Hadron Physics Analysis meeting

N° 1

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GSI

GlueX Analysis Steps

1. Monte Carlo Simulation:

- **Event generation**: specifying initial particles produced.

(Programs: *Particle gun, gen8* and *bggen*)

- **Detector Simulation**: following particles journey through the detector.

(Programs: *hdgeant*)

- **Smearing:** introduction of detector resolution at the hit level.

Output: filename**.hddm** (xml-like)

2. JANA: event reconstruction & analysis

Output: ROOT TTree.

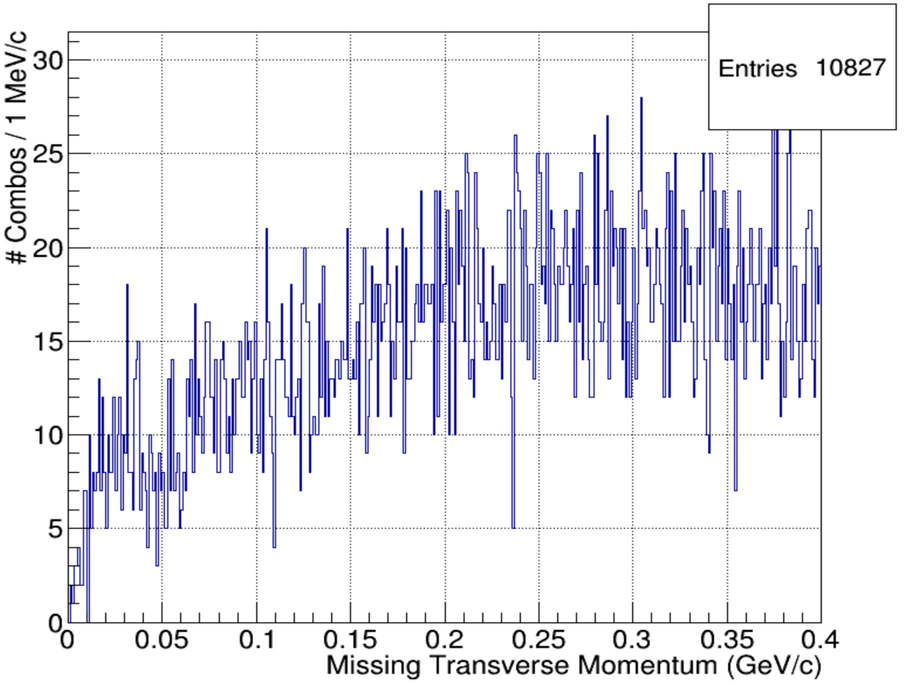
3. AmpTools: Amplitude Analysis.

Process studied here is : $\gamma\ p \rightarrow \omega\ p \mid \omega \rightarrow \pi^+ \pi^- \pi^0 \mid \pi^0 \rightarrow \gamma\ \gamma$

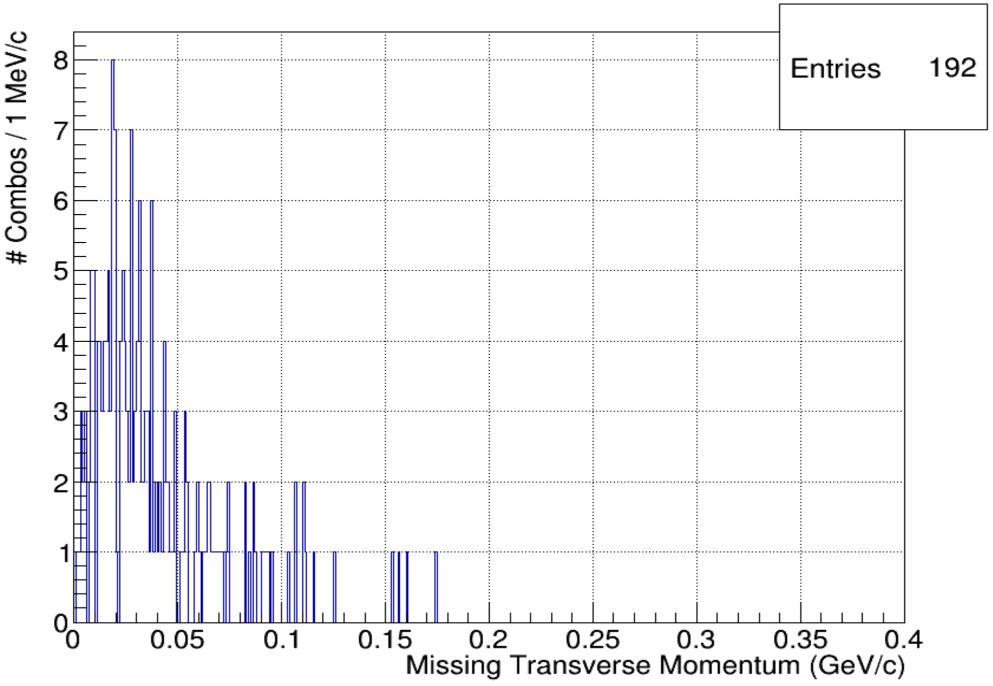
Exercise 2 : Event Selection in JANA

```
        // MISSING TRANSVERSE MOMENTUM
        locReaction->Add_AnalysisAction(new DHistogramAction_MissingTransverseMomentum(locReaction, false, 400, 0.0, 0.4, "PreKinFit"));

        // KINEMATIC FIT
        locReaction->Add_AnalysisAction(new DHistogramAction_KinFitResults(locReaction, 0.05)); //5% confidence level cut on pull histograms only
        locReaction->Add_AnalysisAction(new DCutAction_KinFitFOM(locReaction, 0.0)); // require kinfit converges

        // HISTOGRAM MASSES: POST-KINFIT //false/true: measured/kinfit data
        locReaction->Add_AnalysisAction(new DHistogramAction_InvariantMass(locReaction, Pi0, false, 170, 0.05, 0.22, "Pi0_PostKinFit"));
        locReaction->Add_AnalysisAction(new DHistogramAction_MissingMassSquared(locReaction, false, 400, -0.08, 0.08, "PostKinFit"));
        locReaction->Add_AnalysisAction(new DHistogramAction_InvariantMass(locReaction, omega, false, 300, 0.5, 1.1, "Omega_PostKinFit"));
        locReaction->Add_AnalysisAction(new DHistogramAction_InvariantMass(locReaction, omega, true, 300, 0.5, 1.1, "Omega_KinFit"));
        locReaction->Add_AnalysisAction(new DHistogramAction_2DInvariantMass(locReaction, 1, locXPIDs, locYPIDs, false, 300, 0.5, 1.1, 300, 0.5, 1.1, "PostK\
inFit"));

        // KINEMATIC FIT CUT
        locReaction->Add_AnalysisAction(new DCutAction_KinFitFOM(locReaction, 5.73303E-7)); // +/- 5 sigma confidence level cut

        // HISTOGRAM MASSES: KINFIT CUT //false/true: measured/kinfit data
        locReaction->Add_AnalysisAction(new DHistogramAction_InvariantMass(locReaction, Pi0, false, 170, 0.05, 0.22, "Pi0_KinFitCut"));
        locReaction->Add_AnalysisAction(new DHistogramAction_MissingMassSquared(locReaction, false, 400, -0.08, 0.08, "KinFitCut"));
        locReaction->Add_AnalysisAction(new DHistogramAction_InvariantMass(locReaction, omega, false, 300, 0.5, 1.1, "Omega_KinFitCut"));
        locReaction->Add_AnalysisAction(new DHistogramAction_InvariantMass(locReaction, omega, true, 300, 0.5, 1.1, "Omega_KinFit_KinFitCut"));
        locReaction->Add_AnalysisAction(new DHistogramAction_2DInvariantMass(locReaction, 1, locXPIDs, locYPIDs, false, 300, 0.5, 1.1, 300, 0.5, 1.1, "KinFi\
tCut"));

        // MISSING TRANSVERSE MOMENTUM
        locReaction->Add_AnalysisAction(new DHistogramAction_MissingTransverseMomentum(locReaction, false, 400, 0.0, 0.4, "KinFitCut"));

        // KINEMATICS
        locReaction->Add_AnalysisAction(new DHistogramAction_ParticleComboKinematics(locReaction, true, "KinFit")); //true: kinematic-fit data
        locReaction->Add_AnalysisAction(new DHistogramAction_TrackVertexComparison(locReaction));

        // KINEMATICS COMPARISON
        locReaction->Add_AnalysisAction(new DHistogramAction_ParticleComboGenReconComparison(locReaction, false, "Measured"));
        locReaction->Add_AnalysisAction(new DHistogramAction_ParticleComboGenReconComparison(locReaction, true, "KinFit"));

        _data.push_back(locReaction); //Register the DReaction with the factory

        return NOERROR;
}
```

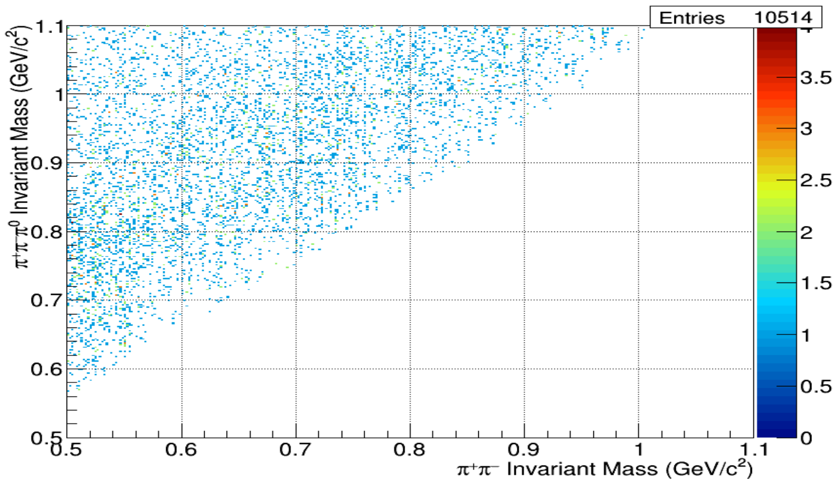
Exercise 2 : Event Selection in JANA



After 5σ CL cut

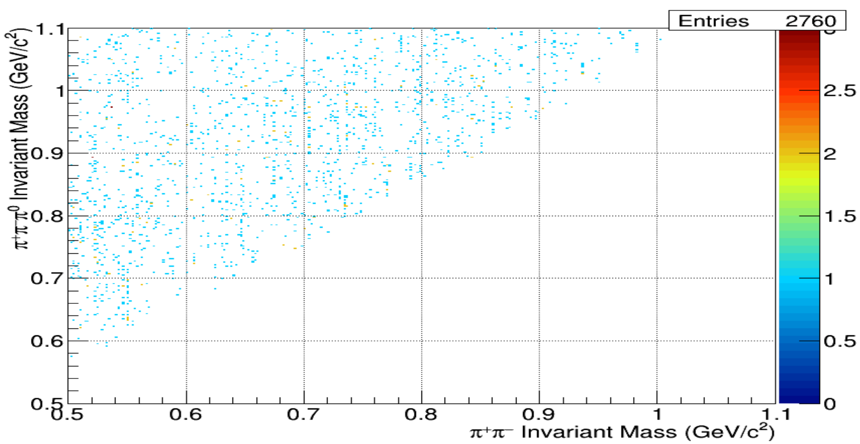


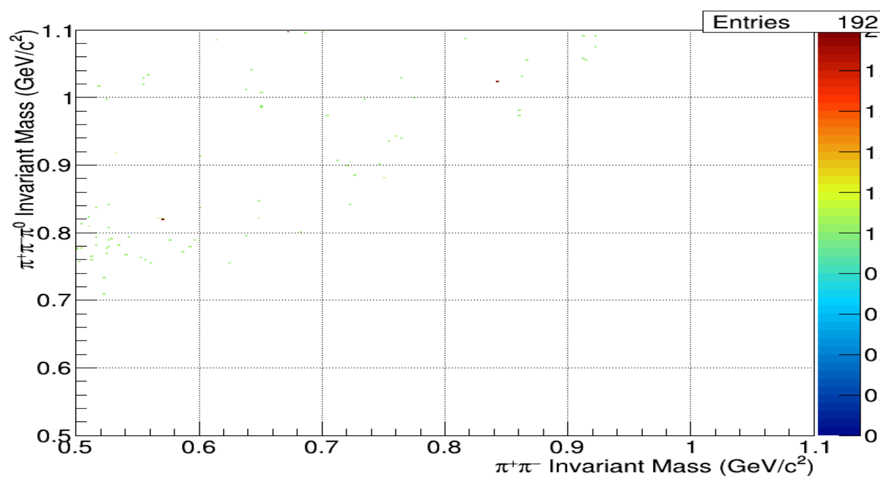
Exercise 2 : Event Selection in JANA



After 5% CL cut

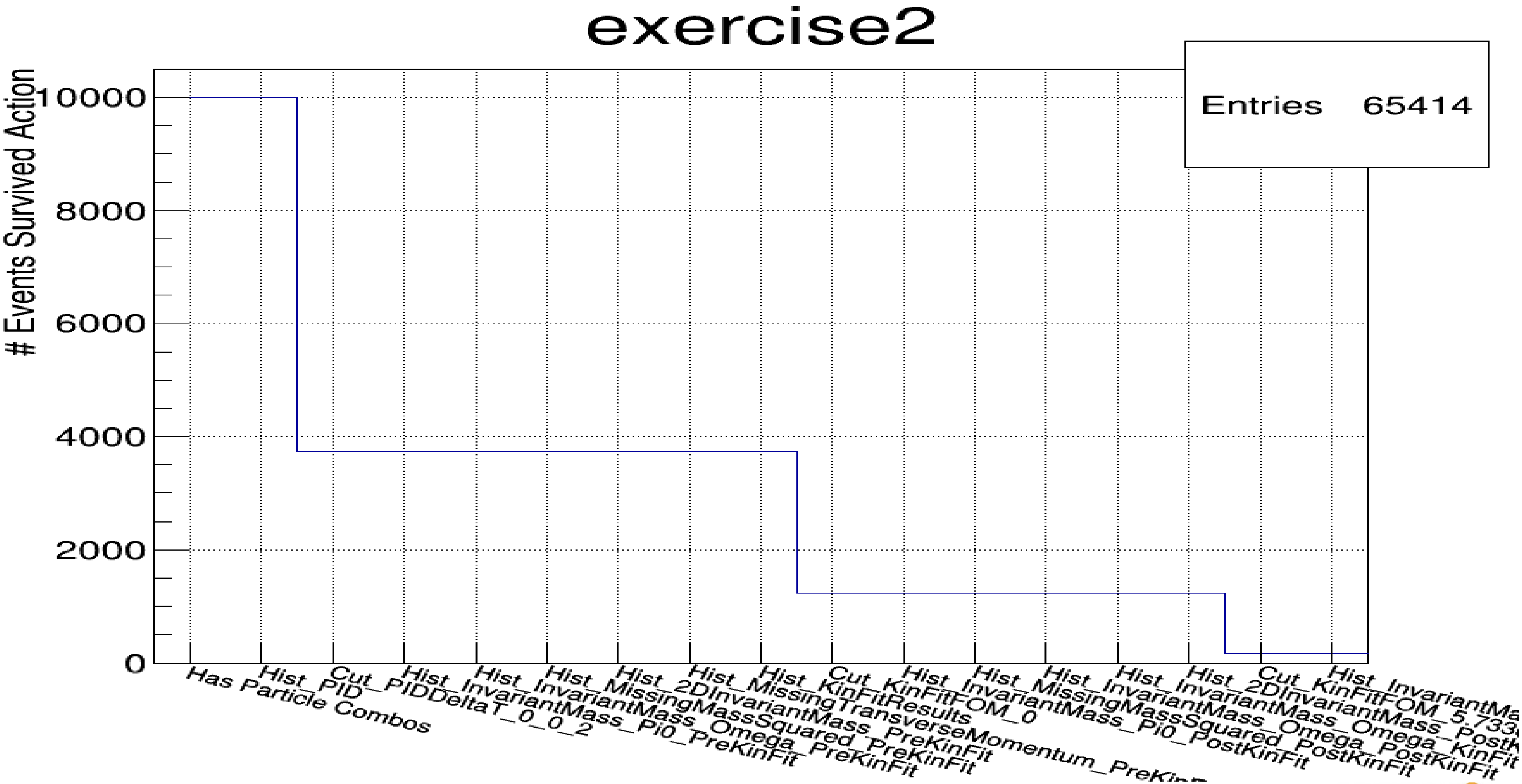
After 5σ CL cut





Exercise 2 : Event Selection in JANA

Summary of the selections



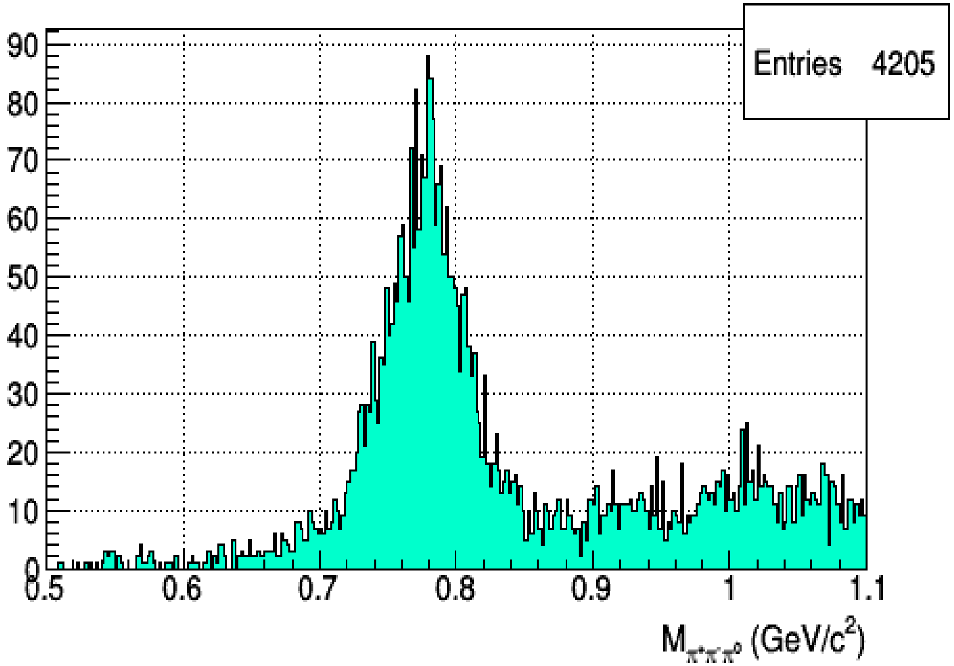
Exercise 3a : TTree's & DSelector's

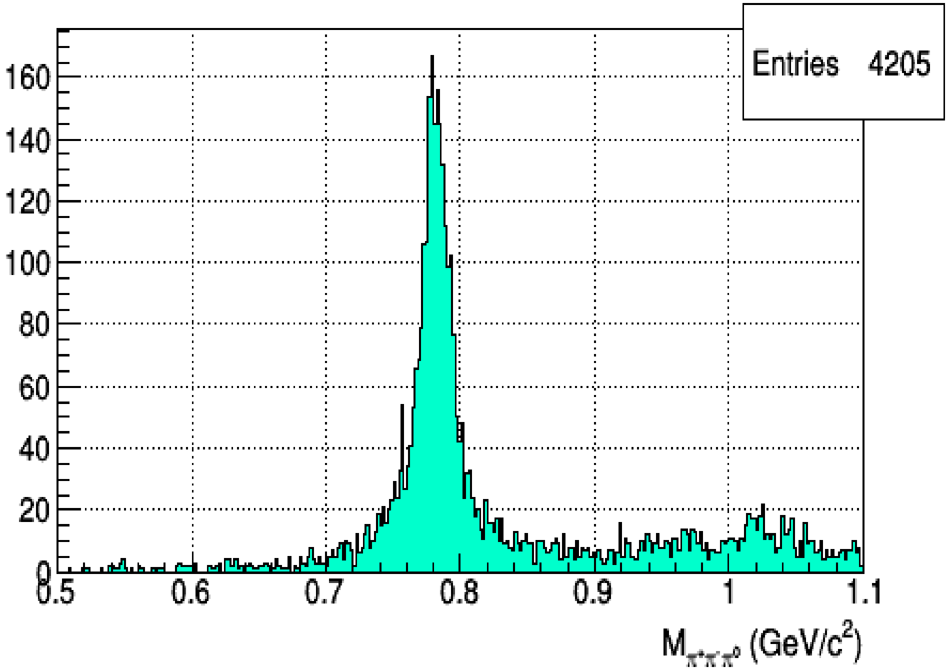
```
/**************************************************** Exercise3a ****************************************************/

dHist_KinFitCL = new TH1I("KinFitResults", ";Kinematic Fit Confedence Level", 500, 0.0, 1.0);
dHist_OmegaMass_Measured = new TH1I("OmegaMass_Measured", ";M_{#pi^{+}#pi^{-}#pi^{0}} (GeV/c^{2})", 300, 0.5, 1.1);
dHist_OmegaMass_KinFit = new TH1I("OmegaMass_KinFit", ";M_{#pi^{+}#pi^{-}#pi^{0}} (GeV/c^{2})", 300, 0.5, 1.1);

set<map<Particle_t, set<Int_t> > > locUsedSoFar_OmegaMass;

double KinFitCL = dComboWrapper->Get_ConfidenceLevel_KinFit();
if(KinFitCL < 5.73303E-7)
  continue;
dHist_KinFitCL->Fill(KinFitCL);

double OmegaMass_measured = (locPiPlusP4_Measured + locPiMinusP4_Measured + locPhoton1P4_Measured + locPhoton2P4_Measured).M();
double OmegaMass_KinFit = (locPiPlusP4 + locPiMinusP4 + locDecayingPi0P4).M();
map<Particle_t, set<Int_t> > locUsedThisCombo_OmegaMass;
locUsedThisCombo_OmegaMass[PiPlus].insert(locPiPlusTrackID);
locUsedThisCombo_OmegaMass[PiMinus].insert(locPiMinusTrackID);
locUsedThisCombo_OmegaMass[Gamma].insert(locPhoton1NeutralID);
locUsedThisCombo_OmegaMass[Gamma].insert(locPhoton2NeutralID);

if(locUsedSoFar_OmegaMass.find(locUsedThisCombo_OmegaMass) == locUsedSoFar_OmegaMass.end())
  {
    dHist_OmegaMass_Measured->Fill(OmegaMass_measured);
    dHist_OmegaMass_KinFit->Fill(OmegaMass_KinFit);
    locUsedSoFar_OmegaMass.insert(locUsedThisCombo_OmegaMass);
  }
```

Exercise 3a : TTree's & DSelector's

Measured

5σ CL





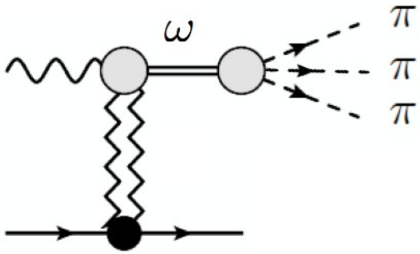
Exercise 5a : Extracting ω SDMEs

Spin-density matrix elements (SDMEs) are an alternate way of expressing polarization observables of non-zero spin objects. In our case, spin-1 (vector) mesons. The density matrix, r , represents the state (pure, mixed or both) of a particle with non-zero spin.

We will construct a **toy model** of omega photoproduction where we have:

$$\text{Intensity} = \text{norm} * PS * BW * W(cos\theta, \phi, \Phi) * e^{At}$$

This talk will mostly focus on $W(cos\theta, \phi, \Phi)$



$$W(\cos\theta,\phi,\Phi) = \frac{3}{4\pi}\Big[\tfrac{1}{2}(1-\rho^0_{00}) + \tfrac{1}{2}(3\rho^0_{00}-1)\cos^2\theta - \sqrt{2}\,\mathrm{Re}\rho^0_{10}\sin 2\theta\cos\phi - \rho^0_{1\,-1}\sin^2\theta\cos 2\phi$$

$$- P_\gamma\cos 2\Phi\,(\rho^1_{11}\sin^2\theta + \rho^1_{00}\cos^2\theta - \sqrt{2}\,\mathrm{Re}\rho^1_{10}\sin 2\theta\cos\phi - \rho^1_{1\,-1}\sin^2\theta\cos 2\phi)$$

$$- P_\gamma\sin 2\Phi\,(\sqrt{2}\,\mathrm{Im}\rho^2_{10}\sin 2\theta\sin\phi + \mathrm{Im}\rho^2_{1\,-1}\sin^2\theta\sin 2\phi)\Big].$$

$\Phi \equiv$ Angle between production plane and photon polarization plane

$\theta, \phi \equiv$ Angles relative to the chosen quantization axis

Parameter Selection

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Vector-Meson Production by Polarized Photons at 2.8, 4.7, and 9.3 GeV*

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(Received 13 November 1972)

Limited measurements for photoproduction at GlueX energies. We will use values from Ballam, et al. (1973)

TABLE VIII. Reaction $\gamma p \to p\omega$ at 2.8, 4.7, and 9.3 GeV. Total cross sections and forward differential cross sections $d\sigma/dt|_{t=0}$ and slopes A from a fit of the form $d\sigma/dt = d\sigma/dt|_{t=0}e^{At}$.

	E_γ (GeV) 2.8	4.7	9.3
σ (μb)	5.3±0.5	3.0±0.3	1.9±0.3
$\frac{d\sigma}{dt}\Big\|_{t=0}$ (μb/GeV²)	33.2±3.6 [a]	22.0±3.2 [a]	13.7±1.6 [a]
A (GeV⁻²)	6.8±0.6 [a]	7.9±0.9 [a]	7.5±0.8 [a]
σ^N (μb)	2.4±0.4	1.7±0.3	1.8±0.3
$\frac{d\sigma^N}{dt}\Big\|_{t=0}$ (μb/GeV²)	14.5±5.1 [b]	14.6±4.8 [b]	11.4±2.1 [a]
A^N (GeV⁻²)	7.3±2.4 [b]	8.5±2.4 [b]	6.6±1.1 [a]
σ^U (μb)	2.9±0.4	1.3±0.3	0.1±0.2

[a] Fit interval $0.02 \le |t| \le 0.5$ GeV².
[b] Fit interval $0.014 \le |t| \le 0.4$ GeV².

$\|t\|$ (GeV²)	E_γ = 9.3 GeV 0.02–0.06	0.06–0.15	0.15–0.60
ρ^0_{00}	0.00±0.07	0.02±0.06	0.20±0.07
ρ^0_{1-1}	0.16±0.08	0.06±0.06	−0.05±0.07
$\mathrm{Re}\rho^0_{10}$	−0.03±0.05	0.01±0.04	0.01±0.06
ρ^1_{00}	−0.08±0.13	−0.13±0.11	−0.01±0.14
ρ^1_{11}	0.09±0.12	0.14±0.10	0.05±0.10
ρ^1_{1-1}	0.38±0.14	0.29±0.12	0.54±0.13
$\mathrm{Re}\rho^1_{10}$	0.04±0.08	−0.11±0.08	−0.02±0.10
$\mathrm{Im}\rho^2_{1-1}$	−0.19±0.14	−0.29±0.14	−0.21±0.13
$\mathrm{Im}\rho^2_{10}$	0.01±0.09	0.10±0.08	0.12±0.09
P_σ	0.9±0.3	0.7±0.3	1.1±0.3

We will use the following parameters for our simulation.

t-slope = 7.5 GeV $^{-2}$

$\rho^1_{1-1} = 0.4$

$\mathrm{Im}\ \rho^2_{1-1} = -0.2$

The rest of the SDMEs are set to 0

Exercise 5a : Extracting ω SDMEs

Need some help to interpret this !!!

```
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=621008 FROM MIGRAD    STATUS=CONVERGED     317          318 TOTAL
                     EDM=5.76642e-05    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                                STEP         FIRST
 NO.   NAME                  VALUE            ERROR          SIZE      DERIVATIVE
   1 Pi+Pi-Pi0::xpol::omega_re          1       fixed
   2 Pi+Pi-Pi0::xpol::omega_im          0       fixed
   3                   rho000       0.022323    0.0012878     0.0011305       7.5139
   4                   rho100       0.023653    0.0010596    0.00092512      -1.3996
   5                  rho1m10      -0.043592    0.0019788     0.0017338      0.19653
   6                   rho111      0.0057774    0.0056698     0.0045815     -0.19074
   7                   rho001      -0.013252    0.0048171     0.0038922       0.3033
   8                   rho101      -0.011167    0.0039955     0.0034778     -0.39718
   9                  rho1m11        0.37541    0.0073812     0.0070262      0.38232
  10                   rho102    -6.8887e-05    0.0037722     0.0033392     -0.71528
  11                  rho1m12       -0.18531    0.0073029     0.0065822      0.14708
```

	$E_\gamma = 9.3$ GeV		
$\|t\|$ (GeV^2)	0.02–0.06	0.06–0.15	0.15–0.60
ρ^0_{00}	0.00 ± 0.07	0.02 ± 0.06	0.20 ± 0.07
ρ^0_{1-1}	0.16 ± 0.08	0.06 ± 0.06	-0.05 ± 0.07
$\mathrm{Re}\,\rho^0_{10}$	-0.03 ± 0.05	0.01 ± 0.04	0.01 ± 0.06
ρ^1_{00}	-0.08 ± 0.13	-0.13 ± 0.11	-0.01 ± 0.14
ρ^1_{11}	0.09 ± 0.12	0.14 ± 0.10	0.05 ± 0.10
ρ^1_{1-1}	0.38 ± 0.14	0.29 ± 0.12	0.54 ± 0.13
$\mathrm{Re}\,\rho^1_{10}$	0.04 ± 0.08	-0.11 ± 0.08	-0.02 ± 0.10
$\mathrm{Im}\,\rho^2_{1-1}$	-0.19 ± 0.14	-0.29 ± 0.14	-0.21 ± 0.13
$\mathrm{Im}\,\rho^2_{10}$	0.01 ± 0.09	0.10 ± 0.08	0.12 ± 0.09
P_σ	0.9 ± 0.3	0.7 ± 0.3	1.1 ± 0.3

whats next ?

- First, submit some jobs.
- Next, make an analysis test of $\gamma\ p \rightarrow \omega\ p\ |\ \omega \rightarrow \pi^{+}\pi^{-}\pi^{0}\ |\ \pi^{0} \rightarrow \gamma\ \gamma$.
- Then, jump into exotica.

(Need your advices & orientations)