Low pressure gas detectors

Short review on low
and very low pressure gas detection

Examples of detection systems at GANIL

Julien Pancin

Instrumentation days on gaseous detector
June 25/26th

Why very low pressures?

Use of low energy beam

- Few materials in beam (few angular or energy straggling for medium/heavy nuclei) and operation in vaccum ⇒ low pressure gas detector
- Use of pure iC_4H_{10} (or other quenching gas) for its low ionisation energy (100 % efficiency needed) and its high quenching power (very low pressure of several mbar)
- Mean free path of electrons much higher : high electron drift speed, early avalanche and good timing resolution
- Important gain (E/P…) even in low field region : natural spread of the avalanche, good spatial resolution with low granularity, low threshold applications
- Low drift gap and fast ion collection for high rate capabilities

Signal at low pressure (…vs NTP)

laboratoire commun CEA/DSM CNRS/IN2P3

- No differences in the ionization process (apart for delta electrons…)
- Amplification process easier at low pressure: Minimum field E_c for avalanche multiplication $\approx$ 40 V/cm/torr

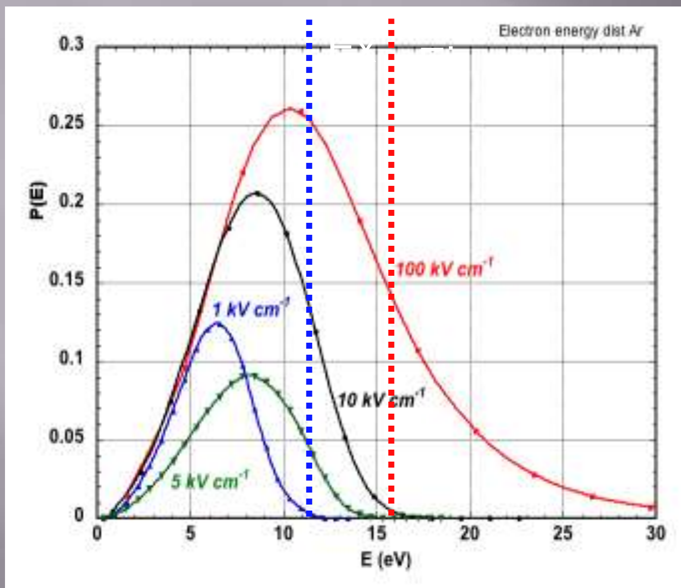
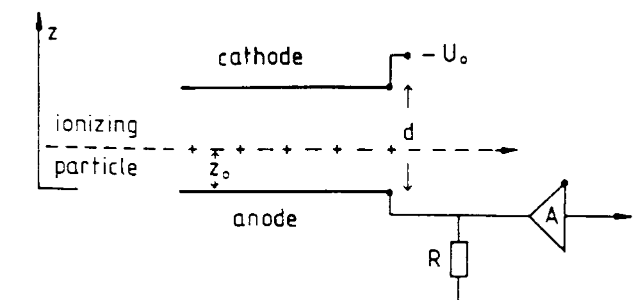
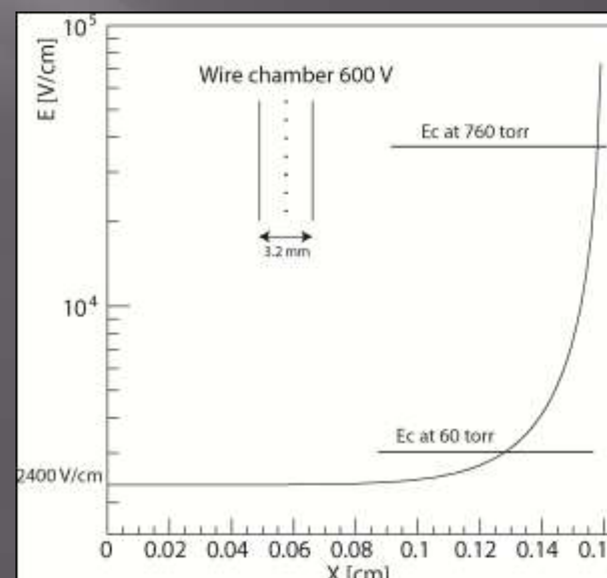


Fig. 2.1. Parallel-plate ionization chamber (schematic).



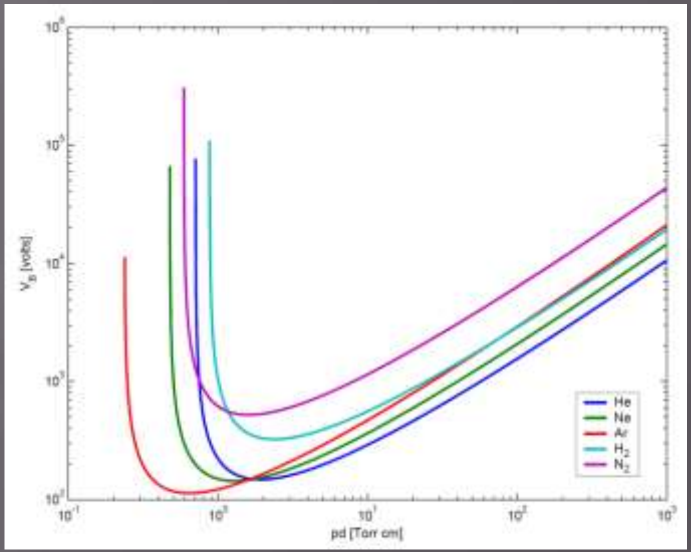
d= 3 mm$\Rightarrow V_c \approx$50 kV at 1bar but 500 V at 10 mbar

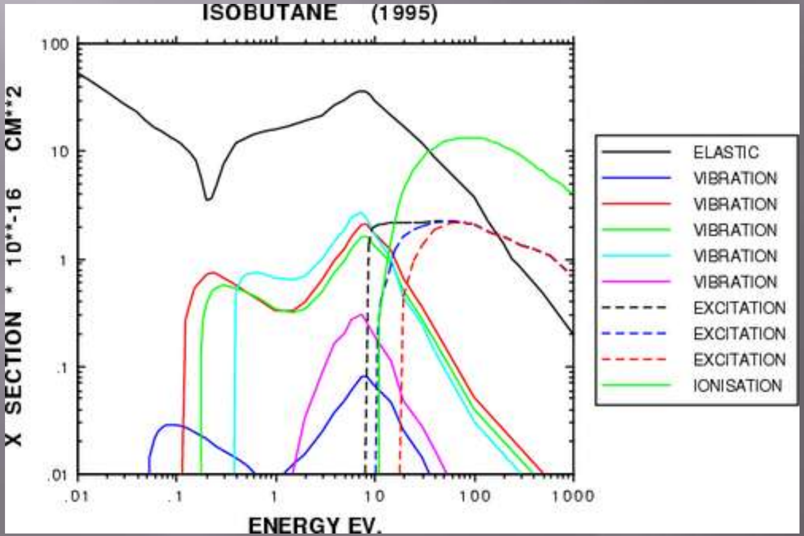
- Increase E: wire chamber (α 1/r)
- Decrease gaps: MPGD (micromegas, GEMs, MSGC)
- Decrease Pressure

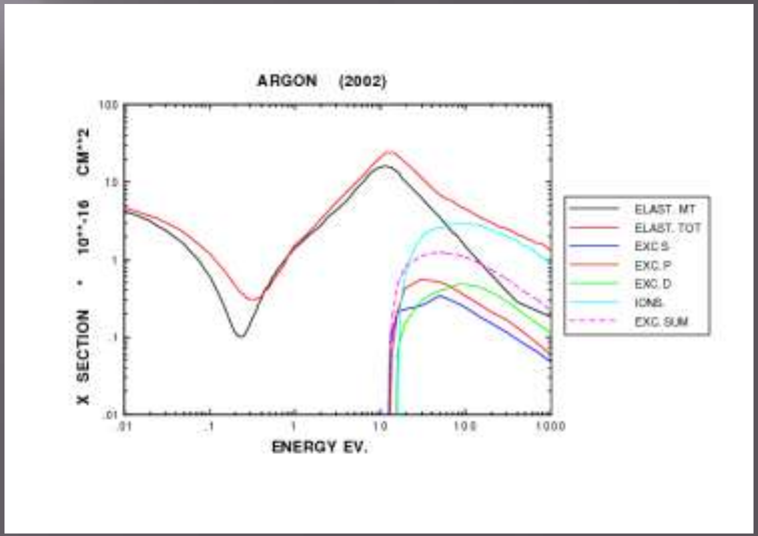


Signal at low pressure (…vs NTP)

- Gas mixture at NTP but pure at low pressure
- Polyatomic gases (several vibration and rotation modes: non radiative mode)
  - Absorbe the radiated photons
  - Limit the breakdown (at low pressure!!!)
  - Low ionization energy with higher XS
  - Typical quenchers: $i\text{-}C_4H_{10}$, CF_4...CO_2, CH_4

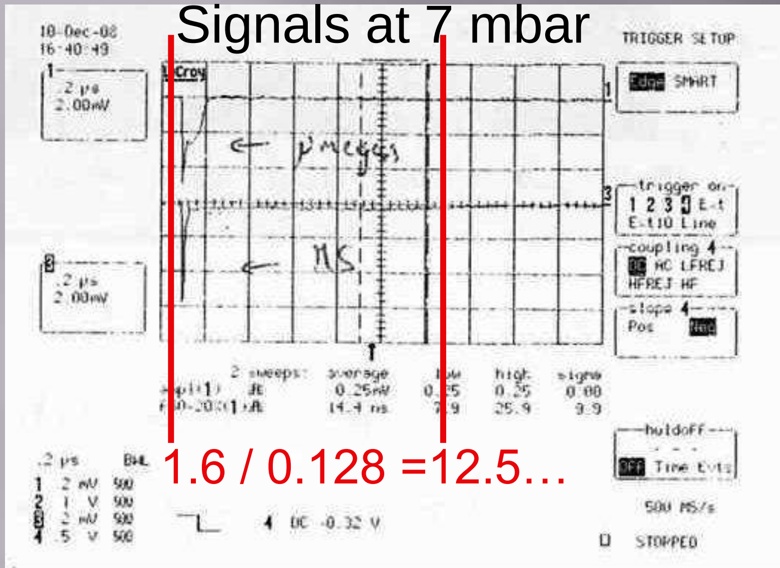




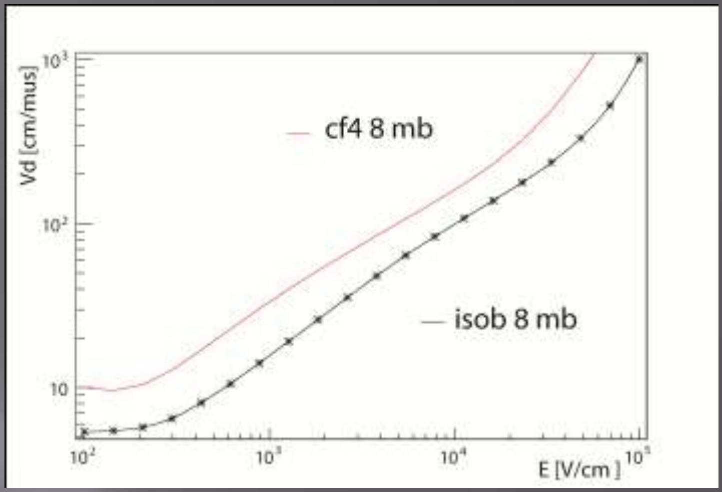


Electons and ions drift speed

laboratoire commun CEA/DSM CNRS/IN2P3



High electron drift speed, fast rise time (~2 ns)



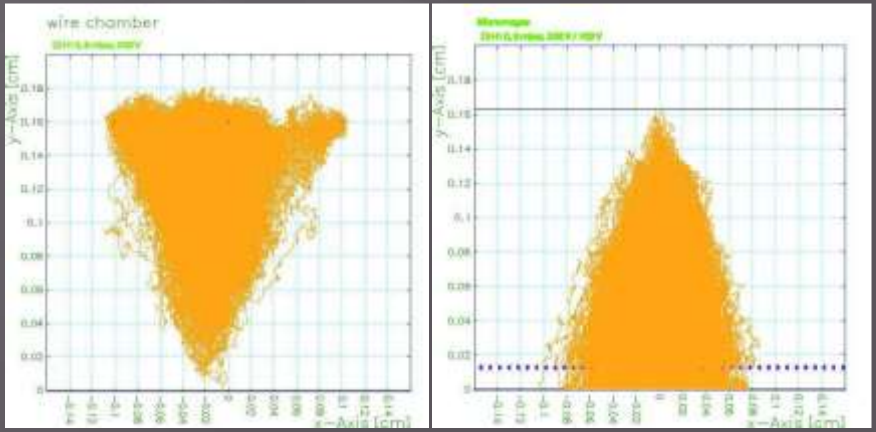
- Mobility of iC_4H_{10} ion in itself: $w=0.61\ cm^2V^{-1}s^{-1}$

$v= wEP_0/P \Rightarrow v \approx 200*wE$ at 5 mbar, which gives $v \approx 0.2$ cm/µs at 2 kV/cm

- WC with same counting rate capabilities as MPGD at NTP

good trackers for nuclear physics

- Improve the space charge problem in TPCs for instance

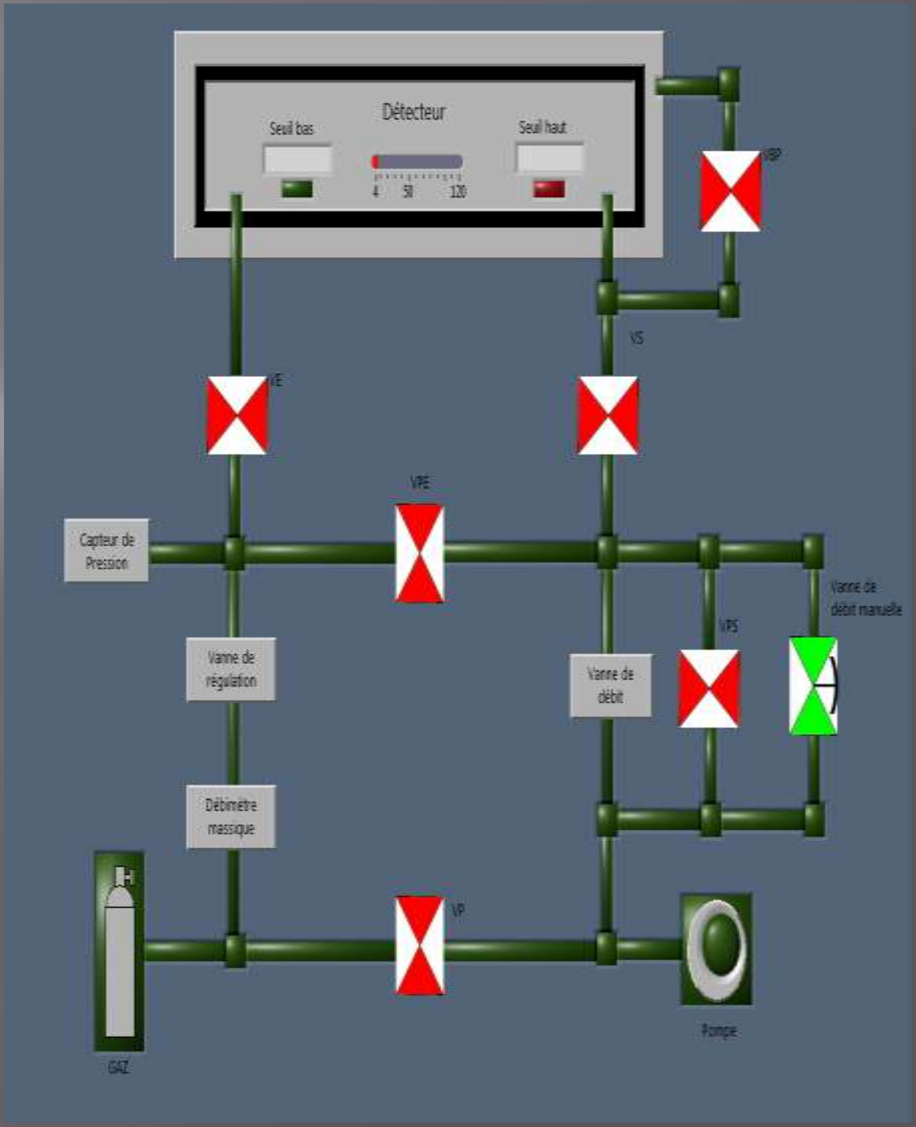


⇒ high couting rate capabilities

Detection systems used at low pressure at GANIL

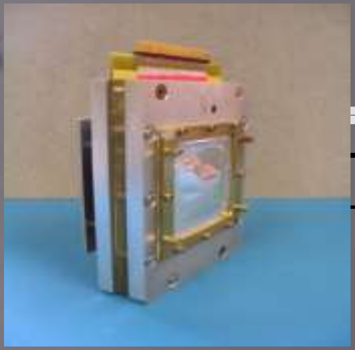
- Gas system
- Tracking (X,Y,t) with Wire Chambers or Secondary Electron Detector
- VAMOS spectrometer
- Active targets like ACTAR or MAYA

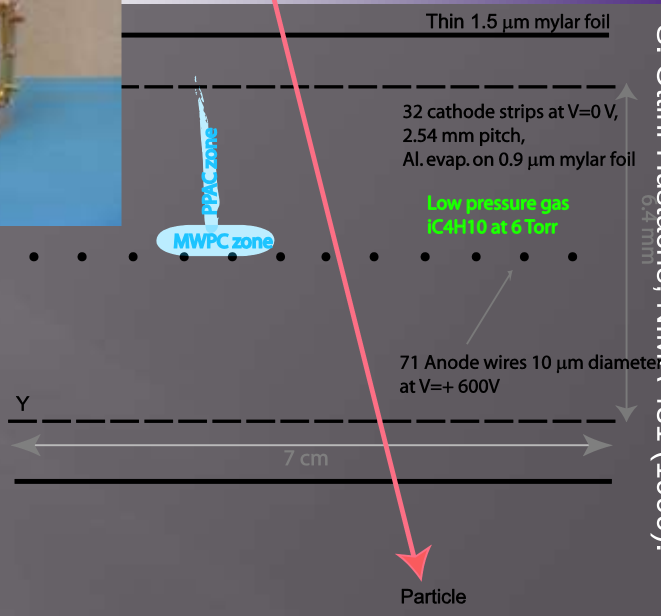
Gas Systems: mixer and pressure regulation



No re-circulation…no filtering…

Beam Tracking Detectors (E>10 A.MeV)





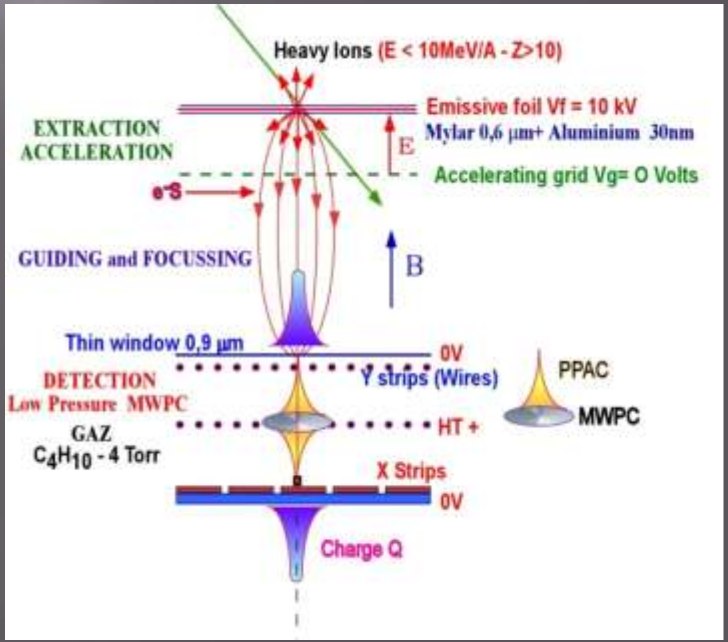
S. Ottini-Hustache, NIMA 431 (1999).

CATs for E>10 A.MeV

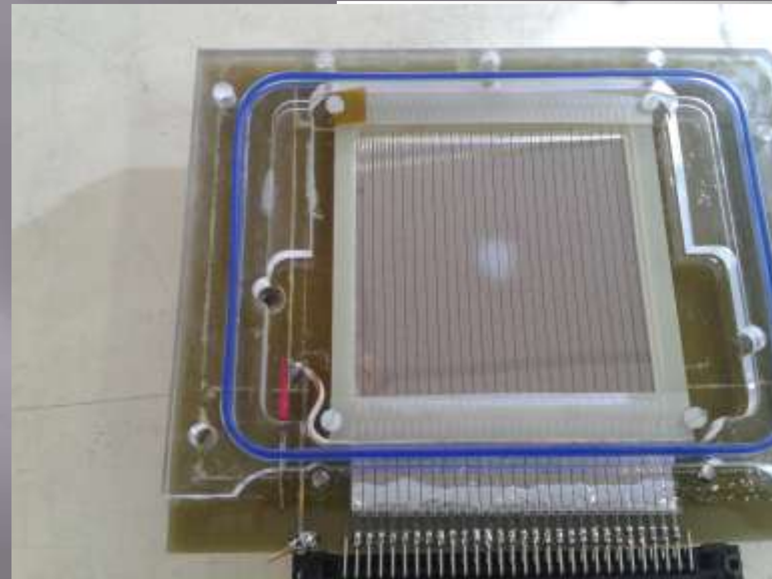
- Constant field zone: PPAC, position signal on the strips +High gradient field zone: MWPC, time signal on the wires
- σ_t<200 ps, σ_s<0.5 mm
- Counting rate 10^5 pps/cm^2
- Material in beam 550 µg/cm^2

SED for E<10 A.MeV

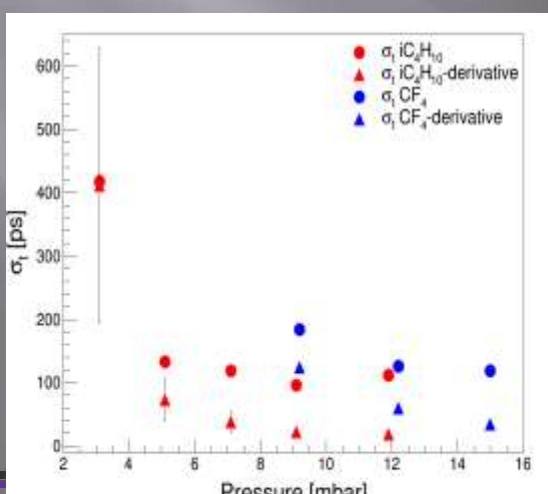
- For S3 or NFS/Falstaff
- σ_t<200 ps, σ_s<0.6 mm
- Counting rate >10^5 pps/cm^2
- Material in beam <150 µg/cm^2

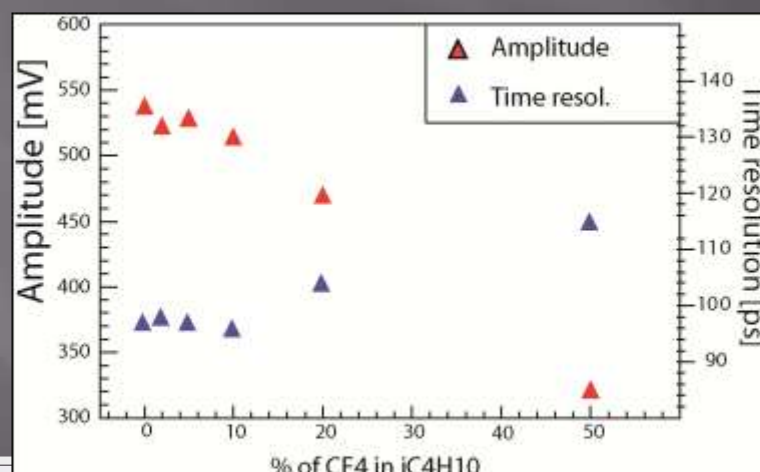


Gas tests performed recently



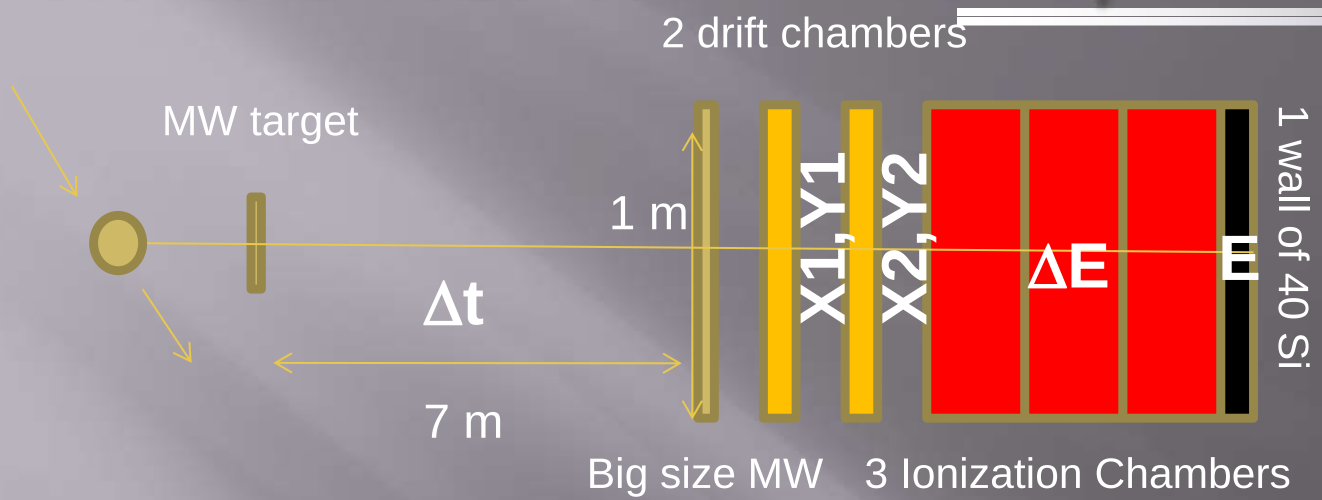
- Gas circulation at 500 cm^3/min at low pressure
- Aluminized stripped get damaged at 4×10^{10} nuclei (total charge conserved)
- No improvement using isopropanol





iC4H10 still the best candidate

Detectors used on VAMOSII Spectrometer



A, Z, Q and v to measure for each nuclei entering spectrometer

- energy $E=1/2\,Av^2$, with Si detectors
- Energy loss $\Delta E \approx AZ^2/E$ for Z, with Si detectors and ICs
- Magnetic rigidity $B\rho = Av/Q$ with the spectrometer and the DCs

-Velocity v by TOF with the MW

Dedicated to energy below 10 A.MeV : use of low pressure to minimize material in beam for all detectors: isobutane for MW and DC and CF4 for CHIOs

Big volume of about 100 l , renewal every 1 h

Plan to use C3F8 for CHIOs to increase stopping power

No re-circulation or filtering: to be studied

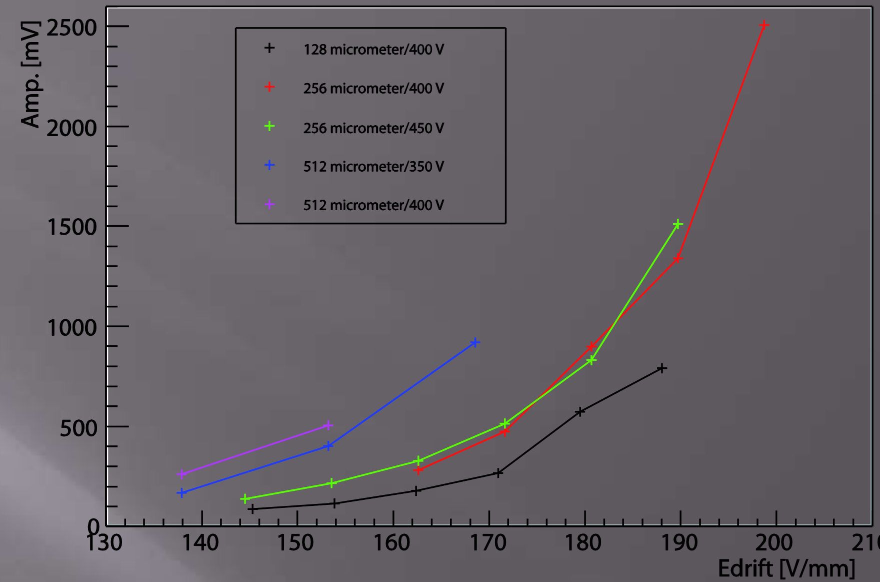
M. Rejmund et al., *Performance of the improved larger acceptance spectrometer: VAMOS++*, Nucl. Inst. And Meth. A, 646 (2011), p 184-191.

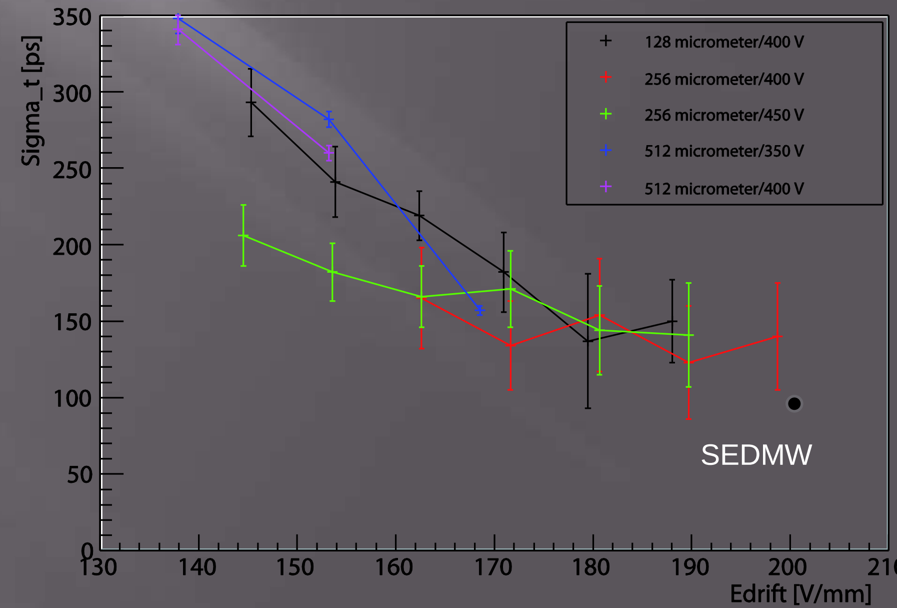
Micromegas results < 10 mbar

3 micromegas prototypes tested so far: 128, 256 and 512 μm amplification gap

- Not really used at low pressure
- Counting rate: same advantages than at NP ??
- S/N ratio
- Time and spatial resolutions

- Good S/N ratio (efficiency with alphas around 40 %), much better than simple PPAC or WC, working in preamp mode
- Poor energy resolution
- Clear influence from ampl. gaps
- No so sensitive to ampl. Voltage for low gaps: α saturation at VLP
- Sparking limit due to bulk process and LP: no real gain at high counting rate…
- Good time resolution (2 mm gap)
- PPAC behavior
- Spatial resolution to measure





J. Pancin & B. Fernandez et al, JINST2012-7-C03017.

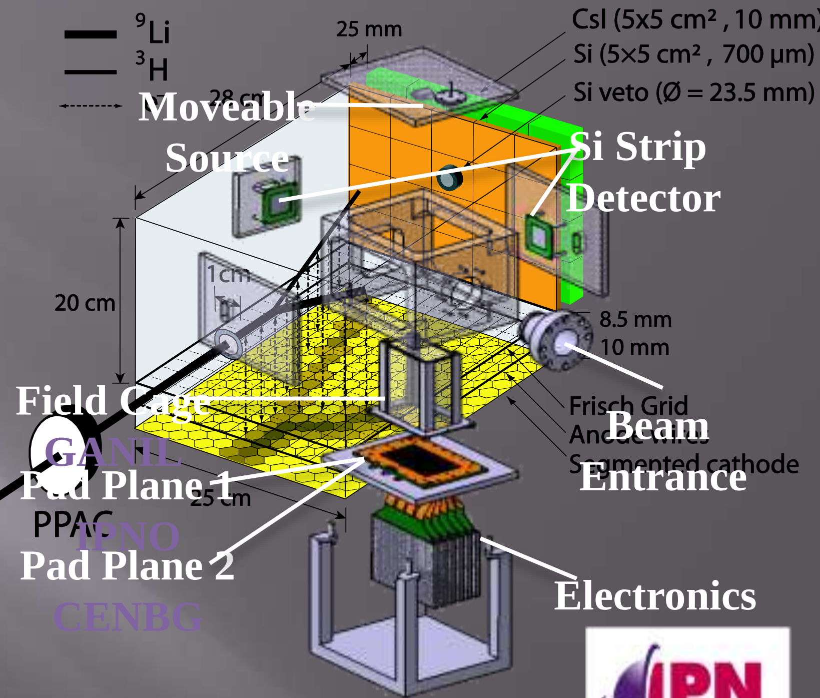
Active targets: MAYA and ACTAR

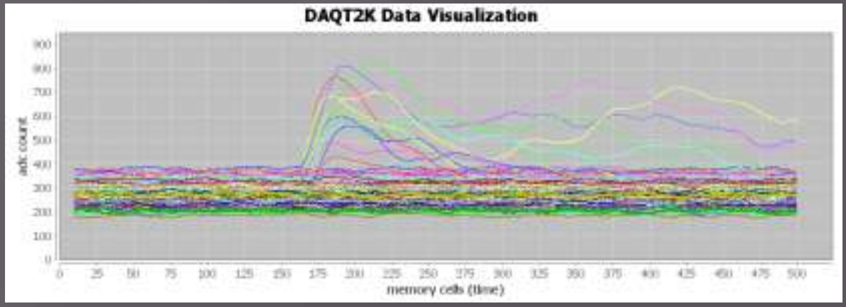
Beam/Energy [MeV/u]	Date	Reaction	Gas	Mixture [%]	Pressure [mbar]
^{8}He @ 3.9	2003	^{8}He(p,p')	C_4H_{10}	100	1000
^{8}He @ 3.5	2003	^{8}He(p,d)^{7}He	C_4H_{10}	100	525
^{25,26}F @ 50.0	2004	^{25}F(d,^{3}He)^{24}O	D_2	100	2200
^{56}Ni @ 50.0	2005	^{56}Ni(d,d')	D_2	100	1050
^{8}He @ 15.4	2005	^{8}He(^{12}C,^{13}N)^{7}H	C_4H_{10}	100	30
^{11}Li @ 3.6	2006	^{11}Li(p,d)^{10}Li	C_4H_{10}	100	150
		^{11}Li(p,t)^{9}Li	C_4H_{10}	100	664
^{6}He @ 3.5	2007	^{6}He(p,n)^{6}Li	C_4H_{10}	100	107
^{68}Ni @ 50.0	2010	^{68}Ni(d,d')	D_2	100	1040
		^{68}Ni(α,α')	He + CF_4	98/2	500
^{56}Ni @ 50.0	2011	^{56}Ni(α,α')	He + CF_4	98/2	1200
^{8}He @ 15.4	2011	^{8}He(^{19}F,^{20}Ne)^{7}H	He + CF_4	10/90	175
^{12}Be @ 3.0	2012	^{12}Be(p,p')	C_4H_{10}	100	100

ACTAR:

demonstrator (2kchan of 2*2 mm^2)

- Final detector for end 2016 (Financed with an ERC grant ,G. Grinyer)





Light emission in He+CF_4 at 300 mbar

C.E. Demonchy

Conclusion

- Big flow at low pressure: no gas pollution
- We have to think to re-circulation and gas exhaust storage
- Still some studies to do on detector aging