

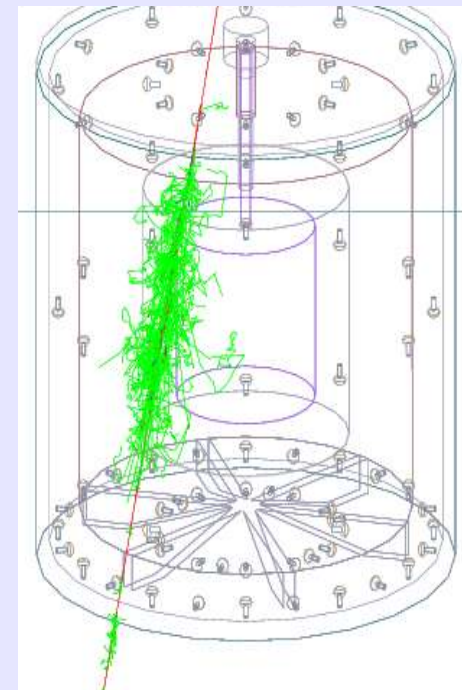
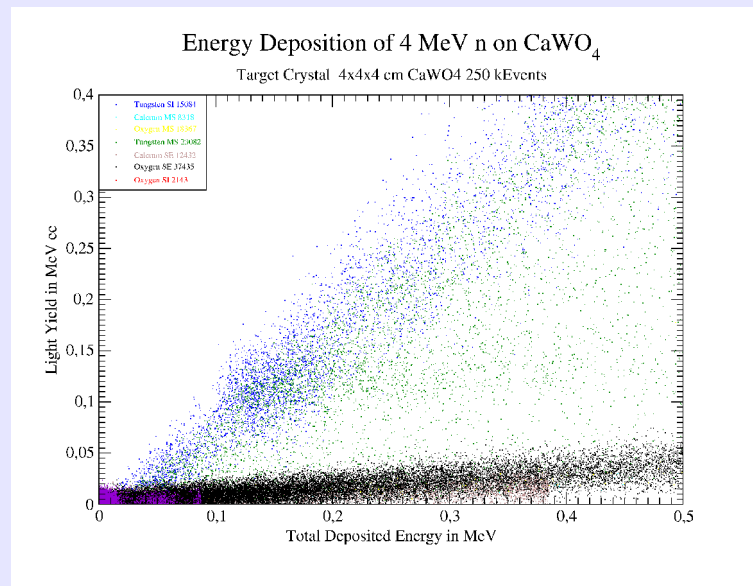
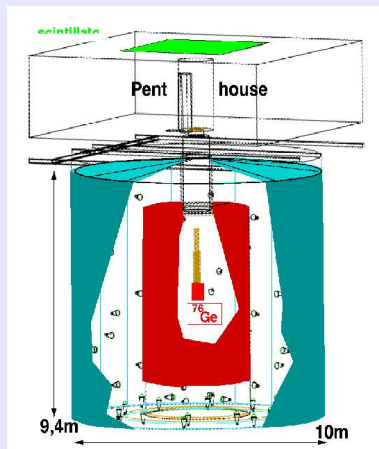


# High Precision Neutron Simulation for low background experiments

Stephan Scholl  
Physikalisches Institut  
Eberhard-Karls-Universität Tübingen

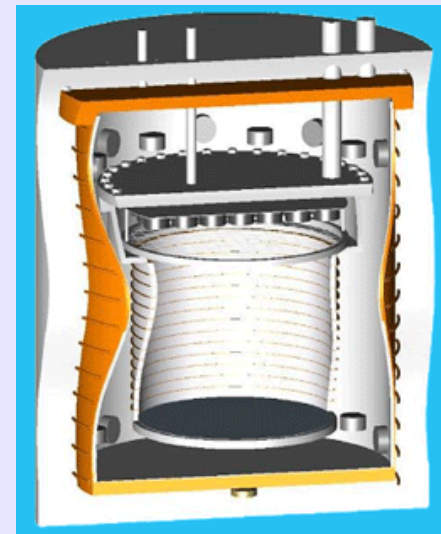
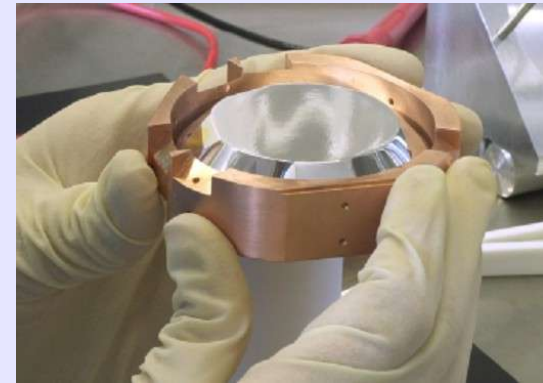
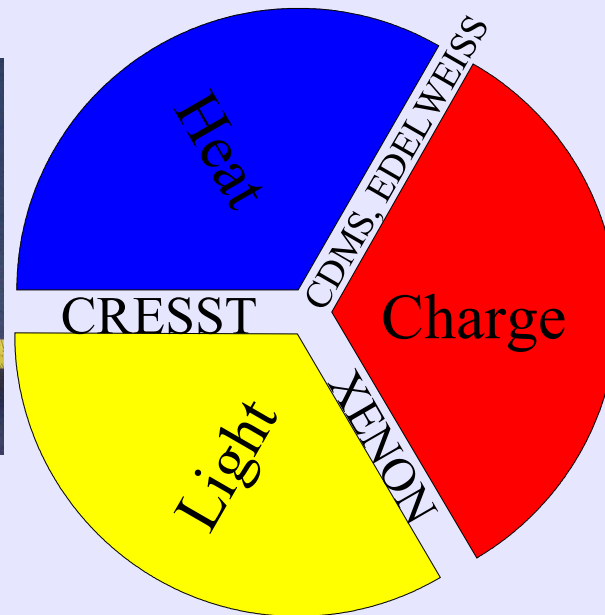
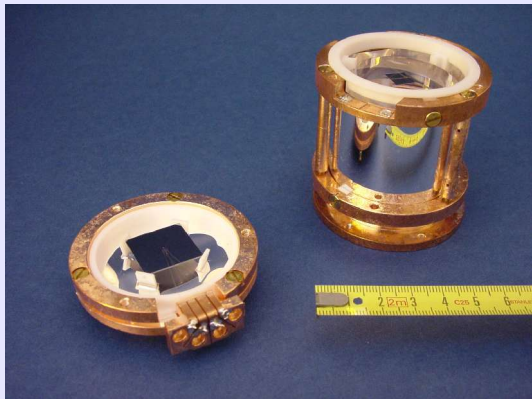


# GEANT 4 Applications in Tuebingen





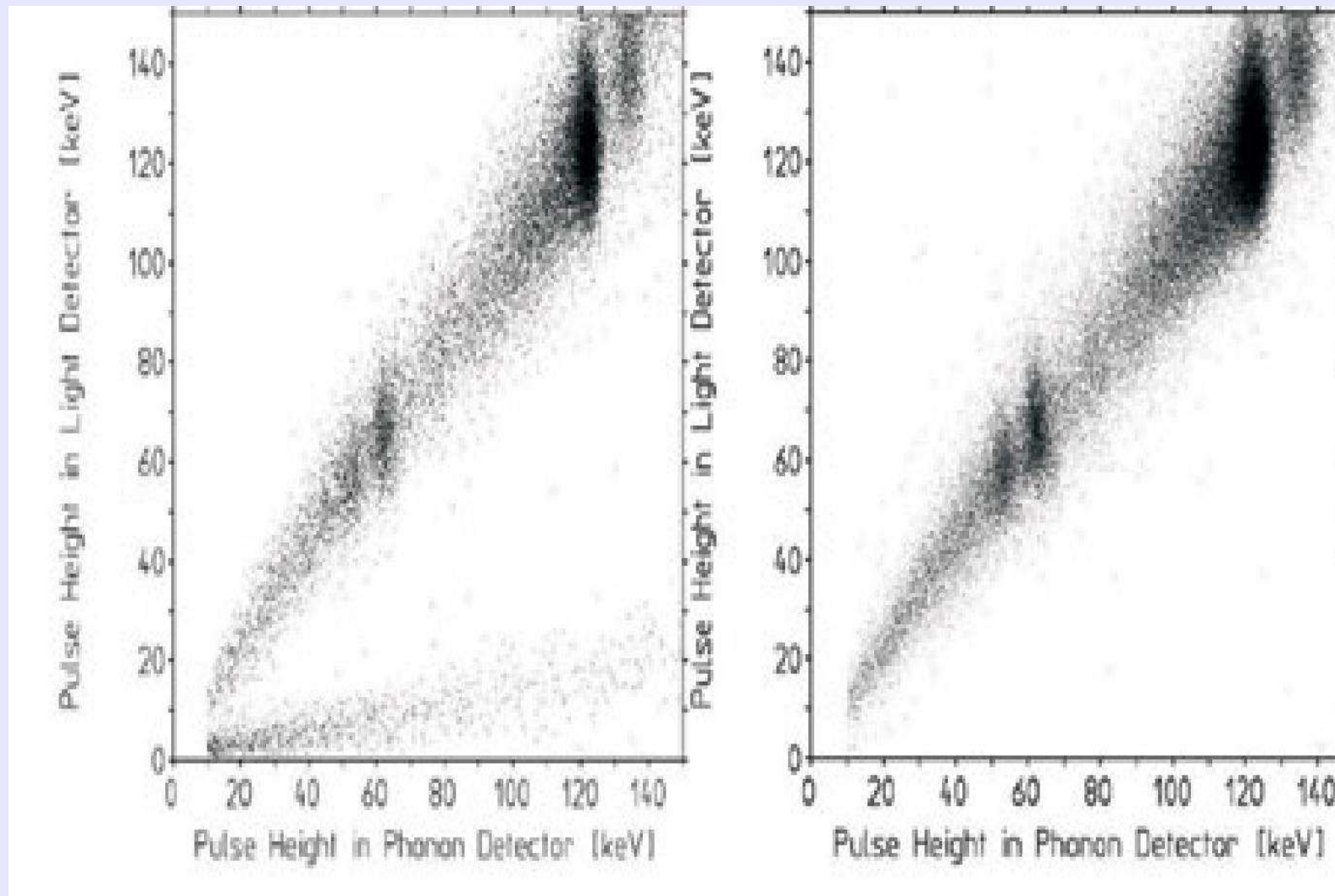
# Direct Detection Dark Matter Experiments



The ratio of the deposited energy depends on the type of particle (quenching), the simultaneous readout of two channels provides a method for the discrimination of the electro-magnetic background.



# Background in Direct Detection Experiments

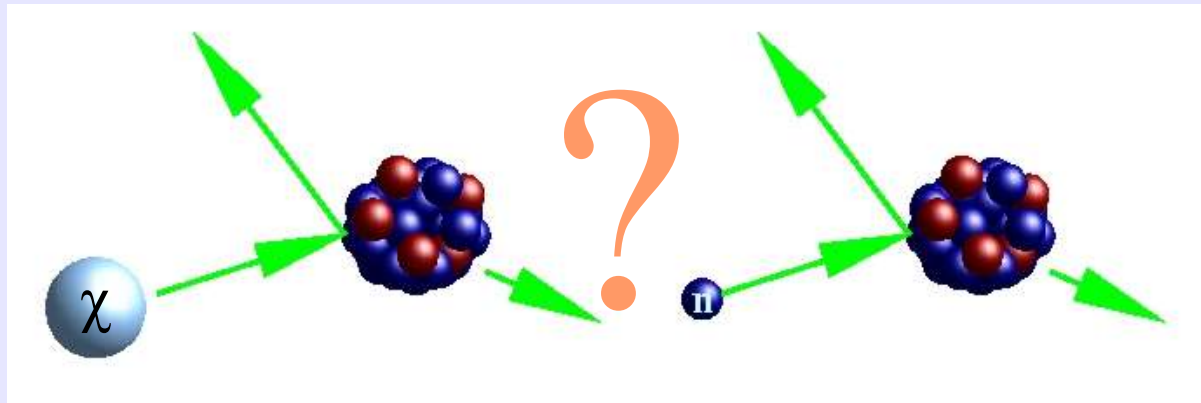






# Neutral Background

Electrons and Photon provide no background, but what about neutrons ?



Detector material		Maximum Recoil in keV	
Nucleus	Mass in GeV/c <sup>2</sup>	Neutron	WIMP(Mass 60GeV/c <sup>2</sup> )
O	16	221	20
Si	28	133	26
Ca	40	95	29
Ge	73	53	30
Xe	131	30	26
W	184	22	22

Neutrons are the principal background for WIMP detection, so it is important to understand and simulate the neutron background to achieve a good sensitivity.



# The Neutron Interactions in G4NeutronHP

The interactions of neutrons are split into four different parts which are treated as different models :

## **Elastic scattering (n,n) :**

The final state of this process is given by sampling the differential cross-sections.

## **Inelastic Scattering (n,n'X) :**

A variety of different reaction channels are supported. The data is based on the ENDL evaluated neutron data library.

## **Fission :**

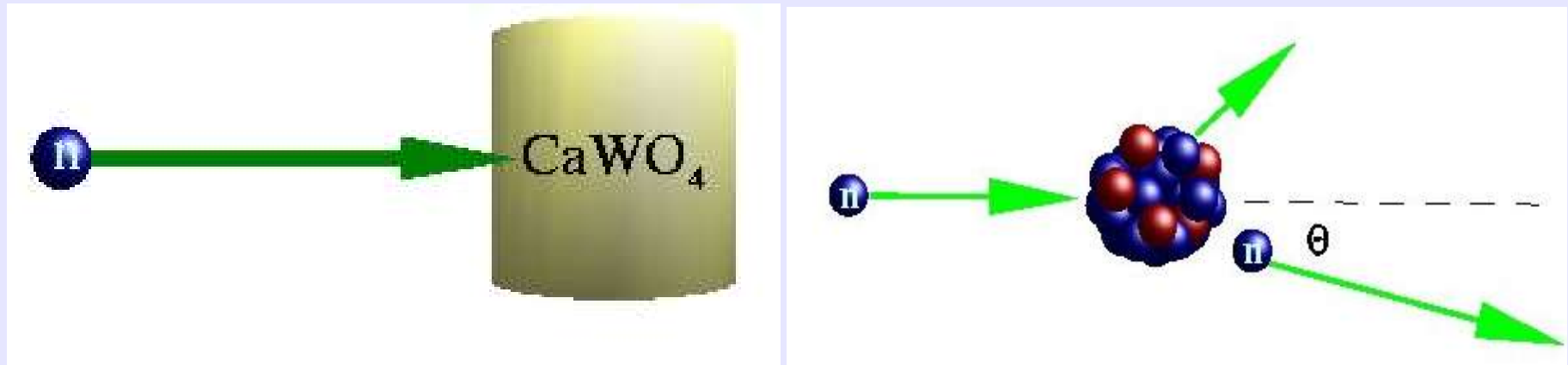
First to fourth chance fission are considered for creating the final state.

## **Radiative Capture (n,x $\gamma$ ) :**

In this case, the final state is given by the produced photons.



## The Test Setup

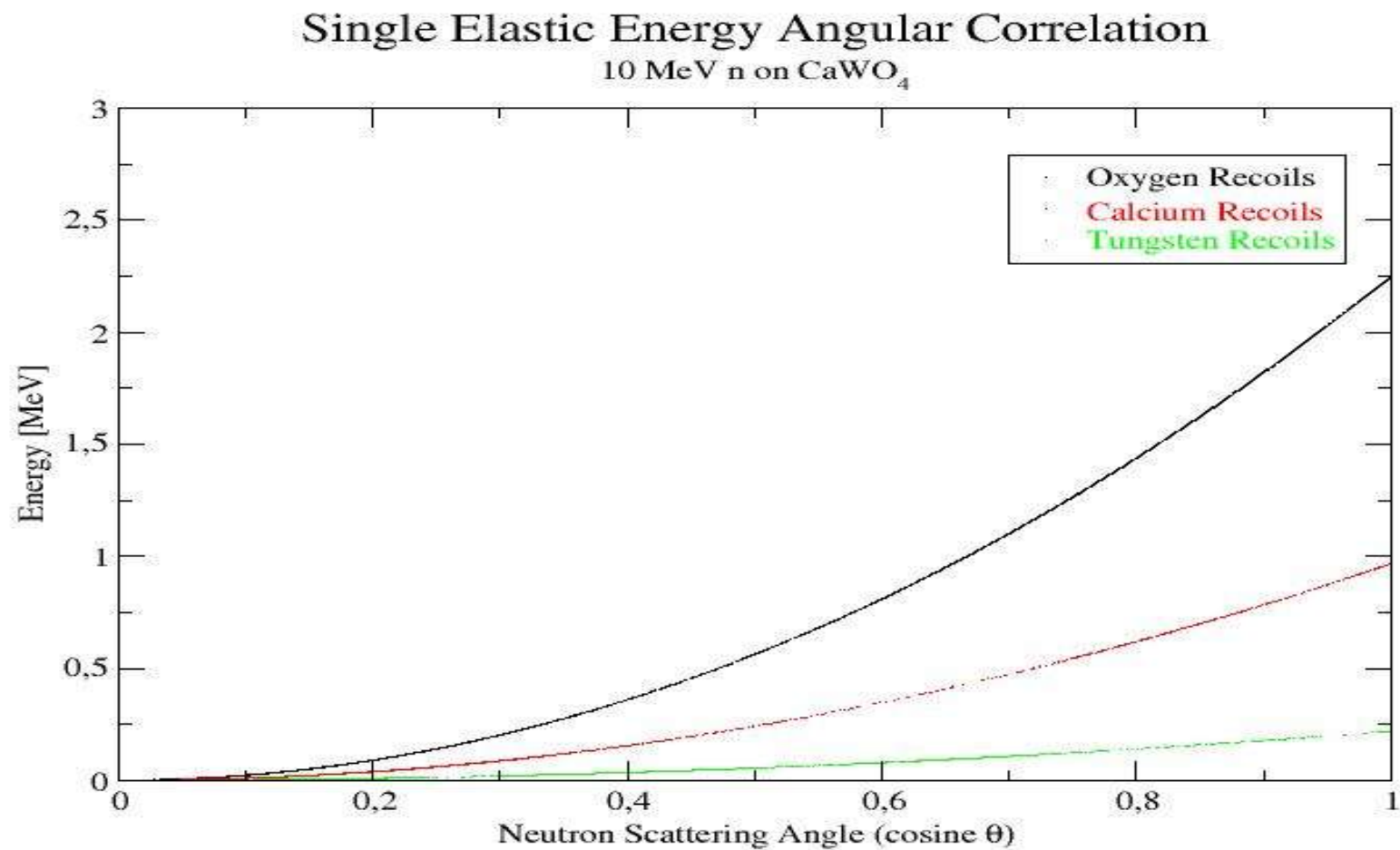


Target : small cylinder of CaWO<sub>4</sub> (4cm height, 4cm diameter)

Beam : monoenergetic neutrons of 10 MeV



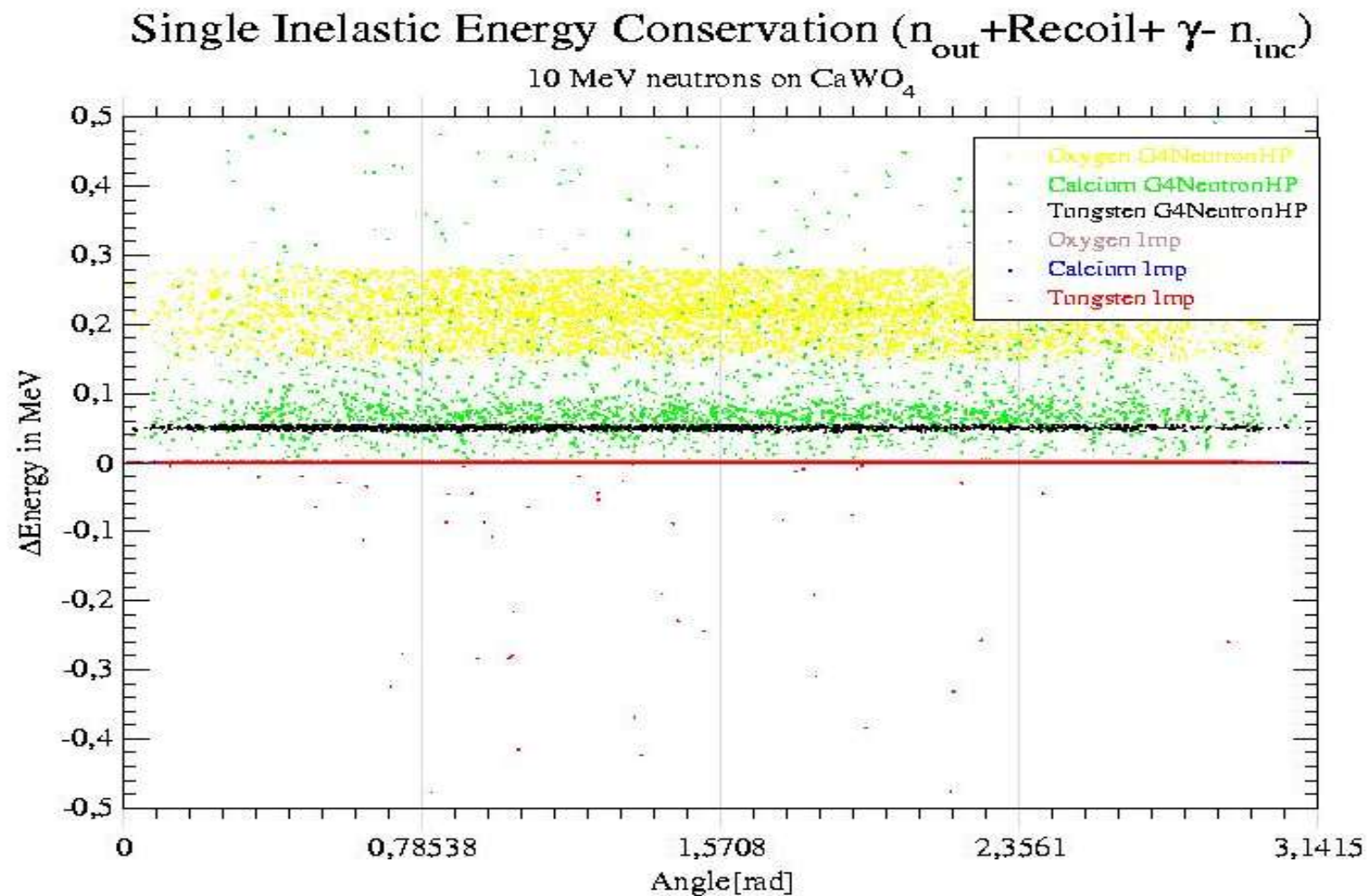
# Energy Angular Correlation in the Elastic Reaction





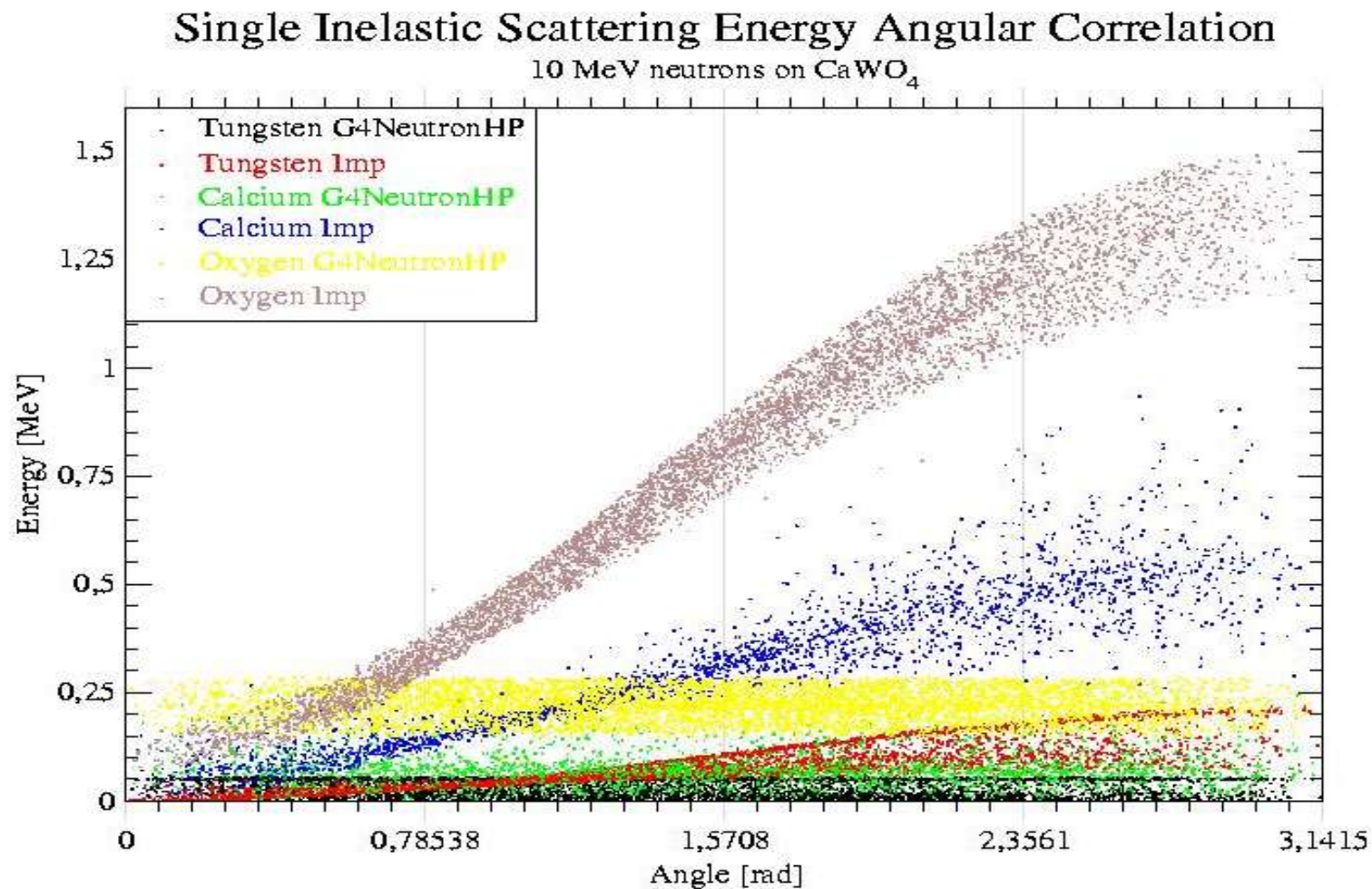


# Energy Conservation in the Inelastic Reaction



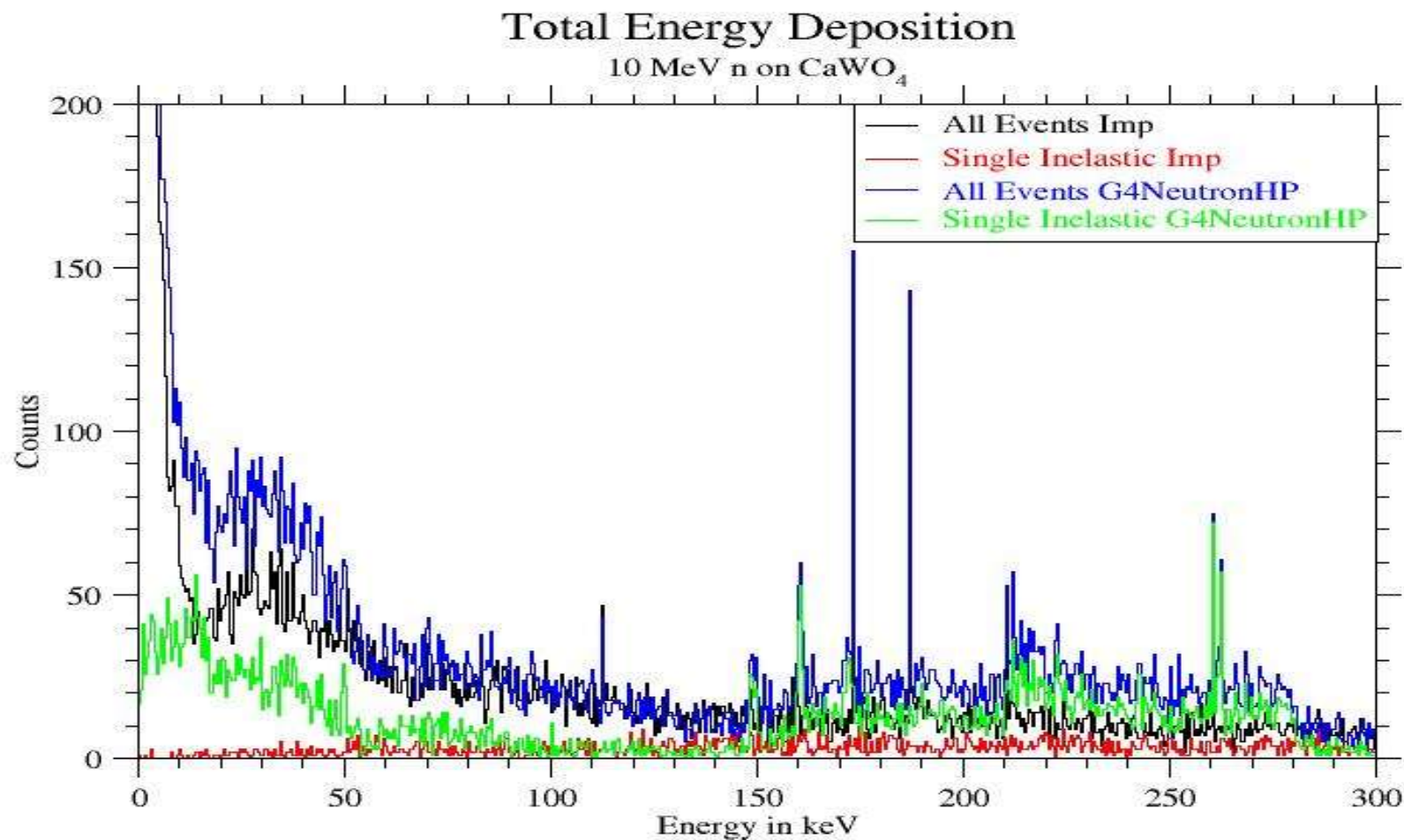


# Angular Distribution in the Inelastic Reaction





# Total Deposited Energy







## Test Results

The most dangerous neutron background contribution, the elastic scattering process works as expected in regards of energy conservation and energy-angular correlation of the neutron.

The original inelastic process has to be modified since:

No energy-angular correlation of the neutron (and the recoiling nucleus)

A systematic violation of the energy conservation is observed

In the original code, the amount of low energy events is overestimated, since the smearing due to the kinematics is absent.





# Calculating the Recoil Energy in a more sophisticated manner

Two observables are given by GEANT4 :

- The direction of the neutron in the lab system

(The neutron has not the correct kinetic energy, its kinetic energy is given by  $E^* = E_n + E_{rec}$ )

- The length of the momentum vector in the CMS

$$p_f = \frac{1}{2\sqrt{s}} \sqrt{\{s - (m_n - m_{rec})^2\} \{s - (m_n + m_{rec})^2\}}$$

The given neutron energy in the Lab system is transformed in the CMS, then its length is set to  $p_f$ .

The resulting vector in the Lab system is rotated in the direction of  $p_n$ .

This algorithm is applied until the resulting vector is close enough to  $p_n$ .



## Identified Problems

If energy spectrum data is used for final state particles, quite often the produced final states do not respect energy conservation.

On the other hand, if the level schemes for the isotopes is used, energy conservation is respected, but the wrong gammas are produced.

The usage of cross-sections for natural abundancies leads to unphysical final states corrupting energy conservation.

$(n,\alpha)$  and  $(n,p)$  reactions produce no gammas



## Problems with the Data Base

The 'Gallium Bug' : Missing isotope data in the final state data will cause the usage of the data from the next lightest element.

In G4.9. a warning will be issued if the data is incomplete.

The data base can be extended for new cross-sections quite easily, but the formats for angular and energy spectrum data are rather cryptic.



## Appendix : Missing Isotope Data in GEANT4

Cross-section data for several isotopes and elements are missing for bot elastic and inelastic scattering!

Missing Isotopes:

$H^3, O^{18}, V^{50}$

Only data for natural abundancy is given:

C, Mg, Si, Cl, K, Ca, Ti, Ga, Zr, Mo, In, Sn, W

No data given at all:

Ne, Sc, Zn, Se, Br, Kr, Rb, Sr, Y, Tc, Ru, Rh, Pd, Ag, Sb, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Re, Os, Ir, Pt, Hg, Tl, all heavier Elements except U