Cosmogenic backgrounds in Darkside20k with GEANT4

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Backgrounds by Cosmogenic activation of materials in Darkside20k with GEANT4

- Geant4.10.6 simulation of 10 years flux of muons and secondary's in Hall C (the flux was taken from Fluka simulation for DS-50), crossing the DS-20k.

- 33 beta-n decay isotopes are produced be cosmic muons and secondary's in DarkSide20k materials, according to GEANT4.10.6:

38P, 37Si, 36Si, 36A,l 35Al, 34Al, 33Al, 32Al, 31Al, 32Mg, 31Mg, 30Mg, 28Na, 27Na, 27Ne, 26Ne, 24F, 23F, 22F, 23O, 22O, 19N, 18N, 17N, 17C, 16C, 15B, 14B, 13B, 12Be, 11Li, 9Li, 8He.

- NEUTRON YIELDS from cosmogenic activation for DS-20k construction DS-20kA materials (Acrylic, Gd-loaded Acrylic) are much less, than NEUTRON YIELDS from alpha-n reaction s and spontaneous fissions in materials, except for argon.

- NEUTRON YIELDS from cosmogenic activation in Argon are rather high (2.3 beta-neutron decay/year/50 ton) and should be cutted by MUON VETO.

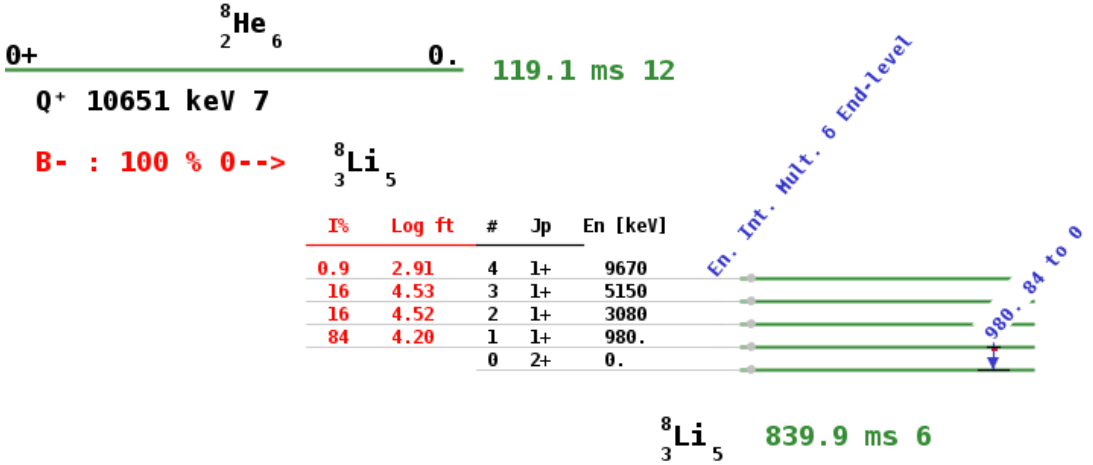
Produced beta-n isotopes in 50 tonn AAr target (10 years)

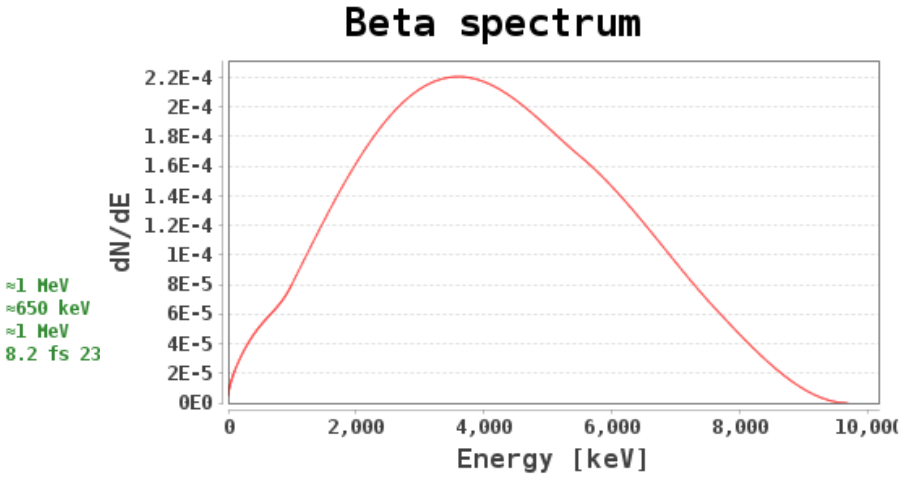
isotope	Number of isotopes	(β- , n) probability	(β-,2n)	(β-,3n)	Number of neutrons	T1⁄2 (ms)	Rejection by VETO in TPC (10s after mu)
P38	11.1	12.50%			1.388	640	2.75E-05
Si37	0.6	17.00%			0.099	90	3.60E-35
Si36	3.5	12.50%			0.438	450	8.99E-08
Al36	0.6	30.00%			0.175	90	6.36E-35
Al35	0.6	38.00%			0.222	37.2	2.76E-82
Al34	0.0	26.00%			0.000	56.3	0.00E+00
Al33	1.2	8.50%			0.099	41.7	6.65E-74
Al32	7.6	0.70%			0.053	33	3.34E-93
Al31	39.7	1.60%			0.636	644	1.35E-05
Mg32	0.6	5.50%			0.032	86	3.24E-37
Mg31	2.3	6.20%			0.145	326	8.49E-11
Mg30	1.8	0.06%			0.001	313	2.55E-13
Na28	1.2	0.58%			0.007	30.5	1.42E-101
Na27	5.8	0.13%			0.008	301	7.62E-13
Ne27	0.6	2.00%			0.012	31.5	3.33E-98
Ne26	0.6	0.13%			0.001	197	4.01E-19

isotope	Number of isotopes	(β- , n) probability	(β-,2n)	(β-,3n)	Number of neutrons	T1⁄2 (ms)	Rejection by VETO in TPC (10s after mu)
F24	1.75	5.90%			0.103	384	1.50E-09
F23	4.68	14.00%			0.655	2230	2.93E-02
F22	12.27	11.00%			1.350	4230	2.62E-01
O23	0.00	7.00%			0.000	97	0.00E+00
O22	1.17	22.00%			0.257	2250	1.18E-02
N19	0.00	41.80%			0.000	336	0.00E+00
N18	1.17	7.00%			0.082	619.2	1.13E-06
N17	5.84	95.00%			5.552	4173	1.05E+00
C17	0.58	28.40%			0.166	193	4.23E-17
C16	0.00	97.90%			0.000	747	0.00E+00
B15	0.58	93.60%	0.40%		0.552	9.93	4.51E-304
B14	2.34	6.04%			0.141	12.5	2.38E-242
B13	4.09	0.28%			0.011	17.33	2.46E-176
Be12	1.75	0.50%			0.009	21.5	9.09E-143
Li11	2.34	86.30%	4.10%	1.90%	2.342	8.75	0.00E+00
Li9	15.19	50.80%			7.719	178.3	1.02E-16
He8	4.68	16.10%			0.753	119.1	4.04E-26
Sum	**136**				**23.0**		**1.36**

Generators for beta-n isotopes for G4DS
8He, 9Li, 17N, 22O, 22F, 23F
(absent in standart GEANT4 release)

decay scheme 8He





Generator decay 8He

```
//--------------------------------------------------------------------------
//    Energy Shooter for electrons from He spectrum
//--------------------------------------------------------------------------

G4double BxGeneratorLi9He8::ShootEnergyElectronHe(G4double Egr) {

    G4double E0 = Egr; //  end-point kinetic energy

    G4double sum   = 0.;
    G4double norma = 0.;
    G4double Probability[1000];
    G4double EnergyBin[1000];
    G4double Z0 = 3.; // 7. - electron (N), 5. = positron (B): doughter
nucleus charge
    G4double xE;      // beta kinetic energy
    G4double me = 0.511;
    G4double kk = 4.586E-2, FF = 0., xx = 0.; // Fermi function, kk=1/137*2*pi
    G4double a1 = -1. / 2., a2 = -1. / 24.;   // "-" - electron, "+" - positron
    G4double scale = E0 / 1000.;
    G4double deltaX, x, y;
    G4double PositronEnergySp[1000];

    for (G4int i = 0; i < 1000; i++) {

        xE                  = scale * (G4double(i) + 0.5);
        EnergyBin[i]        = xE;
        PositronEnergySp[i] = 0.;

        xx = kk * Z0 * (xE + me) / (sqrt(xE * xE + 2. * me * xE));
        FF = xx / (xx + a1 * xx * xx + xx * xx * xx / 6. + a2 * xx * xx * xx *
xx); // Fermi function calculation, the

exponential is expanded in Taylor's

series
        if (xE < E0) PositronEnergySp[i] = FF * (E0 - xE) * (E0 - xE) * (xE +
me) * sqrt(xE * xE + 2. * me * xE);

        norma += PositronEnergySp[i];
    }
```

```
//--------------------------------------------------------------------------
//    Energy Shooter for neutrons for He spectrum
//--------------------------------------------------------------------------

G4double BxGeneratorLi9He8::ShootEnergyNeutronHe(G4int Ch) {
    G4double EnergyBin;
    if (Ch == 1)
        EnergyBin = 0.7;
    else
        EnergyBin = 2.9;
    return EnergyBin;
}
```

```
//--------------------------------------------------------------------------
//    Energy Shooter for electrons from He spectrum
//--------------------------------------------------------------------------

G4double BxGeneratorLi9He8::ShootEnergyElectronHe(G4double Egr) {

    G4double E0 = Egr; //  end-point kinetic energy

    G4double sum   = 0.;
    G4double norma = 0.;
    G4double Probability[1000];
    G4double EnergyBin[1000];
    G4double Z0 = 3.; // 7. - electron (N), 5. = positron (B): doughter
nucleus charge
    G4double xE;      // beta kinetic energy
    G4double me = 0.511;
    G4double kk = 4.586E-2, FF = 0., xx = 0.; // Fermi function, kk=1/137*2*pi
    G4double a1 = -1. / 2., a2 = -1. / 24.;   // "-" - electron, "+" - positron
    G4double scale = E0 / 1000.;
    G4double deltaX, x, y;
    G4double PositronEnergySp[1000];

    for (G4int i = 0; i < 1000; i++) {

        xE                  = scale * (G4double(i) + 0.5);
        EnergyBin[i]        = xE;
        PositronEnergySp[i] = 0.;
```

decay scheme 9Li

$^{9}_{3}Li_{6}$

3/2- 0.0 178.3 ms 4

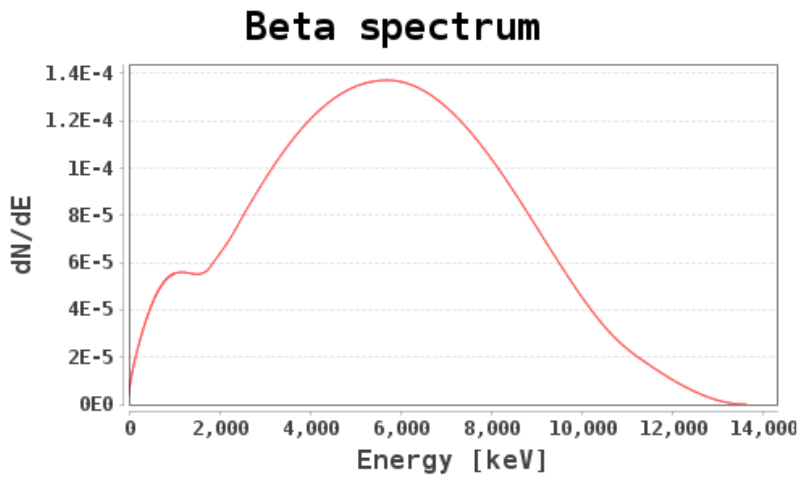
Q⁺ 13606.7 keV 19

B- : 100 % 0--> $^{9}_{4}Be_{5}$

I%	Log ft	#	Jp	En [keV]
2.7	2.56	5	5/2-	11810
1.1	3.43	4	(7/2-)	11282
1.5	5.04	3	(5/2-)	7940
15.8	5.34	2	1/2-	2.78E+3
29.7	5.13	1	5/2-	2429.4
49.2	5.325	0	3/2-	0.0

$^{9}_{4}Be_{5}$ STABLE

400 keV 30
575 keV 50
≈1 MeV
1.10 MeV 12
0.78 keV 13

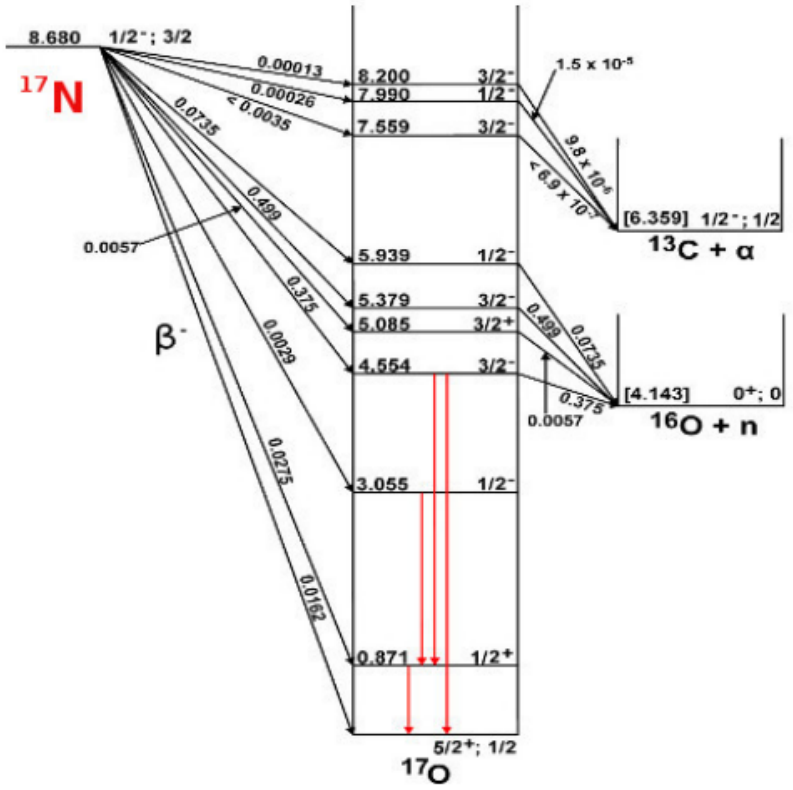


Generator decay 9Li

```
//--------------------------------------------------------------------------
//    Energy Shooter for neutrons for Li spectrum
//--------------------------------------------------------------------------

G4double BxGeneratorLi9He8::ShootEnergyNeutronLi(G4int Ch) {

    // This is the high energy neutron spectrum - which should correspond to
the
    // beta decay to high energy levels
    // from 0 up to 3 MeV

    G4double NeutronEnergySpHigh[16] = {0.0, 2.24, 5.0, 7.94, 11.2, 12.6,
11.0, 10.0, 7.9, 5.0, 4.0, 3.2, 2.0, 0.5, 0.1, 0.0};

    // This is the low energy neutron spectrum - which should correspond to the
    // beta decay on low energy levels
    // From 0 up to 1 MeV

    G4double NeutronEnergySpLow[21] = {
        0.0, 2100.0, 5447.74, 6500, 7306.69, 7000., 6625.06, 5000., 3322.82,
2200., 1149., 900., 911.57, 2100, 955.64, 100.0, 0.36, 0.08, 0.08, 0.0, 0.0,
    };

    G4double ProbabilityHigh[16];
    G4double ProbabilityLow[21];
    G4double EnergyBinHigh[16];
    G4double EnergyBinLow[21];

    G4double sum   = 0;
    G4double norma = 0;
    G4double deltaX, x, y;
    G4int Num;
    G4double scale;

    if (Ch == 2) {
        Num   = 16;
        scale = 200;

        norma = 0;

        for (G4int i = 0; i < Num; i++) {
            norma += NeutronEnergySpHigh[i];
        }
```

```
//--------------------------------------------------------------------------
//    Energy Shooter for electrons from Li spectrum
//--------------------------------------------------------------------------

G4double BxGeneratorLi9He8::ShootEnergyElectronLi(G4double lll) {

    G4double E0 = lll; //  end-point kinetic energy

    G4double sum   = 0.;
    G4double norma = 0.;
    G4double Probability[1000];
    G4double EnergyBin[1000];

    G4double Z0 = 4.; // 7. - electron (N), 5. = positron (B): doughter
nucleus charge
    G4double xE;      // beta kinetic energy
    G4double me = 0.511;
    G4double kk = 4.586E-2, FF = 0., xx = 0.; // Fermi function, kk=1/137*2*pi
    G4double a1 = -1. / 2., a2 = -1. / 24.;   // "-" - electron, "+" - positron
    G4double scale = E0 / 1000.;
    G4double deltaX, x, y;
    G4double PositronEnergySp[1000];

    for (G4int i = 0; i < 1000; i++) {

        xE                  = scale * (G4double(i) + 0.5);
        EnergyBin[i]        = xE;
        PositronEnergySp[i] = 0.;

        xx = kk * Z0 * (xE + me) / (sqrt(xE * xE + 2. * me * xE));
        FF = xx / (xx + a1 * xx * xx + xx * xx * xx / 6. + a2 * xx * xx * xx *
xx); // Fermi function calculation, the

exponential is expanded in Taylor's

series
        if (xE < E0) PositronEnergySp[i] = FF * (E0 - xE) * (E0 - xE) * (xE +
me) * sqrt(xE * xE + 2. * me * xE);

        norma += PositronEnergySp[i];
    }

    for (G4int i = 0; i < 1000; i++) {
        sum += PositronEnergySp[i] / norma;
        Probability[i] = sum;
```

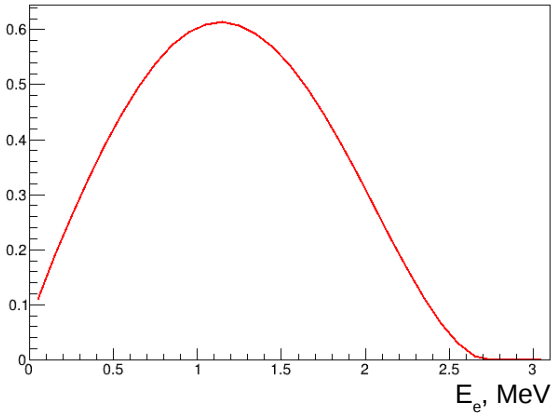
decay scheme 17N



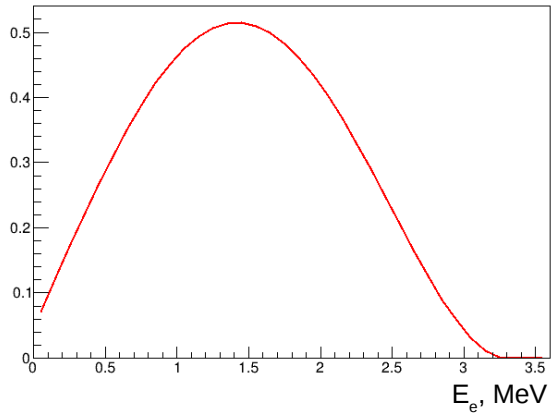
Neutrons energy:
Level 5.939 — 1700 keV
Level 5.379 — 1170 keV
Level 5.085 — 884 keV
Level 4.554 — 383 keV

Beta spectrums

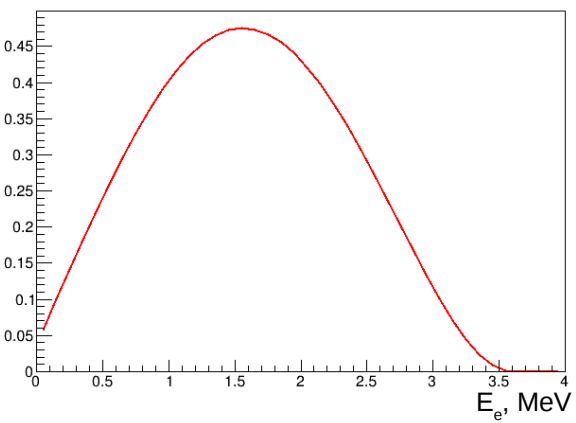
Intensity 0.0735
$1/2^-$ to $1/2^-$



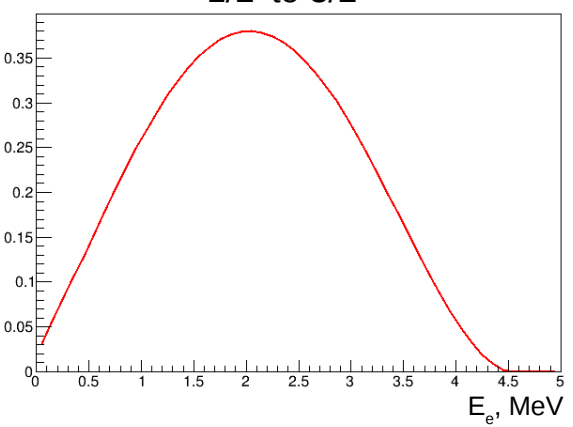
Intensity 0.499
$1/2^-$ to $3/2^-$



Intensity 0.0057
$1/2^-$ to $3/2^+$



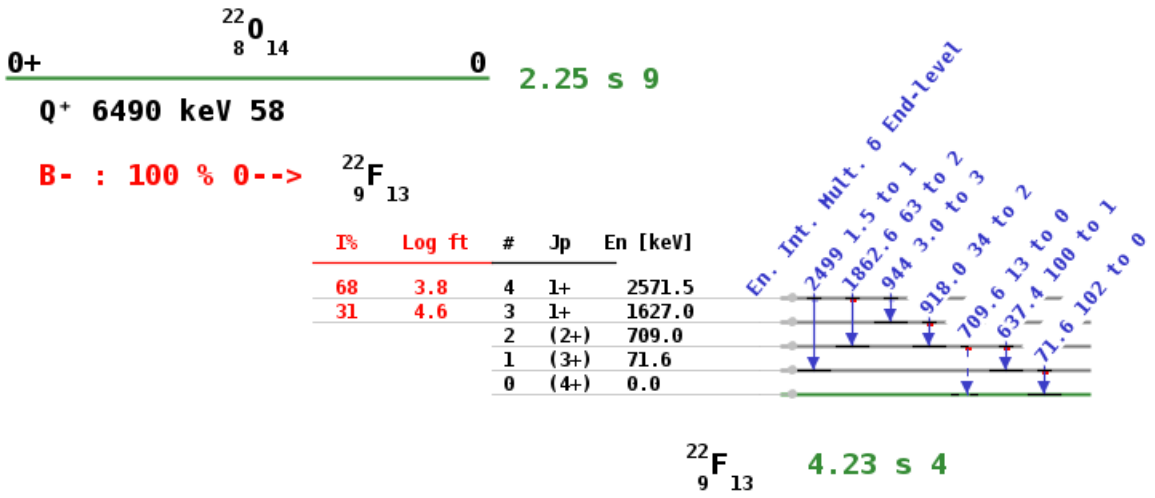
Intensity 0.375
$1/2^-$ to $3/2^-$

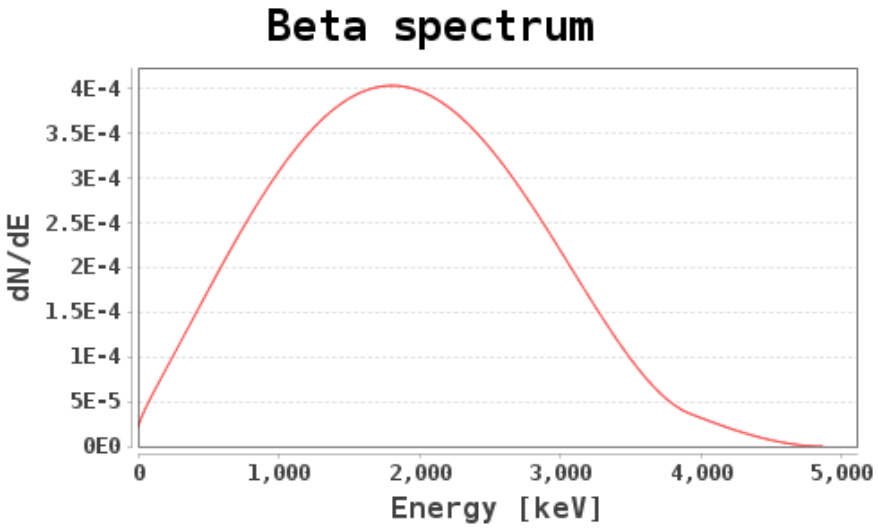


Generator decay 17N

```
  G4ThreeVector zero(0., 0., 0);
    fSPSAng->SetVerbosity(0);
    fSPSAng->SetAngDistType("iso");
    fSPSAng->SetPosDistribution(fSPSPos);

  G4String particleName;

G4double q = G4UniformRand();

G4ParticleTable* particleTable = G4ParticleTable::GetParticleTable();
  fParticleGun->SetParticlePosition(zero);
    fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
      G4ParticleDefinition* particle;

if (q<=0.0735) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(2.741)*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

 particle   = particleTable->FindParticle(particleName="neutron");
  fParticleGun->SetParticleDefinition(particle);
    fParticleGun->SetParticleEnergy(1.690*MeV);
    fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
    fParticleGun->GeneratePrimaryVertex(anEvent);
  }

else if (q>0.0735 && q<=0.5725) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(3.301)*MeV);
      fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

 particle   = particleTable->FindParticle(particleName="neutron");
  fParticleGun->SetParticleDefinition(particle);
    fParticleGun->SetParticleEnergy(1.163*MeV);
    fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
    fParticleGun->GeneratePrimaryVertex(anEvent);
  }

else if (q>0.5725 && q<=0.5784) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
```

decay scheme 22O





neutron energy — 570 keV

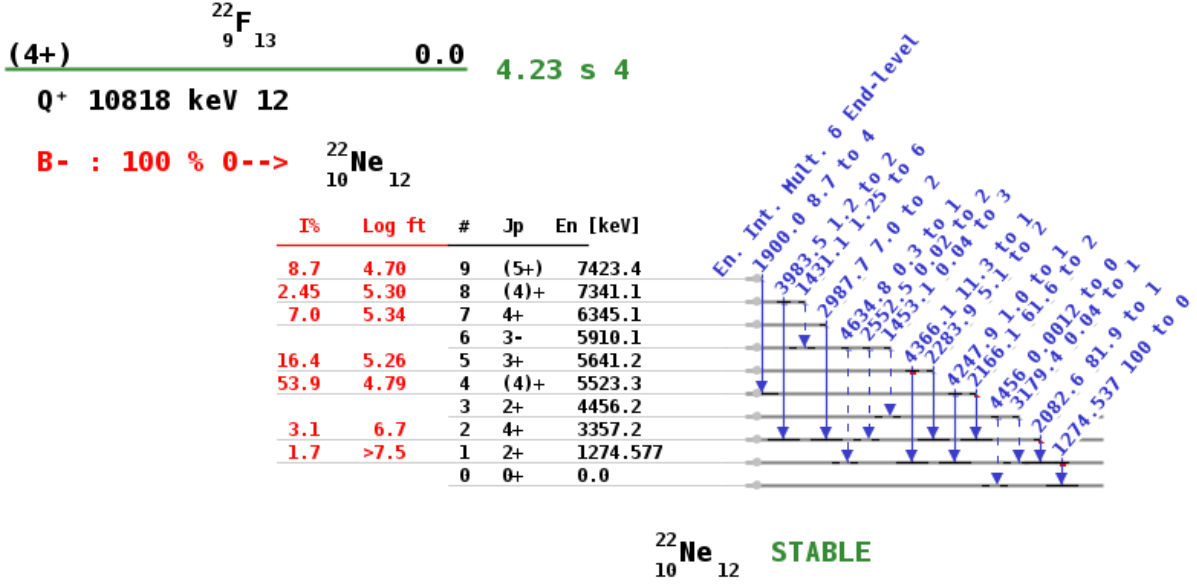
https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html

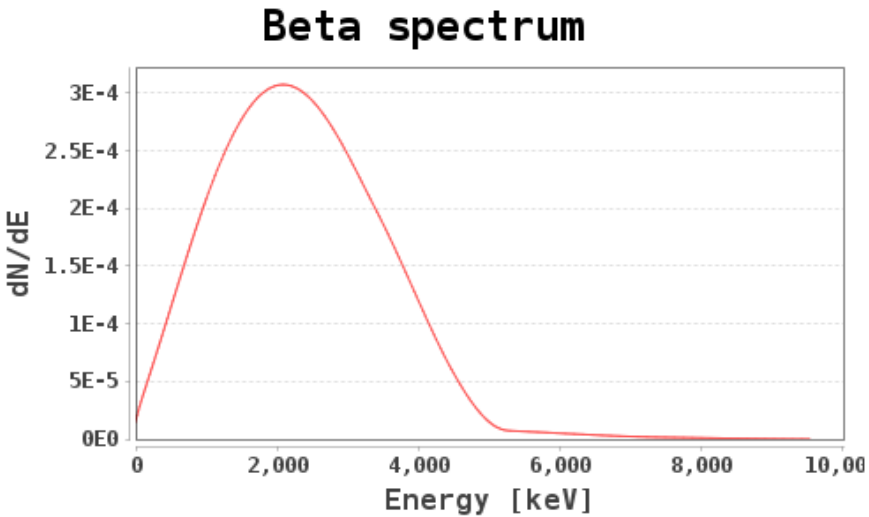
Generator decay 22O

```
////////////// electrons ////////////////////

if (q<=0.68) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(3.919)*MeV);
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=2;
  }

else if (q>0.68 && q<=0.99) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(4.863)*MeV);
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=1;
  }

////////////// neutron //////////////

else { //1%
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(6.90)*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

  particle
    = particleTable->FindParticle(particleName="neutron");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.57*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
}
```

```
////////////// gamma ///////////////

if (w==2){

      if(q<=0.02){
      particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(2.499*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

      particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.0716*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
 }
      else if (q>0.02 && q<=0.65){
  particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(1.8626*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

  particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.637*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
    particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.0716*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
       }
       else {
        particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.944*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
```

decay scheme 22F





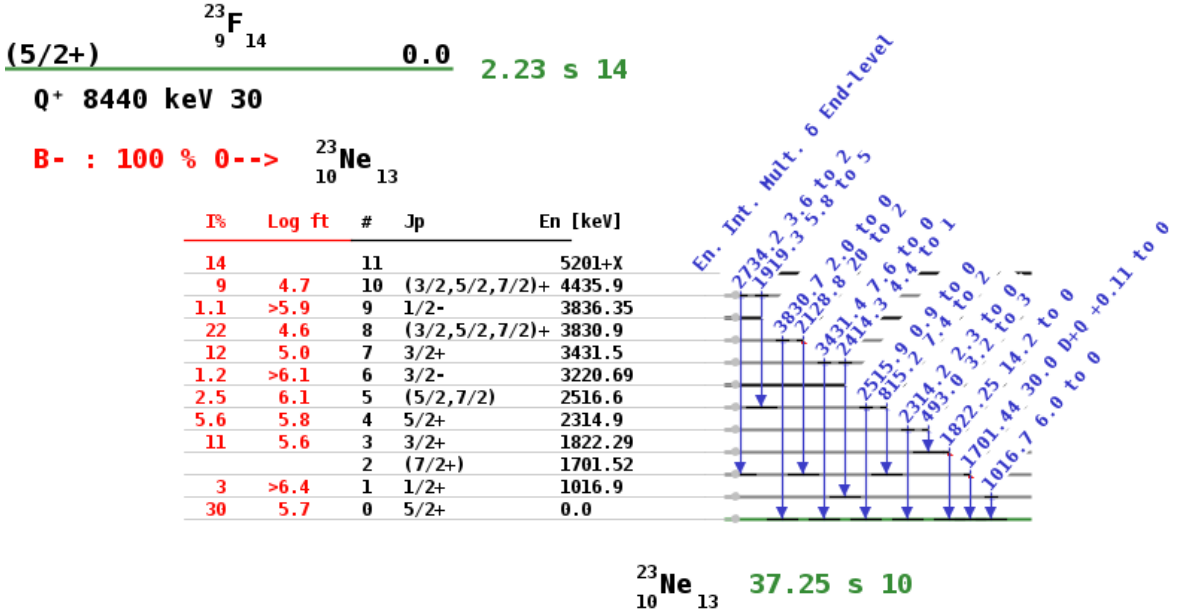
neutron energy — 454 keV

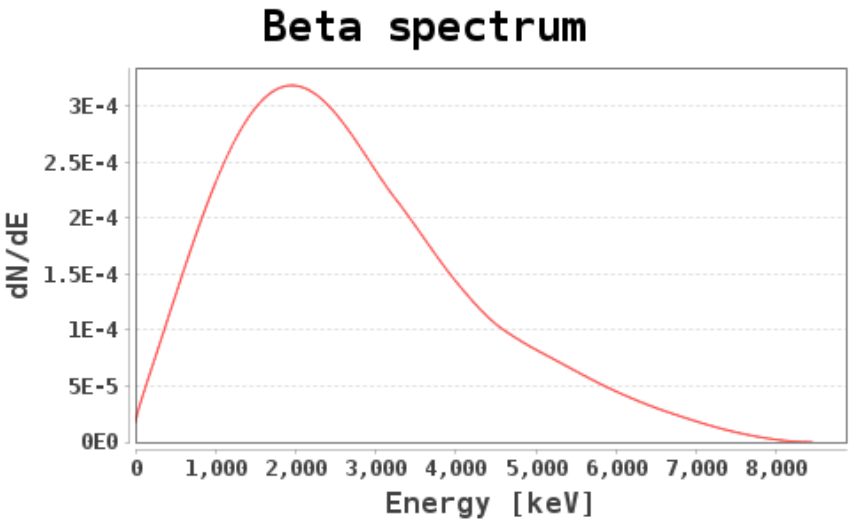
Generator decay 22F

```
////////////// electrons ////////////////

if (q<=0.087) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(3.48)*MeV);
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=9;
  }

else if (q>0.087 && q<=0.1115) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(3.477)*MeV);
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=8;
  }

else if (q>0.1115 && q<=0.1815) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(4.67)*MeV);
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=7;
  }

else if (q>0.1815 && q<=0.3455) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(5.177)*MeV);
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=6;
  }

else if (q>0.3455 && q<=0.8845) {
particle
    = particleTable->FindParticle(particleName="e-");
```

```
////////////// neutron //////////////

else if (q>0.9155 && q<=1) { //8.45%
particle
    = particleTable->FindParticle(particleName="neutron");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.454*MeV);
  fParticleGun->GeneratePrimaryVertex(anEvent);
}


////////////// gamma //////////////

if (w==9){
particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(1.900*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

  particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(2.1661*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

  particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(2.0826*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
}

if (w==8){
       if(q>0.087 && q<=(0.087+0.012)){
particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(3.9835*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

    particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(2.0826*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
```

decay scheme 23F





neutron energy — 2980 keV

Generator decay 23F

```
////////////// electrons ////////////////////

if (q<=0.09) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(4.004)*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=10;
  }

else if (q>0.09 && q<=0.31) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(4.609)*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=8;
  }

else if (q>0.31 && q<=0.43) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(5.009)*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=7;
  }

else if (q>0.43 && q<=0.455) {
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(ShootEnergyElectron(5.923)*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
w=5;
  }

else if (q>0.455 && q<=0.511) {
particle
    = particleTable->FindParticle(particleName="e-");
```

```
////////////// neutron //////////////

else if (q>0.951 && q<=1) { //4.9%
particle
    = particleTable->FindParticle(particleName="e-");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.15*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

  particle
    = particleTable->FindParticle(particleName="neutron");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(2.98*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
}


////////////// gamma //////////////

if (w==10){

        if(q<=0.036){
        particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(2.734*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

        particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(1.701*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);
 }
        else{
  particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(1.919*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
  fParticleGun->GeneratePrimaryVertex(anEvent);

  particle
    = particleTable->FindParticle(particleName="gamma");
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(0.815*MeV);
  fParticleGun->SetParticleMomentumDirection(fSPSAng->GenerateOne());
```

Next steps

- *g4ds background simulation with new generators for 6 beta-n isotopes*

  8He, 9Li, 17N, 22O, 22F, 23F

- *Upgrade of g4ds to last GEANT4 version and investigation for possibility to make the long VETO (~50s) for high-energy events (E_{veto}+E_{TPC} > 100 MeV) in argon. The dead time of the DS should be zero.*

  Two new young researches from Russia want to participate in GEANT4 cosmogenic background simulations starting from now:

  Taya Smirnova – Kurchatov Institute

  Vitaly Dronik – Belgorod State University