Micromegas in Xe-TMA mixtures at high pressure: an update

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On behalf of University of Zaragoza

Outline

- Introduction
- Summary of published results.
- The Si-MM setup.
- New results: mean electron lifetime & drift velocity.
- Conclusions & outlook.

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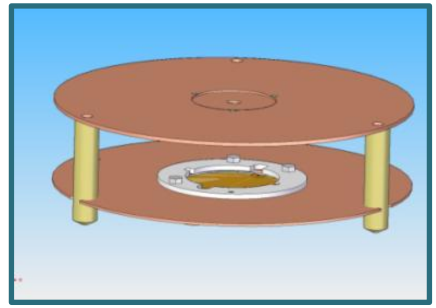
Introduction

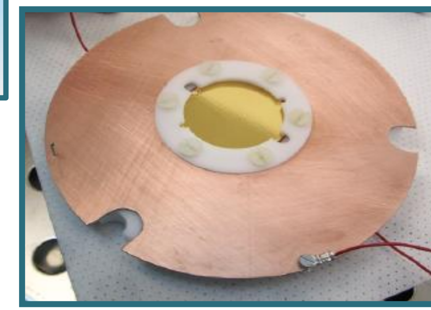
- **Study of Penning mixtures:** an additive gas with ionization potential below and closer to the first metastable level of the main gas. Better performance expected: higher gain, better energy resolution.
- **For Xenon**, these mixtures are attractive for **double beta decay** as the Fano factor may be reduced, keeping the good scintillator properties of Xenon (D. Nygren *et al.*, *J. Phys. Conf. Ser.* **309** (2011) 012006).
- **Results:** S.Cebrian et al., *JINST* **8** (2013) P01012, arXiv:1210:3287.
- **This talk**: attachment effects & drift velocity measurement.
- **Plans:** new microbulk MM detectors of 25 & 50 μm gap with different hole diameters & pitch distances will be characterized in Xe-TMA mixtures. Already tested in Ar+2%iC_4H_{10}.

Experimental setup & procedure

Setup:

- Gas & vacuum systems.
- Mass spectrometer.
- Stainless steel vessel of 2 liters.
- Drift distance of 1 cm.
- Circular microbulk MM detector (35 mm diameter, 50 μm gap).

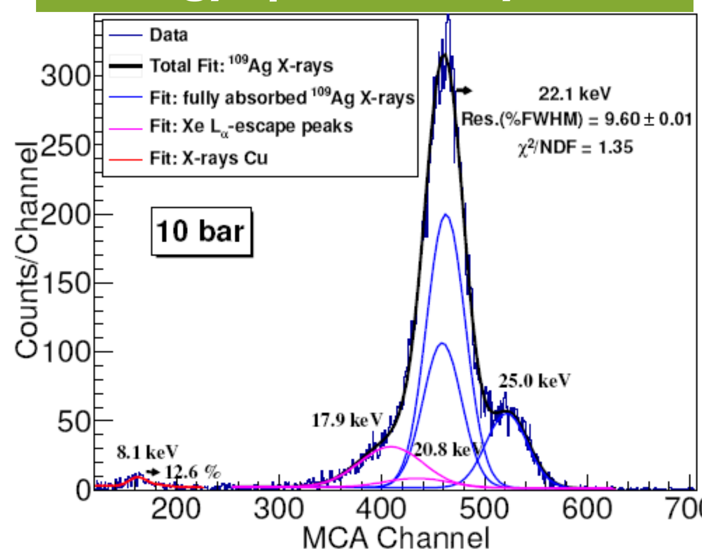




Procedure:

- Vessel pumped & baked out.
- Gas introduced & recirculated by a SAES filter during the data-taking.
- Determination of the operating point for a fixed amplification field.
- Gain & energy resolution measured.
- Gas composition measured.
- Gas recovery.

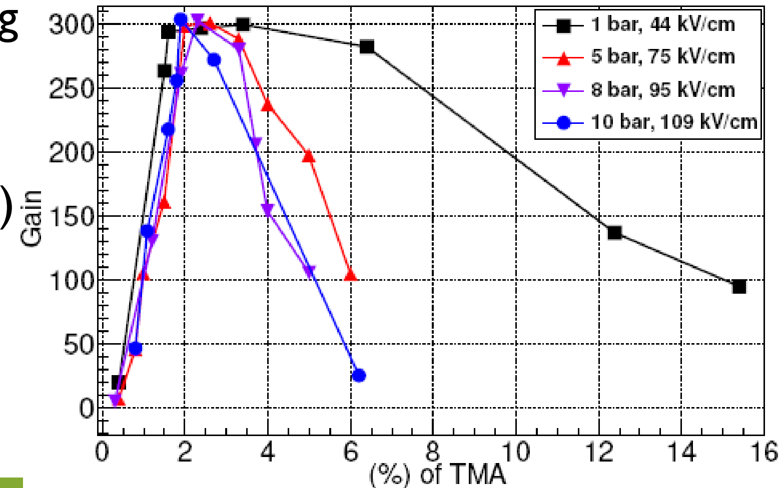
Energy spectrum by ^{109}Cd



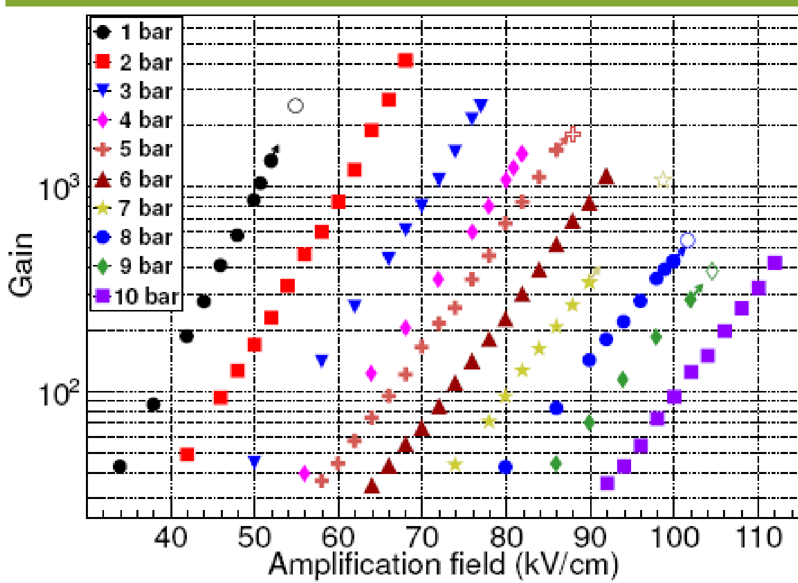
Published results

- Xe-TMA mixtures at 1-10 pressures, using a ^{109}Cd source (22.1 keV x-rays).
- Best performance for 1.5-2.5% TMA.
- Maximum gain of 2×10^3 (5×10^2) at 1 (10) bar, i.e., x3 than in pure xenon.
- Energy resolution: 7.3 (9.6) % FWHM at 22.1 keV for 1 (10) bar, i.e., a factor 2 (3) better than in pure xenon.

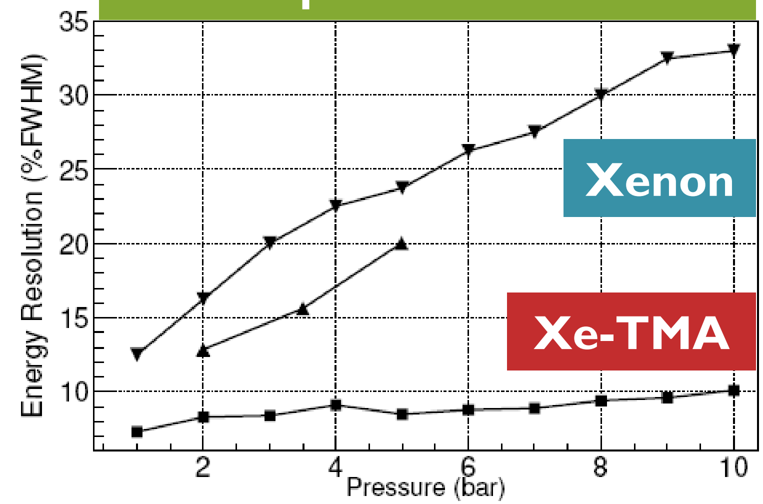
Gain vs %TMA for a fixed amplification field



Gain vs Eamp for 2%TMA & 1-10 bar



Gain vs %TMA for a fixed amplification field

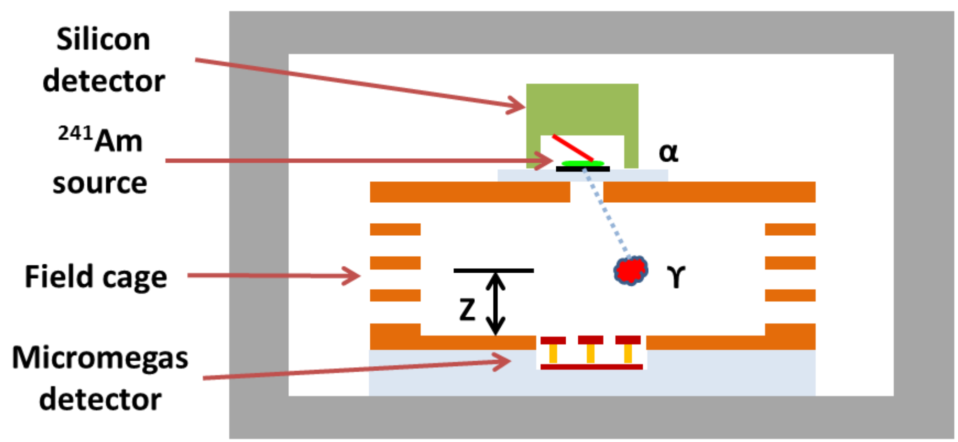


The Si-MM setup: Motivation

- Xe-TMA measurements made with < 30 ppm O_2. Evidence that attachment effects were little but no measurement made.
- **^{241}Am**: a 5.5 MeV alpha & gammas (26.3 or 59.5 MeV) in coincidence.
- The gamma may deposit its energy in the fiducial volume, creating a cluster of electrons. They will then drift and induce a signal at the mM.
- If the alpha is detected by the Si detector, the time difference between both signals is just the drift time of electrons.

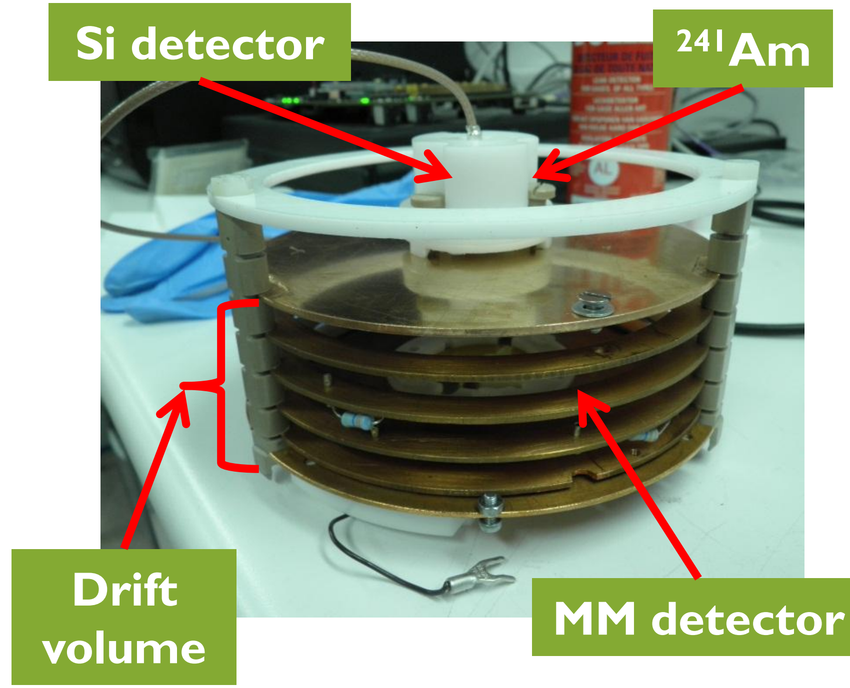
Good measurement of:

- Mean electron lifetime (gas purity, attachment coefficients)
- Drift velocity in Xe-TMA (comparison with Magboltz).



The Si-MM setup: Photos & runs

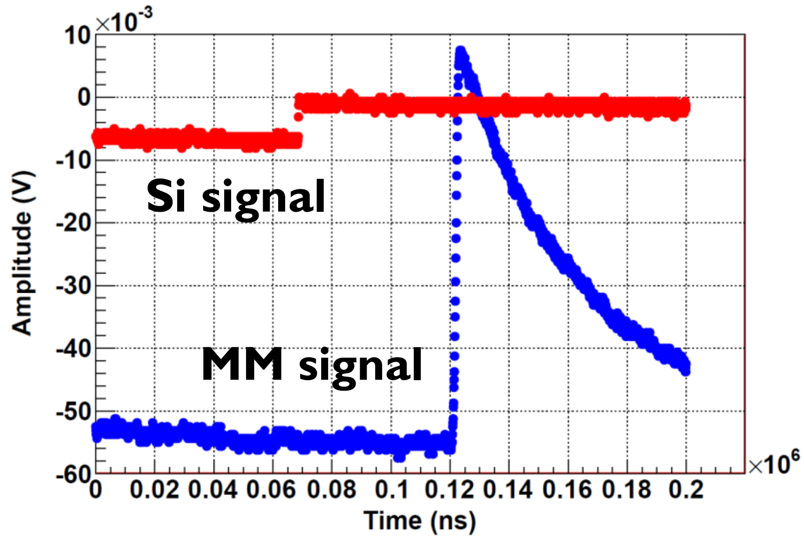
- Same vessel & gas/vacuum systems.
- The ^{241}Am source & the Silicon photo-diode are encapsulated in a plastic piece to isolate them from the cathode.
- The drift volume (4 cm distance) is composed of copper rings, linked by resistors, to make uniform the field.
- Si & MM signals were acquired by an oscilloscope for an offline analysis.
- Three set of runs were taken, in different gas conditions.



1st set:	2.0%TMA, 4 bar	Close gas mode (~2000 ppm O_2)
2nd set:	3.5%TMA, 4-6 bar	Recirculation mode (< 45 ppm O_2)
3rd set:	1.5%TMA, 3-6 bar	Recirculation mode (15-45 ppm O_2)

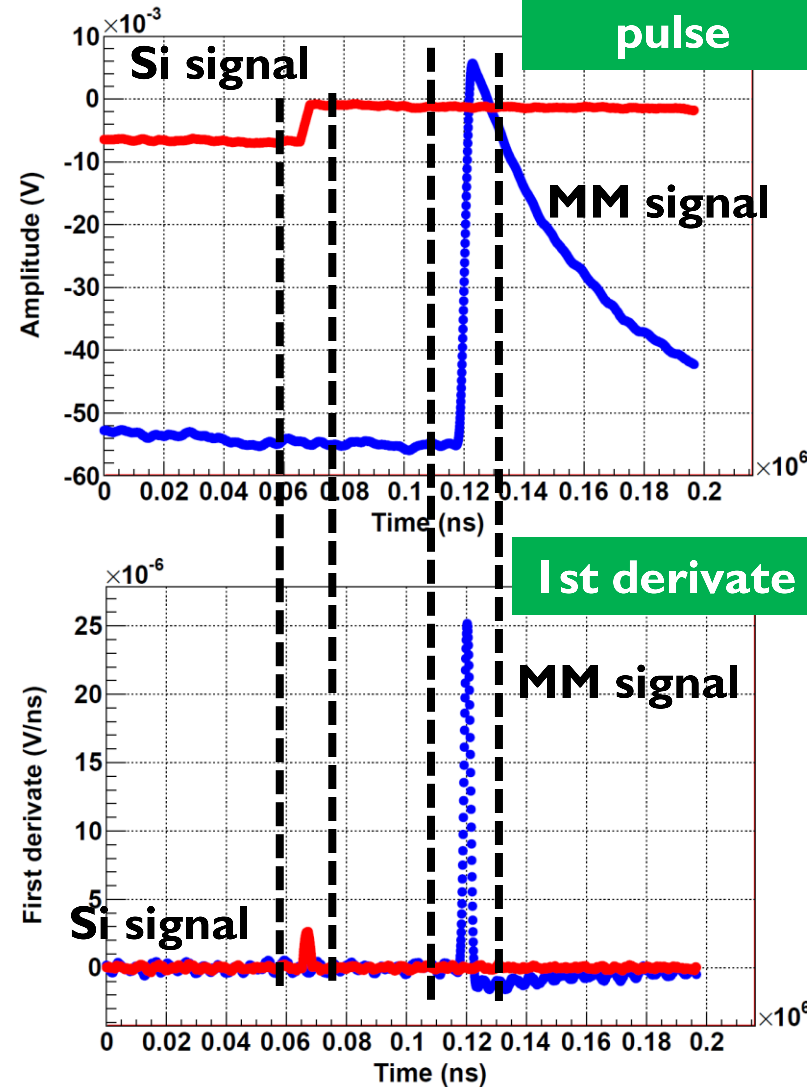
Some words about the off-line analysis

Raw pulse



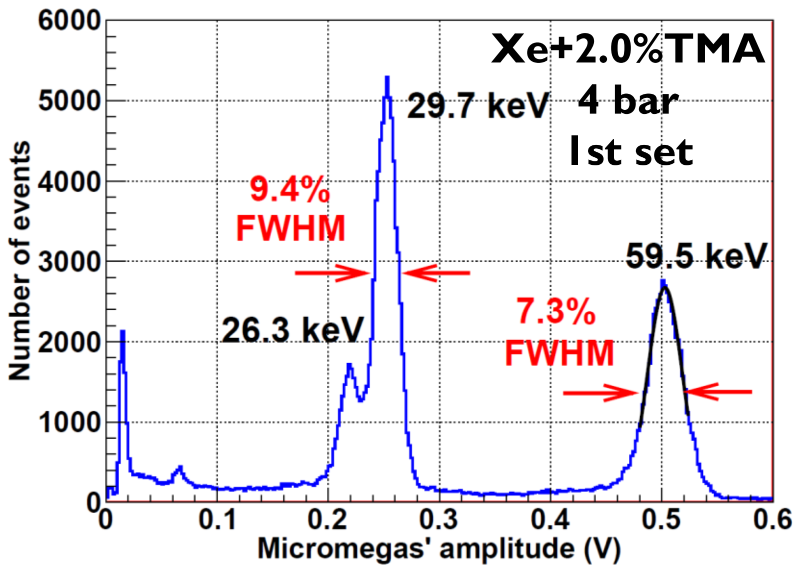
Smoothed pulse

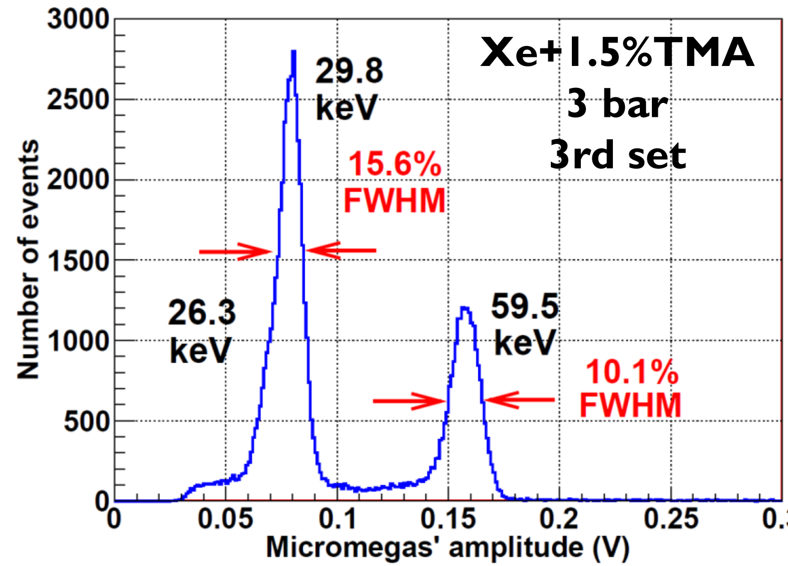
1st derivate



- The first derivate is first used to find the temporal position of each pulse & a window to analyze pulses.
- Pulses are then smoothed, making the mean of each point with 10 on the left & 10 on the right.
- Finally, the smooth pulse is used to calculate the amplitude & risetime.

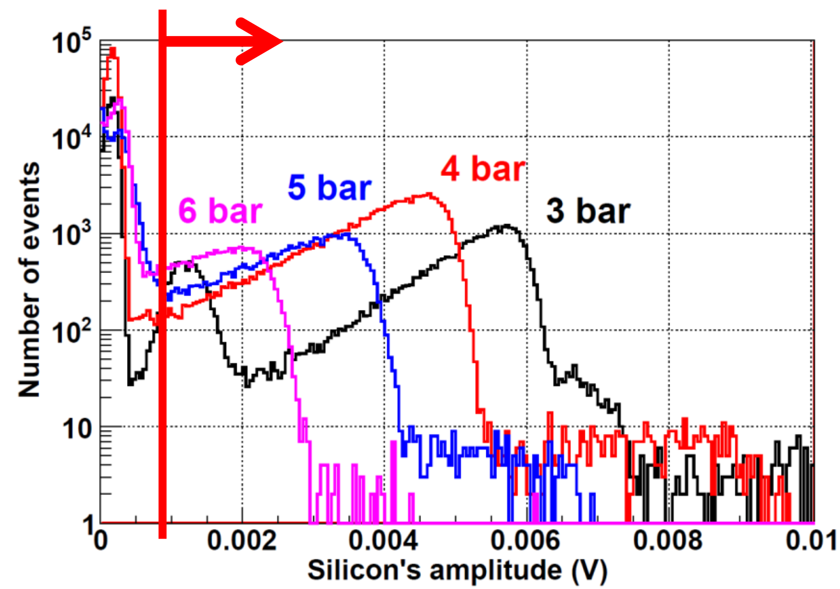
Energy spectrum of μM detector





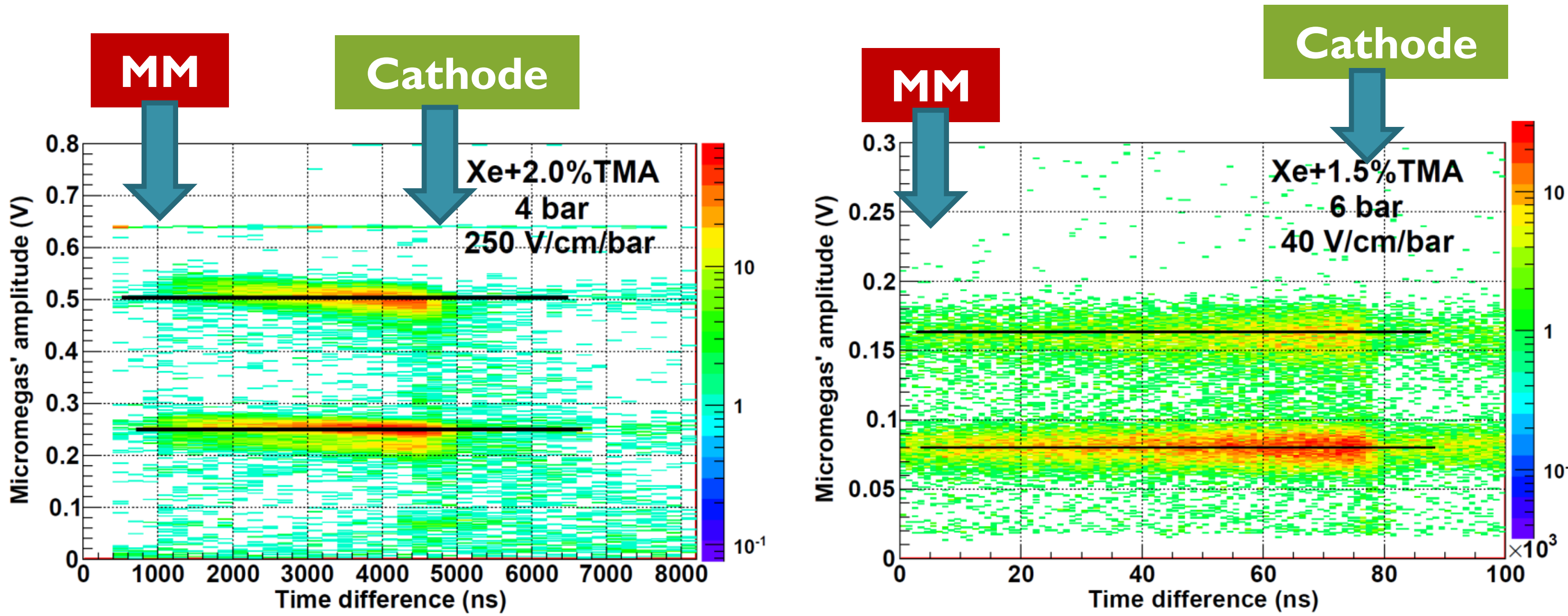
- The two γ peaks of ^{241}Am observed in spectrum (& a escape peak).
- Resolution: 9.4% (1st set) & 23.2% (2nd) &15.6% FWHM (3rd) at 29.8 keV.
- Worst values for 2nd & 3rd sets due to worse detector performance (reused detector, lower gain). Still good enough for measuring the drift velocity & attachment effects (3rd set).

Selection of Si-MM coincidences



- A pulse is always found in our analysis.
- No pulse means amplitude compatible with baseline variations.
- Si-MM coincidences are selected by a threshold in Si amplitude.
- Si signals are weaker when pressure is increased (not observed at 8 bar).
- Thresholds: 5 mV (1^{st} set) & 1-2 mV (2^{nd}-3^{rd} set).

Correlation of MM amplitude vs Si-MM time difference

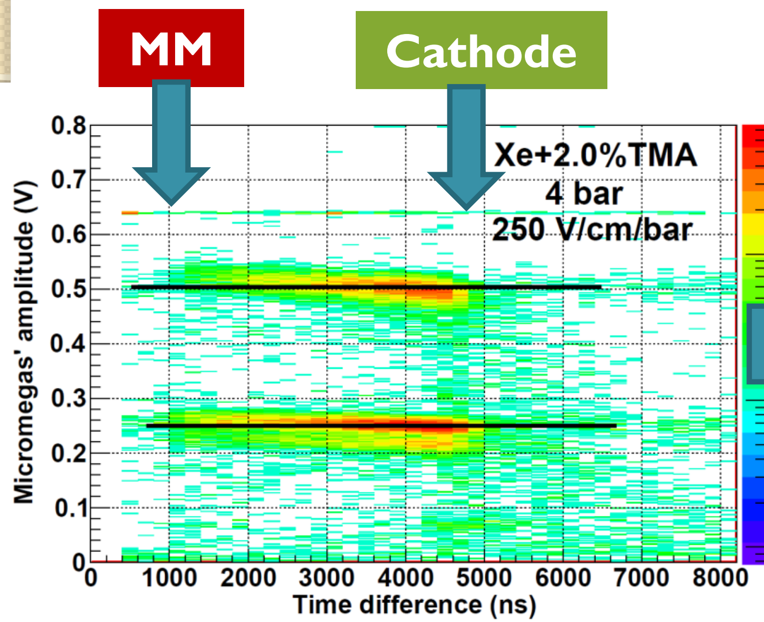


Close mode, ~2000 ppm O_2
Lifetime: 58 ± 2 μs

Recirculation, 45 ppm O_2
Lifetime > 7.8 ms at 90% CL

- Note the differences between a dirty & a clean situation!!!
- The mean electron lifetime can be calculated in both cases.

The mean electron lifetime (τ)



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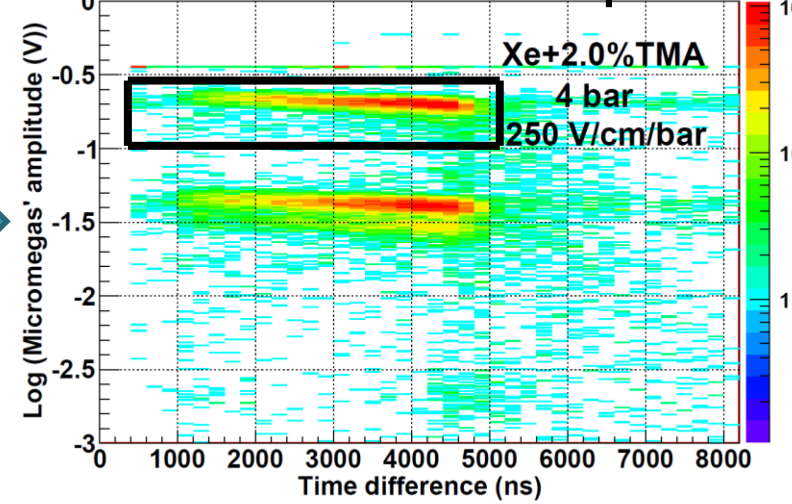


- MM amplitude into log scale.
- Selection of events at 59.5 keV peak.
- A linear fit to all points is then made.
- If mean value of slope is compatible with zero, a lower limit can be set from the deviation.

$$N(t) = N(0)\exp\left(-\frac{t}{\tau}\right)$$

$$\log(Amp) = log\,(Amp_0) - \frac{1}{\tau}\,\Delta t$$

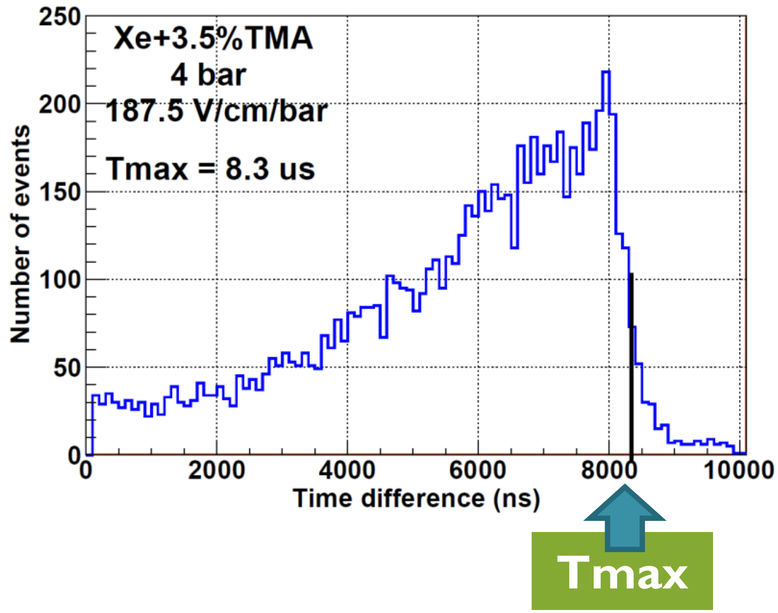
$$\tau > {}^{1}/_{2\,\sigma}\ at\ 90\%\ CL$$

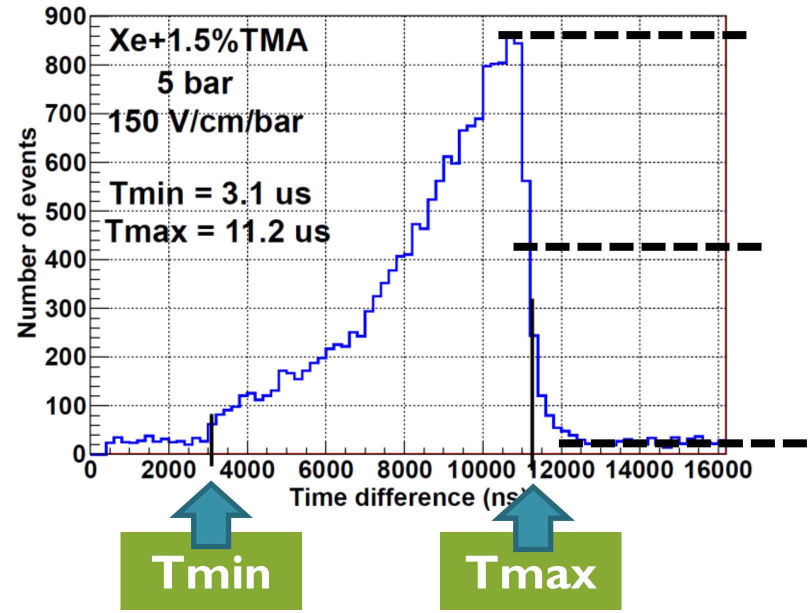
Measured mean electron lifetime in Xe-TMA mixtures

Pressure	Reduced drift field (V/cm/bar)		
bar	50	75	100
3.0	> 5.9 ms	–	2.2 ± 0.6 ms
4.0	3.6 ± 0.5 ms	> 4.3 ms	> 6.0 ms
5.0	> 3.8 ms	> 5.3 ms	> 2.1 ms
6.0	> 7.8 ms	> 2.8 ms	–

- A limit of **5 ms** set for **3-6 bar** and fields **>50-100 V/cm/bar**.
- For a fix pressure, the mean electron lifetime improves when drift field is increased, except for some fit limitations.
- Worst value (**2.2 ± 0.6 ms**) set just after gas filling (recirculation of 30 min & outgassing rate 4 x 10^{-5} mbar l/seg). Improved along time.

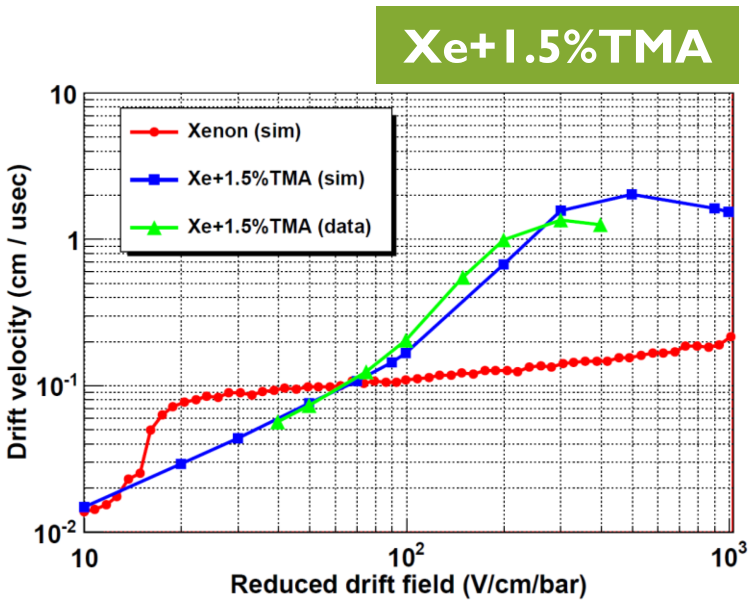
Time difference distributions

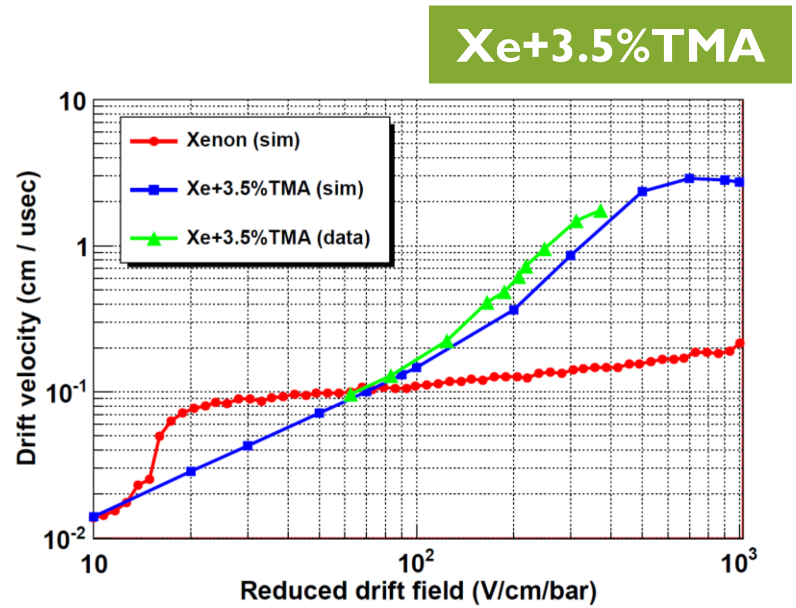




- 2nd set: Minimum at 0 μs for the time difference.
- 3rd set: Different minima observed, correlated with the MM amplifier integration time (longer time, higher minimum).
- The minimum (MM) & maximum (cathode) of each time difference distribution were calculated from the edges.

Measured drift velocity vs Magboltz 9.0.1





- Drift velocity calculated dividing the drift distance (4 cm) by the difference between the maximum & minimum of time differences.
- Values does not match with Magboltz 9.0.1, within errors (< 10%).
- There is a divergence for drift fields higher than 100 V/cm/bar.
- As a first cross-check, the gas composition analysis (method & calibrations made) is being reviewed now.

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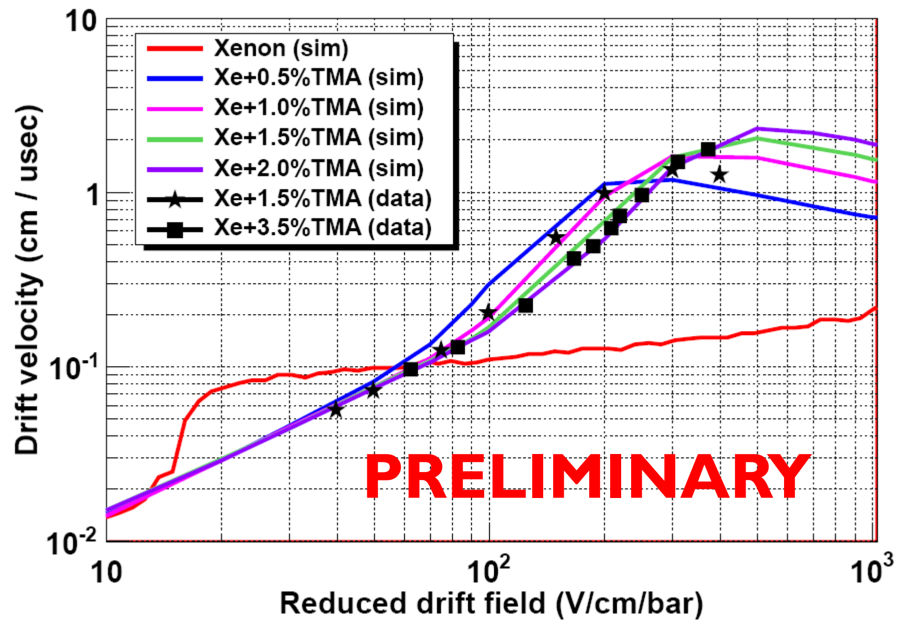

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Conclusions and outlook

Conclusions

- A Si-MM setup has been installed in our system to measure both attachment effects & drift velocity in Xe-TMA mixtures.
- In recirculation mode, no clear attachment effects observed in our gas (4 cm of drift), in agreement with published data (< 30 ppm O_2).
- A minimum value of **5 ms** (90% CL) set for **3-6 bar**.
- The drift velocity for Xe + 1.5 & 3.5% TMA mixtures has been measured, with clear divergences with Magboltz 9.0.1 for fields over 100 V/cm/bar. The gas composition analysis is being reviewed.

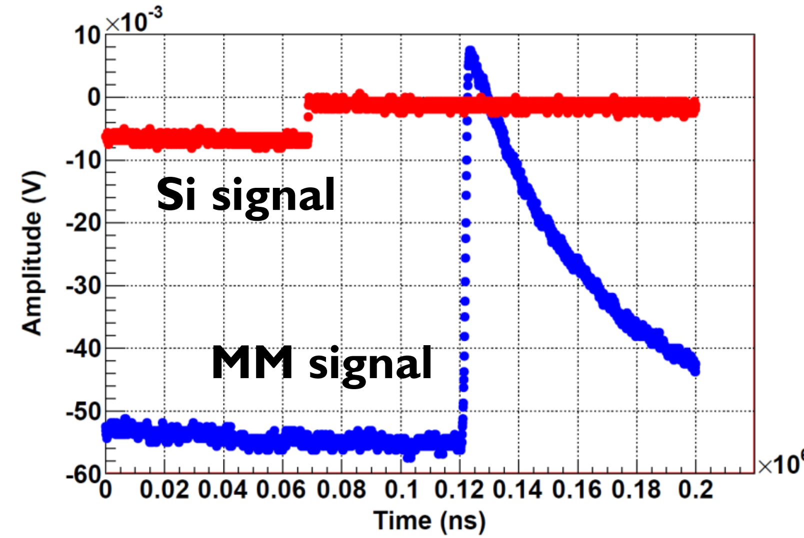
Outlook

- More precise results for attachment & drift velocity are expected for NEXT-MM due to its longer drift distance (~30 cm).
- New MMs of 25 & 50 μm gap with different hole diameters & pitch distances will be characterized in Xe-TMA mixtures.

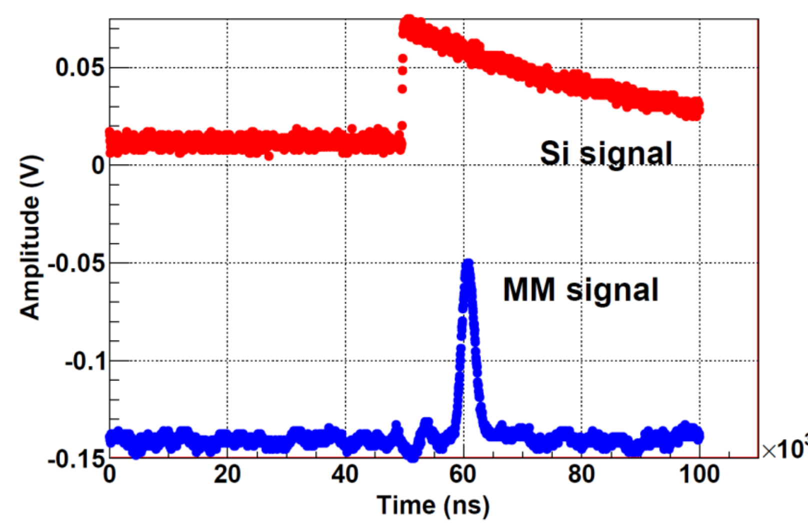
BACK-UP

Some words about the DAQ

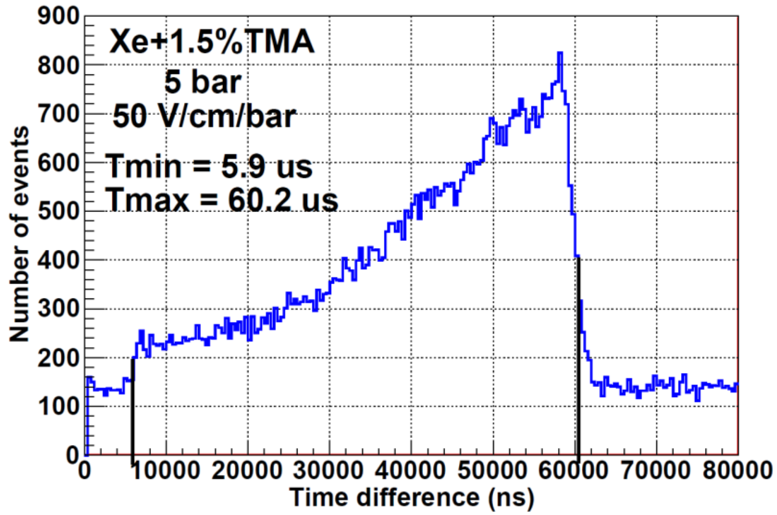
- 1st & 2nd set of runs:
  - Xe+2.0%TMA (1st, dirty gas)
  - Xe+3.5%TMA (2nd, clean gas)
  - Si signal: ORTEC pre.
  - MM signal: CANBERRA pre.
  - Osciloscope trigger: MM signal.
  - Time situation: 1st derivate's maximum.

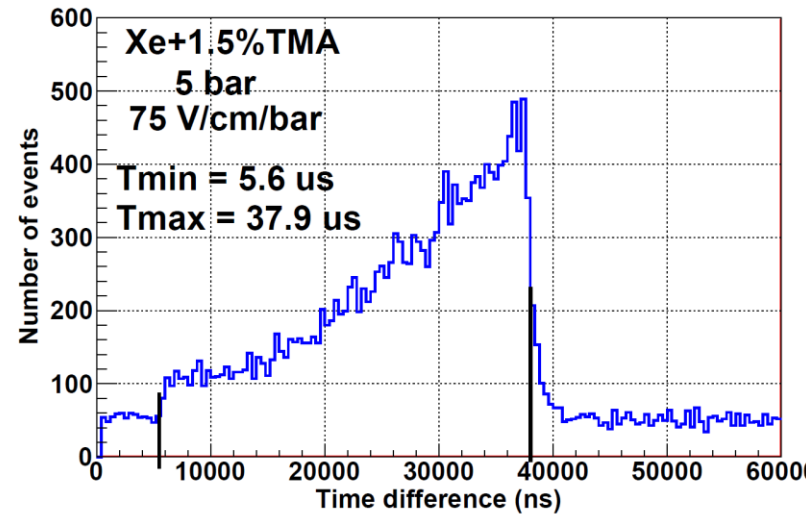


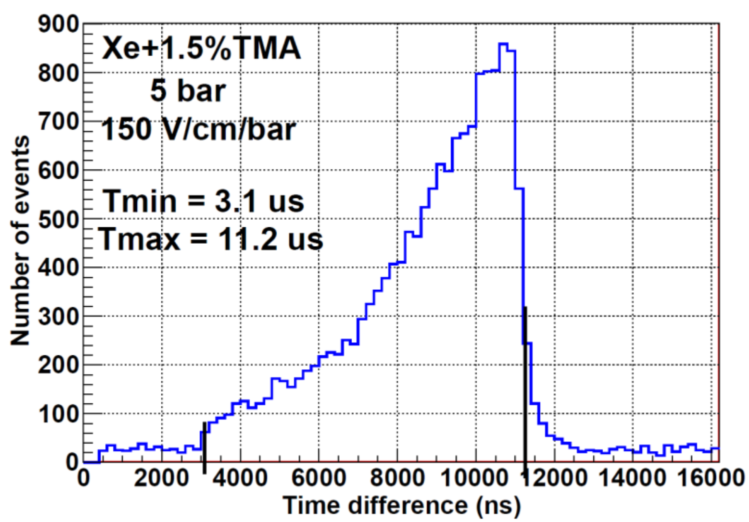
- 3rd set of runs:
  - Xe+1.5%TMA (clean gas)
  - Si signal: CANBERRA pre.
  - MM signal: ORTEC pre + CANBERRA amplifier (0.5 – 2 us).
  - Osciloscope trigger: MM signal.
  - Time situation: Pulse's maximum.

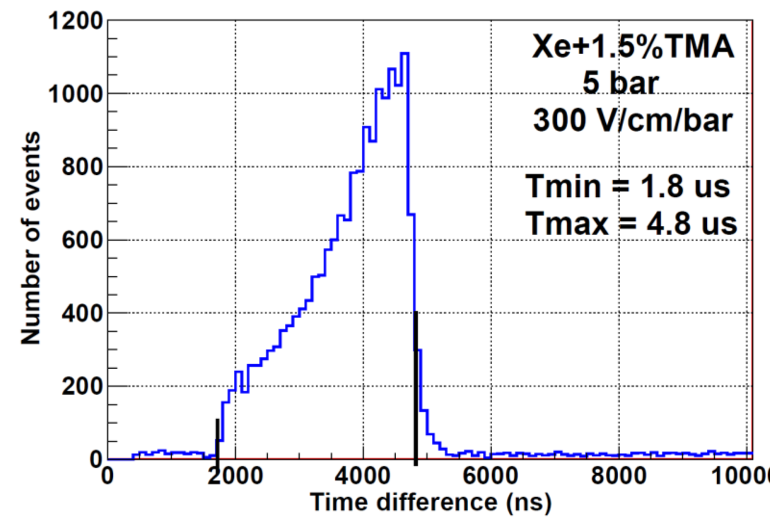


Time difference distributions for Xe+1.5%TMA at 5 bar









Time difference distributions for Xe+3.5%TMA at 4 bar