Progress in Thick GEM-like (THGEM)-based Detectors

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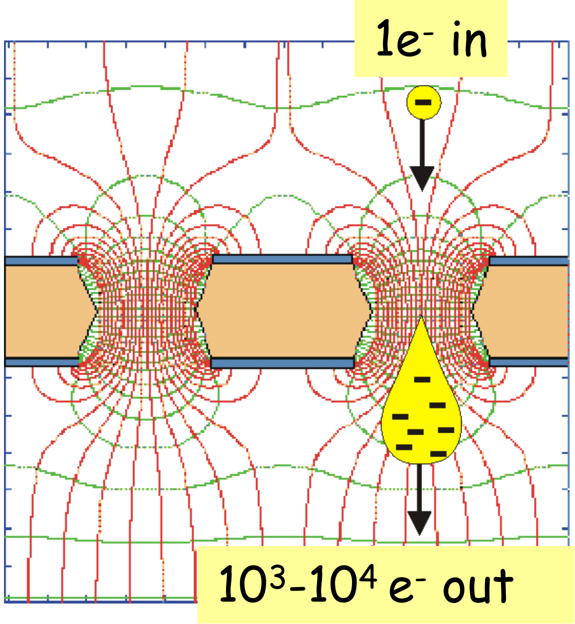
MOTIVATION:

Robust, economic, large-area radiation imaging detectors
FAST, HIGH-RATE, MODERATE LOCALIZATION RESOLUTION

Gaseous multiplication in holes

- Avalanche confined within a small volume
- Secondary effects confined/reduced -> high gains
- True pixilated structures
- Possibility to CASCADE multipliers -> further higher gains



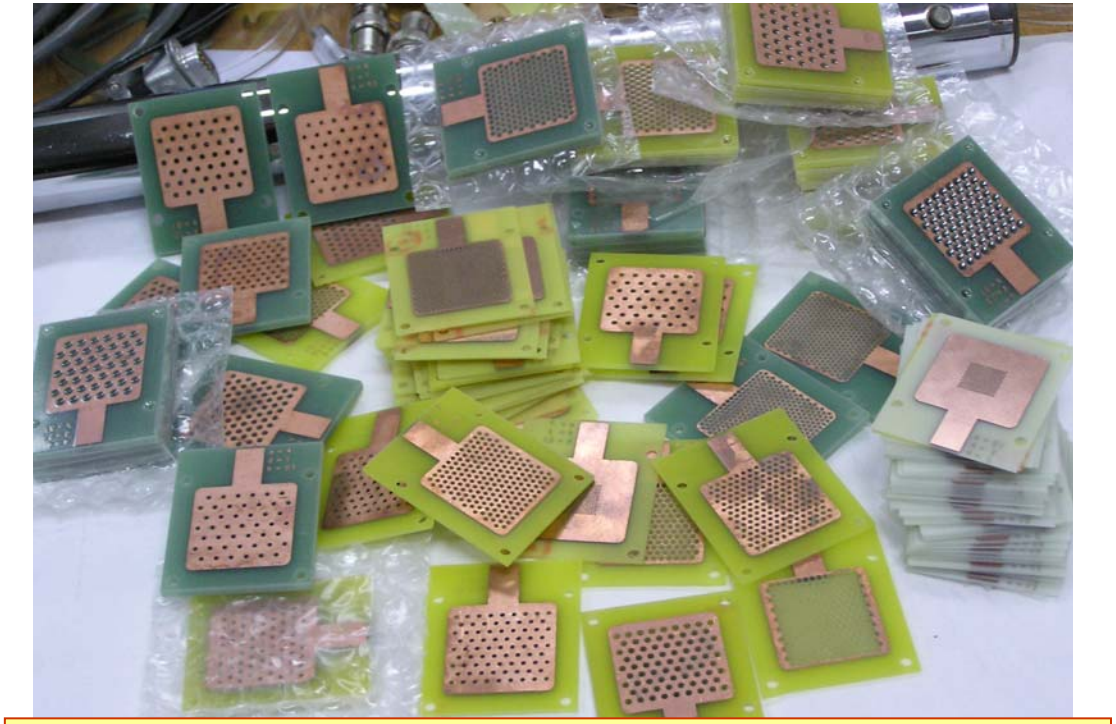
High electric field in the holes

- Breskin, Charpak NIM108(1973)427 Discharge in glass capillaries
- Lum et al. IEEE NS27(1980)157, & Del Guerra et al. NIMA257(1987)609 Avalanches in holes
- Sakurai et al. NIMA374(1996)341, & Peskov et al. NIMA433(1999)492 Glass Capillary plates
- Sauli NIMA386(1997)531 **GEM**
- Ostling, Peskov et al, IEEE NS50(2003)809 G-10 "Capillary plates"
- Chechik et al. NIMA535(2004)303 & Physics/0502131 **THGEM**

Thick GEM-like multipliers: THGEM

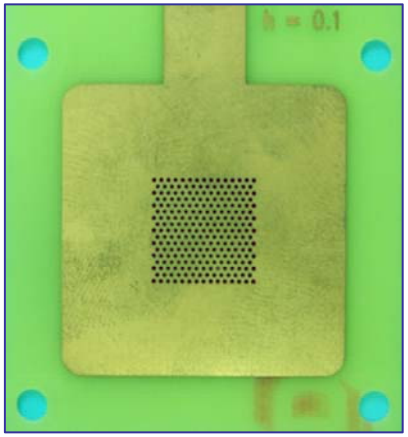
R. Chechik et al. NIM A535 (2004) 303-308
& R. Chechik et al. NIM A553 (2005) 35-40

Manufactured by standard PCB techniques of
precise drilling in G-10 (+other materials) and **Cu etching**.



ECONOMIC & ROBUST !

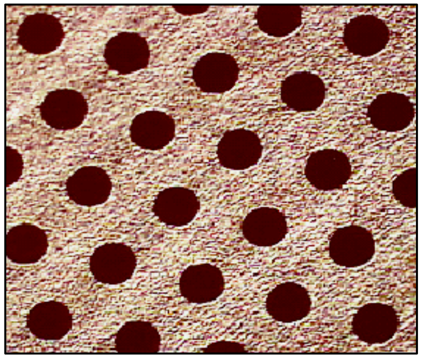
Hole diameter	d= 0.3 - 1 mm
Dist. Bet. holes	a= 0.7- 4 mm
Plate thickness	t= 0.4 - 3 mm



A small THGEM costs ~3$ /unit.
With minimum order of 400$ → ~120 THGEMs.
~10 times cheaper than standard GEM.

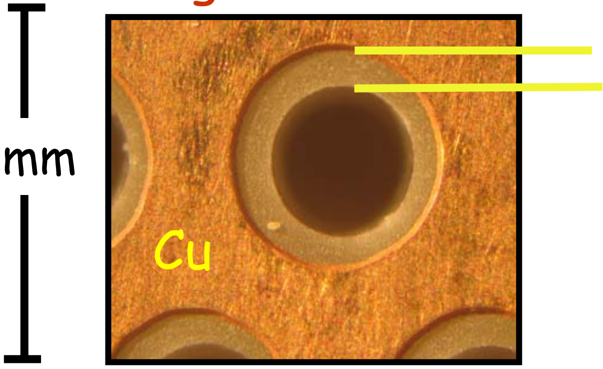
Standard GEM

10^3 gain in single GEM



THGEM

10^5 gain in single-THGEM



Important:
0.1mm G-10 rim.
reduces discharges
-> high gains!

Is THGEM an "Expanded" GEM ?

expanded

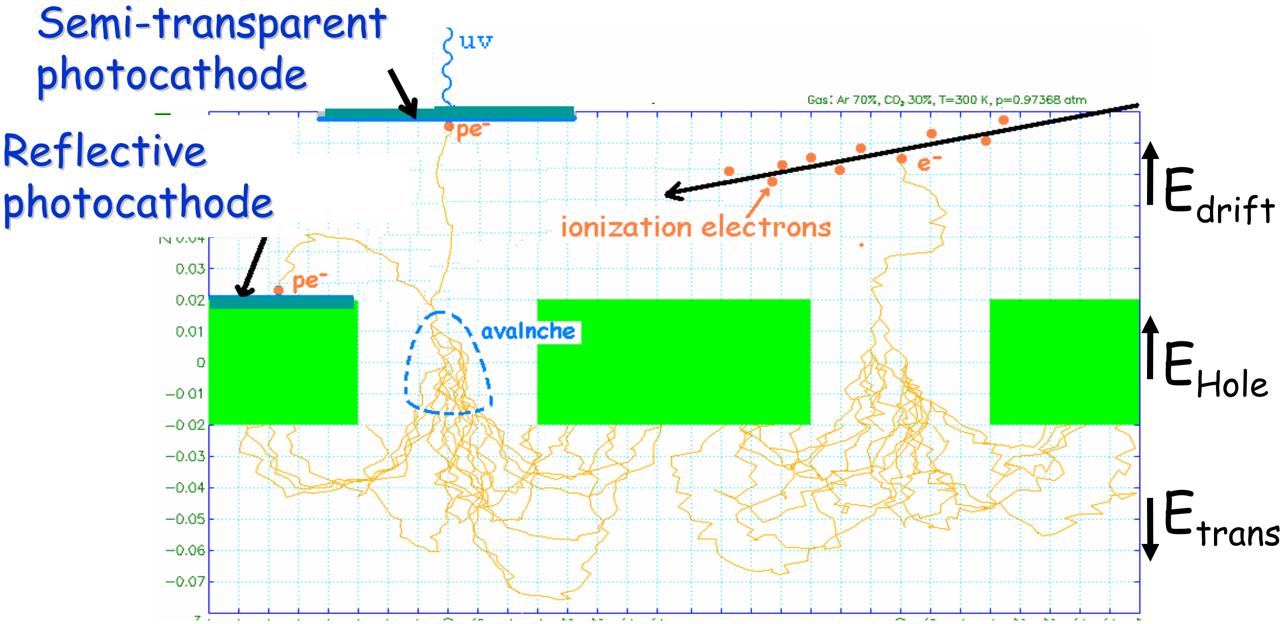
- The dimensions

does not scale up

- Electron diffusion & transport
- Electric fields
- Gain
- Timing properties
- Rate capability
- Ions transport

It is a new device that has to be studied.

Operation mechanism (role of all fields)



Garfield simulation of electron multiplication in Ar/CO_2 (70:30)

Need to study the effect of all fields on:

e^- and ion transport in/out holes

- -> efficiency to single-electron events
- -> cascade THGEMs
- -> ion backflow to the conversion gap

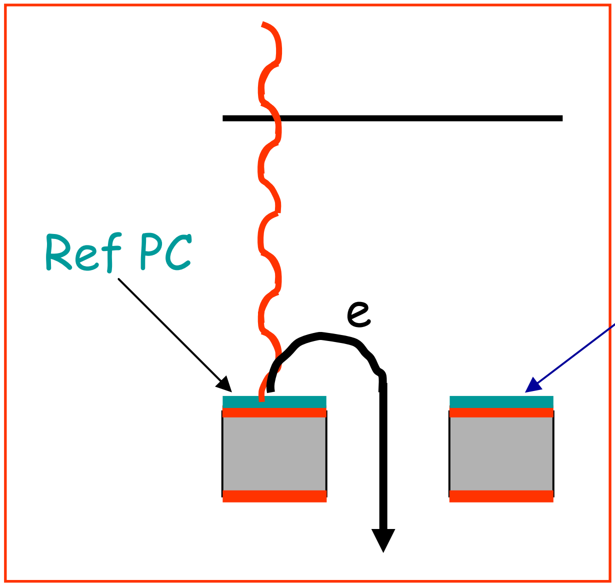
Electric fields at photocathode surface

- -> operation with solid photocathode

Gain, signal rise-time, rate capability, localization, etc

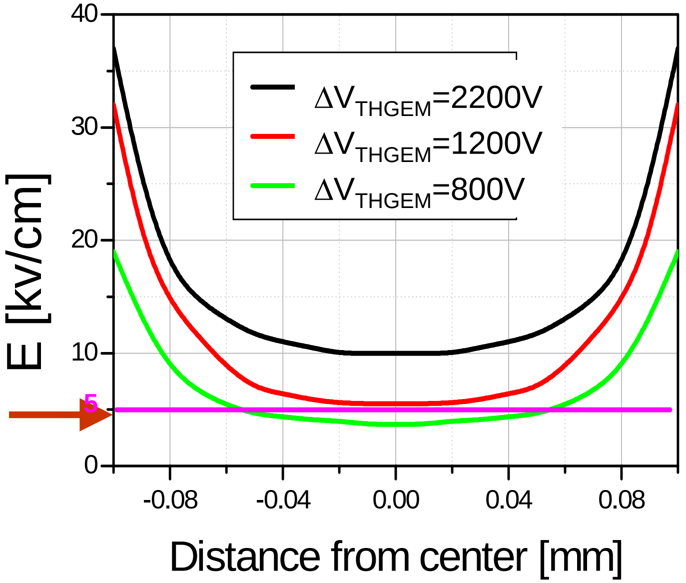
Example: Photon detector w reflective CsI PC deposited on the THGEM top face

(e.g. RICH photon detectors)



0.4mm thick
0.3mm holes
0.7mm pitch

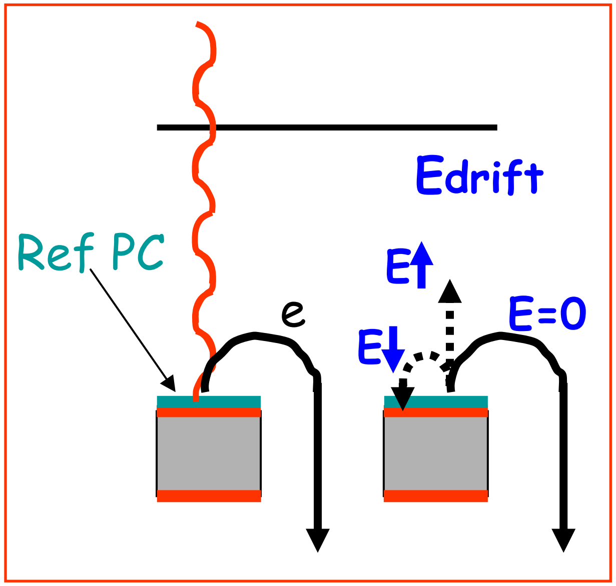
Electric field on photocathode surface created by the hole dipole field

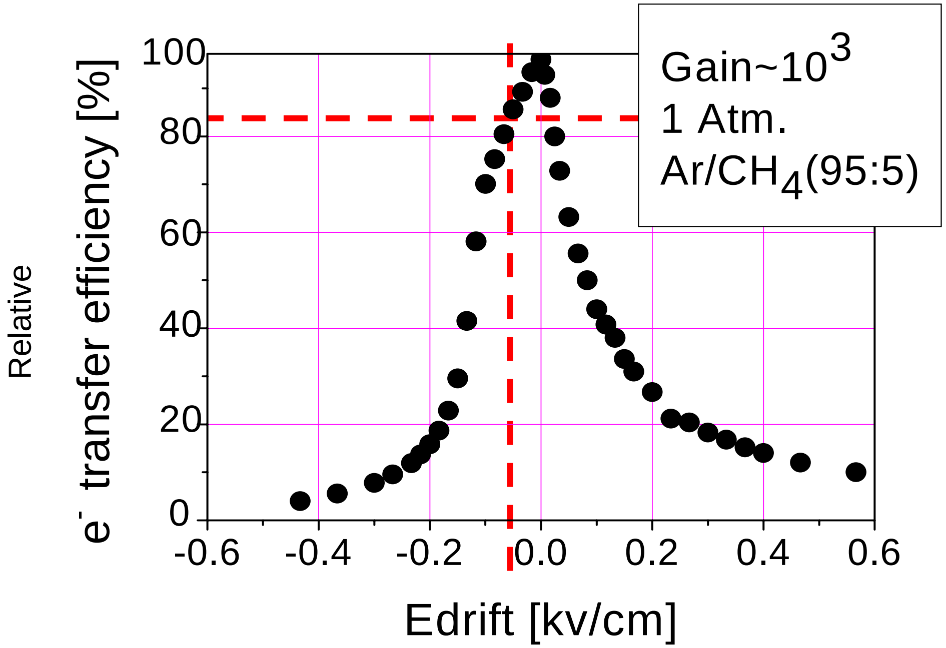


>3kV/cm

Require:
- High field on the PC surface (for high QE).
- Good e^- focusing into the holes (for high detection efficiency).
- Low sensitivity for ionizing background radiation (e.g. RICH).

Photon detector w reflective CsI PC deposited on the THGEM top face (2)

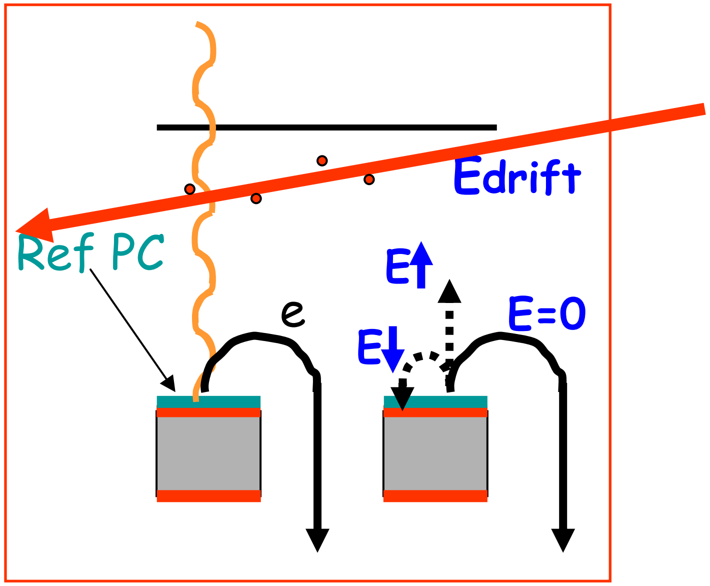


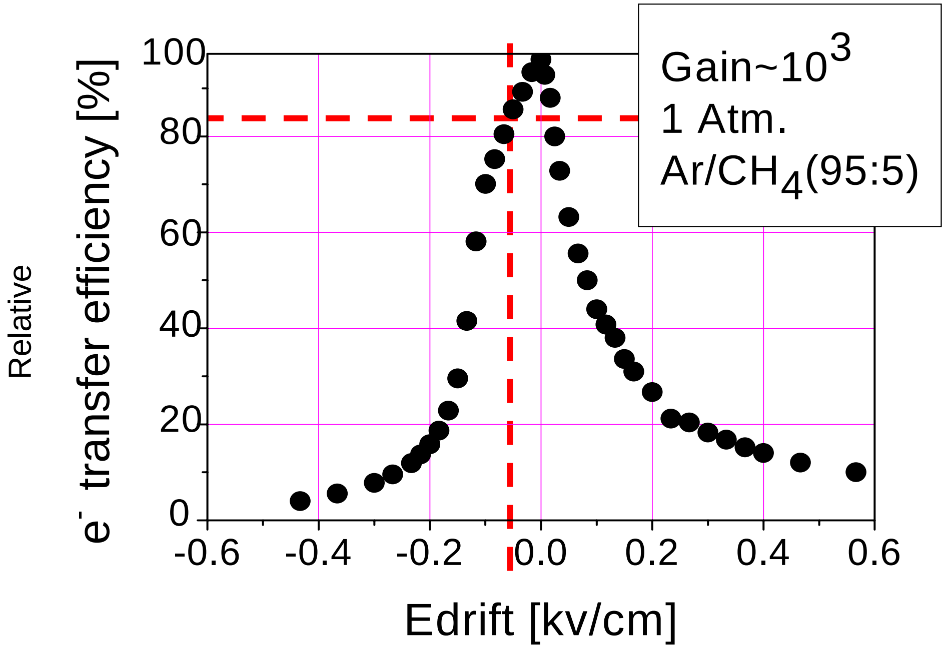


Focusing is done by hole dipole field.

- Maximum efficiency at E_{drift} =0.
- Slightly reversed E_{drift} (50-100V/cm) good photoelectron collection low sensitivity to MIPS !

Photon detector w reflective CsI PC deposited on the THGEM top face (2)





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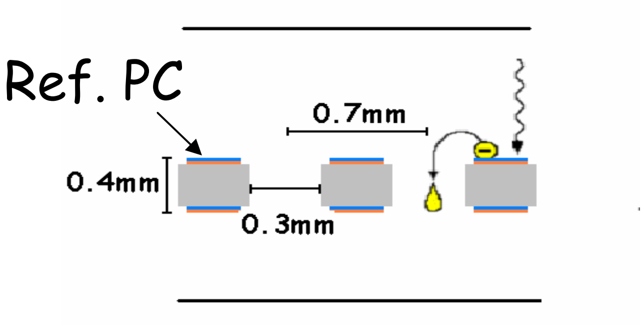
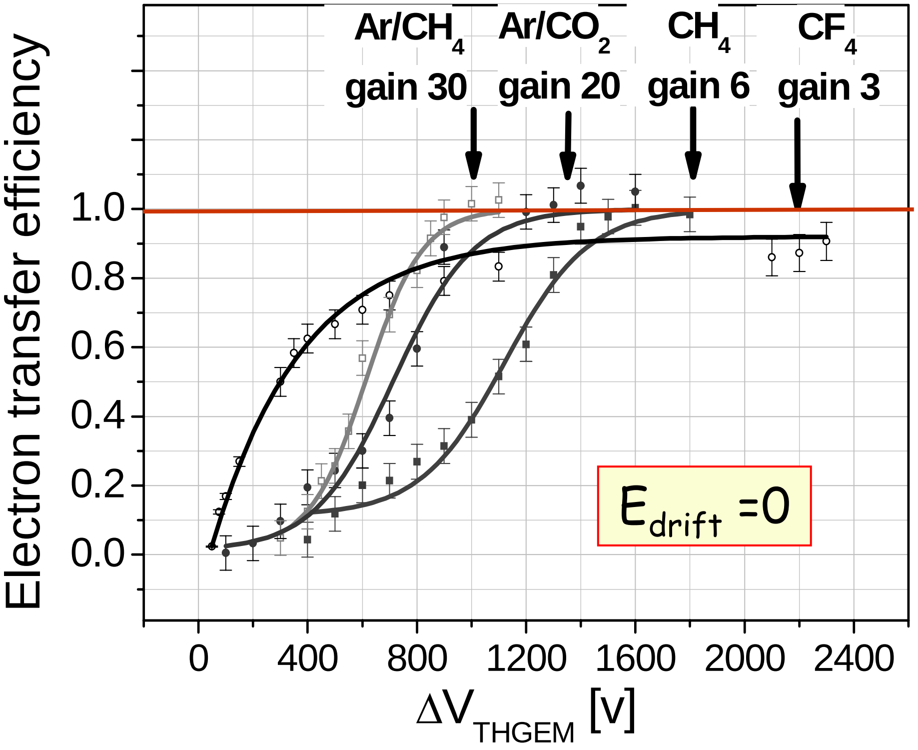
Single-THGEM: e^- transport into holes. Role of E_{hole}



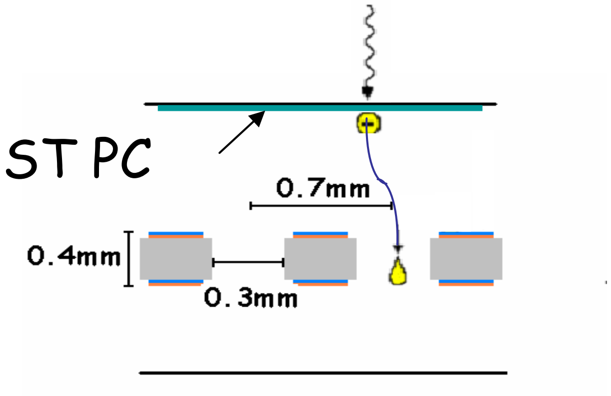


Full electron transfer efficiency into the holes, already at low gain.

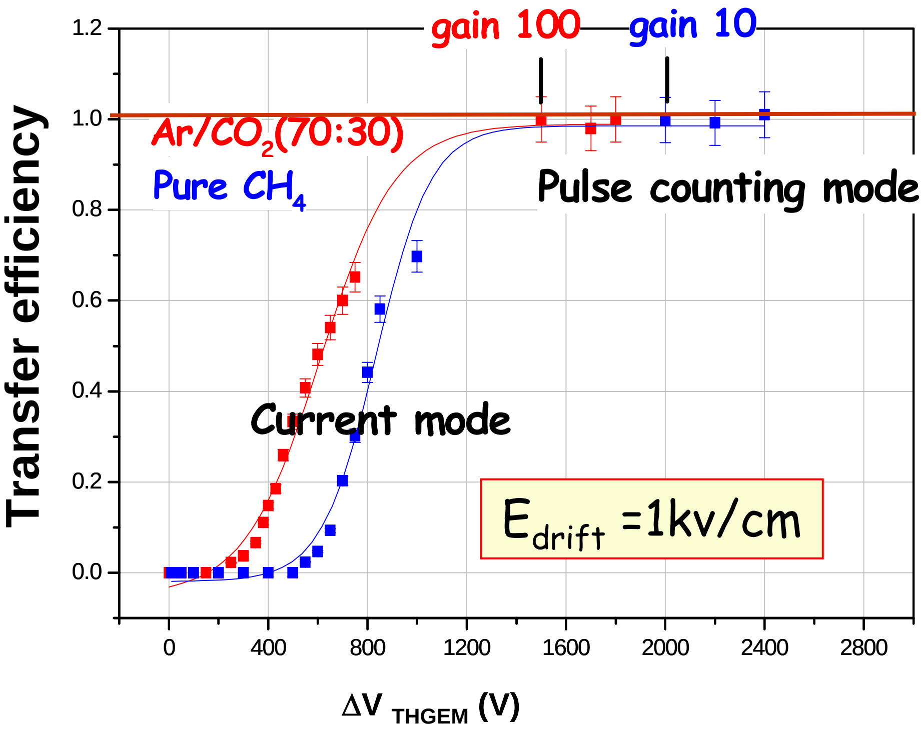
-> good single-electron detection efficiency

-> good energy resolution with highly ionizing radiation

Single-THGEM: e- transport into holes. Role of E_{hole} (2)



With ST PC require:
E_{drift} ~1kV/cm



Full electron transfer efficiency into the holes, already at low gain.

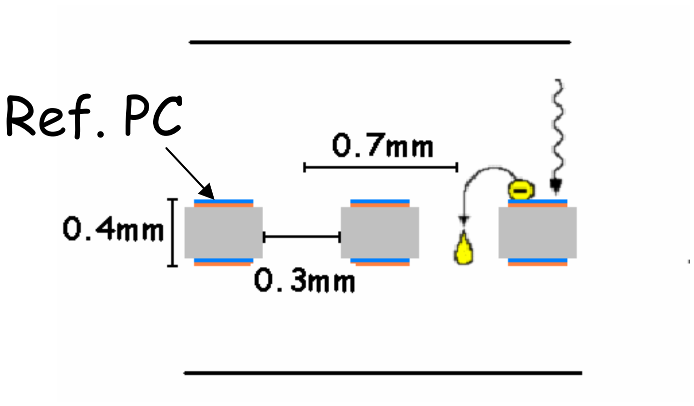
-> good single-electron detection efficiency

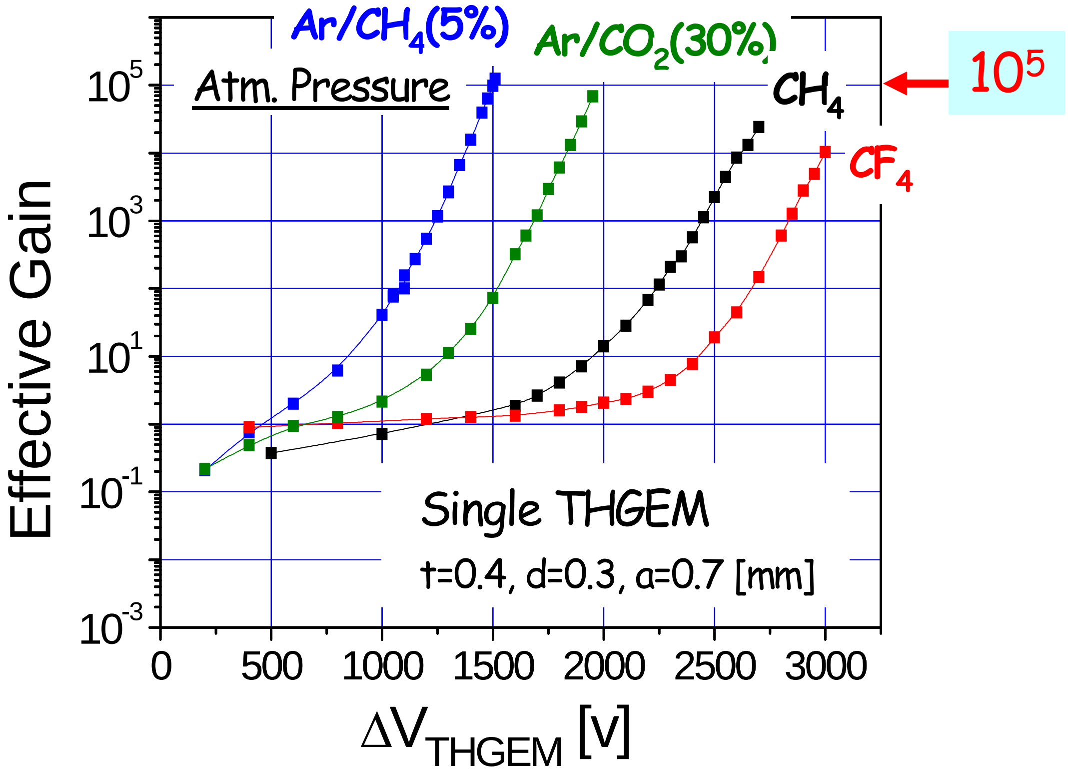
-> good energy resolution with highly ionizing radiation

Single-THGEM: gain

Example: THGEM photon detector with reflective CsI photocathode.

R. Chechik et al. NIMA553 (2005) 35-40

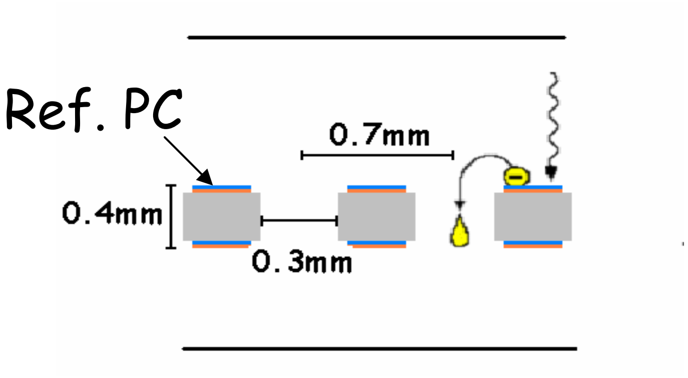


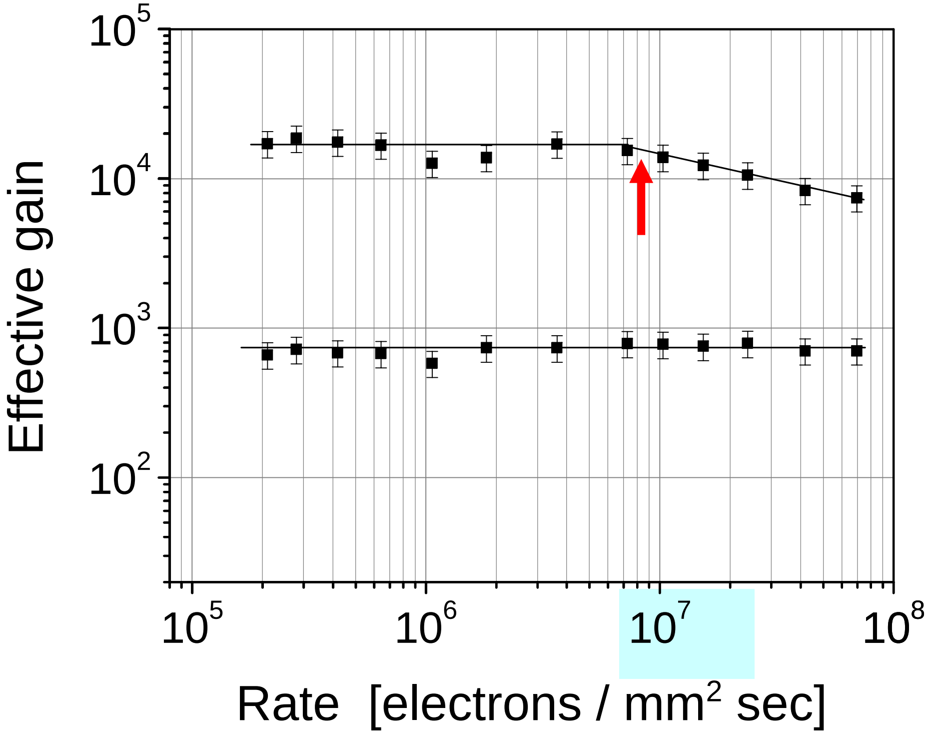


- Gain up to 10^4-10^5 with single electrons (sparks)

Similar gain w ST PC.

Single-THGEM: counting rate

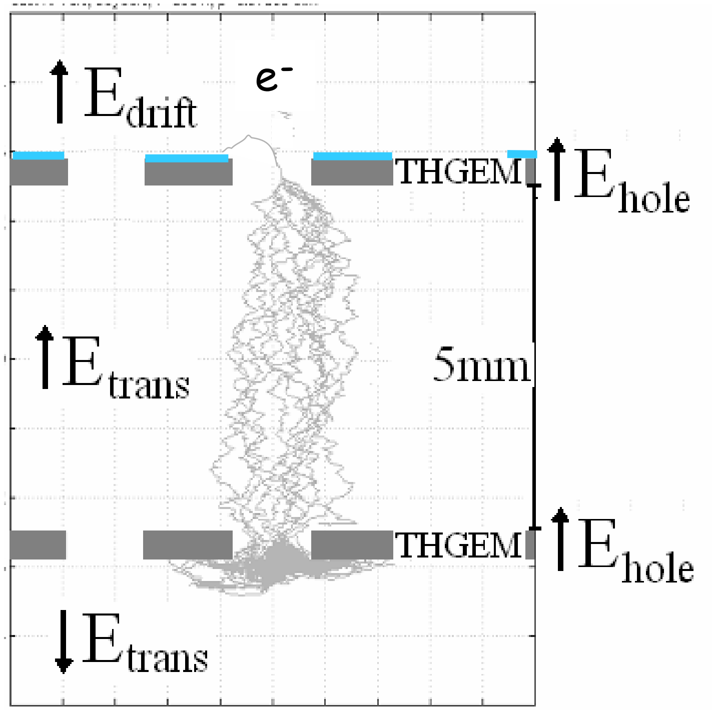




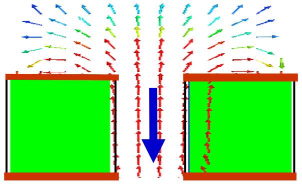
- Signal rise time < 10ns
- Rate capability: ~10MHz/mm^2 (space charge)

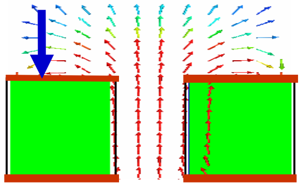
Double-THGEM: Cascaded operation role of E_{trans}

C. Shalem et al. NIM A558 (2006) 475-489



$E_{hole} > E_{trans}$
e^- focused into hole



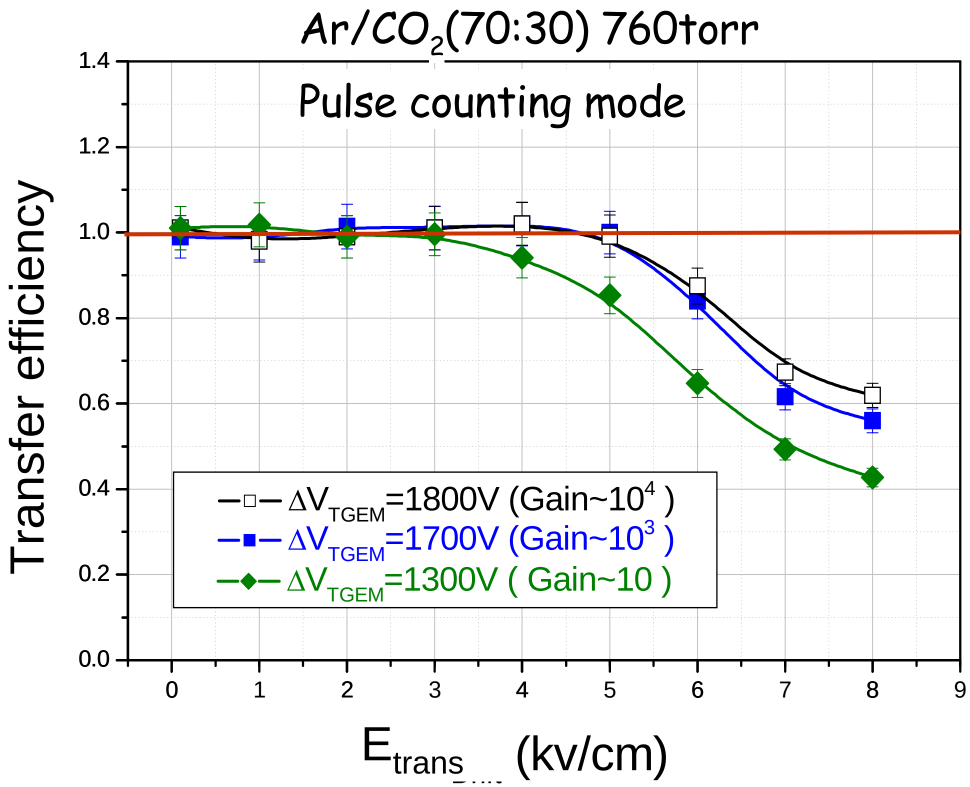


$E_{hole} < E_{trans}$
e^- collected on GEM top

Require: Large E_{trans} for good extraction from $THGEM_1$
Small E_{trans} for good focus sing into $THGEM_2$
→ Optimization

Double-THGEM: cascaded operation
Role of E_{trans} (2)

Both
0.4mm thick
0.3mm holes
0.7mm pitch

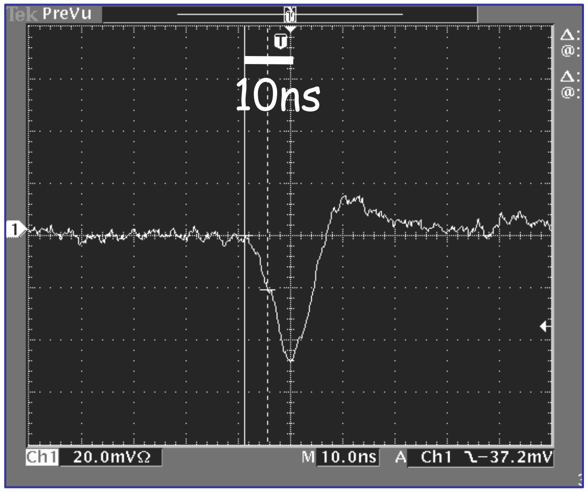


efficient transfer to the 2nd THGEM:

- up to high E_{trans} (e.g. 3kV/cm).
- at relatively low THGEM gains.

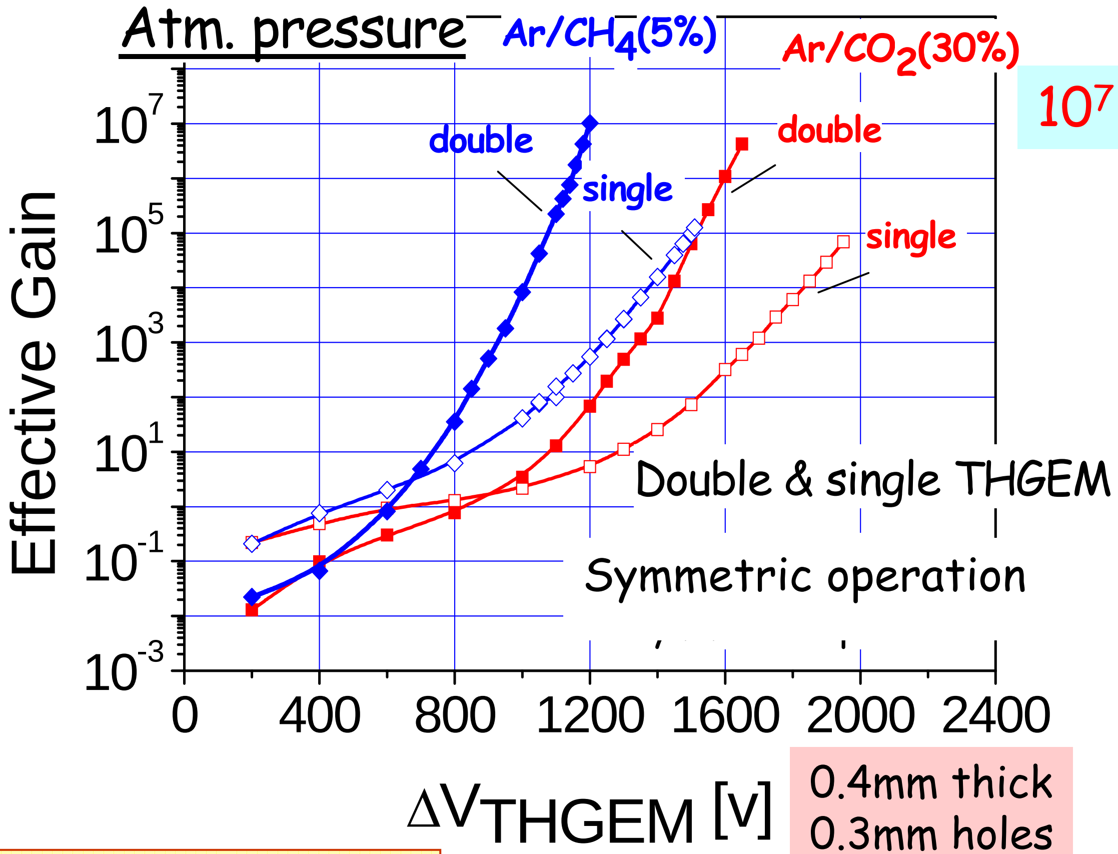
Double-THGEM multiplier: Gain, rise time

R. Chechik et al. NIMA553 (2005) 35-40



Fast signals, Double THGEM ($t=1.6mm$ $d=1mm$, $a=1.5mm$). Atm. Pressure $Ar/30\%CO_2$ Total gain=~ 10^6

$E_{trans}=3kV/cm$



10^7

Double & single THGEM

Symmetric operation

0.4mm thick
0.3mm holes
0.7mm pitch

- Higher total gain (10^6-10^7) w single e^-.
- >10^3 higher gain at <u>same</u> ΔV_{THGEM}
- Better stability

Double-THGEM multiplier: ion backflow

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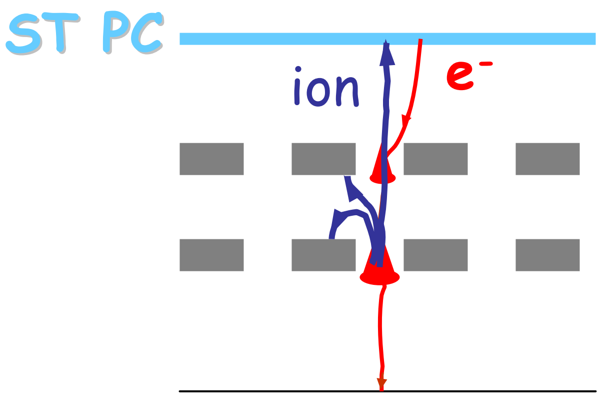
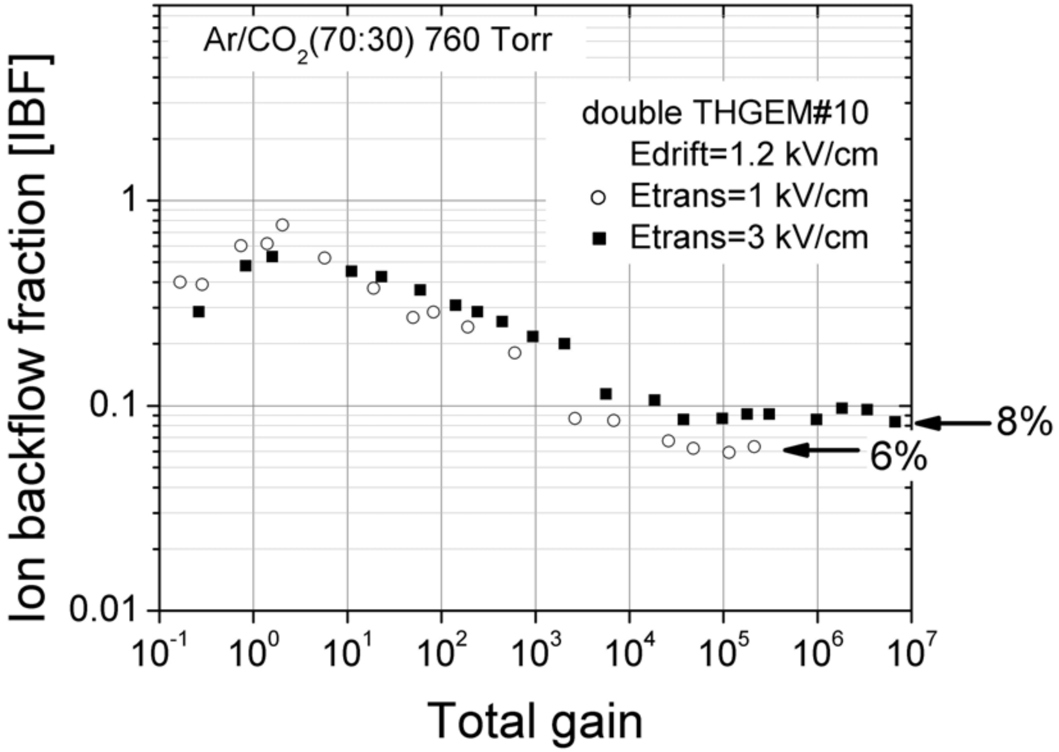
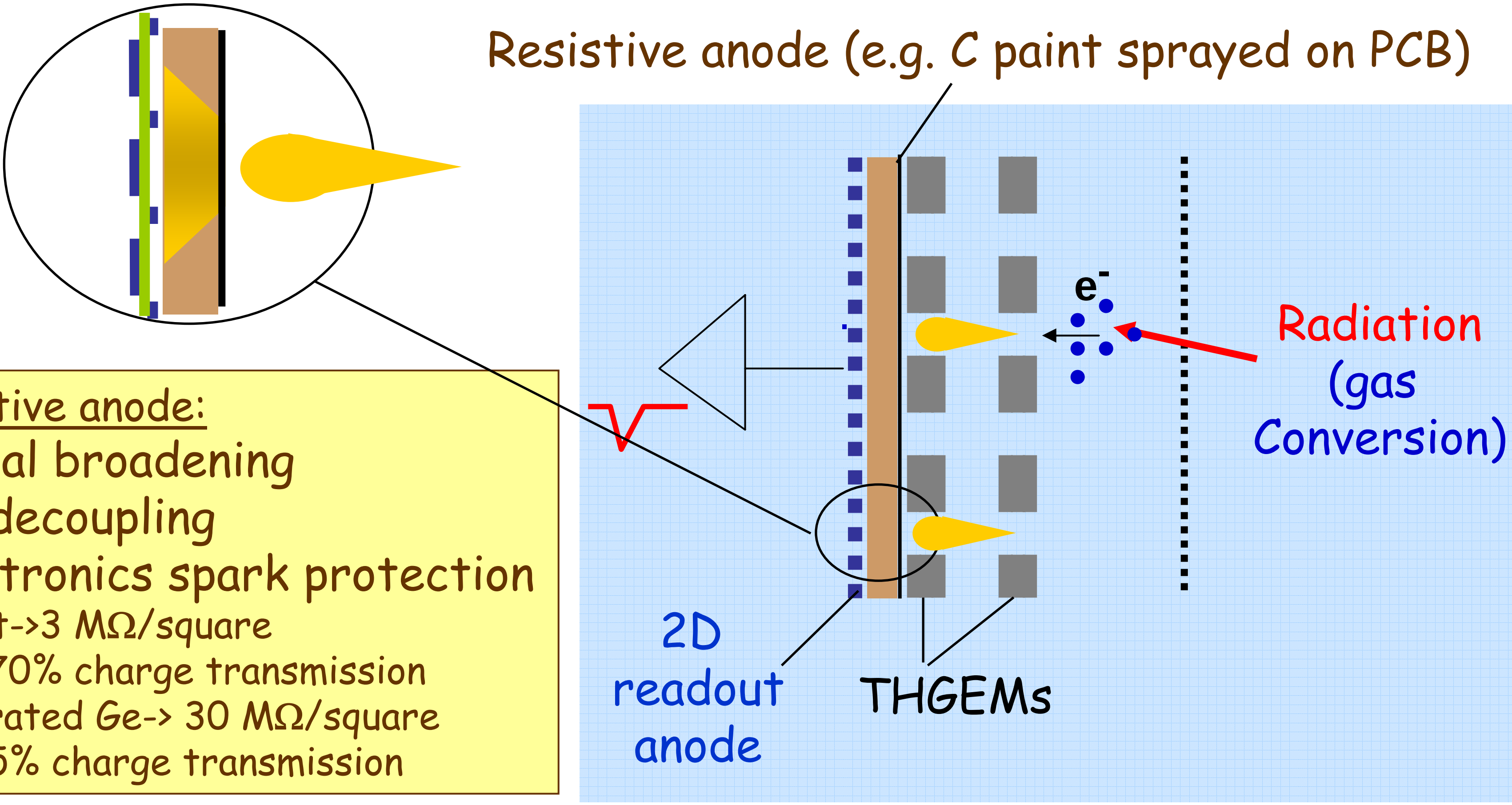




Ion backflow smaller than with 4-GEM multiplier.
Prolonged PC life-time.

2D double-THGEM detector: a <u>flat</u> imaging detector



<u>Resistive anode:</u>

- Signal broadening
- HV decoupling
- Electronics spark protection

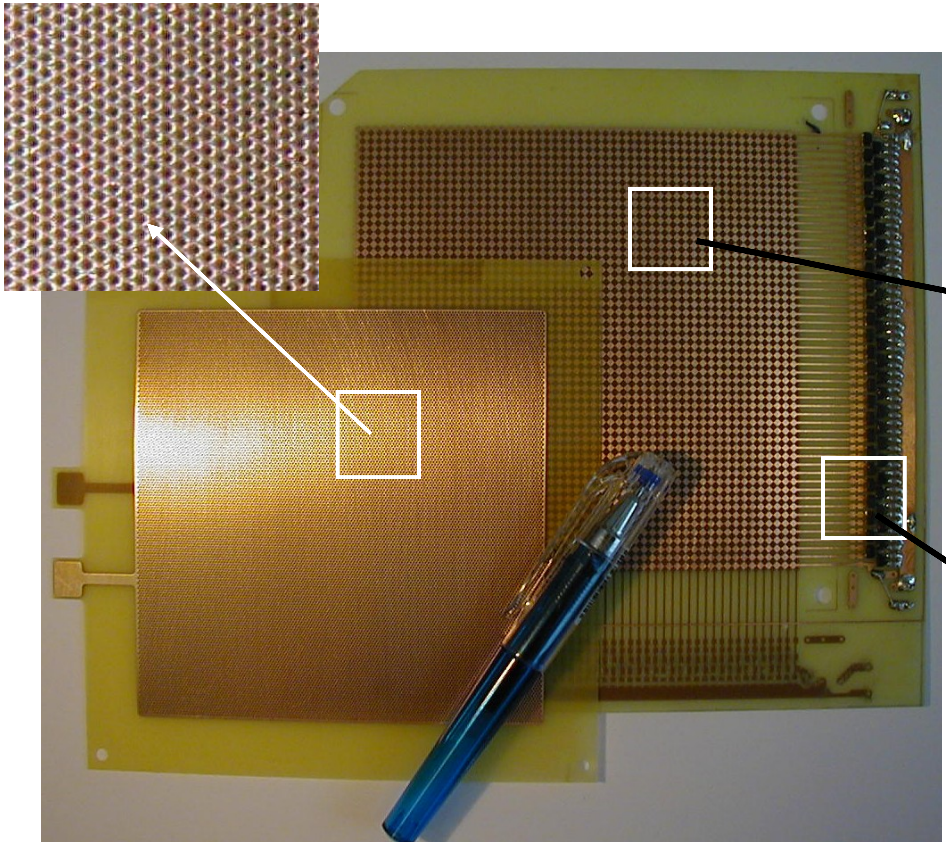
C paint->3 MΩ/square
-> ~70% charge transmission
evaporated Ge-> 30 MΩ/square
->~95% charge transmission

Simple and economic readout scheme.
Induced-signal width matched to readout-pixel size.

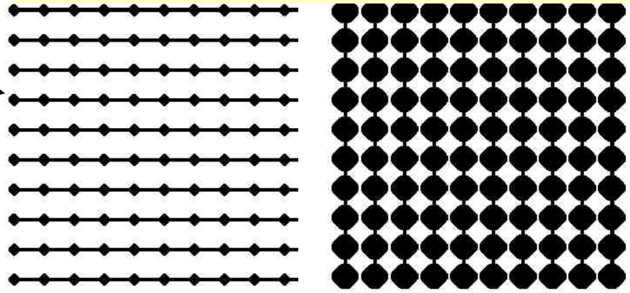
10x10 cm^2 2D double-THGEM detector

- 2x 10x10cm^2 THGEM
- 2-sided pad-string anode (0.5mm thick)
- Delay-line readout (SMD)

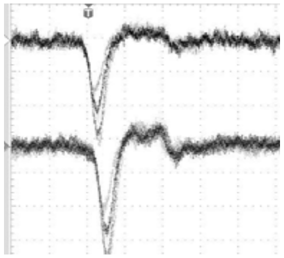
0.4mm thick,
0.5mm Ø holes,
1mm pitch



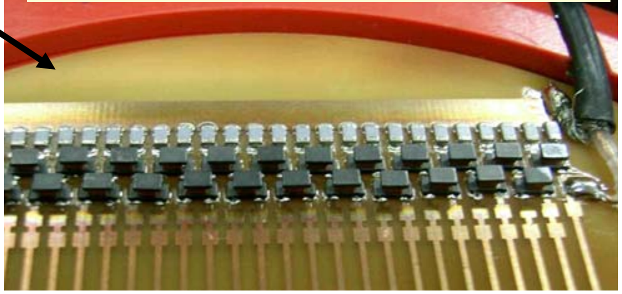
front side back side



X & Y
DL-signals



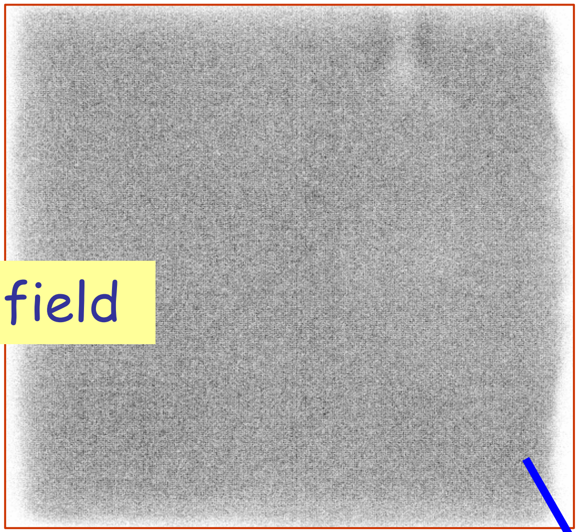
2 mm pitch, 1.35ns/mm



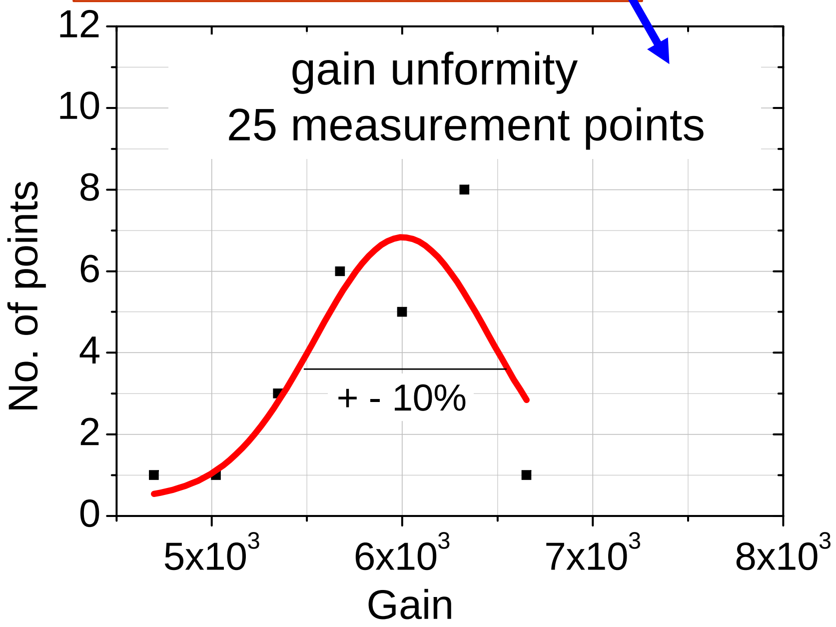
Gain and uniformity

Ar/CH4 (95:5)   8keV x-rays
Conversion gap = 10 mm, 1kV/cm
Transfer Gap   = 2 mm, 3.5 kV/cm
Induction Gap   = 1 mm, 4 kV/cm
ΔV_{THGEM}=1210 Volt

Gain =6×10^3

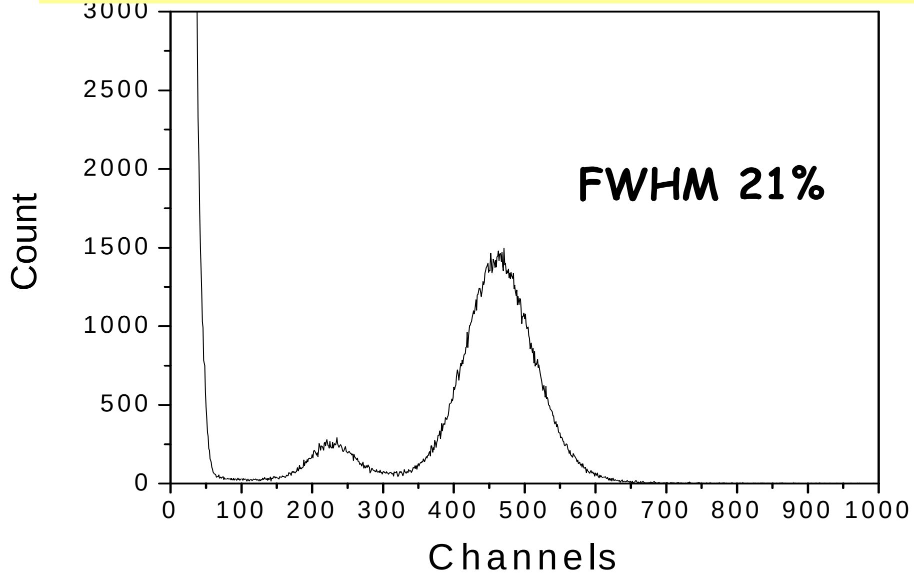


Flat field



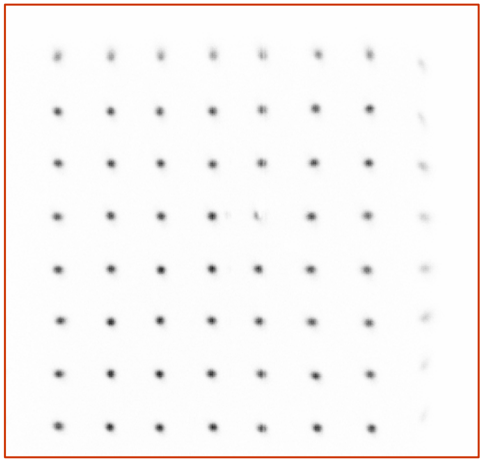
Energy resolution

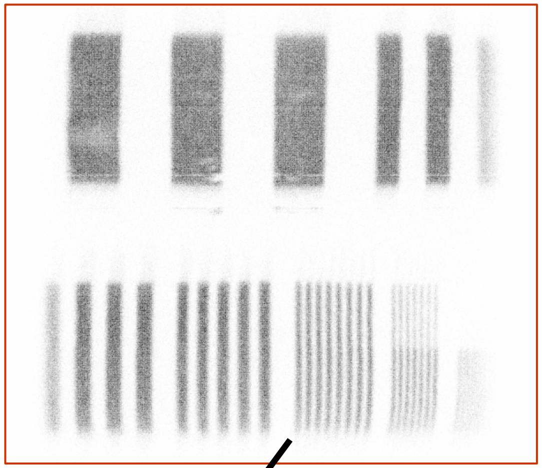
Local energy spectrum of 6 keV x-rays

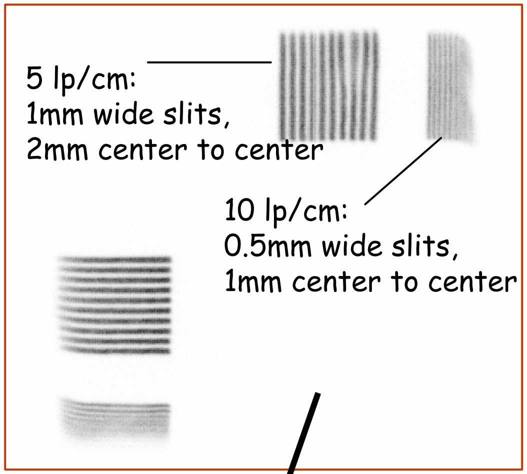


Localization : linearity, resolution

Gain =6x10^3

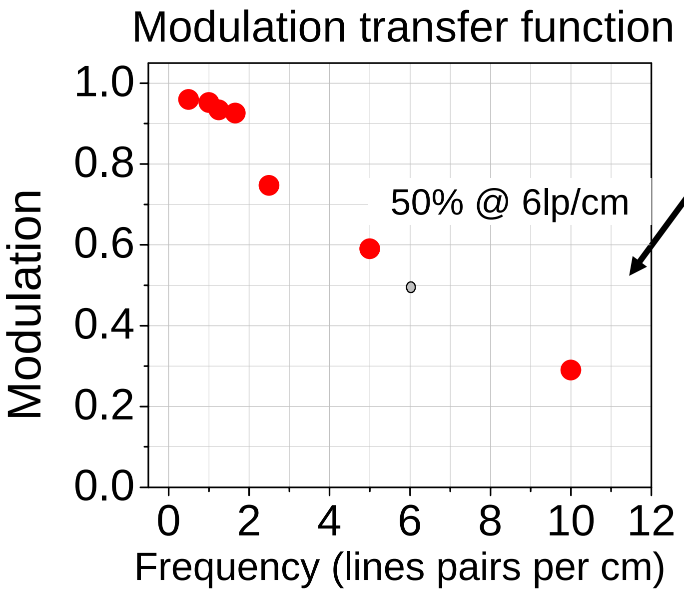




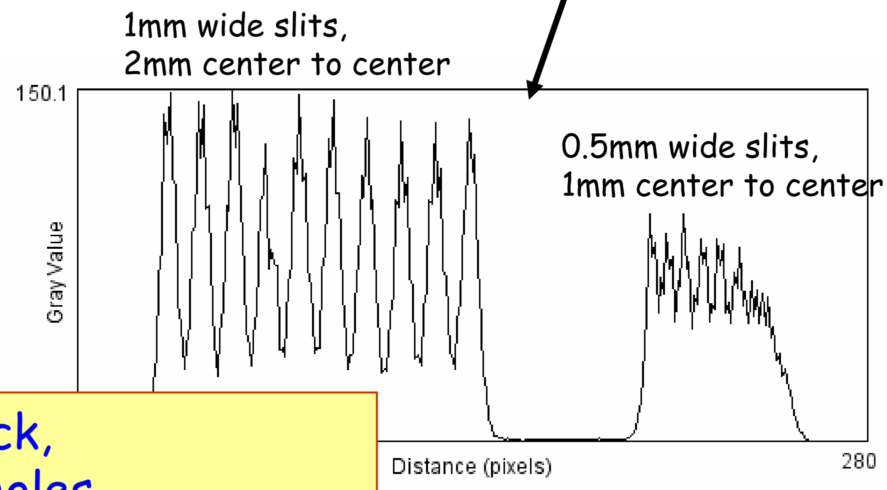


5 lp/cm:
1mm wide slits,
2mm center to center

10 lp/cm:
0.5mm wide slits,
1mm center to center



50% @ 6lp/cm



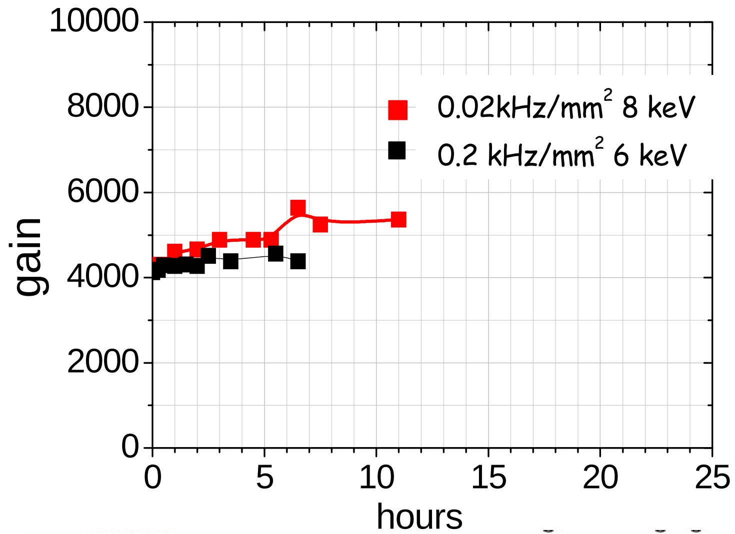
1mm wide slits,
2mm center to center

0.5mm wide slits,
1mm center to center

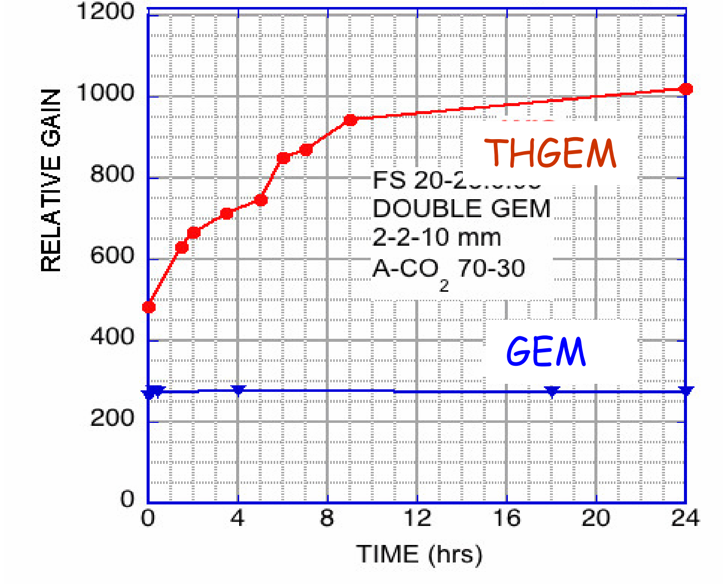
0.4mm thick,
0.5mm Ø holes,
1mm pitch

Sub-mm resolution !

Long-term stability



Our 10x10 cm^2 double THGEM detector
Ar/CH$_4$, 6 & 8 keV x-rays, low rate
~25% changes



Sauli:
double THGEM, Ar/CO$_2$, 6keV x-rays, 1kHz/mm^2.
Stabilize ~12 hours, x2 gain rise.

- Charging up?
- Insulator polarization?

results from
HV? Rate? total current? history?

SNIC @ SLAC April 2006

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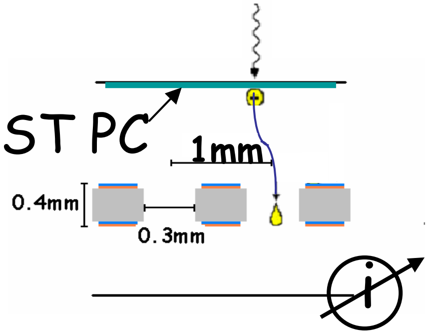
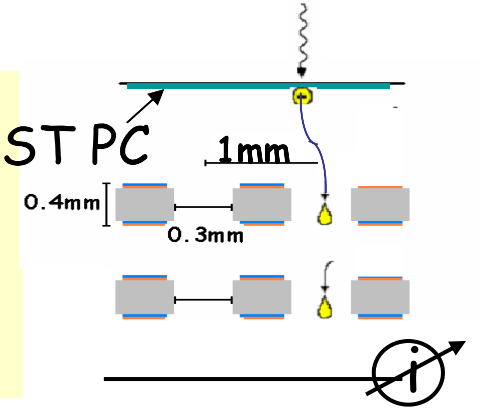
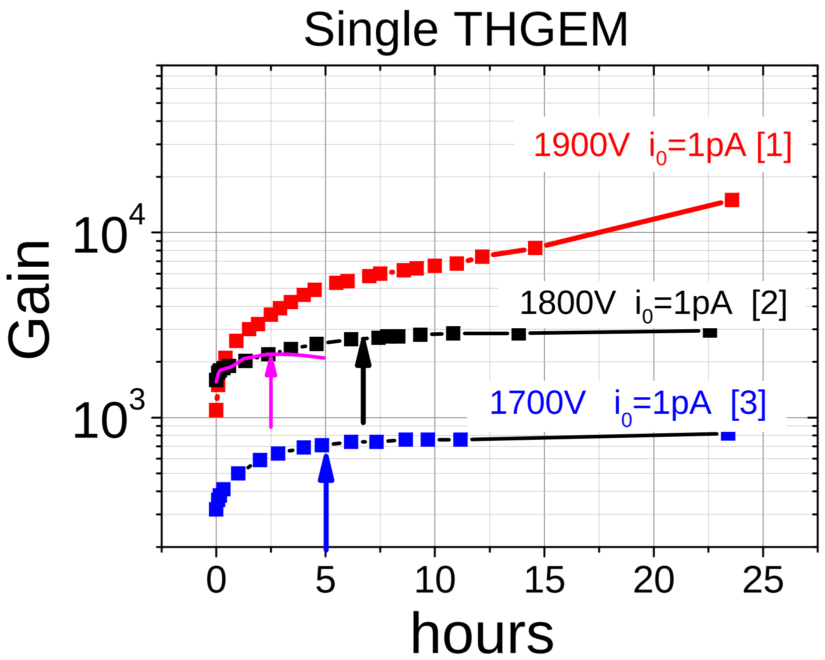
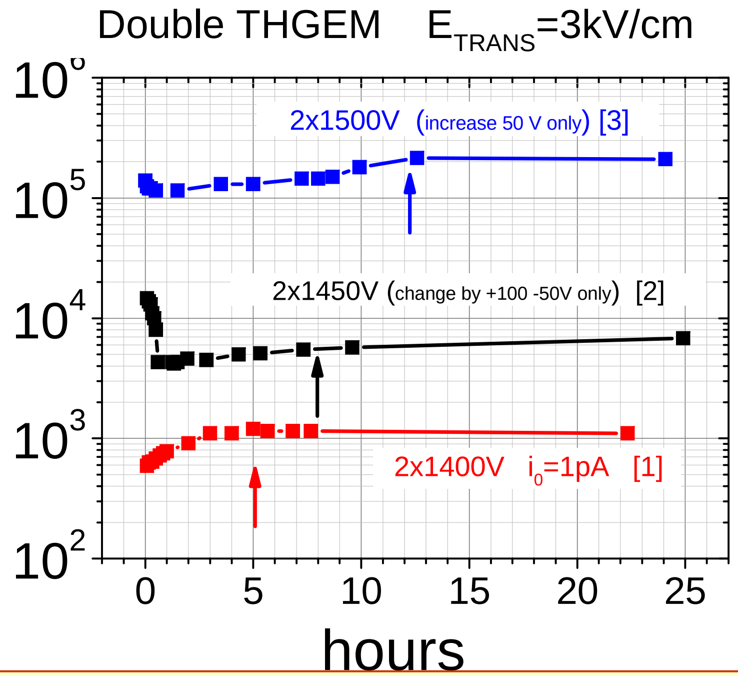
Long-term stability (2)



- Measured currents w UV + ST PC.
- E_{drift}=0.15kV/cm.
- Initial flux 5×10^5 e^-/mm^2 (~1kHz/mm^2 x-ray). Could not be raised due to PC decay.
- Possible additional effects from p, temp & HV instability.



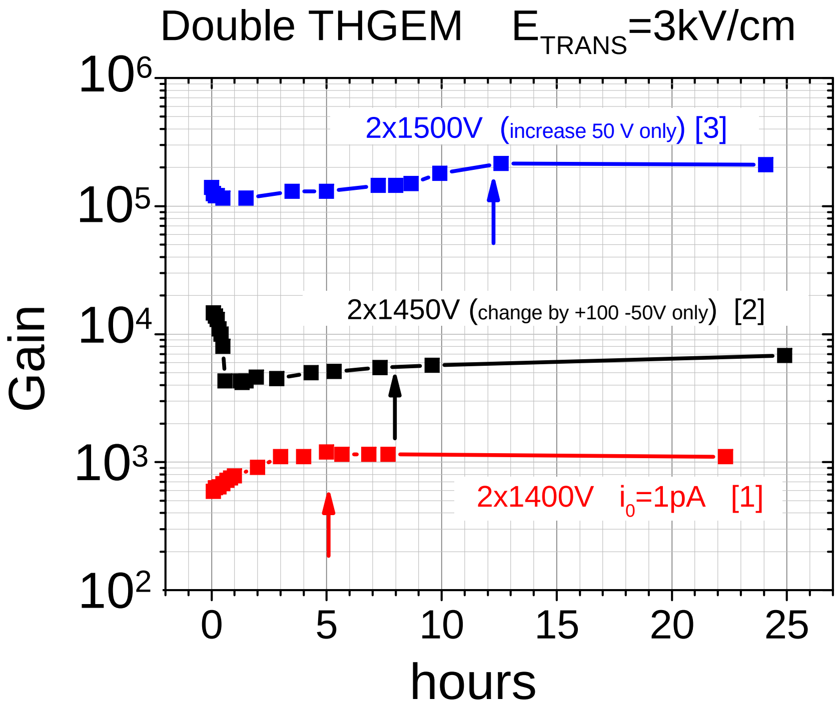




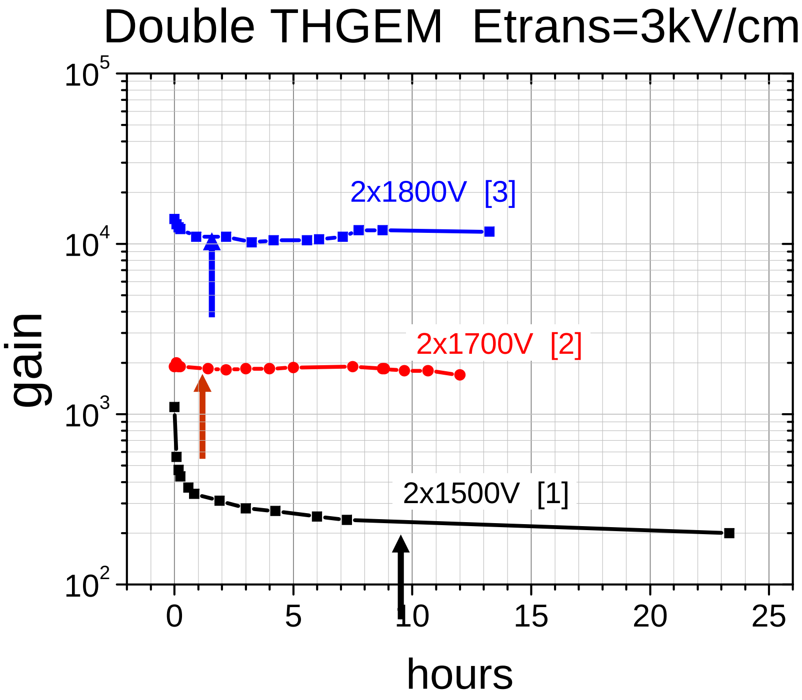
- THGEMs require a few hours of stabilization.
- Stabilization time depends on total gain/current.
- gain variation ~ factor 2.
- could depend on history (time after THGEM & gas introduction).

Long-term stability (3)

0.4mm thick,
0.3mm Ø holes,
1mm pitch



0.4mm thick,
0.6mm Ø holes,
1mm pitch



- Larger hole → shorter stabilization time. Effect of the bare insulator??
- Evidence for combined dependence on history + total gain/current

Planned studies

1. Systematic study on **long-term stability** vs. **rate** (with x-ray).
2. Understanding the **effect of the 0.1 mm rim** (e.g. reduce it).
3. Studying THGEMs of different **materials**;
   e.g. CIRLEX = polyimide (Kapton).

Applications

LARGE-AREA DETECTORS, ROBUST, MODERATE COST

ns, sub-mm, MHz/mm^2

- **Particle** tracking at moderate (sub-mm) resolutions.

  e.g. muon-detector @LHC2.
- **TPC** readout.
- Sampling elements in **calorimetry**. (ILC??)
- Readout of light from LXe detector (XENON).
- Moderate-resolution, fast (ns) **X-ray** and **n** imaging.
- **Single-photon** imaging.

  e.g. Ring Imaging Cherenkov (**RICH**) detectors (presently w GEMs).

advantages: robust,
high eff. for single photons,
low sensitivity to ionizing BG.