The MUNU Experiment

A measurement of the neutrino magnetic moment

The MUNU Collaboration

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Outline:

- Standard model predictions
- Present experimental situation
- The MUNU Detector
- Event rates and background
- Status of the experiment
- Reaktor ON vs OFF
- Conlusion

Standard model predictions for μ_ν

$$\mu_\nu = \frac{3}{8\pi^2\sqrt{2}}\, \mathrm{e}\, \mathrm{G_F}\, \mathrm{m}_\nu = 3 \times 10^{-19}\, \frac{\mathrm{m}_\nu}{\mathrm{eV}}\, \mu_\mathrm{B}$$

$$\mu_\mathrm{B} = \frac{\mathrm{e}}{2\mathrm{m_e}} \qquad \text{is the Bohr magneton}$$

$$\mathrm{m}_\nu < 10\,\mathrm{eV} \rightarrow \boxed{\mu_\nu < 3 \times 10^{-18} \mu_B}$$

wheras laboratory upper limits are $\sim 10^{-10}\mu_\mathrm{B}$!!

Any evidence for a “large” magnetic moment
of the neutrino means
new physics beyond the standard model

The cross section for the $\overline{\nu}_{\mathrm{e}}\mathrm{e}^-$ scattering

$$\frac{d\sigma}{dT} = \frac{2G_F^2 m_e}{\pi}\left[g_R^2 + g_L^2\left(1 - \frac{T}{E_\nu}\right) - g_R g_L \frac{m_e T}{E_\nu^2}\right]$$

$$+\frac{\pi\alpha^2}{m_e^2}\left(\frac{\mu_\nu}{\mu_B}\right)^2 \frac{1 - T/E_\nu}{T}$$

where the last term is due to the magnetic moment

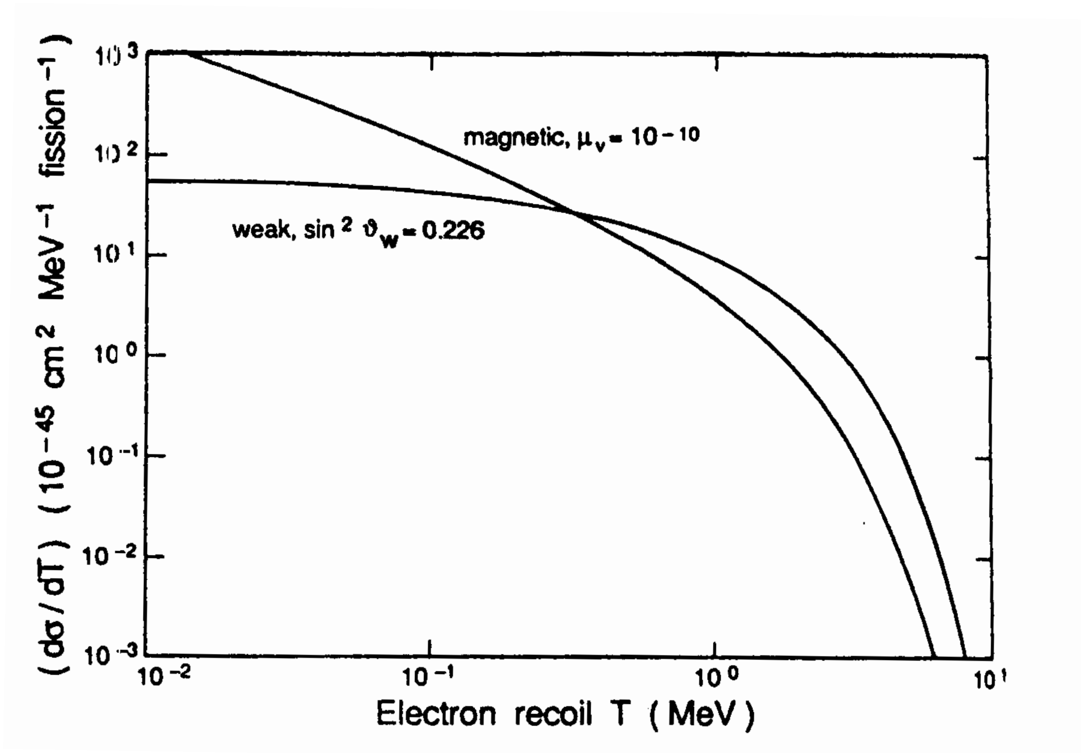
we know:

- number of incoming neutrinos
- cross section for $\overline{\nu_e}$ electron scattering in the standard model
- number of target electrons

we count the number of single electrons in the detector

if there are too many, the magnetic moment is not zero

The cross section behaviour



The effect of $\mu_\nu > 0$ is larger at lower energy.

- detector with low energy threshold, 300 keV
- many target electrons because of small cross section (large detector mass)
- low background, few other interactions creating a single electron in the detector

Parameters to be measured:

- Recoil kinetic energy T
- scattering angle θ of the electron

Present experimental situation

SN 1987A, from the observed duration of the neutrino burst (in case the neutrino is a Dirac particle):

$$1 - 20 \cdot 10^{-13}\ \mu_B$$

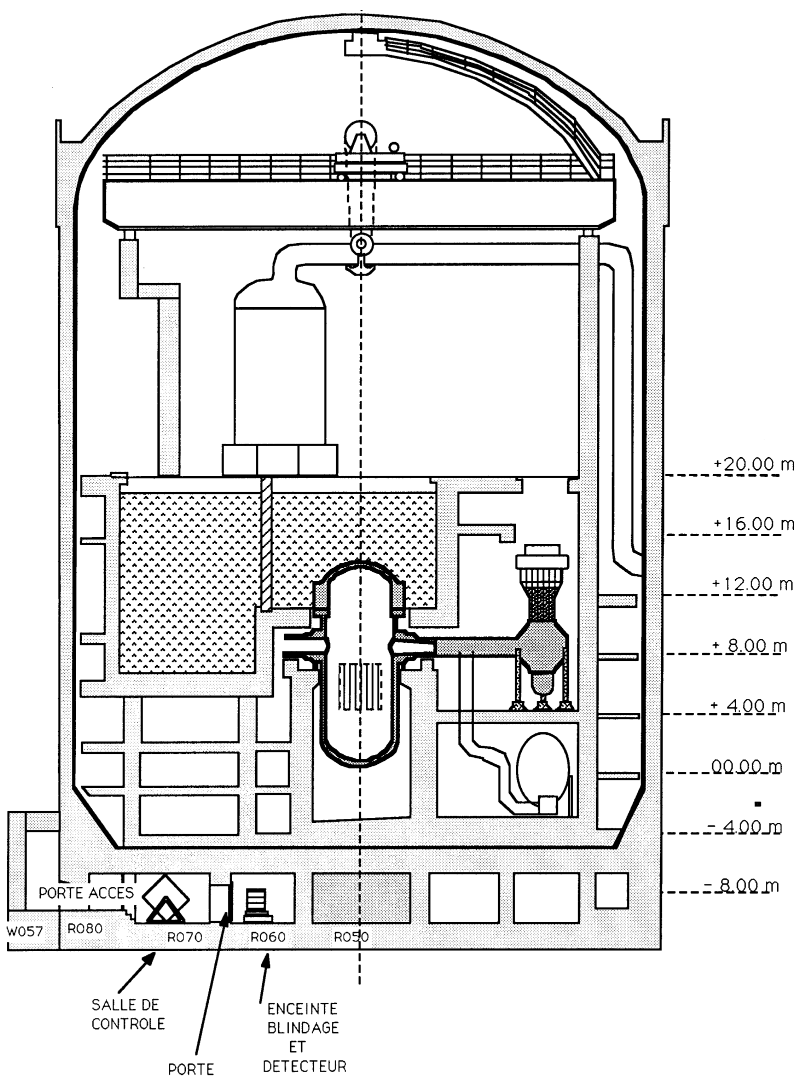
Stellar cooling, neutrinos transport energy, if they have a larger cross section this process is slowed down (model dependent):

$$10^{-12} - 10^{-11}\ \mu_B$$

Experiments:

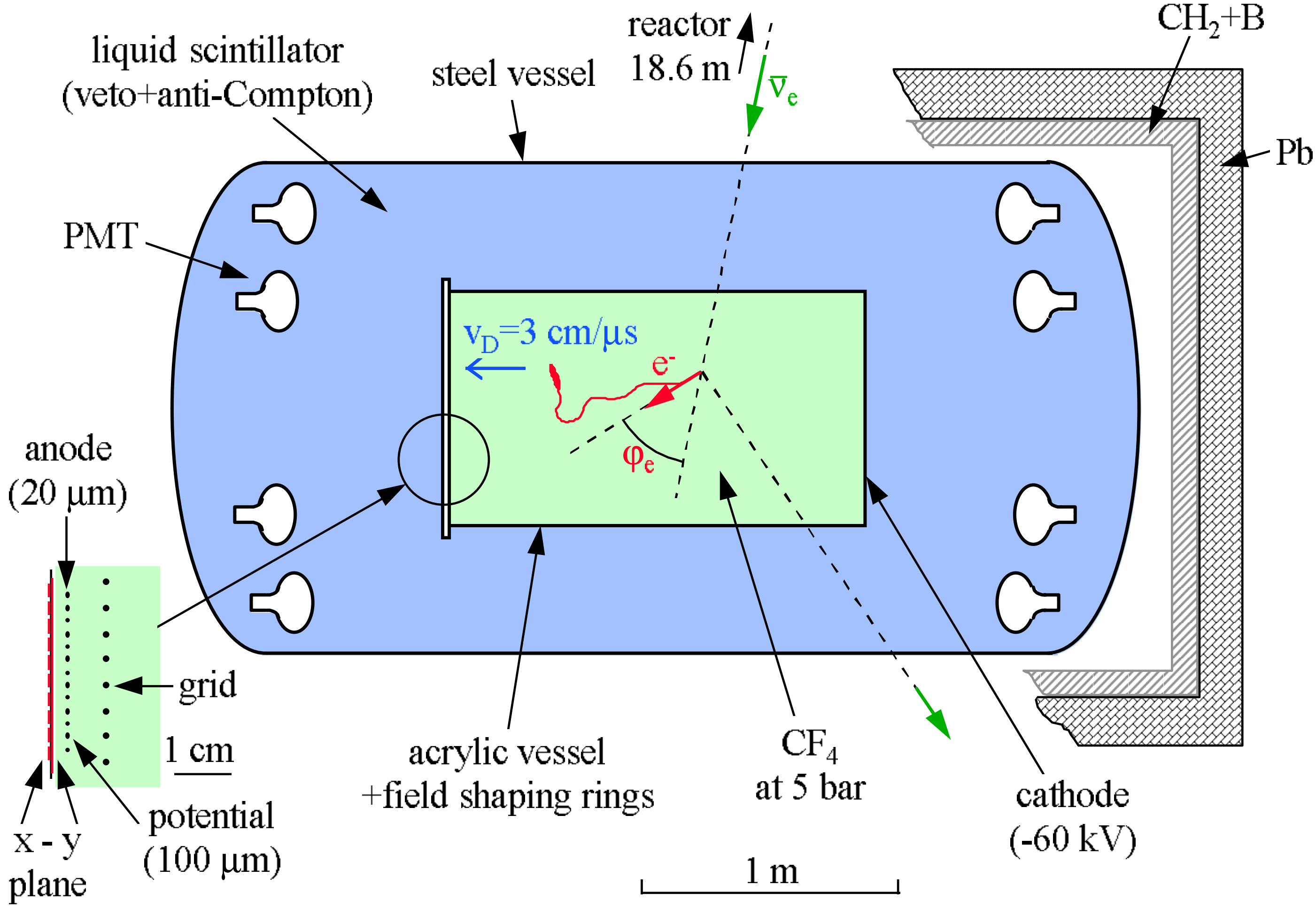
method	$\mu_\nu[10^{-10}\mu_B]$	group
$\overline{\nu_e} + e^- \longrightarrow \overline{\nu_e} + e^-$ at a reactor	$<$ 14	UC Irvine
$\overline{\nu_e} + e^- \longrightarrow \overline{\nu_e} + e^-$ at a reactor	$<$ 2.4	Kurtchatov
$\overline{\nu_e} + e^- \longrightarrow \overline{\nu_e} + e^-$ at a reactor	$<$ 1.8	Rovno
$\nu_e + e^- \longrightarrow \nu_e + e^-$ beam dump	$<$ 10.8	Lampf

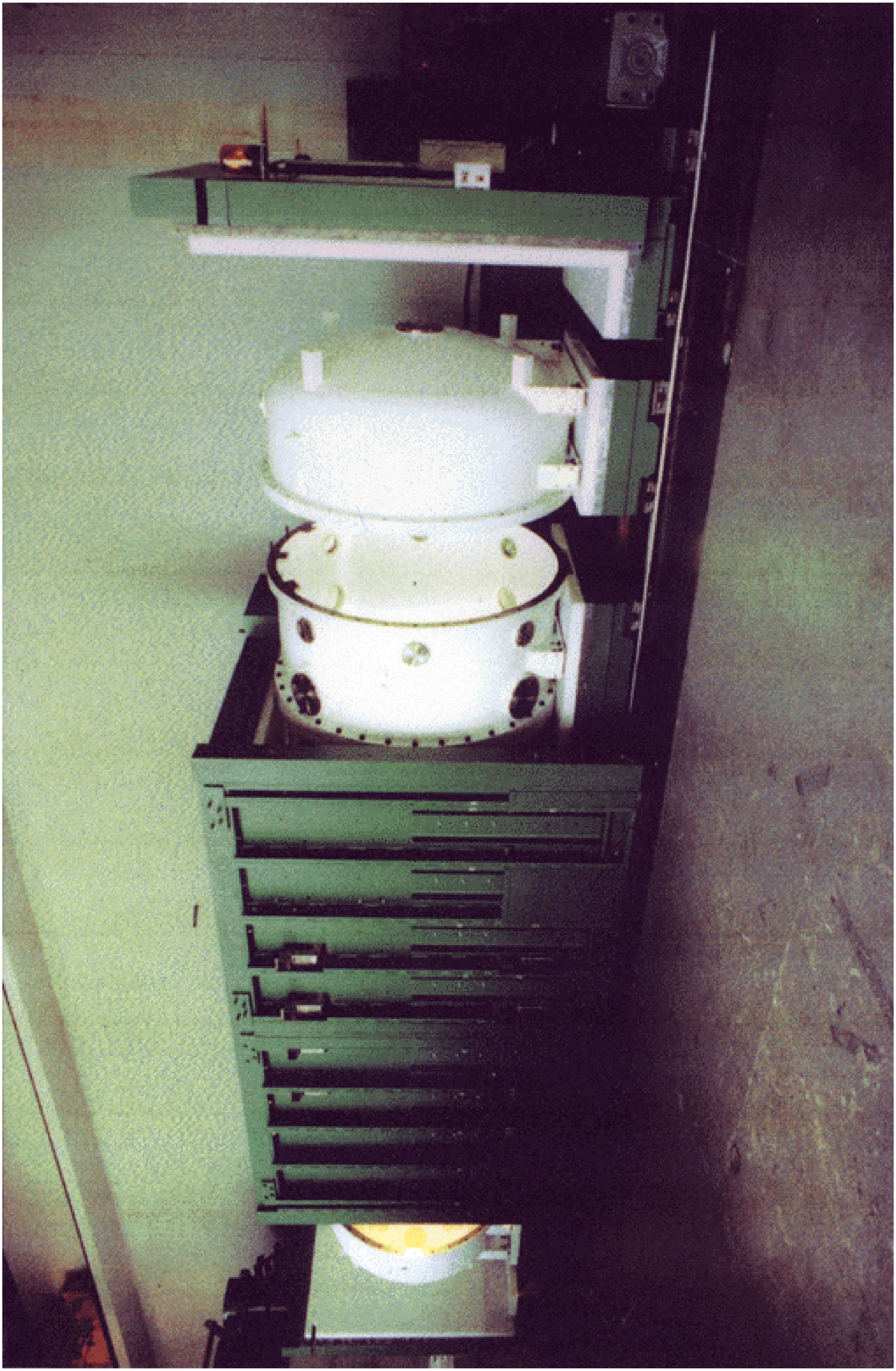
all at 90% C.L.

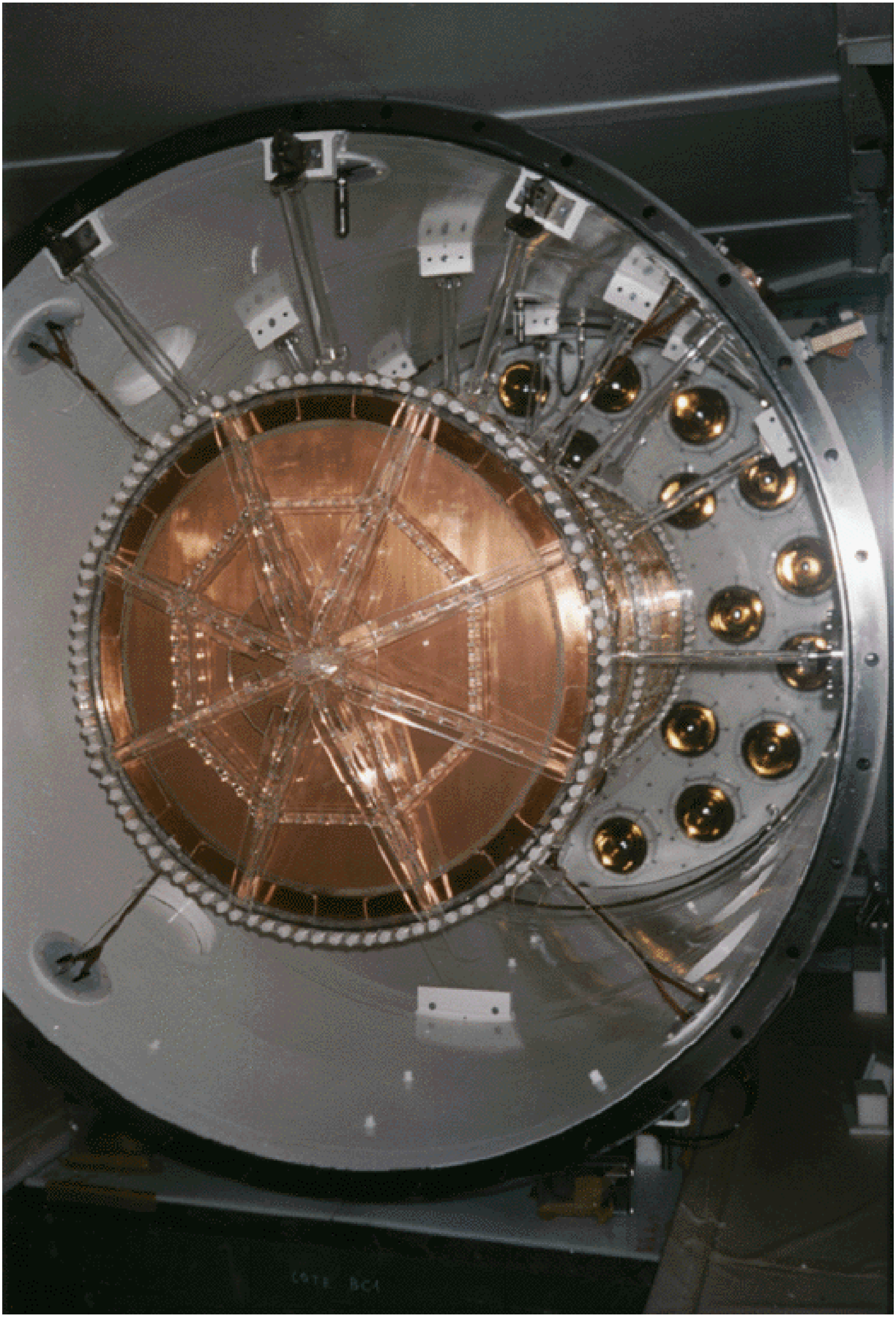

+20.00 m
+16.00 m
+12.00 m
+ 8.00 m
+ 4.00 m
00.00 m
- 4.00 m
- 8.00 m
PORTE ACCES
W057
R080
R070
R060
R050
SALLE DE
CONTROLE
PORTE
BLINDEE
ENCEINTE
BLINDAGE
ET
DETECTEUR

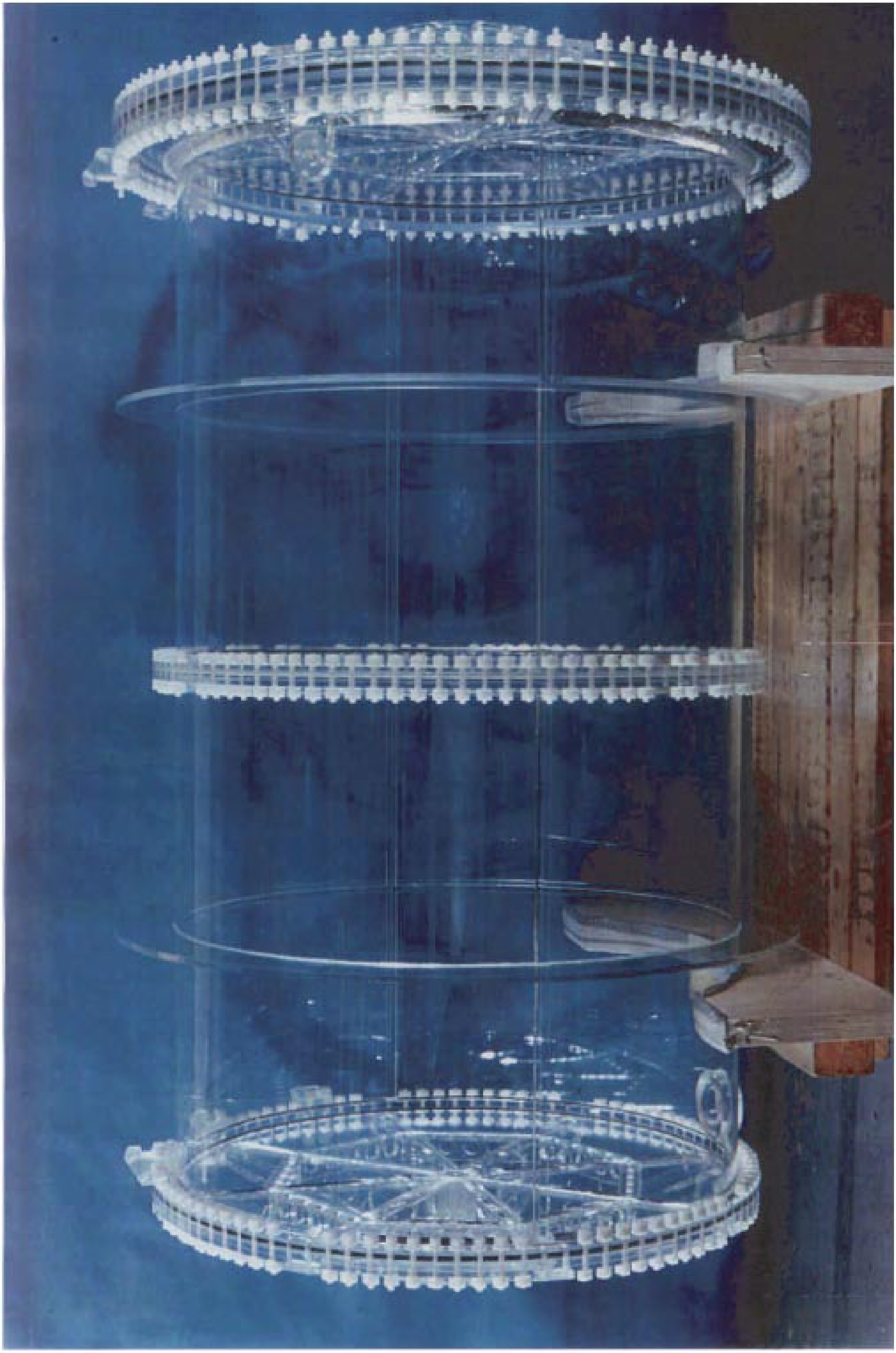
The MUNU Detector

schematic overview

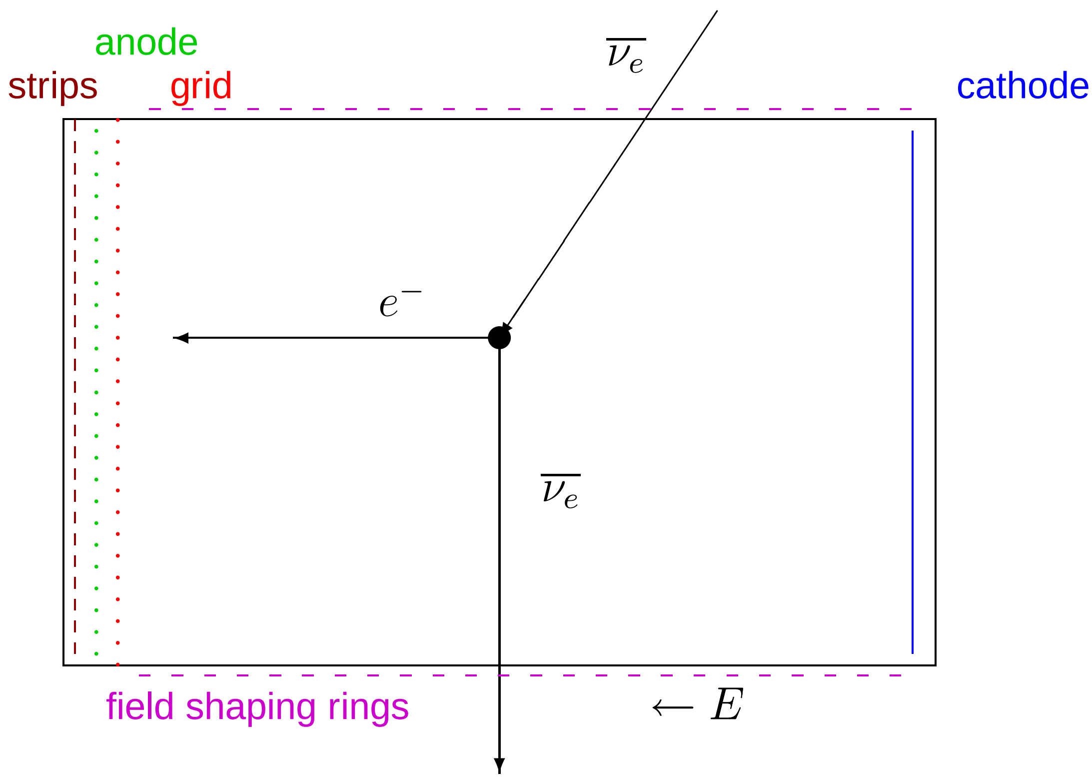








Central Detector, the TPC



The TPC is an acrylic chamber, diameter 90 cm, length 160 cm filled with 3 bar CF4 gas.

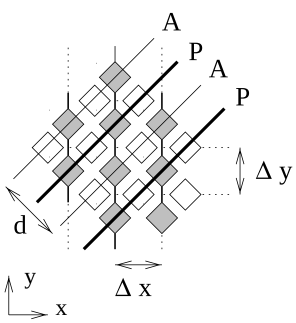
Cathode, grid and field shaping rings provide an homogeneous electric field inside (220 V/cm).

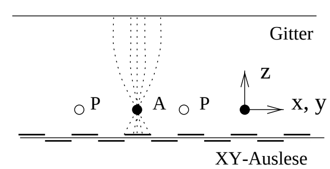
Electrons get amplified around the anode wires, (spacing 4.95 mm).

An induced signal is seen on the strips (pitch 3.5 mm).

How does a TPC work?

- If the neutrino hits an electron, the electron moves inside the gas and ionizes it.
- The ionization electrons drift towards the anode and spread out due to diffusion in the gas.
- At the anode wires the ionization electrons get amplified. The signal seen is proportional to the energy of the initial electron.

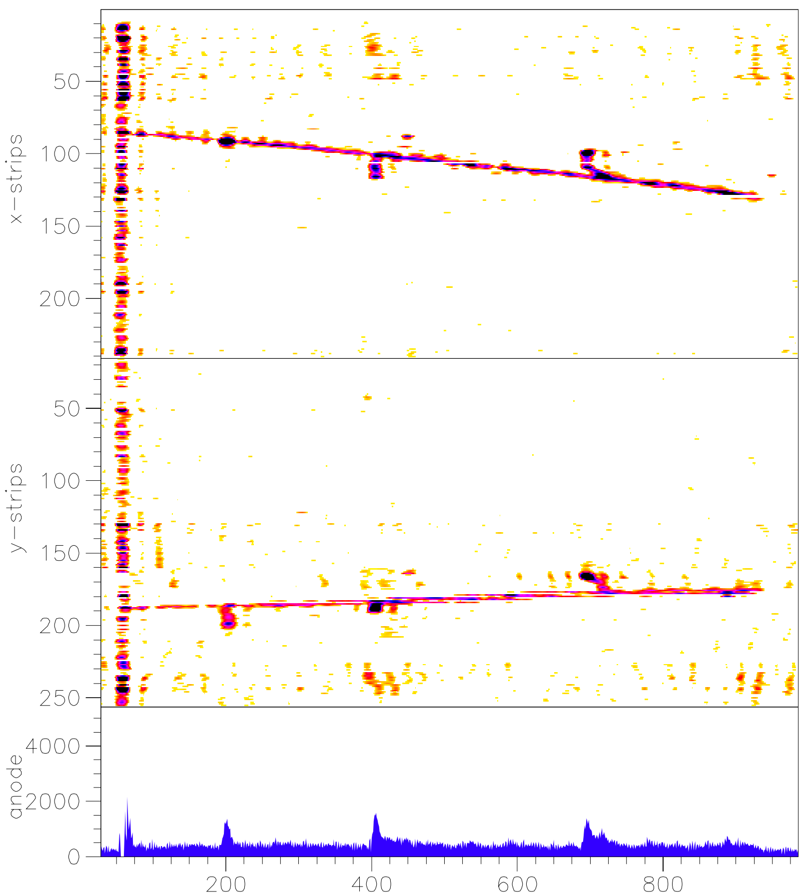




- Behind the anode is an xy-plane picking up the induced charge. This provides spatial resolution in x and y.
- The spatial information in z comes from the time evolution of the signals
- Readout: for every channel a preamplifier and an 8 bit FADC with 80 ns sampling and 1024 words of memory. This covers the whole chamber as our drift time is $72\mu s$. There are 512 strips and the anode read out this way.

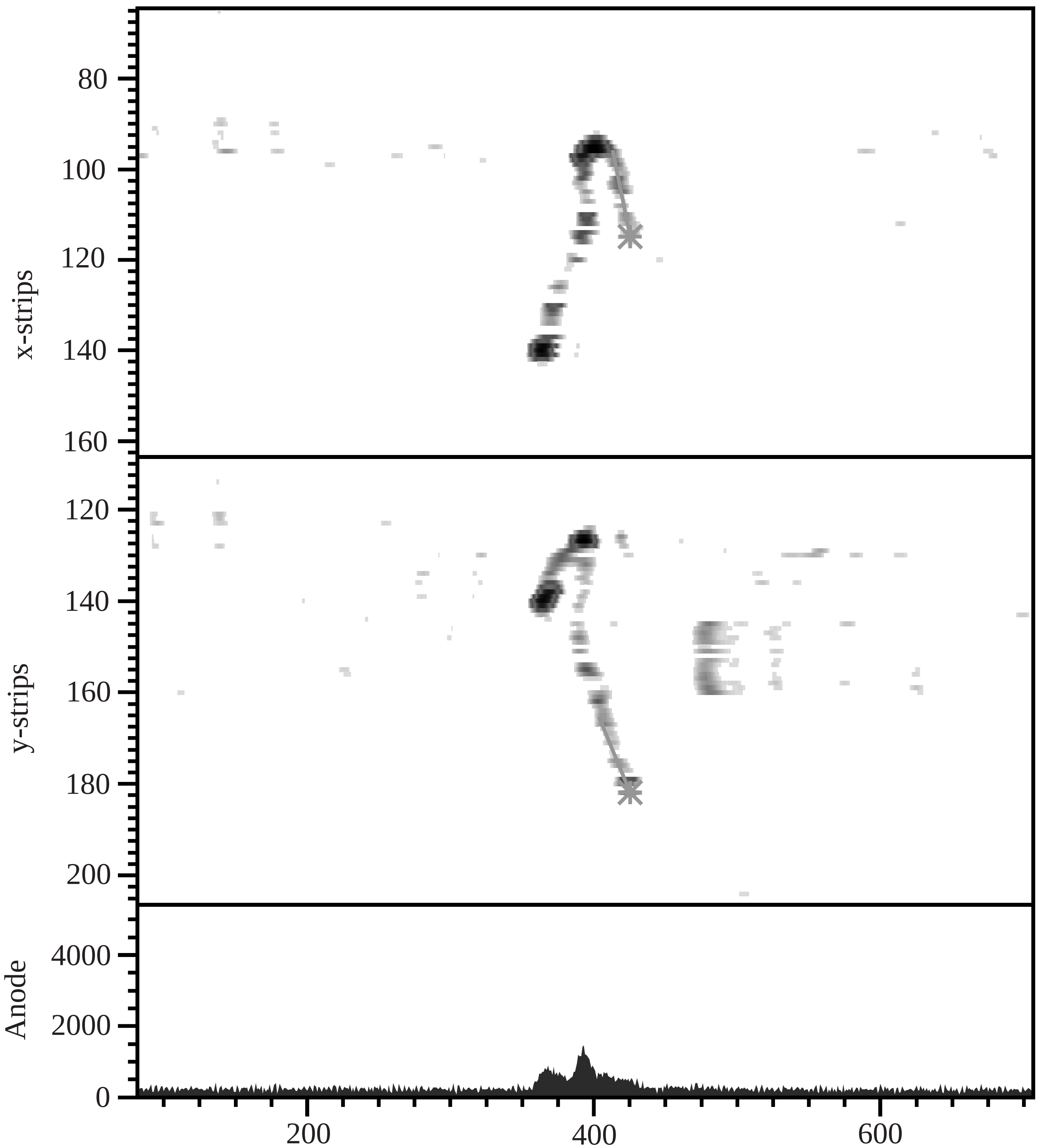
$\Longrightarrow$ events are seen in 2 projections, xz and yz

A muon



x−strips
50
100
150
200
y−strips
50
100
150
200
250
anode
4000
2000
0
200
400
600
800

An electron of 925 keV with direction fit and vertex



Contamination

- After several months running, the AC rate is 900 Hz for E $>$ 100 keV as expected from μ and internal radioactivity

- The TPC rate was in a first periode:

e	$T > 300$ keV	10 Hz
	$T > 800$ keV	0.15 Hz
α	gas	35 Hz
	cathode	0.05 Hz

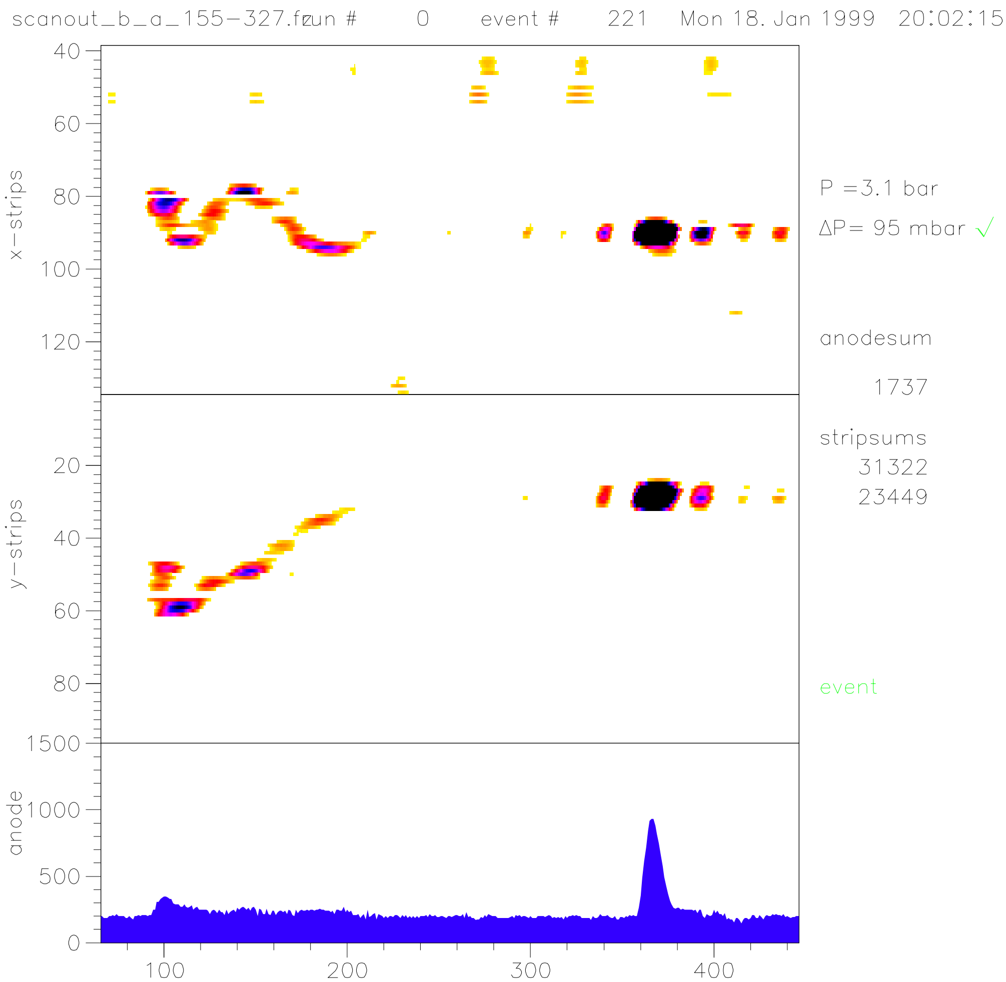
- The first data revealed a high radon background due to a contamination of the filter (oxisorb). After changing the filter:

			improvement
e	$T > 300$ keV	0.1 Hz	10^2
	$T > 800$ keV	$1.5 \cdot 10^{-3}$ Hz	10^2
α	gas	$< 5 \cdot 10^{-3}$ Hz	10^4
	cathode	0.05 Hz	$=$

- The count rate was still larger than expected.
  We exchanged the cathode on which we found a ^{210}Pb contamination.

			improvement
α	cathode	$5 \cdot 10^{-4}$ Hz	10^2

A Beta-alpha


scanout_b_a_155-327.fz run # 0 event # 221 Mon 18. Jan 1999 20:02:15
x-strips
y-strips
anode
P =3.1 bar
ΔP= 95 mbar √
anodesum
1737
stripsums
31322
23449
event

Event rates and background

- **Expected event rate** in the TPC for P = 3 bars

  $T > 300 keV$

weak	6 evt/day
elm $10^{-10}\mu_B$	3.2 evt/day

  $T > 800 keV$

weak	1.7 evt/day
elm $10^{-10}\mu_B$	0.5 evt/day

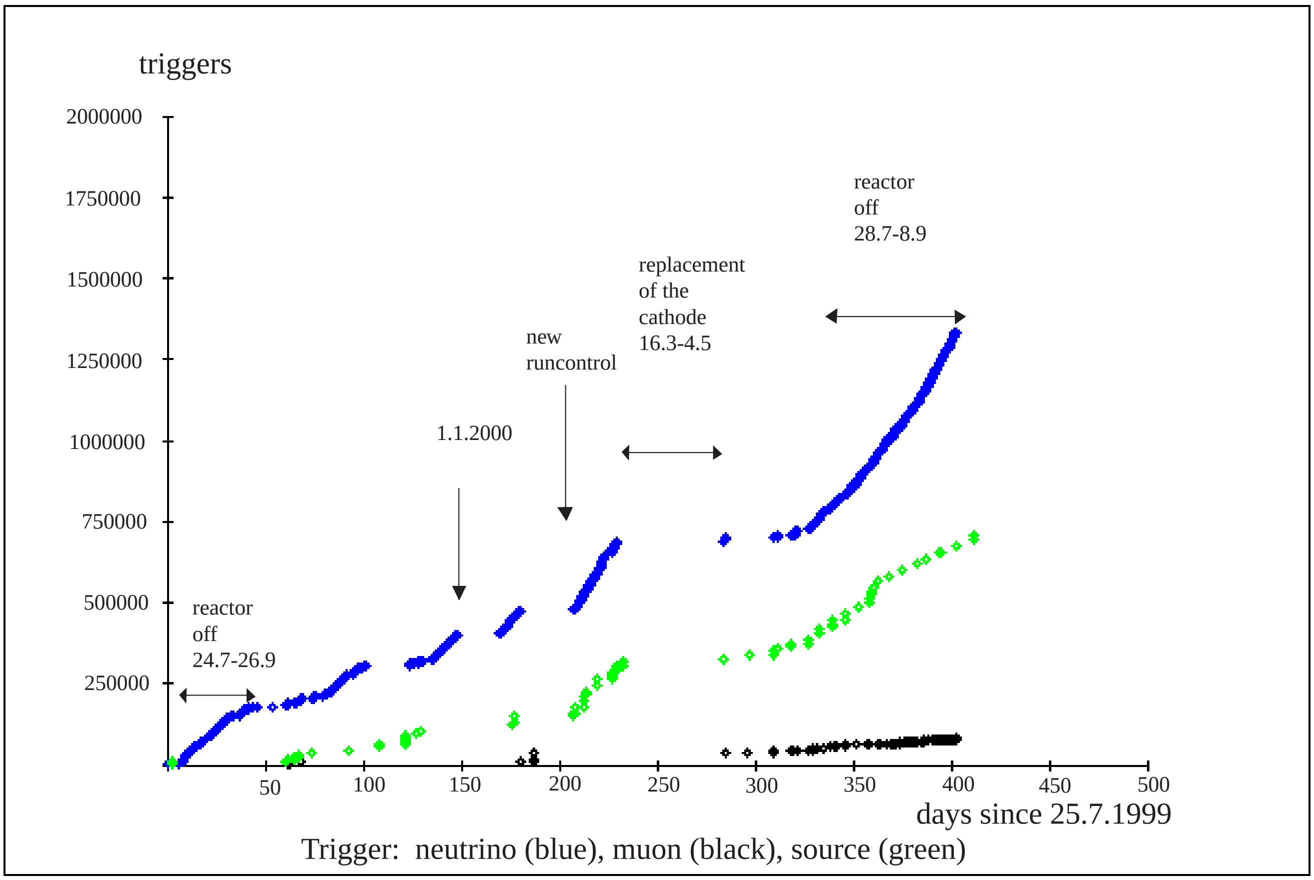
- **Internal background:**
  - β γ from U, Th, K, ...

    to limit the background from natural activities, the whole detector has been made from radiochemical pure materials
  - Neutrons (from cosmic muons)
    * $n + p \rightarrow d + \gamma$ (2.2 MeV)
    * $n + (A, Z) \rightarrow (A, Z') + \gamma$
- **External background:**
  - stopped cosmic muons: in the scintillator and lead shielding

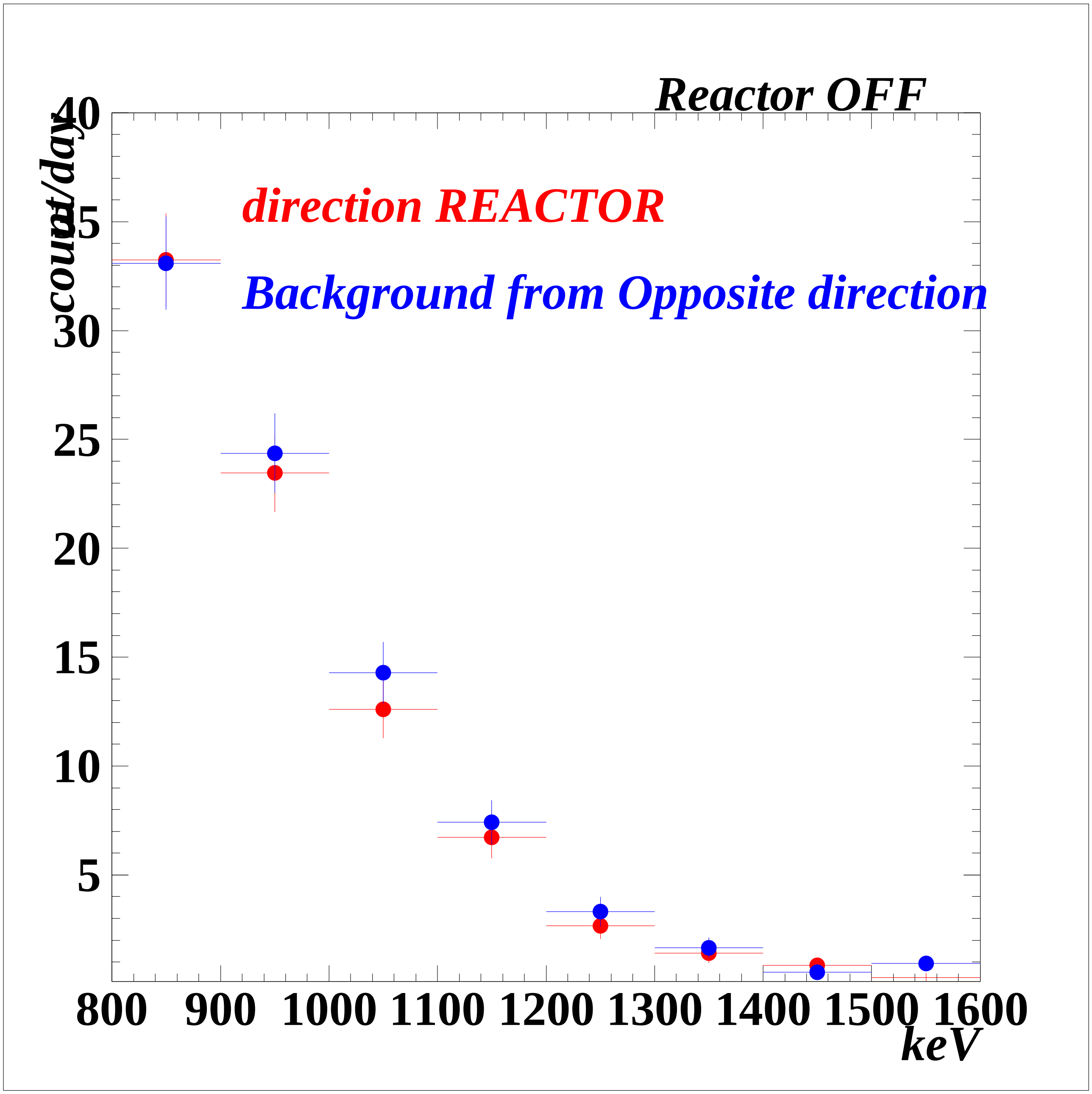
    create a beta activity.
  - reactor antineutrino in the scintillator: $5 \cdot 10^{13}/\mathrm{cm}^2\mathrm{s}$
- We expect 6 evt/day for the background with $\mathrm{E}_{\mathrm{TPC}} > 300$ keV.

Status of the experiment

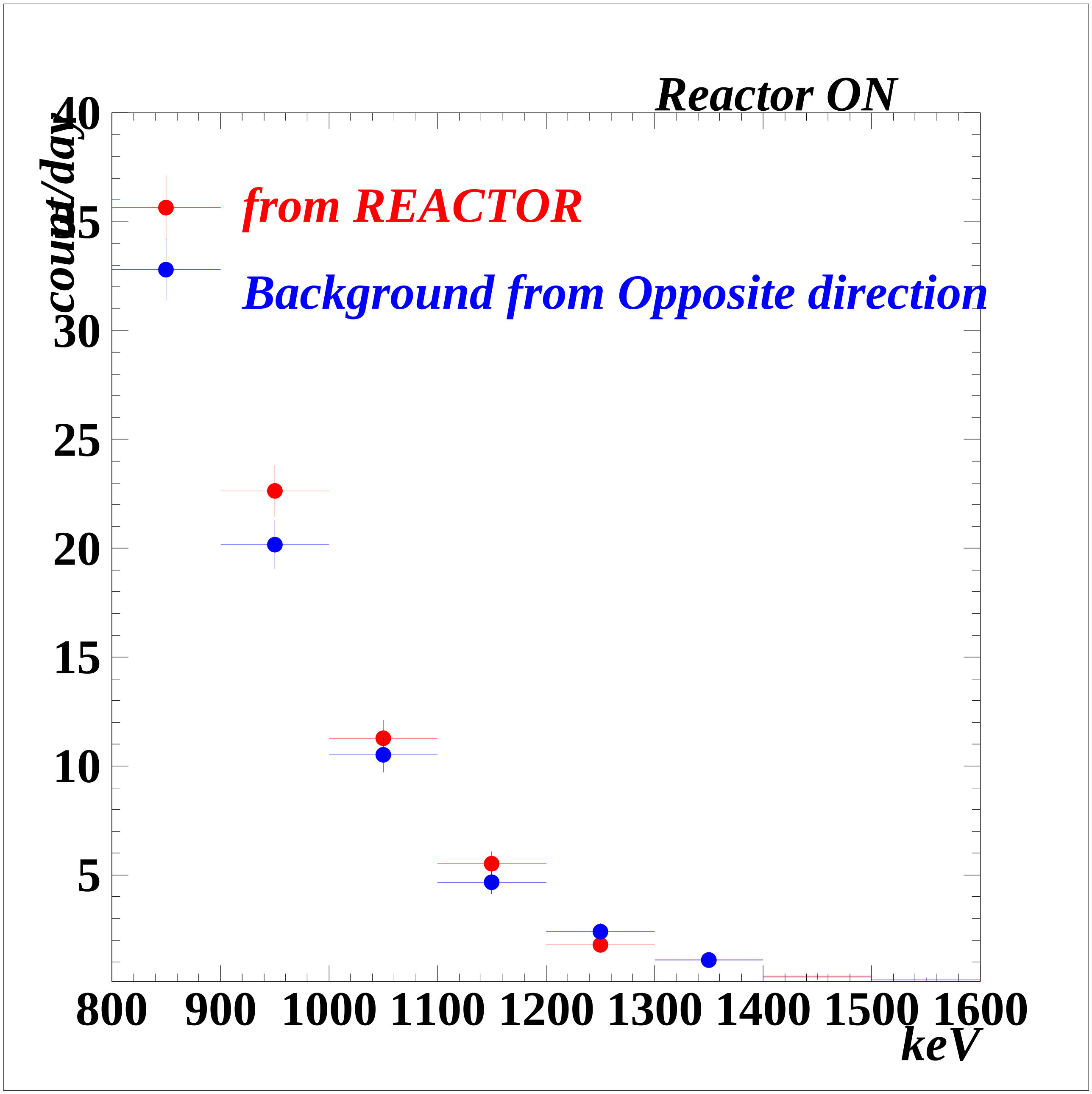
MUNU is running and taking data since more than a year.



Reaktor OFF


Reactor OFF
direction REACTOR
Background from Opposite direction
count/day
40
35
30
25
20
15
10
5
800 900 1000 1100 1200 1300 1400 1500 1600
keV

Reaktor ON



Reactor ON
count/day
40
35
30
25
20
15
10
5
800 900 1000 1100 1200 1300 1400 1500 1600
keV
from REACTOR
Background from Opposite direction

Conclusions

The experiment is running stable since more than a year.

The systematics have been studied and understood.

We had serious problems due to $^{222}\mathrm{Rn}$

Background reduction by a factor 10^4

Now taking reactor ON data until next year

$\Rightarrow$ interesting limit or value for μ_ν will come out, needs about 1 y of data