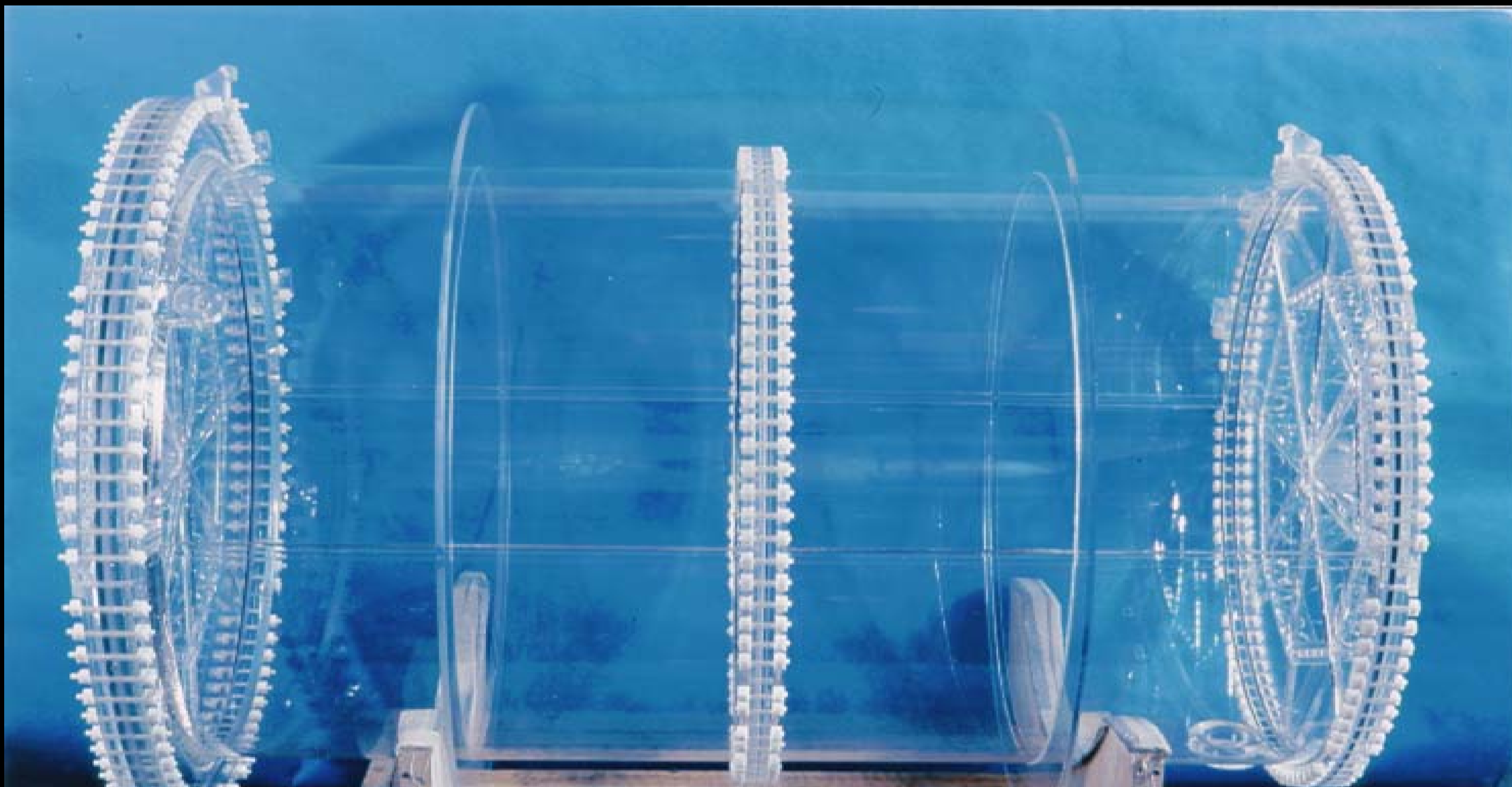
MUNU RESULTS
AND
PROSPECTS FOR TPC'S IN NEUTRINO PHYSICS



Zornitza Daraktchieva for MUNU Collaboration

NEUTRINO 2006, June 15, Santa Fe

MUNU collaboration

Laboratoire de Physique Subatomique et de Cosmologie, Grenoble, France

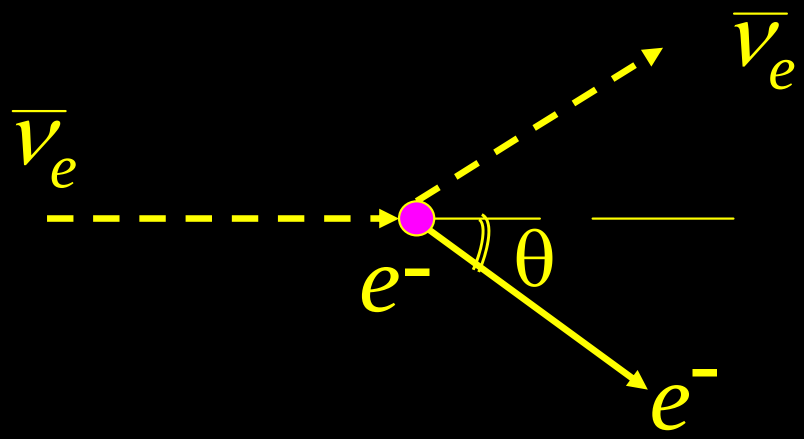
Institut de Physique, Neuchâtel, Switzerland

INFN, Padova, Italy

Physik Institut, Zürich, Switzerland

MUNU is an $\bar{\nu}_e - e^-$ elastic scattering experiment

$$\frac{d\sigma}{dT_e} = \left(\frac{d\sigma}{dT_e}\right)_W + \left(\frac{d\sigma}{dT_e}\right)_{EM}$$



$$\left(\frac{d\sigma}{dT_e}\right)_{EM} = \frac{\pi\alpha^2\mu_\nu^2}{m_e^2}\frac{\left(1-\frac{T_e}{E_\nu}\right)}{T_e}$$

need low energy neutrino source-reactor and low detection threshold to study neutrino magnetic moment

for reactor experiments L~0 and measured magnetic moment μ_e^{rea} depends only on the mixing matrix U_{ek} and μ_{jk} :

$$(\mu_e^{rea})^2 = \sum_j \left| \sum_k U_{ek}\ \mu_{jk} \right|^2$$

MUNU experiment

$\bar{\nu}_e$ source - nuclear reactor (2800 MWth) Bugey, France

Neutrinos are mostly produced in the β decay of fission fragments of the following four fuel isotopes :
235U(54%),239Pu(33%),241Pu(6%),238U(7%)

distance =18m at 20 m.w.e

$\Phi_{\nu lab}=10^{13}$ ν. cm $^{-2}$. s $^{-1}$

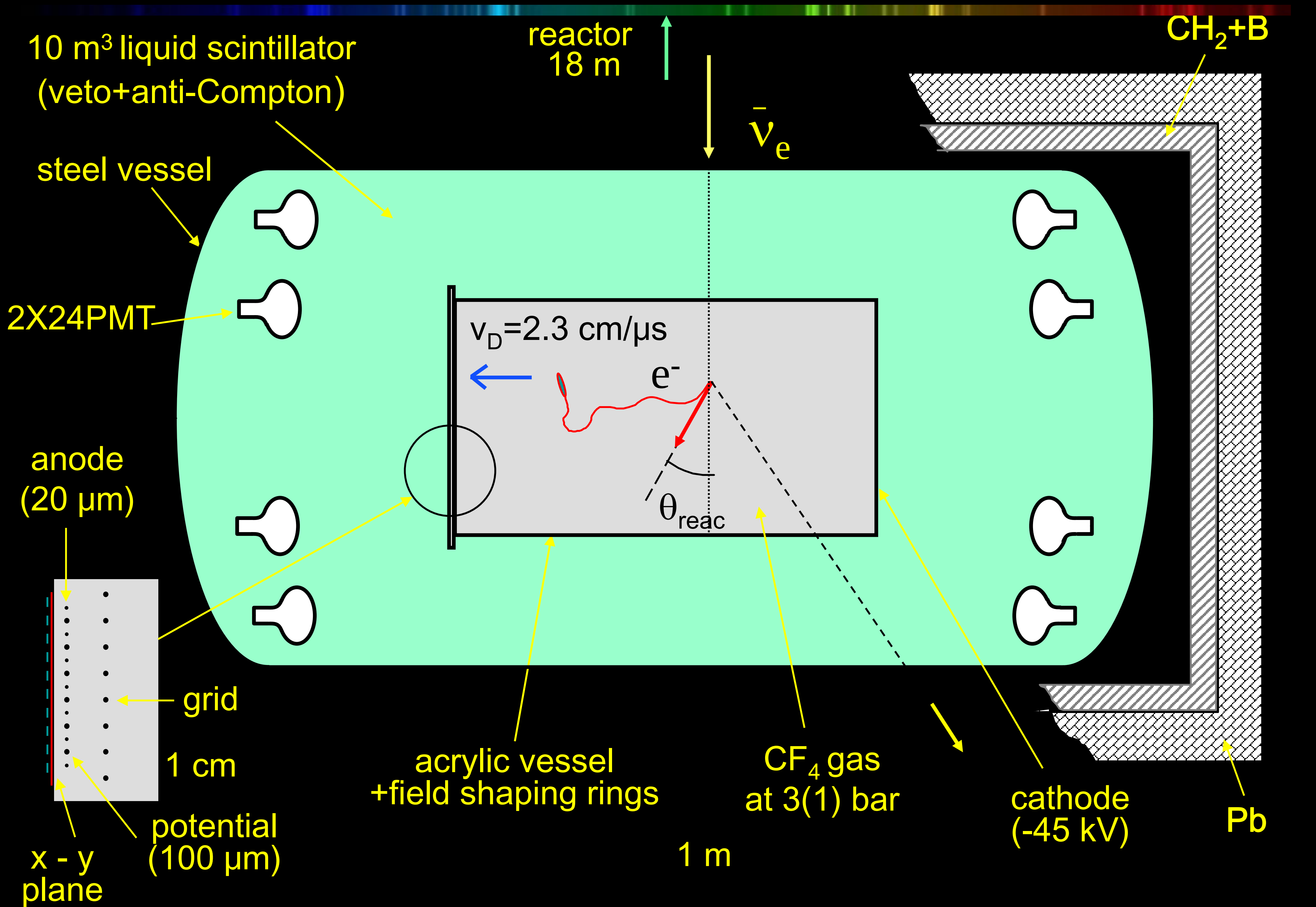
E_ν =(0 ÷ 8 MeV)

Neutrino spectrum:

E_ν > 1.8 MeV : the spectrum is reconstructed from the measured β decay of fission fragments (ILL), 5 % uncertainty

E_ν < 1.8 MeV : calculations (Vogel et al, Kopeikin), 20 % uncertainty

MUNU (Grenoble-Neuchâtel-Padova-Zurich)



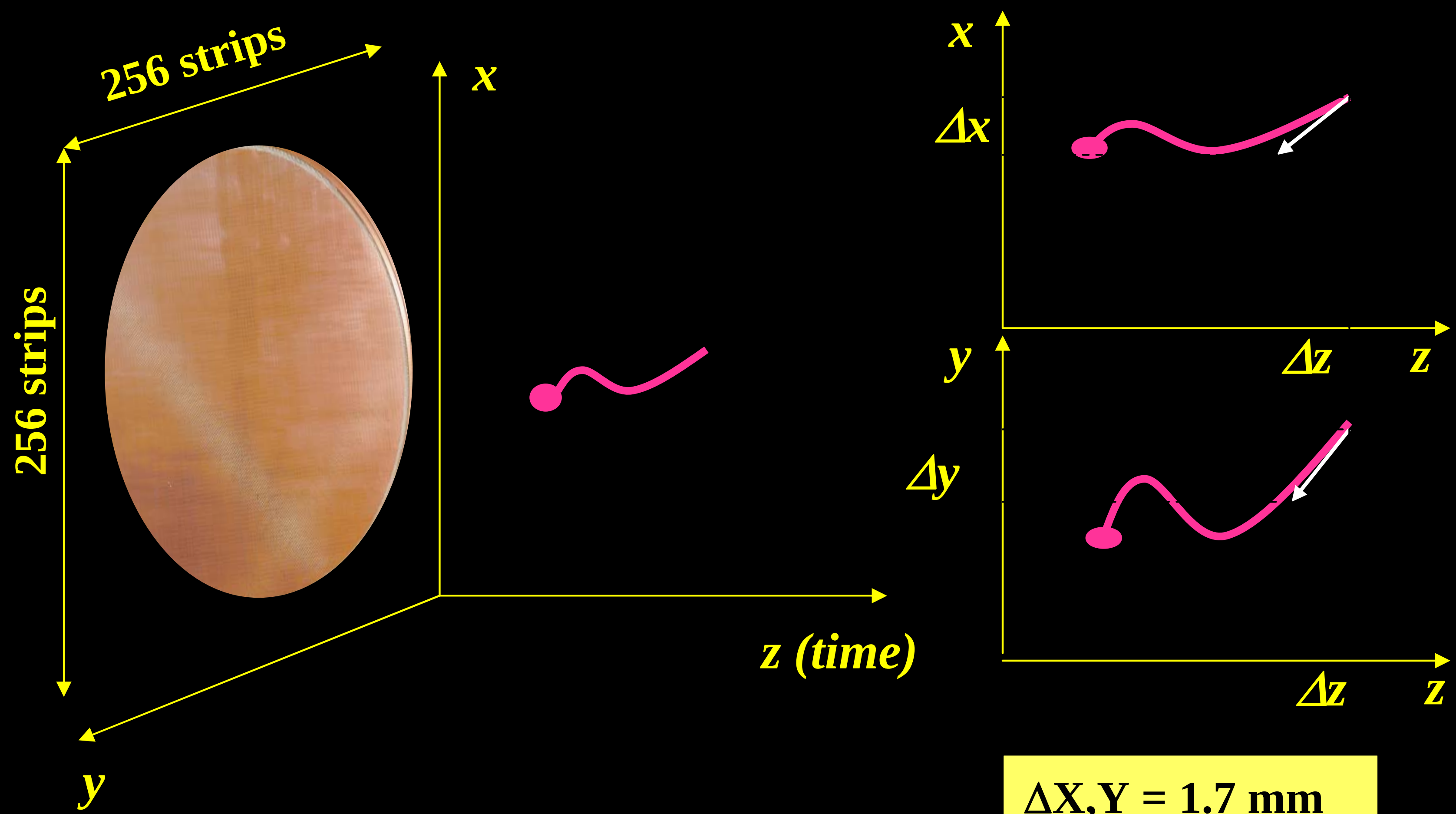
The central tracking detector is a 1m^3 Time Projection Chamber

acrylic vessel
L =162 cm
Φ = 90 cm

11.4 (3.8) kg CF_4 gas
at 3 (1) bar pressure

Why CF4?
- absence of free protons (no $\overline{\nu}_e + p \longrightarrow e^+ + n$)
- high density (3.7 g /l at 1 bar)
- low Z (less multiple scattering)

The *xy* plane provides spatial information in *x* and *y* directions. The spatial information along *z*-axis is obtained from the time evolution of the signal

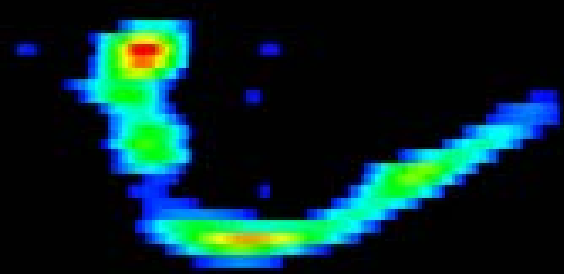


ΔX,Y = 1.7 mm

ΔZ = 1.7 mm

Selection of Neutrino Candidates

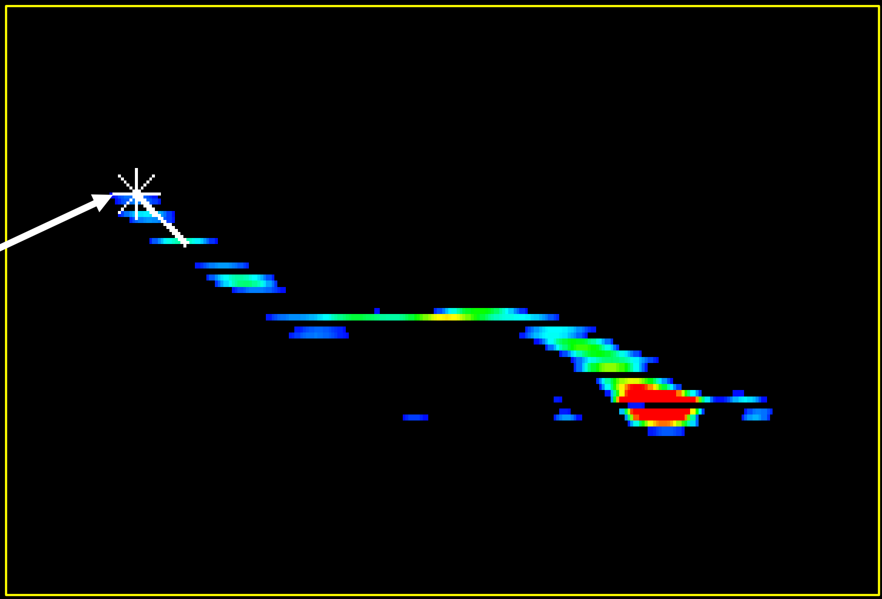
1. Automatic filtering rejects Compton electrons, muons, **α's** discharges and uncontained electrons
2. Selection of good electron events



Neutrino candidate is every single electron with clearly distinguishable start and end of track (blob) inside of the fiducial volume (R<42 cm), with no energy deposition in the anti-Compton detector

Visual scanning analysis

Operator selects the contained single electrons and fits the first cm of the electron track by eye



from the fitting :

θ_{rea} (scattering angle with respect to the reactor-detector axis)

$$\theta_{rea} = \arccos \frac{\Delta y \cos \varphi_{drea} - \Delta x \sin \varphi_{drea}}{\sqrt{(\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2}}$$

from the Kinematics :

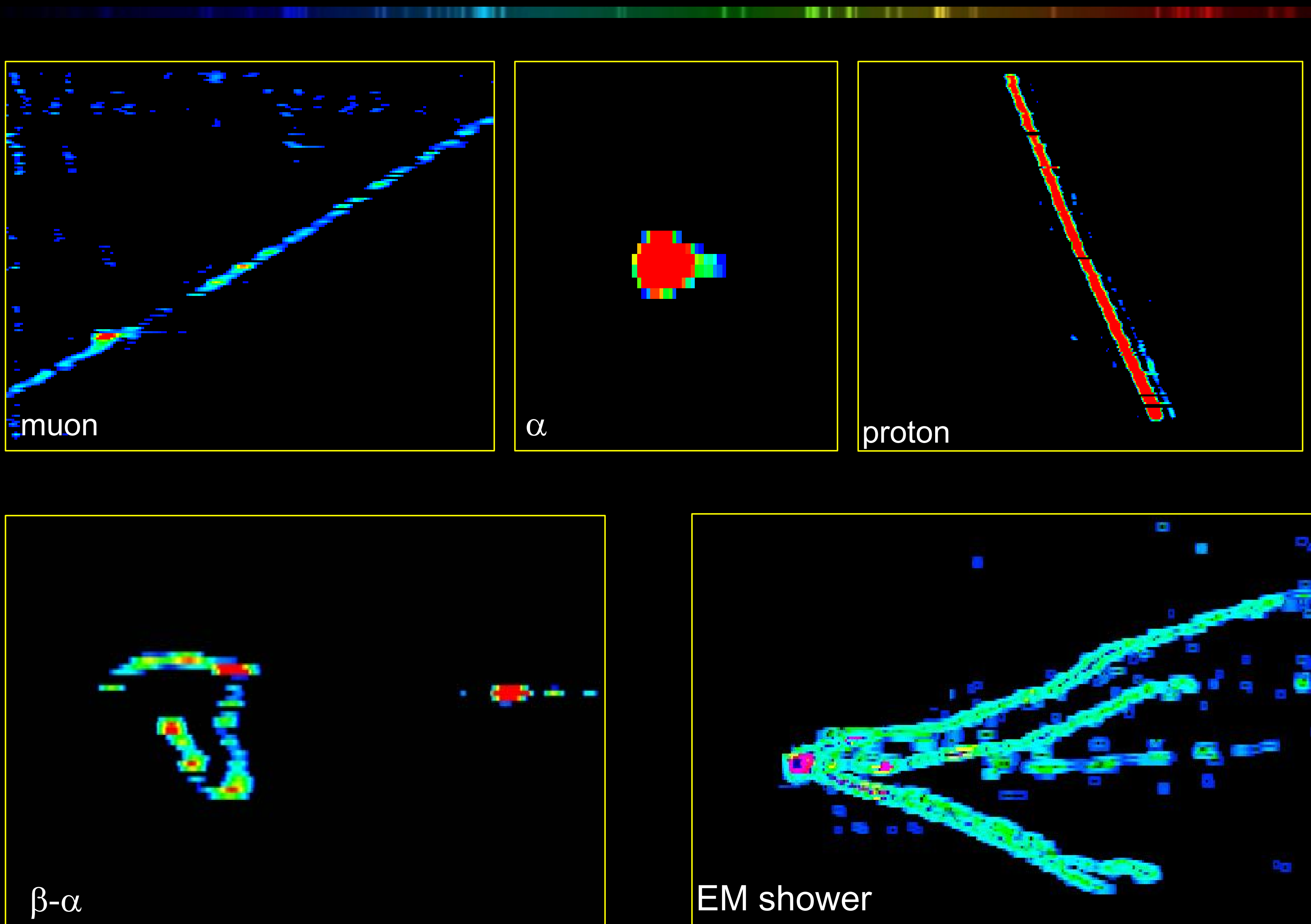
incident neutrino energy E_ν (Te , θ_{rea})

$$E_\nu = \frac{m_e c^2}{\cos\theta_{rea}\sqrt{\frac{T_e + 2m_e c^2}{T_e}} - 1}$$

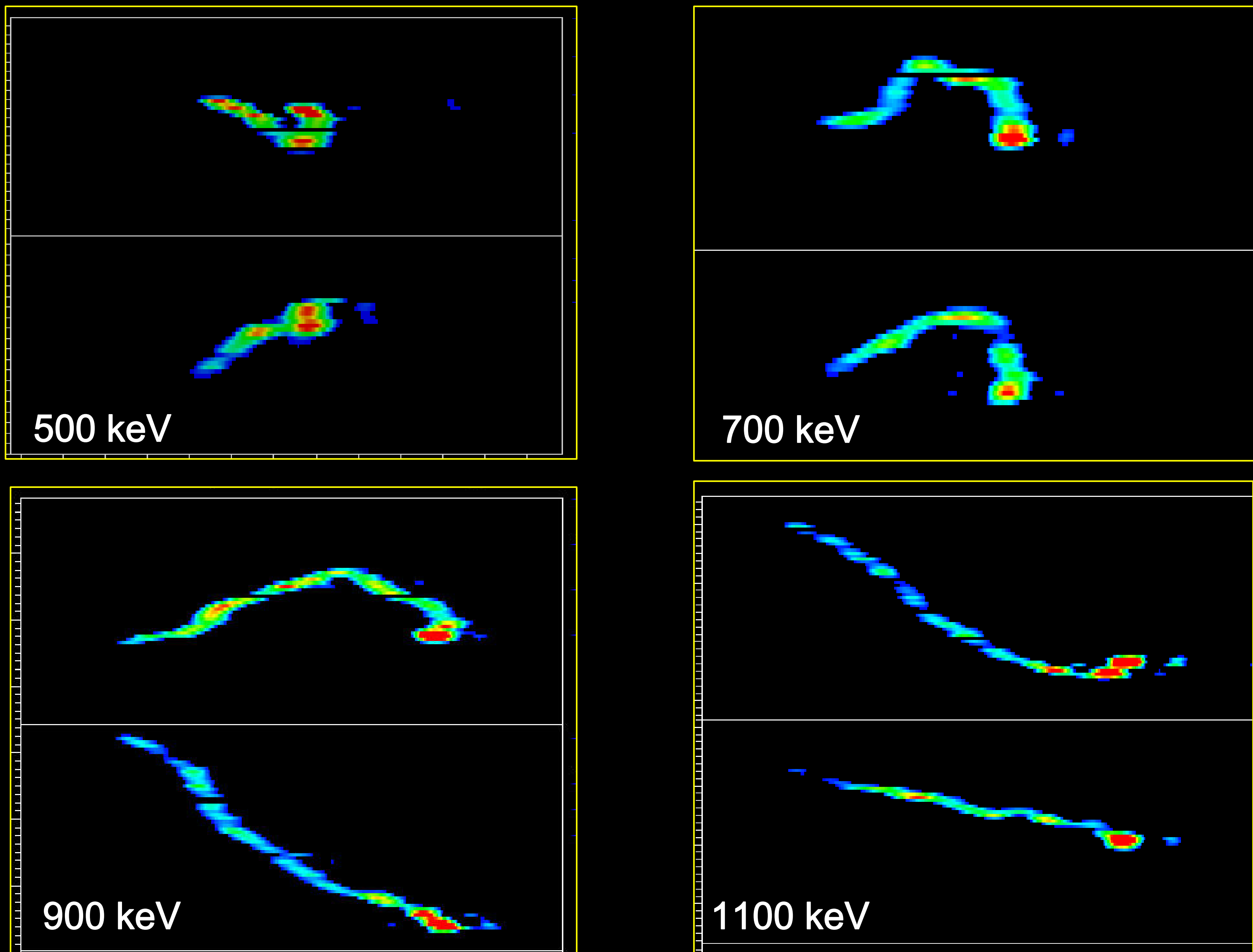
Results from visual scanning analysis

3-bar data analysis

Examples of background events at 3-bar pressure



Examples of electron events at 3-bar pressure



The advantages from the tracking capabilities of MUNU TPC

•We can measure the angular distribution of electron tracks

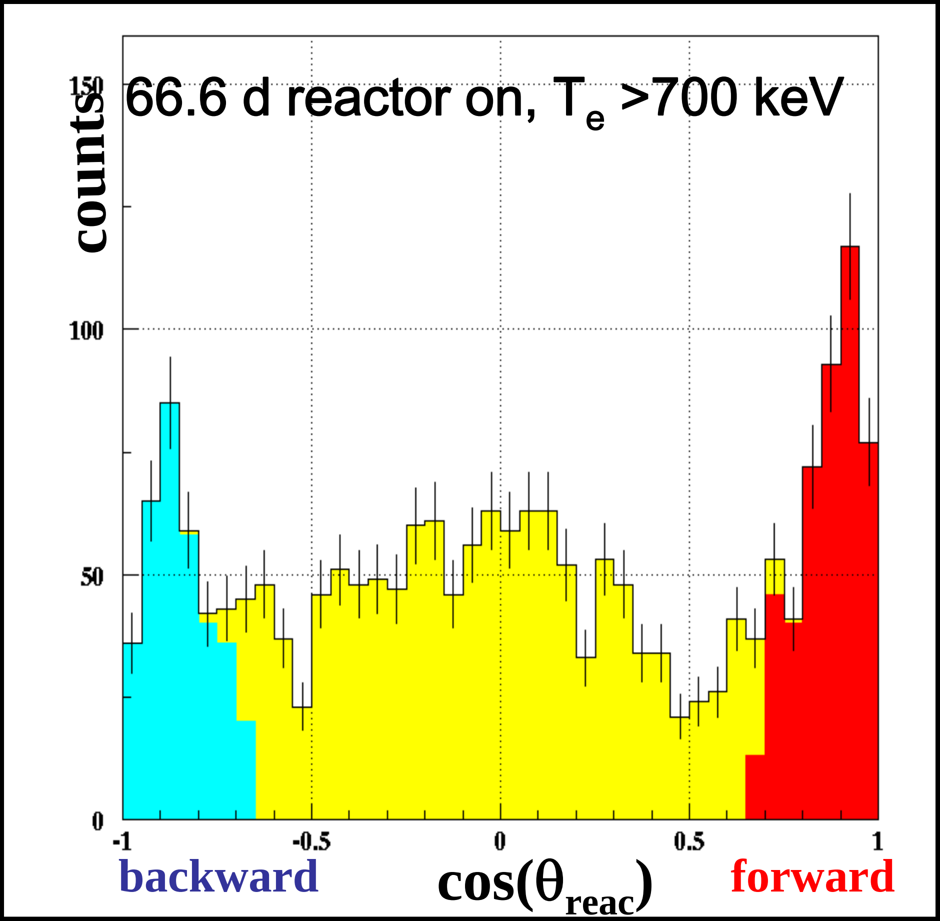
•The signal and background are measured simultaneously which solves the problems with detector or source instability over long periods of data taking

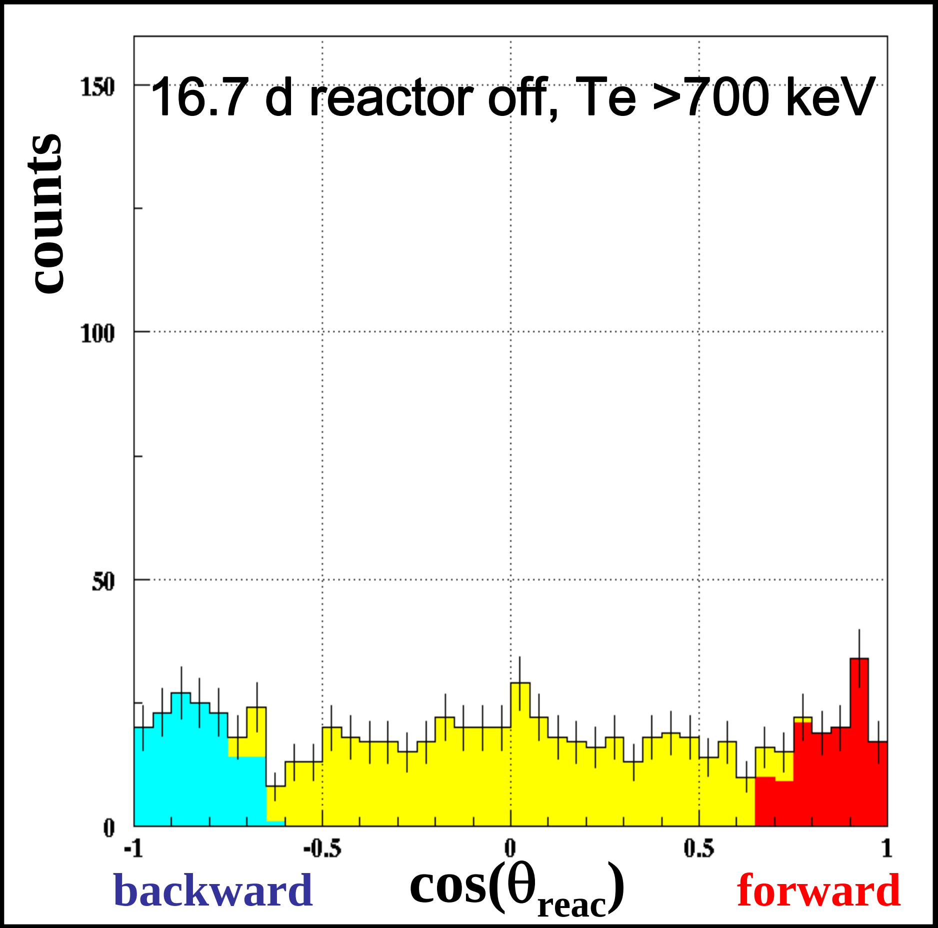
•Moreover the TPC is absolutely symmetric between forward and backward directions with regards to the reactor-detector axis:

-it is positioned orthogonally to the reactor-detector axis, which coincides with the axis of symmetry between x-y strips in the pickup plane

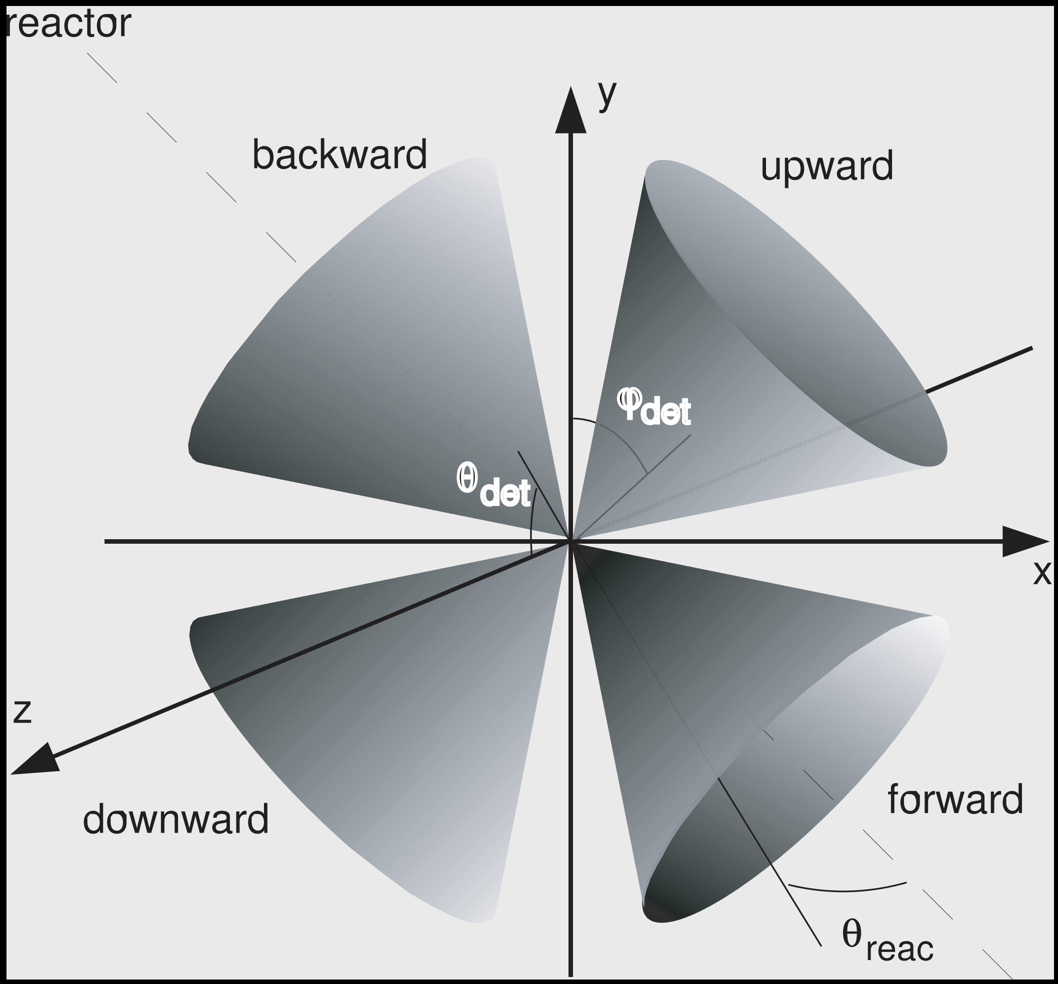
-anode wires are rotated by 45° with respect to the x-y plane

Angular distributions of electron tracks





Forward –Normalized Background Analysis

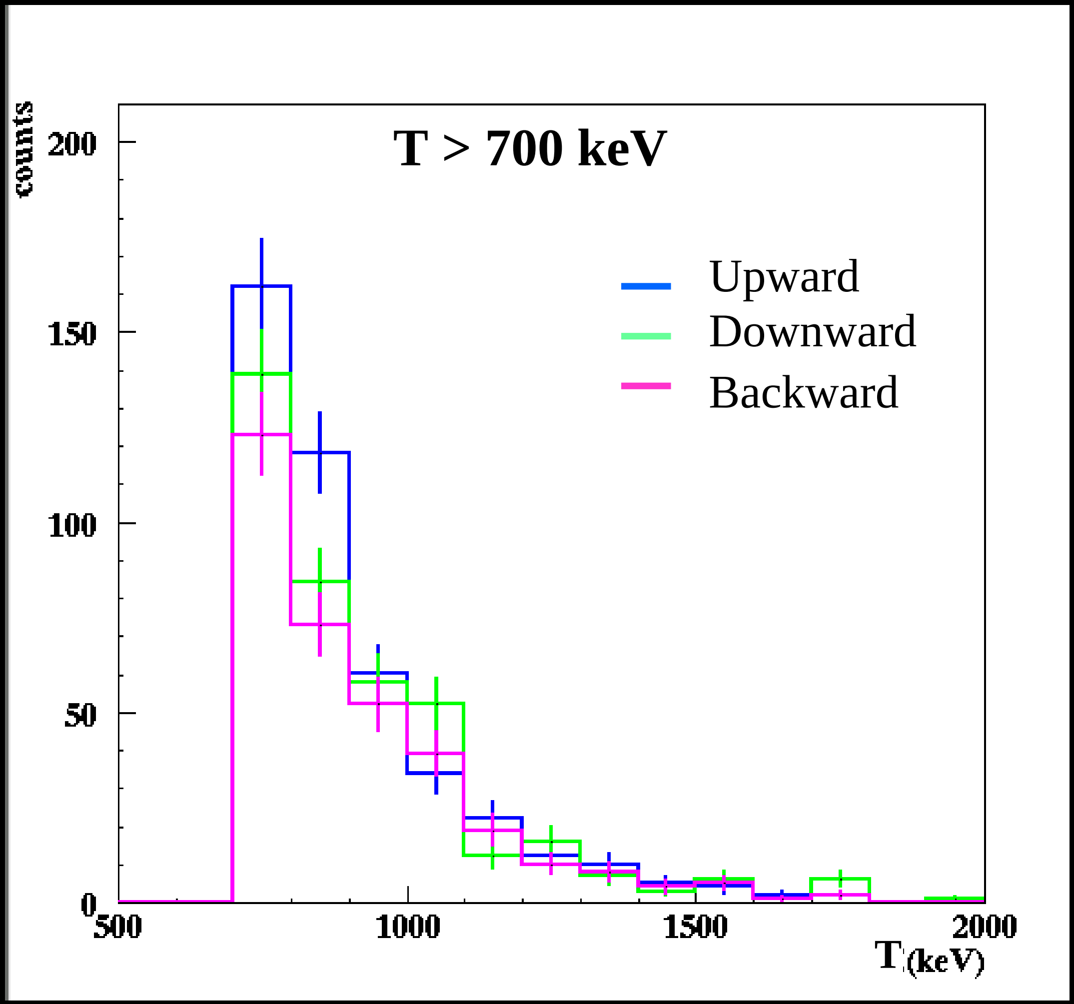


Normalized Background =(Upward +Downward +Backward)/ 3

Signal = Forward – Normalized Background

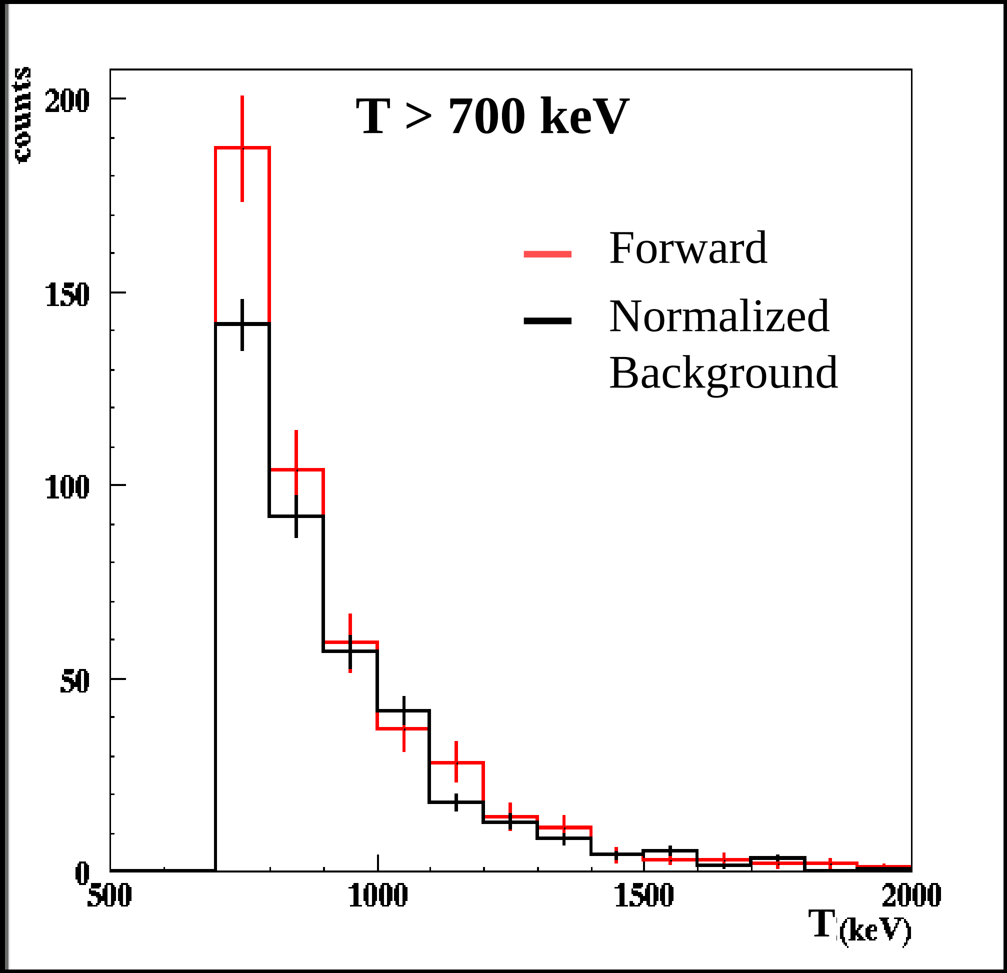
Results 3-bar Forward –Normalized Background Analysis

Energy distributions of the background electrons
66.6 days reactor-on



Background electrons are 1154 ± 34 in total

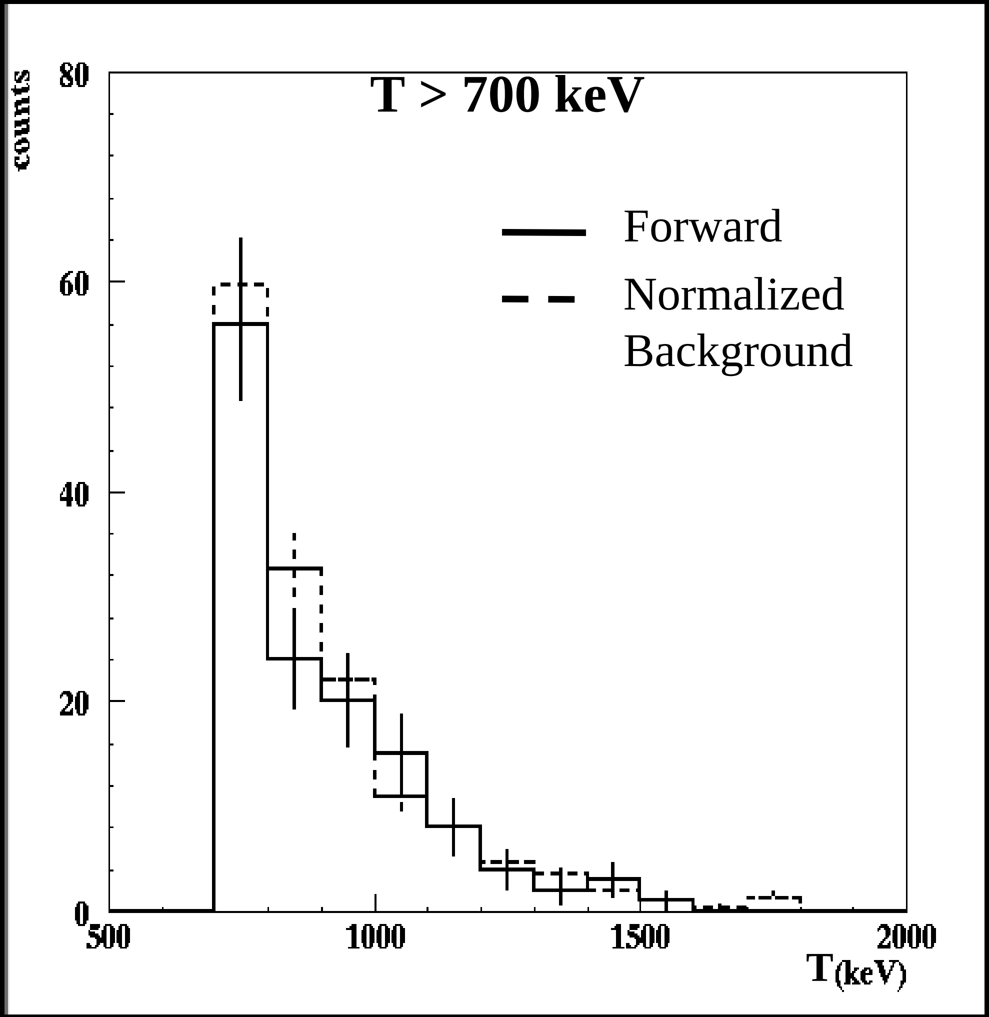
Energy distributions of the forward (S+B) and normalized background electrons (B), 66.6 d reactor-on



Forward electrons are 455 ± 21

Normalized Background electrons are 385 ± 11

Energy distributions of the forward (B) and normalized background electrons (B) 16.7 days reactor-off

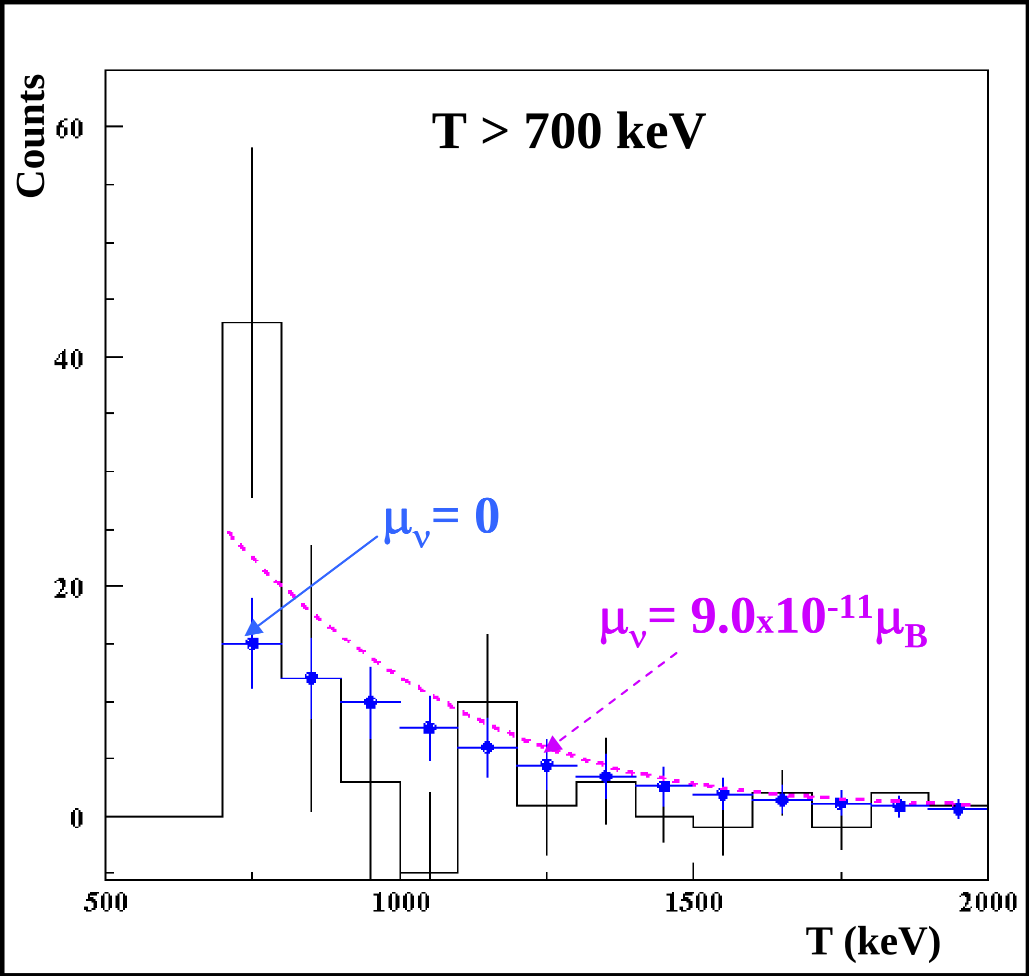


Forward electrons are 133 ± 11

Normalized Background electrons are 147 ± 7

-0.8 ± 0.8 cpd

Energy distribution of the forward – NB electrons
66.6 d reactor-on



T_e >700 keV

measured : 1.05 ± 0.36 cpd

expected μ_ν =0 : 1.0 ± 0.1 cpd

$\mu_\nu < 9.0 \times 10^{-11}\ \mu_B$ (90%CL)

PLB 615 (2005) 153

70 events for 66.6 days
1.05 ± 0.36 cpd

1-bar data analysis

Motivation:

•Better energy resolution

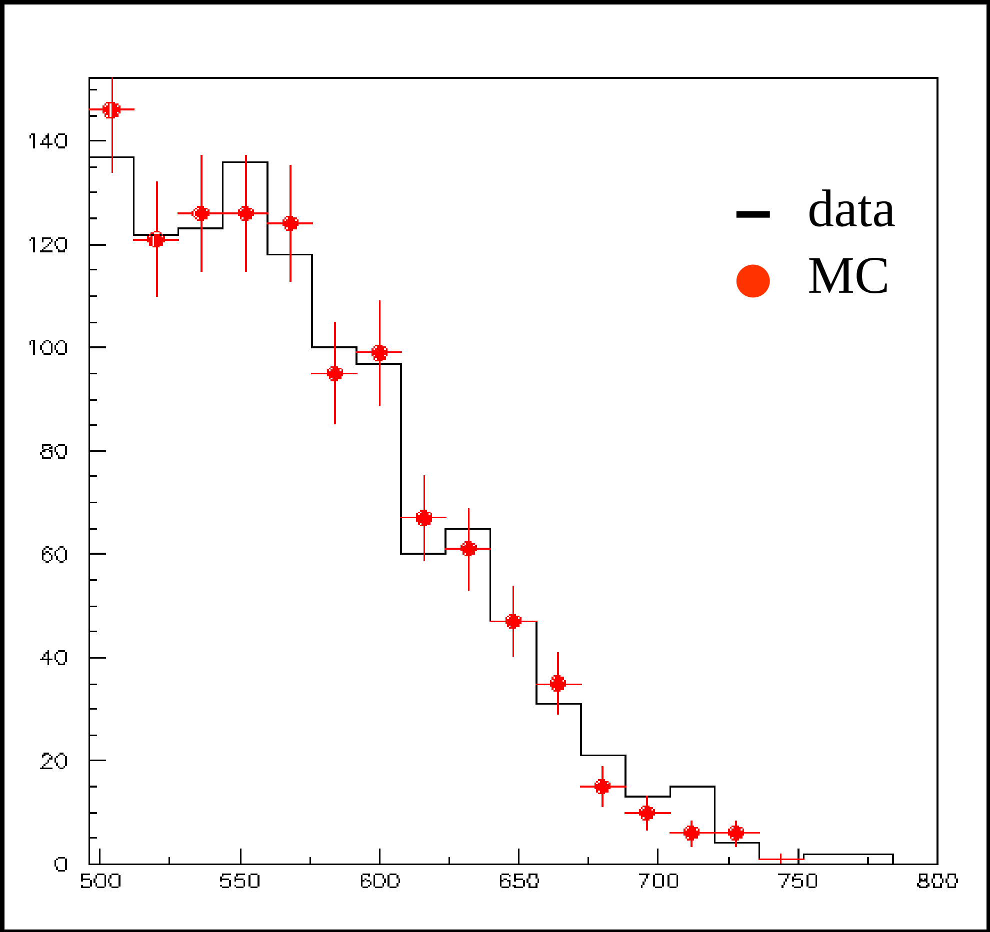
•Smaller background

•To measure low energy electron events down to 100 keV

•To measure not only the energy but also the direction of the recoil electrons above 150 keV

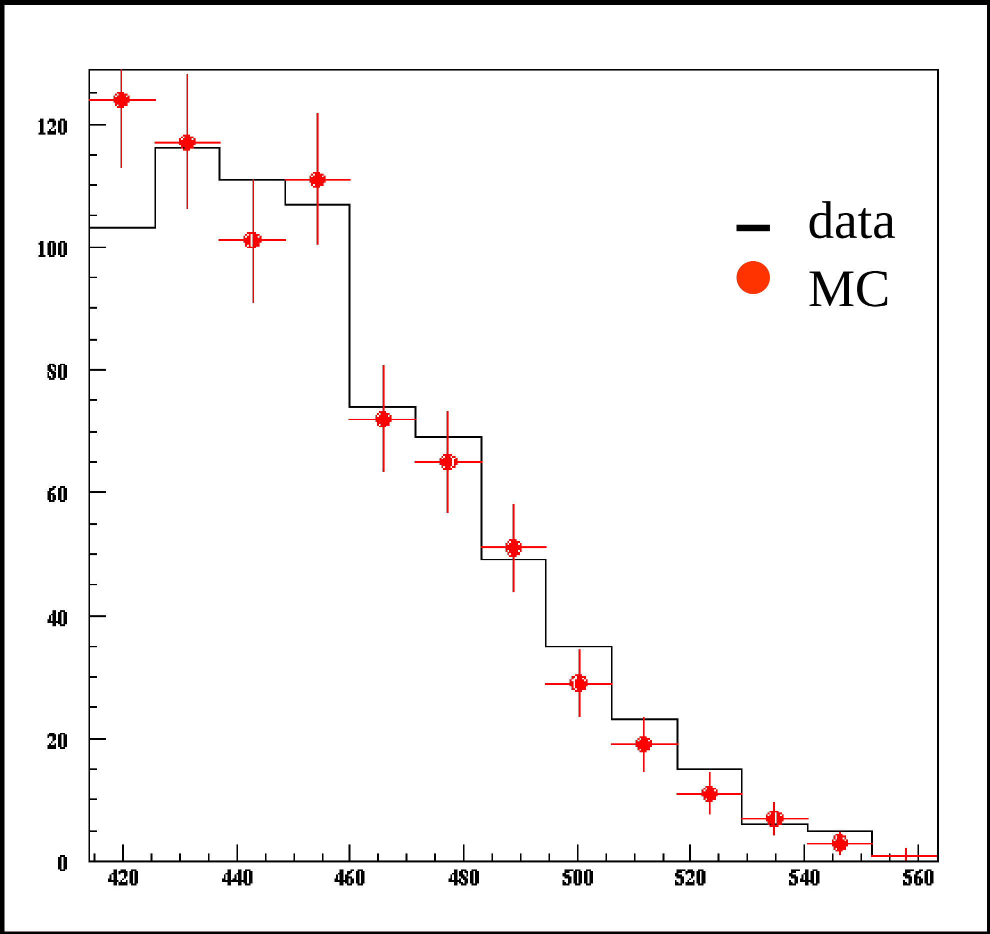
Calibrations with ^{54}Mn and ^{137}Cs

^{54}Mn



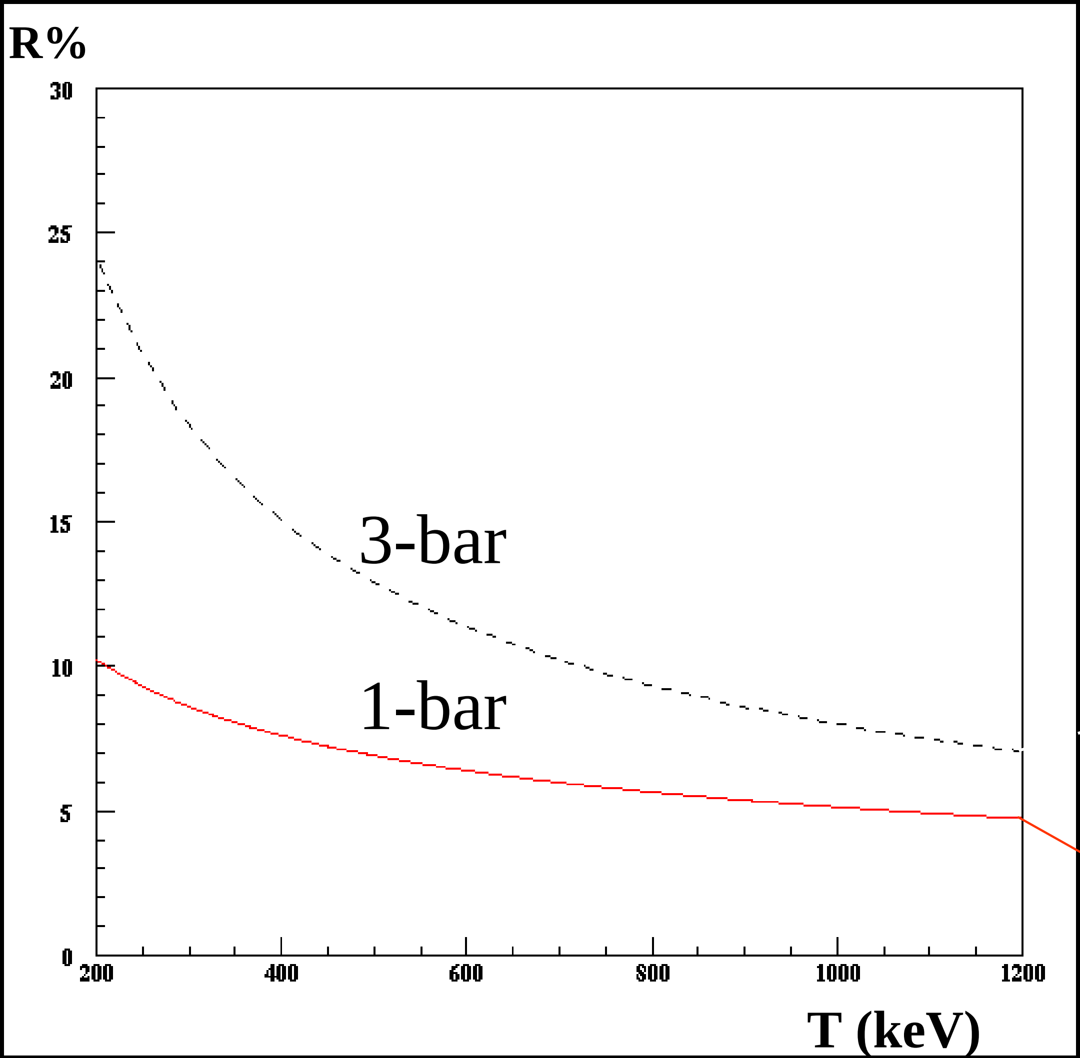
T(keV)

^{137}Cs



T(keV)

TPC energy resolutions at 1-bar and 3-bar



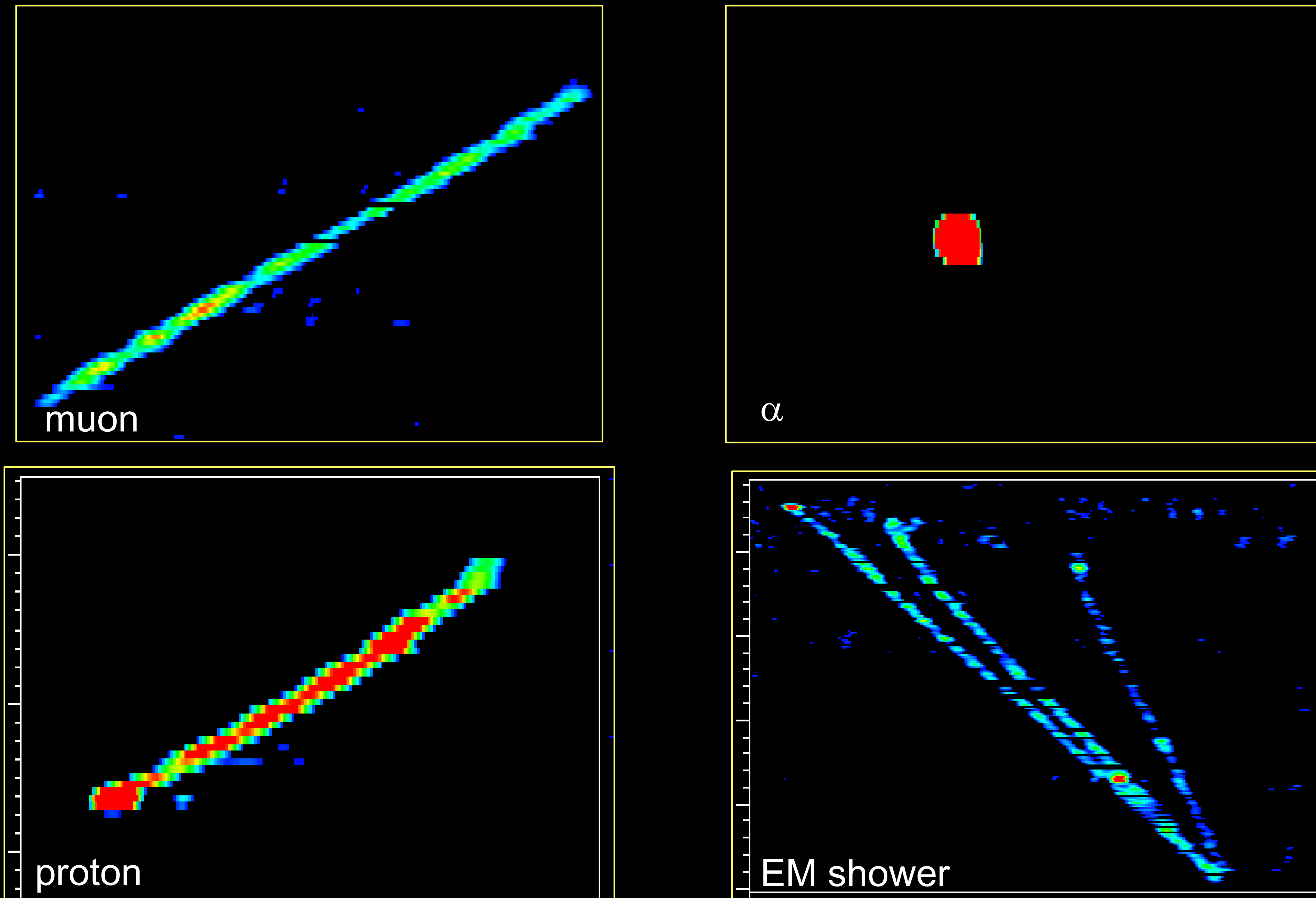
T (keV)	R % (3-bar)	R%(1bar)
200	24	10
400	15	7.6
600	11.4	6.4
1000	8	5

$$R = \frac{80\left(\frac{T}{1000}\right)^{0.31}}{T}$$

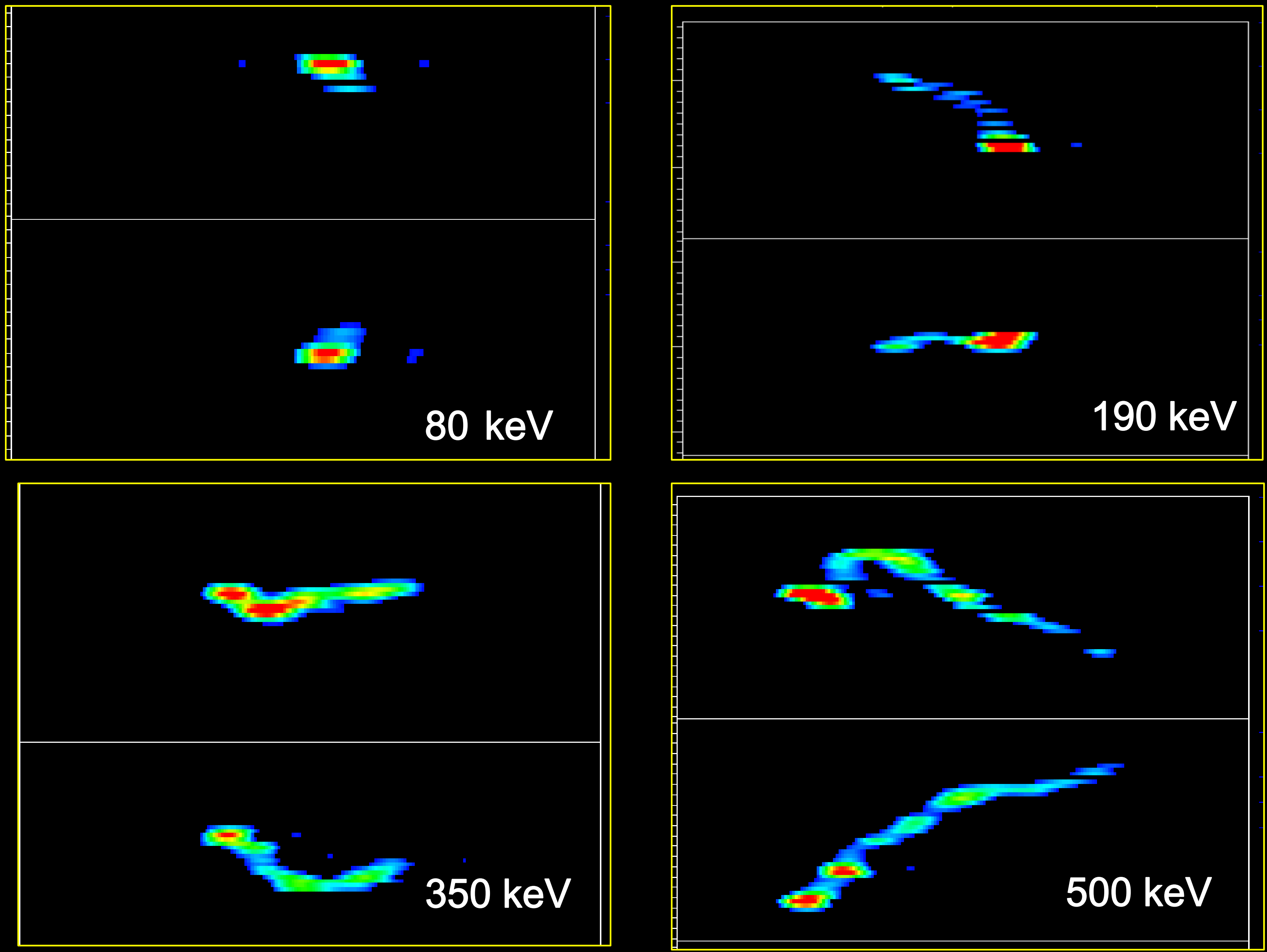
$$R = \frac{T^{0.57}}{T}$$

Energy resolution at 1-bar is about 2 times better then that at 3-bar

Examples of background events at 1-bar pressure

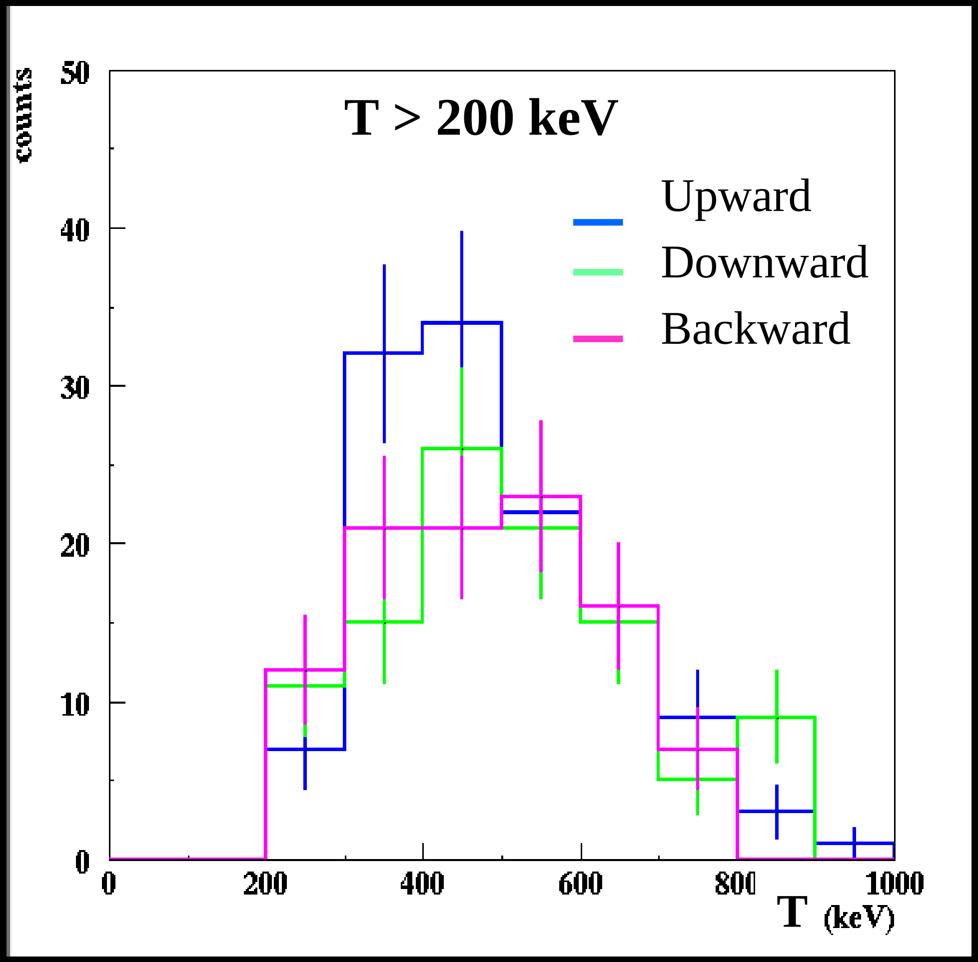


Examples of low energy electron events at 1-bar pressure



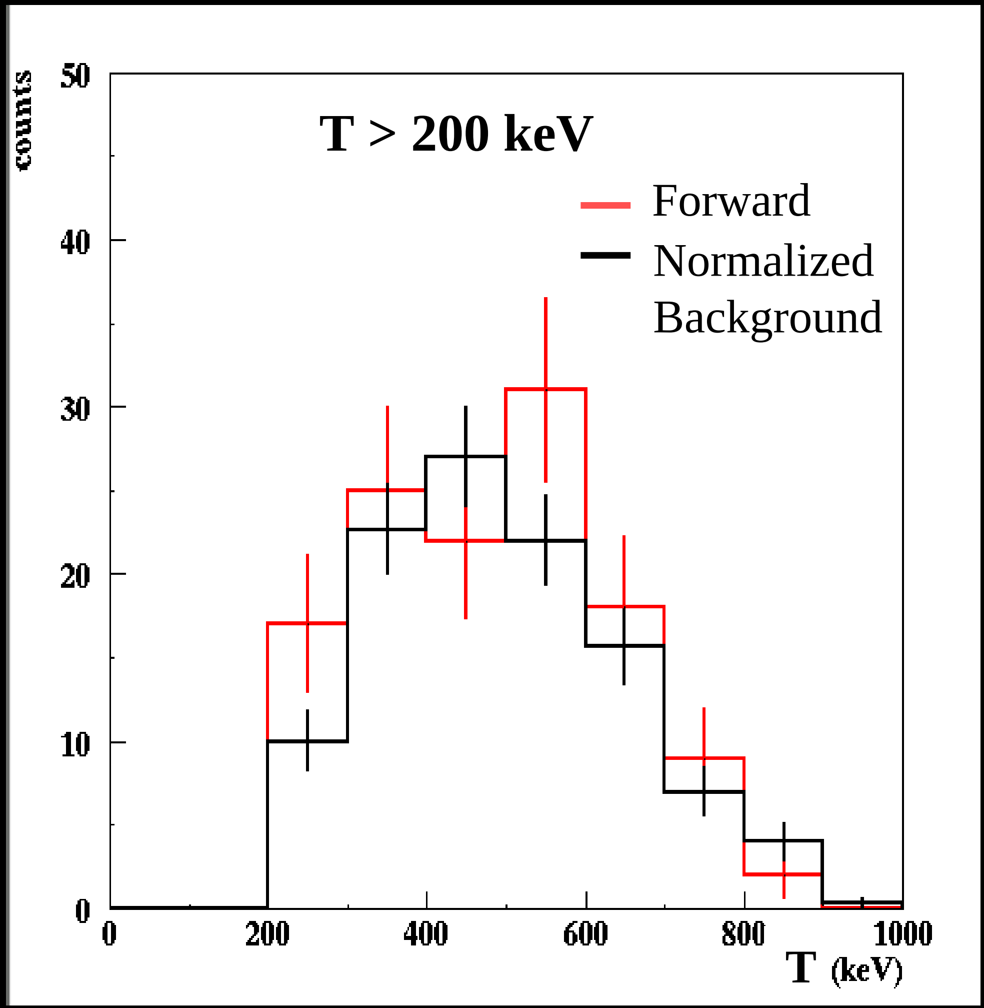
Results 1-bar Forward –Normalized Background Analysis

Energy distributions of the background electrons
5.3 d reactor-on



Background electrons are 326 ± 18 in total

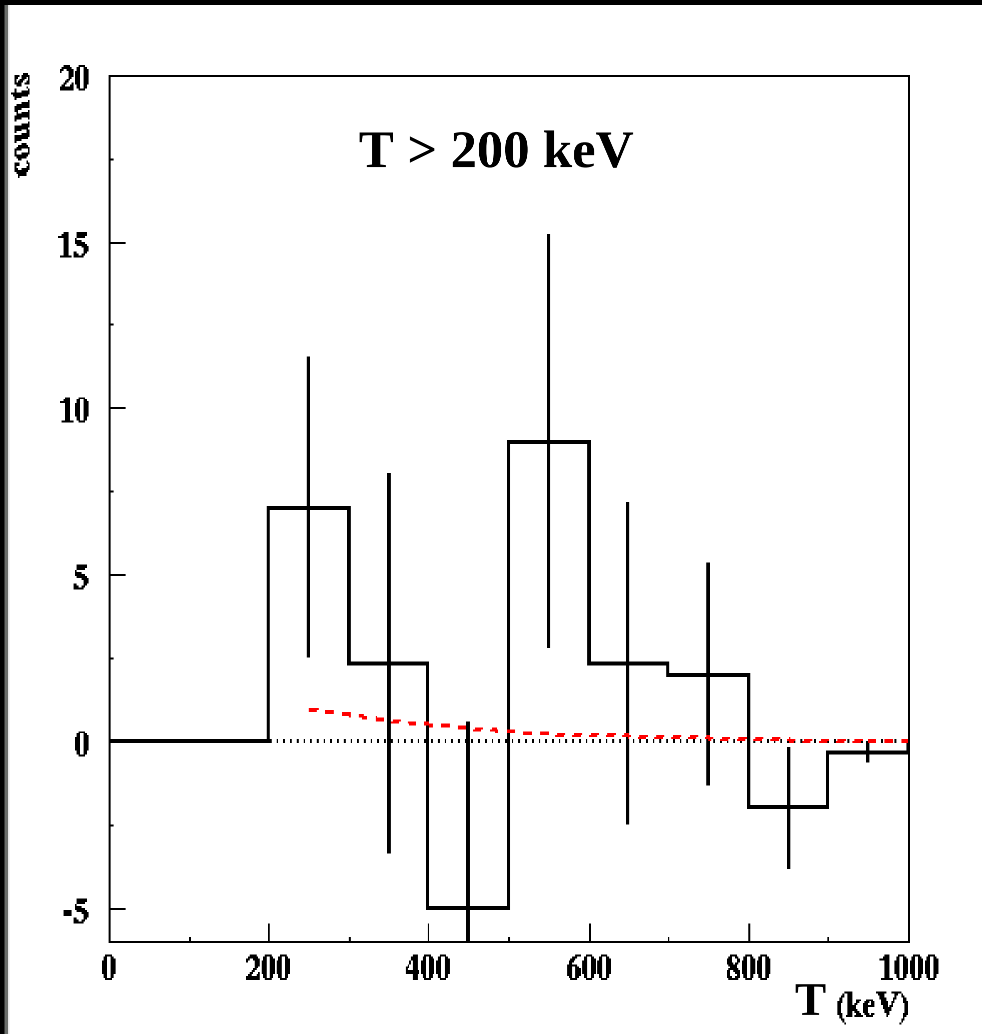
Energy distributions of the forward (S+B) and normalized background electrons (B) 5.3 d reactor-on



Forward electrons are 124 ± 11

Normalized Background electrons are 109 ± 6

Energy distribution of the forward – NB electrons
5.3 days reactor-on



T_e > 200 keV

measured	:	**2.89 ± 2.39 cpd**
expected	**μ_ν =0 :**	**0.49 ± 0.12 cpd**

15 events for 5.3 days above 200 keV

This is the first measurement of the recoil electron spectrum from *νe⁻* scattering down to 200 keV

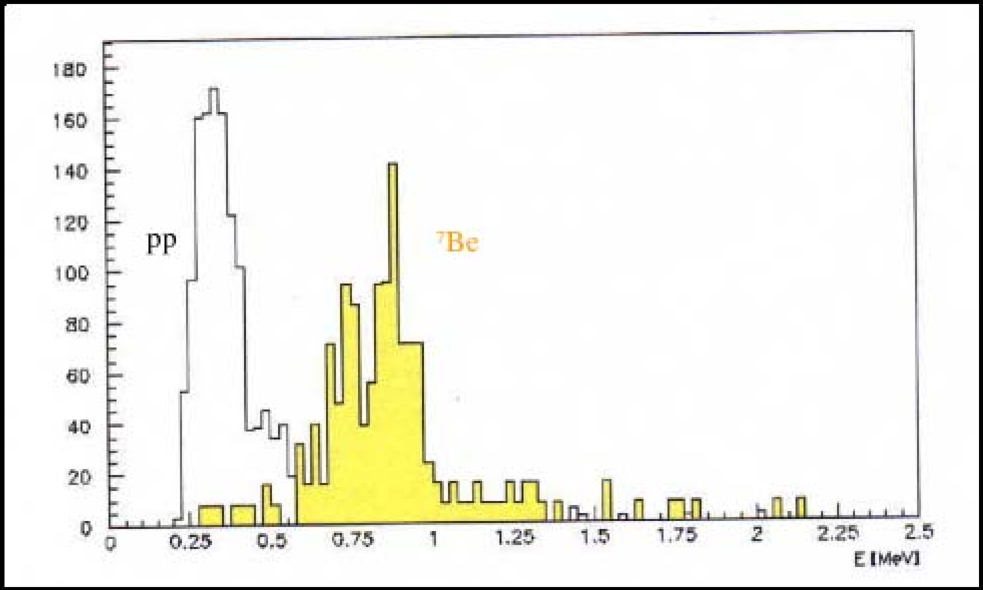
Prospects for the future

The technology of *MUNU* can (almost!) be used for other applications in low energy neutrino physics.

solar neutrino spectroscopy, 200 m^3 ($4x50m^3$) TPC filled with CF4 at 1bar

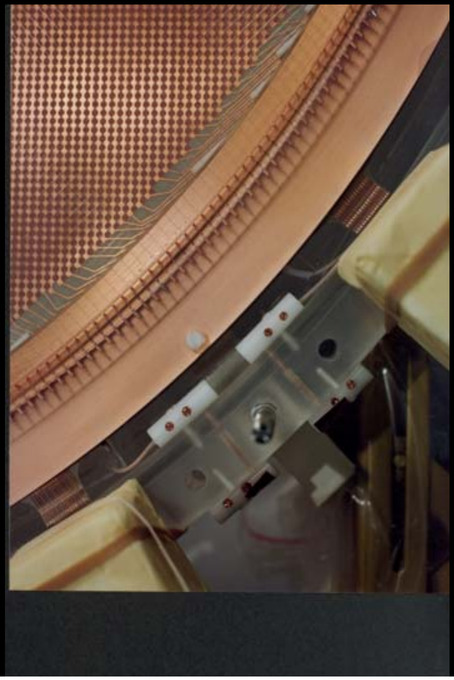
reconstruct E_ν from T_e, θ_e

10 years:

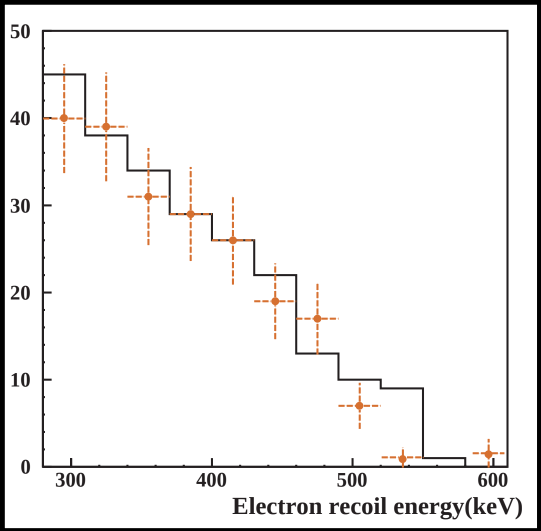


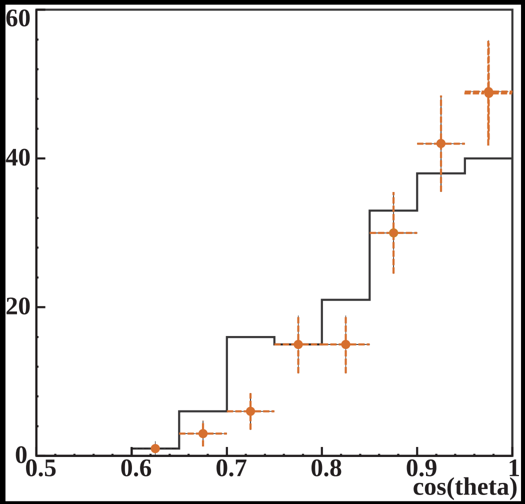
L_{drift}= 33 m at 2 bar for V_{drift}=50 kV $cm^{-1}bar^{-1}$ demonstrated

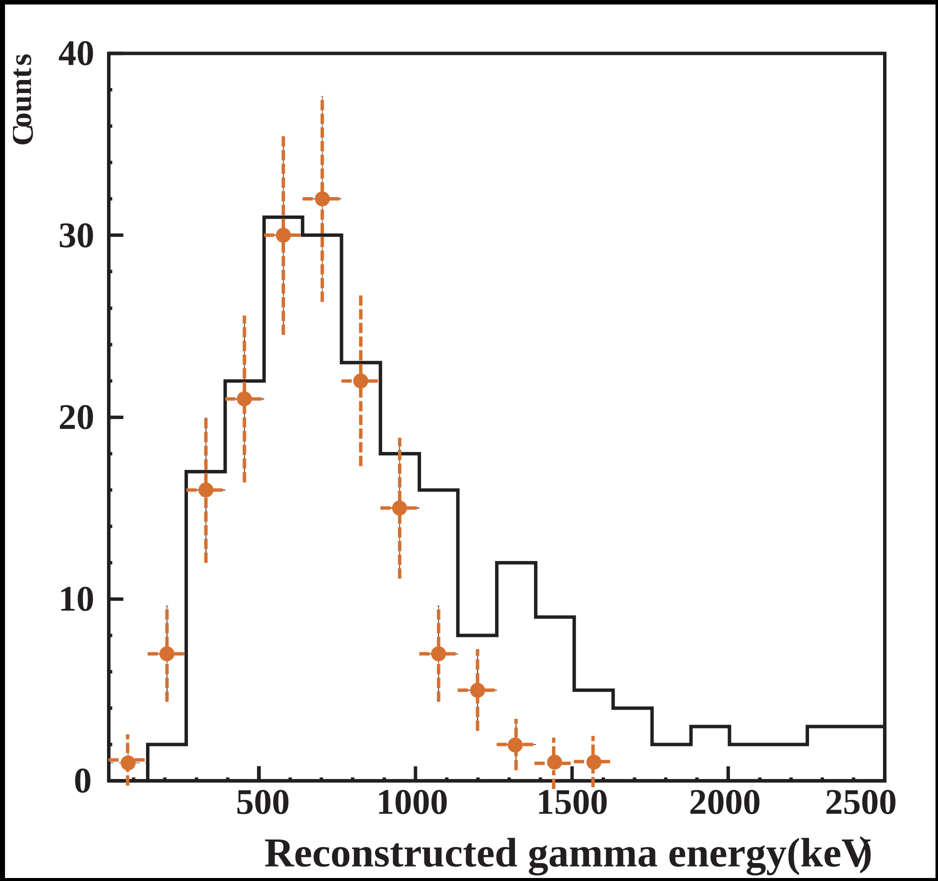
Problem: large area reliable read-out planes!
(MUNU: 20 μm wires)



Reconstructed ^{137}Cs(662 keV) photopeak from the Compton scattering of γe^-, $E_\gamma(T_e, \theta_e)$, *1 bar of CF4*



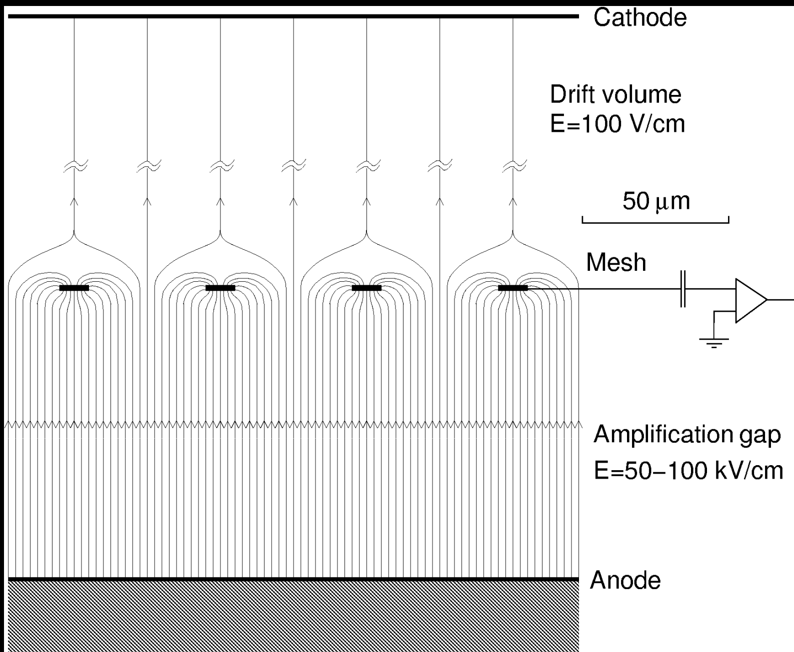




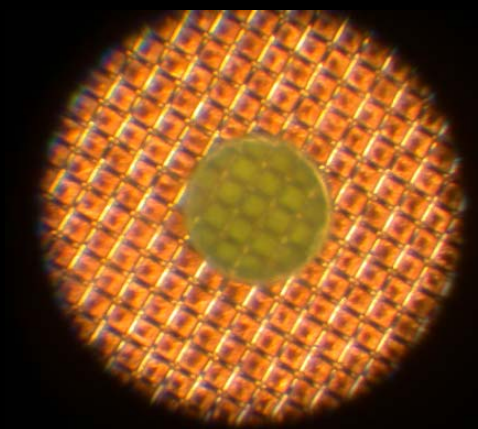
The σ of the reconstructed peak at 662 keV is 220 keV

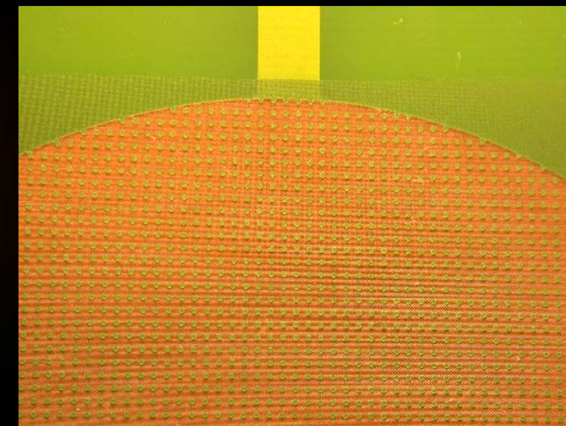
Neutrino energy E_ν can be reconstructed in the same way from T_e, θ_e

Results from measurements with Micromegas (L. Ounali)



use primary light for t_0

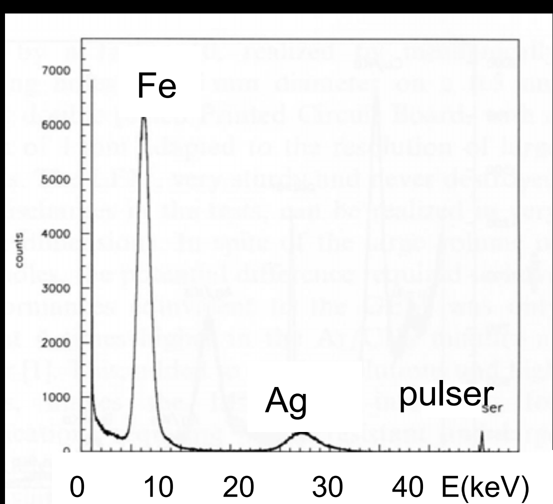




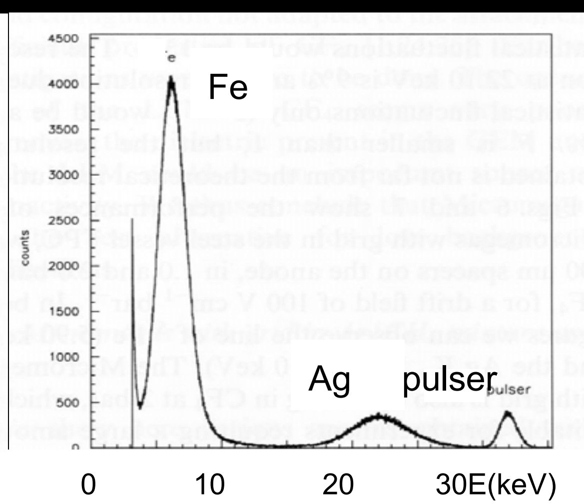
Woven mesh

stainless steel with spacer

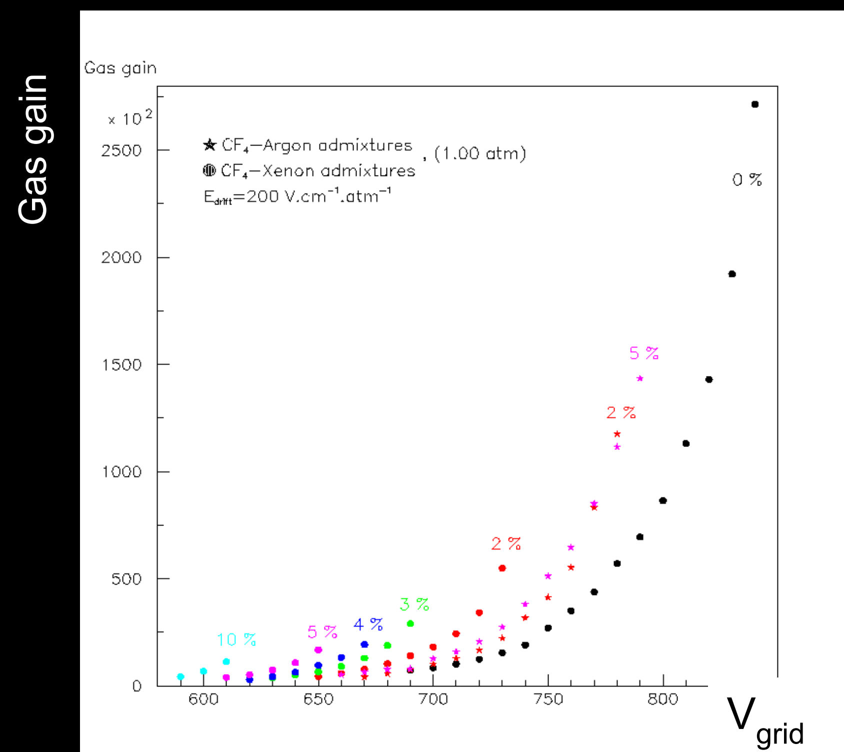
Neuchâtel-CERN: pure CF_4



1 bar

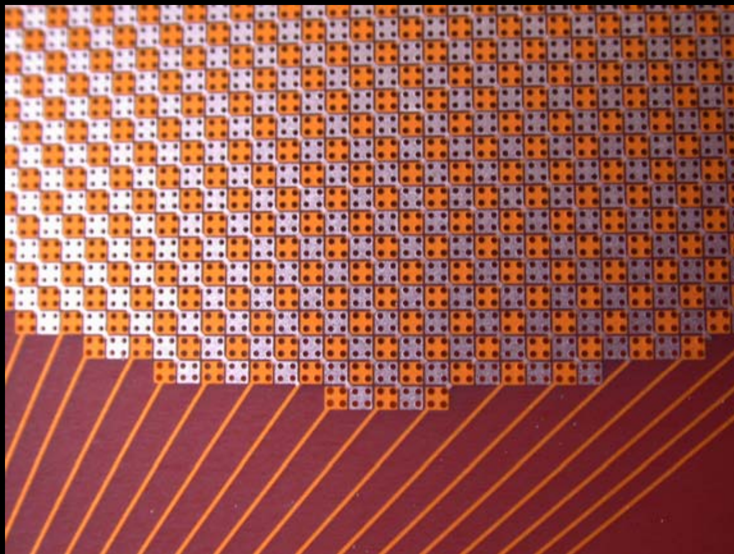


2 bar

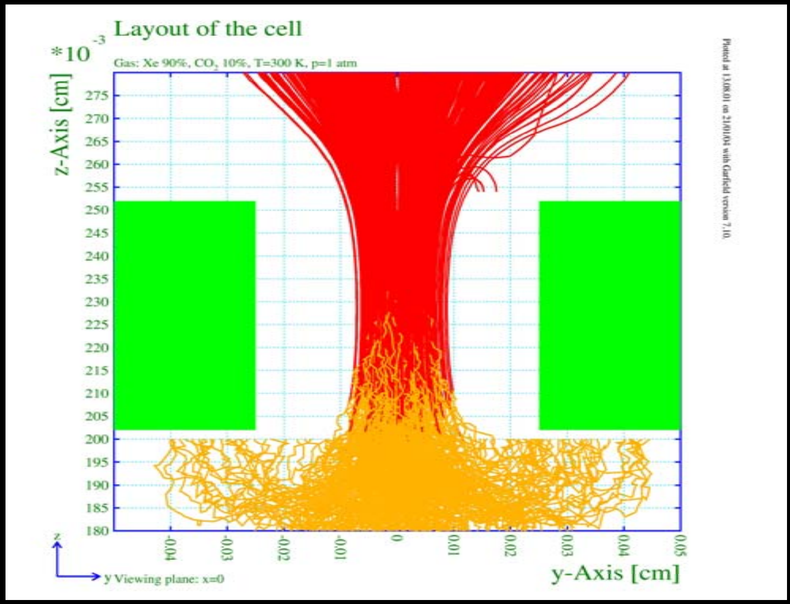


Reduce attachement with Ar, Xe admixture

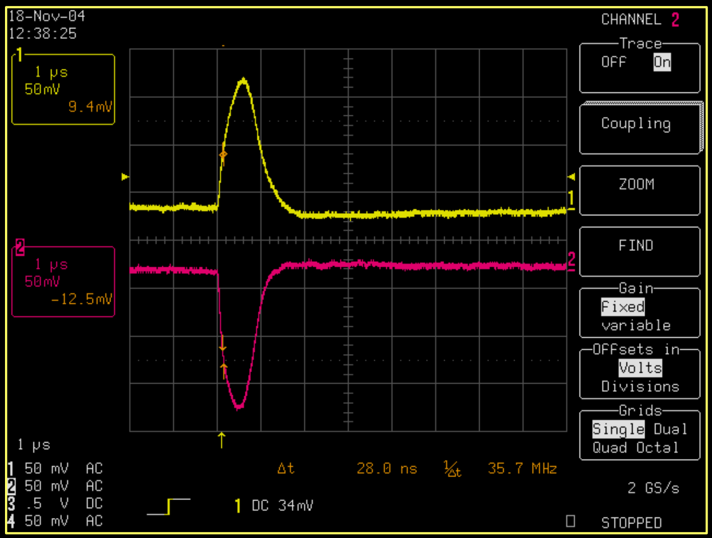
Results from measurements with SILEM (P. Weber)



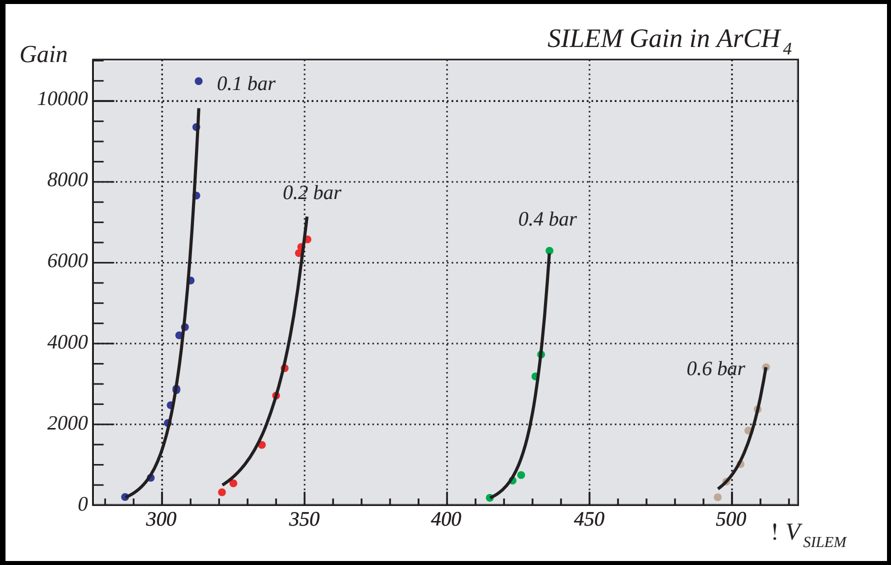
SILEM (pixel version); holes diameter 300 µm



Maxwell/Garfield simulation



Ions/electrons charge signals



Grid gain in ArCH4 gas