PHENIX meeting
Montaux, March 21-23, 2001

GEM photomultipliers with CsI photocathodes:

A possible solution for RICH

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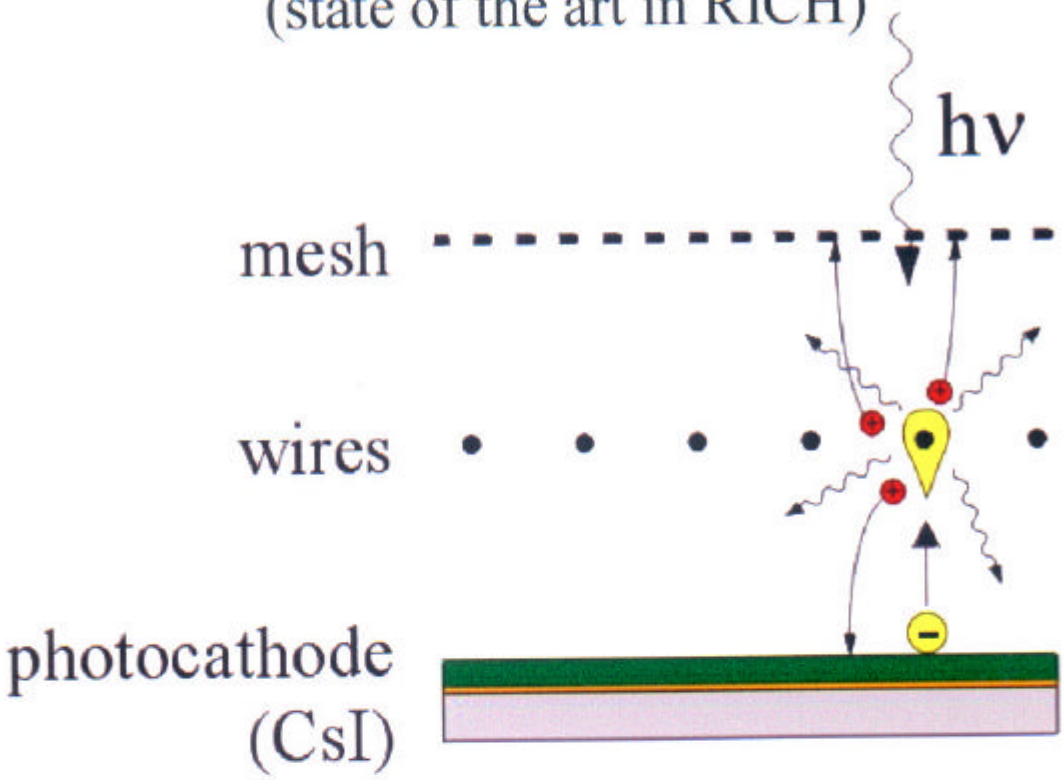
D.Moermann

- Gas-avalanche detectors + solid photocathodes
- CsI-based detectors
- Multi-GEM PMTs
- Operation with CF_4
- Discussion

A gaseous photon detector

(state of the art in RICH)

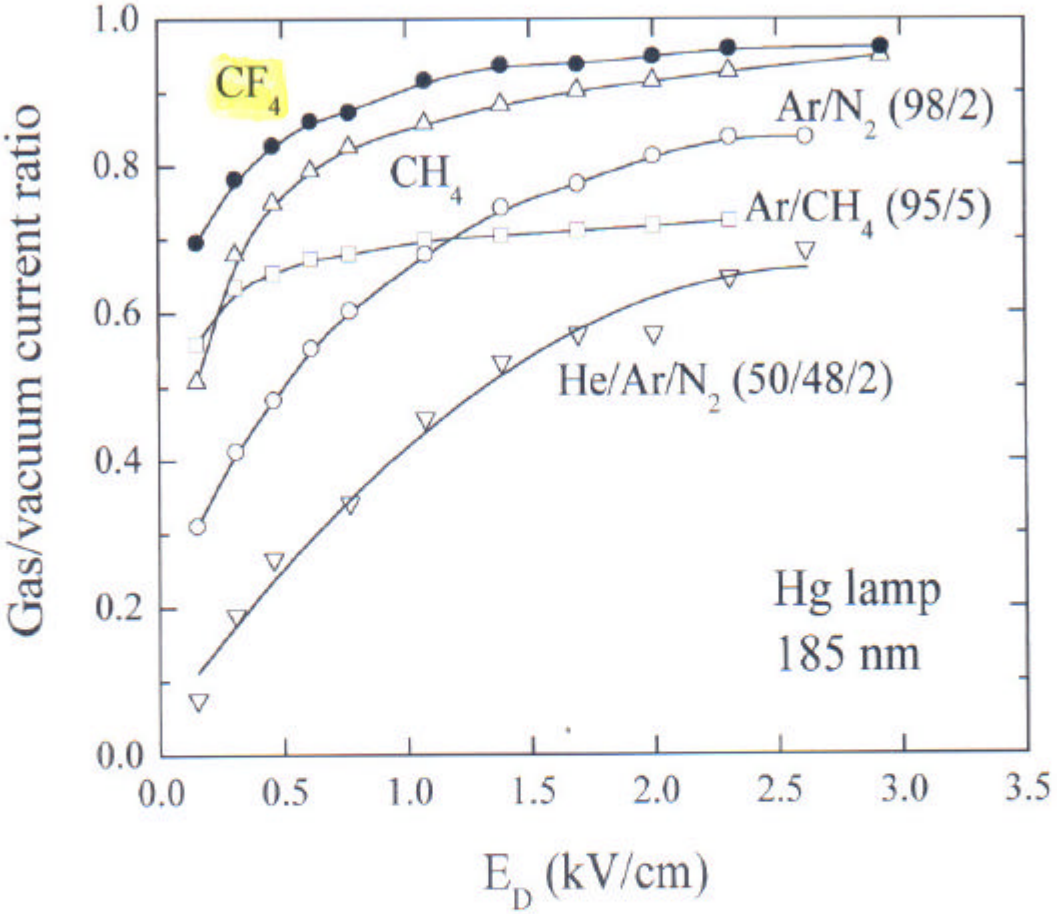


But: photon and ion feedback
=> limited gain and/or lifetime
=> limited localization resolution

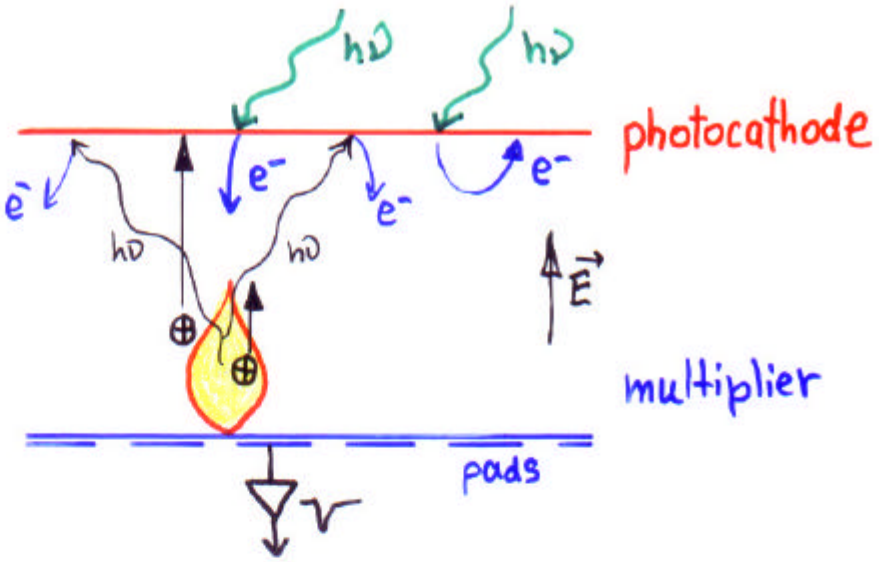
Present applications: ALICE, COMPASS (CERN)
HADES (GSI)
STAR (BNL)
etc.

F. Piuz et al. NIM A 433 (1999) 178

Backscattering effect



Factors governing single-photon detection



QE

- photocathode deposition method

Electron extraction efficiency

- backscattering, f(gas, E/p @ pc surface)

Detector efficiency

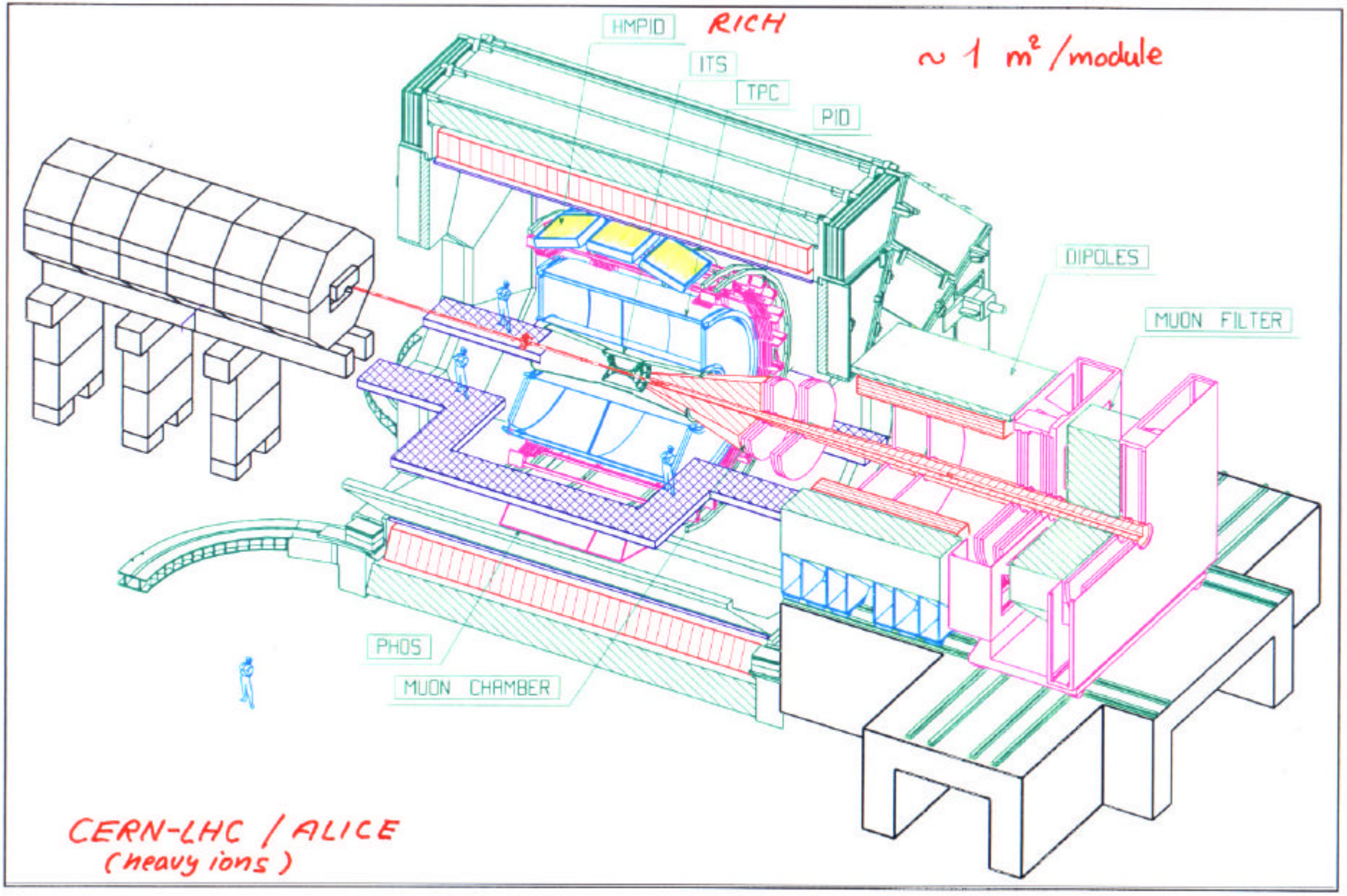
- max gain (under "real" exp.conditions)
- S/N (pad size, integration time…)

Timing & localization properties

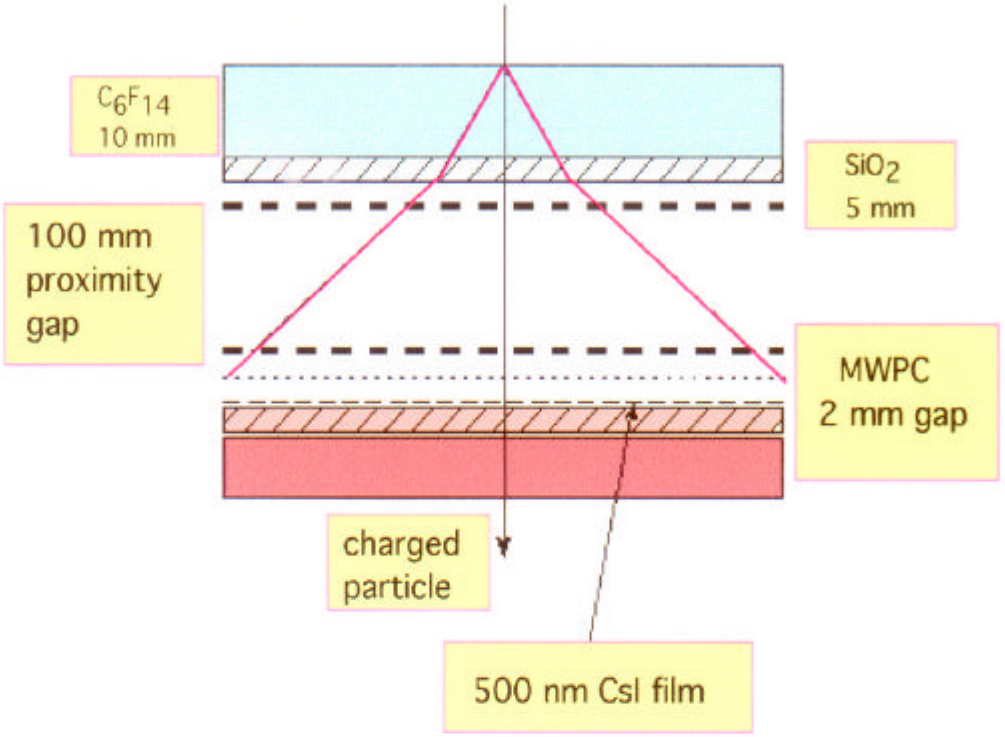
- both are inherently very good (surface-photoemission). Generally "spoiled" by readout. Beware of photon-feedback!

Photocathode stability

- photocathode aging (chemical, ion-feedback)


HMPID
RICH
ITS
TPC
PID
~ 1 m²/module
DIPOLES
MUON FILTER
PHOS
MUON CHAMBER
CERN-LHC / ALICE
(heavy ions)

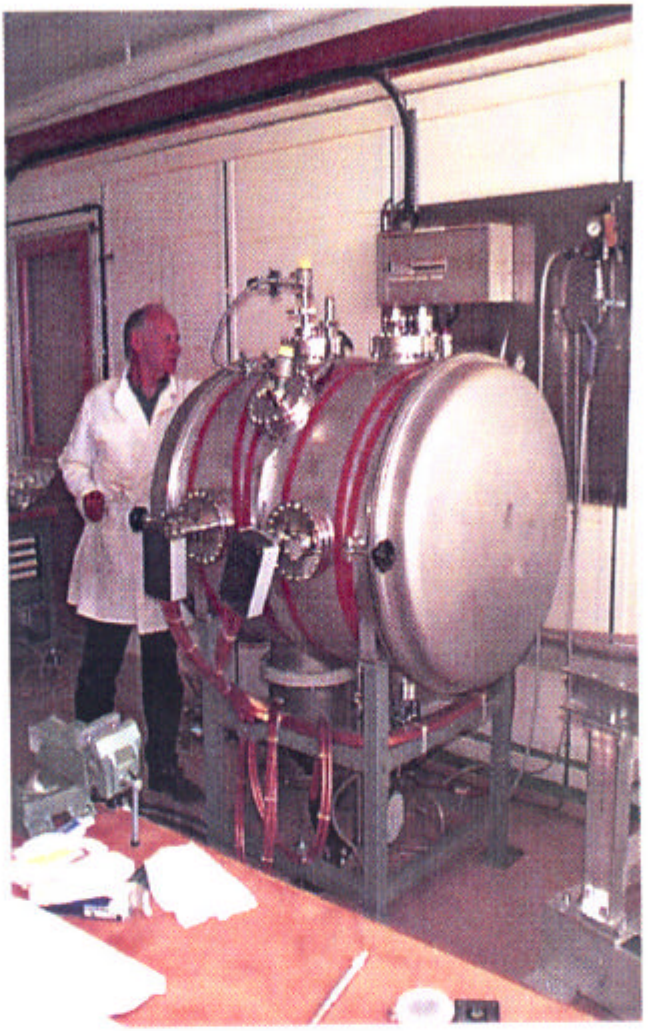
THE HMPID CsI-RICH CONFIGURATION

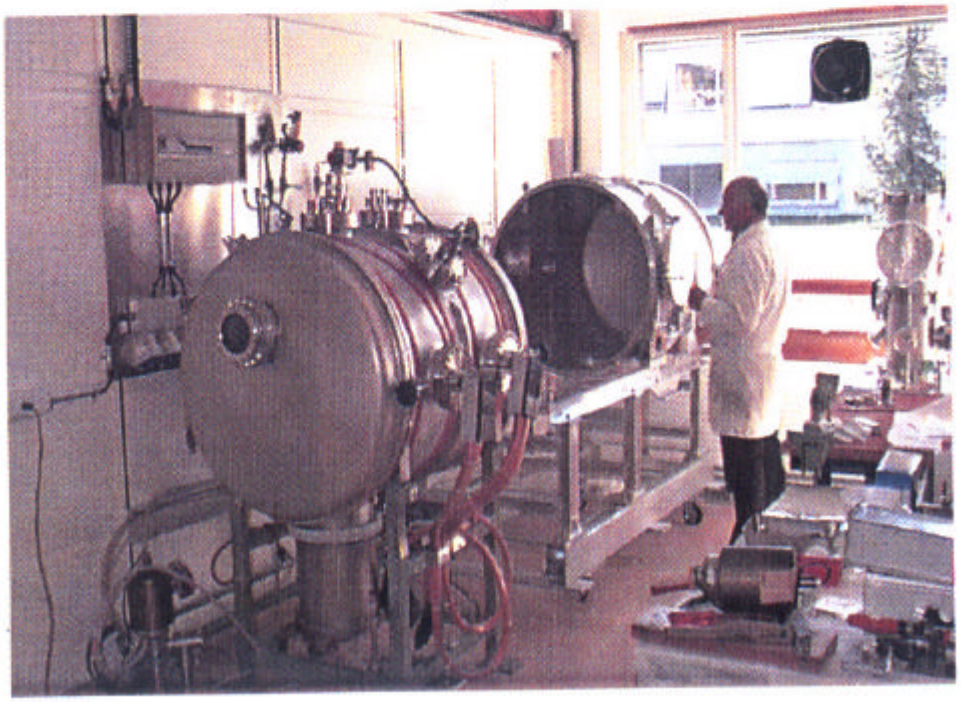


- **Radiator**: 10 mm of C_6F_{14} (n=1.28 @ 7 eV)
- **Photodetector**: MWPC operated with CH_4, 8x8 mm^2 pads, 2 mm gap, 4 mm pitch, 20 μm anode wires
- **Electronics**: VLSI 16 channel chip DIGITPLEX, with locally multiplexed 10 bit digitization and zero suppression (full conversion in less than 4 μs)

production of large area CsI photocathodes

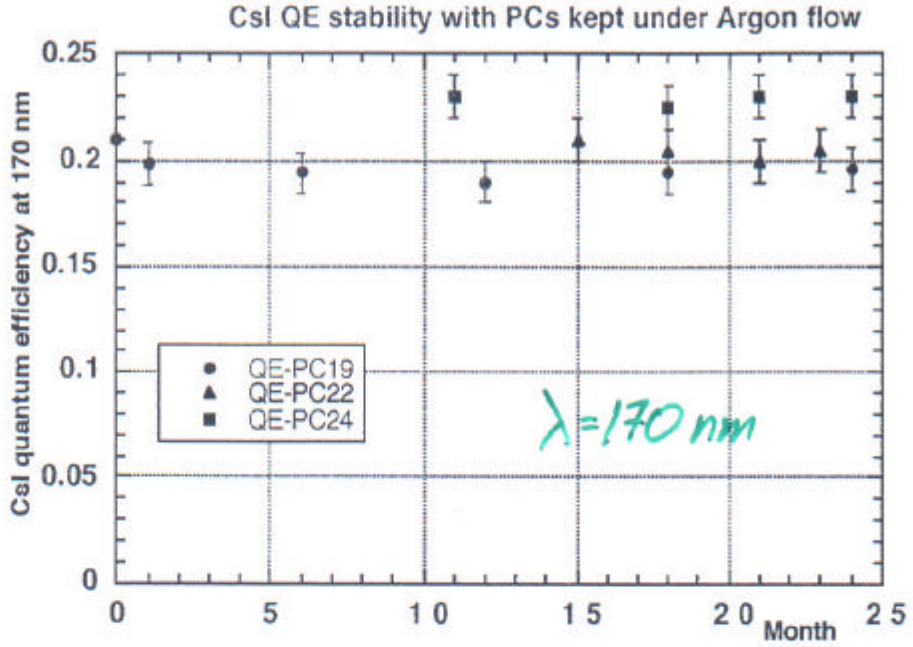
A. Braem
CERN



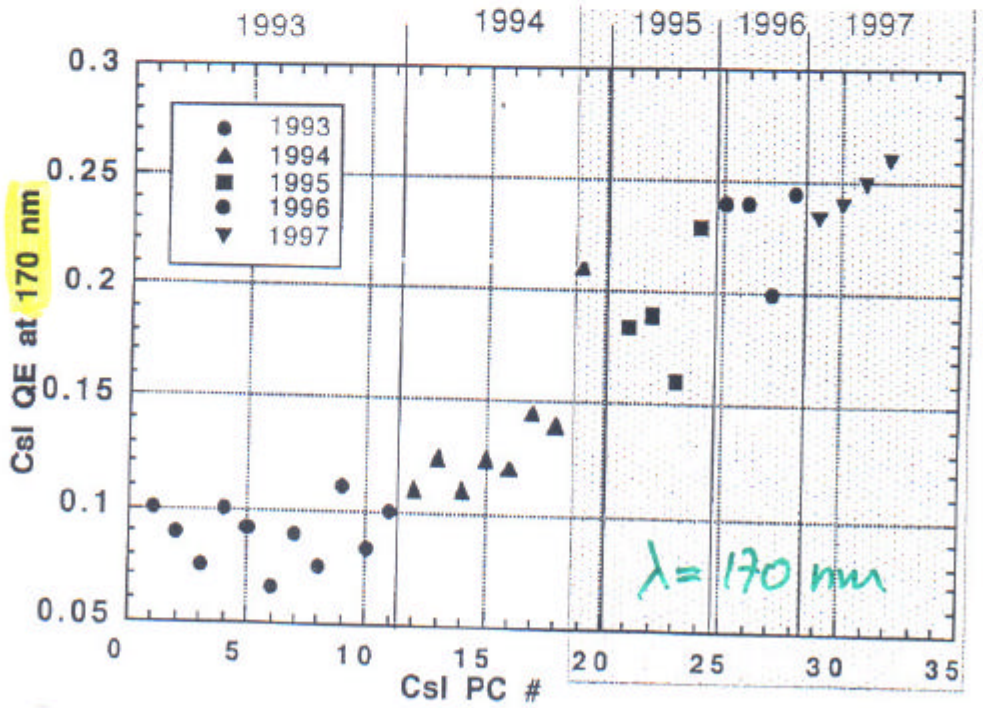


HMPID: fast RICH with CsI pad photocathode

==> Photo-electric yield (QE): stable over 2 years

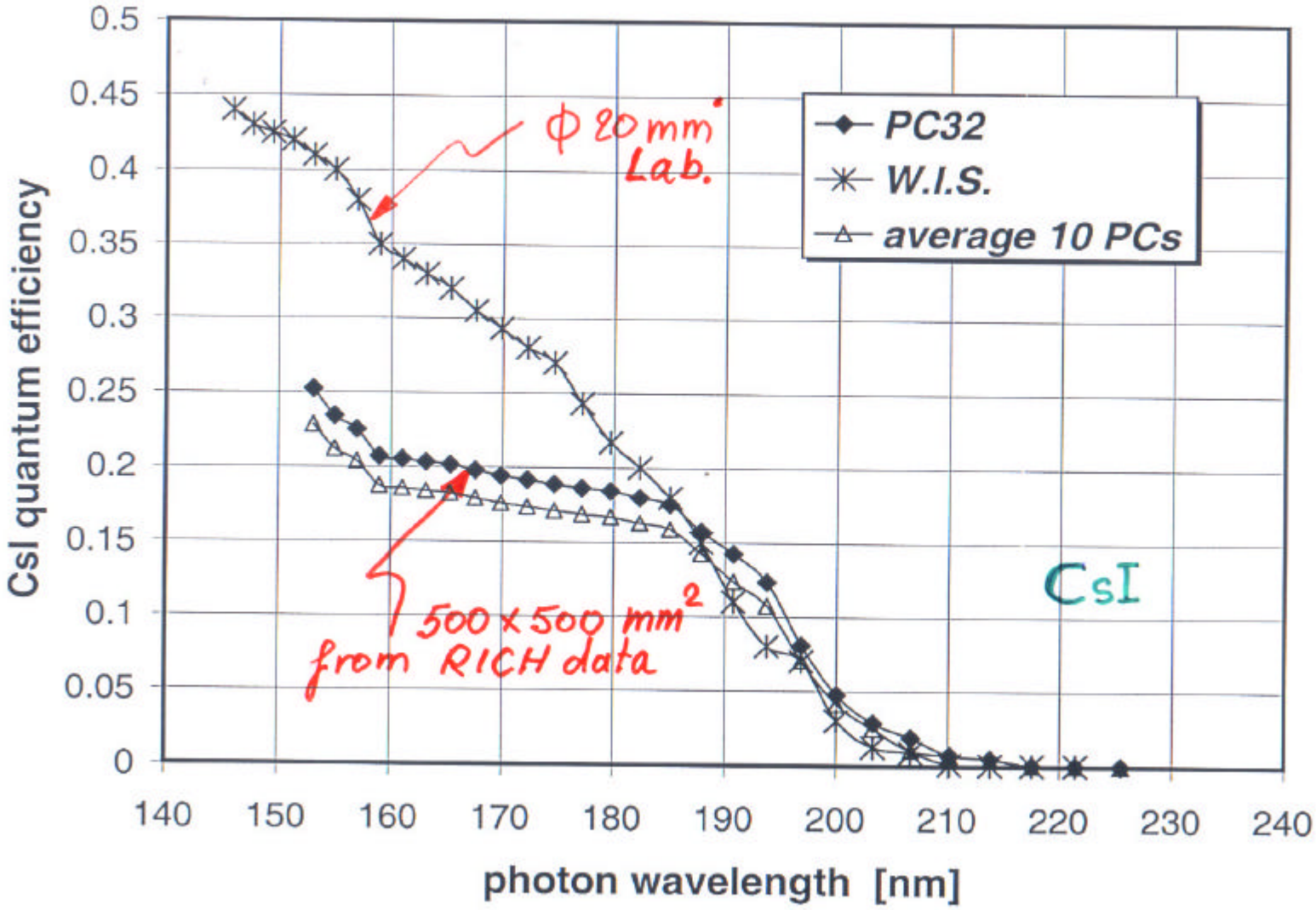


==> Processing of large CsI PCs converges towards hig reproducible QE value



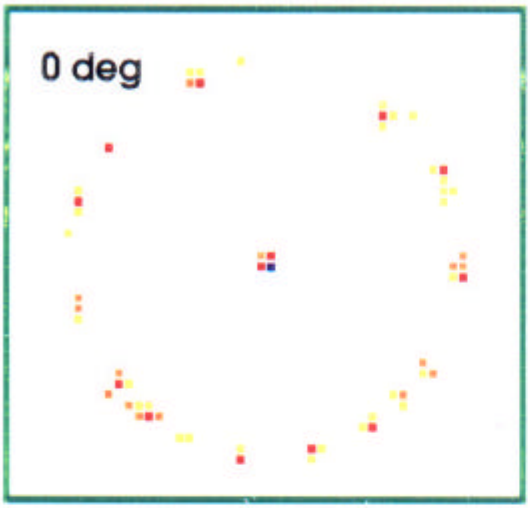
==> large prototype (2/3 of a module) under test fully equipped with 4 CsI-PCs of 65 x 42 cm²

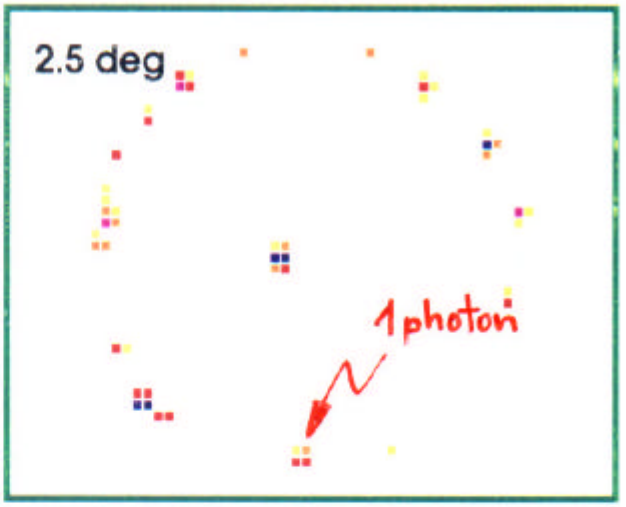
F. Piuz et al.

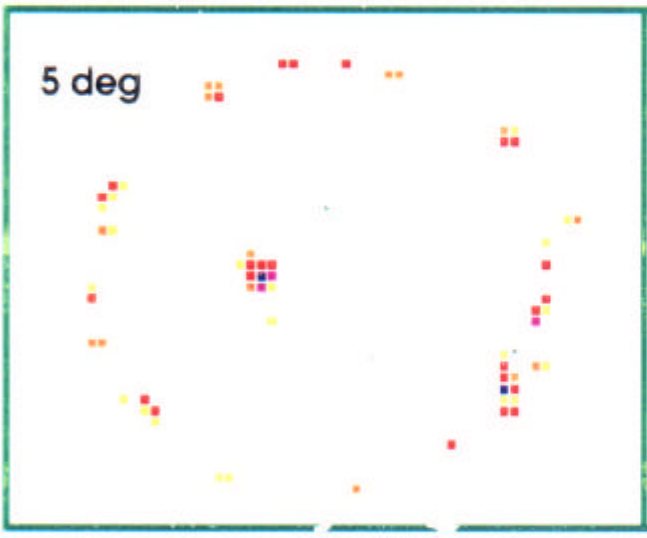


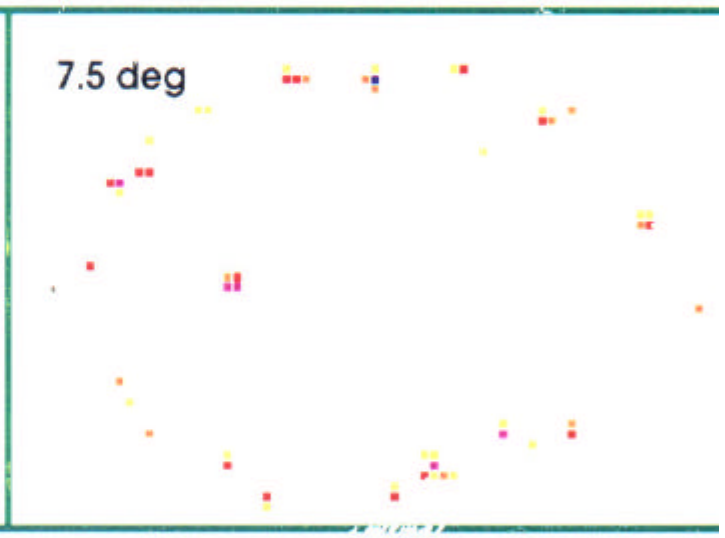
F. Piuz et al. CERN

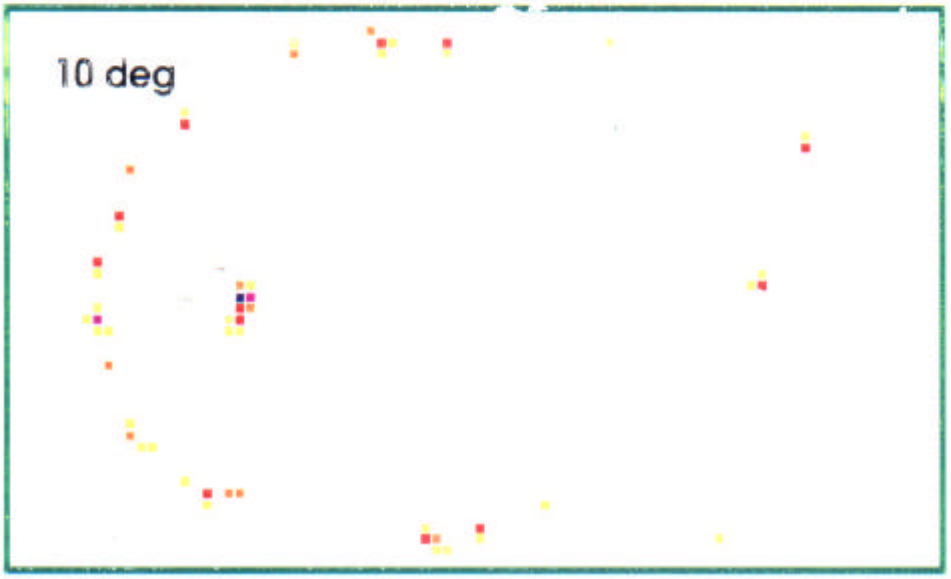
CHERENKOV PATTERNS IN HMPID RICH











F. Piuz et al.
CERN / ALICE

Some facts about CsI

1. Although high resistivity material (~10^{11} ohm/sq.), no problems encountered under gas multiplication of ~10^6.
   Rate limitations expected above 10KHz/mm^2.

2. Transfer in ambient air: no harm 1/2h.

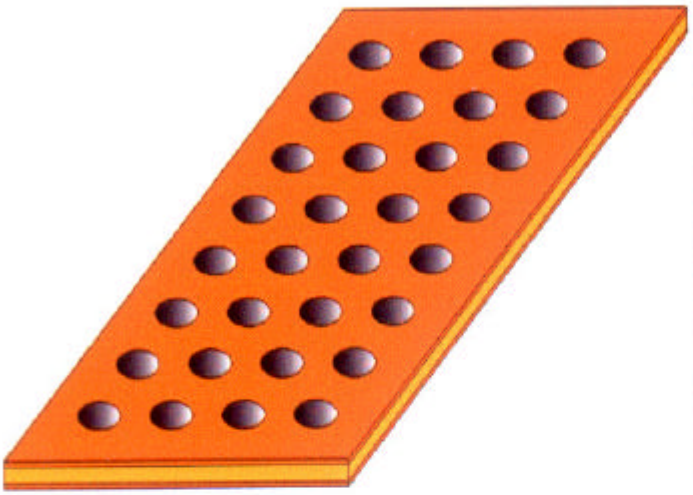
3. Damage under UV irradiation (no gain):
   No aging up to 10^{16} ph/mm^2.

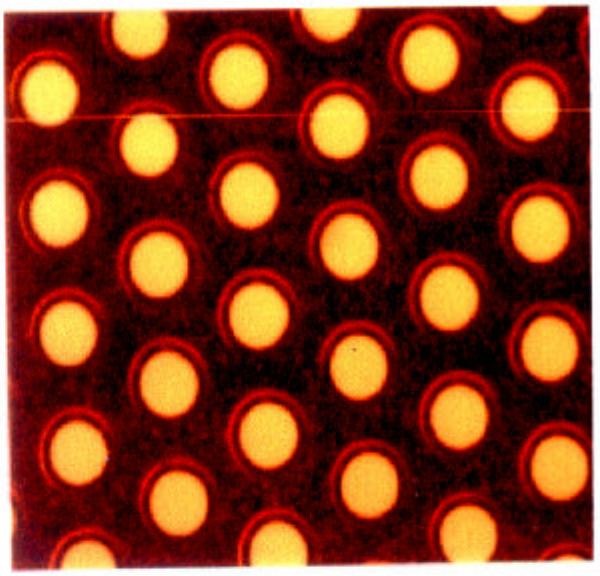
4. Damage due to avalanche ions:
   Up to 10-20% decay of QE @ 10^{14} ions/mm^2.
   But: in parallel-plate multiplication geometry, which is the worst case:
   → 100% feedback of energetic ions!

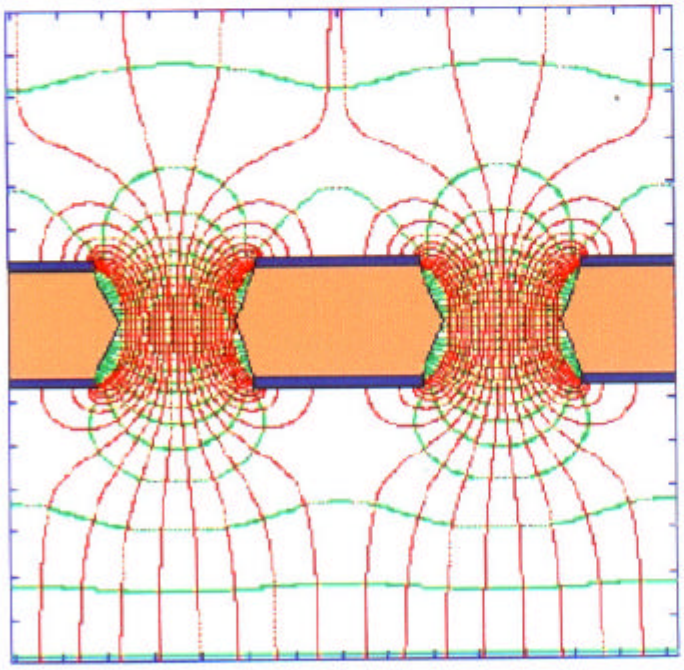
The Gas Electron Multiplier (GEM)

F. Sauli NIM A 433 (1997) 531

Gas amplification in the GEM holes

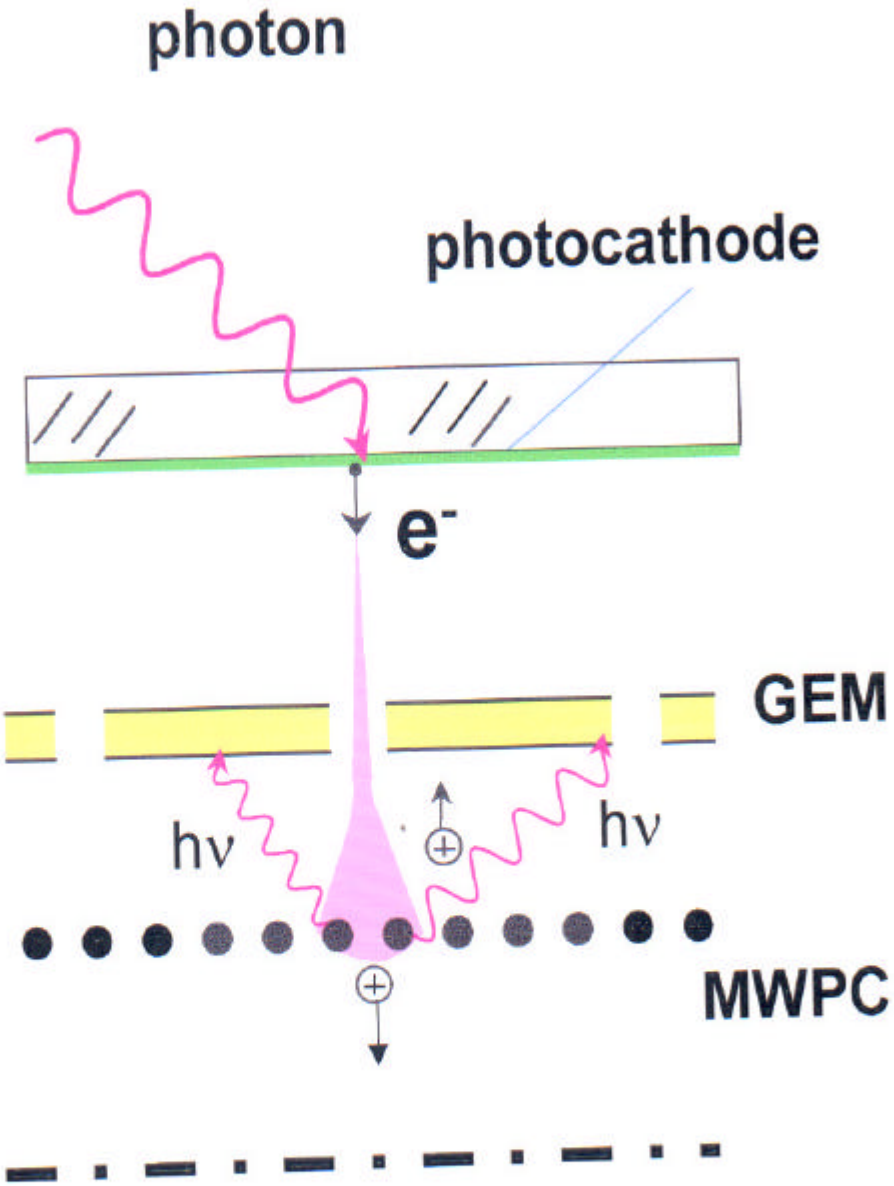






50μm Kapton
metal coated
60-100μm holes
100-200μm pitch

Photon feedback screening by the GEM

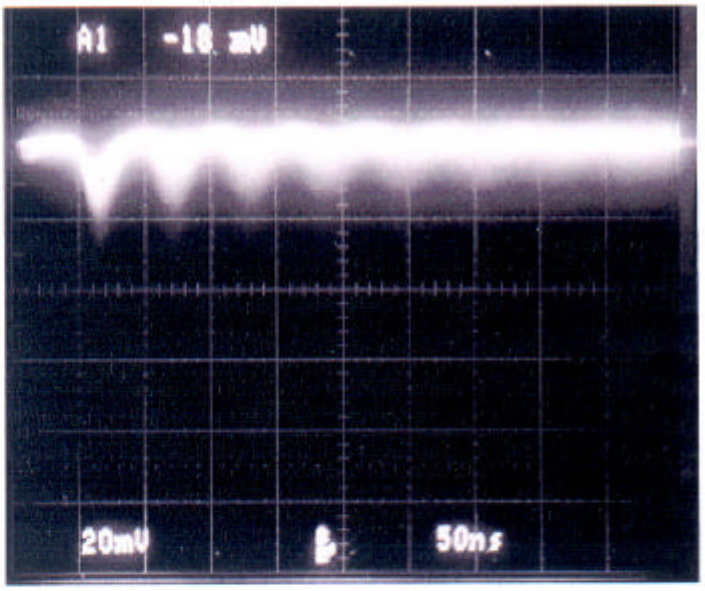


Screening of photon feedback

methane, 40 torr, single electron pulses

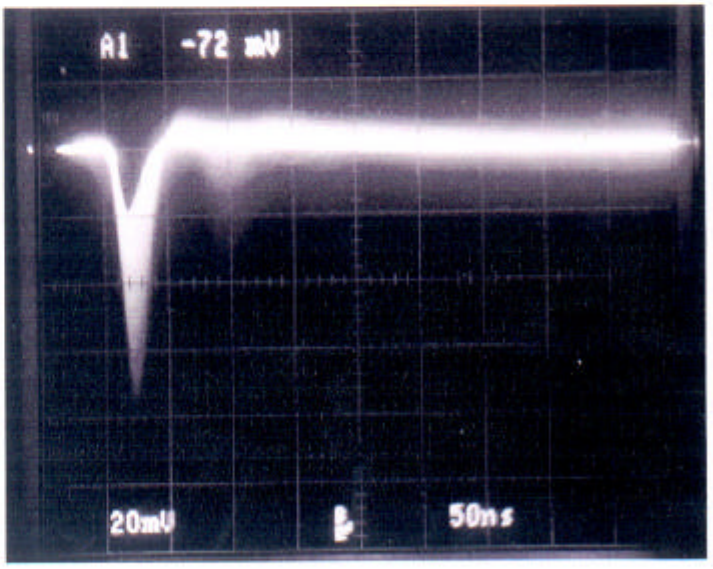
MW + photocathode

multiple photon feedback. severe gain limitation 8×10^4



MW + GEM (gain 1) + photocathode

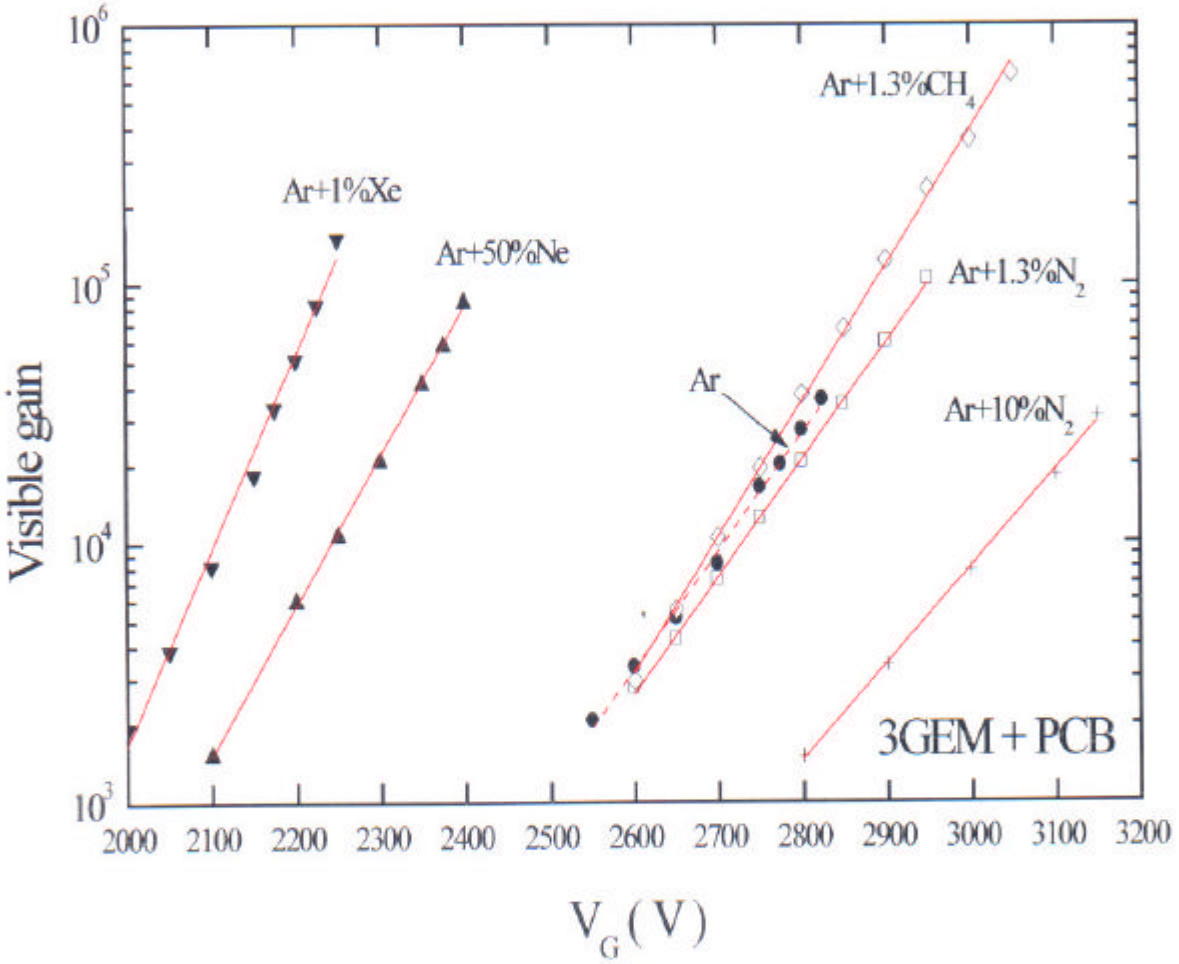
some photon feedback.
gain 3×10^5



R.Chechik, et al., NIMA419 (1998) 423

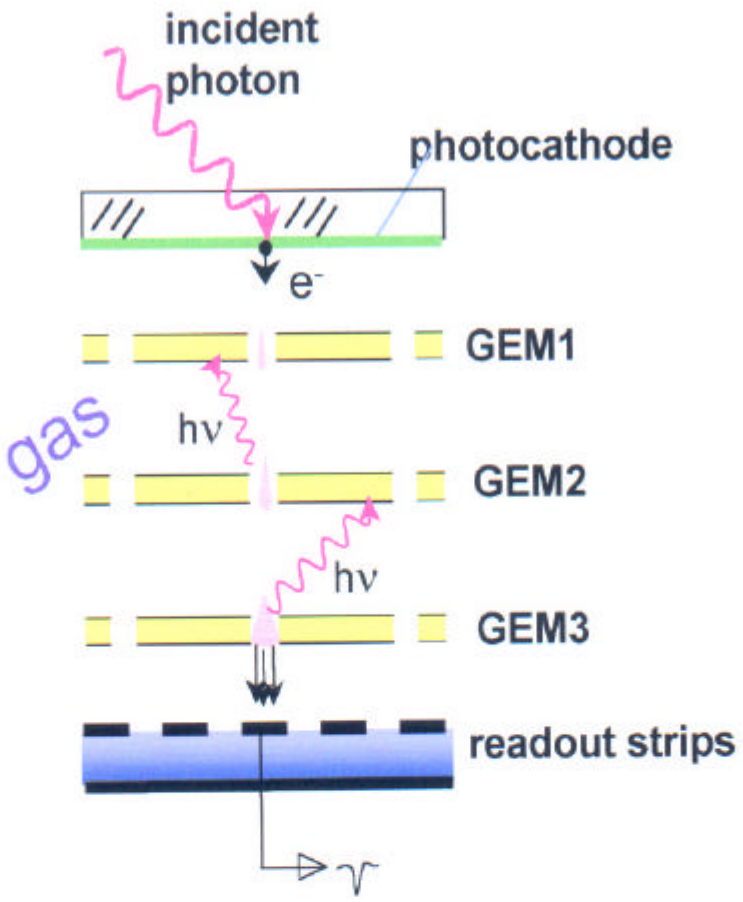
Non-ageing noble gas-based mixtures

Beaune'99 data



Refs: A.Buzulutskov et al., NIM A 443(2000)164

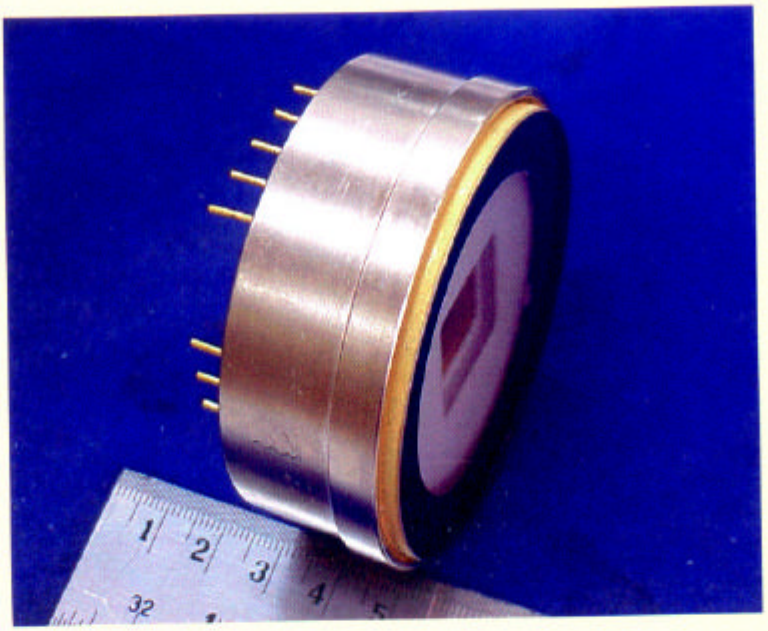
The GEM photomultiplier (GPM)



- **large-area, flat**, position sensitive PMT
- **reduced** photon and ion **feedback**
- **insensitive** to **magnetic** field
- operates in **non-ageing noble gases**
- gas gain : pure Ar/N_2 ~10^5, Ar/CH_4 ~10^6
- **single-photon** sensitivity in UV & visible range
- **sealed mode** with a multi-GEM multiplier

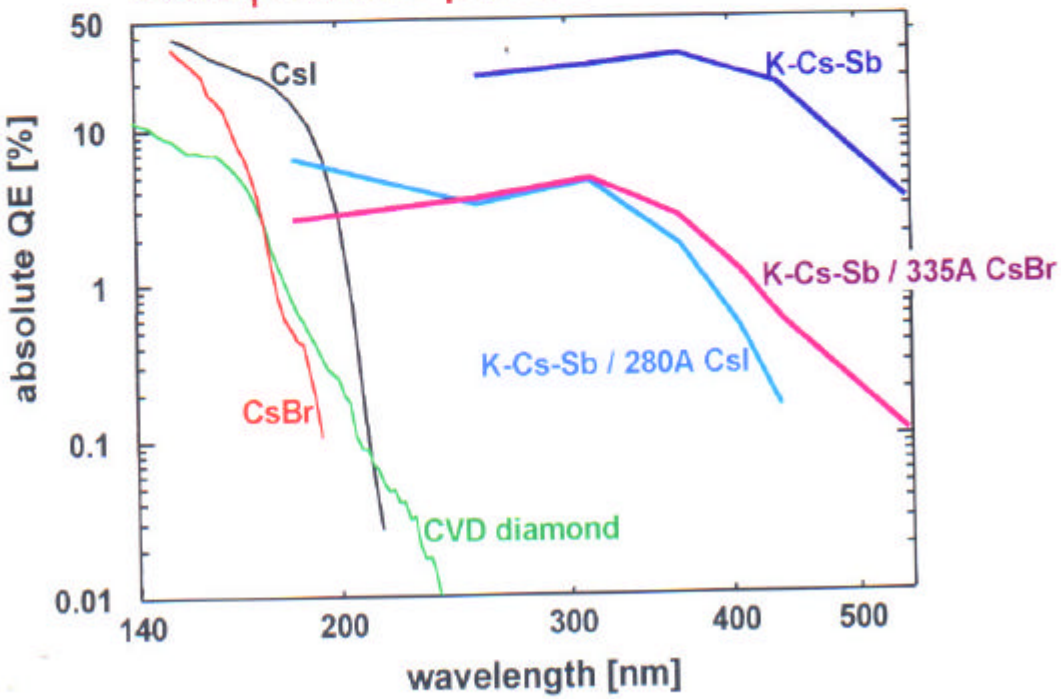
Refs: F.Sauli, NIM A 386(1997)531
R.Chechik et al., NIM A 419(1998)423
A.Buzulutskov et al., NIM A 443(2000)164

Sealed gas avalanche photomultipliers

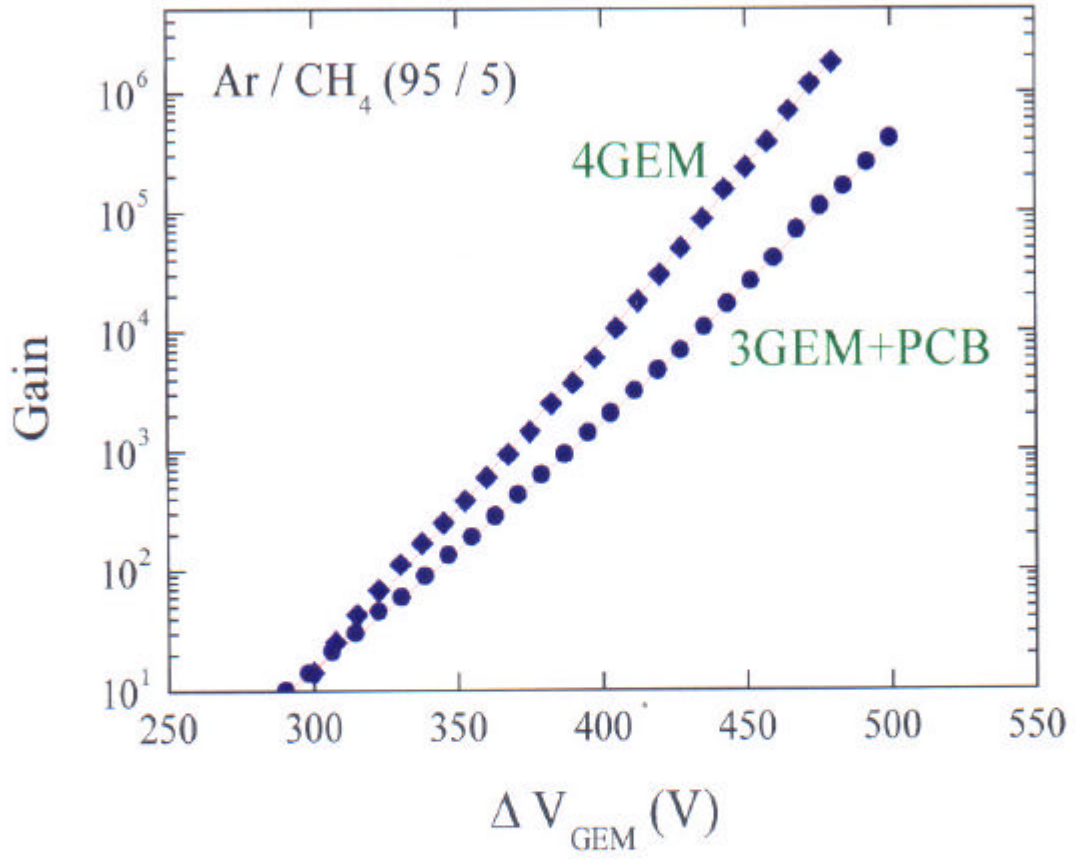


A photocathode coupled to a multi-GEM gas avalanche electron multiplier

compatible photocathodes:

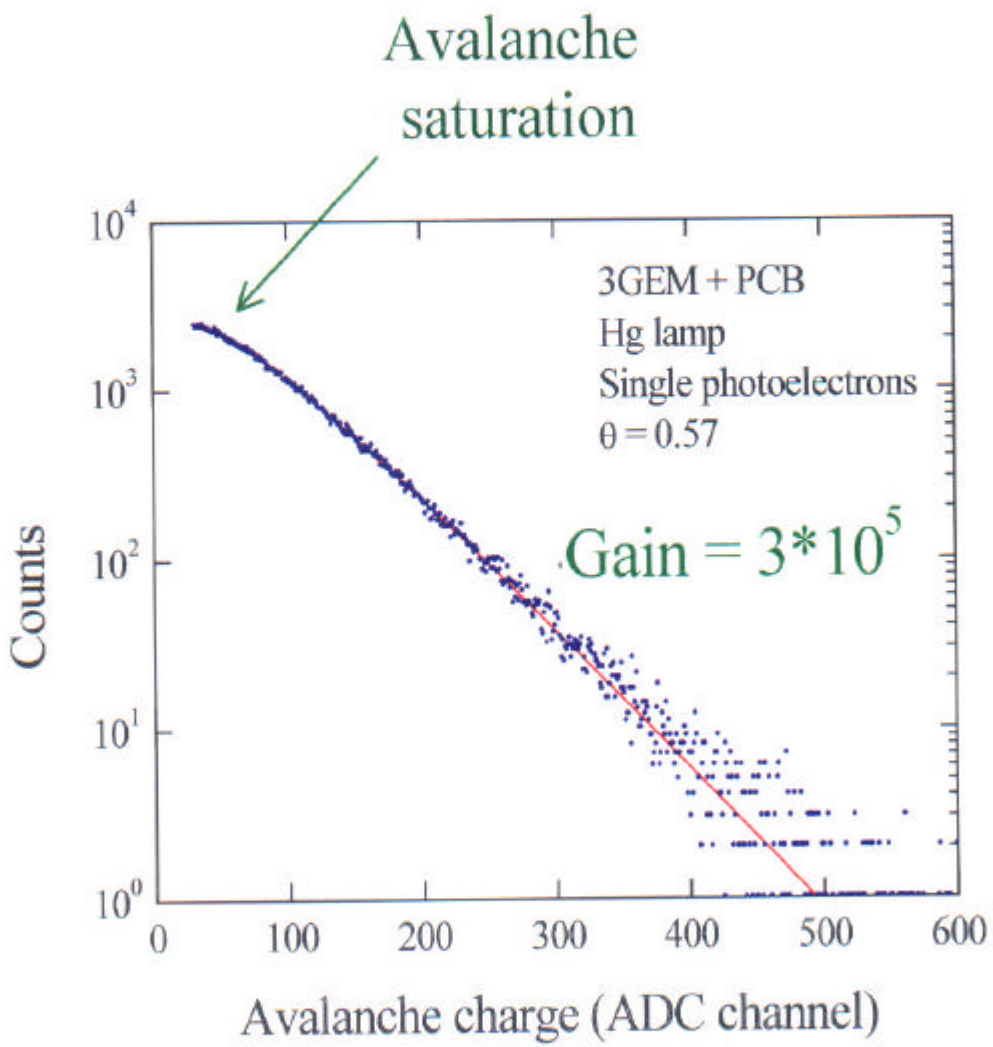


GPM gain



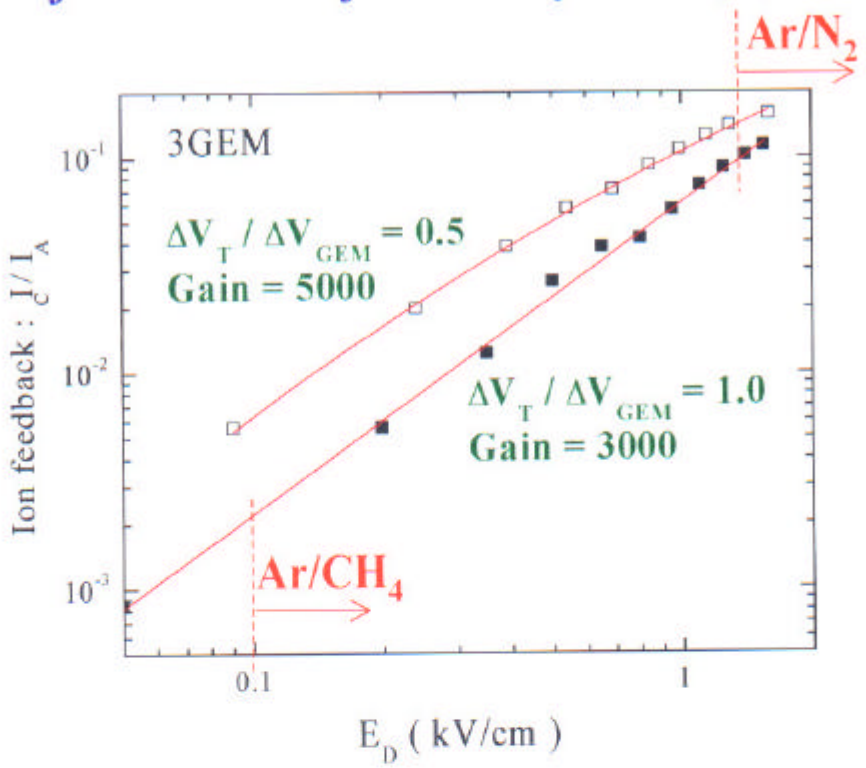
High gains have been obtained:
- close to 10^6 in 3GEM+PCB
- well above 10^6 in 4 GEM

Single p.e. pulse-height spectrum

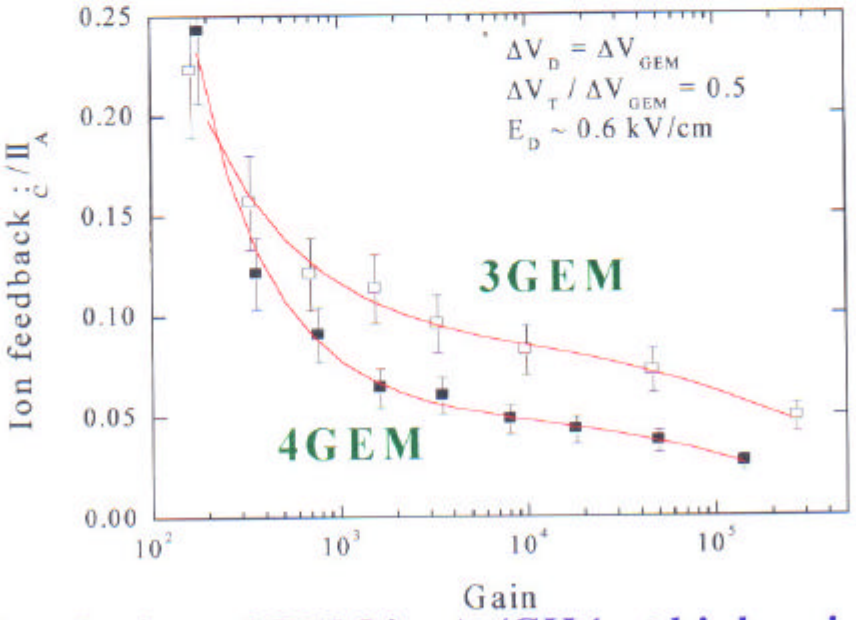


Ion feedback to the photocathode

Ion feedback as a function of the drift field

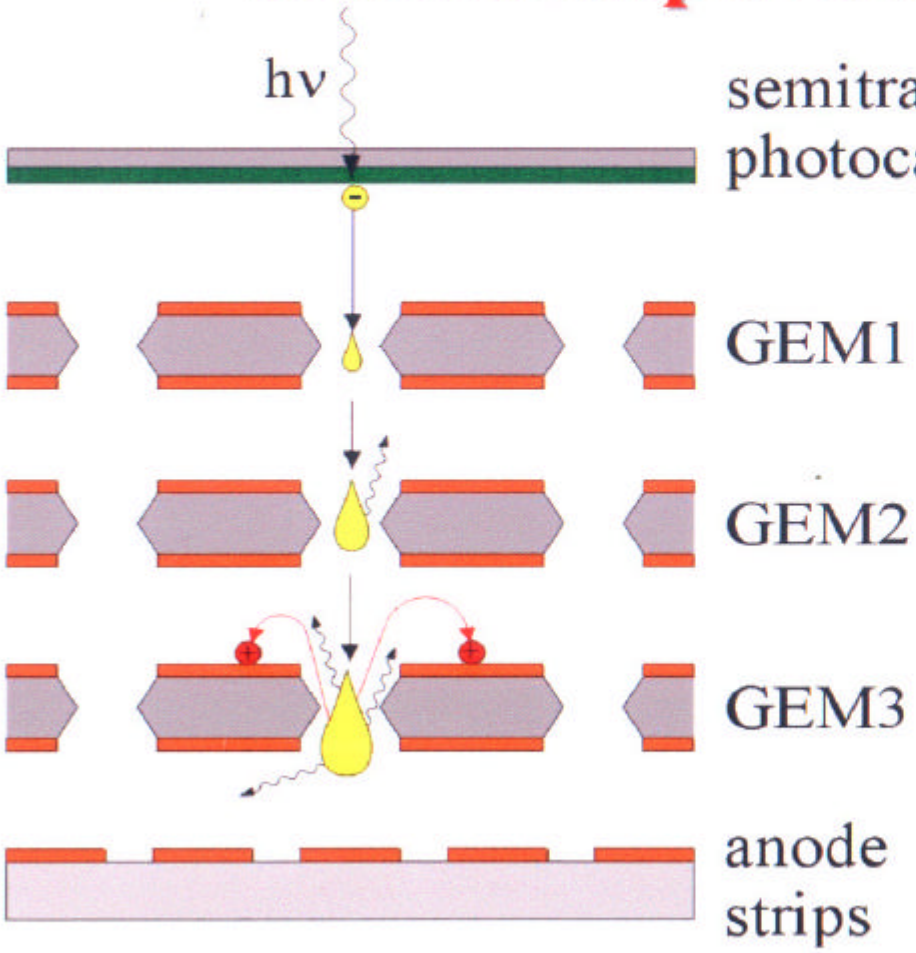


Dependence on the gain. 3GEM vs 4GEM



Conclusion: 4GEM in Ar/CH4 at high gain:
sufficient p.e. extraction efficiency
and low ion feedback

GEM photodetector with semitransparent photocathode

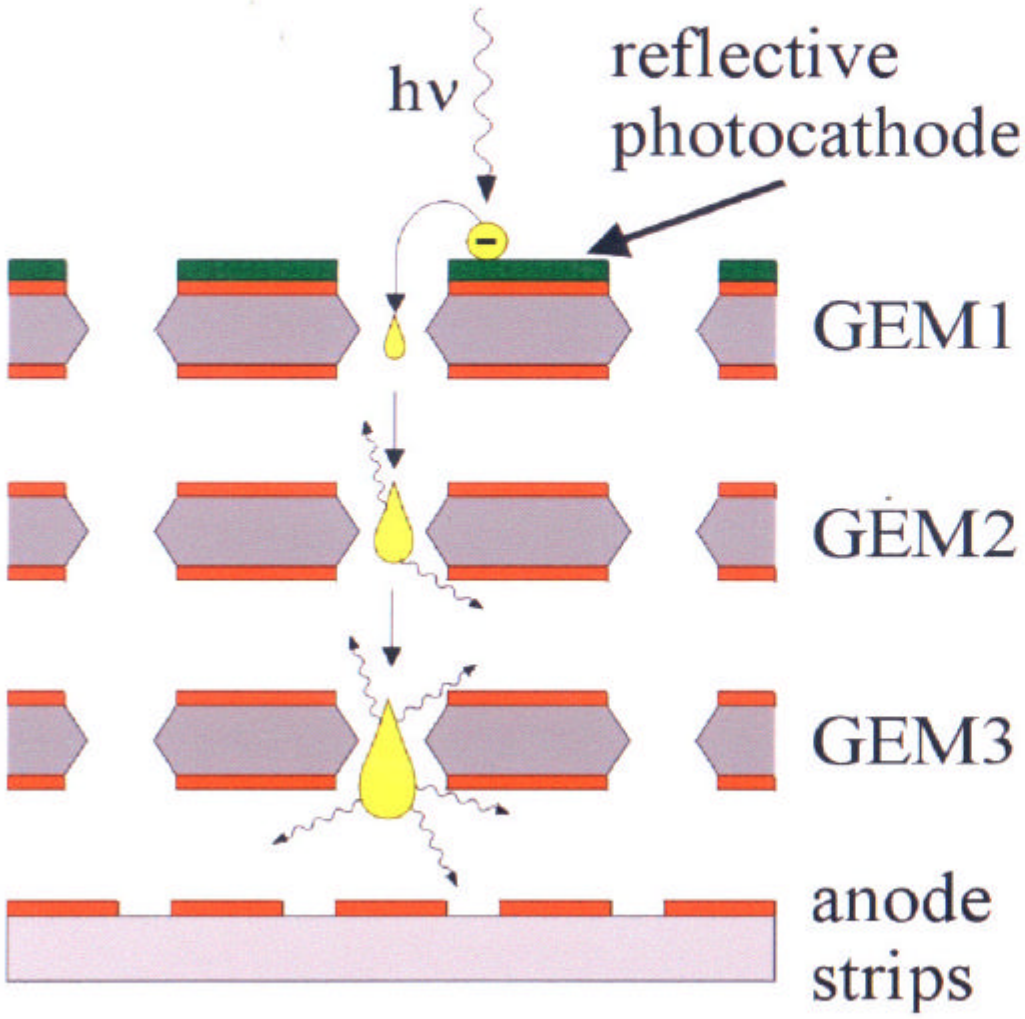


drastically reduces
- ion feedback
- photon feedback

=>
- higher gain
- pure noble gases
- longer lifetime

A. Buzulutskov et al. NIM A 443 (2000) 164

GEM photodetector with reflective photocathode

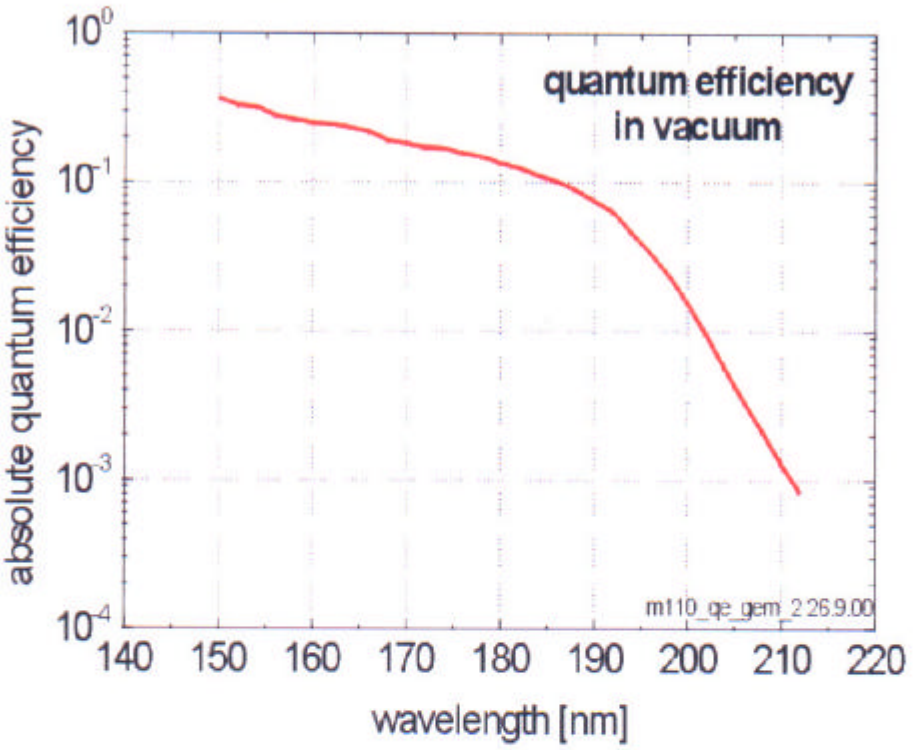


no photon feedback:
- higher gain
- longer lifetime

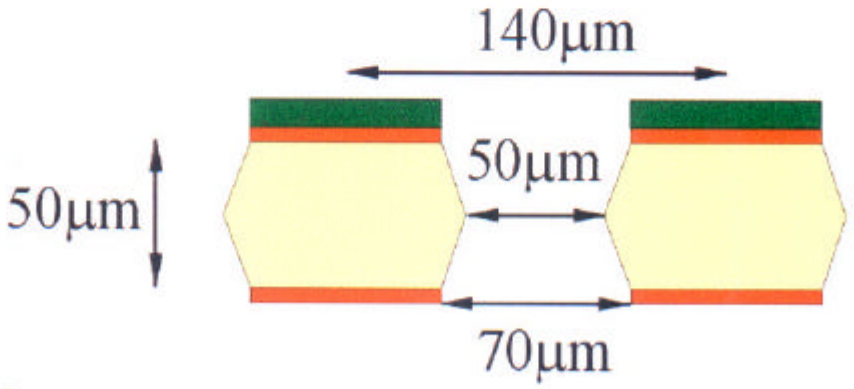
reflective photocathode:
- higher quantum efficiency
- easier to produce

in addition:
- high gain
- reduced ion feedback
- good time resolution
- 2D readout
- ...

High quantum efficiency

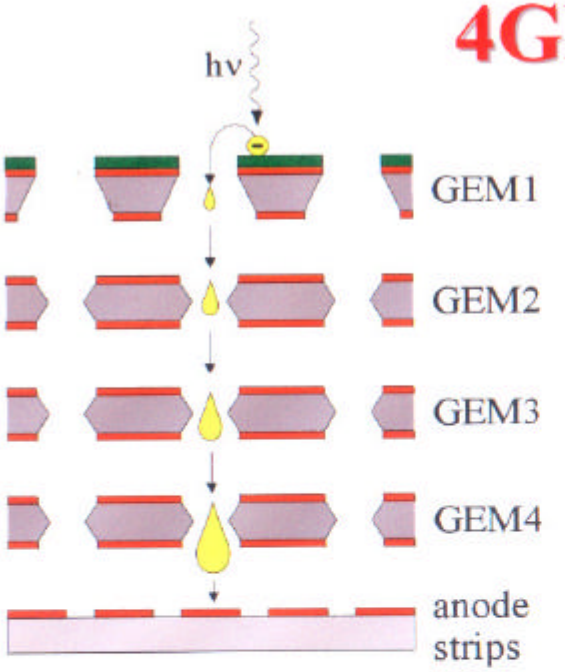


2500Å CsI on gold-coated standard GEM

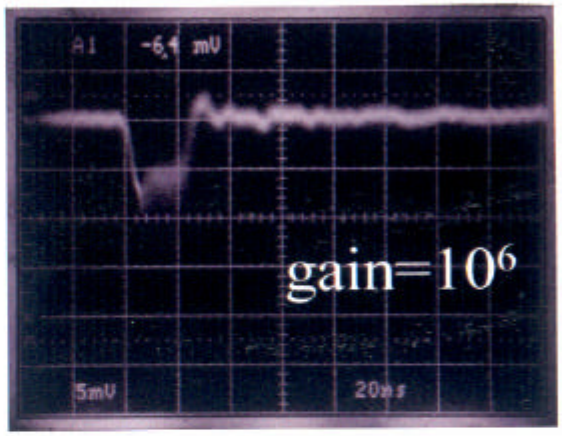


=> 23% of the area consists of holes

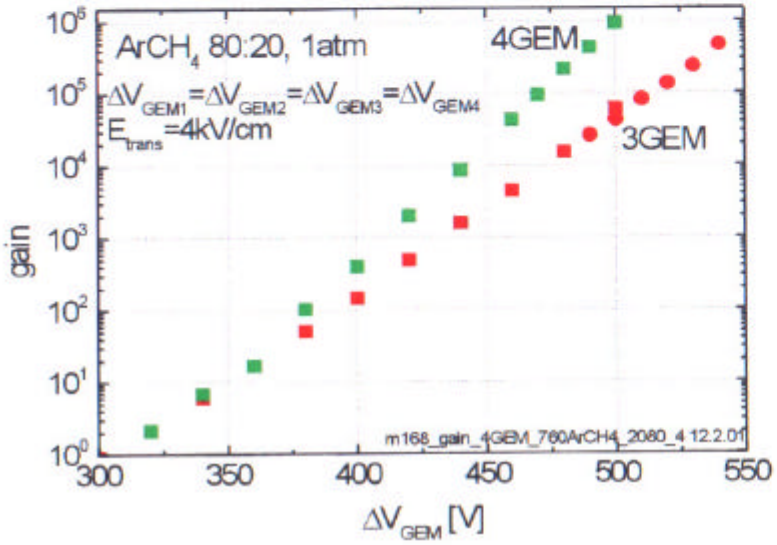
4GEM detector



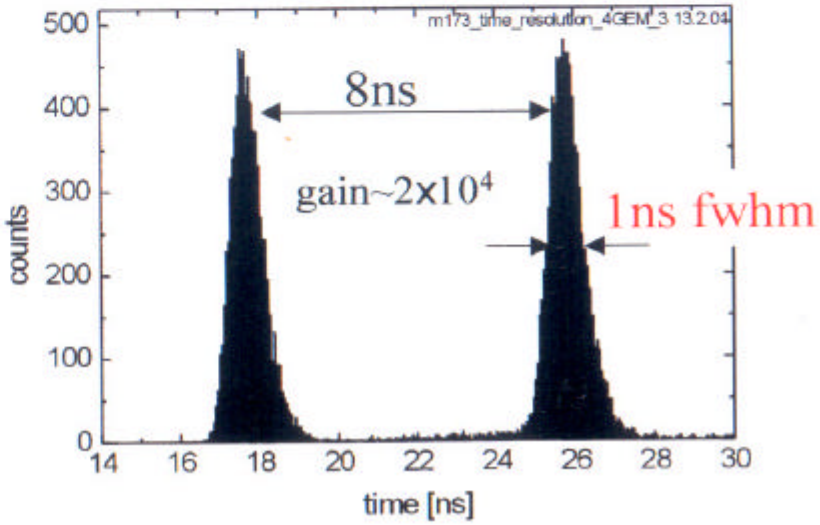
Single photon pulses (5ns risetime)



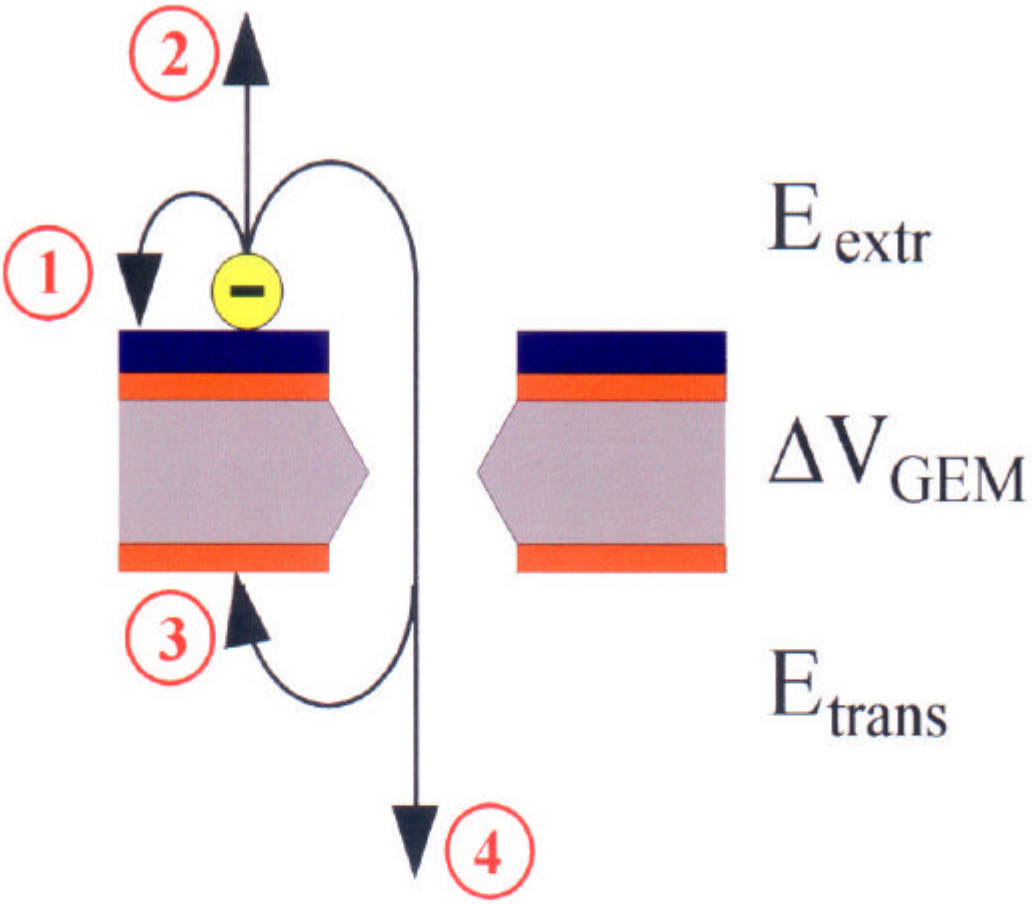
High gain



Good time resolution (300 photo-electrons)



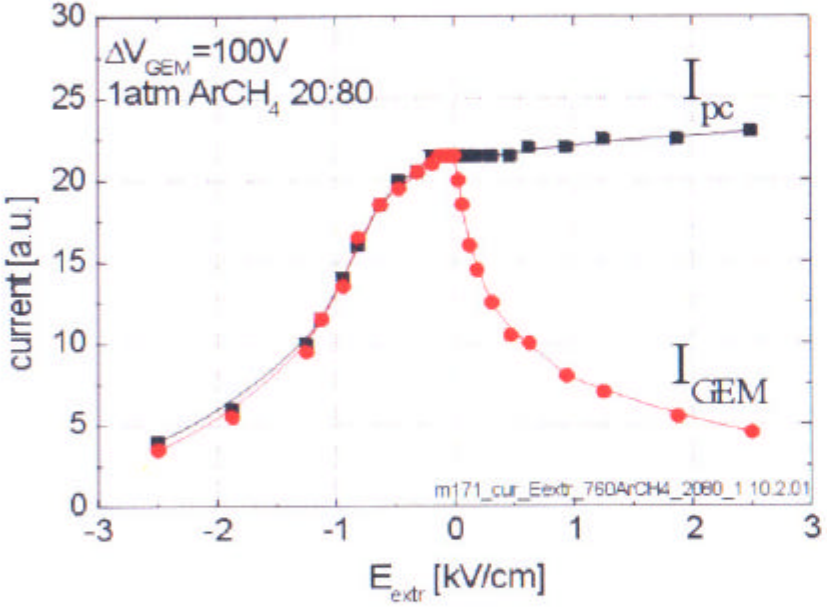
Electron transfer in GEM

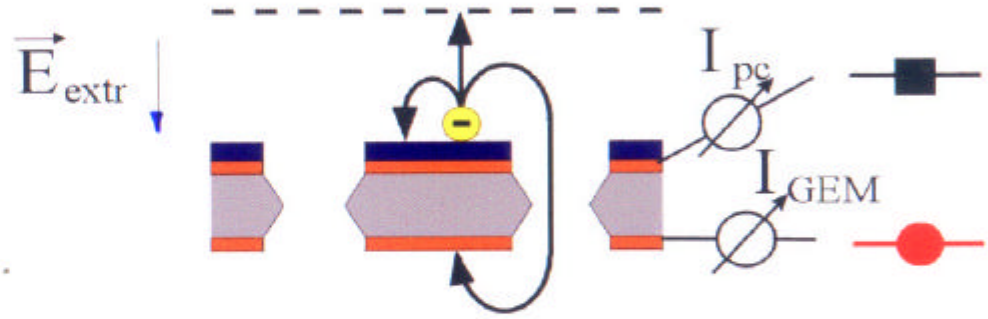


1. low field on photocathode surface ("*backscattering*")
2. high $E_{extr}/\Delta V_{GEM}$
3. low $E_{trans}/\Delta V_{GEM}$
4. not 1 and not 2 and not 3

Influence of E_{extr}

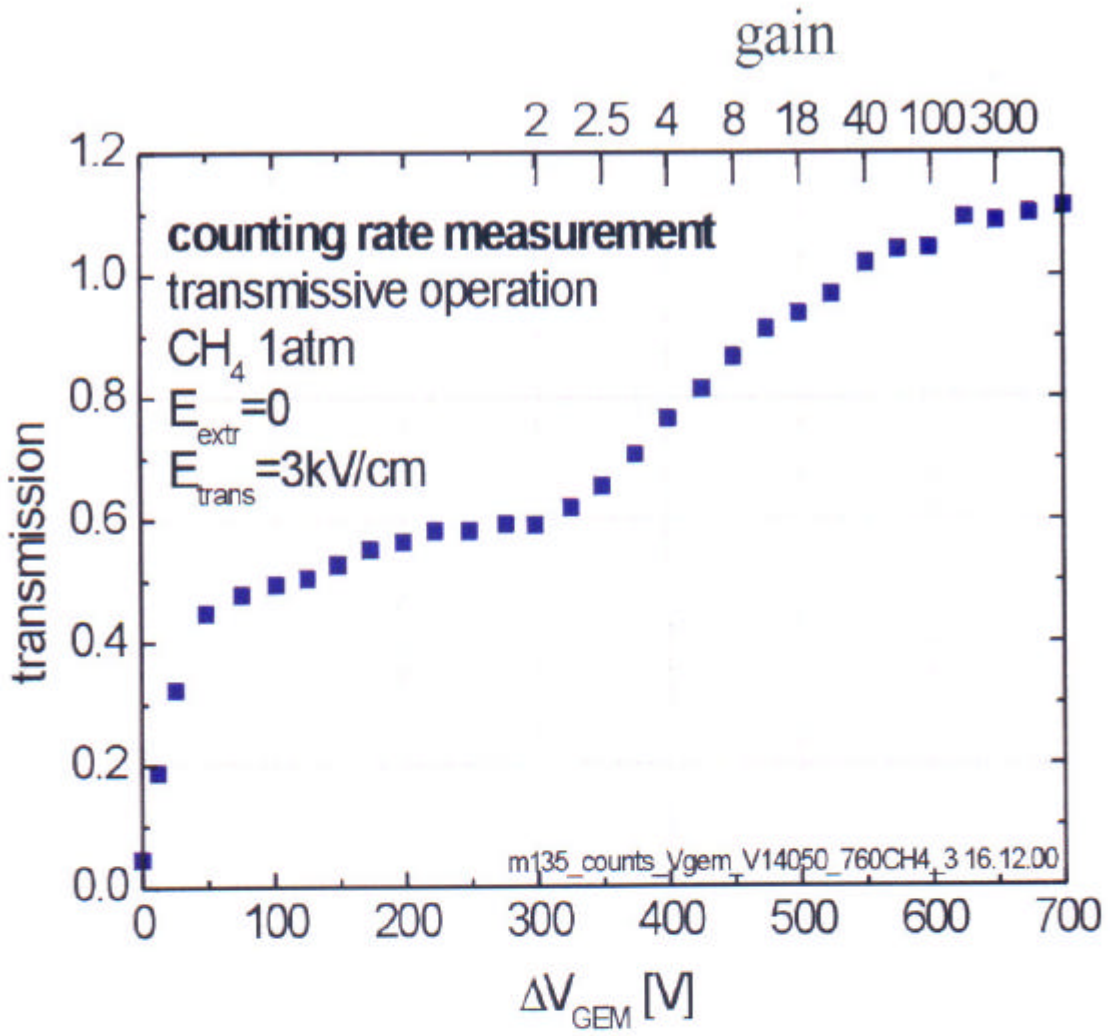
current measurement





$E_{extr}>0$ => electrons go to mesh instead through holes
$E_{extr}<0$ => reduced field on GEM surface

=> optimal operation at $E_{extr} \sim 0$

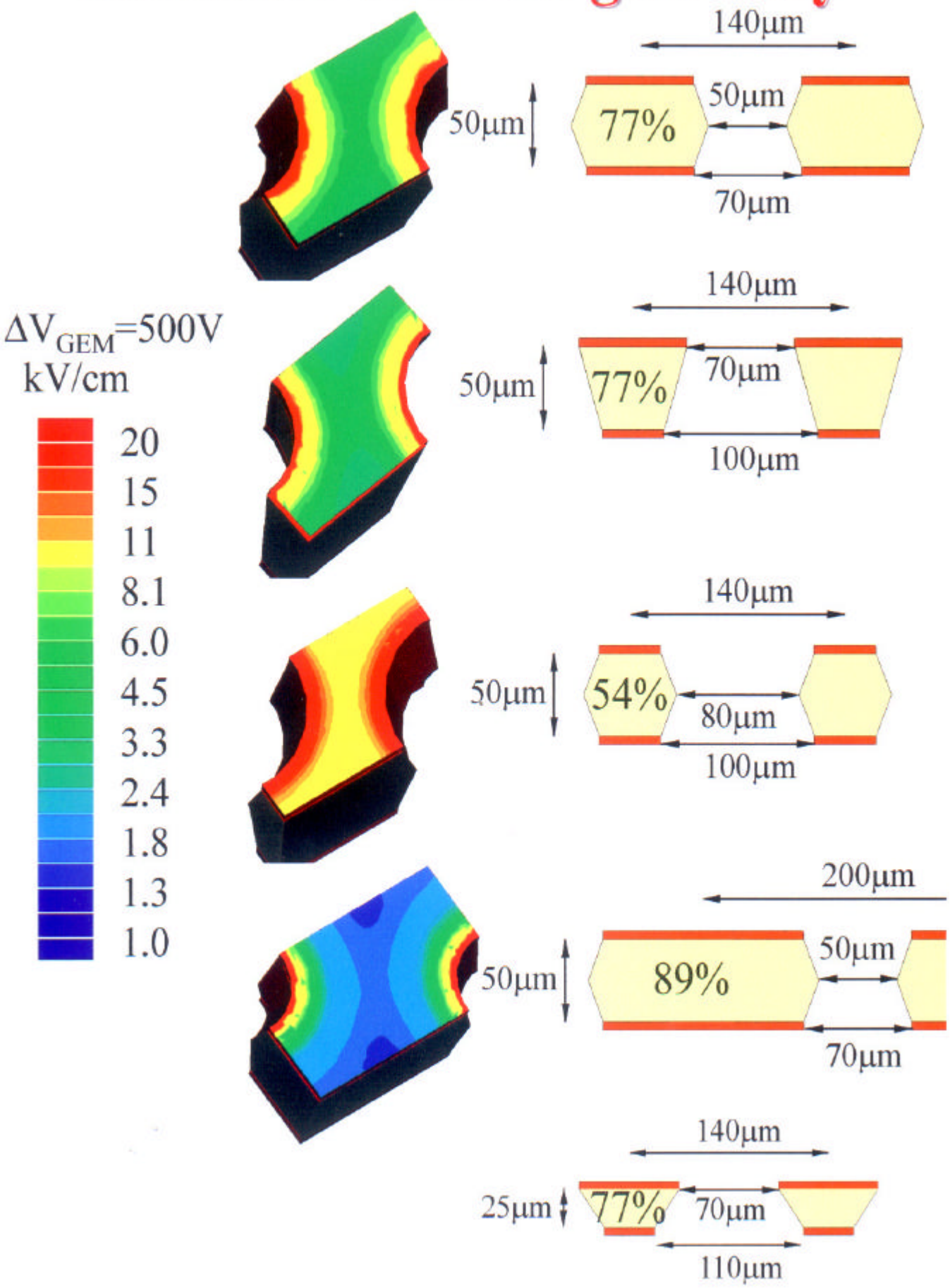


gain compensates
for losses

=> optimal operation at high E_{trans} and at sufficient gain

Don't forget next GEM (not too high E_{trans}!)

Influence of GEM geometry



CsI-coated UV GEM photodetector

Principal advantages:

1. no photon feedback
- high gain operation also with non-standard gases: noble gas mixtures, CF_4
- no "satellite" avalanches

2. very low ion feedback
- longer photocathode lifetime
- smaller secondary effects

3. low sensitivity to dE/dx (E_{drift}=0)
- low response to charged particles
- low sensitivity to highly ionizing recoils reflected in possibly low spark rate

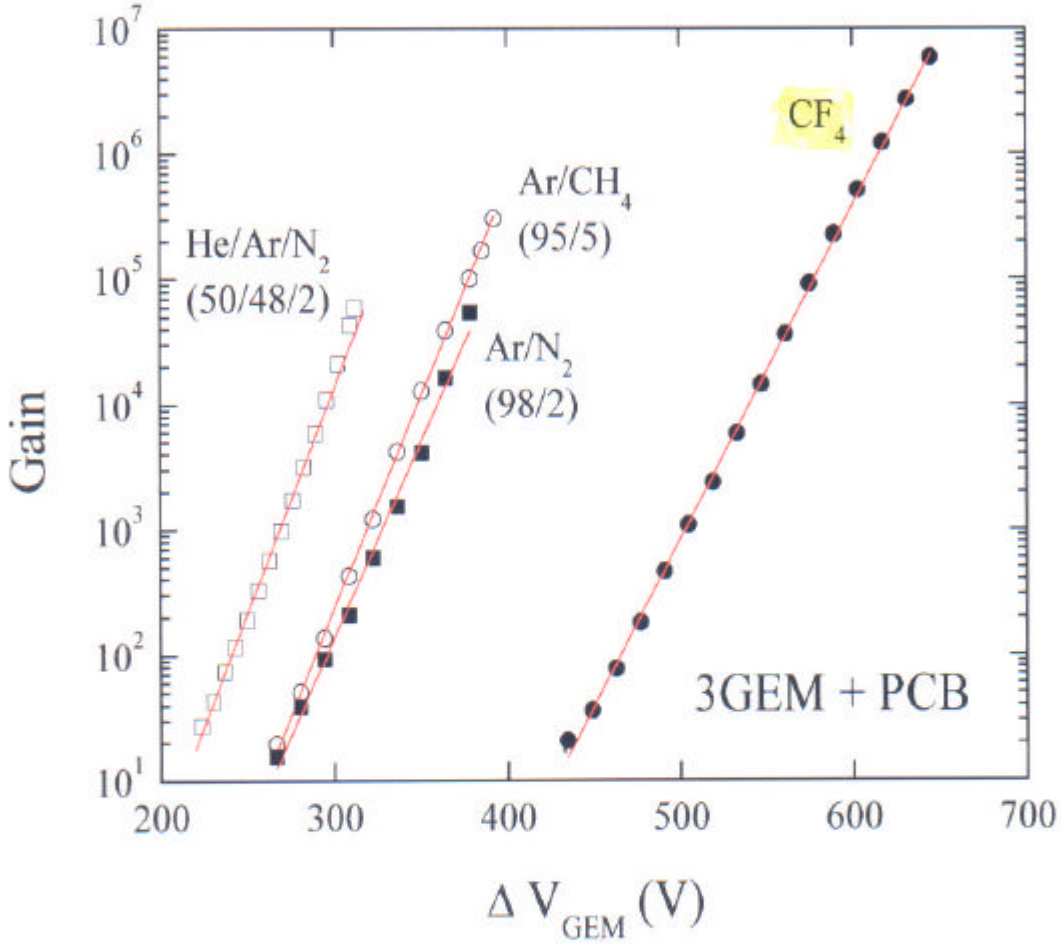
4. fast (ns) response

5. flexible geometry, simple 2D strip/pad readout

possible drawback:

no wires → no charge saturation
could affect the spark limit

Gain curves for a 3-GEM detector

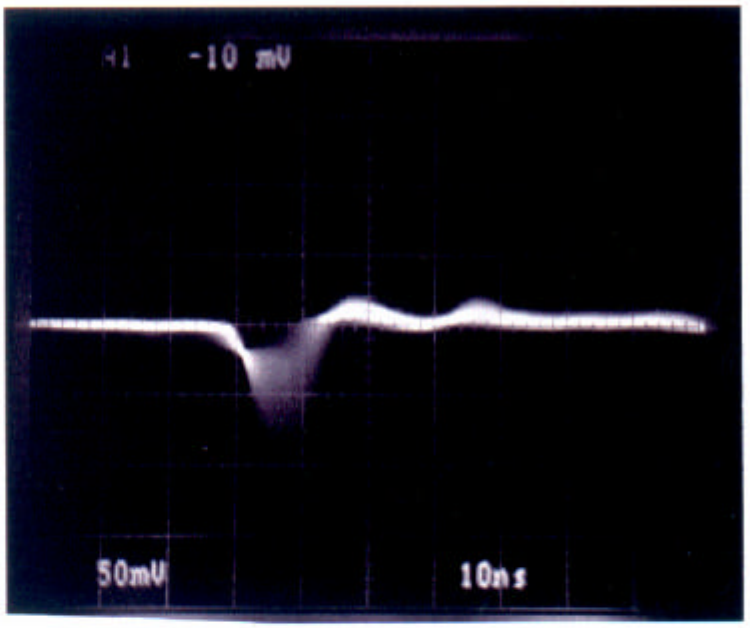


CF_4: pulse counting mode
other mixtures: current mode
solid line: fit to data

Fast photon pulses in CF_4 *

Single photons

Gain $2 \cdot 10^6$

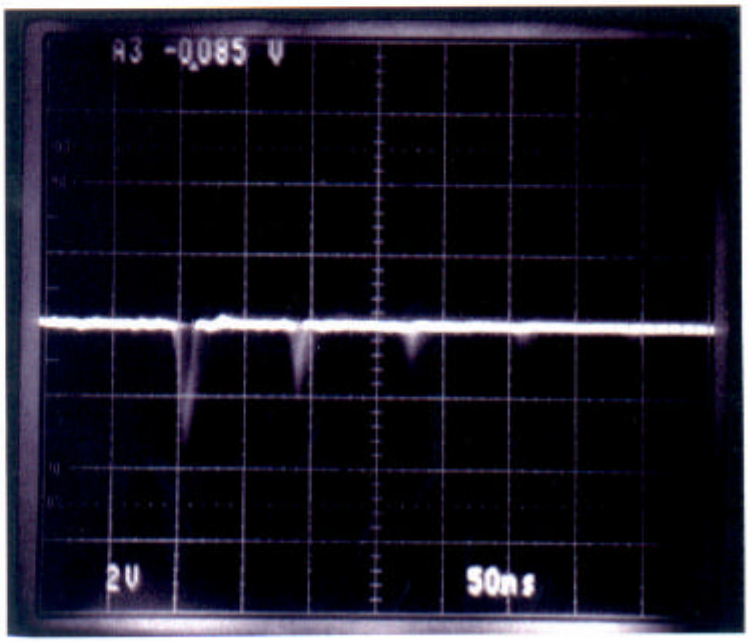


Multiple photons

Gain $6 \cdot 10^6$

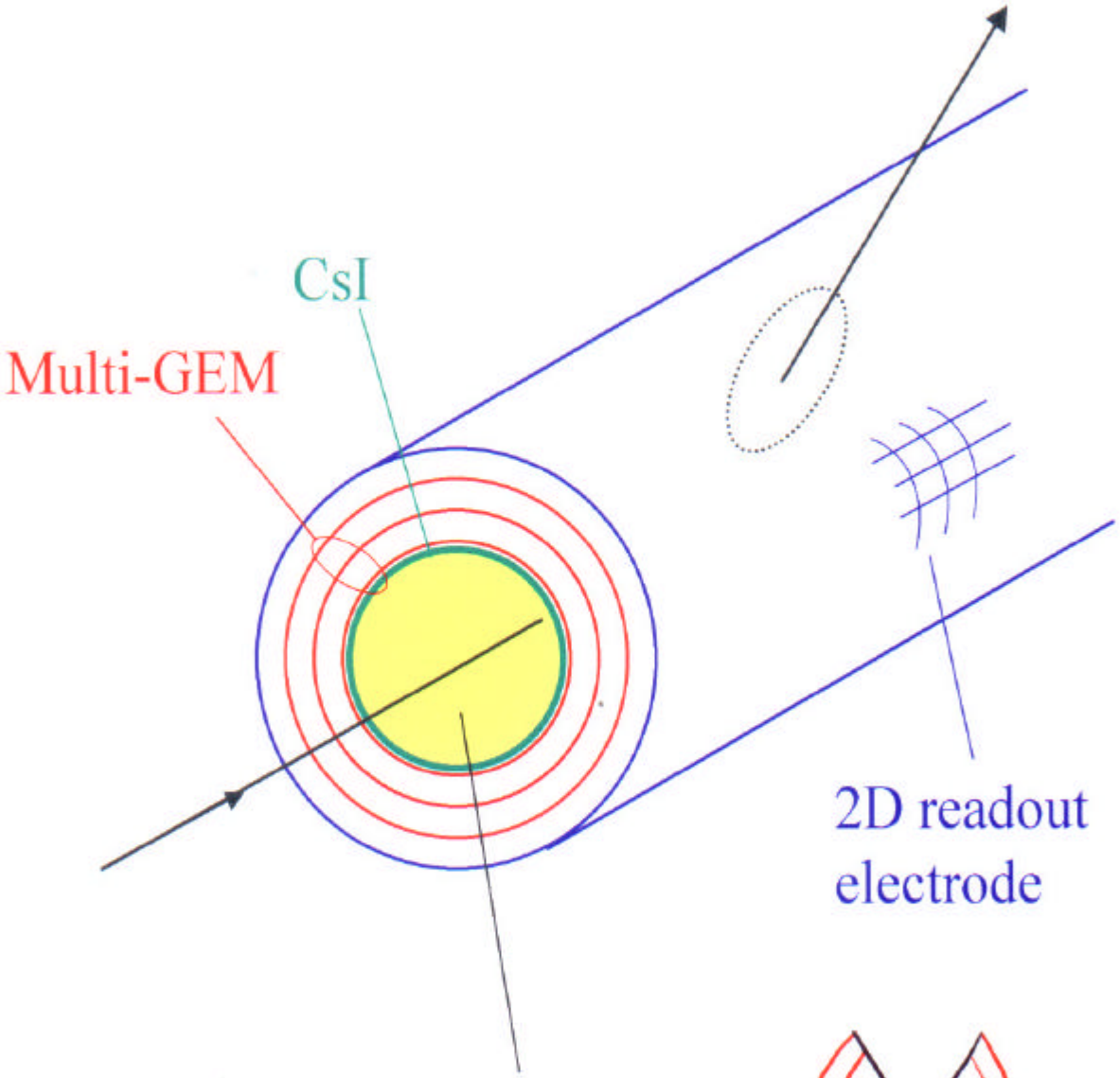
Notice

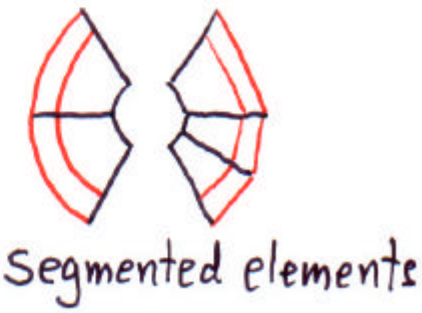
Photon-feedback!



* semitransparent CsI + 3 GEMs

The MultiGEM RICH



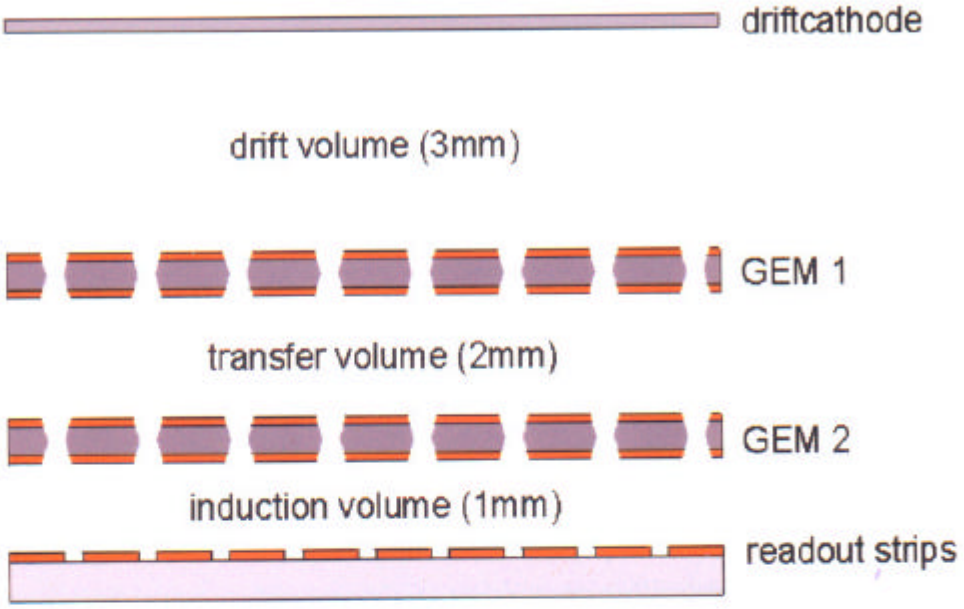


a windowless device*: Radiator + detector

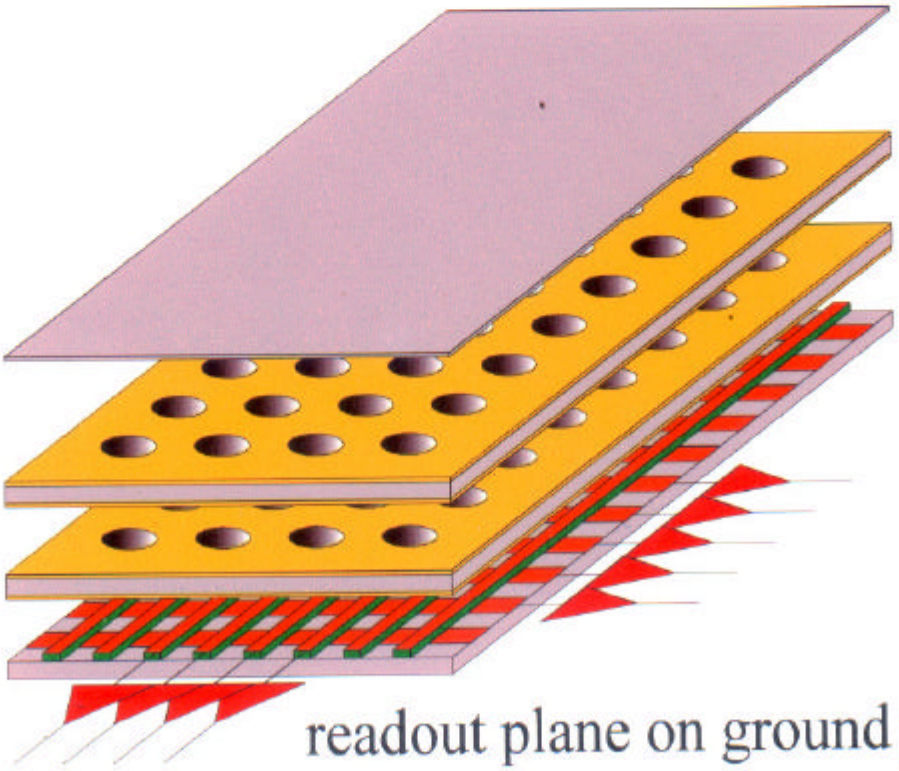
CF_4

* A. MILOV

The Double GEM (DGEM) detector



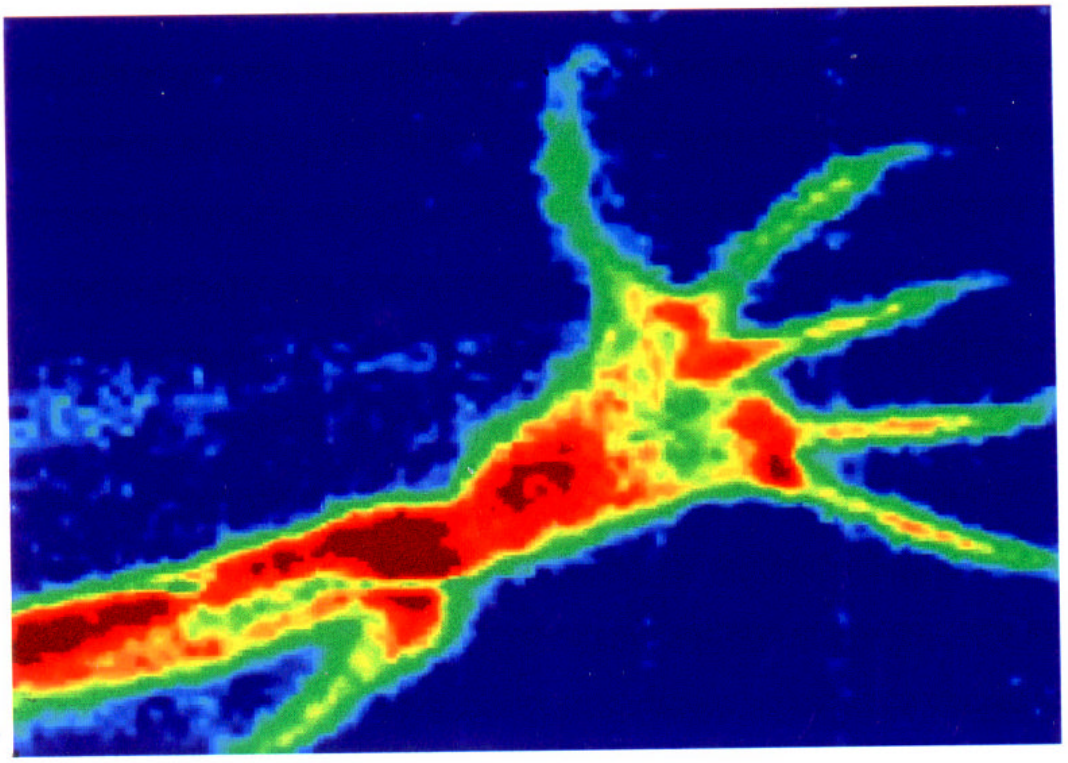
Simple printed circuit board (PCB) readout strips



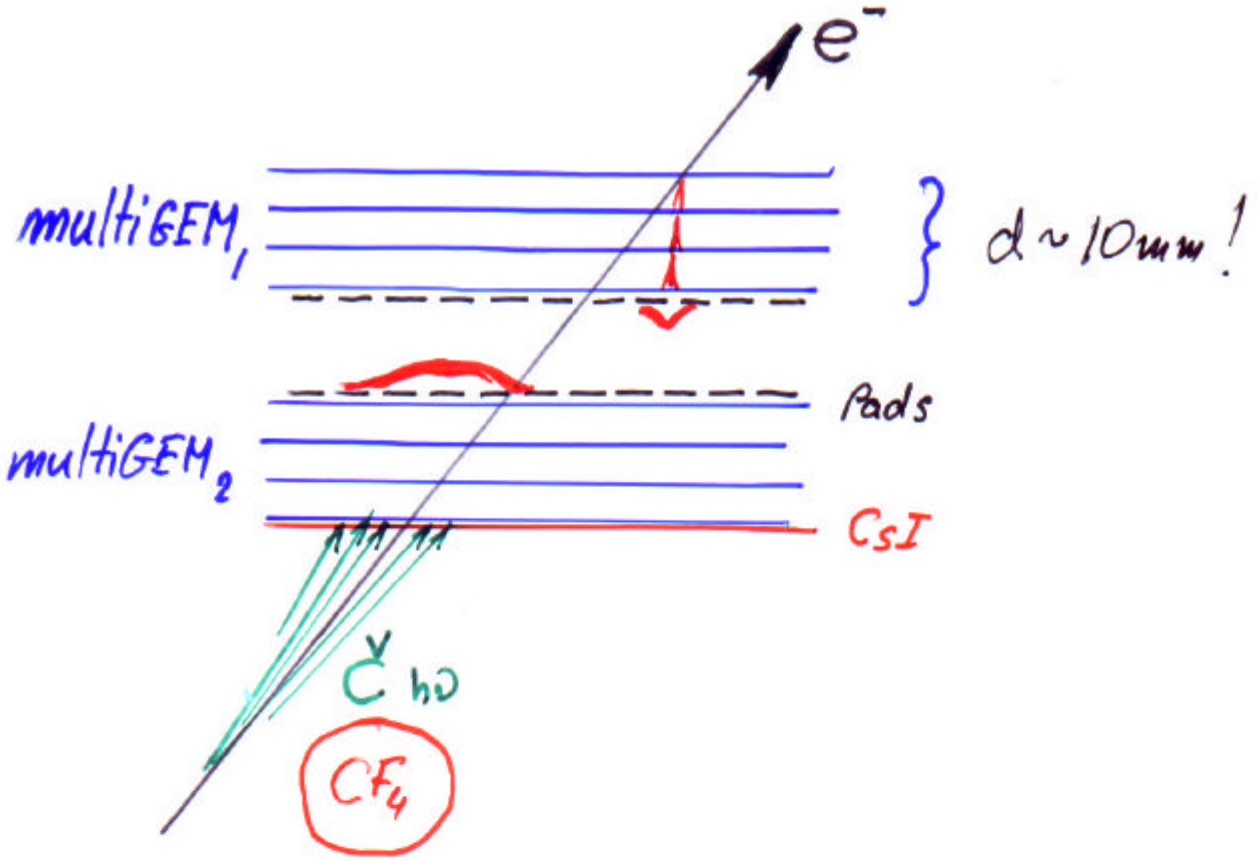
readout plane on ground potential!
(no HV capacitors needed)

X-ray image of a bat's claw

5 mm



A Possible RICH-TRACKING module



1. may be common pad readout ?
   e.g. signals from one multiplier can be delayed by drift in gas!

2. Could we incorporate "optical readout"?
   CF_4 is an excellent scintillator!
   → measure locally visible light emitted from the last GEM electrode

Summary

1. CsI-based UV "wire chambers" are considered as a mature technique for RICH.

2. Multi-GEM detectors have advantages:
   - reduced photon- and ion-feedback
   - high gain , also in noble gas mixtures
   - flexible geometries (also cylindrical!)

3. CsI-coated GEM detectors:
   - no photon feedback
   - ion feedback can be very low
   - **very low sensitivity to charged particles:** best e-collection at drift field ZERO above photocathode!
   - QE: ~80% of regular
   - ns response

4. Multi-GEM with CF_4:
   - very large attainable gains (close to 10^7)
   - stable operation
   - high e-extraction at low fields (low backscattering)

5. CF_4 : possible windowless RICH devices !

Will multi-GEM PMTs have stable operation under large particle flux?

CF_4 : chemical stability ?