SIMULATION OF MEDEA RESPONSE TO NEUTRONS

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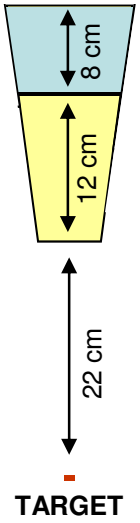
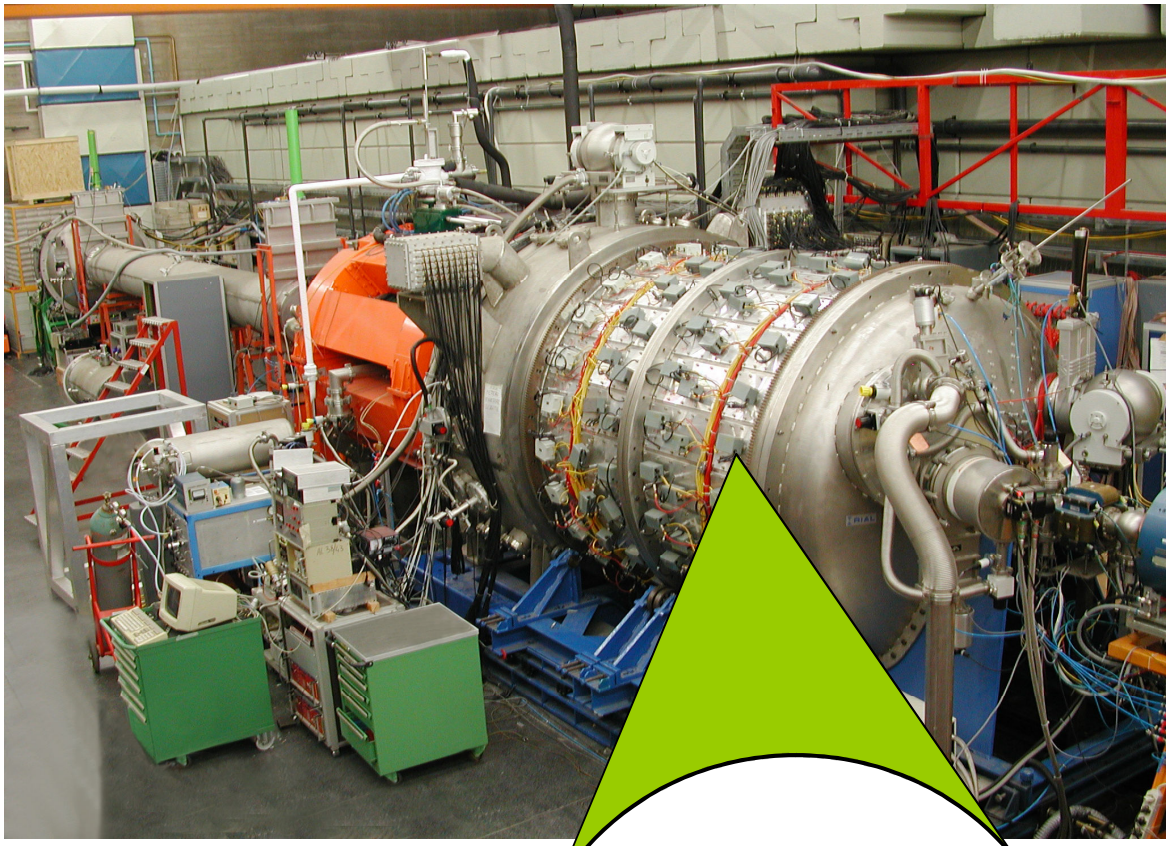
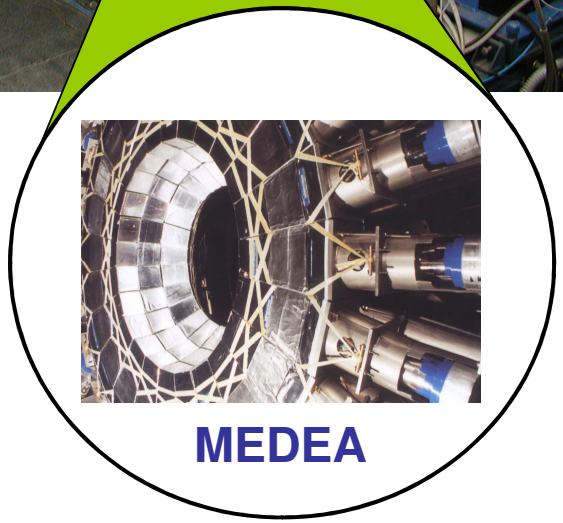
MEDEA ARRAY



$$\left(\frac{\Delta E}{E}\right)^2 = 4\left[\left(\frac{\Delta L}{L}\right)^2 + \left(\frac{\Delta t}{t}\right)^2\right]$$

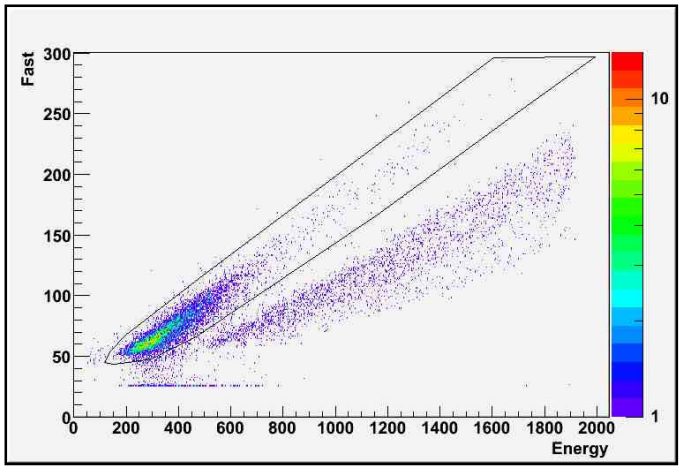




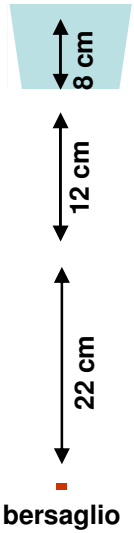
MEDEA consists of a ball of 180 BaF_2 scintillators. It allows the detection of **gamma-rays** up to 200 MeV and **light charged particles** (Z=1,2) from 30° to 170°.

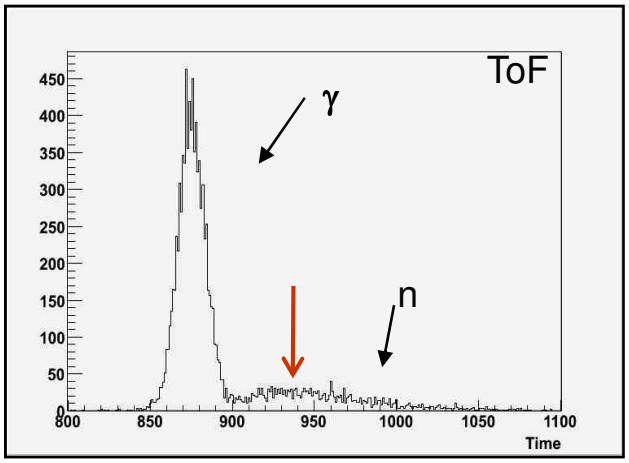
8 cm BaF2 experimental response to neutrons

Neutron information gives a better control on the reaction dynamics



$^{116}Sn + ^{12}C$ @ 23 MeV/A

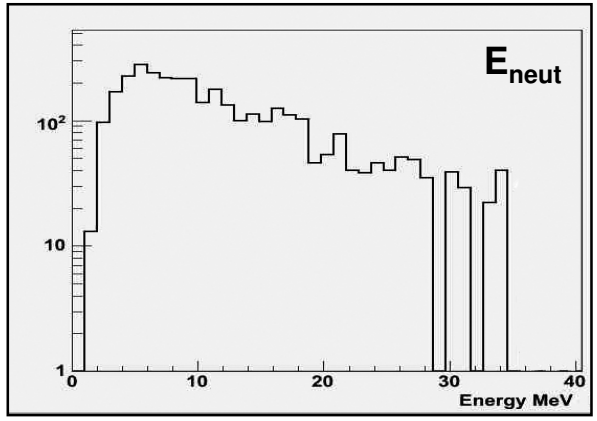




$^{116}Sn + ^{12}C$ @ 23 MeV/A

Experiment done at LNS cyclotron

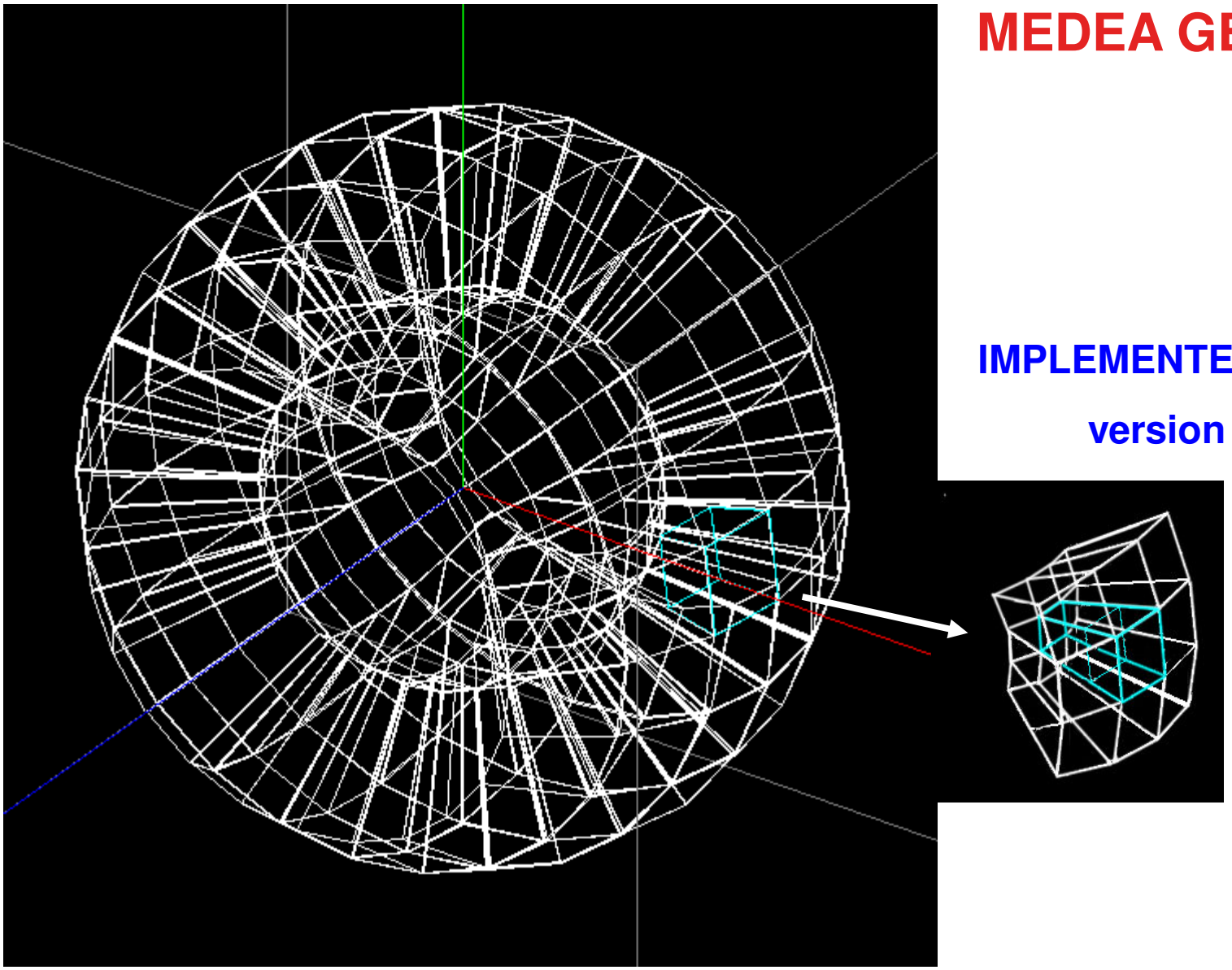
Energy deduced by the time of flight assuming that the neutron interacts in the middle of the crystal



GOALS OF THE SIMULATION

- Single detector response to neutrons of different energies for shortened and standard detector
- Detection efficiency as a function of incident energy
- Multiple firing on MEDEA apparatus

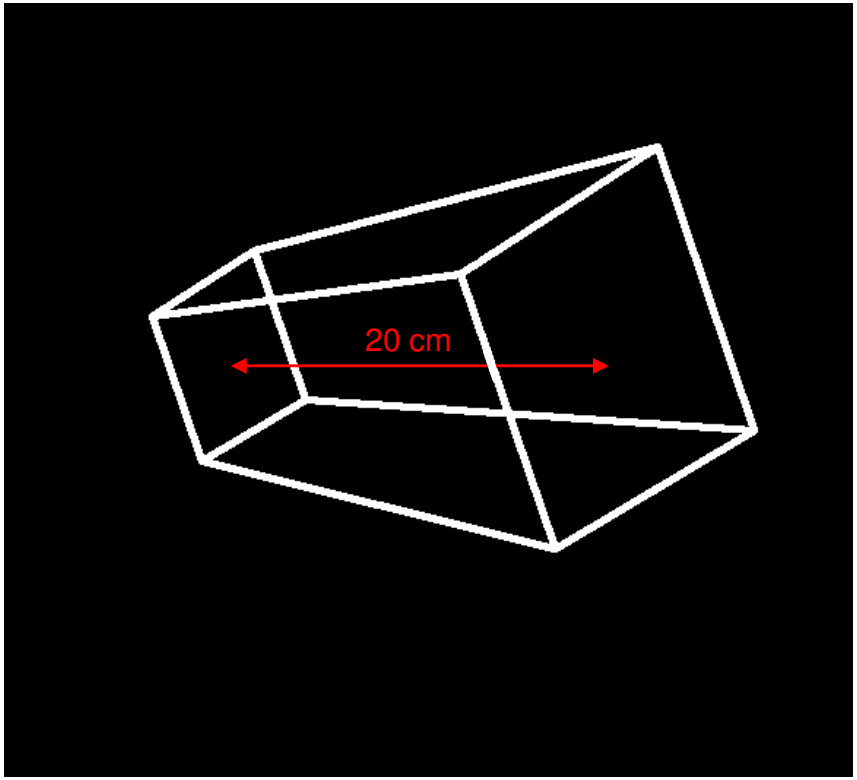
MEDEA GEOMETRY



IMPLEMENTED IN GEANT4

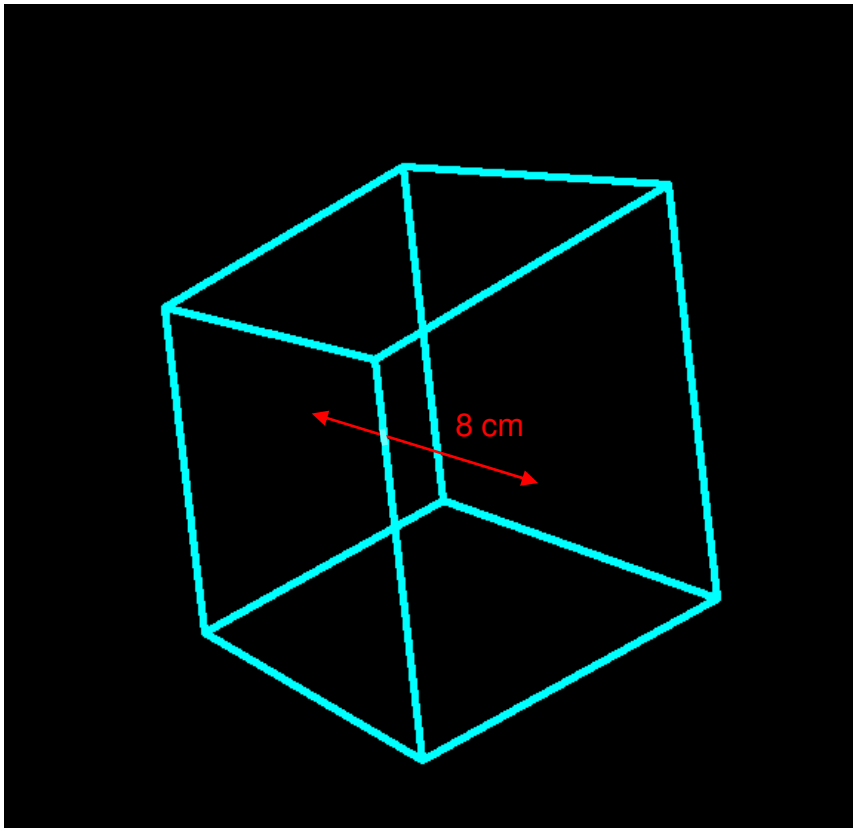
version 9.2.p01

CRYSTAL GEOMETRY



← **STANDARD MEDEA MODULE**

SHORTENED MEDEA MODULE →



G4Trap(const G4String& pName, G4double pDz, G4double pTheta, G4double pPhi, G4double pDy1, G4double pDx1, G4double pDx2, G4double pAlp1, G4double pDy2, G4double pDx3, G4double pDx4, G4double pAlp2)

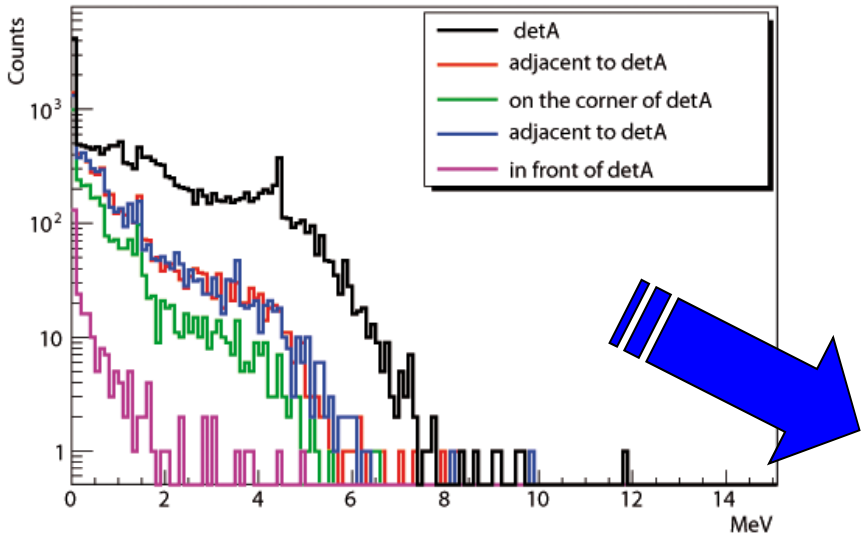
LOW ENERGY NEUTRON PHYSICS

High Precision Neutron Models and Cross Section Data Set (library G4NDL3.13)

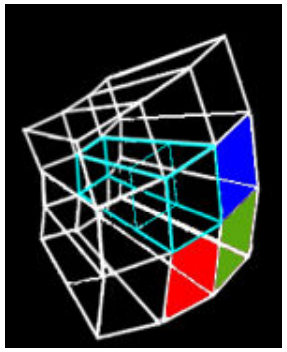
Implemented processes:

Elastic, Inelastic, Capture, Fission

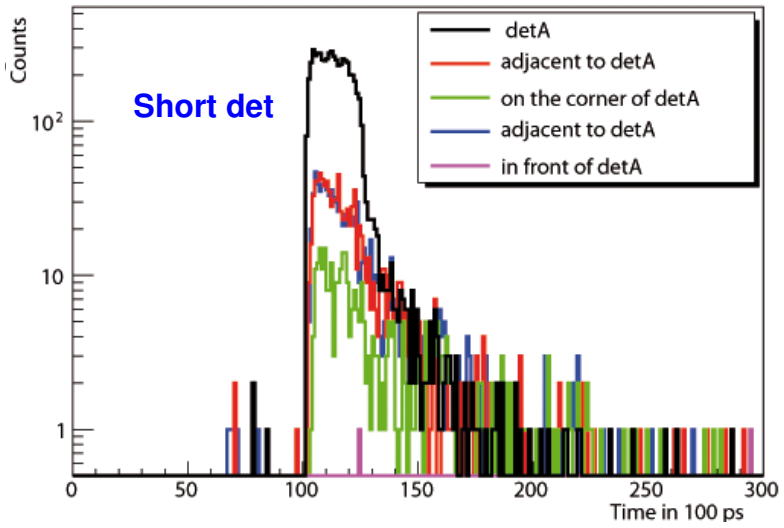
Simulations: response to 6 MeV neutron energy



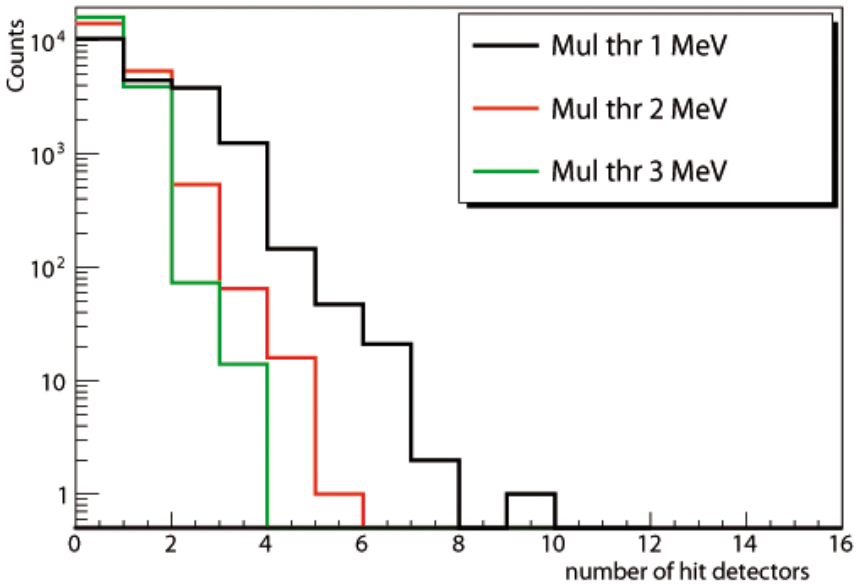
Energy spectra of deposited energy in selected detectors for 6 MeV neutrons randomly incident on detA



The time of flight spectra are incremented only if the deposited energy in the detector is larger than 1 MeV



Simulations: response to 6 MeV neutron energy



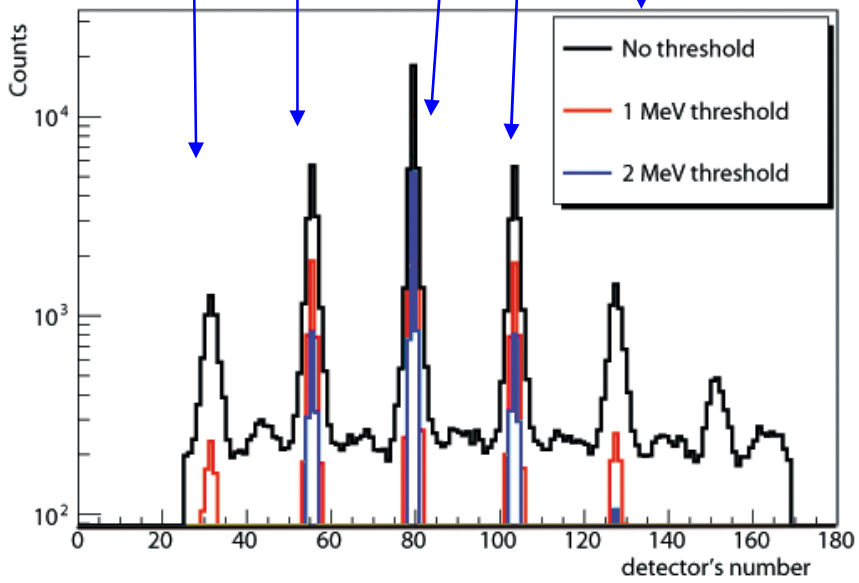
MEDEA multiple firing for 6 MeV neutrons randomly incident on detA and a threshold condition on energy deposited in the detector

Pattern of firing for different threshold on the deposited energy

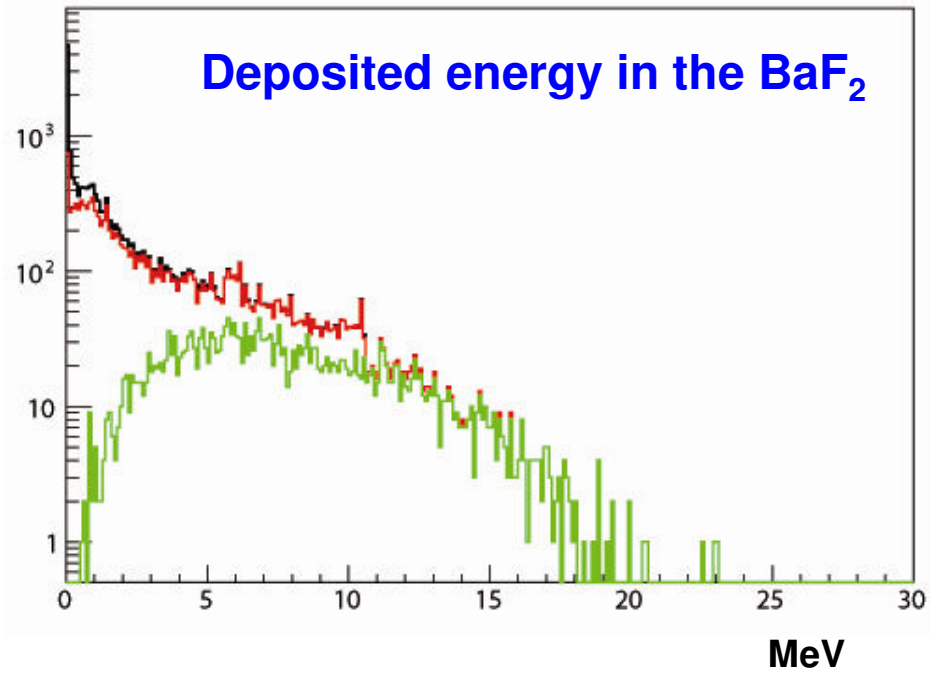
	32	56	81	105	129
	31	55	80	104	128
φ	30	54	79	103	127
	29	53	78	102	126
	28	52	77	101	125

51° 68° 82° 97° 113°

θ



And now few anomalies I have found …

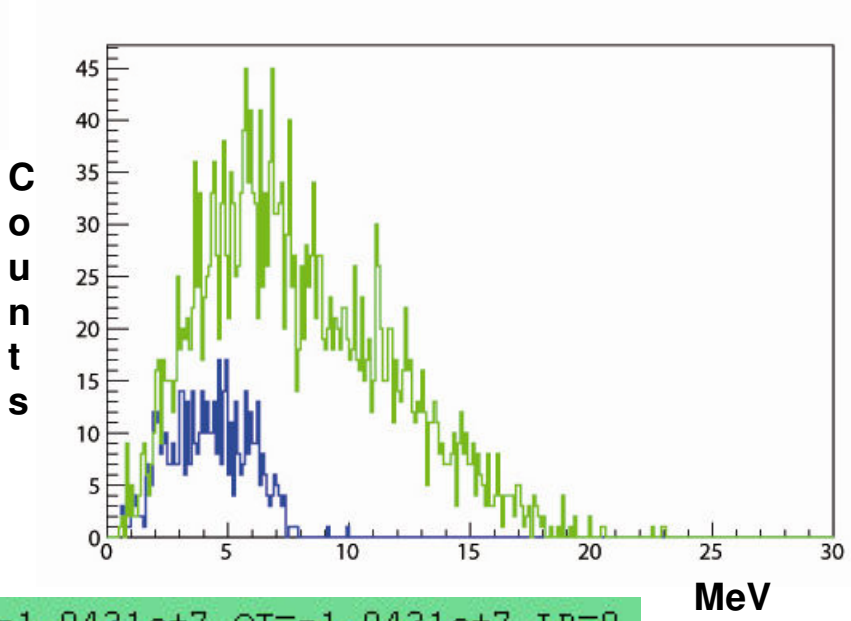


12 MeV incident neutron

All process

All inelastic process

$^{19}F(n,n\alpha)^{15}N$



no control on the energy of secondaries

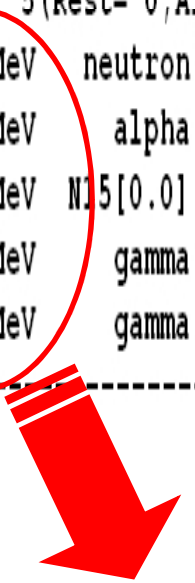
G4RunManager::GetRunManager()->
AbortEvent();
if energy of secondaries exceeds input
neutron energy

```
F-19(N,2N)F-18.SIG        MT16   QM=-1.0431e+7 QI=-1.0431e+7 LR=0
F-19(N,N+A)N-15,SIG       MT22   QM=-4.0129e+6 QI=-4.0129e+6 LR=0
F-19(N,N+P)O-18,SIG       MT28   QM=-7.993e+6  QI=-7.993e+6  LR=0
```

… few anomalies I have found …

```
**********************************************************************************************************
* G4Track Information:   Particle = neutron,   Track ID = 1,   Parent ID = 0
**********************************************************************************************************

Step#      X         Y         Z        KineE    dEStep   StepLeng  TrakLeng    Volume     Process
    2   22.4 cm   3.67 cm   1.06 cm     18 MeV     0 eV      0 fm   22.7 cm        BAFA    initStep
    3   26.4 cm   5.76 cm   2.28 cm      0 eV      0 eV   4.65 cm   27.4 cm        BAFA  NeutronInelastic
    :----- List of 2ndaries - #SpawnInStep=  5(Rest= 0,Along= 0,Post= 5), #SpawnTotal=  5 --------------
    :   26.4 cm   5.76 cm   2.28 cm   7.53 MeV   neutron
    :   26.4 cm   5.76 cm   2.28 cm   2.35 MeV     alpha
    :   26.4 cm   5.76 cm   2.28 cm   2.63 MeV  N15[0.0]
    :   26.4 cm   5.76 cm   2.28 cm   5.26 MeV     gamma
    :   26.4 cm   5.76 cm   2.28 cm   13.4 MeV     gamma
   :---------------------------------------------------- End0f2ndaries Info --------------
```

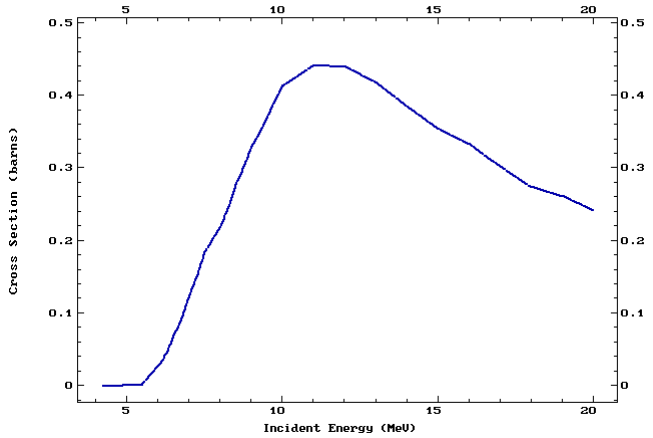


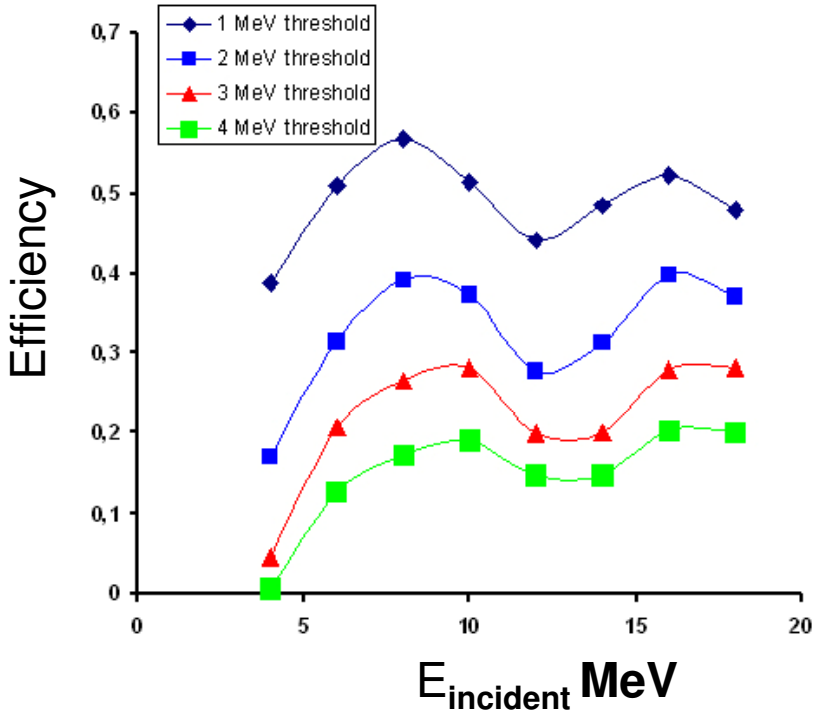
=31.17 MeV for 18 MeV of incident neutron

DETECTION EFFICIENCY

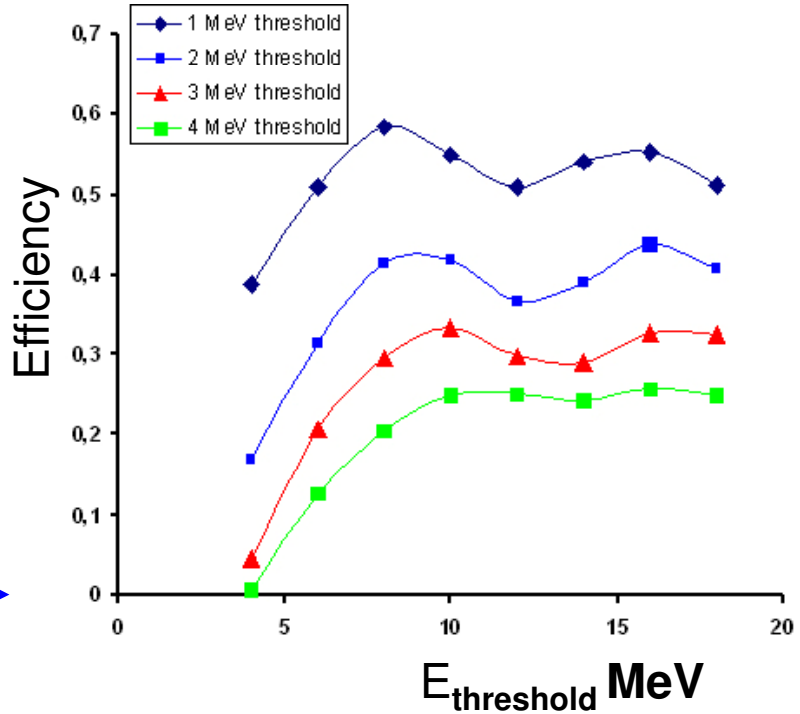
Is this trend due to the rejection of events $F^{19}(n,n\alpha)N^{15}$ with not correct energy conservation?!

Cross Section $F^{19}(n,n\alpha)N^{15}$





Assuming that all bad events release the energy necessary to overcome the threshold the new curves become



Collecting statistics for different energies…

Having in mind the goal of collecting statistics for both modules from 4 MeV up to 18 MeV incident neutron in steps of 2 MeV , runs of 10000 events at different energies have been executed. But… some runs didn't come to the end and the program seemed to enter in a infinite loop…

No report of segmentation fault…

The cpu was busy at 90% of its time…

Collecting statistics for different energies…

Any attempt to debug bad events using "tracking/verbose 2" doesn't highlight the origin of the anomalies

```
*************************************************************************************************
*******
* G4Track Information:   Particle = e-,   Track ID = 15,   Parent ID = 6
*************************************************************************************************
*******

Step#      X         Y         Z        KineE    dEStep   StepLeng  TrakLeng    Volume
Process
    0   37.5 cm   7.78 cm   1.83 cm   2.25 MeV     0 eV      0 fm      0 fm        BAFA
initStep
    1   37.5 cm   7.78 cm   1.82 cm   2.02 MeV   220 keV   371 um    371 um        BAFA
LowEnBrem
    :----- List of 2ndaries - #SpawnInStep=  1(Rest= 0,Along= 0,Post= 1),
#SpawnTotal=  1 ---------------
    :   37.5 cm   7.78 cm   1.82 cm   17.5 keV     gamma
    :---------------------------------------------------------- EndOf2ndaries Info ---------------
```

Collecting statistics for different energies…

Changing the seed of the random generator all the statistics has been collected

```
G4long myseed = 345349
CLHEP::HepRandom::setTheSeed(myseed);
```

Up to this point, the low electromagnetic physics has been used.

Replacing it with the standard electromagnetic physics, the program was running without problems up to 20000 events. Some problems of different nature appeared requiring 50000 events/run or higher.

In these cases the entire VMWARE crashed!!!

Does some variable G4int go in overflow?

AIDA interface has been used to build the spectra in ROOT format.

Conclusions

The geometry of MEDEA array has been implemented

Deposited energy and time of flight spectra have been built

Efficiency has been calculated

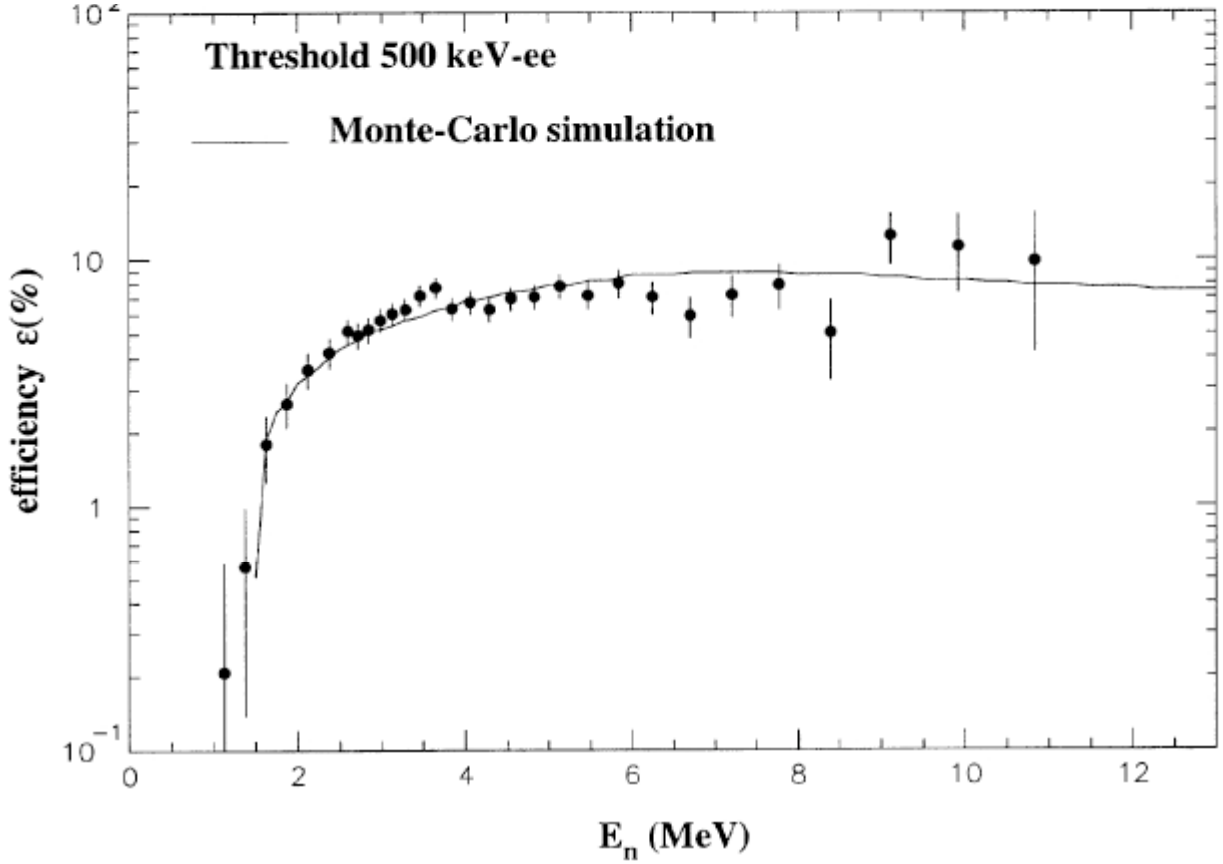
…some helping hand to solve the encountered problems…..

…more…

and some simple instructions in order to simulate the photon collection for a BaF2 wrapped with teflon

Thank you

IL NUOVO CIMENTO VOL. 110 A, N. 5 Maggio 1997



A neutron detection efficiency study for BaF_2 crystal

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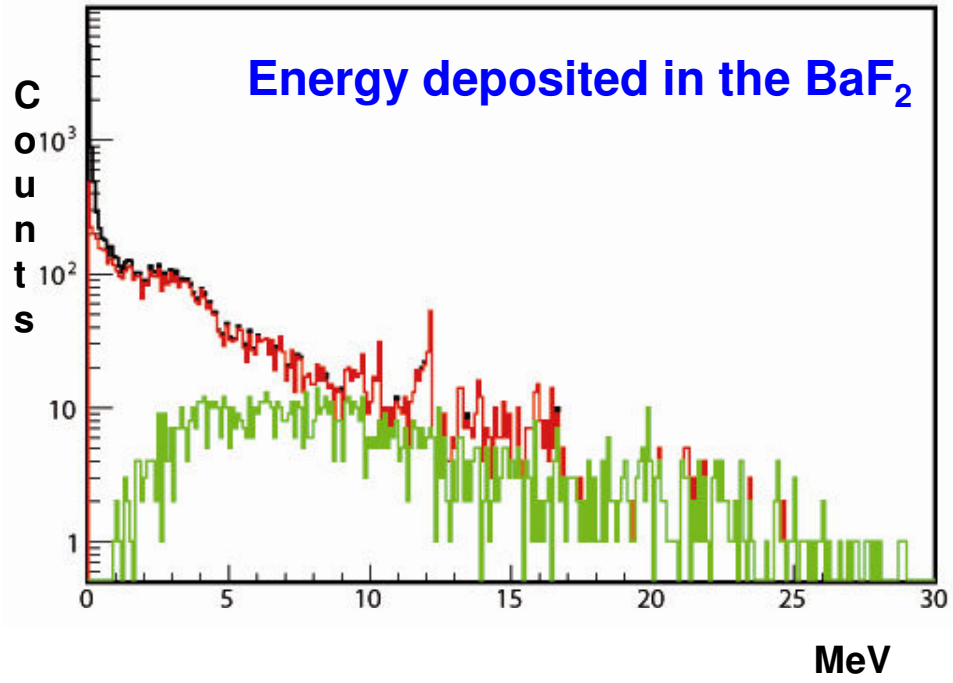
N. COLONNA (2), G. D'ERASMO (2), E. M. FIORE (2) and A. PANTALEO (2)

(1) *INFN and Dipartimento di Fisica - Corso Italia 57, 95129 Catania, Italy*
(2) *INFN and Dipartimento di Fisica - Via Amendola 173, 70126 Bari, Italy*

```
********************************************************************************************************
* G4Track Information:   Particle = neutron,   Track ID = 1,   Parent ID = 0
********************************************************************************************************

Step#      X         Y         Z        KineE    dEStep   StepLeng  TrakLeng    Volume     Process
    0      0 fm      0 fm      0 fm     18 MeV     0 eV      0 fm      0 fm        World    initStep
    1   21.8 cm   3.57 cm   1.03 cm     18 MeV     0 eV   22.1 cm   22.1 cm        World  Transportation
    2   22.4 cm   3.67 cm   1.06 cm     18 MeV     0 eV   6.59 mm   22.7 cm         BAFA  HadronElastic
    :----- List of 2ndaries - #SpawnInStep=  1(Rest= 0,Along= 0,Post= 1), #SpawnTotal=  1 ---------------
    :   22.4 cm   3.67 cm   1.06 cm   19.5 keVBa137[0.0]
    :---------------------------------------------------------- End0f2ndaries Info ---------------
Track (trackID 1, parentID 0) is processed with stopping code 4
A new track 0xcc423d8 (trackID 2, parentID 1) is passed to G4StackManager.
### pop requested out of 2 stacked tracks.
Selected G4StackedTrack : 0xcc427e8 with G4Track 0xcc423d8 (trackID 2, parentID 1)
Track 0xcc423d8 (trackID 2, parentID 1) is passed to G4TrackingManager.

********************************************************************************************************
* G4Track Information:   Particle = Ba137[0.0],   Track ID = 2,   Parent ID = 1
********************************************************************************************************

Step#      X         Y         Z        KineE    dEStep   StepLeng  TrakLeng    Volume     Process
    0   22.4 cm   3.67 cm   1.06 cm   19.5 keV     0 eV      0 fm      0 fm         BAFA    initStep
    1   22.4 cm   3.67 cm   1.06 cm      0 eV   19.5 keV  63.6 nm   63.6 nm         BAFA         msc
Track (trackID 2, parentID 1) is processed with stopping code 2
### pop requested out of 1 stacked tracks.
Selected G4StackedTrack : 0xcc427d0 with G4Track 0xcc42528 (trackID 1, parentID 0)
Track 0xcc42528 (trackID 1, parentID 0) is passed to G4TrackingManager.
********************************************************************************************************
* G4Track Information:   Particle = neutron,   Track ID = 1,   Parent ID = 0
********************************************************************************************************

Step#      X         Y         Z        KineE    dEStep   StepLeng  TrakLeng    Volume     Process
    2   22.4 cm   3.67 cm   1.06 cm     18 MeV     0 eV      0 fm   22.7 cm         BAFA    initStep
    3   26.4 cm   5.76 cm   2.28 cm      0 eV      0 eV   4.65 cm   27.4 cm         BAFA  NeutronInelastic
    :----- List of 2ndaries - #SpawnInStep=  5(Rest= 0,Along= 0,Post= 5), #SpawnTotal=  5 ---------------
    :   26.4 cm   5.76 cm   2.28 cm   7.53 MeV   neutron
    :   26.4 cm   5.76 cm   2.28 cm   2.35 MeV     alpha
    :   26.4 cm   5.76 cm   2.28 cm   2.63 MeV  N15[0.0]
    :   26.4 cm   5.76 cm   2.28 cm   5.26 MeV     gamma
    :   26.4 cm   5.76 cm   2.28 cm   13.4 MeV     gamma
   :---------------------------------------------------------- End0f2ndaries Info ---------------
```

… few anomalies I have found …

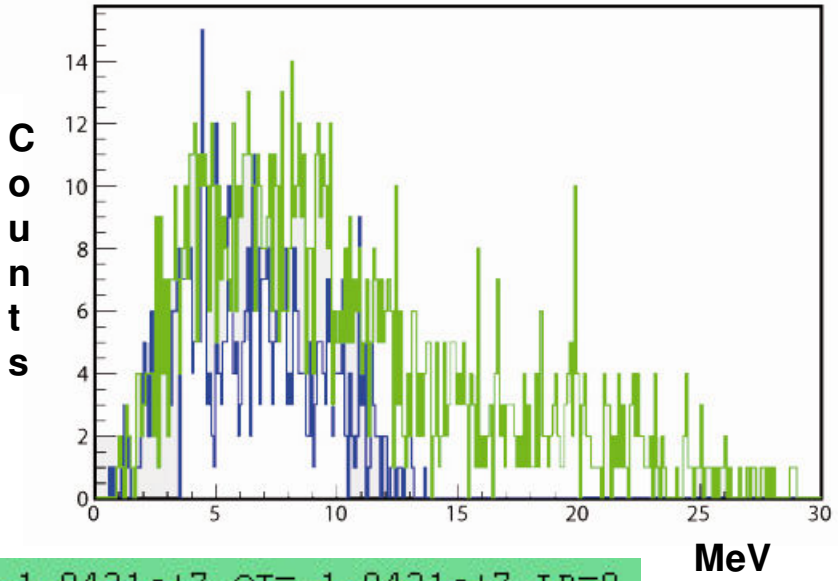


18 MeV incident neutron

All process

All inelastic process

$^{19}F(n,n\alpha)^{15}N$



no control on the energy of secondaries

G4RunManager::GetRunManager()->
AbortEvent();
if energy of secondaries exceeds input
neutron energy

```
F-19(N,2N)F-18.SIG        MT16   QM=-1.0431e+7 QI=-1.0431e+7 LR=0
F-19(N,N+A)N-15,SIG       MT22   QM=-4.0129e+6 QI=-4.0129e+6 LR=0
F-19(N,N+P)O-18,SIG       MT28   QM=-7.993e+6  QI=-7.993e+6  LR=0
```

LOW ENERGY NEUTRON PHYSICS

High Precision Neutron Models and Cross Section Data Set (library G4NDL3.13)

Implemented processes:

Elastic, Inelastic, Capture, Fission

```
// elastic scattering
theNeutronElasticProcess = new G4HadronElasticProcess();
G4LElastic* theElasticModel1 = new G4LElastic;
G4NeutronHPElastic * theElasticNeutron = new G4NeutronHPElastic;
theNeutronElasticProcess->RegisterMe(theElasticModel1);
theElasticModel1->SetMinEnergy(19.*MeV);
theNeutronElasticProcess->RegisterMe(theElasticNeutron);
theElasticNeutron->SetMaxEnergy(20.*MeV);
G4NeutronHPElasticData * theNeutronData = new G4NeutronHPElasticData;
theNeutronElasticProcess->AddDataSet(theNeutronData);
pmanager->AddDiscreteProcess(theNeutronElasticProcess);
```

LOW ENERGY NEUTRON PHYSICS

High Precision Neutron Models and Cross Section Data Sets (library G4NDL3.13)

Process: Elastic, Inelastic, Capture, Fission

```
// inelastic
G4NeutronInelasticProcess*  theNeutronInelasticProc=
new G4NeutronInelasticProcess();
G4NeutronHPInelastic* theHPNeutronInelasticModel =
new G4NeutronHPInelastic();
theHPNeutronInelasticModel->SetMaxEnergy(19.*MeV);
theNeutronInelasticProc->RegisterMe(theHPNeutronInelasticModel);
G4NeutronHPInelasticData * theNeutronData1 = new G4NeutronHPInelasticData;
theNeutronInelasticProc->AddDataSet(theNeutronData1);
pmanager->AddDiscreteProcess(theNeutronInelasticProc);
```

LOW ENERGY NEUTRON PHYSICS

High Precision Neutron Models and Cross Section Data Sets (library G4NDL3.13)

Process: Elastic, Inelastic, Capture, Fission

```
//capture
theCaptureProcess =new G4HadronCaptureProcess;
G4LCapture* theCaptureModel = new G4LCapture;
theCaptureProcess->RegisterMe(theCaptureModel);
theCaptureModel->SetMinEnergy(19.*MeV);
G4NeutronHPCapture * theHPNeutronCaptureModel = new G4NeutronHPCapture;
theCaptureProcess->RegisterMe(theHPNeutronCaptureModel);
G4NeutronHPCaptureData * theNeutronData3 = new G4NeutronHPCaptureData;
theCaptureProcess->AddDataSet(theNeutronData3);
pmanager->AddDiscreteProcess(theCaptureProcess);
```

LOW ENERGY NEUTRON PHYSICS

High Precision Neutron Models and Cross Section Data Sets (library G4NDL3.13)

Process: Elastic, Inelastic, Capture, Fission

```
// fission
theFissionProcess =new G4HadronFissionProcess;
G4LFission* theFissionModel = new G4LFission;
theFissionProcess->RegisterMe(theFissionModel);
pmanager->AddDiscreteProcess(theFissionProcess);
```