



First results from a 10bar Xe-TPC with 1kg fiducial mass, read out with Micro-Pattern Gas Detectors

Diego Gonzalez Diaz
for the NEXT collaboration

Index

- Short overview of NEXT.
- The Micromegas-TPC (NEXT-MM).
- Results for 1-3bars.
- Results for 10bars.
- Stability.
- Conclusions and scope.

IS NEUTRINO MAJORANA OR DIRAC (-TYPE)?



Majorana

Keep it simple:
reduce the degrees of freedom!

Baryogenesis

- +non-thermal equilibrium.
- +CP violation sources.
- +sphaleron process.

Smallness of neutrino mass scale

- +see-saw mechanism

Dirac

Keep it simple:
respect analogy with charged leptons and conserve lepton number!



How to answer?

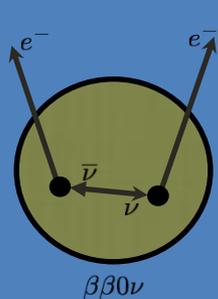
Access to the neutrino mass scale

- +Nuclear physics.
- +Physics beyond SM.
- +Accurate measurements.



Most promising way:

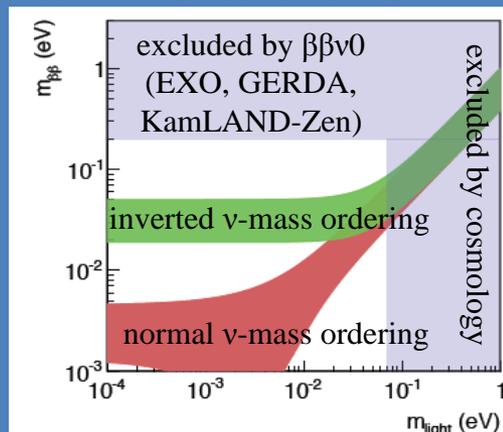
Study neutrino-less double beta decay ($\beta\beta 0\nu$) for checking the Majorana hypothesis!



- +Neutrino oscillations.
- All neutrino flavors are massive!
- “If it is (Majorana-type), it will happen ($bb0\nu$)”**

+Black box theorem (Schechter-Valle, 1982):

“If it happens ($bb0\nu$), it is (Majorana-type)”



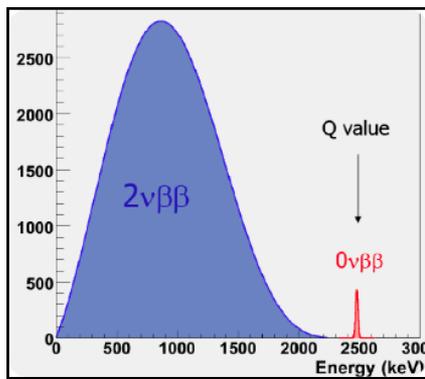
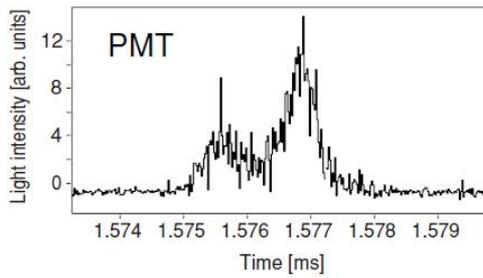
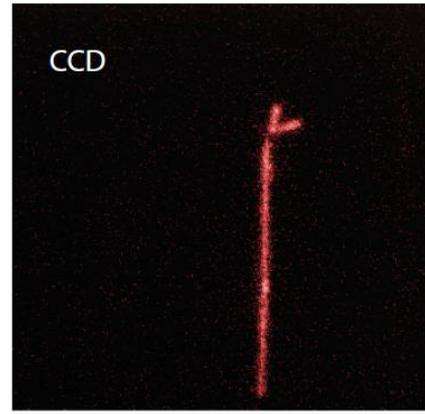
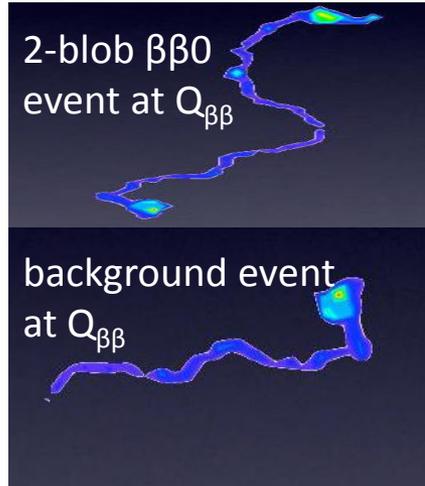


@next

Conceived to simultaneously optimize energy resolution and tracking (specifically: double-blob recognition) for $\beta\beta_0$ reconstruction

Neutrino Experiment with a Xenon TPC

M. Pomorski et al., 'First observation of two-proton radioactivity in ^{48}Ni ', *Phys. Rev. C* 83, 061303(R), 2011



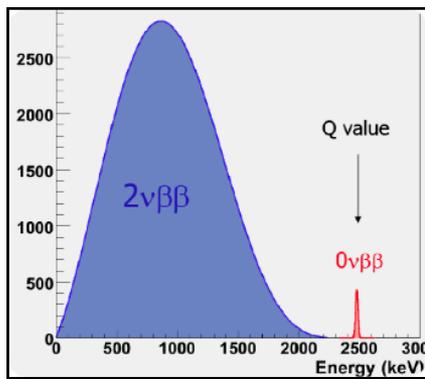
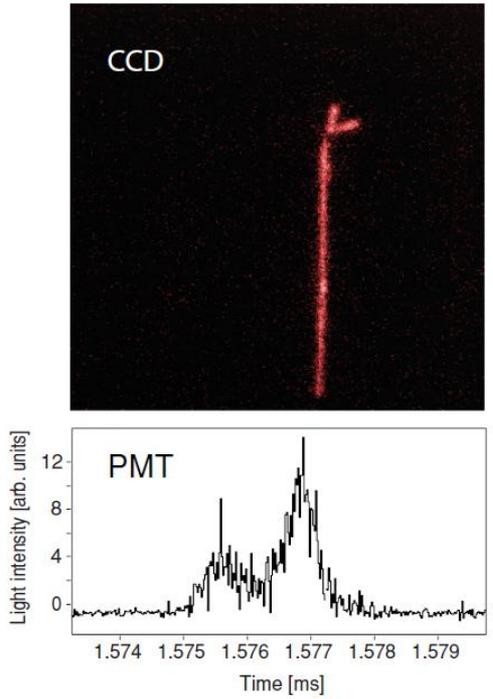
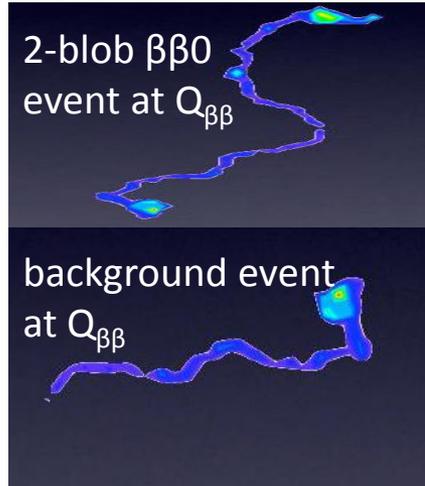


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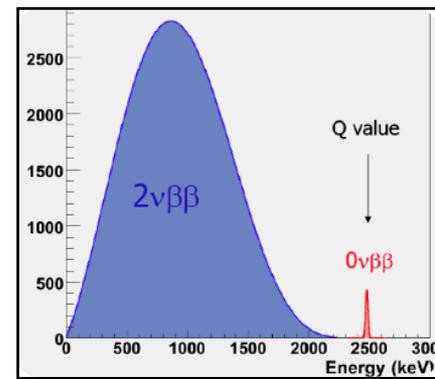
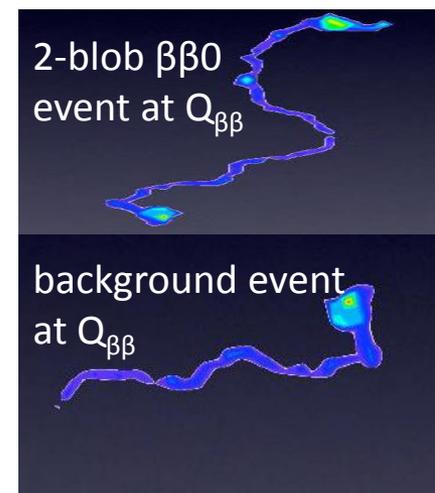
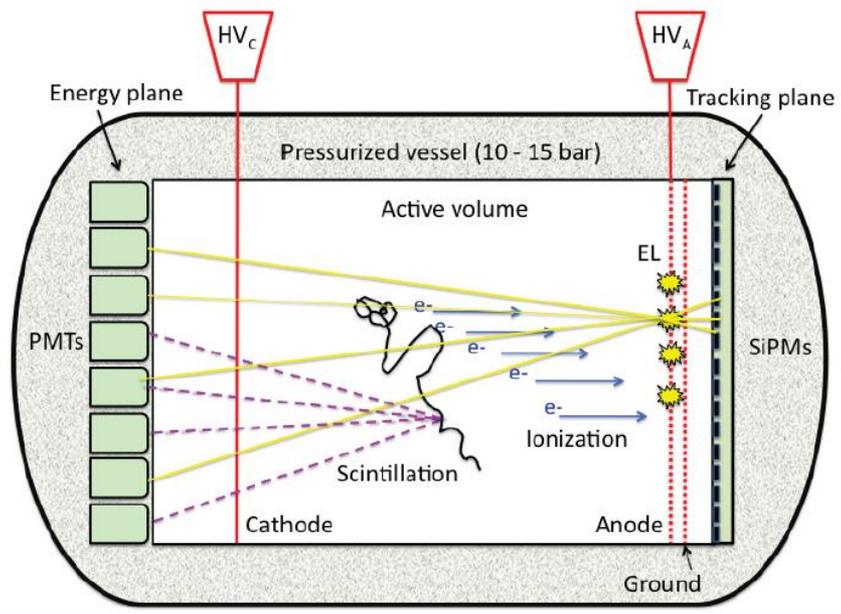
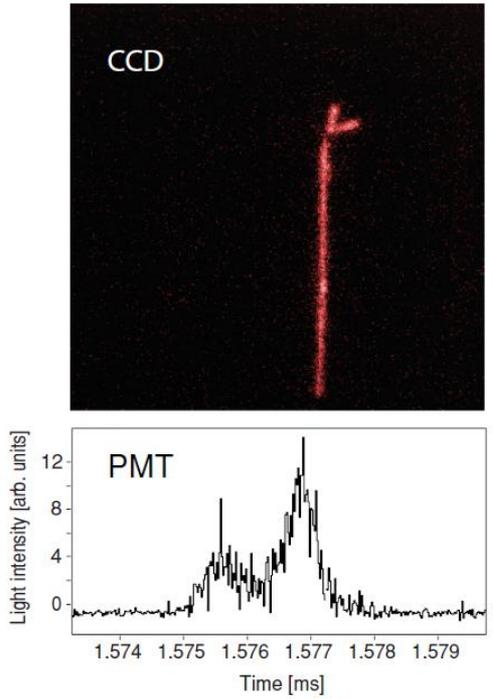


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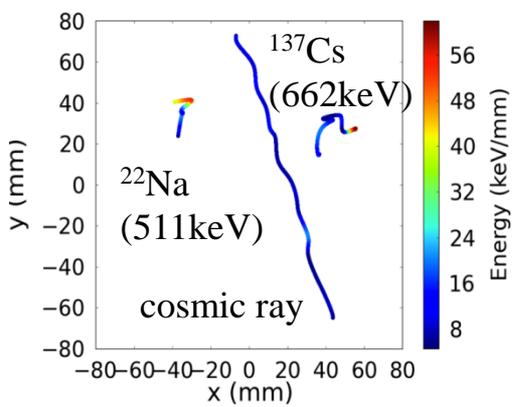
The NEXT concept



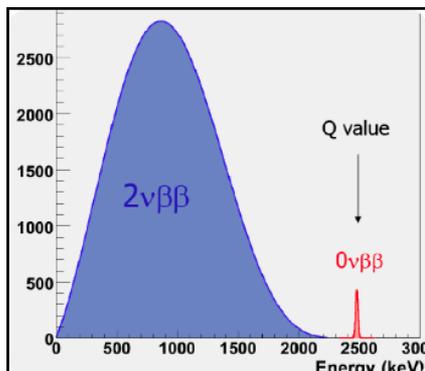
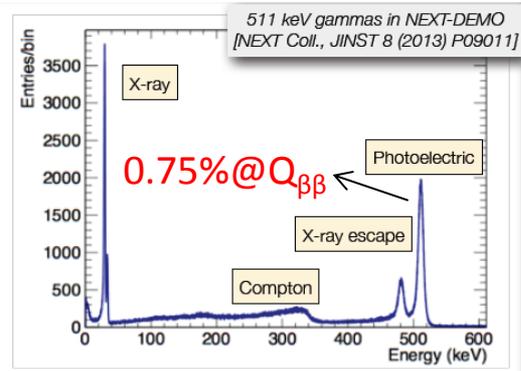
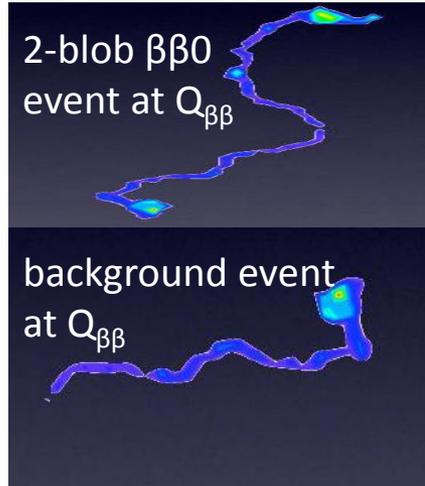
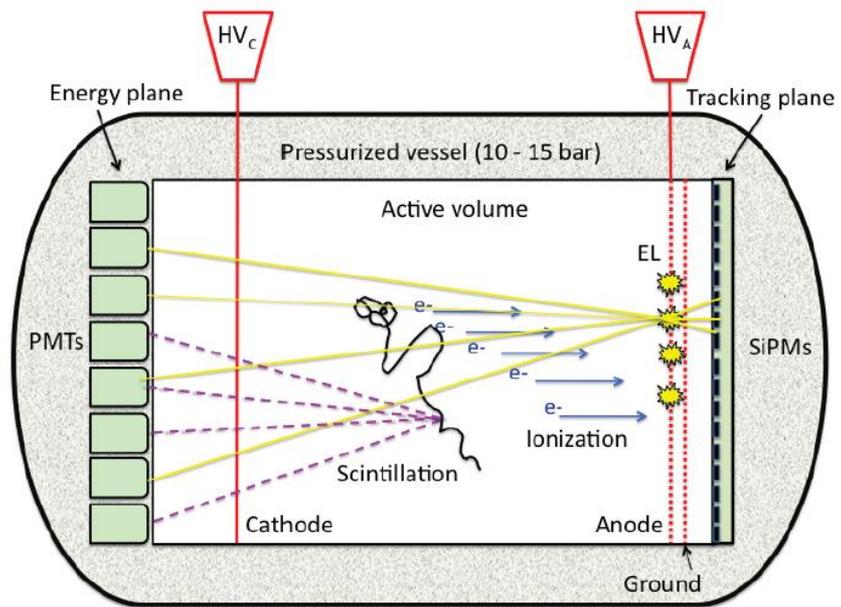


Conceived to simultaneously optimize energy resolution and tracking (specifically: double-blob recognition) for $\beta\beta 0$ reconstruction

Neutrino Experiment with a Xenon TPC



The NEXT concept

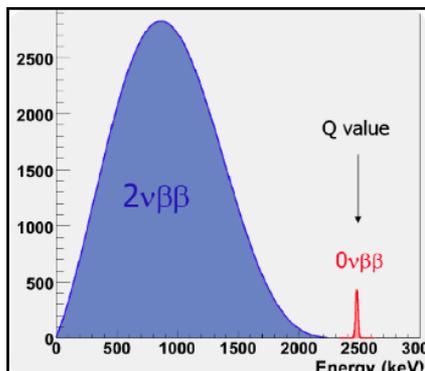
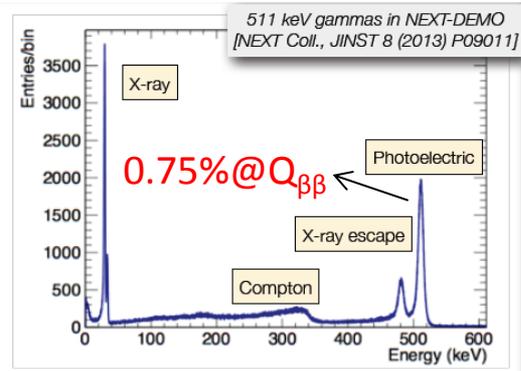
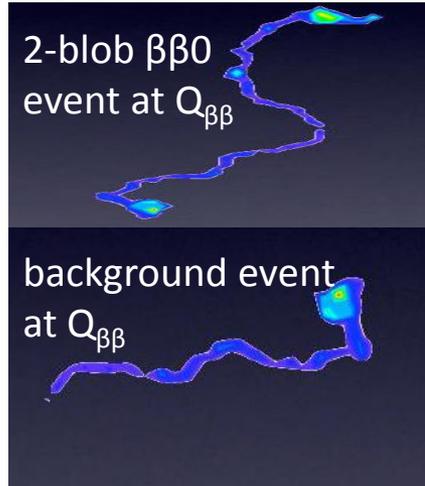
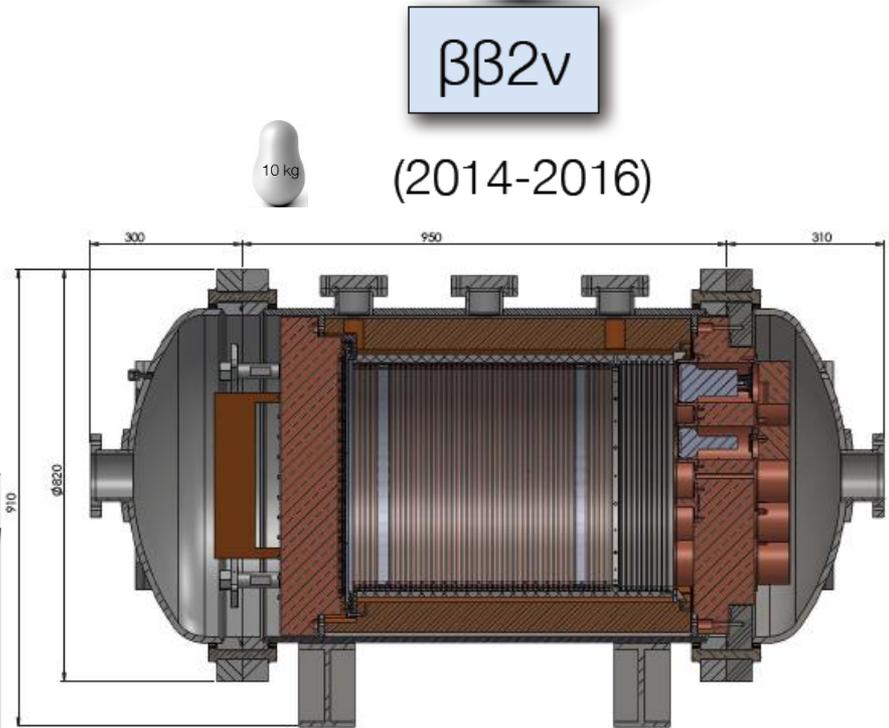
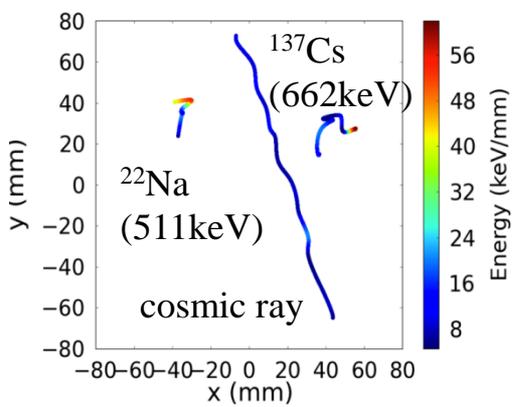




@next

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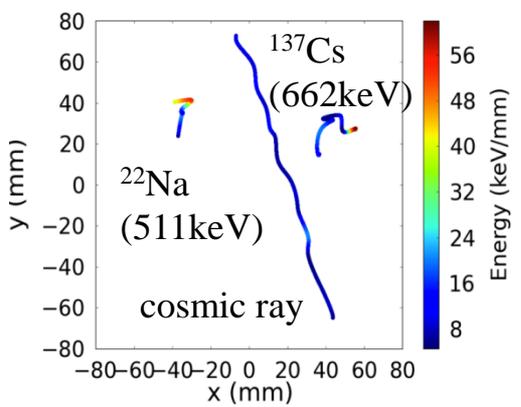
Neutrino Experiment with a Xenon TPC





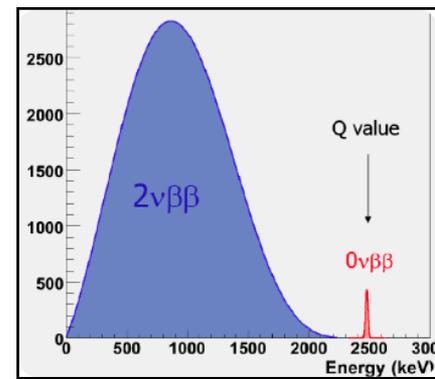
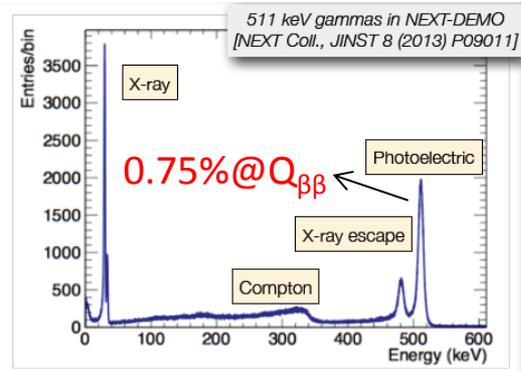
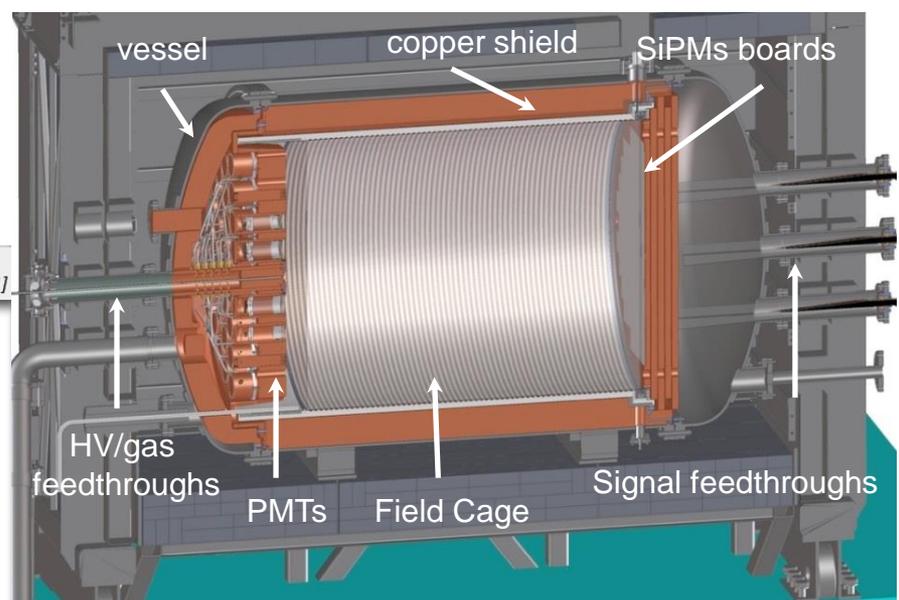
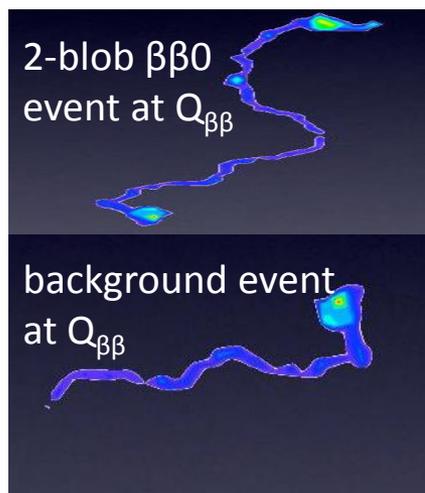
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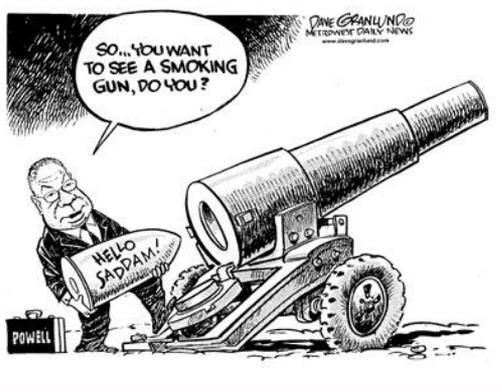
Neutrino Experiment with a Xenon TPC



$\beta\beta_0\nu$ (100 meV)

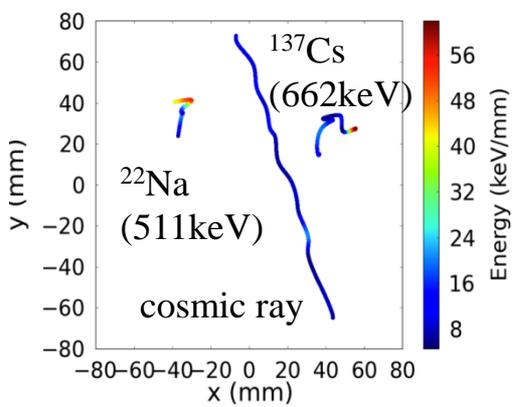
(2016-2020)



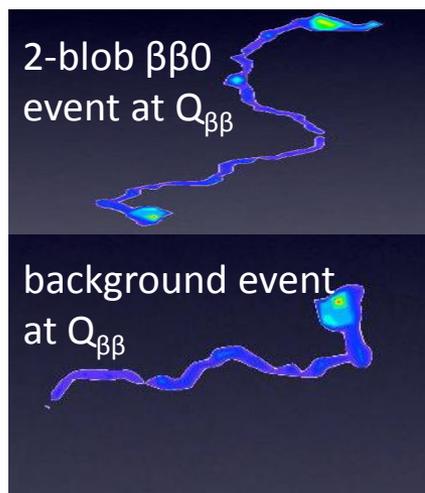


Conceived to simultaneously optimize energy resolution and tracking (specifically: double-blob recognition) for $\beta\beta_0$ reconstruction

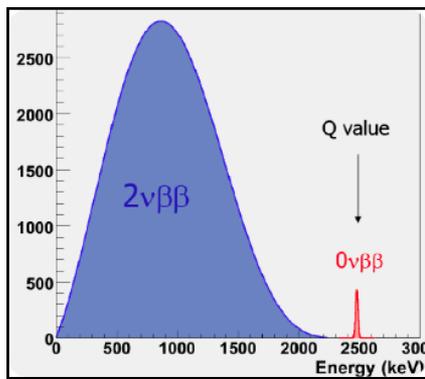
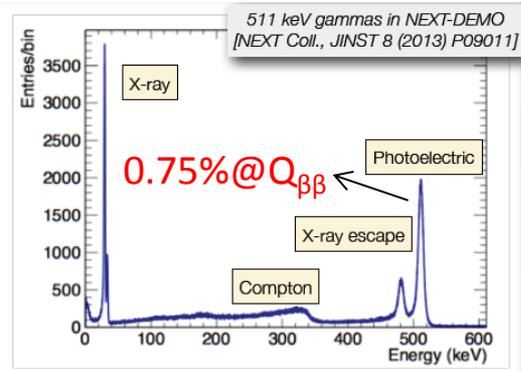
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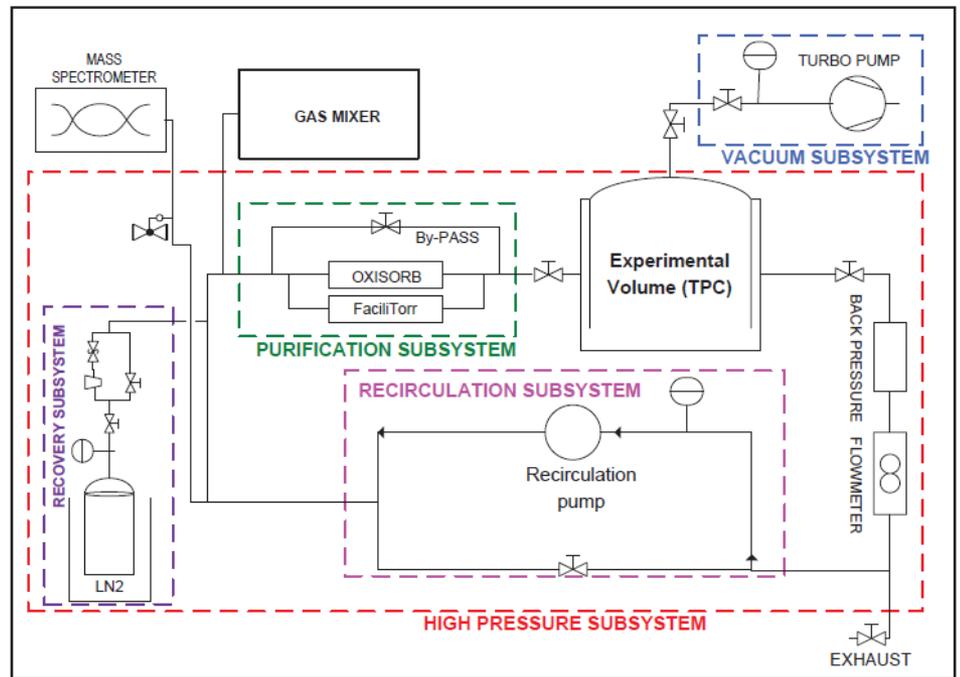
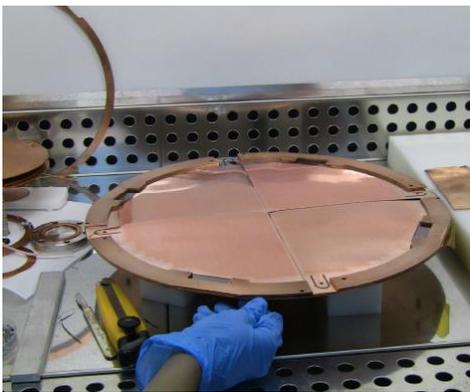
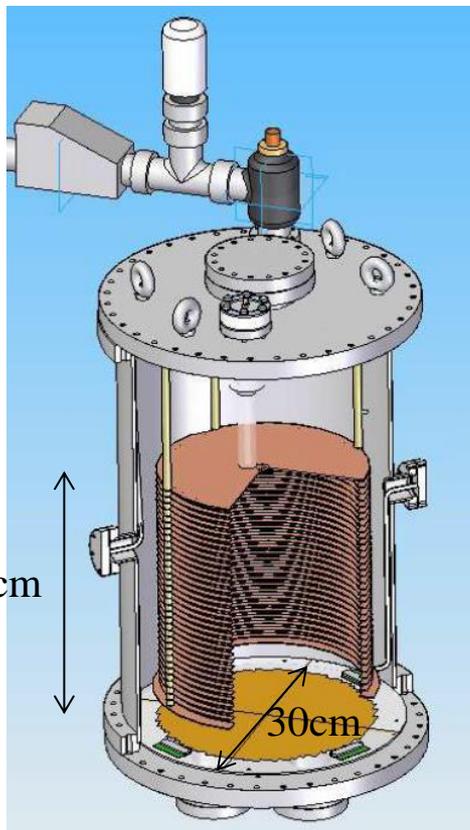


$\beta\beta_0\nu$ (20 meV)
(2020?)



- Scale-up the concept, in principle possible.
- Optimize the gas mixture to boost topological information and/or energy resolution?
- More exotic: Ba-Ta, B-field, others?.

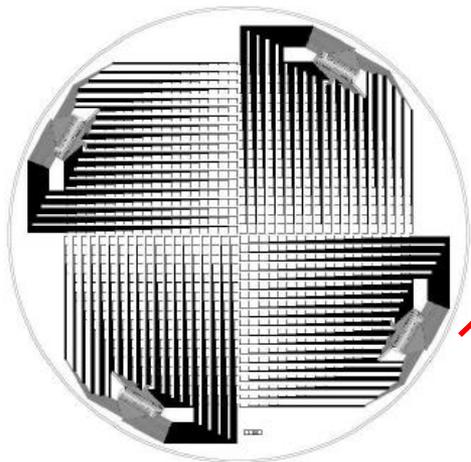




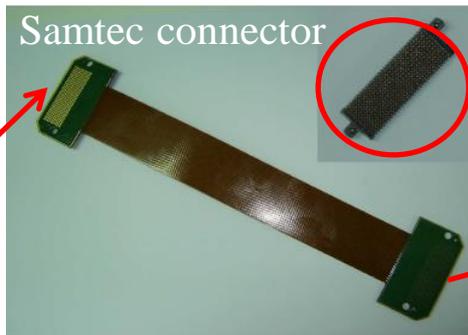
Description and commissioning of NEX-T-MM prototype
JINST 9 P03010

Simplified scheme of the signal routing

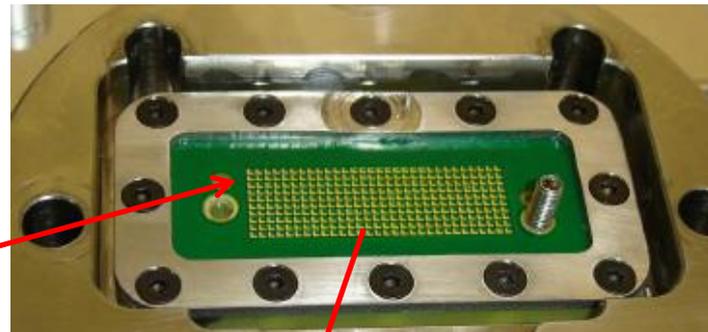
Micromegas routing



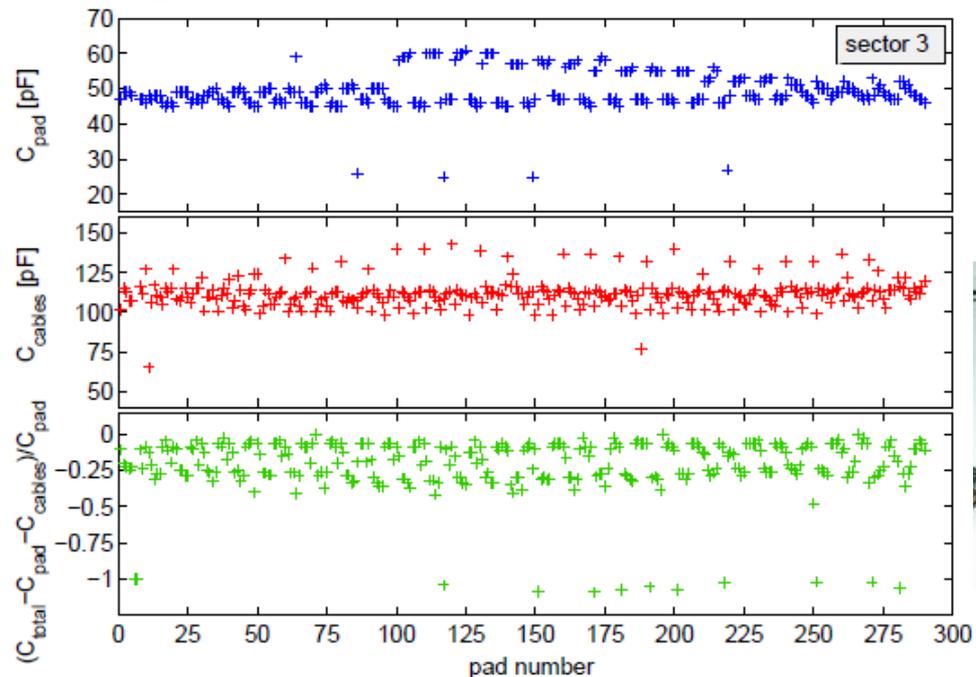
300-pin flat cable



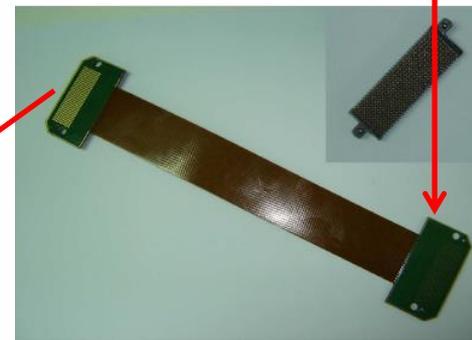
PCB feedthrough



Several design-defects jeopardized connectivity, forcing us to find 'ad hoc' solutions. In the end:

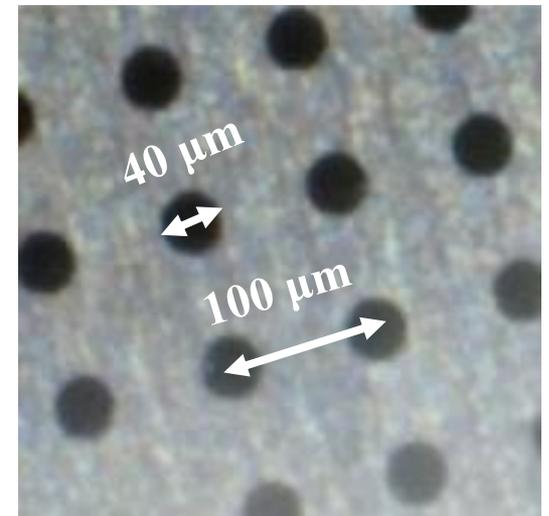
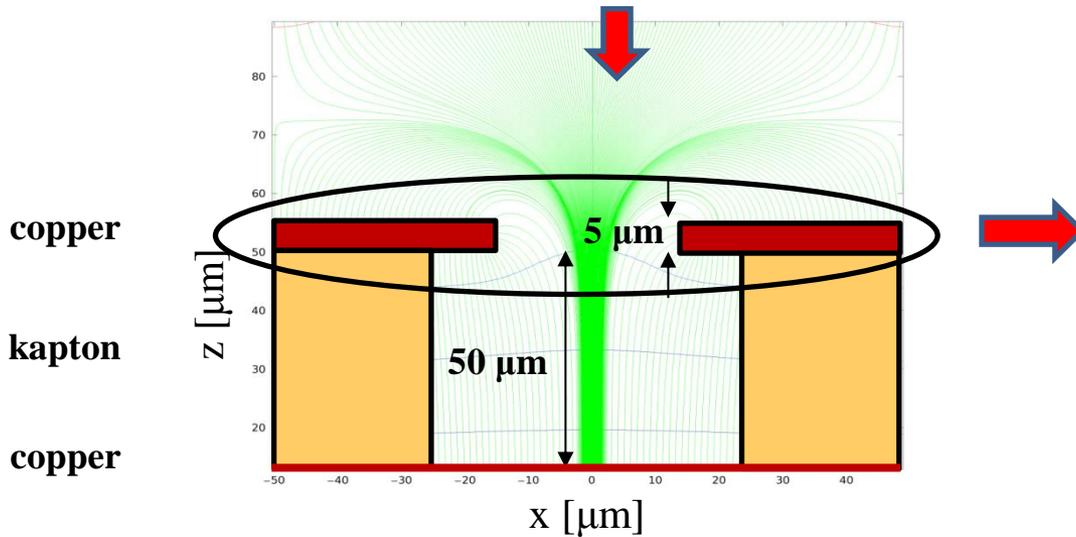
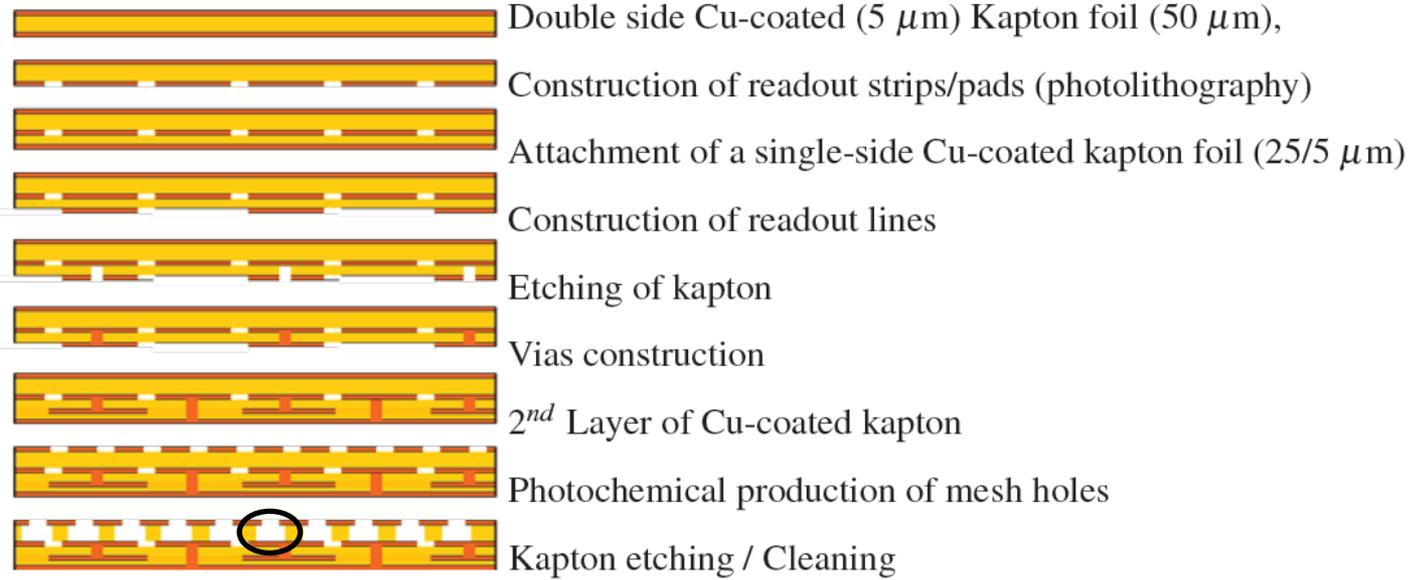


AFTER-based electronics



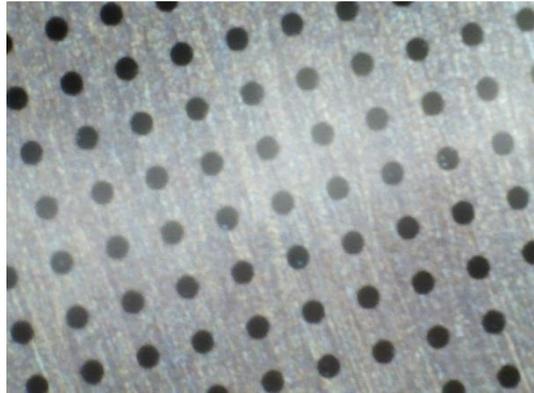
High-end micro-pattern single-gap amplification structure (‘microbulk MicroMegas’)

CERN workshop:
Rui Oliveira et al



up view

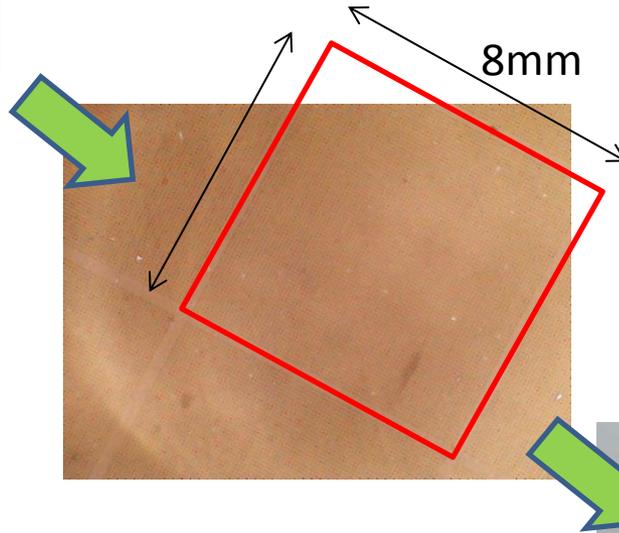
(Radiopure: $<30 \mu\text{Bq}/\text{cm}^2$ for ^{235}U , ^{238}U , ^{232}Th chains)



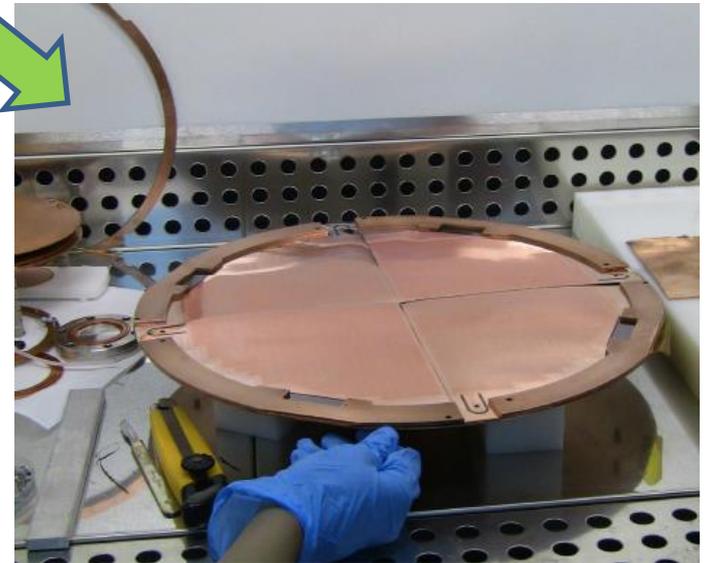
~100 holes

5900 holes/pixel

8mm

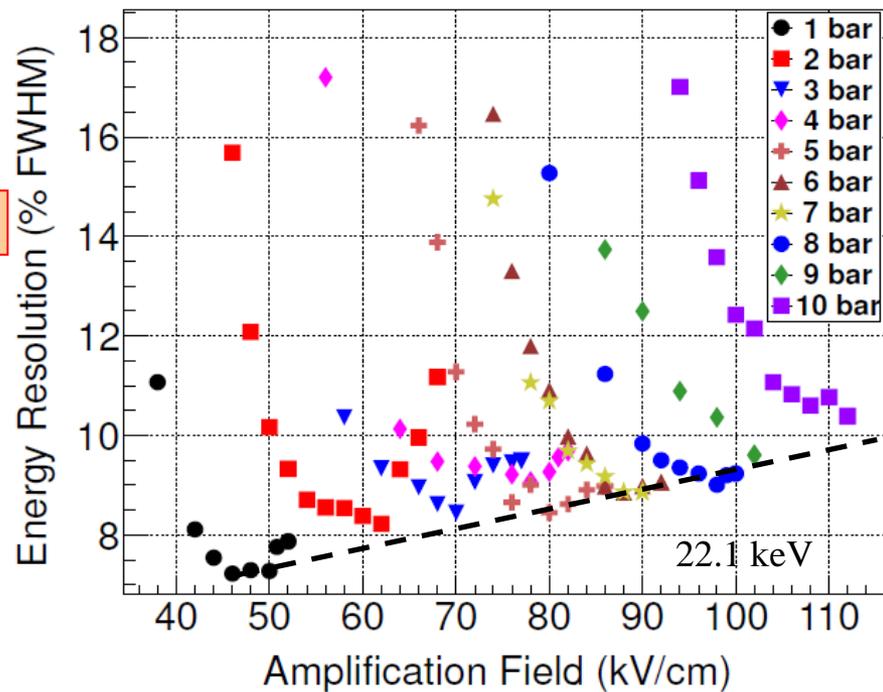
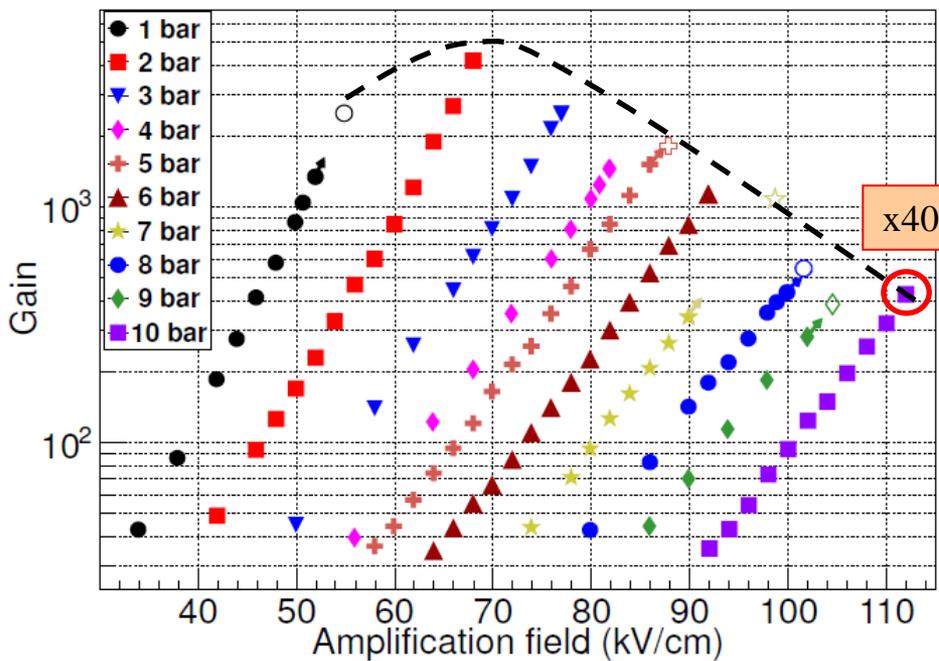
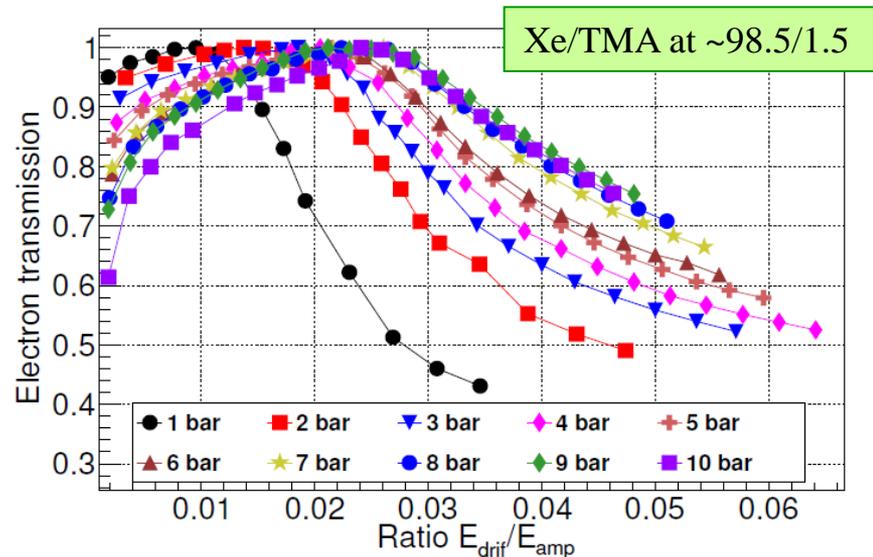


6796800 holes/readout plane



Largest Micromegas manufactured in the microbulk.
No existing experience in a similar system.

step 0: measurements in a small setup and general behavior



Commissioning strategy

- HV, vacuum and pressure tests.
- Preliminary studies with alphas in Ar-ibutane.
- Studies with low energy γ -rays and characterization of the e-cloud properties in the pressure range 1-3bar for Xe-TMA. (~30 live days)
- Run at 10bar with γ -rays (511keV, 1275keV) close to $Q_{\beta\beta}/2$. (~40 live days+)

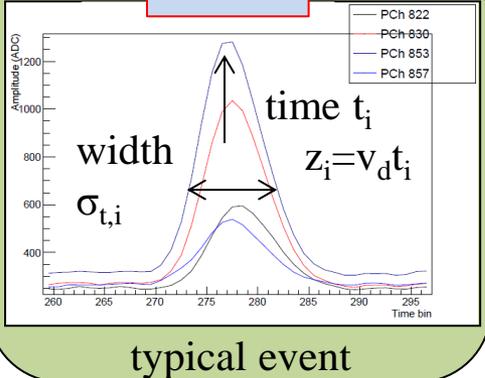
1-3bar

Analysis strategy [1-3bar]

$$\vec{r}_{evt} = \sum_{i=1}^{N_{pixels}} \frac{\epsilon_i}{\epsilon_{evt}} \vec{r}_i$$

$$\vec{r}_M = \vec{r}_i (Q_i == \max(Q_i))$$

0. PSA



1. Calibration

(on $\sim 15\text{keV} < \epsilon < \sim 45\text{keV}$ sub-sample)

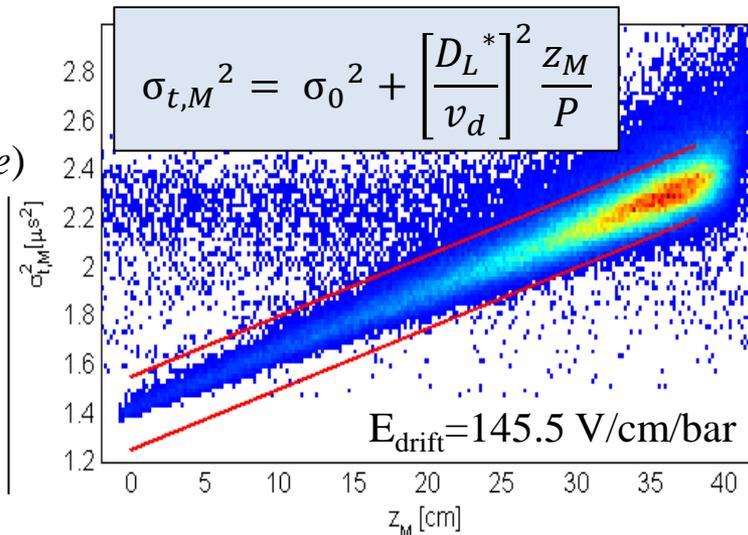
1. Sector equalization (10-20%)
2. Pixel equalization (10%)
3. Transient correction (5-10%)

2. Track quality cut

(on the sample to analyze)

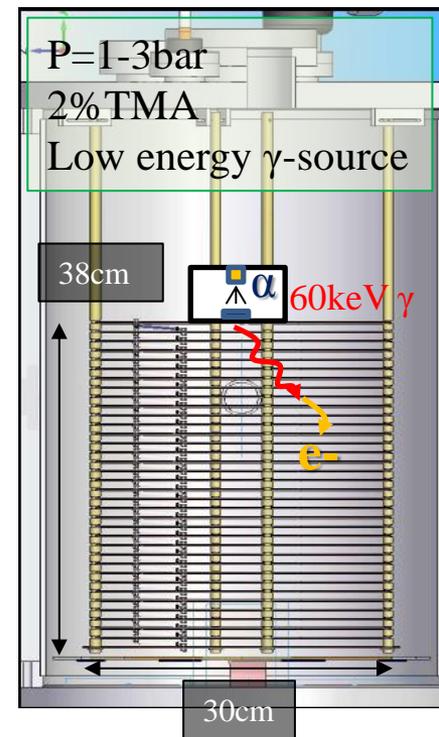
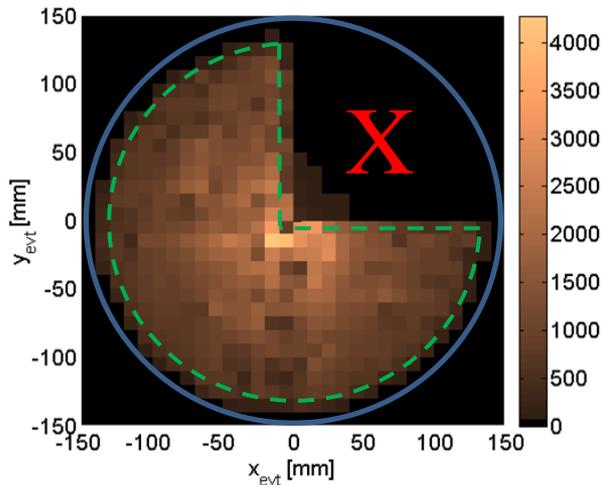
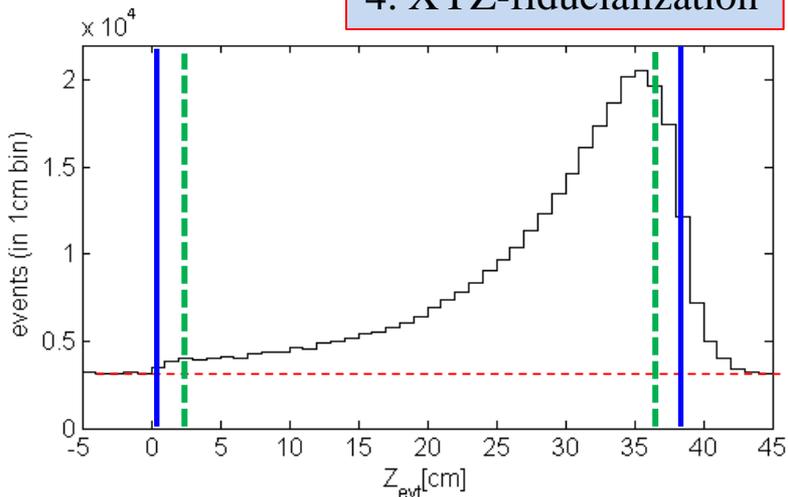
1. Cosmic ray cut (z-extension < 5cm).
2. Baseline quality.
3. Single-track.

3. Suppression of random coincidences



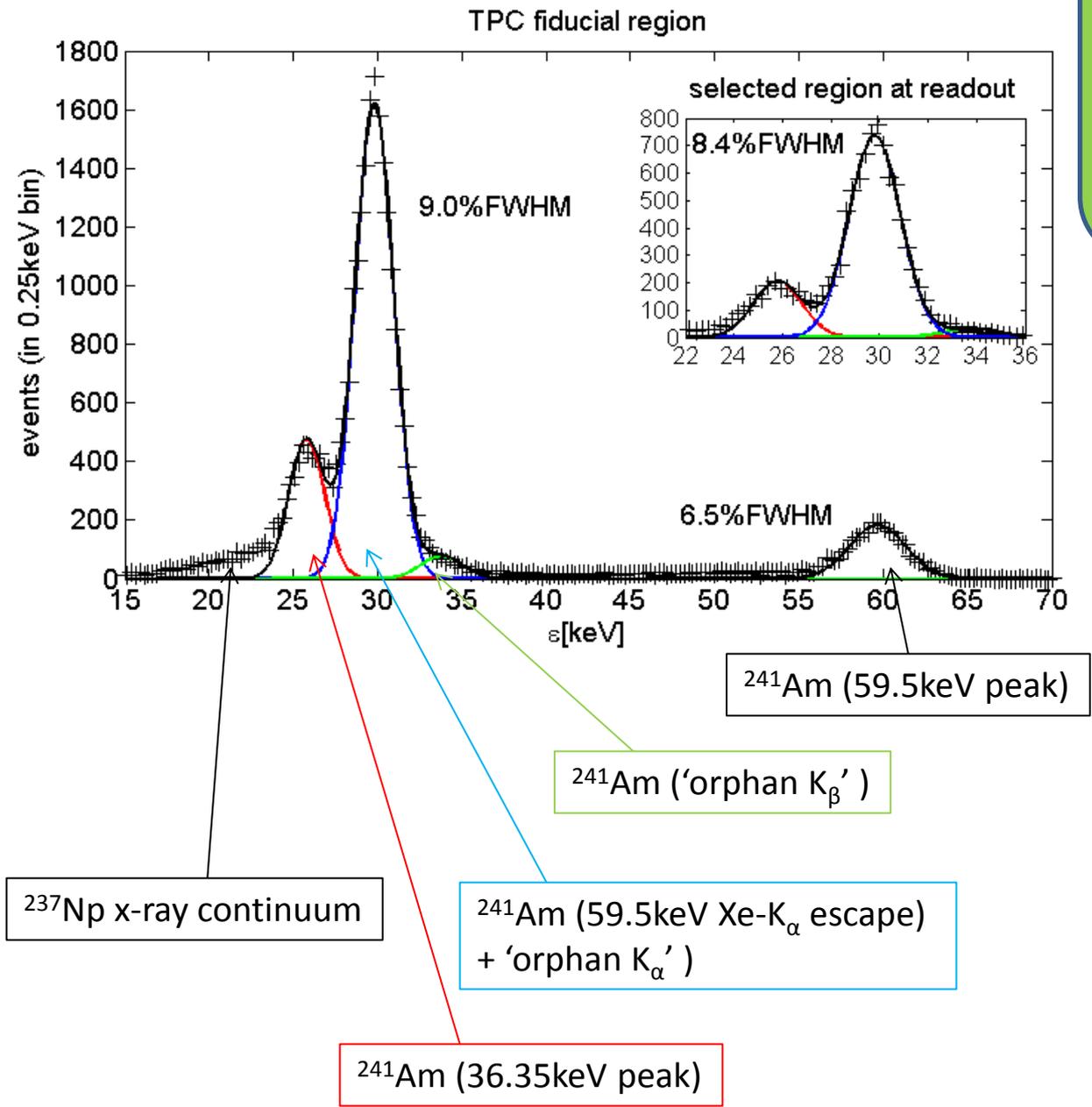
Physical criteria for longitudinal diffusion

4. XYZ-fiducialization

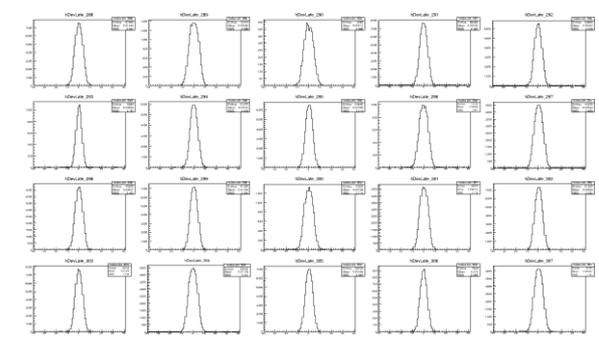


Energy spectrum after calibration at 1-3bar

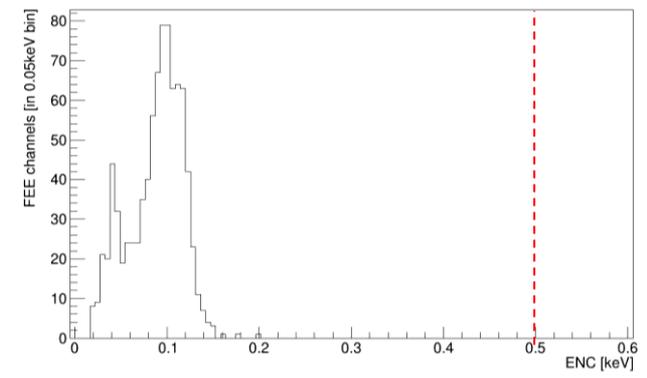
- Mixture: Xe-TMA (97.8/2.2)
- Micromegas gain: 2000
- FEE ENC: <0.12keV(95%ch)
- Pixels' threshold, ϵ_{th} : ~0.5keV
- Trigger threshold: 10-15keV
- Edrift=145.5V/cm/bar
- P=1.0bar
- Electron attachment: <10%/m



Base-line spread for 20 random FEE channels

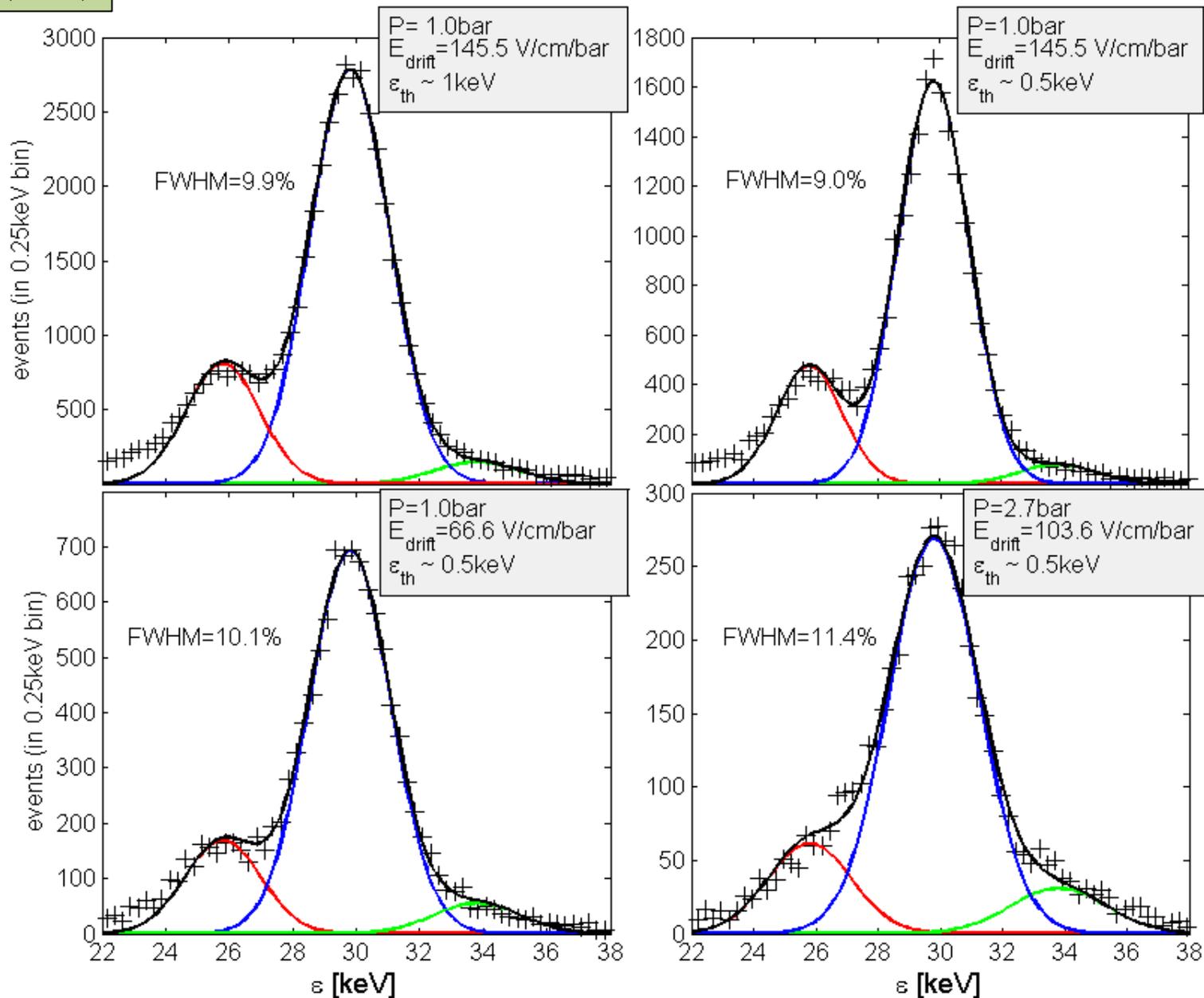


threshold



Xenon escape peaks for ^{241}Am in various conditions

Xe/TMA (98/2)

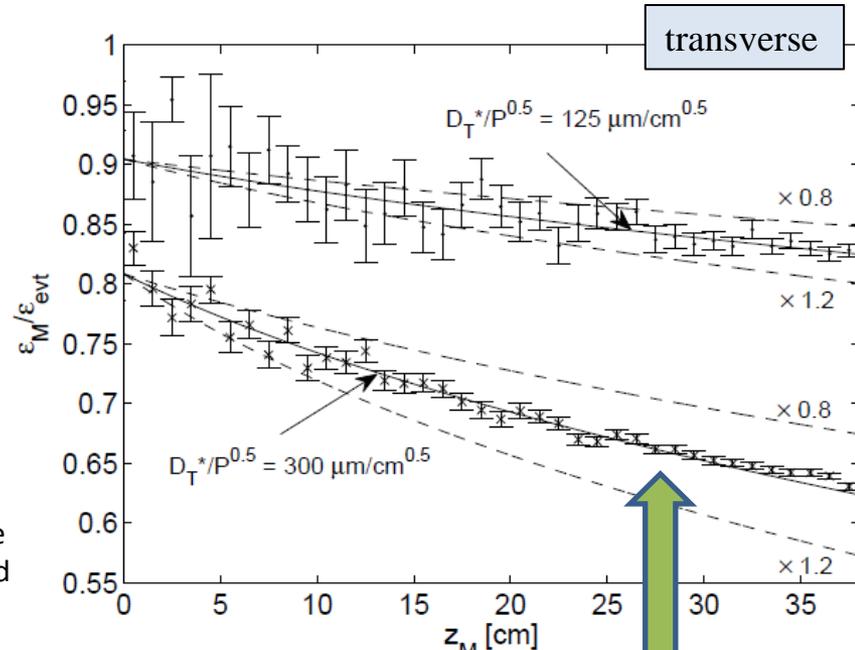
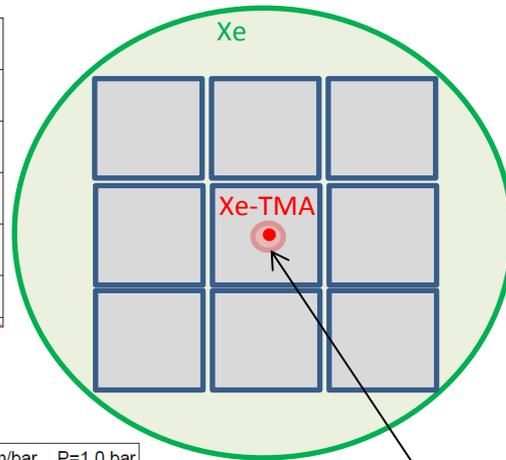
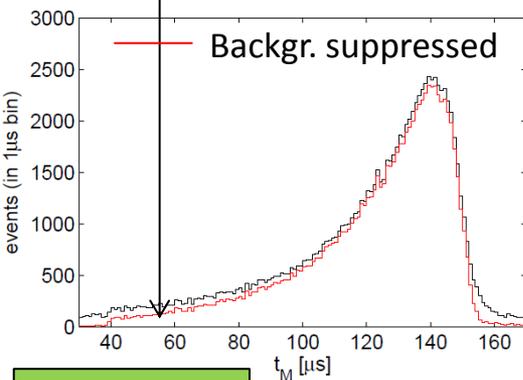
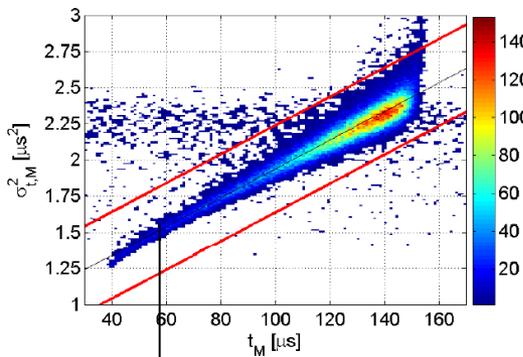
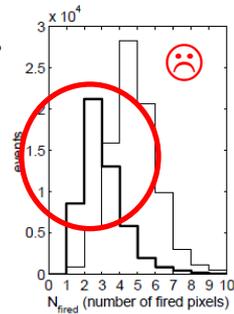


Extraction of diffusion coefficients at 1-3bar

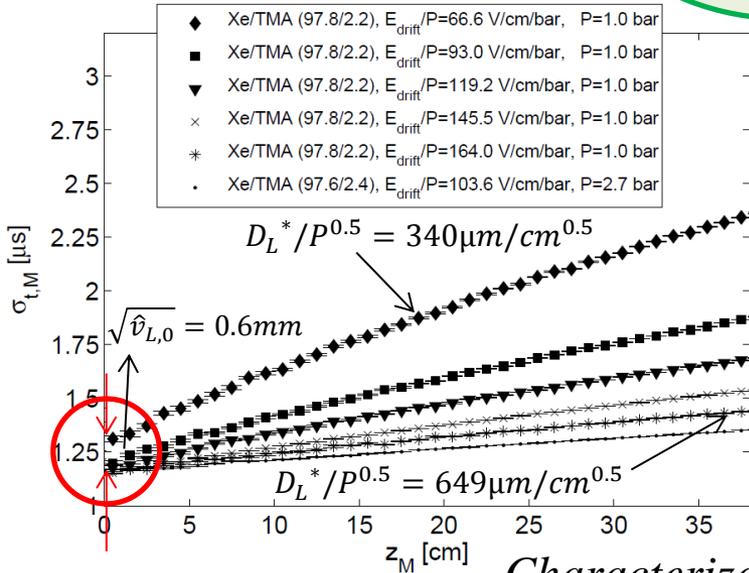
use the following convention

$$D_L^* = \sqrt{\frac{T_0}{T} \frac{2P}{v_d} D_L} \quad \left[\frac{\mu\text{m}}{\sqrt{\text{cm}}} \times \sqrt{\text{bar}} \right]$$

$$\sigma_{L,T} = D_{L,T}^* \frac{\sqrt{z}}{\sqrt{P}}$$



longitudinal



Typical transverse size of the ionization cloud for 38cm drift @1bar (1- σ)

$$\left\langle \frac{\epsilon_M}{\epsilon_{\text{evt}}} \right\rangle = \left[\frac{1}{L} \int_{-L/2}^{L/2} dx \int_{-L/2}^{L/2} \frac{1}{\sqrt{2\pi\hat{v}_r}} e^{-\frac{(x-x_0)^2}{2\hat{v}_r}} dx_0 \right]^2$$

$$\left\langle \frac{\epsilon_M}{\epsilon_{\text{evt}}} \right\rangle = \frac{\left[2\hat{v}_r \left(e^{-\frac{L^2}{2\hat{v}_r}} - 1 \right) + \sqrt{2\pi} L \sqrt{\hat{v}_r} \text{erf} \left(\frac{L}{\sqrt{2\hat{v}_r}} \right) \right]^2}{2\pi L^2 \hat{v}_r}$$

$$\hat{v}_r = D_T^{*2} \times \frac{z_M}{P} + \hat{v}_{r,0} \longrightarrow \sqrt{\hat{v}_{r,0}} = 1 \pm 0.1\text{mm}$$

10bar

Analysis strategy [10bar]

3. No suppression of random coincidences (yet)

$$\vec{r}_{evt} = \sum_{i=1}^{N_{pixels}} \frac{\epsilon_i}{\epsilon_{evt}} \vec{r}_i$$

$$\vec{r}_M = \vec{r}_i (Q_i == \max(Q_i))$$

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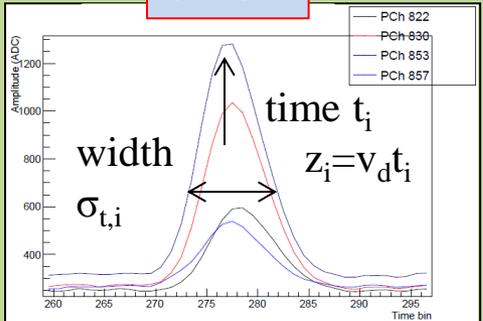
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2. Track quality cut

(on the sample to analyze)

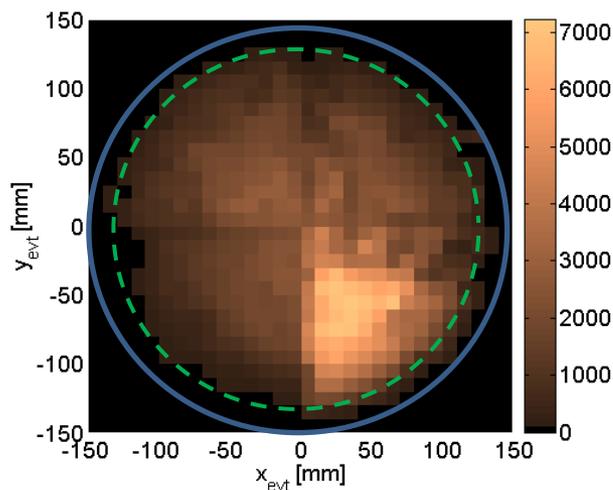
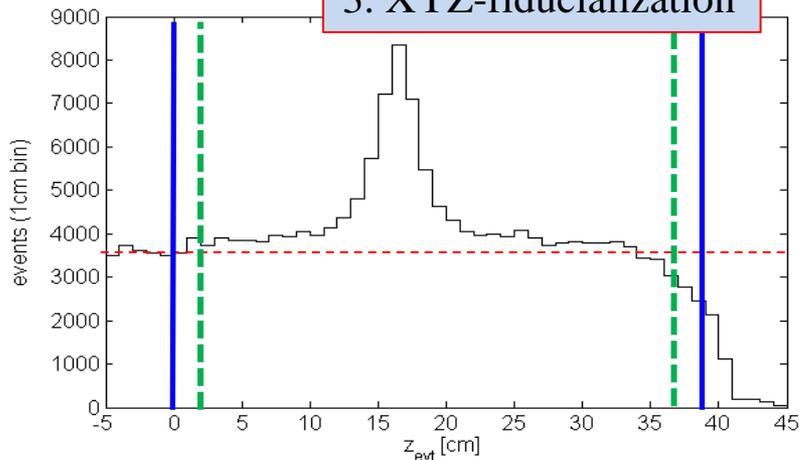
1. Cosmic ray cut (z-extension < 5cm).
2. Baseline quality.
3. **Tracks with 1-3 clusters.**

0. PSA

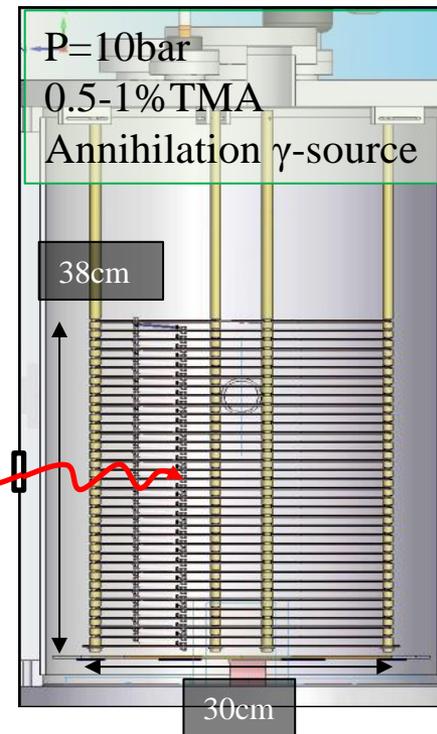


typical event

3. XYZ-fiducialization



— approximate source position

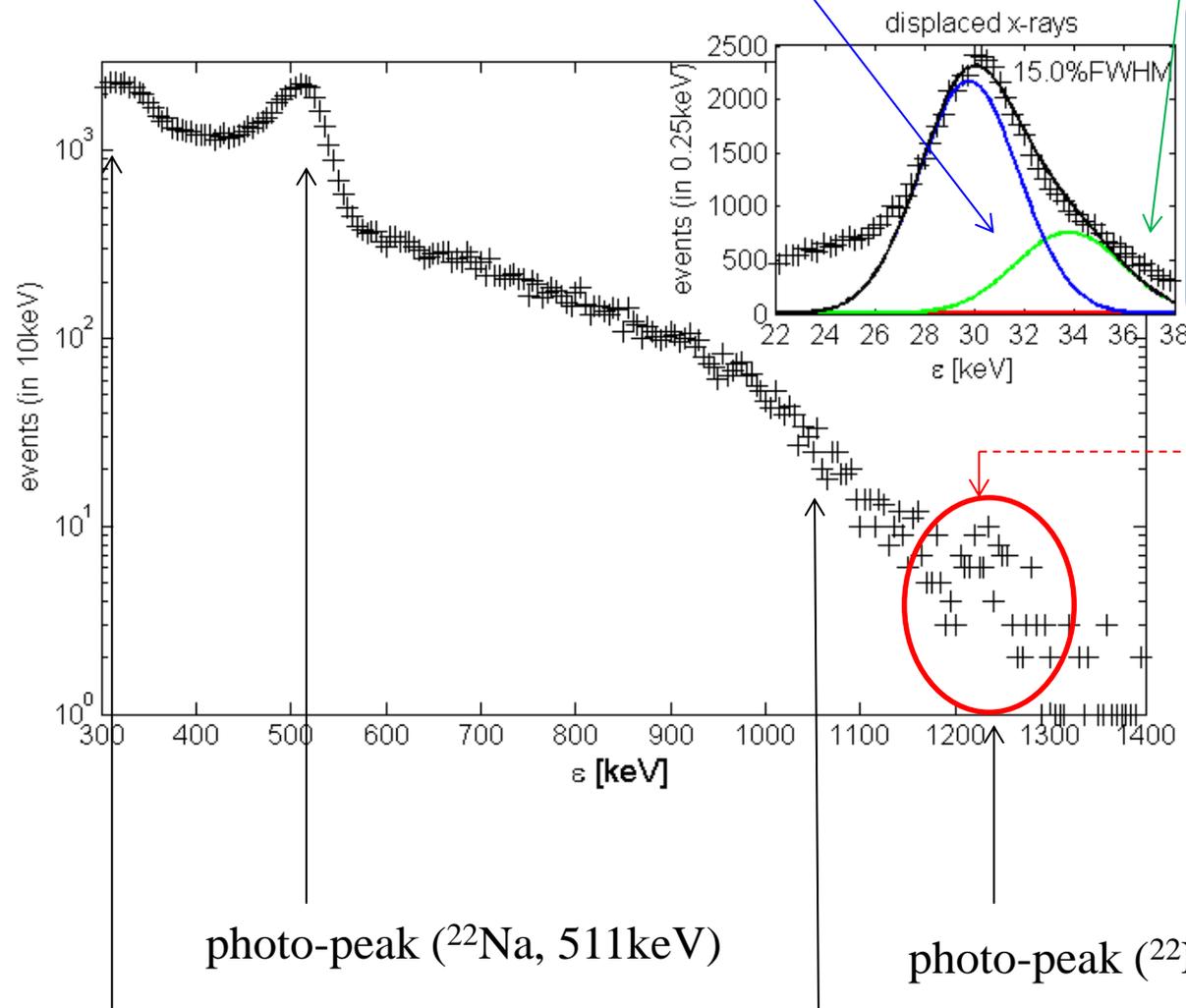


Energy spectrum after calibration at 10bar

(29.8keV Xe-K $_{\alpha}$ emission)

(33.64keV Xe-K $_{\alpha}$ emission)

- Mixture: Xe-TMA (99.0/1.0)
- Micromegas gain: 150-250
- FEE ENC: <2keV(95%ch)
- Pixels' threshold, ϵ_{th} : ~7.5keV
- Trigger threshold: 250-300keV
- Edrift=80V/cm/bar
- P=10.1bar
- Electron attachment: small (?)



$$\sim Q_{\beta\beta, 136\text{Xe}}/2$$

threshold

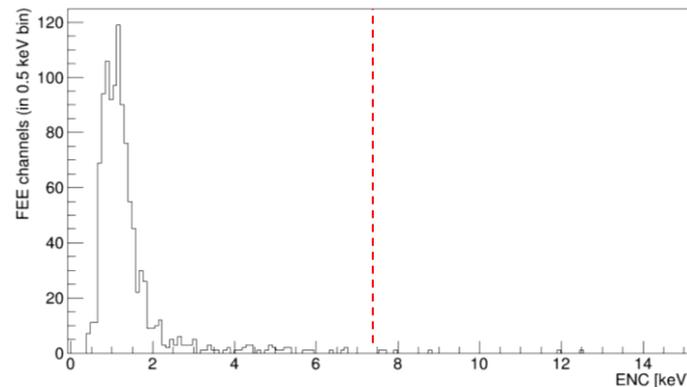


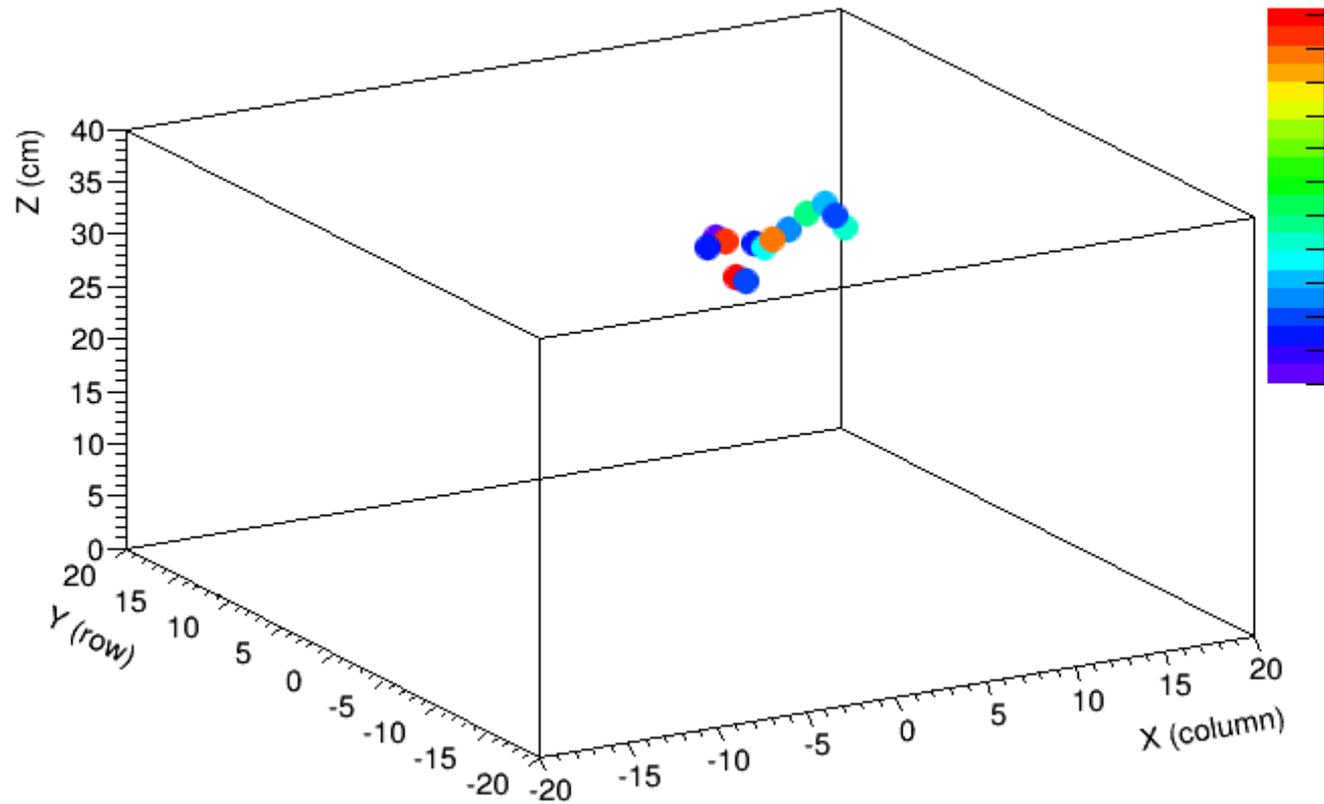
photo-peak (²²Na, 511keV)

photo-peak (²²Ne*, 1275keV)

Compton edge (²²Na, 511keV)

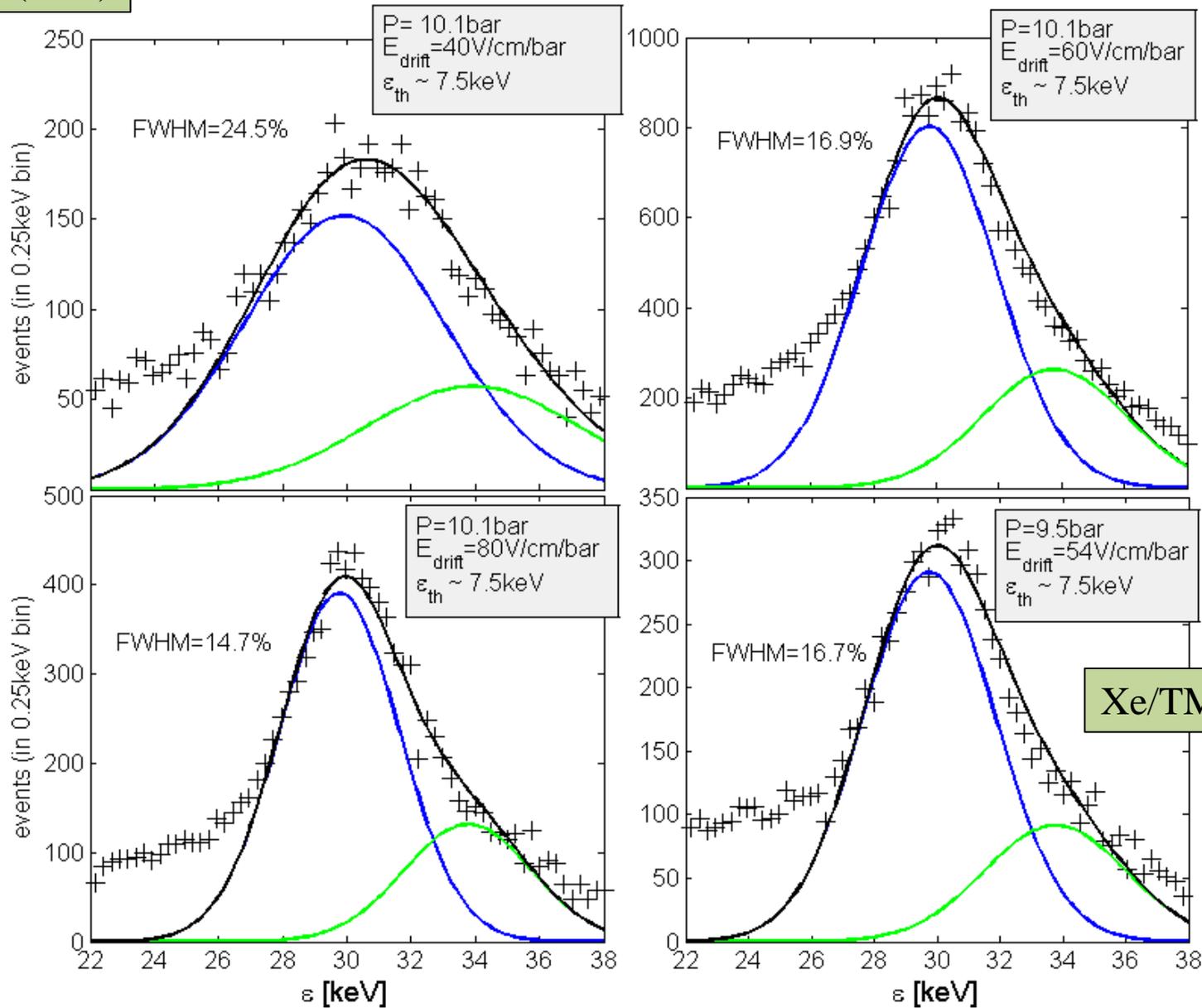
Compton edge (²²Ne*, 1275keV)

selected events in the 1.2MeV region (from $^{22}\text{Ne}^*$)



Xe characteristic $K_{\alpha,\beta}$ peaks of Xenon for various conditions

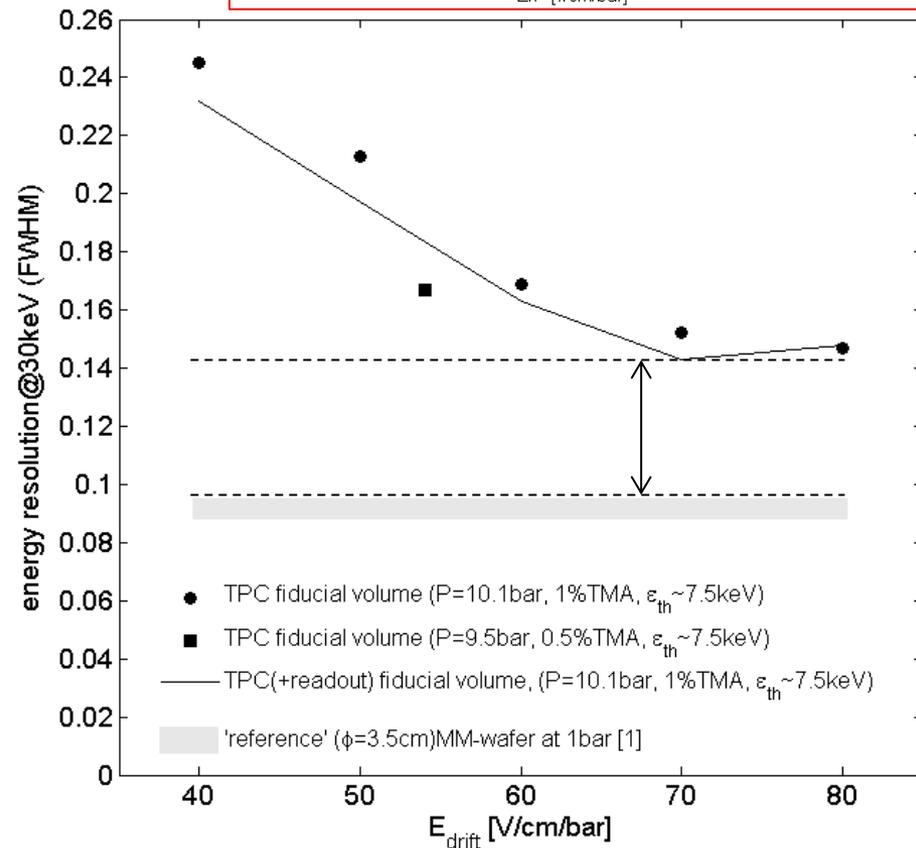
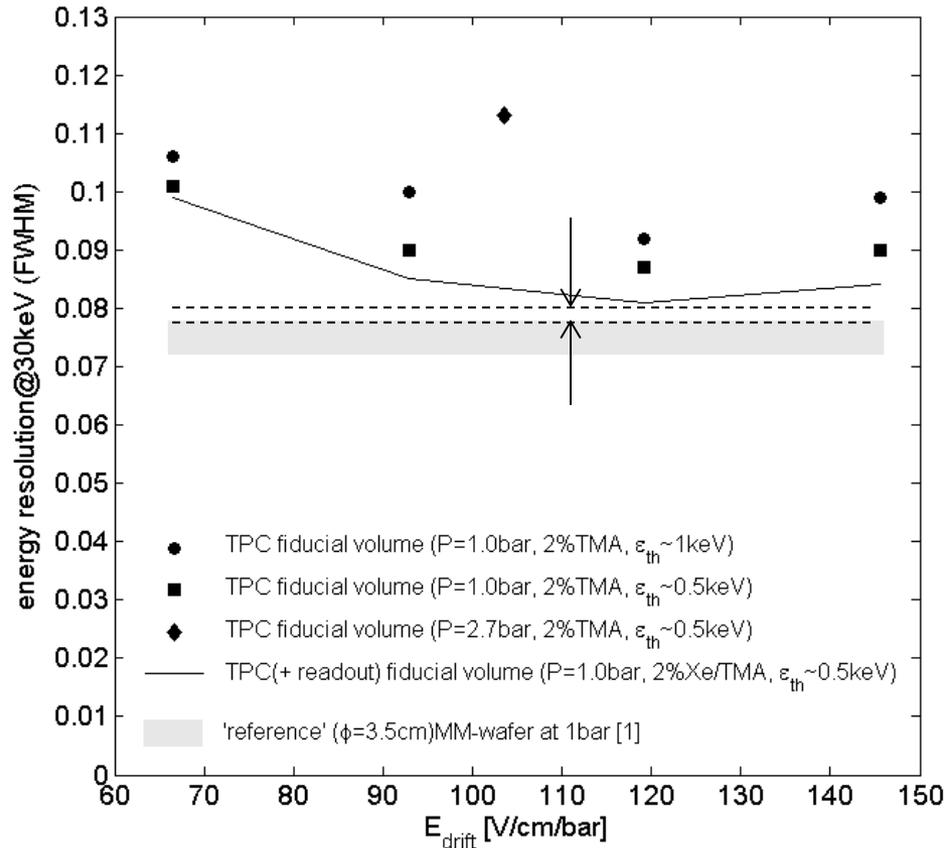
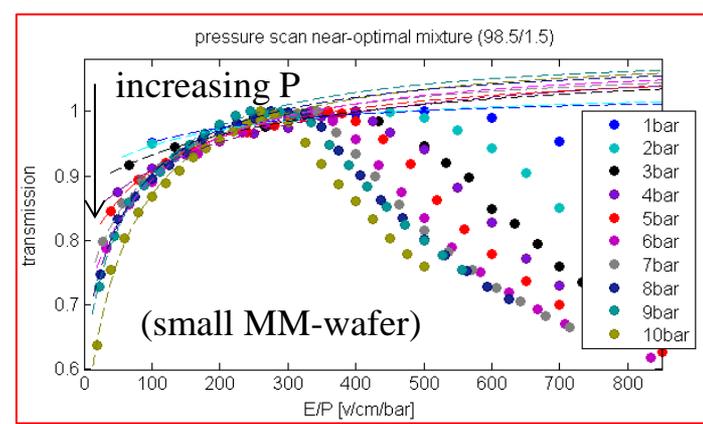
Xe/TMA (99/1)



Xe/TMA (99.5/0.5)

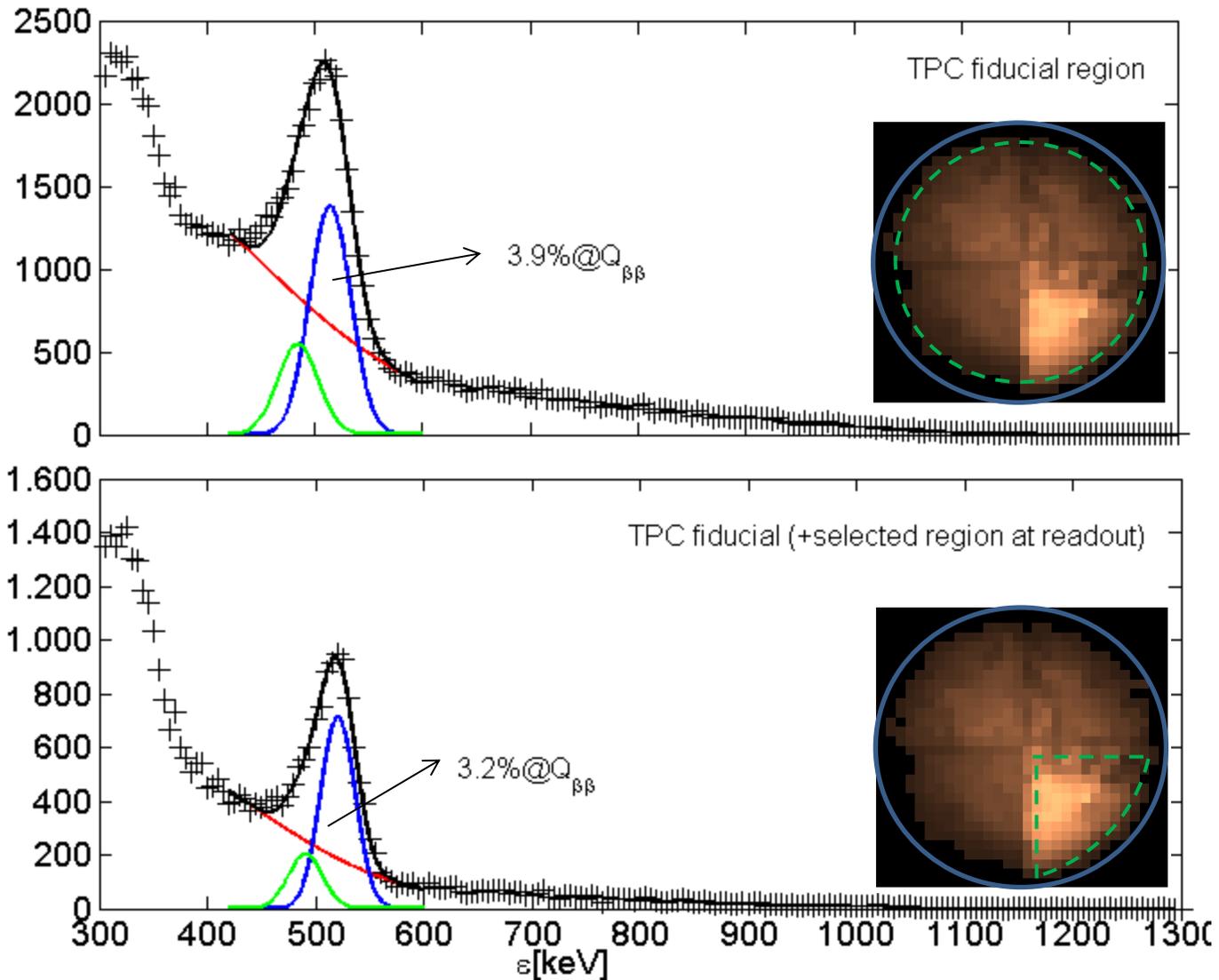
Results for 30keV in a nut-shell

Deterioration already at the level of small variations in the technological process



Deterioration presumably coming mainly from missing energy ($\epsilon_{\text{th}} \sim 7.5\text{keV}$) and higher recombination at HP

Energy resolution at the 511 annihilation peak



Status

1-3bar campaigns (6months/30live days)

level of connectivity: **92%**
unconnected pixels: **8%**
of which
unclear origin: **1%**
understood(solvable): **5.2%**
damaged pixels: **1.8%**

sector 1 **not functional.**

P=1-2.7bar

%TMA=2.2-2.4

E_{drift} =66-170 V/cm/bar

gain=1600-2000

η <10%/m

Am-source (30-60keV)

HP campaigns (3months/40live days)

level of connectivity: **~90%**
unconnected pixels: **10%**
of which
unclear origin: **1%**
understood(solvable): **4.5%**
damaged pixels: **4.5%**

full plane operative

P=9.5-10bar

%TMA=0.45-1%

E_{drift} =40-80 V/cm/bar

gain=200

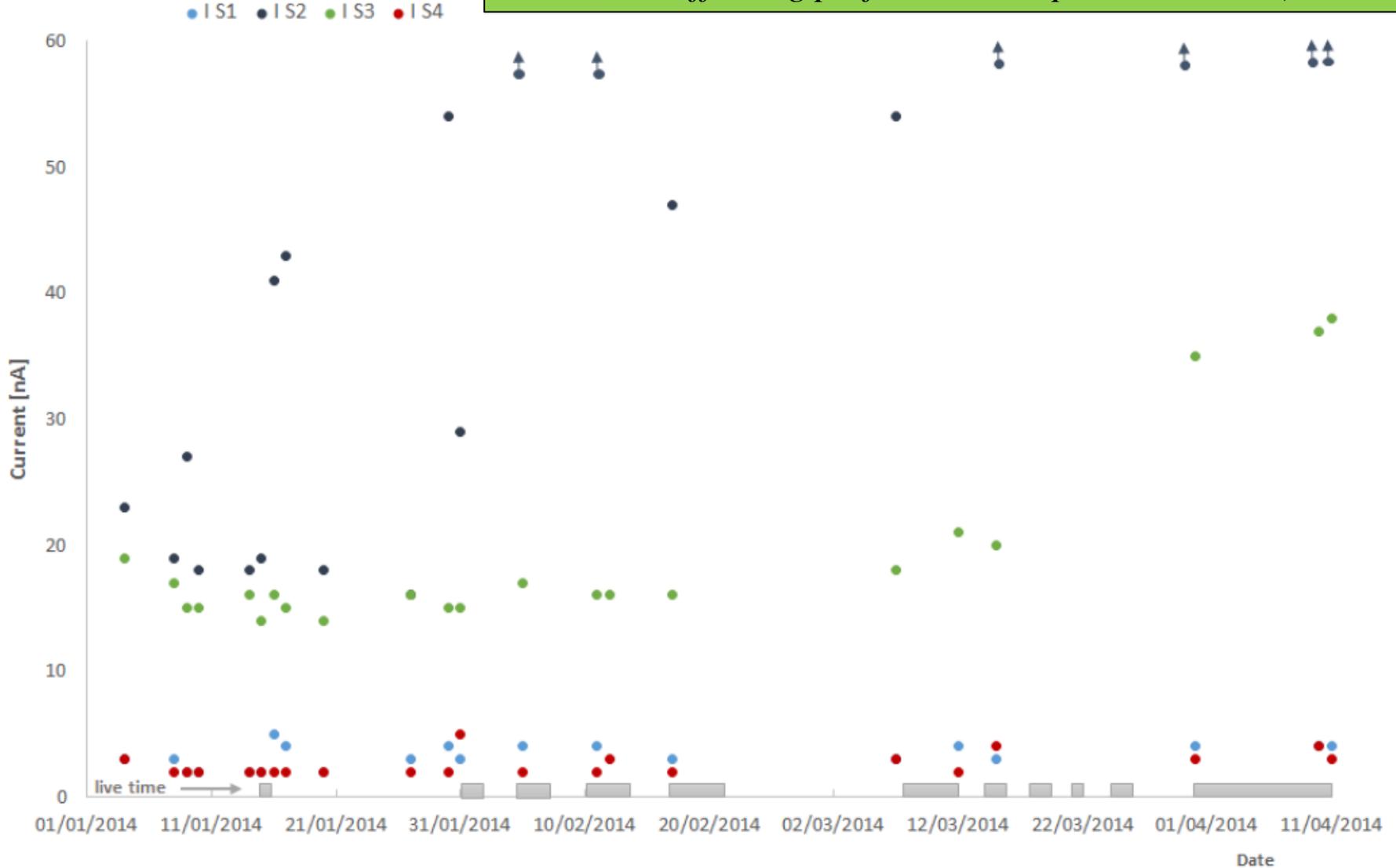
η =? (no strong indications)

Na-source (511-1270keV)

running continuously at the moment!

Behavior of current with time

For S2 a high leak current was observed (stabilized at about 350nA, not affecting performances –parallel source)



Stability and effective exposure

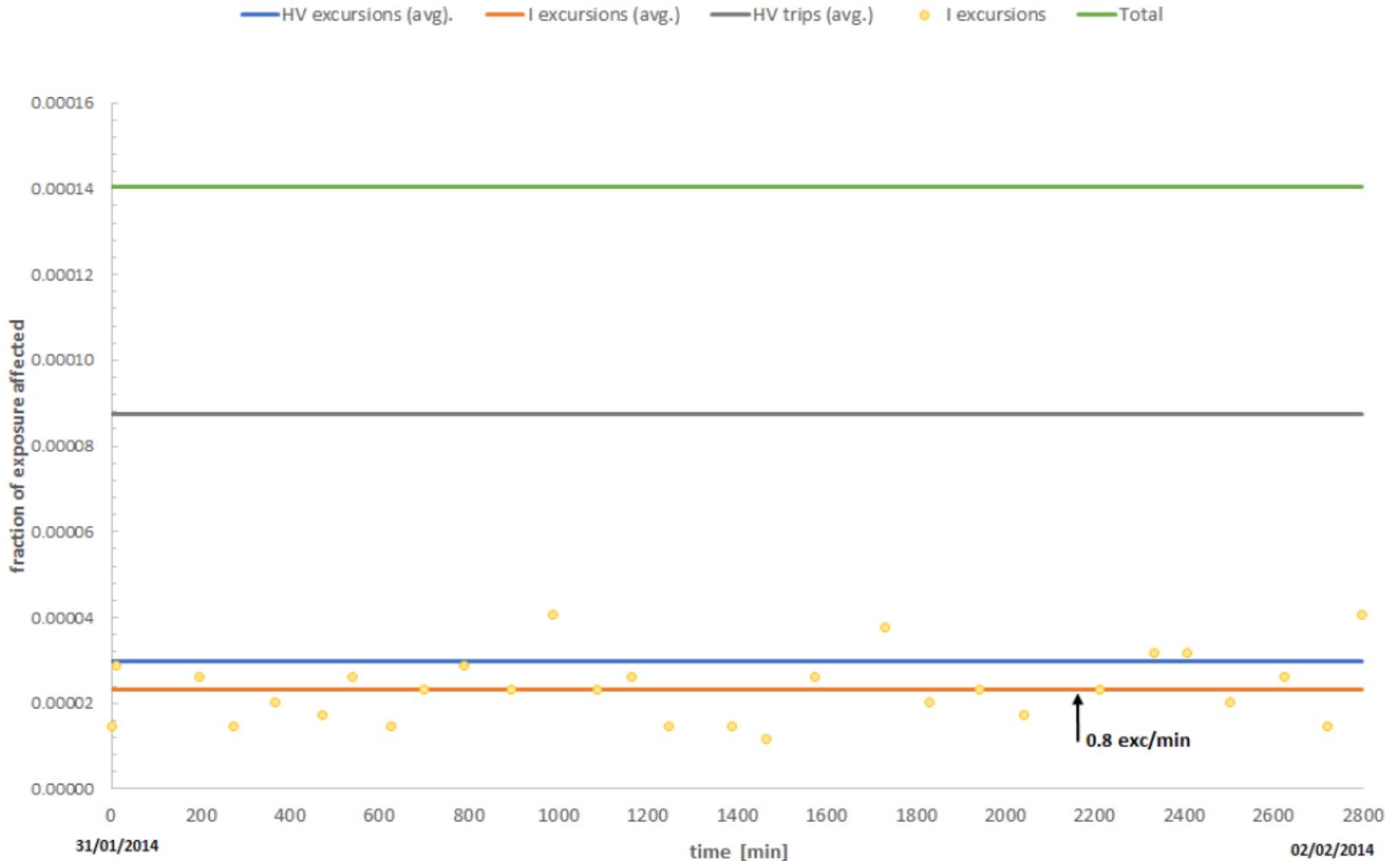
$$T_{1/2}^{-1} \propto a \cdot \epsilon \cdot \sqrt{\frac{Mt}{\Delta E \cdot B}} \quad \leftarrow \text{exposure}$$

Besides general maintenance and calibration activities, assume 3 main sources of loss of exposure connected to the readout plane:

- Current excursions. Only a hole/pixel is affected during ~2s.
- HV excursions. The voltage of a whole sector ramps (some %) down for ~5-10s.
- HV trips. Full ramp-down/up cycle needed, ~1-2min.

$$\frac{Mt|_{loss}}{Mt} \cong \frac{A_{affected} \times \Delta t_{affected}}{A \times t}$$

Stability and effective exposure



Conclusions and outlook

1. NEXT-MM working **stable** (24/7) at 10bar, for 40 live days+, in a Xe/TMA mixture at 99/1. Virtually no experiment-shifts except for safety (pressure, high voltage, leaks).
2. **Only 2** pixels experienced further damage during the 40 days of the 10bar campaign.
3. Loss of exposure for the 10 bar campaign due to instrument unstabilities (current and HV excursions, HV-trips) quantified to be **0.014%**.
4. Assigning the observed pixel damage (**4.5%**) to defects in the micro-fabrication of the sensor, it translates to a probability of a defect of **8ppm**. A further reduction can be envisaged, specially since part of the damage was certainly caused during sensor manipulation. *Higher pixelization will reduce the probability of pixel damage proportionally. **An intriguing option!***
5. Energy resolution a bit shy of **3% $Q_{\beta\beta}$** , a factor x2 far from 1/VE scaling. Improved PSA and track-geometry studies will follow to clarify if the limitation comes from the drift region or the MM-sensor (recombination, finite threshold or calibration). It is unclear whether MM can contribute to the energy estimate coming from the EL region in NEXT, however it offers uparalleled performance as a tracking plane.
6. The reported **ENC is about x10** higher than obtained in T2K experiment, so there is room for improvement by professional cable design!
7. NEXT-MM is probably **the best possible test-bed to date (?)** for topological studies of high energy e- tracks in low-diffusion Xenon-mixtures. There is a claim that this particular setup can increase the γ -suppression in at least a factor x3 as compared to pure Xenon [J. Phys. G: Nucl. Part. Phys. 40 125203], **encouraging!**

the Zaragoza group

Theopisti Dafni

Igor Irastorza

Juan Antonio Garcia

Juan Castel

Angel Lagraba

Diego Gonzalez-Diaz

Francisco Iguaz

Gloria Luzon

Susana Cebrian

Elisa Choliz

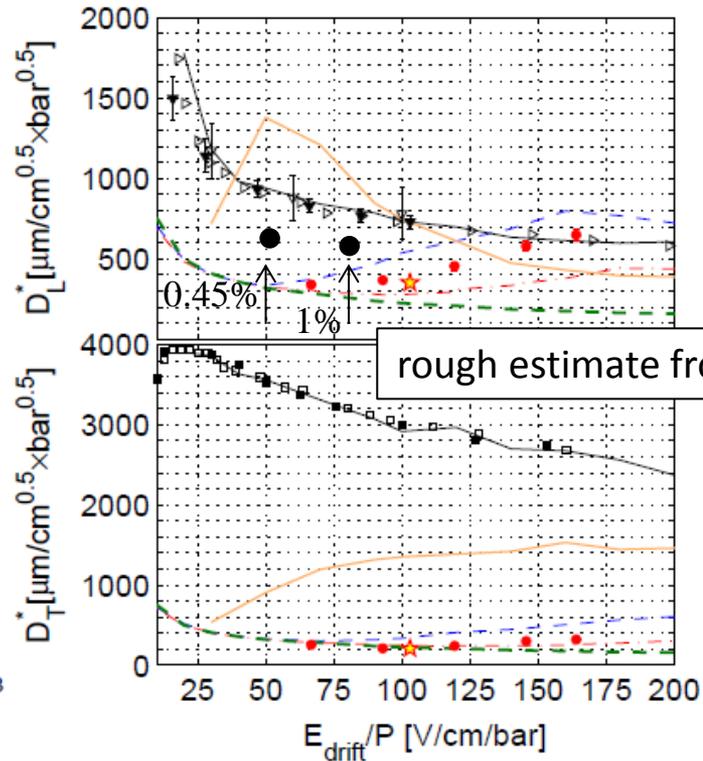
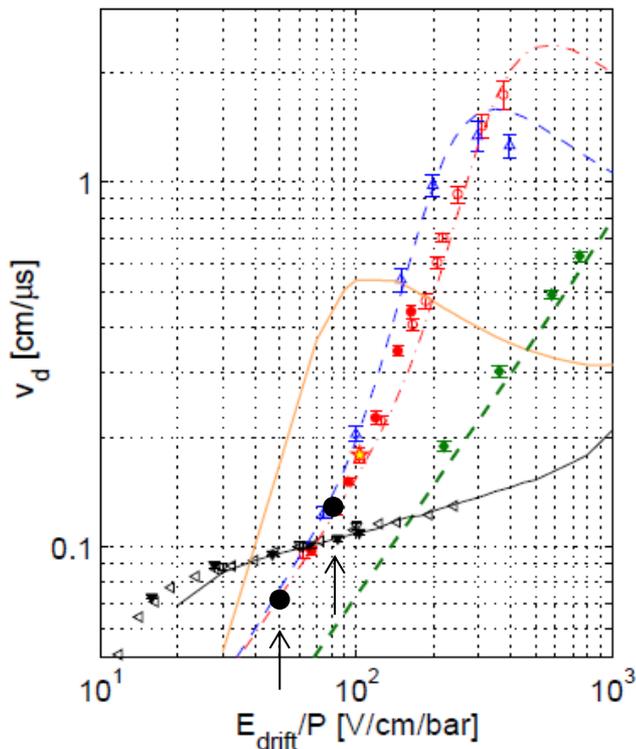
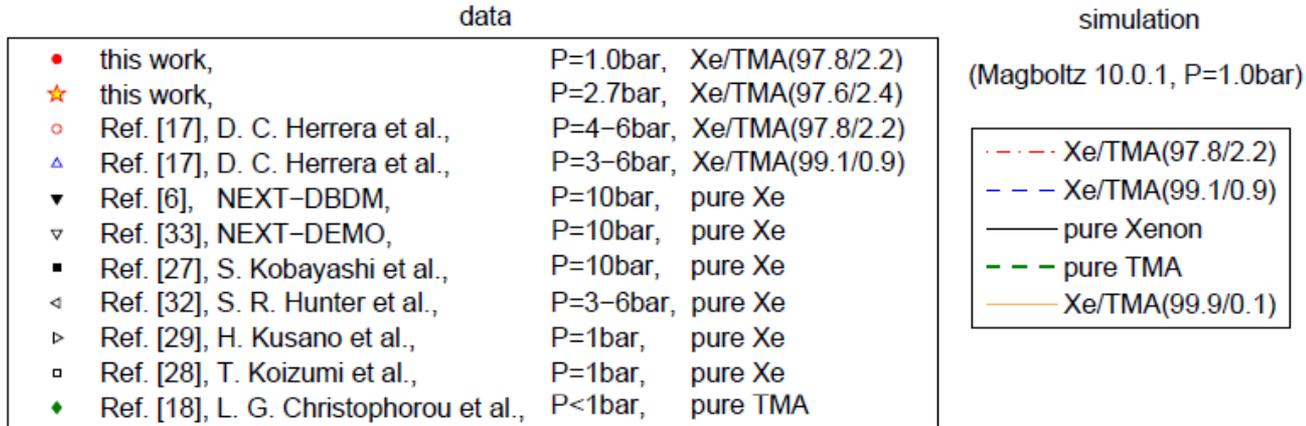
Javier Gracia

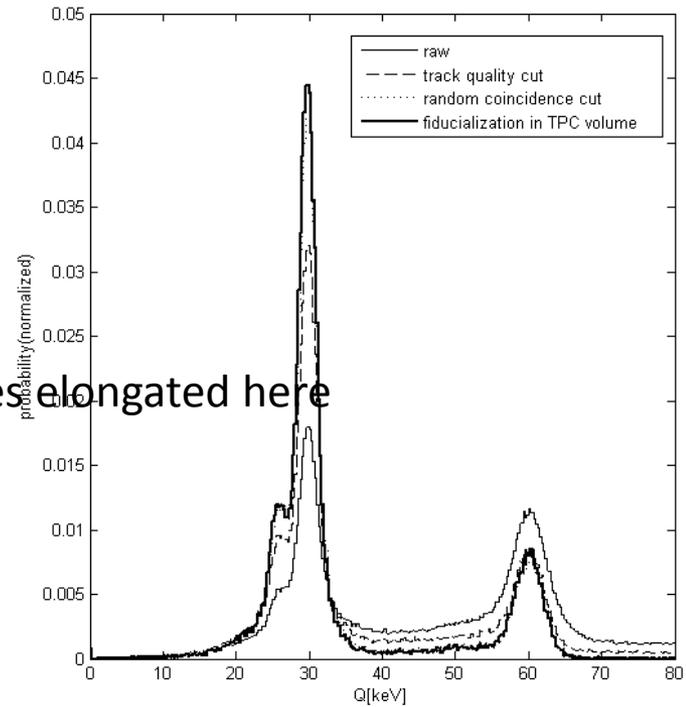
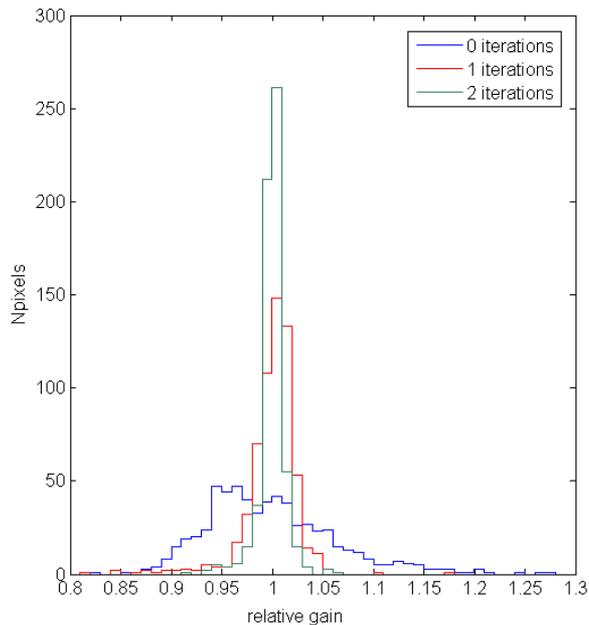
Diana Carolina Herrera

special thanks to Saclay-
IRFU and to the CERN
workshop

appendix

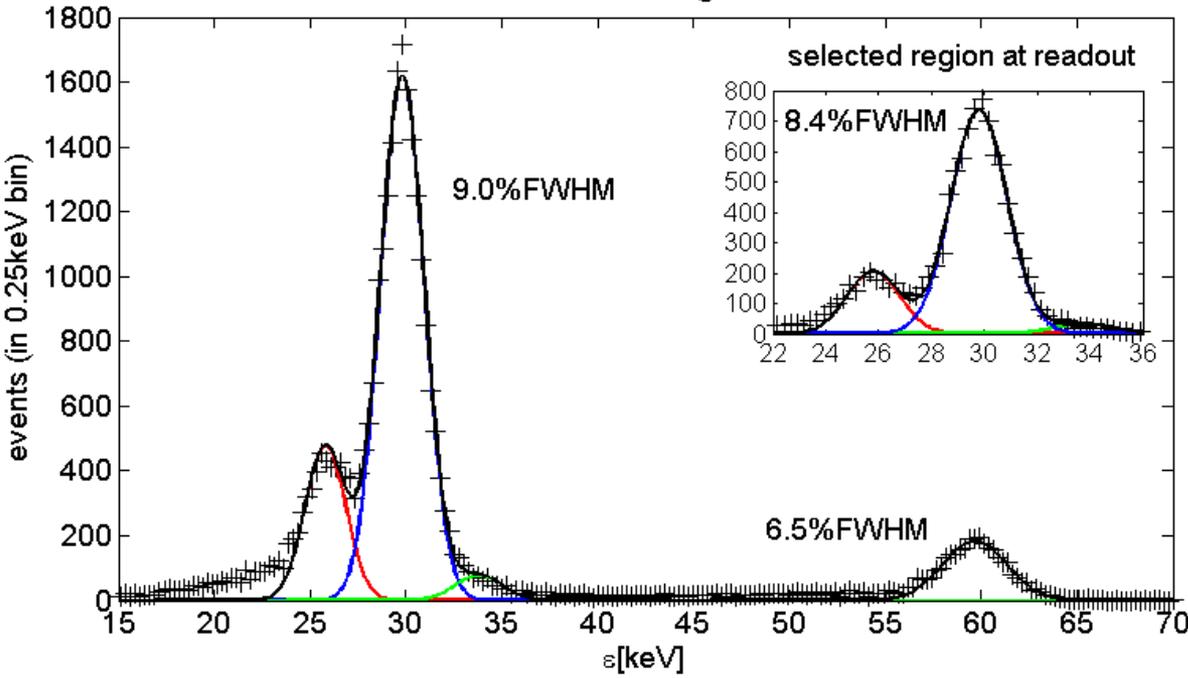
drift velocity and diffusion systematics





Make figures elongated here

TPC fiducial region



Mixture: Xe-TMA (97.8/2.2)
 Micromegas gain 2000
 FEE ENC<0.12keV(95%ch):
 FEE threshold: 0.5keV
 Edrift=bla
 P=1bla

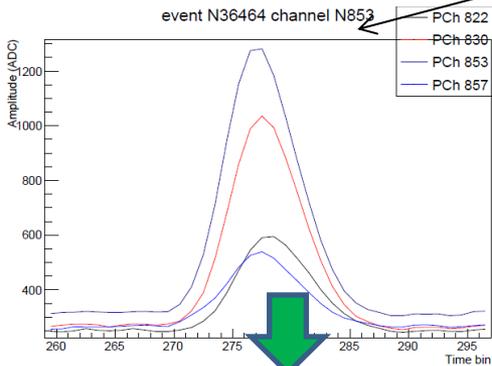
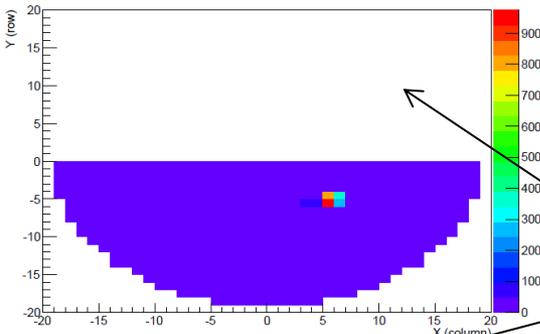
fully digitized pulses

mixture: Xe/TMA (~98/2)

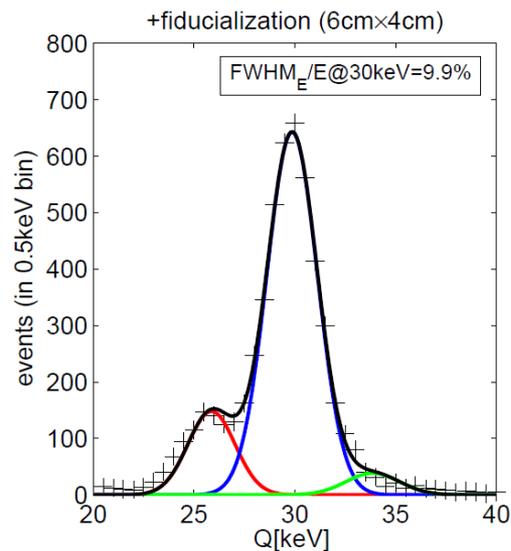
summary (reminder)

list of observable x-ray photons (~above 1% probability)

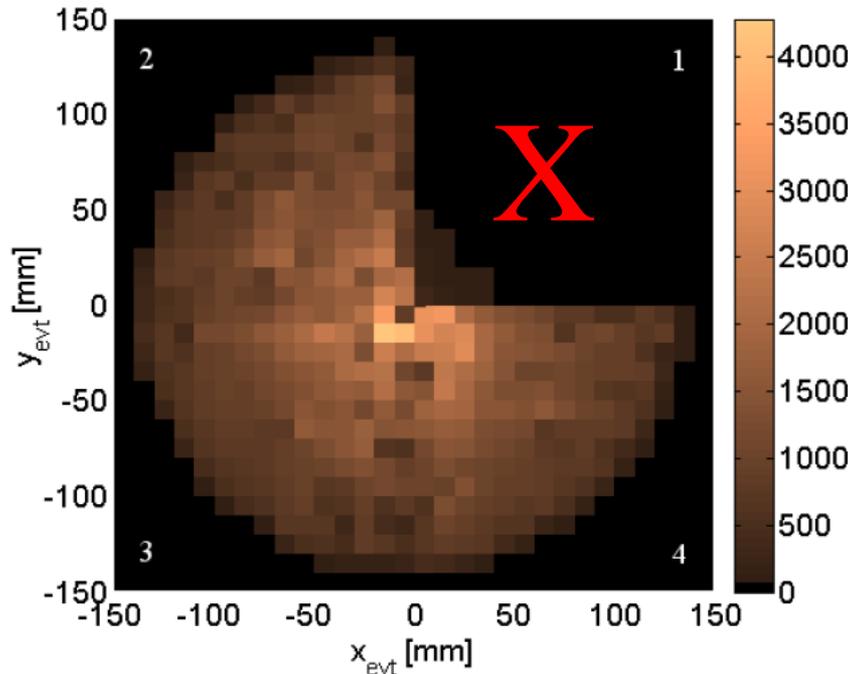
- | | | | | |
|----|------------------------------------|----------------------------|---|---|
| 1. | full absorption main Am-peak: | 59.54 keV | → | 1 |
| 2. | orphan K_{β} : | 33.64 keV | → | 2 |
| 3. | escape K_{α} : | $59.54 - 29.8 = 29.74$ keV | } | 3 |
| 4. | orphan K_{α} : | 29.80 keV | | |
| 5. | escape K_{β} : | $59.54 - 33.6 = 25.94$ keV | } | 4 |
| 6. | full absorption secondary Am-peak: | 26.3keV | | |



energy resolution



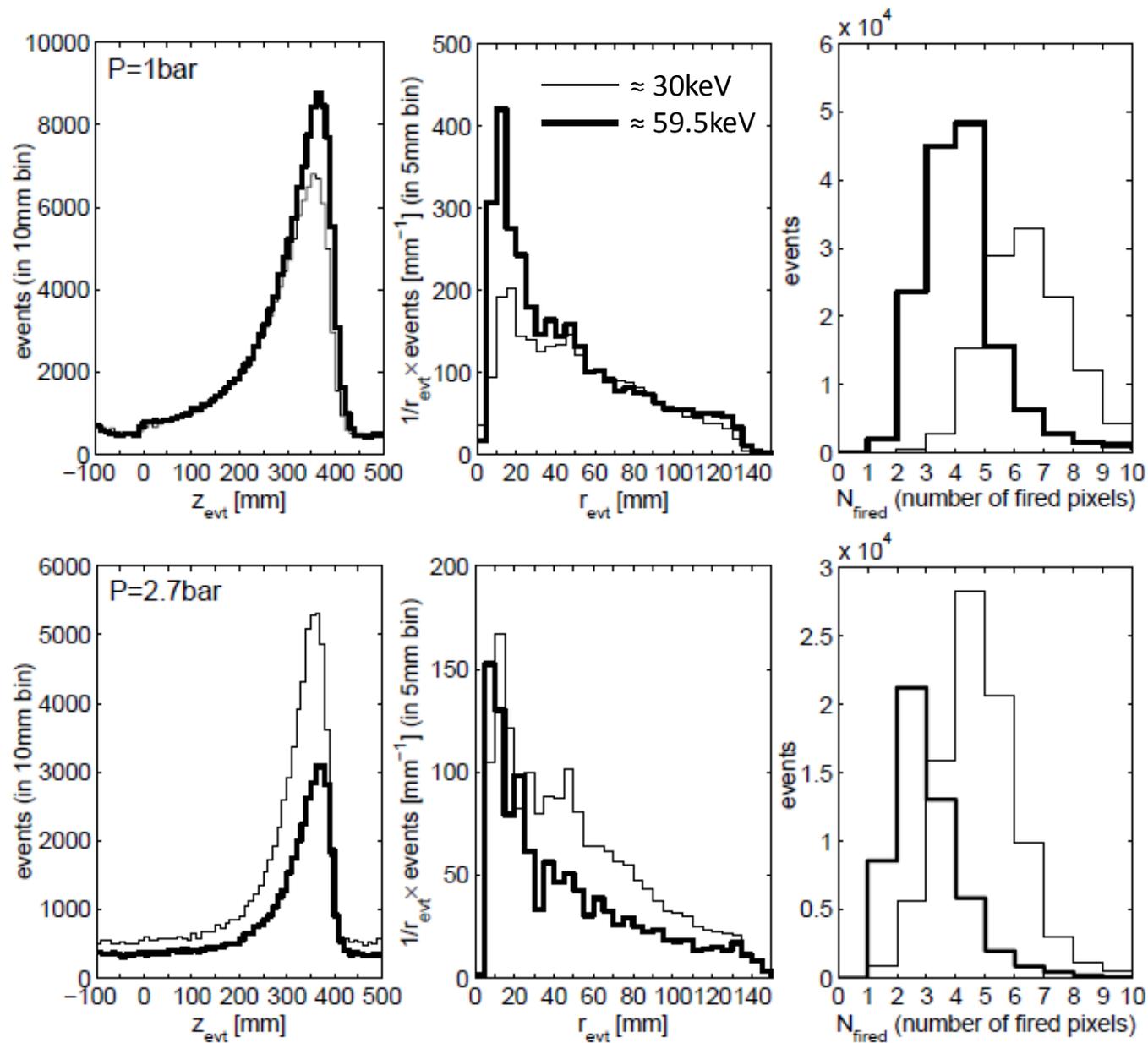
mean position of the event



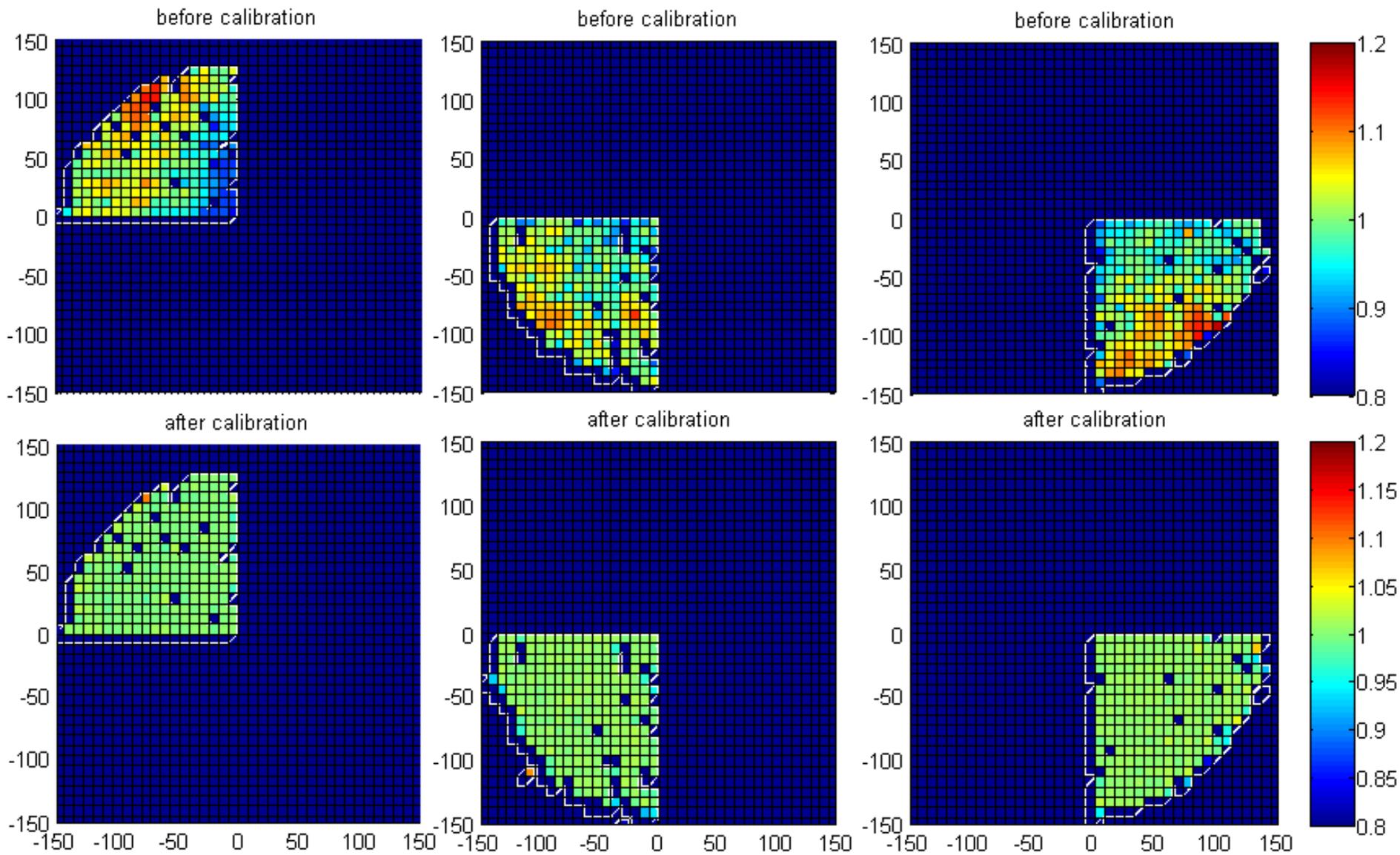
level of connectivity: **92%**
 unconnected pixels: **8%**
 of which
 unclear origin: **1%**
 understood(solvable): **5.2%**
 damaged pixels: **1.8%**

sector 1 to be **damaged**
 (**repaired** for the 10bar-campaign)

main characteristics of low-energy X-ray deposits at 1-2.7bar

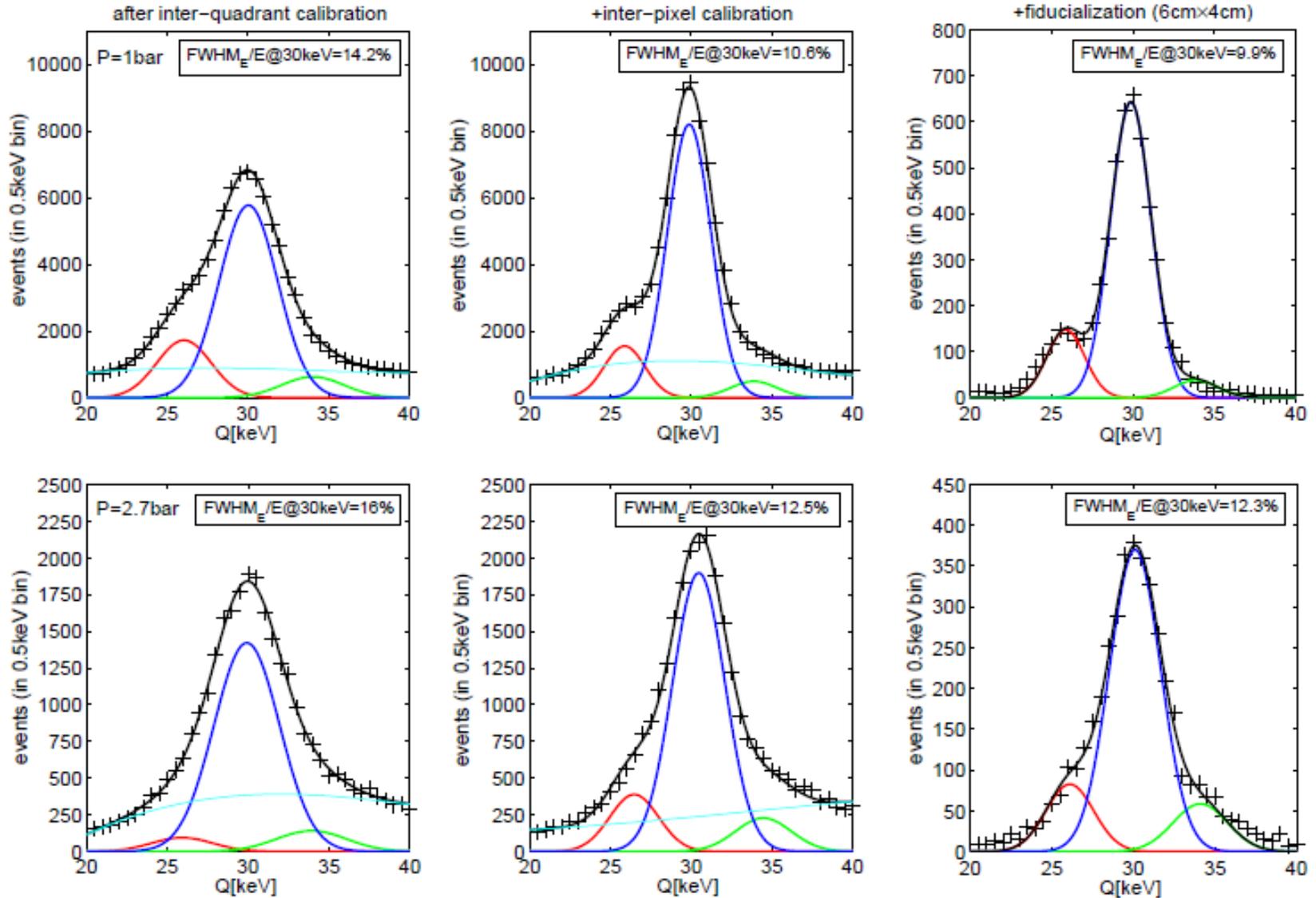


gain maps are necessary in order to achieve ultimate resolution

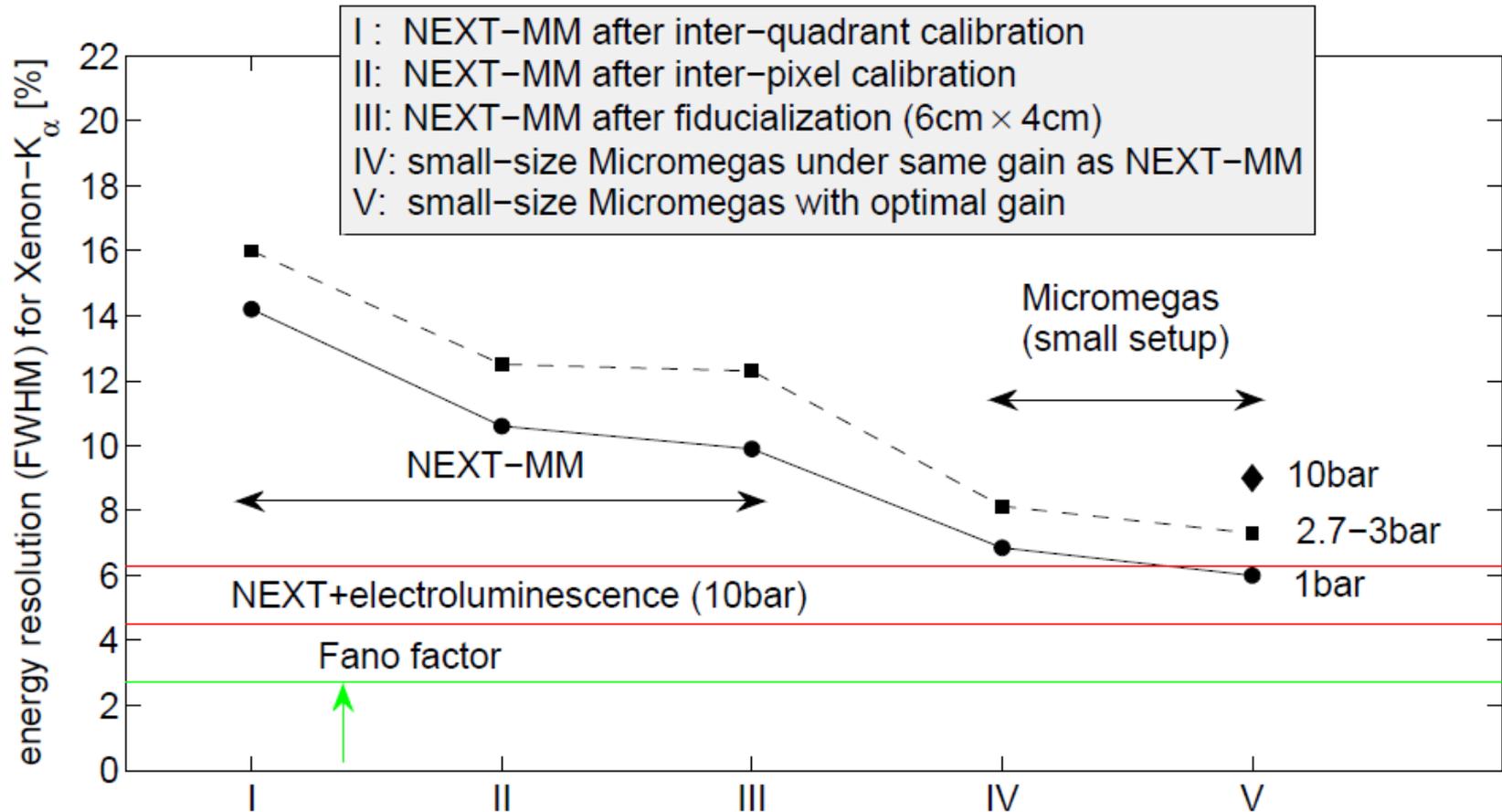


obtained by aligning the 30keV peak pixel by pixel

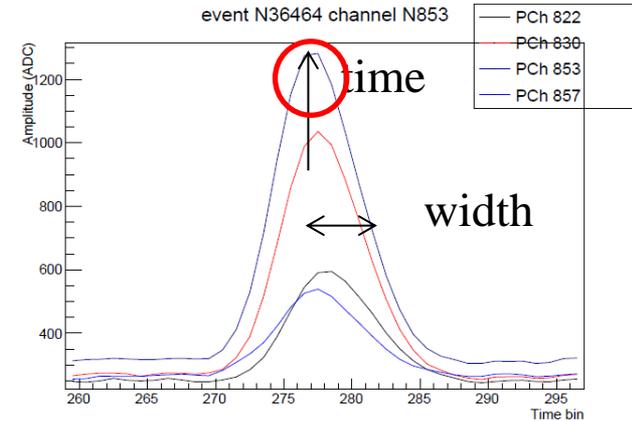
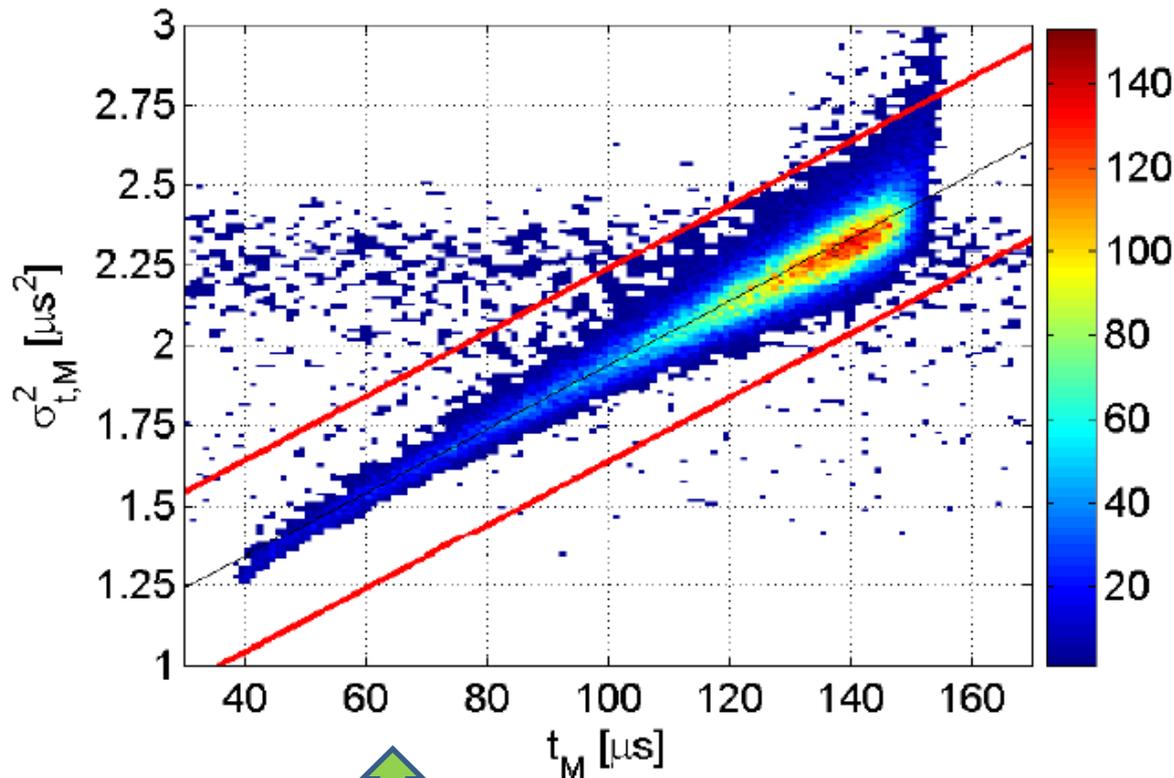
main performance with low energy X-rays in the 1-2.7bar regime



half-way performance cross-comparison (with a grain of salt)



time-width pulse correlations through drift & longitudinal diffusion

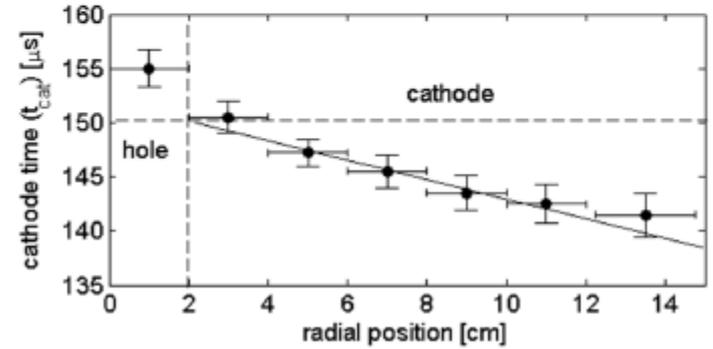
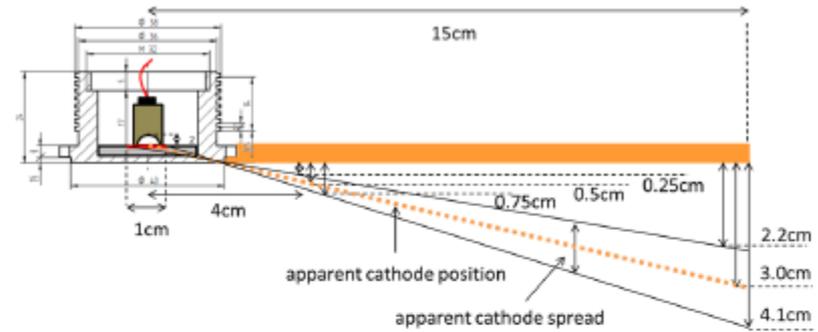
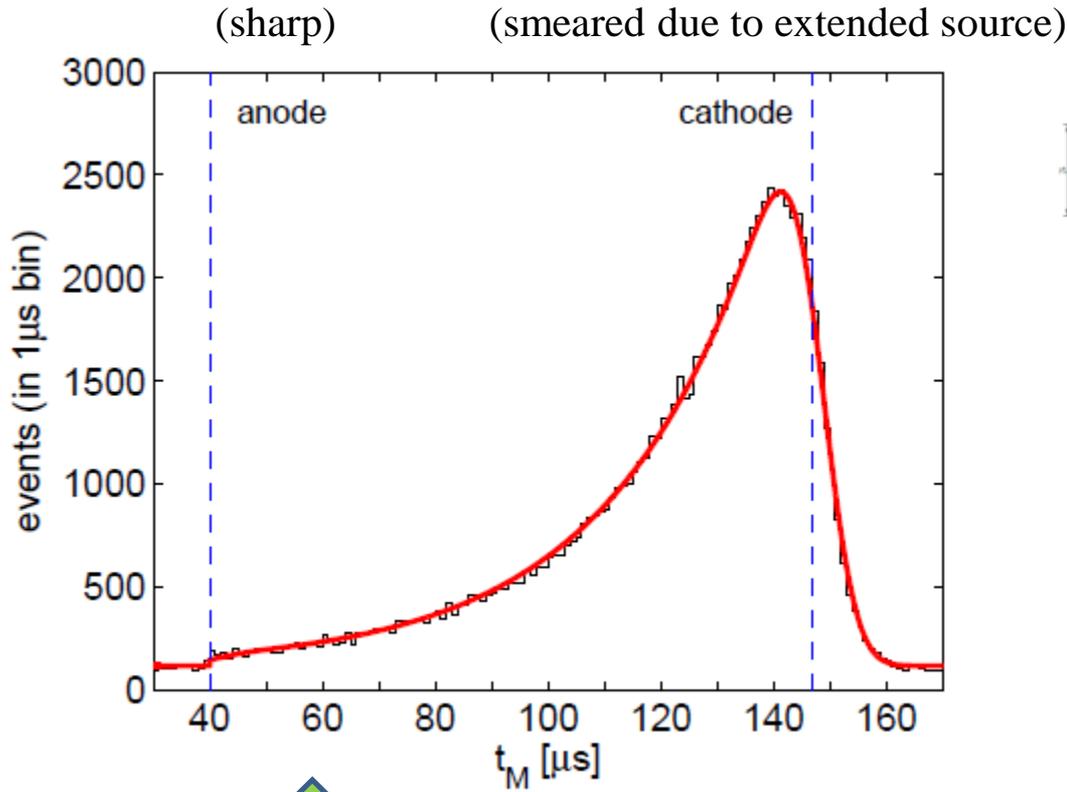


- Select **30keV events**.
- Take pulse with highest charge.
- Take a fiducial distance of 2.5cm with respect to the chamber edge

$$\sigma_{t,M}^2 = \sigma_0^2 + \frac{2D_L}{v_d^2} t_M$$

electronics response function + size of ionization cloud (+ ion transit time)

determining the total drift time (and hence the drift velocity)



operational fit to exponential convoluted with Gauss

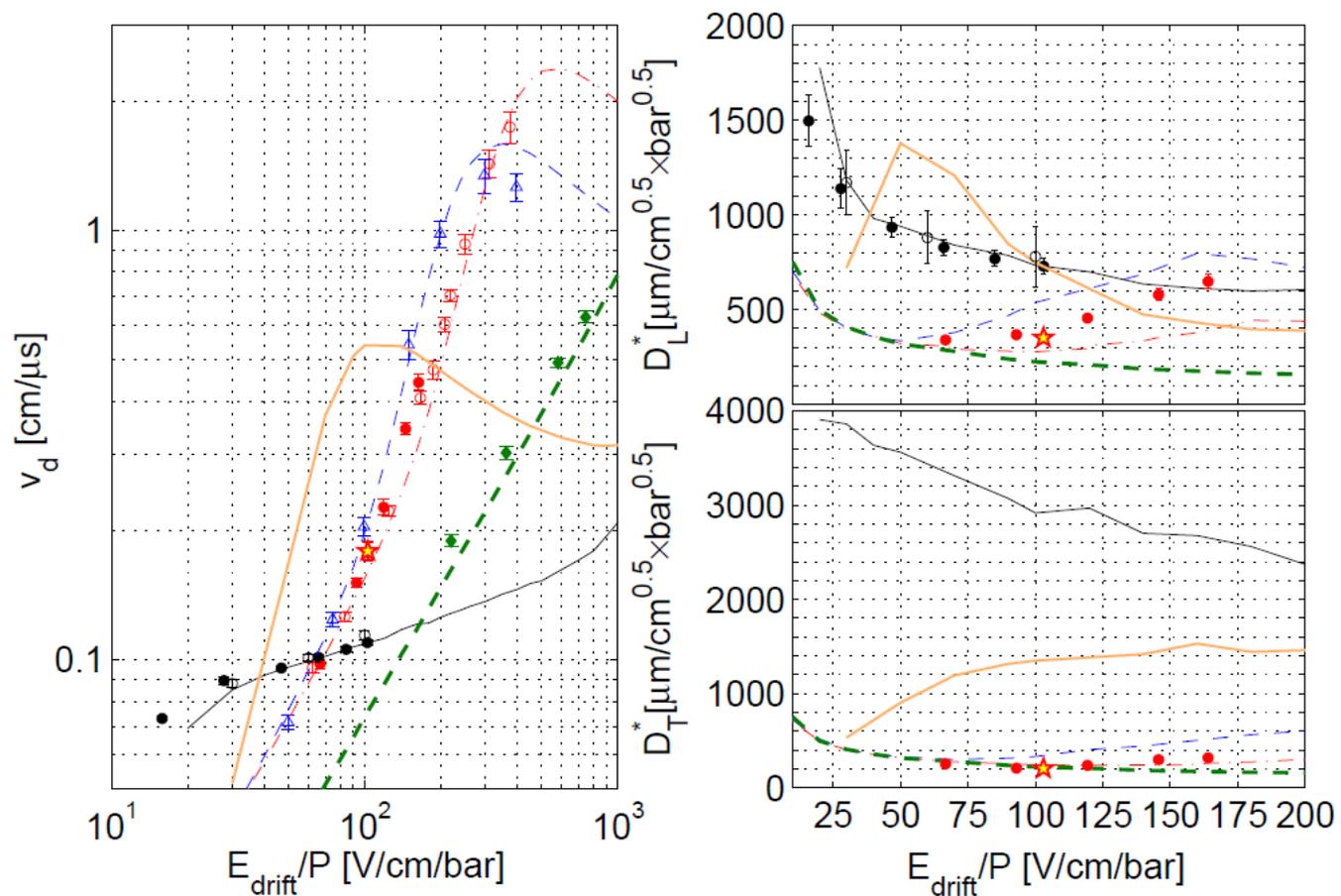
$$v_d = \frac{t_{\text{cat}} - t_{\text{ano}}}{D (= 38\text{cm})}$$

$$f(t_M) = \mathcal{C} e^{t_M/\tau^*} \left[\text{erf} \left(\frac{t_{\text{cat}} - \sigma_g^2/\tau^* - t_M}{\sqrt{2}\sigma_g} \right) - \text{erf} \left(\frac{t_{\text{ano}} - \sigma_g^2/\tau^* - t_M}{\sqrt{2}\sigma_g} \right) \right] \Theta(t_M - t_{\text{ano}}) + B$$

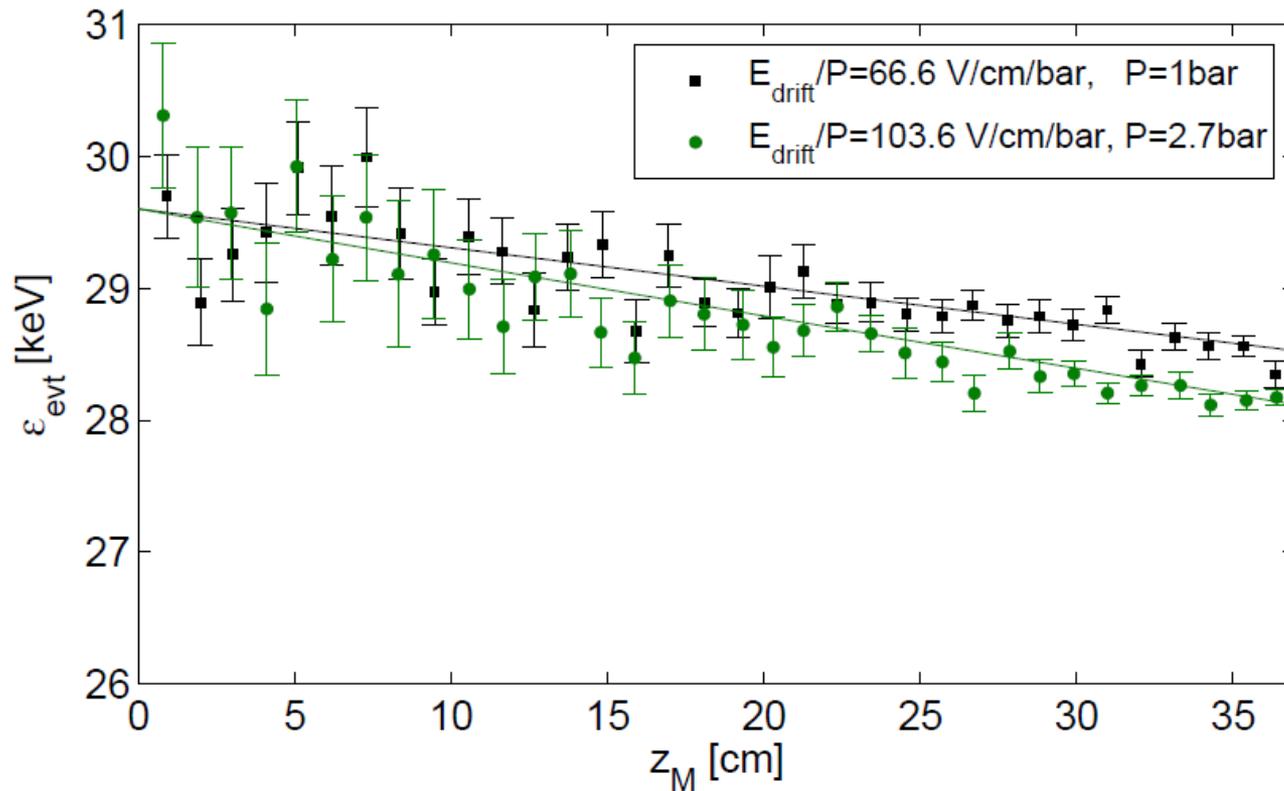
Xe-TMA properties in a nut-shell



- this work, P=1.0bar, Xe/TMA(97.8/2.2)
- ★ this work, P=2.7bar, Xe/TMA(97.6/2.4)
- Ref. [17], P=4–6bar, Xe/TMA(97.8/2.2)
- △ Ref. [17], P=3–6bar, Xe/TMA(99.1/0.9)
- NEXT-DBDM Ref. [6], P=10bar, pure Xe
- NEXT-DEMO Ref. [27], P=10bar, pure Xe
- ◆ Ref. [18], P<1bar, pure TMA
- - - Magboltz 10.0.1, P=1.0bar, Xe/TMA(97.8/2.2)
- - - Magboltz 10.0.1, P=1.0bar, Xe/TMA(99.1/0.9)
- Magboltz 10.0.1, P=1.0bar, pure Xe
- - - Magboltz 10.0.1, P=1.0bar, pure TMA
- Magboltz 10.0.1, P=1.0bar, Xe/TMA (99.9/0.1)



attachment coefficient



$E/P[\text{V/cm/bar}]$	$v_d[\text{cm}/\mu\text{s}]$	$D_L^*[\mu\text{m}/\sqrt{\text{cm}} \times \sqrt{\text{bar}}]$	$\eta[\text{m}^{-1}]$	TMA(%)	$P[\text{bar}]$
66.6 ± 1.3	0.097 ± 0.005	340 ± 19	0.10 ± 0.01	2.2	1.0
93.0 ± 1.9	0.151 ± 0.007	368 ± 20	0.08 ± 0.02	2.2	1.0
119.2 ± 2.4	0.227 ± 0.011	456 ± 25	0.08 ± 0.01	2.2	1.0
145.5 ± 2.9	0.345 ± 0.017	579 ± 32	0.10 ± 0.01	2.2	1.0
164.0 ± 3.3	0.442 ± 0.022	649 ± 36	0.07 ± 0.04	2.2	1.0
103.6 ± 2.1	0.179 ± 0.009	351 ± 18	0.14 ± 0.01	2.4	2.7

new hardware

new bottles and piping

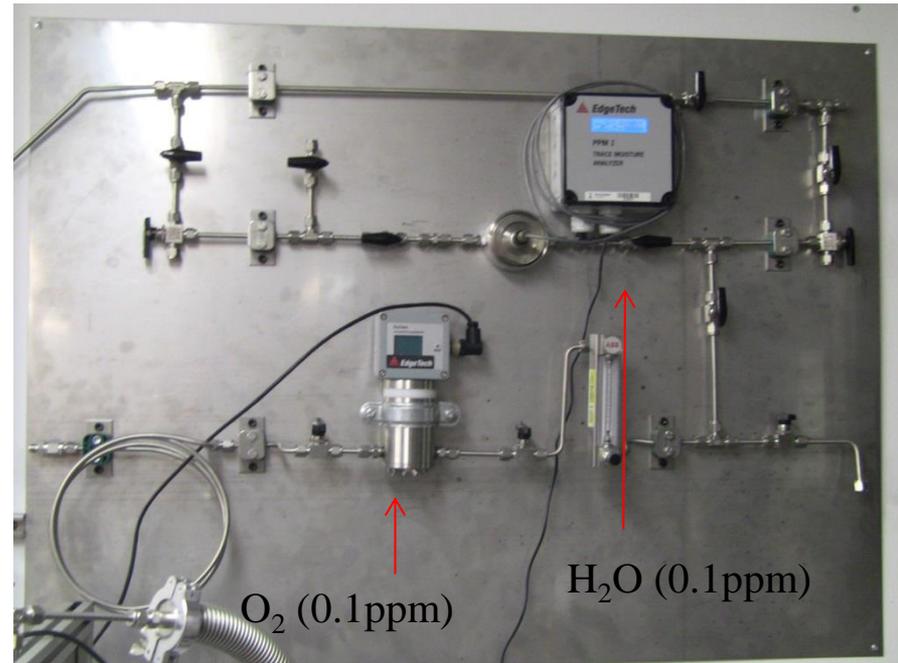


TREX-light (pure Xenon line)

NEXT-MM recovery bottle

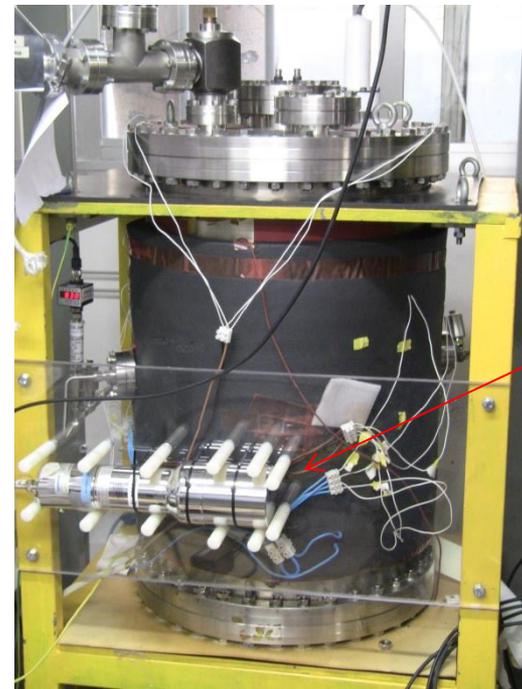
NEXT-MM expansion chamber

sensor panel



O₂ (0.1ppm)

H₂O (0.1ppm)



NaI detector
and Na source

GUI T2K Pulse Viewer

Date: 2013-11-20 11:48:03

Input parameters

Run#

Step size#

Analysis type

Run type

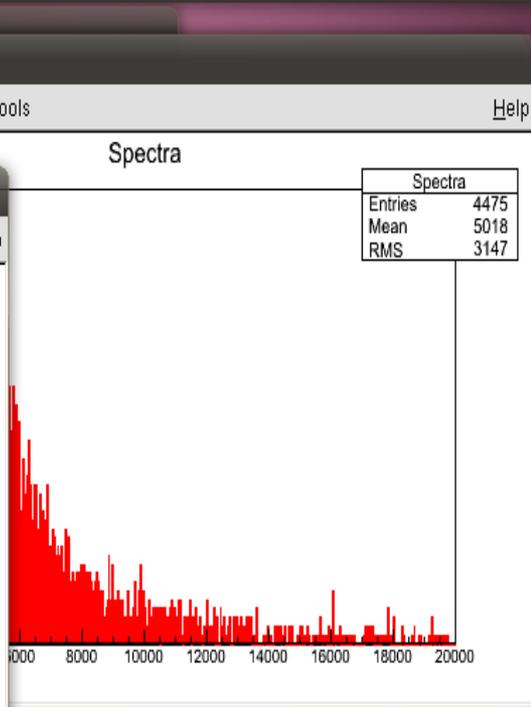
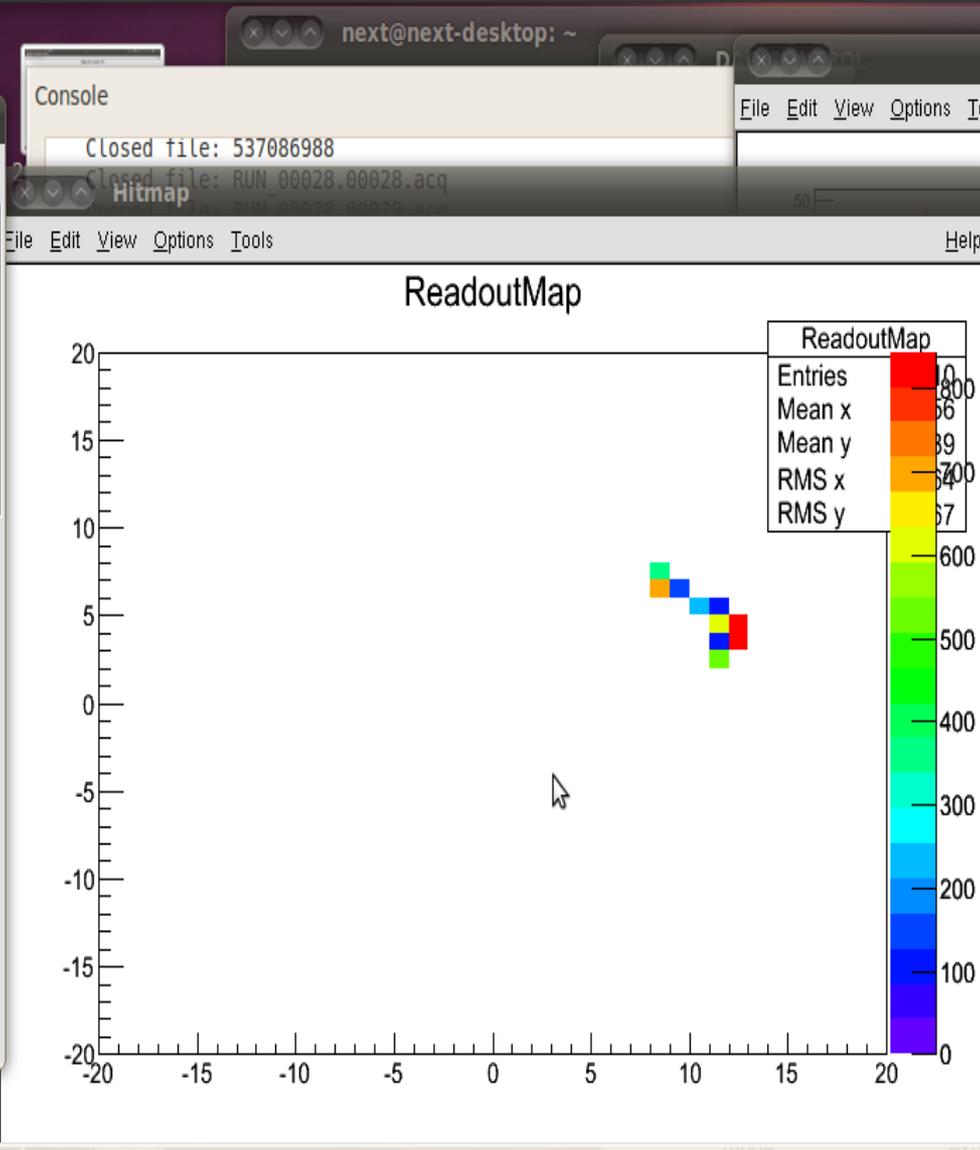
Run Index

Config file

Output parameters

Rate 10.8726 Hz

Events: 6905



Run UID

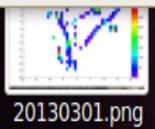
Data (MB)

Events

Data Files

Data File

Config File



GUI T2K Pulse Viewer

Date: 2013-11-20 11:48:03

Input parameters

Run#

Step size#

Analysis type

Run type

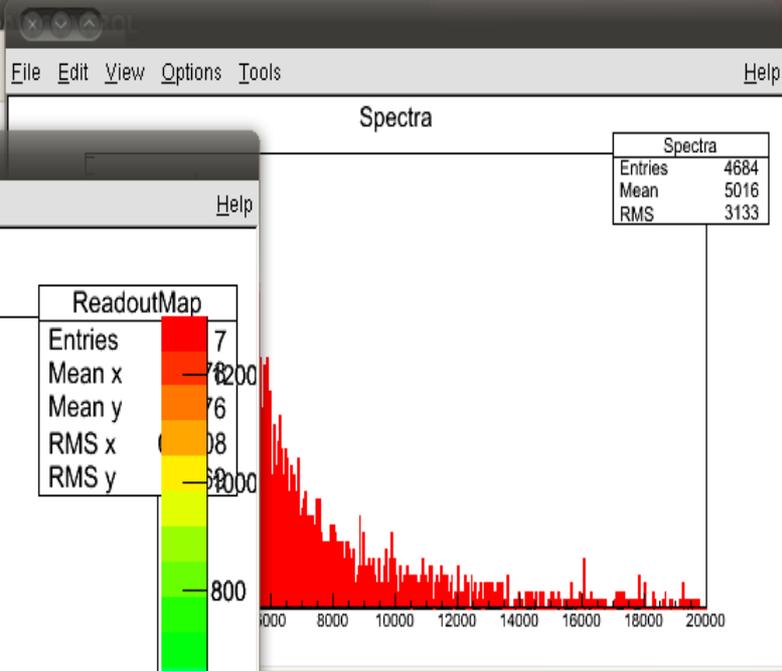
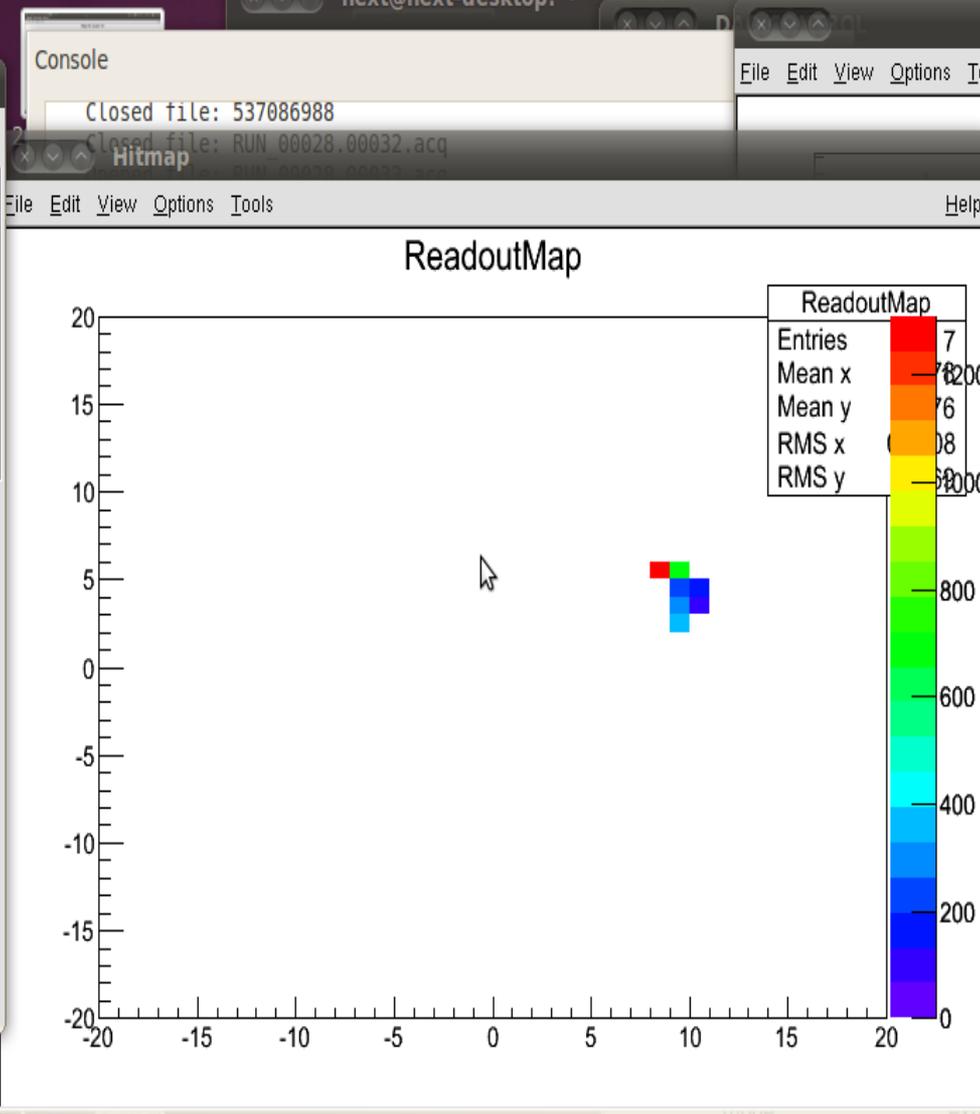
Run Index

Config file

Output parameters

Rate 9.0119 Hz

Events: 7275



Run UID

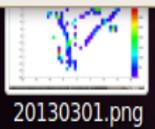
Data (MB)

Events

Data Files

Data File

Config File



GUI T2K Pulse Viewer

Date: 2013-11-20 11:48:03

Input parameters

Run#

Step size#

Analysis type

Run type

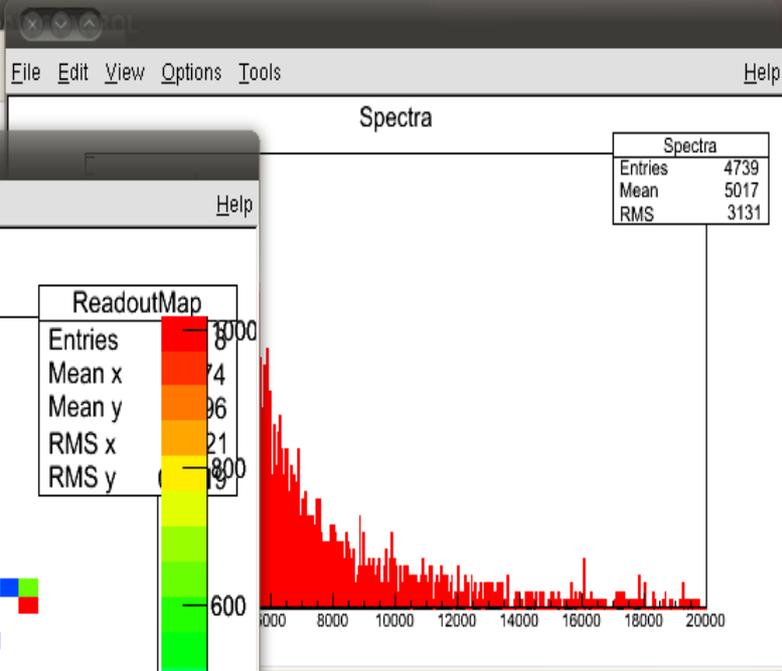
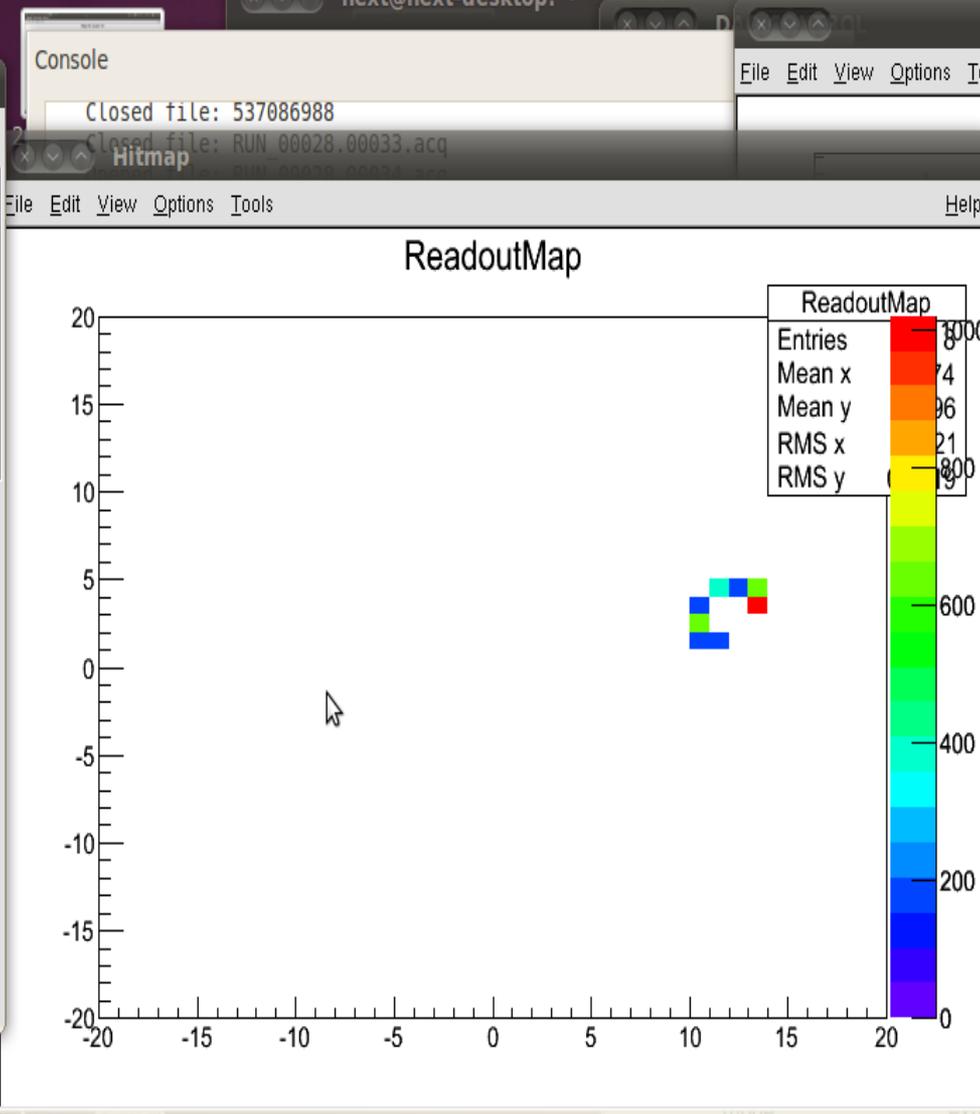
Run Index

Config file

Output parameters

Rate 9.9170 Hz

Events: 7350



Run UID

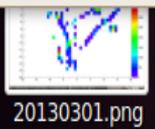
Data (MB)

Events

Data Files

Data File

Config File



GUI T2K Pulse Viewer

Date: 2013-11-20 12:53:01

Input parameters

Run#

Step size#

Analysis type

Run type

Run Index

Config file

Output parameters

Rate 9.2671 Hz

Events: 540

Console

```

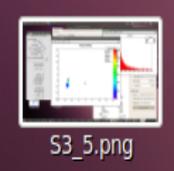
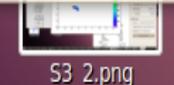
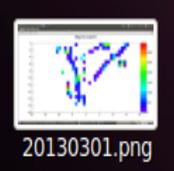
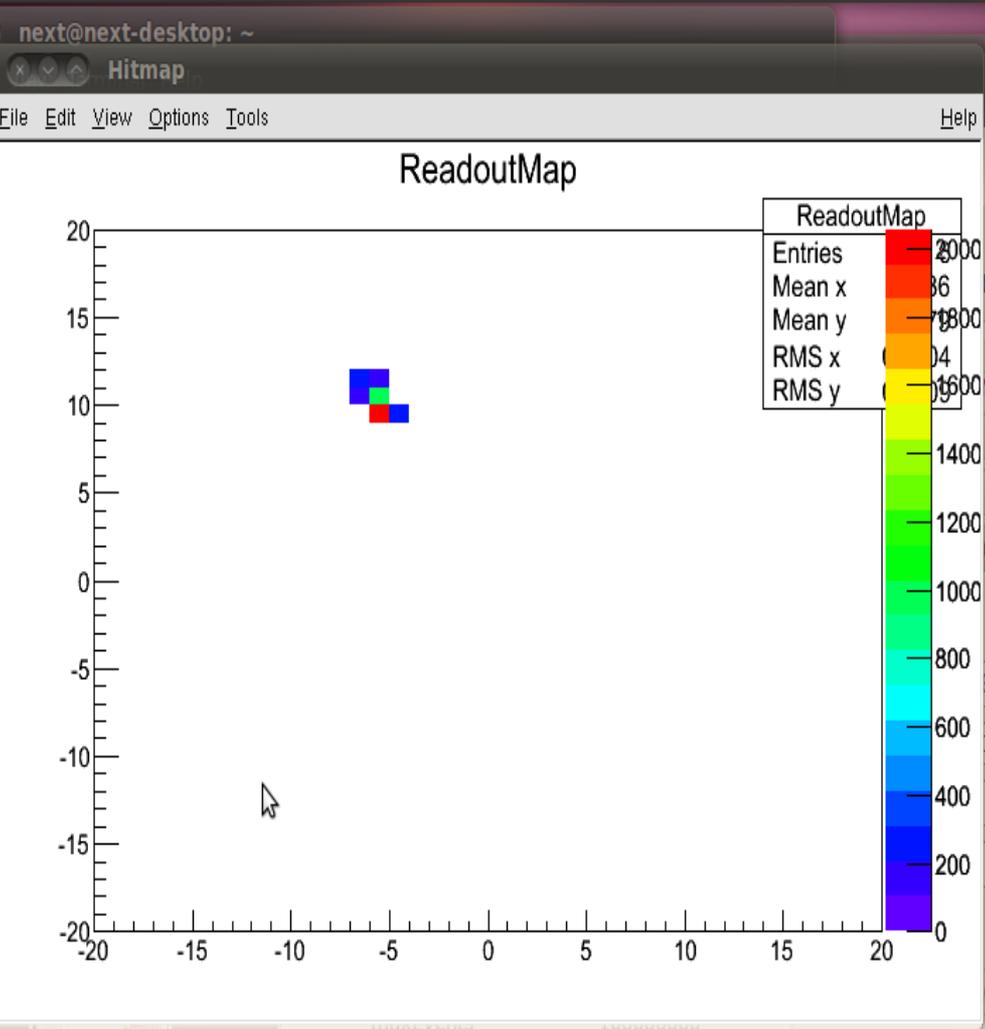
Closed file: *****
Closed file: *****
Opened file: Loading
Closed file: Npixels
Closed file: File UID
Opened file: 2013 11
R2013.11
Pausednt
Restarti
Pauseder
Restarti
Pauseder
Restarti
Pauseder
Restarti
Error re
... or e
File UID
Pauseder
Restarti
Pauseder

```

20130312_15.png

20130318_13_22.png

20130326_5_51_277.png



dccServerLoopNu... 0

Trigger

- waitforevent 1000000
- mode external
- Type Cosmic
- Latency 2000
- maxRetries 10000

File

- maxSize 0x1FF MB
- maxFiles 1000

Data File

Config File

GUI T2K Pulse Viewer

Date: 2013-11-20 12:53:01

Input parameters

Run#

Step size#

Analysis type

Run type

Run Index

Config file

Output parameters

Rate 9.2871 Hz

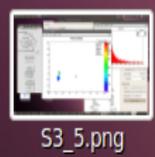
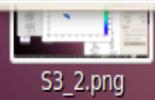
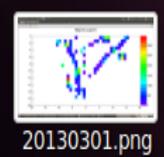
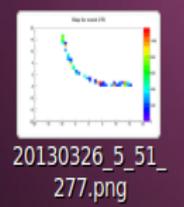
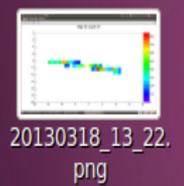
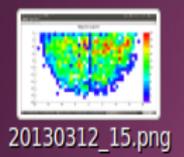
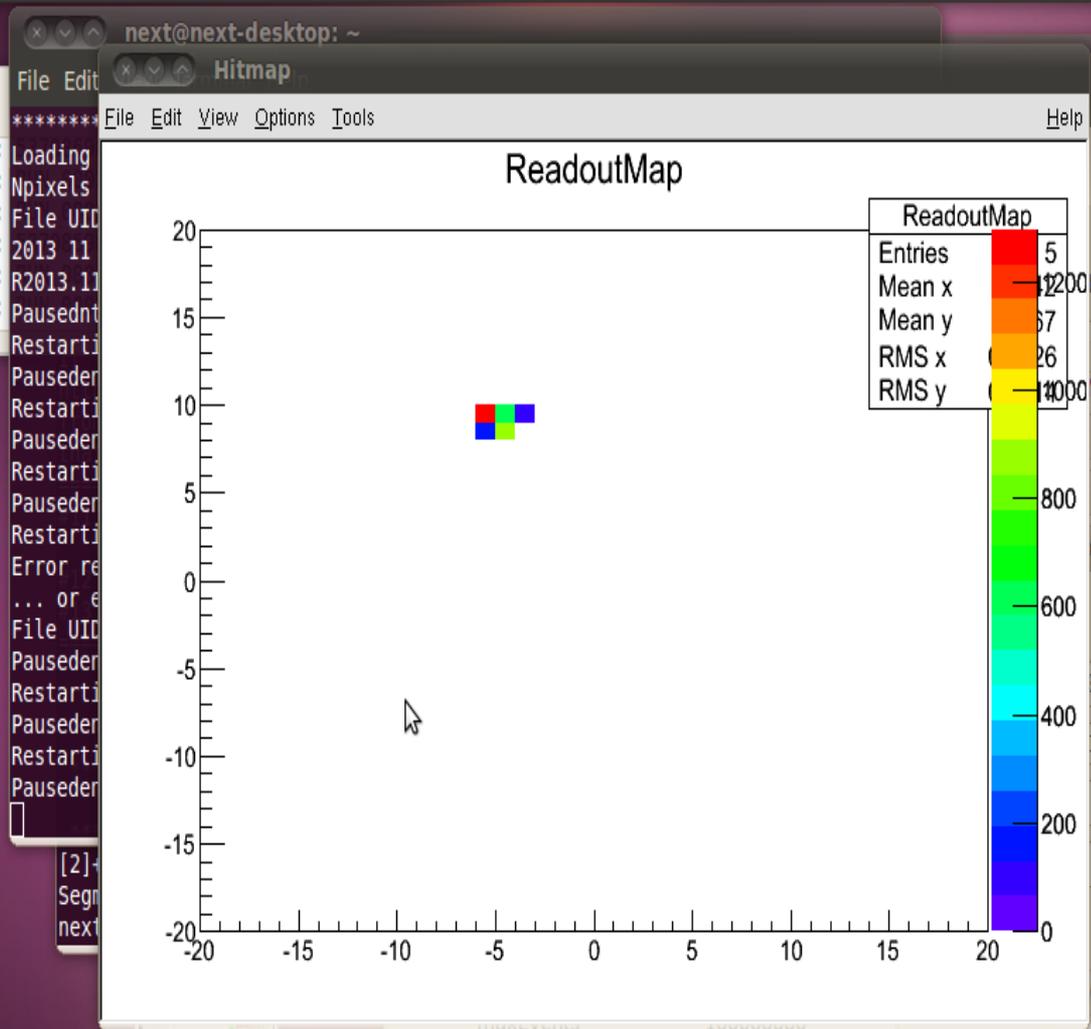
Events: 620

Console

```

Closed file:
Closed file:
Opened file:
Closed file:
Closed file:
Opened file:

```



```

dccServerLoopNu...      0
Trigger
  waitforevent          1000000
  mode                   external
  Type                   Cosmic
  Latency                2000
  maxRetries             10000
File
  maxSize                0x1FF MB
  maxFiles               1000

```

Data File

Config File

GUI T2K Pulse Viewer

Date: 2013-11-20 11:48:03

Input parameters

Run#

Step size#

Analysis type

Run type

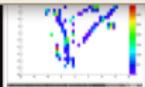
Run Index

Config file

Output parameters

Rate 10.0168 Hz

Events: 7785



20130301.png

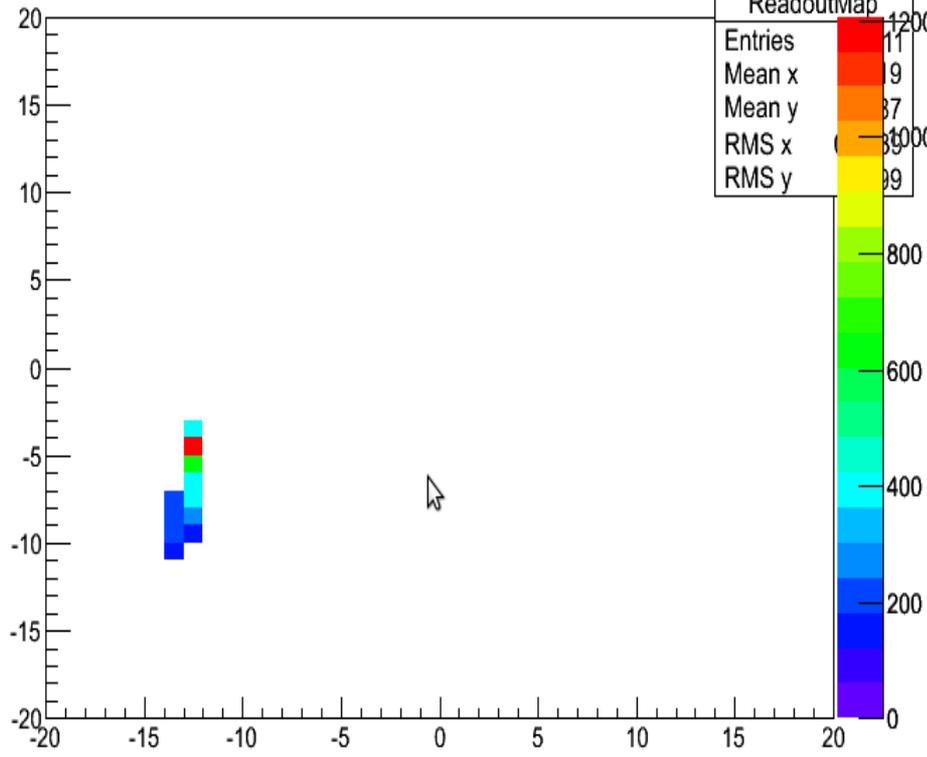
Console

Closed file: 537086988

Closed file: RUN_00028_00035.acq

File Edit View Options Tools Help

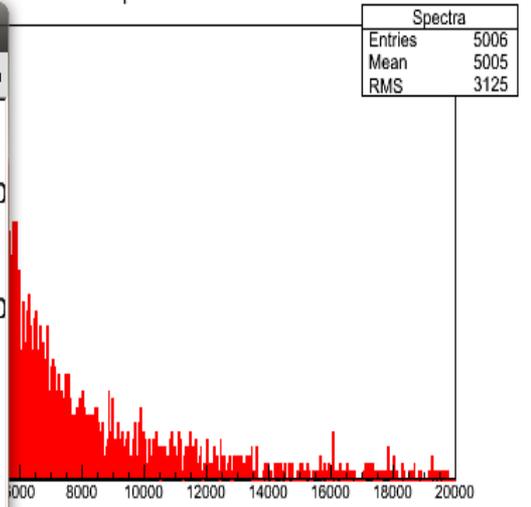
ReadoutMap



S1_1.png

File Edit View Options Tools Help

Spectra



Run UID

Data (MB)

Events

Data Files

Path...

Data File

Config File

Type Cosmic

Latency 2000

maxRetries 10000

File

maxSize 0x1FF MB

maxFiles 1000

GUI T2K Pulse Viewer

Date: 2013-11-20 11:48:03

Input parameters

Run#

Step size#

Analysis type

Run type

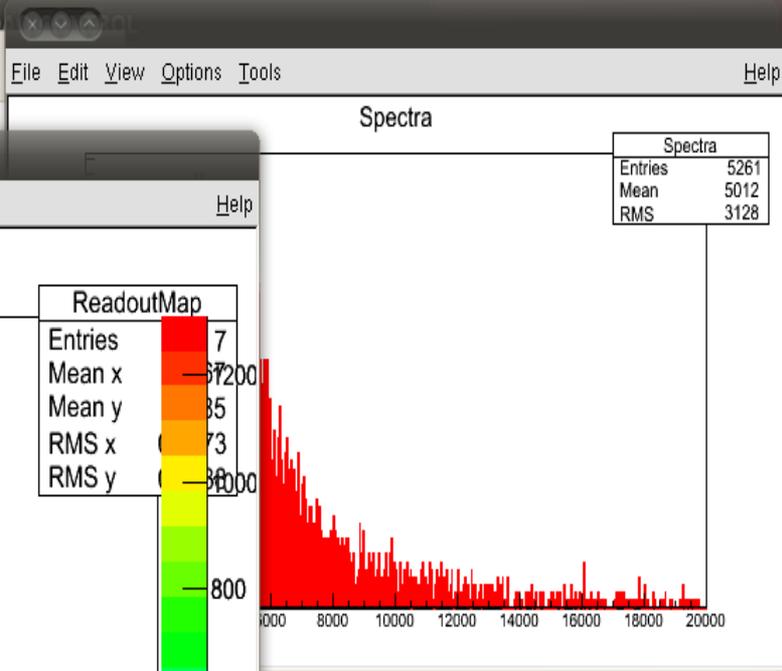
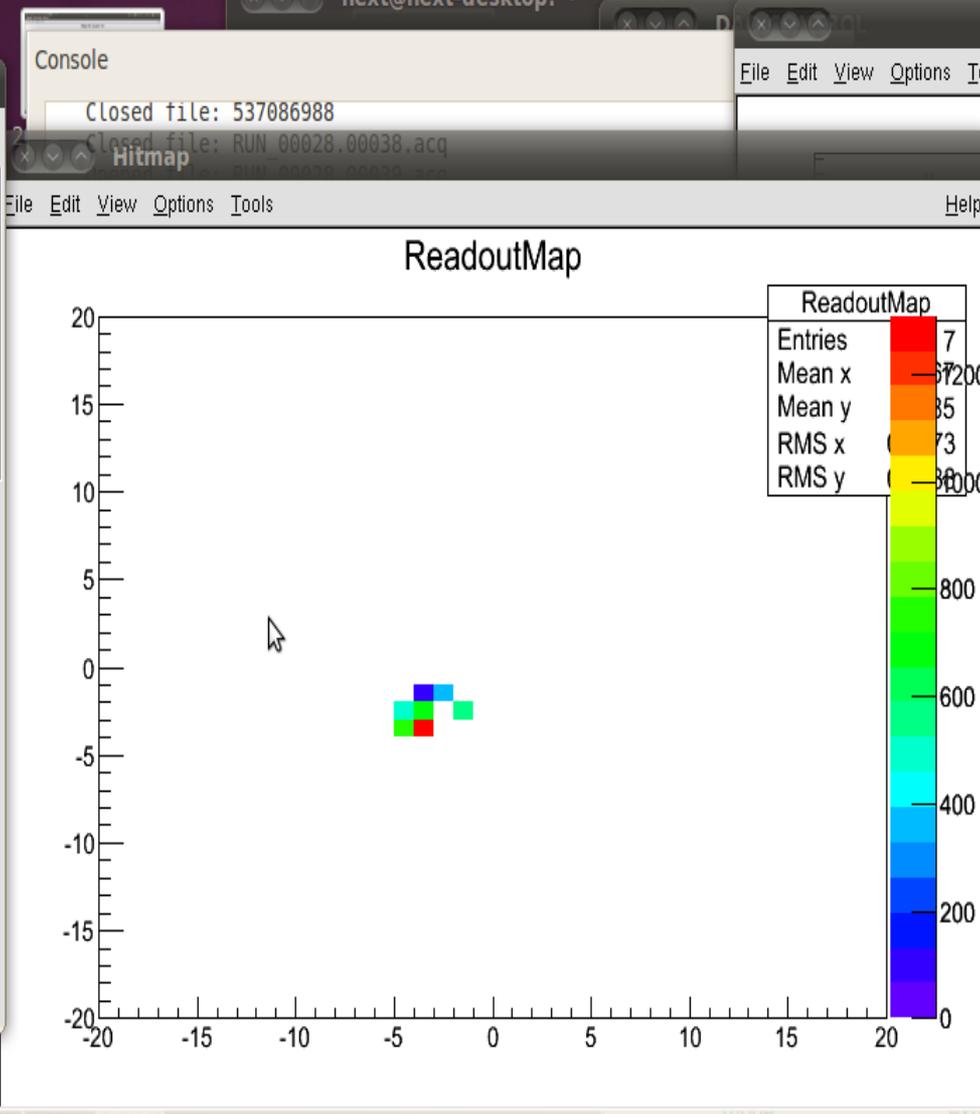
Run Index

Config file

Output parameters

Rate 10.0707 Hz

Events: 8195



Run UID

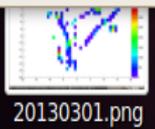
Data (MB)

Events

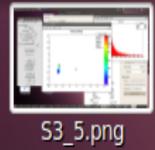
Data Files

Data File

Config File



S1_1.png



GUI T2K Pulse Viewer

Date: 2013-11-20 12:53:01

Input parameters

Run#

Step size#

Analysis type

Run type

Run Index

Config file

Output parameters

Rate 9.5536 Hz

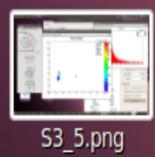
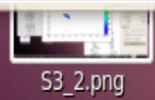
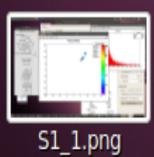
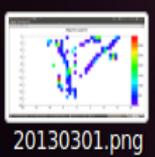
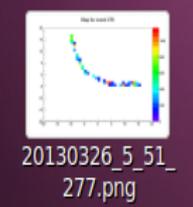
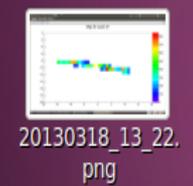
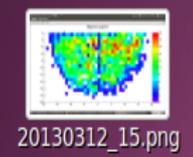
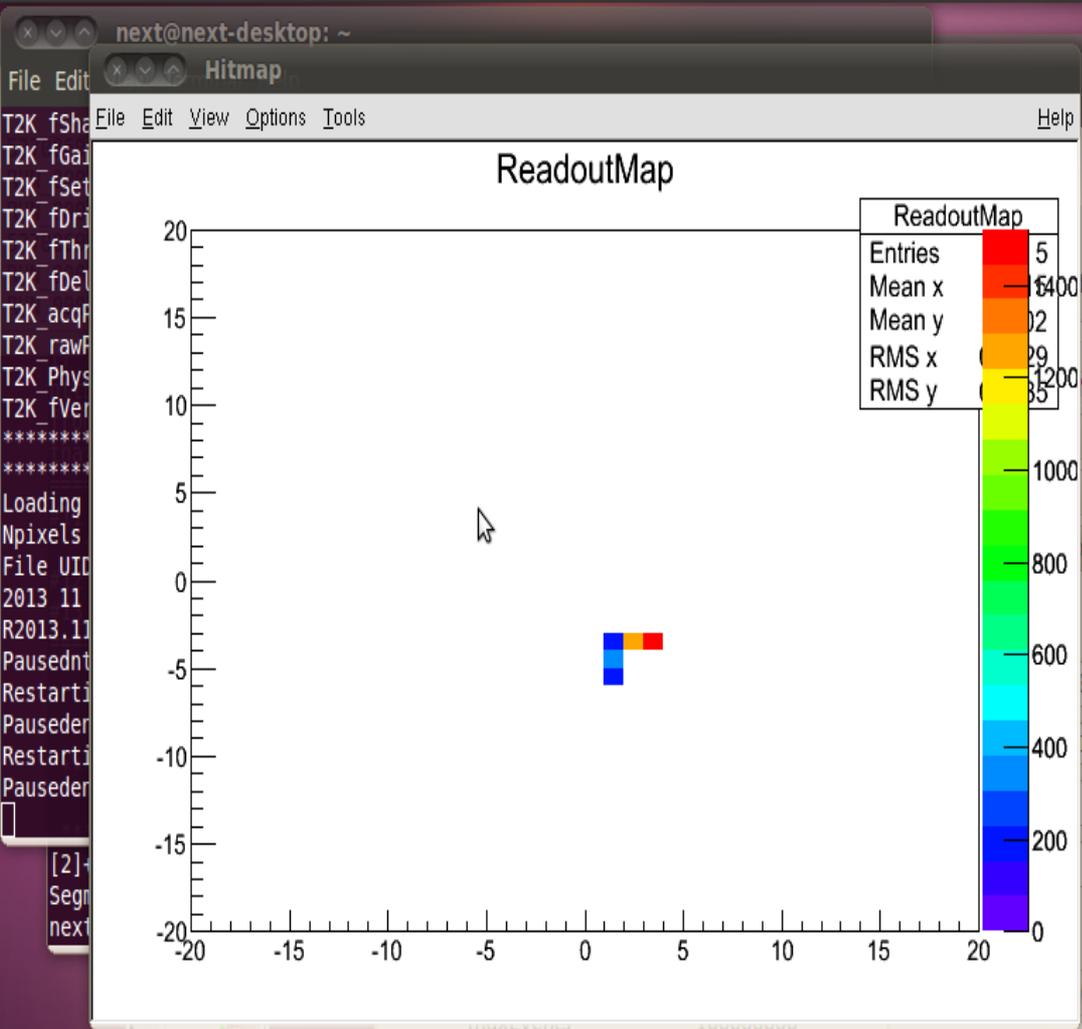
Events: 310

Console

```

Closed file: T2K fSha
Closed file: T2K fGa
Closed file: T2K fSet
Opened file: T2K fDr
Closed file: T2K fThr
Closed file: T2K fDe
Opened file: T2K acqF
T2K rawF
T2K Phys
T2K fVer
*****
*****
Loading
Npixels
File UID
2013 11
R2013.11
Pausednt
Restarti
Pauseder
Restarti
Pauseder

```



```

dccServerLoopNu... 0
Trigger
  waitforevent 1000000
  mode external
  Type Cosmic
  Latency 2000
  maxRetries 10000
File
  maxSize 0x1FF MB
  maxFiles 1000

```

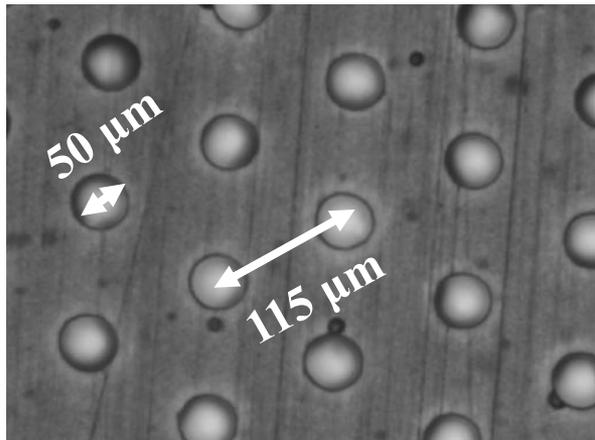
Data File

Config File

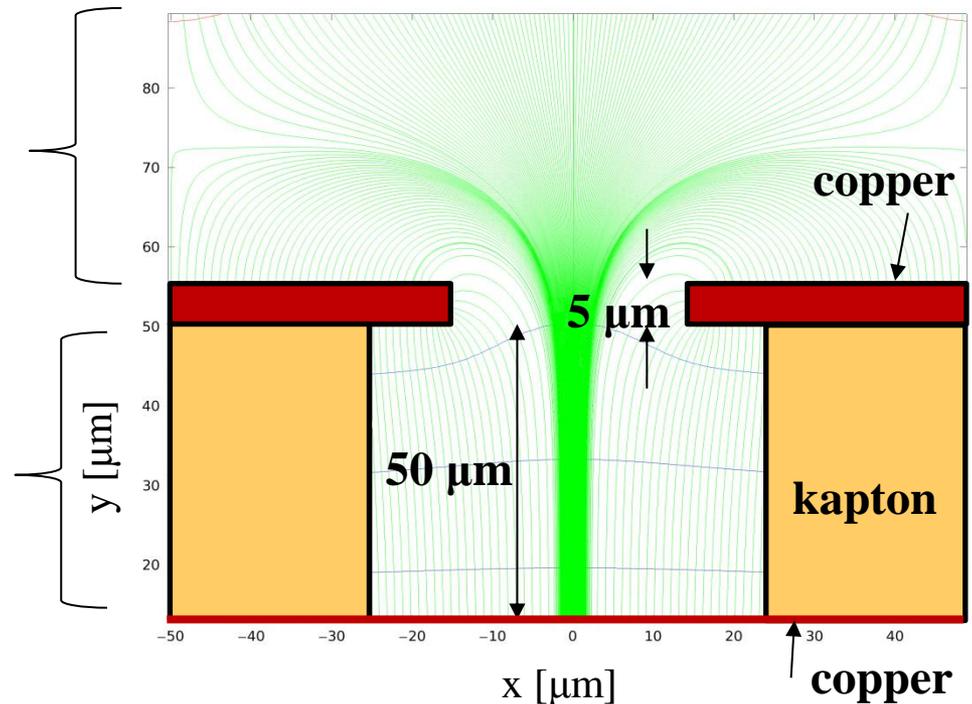
Part 4:
Status of Xe-TMA modeling of Penning transfer (ongoing)

description of the microscopic simulations

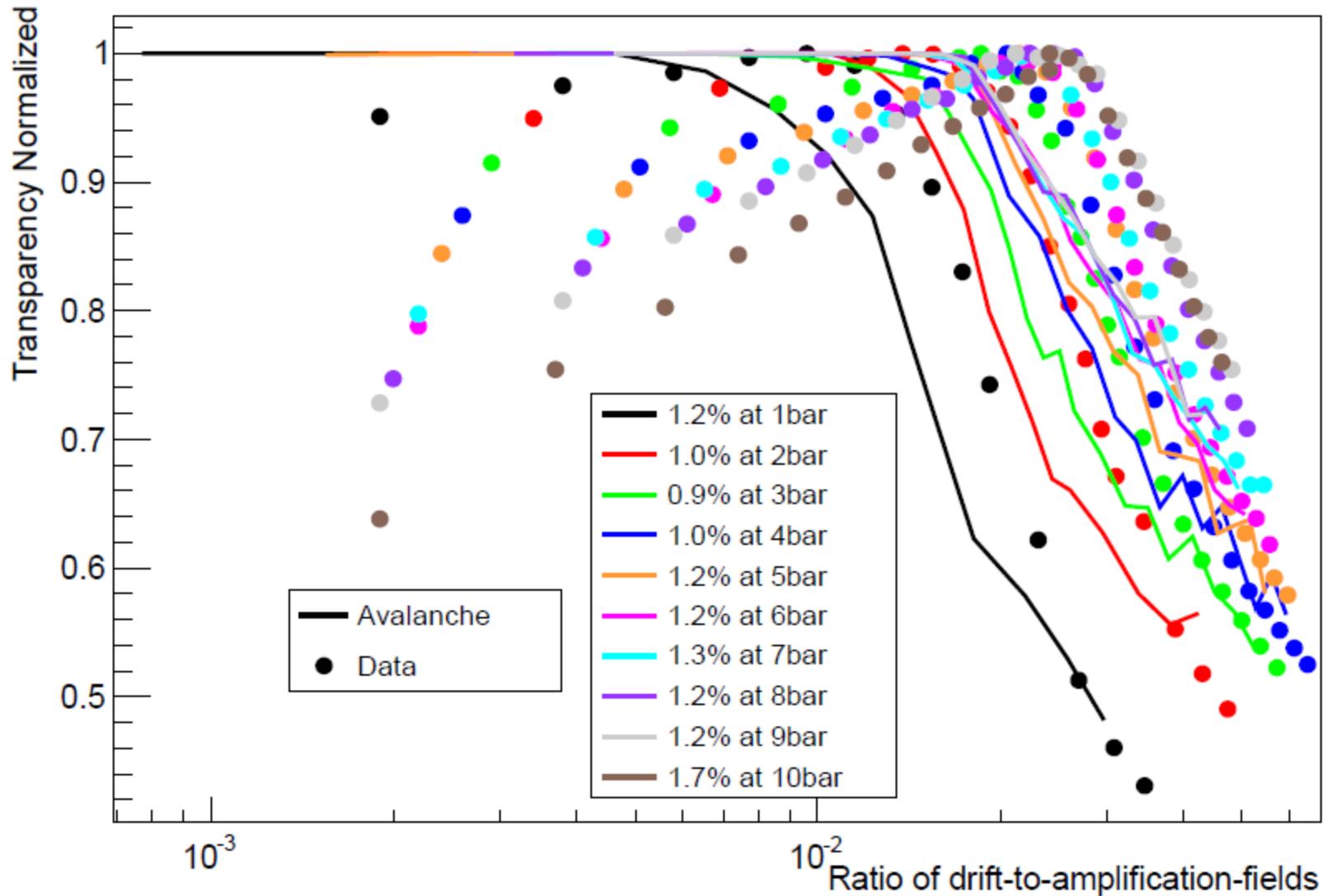
- A proper simulation of the electrons drift through the field lines can not be performed based on a pure hydrodynamic modeling based on the parameters of the swarm, due to the strong field gradients.
- Electrons will not fully achieve (in general) statistical equilibrium before the field orientation and module changes appreciably.
- A microscopic modeling is enforced -> Garfield++.



(Garfield++
& COMSOL)

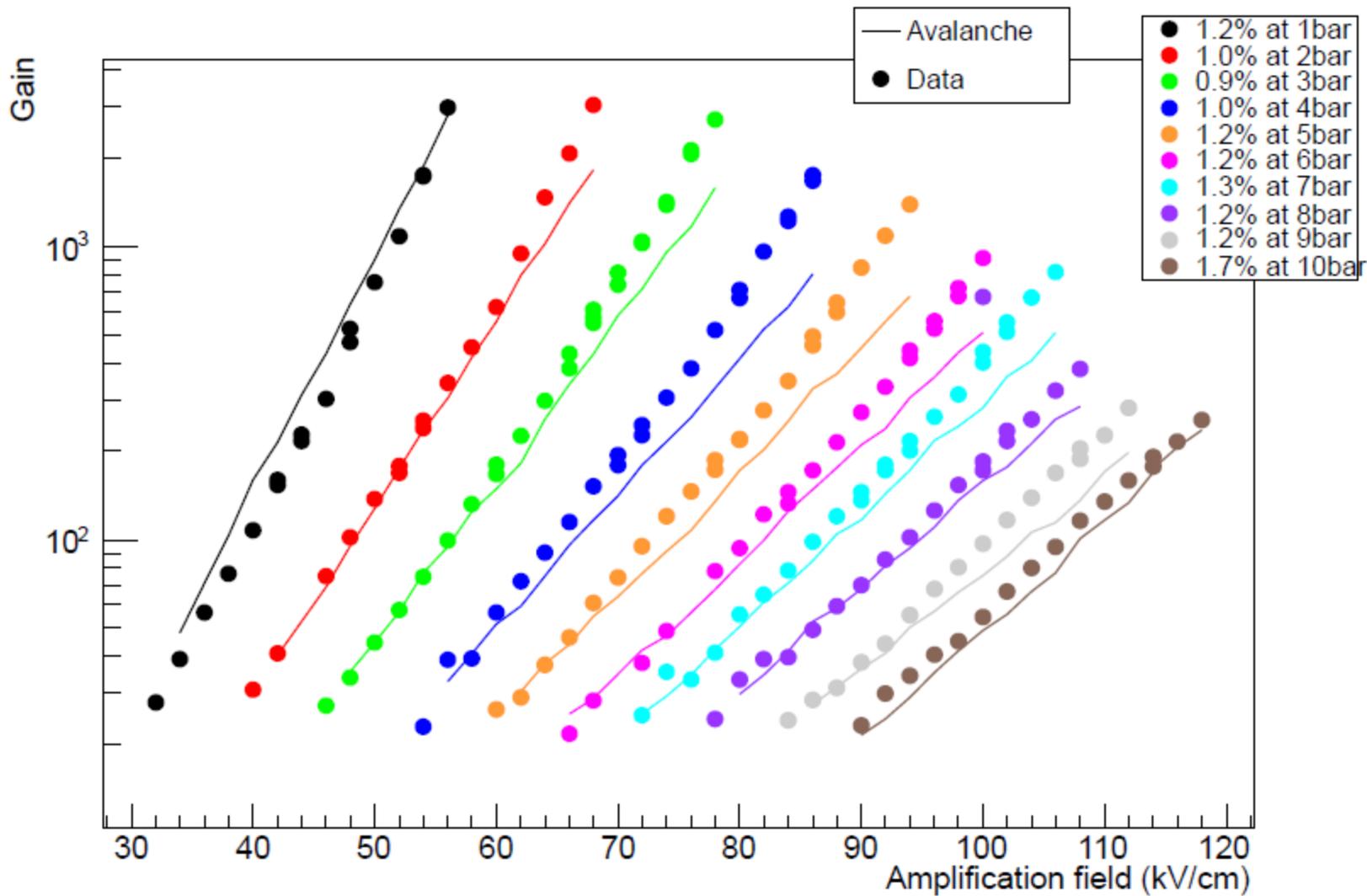


Micromegas transparency



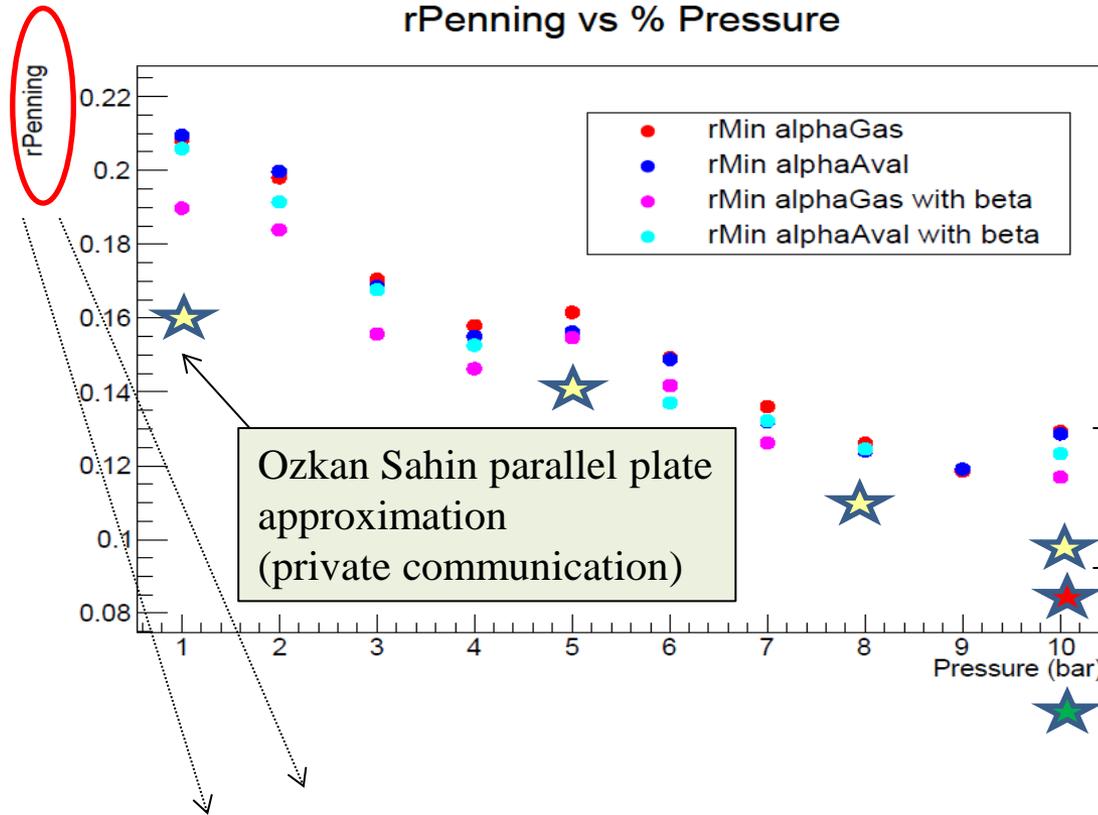
(several mistakes found related to the field implementation and gas mixture estimate in previous presentation)

Micromegas gain



not good news for Fano (*but more work needed*)

rPenning vs % Pressure



Decreasing trend with pressure? (not easy to interpret)

%TMA~1.5%

%TMA~3.8%

%TMA~0.4%

$$F^* \cong F_{xe} (1 - r) + rF_1$$



G. D. Alkhozov, A. P. Komar, A. A. Vorobeb, *Ionization fluctuations and resolution of ionization chambers and semiconductor detectors*, NIM A, 1966.

(Eq. 11)

-> F_1 is a complex (**defined-positive**) function.

-> σ is the probability that an excited state causes an ionization by photo-ionization or Penning. ('probability of de-excitation followed by additional ionization', in Alkhozov words—*this old reference is still used by Aprile and Knoll*). Here it has been replaced by r in first order.