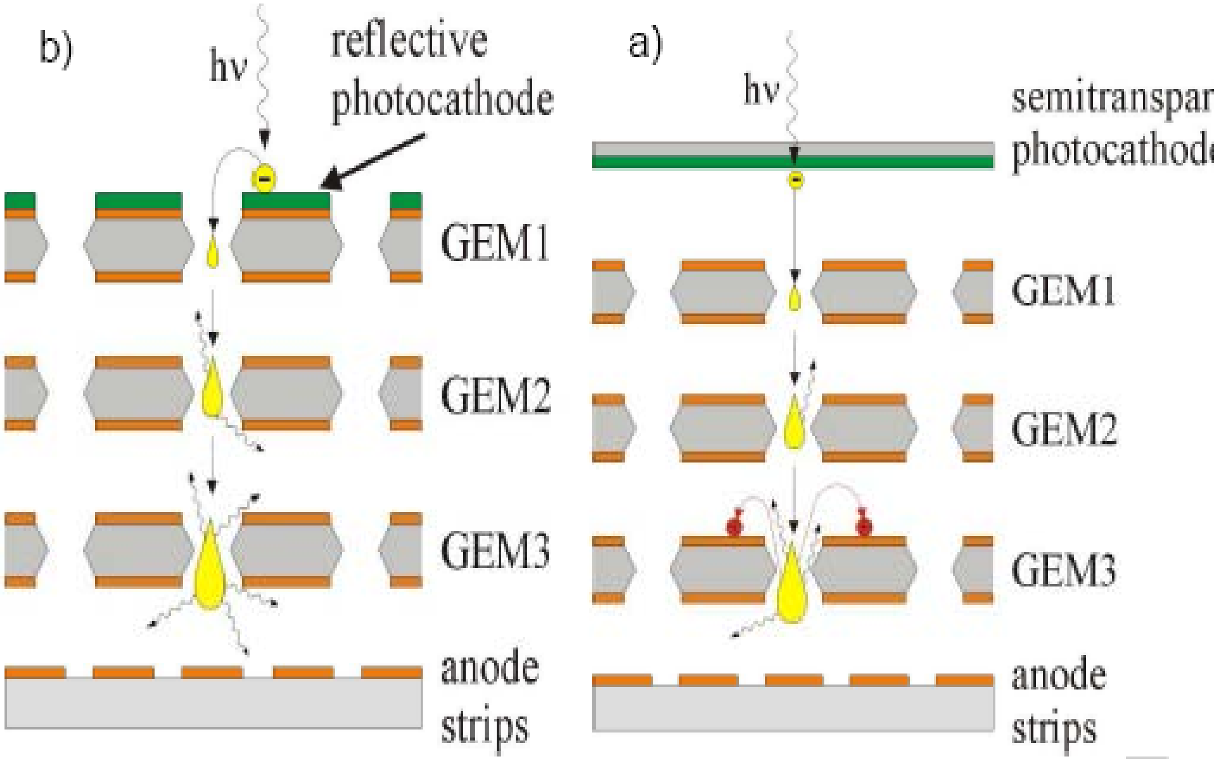


MICROMEGAS



GEM

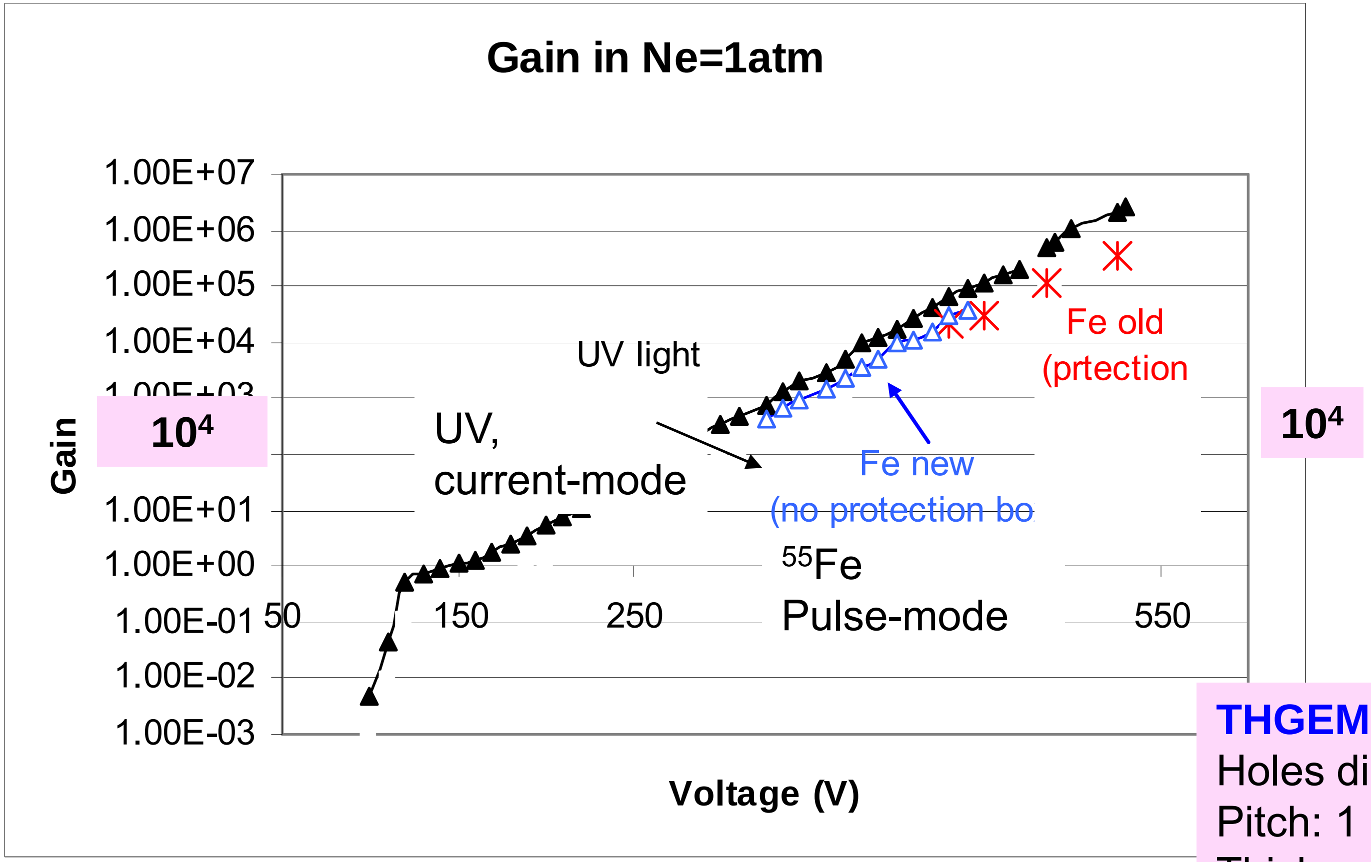
Empirical way to increase the Raethet limit: multistep detectors



Raethre limit increases due to the diffusion effect?

Gas optimization?

Single-THGEM: Ne



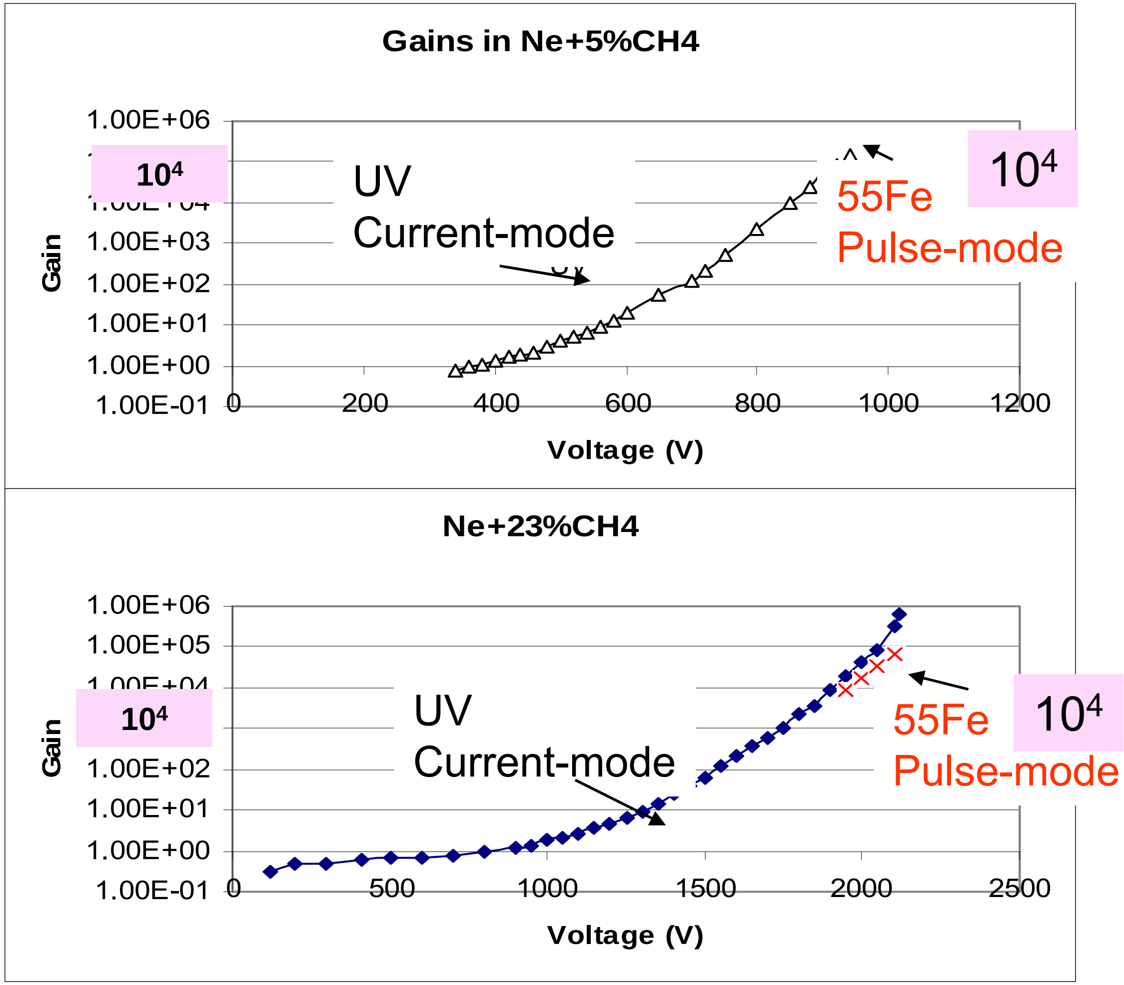
THGEM geometry:
Holes dia: 0.5 mm
Pitch: 1 mm
Thickness: 0.8 mm
Rim: 0.1mm

The maximum gains with x-rays in Ne are higher than in Ar+5%CH_4.
In Ne breakdown voltages with UV and X-rays are closer.

A. Breskin, V. Peskov et al, Report at the RD51 meeting in Paris, 2008

Single-THGEM: Ne + CH_4

THGEM geometry:
Holes dia: 0.5 mm
Pitch: 1 mm
Thickness: 0.8 mm
Rim: 0.1mm



Same as with Ne: maximum gains with x-rays in Ne+CH_4 are higher than in Ar+5%CH_4 and breakdown voltages with UV and X-rays are close.

A. Breskin, V. Peskov et al, Report at the RD51 meeting in Paris, 2008

A possible interpretation:

- Raether limit: established in large-gap avalanche detectors but valid for MPGDs (Ivanchenkov NIM A 1999), though may be different

- $A*n_0=10^6-10^7$ electrons

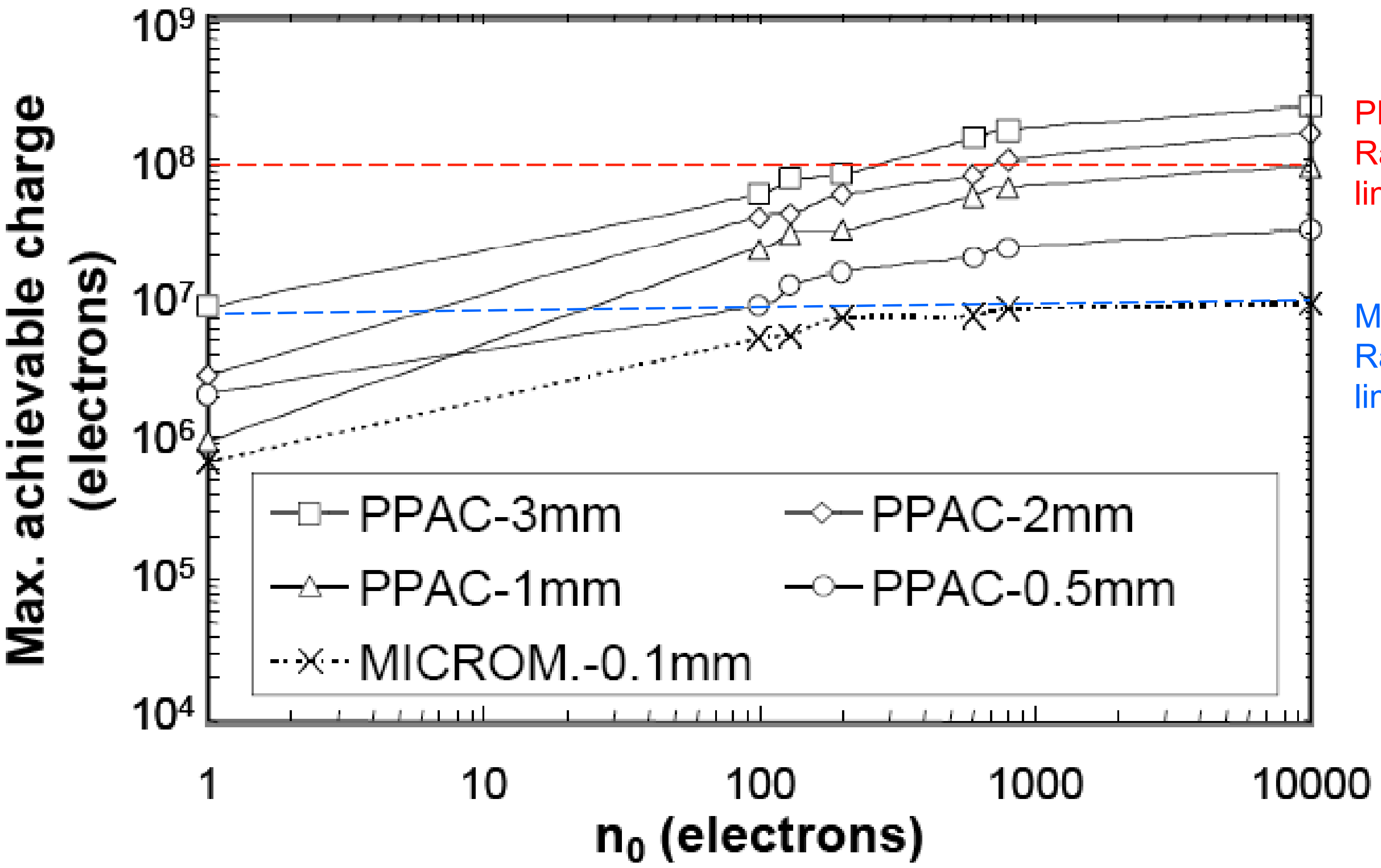
  where A is the maximum achievable gain, n0-number of primary electrons deposited by the radiation in the drift region

  ➔ X-rays: different gain compared to UV

- In Ne/CH_4 Raether limit possibly differs from Ar/CH_4 due to ~ 5-fold longer range of ^{55}Fe photoelectrons (~1mm), resulting in lower ioinization density per “hole”.

More details…

Raether limit for PPAC and MICROMEGAS is reached at n_0>50 electrons

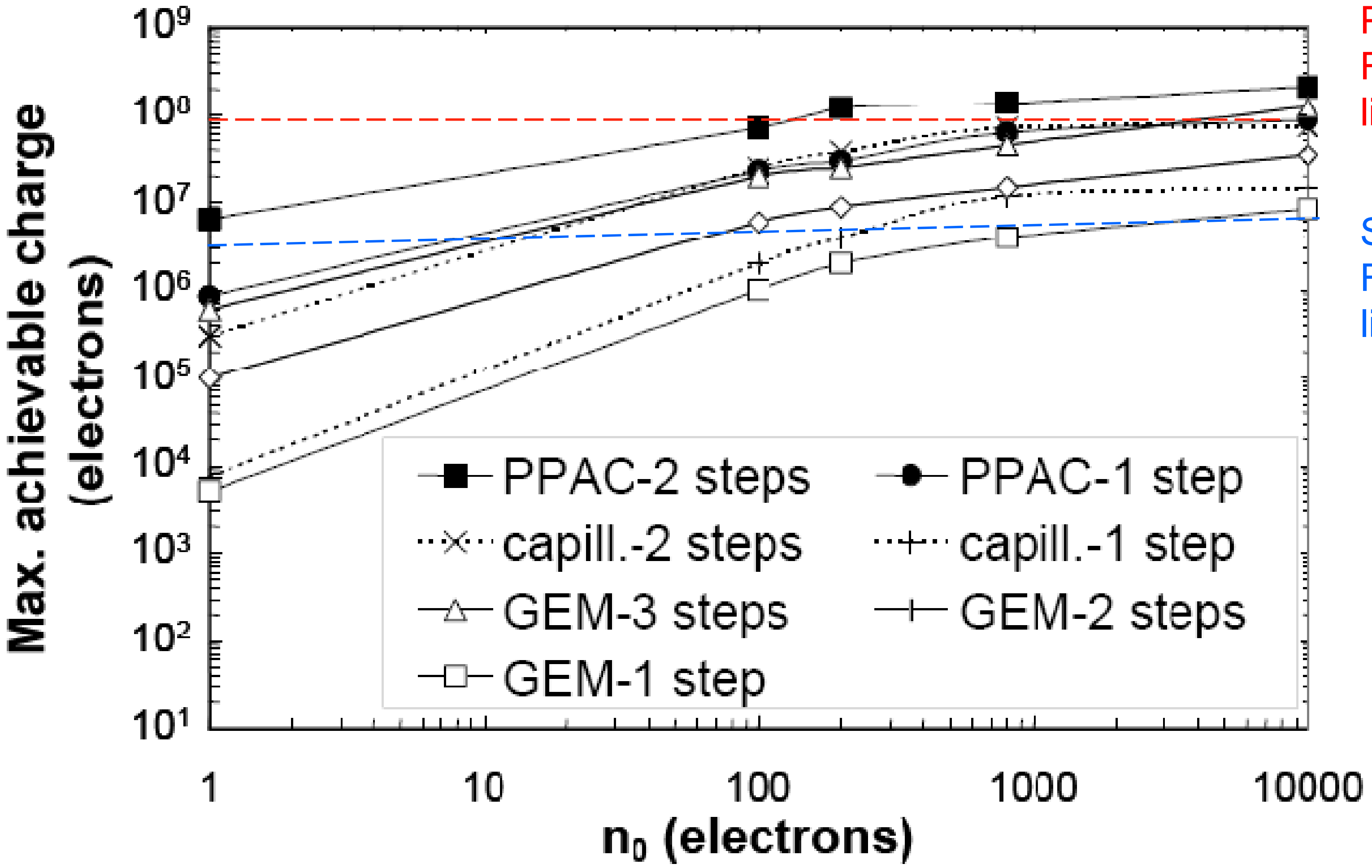


PPAC
Raether
limit

MICROMEGAS
Raether
limit

V. Peskov et al., IEEE Nucl. Sci. 48,2001,1070

..similar for GEM-type detectors



PPAC
Raether
limit

Single GE
Raether
limit

For n_0>50 electrons “Rather” limit works well, however for n_0<20 electrons other factor starts dominating like field emission from sharp edges, gain fluctuation…

V. Peskov et al., IEEE Nucl. Sci. 48,2001,1070

Proposed “common standards" in discharge studies and comparisons

- Discharges should be randomly distributes over the detector surface.
- For Raether limit verification use: UV light, ^{55}Fe and alphas
- Measure not only discharge rate vs. applied voltage, but the discharge energy and evaluate the destructive effect (some detector may die after one sparks others withstand hundred of sparks)

2) Rate effect

Parallel plate detector (PPAC)

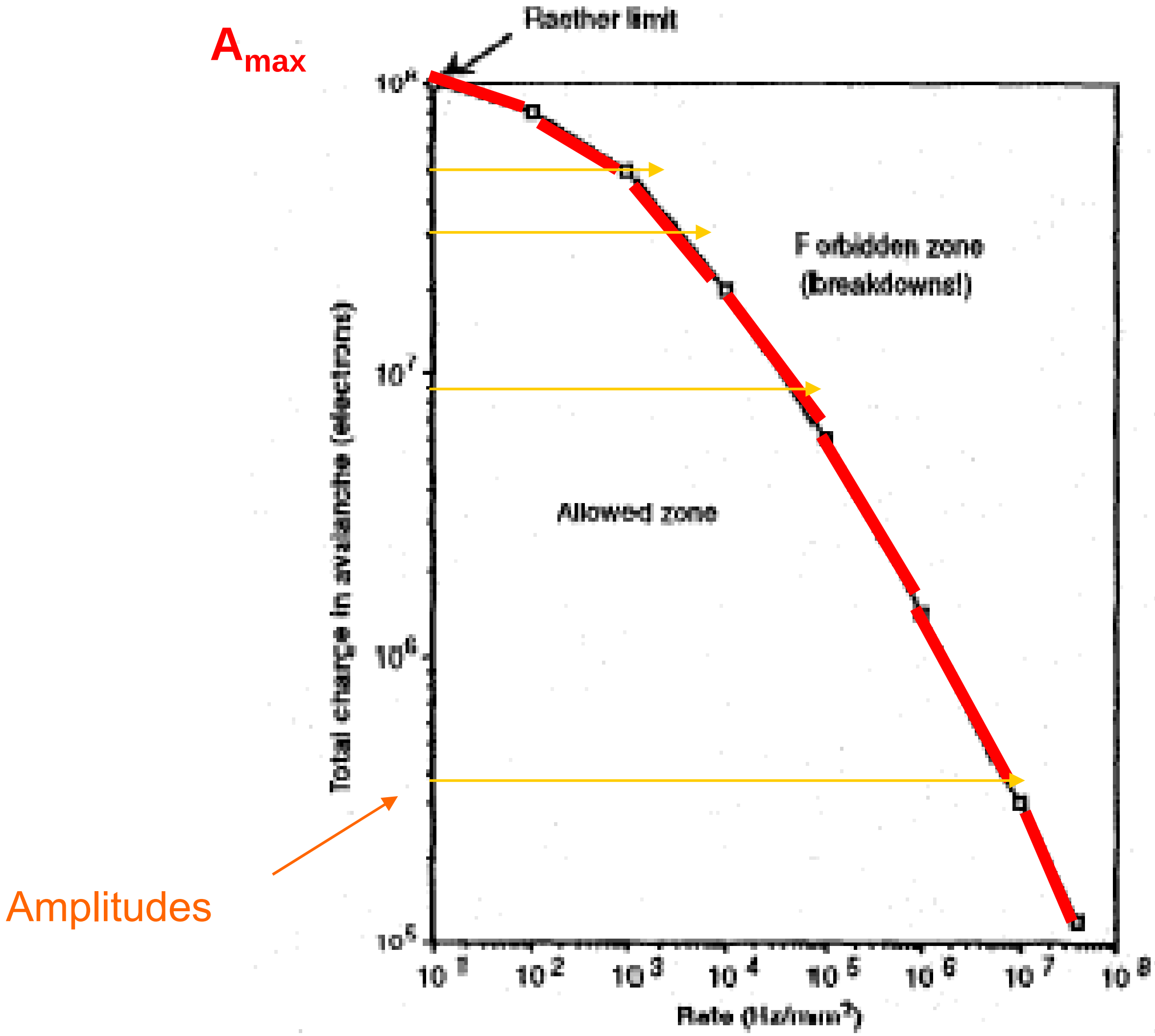
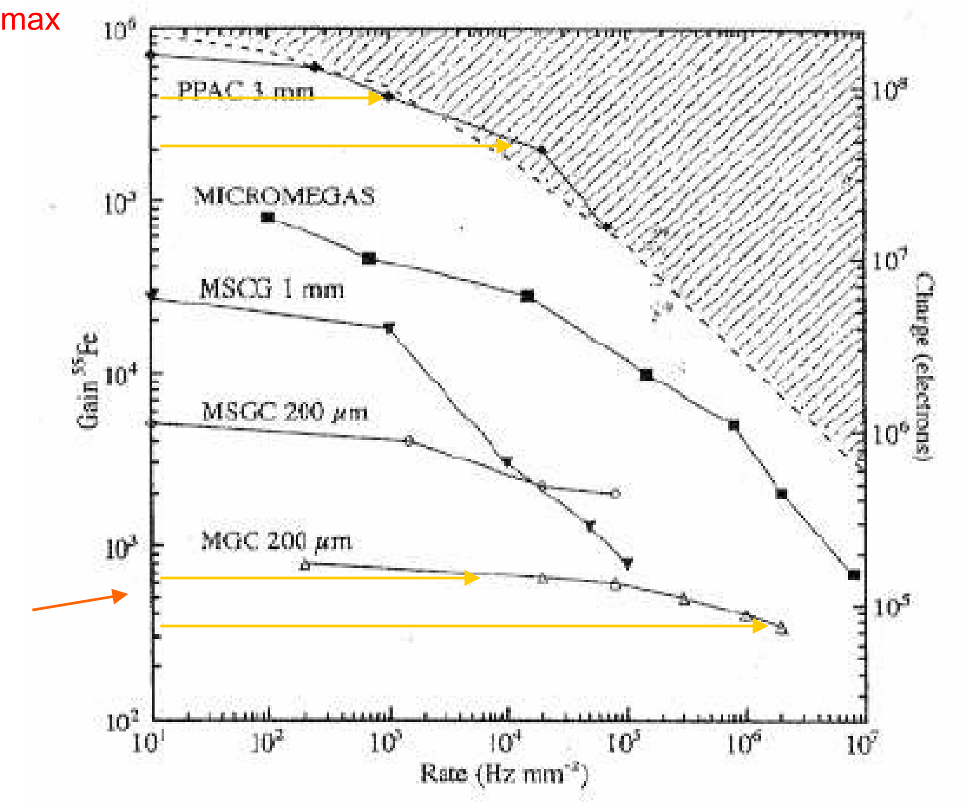


Figure 1: General curve reflecting gain limitation with rate for gaseous detectors.

P. Fonte et al IEEE Nucl. Sci 46,1999,321

Signal amplitude does not drop with rate, however there is a rate limit for each amplitude

Rate limit of micropattern gaseous detectors



A_{max}

Amplitudes

P. Fonte et al,
NIM A419,1998,405

For each micropattern detector the amplitude remains unchanged with rate, however the maximum achievable gain drops with rate

Common “standards”:

When reporting rate indices sparks one have to mention at what gas gain this was measured/observed

3) Jets

Electron jets:

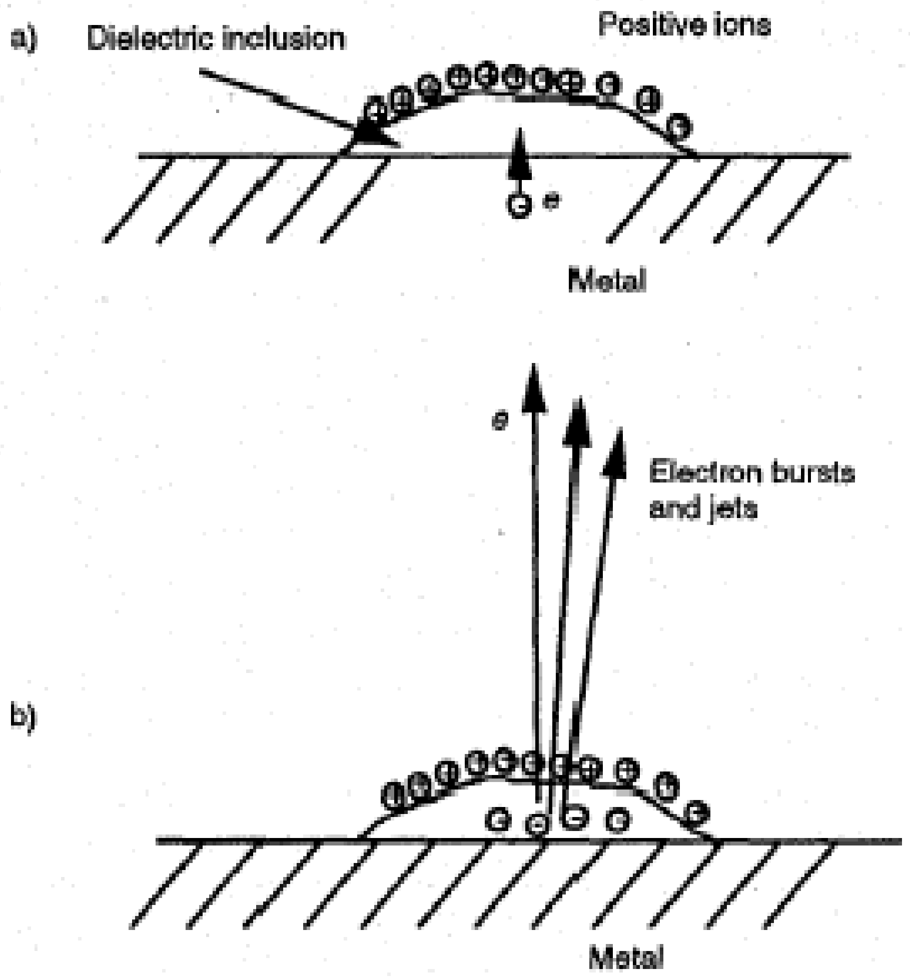


Figure 3: Schematic illustration of a two-step process which leads to emission of jets and bursts from thin dielectric films.

P. Fonte et al.,
IEEE Nuc. Sci
46,1999,321

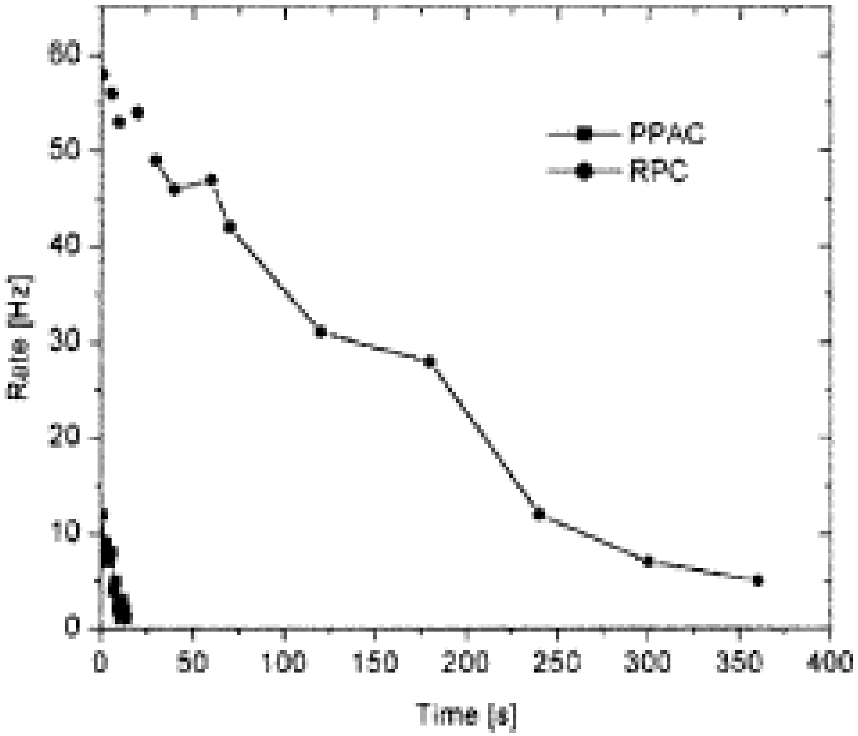


Fig. 11. The rate of the afterpulses for the PPAC (Cu-electrodes) and the RPC (Si). Gas mixture Xe (20%)+ Kr (40%)+CO_2 (20%) at 1 atm.

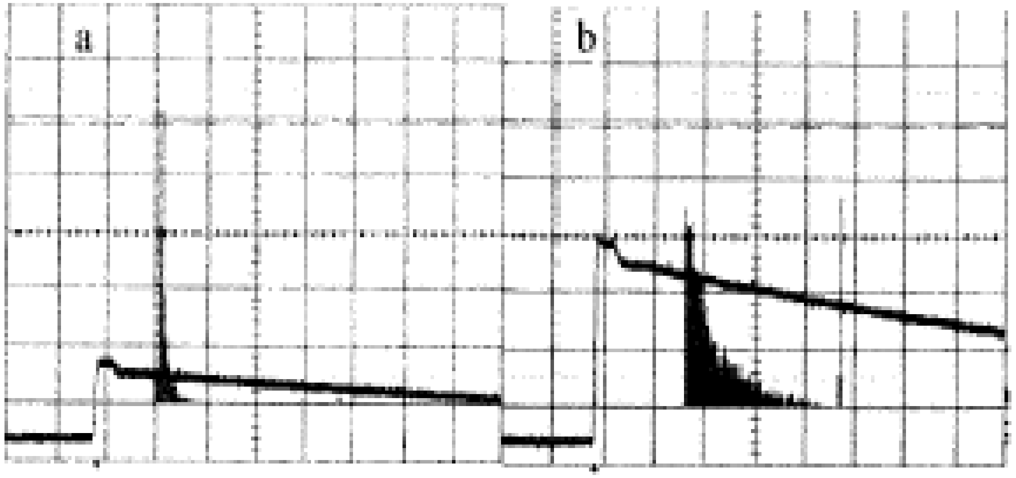


Fig. 6. Pulse-height spectra of signals from RPCs measured in the case of single primary electrons produced from the cathode by (a) UV emission and (b) in the case of noise pulses. The gas mixture Xe (40%)+ Kr (40%)+ CO_2 (20%) was used (1 atm).

Other evidences:

Hysteresis: one cannot apply the voltage immediately after the breakdown

("Memory effect" well documented in the case of RPC and Compass RICH

Depends on gas

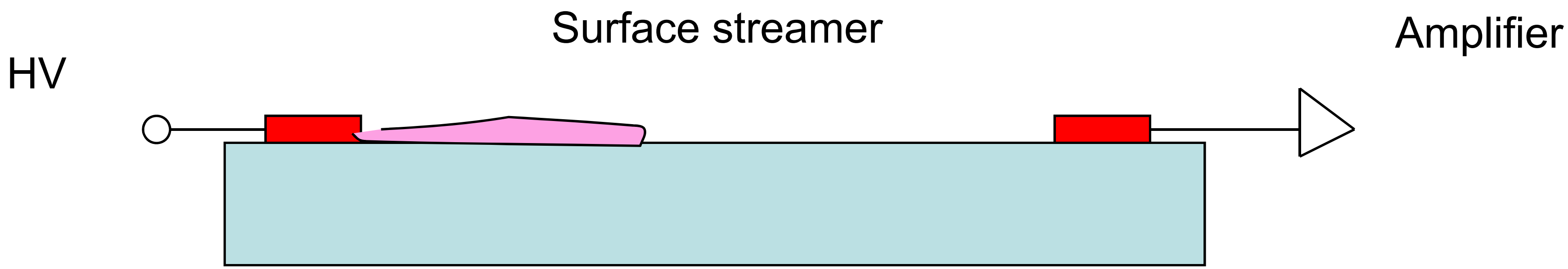
This effect should be studied as well

4) Feedbacks (essential for detector operating in noble gases or combined with photocathodes)

$A_f\gamma=1(A_f\gamma_+=1$ or $A_f\gamma_{ph}=1)$-”slow” mechanism of discharges

The probabilities γ_+ and γ_{ph} are increasing with the increasing the photocathode QE and it’s sensitivity to visible light and
with electric field near the cathode

5) Surface streamers



Surface streamer

HV

Amplifier

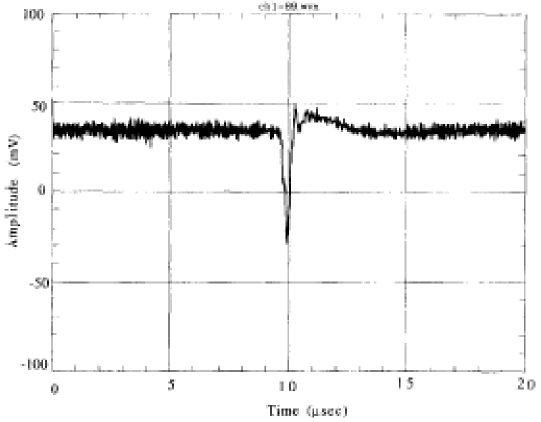


Fig. 4. Typical streamer current pulses for E-MSGCs with substrates.

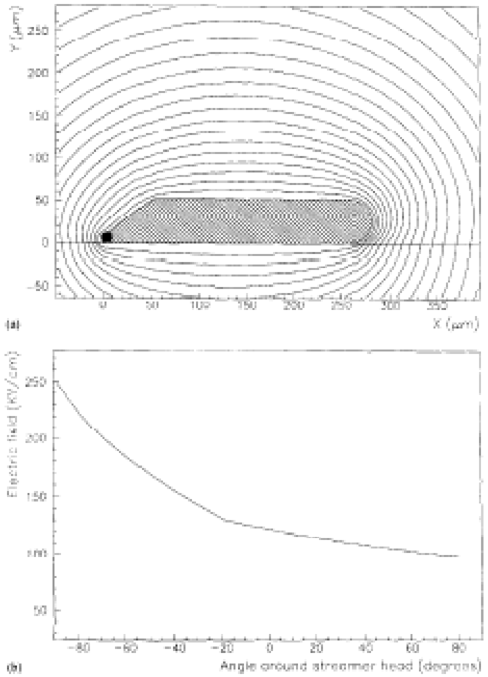


Fig. 16. Field calculations for a streamer close to the substrate surface (this case corresponds to the E-MSGC with substrate and the MSGC): (a) field map; (b) field around the tip.

V. Peskov et al., NIM A397,1997, 243

Discharges “prevention:”

- Increase or “bypass” the Raether limit(gas optimization, detector geometry optimization/multistep approach)
- Reduce feedbacks (when it is essential)
- Any other measures..? Not too much…

Spark-proofed MPGDs

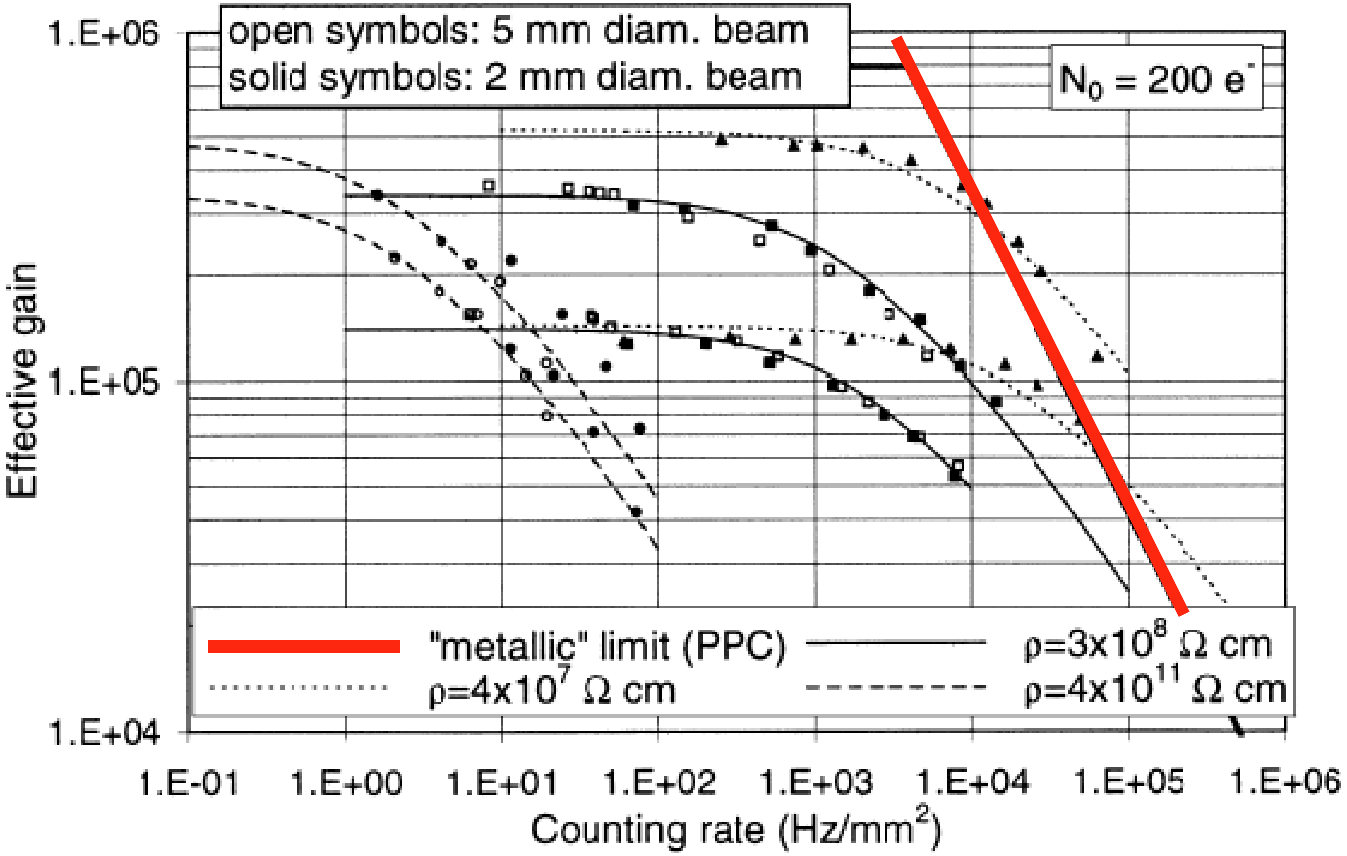
Examples:

_*_Resistive GEMs

* Strip electrodes terminated on resistors (V. Peskov et al report at IEEE Nucl Sci, Dresden 2008)

* MICROMEGAs with resistive coating (see Van Der Graaf presentation)

Optimization of the RPC electrodes resistivity



Instead of conclusions:

- A lot of work is required to better understand discharges and protection against the discharges
- We can try to identify today who is interested to participate in these studies and how
- One of the possible way is to cluster these studies around CERN-Coimbra –Weizmann institute where this activity was already started and enforce the local teams with visitors
- Any other suggestion are very welcome

Spairs

Possible discussion topics at WG-2 meeting at CERN:

1. Raether limit for micropattern detectors:

a)Experimental evidence, simulations, possible ways of its increasing (gases, geometry)

b)Rate induced breakdowns:

Avalanche overlapping and Raether limit

2. Cathode excitation effect at low and high counting rates :

a) Hysteresis in breakdown voltage

b) Long-term discharge memory effect

c)Jets of electrons

3. Common “standards”:

a) Speaks measurements (distinguish sparks due to defect from sparks due to the Raether limit)

How we compare sparks: spark energy, sparks rate

How we evaluate spark damages (after how many spars the detector dies?)?

b)Gain measurements: ionization chamber vs. charge injection methode

c) Gain stability (due to the charging up effect and dielectric polarization):

Low rate

High rate

Short-term stability

Long-term stability

d) Quantum efficiency measurements for photosensitive micropattern detectors- what should be a common reference: TMAE, calibrated detectors, Cherenkov light?