# ions in the LC-TPC

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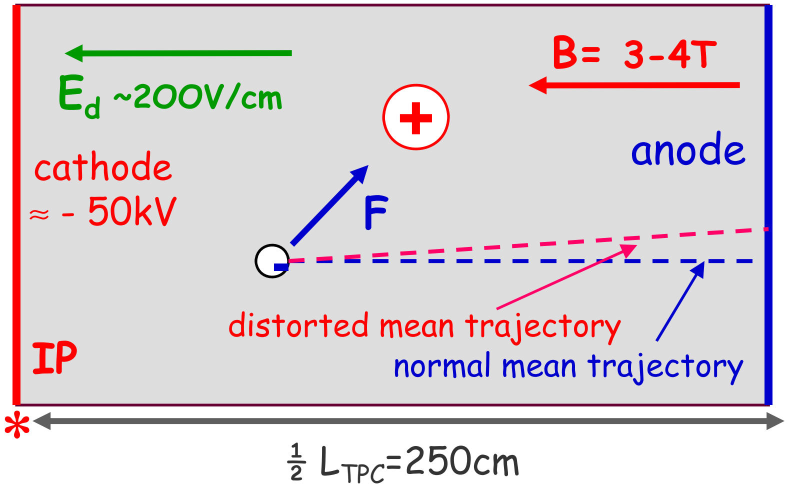
## outline

- introduction: what is the problem with the ions in a TPC?
- primary and secondary ions in the ILC-TPC
- gating of ions
  - natural gating in the MWPC and MPGD R&O TPC
  - wire gating
  - passive GEM gating
  - new ideas for gating
- conclusion

# introduction: ions in a TPC




→ during an ILC train (1 ms), in a « perfect TPC » ( no cage distorsion, MPGD, E//B) and without ion feedback from the anode, the TPC volume is naturally positively charged, due to the presence of primary ions (from physics and mostly from background from the machine) since electrons are quickly collected by the anode.

→ due to these charges any drifting e will experience an electric force not parallel to $E_d$, and consequently an ExB force, so causing distortion on its trajectory.

→ during the multiplication of electrons a second family of ions numerously much more important will be produced, and depending on the presence and the efficiency of the gating system, the secondary ions will slowly fill the TPC volume, and increase the distortions.

→ in the ILC case, it is crucial:

- to know what is the expected primary ionisation, (important also for the TPC occupancy)
- to estimate the ion feedback at the working conditions of the TPC (electric fields, gas, etc.)
- to determine if a gating system is mandatory, and, if it is the case which one?

previous meetings and presentations on ions in the ILC-TPC since one year:

ACFA-2007@Beijing, Feb. 2007 presentation by Atsushi Aoza

TPC Jamboree,Aachen, March 14-16th, 2007: presentations by Adrian Vogel and VL

LCWS07@DESY June 2nd 2007 special session with presentations by:

Ron Settles, Adrian Vogel, Astrid Munnich, Akira Sugiyama, Dean Karlen, VL

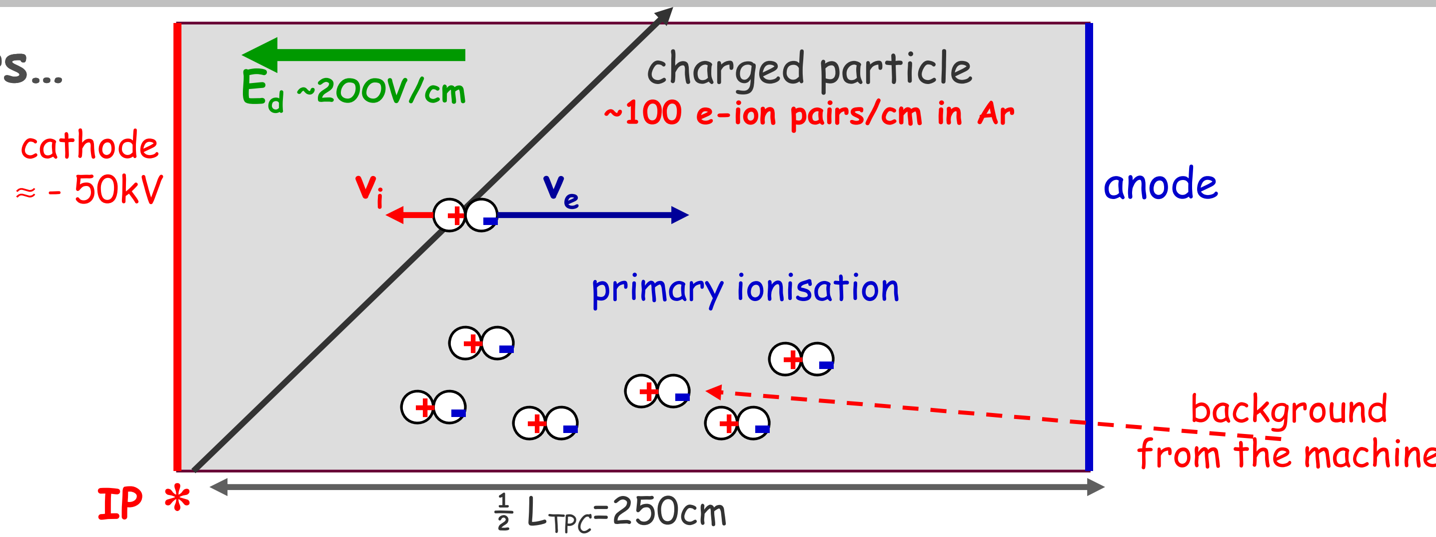
EUDET meeting@Palaiseau and Orsay Oct. 11th 2007, special ion TPC session, with presentations by:

Takeshi Matsuda, Ron Settles and VL,

+ many discussions inside the ILC-TPC collaboration + Fabio Sauli, Rob Veenhof, etc.

# ions in the LC-TPC

a few numbers…



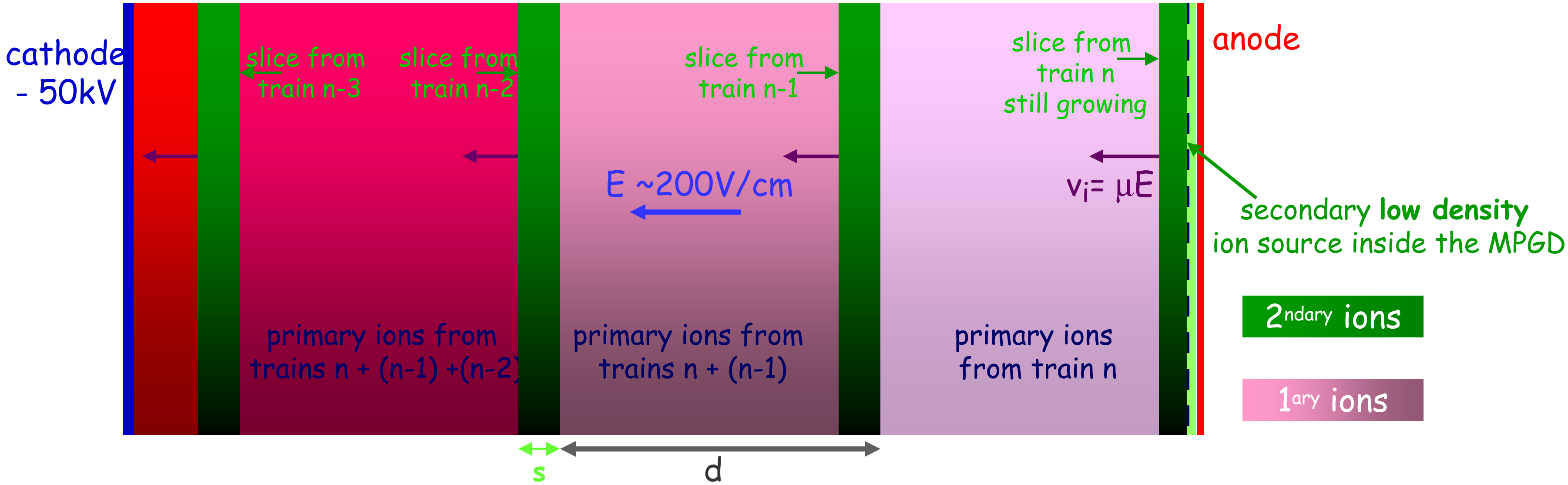

**primary ionisation:**

- electron:
  - drift velocity ~ 6-8 cm/µs @200V/cm
  - mobility µ ~ 30-40000 $cm^2/(Vxs)$
  - (max.) collection time ~ **40µs**
- ion:
  - mobility µ~ $2cm^2/(Vxs)$ in a "classical mixture" (**Ar** + a few % CH4/CF4/isobutene/CO2)
  - (max.) collection time ~ 600ms@200V/cm > time between 2 trains
  - higher mobility in light gases (Ne, He…) but spatial resolution worse in te presence of B
  - typical displacement between 2 trains d=µxExΔt ~80cm ~ 1/3 TPC half-length
  - displacement during one train ~ 4mm

→ electrons see ions at rest during their drift to the anode

"typical values" for an LC TPC

# ions in the LC-TPC (secondary ions)




**what is the status during the $n^{th}$ train of bunches (1ms) ?**

→ a slice of ions is growing from the secondary ion source in the MPGD device, and partially flow back into the drift volume through the amplification device.

→ a few more slices ( 2-3, s ~4mm-thick for Ar-mixture@200V/cm) are still in the TPC volume, at rest for an electron, generated by the previous trains, and equally spaced (d~ 80cm),

→ a primary electron created in the TPC volume will experiment the electric field created by each of the 3-4 ion slices,

→ it will experiment also the electric field generated by all primary ions created since the beginning of the 3 last trains, and still present in the TPC volume.

→ mean charge density in the slice: $\rho_s = \rho_p \times G \times \beta \times 3/8 \times 200$

total secondary ion charge $Q_s = Q_p \times G \times \beta \times 4/7$

primary ionisation; MPGD gain; MPGD ion backflow; pile-up factor; time ratio intertrain/train

$G \times \beta$ is the key parameter for the secondary ion backflow.
- if $G \times \beta$ ~< 1, do we need a gating device?
- can we work the TPC at low $G$?

# gating of ions in the LC-TPC

## natural gating of ions in a MWPC readout TPC

→ almost all « classical » TPC working close to an accelerator, for ion and particle physics are (were) equiped with a MWPC (multiwire proportional chamber) readout:

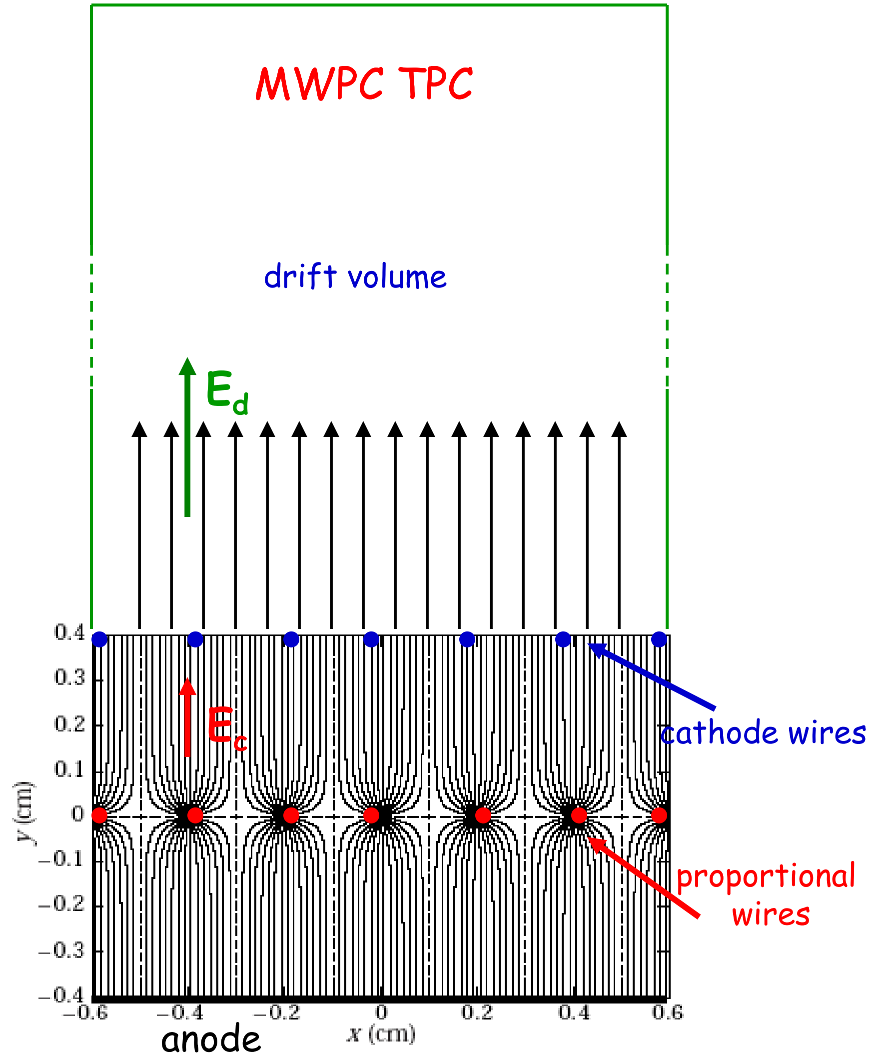
PEP4, TOPAZE, ALEPH, DELPHI, STAR, ALICE…

→ secondary ions are produced very close to the proportional wires, they follow field lines, and many of them flow back to the drift volume.

→ the backflow coeff. β is relatively large: ~5-10% depending on the electric field conditions ($E_d$ and $E_c$)

→ in that case, for a gain of 5000-10000, the secondary ionisation present in the drift volume is more than 100 times the primary one!

**so a gating device is mandatory!**



# gating of ions in the LC-TPC

## natural gating of ions in a MPGD readout TPC

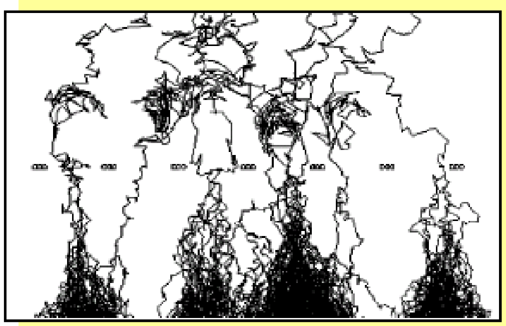
[ I restrict my explanation to the **Micromegas case**, since it is a simpler device]

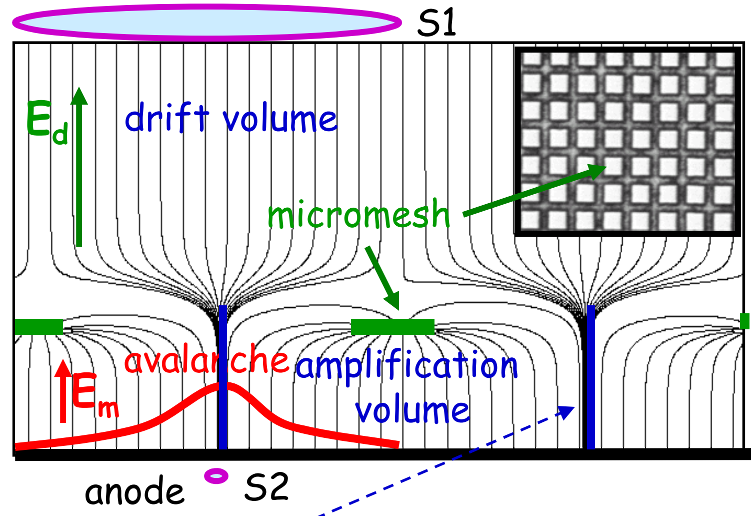
→ the Micromegas micromesh separates the drift volume from the amplification gap, with very different electric fields $E_d$ and $E_m$ (typical field ratio α ~ 300-500)

→ so it is fully transparent to primary electrons which multiply in the drift volume and are collected on the anode.

→ electrons and ions have a different behavior:
- e- diffuse and spread along the avalanche
- ions experiment a very small diffusion, and they follow the electric field lines.

→ only ions produced in the very central part of the the avalanche will flow back into the drift volume (▬)

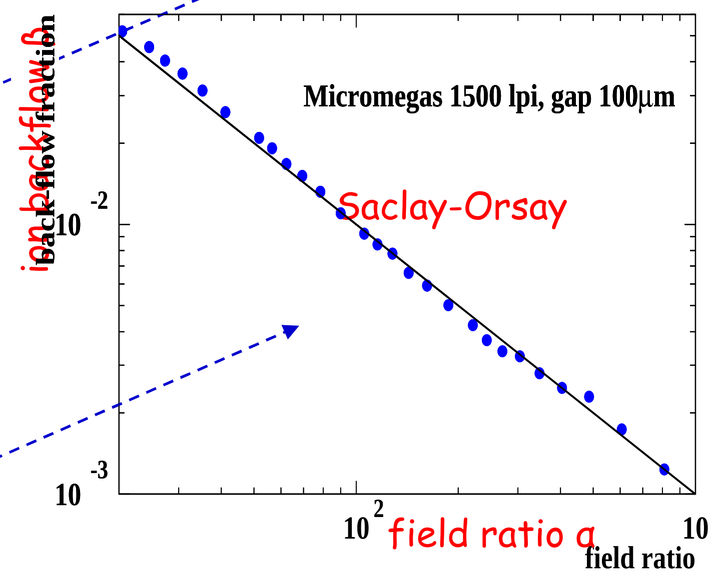





→ it can be shown that under conditions on the size of the avalanche relatively to the mesh pitch, the ion backflow is:

$\beta = 1/\alpha$ = S2/S1 (Gauss teorem)

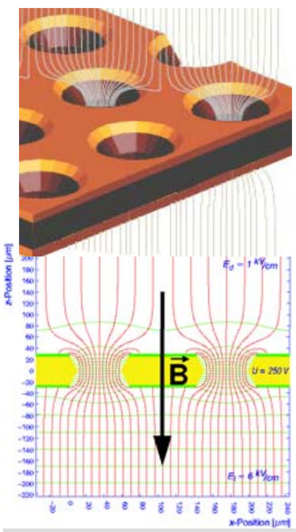
experimentaly well verified over 2 decades



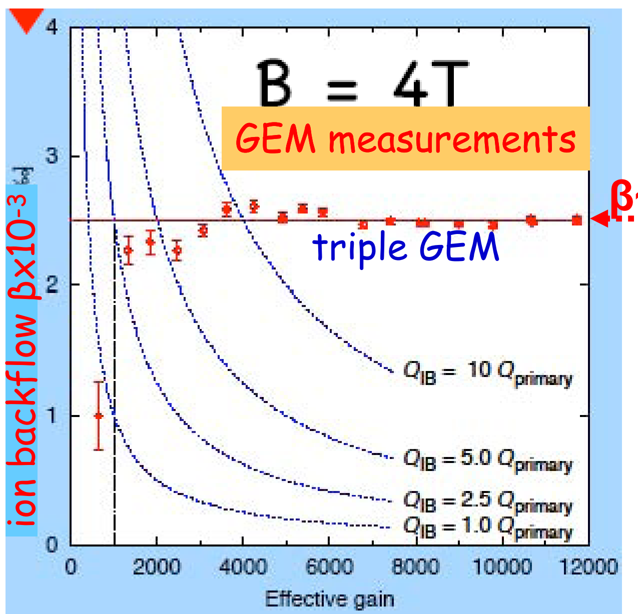
# gating of ions in the LC-TPC

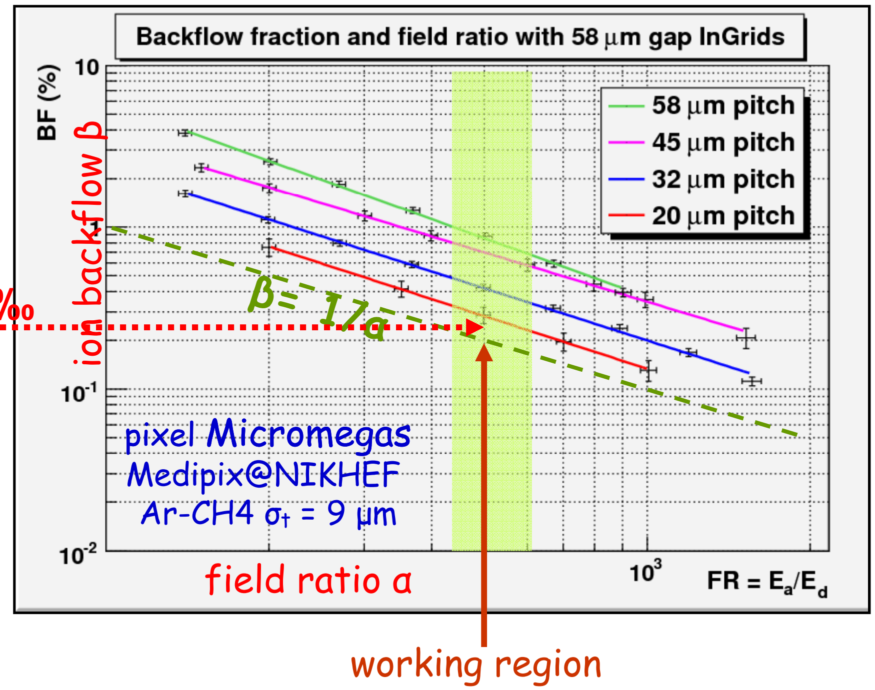
## natural gating of ions in a MPGD readout TPC (cont'd)

some other measurements of ion feedback in MPGD readout TPC's.




Akira Sugiyama, Saga U.
TPC intern. Workshop,
Berkeley, March 05
results from Aachen



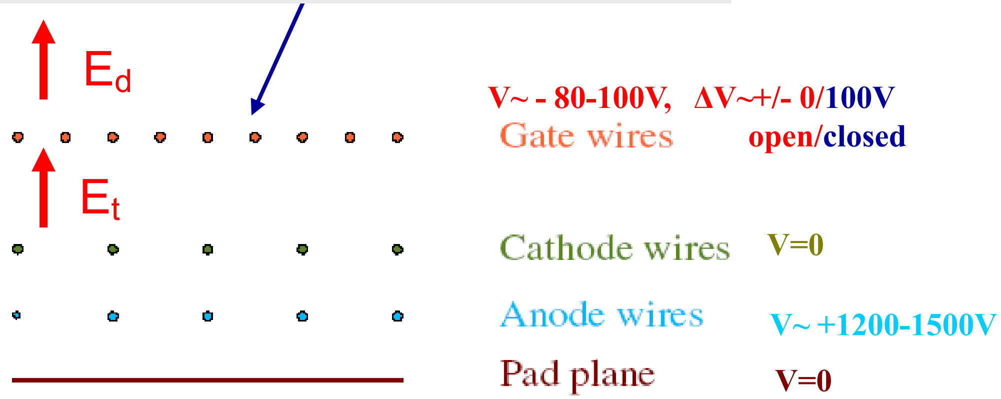

**conclusion:**

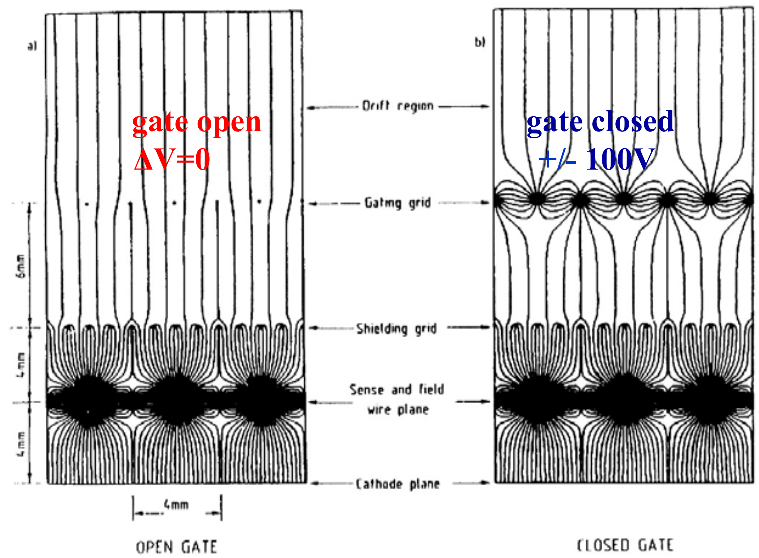
- ion backflow β in a simple MPGD cannot be decreased down to less than 2-3 ‰
- if we assume a gain G equal to 2000-5000, the total secondary ion charge in the TPC volume will be ~5-10 times greater than the primary one.
  - → is it acceptable?
  - → if not, what can we do?
- if we can work at small gain (≤ 500), ~ same number of primary and secondary ions probably we don't need a gate, but what's about the gain fluctuation?

# gating of ions with a wire grid

how does it work?
just add an extra wire plane at the end of the drift volume
with two potential states: same, or alternate on 1/ 2 consecutive wires

typical wire diam. w=50-100µm
typical wire pitch s=1-2mm
typical distances between wire planes ~ 4-6mm



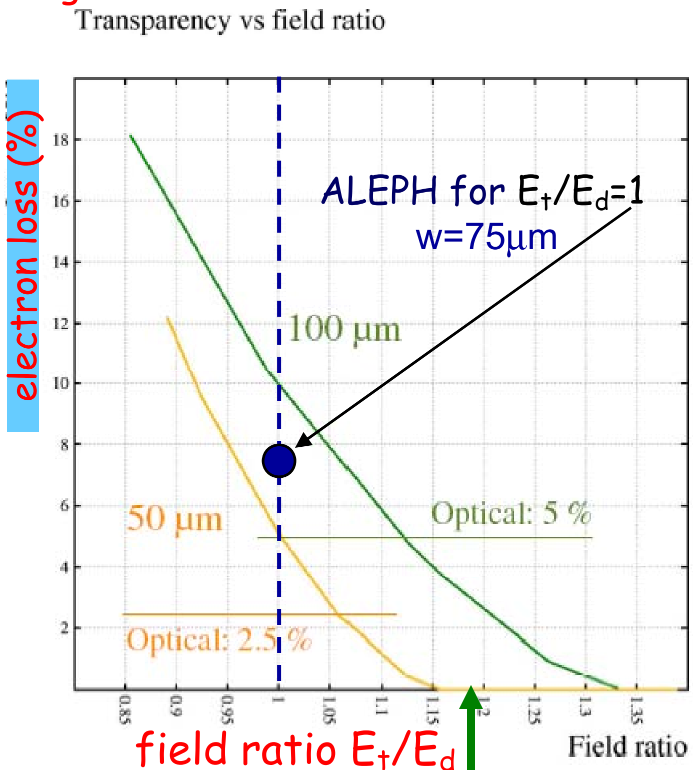




+ easy to implement
+ very efficient
– needs a frame to support wires
– possible loss of electrons/distortions ?

# gating of ions with a wire grid

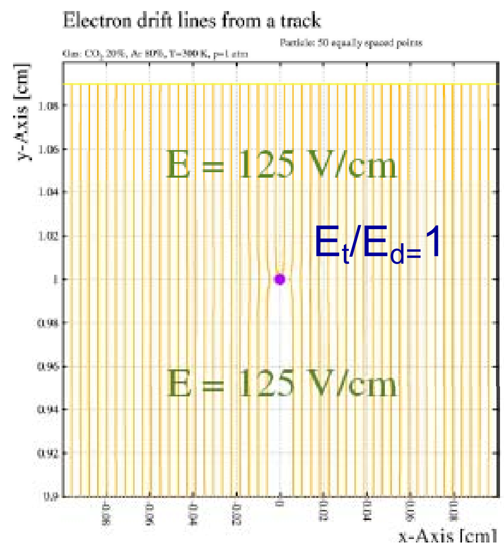
**a few limitations:**

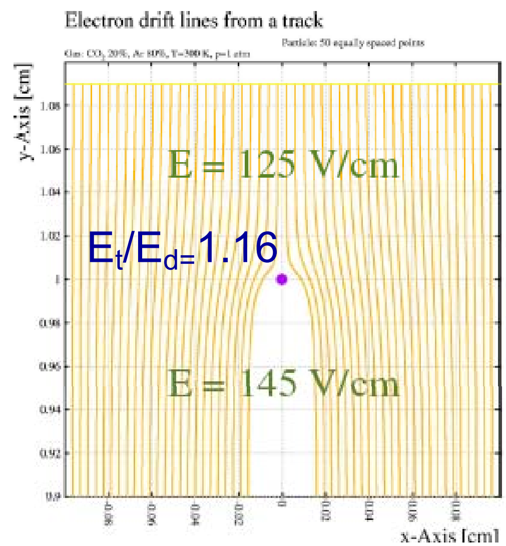
due to the finite size of the gating wires,
lack of transparency for electrons:
electron loss ~ 2x w/s ~ 5-10%
w=wire diameter, s=wire pitch
recent simulation by Rob Veenhof
http://cern.ch/rjd/Garfield/gatetrans.pdf
agreement with ALEPH measurements




full transparency reached
for $E_t/E_d \approx 1.1$-$1.2$ **BUT…**

…**BUT:** distortions (large?) close to the gating grid wires
+ **ExB** effects?
these distortions are acceptable on a classical MWPC TPC
but are they on a MPGD TPC?
is it realistic to put a **Macro-PGD** for a **Micro-PGD**?



# gating of ions with a wire grid

from presentation by Akira Sugiyama at DESY LCWS, June 2th 2007

**simulations with the gate open**

Before going to GEM gating

Is Wire a perfect gating method ?

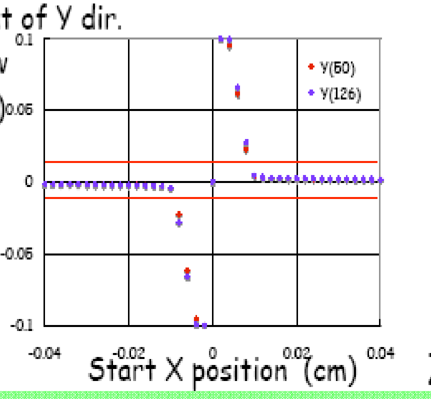
Existing wires deteriorate electric field around a wire.

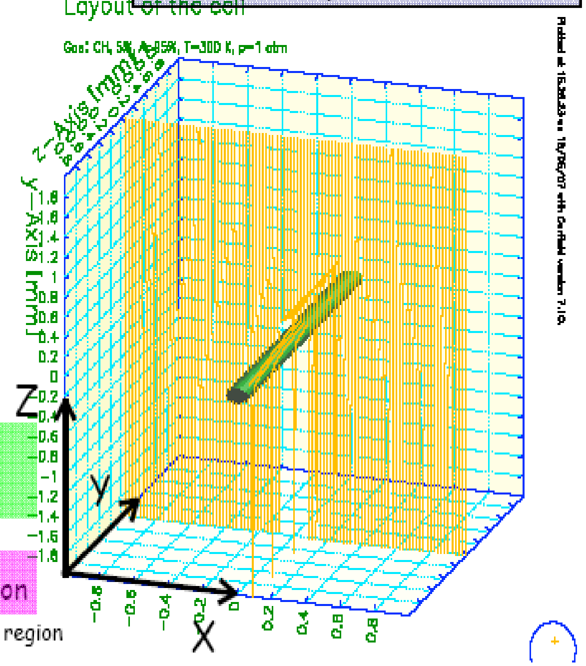
It introduces some EXB effect !!

size of ExB effect and affected area are in question

| | |
|---|---|
| Gas: | Ar:CF4 (95:5) |
| Magnetic Field | 4T |
| drift/transfer E | 100V/cm (gate:open) |
| gate wire diam. | 126um/50um |
| spacing | 2 mm |
| gate-pad gap | 1cm |

Electron transmission (@Gate Open)



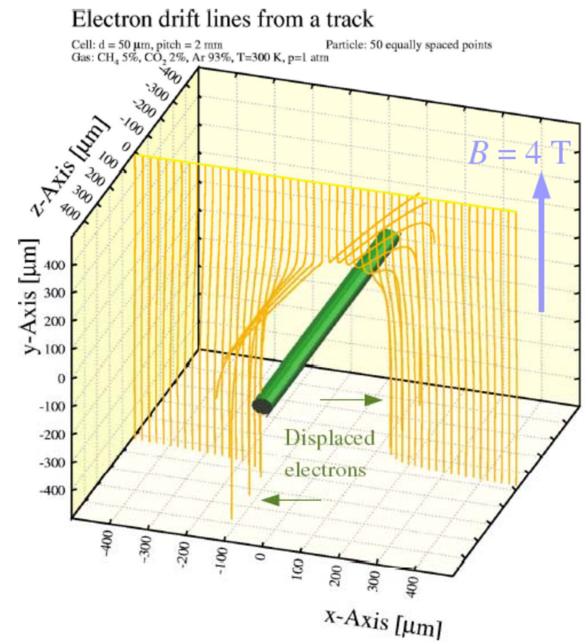

displacement > 100 um @ |x - xwire| < 100 um

this result is not depend on wire diameter

10% of region provide deteriorated information

these electrons are also diffused @ transfer/MPGD region

simulation by Rob Veenhof (CERN) 2007 **gate open**




**my conclusions:**

need for **measurements** with MPGD + wire gate

# gating of ions with a "passive GEM"

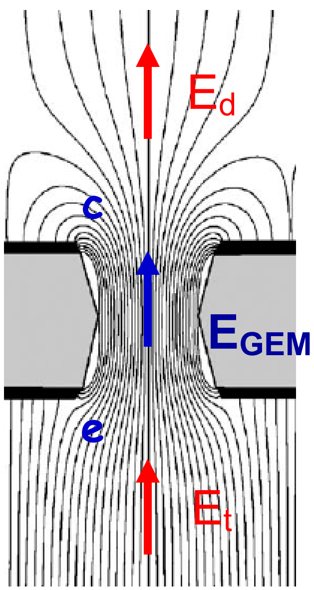
**idea: set a "passive" GEM plane (without gain) in front of the MPGD**

Ion feedback suppression in time projection chambers — measurements

F. Sauli*, L. Ropelewski, P. Everaerts — LBL TPC'06 and NIM A560(2006)269

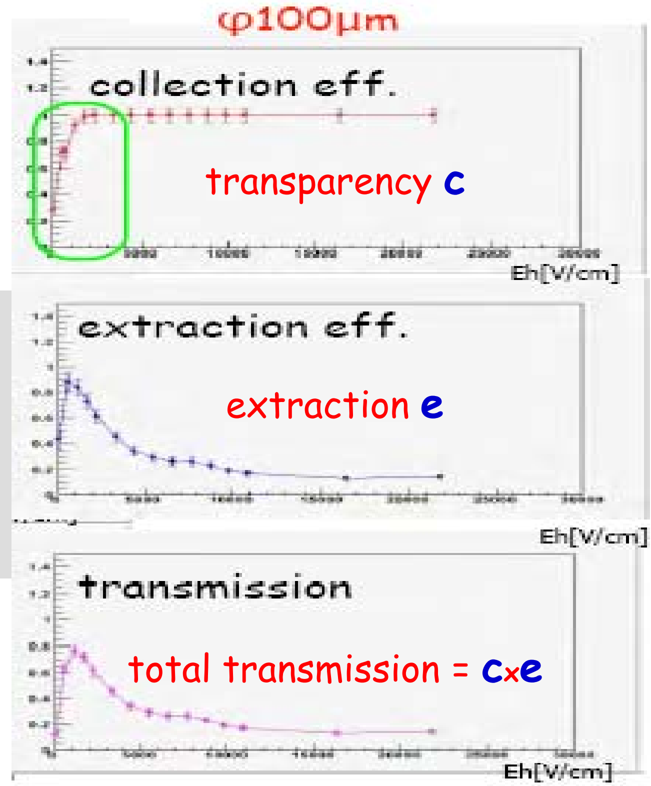
the GEM :

- is located at the end of the drift space, at a such a small distance over the MPGD that secondary ions arrive after the bunch train (1ms), after what it is possible to reverse the voltage on the GEM in order to block ions.
- is set at a low voltage (a few 10V, with no gain)
- the compromise between the 3 fields Ed, $E_{GEM}$ and Et is difficult since you should have if possible a full transparency of electrons to GEM and a full transfer to MPGD multiplication region.




idea and measurements by F.Sauli et al.
then simulation, and now measurements by Japanese groups .

presentation to-day by Hirotoshi Kurosawa
Saga University



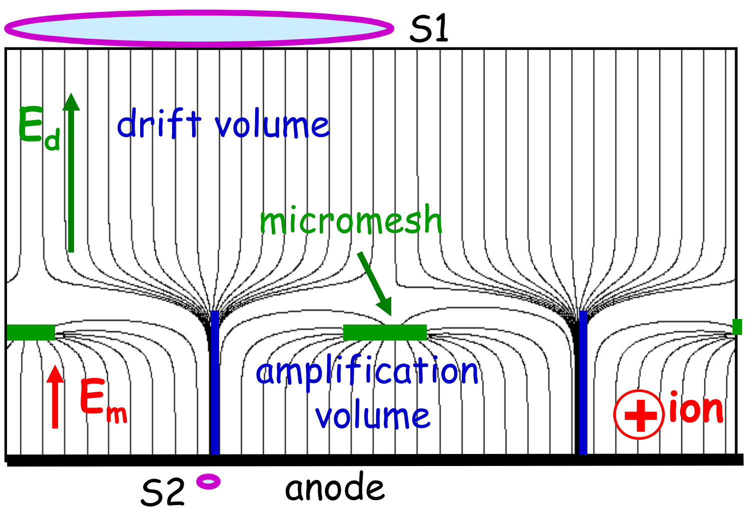

sharp tuning of both collection and extraction coefficients !

# new ideas for gating ions?

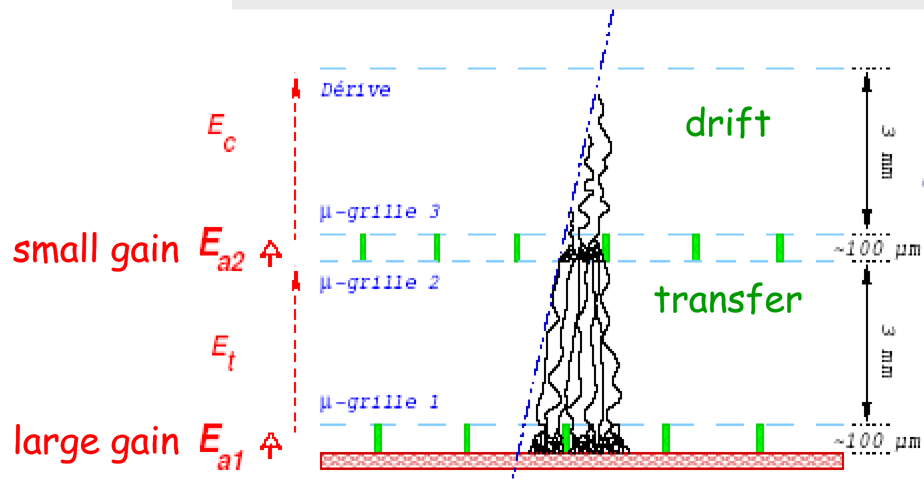
**1rst idea:** comes from the fact that in a simple detector like Micromegas, **secondary ions** have only a little chance to jump from a **high electric field** region to a **low field** one:

the maximum probability for an ion to jump is $P = E_d/E_m$ , typically a few ‰.

from that, the **new idea** is to transfer remaining secondary ions from a low or medium field region to a higher one, and make them **jump a second time**, with again a small chance to succeed and to flow back in the drift volume.

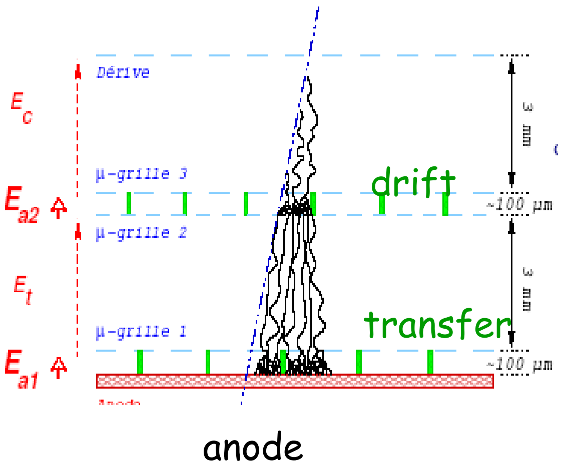



such a detector exists:
the PIM (Parallel Ionisation Multiplier)*
it consists into two amplification stages
made of micromeshes
and separated by a transfer space.




(*) successfully developed by SUBATECH lab. at Nantes (F) in order to decrease sparking in MPGD

# new ideas for gating ions?




## what are the constraints for an ILC-TPC?

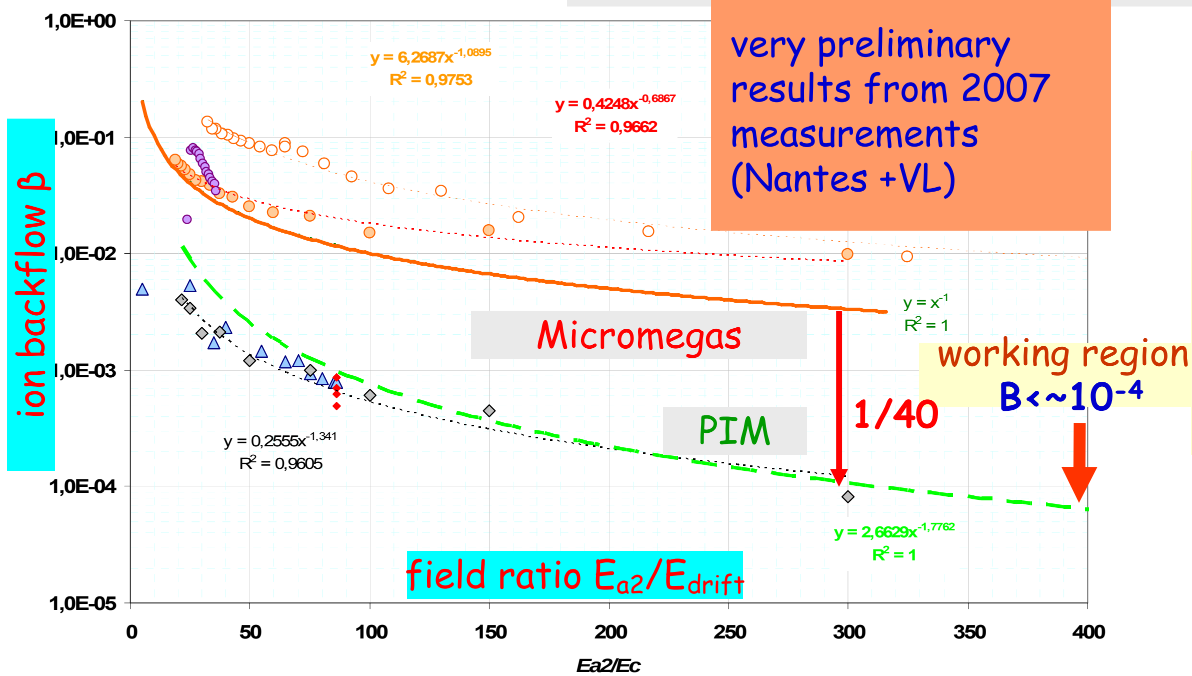
- $E_{drift}$ is fixed (~200V/cm)
- the 1rst stage multiplication field $E_{a2}$ should be small enough in order to limit the ion backflow from this stage (gain <~100)
- $E_t$ should be large enough for a "reasonable" transmission (15-20% can be reached with a field ratio $E_t/E_{a2}$ ~5-10%(*) ) and small enough to limit ion backflow from second multiplication stage → $E_t$~2kV/cm
- $E_{a1}$ is less critical and pilots the total gain

**a very naive expectation for the ion feedback is:**

$\beta = (E_t/E_{a1}) \times (E_c/E_{a2})$,

with a relative gain $E_{a2}/E_t$~ **40** as compared to a simple micromegas

very preliminary results from 2007 measurements (Nantes +VL)



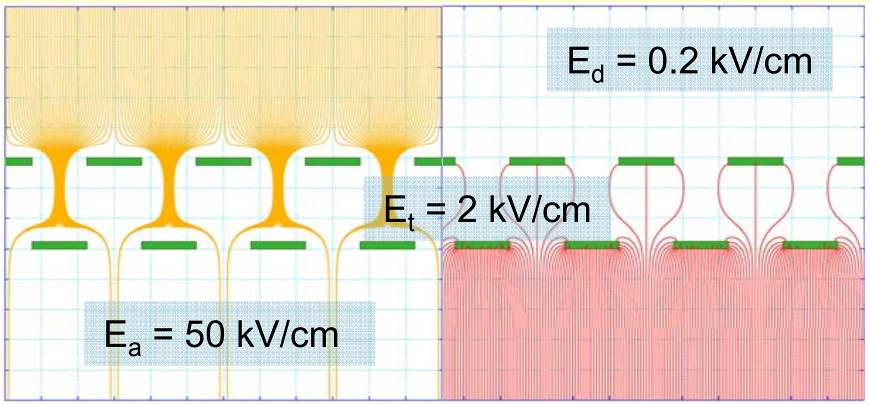

more work to be done !
- -optimisation of parameters (geometry and fields)
- new measurements
- energy resolution?

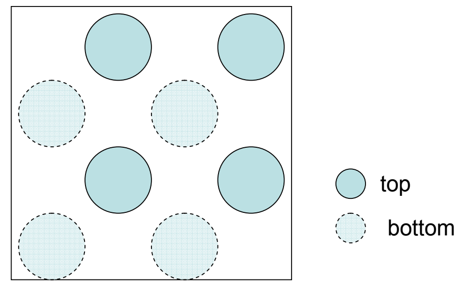
(*) see Jérome Beucher PhD, SUBATECH, Université de Nantes, novembre 2007

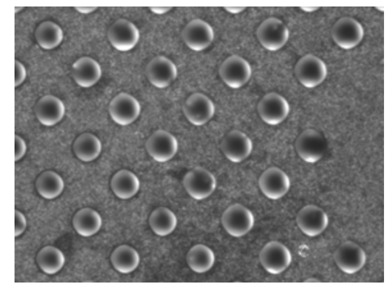
# new ideas for gating ions?

**2nd idea:** double mesh

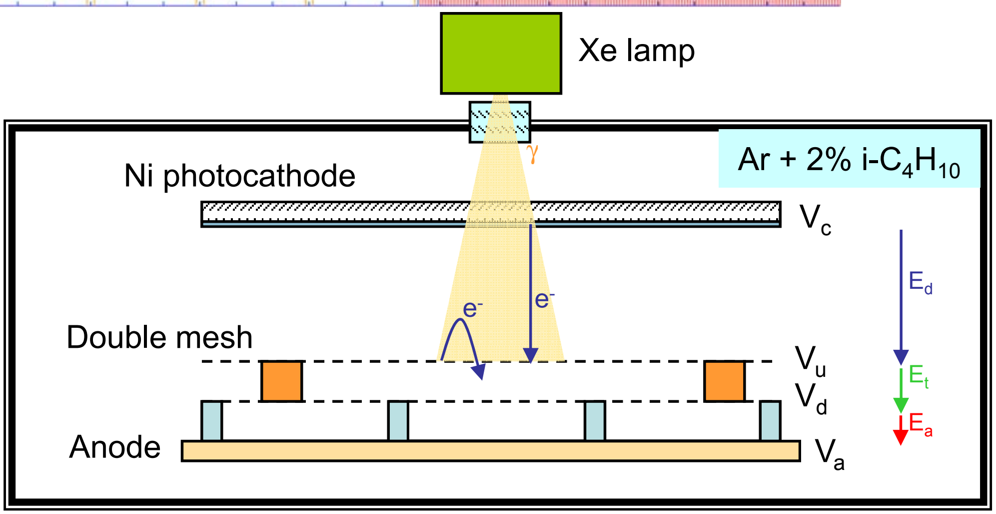
since ions and electrons have a so different behavior in drifting in gas, I proposed in 2006 to replace replace a simple Micromegas by a double one, with the two meshes fully misaligned. Again, a low gain on the first stage, and most of the gain on the second one: ions from the second amplification region will have to go through the two meshes before entering the drift region.



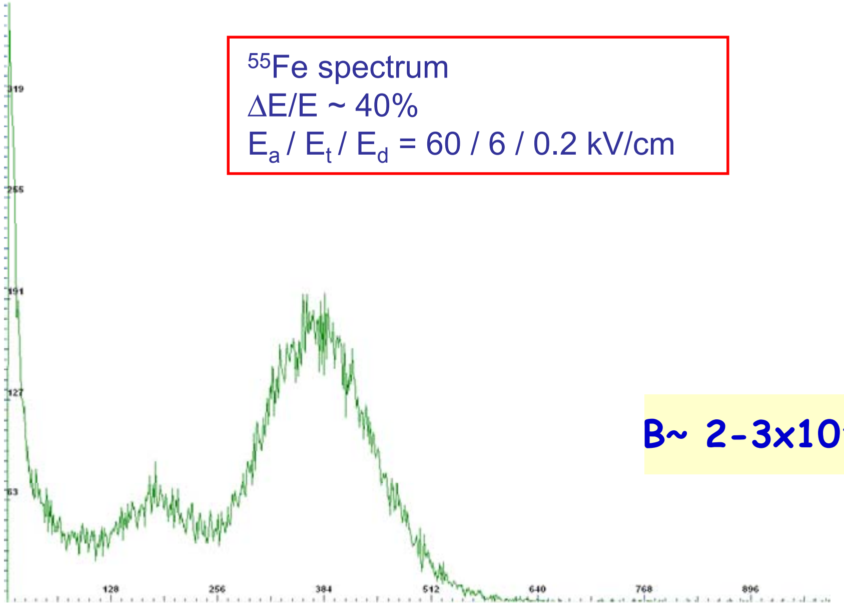



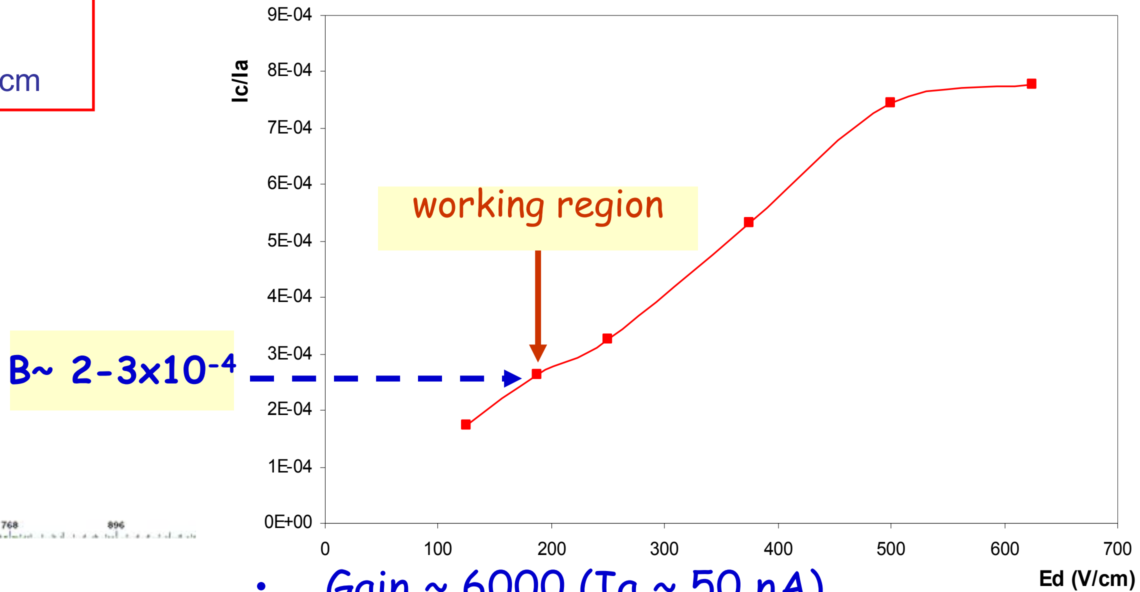



double mesh
manufactured at CERN



# new ideas for gating ions?




- Gain ~ 6000 (Ia ~ 50 nA)
- ion gating enhanced by more than 1 order of magnitude as compared to single mesh mode
- obtained without any optimisation, one day only measurements

- very preliminary results obtained (Saclay +VL) from Oct. 2007 measurements.
- new measurements very soon ( a few weeks) with a new double-mesh from CERN

# ions in the LC-TPC: my personal conclusions

**the MPGD LC-TPC case**

- assuming a gain of ~5000 on the MPGD, secondary ion feeding is expected to be ~5 times greater than the primary one, but with a density higher by 3 orders of magnitude!
  we should know the effects of these high density ion slices on electrons.
- is it possible to decrease βG down to less than 1?

## possible solutions:

1. work the MPGD at small gain (~500)
   to be investigated, especially for the gain fluctuation, crucial for the position resolution:
   some people is working on this problem in Japan, France and Netherlands (gain fluctuation and single electron response)
2. work with a gas mixture with a large ion mobility (greater than 6 $cm^2/(Vxs)$) and remove all secondary ions between two trains (except the slice of ions growing in the MPGD):
   to be excluded, too much diffusion in He mixtures, so a very bad spatial resolution is expected.
3. to gate ions, a few possible solutions:
   - gating with a wire grid
     - frame for supporting wires -> dead zone?
     - we have to choose between a 5-10% loss of primary electrons, and some ExB distortion effects
     - are they tolerable? tests of a wire gate to be done with a MPGD prototype.
   - gating with a passive GEM
     - sharp tuning of parameters, especially electric fields, also very dependant on the gas choice,
     - electron transmission ~70%, is it possible to do better? next talk by Hirotoshi
     - studies are being done at Saga Univ. (simulations and experiments, need a magnetic field)
   - new ideas with two meshes
     - very promising: a gain of more than 10 in feedback has been measured (very preliminary).
     - optimisations and new measurements are needed (and will be done soon).