Pythia and PISA

Ralf Seidl (RIKEN)

Main use of MC

- Use of MC to
  - simulate your signal,
  - Simulate background processes
  - obtain kinematics and
  - acceptance
  - Study false effects (esp asymmetries – usually requires reweighting)
- Including detector simulation (such as PISA) also:
  - reconstruction efficiencies
  - detector smearing
  - Material effects (secondary particles, energy loss)
  - Additional detector based backgrounds

MC Generator: Pythia

- Pythia: also known as oracle from DELPHI in Greek Mythology
- Very fitting name for a program which tells you your (measured) future *
- Originally build around the LUND string fragmentation model and its MC program JETSET (but other models now also included – but not as good)
- Includes DIS, e+e- and pp processes,
- until Pythia6 only LO but some higher order processes included
- Pythia 6 and older is fortran based and very well used
- Pythia 8 is c++ based, fixed order with various NLO generators usable, but not as straightforward yet

Ptyhia implementations

- Overall Pythia Manual (highly recommended to check at least the meaning of event record and the parameters you use): https://arxiv.org/pdf/hep-ph/0603175v2 by the Authors
- General fortran code code can be combined with Root: TPythia6 –good for simple standalone studies
- Wrapper in PHENIX: PHPythia and recently also in fs/ePHENIX: PHPythia6 (with HEPMC output) – both very useful to combine with PISA simulations as well as using Triggering (PHPyTrigger) and Particle preSelection (PHParticleSelect)
- Normally run as (requires pythia.cfg file in directory):

```
root -l -b -q phpythia.C¥($ngenevents¥)
```

Pythia setup: config files (pythia.cfg)

DY into electrons

```
roots 510
proj p
targ p
frame cms
msel 0
msub 1 1 // qqbar->gamma*/Z
mdme 174 1 0
mdme 175 1 0
mdme 176 1 0
mdme 177 1 0
mdme 178 1 0
mdme 179 1 0
mdme 180 1 0
mdme 181 1 0
mdme 182 1 1 # Only allow decays to electrons
mdme 183 1 0
mdme 184 1 0 # Only allow decays to muons
mdme 185 1 0
mdme 186 1 0
mdme 187 1 0
mdme 188 1 0
mdme 189 1 0
mstp 52 2 // use LHAPDF
mstp 51 10041 // CTEQ6LL
mstp 91 1
parp 91 1.5
ckin 1 0.5 // min parton sqrt(s)
```

sub-process switch

Explicit g/Z decay modes on/off

Minbias

```
roots 510
proj p
targ p
frame cms
msel 1
mstp 52 2 // use LHAPDF
mstp 51 10041 // CTEQ6LL
mstp 91 1
parp 91 2.5
pmas 4 1 1.5
pmas 5 1 4.8
```

CMS energy

Protons for both beams (proj, targ)

CMS frame

Master process switch

MSEL 0: specify each sub process yourself via msub
MSEL 1: MINBIAS
MSEL 4,5,6,7,8 heavy flavor (but not complete, better use Minbias
MSEL 10: prompt photon
MSEL 11-1: W and Z production (+ NLO like W+jet,Z+jet)

Particle information according to Lund/HEP classification (see for example here)

Pythia event record

Event listing (summary)

I	particle/jet		KS	KF	orig	p_x	p_y	p_z	E	m	
1	!p+!		21	2212	0	0.000	0.000	249.998	250.000	0.938	Initial particles
2	!p+!		21	2212	0	0.000	0.000	-249.998	250.000	0.938	
=====											
3	!g!		21	21	1	-0.189	-0.167	52.234	52.235	-0.000	Initial partons
4	!u!		21	2	2	-0.554	0.265	-133.423	133.424	-0.000	
5	!dbar!		21	-1	3	0.345	1.498	16.160	16.233	0.000	“evolved partons”
6	!u!		21	2	4	-2.571	11.180	-99.046	99.709	0.000	
7	!W+!		21	24	0	-2.225	12.679	-82.887	115.941	80.041	
8	!dbar!		21	-1	7	-19.463	-23.165	-8.241	31.360	0.330	Outgoing partons
9	!u!		21	2	7	17.238	35.843	-74.646	84.581	0.330	
=====											
10	(W+)		11	24	7	-2.225	12.679	-82.887	115.941	80.041	
11	(d)	A	12	1	3	-2.465	-0.124	5.893	6.397	0.330	
12	(uu_1)	V	11	2203	1	0.017	0.384	88.924	88.928	0.771	
13	(dbar)	A	12	-1	8	-2.452	-9.473	-3.661	10.453	0.330	One gluonic string
14	(g)	I	12	21	8	-2.337	-3.891	-2.602	5.232	0.000	
15	(g)	I	12	21	8	-0.682	-0.874	-0.610	1.265	0.000	
16	(g)	I	12	21	8	-8.735	-6.187	-2.726	11.045	0.000	
17	(g)	I	12	21	8	-4.561	-1.920	-0.389	4.964	0.000	
18	(g)	I	12	21	8	-0.129	0.234	-0.043	0.271	0.000	
19	(g)	I	12	21	9	0.072	-0.097	-0.062	0.136	0.000	
20	(g)	I	12	21	9	-0.184	0.228	-0.670	0.731	0.000	
21	(g)	I	12	21	9	0.458	1.011	-1.037	1.519	0.000	
22	(u)	V	11	2	9	16.325	33.647	-71.087	80.325	0.330	
23	(d)	A	12	1	1	0.172	-0.217	8.146	8.158	0.330	
24	(g)	I	12	21	3	1.315	-0.376	15.936	15.995	0.000	
25	(g)	I	12	21	3	-0.200	-0.453	9.184	9.198	0.000	

Strange and charm jets!

```
   1 !p+!          21    2212     0     0.000     0.000  249.998  250.000     0.938
   2 !p+!          21    2212     0     0.000     0.000 -249.998  250.000     0.938
=================================================================================
   3 !u!           21       2     1     1.417    -0.389  133.721  133.729    -0.000
   4 !dbar!        21      -1     2     0.211     1.032 -118.877  118.882    -0.000
   5 !u!           21       2     3    -4.175    -0.871   14.149   14.778     0.000
   6 !dbar!        21      -1     4     0.198     0.968 -111.503  111.508     0.000
   7 !W+!          21      24     0    -3.977     0.097  -97.355  126.286    80.339
   8 !sbar!        21      -3     7    13.492    20.107  -96.685   99.672     0.500
   9 !c!           21       4     7   -17.468   -20.010   -0.670   26.613     1.500
=================================================================================
```

Minbias events

```
 I particle/jet KS      KF  orig    p_x       p_y       p_z        E         m

   1 !p+!         21    2212     0     0.000     0.000   249.998   250.000     0.938
   2 !p+!         21    2212     0     0.000     0.000  -249.998   250.000     0.938
 ==============================================================================
   3 !g!          21      21     1     0.213     0.133     2.926     2.936    -0.000
   4 !g!          21      21     2    -0.357     0.321    -4.822     4.846    -0.000
   5 !g!          21      21     3     0.213     0.133     2.926     2.936     0.000
   6 !g!          21      21     4    -0.357     0.321    -4.822     4.846     0.000
   7 !g!          21      21     0    -0.609     0.707    -4.770     4.860     0.000
   8 !g!          21      21     0     0.465    -0.254     2.874     2.922     0.000
 ==============================================================================
   9 (u)        A 12       2     7    -0.757     0.638    -1.322     1.684     0.330
  10 (ud_0)     V 11    2101     2    -0.024     0.590  -236.709   236.711     0.579
  11 (ubar)     A 12      -2     7     0.457     0.360    -2.506     2.593     0.330
  12 (g)        I 12      21     7    -0.159    -0.418     0.104     0.459     0.000
  13 (g)        I 12      21     8    -0.963     0.189     0.293     1.024     0.000
  14 (g)        I 12      21     8     1.278    -0.315     1.534     2.021     0.000
  15 (u)        V 11       2     1    -0.152    -0.155    25.623    25.626     0.330
  16 (ud_0)     A 12    2101     1    -0.061     0.022   221.400   221.400     0.579
  17 (u)        V 11       2     2     0.381    -0.911    -8.417     8.481     0.330
 ==============================================================================
  18 (string)     11      92     9    -0.781     1.228  -238.032   238.395    13.083
  19 (pi0)        11     111    18    -0.033    -0.381    -0.602     0.726     0.135
  20 (eta')       11     331    18    -0.562     0.577   -19.491    19.531     0.958
  21 (rho+)       11     213    18     0.357    -0.058    -3.569     3.616     0.451
  22 (K*0)        11     313    18    -0.251     0.501   -19.377    19.410     0.973
```

Outgoing partons

Some final state particles (and decays)

67	(string)	11	92	11	-2.448	0.260	94.817	95.325	9.523
68	(rho-)	11	-213	67	-1.542	-0.310	4.933	5.244	0.828
69	(Lambda0)	11	3122	67	-0.691	0.113	6.457	6.590	1.116
70	(Sigmabar0)	11	-3212	67	-0.224	0.847	21.056	21.108	1.193
71	(Delta++)	11	2224	67	0.010	-0.390	62.370	62.384	1.230
72	(string)	11	92	[illegible]	-2.225	12.679	-82.887	115.941	80.041
73	pi+	1	211	72	-0.858	-3.726	-1.841	4.246	0.140
74	(omega)	11	223	72	-1.530	-3.281	-1.657	4.058	0.782
75	(rho-)	11	-213	72	-0.996	-3.876	-0.954	4.141	0.471
76	pi+	1	211	72	-2.746	-3.056	-1.706	4.450	0.140
77	(rho0)	11	113	72	-2.486	-1.333	-0.556	2.970	0.745
78	pi-	1	-211	72	-0.704	-0.829	-0.702	1.302	0.140
79	(rho+)	11	213	72	-1.888	-1.253	-0.508	2.438	0.742
80	nbar0	1	-2112	72	-4.417	-3.471	-1.816	5.978	0.940

Particles created from string in #67

48	(rho0)	11	113	44	-0.338	-0.535	18.772	18.805	0.925
49	(eta)	11	221	44	0.560	0.693	31.344	31.361	0.547
50	(pi0)	11	111	44	0.268	0.440	4.056	4.091	0.135
. . .									
79	pi-	1	-211	48	-0.416	-0.583	18.033	18.047	0.140
80	pi+	1	211	48	0.078	0.048	0.739	0.758	0.140

Pions from rho0 decay in #48

Other Pythia output

```
==============================================================================
I                                  I                            I            I
I            Subprocess            I      Number of points      I    Sigma   I
I                                  I                            I            I
I----------------------------------I----------------------------I    (mb)    I
I                                  I                            I            I
I N:o Type                         I    Generated         Tried I            I
I                                  I                            I            I
==============================================================================
I                                  I                            I            I
I   0 All included subprocesses    I       100000       2679890 I  5.942D+01 I
I  11 f + f' -> f + f' (QCD)       I        16143             0 I  9.710D+00 I
I  12 f + fbar -> f' + fbar'       I           16             0 I  9.624D-03 I
I  13 f + fbar -> g + g            I           18             0 I  1.083D-02 I
I  28 f + g -> f + g               I        13425             0 I  8.075D+00 I
I  53 g + g -> f + fbar            I          456             0 I  2.743D-01 I
I  68 g + g -> g + g               I        22182             0 I  1.334D+01 I
I  91 Elastic scattering           I        19396         19396 I  1.134D+01 I
I  92 Single diffractive (XB)      I         9404          9404 I  5.523D+00 I
I  93 Single diffractive (AX)      I         9511          9511 I  5.523D+00 I
I  94 Double  diffractive          I         9449          9483 I  5.613D+00 I
I  95 Low-pT scattering            I            0         53054 I  0.000D+00 I
I                                  I                            I            I
==============================================================================
```

Important information on the cross section: All included processes
→ Total cross section for these Pythia settings
→Use together with # of generated events to calculated sampled lumi and normalize to your data lumi

PHPythia Triggering and ParticleSelection

- Create your own trigger and particle selection modules to reduce amount of particles to be calculated in PISA
- Triggering → select only events fulfilling your criteria (eg. At least one muon in $1.1<\eta<2.6$ region)
- Selection → Only keep selected particles (eg. signal particles you are interested in, or all particles in one rapidity region, etc)

Example scripts

```
void phpythia(
  const int nevents = 100000,
  const char *outputname = "phpythia.root",
  const char *oscar_outputname = "oscar.txt"
  )
{
  //gSystem->Load("libfun4allfuncs.so");        //
framework only
  gSystem->Load("libfun4all.so");       // framework +
reco modules

  gSystem->Load("libPHPythiaEventGen.so");
  gSystem->Load("libPHPythia.so");
  gSystem->Load("libPHPyTrigger.so");           // For
PHPyTrigger derived classes
  gSystem->Load("libPHPyParticleSelect.so");    // For
PHPyParticleSelect derived classes

gSystem->Load("libAnaPHPythia.so");
  gSystem->Load("libsimreco.so");       // framework +
reco modules
  recoConsts *rc = recoConsts::instance();
  rc->set_IntFlag("RUNNUMBER",0);


////////////////////////////////////////////////////////
/////////
  //  Server...
  Fun4AllServer *se = Fun4AllServer::instance();


////////////////////////////////////////////////////////
/////////
  //  Reconstruction Modules...

  SubsysReco *sync = new SyncSimreco();
  se->registerSubsystem(sync);

  PHPythia *phpythia = new PHPythia();
```

```
 SubsysReco *sync = new SyncSimreco();
  se->registerSubsystem(sync);

  PHPythia *phpythia = new PHPythia();

  // Set your own seed, otherwise, seeds from
/dev/random
  //phpythia->SetSeed(1999);

  se->registerSubsystem(phpythia);

  //** You can force the generated particles to use a
vertex read from a file,
  //** in place of the default (z=0) value
  //** this is needed for instance when you want to have
matching vertices between
  //** different types of simulated files, prior to
sending that to PISA
  // se->registerSubsystem( new
PHPyVertexShift( "PHPyVertexShift", "./events.txt") );

  //currently selects only events with pt>4 muon close
to muon arms
  PHPyTrigger *pytrig =  new PHPyTrigger();
  //     pytrig->SetVerbosity(1);
  pytrig->SetPtThreshold(4.0);
  //6 is all high pt muons, 7 is W,Z mu decays, 8 W,Z-
>tau ->mu, 9 W,Z had mu
  pytrig->SetTrigger(7);
  se->registerSubsystem( pytrig );

  //** You can select only particular particles to write
out
  PHPyParticleSelect *pselect = new
PHPyParticleSelect(  );

  //        PHPyParticleSelect *pselect = new
PHPySelectMuonarmall() ;

  se->registerSubsystem( pselect );
```

Trigger

Particle selection

PISA (PHENIX Integrated Simulation Application)

- Main PHENIX detector simulation
- Based on GENT3 (fortran)
- Run in standalone mode: pisa < pisa.input
- Output file PISAEvent.root can than be handled within Fun4All framework
- Interactive running (for displaying certain detector geometries, etc possible)
- Safest way to get proper year-dependent settings: use linker, e.g. see https://www.phenix.bnl.gov/WWW/offline/wikioff/index.php/PISA_2015

Important files

- phnx.par: variable detector information – absorber thicknesses, etc
- glogon.kumac: main control macro
- Pisa.kumac: GEANT3 settings, magnetic field, active detectors
- pisaFile.cZ : material file used for energy loss in muon analysis

```
macro glogon.kumac
0
N
0
pisafile PISAEvent.root
phpythia 1 phpythia.root
ptrig 10000
exit
mess this is another test
return
```

- Similar settings for HIJING (Heavy ions) or single particles available

Particle information according to GEANT classification (see for example here)

pisa.kumac

```
* $Id: pisa.kumac,v 1.37 2010/02/11 09:21:21 ravini Exp $
* PISA kumac file for Central Arm only (No Muon Arm volumes)
*
SETRHIC 11 2                    ! Run11 and later
PISAFILE 'PISAEvent.root'
*
* Random number seeds (using internal GEANT seeds from 001 to 215)
* keep the second input as 0 all the time, change only the first
RNDM 001 0
*
* Tracking thresholds
CUTS  .001 .001 .010 .010 .010 .001 .001 1.e+4 1.e+4 .010 4.e-7
*
* NOTE: As of December 1, 1999 the compressed ZEBRA output format is not used by default
* The FOUT line will be used only if the SWIT(1) value is changed to 6 in gffgo.dat
*
FOUT 'phnx.dat.cZ'              ! Name of output hits file
FPAR 'phnx.par'                 ! Name of namelist parameter file for geometry
STEE 'KINE' 'HITS' 'DIGI'       ! Output data structure control
DOUT 'DIGI'                     ! Output data structure control
MAGF '3D++' 1.00 0001  0.0 0.0
*
* geometry with/without helium bag HBAG/HBGN, beampipe PIPE/PIPN, old absorber ABSO or new absorber RABS
* GEOP 'ENDC' 'CENT' 'PIPE' 'NOSE' 'PLUG' 'BCOL' 'PHSH'
GEOP 'ENDC' 'CENT' 'PIPE' 'NOSE' 'PLUG' 'BCOL' 'PHSH' 'RABS'
*
DCAY  1                         ! GEANT command for decay on
ANNI  1                         ! GEANT command for annihilation on
BREM  1                         ! GEANT command for bremsstrahlung on
COMP  1                         ! GEANT command for Compton scattering on
LOSS  2                         ! GEANT command for Landau fluctuations on
DRAY  0                         ! GEANT command for Delta no ray (Landau is on)
HADR  4                         ! GEANT command for hadrons using FLUKA
MULS  1                         ! GEANT command for multiple scattering on
PAIR  1                         ! GEANT command for pair production on
PHOT  1                         ! GEANT command for photoelectric effect on
MUNU  0                         ! GEANT recommendation when HADR 4 is used
```

Pisa.kumac continued

```
***************************************************************************
*
*       To install a detector turn the switch 'ON'
*
***************************************************************************
*
* central arm detectors
*
ZDC  'OFF' 'FULL' 'ETOT' 'FULL' 'ZCAL' 'FRG1' 'HB00' 37.89
SVX  'ON' 'FULL' 'P_ID' 'FULL' 'ELEM' 'NEUT'   ! This is the Silicon Vertex Tracker (upgrade)
FCL  'OFF' 'FULL' 'P_ID' 'FULL' 'ELEM'          ! This is the FCL (forward calorimeter)
BBC  'ON' 'FULL' 'ETOT' 'FULL' 'BCAL' 'STCK'    ! BBC on with track stack used
ITR  'OFF' 'IT96' 'ETOT' 'FULL' 'TRKS'           ! Latest version of Dch and PC1
CRK  'OFF' 'FULL' 'P_PZ' 'FULL' 'CCAL' 'CO2 '    ! RICH with CO2 radiator gas
PAD  'OFF' 'PC98' 'P_ID' 'FULL' 'PCAL'           ! Latest version of PC2/PC3
AER  'OFF' 'FULL' 'P_ID' 'FULL' 'ELEM'           ! This is the AER (aerogel counter)
TFW  'OFF' 'FULL' 'P_ID' 'FULL' 'ELEM'           ! This is the TFW (TOF-West)
TRD  'OFF' 'FULL' 'P_ID' 'FULL' 'TCAL'           ! This is the TEC
TOF  'OFF' 'FULL' 'P_ID' 'FULL' 'FCAL' 0.0 0.0   ! Time of Flight
EMC  'OFF' 'FULL' 'FULL' 'FULL' 'ECAL' 'AUAU' 'CTRK'  ! EMCal, H.I. with Cerenkov
HBD  'OFF' 'FULL' 'P_ID' 'FULL' 'ELEM' 'STCK'    ! This is the HBD

*
* forward rapidity (muon arms) detectors
*
MUM  'ON' 'FULL' 'ETOT' 'FULL' 'MCAL' 0. 0. 0. 'STCK' 'NNEU'  ! Muon trackers
MUI  'ON' 'FULL' 'ETOT' 'FULL' 'NCAL' 0. 0. 0. 'STCK' 'NNEU'  ! Muon identifier
RXN  'OFF' 'FULL' 'P_ID' 'FULL' 'ELEM'           ! reaction plane detector on with track stack used
MUPC 'ON' 'FULL' 'P_ID' 'FULL' 'PCAL'          ! Pad chamber for Muon Trigger
MPC  'OFF' 'FULL' 'P_ID' 'FULL' 'PCAL'          ! Muon Piston Calorimeter
*
RLT  'OFF' 'FULL' 'P_ID' 'FULL' 'PCAL'          ! Relative Luminosity Telescope
```

Next steps:

- Use `/afs/rhic.bnl.gov/phenix/PHENIX_LIB/simulation/run*/pisaToDSTLinker.csh` to obtain adequate Fun4 script to create DSTs
- Run it to get DST files : eg.

```
root -b -q pisaToDST.C
```

- Analyze the “data”, etc