

## Contents

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### Recent Updates:

v304: Fixed a serious bug in `gammaaluminosity.cpp` lines 404, where `photonDensity` was called with its arguments reversed. This bug is somewhat less serious than it sounds, but it is still very serious, and leads to changes in the vector meson photoproduction cross-section.

v299: Added hard-coded Woods-Saxon radii, thickness and density for  $^{96}\text{Ru}$  and  $^{96}\text{Zr}$ , for the RHIC isobar run. Data is from arXiv:1607.04697

v297: Changed normalized for Woods-Saxon density for non-predefined (i. e. not gold, lead, xenon or copper or nuclei with  $Z < 7$ ) so that the density is properly normalized  $\int d^3r \rho(r) = A$ . The normalization was previously done for a hard-sphere nucleus, so this over-estimated the cross-sections by 5-10%.

v295: Added hard-coded values for xenon-129 to match the recent LHC run. Radius=5.36 fm, density=0.18406

v293: Introduced shared random number generator which can be externally passed by the user. All particle constants (masses, widths, branching ratios, and spins) can now also be set by the user, but should be changed from the default values with care.

v290: Added an new `BREAKUP_MODE` option to generate two-photon events in peripheral collisions. `BREAKUP_MODE=8` sets a fixed impact parameter range, regardless of the presence of nuclear breakup; it is intended to study two-photon production in peripheral collisions. It requires two additional otherwise optional input lines, `BMIN` and

BMAX, to set the impact parameter range. It does not (yet?) work for photonuclear interactions.

278: Added two new optional parameters:

IMPULSE\_VM Normally 0, but can be set to 1 to perform an impulse approximation calculation (i.e. ignoring nuclear effects)

QUANTUM\_GLAUBER. When set to 1, performs a quantum Glauber calculation, rather than a classical one. This leads to greatly increased rho and omega cross-sections for heavy nuclei, little effect for heavier mesons.

Also added a final state, 4432212, for J/psi -> pbar p

v276: Added two new optional parameters (BSLOPE\_DEFINITION and BSLOPE\_VALUE) for the  $p_T$  spectrum ('bslope') for proton targets or incoherent production on nuclei

v275: Added  $\gamma\gamma$  to axion channel as two-photon channel 88, per S. Knapen et al., arXiv:1607.07083 v273: "Baseline" version, described in arXiv:1607.03838)

## Overview:

The STARlight Monte Carlo models 2-photon and photon-Pomeron interactions in ultra-peripheral heavy ion collisions. The physics approach for the photon-Pomeron interactions is described in Klein and Nystrand, Phys. Rev. C60, 014903 (1999), with the  $p_t$  spectrum (including vector meson interference) discussed in Phys. Rev. Lett. 84, 2330 (2000). The 2-photon interactions are described in Baltz, Gorbunov, Klein, Nystrand, Phys.Rev. C80 044902 (2009).

STARlight has several input files, all of which are expected to be in the same directory as the starlight code. User-specified input parameters are read from a file named "slight.in"; these parameters are described below in [Input](#).

The simulated events are written to an ASCII file named "slight.out", which is described below in [Output](#).

## Installation:

To install & run STARlight in a \*nix based environment, follow these steps (README):

Download the starlight package from 'Downloads' on the left sidebar of the homepage. The version in the example might be outdated.

```
-wget 'https://starlight.hepforge.org/downloads?f=starlight_r300.tar'
-mv 'downloads?f=starlight_r300.tar' starlight_r300.tar
-tar xvf starlight_r300.tar
```

Alternatively, one may obtain the latest version via svn.

HEPforge uses phabricator and no longer allows for anonymous checkouts of the repository. (Please read <https://www.hepforge.org/guide.pdf> .)

To obtain an account, register here: <https://www.hepforge.org/register>

Once you are registered, login:

<https://phab.hepforge.org/auth/start/?next=%2F>

Set up a version control settings (VCS) password under your account's Settings->AUTHENTICATION->VCS password . The VCS password is needed to checkout the code.

(For remote users) To identify yourself, upload a SSH public key under account's Settings->AUTHENTICATION->SSH Public Keys with the button SSH Key Actions->Upload Public Key. This key will provide your identity when checking out the code as VCS. If you do not have a public ssh key to upload, you may generate a pair on the same SSH Public Keys page with the button SSH Key Actions-> Generate Keypair.

With the private ssh key loaded on your machine (and public on their machine), use svn to checkout the trunk/:

```
-svn co svn+ssh://vcs@phab.hepforge.org/source/starlightsvn/trunk
```

Change to the installation directory of your choice

```
-mkdir /home/my/installation/dir
```

```
-cd /home/my/installation/dir
```

Setup the compilation with cmake

```
-cmake /path/to/trunk
```

Compile with (g)make

```
-gmake
```

Setup the input file, slight.in, for your simulation needs

```
-cp /path/to/trunk/config/slight.in .
```

```
-vim slight.in
```

Run

```
./starlight >& output.txt&
```

For more information and special scenarios, such as running with PYTHIA or DPMJET, consult the README files located in trunk/

If you would like to browse the code, please visit:

<https://phab.hepforge.org/source/starlightsvn/>

-----Before HEPForge updated their repository management system-----

To obtain the latest version:

-svn co <http://starlight.hepforge.org/svn/trunk>

Alternatively:

-Visit <https://starlight.hepforge.org/trac/browser>

-Download the trunk [click on the download symbol in the Size column]

-Unpackage the zip file. The trunk/ represents <PathToSource>

To build Starlight:

- First create your build directory <BUILDDIR> (e.g. mkdir bin)

- \$ cd <BUILDDIR>

- \$ cmake <PathToSource>

- \$ make

This creates an executable file, starlight, in the build directory.

To clean the build:

- \$ make clean

To run starlight, a configuration file, slight.in, is needed. Examples of slight.in may be found in the config/ directory.

To run:

\$ ./starlight

Enabling Pythia:

To simulate the  $\eta$ ,  $\eta'$ , and  $\eta_c$  channels, you need Pythia v8.2 or higher to handle their decays. To enable Pythia support you need to run cmake with the option -DENABLE\_PYTHIA=ON and have \$PYTHIADIR pointing to the top directory of Pythia8. [Note: when building Pythia, be sure to enable shared libraries(.so). ./configure --enable-shared before compiling Pythia.]

\$ setenv PYTHIADIR /my/local/pythia8

\$ cmake <PathToSource> -DENABLE\_PYTHIA=ON

Note: v8.2+ is necessary since the Pythia directory structure changed[trunk/cmake\_modules/FindPythia8.cmake depends on the structure layout], liblhpdfdummy was removed, and Standalone:allowResDec was removed.

To enable DPMJET, please see the passage on [DPMJET](#)

## Input:

The input parameters are listed below with typical values for LHC Pb-Pb running given in parentheses. Optional parameters are denoted with \*.

```
baseFileName      # The name of the output files. STARlight will
                  # copy the input slight.in to baseFileName.in, and
                  # produce output files baseFileName.txt and
                  # baseFileName.out. (slight)
BEAM_1_Z = 82     # Charge of beam one projectile. (82)
BEAM_1_A = 208    # Atomic number of beam one projectile. (208)
BEAM_2_Z = 82     # Charge of beam two projectile. (82)
BEAM_2_A = 208    # Atomic number of beam two projectile. (208)
BEAM_1_GAMMA = 1470 # Lorentz boost for beam one projectile(pz>0).
                  # (1470)
BEAM_2_GAMMA = 1470.0 # Lorentz boost for beam two projectile(pz<0).
                  # (1470)
W_MAX = 12.0      # Maximum value for the gamma-gamma center of mass
                  # energy,  $W = 4E_1E_2$ , in GeV. Setting W_MAX = -1
                  # tells STARlight to use the default value specified
                  # in inputParameters.cpp (recommended for single
                  # meson production). For single mesons, the default
                  # W_MAX is the particle mass plus five times the
                  # width. For lepton pairs, the default W_MAX is
                  # given by  $2\hbar c \sqrt{\frac{Y_1 Y_2}{R_1 R_2}}$ . These are defined in
                  # src/inputParameters.cpp (-1)
W_MIN = -1        # Min value of w. Minimum value for the gamma-gamma
                  # center of mass energy,  $W = 4E_1E_2$ , in GeV. Setting
                  # W_MIN = -1 tells STARlight to use the default
                  # value specified in inputParameters.cpp
                  # (recommended for single meson production). The
                  # default W_MIN is the larger of the kinematic limit
                  # ( e.g.  $2m_\pi$  for  $\rho$  decays) or the particle mass
                  # minus five times the width. (-1)
W_N_BINS = 40     # Bins w maximum and minimum values for w (the
                  # gamma-gamma center of mass energy,  $w = 4E_1E_2$ ), and
                  # the number of w bins in the lookup tables (40)
RAP_MAX = 8.      # Maximum rapidity of produced particle. (8)
RAP_N_BINS = 80   # Number of rapidity bins used in the cross
                  # section calculation (80)
CUT_PT* = 0       # Specifies whether the user chooses to place
                  # restrictions on the transverse momentum of the
                  # decay products. 0= no, 1 = yes. (0)
PT_MIN* = 1.0     # If a transverse momentum cut is applied, this
                  # specifies the minimum value produced, in GeV/c.
                  # (1.0)
```

```

PT_MAX* = 3.0      # If a transverse momentum cut is applied, this
                   # specifies the maximum value produced, in GeV/c.
                   # (3.0)
CUT_ETA* = 0       # Specifies whether the user chooses to place
                   # restrictions on the pseudorapidity of the decay
                   # products. 0= no, 1 = yes. (0)
ETA_MIN* = -10     # If a pseudorapidity cut is applied, this
                   # specifies the minimum value produced. (-10)
ETA_MAX* = 10      # If a pseudorapidity cut is applied, this
                   # specifies the maximum value produced. (10)
PROD_MODE = 2      # PROD_MODE=1: Two-photon interaction.
                   # PROD_MODE=2: Coherent photonuclear vector meson
                   # production assuming narrow resonances. This option
                   # should also be used for exclusive vector meson
                   # production in pp collision. In pA or pp
                   # collisions, this option means that the proton
                   # emits the photon and that the gamma-A interaction
                   # is coherent.
                   # PROD_MODE=3: Coherent photonuclear vector meson
                   # production assuming wide resonances. This option
                   # should in be used for exclusive  $\rho^0$ 
                   # production.
                   # PROD_MODE=4: Incoherent photonuclear vector meson
                   # production. In pA collisions, this option means
                   # that the nucleus emits the photon. Do not use for
                   # pp.
                   # PROD_MODE=5: Photonuclear one photon exchange
                   # uses DPMJET single.
                   # PROD_MODE=6: Photonuclear two photon exchange
                   # (both nuclei excited) uses DPMJET double.
                   # PROD_MODE=7: Photonuclear single pA uses DPMJET
                   # Single, proton mode.
                   # PROD_MODE=8: [not supported/verified] Photonuclear
                   # single pA uses Pythia 6
N_EVENTS = 10      # Number of events produced (1000)
PROD_PID = 443013  # For PROD_MODE 1 through 4, this selects the
                   # channel to be produced, in PDG notation. Currently
                   # supported options are list below. (443013)
RND_SEED = 34533   # Seed for random number generator. (34533)
BREAKUP_MODE = 5   # Specifies the way nuclear break-up is handled.
                   # This option only works for lead or gold. It has no
                   # meaning in proton-proton or proton-nucleus
                   # collisions
                   # 1 = hard sphere nuclei (no hadronic break-up if
                   # impact parameter is greater than the sum of
                   # nuclear radii, no restriction on Coulomb break-
                   # up).
                   # 2 = requires Coulomb break-up of both nuclei, with
                   # no restriction on the number of neutrons emitted
                   # by either nucleus (XnXn).
                   # 3 = requires Coulomb break-up of both nuclei, but
                   # requires that a single neutron is emitted from
                   # each nucleus (1n1n).

```

4 = requires Coulomb break-up of neither nucleus.  
 (0n0n)  
 5 = requires that there be no hadronic break up,  
 no restriction on Coulomb break-up (This is  
 similar to option 1, but with the actual hadronic  
 interaction probability).  
 6 = requires Coulomb break up of one or both  
 nuclei, with no restriction on the number of  
 neutrons emitted (XnXn + 0nXn + Xn0n).  
 7 = requires Coulomb break up of only one nucleus,  
 with no restriction on the number of neutrons  
 emitted (0nXn+ Xn0n).  
 8 = selectable input parameter range (i.e. for  
 peripheral collisions, not UPCs) regardless of  
 nuclear breakup. Fixed input range between BMAX  
 and BMIN (set by two otherwise optional cards,  
 below)

INTERFERENCE = 0 # Specifies whether interference based on the  
 ambiguity of which nucleus emits the photon is  
 included. The effect of this interference is only  
 visible at very small transverse momentum. 0 =  
 interference off, 1 = interference on. (0)

IF\_STRENGTH = 1. # If interference is turned on, specifies the  
 percentage of interference. The range is -1.0 -  
 1.0.; 1 is the standard value for ion-ion  
 collisions, while -1.0 is expected for proton-  
 antiproton collisions. (1)

INT\_PT\_MAX = 0.24 # Used only when the interference option above is  
 turned on. This specifies the maximum transverse  
 momentum considered, in GeV/c. (0.24)

INT\_PT\_N\_BINS = 120 # Used only when the interference option above is  
 turned on. This specifies the number of bins in  
 transverse momentum to use. (120)

INT\_PT\_WIDTH = 0 #Used only when the interference option above is  
 turned on. This specifies the width of bins in  
 transverse momentum to use. (0)

XSEC\_METHOD\* = 0 #Determines which method is used to calculate the  
 cross-section for  $\gamma\gamma$  cross-sections. XSEC\_METHOD=0  
 is faster, but works only for symmetric collisions  
 (i.e. with identical nuclei). XSEC\_METHOD=1  
 always works, but is slower. (0)

BSLOPE\_DEFINITION\*=0 Used for proton and nucleon (i. e. incoherent  
 nuclear) collisions to set the t-spectrum,  
 $dN/dt = \exp(-bt)$ . When BSLOPE\_DEFINITION=1, then the  
 slope is determined by BSLOPE\_VALUE (below). When  
 BSLOPE\_DEFINITION=2, the slope is calculated as a  
 function of  $\gamma p$  center of mass energy per the H1  
 analysis, Eur. Phys. J. C46, 585 (2006):  
 $b = 4.63/\text{GeV}^2 + 4\alpha \ln(W_{\gamma p}/90 \text{ GeV})$   
 The default value, BSLOPE\_DEFINITION=0 has no  
 effect.  
 Note that this affects the t-slope only; it does  
 not affect the total cross-section



BSLOPE_VALUE*	WHEN BSLOPE_DEFINITION=1, this determines the exponential slope for $dN/dt = \exp(-BSLOPE\_VALUE * t)$
SELECT_IMPULSE_VM	When set =1, performs an impulse approximation calculation (this ignores most nuclear physics, including shadowing). Default=0; no change
QUANTUM_GLAUBER	When set =1, perform a quantum Glauber calculation, rather than classical, which is the default (or when set =0)
BMIN	Needed for Breakup_mode=8. Sets the minimum impact parameter
BMAX	Needed for Breakup mode=8. Sets sthe maximum impact parameter.

The physics constants used by STARlight can be set with the following parameters:

deuteronSlopePar	deuteron slope parameter (effective temperature) $[(GeV/c)^{-2}]$
protonMass	mass of the proton $[GeV/c^2]$
pionChargedMass	mass of the $\pi^{+/-}$ $[GeV/c^2]$
pionNeutralMass	mass of the $\pi^0$ $[GeV/c^2]$
kaonChargedMass	mass of the $K^{+/-}$ $[GeV/c^2]$
me1	mass of the $e^{+/-}$ $[GeV/c^2]$
muonMass	mass of the $\mu^{+/-}$ $[GeV/c^2]$
tauMass	mass of the $\tau^{+/-}$ $[GeV/c^2]$
f0Mass	mass of the $f_0(980)$ $[GeV/c^2]$
f0Width	width of the $f_0(980)$ $[GeV/c^2]$
f0BrPiPi	branching ratio $f_0(980) \rightarrow \pi^+ \pi^-$ and $\pi^0 \pi^0$
etaMass	mass of the eta $[GeV/c^2]$
etaWidth	width of the eta $[GeV/c^2]$
etaPrimeMass	mass of the eta' $[GeV/c^2]$
etaPrimeWidth	width of the eta' $[GeV/c^2]$
etaCMass	mass of the eta_c $[GeV/c^2]$
etaCWidth	width of the eta_c $[GeV/c^2]$
f2Mass	mass of the $f_2(1270)$ $[GeV/c^2]$
f2Width	width of the $f_2(1270)$ $[GeV/c^2]$
f2BrPiPi	$[GeV/c]$ $f_2(1270) \rightarrow \pi^+ \pi^-$
a2Mass	mass of the $a_2(1320)$ $[GeV/c^2]$
a2Width	width of the $a_2(1320)$ $[GeV/c^2]$
f2PrimeMass	mass of the $f'_2(1525)$ $[GeV/c^2]$
f2PrimeWidth	width of the $f'_2(1525)$ $[GeV/c^2]$
f2PrimeBrKK	branching ratio $f'_2(1525) \rightarrow K^+ K^-$ and $K^0 \bar{K}^0$
zoverz03Mass	mass of four-quark resonance ( $\rho^0$ pair production) $[GeV/c^2]$
f0PartialggWidth	partial width $f_0(980) \rightarrow g g$ $[GeV/c^2]$
etaPartialggWidth	partial width eta $\rightarrow g g$ $[GeV/c^2]$
etaPrimePartialggWidth	partial width eta' $\rightarrow g g$ $[GeV/c^2]$
etaCPartialggWidth	partial width eta_c $\rightarrow g g$ $[GeV/c^2]$
f2PartialggWidth	partial width $f_2(1270) \rightarrow g g$ $[GeV/c^2]$
a2PartialggWidth	partial width $a_2(1320) \rightarrow g g$ $[GeV/c^2]$
f2PrimePartialggWidth	partial width $f'_2(1525) \rightarrow g g$ $[GeV/c^2]$
zoverz03PartialggWidth	partial width four-quark resonance $\rightarrow g g$ ( $\rho^0$ )

	pair production) [GeV/c <sup>2</sup> ]
f0Spin	spin of the f <sub>0</sub> (980)
etaSpin	spin of the eta
etaPrimeSpin	spin of the eta'
etaCSpin	spin of the eta <sub>c</sub>
f2Spin	spin of the f <sub>2</sub> (1270)
a2Spin	spin of the a <sub>2</sub> (1320)
f2PrimeSpin	spin of the f' <sub>2</sub> (1525)
zoverz03Spin	spin of the four-quark resonance -> g g (rho <sup>0</sup> pair production)
axionSpin	spin of the axion
rho0Mass	mass of the rho <sup>0</sup> [GeV/c <sup>2</sup> ]
rho0Width	width of the rho <sup>0</sup> [GeV/c <sup>2</sup> ]
rho0BrPiPi	branching ratio rho <sup>0</sup> -> pi <sup>+</sup> pi <sup>-</sup>
rho0PrimeMass	mass of the rho' <sup>0</sup> (4 pi <sup>+</sup> / - final state) [GeV/c <sup>2</sup> ]
rho0PrimeWidth	width of the rho' <sup>0</sup> (4 pi <sup>+</sup> / - final state) [GeV/c <sup>2</sup> ]
rho0PrimeBrPiPi	branching ratio rho' <sup>0</sup> -> pi <sup>+</sup> pi <sup>-</sup>
OmegaMass	mass of the omega [GeV/c <sup>2</sup> ]
OmegaWidth	width of the omega [GeV/c <sup>2</sup> ]
OmegaBrPiPi	branching ratio omega -> pi <sup>+</sup> pi <sup>-</sup>
PhiMass	mass of the phi [GeV/c <sup>2</sup> ]
PhiWidth	width of the phi [GeV/c <sup>2</sup> ]
PhiBrKK	branching ratio phi -> K <sup>+</sup> K <sup>-</sup>
JpsiMass	mass of the J/psi [GeV/c <sup>2</sup> ]
JpsiWidth	width of the J/psi [GeV/c <sup>2</sup> ]
JpsiBree	branching ratio J/psi -> e <sup>+</sup> e <sup>-</sup>
JpsiBrmumu	branching ratio J/psi -> mu <sup>+</sup> mu <sup>-</sup>
JpsiBrppbar	branching ratio J/psi -> p pbar
Psi2SMass	mass of the psi(2S) [GeV/c <sup>2</sup> ]
Psi2SWidth	width of the psi(2S) [GeV/c <sup>2</sup> ]
Psi2SBree	branching ratio psi(2S) -> e <sup>+</sup> e <sup>-</sup>
Psi2SBrmumu	branching ratio psi(2S) -> mu <sup>+</sup> mu <sup>-</sup>
Upsilon1SMass	mass of the Upsilon(1S) [GeV/c <sup>2</sup> ]
Upsilon1SWidth	width of the Upsilon(1S) [GeV/c <sup>2</sup> ]
Upsilon1SBree	branching ratio Upsilon(1S) -> e <sup>+</sup> e <sup>-</sup>
Upsilon1SBrmumu	branching ratio Upsilon(1S) -> mu <sup>+</sup> mu <sup>-</sup>
Upsilon2SMass	mass of the Upsilon(2S) [GeV/c <sup>2</sup> ]
Upsilon2SWidth	width of the Upsilon(2S) [GeV/c <sup>2</sup> ]
Upsilon2SBree	branching ratio Upsilon(2S) -> e <sup>+</sup> e <sup>-</sup>
Upsilon2SBrmumu	branching ratio Upsilon(2S) -> mu <sup>+</sup> mu <sup>-</sup>
Upsilon3SMass	mass of the Upsilon(3S) [GeV/c <sup>2</sup> ]
Upsilon3SWidth	width of the Upsilon(3S) [GeV/c <sup>2</sup> ]
Upsilon3SBree	branching ratio Upsilon(3S) -> e <sup>+</sup> e <sup>-</sup>
Upsilon3SBrmumu	branching ratio Upsilon(3S) -> mu <sup>+</sup> mu <sup>-</sup>

The following parameters are used only when interfacing with the PYTHIA and/or DPMJET interfaces:

MIN_GAMMA_ENERGY = 6	#Allows the user to set the minimum photon energy (in GeV) in the rest frame of the target nucleus. The default is 6.0 GeV and it should never be set
----------------------	-------------------------------------------------------------------------------------------------------------------------------------------------------

```

                                below this value since DPMJET was not designed to
                                handle low energy interactions.
MAX_GAMMA_ENERGY = 600000
                                #Allows the user to set the maximum photon energy
                                (in GeV) in the rest frame of the target nucleus.
                                The default is 60000.0 GeV.
PYTHIA_PARAMS = ""            #Used to supply input parameters to the PYTHIA
                                interface. This takes a string to pass on semi-
                                colon separated parameters to PYTHIA 6. eg:
                                "mstj(1)=0;paru(13)=0.1" (the default is a blank
                                string " ")
PYTHIA_FULL_EVENT_RECORD = 1
                                #Determines whether the full event record from
                                PYTHIA is written to slight.out. true = yes,
                                false = no (false). The additional information
                                added is as follows: daughter production vertex (x
                                [mm], y [mm], z [mm], t [mm/c]), mother1, mother2,
                                daughter1, daughter2, PYTHIA particle status code.
                                PYTHIA 8 Particle Properties page describes in more
                                detail the properties of mother, daughter, and
                                status code designations.

```

---

## Channels of Interest:

### 2-Photon Channels

Currently supported 2-photon (prod. mode = 1) channel options:

jetset id	particle
-----	
221	eta
331	eta-prime
441	eta-c
9010221	f0(975)
225	f2(1270)
115	a2(1320)
335	f2(1525)
33	rho0 pair
11	e+/e- pair
13	mu+/mu- pair
15	tau+/tau- pair
88	axion-like particle (ALP)

Process 88 refers to the single production of a hypothetical axion-like particle (ALP), which decays to a pair of photons. The ALP mass has to be specified by the user through the parameter AXION\_MASS. The narrow width approximation is assumed here, with a fixed axion decay constant of  $\Lambda=1$  TeV. (See equation (1) of arXiv:1607.06083 for the appropriate conventions.) The cross section can be then rescaled to arbitrary  $\Lambda$ , as long as the narrow width approximation remains valid.

### Pomeron-Photon Channels

Currently supported vector meson (prod. mode = 2/3/4) options:

jetset id	particle
-----	

113	$\rho^0$
223	$\omega$
333	$\phi$
443011	$J/\psi \rightarrow e^+e^-$
443013	$J/\psi \rightarrow \mu^+\mu^-$
4432212	$J/\psi \rightarrow \text{proton antiproton}$
444011	$\psi(2S) \rightarrow e^+e^-$
444013	$\psi(2S) \rightarrow \mu^+\mu^-$
553011	$\Upsilon(1S) \rightarrow e^+e^-$
553013	$\Upsilon(1S) \rightarrow \mu^+\mu^-$
554011	$\Upsilon(2S) \rightarrow e^+e^-$
554013	$\Upsilon(2S) \rightarrow \mu^+\mu^-$
555011	$\Upsilon(3S) \rightarrow e^+e^-$
555013	$\Upsilon(3S) \rightarrow \mu^+\mu^-$
913	$\rho^0 + \text{direct } \pi^+\pi^- \text{ (with interference). The direct } \pi^+\pi^- \text{ fraction is from the ZEUS results, EPJ C2 p247 (1998)}$
999	four-prong final states ( $\rho'$ -like to $\pi^+\pi^-\pi^+\pi^-$ )

## DPMJET:

Simulation of photonuclear interactions with STARlight is possible through an interface with DPMJet. These interfaces can be enabled through options passed to cmake during the configuration process. [Deprecated: Using Pythia 6 as a substitute for DPMJet]

The gfortran compiler is required to use the photonuclear interfaces.

===== 1. Photonuclear interactions with DPMJet =====

----- 1.1. Obtaining and installing DPMJet -----

The DPMJet package can be obtained by contacting the authors as explained here: <http://sroesler.web.cern.ch/sroesler/dpmjet3.html>

Once you have the code proceed with these steps:

Change the line containing the OPT variable in the DPMJet Makefile:

```
OPT = -c -C -std=legacy -O -O3 -g -fexpensive-optimizations
      -funroll-loops -fno-automatic -fbounds-check -v -fPIC
```

----- 64-bit -----

Make sure that all -m32 options are removed from the Makefile.

Unfortunately, the DPMJet package depends on a floating point exception trap implementation, and only a 32-bit version of that is included in the package, which needs to be replaced. An example implementation can be found here:

<http://www.arsc.edu/arsc/support/news/hpcnews/hpcnews376/>

Under "Fortran Floating Point Traps for Linux" there is a code example. A file based on this, fpe.c, can be found in the external/ directory in STARlight. Move that to your DPMJet directory to replace the original file and run:

```
$ gcc -o fpe.o fpe.c
```

**Note:** if the above command returns the following error:  
*/usr/lib/../lib64/crt1.o: In function `\_start':  
(.text+0x20): undefined reference to `main'  
/tmp/ccs2CQsd.o: In function `enable\_exceptions':  
fpe.c:(.text+0xe): undefined reference to `feenableexcept'*

*collect2: error: ld returned 1 exit status*

**Try:** gcc fpe.c -Wall -g -c

feenableexcept is a gcc extension and gcc may need all of the headers present.

----- End 64-bit -----

Then in the DPMJet directory run:

\$ make

Note: When compiling at RCAS(BNL), needed to change g77 → gfortran, needed to install fluka and setenv FLUPRO /path/to/fluka, and modify phojet before compiling. The changes for phojet is at line 29875, from:

```
PRINT LO, 'PHO_DIFSLP:ERROR: this option is not installed !'
```

to:

```
WRITE(LO, '(//1X,A,I2)')  
& 'PHO_DIFSLP:ERROR: this option is not installed  
& !', ISWMDL(13)
```

----- 1.2. Compiling Starlight with DPMJet interface -----

To enable the compilation of the DPMJet interface please follow these steps:

CMake uses an environment variable \$DPMJETDIR to locate the DPMJet object files, so define it.

\$ export DPMJETDIR=<path to dpmjet>

Then create a build directory for STARlight

\$ mkdir <build-dir>

and change into it

\$ cd <build-dir>

Run CMake with the option to enable DPMJet

\$ cmake <path-to-starlight-source> -DENABLE\_DPMJET=ON

Then build it

\$ make

Note: When compiling at RCAS(BNL), needed to add the gfortran library to the CMakeLists.txt and left it there.

----- 1.3. Running Starlight with DPMJet interface -----

To run Starlight with the DPMJet interface a couple of files are needed in the directory where you want to run Starlight.

The files needed are:

**slight.in** (Starlight config file. An example suitable for DPMJet can be found in config/slight.in.dpmjet)  
**my.input** (DPMJet config file. An example can be found in config/my.input)  
**dpmjet.dat** (Can be found in the DPMJet source directory)

In the slight.in file the relevant production modes (PROD\_MODE) for DPMJET is:

5: A+A single excitation  
6: A+A double excitation  
7: p+A single excitation

In addition the minimum and maximum gamma energies must be set. These must be within the interval set in the my.input file.

**To run:**

```
$ ./starlight < my.input  
[DPMJET reads from direct input/interactive]
```

## Output

STARlight outputs an ASCII file named slight.out.

For each event, a summary line is printed, with the format

**EVENT:** n ntracks nvertices ,

where n is the event number (starting with 1), ntracks is the number of tracks in the event, and nvertices is the number of vertices in the event (STARlight does not currently produce events with more than one vertex).

EVENT line is followed by a description of the vertex, with the format

**VERTEX:** x y z t nv nproc nparent ndaughters ,

where  $x$ ,  $y$ ,  $z$  and  $t$  are the 4-vector components of the vertex location,  $nv$  is the vertex number,  $nproc$  is a number intended to represent physical process (always set to 0),  $nparent$  is the track number of parent track (0 for primary vertex) and  $ndaughters$  is the number of daughter tracks from this vertex.

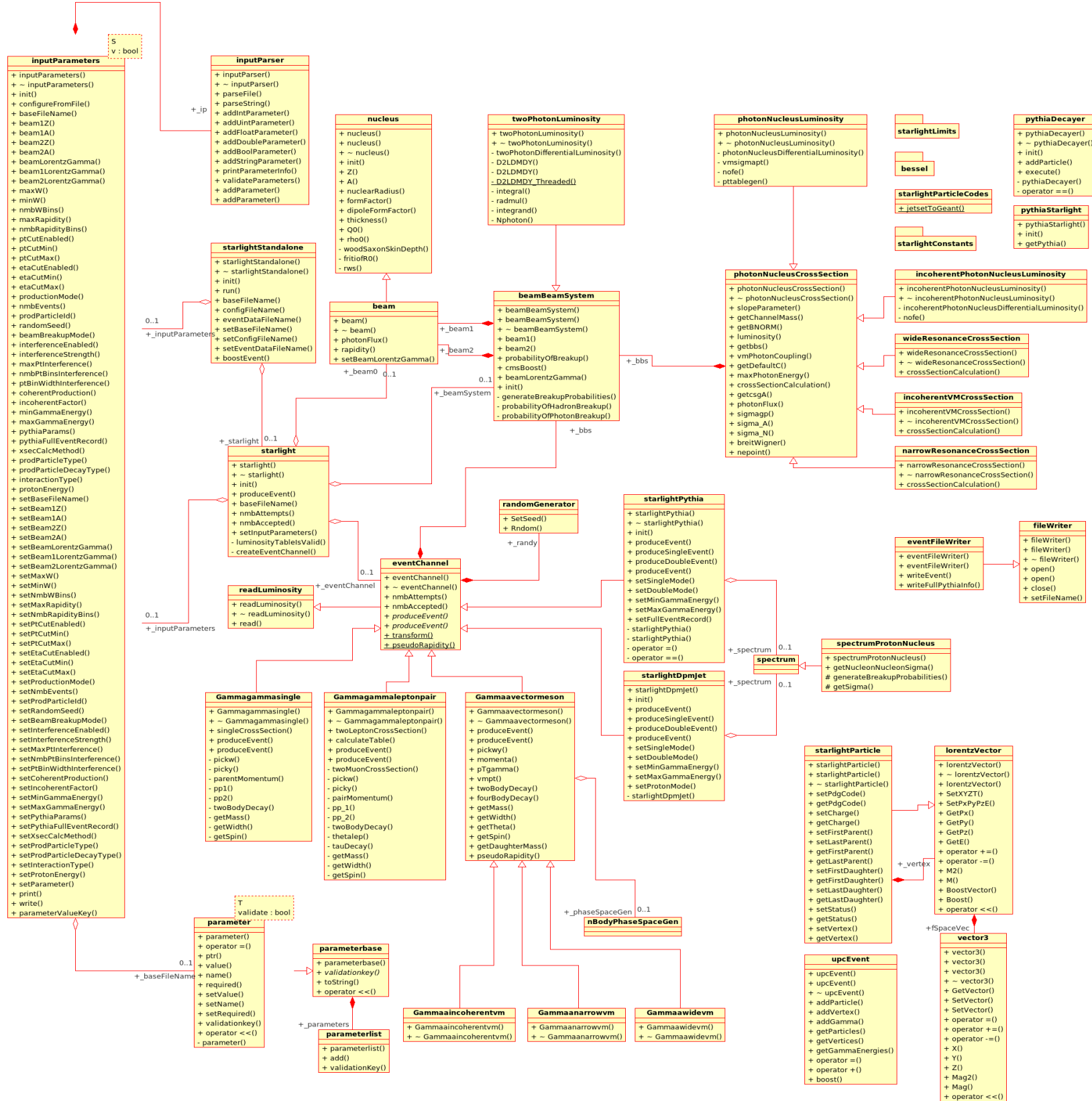
This is followed by a series of lines describing each of the daughter tracks emanating from this vertex. Each track line has the format

**TRACK:** GPID px py pz nev ntr stopv PDGPID ,

where GPID is the Geant particle id code,  $px$ ,  $py$  and  $pz$  are the three vector components of the track's momentum,  $nev$  is the event number,  $ntr$  is the number of this track within the vertex (starting with 0),  $stopv$  is the vertex number where track ends (0 if track does not terminate within the event), and PDGPID is the Monte Carlo particle ID code endorsed by the Particle Data Group.



## Class Diagram



## File Descriptions

### Readme.pdf

[This file.] provides information on the installation, operation, and construction of STARlight.

### CMakeLists.txt

controls STARlight compilation. For details, please see above in [Installation](#). This is the default/supported compilation method.

### Makefile

A sample Makefile for compilation on \*nix systems. This file is not actively supported. Please use CMake.

### starlightconfig.h.in

passes on some compiler settings; such as enabling the Pythia/DPMJet sections within the source code.

### starlightDoxyfile.conf

Doxygen configuration file.

### CMake Modules:

#### FindPythia8.cmake

used by CMake to find the Pythia 8 files needed to compile STARlight with Pythia 8 dependent options enabled. It searches for: Pythia.h, Index.xml, libpythia8

#### FindPythia6.cmake

used by CMake to find the Pythia 6 files needed to compile STARlight with Pythia 6 dependent options enabled. It searches for: libPythia6. *Pythia 6 functionality has been deprecated.*

#### FindDPMJet.cmake

used by CMake to find the DPMJET files needed to compile STARlight with DPMJET dependent options enabled. It searches for: dpmjet3.0-5.o, pythia6l15dpm3v1.o, and phojet1.12-35c4.o

#### FindROOT.cmake

used by CMake to find the ROOT files needed to compile STARlight with ROOT dependent options enabled. It searches for: root-config. root-config is then used to set the rest of the paths/options needed to enable ROOT within STARlight.

#### CommonMacros.cmake

A collection of useful cmake macros.

#### FindLHAPDF.cmake

used by CMake to find the LHAPDF dependent options enabled. This was necessary for older versions of Pythia8, but this is no longer the case. However, this file is being kept in the

distribution for users that would like to re-enable it. It searches for: Pythia.h and liblhpdfdummy

#### Config files:

my.input

A sample DPMJET configuration file.

slight.in

A sample STARlight input file, to select the desired final state and associated options. The section [Input](#) has more information.

slight.in.dpmjet

A sample slight.in file to use the DPMJET options (eg: PROD\_MODE = 5, 6, 7, and MIN\_GAMMA\_ENERGY, and MAX\_GAMMA\_ENERGY.).

slight.in.ee\_rhic

A sample slight.in file for e+e- production by Au-Au at top RHIC energies

slight.in.jpsi\_lhc

A sample slight.in file for J/ $\psi$  production by Pb-Pb at the LHC.

slight.in.pPb\_lhc

A sample slight.in file for J/ $\psi$  production by p-Pb at the LHC.

slight.in.rho\_rhic

A sample slight.in file for  $\rho$  production by Au-Au at top RHIC energies.

#### dpmjet:

dpmjetint.f

This is a DPMJET library, used in the CMakeLists.txt file to link when enabling DPMJET.

#### external:

fpe.c

corrects for the floating point trap differences between 32 and 64-bit. The [DPMJET section](#) has more information.

#### pythia6:

pythiainterface.h

interfaces Pythia6 with STARlight. *Pythia 6 functionality has been deprecated.*

#### utils:

#### Ana.C

This macro runs Analyze.cxx, which takes as input an ASCII STARlight output file, slight.out, and creates a standard set of histograms, which are stored in histograms.root

#### Analyze.cxx

This macro reads in a starlight output file and creates histograms of the  $p_T$  and rapidity of the daughters, as well as the  $p_T$ , rapidity and mass of the parent. It assumes there are only 2 daughter tracks that are electrons, muons, or pions. The histograms for the daughter particles are called fPt2, fPt2, fRap1, and fRap2. Parent histograms are created for each possible daughter species (e.g., parent  $p_T$  histograms are created with the names fPtEl, fPtMu, and fPtPi), but only the ones corresponding to the actual daughter particle are filled. The histograms are saved in a file called histograms.root.

To use this Analyze.cxx, modify the file Ana.C to call your input file (as downloaded, it calls slight.out) and the number of events you wish to process (as downloaded, it processes 20 events). Then open root and type ".x Ana.C" .

#### Analyze.h

The header file for Analyze.cxx and Ana.C.

#### AnalyzeTree.cxx

This macro reads the starlight.root file produced by ConvertStarlightAsciiToTree.C, which contains TLorentzVectors for the parents and a TClonesArray of TLorentzVectors for the daughters. It creates histograms of the  $p_T$  and rapidity of the daughters, as well as the  $p_T$ , rapidity and mass of the parent. While the parents may have been created as the vector sum of any number of daughter particles, this macro currently produces histograms for only the first two daughter particles. The daughter histograms are called D1Pt, D2Pt, D1Rapidity, and D1Rapidity. Parent histograms are named ParentPt, ParentRapidity, and ParentMass. The histograms are stored in starlight\_histos.root.

To use Analyzetree.cxx, first run ConvertStarlightAsciiToTree.C to produce the starlight.root file. If needed, modify the file AnalyzeTree.h to call your input file (as downloaded, it calls starlight.root). Then open root and type .x AnaTree.C .

#### AnalyzeTree.h

The header file for AnalyzeTree.cxx.

#### AnaTree.C

compiles and runs AnalyzeTree.cxx, which takes as input the starlight.root file produced by ConvertStarlightAsciiToTree.cxx output histograms are stored in starlight\_histos.root

#### ConvertStarlightAsciiToTree.C

reads a starlight output file (default name slight.out) and creates a root file with TLorentzVectors for the parent and a TClonesArray of TLorentzVectors for the daughter particles. The output is stored in a root file (default name starlight.root) with one branch labeled "parent" and the other labeled "daughters". Any number of daughter tracks can be accommodated. Daughter species currently accommodated are: electrons, muons, charged or neutral pions, charged or neutral kaons, and protons.

To use AnaTree.C, open root and then type `.x ConvertStarlightAsciiToTree.C("inputfilename", "outputfilename")` The root file produced can be examined in a root TBrowser.

A macro to read this root file and make some standard plots is also provided. This macro is called AnalyzeTree.cxx; it can be compiled and run with the AnaTree.C macro by opening root and typing `.x AnaTree.C()`

#### Source Files:

##### beam.cpp

generates the beam class, which inherits from the nucleus class (cf. [nucleus.cpp](#)). The object represents an accelerated nucleus, or a beam.

##### Functions:

```
beam::beam
beam::~beam
beam::photonFlux // calculates the "photon density" given
the impact parameter and energy.
```

##### beambeamssystem.cpp

represents the colliding system of interest.

##### Functions:

```
beamBeamSystem::beamBeamSystem
beamBeamSystem::~beamBeamSystem
beamBeamSystem::probabilityOfBreakup
beamBeamSystem::generateBreakupProbabilities
beamBeamSystem::probabilityOfHadronBreakup
beamBeamSystem::probabilityOfPhotonBreakup
```

##### bessel.cpp

calculate modified Bessel functions of the first and second kind.

##### Functions:

```
bessel::besI0
bessel::dbesk0
bessel::dbesk1
bessel::besI1
```

##### eventchannel.cpp

inherits from readLuminosity. It is a base for class for functions to produce events that is overloaded by other classes (Gammagammaleptonpair, Gammagammasingle, Gammaavectormeson, starlightDpmJet, and starlightPythia).

**Functions:**

```
eventChannel::eventChannel
eventChannel::~~eventChannel
eventChannel::transform // Lorentz Tranforms the frame
eventChannel::pseudoRapidity // calculates the
    pseudorapidity with the input from px, py, and pz
```

eventfilewriter.cpp

writes event information in the output file.

**Functions:**

```
eventFileWriter::eventFileWriter
eventFileWriter::~~eventFileWriter
eventFileWriter::writeEvent
```

filewriter.cpp

The base class for eventFileWriter, which is writes event information in the output file.

**Functions:**

```
fileWriter::fileWriter()
fileWriter::~~fileWriter()
fileWriter::open
fileWriter::open(filename)
fileWriter::close
```

gammaaluminosity.cpp

contains the photonNucleusLuminosity class, which inherits from photonNucleusCrossSection. It calculates the differential cross-section for gamma-A interactions.

**Functions:**

```
photonNucleusLuminosity::photonNucleusLuminosity
photonNucleusLuminosity::~~photonNucleusLuminosity
photonNucleusLuminosity::photonNucleusDifferentialLuminosity //Calculates and outputs the differential luminosity
photonNucleusLuminosity::pttablegen // Calculates the pt spectra for VM production with interference per S. Klein and J. Nystrand, Phys. Rev Lett. 84, 2330 (2000).
photonNucleusLuminosity::vmsigmapt //calculates th effect of the nuclear form factor on the pt spectrum, for use in interference calculations. It calculates the cross section suppression SIGMAPT(PT) as a function of pt. The input pt values come from pttable.inc
photonNucleusLuminosity::nofe //calculates the 'photon density'd^2N_gamma/db^2
```

gammaavm.cpp

is responsible for classes Gammaavectormeson, Gammaanarrowvm, and Gammaawidevm. Both Gammaanarrowvm and Gammaawidevm inherit from Gammaavectormeson, which inherits from eventChannel. The classes are responsible for generating and decaying the vector mesons produced by photon-nucleus interactions.

**Functions:**

```

Gammaavectormeson::Gammaavectormeson
Gammaavectormeson::~~Gammaavectormeson
Gammaavectormeson::pickwy //responsible for selecting the
events center of mass energy and rapidity
Gammaavectormeson::twoBodyDecay // This routine decays a
particle into two particles of mass mdec, taking spin into
account
Gammaavectormeson::fourBodyDecay // decays a particle into
four particles with isotropic angular distribution
Gammaavectormeson::getDaughterMass //returns the daughter
particles mass, & the final particles id...
Gammaavectormeson::getTheta //This depends on the decay
angular distribution
Gammaavectormeson::getWidth
Gammaavectormeson::getMass
Gammaavectormeson::getSpin //it's a VM, returns 1
Gammaavectormeson::momenta // calculates momentum and
energy of vector meson given W and Y, without
interference.
Gammaavectormeson::pTgamma //finds the photon pT
Gammaavectormeson::vmpt // calculates momentum and energy
of a vector meson given W and Y, including interference.
It gets the pt distribution from a lookup table.
produceEvent
pseudorapidity
Gammaanarrowvm::Gammaanarrowvm
Gammaanarrowvm::~~Gammaanarrowvm
Gammaanarrowvm::gammaaincoherentvm
Gammaawidevm::Gammaawidevm
Gammaawidevm::~~Gammaawidevm

```

gammagammaleptonpair.cpp

inherits from eventChannel. It calculates the lepton pair's cross-section and generates and decays the lepton pairs.

**Functions:**

```

Gammagammaleptonpair::Gammagammaleptonpair
Gammagammaleptonpair::~~Gammagammaleptonpair
Gammagammaleptonpair::twoLeptonCrossSection // calculates
section for 2-particle decay, per, see STAR Note 243, Eq.
9. It calculates the 2-lepton differential cross section
Gammagammaleptonpair::twoMuonCrossSection // gives the
two muon cross section as a function of Y&W, per G.Soff
et. al Nuclear Equation of State, part B, 579
Gammagammaleptonpair::pickw // Picks a w for the 2- photon
calculation.
Gammagammaleptonpair::picky // Picks a y given a W
Gammagammaleptonpair::pairMomentum // calculates
px,py,pz,and E given w and y
Gammagammaleptonpair::pp_1 // For beam 1, returns a
random momentum drawn from from pp_1(E) distribution
Gammagammaleptonpair::pp_2 // For beam 2, returns a
random momentum drawn from from pp_2(E) distribution
Gammagammaleptonpair::twoBodyDecay //decays a particle
into two particles of mass mdec, taking spin into account

```

```

Gammagammaleptonpair::thetalep // calculates the cross-
section as a function of angle for a given W and Y, for
the production of two muons or taus, per Brodsky et al.
PRD 1971, 1532 equation 5.7
Gammagammaleptonpair::produceEvent //returns the vector
with the decay particles inside
Gammagammaleptonpair::calculateTable //calculates the
tables that are used elsewhere in the Monte Carlo the tau
decay follows V-A theory,  $1 - 1/3 \cos(\theta)$  the energy of
each of the two leptons in tau decay is calculated using
formula 10.35 in "Introduction to elementary particles by
D. Griffiths," which assumes that the mass of the electron
is 0. The maximum electron energy in in such a system is
 $0.5 * \text{mass of the tau}$ 
Gammagammaleptonpair::tauDecay // assumes that the
tauons decay to electrons and calculates the directons of
the decays
Gammagammaleptonpair::getMass
Gammagammaleptonpair::getWidth
Gammagammaleptonpair::getSpin

```

gammagammasingle.cpp

inherits from eventChannel. It calculates the cross-section for single mesons and generates and decays the single mesons from gamma-gamma interactions. It also generates single mesons which are then decayed by Pythia 8.

**Functions:**

```

Gammagammasingle::Gammagammasingle
Gammagammasingle::~~Gammagammasingle
Gammagammasingle::singleCrossSection // calculates the
cross-section in the narrow-width approximation, per STAR
Note 243, Eq. 8
Gammagammasingle::pickw // picks a w for the 2-photon
calculation.
Gammagammasingle::picky
Gammagammasingle::parentMomentum // calculates
px,py,pz,and E given w and y
Gammagammasingle::pp_1 // For beam 1, returns a random
momentum drawn from from pp(E) distribution
Gammagammasingle::pp_2 // For beam 2, returns a random
momentum drawn from from pp(E) distribution
Gammagammasingle::twoBodyDecay //decays a particle into
two particles of mass mdec, taking spin into account
Gammagammasingle::produceEvent
Gammagammasingle::getMass
Gammagammasingle::getSpin

```

incoherentPhotonNucleusLuminosity.cpp

is responsible for the incoherentPhotonNucleusLuminosity class and inherits from photonNucleusCrossSection. It houses the differential luminosity calculation for incoherent gamma-A interactions.

**Functions:**

```

incoherentPhotonNucleusLuminosity::incoherentPhotonNucleus
Luminosity

```



```

        incoherentPhotonNucleusLuminosity::~incoherentPhotonNucleu
        sLuminosity
        incoherentPhotonNucleusLuminosity::incoherentPhotonNucleus
        DifferentialLuminosity
        incoherentPhotonNucleusLuminosity::nofe //Function for the
        calculation of the "photon density".

incoherentVMCrossSection.cpp
    inherits from photonNucleusCrossSection. It calculates the
    cross-section for incoherent photon-nucleus interactions.
Functions:
    incoherentVMCrossSection::incoherentVMCrossSection
    incoherentVMCrossSection::~incoherentVMCrossSection
    incoherentVMCrossSection::crossSectionCalculation //
    calculates the vector meson cross section assuming a
    narrow resonance. For reference, see STAR Note 386.

inputParameters.cpp
    sets and stores STARlight's input parameters.
Functions:
    inputParameters::inputParameters
    inputParameters::~inputParameters
    inputParameters::init
    inputParameters::configureFromFile
    inputParameters::print
    inputParameters::write
    inputParameters::parameterValueKey

inputParser.cpp
    parses the input files and stores the information in the
    inputParameters.
Functions:
    inputParser::inputParser()
    inputParser::~inputParser()
    inputParser::parseFile
    inputParser::parseString
    inputParser::addIntParameter
    inputParser::addUIntParameter
    inputParser::addFloatParameter
    inputParser::addDoubleParameter
    inputParser::addBoolParameter
    inputParser::addStringParameter
    inputParser::printParameterInfo
    inputParser::validateParameters

lorentzvector.cpp
    holds Lorentz 4-vectors.
Functions:
    lorentzVector::lorentzVector
    lorentzVector::~lorentzVector
    SetXYZT

main.cpp
    the "main" file/function—where the program starts.

narrowResonanceCrossSection.cpp

```

inherits from photonNucleusCrossSection. It calculates the cross-section for narrow resonance vector mesons.

**Functions:**

```
narrowResonanceCrossSection::narrowResonanceCrossSection  
narrowResonanceCrossSection::~~narrowResonanceCrossSection  
narrowResonanceCrossSection::crossSectionCalculation //  
calculates the vector meson cross section assuming a  
narrow resonance, per STAR Note 386.
```

nBodyPhaseSpaceGen.cpp

is responsible for the kinematics used in the four-prong decays.

**Functions:**

```
nBodyPhaseSpaceGen::nBodyPhaseSpaceGen  
nBodyPhaseSpaceGen::~~nBodyPhaseSpaceGen  
nBodyPhaseSpaceGen::setDecay // sets decay constants and  
prepares internal variables  
nBodyPhaseSpaceGen::generateDecay// generates event with  
certain n-body mass and momentum and returns event weight  
general purpose function  
nBodyPhaseSpaceGen::generateDecayAccepted// generates full  
event with certain n-body mass and momentum only, when  
event is accepted (return value = true) this function is  
more efficient, if only weighted events are needed  
nBodyPhaseSpaceGen::pickMasses// randomly chooses the (n -  
2) effective masses of the respective (i + 1)-body systems  
nBodyPhaseSpaceGen::calcWeight// computes event weight (=   
integrand value) and breakup momenta uses vector of  
intermediate two-body masses prepared by pickMasses()  
nBodyPhaseSpaceGen::calcEventKinematics// calculates  
complete event from the effective masses of the (i + 1)-  
body systems, the Lorentz vector of the decaying system,  
and the decay angles uses the break-up momenta calculated  
by calcWeight()  
nBodyPhaseSpaceGen::estimateMaxWeight// calculates maximum  
weight for given n-body mass  
nBodyPhaseSpaceGen::print
```

nucleus.cpp

defines the basis properties of a nucleus such as radius, form factor, and thickness.

**Functions:**

```
nucleus::nucleus  
nucleus::~~nucleus  
nucleus::init  
nucleus::nuclearRadius  
nucleus::formFactor  
nucleus::dipoleFormFactor  
nucleus::thickness// calculates the nuclear thickness  
function per Eq. 4 in Klein and Nystrand, PRC 60
```

photonNucleusCrossSection.cpp

calculates the cross-section for coherent photon-Nucleus interactions.

**Functions:**

```
photonNucleusCrossSection::photonNucleusCrossSection
```

```

photonNucleusCrossSection::~~photonNucleusCrossSection
photonNucleusCrossSection::~getcsgA // returns the cross-
section for photon-nucleus interaction producing vector
mesons
photonNucleusCrossSection::~photonFlux // gives the
photon flux as a function of energy Egamma for arbitrary
nuclei and gamma. The first time it is called, it
calculates a lookup table which is used on subsequent
calls. It returns dN_gamma/dE (dimensions 1/E), not dI/dE
energies are in GeV, in the lab frame
photonNucleusCrossSection::~nepoint// gives the spectrum of
virtual photons, dn/dEgamma, for a point charge q=Ze
sweeping past the origin with velocity gamma, integrated
over impact parameter from bmin to infinity, per Eq. 15.54
of Jacksons Classical Electrodynamics
photonNucleusCrossSection::~sigmagp// gives the gamma-
proton --> VectorMeson cross section. Wgp is the gamma-
proton CM energy. Unit for cross section: fm**2
photonNucleusCrossSection::~sigma_A// Nuclear Cross Section
sig_N,sigma_A in (fm**2)
photonNucleusCrossSection::~sigma_N// Nucleon Cross Section
in (fm**2)
photonNucleusCrossSection::~breitWigner// uses simple
fixed-width s-wave Breit-Wigner without coherent
backgorund for rho' (PDG '08 eq. 38.56)

```

pythiadecayer.cpp

links Pythia 8 and STARlight, and initializes Pythia 8.

**Functions:**

```

pythiaDecayer::pythiaDecayer
pythiaDecayer::~~pythiaDecayer
pythiaDecayer::init
pythiaDecayer::addParticle
pythiaDecayer::execute

```

randomgenerator.cpp

STARlight's random number generator, using the same algorithm as ROOTs TRANDOM3 class. It is based on M. Matsumoto and T. Nishimura, Mersenne Twistor: A 623-dimensionally equidistributed uniform pseudorandom number generator. For more information see

<http://www.math.keio.ac.jp/~matumoto/emt.html>

**Functions:**

```

randomGenerator::SetSeed
randomGenerator::Rdom

```

readinluminosity.cpp

reads in the luminosity tables from slight.txt, which is generated in the early stages of the program.

**Functions:**

```

readLuminosity::readLuminosity
readLuminosity::~~readLuminosity
readLuminosity::read

```

spectrum.cpp

sets up functions needed to make cross-section calculations for general photonuclear interactions modeled with DPMJET.

**Functions:**

- spectrum::spectrum
- spectrum::generateKsingle
- spectrum::generateKdouble
- spectrum::drawKsingle
- spectrum::drawKdouble
- spectrum::generateBreakupProbabilities
- spectrum::getFnSingle
- spectrum::getFnDouble
- spectrum::getTransformedNofe

spectrumprotonnucleus.cpp

sets up functions needed to make cross-section calculations for general photonuclear interactions modeled with DPMJET.

**Functions:**

- spectrumProtonNucleus::spectrumProtonNucleus
- spectrumProtonNucleus::generateBreakupProbabilities
- spectrumProtonNucleus::getSigma

starlight.cpp

initializes and then produces and decays events.

**Functions:**

- starlight::starlight
- starlight::~~starlight
- starlight::init
- starlight::produceEvent
- starlight::luminosityTableIsValid
- starlight::createEventChannel

starlightdpmjet.cpp

hosts the class starlightDpmJet which inherits from the eventChannel class. It includes methods to generate diffractive events with DPMJET.

**Functions:**

- starlightDpmJet::starlightDpmJet
- starlightDpmJet::init
- starlightDpmJet::produceEvent
- starlightDpmJet::produceSingleEvent
- starlightDpmJet::produceDoubleEvent

starlightparticle.cpp

is a container to store particle information.

**Functions:**

- starlightParticle::starlightParticle
- starlightParticle::~~starlightParticle

starlightparticlecodes.cpp

converts jetset particle numbers to the corresponding GEANT code.

**Functions:**

- starlightParticleCodes::jetsetToGeant

starlightpythia.cpp

inherits from the eventChannel class. It includes methods to calculate diffractive events with Pythia6. *Pythia 6 functionality has been deprecated.*

**Functions:**

```
starlightPythia::starlightPythia
starlightPythia::~~starlightPythia
starlightPythia::init
starlightPythia::produceEvent
```

starlightStandalone.cpp

is used by Main.cpp and in turn calls methods from the starlight class.

**Functions:**

```
starlightStandalone::starlightStandalone
starlightStandalone::~~starlightStandalone
starlightStandalone::init
starlightStandalone::run
starlightStandalone::boostEvent
```

twophotonluminosity.cpp

inherits from beamBeamSystem, and is responsible for calculating the two photon luminosity table based on W and Y.

**Functions:**

```
twoPhotonLuminosity::twoPhotonLuminosity
twoPhotonLuminosity::~~twoPhotonLuminosity
twoPhotonDifferentialLuminosity
twoPhotonLuminosity::D2LDMDY
twoPhotonLuminosity::D2LDMDY_Threaded
twoPhotonLuminosity::integral
twoPhotonLuminosity::radmul
twoPhotonLuminosity::integrand
twoPhotonLuminosity::Nphoton
```

upcevent.cpp

stores the final event information.

**Functions:**

```
upcEvent::upcEvent
upcEvent::operator=
upcEvent::operator+
upcEvent::boost
```

vector3.cpp

is a container for 3D-vectors.

**Functions:**

```
vector3::vector3
vector3::~~vector3
vector3::SetVector
```

wideResonanceCrossSection.cpp

inherits from photnNucleusCrossSection. It is responsible for calculating the cross-section of vector mesons with a wide resonance (eg. Rho).

**Functions:**

```
wideResonanceCrossSection::wideResonanceCrossSection
wideResonanceCrossSection::~~wideResonanceCrossSection
```

```

wideResonanceCrossSection::crossSectionCalculation //
calculates the cross-section assuming a wide(Breit-Wigner)
resonance.

```

## Include Files:

```

beam.h //This class includes a single beam of nucleons

```

### Included in files

```

beambeamsystem.h
twophotonluminosity.h
beam.cpp
gammaaluminosity.cpp
incoherentPhotonNucleusLuminosity.cpp
spectrumprotonnucleus.cpp
twophotonluminosity.cpp

```

### Functions

```

beam
~beam
rapidity
photonFlux
setBeamLorentzGamma

```

```

beambeamsystem.h //This class covers a coliding beam system

```

### Included in files

```

eventchannel.h
gammaaluminosity.h
gammaaavm.h
gammagammaingle.h
incoherentPhotonNucleusLuminosity.h
photonNucleusCrossSection.h
starlightpythia.h
twophotonluminosity.h
beambeamsystem.cpp
gammaaluminosity.cpp
incoherentPhotonNucleusLuminosity.cpp
spectrum.cpp
spectrumprotonnucleus.cpp
twophotonluminosity.cpp

```

### Functions

```

beamBeamSystem
~beamBeamSystem
cmsBoost
beamLorentzGamma
beam1
beam2
probabilityOfBreakup
init
generateBreakupProbabilities
probabilityOfHadronBreakup
probabilityOfPhotonBreakup

```

```

bessel.h

```

### Included in files

```

beam.cpp
beambeamsystem.cpp

```

[bessel.cpp](#)  
[gammaaluminosity.cpp](#)  
[incoherentPhotonNucleusLuminosity.cpp](#)  
[photonNucleusCrossSection.cpp](#)  
[twophotonluminosity.cpp](#)

#### Functions

besI0  
dbesk0  
dbesk1  
besI1

eventchannel.h

#### Included in files

[gammaavm.h](#)  
[gammagammaleptonpair.h](#)  
[gammagammasingle.h](#)  
[starlight.h](#)  
[starlightdpmjet.h](#)  
[starlightpythia.h](#)  
[eventchannel.cpp](#)  
[starlight.cpp](#)

#### Functions

eventChannel  
~eventChannel  
nmbAttempts ///< returns number of attempted events  
nmbAccepted ///< returns number of accepted events  
produceEvent  
transform ///< Lorentz-transforms given 4-vector  
pseudoRapidity ///< calculates pseudorapidity for  
given 3-momentum

eventfilewriter.h

#### Included in files

[eventfilewriter.cpp](#)  
[main.cpp](#)  
[starlight.cpp](#)  
[starlightStandalone.cpp](#)

#### Functions

eventFileWriter  
writeEvent /\*\* Write an UPC event to file \*/  
writeFullPythiaInfo /\*\* Set if we want to write full  
pythia information \*/

filewriter.h

#### Included in files

[eventfilewriter.h](#)  
[eventfilewriter.cpp](#)  
[filewriter.cpp](#)  
[main.cpp](#)  
[starlight.cpp](#)  
[starlightStandalone.cpp](#)

#### Functions

fileWriter  
~fileWriter  
open //opens the file  
setFileName//set the filename we're writing to

gammaaluminosity.h

**Included in files**

[gammaaluminosity.cpp](#)  
[starlight.cpp](#)

**Functions**

photonNucleusLuminosity  
~photonNucleusLuminosity  
photonNucleusDifferentialLuminosity  
vmsigmapt  
nofe  
pttablegen

gammaavm.h

**Included in files**

[gammaavm.cpp](#)  
[starlight.cpp](#)

**Functions**

Gammaavectormeson  
~Gammaavectormeson  
produceEvent  
pickwy  
momenta  
pTgamma  
vmpt  
twoBodyDecay  
fourBodyDecay  
getMass  
getWidth  
getTheta  
getSpin  
getDaughterMass  
pseudoRapidity  
Gammaanarrowvm  
~Gammaanarrowvm  
Gammaawidevm  
~Gammaawidevm  
Gammaaincoherentvm  
~Gammaaincoherentvm

gammagammaleptonpair.h

**Included in files**

[gammagammaleptonpair.cpp](#)  
[starlight.cpp](#)

**Functions**

Gammagammaleptonpair  
~Gammagammaleptonpair  
twoLeptonCrossSection  
calculateTable  
produceEvent  
twoMuonCrossSection  
pickw  
picky  
pairMomentum  
pp\_1  
pp\_2



twoBodyDecay  
thetalep  
tauDecay  
getMass  
getWidth  
getSpin

gammagammasingle.h

**Included in files**

[gammagammasingle.cpp](#)  
[starlight.cpp](#)

**Functions**

Gammagammasingle  
~Gammagammasingle  
singleCrossSection  
produceEvent  
pickw  
picky  
parentMomentum  
pp  
twoBodyDecay  
thephi  
getMass  
getWidth  
getSpin

incoherentPhotonNucleusLuminosity.h

**Included in files**

[incoherentPhotonNucleusLuminosity.cpp](#)  
[starlight.cpp](#)

**Functions**

incoherentPhotonNucleusLuminosity  
~incoherentPhotonNucleusLuminosity  
incoherentPhotonNucleusDifferentialLuminosity  
nofe

incoherentVMCrossSection.h

**Included in files**

[gammaavm.cpp](#)  
[incoherentVMCrossSection.cpp](#)

**Functions**

incoherentVMCrossSection  
~incoherentVMCrossSection  
crossSectionCalculation

inputParameters.h

**Included in files**

[beam.h](#)  
[gammaaluminosity.h](#)  
[incoherentPhotonNucleusLuminosity.h](#)  
[readinluminosity.h](#)  
[starlightpythia.h](#)  
[beam.cpp](#)  
[beambeamsystem.cpp](#)  
[gammaaluminosity.cpp](#)  
[incoherentPhotonNucleusLuminosity.cpp](#)

[inputParameters.cpp](#)  
[nucleus.cpp](#)  
[readinluminosity.cpp](#)  
[starlight.cpp](#)  
[starlightStandalone.cpp](#)  
[twophotonluminosity.cpp](#)

## **Functions**

parameterlist  
add  
validationKey  
parameterbase  
toString  
operator<<  
parameter  
operator=  
ptr  
value  
name  
required  
setValue  
setName  
setRequired  
inputParameters  
~inputParameters  
init  
configureFromFile  
baseFileName  
beam1Z  
beam1A  
beam2Z  
beam2A  
beamLorentzGamma  
beam1LorentzGamma  
beam2LorentzGamma  
maxW  
minW  
nmbWBins  
maxRapidity  
nmbRapidityBins  
ptCutEnabled  
ptCutMin  
ptCutMax  
etaCutEnabled  
etaCutMin  
etaCutMax  
productionMode  
nmbEvents  
prodParticleId  
randomSeed  
beamBreakupMode  
interferenceEnabled  
interferenceStrength  
maxPtInterference  
nmbPtBinsInterference  
ptBinWidthInterference  
coherentProduction  
incoherentFactor

```

minGammaEnergy
maxGammaEnergy
pythiaParams
pythiaFullEventRecord
xsecCalcMethod
prodParticleType
prodParticleDecayType
interactionType
protonEnergy
setBaseFileName
setBeam1Z
setBeam1A
setBeam2Z
setBeam2A
setBeamLorentzGamma
setBeam1LorentzGamma
setBeam2LorentzGamma
setMaxW
setMinW
setNmbWBins
setMaxRapidity
setNmbRapidityBins
setPtCutEnabled
setPtCutMin
setPtCutMax
setEtaCutEnabled
setEtaCutMin
setEtaCutMax
setProductionMode
setNmbEvents
setProdParticleId
setRandomSeed
setBeamBreakupMode
setInterferenceEnabled
setInterferenceStrength
setMaxPtInterference
setNmbPtBinsInterference
setPtBinWidthInterference
setCoherentProduction
setIncoherentFactor
setMinGammaEnergy
setMaxGammaEnergy
setPythiaParams
setPythiaFullEventRecord
setXsecCalcMethod
setProdParticleType
setProdParticleDecayType
setInteractionType
setProtonEnergy
setParameter
print
write
parameterValueKey
instance

```

inputParser.h

**Included in files**

[inputParameters.h](#)  
[inputParameters.cpp](#)  
[inputParser.cpp](#)

**Functions**

inputParser  
inputParser  
parseFile/\*\* Parse a file \*/  
parseString  
addIntParameter  
addUIntParameter  
addFloatParameter  
addDoubleParameter  
addBoolParameter  
addStringParameter  
printParameterInfo  
validateParameters  
\_parameter  
operator==  
operator<  
printParameterInfo  
addParameter

lorentzvector.h

**Included in files**

[nBodyPhaseSpaceGen.h](#)  
[starlightparticle.h](#)  
[lorentzvector.cpp](#)

**Functions**

lorentzVector  
~lorentzVector  
SetXYZT  
SetPxPyPzE  
GetPx  
GetPy  
GetPz  
GetE  
operator +=  
operator -=  
M2  
M  
BoostVector  
Boost  
operator <<

narrowResonanceCrossSection.h

**Included in files**

[narrowResonanceCrossSection.cpp](#)  
[gammaavm.cpp](#)

**Functions**

narrowResonanceCrossSection  
~narrowResonanceCrossSection  
crossSectionCalculation

nBodyPhaseSpaceGen.h

**Included in files**

[gammaavm.h](#)

[nBodyPhaseSpaceGen.cpp](#)

#### Functions

Factorial  
breakupMomentum  
nBodyPhaseSpaceGen  
~nBodyPhaseSpaceGen  
setDecay  
random  
generateDecay  
generateDecayAccepted  
setMaxWeight  
maxWeight  
normalization  
eventWeight  
maxWeightObserved  
resetMaxWeightObserved  
estimateMaxWeight  
eventAccepted  
daughter  
daughters  
nmbOfDaughters  
daughterMass  
intermediateMass  
breakupMom  
cosTheta  
phi  
print  
operator <<  
pickMasses  
calcWeight  
pickAngles  
calcEventKinematics  
eventAccepted

nucleus.h

#### Included in files

[beam.h](#)  
[beambeamsystem.h](#)  
[twophotonluminosity.h](#)  
[gammaaluminosity.h](#)  
[incoherentPhotonNucleusLuminosity.cpp](#)  
[nucleus.cpp](#)  
[spectrumprotonnucleus.cpp](#)  
[starlightdpmjet.cpp](#)  
[starlightpythia.cpp](#)  
[twophotonluminosity.cpp](#)

#### Functions

nucleus  
~nucleus  
init  
Z  
A  
nuclearRadius  
formFactor  
dipoleFormFactor  
thickness

```

Q0
rho0
woodSaxonSkinDepth
fritiofR0
rws

```

photonNucleusCrossSection.h

#### Included in files

```

gammaaluminosity.h
incoherentPhotonNucleusLuminosity.h
incoherentVMCrossSection.h
narrowResonanceCrossSection.h
wideResonanceCrossSection.h
gammaavm.cpp
photonNucleusCrossSection.cpp

```

#### Functions

```

photonNucleusCrossSection
~photonNucleusCrossSection
slopeParameter///< returns slope of t-distribution
[(GeV/c)^{-2}]
getChannelMass ///< returns mass of the produced
system [GeV/c^2]
getBNORM
luminosity///< returns luminosity [10^{26} cm^{-2}
sec^{-1}]
getbbs///< returns beamBeamSystem
vmPhotonCoupling ///< vectormeson-photon coupling
constant f_v / 4 pi (cf. Eq. 10 in KN PRC 60 (1999)
014903)
getDefaultC
maxPhotonEnergy///< returns max photon energy in lab
frame [GeV] (for vectormesons only)
crossSectionCalculation
getcsgA
photonFlux
sigmagp
sigma_A
sigma_N
breitWigner
nepoint

```

pythiadecayer.h

#### Included in files

```

gammagammasingle.h
pythiadecayer.cpp

```

#### Functions

```

pythiaDecayer
~pythiaDecayer
init// Initialize
addParticle// Add particle to current event
execute// Execute event and return starlight type
event
pythiaDecayer
operator==

```

PythiaStarlight.h

**Included in files**

[starlight.cpp](#)

**Functions**

pythiaStarlight  
init  
getPythia

randomgenerator.h

**Included in files**

[eventchannel.h](#)  
[gammaavm.h](#)  
[gammagammasingle.h](#)  
[nBodyPhaseSpaceGen.h](#)  
[inputParameters.cpp](#)  
[randomgenerator.cpp](#)  
[spectrum.cpp](#)

**Functions**

SetSeed  
Rndom  
randomGenerator  
instance

readinluminosity.h

**Included in files**

[eventchannel.h](#)  
[gammaavm.h](#)  
[gammagammaleptonpair.h](#)  
[gammagammasingle.h](#)  
[readinluminosity.cpp](#)

**Functions**

readLuminosity  
~readLuminosity  
read

reportingUtils.h

**Included in files**

[inputParser.h](#)  
[nBodyPhaseSpaceGen.h](#)  
[beam.cpp](#)  
[beambeamsystem.cpp](#)  
[inputParameters.cpp](#)  
[main.cpp](#)  
[nucleus.cpp](#)  
[photonNucleusCrossSection.cpp](#)  
[pythiadecayer.cpp](#)  
[starlight.cpp](#)  
[starlightStandalone.cpp](#)

**Functions**

getClassMethod\_\_  
printErr  
printWarn  
printInfo  
svnVersion  
printSvnVersion  
compileDir  
printCompilerInfo

```

operator <<
progressIndicator
trueFalse
yesNo
onOff
enDisabled

```

spectrum.h

#### **Included in files**

```

spectrumprotonnucleus.h
starlightdpmjet.h
spectrum.cpp
starlightdpmjet.cpp

```

#### **Functions**

```

spectrum // Spectrum must be constructed with beam-
beam system, default constructor disallowed
generateKsingle // Generate a table of photon energy
probabilities. Use NK+1 logarithmic steps between
Et_min and Eg_max
generateKdouble // Generate a 2-D table of photon
energy probabilities. Use NK+1 x NK+1 logarithmic
steps between Et_min and Eg_max
drawKsingle // Get the energy of a single gamma
@return energy of the gamma
drawKdouble // Get the energy of a single gamma
@param egamma1 variable passed by reference to get
the energy of the first gamma @param egamma2 variable
passed by reference to get the energy of the second
gamma @return energy of the gamma
setBeamBeamSystem // Set the beam beam system
setMinGammaEnergy //Set the minimum gamma energy
setMaxGammaEnergy / Set the maximum gamma energy
setBmin //Set minimum impact parameter
setBMax //Set maximum impact parameter
generateBreakupProbabilities //Generate the hadron
breakup probability table
getSigma ---1.05?
getTransformedNofe
getFnSingle
getFnDouble

```

spectrumprotonnucleus.h

#### **Included in files**

```

spectrumprotonnucleus.cpp
starlightdpmjet.cpp
starlightpythia.cpp

```

#### **Functions**

```

spectrumProtonNucleus
getNucleonNucleonSigma --- 7.35?
generateBreakupProbabilities
getSigma

```

starlight.h

#### **Included in files**

```

main.cpp
starlight.cpp

```



[starlightStandalone.cpp](#)

**Functions**

starlight  
~starlight  
init  
produceEvent  
configFileName  
nmbAttempts  
nmbAccepted  
luminosityTableIsValid  
createEventChannel

starlightconstants.h

**Included in files**

[eventchannel.h](#)  
[gammaavm.h](#)  
[gammagammaingle.h](#)  
[gammagammaleptonpair.h](#)  
[inputParameters.h](#)  
[nBodyPhaseSpaceGen.h](#)  
[photonNucleusCrossSection.h](#)  
[upcevent.h](#)  
[beam.cpp](#)  
[beambeamsystem.cpp](#)  
[gammaaluminosity.cpp](#)  
[gammagammaleptonpair.cpp](#)  
[gammagammaingle.cpp](#)  
[incoherentPhotonNucleusLuminosity.cpp](#)  
[incoherentVMCrossSection.cpp](#)  
[inputParameters.cpp](#)  
[narrowResonanceCrossSection.cpp](#)  
[nucleus.cpp](#)  
[photonNucleusCrossSection.cpp](#)  
[readinluminosity.cpp](#)  
[twophotonluminosity.cpp](#)  
[wideResonanceCrossSection.cpp](#)

**Functions**

N/A

starlightdpmjet.h

**Included in files**

[starlight.cpp](#)  
[starlightdpmjet.cpp](#)

**Functions**

starlightDpmJet  
init  
produceEvent  
produceSingleEvent  
produceDoubleEvent  
setSingleMode  
setDoubleMode  
setMinGammaEnergy  
setMaxGammaEnergy  
setProtonMode

starlightlimits.h

**Included in files**

[gammagammaleptonpair.h](#)  
[readinluminosity.h](#)  
[twophotonluminosity.h](#)

**Functions**

N/A

starlightparticle.h

**Included in files**

[pyhthiadcayer.h](#)  
[upcevent.h](#)  
[starlightparticle.cpp](#)

**Functions**

starlightParticle  
~starlightParticle  
setPdgCode  
getPdgCode  
setCharge  
getCharge  
setFirstParent  
getFirstParent  
setLastParent  
getLastParent  
setFirstDaughter  
getFirstDaughter  
setLastDaughter  
getLastDaughter  
getStatus  
setStatus  
setVertex  
getVertex

starlightparticlecodes.h

**Included in files**

[eventfilewriter.cpp](#)  
[starlightparticlescodes.cpp](#)

**Functions**

jetsetToGeant//Converts a jetset code into a GEANT  
codes

starlightpythia.h

**Included in files**

[starlight.cpp](#)  
[starlightpythia.cpp](#)

**Functions**

starlightPythia  
~starlightPythia  
init  
produceSingleEvent  
produceDoubleEvent  
produceEvent  
setSingleMode  
setDoubleMode  
setMinGammaEnergy  
setMaxGammaEnergy  
setFullEventRecord

starlightStandalone.h

**Included in files**

[main.cpp](#)

[starlightStandalone.cpp](#)

**Functions**

starlightStandalone  
~starlightStandalone  
init  
run  
configFileName  
eventDataFileName  
setConfigFileName  
setEventDataFileName  
boostEvent

twophotonluminosity.h

**Included in files**

[starlight.cpp](#)

[twophotonluminosity.cpp](#)

**Functions**

twoPhotonLuminosity  
~twoPhotonLuminosity  
twoPhotonDifferentialLuminosity  
D2LDMDY  
D2LDMDY\_Threaded  
integral  
radmul  
integrand  
Nphoton

upcevent.h

**Included in files**

[eventchannel.h](#)

[filewriter.h](#)

[gammaavm.h](#)

[pythiadecayer.h](#)

[starlight.h](#)

[starlightpythia.h](#)

[starlight.cpp](#)

[upcevent.cpp](#)

**Functions**

upcEvent  
~upcEvent  
addParticle  
addVertex  
addGamma  
getParticles  
getVertices  
getGammaEnergies  
operator=  
operator+  
boost

vector3.h

**Included in files**

[lorentzvector.h](#)  
[vector3.cpp](#)

**Functions**

vector3  
~vector3  
GetVector  
SetVector  
operator +=  
operator =  
operator -=  
X  
Y  
Z  
Mag2  
Mag  
operator <<

wideResonanceCrossSection.h

**Included in files**

[gammaavm.cpp](#)  
[wideResonanceCrossSection.cpp](#)

**Functions**

wideResonanceCrossSection  
~wideResonanceCrossSection  
crossSectionCalculation