ISINN-23, Dubna, Russia, May 23-27, 2016

# Applications of Low-Pressure Gaseous Multiwire Detectors to Measurement of Angular Distributions of Nuclear Fission Fragments and for Monitoring of Neutron Beam Profile at Neutron Spectrometer GNEIS


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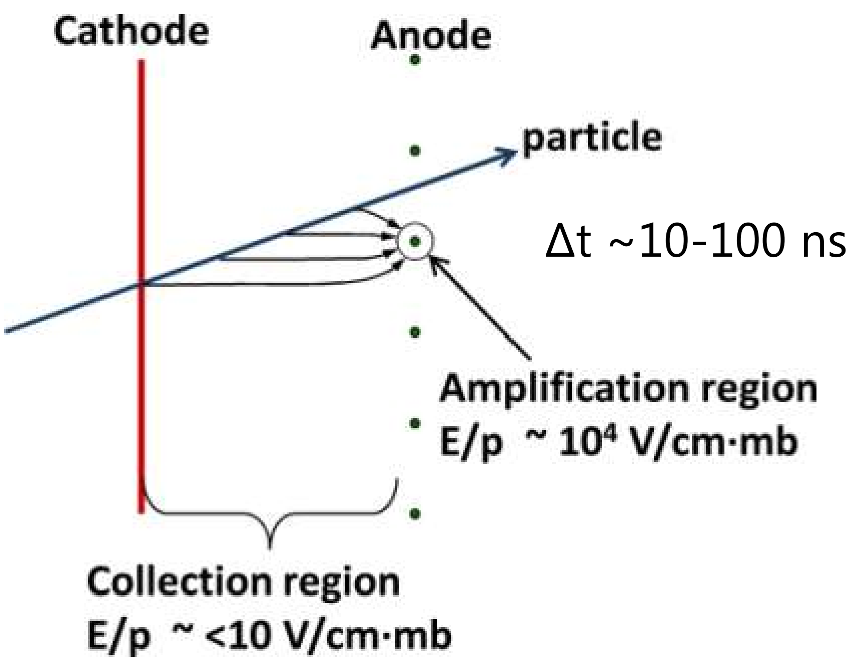
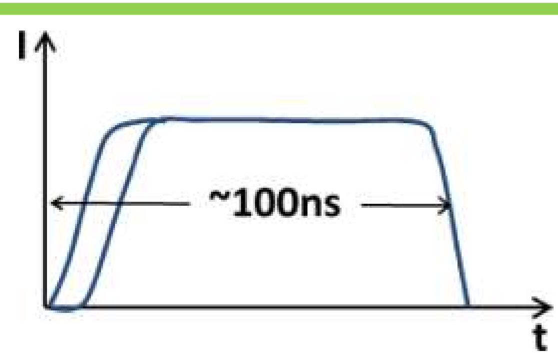
Gatchina, Russia

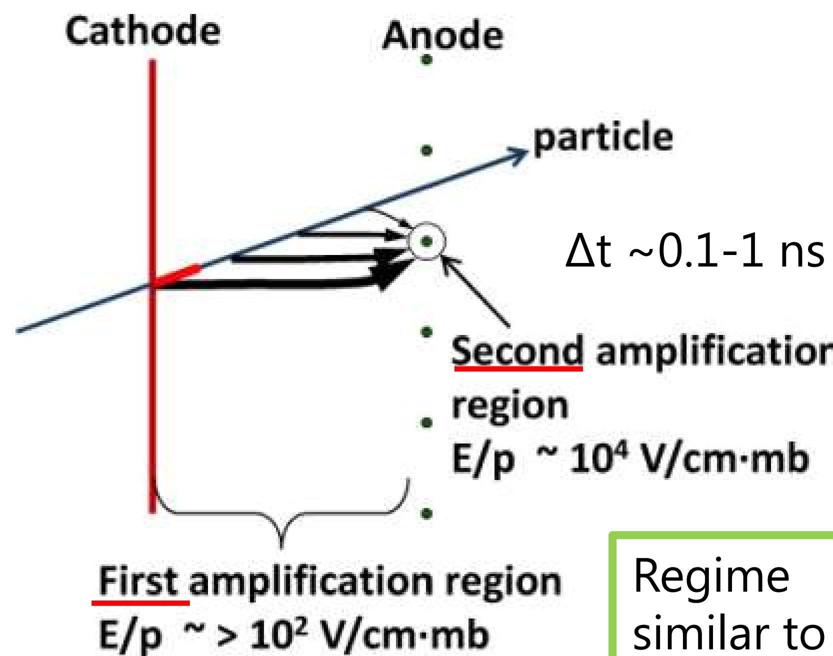
# Operation principle of low-pressure MWPCs

**Convential MWPC**:
G. Charpak, Ann Rev. Nucl. Sci. 20 (1970), p. 195.

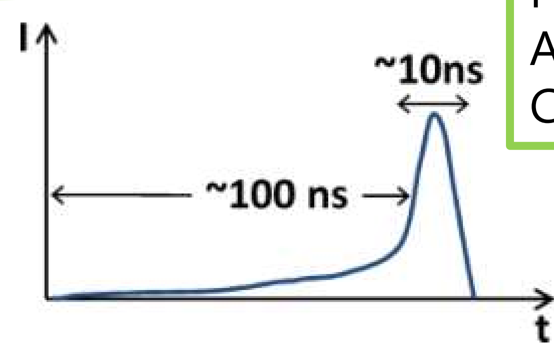



**Low-pressure MWPC:**
F. Binon et al., NIM 94 (1971), p. 27.
A. Breskin, NIM 196 (1982), p. 11. (review)




Regime similar to Parallel Plate Avalanche Counter



# Main characteristics of low-pressure MWPCs

Working pressure: **~0.1-10 mbar**

Counting gases: **isobutane, heptane, ethylene**

Anode-cathode gap: **~1.6-3.2 mm**

Anode wire spacing: **~1 mm**

Anode wire diameter: **~10-25 μm**

Reduced electric field in the constant field region: **$\sim 10^2$-$10^3$ V/(cm·mb)**

Reduced electric field on the wire surface: **$\sim 10^4$-$10^5$ V/(cm·mb)**

Gas amplification: **$\sim 10^4$-$10^6$**

Amplification on the wires: **$\sim 10^1$-$10^3$**

Current pulse rise time: **~2-5 ns**

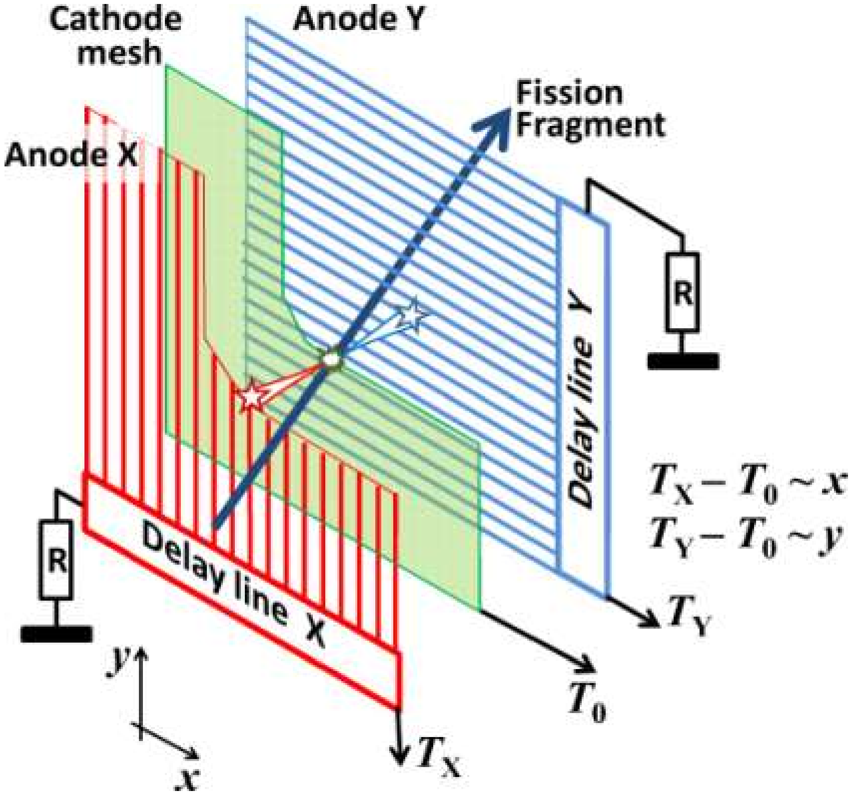
Timing resolution **~0.1-1 ns**

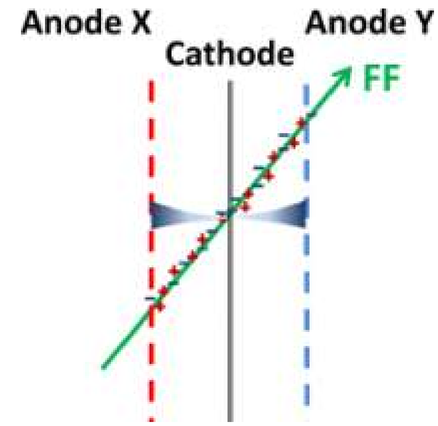
**Main advantages**

- Excellent timing characteristics
- High efficiency
- High transparency and Low energy losses inside
- Large surface area
- High rate capability
- Good position resolution with proper readout
- Good stability
- Simple, cheap, effective

**Very well suited for Fission Fragments registration**

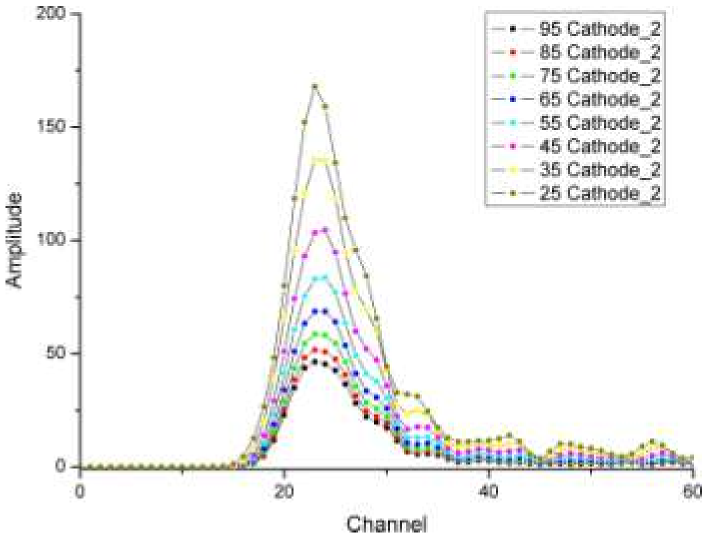
# Detector construction

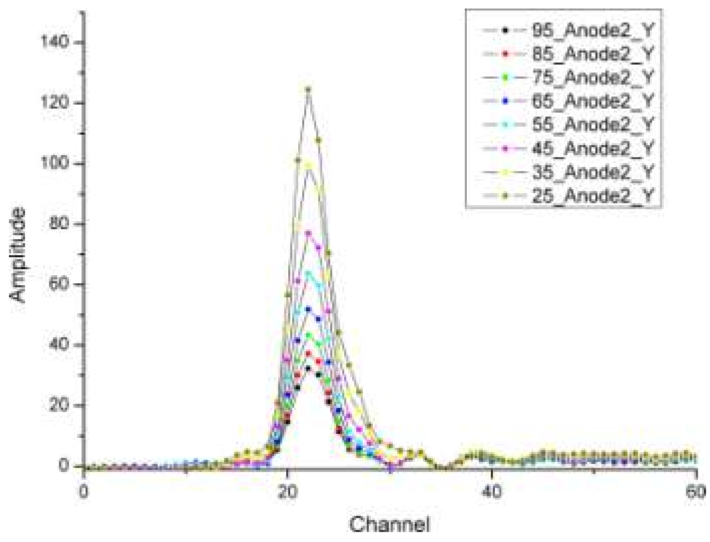


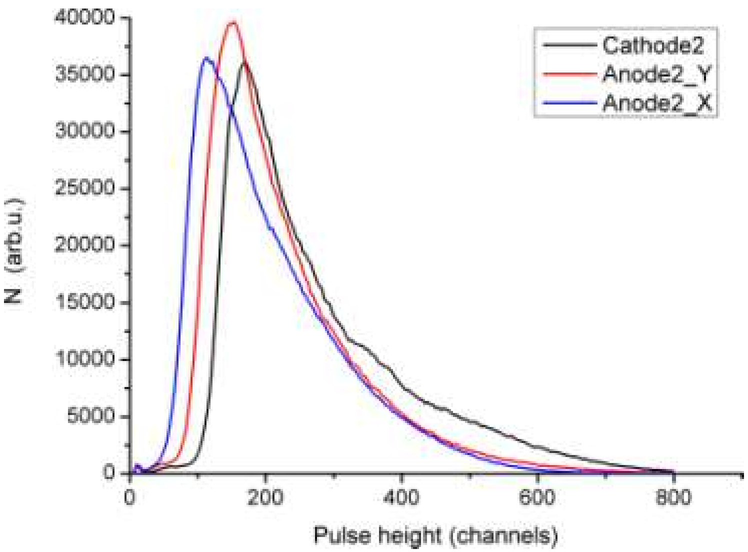

Sizes 140×140 mm;
Distances between electrodes planes 3.2 mm;
Anodes are made of 25 μm gold plated tungsten wire 1 mm spacing;
Cathodes are made as square mesh of the same wire 1 mm spacing;
Each 2 wires are connected to delay lines taps (50 Ω impedance, 2 ns per tap);
Working gas is Isobutan at 8 mbar;
$HV_{anode\text{-}cathod}$ = 560 V

# Signals from the detectors




**Average signals waveform**




**Pulse height distributions from electrodes.**

# Fission fragments angular distributions studies

The angular distributions of fission fragments are related with the properties of transition states of a fissioning nucleus at the saddle point. The studies always considered as an important tool to access the key characteristics of the fission process.

The angular distributions data are very important for precise measurements of the fission cross-sections, because it should be taken into account as efficiency correction for non 4π detectors.

So, these data are not only of high scientific value, but of great significance for nuclear technologies as well (accelerator-driven systems.
Nowadays there is considerable interest to nuclear fission at intermediate (En < 200 MeV) and higher neutron energies

# Fission fragments angular distributions studies

Fragments angular distribution in the model of axially symmetric transition states at the saddle of fissioning nucleus (wave functions of axially symmetric top) :

$$W^J_{M,K}(\theta) = \frac{2J+1}{2}\left|d^J_{M,K}\right|^2$$

For low excitation energies we need a proper sum over *M* distribution, and few available *J*, *K* (fission channels ):

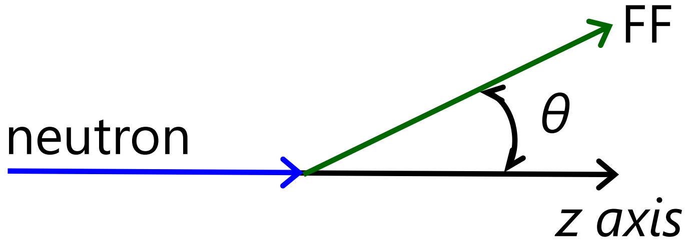
$$W(\theta) \sim \sum_{n_{even}} A_n P_n(\cos\theta)$$

At higher excitations with many opened fission channels one can use statistical model for the *K* projection distribution – *ρ*(*K*) :

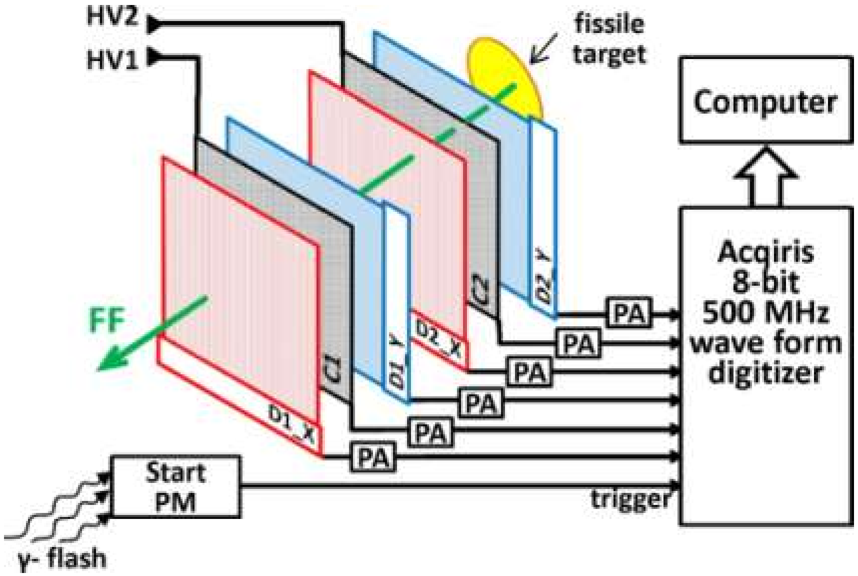
$$W(\theta) \sim 1 + A\cos^2\theta$$

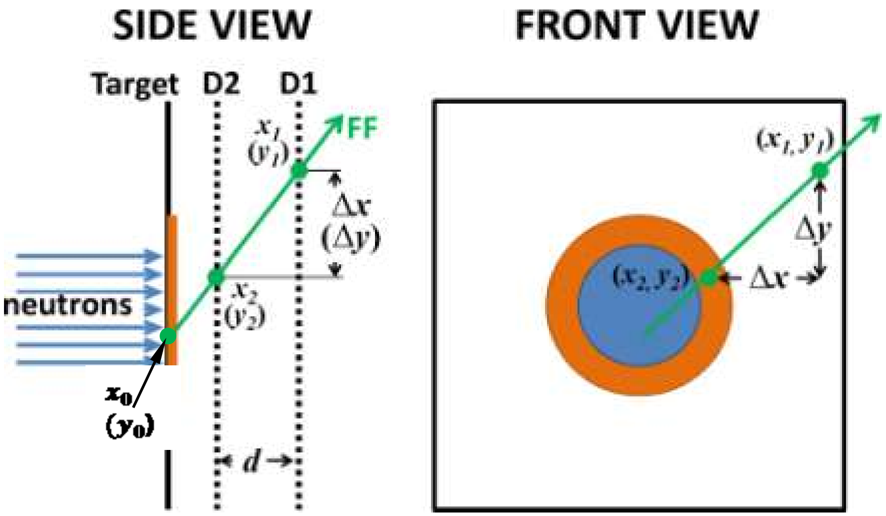
Parameter measured in experiments:

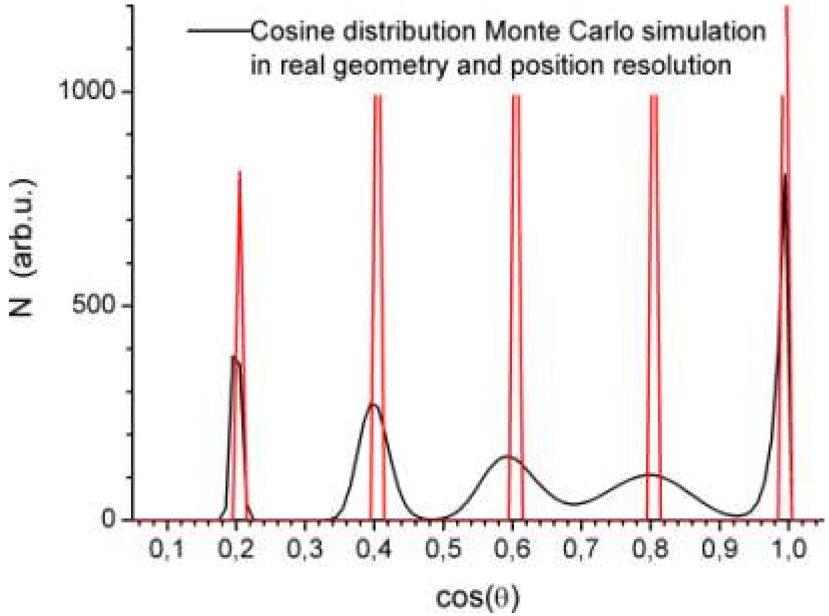
[redacted]



# Experimental setup for fragments angular distributions studies



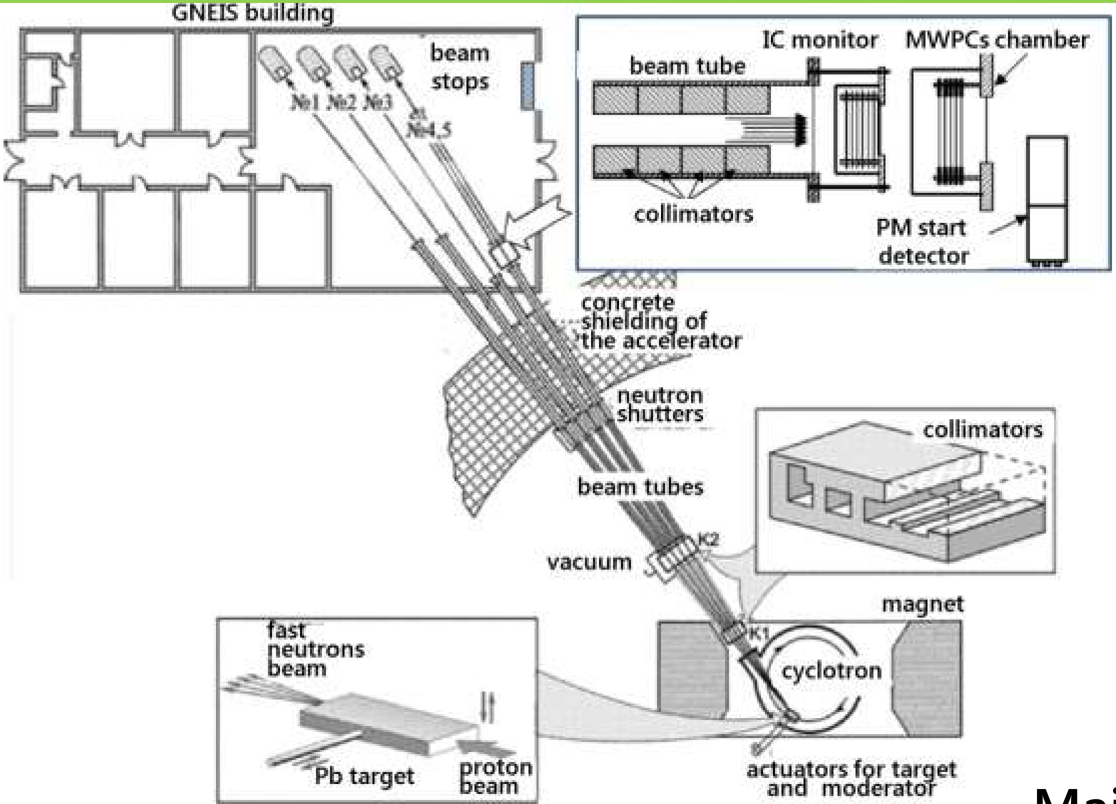



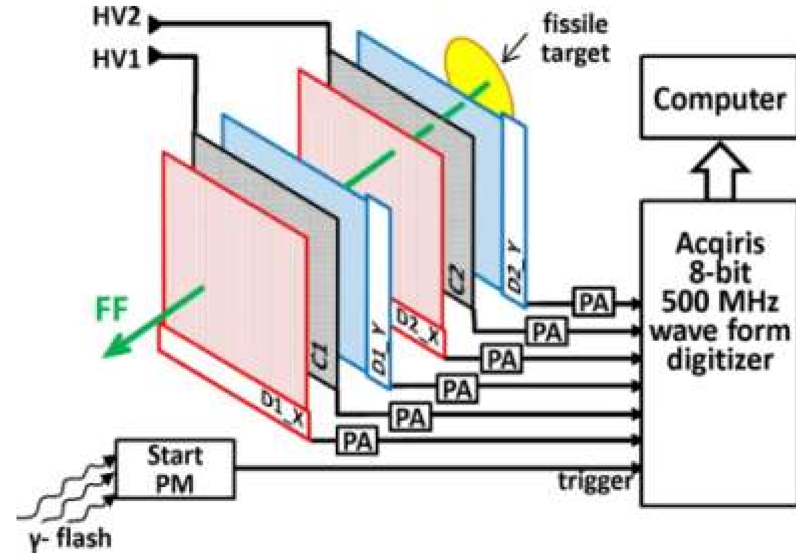

$$\cos\theta = \sqrt{\frac{d}{(\Delta x)^2 + (\Delta y)^2 + d^2}}$$

$$(x_1, y_1), (x_2, y_2) \rightarrow (x_0, y_0)$$

# Experimental setup for fragments angular distributions studies

## in fission induced by 1-200 MeV neutrons at neutron spectrometer GNEIS




[redacted]

**Main parameters of GNEIS:**

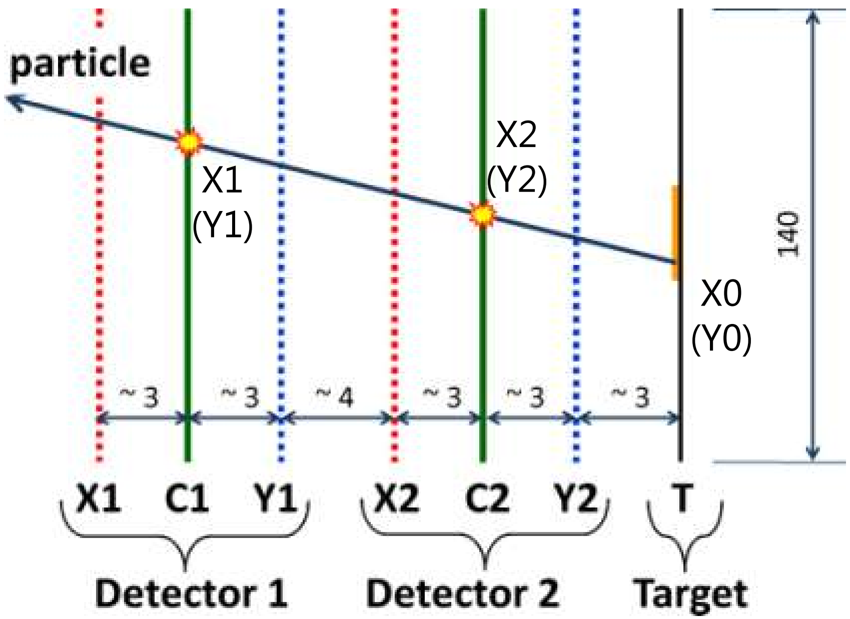
$E_p = 1$ GeV; $\Delta t \approx 10$ ns;

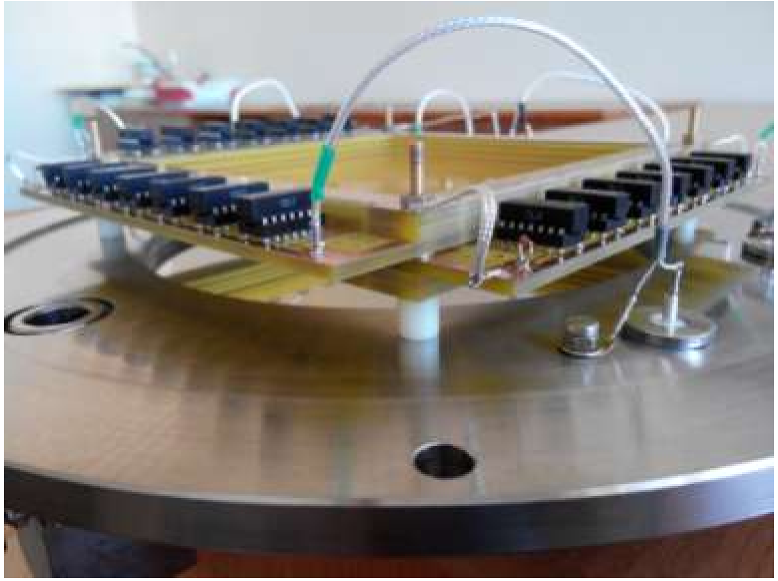
$f \approx 50$ Hz; $\Phi \sim 3 \times 10^{14} \frac{\text{n}}{\text{s}}$;

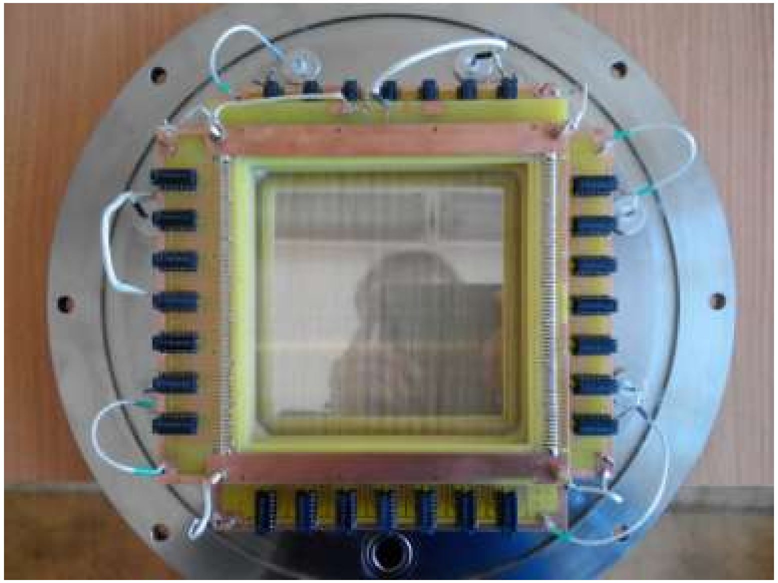
$L = 35.5$ m

[redacted]

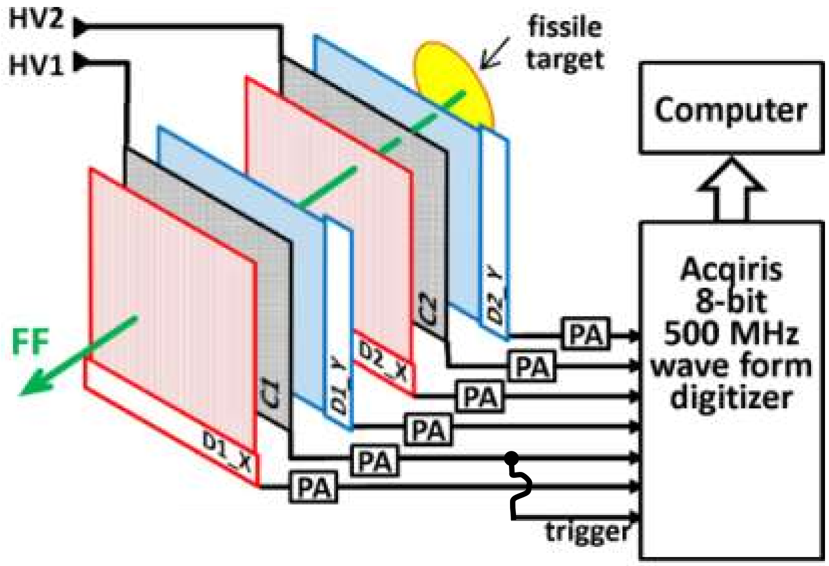
# Experimental setup





# Tests with 252Cf spontaneous fission source

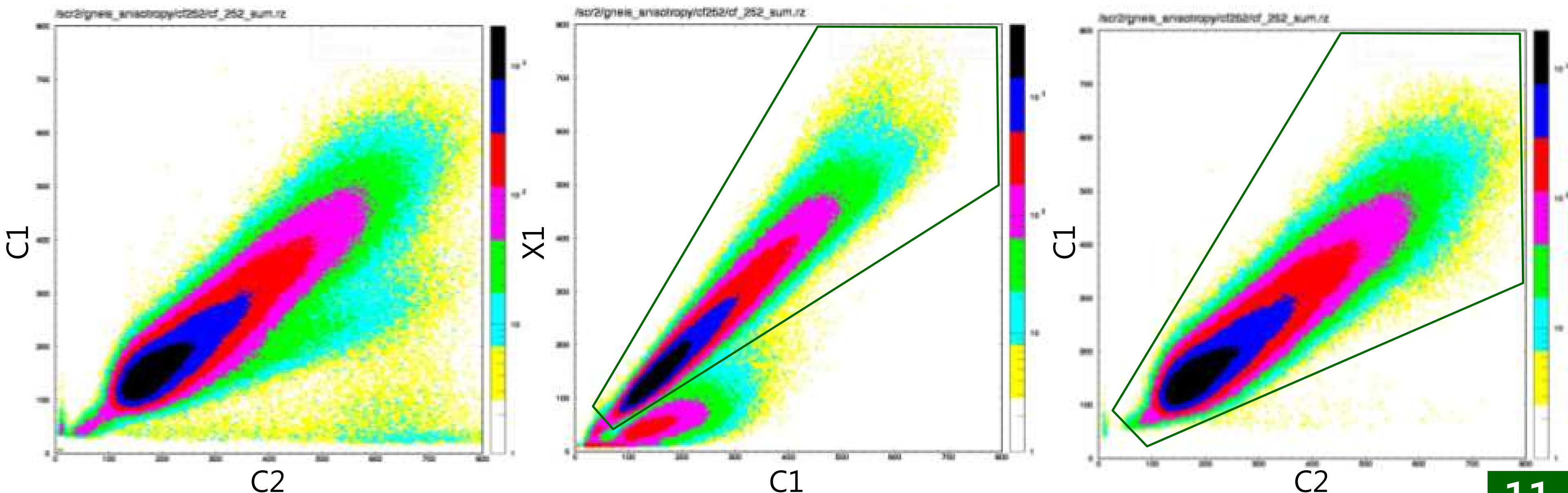



**Diameter ~10 mm**

**Intensity ~ $10^4$ fissions/s**

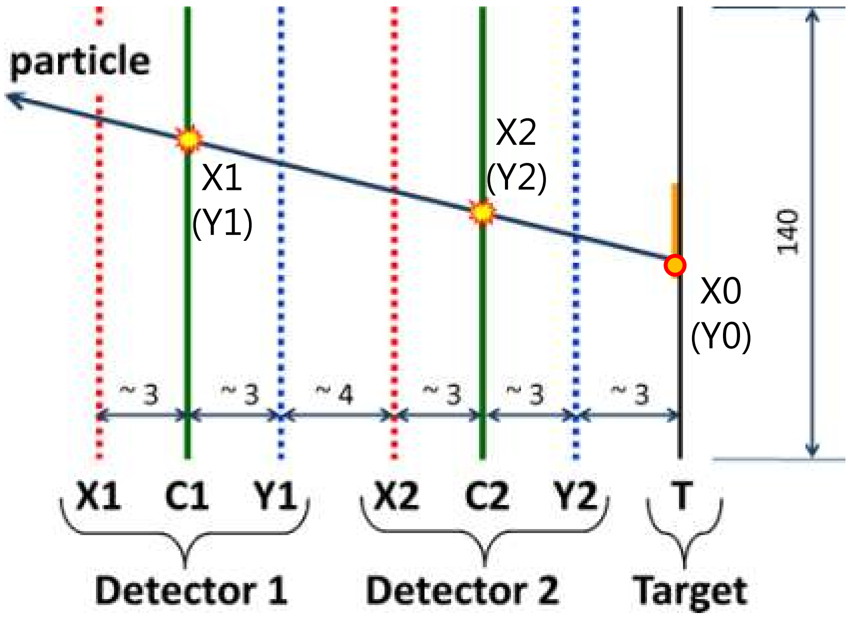
**Isotropic source !**

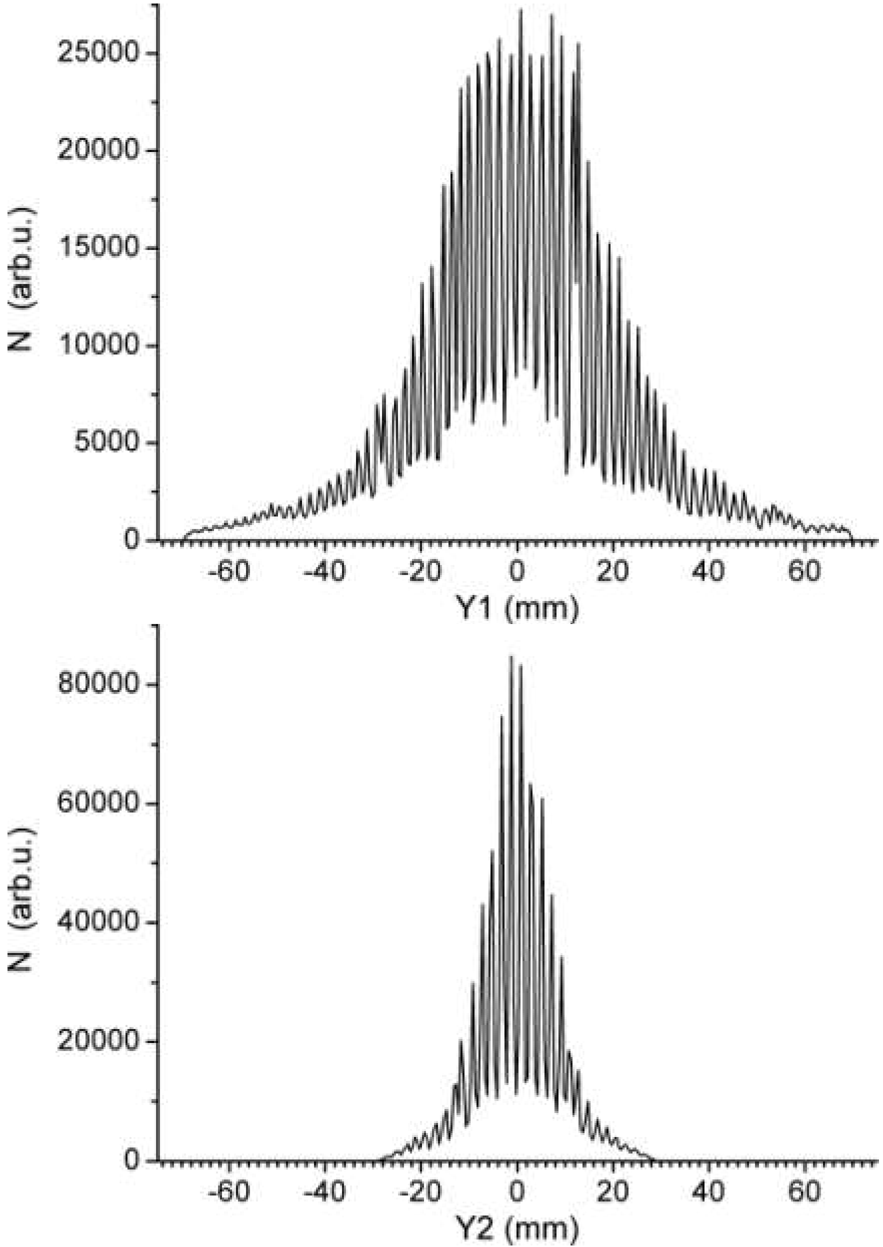
## Signals amplitudes distributions and events selections



# Tests with 252Cf spontaneous fission source

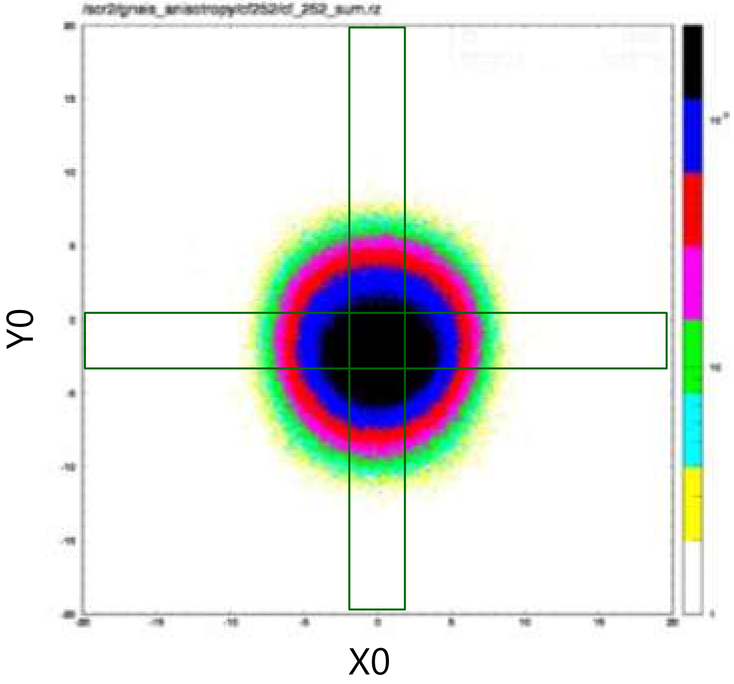
## Positions determination

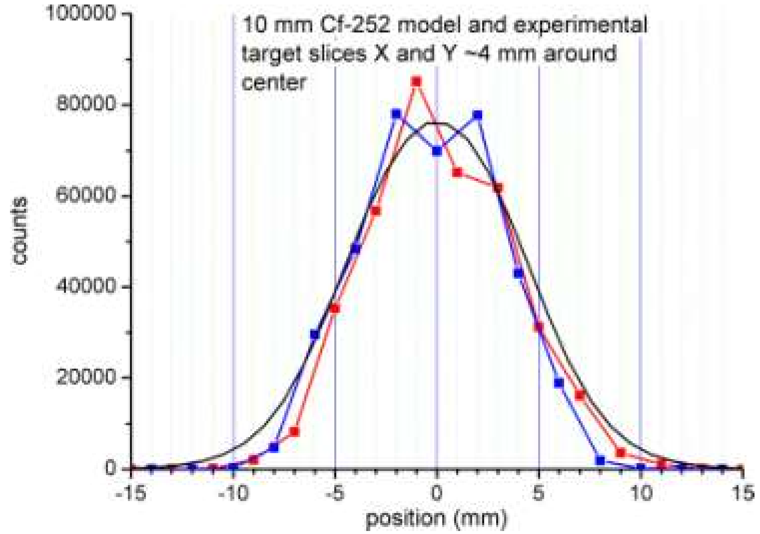


# Tests with 252Cf spontaneous fission source

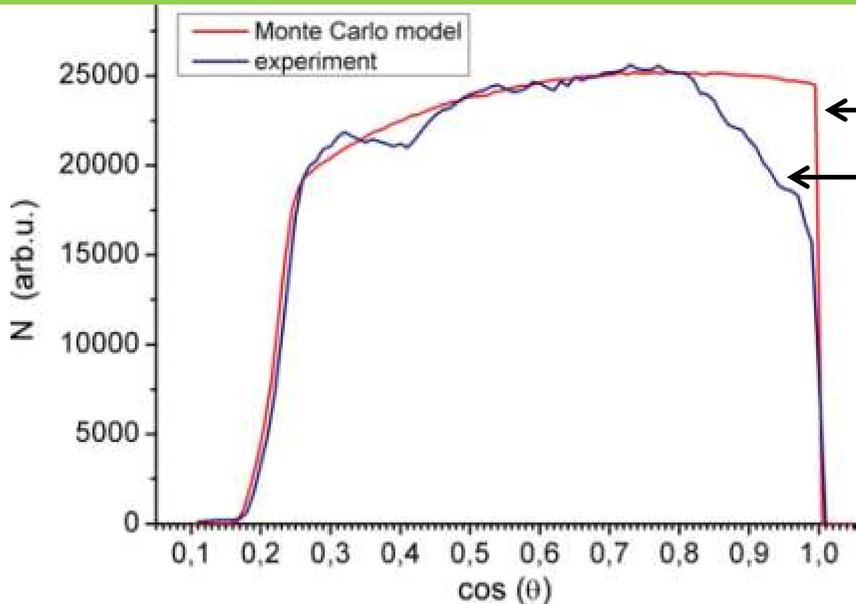
## Positions determination



# Tests with 252Cf spontaneous fission source

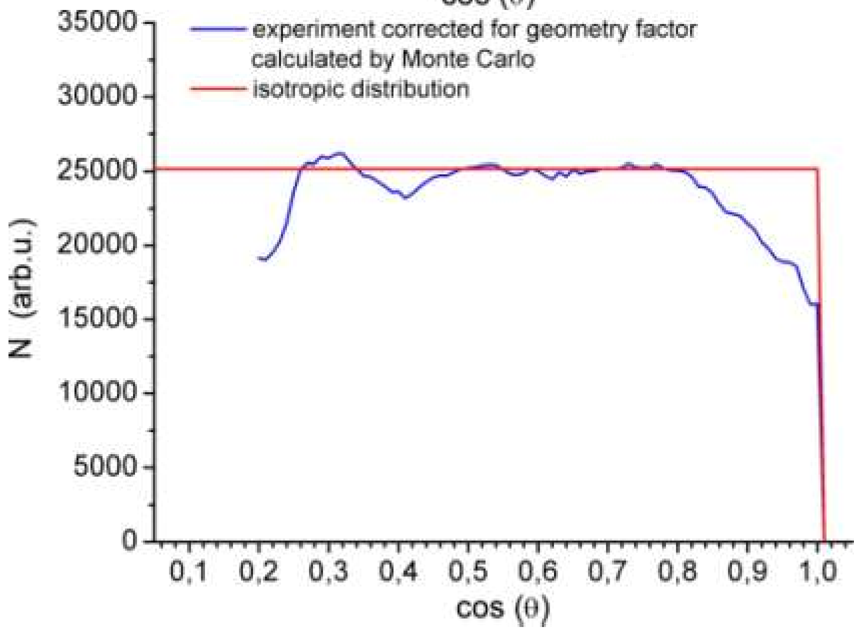
## Cosine distributions




$W_{MC}(\theta)$

$W_{exp}(\theta)$

$$k_{geom} \sim \frac{1}{W_{MC}(\theta)}$$




$$W_{geom}(\theta) = k_{geom} \cdot W_{exp}(\theta)$$

[redacted]

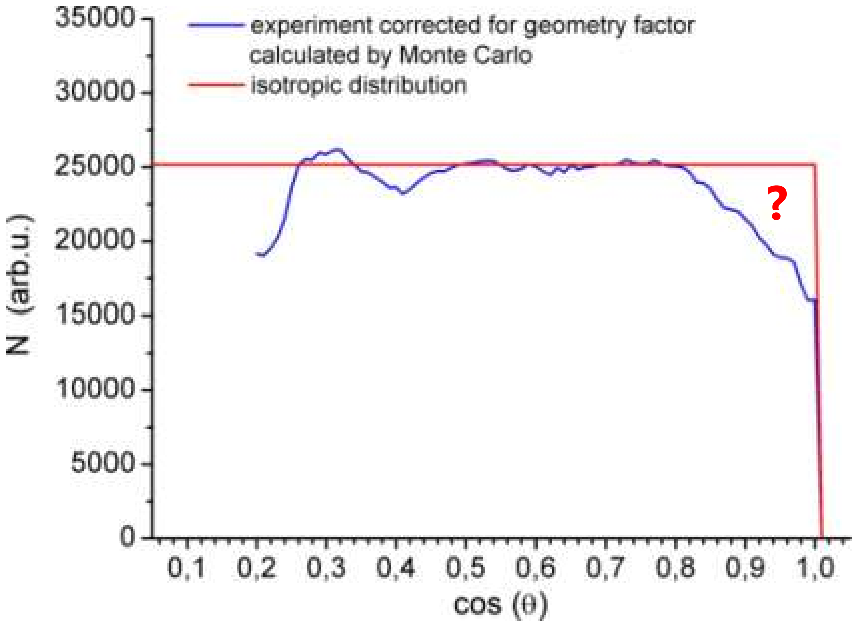
**Total correction factor:**

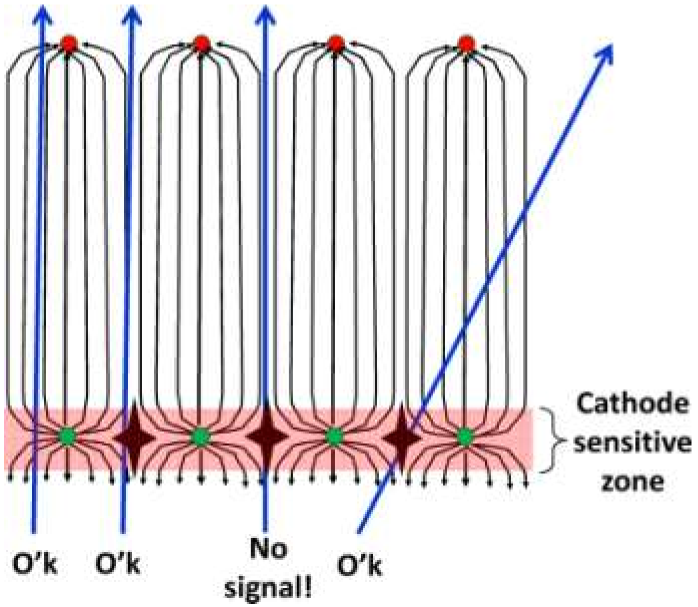
$$k = k_{geom} \cdot k_d$$

# Tests with 252Cf spontaneous fission source

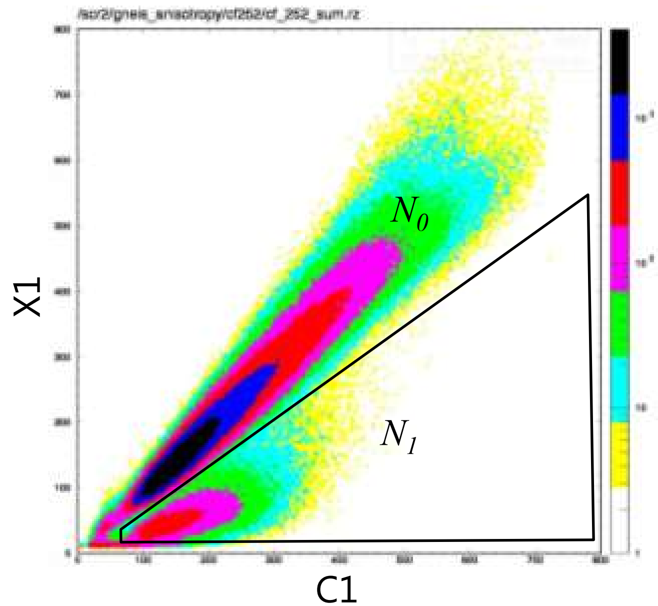
## Cosine distributions

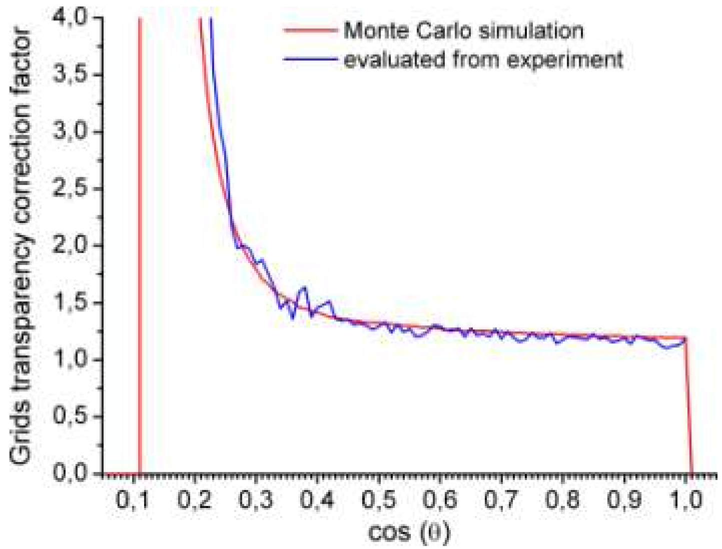
The question arises, what is the reason for
the difference from
pure geometrical correction?



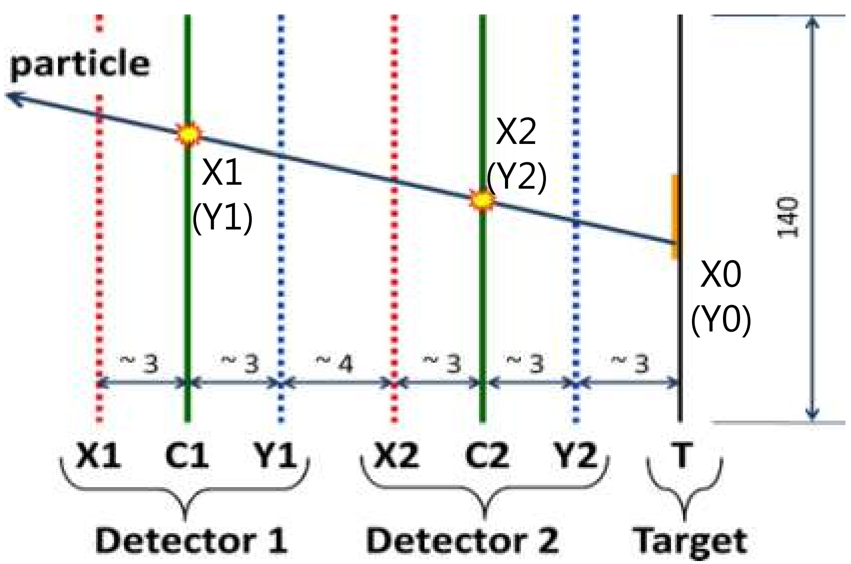



# Grids transparency

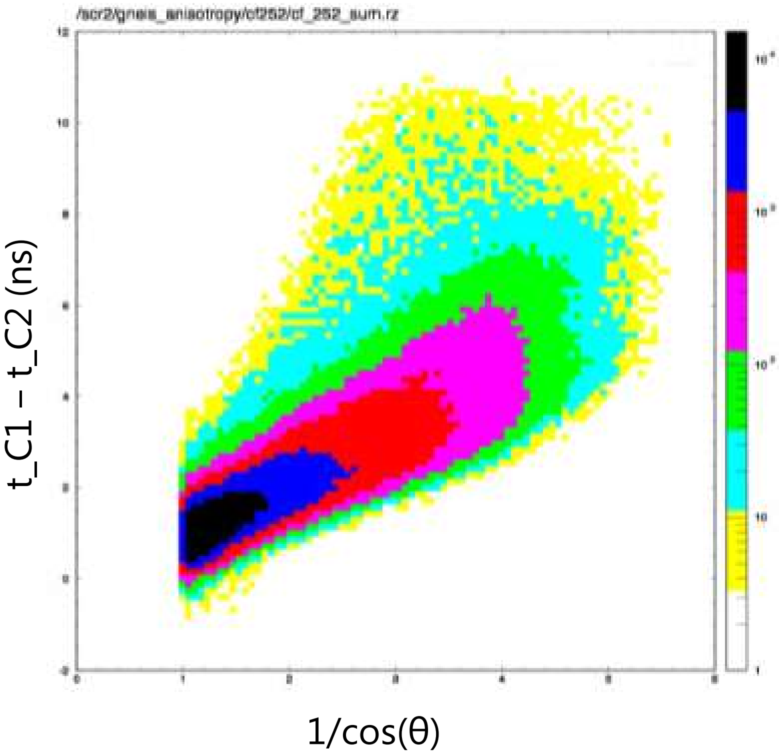


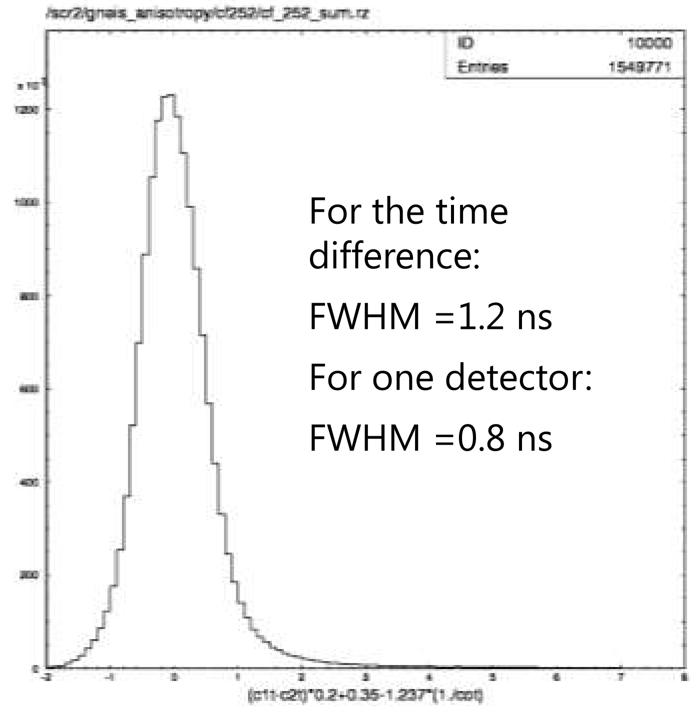




[redacted]



# Time resolution



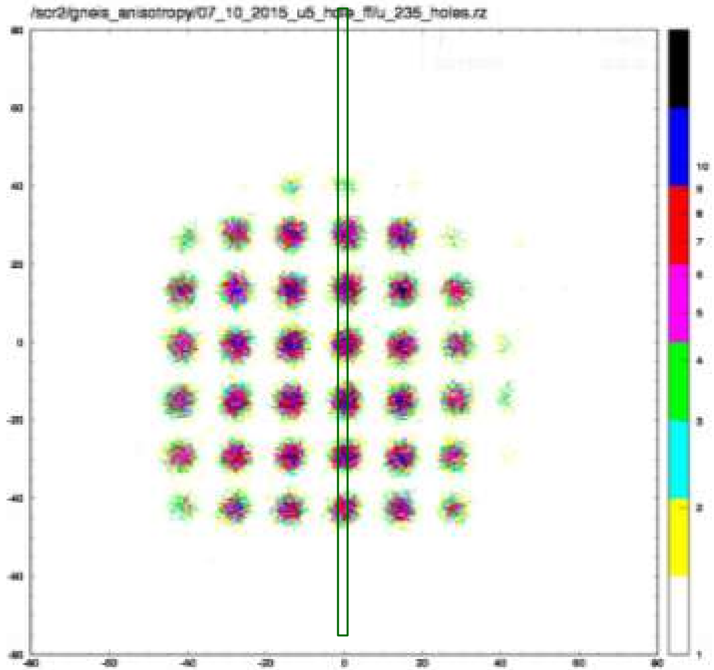

For the time difference:

FWHM =1.2 ns

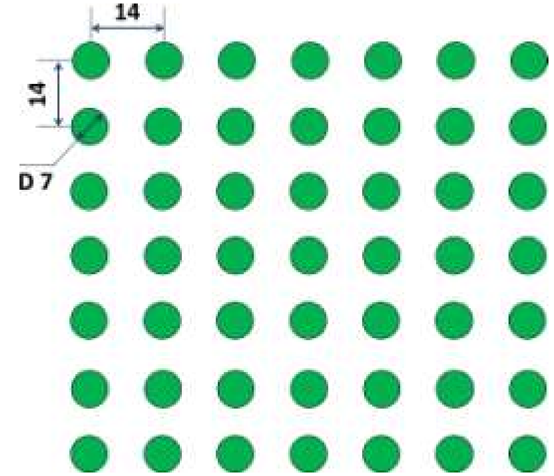
For one detector:

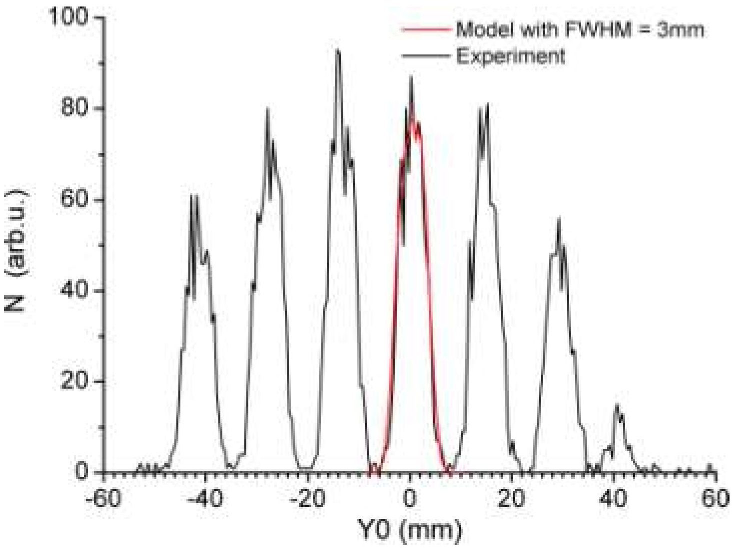
FWHM =0.8 ns

# Tests with "points like" 235U target (induced fission)



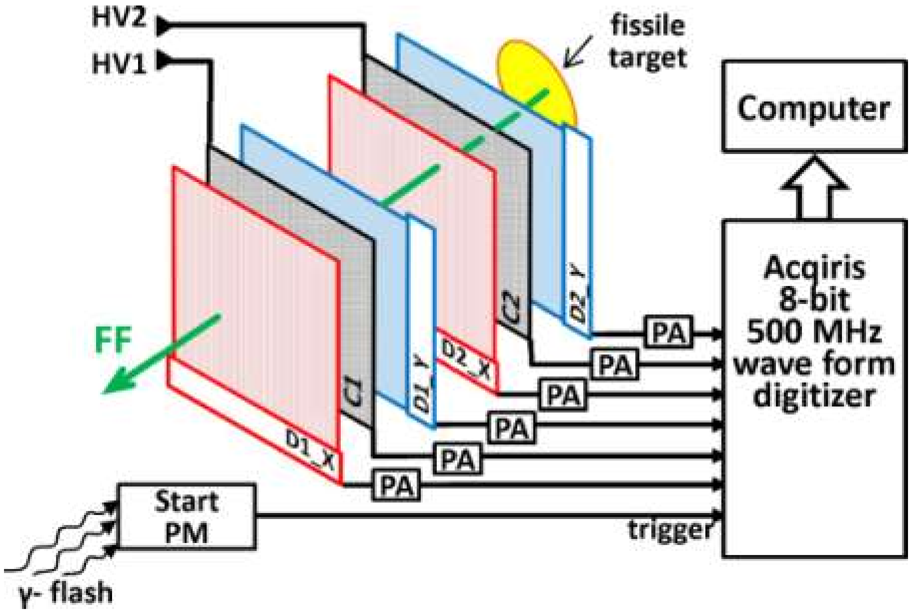
Mask for vacuum deposition of 235U (tetrafluoride) on Mylar foil



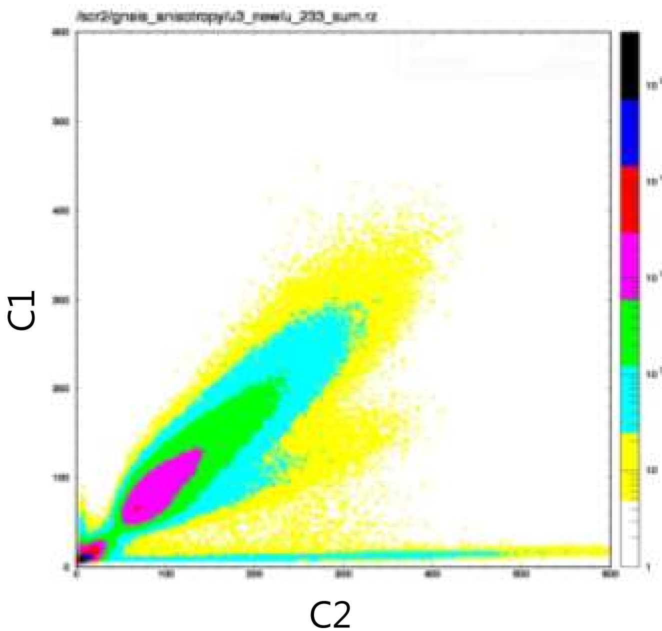



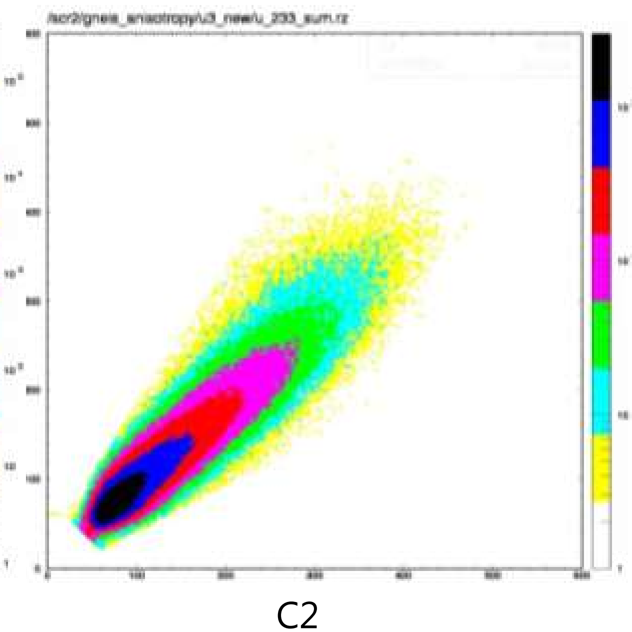

**Position resolution of reconstructed target image is 3 mm**

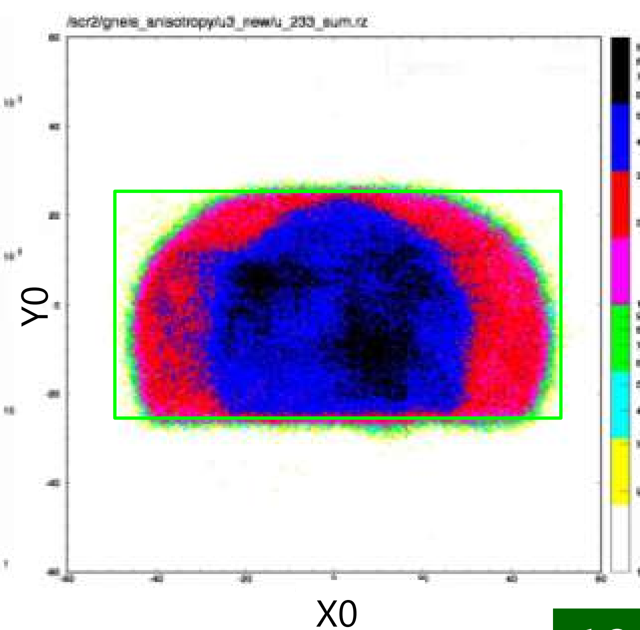
# Experiment with 233U target (induced fission)



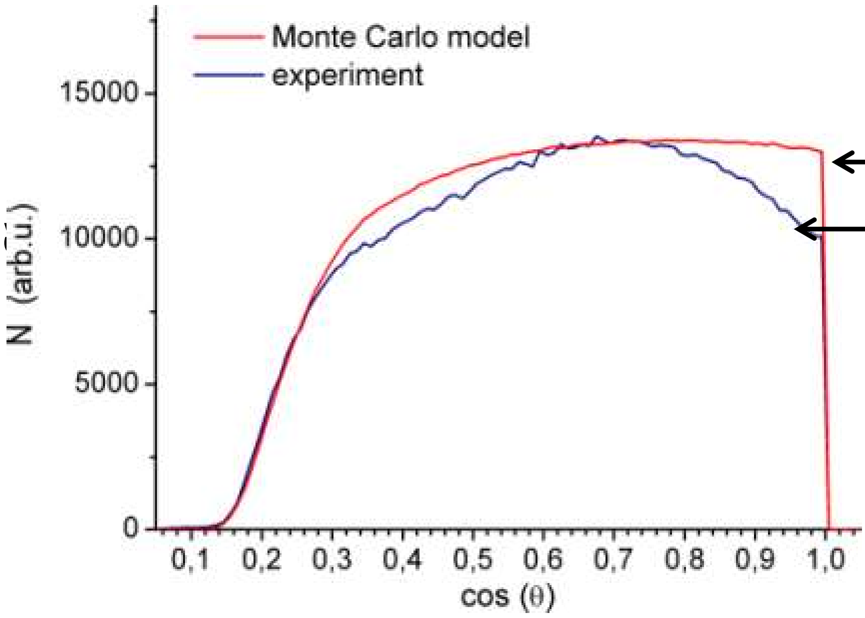

**Rectangular 233U target (100 × 50 mm) on Aluminum foil (0.1 mm)**



# Experiment with 233U target (induced fission)




$W_{MC}(\theta)$

$W_{exp}(\theta)$

$$k_{geom} \sim \frac{1}{W_{MC}(\theta)}$$

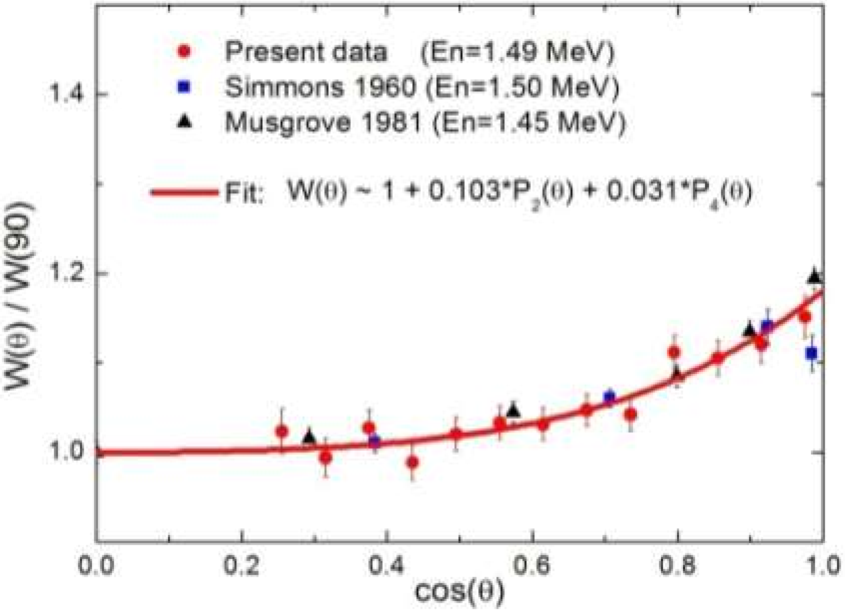
$$W_{correct}(\theta) = k_d \cdot k_{geom} \cdot W_{exp}(\theta)$$

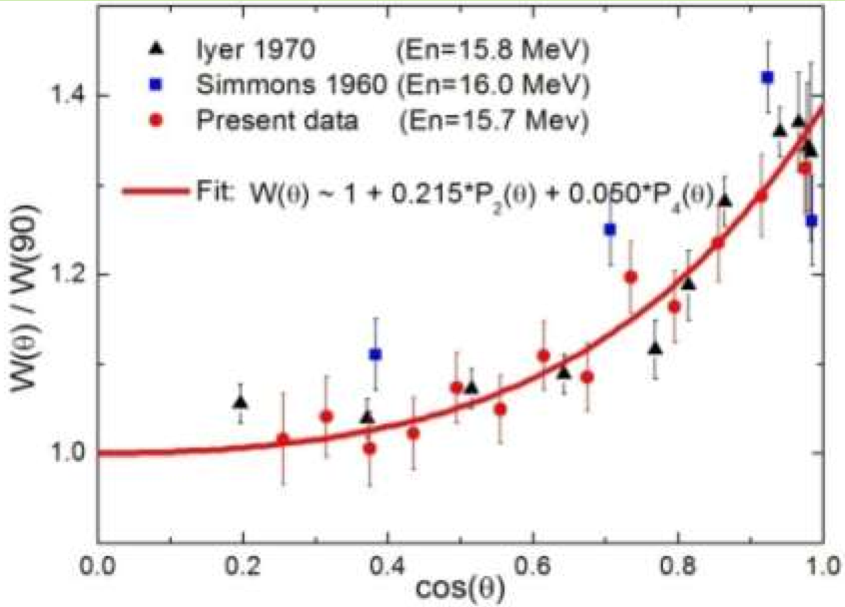
↑

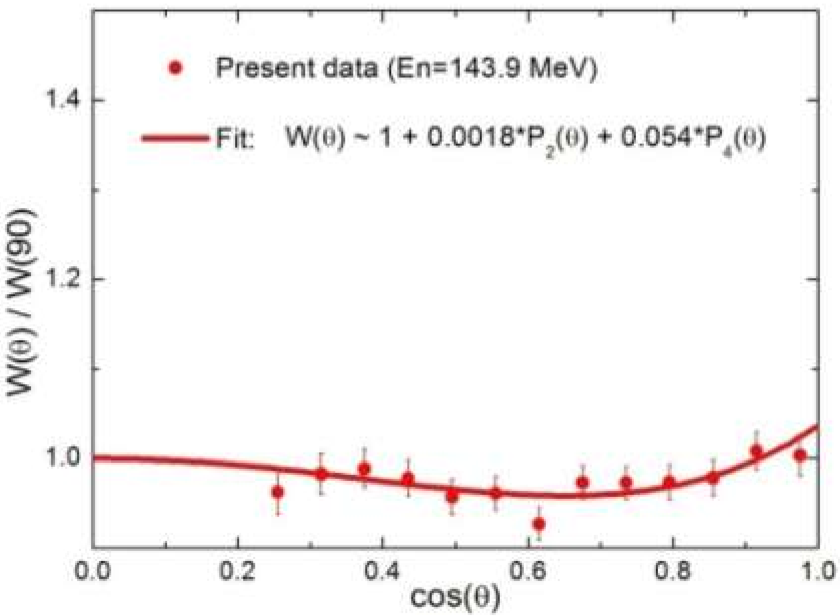
**Correction factor obtained from measurements with isotropic 252CF source**

# Experiment with 233U target (induced fission)

## Corrected angular distributions for some neutron energy ranges



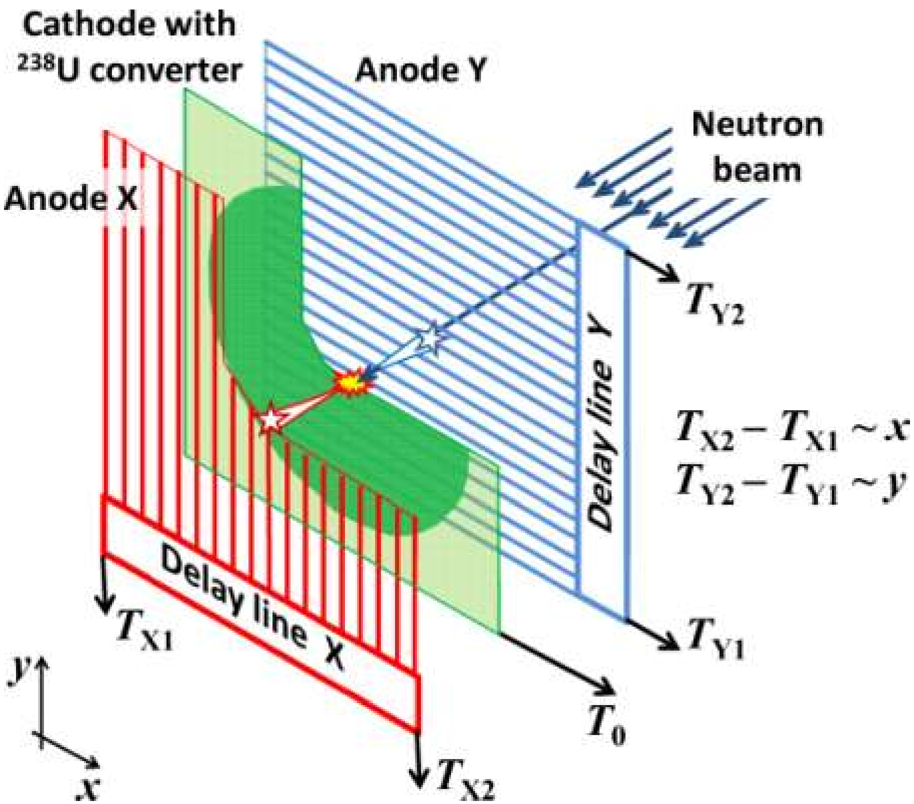




**Complete results of the analyses you will here tomorrow in A. Vorobiev talk.**

# Neutron beam profile monitor

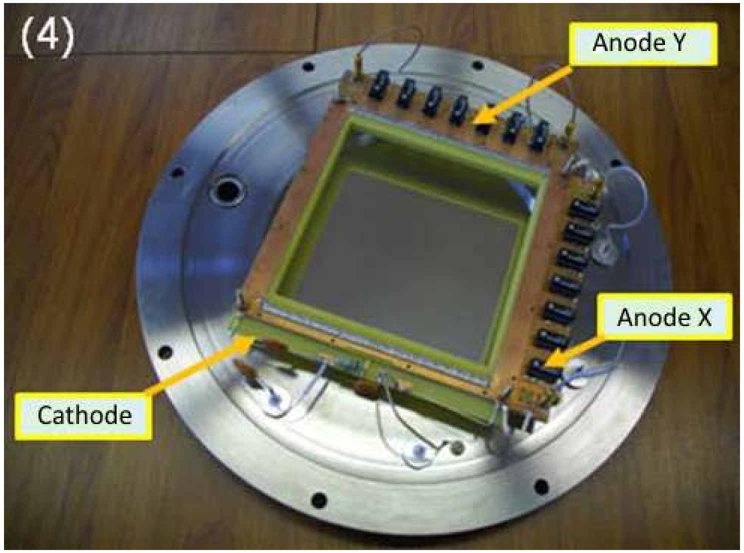
## for electronic components testing facility at neutron spectrometer GNEIS




There was a task to measure neutron beam profile with position resolution < 5 mm, and accuracy <10 % during the IC radiation tests.

Two approximately collinear fragments are emitted in fission. Uranium converter is deposited on thin Mylar cathode (~2μm). Then one fragment determines X coordinate, another determines Y

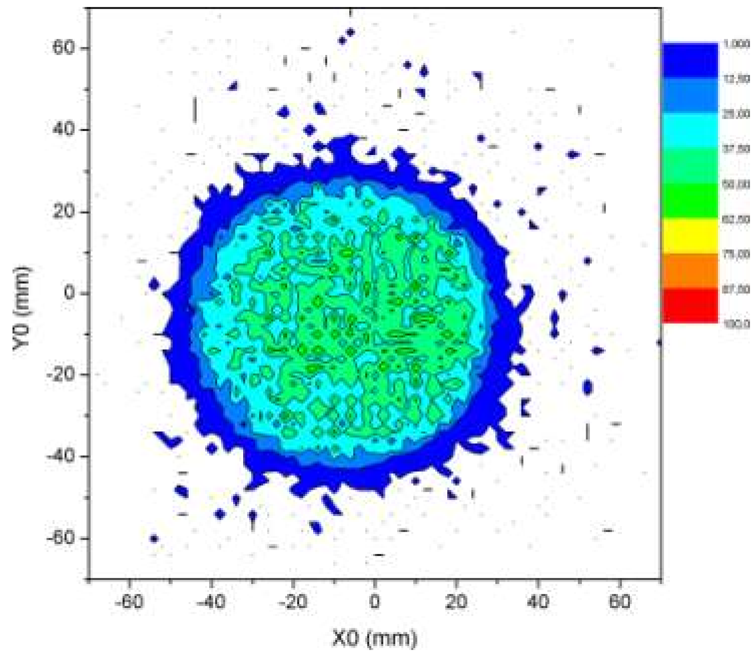
Target (converter): $^{238}$U (tetrafluoride ) ~500 μg/cm$^2$ made by vacuum deposition on 2 μm thick Mylar foils with homogeneity <10 %

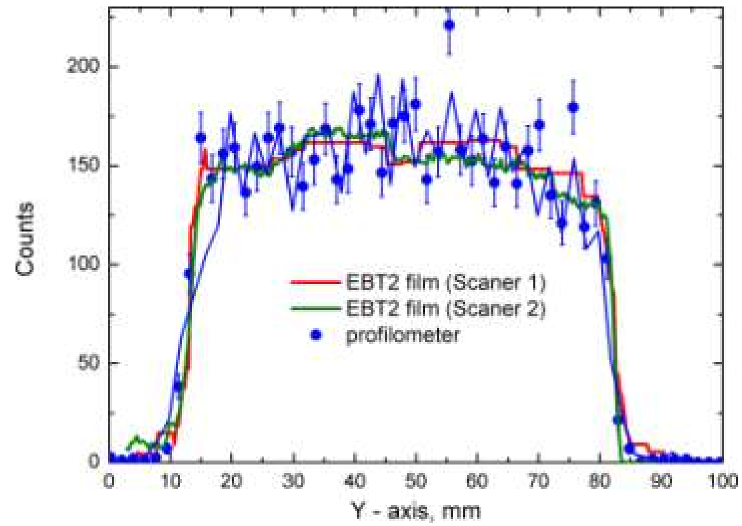


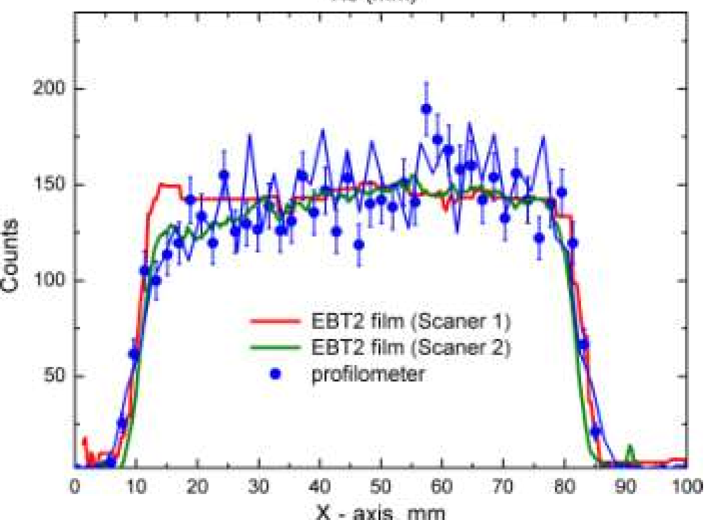
# Neutron beam profile monitor

## for electronic components testing facility at neutron spectrometer GNEIS

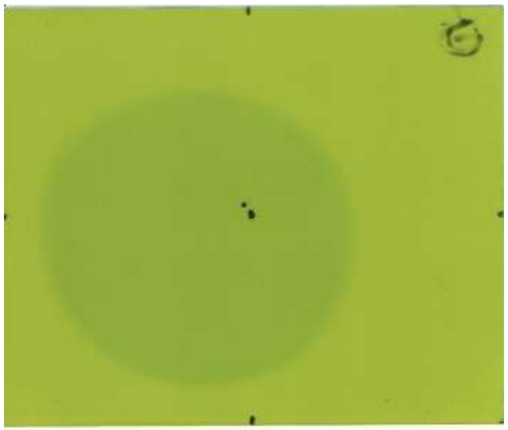
Neutron beam collimator   Ø 75 mm




GAFCHROMIC® EBT2 film



# Conclusion

- Experimental setup based on two low pressure multiwire proportional counters was developed for measuring angular distributions of fission fragments

  The main characteristics of the setup are:

  Practically accessible θ angular range <75$^o$

  Efficiency at average angle ~80% (transparency of wires planes of two MWPCs)

  Time resolution <0.8 ns

  Position resolution of reconstructed fission coordinates ~3 mm

- Neutron beam profile monitor was constructed based on low pressure multiwire proportional counter with 238U converter deposited on the cathode. The "profile meter" was tested and now is exploiting on electronic components testing facility at neutron spectrometer GNEIS

  The main characteristics of the device are:

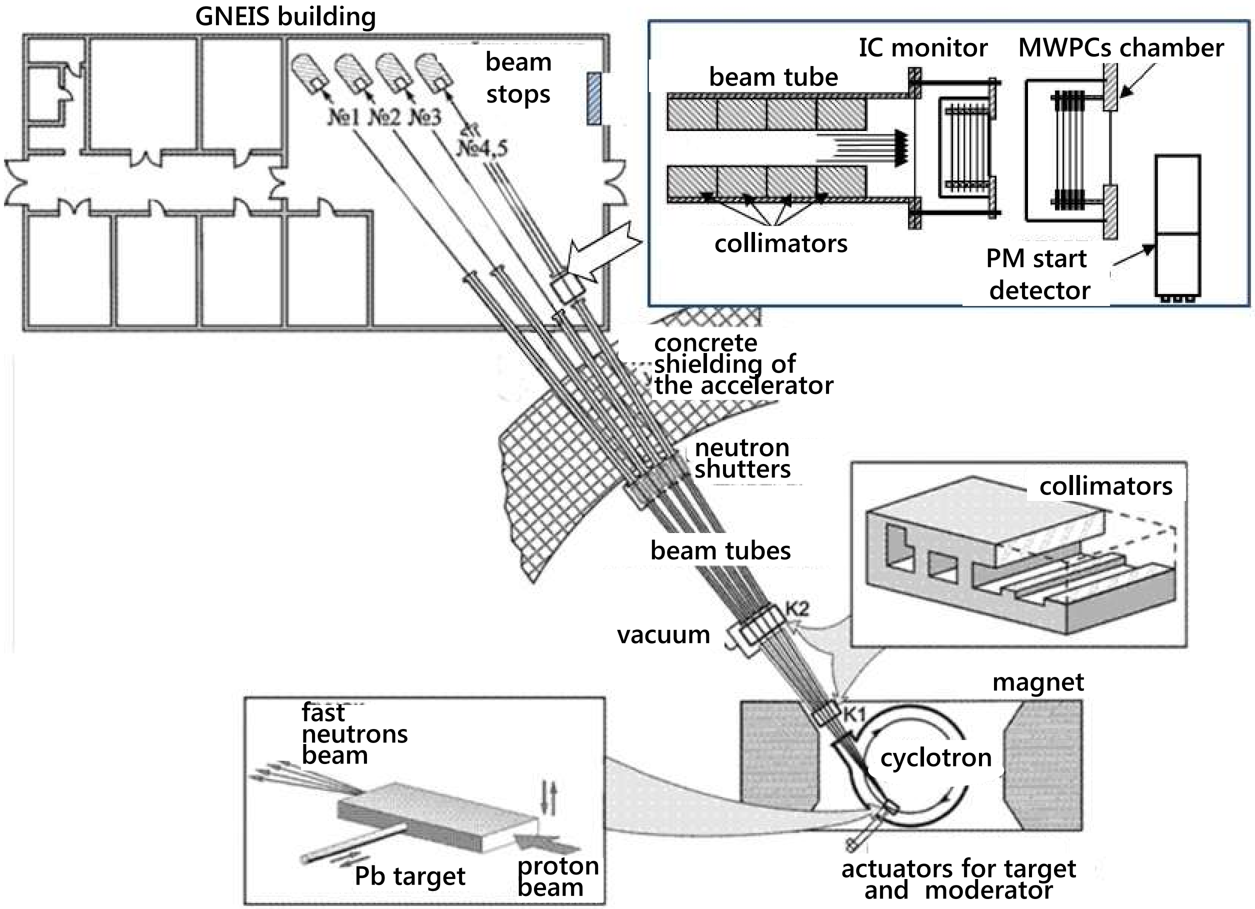
  Area 140 × 140 mm$^2$

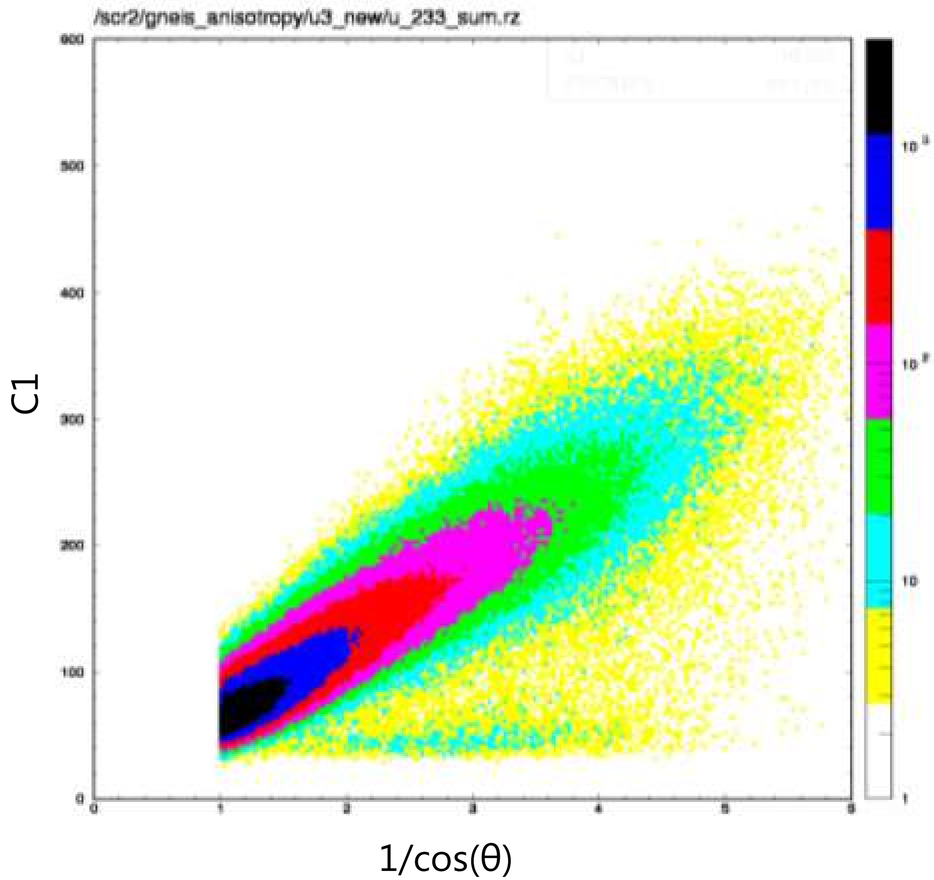
  Efficiency ~$10^{-6}$ (for immediate energy neutrons $\sigma_f$ ~1 barn)

  Time resolution <0.8 ns

-

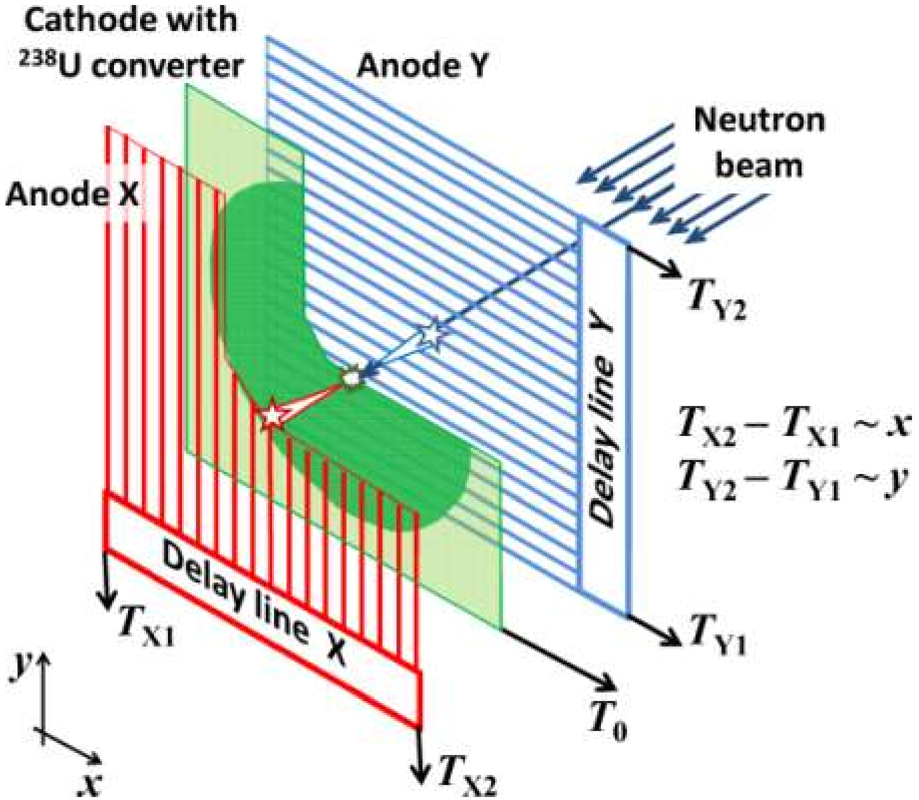
# Thank you for attention

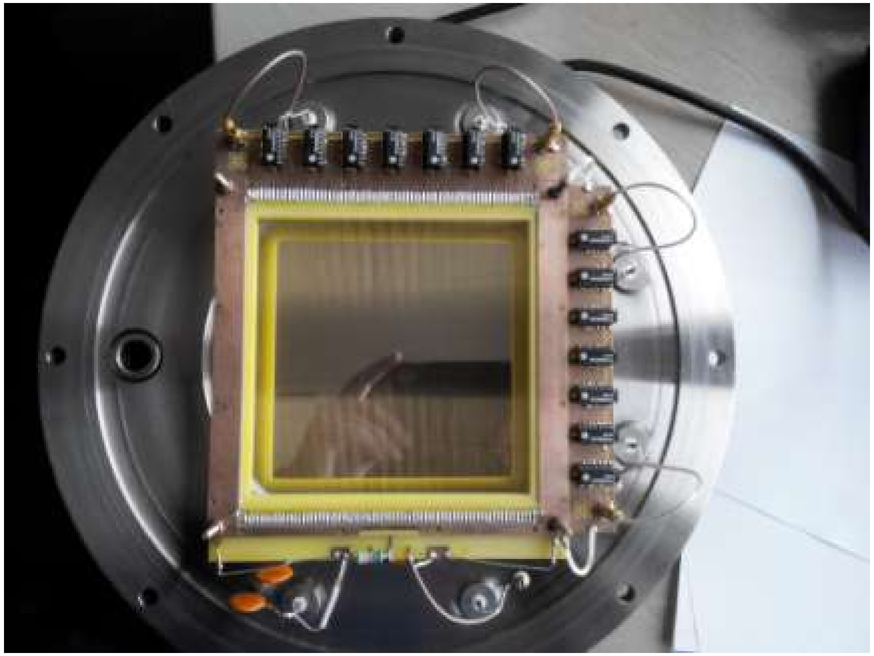

GNEIS building
beam stops
№1 №2 №3
№4,5
IC monitor
MWPCs chamber
beam tube
collimators
PM start detector
concrete shielding of the accelerator
neutron shutters
collimators
beam tubes
K2
vacuum
magnet
K1
cyclotron
fast neutrons beam
Pb target
proton beam
actuators for target and moderator


/scr2/gneis_anisotropy/u3_new/u_233_sum.rz
C1
1/cos(θ)
0
100
200
300
400
500
600
1
2
3
4
5
6
1
10
$10^2$
$10^3$

# Neutron beam profile monitor

**Neutron radiation testing of electronic components facility at the 1 GeV synchrocyclotron of PNPI**

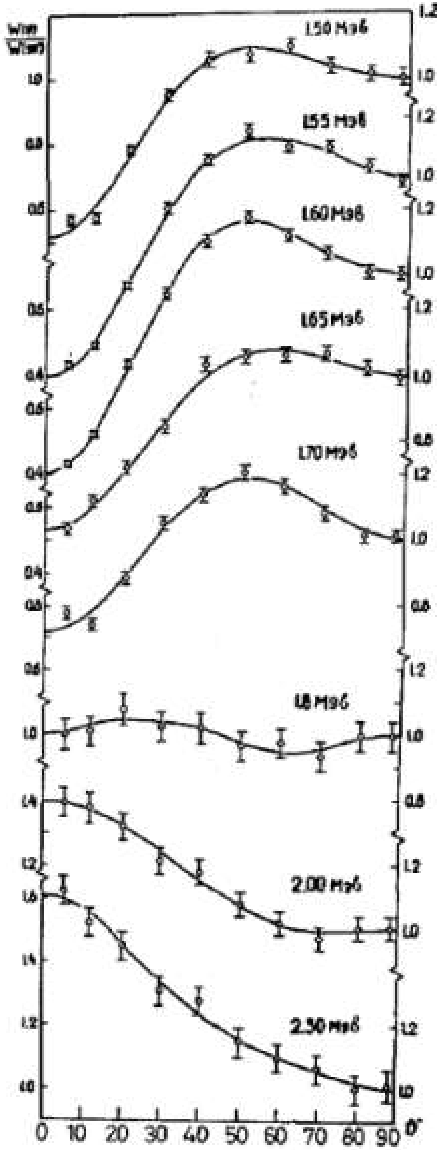


Targets (converter): $^{238}U$ (tetrafluoride ) ~500 μg/cm² made by vacuum deposition on 2 μm thick Mylar foils

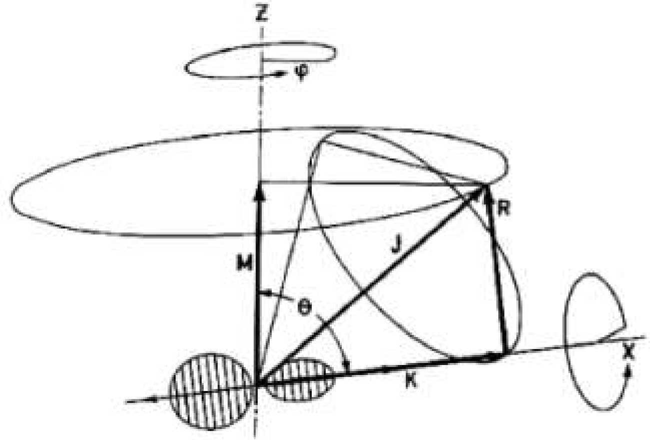
# Introduction

$^{232}$Th(n,f)
Androsenko et al. (1969)




[redacted]

For low excitation energies we need a proper sum over *M* distribution, and few available *J*, *K* (fission channels).




[redacted]

At high excitations with many opened fission channels one can use statistical model for the *K* projection distribution – $\rho(K)$ :

$$\rho(K) \sim \exp\left(-\frac{E_{rot}}{T}\right)$$

[redacted]

$$J_{eff} = \frac{J_\perp J_\parallel}{J_\perp - J_\parallel}$$

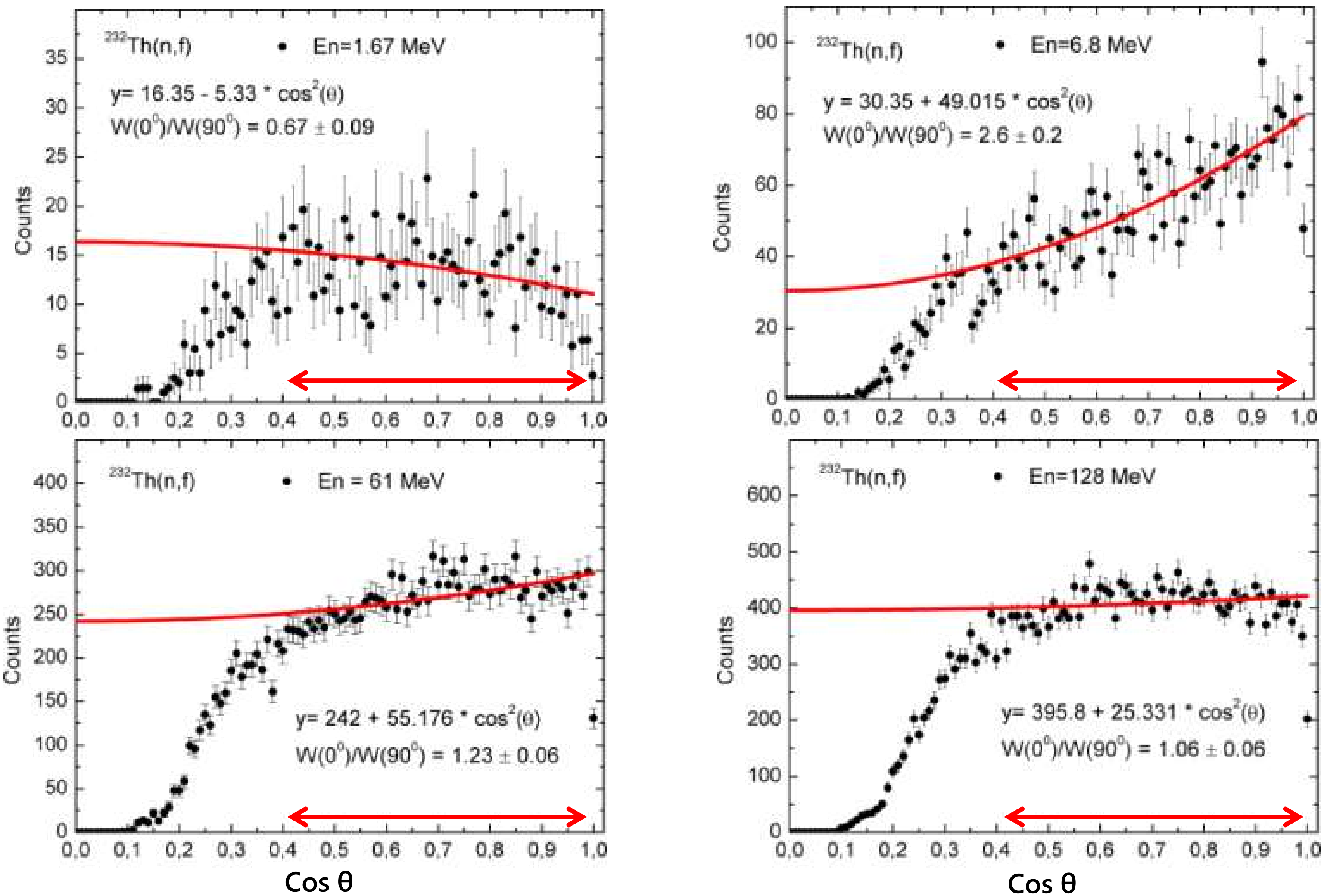
$E_p = 1$ GeV; $\Delta t \approx 10$ ns;
$f \approx 50$ Hz; $\Phi \sim 3 \times 10^{14} \frac{\text{n}}{\text{s}}$;
$L = 35.5$ m

$$\rho(K) \sim \exp\left(-\frac{K^2}{2K_0^2}\right)$$

In transition state statistical model:

[redacted]

# Results (examples of cos θ fits)




[redacted]os θ fitting range was 0.42– 0.98