EvtGen & Pythia

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EvtGen use of Pythia

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- Mainly discussing how Pythia is used within EvtGen, not really in question of EvtGen would be called from Pythia
- What EvtGen does is decays of especially heavy flavour hadrons
  - Long list of possible decay modes with dedicated decay models with “correct” physics
  - Possible decays are based on existing experimental knowledge, various predictions and some assumptions based on experimental results and/or predictions
    - Lot of these are not very well documented
- Problem with *b*- and *c*-hadrons is that despite long list of decays known, there is still large fraction which is unmeasured/unknown
- To get unknown bit, create quark and/or diquark configurations and pass those to Pythia

B^+/B^0 mesons

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B^+

```
#  Lam_c X  / Sigma_c X
#
#0.04000 anti-cd_1 uu_1 PYTHIA 63;
0.032572352 anti-cd_1 uu_1 PYTHIA 63;
#
#  Xi_c X     2.4%

#0.02400 anti-cs_1 uu_1 PYTHIA 63;
0.008883411 anti-cs_1 uu_1 PYTHIA 63;
#
#
0.211960282 u anti-d anti-c u PYTHIA 23;
0.040460124 u anti-d anti-c u PYTHIA 43;
0.022208435 u anti-s anti-c u PYTHIA 43;
#lange - try to crank up the psi production....
0.073041080 c anti-s anti-c u PYTHIA 43;
0.003948141 c anti-d anti-c u PYTHIA 43;
0.002961106 u anti-d anti-u u PYTHIA 23;
0.003948141 c anti-s anti-u u PYTHIA 23;
# JGS 11/5/02 This and similar a few lines above have been divided by two
# to solve a double-counting problem for this channel
0.002023436 u anti-u anti-d u PYTHIA 23;
0.000069112 d anti-d anti-d u PYTHIA 23;
0.000088858 s anti-s anti-d u PYTHIA 23;
0.002171534 u anti-u anti-s u PYTHIA 23;
0.001776701 d anti-d anti-s u PYTHIA 23;
0.001480600 s anti-s anti-s u PYTHIA 23;
0.004935177 anti-s u PYTHIA 91;
```

B^0

```
#  Lam_c X  / Sigma_c X      4.0 %
#
#0.01000 anti-cd_0 ud_0 PYTHIA 63;
#0.03000 anti-cd_1 ud_1 PYTHIA 63;
0.010520663 anti-cd_0 ud_0 PYTHIA 63;
0.021041421 anti-cd_1 ud_1 PYTHIA 63;
#
#  Xi_c X    2.5%
#
#0.00600 anti-cs_0 ud_0 PYTHIA 63;
#0.01800 anti-cs_1 ud_1 PYTHIA 63;
0.002869298 anti-cs_0 ud_0 PYTHIA 63;
0.005738595 anti-cs_1 ud_1 PYTHIA 63;
#
#
0.251926466 u anti-d anti-c d PYTHIA 23;
0.042944682 u anti-d anti-c d PYTHIA 43;
0.020084989 u anti-s anti-c d PYTHIA 43;
0.017215691 u anti-c anti-d d PYTHIA 23;
0.000860770 u anti-c anti-s d PYTHIA 23;
#lange - try to crank up the psi production....
0.070775534 c anti-s anti-c d PYTHIA 43;
0.005738595 c anti-d anti-c d PYTHIA 43;
0.002869298 u anti-d anti-u d PYTHIA 23;
0.003825730 c anti-s anti-u d PYTHIA 23;
# JGS 11/5/02 This and similar a few lines above have been divided by two
# to solve a double-counting problem for this channel
0.001960649 u anti-u anti-d d PYTHIA 23;
0.000066973 d anti-d anti-d d PYTHIA 23;
0.000086068 s anti-s anti-d d PYTHIA 23;
0.002104095 u anti-u anti-s d PYTHIA 23;
0.001721541 d anti-d anti-s d PYTHIA 23;
0.001434649 s anti-s anti-s d PYTHIA 23;
0.004782163 anti-s d PYTHIA 91;
```

B_s^0 and Λ_b

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B_s^0

```
#  Start with B to baryons:
#  fkw 3/28/01 I don't know what I'm doing here!!! This needs to be checked!!!
# Mark Whitehead 30/4/2010 Weight PYTHIA to get Total BF=100%
0.019574780 anti-cs_0 ud_0 PYTHIA 63;
0.039129957 anti-cs_1 ud_1 PYTHIA 63;
#
#  Next come external W-emission:
0.301256716 u anti-d anti-c s PYTHIA 23;
0.048443906 u anti-d anti-c s PYTHIA 65;
#  Now the internal W-emission:
0.019086636 u anti-c anti-d s PYTHIA 23;
#  Then some b->u external W-emission with upper vertex charm
0.003912996 c anti-s anti-u s PYTHIA 23;
# and finally some cabibbo suppressed external and internal W-emission
0.014683536 u anti-s anti-c s PYTHIA 23;
0.002152148 u anti-s anti-c s PYTHIA 65;
0.000880424 u anti-c anti-s s PYTHIA 23;
# and some c cbar d stuff as well as c cbar s
0.005391151 c anti-d anti-c s PYTHIA 43;
0.001468354 c anti-d anti-c s PYTHIA 43;
# and some miscellaneous charmless stuff
0.003521696 u anti-u anti-d s PYTHIA 23;
0.000684774 d anti-d anti-d s PYTHIA 23;
0.000880424 s anti-s anti-d s PYTHIA 23;
0.001956498 u anti-u anti-s s PYTHIA 23;
0.001565198 d anti-d anti-s s PYTHIA 23;
0.001271724 s anti-s anti-s s PYTHIA 23;
0.004891245 anti-s s PYTHIA 91;
```

Λ_b

```
# PR LHCb 27 Apr 2004, addition of Pythia decays
0.398544837 anti-u d c ud_0 PYTHIA 23;
0.082218903 anti-u c d ud_0 PYTHIA 43;
0.072280354 anti-c s c ud_0 PYTHIA 43;
0.010842053 anti-u d u ud_0 PYTHIA 22;
0.010842053 anti-c s u ud_0 PYTHIA 22;
```

- For b-hadrons, about 30% up to 55-60% goes through Pythia
- Charm is better, mesons fully done in EvtGen, baryons go to large extend to Pythia

Loose ends

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- Long time ago in days of Pythia6 we did veto results with decays present also in our decay table
- As we realised recently, this got lost when we moved to Pythia8
  - Hopefully will be added soon
- Small issue is that particle properties do not have to be completely consistent
  - Potential small differences in masses and widths/lifetimes
  - Small differences where we cut-off Breit-Wigners and maybe some other cases I'm not aware off
- I looked through the question, whether we could just leave quark configurations in event record without calling Pythia and let Pythia (or who called EvtGen) deal with those
  - Not simple right now, I think it will require some work in a sense, that even kinematics of these configurations is done by Pythia, so without calling Pythia we do not have anything to put into event record

Other potential uses

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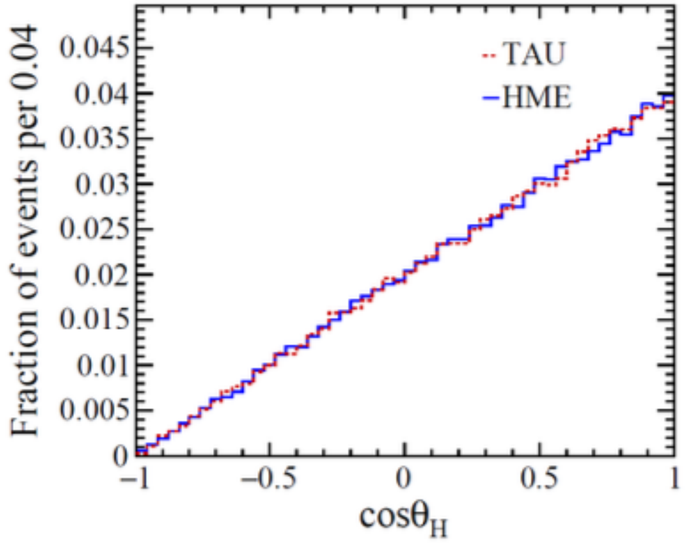
- With demand of thread safety PHOTOS and TAUOLA became bottlenecks
- As Pythia has practically same functionality for tau decays, try to use it instead of TAUOLA
- Benefit for EvtGen is that one could actually take into account complete spin structure
  - Tricky bit is that the two packages calculate things in different spin basis and translation looks simple but details here really matter
  - Kind of close, but still some difference in translation between spin basis
- QED radiation started to be also floated in the context of Warwick-Monash alliance

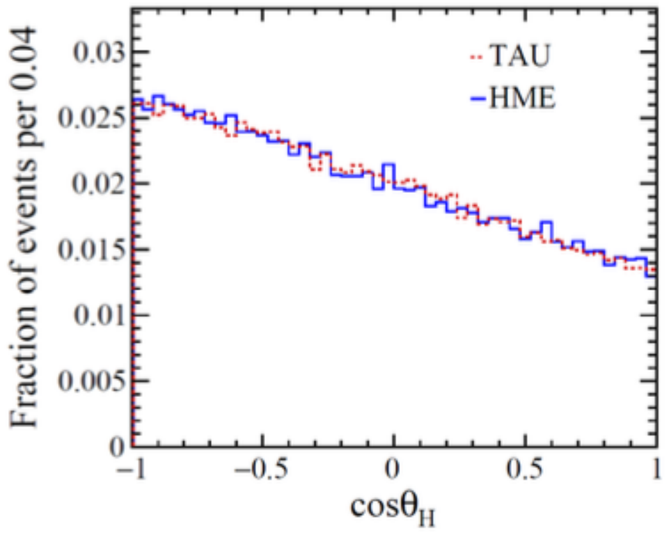
Tau decays

- When we fudge translation between spin basis by hand, output looks as expected
- Need to iron out details to be sure we get it right also in cases where it is less obvious whether we “fudge” it correctly

$B^+ \rightarrow \tau^+(\rightarrow \pi^+\bar{\nu}_\tau)\,\nu_\tau$



$B^+ \rightarrow \tau^+\left(\rightarrow \mu^+\nu_\mu\bar{\nu}_\tau\right)\nu_\tau$



QED radiation

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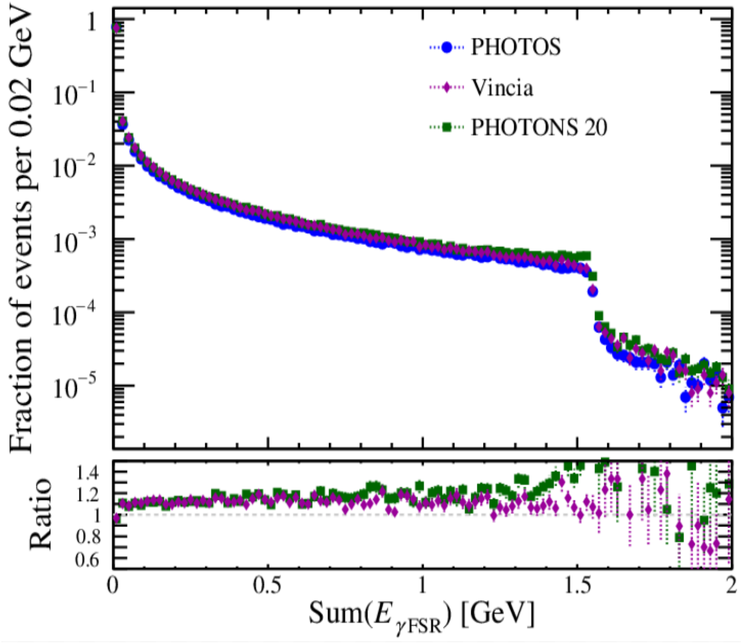
- We started from developments by Peter and Giacomo in Vincia
- Got some interface to allow Giacomo to have some tests and comparisons to PHOTOS
- EvtGen does QED radiation when given part of the decay chain is generated
  - We had some discussion to do it for the whole chain in one go at least in some cases, but requires bit of work to fit it in
- In UK context, there was also desire to look for possibility to use Sherpa for QED radiation
  - We have now interface to both Pythia and Sherpa and people will be able to choose which one they wish to use

QED radiation

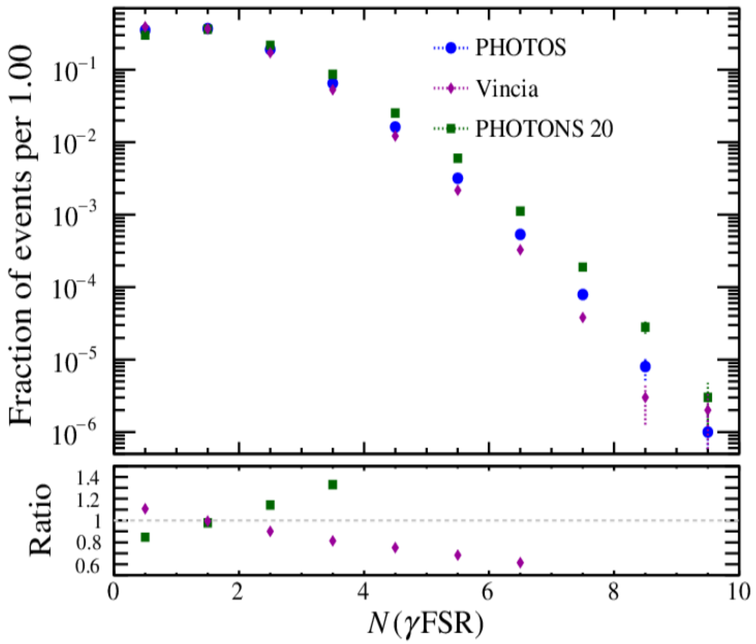
➡ Main difference with collinear singularities being less pronounced in Vincia

$J/\psi \to e^+e^-$

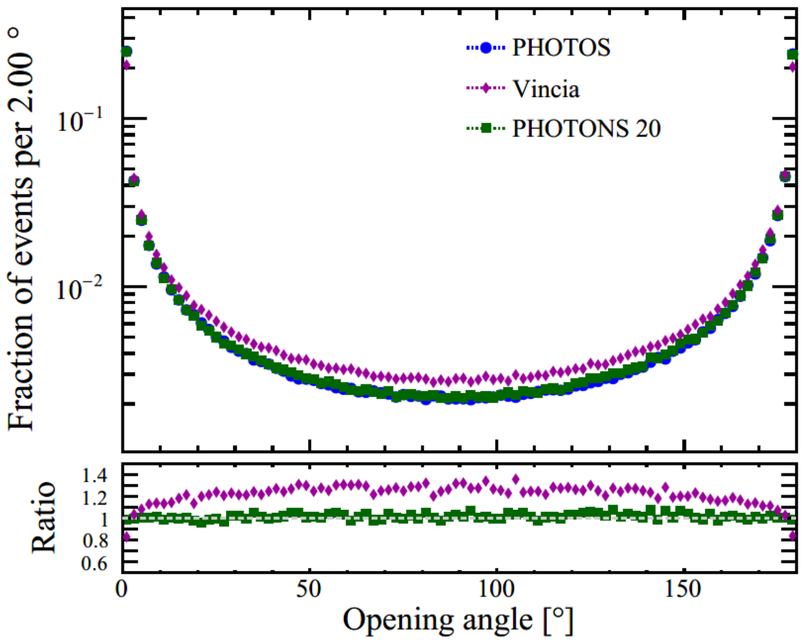
Amount of radiated energy



Number of photons



Angular distribution of photons

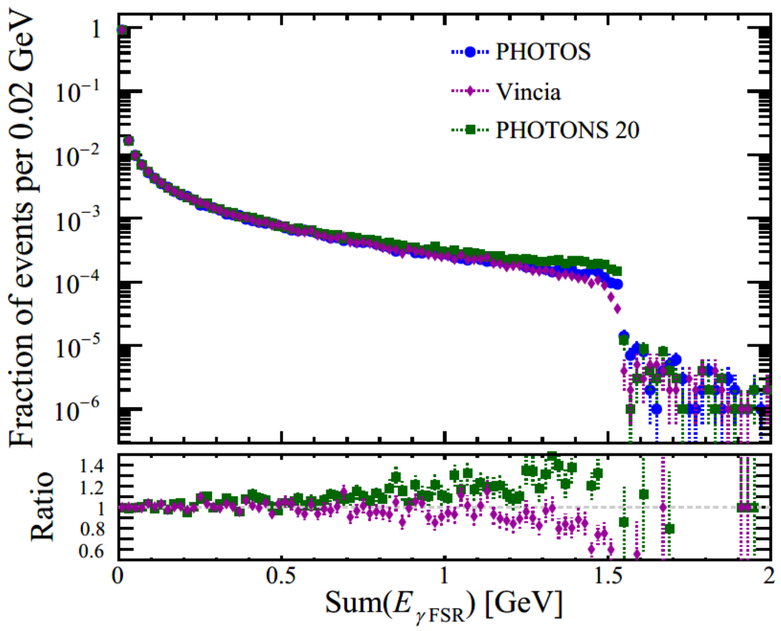


QED radiation

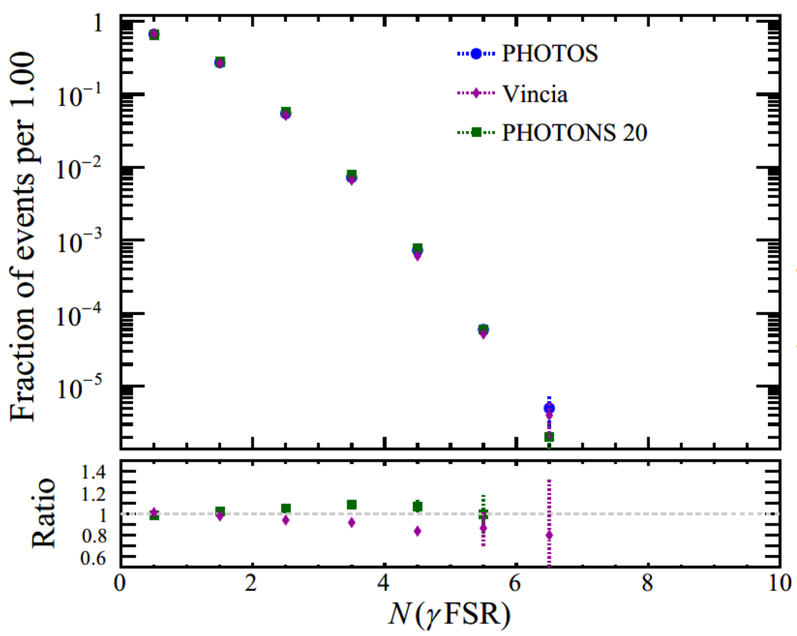
- Generally generators very similar

$$J/\psi \to \mu^+\mu^-$$

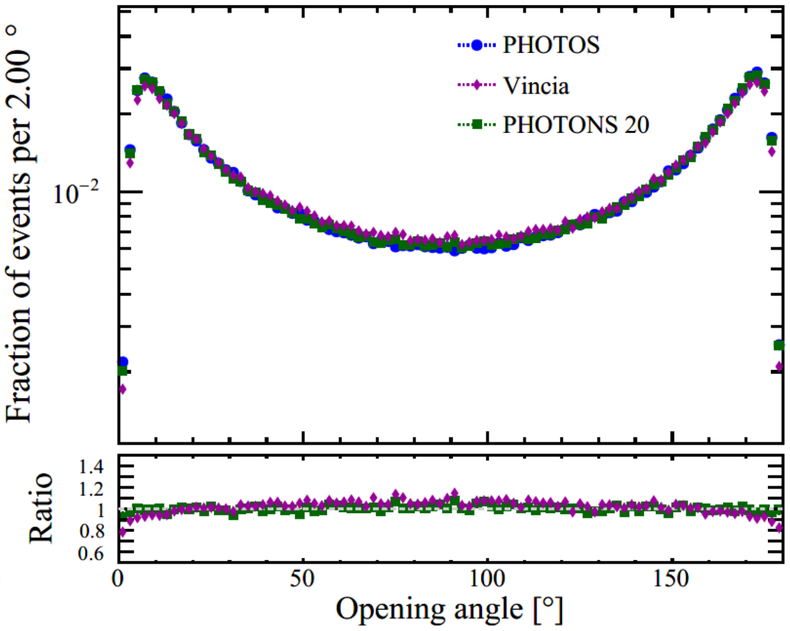
Amount of radiated energy



Number of photons



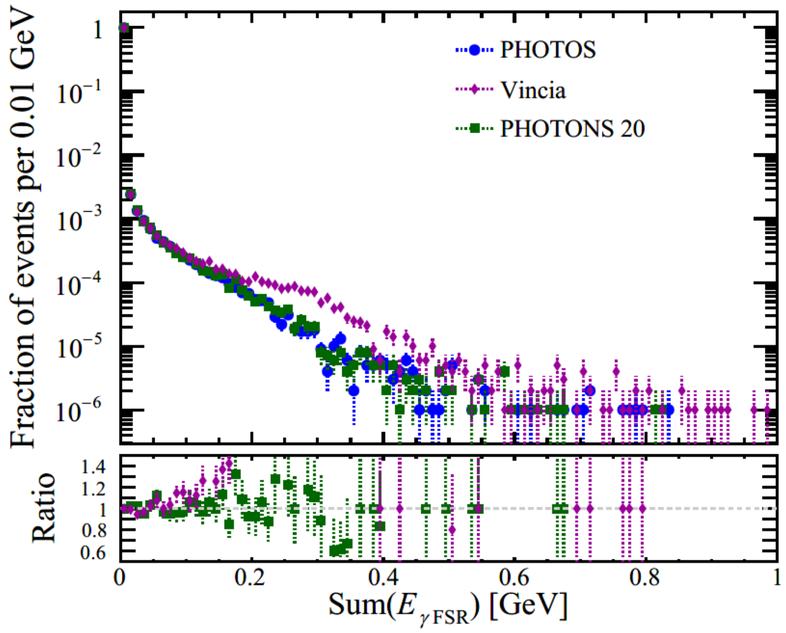
Angular distribution of photons



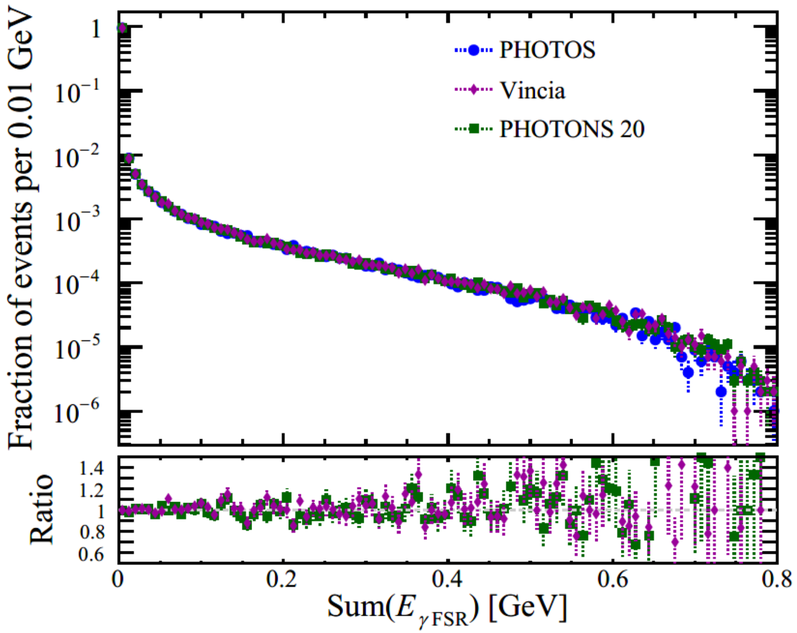
QED radiation

- Generally very similar
- Bit larger differences with charged mother

$\rho^+ \to \pi^+\pi^0$



$D^0 \to K^-\pi^+$



$B^0 \to K^+K^-\pi^+\pi^-$