PrimEx-eta MC production

1/ Event generator
   A/ Differential cross-section calculation
   B/ gen_primex_eta_he4
2/ MCWrapper
   A/ evtgen, post processing η(') decays
   B/ Photon flux weighted
   C/ Random background
   D/ plugins
3/ Integrated luminosity simulated calculation
4/ Sanity check

Differential cross-section calculation

$HALLD_SIM_HOME/src/programs/Simulation/gen_primex_eta_he4

```
ds_eta_he4          ◄──────────────────  Combined Coulomb & Strong
ff_coulomb          ◄──────────         Primakoff
ff_strong
gen_primex_eta_he4.cc          ◄──────  Nuclear Coherent
HddmOut.h
inc_eta_he4          ◄──────────         Nuclear Incoherent
SConscript
```

- Use Ilya's fortran coding of Sergey's calculation

  S. Gevorkyan, A. Gasparian, L. Gan, I. Larin, and M.Khandaker,Phys. Rev. C80, 055201 (2009).

  S. Gevorkyan, A. Gasparian, L. Gan, I. Larin, and M.Khandaker,arXiv:0908.1297.

- Generate 2D histo (Eγ,θ)

halld_sim event generator

$HALLD_SIM_HOME/src/programs/Simulation/gen_primex_eta_he4

```
ds_eta_he4
ff_coulomb
ff_strong
gen_primex_eta_he4.cc
HddmOut.h
inc_eta_he4
SConscript
```

```
ifarm1901.jlab.org> ls -lrth /work/halld/home/gxproj2/g
jg/configurations
total 1.0K
drwxr-sr-x 2 gxproj2 halld 2 Jul  7 21:50 generation
drwxr-sr-x 2 gxproj2 halld 3 Jul  7 21:51 geant
```

```
# path and root file name
rfile: /work/halld/home/ijaegle/he4_eta_primakoff/PRIMEX-D_etap_he4-corrected-08062023-notree.root
# xs_tot/xs_prim/xs_int/xs_coh/xs_inc
histo: xs_coh_vs_egamb
binning: 5999 10599 4600 450 0 4.5
target: Helium
decay: eta'
```

4 components simulated:
- Primakoff
- Nuclear Coherent
- Nuclear Incoherent
- All components combined including Interference between Primakoff & Nuclear Coherent

Post processing

- Use evtgen

```
Decay eta'
1.0 gamma    gamma                                    PHSP; #[Reconstructed PDG2011]
#0.325700000 pi0      pi0      pi0                         PHSP;#ETA_DALITZ_3PI0_GLUEX -0.0288 0.0 0.0; #[Reconstructed PDG2011]
#0.227400000 pi-      pi+      pi0                         ETA_DALITZ;#ETA_DALITZ_GLUEX; #[Reconstructed PDG2011]
#0.046000000 gamma    pi-      pi+                         PHSP;#ETA_PIPIGAMMA_GLUEX 1.32; #[Reconstructed PDG2011]
#0.007000000 gamma    e+       e-                          PHSP; #[Reconstructed PDG2011]
#0.000310000 gamma    mu+      mu-                         PHSP; #[Reconstructed PDG2011]
#0.000270000 gamma    gamma    pi0                         PHSP; #[Reconstructed PDG2011]
#0.000214200 pi+      pi-      e+       e-                 PHSP; #[Reconstructed PDG2011]
#0.000004800 mu+      mu-                                  PHSP;  #[New mode added] #[Reconstructed PDG2011]
#0.000001    pi0      e+       e-                          PHSP;
Enddecay

End
```

plugins

- In simulation directory, there is a cfg/ directory with the MCWrapper configuration file

- PLUGINS [analysis plugin(s)],mcthrown_tree

Integrated luminosity simulated calculation (simu_lum.c)

- Integrated luminosity $[\text{pb}^{-1}]$ = Number of events thrown(E_γ, θ) / differential cross-section(E_γ, θ)

- In practice:

```cpp
TFile * ifile_theory = new TFile("/work/halld/home/ijaegle/he4_eta_primakoff/PRIMEX-D_eta_he4-corrected-10112021-notree.root");
TFile * ifile_simulation = new TFile(file_name);
TString str_compo = str_comp;
if (str_comp == "interp")
  str_compo = "intp";
if (str_comp == "intern")
  str_compo = "intn";
if (str_comp == "inc_n")
  str_compo = "inc";
if (str_comp == "inc_p")
  str_compo = "inc";

TH2F * h_xs_vs_egam_theory = (TH2F *) ifile_theory->Get(Form("xs_%s_vs_egamb", str_compo.Data()));
TH2F * h_xs_vs_egam_simulation = (TH2F *) ifile_simulation->Get("theta_eta_vs_egam");
h_xs_vs_egam_simulation->Divide(h_xs_vs_egam_theory);

int bin_Eg_min = h_xs_vs_egam_theory->GetXaxis()->FindBin(Eg_min);
int bin_Eg_max = h_xs_vs_egam_theory->GetXaxis()->FindBin(Eg_max);
TH1F * h_theta = (TH1F *) h_xs_vs_egam_simulation->ProjectionY("theta_lum", bin_Eg_min, bin_Eg_max);//nb
double int_lum = h_theta->Integral() * 1e-6;//nb to pb -> 1e-3 & Delta\theta = 1e-6
```
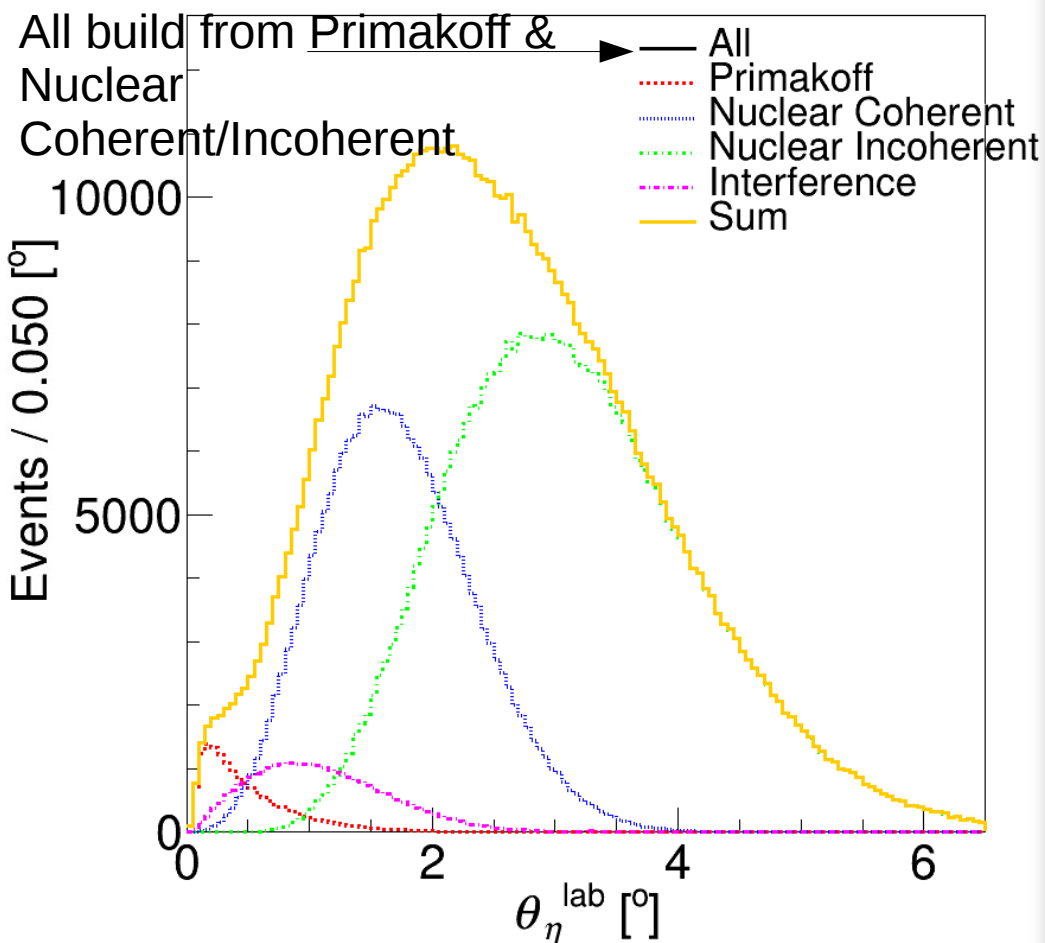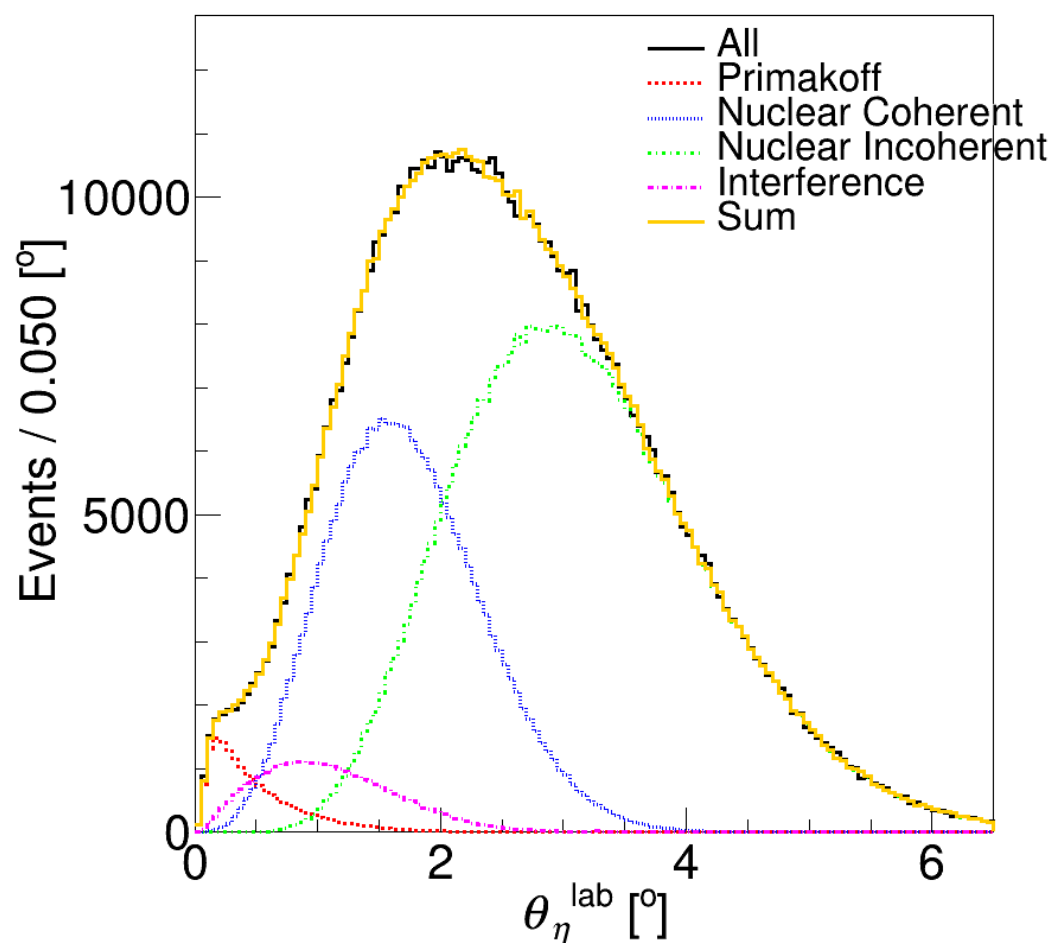
Sanity check
(check_simu_primex_eta.c)

- Normalized all simulation to the same integrated luminosity

- Scale Primakoff to remove the width contribution

- 2 fits

  - "All" build from Primakoff, Nuclear Coherent, Nuclear Incoherent, & assuming a 510 eV decay width & 57.5 degrees interference-phase-angle

  - All components simulated together which also assumed a 510 eV decay width & 57.5 degrees interference-phase-angle

Sanity check
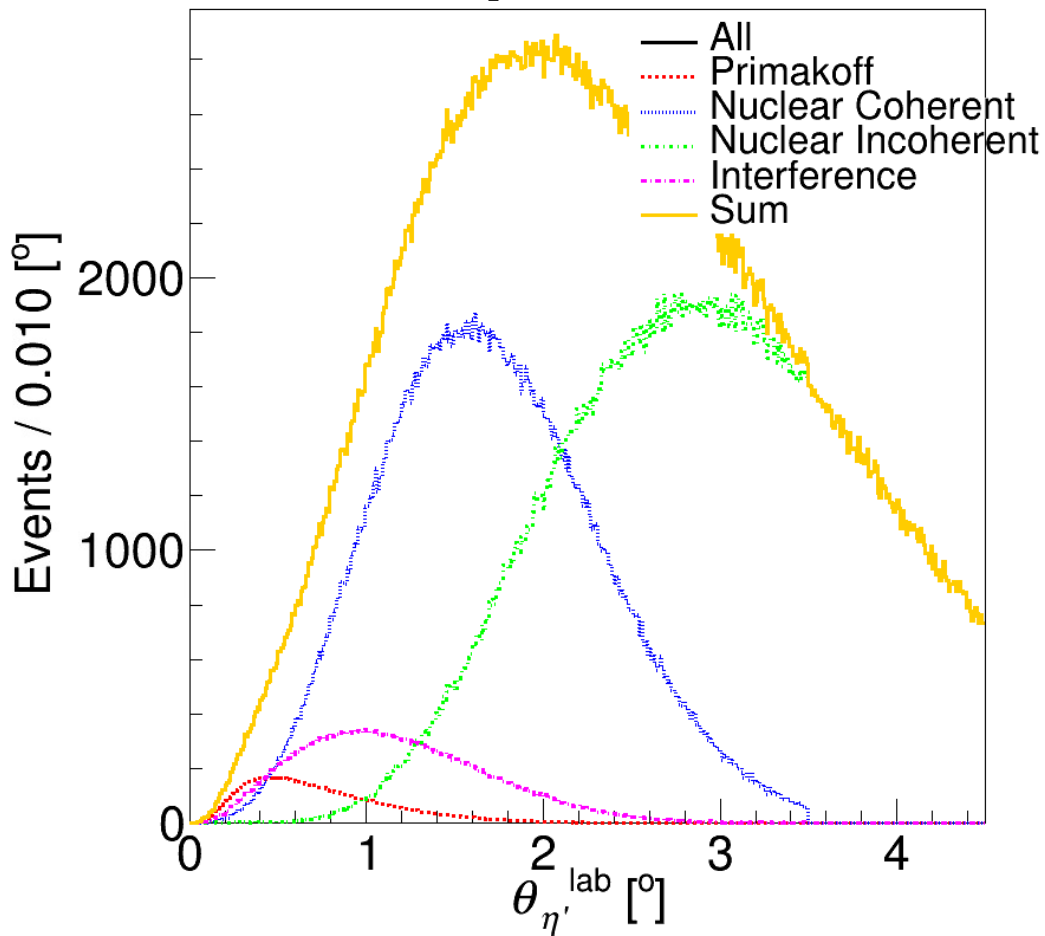

All build from Primakoff & Nuclear Coherent/Incoherent

Fit 1 =====
chi2 / ndf 2.55534e-11
parameter 0 = 0.51 error 0.00799927
Width error 1.56849 %
parameter 1 = 1 error 0.00492527
parameter 2 = 1 error 0.00198642
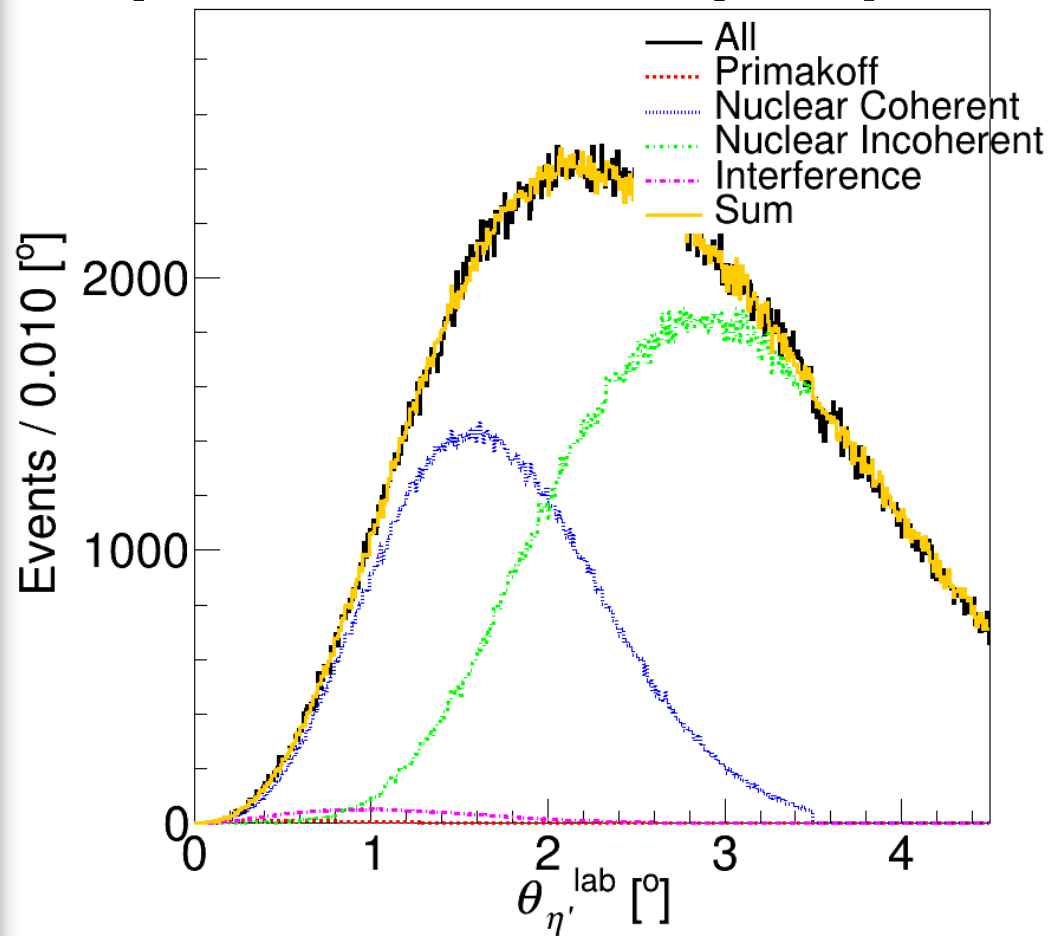parameter 3 = 57.2958 error 1.23273
Phi error 2.15153 %

Fit 2 =====
chi2 / ndf 1.72396
parameter 0 = 0.541508 error 0.0084385
Width error 1.55833 %
parameter 1 = 0.967617 error 0.00493852
parameter 2 = 1.01559 error 0.00201108
parameter 3 = 57.1402 error 1.24323
Phi error 2.17576 %

Sanity check(check_simu_primex_etap.c)

Fit 1 =====
chi2 / ndf 6.37347e-12
parameter 0 = 4.28 error 0.159015
Width error 3.71531 %
parameter 1 = 1 error 0.00543794
parameter 2 = 1 error 0.00204435
parameter 3 = 57.2958 error 1.92981
Phi error 3.36814 %

Fit 2 =====
chi2 / ndf 1.55524
parameter 0 = 0.250934 error 0.0903279
Width error 35.9966 %
parameter 1 = 0.787185 error 0.00450634
parameter 2 = 0.971823 error 0.00196462
parameter 3 = 67.8317 error 7.72157
Phi error 11.3834 %
pull error1 2.83388
pull error2 2.21564e-06
pull error3 1.24285