ions in the ILC-TPC

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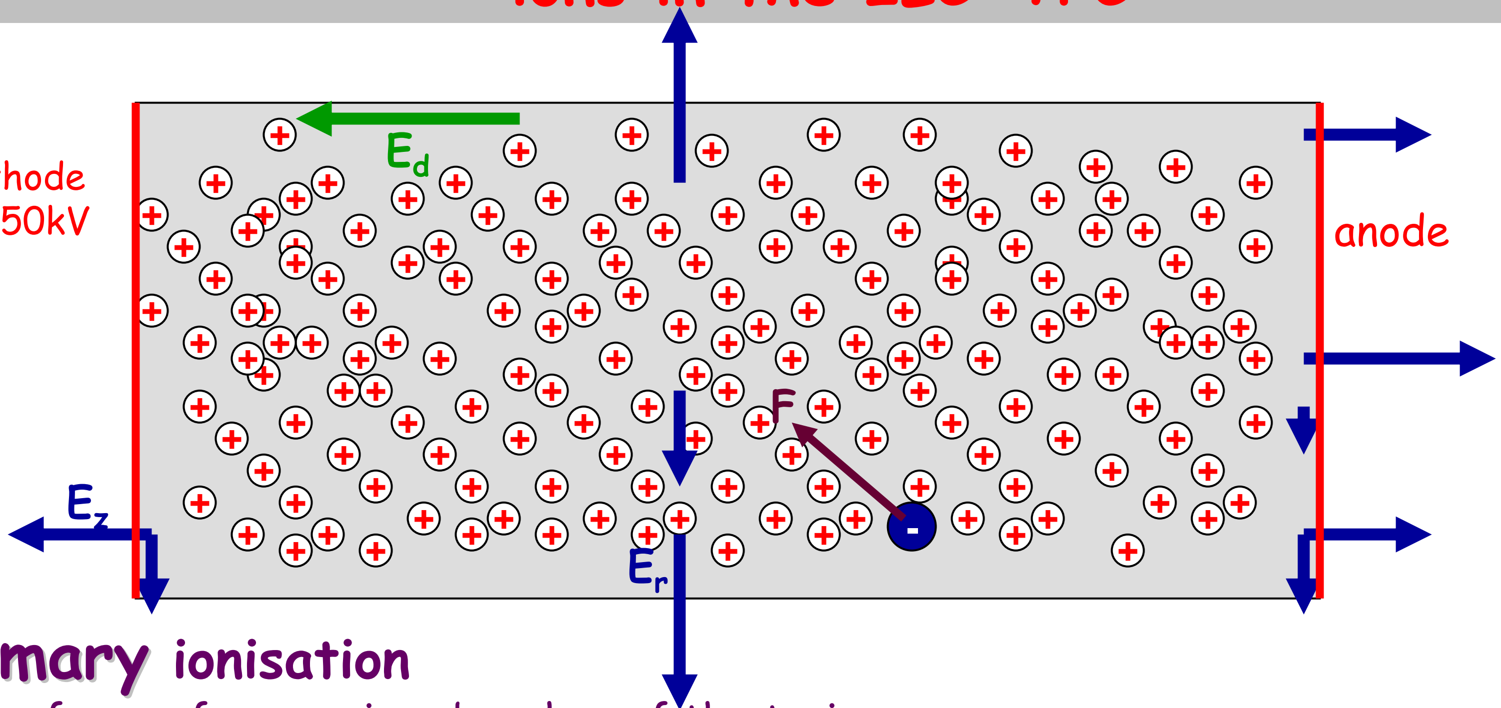
outline

- introduction: what is the problem with the ions in the TPC?
- how to suppress secondary ions?
- how to translate occupancy into ion density?
- conclusion

ions in the ILC-TPC



primary ionisation

- ions from a few previous bunches of the train, still in TPC and not yet collected
- non-uniform **feeding** of the whole volume
- ions **at rest** for a drifting electron
- creates **an attractive force** $\vec{F}$ on an electron

$$\vec{F} = (1/4\pi\varepsilon_0)q^2\,\Sigma_{ions}(1/r^3).\vec{r}$$

in the case of uniform feeding:

E_z max and // E_d at the cathode
null in the center
max. and opp. direction to E_d at the anode

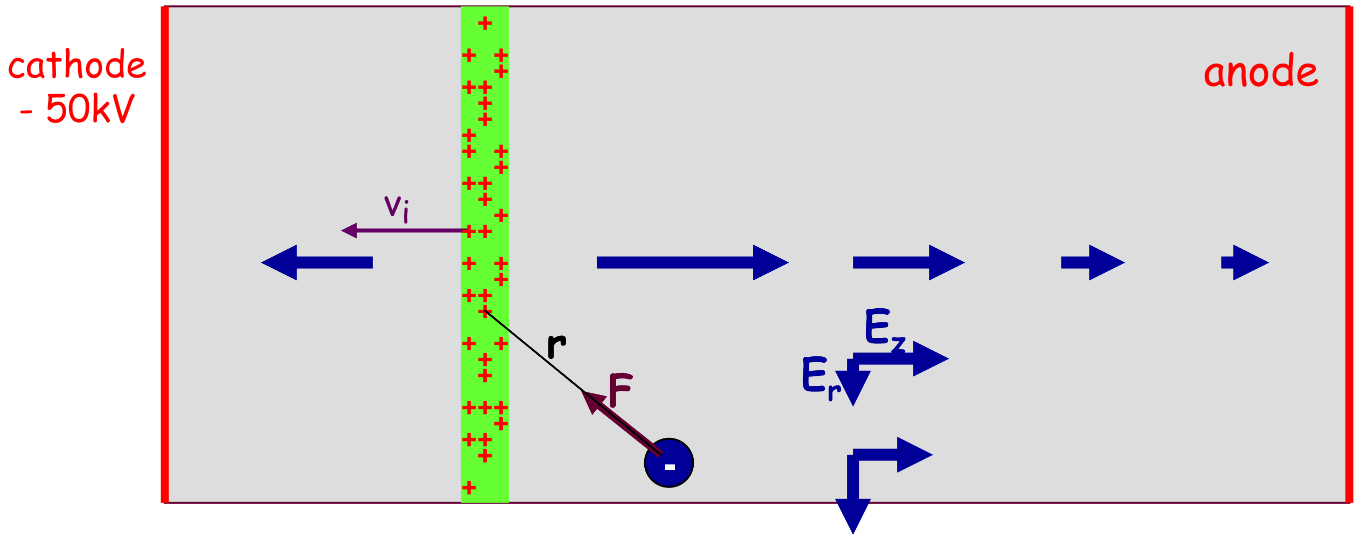
to be added to the drift field E_d

E_r

attractive force to the center of the volume
max in the middle
min at both ends

generates an ExB effect

ions in the ILC-TPC



secondary ionisation

- produced by the avalanches induced by (a few) previous train(s) and not yet collected by the cathode plane
- total secondary population: $N_s = N_i \times G \times \beta$ (N_i= primary ionisation, G=gain, β=ion feedback)

  for a MPGD: G=1000-5000, $\beta=2\text{-}10\times10^{-3}$ -> $N_s \approx 2\text{-}10 \times N_i$ **but $\rho_s \approx (Ns/Ni) \times 200 \times \rho_i \approx 10^3 \times \rho_i$**
- **small slice of ions, at rest** for an electron ($v_i \ll v_e$)

  slice size $s = v_i.\delta t$ (δt =1ms) ≈ a few mm.
- creates **an attractive force** $\vec{F}$ on a drifting electron **$\vec{F} = (1/4\pi\varepsilon_0) q^2 \, \Sigma(1/r^3).\vec{r}$**

in the case of uniform feeding of the ion slice:

E_z is added (sudtracted) to the drift field **E_d**

E_r creates a radial drift + **ExB** effects

→ **distortions of the trajectory HOW MUCH???**
simulation and/or analytic calculation needed

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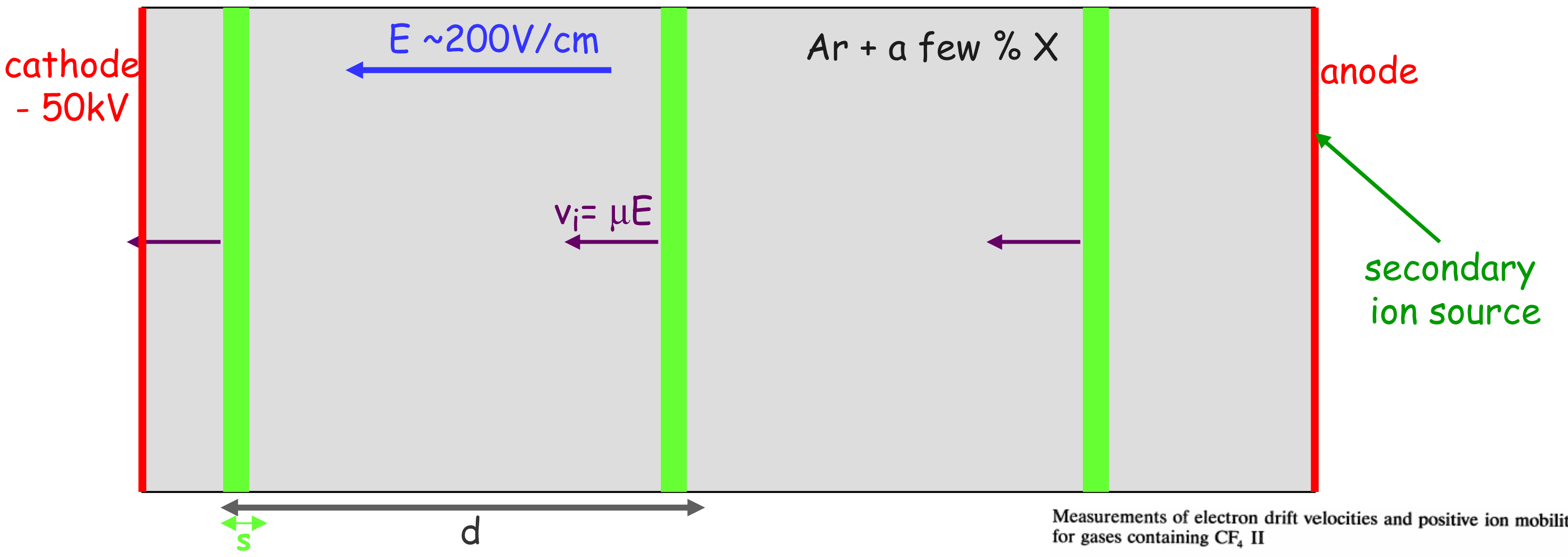


gas mixture: Ar dominant
ions X^+
transport properties of ions
dominated by **Ar**

typical values

- $\mu \approx$ **$2cm^2/(Vxs)$ in Argon** (Kr:1, Ne:4, He:5-10)
- slice s = μxExδt = **4mm** for δt=1ms
- distance between 2 slices separated by Δt=200ms:
  d = μ xExΔt = **80cm**

so with Ar+a few % X:
n~3 slices of ions together in the TPC with $L_{TPC} \approx$240cm

dream: to have d $\approx$ L_{TPC} -> n=0 slice

extrapolation for
Ar-3%CF_4-2%iso
$1/\mu \approx 0.5$ $(V.s/cm^2)$

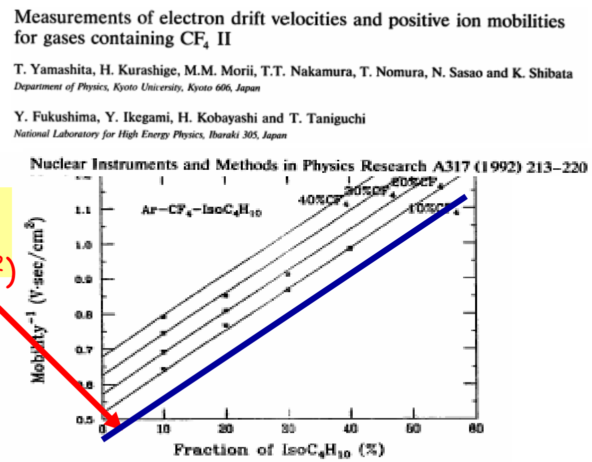


Fig. 13. Inverse mobility of positive ions as a function of the iso-C_4H_{10} fraction for gas mixtures of Ar+CF_4+iso-C_4H_{10}. Solid lines indicate fitted results with Blanc's law.

also measurements by D. Schutz, G. Charpak, F. Sauli, J. Phys. Appliquée, 12(67)1977
«mobilities of pos. ions in some gas mixtures…»: $\mu_{Ar} \approx 2cm^2/(Vxs)$

how to suppress the secondary ionisation?

-> collect ions before the next train (200ms)

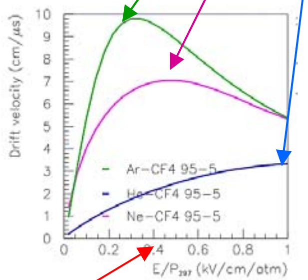
1. collect secondary ions on the cathode

to have 0 slice of ions in the TPC after 200ms

-> time collection: $T=L_{TPC}/\mu E$ = 240/2x200 ≈ **600 ms** and we want **200ms !!!**

Ar Ne He

ωT= 14 7 1



- **decrease L_{TPC}** to 80cm **NO!**
- **increase** μ by a factor 3

  for Ar, μ≈ 2cm2/(V.s), for lighter gases the mobility is higher

  for Ne μ≈ 3-4,

  for He μ_{He+}=10, but we have measured less than 5 at Saclay in 2002

  Blanc's law for additivity of 1/μ: $1/\mu=\Sigma(\varepsilon_i/\mu_i)$

  we can imagine to add to Ar (a lot of) Ne or He

  BUT v_e is smaller for mixtures with these gases, and max at higher E_d

  so three disadvantages at the same time:

  - less ionisation,
  - ωT smaller ex. 5%CF4@4T ωT=14 (Ar), 7(Ne), 1(He)
  - larger HV on the cathode

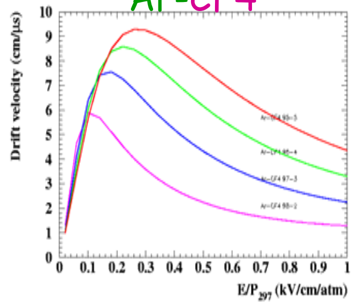
- **increase E or μE** by a factor 3

  ex. use a mixing with Ar+He+ 5-6%CF4+iso-C4H10 with 400V/cm

  -> same problem with HV

  I think that the maximum we can get is a factor 1.5 to 2, not 3

Ar-CF4



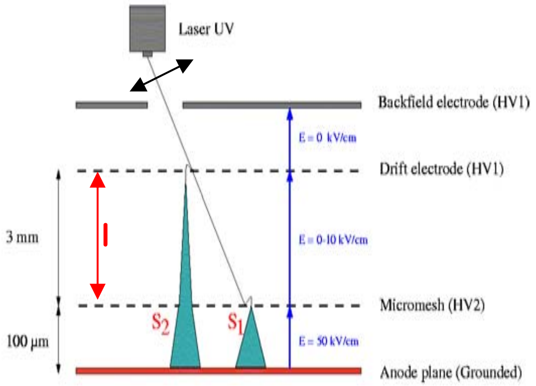
→ **conclusion:** the TPC is at least 1.5 times too long for the 200ms time between trains

do we need to measure ion mobilities?

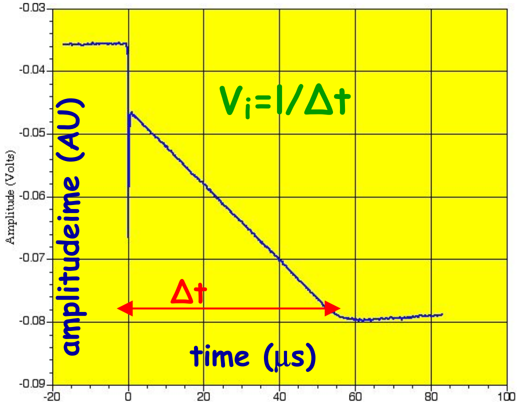
probably YES if we want to put a gating device.

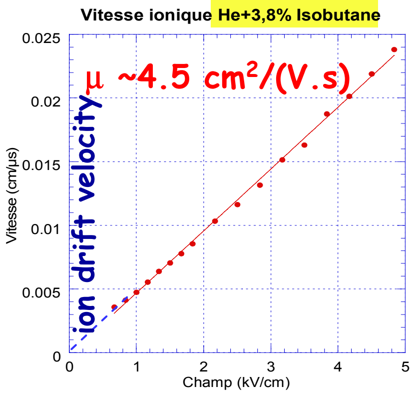
ions in the ILC-TPC

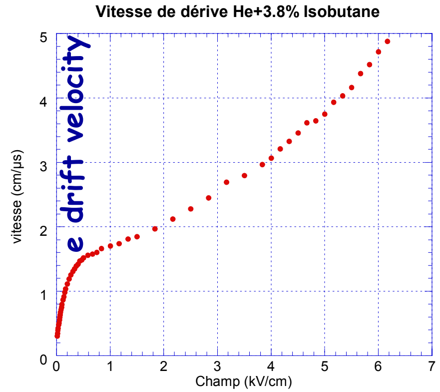
how to measure ion mobility?

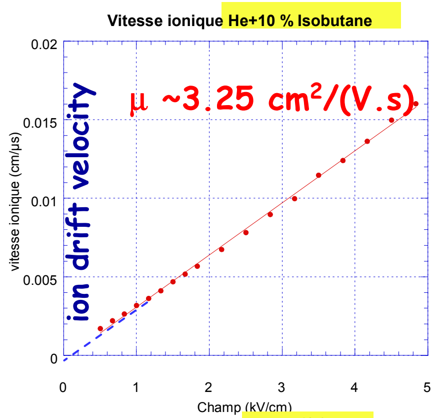


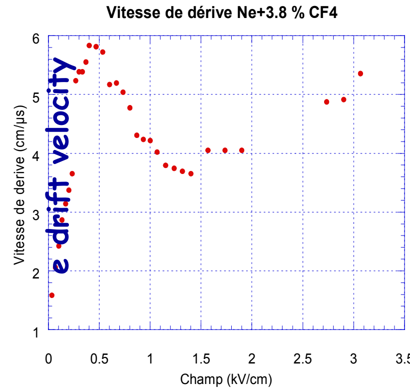
very simple device already used at Saclay for e drift velocity measurement
P. Colas, et al., NIMA478(215)2002.
(results on ions not published)

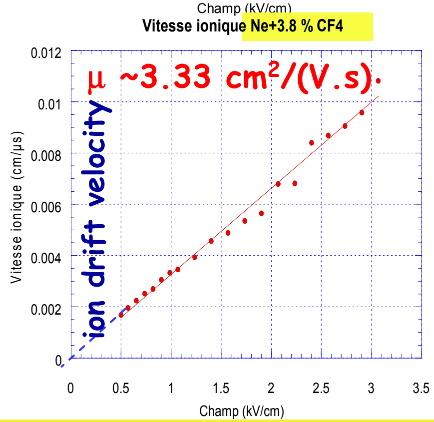


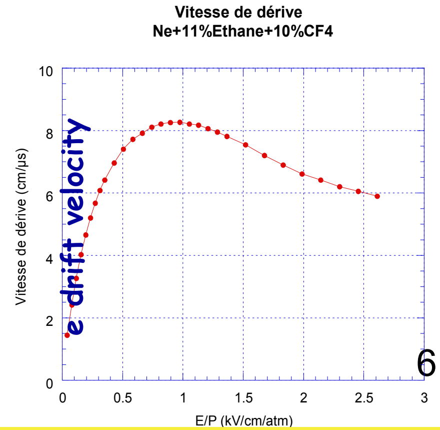








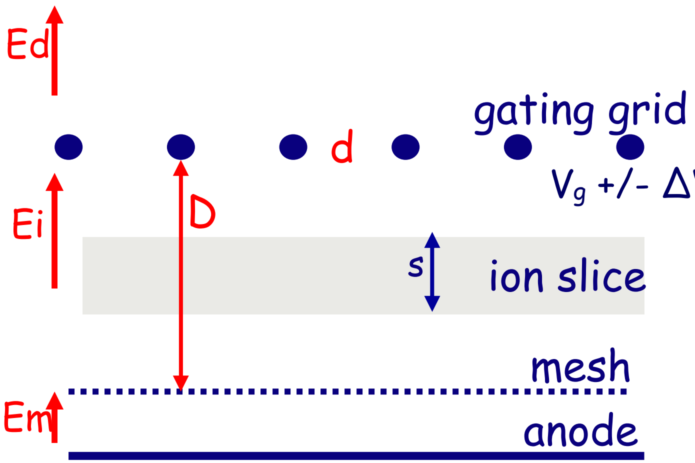




ions in the ILC-TPC

2. gating with a grid

MPGD configuration (Micromegas)



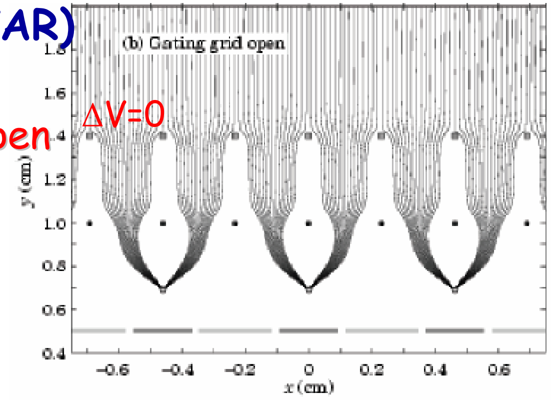
in principle: OK, very efficient, BUT…

- one needs a full electron transparency
  do we have to increase E_i? probably $E_i > E_d$
  s is increased proportionally
- wires pitch d ≈1mm, is it possible to do less?
  -> transverse kick on the electrons through the gate
    -> distortion, how much? O(100μm)? -> simulation needed
    + small ExB effect
    + frame for the wires:

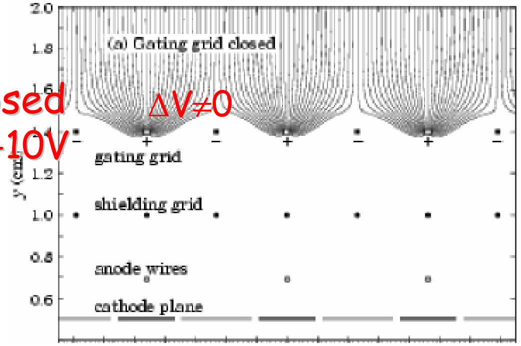
for example for a 40x40cm² detector, with d=1mm and a tension of 100g on each wire:
F= 40x10x100g= 40kg

gating system on the DELPHI TPC (also ALEPH and STAR)

gate open
ΔV =0



gate closed
ΔV ~ +/-10V



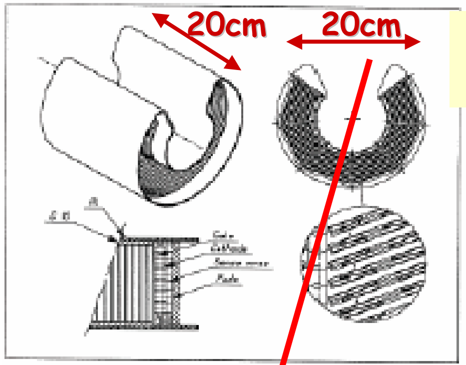
electrons AND ions catched by the gate grid

LAL-LBL-Cincinnati mini-TPC for SLAC B-factory commissioning NIMA419(525)1998.

ions in the ILC-TPC

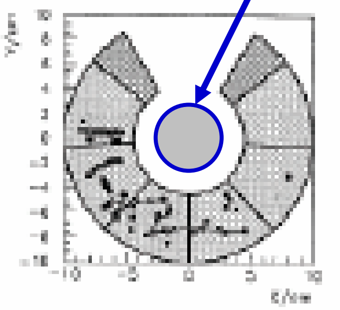
field distortion examples:

example 1: LAL(VL)-LBL(Mike Ronan)-Cincinnati mini-TPC for PEP-II commissioning at SLAC (1997) before Babar

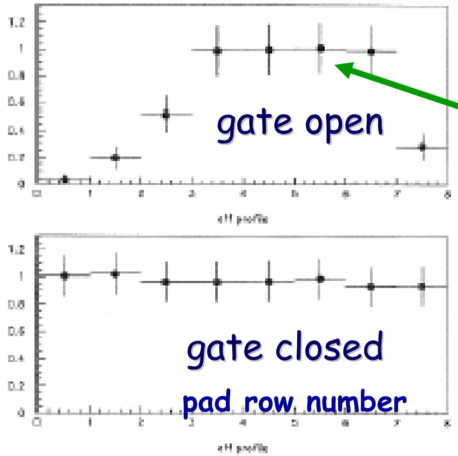


8 wires & pad rows
6 sectors

PEPII beam pipe



test beam at CERN



ions are attracted from the edges to the center

ion feeding equivalent to a transverse field ~ 50-100 V/cm

"a mini-TPC for SLAC B-factory commissioning"

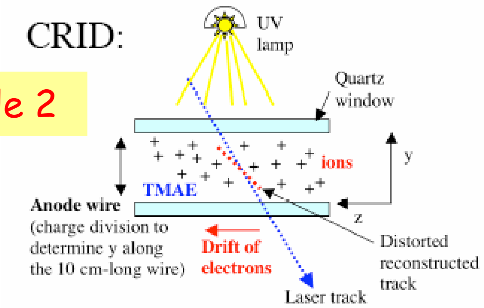
R. Cizeron et al. NIMA419(525)1998.

Suppression of Ion feedback in TPC

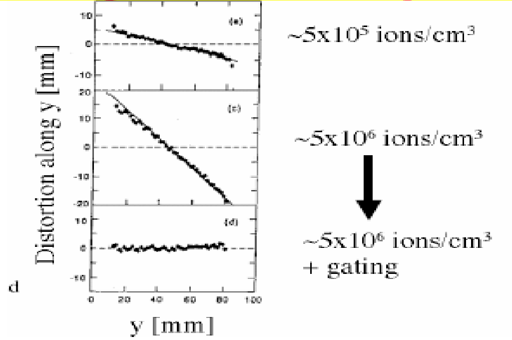
J. Va'vra,
Stanford Linear Accelerator Center
LBL Workshop 2005

CRID group, SLAC-PUB-5365, 1991

example 2



- **CRID measurement:**
  ~100μm distortion over a ~10cm long track segment is caused by ~10^4 ions/cm^3
- **Gating can fix the distortion problem.**

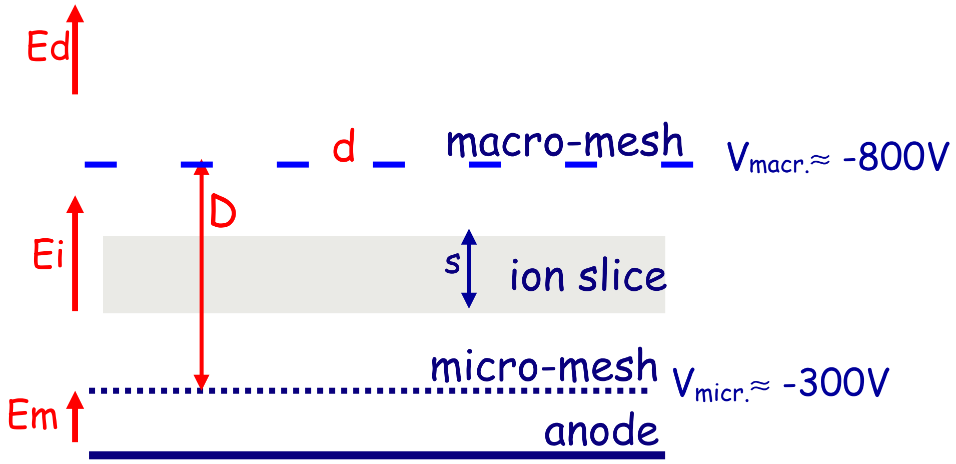


<u>ILC TPC mental excercise:</u>
100 tracks/event, 3m dia., 4m long, volume=3x10^7 cm^3, ~1.5x10^6 primary ions, ~0.05 primary ions/cm^3, assume gain ~5x10^3, ~3x10^2 secondary ions/cm^3,
Expect no distortions for this example

ions in the ILC-TPC

2. gating with a MPGD device

gating with a **macromegas**



new idea (may be not a good one…):

gate the ions with a "macro-mesh" with a large pitch d (200μm?)
in order to ensure a full electron transparency
-> probably needs also $E_i > E_d$ $E_i = 2\text{-}3 \times E_d$?
s is increased proportionally from 4mm to ~ 1cm -> D>1cm
-> no kick on the electrons
-> very small ExB effect

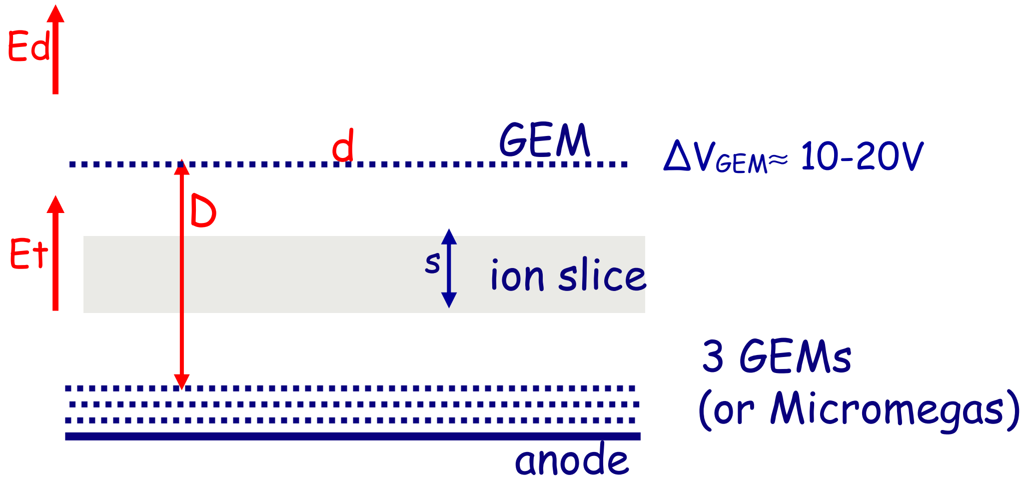
-> problems:

1. after the train (1ms) the macromesh voltage has to be increased by more than 500V within less than a few 100 μs, in order to push back ions to the micromesh
is it possible? may be not, to be studied…
2. how to hold this macromesh ?

ions in the ILC-TPC

2. gating with a MPGD device

gating with a **GEM**



original idea by Fabio Sauli 2006:

Ion feedback suppression in time projection chambers

F. Sauli*, L. Ropelewski, P. Everaerts

Nuclear Instruments and Methods in Physics Research A 560 (2006) 269

gate the ions with a GEM without multiplication (ΔV very small)
the same problem is to have a full electron transparency,
and, also, a full transmission from this GEM to the amplification device
of course this transmission depends on the transfer field Et.

measurements by Fabio et al. AND recent simulations by a Japanese group

ions in the ILC-TPC

Ion feedback suppression in time projection chambers

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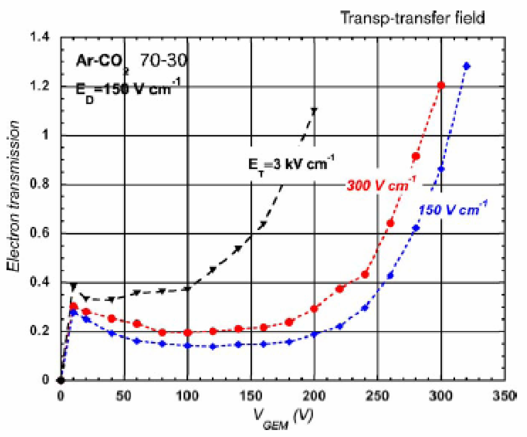


Fig. 4. Electron transmission of a standard GEM foil, measured in the pulse mode, for standard high (3 kV cm^{-1}) and low transfer fields (150 and 300 V cm^{-1}), as a function of GEM voltage. Drift field: 150 V cm^{-1}, gas filling A–CO_2 70–30 at STP.

influence of the transfer field Et

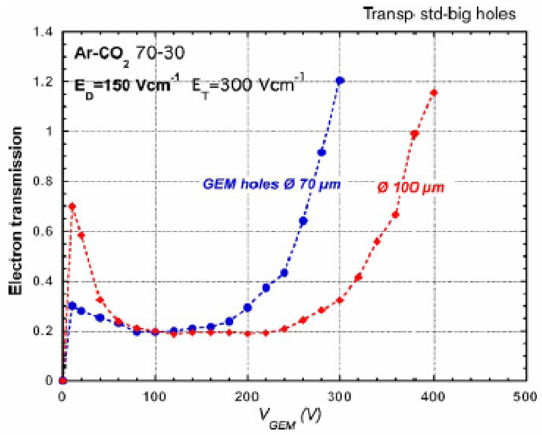


Fig. 6. Comparison of electron transmission for two GEM foils: standard (70 μm holes at 140μm pitch) and large (100 μm holes at 140 μm pitch). Gas filling: A–CO_2 70–30.

influence of the GEM hole size

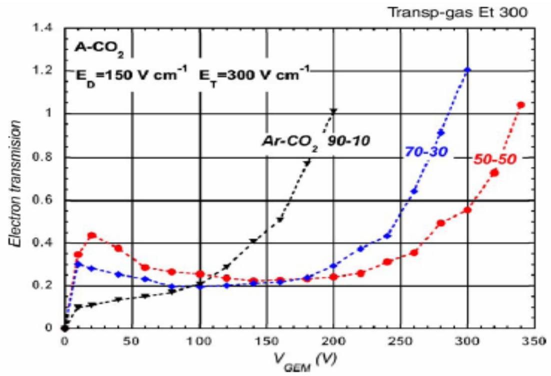


Fig. 5. Electron transmission of a standard GEM, for low transfer field (300 V cm^{-1}), as a function of GEM voltage and for three A–CO_2 mixtures: 90–10, 70–30 and 50–50.

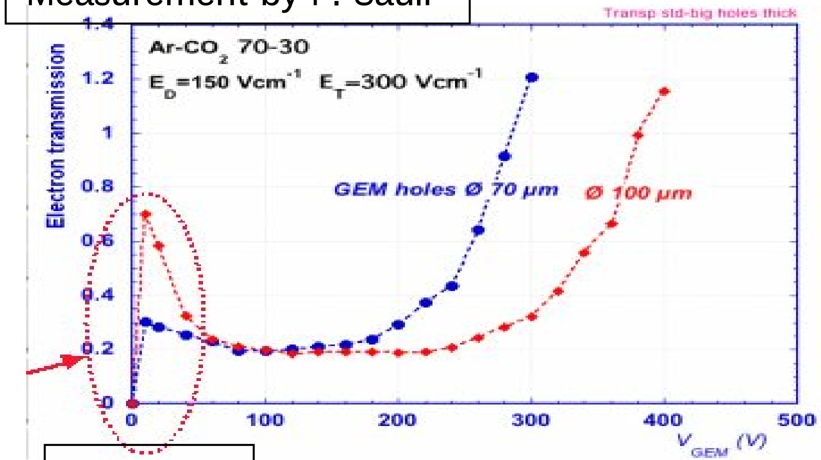
influence of the gas mixture

ions in the ILC-TPC

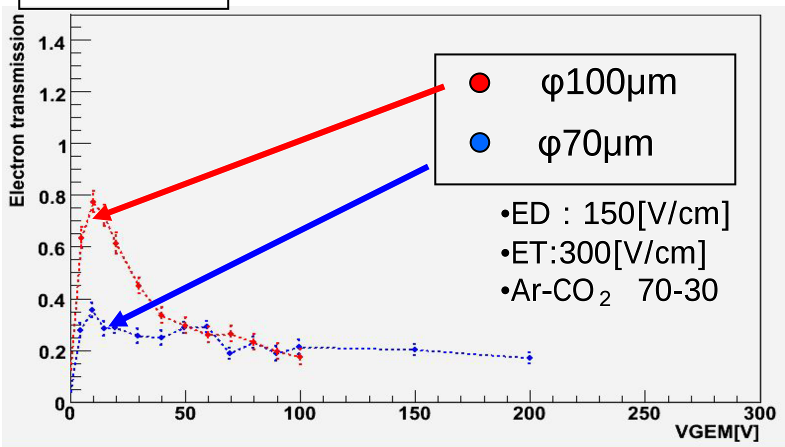
a simulation study of GEM gating at ILC-TPC presented at
ACFA-Beijing by Atsuhu Aoza (Saga Un.) for the Japanese TPC group

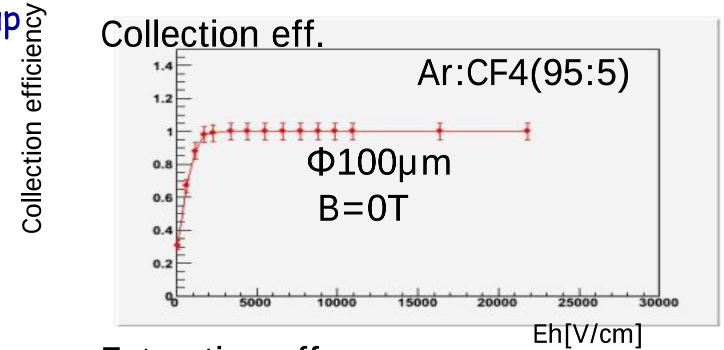
A.Ishikawa, A.Sugiyama, H.Fujishima, K.Kadomatsu(Saga U.)
K.Fujii,M.Kobayashi, H.Kuroiwa,T.Matsuda(KEK)
O.Nitoh(TUAT),T.Watanabe(Kogakuin),Y.Kato (Kinki)

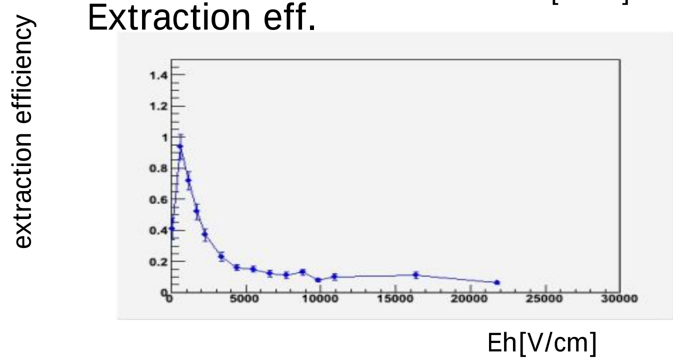
Measurement by F. Sauli

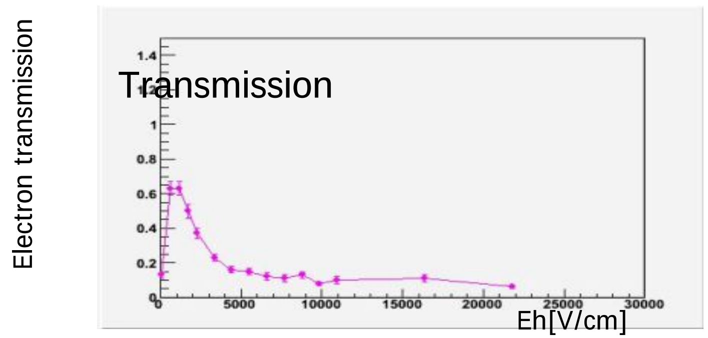


simulation HOLE DIAMETER EFFECT









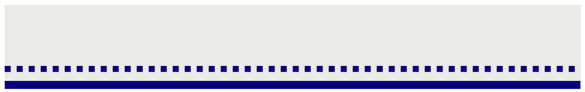
conclusions of this presentation:
we need gas with low diffusion even at high electric field
we still don't understand detail some part yet

ions in the ILC-TPC

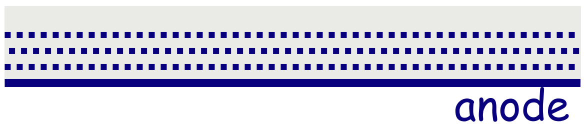
influence of ions on the multiplication process?

an electron arriving in the multiplication region **always experiment** a slice of secondary ions, with a variable size ≤s, produced since the beginning of the train near the anode plane.
so the multiplication region is never "ion free"

- Micromegas case
  - due to their very high velocity (500 times higher than in the drift region) ions escape 500 times faster, but there are 500 times more ions (no gating by Micromegas) so the ion density in this gap is quite the same.
  - moreover the electric field is so high in this region that probably electrons "will not see" these ions, and also the gap is very small
  - -> probably no effect



- GEM case
  - most of the ions originate from the last GEM hole
  - due to the various regions (inside and between the GEMs) the problem is a little bit more complicate….
  - will there be a problem (distortion) on the electrons? may be not…



ions in the ILC-TPC

how to estimate ion density in the TPC from occupancy?

- difficult exercise, may be an answer from Adrian Vogel simulations very soon…
- depends also on background, gas choice (neutrons), gain, ion feedback…

fast calculation yesterday evening, assuming:

- numbers from Adrian for the hits
- gain G=5000
- ion backflow $\beta=2\times10^{-3}$
- ion mobility $2cm^2/(V.s)$
- v_e=8cm/μs
- E_{drift} = 200V/cm and R=120cm, L_{TPC}=240cm
- 10^9 voxels in the TPC

1. TPC occupancy

the max. drift time for electrons is 60μs, corresponding to ~200 bunches
from Adrian, there are ~4×10^5 "hits" during this time in the TPC.
I assume that a hit will occupies after diffusion ~20 voxels
-> $20\times4\times10^5 = 8\times10^6$ voxels "occupied"
-> occupancy ~ 1%

2. ion density

- I assume **very arbitrarily** that 1 hit => 100 electrons released
- total number of electrons producing ions during 600ms= 3 trains (time for ions to be collected by the cathode):
  $N_e=4\times10^5\times100\times(3300/200)\times3 \sim 2\times10^9$ … and the same number of primary ions,
- total number of secondary ions: $N_i = N_e \times G \times \beta = 2\times10^9\times5\times10^3\times2\times10^{-3} \sim 2\times10^{10}$ for 3 ion slices.
- total charge per slice $Q=0.7\times10^{10}\times1.6\times10^{-19}$ = 1 nC
- slice volume, with s=4mm: $V\sim1.7\times10^4$cm3
- charge density in the slice $\rho=Q/V \sim 60\ fC/cm^3$ ($6fC/cm^3$ if $G=1/\beta$)

is it a problem for an electron crossing this «wall» of ions????

conclusion

primary ionisation

nothing to do except to collect ions « quickly » in order to decrease its density in the TPC
need to do more simulations (calculations) on the distortions induced by these ions

secondary ionisation

- probably **impossible to collect** secondary ions on the cathode before 200 ms
- do we need a **gating device**?
  - if Ns ≈ Ni, may be not, except if the high density secondary ions slice is a problem,
  - if Ns large, probably yes we have to gate secondary ions,
- simulations (and/ore calculations/experiments) of the **distortions** induced on electron drift (with B) are needed,
- **ion mobility** measurements (or calculations) are probably needed for gate optimization
- more work and thinking on gating devices:
  - a gate should be **transparent** to electrons,
    - should not induce **distortions** and **ExB** effects
    - should be optimized for a given **gas mixture**

… more work to be done!